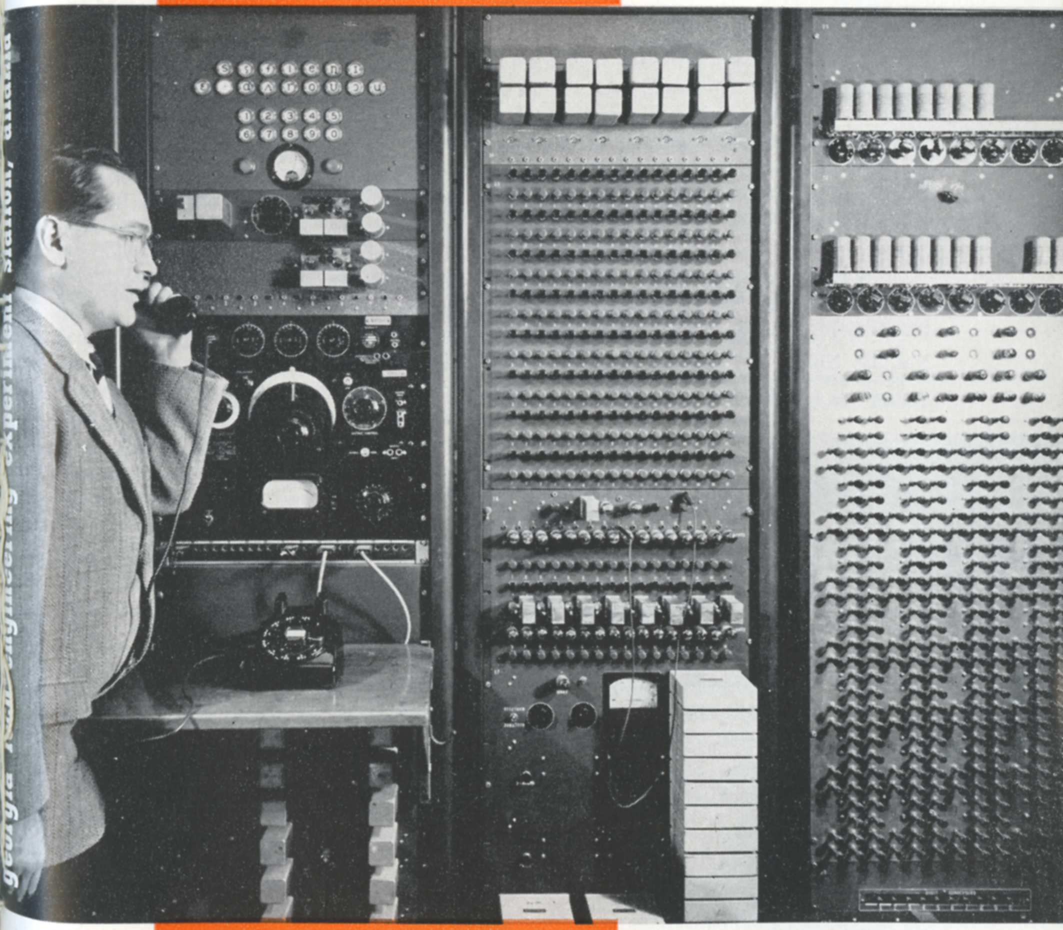
the research engineer

july 1955



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ears for computers

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AAAS

Atlanta will be the scientific capital of America, and Georgia Tech one of the host institutions, when the American Association for the Advancement of Science meets here next December 26-31. This will be the AAAS's 122nd convention, the first in the southeast since 1938 (Richmond), the first in the South generally since 1941 (Dallas). The meeting will emphasize "consideration of the serious situation confronting the United States today, of too few college students electing majors and graduate work in the sciences and engineering, and the related problem of the growing shortage of qualified science teachers at both the high school and college levels."

Georgia Tech is interested in the meeting, first, because many of the sessions will be held on our campus; second, because the emphasis described above articulates a problem which is real to Georgia Tech; and finally, because many of our most able scientists are going to take active parts in the meeting. Among them will be Dr. Robert S. Ingols, research professor in the Engineering Experiment Station, AAAS vice-president and chairman of the chemistry section; Dr. Mario J. Goglia, professor of mechanical engineering, program chairman of the engineering section; and Dr. Joseph H. Howey, director of the School of Physics, program chairman of the physics section. Many of the 15 other sections, including agriculture, industrial science, and mathematics, also will meet at Georgia Tech.

The AAAS is the world's largest and most influential group of related scientific organizations. By collecting the disciplines into one house, it dramatizes the unity of science, engineering, education, and industry.

EARS FOR COMPUTERS

"AUDREY" (which stands for Automatic Digit Recognizer) can "hear" 10 numbers and 16 of the 40 basic sounds in English, but just like the Victrola dog, prefers her master's voice

EDWARD E. DAVID, JR., EE '45

How often, on waking of a cold morning, we have wished for a robot we could command to shut the bedroom window. To design a machine that could "hear" and "understand" speech is certainly an old dream of mankind. In our age of technology we can think of myriads of ways to put such a machine to work — from printing a dictated speech to answering the telephone or operating a factory on spoken commands.

Some recent experiments suggest that we may at last be on the way to making the dream a reality. This article will describe an experimental computer which can "recognize" some elements of speech, can discriminate between the spoken numbers from zero to nine and can translate a code number into a command to perform a given task. This computer is called "Audrey" (which stands for Automatic Digit Recognizer) and is shown in the cover photograph. It is described later in the article, as is the Vocoder, shown in Figure 1, which is Audrey's ancestor.

A machine of this kind obviously needs three things: an "ear" to "hear" speech, a "brain" to interpret it and "muscles" to carry out the appointed task. These components are at hand: a microphone can hear, a computer can interpret properly prepared data, and a motor can do the work. The problem is to analyze speech into its meaningful sounds and design a computer which will recognize the meanings.

Just what kind of information is there in human speech? And what are the characteristics that make an English word understandable whether it is spoken in the treble of a child in Tennessee or in the very different accent and pitch of a farmer in Maine? Clearly some properties of the spoken word are necessary for understanding, others irrelevant. Such quali-

Figure 1. Vocoder, which compresses voice signals, is operated by Ralph Miller.

Dr. David is a supervisor on the technical staff of the Bell Telephone Laboratories, Murray Hill, N. J. His article is reprinted, with his permission, from *Scientific American*, Vol. 192, No. 2, February 1955, and with permission of the publishers, Scientific American, Inc., 2 West 45th Street, New York 36.

THE COVER PHOTO shows "Audrey" (Automatic Digit Recognizer) at the Bell Telephone Laboratories with S. Balashek, one of its chief designers. Just above and to the right of his head are four rows of symbols representing the sounds the machine can recognize. The bottom two rows indicate numbers; the top two, 16 basic sounds of English speech. As Balashek says "a" as in "had," the corresponding symbol lights up. – Photo by Paul Weller.

ties as pitch, inflection, and loudness or stress convey shades of meaning, but to begin with we shall do well if we can identify the key features that would enable the machine to "recognize" words.

A human being, by combining manipulations of the vocal cords, oral and nasal cavities, tongue, mouth, teeth and lips in various ways, can make hundreds of different sounds. But only about 40 distinct sounds are used as the basic building blocks of English speech. Our language has, for example, some 10 common vowel sounds, illustrated by the following words or syllables: heed, hid, head, had, hod, hawed, hood, who'd, hud (as in Hudson), and heard. Each of these words is identifiable even though it may be pronounced in slightly different ways by different speakers (for example, "hoid" or "herd" for heard). The 40 basic sounds are called phonemes, and phoneticians have adopted symbols to represent them.

Translation Required

The question is, can a computer be made to distinguish these 40 phonemes from one another and derive meaning from a sequence of them? The first requirement is to translate an acoustic wave into some measurable physical representation. Recently developed devices which make speech "visible" have suggested how this may be done. One such device records the energy "spectrum" of a person's speech; that is, it analyzes the sound at a given instant into the relative amount of energy at each frequency in the band covered by the speaker's voice, as shown in Figure 2. By electronic means it makes each energy concentration visible as a dark spot on a paper sheet. As the recording proceeds, the series of spots form dark bars, as shown in Figure 3. These bars show how the pattern of energy distribution changes as the speaker utters successive sounds.

Since the pattern changes at about the same rate that a speaker enunciates phonemes (about 10 per second), we can suppose that each given pattern represents a phoneme. The problem then is to identify each phoneme with a specific pattern. This is not a simple matter, because the frequency pattern combines the phonemic characteristics of the sound with irrelevant qualities of the individual speaker's voice, such as pitch; a man, a woman, and a child produce different bar positions in pronouncing a given phoneme. However, it has been found that the ratio of the bar positions tends to be more nearly the same for the types of voices than the positions themselves; hence the bar ratios may, in a crude way, identify phonemes.

