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the Wisconsin engineer

February, 1949

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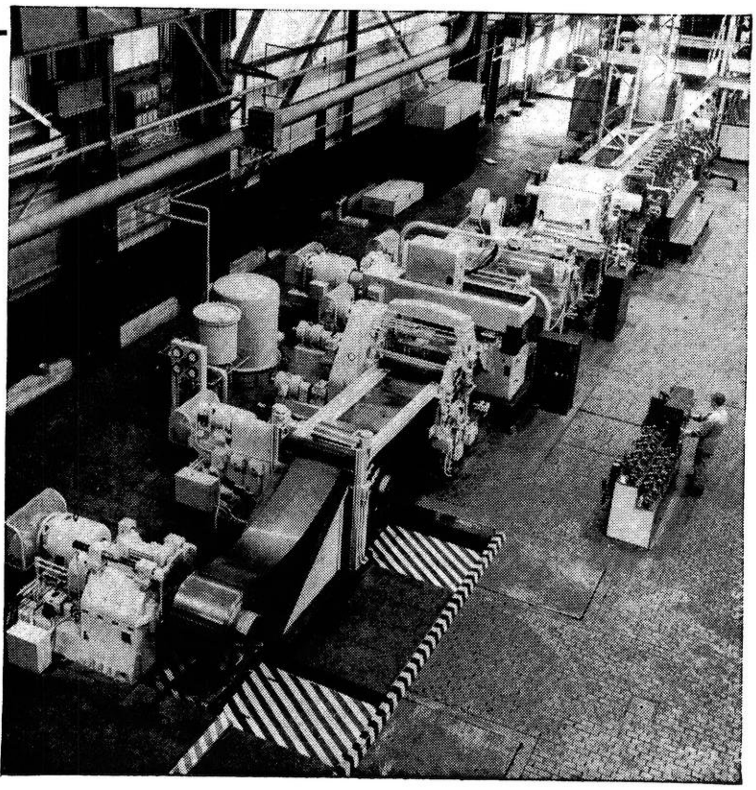
Science Highlights

15¢

Electrolytic tinning process stretches tin supply

—makes better, less expensive tin-plated products

•pioneered by Carnegie-Illinois Steel Corporation



▶ Before the war, almost all tin plate was made by the hot-dip method in which a sheet of steel was coated by dipping it into molten tin. In the 1930's, Carnegie-Illinois Steel Corporation, a member of the United States Steel family, played an important role in the research work and the technological development of the *electrolytic process*—an improved tinning method in which a strip of steel is given a thin, uniform coating of tin by passing continuously and rapidly through a bath of special plating solution. This process necessitated the development, by Carnegie-Illinois engineers, of complex mechanical equipment completely revolutionary in the industry.

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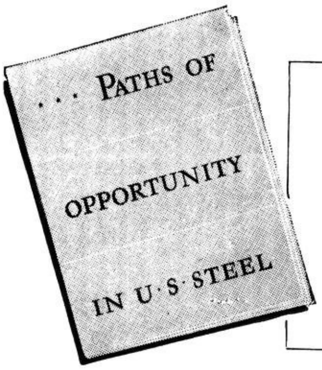

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COVER: *(Photo by Wahlin)*

Members of an M.E. 62 class are discussing the boiler feed pumps on their field trip to the Sheboygan Power Plant.

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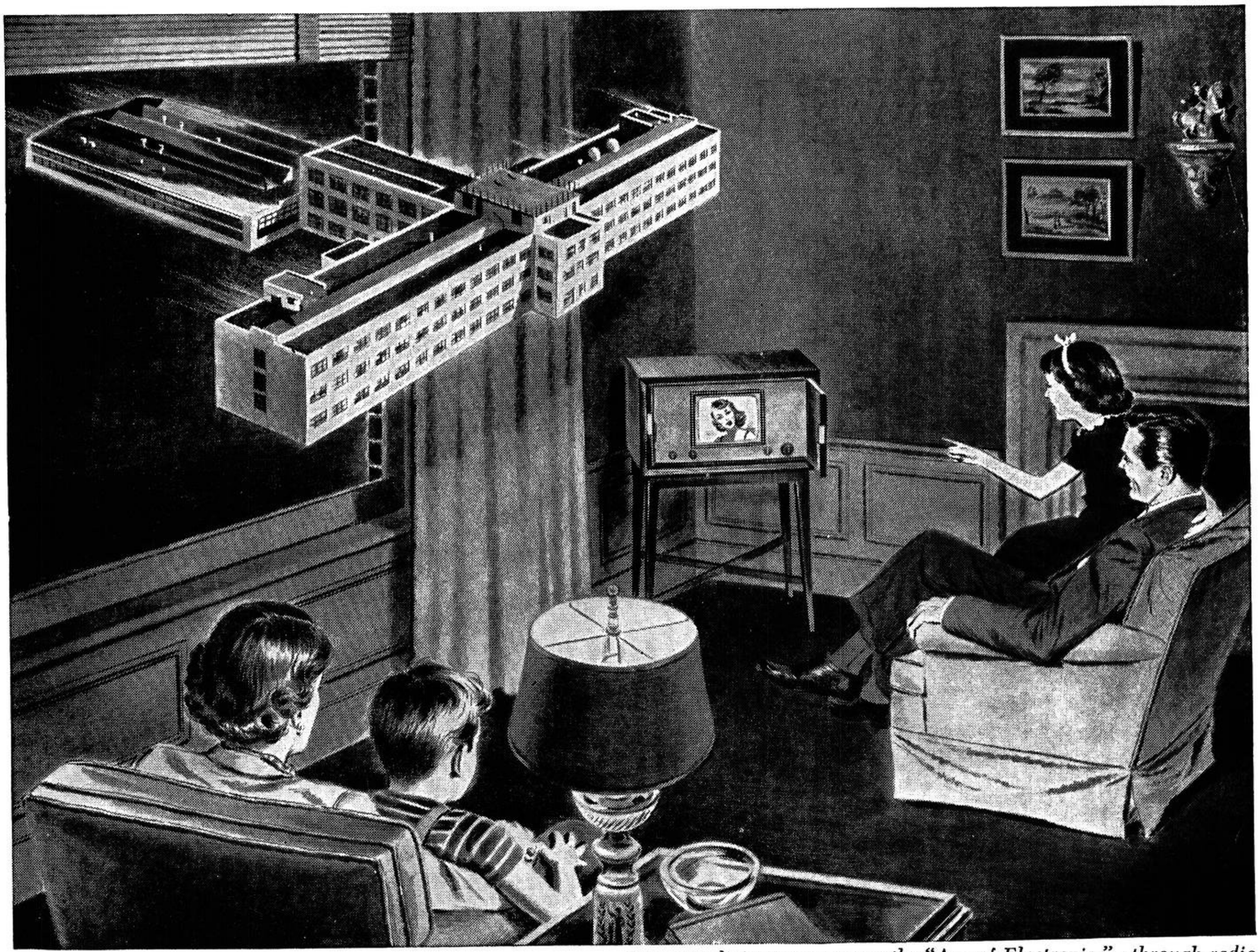
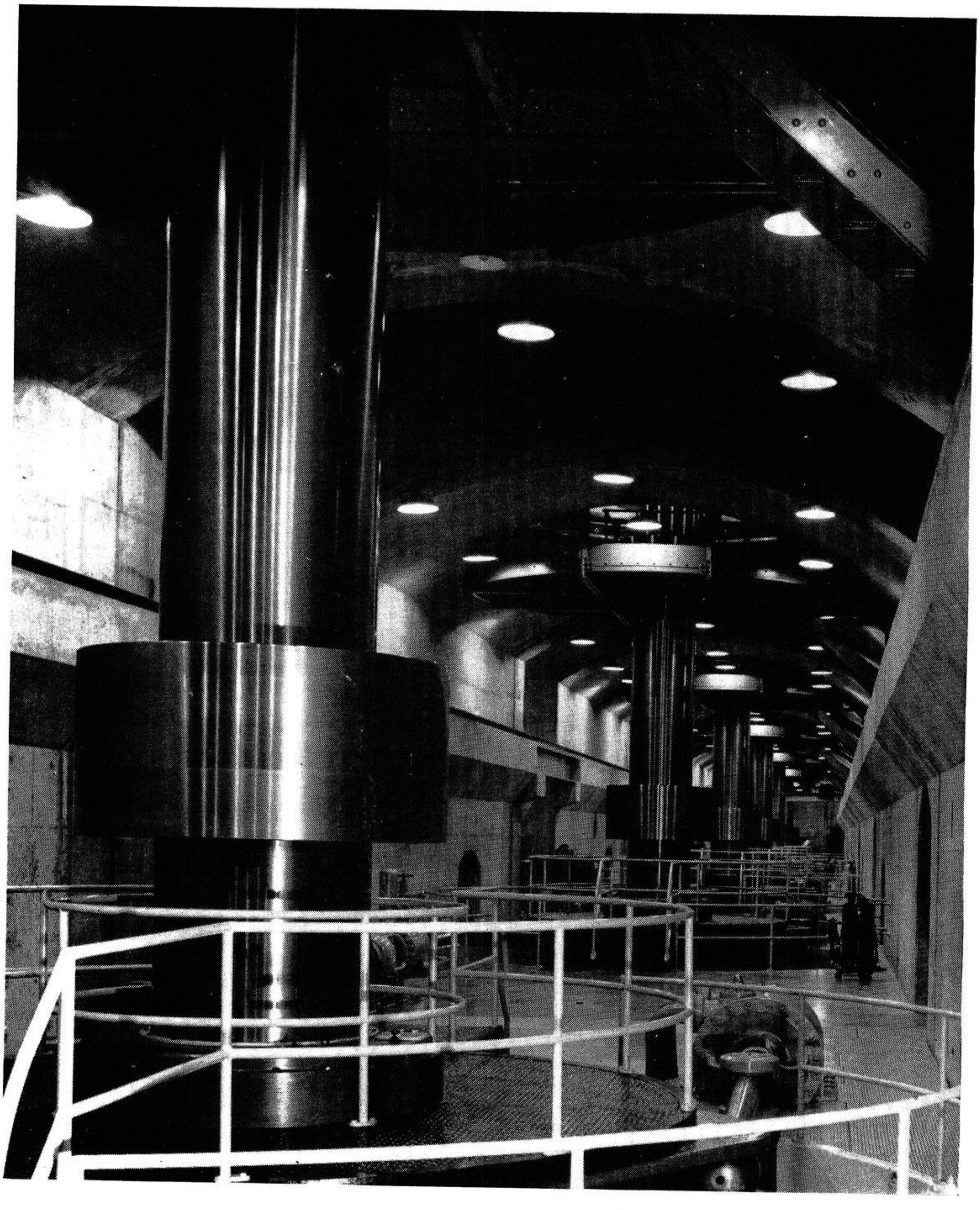
CORRECTION:

The illustration in the "Continuous Casting" story on page 8 of the January issue should have been credited to *Iron Age*.



Into your living room comes the "Age of Electronics"—through radio and television research achievements of RCA Laboratories.



Cut courtesy Westinghouse Electric Corporation

Rotated by torrents of water released from Boulder Dam, these shafts transmit energy from the water wheels below to six 82500-kva Westinghouse generators above.

CONTOUR PRODUCTION

by Russell Pipkorn m'49

The WISCONSIN ENGINEER wishes to acknowledge the assistance of the following companies for supplying some of the information which was incorporated in the following article: American Broach & Machine Company, DoAll Company, Barber-Colman Company, Fellows Gear Shaper Company, Pratt & Whitney Company, and the Thompson Grinder Company.

R.H.P.

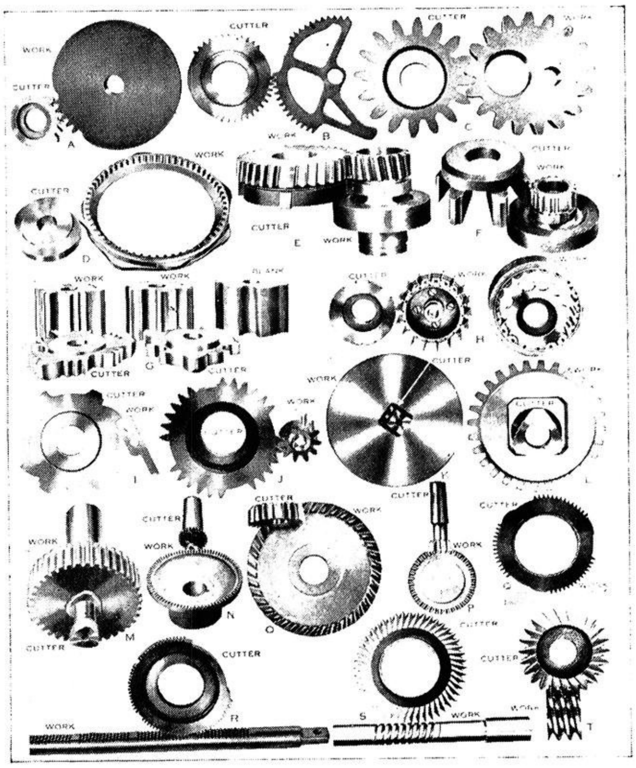
Have you ever wondered about the designs in the world around you? Curves and contours are the basis of many of the designs so prevalent in modern design. The production of these contours is done by some interesting methods now common to production but which required years of development. This article includes some of the more interesting methods of producing contours. Starting with the conventional production methods, such as dies and molds, the story of contour controls is carried all the way through to the very modern servomechanism controls now in use on production machinery.

Two Classifications of Parts

Contour parts will generally be classified into two groups; sheet metal parts and solid parts. Their production problems are different in many respects. Sheet metal contours are best exemplified by the body parts of the modern car which are pressed from sheet metal, as well as by those flat metal pieces which are cut out to some regular or irregular shape .Solid parts might be exemplified by the dies required to manufacture these parts. Another example of solid parts are those with contours in two dimensions such as involute gears or other similar shapes.

As the parts vary, so do the methods of production. Sheet metal parts of the type described are manufactured on presses using forming dies. The dies used are the backbone of the forming processes. The production of these dies will be discussed under the production of solid parts. Spinning is another method used for making such parts as solids of revolution. This operation begins with a flat sheet of metal, and by continuous "pushing" of the metal over a form with some type of roller tool while the sheet rotates, a finished part is produced. This method of production is common in cooking utensils.

