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GENERAL ELECTRIC Review

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COVER—Full production of on-the-wall refrigerators began in March 1955 at General Electric's Appliance Park, Louisville, Ky. Available in six mix-or-match colors—white, petal pink, canary yellow, turquoise green, wood tone brown, and cadet blue—this new concept of refrigeration is helping to revolutionize the kitchen. For more details about this appliance, see page 18.

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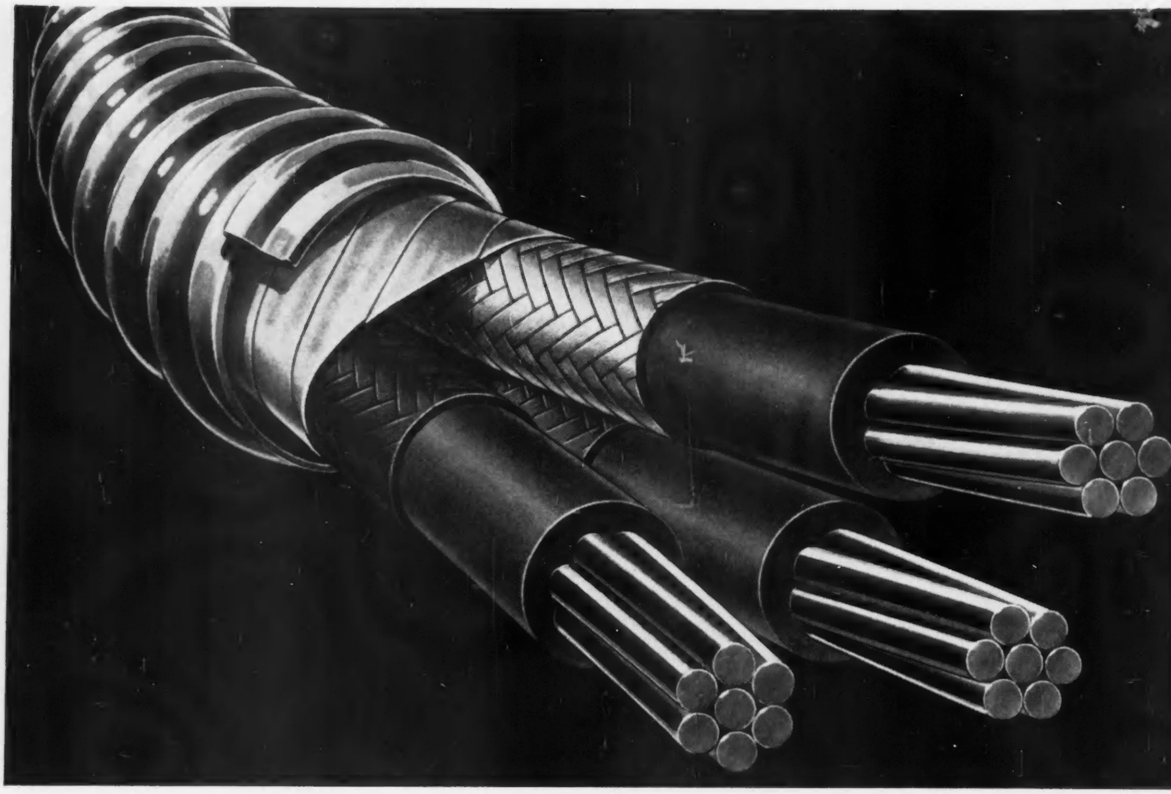


What goes into a G-E Silicone-rubber Cable?

Silicone-rubber insulated cable being subjected to 1400°F flame for 24 hours in laboratory tests. Superior materials and rigid testing go into each G-E cable.

How can G-E silicone-rubber insulated cable keep control circuits in operation—although engulfed in flame? Why can this cable operate at temperatures up to 257° F? What gives it the moisture resistance of the best grades of rubber? In short, what makes it an outstanding cable for vital control circuits, for boiler room installations, and for high-temperature processing operations?

The answers to all these questions are the unique properties of the special silicone-rubber insulation—and each vital property has a history of G-E research, development engineering, and testing. Flame tests at 1400°F proved that this new insulation would remain nonconducting even when completely oxidized. Accelerated-aging tests proved that the cable would dependably withstand continuous ambient or conductor temperatures up to 257°F. Silicone rubber was compounded in many different ways and proportions to produce a cable that would retain its electrical and physical properties through prolonged water-immersion tests—and that could be handled and terminated as easily as an ordinary rubber-insulated cable.

When you specify G-E silicone-rubber insulated cable or any G-E cable you can be sure that the research, knowledge and equipment of the entire General Electric Company have been combined to produce the best possible product. For more information write Section W137-737, Construction Materials Division, General Electric Company, Bridgeport 2, Connecticut.

Progress Is Our Most Important Product

GENERAL ELECTRIC

THE ENGINEER—
AND THE SECOND MILE

It was Dr. William E. Wickenden who brought us the vision of the Second Mile.

From his life experience—great engineering educator that he was—he clearly saw the engineer as he daily worked to bring forth the products of his dreams. Beyond all this he saw the engineer serving his fellow men outside the line of duty. And he quoted from the Sermon on the Mount . . .

> "Whosoever shall compel thee to go one mile, go with him twain."

This, said Dr. Wickenden, is the mark of the professional man. Every calling has its mile of compulsion, its round of tasks and duties, its code of man-to-man relations, which one must traverse day by day if he is to survive. Beyond that lies the mile of voluntary effort where men strive for special excellence, seek self-expression more than material gain, and give that unrequited margin of service to the common good which alone can invest work with a wide and enduring significance. The best fun of life and most of its durable satisfactions lies in this Second Mile, and it is only here that a calling can attain to the dignity or distinction of a profession.

Dr. Wickenden spoke those words in the midst of that era from 1935 to 1950, when the great ability of American industry brought forth, among other things, atomic energy, nylon and the other synthetic fibers, radar and television, the continuous-flow chemical plant, the diesel-electric and gas-turbine electric locomotives, high-octane gasoline, silicons, synthetic rubber, penicillin and other antibiotics, cortisone, the jet engine, magnesium and titanium for structural use, the electrically controlled automatic machine tool, the electronic computer, and the germanium diode and transistor.

It was a great achievement of American industry to bring these products into widespread application in this productive period, although some of them had been discovered or were in existence before 1935. And in each and every product accomplishment there was the hand, the head, and the heart of the scientist and the engineer.

Dr. Wickenden saw the role of the engineer clearly in this period of great engineering and scientific expansion. And he had faith in the engineer from what he knew of him. But in those days it was not so with everyone. Some even asked: "Is engineeering a profession?" Dr. Wickenden answered: "The engineer has been the pioneer in the professionalization of industry, and his task is only begun." There are still many Second Miles to go.

Today, one of the more urgent Second Miles is for the engineer to bring his story to our youth that those of scientific and engineering minds will be encouraged and guided to aim their abilities in these directions. And of equal importance, to assure that the schools of our land are undergirded with teachers of ability and understanding and recognition of these things. It is inspiring to me, as I have been privileged to travel and to meet with engineers, to see the widespread interest and active participation of those who are working in their advancement of these activities. Truly, it is a Second Mile of the engineering profession.

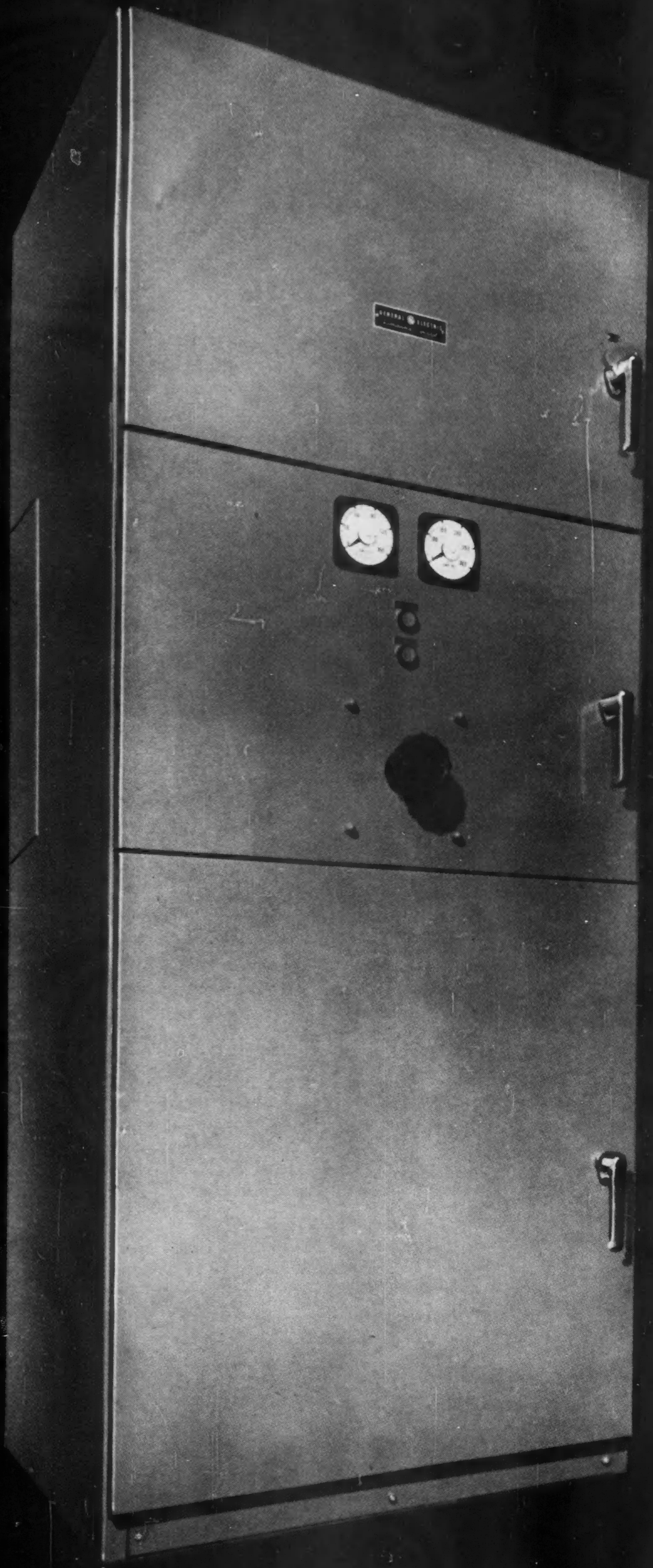
But the scientist and engineer cannot carry the burden alone. Others have this responsibility, too. And to those people the engineer can be most helpful.

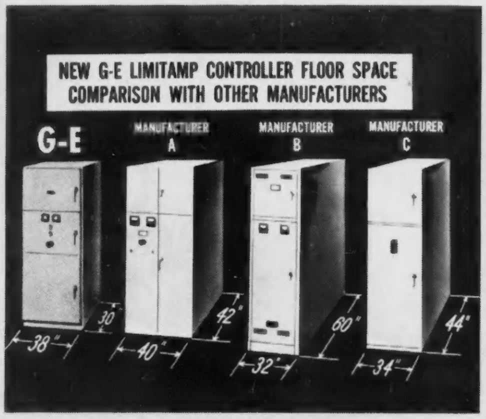
For example, the engineer in particular can bring about an understanding of the situation; he can work for more recognition of what is needed, and what must be done to obtain it. One of the methods of accomplishing this is for him to work with neighbors, friends and leaders in education and government. Thus he can supply the leadership that is essential—a leadership of which he is singularly capable if he will but recognize it. In this fashion he can work for maximum accomplishment in the advancement of the common good.

And in doing so, may he go his Second Mile.

Everett S. Lee

EDITOR





356 SQ. IN. LESS area than next smallest starter.

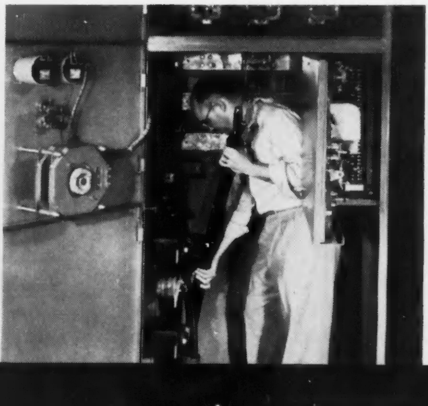
General Electric Announces . . .