It is interesting that the human ear, as physiologists have discovered, performs an energy-frequency analysis of incoming sounds and transmits the data to the brain cortex. It may be that the brain recognizes a phoneme by "matching" the pattern of incoming sound with its own pattern for pronouncing it. Sound engineers long ago had built machines which "talk," as shown in Figures 4 and 5; why not machines to "hear?"

In designing a voice-actuated machine, one might logically use electronic coincidence circuits which would measure the bar ratios and match them with a set of predetermined coincidences stored in the machine to identify the phonemes. A second coincidence detector would assemble the phonemes received from the first one and similarly match a series of them with stored sequences to recognize words.

Unfortunately it is found that the bar ratios do not identify phonemes, as spoken by different subjects, with sufficient reliability to permit the building of a finely discriminating machine. It may be easy enough to distinguish among a few commands using very different sounds; for example, there would be little difficulty in discriminating be-

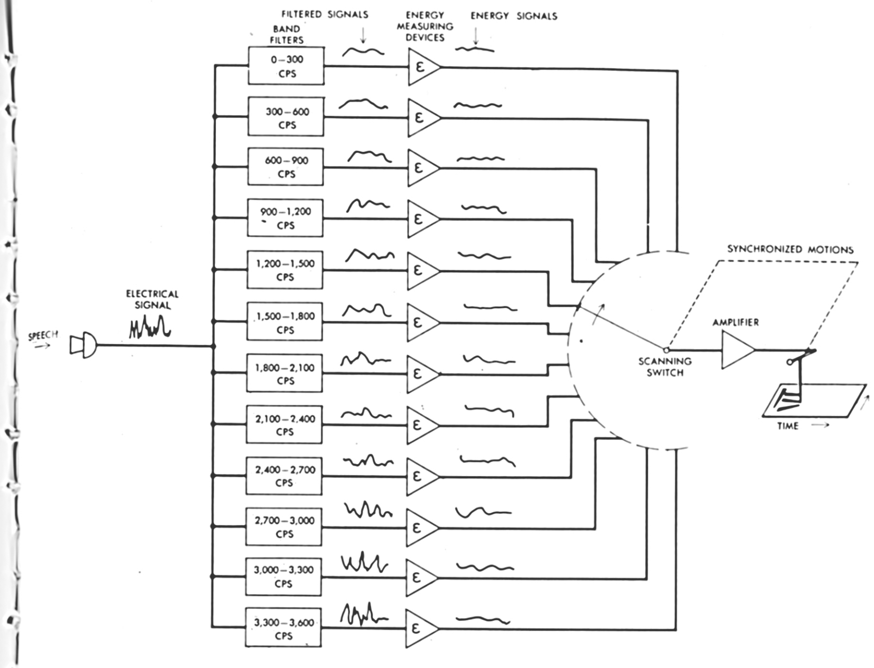
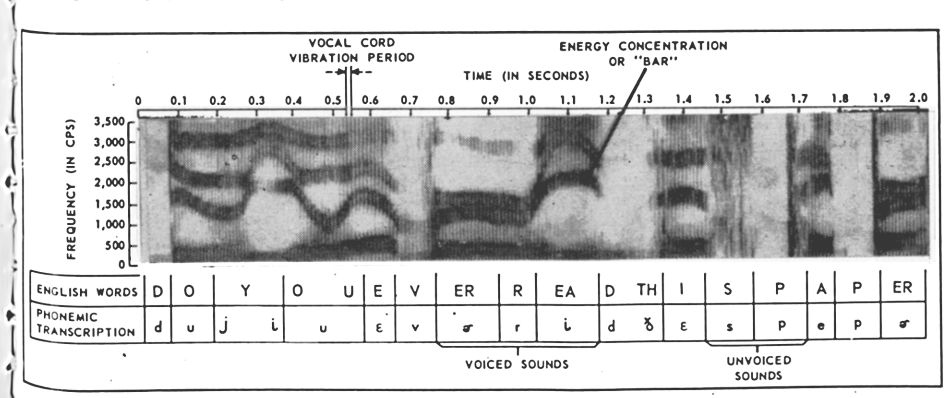


Figure 2. (Above) Sound spectrograph makes speech visible by dissecting it with 12 filters, each of which passes a band of frequencies in the range covered by the speaker's voice. The relative amount of energy in each band is recorded on a paper tape (shown below).

Figure 3. (Below) Sound spectrogram is the record produced by the sound spectrograph. This spectrogram records the words: "Do you ever read this paper?" The words are related to the spectrogram by the line immediately below it. Below this line are the corresponding phonemic symbols. Other elements are captioned. (For details, see text.)



Edward E. David, Jr., served on an aircraft carrier during World War II. At Georgia Tech he was on the wrestling team and editor of the *Blue Print* before receiving the B.E.E. degree in 1945. He went on to MIT to study microwaves and noise theory and to receive the Sc.D. in 1950. Since then he has been on the technical staff of the Bell Telephone Laboratories. He was selected by Eta Kappa Nu honor society as one of the Outstanding Young Electrical Engineers of 1954.

tween the commands "open" and "shut." But phonemes or combinations of them that sound much alike (*e.g.,* "shut" and "shoot") are too perplexing.

Challenge to Machine

Reliability might be greatly improved by considering the dynamic aspects of speech; that is, instead of attempting to identify a phoneme merely from the static measurement of the speech wave at a given instant, we might also take into account the preceding and following values of the bar ratios. The study of interactions among phonemes — the phonemic context — may well help in their identification. This promising idea is being investigated by many researchers. But for the present the machine to be described here is based on the available energy-distribution method.

The situation that confronts us, in effect, is that the machine must make sense out of speech which is contaminated with a great deal of structure which is superfluous for understanding and makes it difficult to recognize the essentials. Two means are available to circumvent this difficulty. The first, already mentioned, is to limit the machine's vocabulary to easily distinguishable words. The second is to make use of the redundancy of human speech. We generally use many more words and phonemes in speech than we need to convey our meaning in writing (compare it with the abbreviated language of a cablegram, for instance). It is this redundancy in common speech that enables us to understand what people are saying even when their words are distorted by emotion, poor pronunciation or speech defects. Similarly a machine may be expected to extract the correct meaning from a sentence or phrase even though it might be uncertain about individual words or phonemes. Both methods — the limited vocabulary and the linguistic context — have been utilized, though not simultaneously, in the experimental computer called "Audrey," or Automatic Digit Recognizer, and mentioned above.

This machine was originally constructed at the Bell Telephone Laboratories to recognize just the words denoting the digits from zero to nine. In order to do this, the computer has stored in it the energy-frequency patterns of the 10 words as enunciated by the machine's chief designers, K. H. Davis and S. Balashek.

How Audrey Hears

When the machine "hears" a word, the incoming sound is first analyzed by a group of circuits into its spectral distribution. This information is then fed to the computer, which compares it to each of the stored patterns and calculates which is the nearest "match." Within about a fifth of a second the machine lights a bulb that indicates which digit has been spoken. The machine always picks the most probable choice, unless the incoming sound has practically no resemblance to any of its stored patterns; in that case it simply gives no answer.

Audrey makes few mistakes when Balashek speaks to her, but she responds incorrectly about 10 to 30 per cent of the time to other males. Probably her general performance would improve if the patterns stored in her were averaged from a number of speakers instead of from only two. Audrey's construction does not permit her to respond well to females' or children's voices. However, the addition of further circuitry might enable her to do so.

The same signals that operate the indicator lamps can be used to ring telephones or perform other tasks coded into the machine's number language. Also, an automatic printer can record the numbers on paper as they are spoken. Such a function might be useful for applications in which large amounts of data have to be recorded in a readily available form.

Audrey has recently been modified so that she can speak a language which contains 16 phonetic elements. Although these elements do not necessarily correspond to phonemes, Audrey's efforts to reproduce human speech are surprisingly understandable. This feat is accomplished with the aid of the listener, who recognizes the words from the context.

A "Voice-Typewriter"

Audrey represents a first step toward a voice-typewriter which would automatically translate the spoken to the printed word. To design a machine which could accurately transform a phonemic transcription into printed English words, with the usual spelling, seems too much to hope for in the near future, but it seems a reasonable present objective to build one that will produce a printed phonemic English easily read by the average person after he has had a little training.

