GENERAL ELECTRIC Review

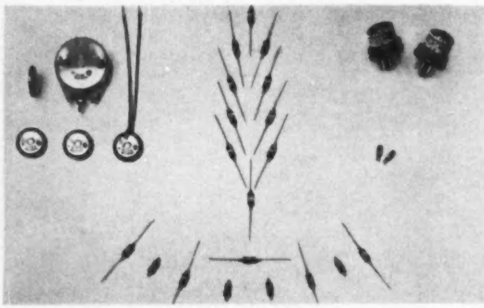
MAY 1952

G-E ELECTRONIC DEVELOPMENTS SPUR MANUFACTURING, COMMUNICATIONS, BROADCASTING

NEW APPROACH TO UHF. To get maximum effectiveness from UHF power, Electronics Park engineers designed this helical antenna—lighter, stronger, more efficient than any in television use today. In 4-bay form, it delivers an impressive 20-to-1 power gain. Its G-E partner, the Klystron tube, amplifies the signal 100 times in a single transmitter stage. Together, the two developments achieve the highest known TV power in these frequencies, and actually make UHF television a reality.

FAST COMMUNICATION AT LOW COST. Two-way radio, once primarily an emergency tool, is rapidly winning more and more recognition in every business where wide-area operational control is essential. These include mining, lumber and logging, construction, petroleum production and distribution, trucking and manufacturing. Materials handling, a complex activity plagued by rising costs, has long been a target for G-E communications engineers who seek to speed it up with mobile radio systems.

MAKES THE TV SERVICEMAN'S JOB EASIER. With 15 million TV sets in use today, reliable television test equipment has become the keystone of a successful service operation. Simplicity is the prime feature of G.E.'s "TV Test Package"—oscilloscope, variable permeability sweep generator, and marker generator. Technicians with a minimum of training can use them to shoot circuit troubles and repair sets quickly and with exceptional accuracy. Typical General Electric products, these units have won a reputation for unexcelled quality among television servicemen.



ALMOST EQUAL IN VALUE TO GOLD, germanium is the new "*wonder element*" in electronics. Germanium diodes and transistors are minute in size and weight, highly resistant to heat and moisture, require no cathode power, and are endowed with indefinite "life". Rectifiers small enough to hold in one's hand have been known to handle 1000 amperes. By far the most revolutionary group of G.E.'s electronics components, germanium products (samples shown above) are turned out at a rate of over 500,000 a month at a special plant in Clyde, New York.

For literature on the products shown on this page, write:
General Electric Company, Electronics Park, Syracuse, New York

GENERAL ELECTRIC

ALL-ELECTRIC Home Heating and Cooling COMES OF AGE

Latest news about General Electric's Heat Pump—the exciting year 'round air conditioner that cools and heats... yet burns no fuel

Year 'round comfort from a single, packaged, all-electric unit has long been a dream of engineers. Now it's come true. After years of pioneering leadership, General Electric is introducing in 1952 a packaged Heat Pump in several U. S. markets. Interest has been tremendous, for this is the home comfort system of the future... it is capturing the imagination of everyone.

1. WHAT IT DOES

When the weather is hot and sticky, the G-E Heat Pump cools and dehumidifies. When it is cold, it heats... *without fire, without burning fuel.* Once the thermostat is set, the home is automatically air conditioned just the way the family likes it—no matter what the season. Switchover between cooling and heating is completely automatic—from season to season, within the same day, or hourly.

2. IT WORKS SIMPLY

The key is G.E.'s adaptation of reverse-cycle refrigeration. To cool, the G-E Heat Pump extracts heat and moisture from indoor air just like conventional air conditioners. To heat, its cycle automatically reverses to extract warmth from the outside air even when it's cold outdoors... using this warmth to heat the entire home. G-E design requires no ground coil, no well or other water source for its heat supply. Supplementary electric resistance heating is available as an accessory to meet extreme conditions where required.

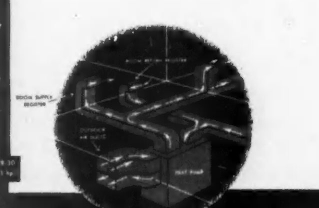
3. BENEFITS ARE MANY

The homeowner neither buys nor stores fuel. He gets ideal comfort in all seasons. His home stays quieter and cleaner. Porches, fireplaces, windows that open, flues and chimneys are no longer necessities. The Heat Pump is clean, convenient and safe.

4. THE HEAT PUMP NOW AND TOMORROW

G.E. is now turning out packaged Heat Pumps on a commercial basis for sale in selected areas. Operating cost is surprisingly low—the G-E Heat Pump gives about three units of heat for each heat unit of electricity and uses no water, only air and electricity. Undoubtedly it will influence home design in coming years. 1952 is the pioneer commercial year. In the years ahead, the G-E Heat Pump will take on increasing importance for homeowners, builders, architects, and utility companies. General Electric Co., Air Conditioning Division, Sec. GER-6, Bloomfield, N. J.

G-E Packaged Heat Pumps available in two compact models with 3-HP and 5-HP compressors. They will pass through 28-inch door. Existing duct work often usable.



Air-flow diagram shows how G-E uses outside air as heat source.

GENERAL ELECTRIC

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GENERAL ELECTRIC Review

EVERETT S. LEE • EDITOR PAUL R. HEINMILLER • MANAGING EDITOR

THE COVER **shows control panels—vital components of punched card calculators. How calculators can aid engineers is described starting on page 8. Photo by Robert L. Mize.**

THE GENERAL ELECTRIC REVIEW IS ISSUED IN JANUARY, MARCH, MAY, JULY, SEPTEMBER, AND NOVEMBER, BY THE GENERAL ELECTRIC COMPANY, SCHENECTADY, NY, AND IS PRINTED IN THE U. S. A. BY THE MAQUA COMPANY. IT IS DISTRIBUTED TO SCIENTISTS AND ENGINEERS THROUGHOUT INDUSTRIAL, CONSULTING, EDUCATIONAL, PROFESSIONAL SOCIETY, AND GOVERNMENT GROUPS, BOTH DOMESTIC AND FOREIGN. . . . THE CONTENTS OF THE GENERAL ELECTRIC REVIEW ARE ANALYZED AND INDEXED BY THE INDUSTRIAL ARTS INDEX, THE ENGINEERING INDEX, AND SCIENCE ABSTRACTS. . . . SIX WEEKS' ADVANCE NOTICE, AND OLD ADDRESS AS WELL AS NEW, ARE NECESSARY FOR CHANGE OF ADDRESS. . . . ADDRESS ALL COMMUNICATIONS TO: EDITOR, GENERAL ELECTRIC REVIEW, SCHENECTADY 5, NEW YORK.

The CHARLES A. COFFIN AWARDS

to the Outstanding Accomplishments of Men

One of the finest things in life is the recognition given to a man by his fellow men for a job well done. It is the pat on the back that counts. It makes everybody feel good. It reveals man at his very best.

I well remember how Mr. Swope used to say to us so frequently when speaking of men—ability, personality, character, but the greatest of these is character. And in my reading of Mr. Coffin's life it was men—always men—that Mr. Coffin sought, the driving force behind all enterprise, the dynamic source of all progress and success. In the recognition of men for outstanding accomplishment we see anew ability, personality, character, vision, courage, progress, attainment, service.

Charles A. Coffin was a great leader of commerce. He looked decades into the future and guided his policies toward ultimate ends. Visioning the opportunities in the electrical manufacturing field, then in its very infancy, he left his successful shoe business and joined in the organizing of the Thomson-Houston Electric Company, which was moved to Lynn, Massachusetts, in the latter part of 1883. The Company had rich human talent. It had a great scientist-inventor in Elihu Thomson, a keen engineer in E. W. Rice, Jr., a capable factory manager in George Emmons, and a genius of sales and finance in Charles A. Coffin.

No man more completely held the trust and admiration of his co-workers than did Mr. Coffin. No man exercised his leadership with greater simplicity, greater humility, greater regard for others.

Mr. Coffin would never be satisfied until the day he offered his customers complete electric service. This long-range objective was appraised in 1904 in the AIEE Schenectady Section Handbook. Referring to the merger of the Thomson-Houston Company and the Edison General Electric Company to form the General Electric Company, it said:

"Never in the industrial world did organization effect a more magical change in releasing pent-up energy. Guided by master hands, electrical arts leaped into industrial prominence; the volume of manufacture of appliances, progress of invention, public confidence in electricity, and its general utilization, all took long strides forward."

Mr. Coffin took great pride in the human part of his organization. He wanted fitness and loyalty; but he wanted the loyalty to be spontaneous. He wanted both opportunity and commendation for his associates.

This ideal lives in the Charles A. Coffin Awards. It is the ideal of a great leader. It is the ideal of a great man. It is an ideal that underlies human achievement. And in the annual Coffin Awards the great strength of this ideal is reaffirmed in all of us.

On February 15 just passed, announcement was made of the Awards for the year 1951 to men of General Electric. Twenty-seven men were honored with this highest Company Award. There were fourteen engineers, a designer-draftsman, six manufacturing supervisors, two production workers, a clerk, a laboratory assistant, an engineering assistant, and an auditor.

All groups throughout the Company were represented, for there is always opportunity for advancement in every operation of a great company. The engineers open the doors to new attainment; their associates effectively produce.

The world is thus the richer for all that these men have done. Electric apparatus is the better, the cost is lower, and applications are more widespread. Equipment for our Armed Forces is superior. Progress in nuclear development has been advanced. Necessary data on materials for design are more accurate and are obtained in shorter time. More power is available from each pound of copper in these days of copper shortage. Better paper products are produced in even larger quantity. More accurate measurements of power are provided. Increased plant output is obtained.

Awards to the men for these advances attest to the great truth that there is always a better way; that there is always opportunity for the engineer to bring forth new products and to improve the old; that men with ability, personality, character, with vision and courage, bring progress, attainment, service. There is always opportunity for advance.

The recognition of these outstanding accomplishments brings them into bold relief. And we see that they are of men—always of men—the driving force behind all enterprise, the dynamic source of all progress and success.

Everett S. Lee

EDITOR

CHARLES A. COFFIN

1844—1926

Once each year from the nearly quarter of a million men and women of General Electric a few are honored with the Charles A. Coffin Award—the Company's highest award. These are chosen because their outstanding accomplishments best reflect the qualities of initiative, perseverance, courage, and foresight, exemplified by the Company's founder and first president, Charles A. Coffin. Each year businesses and students are also honored with awards for extraordinary contributions. The names and citations of the engineers honored with the Coffin Award for 1951 are below.

ELMER LEROY ANDERSON . . . for his admirable judgment, initiative, and persistence in the face of obstacles in bringing about the construction of a high-speed precision balancing pit for turbine generators.

HENRY B. BARROW . . . for his many valuable contributions to the development and improvement of modern paper-machine drives, and for outstanding work in establishing and maintaining improved customer relations in the paper-mill field.

ALEXANDER W. BEDFORD, JR. . . . for his exceptional originality and teamwork in collaboration with Ernest F. Goetz, designer-draftsman, in the development of a new line of d-c magnet brakes.

FLOYD H. BUSCH . . . for his outstanding contribution to the certified I-50 watthour-meter program.

WILLIAM F. HAFSTROM . . . for his outstanding vision and persistence in establishing a program for the development and marketing of air-borne radar.

WALTER HAUSZ . . . for his ingenuity and creative ability, in collaboration with Oliver H. Winn, in the development of a radar system which provided a new automatic tracking technique.

JOHN M. HOLEMAN . . . for his ability and ingenuity in the development of optical instruments with characteristics beyond any previously available.

GEORGE F. LINCKS . . . for his outstanding perception and persistence in demonstrating the value of the locked-closed recloser with fuse cutouts.

JAMES MILLER . . . for his work in collaboration with Frank R. Larson, laboratory assistant, in the discovery and application of time-temperature relationships to creep-and-rupture test data of alloys.

KONSTANTIN K. PALUEV . . . for his contributions to transformer design over many years, and particularly for his persistence and ingenuity in pioneering the development of forced-oil-cooled transformers.

CHARLES L. ROUAULT . . . for his unusual foresight and resourcefulness in the development and design of a selective tone-amplifier circuit.

JOHN D. STACY . . . for his unusual initiative and aggressive leadership in the standardization and cost control of specialty capacitors.

MILTON J. SZULINSKI . . . for his work in collaboration with William N. Mobley, manufacturing supervisor, in devising means for increasing the productive capacity of the Hanford Works.

OLIVER H. WINN . . . for his ingenuity and creative ability, in collaboration with Walter Hausz, in the development of a radar system which provided a new automatic tracking technique.

Let Punched Cards Solve That Problem

By RUDOLPH HABERMANN, JR. and FRANK J. MAGINNISS

Calculating machines are so essential to the modern engineer or scientist that fabulous computers have been built to serve him. But there are many situations where the cost of these so-called mathematical robots could not be justified, even though they are badly needed. In other words, there is a wide gap between the portable or desk-type calculator and the computer costing anywhere from a half million to a million dollars.

Punched-card equipment can help fill this gap. Formerly of interest to accountants only, punched-card calculating machines now have very practical possibilities in the everyday work of the engineer or scientist.

There are many types of such machines. Most important of all, however, is the calculator. Such a machine can recognize the holes in standard punched cards as numbers. It can perform the elementary arithmetic operations of addition, subtraction, multiplication, and division on these numbers, and record the answers in the form of additional holes which it punches in the cards.

Such a machine also has some memory; that is, it can place in storage the values of the numbers it reads from the punched cards until it has performed the necessary calculation on those numbers.

Furthermore, the calculator has at least some capacity for sequential calculation—a very valuable property indeed—for it will allow the machine to do a sequence of operations on the numbers found on the cards as they pass through the calculators.

For example, we might want to find the value of y corresponding to a large number of values of x in the polynomial

$$y = 35x^2 + 17x + 2.7$$

The constant numbers 35, 17, and 2.7 can be entered in the storage of the machine, where they will be available at all times during the calculation. A deck of cards, one card for each of the values of x in which we are interested, can then be fed into the machine. The value of y can now be calculated and punched on each card to go with the corresponding value of x.

How do we tell the machine to evaluate y ? The answer lies in the control panel. This is the nerve center of the machine, causing it to perform the required arithmetic calculations by interconnecting the machine's internal circuits.

One possible sequence of instruction which might be wired into the control panel, thus causing the calculator to do what we want, would be:

Step 1: Read the value of x from the card into storage.

Step 2: Multiply x by 17, and store the product.

Step 3: Add the result of Step 2 to the number 2.7, which is in storage, and store the sum $(17x + 2.7)$ for future use.

Step 4: Take the value of x from storage and multiply it by itself, giving x^2.

Step 5: Multiply the x^2 from Step 4 by the number 35, which is found in storage, giving $35x^2$.

Step 6: Add the results of Steps 3 and 5, giving the result $35x^2 + 17x + 2.7$.

Step 7: Punch this result on the card and go on to the next card with its new value of x.

This process could be repeated over and over again for as many values of x as we care about and with no further attention to the machine on the part of the operator.

One type of IBM calculator in common use operates at the rate of 100 cards per minute. Thus, if we should wish to evaluate y for 1000 different values of x in the foregoing equation, the actual calculating time would be only 10 minutes. To this, of course, must be added the time required to plan the work, make up the control panel, and punch original data into the cards. This is a very simple example, but its extension to a more complicated calculation is obvious.

There are a number of auxiliary machines available to serve the calculator. There is, for example, a keypunch, which punches holes in the cards to represent the initial data of the problem. Then there is a sorter for arranging the cards in numerical order according to the holes punched in them. A reproducer transfers specified data from one deck of cards to another. A tabulator prints data punched in cards and obtains specified subtotals and totals as controlled by coding on the cards. A collator merges decks of cards according to some prearranged scheme. These machines can be combined to form a very flexible tool, which allows the efficient and rapid solution of numerous types of problems.

Of course, no computing installation is any better than the personnel operating it. Although the machines we have described are not themselves complicated to operate, it pays dividends to have high-caliber operators who will be alert to spot any errors caused by improper interpretation of the physics or mathematics of the problem.

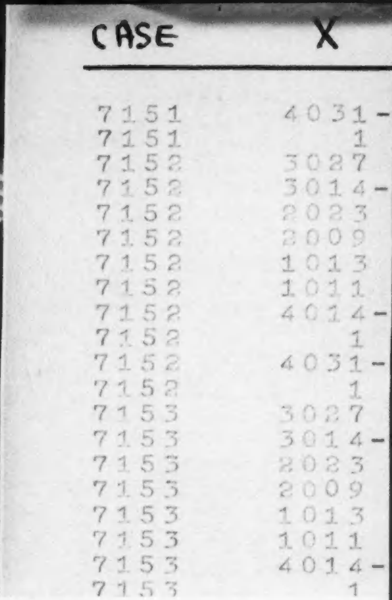
Three installations of such machines are now in use at Schenectady. As examples of the kinds of job which can be done with them, a few problems have been chosen from the many which have been undertaken. Not all are necessarily typical, but each illustrates a different computing technique.

PROBLEM—*To Determine the Power Requirements for a Welding Installation*

When a large number of welders are to be supplied from a single source of power, it becomes necessary to decide what size power source to use. An extreme solution would be to supply a source so large that, even though all the welders were welding at the same

◀ **INSTALLATIONS VARY but these are typical. The two units *(top)* operate as a single calculator. The one in the foreground reads the data from the cards and punches the results into the same group of cards; the other, depending on the impulses received from the one in front, electronically performs the calculations called for. The machines in the bottom picture are *(from left)*: tabulator, reproducer, and calculator**

MINOR MODIFICATIONS to the wiring of the control panels can be made quickly with the panels still in the machines. Circuit plugs are easily removed or inserted



CASE X

7151	4031-
7151	1
7152	3027
7152	3014-
7152	2023
7152	2009
7152	1013
7152	1011
7152	4014-
7152	1
7152	4031-
7152	1
7153	3027
7153	3014-
7153	2023
7153	2009
7153	1013
7153	1011
7153	4014-
7153	1

RESULTS are printed on continuous sheets about 15 inches wide. This section of an

time, the voltage drop at any welder would still be small enough to permit a satisfactory weld. If, however, each welder has a short-duty cycle—that is, if he is drawing current for only 5 or 10 percent of the time—it may be a very uneconomical type of solution. Possibly a very much smaller source could be used without too much risk of too low a voltage for any appreciable fraction of the time. Moreover, there will always be some unsatisfactory welds from causes other than low voltage; consequently, it may be reasonable to allow for some rejects because of low voltage.

If we can tolerate a certain number of poor welds due to low voltage, the problem becomes one of determining the required size of power source which can be reasonably expected to yield no more than this minimum number of inadequate welds. This will depend largely on two things: the accuracy with which we know the duty cycles of the various welders in the installation, and the voltage required to give a satisfactory job. The problem, then, is one of finding the probability that enough men will be welding at the same time to reduce the voltage below the safe limit. This can be translated into a figure which will give the fraction of poor welds to be expected.

As in all studies involving probability, the solution becomes more and more reliable as the data considered are more voluminous. If the number of welders is of the order of 30 to 50, and if their duty cycles are fairly well determined, it would seem that we could put a good deal of confidence in the results. The calculation of overlap probabilities for a study of these dimensions would be prohibitively long and tedious without the use of automatic calculating machinery.

In the use of a punched-card installation, the main part of this job consists of calculating and tabulating large masses of probability data. These data, once obtained, are stored permanently on cards. For any particular data it is necessary merely to extract the needed cards from the files and rearrange and retabulate them to suit the problem at hand.

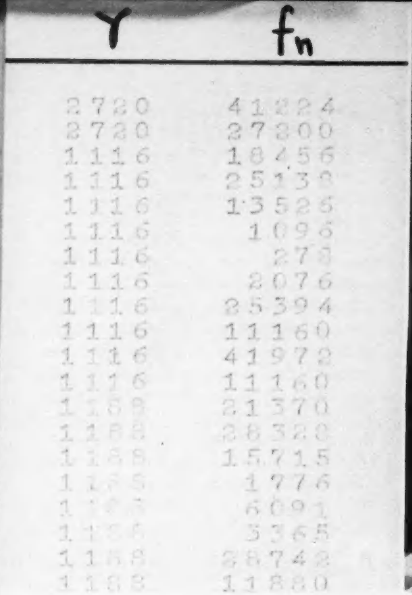
In this instance, for example, we may be interested in the probability of a certain amount of welding overlap for installations of 30, 35, 40, 45, and 50 welders with duty cycles of 5, 10, 20, and 40 percent. The various combinations of these few numbers already indicate that automatic methods of computation will be of inestimable value. When, in addition, we consider that various fractions of each group may each have a different duty cycle, the scope of the problem becomes such as to make machine methods of calculation imperative if the job is to be economically feasible.

PROBLEM—*To Determine the Pressure Distribution in an Oil Film*

Numerous kinds of field problems confront the engineer. Knowledge of the distribution of magnetic flux density in an electromagnetic device is necessary to determine the magnetic forces acting on various parts of the device. The distribution of stress in an elastic member is of vital importance in determining the safety of a structural member. Many other field quantities, such as velocity and pressure in a fluid field or the potential in an electrostatic field, the engineer would like to have some easy way of deter mining.

The characteristic common to all field problems is the fact that they give rise to partial differential equations. Now, in all but the very simplest cases it is impossible to obtain solutions of such equations analytically. One method for the approximate solution of such equations is to replace them by a system of finite difference equations. For example, instead of trying to calculate the smooth continuous distribution of flux density

In the Special Investigations Section of General Electric's Analytical Division, Mr. Habermann is responsible for assigned projects such as engineering aspects of digital analyzer studies.



Y	fn
2720	41224
2720	27200
1116	18456
1116	25138
1116	13525
1116	1096
1116	278
1116	2076
1116	25394
1116	11160
1116	41972
1116	11160
1168	21370
1188	28320
1188	15715
1185	1776
[illegible]	6091
1186	3365
1188	28742
1188	11880

actual result sheet is full size. Up to 80 figures can be printed across a page

TABULATOR transfers the information on the punched cards—the results of a problem, for example—into printed figures. Section of an actual result sheet is at the left

in a magnetic field, we calculate its values at a finite number of points in the field, separated from each other by definite space intervals. This may result in a very large number of simple algebraic equations, depending on the size of space increment, which must be satisfied simultaneously. If the number of them is not too great, they may be handled as a set of linear simultaneous equations and solved once for all.

When, however, the number of these equations is large, we may have to resort to an iterative procedure. This consists of making a guess—presumably an educated one—at the value of the function at each point within the known boundaries of the field, then, for each point in turn a new value of the function is determined by substituting the guessed values into the corresponding algebraic equation. In this manner the field can be traversed a number of times, until the values of the function at all interior points settle down and appear to be approaching steady values.

This iterative method of solution was applied to the problem of determining the pressure distribution in the oil in a slider bearing of finite space dimensions, taking into consideration the effect of variable viscosity. After appropriate assumptions have been made, this results in a somewhat formidable partial differential equation, expressing the oil pressure everywhere over the surface of the bearing in terms of the x and y coordinates of the point on the surface.

As a preliminary to the punched-card set-up for this problem, an analogous d-c network was set up to represent the pressure field. Voltage readings at node points in this network corresponded to pressures at these points, thus giving an educated first guess for approximate interior values. Having now the starting values, a punched-card procedure was set up to carry out the process of improving values at all points.

In such procedures, a number of problems can be handled at the same time. We may, for example, be interested in the effect of minimum clearance, the ratio of maximum to minimum clearance, the type of oil (as shown by the shape of the viscosity curve), or the effect of temperature distribution, which will also determine the viscosity values.

As manager of the Special Investigations Section, Mr. Maginniss is concerned with the application of various types of computing devices to the numerical analysis of engineering problems.

Problem—*To Calculate the Critical Speeds of Turbine-generator Units*

Before the advent of relatively inexpensive high-speed computing devices, the lateral critical speeds of long multi-span turbine-generator units were calculated only very approximately. In a four-bearing installation on a single shaft—for example, a high-pressure turbine, a low-pressure turbine, and a generator—the assumption was generally made that the three units were independent; consequently, the single-span critical speeds for each of these was determined independently. This neglected completely the fact that all the machines are carried on the same shaft and, consequently, a close coupling exists between them. The ideal procedure is to include all masses and the entire shaft length in one calculation to find the critical frequencies of the over-all installation. Moreover, it would be desirable to include the effect of bearing flexibility.

Several years ago a set of punched-card machines was installed by our turbine designers for the purpose of making such calculations. Briefly, the method of calculation is as follows: The shaft is divided into a number of sections, perhaps 30 or 40, for each of which the geometry and weight load are known. A shaft rotation speed is assumed, and equilibrium conditions for shear, moment, deflection, and angle are calculated for the end of each section, in terms of these quantities at the initial point of the section. The calculation proceeds step-by-step until the far end of the shaft is reached.

PERMANENT CONTROL PANELS for basic operations common to many problems are stored for future use. Cabinets contain punched cards needed for future reference

At this point, all the far-end boundary conditions can be satisfied only if the rotational speed assumed corresponds to a lateral natural frequency of the system. In particular, if the chosen frequency, is not a natural frequency, the moment at the free end will not be found to be zero, but rather there will be a residual moment at this point. By choosing a number of rotational speeds and repeating the above calculations, a plot of residual end moment versus rotational speed can be made, and the zero crossings of this plot will correspond to the lateral critical frequencies. Range of interest to turbine designers, 0 to 5000 rpm, can be covered in about 25 such calculations, using speed increments of 200 rpm.

PROBLEM—*To Determine the Frequency Response of an Amplifying System*

With the advent of complicated servomechanisms and dynamic control systems, it becomes almost essential to find some rapid means of calculating the performance of an amplifying circuit which can contain many feedback loops and mutual elements. Short-cut hand-calculation methods have been devised for plotting the gain and phase shift of such systems, but these are used at the expense of accuracy. Where it becomes necessary to determine with a good deal of accuracy the frequency response of a system such as the one schematically shown below, rigorous mathematical methods must be applied.

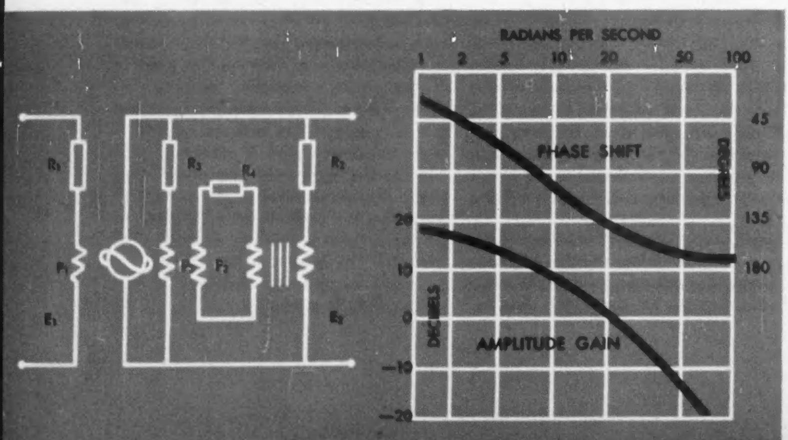
In the example shown, there are four loops around which the complex steady-state voltage-drop equations can be written. In writing the steady-state equations, we are assuming that, when a sinusoidal input voltage is applied to the system, the output voltage will also be sinusoidal but changed both in magnitude and in phase from the input. It is these quantities we wish to find—the change in magnitude or gain, and the phase shift of the output with respect to the input. Moreover, since the coefficients of the unknown currents in the mesh equations are dependent on frequency, the gain and phase shift will also vary as the frequency of the input voltage is changed.

For any given frequency, the mesh-current equations are four equations with complex but constant coefficients. These may be reduced to eight equations with constant real coefficients. By solving this set of eight equations, we can calculate the value of both magnitude and phase of the output voltage with respect to the input.

The manual solution of a set of eight simultaneous equations would be nearly as easy as the same calculation done on punched-card equipment, provided only one such set of equations was to be solved. In the given example, however, one solution gives us the gain and phase shift for only one frequency of the input. An average frequency-response curve may require that we try 12 or 15 different values of frequency. Moreover, it will probably be interesting to find out how the frequency-response curve is affected by variation of some of the circuit parameters. For each new circuit investigated, the multiplicity of sets of equations increases rapidly—we may find ourselves with 150 to 200 sets.

And that is where the punched-card calculator really pays off. Carrying along a number of sets in parallel greatly reduces the unit time of solution. All of this illustrates the fact that punched-card machine computation is most effective when a large number of repetitive calculations must be performed.

CIRCUIT DIAGRAM of a stabilized amplidyne control element referred to in the text. Results of the problem are plotted to show phase shift and amplitude gain



Good Aluminum Welding Starts with the Engineer

By R. M. CURRAN

There are very few machines or parts manufactured nowadays that don't involve welding. In view of the nature of the welding process, the design engineer can help his organization avoid trouble by being careful in specifying materials to be used. This is especially true of aluminum alloys.

The choice of an aluminum alloy, for example, is not simply a matter of selecting the strongest material. This may be true for a number of reasons, but it is particularly true of an assembly that is to be welded.

For the strong alloy may be relatively unweldable. The result, therefore, could be a weld with a tensile strength no greater than that of the weaker and more weldable alloy which the engineer could have used in the first place.

Hot Cracking

Welds made in the aluminum alloys by any of the common welding processes are subject to hot cracking at elevated temperatures near the melting point. The tendency of these metals to crack in this manner varies greatly from alloy to alloy. Apparently it is associated with the melting range of the alloy.

In the pure state, molten aluminum which is being cooled very slowly begins to solidify at 1220 F (660 C); at 1219 F the melt will be completely solidified.

When alloying additions are made, however, solidification begins at a lower temperature. In addition, the temperature at which solidification will be complete is lower—appreciably lower than the temperature at which solidification begins.