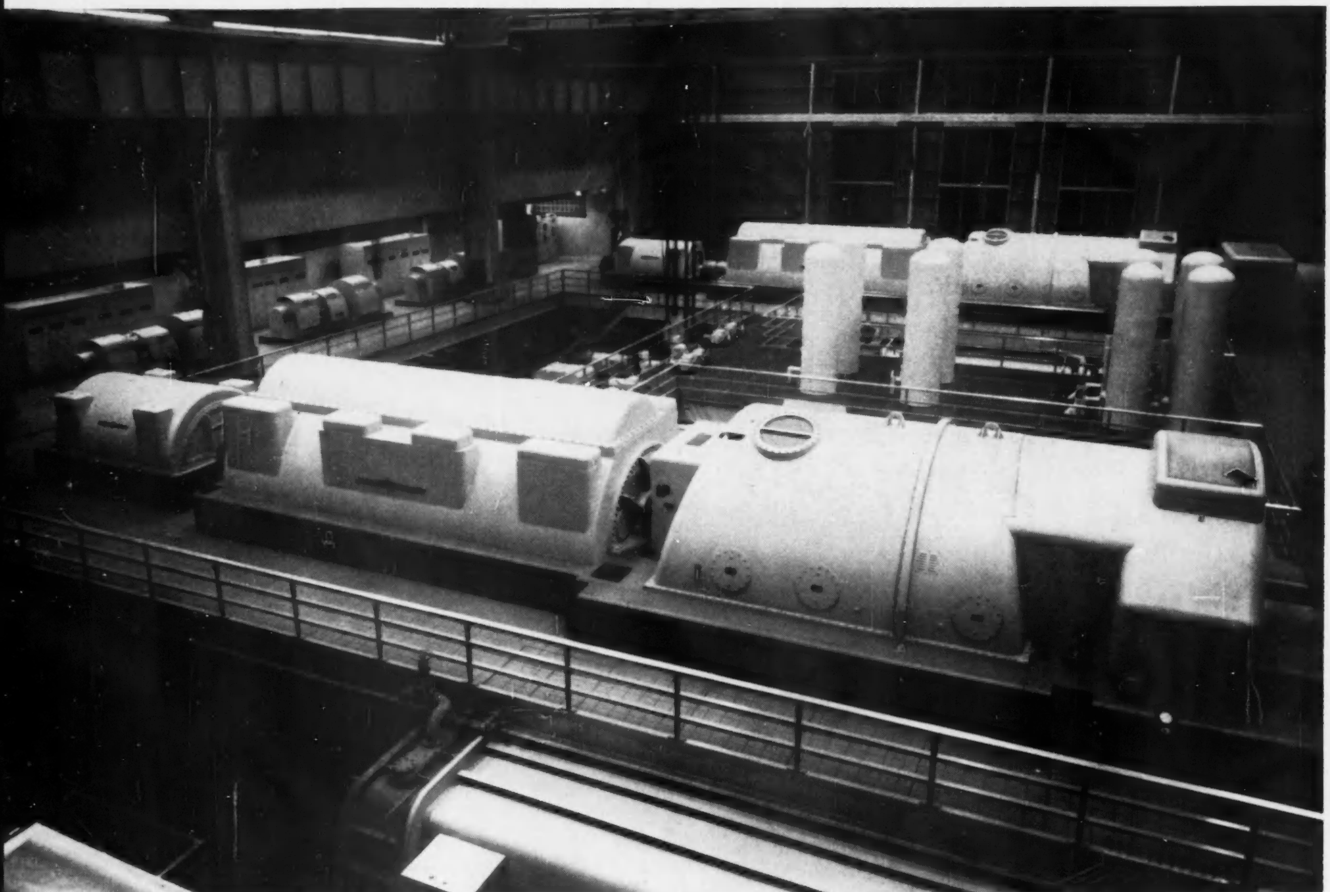
NEW Limitamp*

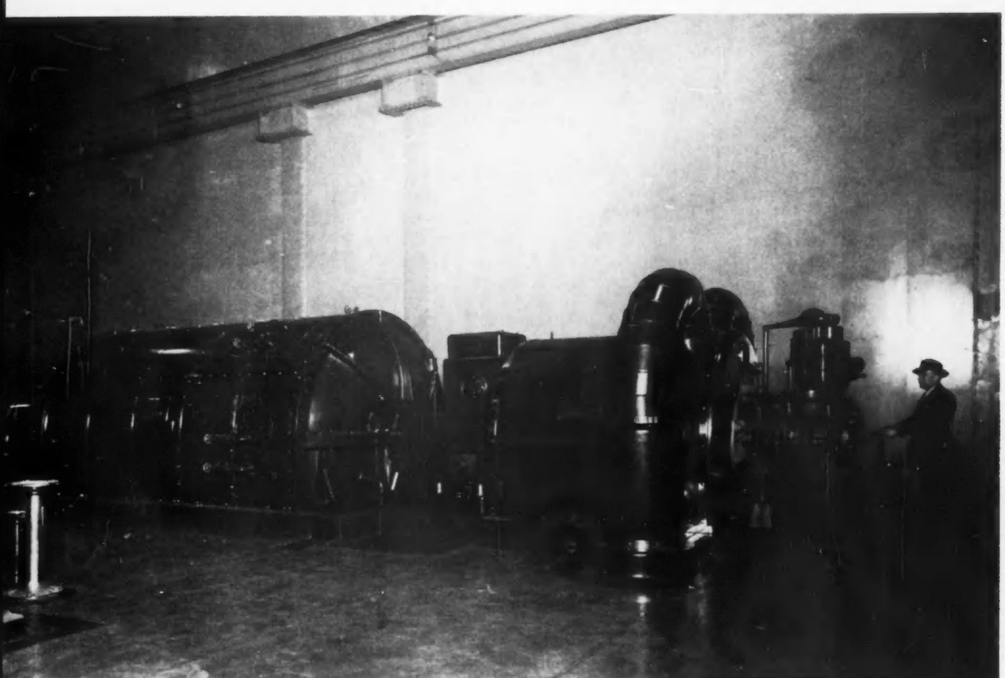
- Gang-operated disconnect switch on all units
- Entirely front connected
- 30-inch depth
- Low-voltage panel hinged to swing out of enclosure
- Contactor rolls in or out of cabinet

NEW DESIGN

INSTALLATION IS SIMPLIFIED. A man can easily enter enclosure to make connections.







NOW Modern turbine-generators incorporating the resuperheat cycle account for more than 85 percent of the 6.5-million kilowatts of large turbine-generators shipped last year by General Electric.

THEN One of the early hydrogen-cooled generators—a 25,000-kw unit installed in 1937—still delivers kilowatts. Its internal cleanliness permitted a number of improvements such as rotor cooling.

Steam Turbine-Generators of the Future

By R. S. NEBLETT

The springboard for realizing still greater efficiency and reliability in steam turbine-generators of the future is the tremendous amount of documented engineering knowledge that has been obtained and applied over the years. Highlighted here are but a few of the vast number of research and engineering accomplishments covering the broad development that has gone into turbine-generators currently in operation. Some long-range developments mentioned will influence the character and performance of steam turbine-generators of the future.

Generator Development

The development of large electric generators has been directed toward overcoming the basic physical limitations that determine how these machines will be built. The challenges involved cover a number of areas of engineering including: magnetics—how to carry more flux; electricity—how to conduct more effectively; dielectrics—how to contain voltage; fluid flow and thermal dispatch—how to convey heat; and mechanics—how to build construction features that permit the proper performance of the preceding functions.

Progress has been made in each of these five areas. And the more prominent landmarks of the past serve to illustrate how generators have benefited from these activities, until today their efficiency and reliability approach and sometimes exceed 99 percent.

All early generator frames (photo, right, next page) were made of iron and steel castings, bolted and riveted together in sections for large structures when the frames themselves became too involved for a single casting. By 1928, these frames had become so large and difficult to manufacture that they presented serious problems in cost, assembly, shipment, and installation. Fortunately, welding techniques were then sufficiently advanced to permit the replacement of these cumbersome structures with fabricated frames (photo, left, next page), creating opportunities for improved manufacturing techniques and an increase in size.

However, even with the advantages of welded structures, frames became so large that they had to be split for shipment. This splitting technique, practicable in a welded frame but difficult with the cast frames, made possible a number of the largest generators. To meet present transportation limitations, the largest generators being designed and built today incorporate similar multipiece frame construction. The outer frame for these units—divided into three sections for shipment—is welded together at the installation site. The inner cage and core assembly are then skidded into position.

Cooling has always posed major problems in generator design. General Electric engineers began studying in 1921 and put on test in 1924 the first hydrogen-cooled generator (Box, page 13). In 1937, GE installed the first commercial machine of this construction, a 25,000-kw unit for the Dayton Power and Light Company—and it is still delivering kilowatts (photo, lower).

This early application of hydrogen in a completely enclosed casing permitted a number of other improvements because of the machine's internal cleanliness. In 1947, an improvement in rotor cooling, termed three-tunnel ventilation, was applied to the rotors of large 3600-rpm generators. Cooling gas flows through the three tunnels so that the copper of the field coil is virtually surrounded by the cooling surfaces. In addition to its obvious advantages, three-tunnel ventilation allows introducing cool gas to the lengthwise center portions of the rotor, thus making long rotors much cooler than otherwise possible.

By 1950, machines had progressed to the point where 160,000-kva 3600-rpm turbine-generators were under construction, and 220,000-kva 1800-rpm machines were operating. The physical size and weight had exceeded the reasonable limit of convenient rail transportation. Today, however, even these large sizes appear to be too small to meet the industry's needs in the foreseeable future. Therefore, the trend of development, which up to this time had sought solutions to the problems of the greater generator capacity both by building larger machines and getting more output from a given size of machine, had to shift its emphasis to obtain greater kilowatt output from a given frame size.

As the result of many years of research and development, two new generator materials are now being used in many of the modern machines. The first, Cond-Al—long a successful field conductor—possesses the physical properties of silver-bearing copper. This aluminum alloy, having only two thirds the conductivity-weight ratio of copper, offers a means of increasing the diameters and therefore the outputs of large high-speed rotors.

The second new material, grain-oriented strip steel for armature punchings, reduces the core losses and increased the flux-carrying ability of the magnetic structure. These two new materials enabled the building of 220,000-kva 3600-rpm units and also 250,000-kva 1800-rpm units in 1953.

Steam-turbine Development

As with the generator, turbine progress, too, is based on long and continuous research and developmental activities.

