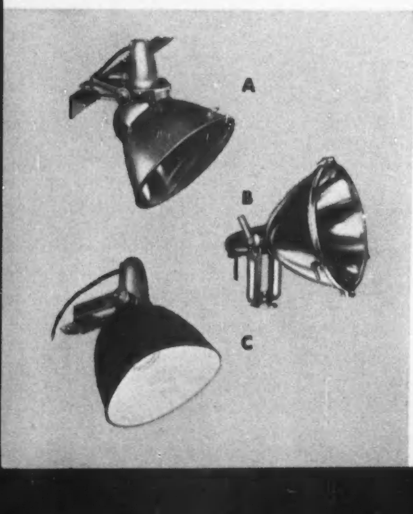
GENERAL ELECTRIC Review

JULY 1952

"DEAD STORAGE" AREA AT NIGHT . . . . . . TRANSFORMED INTO ACTIVE MARSHALLING YARD BY G-E OUTDOOR INDUSTRIAL LIGHTING

Small investment in G-E lighting doubles value of outdoor work areas

A LIGHT FOR EVERY NEED is available from G.E.'s full line, for example: **A** High efficiency, lightweight, easy-to-install area floodlight for crossarm mounting, with three beam spreads; **B** Heavy-duty, wide variety of mountings and beam spreads; **C** Inexpensive, open floodlight for closer-range illumination.



You can use your plant's outdoor areas just as efficiently at night as you do during the day by adding outdoor lighting. And the cost of this productive lighting is insignificant compared to your present investment in outdoor work areas.

SPEED UP MATERIALS HANDLING

Tighter production schedules, congested plant facilities, and many other factors make it necessary for you to handle raw materials, parts, and products at night. With 'round-the-clock "daytime" provided by G-E outdoor lighting, fast, efficient materials handling is made possible, with a minimum of mistakes or damage. In the plant pictured you can see how an area, almost useless in the dark, became a productive asset.

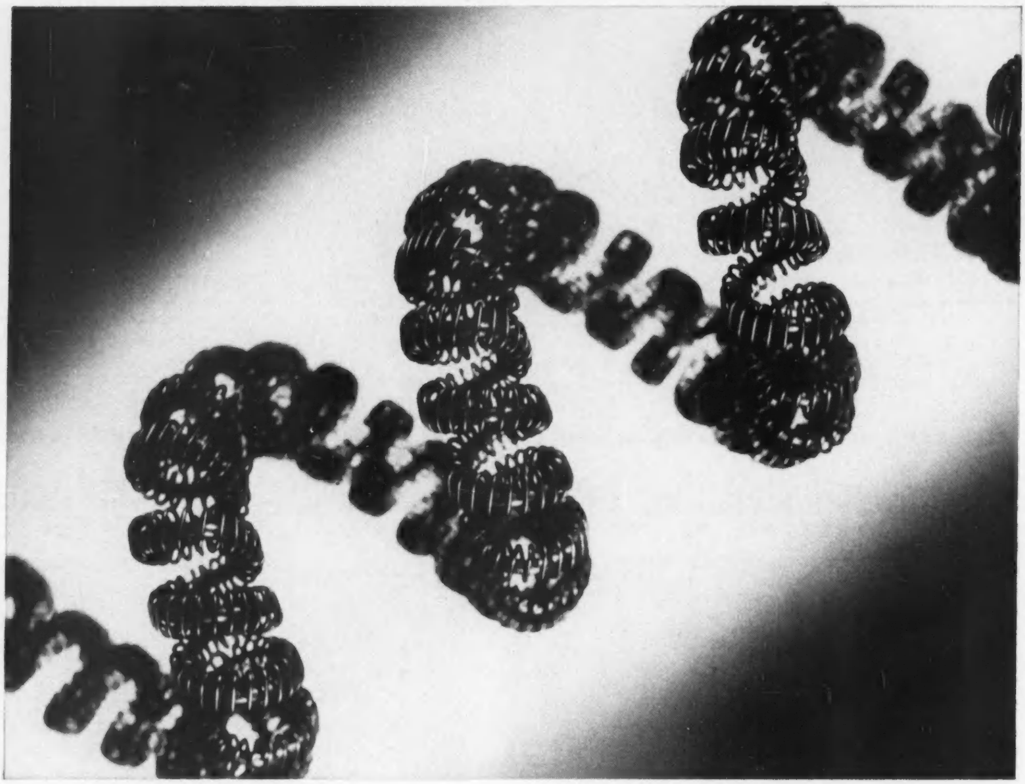
PROTECT PERSONNEL, PLANT PROPERTY

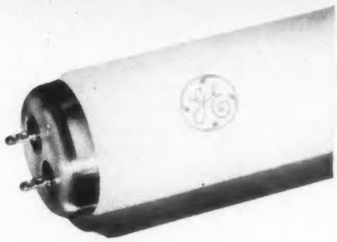
The right outdoor lighting can pay big dividends in preventing accidents, pilfering and sabotage. But it is important to get lighting that serves your needs best—money spent on inadequate lighting is often wasted. To get more information on General Electric's full line of outdoor lighting for industrial plants, write for bulletin GEA-3640, to *Section 451-172, General Electric Company, Schenectady 5, N. Y.*

OUTDOOR INDUSTRIAL LIGHTING

GENERAL ELECTRIC

New G-E fluorescent lamp starts fast, needs no starter





THE TRIPLE COIL filament developed by G.E., and shown greatly magnified above, now helps make possible another great new fluorescent lamp.

It's the *G-E Rapid Start* fluorescent lamp. Used with another new General Electric development, the *G-E Rapid Start* ballast, it starts almost instantly, gives smooth, simple operation. There's no starter needed, so maintenance is easier and more economical.

General Electric Rapid Start fluorescent lamps and ballasts will be available soon. These two newest developments of General Electric research are another reason why you can *expect* the best value from G-E fluorescent lamps.

You can put your confidence in—

GENERAL ELECTRIC

JULY 1952 • VOLUME 55 • NUMBER 4

GENERAL ELECTRIC Review

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

COVER—In the control building of the new Switchgear Development Laboratory in Philadelphia (story begins on page 7), engineers check over test results on oscillograph films while a control operator looks over a test setup in the high-voltage test yard. Photo by George Burns.

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 FOURTH OF JULY

When we were kids the Fourth of July was the big bang. We slept out in the barn the night of the third with our stock of precious firecrackers that had been built up during the preceding weeks—a quarter's worth carefully selected to produce the loudest noise. Up at three, by six in the morning we were already tired out. But still ahead of us was the big day with the morning parade, the picnic at noon, the patriotic speeches in the afternoon, and the band. Then at night there was the great fireworks' display where in unison we all joined in the chorus of ahs and ohs. We went to bed tired out; we had celebrated the birth of our nation. It was a great day.

But next morning the papers carried the casualty lists. There were burned fingers and arms and bodies; there was lockjaw; there was blindness. Today the firecrackers are no more. The bang has gone out of the Fourth of July.

But the foundation principles of our nation live on. After "the shot heard round the world," these principles were forged for us, in the white heat of The unanimous Declaration of the thirteen united States of America, in Congress, July 4, 1776; burning words which read in part:

> "......we hold these truths to be self-evident: That all men are created equal; that they are endowed by their Creator with certain inalienable rights; that among these are life, liberty, and the pursuit of happiness; that, to secure these rights, governments are instituted among men, deriving their just powers from the consent of the governed, ..."

Eleven years later, September 17, 1787, the Constitution of the United States of America was wrought on the foundation of these basic truths, and on April 30, 1789, George Washington was inaugurated the first President of the United States.

But nearly a hundred years later there was a great threat to our nation, and we find Abraham Lincoln at Gettysburg, November 19, 1863, dedicating the national cemetery following the battle of Gettysburg, July 1 to 3, 1863. Again we hear of these truths:

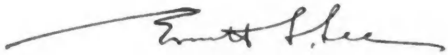
> "Four score and seven years ago our fathers brought forth on this continent a new nation, conceived in liberty, and dedicated to the proposition that all men are created equal ......It is rather for us to be here dedicated to the great task remaining before us: ......that we here highly resolve that these dead shall not have died in vain; that this nation, under God, shall have a new birth of freedom; and that government of the people, by the people, for the people, shall not perish from the earth."

And now, on this Fourth of July nearly another hundred years later, we find our nation in a position of world leadership. It has endured. These truths do live.

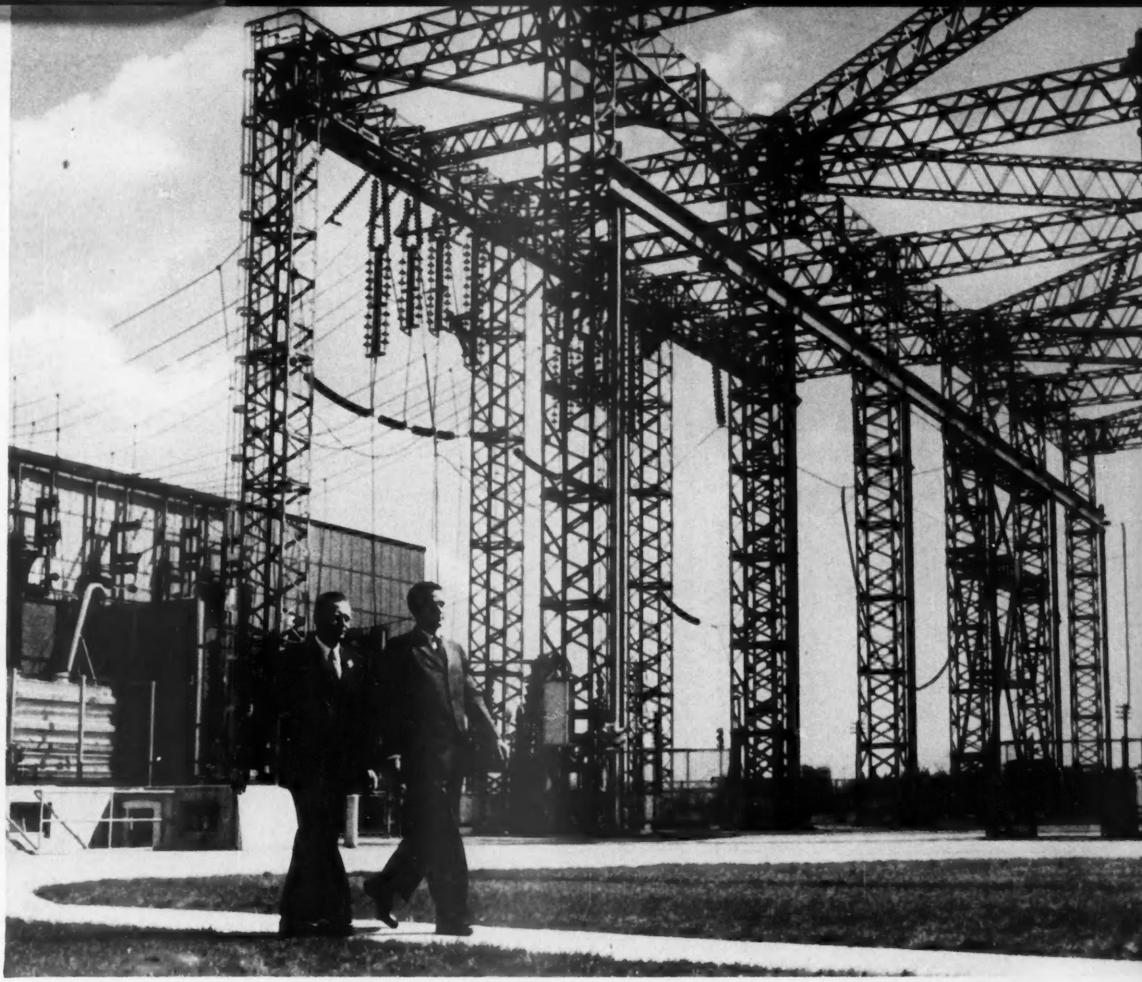
We look back to the days of George Washington. They were days of many problems—national and international. They were days of discouragements. They were days of disagreements. They were days of privation. And yet, through vision and wisdom and courage and the will to succeed, they were days of victory.

We look back to the days of Abraham Lincoln. They were days of many problems—national and international. They were days of discouragements. They were days of disagreements. They were days of privation. And yet, through vision and wisdom and courage and the will to succeed, they were days of victory.

Today we have many problems—national and international. There are many discouragements. There are many disagreements. There is even privation. But there are also many good things for which we can be thankful. And through vision and wisdom and courage and the will to succeed, there will be the victory. This is the bang that we can put into the Fourth of July.



EDITOR



YOUR HOSTS FOR THE NEXT SIX PAGES WILL BE V. L. COX *(LEFT)* AND L. R. GATY. THEY'LL TAKE YOU ON A PICTURE TOUR AS A . . .

New Switchgear Laboratory Goes into Operation

Review STAFF REPORT

Late last month on the flatlands of southwest Philadelphia, General Electric's new high-capacity switchgear development laboratory was officially dedicated.

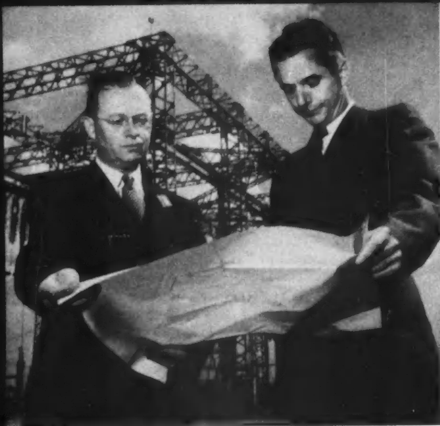
With Company spokesmen looking ahead to an annual U.S. power consumption of possibly a trillion kw-hrs by 1965—more than triple the amount now being used—the new laboratory will aid in the development of switchgear of higher ratings to keep pace with this phenomenal growth.

Before the dedication, and while construction was being finished and early testing was taking place, a cameraman and a REVIEW editor went on a tour of the new facilities with V. L. Cox, Manager of Engineering of GE's Switchgear Department in Philadelphia, and L. R. Gaty, chairman of the EEI-AEIC-NEMA joint committee on power circuit breakers, and Manager of Engineering of the Philadelphia Electric Co.

Since the installation of the first switchgear testing laboratory in Schenectady in 1921 and the second in 1928, Cox told the REVIEW that about 300,000 tests have been made either to improve designs or to develop better interrupting techniques. With this new laboratory, he stated, more tests can be made in a given time with a subsequent speed-up of development projects.

Your tour with your two hosts begins on the next page . . .

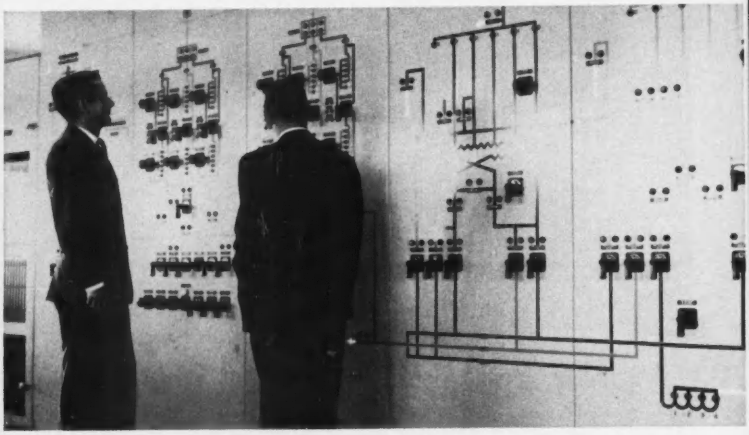
(Technical highlights of the switchgear development laboratory will be presented in the next issue of the REVIEW.)



1 Standing near the high-yard, Cox *(left)* and Gaty check their route. Their starting point will be the . . .

2 Master control benchboard in the control building. All testing operations are controlled from this point. Microphones tie operators into a two-way public-address system that covers outdoor and indoor areas

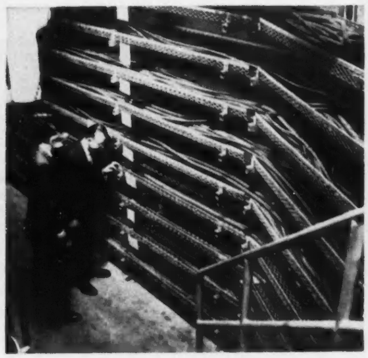
3 Test engineers act as control operators and help set up various tests. In background is the . . .



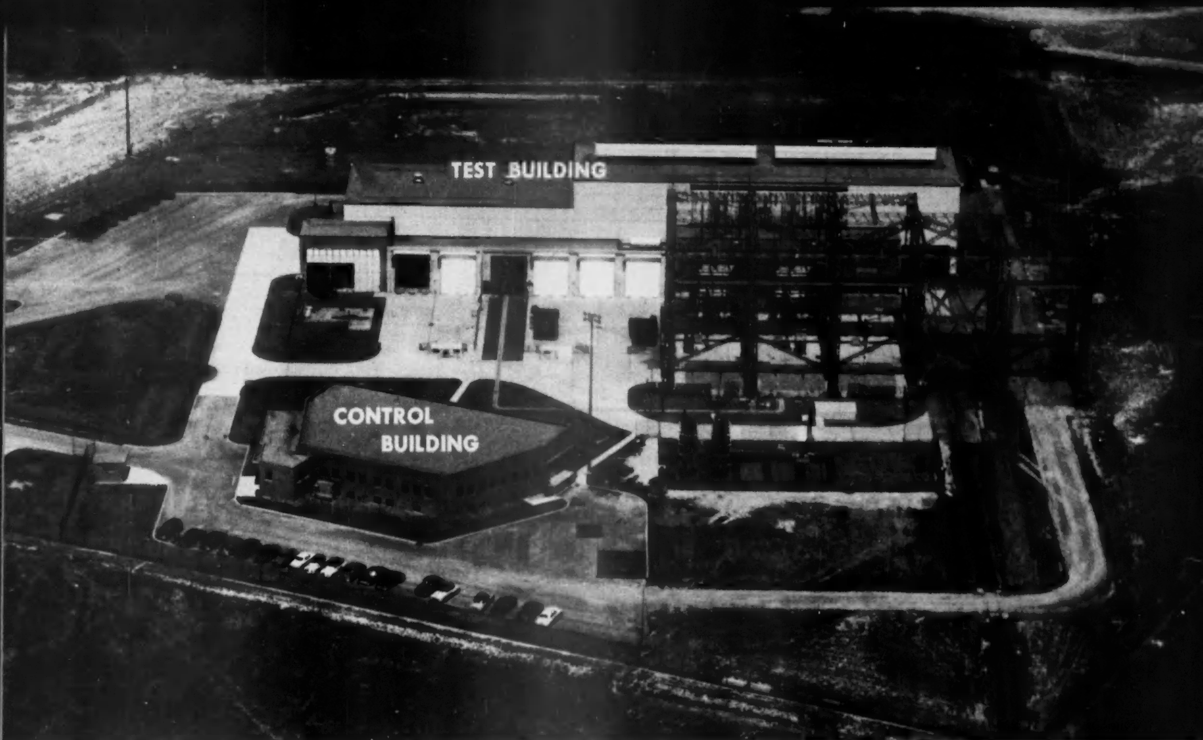
4 Switchboard where power circuits for tests are set up. Mimic bus diagram and lights help engineer visualize circuit as he sets it up by operating the control switches on the board. One-line diagram is in color on face of switchboard

5 Sequence and time intervals of steps in a test are set up on a program selector to energize . . .

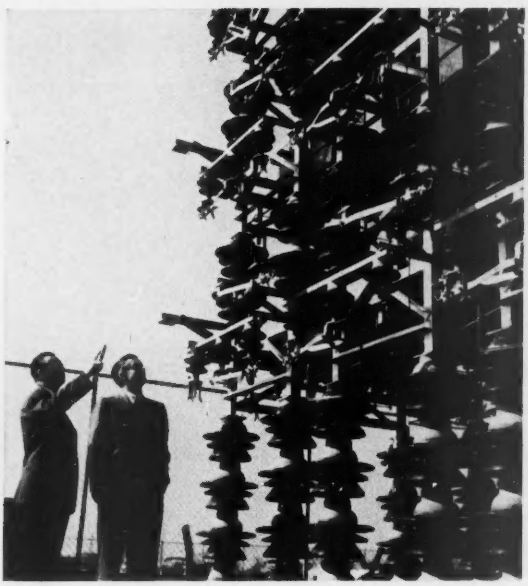
6 Testing circuits from this drum timer—90 contacts in succession at one-cycle intervals



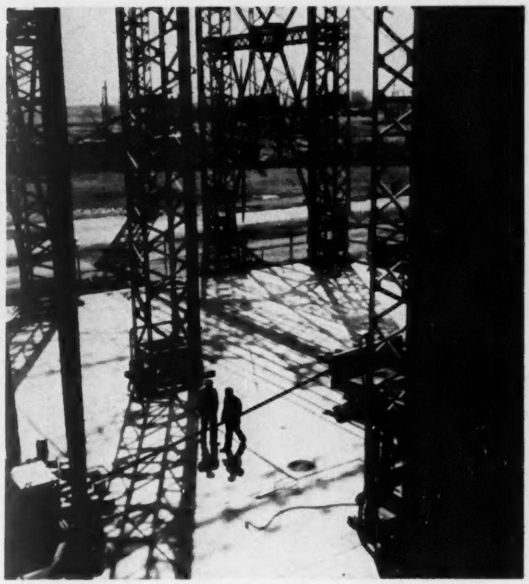
7 Tunnel connects control and test buildings. Trays on either side carry all control cables



ON 20 ACRES IN SOUTHWEST PHILADELPHIA, GE'S NEW SWITCHGEAR LABORATORY GOES TO WORK FOR AMERICA'S ELECTRICAL FUTURE

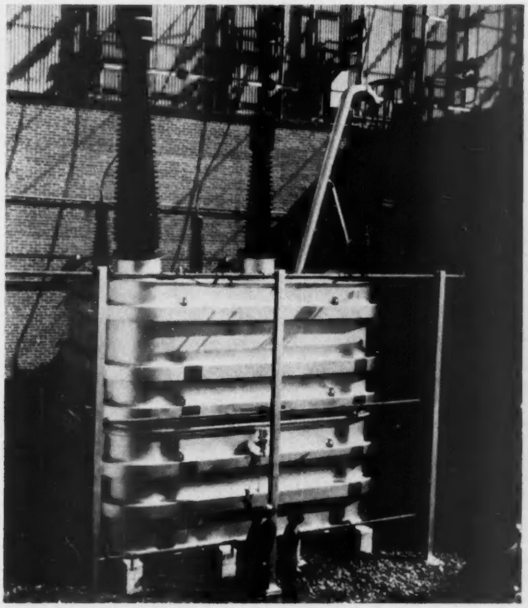


8 This 10,800-kva capacitor bank—one of two at the switchgear development laboratory—simulates charging currents equivalent to that of hundreds of miles of transmission lines



9 Large power circuit breakers up to 440-kv can be tested in the high-voltage test yard. This yard and all test cells can be brightly illuminated to facilitate night testing

10 Stretching across the foreground is the blade arm of one of the two five-position transformer tap selector switches. Motor-driven, they are operated from the control building to select the desired transformer tap

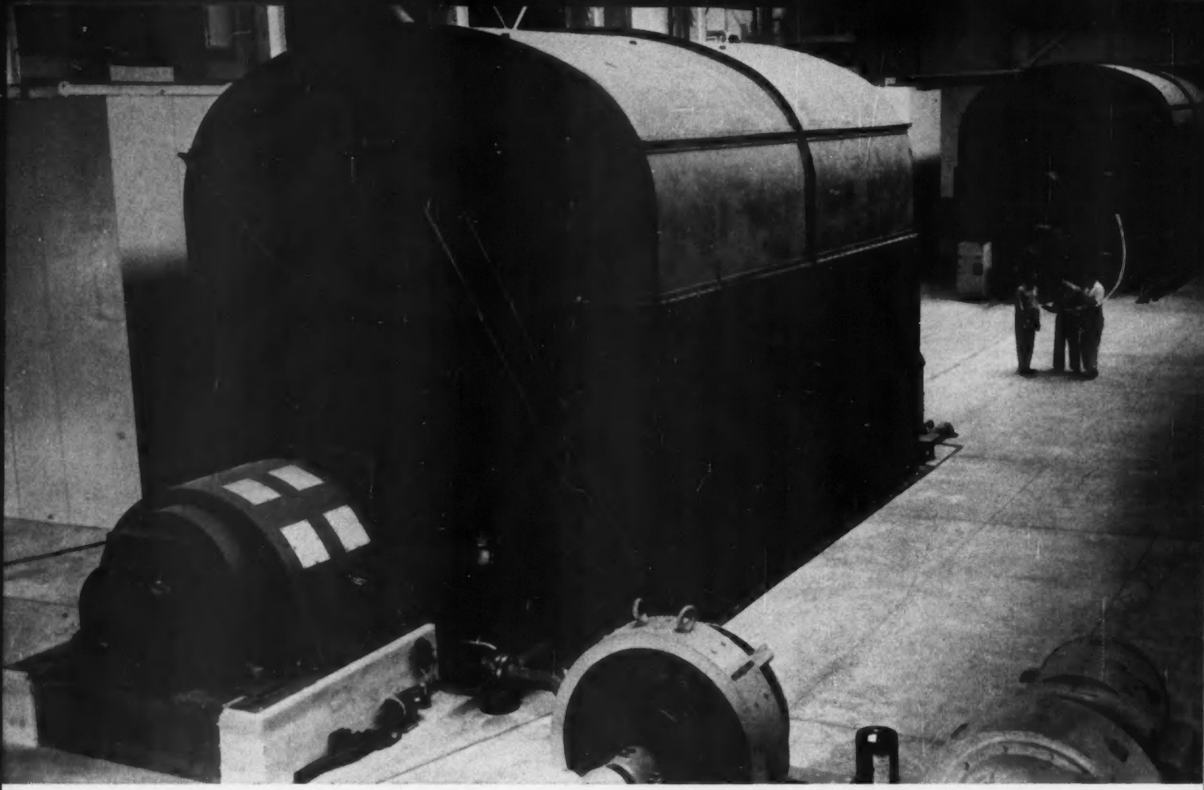


11 Two 100,000-kva single-phase power transformers supply test power up to 440-kv single phase, 220-kv three phase. They have low reactance to give maximum short-circuit kva

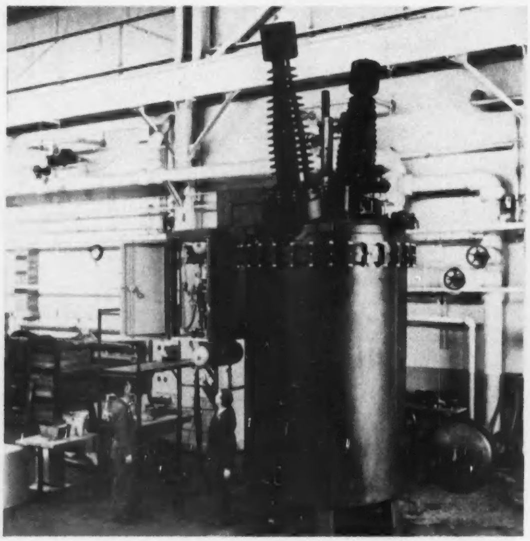
12 In the test building, two cathode-ray oscillographs record transient phenomena—in millionths of a second—far too rapid to be picked up by magnetic oscillographs

13 Connections from generator to test cells and power transformers are made with isolated-phase bus runs of conventional design but braced for high momentary current

14 Power for driving motors of the testing generators goes through this 4.16-kv metal-clad switchgear in test building. Substation in background is for auxiliary services



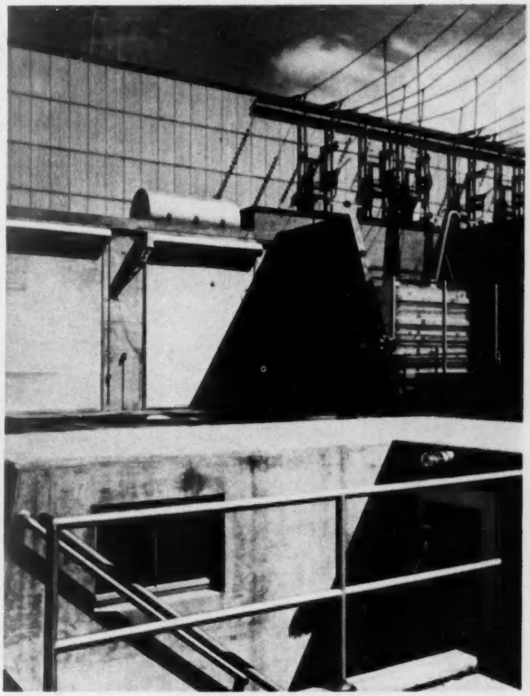
15 These generators supply the highest short-circuit current available in any laboratory. Together they can deliver at the test bus an asymmetrical three-phase short circuit of 5,250,000-kva (3,200,000-kva symmetrical) at 15.5-kv



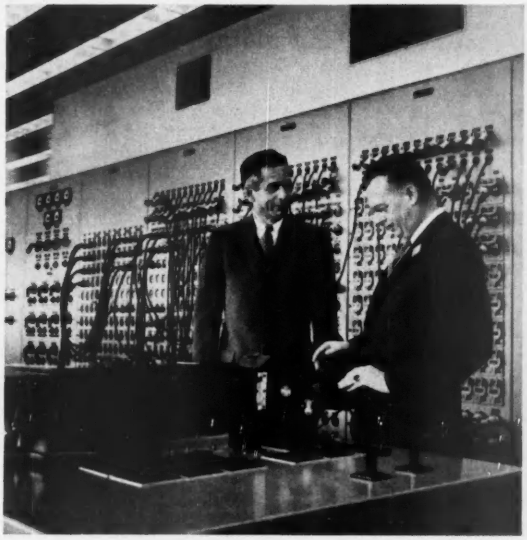
16 In the assembly shop of the test building, apparatus is prepared for test. After the equipment is assembled on a test car, it is taken to a test cell or the high-voltage yard

17 Into one of the five test cells in front of the test building goes a circuit-breaker equipment on its test car. Before it was moved to the cell it went through a "dry-run"

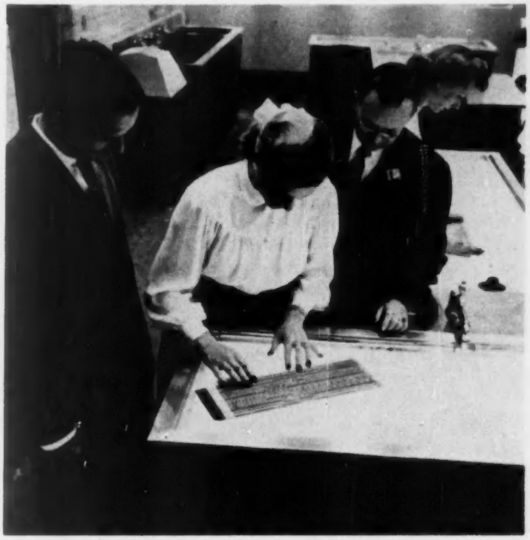
18 Disconnecting devices on the test car engage with the de-energized generator bus in the test cell



19 For safety in emergencies, observer in bombproof shelter can instantly halt a test and de-energize all circuits



20 Back in the control building, Gaty and Cox examine one of the six magnetic oscillographs used for recording test results. Test connections are made on the plug board



21 Two minutes after a test, the still-wet oscillograph films are checked on a "wet" reading table. Essential calculations are made to guide in setting up the next test

Engineering the *Automatic* Washer

By CARL F. SCOTT

The automatic clothes washer is a simple device—to the housewife. She throws in the laundry, sets a control dial, and goes about her telephoning. A short time later she removes the laundry—washed and damp-dried.

