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Rose Technic Staff

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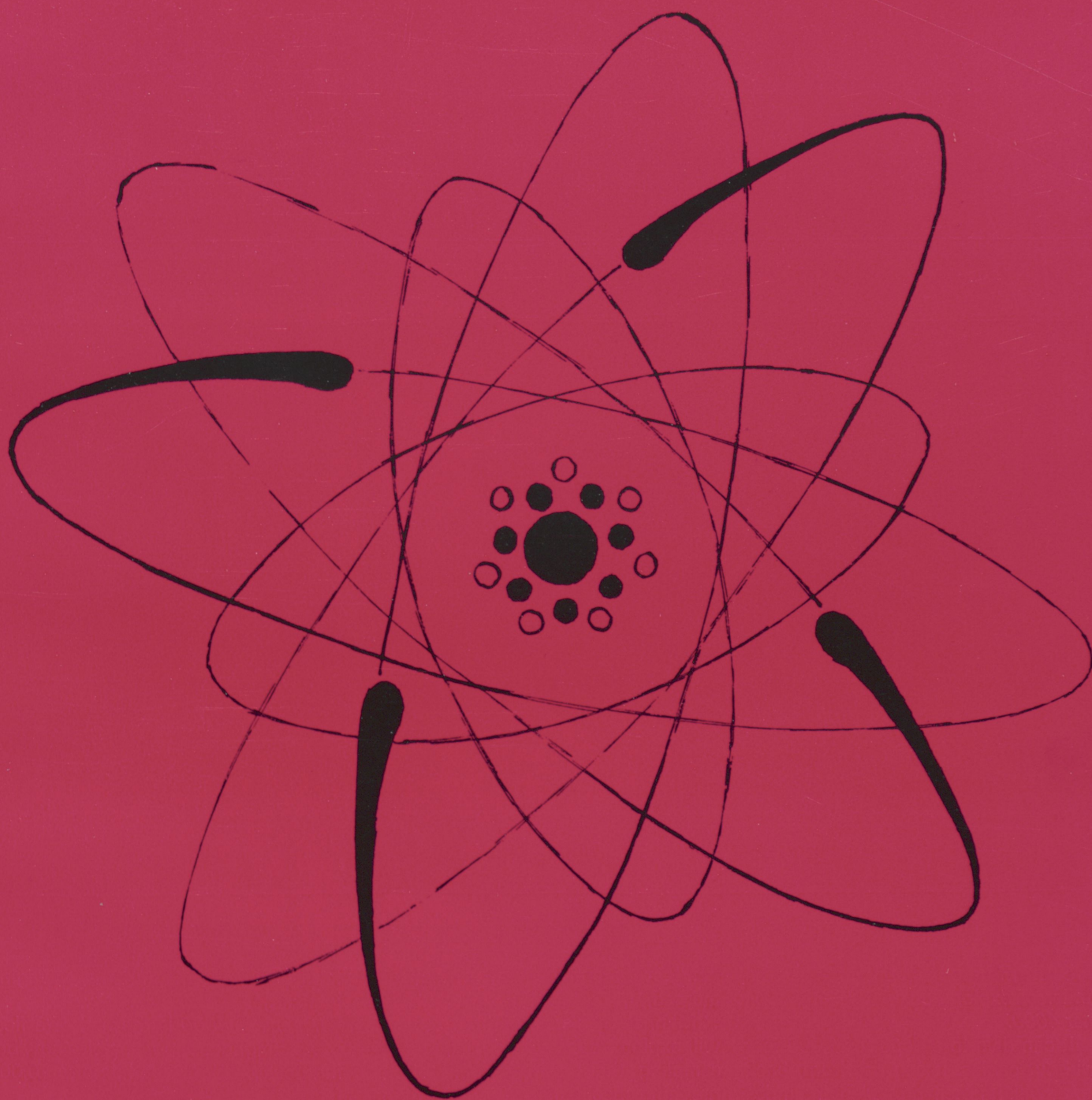
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# Rose Technic

*December*

*1965*



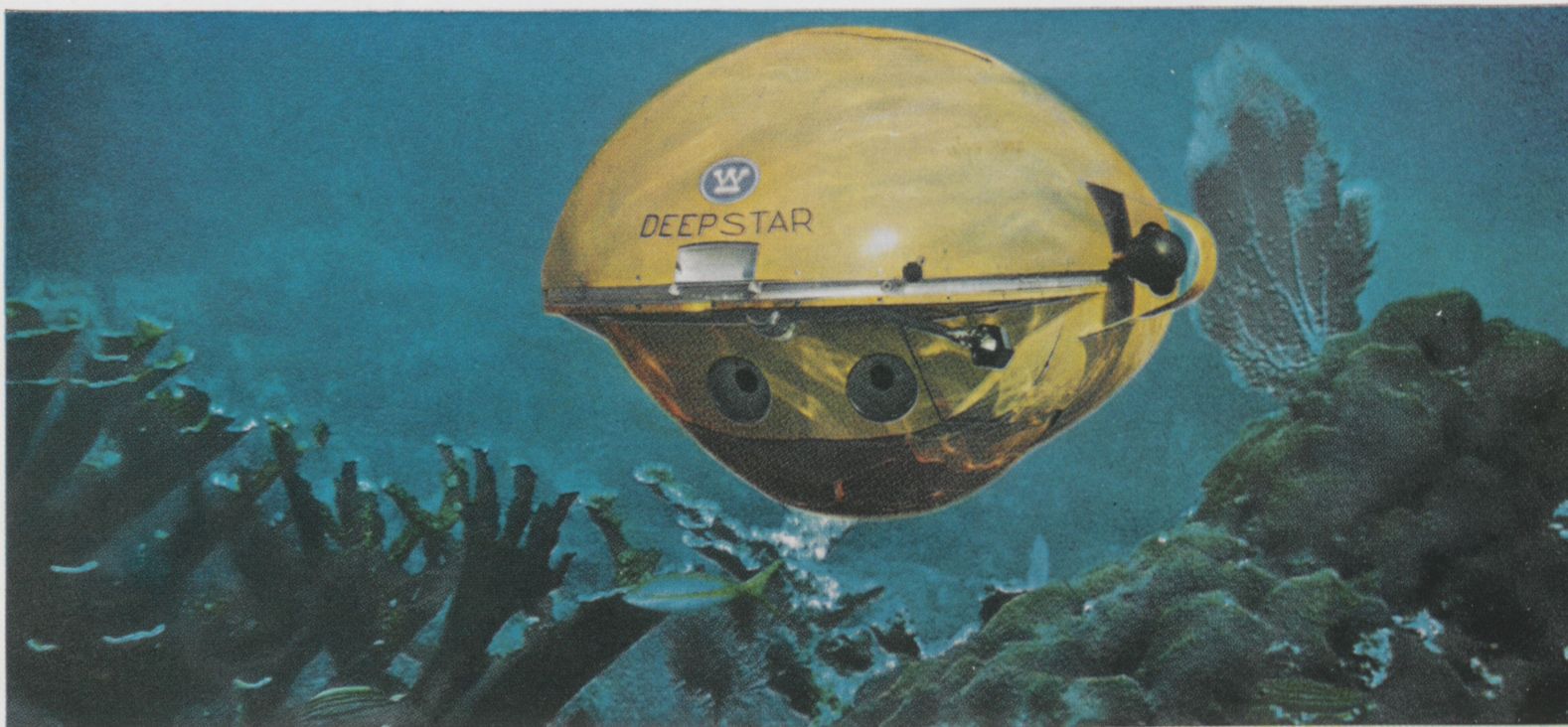
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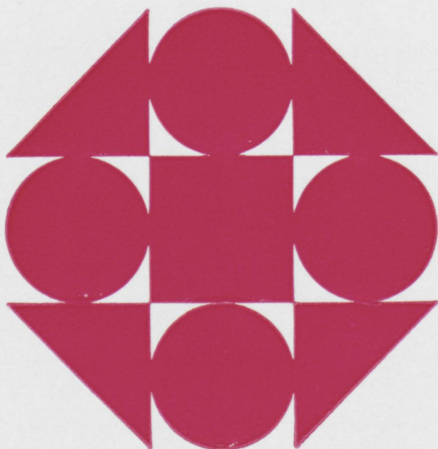
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## IN THIS ISSUE

The first of three articles on Quantum Electronics by Dr. H. A. Sabbagh begins on page 8. These three articles will be presented as a series and will focus some light on a new approach to electronic theory.

In a speech given a year ago this December, Dr. James Rhyne Killian, Jr., expressed a need for increased involvement of the engineer in society. The article which begins on page 10 is taken from that speech. All Rose men should read the article and give thought to its message.

On page 14 begins Fluid Amplifiers, written by Bob Allen. Primarily a discussion of the concepts of fluid amplifier control, it includes such topics as the coanda effect, digital fluid devices, and manufacturing techniques. The many illustrations which are included make this an interesting and easily understood article.

## COVER NOTE

This month's cover is by Alan Espenlaub.  
It is entitled "The Electron."

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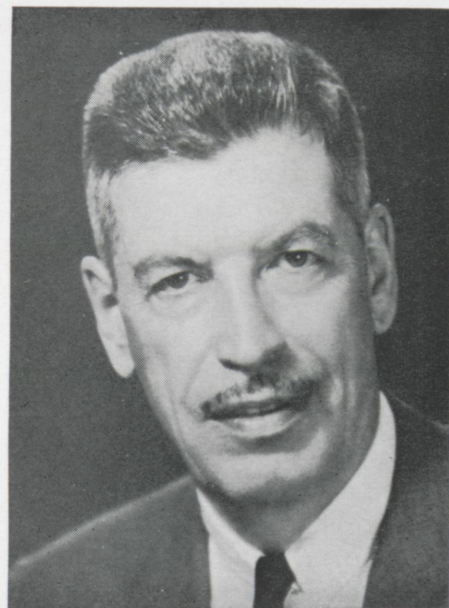
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# Plaidoyer Pour L' Ingenieur



President John A. Logan

One of the last places one might look for an article on engineering education is *REALITES*, the slick-paper French publication which features articles on art, music, literature and politics — Nouriev, Paul Klee, Arthur Koestler, Picasso and Pierre Balmaine compete with authors describing life in primitive New Guinea or the “in” place to stay on the Riviera. However, in the November 1965 issue Louis Armand, a *Realites* feature writer, makes a plea for the acceptance of engineers on the managerial level by government and industry if France is to be competitive in world markets. He points out that economists, lawyers and financiers have traditionally been the leaders of French industry and that for an engineer to rise to the top he had to be re-educated as an economist, a lawyer or financier. The future of French industry, however, depends on the development of new equipment, new products and new solutions to technical problems, and these will have to be furnished by engineers.

Although France was one of the first countries in the world to develop modern engineering education (the *Ecole Polytechnique* founded by Napoleon has served as a model for many of the world's engineering schools—including *Rose Poly*), France was slow to recognize the new role of the engineer as a leader in science, industry and government. This radical change has been forcibly called to the attention of Americans by the *Scientific American Study*, “U. S. Industry:

Under New Management” indicating that the percentage of top corporation officials having a degree in science or engineering rose steadily from 6.8% in 1900 to 20% in 1950, to 36% in 1963; it is projected that by 1980 this figure will rise to 50%.

*Rose Polytechnic* has always had an unusually high percentage of its graduates in leadership positions in industry and government, and our new curricula recognize our obligation to provide graduates with the background to prepare them for these future responsibilities. Incidentally, it is interesting to note that the changes in curricula proposed by the American Society for Engineering Education includes a number of features already incorporated in the *Rose* program. (These recommendations are highly significant and should be reviewed in a forthcoming issue of *THE TECHNIC*.)

In summary, education in science and engineering is rapidly coming into its own as the ideal preparation for life in the Twentieth Century; *Rose Polytechnic* must continue to provide innovation and leadership in this vitally important field.

A stylized, handwritten signature in dark ink, appearing to read 'John A. Logan'.

JOHN A. LOGAN, President



During a student's college career many questions arise which concern his entire future. One such question is why should I or anyone in college join a social fraternity? My own experience prompts me to say that I believe that fraternity membership is the college man's smallest expense for his greatest long-run benefit.

How many students would pass up getting twice as much of anything for practically the same price? That's right, I am saying that cost isn't even relative to the added benefits the fraternity member has for his taking. Many of the tangible benefits naturally come under social life, while others come in the form of added opportunities for responsibility and leadership. These and the other tangible benefits available to the fraternity member can also be obtained in a less ready manner by any student. The true difference between dorm and fraternity life comes in the form of the many intangible benefits available to only the fraternity member. A few of these are:

The fraternity house, unlike the dorm, provides a true "home away from home." The fraternity member feels that he shares in the ownership and is proud to invite friends and family there. He feels more relaxed knowing that he belongs and has formed intimate friendships with all of his brothers.

Practically all fraternity alumni will testify that the fraternity helped them develop more acquaintances, and to form more lasting friendships than they could have in another environment. Many of these friendships continue to be of added value in business life for gaining acceptance and making new acquaintances.

Fraternity life teaches the undergraduate many valuable things not obtainable from strictly campus life. These lessons range from table manners and social poise to self reliance and the art of living and working with others on a team.