Solid parts are produced by a variety of methods, some of which are more common and less costly in their use. Casting fluid material in molds, either sand, metal or some other material, either with or without pressure is a common method of producing contour pieces. Since this method is a topic in itself, this type of production will not be discussed. The making of molds for such operations as die-casting (casting metals under pressure) will be discussed with the making of dies. Forging is another method of producing contour parts. Its principle is to form the metal in dies when it is in a plastic state at an elevated temperature. The actual production is done with dies mounted in forging presses which hammer the metal into the die. These dies will be discussed later with other types of dies. Extrustion — the operation of forcing metal through a die to produce a bar of some regular or irregular shape — has been employed extensively in nonferrous metals such as brass and aluminum. Rolling in large mills has been used in producing steel bars of a variety of shapes by using formed rollers. An example is the steel rails which are made in this way. Machining is still another method employed to produce contours. Beginning with a solid block of metal, or even a casting or forging, the final part is produced by the action of a cutter.



Photograph courtesy Fellows Gear Shaper Co.

Several samples of the types of contours being generated, with the cutters used.

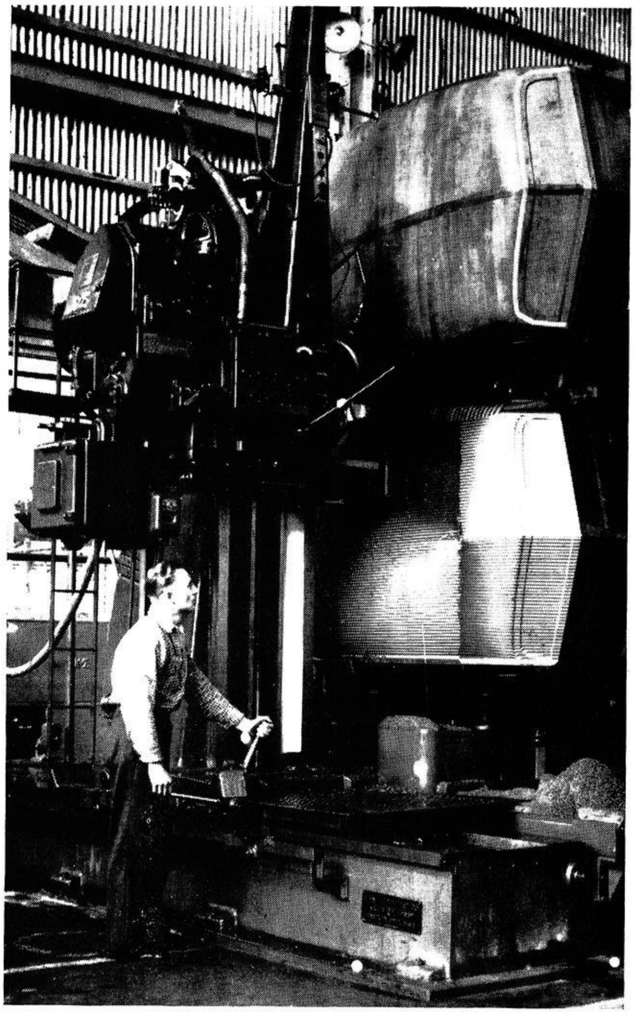
Form Tools and Sawing

The easiest method of machining a simple contour is by a form cutter. Form cutters are made of cutting steel and have a shape opposite to the contour being cut. They are employed as flat tools to form cylindrical contours on lathes, or as circular cutters with teeth, in milling machines to cut two dimensional contours of some length.

Another simple method which involves a minimum of waste is the metal cutting saw. Contour saws using specially designed saws for various materials have been successfully used in making, among many other production items, punches and dies. A punch and a die are cut from a single piece of material, and the process requires a minimum of hand finishing. The angle of cut compensates for the difference in size of the punch and die due to the width of the saw blade. The operation of sawing is employed where production is low because a minimum of tooling is required — only a template — for this as well as for high production.

Broaching Internal Contours

Broaching is a very important method for use in high production techniques. Simply explained, broaching is a method of cutting a contour either internally or on a surface by a broach which is pulled or pushed through or along the work. A broach is a tool having a number of cutting teeth which progressively cut away on the working piece until the final few teeth give the finished shape. A square hole might be used as a simple example of internal broaching. The broach begins in a round hole and the teeth of the broach gradually cut out the corners until the final few teeth will cut all four sides forming the finished square hole. In this type of broaching, the broach itself is pushed or pulled through the part.



Photograph courtesy Pratt & Whitney Co.

A Keller Tracer-controlled Contour Milling, Type BG, machining a body die for an automobile body top. Note the parallel cuts used in machining the contour. Further finish machining will produce a smooth surface.

Generally the initial hole sets the location, and in the case of the pulling operation the end of the broach is free. It is connected to the ram only by means of the puller. Surface broaching is employed to rapidly finish surfaces of a simple or complex form. As the teeth of the broach pass over the surface each successive tooth cuts away a little more of the material until the final few teeth finish the surface to size. In this type of broaching the broach is rigidly mounted on a moving ram and the work piece is held rigidly in a fixture. A simple example of broach machining is the jaws of a pair of pliers. One company has set up a fixture to broach both the mating plier halves at one time at the rate of 120 pairs per hour.

Two Types of Hobbing

Hobbing has been employed in the production of two dimensional contours. Primarily it has been used in the cutting of gear teeth. In hobbing, the work revolves on its axis and the cutter revolves on an axis nearly at right angles to the work and above it, depending on the size of the cutter, or hob, and the work. The important part of the operation is the geared connection between the hob and the work, which is in turn dependent on the design of the hob.

A comparatively new method of producing irregular cavities is an operation also called hobbing, but which should not be confused with the hobbing of gears. The bulk of the material to be removed from a cavity is first removed with standard machines, lathes or mills. A hardened "hob" is then made which has the exact shape of the required cavity. This "hob" is then forced into the cavity in a hydraulic or equivalent press to finish the cavity to the shape desired. This method eliminates difficult and sometimes impossible machining.

Contours by Generation

Another method of machining two dimensional contours is the method of generating as employed by the Fellows Gear Shaper Company. The work revolves slowly on one axis and the cutter revolves slowly on another at a fixed relationship to the work as it reciprocates and removes a cut. The operation has been known for its use in generating gear teeth, but many more shapes have been cut. The shape that can be cut, either internal or external, depends on a successful design of a cutter to produce the correct shape. The actual machining is comparable to shaping or slotting but the important difference is the design of cutter and the working relationship between work and cutter. The generating principle has been applied to cams and other shapes of seemingly impossible machinability. The photograph of some of the shapes which have been cut by generation give some idea of the possibilities of the method.

Crush Form Grinding in Production

Within the last fifteen years a method of form grinding has been developed to produce irregular shapes. It is known as crush form grinding, from the method used in forming the grinding wheel. A slowly revolving power op-

(please turn to page 24)

GRADUATE STUDY

Is it worth while?

by Robert Johnson e'50

(*Charts courtesy of "The Engineering Profession in Transition"*)

What are YOU going to do when you graduate? Competition is going to be rough; jobs may be hard to find; the question of post graduate occupation is one of universal interest for all engineering students. "What should I do; for whom should I work; have I had enough education, and was it of the right type?" These are a few of the questions arising in the minds of most engineers as they approach graduation. Many do not know what they're really interested in, nor how to look for the type of work for which they are best adapted. Will these men find their answer in continued study for advanced degrees, will they find it in on-the-job training courses, or will they find it in the acceptance of direct assignment positions in the heart of industry?

These questions are difficult to answer even for a specific individual. However, a study of the factors considered by many students contemplating graduate work may facilitate an intelligent and worthwhile decision. Formal education has a definite role in industry and applied engineering. One definition of engineering that has been offered is "the art of applying the fundamental principles of science to the solution of practical problems in industry and society." College is supposed to equip one with the ability and capacity to work with and understand these fundamental principles. The ability to apply this knowledge to specific problems comes only through practical experience generally found most readily in industry. A good many men enroll for graduate study without having had the practical experience of industrial work; as a result they have little idea of the direction in which to aim their studies. One trouble is that they do not know what type of work they'll be doing and what to study in preparation for it. According to Mr. K. B. McEachron, Jr., the manager of General Electric's Technical Education Division,

"Graduate training will be of real value only if a man has had some experience with industry, knows definitely what he hopes to achieve by such study, and recognizes that he will receive no preference except in starting rate when he is finally employed in industry."

This however, is but one of the factors to be considered by the present undergraduate engineer approaching graduation. What other elements should he consider when making his decision? Four general categories may be cited:

1. Actual cost, to the student, of further study
2. Remuneration and Advancement
3. Interests and Aptitudes
4. Educational Objectives

Actual Costs

The expense for himself is often one of the first problems confronting a student engineer who would like to continue his education. Many students on the verge of graduation find that four years of college have exhaused their financial resources. The G.I. bill may have run out, and the young engineer is left almost without a cent on

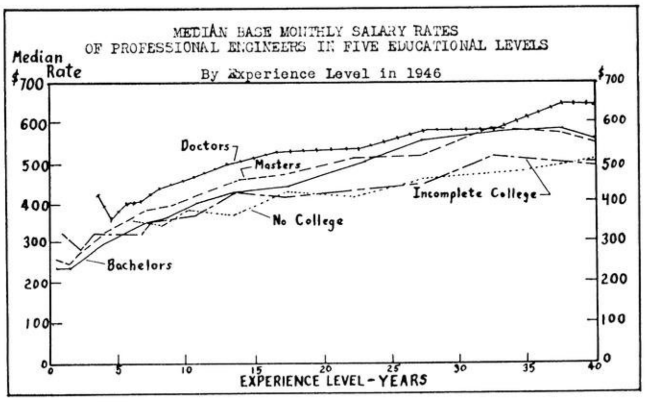


Chart I.

which to stand. Understanding this situation, many universities and industries have set up a system of scholarships, fellowships, and assistantships which will enable these men to continue their studies. Actually there is a large number of adequate fellowships here at the University of Wisconsin which offer excellent inducement for continued work. There are also quite a few opportunities for work under graduate assistantship status. One of the advantages of teaching experience is that the instructor must review the subject himself and then present it to others. In so doing he naturally learns the material much more thoroughly and thereby increases his grasp on the knowledge of fundamentals—a point stressed strongly by modern industry. This work provides funds and still leaves the student plenty of time to study his other courses. If a capable and ambitious engineer would like to continue his studies but is financially limited, he should by all means consult with one of his professors or with the Dean of the Engineering school about the possibility of his receiving one of these jobs or awards.

Salaries and Advancement

At the present time, starting salary rates for many companies are placed on a differential basis with M.S. and Ph.D. recipients receiving respectively higher beginning wages. E. I. DuPont Corporation, for example, has set up the following monthly wage scale for technically trained but inexperienced personnel:

B.S.	$295.00
M.S.	355.00
Ph.D.	445.00

Many companies follow a similar procedure since the man starting with a higher degree is generally capable of more difficult work. Some industrial concerns like Allis Chalmers, which conduct extensive Graduate Training Courses, do not make any immediate wage discrimination since nearly all new engineers employed by them go through this course. A very complete survey compiled for the Engineers Joint Council Committee on the 1946 Status of the Engineering Profession showed that most men entering the profession at that time received approximately equivalent salaries. This study was based on statistics collected from the 317,467 registered engineers in the United States and was compiled by Mr. Andrew Frazer for the EJC Committee on the Economic Status of the Engineer. These committees were comprised of members of the National Society of Professional Engineers, American Society of Civil Engineers, American Institute of Mining and Metallurgical Engineers, and the American Institute of Chemical Engineers. The initial wage advantage held by men with advanced degrees was maintained over a long period of years, and it was found that these men generally achieved positions of higher responsibility. This survey showed that engineers with advanced degrees tend to earn larger salaries than those with less education, particularly as they gain experience. As chart I shows, this holds through the first twenty year period with a few discrepancies developing afterwards. The earnings of men with doctorates, for example, average some $75 more per month than those for engineers with only a B.S. degree. Considering only this first twenty year period, this salary difference alone would amount to some $18,000.00, and their earnings hold up better even after thirty five years.

A more recent study conducted by the personnel department of the Los Alamos Scientific Laboratory operated in conjunction with the University of California displayed the result that Ph.D.s maintained an overall advantage of about $150 a month, and that the wage differential was essentially maintained as the men gained professional experience. The survey was conducted principally in industrial and scientific laboratories where the advantages of high degrees are often multiplied, but this idea should be kept in mind for those engineers interested in industrial development and research work. Some 9000 professional men were consulted, the data computed and averaged along a weighted least squares line, and the following results obtained:

a). Starting Salaries

Computed by extrapolation of the weighted least squares line.

Bachelors	$257.29
Ph.D.	400.55

b). Incremental increase per year of additional experience.

Bachelors	$16.30
Ph.D.	15.59

c). Recommendations of the Committee on Scientific Personnel for the Atomic Energy Commission:

	Starting Salary	Yearly Increment
Bachelors	$250.00	$20.00
Ph.D.	400.00	30.00

The lower increment figures actually found for Ph.D.'s are unusual, although it must be considered that the administrative practices of the groups studied varied widely as regards salary increases.

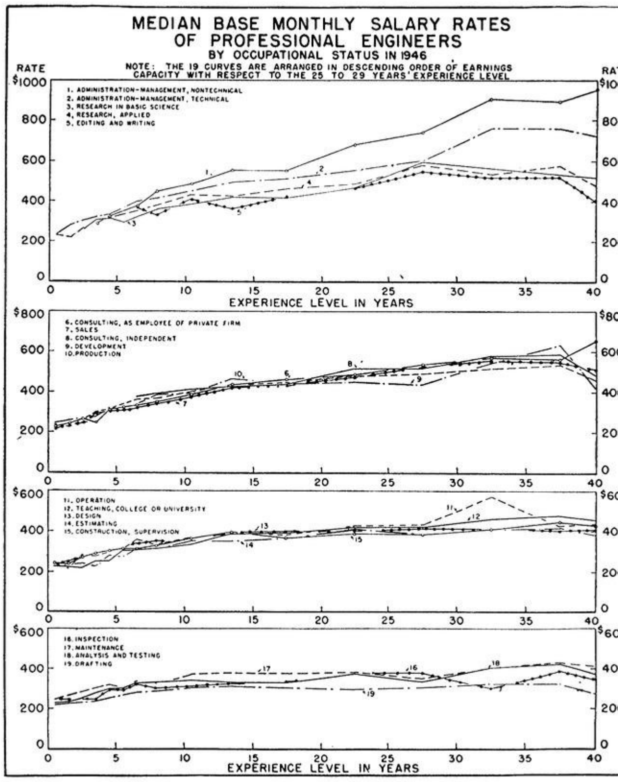


Chart II.