Even this initial step toward an automatic written transcription of speech will be an important aid in communication. Consider for a moment the communication links between our cities. Like pipelines, these channels have a limited capacity. The latest microwave relay system has a capacity, or band width, of four million cycles per second for each channel. This is just enough to transmit one television program, or several hundred telephone messages (each requiring a band width of 3,500 cycles per second) or some thousands of telegraph messages (each using a band width of 170 cycles per second). The wider the band width, the more expensive the circuit. Hence there is a strong incentive to reduce the signals that must be transmitted for a given message or program so that they will use a smaller part of the channel capacity.

The Vocoder

Some years ago H. W. Dudley of the Bell Laboratories invented a device, called the Vocoder, shown in Figure 1, to compress voice signals. The raw speech is passed through a bank of 10 or more filters which produce corresponding signals indicating the energy distribution as a function of time. Such signals can carry nearly all the information present in the original speech, yet each occupies a band of only 30 cycles; all 10 can be transmitted over a 300-cycle band. At the receiving point an "inverse" piece of equipment remakes the speech according to the energy picture it receives. Thus the Vocoder reduces to about one tenth the band width necessary to send speech. The processing introduces some distortion, so that the reproduced speech is not of sufficiently high quality for some applications, such as radio broadcasting. But it could serve satisfactorily in uses such as military communication.

Dudley envisioned an even more efficient compression system based on a computer somewhat like that which later took form in Audrey. He suggested that the system would break speech down into phonemes, transmit signals representing the phonemes and reconstruct the speech from phoneme building blocks available in a synthesizer at the receiving end. In other words, coded signals rather

Figure. 4. Tone generator produces vowel sounds. Keys are set for "a" in "had."

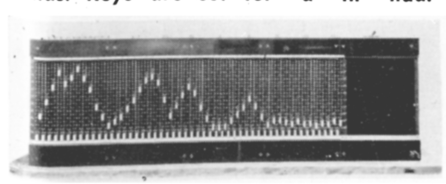
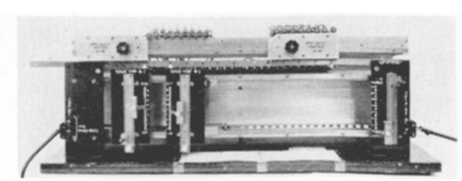


Figure 5. Electrical vocal tract can produce both vowel and consonant sounds.



than the phoneme symbols themselves would be transmitted. It is estimated that in an idealized system the coded signals corresponding to speech could be sent with good fidelity over a band of no more than 10 cycles per second, though engineering factors would argue against carrying band-width reduction to this extreme. In the elementary form of the system envisaged by Dudley, the transmitted speech would be entirely artificial, devoid of the inflection or other characteristics of the original speaker's voice. As we have mentioned, the Audrey computer can be used to reduce speech to a series of phonetic elements. Signals corresponding to the elements could be transmitted to a distant point in a band of about 30 cycles per second. In order to restore some of the naturalness and quality of the original speaker, Audrey has acquired a pitch circuit which permits her to reproduce inflections. This information can be sent with an addition of only 20 cycles per second to the band width.

The computer equipment and circuits that are needed for such a system may seem too expensive, but as a matter of fact a great deal of electronic circuitry is already in use in communication systems throughout the country, and it has justified its cost.

Robots That Listen

Application of voice-actuated machines to the fields of data processing, communications, and automatic control is in its infancy. At first the versatility of the machines will be somewhat limited by the variability among speakers and the complicated interrelations between phonemes, words, and sentences. However, many groups are doing basic research in the speech field, and rapid progress is being made. The new theory of communication has focused the attention of scientists on the statistical nature of the process and has brought together workers from physics, engineering, physiology, mathematics, psychology, linguistics, and phonetics. Their combined insights should put speech on a measurable basis and bring us closer to the talking, and listening, robot.

Weber Named New Dean of Faculties


Dr. Weber

Dr. Paul Weber, director, School of Chemical Engineering, on July 1 became dean of faculties of Georgia Tech.

Dr. Weber was appointed by President Blake R. Van Leer in an internal reorganization which also saw the following changes:

1. The vice-presidency was not filled after the retirement of Cherry L. Emerson;
2. The dean of faculties, Prof. Lloyd W. Chapin, was transferred to a new position as regents' professor of English.
3. Executive Dean Phil B. Narmore was named regents' professor of mechanics, and the executive deanship likewise was left unfilled.

The new dean of faculties, Dr. Weber, has been associated with Georgia Tech for 28 years, primarily in the school of chemical engineering. He was assistant director of the Engineering Experiment Station, 1941-48, and acting dean of engineering, 1953-54. Since 1948 he has been director of the School of Chemical Engineering.

Since 1950 he also has been associate editor of *The Research Engineer*, a capacity in which he will continue.

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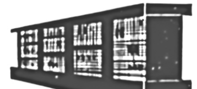

the computer center

Two electronic computers have been acquired, and a well-qualified staff assembled, preparatory to the opening this fall of the Rich Electronic Computer Center, a division of the Engineering Experiment Station.

"Much progress has been made since the Rich Foundation of Atlanta, a little over a year ago, implemented the establishment of the computer center by an initial gift of $85,000," said Dr. Eugene K. Ritter, chief of the center. "Two modern machines now are being installed, and by the time the laboratory is in full operation, the staff will number about 20 mathematicians, engineers, scientists, technicians, and others."

The two machines are the CRC-102D, a medium-scale electronic computer manufactured by the Electronics Division, National Cash Register Co., and the ERA-1101, a large-scale, high-speed electronic computer manufactured by the Engineering Research Associates Division, Remington Rand, Inc.


Dr. Perlin

Dr. Irwin E. Perlin, professor of mathematics, has become a full-time member of the staff of the computer center. Dr. Perlin holds two degrees from Northwestern University, B.S., 1932, and M. S., 1933, as well as the Ph.D. from the University of Chicago, 1935. He has been an instructor at Northwestern, assistant professor at Illinois Institute of Technology, and an ordnance instructor and gunnery officer, with the rank of Lt. Comdr., in the U. S. Navy. He has been at Georgia Tech, on the faculty of the School of Mathematics and the Engineering Experiment Station, since 1945. His article, "Electronic Computing Machines," appeared in *The Research Engineer* for January. His textbook, *Trigonometry*, was published in March.


Mr. Bezaire

William A. Bezaire is head, operations and maintenance group. He received the B.S. in physics and mathematics, *summa cum laude*, in 1950 from the University of Detroit. He was awarded a fellowship for graduate study at the University of Michigan. He served twice in the U. S. Navy. For the past four years, first as an officer, then as a civilian specialist, he was a supervisory electronic engineer with the National Security Agency, Washington, D. C. In that position he gained extensive experience in engineering, maintenance, and operation of electronic computers.


Mr. Eskew

Robert E. Eskew has been assigned to the computer center. He attended the University of Tennessee and holds two degrees from Georgia Tech, the B. of I.E., 1948, and the M. of I.E., 1955. He has worked for a bank, an aircraft manufacturer, and an architectural and engineering firm. He was assistant to the director, Georgia Tech Engineering evening School, 1948-50, and acting director of short courses and conferences, 1950-52. From 1952 to 1954 he lived in Columbus, Ga., where he was successively second vice-president of a construction company and dealer-sales manager of an air-conditioning firm. A year ago Mr. Eskew returned to Georgia Tech, as associate professor and director of short courses and conferences.

publications

Ingols, R. S., H. W. Hodgden, and J. C. Hildebrand, "Taste and Odor, Study of Tastes and Odors Produced by Chloridation of Simple Nitrogenous Compounds." Reprinted from *Agricultural and Food Chemistry*, Vol. 2, No. 21, pp. 1068-1070, October 13, 1954. Reprint 88. Twenty-five cents.

Of 25 amino acids and related compounds studied, alanine, phenylalanine, arginine, and proline produced taste upon reaction with hypochlorous acid and monochlramine, and proline and phenylalanine produced taste with chlorine dioxide. Proline and phenylalanine have taste threshold concentrations of a few parts per billion. All four amino acids are found in common proteins. Other amino acids have been found in lakewater in these concentrations. Attempts to find or produce any of the four amino acids in waters about Atlanta during the summer of 1952 were unsuccessful. Methods and results are discussed in this paper.

Burrows, W. H., "Direct Construction of Nomographs from Tables." Reprinted from *Industrial and Engineering Chemistry*, Vol. 41, pp. 33-37, January 1955. Reprint 89. Twenty-five cents.

Because of their desire to represent data in a manner which facilitates its use, many chemical engineers are interested in nomographic methods. The tedium of deriving empirical formulas for the construction of such nomographs, however, leads them to seek direct methods of constructing nomographs from the particular data in which they are interested.

Although the construction of nomographs from formulas is well standardized, construction directly from a table of values involves poorly understood techniques. This paper presents practical methods of procedure for the direct construction of such charts.