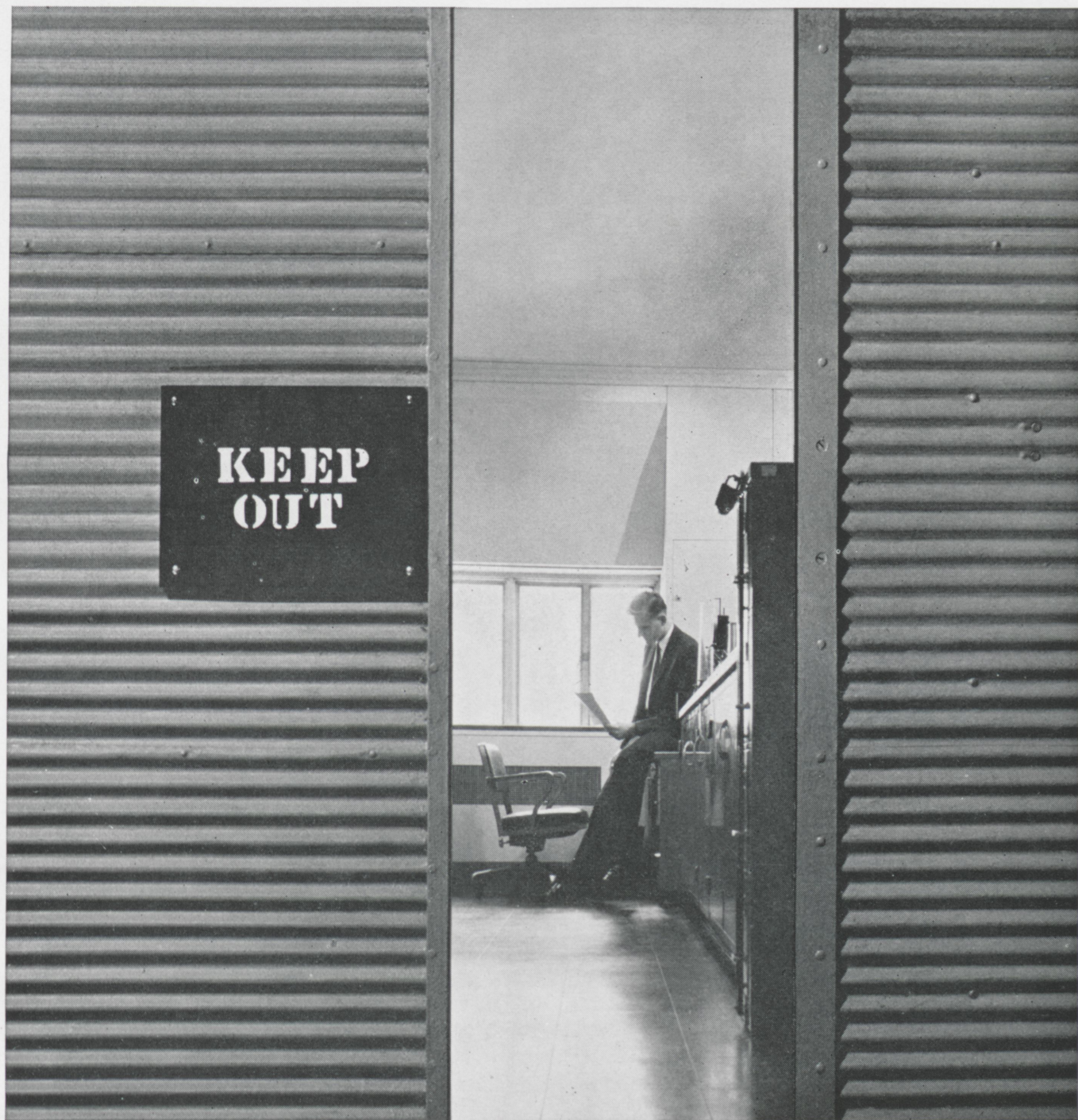
Membership in a fraternity will often stiffen the student's resolve to stay in school until graduation. A recent study by the U.S. Office of Education found that fraternity membership was clearly associated with a "persistence to graduate." The national inter-fraternity council, campus inter-fraternity councils, and individual chapters put a great emphasis on scholarship and offer awards and scholarships for the chapters and men who attain high standings.

Membership in a fraternity often enables a young graduate to get an easier start in a better job, because many employers feel that the fraternity man is better adjusted, better able to get along with people, and possessed with more of a will to succeed. A 1965 survey of the chief executives of the nation's largest corporations revealed that 75% of such executives who attended colleges where there were national fraternities are fraternity members.

The fraternities at Rose are unique in as much as Rose and each fraternity has unique characteristics. However, each fraternity is similar in that the same tangible and intangible benefits are offered. The fraternities are also the same in that they are looking for men who have good character, scholarship, and fellowship and wish to improve on these and all other qualities. I strongly urge every student at Rose who finds a mutual suitability between himself and a fraternity to become a member.

J. S.





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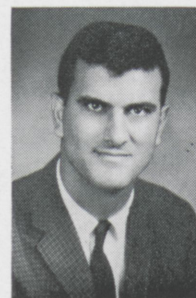
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# Quantum Electronics

## Part 1

by Dr. H. A. Sabbagh



Dr. Sabbagh was born in Lafayette, Indiana, and lived there until graduation from Purdue University in 1958. Upon entering the U. S. Navy, he was stationed aboard the U.S.S. Bayfield out of San Diego. Then from 1959 to 1961 he taught courses in Electrical Engineering at the U. S. Naval Academy. In 1961 he returned to Purdue and received his doctorate in Electrical Engineering in 1964. He has been at Rose since that time and has a primary interest in quantum and physical electronics.

This article is the first part of a three part serial dealing with the mathematical and physical principles of a new branch of engineering science, quantum electronics.

The first part treats some of the mathematical concepts applicable to the theory. Part two will deal with the quantization of distributed systems (i.e., fields), and the final article will tie the preceding two together in a treatment of parametric amplification and frequency conversion.

### 1. Warming up the Subjects. Some New Concepts.

The mathematical foundations of quantum electronics are precisely those of quantum mechanics. Indeed, we could define quantum electronics as the systematic application of quantum mechanics to engineering problems. Anyway, the mathematical theory underlying quantum mechanics is that which is called Hilbert Space theory\*. We shall introduce a few of the notions of the theory in an abstract form and then give specific examples in quantum mechanics.

#### Vector Spaces

**Definition 1.** An abstract linear vector space is a collection of objects  $x, y, z, \dots$ , called *vectors*. The zero vector,  $\theta$ , is in the collection as is the negative,  $-x$ , of any vector  $x$ . The following *axioms* are assumed:

- (A) If  $x$  and  $y$  are any two vectors then there exists a *sum vector*  $x+y$  within the collection. The sum of two vectors satisfies the rules:
- (A1)  $x+y = y+x$   
(commutative law)
- (A2)  $x+(y+z) = (x+y)+z$   
(associative law)

$$(A3) \quad x+\theta = x$$

$$(A4) \quad x+(-x) = \theta.$$

(M) For each scalar  $\lambda$ , (i.e., each complex number), and each vector  $x$ , there exists the vector  $\lambda x$ . The product of a vector by a scalar satisfies the rules:

$$(M1) \quad \lambda(x+y) = \lambda x + \mu x$$

$$(M2) \quad (\lambda + \mu)x = \lambda x + \mu x$$

(distributive laws)

$$(M3) \quad (\lambda\mu)x = \lambda(\mu x)$$

(associative law)

$$(M4) \quad 1x = x$$

$$(M5) \quad \lambda\theta = \theta$$

$$(M6) \quad 0x = \theta$$

**Definition 2.** A pre-Hilbert space is a vector space. For each pair of vectors  $x, y$ , there is determined complex number called the *scalar product* of  $x$  and  $y$ , and denoted by  $\langle x|y \rangle$ . By assumption the following rules hold:

$$(P1) \quad \langle y|x \rangle = \langle x|y \rangle^*$$

(\* denotes complex conjugate)

$$(P2) \quad \langle x+y|z \rangle = \langle x|z \rangle + \langle y|z \rangle$$

$$(P3) \quad \langle \lambda x|y \rangle = \lambda \langle x|y \rangle$$

$$(P4) \quad \langle x|x \rangle \geq 0$$

when  $x = \theta$

(note that  $\langle x|x \rangle = \langle x'|x \rangle^*$ , which implies that  $\langle x|x \rangle$  is real).

**Definition 3.** If  $\langle x|y \rangle = 0$ , then the two vectors  $x$  and  $y$  are said to be *orthogonal*. If the *norm* of  $x$ , denoted by  $\|x\|$ , and defined by  $\|x\|^2 = \langle x|x \rangle$ , is unity then  $x$  is said to have *unit norm* (or unit "length"). A collection of vectors is said to be *ortho-normal* if each vector in the collection has unit norm and each pair of vectors is orthogonal.

**Definition 4.** The vector  $x$  is said to be the *limit* of the sequence of vectors  $x_n$  if  $\|x - x_n\| \rightarrow 0$  as  $n \rightarrow \infty$ . If any sequence of vectors satisfies  $\|x_n - x_m\| \rightarrow 0$  as  $m, n \rightarrow \infty$ , i.e., the vectors get "closer and closer", and if such a sequence has a limit, then the pre-Hilbert space is complete, because it contains all of its limit vectors.

**Definition 5.** A sequence of vectors  $x_n$  is called an *ortho-normal basis* for a Hilbert space if: (1) it  $x$  in the space may be written as is orthonormal, and (2) each vector  $x$  in the space may be written as

\*David Hilbert, in the early years of this century, laid the foundations of the theory while investigating integral equations. See Sterling K. Berberian, *Introduction to Hilbert Space*, Oxford University Press, 1961.



$x = \langle x | x_n \rangle x_n$ . The complex numbers  $\langle x | x_n \rangle$  are called the *expansion coefficients*. The equality in (2) is to be interpreted as

$$\left\| x - \sum_{n=1}^k \langle x | x_n \rangle x_n \right\| \rightarrow 0$$

as  $k \rightarrow \infty$ , or as

$$\|x\|^2 = \sum_{n=1}^{\infty} |\langle x | x_n \rangle|^2.$$

**Definition 6.** A linear operator,  $L$ , on a Hilbert space transforms a vector into another vector lying in the same space. The following rules define the properties of  $L$ : (1)  $L(x+y) = Lx + Ly$  for all vectors,  $x$  and  $y$ , (2)  $L(\lambda x) = \lambda(Lx)$  for any vector  $x$  and scalar  $\lambda$ . The *identity operator*,  $I$ , satisfies  $Ix = x$  for every  $x$ , and the zero operator,  $O$ , satisfies  $Ox = \theta$ , for every  $x$ .

**Definition 7.** Every linear operator,  $L$ , has an *adjoint operator*,  $L'$ , which satisfies  $\langle L'x | y \rangle = \langle x | Ly \rangle$ . The adjoint of an operator is analogous to the conjugate of a complex number.

**Definition 8.** An operator,  $L$ , is said to be *self-adjoint* (or Hermitian) if  $L = L'$ . Such operators are extremely important in quantum mechanics because they correspond to physical observables.

### Eigenvectors and Eigenvalues

**Definition 9.** A vector  $x$  in a Hilbert space is said to be an *eigenvector* (proper vector, or characteristic vector) for the operator  $L$  if: (1)  $x$  does not equal  $\theta$ , and (2)  $Lx = \mu x$  for some suitable scalar  $\mu$ .

**Definition 10.** A scalar  $\mu$  is said to be an *eigenvalue* for the operator  $L$  if there exists a vector  $x$  other than  $\theta$  such that  $Lx = \mu x$ . Thus, a linear operator transforms each of its eigenvectors into a multiple of itself. The set of all eigenvalues of an operator will be called the *spectrum* of that operator.

According to the principles of quantum mechanics, measurements of physical quantities can only yield eigenvalues of the corresponding physically observable operators. Since these measurements must

yield real values it would be reassuring to know that there exists a class of operators whose eigenvalues are always real. This class is called Hermitian, and we now understand the last statement in Definition 8.

## 2. Quantum Mechanics, At Last. The Schrodinger and Heisenberg Pictures.

Quantum mechanics tells us that the *state* of a physical system is defined by a vector\* in a Hilbert space. This *state vector*,  $v$ , is a function of time and satisfies *Schrodinger's equation*

$$(2-1) \quad i\hbar \frac{dv}{dt} = Hv,$$

where

$$i = \sqrt{-1}, \quad \hbar = 1.054 \times 10^{-34}$$

joule-sec (being Planck's constant divided by  $2\pi$ ), and  $H$  is a linear, self-adjoint operator called the *Hamiltonian operator* for the physical system. In order to say more about this operator we first digress to say something about the Hamiltonian\*\* in classical mechanics.

A particle of mass  $m$  moving with momentum  $p$  (consider one-dimensional motion, only) in a force-field of potential  $U(x)$  satisfies the equations (2-2)

$$(a) \quad \frac{dp}{dt} = -\frac{\partial U}{\partial x}$$

$$(b) \quad \frac{dx}{dt} = \frac{p}{m}$$

The first equation is Newton's second law, and the second defines momentum in terms of the rate-of-change of displacement (i.e., velocity).

The *Hamiltonian function* is any function,  $H(p, x)$ , of momentum and displacement, which, when substituted into the *cononical equations of Hamilton*,

\*Note, again, the abstract use of the term "vector". It is not to be confused with the usual 3-dimensional vector with which the reader is familiar.

\*\*Named in honor of W. R. Hamilton, an Irish mathematician of the last century who developed an elegant formalism of classical mechanics. See H. Goldstein, *Classical Mechanics*, Addison-Wesley, 1950.