Simply stated, the function of a domestic washing machine is to get the laundry clean, rinse out the detergent, and extract most of the water. For a third of the century these operations were performed with a machine in which the laundry was manually lifted from the tub and fed through a water-extraction device. Most of these devices were wringers, powered by the washing-machine motor. A limited number were the centrifugal-extraction type using the same or a separate tub.

A designer of an automatic washer not only has to design a complicated piece of portable machinery, he also has to design against user abuse. True, an electric refrigerator is also an automatic appliance, but it's difficult for a buyer to bully a refrigerator. You can leave the door open, overcrowd the shelves, and place the cabinet too close to the back wall, for the refrigerator is designed to operate year in and year out in temperatures as high as 100 F under these or any less severe conditions.

Not so with an automatic washer! The tub can be jammed too full of clothes; too much, too little, or the wrong kind of detergent can be used. The water supply can be hard, not hot enough, or insufficient. Washing results may vary widely, and some stains won't come out in *any* washing machine. The designer does provide safety against overloading—a fuse will blow before the motor burns out or a part breaks. But that's about the extent to which the designer can protect the machine.

Tumbling or Agitation?

Clothes can be washed with some degree of effectiveness simply by tumbling them in a basket that rotates about a horizontal axis. The basket is enclosed in a tub partially filled with water. The basket can then be rotated at a higher speed to extract part of the water from the clothes, while the water in the tub is pumped out. A combined washing and water-extraction cycle of this sort involves a simple gear-change set.

But since the oscillating-agitator motion used throughout the years has given superior results, we took the more difficult task of combining on one shaft mechanisms that would provide for the oscillating agitator motion and spinning the basket at high speed.

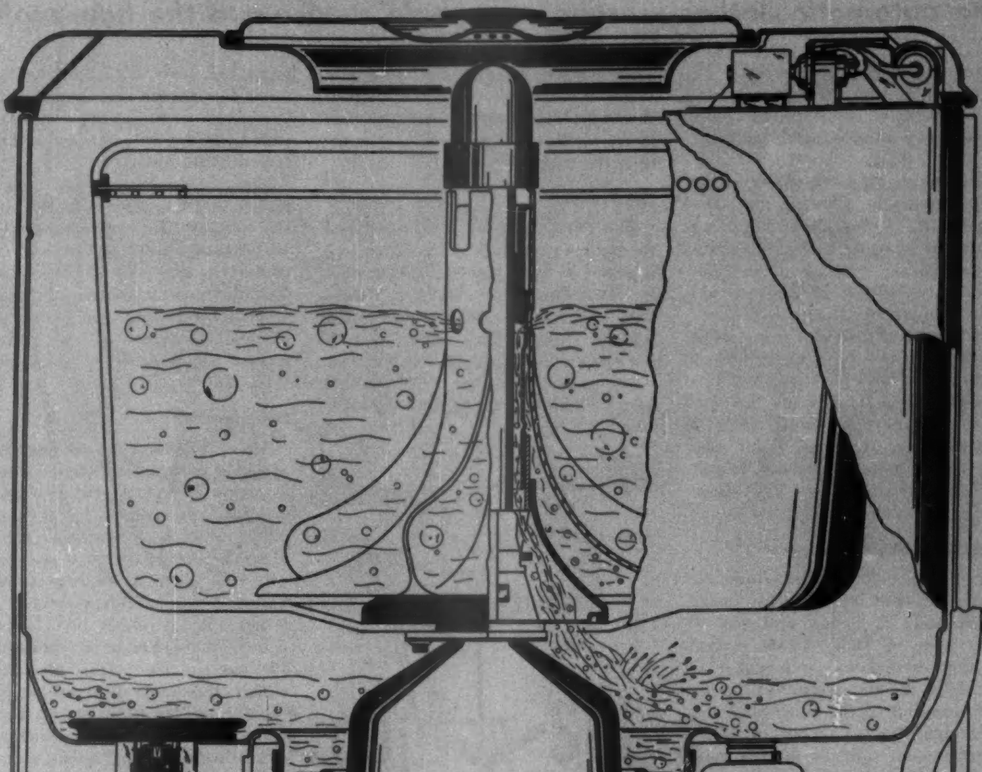
Balancing Is a Problem

It's one thing to build a basket that will be in balance when empty—it's another to provide for the effect of unbalanced distribution of the laundry. A typical load may cause a four to five pound unbalance. In a 21-inch basket, spinning at 650 rpm, this unbalance would produce a side thrust of around 600 pounds. The water itself which is in the basket at the start of the spinning operation has considerable flywheel effect.

This problem was circumvented, so to speak, by using a basket much heavier than the weight of the laundry (an

•

Forty years ago this past May, the REVIEW *published Mr. Scott's first article, "The Control of Electrically Driven Rotary Newspaper Presses." At General Electric in Bridgeport, he is at present Assistant to the Manager of the Engineering Department, Major Appliance Division.*



ONE BELT DRIVES THE GEAR-REDUCTION UNIT FOR AGITATING ACTION, THE OTHER DRIVES THE BASKET DIRECTLY FOR SPIN DRYING average nine-pound load weighs 27 pounds soaking wet), thereby minimizing the unbalance. The 70-pound basket is formed from a single steel blank more than ¼-inch thick.

The structure supporting the rotating basket is movable, allowing for some displacement. The machine won't creep because it's hung on springs that provide mechanical damping of the displacement, as shown in the sectional view on the preceding page.

You may wonder at this point about the water that is present in the basket. Couldn't it be used for balancing? Undoubtedly it could. This method has been sought for over 50 years by builders of centrifugal extractors. Right now there are a number of patents in this field, and probably some day water-balancing will come into general use.

Reversible Drive Motor

Current models of the automatic washer are built in a square casing approximately 27 inches wide and 36 inches high. A ⅓-hp 4-pole vertical induction drive-motor is mounted to one side of the *main-shaft*. On the upward extension of the *motor-shaft* two overrunning clutches are located. When the drive-motor turns in the clockwise direction, one is brought into place and the other is kept from operating. An automatic control reverses the drive-motor at the proper moment and causes the other clutch to be engaged. These clutches are called the *activate-clutch* and *spin-clutch* because they transmit power that activates the agitator or spins the basket. Power is transmitted by means of two belts: one driving the gear-reduction unit for agitating action; the other driving the basket directly.

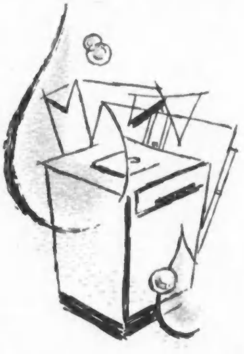
Incidentally, gradual acceleration of the basket from rest to full speed of 650 rpm is accomplished through a hydraulically operated torque-controlled clutch. This is necessary because the motor is up to speed at the beginning of the spin-cycle.

A drain-pump located farther up the motor-shaft is so designed that for clockwise rotation it delivers no head—actually the head is slightly negative. Counterclockwise rotation drains the tub.

The agitator sweeps through an angle of 202 degrees, approximately 68 times a minute—which is nearly ideal washing action. Positive oil circulation is provided by a built-in pump, the upper part of the crankcase being cooled by water from the outer tub.

The Process

The top-opening lid is removed and the clothes inserted. A suitable detergent is placed in the receptacle and the control turned on. Then begins a process that is the result of engineering a rather intricate system. If it's desired to soak the clothes, turn the control to the SOAK position; if not, to the WASH position (the wash-cycle is adjustable from three



to fifteen minutes in length). Without going into details the following things happen: 1) water is admitted through solenoid-operated valves, mixed to a temperature indicated on the temperature-setting dial; 2) the water rises in the basket until a port in the agitator hub is reached—excess water drains via the port to the surrounding tub and operates a pressure-switch that in turn starts the agitator going; 3) next, the spin-cycle begins, and the wash-water drawn off by centrifugal extraction is pumped out; 4) then, the solenoid-operated valves admit rinsing-water, the excess rinsing-water activates the agitator, and the spin-cycle is repeated; 5) the clothes now washed and damp-dry, the motor shuts off automatically. This automatic sequence of operation is controlled by a motor-driven timer whose electrical contacts control the drive-motor and solenoid-operated valves.

Laundry capacity of the machine is nine pounds, requiring 17 gallons of water for each fill. To economize on water for smaller amounts of laundry the height of the overflow port can be varied. The lower limit obtained by this feature is 10 gallons.

Many housewives operate under the notion that the more suds the cleaner the laundry. To compensate for this mistaken idea there is a *suds-kill* pause that occurs after the first excess of water is spun from the basket following the wash-cycle. During the pause—about one minute—most of the suds are pumped down the drain. This prevents "suds-lock."

Detergents

Many of the washing compounds now available are combinations of soap and synthetic detergents, and they present a definite problem to the designer of automatic washers. Synthetic detergents characteristically decrease surface tension and increase emulsifying effect. They also tend to soften water.

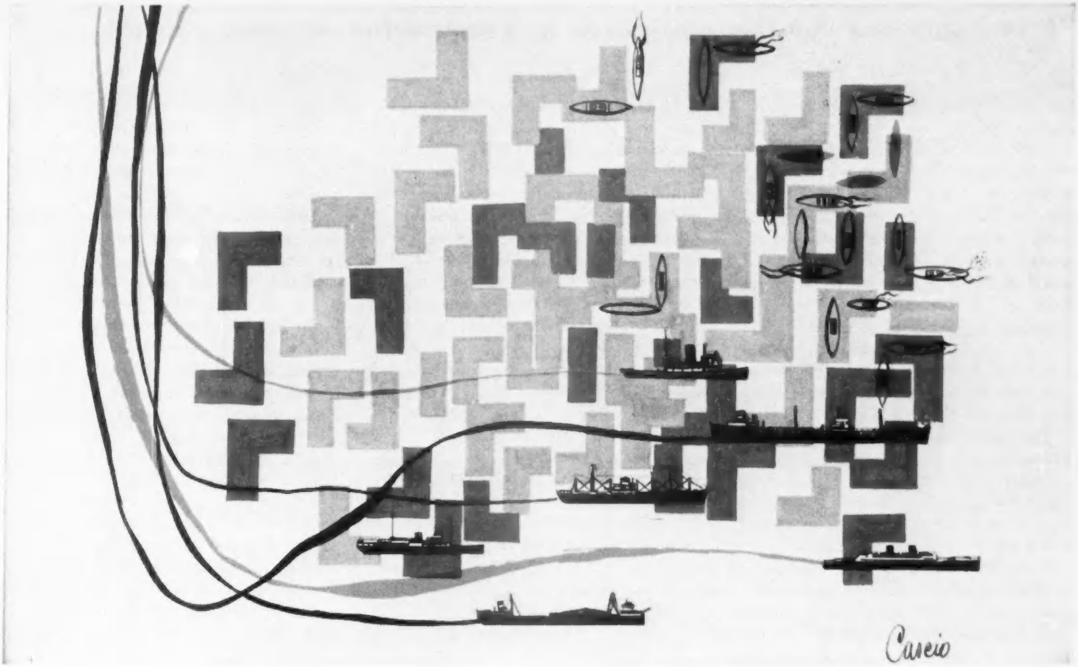
The rate at which these synthetic detergents attack materials varies widely. Platings and die-castings of zinc, and certain aluminum alloys are subject to rapid attack. Natural soaps, on the other hand, tend to leave a film which serves as a protective coating against corrosion.

You might wonder why a washing-machine manufacturer doesn't market a compound of his own along with the machine. From the practical standpoint of consumers buying habits this won't work. However, the soap industry has, on the whole, made suitable detergents available.

Yardstick

The nearest approach to a generally acceptable yardstick of washing effectiveness (which is what counts) is a procedure recommended by the engineering committee of the American Home Laundry Manufacturers Assn.

In this procedure pieces of white cotton cloth are dirtied with a soil of specified composition. After washing, the samples are placed in a reflectometer where the amount of light reflected from their surface is compared with the reflection from the original samples. Though this is the best-suited method so far, it's not regarded as ideal. New techniques for gauging washing effectiveness are still being sought.



Stopping Ships

By H. J. CHASE and A. L. RUIZ

Even with modern navigating and communication aids there are times when things get out of hand and a collision of ships appears imminent. The need for meeting this situation—rare though it may be—has an influence on the design of ships' power plants.

Most large and fast ships are powered by a steam turbine that drives the propeller through suitable gearing and shafting. The *astern* power that is used for stopping a ship is provided by a comparatively small separate section of the main turbine. The question immediately arises as to why the astern element can't be given the same power as the ahead element. Well, it can. The simplest arrangement would be another turbine of the same size geared to drive the propeller backwards.

Because backing power isn't needed as often as ahead power, it wouldn't be economical to provide too large an astern unit with all its additional weight, space, and equipment. Also, friction and windage losses increase with the size of the astern element because it is driven backwards during normal ahead operation. So, for these and other reasons, the smaller the astern element is the better, as long as it can stop the ship when necessary. In current practice a compromise has been reached. An astern turbine designed to deliver an astern torque of 80 percent of the rated ahead torque at an astern speed of 50 percent of the rated ahead speed has proved to be an economical and simple installation.

When the authors were with General Electric's Federal and Marine Engineering Division in Schenectady, they received the Captain Joseph H. Linnard Prize, one of the highest awards conferred by the Society of Naval Architects and Marine Engineers. This was in recognition of a paper formulating a new basis for rating astern turbines. At present Mr. Chase is a marine engineer, Turbine Division, and Mr. Ruiz is with the advanced development section, Aeronautics and Ordnance Systems.

In designing a power plant the engineer must analyze its ability to stop a ship. But to make such a study he must get special solutions to problems that involve characteristics of the ship and its power plant. Torques acting on the propeller-gear-turbine system, the momentum of the ship, and its own resistance in the water are prime factors.

The torques in the rotating system are shown in Fig. 1. The turbine torque for fixed steam conditions and steam flow depends on propeller speed. The propeller torque depends on both propeller and ship speeds while an allowance must be made for friction torque due to shaft bearings and stern tube. The sum of these torques must be in balance with the rate of change of angular momentum of the system.

The forces acting on the ship are the propeller thrust and the ship's resistance as shown in Fig. 2. The propeller thrust depends on both propeller and ship speeds, while the ship's resistance opposes its motion and depends on ship speed alone. The sum of these forces must be in balance with the rate of change of the ship's momentum.

From these balances of torques and forces are derived the basic differential equations that define the motions of the propeller and the ship.

These equations involve experimental functions and we can't solve them by ordinary methods. Numerical solutions can be obtained by laborious step-by-step computations if the experimental functions are available after tests.

A much easier way to obtain solutions as families of curves is by mechanical means, such as a differential analyzer. The solutions obtained will give us the ship and propeller velocities as functions of time. But for practical purposes, a more useful result is the predicted "head reach"—the distance traveled while the ship comes to a stop. This result may be obtained from the ship's velocity curve.

Even though the arrangement and solution of the equations is straightforward, the development of the experimental functions that describe the interactions of the propeller, hull, and water under the transient conditions involved presents more of a problem.

Operations Are Expensive

Information for the experimental functions comes mainly from tests on models. Occasionally checks are made on full-size ships, a project that usually turns out to be a big undertaking. While the time consumed in the actual testing is not too great, it is expensive to operate the ship, and the preparations required are extensive. This was apparent to the authors who were included in tests of this type on a large tanker. The design, construction, and installation of the special equipment, as well as the detailed planning and scheduling, took three to four months. The six reversing tests took only three hours but required the services of 12 men in addition to the ship's regular crew. To analyze the results and put them in useful form took three men a total of six months.

Information on the thrust of the propeller was obtained from these tests. Although the propeller thrust appeared as loading on the main thrust bearing, it wasn't necessarily the actual thrust force exerted on the ship. The effect of the ship's wake was the disturbing factor. The stern propeller causes variations in the flow paths of the water, that may appear as unknown forces acting on the hull (Fig. 3). As the water flows past the stern it may create a suction that tends to pull the ship back. The effect may be considered as an increase in ship's resistance and is called "resistance augment" by some authorities. Or, it may be treated as a decrease in propeller thrust and is sometimes called "thrust deduction." Regardless of what it is called we can determine the effect only by an accurate measurement of the actual force moving the hull. For this we must resort to model testing.

Torque Measurement Is Direct

Determination of the torques in the system is easier. Turbine torque can be determined from design data and factory tests. Propeller torque can be determined from model and full-scale tests. The measurement is direct—the only modifications necessary are for the effects of inertia during speed change and for bearing friction. Usually both are small. The moment of inertia is easily calculated from the dimensions of the rotating system, and bearing friction can be estimated closely.

Typical propeller-torque curves are shown in Fig. 4. Actually, these are part of a whole family of curves for different ship speeds. A turbine-torque curve is also shown in Fig. 4.

Ship's resistance is usually determined from model tests. It can also be calculated from data taken during full-scale ship tests when steam to the turbines is shut off and the ship is allowed to coast to a stop.

With the experimental functions determined, the equations can be solved by mechanical means. As an example of the results that will be obtained, Fig. 5 shows both test and computed ship-speed curves for a stopping maneuver. In addition, the test data for the propeller speed, torque, and thrust are plotted to show their relationship during the time of stopping. These computations and also the tests were made on a typical large tanker.

Because an extensive analysis of reversing stops is a time-consuming project, and because in a design study there are many possible variables to consider, it is desirable to have some handy means for making preliminary estimates. You'll note that Fig. 5 shows that during the greater part of the stopping time the propeller torque and thrust are reasonably constant, particularly as the ship slows down to a stop or is "dead in the water." We can take advantage of this fact and construct a chart (Fig. 6) that will give fairly accurate solutions for head reach in terms of designed turbine torques, initial ship speed, and ship characteristics. The variables have been grouped in combinations that are customarily used in marine engineering work.

Stopping Abilities Vary

As an illustration of the effect of vessel type and speed on her ability to stop, Fig. 7 was drawn based on Fig. 6 but modified by test data available from each type of vessel. To show the effect of the underwater form of the vessel's hull, a number representing the full-speed resistance divided by the midship cross-section area was assigned to each vessel. All three curves are drawn with the same ratio of astern torque to ahead torque. These curves, however, show a great difference in the stopping ability of a ship that is quite aside from the astern torque capability designed into the power plant.

By using methods such as those outlined here, it is possible to determine the characteristics of an astern turbine that will deliver any specified performance. On the other hand, for a given vessel with a given design of astern turbine, predictions can be made of its stopping ability.

It is particularly important for the navigator to know what his ship can be expected to do in any emergencies. Knowledge of "head reaches" for various speeds, for instance, will help him decide how fast it is safe to go when visibility is limited.

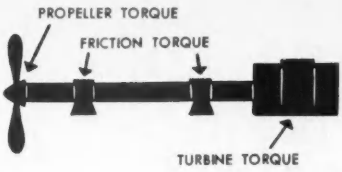


FIG. 1. TORQUES IN THE ROTATING SYSTEM

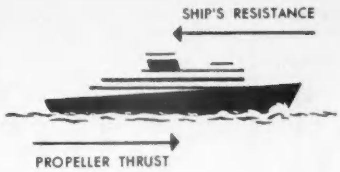


FIG. 2. FORCES ACTING ON THE SHIP

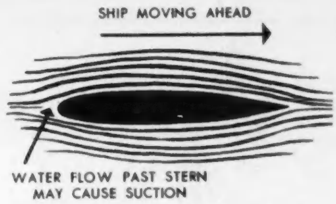


FIG. 3. FLOW PATHS AROUND THE SHIP

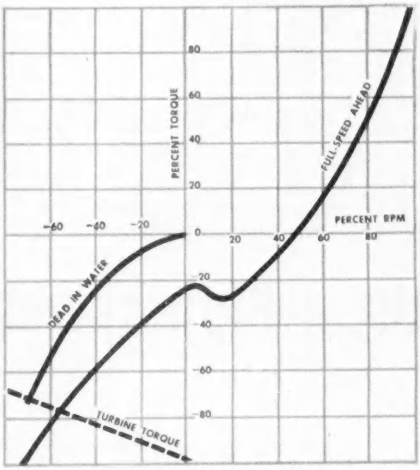


FIG. 4. TYPICAL PROPELLER AND TURBINE TORQUES

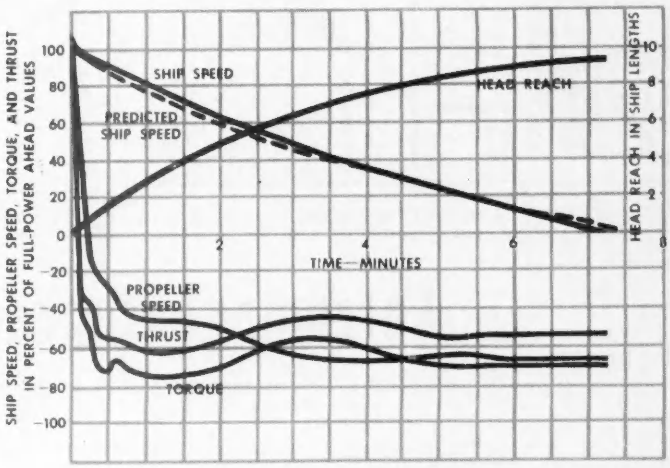


FIG. 5. SHIP-SPEED CURVES FOR A STOPPING MANEUVER ON A TANKER

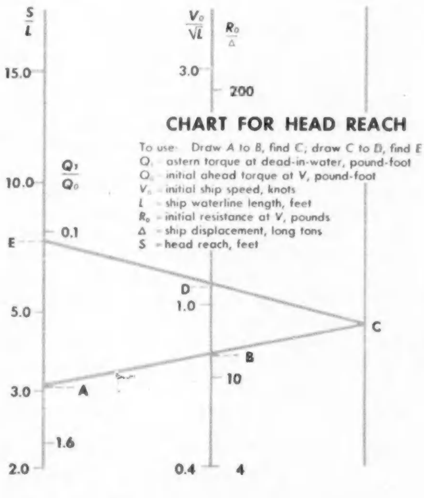


FIG. 6. CHART FOR DETERMINING HEAD REACH

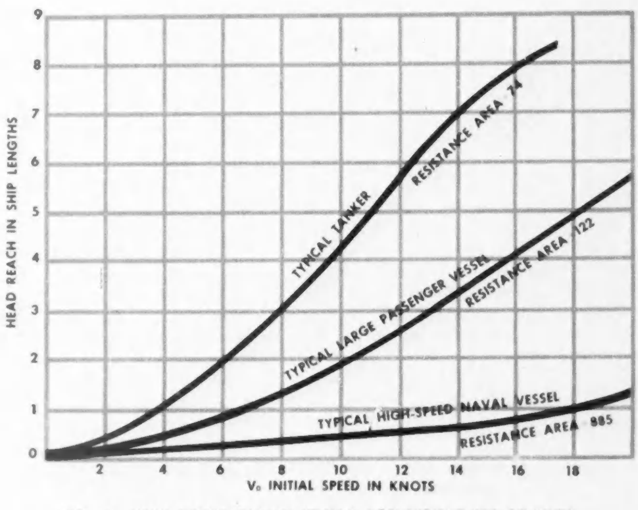


FIG. 7. HEAD REACH IN SHIP LENGTHS FOR THREE TYPES OF SHIPS

1 Johann Gutenberg's printing methods have been improved over the years to keep abreast of the times. But . . .

2 High-speed data-handling machines with big outputs make for new printing problems. A solution may be . . .

Ferromagnetography — High-speed

By T. M. BERRY and J. P. HANNA

Contrary to general belief printing did not originate with Gutenberg; to the ancient Chinese belongs the credit. They made engravings—used mainly for printing on silk cloth—by carving figures out of wooden blocks. Later, around 1120 BC, they introduced wooden blocks of movable type.

Modern printing, on the other hand, began in the middle ages—about the year 1423. It was during this period that Johann Gutenberg, a German stonemason, had the idea of printing with movable type. So he set about his skill, cutting alphabets out of small wooden blocks to be used for typesetting. A friend advised him to use metal instead of wood, since it wouldn't wear out so easily. This he did. As you can imagine, this task required many years and a large expenditure of money. He financed his operations by borrowing money on the type he'd already completed. Then, to prove to his creditors and the many cynics the worth of his efforts, he completely reproduced the Bible in print.