The preparations of the log mean temperature difference nomograph is used to illustrate the symmetrical case. The development for the general case-unsymmetrical tables—not only includes the preparative method but also outlines means of selecting a suitable scale function for the dependent variable.

Ingols, Robert S., "Evaluation of Toxicity." Reprinted from *Sewage and Industrial Wastes*, Vol. 27, No. 1, pp. 26-33, January 1955. Reprint 90. Twenty-five cents.

This review discusses the many factors which affect the toxicity of a given substance. There are, in general, two types of toxic substances—those which are similar to normal cell constituents and are called antimetabolites, and those which are foreign to biological life. With those toxic substances which are foreign matter, the percentage reduction in the metabolic rate is progressively greater as the other factors in the environment become less favorable for growth. With the antimetabolites, the percentage reduction in the metabolic rate will be larger in the absence of the normal, corresponding substance where the other environmental factors approach the optimum values.

Hine, Jack, John A. Brown, Leon H. Zalkow, William E. Gardner, and Mildred Hine, "The Synthesis of Bicyclo[2,2,2]-2,5-octadiene." Reprinted from the *Journal of the American Chemical Society*, Vol. 77, pp. 594-598, February 5, 1955. Reprint 91. Twenty-five cents.

A synthesis is reported for a compound which has particular interest because of unusual possibilities for interaction between nonconjugated double bonds. Two syntheses, one involving the dehalogenation of 2,3-dichlorobicyclo[2,2,1]-5-heptene and the other the dehydrohalogenation of 2-chlorobicyclo[2,2,1]-5-heptene, are reported also for the related compound bicyclo[2,2,1]-2,5-heptadiene (I). The preparation of II was accomplished by the dehydrohalogenation of a mixture of monochloro-2-bromobicyclo[2,2,2]octanes. The structures of I and II are proven by their reduction (by two moles of hydrogen) to the corresponding saturated hydrocarbons. In addition, II has been shown to form a crystalline tetrabromide and to yield ethylene and benzene upon pyrolysis. An improved method of preparing 1,3-cyclohexadiene also is reported.

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Microwave Spectroscopy

THE BUREAU OF STANDARDS' atomic clock is perhaps the best known application of microwave spectroscopy. The development of electronic equipment for radar during World War II made possible a completely electronic microwave spectrograph

QUITMAN WILLIAMS AND THOMAS L. WEATHERLY,
associate professors of physics and research associates

ONE OF THE MOST VALUABLE CLUES to the structure of matter is the radiation which all matter emits and absorbs. The analysis of this radiation was begun in 1860 with the invention of the optical spectroscope by Bunsen and Kirchoff. Spectroscopic analysis has since been extended upward to frequencies in the ultra-violet, x-ray, and γ-ray regions and downward to frequencies in the infra-red, microwave, and radiofrequency regions. The microwave region, which this paper concerns, embodies frequencies from about 1,000 to 300,000 megacycles and wavelengths from 30 to 0.1 centimeters.

The first microwave spectrograph was constructed by C. E. Cleeton and N. H. Williams in 1933 for an investigation of the inversion spectrum of ammonia. This instrument incorporated both optical and electronic components. It used a magnetron oscillator as a source of radiation, an optical collimating system of parabolic mirrors and a phosphor-bronze crystal connected to a galvanometer for the detection of radiation. Wavelengths were measured with an echelette grating.

The development of electronic equipment for radar during World War II made possible a completely electronic microwave spectrograph. This instrument is best adapted to the measurement of the absorption spectrum of a gas at pressures of 10^{-1} to 10^{-4} millimeters of mercury. At such pressures the translational motion of a molecule does not appreciably affect its spectrum. The remaining energy of the molecule may be roughly divided into three types, electronic, vibrational, and rotational. The electronic energy consists of the potential and kinetic energy of the electrons with respect to the nuclear framework; the vibrational energy consists of the potential and kinetic energy of the vibrating nuclei; and the rotational energy consists of the kinetic energy of rotation of the nuclear framework about its center of mass.

This division of the total energy is possible because of the great difference in the speeds of the three types of motion. Making a purely relative comparison, one might say the electronic motion is exceedingly fast, the nuclear vibration much slower, and the molecular rotation very slow indeed. Thus, as far as the electrons are concerned, the nuclei are practically stationary. The nuclear vibration, on the other hand, is so much slower than the electronic motion that the nuclei may be assumed to vibrate in a potential field determined by the average electronic distribution. However, this vibration is so much faster than the molecular rotation that the vibrational energy is almost unaffected by it. Finally, the molecular rotation is so much slower than the nuclear vibration that, for the purpose of computing rotational energy, the nuclei may be assumed to occupy their average positions.

Thus, if we designate the electronic

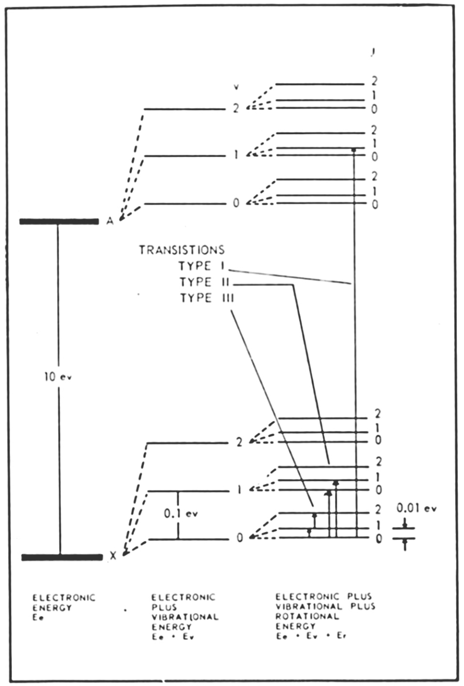


Figure 1. Molecular energy level diagram.

energy by E_e, the vibrational energy by E_v, and the rotational energy by E_r we may write for the total energy,

$$E = E_e + E_v + E_r.$$

Now the quantum theory tells us that the total molecular energy is quantized, that is, takes only certain discrete values, and a molecule possessing one of the discrete energy values is described as existing in a stationary energy state. As a good approximation, one may say that the three types of molecular energy are quantized separately. The situation is best described in terms of an energy level diagram as shown in Figure 1. In this figure energy differences between stationary states are represented by the vertical separation of the horizontal lines representing those states.

On the left of Figure 1 energy levels have been drawn taking into account electronic energy only. The level X is the lowest electronic state, or the electronic ground state, and the level A is the next lowest, or first excited electronic state. A stable molecule may have other excited electronic states B, C, etc., which are not shown. The levels at the center of the figure were obtained by also considering vibrational energy. The electronic levels X and A have been split into a large number of levels by the addition of vibrational energy. Three of these vibrational levels for each electronic state are shown labeled according to their vibrational quantum number v. These vibrational levels would extend upward to higher quantum numbers, the limit being determined by the dissociation of the molecule because of excessive vibration. On the right of Figure 1 the rotational energy of the molecule has been added with the result that each vibrational level has been split into many rotational levels. Three rotational levels for each vibrational state are shown in the figure, each designated by its rotational quantum number J. For the purpose of comparison, the energy differences between adjacent levels are approximately 10 ev (electron volts) for electronic levels, 0.1 ev for vibrational levels, and 0.01 ev for rotational levels.

A molecule may increase its energy from an initial value E_i to a final value E_f by the absorption of an amount of electromagnetic energy corresponding to the difference $E_f - E_i$. The frequency of the absorbed photon is given by the Bohr frequency condition

$$\nu = \frac{E_f - E_i}{h}$$

Quitman Williams, associate professor of physics and research associate, holds three degrees in physics, the B.S., 1943, from Centenary college of Louisiana, M.S., 1948, from Georgia Tech, and the Ph.D., 1952, from Duke University. During World War II he served for three years as an electronics officer in the U.S. Air Force. He has been teaching and doing research since 1946. His fields of greatest interest are microwave spectroscopy and radiofrequency spectroscopy.

where the energies are in ergs, ν is the frequency in cycles/sec and h is Planck's constant expressed in erg seconds. Transitions to lower energy states occur with a corresponding emission of energy.

Transitions of type I, as indicated in Figure 1, which involve a change in the electronic energy of the molecule, occur with the absorption of a high energy photon with frequency in the visible or ultraviolet region of the spectrum. Those of type II, which involve only a change in the vibrational and rotational energy, fall in the near infra-red and those of type III, which involve only changes in rotational energy, fall in the far infra-red or microwave region. A microwave spectrometer is used principally to examine this latter type.