Considerable turbine-wheel and turbine-bucket breakage occurred 30 to 35 years ago, which led to laboratory investigation of the phenomena of resonant vibration. A high-speed rubber wheel with simulated wire buckets first demonstrated the fundamental wave form of the resonant vibration of rotating wheel-and-bucket systems. This and subsequent laboratory and field testing on full-size wheels and buckets culminated in a rather complete understanding of these phenomena. A system of oscillograph vibration testing reduced this wheel-and-bucket difficulty

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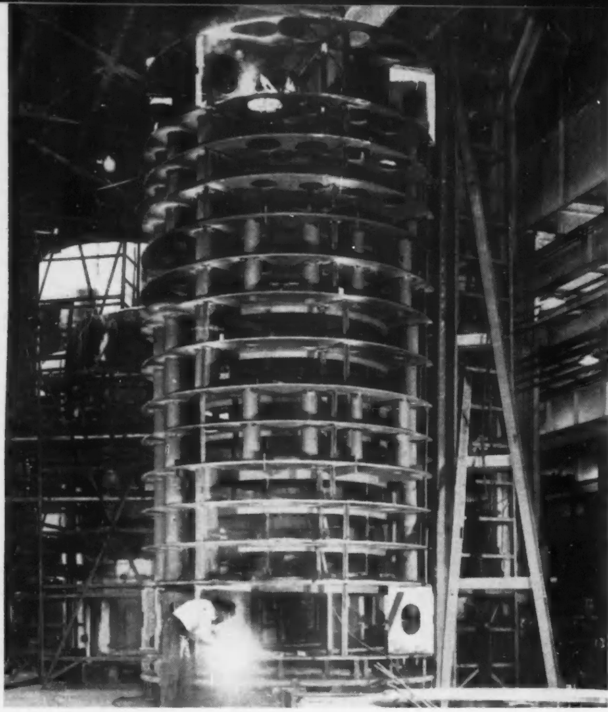
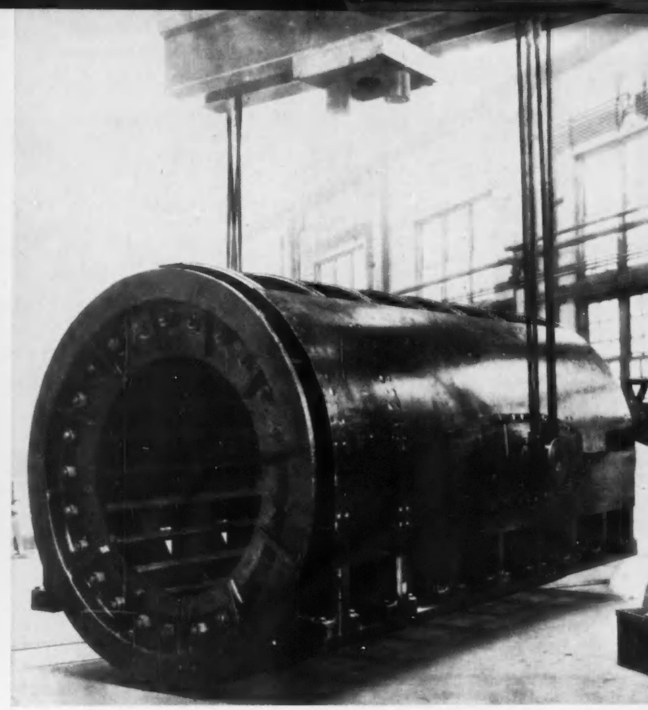
Mr. Neblett began his career with GE on the Test Course 32 years ago. He was awarded the Navy's Certificate of Commendation during World War II while Manager of Aircraft, Federal and Marine Divisions. This was followed by administrative assignments in various atomic energy and nucleonics projects. Presently Mr. Neblett is Manager—Marketing, Large Steam Turbine-Generator Department, Schenectady.





ADVANCED WELDING TECHNIQUES permitted the fabrication of large generator stator frames (left), replacing cumbersome structures made of iron and steel castings bolted and riveted together in sections. This made way for improved manufacturing techniques.

to a small fraction of what it had been. In fact, this technique was widely adopted for designing and protecting turbine wheels and buckets, making way for the modern steam-turbine, gas-turbine, and turbojet design.

A brief picture cannot do justice to the infinite amount of research and development work underlying turbine-bucket design when considering aerodynamic shape, bucket attachment, strength, and protection against resonant-forced vibrations. Extensive research and testing programs have been necessary to provide designers with adequate data for producing reliable machines. Last-stage buckets in two series, 3600- and 1800-rpm, vibrate in 10 to 20 different resonant patterns (photo, left, opposite page). These must be evaluated and the frequencies determined in relationship to the frequencies of the possible exciting forces and the probable magnitudes. The responses must be calculated to determine whether they will safely withstand service.

Materials and Tests

Continued turbine-generator progress involved a tremendous amount of research and development in materials testing. The processing of the residual shell defects, as guided by x ray or by a 15-million-volt betatron and other laboratory tests, constitutes another development necessary for successful turbine casings.

To get forgings not only of the needed soundness and strength but also of adequate ductility and stability requires the most careful co-operation between steel companies, forging manufacturers, turbine-generator engineers, and laboratories. The development of ultrasonic testing has permitted us to spot the slightest defect in forgings 5 feet in diameter and 30 feet long.

Turbine-generator Development

Turbine rotor forgings, after final machining (photo, right, opposite page), undergo a heat-stabilization operation. The rotor is slowly heated while it rotates in the heat lathe furnace at a temperature beyond a certain critical value. This treatment is also applied to large generator rotors. When heated, most forgings bend or become crooked, the amount depending on the structure of the material and the strains left in it by machining. When the limiting temperature is reached, the forging quickly returns to a nearly straight condition, maintaining it throughout the cooling and subsequent heating cycles.

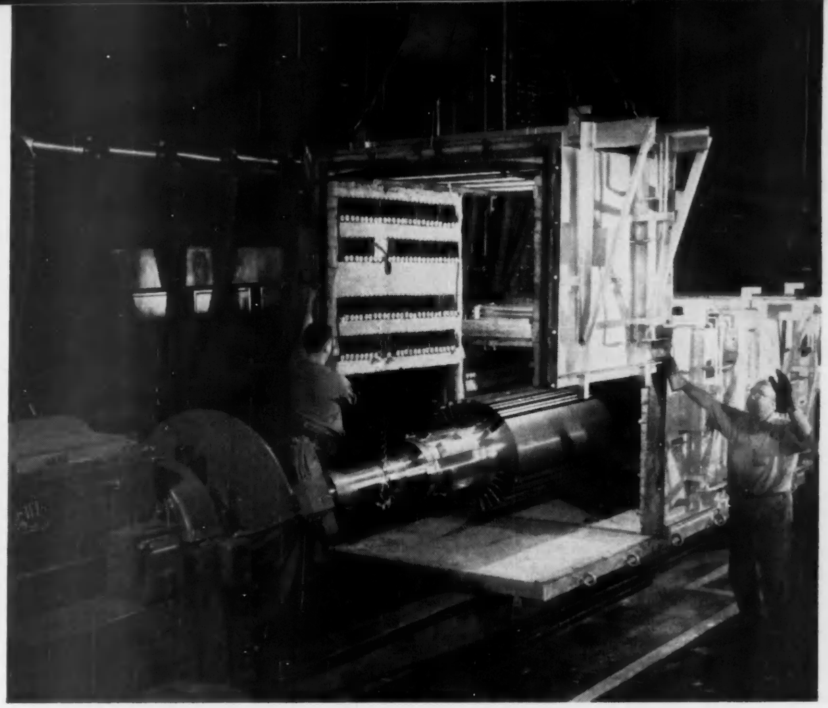
Another extensive study concerns the critical speeds of multiple spans of turbine-generator shafts that require as many as six bearings for support. Such shafts have many so-called critical speeds and these in turn are affected differently by the resilience or softness in the bearings themselves.

These critical speeds can be effectively determined. Based on the data taken in a large number of tests, IBM punch-card calculators quickly solve the many simultaneous equations. Careful analyses of these calculations and subsequent redesigns and recalculations permit the design and building of machines that have much less sensitivity to unbalance and hence better running characteristics than were possible a few years ago.

Although significant, these tests are not enough. A turbine-generator manufacturer must also rely on tests of the complete unit in the customer's plant to obtain the final over-all results. Installing load-absorbing equipment, boiler-plant auxiliaries, and condensers to make factory full-load tests on these large machines would be practically impossible. Furthermore, such equipment would be obsolete within a few years. Consequently, the manufacturer must rely on the good will and co-operation of users in making these tests in their plants.

The bulk of the 117 machines placed in service in the past 25 years have met their guarantees with a substantial margin (illustration, top left, page 12). A few have not, but most of these have been corrected by changes in construction, design, or a retest after the unit was put in better operating condition. The average of all these points is 1.2 percent better than guarantee. Also, it is well to recognize that throughout the

LAST-STAGE BUCKETS of the 3600-rpm series vibrate in 10 to 20 resonant patterns.



HEAT-STABILIZATION TREATMENT that generator rotor forgings and large generator rotors undergo has resulted in greatly improved turbine-generator operation.

years the pounds of coal per kilowatt-hour has constantly decreased (illustration, top right, next page).

Today's Turbine-generators

Some of tomorrow's steam turbine-generators are here today. The modern reheat turbine with the reintroduction of the resuperheat cycle in 1950 has practically taken over the industry. The percentage of G-E units sold with this reheat feature versus nonreheat has grown from 19 percent of our total kilowatts shipped in 1950 to more than 85 percent of the 6.5-million kilowatts of large turbine-generators shipped in 1954. The first of this new line of machines incorporated the opposed-flow design and the confinement of high-temperature steam in the middle portion of the casing. Approximately 100 units, ranging from 50,000 to 125,000 kw, have been built and shipped or are on order. The machines (photo, page 13) in operation have an outstanding record of reliability and economy. The simplicity of this unit, whose length and foundation area is practically the same as a single-casing nonreheat machine, has done much to reinstate the practice of resuperheating with its improvement in economy.

The next size 3600-rpm tandem-compound unit for resuperheat incorporates a triple-flow low-pressure element and is built in capacities up to 175,000 kw.

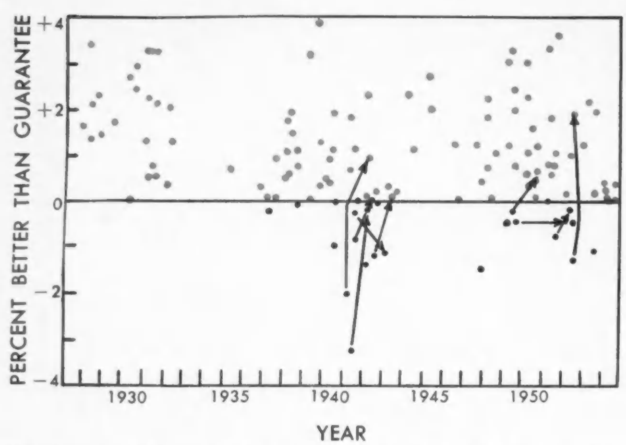
A further development of these 3600-rpm triple-flow machines is a unit for operation at 2300-pounds pressure at 1100 F initial temperature and 1050 F reheat. Here again, a relatively small portion of the high-pressure turbine is exposed to 1100 F steam. Two of these 145,000-kw units (photo, top, page 8) are in operation at the Kearney Station of the Public Service Electric and Gas Company, NJ. These units are typical of turbine construction that is being carried right on up to 250,000 kw, with 2300-pounds pressure, and to these high temperatures, if desired.

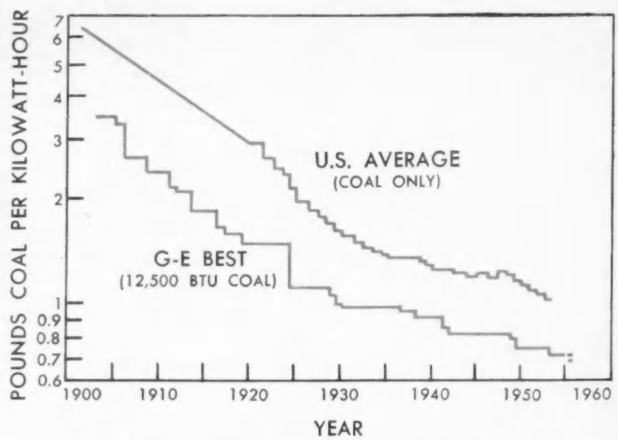
The world's largest 3600-rpm turbine-generator unit installed to date is located in the Cromby Station, Philadelphia Electric Company. Placed in service during December 1954, the generator is rated 220,588 kva at 0.85 power factor and 30-psig hydrogen pressure and incorporates conventional ventilation.

As in tandem-compound units, practically all the cross-compound machines recently built and on order incorporate resuperheating. Cross-compound units consist of two separate turbines. The steam flows first through the high-pressure turbine and then crosses over to flow through the low-pressure turbine. Reheating can be done as steam goes from one turbine to the other or as it expands through the high-pressure section.

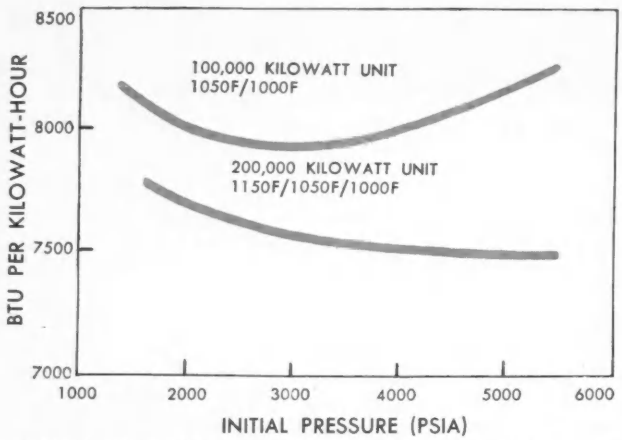
Cross-compound turbines have been designed and built with many variations of load splits and arrangements. One basic arrangement, however, has proved to be most generally satisfactory. The high-pressure turbine is similar to the high-pressure section of the tandem-compound turbines. The primary steam enters at about the center, flows forward and out to the reheater, re-enters adjacent to the primary admission, and flows toward the generator and out to the crossover pipes to the low-pressure section—a double-flow turbine with the exhaust ends facing each other. Half of the flow from the high-pressure section enters at each end and flows toward the center and down through a common exhaust opening to the condenser.