(2-3)

$$(a) \quad \frac{dp}{dt} = -\frac{\partial H}{\partial x}$$

$$(b) \quad \frac{dx}{dt} = \frac{\partial H}{\partial p}$$

yields, identically, the equations (2-2). Usually, but not always,  $H(p, x)$  may be identified as the total energy written as a function of  $p$  and  $x$ . Thus, in the simple example just considered we have

(2-4)

$$H(p, x) =$$

$$\frac{p^2}{2m} + U(x)$$

kinetic potential  
energy energy

Now in going from classical mechanics to quantum mechanics we *quantize* the physical system by substituting Hermitian operators for the variables appearing in the classical Hamiltonian function. The resulting Hermitian operator is called, as we have already said, the *Hamiltonian operator*. Just how the operators which go into the Hamiltonian are chosen may not always be obvious and depend on the nature of the physical system. We require, for example, that the operators  $P$ ,  $X$ , corresponding to the classical quantities  $p$ ,  $x$ , respectively, satisfy the *operator commutator relation*

(2-5)

$$[X, P] = XP - PX = i\hbar I,$$

where the first term is called the *commutator* of  $P$  and  $X$ , and  $I$  is the identity operator (see Definition 6). We should point out that, in general, operators don't commute; that is,  $XP$  operating on a state vector is not necessarily equal to  $PX$  operating on the same vector. Hence, the Hamiltonian operator corresponding to (2-4) is

(2-6)

$$\frac{p^2}{2m} + U(X)$$

In the Schrodinger picture the state vector,  $v$ , is a function of the coordinates of the system, as well as of time. This function is called the *wave function* of the system.

(Continued on Page 31)



# Lift The Human Spirit

by Dr. James Rhyne Killian, Jr.

Dr. Killian is chairman of the board of the corporation of Massachusetts Institute of Technology. Last December, in the annual Roy V. Wright Lecture to the American Society of Mechanical Engineers, he summoned the engineering community—then in the throes of organizing a new National Academy of Engineering—to loftier levels of expression akin to poetry. His text here is derived from those remarks.

Outworn stereotypes of the engineer need to be cast aside. The quarterly publication of the Engineers Joint Council recently pointed to one of these in C. P. Snow's novel, *The New Men*. In noting the absence of engineers from a meeting of scientists called to express their grave concern about the awesome danger to mankind of nuclear weapons, Snow says, in the words of a character in the novel:

"It struck me that all the top scientists . . . were present but none of the engineers. As an outsider, it had taken me years to understand this rift in technical society. . . . The engineers . . . who used existing knowledge to make something go, were in nine cases out of ten conservatives in politics, acceptance of any regime in which they found themselves, interested in making the machine work, indifferent to long-term social guesses.

"Whereas the physicists, whose whole intellectual life was spent in seeking new truths, found it congenial to stop seeking when they had a look at society. They were rebellious, questioning, protestant, curious for the future and unable to resist shaping it. . . ."

This episode expresses a cliché that dies hard. Even had it ever been true, it is wide of the mark today. It is an out-of-date stereotype to type engineers as not interested

in seeking new truth. Engineers are working side by side with scientists in many research programs, and more and more the education of engineers provides them with the fundamental training and the motivation to enable them to become highly successful innovators. And this kind of intensive creativity encourages independence and nonconformity.

So we need to dump these stereotypes, frequently held by engineers themselves, if the engineer is to be of maximum usefulness in the public domain. Our societies need independent-minded, questioning, concerned engineers as well as scientists with these traits.

New educational programs that are underway seek to give new dimensions to engineers so that they can perform effectively in the public arena. Not only have there been changes in the undergraduate program giving greater emphasis to the fundamentals of science and the humanities, a steadily lengthening of engineering education by graduate and postdoctoral study; increasingly, engineers choose to study management and public administration either through electives in undergraduate school or full time at the graduate level. I, among others have become convinced of the importance of a continuing study of the impact of technology on government

and on foreign affairs and of a cross-fertilization between engineering and political science.

For the past several years I have had the stimulating experience of giving an occasional graduate seminar to engineers, scientists, and political scientists on science, technology, and public policy. Both undergraduate and graduate students have afterward come to me to inquire how they can enter the service of the government or contribute to the public service. In general, my inclination is to tell them that they must first establish themselves firmly in their professions, achieving a record in the practice of science and engineering. They are then in a much stronger position to make their talents effectively available in government. At the same time, however, it must be recognized that with the preparation now available in public administration and in political science in an increasing number of universities, increasing numbers of young people find it possible to move immediately into the government service.

Let me note five areas of public service where the specialized skills of the engineer are increasingly in demand and where the profession is qualified to make an even larger contribution. I leave out such major but obvious areas as defense and



space technology which, taken together, constitute the largest government use of engineering talent.

First, there is the difficult area of arms limitation. The engineers of our generation face a magnificent challenge to join in interdisciplinary concert with military and political experts in supporting our government leaders in finding sound, safe approaches to arms limitation. Dr. Jerome B. Wiesner, for example, working with other engineers and with scientists, has assisted policy-makers in shaping these national policies that led to our treaty with the Soviet Union for a limited nuclear test ban. All efforts to achieve arms limitation require a very high level of technical study and judgment, and engineers have special qualifications to be helpful.

Second, with increasing frequency our society must make knotty, vexing decisions on the desirability of costly technological ventures such as the supersonic transport plane and the accompanying system of airports and air traffic control. The engineering profession must provide men of statesmanlike judgment to help make these decisions, which involve finance, technology, industry, government, and social priorities, not to mention sonic booms.

Third, our society faces the job of deploying a new technology that is regional, continental, or even global in scale, and must look to engineers for guidance.

Take transportation. It becomes increasingly clear that we cannot solve our transportation problems by a piecemeal approach. Highways, rapid transit, railroads, and air transport must be treated as a system requiring a new order of technological, financial, political, and managerial ingenuity. We now have on the agenda bold proposals for an integrated transportation system for the northeast corridor stretching from Boston to Washington. This concept, made both possible and necessary by technological advance, may involve the development of really high-speed rail transport with other

collateral transport systems deployed in association with it, and all breaking across municipal, county, and state lines requiring new political arrangements.

We hear spectacularly bold engineering proposals to meet current national and international needs. For example, there is the international North American Water and Power Alliance proposal to store water at high elevations, mainly in Canada, after collection in Alaska and Canada, and to distribute it throughout the southern provinces of Canada, and in the United States and northern Mexico. Similarly, there is the proposed Hamilton Falls hydroelectric project to generate economically useful power not only for Canada but for parts of New England and for New York City. These great concepts represent the regional and continental scale of that modern engineering which we must have to serve the nation; they point up the importance of leaders who are masters of the technology required but who also understand the confluence of technology with government finance, management, regional planning, and sociology.

The spectacular growth of computers and data processing, a technological revolution that is really just beginning, leads to conjectures about utility systems devoted to data processing.

We must have engineers of an intellectual scale and scope to match these great enterprises, to evaluate them, to master their social and political complexities, and to discipline them to serve man and not to dominate him.

Fourth, the impact of science and technology on foreign affairs has created a need for engineers with many different kinds of orientation to serve our foreign policy. The State Department now has Scientific Attachés, some of whom are engineers, in its major embassies, and of course our technical aid programs have enlisted many engineers for foreign service. Even so, there is still need for more engineers in the

foreign service—and a greater recognition on the part of government that it needs them.

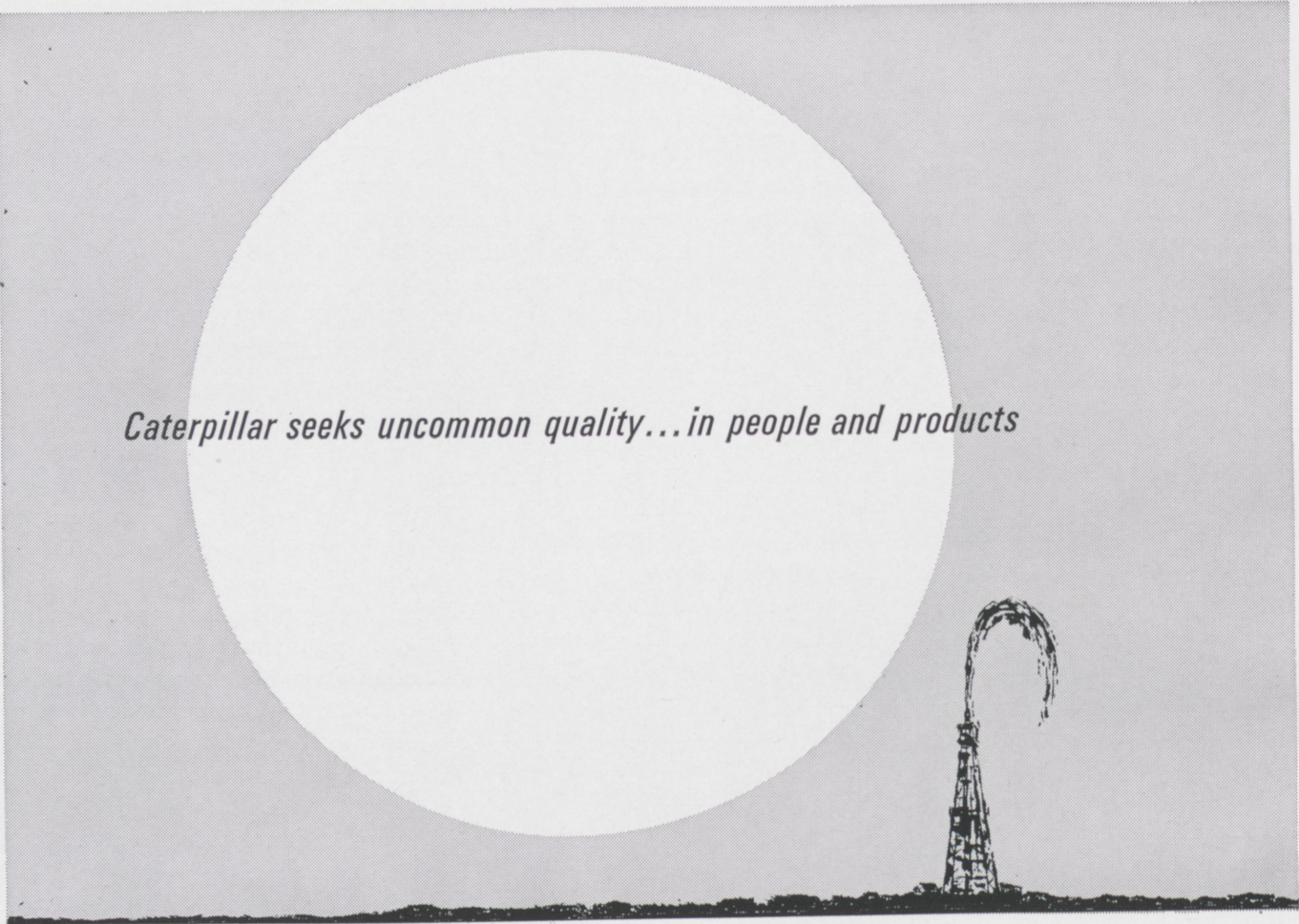
In this era of awakening nations the engineer has an unprecedented opportunity to work sensitively in strange cultures to give them in their own terms the technology they need and can use to become self-sustaining. In all of these ways he performs a unique service for the human community.

Since our principles and policies impel us to aid the new and less developed nations, we must face the fact that our knowledge of how to do it is frequently as underdeveloped as the nations we would help. Our aid programs should be supported and guided by a research program as intensively and professionally pursued as the research and development programs underlying our defense. An idealistic impulse to aid is not enough; we must bring together teams of specialists—engineers, economists, agriculturists, sociologists, educators—carefully prepared and armed with research results for work in the specific area to be aided.

Let me give a striking example of this. In 1961, the President of Pakistan, who had been primed by his science adviser, described to President Kennedy the problems of waterlogging and salinity that was progressively reducing the fertility of vast acreages of irrigated farm land in Pakistan. President Kennedy promptly asked his Special Assistant for Science and Technology, Dr. Wiesner, to see what he might do in helping to find a solution to this problem. Dr. Wiesner mobilized a panel of twenty U. S. specialists, both technical and nontechnical, and a solution was found. Computer models were constructed at Harvard's School of Applied Science which not only yielded a solution to this specific problem but also went further and yielded a balanced, comprehensive plan of soil improvement, agricultural development, including the use of fertilizers, weed

*(Continued on page 26)*





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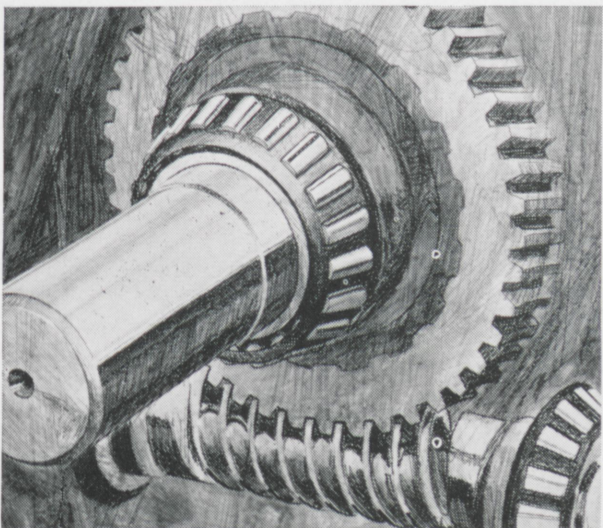
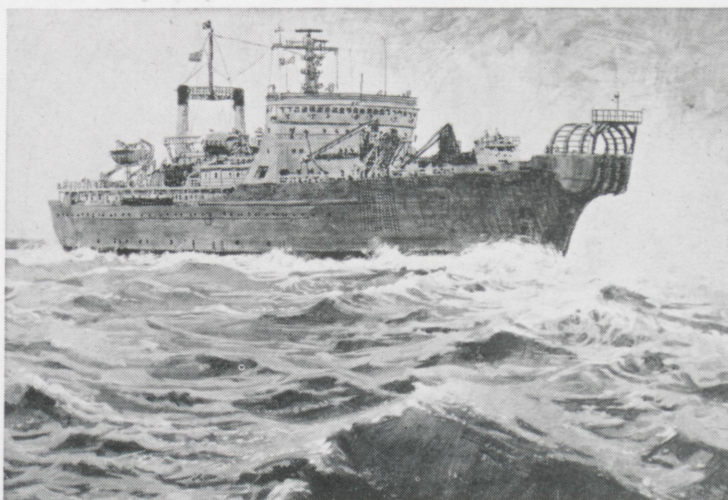
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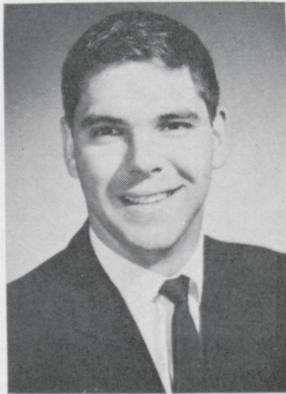
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# FLUID

# AMPLIFIERS

by Bob Allen



Robert C. Allen

Robert Allen is a graduate student in Electrical Engineering. He is a member of Eta Kappa Nu honorary fraternity, IEEE, and Lambda Chi Alpha Fraternity. He has a primary interest in control systems.

