GENERAL ELECTRIC Review

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GENERAL ELECTRIC Review

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COVER—General Electric's diesel-electric test locomotive operates in fast freight service on the Erie Railroad. Built for evaluating components used in locomotives for export service and improving existing apparatus and locomotive design and performance, this 4-unit locomotive weighs 490 tons, is 212 feet long, and develops 6000 hp. For the diesel-electric's past, present, and future, see page 13.

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Burned-out plant re-equipped fast to minimize production loss

A raging fire recently burned out a large industrial plant, reducing machines to rubble. Management's first concern was to resume production quickly in new quarters. What resources could General Electric's Apparatus Sales Representative marshal to help?

Instantly and on many fronts, G-E engineering services were alerted. Service Shop specialists were on the scene at once. G-E Service Shops, working closely with customer and machinery manufacturers, repaired salvageable electric equipment in record time.

Within 24 hours, motor replacements for vital machine tools were pushed through G-E factories and on the way. A new 90-foot roller-hearth furnace, built from scratch at another G-E factory, was delivered and producing in only ten weeks. Additional G-E plants came through ahead of schedule with new control devices, dynamometers, other electric equipment.

Emergency service like this is one of many services available to you through G.E.'s Apparatus Sales Division. Maintenance Service and Field-Service Engineering help protect your equipment investment throughout the life of the equipment. In addition, General Electric Product Development, Application Engineering, Analytical Engineering, and Project Co-ordination assure that you will receive the right equipment properly applied and installed on schedule.

Whether you are a ***direct user*** of electric equipment or whether you ***incorporate electrical components*** in your product, your G-E Apparatus Sales Representative can put these engineering services to work for you. Contact him early in your planning. Meanwhile for the full story on G-E engineering services, write for brochure GED-2244 to General Electric Co., Section 672-13A, Schenectady 5, N. Y.

GENERAL ELECTRIC

THESE G-E ENGINEERING SERVICES HELP PROTECT YOUR EQUIPMENT INVESTMENT

PRODUCT DEVELOPMENT provides improved equipment to meet tomorrow's increasing demands

APPLICATION ENGINEERING combines latest products and techniques into efficient electrical systems for your specific needs

MAINTENANCE SERVICE helps keep your plant electric equipment operating at peak efficiency

PROJECT CO-ORDINATION simplifies purchasing, plans deliveries to speed construction schedules

FIELD-SERVICE ENGINEERING facilitates equipment installation, expedites start-ups, helps train personnel for proper operation

ANALYTICAL ENGINEERING solves complex system problems, cuts time used in system design

AFTER YOU GRADUATE...

How will you help to sharpen radar's "eyes"?

Exact range and accuracy of the radar antennas shown here are classified. But this can be told—the radio energy transmitted can light fluorescent lamps 100 feet away.

Progress in radar, as in the entire field of electronics, has been rapid. At General Electric much credit for these advances belongs to engineers who are recent college graduates. Take, for example, E. B. Carrillo, EE, Pratt Institute, '49, responsible for manufacture of servo- and time-sharing systems, and G. G. Wilson, EE, N. Y. U., '48, in charge of design and development of remote control equipment.

The work of these young men typifies GE's emphasis on young, creative engineers from such fields as electrical, mechanical, metallurgical and aeronautical engineering, and from the scientific fields of physics and chemistry. Like other graduates, Carrillo and Wilson were able to increase their engineering awareness in the after-graduation G-E program of technical assignments. In this program, the engineer selects the fields, the locations himself. And at G.E. you will be able to make real contributions early in your career in activities ranging from plastics to large electrical apparatus, electronics to jet propulsion, automation components to atomic power.

In all these fields as in radar, much work is still to be done. What you can do depends largely on your interests and skills. For full information on the job at G.E. suited to you, consult your college placement officer. TR-2

Progress Is Our Most Important Product

GENERAL ELECTRIC

ALMA MATER

"Alma mater" is one of our beautiful expressions. It is the classroom, with the students in their seats and the professor at the board. It is the campus, with beautiful grass and trees and buildings—with students rushing and with students strolling. It is the football stadium, where thousands cheer their heroes in the game being unfolded before them. It is memories of all these—and more. It is the gateway to the future. And the future is bright where alma mater is held in reverence.

In this wonderful country of ours, the universities and colleges have from the earliest days led the way to an understanding in every avenue of life. They are at the end of every beginning. They reveal the architecture of the universe. They impart to youth and mankind the inspiration to achievement. They are one of democracy's foundations.

One of the greatest miracles in life is growth. And it is to the growth of our people in knowledge and human understanding, in health, in work and enjoyment that our great schools have made fundamental contributions. And as our country has grown in numbers, has prospered, and has grown in national and international stature, that growth is undergirded, guided, directed, and strengthened by our educated people. In this growth the college and the university stand at the fountainhead of knowledge.

In the heart of every boy and girl, the urge of youth is ever upward. College is the open sesame. Now and in the years immediately ahead, more young men and women will be entering our American colleges than ever before. Reports from the colleges and universities show an enrollment of 2,472,000 students.

It is to the outstanding credit of our people that they have supported their leaders in providing the needful money for the education of their youth. This money has come from the community, the state, and the nation. And it has been augmented bv gifts from industry and by private contributions. All have contributed to the strength and the greatness of our educational system.

It is the alumni of the colleges who should have the best understanding of these things. Experience has shown this to be so. While great gifts have come to our schools from great fortunes, many, many small gifts have come from loyal alumni who have understanding and recognition and love for their alma mater.

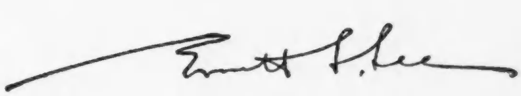
Last year in our Company a survey was made of the giving habits of 16,000 college graduates in the General Electric family with earned degrees from more than 540 United States colleges. It was found that one third customarily contributed to their alma mater in any one year, and the average annual gift was $17.85. Extended to the whole Company, this would mean an eighth of a million dollars just from the alumni in one American company in one year.

In recognition of these alumni contributions, and to augment them, the Trustees of the General Electric Educational and Charitable Fund, on November 15, 1954, set up the Corporate Alumnus Program. Under this program the Fund will match the contributions of any college graduate up to $1000 within the year. The graduate must have at least a year's service with the Company, the contribution must be an actual gift and not merely a pledge, and it must be made to an accredited U.S. college or university of which the contributor is an earned degree holder, and for a purpose to realize or foster the primary needs and objectives of an institution of higher learning as covered in the provisions of the Program.

The Program took effect January 1, 1955, and will run until December 15, 1955. At the end of that time the Trustees will consider whether it should be extended, and whether experience has indicated changes that might improve it.

The Corporate Alumnus Program of the General Electric Educational and Charitable Fund is an additional element in the over-all education-assistance program to which the General Electric Company contributes. This broad program, which has been in effect for many years, has consisted of gifts and endowments, grants-in-aid, equipment for instructional purposes, scholarships, fellowships for graduate study, and various kinds of co-operative undertakings. The annual contributions under this entire program will probably exceed a million dollars.

Thus comes an added opportunity to the sons and daughters of their alma mater.



EDITOR

Combination washer-dryer has a full wash-rinse-dry cycle plus such extras as a built-in water heater and a seven-minute triple-rinse cycle—double the rinsing time of other tumble-washers.

How We Styled the New Washer-Dryer

By C. F. GRASER

The appearance story of General Electric's 1955 major appliance line began as early as the fall of 1952. At that time, the Product Planning Manager began setting up marketing specifications for models of 1955, including features expected to give the product a competitive advantage. From these specifications, the appearance designer began making rough sketches of new shapes, component arrangements, control panels, and additional features he thought would give the product a new look, a striking appearance, and operating ease. The appearance design group studied these sketches to 1) determine which design should be carried further, 2) decide which elements could be co-ordinated within the entire line of major appliances, and 3) achieve a family relationship of appearance.

After the selection of about a half dozen promising designs, artists produced finished renderings—their conception of the product, usually created with pastel chalk, air-brush painting, water color, or other media that present good visuals of the product. The completed renderings were presented to department management at a product-planning meeting. After engineering, marketing, manufacturing, and cost considerations were made for each submitted design, the best all-round design and an alternate were chosen to be made into model form.

Because some design shapes were complex, the designer made and studied clay models before starting them in plaster or wood. Being three dimen-

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Mr. Graser came to GE in 1948, first working on technology and design of molded plastics. Soon he joined the Appearance Design Division and in 1951 moved to Major Appliance Division, Appliance Park, Louisville, Ky., creating appearance design on Home Laundry Department products. He is now similarly engaged on products for the Room Air Conditioner Department.

sional, a clay model allows the designer to view the shape from many angles—impossible on a two-dimensional rendering, or drawing. For example, the backsplash, or vertical projection, in back of a range cover is sometimes a complex shape. To be certain that adequate space has been provided, he can also incorporate into it some fixed components such as standard controls, timers, and lamps.

When the designer was satisfied with the clay form, he had the Appearance Design Model Studio make a full-sized finished model in either plaster or wood, depending on the product's shape. Metal trim helped to make it a perfect prototype of the final product. When completed and refined, the model was ready for recommendation to the department management. After review and approval, the appearance model was submitted to the Product Review Committee, consisting of the general managers of the division and departments and the manager of appearance design.

They thoroughly reviewed aspects of marketing, engineering, manufacturing, and costs, as well as appearance design. Usually at this stage the product is not significantly changed, because the marketing, engineering, manufacturing, and finance groups have worked closely with the designer to iron out problems before this final presentation.

The time from the first product-planning meeting, where the product specifications were presented, to the final model presentation averaged about 14 months for the 1955 line of major appliances. When the new models began rolling off the assembly line—and the dealers, distributors, and consumers were admiring the new product—the designer already considered it obsolete.

Many problems were involved in the design program of GE's 1955 washer-dryer.

The Design Story

Although normal in most aspects, the design process was complicated because General Electric had never before mass-produced such a machine. This meant many marketing-plan changes before the product could take its final form. To meet these changing marketing objectives, engineering and appearance design also had to change.

Some of numerous questions to be considered were: What should a washer-dryer combination look like? should its appearance differ from a washer or dryer? should it be designed for use in the kitchen as well as utility rooms and basements?

WHY STYLE?

In consumer goods, product appearance is one of the most prominent areas of competition because of the visual impact of one brand over another in the salesroom. The automotive industry has done a thriving business on the appeal of styling, which the consumer parades before his fellow men with a tremendous spirit of pride and well-being.

Product appearance is also important in the appliance industry. Perhaps you can recall walking into a store and being attracted to an appliance that was outstanding in appearance. With many different brands of the same appliance on the floor, one design's ability to catch your attention may be instrumental in its final sale.

Or as *Business Week* says in commenting on a recent study of the reasons people give for buying major appliances: ". . . people sometimes take a lot more time and trouble buying something for which they have no pressing need. They are often discouraged when a product is technically difficult to understand or when its quality is hard to judge. They dawdle with pleasure over an item where there's a question of style or appearance. This is the wild card in the deck."

To integrate good appearance design with sound engineering, General Electric has a staff of 30 in the Appearance Design Section of Appliance Park, Louisville, Ky. The group consists of industrial designers, model makers, and office personnel.

The designer's opinions alone are by no means the criteria for creating or judging a design. The final judgment is made by the consumer.

To determine what the customer wants in appearance, function, and features requires the marketing group to relay past experience and consumer-survey information to the designer. This material is in turn compiled by the Product Planning Manager, who works closely with the appearance designers and engineers during design conception.

So that the customer would not mistake it for just a washer or just a dryer, it was decided that the unit should look like a combination of a separate washer and dryer. A family relationship between the new unit's cabinet, control area, and trim and those of the 1955 automatic washer and the automatic dryer gave the appearance that two separate units were shoved together into a common cabinet.

Because both the washer and dryer had only one control knob on the backsplash, the combination machine was designed with *two*—one for washing, the other for drying. To insure correct identification, the words WASH and DRY were placed next to the respective knobs on the backsplash escutcheon. In addition, the words WASHER-DRYER COMBINATION were put on the front trim strip.

The question of cabinet dimensions hinged largely on whether the combination unit should be designed for the kitchen as well as the utility room and basement. Initially, engineering had designed units that were 36 inches wide to allow room for the mechanism, but from an appearance and marketing viewpoint this was too large. Engineering ultimately reduced the width to 31 inches for a free-standing unit, 30 for an undercounter model.

The smaller dimensions made the combination unit more practical for kitchen and utility-room installations where space is important. The height of the work-surface cover was also designed to line up with the standard 36-inch counter tops in the home.

Although the questions concerning the appearance of the combination unit were answered logically, they led to other questions. Because the unit was being designed to fit into the kitchen as well as in other locations, its appearance and function as a kitchen appliance had to be considered. As such, it would need a lamp on the backsplash above the work surface; an observation window in the door of the free-standing model; and lighted green and red areas behind the knobs to indicate the washing and drying controls respectively.

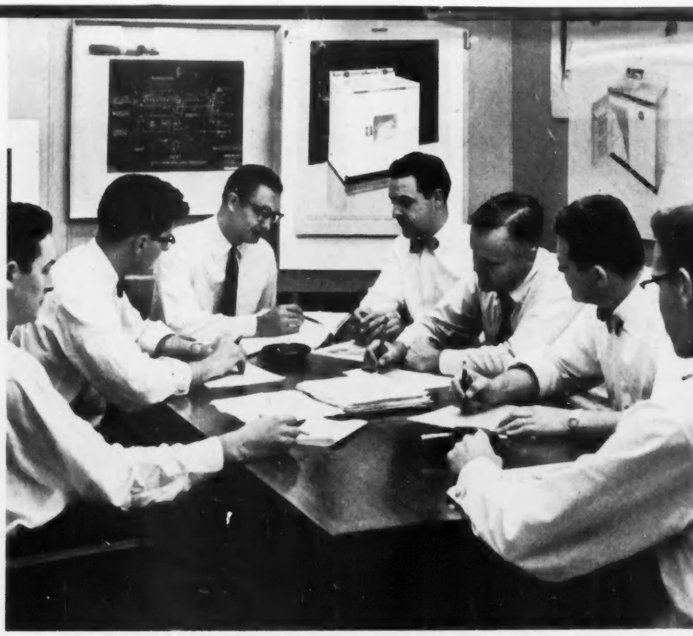
And in a dark basement or utility room, a lamp and lighted controls would also be useful.

The engineers could not be convinced immediately that these added cost features would help sell the unit. The Product Planning Manager of the Home Laundry Department was consulted about a mock-up of a lamp on a model that also had a door observation window and lighted controls. He agreed that the lamp should be shown on an alternate model for the Product Review Committee. The lighted controls became a must because of the excellent reaction they received on GE's automatic washers and dryers.

TEXT CONCLUDED ON PAGE 12

OVERLEAF: PICTURE STORY OF THE NEW WASHER-DRYER

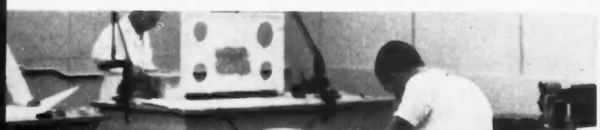
1 Author (*left*) and Product Planning Manager F. R. Amthor study early sketches of washer-dryer.



2 A. N. BecVar, Manager of Appearance Design (*third left*), discusses the family relationship of the entire major appliance line.

HOW WE STYLED THE NEW WASHER-DRYER (Story begins on page 8)

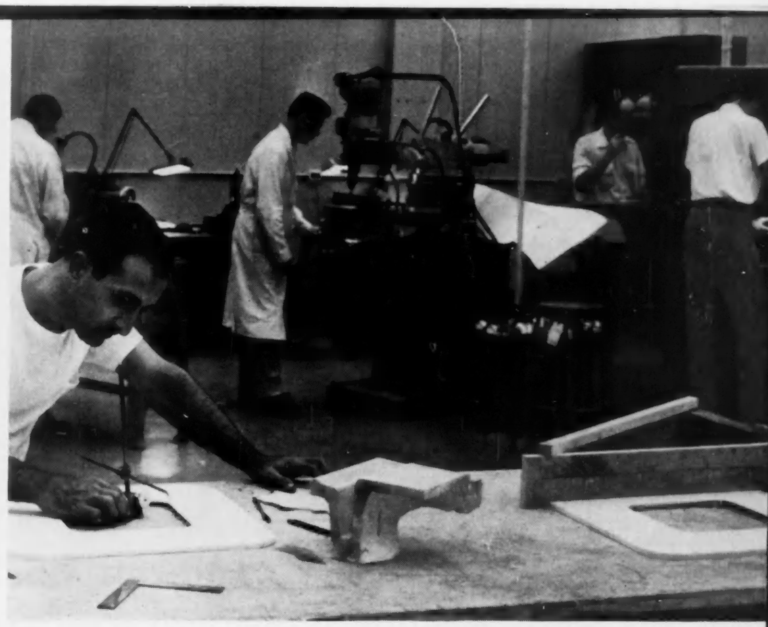
Sketches, Models, and Meetings



5 After completion and refinement, wood model goes to the Product Review Committee for approval.

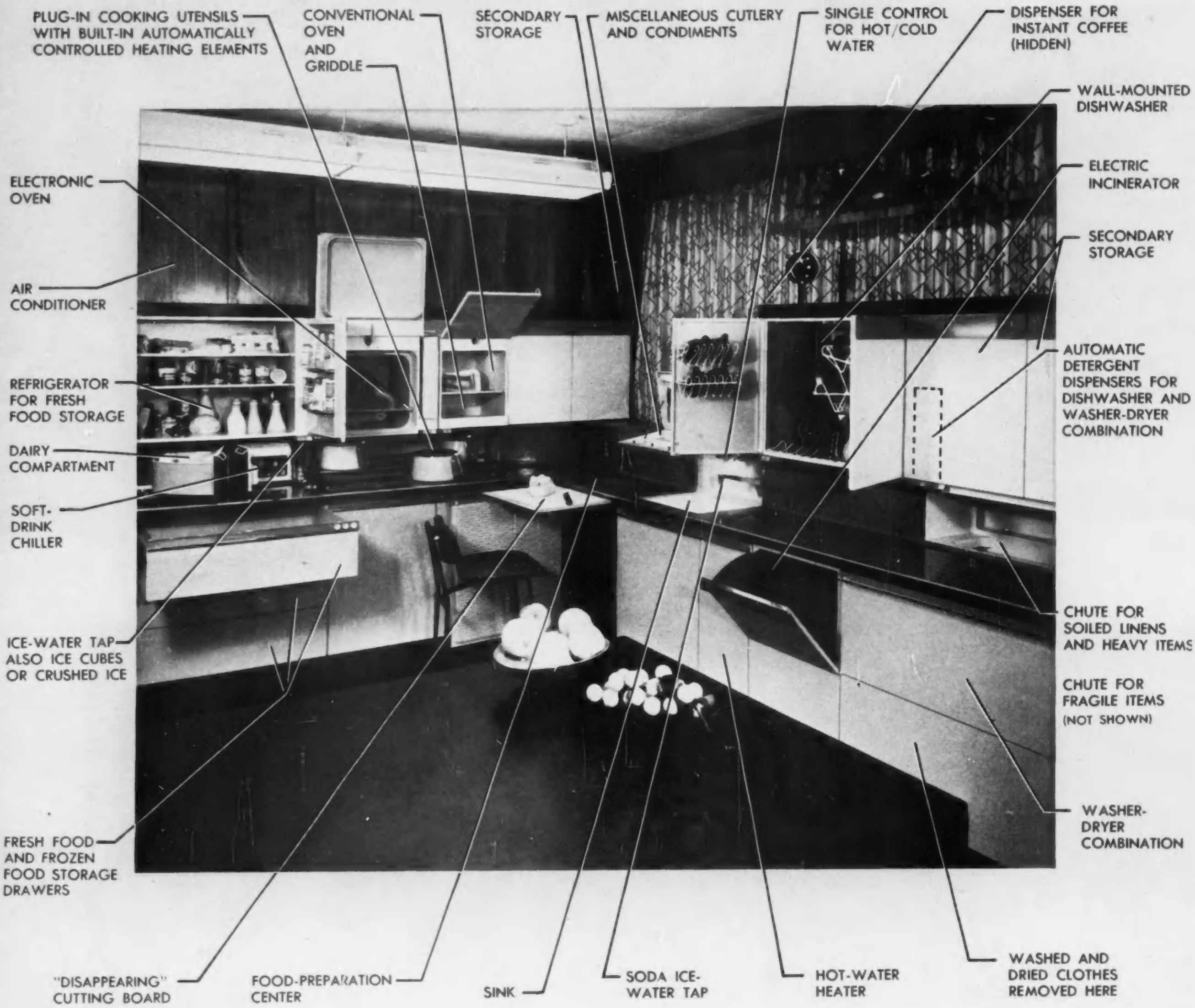
6 J. C. Worst, Engineering Manager, and Graser work out details of production drawings.

3 For a three-dimensional view, the designer studies clay shapes before starting a plaster or wood model.



4 When the designer is satisfied with the clay form, skilled craftsmen make plaster parts and metal trim for a full-sized finished model.

7 Finished model will be reviewed for aspects of marketing, engineering, manufacturing, and costs as well as design. The product is not usually changed much because all groups have worked closely with designer. Next step: the production line.



TOMORROW'S KITCHEN Appearance designers constantly create advanced experimental designs based on living trends. Already available are colored appliances and the wall-mounted refrigerator.

To avoid confusion during the operation of the machine, arranging controls properly was important. Appearance Design recommended placing the WASH knob on the left side of the backsplash and the DRY knob on the right side, with five push buttons between them. Housewives tested this arrangement for their reaction.

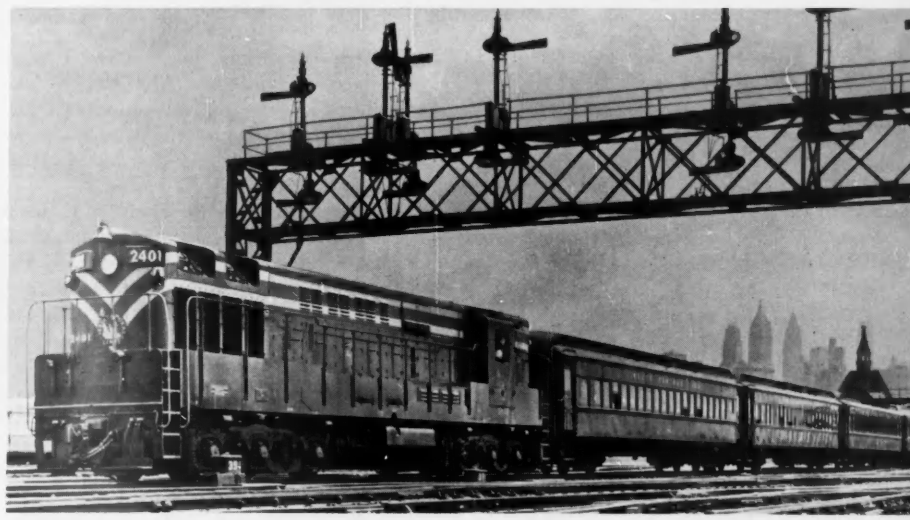
The legibility and clearness of the dial legends were also checked. Even the feel of the controls is important in customer reaction. If an appliance does not give the feeling or appearance of quality when controls are operated or doors closed, the customer will think the mechanical quality is poor also. The operation and arrangement of controls were further checked during the exhaustive washing and drying tests. In all, about six different legends were tried on the combination unit's washer and dryer knobs before the best was selected.

As you can see, the design road is not always a smooth one; but the harmonious relationship between the groups that are involved smooths out the bumps before final production.

Year after year the story of the 1955 line of major appliances is repeated. The appearance of a new product must impress the consumer enough to create a desire for ownership and to stimulate sales. Even during years when new features are not incorporated into the product, appearance changes such as new colors or trim can help increase or maintain demand.

As indicated by their present desires for new arrangements (photo) and colors in the kitchen, consumers are demanding more rapid steps in design. The built-in oven, wall refrigerator, undercounter models, and colored appliances resulted from the housewife's interest in her kitchen's appearance.

Survey results and living trends suggest new concepts to appearance designers who are doing advanced experimental designs in appliances. Eventually, the best elements of these projected designs will appear in your appliances, just as advanced ideas of 10 years ago are appearing in your products today. Ω



Summer of 1924 saw the demonstration of an "oil-electric" locomotive (*top*) on the New York Central in Manhattan. The *Evening Post* thought it might revolutionize railroading. But the thoughts of the horseback rider who preceded it down the street, waving a red flag in accordance with a city ordinance, will never be known. Today a 2400-hp *Trainmaster* (*lower*) heads a commuter train out of the Jersey City Terminal, indicating the trend toward more power per unit.

PAST, PRESENT, AND FUTURE—

The Diesel-Electric Locomotive

By P. H. HATCH

The newspapers in recent months have carried repeated announcements of one railroad or another becoming completely dieselized. In fact, the diesel-electric locomotive has displaced the steam locomotive to such an extent that it is becoming somewhat of a novelty to see a steam locomotive pulling a passenger or freight train.

Already dieselization has reached the stage where the question is being asked, where do we go from here?

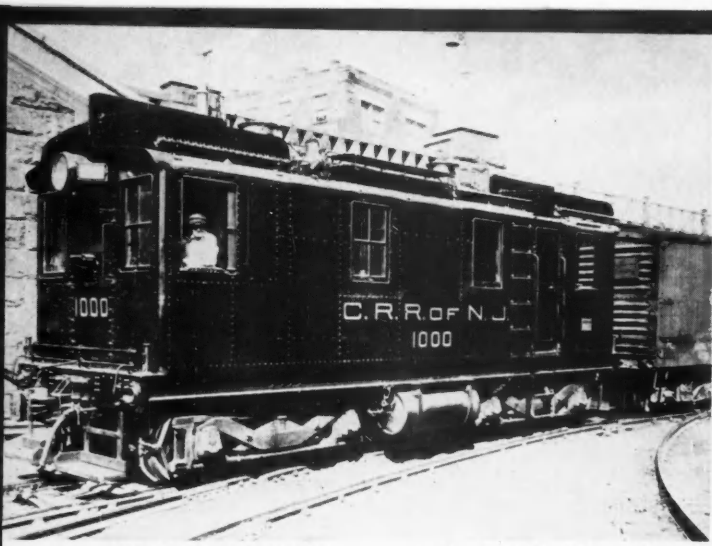
With this situation in mind, let's trace briefly the origin and growth of the diesel-electric locomotive and note the reasons for its wide acceptance. We can thus formulate future expectations of this type of railroad motive power.

Late in the summer of 1931, a decidedly novel switching locomotive appeared as a demonstrator on an eastern railroad. With a 6-cylinder oil-burning engine under a hood and an operating cab at one end, it looked like a strange combination of automobile and street car. No one thought of it as the prototype of today's diesel-electric switching locomotive, either in appearance or arrangement.

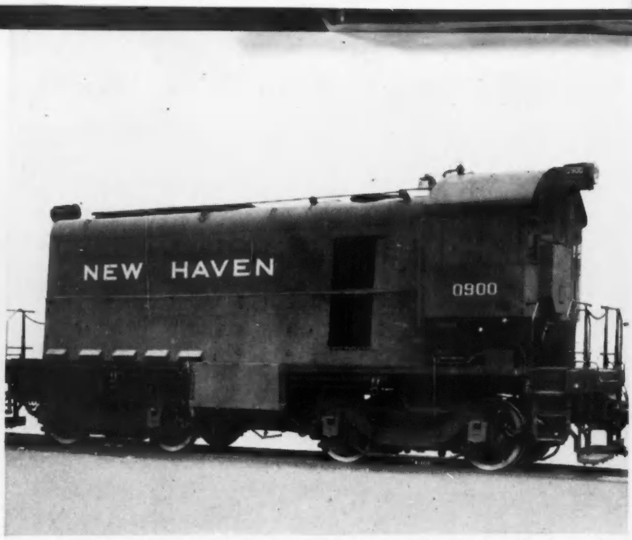
In a predominantly skeptical atmosphere the locomotive was put to work on a 24-hour-day switching assignment. An all-out effort was made to keep it in continuous service. In spite of the inevitable bugs requiring correction and the abuse resulting from unfamiliarity, the locomotive made an impressive record.

During this somewhat hectic period, several significant facts came to light. For instance, the slower the locomotive's speed the harder it pulled. Of course, the characteristic curves showed this; but the operating man needs more than curves to convince him. Repeatedly, the diesel-electric kept operating where the steamer it replaced would have stalled.

Other facts also became apparent. The new switcher could work from midnight Sunday until midnight the following Saturday without once seeing the inside of a shop or roundhouse, or even stopping work except for crew changes and fueling. The fuel bill was only one third to one half that for a steam locomotive doing the same work. Moreover, the engine crews liked the new locomotive; they could get considerably



FIRST DIESEL-ELECTRIC to operate in the U.S.—Jersey Central's 60-ton 300-hp No. 1000—is still in service after 29 years.



EXTENSIVE DIESELIZATION began in 1931 with the installation of a 600-hp switcher fitted with G-E electric equipment.

more work done comfortably in the course of a tour of duty.

As a result, the road purchased the new locomotive in less than five months. This started one of the earliest and, for many years, most extensive dieselization programs in the United States.

This success story came from one railroad in one section of the country. As the diesel tide advanced, it was repeated on other railroads throughout the country with slight differences in detail and timing. Today the diesel-electric locomotive is the accepted motive power of American railroads, and their dieselization is better than 80 percent completed.

Fundamental Differences

Railroad operation grew up around the steam locomotive. In comparison, what does the diesel-electric locomotive have that explains its phenomenal growth?

The steam locomotive is basically an assembly of a few large parts. It was largely custom-built not only for each individual railroad but also for certain services or territories on the property. This resulted in even moderate-sized roads having 30 or 40 different classes of steam locomotives. Consequently, costs were higher than necessary.

The diesel-electric locomotive consists primarily of a multiple assembly of standard items of equipment. For example, the same diesel engine, perhaps in various sizes, serves in passenger, freight, and switching locomotives. The same traction motor and the same or similar electric generating and control equipment can also be used on all three.

The maintenance patterns for both steam and diesel-electric locomotives are set by their respective construction. When entering the backshop for heavy repairs, a steam locomotive is completely dismantled. The boiler, machinery, running gear, cab, tender, and other components are separately repaired or rebuilt and then reassembled to form the locomotive again.

But when a diesel-electric needs heavy repairs, the engine and its auxiliaries, electric apparatus, trucks, and traction motors are removed. After giving required attention to the stripped-down chassis, the repaired or reconditioned units of similar equipment are installed in their places. Use of such standard equipment not only permits manufacture on a production basis but also enables each railroad to handle its own production repair.

When a steam locomotive operates, the horsepower output varies substantially with speed: at low speed the cylinders are limiting and at high speed the boiler is limiting. The diesel-electric, however, develops practically constant horsepower over most of its speed range. And because most or all weight is on driving wheels, the diesel-electric can develop high tractive effort at low speed without sacrificing its ability to operate at high speed.

Further, the all-round flexibility of the diesel-electric locomotive makes for ready adjustment to traffic requirements, plus interchangeability for all three types of service. And units can be combined to form locomotives of different sizes as required. Thus an entire railroad can operate with but one class of motive power. Such flexibility marks the diesel-electric locomotive as one of the most effective transportation tools of all time. Its many advantages appear in the Box.

ADVANTAGES OF THE DIESEL-ELECTRIC . . .

- Fuel economy
- Lower maintenance expense
- High availability for service
- Rapid acceleration
- Smooth starting
- Use of dynamic braking
- Reduction in stops enroute for fuel and water
- Excellent visibility for crew
- Improved comfort for crew
- Reduction in terminal facilities
- Less vulnerability to winter weather
- Decreased maintenance of track and structures.

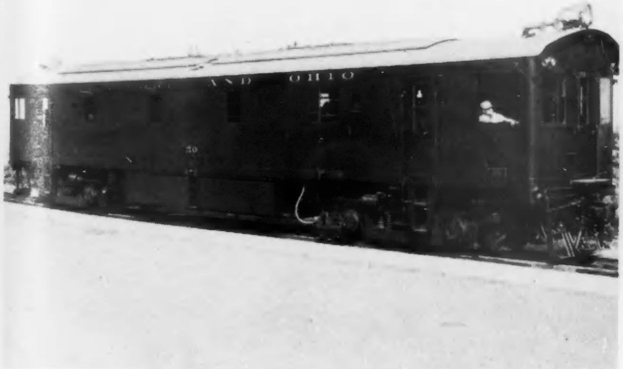
Six Steps of Dieselization

In an age of rapid technical progress, few advances can match the speed of dieselization development. Its life span of 30 years dates back to 1923–25 when the first commercially successful locomotive was built. First, the switching locomotive was developed and sold, followed by the passenger and finally the freight locomotive, together with various combinations. Most of the activity has occurred in the last 15 years.