It should be noted, however, that transitions between rotational levels are not the only transitions which give rise to spectra in the microwave region. The electronic levels of some atoms are split into doublets, the separation of which will produce transitions in this region. In a molecule like ammonia there is a splitting of the vibration levels due to inversion of the molecule. This splitting produces transitions in the microwave region. Actually it was these transitions in ammonia which were first detected by Cleeton and Williams in 1933, and it is this date that is usually given as the beginning of microwave spectroscopy. No pure rotational spectra using electronic oscillators was detected prior to World War II.

The rotational energy of a diatomic molecule is given by the expression

$$E_r = \tfrac{1}{2} I\omega^2 = \frac{P^2}{2I}$$

where I is the moment of inertia, ω is the angular velocity and P is the angular momentum. Quantum mechanics yields for P the discrete values

$$P = \sqrt{J(J+1)}\ \frac{h}{2\pi}$$

where the rotational quantum number J takes the integral values

$$J = 0, 1, 2, 3, 4 \ldots\ldots$$

When the value of P is substituted into the energy expression one obtains

$$E_r = \frac{h^2}{8\pi^2 I} J(J+1).$$

This is the equation which determines the position of the rotational energy levels in Figure 1.

If the diatomic molecule has an electric dipole moment then the action of electro-

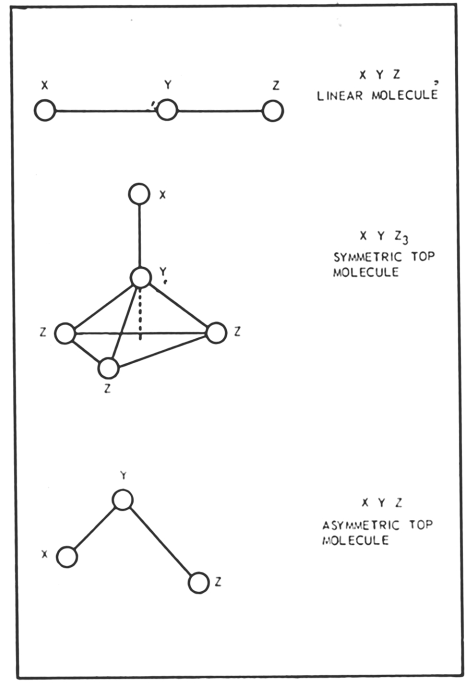


Figure 2. Three types of molecular structures.

Thomas L. Weatherly, associate professor of physics and research associate, holds two degrees in physics, both from Ohio State University, the B.S., 1947, and the Ph.D., 1951. During World War II he served for three years as an officer in the U.S. Air Force. He has been teaching and doing research since 1946. His fields of scientific specialization include radiofrequency spectroscopy, microwave spectroscopy, and molecular physics.

magnetic radiation on this moment can produce transitions to either the next highest or next lowest level. This effect is expressed by the selection rule

$$\Delta J = \pm 1$$

For a transition from a lower rotational state J to the higher state J + 1 the frequency of the absorbed radiation is

$$\nu = \frac{E_{J+1} - E_J}{h} = \frac{h}{4\pi^2 I}(J + 1).$$

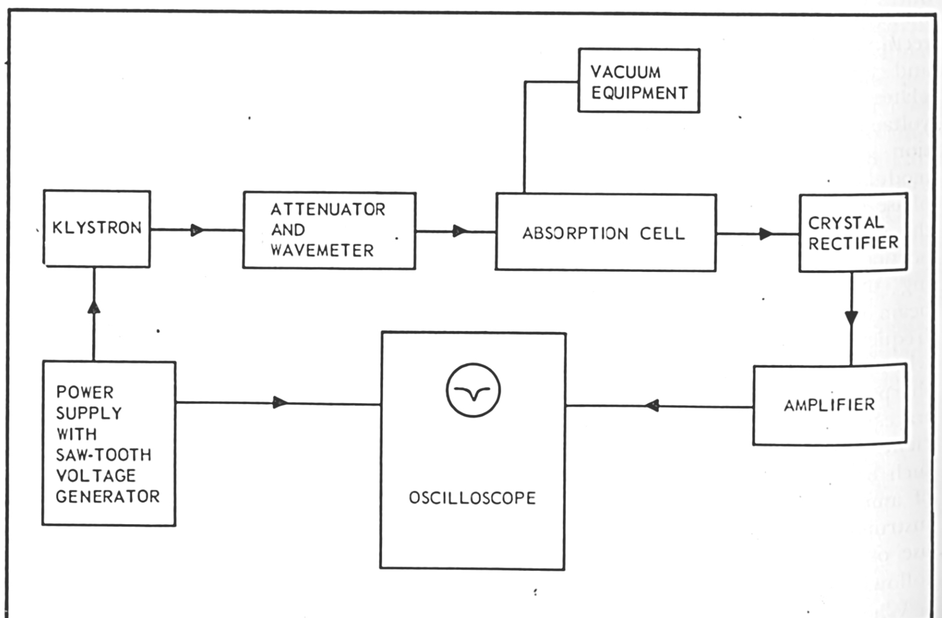
Measurement of the frequency and proper assignment of the J value will then yield the moment of inertia I. The assignment of J is not difficult. Since it is a whole number it can be determined from an approximate value of the moment of inertia. Then the proper value of J will yield a more exact I.

When this moment of inertia is found for a diatomic molecule one can calculate the distance between the atoms. In the case of a linear triatomic molecule, as shown in Figure 2, one known moment of inertia is not enough to determine the two bond lengths. However, two different isotopic species of the same kind of molecule will give two separate spectra and two different moments of inertia. Since, to a high order of approximation, the bond lengths depend upon the electrical properties of the atoms and not upon their masses these moments of inertia will yield two expressions which can be solved simultaneously for the distances.

Actually the molecule is vibrating during this transition from one rotational level to another so that the moment of inertia obtained is an average value. The distance involved depends upon the vibration energy and is slightly different for different isotopic species. This introduces an inconsistency in bond lengths of the order of 0.2 per cent or less. Occasionally, when I is determined for several vibration states, the I for the nonvibrating state can be calculated, and then this inconsistency does not exist.

The structure of symmetric top molecules like monochloromethane, CH_3Cl, can be determined from the rotation spectra of three different isotopic species such as $C^{12}H_3Cl^{35}$, $C^{12}H_3Cl^{37}$, and $C^{13}H_3Cl^{35}$. The spectrum of the $C^{13}H_3Cl^{37}$ molecule would be useful in estimating the error introduced by the vibration energy.

Figure 3. Block diagram of simple microwave spectrograph.



The most common type of molecule is the asymmetric rotator, and unfortunately its structure is the most difficult to determine from microwave data. The frequencies of its spectral lines are determined by the moments of inertia about three mutually perpendicular axes fixed in the molecule. These moments are called the principal moments of inertia, and they can be computed from the spectrum. The positions of the atoms in an n-atomic molecule can then be calculated if isotopic substitutions are made for n-2 atoms. Even if these substitutions are possible the determination of the structure is very difficult except for the simplest asymmetric molecules.

A block diagram of the simplest type of microwave spectrograph is shown in Figure 3. In this figure the klystron is an electronic source of monochromatic radiation of variable frequency. The attenuator serves to adjust the amount of power, and the wavemeter is used for frequency measurement. The radiation passes through an absorption cell consisting of a waveguide of rectangular cross-section containing the gas to be investigated. The amount of power transmitted through the cell is detected by a crystal rectifier. This rectified signal is amplified and applied to the vertical deflection plates of an ocilloscope. A saw-toothed voltage is applied to the horizontal deflection plates and to the klystron repeller, modulating the klystron frequency in phase with the horizontal sweep. Since the signal on the vertical plates is proportional to the amount of power passing through the gas, the oscilloscope beam plots a graph of absorption versus frequency. When an absorption line falls within the sweep range of the klystron a sharp dip appears on the oscilloscope trace. This type of spectrograph is sufficient to detect strong absorption lines such as those in the inversion spectrum of ammonia. However, a more sensitive instrument can be obtained by making use of the Stark effect described in the following paragraph.

When an electric field is applied to the gas the rotational energy levels are split into several sublevels. The exact location of these sublevels depend upon the particular rotational state involved, the dipole moment of the molecule, and the magnitude of the electric field. If one were viewing an absorption line on the oscilloscope this line would be split into several components of different frequencies when the electric field is applied. This is because there are now many transitions from one group of sublevels to another group of sublevels. The original absorption line is then reduced in magnitude or sometimes completely vanishes. This splitting of the energy levels into sublevels by an electric field is called the Stark effect.