The highest temperature at which the metal is completely solid is known as the solidus temperature. Conversely, the lowest temperature at which a metal is completely liquid is the liquidus temperature. The temperature between the two is the melting range. In pure aluminum the melting range is very narrow, but aluminum alloys usually have a wider melting range.

Generally speaking, best welding results will be obtained by using alloys with the narrower melting ranges. In aluminum alloys, melting begins at the boundaries between the grains in the crystalline structure of the metal. Conversely, these boundaries are the last areas to solidify in cooling. The melting range of an aluminum alloy is, in general, a measure of the difference between the melting of the grain-boundary material and that of the matrix, or grain proper.

In welding, the material in the area adjacent to the weld is subjected at the same time to both high temperatures and shrinkage stresses. These conditions tend to disrupt the lower melting (and consequently weaker) material which makes up the boundaries of the grains. The lower the melting point of the grain-boundary material and the greater the difference between the melting points of the grain-boundary material and the grain matrix, the greater the tendency toward this type of cracking.

The melting ranges of several of the more common aluminum alloys, and hence their tendency toward cracking when welded, is given in Table I on page 14.

No sharp line can be drawn, of course, to demarcate the melting range above which welding is impossible. Factors such as restraint, preheat, procedure, and welding process used also determine whether a particular alloy may be welded satisfactorily in a specific application. In general, however, as already mentioned, alloys with a wide melting range will be more subject to cracking than those with a narrow one.

Various Welding Processes

In brazing and in the arc- and gas-welding processes, the lower limit of the melting range must also be considered. It is not practical, for example, to braze a material which has a melting temperature lower than the flow temperature of the brazing alloy. This prevents the use of brazing on alloys whose lower melting point is below 1080 F (582 C).

Essentially, this limits the use of brazing to 2S, 4S, 52S, 53S, 61S, and 63S wrought-aluminum alloys, plus A612 and C612 cast-aluminum alloys. The brazing of 61S material is more critical because of the narrow range between the lower melting point of the base material and the upper melting temperature of the filler materials.

Since the area of heat application is localized in arc and gas welding, it is possible to weld by those methods materials whose melting points are lower than the upper melting temperature of the filler metal.

Difficulties arise, however, when the solidus temperature of the base metal is lower than the solidus temperature of the filler material. In this case, as the weld cools from welding temperature, it solidifies while the adjacent base metal is still in a semifluid state. Consequently, fusion-line cracking often results.

For this reason, the use of filler materials which have solidus temperatures higher than that of the base material should be avoided. And materials with solidus temperatures lower than 1070 F should not be welded with the filler materials listed in Table I until extensive tests, representative of production welding conditions, indicate that the results will satisfy engineering requirements.

Although the use of the base metal as a filler material for welding the alloys with low solidus temperatures might be satisfactory in eliminating fusion-line cracking, the wide melting ranges of these materials may lead to weld-metal cracking.

In resistance welding, no filler is added. Hence, many of the alloys which cannot be welded by the arc or gas processes—or brazed—may be joined by this method. The alloys which have a wide melting range, such as 24S and

Mr. Curran is engaged in development work and factory applications involving the arc- and gas-welding processes. He has been a member of the Welding Section of General Electric Schenectady Works Laboratory since 1948. He is now making further metallurgical studies in the pursuit of a Ph.D. degree at RPI, Troy, NY.

75S, however, are prone to crack in spot welding. Since the major stresses imposed in flash welding are compressive, neither melting range nor lower melting point cause difficulty in producing sound welds.

Properties After Welding

Aluminum alloys attain their properties by one of three mechanisms: solution of alloying additions, precipitation hardening, and strain hardening. During the welding process, the increase in strength produced by all but one of these mechanisms (the effect of alloy solution) is to some extent lost. The degree to which physical properties are destroyed during welding depends upon the time-temperature cycle to which the alloy is subjected.

The final strength of a welded joint in aluminum will depend upon the process, procedure, and joint geometry used, as well as upon the initial condition of the material. The welding processes might be rated, in the order of their increasing softening effect, as follows, where resistance welding has the least softening effect:

Resistance welding
Inert-gas-shielded metal-arc welding
Inert-arc welding
Metal-arc welding
Atomic hydrogen welding
Gas welding and brazing.

Yield Strength

Since most design values are based on yield strength rather than on tensile strength, the yield strength of welded joints should be considered. Yield strength of homogeneous materials is usually determined by placing an extensometer on a 2-inch gage length (arbitrarily selected as a standard) and obtaining data so that the stress-strain curve may be plotted.

In a uniform material, the results may be interpreted to indicate that, when the material is stressed to the yield point, a permanent elongation of 2 mils will occur in each inch of length. In other words, in 1000 inches the permanent "set" due to the stress would be 2 inches.

In a welded joint, however, elongation does not take place uniformly over the entire gage length; it is confined to a narrow band which may represent as little as one-sixteenth of the total gage. If yield strength is measured in the same manner as for uniform materials, therefore, the locally yielding area must elongate approximately 16 times as much as the material in a uniform test.

The significance of this fact will be obvious when it is realized that very few structures are designed with 2-inch gage lengths. In a 1000-inch-long structure, welded at its center and stressed to the yield point of the weld (as determined by the standard test), the permanent set will be 2 mils rather than 2 inches as it would be for a uniform material stressed to its yield point. In a structure one inch long with a weld at the center, the permanent set would still be 2 mils, as compared with 1 mil for the uniform material.

Thus it can be seen that yield strength of welded joints in aluminum is a fictitious value when based on a 2-inch gage length, and it should be used with caution.

Ductility

When we consider the ductility of welded joints as measured by the percent elongation in 2 inches, the situation is much the same as for yield strength. If the heat-affected zone, representing one-sixteenth of the total gage length, should elongate 50 percent, the reported elong-

TABLE I—MELTING RANGES OF SOME COMMON ALUMINUM ALLOYS

Alloy	Melting Temp (degrees F)	Melting Range (degrees F)	Alloy	Melting Temp (degrees F)	Melting Range (degrees F)
Cast Alloys			*Wrought Alloys*		
13	1055 to 1090	35	2S	1190 to 1215	25
43	1055 to 1155	100	3S	1190 to 1210	20
85	970 to 1155	185	4S	1165 to 1205	40
108	960 to 1170	210	11S	995 to 1190	195
112	950 to 1150	200	14S	950 to 1180	230
113	950 to 1150	200	17S	955 to 1185	230
122	920 to 1155	235	18S	945 to 1180	235
132	970 to 1030	60	24S	935 to 1180	245
138	990 to 1170	180	25S	970 to 1185	215
142	960 to 1190	230	32S	990 to 1060	70
195	965 to 1180	215	A51S	1025 to 1200	175
212	960 to 1160	200	52S	1100 to 1200	100
214	1075 to 1185	110	53S	1075 to 1205	130
218	990 to 1140	150	56S	1055 to 1180	125
220	840 to 1150	310	61S	1085 to 1205	125
319	950 to 1120	170	63S	1140 to 1205	65
355	1000 to 1160	160	75S	890 to 1180	290
356	1055 to 1145	90	*Filler*		
360	1035 to 1105	70	*Metals*		
380	970 to 1090	120	43S	1075 to 1165	95
750	445 to 1200	755	711S	1065 to 1155	90
40E	1060 to 1140	80	713S	1070 to 1135	65
A612	1105 to 1195	90	716S	970 to 1085	115
C612	1120 to 1190	70	718	1070 to 1080	10

TABLE II—APPLICABILITY OF RESISTANCE WELDING

UPSET FLASH WELDS				SINGLE SPOT WELDS		
Alloy	Condition	Tensile Strength	Yield Strength	Alloy	Gage (inches)	Strength per Spot
2S-0	AW	17,990	14,900	2S-0	0.030	150
				2S-½H	0.064	400
3S-0	AW	16,590	7800	3S-0	0.094	630
					0.125	800
52S-0	AW	29,800	14,300	2S-H	0.030	190
52S-½H	AW	33,390	25,200	3S-½H	0.064	565
				61S-0	0.094	900
61ST	AW	16,200		52S-0	0.125	1050
	HT	38,400				
				52S-½H	0.030	220
24ST	AW	24,300		52S-H	0.064	625
	HT	62,100		53S-T	0.094	1065
				61S-T	0.125	1625
75ST	AW	36,400				
	HT	73,300		24S-T	0.030	235
				75S-T	0.064	690
				R301	0.094	1345
				R303	0.125	21,120

Values reported are neither minimum nor average, but were obtained on individual specimens. AW means as welded; HT, heat-treated. Tensile and yield strength in psi, strength per spot in pounds.

* Not recommended for general application.

ation in 2 inches would be 50/16, or 3 percent. It should be realized that this low value arises from the heterogeneity of the section tested; it does not indicate brittleness.

The low elongation values encountered in welding aluminum present a serious problem when a structure is subjected to tensile impact loading; for the energy absorbed by such a structure under that type of load is proportional to the product of the volume of material deformed and the stress necessary to cause deformation.

In high-strength aluminum alloys, the total volume of metal deformed in tensile impact loading is small. The reason for this is that the yield strength of the heat-affected zone or weld metal usually is less than that of the parent metal, and the elongation is confined to the narrow area in the vicinity of the weld.

In tensile impact loading, the use of alloys in the annealed condition will, therefore, usually result in higher energy absorption than will the use of hard-tempered materials. And the reason is that the lower yield strength is more than compensated for by the great increase in the volume of metal deformed, which results from the uniform yield strengths of weld and base metal.

The modulus of elasticity is essentially the same for all aluminum alloys and is not affected by heat treatment or the softening effects of welding.

From the foregoing discussion, it may be seen that welded joints in the aluminum alloys will have lower tensile and yield strengths and lower ductility, as measured by conventional tests, than the base metal prior to welding. Because the extent of the reduction of these properties depends upon a great many factors, it is impractical to present data on the strength of welded joints in these materials except for test results obtained with plates welded with a given process under controlled laboratory conditions.

Table II contains typical results of tests made on welds in several of the wrought alloys; this may be used as a guide in selecting alloys from the standpoint of mechanical properties. Design values for weldments in these materials, as well as in wrought and cast alloys not listed, should be determined by further tests representative of the application.

Table II includes no data on the strength of brazed joints, since the strength of such joints is greatly dependent on joint design. In general, the use of proper lap-joint design will permit the attainment of joint strengths in 2S, 3S, 4S, 52S, 53S, 61S, and 63S equal to or greater than the strength of the annealed base material.

The use of butt joints in brazing aluminum alloys is not normally recommended; they are more difficult to align and hold at proper clearance. In addition, they tend to be weaker than properly designed lap joints.

Finally, here is a suggested procedure to follow when selecting aluminum alloys for welded construction:

1. On the basis of joint design, material thickness, and volume of production, select the welding process which is most applicable.

2. From Table I, select the alloys which are recommended for fabrication by the process selected.

3. Determine the approximate weld properties from Table II. If your alloy isn't listed in this table, refer to the annealed properties in publications of the aluminum companies or the ASM.

CAUTION—*Be sure your alloy is available in the shape you need.* This information can be obtained from publications of the aluminum companies.

WELDING PROCESSES FOR WROUGHT ALUMINUM ALLOYS

INERT-ARC PROCESS

Alloy	Condition	Tensile Strength	Yield Strength	Filler (Rod)
2S	AW	12,800		2S
3S	AW	16,900	7200	2S
4S	AW	22,400	10,800	2S
	AW	28,800	12,600	4S
	AW	26,000	14,200	43S
14S-T6*	AW	42,000	40,000	14S
	HT	70,000	63,000	14S
24S-T4*	AW	42,000	40,000	24S
75S*	AW	49,600	45,900	75S
52S	0 Temp	25,500	11,800	43S or
	¼H	28,000	14,300	52S
61S-T6	AW	30,000	22,000	43S or
	HT	45,000	40,000	718

METAL-ARC PROCESS

Alloy	Condition	Tensile Strength	Yield Strength	Filler (Rod)	Thickness (inches)
2S	AW	14,095		2S	0.125
3S	AW	17,590		2S	0.247
4S	AW	26,240		2S	0.250
14S-T6*	AW	35,490		43S	0.250
	HT	58,355		43S	0.250
24S-T4*	AW on HT Stock	45,000	43,000	43S	0.064
75S*	AW HT Stock	50,000	48,480	43S	0.064
52S	0 Temp	24,450	14,350	43S	0.400
	¼H	41,500	38,600 (400 F preheat)	43S	0.156
61S-T6	AW	26,830		43S	0.372

GAS WELDING

Alloy	Condition	Tensile Strength	Yield Strength	Filler (Rod)	Thickness (inches)
2S	AW	12,087		2S (Oxyhyd)	0.252
3S	AW	15,490		2S (Oxyhyd)	0.304
4S	AW	25,245		43S	0.160
	AW	22,745		2S (Oxyhyd)	0.159
14S-T6*	AW	21,015	12,400	14S	0.162
	AW	24,810	15,100	43S	0.162
	AW	20,515	13,150	2S (Oxyhyd)	0.162
24S-T4*	AW on HT Stock	45,000	30,000	43S	0.064
75S*	AW on HT Stock	50,000	34,000	43S	0.064
52S	0 Temp	28,675	12,150	5% Si Wire	0.064
	0 Temp	27,975	11,450	2S Wire	0.065
	0 Temp	28,765	11,900	52S Wire	0.064
	¼H	28,475	13,700	2S Wire (Oxyhyd)	0.040
61S-T6	AW	23,370		43S Wire	0.064
	HT	41,115		43S Wire (Oxyacet)	0.064

QUALITIES INDUSTRY WANTS IN ITS ENGINEERS

By

J. KENNETH SALISBURY

Have you ever asked yourself the question "Why did I know so little 10 years ago about what really is important?" Every one of us would conduct his life differently if today he had the wisdom of 10 additional years. There is only one reason for the nonexistence of this happy situation: none of us really understands a situation that he himself has not experienced. Wisdom simply is not made of secondhand knowledge of the lessons learned by others.

Every normal industry in this nation that is led by intelligent forward-looking executives wants to improve. Industry does not assume the character of its financial statement or of its physical facilities; rather, it assumes the character of its people—people who are identified by their personal characteristics. In the long run, therefore, industry can improve itself only by adding employees with desirable characteristics.

What are the desirable characteristics that we'd like to find in engineers? What are these qualities in terms that are tangible and specific? To me, there are 15 vital qualities, and I'd like to present them in approximate order of importance.

The first five qualities are absolutely essential for an engineer to attain the acme of professional accomplishment and standing. We may class these qualities, therefore, as INDISPENSABLE. The second group we may class as ESSENTIAL; the third can be called IMPORTANT, although I doubt that this word is strong enough.

Any single engineer who possesses all of these good qualities is a superman. All of us, on the other hand, have most of these qualities to some degree. Let us now consider each of the qualities in the order named.

Indispensable Qualities

Technical ability, although developed formally in a college engineering course, usually is also the product of one's environment, hobbies, and natural inclinations. It can be divided into two major subdivisions: creativeness and ingenuity; and analytical ability. Only rarely does an engineer of high technical ability possess both to an outstanding degree.

One normally tends to catalog engineers either as analyzers or as synthesizers—the analyzers are the appraisers and evaluators; the synthesizers are those who are creative and ingenious in devising new ways of doing things. This sharp division is somewhat fallacious, however, because there is considerable overlapping.

I think I am reasonably safe in placing technical ability on the top of the list of essential qualities. It is a prerequisite to notable success in engineering. It is not, however, as the mathematicians say, a "necessary and sufficient condition."

Aggressiveness must accompany technical ability. One must, for example, have the energy, the vigor of intellect, and the spark to exercise his technical ability, or it avails him nothing. He must have the will to win.

Every engineer with experience in industry has encountered the person of superb technical competence, capable of handling with ease fourth-order differential equations, or solving the most difficult problem in thermodynamics, but incapable of initiating the accomplishment of any useful objective.

These people tend to sit in a corner and wait for their problems to come to them. They perform beautifully when given a specific assignment and a date on which it must be completed. They never go to the boss and say, "I have been thinking about this project, and I think I see a solution to this major problem." They do not initiate new work in which they can make full use of their talent.

On the other hand, all of us have known people with mediocre technical ability who are continually thinking about the job, and who perform assigned work expeditiously to the full extent of their somewhat limited abilities.

These are the aggressive ones—the ones who are outstanding performers when used within the limits of their technical abilities. They move swiftly and surely. Things happen when they are around. Often such people have a high degree of intelligence and horse sense but are not naturally gifted in technical matters. They recognize their limitations, and it is the problem of management to make available for their assistance others who excel them in purely technical matters. Thus is formed a team that has more capacity than the sum of the capacities of the individuals.

Leaders in industry frequently have aggressiveness as their outstanding characteristic. It is the high-octane quality that drives them to top accomplishment. Aggressiveness to a high degree, however, may have unfortunate consequences unless it is accompanied by the third indispensable characteristic.

Understanding of human relations is vital in the business world. The aggressive engineer who does not comprehend through his understanding of human relations the effect of his aggressiveness on his associates is likely to incur their serious displeasure, and as a result fail to obtain their co-operation.

Skill in human relations implies an innate personal kindness—a tolerance toward the shortcomings of others. Above all, it requires fairness in dealing with people and a generosity of spirit. In a supervisor it requires a comprehension of the things that motivate the individual, a recognition of his merits, and a knowledge of his weaknesses.

Only rarely in industry does an engineer make a complete failure of his career through lack of technical ability alone. He may be consigned forevermore to the ranks of mediocrity, and his professional attainment may be at a very low level. Nevertheless, he usually is permitted to earn a satisfactory living, and to fill a place in industry however lowly it may be, provided he gets along with his fellow workers.

On the other hand, there are numerous failures in industry that result from lack of understanding of human relations. These are the people who within the first minute of a conversation arouse a feeling of antagonism. These are the ones who disregard the rights and sensibilities of others, who rise by stepping on the shoulders of their associates. Such gains are transient. They are effective for a brief moment, but they build up a permanent deficit in the human-relations account. They presage the future lack of co-operation by others that limits the engineer's accomplishments.

One must dispense compliments to subordinates sparingly, and only with complete sincerity. In fact, it has long been my opinion that the key to all understanding of human relations lies in a single word: sincerity. The man who is really and truly sincere never has difficulty in getting along with his associates. His objectives, his motives, and his activities are known and understood by everyone.

It is the cagey ones, the tricky ones, and ones with ulterior motives who

"The man who is really and truly sincere never has difficulty in getting along with his associates."

have difficulty. It is the ones who "speak not as they think" that have trouble. This does not, obviously, prohibit the use of tact in one's dealings with his fellow engineers, but it does completely eliminate untruths and half-truths, and concealment of pertinent facts.

Responsibility is the fourth indispensable characteristic. The successful engineer must have high personal and company standards of responsibility. He must be willing to accept responsibility even though it is not specifically thrust upon him. He must assume that he is personally responsible for the success of the endeavors in which he is engaged. He must accept responsibility for failures like a man, and he may also, though modestly, take unto himself responsibility for successes.

Moreover, he must realize that he and his company are one and the same. He must relieve his boss of concern for the project assigned to him. In return his boss is obligated to support him in all reasonable requests for assistance. He must make decisions, but at the same time have the good judgment to consult his superiors on any questionable decision that he may be called upon to make, because this is the essence of responsibility. The individual must make decisions, and he must make progress to the fullest extent of his ability. At the same time, he must recognize his limitations and assume complete responsibility for determining when he has reached the limit of his ability to make decisions.

Personal integrity, the fifth indispensable quality, may also be called high-mindedness. It is the all-consuming insistence of the engineer that he do what is right at all times. It is character. A former president of the General Electric Company once stated that, "Essential qualities for engineers are ability, personality, and character—that the greatest of these is character." Those who lack it—who are too smooth, who are too clever in the reprehensible sense—are limited forever.

Personal integrity implies an intrinsic honesty, an intellectual fairness in all things, and good judgment. It is sincerity. It is the quality that speeds transaction of the day's business. It is identified by promises that are kept, though made in a word or two, even when forgetfulness might provide a plausible excuse. It eliminates the need for written instructions, and for confirming memoranda.

Essential Qualities

Leadership and organizing ability are the first of the qualities essential to a brilliant career. They can be developed by all engineers, even in the earlier years. Leadership is the product of many things, including the five indispensable characteristics.

Invariably, leadership includes the important ability to inspire one's associates. Inspiration frequently is the result of one's conduct of his own personal job. An emulation of the boss's approach to problems is natural and normal. The members of his organization nearly always reflect his standards and aspirations. For this reason, then, if for no other you may demand that your boss be a superior person. Indeed, he must be, if you wish to improve yourself. Subconsciously you will acquire at least some of his personal characteristics.

Administrative ability has been typified by one accomplished engineer of my acquaintance in one word—persuasiveness. To convince others to do things, one must clearly explain the over-all objectives, the logic behind the method of procedure, and the worthwhileness of the objective. Only when subordinates can carry on without assistance from the leader has he accomplished the basic purpose of organization: delegation of responsibility.

Responsiveness is my own private term for a combination of characteristics. It is a willingness to see the boss's point of view, and an intense desire to carry out any reasonable objectives laid down by him. It is co-operativeness, promptness, reliability, dependability.

Also, it is important to your boss that reports, either verbal or written, be accurate. He doesn't want a situation exaggerated or minimized—he wants facts. Responsiveness and reliability are highly valued by any supervisor, and usually well rewarded.

Engineers in industry are expected to have initiative and originality, and to require only occasional supervision. A large part of what they actually do is self-inspired, and intended to be. Occasionally, however, a specific instruction is given by a superior, either on a small task, or on one of considerable duration. Such instructions should take priority over self-inspired work, which must be deferred until the specific objective is accomplished. Responsiveness is that characteristic which causes the engineer to set to with a will, finishing the work competently, and in the shortest possible time.

Adaptability increases the usefulness of any engineer. He must be willing to undertake any assigned job, and to

devote his every effort to mastering it, regardless of whether it is his personal choice.

Adaptability is a willingness to work under handicaps. Regardless of where an engineer works, there are situations that are not palatable to him, that make it more difficult for him to carry out his assigned responsibilities, and that slow him down. There are always handicaps. One must live with them and make the best of them. One must be adaptable, and willing to accept these things, because they exist universally, and appear in many forms.

Perspective is the quality that permits an engineer to assign correct relative importance to all things within his scope. It is the quality that permits him to make approximations when they are

"Skill in human relations implies an innate personal kindness . . . toward the shortcomings of others."

justified; it is the quality that impels him to work on things which are important to his company, or which may be important in the future. The man who has perspective invariably does first things first, relegating nonessential items to a later time in his work schedule.

Perspective is the quality that enables an engineer to understand his position in an organization and in a company. Also, it enables him to assume authority when he should, to delegate it when he can, and to consult his superiors when it is advisable. An engineer without perspective is a ship without a rudder. Although experience is bound to improve perspective, perspective is basically a native talent. Engineers with perspective are able to select the critical problems, the ones that are really pressing, because they clearly see the over-all size and shape of the main issue.

Mr. Salisbury is presently the Division Engineer of the Thermal Power Systems Division, General Engineering Laboratory at Schenectady. His responsibilities include the direction of engineering development work on thermal prime movers and associated apparatus, including turbines for aircraft use and aerodynamic and combustion devices. Mr. Salisbury is author of numerous technical articles, papers, and discussions, and he has served on several ASME committees. In 1950, he was elected honorary member of Pi Tau Sigma; in 1951, he received the ASME Richards Memorial Award for mechanical engineering achievement.

Introversion and extroversion are very personal qualities which, when they appear in combination, are of tremendous value to an engineer. The introvert is the thinker—the man with internal self-confidence that can result in useful, progressive, forward movement. On the other hand, for maximum achievement the engineer must combine a modicum of extroversion with his normal introversion. His introversion enables him to seclude himself, and after objective study, to arrive at the right answer. However, his extroversion then enables him to sell it to his associates and to his superiors. No idea, regardless of its worth, is of value until it is implemented.

The inarticulate engineer, no matter what his competence, may be doomed to a life of monotonous intellectual activity and investigation. He lacks the ability to communicate thoughts. The pure extrovert is doomed to remain forever a front man, a hand-shaker, and a back slapper.

But the man who combines introversion and extroversión can do his research and investigation to arrive at a course of action that should be pursued. He then can take his plan to the court of authority that exists in every company and convince this court of the wisdom of adopting his suggestions. If he makes a design, he can convince the draftsman to put it on paper. Likewise, he can convince the shop man to build it. Neither extroversion nor introversion is important; a combination of the two in various proportions is, however, desirable.

These, then, are the indispensable and the essential characteristics of successful engineers, as I see them. And now let us consider more briefly some additional important ingredients of success.

Important Characteristics

Ethics, both company and business, are the responsibility of the engineer. So many safeguards are set up in the modern industrial organization that it is nearly impossible for any individual engineer to violate his company's code of ethics. He should strive not only to live by this code but also to spread its implications among all his associates. It is a most precious asset for any company. It is easy for an engineer to live in his environment if his personal code of ethics is consistent with that of his company. It is hazardous and unpleasant for him if it is not.

Cost consciousness is an important attribute—consciousness not only of dollars but also of manpower, of materials, of effort. Every engineer eventually controls to some degree the expenditure of these ingredients of his company's products. He must exercise this control wisely, and with perspective.

Confidence is tremendously desirable. The engineer must have confidence in success, in himself, and in his company. He can then give to those with whom he works the strength of spirit and the morale that are essential to forward progress. Confidence does not mean cockiness. It is rather a quiet conviction of competence and adequacy. Confidence is the quality that lends us strength. It is born of experience—past successes.

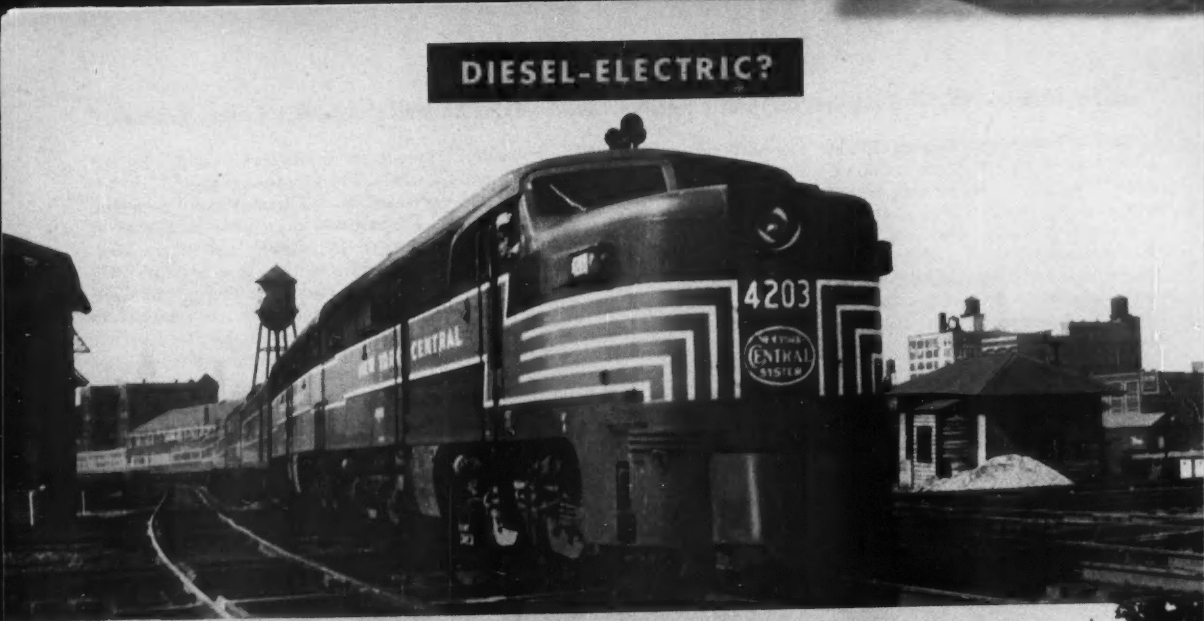
Efficiency causes one to economize on his time, to plan his work well, and to exercise extreme self-discipline. To a very considerable extent, it is the young engineer's integrated effort over his first 10 years in industry that measures his accomplishment at the end of that period. His work is not only in the interest of his company but even more in the interest of self-development. It is my firm belief that the individual profits far more by his own intensive effort than does his company. Your company can survive with a low level of effort on your part, but you cannot.

Optimism is a virtue the world around. All of us have known the man with a negative attitude. He can be convinced, but it takes hours of valuable time. He usually is the ultracautious conservative type. He never can be an outstanding member of any organization.

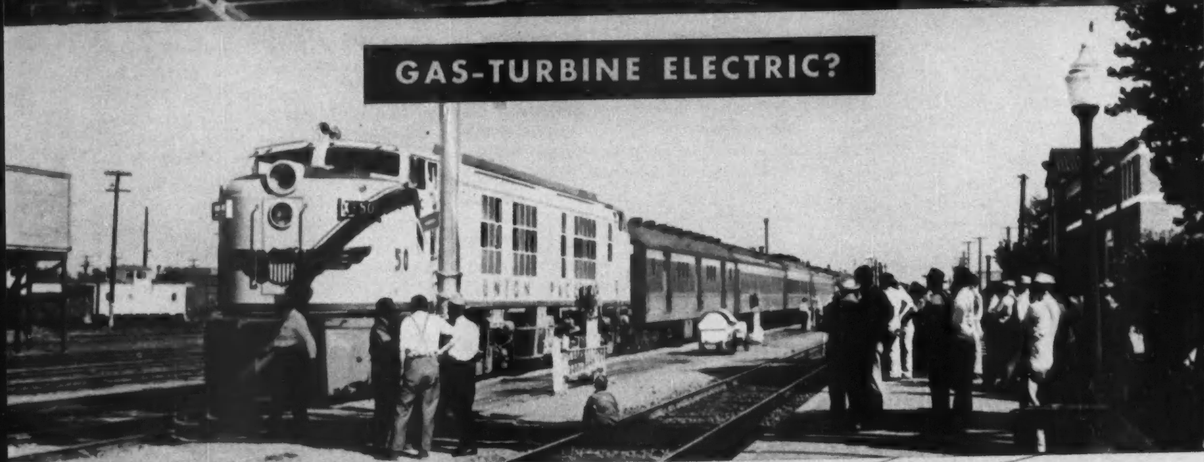
Then there is the boss who is predisposed to accept your solution. He assumes you are right until he uncovers evidence to the contrary. He believes in you as an intelligent conscientious human being. You like him. You enjoy working with him, being around him. He attracts competent people, for this reason alone. They cooperate, and his business prospers.