This invasion of the 100-year-old steam-locomotive empire can be conveniently divided into six steps . . .

• The earliest diesel-electric locomotives were developed, built, and tested in actual service.

• Diesel-electric locomotives were purchased and assigned to selected trains in locations where they could be used to best possible advantage—on



DIESEL-ELECTRICS having a G-E box cab invaded the passenger field in the mid-30's with 12 times the power of the early "oil-electric."

FORERUNNER OF THE TRANSFER, GE's 170-ton diesel-electric switcher with a 2000-hp engine was built in 1936 for Illinois Central.

high-mileage passenger and freight trains and in 24-hour-a-day switching service.

- Divisions, territories, and even entire railroads were dieselized so that steam locomotive facilities—coaling plants, ash-handling equipment, and water stations—could be scrapped, eliminating attendant costs.
- Currently, completion of dieselization and perfection of operating and maintenance techniques are under way to obtain maximum utilization and economy.
- Considering its past experience and future needs, the present diesel-electric locomotive is being evaluated. Important to both builders and operators, this will determine what changes should be made in locomotives purchased either as additions or as replacements.
- The concluding step could be the emergence of a new type of self-propelled locomotive sufficiently superior to ultimately displace the diesel-electric. Competitive types are appearing from several different directions, all contending against the solid background of diesel investment and experience.

The diesel-electric locomotive is likely to be affected by many changes. How serious these will be is indicated by some questions and the discussion that follows: Are present sizes and types best suited to the railroad transportation picture in the foreseeable future? should horsepower be utilized in different proportions of speed and tractive effort in tomorrow's locomotives? as the art of designing and building locomotives advances, what modifications will be desirable? how much standardization should there be? is there a need for another and competing type of motive power? has the diesel-electric locomotive ended further railroad electrification?

Future Suitability

Today, diesel-electric locomotives are more or less stabilized: 1000 to 1200 hp for switching locomotives; 1500 to 1750 hp for freight and some passenger locomotives; 2250 to 2400 hp for passenger locomotives; and 1500 to 2400 hp for road switchers—a long step from the 300 hp of the pioneer locomotive.

The development of larger diesel engines permitted building larger locomotives up to a certain point. Beyond this, however, other factors began to influence size. For one thing, horsepower was utilized far more effectively than by the steam locomotive, removing some of the pressure to build ever more powerful diesel engines. Also, increasing experience enabled the railroads to use all sizes of diesel-electric locomotives to better and better advantage. Finally, where additional horsepower was clearly needed, units could easily be combined to provide the required total horsepower.

No doubt if more horsepower were available, ways would be found to use it. But the greater the horsepower required in a locomotive the more desirable it becomes not to have it all concentrated in a single unit, as with the steam locomotive. Here, failure means changing power or towing the train in, causing lost time and disrupted schedules.

As to diesel-electric locomotive types, the familiar streamlined units are generally favored for mainline passenger and freight trains. The hood-type road switcher—a natural for secondary and branch line operation—is finding increasing use on many mainline trains, both passenger and freight. And on a number of lines the switcher is completing dieselization.

The economic aspect of locomotive sizes also merits some thought. An undersized unit creates transportation difficulties and reduces the capacity of a railroad; an oversized unit increases motive power investment and probably operating costs. The general satisfaction with present sizes and types of diesel-electric locomotives may be a tribute to manufacturers and users alike, but it is also a caution signal against making unnecessary changes. It clearly indicates the necessity for a continuing impartial evaluation of motive power.

Locomotive builders and railroads are continuing to work in close co-operation along this line. For instance, a test locomotive recently built by General Electric is currently being operated in mainline freight service (cover) for the purpose of evaluating the performance of the latest design components.

More Horsepower?

Let's assume that future diesel-electric locomotives will be built with more horsepower. How can it be used to advantage in operating a railroad?

Horsepower—the product of tractive effort and speed—if increased will produce more tractive effort, more speed, or a combination of both. Such an increase would first provide a choice between hauling present trains at higher speeds or heavier trains at present speeds where conditions permit. An intermediate zone allows some increase in both tonnage and speed, fulfilling the competitive necessity to operate more and more freight trains on a schedule basis. Second, it would provide a certain amount of operating margin that would often be useful. And third, more horsepower would make a better proportioned locomotive. So far, diesel-electric locomotives have had a low horsepower-weight ratio compared with other types. In certain services an improvement in this area would be beneficial.

EACH CAB of New Haven Railroad's fleet of 4000-hp passenger diesel-electrics of the early 40's carried two 1000-hp engines.

THREE-UNIT 4800-HP DIESEL ELECTRIC, using G-E electric equipment, typifies today's freight and passenger locomotives.

A combination of high weight per horsepower and a mechanical arrangement that puts most of the weight on driving wheels makes the diesel-electric a high tractive-effort type of motive power. For example, passenger locomotives have either 66⅔ or 100 percent of their total weight on driving wheels; freight locomotives and switchers have 100 percent on driving wheels. In contrast, a typical modern steam-freight locomotive, including tender, has only 34.2 percent of its total weight on driving wheels.

After years of struggling with the steam locomotive, a locomotive with plenty of tractive effort has been a boon to the railroad operating man.

The high tractive effort of diesel-electric locomotives is fully utilized for heavy-grade operation or for hauling drag, or slow, freight trains. Where time is important, however, the locomotives must be filled out with additional units to get the required horsepower, resulting in considerably longer and heavier locomotives. Some increase in horsepower per unit would be of operating and economic advantage without jeopardizing the accepted pattern of diesel-electric locomotive operation.

Let's consider two kinds of speed: the locomotive's maximum speed, governed by mechanical design and traction-motor gearing; the other, and more important, the speed of getting trains over the road between terminals.

Accumulated evidence indicates that passenger train speeds have reached their limits with present equipment. We realize that ground transportation cannot compete with air transportation in speed. In future long-distance rail travel, emphasis should be on comfort and convenience rather than on time cutting.

In freight-train operation, on the other hand, the time element is all-important with no lack of emphasis on ways and means to speed up service. Railroads are spending millions on new yards and terminals, grade and curve reduction, centralized traffic control, passing sidings, radio communication, improvements to equipment, and many other features—all designed to move freight faster.

The costliest and least effective solution is to raise maximum permissible operating speeds. However, the inherent ability of the diesel-electric locomotive to increase schedule speeds enables it to play an important part in the picture. Here also an increase in horsepower would be beneficial.

Modification Essential?

The extremely rapid transition from steam to dieselization has been accomplished in an orderly, consistent, effective way with a minimum of impractical digressions, resulting in a more or less standard form of diesel-electric locomotive for the past several years. Thus we can logically expect future modifications to appear as refinements rather than radical changes. Horsepower-weight ratio improvement would be in this category.

Other refinements as they relate to reliability and low-cost maintenance are the design and arrangement of locomotive and equipment. Reliability requires easy operating methods and simple, sturdy apparatus, installing only what is fundamentally necessary to do the work and arranging it accessibly in the locomotive. A high degree of efficiency and refinement is unnecessary, and even undesirable, if it interferes with reliability.

Everything bearing on maintenance cost warrants the closest scrutiny. Attention should be given to building longer life into wearing parts, enclosing apparatus to protect it against dirt, improving cleanliness of diesel-engine air and fuel, reducing attention required between repairs, simplifying equipment by the elimination of unnecessary functions, and designing locomotives specifically for easy and low-cost maintenance.

Supporting a highly refined, expensive fuel oil will become increasingly difficult. Thus ways and means of improving fuel economy through better efficiency or the use of lower grade fuel should be studied. During the life of a locomotive, many times the initial investment is spent for fuel and maintenance—a good reason for improving these two operating factors.

Standardization

Although standardization has helped the diesel-electric locomotive attain acceptance, a rapidly growing product unfortunately cannot be too rigidly bound to it and certain gaps are bound to occur. The result presents a situation somewhat less than perfect.

When purchasing locomotives, a dieselized railroad wants as much locomotive similarity as possible for use within and between each service. Such standardization would result in minimum spare parts, low material inven-

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After a brief period on GE's Test Course in the 1920's, Mr. Hatch left to follow a career in railroading. In 1951 he returned as Application Engineer, Locomotive and Car Equipment Department, Erie. In this capacity he traveled widely to evaluate design and performance of diesel-electric locomotives. Since July he has been Chief Mechanical Superintendent, Long Island Railroad Co.

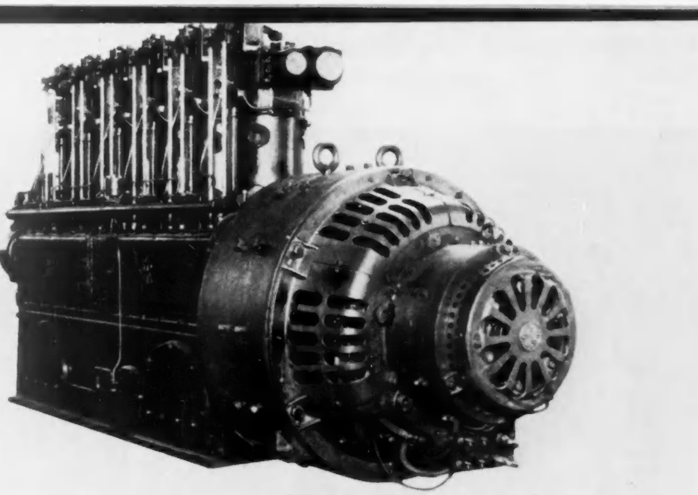
tory, and similar operating and maintenance methods. Departures from the original standards will be accepted if they give direct benefits in lower first costs, improved performance, lower operating cost, lower maintenance cost, or a combination of these.

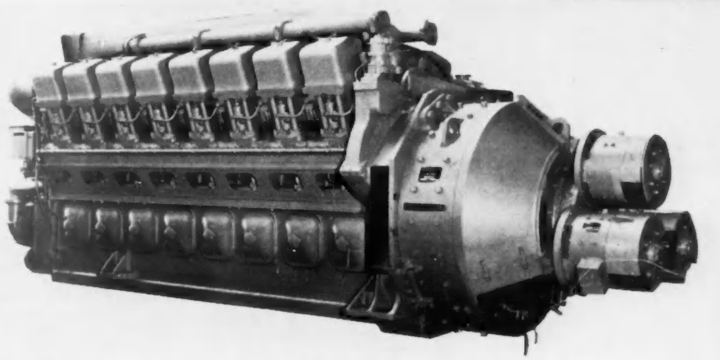
Each proposed change should be evaluated in the light of its benefit to the user and abandoned or postponed if it cannot be justified. A middle course is to design the changes so that they can ultimately be applied to the older locomotives.

Then, too, the manufacturer has a responsibility to improve his product, achieve cost reduction, and continue to progress. All this may collide head-on with standardization principles. These things should be done at a time and in a way that benefit the user most or hinder him least.

Most railroads purchase diesel-electric locomotives from two or more manufacturers, finding standardization of different makes practically nonexistent. Although standardization of certain parts is possible, little has been done about it. Where standardization of components making up certain items is not practical, interchangeability of the items as a whole is often possible. Again, little has been accomplished. But railroads can insist on more standardization and interchangeability in the future.

Growing in importance and becoming a must of the future is standardization in operation that involves standardized location and arrangement of control, indicating, and protective equipment. Crews qualified on one make of locomotive can thus operate another without a sense of strangeness and uncertainty.





ENGINE AND GENERATOR DESIGN of today's 16-cylinder V-type 2250-hp diesel engine (*lower*) contrasts sharply with early 6-cylinder 300-hp engine, showing 30 years of progress.

Does Dieselization Need a Competitor?

To keep the diesel-electric locomotive progressing, as well as to produce new types of motive power, requires competition. Considering the present situation, any new competitor will have to hurdle some imposing obstacles.

Within a few years, dieselization in this country (except for electrified sections) will be virtually complete, representing tremendous investments in locomotives and facilities. Operating and maintenance procedures, personnel training, possibly even track and structures will all have been adapted to the diesel-electric locomotive.

Barring a drastic change in fuel supply, a new type of locomotive would have to offer certain advantages in one or several areas to justify its displacing the diesel-electric: transportation abilities, first cost, fuel economy, or maintenance expense. What did the diesel-electric locomotive offer to justify its displacement of the steam locomotive? Every one of these factors was offered but first cost and that has been kept within reasonable limits.

Inevitably, new types of locomotives superior to the diesel-electric will be developed. A diesel locomotive with mechanical or hydraulic drive, a gas-turbine electric locomotive, or combinations of these or others are possibilities. Perhaps one or more will fit only certain applications. To effect a broad displacement, a new type must have some overall superiority—difficult to obtain when considering the diesel-electric's future potentialities.

To say that the diesel-electric locomotive will never be superseded would indeed be rash. But it would be equally so to discount its leading place in American railroading today.

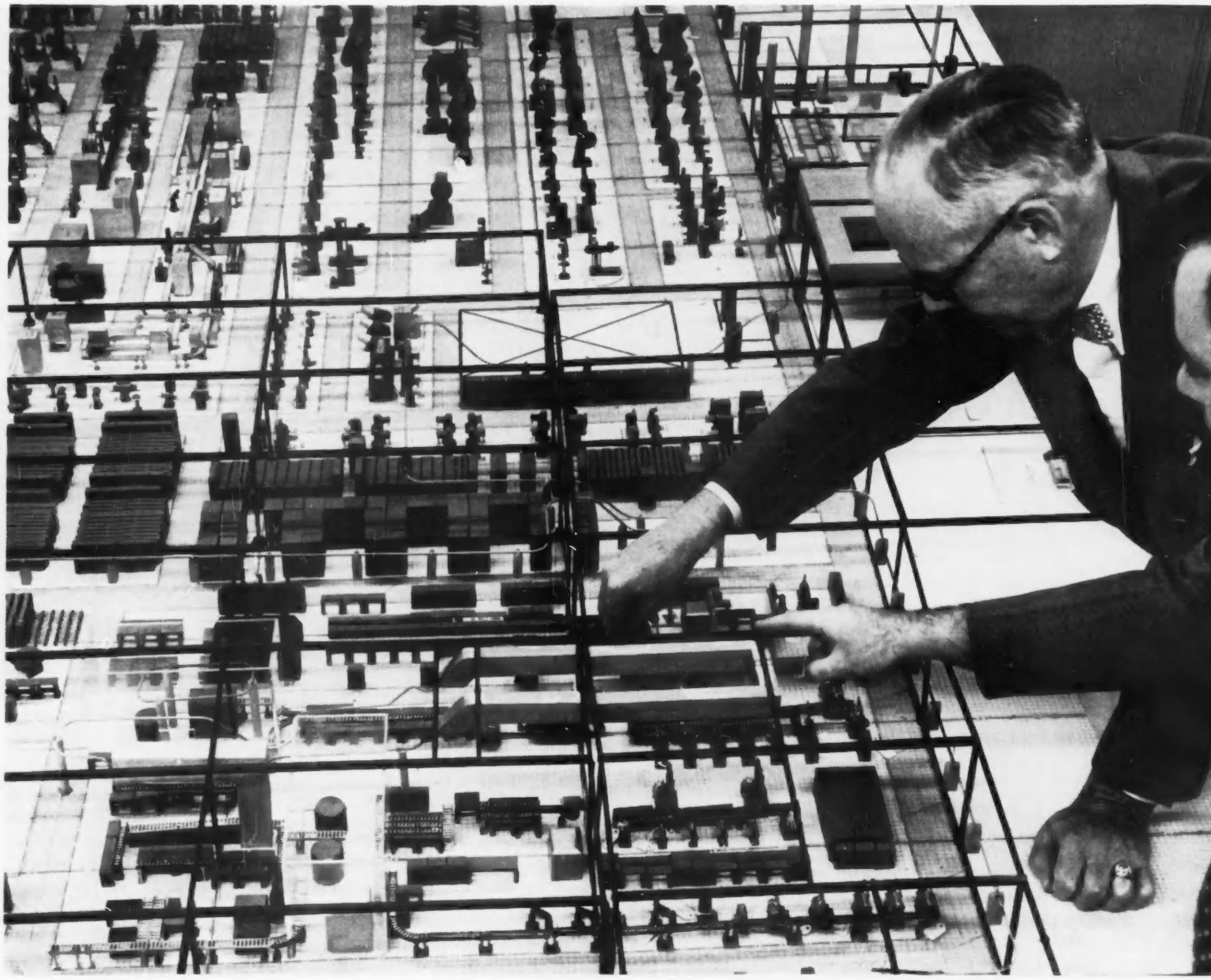
Diesel-electric vs Electrification

You may ask: What effect will the diesel-electric locomotive have on future railroad electrification? Currently, it not only has put a stop to electrification but also has caused a number of short or special-purpose electrifications to be abandoned. As long as fuel oil remains plentiful, this situation can be expected to continue, even though no other form of motive power can touch the electric locomotive in performance.

Present reluctance to consider electrification in the United States arises from three factors: the lack of low-cost electric power, the investment represented by the power distribution and contact systems, and the preference of operating people for locomotives independent of an external power source.

In effect, the diesel-electric locomotive is an electric locomotive with a self-contained power supply. As such, it has many of the electric locomotive's advantages, plus the ability to go anywhere at any time on any railroad where clearance and weight restrictions permit —a valuable characteristic.

Let fuel oil supply diminish, and electrification activity might well be revived. Should this occur, the experience and background gained in diesel-electric operation could readily be applied to full-electric operation. Until fuel oil becomes scarce, however, the diesel-electric locomotive gives indication of continuing its dominance of the railroad motive-power field. Ω



EQUIPMENT MODELS DISPLAYED IN LAYOUT OF A NEW MANUFACTURING PLANT AT BLOOMINGTON, ILL., ARE POSITIONED BY AUTHOR.

The Why and How of Plant Layout

By H. B. CARTER

Planning and executing a plant layout is a science. And properly executed, it's one of the foremost methods for reducing manufacturing costs. What is plant layout? More than just physical placement of machines in a factory, it visually presents all manufacturing planning (photo). The object of good plant layout is efficient utilization of a given factory area by providing a smooth flow of work, minimizing the handling of materials, and establishing good working conditions. Long-range planning decreases future problems that may arise from, say, changing manufacturing methods or output fluctuations. Such planning, incidentally, involves marketing, engineering, financial, and manufacturing groups in a co-operative venture.

American industry today recognizes the importance of good factory layout. For no other single means more readily evaluates or reveals the benefits of a completed manufacturing operation. Yet the most efficient means of preparing such a layout isn't well understood.

Which One?

Deciding on the most desirable arrangement of buildings and facilities and then making a practical adaptation of the ideal is your best approach to plant layout. The immediate problems are how to make the model layout accurately while producing results that are easily understood and how to keep the cost of the small-scale layout within reasonable limits.

As your first step in selecting the proper layout for a specific operation, consider the type of production. Basically, plant layouts can be classified in two types: process and product. Conflicting objectives requiring some degree of compromise often prevent the use of either type in its pure form.

When a product is not and cannot be standardized, you might select the process layout. This is used when the volume of like work requires a layout according to the processes performed and when flexibility in the sequence of manufacture is needed. In a process layout less duplication of equipment occurs—hence, lower total investment. Specialization makes possible not only more flexible production but also better and more efficient supervision. Individual workers have greater incentive to raise their level of performance, improving the possibility of individual incentive-pay plans. Additionally, the process layout permits better control of complicated or precision processes, especially under frequent inspection. And when equipment breakdowns occur, work is more easily transferred to another machine or station.

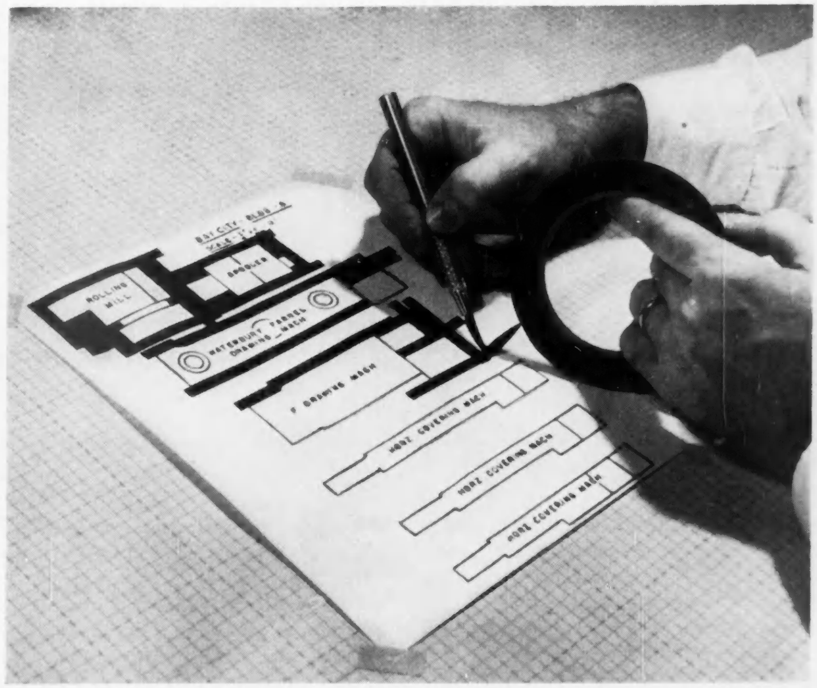
The product layout, on the other hand, must be used wherever a well-standardized item is produced in large volume. Sometimes a line of machines may be set up to produce a given order of a few parts and then rearranged for the next order.

Usually, the product layout adapts best to the mass-production industries. Some of its advantages are lower total materials-handling cost and lower total production time. Further, there is less work in a partial state of completion and more incentive for groups of workers to raise their performance level; thus a greater possibility exists for group incentive-pay plans. Less floor area per unit of production results from using the product layout. Not only is control of production simpler because fewer controls and records are needed, but also accounting costs are lower.

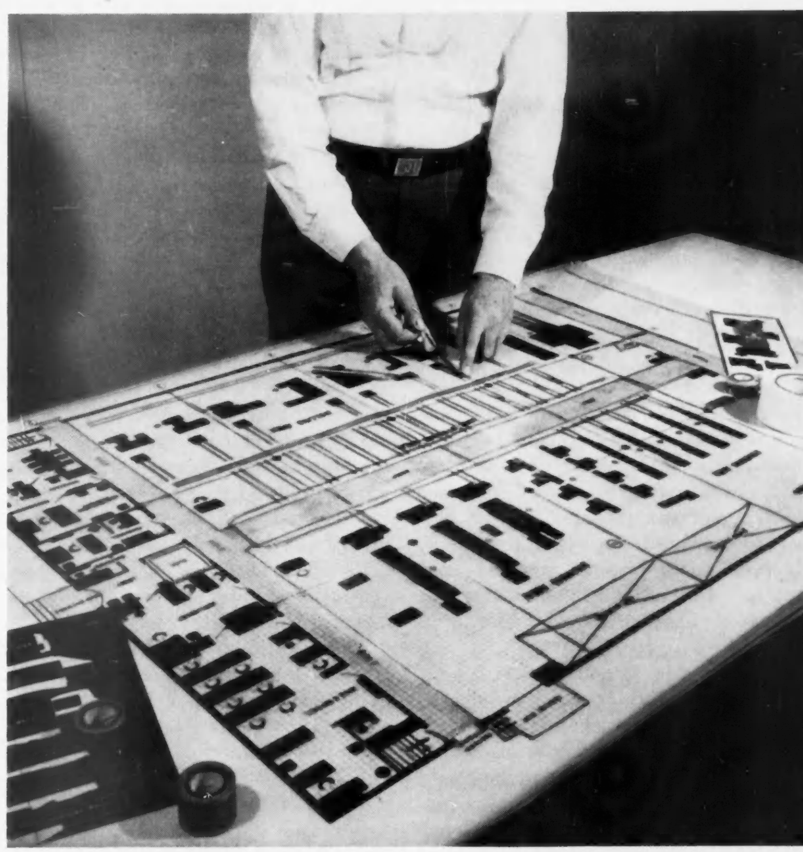
For the next step, after you have decided on the type of production, make a block layout on a small scale. The general factory area to be laid out is blocked in on the floor plan to signify general location of only major features and facilities. Its value lies in formulating preliminary decisions on the type of layout you have in mind.

Now you are ready to make the actual layout. Depending on the manufacturing operation, available facilities, and the amount of overhead structure planned, you have two choices: the two-dimensional transparent layout, recommended for all general purposes; and the three-dimensional model layout, recommended for all new plants, major rearrangements, or installations of extensive overhead equipment and conveyor systems.

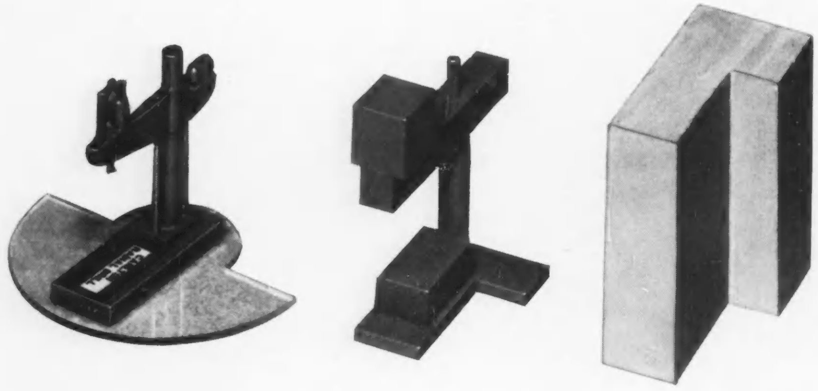
For either type of layout, the scale of one-quarter inch to one foot is most



ONE-FOURTH-INCH BLACK TAPE or opaquing ink fills in the outside areas of complicated outlines so that the template can be easily cut out when reproduced.



DOUBLE-COATED SELF-ADHERING TAPE holds the outline, or template, to the transparent floor layout. All lettering not in the template is similarly handled.



VARYING DEGREES OF DETAIL of a radial drill model show that a good three-dimensional model (*center*) must be recognizable yet easily fabricated and simply detailed.

satisfactory. Architects and engineers specializing in industrial plant layouts have used this scale for years. Large enough to permit you to study and arrange equipment, it is also sufficiently small to lay out large plants on a comparatively moderate-sized surface.

Let's consider the various techniques involved in using either of these layout forms.

Two Dimensions . . .

The two-dimensional transparent-template layout takes in three major operations: making the master floor plan, making the equipment and nomenclature templates, and completing the layout itself.

MASTER FLOOR PLAN—This is a plan view of all building columns, walls, elevator shafts, stairs, doors, and any other permanent elements of the floor. Equipment machinery, conveyors, or services do not appear on the master floor plan.

EQUIPMENT AND NOMENCLATURE TEMPLATES—One of the most important phases of layout work is making master-equipment template tracings for later use. Carefully made measurement of shop equipment requires two people: one to measure, the other to sketch. Machine identification numbers and services needed—air, water, steam, horsepower, and so on—should also be recorded.

In making a two-dimensional template, a plan view must show length, width, maximum travel, operator's location, and flow of materials. A machine's name and number are added to the inside of the sketch with lettering equipment. To fill in outside areas of completed machines, you can use opaquing ink or black tape (photo, top, preceding page) so that the template is easy to cut out when reproduced.

The next problem, of course, is to get this outline on a film or a transparent background necessary for reproduction. Templates of the ink tracing can be made directly on contact film or on a special type of sensitized foil material. To make film negatives of the templates, we suggest a regular photographic darkroom and standard photographic techniques. If made on sensitized foil, a paper or film negative must be produced first. Copies are then available from the negatives.

All these steps are taken to get an accurate outline of the equipment so that you can reproduce it on film or other media. The reproduction, or negative, can then be processed through a diazo print machine for additional copies.

Next, the outline, or template, is fastened down against the transparent floor layout with double-coated self-adhering tape (photo, lower, preceding page). All lettering required on the layout but not included in the template is similarly handled. Templates fastened to the floor plan result in dark templates against the light background of the floor plan. For additional copies the master layout is held against a piece of conventional printing paper and processed through a diazo print machine.

Ability to follow the work in process is one of the aims of a good layout. And to this end, colored flow layouts are generally made to show how the materials move through machines and sections of the plant. Such layouts can be of the block or transparent template types. Arrow tape indicates the direction of flow. On a negative print—white lines against a black background—the white flow arrows can be colored to illustrate movement of materials.

To avoid confusion, it is advisable to show all plant facilities—such as steam, water, and air—on a completely separate layout. This layout is made on transparent sensitized paper after completion of the master template layout. Like the master, copies can be reproduced on a diazo print machine.

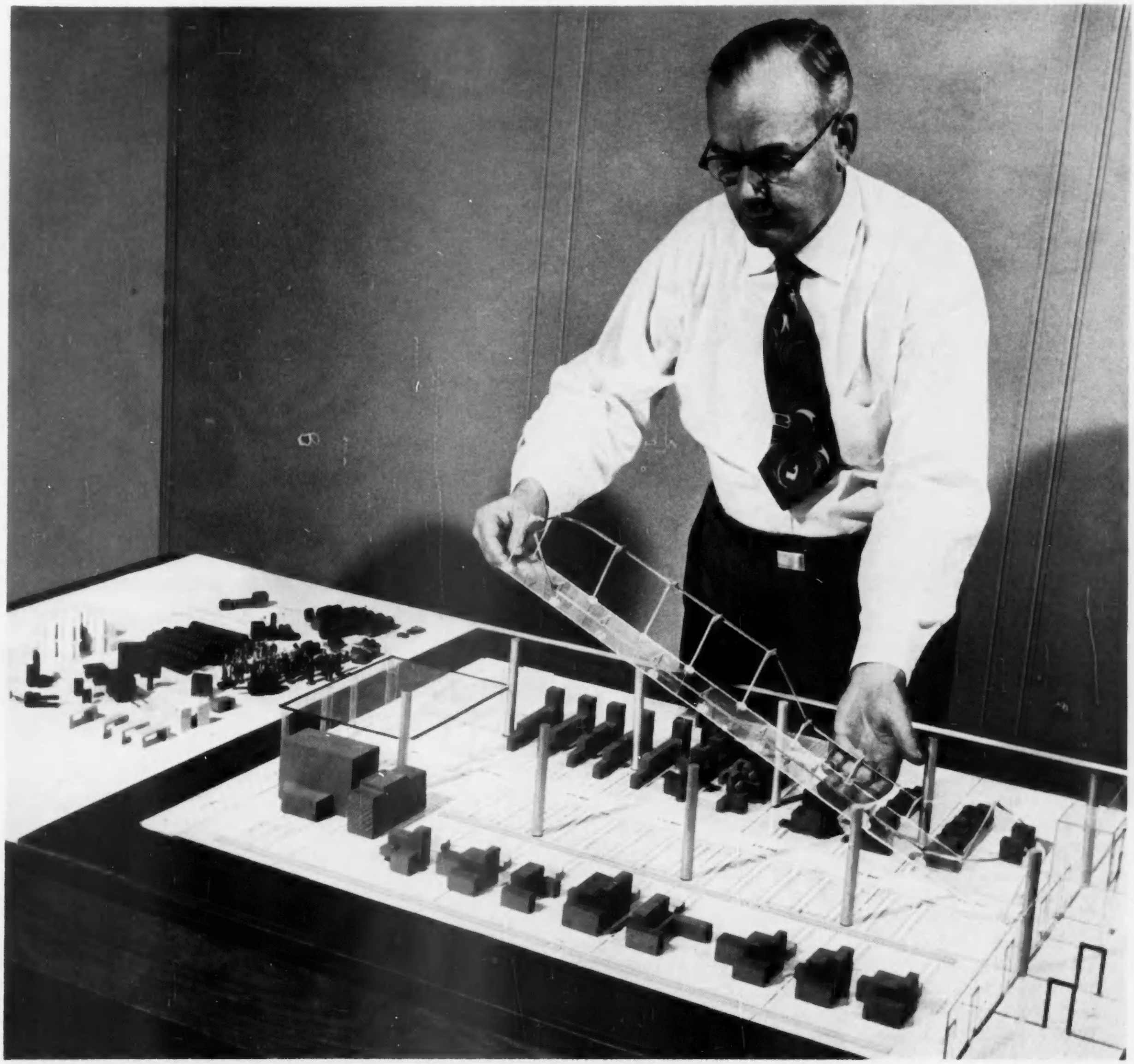
. . . and Three Dimensions

Perhaps you will think that a model factory layout in three dimensions is the best type for visualizing and selling a proposal. That is true. And what's more, the additional cost of three-dimensional models is insignificant compared with the savings you make through better layouts.