Another survey conducted by the City College of New York and its undergraduate placement director John F. X. Ryan produced the following conclusions from 45.8% of the 1100 June 1947 graduates of the College:

Per annum wage:

Electrical Engineers	$3,350
Civil Engineers	3,180
Chemical Engineers	3,025
Mechanical Engineers	2,900
Social Science	2,600

Arts and Business Administration	2,500
Accountancy	2,300
Education	2,200

In response to various questions on their questionnaires, the former students suggested vocational aptitude tests, out of town job hunting, and graduate study as means for improving their economic and professional status. Many students suggested changes in the curriculum and one said that "High degrees are practically a necessity for a decent job and a salary." Mr. Ryan slightly modified these and most other starting salary considerations by saying,

"Immediate rewards are not the factor of prime importance to professional men. The average graduate's salary runs from $2000 to $3000 per year and is normal; he has to grow in his profession for more than that."

In considering advancement, it must be remembered that technical ability alone is not the determining factor. The author conducted a small survey of his own among various industrial concerns. Around twenty of the more prominent corporations replied to a letter sent them asking for their opinions and advice regarding graduate training in engineering. The general response to the question concerning starting salaries and probable advancement was that initial wage differentials were made; but that the continuance of these advantages for the men with advanced degrees was dependant upon the individual, his personality, and the advantage he took of his opportunities. In addition, both Mr. McEachron from General Electric and Mr. C. M. Rawles from Allis Chalmers pointed out that the difference in starting salaries is little greater than would exist between men just entering the company and those who had had service equivalent to the time required to obtain an advanced degree.

Aptitudes and Interests

The two factors in this subhead maintain an important role in the success and professional advancement of the engineer. One must remember that satisfaction with his job will determine a large portion of his success and happiness. Economic considerations must be made, but one is much more likely to be a success in a field that he enjoys rather than in one he detests. The cardinal results of the author's poll of personnel and employment directors revealed their opinion that graduate work was of great importance to those men interested in technical, development, and research applications of their training. Considering the multitude of technological advances made in recent times and the limited time of college preparation, these men felt that advanced college preparation was an excellent asset for technical work in industry. On the other hand, nearly every one of the companies replied that advanced degrees were of little practical use to those men entering sales, production, or personnel work. This would seem to imply that highly technical electives would be of little value to this class of graduates. Mr. W. S. Idler from the Aluminum Company of America replied,

"It is our opinion that where a man's primary interest is in a specialized technical field, graduate work is helpful to him and offers a broader field of opporunity; but the man interested in general production or sales work could better devote the two or three years required to receive a graduate degree to building up from good practical experience."

The EJC survey offers some interesting material on this subject of different branches of engineering. The following table gives an idea of the distribution of engineers in the various occupations for three different years.

Percentage Distribution in the Engineering Profession

Occupational Status	Year 1939	1943	1946
Administration-management—technical	22.6	26.6	30.4
Design	14.2	15.3	14.9
Development	5.2	7.0	6.8
Research, applied	4.9	6.0	5.8
Construction, supervision	7.6	6.3	4.7
Teaching	5.3	4.8	4.4
Consulting, private	3.5	3.5	4.2
Sales	4.1	2.9	4.1
Administration-management—nontechnical	2.7	3.0	3.6
Operation	4.2	3.5	2.4
Production	2.2	3.2	2.1
Drafting	3.3	1.7	1.1
Writing and Editing	0.5	0.6	0.7
Research, basic	0.6	0.5	0.6
Personnel	0.2	0.2	0.2
Unspecified occupational status	18.9	14.9	14.0
Totals	100.0	100.0	100.0
Engineers Reporting	30,922	36,434	37,545

This study indicates that the percentage of employer engineers is small. In 1946 only 7% of the engineers who entered the profession before 1940 were in this classification. Among younger engineers the percentage is extremely small; only 2 percent of those who entered professional practice since 1944. Chart II shows the relative salary rates for various experience levels for the several occupational classifications. At the time the EJC report was published, the median starting salary for young engineers was about $200 a month. A comparison of the increases between the various branches is revealing. For example, an engineer with some 35-40 years of professional experience employed in nontechnical management administration was averaging between $900-1000 per month. But an engineer with equivalent experience who was employed on drafting work was making slightly over $250 per month.

These observations should be kept in mind when analyzing the problem of continued graduate study. Very few engineers appear to reach the employment heights of non-technical management, but those who do make very good money. There are quite a large proportion of

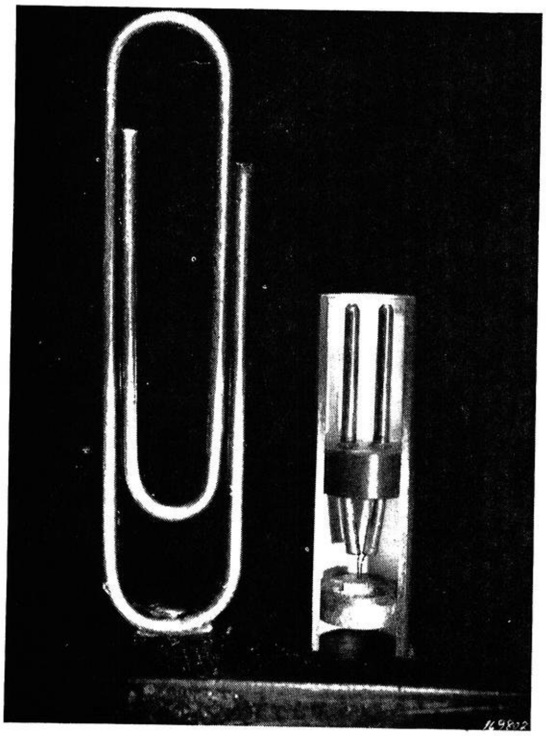
(please turn to page 30)

The Transistor

by Harold Mueller e'49

Semi-conducting crystals are not new to the electronics industry, where they have been used for a long time for rectifiers, for modulation and demodulation in telephone work, and more recently in UHF for detection; but not until the recent development of the Transistor by Bell Telephone Laboratories has a crystal ever served as an amplifier.

Although the Transistor is an extremely simple device, it is capable of performing efficiently nearly all of the functions of the ordinary vacuum tube. It operates on an entirely new physical principle discovered by the Laboratories in the course of fundamental research into the electrical properties of solids.



Cross-section view of a transistor.

The whole apparatus is housed in a tiny cylinder less than an inch long. It will serve as an amplifier or an oscillator, yet it bears almost no resemblance to the ordinary vacuum tubes now used to do these basic jobs. It has no vacuum, no glass envelope, no grid, no plate, no cathode and, therefore, no warm-up delay.

Instead of the one wire (cat's whisker) used in the ordinary crystal detector, two hair-thin wires touching a pinhead of solid semiconductive material are the principal parts of the Transistor. The semiconductive material is soldered to a metal base, and the complete assembly enclosed in a simple metal cylinder not much larger than a shoe-lace tip. More than a hundred of them can easily be held in the palm of the hand.

While many scientists and engineers have been associated with the work during the project, key investigators who brought the Transistor into reality were Dr. John Bardeen and Dr. Walter H. Brattain, working under the direction of Dr. William Shockley. Dr. John Bardeen is the son of the late Dr. Charles R. Bardeen, former dean of the medical school at the University of Wisconsin.

Theory

The amplification process can be understood in terms of the discovery made by Dr. Bardeen and Dr. Brattain that the input point is surrounded by an "area of interaction". Within this area the electronic structure of the semiconductor is modified by the input current. This control of output current by input current is the basic mechanism of amplification.

These materials, whose electrical properties are intermediate between those of metals and insulators, offered particular promise of useful electrical applications, since their ability to carry electrical current can be changed over wide ranges in various ways. Like any substance having the ability to conduct electrical currents, these materials rely for conductivity on the presence of current-carrying electrons. In metals, which are good conductors, there is a ratio of approximately one current-carrying electron to every atom. In insulators, there are practically no such electrons and, therefore, little conductivity.

In semiconductors, such as silicon and germanium, some metallic oxides and other compounds, there may be as few as one current-carrying electron for every million atoms. But (and this is the significant feature) this number of carriers may be varied a thousand-fold or more by changing the electronic structure of the materials. Hence, the current flowing through the material can be controlled.

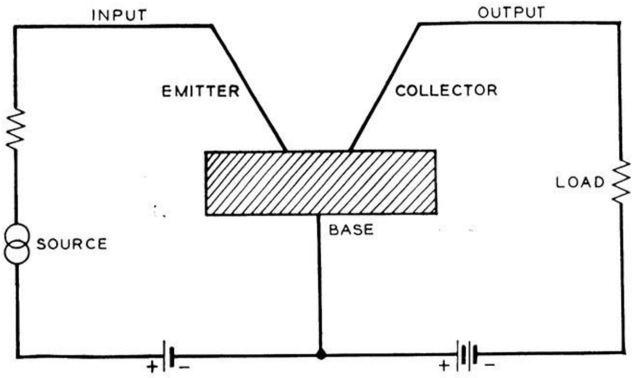
In critically examining the implications of the prevailing theory of electrical conduction in semiconductors, Dr. Shockley was able to predict that it should be possible to control the meager supply of electrons inside a semiconductor by influencing them with an electric field imposed from the outside without actually contacting the material. Realizing the practical implications of such a possibility, he devised some experiments to test his hypothesis but was unable to secure positive results. The electrons seemed to get trapped in the surface of the material and did not behave exactly as anticipated.

As explained by Dr. Bardeen, Transistor action depends upon the fact that electrons in a semiconductor can carry current in two distinctly different ways. This is because most of the electrons in a semiconductor do not contribute to carrying the current at all. Instead they are held in fixed positions and act as a rigid cement to bind together the atoms in a solid. Only if one of these electrons gets out of place, or if another electron is introduced in one of a number of ways, can current be carried. If, on the other hand, one of the electrons normally present in the cement is removed, then the "hole" left behind it can move like a bubble in a liquid and thus carry current.

In a Transistor made of a semiconductor which normally conducts only by the extra electron process, current flows easily into the input point, which is at a low positive voltage, and out at the output point, which is at a higher negative voltage. The area of interaction is produced by "holes" introduced by the input current and collected by the output point.

Semiconductors which conduct by the "hole" principle are referred to as P-type because conduction appears to be by positive charges, whereas, if conduction is obtained by virtue of negative charges moving under the influence of electric fields, the semi-conductors are called N-type. Both types of conduction were normally attributed to impurities. Silicon alloyed with a minute percentage of phosphorous, for example, is an N-type conductor, and conduction is explained by the fact that phosphorus has five valence electrons, four of which form bonds with the four valence electrons in a silicon atom, leaving one electron free for carrying current.

If the impurity in the silicon crystal is boron instead of phosphorus, there is one incomplete bond between each boron and its neighboring silicon atom, since boron has only three valence electrons, thus leaving a hole in the atomic structure. Because the percentage of boron impurity is very low, not many silicon atoms are in this manner bound. Hence the hole in the bond of one silicon atom with a boron atom can be filled with an electron from an adjacent silicon atom which is under the influence of an external electricfield, leaving a hole from which this electron came. This hole is free to move from atom to atom and, consequently, constitutes a current. Where as a negative electron will migrate from a negative region toward a positive region when voltage is applied, a hole will migrate from a positive region to a negative one. This theory of conduction by "holes" applies also to germanium.



TRANSISTOR USED AS AN AMPLIFIER

In conjunction with the development of the theory of the state condition of surfaces which resulted in the discovery of the Transistor, the Bell Laboratory's investigators noted a surface layer having peculiar characteristics. To account for these characteristics they postulated, and later showed by experiment, that there is a thin layer of electrons at the surface of germanium. This surface layer would prevent an externally applied field from penetrating into the body of the semiconductor and thus account for the minor changes in resistance observed experimentally. The field created by these surface electrons causes the formation of holes in the adjacent material, and these holes conduct current. The conducting layer may be caused by an excess of impurities, such as boron, near the surface which accept electrons into bonds and thus create holes, as explained above, or else by a space-charge barrier layer. Between this P-type layer and the N-type interior is a rectifying barrier.

When a single point contact is made, as in the ordinary (cat-whisker) crystal, the surface layer determines the conductivity for reverse currents or small forward currents. For large forward currents there is an increase in the concentration of electrons and holes. In either case a large part of the current is carried by the surface conducting layer within an area of interaction very close to the point of contact. Within this area the conductivity, which is mainly by holes, is much greater than elsewhere in the semiconductor. The second point contact for the Transistor is made within this area of interaction.

Electrical Characteristics

According to Dr. Shockley, the positive point contact in a transistor causes the release of holes in the surface layer of the germanium. These holes spread away from the point, flowing in all directions along the surface. The holes reach the other contact point, or cat's whisker, which is 0.005 centimeters away, in less than $1/10^7$ seconds. This is the transit time that limits present performance to frequencies below about ten megacycles. From this observation it is estimated that the holes travel at the order of 10^5 cm./sec. Higher applied potentials and smaller spacings, as used in vacuum tubes to increase high-frequency performance, may reduce this transit time and increase the upper frequency limit of the transistor.

In the absence of hole conduction produced by the emitter, the negative bias applied to the collector causes a very small current to flow from the germanium. When the positive bias is applied to the input, however, holes are attracted to the output point contact which is biased negatively, thus increasing the output current and producing the desired amplification. Variations in the input current change the number of holes released toward the collector and vary proportionately the output current. The Transistor is, consequently, similar electrically to a grounded-grid triode circuit.

(please turn to page 40)

WELDED RAILS

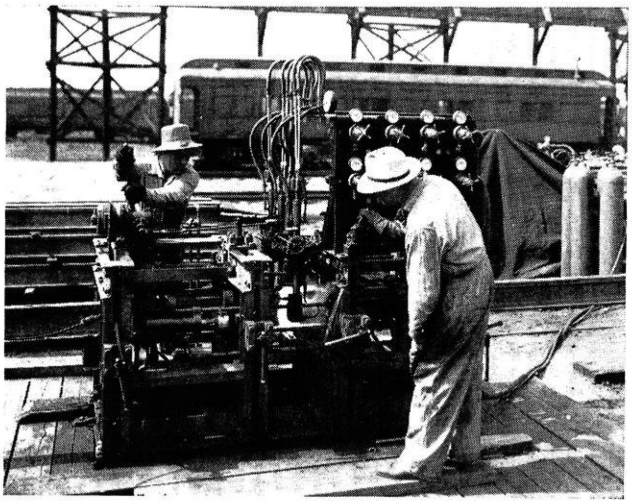
ADVANTAGES, PROBLEMS, AND PREPARATION

by John Misey e'49

(Photos courtesy Oxweld Railroad Service Company)

The following article was prepared for publication by John Misey e'49 from a technical paper by Mr. Torbert of the Oxweld Railroad Service Company, a subsidiary of Union Carbide and Carbon Corporation. This paper was presented before the student chapter of ASCE last April.