The fluid amplifier's operation is based on principles which have been known for centuries. However, the application of these principles to construction of devices for power control was not recorded until 1938. In that year Coanda presented a paper at the Fifth International Congress of Applied Mechanics.<sup>1</sup> In his paper, Coanda set down the ideas for a fluid relay or flip-flop. During the 40's, British and United States patents were awarded for a "mechanical relay of the fluid type," but it was 1960 before the concept of fluid control began to develop fully. Research at M.I.T. and Diamond Fuse Laboratory (now Harry Diamond Laboratory) was the beginning of about 15 to 20 major corporate efforts in fluid amplifier development.

The fluid amplifier is a power amplifier of either of two types . . . 1) digital or 2) proportional (analog). In either case, their operation is based on a momentum exchange between control streams and power streams.<sup>2</sup> The primary difference between proportional and digital devices is the difference of the geometry of the momentum exchange region. (See fig. 1). The digital de-

vice is governed by boundary layer phenomena as well as stream interaction.

Through the stream interactions in fluid devices proportional and digital control is possible. As a means of automatic control fluid de-

vices have great promise in a variety of control problems. The basic advantages to fluid amplifiers are extreme simplicity, low cost in mass production quantities, and high reliability over a wide range of environments.

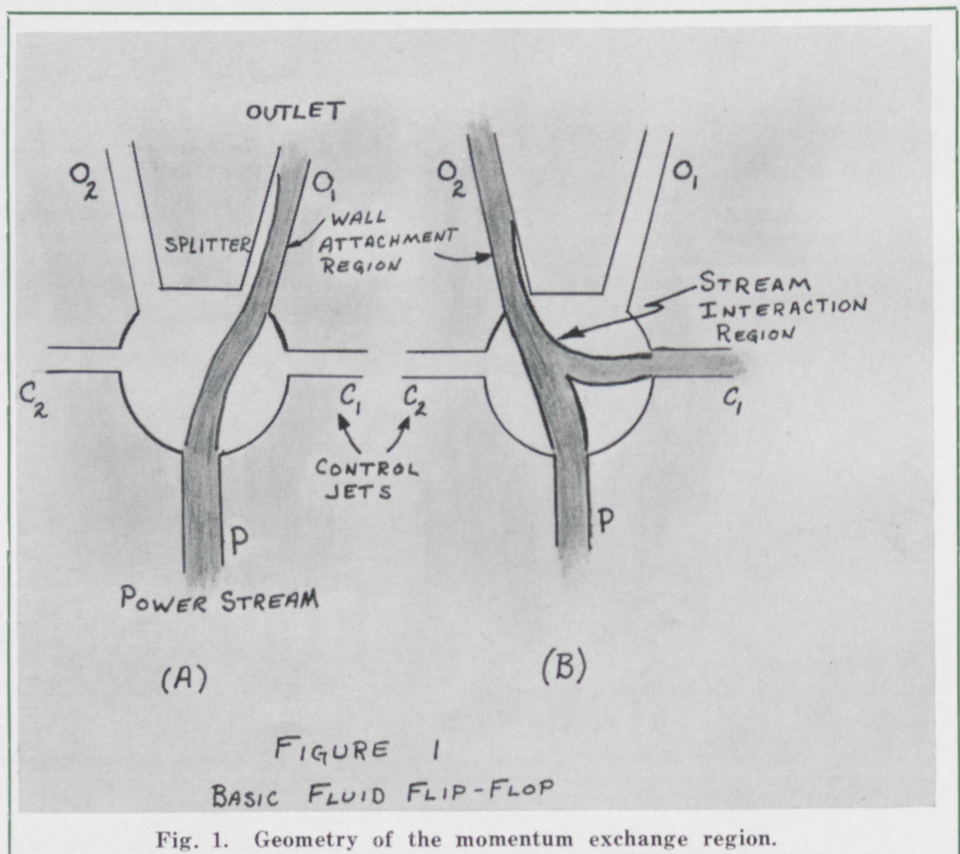


Fig. 1. Geometry of the momentum exchange region.



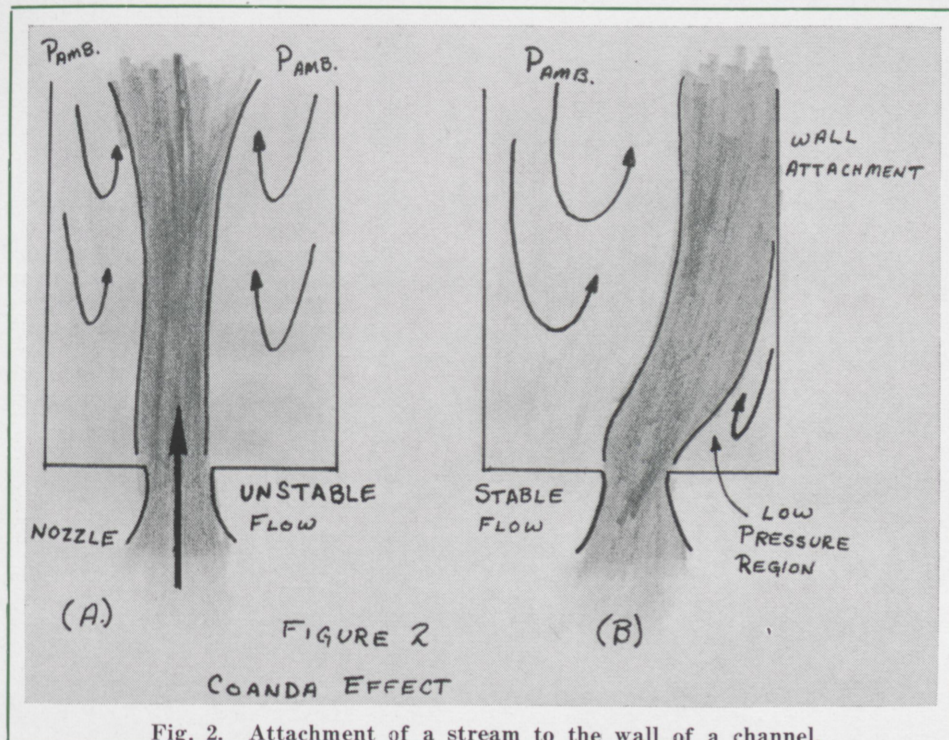


Fig. 2. Attachment of a stream to the wall of a channel.

### COANDA EFFECT

The wall attachment phenomenon is important to the digital fluid device. As we see in Figure 1, the momentum exchange in the interaction region will divert the power stream, but were it not for the boundary layer phenomenon the stream would not remain in the desired output channel after the control stream shut off. The attachment of a stream to the wall of a channel is known as the Coanda Effect. In Figure 2, (a and b) we see how the attachment occurs.

As the fluid is injected into a container which is vented to the ambient pressure of the system, the stream entrains fluid along its sides and becomes broader. This process carries more fluid toward the outlet, causing a low pressure area between the walls and the stream (Fig. 2b). An unstable situation results. Any external disturbance will cause the stream to deviate from the center of the outlet and move toward one of the low pressure regions.<sup>3</sup> As a boundary layer forms between the stream and the wall, the stream is held against the wall by the counter flow from the ambient pressure region. Thus, we say the stream has attached itself to the wall of the channel.

### DIGITAL FLUID DEVICES

Figure 1 shows the basic shape of the flip-flop. The flow entering the device from the power jet at P will be turbulent at first, then will select either  $O_1$  or  $O_2$ . The stream will attach itself to that outlet wall and become laminar.

Assume flow is established in  $O_1$  and  $O_2$ . Switching is accomplished

by means of control jets that add a transverse component to the flow. the added momentum of the control jet forces the stream to the other side of the splitter. During switching the interaction region becomes momentarily turbulent. Soon the stream attaches itself to the wall of  $O_2$  and the switching process is complete. Once the stream has attached itself to the wall, the stream will continue to flow to that outlet, unless changed by the control jet. Thus a pulse of fluid from the control jet is sufficient to switch the flow.

### FLUID LOGIC ELEMENTS

The basic flip-flop in Figure 1 may be made to perform OR, NOR and AND logic functions with only minor modifications. The OR function is performed at outlet  $O_1$ , in Figure 3 if the bias supply is of low enough value for either  $C_1$  or  $C_2$  to divert the power jet from its undisturbed flow to  $O_2$ . When the control jet shuts off the bias supply returns the power stream to  $O_2$ .<sup>4</sup> The NOR function is performed at  $O_2$  during the operation of OR at  $O_1$ .

The AND function is easily obtained by increasing the bias flow to  
(Continued on page 24)

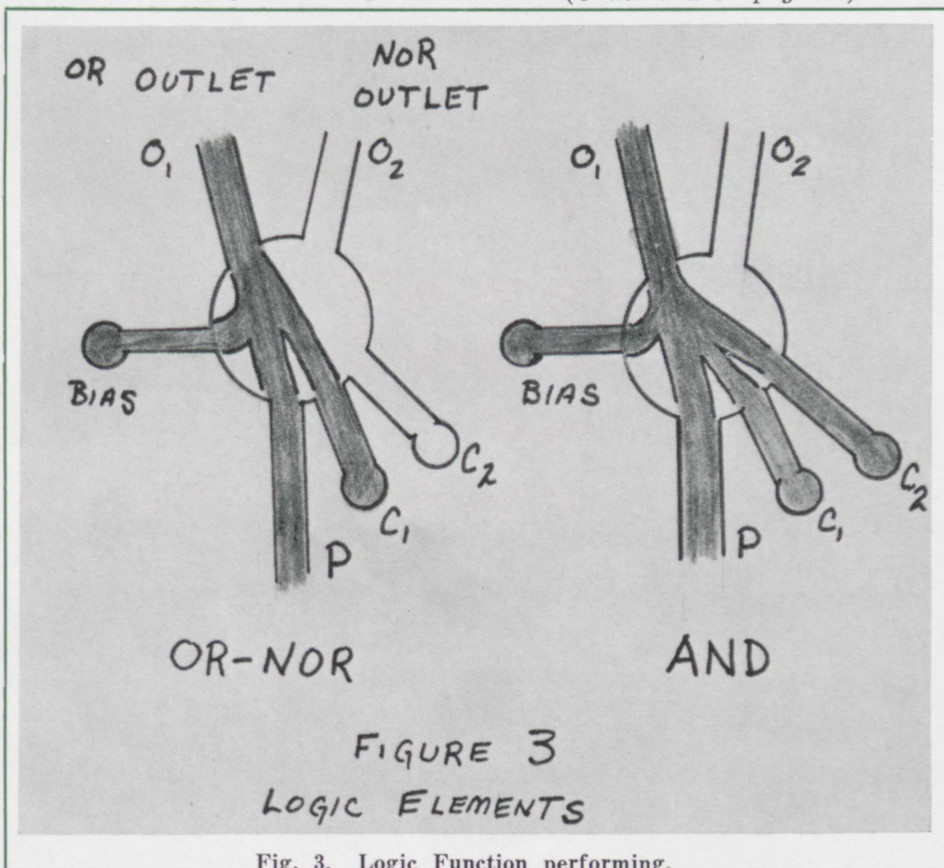
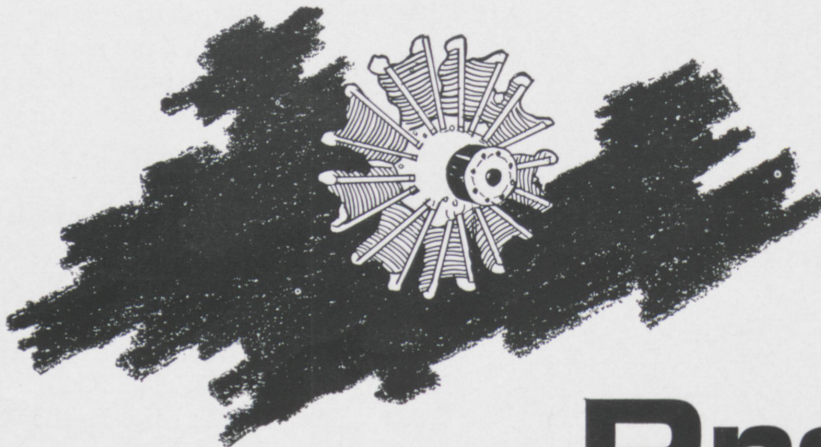


Fig. 3. Logic Function performing.