At least three techniques are at your disposal. In the least expensive one, you can place three-dimensional models directly on a white-surfaced layout table with a foil grid taped on it. A somewhat more expensive method involves placing the floor-plan print on a one-quarter-inch sheet of fiberboard and covering it with a one-sixteenth-inch sheet of transparent plastics. The models are placed directly on the plastics sheet. In the third and most expensive technique, the layout is made directly on a plant-layout grid board—one-quarter-inch grid paper laminated in plastics and mounted on a lightweight paper or an aluminum core. You can push or fasten together several of these boards to make a layout of a large area.

The three-dimensional models can be made or purchased. In making them, a certain amount of judgment must be used in the matter of detail. For example, a model of a radial drill graphically illustrates varying degrees of detail (photo). You'll note that the center model has sufficient detail to be recognizable and is more easily fabricated than the highly detailed model at its left. Lack of detail on the model at the right makes it unsatisfactory.

If you decide to have models made, an experienced model maker should build them, working from isometric drawings of the equipment. (In addition to a plan view, three-dimensional model layouts need isometric sketches—drawings in three planes—with full dimensions.) Models should be painted in accordance with the plant color scheme. When a double-coated adhesive tape is applied to their base to hold them steady on the layout board, they are ready for use.



AUTHOR CARTER ATTACHES OVERHEAD PLASTIC CONVEYOR ASSEMBLY TO BUILDING STRUCTURE OF A THREE-DIMENSIONAL MODEL LAYOUT.

Building columns for the three-dimensional model are put in place by taping them to the plastics top or by drilling a hole in the plastics and fastening them underneath. Traffic aisles are added with self-adhering opaque tape. And as before, double-coated adhesive tape will hold the models in place once you have properly positioned them. Mezzanine, stairways, and office partitions are usually made of plastics. As with overhead conveyors, these can be added as subassemblies or attached to the building structure (photo). Addition of materials-handling equipment, materials, and personnel completes your three-dimensional model. If you desire, outside building walls can be attached for a still more complete representation.

Sometimes at this point it's advisable to photograph the model for record purposes or study by various interested groups throughout your organization. Also—and this is worth emphasizing—you can have copies of this layout made with the two-dimensional transparent template technique described earlier.

Summing It Up

Techniques of modern plant layout go far beyond the older concept of merely arriving at a pleasing arrangement of factory equipment. Outdated and unnecessary are the detours and tie-ups of old-fashioned layouts that cost time and money.

Today, good plant layout requires specialized knowledge and skills. With careful thought and planning, it will always speed production. Ω

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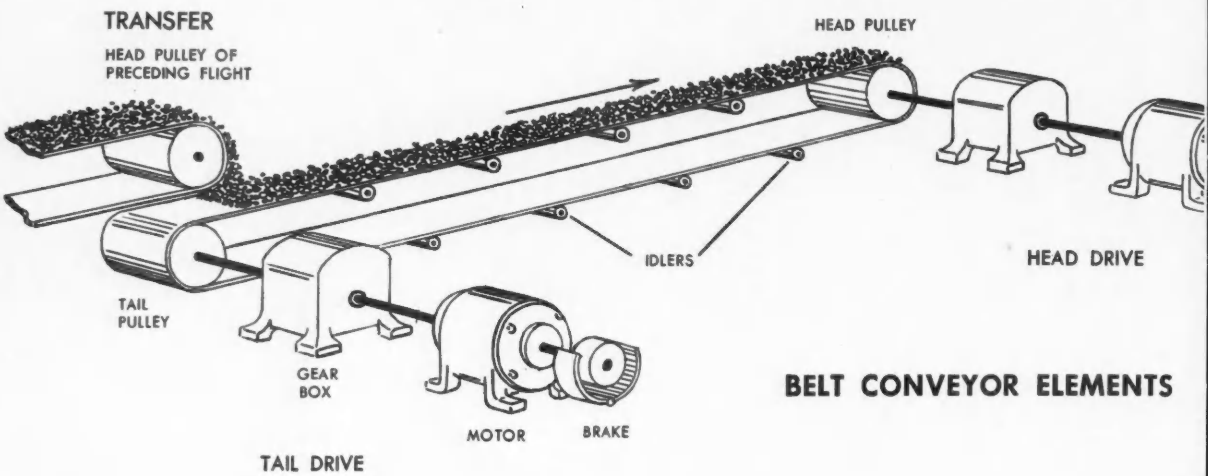
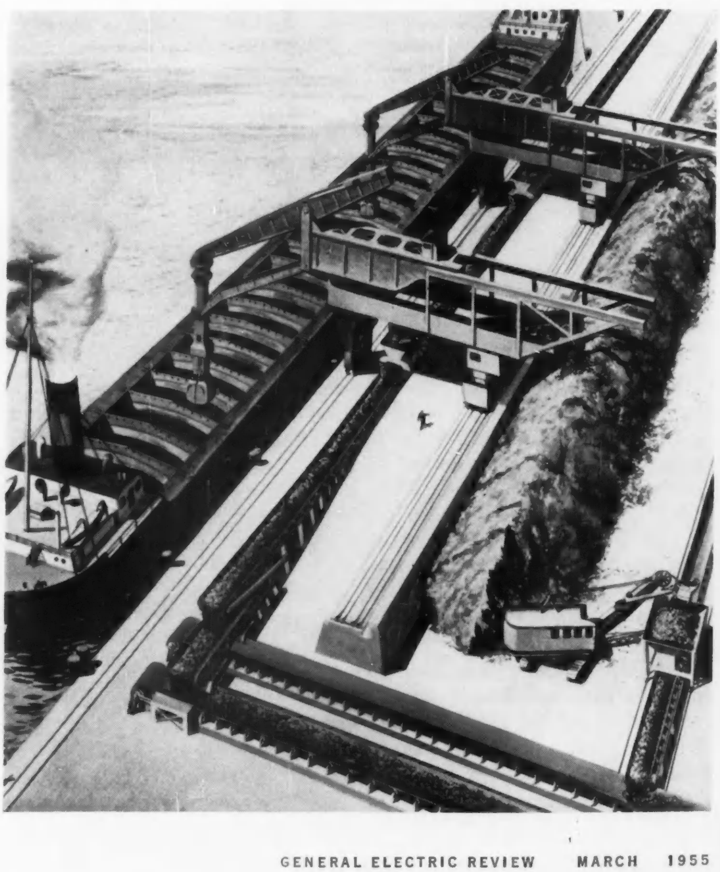
With General Electric since 1947, Mr. Carter is Consultant, Plant Layout, Manufacturing Services Division, Schenectady. His service with the Company was preceded by more than 16 years of experience in related fields. Together with his other duties, he is responsible for the training of men for plant layout positions throughout the Company.



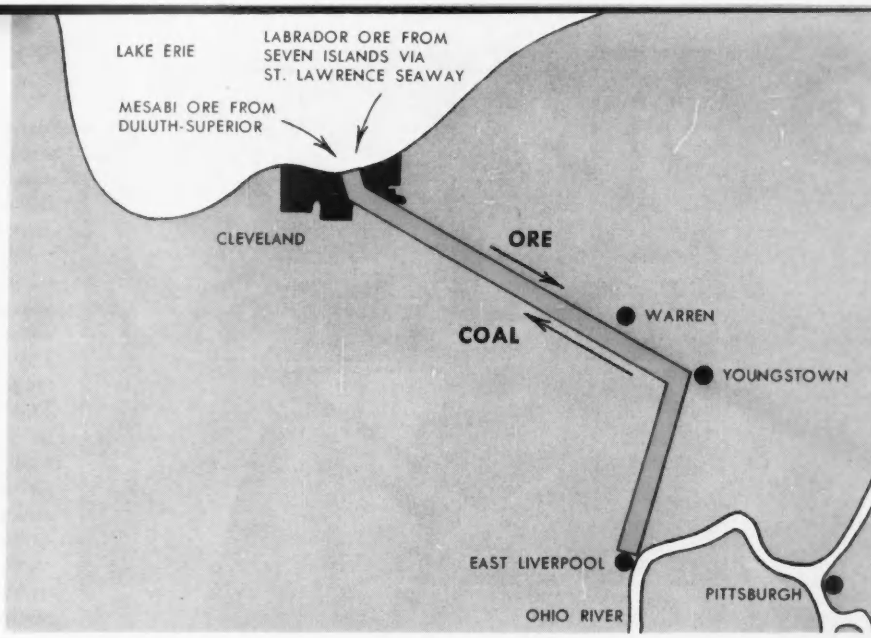
BELT CONVEYOR ELEMENTS

BELT—primary element in a belt conveyor—has rubber covering to protect the cotton duck, nylon, or steel-cable core from abrasion and weather. Idlers, pulleys, power drives, and supporting structure form the supplementary parts. Combined with others, one belt becomes a flight in a long-distance conveyor like the Riverlake proposal.

Riverlake Belt Conveyor: An



EARLY CONCEPTION of Riverlake: Hulett-type unloaders at new dock facilities on Lake Erie at Cleveland would unload ore vessels at high speed (*left*); mainline conveyor resembling a huge steel tube would simultaneously transfer coal and ore from one flight to the next (*center*); coal unloaders at river terminal would unload the barges.



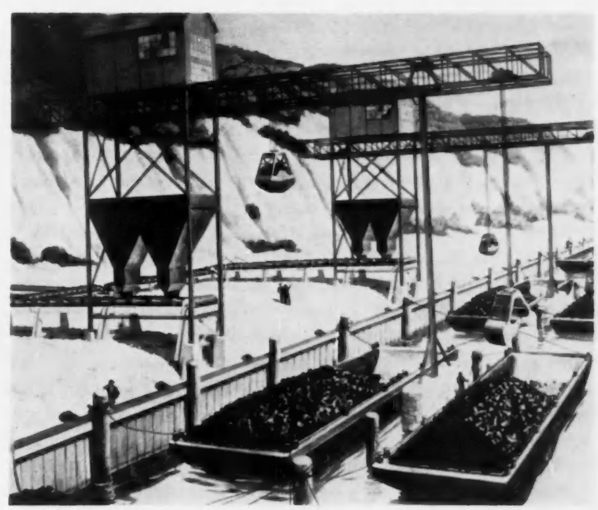
PROPOSED 100-MILE RIVERLAKE Belt Conveyor would carry coal from Ohio, Pennsylvania, and West Virginia fields to industries and utilities in Northeastern Ohio and to the lake terminal for shipment to other industrial areas. It would also transport ore from lake vessels to the river terminal for shipment via barges to steel plants in the three states.

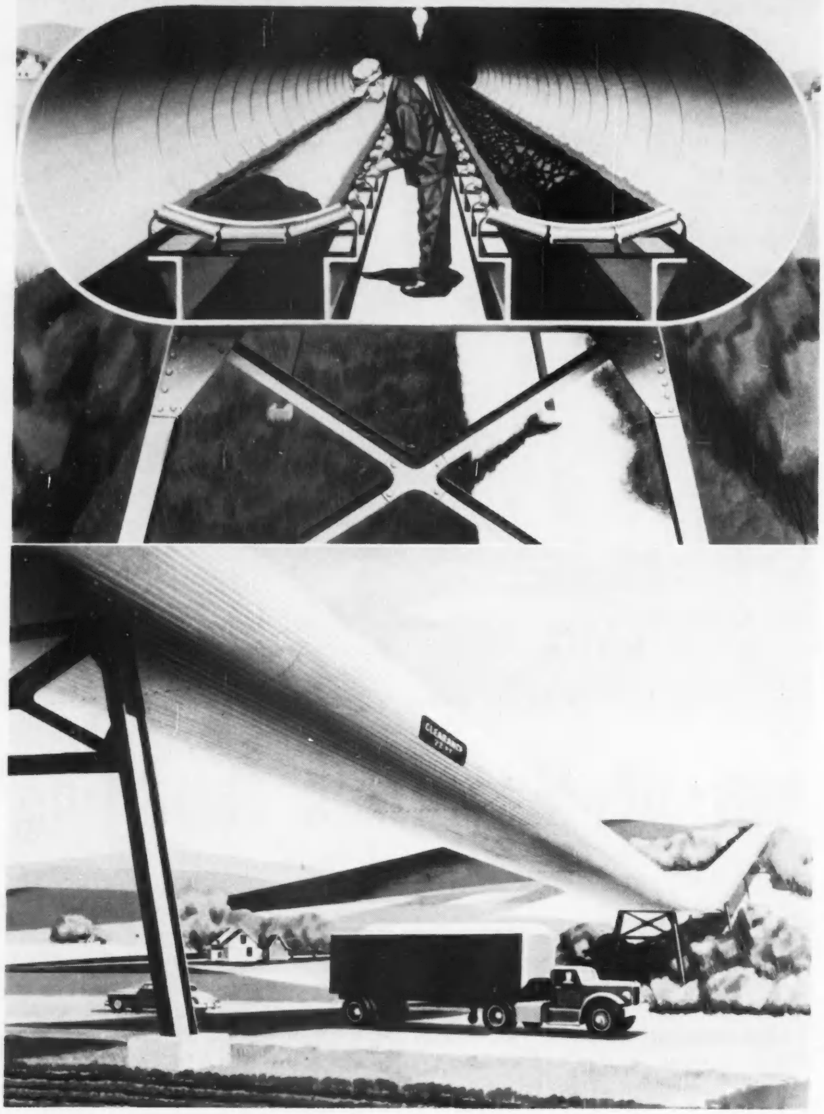
Advanced Concept of Materials Handling

By J. J. W. BROWN

To be associated with the emergence and success of a new transportation system is a rare and fascinating opportunity. Years ago our predecessors had this opportunity with the growth and integration of the vast railroad system that today spans and ties this country together. Electric utility engineers have seen the small power and light companies of 50 years ago grow and interconnect into the present huge electric energy transportation system. Within the last 15 years, engineers in the gas and petroleum industry have seen a vast system of oil and gas pipelines emerge. And now for the first time, the Riverlake Belt Conveyor offers a similar opportunity to the materials-handling engineer.

Since the middle 1850's, materials-handling engineers have seen belt conveyors grow from a small start in grain elevators to many spectacular installations. Besides their universal use in ore and coal preparation plants and power plants, small belt conveyors transport bulk materials overland and underground for considerable distances. One of the oldest belt conveyors in continuous service today is the 30-year-old 4½-mile underground conveyor in the





RIVERLAKE CONVEYOR WOULD SPAN HIGHWAYS, RAILROADS, RIVERS, AND FARMLAND.

Colonial Dock mine of the H. C. Frick Coke Company. Another mining conveyor is remarkable because of its 10,900-foot length for a single continuous flight. The highest lift for a single flight is also in a mine—900 feet from tail to head.

But long overland belt conveyors have made the most spectacular successes. They proved their worth in the great dam-building decade of the 30's, handling the bulk materials for Grand Coulee, Shasta, Friant, Anderson Ranch and others.

The belt conveyor at Shasta was 9½ miles long and carried over 12-million tons of sand and gravel during construction. The latest long belt conveyor was the 7-mile belt used for Bull Shoals Dam located on the White River in Arkansas.

Riverlake Belt Conveyor

These accomplishments become relatively insignificant when compared with the installation proposed in February, 1949, by the Riverlake Belt Conveyor Lines, Inc. They plan to build and operate a 100-mile overland belt conveyor extending from Cleveland on Lake Erie to East Liverpool on the Ohio River via Youngstown and Warren.

The Riverlake system would use two separate belt conveyors: one to carry ore south, the other to carry coal north. Lake Erie ore vessels would be unloaded in Cleveland at new dock facilities designed to handle at high speed the contemplated annual traffic of 27-million tons of iron ore. Normally, the ore would go directly into surge bins and then on the mainline ore belt to the river terminal for shipment to steel plants in Pennsylvania and West Virginia by Ohio River barges. Facilities near the lake terminal would provide for conveying, stockpiling, and reclaiming the ore.

Coal arriving at the lake terminal by conveyor would be stored in another area and reclaimed for loading onto lake vessels. River barges would be loaded and unloaded with the most modern facilities at the Ohio River terminal. The terminals and conveyor belt would be designed to handle up to 28-million tons of coal annually. This coal would go on the mainline belt to industries and power plants in northeastern Ohio or to the lake terminal for vessel shipment to other lake ports.

Although the individual items of equipment required for Riverlake are not new, their integration into an operating transportation system requires over-all project planning and co-ordination beyond the scope necessary for previous applications. For instance, Riverlake would require a power transmission and distribution system of more than 250,000-kva capacity, extending over a 100-mile distance and taking power from three public utilities.

Unattended over its entire length, the system would be electrically operated and controlled from dispatchers' stations at the terminals. By pushing buttons at these stations, the operator could control operation of both mainline belts, as well as divert loads to storage or to customers' plants along the mainline. Although accompanied by economic advantages, unattended operation necessitates supervisory indication of equipment all along the line. Should trouble arise, a radio and telephonic communication network would enable the operator to quickly contact and dispatch maintenance and repair crews.

Mr. H. B. Stewart, Jr., President of Riverlake Belt Conveyor Lines, Inc., envisioned this new transportation system. However, before the company can build and operate the proposed conveyor line, the Ohio State Legislature must classify belt conveyors as common carriers with the right of eminent domain. In recent years this classification has been extended to oil and gas pipeline companies and later to the Ohio Coal Pipeline in 1951 for the transportation of powdered coal. Prior to the 1955 session, the Ohio Legislature had not acted favorably on the inclusion of belt conveyors in this classification. And until this is done, Riverlake cannot become a reality.

Following the first announcement of this project after its feasibility had been established, proponents of Riverlake consulted leading materials-handling and electric equipment manufacturers, consulting engineers, and the public utilities who would supply the power. They confronted the engineers with many problems: How should this new transportation system be built and operated? how much would it cost? can the reliable co-ordinated operation required by Riverlake be obtained and maintained? Positive and accurate answers to these questions were a challenging assignment for these engineers. A résumé of their work will show how they accepted and met this challenge.

Mainline Belt Conveyors

In the design of Riverlake the first step was the layout of the two mainline belt conveyors based on the desired tonnages of coal and ore to be moved. Aerial photographs of more than 282 miles of possible right-of-way aided the selection of the best possible route to avoid present highway and railway junctions, farm and home buildings, industrial plants, and towns. Establishing the route centerline in turn fixed the vertical profile of the line, making it possible to lay out the individual belt flights. The belt speed was fixed at 600 fpm—the highest in widespread use. This made the selection of a 72-inch-wide belt for coal and a 48-inch-wide belt for ore necessary to carry the desired tonnages per year.

The strength of conveyor belts has economical limits that naturally restrict the maximum length of a single belt flight. A combination head and tail drive—a drive at each end of a flight—utilizes the maximum belt strength, thus keeping the total number of flights to a minimum. This was accomplished with the head drive pulling the loaded belt and the tail drive pulling back the empty belt. Some flights were shorter than the maximum because of the need to change the direction of the mainline conveyors, requiring a transfer from one flight to the next. (The problems associated with bending a single flight around a corner have not yet been solved.) Shorter flights not requiring full belt strength have only a conventional head drive; downhill flights have only tail drives because they are regenerative, the motors being driven by the loaded belt.

This optimum layout was modified to end and start as many coal and ore flights as possible at the same location, thereby using common transfer-house structures, electric substations, and so on. Final plans show 162 ore flights from lake to river, varying from 700 to 8500 feet in length, and 118 coal flights from river to lake, ranging from 700 to 11,000 feet in length. Even though the coal and ore belts use many common facilities, their operation is entirely separate.

Motor Drives

The individual head and tail drives would consist of a speed-reducing gear, an electric drive motor, and an electrically operated brake. The brake was considered necessary not only to hold the downhill flights stationary when the belt was not running but also to make emergency stops in the shortest possible time. The most common ore conveyor flight, utilizing the maximum belt strength, would have a 450-hp head drive and a 150-hp tail drive. A similar coal flight would have a 700-hp head drive and a 250-hp tail drive. However, some drives would be as small as 100 hp. For the two mainline conveyors, 472 motors would be required ranging from 100 to 700 hp with 440 volts as the most practicable voltage.

Most large belt conveyors have used wound-rotor induction-motor drive with rotor resistance control for starting. For Riverlake, this would also be the most economical drive. Because all the drive and control equipment would be inside the transfer house, standard dripproof motors were selected.

The starting control for these motors had to meet several requirements. First, the pull applied to the belt, particularly during starting and stopping, must be limited to prevent overstress. Second, the individual flights must be started in sequence—the discharge flight first and so on back to the first flight—so that the material will not be discharged onto a stationary flight, causing pileup and spillage. Normal stopping must likewise be accomplished but in reverse sequence, with the feeding conveyor stopping first and so on down the line to the discharging flight. And third, because of the project's magnitude, the starting had to be so arranged that the 250,000-kw load would gradually build up without undue strain on the utilities. This requirement was met inherently with the sequence starting control, provided the utilities were notified in advance and given the belt-line operating schedule.

The control required to keep the pull on the belt within allowable limits during starting was not so simple, for it varied depending on flight conditions—length and uphill and downhill. For the most common type of flight with combination head and tail drive, the tail drive would be started first, picking up the returning empty belt that would carry a fresh load. Shortly after, the head drive is started, and they are then controlled to come up to speed together. As soon as the discharge flight moves, the flight that feeds it is started. This sequence continues until the entire 100-mile conveyor is moving at full speed. After the initial starting signal, both coal and ore conveyor belts will be running at full speed in approximately 30 minutes.

Safety and Supervisory Features

Starting a complete 100-mile conveyor with the push of a single button required a complete system of interlocks to assure proper operation, as well as to provide the necessary safety features. An electric interlock system would give the sequence control needed for normal starting and stopping of the belt; a similar system would give the proper starting sequence for the two motors on head- and tail-drive flights. Another system would instantly shut down all the preceding flights whenever one conveyor flight stops for any reason. A belt delivering 4000 tons per hour would pile up 66 tons if it were left running one minute after the following flight stopped.

Because maintenance men will patrol the conveyor on a planned schedule, a stop cord for emergencies will extend along the entire length of the mainline belt. Electric interlock systems actuated by mechanical arrangements will stop the belt for belt breakage, jammed material in a transfer chute from one flight to another, shaft or gear breakage in the motor drive, or for fire inside the conveyor.

The operator of the mainline ore conveyor at the lake terminal must know during starting that the sequence is proceeding satisfactorily from flight to flight. Supervisory indication provides this information. The operation of other sequence and interlock controls is indicated to the operator to keep him fully advised of belt operation. Indication is also provided for various safety functions.

Considering Riverlake's size, it is not surprising to find more than 1500 separate indications at the operator's station at each end of the mainline belt. Direct-wire, supervisory code-type signals, and microwave relay stations may be necessary to make practicable the collection of these signals along the line and their transmission to the terminals.

To make use of the information from the indication system, the operator must have at his fingertips a communication network that will keep him in touch with maintenance, inspection, and repair crews. All maintenance depots and trucks will have a two-way radio link with the operators' stations. For routine communication, a private telephone system will be installed at operators' stations, maintenance depots, transfer houses, and along the mainline. With such complete indication and communication systems, any troubles on Riverlake will be quickly detected, located, and repaired.

Lake Terminal

Like all features of Riverlake, the contemplated terminal facilities at the lake would be larger and more extensive than any now in service. The entire operation would start at dockside with Hulett-type unloaders removing the ore with 20-ton bites. Eight of these giants would handle the yearly ore tonnage during the lake season, unloading two ore vessels every six hours. The ore would then go by conveyors to surge bins for future transfer to storage or to the mainline belt. Two large traveling bridges would stack the storage ore in piles according to ownership and type. Some ore may go directly from the surge bins to the mainline belt at 3900 tons per hour. Storage ore will later be reclaimed by the same process.

River coal from the south will be unloaded directly from the mainline belt into storage piles at 4000 tons per hour. Fed by chutes beneath the storage piles, underground belts will move the coal to dockside for loading the vessels. Two high-capacity belts will permit loading a vessel in less than 1½ hours.

All the coal- and ore-handling equipment at the lake terminal will be controllable from a central operator's panel, with the exception of the Hulett unloaders, the reclaiming bridges, and the vessel-loading chutes. Approximately 25,000 hp of electric motors at the lake terminal will drive and control this equipment.

River Terminal

Because all the storage and reclaiming facilities would be located at the lake terminal, the river terminal would not be so extensive. However, three elevator-type unloaders, larger than any built today, would unload river barges in three passes by an unloader. The coal would go from the unloaders to surge bins by belt conveyor and from the bins to the mainline conveyor. Surge bins level out the flow from the unloaders so that the mainline belt can be uniformly loaded to capacity. The incoming ore goes through surge bins and then by gravity feed into waiting barges. These bins store the incoming ore during the short periods that barges are being changed under the loading chutes. About 7500 hp of motors will be required for handling coal and ore at the river terminal.

Power Supply System

Riverlake's power system is equally spectacular—a 100-mile 34.5-kv double-circuit transmission line with five 138-kv feeds totaling 275,000 kva—but even more so when you consider that this entire system is for Riverlake alone. However, the design of this power system was relatively simple, for it was realized at the beginning that there would be a limited number of high-voltage 138-kv feeders, probably five or six, from the public utilities to Riverlake. The motor voltage could thus be established independently of the power supply, because a subtransmission level of about 34.5 kv would be required regardless of the motor-voltage level selected. Even if 4000-volt motors had been practical, a single transformation of 138 to 4.16 kv would not have been economically feasible. With this freedom of choice, a 480-volt utilization level and 440-volt motors were natural selections.

The five 138-kv feeds were located uniformly, one near each terminal, and the other three equally spaced between them. While one utility would supply two of these feeders, all had to be considered as separate supplies because none of the 138-kv feeds could be interconnected through the subtransmission system of the Riverlake project.

The selection of the 34.5-kv level was also relatively simple, although a detailed comparison of 34.5 and 69 kv was made before the final decision. The 69-kv subtransmission line was considerably cheaper because less copper was required. But the difference in the transfer-house transformers supplying 480 volts from the subtransmission line became the deciding factor. With 220 transformers involved, the extra cost for 69-kv insulation as compared with 34.5-kv was almost 20 percent of the power supply system's total cost—a factor sufficient to dictate the selection of a 34.5-kv subtransmission level.

Reliability

Completion of the project's design convinced everyone that Riverlake could be engineered and built. But how would it run, and how reliable a service could it provide? Here too, the engineers felt confident in saying that Riverlake would operate as reliably as any transportation system in service today, if not more so. The Colonial Dock mine conveyor ran 27,000 hours between 1931 and 1943, carried 40-million tons of coal, and lost only 27 hours. This amazing record first indicated the reliability of conveyor belts.

Reliability of many of Riverlake's components had already been proved by their use with similar electric and mechanical equipment in every industry in the country. Records were also available on the high reliability of all types of materials-handling equipment used at the terminals. And an additional factor in Riverlake's favor was careful planning for regular inspection and maintenance of all equipment. These investigations, plus careful weighing of the evidence, resulted in unanimous agreement that Riverlake could be a reliable transportation system.

Meeting the Challenge

The engineers advising the Riverlake Belt Conveyor Lines, Inc. have met the challenge given them in 1949 by engineering a 100-mile-long high-capacity belt-conveyor system. Eagerly they await the final part of this challenge—the actual construction and operation of Riverlake. Ω

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Mr. Brown is Manager, Materials Handling and Testing Equipment, Apparatus Sales Division, Schenectady. Not a newcomer to the REVIEW, *he is the author of "How Good Is the Magnetic Amplifier?" that appeared in the July 1954 issue.*

SPHERICAL MERCURY LAMP displayed by Dr. Buttolph finds industrial application in the 100- to 1000-watt range; tubular lamps for photochemical use range from 1000 to 5000 watts.

Mercury Lamps— Light Made to Order

By DR. L. J. BUTTOLPH

It may come as a surprise to you that in the United States mercury now accounts for more artificial light than tungsten does. And yet, possibly twice as much electric energy is still used to heat incandescent lamps.

Mercury vs Tungsten

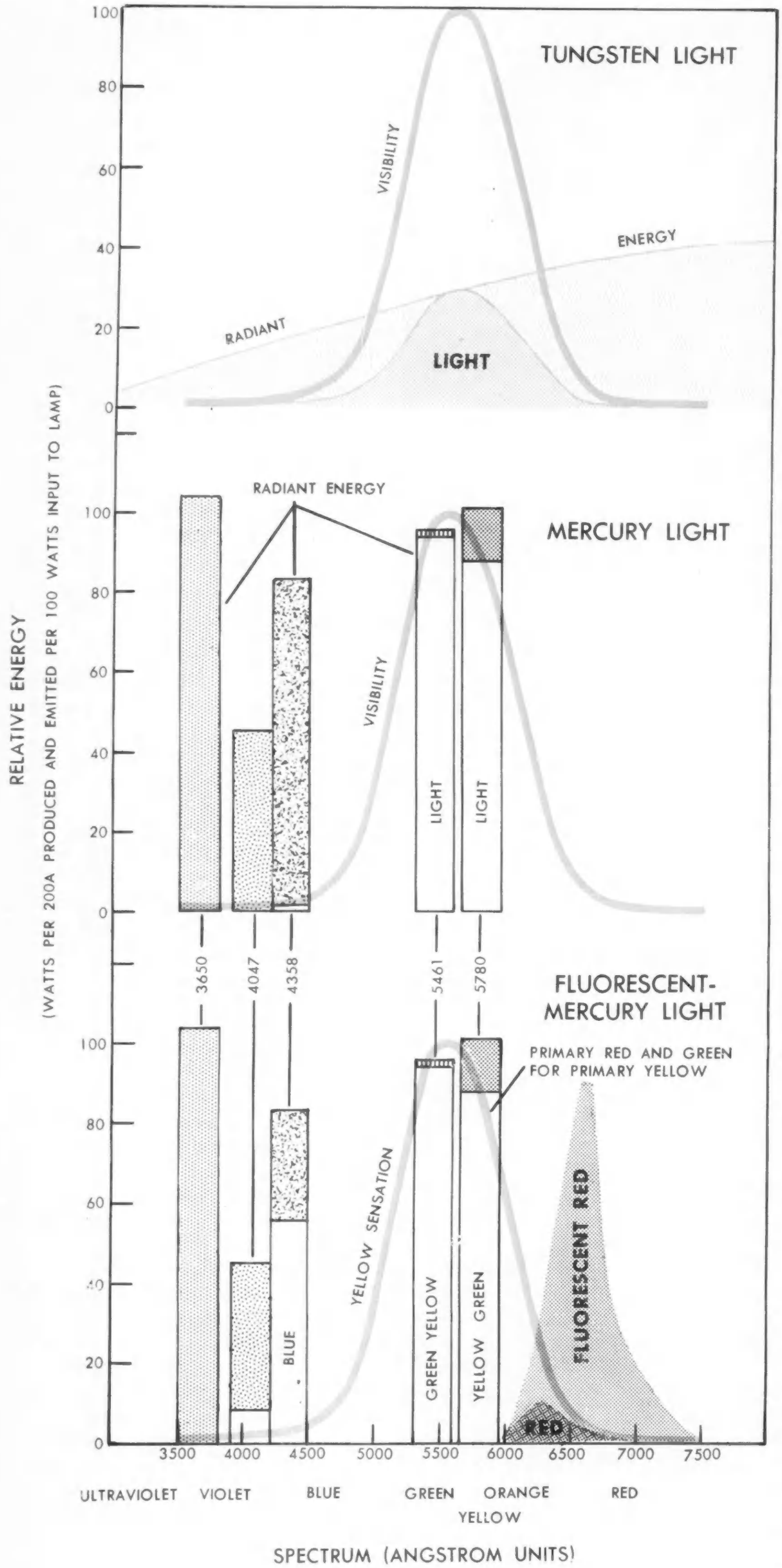
Although tungsten has the highest boiling point, 8540 F, of all metals, mercury has the lowest, 675 F. Inside a glowing incandescent lamp, tungsten's electric resistance remains nearly constant through the whole range of filament temperatures—400 to 5600 F. In contrast, the resistance of a tube of mercury vapor changes in a complicated way with vapor pressure, which varies from a fair vacuum to more than 1500 pounds per square inch through the normal range of mercury temperatures —100 to 1400 F.

The mechanical problems associated with tungsten filaments make the incandescent lamp an inherently compact, somewhat spherical structure. But the filament's length and diameter limit its range of operation from 1½ to 300 volts. At 1½ volts the filament is so short and thick that it becomes difficult to heat without excessively heating its supporting wires. At voltages in the order of 300 volts, the filament is so long and slender that it is fragile and difficult to support. (Of the common large tungsten lamps, 99 percent are used on standard 115-volt circuits.)

On the other hand, the range of a mercury lamp is governed by the length and diameter of its quartz-glass tube (photo)—but not to the extent that a tungsten filament governs the wattage rating of an incandescent lamp. Dimensions of the quartz-glass tube do not fully define the mercury lamp's electrical characteristics. For in a tube of any given length, you can adjust voltage drop over a wide range by changing the operating vapor pressure—controlling, in other words, the temperature and amount of mercury in the tube. This permits you to design a mercury lamp for practically any voltage greater than about 20 volts. And the higher the voltage the better its efficiency and the color of its light. The lamps range up to 2000 volts (illustration, page 29; Table, page 31).