These, then, are a few of the qualities that help make a success of any chosen career. All of them are characteristics of the individual and only a few pertain to his degree. One's education represents the minimum qualification. It does not guarantee success. The qualities discussed, on the other hand, if one has them in full measure, will insure his rise above the median, not only in engineering, but in any profession.

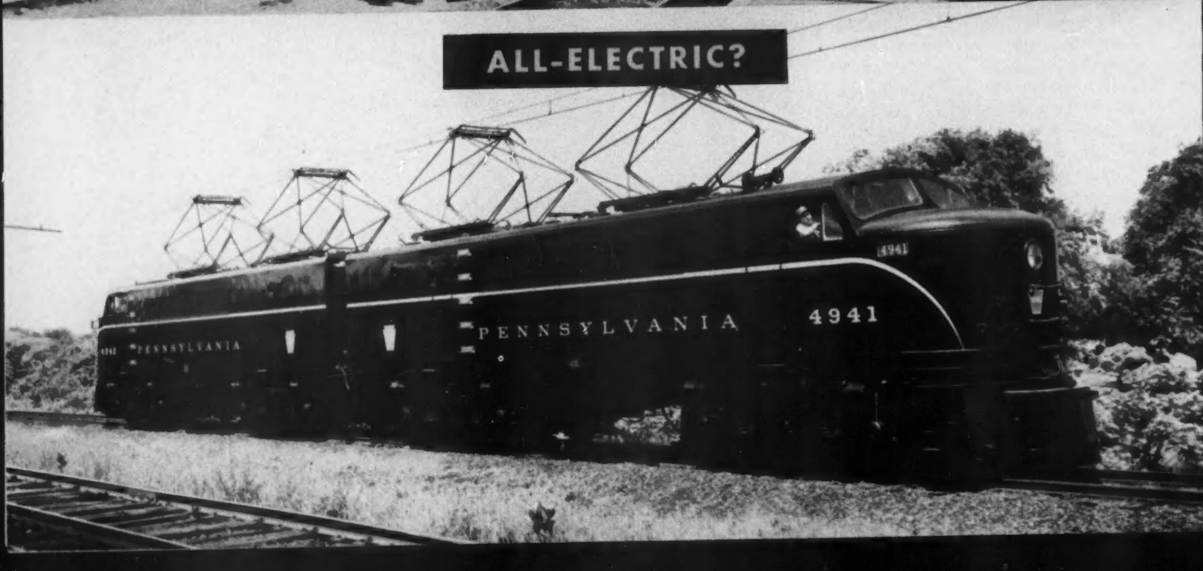
DIESEL-ELECTRIC?



GAS-TURBINE ELECTRIC?



ALL-ELECTRIC?



What's Ahead in Rail Motive Power?

By G. W. WILSON

Ask anyone who is reasonably familiar with railroads what the future holds in the way of motive power and a reasonable answer would be that in a few years all the main lines will be powered with diesel-electric locomotives. You also may get some replies to the effect that the gas-turbine-electric locomotive may offer some strong competition even to the diesel-electric.

These answers are logical, but I do not believe that either is the final one. To me, only the straight-electric locomotive offers the ultimate in operating effectiveness.

True, the diesel-electric locomotive has gained a tremendous foothold, even though it sells at approximately $100 per horsepower—just twice the cost of its steam-driven predecessor. Greater reliability and decreased operating cost is the answer. As a result, we have seen a multibillion-dollar market born almost overnight.

Holding great promise for the future is the gas-turbine-electric locomotive, one of the most spectacular developments in the transportation field. Although the first unit of its kind has been on test for the past two years, it will not be until the 10 now being delivered to the Union Pacific Railroad are in regular service that we will be able to evaluate fully this new form of motive power.

Both of these engineering achievements, significant as they are, still leave further operating advantages to be desired.

It is generally agreed that electrification of lines with sufficiently dense traffic would solve many of the annoying problems that beset railroads today. The efficiency, reliability, and overload capacity of the all-electric locomotive make it an outstanding form of motive power.

The inevitable question is, "If the electric locomotive is such an efficient piece of apparatus, why isn't it used universally on the railroads?"

The answer isn't hard to find—merely that it takes a tremendous capital expenditure to put a completely electrified system in operation. If anything can be done to cut this cost, we will immediately see more railroads turning to pure electrification.

One important step in this direction has been taken. After many years of controversy, the electrification system for American railroads has emerged as a well-standardized form. Today, the great majority of straight-electric locomotives operate from an 11,000-volt 25-cycle single-phase a-c trolley wire. Unfortunately, the similarity among systems stops right there, because of the widely different styles and types of locomotives that are now in operation.

To continue the trend toward standardization, the railroads need an electric locomotive that can be placed anywhere on the system; and, once it gets there, it must be able to haul regular trains over the entire profile. Such a locomotive would bring important economies in the cost of motive power, because this figure currently represents about 40 per cent of the total cost of electrification.

General Electric's contribution toward the solution of this problem is the new low-cost 25-cycle locomotive with a-c commutator motors. The design is based on fundamentals proved to be sound by operating experience with thousands of diesel-electric locomotive units. In this new locomotive—designed for quantity production—the entire weight of 120 tons is carried on the drivers for maximum operating efficiency. This relatively high power rating per axle gives a total of 2500 hp at the rail in a unit that is only slightly more than 54 feet long. This not only represents highly efficient utilization of space, but compares to a length of about 65 feet for a typical diesel-electric "A" unit, and 83 feet for the gas-turbine-electric locomotive.

Mr. Wilson, General Manager of the Locomotive and Car Equipment Department, has spent all of his 29 years with General Electric in the transportation field, beginning with six months on the Test Course. His department, with headquarters in Erie, Pa., has been responsible for the development of the first gas-turbine-electric locomotive, undercar power plants for railroad cars, and other significant transportation advances.

To give the railroads sufficient overload, each unit is capable of developing 5000 hp for a short time; for example, when accelerating a train. Adaptability is complete—the locomotive units can operate in multiple to give prime movers of 5000, 7500, or 10,000 hp as required.

There is another approach that I believe will help the railroads in providing even more efficient transportation. At the present time, the engineering approach to the problems of the transportation industry is undergoing a desirable change. In years past, the manufacturer sold what was primarily an engineering service to the customer. He also supplied the electric equipment to do the job.

Today this "tailor-made" style is passing from the picture, a trend that I know will prove to be of benefit. Manufacturers now have several lines of products that are completely designed, field-tested, and ready for quantity manufacture before they are offered to the trade. In the future, I believe, engineering in the transportation field will be directed along the line of more of this standard-unit business. The objective of such an effort is to develop designs that the manufacturer can build in quantity. Yet they will be designs that have good all-round performance characteristics. Of even greater benefit will be the savings in time and labor—savings that will enable us to offer the transportation industry far better products at lower cost.

This change certainly does not mean the stagnation of engineering development. Now, as in the past and in the future, we need better products in every line and new products engineered for quantity production.

Whether the future will see increasing electrification of the nation's railroads is something that remains to be seen. But it definitely has been indicated that the all-electric locomotive holds by far the greatest promise for the future of railroad transportation.

For certain high-temperature applications . . .

Liquid Metals Are Good Heat-transfer Agents

By THOMAS TROCKI

Liquid metals have singular advantages as heat-transfer agents for certain high-temperature applications in our modern industrial economy. Water, although an excellent heat-transfer fluid and the most widely used medium for this purpose, has certain disadvantages above 500 F. These include high vapor pressure and a tendency to break down into hydrogen and oxygen. Metals, however, have much higher boiling points and consequently negligible vapor pressure at those temperatures. Furthermore, their very high thermal conductivity yields higher heat-transfer coefficients.

Aside from mercury power plants, no applications of any consequence have yet been made. Possibilities include the use of liquid metals as coupling fluids in power and process applications, such as steam reheating, regenerative heat exchangers for gas turbines, and chemical processes requiring uniform heating and cooling. Liquid metals also appear to be particularly suitable as coolants for high-temperature nuclear reactors.

From a practical standpoint, liquid metals offer the following advantages:

1. A high boiling point means less likelihood of localized boiling and overheating; lower fluid pressure produces lower stresses in tube walls.
2. High heat-transfer rates result in cooler tube walls, longer tube life, and more uniform cooling and heating.
3. Thermal and chemical stability permits the use of higher operating temperatures.
4. Liquid metals do not decompose when subjected to nuclear radiation, although they would become radioactive in passing through a reactor.

Liquid metals have a disadvantage in their relatively low heat-storage capacity. A larger quantity of liquid metal than of water is needed to remove a given quantity of heat. But this is not a serious limitation to their use.

Handling Problems

With the exception of mercury, the use of liquid metals as heat-transfer media is a comparatively recent development, and some of the technology is classified for reasons of national security. There is, however, sufficient general information available to permit some evaluation of the subject.

The main problems in handling liquid metals stem from their corrosion of structural materials and their chemical activity or toxicity at the high temperatures involved.

Compared with ordinary materials in general industrial use, the liquid metals *are* relatively difficult to handle—but this is an unfair comparison; for the handling of *any* fluid at high temperature is hazardous to personnel, and the precautions required for handling it safely go a long way toward reducing the chemical activity or toxicity hazard. So the handling of liquid metals should more properly be compared to the handling of high-pressure high-temperature steam in modern power plants, or to active chemicals in many chemical processes. The hazard involved is not much different.

The basis for the successful handling of chemically active or personally hazardous materials is to contain them in an inert atmosphere and prevent leakage which might be injurious to personnel or result in fire or explosion. The chemical and power industries have established the practicality of this procedure by thousands of hours of operating high-temperature power plants and industrial processes. They have pioneered in the development of adequate techniques for the design, construction, inspection, and pretesting of piping and equipment. These techniques are applicable to systems for handling liquid metals, with some minor provisions for the unique requirements of the latter.

Obviously, the success of any such system depends on the use of a structural material which will not be corroded by the contained liquid metal. It is, therefore, fortunate that many of the high-temperature structural materials are compatible with liquid metals as long as proper precautions are taken to purify the liquid metals initially and keep them clean.

Oxygen appears to be the principal contaminant affecting corrosion, and it must be kept to a minimum. This requirement, however, is not restricted to liquid metals. In a modern power plant, considerable attention is devoted to the control of oxygen in the boiler water. The limit of oxygen contamination for boiler water is actually more stringent than it is for liquid metals. In boiler water the oxygen content is controlled by removing the oxygen at low temperature, when it is practically insoluble in water, and depending upon chemical "getters" at high temperature, when any remaining oxygen is released—and is most corrosive.

Oxygen solubility in liquid metals is also temperature dependent, and this is used as the basis for oxygen removal. Getters have also been investigated for liquid metals, but their effectiveness has not been established.

It can be seen from the foregoing that leak-tightness is the most important single requirement for a liquid-metal system. The difficulties resulting from leakage of liquid metal in such a system vary with the liquid metal concerned. Some of the metals—like lithium, sodium, and potassium—burn in air; others—like lead and mercury—are toxic. And any material at high temperature will burn flesh.

Leakage of air into the system results in contamination of the liquid metals, and this increases their corrosiveness.

The last half of Mr. Trocki's 10 years with General Electric has been with the Knolls Atomic Power Laboratory, where he is responsible for liquid-metals engineering. His part in the first large liquid-metal heat-transfer system contributed to its successful operation. He is one of the editors of LIQUID METALS HANDBOOK, *a joint Navy and AEC publication.*

Broadly speaking, the development leading to the successful handling of liquid metals has been devoted, first, to gaining an understanding of the limits and control of liquid-metal contamination, with the object of controlling corrosion; and, second, to developing leakproof heat exchangers, pumps, valves, and system auxiliaries. Some developments in the second category, for heat-transfer systems using sodium and a sodium-potassium alloy as the liquid metal, are described in the following paragraphs.

Heat Exchangers

The need for leak-tightness is an important factor in the design of heat exchangers for liquid metals. Flanged joints and the joints formed by tubes rolled into tube sheets, commonly used in heat exchangers, do not appear satisfactory for containing liquid metals at high temperature. For this reason, the liquid-metal circuit of a heat exchanger is completely welded. However, on the steam or air circuits, where there is little possibility of contact with liquid metal, conventional practice is acceptable.

The chemical reactivity of the alkali metals—lithium, sodium, and potassium—with water requires more than usual precautions to prevent their mixing. For extra safety in a liquid-metal-heated steam generator, concentric independent tubes are used, welded into separate headers. The annulus between the tubes is filled with mercury, to provide a good heat-transfer bond and permit differential expansion.

The high heat-transfer coefficients of liquid metals have an interesting effect in the design of heat exchangers. In conventional heat exchangers, the heat-transfer resistance of the fluid films is usually a controlling factor in the over-all resistance of a heat-exchanger wall. Liquid-metal heat-transfer coefficients are comparatively high; hence their equivalent film resistances are low, and they usually are a minor part

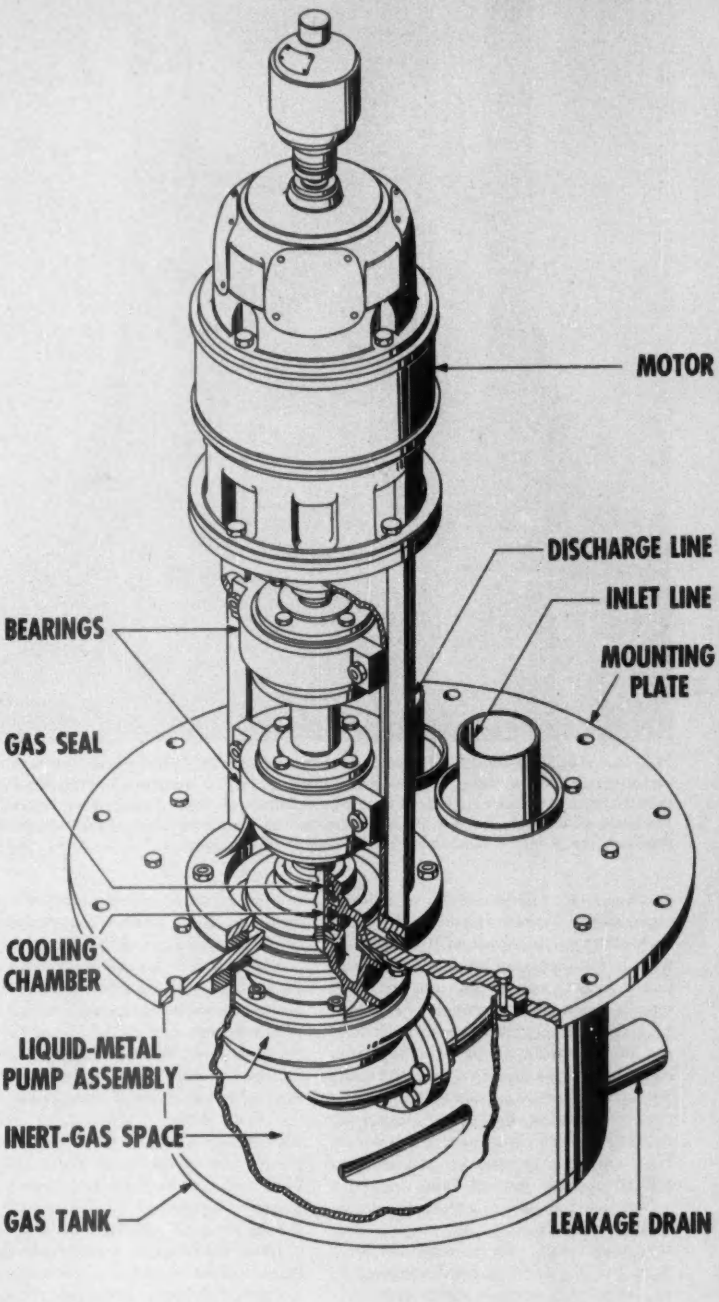


FIG. 1. CENTRIFUGAL PUMP for liquid sodium. In this design, an ordinary water pump is overhung in a can containing an inert-gas atmosphere. The gas is sealed at the shaft with a stuffing box or mechanical seal. The stuffing box shown here has been replaced by a carbon-face-type mechanical seal. This pump is still in operation after several thousand hours, with only occasional seal replacement

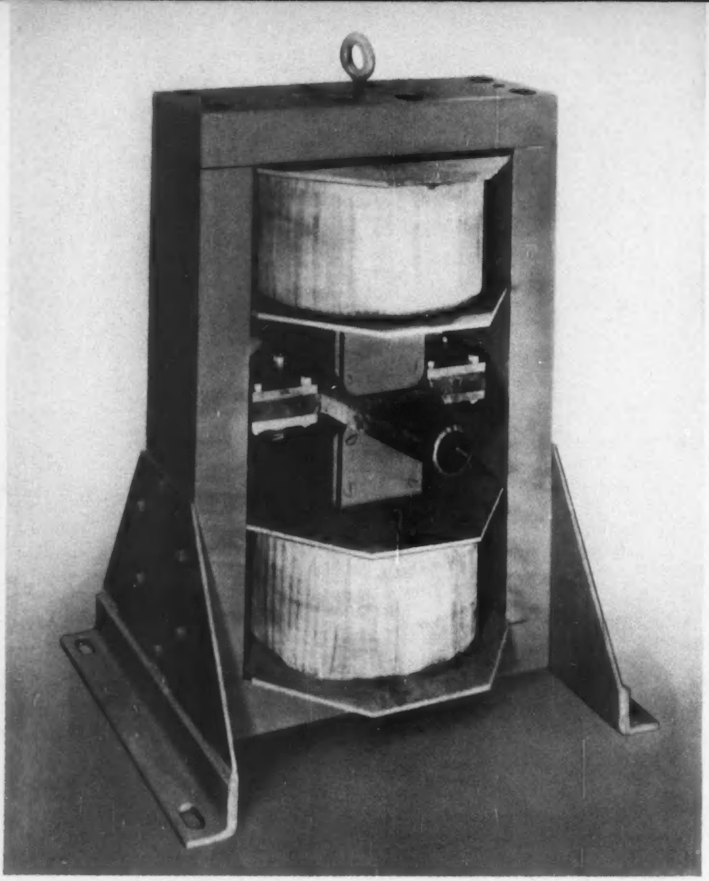


FIG. 2. ELECTROMAGNETIC PUMP (d-c) for liquid metal. The pump cell is a flat rectangle in cross section, inserted into the air gap of a magnet. A relatively large current at low voltage is supplied to the cell through heavy conductors brazed to the sides of the cell. The current flows through the liquid metal at a right angle with the flux. The pumped fluid follows the motor left-hand rule

of the total resistance. In a liquid-metal-to-liquid-metal heat exchanger, both film resistances are low; hence the wall resistance becomes the major factor in determining the heat-transfer rate. Economy of surface can be effected by reducing this resistance through the use of thin walls of high-conductivity material. The comparatively low working pressure of liquid metals at high temperature permits the use of thin-wall tubes. The lower limit in wall thickness is, of course, determined by fabrication difficulties with thin-wall tubes.

Because the major part of the total temperature drop occurs across the tube wall rather than in the fluid film, as it usually does, thermal stresses in the tube wall become significant, and the total temperature drop for a heat exchanger must be selected with this fact in mind. Steady-state thermal stress in a tube wall is directly proportional to the temperature difference across the wall. There is only very limited experience available today from which values of allowable design stress for thermal stress can be selected. Some arbitrary limits have been assumed that permit the use of stresses beyond the elastic limit of the material at the temperature involved, on the basis that plastic flow of the metal occurs. Much work needs to be done to advance our understanding in this field similarly to that of design by elastic theory.

Heat exchangers transferring heat from sodium to sodium-potassium and steam generators using sodium-potassium as the heating fluid have been built and operated successfully in a pilot plant of considerable size. No particular difficulty has been encountered in operation up to a maximum temperature of 1000 F, and the measured performance checked with predicted performance at the design point. A significant discrepancy in performance was noted at partial-load conditions.

Pumps and Valves

In the liquid state, the light metals have fluid properties similar to those of water or alcohol. The hydraulics of pumping liquid metals is not much different from that of pumping the more common fluids. The problems in pumping liquid metals arise from the elevated temperatures of the applications and the necessity of absolutely preventing metal leakage out or air leakage in.

The no-leakage requirement practically eliminates a stuffing box or mechanical seal for the liquid metal. This requirement has led to the adoption of several schemes to meet the sealing problem. An early design devised at the Knolls Atomic Power Laboratory, Schenectady, NY, for pumping sodium and sodium-potassium at 500 to 700 F is shown in Fig. 1.

Improved designs of mechanical pumps have solved the seal problem by using a submerged-rotor type of construction. In this design, the pump impeller, shaft, and motor rotor are all submerged in the fluid, with the seal consisting of a thin diaphragm in the motor air gap. The main problems introduced by this construction involve the operation of bearings in the liquid metal and the cooling of the motor. Several designs of this type have been built and operated.

As in pumps, the main special requirement for valves in a liquid-metal system is leak-tightness to the atmosphere. It is understood, of course, that it is desirable to hold leakage across the seat to a minimum as is done with any valve. Packing around the stem is not considered satisfactory for liquid metal use. Bellows-sealed—so-called packless—valves have proved quite satisfactory. In these the bellows are welded to the valve disk and valve body, forming a complete and continuous metal seal. There have been some bellows failures, but the percentage of these has been reasonably small, and the leaks were detected without damage or injury.

The metallic properties of liquid metals open the door to a very interesting possibility—pumping by direct action of electromagnetic forces. The motive force in the several basic types of motor design can be directed to act on the liquid metal instead of on the armature conductors. Pumps similar in principle to d-c and a-c motors have been built and operated. The performance of such units can be predicted on the basis of motor calculations adjusted to account for a continuous fluid conductor instead of for separate solid bars or wires. A d-c pump is illustrated in Fig. 2.

A-c units of both conduction and induction types have been built. The former are similar to d-c pumps in construction. Small units using transformer action to provide the large armature currents are commercially available and are in common use in several laboratories engaged in liquid-metal development work. Although they are relatively inefficient, they are convenient because they can be plugged into a standard power outlet.

A-c induction pumps seem promising for large pump applications. They are similar to induction motors in principle and can be built in different configurations. A unit built like a locked-rotor induction motor is shown in Fig. 3.

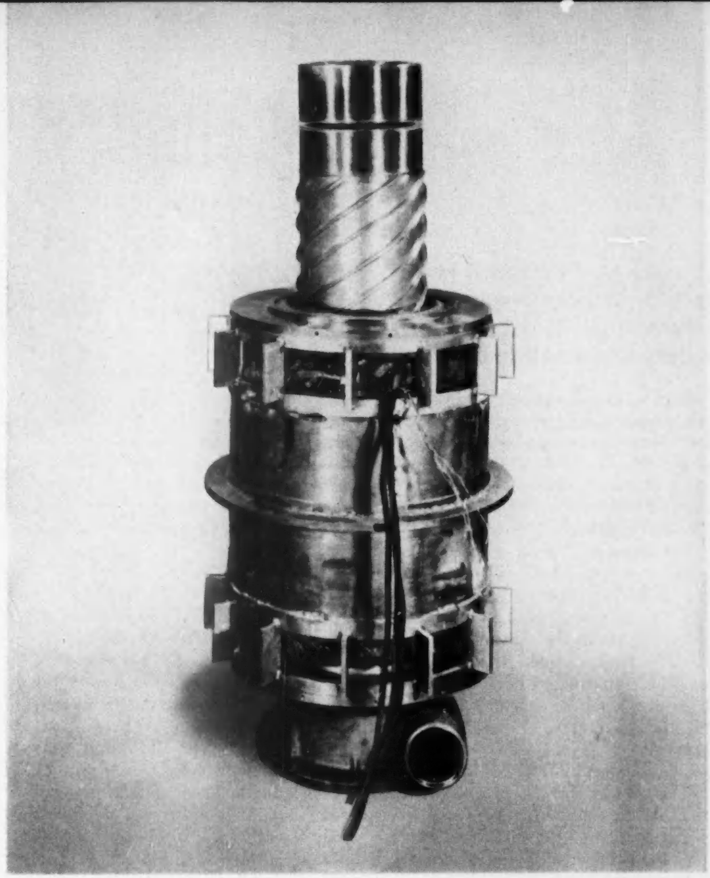


FIG. 3. "ROTOR" of electromagnetic pump (a-c) for liquid metal being lowered into the stator. In operation, the rotor remains locked. The liquid metal is introduced into the air gap and guided in an axial direction by helical vanes. A unit of this type has operated successfully for an extended time. It is similar to a standard induction motor in electrical performance

Instrumentation

The metallic properties of the liquid metals also lend themselves readily to measurement by electromagnetic means. An accurate flow measurement can be taken by measuring the emf generated by liquid metal flowing in a magnetic field. A singular advantage of this method of measurement is that it can be installed outside the piping.

Measurements of liquid level can be made by measuring the effect of the liquid metal on the inductance of a coil immersed in it. Level can also be determined by measuring the resistance of a wire immersed in direct contact with the metal and short circuited by it to the depth of immersion.

Pressure measurements are somewhat more difficult. An indirect method measures the pressure of inert gas over the liquid metal; another uses a sealed pressure transmitter in which a balance of pressure is maintained across a diaphragm. The balancing pressure is measured, and this gives an accurate indication of the liquid-metal pressure.

Piping and Auxiliaries

The need for leak-tightness also affects the piping and vessels, but to a lesser degree. It has led to the development of adequate fabrication and inspection techniques to assure soundness and a high order of leak-tightness. A pipe failure in a modern high-pressure high-temperature power plant is technical news today. And the same design, construction, and inspection methods are generally adequate for liquid-metal systems.

One variation results from the low design pressure of liquid-metal systems and also from the ability of liquid metal to leak through extremely small cracks. The hydrostatic test pressure for a high-pressure power plant will locate practically all flaws that may leak steam. The low design pressure of liquid-metal systems limits the hydrostatic test pressure to a nominal value, and leaks that later may leak liquid metal can go undetected.

A more sensitive low-pressure leak test is therefore desirable, as leaks can usually be repaired more easily and cheaply before than after a system has been filled with liquid metal. Either the helium mass-spectrometer leak tester, used in testing vessels made for vacuum use, or the halogen-type leak detectors now used in locating leaks in refrigerator unit assemblies, is applicable to this service, and liquid-metal piping systems leak-tested by these methods are usually satisfactory. The leaks that are not detected by these

(Continued on page 60)

Visibility

By SYLVESTER K. GUTH

. . . can be evaluated in definite and simple terms; such information is of value to safety and lighting engineers

How visible is visible? Obviously, we can see some things better than others, but how much better? Is visibility determined by the size of the object, its distance away from the observer, the amount of light on it; or, is it all of these factors combined?

For example, when you view this page at normal reading distance, all of the print is visible, regardless of the size of the type. Thus, all the printed matter is above the *threshold* of visibility—the point of being barely seen. You can read the headline on this page from a greater distance, or with a lower level of illumination, than the text matter that you are reading now. In other words, the headline has a higher visibility, or greater suprathreshold visibility, than the text matter because it provides a stronger stimulus for visual perception than the smaller sizes of type.

Some scheme must be available, some scale of measurement developed that can be used to evaluate visibility on a definite numerical basis. True, such a system that expresses visibility must be arbitrary, but aren't units such as the meter, decibel, and degrees Fahrenheit arbitrary items?

Evaluating Visibility

To set up a system, we will assume that all measurements of visibility must be based upon threshold observations, and that unlike objects—regardless of their size or shape—are equal in visibility if they all are at threshold visibility.

To evaluate visibility, it follows that we must find some means for reducing all objects to their threshold condition. This can be done by making the objects smaller, decreasing their contrast with their background, reducing the illumination on them, or by reducing the time they are exposed to view. We can then assume that the relative visibilities of different objects are proportional to the amount of decrease in size, contrast, brightness, or time required to get them to threshold conditions.

Theoretically, we should be able to determine the relative visibility of any object by comparing, for example, its size and contrast with the basic threshold relationships of the four factors just mentioned. This, however, is virtually impossible because most visual tasks and objects are just too complex. We must, therefore, find some means to compare their visibility with standard test objects of equivalent visibility.

Visibility Meter

A simple portable visibility meter that relates the visibility of any object or visual task to a standard object is shown in Fig. 1. It consists essentially of two colorless photographic filters (Fig. 2), with circular gradients in density and diffusion. These filters are rotated in front of the observer's eyes while looking at an object or performing a visual task. The gradient filters reduce the apparent brightness of the visual field and simultaneously lower the contrast between an object and its background. Thus, threshold conditions are obtained, and the visibility of the object can be expressed in terms of one of the fundamental variables of the visual threshold.

The primary scale associated with the Luckiesh-Moss visibility meter (Fig. 1) is correlated with the visibilities of a series of parallel-bar test objects, similar to those in Fig. 3. They vary in size from the smallest that is visible by persons with average normal vision to one that about covers the most sensitive portion of the retina of the eye. Therefore, we see that this arbitrary scale of relative visibility has a rational basis at both ends; but it is no more arbitrary than, say, the scale of a thermometer.

In charge of Lighting Research activities for General Electric's Lamp Division at Nela Park, Cleveland—Mr. Guth developed many of the techniques used in evaluating visibility, contrast sensitivity, and visual acuity. He also devised demonstration materials to illustrate the effectiveness of illumination upon these factors.