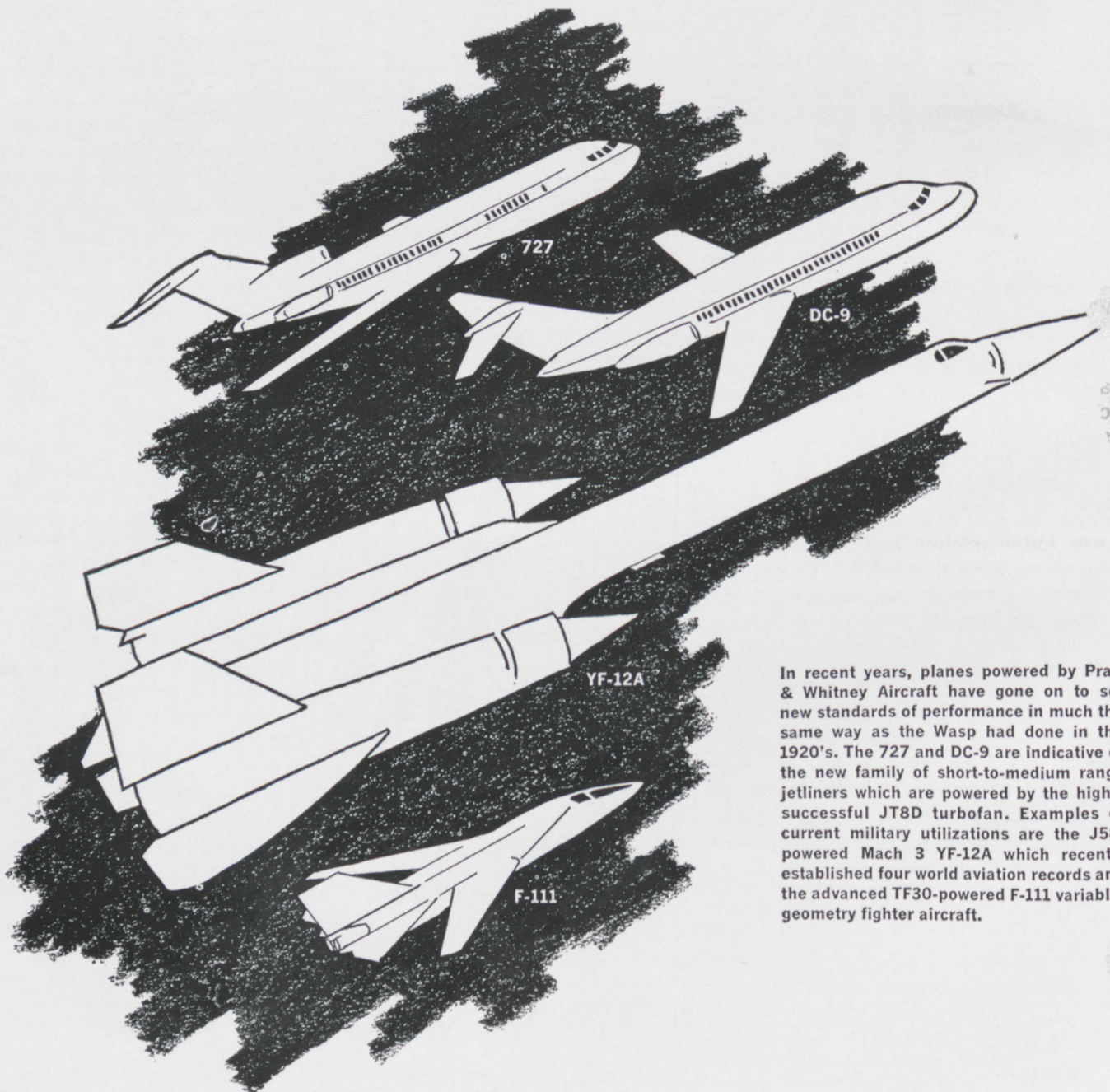


# Past



The Company's first engine, the Wasp, too, to the air on May 5, 1926. Within a year the Wasp set its first world record and went on to smash existing records and set standard for both land and seaplanes for years to come, carrying airframes and pilots higher, farther, and faster than they had ever gone before.

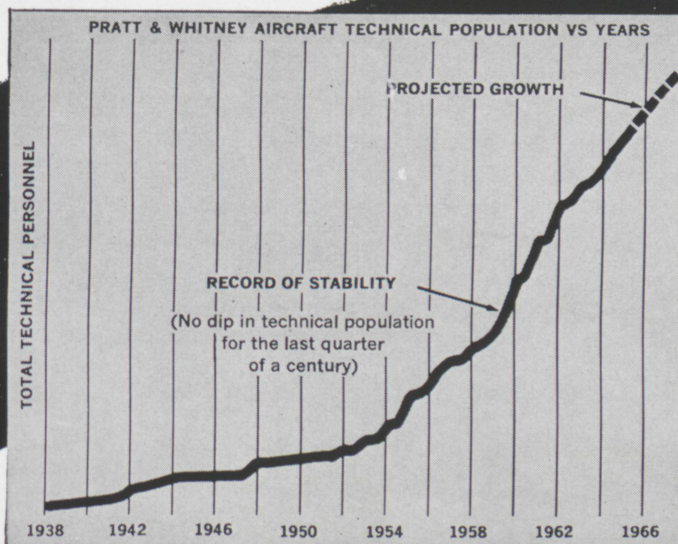
# Present



In recent years, planes powered by Pratt & Whitney Aircraft have gone on to set new standards of performance in much the same way as the Wasp had done in the 1920's. The 727 and DC-9 are indicative of the new family of short-to-medium range jetliners which are powered by the highly successful JT8D turbofan. Examples of current military utilizations are the J58-powered Mach 3 YF-12A which recently established four world aviation records and the advanced TF30-powered F-111 variable-geometry fighter aircraft.



# Your and the Future



Take a look at the above chart; then a good long look at Pratt & Whitney Aircraft—where technical careers offer exciting growth, continuing challenge, and lasting stability—where engineers and scientists are recognized as the major reason for the Company's continued success.

Engineers and scientists at Pratt & Whitney Aircraft are today exploring the ever-broadening avenues of energy conversion for every environment... all opening up new avenues of exploration in every field of aerospace, marine and industrial power application. The technical staff working on these programs, backed by Management's determination to provide the best and most advanced facilities and scientific apparatus, has already given the Company a firm foothold in the current land, sea, air and space programs so vital to our country's future. The list of achievements amassed by our technical staff is a veritable list of firsts in the development of compact power plants; dating back to the first Wasp engine which lifted the United States to a position of world leadership in aviation. These engineering and scientific achievements have enabled the Company to obtain its current position of leader-

ship in fields such as gas turbines, liquid hydrogen technology and fuel cells.

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# For December



To take the chill from those cold winter days ahead, the Technic staff presents Miss Denny Hubbell as December's Miss Technic.

A junior at ISU, Denny is taking liberal arts. This 5'4" beauty is fond of water skiing and music and is a native of Speedway. "Gentlemen, start yer engines!"

Denny's curvacious parameters of 35-23-35 will certainly effect any engineer's heat transfer coefficient, conduction or radiation.



# library notes

by HERMAN COLE  
Librarian

Following are the bibliographic entries for a random sampling of some of the new books that were added to the library since the last column in the Rose Technic. . . .

BIOTECHNOLOGY: CONCEPTS AN APPLICANTS, by Lawrence Fogel. Prentice-Hall, 1963.

COMPLEX ORGANIZATIONS; A SOCIOLOGICAL READER, by Amitai Etzioni. Holt, 1961.

SYMBOLIC LEADERS: PUBLIC DRAMAS AND PUBLIC MEN, by Orrin E. Klapp. Aldine Pub. Co. 1964.

THE PHILOSOPHY OF LAW IN HISTORICAL PERSPECTIVE, by Carl Friedrich. Univ. of Chicago Press, 1958.

THE INDEPENDENT STUDY PROGRAM IN THE STATES, by Robert Bonthius. Columbia University Press, 1957.

THE REVOLT OF THE COLLEGE INTELLECTUAL, by Everett Hunt. Human Relations Aids, 1963.

PERTURBATION TECHNIQUES IN MATHEMATICS, PHYSICS, AND ENGINEERING, by Richard Bellman. Holt, 1964.

STATISTICAL METHODS IN BIOLOGY, by Norman Bailey. English Univ. Press, 1959.

ATOMIC THEORY OF GAS DYNAMICS, by John W. Bond. Addison-Wesley, 1965.

DEVELOPMENTS IN HEAT TRANSFER, by Warren Rohsenow. M.I.T. Press, 1964.

THERMAL CONDUCTIVITY OF GASES AND LIQUIDS, by Nikolai Tsederberg. M.I.T. Press, 1965.

MOLECULAR THERMODYNAMICS, by James A. Fay. Addison-Wesley, 1965.

ROBERT OPPENHEIMER, THE MAN AND HIS THEORIES by Michel Rouze.

DICTIONARY OF RE-ELECTRON CALCULATIONS, by C. A. Coulson. Freeman, 1965.

COMBUSTION THEORY, by Forman Williams. Addison-Wesley, 1965.

ANTHROPOLOGY; CULTURE PATTERNS & PROCESSES, by Alfred Kroeber. Harcourt, 1963.

RADIOTRACER METHODOLOGY IN BIOLOGICAL SCIENCE, by Chih Hsing Wang. Prentice-Hall, 1965.

THE IMMENSE JOURNEY, by Loren Eiseley. Random House, 1957.

BIOLOGICAL EFFECTS OF MAGNETIC FIELDS, by Madeleine F. Barnothy. Plenum Press, 1964.

MEDICAL PHYSICS, by Otto Glasser. Year Book Publisher, 1944-60.

VECTOR ELECTROCARDIOGRAPHY, by Herman Uhley. Lippincott, c1962.

PRINCIPLES OF BIOASTRONAUTICS, by Siegfried Gerathewohl. Prentice-Hall, 1963.

ELEMENTS OF MECHANICS OF ELASTIC SOLIDS, by Wei, Lai. Addison-Wesley, 1965.

INFORMATION THEORY AND ITS ENGINEERING APPLICATIONS, by David A. Bell. Pitman Pub. Corp., 1962.

THE AGE OF ELECTRONICS, by M. I. T., McGraw-Hill, 1962.

MECHANICS AND THERMODYNAMICS OF PROPULSION, by Philip G. Hill. Addison-Wesley, 1965.

BASIC SERVOMECHANISMS, by Edward Bukstein. Holt, 1963.

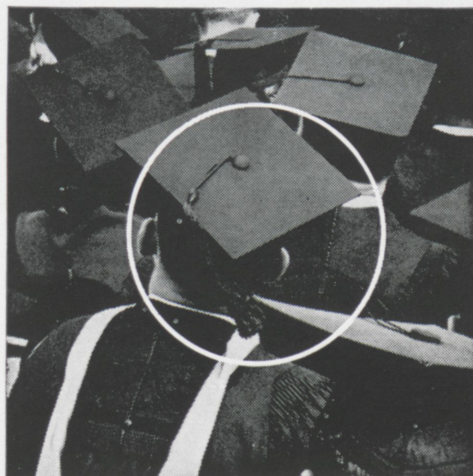
DICTIONARY OF DATA PROCESSING, by Lillian Trollhann. Elsevier, 1964.

IS PARIS BURNING?, by Larry Collins. Simon & Schuster, 1965.

KENNEDY, by Theodore C. Sorensen. Harper & Row, 1965.

THE MAKING OF THE PRESIDENT, 1964, by Theodore White. Atheneum, 1965.





## John Lauritzen wanted further knowledge



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John attended one of Western Electric's three Graduate Engineering Training Centers and graduated with honors. Now, through the Company-paid Tuition Refund Plan, John is working toward his Master's in Industrial Management at Brooklyn Polytechnic Institute. He is currently a planning engineer developing test equip-

ment for the Bell System's revolutionary electronic telephone switching system.

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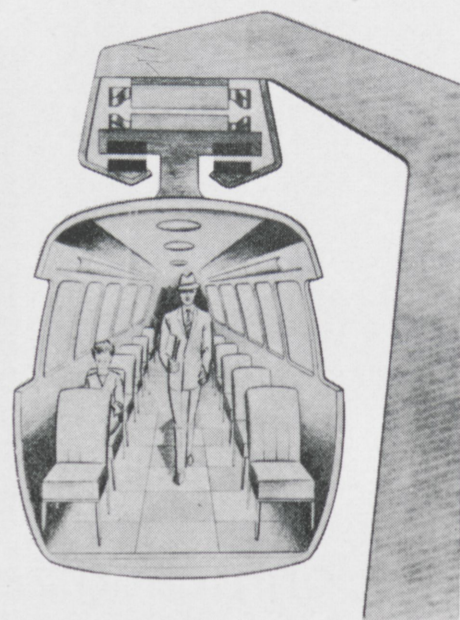
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# R & D

## Westinghouse MAGNETIC HIGHWAY

edited by Bob Johnson



Magnetic Highway

Commuters someday may be riding over an elevated "magnetic" highway in cars without wheels. The system would float the vehicle magnetically and drive it with an electric motor that has no rotating parts. Thus, the magnetic highway would take over the two basic functions of the wheel in transportation systems—supporting the vehicle and transmitting the power needed to make it move.