The mechanical and electrical features of commercial mercury lamps give rise to five radically different types: 1) low-pressure low-voltage lamps in long tubes, such as fluorescent and germicidal lamps; 2) high-pressure low-voltage lamps in short tubes used for industrial lighting; 3) high-pressure high-voltage lamps in long tubes for photochemical and photocopying purposes; 4) very-high-pressure and very-high-voltage lamps in very short tubes, such as a water-cooled 1000-watt lamp; and 5) very-high-pressure but relatively low-voltage lamps in spherically shaped bulbs.

In a tube of mercury vapor with electrodes connected to a source of power, a small amount of general ionization will start a chain reaction. Any current at all produces more ionization by collision with atoms, says the physicist, and so more current flows. All electric discharge lamps have this unstable relationship between their current and the voltage supplied. In fact, the practical limit to mercury vapor's current-carrying capacity is how high a temperature its enclosing tube can take without rupturing. Only by connecting impedance in series with the lamps can you control their current. In practice, about one half the supply voltage is absorbed by such a series ballasting device—the function of fluorescent-lamp ballasts.



TUNGSTEN RADIATES all the visible wave lengths (*top*), while mercury (*center*) emits only four of the distinctly visible wave lengths. Phosphors convert mercury's invisible ultraviolet to red light (*lower*).

Synthetic White Light

A further comparison with tungsten may help you to understand how mercury produces light.

When sufficiently heated by electric current, the atoms of tungsten vibrate at such various high frequencies that they radiate energy of corresponding wave lengths (illustration, top). Our eyes are sensitive to this energy. It, and the sensation it produces in our eyes, is called light. The higher the tungsten temperature the more and the bluer the light.

Mercury vapor is seldom heated to a high enough temperature to emit light that way. For when electricity passes through it, some of the energy is absorbed by the atoms and they become excited independently of any heating effect. Their complicated internal structures, like miniature solar systems, are momentarily disturbed. (But, of course, they are not disturbed sufficiently to cause fission; that takes much higher speed electrons than are generated in a mercury arc.) The excited mercury atoms then return to their normal condition by emitting the energy that previously excited them.

Thus you see that while hot tungsten emits light from its vibrating atoms, relatively cool mercury emits light from the movements of electrons entirely inside its atoms. Remarkably, the emitted energy from mercury vapor bears little or no resemblance to the previously absorbed electric energy. Instead of containing the full range of visible wave lengths characteristic of white light from hot tungsten, the mercury-vapor energy radiated contains only four distinctly visible wave lengths —yellow, green, blue, and violet (illustration, center). When mixed in the eye, they produce the sensation of bluish-white light.

Within the mercury discharge itself, energy is radiated that ranges in wave length from invisible infrared to invisible ultraviolet. This energy emission is further defined by the filtering action of the glass tube that encloses the vapor and by the lamp's particular application. For example, germicidal lamps have an outer bulb that transmits all the radiation, including the lethal germicidal wave length, 2537 A. (Wave length is measured in angstrom units equivalent to 10^{-8} cm.) In contrast, a clear glass bulb used for illuminating purposes transmits all the visible radiation but none of the germicidal and sunburning ultraviolet.

Light and Illumination

Every individual wave length of visible light produces a sensation of intense color in the eye when isolated by a spectroscope from all other wave lengths. They show up as brightly colored lines, the distance between them depending on the difference in their wave lengths. Ionized mercury vapor has, for practical purposes, only four visible lines. On the other hand, light from the sky or an incandescent lamp contains an infinite number of lines and accompanying wave lengths, and the colors of their continuous spectra blend imperceptibly into one another.

Hot tungsten and the sun emit practically all wave lengths of visible energy, with a difference only in the relative amounts of energy in the various wave lengths. The relatively great differences between tungsten and the sun at extreme ends of the spectrum—the red and the violet—are minimized by their relatively low visual effects.

In the higher pressure mercury lamps, a large number of lines through the whole invisible ultraviolet spectrum are produced along with the four strongly visible lines. The energy in these ultraviolet lines may vary from one half to double the visible energy, depending on the lamp's design and the transmission characteristics of its glass tube, or bulb.

The four visible mercury lines are of wave lengths that when blended in our eye produce the maximum visual effect consistent with a nearly white color of the light itself. This is possible only because about one half the energy in these lines is at yellow and green wave lengths of nearly maximum visual effect. Violet and blue wave lengths account for the other half. Our eyes combine these colors to give us the sensation of blue-white light, producing an effect similar to that of uniformly distributed energy of all wave lengths.

These peculiarities raise interesting questions: How much visible energy of the continuous and line-spectrum type do you need to produce a given sensation of light? how does a mixture of two highly different colored kinds of light produce an apparently white, or colorless, effect? and how do colored objects appear when illuminated by such synthetic white light? Let's look at some of the answers . . .

Light and Energy

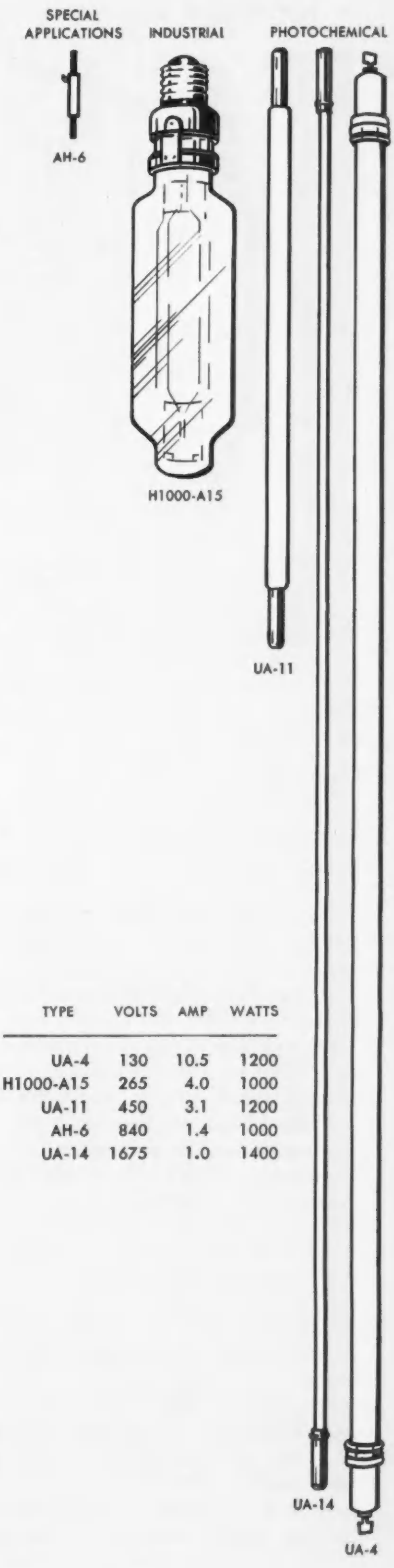
Light, heat, sound, x rays, gamma rays, cosmic rays are all in the form of radiant energy when passing through space. The color of a luminous object—such as the sun, incandescent tungsten, or ionized mercury—depends on the frequencies of its radiations.

Color sensation arises in a variety of ways. If all colors of a continuous spectrum overlap to form a single patch of light, the resulting beam is white. But by combining a pair of complementary colors—the yellow and blue portions of the spectrum, for instance—a white light is also produced that you can't distinguish from the other.

About five thousandths of a watt (5 mw) of radiant energy uniformly distributed throughout the visual range of the spectrum produces one lumen of white light. Concentrated in a single yellow-green wave length of maximum visibility, only about 1½ mw would be needed. A mercury lamp's yellow and green lines are so nearly of maximum visibility that it provides light at 1.6 mw per lumen but inseparably from both the relatively invisible blue and violet lines and the entirely invisible ultraviolet line. The complementary yellow-green and violet-blue lines produce an effect of white light. As with hot tungsten and sunlight, about twice the energy is needed to provide white light than is required for yellow-green light. By contrast, only about one half as much total visible energy in mercury lines produces the effect of white, or colorless, light. Of this energy, the half in the yellow and green lines produces nearly all the sensation of light; the half in blue and violet lines merely adds the blue-white effect.

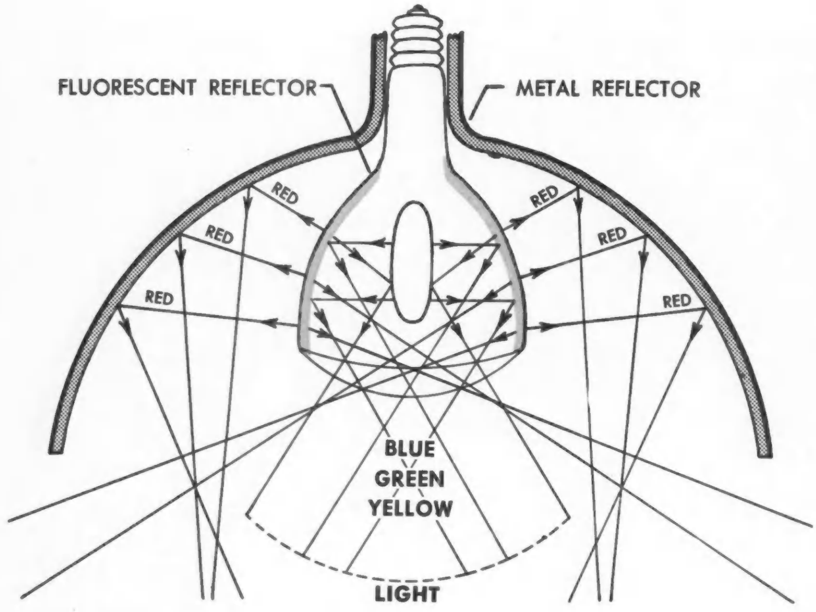
When visible energy is produced, much invisible heat and some ultraviolet is lost from both tungsten and mercury lamps. Over-all, the tungsten lamp takes 50 mw of electricity for each lumen of light given off, but the mercury lamp only 20. Their efficiencies are only about 10 and 12½ percent respectively, but the high visibility of mercury lines doubles their light production. Thus as a light source, the mercury lamp is two to three times more efficient than the

MERCURY LAMPS



TYPE	VOLTS	AMP	WATTS
UA-4	130	10.5	1200
H1000-A15	265	4.0	1000
UA-11	450	3.1	1200
AH-6	840	1.4	1000
UA-14	1675	1.0	1400

LENGTH AND DIAMETER of a mercury lamp's glass tube, together with pressure of the mercury vapor inside it, determine electrical characteristics. Higher voltage means higher efficiency and better color of light.



FLUORESCENT REFLECTOR utilizes light from both sides of phosphor coating that also reflects light from the arc, and it provides five percent more output than nonreflector lamps.

tungsten lamp. This remarkable efficiency offsets to some extent the mercury lamp's inherent faults of high brightness, color distortion, and need for ballasting.

Color Sensation

The sensation of color is additional and secondary to our simple sensation of light. The sense of colorless light from colored lines is a fusion in the eye and brain of the three physiological, or fundamental, primary color sensations —blue, red, and green. One or all of these senses may be lacking with little effect on our black and white vision.

These primary color sensations are thought to be characteristics of three different sets of cells in the eye's retina or of three distinctly different effects in all the cells. One or more of these sensations, each extending over a broad range of wave lengths, can be produced by energy of limited wave-length range. In the same way a single line of ultraviolet produces a broad emission of light from phosphors such as are used in fluorescent lamps.

The yellow and green lines of mercury vapor are approximately the wave lengths that most effectively produce the primary red and green sensations in the eye. They produce little or no primary blue sensation. Similarly, the blue and violet mercury lines are approximately the wave lengths most effective in producing the primary blue sensation—with little or no red or green sensations. Also, the amounts of energy in the yellow-green and complementary blue-violet lines are such that they produce an effect of white light similar to but somewhat bluer than light in the northern sky. Anything that even slightly disturbs the balance of these complementary colors changes the apparent color of a mercury lamp. A haze of smoke and moisture, for example, scatters and absorbs blue light, making the lamp appear greenish yellow.

Color Rendition

How do colored objects appear when illuminated by the synthetic white light of a mercury lamp, itself by no means containing the infinite variety of spectral shades represented in textiles, flowers, birds, and butterflies? A red flower can reflect none of the blue in mercury light and barely enough of the greenish yellow to be seen in its surroundings. However, certain blue and yellow colors need only the limited spectral range of a mercury light for a daylight appearance. But by and large, few other colors have a daylight or tungsten-light appearance when illuminated by mercury.

As you know, the color of merchandise and the appearance of people is fundamental to commerce and life. In such applications any departure from either daylight or incandescent-light appearance poses an almost insurmountable problem with mercury lighting. However, the mercury lamp can be successfully used in many lighting applications because, fortunately, our vision is usually unimpaired by color imperfections. For special industrial problems of identifying color-coded materials, incandescent lamps are added to mercury-lamp installations on an equal wattage basis. Fluorescent red light is also added to mercury lamps to show up red objects that would otherwise appear black.

Fluorescent Effect

Inside the higher pressure mercury lamps, invisible ultraviolet is produced with an energy content equal to that of the four visible lines. It is double that of the yellow and green lines which alone account for 95 percent of the light output. The ultraviolet lines contribute no light, however.

To utilize them, phosphors were developed that convert their energy—and some in the blue and violet lines—to a deep red fluorescent light (illustration, lower, page 28). This addition of red, plus partial suppression of visible blue-violet, is a worthwhile color improvement. Phosphors are used either as a complete coating on the inner surface of the mercury lamp's glass bulb or on the reflecting surface of a reflector-type glass lamp. (Practically all high-pressure lamps are made of fused quartz enclosed in an outer glass bulb.)

As a complete coating, the phosphor diffuses all the light from the mercury arc and also absorbs some of it. However, it adds enough light to offset by fluorescence much of the absorption. Coated only on the upper surface of a reflector-type lamp, the phosphor adds fluorescent red to the reflected as well as directly transmitted light. Along these lines, a fluorescent reflector just recently developed (illustration) utilizes to practical advantage for the first time the phosphor coating on both sides of a mercury lamp. This coating is at the same time a good reflector of light from the mercury arc itself. In addition to controlling light output, the fluorescent reflector provides five percent more total light than the ordinary fluorescent mercury lamp. Previously, the light emitted by either fluorescence or reflection from the inside surface of the phosphor coating on a mercury lamp was almost entirely trapped within the lamp. And the only effective use of the phosphor was as an emitter of light by fluorescence from its outer surface.

CLASSIFICATION OF MERCURY LAMPS

Common Names	Atmospheric Pressure (Psi)	Arc Length (Inches)	Arc (Volts)	Arc (Watts)	Use
Germicidal	0.00001	8 to 30	25 to 95	4 to 36	Air and product sanitation
Fluorescent	0.00001	4 to 90	35 to 285	4 to 100	General illumination
Ozone	0.00001	0.25	10 to 12	4	Odor control
High-pressure	1 to 30	1 to 48	135 to 535	100 to 3000	Industrial illumination
Photochemical	1 to 2	3 to 60	100 to 2000	250 to 5000	Photocopying
Compact	30	0.25	75	1000	Searchlight signalling
Capillary, air and water cooled	80	1.0	840	1000	Special applications

Some Applications

Mercury lamps are of high value to industrial lighting, street lighting, and flood lighting, where exact duplication of either daylight or incandescent color rendition is unimportant. In these applications, high mounting of the lamps permits the use of fewer high-wattage units, minimizing replacement costs.

Within such mercury lamps as the germicidal and fluorescent, about 60 percent of the electric input is converted to two wave lengths in the ultraviolet region. One of these wave lengths is 2537 A—the most lethal for killing bacteria, viruses, and mold spores. (See May 1953 REVIEW, page 8.) The germicidal lamp, transmitting about two thirds of this lethal energy through its glass tube, has extensive application in air sanitation and product protection. Fluorescent lamps, on the other hand, convert the germ-killing ultraviolet to visible light by means of phosphors. From either germicidal or fluorescent lamps, little light results directly from the visible mercury lines. So they are not considered mercury light sources. (See July 1954 REVIEW, page 34.)

Mercury lamps in the 100- to 400-watt compact form are sold for home and therapeutic uses. In addition to their germicidal effects on such superficial infections as ringworm, they also aid body metabolism by preventing and treating rickets in young children. Similar but smaller lamps of limited ultraviolet output are sold to the public as sun lamps.

Other mercury lamps with filters to absorb the visible light are used for their fluorescent effect. Called black-light lamps, and sometimes Wood's lamps, they are enclosed in a filter-glass bulb that looks black and in effect is black because it transmits only the relatively invisible ultraviolet. Many materials—white ink, for one—convert this invisible ultraviolet into blue, green, or red light by fluorescence. Black-light lamps are used for theatrical and advertising effects; detection of counterfeits, forgeries, and the like; and for medical diagnosis.

Another application of mercury lamps is in the chemical industry. Here, lamps with high ultraviolet output are used to catalyze chemical reactions, alter the physical properties of plastics materials, and duplicate the bleaching, or fading, action of sunlight.

The most recent mercury lamp, like the oldest carbon-arc lamp, has a short, compact high-current arc. In it, tungsten electrodes pass current through mercury vapor held at many atmospheres of pressure in spherical quartz-glass bulb. Because xenon gas facilitates starting such lamps, they are also known as mercury-xenon. Their adaptability to searchlight reflectors is leading to extensive military applications. (Lamps containing only xenon are being developed.)

Bright Future

In craneways, hangars, and aircraft assembly plants, lamps are suspended at great heights. Such applications obviously call for a minimum number of long-lived units with high light outputs. Lamps that operate at high voltages are also needed. For today the trend is toward high-voltage power distribution systems. In both instances, modern mercury lamps are the answer.

An immediate need—and a continuing one—is higher levels of illumination on our streets and highways. The size and number of automobile parking lots in America steadily expands, as does high-intensity protective lighting. Here again the economy, efficiency, and long life of mercury lamps are definite advantages. They may have similar applications for floodlighting buildings and grounds, their slight color distortion in some instances being an asset.

Truly, mercury lamps occupy a unique position among our artificial light sources. While inherently adaptable to far higher operating voltages than the incandescent lamp, they possess not only its compactness and high-wattage possibilities but also a fluorescent lamp's efficiency and long life.

Until some new and unforeseen light source can better such an unusual combination of properties, the mercury lamp's future seems assured. Ω

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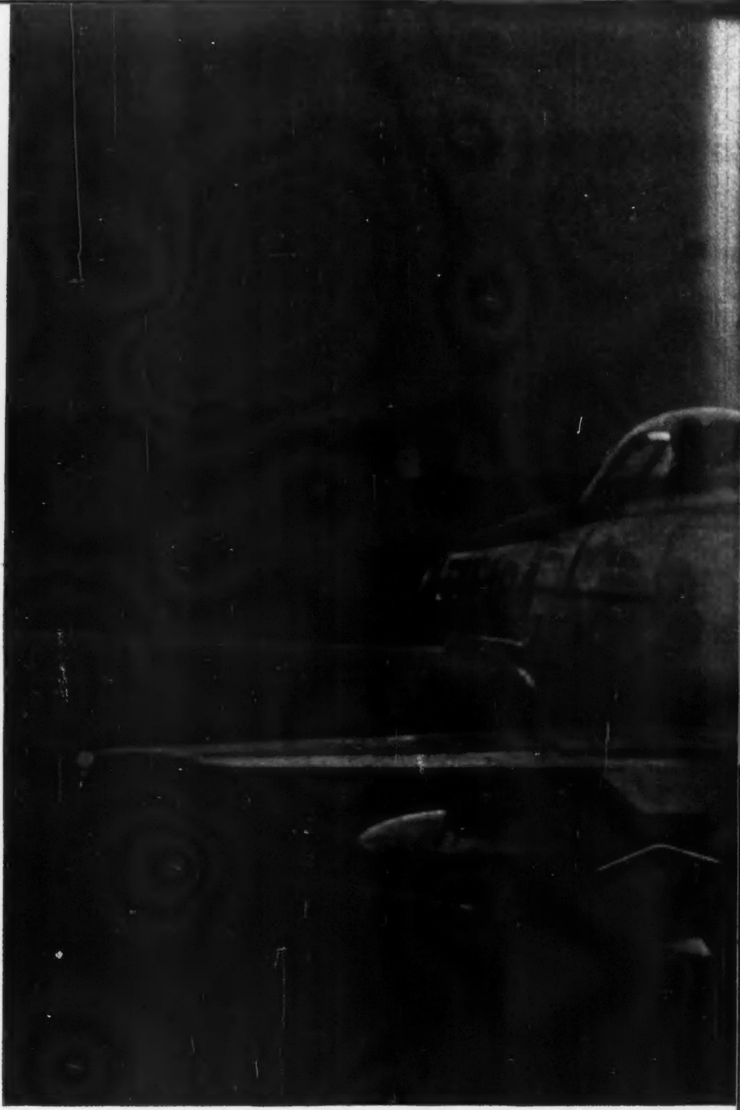
Dr. Buttolph—Illuminating Engineer at General Electric's Nela Park, Cleveland —has been with the Company since 1919. During his service, he has specialized in the design and application of mercury-discharge lamps. A previous contributor to the REVIEW, *Dr. Buttolph wrote "Killing Germs with Invisible Ultraviolet Radiation," May 1953 issue.*



White hot gases thrust this North American F86-D *Sabre Jet* skyward within minutes of an alert. They heat metal surfaces contacting the engine lubricant to 500 F —enough to decompose natural petroleum oils. Engineers will probably resort to synthetic lubricants as a partial solution to the problems of . . .

Lubricating Turbojet Engines for All Flight

By W. H. WETMORE

Engineers agree that the jet engine's future relies strongly on advancements in aerodynamics, metallurgy, and machine design. Yet for all the emphasis in these directions, the importance of lubrication can't be overlooked (photo).

Consequently, the lubricating system of a jet engine receives the utmost detailed attention. Engineers constantly chip away at the problem of lubricating —and keeping lubricated—a powerful high-speed high-temperature gas engine that not only operates at increasingly higher altitudes but also is subjected to high-G loads.

No Garden Hose

The whole objective of jet propulsion is to develop thrust from a momentum change. All design effort thus aims at producing a high-velocity jet exhaust stream.

If engineers could propel an airplane with a garden hose, they undoubtedly would. But they can't. They need a gas generator, which in a jet engine is considered everything forward of the exhaust nozzle. This generator needs rotating parts. And there begins the source of lubrication difficulties. For rotating parts require bearings, and bearings must be cooled and operated with a thin film of lubricant, known as a film-pressure layer, between their surfaces.

Inner Workings

Four main bearings support the rotating components of a typical jet engine (illustration, page 34). To lubricate them, you need a tank for oil storage, oil pumps, jets to spray the oil in a desired pattern, oil coolers, filters, air vents, and all the associated oil lines.

Oil pumps are driven from a combination of gears, or accessory drives, powered by the compressor shaft. The

Conditions—At Higher and Higher Altitudes

forces exerted by these gears on one another are transmitted through films of oil between their contacting surfaces. Maintaining these film-pressure layers is still another function of the jet-engine lubrication system.

Additionally, the fuel-control system of many jet engines operates hydraulically. Under this condition the oil used as the controlling medium also lubricates the gears and bearings. And so as a third requirement, the lubricating system supplies sufficient oil to fuel regulators and other control components.

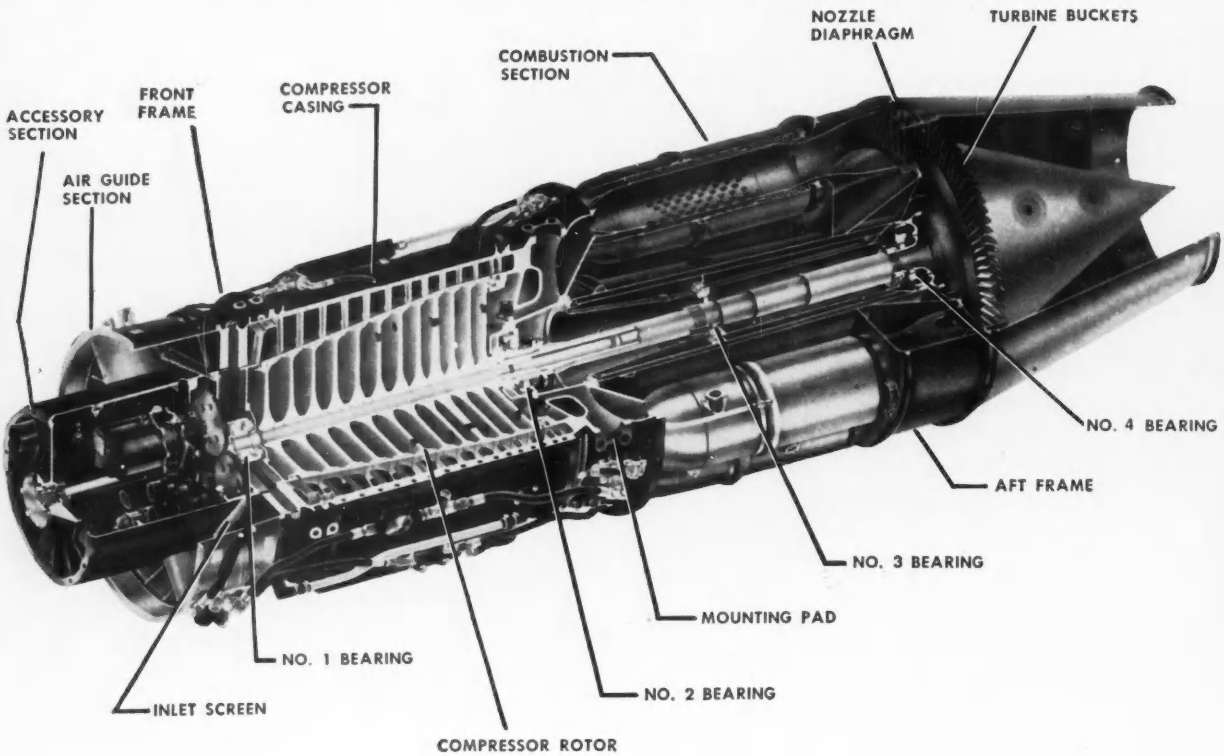
With these requirements in mind, let's look briefly at some specific functions of a lubricating system's components.

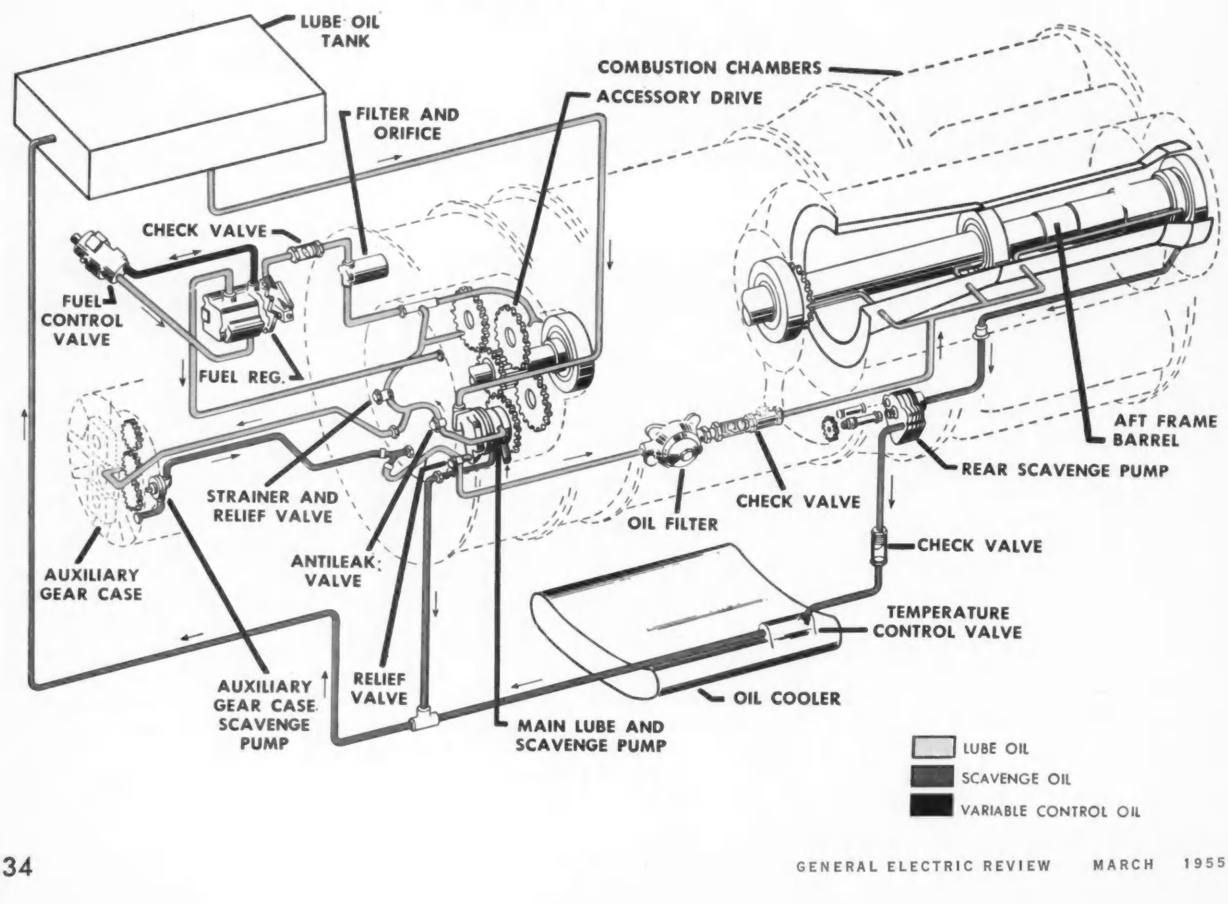
The tank for storing oil is normally mounted on the aircraft. Its capacity of 3.3 to 10 gallons is great enough so that oil consumption does not limit the range of an aircraft. Because the jet engine's lube system depends completely on gravity, the oil tank is located above the engine and high enough over the lube pump to insure a satisfactory pressure head.

The limited space in an aircraft requires that the oil tank be as small as possible. However, the oil is subjected to the churning action of bearings and gears and absorbs a lot of air, resulting in air entrainment and oil foaming. Thus the oil returned to the tank resembles a frothy milkshake. The tank must have sufficient storage capacity to decrease the air entrainment and oil foaming.

Absorbed air has a detrimental effect on the lubricating system because volumetric pumps are used to move the oil. In other words, an increase in air entrainment in effect decreases the amount of "solid oil" available for lubrication and cooling. Thus in practice you find fairly elaborate tank designs—some with built-in baffles, deaerators, or centrifuges—to assist in removing the air. The period of time that the oil remains

JET ENGINE LUBRICATION SYSTEM





in a given tank—known as the dwell time—is a function of the tank's size. And so to insure enough time for the entrained air to be removed—via vents, for example—the tank must be sufficiently large.

The volumetric pumps used to circulate the oil are not in themselves unusual, reliability being their most important feature. Several pumps are, however, incorporated in a single pump housing because the number of accessory drives are limited. (Accessory drives also power, for example, the aircraft's electric generator, tachometer, and fuel regulators.)

Normally you'll find three separate gear pumping elements, or sections, in a jet-engine lube pump. Two elements supply oil to the bearings, gears, and hydraulic fuel controls. The third section, the scavenge pump, draws oil from the bearing sumps for return to the storage tank.

Next is the matter of obtaining the necessary oil-spray patterns for the bearings. In practice this is accomplished by feeding the oil through converging nozzles, or oil jets, each so proportioned that the oil satisfactorily impinges on and penetrates the bearings at all engine speeds. But although the jet size must be small enough to adequately lubricate the bearing even at low engine speeds, it can't be so small that foreign particles in the oil will clog or block it. Frankly, the design is a compromise.

In one respect, lube systems are designed for the worst conditions that an aircraft can be operated under. Poor oil storage, plus the possibility of one aircraft's jet wake blowing dust into the inlet of another, could sufficiently contaminate the oil to cause bearing failures. For this reason, screen and magnetic filters are necessary to remove harmful particles. Generally, they will remove any foreign material down to about one fifteenth the size of a salt grain.

The most important single requirement of the scavenge pump is its ability to handle hot aerated oil at extremely low pump-inlet pressures. This function is, in fact, a direct measure of its basic capability. Then, too, the dive and climb attitudes of an aircraft may uncover one of the scavenge pump's inlet ports so that it becomes airbound. In short, it can't pump oil. To minimize this possibility, special attention is given to the design of the pump's internal passages.