The instrument is calibrated in terms of the size of the parallel-bar test object that can just be seen when viewed by observers with normal vision through the circular gradients. Illumination of the test object is 10 foot-candles. Thus, that part of the rotating gradient through which the smallest test object is of threshold visibility is assigned a relative visibility value of *1*. Similarly, that portion of the gradient through which the 2-minute test object can be barely seen is represented by a relative visibility of *2*. This is repeated for the entire range of test objects.

The *1* refers to the fact that the space between the inside of the black bars subtends a visual angle of 1 minute (Fig. 4). To eliminate the factor of viewing distance, a visual angle is used as the variable factor, rather than the physical size of the test objects.

Comparative Visibility

The significance of this scale is readily illustrated by a simple example. Suppose that this printed page with a certain level of illumination is found to have a relative visibility of *6* (*RV=6*) when viewed at the usual reading distance. This means that its visibility under the conditions of measurement is the same as the visibility of the 6-minute parallel-bar test object (Fig. 3). Similarly, another visual task which has a relative visibility of *3* (*RV=3*) is related to the 3-minute test object when the latter is viewed with the conditions of calibration.

It then must be emphasized that the first object (*RV=6*) is not twice as visible as the second object (*RV=3*), any more than 60 F is twice as hot as 30 F. Nevertheless, both scales enable us to make comparisons between different conditions and to assign numerical values to indicate the relative magnitudes on some rational basis.

By this method, various visual tasks can be compared in terms of their respective relative visibilities to determine,

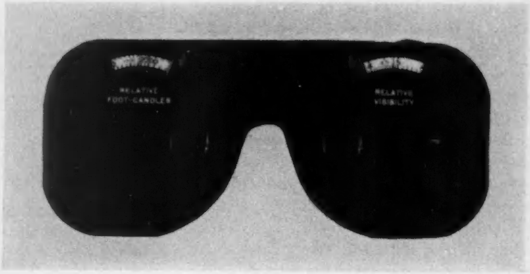


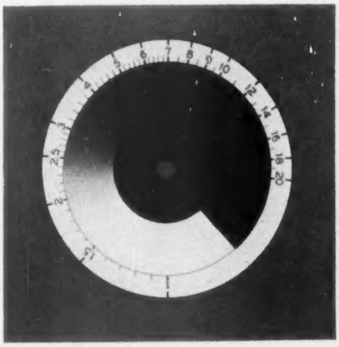
FIG. 1. CHECKING THE VISIBILITY of a photostat *(left)* with the Luckiesh-Moss visibility meter is easily done. Other tasks also shown are slide rule, typewritten copy, steel scale, and telephone directory. With the visibility data obtained it is possible to determine the foot-candles necessary to raise all tasks to the same visibility level. A close-up view of the visibility meter is above. Gradient filters (Fig. 2) are in each eye-piece

for example, how much of a visual safety factor each possesses. Objects and tasks having low visibilities have small factors of safety for quick, accurate, and safe seeing. A safety engineer, for instance, noting such conditions would take steps to improve the visibility in order to obtain better seeing conditions.

Visibility and Illumination

Of the fundamental factors that govern the degree of visibility of objects above the threshold, level of illumination is the most universally controllable. The other factors—size, contrast, and time—generally can be varied only between small limits. To the seeing specialist, therefore, it is important to be able to relate visibility and illumination in such a way that visibility can be used to determine the amount of light necessary to see. Such a relationship has been worked out.

FIG. 2. TWO GRADIENT FILTERS, both identical, are used in the meter; the scale is calibrated with the test objects



A scale of relative foot-candles has been developed to enable the user of the L-M visibility meter to determine the foot-candles required to raise a task to any desirable and obtainable visibility level. This scale of relative foot-candles is based upon the premise that the ratio of the foot-candles for a specific visibility level to the foot-candles for threshold visibility will always be the same regardless of the task. True, the actual foot-candle values for the threshold and the specific visibility level above the threshold are different for various tasks, but the foot-candle ratios are constant. In other words, each visibility level can be specified by a corresponding foot-candle ratio, or relative foot-candle value.

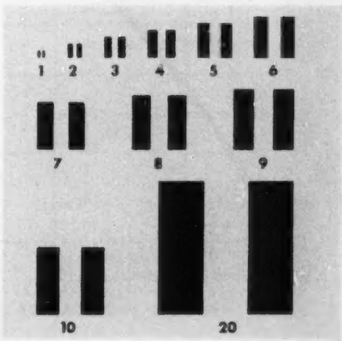
The scale of relative foot-candles is based upon the curve illustrated in Fig. 5. It represents the relationship between visibility level and foot-candle level for well-printed 8-point type when viewed by observers possessing normal vision. The illumination required to be able to barely read this type when viewing it directly without the visibility meter is 0.01 foot-candle. Thus, 0.01 foot-candle is the absolute threshold illumination for this particular visual task.

The inner left-hand scale in Fig. 5 indicates the actual foot-candles required for the various visibility levels. The relative foot-candles with respect to the threshold foot-candle level are indicated by the outer left-hand scale, on which the threshold value has been given a value of unity. Thus, any value above the threshold can be expressed as being a specific multiple of the threshold foot-candle level. For example, the foot-candle level necessary for a visibility level of *3* is 5.9 which corresponds to a relative value of 590. In other words, a suprathreshold visibility level of *3* requires an illumination that is 590 times the threshold illumination.

Alternate Method

An alternate method of expressing suprathreshold foot-candle levels is indicated by the right-hand ordinate in Fig. 5. This scale represents equal logarithmic steps above the threshold foot-candle level, each unit correspond-

FIG. 3. PARALLEL-BAR test objects, similar to the series reproduced below, are used to calibrate the visibility meter



ing to one log-cycle of illumination. Thus, 5.9 foot-candles is equal to 2.77 log-units above the threshold illumination. This may be stated as 10 raised to the 2.77 power, or 590 times the threshold foot-candle level.

The curve you see in Fig. 5 is a universal curve. This curve, and the relative foot-candle scale, applies to any condition, regardless of the size, shape, or contrast of the object. The inner scale on the left-hand side relates *only* to the foot-candle level for 8-point type. You would need a different foot-candle-level scale for different objects.

Scales for converting the scale of visibility of the L-M meter to relative foot-candles and log-units above threshold are shown in Fig. 6.

Using the Visibility Meter

From the foregoing we can see that the visibility meter is a useful instrument for the study of visual tasks and the illumination requirements for those tasks. It is a simple matter to determine the foot-candle level required to obtain a desired visibility level for a given visual task. Conversely, we can determine the new visibility level if a higher

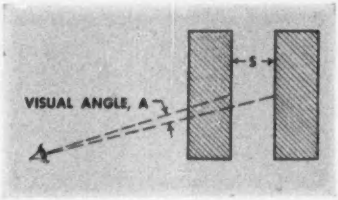


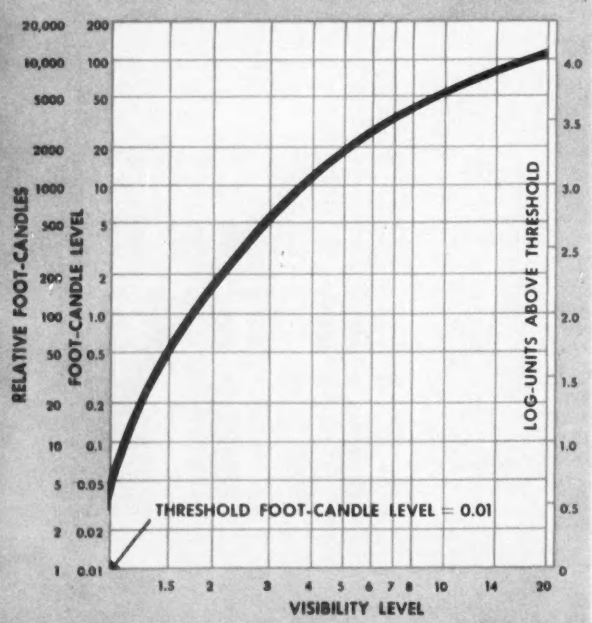
FIG. 4. VISUAL SIZE of the test object is the angle *A* in minutes subtended by width *S* when the line of sight is perpendicular to the plane of the test object

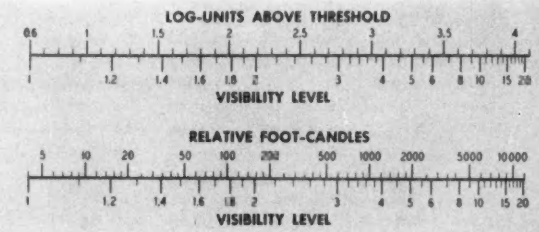
level of illumination is provided. It is necessary to determine only how much an existing foot-candle level is above the threshold, and then compute the factor by which this foot-candle level must be increased to raise the object or task to the desired visibility level above the threshold. For example, suppose that the observed visibility level of a specific task when illuminated with 25 foot-candles is *4*. From Fig. 5 or 6 we find that this visibility level corresponds to a relative foot-candle level of 1210. Now, we want to determine the foot-candle level that will raise the visibility level of the task to *9*, which corresponds to a relative foot-candle level of 5000. The ratio of 5000 to 1210, or 4.13, indicates the factor by which the existing illumination of 25 foot-candles must be multiplied to raise the task to the desired level. Thus, to obtain the desired visibility level of *9* it is necessary to provide $25 \times 4.13 = 103$ foot-candles for this specific task.

Typical Tasks

The Table gives the foot-candle levels required on various visual tasks to raise them several specific visibility levels. The foot-candle levels for visibility levels of *6* and higher were obtained by multiplying the experimentally determined foot-candles required for a visibility level of *4* by ratios obtained from the relative foot-candle scale in Fig. 6, as illustrated by the preceding example. Relationships such as these have been experimentally checked and excellent agreement found between observed and calculated values. Also from the Table you can see that, while some tasks require only moderate levels of illumination for even the higher visibility levels, others require very high foot-candle levels for even the low visibility levels.

FIGS. 5 & 6. RELATIONSHIP between visibility level and foot-candle level for 8-point type is shown below. Values on outer left-hand scale are relative foot-candles above threshold foot-candle level. Right-hand ordinate represents equal logarithmic steps above threshold foot-candle level. Scales for converting visibility levels to relative foot-candles are given in Fig. 6 *(below)*



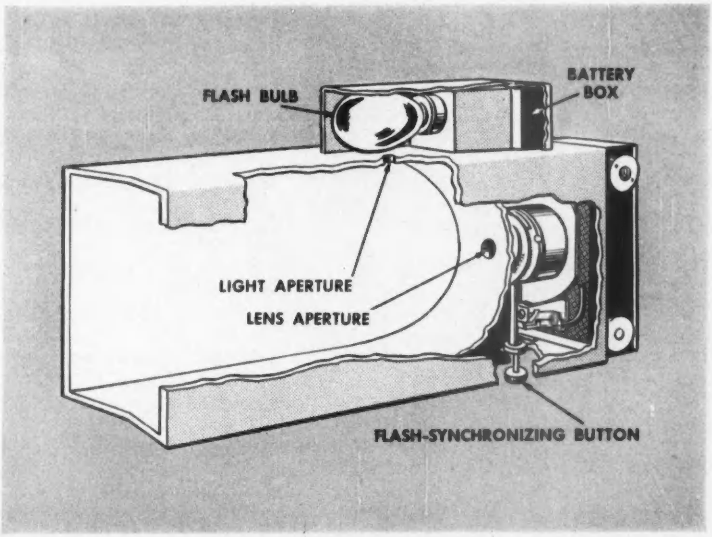


FOOT-CANDLE LEVELS FOR TYPICAL VISUAL TASKS

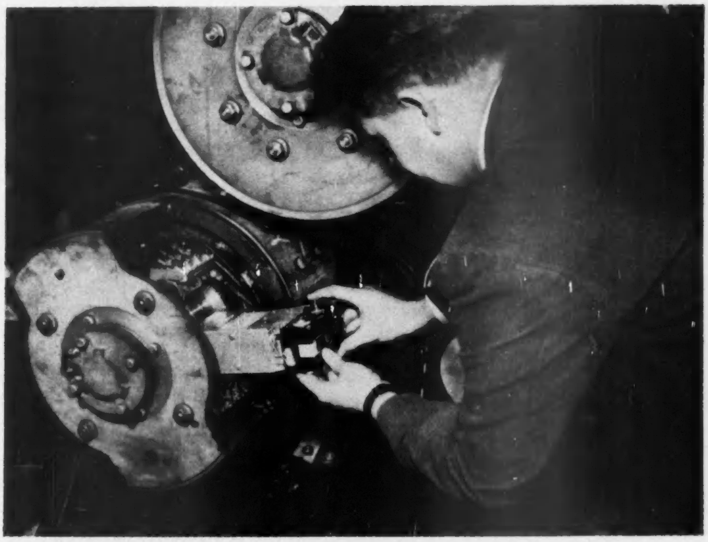
Task	Visibility Level 4	6	9	13	20
Well-printed novel	5	11	20	30	50
Magazine text	14	30	60	90	135
Newspaper text	25	55	100	160	240
Telephone directory	80	175	330	500	770
Typing on white paper	6	13	25	40	60
Mimeographing	10	22	40	65	100
Handwriting in pencil	28	60	115	175	270
Distinguishing black thread on black cloth	525	(More than 1000 foot-candles necessary)			
Micrometer caliper					
with small-area light source	800	(More than 1000 foot-candles necessary)			
with large-area light source	13	29	54	80	125

Diagnosing Commutation Trouble with a Camera

By M. J. BALDWIN and R. A. PETTERSEN



CAMERA to photograph commutators is mounted on the box at the proper focal distance. Interior of the box is painted flat white to help avoid high lights and diffuse the light



PHOTOGRAPHING commutators in the field is no longer a complex job with the modified camera. The unit is small enough to get into difficult places and operation is simple

One of the problems involved in the use of direct-current motors and generators is the deterioration of brushes and commutators. Constant efforts are being made to reduce or simplify the work of maintaining these parts in suitable repair.

Inspection is an essential element in such maintenance work. A trained observer can often tell the probable nature of commutation trouble from the appearance of the commutator.

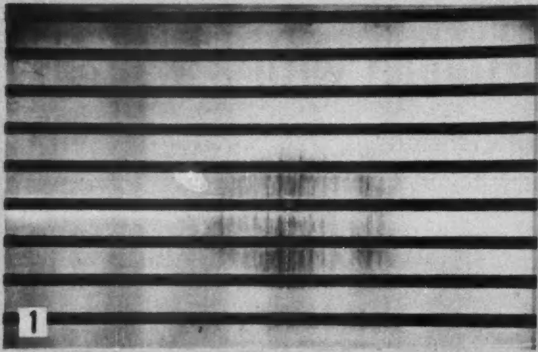
But for economic reasons it is not always possible to have sufficiently well-trained observers stationed at all points where they may be needed. As a result, there has been an increasing need for methods which would enable anyone, no matter how untrained, to report with reasonable accuracy the condition of a commutator—or brushes.

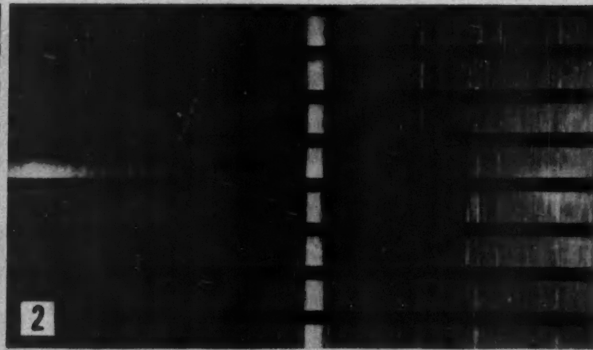
A similar situation exists in the factory. Test runs, to determine the effect on commutation of various factors, such as alternate brush grades, pole-face shapes, or armature pitchings, can rarely be made concurrently and compared directly. And it is usually impossible to make such runs of long duration. Thus accuracy becomes very important in recording the results of such runs.

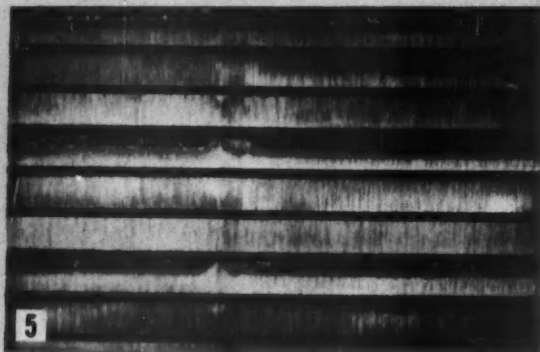
In the past, the best means of making comparisons has depended on the eye and memory of a single observer. Inasmuch as observers change with the passage of time, and human memory is not reliable, a more satisfactory method had to be sought.

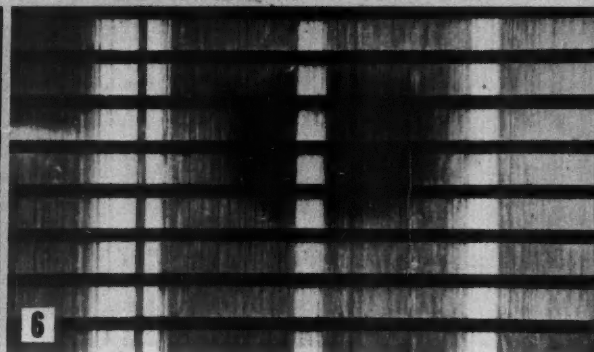
General Electric railway-motor engineers have had considerable success

In General Electric's Locomotive and Car Equipment Department at Erie, Pa., Mr. Baldwin and Mr. Pettersen closely co-operated in photographing traction-motor commutators. Ever since Mr. Baldwin designed the first camera box for this purpose about 12 years ago, he has been actively following and developing this technique. Mr. Pettersen, now a field engineer, makes extensive use of these photographic techniques in his observations of equipment on locomotives in service.









TYPICAL COMMUTATOR CONDITIONS

Fig. 1 shows a commutator which has as yet not had a brush on it nor turned a single revolution. The polish of such commutators is usually dull. This is indicated by the fact that the dark spot in the center, caused by the lens reflection, is barely visible.

Fig. 2 is a used commutator in good condition, with a good polish.

Fig. 3 shows a highly polished commutator with "light threading." In other words, the brush film has caused fine lines around the circumference of the commutator. (When these grooves can be felt with the fingers, it is called "heavy threading.")

Fig. 4 shows a commutator with a dull polish. There is an "appreciable" third-bar color "pattern" (two dark, one light, two dark, one light, etc.). The third bars are also "marked."

Fig. 5 shows a pronounced form of "etching"—that is, the

with a photographic method. They have found that a good photograph tells the story almost at a glance.

Furthermore, typical reference photographs showing a variety of different commutator conditions will help an observer to clearly describe the commutators he inspects.

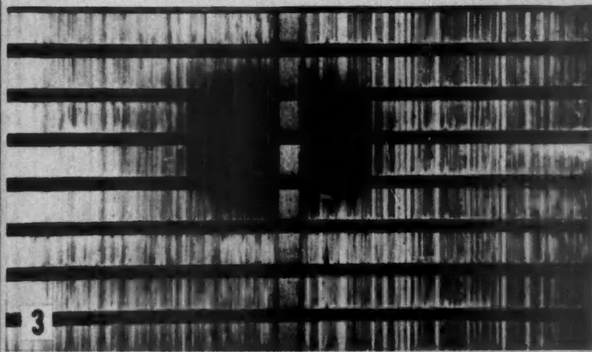
Modified Camera

A simple modified camera was devised for this purpose. (See illustrations preceding page.) With it, photographs can be made of typical commutator conditions, enabling an observer to report his findings in accurate, understandable terms.

In the past, only a skilled photographer has been able to take a suitable commutator picture. The equipment needed to obtain proper light diffusion is cumbersome. Surface high lights, considered desirable in ordinary illustrations, serve only to hide commutator surface conditions. And avoiding them is difficult, because photographing a commutator is like taking a picture of a curved mirror. Other complicating factors include the need to maintain true focal distance, to have uniformity of light control, and to eliminate light from outside sources.

The modified camera overcomes these difficulties. A small box, placed against the commutator, supports the camera at the proper focal distance and excludes outside light. The light source (a No. 5 photoflash bulb) is outside the box. It is so located that the flat inside surfaces of the box are illuminated, but no light shines directly upon the commutator. The focus is laboratory adjusted, and is not subject to alteration in the field. The flash and camera shutter are synchronized. The unit is compact enough to be carried in a small bag or suitcase.

To be able to compare results of commutation tests made under controlled conditions, it is important that the developing and printing of the pictures be done with the same material and in the same manner for each photograph. The same size flash bulb should always be used. Fine-grain film and contrasty printing paper are recommended. Good results have been obtained using Panatomic X film and No. 2 printing paper. The proper techniques can best be worked out by experience.



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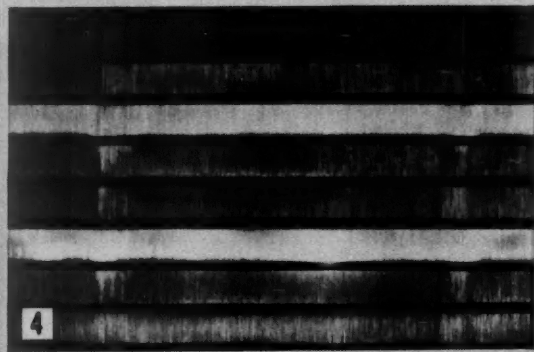


4

7

8

edges of certain bars are burnt. This results in a definite third-bar color pattern.

Fig. 6 is included to indicate what is meant by the term "banding." The film on the commutator is uniform except for bands of irregular width around the circumference, where the brush film has for some reason been removed. If the film is removed for an integral number of full brush widths, the term "tracking" is used; provided there remains an integral number of brush "tracks" which retain film for the full width of each.

"Copper drag" is said to be present when copper projections build out from the trailing bar edges, as shown in Fig. 7. The extent to which the projections bridge the mica slot is expressed as follows: Light copper drag—bar edges feathery; medium copper drag—bridges mica 20 percent or more; heavy copper drag—bridges mica 50 percent or more.

Another use for the commutator camera is illustrated by Fig. 8. This picture records the appearance of the faces of the test brushes after a cyclic run is finished.

Terminology

Space permits reproducing but a few typical pictures here, but currently accepted descriptive terms are used.

The term "pattern" used with some of the illustrations, for example, Fig. 4, indicates uniform repetition. A "noticeable" color pattern is one which can be photographed with the camera box but can usually be seen only with diffused light. When the pattern stands out clearly in any kind of light, it is called "appreciable." If it gets so bad that the darker bars become dull or flat black, it is "pronounced."

Color pattern is a symptom of the film on the commutator surface—or, in extreme cases (flat black bars), with surface pitting of the bars. It should not be confused with "marking." Marking refers to the black, usually somewhat shiny, brush deposit which sometimes appears along the edges of certain bars. Occasionally this marking extends back in decreasing tone from the blackened edge of the marked bar, for a distance of two or three bars.

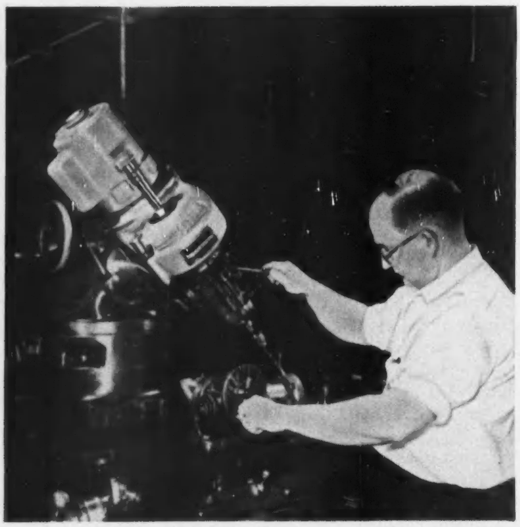
If copper has been removed from the edge of a bar, it is said to be "etched." Very light etching may be detected by comparing bar-edge reflections. The etched edges are easily seen under a bright light. Very slight etching may not always show in a photograph.

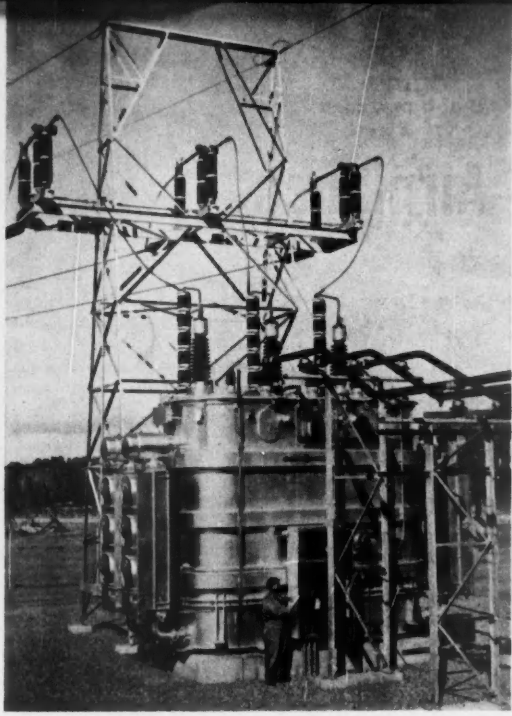
"Selective action" covers the discoloration—or, in extreme cases, the burning off—of the brush shunts. This condition is caused by an unequal distribution of load current between the brushes of the same polarity, or even between wafers of the same duplex brush. It may also cause uneven or streaked commutator film, in which event the commutator appearance is the same as in banding.

"Copper in the brush faces" results from what appears to be electrolytic action. Particles of copper become embedded in the faces of positive generator brushes. The copper may appear as sizeable, individual particles, or it may be almost microscopic, merely causing a coppery hue across the brush face. This condition is normally coincident with banding or tracking, since the copper acts as an abrasive to remove the commutator film.

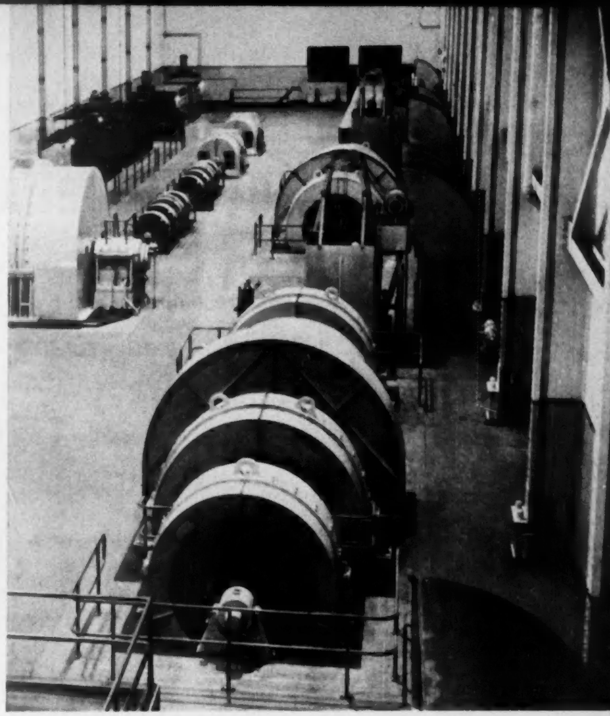
For photographing copper drag, a special box was built to hold the camera at an angle to the commutator surface.


ENGINEERING REPORTS:





POWER TRANSFORMERS now are smaller, lighter, more economical, and better protected because artificial lightning tests have determined just what insulation is needed to protect the windings.



IMPROVED POWER CONTINUITY in industry has resulted from G-E high-voltage engineering. Today, in steel mills like this, both large a-c motors and transformers have proper voltage-surge protection.

AT EQUIPMENT COSTS

G-E engineering reduces size and weight of electric equipment—improves ability to withstand high voltages

Today at General Electric's new laboratory in Pittsfield, Mass., 15,000,000-volt lightning strokes—most powerful ever created by man—are discharged at will under controlled conditions. Here, and in G-E field studies throughout the country, lightning's secrets have been translated into improved designs in electric apparatus of many types, particularly better lightning-protective equipment.

For example, 15 years ago over-insulated power transformers were the rule because designers had to include a large factor of safety against the unknown element, lightning. Today, with exact data on lightning available, and with facilities to lightning-test units, insulation needs can be accurately determined. Result: transformers are smaller and lighter; and with much better protection against voltage surges, costs can be cut as much as $100,000 on a large high-voltage unit.

Many other G-E products—motors and generators, switchgear and control—are smaller, cost less, and perform better as a result of improvements based on G-E high-voltage engineering. And all industry profits from improved power-service continuity brought about by this better-protected equipment.

You can take advantage of this engineering leadership by specifying "G.E." when you purchase apparatus. And on jobs where high-quality system engineering is required, G-E application engineers will draw on this experience in working closely with you and your consultants. Call your G-E Apparatus Sales Division office early in the planning. *General Electric Co., Schenectady 5, N.Y.*

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G-E ENGINEERS J. H. Hagenguth (left) and Dr. K. B. McEachron, manager of Laboratory-Engineering Department, are among General Electric pioneers in high-voltage research.

Put this G-E Engineering to work for you

GENERAL ELECTRIC

Back in 1929 a young G-E engineer wrote down his concept of a new idea . . .

Jet Propelled Airplanes

Here are the highlights of his memorandum, presented to the readers of the REVIEW as an item of historical interest . . .

The following describes what I believe to be a new method of propelling airplanes by means of a jet of combustion gases. By means of this process, it should be possible to propel an airplane at high altitudes at a speed of about 2000 fps (1350 mph), with a high efficiency from the propulsion standpoint and with practically no moving parts in the propulsion equipment excepting the fuel pump. By flying at high speeds at high altitudes (about 80,000 feet), the low landing speed of the plane is preserved at ground level.

This method differs from all previously known and proposed schemes of jet propulsion, so far as the writer knows, in that the air for combustion in the reaction apparatus is all taken from the air through which the plane is moving, and not carried with the plane. The gasoline or oil fuel is all that must be carried with the exception of a relatively small amount of starting fuel and oxygen.—G. B. WARREN, Oct. 6, 1929.