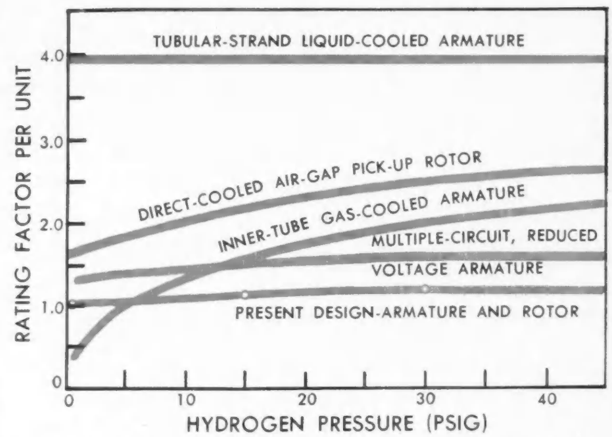
Projecting this unit to the steam turbine of tomorrow leads to a new cross-compound unit for larger capacities and for installation in areas where high vacuum is available. The first of these new units went into service during 1954 in the Will County Station of the Public Service Company of Northern Illinois. Several additional machines of larger capacity but similar design are being installed in the Kyger Creek Station of the Ohio Valley Electric Corporation as well as the Clifty Creek Station of the Indiana and Kentucky Electric Corporation. Another such unit is being constructed for the Detroit Edison Company. A similar one with longer last-stage buckets and with side exhaust to the condensers will be installed in the State Line Generating Station





MAJORITY OF TURBINE-GENERATORS in service since 1930 met or exceeded original guarantees. Most of the few machines below par have been improved (black dots). The steady decrease in coal consumption results from increased turbine-generator efficiency.





INTERNAL HEAT-RATE REDUCTION—smaller on the high-volume flow of a large-capacity 200,000-kw turbine—shows net improvement for the higher pressures. Direct cooling plus other past developments indicate future outputs twice those obtainable today.

of the Commonwealth Edison Company.

Disregarding new units with turbine elements incorporating such design features as single-casing axial-flow exhaust, and high-flow double extraction, we come to the two big factors in the turbine-generator of the future—supercritical steam pressures in turbines and direct cooling of generators.

Tomorrow's Turbine-generators

The American Gas and Electric Company plans to install at the Philo Station a unit operating at supercritical steam conditions of 4500 pounds initial pressure. The initial temperature is 1150 F with two resuperheats—1050 and 1000 F. The first unit of this type, 3600-rpm tandem-compound, will be rated 125,000-kw maximum capacity, chosen to match a predetermined boiler flow. The high-pressure element is essentially a 4500-pound topping unit exhausting at 1240 pounds pressure into a resuperheater where the steam is brought back to the intermediate turbine at 1050 F.

The purchaser and GE acknowledge that this high pressure and temperature may not be economically justified for this size machine, but prudent consideration of the risk involved indicated that it would be better to make the first installation on a unit of approximately this capacity rather than on a 250,000-kw or larger machine. It is expected, however, that this cycle will be admirably adapted to larger size units, and their designs are being carried forward simultaneously with the design of this unit.

Although certain design and manufacturing problems are yet to be solved, the basic approach was easily resolved by agreeing that the best way to build for the future was to utilize the success of the past. Therefore, for the size under consideration, the successful Dunkirk design was employed—so called because the Dunkirk Station of the Niagara Mohawk Power Corporation in New York State was the first station to utilize the outstanding benefit of the new modern reheat designs. In front of this turbine will be a topping unit designed to take advantage of the supercritical pressure and the high-temperature steam from the boiler.

Current studies indicate that supercritical steam pressures are suited only for large-capacity turbines. The net heat rate of a 100,000-kw unit (illustration, lower left) cannot realize further heat-rate reductions for initial pressures higher than 2500 to 3000 psia. The reduction in initial volume flow resulting from increasing initial pressure causes a loss in internal turbine efficiency that offsets the theoretical gain from higher pressures. This reduction in internal efficiency is smaller on the high-volume flow of a 200,000-kw turbine, thus continuing to show a net improvement for the higher pressures.

With the larger turbine capacities expected in the future, and assuming that initial and reheat temperatures will continue increasing at their historic rate of 12 F per year, by 1975 the best station would have steam temperatures of 1400 F/1300 F/1200 F. With such temperatures it appears that 10,000-psi steam pressure is as high as desirable.

The most probable generator advances to come will evolve through increasing the outputs of machines of present-day dimensions rather than an appreciable increase in physical size. A promising field in this area lies in perfecting improved methods of conductor cooling.

To cool conductors in the generator armature and field windings, the heat generated by losses in the conductors will be removed directly from the conductors themselves instead of being dissipated through the major ground insulations.

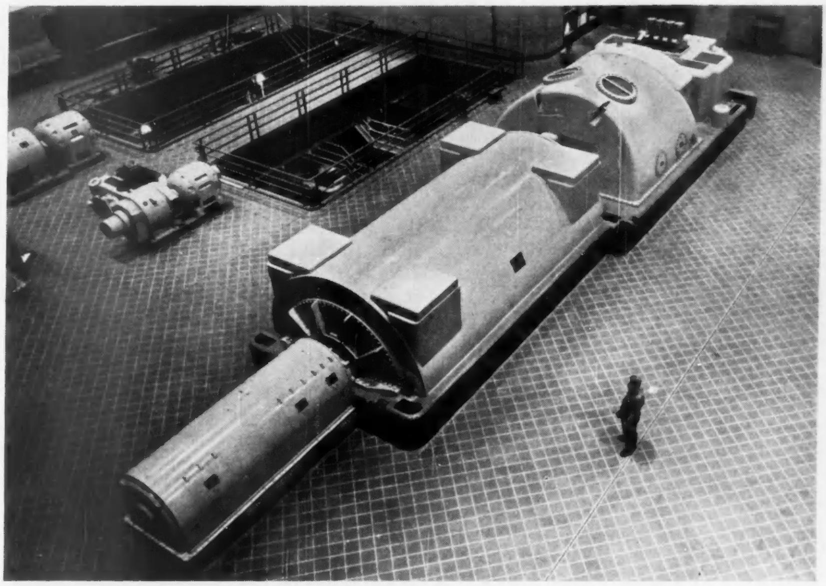
The two types of conductor-cooled circulating systems are gas and liquid cooling. Although each has an area of application, the liquid-cooling method is by far the most effective and versatile means of cooling armature windings. Both systems are currently under construction in 3600-rpm generators: gas cooling of both field and armature in a 156,250-kva machine and a combination of a gas-cooled field with a liquid-cooled armature in a 260,000-kva unit.

Still further possibilities are encouraging for increasing the outputs of generator frames by employing developments of the past plus conductor cooling (illustration, lower right, opposite page). The "rate-up factor" is the ratio of the possible output using direct cooling to the present output of a given frame. The curves indicate that outputs of twice those obtainable today are a distinct possibility.

And the Future?

General Electric's basic thinking concerning tomorrow's generators is to extend the application of present types of generators using conventional cooling systems by improving design and techniques and to pursue further development in application of conductor-cooled generators.

Although these designs are currently being developed and used for 3600-rpm machines, the same combinations of cooling could be developed and applied to 1800-rpm generators. Thus GE can provide generators with a flexibility and versatility of design, utilizing today's conventional cooling system or the various combinations of conductor cooling as will be dictated by the economics of the future.



TODAY'S TURBINE is but the forerunner of future machines that will continue to supply an ever-increasing amount of reliable and inexpensive power.

A MILESTONE IN HYDROGEN-COOLED GENERATOR HISTORY

In the early 20's, Dr. W. R. Whitney, Director of GE's Research Laboratory, Schenectady, wrote to Chester W. Rice, also of the Laboratory, the following longhand memo suggesting that a generator be cooled with hydrogen.

Dear Chester:

Could I create an interest for you in a series of fool stunts which have, I think, the promise in them of some useful outcome?

I'd like to study experimentally (not on paper) because I expect the unexpected when we deal with such a complex subject, and this is it.

I want to take a motor-generator set and enclose it gas-tight, replace the air with hydrogen and run the thing. When this is done, I want to see what the effect was (not before). I want to know whether it ran (1) easier (friction against gas skin friction), (2) cooler because of thermal conductivity of the hydrogen, (3) safer for the insulation because it might stand higher temperature in H_2 than in O_2 without decomposition, safer because it might arc less and electrically break down less easily because in H_2 arcing distances are greater. (4) perhaps the speed attainable economically would go up with the H_2, and speed in such things as turbine alternators and Alexanderson machines is important. This might all lead to substitution of H_2 by CO_2 or vacuum, but we could hardly carry through a series of practical tests without adding a lot to our knowledge, and we might find a real useful application. Don't worry about cost of leakage or danger; I've got that done enough already.

Whitney

Continually growing demands for larger and larger blocks of power plus the probable need for 250,000- or even 300,000-kw units raise the question: How large can turbine-generators get? There probably is no truly definite answer. However, we believe that turbine-generator units of the future will neither be limited by pressures and temperatures of the steam to the turbine nor by the generator output. Rather, limitations will be set by factors over which steam turbine designers have no control, such as economic factors and over-all system design.

Therefore, whether coal, oil, gas, atomic energy, or even the sun's heat furnishes the fuel, a turbine-generator will undoubtedly be used to convert heat into electricity for years to come. Ω

Research Is Many Things

***Review* STAFF REPORT**

To show you the inner workings of one component in General Electric's Research Laboratory in Schenectady, the REVIEW obtained the transcript of a presentation made by some members of the Physical Chemistry Section to a March 1954 conference on gas-turbine combustion problems. Seventy Company engineers attended.

The particular problem tackled by the Physical Chemistry Section involved corrosion difficulties experienced with power-plant and locomotive gas turbines that burned Bunker C oil—the tar-like residue remaining after gasoline, kerosene, and other valuable products have been refined from crude petroleum.

As the story unfolds, you'll see how the Section approached the subject and why research to guide development activities in field equipment was the paramount need. Remember that the work described in the transcript is only one phase of the over-all diversified attack on these problems throughout the Company.

Members of the presentation team were Drs. Herman A. Liebhafsky, Henry H. Marvin, and Edward L. Simons. Liebhafsky is Manager of the Physical Chemistry Section: Marvin is a Liaison Scientist for the Chemistry Research Department, and Simons is Research Associate in the Section. Color slides supplemented the presentation that was made in the Laboratory's auditorium.

The actual unedited transcript follows with certain unimportant items deleted.—EDITORS

LIEBHAFSKY: We have only a few minutes to look at about five man-years of work done by the Physical Chemistry Section in connection with the burning of residual fuels in land-based gas turbines.

The first meeting I attended on this problem was held in Alan Howard's office four years and three days ago. [Howard was then Division Engineer of the Gas Turbine Engineering Division.] At that meeting I had the feeling, "This is where I came in." Why? Because in many ways the problem resembles that of the mercury boiler on which some of us worked 20 years ago. Let's look at the common features in these two situations (Slide 1).

What conclusions can we draw? The second and third features leave no doubt that field tests will be vital.

The fourth feature suggests that a "pink pill" ought to be sought. [A "pink pill" is essentially a one-shot treatment to take care of all of one's ills.] The fifth makes it certain that a satisfactory field test will be difficult to arrange. The sixth indicates that the Physical Chemistry Section, which has diverse responsibilities to the Company and the Laboratory, cannot commit enough effort to the problem to do all the research that seems desirable.

Well, what has Physical Chemistry been able to offer (Slide 2)?

In this diagram, I show the principal activities of the Physical Chemistry Section—consulting, research, and analysis. These activities act on each other to form a regenerative loop. The five man-years of effort was divided among these three activities.