Hot Potatoes

A jet engine is a hot potato; metal surfaces that contact oil are as hot as 500 F. Some provision must be made for cooling the oil to keep its temperature within reasonable limits. Utilized for this purpose is a heat exchanger that transfers heat from the lube oil to the engine's fuel.

The importance of cooling becomes more apparent when you consider that air entrainment and oil foaming are primarily functions of temperature. At extremely high temperatures any incompressible fluid bubbles and foams. The lubricating oil in a jet engine is an incompressible fluid; at elevated temperatures it is highly susceptible to trapping and entraining air.

There's an advantage to using the engine-fuel lube-oil-type heat exchanger: fuel entering the combustion chambers is preheated, helping it to atomize more readily and thus increase the jet engine's combustion efficiency.

Obviously, the best lubricating system—regardless of application—is one that can fulfill all its required functions with the least oil loss. In jet engines, most of this loss is in the form of vapor escaping from the engine. And so the lube-system engineer is fundamentally interested in recovering with a minimum of oil-vapor loss the oil that drains from the jet engine's bearings to the bearing sumps.

To minimize oil-vapor loss, a lower air pressure is maintained in the oil sump rather than in surrounding parts of the engine that the vapor might escape to. This way, air flows into the bearing sumps. (Oil-saturated air leaves the engine through special vents. Adequate vent control is provided to insure sufficient air-flow rate to maintain the low pressure requirement of the sump.)

Good air and oil seals around the bearings are essential to keep the proper pressure in the sumps. Oil seals perform the same function as the piston rings in your automobile engine. That is, they confine the oil in the compartment that it is discharged into. Air seals, on the other hand, prevent too high an air flow into the oil-bearing regions of the engine. Oil foaming and air entrainment are thus reduced by controlling the air flow into the oil-sump regions.

Flies in the Ointment

Briefly, these are the components and functions of a typical jet-engine lubricating system. What types of troubles crop up in practice? Those confronting us today fall into three categories: those peculiar to the jet engine, the engine-aircraft installation, and the operational mission of the aircraft.

Plugged oil jets are one example of a lubrication problem pertinent to the engine. Here, foreign matter and the deterioration of rubber components downstream of the oil filters are the primary causes of plugging. The best way to eliminate rubber deterioration is, of course, to improve the quality of rubber components. Elimination of foreign matter is less clear-cut, however, because it involves emphasizing to personnel at operational bases the need for better oil storage and oil-handling methods.

Oil coking is an ever-present problem in jet engines. During flight, oil is splashed against engine surfaces that may be as hot as 500 F. Decomposing at these temperatures, the oil forms on the engine walls a heavy carbon residue that may flake off and clog the oil filters, causing them to by-pass contaminated oil through the lube system. Fortunately, you can reduce oil coking materially by using insulation blankets to lower the bearing sumps' metal temperature. Also, baffles can prevent the oil from contacting hot surfaces.

Another problem peculiar to the engine is that of high oil consumption—the result of high temperatures, improper air pressures in the bearing sumps, and excessive seal clearances. Here the most effective countermeasure is to improve bearing-sump designs and air-pressure control.

Associated with the engine-aircraft installation is the difficulty of designing the oil tank. You'll recall that the tank must be as small as possible and consistent with the expected range and mission of the aircraft because of weight and space limitations. This in itself is easily done, but other factors complicate the task. The tank not only stores oil but also removes entrained air. Thus it must be large enough to insure a satisfactory dwell time. In addition, the tank's air vent must be carefully designed, because any improper functioning will result in a high loss of oil vapor.

Air pressure inside the aircraft fuselage in the region of the engine's air vents can cause trouble, too. If the fuselage pressure is lower than that in the engine's oil sumps, a high amount of oil vapor continually blows into the

ADVANCED DESIGN of jet engines is one of the author's primary concerns. Supervisor of the Advance Analysis Unit for the J47 project at General Electric's Aircraft Gas Turbine Division, Evendale, Ohio, Mr. Wetmore has been with GE since 1950. He is responsible for evaluating and recommending new designs to increase the utility of the J47 engines.

fuselage. To prevent this, ejectors are employed to keep air pressure in the oil sumps lower than that inside the plane's fuselage.

Lubricating problems peculiar to operational missions, the third category under consideration, generally result from aircraft maneuvers, such as climbing and diving. Three specific situations can arise that indicate malfunction or failure of the lube system.

As an example, a pilot might find that his engines are consuming a large amount of oil. Yet his oil-pressure gage will show no drop in pressure nor will his engine indicate an inability to maintain power. Under certain other flight conditions, an oil-pressure gage indicates an unusually high oil consumption, but there is no malfunction of the fuel-control system that is hydraulically actuated by lube oil. The third and most acute situation occurs when oil consumption is so high that oil-pressure loss prevents the necessary fuel-control components from functioning properly and seriously impairs the engine's ability to maintain power.

Sustained climb attitudes are another operational problem. Some interceptor aircraft may be in a climb attitude for 8 to 12 minutes—more than enough time for all the oil to drain into the rear sections of the engine. If the bearing seals and scavenge pump aren't functioning properly, oil pressure will be lost before the climb is completed and the pilot will have to discontinue his flight and return to base.

Fighter aircraft are characterized by their ability to maneuver rapidly in climbs and dives. Also, a fighter must be versatile enough for use as a dive bomber when necessary. At such times, high-G pull-outs will force all the lube oil out of the engine's mid-frame air vents, materially reducing the fighter's combat capability.

Bombers, like fighters and interceptors, have their own particular lubricating problems. For example, occasionally in flight a pilot will have to shut down one of the bomber's engines because of fire warnings. Normally this shouldn't affect its tactical mission. It does mean, however, that the jet engine will be windmilling possibly for several hours. During this period the lube oil supply might be shut off; thus the oil on the bearings at the time the engine is shut down is the only lubrication available.

On certain heavy bombers, auxiliary jet engines are used for take-offs and climbing but not for normal aircraft cruising. Thus during most of the flight these engines windmill. But even with their lube system functioning, oil from the jets impinging on the bearings is inadequate. For the engines windmill at such low speed that the oil pumps—operated through the accessory drives—can't build up sufficient oil pressure for the proper spray patterns.

These, then, are a sample of the lubrication problems in a typical jet engine. Despite them, the jet engine of today is a remarkably reliable power plant, with its lubrication system doing a good job. Last year, for instance, a B47 *Stratojet* bomber powered by six jet engines completed the equivalent of 10 trips around the world without requiring any engine overhaul.

Looking Ahead

You can be sure that new lubricants and lubrication systems will play a vital role in the future of the jet engine. They will permit operation under increased bearing loads through a greater range of ambient temperatures and at altitudes not now envisioned.

These systems will probably employ synthetic oils rather than the natural petroleum oil used today. For one thing, present lubricants operating at existing engine temperatures begin to boil at 40,000 feet and bubble badly at 50,000 feet. High oil loss results from foaming and evaporation. Synthetic oils appear to be a solution to this problem.

Vertical take-off aircraft will alone present many new lubricating problems. The extended time that the engine is in vertical position requires better scavenge pumps and seals than present types; new lubrication-system designs will be needed.

Among the lubricating engineer's long-range goals, one stands out above all—the development of a lubrication system as effective and functional as that in the human body. Consider the number of times you flex a finger, bend an arm, or move a leg. Think of all the other forms of human motion that require lubrication.

Our human lubricating system is the most amazing and ingenious of all. It is the one that engineers should best understand to find some new approach in the mechanical design of newer and better jet engines. Ω

AMERICAN STANDARDS ASSOCIATION

By VICE ADMIRAL GEORGE F. HUSSEY, JR. (USN, RET.)

Although the American Standards Association (ASA) dates back only 35 years, the history of standards reaches into the early beginnings of mankind.

Words—standards of communication—were man's first use of standards. As civilizations developed, he discovered an increasing need for standards. Man created standards of social behavior, laws, and rituals; standards of measurement and time; standards of money; and standards for the written word, evolving into our modern alphabet, making possible the writing of all literature.

Evolution of Standards

For many centuries, standards developed by a slow process of evolution. A standardized manufacturing skill established by individual craftsmen changed little in the course of time. Then came the industrial revolution. Overnight industrial production upset these time-honored manufacturing methods.

The first mass production is attributed to Eli Whitney. In the 1790's he manufactured 10,000 muskets for the federal government. His method of making the individual component parts interchangeable and of a standardized size was revolutionary.

As industrial production progressed rapidly, individual manufacturers quickly took advantage of the wonderful new engineering possibilities. In their eagerness, they went ahead with their own methods, disregarding what other manufacturers were doing. Before long they knew the confusion caused by too much variation in dimensions, definitions, and performance. And further, it hampered sales and increased costs.

A pioneer in the field of meeting these problems through the use of standards was the Englishman Joseph Whitworth. In 1841 he developed the standard Whitworth screw thread that was adopted in Britain and on the continent. By the turn of this century, the writing of standards had become a major activity in all industrial countries. Great Britain in 1901 created the British Standards Institution—the world's first such body.

In the United States about the same time, hundreds of organizations—engineering societies, trade associations, and government departments—began to turn out standards. They usually acted independently of each other, making duplication, conflict, and overlapping inevitable. Thus need for standardizing the writing of standards became apparent.

Early Organization

In 1916 the American Institute of Electrical Engineers took the first step toward organizing a national clearing-house for standards. They invited four other organizations to join with them in setting up such a group: the American Society of Mechanical Engineers, the American Society of Civil Engineers, the American Society of Mining and Metallurgical Engineers, and the American Society for Testing Materials. Nearly two years were spent in discussions and in drafting constitutions and methods of procedure. But finally, on October 19, 1918, the American Engineering Standards Committee (AESC) was born. Subsequently the Navy, War, and Commerce Departments were invited to become members with founders status.

An ambitious program grew out of these modest beginnings. The five founding members contributed $1500 each for one year's operation, conducted by one secretary and two stenographers. Yet in time, this activity developed into a vigorous national standards movement and a flourishing standards organization.

Today its successor—American Standards Association—has a membership of 114 nationally known trade associations, professional societies, and consumer organizations and about 2300 individual companies.

Present personnel on the permanent staff numbers 60, operating on a $½-million yearly budget. Some 4000 executives, technical experts, and engineers serve on committees that are developing American Standards under ASA's auspices. As many as seven government departments and 64 bureaus have participated at all levels of ASA in the development of American Standards.

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Admiral Hussey retired after 36 years of naval service. For seven years he has been managing director and secretary of the American Standards Association.

Functions of ASA

ASA does not write standards. But it provides the machinery and a common meeting ground for everyone substantially interested in writing a standard. It acknowledges the need for a national standard, performs judicial functions in establishing a standard, and certifies that approval of a standard has been obtained. An adopted standard will then be registered by ASA as "American Standard."

ASA also promotes the knowledge and use of standards and serves as a clearing-house for information on standards in both this country and abroad. The library it maintains contains almost 70,000 standards, specifications, and related material, as well as a file of technical literature. As a member of the International Organization for Standardization (ISO), ASA represents this country as one of 35 other national standard organizations who participate in international discussions and agreements.

Although you may not realize it, we constantly encounter American Standards in our daily lives (photo, next page). Red, amber, and green traffic signals established in 1927 are such a standard. Before that time the signals varied from state to state, making interstate motoring confusing and hazardous. Another product built to American Standard specifications is safety-glass panels on automobiles. An American Standard for rayon and acetate fabrics lists 31 test methods for telling whether the fabric will be suitable for a range of 51 different end uses. Then, too, many cities and several states use an American Standard as a basis for requirements covering the installation, operation, and inspection of elevators, dumbwaiters, and moving

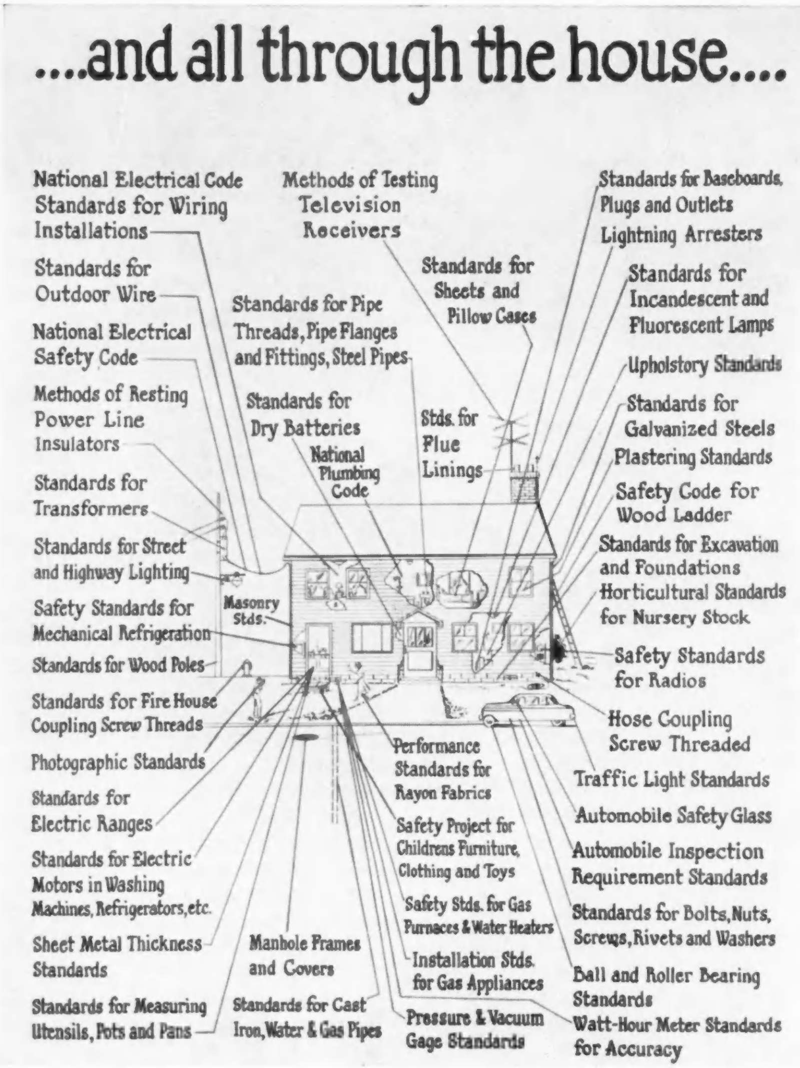


CHART DEVELOPED BY ASA SHOWS THE IMPACT THAT STANDARDS HAVE ON OUR DAILY LIVES.

stairs. And houses are built with cement that meets an American Standard, with walls plastered according to American Standard specifications.

Altogether, 1411 American Standards are in effect today. Of these, about 600 refer to the various branches of engineering; 225 to photography and motion pictures; 160 to various safety fields; and the balance to other areas, such as chemicals, textiles, mining, and petroleum.

Electrical Standardization

A high degree of standardization has been reached in the electrical field. Complete interchangeability for electric lamps, fittings, and appliances prevails from coast to coast. Electrical manufacturers, power companies, fire insurance companies, and others have worked together for many years to develop electrical product standards and safety codes that now include virtually all phases of electrical production, transmission, and use. The 250 American Standards in the field of electrical engineering represent the highest number of standards in any single group.

Electrical standardization created a national market that is probably increasing more rapidly than any other consumer market for engineering products. And the consumer is benefiting by greater convenience, more safety, and lower prices. An electric lamp in 1907, for instance, cost $1.75; today, it costs about 15 cents—and lasts longer. The American Standard Safety Code for Mechanical Refrigeration has now been adopted by 850 cities, counties, and other government bodies.

In the international field, electrical standardization has also reached a high degree of development through the work of the International Electrotechnical Commission (IEC). The United States participates in this Commission through the medium of the U. S. National Committee of the IEC—an arm of the American Standards Association. IEC held its 50th anniversary meeting in Philadelphia last September, with technical experts from 22 countries attending. (See Sept. 1954 REVIEW, pages 46–48.)

Milestones in ASA's History

In the course of its 36-year history ASA has undergone a number of adjustments and reorganizations. The original name of the association—American Engineering Standards Committee—expressed the founders' intention to restrict activities to engineering problems. However, soon after the committee was established, its framework proved too limited.

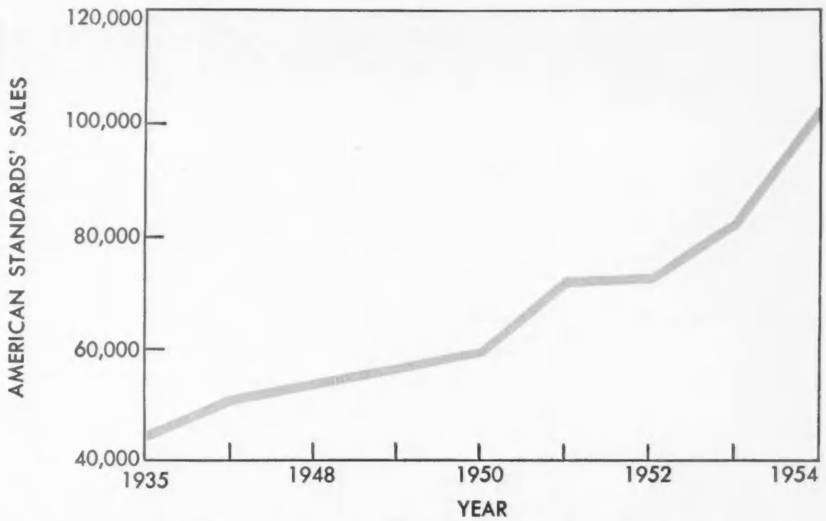
Formulating a national safety code program became the committee's first major job. Executing the program required the co-operation of trade associations other than the founding members. As a result, the AESC reorganized itself by offering full membership to other engineering societies, trade associations, and government departments. Within a year, membership increased to 25 national organizations and government agencies. And the technical work increased correspondingly.

With the work thus increased, the enlarged committee setup no longer fitted the need. And so in 1928, the committee was reorganized into a full-fledged association with the unanimous approval of all members. The name was changed to American Standards Association, and a board of directors was created to handle administration policy and finance.

Another milestone in ASA's history occurred in 1946. The association not only had weathered the depression but also had interrupted most of its peaceful projects to develop American War Standards during World War II. Naturally after many years of government-directed standards work, the question arose: What will happen to the voluntary standards movement in America?

A decision reached by the Secretary of Commerce and a delegation of top businessmen headed by Charles E. Wilson, then president of General Electric, resolved the question. In line with this decision, the federal government accepted ASA as the national clearing-house for standards and encouraged industry to make it possible for ASA to operate as a voluntary private organization. Accordingly, ASA amended its constitution and agreed "to handle any standards or standardization project which deserves national recognition, whether for raw materials, intermediate goods, production goods, consumer goods, for safety, for engineering, or for commercial transaction."

In 1951 the federal government gave further impetus to the voluntary standards movement by 1) reversing the policy of developing its own federal specifications and 2) beginning to make fuller use of industry standards for government purchases. Whenever possible the key procurement agencies based federal and military purchases on recognized standards of industry and technical societies. And for its own use the federal government adopted by reference and transcription a number of American Standards. With policy reversal, industry can now provide the government with standardized products at lower cost instead of retooling for government specifications. This saves large sums of money normally passed on to the taxpayer. Moreover, government agencies began to co-operate more closely with industry and ASA on developing and improving standards.



INCREASE IN SALES OF AMERICAN STANDARDS INDICATES THEIR IMPORTANCE TO INDUSTRY.

Standards for Standards

A basic ASA rule provides that every standard must fill a genuine need and have substantial acceptance by all concerned. Before a standard can be developed under ASA machinery, not only must the need be urgent but also every effort is made when adopting a standard to reach a consensus or near-consensus, rather than make decisions by majority vote. ASA aims at including in its standard committees every group of people legitimately concerned with the particular standard under discussion. A standard committee may include engineers, designers, manufacturers, wholesalers, retailers, consumers, government officials, labor-union representatives, and others strongly concerned. So thoroughly are matters threshed out that a unanimous decision is usually reached.

In ASA's experience, a premature or compulsory standard benefits no one. The premature standard may thwart technical progress by freezing designs. And a compulsory standard may be useless, for people often refuse to accept it.

ASA tries to keep its standards flexible and open to periodical review. In 1953 alone, 185 American Standards were revised, and in 1954 there were 89 revises.

One of ASA's maxims states that a standard is not a ceiling but rather a floor on which to build. A good standard must boost progress, not stifle it.

Present Activities

The present activities of the American Standards Association continue at a high level: In 1953, 81 new American Standards were adopted; in 1954, 64. Recent adoptions include four new standards for power switchgear and four for magnet wire used in great quantities in motors, transformers, control equipment, and coils. The new American Standard Requirements for Transformers will probably bring a saving of more than $10 million in the next three years to industry, utilities, railroads, and public works. A new standard for hearing aids permits manufacturers to accurately test, measure, and compare hearing-aid products. A dangerous hazard of hospital operation has been eliminated by an American Standard for use of medical gases. Nine new standards for cast-iron pipe and fittings should improve cast-iron pipe and reduce failures and corrosion. It took 27 years of committee work to complete these nine standards—probably a world's record in standards writing.

In addition to completed work, almost 400 standardization projects are being discussed and formulated by committees operating under ASA's auspices. This number has increased steadily over the years. Present projects under discussion include such widely differing subjects as safety standards for children's toys and the standardization of the pallets used in industry to handle and transport materials. At the request of the federal government, ASA will develop performance standards for sawmill equipment to reduce waste and conserve wood through increased sawing precision. A new ASA committee is concerned with standards, specifications, methods of test, and rating for components used in electronic circuits.

Foresight for Standards

As science and engineering progress and as technological changes take place, the need for standards will grow. Such new fields as electronics and nuclear physics will present other problems of standardization. And new concepts of production such as automation will require a high degree of standardization.

It is ASA's hope that American industry will meet these new technological problems with foresight and planning. Too often in the past, standards were the outcome of general confusion and emergencies that had proved costly to both producers and consumers. In the words of Roger E. Gay, president of the American Standards Association, "Our plea to American industry is to build a comprehensive, integrated set of true national standards now, in advance of need. The alternative is to build them later in order to unscramble a mess that never should have happened. We believe that standardization is the last great frontier of the American economy where major increases in efficiency and substantial cuts in cost can be made." Ω

Let's Look Objectively at Manpower Development

By D. S. ROBERTS

■ **To meet the increasingly complex operations of business requires the development of responsible leadership in areas of management as well as in the technical areas.**

■ **Such a program must be administered by instructors capable of evaluating the individual and stimulating self-development for fullest realization of his talents.**

Today the young scientific and engineering graduate entering industry directly after college or a tour of duty with the Armed Services faces no employment problem. Industry everywhere needs personnel having such education and interests. Even in a period when professional positions are not so numerous, the alert, capable, sound-thinking progressive individual realizes that college commencement is just that—commencement: the beginning. He senses that he has many things to learn in his field; that many maturing experiences, both professional and personal, will be encountered and richly lived through; that additional education—technical, nontechnical, or a combination of both—will be desirable and necessary.

Further, he feels the need for fully developing his individual talents. Thus in his employment search, he seeks a position with an employer who endorses the principle of individual development as evidenced by operations and past performance. Above and beyond the desire to obtain a position, the individual wants to participate in a group where he believes his performance will be recognized and adequately rewarded. He seeks an opportunity for professional development, accepting the accompanying challenge to continue to merit it.

Industry's Responsibility

The young technical graduate's future employer, usually some business enterprise, is an increasingly complex operation. Besides recognizing its responsibility to share owners, employees, and customers, management increasingly accepts another responsibility—that of being a "corporate citizen" with all its attendant complications. In addition, products are becoming more complex, requiring application of a greater variety of technology to their design and manufacture.

To accomplish such a program, progressive business organizations must have capable leadership at all levels—in both technical specialties and management. To insure this, business must follow planned procedures for evaluating the young professional early in his career. By definite well-thought-out methods, business can develop and recognize each as an individual. Lacking this approach, business will neither hold those with outstanding talents nor attract the best and most capable—all to the detriment of the business enterprise.

Now let's assume that the Technical Recruiting Department of a business has obtained the caliber of young people needed for technical as well as future management requirements. In planning to acquire leaders in both areas, it is important that the individuals have . . .

Sound character and personal integrity.

Vision and imagination.

Well-rounded personal characteristics.

Desire to finish the assigned task.

Ability to think logically and clearly through a problem.

Good native intelligence backed up by sound judgment.

Good basic education in their respective fields of interest.

Initiative and drive.

High degree of motivation.

Well-defined goal within the limit of present capabilities, plus training and education to perceive that goal.

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In 1939 Mr. Roberts came with GE, participating in the Company's engineering program until 1945. For the next seven years he was associated with Technical Recruiting, becoming Manager, Technical Training in 1952. Presently, he is Manager, Engineering Administrative Services, Instrument Department, West Lynn, Mass.

Self-evaluation within the limit of present abilities to judge.

Ability to plan and organize.

These plus other important characteristics must be present in the young people or no development plan devised will produce the desired results.

The Engineers' Council for Professional Development (ECPD) has indicated that ". . . the most critical period of the young engineer's whole career is undoubtedly the first five years after leaving college." Let's go still further and suggest that the first 12 to 18 months are even more decisive. This is particularly true if the individual is married and with his family has moved several hundred miles or more from home. How well each person is guided, counseled, and developed during this critical period may well set the pattern for his future growth and contribution to the business. In our modern world, time and manpower are too precious to allow haphazard selection and development of these young people.

Objectives of a Development Program

Setting up a technical manpower development program for them requires management's strong backing. Further, the program must be administered by well-trained individuals who have a genuine interest in young people. And its objectives should be to . . .

- Evaluate the individual as early as possible.
- Guide, counsel, and develop the individual, both personally and professionally so that he may use all his talents to the fullest.
- Point up and establish clearly with the individual his responsibility for self-development.
- Provide a means whereby the individual becomes acquainted with the company's policies, products, and people.
- Assist the individual in reaching a logical conclusion as to the proper career for him in the organization.

Most important is the evaluation of the individual, for this determines his development program and the future role he will play in the enterprise. Thus it cannot be taken lightly by either the individual or the employer. The best techniques—tests, interviews, or a combination of both, seasoned with good judgment—must be used. A word of caution here: never let good judgment become a minor factor in the evaluation process.

No effective development of an individual is accomplished only by educational classes or reading. These may be helpful for gaining more knowledge, acquiring deeper understanding, or stimulating thinking. But only through the invaluable experience of attacking and solving the day-to-day operating problems of the business does the individual develop. Without reservation we suggest learning-by-doing work assignments—giving responsible work to the individual required to accomplish his assigned task satisfactorily. The assignments must be carefully selected with regard to the over-all good of the business and to the development of the individual, supplying him at the same time with a broad view of the company's products, policies, and personnel

Essential to the seasoning of the young man is that he clearly recognize the responsibility for his own self-development. Work operations demanding his full capabilities can and should provide such opportunities, supplemented with guidance and counseling.

Educational courses must be scheduled as needed. These might be courses the company has prepared and is equipped to give, or they might be courses given by local colleges. However administered, they should always require some real sacrifice by the individual. This might be in any one of several ways: taking the course after work hours, having to pay for it, or doing a major part of the studying on one's own time. This way the course will be more fully appreciated.

MANPOWER DEVELOPMENT

Record of ______

Birth Date ______ Married ______ Single ______

Number of Dependents ______

College ______ Highest Degree Obtained ______

Field ______

Graduate of What Company Training Program ______

Company Sponsored Courses Taken:

COURSE	WHEN TAKEN

Additional College Courses Taken:

COURSE	WHEN TAKEN

Professional License YES ______ NO ______

Work Experience Previous to Coming with Company:

COMPANY	DUTIES AND RESPONSIBILITIES	IMMEDIATE SUPERVISOR	DATES STARTED	DATES FINISHED

Company Work Experience:

DEPARTMENT	DUTIES AND RESPONSIBILITIES	IMMEDIATE SUPERVISOR	DATES STARTED	DATES FINISHED

Inherent Rating (This could be a comprehensive numerical or letter rating or both)

Future Potential:

DATE REVIEWED	PREDICTED MAXIMUM POTENTIAL

Proposed Experience—Program in line with above potential.

EXPERIENCE		DATES	
DEPARTMENT, SECTION, OR UNIT	TYPE OF EXPERIENCE	FROM	TO

Effective Administration

If not properly administered, such a manpower development program is ineffective. Full-time supervisors must be assigned to this work, and they should be responsible only for the guidance and counseling of as many individuals as can be properly handled. Success of the program depends on mutual understanding and respect between the supervisor and the individuals under his guidance.

You may well ask, "Isn't all this expensive?" Manpower development of this type is apt to involve more expense than under the put-him-on-the-job and let-him-sink-or-swim philosophy. This additional expense, if any, depends largely on how well the program is organized and how effectively actual work situations are used in the process. But the forward-thinking progressive business leader realizes that capital allocated for the development of his future technical and management leaders is one of his wisest long-range investments.

Our thinking so far has mainly been concerned with the first 12 to 18 months.

But this matter of developing leadership is a continuing process. After this initial period, although the program will no doubt be more informal and possibly along more specialized lines of education and experience, it will still be mighty important. Necessarily each operating unit must assume its full share of responsibility in developing its own future leaders. This, in turn, obligates each individual of the unit to develop his own successor—one more step in his self-development.

To prevent the less formal period of manpower development from becoming too informal or even nonexistent, it is well to chart individual progress and set up a flexible timetable. A manpower development record for each man can be kept on an IBM card, MacBee card, or a printed form in a loose-leaf book as shown above.

Regardless of the method selected, it must be kept up to date and reviewed periodically. Moreover, the form should be backed up by adequate rating sheets and comments concerning the individual's performance and should be readily available during the reviewing periods.

The development of men when truly activated as a philosophy of operation is an enriching experience for everyone involved. The capable logical-thinking young man is attracted by it and assumes his responsibilities under it. The mature man continues his growth and has the keen satisfaction of seeing young men justify his faith in them. The business prospers under competent technical and management leadership. And society benefits by the presence of a corporate citizen in its midst. Ω

IMPROVED BEARING HOUSING examined by author lessens normal lubrication maintenance of new 10-hp induction motor (*right*). Motor at left illustrates former appearance.

How New Design Improves Motor Performance

By F. W. BAUMANN

In almost every phase of American industry, you'll find a need for a-c induction motors that are smaller and lighter—yet retain the characteristics of well-engineered standardized products. This holds true whether the purchaser uses them to drive machinery in his own plant or in equipment that he fabricates and sells. Additionally, a lighter, more compact motor needs less storage area at the factory or district warehouse—and above all, at the purchaser's plant.

Fortunately, the motor manufacturer can satisfy this need because of continuing advances in design knowledge, motor testing, new materials, and manufacturing processes. Greater horsepower ratings in smaller frame sizes are indicated with no sacrifice in performance.

NEMA

More than 80 percent of the motors currently on the American market are manufactured by 51 companies who are members of the Motor and Generator Section of the National Electrical Manufacturers Association (NEMA), a nonprofit trade organization. Sponsored by manufacturers of electric apparatus and supplies, NEMA promotes the standardization of electric products as its principal objective.

In 1929, NEMA standardized a-c motors for the first time when it fixed their frame sizes to correspond with horsepower ratings. Years later, in 1940, NEMA rerated motors above 30 hp. But not until 1953, after much study, did NEMA revise its earlier frame-assignment standards of a-c motors rated 1 to 30 hp.

Knotty Problems . . .

The motor designer is realistic. He combines pure design fundamentals with practical considerations, or facts of life, of the motor business. Accepting these man-imposed limitations and nature's fundamental laws, he goes to work in the remaining area to solve extremely complex design problems.

When at General Electric we undertook the redesign of our polyphase induction-motor line to meet the new NEMA specifications, we knew many knotty problems would confront us. Electrically and mechanically, the latest concepts in motor design had to be utilized. In appearance, the new motors would have to give visual evidence of their performance, dependability, stability, and protective features. In addition, it was desirable to retain the "family resemblance" that identifies and distinguishes G-E motors (photo).

Further, we would have to consider recent engineering and manufacturing developments in the redesign of the motors. For many new and improved materials had been devised. Basic engineering knowledge—especially in the fields of heat-transfer, bearing systems, and lubricating and insulating materials—had steadily increased in the last few years. New manufacturing processes, as well as the possibility of automating older processes, had evolved. And through the use of such devices as the analog computer, fundamental design concepts could be more readily evaluated.

. . . and Their Solution

With all this in mind, we established the following objectives in laying plans for redesigning the motors . . .

- Maintain standards of performance and quality while reducing size and weight.
- Keep to a minimum the variety of motors.
- Improve physical appearance and protective features for longer life.
- Incorporate in all motors the maximum number of practical features of real value to a user.

All these goals were achieved with high success. Physical size of the motors

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Mr. Baumann, who has been with General Electric since 1935, is Manager of Random Coil Motor Product Engineering, Medium Induction Motor Department, Schenectady.

was cut approximately in half and weight reduced 34 percent. You might at first think that with such a reduction the motor's former operating characteristics couldn't possibly be retained. However, we not only maintained these standards but also improved on them.