To many travelers on the trains the never-ending clickety-clack noise as the train rolls over the joints where the rails are bolted together has been a source of much annoyance and perturbation. Many railroad engineers have attempted to correct this bad feature. Some approached the problem by providing smoother riding coaches with many differently designed shock - absorbing carriages. Others have attacked the problem at the very source; namely, the rails and their inherent difficulties. These latter men experimented with continuous welded rails.



Welding machine developed by Oxweld Railroad Service Co.

The problem of welding rails together has long been a pet idea of railroad engineers. The earliest mention of solving the problem in this fashion was in 1820. At this time a patent was issued to John Birkenshaw for the "tee" rail and, amazing as it may seem, this patent contained his proposal to weld the rail together into longer lengths. By 1830 a base was added to the "tee" rail by the president of the Camden and Amboy Railroad which resulted in a rail section not too different from our present rail design. As early as 1885 attempts were made in England to provide continuous rails. The results of some of the attempts were published, and Trautwine, in his book in 1874, states that "when lengths of from 100 yards to some miles of rails have been perfectly welded (or riveted tightly together) and spiked to ties as usual, no elongation or contraction by heat or cold could be detected." In 1889 a three-mile-long tightly riveted section was installed in the United States in the Lynchburg and Durham Railway, and a similar installation of 1050 feet length was laid by the Pennsylvania Railroad in 1897. Several years passed before any more installations were made. This was primarily because of the failure of the type of connection rather than because continuous rails themselves were impractical. However, the first recent successful installation was made by the Central of Georgia Railroad in two of its tunnels. These rails were replaced in 1937 and again in 1944. They are still in service. Many other railroads have followed suit by laying continuous rails in tunnels and on bridges where wear on the rails is extremely heavy. In 1944 the longest modern welded rail, 12,752 feet, was installed on the Elgin, Joliet, and Eastern Railroad in open track.

There have been four processes used to produce continuous welded rails in the United States in the twentieth century. The most recently developed process and the one that seems to be the most economical at this time is the oxy-acetylene pressure welding process, as developed by the Oxweld Railroad Service Company. A second process, not now in use here, is the electric flash welding process. A third process is the Thermit weld which is more generally used in electric railways. The last process is the oxy-acetylene manual fusion weld which is being widely used; however, the structural strength of this weld is considerably less than the oxy-acetylene pressure welded rail.

The oxy-acetylene pressure welding process consists of six operations:

1. End-preparation of the rails to be welded.
2. Pressure welding of the rails.
3. Trimming off the excess metal at the weld.
4. Heat treatment at the weld area.
5. Grinding and polishing.
6. Inspection of the rail.

In the preparation of the rail ends, the removal of approximately one-sixteenth inch is necessary to eliminate rust and irregularities in the rails as they are received from the mills. This is accomplished by butting the ends of the rails to be welded together and running a power driven saw through the point of juncture. The kerf of the blade provides a matched cut and a suitable welding surface. Surfaces to be welded together are then wiped off with a solvent such as carbon tetrachloride at the time they are placed in the welding machine.

The rails are forced together in the welding machine by two rams, operated by a hydraulic pump, which provides a continuous pressure of 3000 lbs. per sq. in. Another hydraulic pump and clamp assembly holds the rails in alignment and prevents slippage. At the same time heat from an oxy-acetylene flame is uniformly applied to a few inches of each rail. The combination of hydraulic pressure and the application of heat produces the pressure weld. Pressure forces the rails together and forms a bulge at the weld which is called the upset. When the required upset is reached, the flame is shut off immediately; and the pressure is held for one minute until the weld reaches a rigid state.

After the welding, the rail is removed and the upset metal or bulge on the ball and sides of the base is cut off with a cutting blowpipe.

The fourth step in the process is the normalizing or heat treating process. This is accomplished in a special machine having a heating head arrangement similar to that of the welding machine. Here no clamping devise is used and the heating zone covers the entire heat affected zone in the welding process. The normalizing temperature is fixed by the use of temperature pellets at the beginning of each day's run, and subsequent treatments are timed from this established cycle.

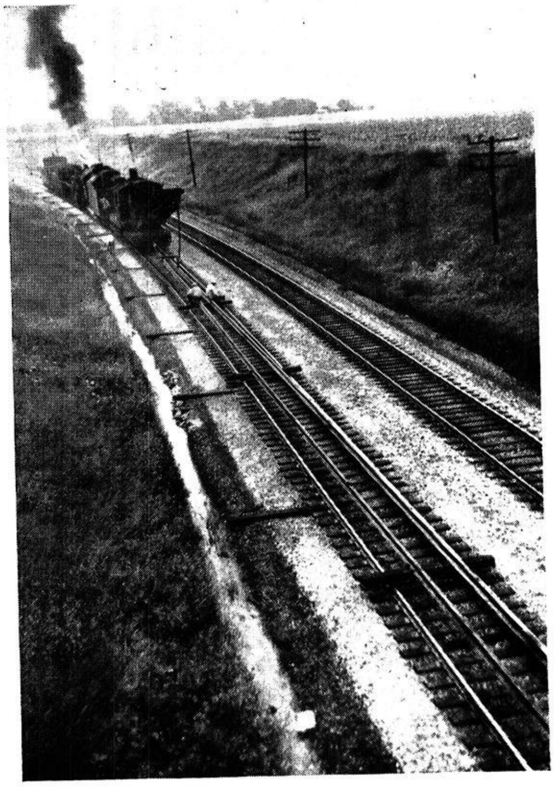
The last two steps prepare the rail for installation. Surface grinding removes the rough edges at the weld while the finish grinding removes the weld seam and polishes the running surfaces. The inspection consists of a Magnaflux test to determine whether flaws are present in the weld area.

The equipment used lends itself readily to both centralized and field operation. It is easily transported and can be set up along the railroad right-of-way. In general, it has been found that it is not economical to make a setup for less than 500 welds. Some railroads have welded near the laying site, while others weld at a central location.

In centralized operations several lengths are welded together and moved to the location of installation by several methods. If the distance is short the completed rail is literally dragged into place by a locomotive. For longer distances it can be moved on push cars and for very great distances the rail is moved in a revenue train on flat cars.

There have been many objections to the use of continuous welded rails, but two things are primarily responsible for the extremely small percentage of this type of rail in the United States.

First of all, railroaders were not sure how long a rail could be made without buckling from contraction or expansion on extreme changes of temperature. Installations with continuous welded rails show a decrease in expansion or contraction. If a test was made on a mile of continuous rail, the change in length would be about the same as that in a conventional thirty-nine foot rail. The predicted



Laying welded rails.

expansion or contraction is neutralized by the restraint of the friction between rail and ties, by the conventional spiking, and by standard anti-creep devices.

Secondly, not all engineers agree that continuous rails in open track were economical or even practical. At first glance the initial cost of installation may appear high: 1,100 dollars more per mile than the conventional track. The additional cost to provide a hundred miles of continuous rail approximates the cost of a new coach, and will save at the same time approximately 1700 tons of steel that are ordinarily needed for joint fastenings. Not only have savings of 30% or more in maintenance labor been achieved through the use of welded rail, but also the life of the rails, ties, and tie fastenings have been prolonged as much as a hundred percent. In fact, engineers handy with a slide rule can produce a graph in no time at all showing that a major railroad with a ten-year fixed program of annual welded track installations can effect savings in maintenance exceeding the total cost of installation by the sixth year. After that, the benefits of continuous track already installed accrue for the life of the rail.

The future outlook for the growth of welded rail programs is indeed gratifying. The experience of the past and the growing evidence that continuous rails wear longer, cut labor costs, solve difficult repair problems, and are just as practical (if not more so) than the conventional track installation, has prompted railroad management to shift the emphasis from improvements in rolling stock and motive power to improvements in track structure by the use of continuous welded rails.

Alumni Notes

by Al Nemetz e'50

EE

Robert E. Moe, ('33), has been appointed Division Engineer for Electronic Receiving Tubes Products line of the General Electric Company's Tube Division. Responsible for all receiving tube design application engineering, and standardizing activities, Mr. Moe will have his headquarters at the Owensboro, Ky., plant of the Divisions.

A native of Appleton, and a graduate of the University with a B.S. in Electrical Engineering, he joined General Electric on the test course in 1934 in Schenectady, N. Y.

From 1935 until 1944 Mr. Moe worked in Receiver Engineering at Bridgeport, Conn., on radio, television, and radar set design. He then handled a number of engineering posts on airborne radar at the Transmitter Division in Schenectady. For the past two years he has worked at Electronics Park, Syracuse, N. Y., in the Receiver Section of Electronics Department, Government Division.

Mr. Moe is a senior member of the Institute of Radio Engineers, and is also affiliated with Tau Beta Pi and Eta Kappa Nu.

LeRoy N. Day, ('41), was married to Ruth V. Swenson recently. They are living at Duluth, Minn., where he is employed by the General Electric Company.

The following February EE grads have accepted the jobs indicated below.

W. O. Battau has taken a job with the Allis - Chalmers Corporation, West Allis, Wis.

J. C. Verwiel has accepted employment with the Bureau of Engineering, State of Wis., Madison, Wis.

F. J. Meyers will be with the Cutler-Hammer Company, Milwaukee, Wis.

R. L. Pleski has taken a job with the Kaiser-Frazer Corporation, Willow Run, Mich.

R. L. Pierce will be with the General Electric Corporation, Schenectady, N. Y.

W. S. Haase has accepted employment with the Wisconsin Telephone Company, Milwaukee, Wis.

W. P. Koppenall has taken a job with the General Electric Corporation, Schenectady, N. Y.

CE

Charles Thuringer, ('93), died on June 9, 1948. He had worked as engineer on the construction of the Pennsylvania Railroad's East River tunnel and on the construction of the LaSalle Street and the Washington Street tunnels in Chicago. From 1910 until 1929 he operated a store in Madison, Wis. From 1930 until his retirement in 1938 he was in the U. S. Engineer Office at Peoria, Ill.

George P. Stocker, ('09), who was dean of engineering at the University of Arkansas for many years, has been retired as dean emeritus.

Walter E. Jessup, ('12), has been made editor of Civil Engineering, the monthly publication of the American Society of Civil Engineers. He had been in charge of the Western headquarters of the society of Los Angeles. The new assignment brings him back to familiar duties, for he was the first editor of the magazine, from 1930 to 1935. Jessup was an assistant in railway engineering at Wisconsin in 1911-12.

William F. Moehlman, ('22), has been re-elected to a second term as president of the Knoxville, Tenn., Chamber of Commerce. He is vice-president of the Tennessee Metal Culvert Company.

George J. Heimerl, ('27), was married recently to Barbara R. Brown. He is with the National Advisory Committee for Aeronautics at Langley Field, Va.

William P. Ward, ('40), was appointed by Governor Rennebohm to the state Highway Commission. He had been an engineer with the Commission since 1932.

Edward N. Rein, ('47), has been with the Oregon Sales Company of Portland, Oregon.

Frederick C. Dreher, ('48), is an engineer with the U. S. Geological Survey, in the Surface-Water division in the Madison office.

The following February graduates in ME have taken the jobs indicated below.

J. F. Polachek will be associated with the Iowa Air Control Company, Des Moines, Iowa.

L. A. Wickens has taken a job with the Barber-Colman Company of Rockford, Ill.

W. J. Searles has accepted employment with the Massey - Harris Company, Racine, Wis.

J. V. Leutgoeb has gone into commerce school here at the University.

R. W. Stremlow will be associated with the Koehring Company at Milwaukee, Wis.

K. A. Drewry has accepted employment with the General Electric Corporation, Lynn, Mass.

M & ME

Sherwood Buckstaff, ('22), has been appointed Exploration Manager of the Houston area of Shell Oil Company.

Kenneth J. Tucker, ('49), has taken a job with the Arcade Manufacturing Company of Freeport, Ill.

J. R. Dodge, ('49), is now with the Shell Oil Company, Houston, Texas.

ON *the Campus*

by Robert Gesteland e'52

ST. PAT

Semester II and we're off again. Most of the same faces are still around the M. E. building lobby, some of them with a little more face foliage than usual. In case there are a few who haven't heard, all of the beard growing is in preparation for the beard growing contest to be judged at the St. Pat dance now only about a month away. Guiding light of the festivities centering around St. Pat's day is Polygon Board, who says, "There's still time to grow your beard."

Proceeds of the dance and engineering button sales go to the student engineering societies. The days of the engineer-lawyer fist fights, as has often been said, are gone forever, but with everybody behind it, St. Pat's day can still be a real success.

OSCAR

"Oscar," the iron man, will be arriving at Triangle Fraternity one of these days. At least that is the rumor floating around the campus. Oscar has been vacationing at his traditional spot in Florida since the Homecoming celebration.

S.A.E.

Mr. Leo Lechtenberg, Development Engineer, Briggs & Stratton Corp., spoke at the January meeting of S.A.E. Illustrating his talk with slides, he stressed the development and research that has been responsible for the modern air cooled engine. In particular, he emphasized the extensive use of die castings, dip rod lubrication, and new and improved magneto ignition systems. In response to numerous questions, he defended the four - stroke cycle against the two - stroke for small engines as the only way to secure long engine life, and pointed out that high - output outboard motors last only a few hundred hours, whereas, his company's engines are in service for several thousand hours without major overhaul. Mr. Lechtenberg brought along several samples of newly developed parts for examination by the students.

On February 15, Mr. C. E. Frudden will speak to S.A.E. Mr. Frudden is Assistant Chief Engineer of Allis - Chalmers Mfg. Co. Tractor Division and is a former national president of S.A.E. All engineers are invited to this outstanding meeting.

A.S.C.E.

The civil engineering seniors reviewed their recent inspection trip with the aid of colored slides at a meeting of the student chapter of the American Society of Civil Engineers on Thursday, January 6. The slides and a running commentary were furnished by Prof. Lenz of the C. E. department. In addition to views of the trip taken last October, Prof. Lenz had a series of pictures of Petenwell dam during various phases of its construction.

The primary business of the evening was the election of officers for the spring semester. Herb Jackson became the new President, W. M. Haas was re-eelcted to the Vice-Presidency, Bill Boyd became Treasurer, and Dick McKillip was elected Secretary. The election of Polygon Board representatives was put off until the new election regulations are prepared by Polygon Board.