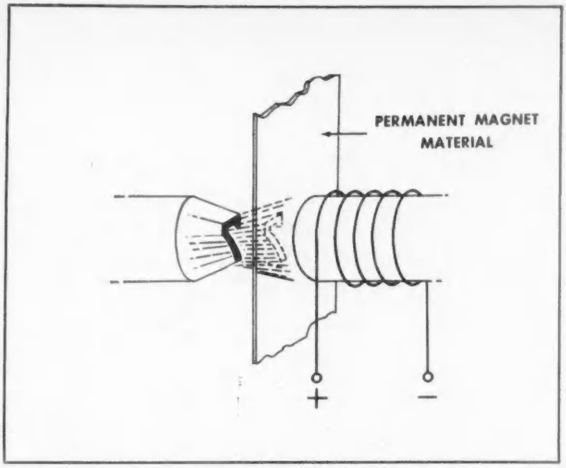
We've come a long way since that time, and the graphic arts have always managed to keep abreast of the needs of business and industry; that is, until the high-speed electronic computing machine came along. That presented a new problem. Business demanded a machine that would solve its problems with the same speed that a digital computer solved the problems of a scientist. But there was this added complication: many of the problems of business, particularly in the field of accounting, involve not only the processing of large amounts of information but also the output of relatively large amounts of printed matter showing the results. Digital computer techniques could be adapted to the solution of such problems only if faster printing techniques could be developed to keep pace with electronic computations.

This leads us to General Electric's development of "ferromagnetography," a new and basic principle in printing. This is a method through which the printed and written text and pictures are reproduced by: 1) forming magnetic images on thin sheets of permanent-magnetic material; 2) making these images visible by the deposition of tiny ferromagnetic particles; 3) transferring these particles to a medium such as paper. These steps are analogous to plate-making, inking, and printing in the graphic arts.

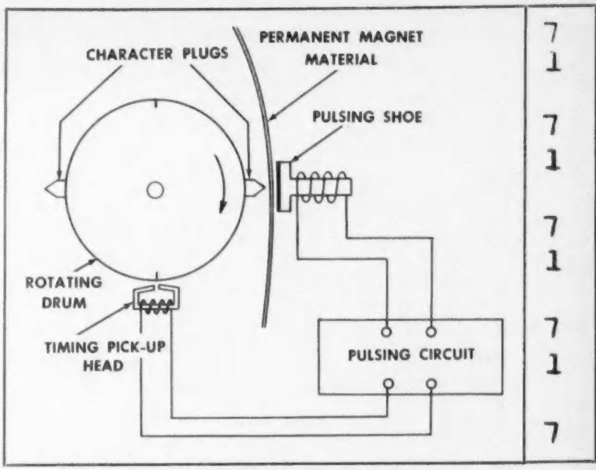
How It's Done

Permanent-magnetic materials retain magnetism only in the regions where they have been exposed to a magnetic field. The retained magnetism is in the shape of the applied field. As you would expect, the formation of a magnetic image requires the use of a permanent-magnetic material plus a magnetic field of some definition.

Magnetizing a thin sheet of permanent-magnetic material—which is initially unmagnetized—causes the magnetic image of the field-shape to be retained throughout its thickness. You can form this image in a variety of ways. A permanent-magnetic stylus (the magnetic field of which is concentrated at the point) can be used for writing and drawing magnetic images. Suppose, instead, you use a permanent-magnetic rod, whose tip or pole is shaped like an alphabetical or numerical character. Then, by placing the tip of the rod on a magnetic sheet, an invisible magnetic image of the character is formed. Because the sheet



3 High-speed printing with shaped magnetic fields. This principle led to the development of a simple . . .



4 Tabulating device that magnetically prints columns of figures (*right*), a line-at-a-time at swift speeds

Printing with Shaped Magnetic Fields

is permanently magnetized, this image remains after the rod is removed.

Magnetic materials with current-carrying coils about them (electromagnets) can be used in place of the permanent magnets to make images. If the current is varied, the strength of the magnetic image also varies. In this way you can vary the magnetic field from zero through maximum to zero in a few millionths of a second. Therefore, magnetic images can be formed at rates up to tens of thousands per second. Here we have the basis for high-speed printing.

One method of image formation is shown in illustration 3. A sheet of permanent-magnetic material is placed between the poles of a magnetic circuit (the air gap). Note that the current coil is placed about the *unshaped* core (the reason for doing this needn't concern us here). When current is passed through the coil, a magnetic image is formed on the sheet. Actually, it's a small magnet in the shape of the figure "7." Now, if you bring a suspension of iron particles into contact with the magnetized portion of the sheet, they form a "7", being held by the force of magnetic attraction. The field strength of the magnetic image determines the number of these iron particles attracted.

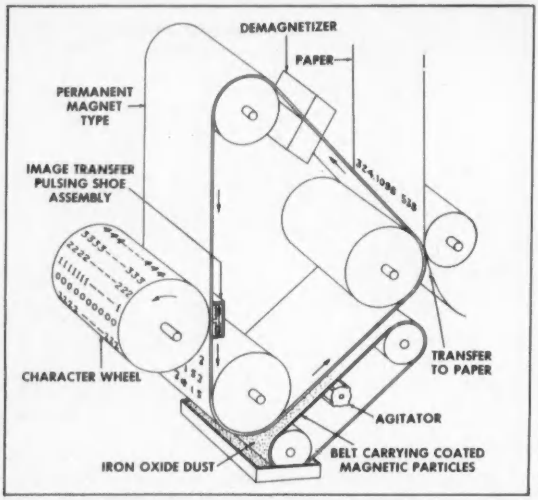
Transfer of this image to paper or other media is a tricky process. One way is by the use of an adhesive or bonding agent. In other words, the adhesive force between the particles and the paper is greater than the magnetic attraction between the particles and the image. Or, instead of removing the particles, you can use the magnetic sheet as the printer uses his press; that is, coat the particles with printing ink and run off copies.

After a transfer is made and the permanent-magnetic sheet cleaned (removing the bonding agent), it can be redeveloped. Since you have a permanent *magnetic* record of the image, as many copies as desired can be produced. When no more are desired, the images are removed by placing the sheet in a demagnetizing field. The sheet is then ready for use another time.

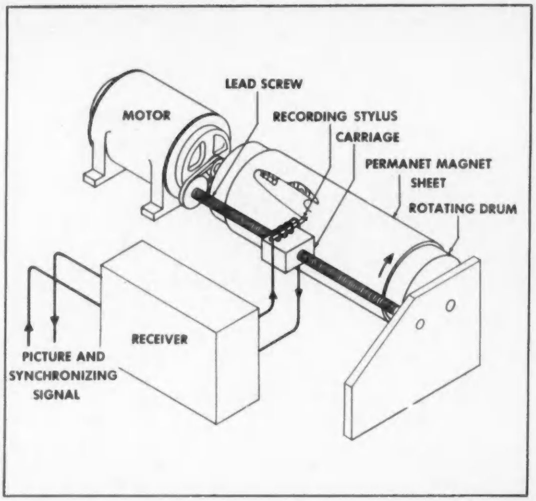
Columns of Figures

The basic principles described were used in the developmental construction of a simple high-speed tabulating device, shown diagrammatically in illustration 4. It works this way: Two permeable-magnetic cores (not permanent-magnetic) are mounted on a rotating metal drum, diametrically opposite each other. One core tip or pole is shaped to form the figure "1"; the other is shaped to form a "7." They are called "character plugs." Concentric with the drum is the "pulsing shoe," a stationary electromagnet. The permanent-magnetic sheet is fed through the air gap of the magnetic circuit formed by a character plug and the pulsing shoe. Current for the electromagnet is fed by a pulsing circuit that is triggered by magnetic index marks on the drum. The pulse is introduced the instant a character plug is opposite the pulsing shoe. Sharpness of the images is attained by the extremely short pulse duration—about 10 microseconds.

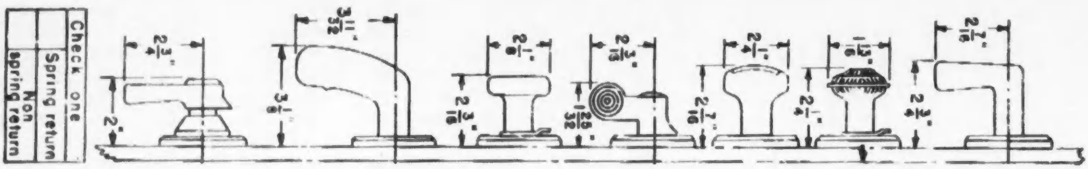
A column printed by the above process is shown to the right of illustration 4. The drum was spinning at 3000 rpm. This means the figures were printed at a rate of 6000 per minute. The column was transferred from the "developed" magnetic sheet with transparent gummed cellulose tape.



ALL FIGURES that this proposed commercial tabulating machine would be called upon to print are mounted around the drum



FACSIMILE reproductions *(below)* were recorded in manner shown schematically at a rate of three square inches per second



TONE AND LINE DRAWING REPRODUCTIONS WERE TRANSFERRED FROM PERMANENT-MAGNETIC SHEET WITH TRANSPARENT CELLULOSE TAPE

A diagrammatic view of a suitable commercial tabulator is illustrated above, left. Mounted around the drum are all the figures the machine would be called upon to print. The width of the column of figures to be printed determines the width of the drum. There is one pulsing shoe for each string of figures. Therefore, all or any part of the figures on the drum could be printed in one revolution—a line at a time. An electronic control mechanism, similar to that used for any high-speed tabulator, would actuate the pulsing shoes at the proper instant. Since the permanent-magnet sheet is continuous, it would pass through developing, printing, and erasing stages before arriving in the air gap again—ready for the next magnetic image.

A Double Take

Ferromagnetography has also been investigated for application to facsimile—a process of reproduction.

A diagrammatic sketch of recording equipment used for this purpose is

(Continued on page 61)

With General Electric for many years, Mr. Berry is a section engineer in the General Engineering Laboratory at Schenectady. Twice recipient of the Coffin Award, he is presently working on high-speed counters, digital computers, servo systems, and machine-tool controls.

Mr. Hanna, also in the General Engineering Laboratory, entered the General Electric Test Engineering Program in 1948. He is at this time concentrating on developmental study of computer instruments.

LATEST OFFICE ACCESSORY—THAT'S WHAT IT WAS IN 1916 WHEN THIS OSCILLATING FAN BECAME ONE OF THE FORWARD STEPS AS TOLD IN...

Cool Breezes—Story of the Electric Fan

By W. K. SKOLFIELD

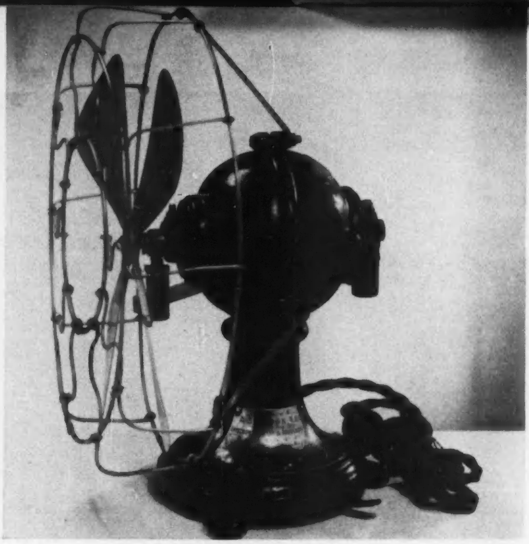
Fans preceded written history by many centuries. Some of the most ancient known fans were those of the Chinese dating back to 3000 BC. And ceremonial fans were used in 1700 BC by the reigning monarchs of Egypt and Assyria. Some thousand years later the "punkah"—a hand-swung lightweight ceiling-suspended fan—was introduced in India, and even today is still in use there.

From exquisitely made folding fans of the Japanese, followed by 17th century Paris creations of surpassing beauty, we come to the practical palm-leaf type and simpler folding fans of grandmother's day.

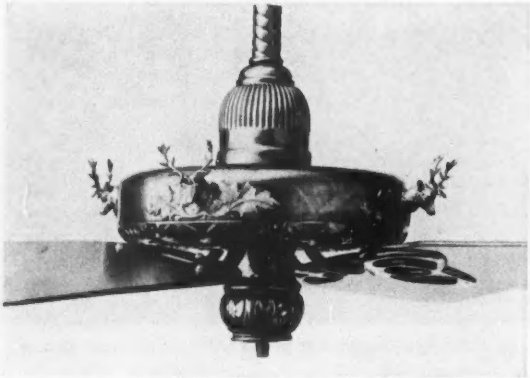
It's not possible to give the exact age of the electric fan—the youngest member of the ancient family of fans. But the earliest record of a U.S. patent awarded for an electric fan was in 1854. This was a ceiling-suspended assembly of several large fan blades, each hinged along one edge to a horizontal rotating arm driven by a battery-operated motor. Arms on the blades struck projections causing the blades to vibrate and thus agitate the air.

There's a good possibility that other motor-driven fans had been in existence before this one. For the problem was not that of substituting one of the new d-c motors for a spring motor, it was

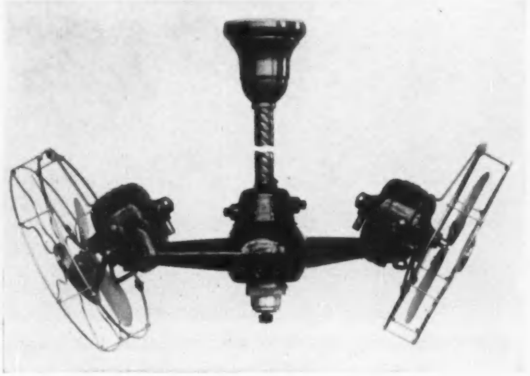
1 Ancient Egyptian fan cools a queen—mural in tomb near Thebes, about 3000 BC. From such simple beginnings the electric fan was developed nearly 5000 years later. And in 1854 the first electric fan was patented. But even in the 90's they were still a novelty and often . . .



2 Fans celebrated major events. One occasion commemorated generation of power at Niagara Falls in June, 1896, when this fan was operated for the first time by current transmitted to New York City. To permit either d-c or a-c operation at frequencies from 20 to 133 cycles . . .



5 Fans were suspended from the ceiling. They had blade diameters of 52 to 56 inches, operated at 250 rpm, and moved large volumes of air at low velocity. This one was standard equipment for the 1912 trophy room. And . . .



6 Another fan for circulating air over large areas was the twin-blower ceiling type. Some ceiling types are still in use today. Other designs of this era brought comfort to people on trains, subways, and ships. Early in the 1930's . . .

finding a more ample supply of electric power. Batteries were crude and expensive, and the comparatively few electric lines at hand were principally to operate the new Edison lamps and some industrial machinery.

It was not until the 1890's—when a combination of motor, blades, blade guards, and base, together made a desk fan—that electric motors to drive fans first reached commercial proportions.

By 1910 engineers developed a desk fan in which the motor and blades moved back and forth, or oscillated, within an arc of 60 to 90 degrees.

The period between 1920 and 1930 saw the evolution from cast iron to steel and die-cast structures in desk fans, with lighter weight housings and larger output of moving air. Most of these fans operated at 1500 to 1600 rpm, which—coupled with the narrow-blade design—resulted in a pronounced humming noise. You may remember that these were nicknamed "buzz fans."

Shortly, a much quieter operating fan was developed by seriously applying to fans, for the first time, the Archimedean screw principle which had been successfully used on ships since about 1836. This led in 1932 to the introduction of a fan with a wide, or overlapping, blade design—the first fundamental change in blade design in more than 40 years.

Reduction of fan noise immediately became an important element in design, and even today it is still emphasized. Noise values are watched just as closely

3 Early fans had a large number of windings. The first a-c fan motor was commutator-type series wound, soon replaced by self-starting induction types. About 1900 . . .

4 Large units mounted on floor columns became popular (*right*). Often ornamental, these fans became popular in the Orient, replacing hand-operated devices. Other . . .

7 A noise-reduction project resulted in this fan with wide overlapping "quiet" blades. It set the pattern for future fans, ultimately led to . . .

8 Today's quiet-operating floor circulator. Two sets of blades thoroughly circulate upper and lower room air. For home use is this . . .

9 All-purpose fan. Large volumes of air are moved quietly and prying fingers are kept from the blades. Plastic and die castings are used

as quantity of air delivered and power consumption.

During World War II United States Navy and maritime ships' crews were afforded greater comfort by a three-speed portable ventilator, reversible and complete with radio filter. This wartime necessity resulted in important design features in postwar domestic units. There is a twin-fan ventilator, for instance, that can be placed in a window for exhausting or drawing in air, or set on the floor or a table for circulating room air. Thermostatic control will turn off the fans if the temperature drops several degrees; as the temperature rises, it will turn them on again.

Plastics and die castings have combined in providing sleek oscillator-type fans, ventilators, and circulators, the mechanism and bearings of which are prelubricated at the factory and require no further attention during many years' use.

The ventilators and circulators of tomorrow will doubtless incorporate features which will be still more novel than today's products. Perhaps some day a "fan" will consist of a mere loop of wire—with air rushing through the loop at high velocity, driven by a technique as yet unperfected.

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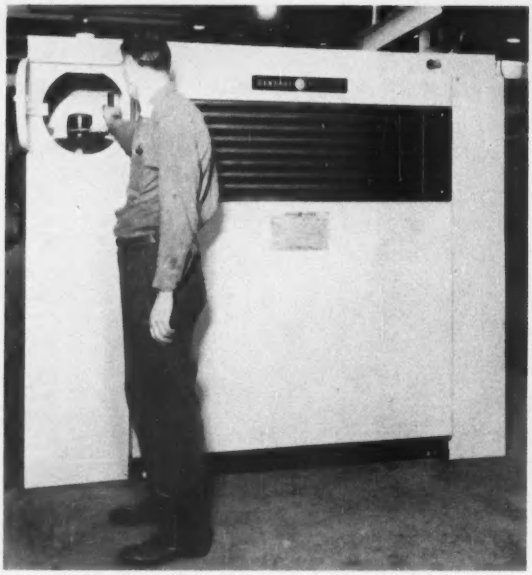
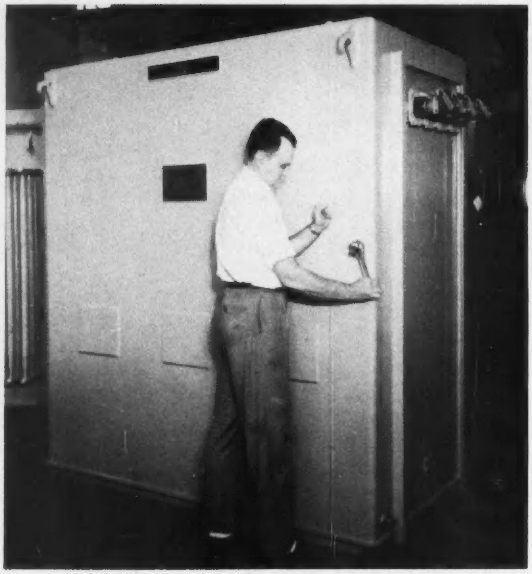
Thirty of Mr. Skolfield's 36 years with General Electric have been spent in design and engineering of electric fans. He is now Manager, Advance Engineering, Vacuum Cleaner and Fan Department, Small Appliance Division in Bridgeport, Conn.





INSULATION IMPROVEMENTS IN VENTILATED (LEFT) AND SEALED DRY-TYPE TRANSFORMERS IS PART OF THE STORY OF . . .

Longer Life for Dry-type Transformers

By G. F. SIMMONS and L. C. WHITMAN

Improvements in dry-type power transformers and their insulations is a good example of how electrical engineers are continually making progress in lengthening the life span of electric equipment and increasing its endurance to higher temperatures.

For many years insulations known as Class A were about the only ones available to the transformer designer. These insulations consisted of materials such as cotton, silk, or paper—impregnated with organic varnishes to give them additional mechanical and electrical strength. They were used in a medium of mineral oil or air. Such insulations were relatively inexpensive but a maximum allowable temperature limit of 105 C was necessary for reasonable life.

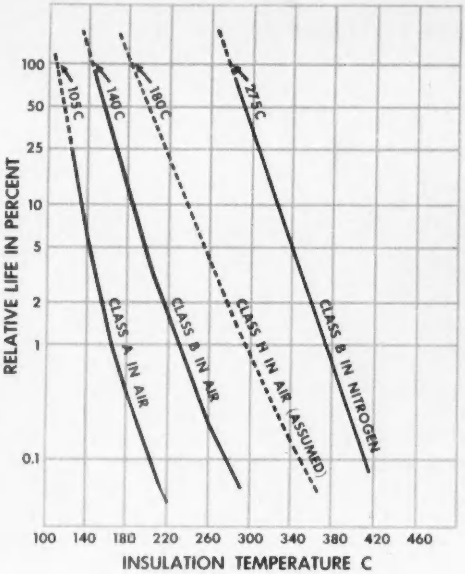
In the early 1930's increased emphasis began to be placed on fire hazard and safety. This resulted in substituting a fireproof material (known as askarel) for mineral oil when the extra cost was warranted. To meet this challenge the dry-type transformer designer in the late 1930's changed the base materials of the insulations he used from organic to inorganic materials such as mica, asbestos, terratex, and fiber glass. The impregnating varnishes were still varieties of the organic materials previously used. These insulations are known as Class B and their top allowable temperature limits are 130 to 150 C.

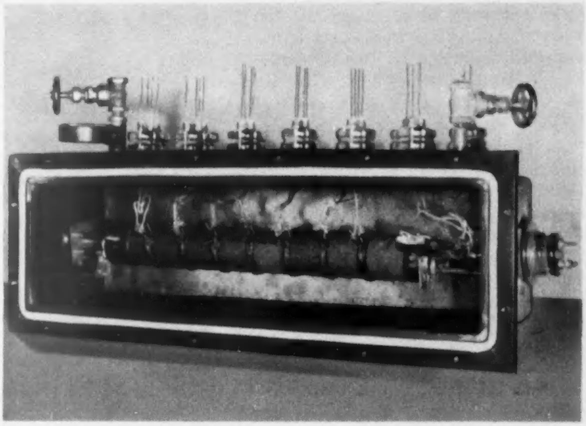
Ventilated Dry-type Transformer

This advance in insulations made possible the ventilated dry-type transformer, one of several varieties now in everyday use (above, left). We have found that the Class B insulation being used gives adequate life for this particular application. Considering cost, weight, losses, and operating maintenance, the ventilated dry-type transformer has for some time been in an excellent competitive position with liquid-filled units for certain applications. True, any ventilated-type transformer is somewhat susceptible to deterioration caused by dirt and moisture; it must therefore be installed in clean and dry locations. All dry-type transformers inherently have less resistance to voltage surges from switching or lightning sources than similar transformers using a cooling liquid having high dielectric strength. Thus adequate protection from these sources of potential trouble is usually provided.

Sealed Dry-type Transformer

In the late 1940's silicone varnishes became available. In these semiorganic varnishes the organic carbon nucleus is replaced with inorganic (SiO) groups. When combined with the inorganic base materials used in Class B insulation, these varnishes made an entirely new class of insulation that was designated as Class H. Based on rather meager data at that time, the top allowable temperature limit of 180 C was assigned. Obviously, to seal out all external air from the traditional ventilated dry-type unit meant much higher operating temperatures. Since this insulation was





TEMPERATURE GAIN made by changing the base insulation material from organic (Class A in Air) to inorganic (Class B in Air) is shown by the curves. To determine the effect of excluding oxygen from Class B insulations, testing chambers *(above)* that used nitrogen as a gas medium were used. The "Class B in Nitrogen" curve shows that a considerable increase in allowable operating temperature is achieved if oxygen is not present

assigned its maximum top allowable temperature, sealed dry-type units utilizing Class H high-temperature insulation were designed and marketed.

The hermetically sealed dry-type transformer (page 26, right) eliminated all dirt and moisture problems. The field of application became greatly broadened and soon included outdoor load-center unit substations, underground vault network systems where periodic submersion is encountered, mining-type installations, industrial plants where contaminants are present, and even locations where extremely high resistance to fire and explosion is mandatory. Customer acceptance, however, was slow because of the higher cost of this type of transformer over the liquid-filled unit. This factor prompted extensive investigations of the life of other insulations at high temperatures.

Evaluating Insulation Life

The limit on Class A maximum operating temperatures has been well established by many years of operating experience. Also, much laboratory work has been done relating Class A insulation life at various temperatures with decrease in tensile strength. But for Class B and Class H insulations, only limited operating experience is available at the present time; and the proposed maximum temperature limits were, and are, open to closer determination.

Because the base materials in Class B and Class H insulations are inorganic, the tensile strength of materials such as terratex and fiber glass are unaffected by relatively high temperatures. Therefore, the tensile-strength test used to measure relative insulation life at various temperatures is not a satisfactory criterion.

We have found that a practical method of evaluating the life of these materials is to determine the time required to reduce the dielectric strength of the insulations to a certain percentage of its initial value. Fifty percent has been used for this allowed percentage deterioration. True, moisture absorption and dirt contamination may introduce other factors that can further affect insulation life in open ventilated units. (These operating conditions are eliminated in sealed units.) It must be remembered, however, that these are *operating conditions* rather than *basic insulation characteristics*, and such conditions can generally be controlled by proper design, application, and maintenance. Thus, the dielectric strength criterion alone is sound and has the considerable practical advantage of direct conversion from laboratory tests to field operating conditions.

A major assumption in this approach is that data obtained for relatively short times at high temperatures can be extrapolated to longer times and lower temperatures. Experimental plots indicate that over small ranges of temperatures the data are essentially in a straight line on semilog paper using the logarithm of the time as one variable. It has also been shown that if the degradation of insulation is chemical in behavior, the temperature abscissas should be the reciprocal of the absolute temperature. Over ranges of more than 50 C this effect begins to be noticeable and should be considered when using data having considerable temperature range.

The question might be asked as to why the voltage criterion was not used in evaluating the life of Class A materials in insulating oils. This case differs because the base material as well as the varnish can be almost completely de-

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Mr. Whitman is author of several AIEE technical papers. As a developmental engineer his interest lies in Class B and Class H insulations and high-temperature dry-type transformers. Mr. Simmons has had experience in distribution transformer design and at present is a product design engineer in charge of dry-type transformers from 112½ to 2500 kva. Both are with General Electric in the Distribution Transformer Engineering Division, Transformer and Allied Product Department at Pittsfield, Mass.

teriorated with little change in the dielectric strength if the sample is undisturbed mechanically. This is because the insulating oils flow in and replace the solid materials. It is well known that Class A insulated apparatus may continue to operate satisfactorily for long periods after the solid portion of the insulation has lost practically all its mechanical as well as its electrical strength. Failure comes whenever a short circuit or other abnormal force acts to disturb the insulation.

At the present time some life characteristic data are available for Class B operation in air using the 50 percent voltage factor. Comparative tests were made at the same time on Class A insulations operated in air (curves, page 27). This clearly shows the temperature gain made by changing the base material from organic to inorganic. In several independent laboratories an extensive program is now in progress under the direction of the AIEE to check the results. Initial pilot tests indicate good agreement with the original data.

Use of Inert Gas Medium

In making the original Class B tests it was decided to determine the quantitative effect of excluding oxygen from these insulations. If the deterioration was largely, or even partly, due to gradual oxidation of the organic components, it was reasoned that much longer life should be obtained if these insulations were operated in an inert gas. Using testing chambers similar to that shown on page 27, and using nitrogen as a gas medium, tests on Class B insulations were repeated using the 50 percent voltage criteria for determining life. The results obtained amply backed up the researcher's basic thoughts. The curve on page 27 labeled "Class B in Nitrogen" shows the tremendous increases in life, or the corresponding considerable increase in allowable operating temperatures that are achieved.