At the meeting in Alan Howard's office, I suggested that the engineers take the lead in looking for pink pills, that the Physical Chemistry Section cooperate with the Large Steam Turbine-Generator Department's Materials and Processes Laboratory in analysis, and that the Physical Chemistry Section do research on the corrosion of metals at high temperatures. I welcomed especially the opportunity to set up such a research program, because it fitted in with our corrosion activities.

Although research is what we like best to do, in cases like the present we have to put analysis first. Why? Let's look at some of the troubles that the pink pills will have to cure. Physical problems first (Slide 3).

The slogan "What sits down, counts" is intended to emphasize that the deposits on the turbine surfaces are of primary concern. No matter what is in the fuel or what is added to the system, we are most primarily concerned with what stays behind. The rest of the list is obvious enough—notice that each of the slogans indicates a need for analytical work.

Corrosion problems next . . . (Slide 4) . . . but in very simple form.

You notice the two arch-criminals, vanadium pentoxide and sulfur, with sodium as accomplice. Sodium, we think, is objectionable mainly because it traps sulfur to form sodium sulfate, which leads to low-melting deposits and which can attack alloys—especially those containing nickel. The two criminals, if present together, can interact to modify each other's behavior.

How do we know where we are (Slide 5)?

Take the second question. Ought we to worry first about vanadium pentoxide or about sulfur? Even though we find vanadium pentoxide on a turbine surface, how do we know it has given trouble? Is sodium sulfate objectionable mainly because of its low melting point or because of its chemical effects? How do we know whether a pink pill is effective? (Please don't think I underrate pink pills. I only wish I could think of an all-purpose remedy for gas-turbine troubles.)

In cases like the present, the analytical chemist is somewhat in the position of the veterinarian. Neither set of patients can talk, but you must find out what they would say if they could.

Ed Simons will now give you a single case history chosen to illustrate what I've tried to say.

SIMONS: In the spring of 1952, a 5000-kw gas-turbine installation at the Rutland station of the Central Vermont Public Service Corporation began a period of operation during which the regular fuel supply of Bunker C oil was supplemented by the injection into the combustion system of a suspension of calcium carbonate in diesel fuel. After about 800 hours of operation, the turbine was dismantled and parts sent to this laboratory for examination.

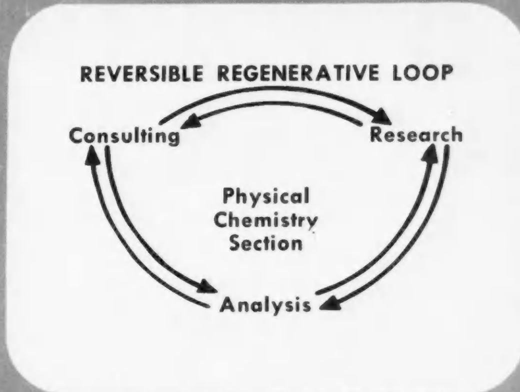
A section of the first-stage nozzle as it was received by us is shown in Slide 6. The most significant feature is the marked nonhomogeneity of the deposits, both with respect to color and texture. The light-colored ash is a fine powder which can be wiped off with one's finger or washed off with a gentle water stream. The dark deposit is hard and so tightly adherent that it can only be removed with severe chopping or abrasive action.

What was the cause of this range of color and texture? Spectrographic analysis of both light and dark ashes at the Materials and Processes Laboratory showed them to be qualitatively the same. Chemical analysis at this laboratory showed that the principal components of both deposits were sodium

SOME COMMON FEATURES

1. Power-generating equipment
2. Hot spots possible
3. Several serious troubles (relative importance unknown; all complex)
4. Help urgently needed
5. Partial or complete customer control
6. Extensive research programs possible

SLIDE 1



SLIDE 2

SOME PHYSICAL PROBLEMS

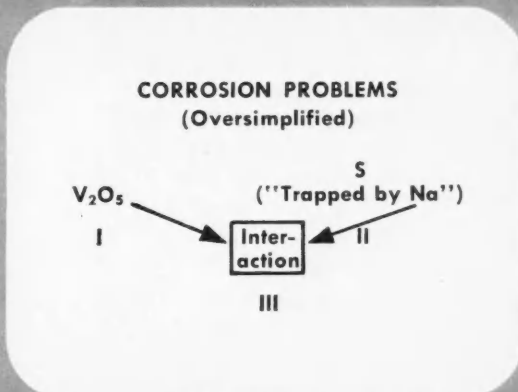
Deposition

("What sits down, counts.")

Melting and Sintering

("Keep the melting point up.")
("Keep sodium out.")

SLIDE 3



SLIDE 4

SOME QUESTIONS ANALYSIS MUST ANSWER

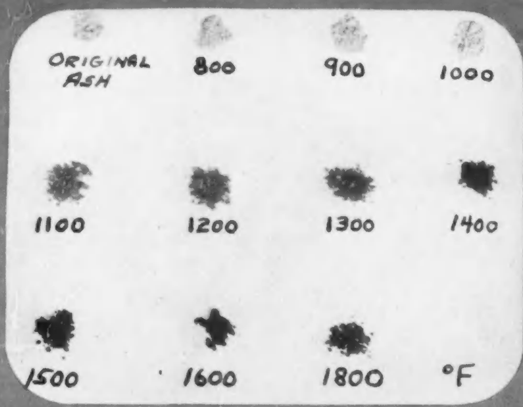
1. What are the troubles?
2. What is their relative importance?
3. Are the remedies effective?

SLIDE 5

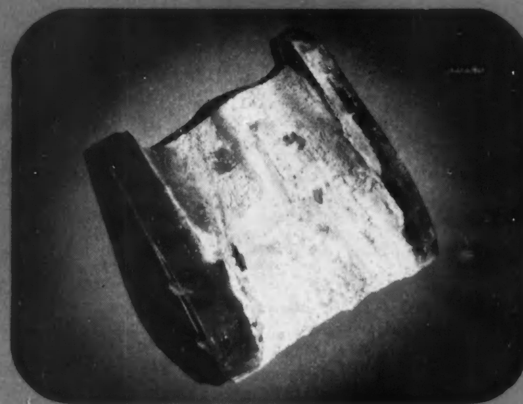
SLIDE 6

and calcium sulfate, with the sodium-to-calcium ratio being higher in the darker than in the lighter areas. The color of the ashes is produced by the metal oxides that they contain, principally those of vanadium, iron, nickel, and chromium.

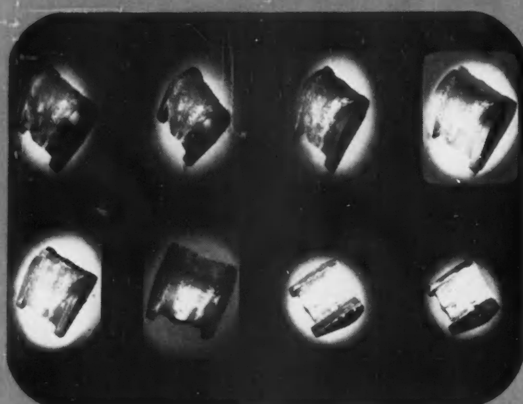
This quantitative difference, of itself, is not sufficient to explain the markedly different appearance of the two deposits. Experiments soon disclosed that another variable was temperature. Small samples of the light-colored ash were placed upon pieces of platinum foil and heated in a furnace for 20 minutes at various temperatures. The results are shown in Slide 7. You will notice the progressive darkening of the ash as the temperature is increased, and, in the case of the samples heated to about 1600 F and higher, sintering has occurred. The high-temperature ashes are no longer soft, loose powders but are hard cakes, strongly adherent to the platinum sub-



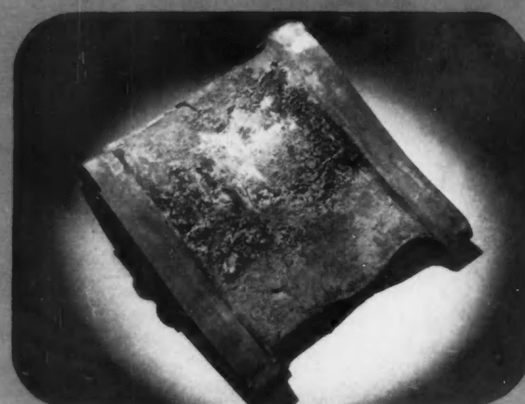
SLIDE 7



SLIDE 8



SLIDE 9



SLIDE 10

SLIDE 11

PHYSICAL CHEMISTRY SECTION—SUGGESTED FUTURE PROGRAM

1. Withdraw from present analytical work.
2. Apply x-ray fluorescence.
3. Resume corrosion studies.

SLIDE 12

strate and staying on it even when the platinum sheet is upside down.

The next step was to demonstrate that this effect of temperature could also be observed on the nozzle partition itself. The first-stage nozzle partition shown in Slide 8 was subjected to successive half-hour exposures in a furnace at temperatures of from about 1300 to 1850 F in approximately 90-degree increments. After each heating period, the sample was photographed and a composite of these pictures prepared (Slide 9). The same general increase in sintering and darkening of color was observed in these experiments. To show more clearly the change in color and texture, a close-up was taken of the partition after its exposure at about 1650 F (Slide 10).

A word of caution must be inserted at this point. All turbine deposits do not show this same variation of color and texture with temperature. There is no general relationship between temperature and color and texture that is applicable to any turbine deposit. My purpose in performing these experiments was to demonstrate that, for the type of deposit formed on this turbine during this period of operation, the color and texture of the ash provided a graphic illustration of the temperatures to which it had been subjected. These experiments were not designed to set up a color chart in terms of which the temperature history of any ash deposit could be determined. They were designed to give support to the hypothesis that the nonhomogeneity of the deposits on this particular first-stage nozzle section was caused by a nonuniform combustion process which resulted in a wide spectrum of temperatures over the partitions.

In the case of the deposits shown in these figures, why did increasing temperature produce the observed darkening and sintering? The answer to this question was found in an examination of data available in the chemical literature on the melting behavior of mixtures of sodium sulfate and calcium sulfate. Without going into all of the details, it is sufficient to say that these data plus experiments performed here in the Laboratory show the following facts. . .

- All mixtures of sodium sulfate and calcium sulfate containing more than 33 percent of the latter will undergo at least partial melting at about 900 C (1652 F). The higher the temperature or the higher the percent sodium sulfate in the ash the larger will be the relative portion of the ash that melts, and the molten phase will be richer in sodium sulfate than the ash from which it forms.
- The colored oxide constituents of the ash, particularly iron oxide, not only get darker in color as they are heated, but they are insoluble in the molten salt phase and tend to segregate at its surface. This latter point is illustrated in Slide 11, which shows a cross section through a partition. The dark ash deposit is actually dark only at the upper surface where the colored oxides have concentrated. The underlying layer is a mixture of the white sulfates of sodium and calcium.

Thus it is a combination of the melting behavior of sodium sulfate, calcium sulfate mixtures, and the insolubility of the colored metal oxides in the resulting liquid phase that explains the fact that increasing temperature could convert the light, homogeneous fine powder into a dark, hard, and heterogeneous scale.

There are two undesirable consequences of this melting behavior of sodium sulfate-calcium sulfate mixtures.

- The heavy deposit build-up that can result reduces operating efficiency of the turbine by reducing air flow space.
- Under cycling-reducing and oxidizing conditions, sodium sulfate deposits, above 800 C (1472 F), can be very corrosive to alloy steels.

These undesirable consequences of the presence of sodium sulfate in the deposit justify the large-scale and successful efforts by the Gas Turbine Engineering Section to wash out the sodium compounds from the oil before it is burned.

In this presentation I have tried to show, in terms of a case history, how the Analytical Chemistry Unit at the Research Laboratory tried to assist directly in the solution of technical problems by supplementing formal chemical analysis with experiments and interpretation which give added significance and meaning to the results of the analysis.

LIEBHAFSKY: So much for analysis. Now for a quick look at research. Marvin will speak mainly on his work with vanadium pentoxide.

MARVIN: The research I wish to summarize was directed specifically at the reaction of vanadium pentoxide with Type 310 stainless steel (25 Cr—20 Ni).

[The preliminary portion of Marvin's report deals primarily with properties of vanadium pentoxide and its corrosion reaction with certain steels at various temperatures. From the experimental results observed in the reaction of vanadium pentoxide with a number of metals and alloys, an hypothesis has been proposed that predicts good resistance to this chemical by a material whose normal protective film consists of oxides of chromium, aluminum, or silicon.]