To demonstrate the principle of the magnetic suspension system, a small, one-passenger vehicle has been constructed at the Westinghouse Research Laboratories. The feasibility of the proposed linear, non-rotating electric drive was established by Westinghouse some 20 years ago.

The laboratory test vehicle is supported by strong, ceramic-type permanent magnets placed lengthwise along the underside of the vehicle. Similar magnets, of the same polarity, form a double track beneath it.

Since magnets of like polarity repel each other, the experimental car floats about one-fourth of an inch above its magnetic track. There is no physical contact and, therefore, no friction between the vehicle and its magnetic rails. The vehicle simply "rides" on a layer of air.

"While not yet a proven system of vehicle suspension, the use of permanent magnets merits consider-

ation for future systems because of several potential advantages," Ray H. Fields, manager of the Westinghouse transportation systems department, pointed out.

"Magnetic suspension would provide vehicles with excellent riding qualities; it would reduce propulsion power requirements; it would eliminate noise; and it would push land travel above 150 miles per hour.

"Data from our laboratory model show that freight and passenger loads comparable to those transported by present methods of transit can be supported by such a magnetic suspension."

A magnetic suspension system requires that the magnets not only be strong, but also be extremely resistant to loss in strength over extended periods of time. New ceramic materials, commonly known as "ferrite" permanent magnets, have the strength to supply the necessary force of repulsion, or lift, and they resist magnetic loss, or demagnetization, some three to five times better than materials available only a few years ago.

"In a full-scale system, the vehicle would likely be suspended from overhead, instead of being supported from below as in the laboratory test model," Mr. Fields said. "The magnetic suspension and electric drive thus could more easily be shielded

from the weather.

"The stator, which is the stationary part of any electric motor, would be stretched out lengthwise and would be mounted on the overhead roadway structure. The rotor, which ordinarily is made to rotate, would also be constructed in linear form and would be mounted atop the vehicle, directly beneath the stator. Electricity, flowing in the stator, would drag the rotor and the attached vehicle ahead, for the same reason that it spins the rotor in a conventional electric motor."

Ray H. Fields cited the magnetic highway as typical of the "bold, new ideas that are emerging for the improved mass movement of people."

"New technologies—for example, automatic control by electronic computer—are increasingly being incorporated into modern rapid transit systems, with the aim of making them faster, safer, more comfortable and more convenient," he said. "Today's broad growth in science and technology assures that this trend will continue; we can expect to see entirely new concepts of mass transportation come from this investment in research.

"The magnetic highway is such a concept. It appears to have promise for high-speed, point-to-point, intercity land transportation systems of the future."





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## FLUID AMPLIFIERS

(Continued from page 15)

the point that  $C_1$  and  $C_2$  must be on to divert the power jet to  $O_1$ . With the OR, NOR, and AND logic functions available, many control problems may be solved with fluid systems at a savings in investment and an improvement in reliability. Where high switching speeds are not necessary flip-flops costing about 10¢ each may soon replace its electronic counterpart which costs about \$3.00 each.

### PROPORTIONAL AMPLIFIERS

Digital control is fine for many applications, but continuous proportional control is often desired. We can readily obtain a proportional fluid amplifier from our basic flip-flop. As noted earlier the stream interaction region geometry is the major difference between digital and proportional fluid amplifiers. By making two lobes in the interaction region as shown in Figure 4a, it is possible to prevent wall attachment. The flow or pressure differential between  $C_1$  and  $C_2$  is amplified and

appears as a flow or pressure differential between the outlets  $O_1$  and  $O_2$ . Figure 4b displays the amplifier's transfer characteristics.<sup>5</sup> The difference amplifier is a very natural device to use as an error detector, where  $C_1$  is established as a reference and the pressure difference between  $O_1$  and  $O_2$  is an error signal.

### APPLICATIONS

**Rocket Engine Control** — Present rocket steering systems involve adjustment of nozzles, vanes or the whole combustion chamber. These devices are relatively complicated mechanically and require a great deal of power to operate. In addition, the response times are slow, and moving parts are always subject to failure. A fluid control device, which operates on the rocket exhaust jet, itself, attacks the problem in a very direct manner. The large exhaust jet is controlled by a small control jet and the power stream which  $C_1$  and  $C_2$  control is taken from the combustion chamber. The control jets are controlled by sole-

noid valves which open and close on signals from the rocket's guidance system.

**Torpedo Control** — The Navy has been involved in research in fluid control applications since about 1960. Several operating systems resulted from the research effort. A fluid system was developed to replace electronic control in torpedoes. In the conversion scheme, components were substituted on a functional basis rather than on a one-to-one substitution.<sup>7</sup> High cost and unnecessary fast switching speeds of the electronic control motivated conversion to fluid control. Here fluid control has the advantages of saving space, indefinite shelf life, insensitivity to shock, and lower mass production cost.

**Turbine Speed Control** — In another investigation of fluid amplifier applications the Navy developed a steam turbine which was controlled by a hybrid fluid system.<sup>8</sup> Analog components include an oscillator, a best frequency detector and a pro-

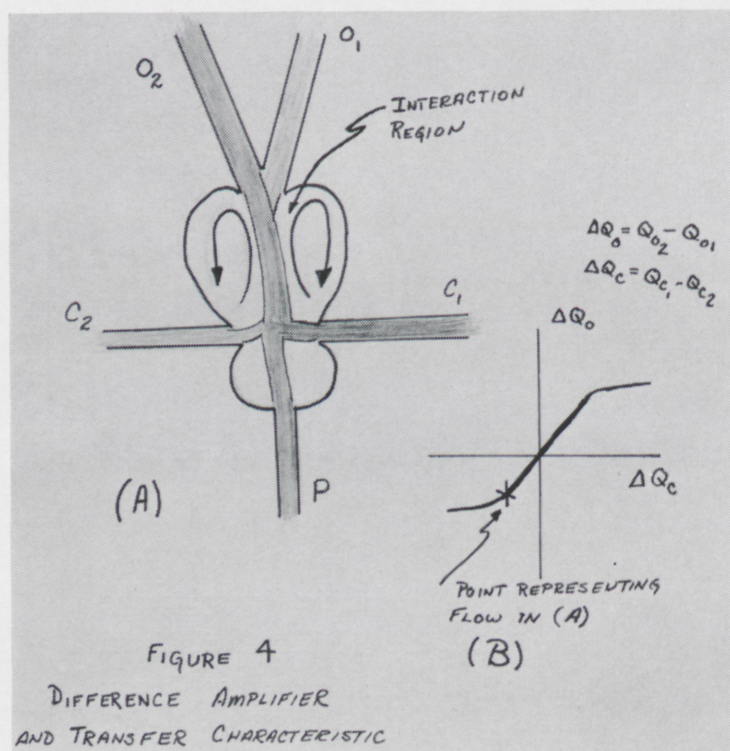


Fig. 4. Amplifier transfer characteristics

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portional power amplifier. The power amplifier is used to inject a retarding flow then the throttle is cut back. Digital components include a resettable counter and NOR logic to control a digital throttle.

#### MANUFACTURING TECHNIQUES

The materials used to produce fluid amplifiers depend on the working fluid, operating temperatures and pressures, and mechanical shock. Materials such as glass, thermo-setting plastic and metals which are easily machined are the most desirable production materials. If the working fluid is at low pressure, amplifiers may be injection molded from plastic at very low costs. Glass components and ceramic components have great promise for amplifiers whose working fluid is corrosive or very hot gases. Glass elements are easily produced by photo-etching processes similar to printed circuit techniques. After etching the open channels may be covered by heat sealing a glass cover to the channel substrate. The heat sealing tech-

nique provides a strong, tight mechanical seal. Standard machining techniques may be used on metal amplifier elements. Other metal shaping methods may also be used. Die casting and electro-erosion are possibly the most interesting of the proposed processes.

#### SUMMARY

Fluid amplifiers have many applications in control systems. Fluid amplifiers are simple, reliable, and inexpensive means of control. At the present time electronic control is more expensive and reliable in temperatures ranging from  $-50^{\circ}\text{C}$  to  $+150^{\circ}\text{C}$ , but environments cannot always be in that range. In unusually poor environmental conditions electronics systems become troublesome. Electronic control breaks down in the vicinity of ionizing radiation, but fluid systems are relatively undamaged. Thus, in the weapons and space efforts fluid control has many possibilities. Industrial control of automatic machines, conveyors, and chemical processes

hold great promise for fluid systems due to the simple operation and power consumption. Electronics will not disappear as an important method of control, but fluid amplifiers will begin to do some of the jobs that electronics cannot for physical or financial reasons.

#### FOOTNOTES

<sup>1</sup>Fluid Amplifiers; Capabilities and Application, W. E. Gray and Hans Stern, Control Engineering, vol. 11, February 1964, p. 57

<sup>2</sup>Fluid Amplifiers Now, Control Engineering, vol. 11, September 1964, p. 75.

<sup>3</sup>Fluid Control Devices, Stanley W. Anrist, Scientific American, vol. 211, February 1964, p. 83.

<sup>4</sup>Fluid Amplifiers, Control Engineering, February 1964, p. 60.

<sup>5</sup>Ibid p. 60

<sup>6</sup>Fluid Control Devices, Scientific American, February 1964, p. 84.

<sup>7</sup>Fluid Amplifiers, Capabilities and Application, p. 63.

<sup>8</sup>Ibid, p. 64.

## CIVIL ENGINEERS:

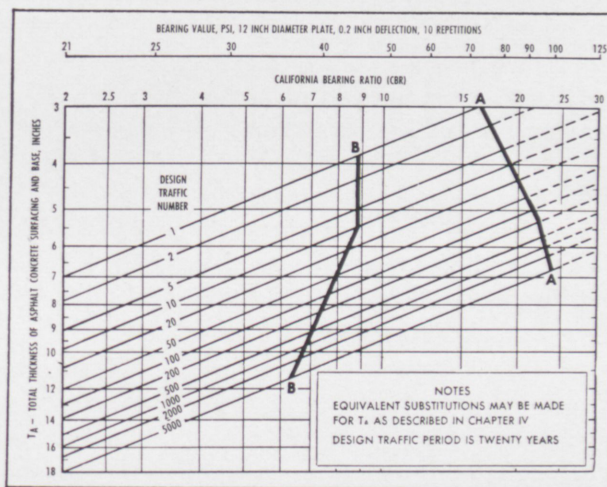
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\*Asphalt Surface on Asphalt Base



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## HUMAN SPIRIT

(Continued from page 11)

killers, and pesticides, the development of suitable plant varieties, and sound marketing.

Another case in point is the study undertaken by our Center for International Studies at M.I.T., jointly with the General Electric Company, to determine the feasibility of certain electrification projects in India and in South American areas. This joint effort on the part of social scientists and engineers concluded that such electrification would not be economic and thus they were able to save large sums of money for the countries involved.

For a most interesting example of the secondary effects of technological development on societies and on international relations, I am indebted to Henry M. Boettinger of the American Telephone and Telegraph Company. He has called attention to one of the underlying causes of what is currently happening in the Arab world; where we note today a growing sense of destiny; nationhood and unity, some of it creating problems for our own foreign policy. He reports that a perceptive journalist has explained the sudden renaissance of Arab unity after a lapse of nearly a thousand years as being greatly influenced by the Japanese transistor radios distributed widely in that area. The journalist pointed out that "every camel driver, every oasis, every little village now had Japanese transistor radios which tuned to the Voice of the Arabs, the characteristic name for Radio Cairo. . . . Now these widely scattered people, many illiterate, are suddenly able to receive a message in their own tongue which calls them to power and glory." When Brittain, Bardeen, and Shockley were inventing the transistor around 1948, they hardly visualized this ultimate kind of impact of their invention.

Fifth, increases in population, growing urbanization, and the deterioration of urban environments are together creating undesirable changes in our urban life. Indeed,

we face a crisis in avoiding blight and the dehumanization of our crowded cities.

All about us today we see the encroachment of ugliness and crass utility on the beauty and benignity of our living environment. We are in a constant struggle against ugliness and bad taste, with ugliness too often triumphing. We see our wilderness areas invaded and our streams and harbors polluted. We see ugly structures built and land developments misplanned that in the long run can only be an economic waste and hurtful to the human spirit. We are in the midst of changes in which America the beautiful is in danger of becoming America the slum and America the blotched, unless courageous citizens and especially courageous engineers and economists and architects and politicians, both as professional men and as citizens, are willing to stand up and work and vote for a new level of humaneness and benignity and conservation in our land.

If our society is to alleviate these ill effects of population growth, bad planning, bad taste, and misused technology, the engineer must bring to the battle his special insights and specialized competence, his knowledge of technological trends and alternatives, pooling them with the specialized insights and competencies of other kinds of concerned professional men, including the politicians.

We hear too often today the excuse that the misuse of technology is not the responsibility of the scientists and engineers who create it but rather of those nonscientists and non-engineers who misuse it. The new engineer of whom I speak believes that this is not a defensible position for any professional man to take in our society. On the contrary, he believes that, if the engineer is to be genuinely professional, he must be concerned with the social impact of his labors. He must feel his responsibility to join with other professional men in shaping technology to enrich the human condition and not to dehumanize it.