This is an example of a thorough investigation provoking still further ideas and investigations. These related investigations, followed in all their ramifications, resulted in expanded data that can in turn be applied to practical designs that produce definite advances.

Class B Sealed Dry-type Transformer

The remarkable resistance to high temperatures and long life of Class B insulations operated in nitrogen were immediately utilized in the design of the sealed dry-type transformer. The resulting transformer, with all the characteristics of the Class H sealed dry-type transformer, has the further desirable feature of reasonable cost. In addition, it was proved that the allowable temperature of 180 C is very much below the maximum temperatures the insulation will stand. This type of transformer should thus have a life expectancy equal to or better than the conventional transformer, which has demonstrated many years of satisfactory operation.

This new Class B sealed dry-type transformer should be considered from more than the life viewpoint when examining its probable future. One must make a fairly thorough comparison of such characteristics as audio sound level, vulnerability to lightning, operation and maintenance, fire and explosion resistance, and dimensions. The table above gives a fairly complete comparison of each of these characteristics.

COMPARISON OF TRANSFORMER TYPES

Type of Transformer	Liquid-filled: Fireproof Askarel	Dry-type: Open Ventilated	Dry-type: Sealed Class B	Dry-type: Sealed Class H
Price comparison (approx)	100%	100%	110%	120%
Impulse strength	100%	50%*	50%*	50%*
Insulation class	A	B	B	H
Temperature ratings				
Average coil rise above amb	55 C	80 C	120 C*	120 C*
Hottest spot rise above amb	65 C	110 C	140 C*	140 C*
Audio sound level	X db	(X+10 db)	(X+10 db*)	(X+10 db*)
Weights	100%	65%	100%	100%
Dimensions				
Floor space	100%	100%	120%	120%
Height	100%	90%	100%	100%
Normally available for application				
Indoor, outdoor, or submersible	All	Indoor only	All†	All†
Fire resistant	Yes	Yes	Yes (plus)	Yes (plus)
Explosion resistant	Yes	Yes (plus)	Yes (plus)	Yes (plus)
Maintenance required				
Liquid	Infrequent	None	None	None
Internal cleaning	None	Frequent	None	None
External cleaning & painting expense	Normal	Minimum	Minimum	Minimum
Special precautions before energizing either initially, or after shutdown	None	Yes	None	None

* Not yet covered by industrial standards.
† Applicable for all types of installation assuming no exposure to lightning or assuming adequate protection against impulse voltages can be provided.

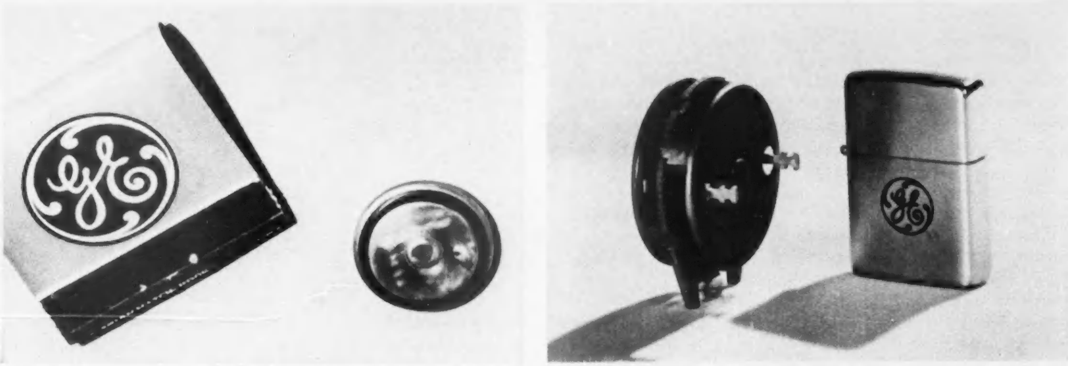
Although the dry-type transformer has basically a higher audible sound level and a lower impulse level than its liquid-filled counterpart, and although the sealed dry type is somewhat more expensive than either the liquid unit or the ventilated dry type, it is felt that the desirable features of greater fire and explosion resistance, as well as low operating and maintenance costs, outweigh the disadvantages for many customers and many applications.

Future Investigations

There is a possibility that Class H insulations operated in an inert gas such as nitrogen may also have their allowable temperature limits raised over the 180 C limit.

Assuming that 180 C is the proper allowable temperature limit for Class H operated in air, it is probable that when it is operated in an inert gas, the temperature increase will be less than the increase achieved in operating Class B in inert gas (140 to 275 C). The reason for this is that Class B insulations have less organic components to deteriorate by oxidation.

Another practical design problem is the balancing of the cost of load losses against the possible reduction in materials with higher operating temperatures. These tests come under the heading of "unfinished business," and are a part of the task of the engineers of tomorrow.



BUTTON RECTIFIER (LEFT) IS ONE OF CAREFULLY SELECTED PAIR THAT IS CONNECTED IN SERIES AND ASSEMBLED TO FORM THE G10 (RIGHT)

The G10 Germanium Rectifier

By TRINDEL J. FERGUSON

In 1886 a German chemist by the name of Alexander Winkler found an unknown metal sulfide and isolated the element which he called germanium. It has a shiny metallic appearance, is extremely hard and brittle, and is recovered as a by-product in the smelting and refining of zinc ores.

Because germanium falls into group four of the periodic table, it has some of the chemical characteristics of the elements on either side of it. Germanium is both an electrical conductor and an electrical insulator, depending on its temperature, and is classed as a semiconductor.

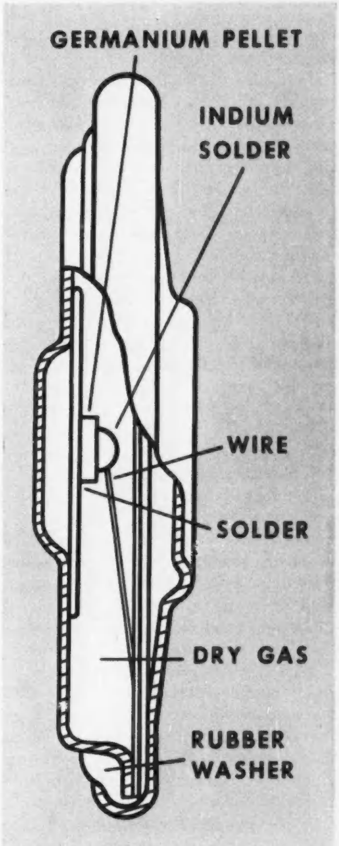
As explained by Dr. W. C. Dunlap, Jr. in his article "Germanium Photocells" in the March 1952 issue of the REVIEW, one of the important properties of germanium is that it can be treated in such a way that it becomes possible for one section of a piece of the metal to conduct only negative charges while another section conducts only positive charges.

The metal containing the two sections is said to have a "P-N junction." The P-N junction, together with its modifications, has properties that can be utilized for amplification, photoelectric effects, and rectification.

These properties have been used in the design of a new line of rectifiers, designated the G10, that are vastly superior to other types of crystal rectifiers. Functionally, these new rectifiers were designed for power conversion in television, radio, and other similar devices, where size, weight, and the nature of the materials in the rectifiers are of major consideration. They have also been found to be useful as switching devices in intricate computing machines and radar equipment.

Theoretically, an ideal rectifier would have no forward resistance but an infinite back resistance. That is, current would flow in the forward direction with nothing to hamper it, but the current would be completely blocked if it tried to flow in a backward direction. Also, an ideal rectifier would have a very small capacitive reactance over a considerable range of voltages and frequencies, in addition to other desirable characteristics. With this in mind, the new G10 germanium rectifier approaches the ideal in that it has a lower forward resistance and a higher back resistance than any previously designed rectifier. Coupled with this, the effective capacitance of the rectifier at operating voltages is small compared not only with selenium and other types of semiconductor rectifiers but also with many vacuum tubes.

The G10 is composed of two "button" rectifiers (left, and lower right) in series, each consisting in part of a one-eighth-



EIGHTH-INCH square pellet of spectroscopically pure germanium is mounted in the center of the button rectifier inch square pellet of spectrographically pure germanium, located in the center of a metal cup, and sealed with butyl rubber. Before assembly, button rectifiers are stabilized electrically by 24 hours of continuous operation at full load. This stabilizing process seems to remove gaseous impurities from the rectifying surface and also relieves mechanical strains within the button.

After the stabilization procedure, the button rectifiers are soft-soldered to heat-dissipating fins. The solder is used primarily to provide a better thermal junction between the fin and the button.

Next, a selection test is made to pair button rectifiers that have similar back currents. This selection is necessary to insure an equal division of the peak back voltages across series-connected rectifiers, such as the G10, thus obtaining efficient operating characteristics, long life, and reliability.

There are two factors that vary from rectifier to rectifier that must be considered when selecting them for their back currents. The first is the heat generated by their forward and back current; the second is determined by the thermal characteristics of the contacts between the rectifiers and the dissipating-fin assembly. Fortunately, both of these factors can be evaluated together during the selection test.

The selected button rectifiers—with dissipating fins attached—are then assembled with springs, terminals, mounting bolt, and center support plate, as shown on page 29, upper right.

Fig. 1 gives the static characteristics of an average G10 rectifier taken at different ambient temperatures. The rather rapid increase in back currents at the higher temperatures tends to place an upper limit on the useful temperature range. However, an upper limit is inherent in most semiconductor devices. Back currents, incidentally, are believed to be generated by thermal agitation at the rectifying surface.

Fig. 2 shows the static resistance at room temperature of an average G10 rectifier. Note here that the rated peak inverse voltage, namely 400 volts, nearly coincides with the point of maximum resistance, thus justifying the voltage rating.

Some typical characteristics of the G10 are shown in Figs. 3 and 4 with an average selenium rectifier characteristic for comparison. The slopes of the curves obtained are mainly functions of the filter capacitor size; the efficiency of the rectifier determines the positions of the curves. The rectifier circuit shown in Fig. 3 is used in radio sets and small power supplies. The one shown in Fig. 4 is a half-wave voltage doubler circuit, which is used in applications where a higher voltage is required—for example, in supplying B+ voltage in television sets or furnishing high plate voltages to vacuum tubes in other devices where a transformer would be inconvenient.

ELECTRICAL CHARACTERISTICS OF THE G10 GERMANIUM RECTIFIER*

Ambient Temperature	40C	55C	60C
Volts input, rms	130	130	130
Amperes input, rms	1.2	1.2	0.2
Milliamperes output	400	350	50
Amperes surge, d-c	25	20	2.5
Amperes, peak forward	3	3	0.5
Volts, peak inverse	400	400	400
Voltage drop, full load	1.5	1.4	1.3
Frequency, kilocycles	50	50	50

* Rated 370 volts, peak to peak

Excessive overload in the half-wave voltage doubler circuit generally causes the rectifier to short circuit. Usually, a series fuse or current-limiting resistor is opened as a result, and the rectifier is ruined. When this occurs with the G10, however, there is no disagreeable odor, as there is with selenium or similar rectifiers.

The recommended current-limiting resistances have similar values to those used for selenium rectifiers, namely, five ohms. There is some indication, however, that it may be reduced to half this value. This will probably come about through the use of a series capacitor with a higher ripple-current rating. Even at five ohms the present ripple-current rating of capacitors is not sufficient to prevent capacitor damage, because high-surge and large-ripple currents pass through the low forward resistance of the G10.

In most circuits the "efficiency" of the G10 is at least 98 percent. For example, with a 50-watt resistive load and an ambient temperature of 50 C, the power dissipated within the rectifier as heat is usually less than one watt. Other types of rectifiers may lose as much as five percent of their efficiency at this temperature.

The low effective capacitance of the G10, usually about 20 mmf, makes it possible to operate dry disk-type power supplies within the range of 25 cycles to about 50 kc. This characteristic is of particular advantage in lightweight installations such as aircraft and mobile power units. Here, a high-frequency alternator with a G10 rectifier and small filter will provide low-noise and low-ripple content d-c power over wide extremes of temperature, vibration, and altitude.

The G10 is not seriously affected by humidity. Several units have successfully completed 50 or more test cycles of operation. The cycle consists of a period of four hours of complete operation under maximum load conditions and at 90 to 95 percent relative humidity, followed by an eight-hour period of inactivity. Similar units have successfully completed 100 hours of the Navy salt-spray test.

Normal useful life of the G10, under full load and at an ambient temperature of 40 C, is expected to be in excess of 10,000 hours. Several units on test under these conditions have operated 4000 hours with no significant change in their electrical characteristics.

Additional work is in progress to improve upon the accuracy of the tests and to provide a faster and more complete stabilization of the rectifying elements. We are also striving for higher ambient temperatures and larger electrical loads than is presently possible.

Although the G10 was initially designed for television use, its unique properties make it suitable for many general voltage and current applications of the order of magnitude shown in the graphs.

Mr. Ferguson has been with the Electronics Division, Syracuse, since January 1951 when he joined General Electric as an engineering trainee. He is currently working with a production engineering group on the G10 germanium power rectifier.

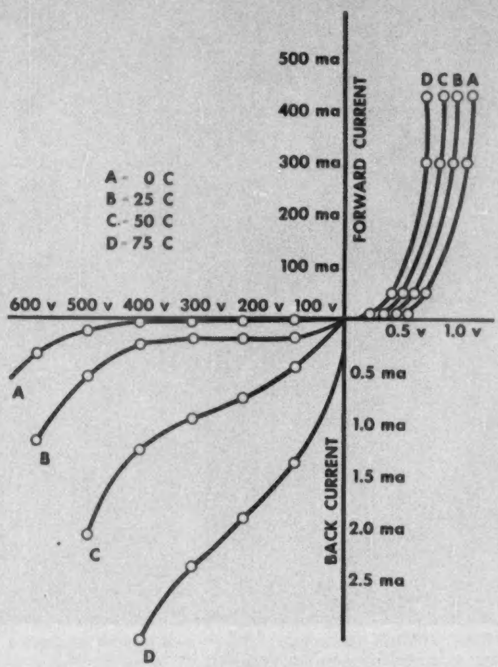


FIG. 1. TEMPERATURE CHARACTERISTICS OF THE G10 RECTIFIER

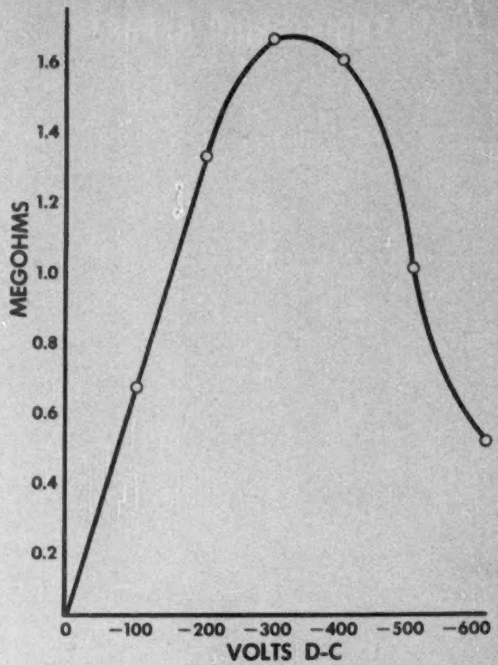


FIG. 2. RESISTANCE OF THE G10 GERMANIUM POWER RECTIFIER

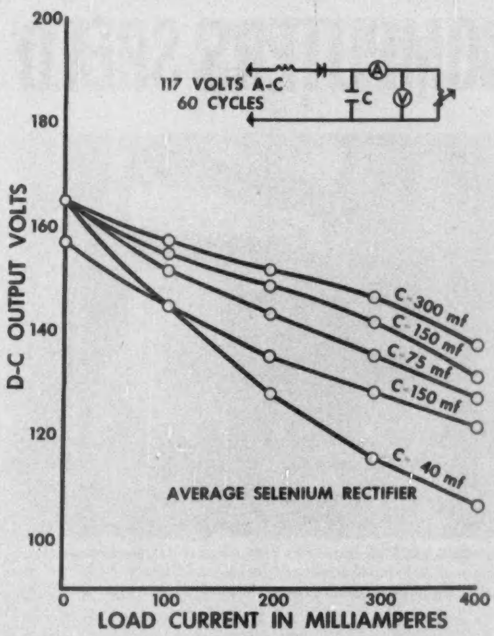


FIG. 3. REGULATION—CAPACITOR CHARACTERISTICS OF THE G10

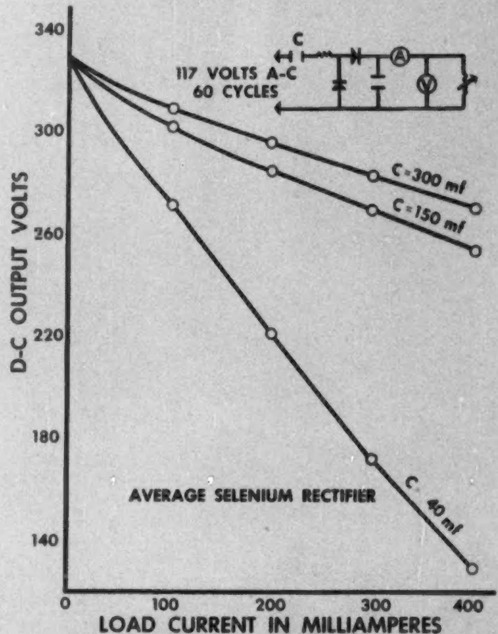
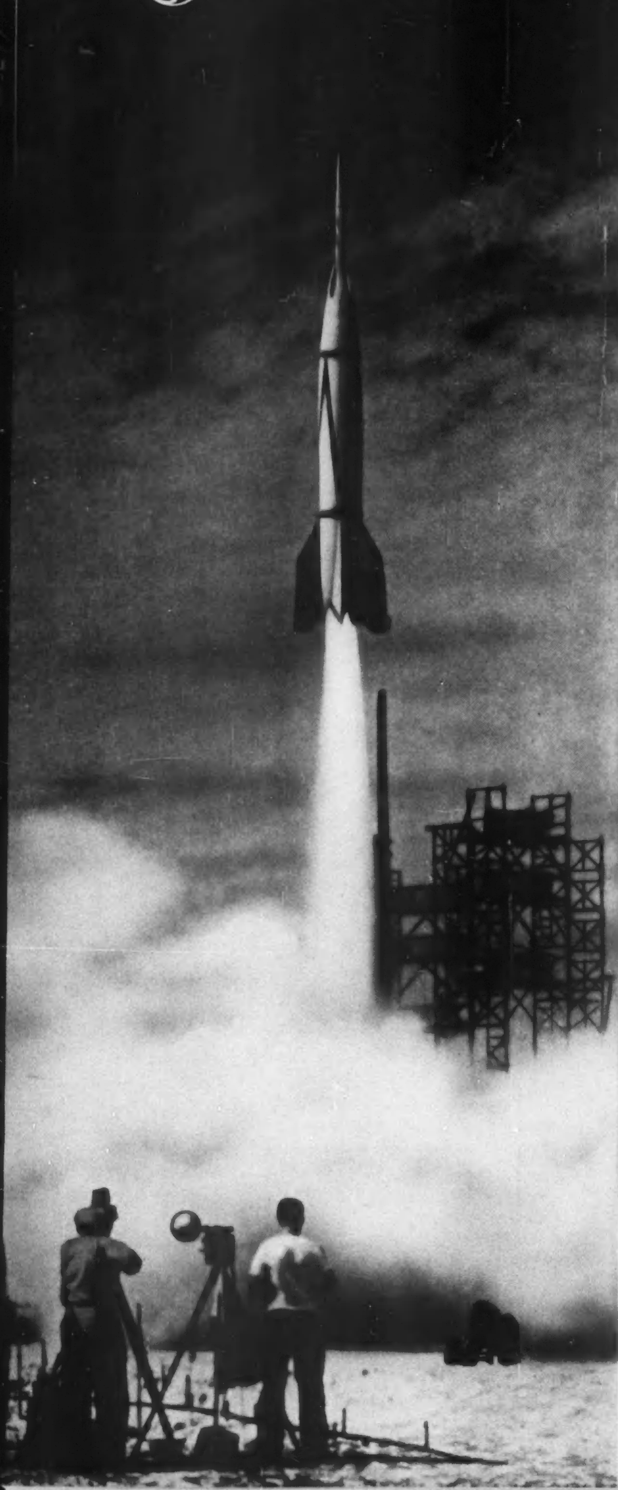


FIG. 4. STATIC CHARACTERISTICS OF A VOLTAGE DOUBLER CIRCUIT

ENGINEERING REPORTS:



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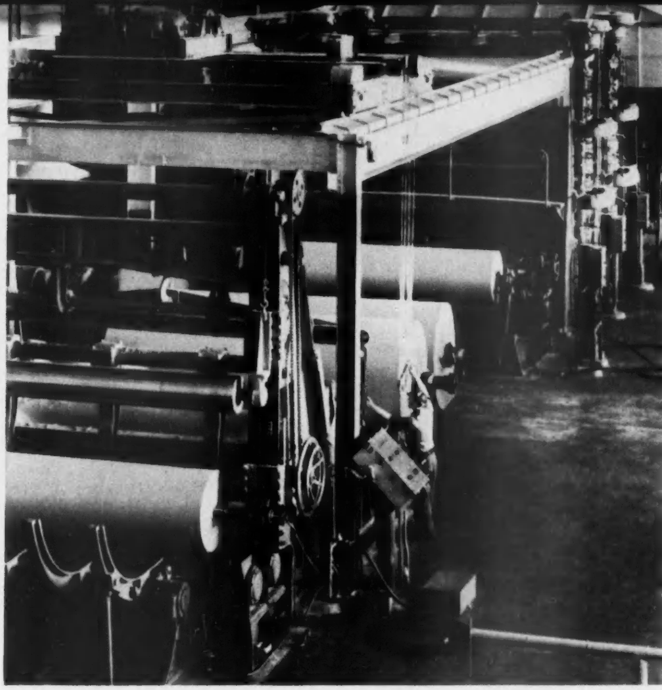

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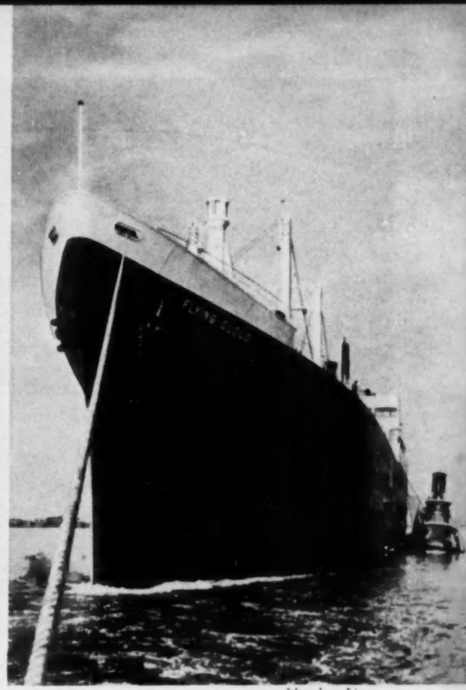

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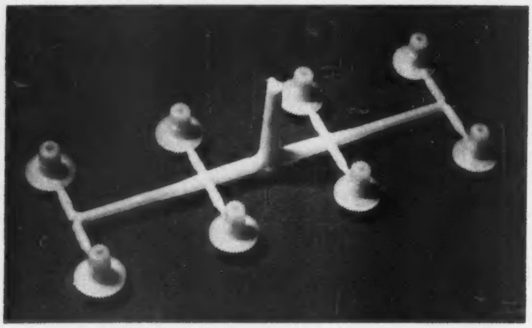

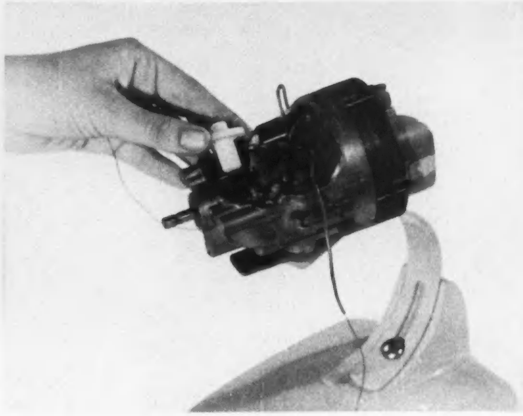

LIFE TESTS show this nylon pinion and worm wheel, molded in one piece with gear teeth, is equal to the previously used two-piece steel pinion and laminated worm wheel it replaced in th motor of this 10-inch oscillating household fan

Nylon for Bearings and Gears

By ROBERT LURIE

Although nylon is generally associated with such decorative items as stockings and sweaters, we have found that its versatility extends well into the fields of bearings, gears, and other workaday applications.

Nylon is tough at low temperatures, is resistant to abrasion, has strength in thin sections, is light in weight, has certain self-lubricating qualities, and is resistant to many chemicals. Properties are given in the table on the opposite page. Exact characteristics and specifications can be found in the literature put out by the manufacturers of nylon molding powders.

Bearing Tests

Of interest to design engineers is published data that shows the effect of wear on nylon when used as a bearing material. Results of tests using nylon against nylon, steel, and brass under various loads and speeds, and with various lubricants, are given on page 35. As you may suspect, the lowest rates of wear are found when nylon is run against nylon in a dry condition, as well as when nylon is run against steel lubricated with SAE 10 oil. When nylon is rubbed against brass, the metal flakes off and contaminates the bearing surface.

Rate of wear is greatest at the start but it tapers off with further operation. The reason is that after the surface of the nylon is glazed more intimate contact is established, with a resultant decrease in unit pressure. This rate of wear appears to reach a minimum after about 0.001 to 0.002 inch of surface is removed. In contact with steel or brass this figure represents the amount of nylon that will be removed in smoothing the metal to prevent further wear. The coefficient of friction decreases during the first few hours of operation and then remains constant; at the same time the rate of wear becomes practically negligible.

When nylon is rubbing against steel, the limiting load is 550 psi without lubrication. Water lubrication will increase this limiting load 91 percent; SAE 10 oil will increase it 182 percent.

Wall thickness greatly influences the life of a bearing. For instance, tests showed that a bearing having a wall thickness of 0.125 inch failed after 240 hours of operation. It melted. This bearing was operated at a rubbing speed of 525 fpm, under a 200-psi load, and lubricated with SAE 10 oil.

Another bearing, tested under the same conditions, but having a wall thickness of only 0.020 inch showed no sign of failure after 360 hours of operation. Results were the same when water was used as a lubricant or when no lubricant at all was used. The advantage of a thin-walled bearing is that the heat of friction is more rapidly dissipated than that of a heavier bearing where the nylon acts as an insulator.

Gear Design

Where speeds or loads may be excessive, you must give consideration to the low heat conductivity of nylon, namely, 1.7 Btu per hour per square foot per degree Fahrenheit per inch. Allowance must also be made for heat dissipation; otherwise the nylon will soften and deform because of a heat build-up.

Developmental gears have been made with nylon around a copper insert to facilitate conduction of heat away from the gear-tooth area. Thus, in the more critical gear designs the problem of heat dissipation is minimized, and at the same time the beam strength of the gear is increased.

The horsepower transmitting capacity of a nylon gear can be determined through the use of the Lewis formula,

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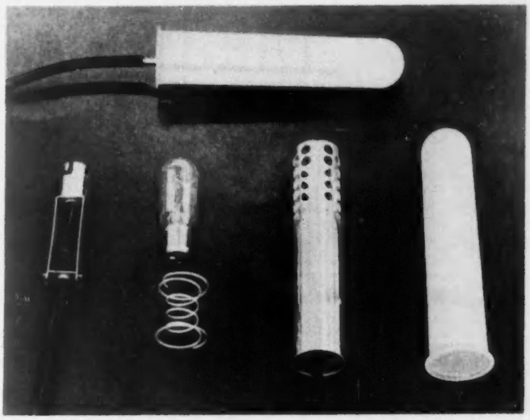
For the past two years Mr. Lurie has been an application engineer in General Electric's Chemical Division at Pittsfield, Mass. During this time he has been working toward the development, engineering, and promotion of new applications of plastics.