I wish to speak briefly of the broader aspect of the Bunker C corrosion problems as I have observed it in the literature, as well as in the various experimental investigations in Schenectady. It appears to me that the role of vanadium pentoxide in the practical corrosion reaction is subject to question. Certainly, the principal corrodent is sulfur in the form of sulfide. Of the field specimens examined, none have failed to show evidence of sulfide deposits under the scale. This indicates the existence of a localized reducing condition. We know the vanadium pentoxide does not attack stainless steel under reducing conditions. Then the active agent would appear to be sulfide with the vanadium pentoxide serving as an oxygen source and carrier.

The effort required to complete the investigation of the attack by vanadium pentoxide is a laboratory study of the efficacy of such additives as calcium and magnesium.

In summary, the work I have reported and that which I have observed suggest the following salient points. . .

- The primary solution to the corrosion problem lies in avoiding overheating. The attack in both vanadium pentoxide and sulfide becomes rapid at temperatures slightly above normal operating temperatures of the gas turbine.
- The deposition of sulfur as sodium sulfate can be reduced by washing sodium from the oil, as is being done in the Rutland tests. This decreases the scale and should greatly reduce the attack by sulfide.
- In my opinion, the importance of attack by vanadium pentoxide has been exaggerated, and I suspect that the primary role of the vanadium pentoxide is that of abetting the attack by sulfide. The use of alloys other than those with high nickel content should minimize this co-operative attack.

LIEBHAFSKY: Finally, a few words about our suggested future program (Slide 12). . .

We want to prove that x-ray fluorescence will simplify further analyses. And we want to resume our corrosion studies as a long-term research activity.

EPILOGUE: With this presentation, the Physical Chemistry Section bowed out of the immediate problem of corrosion in gas turbines except for some additional studies on the use of the x-ray emission spectrograph to detect traces of heavy metals in Bunker C oil.

The program currently being used by GE's Gas Turbine Engineering Section at the Rutland station involves. . .

- Washing of the oil to remove water-soluble sodium compounds that would otherwise become harmful deposits of sodium sulfate
- Addition to the oil of a magnesium compound to combine chemically with the vanadium pentoxide and thus reduce danger of corrosion by this agent.

Operating experience shows that the total cost of treating Bunker C oil is one-half cent or less per gallon.

Oil already treated by the producer is used for General Electric gas-turbine electric locomotives on the Union Pacific. Ω

Reaction to the wall refrigerator is overwhelming. Originally considered a luxury item, public interest has become so widespread that builders throughout the country are including it as standard kitchen equipment.

New Concept in Refrigerator Design

By K. B. McEACHRON, JR.

From the beginning, attempts to improve accessibility in household refrigerators have characterized the progress of this appliance. In the first electric refrigerator, a refrigerating machine merely replaced the ice chest, and the storage space remained difficult to see and reach.

The first step toward improving the accessibility shifted the machine from the top of the cabinet to the bottom. As the public demanded more and more refrigerated volume, the space required by this mechanism was reduced —sacrificing accessibility for increased volume.

Revolving shelves, introduced in the largest 1953 refrigerators, make every item readily available to the customer. In the latest combination refrigerator food-freezer model, the freezer is located below the refrigerator portion because the freezer is used less frequently. Although some thought was given to hanging a refrigerator on a wall or placing one on a counter, the sheer bulk of such a refrigerator formerly prevented serious consideration of this possibility. Occasionally, some of the smallest refrigerators were built in.

In the average-size refrigerator, insulation consumes nearly as much volume as food storage—a serious concern of refrigerator manufacturers. However, reducing insulation thickness produces other problems.

Thinner Insulation

Because thinner insulation increases thermal losses, more heat must be removed from the refrigerator to maintain satisfactory operation. More efficient compressors now in use will help to keep the additional power consumption to a minimum even with this thinner insulation.

Reduction in temperature of the outer case, possibly resulting in sweating, presents a second and much more serious problem. Heat flowing through a refrigerator wall (illustration, page 21) must pass through five areas: air film at the outer surface, enamel and steel of the outer case, insulation, steel and porcelain enamel of the liner, and air film at the liner surface. As the amount of insulation thickness is decreased, the liner temperature rises and the outer-case temperature falls by about the same amount. When the outer-case temperature equals the wet-bulb, or dew-point, temperature of the surrounding air, water vapor in the air condenses on the outer case. Thus a definite design limit exists for the minimum outer-case temperature under the most extreme humidity and temperature conditions such as prevail in the Gulf States for several months each year.

Attempts have been made within these limitations to minimize the amount of refrigerator insulation. In their constant search for an insulation with lower thermal conductivity, engineers and scientists have considered scores of materials —even gas-filled and vacuum insulations. However, the latter insulations have not yet justified mass production of refrigerators that would be sufficiently low in cost and high in performance.

During the search for new insulations, the importance of thinner insulation to the customer has been the subject of considerable discussion. How much will she pay for it? An application requiring minimum exterior dimensions for maximum interior volume had to be chosen. Generally, customers of standard refrigerators are little concerned about the exterior dimensions, provided that the refrigerator can be moved in and out of the house. Therefore, thinner insulation would not be as important a feature in such models. After much study, a wall refrigerator located in the same relative position as wall cabinets was selected as an application that would benefit from thinner insulation.

Shortly after this decision a model of such a refrigerator was shown in January 1953 at the Furniture Mart in Chicago. Constructed of wood, its design merely showed the ultimate possibilities of thin insulation in a particular application. The public's reception of this new concept suggested that the unique design intrigued people more than reduction in insulation.

From Initial Development . . .

Based on these results, a preliminary design was prepared, keeping insulation thickness to a minimum but placing emphasis on the new concept of an on-the-wall refrigerator. The design was planned for the production of 1000 refrigerators.

During this time a survey was made of the potential market for the wall refrigerator. Several hundred women were interviewed for their opinions after they had seen full-size models of the projected wall refrigerator, as well as the latest upright model. Result: the wall refrigerator received a surprisingly favorable reception in spite of the improved accessibility of the upright model over earlier ones.

Although particular attention was devoted to keeping costs low, consistent with quality and appearance, a cost analysis of the final design indicated an excessively high cost per refrigerator—the result of low production quantity.

These considerations emphasized the importance of customer reaction to a working model scheduled for display at the Furniture Mart one year after its initial showing as an appearance model.

. . . to Market Demand . . .

The reaction to the wall refrigerator proved to be overwhelming. Shown on three television programs describing the highlights of the show, it appeared to be the most exciting new product on display. Again, the wall-mounted feature rather than the thin insulation created the marketing appeal. Immediately, the design was modified to make it suitable for mass production.

Since January 1953, literally thousands of requests have been received for information concerning availability, installation, and price. And interest in the new refrigerator has remained high, culminating in an article in the December 13, 1954, *Life* magazine describing the wall refrigerator in the kitchen of the future.

. . . to Production

To obtain firsthand customer reaction and performance data, test models were installed in a number of homes during the summer and fall of 1954. Design modifications resulted, and a preproduction run was completed that fall. Full production in six colors—white, petal pink, canary yellow, turquoise green, wood tone brown, and cadet blue—began in March 1955.

Refrigerator Dimensions

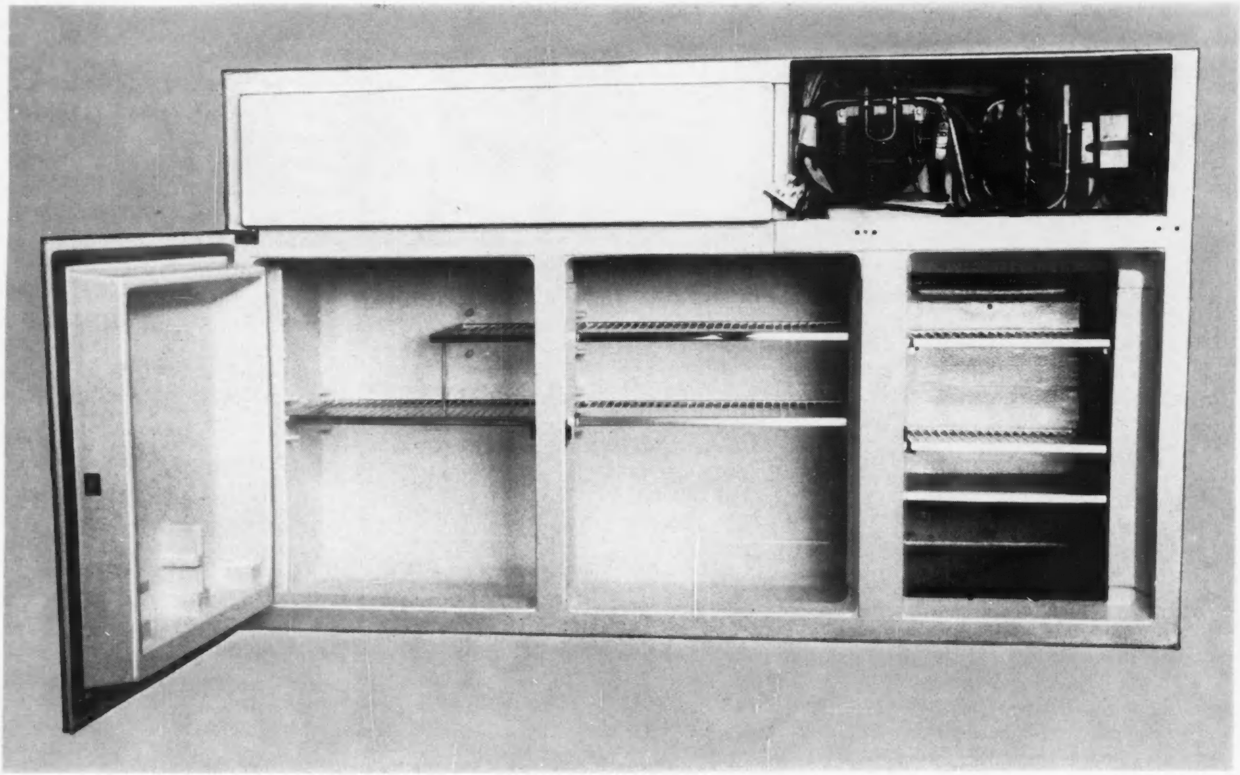
As soon as the first sketch was made, the critical nature of the dimensions became apparent. In attempting to approximate the normal wall-cabinet depth of 13 inches, designers initially chose a 15-inch depth. As a result of the survey, this dimension was increased to 16 inches—and finally 17½—to accommodate larger food platters. These dimensional changes, translated into field models and installed in homes, proved most acceptable.

Initial designs were based on a maximum 5-foot width, thought to be practical for a kitchen wall. However, to obtain sufficient interior volume for normal use, the total width was increased to 64 inches.

Two factors present in most kitchens determine the 39½-inch height of this refrigerator: the 84-inch height from the floor to the usual soffit and the 36-inch counter height. Considerable study and experimenting revealed that the space between counter top and refrigerator bottom must be a minimum of 10 inches for the most practical use. For instance, this space will allow the door to clear quart-size milk bottles or containers placed in front of the doors. However, in the final design, performance was improved and the door clearance unimpaired by 1½ inches of

•

Mr. McEachron—formerly Project Engineer, Household Refrigerator Dept., Louisville, Ky.—joined General Electric on the Test Course 18 years ago. A leader in educational activities in the Company, and the author of many articles on education in industry, he wrote "What Does Industry Owe the Young Engineer?" for the G-E REVIEW, *November 1952 issue. On June 1, 1955, he became Dean of the Undergraduate School, Case Institute of Technology, Cleveland, Ohio.*



DECEPTIVE STORAGE CAPACITY OF ON-THE-WALL REFRIGERATOR INCLUDES 8.7 CUBIC FEET FOR FRESH FOOD, 2 FOR FROZEN FOODS.

insulation to the bottom of the outer case behind the doors.

Mounting

Mounting a wall refrigerator—key to its whole design—must be simple, easy, and inexpensive, yet must supply sufficient strength. Except for its weight, the refrigerator must be as easy to install and remove as a picture, suggesting the use of a simple hook-and-bracket principle. A channel welded to the under side of the refrigerator top forms a three-eighths-inch flange, or hook, at the rear of the top. A steel bracket mounted on the wall with lag screws engages this flange securely. Although installation specifications require a minimum of six lag screws in three studs, tests have shown that two screws will support the refrigerator.