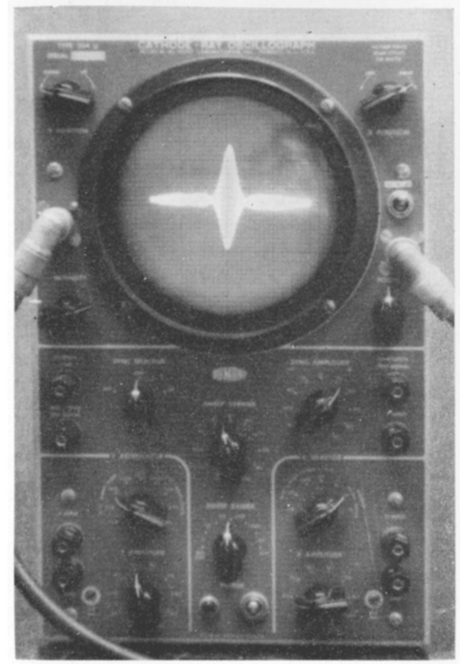


Figure 4. Rotational absorption line on a Stark modulated microwave spectrograph.

The microwave spectrograph at Georgia Tech utilizes this Stark effect as an aid in searching for absorption lines. Using a method introduced by E. B. Hughes and E. B. Wilson, Jr., in 1947 an electrode is placed in the absorption cell and an r-f voltage applied to it. This voltage is usually a square wave which alternates between zero and several hundred volts splitting the spectral lines into components during one-half of each cycle. Amplitude modulation of the microwave energy is then produced when the klystron is tuned to an absorption line, and a radio receiver tuned to the r-f frequency will detect this modulation. When the receiver output is applied to the vertical deflection plates of the oscilloscope a spectral line appears as shown in Figure 4. Such a system is more sensitive than the simple spectrograph described above because the noise output of the crystal is less at r-f modulating frequency and because a very narrow band detector can be used at this frequency.

In addition to its greater sensitivity this type of spectrograph detects the Stark components as well as the original spectral line. From the frequencies of the Stark components and the electric field intensity one can calculate the electric dipole moment of the molecule. The Stark components are also useful for identifying the transition.

For accurate frequency measurements a secondary frequency standard is used. Such a frequency standard usually starts with a 5 or 10 mc oscillator which may be compared with radio station WWV of the National Bureau of Standards. This frequency is multiplied by ordinary electronic tubes up to several hundred megacycles and then crystal-multiplied. In this way known frequencies can be produced 30, 50, or 90 mc apart in the microwave region, and these can be beat against the klystron frequency. If the beat frequency is measured using a calibrated communication receiver then the klystron frequency can be determined.

It should be pointed out that molecular rotation spectra are sometimes observable as the fine structure of a vibrational transition in the infra-red region (transitions of type II in Figure 1). In most cases this fine structure cannot be resolved. Rotational lines which are barely resolvable in the infra-red region are separated by thousands of megacycles when observed as a pure rotation spectrum in the microwave region. Line breadths on the other hand, can be reduced to approximately one megacycle, with the result that structural determinations are greatly improved. In addition hyperfine structure produced by nuclear quadrupole interaction is frequently resolved. From this hyperfine structure information has been obtained concerning nuclear quadrupole moments, nuclear spins, and the electronic structure of molecules.

At present microwave spectroscopy is not widely used for chemical analysis. Although its use is limited to gases at low pressure it offers some distinct advantages in this limited field. Extremely small amounts of sample are required, and the spectra of different molecules do not overlap greatly because of the small line breadths. In many cases positive identification could be obtained by an absorption measurement at a single frequency. The National Bureau of Standards' circular 518, "Molecular Microwave Spectra Tables," published June 23, 1952, lists absorption lines by frequency and by molecule. As these tables grow in length microwave spectroscopy will become increasingly important in chemical analysis.

Perhaps the most widely publicized application of microwave spectroscopy is in the atomic or molecular clock built by the National Bureau of Standards. This device utilizes an ammonia absorption line to stabilize an oscillator. By means of frequency division it can be made to drive a clock mechanism. A stability comparable to the mean solar day (a few parts in 10^8) for a period of several days has been achieved. If stability can be improved to a few parts in 10^9 then such a device may become a primary, rather than a secondary, frequency standard.

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American Engineering Education, 1880-1955

BLAKE R. VAN LEER, president,
Georgia Institute of Technology

THE FIRST THING which attracts attention, in a review of the highlights of engineering education over the past 75 years, is the large growth in enrollment in engineering colleges, as shown graphically in the two-color figure on page 21.

In 1880-1881 we had but 85 institutions, with an enrollment of about 1,000, offering engineering degrees. Today there are 218 institutions, of which 150 have curricula accredited by the Engineers' Council for Professional Development; the enrollment of all 218 is more than 214,000, and the enrollment of those accredited is over 187,000. That is a fabulous growth, but it does not tell anything like all the story. In those early days, many of the 85 institutions had, of necessity, to teach many courses in drawing, shop, mathematics, etc., which are today taught in vocational high schools. In the early days, if an engineering student fell by the wayside he frequently became a "skilled worker" or a technician. Many of our engineering colleges in 1880 had curricula very similar to what you find today in vocational high schools. It is little wonder that their highbrow sister institutions teaching Greek, Latin, and philosophy looked down their noses at such pedagogical upstarts. You had to have plenty of courage in the 1880's to be an engineering teacher and, one might assume, not many of those teachers had earned Ph.D.'s.

Engineering education evolved rapidly, just as did our country's industrial development, and it wasn't long before most of the so-called engineering colleges were teaching about what is taught today in good technical institutes. That was during the period 1900-1910. But by 1920-1930 all of the reputable engineering institutions of higher learning had become engineering colleges as we know them today. At about the same time, a few of these colleges were becoming "technological universities" and

Address delivered by President Van Leer at Stevens Institute of Technology, Hoboken, N. J., April 16, 1955, on a program commemorating the 75th anniversary of the founding of the American Society of Mechanical Engineers.

offering master's degrees and a very few, doctorates, in engineering. Today, we have about 125 engineering institutions, with an enrollment of about 4,000 graduate students, offering the master's degree or higher. This is the outstanding phenomenon in engineering education in the last twenty-five years: Our graduate schools of engineering have grown bigger and better.

America today has several thousand times as many young people devoting themselves to what were considered in 1880 to be engineering education subjects, and almost 200 times as many studying professional engineering subjects today as it had in all classifications in 1880.

Students

Let us consider the students we get today as compared to those in 1880. By all standards it seems to me that they are much better. They are better prepared, more mature, and more serious-minded, and by the time they are graduated from any first-class engineering college they know more and they can do more things better.

I know we hear it said that the high schools today do not teach the boys and girls reading, writing, spelling, or grammar. That is true of some, but it is also not true of a great many. If you doubt it, attend a student branch meeting of the ASME or some other engineering society, and see how well these young people conduct their affairs. Many times they handle themselves better than the adult members do. Or invite one of these young men to speak to a local section. He will almost always do it well. There is no doubt in my mind that in spite of the fact that we eliminate about 50 percent of the students who enter our engineering colleges, we are turning out not only more engineering graduates but also better ones.

One of the characteristics of engineering education is the fact that we have always given the students plenty of work. This was, no doubt, forced on the educators back in 1880 because the old boys, teaching the classics, would not give up any of their courses as prerequisites to graduation, so the engineer simply had to add his courses to an already existing curriculum. Plenty of work is still one of the cardinal virtues of the engineering curriculum. The average engineering student in whatever curriculum or whatever college does about 25 to 30 percent more actual work than his counterpart in the liberal arts college.

We are frequently criticized for that. We are told we do not give the student any time to think. My grandmother taught me that "an idle mind is the devil's workshop," and after almost 50 years of observation and experience with adolescent boys, I am convinced the old lady was right. If you give an adolescent too much time to think, he doesn't think; he gets into mischief. We educators have decided to let him think when he gets one of those 40-hour-a-week jobs with industry. We still believe that 60 hours a week are good for his soul. He thus learns to think while he is working, to think when he is under pressure and in a hurry. When taking an engineering curriculum, he is supposed to be thinking all the time. He learns to think, and, above all, he receives the best type of education and training for twentieth century living.

These fundamental principles have not been changed in the last 75 years. Engineering students have always been required to accustom themselves to carry heavy intellectual loads. This principle has not been changed. However, we are under great pressures to change it. These pressures come from all sides. There are those who would convert the doer into a purely abstract thinker. There are those who would first give the student a liberal arts education and then try to make an engineer out of him. There are those who think a student never learns anything unless he gets it from a professor or a textbook. There are those who think the fundamentals of science and engineering have increased so much that they can no longer be taught in four years. There are those who think the engineer should be taught, while he is in college, everything he will ever need to know. There are those who think that new creative work is the only thing about an engineer's education that counts, so they want him educated as a pure scientist in only the fundamentals of all sciences.