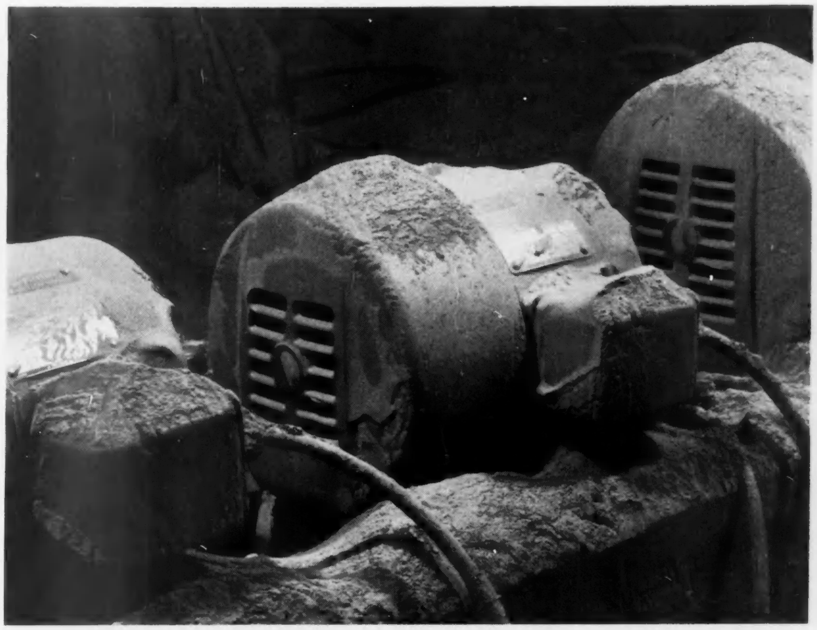
The motors were designed more compactly. For one thing, we used the prewound stator-core construction successfully employed in hermetically sealed refrigerator motors. (In the prewound core, windings are assembled on the stator core separately and the whole unit inserted into the motor.) This construction makes practical an automatic varnish treatment of cores that assures better and more uniform quality. The same prewound core, varnished in an identical manner, is used for both open and fan-cooled motors. The prewound core accounted for most of the physical reduction of the motors by dispensing with the wasted air space of former models.

Magnitude of noise was also significantly reduced in these Tri-Clad 55 induction motors—General Electric's registered tradename for the line. This we did by carefully designing frames, endshields, and mechanical structures to insure that none of these parts resonated with excitation forces. Punching proportion, endshield motif, stator-frame internal ribs, and frame-base construction all contributed to lower noise level.

Many rotor-stator slot combinations were thoroughly analyzed and tested to keep magnetic exciting forces to a minimum. Extraneous mechanical noise, as well as windage noise, was reduced. Over-all results in this respect were extremely good. The new 10-hp motor, for example, has a full-load noise level comparable with that of our old 2-hp motor. In the same way, the new 20-hp motor favorably compares with the old 5-hp model.

Through a careful balance of tolerances in both mechanical and electrical parts, quality was achieved in the new motors by a judicious choice of parts to be subassembled. Mechanical excellence of each motor produced is assured by quality control and effective testing (photos, next page).

Making one component serve the purpose of several and anticipating variations from the standard minimized the variety of motors. (The four motors standardized by NEMA are dripproof, splashproof, explosion-proof, and totally enclosed.) For example, a standard dripproof motor can be converted to a splashproof motor simply by adding two louver covers to the frame. Protected to such a degree, you can use it for substantially all applications on which splashproof motors were formerly required. Similarly, you can easily add screens to keep out snakes, rodents, and other pests.



FINE METALLIC dust particles envelop new totally enclosed motors that are undergoing severe operating tests. Both motor frames and endshields are made of cast iron.

Another characteristic of a good motor is its exterior finish. For this we selected a chip-free weather-resisting enamel of medium gray. Highly resistant to marring and scratching, heat or cold, oil, and high humidity, the paint also has good qualities of adhesion and flexibility. Should the customer choose to paint a motor to fit in with his own color scheme, this finish provides an excellent base.

Frames and endshields of the Tri-Clad 55 motors are made of cast iron. The internal parts are thus protected from falling objects, external blows, and metallic particles. We made complete tests to be sure that the motors would withstand severe shock, vibration, and adverse environmental conditions (photo). The testing included simulated pull of a driving belt and the effect of overhung load and flange mounting, frame rigidity of a wound core in a stator frame and of the endshields, simulated load made by bolting the motor down to an uneven surface, and impact of the endshields and motor feet.

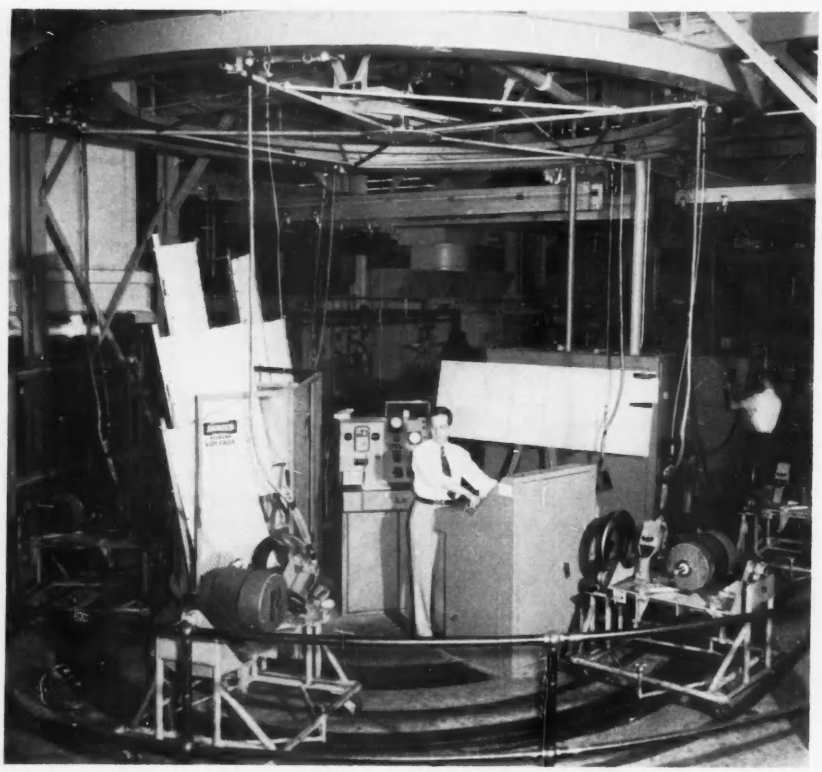
One of the most significant improvements in the new motors is their insulation system. Stator windings are protected with phase insulation made of a new synthetic polyester film. An outstanding material, it offers superior mechanical and dielectric strength, extreme resistance to moisture, and excellent heat-aging life. Used in combination with insulated wire and varnish, it provides the best insulation system we've ever tested. Even so, something more has been added. The complete stator-core assembly is coated with silicone varnish that repels moisture and increases insulation life in a salt-fog test about sixfold. (See November 1954 Review, page 29.)

Human Factor

Our final objective was to incorporate in the motors the greatest number of practical features for the user. These divide into two categories: those that aid installation and those that tend to ease maintenance problems.

Among the many installation features is a diagonally split conduit box that provides plenty of room for wiring and taping. After considerable study, the box sizes selected were those most likely to have the greatest acceptance consistent with standardization. To assist in easily identifying connection wires, we introduced perma-numbered leads—terminal numbers permanently im-

INDUCTION MOTORS in last phase of production receive acoustical tests for noise, mechanical tests for dynamic balance, or vibration, and several electrical tests.



MERRY-GO-ROUND testing apparatus gives motors a final and different operational check at each station. The operator initiates tests from control consoles at center.

printed the full length of the cable. The nameplate and wiring diagram, both made of stainless steel and easy to read, are located on the conduit-box side of the motor for improved accessibility.

The provision for mounting motors on a side wall or ceiling also provides easier, more efficient installation. Endshields can be rotated so that the air intake always faces downward. Thus you can make a motor dripproof in any position.

To ease the user's maintenance problems, we designed long life into the motors by using bearings of more than adequate size. As for periodic lubrication, our basic philosophy is that you should be able to relubricate when needed, but the motor shouldn't provide an invitation to unnecessary lubrication. To this end, a pipe plug is furnished at the top and bottom of the bearing housing on the smaller motors where relubrication under normal conditions is seldom required for intervals of at least five years. On the larger motors, where more frequent lubrication is necessary, grease fittings are furnished.

We are, incidentally, using a new grease that has an indicated life at least five times that of former lubricants. With it, the number of times a motor needs regreasing should be a minimum. The important point, however, is that for all practical purposes we have a closed-bearing housing that can be relubricated when extreme conditions demand it.

For maintenance inside the motor, large knock-off lugs are so positioned on the endshield that removal is simple.

More To Come

This age of greater productivity finds more and more uses for electric motors. And though they are one of the oldest electric devices, important design advancements are still being developed.

The improvements made on the Tri-Clad 55 induction motors bring them in step with the times. Their standards of performance are maintained while size and weight are considerably reduced. They give their user longer, better, and more versatile service with less attention to maintenance.

But this isn't the end. Undoubtedly many more new materials and manufacturing methods will be discovered during the next few years. You can be certain that these, too, will even further improve on the design and performance of electric motors. Ω

Making Atomic Piles Behave

By IVAN M. A. GARCIA

Properly controlling the operation of a nuclear reactor by one of several methods is imperative to maintain this useful device as a powerful source of energy.

In the design of the control circuits, the engineer must include the important principles of duality, fail-safe, sequential, and reliability to assure safety and prevent shutdown.

One of the most expensive devices ever built, a reactor must be operated within established limits or certain destruction would render it completely unusable.

Nuclear reactors represent an investment of millions of dollars that the engineer must protect with properly designed safety circuits and devices. A properly controlled reactor is a useful device, but if the safety circuits fail, it can become a potential package of uncontrolled energy.

Reactor Controls

A nuclear reactor can be controlled by inserting a neutron-absorbing material, by removing charges of reacting material, or by changing the physical interrelationship of the critical materials.

Proper positioning of a highly neutron-absorbent media, usually rods, is a common method for maintaining power level. When the rod is removed, more neutrons are available and the power of the reactor increases; when inserted, fewer neutrons are available and reactor power decreases (illustration, next page).

The rods can be actuated by electric or pneumatic motors through geared drives and controlled from a central desk. For quick shutdowns, safety rods can be inserted rapidly into the reactor, triggered by signals given by sensing circuits or at the will of the control-desk operator. To operate even during a complete power failure, the rods must use some sort of stored energy for motive power.

For control-rod drives, the engineer has applied various industrial systems: two a-c motors with differential gears and reversing switches; adjustable-speed a-c motors of the brush-shifting type; a-c gear-motors with reversing switches; d-c motors with field control and fixed armature current; and d-c motors with armature control and fixed fields. Ingenious combinations of these systems are being used successfully (illustration, page 47).

For the safety-rod drives, winches with magnetically held clutches are used.

A typical control-rod circuit (illustration, page 48) uses a feedback closed-loop system for position control. The operator at the control desk turns a switch handle clockwise or counterclockwise; the rod moves in or out of the reactor, depending on the direction of the switch. Speed of response is proportional to the amount of the switch handle's displacement, and the length of travel is proportional to the length of time that the switch is displaced. Limit switches control the travel in both directions, with lights indicating when the limits are reached.

Auxiliary devices show the operator the rod location at any particular instant, and brakes prevent creeping of the rod. The system must operate positively and efficiently both in magnitude and direction.

The circuit consists of a number of sentinels that monitor certain conditions and properties, reporting through time-delay relays to a series circuit that controls a set of trip relays. Powered by the relays, magnetic clutches hold the rod that, accelerated by gravity, falls into the reactor when power is cut off. Again, limit switches control the length of travel, with lights indicating whether the rod has penetrated. Annunciator drops single out the abnormal condition and hold a target and an alarm until acknowledged. By-pass switches enable different portions of the circuit to be worked on or removed from the system. Time-delay relays are adjustable to set up a system of priorities in the operation of the various devices, the most critical taking the highest priority.

The engineer finds little difficulty in applying known and tested types of industrial adjustable- and variable-speed drive systems to the essentially similar problems of reactor rod control. Sometimes, the engineer finds the components readily available from leading manufacturers; at other times, the parts are fabricated. For the latter purpose, industry has always met or surpassed the required characteristics.

Sensing Circuits

Entrusted with the most important job in a nuclear-energy installation are the devices in the circuit on page 48 that monitor the critical conditions and properties of a reactor. This applies to the experimental research reactors and the production reactors at AEC's GE-operated Hanford Atomic Products Operation in Richland, Wash., and will also be true of power reactors. For best efficiency, these machines must operate at the highest neutron fluxes and the highest temperatures consistent with safety both to reactor materials and operating personnel. If certain limits are exceeded, disasters can occur that render the reactor completely unusable and ruined for posterity; further, contaminated products could be spread to a large area. Because reactors are one of the most expensive devices ever built, the utmost care must be taken to prevent exceeding the limits established for efficient operation.

Monitoring neutron flux—most important of the characteristics—is accom-

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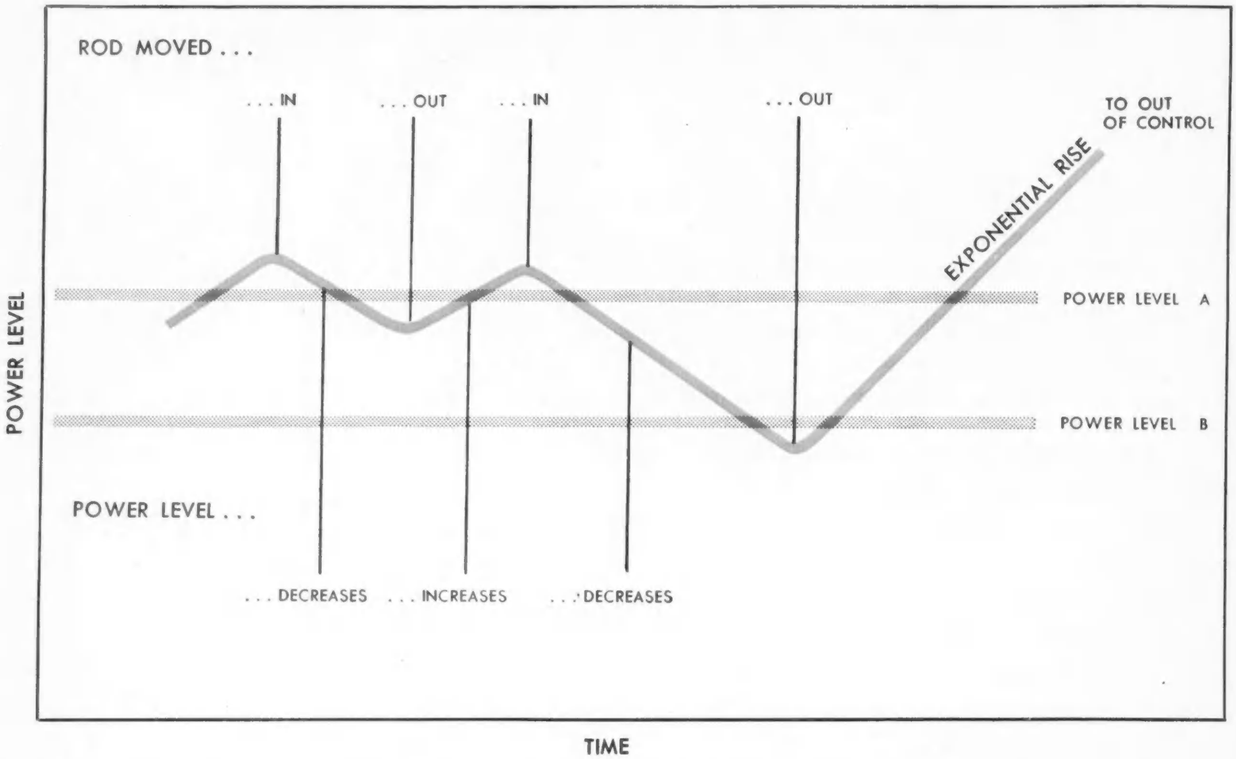
With General Electric seven years, Mr. Garcia is an electrical engineer in the Design Section, AEC's GE-operated Hanford Atomic Products Operation, Richland, Wash. His responsibilities include process and inside electrical design.



NUCLEAR REACTORS can be controlled by inserting rod-like neutron-absorbing materials. In this method, removal of the rod results in more neutrons and increased reactor power; insertion of the rod causes fewer neutrons and, consequently, decreased power.

plished by ionization chambers. Strategically located throughout the reactor, ion output is amplified by electronic amplifiers, with the resulting signals fed to the safety circuit. This output is proportional to the neutron field intensity at the point where the chambers are located. The physicists have provided the relationships necessary to correlate such readings with the total, maximum, and average flux in the different regions of the reactor. Electrically, the signal resolves itself into a "go" or "no go" proposition to continue operation or to shut down. And when a shutdown, or "scram," signal is received, we wish we had shut down already. Scram is a colloquial term for a quick, unexpected shutdown of a reactor.

The Hanford reactors use large amounts of water as a coolant to remove the heat generated during operation. Other reactors use air for their coolant, and the power reactors now in the drafting-board stage may use liquid metals as a heat-transfer media for the production of useful power. As it enters the reactor, the pressure of this closely regulated coolant is monitored by common industrial pressure switches installed at the inlet headers. Again electrically, the circuit sees either a closed or an open contact at the switch.

The coolant's exit temperature limits the power level of reactor operation. If allowed to rise indiscriminately, a liquid coolant can flash to vapor with subsequent damage to the reactor and fuel charges. Through relays, thermocouples give the "go" or "no go" signal that is also fed into the safety circuits.

An earthquake can cause lateral or vertical displacement of the reactor materials, preventing the rod from penetrating into the active zone. Thus at the first indication of a heavy quake, a seismoscope triggers the safety circuits through a relay, with the signal again appearing as a closed or open contact on a relay.

Loss of power to a reactor building, its auxiliaries, and controls is the equivalent of a car hurtling down a highway at an ever-increasing speed, the driver having no control of steering wheel or brakes. Destruction would be certain. Undervoltage relays of proved industrial types watch the voltage and signal when it falls below a prescribed limit. These undervoltage relays monitor the voltage at the main substation, the building incoming lines, and the feeder to various rod controls. Through a power-failure relay, they also indicate whether operation should be continued or shut down.

When the operator finds it necessary to quickly shut down the reactor, he depresses a push button at the control desk. Then the circuit sees electrically a pair of contacts open or closed.

Sometimes a multiplicity of these sensing devices is used; at other times they are used singly. Before a reactor can be brought up to power or even started, the safety circuit must see each one of the devices at its proper value.

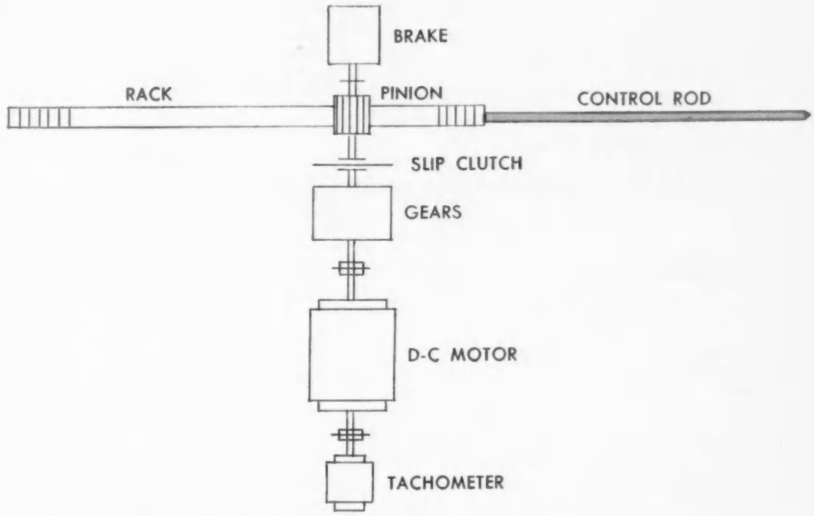
Interlocks

Interlocked circuits to exclude all possibility of human error or misoperation are desirable but, of course, impossible. The unrestricted addition of interlocks quickly makes the whole system of controls inoperable, forcing the engineer to strike a balance. He must remove from human control potential hazard possibilities that would result in disaster or operation without safety devices and yet leave the circuits flexible enough to protect in all other situations. The bypassed interlock is worthless; the trigger-happy one, an operational nuisance. Judicious use of interlocking is a must in a good design job and an asset to the continued safe operation of a nuclear reactor.

A typical interlock circuit has, at different points, four ionization chambers that monitor pile activity. Each chamber can be bypassed, provided an alarm indicates that the respective safety device is no longer in the circuit. If two chambers are removed from the circuit and an attempt is made to bypass the third one, annunciators, or alarms, are no longer reliable and the reactor must shut down automatically.

Interlocks protect equipment, limit travel, restrict operations to orderly procedures, and protect areas and personnel. Throughout the circuiting, the engineer applies them in the form of key-operated and limit switches, interposing and timing relays, and even mechanical linkages.

Not considered a serious design problem except when carried to excess, interlocking in this application is in many ways simpler than in a continuous process industrial plant.



ENGINEERS APPLIED various industrial systems for the operation of the control-rod drives, and ingenious combinations of these systems are now being used successfully.

Bypasses

Although bypasses appear to be in direct opposition to the use of interlocking, they are necessary to enable hot maintenance of the safety circuits. "Hot" means that the series safety circuit is energized through the bypass switch and the sensing device circuit de-energized for maintenance or other reasons. Also, with experience in reactor operation, a particular monitor could be judged not so critical and its bypass switch left closed. Bypasses also enable certain sensing devices to be in the circuit for short periods of time, such as during start-up of the reactor, and then removed for the continued operation at higher power levels.

The mechanical features of the typical bypass control switch include a target for visual indication, a key-operated lock in the handle or above the switch, and spring return to neutral, or normal, position, known as "unbypassed"—a term meaning a bypass switch in its normal position.

Intelligence

Target-drop and bull's-eye annunciators keep the main operator in the control room informed of the vital circuits' status throughout the building. This large scoreboard tells at a glance what equipment or circuit has misoperated, the drops being arranged in the relative order of their importance. Industrial-type annunciators without modifications have been used in this link of communications. However, with a large number of drops, the size becomes too large and takes vital space off the control panels. Need is great for a simple annunciator with a memory of at least three drops.

A typical annunciator circuit operates like this: When the remote contact closes, it energizes a relay, lights a bull's-eye, and rings a bell. The operator silences the bell by operating the switch. When the fault is corrected, the light goes out and the bell sounds again, reminding the operator to reset his silencing switch.

Other visual indications in the form of meters, counters, lights, and recorders supplement the main annunciator in delivering information to the control and monitoring room. The circuits for these are simple, usually consisting of a normally open remote contact in series with an indicating light.

Power Supplies

The force of gravity—the most reliable known—can be used to accelerate the safety rods into any nuclear reactor. Always present, it is also unidirectional, and this direction being downward does not readily lend itself to use for horizontal travel. Engineers have therefore devised complicated hydraulic systems (illustration, left, page 49) with potential energy stored in elevated masses to enable the use of gravity power for horizontal penetration of a reactor. But an equivalent all-electric system (illustration, right, page 49) with the stored energy in the form of batteries can be used.

Utility power can be used to operate both the safety and control rods through a-c and d-c motors. But when this is lost, the horizontal control rods can be driven into the reactor by the storage batteries, and the vertical safety rods can be inserted into the reactor by the ever-present force of gravity.

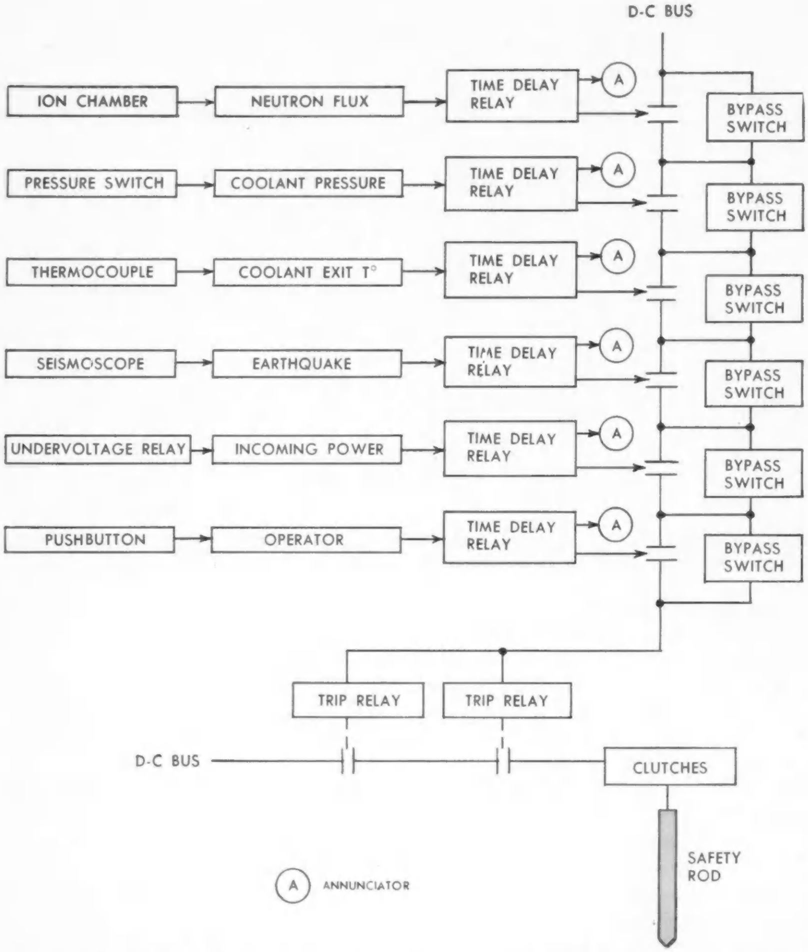
Great care is taken to protect the batteries from electrical and mechanical damage, and their capacity in ampere-hours is chosen to permit hundreds of successive shutdown operations without recharging. The batteries can be used also for station control batteries, the electric operation of circuit breakers, the annunciator supply, and control-circuit supplies.

Design Principles . . .

In the design of control circuits, the engineer draws freely on the experience of industrial application engineers, as well as that gained from the operation of reactor controls for nearly a decade. Although no hard and fast rules can be given for circuit designs, certain principles have slowly emerged and are evident in job after job. These furnish a rudimentary check list for measuring a design's fundamental correctness. Several principles follow . . .

. . . Duality

Every important utilization point has two complete dual channels of power feed—normal and alternate. This is carried through at the main building



A CONTROL-ROD CIRCUIT consists of a number of sentinels that monitor certain conditions and properties, reporting to a series circuit that controls a set of trip relays.

substation with two incoming lines and two transformers, duplicate feeders to motor control centers, and duplicate feeders to lighting panels. Great efforts are made to electrically and physically isolate the parallel feeds so that failure in one will not affect the other.

For each critical control function, two relays are used with one backing up the other. Their coils are in parallel, with interlocks connected to a common reset button.

. . . Fail-safe

Because every reactor control circuit must be fail-safe, the engineer must anticipate misoperation resulting from personnel errors. He must further guard against it by so interlocking the circuits that, at worst, human failure results in an accidental shutdown of the reactor without permanent damage to any of its vital parts. Even deliberate attempts to disable the reactors by malicious misuse of control components must not be successful.

Similarly, to a larger degree, equipment failures must be guarded against. Circuits are always so designed that the reactor will remain under control or will shut down at the time of the failure. Worst offenders in this respect are holding relays, burned-out coils on continuously energized circuits, and sticking relays. Examples of fail-safe operations are loss of a pressure switch seen by the circuit as low pressure; loss of an undervoltage relay seen as power failure; and accidental jarring of a seismoscope interpreted as an earthquake. In other operations a duplicate facility takes over the operation; if the time interval permits, automatic transfer of one to the other is effected, with proper annunciators warning the operator that he is on the stand-by device.

The engineer must also foresee misoperation caused by a series of unrelated events that would disable the control or safety circuits. He evaluates the probability of two relays failing at the same time or two physically isolated devices failing within a short time of each other. He may talk of probabilities in the order of once in 4000 years.

. . . Sequential

Long before the reactor is actually started, the engineer in his own mind and in discussions with associates has taken it through the start-up sequence and through innumerable shutdown sequences. The circuitry is checked to allow the varied operations necessary for start-up, and the interlocks are checked to permit only one order of operation. Necessary variations are covered in a bypassing sequence that forms part of the operating procedures. A similar sequence organizes the operations for slow shutdown. For quick shutdowns, the time-delay relay's sequence is checked and co-ordinated with other circuits, and bar time charts are prepared for all foreseeable emergency conditions.

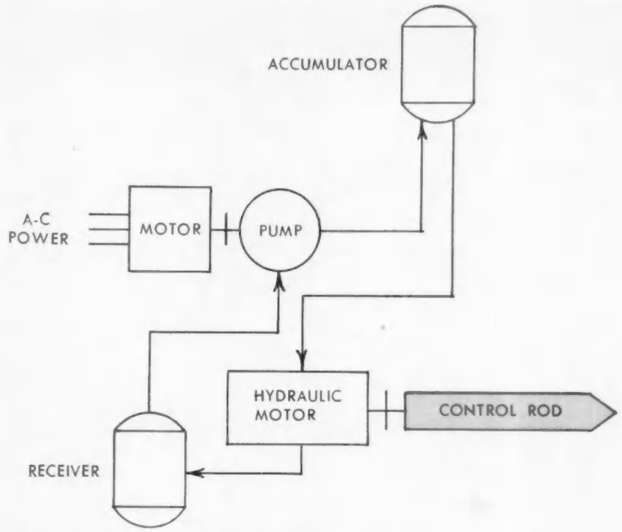
Total times are estimated for all shutdown sequences in number of cycles (60 cps base). Whether normal or emergency, the shutdowns are in an orderly and predictable sequence. The random sequence—neither predictable nor easily provided for—poses the real problem. At best, the engineer provides a tightly co-ordinated set of circuits for the various systems.

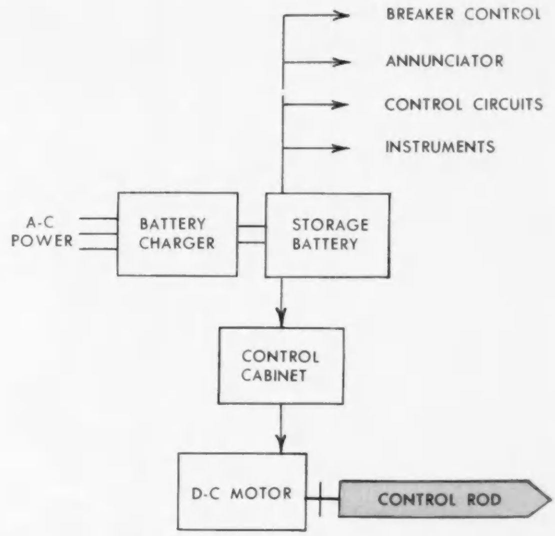
. . . and Reliability

Circuit reliability and circuit simplicity are practically synonymous terms for reactor controls and auxiliaries. A control scheme is divested of all unnecessary frills, and the number of circuit components is reduced to a minimum. In weighing the relative merits of two control schemes for an application, the one with the least number of parts and nonstandard devices is usually selected.

Equal in importance to circuit reliability is equipment reliability. To develop a design created around load-center unit substations, motor control centers, and control cabinets, the engineer obtains equipment of proved performance from reliable vendors.

Although a vague and elusive term not measurable in dollars and cents, reliability becomes a strong argument when evaluated in terms of shutdown hours or the duration of the outage caused by its failure. Frequently, the





HORIZONTAL PENETRATION of a nuclear reactor can be accomplished by one of two systems, both utilizing the force of gravity: the hydraulic system with energy stored in elevated masses and the electric system with energy stored in the form of batteries.

cost of the best piece of equipment more than compensates for the cost of lost productivity if it prevents even one shutdown in its design life.

Reliability is not limited to circuits and equipment: it can also be obtained by providing such items as spare relays in a cabinet and spare feeders in a duct bank; by having sleeves through shielding walls; and by choosing manufacturers for their ability to furnish spare parts, repair facilities, and service engineering.

Practical Design Limits

Many a concept generally assumed to be true is shattered when the behavior of a physical system does not follow the theoretical norms that it was designed for. Such discrepancies arising mainly from mechanical, magnetic, or electrical inertia are usually of no great significance in everyday applications. But they must be recognized and allowances made in the design of reactor control circuits.