When beautifully conceived and designed communications systems, such as TV, are put to tawdry and meretricious use, the engineer, no less than sociologists or ministers, has a responsibility to speak up for higher standards of taste.

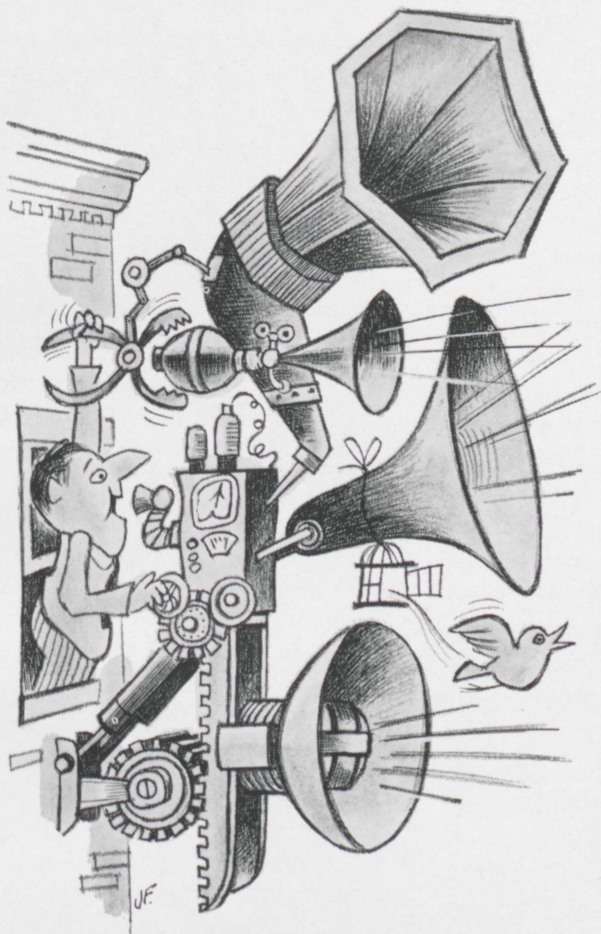
When a new highway, even though competently engineered, destroys recreational areas, or in other ways does avoidable damage to communities in its path, or in ugly and hurtful to the human spirit, engineers in that community share a responsibility to seek better solutions. Some of my colleagues at M.I.T., notably Professor Kevin Lynch, who have been studying the visual aspects of roads, emphasize the possibility of designed highways to enhance the visual quality of a city and to be more nearly works of art.

When engineer-designed plants or devices, through improper use or regulation, pollute our air or waters or cause avoidable hazards to man, the engineer, with his specialized understanding of these plants and devices, has a responsibility to give other citizens the professional insights he, and only he, can bring to the problem and join them in seeking solutions. When advancing technology, even though it be temporary, causes dislocations and loss of jobs, the engineer must share in the management responsibility of cushioning the effects of the technological change he produces. He should not be neutral or indifferent or take the position that engineers can be responsible only for the quality of the engineering and not for its social consequences.

I am not trying to encourage engineers to move out of industry or education into government or other kinds of public service in a way that would reduce the engineering strength of any field. I am arguing for their immense contributions to the common account and a greater recognition by engineers themselves of the unfolding opportunities for still greater service in the public domain. Our objective should be to

(Continued on page 28)





Yell it out the window!



... or whisper it over his MOTRAN Radio\*

## THE PROBLEM: HOW CAN YOU BE

SURE YOUR MAN IN THE TRUCK MAKES THE SECOND STOP FIRST?

You might try the megaphone if you're not too concerned about the message. But if it's one that *has* to get through . . . better you flip a switch and tell it to him over his Motorola MOTRAN 2-way radio.

As a matter of fact, for any 2-way communications problem, Motorola engineers more than likely have the solution . . . or they'll find it. They've been in

the business since it began, and just about every significant development in 2-way radio since 1940 has been by Motorola.

It was no small task to design a pocket-sized radio pager that could reach a doctor 20 miles away on a golf course.

Motorola did *that* too!

\*MOTRAN — Motorola Mobile 2-way Transistor Radio

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## HUMAN SPIRIT

(Continued from page 26)

have enough engineers well enough educated to serve the needs of the civilian sector as well as of the governmental sector for engineers. It is especially important today that scientists and engineers not be diverted from our civilian economy in a way that would weaken the technological strength of this sector in the face of increasing competition from abroad, and we must be aware of our current acute shortage of teachers of engineering.

Neither do I urge that all engineers should include service in the public arena in their career patterns. There must always be an honorable estate and ample opportunity for those engineers whose talents are most productive when narrowly applied. Many creative minds find themselves most creative when working in monastic seclusion or highly specialized ways. And the engineer's first responsibility is to be competent as an engineer.

I emphasize finally that I have no sympathy with "techocracy" or any other concept of society that fails to recognize that government decision-making must be in the hands of political leaders accountable to the public. These political leaders in the end must rely on their own good judgment, insights, and values, but increasingly, as our society grows more technologically complex, they find it helpful to call upon specialists and scholars for expert advice. Increasingly, our political leaders draw upon expert counsel from all the great disciplines—from science, engineering, social sciences, and humanities—favoring none above the other except the one most relevant and useful for the problem at hand.

The engineering profession has a place of its own in the public service because of that diversity of roles among its members which I have noted, a many-sidedness that encompasses a concern for men as well as things, the humanities as well as science. The engineer has a style, a professional individuality arising out

of this range of interests. He is marked by a commitment to be innovative while giving his creative accomplishments practical utility. He is concerned with feasibility, manufacturability and reliability; and is accustomed to weighing the value of his works against their costs, to meeting schedules and budgets, to making judgments about priorities and choices among technological alternatives. But he is also expected to be sensitive to humane values in discharging these essential utilitarian tasks. He is expected to mobilize, lead, and inspire the loyalties of the men required to achieve these other objectives.

What I have been describing is a new kind of engineering—Simon Ramo has called it "the greater engineering"—deeply committed and sensitively attuned to the humanistic goals of our society. This kind of engineering, as a tie between science and the humanities, stands for a technology shaped, disciplined, and controlled first and last to enhance, not to corrode, humanity.

**MEN**

**of  
ROSE**

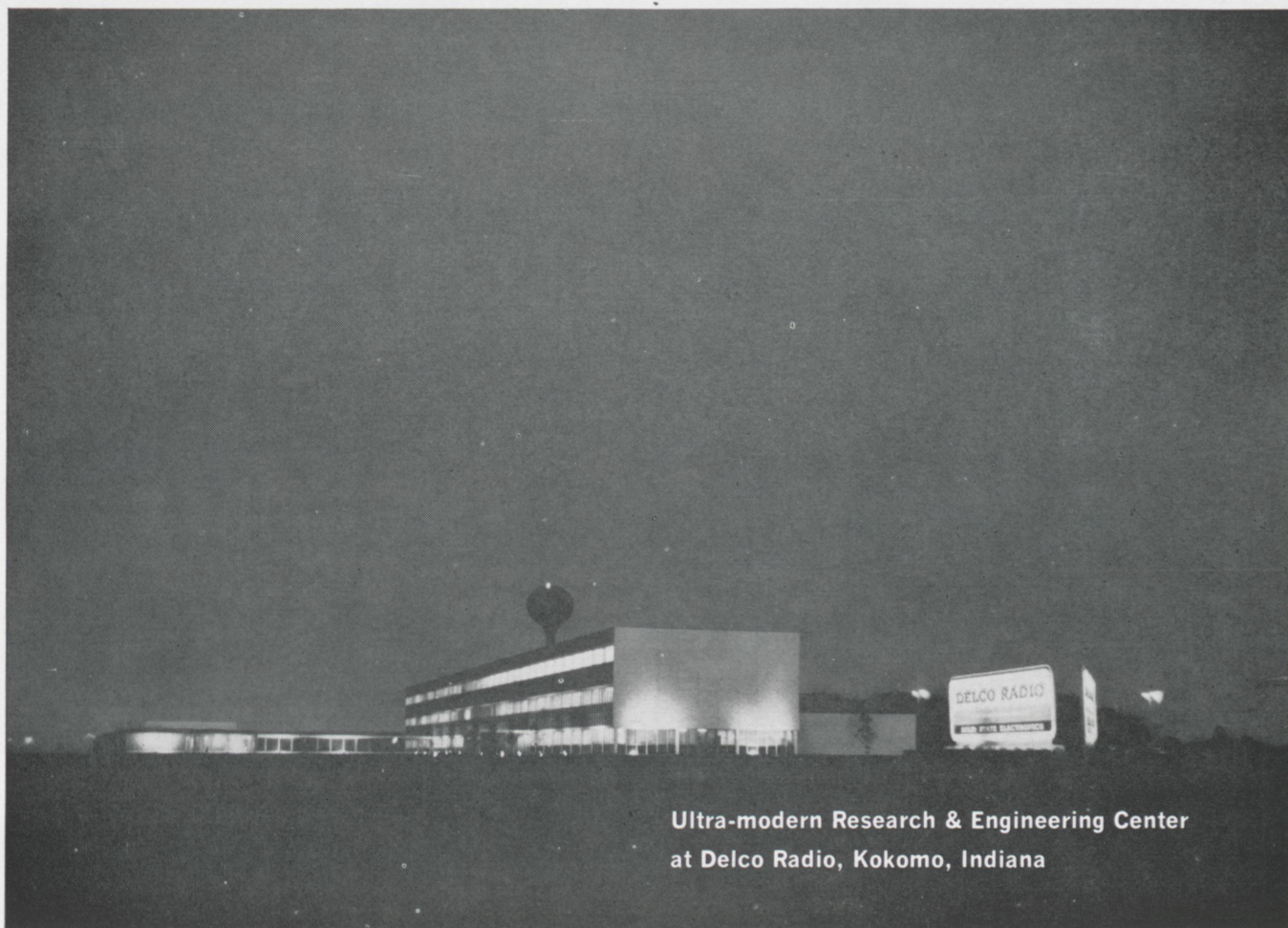
Remember that  
Special Occasion

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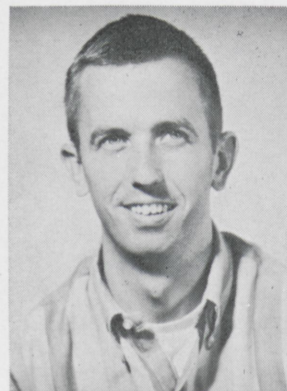
# SPORTS

## Un-illustrated

by

DENNY

LIND



Denny Lind is a senior majoring in mathematics. He comes from Brooklyn, Indiana. He is a member of the Rose cross-country team and of Lambda Chi Alpha fraternity.

Both the cross country and the football teams finished the season with winning records; both were 5-3. They continued the streak started last spring by the baseball and golf teams. The golf team won the conference championship and the baseball team tied for first in the conference.

The cross country team was led by captain and M.V.P. John Lynn and his younger brother Larry. They finished one and two in all meets except one, the Wabash meet. They were supported by Larry Sachs, senior from Indianapolis; Don Gregurich, Freshman; Tom Foltz, Sophomore; Larry Olson, Freshman; Len Duszynski, Sophomore; and Jack Braun, Senior.

In the final game, the football team fulfilled two of their season's goals, a winning season and a victory over Hanover. Three outstanding seniors played their last game for Rose. Quarterback Gib Bosworth completed 60 out of 158 passes attempted for 831 yards and was named the "outstanding back" on this year's team. Three year letterman Joe Tynan was the third leading receiver with 10 receptions good for 135 yards. Bill Lewis, Senior fullback and middle linebacker, was named the "most valuable player" for the third straight year and also

was named to the all PCC team. Bill led the team in defensive points by an overwhelming margin.

Joining Lewis on the all PCC team were end John Ward (14 receptions for 191 yards, guard Jack Mehok (named the outstanding lineman for the Rose team), center John Shambach, and defensive halfback Ben Bradburn. Two freshmen, Lon Minarich and Charles Hills, were responsible for most of the ground work on this year's team. Minarich ran the ball 127 times for 493 yards, 3.88 a carry. Hills gained 309 yards from his halfback spot in 90 carries, a 3.43 average. Mike Mefford, sophomore from Bloomington, was the leading receiver with 23 receptions good for 342 yards. Two sophomores Steve Mueller and Terry Joyce were second and third in defensive points behind Lewis.

This year's basketball team should be slightly stronger for two reasons 1) With one exception, the same men are back that played last year and they are one year older in a valuable area, experience. 2) For the first time since Coach Mutchner has been at Rose, the team has legitimate depth. Back for another year is MVP Tom Curry, who led the team in rebounding and scoring last year and who will serve as team captain this year. Coach Mutchner expects Curry will get off to a slow start

because of a jaw injury sustained in a fraternity football game which has forced him to wear a softball mask. Also returning is 6-2 sophomore Jim Pettee who has been moved to guard to add more height to the team and thus far has made the adjustment real well. Jerry Wones, 6-2 sophomore from Dayton, Ohio, and 6-4 Tom Michaelis will team with Curry at forward. Center will be handled by 6-4 George Shaver and 6-4 Dave Shewmaker. At the other guard spot will find 5-9 junior Joe Trueblood, 5-10 sophomore Dave Yeager and 5-11 freshman Eric Dany.

Rounding out the ball club will be freshman Jim Tucker, 6-3 freshman Hugh Crome, 5-11 freshman Jack Uhlenbrock, 6-1 sophomore Don Baker, 6-0 freshman Rex Stockwell, and 5-10 freshman Alan Heath.