TAU BETA PI

Tau Beta Pi, the all-engineering society whose fame is comparable with the liberal arts society, Phi Beta Kappa, initiated the following men at the Loraine Hotel on Thursday, December 16.

Seniors initiated include: Lionel Ames, Warten Anderson, Walter Battau, Oscar Bieck, Norman Bienenfeld, John Conley, Louis Csepella, Merrill DeMerit Jr., George Dick, Jay Dodge, Cyril Downham, Robert Doyle, Richard France, Sidney Gunderson, Wilbur Haas.

Russell Hackbarth, John Hahn Jr., Eugene Haupt, Alden Hendricks, Russell Henke, Valerius Herzfeld, Douglas Holt, Nan-Teh Hsu, Kenneth Hub, Kenneth Huebbe, Richard Jacobson, Albert Jones, Douglas Kanitz, Alvin Kasberg, Arnold Klimke, Wallace Knutsen, William Koth, Robert LaFond, Chester Larson.

Lester Maresh, Ralph Michael, David Mickelson, George Miller, Leonard Montie, Harold Mueller, William Nash, John Norris, James Novak, Robert Olson, Robert Oppenheim, Gilbert Ormson, Harold Pearce, William Peterson, Gilbert Peterson, David Pickering, Calvin Pipal, Russell Pipkorn, William Plummer, Raymond Powers, Glenn Purdy, Wilton Quant.

George Raeburn, Richard Rayford, Richard Sabroff, Stephen Sanders, Ralph Schlintz, Carl Schultz, Robert Sell, John Shelendich, Robert Spaulding, Paul Spink, Thomas Steele, Morris Thorson, Frederick Timmel, Robert Troller, Robert Vetter, Harlan Young, and Walter Zarris.

Science Highlights

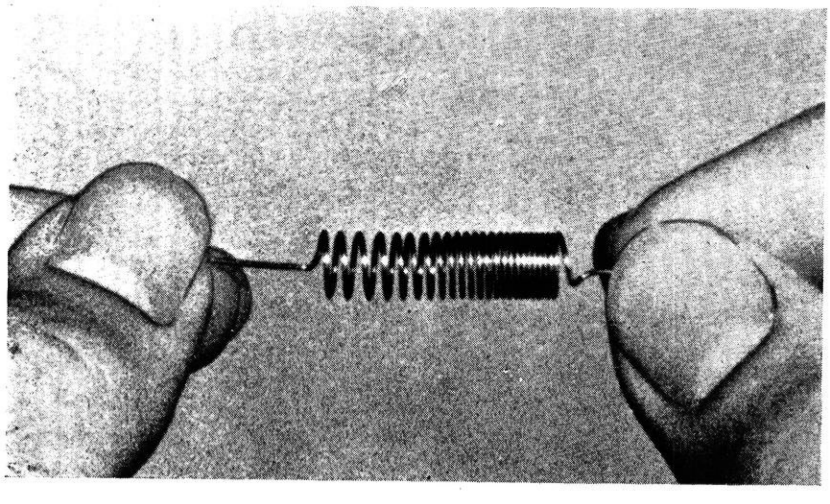
by Howard Traeder m'48

VARIABLE-RESISTANCE SPRING

Movements of as little as 0.00001 of an inch can be detected by a trick spring developed by the National Bureau of Standards. The spring is the active element of a mechano-electrical transducer which transforms small displacements into large changes in resistance, current, or voltage.

The spring, which may be either helical or conical, is wound in such a way that the initial tension varies slightly along its length. Thus, when the ends of the spring are pulled apart, the turns separate one by one rather than simultaneously. When the spring is completely closed, it has an electrical resistance approximately that of a cylindrical tube. When it is completely open, its resistance is that of the total length of the coiled wire. The resistance can thus be varied over a wide range by stretching the spring.

The preferred construction for the transducer is a four-arm bridge with each arm comprising a variable resistance spring. An increase in applied tension elongates one pair of springs and shortens the other pair. The resistive unbalance of the bridge, as indicated by a galvanometer, thus gives a measure of the displacement that has occurred.



The new mechano-electrical transducer.

MOISTURE MONITOR

General Electric engineers have developed a new electronic instrument which can measure continuously the amount of moisture in moving sheets of materials such as paper and textiles. The device can also be set up to monitor the percentage of volatile materials—easily vaporized fluids—in sheet plastics. Materials to be checked are fed between two metal plates and a dial on the instrument's control panel registers the moisture or volatile material content in per cent.

The "monitor" takes advantage of the fact that moisture in sheet materials like paper, textiles, rubber, rayons, nylons, etc., makes them better conductors of electricity, so that their conductivity can be used to indicate how much moisture they contain. In the case of testing plastics for volatile materials, it has been found that the capacitance, or force between two electrodes separated by a non-conductor (like a plastic), varies with the volatile material content. The instrument monitors changes in the capacitance of two plates separated by a moving sheet of plastic to find how much volatile material is present. In the past, sheet materials being manufactured have had to be checked periodically by time-consuming methods, whereby samples have had to be torn from the moving sheets, baked, and weighed.

ATOMIC POWER UNIT

The Westinghouse Electric Corp. has announced that it has been selected by the atomic energy commission to build the world's first atomic power unit for transportation purposes. The primary purpose of the experimental power plant will be the propulsion of U. S. navy ships by means of a nuclear reactor — a uranium furnace with a function quite similar to ship's fireboxes that consume coal or oil.

SNOW-MELTING HIGHWAY

The dream of every motorist and every highway engineer — a snow-melting highway — was scheduled to open January 1st in the town of Klamath Falls, Oregon.

In the first application of radiant heating principles to a public road, the highway will be heated in bad weather by hot water from an underground spring circulated through a network of welded wrought iron pipe laid in the concrete. Four lanes wide, and 450 feet long with an eight per cent grade, this dangerous road area is designed to remain clear and skid-free in all weather by automatically melting up to one inch of snow or one-tenth inch of ice per hour.

The hot well-water itself is not run through the roadway piping. Instead, a coil of two-inch pipe is submerged deep in the well-water,

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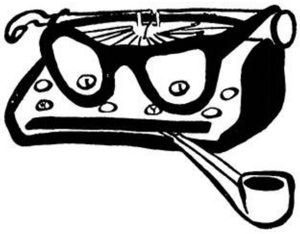


THE WISCONSIN ENGINEER

What makes it tick? — Students!

The Way We See It

How many engineering students at Wisconsin know anything about their student publication, **The Wisconsin Engineer?** Do they realize it is composed of an all-student staff who write the stories, collect the jokes, take the pictures, solicit the ads, take complete charge of circulation and finances, and still operate in the black without financial help from the University? Sometimes that is quite a job, and none of the fellows are professionals. Some twenty-five regular engineering undergraduates do this, not because of any remuneration, but because of the fun they derive from their association with the other staff members, because of the experience they obtain in reading and writing technical articles, and because of the business and personnel experience acquired on the business staff.

Perhaps YOU would be interested in working on this magazine. Wait — don't run off saying "I'm no good at English" or "I have twenty credits and not nearly enough time alone for study". That may be what you feel at the moment, but stop and read this short description of the activities on the **Wisconsin Engineer;** decide in which you are most interested and would receive the most experience, and then come up and talk to the editor, Bill Haas, in room 352 M.E. building.

The magazine staff is divided into two general classifications, business and editorial. The business staff consists of the business manager, Bob St. Clair, an M&M senior; and his staff of an assistant business manager, an advertising manager, and a circulation manager. These men supervise the activities of the other men on the business staff whose duties range from paying and collecting bills, keeping books and accounts, soliciting and filing all national and local ads, maintaining the current subscription files as well as soliciting new subscriptions, and distributing the magazine every month to the various news stands and the post office. These activities afford excellent practical business experience, the application of which is not limited to work on publications alone. In fact, this is the type of experience many companies desire in men seeking sales or personnel jobs.

The editorial staff is composed of men who collect and write the material for the regular departmental features such as the alumni, campus, science, and "humor" columns; and the regular staff writers who do the correspondence, reading, and writing required to prepare a good article for the magazine. In these branches of the staff there are a great variety of jobs to be done. Consider the alumni and campus departments. The men in charge of those columns make contact with the students and faculty of the entire campus collecting their material, and in this way obtain considerable experience in both personnel and editorial work. The writer who keeps up-to-date on recent developments in engineering for the science department gets a very good background in modern technical accomplishments; and the joke editor has a riotous, and sometimes difficult, job collecting the multitude of good jokes required each month.

The staff writers who prepare the five or six articles appearing in each issue have an unlimited choice of ideas on which to write although items of current interest among the student body of engineers are not always easy to find. In fact, the staff is always very glad to receive ideas presented by anyone for future stories. The actual preparation of the material is then delegated to a staff writer who proceeds to obtain information from as many sources as possible (other publications, prominent industrial or academic engineers, and other scientific personnel—whose acquaintance at a future time might, incidentally, be beneficial to the embryo engineer). Not only does the writer gain ability and notice for his technical writings, but he also broadens his own technical knowledge and develops his professional capacity considerably more than by a mere formal education. Of course there are still the many jobs concerned directly with the actual publication of the magazine: story and advertising make-up, proof reading, decisions regarding titles and captions, arranging for printing and photo-engraving, and the many other odd jobs always concerned with the monthly preparation of a forty page magazine.

What do you think? Doesn't this sound like quite an opportunity for a fellow looking for chances to improve himself and his ability in his chosen profession? Outstanding technical ability is not always the sure road to success, and an outstanding extra-curricular activity like the **Wisconsin Engineer** is a definite asset on job application blanks. Read over this description of the staff, think about what you might like to do to fit in with its activities, and then come up to 352 M.E. We'll be glad to have you, and you do not have to be an expert; none of us are.

R. R. J.

STATIC

by I.R.Drops

"Did you hear about John? He's cut his drinking by 50%."

"Yes I know. He doesn't take chasers any more."

* * *

We heard this in thermo the other day; from an E. E.

Four requirements of a good refrigerant are: low boiling point, cheap, non-corrosive, and non-intoxicating.

* * *

"What are you knitting, a sweater?"

"Yes, something to make my boyfriend happy."

"Oh, for him?"

"No, for me."

* * *

It takes you ten minutes per day to shave. You can save 50 minutes per school week if you grow a beard. That's enough time for a short lab report or a couple problems in mechanics. You can save up your time for a few weeks and take in a show (dutch of course).

* * *

"Guess I'll have another round," said the electron as he left the transformer.

* * *

Look out, when she starts stroking your hair, she's probably after your scalp.

* * *

"Let's play pony express."

"What's that? I never heard of it."

"Oh, it's the same as postoffice only with more horsing around."

* * *

Then there is the co-ed that claims that a gentleman is just a worn out wolf.

* * *

But then there was the girl who didn't get a fur coat to keep her warm but to keep her quiet.

"Bob is so frank. He always calls a spade a spade."

"Well he didn't yesterday when he dropped one on his toe."

* * *

"What's the big hurry?"

"I just bought a new physics book and I want to get to class before they put out a new edition."

* * *

When teaching a girl how to pucker for a kiss don't have her say prunes or peaches but alfalfa.

* * *

It has been said that the meanest man in the world is the warden who put a tack in the electric chair.

* * *

"Daddy, why does that man have all that hair on his face?"

"He's in a contest, son."

"What contest, Daddy?"

"A beard growing contest for St Pat's day."

"Who was St. Pat, Daddy?"

"Why he was the first engineer, son, and every year the engineers grow beards and have a dance in his honor."

"Well, if they are engineers, Daddy, why don't they wear caps like the choo-choo men do?"

"Some of them do, son. Now shut up and drink your beer."

* * *

A little old lady from the country had registered at the hotel and a bell boy was taking her to her room. "I won't take this room," she said, "it's no bigger than a closet, the floor is dirty and there isn't even a bed here." "Get in, get in lady," retorted the bell hop, "this is the elevator."

* * *

Someone remarked the other day that a debutante is just a young tomato with lots of lettuce.

We've proved it!

Problem: To hold down costs, and speed the extension of telephone service.

Solution: High-strength wire whose use allows the span between poles to be increased from 150 feet to more than 300. One pole now does the work of two.

The problem, of course, is a continuing one for telephone people. High-strength wire with required electrical qualities is only one of many things they have developed to help solve the problem in these days of high construction costs.

In total, their developments are the reason why telephone service here is the best in the world—the reason why it remains low in cost.

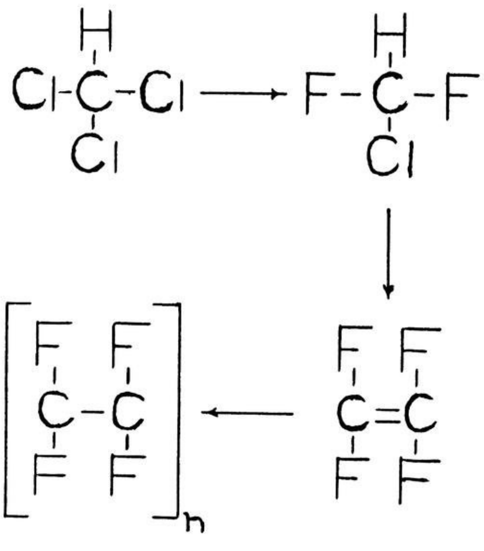
BELL TELEPHONE SYSTEM

TEFLON . . .

by James E. Wille che'50

For many years, the chemical industry has been searching for a construction material that combines the properties of chemical inertness and heat resistance. This material is required for use as filters, gaskets, packing and the like for equipment that must be continuously in contact with high temperatures and corrosive materials. Recently Teflon, a DuPont product, has been placed on the market; and according to present reports, it is meeting the demand remarkably well.

In producing Teflon, chloroform is fluoronated in two stages to produce tetraffuoroethylene. This gaseous chemical is then polymerized to produce a solid, granular resin. It is then treated by special process to yield rods, tubes, sheets and some molded articles.



Structural diagram of Teflon.

One of Polytetrafluoroethylene's most outstanding properties is its remarkable stability. No known chemical, hot or cold, will attack it, except molten sodium and potassium, and free fluorine under superatmospheric pressures, and these chemicals are seldom found in industrial processes. It has served with excellent results in contact with hot sulfuric and nitric acids, hot concentrated alkalis, and in many other cases where contact with corrosive materials is necessary.