Installation includes a wall outlet for the refrigerator behind the upper right-hand section.

Refrigerating Machine

The refrigerant system, similar to that used on conventional refrigerator food-freezer combinations, automatically defrosts the fresh-food evaporator during the off cycle. However, a fan rather than natural draft cools the condenser, a necessity imposed by the limited space of 10x25 inches occupied by the refrigerating machine above the freezing compartment.

The decision was soon made to mount the refrigerating machine from the front rather than the rear, so that units can be replaced without removing the refrigerator from the wall. Three basic elements—the fresh-food evaporator; the freezer evaporator; and the pump, condenser, and fan assembly—are assembled into three separate areas in the cabinet. The removable mullion between the freezer and fresh-food sections is not in place when the system is installed in the cabinet. The refrigerating tubes between the compressor and the two evaporators, as well as the electric wiring for the cabinet, cross the horizontal transom below the unit compartment in a recess, or well, in the transom. After placement of the right-hand mullion, a vapor seal is made around the refrigerating tubes in the transom well.

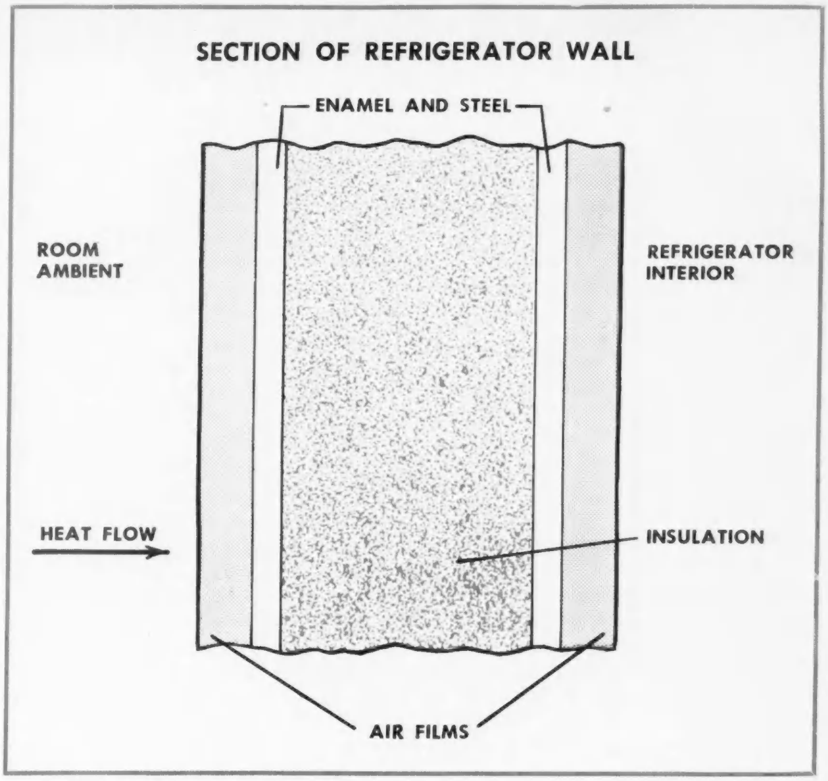
The fresh-food evaporator consists of a single-finned aluminum tube wound into a serpentine evaporator grid. The fin provides necessary additional heat-transfer surface to cool the fresh-food section. The freezer evaporator is an aluminum shell with refrigerating tubes brazed over the entire surface of the refrigerated shelf.

Removing defrost moisture from the fresh-food section has always been a serious problem. In the conventional combination, the moisture from the fresh-food compartment drains into the machine compartment at the bottom of the refrigerator where it evaporates. In the wall refrigerator, however, the compartment that contains the source of heat for moisture evaporation is located at the top. In all combinations, defrosting occurs when warm refrigerant moves back into the evaporator during the off cycle, raising the temperature above freezing. By tipping the "serpentine" to the rear, the melted ice runs down the tubes into a drain trough at the rear and empties into the evaporator pan located on the floor of the compartment.

A circulating fan draws cool air into the grill at the front of the refrigerator, through the condenser, over the compressor, and back into the room through the left-hand side of the grill. To provide sufficient surface to cool the compressor adequately, an oil cooler with several fins was added. The fins direct a portion of the air leaving the machine compartment over the surface of the evaporating pan to remove defrost water. A portion of the warm air from the machine compartment is forced through a one-half-inch gap between the refrigerator and the wall to prevent condensation on the wall.

Door Closure

The absence of door handles or mechanical latches on the original wood and metal models preserved the clean lines of the refrigerator cabinet. A magnetic type of closure, similar to that used on some upright models, permitted us to retain this important appearance feature. A gentle pull on the almost indistinguishable door pull readily opens the door. Attractive aluminum panels cover the lower 8 inches of the three outer doors. These panels are designed not only to continue the bottom line of regular kitchen cabinets—normally 8 inches shorter than the 39½-inch wall refrigerator—but also to protect the doors from fingerprints and wear. Removable by the customer, they can be replaced by laminate to match individual counter patterns or other kitchen motif.



WALL REFRIGERATOR PROVED TO BE IDEAL APPLICATION OF THINNER INSULATION.

Interior

The usable fresh-food volume has increased to 8.7 from the original 8 cubic feet because the volume above the transom is practical for tall bottle storage. Separate sections with sliding plastics doors provide storage space for fruits and vegetables. The vegetable section is designed for higher humidity to improve food preservation. For cleaning, these sections may be completely disassembled by the customer. The other fresh-food shelves can be removed and repositioned. The light bulbs located above the transom are concealed, eliminating any glare. Each fresh-food door operates a light switch to illuminate the interior when the door is opened. Adjustable and removable door shelves provide flexible storage space, particularly for soft drinks, baby bottles, and other small items.

Two door shelves are equipped with removable egg trays that hold up to 16 eggs. A temperature-controlled butter conditioner located in the left door is separated from the fresh-food compartment by small sliding doors. Heating wires for the conditioner are carried into the door by a hollow pivot hinge that maintains a good moisture seal with minimum wire wear. Almost completely hiding the wires, this method shows considerable improvement over methods used on other refrigerators.

The 2-cubic-foot freezer contains one freezing shelf for quick freezing of ice cubes and two removable shelves for most efficient use of frozen-food volume. Removable door shelves accommodate small frozen-food packages. The top shelf in the door is maintained at a desirable temperature for the storage of frozen juices.

Installation

To date, most wall refrigerators have been hung on the wall using the bracket described earlier, flanked by standard kitchen cabinets. In kitchens designed with a plaster niche slightly larger than the refrigerator, clearances on sides and top have then been covered with trim strips. If the refrigerator is built in on all sides, provision must be made below the cabinet for the circulated air to return to the room.

The second most popular installation appears to be as an island divider between the kitchen and breakfast nook or dining area. The refrigerator is supported on one end by a pedestal below and adequate support above; provision must be made to spread the load over a large portion of the bottom of the outer case.

Several interesting comments arose as a result of field installations made approximately a year ago. Customers actually open these refrigerator doors less frequently than other refrigerators. With a counter immediately below the refrigerator, every item required for a meal is removed from the refrigerator at one time and replaced in similar fashion. Most items in the refrigerator are immediately visible at eye level, eliminating the tendency to overlook leftovers. In actual practice, customers are finding the interior arrangement so convenient that efficient use of the volume is as effective as a much larger volume in an upright refrigerator. And when given a choice, women seem to prefer stretching to stooping.

Originally considered a luxury item, public interest in this new idea in household refrigerators has become so widespread that builders throughout the country are including it as standard kitchen equipment. Present estimates indicate that soon many new homes will be sold with the on-the-wall refrigerator included along with the range, storage cabinets, and electric sink. Ω

The Feedback Principle in Community Relations

By L. R. BOULWARE

One of the most useful tools of the engineer is the feedback principle—a return of an output signal to the input. The mechanical engineer applies it to a governor for regulating fuel, increasing the stability of his operation by reducing the surge and the overshoot. The electrical engineer feeds back a fraction of an output signal to reduce distortion, produce higher fidelity, improve accuracy, or to achieve higher quality. Throughout engineering, the varieties of feedback applications utilize the basic principle that involves a return from the output to the input to make the output itself better.

In industry's community relations the feedback principle is perhaps even more essential than in engineering. And for the same objective of making the output itself better, industry and communities must learn to use this principle.

Industry cannot survive competitively even for a short time unless its employees and neighbors return at least a portion of a business's output to the community by feeding it back as their input to the business. Long-term survival depends on achieving a more balanced relationship between input and output. Neither group can or ought to hope for even a degree of advantage at the other's disadvantage; the relationship must be a fair exchange according to the value of what each does for the other. To be a rewarding arrangement for both, the inputs and outputs must balance fairly—and must be known to do so.

Figures recently released by the *Manufacturers Record* indicate some measure of businesses' output to the community . . .

"A new industry coming into a community and employing 150 men would mean an average plant investment of $200,000 and provide an annual payroll of $500,000. It would also serve as the major support of 33 retail establishments, maintain a 33-room schoolhouse with 18 teachers, and be the means of support of approximately 1000 people. It would also mean sales and services for 449 automobiles, $199,999 annually for the railroads, and opportunities for 24 professional men. A taxable valuation of $2,500,000, yearly markets for $350,000 in agricultural products, and annual expenditure in trade of $1,500,000."

The consequences of General Electric's presence in over 100 communities is obviously about 1500 times the effects indicated for employment of 150 people.

No wonder communities are in keen and constant competition to get and keep good employers. And yet many sadly ignore the feedback principle. The success of communities in attracting business depends on how much of the output of a business they are willing to return as an input of enthusiasm for creating a favorable business climate.

A balanced relationship between the output of a business and the input of a community can improve the output itself in at least six specific areas . . .

- An output of good jobs for an input of good employees
- An output of good local purchases for an input of good business facilities
- An output of good tax payments for an input of good civic facilities
- An output of good contributions for an input of good charitable, religious, health, and medical facilities
- An output of good business neighbors for an input of good community neighbors
- Good understanding—both ways.

Jobs for Employees

At each location, local G-E management tries its best to create good jobs. With money coming into an industrial community from all over the world, managers compensate jobs that are the best that they can provide, using all the assistance at their disposal.

A corporation must voluntarily strive for competence in maintaining proper standards for pay, pensions, insurance, and other forms of material compensation. These efforts will help to create confidence that industry never has to be dragged unwillingly along to do what's right in this field.

Such an attitude should be extended to the whole area of human association. An employee does not live by bread alone. He naturally wants all the emotional security and satisfaction possible from his job. He wants a boss who is on his side; who respects and protects the employee's dignity; who engages in two-way man-to-man communication on the things of consequence to the employee; who provides a sense of importance, significance, and genuine participation; and who has a personal interest in the employee both as an individual and as a welcome and appreciated associate in the exciting and rewarding activity they are carrying on together.

Despite all its earnest efforts to provide an output of good jobs, a corporation's ultimate performance here will depend to a large extent on the feedback, or input of its employees, for their attitudes and actions are the governors on that performance.

An employee can return output of material compensation by trying, in his own interest, to voluntarily and honestly apply his skill, care, and effort in doing a full day's work by reasonable modern standards. He can make suggestions, improve quality, avoid spoilage, care for equipment, and eliminate all forms of waste—time, materials, and efforts of both himself and others—including the elimination or rejection of any self-imposed, group-imposed, or union-imposed production ceilings that are below a full, honest day's work.

Employees, too, can return output in the area of human association. They must want to be agreeable and open-minded. Further, they must want to relax any preconceived resistance and be properly responsive to the directions and wishes of an able and fair management. In short, they can return output only by wanting to accomplish something significant, participating in the problems as well as the triumphs, and wanting to receive and give reliable news rather than irresponsible gossip.

Purchases for Business Facilities

Industries, as far as possible, spend the money brought in from all over the

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world right in the communities where they operate before buying the remaining requirements from outside suppliers of goods and services. Thus money circulates in the community not only through payrolls, benefits, and taxes but also through direct, local purchases of goods and services.