One of the outstanding characteristics of our engineering education has been its freedom. Each of the 150 engineering colleges adopts its own curriculum. Most of the theories mentioned above are now being tried out in one or more engineering colleges. That is the American way.

The great majority of our engineering graduates go into industry, and it seems likely they will continue to do so. There are needed all types: the sales engineer, the production man, the professional engineer, the researcher, the executive. We shall undoubtedly need more professional engineers and more scientists in the future, but the great majority of the output of our engineering colleges will continue to find four years of academic work enough, regardless of how the professors apportion it out, to meet our changing times.

The Morrill Act

During the Civil War, the United States became woefully short of young military leaders such as are now produced through the ROTC programs. It was also short of foodstuffs of all kinds. This gave an opportunity to aid in the establishment of our great land-grant colleges and universities. The Morrill Land-Grant Act, which was signed by President Abraham Lincoln in 1862, offered grants of public lands to the several states for aiding in the maintenance of colleges whose purposes would be to teach such branches of learning as are related to agriculture and the mechanical arts and afford military training to all students. Following this, engineering instruction was started at Cornell, MIT, Illinois, Wisconsin, Iowa State, Purdue, Ohio State, Pennsylvania State, Georgia Tech, and others. About one-half of the students studying engineering in the United States today are enrolled in land-grant colleges and universities.

This has proved to be a most wise piece of legislation and has led to the establishment, growth, and development of some of our greatest engineering colleges and universities.

The Curricula

Since the activation of the Morrill Act, the engineering curricula have evolved greatly with fewer and fewer purely vocational courses being included. We have now reached a period where many believe a four-year curriculum of formal education is inadequate for the twentieth-century needs of a professional engineer. We see several experiments going on.

In 1906 the University of Cincinnati began the "cooperative plan," in which students alternate between periods of class attendance, and industrial employment under the supervision of the engineering college. In 1953-1954, cooperative programs were conducted in 35 colleges and 8 technical institutes. These included 33 different curricula leading to B.S. degrees and 13 different non-degree courses. The 22,528 students enrolled under this plan in 1953-1954 were employed by 4,340 industrial firms and governmental agencies.

With more and more engineers occupying positions of leadership in the business, manufacturing, and governmental fields, there has developed a new plan of engineering education that will provide more courses in liberal arts, physical sciences, and mathmatics than are possible under the regular engineering curriculum. Under the plan, a student may attend a cooperating liberal arts college for three years and then one of the engineering

Blake R. Van Leer, president of Georgia Tech, is in Europe, visiting the universities of Caen, in France, and Munich, in Germany, where he took graduate studies following military service in World War I. He was dean of engineering, University of Florida, 1932-37, and dean of engineering, North Carolina, 1937-44. During World War II he was chief of facilities, Army Specialized Training Division. On July 1, 1955, he completed 11 years as president of Georgia Tech.

colleges for two years. Upon satisfactory completion of the entire five-year program, he becomes eligible for the appropriate bachelor's degree from his original college and for the bachelor of engineering in his particular field from the engineering college.

In 1954 there were 27 engineering colleges in 13 states cooperating with approximately 130 different liberal arts colleges in 34 states in the conduct of about 200 three-two programs. Since this activity on a large scale is only about six years old, it is still regarded, by its participants and by the U. S. Office of Education, as an "educational experiment."

Others believe in the program of four years of engineering education plus whatever is necessary (one to five years) to secure a master's degree or a doctorate. This is traditional and to many it is the standard or preferable method. To many it seems that four years of formal education after high school are enough for the 75 percent who will enter industry immediately upon graduation. These experiments in lengthening the normal engineering curriculum will no doubt continue with varying degrees of success, but the future seems to indicate that, for a long while yet, a four-year undergraduate course leading to a bachelor's degree with variations will be the standard required for entrance into industry in technical fields leading to positions of leadership.

Postgraduate Education

More than 20,000 full- and part-time graduate students are enrolled in colleges and universities with ECPD accredited engineering courses during the current academic year. Between 1890 and 1950, enrollment in all institutions of higher education increased seventeenfold, and in graduate schools one-hundredfold.

The number of graduate degrees in engineering granted during various years from 1930 to 1954 was as follows: 1930, 812; 1940, 1,460; 1950, 4,913; 1951, 5,345; 1952, 4,620; 1953, 4,084; 1954, 4,857. About one-eighth of our engineering college graduates acquire graduate degrees. This healthy situation has been brought about by our highly complex technical civilization and by the ever-increasing needs for engineers with a broad scientific foundation, and with training in creative thinking. Industrial firms, especially those which depend greatly on scientific advances for their existence and growth, place a premium value on engineers with postgraduate education. This is evidenced by their recruiting efforts, by their phenomenal salary offerings, and by their advancement of engineers with graduate degrees to upper echelons of responsibility.

Postgraduate education in engineering has reached maturity and, together with undergraduate education and fundamental research, forms the basis of a well-balanced and properly coordinated program in any top-ranking engineering college. It is through these activities that an engineering institution of higher learning is able to carry out its functions of disseminating and extending knowledge.

Although in many areas of graduate study there is a tendency to specialize in a narrow field, we find that in engineering there exists a broader field, since engineering depends on a common base of science and mathematics as well as human understanding. This type of training makes the engineer with a graduate degree an individual who can keep on growing intellectually and who is capable of mastering new techniques in numerous fields.

Experience of engineering educators indicates that not every student who received a bachelor's degree is qualified for graduate work. Current statistics show that the best-qualified candidates for master's degrees come from the top quarter of their graduating class, while those working for their doctorates will be in the top tenth. Methods of selection and the requirements of each college will cause variations in these figures.

There is such a great demand by industry for engineers with post-graduate training and creative talent that more and more companies are aiding graduate programs in engineering colleges with fellowships, equipment, sponsored research projects, and industry-university relationships. In large metropolitan areas, colleges and universities have been cooperating by providing opportunities for part-time graduate study through late afternoon and evening programs. Elsewhere there are off-campus graduate programs given either in the industrial plant or in facilities provided by the local community. It is important that both types of such programs be conducted on a high level, equivalent to the full-time resident program offered by the participating institution. Otherwise, the part-time student will waste his time through a false sense of achievement. In order for post-graduate engineering education to continue to grow and add to the advancement of science and engineering, it must be conducted under the supervision of a distinguished graduate faculty.

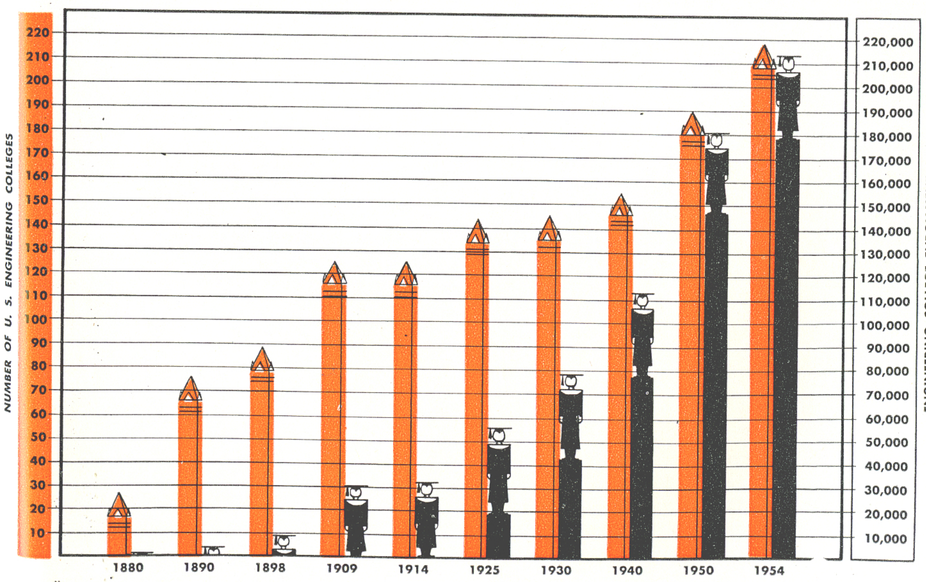
The ECPD

An entire paper could be devoted to the contribution which the Engineers' Council for Professional Development (ECPD) has made to United States engineering education in the last 25 years. It has done much to standardize our basic courses and the general curricula leading to the bachelor's degree. It has done much to improve standards. It is so organized that it has a good balance of representation of the professional engineers, the engineering societies, and the engineering teachers. There is no doubt that engineering education would receive a setback if the accrediting of engineering curricula fell exclusively into the hands of any one — the professional engineers, the societies, or the teachers. Each of these groups is influenced strongly by objectives which are fine in themselves but which would be dangerous if carried too far in controlling engineering education. The great danger in the ECPD is that it might carry standardization too far and thus stop the growth and evolution of undergraduate engineering education.