LIGHT-BULB HOUSING OF MOLDED NYLON WITHSTANDS 250 F HEAT IN AUTOMATIC CLOTHES WASHER. WALL THICKNESS IS 0.040 INCH

PROPERTIES OF MOLDED NYLON (FM-10001)

Property	Values
Tensile strength, 70 F	15,700 psi
77 F	10,900 psi
170 F	7600 psi
Elongation, 70 F	1.6%
77 F	50%
170 F	320%
Modulus of elasticity, 77 F	400,000 psi
Flexural strength, 77 F	14,600 psi
Creep in flexure*	90
Hardness, Rockwell	R118
Flow temperature	>480 F
Thermal conductivity	1.7 Btu/hr/sq ft/F/in
Heat distortion temp, 264 psi	150 F
Volume resistivity	4.5×10^{13} ohm-cm
Dielectric constant, 60 cycles	4.1
Power factor, 60 cycles	0.014
Water absorption	1.5%
Specific gravity	1.14

* Creep in flexure is a measure of the deformation under a prolonged standard load. Results here represent mils deflection in 24 hours of a 1/8 x 1/2 inch bar 4-inch span, center-loaded flatwise to 1000 psi, minus the initial deflection. Thermal conductivity measured by Cenco-Fitch apparatus.

RATES OF WEAR TESTS

Rubbing Agents	Load (psi)	Lubricant	Rubbing Speed (fpm)	Wear (mils)	Average Friction Coefficient
Nylon vs nylon	1050	None	156	1.6	0.039–0.099
Nylon vs cold-drawn steel	1050	Water	156	9.0	0.494
Nylon vs cold-drawn steel	1050	SAE 10 Oil	156	0.9	0.140

Data are during the "breaking-in periods." After this period, rate of wear becomes negligible.

EFFECT OF LUBRICANT ON LIMITING LOADS DURING RUBBING TESTS

Rubbing Agents	Limiting Loads (psi)	Lubricant
Nylon vs steel	1550	Oil
Nylon vs steel	1050	Water
Nylon vs steel	550	None

Tests do not indicate effect of frictional heat.

Data are not available for nylon vs brass, for when you rub nylon against brass the latter flakes off and you are soon measuring brass vs brass.
Information obtained from Bulletin 21, E. I. Dupont de Nemours & Co., Inc.

which you can find in any standard handbook for mechanical engineers. In the Lewis formula the safe working stress is the product of the static stress factor and velocity factor. In gear work, nylon has been assumed to have a conservative figure of 6000 psi as a static stress factor. The velocity factor for nonmetallic gear materials, such as nylon, has been worked out by the Massachusetts Institute of Technology, and is

Velocity factor =
$[(150)/(200+\text{pitch line velocity})]+0.25$

The Lewis formula was originally derived for rigid metal gears, where slight inaccuracies of tooth form and spacing create high dynamic loads that must be sustained by a single tooth. Under load conditions, however, the resiliency of nylon may allow contact of two or more teeth. Consequently, results obtained from this formula are conservative.

Gear Applications

An interesting application of a nylon gear is that found on the oscillating fan shown on page 34. Here, a two-piece steel pinion and laminated worm wheel was replaced by a nylon pinion and worm wheel, molded in one piece with gear teeth. Life tests show it equal to the previous gears. In addition, the noise level of the fan was significantly decreased, and a parts cost saving of 65 percent was realized. The worm wheel is a helical gear having a helix of 5° 45′ (right hand), 47 teeth, and a pitch diameter of 0.9841 inch. Although the gear teeth actually form an undercut in molding that would make releasing the gear from the mold difficult under ordinary conditions, the manufacturing process for molding gears has been developed whereby a helical gear is actually made to rotate and pop free of the mold.

In this connection we should mention that nylon moldings offer substantial

(Continued on page 61)

The Unit Cost of Light

By PHELPS MEAKER

● Analytical studies of lighting costs may point up ways of saving money. There are other things to be considered besides costs of fixtures, installation, and electricity

● Lamp replacement, labor costs, and cleaning schedules are all variable factors. The effect of changing these and other factors is clearly shown by the unit cost of light method

There's more to figuring the cost of a lighting system than adding up the prices of fixtures, installation, and electricity. A tabulation of over-all annual costs that the customer may expect to pay appeals to the businessman, because it is expressed in his own language. But further analytical cost studies of operating and maintenance methods and lamp efficiencies may show you the way to worth-while savings or better lighting for the same expenditure.

To help you along this economic pathway a relatively simple formula has been devised. It is referred to as the "unit cost of light" method. In its most flexible form it deals with the raw light as generated by the lamps in just one fixture. Then, once the unit cost of light in dollars per million lumen hours is known, you can easily apply it to a specific installation if over-all costs are also desired.

Three Simple Terms

The formula consists of three terms and a common multiplier. Each of the three terms is treated as a separate unit of cost, and each is expressed simply in cents per 1000 hours of use. Here's the derivation of the terms of the formula, beginning with . . .

Fixed Cost and Maintenance—Assume that because of obsolescence the fixture will be replaced in 10 years; when we include taxes, interest, and insurance, the fixed cost F for one year will be covered by the convenient figure of 15 percent of the initial cost in cents. Add to this the yearly cleaning and repair cost M and divide the whole by thousands of hours H of yearly use. Thus $(F + M)/H$ = cents per 1000 hours of operation.

Electrical Energy Cost—The energy cost is a function of the average rated watts W and the prevailing rate of electrical energy R. Note that R is the rate in cents per 1000 watthours. Therefore, $R \times W$ = cents per 1000 hours of operation.

Lamp Replacement and Labor Cost—Labor costs for putting a lamp in a socket may even exceed the cost of the lamp itself. To compute this term add to the cost P of the lamp, or lamps, for one lighting unit, the labor charge h for replacement. Divide the whole by the life of the lamp L in thousands of hours. Thus $(P + h)/L$ = cents per 1000 hours of operation.

The sum of the three terms gives you the total owning and operating cost of the lighting fixture in cents per 1000 hours. Now perform the following: divide by 100 to get dollars; multiply by 1000 to get dollars per million hours; divide by the average generated lumens Q to get, finally, the unit cost of light U. The formula then takes the form

$$U = [(F + M)/H + R \times W + (P + h)/L]\ 10/Q$$

Using the Formula

It may occur to you that dividing each of the bracketed terms by the rated watts of the unit puts them in the familiar units of cents per kilowatt-hour. You may prefer this basis for comparing the items that make up the total lighting cost. The effect of changing one or more cost factors in each term is thus more readily seen.

The applications of this formula can be extended by substituting related terms. For example, take an ordinary filament lamp where the quantities W, L, and Q are all related to the voltage V by well-established exponents. Substituting V to some exponential power for each of these quantities results in an expression of one variable. This in turn can be differentiated and set equal to zero. Consequently, you can find the voltage at which the lamps should be operated to get the highest over-all economy.

Finding a solution for lamp life L by the preceding process gives the most economical design life of the lamp. This solution is complicated by the fact that the usual exponents do not apply exactly. However, it provides a handy tool to the lamp manufacturer in surveying the economic status of any one lamp.

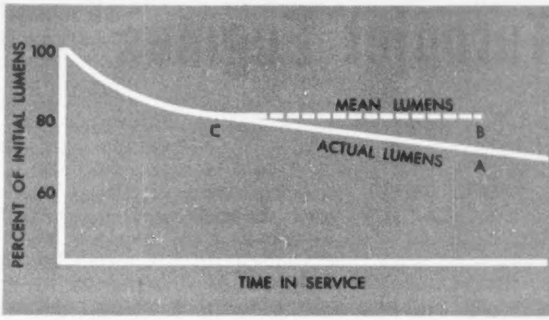
If all operating conditions were uniform throughout the country, the lamp manufacturer's task of adjusting lamp life for best economy would be a simple one. Who's to say what is the true average power rate? And the universal lamp discount? Or even the wage rate of the man who installs the lamp? What may be good for you may not be good for the next fellow.

But through the use of the formula you can adjust your *operating* conditions—voltage in the case of filament lamps, throw-away period in the case of fluorescent lamps—and profit from it.

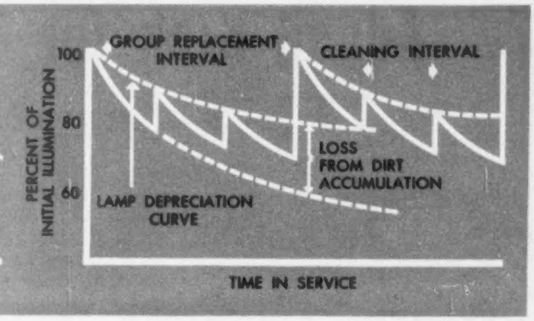
A Typical Problem

An area of 40,000 square feet is to be illuminated to a level of 50 footcandles, using an industrial fixture containing two 96-inch slimline lamps. The fixture costs $70 installed and will be used 4000 hours yearly. Assume the fixture will be cleaned once a year at a cost of 75 cents. A typical figure for the coefficient of utilization of light is 0.63. A typical maintenance factor, which includes lamp depreciation and the effect

Since Mr. Meaker first came to General Electric in 1925, he has devoted his time and study almost exclusively to lighting and the development of luminaires. He is at present a lighting engineer, Lamp Division, Nela Park, Cleveland, Ohio.



RELATIONSHIP between actual and mean lumens of a fluorescent lamp. Lamp remaining in service to point *A* supplies mean value shown at *B*. On the time scale, C is 41 percent of *A*



GROUP REPLACEMENT of fluorescent lamps at every third cleaning period. A maintenance program following the heavy line provides a practical approach to uniform illumination

of dirt collection on the lamp and reflector, is 0.65. To solve the problem we begin with . . .

Fixed Cost and Maintenance—Substituting for *F*, *M*, and *H* in the first term of the formula gives: $(7000 \times 0.15 + 75)/4 = 281$ cents per 1000 hours.

Energy Cost—We determine that 184 watts are consumed by the lamps and their ballast. Assume an energy rate of 1.5 cents per kilowatt-hour. Substituting for *R* and *W* in the second term gives: $184 \times 1.5 = 276$ cents per 1000 hours.

Lamp Replacement and Labor Cost—The two lamps that equip this fixture may have a net cost of $5.30 with an assumed labor charge of 60 cents for replacing each of them. The rated life of a lamp is 6000 hours. Therefore, substituting for *P*, *H*, and *L* in the third term gives: $(530 + 120)/6 = 108$ cents per 1000 hours.

Unit Cost of Light—The initial value of *Q* for the standard cool-white lamp is 4800—or 9600 lumens for both. Therefore, substitution of all the foregoing values into the formula gives: $[281 + 276 + 108] \times 10/9600 = \$0.692$ per million lumen-hours.

Application—The illumination of the 40,000-square-foot area to a level of 50 foot-candles for a period of 4000 hours requires $40{,}000 \times 50 \times 4000 = 8000$ million lumen-hours delivered to the work plane. A square foot of plane surface illuminated to a level of one foot-candle requires one lumen of luminous flux. Applying the coefficient of utilization and the maintenance factor increases this requirement considerably, thus: $8000/0.63 \times 0.65 = 19{,}550$ million lumen-hours. To find the total annual cost multiply by the unit cost of light per million lumen-hours: $19{,}550 \times \$0.692 = \$13{,}520$ total annual cost.

Why Use Average Values?

Little is gained by figuring costs on the basis of initial conditions—that is, when the fixture is first installed. You should be concerned with results and costs under the average yearly operating conditions.

As an example, take again the filament lamp. Its operating characteristics are so well known that it is safe to generalize. Average wattage of the gas-filled types is between 98 and 98.5 percent of the initially rated value. For sizes up to 500 watts the average lumen output varies between 88 and 95 percent. Therefore, it is essential that your maintenance factor include this effect. However, if you are investigating or comparing the performance of lamps without reference to any external factors, you will want to use the average value of *Q* in the formula.

Fluorescent lamps do not significantly change consumed wattage during their life. Actual lumen output, however, decreases over the life span of the lamp. The mean light output, as shown by the curve (upper left), is equal to the actual output of the lamp after about 40 to 45 percent of its usable life. Fluorescent lamps are a relatively recent development; and progress continues to be made in reducing losses in lumen output.

Make an Ally of Soap and Water

The custom of wiping out a reflector when a lamp is replaced and then forgetting it is all too prevalent. If you place any value on light as a production or merchandising aid, then you must come to grips with dirty lighting equipment. Not only does it drastically reduce illumination, but you suffer economic loss as well.

In the previous problem one annual cleaning was assumed, and a corresponding maintenance factor of 0.65 was used. It's a safe bet that with three cleanings per year the maintenance factor could be raised to 0.75. Let's recalculate the problem on this basis . . .

Fixed Cost and Maintenance—The annual *maintenance* cost in this term increases threefold; therefore $[7000 \times 0.15 + 3 \times 75]/4 = 319$ cents per 1000 hours. The cost per million lumen-hours then becomes $[319 + 276 + 108] \times 10/9600 = \$0.732$. With the new maintenance factor of 0.75, the number of million lumen-hours required decreases to a value of $8000/0.63 \times 0.75 = 16{,}950$ million lumen-hours. The new annual cost is therefore $16{,}950 \times \$0.732 = \$12{,}400$. This is a saving of $1120 on the previously calculated cost.

Let's look at it from a different angle. At the new unit cost of light the original $13,520 will buy 18,470 million lumen-hours of light. Applying the utilization and maintenance factors to this figure gives: $18{,}470 \times 0.63 \times 0.75 = 8720$ million lumen-hours of actual light output. This represents an increase of nearly 10 percent in average illumination at no additional cost.

Still another way of looking at it, and getting nearer to brass tacks, is to examine the unit cost of light on the basis of maintained lumen values. With

(*Continued on page 61*)

Added Kick for Turbojet Engines

By G. W. LAWSON and W. C. ALEXANDER

Additional thrust is accomplished through means of liquid injection. The liquid—a water and alcohol mixture—increases the energy available in gases leaving the burner

Getting an 80-ton airplane into the air in a matter of seconds is no easy job. The problem is one of providing more than normal maximum thrust or "kick" at take-off. In the case of B-45 and B-47 jet bombers, their power plants (J-47 turbojet engines—one is shown on the adjacent page) were equipped with combustion-chamber water-alcohol injection systems for augmenting thrust.

Variations of these systems boost the take-off thrust from 15 to 25 percent or higher. As a result, heavy jet-powered aircraft can take off from minimum-length runways with maximum safety.

What It Does

The use of water injection in aircraft power plants isn't new; its use to increase power output in reciprocating aircraft engines has been common for many years. Power output in this type of engine is limited by detonation, pre-ignition, and decreased density of charge because of high inlet-air temperatures. To offset this limitation a water-and-alcohol mixture is injected as a *coolant*.

On the other hand, the use of water-alcohol injection in the turbojet engine not only is new, but also its purpose is quite different. Here there are no pre-ignition or detonation difficulties to contend with.

An indirect purpose of water injection is to decrease compressor inlet temperature. The main purpose, however, is to increase the *mass flow* through the turbine and to increase the *pressure ratio* (discharge pressure divided by inlet pressure). Output or thrust of the cycle is thereby increased. An equation for the gross thrust, showing how the increase comes about, is at the end of this article.

The detailed process whereby 60 gallons of water a minute is forced into the *combustion* system without extinguishing the flame is an interesting problem. It's one of the many that required solution during development of the turbojet liquid-injection system. In fact, various developments over a two-year period raised the efficient liquid-injection limit to a rate of over 125 gallons per minute.

It's true that the effect of introducing a liquid into the combustion zone is harmful to combustion efficiency. But the increased gas flow and higher compressor-pressure ratio results in a larger amount of energy available in the gases leaving the burner. What you might call a secondary but nonetheless significant effect also occurs—this is a further increase in output because of the higher specific heat of the liquid-and-gas mixture.

Liquid injection in turbojet engines isn't limited to combustion systems. Important gains are also realized in reducing the work of compression by cooling the air before it enters the compressor or during the compression cycle. Because of their high latent heats of vaporization, water or water-alcohol mixtures are ideal fluids.

Combustion Injection

All the water injected into a combustion burner must be evaporated within the burner for best results. This process is analogous to that of a flash boiler. That is, additional fuel is required to evaporate the water and heat it to the burner-exit temperature. This additional fuel is supplied by adding alcohol (or some other combustible fluid) to the water.

Development of the combustion-injection method started with a *low-flow* system that was installed in standard combustion chambers. To effectively operate the water system, a pump and control system was developed, shown schematically on the opposite page. It consists of an air-driven centrifugal water pump, water valving, and air valves. The pressurized tank and priming valve insures that the pump-inlet cavity is always full. If the pressure drops below a certain limit, a pressure switch located at the pump discharge closes the solenoid air valve immediately. This rapid action is necessary to prevent the unloaded pump from overspeeding when the tank is emptied. The check valve prevents the flow of hot gas from the engine to the pump during the "off" period.

Compressor Injection

In practice, a water-and-alcohol mixture is sprayed into the air intake ahead of the compressor. The compressor then takes over and the mixture passes through a series of nozzles (stationary blades) between stages.

Several conditions determine the amount of water that will be evaporated ahead of the compressor. They are: fineness of spray; temperature and relative humidity of the air; quantity of the liquid, and the time required; for mixing. Evaporation at this point causes a decrease in the temperature of the inlet air. The lower temperature increases the density of this incoming air with a resultant increase in the mass flow of air through the engine. Increase in mass air flow results in an increase in compressor-pressure ratio, to produce an over-all rise in the total thrust of the cycle. This is accomplished without increasing the work of compression or delivery per unit mass of the air.

Which Method?

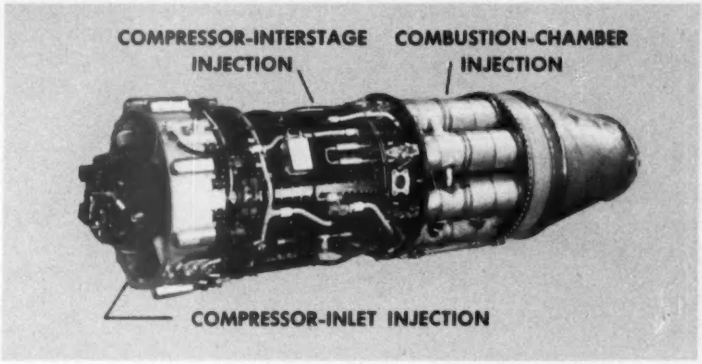
From the efficiency point of view, compressor injection appears more desirable. Yet this method imposes several serious operational disadvantages. For instance, demineralized water is sometimes necessary to prevent performance losses. These losses result from calcium-bearing minerals in the water that are

As project engineer, Mr. Lawson is responsible for thrust augmentation development of turbojet engines. Mr. Alexander is concerned with application designs of thrust augmentation systems. Both are with General Electric's Aircraft Gas Turbine Division, River Works, West Lynn, Mass.

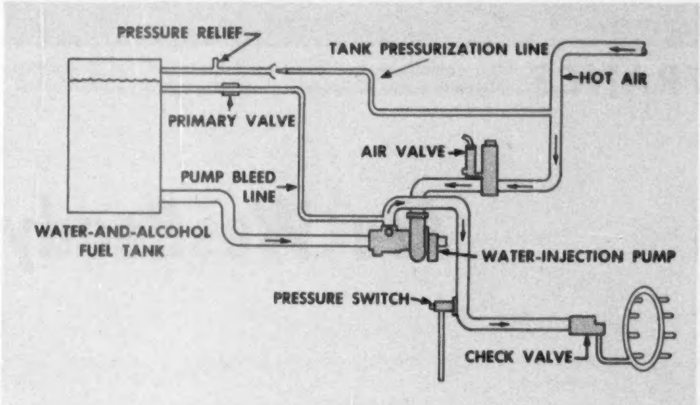
deposited on the compressor and turbine blades. Also, if compressor air is bled off for cabin-air supercharging or for wing deicing, undesirable water and moisture finds its way into the cockpit and cabin and various other components. And, of course, water freezes in cold weather and at high altitudes. True, alcohol added to the water may prevent freezing. But if compressor air passes through the cabin during thrust-augmenting periods, its use is obviously out of the question.

Another serious problem of a mechanical nature limits the quantity of liquid that can be injected into the compressor. This limitation is imposed because the contraction of the relatively thin stator casing is greater than that of the rotor with its heavier mass. The result is that the rotor blades rub on the stator casing at higher liquid flows. The blade clearance can be increased to allow for this differential contraction during the injection, or cooling, process. But then decreased performance during the nonaugmented, or dry, period must be considered.

The combustion-injection method isn't as attractive from the percent-augmentation versus water-rate point of view. However, it does not have the disadvantages currently associated with the compressor method. Not that the combustion method is without its problems. The difference is that at the present state of development they are more readily solved. It's because of this that successful progress has been made with the combustion method.



VARIATIONS OF INJECTION SYSTEMS BOOST TAKE-OFF THRUST 15 TO 25 PERCENT



LIQUID INJECTION INTO COMBUSTION BURNER BEGAN WITH THE LOW-FLOW SYSTEM

Improvement Progress

Attempts to completely vaporize larger quantities of water-and-alcohol mixtures within the combustion chambers take various forms.

A discovery made during the analysis and development of different systems indicated that changes in the basic design of the combustion chamber had big effects on water-injection performance. The water-injection program, therefore, was run in parallel with a combustion-chamber improvement program. The dual program has fostered many changes in design of the combustion chamber and in the water system.

Several different nozzle configurations were tried. Some showed promise but didn't give enough improvement to justify their incorporation. A *high-flow* configuration that more than doubled the amount of water and alcohol that could be vaporized in the combustion chamber was finally developed. This, of course, resulted in correspondingly higher thrust augmentation.

Simultaneously with these, another program saw improvement on the accessories and controls for the water-and-alcohol system. The turbine-driven pump was redesigned to give the higher flow and discharge pressure required by the new high-flow system. Faults in the original pump, such as susceptibility to corrosive attack by the water-and-alcohol mixture, were corrected in the new design. Similarly, other control components of the system, shown in the schematic diagram, were redesigned for better results.

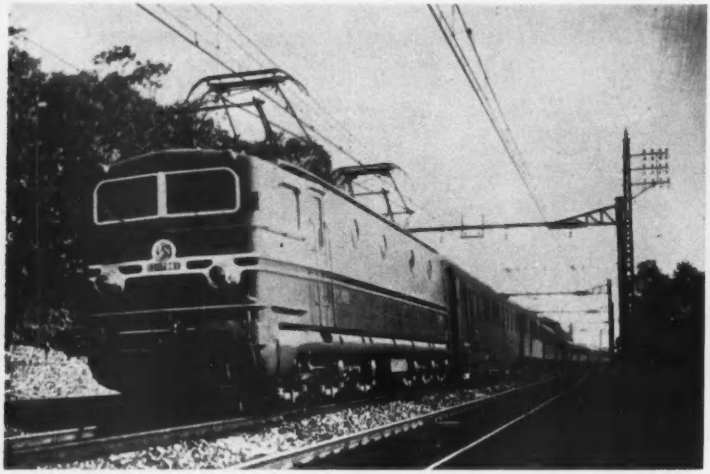
The improved control system has gone through several hundred hours of performance and endurance tests under simulated field conditions. They were trouble-free hours and proved the reliability of the improved system.

The equation for the gross thrust per cycle is

$$F_g = \frac{W}{g}\left[K\sqrt{T_n}\sqrt{1-\left(\frac{P_a}{P_n}\right)^{\frac{\delta-1}{\delta}}} - V_a\right]$$

where

F_g = gross thrust per cycle
T_n = total temperature at jet nozzle
P_n = total pressure at jet nozzle
P_a = ambient static pressure
V_a = airplane velocity
δ = ratio of specific heat of mixture
W = mass flow of mixture



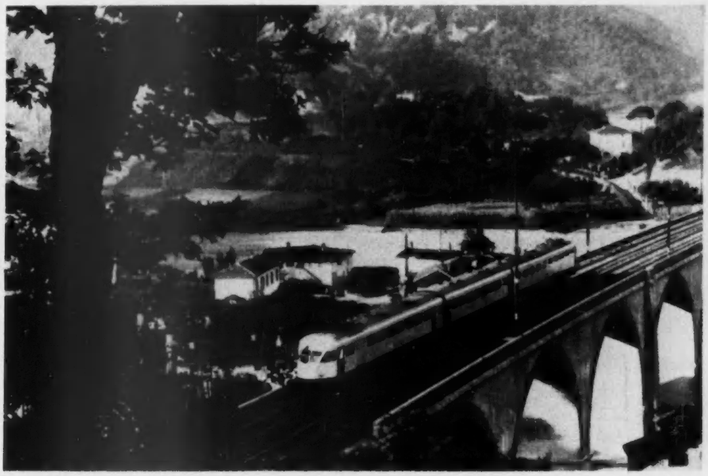
FRANCE The newest SNCF high-power high-speed C-C locomotive highballs under the widely used 1500-volt d-c power

SWITZERLAND

Are We Ready for Railroad

UNITED STATES Under 11,000-volt 25-cycle power, this new G-E demonstrator locomotive with a-c commutator motors is in service on the heavy mountain grades of the Great Northern

A modern CFF express heads through a valley on a 16⅔-cycle 15,000-volt a-c line



ITALY In the country of the famed Legions this high-speed extra-fare mainline motor-car train operates under 3000-volt d-c power

Electrification in the U.S.?

By JOHN C. AYDELOTT

Admittedly, widespread electrification in the United States is not just around the corner. But there is an element in the cost of railroad electrification and in the success of operation through the ensuing years that can not be settled too soon. This all-important factor is standardization. And standardization is so important primarily because it permits repetitive manufacture. Standardization, of course, offers other advantages that may be more familiar, but every day brings new evidence that a custom-designed article built in a job shop cannot compete with a highly engineered item produced under conditions of repetitive manufacture.

It is time for all who may have a hand in railroad electrification in the United States to start sifting out the alternatives and to find agreement on what may be the standard system of electrification in this country. Let us speak briefly about the prospects of electrification and then expand the theme of standardization.

A Brightening Outlook

When will we see railroad electrification resumed in the United States? The answer depends largely on costs, with the cost of fuel or energy being a big part of the expense of locomotive operation.

When we compare the cost of diesel fuel with the cost of purchased electric power at the figures current today, we find them roughly equivalent. We are speaking, of course, of gallons of fuel oil or kilowatt-hours of electricity at the locomotive. As long as power costs in these two forms are even approximately equal, it is obvious that the diesel-electric locomotive with its lower investment is the correct answer for new installations. At the same time this approximate equality tells us that extensive electrified systems already installed should continue to be operated.

And if you lump together enginehouse expense, maintenance of rolling stock, and maintenance of fixed property—including the trolley wire and substations for electrified systems—the total is less for electrified systems than it is for diesel-electric operation. The difference in favor of electrification is about half present-day fuel or power costs. This over-all maintenance item will continue to favor electrification because other items of operating expense are and will be practically a standoff. The item to watch is variation in the cost of fuel or power.

When the diesel-electric locomotive was getting underway with its phenomenal displacement of steam, the cost of diesel fuel was half what it is today. In other words, diesel fuel today costs twice as much as it did 10 years ago. As this trend continues, you can expect the differences in favor of electrification to increase. You will see a resumption of railroad electrification as soon as the added investment necessary to convert to trolley operation can be paid off in an attractively short period of time.

Recently an old stumbling block to electrification has been removed. In the past the treatment of telephone and telegraph lines along the railroad right-of-way, to avoid interference from the trolley circuits, was a considerable part of the first cost of electrification. Short-wave-radio relay towers are now available to handle this kind of communication. Already some railroads, simply to realize a saving in maintenance of the communication system, are replacing all their telephone and telegraph lines with short-wave radio, and are providing wayside-to-train communication at the same time. Such conversions are more than able to pay their own way.