Consider an opening in an air stream followed by an expanding passageway (Fig. 1). If the air stream is moving relative to the opening, or the opening relative to the air stream with a velocity V_1 less than the sound velocity, the air will flow in with V_1 velocity as shown and, because of the shape of the passage, the velocity will be reduced to V_2. The pressure will rise as a result of the conversion of velocity energy into the energy of adiabatic compression, as shown on the curve, and P_2 will be less than $\frac{P_1}{0.53}$. A force will be required to push the pipe thru the air stream and the work done will go into compression and acceleration of the air in the pipe. There will also be a rise in temperature of the air.

Conversely, consider a pipe with a constricted end thru which a stream of air is issuing (Fig. 2). The velocity will change from V_2 to V_3, and the pressure will drop from P_2 to P_3. For efficient operation in this case, P_3 must be greater than 0.53 P_2. There will here be a drop in temperature, and a reactive force will be exerted on the pipe in a direction opposite to that in which the air is flowing.

The simplest form of propulsion device (Fig. 3) is, however, an inefficient form. Consider a chamber, which may be circular in the transverse cross section (Fig. 3), immersed in a stream of moving air, or else moving itself in stationary air. The air will enter at the left with velocity V_1, which must be less than the sound velocity. It will be compressed from P_1T_1 as it passes along the expanding section to P_2T_2. When it reaches the parallel portion, it is mixed with a fuel, ignited, and burned. The products of combustion will increase in temperature to T_3 and will issue from the constricted nozzle at $P_4=P_1$ and at T_4. In this case, if $T_3=4T_2$ (T denotes absolute temperature), then V_4 will be approximately $2V_1$. The force required to push the apparatus thru the air is approximately $\frac{WV_1}{G}$ where W is the pounds of air flowing thru per second, while the reaction of the rear jet is $\frac{(W+w)\ V_4}{G}$ where w is the pounds of fuel burned per second. The net reaction is then

$$R=\left[\frac{(W+w)V_4}{G}-\frac{WV_1}{G}\right]$$

and the work done per second is RV_1.

Since this is an internal combustion engine cycle, the efficiency is dependent upon the compression ratio; and so, since $\frac{P_2}{P_1}$ is small, the efficiency will be low. Thus at velocities of 400 fps, or approximately 275 mph, a propulsion force of 2500 pounds could be obtained from such a device with a 3-foot diameter inlet and a 4¼-foot outlet diameter, but the efficiency would be but ¾ percent, and the fuel consumption would be enormous.

At 900 fps efficiency would be roughly 4 percent.

To control such a device—that is, to obtain varying degrees of propulsive force—it is necessary to control only the amount of fuel fed in. This is, however, an inefficient means of operation at any load other than the designed condition, since the temperature rise during combustion should have a definite relationship to the inlet and outlet area ratios. In order to overcome this difficulty, an arrangement might be used in which a tapered conical plug can be moved into or out of the discharge nozzle, simultaneously with a change in the fuel supply (Fig. 4). Such an arrangement should permit rather wide variations in the propulsive force similar to the action of the throttle on the usual engine.

Operation Beyond Sound Velocity

Consider a convergent-divergent passageway (Fig. 5), in which the relative velocity is above that of sound in air. The air upon entrance will first undergo a compression from P_1 to P_m in the throat, and the velocity at the throat will be the sound velocity. From the throat to the parallel passageway, the air will undergo a further compression of about 2 to 1. The temperature will rise.

Similarly, but in the reverse direction, Fig. 6 shows the action of a convergent-divergent nozzle, in which the final velocity V_2 is beyond the sound velocity.

In both of these cases $P_1 < 0.53\ P_2$.

If now these two elements are combined into a propulsion equipment (Fig. 7) and, if the whole is moved thru the air at high velocity (1500 to 2500 fps), the device will, when fuel is fed in and burned, act so as to produce a force in the direction of motion by the excess of the reaction of the issuing jet

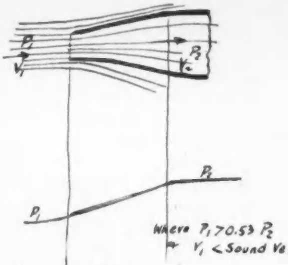

Fig. 1

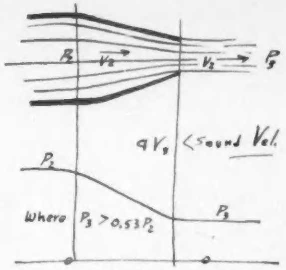

Fig 2

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7/28/29

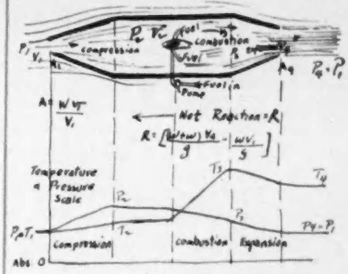

Fig 3 Jet Propulsion Apparatus
Case I (V_1 < Sound Vel.)

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7/29/29

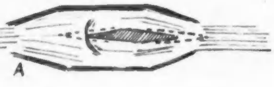

Fig. 4

Device for Controlling
Exit Area and
Hence Reaction Force

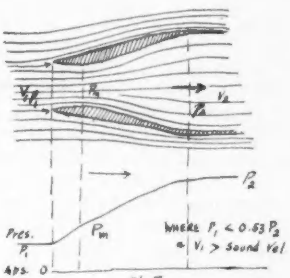

Fig 5
Compression

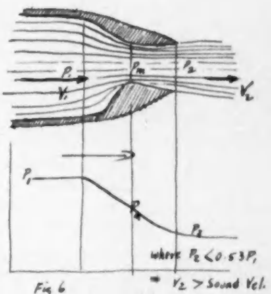

Fig 6
Expansion

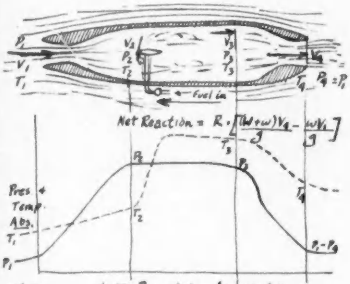

Fig. 7 Jet Propulsion Apparatus
Case II (V_1 > Sound Vel)

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8/3/29

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8/3/29

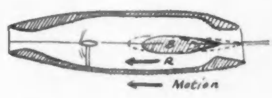


Fig 8 -

Device for Controlling
Exit Area And
Hence Reactive Force

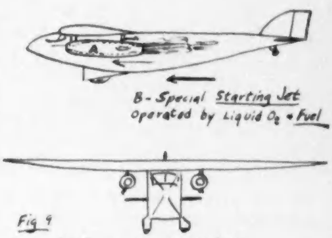


Fig 9

Airplane With Dual Jet
Propulsion Apparatus

g. B. Warren
8/3/29

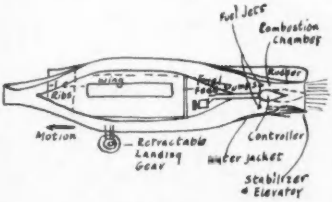


Fig 10
Jet Propelled Air Plane
In Built Propulsion System

g. B. Warren
Jan 21, 1929

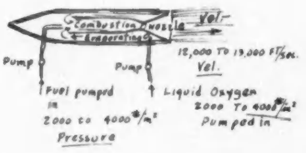
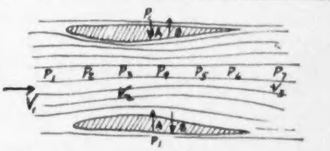


Fig 11 - Starting Jet

Operated by Liquid O_2 + Fuel,
Capable of developing thrust
of about 3000# with nozzle
Throat Dia. of about 1" -

g. B. Warren
8/3/29



Case I V_1 < Sound Vel.
Then $P_1 > P_2$, or P_3, or P_4, or P_5, or $P_6 < P_7$
& $V_2 > V_1$
& Lift is as A-A

Case II V_1 > Sound Vel.
Then $P_1 < P_2$, or P_3, or P_4, or P_5, or $P_6 > P_7$
& $V_2 < V_1$
& Lift is as B-B

Theory as to Direction of Lift Above Sound or Acoustic Vel.

Fig 12

over that of the force required to push the front end thru the air.

That it is not a "bootstrap" proposition can be seen by an analysis of the pressures throughout the inner surfaces of the chamber, and it can easily be seen that there is an excess of pressure on the projected inner walls, tending to push the chamber in the direction of motion once it is set in motion by external means.

The control of the propulsion force of such a device could be obtained by a variable plug B (Fig. 8), as described before.

These propulsion devices could be mounted on an airplane (Fig. 9), or the body of the plane could be used as part of the propulsion device (Fig. 10).

The combustion end of the combustion chamber and the nozzle could be cooled by water jacketing or by fins.

The starting of a plane of this type could be accomplished quite simply by a starting jet or rocket built as shown (Fig. 11) and utilizing liquid 0_2 and fuel oil or gasoline pumped into the device under from 1000 to 4000 psi pressure. The evaporation of the liquid 0_2 would probably keep the inner walls sufficiently cool; but if not, since they stand no pressure difference, they could be made of some material such as fused quartz. Such a device could be made to produce very high propulsion forces.

Velocity Effect on tha Human Body

It might be thought that the attaining of such high velocities as 1350 mph would be injurious to people in the machine. Such would not be the case, since it is only acceleration or change of velocity which one is able to detect. A modern pursuit plane gets off from a standing start to 60 mph in 5 seconds, or an acceleration rate of 12 mph. Such a rate of acceleration if continued for 180 seconds or 3 minutes would produce the desired speed.

The cabins could be tight but ventilated and supercharged, and no discomfort would be experienced. The velocity thru the air would probably heat the walls sufficiently (to probably 700 F absolute or 240 F temperature) so that no further heating would be necessary in the cabin. The problem will be to keep the cabin sufficiently cool despite the −60 F outside.

Starting

A rough calculation indicates that about 1200 pounds of liquid 0_2 would be required to start and accelerate such a 10,000-pound plane to 1500 fps. The power of the propulsion devices should then be sufficient to do the rest. This would interpose but little hardship in taking off due to the tremendous power made available by the starting jets—the equivalent of more than 30,000 hp.

It is quite probable that much more of this acceleration could be made on the main propulsion devices although at low fuel efficiency. A calculation would have to be made to determine whether the net efficiency would be better than with the oxygen.

For low speed (100 mph) near ground flying prior to landing, the regular propulsion equipment should function but at very much reduced efficiency.

Aerodynamics of Such High Speeds

The real problem is going to be in the aerodynamics of the airplane at these speeds—that is, above the velocity of sound. So far as the writer knows, there is little if any data relative to this factor. It is a well-known fact that near the velocity of sound the efficiency of an aerofoil drops quite low. It is the writer's opinion, based on theory alone and unsupported as yet with tests, that at speeds appreciably above the velocity of sound the lift and efficiency of an aerofoil is again good, but that the lift is in a direction opposite to that at velocities below the velocity of sound.

This theory is based upon the following reasoning: Fig. 12 shows two aerofoils, at a rather small distance apart. If the air is flowing between them, it is speeded up as it passes the constricted portion and, in accordance with the law of the conservation of energy and of compressible fluid flow, the pressure is reduced. Consequently, the two aerofoils tend to be forced together. The "lift" is in the direction of arrows *A-A*.

On the other hand, if velocity V_1 is above the sound velocity, according to the same laws of compressible fluid flow, it cannot pass the constricted portion unless its pressure is increased and the velocity reduced. Pressures from P_2 to P_6 will accordingly be higher than P_1 and P_7 and the aerofoils will be forced apart; in other words, the "lift" will be in the direction of the arrows *B-B*.

In order to take off and land with an aerofoil of the proper shape for low velocities and fly with an aerofoil of the proper shape for high speed (beyond sound velocity), it will be necessary to either turn the *entire plane upside down* or build a variable chamber or slotted-wing structure. Either should be practicable.

Many things are unknown and as yet unworked out as to the resistance of the fuselage and other parts, at these speeds. If these resistances obey the "square law," they will not be any more serious than at present, due to the law of density; but if they go with the velocity at a greater rate than this, then these resistances may become a serious factor.

It seems to the writer that this method of propulsion offers sufficient attractive features to make it worth serious consideration by interested parties. Travel at such speed may not be as far off as is sometimes thought.

Today, Glenn B. Warren is General Manager of General Electric's Turbine Division. After reading over his ideas of 23 years ago, Mr. Warren commented, "Although I have always been very much interested in the fact that I apparently thought as early as I did of the mechanism which is now generally called the 'ramjet,' I have been very chagrined at myself that, with all of my turbine and gas turbine background, I did not conceive at that time of the application of a compressor and turbine to this device which greatly increases its efficiency, and makes it a practical machine for propulsion at 400 to 700 mph, as is now done by the turbojet."

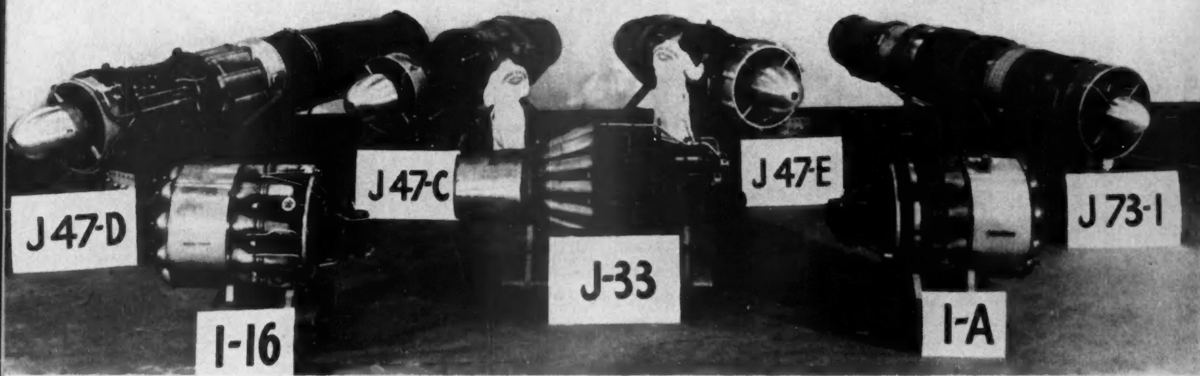
In a Closely Guarded Area . . .

. . . of General Electric's River Works at Lynn, Mass., an awkward-looking object about the size of an office desk roared and shuddered on a test stand. The date was March 18, 1942; the event was the successful operation of America's first jet engine. Six months later the nation's first jet plane made its initial flight.

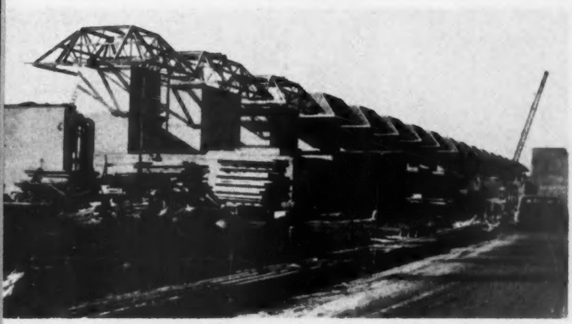
On March 18, 1952, General Electric dedicated its new jet center at Lockland, Ohio, north of Cincinnati. Covering nearly four million square feet of floor space, it is the most complete facility of this type in the nation.

On the opposite page are scenes from the new jet center; on pages 38 and 39 are pictures of GE's contributions to the development of the jet engine. Starting at the top of the next page is the story of . . .

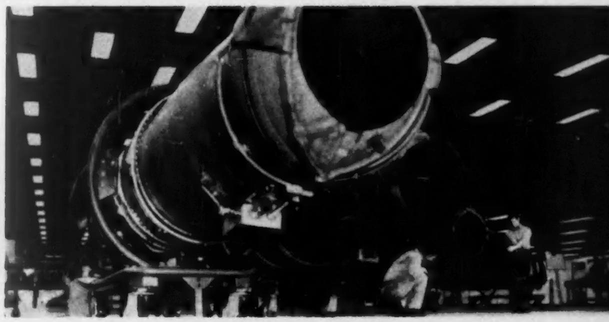
The Fastest 10 Years in History



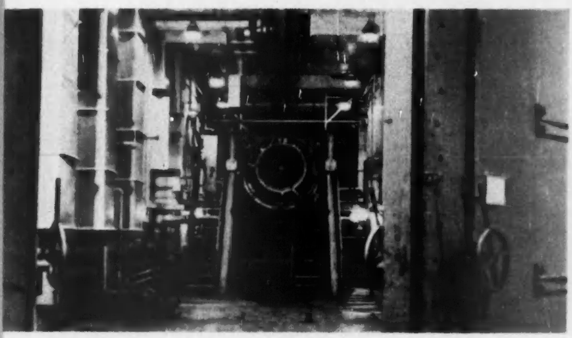
FAMILY PORTRAIT shows General Electric turbojet engines from the early I-A, first jet engine to be run in America, through the J-73, latest of the series. Thrust has increased from the 1300 pounds of the I-A to several times that figure in the new engines. Units with centrifugal compressors were the I-A, I-16, and J-33, produced in that order. They were followed by axial-flow compressor designs which led to the J-47 series. The J-47D has an "afterburner" for added thrust. It is used on the F-86D



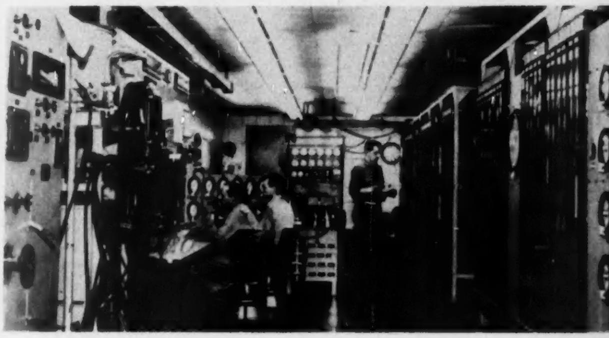
TEST CELLS at Lockland are a major part of the facility. Modern test cells are needed to help muzzle the blast of turbojets with . . .



"AFTERBURNERS." Raw fuel is fed into the extended section of the tailpipe where it burns to give added thrust for faster climb

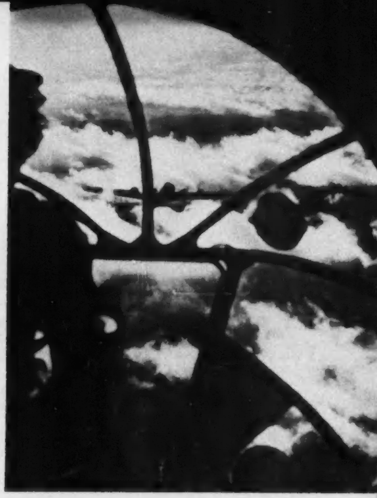


TESTING a turbojet is a complex process, but the modern test cells at Lockland help speed the process. Readings are centered in the . . .



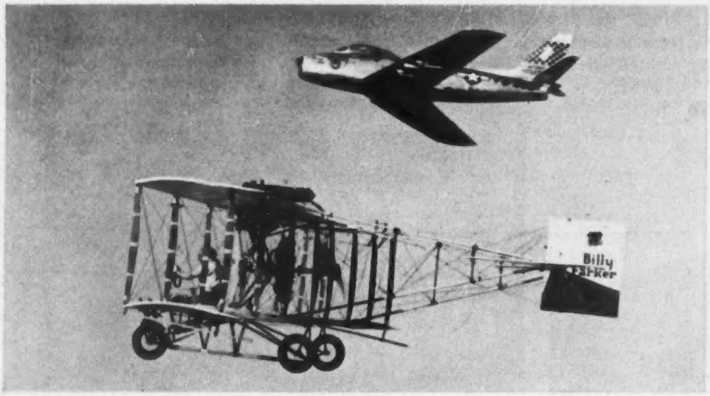
CONTROL ROOM. From this air-conditioned operation center, engineers observe the performance of turbojet engines on test

The Fastest 10 Years in History *(Continued)*



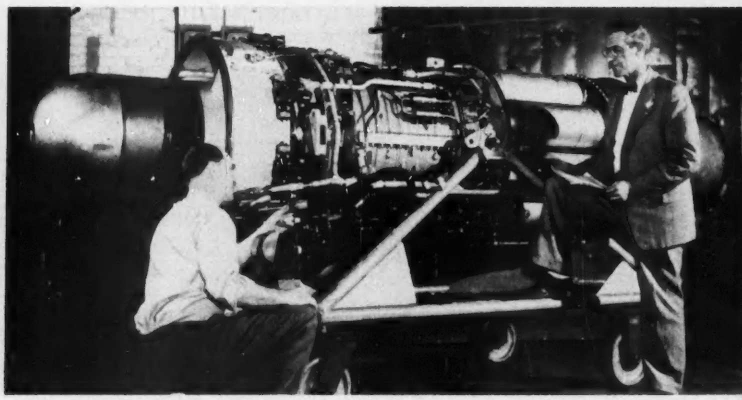
1 Turbosuperchargers aided development of the jet engine by giving engineers background on the behavior of metals at high temperatures. G-E unit *(arrow)* helped get this biplane to 40,800 feet in 1921. During World War II . . .

2 Bombers and fighters were given an extra lift with turbosuperchargers for high-level bombing



5 Production J-47 turbojets are used in the F-86 *Sabrejet* series of fighters built by North American. It is more than 11 times as fast as the 1912 model pusher

6 Testing can take place on the ground, but flight-test laboratories,



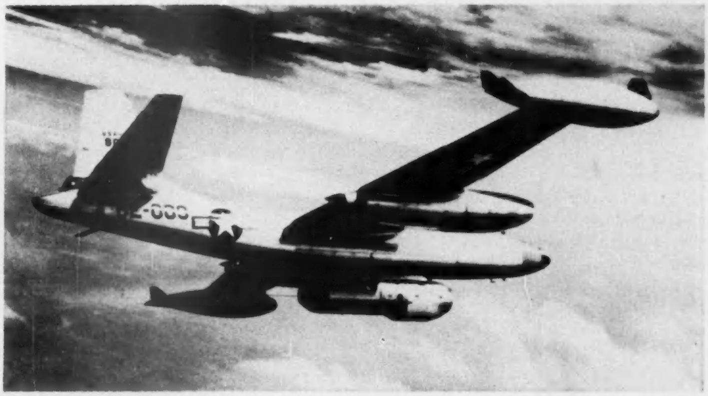
8 Accessories below nose increases air intake area on this turbojet

9 Advanced model, the J-47-GE-27, has a thrust rating in excess of 5800 pounds, about 10 percent more than engine used in F-86 *Sabrejets* now in combat

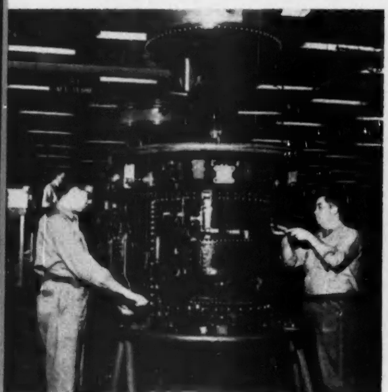
3 Late in 1942, the first American jet-propelled plane—the Bell P-59 Airacomet —was flown with G-E turbojets. It was the forerunner of many jet aircraft including the Lockheed P-80, Republic F-84 and XF-91, Martin XB-51, and the . . .

4 Boeing B-47 Stratojet bomber seen here reaching for altitude with six jet engines and full rocket boost

such as GE's at Schenectady, contribute further knowledge. A new addition is . . .



7 The nation's first jet-propelled laboratory—a four-jet North American B-45 with a test turbojet in a specially designed nacelle under the bomb bay



10 Vertical assembly is more efficient than horizontal method

11 Security restrictions don't hamper "*Jet*" from overseeing all activities

12 Reusable shipping containers will float even with turbojet inside

Good Engineer—but Good Citizen, Too

By L. R. BOULWARE

How to be the truly good engineer—that's the question every ambitious or even conscientious engineer must ask himself continuously.

Engineers formerly considered themselves good when they did good engineering.

Engineers now tell me they are suddenly discovering that this good engineering—no matter how superbly good—is not, of itself, good enough.

There is a still larger duty to perform—beginning *now*—despite engineers already being overburdened with the superimposed defense program.

Some of this extra duty springs from the typical engineer's natural ability, as further implemented by education and experience. This combination puts him in a position of wide influence and opportunity. It imposes upon him—as a leader and a free citizen—an obligation to the public commensurate with his opportunity. Moreover, it imposes on him—as an engineer and a participant privileged way above the average—a selfish obligation to himself, his family, and his fellow workers in the upper ranges of the professions.

Still more of this further duty arises from the engineer's own good work—along with its good economic and social consequences—having been misjudged, misrepresented, and at times even resisted as something bad. This might be considered retributive justice; but only if the engineer fails to become competent, vocal, and effective in helping to have his work understood and properly valued in relationship to the work of all of us other 65 million specialists of the country's work force, who want our services and rewards to fit in with the desires and balanced best interests of free customers, free workers, free suppliers, free riskers of their savings, free tax collectors, and the whole free public.

Over the past century, the engineer has led the way in opening vast new areas of material well-being.

Free individuals voluntarily saved by foregoing current consumption in the hope of future profits; then they invested the resulting savings in backing the engineers' plans for better materials, designs, equipment, methods, and other facilities.

These savers also backed the market research, sales, and advertising investment required for the mass distribution that made mass production possible with its high-pay, low-cost, and low-price benefits, and with still the possibility of a profit.

The engineer lived a life of growing and thrilling accomplishment—but with a new and expanded demand for still further creativeness promptly superimposed on each successive triumph.

This load of duty almost inevitably pushed him into specialization and more and more out of contact with the full range of the other specialists in and out of engineering, business, and the economy as a whole.

This was a temptation hard for the engineer in particular to resist. At a time when things outside were becoming more indefinite and confusing, there were rapidly expanding areas of definite knowledge and accepted accuracy to supply ever greater attraction and more positive rewards within engineering.

But, in the process, the engineer's good work was making specialists of us all. Each new development in materials, machines, or methods seemed to result in a further subdivision of operations. So—like the engineer—the salesman, the superintendent, the accountant, the office employee, the hourly worker in the factory, and even the manager, as well as most other members of the public, all more and more became specialists.

The more we approached being "single-purpose" people to match our single-purpose machines—that is, the more we did just one operation on one bolt instead of making the whole automobile—then, the more dependent we became on a growing host of other similar interdependent specialists, whom we could meet in the free market in the exchange of a very little of the products of our own narrow specialization, thus accumulating from all the whole of what we each individually wanted, in return for our highly specialized day's work.

Unfortunately for all of us—engineers included—our growing competency as to our individual specialties has not been matched by a similar growth in our understanding of, or competency to deal with, the over-all complications which our expanding and ever more delicate interdependence has been bringing to the free market.

We are late, and sadly, coming to realize that we have to work at being free just as we have got to work at producing goods. Freedom does not come free. It has to be nurtured, defended, and paid for—earned with physical, mental, and moral sweat.

If we are to be permitted to go around free and do largely as we please—at work, at the grocery, at play, on the road, in church, in school, in the voter's booth, at meetings, on television or soapbox—we have got to know what is the *right* thing to do in the balanced best interests of all, must be not only willing but also determined to do that right thing *voluntarily*, and then must actually *do* it whether a policeman or other agency of physical or moral force is watching.

If we are to continue largely free, a safe majority of us 65 million interdependent specialists have simply got to face the tedious job of learning what we do for each other, what the specialized part we each play is worth to the other fellow and why, and what we each can do to deserve and get more of what we want, and still have our in-

Mr. Boulware is a man of broad experience in the fields of finance, purchasing, manufacturing, sales, and administration. After his resignation as Operations Vice Chairman of the War Production Board, General Electric's former President Charles E. Wilson persuaded him to join the Company. He is now Vice President—Employee and Plant Community Relations.

dividual take viewed as fair and fully warranted by all concerned.

Engineers are desperately needed in the forefront of this campaign. Because of their ability, education, and experience, they are in a preferred position to help guide others. They are fortunately in a spot where their patriotic duty also matches their immediate selfish ends.

Engineers—like management and all the rest of us who can teach and lead—need to acquire for themselves and then start helping others to get economic education, moral reawakening, and political maturity.

We must stop leaving to others the economic and political explanation and interpretation of our business and of the free system of incentives and competition within which ours and other business produces and distributes its gains for the public through the free person and free market process.

The study and teaching of economics at all levels will help our associates and neighbors know where jobs come from, how we all work for each other, how savings do "work" just as minds and muscles do, how to keep jobs steady, how to earn more money that is real money, how to raise our level of living, and how to obtain security for old age.

For instance, on the question of productivity, which has been so much before us for the past year, economics will teach us the relationship and manner of participation of the various product-output-improvement factors; such as volume and other customer influences on product variations and mix; improved designs and material substitutions; expanded and bettered capital facilities; quality of raw materials and proportion of outside purchases of goods and services; improved methods and practices of management; and more skill, care, effort, and hours applied to employee performance.

Moral reawakening will bring the realization not only that we can't get something for nothing but that, in a country like this, we ought to be ashamed to be caught even thinking of trying by force or otherwise to get something for nothing. We ought to realize we must stop dividing ourselves up into "pressure blocks"—big blocks, little blocks, or individuals trying to act like blocks—and start recognizing that the only worthy as well as truly expedient way to act is for each to try freely to do his part in return for the rewards our free and informed fellow specialists will offer willingly for what's done for them.

That's a big order—to attain a knowledge of economics and concept of morals that will provide the inner compulsion for enough of us to do right voluntarily in a free market. But, unless we work diligently toward that end, there will be no free markets and no free persons—and, what's more, no free engineers.

So—as engineers and other leaders—let's not only do our individual parts toward such an attainment in economics and morals, but also our individual parts in advancing political maturity to the point that we will be proof against being diverted by the demagogues from the sound and honorable paths that lead to progress.