Another of its remarkable properties is its heat resistance. Tensile bars heated to 480° showed a negligible decrease in tensile strength after several month's exposure, however, at temperatures above 400° F., care must be taken, for small quantities of fluoronine-containing gases are liberated. Furthermore, it shows very little tendency towards embrittlement at low temperatures.

The non-adhesiveness of the resin has caused problems, but it has also been used to advantage in many cases. One application made possible by this property is its use as a liner for spray towers where buildup of solids on the walls has been a problem. It has also been used as a coating for the rollers used in the production of some synthetic rubbers. In all cases, it is necessary to fasten Teflon to the material being covered by mechanical means.

Unfortunately, the very advantages which give Polytetrafluoroethylene its unusual position among plastics contribute difficulties in working it. Since it never becomes molten, even at high temperatures, the ordinary techniques of molding and extrusion are not applicable. However, it can be extruded into heavy-walled tubes. This process is not too efficient, and the rates are measured in terms of feet per hour instead of feet per minute as is the case of most thermoplastics.

This plastic has proved very adaptable to ordinary machining operations, and this enables users to produce objects of rather complicated structure. However, collants must be used during the process to guard against the production of toxic gases. It may also be molded by hydraulic pressure. The designs must be simple when produced by this method, but development of this process is seen as a solution to the problem.

The uses of this comparatively new material are many and varied. Because of its arc resistance and low electrical loss, it is finding use as the dielectric in coaxial cable. Even when arcing does occur the surface is merely scarred, and no conducting carbon coating is formed. Bound with fiber, it can be molded into packing rings that are very suitable for high speed pumps. A recent development consists of Teflon filled with micro-pulverized glass; preliminary tests indicate that this combination results in a material having resistance to abrasion coupled with its other properties.

Since the material is currently being evaluated by individuals and concerns representing a wide industrial range, many new uses for it may be developed in the future. However, it should be pointed out that this material is not recommended for use where substitute products will serve equally as well. It should be considered only where its service life and consequently low replacement cost will compensate for the relatively high initial cost.

Contour Production . . .

(continued from page 8)

erated, formed work roll is fed into the grinding wheel which is revolving at a slow speed. The wheel is formed to the desired shape by the same principle as corrugated or star type metallic wheel dressers. The crushing rolls are formed to the shape of the work and are slotted across the periphery. The wheel receives its final, or sizing dressing from a reference roll which is not power driven. After dressing, the wheel is brought up to grinding speed, and the desired shape is ground on the work. The type of grinder is special for the job—a typical surface grinder, but equipped with very heavy wheel bearings to withstand the dressing pressures, and having the driven work roll mounted on one end of the table and the reference roll mounted at the other end. The crushing roll is the important part of the equipment. Most of the rolls are made of ordinary high speed steel, hardened to Rockwell "C" 62-65 and ground to shape. One set of rolls, work and reference, have been used for as many as 125 crushings before regrinding was necessary.

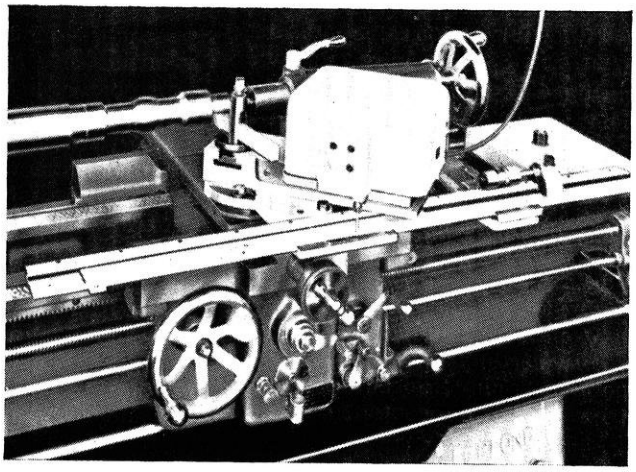
Another grinding operation associated with crush grinding is form grinding from layouts. Employing layouts many times its size, the form is ground with a single wheel as the operator follows the layout with a stylus, and through levers. The finished shape is ground on the work, the accuracy is determined by that of the layouts. Its use has become important in the grinding of crush rolls and form tools.

Keller Contour Milling

The manufacture of contour parts such as dies was accomplished in the past by roughing as close to shape as possible on standard machines and finishing by hand, which amounted to a great deal of work. Today machines are available which are able to finish complicated three dimensional contours to great accuracy and requiring very little hand finishing. The requirement for the machine is a model of wood, or some easily worked material, of the exact shape of the part required.

A machine known for its ease of manufacture of very complicated shapes is the Keller milling machine made by the Pratt and Whitney Company. The basic and most remarkable feature is the automatic electric tracer control, which sensitively and accurately follows practically any shape or contour. The tracer is mounted horizontally in a bracket on the verticle slide above the horizontal cutter spindle. The tracer is adjustable in all dimensions and the cutter spindle transversely. Once the proper position of the cutter relative to the work and the tracer relative to the master has been established, the tracer and cutter move in unison — the tracer following the shape of the master form and the cutter duplicating that shape.

Two types of operations are performed on the machine, profile machining and three dimensional machining. The first type employs a sheet metal template either for internal or external work. The cutter having been set to depth required, the tracer need take care of only horizontal and vertical movements. The tracer point is in continuous contact with the master. The back end of the tracer carries four electrical contact points which control up and down and right and left movements. A very slight pressure of the tracer point against the mast is sufficient to break one of the electrical contacts and additional pressure closes another. This instantly changes the direction of travel by changing the energization, through relays, of the various clutch magnets which govern the direction of rotation of the vertical and horizontal lead screws on the milling machine.



Photograph courtesy Barber-Colman Co.

A contouring attachment as produced by the Barber-Colman Company for use on the LeBlond Lathes. The control box, mounted on the compound rest and connected to the lead screw, controls the movement by means of the template attached to the bed.

Three Dimensional Contour Milling

Another type of tracer control is used for three dimensional work, either internal or external. The machine set up is completely automatic. The controls are set so that the tracer covers the entire surface of the master in a series of parallel strokes, either vertical or horizontal. The length of the strokes are controlled through reversing dogs, or by hand, and the feed is automatically controlled. The depth of cut is automatically controlled, since when the point is not in contact with the master the machine is caused to travel in. Varying pressures on the traced point causes the machine to travel in and out as the machine feeds in its predetermined direction, vertical or horizontal. This type of machining is employed for machining forging dies, die casting dies, forming dies, punches and draw rings, metal patterns and core boxes, molds and forms for plastic, and miscellaneous work.

Contour Lathes and Contour Attachment

A similar tracer guided lathe has been successfully used which cut irregular shapes with a single point tool.

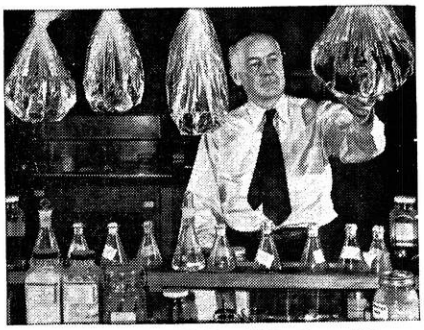
(please turn to page 26)

DU PONT *Digest*
For Students of Science and Engineering

Cellophane has become *the nation's symbol for modern packaging. Since 1927, continuing research has developed over fifty different types.*

The story of A CHEMICAL ACHIEVEMENT

How Du Pont scientists found a way to Moistureproof Cellophane



Dr. Hale Charch, *Ph.D., Ohio State '23, re-enacts discovery of moistureproof Cellophane film. Bag at far right held water for weeks; other control bags showed evaporation.*

There's no secret to Du Pont's successful system for making chemical discoveries. It is simply research through teamwork.

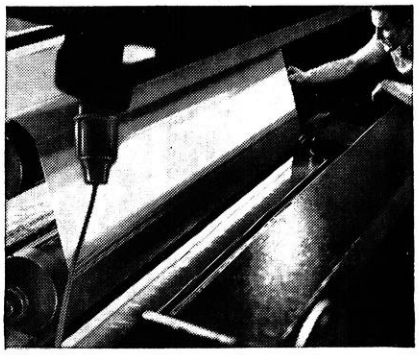
As each new problem in research arises, it is tackled by men and women whose training and skill qualify them to master it. Backed by ample funds and facilities, they are continuously extending the field of scientific knowledge.

Take the case of moistureproof Cellophane. Plain, transparent Cellophane was strong, clear and protective. As a packaging material it had eye appeal. Its uses were limited, however. Perishable foods wrapped in this cellulose film were protected from contamination and were good to look at, but they did not retain their freshness. They either lost or absorbed moisture, depending on the nature of the food and atmospheric conditions.

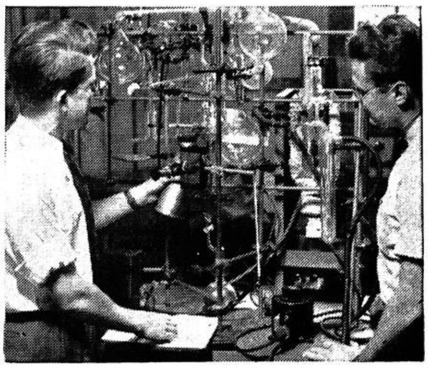
That was a challenge to Du Pont research people. They set out to find materials that would moistureproof Cellophane without materially affecting its thinness or transparency. After developing a basic test to measure moistureproofness, they tried various procedures—adding ingredients to Cellophane dope before casting, impregnating sheets in baths and coating the film.

Coating showed the most promise. Had you been a member of the research team on this job, you might have helped mix and test several hundred different coating formulae over a 10 months' period. With successful coatings in sight, a small pilot operation was set up. Then—to make sure the new Cellophane was right—doughnuts, cookies and cakes were wrapped in it and sent to market. Finally, engineers were called on to design machinery for full-scale operation.

Now everything from chewing gum to porterhouse steaks is being sold in moistureproof Cellophane. Another scientific achievement is helping change the food packaging and food buying habits of America!



Cellophane is made *by extruding viscose through a slit into an acid bath where it coagulates into sheets. Moistureproofing follows.*



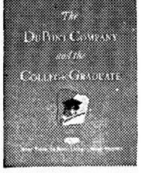
Organic Chemist M. L. Ward, *Ph.D., Illinois '42, and Physical Chemist P. E. Rouse, Jr., Ph.D., Illinois '41, conducting research on the permeability of thin membranes, including Cellophane.*

Using your training at Du Pont

Diverse problems call for diversified talents. At any one time, there are hundreds of interesting projects under way in the Du Pont laboratories. You may be trained in chemistry, engineering or physics. You may have studied in the fields of botany, entomology, parisitology, pharmacology or plant pathology. In fact, almost all the sciences are put to use at Du Pont.

Working as a member of a small team, the individual is afforded every opportunity to show his talent and capabilities.

This is a booklet you shouldn't miss



Before deciding on your first job, send for your free copy of "The Du Pont Company and the College Graduate." Describes opportunities for men and women with many types of training. Explains how individual ability is recognized and rewarded under the group system of operation. Address: 2518 Nemours Building, Wilmington 98, Delaware.

WRITE TODAY *for "The Du Pont Company and the College Graduate"*

DU PONT
REG. U. S. PAT. OFF.
BETTER THINGS FOR BETTER LIVING
. . . THROUGH CHEMISTRY

More facts about Du Pont — Listen to "Cavalcade of America" Monday Nights, NBC Coast to Coast

Contour Production . . .

(*continued from page 24*)

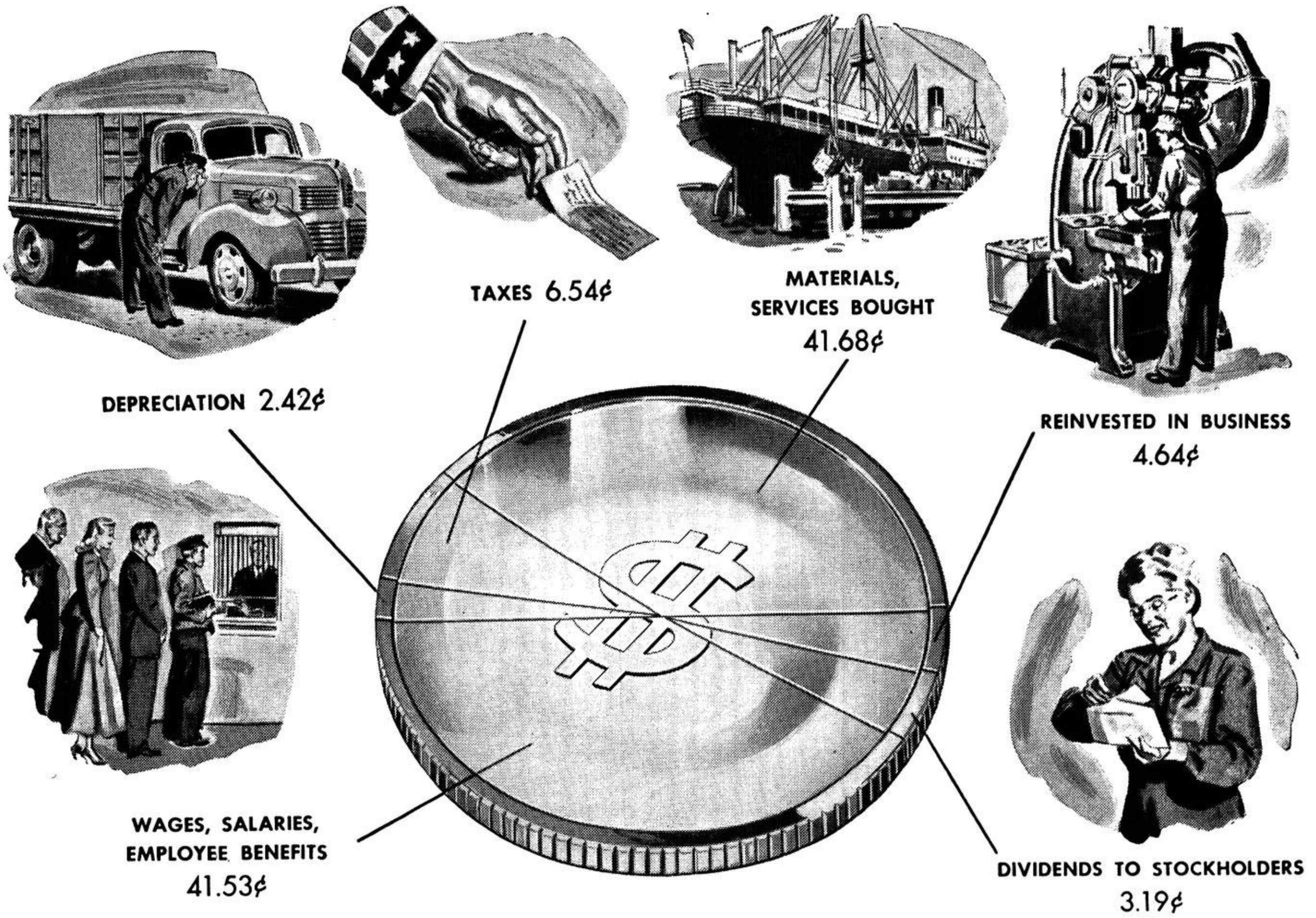
These might be exemplified by the mold cavity for a glass bowl of a general round or oval form. The movements are controlled through electrical devices similar to the milling machine.