Fruitless Battle of the Systems

How are we to choose a standard system of electrification for this country? A look at some typical European electrifications is of interest. The widely used system of electrification in France is 1500 volts d-c. In Switzerland it is $16\frac{2}{3}$ cycles, 15,000 volts a-c; and in Italy 3000 volts d-c. When riding the trains in these countries you get the impression that these three systems of electrification are all doing a first-class job. The differences that exist in the over-all railroading job to be done in the various countries certainly do not justify or explain the choice of a different system of electrification; but all of these systems work well.

Anyone favorably inclined toward railroad electrification will, I believe, if he stops to think about it, regret that there are so many systems from which to choose. We have all grown tired of the battle of the systems. But the fact that so many different systems have been made to work successfully is a tribute to the skill and perseverance of many good engineers. The fact that, after 50 years, the battle of the systems has not yet been decided in favor of any one system indicates that there is very little to choose between them, and that we will not find an outstanding economic superiority of one system over another.

Such a broad statement certainly requires further discussion. In the past it has been customary to look at a piece of electrification as an isolated problem. It is easy to say that for an installation with a lot of miles and a few locomotives you can save money by using a system with low-cost overhead even though the locomotives are expensive. On the other hand, so they say, if you have a short piece of railroad and a lot of rolling stock to buy, you should use a system offering low-cost motive power even though the power supply installation may be fairly expensive. This is easy to say but really isn't very sensible when we recognize that most railroads have a variety of such conditions under one management, possibly even contrasting conditions between one portion of the main line and another. Those who are sure that one system of electrification far excels any other are probably looking at only part of the picture.

Forward-looking railroad managements may study the economics of various systems as applied to some initial project but will naturally keep future extensions in mind. What we all want to know is: What system is best when we look at electrification for a whole railroad or, beyond that, for all the heavy traffic lines in America?

In the past enough studies have been made to permit some pretty sweeping statements about the fallacy of trying to lower electrification costs by finding either a unique solution for each railroad's electrification problem or one system of electrification that will show appreciably lower costs than some other system. From time to time these studies in various parts of the country have been made on railroads with a wide range of traffic and operating conditions. In each case two or more systems have been investigated to see which would show the lowest cost. When everything was added up, the different systems totaled very nearly the same figures, in fact within a few percent. What was "lost on the peanuts was made up on the bananas," or vice versa. It is no wonder that thus far no victor has emerged from the battle of the systems.

Electrification at 60 Cycles

In view of this evenly matched battle through the years, can we expect a new contender in the field—railroad electrification at industrial frequency—to be outstandingly more economical, and why?

Mr. Aydelott, who has spent many years in the study of railway transportation, is Application Engineer—Product Planning, Transportation Department, Erie, Pa. He was the United States National Committee representative at the International Electrotechnical Commission meeting in London, September 1951, considering standardization of electric traction equipment. While there he toured England and Europe observing railroad systems and equipment.

Two factors affecting the choice of an electrification system are different today from what they were when most of the present electrification systems were adopted.

Industrialized countries today are covered with a network of transmission lines which could make power available to the railroads at not too widely separated points along the right of way. This is in contrast to the day when practically the only transmission lines anywhere were the ones that the railroads built for themselves.

If all the railroads were electrified, the total power required would be only a relatively small fraction of the total generating capacity in any industrialized country. Again, this is in contrast to the early days when the generating stations built for railroad electrification were as big or bigger than then-existing stations built to supply all other loads.

The leaders of the French railroads (SNCF) believe that these two factors justify a complete reconsideration of the system of railroad electrification, and most likely the adoption of single-phase a-c electrification at their industrial frequency of 50 cycles, and at 20,000 to 25,000 volts trolley potential.

In October, 1951, at Annecy in the Haut Savoie in France, the SNCF were hosts to 250 railroad operators and representatives of manufacturers from all the free countries of Europe. The writer was also an invited guest.

Annecy is at the center of a trial installation, 78 kilometers in length, of single-phase 50-cycle 20,000-volt electrification. Four locomotives and three motor-car trains were exhibited, and 35 papers were presented. The whole meeting reflected French hospitality and thoughtfulness. And, as its sponsors intended, it certainly served to focus attention on electrification at industrial frequency.

Favorable Considerations

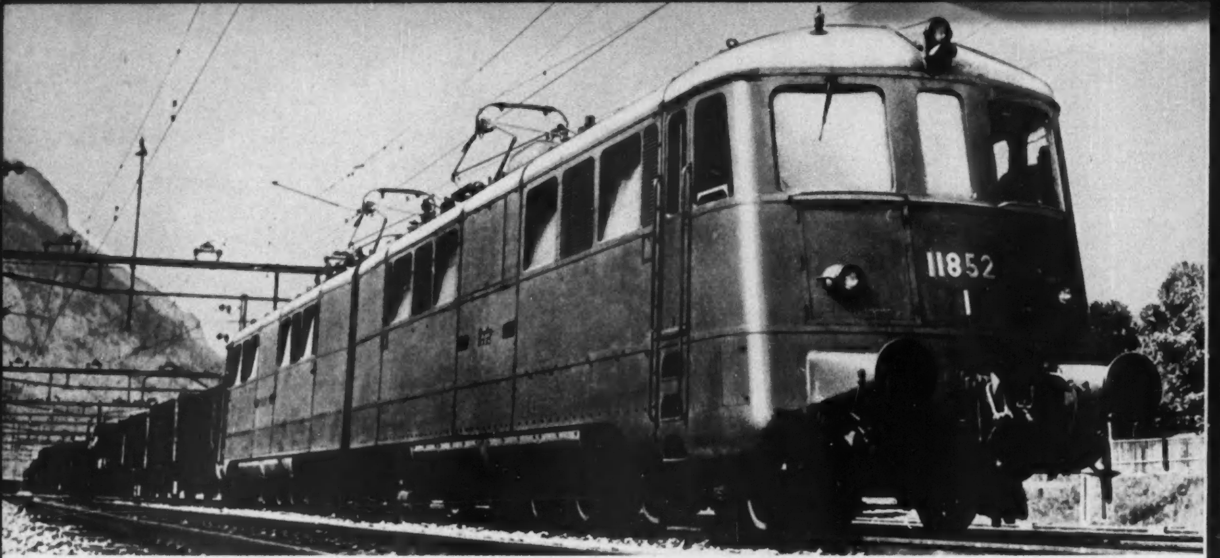
The idea is very attractive—some people think that all you need to do to electrify a railroad is to string a light piece of wire over the track and hook onto some electric utility's nearby transmission lines. You would, of course, hook onto the same transmission line or other transmission lines at more or less equal intervals along the right of way. (The French propose to solve the interference problem by putting communication lines in underground cables

HIGHBALLING ON THE HIGH IRON, THIS 2D2 WAS CAUGHT ON THE PARIS-DIJON LINE, A RUN OF ABOUT 200 MILES. IT AVERAGES 77 MPH

no matter what system of electrification is used.)

Why is this idea so attractive? Apparently less investment is required. Certainly less investment is required on the part of the railroads themselves, and railroads particularly find it difficult to get money. Furthermore, the system lends itself to piecemeal installation—a little now and a little later—as money is available. In these times of distorted economics, when some items of expense come before taxes (large taxes) and others after taxes; when a dollar in one account has an entirely different significance from a dollar in another account; and when so many undertakings are being subsidized, these are powerful considerations.

From all the evidence that came to my attention, the French railroads are receiving full co-operation from the electric utilities. Perhaps because of the prevalence of water-wheel generators with heavy amortisseur windings the possibility of phase unbalance seems not to be considered too serious. Furthermore, the French electric utilities may be willing to supply power at many points but consider load factor on the basis of the railroad system as a whole. If they do take such a constructive attitude toward railroad electrification, it seems reasonable that there should be an over-all saving in the investment in transmission lines and equipment.



POWERFUL CFF ELECTRIC HAULS A STRING OF BOX CARS ON ONE OF SWITZERLAND'S MAINLINES UNDER 15,000-VOLT A-C POWER

The final answer will be expressed, of course, in the rate at which the electric utilities are willing to sell power to the railroads. I have not seen a statement anywhere as to how much the French railroads will have to pay the electric utilities for power on these terms.

. . . and Unfavorable Considerations

No intent to overemphasize the unfavorable considerations should be read into the following statements, but it is well to look at both sides of the picture. The use of industrial frequency on the trolley wire is as old as railroad electrification itself. Some of the earliest attempts were soon abandoned. There are single-phase 50-cycle installations in Hungary at 15,000 volts and in Germany at 20,000 volts, on which years of experience have been accumulated. Hungary was not represented at Annecy. The German delegation stated that they had not had sufficient operation on the Hollenthal line since 1933 to join in a blanket endorsement of the 50-cycle system.

The electric utility companies like to sell balanced three-phase power. However, no one now advocates the use of two trolley wires and the railroad load is accepted as necessarily single phase at any one point. How the single-phase load can be supplied from a three-phase system has been the subject of much study. Different power companies may offer different solutions.

Over enough miles of railroad, a diversity factor should tend in the direction of phase balance if the same electric utility's lines extend far enough, and if the same generating equipment is involved. Or possibly some kind of switching arrangement can be devised and an automatic control used to transfer some of the load from the heavily loaded phase to the lightly loaded phase.

Railroad operation being what it is, the load factor at the various feed-in points taken individually is bound to be poor. Metering, demand charges, and power rates as set up for more easily controllable load may well be prohibitive. Possibly a metering system based on a summation of the instantaneous loads at various power-supply points can be worked out. Or the electric utility may be willing to forego demand charges, assume some reasonable load factor, and simply charge for the total kilowatt-hours consumed.

One way or another, added investment on somebody's part is necessary to handle the railroad load composed of large intermittent slugs of single-phase power. That is, extra generating equipment is needed if the utility elects to take the load just as it comes; or some special equipment is needed if an attempt is made to improve the phase balance or local load factor. For the railroad itself to make the lowest investment, all of these things must be expressed in the power rate.

Comparison Is Still a Standoff

Some say that railroad power lines should be isolated from industrial power lines anyway, and that the only way to get from single phase to balanced three phase is through motor-generator sets. They further say that, when all is said and done, it will be just as economical to install conversion equipment, electrify at a frequency more suitable for railway work, and benefit by lower cost for the motive power.

Whatever the system of electrification, the utility companies may be the logical ones to carry a large part of the burden of investment. It may be that they will lean toward electrification at industrial frequency. But lower figures in the railroads' capital account may be offset by higher charges for power.

When all the costs are added up, there is the possibility that wide-scale railroad electrification at industrial frequency will come out at about the same place as all the other contenders in the battle of the systems. The hope of getting something for nothing is always attractive, but the lamp of experience does not reveal much basis for optimism.

Get the Most for Your Money

You cannot look for electrification in the United States until it is economically justified. But as we try to select a standard system for this country, let's be sure our choice offers all the benefits that electrification should provide.

STANDARD 3000-VOLT D-C LOCOMOTIVE TAKES A LONG PASSENGER TRAIN OVER SOME ROLLING HILLS ON THE ITALIAN STATE RAILWAYS

For the relatively lightweight European trains, the locomotives have very high horsepower. European engineering has progressed to the point where on new designs every locomotive axle is motored, and motored up to the adhesion limit. A fundamental of motor design is that motor torque largely determines motor weight or the amount of material needed. A high-horsepower motor weighs little if any more than a low-horsepower motor of the same torque. Within limits this horsepower gain may be thought of as simply applying a higher voltage to the same motor. So why should we not have high horsepower, as long as the material has to be there anyway to develop tractive effort?

Horsepower Not a Limitation

On electrified railroads in Europe the locomotives are running much of the time at something less than their full-power and full-speed capabilities. Locomotive tractive effort based on adhesion must always be a limitation. But electrification permits, at little if any extra cost, a type of railroad operation in which locomotive horsepower is *not* a limitation. It's a wonderful feeling to know that there is always more available if you want it. With the whole power system to draw on, high horsepower is therefore the birthright of the electric locomotive.

An attractive thought is that when electrification comes in this country, it will be possible to salvage much of the enormous investment already in diesel-electric locomotives. Conversion equipment installed in place of the diesel engine will supply the existing traction motors, and undoubtedly there will be many such conversions. It is well to note that the use of existing motors will limit the horsepower of such a locomotive.

For higher-horsepower locomotives, one solution might be to use a similar conversion system and low-voltage d-c motors designed for high power. Another solution, avoiding superfluous transformations of energy if a suitable system has been selected, will be the use of motors capable of handling the kind of power supplied by the trolley. In this way you can easily have almost unlimited horsepower—certainly all the horsepower that can possibly be used in the handling of trains.

In this country the trend is toward very heavy trains, and speeds are gradually increasing as roadbeds are improved and better riding cars replace the old ones. High horsepower to handle such trains in the future comes easily with electrification—provided we look ahead in the selection of a suitable system. It will be to no one's benefit to be tied to a system that inherently limits the horsepower that can be made available to a train, or a system, that is not equally adaptable to high-horsepower locomotives and conversion of existing diesel-electric locomotives.

Can We Standardize?

The urge to lower the cost of electrification is, of course, what prompts us to look hopefully at every possible system. But there are other proved ways of getting costs down that are far more effective than starting with a blank piece of paper and a new dream every time the question of railroad electrification comes up. I am referring, of course, to the genius of American repetitive manufacture. There is far greater benefit to be realized by standardization—both in manufacture and in operation—than can ever be hoped for by hunting for a unique solution for a given set of conditions on some particular railroad.

There is not much prospect of railroad electrification in this country at the present time, but conditions may change. If the day comes when electrification is attractive with one system, it will also be attractive with other systems, and therein lies a great danger. We must certainly be careful not to ride off in all directions at once.

As we look forward to new railroad electrification here, let's remember the overriding benefits that accrue from familiarity with a job, refinement of design, and improvement of the manufacturing processes—all characteristics of American repetitive manufacture—and let's hope by that time agreement will have been reached on the right standard system of electrification for the United States.

Why Write a Description of Your Position?

By HAROLD F. SMIDDY and BYRON A. CASE

The successful attainment of the future predicted growth figures of the electrical industry depends upon the manpower to staff and manage the industry organizations. And within the manpower of each organization it is essential that there be a clear understanding of the respective positions and how they fit into the organization. To this end the authors describe a method for the preparation of position descriptions which has been found to be effective.

Mr. Smiddy is Vice President, Management Consultation Services, General Electric Company. Mr. Case is working with Mr. Smiddy in this field.—Editors.

A position description or guide may be defined as a document that gives a complete understanding of the content and objectives of a position by adequately defining its functions, responsibilities, authority, relationships and accountability.

The objective of this article is to point out how the preparation and use of adequate descriptions of the positions within an organization component can be extremely valuable to all individuals in the organization. However, before getting into the more specific aspects of this subject, let us consider some of the basic reasons why there is a need for "better understanding" on the part of the people who make up the large, complex and ever-changing organizations of today. If organization structures were static and the positions were filled with the same incumbents for long periods of time, it would be relatively easy for them to understand the objectives and relationships involved. However, this is not the case.

The numerous changes in organization structure and patterns within the General Electric Company which have been required since the end of World War II, arose not merely from the general fact that the organization process is naturally an evolutionary and continuing phase of any growing business, but specifically from the success brought about under earlier forms of organization, in expanding the size and volume of the Company's business, the diversity of its products, the complexity of its facilities and the resultant need and opportunities for large numbers of men with both the ability and the experience to handle managerial and functional work.

The work of management, as such, falls into four principal categories, namely, planning, organizing, coordinating and controlling. The bigger and more complex the enterprise, the greater the difficulty, and hence the greater the need, to reserve adequate time for the planning and organizing phases of the work.

This planning and organizing work within General Electric is wide in scope and embraces research, products, plants, machinery, new markets and distribution practices, and, above all, manpower to staff and manage the growing organization.

The whole process, both generally and specifically as it is operating at General Electric, may be likened to the matter of the growth and life of a tree. There are two old sayings that: (1) "Trees do not grow to the sky," and (2) "Trees die from the top." In a sense an organization is like a tree in that it is a living thing with definite limits on the height to which it may grow as a single, compact, product business, and in the fact that if it gets too old or too top-heavy it may perish, either from obsolescence or inability to stand the buffeting of business storms. On the other hand, if proper seed be taken from a single tree and suitably planted and nourished, a forest can be developed so that it will remain growing, strong and expanding, even though some of the original trees reach their top height and ultimately perish. The present organization pattern of General Electric in this sense contemplates a strong, healthy forest, rather than an oversized, and ultimately a weakened, single tree.

The obvious way to meet the challenge of size and of the cumbersomeness, slowness and dangers that come with it, is to divide the enterprise into smaller pieces for management purposes. This decentralization of responsibilities, and the delegation of authority to make decisions and establish policies, to successive echelons of executives and supervisors, follows the great principle of getting decisions made as close to the work as possible. Decentralization gives added responsibilities and authority to more individuals and thus emphasizes the necessity of better definitions of the functions, responsibilities, authority, relationships and accountability of each position.

Organization charts have been used for years as a means of showing the functions and relationships of the more important positions in an organization. A functional organization chart is one which includes a brief statement of the functions of each position. Although this type of organization chart can be very useful in giving a picture of the organization structure and the basic functions and relationships of the positions, it does not of itself provide a fully adequate definition of responsibilities, authority, accountability and relationships outside the line of authority, for each position.

Two additional "tools" are being used for this purpose, namely:

First, general Notes on the Organization Chart (See Figures 1 and 2), to define the meaning of *Authority and Responsibility*, and of *Accountability*, especially as to the personal nature of responsibility for making decisions, and, simultaneously, to show that flow of information and *Channels of Contact*, and hence *Relationships*, are controlled by common sense and good judgment, rather than solely by lines on a chart; and

Second, *Position Descriptions*, which have been found to be very valuable alike in the solution of *management* problems and in helping *individuals*—be they managers or be they engineers or other functional experts—to gain a better understanding of the organization, of its objectives and, above all, of the opportunities for the individual to render useful and productive contributions to its progress by such understanding as will permit both maximum personal initiative and also greatest voluntary contribution to harmonious teamwork throughout the organization as a whole.

Uses of Position Descriptions

So used, by both management and individual employees, Position Descriptions have proved to be very useful in many ways, prominent among which are the ten listed in Table A.

Contents of Position Descriptions

Although many satisfactory techniques and forms have been used in the preparation of Position Descriptions, it is desirable to maintain reasonable uniformity in such organizational tools for positions within the same organization. One form, as illustrated in Figure 3, that has been used quite extensively and has proved to be very satisfactory contains sections covering Function, Responsibilities and Authority, Relationships, and Accountability. The following brief statements indicate the content of these sections:

Function—This section summarizes the general functions of the position by stating briefly and succinctly its basic objectives and responsibilities. It should enable anyone reasonably familiar with the organization to understand the primary purpose of the position and those major aspects which distinguish this particular position from others.

Responsibilities and Authority—This section lists the major specific responsibilities assigned to the position. Minor responsibilities and duties which are of a routine nature are usually briefed or covered by general language applicable to many positions. The major responsibilities will constitute the objectives of the position referenced to factors or other standards against which performance can be measured and appraised.

As a general principle, the position should be given authority, to be used with good judgment and as the incumbent sees fit, to do everything that is necessary to accomplish the responsibilities, and hence the objectives, of the position. Authority should be withheld only as warranted and the specific limitations adequately covered by reference to policies or instructions: and where so limited or withheld, the responsibility has to be tailored accordingly. Scope of authority defines an important relationship between the incumbent and his superior and the superior is the only person who can withhold delegation of authority from the incumbent, realizing that when he does so he inevitably also retains personal responsibility in the undelegated area.

TABLE A

10 SIGNIFICANT WAYS IN WHICH GOOD POSITION DESCRIPTIONS CAN BE USED TO HELP BOTH MANAGERS AND INDIVIDUALS

1—To provide a check on the soundness of an existing or a new organization structure.

2—To serve as an aid in accomplishing the proper assignment of functions to positions.

3—To provide a means of encouraging the incumbent to thoroughly analyze his position, and to record the work to be done and the objectives to be accomplished.

4—To facilitate discussion between the incumbent and his superior to use in developing mutual understanding and agreement on the objectives to be accomplished, the scope and limits of authority and responsibility, important relationships, and the factors to be used in measuring specific accountability for performance.

5—To focus constructive discussions with subordinates and associates so as to develop understanding both of relationships between positions and of teamwork responsibilities.

6—To afford a basis for sound evaluation of the differences in skills and abilities required to perform acceptably the work of specific positions.

7—To use as a basis for developing a definite and clear list of skills and abilities required of incumbents of each position, so that adequate "man-specifications" can be prepared; and so that positions can then be staffed with individuals who have been definitely appraised as able to at least meet minimum requirements for each particular position.

8—To guide discussions with candidates for positions; and incidentally, as a means for quickly informing newly appointed incumbents with respect to their position.

9—To allow incumbents of jobs whose work interlocks as to different parts of the Company's business to have sympathetic appreciation of each other's objectives and requirements.

10—To assist both managers and individuals so to schedule, perform and control the efforts of all members of the organization "team" as to insure smooth, profitable and mutually satisfactory pace, turnover and competitive flow of the business as a whole.

Authority and Responsibility, and Accountability
Management authority and responsibility, and accountability, for (a) **Operations**—deciding and taking action, and (b) **Services**—functional service (assisting, teaching, advising, counseling and recommending) and functional audit, or "right to look," (reviewing, finding, appraising, recommending and reporting) and their relationships at all levels of the organization, are denoted by the lines and text of the chart. In particular, authority and responsibility for decision-making are so indicated, for each position, by the chart; irrespective of the circumstances or context in which an incumbent of a position may be when exercising his decision-making authority and responsibility. The fact that specific decisions may be made by an individual while in contact with other members of the organization or while participating in a group or committee meeting does not alter this personal nature of the authority and responsibility involved as to decision-making.

FIG. 1. TYPICAL BOX FROM ORGANIZATION CHART

Channels of Contact
While the organization structure and organization chart define lines of responsibility and authority (and of accountability) —and especially so as to personal responsibility for decision-making—they do not indicate or limit **Channels of contact,** or **flow of information,** between or among members of the organization. Organization policy permits and expects exercise of common sense and good judgment, at all organization levels, in determining the best channels of contact for expeditious handling of Company work. Contacts, and flow of information, between people and components of the organization should be carried out in the simplest and most direct way which is practicable. In making such contacts, however, it is the duty of each member of the organization to keep his superior promptly informed regarding any matters (1) for which his senior may properly be held accountable by others (2) as to which there is, or which is likely to cause, disagreement or controversy; especially between different components of the organization (3) which require the advice of his superior or coordination by his superior with other components of the organization (4) which involve recommendations for change in, or variance from, established policies.

FIG. 2. BOX DEFINING "CHANNELS OF CONTACT"

Relationships—This section describes the major relationships that are vital or frequent both up and down within the line of authority and at all levels outside of the line of authority. The subordinate positions directly supervised by the position being described are usually included.

As indicated in Figure 2, organization policy permits and expects exercise of common sense and good judgment at all organization levels, in determining the best Channels of Contact for expeditious handling of Company work. Relationships should be defined in such a way as to encourage rather than impede individual initiative in accomplishing the objectives of the position.

The fundamental reason for spelling out Relationships, either on an Organization Chart or in a Position Description, is to facilitate dynamic organization. The purpose of such organizational tools is to foster understanding of goals, policies and objectives by *all* employees; thus creating the most favorable working climate so that constructive initiative and voluntary teamwork may be united to give synchronized flow and progress to the work of all individuals jointly and collectively as they strive to achieve the goals of the enterprise.

Accountability—After objectives have been made clear and the responsibilities and authority defined, the incumbent is accountable to his superior for success or failure in accomplishing these objectives.

The accountability section of the position description records the standards to be used for the measurement of performance. Performance can then be measured and appraised with respect to standards established by objectives and policies as expressed in budgets, scheduled projects and long-range planning.

The essence of Accountability is threefold. *First*, executives or supervisors realize that delegations of authority must be sincere and definite so that they then can fairly hold those to whom it is delegated, responsible. *Second*, responsibility commensurate with such authority must be genuinely accepted and exercised, especially as to decision-making, by those to whom it is delegated. *Third*, accountability then necessarily includes need for personnel policies based on measured performance, defined and enforced standards, and removal for incapacity or poor performance.

Preparation of Position Descriptions

Some methods of preparing position descriptions provide more benefits than others. The following example describes a method which has been found to be very effective. This example has been written to illustrate the preparation of position descriptions for a Company component such as an Operating Department, but the same approach is, of course, equally applicable for Service Department jobs:

First Step—The General Manager, working with his superior, and after general exploratory talks with all individuals reporting directly to him, prepares a draft of his position description and a preliminary functional organization chart showing his position and the positions of all such individuals who will continue to report directly to him.

If a new organization structure is being established, the General Manager will assign functions to positions in the way he believes will best permit him to accomplish his over-all management objectives, being sure that all needed work is covered, without gaps, overlaps or unnecessary jobs or effort. If the organization structure is already in place, the General Manager will at this point further consider how he can eliminate either unnecessary levels or unduly short spans of control, and also how he can reassign functions or otherwise modify his organization pattern to provide an improved organization structure for the future.

Second Step—After the General Manager and his superior are in essential agreement with respect to organization structure and functions, he will call together the incumbents of the positions that are under his direct supervision and discuss with them the draft of his position description and the preliminary functional organization chart. The important point here is that each shall both understand clearly his own part of the job and shall also understand, accept and

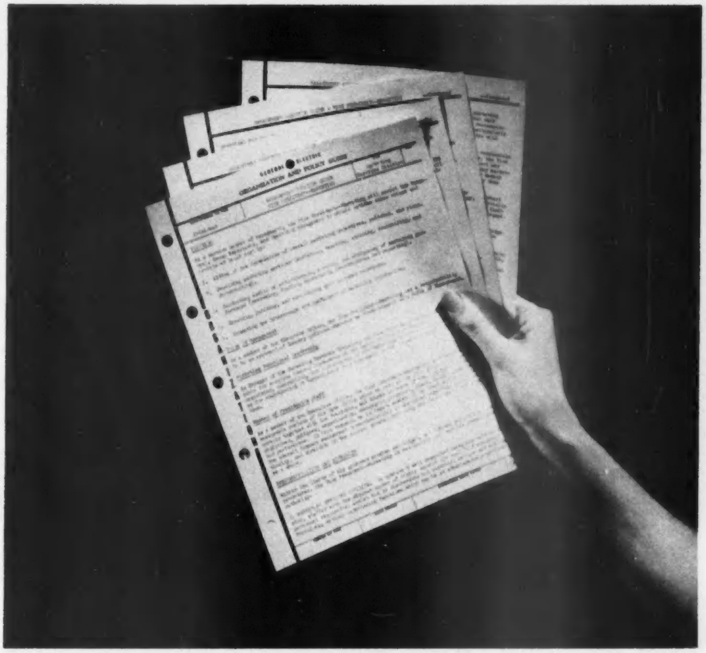


FIG. 3. FORM FOR POSITION DESCRIPTION

respect the parts of all the others on the team.

Third Step—Each incumbent who reports directly to the General Manager analyzes his own position and prepares lists of the "objectives to be accomplished" and the "work to be done."

Fourth Step—The incumbents of this "team" will discuss their "lists" with each other and will endeavor to reach agreement as to how their positions should mesh together without overlap or gaps.

Fifth Step—Each subordinate meets with the General Manager, reviews his "lists," the General Manager's position description and the functional organization chart with him, and then prepares a draft of his position description.

Sixth Step—The General Manager's subordinates hold a series of meetings, preferably with him present only when his specific counsel is essential, and they work together to the end that complete, mutual understanding and agreement is reached with respect to organization structure, functional organization chart, and all position descriptions. This provides an opportunity for teamwork participation and for the consideration of alternative solutions before agreeing on which is best for the business and its future, with the General Manager still having final responsibility to make decisions among alternative solutions or where differences of viewpoint may exist.