Then, such engineers not only will be as good at *engineering* as before, but they will be equally applauded for the *good citizenship* they have attained and are practising in their own and the public interest.

"We must stop leaving to others the economic and political interpretation of our business and of the free system of incentives and competition within which business produces and distributes"

18 to 6—A Story of Color TV

By DR. L. T. DEVORE

For the greater part of the 25 years that General Electric has been in the television field, electronic engineers and scientists have known practical ways to transmit a color TV picture. But the *best* way of adding color to TV has not yet been found.

Many color TV systems have been proposed and worked on during the past few years by various organizations and companies. One of these systems was selected by the Federal Communications Commission (FCC) to be the standard for color TV transmission in the nation; the furor that resulted is familiar to all.

Many engineers and scientists felt that the chosen system was inadequate, primarily because it was incompatible—the owners of the nearly 16 million black-and-white sets in America would be required to substantially modify their sets before they could see, even in black-and-white, a color telecast by this system.

Following the FCC's decision, the various members of the television industry that make up the National Television System Committee (NTSC) again met to consider systems that would be compatible. Another purpose of the meeting was to attempt to prepare and submit to the FCC proposed new standards for a compatible system.

NTSC members weighed the advantages and disadvantages of the various systems that were available. Finally, the best features of many systems were brought together to form the basis for proposed new standards for a color TV system that is not only strictly compatible, but that also seems to operate best within existing bandwidth limitations.

Bandwidth a Problem

The principal hurdle in any television system—color or black-and-white—is bandwidth. There is only so much space available in the frequency spectrum. And in that space there must be room for satisfactory operation of television stations, police and aircraft communication systems, military electronic systems, and myriad other "competing" devices.

The amount of bandwidth is important because it determines how much detail you see in the picture on the television set in your home—a good TV picture takes a lot of bandwidth. For black-and-white transmission, the FCC decided that a bandwidth of 6 megacycles was the best compromise between the public's demand for a sharp picture and rival demands for space in the frequency spectrum.

The full blossoming of interest in color television almost tripled the bandwidth headaches. For, until a few years ago almost everyone thought that because a color picture requires three quantities—such as the brightness of the three primary colors—to be given for each point of the picture, a bandwidth of 18 megacycles would be needed for a color picture to have the same sharpness as present black-and-white pictures.

This meant one of two things: that only one-third as many television stations could operate as was originally thought, or that some of the other services would have to give up their badly needed space to make room for color TV.

But the transmission of television signals as such had been allocated to a relatively few bands in the frequency spectrum, and the idea of any color system, forgetting compatibility and everything else, that used more than the present allowable bandwidth was just out of the question. All information—color or otherwise—had to be confined within the 6-megacycle limit.

Compatibility was another critical factor. An ideal color system must have complete compatibility. That is, it must not only provide a top-quality color picture on color TV sets, but also produce a high-grade black-and-white picture on existing black-and-white sets. The latter should be possible without any changes in the sets. Likewise, the color receiver tuned to a black-and-white transmission must be able to pick up a satisfactory black-and-white picture. When you fulfill these conditions, you have complete compatibility.

The story of how a reasonably good—and strictly compatible—color picture could be squeezed into the 6-megacycle space normally used for black-and-white transmission is a story of progress that involved, among other things, learning more about the physiology of color. Also, the story is closely tied to various systems that were proposed to give the best possible results to the viewing public.

Engineers in General Electric's Electronics Division at Syracuse, NY, including Robert B. Dome and Walter Hausz, developed a number of ideas that were considered by the National Television System Committee. Three of these ideas were demonstrated before an NTSC subcommittee during February 1951; they bore the somewhat cryptic names *frequency-interlace* system, *alternating-highs* system, and *alternating-lows* system. In each system the best way was being sought to squeeze color information into the 6-megacycle limit with the least damage to picture detail or to the black-and-white picture.

Frequency-interlace System

For many years it has been known that in conventional television transmissions a part of the available bandwidth is not being used. The reason is that various frequencies of the signal bunch themselves around harmonics of the frequency that form the lines on a TV screen. In between these bunches there is nothing; the result is that a part of the available bandwidth is wasted.

Knowing this, it was suggested that color signals might be sandwiched between the harmonics of the line frequency without objectionable or observable interference. By putting this additional color information within the

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Manager of the Electronics Laboratory at Electronics Park, Syracuse, since 1950, Dr. DeVore is one of this year's recipients of the IRE Fellow Award. He also holds the War Department Exceptional Civilian Service Medal.

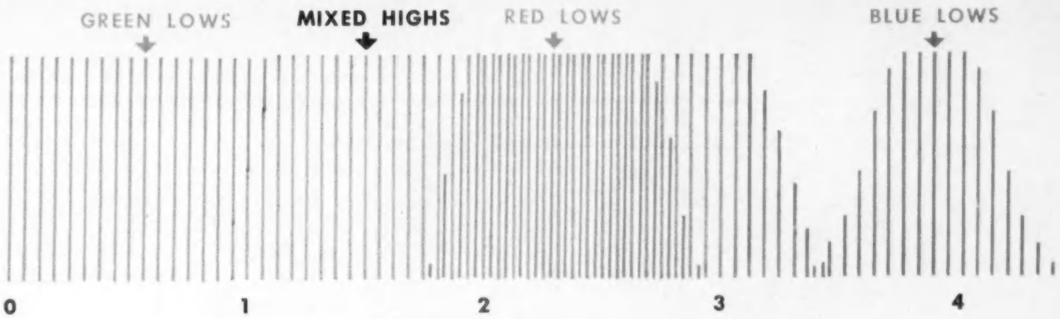


FIG. 1. UTILIZATION OF SPECTRUM SPACE in the frequency-interlace color TV system is shown. High-frequency components of all three color signals are combined and transmitted as mixed highs over a relatively wide frequency band

present 6-megacycle bandwidth, it should be possible to keep the total bandwidth requirements within the FCC limits.

Other ideas followed in the development of the frequency-interlace system. For instance, from the work of previous researchers in the field, it was known that additional band space could be saved if the high-frequency components of all three color signals were combined and transmitted as *mixed highs* over a relatively wide frequency band. At the same time, the low-frequency parts of the three colors could be sent separately over much narrower bands (Fig. 1) well within the FCC's 6-megacycle limitation.

In this system the picture is formed in a way that is similar to an artist drawing a colored comic strip. The mixed highs give the sharp outline of the picture—like the artist's pen outline of his scene. Next, the lows are transmitted and act to color in the areas that the mixed highs have outlined, much as an artist would brush in colors to fill in his pen outline.

Fooling the Eye

The psychological information about what the eye demands in a good color TV picture was becoming more and more evident as color development went along.

The eye can be fooled in a number of ways. It doesn't demand as much detail in regard to changes in color as it does for changes in brightness. For instance, the eye is sensitive to green detail, because the green detail is bright. Red requires about half as much detail, and blue takes a very small amount. These facts were used in dividing the total available bandwidth among the three colors. In the frequency-interlace system it was found necessary to use a very small bandwidth for blue and a somewhat larger bandwidth for red. This factor further helped to reduce the total over-all bandwidth by giving each color just the width it required, and no more.

During the demonstration of the frequency-interlace system in February, 1951, the following scheme was used: The green signal (low frequencies only) and the mixed highs of all three colors were directly impressed on the main carrier. The low-frequency components of the red and blue modulated (caused to vary) two separate carriers, called "subcarriers," that were sandwiched halfway between two high harmonics of the line frequency. As Fig. 1 shows, the band allocated to mixed highs completely overlapped the low-frequency red band.

This system has several advantages and some disadvantages. Compared with similar schemes that used only one subcarrier for several signals, it has an advantage in that it requires no phase synchronization between transmitter and receiver. On the negative side, there is a danger of interference between the two subcarriers, and consequently of beat frequencies between them.

In all of these developmental systems certain things had to be given up. It

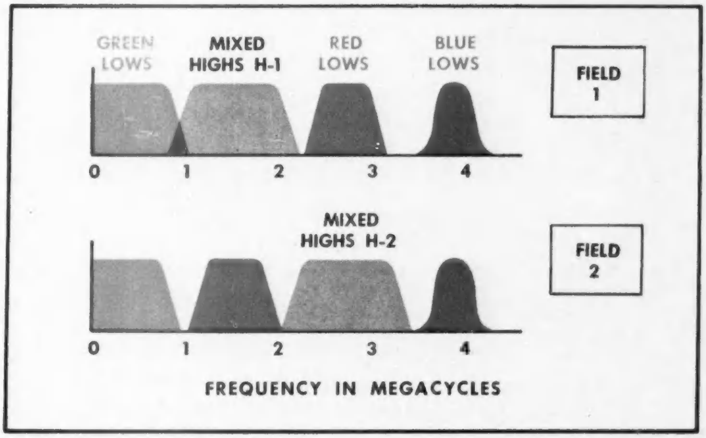
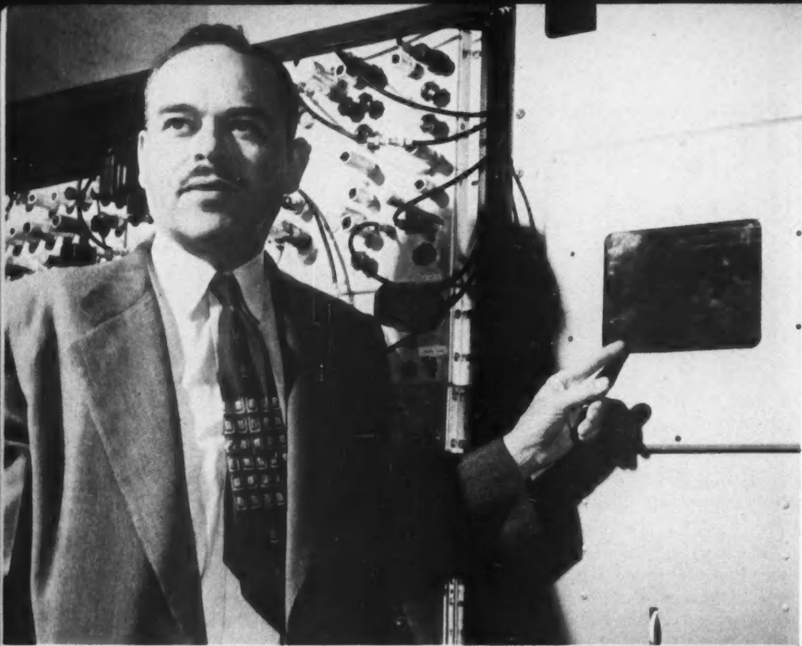
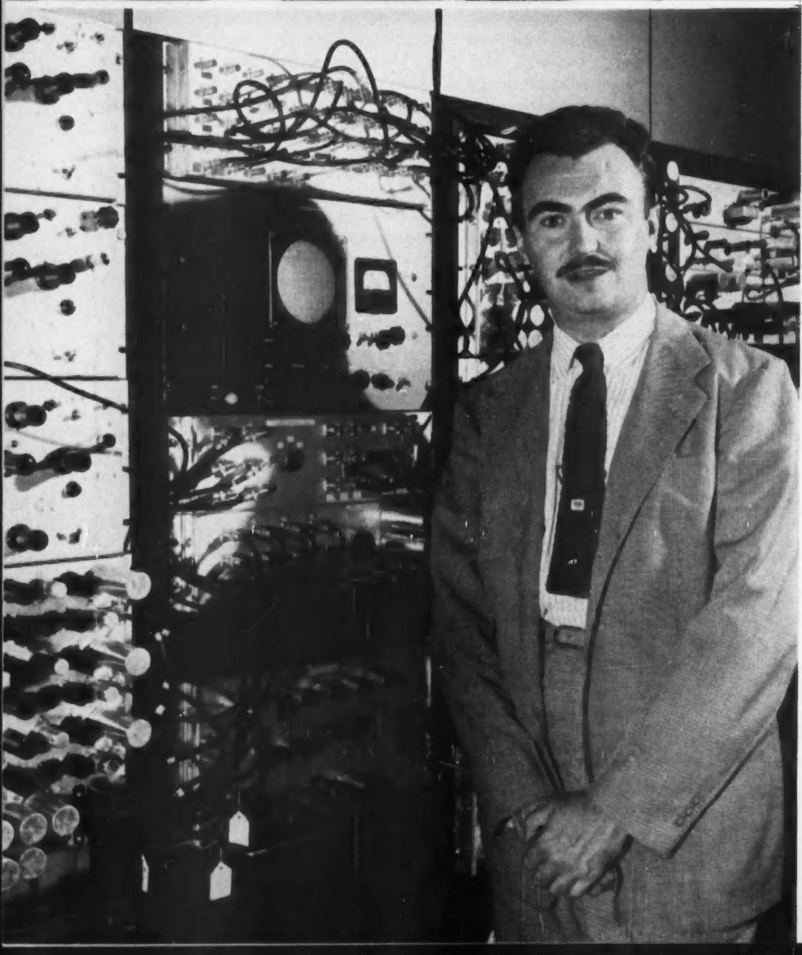


FIG. 2. MIXED HIGHS are split into two parts in the alternating-highs color TV system. H-1 represents the lower-frequency part, while H-2 is the higher-frequency part





was up to the engineer to decide what things could be omitted without sacrificing picture quality or getting into further difficulties. This "give and take," this constant juggling of factors, led from one development to another.

As has been related, the thought behind frequency-interlace was that, because part of the available bandwidth was not being used, perhaps color information could be squeezed into the vacant space. The system was tried to see what would happen. In addition to the disadvantages mentioned before, an objectionable dot pattern, much like a halftone engraving in a newspaper, appeared in the picture. This wasn't regarded as too much of a drawback. The thought was, "Let's try some other variation and see what will happen." Further development not only got rid of the dots but led to the . . .

Alternating-highs System

To clear up the dots, one of our engineers developed the alternating-highs system. In the frequency-interlace system, the mixed highs completely overlap the red lows (Fig. 1), as has already been described. In the alternating-highs system, the mixed highs are split into two parts that we can designate as H-1 and H-2. H-1 represents the lower-frequency part of the mixed highs, while H-2 is the higher-frequency part. H-1 and H-2 are alternately transmitted next to—but not overlapping—the red lows, and are located in such a way that all the necessary high-frequency information for a complete picture is furnished in a cycle consisting of two fields (Fig. 2). A "field" is the area covered during one vertical sweep of the scene by the scanning element.

The bands H-1 and H-2 also might be characterized as giving, respectively, fine detail and very fine detail, to the picture. In the development of the alternating-highs system, experiments were carried out to see if it was necessary to retain all the fine detail and the very fine detail. If some detail could be left out, bandwidth could be saved.

All this was based on fooling the eye. Because of the persistence of vision, the human eye doesn't have to see anything more often than about 30 times a second

TWO ENGINEERS—Robert B. Dome (*top*) and Walter Hausz (also see page 7)—of the Electronics Division who aided in the development of color television systems

to retain an image. Sometimes where very small areas are involved you can get by with even less. But flicker would be apparent in large areas if the brightness was changing *less* than 30 times a second.

The idea basically was that there could be a reduction in the rapidity with which the high-frequency or picture-detail information was transmitted. On one line *fine* detail would be transmitted in its proper place in the spectrum, and on the next line *very fine* detail would be transmitted in *its* proper place in the spectrum. In both cases a portion of the spectrum is left vacant in which color information can be squeezed. In the first case you can squeeze it in where the *very fine* detail belongs, and in the second case you can squeeze it in where the *fine* detail belongs.

Besides alternating the mixed highs at a field rate (Fig. 2), several other alternating rates were tried and three were demonstrated to an NTSC subcommittee: switching on alternate fields; transmitting two lines of the lower-frequency part of the mixed highs (H-1), followed by one line of the higher frequency (H-2); and following three lines of the lower (H-1) by two lines of the higher (H-2).

Alternating-lows System

In the two schemes described, the red and blue color information were assigned relatively small bandwidths on the basis that the eye could tolerate absence of fine detail in these colors as long as the detail was present in the green signal.

It was also noted by an engineer in the Electronics Division that, while bandwidth was being saved by reducing red and blue sharpness *along* each line, that is, horizontal detail, all three colors were being transmitted on every line so that the vertical detail, determined by the 525 lines in a standard picture, was the same for each color.

He reasoned that, because the relative need for detail in the three colors was the same psychologically, both in the vertical and in the horizontal, further savings in bandwidth were possible by giving less vertical color detail.

Theoretically, if in the other systems we could reduce the bandwidth of the blue channel to 1/10 that of the green on the basis of horizontal detail, we should be able to reduce it similarly in the vertical detail so that only 1/100 of the green bandwidth is required for blue.

In actual practice all of this could not be realized, but it was felt that a substantial saving in complexity could be gained by transmitting red and blue alternately, and using only one color subcarrier. For example, red and blue might be transmitted on alternate lines, but for several reasons it was found better to have two red lines followed by one blue line. For one thing, this combination eliminated "crawl"—a pattern in the picture that moves up or down the screen at a slow, uniform rate—because three lines per group go evenly into the 525 lines in a picture. Also, more detail is needed for red than for blue, and the red phosphor used was not as bright as the blue phosphor available. To eliminate any coarse-line structure from the alternation of the colors, it was found that suitable defocusing of the red and blue pictures could be used. These are, in brief, the principles on which the alternating-lows system is based.

This system has several advantages—bandwidth is saved because only one color subcarrier is used. The equipment required for on-off switching or time-sharing between red and blue is much simpler and more reliable than that needed for putting both colors simultaneously on the same subcarrier by having them in quadrature to each other, that is, two phase. In the latter case precision equipment to phase-synchronize the demodulation equipment in the receiver is needed, or interference between the two signals will result. A better signal-to-noise ratio with a given power can be achieved with time-division than with simultaneous modulation by two signals.

All the systems described have one common disadvantage. A picture received on a conventional black-and-white set would be the green signal. Of course, the picture would appear as black-and-white on the screen, but actually it would be the same picture you would see if you were looking at the original scene through a green filter. Also, the picture would look like an old-fashioned photograph where lips or red apples appeared black. Therefore, these systems were not strictly compatible.

The NTSC report of April 19, 1951, recommended a set of standards for a compatible television system, but the new system did not include the major features of the systems that have been described here, although they had their effect, and features from them will be found in the final system.

After the report was issued, General Electric proceeded to set up apparatus to experiment with the proposed NTSC standards. Field testing at present involves subtle variations of factors in the system.

Different Approach to Color

One feature selected by the NTSC from the accumulated knowledge of the participating companies was a different approach to color.

Three quantities are necessary to define a color, but instead of using the three primary colors—red, green, and blue—as was done on the systems described previously, it was decided to use absolute brightness as one of the quantities, and two other quantities for color that were ratios, independent of brightness.

This brightness signal corresponds well with the shades of gray in a panchromatic picture. Complete compatibility is thus achieved because the brightness signal gives a fine picture on existing black-and-white sets, without *any* changes in the sets.

In the color receiver the three signals could be combined and separated again to reconstruct the primary colors on the picture tube.

Because the frequency-interlace and alternating-highs systems utilized three color channels at all times, adaptation to this new principle could easily be made. The alternating-lows system could not readily be adapted for this particular receiver because it transmitted only two signals on any one line.

A review of the system to be used by General Electric in its field tests was held for members of an NTSC panel on August 6, 1951.

A standard very-high-frequency (VHF) transmitter, modulated by these signals, transmitted the color pictures during the review, and the compatible pictures were picked up and demonstrated on standard home-type receivers.

The work under way by General Electric in the immediate future will entail continued analyses and testing, and other contributions to the joint effort that is aimed toward the evolution and formation of final recommended standards for consideration by the FCC.

Nitrile Rubber Gaskets Make Better Seals

By T. C. AITCHISON and B. N. BOWERS

Until a few years ago, the reliability of such liquid- or gas-filled machines as transformers and circuit breakers was limited by the persistent problem of leakage. Regardless of whether the liquid or gas leaked out of the machine, or water or moist air leaked into it, such leakage interfered with satisfactory operation and increased the requirements for service and maintenance.

The chief sources of leakage are welded seams and gasketed joints. With the introduction of improved methods and processes, leakage at welded seams has been practically eliminated. And in the past few years the remaining problem of making gasketed joints more reliable has been solved with the development of nitrile rubber, a new synthetic compound.

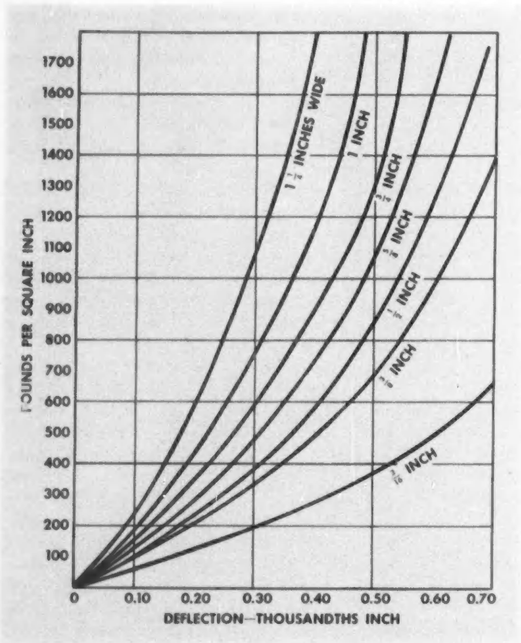
For many years the principal gasketing material was composition cork. This consisted of cork granules combined with natural or synthetic resin and coated with an adhesive. But this material, when not in contact with oil, is not a good seal against the entrance of moisture and air. And under certain conditions it didn't stand up; frequent replacement was necessary.

In searching for an improved gasket material, General Electric engineers first tried a specially compounded rubber known as No. 1000 compound. This is vapor-tight and also more resistant to oil than rubber compounds formerly available. It was used for several years on some high-voltage-bushing applications, and satisfied the urgent need for a gasket material that would effectively seal against air, moisture, and oil.

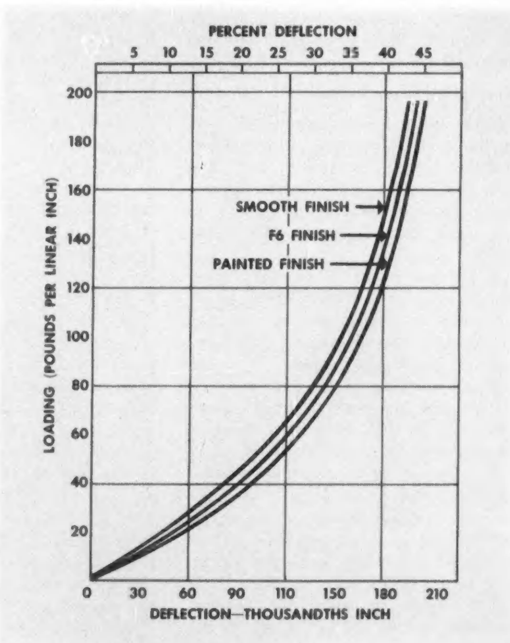
But No. 1000 compound swells when in contact with oil. This is all right in certain applications where the gasket is confined in a recess without follow-up pressure, for the swelling effect then serves to improve the seal. But swelling is a disadvantage in other applications, and this limits the versatility of the compound.

Neoprene cork—cork granules combined with neoprene synthetic rubber—is also used for gasket seals. It is, however, unsatisfactory for many applications because it tends to deform permanently.

The development of nitrile rubber, however, has revolutionized gasket practice. Because of its desirable character-



LOAD-DEFLECTION CURVES for various widths of $\frac{3}{16}$-inch flat nitrile-rubber gaskets. Test plates had F6 finish surfaces; samples were 6 inches long. Durometer hardness of samples: 65 ± 5



DEFLECTION of round nitrile-rubber gaskets $\frac{7}{16}$-inch in diameter and 6 inches long for the three test-plate surfaces indicated is shown on these curves. Durometer hardness of samples: 65 ± 5 istics, General Electric has adapted it to certain gasketing applications in electric apparatus. For such applications, it has virtually replaced composition cork, neoprene cork, and other types of special rubber compounds.

The characteristics of nitrile rubber make it an almost ideal gasket material for sealing the joints of liquid-filled electric apparatus against oil, non-inflammable insulating liquids—such as askarel, air, and moisture, because it

- Resists attack by hot insulating oil or askarel
- Will not swell in contact with hot insulating oil
- Does not become contaminated from insulating liquids
- Has very slight permanent deformation under compression
- Ages and weathers well
- Has low permeability to water vapor
- Is reasonable in cost
- Seals without the use of adhesives.

To utilize fully all of these desirable characteristics, it was necessary to make some radical changes in previous gasket practices, such as bolting pressures, component joint parts, and in many cases gasket shapes. The drawings which accompany this article illustrate in detail some of the new practices. Included among them is some information on the use of No. 1000 compound, since that material is still employed for a few applications. The use of this material, however, is limited to applications where the gasket is totally confined and is required to seal against oil, which, in contact with the gasket, improves the sealing qualities.

Mr. Aitchison and Mr. Bowers are supervisors of engineering planning for General Electric's Transformer and Allied Products Division at Pittsfield, Mass. Both specialized for a number of years in high-voltage bushings, and are previous contributors to the G-E REVIEW. *Mr. Aitchison in 1949 received General Electric's Coffin Award for his work in the development of low-cost cast-glass bushings.*

Nitrile rubber, like any elastomer, changes shape readily but it does not change in volume when subjected to pressure. This characteristic is used to advantage in making totally enclosed gasketed joints. In such applications, however, it is necessary to calculate accurately the volumes of the gasket and the gasket recess, to insure that the gasket will adequately fill the recess when fully compressed.

In general, it is desirable to use totally enclosed gaskets to seal between two metal surfaces. When the gasket is used between a metal and a porcelain surface, however, it should be only partially enclosed, because it is undesirable to bring the metal surface in direct contact with the porcelain surface. Then again, there are instances in which no confinement of the gasket is possible—for example, where a thin metal flange is to be sealed against porcelain.

Although nitrile rubber requires no adhesive to make a positive seal, in some applications small spots of rubber cement are used to hold the gasket in position at assembly.

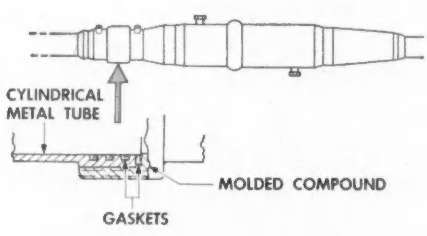
Characteristic load-deflection curves are shown on page 46.