A new development for contour turning on a standard engine lathe has been developed by the Barber-Colman Company. For contour turning, this method uses a constant longitudinal feed and a template guided, electrically controlled feed on the compound which is set for any desired angle (the template must be designed for a particular angle). The automatic control equipment is mounted directly on the compound rest and is geared to the screw so that it can move the compound rest forward and backward. In this case the main lead screw provides constant lengthwise motion and the control equipment drives the movement along at 45°, the angle shown in the illustration. This method can be applied also to profiling. Here the longitudinal feed is used only to adjust the depth of the cut, while the cross feed provides the constant feed across the work and the compound provides the variable movement on the 45° angle.

The control unit is a servo, using 1/12 hp. motor connected to a pair of pulleys through a V-belt. Each pulley drives a magnetic clutch. The output shafts of the two clutches are geared together by idler gears and are also geared to the compound screw. The screw may therefore be operated in either direction, depending on which clutch is energized. The clutches are energized by means of electrical contacts, controlled by the stylus, and actuate a single pole, double throw switch. The circuit is such that only one clutch is energized at a time. The stylus is operated by means of a template of proper design mounted parallel to the lathe bed. A flywheel is attached to the motor pulley to increase the amount of available power for short periods. By means of a friction flywheel the shaft is accelerated gradually so that in actual operation, the servo moves smoothly enough to produce a finish which is satisfactory on a majority of jobs.

Contour Production, a Progressive Operation

The production of many of the contour parts commonly seen are the result of several progressive methods of producing contours. The formed automobile part, for example, is the result of a stamping or forming operation; but the tools for production are the result of further contour machining methods not so commonly known. The present widespread use of such contours are the result of our system of mass production, since each of the many parts produced on a forming die absorbs part of the cost of making the die.



HOW TO DIVIDE UP A DOLLAR

. . . the American Way

It may interest you to know the mistaken notions most folks have about the profits of American companies.

They tell interviewers that they *think* such companies are entitled to make 12 to 15 cents on every dollar of income, as a fair return. Yet, they add, it's their guess that manufacturers *actually do* make about 25 cents!

The facts are that in normal years American companies average about *nine cents* profit per income dollar.

Take Aluminum Company of America in 1947, for example. Out of each dollar received last year by Alcoa and its subsidiaries, the net profit amounted to *less than eight cents*. We show above where the rest of that dollar went. Nearly half of it in wages, salaries, and employee benefits, to Alcoans. Almost another half for materials and services we bought. Over six and a half cents for taxes.

The dollars-and-cents story of Aluminum Company of America represents the kind of facts you'll get from any typical American enterprise. Facts that show a fair return for a good product.

By dividing up a dollar, the American way, Alcoa has provided secure employment for 46,000 aluminum workers and has helped America to gain world leadership in aluminum production and research.

ALCOA ALUMINUM ®

Aluminum Company of America

Science . . .

(*continued from page 18*)

which tests at 190°F., so that the well serves as a boiler. A pump sends ordinary water and anti-freeze through the well coil, where it is heated or reheated to not less than 160 degrees. A two-inch pipe runs from the well to the pavement and then parallel to the road for a distance of about 400 feet. In the pavement slab are embedded 15,000 feet of three-fourth-inch wrought iron pipe, made up into one grid for each of a series of 30-foot road panels. Each of these 15 panels is connected with the two-inch water main by valves.

The pump, thermostatically controlled, automatically begins to circulate the water when the air temperature drops to freezing and continues to operate until the temperature rises above freezing. Another pump draws water from the well since it loses its heat value as the cool water flows from the road through the heat transfer coils. Hot water then bubbles up from the earth back into the well.

ORLON

A new synthetic fiber, du Pont's Orlon, has been developed to fill the gap in price and performance between the two older synthetics, rayon and nylon.

Rayon, made from wood pulp, costs relatively little but has drawbacks, notably weakness when wet. Nylon, made from coal tar or petroleum, is strong and elastic and has other desirable properties as well. However, it is expensive. Orlon, an "acrylic" fiber made from natural gas or petroleum, provides many of nylon's desirable qualities at a cost which will probably be nearer that of rayon.

Orlon resists fading, is easy to wash, and is resistant to many chemicals, high temperatures, and insects, although it won't take colors as well as other textiles.

At present, only small quantities of Orlon are being produced for test purposes in the pilot operation at du Pont's Waynesboro, Va., plant. The company plans to start building a multi-million dollar plant for Orlon manufacture next March near Camden, S. C. Construction will take about 18 months; thus, Orlon may be in mass production within two years.

ON-A-LITE

The perennial problem of placing the Christmas tree lights artistically while staying within the limited range provided by the cord has been solved for the purchasers of a new and unique type of lights. Specially constructed two-part light sockets fit around the cord and screw together to make contact through the cord to the wire itself. The cord can be draped around the tree first and as many sockets as desired placed in any desired location.

Called On-A-Lite by the Portland, Oregon, corporation of the same name, and manufactured by Portland's Iron Fireman Manufacturing Company, this boon to tree decorators is in a class by itself. On-A-Lite screw-on sockets are molded of Monsanto's phenolic resin, Resinox, by Beaman Plastic Products and Owens-Illinois Glass Company.

LIGHT FOR TRAFFIC TUNNELS

The longest continuous lighting installation in the world, in which four ribbons of fluorescent light will extend almost two miles, has been designed by New York City's Triborough Bridge and Tunnel Authority in collaboration with engineers of the General Electric Company.

First of its kind, the installation will illuminate the new Brooklyn-Battery tunnel now being constructed under New York Harbor by the Triborough Bridge and Tunnel Authority. The tunnel, which will be one of the world's longest, is expected to be completed in 1950.

Each of the tunnel's two tubes will carry two lanes of traffic, and will be lighted by twin rows of white

(*please turn to page 32*)

Graduate Study . . .

(*continued from page 11*)

men involved in technical applications, but these men do not always realize the very high salaries of other fields. Then too, there is the growing movement in industry to employ engineers for more and more of the managerial positions. Standard Oil Company of Indiana for example, reports that seven of the eleven directors of the company, including Dr. Robert E. Wilson, chairman of the board, and A. W. Peake, president, are engineers. This would indicate that engineering and scientific training provides a broad, solid base upon which to begin a career in business. According to Mr. M. T. Carpenter, the executive director of the research department's Whiting, Indiana, laboratories, men with this type of training are able to apply scientific methods and thinking to all types of jobs. This sounds good for the engineers looking for jobs, but they must remember that each of them will also have to utilize and expand the training they received in college in order to advance to positions of responsibility and high pay.

Technical ability will take a man just so far; after that his personality, adaptability, and aptitude for work are the elements which help the young engineer get ahead. In the opinion of most personnel men, these last qualities are not greatly strengthened by graduate study. Extra-curricular and campus activities are the character builders mentioned most frequently as being highly desirable.

Mr. G. L. Bussard of the DuPont Corporation submitted to the author the two general points on which they base their employment: 1). Professional Competence, and 2). Personal Characteristics.

"Under Professional Competence, some of the factors on which we place emphasis are: motivation, preference for particular types of work, depth of understanding of the subject, practical intelligence as indicated by one's attitude toward utilizing his training, and the trend of the curve indicating his scholastic accomplishment. Certainly graduate training should strengthen some of these factors.

"In the area of Personal Characteristics, qualities which we look for are: sincerity and friendliness, good general appearance, poise in manner and speech, general conversational ability, physical and mental alertness and enthusiasm, ability to work smoothly as a team member, emotional stability, leadership qualities, and overall maturity."

Objectives of Engineering Education

Engineering has been defined as "The art of directing men and controlling the forces and materials of nature for the benefit of the human race." This means that an engineering education involves more than just a high technical proficiency; engineers must be solid, civic minded citizens willing to take their share of responsibility for modern society and its improvement. In addition to his technical knowledge, such a man must have a well

(*please turn to page 38*)

Science . . .

(*continued from page 28*)

fluorescent lamps. A total of 5776 individual lamps, each six feet long, will comprise the entire installation. The lamps will be housed in clear Pyrex "pipe" near the top of the sidewalls of the tubes.

The continuous lighting will prevent a succession of bright spots and shadows along the tunnel. Astronomical clocks will turn on a higher intensity of light in the portal sections of the tunnel during daylight hours to make it safer for motorists to drive from bright sunlight into the tunnel at normal traffic speeds, by allowing the driver's eyes to become gradually accustomed to the lower light level inside. The lighting level will be three to four footcandles on the roadway, grading up to 20 footcandles in the portals to compensate for bright sunlight outside the tunnel. The engineers say this illumination is equivalent to that of the nation's brightest lighted street.

Twelve separate lighting circuits, all in continuous use, will serve each tube. The supply of power to the lighting system is so interspersed that loss of any part of the power supply, including complete loss at one end of the tunnel, will not leave any section of the tunnel in darkness.

COLOR ANALYZER

Color density is determined by an electronic analyzer so sensitive that it can measure 1/100,000,000 of the amount of light from a car headlight. The analyzer is designed for use in color photography but can also be used to measure or match colors in textiles, paints and dyes. The device, developed by Ansco, looks like an oversize record player. Inside the arm is an electron-multiplier photo-tube which gives the instrument its sensitivity. The measuring arm may be detached and used at distances up to six feet. The analyzer is used for making accurate emulsions for films.

A wedding ring is like a tourniquet—it stops your circulation.

* * *

"Boy, he sure is a card."

"Which, a joker or an ace?"

* * *

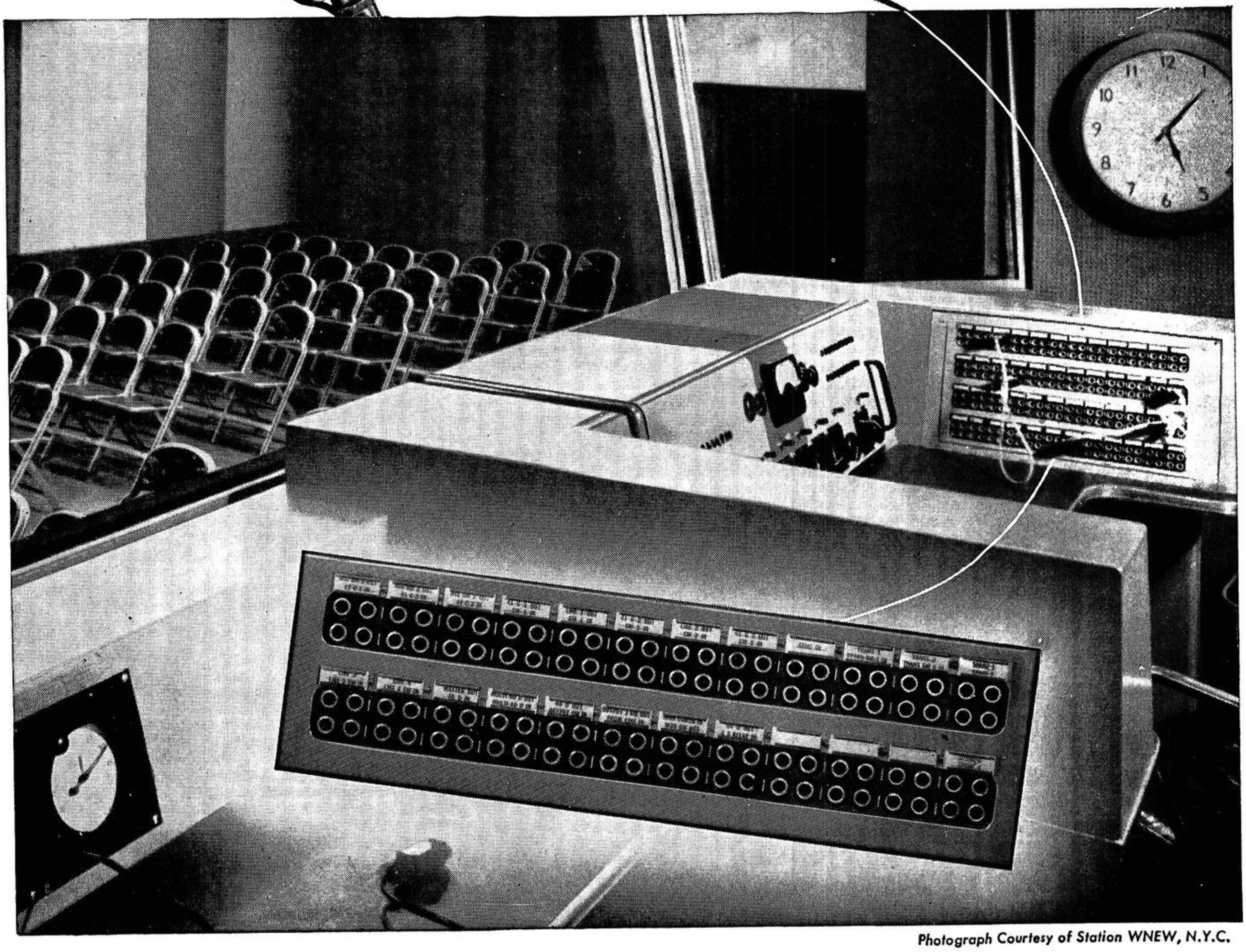
Sunday School Teacher: "What binds us together and makes us even better than nature intended?"

Little Mary: "Girdles."

* * *

Any live wire would be a dead one without the proper connections.

Plastics where plastics belong . . .
for insulation and appearance



Photograph Courtesy of Station WNEW, N.Y.C.

Synthane . . . where synthane belongs

USES for Synthane laminated plastics are almost unlimited because of their combination of chemical, electrical and mechanical properties. Synthane is corrosion and moisture resistant, light in weight, quickly and easily machined. It is also hard, dense, strong, one of the best electrical insulators known. The "set" plastic, Synthane is stable over a wide range of temperatures.