Coach Mutchner was quoted as saying, "The fans can expect this year's team to run more because they will be able to rebound better. If we can get off to a decent start this year, we might surprise a few people along the way."

On the team's three game trips in New York state against Rensselaer Poly, New York Tech, and Brooklyn Poly, the team plans to see Niagara Falls, tour New York from top to bottom, and visit Philadelphia on their way back.



Thus, the appropriate Hilbert space in the Schrodinger picture is a *function space*.

Suppose we write

$$v(t) = u e^{-iEt/\hbar}$$

where  $u$  is an abstract vector not depending on time, and  $E$  is a scalar which has the dimensions of energy. Hence,  $e^{-iEt/\hbar}$  is a scalar, and

$$Hv = He^{-iEt/\hbar} u = e^{-iEt/\hbar} Hu.$$

As a result,

Schrodinger's equation becomes

$$(2-7) \quad Hu = Eu$$

This equation, called the *time-independent wave equation*, is an eigenvalue equation for the operator  $H$ . The eigenvalue is  $E$ , and the corresponding eigenvector is  $u$ .

In the Schrodinger picture we let the operator  $P$  be  $\frac{\hbar}{i} \frac{\partial}{\partial x}$  and the op-

erator  $X$  be simply  $x$ . Making these substitutions in (2-6) gives for the Hamiltonian operator

$$(2-8) \quad H = -\frac{\hbar^2}{2m} \frac{\partial^2}{\partial x^2} + U(x)$$

The reader may verify that

$$(2-9) \quad \frac{\hbar x \partial u}{i \partial x} - \frac{\hbar \partial x u}{i \partial x} = i\hbar u,$$

$$[x, \frac{\hbar}{i} \frac{\partial}{\partial x}] = i\hbar I,$$

and, therefore, (2-5) is satisfied.

Employing (2-8) and letting the abstract vector  $u$  be a function  $u(x)$ , (2-7) becomes

(2-11)

$$-\frac{\hbar^2}{2m} \frac{\partial^2 u(x)}{\partial x^2} + U(x)u(x) = Eu(x).$$

Because  $H$  is Hermitian\* we know that the eigenvalues of (2-11) are real. These eigenvalues are the *energy eigenvalues* or *energy levels* of the system. In general there will be only a discrete number of energy levels,  $E_n$ , with their associated eigenvectors,  $u_n(x)$ ,  $n=1,2,3, \dots$ . The eigenvectors may be made into an orthonormal basis (Definition 5)

\*See, e.g., E. Merzbacher, *Quantum Mechanics*, John Wiley, 1961.

which means that any function  $\psi(x)$  may be written as

(2-12)

$$\psi(x) = \sum_{n=1}^{\infty} a_n u_n(x),$$

where the constants  $a_n$  are given by

(2-13)

$$a_n = \langle \psi | u_n \rangle = \int (x) u_n^*(x) dx.$$

The integral appearing in (2-13) defines a perfectly good inner-product on the Hilbert space of functions  $\psi(x)$ ,  $u_1(x)$ ,  $u_2(x), \dots$

Because the  $u_n$  form an orthonormal basis, (2-12) tells us that

(2-14)

$$\langle \psi | \psi \rangle = \left\| \sum_{n=1}^{\infty} a_n u_n \right\|^2 = \int \psi(x) \psi^*(x) dx = \sum_{n=1}^{\infty} |a_n|^2$$

(see Definition 5). If we let  $\|\psi\| = 1$ , which means that each  $|a_n| < 1$ , but that the sum over all  $n$  is equal to unity, we can interpret the number  $|a_n|^2$  as being the *probability that the system is in the  $n$ th eigenstate*. This completes our description of the Schrodinger picture.

We go from the Schrodinger picture to the Heisenberg picture by first requiring that in the two pictures corresponding eigenvalues and probabilities must be equal. Hence,

(2-15)

$$\langle \bar{x} | \bar{A}(t) | \bar{x} \rangle = \langle x | Ax \rangle$$

where  $x$  is any state vector referred to the Heisenberg picture,  $A(t)$  is a (time-dependent) operator in the Heisenberg picture,  $x$  is the same state vector in the Schrodinger picture, and  $A$  is the same operator in the Schrodinger picture. Equation (2-15) states, in effect, that measurements of physical quantities must yield the same results in the two pictures.

To proceed with (2-15) we define an operator,  $U(t)$ , satisfying

(2-16)

$$(a) \quad -i\hbar \frac{dU}{dt} = UH$$

$$(b) \quad i\hbar \frac{dU^\dagger}{dt} = HU^\dagger.$$

Again,  $H$  is the Hamiltonian oper-

ator, and  $U^\dagger$  is the adjoint operator associated with  $U$ . We postulate

(2-17)

$$(a) \quad x = U^\dagger \bar{x}$$

$$(b) \quad \bar{x} = Ux,$$

which means that  $U^\dagger U = UU^\dagger = I$ , the identity operator.

Upon substituting (2-17) into (2-15) we get

(2-18)

$$\langle \bar{x} | \bar{A} \bar{x} \rangle = \langle U^\dagger \bar{x} | AU^\dagger \bar{x} \rangle = \langle \bar{x} | UAU^\dagger \bar{x} \rangle,$$

the second equality following from Definition 7 of the adjoint of an operator. If (2-18) is to be true for all state vectors,  $\bar{x}$ , we require that

(2-19)

$$\bar{A} = UAU^\dagger.$$

This is the transformation law for operators in the two pictures and corresponds to (2-17) for state vectors.

If we differentiate (2-19) formally as though each quantity were a conventional function of time (rather than an operator), we obtain

(2-20)

$$\begin{aligned} \frac{d\bar{A}}{dt} &= \frac{dU}{dt} AU^\dagger + U \frac{dA}{dt} U^\dagger + UA \frac{dU^\dagger}{dt} \\ &= \frac{1}{i\hbar} UHAU^\dagger + \frac{1}{i\hbar} UAHU^\dagger + \frac{\partial \bar{A}}{\partial t} \\ &= \frac{1}{i\hbar} (UAU^\dagger H - HUAU^\dagger) + \frac{\partial \bar{A}}{\partial t} \\ &= \frac{1}{i\hbar} (\bar{A}H - H\bar{A}) + \frac{\partial \bar{A}}{\partial t} \end{aligned}$$

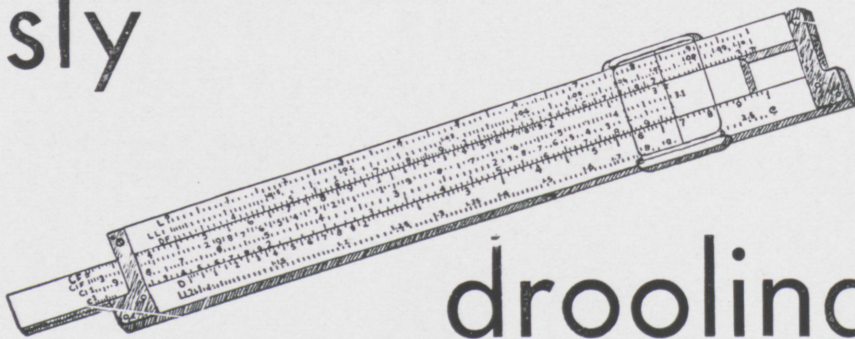
where  $\frac{\partial \bar{A}}{\partial t} = U \frac{dA}{dt} U^\dagger$  and we are as-

suming that  $H$  commutes with  $U$ , so that  $UH = HU$ . Equation (2-20) is called the equation of motion of the operator  $\bar{A}$  in the Heisenberg picture and shall be used often. Incidentally, because  $x$  satisfies Schrodinger's equation, (2-1), it may be easily proved by differentiating (2-17) (b) and using (2-16) (a)

that  $\frac{d\bar{x}}{dt} = 0$ . Thus, in the Heisenberg picture the state vectors are stationary in time, while the operators change in time. The opposite is true in the Schrodinger picture, although occasionally one finds operators which depend on time in this picture.



sly



# droolings

Stolen by Chuck Risch, Jr. M.E.

These days, too many beautiful women are spoiling their attractiveness by using four-letter words—like don't, and can't, and won't.

\* \* \*

Two goldfish in a bowl were talking. They were discussing religion and finally one said in disgust, "But if there's no God, who changes the water every day?"

\* \* \*

Having been married 20 years, a couple decided to celebrate by taking a little trip. While talking over their plans one evening, the husband now and then glanced into the next room where a little old lady sat knitting. "The only thing," he said in a hushed voice, "is that for once I'd like to be by ourselves. I'd like to take this trip without your mother."

"My mother!" she exclaimed. "I thought she was your mother."

\* \* \*

The sergeant was explaining the new ammunition to a bunch of ROTC cadets like this: "This type of bullet will penetrate two feet of solid wood. So remember to keep your heads down."

Voice on phone: "John Smith is sick and can't come to class today. He requested me to notify you."

Professor: "All right, who is this speaking?"

Voice: "This is my roommate."

\* \* \*

"So you had a date with an engineer."

"No, I tore my dress on a nail."

\* \* \*

Two young sisters had been given parts in a Christmas play at

school. At dinner that night they got into an argument as to who had the most important role. Jody, aged 11, was very superior.

"Why, of course mine's the biggest part," she told five-year-old Ludy. "Anybody'll tell you it's much harder to be a virgin than an angel."

\* \* \*

Cop: "What're you doing on the streets at this hour?"

Drunk: "I'm going to a lecture."

Cop: "You won't find any lectures around here at 3 a.m."

Drunk: "Wanna bet? Follow me home!"

\* \* \*

Say it with flowers, say it with sweets,

Say it with kisses, say it with eats,

Say it with jewelry, say it with drink,

But never, oh never, say it with ink.

\* \* \*

Whoever said "Live and Learn" was a dreamer. In this school we have time to do one or the other, but never both.

\* \* \*

Cadet Col.: "Does your uniform fit satisfactorily?"

Basic Cadet: "Well, the jacket is okay, sir, but the pants are a little snug under the armpits."

\* \* \*

Then there was the groom who finished his wife's first breakfast, muttering, "Can't cook either."

\* \* \*

All it really takes to separate the men from the boys is girls.

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## Who creates the "star" that dances?

**The same Union Carbide  
that makes carbon floors  
for blast furnaces.**

With every change of light, the star in the Linde created Star Sapphire moves, shimmers, and dances—matching the brilliance and beauty of the fabulous star rubies and sapphires of the Far East.

At Union Carbide we grow these and other crystals every day—not only for use in jewelry, but also for use in electronic equipment. And for the past several years we've been growing crystals for the heart of the laser beam, the miracle light that can vaporize diamonds, perform eye surgery, and slice through metal.

We're growing in lots of directions. Our carbon floors for blast furnaces have reached the point

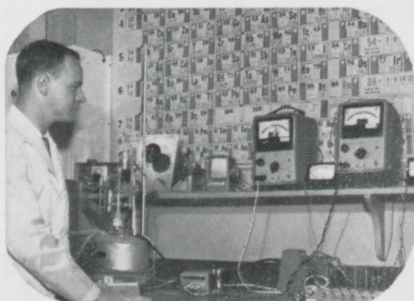
of wide acceptance by the steel industry. Our activated carbon is being increasingly used to purify and deodorize air in hospitals, homes and factories. And Glad Wrap, our new polyethylene wrapping for home use, is rapidly gaining popularity as a superior way to keep foods fresh longer.

To keep bringing you these and many other new and improved products, we'll be investing half a billion dollars on new plant construction during the next two years.

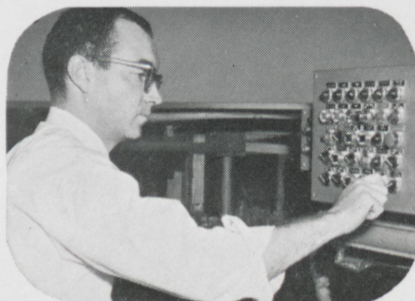




ONE RESULT of product innovation is G.E.'s modern manufacturing facility in Brockport, N. Y.



**OUTPUT VOLTAGES** from nickel-cadmium cells are examined by engineer John Bliven, BSEE, Union College '63 on assignment at G.E.'s Battery Business Section.



**PRODUCT RELIABILITY** of electric slicing knife components is the responsibility of Mike Reynolds, BSME, New Mexico State, a recent Manufacturing Training Program graduate.



**PRICE AND DELIVERY** information on nickel-cadmium batteries is supplied by Bob Cook, BSME, Univ. of Florida '65 on a Technical Marketing Program assignment in Gainesville.

A PREVIEW OF YOUR CAREER AT GENERAL ELECTRIC:

## Creating New Growth Businesses

At our Brockport, N. Y., plant, the new business of manufacturing cordless slicing knives is **rush**. So is that of the rechargeable-battery supplier, our two-year-old plant at Gainesville, Fla., which has just doubled its working area. Its sealed, nickel-cadmium batteries, in hundreds of shapes, sizes and ratings, are meeting growing customer demands in the consumer, defense, and aerospace industries—with applications from power tools to satellites. At General Electric, new ventures are a way of life. In both their formative and growth stages, these ventures call on the skills and

enthusiasms of experts in more than 120 product departments—in engineering, manufacturing and technical marketing. To define your career interest at General Electric, talk with your placement officer, or write us now. Section 699-15, Schenectady, N. Y. An Equal Opportunity Employer.

*Progress Is Our Most Important Product*

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