Research

With the growth of our graduate schools has also come a great growth in research work by our engineering colleges. This research is being directed by three agencies: by the departments or colleges, by

This graph shows the steady growth of both engineering colleges and their total enrollment.



engineering experiment stations, and by specially incorporated research institutes. The research itself may be divided into two general classifications, sponsored and unsponsored. The sponsored research is paid for by the sponsor who, in general, controls the objective sought. The unsponsored research usually is paid for by the college or institution itself, and is controlled by the institution. The growth of research has been fabulous. In 1880, the colleges were spending practically nothing on research. Today, the figure is approximately $200 million. By means of this work, engineering educators add new knowledge and give valuable training and experience to future research workers.

The Future

Seventy-five years after the memorable founding of the American Society of Mechanical Engineers in 1880, we find that American engineering education:

1. has grown greatly in enrollment,
2. is producing more and better young bachelors of engineering,
3. is well organized through the ECPD to supervise educational development,
4. has adhered tenaciously to its original ideal to produce a young professional beginner, accustomed to hard work and logical thinking under pressure, and
5. has aided greatly and laid a strong foundation for developing graduate work and research.

There is a great challenge ahead for engineering educators. Facilities must be expanded, enlarged, and improved. More and better teachers must be secured. There is much need for more money for engineering education. This is a serious problem faced by every engineering education administrator in the country. Where the money will come from is the most serious problem. However, since industry is the greatest single benefactor from engineering education, much of it should and will come from our industrial giants and leaders. There are many indications that our great industries have awakened to this need and to this opportunity to profit most by serving best.

letters

EDITORS: You doubtless know that at the last session of the Congress many changes were made in the laws which have proved to be of great benefit to the universities and colleges of the nation.

Not only was the amount of the deduction for gifts to institutions of higher learning increased from 20 percent to 30 percent, but, in addition, the term provided for irrevocable trusts for the benefit of colleges was cut from 10 years to 2 years, a change which will make their creation much more frequent than in the past. . . .

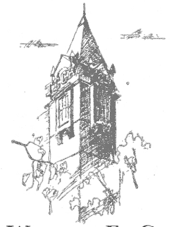
A provision was also inserted in the Internal Revenue Code which permits a boy to make more than $600 without resulting in the loss of his dependency deduction to his father. In addition, in determining the proportion of the support received from his father, scholarships and other school aid are not to be counted. Both of these changes are going to make it easier for students to come to college. . . .

I had the pleasure of working closely with the members of the Senate Finance Committee and the House Ways and Means Committee during the drafting, discussion, and passage of this legislation, and I think you should know that Senator Walter F. George not only brought to our support all of his tremendous influence and prestige, but also gave me wise counsel which aided greatly in the successful outcome of our projects. And perhaps what I valued most, personally, was the kindly warmth with which he treated me as a man.

I am writing this letter to you because I feel that many people in college and university ranks are unaware of how much men like Senator George have done for them. Personally, I am deeply grateful to him, as I am sure others engaged in the work of higher education would be, if only they knew about it. I hope that you can see your way clear to pass this information along to your faculty members, alumni, and other friends of Georgia Tech.

Philip C. Pendleton
Treasurer
University of Pennsylvania
Philadelphia

See page 23 for President Van Leer's comments on Mr. Pendleton's letter.



the president's page

SENATOR WALTER F. GEORGE's statesmanship in the field of foreign affairs recently has attracted nationwide attention. It remained, however, for a Pennsylvanian, Mr. Philip C. Pendleton, treasurer of the University of Pennsylvania, to remind us (in a letter published on page 22) that Senator George is devoted to many other causes, among them education.

Mr. Pendleton writes of his experience in working with Senator George on legislation to benefit the nation's schools, hospitals, and churches. He gives credit to our senior senator for several provisions of the Internal Revenue Code of 1954 which are expressly designed to favor colleges. I should like to elaborate on some of the new law's features:

1. *Contributions.* The limit on the deduction for individuals is raised from 20% to 30% of adjusted gross income; but the extra 10% is allowed only with respect to contributions to schools, hospitals, and churches. For example, a taxpayer has given 20% of his income to a charity which is not a school, hospital, or church. If he should give still more to one of those institutions, his tax deduction would not be any larger. But he could give up to 10% additional of his income to, say, Georgia Tech, and still deduct all his contributions.

2. *Short-term trusts.* There are several new provisions under this heading. One provides that, if the beneficiary is a designated school, hospital, or church, the grantor is to be taxed because of a reversionary interest only if the reversion may occur within less than two years. The effect is that a taxpayer might, by means of a short-term charitable trust, reduce his taxable income while the trust is in existence.

3. *Scholarships and fellowship funds.* As these are, in general, exempt, they may be ignored in determining if the parent provides more than one-half of the child's support.

4. *Research and experimental expenditures.* Inventors (and also certain purchasers of inventions) will have long-term capital gain instead of ordinary income from any assignment or exclusive license agreement that qualifies as a sale or exchange. This is the case whether the inventor is amateur or professional, and whether or not the amount of income depends on profitable use of the patent by the buyer. The inventor's income, if it does not qualify as long-term capital gain, may be "spread" back over the maximum period of 60 months (instead of 36 months).

In addition, research and development expenditures incurred after Dec. 31, 1953, may be (a) deducted as expenses, or (b) capitalized and (where the resulting property has no determinable useful life) written off over 60 months or more. These provisions should benefit the Georgia Tech Engineering Experiment Station and many of the sponsors for whom it develops new products and processes.

The costs of both getting an education and giving an education have risen terrifically in recent years. In such changes as the new income, estate, and gift tax laws, the Congress recognizes the importance of keeping our colleges strong and solvent.

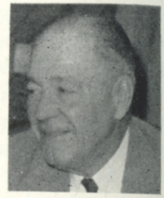
Georgia Tech, its students, faculty, Engineering Experiment Station, and other facilities, all will benefit from these liberalized internal revenue provisions. It is good to know that our distinguished senior senator played a major role in their enactment.

Blake R. Van Leer
President, Georgia Institute of Technology

engineering experiment station news

atlanta, ga.

georgia institute of technology



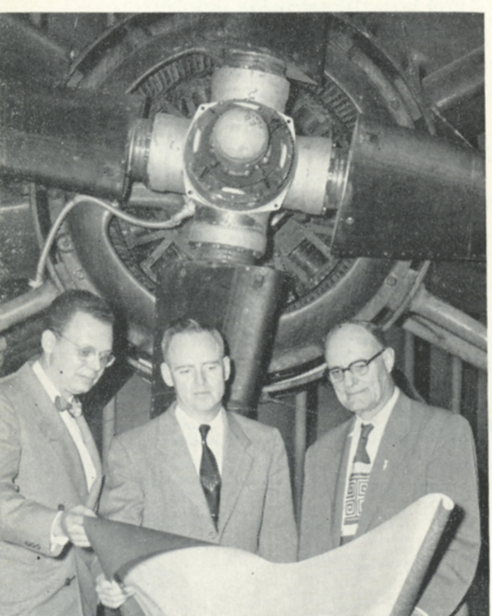
Mr. Emerson

Vice-President Cherry L. Emerson *retired June 30 because of statutory age limitations. Mr. Emerson, a graduate of Georgia Tech in 1908, had had a successful career as an engineering executive before he came back to the campus in 1945 as dean of engineering. In 1948, he was promoted to the new position of vice-president. He supervised the Institute's multi-million dollar expansion program, the Engineering Experiment Station, and other activities. Mr. Emerson plans to enter practice in Atlanta as a consulting engineer. Engineering Experiment Station Director Paul K. Calaway now reports directly to the president of Georgia Tech.*

Georgia Tech and the Lockheed-Georgia aircraft plant are engaged in a $75,000 program to modernize the nine-foot wind tunnel at the Daniel Guggenheim School of Aeronautics. The improved wind tunnel is to be in full operation by January 1, 1956. It will be used to test new designs for aircraft, as well as for other applied research.

"Georgia Tech is especially pleased with this new development," President Blake R. Van Leer said. "I am certain the leadership shown by Lockheed in this cooperative undertaking will encourage other southern industries to begin similar programs. We urgently need this type of assistance if we are to do the requisite job in both education and research."

This is the second major improvement of the tunnel since it was first constructed on the campus in 1932.



Carl F. Friend (left), head of Lockheed-Georgia's aerodynamic engineering dept., is shown discussing plans for Georgia Tech's improved wind tunnel with Prof. Donnell W. Dutton (center), director of the Daniel Guggenheim School of Aeronautics, and President Blake R. Van Leer, of Georgia Tech.