It might be assumed that the force of gravity will accelerate the safety rods at the rate of 32 feet per second per second into a reactor. However, they are not free bodies because they must accelerate the drums and overcome the drag of the winch cables. This increases not only the time of travel but also the time in which a sufficient length of rod is inserted into the reactor to check the nuclear reaction. In the short times considered, this appears as a large percentage.

It might be assumed that as soon as the safety relays open their contacts the rods begin to fall. But with continued operation, some residual magnetism will be present in the clutches, thus introducing a measurable time interval before they release the rods. This time interval varies from clutch to clutch and increases with the time of operation.

Assume further that by closing a switch a relay will pick up instantaneously. However, the magnetic inertia of the coil, plus the mechanical inertia of the armature, will provide enough time lag to appreciably affect some of the total times calculated for the bar charts.

The designer is also concerned with practical limits of equipment. Often, he finds his circuits curtailed by the number of contacts available in a relay or by the maximum capacity of items of standard manufacture. At other times the quantity is not economical for the manufacturer to make special runs.

If the practical limits of delivery cannot be met and the production capacity of manufacturers is unavailable, substitutes have to be accepted and new designs developed for the obtainable equipment.

The engineer is limited because characteristics and appearance of extensions to already installed equipment must match and line up with the existing equipment. Plant standards; availability of spare parts; and mechanical, thermal, and nuclear properties of materials are other limiting factors. Sometimes the answers to such items as the effects of radiation fields on insulating materials are not fully known.

Certain space limitations restrict the amount of cubic inches for circuit components—especially in the faces of a reactor where dimensions are dictated by the rigorous spacing of the graphite lattice.

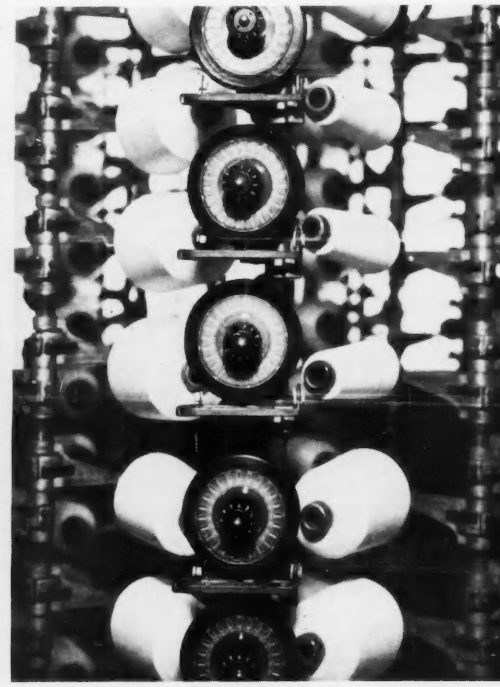
Other critical limitations are on the number and size of conduits allowed in shielding walls. Radiation windows are avoided by the calculation of shielding equivalences and by the use of offsets.

These conditions are but a few of the variables of control-circuit design. With the exception of the problems peculiar to nuclear reactors and radiation, these conditions are similar to those encountered by engineers in other industrial endeavors. By the judicious use of the number and types of a system's components, by the careful choice of conditions to shut down, and by the discriminate use of interlocking, the engineer creates a simple, reliable design that fulfills process, construction, operation, and safety requirements.

But what lies ahead? Two ultimate goals in reactor control-circuit design are the production of a completely automatic self-regulating closed-loop control system and the direct conversion of nuclear energy to electric energy. These goals of the atomic age offer a challenge to the engineering professions. And as leaders in the production of power sources, the engineers will be expected to meet this challenge. Ω

CREDITS

Page	Source
13 (lower)	MODERN RAILROADS
22, 23 (top)	George Friday



YARN-TENSION BRAKE USED ON WARPING CREELS IN TEXTILE INDUSTRY IS BUT ONE OF MANY APPLICATIONS FOR HYSTERESIS DEVICES.

Hysteresis Devices: Torque Independent of Speed

By W. L. BUTLER

Until a few years ago, engineers generally looked on the hysteresis effect in magnetic materials as so much electric energy loss—something paid for but not received. Of course, this is still true to some extent in such electromagnetic devices as motors and transformers.

Today, however, mainly through the advent of high-energy permanent-magnet materials, we are employing hysteresis loss in constant-torque devices. In a broad sense you can compare its use with the utilization of I^2R loss in heating elements of ranges, toasters, sandwich grills, and the like. But where I^2R loss is strictly an electrical phenomenon, hysteresis is magnetic in nature.

Taking Stock

Prior to World War II, the development of a line of small generators led us to study the torques resulting from hysteresis forces. We learned that accurate, controllable torques high in proportion to size of the torque-producing components could be produced. They resulted from a constant force of repulsion, or drag, between a magnet and a magnetic material that rotated relative to one another in a fixed circular path. And these torques did not depend on the speed of rotation.

But before embarking on a program to utilize their properties, we had to envision the various possible applications requiring constant torque. Two general classifications were considered: brakes utilizing the hysteresis effect for retarding purposes and clutches using the effect as a limited-torque driving coupling.

Brakes were given priority for their simplicity and greater potential uses.

One application in this category was the control of yarn tension in the textile industry. Numerous textile operations—winding, twisting, warping, and the like—require that the yarn or thread be held under accurately controlled tension to insure uniformity of the finished product. In warping (photos) some 600 to 1000 threads are wound onto large spools and so placed in a loom that the threads constitute the warp, or lengthwise threads, in the finished cloth. Any appreciable variation in thread tension shows up in the cloth as streaks or other defects.

Hysteresis brakes were equally well suited for industries making or using small-diameter wire. The production of tungsten wire for lamp filaments, as an example, involves numerous drawing and annealing operations that require critical tension control.

Similarly, manufacturers of electromagnetic devices—instruments, electronic components, and others—are also confronted with tension problems. Here, tension on a wire must be high enough to compactly wrap a component, yet not so high that it could break the wire. In the manufacture of capacitors, the

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tension of metal foil and specially treated paper must be controlled. The same is true of the tobacco industry's cigarette paper. And in certain other fields, tension must be regulated within the product itself, as with photographic film in movie projectors.

These are but a few of the applications we considered as possible markets for the hysteresis brake.

How They Work

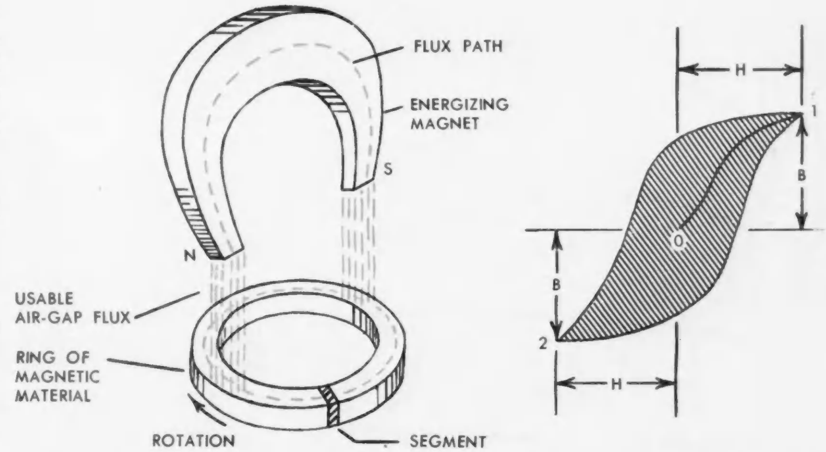
The engineering principle involved in all hysteresis-torque devices is that of driving a magnetic material through its hysteresis loop. As you may recall, the area of the hysteresis loop is a measure of energy consumed during one complete cycle of magnetization. (Because this loss shows up as heat, it might be considered an internal friction loss.)

In the basic arrangement of a hysteresis-torque device (illustration), a ring of magnetic material rotates beneath the poles of a permanent magnet. Let's assume that the magnet's field is strong enough to control the magnetic condition of the ring and that a number of thin, unmagnetized segments make up the ring itself. As one segment passes under the north pole of the energizing magnet, it is subjected to the magnetizing force H indicated by point 1 on the hysteresis loop (illustration). Now, as the same segment passes beyond the north pole, its magnetic induction B changes, but its polarity—direction of magnetization—remains the same. When it passes under the south pole, point 2, it again receives the magnetic induction B but in the opposite direction, reversing its polarity.

To reverse polarity, two like poles—the south poles of the segment and magnet—have been brought together with a consequent repulsion. And to overcome this repelling action, a force, or torque, must be applied to the hysteresis element to offset the segment's internal friction. The same thing happens when the segment, its polarity now reversed, passes under the north pole.

Continued rotation causes the segment to trace and retrace its hysteresis loop. Because an infinite number of these segments form the magnetic ring, the repulsive force is continuous. What's more, it is independent of speed.

Driving the magnetic ring through its hysteresis loop will be recognized as the frequently referred to elastic-band behavior of magnetic lines. The hysteresis brake actually feels elastic: if you rotate the magnetic ring from its free position and release it, the ring tends to return to its original position—the reason why torque functions by displacement rather than by rotating speed.



PRINCIPLE UNDERLYING a hysteresis torque device is continuous tracing and retracing of the magnetic material's hysteresis loop. Repulsive force is independent of speed.

One characteristic of hysteresis brakes, misleading to those unfamiliar with the principle involved, is the occasional appearance of uneven or "bumpy" torque. This can occur in some designs unless adjustment from a high-torque setting to a much lower setting is made while the hysteresis element is rotating. Thus the reduced magnetomotive force at the low-torque, or wide gap, setting is not capable of eliminating the poles induced in the hysteresis element at the high-torque, or small gap, setting. When adjustment is made while the device is rotating or made in small steps with the shaft, or pulley, rotated one or more revolutions between steps, the change in gap per revolution is small enough to permit the element to be demagnetized gradually—much the same as when a magnetized bar is withdrawn gradually from an a-c demagnetizer.

Theory and Practice

Although pure hysteresis torque is independent of speed, unfortunately it is impossible in practice to entirely eliminate the effect of windage and eddy currents, both of which tend to increase torque. These effects increase with speed. Although windage torque alone is negligible, except when using a fan for cooling, eddy currents can be a real source of trouble.

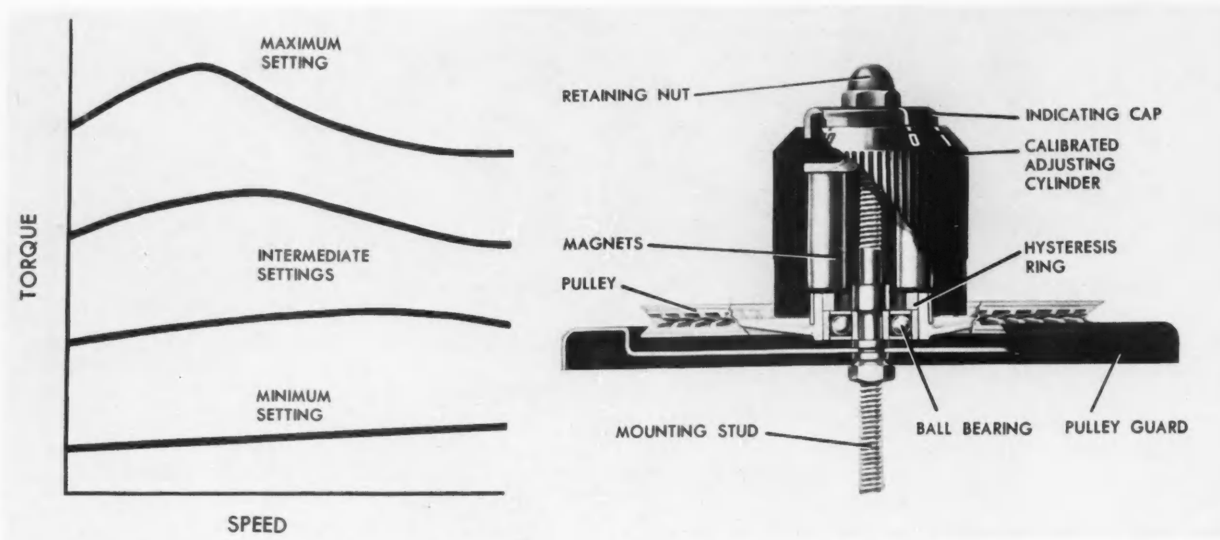
Under certain conditions, however, eddy currents can cause the torque of a hysteresis device to drop below its normal value as speed increases. For example, in the maximum torque setting of one device on which soft-iron pole pieces are used, the torque rises at first (illustration, top left, next page); but as the eddy currents increase, the magnetic poles produced by the latter exert a demagnetizing effect on the pole pieces. This forces a portion of the flux from the energizing magnets into leakage paths, resulting in a reduced amount of usable flux in the air gap. Thus both the eddy-current and hysteresis torques are reduced. As the speed of the magnetic ring, or rotor, increases, the flux drops to a minimum and the eddy-current torque again rises.

At a lower torque setting, the slope of the initial portion of the speed-torque curve diminishes, with the point of maximum torque occurring at an increasingly higher speed. Note how the curves flatten out with low flux density. At the minimum torque setting—maximum air gap—the curve is practically straight, with little rise in slope as the speed increases.

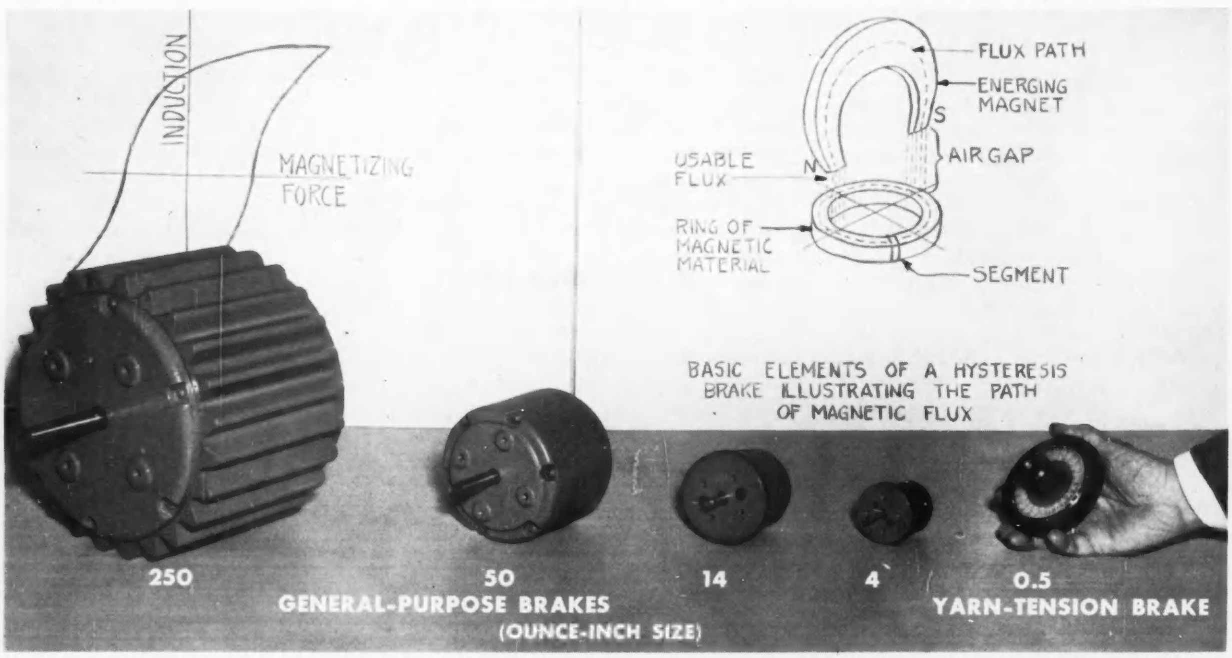
In general, the eddy-current torque can be minimized by reducing flux density, because it varies with the square of flux density. Hysteresis torque, on the other hand, is directly proportional to flux density.

Heat Problem

In an electric motor only a relatively small part of the energy input shows up as heat. But all the energy that is absorbed by a hysteresis device converts to heat. This difference means that you must give particular consideration to the problem of heat dissipation. This is true not only of the nature and area of the device's exterior surface but also of the



SPEED-TORQUE CURVES INDICATE EDDY-CURRENT EFFECT *(LEFT)*; COMPONENTS OF YARN-TENSION BRAKE ARE ARRANGED AS IN CUTAWAY.



FOR GREATER VERSATILITY, TORQUE RANGES OF FOUR GENERAL-PURPOSE HYSTERESIS BRAKES OVERLAP BY A SUBSTANTIAL MARGIN.

path along which the heat must flow from the hysteresis element.

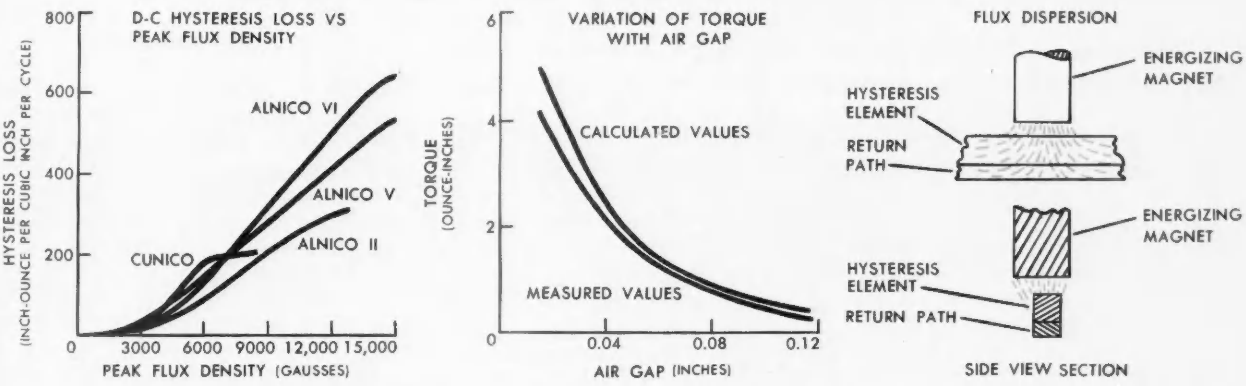
Heating isn't serious in brakes of low torque ratings. Because the device must be physically strong even with small torque output, the components are usually large enough to easily handle the heat-dissipation problem. As the maximum torque increases, however, the heating becomes more serious. For this reason, brakes having a torque of 250 ounce-inches or more are built physically larger than those required by the torque-producing components. (At 3000 rpm, a torque of 250 ounce-inches is roughly equivalent to the output of a ¾-hp motor.) Of course, physical size can always be kept down by resorting to artificial cooling or by limiting the maximum speed.

Sometimes it's possible to reduce the cost of a hysteresis device because of this extra space in larger sizes. For by using a greater amount of less expensive, less efficient magnetic material for the hysteresis element, its lower efficiency is offset by volume increase.

Ideal from the heat dissipation point of view are some devices with hysteresis elements in direct contact with the outer casing. However, the design of energizing magnets becomes more complex. And if electromagnets rather than permanent magnets are used for energization, the design is further complicated because slip rings are needed to supply electricity to the rotating electromagnets.

Which Size?

Immediately following the initial publicity of hysteresis-torque devices,



FLUX DENSITY, LENGTH OF AIR GAP, AND FLUX DISPERSION ARE FACTORS THAT DETERMINE TORQUE OF A ROTATING HYSTERESIS DEVICE.

BASIC FORMULA FOR FINDING TORQUE OF HYSTERESIS DEVICES

The basic formula for finding the torque of a rotating device that utilizes the hysteresis principle is:

$$T = \tfrac{1}{2}\,\pi\,K_1 \frac{P}{2} V K_2$$

where

- T = torque in ounce-inches.
- K_1 = use factor governed largely by flux leakage, flux dispersion, and pole shape.
- P = number of poles.
- V = effective volume of the hysteresis element in cubic inches.
- K_2 = hysteresis loss in inch-ounce per cubic inch per cycle.

In practice, we obtain the hysteresis loss K_2 from experimental data of the magnetic materials under consideration. Generally, data are plotted in a series of curves that show hysteresis loss per pound per cycle versus peak magnetizing force. Hysteresis loss can also be plotted versus peak flux density (illustration, left).

Next, approximate calculations are made of the various flux densities for a typical magnetic circuit whose air gap increases in uniform steps. By substituting these results in the torque formula with an assumed value of K_1, a curve of torque versus air gap (illustration, center) can be plotted. Note the close correspondence of the calculated values with measured values for an actual hysteresis device of the same design.

A number of considerations determine the torque formula's use factor K_1. One is the geometrical arrangement of the magnetic-circuit components. Another is leakage flux, governed chiefly by the arrangement and shape of these components. Additionally, K_1 accounts for the fact that calculated flux density can't always be realized in practice. Depending on the conditions, flux disperses or converges in traversing the air gap and magnetic ring.

For example, note how the maximum flux density occurs at the center of the magnet (illustration, right, top). The value of the maximum flux density depends on the relation between the width of the magnet and the length of the air gap. It is also affected by the relative reluctances of the return paths through the hysteresis element and the soft-iron backing ring.

If the magnet overhangs the hysteresis element, the flux converges (illustration, right, lower). And within limits, you can increase the torque by increasing the overhang. Also, an increase in the diameter of the magnet itself will provide a high average flux density in the peripheral direction as long as the air-gap range isn't altered, again resulting in increased torque.

The ideal condition—flux concentrated in a narrow band across the face of the hysteresis element—might be approached by using soft-iron pole pieces on the energizing magnets. But then the benefits would have to be weighed against the losses caused by increased leakage from the sides of the pole pieces.

we received numerous inquiries from potential users: "How can a hysteresis device be applied to our particular problem?" they asked.

First we tabulated the inquiries and evaluated them in relation to space requirements, maximum speed, and maximum torque of the application. Then we formulated a development program that would eventually lead to a line of permanent-magnet hysteresis brakes. Such a program, we believed, would meet the majority of applications then envisioned.

A device for controlling yarn or thread tension in the textile industry was given priority because 1) the need appeared great, 2) the potential volume was high, and 3) the task of producing a quality product at low cost presented a challenge. The principal requirement of such a device was to provide constant yarn tension. A pulley was needed to adequately grip the yarn without abrasion or other damage.

For larger general-purpose hysteresis brakes—those used in wire-winding applications, for example—we decided on a cylindrically shaped device (photo, lower, opposite) with rotating shaft. In appearance it's similar to a flange-mounted motor. A maximum torque of 250 ounce-inches appeared to satisfy most of the application requirements. By designing each size with a 10-to-1 torque-adjustment ratio, we could limit the number of general-purpose devices to four. Each device overlapped the torque range of the next smaller by a substantial margin.

From the beginning we recognized the critical importance of the inertia of

Industry Promotes Study of the Three R's (PART IV)

• Attitudes and habits of study applied in school or college may later express one's attitude toward work.

• Continued study and learning on the job pay off in achievement, growth, development, and self-improvement.

Last year in our May, September, and November issues we carried reprints of General Electric's booklets "Why Study Math?", "Why Study English?", and "Why Read?" as Parts I, II, and III.

Now we leave the specific and basic three R's to broaden out into other important fields of activity also essential to a student's education. And so, on the following pages we are publishing reprints of GE's articles "Why Stick to Your Studies?" and "Why Work?"

More than ever before in today's competitive society, young people still in school must be urged and encouraged not only to stick to their studies but also to develop helpful and wholesome attitudes of study habits. For their approach to studying may one day parallel their approach to the work they have chosen to pursue as a career. Just as an unhealthy attitude toward one's studies can cause many a defeat, so too a poor attitude toward one's job can be the source of much unhappiness.

As young people begin to mature, it should be made clear to them that learning is not restricted to the student alone. Rather, it is a privilege of all society—a total process and a continuing one that ideally never ends.

Knowledge gained as a result of working is largely incommunicable; it becomes an integral part of the person, coloring the whole personality. It's the measure of a man—what he gives to the job as much as what the job gives him.

The student once situated in business or a profession will live through for the first time some of the universal truths studied in school. Only after they have become realities of experience will he understand the value of why one should stick to his studies and why one should work.

The two reprints published here are from the booklet titled "Four Why's" that also includes "Why Study English?" and "Why Read?" Free copies will be sent to you on request to Public Relations Services Division, Dept. 107-2, General Electric Company, Schenectady 5, NY.

The next reprint of this series will be published in a forthcoming issue.

Hysteresis Devices— *(Continued from preceding page)*

rotating members, especially in the yarn-tension brake, where the pulley would be the principal rotating member. For reasons of strength and lightness, we molded the pulley of nylon.

Inertia didn't appear to be an important factor in the performance of the larger general-purpose sizes. Still, we attempted to keep the inertia-to-torque ratio as low as practicable. For those few applications where inertia of the rotating parts might pose a problem, we felt it could be minimized through special design.

Many manufacturing problems had to be overcome in carrying out our objectives. Especially was this true of the smaller size hysteresis brakes, where variation in bearing friction could easily cause trouble. For the larger size brakes, selecting bearings that would withstand the temperatures generated was another problem.

Yarn-tension Brake

The greatest difficulty, however, turned out to be the pulley of the yarn-tension brake.

In that device (photo, top, page 52), the hysteresis member is in the form of a ring pressed into the hub of a ball-bearing mounted pulley. The bearing's outer race acts as a return path for the flux. To adjust the brake's torque, you simply rotate the calibrated cylinder containing the permanent magnets—in effect, varying the air gap between the magnets and the hysteresis ring.

One problem in designing the nylon pulley was to make sure that it would grip the yarn without pinching or abrading it. Staggered spokes that grip the yarn as it approaches the bottom of the pulley's V-shaped groove solved the problem. Wrapping the yarn a minimum of 180 degrees around the pulley—half the pulley's circumference—eliminates any possibility of slippage.

The method of threading the yarn-tension brake was investigated extensively, too. The pulley guard greatly facilitates threading, in some installations actually guiding the yarn into the pulley. It also protects against sustained external stresses that might be exerted before and during installation. These stresses could physically distort the nylon pulley because of its cold-flow properties.

For satisfactory operation the yarn must remain under tension after the hysteresis brake comes to rest. The brake does this nicely. It has an inherent tendency to reverse its direction of rotation on stopping—again, the effect of the elastic-band behavior.

Friction-type brakes and clutches are notorious for their unpredictable torque characteristics. Contributing to their basic instability are many variables: a brake's starting and running friction differs, and friction between the rubbing surfaces varies with temperature. Additionally, the presence of foreign material such as oil will cause erratic torque output. But wear—the most serious of all variables—makes for high cost in maintaining friction brakes.

No Equal

On the other hand, the torque stability of a hysteresis device at a given speed is constant within close limits. Nor is there any variation between its starting and running torque. A hysteresis device has negligible friction—and this is limited to the bearings. Torque is substantially constant with speed, and at the design stage you can satisfactorily make allowances for any variation.

Finally, after a hysteresis device has stopped, a resisting torque is always present, provided inertia-to-torque ratio is low enough to permit the brake to decelerate faster than the torque-producing, or driving, components.

All these advantages seem to indicate that devices utilizing the simple but unique hysteresis principle will continue to be developed. And you can expect to see rapid expansion of their use throughout American industry. Ω

GENERAL ELECTRIC'S ANSWER TO . . .

why STICK to your studies?

WE at General Electric know a lot about the value of staying in school. For more than sixty years we have been selecting promising high school and college graduates and giving them on-the-job training for positions of responsibility. The more education they bring to us, the faster we can help them climb the success ladder.

Keep on learning

We realize that some boys and girls have to leave school and find work. This doesn't mean they can't climb the ladder. They can if they want to keep on learning.

Two things we know well: when a person is satisfied with the ladder rung he is perched on, he has stopped learning; a man in his mortal life cannot reach far enough upward to touch the top rung of any ladder.

If you agree with us, but know that because of a good personal reason you must soon quit school, here is our advice. Do your level best while you are in school, and then on the job of your choice substitute hard work for the advantages you have missed by leaving school. We think you should shop for work that includes on-the-job training, both for your hands and your head. There are many non-college men in high positions at General Electric. They gave more than was expected of them as they served their apprenticeships and kept on "boning up," as they climbed to assignments of increasing responsibility.

Mainly, these words are aiming to reach boys and girls who drop out of school as early as legally possible to earn a quick dollar. They are the ones who are in effect giving away tens of thousands of dollars.

The 1950 Census Report tells us that in 1949, of all men 25 years and older, those who completed eight years of grade school received a median income of $2533. Those with four years of high school received a median wage of $3285. Those who stuck out four years of college received a median wage of $4407.

Now money is not the chief aim of life. Yet without it, your life partner will experience worry and monotonous toil. Your own children will not have their fair share of the good things of life. You and your family will not have a good house in a good neighborhood. You will likely reproach yourself for not being able to provide your dependents with the things which in your honest moments of self-analysis you know you owe them.

When we say that it's pretty wonderful to own an automatic furnace and an automobile, to dress as well as the next family, and to mingle with above-minimum-standard friends we sound very, very materialistic.

A practical attitude

You may call such an attitude materialistic if you want to. We simply look around us and are forced to call such an attitude practical. Towards the end of this afternoon, thousands of automobiles will leave the parking areas of all our General Electric plants, and in them will ride more thousands of our people, most of them high school and college graduates. They will leave for a few hours the work projects that are progressing in response to their wills. Because they are confident that their own personal progress advances in direct proportion to their own contributions to their Company, they will arrive home with a sparkling frame of mind. None of them needs say to himself or to his family: "I suppose I'll be grinding away on the same old job the next 30 years."

We think it is practical and *right* to study how better to succeed on the job so that you can have a song in your heart when you work—and after hours.

Are you beginning to cite examples of people you term successful, people who ran out on school early in their lives? There are indeed plenty of examples in your community. But you do this: you ask them whether they would advise you to stick to your studies.

Look at the facts

Let's look at statistics.

By grade 8, 20% of all U.S. children have dropped out of school. At the end of grade 12, it's 45%. At the end of college's sophomore year, 89% are not in school. At college graduation time, only 10% are left of the millions of boys and girls who began school at the age of five or six.

Government surveys tell us further that boys and girls drop out before completing the twelfth grade because they (1) dislike school, (2) think it would be more fun to work, and (3) need money for themselves and their families.

Teachers make you work, play favorites, talk too much, do too much of a selling job on staying in school? Sure! Our bosses at General Electric make us work too. And they play favorites: when there are openings higher up the ladder they push along the hard workers. And talk! Teachers talk you into behaving like social creatures, into solving difficult problems and thereby help build in you the elastic-like qualities that will snap you out of the inevitable setbacks and propel you forward. A job of work is no picnic for the person who doesn't tackle the impossible with a whoop and a holler.

Accept the challenge

We with our long memories recall unhappy classmates in the upper grades and college. They were the ones who elected to take the snap courses and dropped out one by one. The happy boys and girls were the ones who conquered trig, physics, chemistry, economics, philosophy, thermodynamics, etc. — and then signed up for even harder courses. The happy man at General Electric is the one who keeps on studying so he dares say to his boss: "The Company's not getting its money's worth out of me. Let me sink my teeth into a really challenging job." This kind of perpetual student is the ideal clockwatcher; he tries to hold back the minute hand as it counts off the never-to-be-regained hours.

We at General Electric, in urging all young people to stay in school, sense very keenly the real reason why so many drop out. It's again a matter of attitude.

Let's imagine you are doing badly in a subject—say plane geometry. But one night you memorize the next day's theorems till you can say them backward. As soon as the class starts next day, you shoot up your hand . . . wave it right at the surprised teacher till she lets you recite. It's like eating peanuts; after one taste it's hard to stop. That's the way with success.

Just once, if you are in the school doldrums, why don't you put on a performance? It might be contagious, and it might be fun.

In our shops, offices, and laboratories, we at General Electric are accustomed to doing jobs that border on the fringe of the impossible. Because so many solutions to problems are trotted out early in the morning, it is obvious that mental wheels often grind away merrily after work hours, from force of habit. Homework? If there's an element of challenge in the assignment, it's homeplay!

Both at school and at work, there are setbacks, and therein lies—especially in new experiences—an opportunity for vigorous workouts. Men with strong character, with a capacity for success, capitalize upon setbacks. Selective Service can, for example, steal so many months out of a man's life, or it can provide such advantages as teaching the fundamentals of electronics, machine tool operation, the mathematics of trajectories, the countless business skills utilized in the handling of men and material.

Out of study: ideas

People who stick to their studies get ideas. When our own scientists and engineers became aware that they couldn't get close enough to the "hot" parts of an atomic reactor to make adjustments and pick up things, they dreamed up remotely controlled mechanical hands. Back in 1944, an engineer looked at a straight fluorescent lamp and said: "Let's bend it in a circle so that it will be adaptable for table lamps and other home uses." There were problems! But research and development men studied how to meet those problems, and the Circline came into being. In the last 15 years, so many problems have been solved at General Electric, so many ideas have been developed that didn't exist before, that, as a result, an estimated 40,000 new jobs have been created.