Seventh Step—Each of the individuals reporting directly to the General Manager then repeats this procedure with his subordinates, and so on, until all position descriptions have been prepared. In this respect, cross-checking between people in different functional sections and units, at each succeeding organizational level, needs to be worked out as carefully as between the members of the General Manager's staff in the first place.

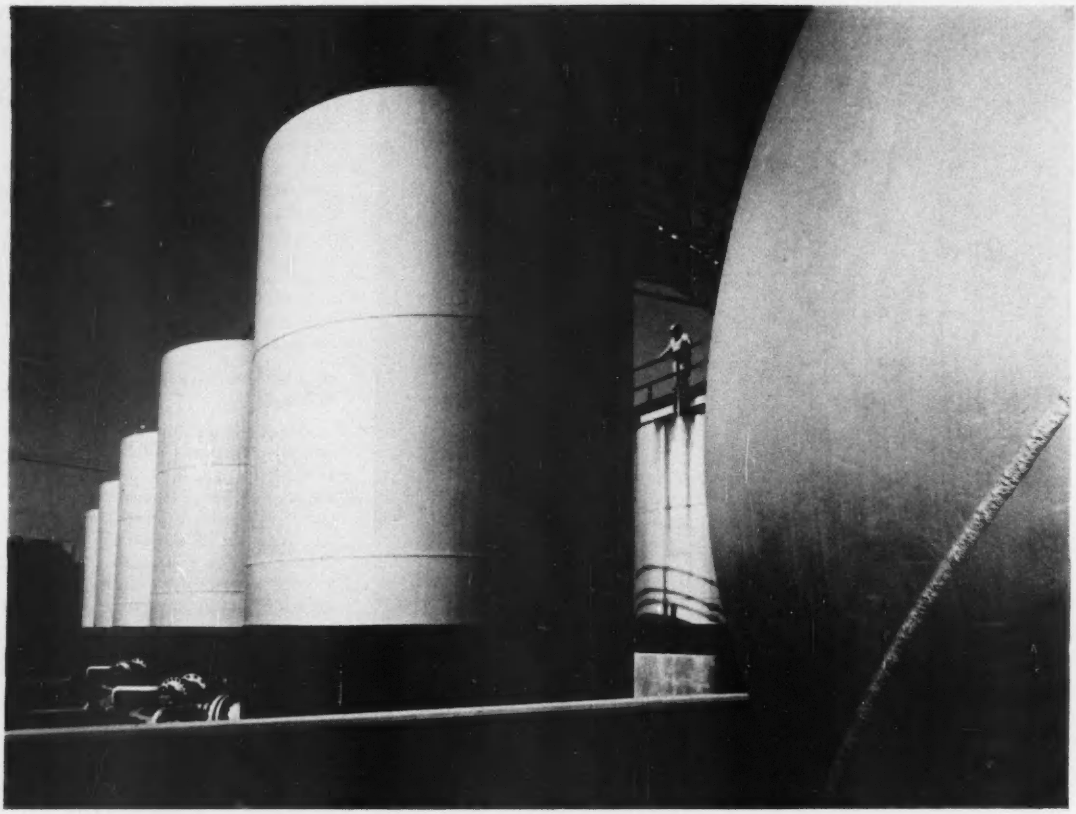
This procedure also, of course, provides each of these managers of functions with his own opportunity to modify or simplify his organization structure, to eliminate unnecessary work, positions and levels and inadequate control spans; as well as to sharpen the assignment of responsibilities and the delegation of authority throughout his own organizational component.

Obviously, the best specific approach will vary with different conditions such as size of organization, position of a product on its life-growth curve, and the kinds of work to be done, so that each organization component should do the job in the way which seems most suitable to them. However, the above pattern is cited as a general example of how an effective method of preparing Position Descriptions can provide the benefits and satisfactions which stem from participation and better understanding, with resultant improvement of the organization, the competitive effectiveness and the profitability of the business.

Why Write a Description of Your Position?

One of the greatest challenges facing society today is that of freeing up individuals so that they may attain the stature and independence of action required to more than offset the tendency of collective action to submerge the individual. The continued growth and success of General Electric depends upon a sufficiency of individuals having the skills and abilities to meet the requirements of the increasingly large number of positions carrying major responsibilities; whether these be managerial positions or positions calling for skill and expertness in a given functional field, be it engineering and research, marketing, manufacturing, finance and accounting, employee and public relations, or law and corporate.

Is it possible to make sure, in the face of such challenging conditions, that the growth and success of the Company will continue as heretofore, and will not be limited by a lack of capable personnel? Many factors will contribute to the answer to this question. However, it is well worth thinking that the most vital factor well may be "on the job" experience obtained by men of potential, working under conditions that "give them the ball." Whether these men are doing primarily executive or supervisory work or doing primarily functional work in one of the functional fields just above cited, it is equally important that they have a clear understanding of the objectives of their respective positions and of how they all fit into the organization. In the long run this can be accomplished only by analyzing the work to be done *at its source*. The Position Description is certainly the handiest and most effective tool readily available to all to do so.



STORAGE TANKS ARE PROTECTED FROM CORROSION AND CHEMICALS KEPT FREE OF IRON CONTAMINATION WITH . . .

New Safeguard for Protective Coatings

By F. J. BURNETT, C. L. CHASE, and DR. R. B. YOUNG

You can best define a plastics material as a synthetic organic substance. At some stage of production it's plastic—capable of being shaped; or liquid—capable of being cast. Furthermore, it's either thermoplastic or thermosetting. If thermoplastic, it softens under heat and can be remolded. If thermosetting, it sets under heat and can't be remolded.

Phenolic materials are thermosetting plastics. And from practically the outset of the industry they've enjoyed an ever-expanding market. They take many and various forms. Probably the most familiar to you are radio cabinets, telephone handsets, buttons, tube bases, mechanical parts, and so on.

Another form—perhaps less familiar but just as important—is that of protective coatings or finishes. You'll find them on food containers, drums, tanks, tank cars, brass fixtures, razor blades, or wherever else their unique hardness and impervious nature are required. And yet their use is restricted or impeded in many areas because of certain limitations. These are: 1) incompatibility—their inability to mix with some other substance to form a homogeneous compound of useful plastics properties; 2) inflexibility—their brittleness isn't conducive to extreme flexing or other rough mechanical treatment; 3) limited chemical resistance—they are somewhat susceptible to caustic chemicals and oxidizing agents.

However, after a good deal of research our chemists have developed a phenolic derivative that overcomes most of these limitations. At the same time they've preserved the good properties of conventional phenolics. This new product is known as R-108 intermediate.

The reason for calling it an "intermediate" is that it's not a finished coating or a resin in the generally accepted sense. R-108 is sold to the paint and finishes industry; they formulate it into a wide variety of finished coatings. These in turn are sold to the many fields requiring a high order of chemical resistance and flexibility.

A test was run to determine R-108's resistance to caustic solutions. Two steel test probes were coated—one with a conventional phenolic coating, the other with an R-108 formulation. They were immersed in a 16-per-cent caustic solution at a temperature of 195 F. The conventional coating was eaten away in just 30 minutes. However, the test on the other probe continued for five months longer. At the end of that time a thorough examination of the R-108 formulation revealed no deterioration. Both probes are shown at right, below.

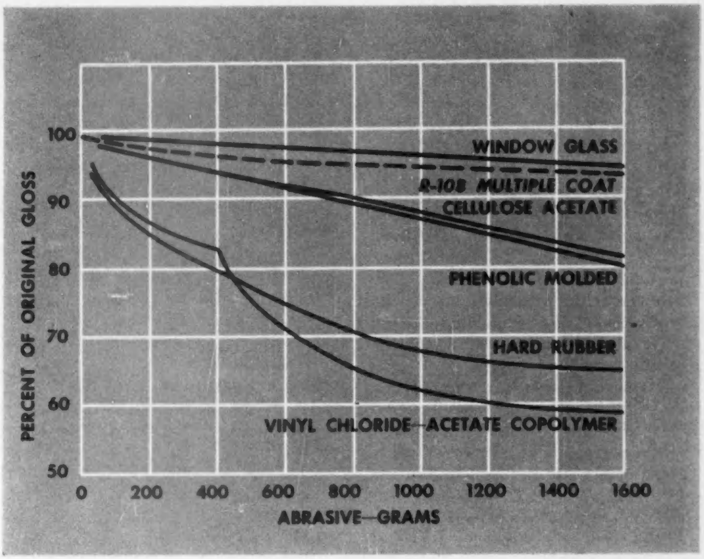
Storage Tanks

One of the first applications of coatings containing R-108 involved the protection of storage tanks. Tanks must be kept free of iron contamination so as not to impair the quality of the product inside. For instance, GE's Chemical Division now has storage tanks (left) protected with coatings formulated of R-108. They range in size from 1000- and 2000-gallon to 12,000-gallon capacity. The coatings provide the basic chemical resistance required by the job. And in addition, they readily respond to cleaning with hot caustic solutions and solvents. In this manner we keep fatty acids, organic resins, and other chemicals free of contamination. Added to this, the tanks themselves are handily protected from corrosion. They are given multiple coatings designed to last for a long time.

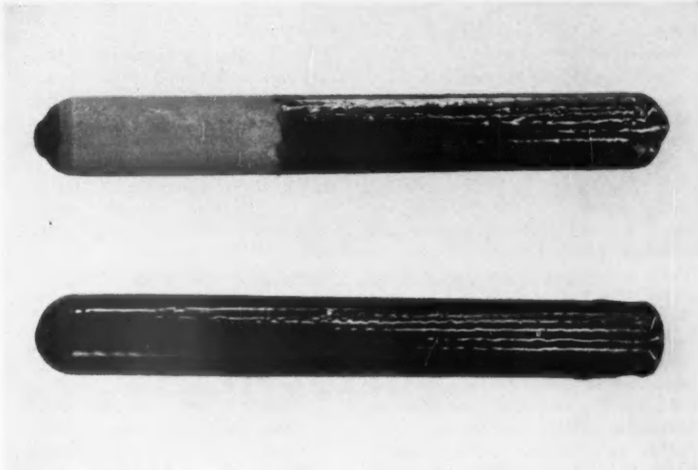
Container Linings

As you would expect, the problem of suitable drum and container linings has plagued the chemical and other industries for years. Not that there aren't good linings in use today—there are. But the search for superior ones that combine better chemical resistance with a high order of flexibility continues. As an example of the magnitude of this problem, let's look at drums and containers in transit. Moving about, they take a terrific beating with the result that their linings are cracked or otherwise rendered ineffective. This naturally takes a big slice out of their useful life.

The drum industry has, as a result of a prolonged search, come up with linings that combine good flexibility with a chemical resistance greater than that of conventional phenolics. These linings are formulated of R-108 in combination with other coating materials, as well as pigments and solvents. Drum manufacturers are furnished the linings this way, and they in turn apply them to the drum or container being fabricated. R-108 would seem to be a good thing for people in the cooperage (drum-reconditioning) business. Thousands of used drums are reconditioned daily, and most are coated on the inside with an organic lining. This business is growing rapidly and under present conditions of metals scarcity will become more important.



MAR RESISTANCE of R-108 multiple coating compared with other materials. Standard ASTM test measures resistance of glossy surfaces to abrasive action



COMPARISON of a conventional coating (*top*) with an R-108 formulation after immersion in a 16 percent caustic solution at temperature of 195 F

(*Continued on next page*)

Household Appliances

Popularity of synthetic detergents with housewives has caused washing-machine manufacturers to be harried by corrosion problems. Here again R-108 is finding application. Laboratory tests show that most conventional organic coatings can stand extremely hot water and soap or detergent solutions for only a few hundred hours—based on continuous immersion. On the other hand, coatings made with R-108 lasted at least five times as long. Incidentally, some washing-machine manufacturers are already using this formulation to protect exposed parts against just such conditions.

Possible limitations in the use of these new coatings in this field may be color, since the lightest color obtainable is light ivory or cream. However, pastel shades of blue, green, gray and others, are available, as well as the clear pale gold color of the unpigmented enamel.

Other Applications

Another field for potential use of R-108 is in insulating varnishes. They look promising for such applications as stator end windings since they combine strength and toughness with very low solvent extraction.

R-108 might also be used as a chemical constituent of other synthesized products. It can be especially useful in the formulation of new and unique resins for the coatings and the electrical industries.

Photography is a potential field for its use. Here, resistance to developing solutions, fixing solutions, acid baths, and toners is essential. In the past, coatings lacked this sort of resistance or flexibility, thereby forcing the use of glass, hard rubber, and the like.

Coatings formulated with R-108 are being investigated by the pulp and paper industry. The emphasis here is on resistance to oxidizing agents.

Other applications worth noting include government specification work. Conventional phenolics are used here, but a greater chemical resistance, a slower rate of heat transfer, and other properties are particularly desirable.

Outside Exposure

For exposure to the weather R-108 coatings stand up exceptionally well, provided metal protection rather than appearance is of prime importance. Outdoor-weathering tests show that coatings dull quickly, but even after long exposures their condition is excellent.

To give you an example, a group of panels were exposed in Florida for 30 months. While the coatings dulled, they showed no sign of checking, cracking, or otherwise deteriorating, except for a tight chalk (chalk-like appearance or deposit on the surface). These results point, therefore, to such applications as pole transformers and brackets and other metal parts exposed to outdoor weathering. Dulling is unimportant in this field; metal protection over a long period is the critical factor. If gloss retention is of key importance, however, R-108 may well find use as an undercoating. Its effect is generally to increase the resistance of the surface coating to water, chemicals, and solvents.

R-108 is also highly resistant to salt spray. It should therefore find considerable use by chemical plants, oil refineries, and other manufacturing installations in and around coastal areas.

Coating Procedure

The nature of R-108 coatings require skilled techniques in applying them to tanks and other chemical process equipment. Specialized companies in the United States apply these and other coatings on a made-to-order basis. For maximum performance, sandblasting or similar type of surface preparation is required before the coating is applied.

Coating procedure consists of coat-by-coat applications. Each one is baked for a short time until an over-all thickness of about five to six mils is obtained. Then, the entire system is baked a longer period for complete curing and fusing of all coats.

Big baking ovens—available in the industry—are capable of handling many sizes of tanks and other equipment. There are, as you know, some jobs too huge to be handled this way or of such a nature that the job must be done at the customer's plant. If that is necessary, the equipment is insulated with glass-wool blankets and cured by means of portable gas-fired blowers. A hard, dense, and infusible coating results—ready to resist many chemicals and essentially as mar-proof as glass (graph, page 51).

Mainly, though, applications require only a single coat—or two at the most. For such uses R-108 formulations coat well over iron and steel, and also aluminum, magnesium, zinc (also its alloys), and other plastics. Examples of applications requiring a single coat are air-conditioning-unit drip pans, steel drain boards and refrigeration panels needing exceptional resistance to water.

As indicated earlier, R-108 offers the formulator and user singular advantages. It does this by combining an outstanding chemical resistance with a wide degree of compatibility. Resistance to acids and solvents is excellent, and it's also impervious to alkalies. Against these and other corrosives, such as oxidizing agents, conventional phenolics have limited or no usefulness.

Dense, hard, and highly resistant films required for chemical process equipment and tanks are easily made with R-108, as well as flexible and tough enamels for coating all types of containers.

You can generally combine R-108 with other coating materials and get a product that will reflect its basic properties. Curing or conversion of such formulations requires a minimum temperature of about 300 F, a temperature that is available in the general type of industrial oven. However, you can vary the curing time by varying the amount of catalyst. As an example, you can have a curing time of 30 to 60 minutes at 330 F, or one of 3 to 12 minutes at 400 F.

Just a few examples of the many applications of R-108 coatings have been given. Like other coating materials it must be properly formulated, handled, and applied for best results.

There are so many different combinations that it's possible to tailor them to fit a specific job. Although no formulation can be expected to fulfill all jobs, R-108 can be employed to great advantage in doing many.

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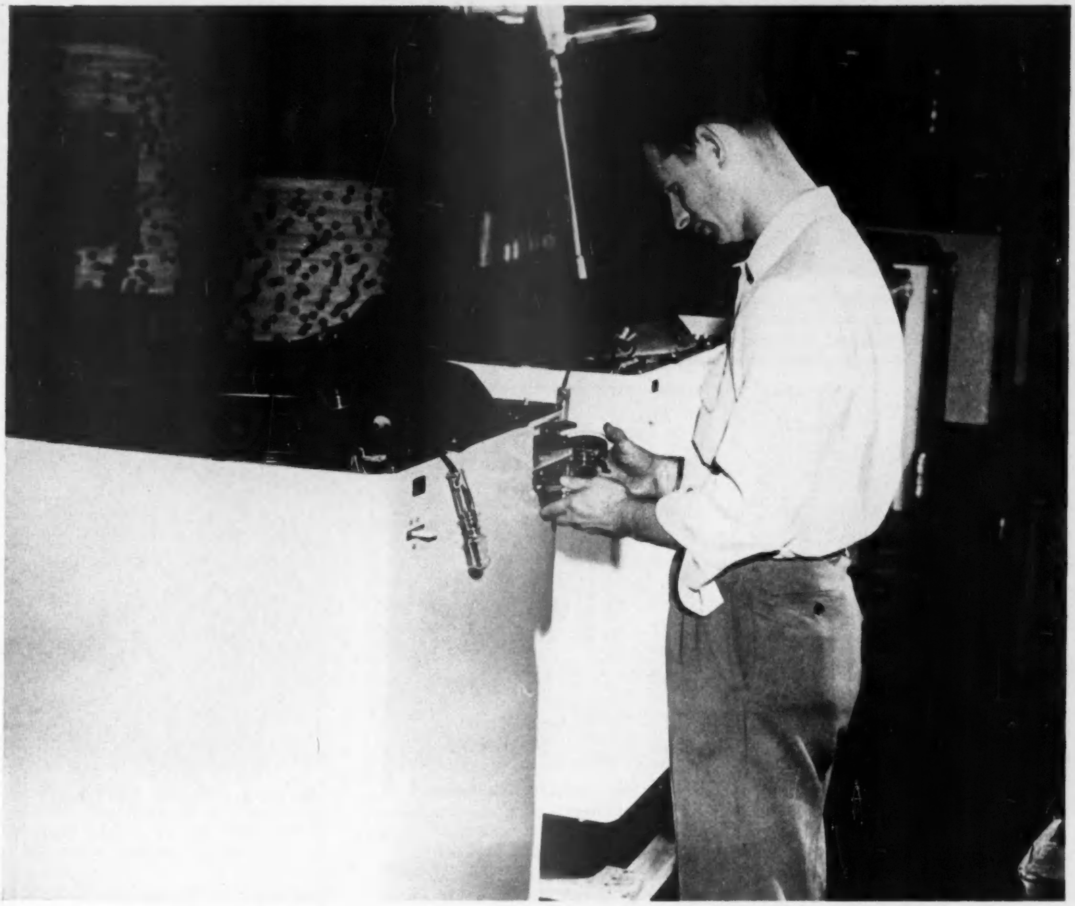
The authors whose service with General Electric totals but 16 years are presently associated with the Chemical Division. Mr. Burnett and Dr. Young are with Alkyd Products Engineering, Chemical Materials Department, Schenectady. Mr. Burnett is group leader of application engineering and Dr. Young is application engineer in that section. As supervisor of commercial development of R-108 in the New Product Development Laboratory, Pittsfield, Mass., Mr. Chase is responsible for commercial development of this coating.



MANUFACTURING COSTS OF TIMERS OF AUTOMATIC CLOTHES WASHERS WERE REDUCED BY THE USE OF . . .

Dollar-sign Engineering (PART II)

By L. D. MILES

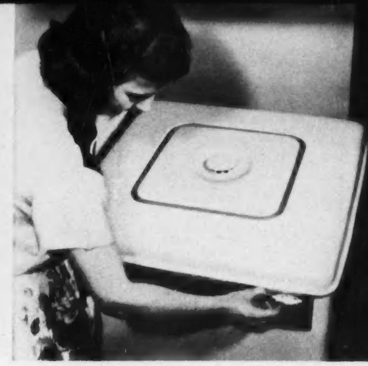
In the March issue of the REVIEW I discussed the background of a project in the Purchasing Department that is taking us on a widespread search for value—the basic value of every part, every item of a piece of apparatus. What we are doing is making a "value analysis."

What does the item do? How important is it in relation to the other parts? Can we eliminate or simplify it? Can we replace it with a standard? Can it be combined with another part? Can it be made from some other material at a lower cost—and better value?

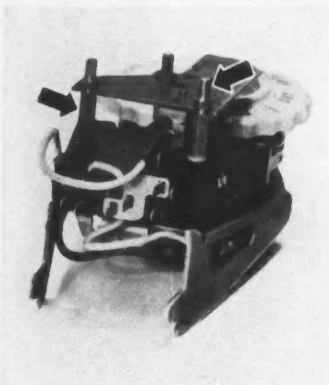
The photo sequence beginning on the next page will show you how a value analyst operates—step by step—on a typical project. Here, it's the timer for the automatic clothes washer. Because space doesn't permit us to show the results of the analysis on every part of the timer, we have selected one part as being typical. (In the actual project more than 30 individual parts of the timer were analyzed for value.)

It should be emphasized that nothing was wrong with the timer when Clarence Pace approached the Value Analysis Unit and requested a survey. The timer operated satisfactorily and costs were in line with similar products. But, as is the case with far-sighted management, they wanted to see if it wasn't possible to further eliminate any unnecessary costs.

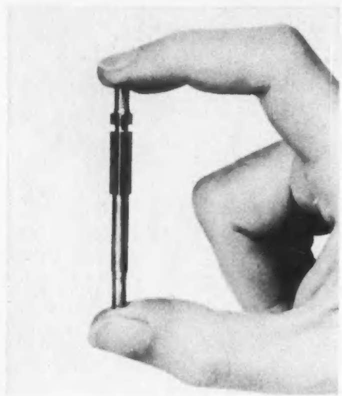
1 Alert management is always looking for new ways to eliminate unnecessary costs in their products. Clarence Pace (right), Supervisor of Purchases of GE's automatic washer plant at Trenton, N J, discusses a problem with L. D. Miles, head of the Value Analysis Unit in Schenectady. The project involves the . . .



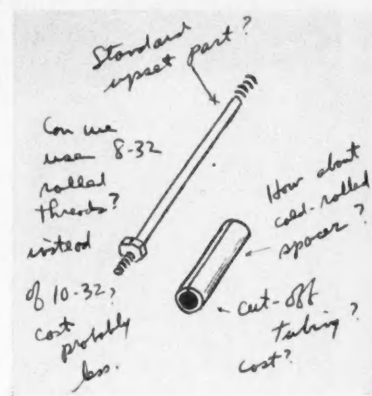
2 Timer for the automatic washer. Pace says the present timer is doing a good job, but they'd like to see if costs could be cut



6 To show how value analysis operates, we've selected the two standoff studs on the timer (arrows). Quantity runs 200,000 a year, and . . .



7 Cost is $52.50 per thousand as a screw-machine part. Material is steel, zinc or cadmium plated. After thorough study . . .



8 Bentley suggests that possibly two parts can do the same job for less—one a cold-headed part, the other a roll-formed spacer. Next . . .

Another thing that the photographs don't adequately portray is the intensity of a value-analysis project. Examinations are short and concentrated because intense concentration and interest cannot be sustained for any length of time. For example, the value-analysis project on the timer was completed in four months.

Two other points should be emphasized. In the first place, we have found that our value analysis men work best in teams of two—not one, not three. Another point is that strong personal contact must be established between the value analysis man and the specialty suppliers. The value-analysis man knows dependable vendors and specialty suppliers who over the years have developed a high degree of ingenuity and technique, each in his own restricted field. By personal contact these men are brought in presented with the problem, and are requested to suggest how their particular facilities can be used to help solve the problem. The specialty supplier becomes not only a member of the value analysis team, but also in many instances he makes vital suggestions that help to eliminate unnecessary costs even further.

In photo 12 you will note that the value-analysis report is turned over to the responsible persons for action. The Value Analysis Unit doesn't make decisions. Our job is to indicate the lack of value and set forth the evidence. The decisions are always made by the men responsible (photo 13)—the engineer, the manufacturing man, or the commercial man. These decisions are made after they have completed sufficient tests to evaluate the evidence.

The savings that are realized by accepting the suggestions of the survey are reported exclusively by the men who make the decisions and have the responsibility. In no cases are reports or claims of dollars saved issued by the value analyst himself.

Our Value Analysis Unit usually does only one project for each product group to prove that value analysis is applicable to *any* product. After seeing that "it can happen here," the various product groups then set up their own value analysis units for further studies.

With a small group of engineers in the Purchasing Department, Mr. Miles has developed methods and techniques that have resulted in eliminating millions of dollars of "wasted" cost from General Electric products. In recognition of this achievement, the Company in 1950 presented him with its highest award, the Charles A. Coffin Award.

3 Miles turns the job over to Al Bentley, a member of the Creative Engineering Program assigned to Miles' staff. Bentley's . . .

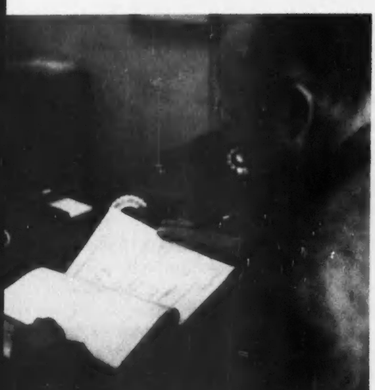
4 First step is to go to Trenton and get all available facts from the responsible engineer, plus costs, quantities, and so forth. Back . . .

5 In Schenectady, Bentley consults with various experts. They disassemble the timer, analyze each part to determine its "value"

9 He takes his ideas to Doug Eagan who works with G-E buyers and knows specialty suppliers. Buyers usually call suppliers . . .

10 In some cases buyer asks value analyst to call supplier direct. Specs follow in the mail. Experience has shown that . . .

11 Personal contact with supplier is important. C. E. Berge of Townsend Co., New Brighton, Pa., makes suggestions for improvement.



12 After parts of timer are analyzed, report is turned over to Pace by Miles. Value Analysis Unit suggests only—it has no authority

13 In Trenton, Pace goes over the report with his engineers and specialty supplier. A proposal is selected and the order is placed

14 Standard upset part and standard spacer are used at a cost of $10.50 per thousand. This compares to the original $52.50 per thousand

Moisture vs Rubber Insulation

By R. B. McKINLEY and C. H. SEABERG

Although rubber compounds are used to waterproof such everyday items as overshoes, raincoats, and garden hoses, rubber compounds in general can't be considered waterproof when used as an insulation for wire and cable.

What works on raincoats may not work on cables—the basic differences are: length of exposure; effect of moisture on the electrical properties. Cables insulated with rubber compounds must withstand years of continual exposure with a consequent absorption of moisture. And moisture absorption has proved to be a contributing factor in cable failures.

How to determine—by a *short-time* method—if a compound has good or bad moisture-resistant characteristics has always been a troublesome problem. At the present time three test methods are generally accepted by the industry:

Electrical Test—Determine the percentage increase in SIC (specific inductive capacity or dielectric constant) of the insulation after two weeks' immersion in water at a temperature of 50 C. This can be done at 60 or 1000 cycles.

Electrical Test—Determine the difference in power factor of the insulation at 40 and 80 volts per mil after 14 days' immersion in water at a temperature of 50 C.

Gravimetric Test—Determine the increase in weight of the insulation after seven days' immersion in water at a temperature of 70 C. This is expressed as milligrams per square inch of surface exposed.

There is some difference of opinion as to which is the best method. For instance, *A* compound may be superior to *B* compound by the first test, but *B* compound may be superior to *A* compound by the second test . . . and so on.

In an effort to solve this predicament, we decided to conduct *long-time* tests under only moderately accelerated conditions and to compare the results with those found by the short-time tests. What's more, the tests were expected to show the effects of voltage and current upon the moisture absorption of the insulation. And, if various compounds fell into a definite pattern, it possibly would help in the selection of the proper one for a given application.