Gasketing practice established for the applications illustrated has proved to be highly satisfactory. Over six million nitrile-rubber gaskets are now in service in electric apparatus. However, as new apparatus designs are developed, new ways of applying nitrile-rubber gaskets will undoubtedly need to be devised. In devising variations from the methods illustrated, we suggest the following:

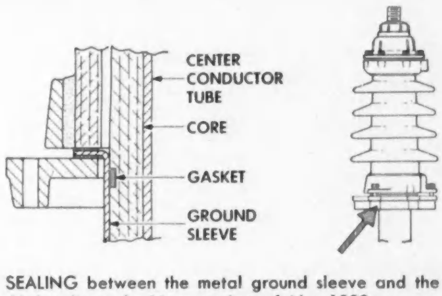
1. Partially or totally confine square-, rectangular-, or round-section gaskets.
2. Keep to the minimum the exposure of nitrile rubber to askarel.
3. Flat, thin-section gaskets do not require a recess, but don't let their edges extend beyond the flat surfaces that compress the gasket.
4. You'll get most successful results with flat gaskets compressed in the range from 600 to 1200 psi, and with round- or square-section gaskets compressed 30 to 40 percent of their initial thickness, with compressive force varying with the width and thickness.
5. Use stops in joints where there is any danger of overcompressing the gasket during assembly.
6. Lubricate, prior to assembly, any gaskets to be compressed by rotating parts.
7. Where gaskets are to be used in flange-clamped joints between porcelain shells and metal parts, it's a good idea to limit the bolting stress in order to keep the stress uniform and within bounds. Use a torque-limiting wrench

A REFERENCE ALBUM OF GASKET APPLICATIONS

Sixteen Illustrations of Uses in Various Electric Assemblies

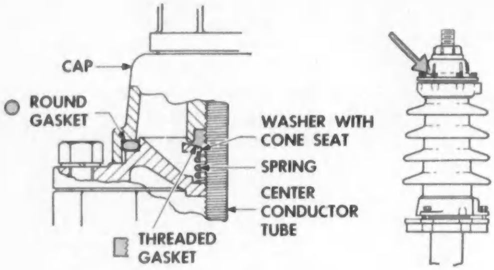


GASKET of No. 1000 compound applied to a sheath insulator used to isolate sections of lead-sheathed high-voltage oil-filled cable. Gasketing bands are set in grooves in the metal insert which is molded and thus compressed in the molded insulator

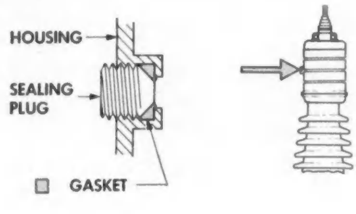


FOR SEALING between the metal ground sleeve and the core of a high-voltage bushing, gasket of No. 1000 compound is used. In assembly, the gasket is placed in the groove in the core, and the sleeve is then forced over core and gasket

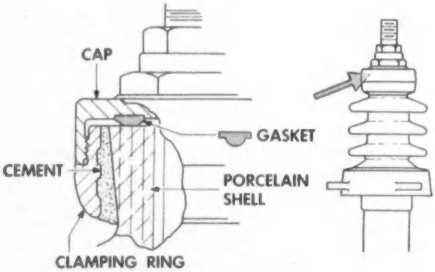
A REFERENCE ALBUM OF GASKET APPLICATIONS (Continued)



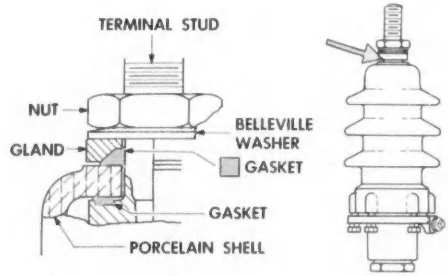
TWO SEALS are made simultaneously at assembly by round and threaded nitrile-rubber gaskets. Deformation of the round gasket into a rectangular recess maintains back pressure. A coil spring provides follow-up pressure on the threaded gasket



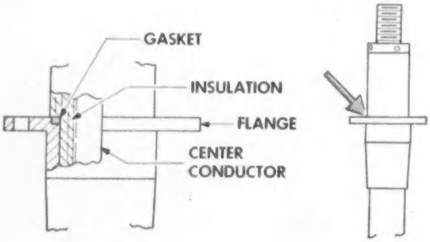
NITRILE-RUBBER gasket seals a treating or filling plug against leakage of oil or gas. Since this type of gasket is foolproof, it is used to seal the last opening to be closed. Initially square in cross section, assembly deforms it to the shape shown



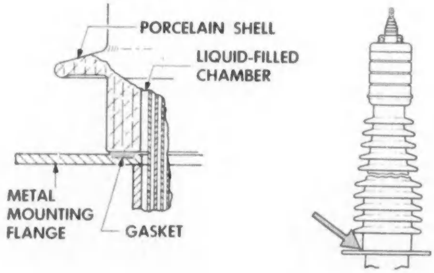
FLAT-HALF-ROUND SECTION of nitrile-rubber gasket. The gasket is accurately positioned by its flat side, which fits the recess in the cap. The rounded side provides the desired resiliency. A definite amount of compression is obtained



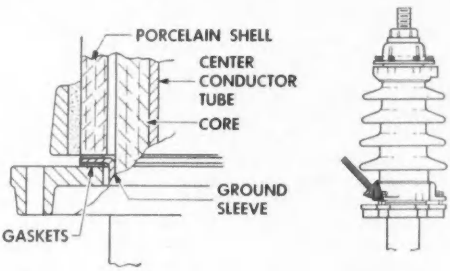
TWO GASKETS of nitrile rubber in one assembly. The lower one seals between the head of the terminal stud and the porcelain shell. Above, a gasket in a conically recessed gland is forced against the terminal stud, making a gland type of seal



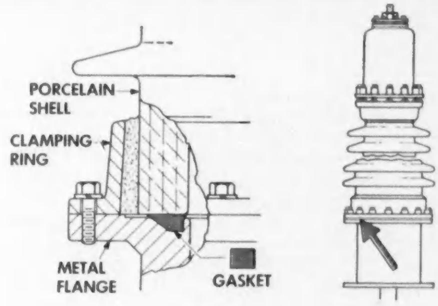
SEAL BETWEEN the support and the insulation of a bushing core is formed by a nitrile-rubber gasket. Here, again, assembly deforms the shape. The gasket starts out with a square cross section; pressure deforms it to the shape shown



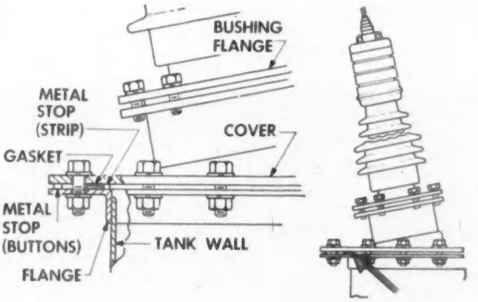
PARTIALLY ENCLOSED nitrile-rubber gasket application. This seals a joint between metal and porcelain surfaces which should not touch each other. A recess positions the gasket. Joints of this type are made with predetermined pressure



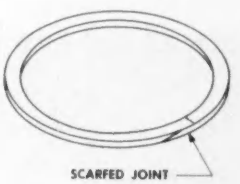
THIN METAL FLANGE is sealed against a porcelain surface, and it is not practical to provide a groove. Side shifting is prevented by flange clamping. The special conducting nitrile-rubber gaskets serve as an electrical connection to the ground sleeve



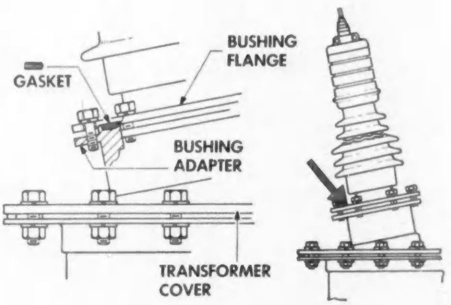
TYPICAL GASKETED JOINT for use on high-pressure gas- or oil-filled-cable potheads. The joint is so designed that the seal is actually improved by the high pressure of the fluid, which forces the gasket into the chambered portion of the recess



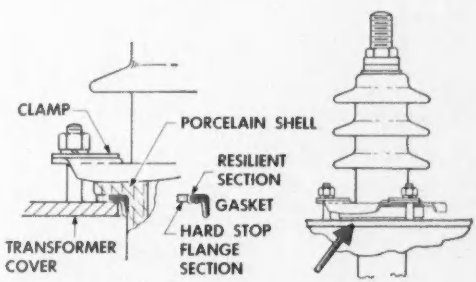
SEAL TYPE for transformer covers. It is not practical to machine a groove to retain the gasket, so stops are provided. Resilience of the deformed gasket exerts adequate back pressure to compensate for slight permanent deformation of the gasket



VULCANIZED JOINT in a strip gasket capable of withstanding twisting, sharp bending, and elongation of 100 without damage. The scarfed ends are coated with adhesive and pressed together under heat

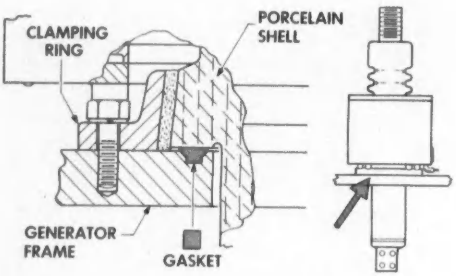


TOTALLY ENCLOSED application for sealing a joint between a high-voltage bushing and a transformer cover. The volume of the gasket is equal to the volume of the recess. Total enclosure eliminates exposure to effects of insulating liquid

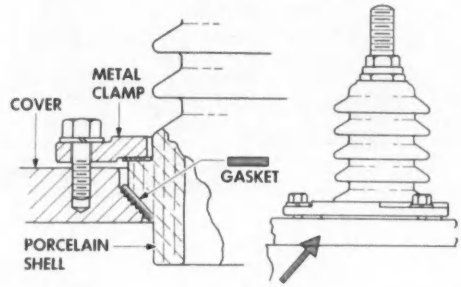


SEALING BETWEEN a bushing flange and a transformer cover is accomplished by having the gasket positioned by an outer flange of hard rubber (vulcanized to it) which serves as a compression-limiting stop

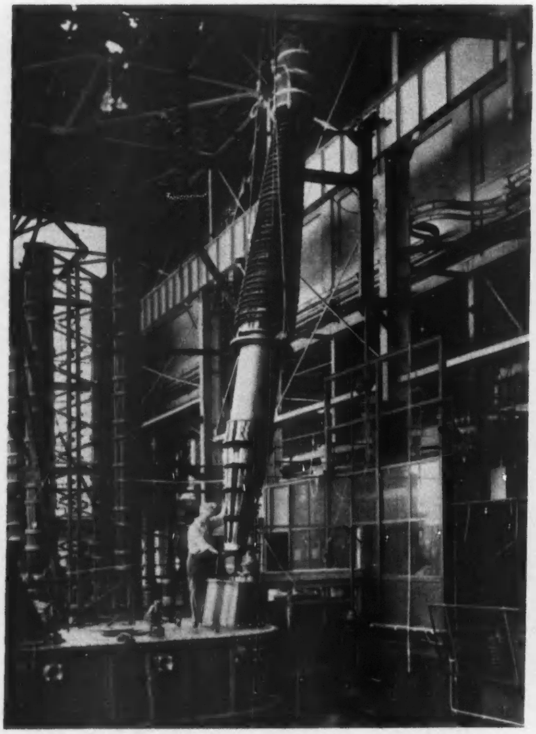
A REFERENCE ALBUM OF GASKET APPLICATIONS (Concluded)



THIS GASKET seals the joint between a high-voltage bushing and the housing of a hydrogen-cooled turbine-generator. The joint is designed to permit high-pressure metal-to-metal clamping without danger of porcelain breakage



FLAT GASKET for a high-voltage cable entrance pothead is deformed into a conical recess in the metal cover by the conical face of a porcelain shell. A stepped contour in the cover recess prevents dislocation during assembly and provides resiliency



NITRILE GASKETS seal this 360-kv high-voltage bushing. All gasketed joints in the bushing structure are center clamped

POWER TRANSFORMERS, such as this unit on the assembly floor, have joints sealed by nitrile gaskets for greater reliability

Development of Engineering Leadership

By E. H. FREIBURGHOUSE, JR.

Getting a better product and efficiently utilizing engineering manpower are some of the results of long-range planning in the development of engineering leadership.

Job horizons are broadened and authority can be spread over a wider area. The latter is especially true where the company is widely diversified and makes a variety of products. All decisions of engineering policy needn't be reserved for top management; they can be delegated to engineering managers and supervisors who must move fast with the right decision when the situation demands it.

Development of engineering leadership also makes it possible for the engineer to assume new responsibilities and thus relegate some of the less-stimulating tasks to assistants. Efficient utilization of engineering talent is particularly important now—and for the next three to four years—because the number of college graduates won't be sufficient to fill the gaps left by the *normal* movement of engineering manpower, much less the demands of defense expansion.

Training programs—training programs that require plenty of hard work from the student and long-term support from management—are one answer to the question, "How do we develop engineering leadership?" For instance, General Electric started its Test Course in 1891 when it realized that the arts and natural science teachings of that era didn't adequately prepare a man for industry.

Training programs don't just spring into full growth because top management says, "Let's start a training program." They require a basic philosphy that is geared to the individual company's demands—a philosophy that must be developed over the years to meet constantly changing situations.

In our experience we have found that the most efficient long-range training is concerned not with a man's present job, even though specific needs are known. The training must be farsighted; if it's not, the student will be prepared for his present job only, and he won't be able to recognize areas into which he and his division can expand. Thus, a large part of our training hinges on generalization and definitely doesn't prepare a man *only* for what he's doing today. Generalized training programs aren't difficult to set up, because certain common denominators have been discovered that provide ample material for training programs of use to all departments. Constant analysis of the problems of various engineering divisions soon points up basic similarities.

A second important factor of this training philosophy is that the trainee must be instilled with a spirit of confidence, an aptitude for entering new and strange situations without fear. It is felt that this facility can't be taught but must be gained by practice and personal toil. A wide variety of work experience must be supplemented by extensive problem-solving practice in the courses.

Direct responsibility for important projects that are real parts of the work assignments furnishes a personal, honest incentive to the trainee, and is an important concept in this basic philosophy.

Finally, the training philosophy must make due allowance for differences between individuals. It must recognize that some men are more willing than others to sacrifice a major portion of their home and social activities, to obtain the greatest professional development. Hence, there should be a variation between the courses offered. Some should be very intense, some more moderate, some short-term, others of extended duration. Also, many of the courses should appeal to different interests, yet all should attempt to develop engineering leadership.

This philosophy can best be described by examining the way in which it is applied. From the educational flow chart below, it can be seen that the educational efforts are widely diversified, although the final product of the different

TWENTY HOURS of homework each week over a three-year period of the Advanced Engineering Program are represented by the stack of workbooks and notebooks. They are all familiar to Mr. Freiburghouse. After his graduation from Rensselaer Polytechnic Institute in 1944, he joined the Company's Test Course and later went into, first, the Creative Engineering Program, and then into the Advanced Engineering Program. At present he is Supervisor of the Advanced Engineering Program and Assistant Manager of the Technical Education Department with headquarters in Schenectady assembly lines is engineering leadership. The "raw material" for our particular educational system is the Test engineer, because the majority of mechanical and electrical engineers who enter the Company do so via this program.

While on Test, the new engineer engages in a series of three-month assignments in factory areas conducting final tests on turbines, meters, radar systems, television sets, motors and generators, and appliances. Some laboratory, engineering, and production control tests are also available. The four to six different Test assignments give him his first opportunity to apply his education and common sense to the unforeseen problems arising daily in the Test areas. Frequently, each new Test assignment is in a different city, and the Test engineer must not only orient himself with regard to his work but also make new acquaintances, find housing, and overcome the vagaries of the local bus system.

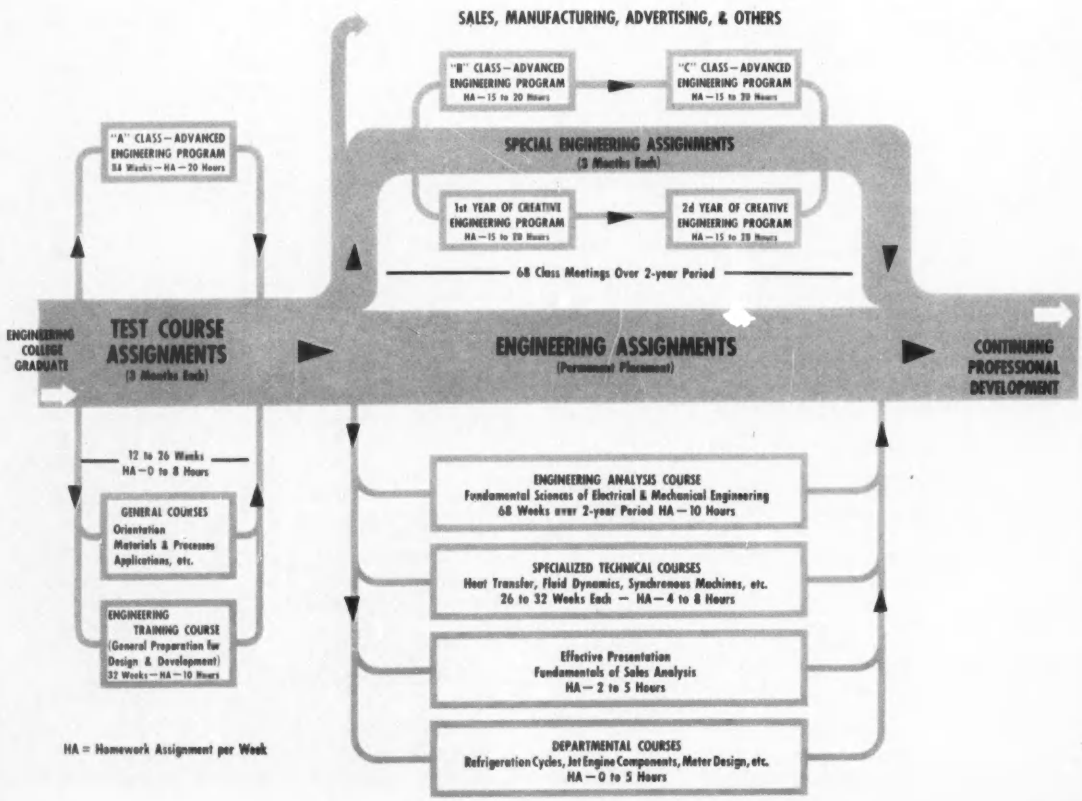
The Test Course, incidentally, is in accordance with the first point of the basic training philosophy—that those problems common to all departments in the Company are significant and worthy of study. The second point also is covered in that the men receive a wide variety of experience.

The Test engineer can supplement his work training by participation in an extensive group of courses. The first of these are the General Courses, which offer class and homework in the areas of Company orientation, materials and processes, applications, economics, and electronic circuits. Any member of Test can participate.

A second opportunity available to the Test engineer is the Engineering Training Course. It prepares the man who will later enter the design and development engineering groups. This course like all others is voluntary, but some screening is done and approximately 90 percent of the applicants are accepted.

Before we discuss the Advanced Engineering Program and the Creative Engineering Program shown on the flow chart, let's assume that a year to 18 months has passed, and that a typical engineer has graduated from the Test course. Does his training stop?

EDUCATIONAL EFFORTS are widely diversified although the final product of the different "assembly lines" is continuing professional development. The "raw material" is the engineering college graduate. This flow chart is typical of education operations at Schenectady, for instance, where more than 5300 men are engaged in the courses shown, plus courses for machinists, draftsmen, technicians and others. Engineering education alone costs General Electric 3 million dollars each year



Upon leaving Test, most men accept permanent positions in the engineering divisions; others divert to the fields of advertising, sales, manufacturing, personnel work, and other careers. (Extensive courses are also offered in those fields, but they will not be covered in this article.)

Training does not stop once a man enters an engineering division. His training can be continued by another group of courses that include the Engineering Analysis Course, Specialized Technical Courses, Effective Presentation, Fundamentals of Sales Analysis, and courses offered by his department.

Members of the Engineering Analysis Course receive an extended study and application of engineering and mathematical fundamentals over a two-year period.

Courses in Effective Presentation and Sales Analysis increase leadership potential through an awareness of human behavior and increased skill of communication.

The only entrance requirements for any of the courses for permanent men is a desire on their part to participate and the approval of their departments.

Departmental courses, as the name suggests, are not Company-wide. They most often deal with the problems encountered when designing and manufacturing the products of the department giving the course.

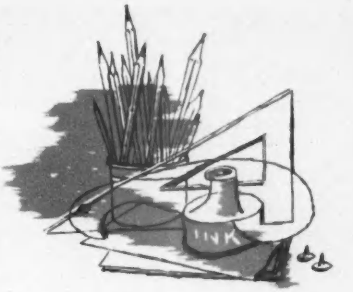
Additional Courses Available

By referring once again to the flow chart, you'll note that when Test engineers first join the Company, they can enter a third course, the Advanced Engineering Program (AEP). From 5 to 10 percent of the *new* Test engineers are selected for participation in AEP. Selection methods are rigorous; about 20 percent of those applying are accepted.

A second selection, made after the first year of work, reduces the number of men engaging in the Advanced Engineering Program by about 50 percent. Those remaining postpone acceptance of a permanent position with some department until two years following graduation from Test.

Graduates of the Test Program can also apply for the Creative Engineering Program (CEP). If accepted, they also delay by two years their acceptance of a permanent job.

Three-month engineering assignments, continued for a period of two



years, succeed the factory experiences on Test for members of AEP and CEP. These men contribute directly to the creation and design of new products. Although expert guidance is always available among the older engineers, the assignee is urged to be solely responsible for large portions of the engineering problem. Often he furnishes the leadership on important projects.

The frequent changes of assignment repeatedly present entirely different sets of conditions that demand rapid adjustments by the student and leave little time for advance studies of the art. He must rely on basic engineering facts common to all fields and intelligently adapt them to the peculiar requirements of the job. Furthermore, the Program member gains a working acquaintance with many parts of the Company in which he witnesses a wide range of engineering philosophies and practices.

The assignment work of the programs is supplemented with four-hour classes held weekly on Company time, and a 15- to 20-hour home assignment. For members of the three-year Advanced Engineering Program, this was also true while they were members of Test. Problems assigned as homework are frequently taken directly from engineering divisions. Advanced methods of attacking these problems are discussed in class and applied at home.

The work of the Advanced Engineering Program heavily stresses fundamental concepts and advanced mathematics, and simultaneously maintains a balanced view of the power and limitations of the various methods of analysis.

Members of the Creative Engineering Program devote their first year as program members, which is also their second year with the Company, to the concepts of new ideas and a development of a logical approach to design problems. No attempt is made to present a definite formula and procedure to invention. Instead, a number of leading inventors describe the processes and techniques they use in developing new devices. Due consideration is given engineering practice and theory. The second year of the Creative Engineering Program is directed toward putting new ideas into practice.

Reports from graduates of the Advanced and Creative Engineering Programs emphasize their appreciation of the self-confidence acquired while completing the wide variety of homework and engineering assignments. Difficult problems in varied fields no longer appear impossible. Part of this confidence stems from the manner in which problems are treated in class. The class, which normally contains no more than 15 or 20, considers the new problem as a conference topic. Faced with a vague engineering need, the class members must first define the problem and ascertain the important and irrelevant factors. The group then spreads into small sections and proceeds with the solution at home.

After the problem is completed, the class again convenes and with the help of an engineer representing the department most interested in the answer, the results are evaluated. Several class members whose solutions are unique briefly outline their approaches, thus affording a glimpse of the engineering judgment at work within the group. After several experiences lead to the question, "Why didn't I think of that?" the student begins to exert greater effort toward intelligently organizing his own studies.

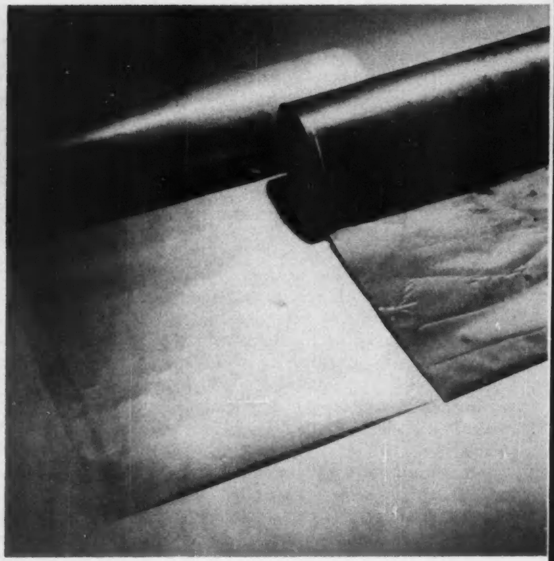
Levels of Leadership

Like the manufacturer who produces several different lines of automobiles, yet all are automobiles, the training effort described produces several levels of engineering leadership. It is not deliberately planned that this be so; rather, it is evident that the several levels of leadership is a function of interest existing among the Test engineers who initially represented fairly uniform raw material.

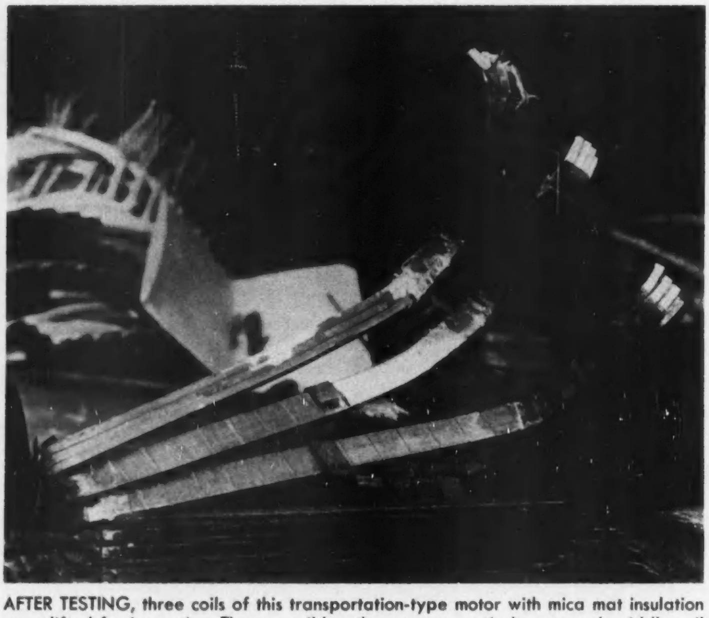
What are the results of training courses? For one thing, it gives a company flexibility because it has a large group of men that are able to competently attack a variety of assignments.

The system also gives the greatest job satisfaction and potentially the best-adjusted employees.

1 Making mica mat is somewhat similar to making paper. The continuous rolls that come off the machine can be made into...



2 Mica mat tapes *(left)*—more regular and uniform than conventional mica tapes *(right)*. Other possibilities are . . .



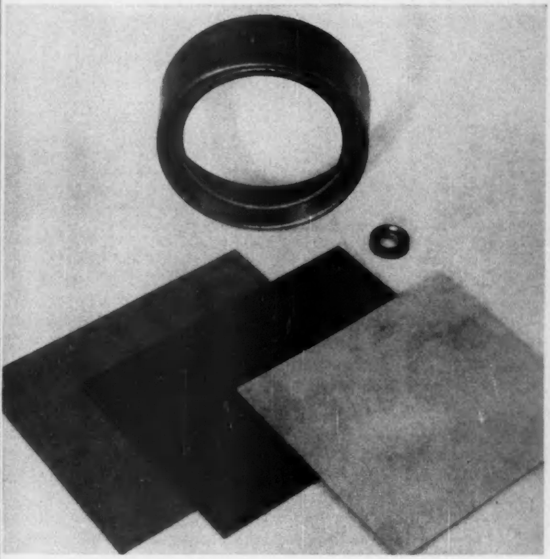
AFTER TESTING, three coils of this transportation-type motor with mica mat insulation were lifted for inspection. The top coil has the wrapper entirely removed; middle coil has portion of wrapper removed; bottom coil has wrapper intact with a portion of the glass tape removed. Insulation is firm in all cases; there is no evidence of any crumbling or harmful "flowing." Mica mat is used by General Electric in the armatures of motors applied to diesel-electric switching locomotives and electric trolley coaches

Mica Mat...

Since the beginning of the electrical industry, mica has played an important role in the design and construction of electric machinery. Almost at the outset, it was found that this material has electrical and thermal properties which make it invaluable for such applications. Certain parts of electric machines had to be insulated from each other, and the only practical insulating material for the purpose was flake mica.

But, although mica has desirable properties, it also has some undesirable ones. It cannot be used in its natural state except for the simplest or crudest applications. To provide the flexibility or adaptability required by most machines, it must be transformed into a more tractable form.

Until recently, most of the mica insulation used by the electrical industry has



3 Mica mat commutator cones and mica mat laminates made with shellac and silicone resins. Other uses include . . .

4 Armature coils wound with mica mat tape in a transportation-type motor for withstanding high operating temperatures

. . .New Tool for the Electrical Designer

By DR. E. A. KERN, H. A. LETTERON, and P. L. STAATS

been composed of mica flakes bonded together with a resinous material such as shellac. But this material has certain disadvantages: First, it is relatively inflexible; and second, the only mica suitable as a raw material is hand-split mica from India.

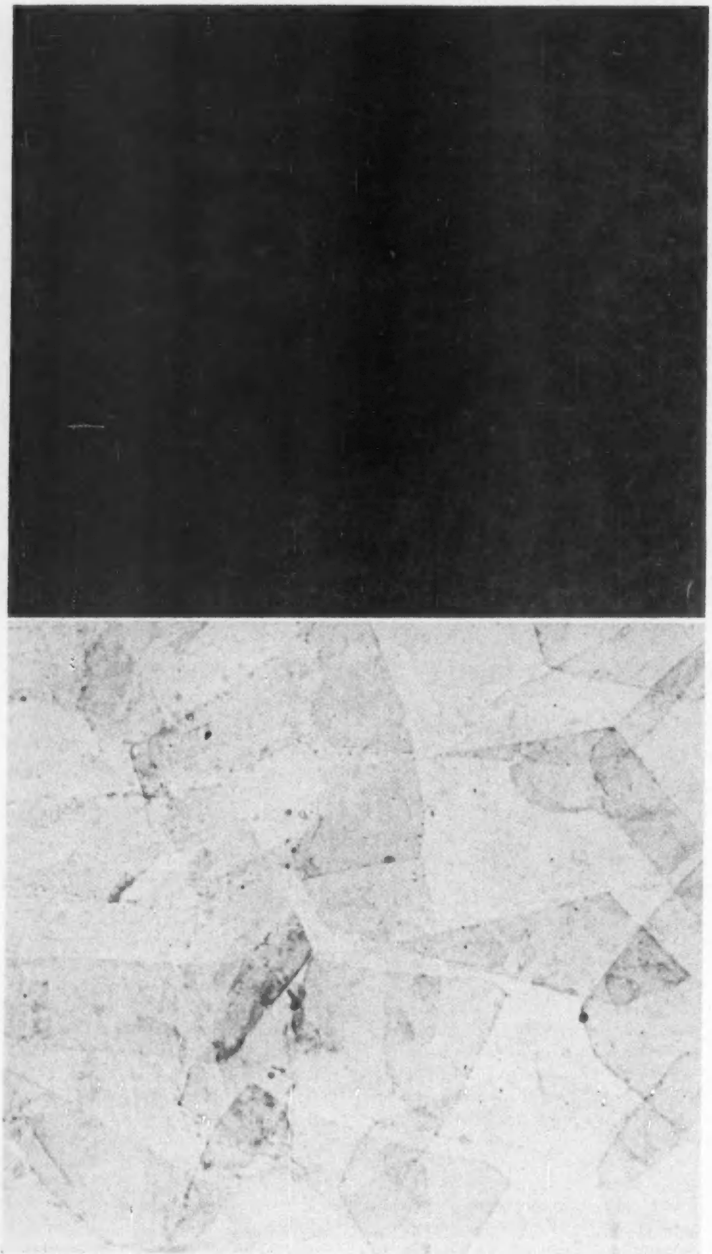
Recently, the General Electric Company announced a new mica insulation, mica mat, which marks the achievement of a long-sought goal. This product is a flexible material in continuous sheet form. It eliminates not only the temperature limitations imposed by cellulose materials but also the stiffness and irregularity of conventional mica products. Moreover, it has the same durability and resistance to destructive forces as conventional built-up mica, because it has substantially the same overlapping structure on a miniature scale. And it can be made with domestic mica.

Natural mica is first broken up into flakes, through the action of heat, and is next ground in an aqueous medium. The insulation is then formed from these flakes in a process somewhat resembling the making of paper. The result is a continuous, uniform, flexible self-supporting ribbon of pure mica. It has a dielectric strength of about 400 volts per mil, a tensile strength of about 1000 psi, and a thickness variation of only 10 percent.

Despite its good physical properties, mica mat has no binding or strengthening agent added during manufacture. In roll form, insulation 24 inches wide and up to 2500 feet long has been produced. Production equipment now being installed will permit the manufacture of 40-inch widths.