Industry has always placed a great deal of value on bold, original thinking. Yet average young people by their very nature are such conformists! It is so much easier to be one of the regular fellows. We read and agreed with some comments in *The New York Times* on this subject the other day: "If (the true business of a liberal education is greatness), education even at the high school level should be aimed at greatness . . . It comes more often from the student who has the determination and courage to swim against patterns around him . . . (The individual thinker) is a pretty important fellow. For details, read the history books."

"How well did you do?"

More companies have an eye on you than you can ever guess. Thousands of recruiting specialists are interviewing high school and college seniors and checking their records. All of them want to know: What subjects did you take? How well did you do in them?

If you are a high school senior seeking permanent employment, will you squeeze dry the employing company's resources to give you as nearly as possible a college education? If you are a college graduate, will you keep on trying to gain more skill and knowledge in an almost endless variety of training opportunities?

General Electric has been a "school" ever since its incorporation in 1892. In one field alone, the Engineering Program, the Company has given on-the-job training to more than 25,000 men.

While you are shopping for opportunity, you will read such paragraphs as the next two, taken from a booklet called "10 Programs for College Graduates."

"These programs, diverse as they are, have certain common characteristics. In all courses, while learning new skills, the individual has a well-paid job and is given commensurate responsibility. He has the best of equipment at his disposal and he works side by side with leading men in his field. Through job rotation during training he learns much about the Company's varied operations and is in a good position to decide which type of work most interests him.

Know what you have to offer

"Nor is his job decision necessarily final. As he moves up, he may be a candidate for any job in any department in the Company. General Electric places no limitations on the career positions for which a man is eligible. The only limitations are that man's own interests and abilities."

Will your job-shopping be real shopping or window shopping? It will be a crying shame if you have to admit sadly to yourself as you read paragraphs similar to the quoted ones that: "These opportunities aren't for me."

Your potential employer wants to know what you have to offer. With that information, he can help you find your starting place on the success ladder. And you can determine with some accuracy your rate of climb.

GENERAL ELECTRIC'S ANSWER TO . . .

WHY WORK ?

LET'S say, first, that work is more fun than anything. We believe that work is the meat and potatoes of the meal of life. Work, like meat and potatoes, makes you feel good. It gives you a base, a foundation, a good conscience—to support the important supplements, such as fishing, playing golf, or unashamed loafing.

This worker really lived!

No one can convince us that the man who set out to invent the electric incandescent lamp, and watched his first successful one "burn" just seventy-five years ago (October 21, 1879), worked like a horse. Rather, he worked like a man.

Searching high and low, he found the earths, minerals, and plants that might solve the problem of the filament. Finally his quest ended at home in Mrs. Edison's sewing basket.

It was on the evening of October 19, 1879, that he had a lamp ready for the important test. His lamp had a carbonized thread inside a sealed glass bulb.

Current was switched on. The lamp responded instantly, glowing with a soft light. Then he and his colleagues began their vigil.

Not one of them had eaten for hours and hours, nor thought of sleep, nor worried about recreation. The gray of a second dawn found them at their vigil. About one o'clock on the second afternoon—more than 40 hours after the lamp had first received the current—the filament burned out.

The spell was broken. The men leaped up *with cries of jubilation.* Edison, then in his 32nd year, said: "That's fine. I think we've got it. If it can burn 40 hours, I can make it last a hundred."

High objectives are important

We at General Electric, lest we run the risk of picturing ourselves as some 200,000 drudges, want to make one point very clear. Simply stated, we believe it is our delight to work hard so that our products and our services will lighten the mind- and body-killing labor that can make living dull and shorten the span of life.

Many of us at General Electric are old enough to remember unpleasant tasks: cutting trees and splitting wood for the cookstove and parlor stove, beating the carpets in the backyard, trimming and washing the oil lamps, cutting acres of oats and buckwheat and hay and processing them for man and beast . . . Why don't you ask grandmother and grandfather for a list of arduous tasks that don't exist today?

The career that you *can* follow *can* have such a challenging objective as increasing the happiness of mankind.

Work did not kill Edison because he saw clearly magnificent objectives and kept on moving towards them. We don't know whether it makes good medical sense, but it is our observation that the person who is aiming to be a ball of fire on his job is too happy to be ill in the mind.

Alternative to high objectives

Since we are addressing ourselves to boys and girls in high school, we know that many of our readers will soon join the work force of America—that is, the group which works for so many dollars per year. Your working years will number 40 to 45. These are your best years.

Here is one system. To get a job you ask your hard-working uncle to speak to an influential personnel man about taking you on. Since your school record is feeble, your uncle will explain that that record is not accurate; that it was your tough luck to study under about 30 incompetent teachers in a sad school system and a sadder college. On the job, you flatter the boss, and become a one-man committee whose function it is to debate the unfairness of job assignments. When rewards for faithful work are passed out, and you are skipped, you stick to your guns. After all, no company can squeeze you dry.

That's one way to spend 40-odd years.

In all fairness, let's admit that there can be an occasional bad teacher and a mistaken boss. But the absolute truth of the matter is that you, an individual, born in a country whose name is synonymous with freedom, can determine your career objectives and not only meet but excel them.

We keep thinking of Edison and what he started. What he started was a revolution whose scientific, engineering, and manufacturing potential is so great that each year challenges feed upon more challenges in increasing proportion.

Never before such opportunity

Because man will continue to work hard, we stand today in relation to harnessing the atom where Edison stood as a young man in relation to putting electric power to man's use. We will carry on in the atomic age—unless our successors let us down—with the same vision, industry, fortitude, and character.

Who can doubt that electricity will be generated commercially from the fission of the atom? Or that television screens will be hung on walls, like picture frames? It has been estimated that we'll probably be using about 24 times as much electric power in 2000 A.D. as we're using now.

We and our children *can* enjoy such marvels in the years to come—but it won't be an automatic process. We will have to *earn* such things, as well as the right to enjoy them. We'll need the same character traits young Edison had when he opened the gateway to the Electrical Age—such traits as optimism, courage, stick-to-it-iveness, intellectual curiosity—but above all, the willingness and the desire to work hard.

What about your record?

Probably *you* haven't a doting, successful uncle to take you on at $1000 per week as soon as you finish school. It is your fate—maybe we should call it good fortune—to be obligated to present a record of accomplishment before someone will swing open a gateway to your chosen career.

What about marks? What you are doing today in all your subjects is being translated into figures that will show on your record for years to come. Now, no future employer will expect to see straight A's after your name, but he will be doubtful of your value to him if he sees evidence of continued failures or even a string of C's.

You may question whether a poor mark in chemistry, for example, will look bad to the future employer who is considering you for a sales position. It will. Or at least it will throw some doubt into his mind. He will reason something like this: "He (you) was given a job to do, but he didn't give that job a good effort. I wonder if he will postpone calling on a tough customer until a worker from some other company has clinched the sale."

What about extracurricular activities? Let's not be unfair. Perhaps you are working like a horse (or like a man) to help keep your family alive. Good for you. You will make out. But we are thinking now of the boys and girls who disappear like a flash when the last bell has rung.

We are not all gifted athletes, and, frankly, we are disturbed when we hear that a football star just gets by in English. We are tremendously impressed when a student displays the sense and judgment to make a creditable mark in both his football and English—and we don't necessarily mean making the all-star selections.

What about outside work? Most of the boys and girls we know work. We are prejudiced in favor of the pupil who can show a succession of summer jobs, because we know that he has gone to the school of experience.

We have been particularly pleased and impressed by what we saw in the summer of 1954. That was a summer when the larger employers didn't have quite enough work assignments to pass out to temporary help. But we saw boys, and at least one girl dressed in overalls, painting houses, working in gardens, washing windows, and (several boys, too) taking care of the neighbors' babies. We know of three boys who picked up a wreck of a truck, a gasoline mower and miscellaneous tools, advertised in the paper, and worked from seven in the morning until the sun dipped over the horizon.

From the records

There will be no names used here, but the following are from General Electric records.

A chemist. Carried papers and was the "boss" of two other routes. With his earnings, he bought and ran a small truck farm.

An engineer. While still in high school, he operated a fleet of trucks and used them to haul construction equipment around oil fields.

A nuclear physicist. Edited high school paper, earned a scholarship to the University of Virginia and worked at odd jobs there.

An engineer. Won letters in high school football, basketball, and track. During summers he worked in a meat-packing plant. At University of Missouri, he played basketball, won several business honor society medals, waited on table, tended furnaces, and tutored.

An editor (woman). Majored in English at Simmons College, wrote for school paper, worked in a factory, waited on table, clerked in stores.

College does not always enter into the picture.

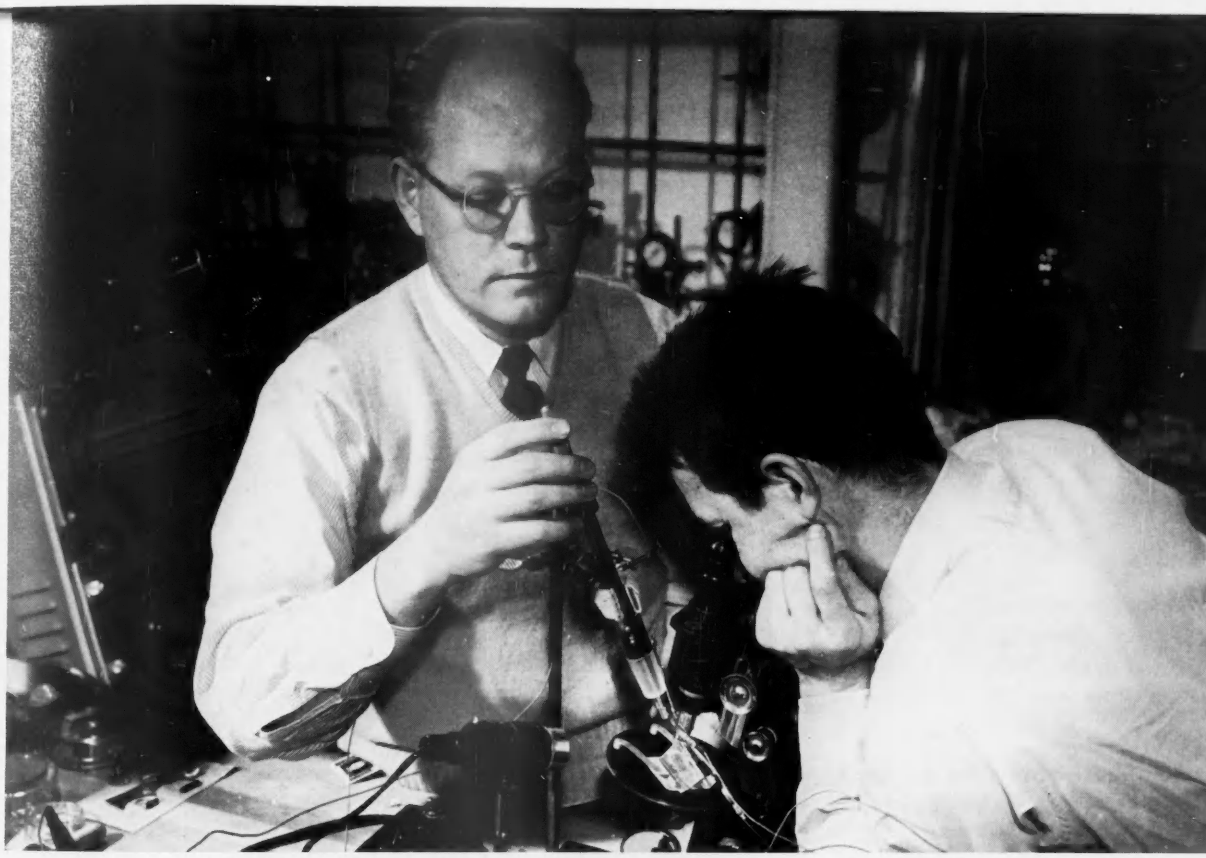
A General Electric photograph and blueprint services manager got his "college" the hard way. At high school he took a college preparatory course, but circumstances forced him to compromise on home extension courses from Indiana University while delivering a milk route.

Significantly, we think, President Cordiner, in a recent talk to General Electric managers, said: "We are interested in competence, not diplomas." He and every manager of the Company are solidly behind youth who do a good job in high school and college, but they know personally hundreds of men who are substituting an honest work record for a sheepskin and are bringing credit and honor to themselves and their employer. These are the men who, had they gone to college, would have earned high averages.

Work with a smile

Even when the going is rough, as it often is in our competitive economy, most of us who work for a living would not trade our work days for a picture-book South Seas existence. We who comprise the U.S. employed group—39 per cent of all people of all ages—have a tremendously exciting job ahead of us.

All of us, then, are presented with a succession of challenges. Our minds and our bodies are capable of meeting those challenges. Without them, and the cheerful determination to meet them, we would be but blunt swords rusting in the damp earth.



RESEARCHERS FLOM *(LEFT)* AND SAVAGE DETECT VARIATIONS IN A SURFACE FILM WITH THEIR SPECIAL WIRE-LOOP APPARATUS.

Insulating Films on Metal Contacts

By DR. D. G. FLOM and R. H. SAVAGE

Thin insulating films on the surfaces of metal contacts are a continual threat to the operation of nearly all types of electric equipment. They affect the successful operation of a broad range of devices such as contacts, switches, commutators, and slip rings. Here they frequently produce excessive energy losses and overheating or even interrupt the main power supply.

These films are difficult to identify. They are often invisible and their origin may be unknown. Their thickness may be less than that of a fingerprint and their mass too slight for easy chemical analysis.

However, to detect the films electrically is a different matter. It is proving to be surprisingly simple, the secret lying in probing the film with a feeler of fine wire too delicate and sensitive to cause puncturing (photo). In the past, the probes have generally been too coarse for this.

We were led to try the fine-wire approach after looking through a microscope at some microtools that we were using in unrelated work. The wire ends of these tools had been tapered nearly to the vanishing point by an electrolytic eating away of the metal. We found that the resulting fibers could be slid on very soft surfaces without producing the usual microscopic scratches.

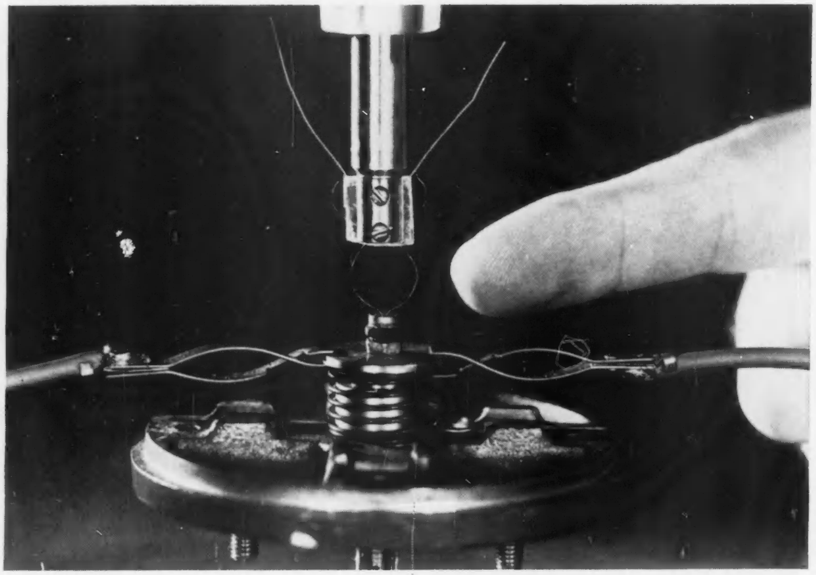
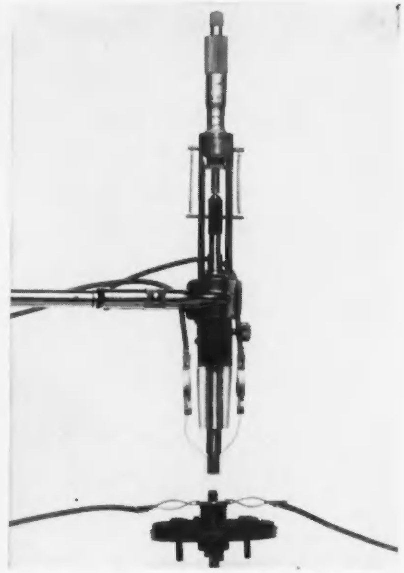
When we first applied these wire hairs to the metal surfaces that were to be explored, the advantages of this technique stood out clearly. The elastic properties of the feeler served to both control and limit the mechanical pressure at the point of contact. Thus damage to the surface was avoided. In addition, the wire could be heated electrically, a trick that makes its surface reproducibly clean for each application.

Both authors are research associates in the Physical Chemistry Section of General Electric's Research Laboratory, The Knolls, Schenectady. They are currently studying the fundamentals of contacts and friction. Dr. Flom joined the Company in 1951, Mr. Savage in 1940.

Initial Work

We started this work with two-mil platinum wire, a size large enough to handle and weld conveniently. Yet when deformed elastically against a surface, the wire was fine enough to provide us with a good range of contact pressure. Platinum was chosen to assure a reproducibly clean surface. (Gold and sometimes fine silver can be used, but coin silver should be avoided.)

We shaped the wire into a loop about one centimeter in diameter but not quite closed at the top (photo, left, next page). In this way we obtained a smooth rounded surface of approximate known geometry for the contact. The loop was attached to a micrometer head (photo, right, next page) so that it could be advanced in controlled increments. Its compression after contact was observed under convenient magnification.

PRESSURE OF THE WIRE-LOOP PROBE ON A CONTACT BUTTON IS INCREASED IN CONTROLLED INCREMENTS WITH A MICROMETER HEAD *(RIGHT).*

To determine contact resistance, we passed current down one side of the loop and measured the voltage drop through the other side with a potentiometer (illustration, left, next page). The loop had previously been calibrated against the pan of an analytical balance (illustration, right, next page), so we knew the force exerted on the contact surface.

Practical Applications

At this stage of the work, several engineering problems were brought to us in the hope that the wire-loop apparatus might prove useful even though it was still in an undeveloped form. These problems concerned faulty metal contacts taken directly from service.

We decided to use the loop in a purely exploratory way to learn something about the normal range of resistances in typical contact devices. Each time, the loop was first placed in contact with a sample under a constant potential of 20 mv. The force was then gradually increased within the range of 1 to 300 mg. Each small area under examination was studied in this way until breakdown occurred, as indicated by an abrupt decrease in contact resistance.

When this method was applied to freshly cleaned metals, the contact resistances were rather reproducibly low, lying well below 10 ohms and usually below 1 ohm. This was true even at the lightest forces at the threshold of contact, which was in the region of 1 mg.

In contrast to clean metals, the contacts from service showed many isolated spots of high resistance. These contacts included make-and-break button switches, slip rings from a contactor device, and commutators from d-c machines. The spread in their resistances extended all the way to 10-million ohms and more. By this we mean that one-tenth microampere through the contact was not detectable at an applied potential of 30 volts. Contact resistances ranged from one hundredth of an ohm through at least 100-million ohms.

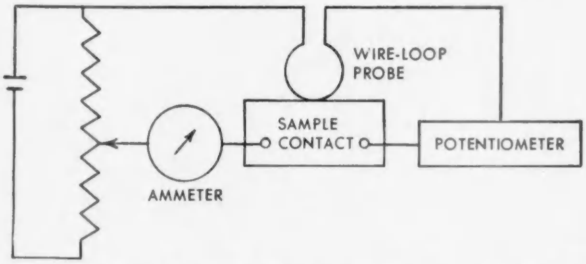
A striking feature common to all the contact surfaces examined was that areas of high and low resistance were adjacent, often having a sharp boundary between them. In addition, many areas of one kind were so small that it appeared uneconomical to study them chemically. Over-all surfaces were thus extremely heterogeneous, having their low-resistance patches electrically in parallel with their high ones.

In the first example, buttons on a make-and-break switch made of platinum-osmium alloy and cemented tungsten carbide were intended to oscillate rapidly against each other. By closing under light pressure, they completed a control circuit intermittently. But service disturbances existed. Investigations revealed that insulating films on these buttons were able to withstand the forces of contact without breaking down mechanically or electrically. High-resistance areas were numerous; some of them withstood 30 volts without damage and had a resistance 100-million times that of the chemically clean metal surfaces.

In the second example, the slip rings on contactor devices were made of silver with varying types of surface finish, only one of which was satisfactory. The problem was to determine the degree to which a given surface finish could modify the resistance properties of a silver ring. In applying our platinum-loop apparatus, silver that was machined without a lubricant and not handled physically had a low contact resistance of less than one ohm. But its resistance became higher and more erratic when physically handled. (It was possible to detect fingerprints in this way.) Finally, when the silver was buffed on a high-speed wheel, relatively stable high-resistance areas developed that withstood even the cleansing action of a solvent. Information of this sort led to a recognition of the best finishing methods, as well as to means of testing the finished surfaces.

Our study of commutators from d-c machines involved large areas of brush tracks. Although seemingly uniform in appearance, these tracks were at once found to be extremely dissimilar in surface-resistance patterns. They were compared by noting a large number of localized contact resistances measured successively around the circumference under constant voltage and force. Values of voltage and force were chosen well below the threshold of film breakdown.

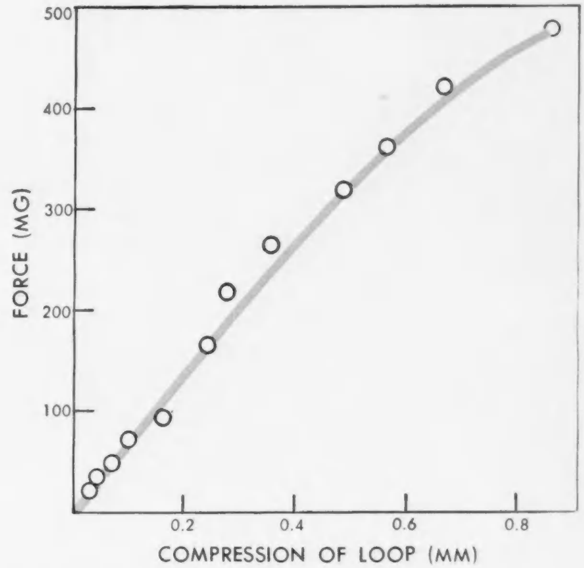
Our results for the entire range of film resistances for two commutators are summarized in the Table. These results show a much greater proportion



ELECTRIC CIRCUIT MEASURES CONTACT RESISTANCE OF SURFACE FILM.

DISTRIBUTION OF COMMUTATOR-FILM RESISTANCES

Film Resistance (Ohms)	Commutator 1 (Percent)	Commutator 2 (Percent)
Below 1000	52	10
Below 5000	88	20
Below 100,000	100	45



CURVE SHOWS CALIBRATION OF PLATINUM WIRE-LOOP PROBE.

of high-resistance areas on commutator 2. We correlated these measurements with the observed behavior of the machine that had been run in service with this commutator. Briefly, the brushes on this machine had failed to pass sufficient current for self-excitation of the generator, and the wire-loop results indicated that the reason for this failure lay in the excessive resistance of the commutator film. (Further field studies with the same probing technique have confirmed this finding.)

Another investigation into practical engineering problems was made on a pencil-size silver commutator. This came from a low-speed motor that had been operated with silver wire as brushes. Failure of the brushes to collect current in a six-volt circuit led to an investigation of the commutator with a wire probe handled under a microscope. The surface of this small commutator was highly conductive for the most part, with only a few spots having resistances greater than a million ohms. Some spots were only 25 square mils in area, but they easily accounted for the trouble. Though the areas were too small for chemical analysis, the loop did point to the trouble.

Micro Effects

Apart from direct measurement of film resistance, the wire loop's extreme sensitivity disclosed some unusual effects, first observed during a study of the high-resistance properties of anodized aluminum.

When an electrically isolated 60-cycle transformer was switched on or off in the vicinity of the sample, we noticed a sharp irreversible drop in contact resistance. With 30 mv applied at the contact, for example, switching the transformer resulted in a permanent current increase—more than a hundred-fold—through the probe, and contact voltage dropped to less than one millivolt because of circuit regulation.

Further studies suggested an electromagnetic effect. Checking this possibility, we found that discharging a condenser through a small inductance—near the contact but in a separate circuit—produced a similar drop in contact resistance. The same thing occurred when we operated a spark coil at distances up to 15 feet from the contact.

These observations confirmed the supposition that the resistance drop was the result of a voltage induced by electromagnetic radiation.

This effect is generally believed to involve the electric breakdown of the surface film under a very high induced voltage gradient, with resultant production of a minute metal bridge at the site of breakdown. Such a bridge would provide the low-resistance path. Its production by induced action, if real in this case, is a striking demonstration of the remarkable micro effects that occur in thin boundary layers.

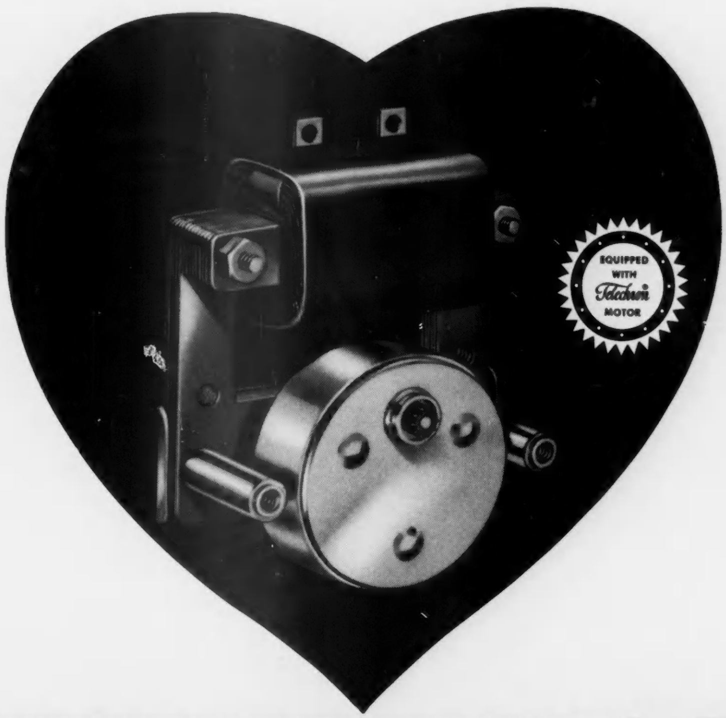
In future studies with this tool, the effects of electrical radiation should be taken into account.

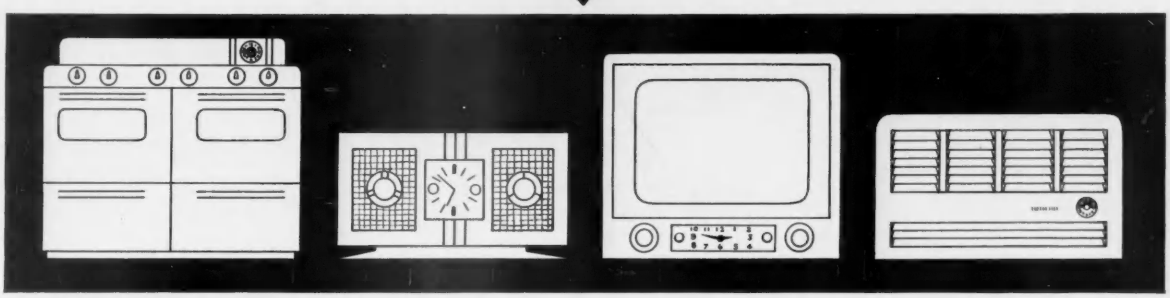
Versatile Tool

The simple method for measuring the resistance of small areas or spots on metal surfaces, which we have described, may be extended to a much broader range of application. The basic tool, a platinum or gold exploring probe formed into a microscopic hairpin, or loop, makes contact with a metal surface over an extremely small area (10^{-8} cm^2 or less). This area is less than one thousandth of the area of a needle point. Because metal surfaces are usually not homogeneous on a microscopic scale, this tool provides a means for determining the nature and magnitude of the local variations without damaging the surface film.

These variations may have an important influence whenever they enter into the electrical surface properties of the metal, and means for studying them has long been needed. The fact that the exploring probe picks up local variations in surface resistance extending through 10 orders of magnitude illustrates the enormous range of variations actually encountered.

Although we have not listed the possible fields of application, something of the breadth or diversity may be noted from the fact that the exploring wire can be used to detect invisible films such as fingerprints, as well as tarnish films on electric contacts. It is already being used in vacuum to measure the influence of films from the atmosphere on the adhesion properties of metals and their contact resistance. Ω





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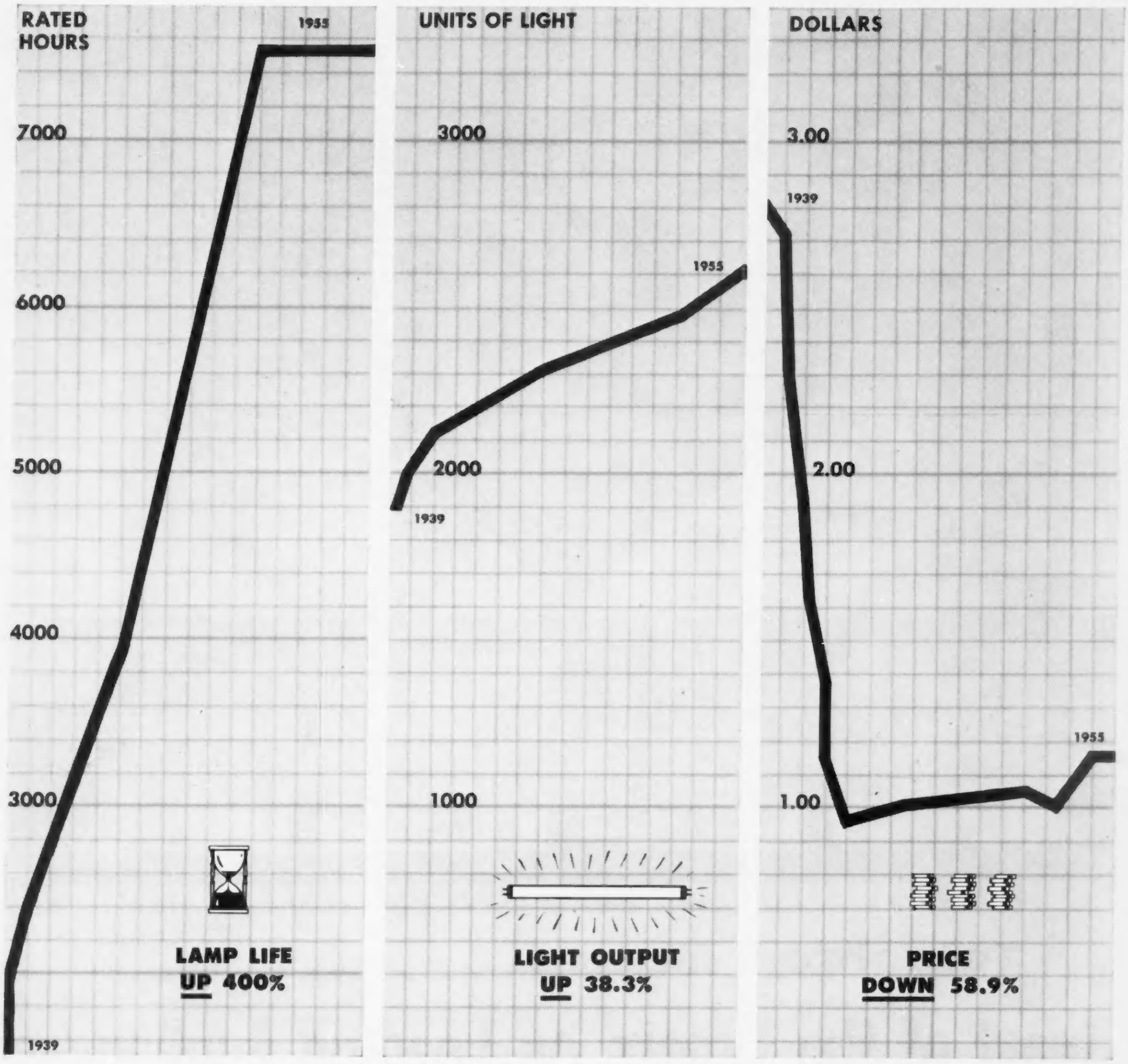

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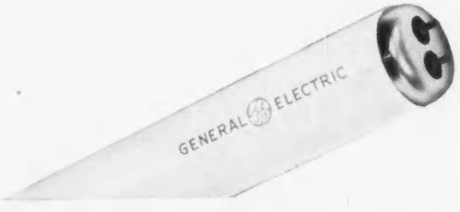

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