With these goals in mind, tests were started on samples under the following conditions: no voltage, no current; 1500 volts applied between the conductor and water, but no current; normal current (for a 60 C rubber compound in air), but no voltage. The temperature of the immersion water was held at 40 C. There were two reasons for this particular temperature. The first was that a cable can operate under conditions higher than room temperature. And second, the 40 C temperature was high enough to accelerate conditions somewhat, yet not high enough to appreciably change the chemical properties of the compound.

During the tests periodic readings were taken of SIC and power factor, at voltages of 40 and 80 volts per mil. Readings of insulation resistance were also taken. In all cases the conductor size was No. 8 Awg, with a $\frac{7}{64}$-inch thickness of insulation—the thickness required to sustain a 2300-volt phase-to-phase rating.

Eight natural rubber formulations and one polyvinyl chloride compound of an early design were chosen, as shown in Table I on page 59. They are compounds covered by standard industry specifications, along with some special moisture-resisting types.

Table I also gives results obtained from the standard short-time tests on compounds. Results of the long-time tests are plotted in curves 1 through 9. Rather than confront you with too many graphs, only those of power factor plotted against time are shown. It should be brought out at this point that the insulations did not fail at rated voltage (a puncture in the insulation constituted a failure) but did fail at the much higher voltage stresses used in taking test readings.

•

Both Mr. McKinley and Mr. Seaberg are with the Construction Materials Division, Wire and Cable General Department, Bridgeport. Mr. McKinley, who has been with General Electric since 1929, is now Manager, Commercial Engineering, Industrial and Transportation Sales. Mr. Seaberg, Designing Engineer, Power Cables, has been with the Company since 1925. With a combined experience of 50 years, they are well qualified as authors of this article on cable insulation.

Comparison of Tests

The only compounds remaining after 252 weeks of test were those—as shown by the gravimetric test—having the low water-absorption value of 10 milligrams per square inch or less. The 60 percent submarine-type insulation passed all three of the short-time test requirements.

If judged solely by the SIC test, the 35 percent moisture-and-heat-resisting compound, along with polyvinyl chloride compound *X*, would have been unacceptable. Yet the gravimetric test indicated that these compounds were acceptable. And they were. At the end of 252 weeks of test they were still intact.

Two of the oil-base compounds (*B* and *C*) passed the requirements of both the SIC and power factor tests, and the third (*A*) easily passed the power factor test. But the gravimetric test indicated that these compounds were unacceptable. By referring to curves 4, 5, and 6, you will see substantiation of this.

How the samples looked after the tests is shown by the photograph on the opposite page.

What Did the Long-time Tests Show?

After a study of curves 1 through 9, you can conclude that:

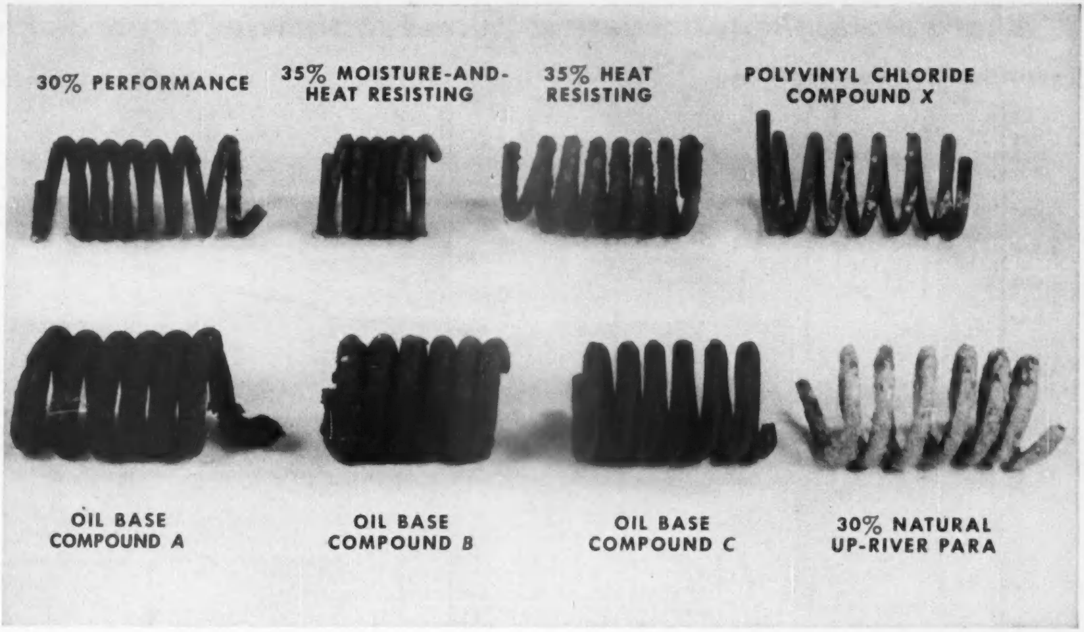
Rated current through the conductor prolonged the life of the insulation in all cases, except for the 60 percent submarine and two of the oil-based types.

Rated voltage accelerated the absorption of moisture, with a consequent shorter insulation life.

Compounds without current or voltage applied usually failed at some intermediate time.

Insulation designed for exceptional moisture resistance outlasted the ordinary types.

Inclusion of antioxidants and organic accelerators prolonged the life of an



EFFECT OF MOISTURE ABSORPTION on rubber insulating compounds after 252 weeks of immersion in water at a temperature of 40 C. Samples originally had same diameter. Oil-base compounds had swollen considerably at the end of 139 weeks, and at the end of 252 weeks they had deteriorated to the extent that the insulation could be readily plucked from the cable

insulation when the cable carried rated current. Compare curve 1 with curves 2 and 3.

The combination of good heat-and-moisture-resisting properties proved the ideal for power cables.

Measurements of SIC and insulation resistance followed somewhat the same trend as the curves shown for power factor. That is, they indicated the approach of failure, shortly before it occurred; but they did not, however, indicate in the first few weeks when and if the failure would occur.

What about Synthetic Rubber?

Polyvinyl chloride, compound *X*, is a thermoplastic synthetic rubber; that is, it hardens only upon cooling. In contrast to a thermosetting material, the mold in which it is formed must be sufficiently cooled before the compound is removed, or distortion will result.

The thermoplastic compound used in the tests (Table I, curve 9) is an early formulation not specifically designed for moisture resistance. At the time of its formulation the high cost of polyvinyl chloride necessitated the inclusion of a disproportionate percentage of mineral fillers. Since then its price has gone down, and coupled with the development of better mineral fillers and plasticizers, new compounds with exceptional moisture resistance have been developed.

One of these samples—polyvinyl chloride, compound *Y*—is still undergoing test after eight years' immersion in water at a temperature of 50 C; whereas compound *X* had to be removed after 120 weeks. Both samples were Awg No. 14 solid conductors insulated with $\frac{2}{64}$-inch thickness of compound. Compared with an insulation thickness of $\frac{7}{64}$-inch, and a water temperature of 40 C used in the other tests, this one is much more severe. Yet, despite the highly accelerated test conditions and the relative thinness of the insulation, compound *Y* shows vastly superior moisture resistance. For example, the initial value of insulation resistance of compound *X* was four megohms per 1000 feet. This value decreased gradually and, when taken off test at the end of 120 weeks, it measured 0.0392 megohms. Contrasting sharply, the insulation resistance of compound *Y* was 125 megohms per 1000 feet at the beginning of the test and decreased gradually to 24 megohms at the end of 75 weeks. Thereafter, for the past 341 weeks, it has varied between 24 and 33 megohms—a rather stable condition. The insulation shows no sign of further moisture absorption, and it's generally conceded that it has reached a state of equilibrium.

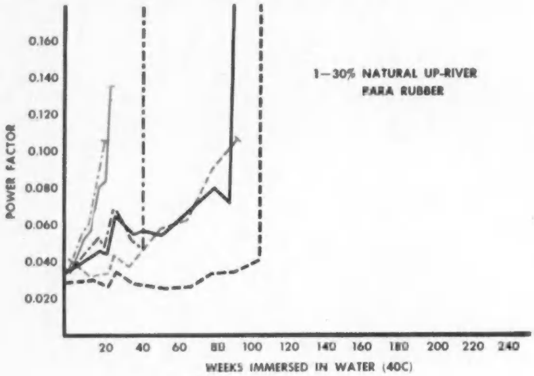
The reliability of the gravimetric test is again substantiated by this long-time test on polyvinyl chloride, compound *Y*. Results of the gravimetric test showed the increase in weight of the insulation to be five milligrams per square inch—only one-fourth the allowable increase.

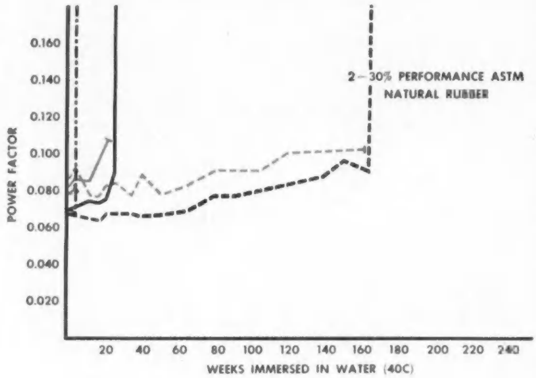
Laboratory tests on polyethylene, another thermoplastic, show the moisture resistance of this insulation to be best of all. It is the ideal insulation for certain applications, such as communication cables, where the lowest electrical values and highest moisture resistance are given precedence over other considerations.

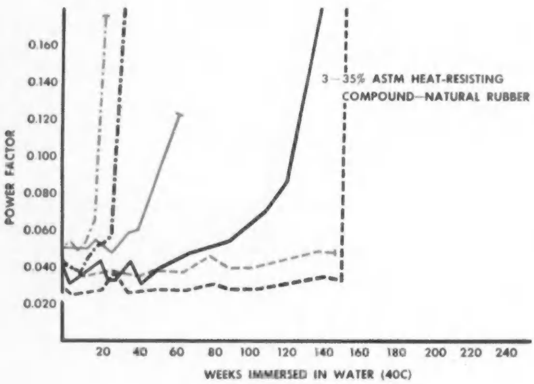
Buna-S and butyl, both thermosetting

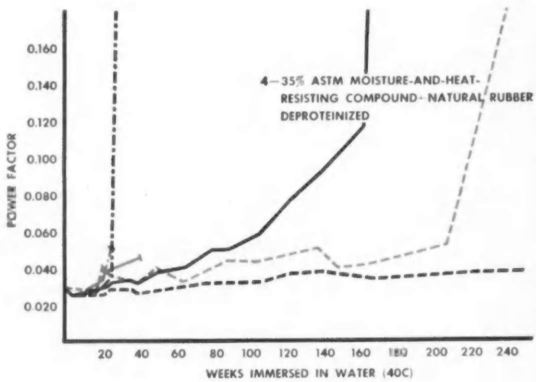
(*Continued on page 60*)

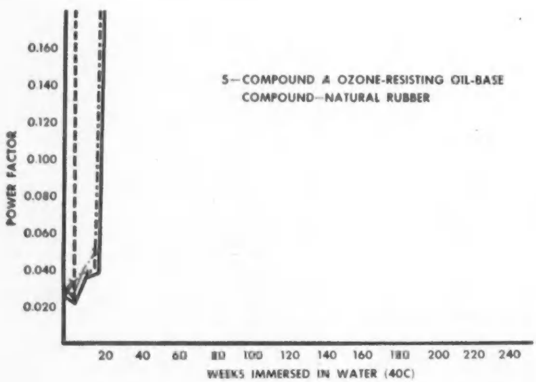
MOISTURE vs RUBBER INSULATION (Continued)

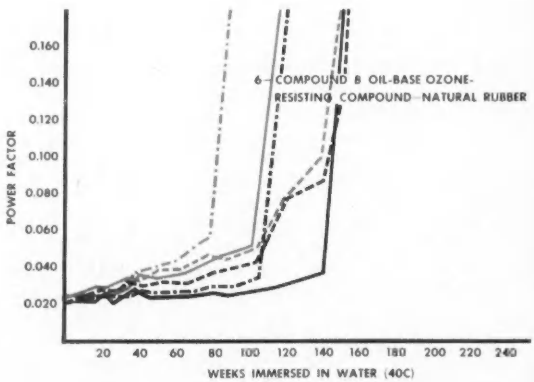




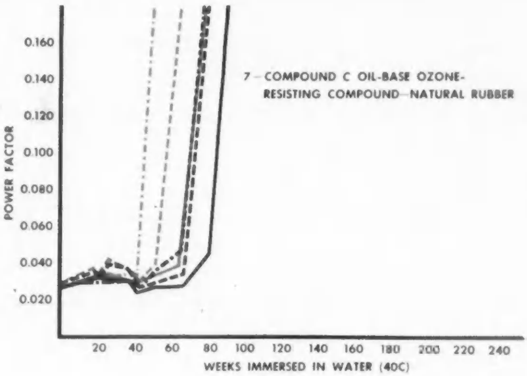


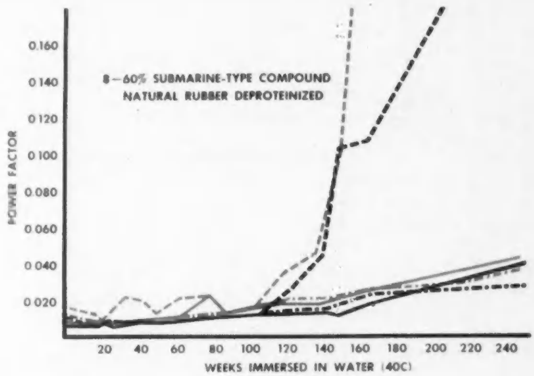






and current upon the moisture absorption of the insulation . . . ."





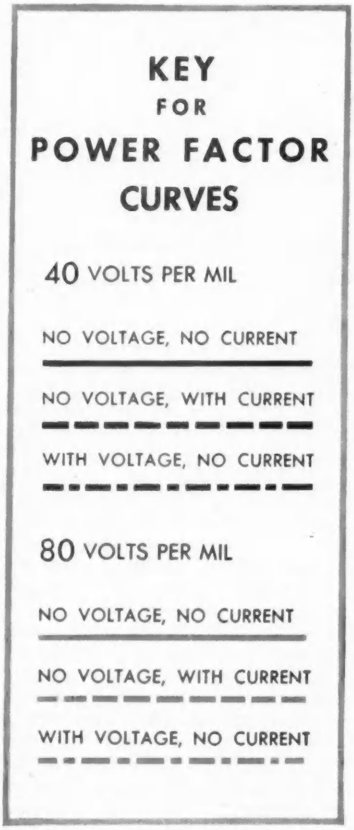
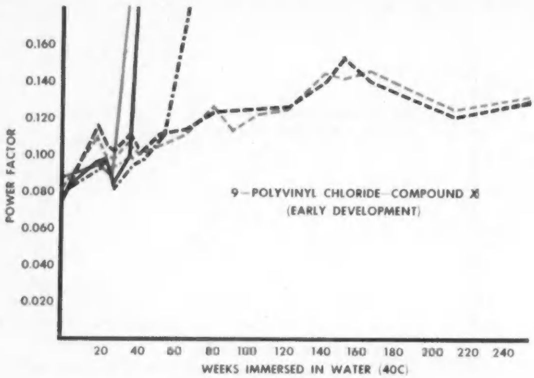


TABLE I
RESULTS OF SHORT-TIME TEST METHODS

Type Insulation	Percent Increase in SIC 60 cycle	Percent Increase in SIC 1000 cycle	Power Factor Difference	Gravimetric Test (Milligrams per square inch)
30% natural Up-river Para rubber (not designed to meet standard accelerated aging tests)	30.5	20.9	0.010	28
30% performance test natural rubber	36.2	35.4	0.011	32
35% heat resisting, ASTM D-469, natural rubber	21.2	18.9	0.009	25
35% moisture-and-heat-resisting natural rubber deproteinized	13.9	11.7	0.002	8
Ozone resisting, ASTM D-574, oil-base natural rubber, compound *A*	22.8	23.0	0.001	78
Ozone resisting, ASTM D-574, oil-base natural rubber, compound *B*	8.2	8.4	0.002	44
Ozone resisting, ASTM D-574, oil-base natural rubber, compound C	8.3	8.1	0.002	49
60% submarine natural rubber deproteinized	9.0	9.2	0.001	9
Polyvinyl chloride, ASTM D-734, (early development) compound *X*	24.6		0.010	9
Typical allowable specification requirements	10.0	10.0	0.010	20



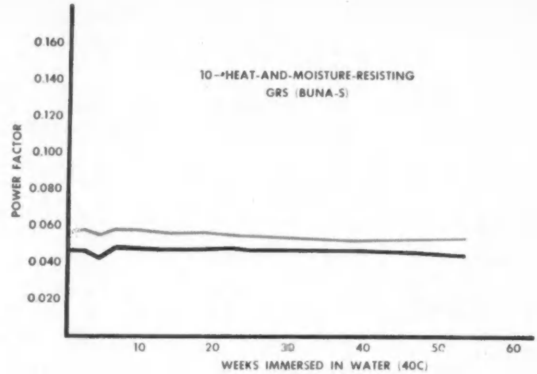
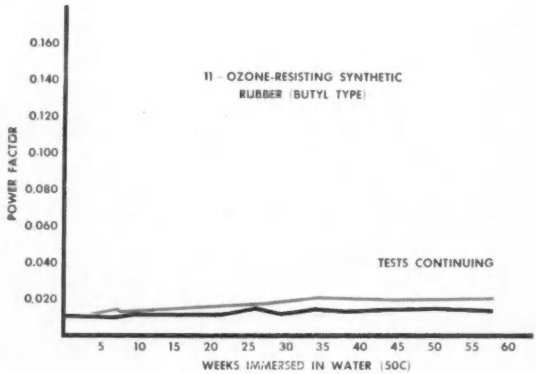


TABLE II
RESULTS OF SHORT-TIME TEST METHODS

Type Insulation	Percent Increase in SIC 60 cycle	Percent Increase in SIC 1000 cycle	Power Factor Difference	Gravimetric Test (Milligrams per sq in)
Buna-S	5.7	5.9	0.004	9
Butyl	0.5	0.5	0.003	4
Typical allowable specification requirements	10.0	10.0	0.010	20



synthetic rubbers, are equal to and in many respects superior to natural rubber for use in insulation compounds. Based on General Electric tests, similarly compounded insulations of either buna-S or natural rubber show generally parallel results. Butyl rubber made possible an ozone-resisting compound having exceptional moisture-and-heat resistant properties, plus good electrical characteristics and aging ability.

The data for curves 10 and 11 were taken from recent tests on buna-S and butyl-rubber compounds. Table II gives typical values of these compounds when tested in accordance with short-time methods. It is interesting to compare them with Table I.

From the foregoing, the gravimetric test gives the best correlation between short-time tests and long-time results. However, the actual milligrams of moisture absorbed cannot be used as a *quantitative* measure to predict the relative insulation life. Nevertheless, there is some maximum value which should not be exceeded. We believe that an average value of 10 milligrams per square inch or less should be used when the cable is operating in wet locations.

For power-cable applications—such as underground feeders, secondary network cable, and the like—the moisture-and-heat-resisting compound is our first choice.

The 60 percent submarine compound is the logical choice for use in communication circuits. Polyethylene also falls into this category, provided a thermoplastic insulation is not objectionable.

A moisture-resisting polyvinyl chloride compound, such as compound Y, is suggested for control and signal circuits. For, in addition to extremely high moisture resistance, it has other desirable properties such as flame, oxidation, and chemical resistance.

For circuits rated more than 2000 volts we endorse butyl-rubber insulation because of its excellent moisture resistance and superior insulating property.

One argument sometimes offered in favor of the short-time electrical test methods is: What difference does it make how much water a compound absorbs if it doesn't appreciably effect the electrical properties? This argument is valid if based on an immersion period of sufficient time. But, as this article has pointed up, a two-week test is too short to show what effect moisture absorption will have on the electrical properties of rubber insulation.

Nylon—

(*Continued from page 35*)

savings. As a specific example, a pound of nylon, although 2.5 times as expensive as a pound of bronze, is only 0.133 as dense. Resultant saving on material is therefore, 66.8 percent. But this is not all because further economies can be realized when you consider the cost of injection molding versus machining operations.

Other Applications

The translucence of thin sections of nylon, plus its ability to withstand shock, make it especially applicable to problems of illumination. One such application is a light-bulb housing used to illuminate the inside basket of the G-E automatic clothes washer. This unit consists of a 15-watt bulb placed inside a perforated aluminum deflector, over which is placed a nylon housing, as shown on page 35. Despite some heat dissipation by the deflector, temperatures of 250 F are reached at the outside surface of the nylon. All other plastic materials tried were badly distorted. The wall thickness of 0.040 inch provides ample strength and permits dissipation of the heat.

Another application on the washer is that of the drain-hose elbow. It replaces a chrome-plated copper elbow and carries water at temperatures up to 195 F. Here, a cost saving of 35 percent was realized in addition to conserving scarce material.

A noteworthy property of nylon is its ability to dampen mechanical vibrations with a consequent reduction of noise. This same property is being utilized in sound-recording and motion-picture equipment.

The "conformability" of nylon—that is, its ability to deform slightly to absorb shock—makes it the choice of material in gears and other applications where impact loading is encountered. This property of conformability enables nylon gears to satisfactorily mesh with metal gears and to "iron out" any irregularity that may be present in gear teeth.

Nylon has been successfully applied as coil forms, pulleys, screws, valve seats, washers, pump impellers, and hydraulic needles. It continues to find use wherever toughness, abrasion resistance, strength in thin sections, and chemical resistance are required.

Ferromagnetography—

(*Continued from page 22*)

shown on page 22 (top, right). Here a sheet of permanent magnetic material is mounted on the rotating drum. A movable carriage is mounted on the motor-driven lead screw, which controls its movement across the drum. On the carriage is a permeable (electromagnet) stylus. The carriage moves in synchronism with the rotating drum. Signals from a facsimile or picture transmitter are used by the receiver to modulate the current through the stylus coil. The drum and carriage are made to run in synchronism with the transmitter. In this way a magnetic image of the picture is formed on the sheet. The scanning definition is 100 lines per inch of transverse movement. Or, taking into account the rotation of the drum, the scanning rate was three square inches per second. Typical reproductions are shown on page 22. Here again the transfer medium was transparent gummed cellulose tape.

The basic principles outlined form a new approach to printing that has several attractive features. It is a high-speed method. Only metallic materials are used, making possible the construction of sturdy equipment. The images produced are stable and permanent, provided they don't come in contact with any demagnetizing fields or extremely high temperatures. Practically an unlimited number of copies can be obtained.

In particular, ferromagnetography promises to fill the need for printing large amounts of statistical data at high speeds, because its "line-at-a-time" technique is capable of printing several thousand lines per minute.

CREDITS

Page	Source
Cover, 7–13	George Burns
14	Allen's Appliances, Schenectady
17	Salvatore Cascio
20, 24	Bettmann Archive (top left)
40, 43	French National Railroads
40, 44	Oerlikon Co.
41, 45	Italian State Railways
54	Allen's Appliances, (top right)
54, 55	Montie Talbert

Unit Cost of Light—

(*Continued from page 37*)

one cleaning per year the unit cost of light becomes \$0.692/0.65 = \$1.065 per million lumen-hours. With *three* cleanings per year the unit cost is \$0.732/0.75 = \$0.976 per million lumen-hours. Therefore, useful light is being obtained at a lower cost.

Economy is the Word

A group replacement program involving removal of all lamps at about 70 percent of their expected life enables you to . . .

- Take advantage of trained crews to make systematic replacement with substantial economies in labor cost.
- Reduce scattered replacements that interrupt production while lamps are being replaced.
- Remove lamps from service before they reach maximum depreciation. This is shown by the curve on page 37 (right).

In the sample problem a labor cost of 60 cents was allowed for an individual lamp replacement. There are plants in which the cost is much higher than this. You can, with a group replacement program, reduce the cost to as little as 15 cents per lamp; and if replacement and cleaning are done at the same time, the cost of putting a new lamp into service is negligible.

Any serious study of over-all lighting economics must be made on the basis of long-term savings. Light is necessary for production. Every bit that is lost through inefficiency or waste means that something that is paid for is never received. An installation is planned to provide a certain amount of illumination. A falling off of this illumination means that the unit cost of light has gone up.

The whole objective of this article is to guide you in deciding—will an additional expense, such as lamps of shorter life and higher efficiency, or a better cleaning schedule, really pay off in the end?

It must be emphasized that the lumen, though it has no dollar sign attached, is the quotient which modifies all items of cost. Therefore, light output efficiency well maintained through life, coupled with *clean* fixtures, *clean* ceilings, and *clean* walls, will give you the best value for your lighting dollar.

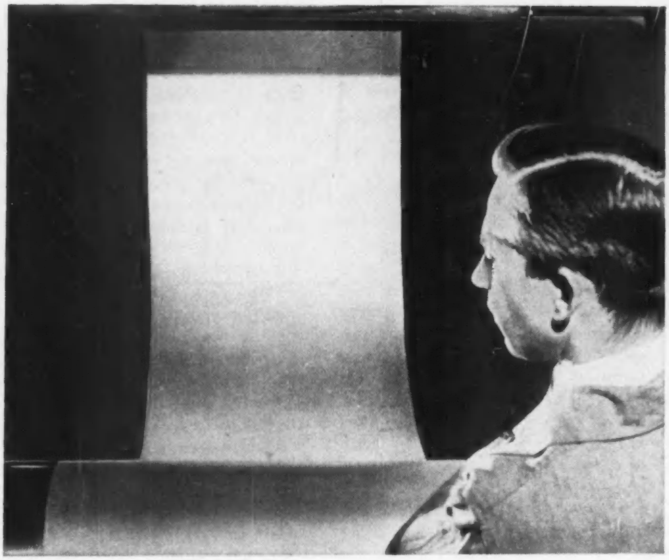
The methods presented in this article were originated by G. S. Merrill and M. D. Cooper.

Chemical Progress

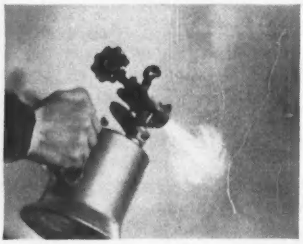
FOR THE FIRST TIME—

mica by the roll!

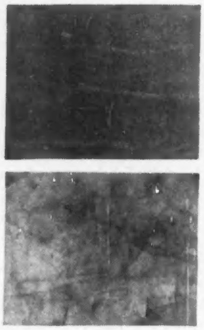
Mica Mat: **A NEW DEVELOPMENT IN MICA INSULATION—MAY FREE U.S. FROM DEPENDENCE ON FOREIGN SOURCES**



Continuous G-E mica mat sheet emerges from machine which forms minute mica flakes into flexible rolls of highly uniform mica insulation.



Blowtorch test *indicates the high temperature resistance of G-E mica mat, which can be heated red-hot without damage.*



Greater uniformity *of new G-E mica mat (above right) is shown in contrast to conventional mica insulating sheet (right).*

Here's the newest product of General Electric chemical research —*mica in continuous sheet form!* This development, which permits the use of low-grade domestic mica for electrical insulation, may free our mica industry from dependence on foreign sources and alleviate a serious shortage threat to the electrical industry.

G-E mica mat is 100% mica in the form of flakes and particles in continuous sheets. It gives better performance than present machine- and hand-laid mica products because of its greater uniformity of thickness and its void-free construction.

Capable of being impregnated with resins and bonded to paper, glass or cloth for greater strength and improved electrical properties, G-E mica mat tapes and sheets can be used in heating devices, molded into shapes for motors and generators, or machine-wrapped on bars and cable.

For a complete technical report on G-E mica mat, write to General Electric Company, Section 100-3A, Chemical Division, Pittsfield, Massachusetts.

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GENERAL ELECTRIC