This roll insulation serves as the raw material for various modifications, according to the insulating need. It can be used to form molded insulating products. Also, it can be treated with silicones or other resins to improve tensile strength and water resistance. Hard resins produce rigid sheets, while softer saturants make mica mat limber and rubbery. The mica mat raw material can be bonded to cloth or paper-backing materials, to improve its tensile and tearing strength.

Many varieties of mica tape have been developed through the years, to give combinations of properties to insulating material. The number of these varieties can be decreased with the use of mica mat; about six combinations should meet all present requirements for rotating electric machinery.



CONTRAST between the uniformity of mica mat (*top*) and conventional mica insulation is graphically shown. To form a continuous dielectric barrier, the hand-laid layers of high-quality mica splittings are overlapped about one-quarter to one-third their surface area (*below*). The layer may consist of four or more thicknesses. The fine-grained structure of mica mat allows uniformity of an entirely different magnitude

For some time, the major interest of Dr. Kern, Mr. Letteron, and Mr. Staats has been in the research and development of mica mat. At present, Mr. Letteron is a product engineer in the Laminated and Insulating Products Department of General Electric's Chemical Division at Coshocton, Ohio. Dr. Kern is Supervisor, Insulation, and Mr. Staats is Supervising Chemist of the Paper Dielectrics Unit of the Transformer and Allied Products Laboratory in Pittsfield, Mass.

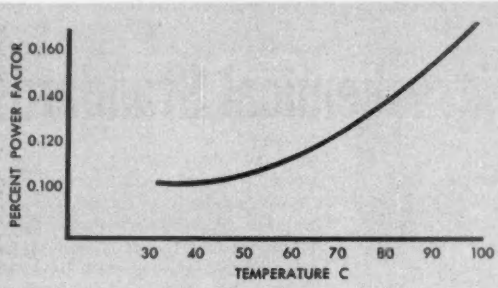
All the tapes listed in Table I, whose characteristics have been determined by laboratory tests, have a uniformity of thickness and pliability unknown in conventional mica tapes. Since a coil is only as good as its weakest spot, a more uniform insulation will make possible a saving in slot space. And, because of their better flexibility, large coils which undergo a molding process with the insulation in place can be molded with lower unit pressures and to closer tolerances. The insulation takes a permanent set and continues to hug the conductor, even after its binder is completely destroyed.

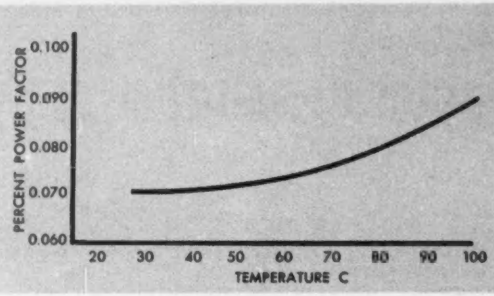
Destruction of the mica mat binder is such an important consideration that an interesting test was conducted to see just what would happen in this event. A number of two-conductor coils were insulated with various materials, each conductor receiving a tape winding, half-lapped. Two of the conductors thus insulated were then held together and given enough half-lapped turns of mica mat insulation to build the same dimensions for all coils. With approximately 3/16- by 3/18-inch conductors, this required three turns of the heavy tapes and five turns of the thin ones to build ½ by ½ inch over all.

The coils were then heated, molded to dimension, and clamped in a fixture suitable for high-potential testing.

One set of coils was tested to breakdown; the results are in the first column of Table II. Another set, while still clamped in the fixture, was baked for three days in an oven, at 350 C, with circulating air. After removal and cooling, these coils were also tested. The results after baking are given in the second column of Table II; the appearance of the baked coils is shown in the picture at the right of Table II.

Direct-current armature coils con-





EFFECT OF TEMPERATURE on power factor. The left curve shows the power-factor characteristics of mica mat as measured in dry air at 60 cycles; the right curve shows the power factor of a stamp capacitor treated with mineral oil measured at 1 megacycle

tain relatively few conductors; the coils are relatively small in cross section, with operating potentials usually under 1000 volts. Space is at a premium, and temperatures are usually higher than in the stationary portion of the machine. Rotational stresses are added to the effects of vibration and heat.

A thin mica tape of uniform thickness and high dielectric strength is required for this application. Suitable synthetic-resin-bonded tapes have been developed for such use.

For railway traction motors, the need for a tape resistant to high temperatures justified a higher cost. Here a silicone-bonded glass-cloth-backed mica mat tape containing no cellulose material is recommended. The pliability of mica mat tapes allows easy and snug wrapping on such small conductors and coils.

Heavy tapes, also, have an important place in certain insulation systems. The ratio of mica to organic materials is high. Fewer layers are necessary in building up a given insulation thickness requirement than is the case with thinner tapes. Cotton-cloth-backed asphalt-bonded mica mat tape combines abrasion resistance with good insulating properties.

(Continued on page 60)

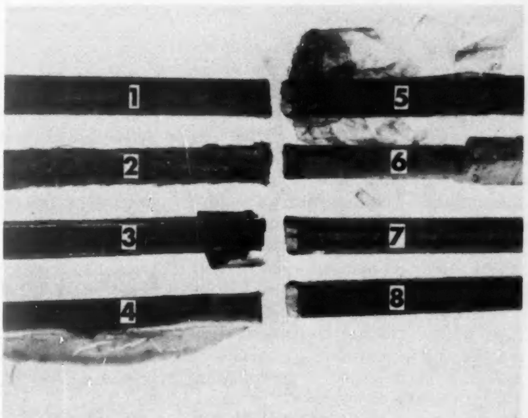
TABLE I
PROPERTIES OF MICA MAT

Material	Thickness (Mils)	Dielectric Strength (Volts per mil)	Tensile Strength (Pounds per inch*)
Resin-treated unbacked	5	900	40
Asphalt-treated paper-backed	9–10	750	15
Asphalt-treated cloth-backed	10–11	600	25
Resin-treated paper-backed	4½–5½	700	15
Resin-treated glass-backed	8–9	500	70

* Pounds per inch refer to stress across section one inch long and one mil thick.

TABLE II
EFFECT OF HIGH-TEMPERATURE TEST

Type Insulation	Dielectric Strength: Before Baking (Volts per mil)	Dielectric Strength: After Baking (Volts per mil)	Percent Change
Teflon	18,000	1700	−90
Varnish glass-cloth tape	9000	1500	−83
Asphalt-bonded paper-backed conventional mica tape	15,500	7500	−54
Asphalt-bonded paper-backed mica mat tape	10,500	6500	−38
Silicone-bonded mica mat tape	13,500	11,000	−19
Silicone-bonded glass-backed mica mat tape (thin)	7500	6500	−13
Silicone-bonded glass-backed conventional mica tape	7500	7300	0
Silicone-bonded glass-backed mica mat tape (heavy)	8000	9000	+12



RESULTS AFTER BAKING two-conductor coils are given in the second column of Table II above; how the coils looked is shown at the right. The varnish was completely removed from the varnish glass-cloth tape (2) leaving a bundle of threads. The Teflon (4) had flowed on heating and cracked on cooling. The asphalt-bonded paper-backed conventional mica tape (5) and the asphalt-bonded paper-backed mica mat tape (3) had lost all their binder and backing material. Each had returned to the original mica from which it was made, but each still constituted a good dielectric barrier. However, the springy mica flakes of (5) tried to leave the coil, while (3) remained wrapped as before. Instead of falling to a powder, the burned off mica mat was still strong enough to be unwrapped from the coil as a continuous ribbon. The silicone-bonded glass-backed conventional mica tape (6) was intact except that it was loose. The silicone-bonded mica mat materials (1, 7, 8) were undamaged

Use of powder metallurgy techniques mean . . .

Faster Preparation of Spectrochemical Standards

By WALTER O. GERBER, JR.

The use of the spectrograph as a tool in chemical analysis has seen a tremendous increase over the past quarter century. This method determines the elements present in a substance by exciting a sample in an electric arc and measuring the intensity of the different wavelengths of light emitted. The time saved by the process is so great that, in spite of the relatively high initial cost of the equipment, installations are being made at an increasingly rapid rate.

One of the greatest difficulties of spectrochemical analysis, however, is the length of time required for the preparation of comparison standards. For, to make an analysis quantitative, the light intensities emitted from the sample must be compared with those of a standard that contains known amounts of the elements that are likely to be found in the sample.

Preparation Takes Time

The usual method is to select or melt down a series of samples containing a wider range of concentration than is to be expected in the sample. This is merely a preliminary step, but it can consume considerable time. The probability of selecting near extremes of concentration is remote, and the ability to melt the samples by conventional procedures to approximate predetermined values for unusual compositions may take several trials.

For this reason, the spectroscopist usually is compelled to accept more samples than desirable to obtain a sufficiently wide range of composition. Then, after the standards are prepared, there is the practically endless task of having the samples analyzed by the wet analysis method in different laboratories. And there is always the difficulty of getting the different analysts to agree.

This task is bad enough for simple analyses, but with brand new alloys it may take so long that the composition may be superseded by the time satisfactory analyses have been obtained.

Work on the preparation of standards by using the new techniques of powder metallurgy began in the Thomson Laboratory in the fall of 1943. Although satisfactory results were obtained, they have not been previously reported for reasons of national security.

An early application of this technique occurred during 1943 in connection with the control of small amounts of aluminum in our foundry heats. At that time, the Bureau of Standards had available no spectrochemical solid standards showing values for small amounts of aluminum.

The wet analysis of steels for small amounts of aluminum is very difficult. For example, in a certain Bureau of Standards certificate for chipped samples only three out of twelve analysts report values for aluminum on one of the samples, and one of the three differed from the other two by 100 percent. Yet each of the three results was undoubtedly the average of several very careful analyses.

As a result of the difficulty of this determination by wet methods, a series of powdered iron samples containing small amounts of aluminum metal powder (Alcoa DC fines) were prepared by weighing out a master mix and diluting with General Aniline Works carbonyl iron powder to provide an aluminum concentration range from 0.001 to 0.03 percent.

These samples were mixed in a Fisher automatic mortar for six hours and briquetted into ¼-inch-diameter pellets ⅛-inch thick in a large ARL briquetting press under a pressure of 250,000 psi. The mold rounded the top of each pellet; this rounding of the surface keeps the arc centralized.

Exposure conditions were 10 seconds with a 10-second preburn to sinter the pellet and to help establish equilibrium in the arc stream. The pellets were then placed on top of a graphite rod and arced against a pointed, graphite, spectroscopic special-purity upper electrode (Fig. 1). The electrical conditions used were 3 amp at 220 volts from a d-c generator with the sample as the negative electrode. Spectra were photographed using the original 21-foot Jaco spectrograph with a dispersion of 2.5 Angstroms per millimeter in the second order.

Bureau of Standards chipped samples containing 0.002 and 0.025 percent aluminum were the only standards of this type that were available to us at the time.

Results Showed Agreement

The samples *C* agreed very well with the points obtained from the synthetics *S* as shown in Fig. 2. This correlation was taken as sufficient evidence that the synthetic standards produced results in the right order of magnitude, and this procedure was used to make the metallurgical investigation at hand. Unknowns were run by cutting off a filed piece and pressing it into the same shape as the pellet. No samples were found to contain less than 0.002 percent aluminum, so the steepness of the curve between 0.001 and 0.002 was of no consequence.

Other standard samples were recently checked and are shown on the graph as points *R* and *B*.

Thus, the Bureau of Standards chipped samples are in good agreement with the synthetic samples, and an incomplete average on the Bureau of Standards rods show better agreement

In 1941 Mr. Gerber came to General Electric and since 1943 has been associated with the spectroscopic group in the Thomson Laboratory in West Lynn. New methods of qualitative analysis which he developed over this period has increased the yearly determinations from 1000 to 34,000. He predicts 50,000 for 1952.

than values obtained by wet methods in different laboratories.

Consequently, from the agreement shown, this synthetic method seems to be a satisfactory approach to the analysis of small amounts of aluminum in other types of steels and metals for which standards are not available. This holds true if matrix elements can be found that contain only a fraction of the amount of aluminum that it is desired to measure.

A similar synthetic approach was applied to the analysis of 19-9-DL alloy, a 19 percent Cr, 9 percent Ni steel containing W, Cb, Mo, and Ti, in combination, using ½-inch-diameter pellets either sintered or melted in a high-frequency coil. Tungsten, columbium, and molybdenum are all close neighbors in the periodic system and thus have similar chemical properties. This, of course, makes their separation difficult. While wet analyses sufficiently reliable are not available to rigidly verify determinations by the synthetic method, results obtained were in the correct range. At least, a continuous curve can be obtained that is not possible from

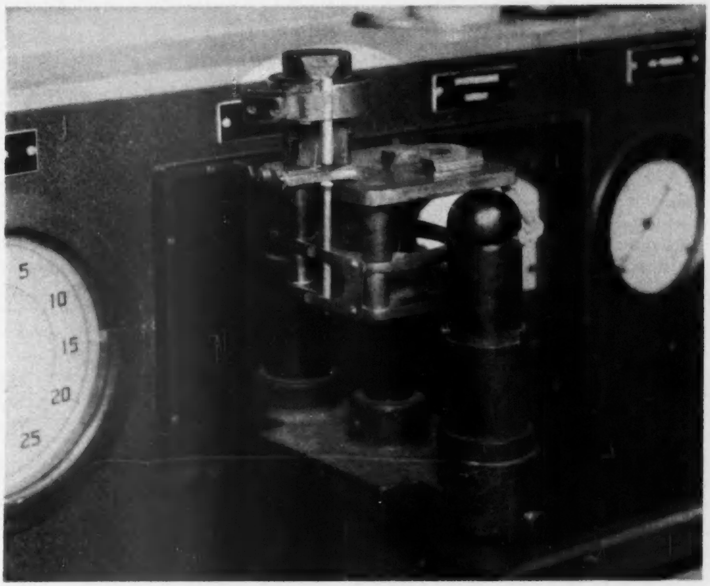


FIG. 1. SMALL PELLET of powdered-iron sample in spark stand prior to arcing. Upper graphite electrode is of special purity. Top of pellet is rounded to centralize arc

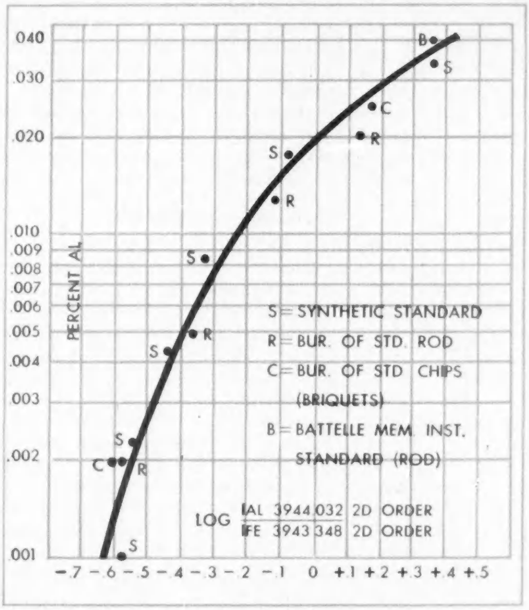


FIG. 2. COMPARISON of synthetic metal-powder pellets *(S)* and Bureau of Standards samples *(C)* for low aluminum content in steel were in agreement and showed that the investigations were on the right track. Recently checked samples *(R* and *B)* also show agreement with the earlier comparison tests

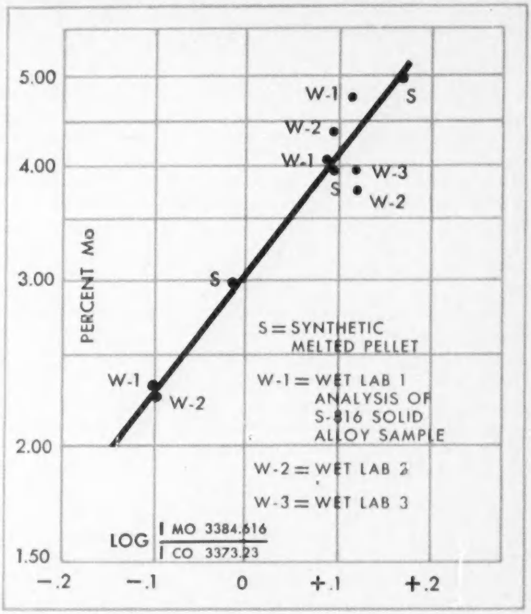


FIG. 3. AGREEMENT is good between the synthetic melted pellet and various analyses by the wet method to determine the percentage of molybdenum in S-816 cobalt-base alloy. The synthetic approach also is valuable in analyzing the tungsten and columbium content of the same alloy

Faster Standards —

(*Continued from preceding page*)

the wet chemical results, and this curve can serve as a yardstick for future reproducible measurements.

This same approach was also applied to S-816 cobalt-base alloy containing the difficult-to-separate elements of tungsten, columbium, and molybdenum. For this alloy the agreement is also very encouraging, as shown by a typical curve in Fig. 3.

Work has been carried out with success in analyzing for aluminum and tin in a 12 percent Cr stainless iron, using sintered standards.

The main advantage of this synthetic approach is its flexibility. Almost unlimited combinations of elements can be mixed and the composition so arranged as to provide any desired concentrational increments.

Also, because the finely divided powders are thoroughly mixed before melting, this procedure eliminates losses in dissolving additions by the usual melting processes. By electronic induction heating, the melting is rapid—in the order of 15 seconds—and easily controlled, and samples can be cast immediately upon melting so as to minimize losses.

Limitations are that samples containing easily oxidized elements, such as titanium and aluminum, should be sintered and not melted, although we have melted stainless-iron samples without losing aluminum. Purity of powders must be carefully examined, not so much from their contribution to the error of the addition, as from the amount of error caused by the presence of a trace element in a major constituent. The preparation and testing of suitable blanks helps eliminate this difficulty. Proper mixing is extremely important.

We also believe that the excitation source has much to do with the comparison between synthetics and solid alloys. This conclusion is an opinion reached not from any data, but from conversation with associates in the field. Some of the difficulties of others regarding metallurgical history and extraneous-element effect have not been experienced with the source used in these tests.

This method is not recommended for the standardization of elements that are easy to analyze by wet methods, but it does provide a quick way of setting up an analytical control method for new compositions that are hard to analyze.

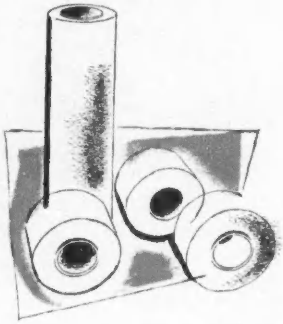
Mica Mat —

(*Continued from page 57*)

Heavy silicone-bonded glass-cloth-backed mica mat tapes provide similar properties for applications involving Class H temperatures.

In the untreated form, mica mat has found application in certain high-frequency capacitors because of its desirable electrical properties, stability, and high corona level in combination with certain liquid impregnants.

Mica mat tapes offer obvious advantages to the designer of electric equipment. For some applications, wide tapes used as wrappers give the same



ease of handling and uniformity of insulation. Composite insulation consisting of mica mat with glass cloth, paper, or fiber give good results as slot liners and phase insulation.

A smooth surface, uniformity of compression without hard and soft spots, and stability under heat, pressure, and shear give promise of better commutator segments using mica mat. Similar properties in molded parts, such as V-rings, mean better commutators with shorter curing cycles.

So the electrical industry, in its constant striving for improvement, finds itself with another new tool. Mica mat provides the designer with a whole series of new materials that should lead to improved equipment of smaller size; for mica mat, with its many advantages, can be used in nearly all places where natural mica is now used. Its versatility is great—not only can it be molded by the usual methods, but simple shapes can and have been formed by vacuum techniques used in the laboratory. Similarly, there are indications that minute flakes can be sprayed with conventional equipment.

Liquid Metals —

(*Continued from page 25*)

tests are not dangerous; they can be detected without difficulty after the liquid metal has leaked. With care, small leaks can usually be detected and repaired without affecting the system.

Other requirements for a liquid-metal system not usually encountered in piping systems are pipe heating and the need for an inert-gas blanket over the free surfaces of the liquid metal. Because many of the liquid metals are solid at room temperature, provision must be made to preheat all parts of the system before filling and to thaw out a system if the metal should solidify in it. The heating is most easily done by winding the pipes with a resistance heating wire of low heating intensity designed for this purpose. High-intensity heaters are used in special places, but they present the danger of overheating on an empty well-insulated pipe. The heating wire is armored with a woven wire mesh for ease in handling and installation.

The inert gas is provided to blanket the free liquid-metal surfaces and to maintain system pressure above atmospheric pressure at all times, thus preventing air leakage into the system. Under conditions of high flow, the pump inlet pressure can drop below atmospheric pressure. It is desirable to supercharge the system, to keep all parts above atmospheric pressure at all times.

Liquid-metal Purification

It has been determined from metallurgical tests and considerable operation in small-scale heat-transfer systems that satisfactory purity of sodium and sodium-potassium can be obtained by low-temperature filtration of these metals. Oxygen, the principal contaminant, is relatively insoluble at low temperature, and it can be removed from the metals with a fine-mesh filter material. Pore size or mesh in the order of microns is desirable for effective filtration.

Hot sodium and sodium-potassium are good agents for the final cleaning of the system, provided reasonable cleanliness was observed in construction. The metals can be filtered at low temperature after having been circulated in the system at high temperature. Although the effectiveness of this method has its limits, cleanliness during construction is worth the effort.

WE ASKED GRADUATES TEN YEARS OUT OF COLLEGE:

WHAT WOULD YOU SUGGEST TO MEN NOW PLANNING THEIR CAREERS?

This advertisement is another in a series written by G-E employees who graduated ten years ago—long enough to have gained perspective, but not too long to have forgotten the details of their coming with the Company. These graduates were sent a questionnaire which they returned unsigned. The quotes below represent only a sample of the suggestions received. For a free, mimeographed copy of the full list of comments, write to Dept. 221C-6, Schenectady, N. Y.

"The advice should go back to the sophomore level and it would be to take as many fundamental engineering courses as possible instead of specializing in one field during junior and senior years. The specialization will come as a matter of course due to participation in a phase of engineering occupation after graduation."

"Obtain working experience in all the jobs you think you know nothing about and avoid your primary interest the first year out of college. Ignore geographic location when selecting a job. Even Schenectady is an enjoyable place to live when you've been there long enough to know how to appreciate it. Respect and admire your boss or change bosses."

"Too many of today's graduates are hypnotized by the glamor fields of rockets, jets, etc., whereas they are overlooking good opportunities in the old standard lines."

"Come with G.E., take advantage of opportunity to find field of most interest and possible reward. Don't jump to any foregone conclusions, and don't hurry to find a 'permanent' job."

"This is for freshmen . . . Go to a school that will give you an excellent background in fundamentals of physics, math, mechanics, and materials. Spend at least 25 to 30% of your time in the study of humanities. Forget about machine shop and drawing courses and practical application. Get your practical experience eventually from a company. In a few years you will be worth 10 times more to them and yourself than the so-called practical student."

"Be thoroughly grounded in engineering fundamentals. Experiment in your likes and dislikes by trying several jobs. Work for a company that helps you do this."

"I think the General Electric Test Engineering Program is the ideal employment for the graduate engineer. He should spend the full time on Test with many assignments to obtain the background that will be of utmost value to him."

"Don't specialize too much. Get your fill of math, physics, and so-called liberal arts."

"Don't be afraid to change either training or vocation if you find you don't like it."

"Get a line of work in which you are sincerely interested; it should be a pleasure to get up and go to work in the morning."

"It is a rare thing, one to be cherished as a golden opportunity, to be able to move around on rotation, look over the best facilities and opportunities of a company and thereby be able to make a much more considered choice of where, finally, to work. These things are all possible on the G-E Test Course."

"The most pleasant life seems to be in the sales end of the business. This is what I would tell the college men to strive for if he is fitted for sales work."

"If you don't find your work interesting after five years or rewarded with responsibility and money after 10 years—quit."

"I have worked with hundreds of young fellows since I was on the Test program. Only a few of them knew exactly what they wanted a year or even two years after graduation. One advantage of working with a large company is that it gives them an opportunity to observe a broad field of activities—everything from betatrons to garbage disposers—locomotives to guided missiles. The most important thing in selecting a job is choosing one that will keep the individuals happy, contented and satisfied."

"Get with the company that offers the best training program—the longer the better."

"G-E Test is the best way to spend first 2 years after school—particularly if the graduate is undecided as to his field."

You can put your confidence in—

GENERAL ELECTRIC

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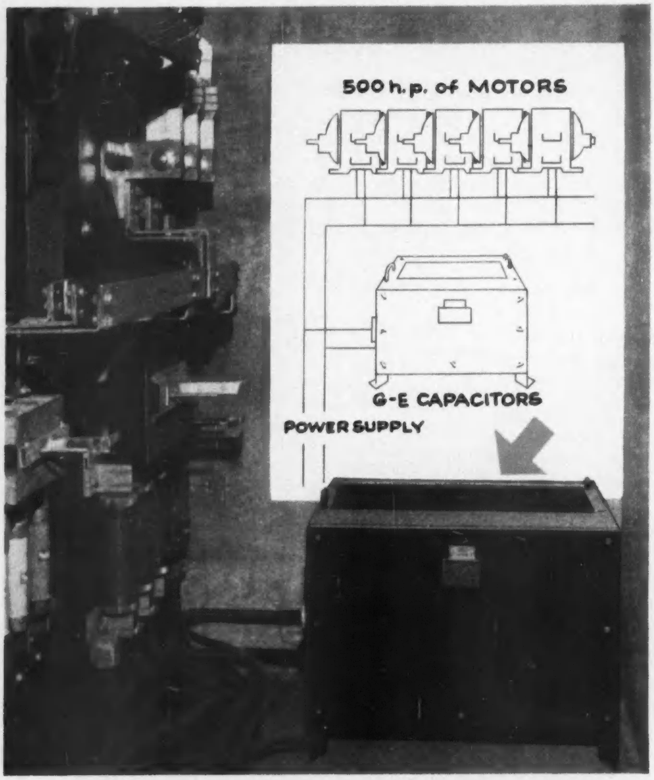


Low power factor was penalizing a West Coast meat packing plant until G-E engineers recommended the installation (arrow) of a 60-kvar, 3-phase 60-cycle, 460-volt G-E capacitor equipment.

$355 investment saves up to $47 every month!

WEST COAST MEAT PACKING PLANT INSTALLS GENERAL ELECTRIC CAPACITORS AND CUTS POWER COSTS

Induction motors caused low power factor. Because it takes about 500 hp of induction motors to run a plant that processes between 1500 and 2000 head of beef a day, a West Coast packing plant had a power factor that seldom got above 81%. Rebates on the plant's power bill were down to about $3 a month.

Power factor raised from 81% to 96%. Then G-E engineers recommended the installation of 60 kvar of G-E capacitors at a total cost of $355*. After the capacitors were installed the power factor rose to better than 96% and stayed there. Rebates on the power bill now average between $45 and $50 every month. Thus, in less than nine months, the company realized a saving greater than the cost of the capacitor equipment. *And these monthly savings will go on indefinitely.*

*Cost of capacitor equipment in 1949. Prices slightly higher now.

Capacitors can help in other ways, too! Besides raising power factor, capacitors often permit your present distribution system to carry 20 to 30% more load without added equipment. Where voltage drop is a problem, capacitors can also provide the needed voltage boost inexpensively.

They're the key to lower power costs. This West Coast plant is just one of the many that are cutting power costs with capacitors. If your power factor is below 85% and if there is a power-factor or kva-demand clause in your power contract, chances are you can make similar worth-while savings. Your local G-E sales office or authorized G-E agent or distributor can help you—or write to Section 407-207 for booklet GEA-5632—"How to Use Capacitors to Reduce Power Costs and Gain System Capacity." *General Electric Company, Schenectady 5, New York.*

GENERAL ELECTRIC

407-207

Chemical Progress

News of developments from General Electric's Chemical Division that can be important to your business.

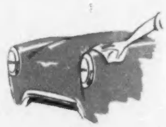
G-E CHEMICAL RESEARCH MAKES POSSIBLE
New Uses for Plastics

Development of G-E rubber-phenolic molding compounds widens use of plastics in applications requiring unusual strength and resilience.

Now General Electric chemical progress has greatly increased practical applications for plastics! G-E rubber-phenolics work successfully where other types of plastics often fail because rubber-phenolics have five to seven times the shock strength of conventional phenolic materials.

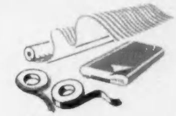
Typical of the new uses for G-E rubber-phenolics are the two dishwasher parts shown here. The silverware basket—formerly made of scarce brass—has the required strength and resilience to withstand dropped utensils and operating vibration. Like the impeller (see inset) it is resistant to hot water, strong detergents.

A few of the present uses for G-E rubber-phenolics include business machine parts, handles for heavy-duty machinery and bobbins for textile mills. Many more are sure to develop as industry takes advantage of this recent contribution of G-E chemical progress—other examples of which appear on this page.

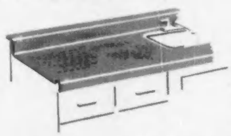


Shining example! The new non-oily, easier-spreading furniture and auto polishes made with G-E silicones show how products may be improved by utilizing the remarkable properties of this new family of materials.

G-E varnished fabrics and tapes, part of the G-E line of insulating materials, have extraordinary resistance to moisture and heat-aging, are proving valuable for many dielectric and insulating uses.



For more information about any of the G-E chemical products or processes described on this page, write to General Electric Company, Chemical Division, Pittsfield 12, Massachusetts.



G.E.'s revolutionary new Monotop work surface (the *one-piece* G-E Textolite* backsplash-counter top for kitchens and vanities) is the result of G-E molding skill plus research in superior resins and varnishes for laminating purposes.

PLASTICS COMPOUNDS • SILICONES • INSULATING MATERIALS • GLYPTAL® ALKYD RESINS • PLASTICS LAMINATING, MOLDING, AND EXTRUDING

*Reg. U. S. Pat. Off.

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GENERAL ELECTRIC