An interesting example of Synthane at work is this jack panel which enables the broadcast technician to plug in or transfer amplifiers, microphones, telephone lines or other equipment, giving the input system greater operating flexibility. This is an appropriate job for our type of plastics because Synthane is an excellent electrical insulator, and contributes to the attractiveness of the control booth. Synthane Corporation, 14 River Road, Oaks, Pa.

SYNTHANE
S

DESIGN • MATERIALS • FABRICATION • SHEETS • RODS • TUBES • FABRICATED PARTS • MOLDED-MACERATED • MOLDED-LAMINATED

GRADUATE STUDY

(*continued from page 30*)

rounded personality. He must be able to express his ideas, think and speak on his feet, lead and organize men, and cooperate with all of his associates. Such qualities are in great demand, especially when coupled with the technical and scientific ability of an engineer. Refer for example to the much quoted statement of the late John D. Rockefeller who said that he would "pay more for the ability to get along with other people than for any other ability."

The answers to some of the employment questions raised by the graduating engineers lie in their own analyses of the status of their education, and the demands to be made on this knowledge by the type of work in which they are interested. Graduate study in a technical field will increase their knowledge, skill and ability. According to Mr. Royce E. Johnson, the chief electrical engineer for Barber Colman Company and head of their general engineering laboratory, graduate study will develop a better understanding of engineering fundamentals, a more complete training in applied mathematics, and a broader knowledge of physics, chemistry, and diversified engineering subjects than can be obtained in a four year engineering course. Some men acquire this background on the job, but one is more certain to acquire it by concentrating on it in the graduate school of a reputable university. Speaking at the recent initiation banquet of Eta Kappa Nu in Madison, Mr. Johnson also emphasized the necessity of better laboratory report technique, the advantage of a broad cultural knowledge of the humanities, and the apparent lack of good lab technique among engineering graduates. Engineers with only a B.S. degree and no lab experience other than in regular classes often have no idea of how to handle a test job or any other direct assignment when first employed. Mr. Johnson said that those men with graduate degrees who have done laboratory thesis work require a much shorter period of training, or no period at all.

Men who are not interested in applied engineering must take stock of their other abilities. Their technical education may be one of the finest; but if they are going into work where it will not be utilized directly, it may be of little immediate value to them. Today's engineering students receive very little training in liberal arts; their technical studies are too numerous and complex to permit an adequate study of the various cultural subjects during a four year course. The engineering work alone has made some schools expand their curricula to five years. In order to put engineering on a full professional basis along with the other accepted professions, many argue that the student should have at least three years of liberal arts study before even beginning his engineering work. This would seem to indicate the need for a more balanced development of the student engineers' character, morals, and knowledge. A further study by the engineer of such humanities as philosophy, economics, speech, sociology, psychology, and history, and a much broader interest—and participation—in extracurricular activities will do much to "knock off the rough corners and accustom him to rubbing shoulders with other people." In the opinion of Lee H. Hill, publisher of the **Electrical World,** this is one of the main reasons manufacturers have developed graduate training courses.

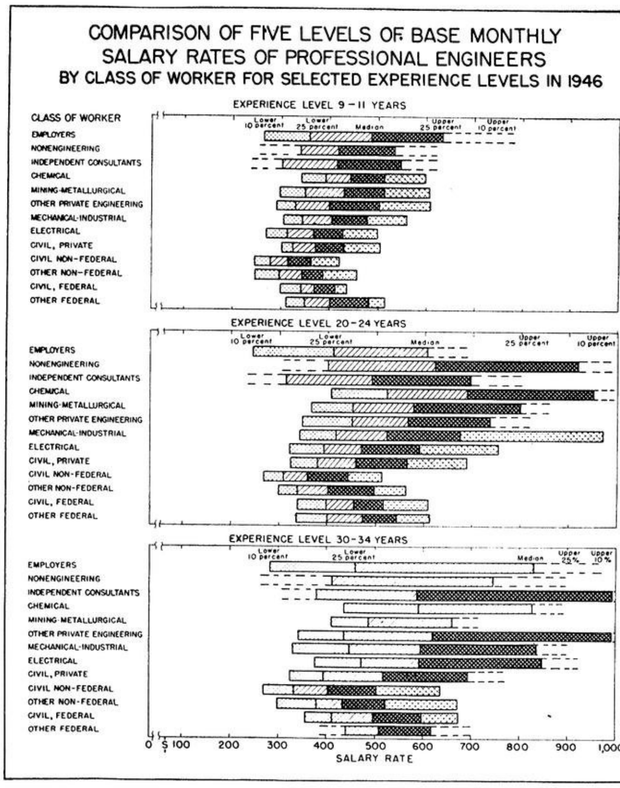
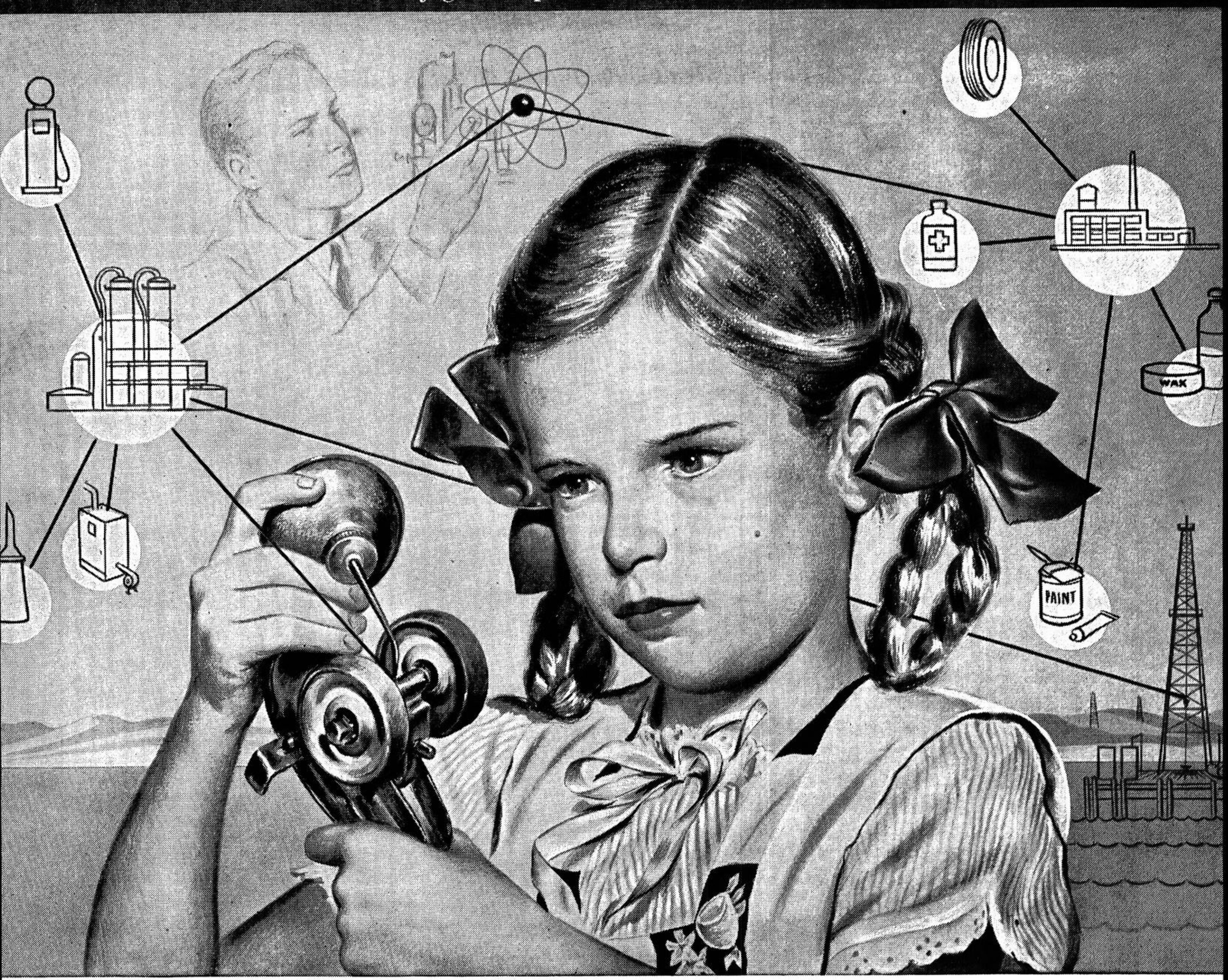


Chart III.

On the other hand, Mr. McEachron for G. E. feels that the purpose of these training programs is to "integrate the segregated courses which men have had in college to such an extent that they will feel confident of their ability to solve any problem no matter how complex, provided the problem is worth solving." Through these additional educational programs industry is attempting to provide a practical "internship in industry." The comparison of graduate study with these training courses must be based on their relative value to the individual. Wages, salaries, and advancement are determined by the actual performance of the engineer. For some individuals, graduate study will provide the best training; for others, industrial experience will be of more benefit. The decision rests on the man's ambitions, interests, financial, and educational limitations and goals.

"—The seeds of godlike power are in us still"—MATTHEW ARNOLD



More and more . . . and better oil

UNDER THE WATERS just off the Gulf Coast alone . . . lie vast new oil fields that may almost double America's oil reserves.

This rich discovery is just one more phase of the better-than-ever job the oil industry is now doing to meet our soaring demands. And back of that job are today's superior skills, advanced engineering, and *better materials.*

Such hard metals as tungsten carbide, used in drills, help make it possible to cut more than three miles into the earth. Essential valves, pumps, and even fractionating towers made of *carbon* are virtually 100% proof against highly corrosive acids.

Such better materials as stainless steel defy heat, pressure and corrosion in refinery operations. With the new oxy-acetylene pressure welding, pipelines can be more swiftly linked into single strong units that extend for hundreds of miles.

Better chemicals, also! Solvents that purify our oil . . . chemicals that draw offensive elements from our gasoline and provide us with anti-knock compounds. All these are helping bring us better medicines, waxes, cosmetics, paints . . . to name only a handful of today's hundreds of superior petroleum products.

The people of Union Carbide produce these and many other materials that help supply us with more and better petroleum products. They also provide hundreds of other materials to help science and industry maintain American leadership . . . in meeting the needs of mankind.

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The Transistor

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The current from the cathode, in a grounded-grid vacuum triode, is controlled chiefly by the potential between it and the grid; the plate potential has comparatively little effect on the cathode current. In the Transistor the emitter bias (about 1 volt positive) causes a small current to flow into the semiconductor. The negative bias of the collector, or anode, is made large enough (about 50 volts) so that it withdraws about the same magnitude of current. Although the collector is a poor emitter of electrons, it is a good collector of holes. A variation of the number of holes in the surface around the two point contacts is produced by changes in the input voltage of the emitter. The change in current due to the change in input voltage causes a relatively large change in output voltage due to the much larger impedance of the output circuit (from 10,000 to 100,000 ohms).

There is little coupling from output to input since the output circuit can influence the input circuit only by electronic conduction, for which the surface resistance is high. Obviously, then, the Transistor is capable of ordinary unilateral amplification.

Possible Applications

The transistor has several serious limitations in its present state of development. Some of these are:

(1) Low power output.
(2) Limited frequency range.
(3) Inherent noise.
(4) Impedance matching difficulties.

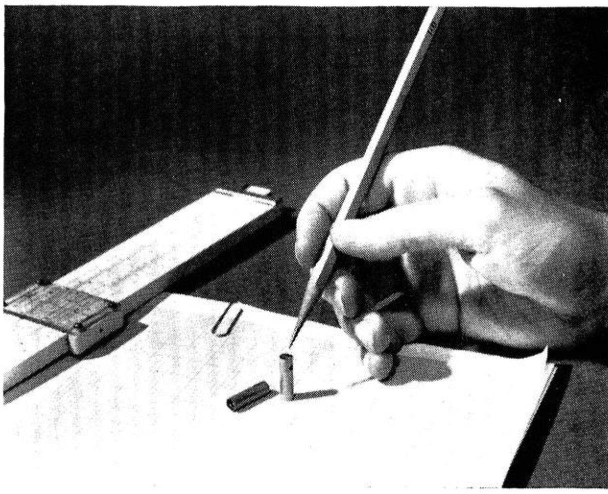
The power output is limited to about 25 milliwatts per unit, although considerably more power can be obtained by using a number of units in push-pull, parallel, or a combination of both.

The upper frequency of operation is limited to about 10 mc. by transit time within the germanium. Hence, the Transistor is at present useful at audio, video, and the lower radio frequencies, but is unsuited to VHF, UHF, or microwave applications.

In its present stage of development the Transistor has considerably greater internally generated noise than a vacuum tube. This, of course, is another limitation on the maximum gain possible. Crystal diodes, on the other hand, are used as mixers and detectors at frequencies well above 300 mc. and appear to have the highest signal-to-noise ratios that can be obtained in these frequency ranges.

One of the principle problems remaining in the development of the Transistor is matching the input and output impedances of the unit to its input and output circuits, respectively. The input impedance of the Transistor is low because the bias in the input circuit causes current to flow in the forward direction through the point contact of the emitter. On the other hand, the output impedance of the Transistor is about a hundred times higher than the input impedance because its bias causes current to flow in the reverse direction through the point contact of the collector. These impedance levels are the opposite of those for vacuum tubes and require a new approach to the coupling circuits between amplifier stages.

In demonstrating the practicability of the Transistor, Bell Telephone scientists designed a radio receiver containing no conventional vacuum tubes whatever. It consisted of a broad-band r-f amplifier, a tuned r-f stage, local oscillator, mixer, three stages of i-f, second detector, and four stages of audio amplification. A total of eleven Transistors were used in the amplifier stages, with two germanium diodes for the mixer and detector stages, and two selenium rectifiers for the power supply.



The relative size of the Transistor.

Under typical operating conditions the Transistor draws only 0.1 watt from the bias sources (about a tenth of the power consumed by an ordinary flashlight bulb) and delivers 25 milliwatts of useful output power, thus having an overall efficiency of 2 percent. It is smaller than a subminiature vacuum tube and seems likely to have a useful life of many thousands of hours because of its simple, sturdy construction. Where portability and low battery drain are necessary, as in hearing aids and personalized radios, the Transistor is the ideal amplifying element. In equipment using large numbers of amplifiers, such as in large-scale computers, the absence of a heater makes it possible to place many units in a confined space without creating any serious heat dissapation difficulties, and interruptions due to tube failures are reduced to a very low value.

In the medium frequency range and at low power levels, crystal diodes and triodes, in conjunction with the new printed circuit techniques, make possible a considerable advance in the present trend toward miniaturization.