Here, the community's input of good business facilities—transportation, power, fuel, and water—will enhance the output of local purchases. Thus the prospect for good purchases in a given community, like its prospect for good business operations, varies in accordance with how that community's transportation facilities aid a business in producing and distributing its products. In addition, the community's transit facilities for its employees and their families are important considerations. Unfavorable transportation facilities or distances naturally have to be offset by advantages elsewhere, or a business would be faced with an impossible competitive operating problem.

Power, fuel, and water facilities also have an important bearing on the output of almost any business. Because availability, reliability, and costs of these facilities vary from community to community, they have to be reconsidered with each proposed, expanded, or reorganized operation.

Tax Payments for Civic Facilities

In General Electric we always try to be a good local taxpayer, paying our full share and not expecting bargains. Of course, government everywhere—at international, national, state, and local levels—has long tended to get bigger and more expensive every day. Government supplies protection and many services: some needed, a few efficient, and many more coming now under increasing scrutiny not only as to wasteful practices but also as to how much some government services are really needed or even how dangerous some might be. Local management may frequently be found trying to do its part in getting and keeping government properly slender, but that same management will always be found ready to pay its full fair part of the government expenses actually incurred.

On the other hand, a community can retain or attract good business taxpayers only if a fair return of their tax output is in the form of an input of good civic facilities—adequate police and fire protection, hazard control, safety measures, and shopping and parking facilities.

High on the list are good educational facilities including the required elementary and high schools and reasonable access to colleges or their equal. Business needs these schools as a source of new employees of good caliber and also as facilities for the high proportion of employees who study to improve their present work or to fit themselves for still more responsible jobs in the future. Also, as parents and interested citizens, employers seek communities where pleasant and stimulating associations are available with teachers and other school officials.

Beyond this, industry finds singularly attractive any community that has a good supply of able public leaders who are dedicated to improving the civic, social, educational, religious, cultural, and moral climate in the community.

Contributions for Charitable Facilities

Rather than a drain on local charities and other worthwhile projects, General Electric always tries to be a generous contributor. And the Company also encourages its employees to contribute personally both money and effort.

Pension, insurance, hospitalization, health, vacation, holiday, and other benefit programs, as well as payrolls, taxes, and local purchases not only keep employees and their families from being a drain on the charities but also tend to make those charities far less of a drain on the other citizens.

At the same time, a community should provide health, hospital, and medical facilities sufficient to meet the needs of employees, their families, and their neighbors and make various types of warranted welfare services available to the needy and indigent. And industry shares in supporting these projects as well as in helping to minimize the need.

More and more the practice of everyday good citizenship depends on a safe majority of the public understanding that freedom is not only an economic and political issue but also a moral challenge. In emphasizing this fact, no group can be as helpful as an alert clergy. To fulfill the requirements of employees and their families for adequate and varied churches and religious organizations, industry prefers to be in communities where the clergy exerts great influence.

Neighbors: Business for Community

In General Electric we do all in our power to be a good housekeeper and be well-mannered as a corporate neighbor. We try to pursue quiet, safety, and cleanliness in and out of our plant. Further, we are ever aware of our obligation as a company and as individuals to live up in every way to the conduct standards of the community and to do our full part in all emergencies, as well as in the accredited common projects of the community.

But good neighborliness can be evidenced not only by what industry tries to do but also by what it tries not to do. For example, industry should not grow too large for any given community. Dependency on one particular industry, let alone one particular company, handicaps a community. With the inevitable and unpredictable ups and downs in customer demand as experienced by industry, the healthiest communities have many companies in broadly diversified industries. This brings a diversity of job opportunities with the various employment peaks coming at different seasons of the year or at different points in the business cycle.

For the good of both community and company, the size of operations should fit comfortably the size and related facilities of the community.

In GE we like to locate a given operation in as small a community as is commensurate with our total employment requirements and other needs. Other things being equal or adequate, we believe that the smaller the community the more materially and emotionally rewarding the life there. At the same time we try to avoid overloading a community's facilities to prevent disrupting its economy or way of life.

In considering new locations, we now try to assure ourselves that our requirements will not exceed 15 percent of the community's work force. Because this work force usually represents about 40 percent of the total population, we initially try to ascertain if our employment needs will be within 6 percent of the population within 25 miles of the plant site.

We have not followed this plan at several of our older locations to which we are so devoted and of which we are so proud. And, although we are trying to follow the plan in selecting new plant sites, it is not a hard and fast rule.

Just as businesses act as good corporate neighbors, so must communities show their good neighborliness in return. They can provide the specific kinds of housing needed for a given size and type of business operation; suitable housing will attract and hold good employees while inadequate housing causes constant difficulty.

Employees and their families should be able to select from the widest feasible range of recreational facilities. Important, too, are organizations that stimulate them in attaining an expanded capacity for cultural appreciation and enjoyment.

Output to a community depends to a vital degree on its input of loyal support to a company's name and products. Thus communities should not be too quick to criticize when a company's best is still not good enough to meet their desires and aspirations. Every citizen in plant communities not only has a vital selfish interest in doing his utmost to have the whole public in those communities and all around the world respect and trust his company but also wants its products and plans to succeed. The number of jobs and even the value of homes in industrial communities depend largely on how much money customers can be persuaded to spend there through the companies who produce and fill their orders. Anybody who defames or maligns any particular company keeps it from getting business and providing its output of jobs, purchases, taxes, contributions, and the like to the community.

Good Understanding—Both Ways

In the final analysis, mutual understanding determines the extent that a balance can be achieved between the mutual problems, troubles, and triumphs of business outputs and community inputs. In being a good employer, buyer of local goods and services, taxpayer, contributor, and genuinely desirable corporate citizen, industry seeks to deserve and get understanding, respect, and fair treatment by the community's public servants in such areas as the courts, taxes, and law enforcement. Receiving this from the public's servants depends, of course, not only on the local public's understanding and approval of a particular company but also on its understanding and approval of business in general.

The outside influences exerted unjustly against business are many and strong—too many and too strong to be offset by the efforts of any one business. Businessmen need to join with each other and with all other thoughtful leaders in the pursuit of these objectives . . .

- Higher development of standards of economic performance and good citizenship in directions properly desired by the community
- Fuller understanding of our free system of incentives and competition on the part of the community as a whole
- Far greater deserved approval on the part of the community for business in general and for the whole free-markets and free-persons concept of the economic and political system that business operates within.

With this development, understanding and approval will come with the local public's insistence that industry has justice at the hands of the public servants.

But top local public servants are also leaders. As such, they have a duty in keeping any public misunderstanding or prejudice from being followed in such matters as tax issues and damage cases. A company is entitled to their help in its effort to explain the relationship of the five interdependent contributors to and claimants on its output: customers, employees, owners, vendors, and the public. Each of these specialized contributors has a part to play but will not and cannot play that part for long unless properly compensated for what that one does for the other four; and all efforts throughout history to reward any one out of proper proportion to what the others deserve has ended in less well-being, if not disaster, for all.

And in too many communities, when public servants encounter anything like labor trouble, they consider it good politics to overlook actions of even flagrant lawbreakers in their abuses of the persons and property of peaceful and law-abiding citizens. Industry recognizes that the local public must be helped by it and other private parties to understand the community's own interest in having its public servants enforce the law instead of using the force of government position to protect lawbreakers who are defying government. Yet again the local public servants are also leaders, and they have an obligation to themselves, as well as to their constituents, to help promote an understanding of the facts so that it will no longer be good politics to protect bad people but be bad politics, as it properly is, to do anything but protect good citizens against lawbreakers or usurpers.

To the extent that certain union officials may be involved—in picket-line violence, for example—General Electric believes that the public servants will be encouraged to find that the public, including a great majority of the work force, does not want unions to go beyond their proper function to the point where the union officials dominate not only union members but also the whole life of a community and all the actions of local and other public officials.

Public officials must be convinced that they are going to be acting in front of a public who will understand whether they are penalizing all lawbreakers alike and protecting all law-abiding citizens alike. To acquire this understanding, the public, including employees, must have the currently too prevalent double standard of law enforcement clarified—particularly in terms of how it affects freedom and the cost of living—and the public must be encouraged to let its public officials know that it wants only one standard for all.

This basic educational job needs to be done in times of peace. Then, with each strike where some press photos show the police doing little or nothing to prevent an illegal and perhaps bloody picket line, the dawn of fair and impartial law enforcement comes much nearer.

Give and Take

Although "something for something" is implicit in a give-and-take relationship, GE makes no attempt to establish it through arms-length bartering on a rigid daily *quid-pro-quo* basis.

For just as we look to the community to feed back our output as its input, we are fully prepared to use that input to make the output even better. In our community relations, we try to live by the basic principle of the feedback in engineering.

All too obviously, this feedback principle is not now working in community relations with anywhere near the precision that it works for the engineer. For certainly all of the more than 100 General Electric communities are not getting all the output they want to get from us nor are they feeding it back with all the input we seek. Nor is management yet proficient at every point in doing its full part to help these communities deliver. But we are encouraged by the response to our initial efforts.

And in time, we believe that by working together with all concerned a proper input-output relationship and accomplishment can be reached in one after another of these communities. Then they will be proud examples of what can be done when a community's alert citizens and their leaders apply the feed-back principle to their business relations. Ω

INSTALLATIONS OF SLIMLINE FLUORESCENT LAMPS ARRANGED IN WALL-TO-WALL ROWS ENHANCE STORE AND SUPERMARKET INTERIORS.

Phosphors Have Invaded Your Home

By C. E. WEITZ

Before the introduction of the fluorescent lamp, few people ever heard of phosphors even though the earliest historical writings record knowledge of light-glowing materials. Phosphors, meaning "light bearer," were first recognized about 350 years ago by an Italian experimenter. After pulverizing and heating some rocks, he noticed that the changed substance seemed to glow in the dark.

A few years later, a new element was isolated, one that tended to glow in the dark and even burst into flame on exposure to air. Because of these properties, this element was called *phosphorus.* Later knowledge disclosed that these two phosphors glowed for entirely different reasons. The light given off by the element phosphorus when it burns in air is called *chemical luminescence,* or *chemiluminescence.* This property of ready combustion led to the development of the friction match in 1827. The glow from the Italian phosphor was not chemical at all; the phosphor simply served as a medium of exchange, like a transformer. It stored and gradually converted the ultraviolet energy present in the sun's rays into visible light long after the sun went down. We now call this process *luminescence.* The phosphors used in the early development of the fluorescent lamp did not make use of the element phosphorus at all. Some present-day phosphors contain a variety of phosphates—not phosphorus as such. Other phosphors are composed of various inorganic chemical combinations, such as silicates, borates, tungstates, sulfides, and germanates.

Although observations of the light-giving properties of hundreds of organic and inorganic materials date back several centuries, scientific studies and appraisals began only a little more than 100 years ago. Since then, the fluorescing characteristics of liquids and solids

EFFICIENCY LOSSES IN STANDARD WARM-WHITE LAMPS

LUMENS PER WATT

680

The eye is most responsive to yellow-green light—5550 Angstroms. If we could devise a lamp to convert electric energy in this single wave length, the maximum efficiency would be 680 lumens per watt. But no one wants to live under yellow-green light such as produced by sodium-vapor lamps.

388

Phosphors produce light over a range of wave lengths that when properly combined give warm-white light. The average luminosity is 57 percent of the maximum, or 388 lumens per watt. Physicists' pure white light is based on equal amounts of energy (watts) being radiated at each wave length throughout the visible spectrum. Top efficiency for this condition is 220 lumens per watt. A lamp giving this distribution has not yet been contrived because there is little need for one.

174

Based on the quantum ratio, the loss in wattage in converting from one wave length of 2537 A to the longer wave lengths is directly proportional to the ratio of 2537 A to the reradiated wave length. For warm-white light the loss is proportional to its integrated energy distribution curve, lower for shorter wave lengths, higher for the longer. But the net conversion efficiency accomplished by the phosphor is 45 percent, or 174 lumens per watt.

105

Here, the major loss is in electrode heating and bulb warmth. A low-pressure mercury-vapor arc—key to fluorescent lamp success—radiates a large amount of its energy at a single wave length that phosphors could be adjusted to respond to. Any improvements over the 60 percent efficiency known today would be a direct proportional gain, unrelated to phosphor potential. With no advance in discharge efficiency, the maximum remains 105 lumens per watt.

90

Certain losses of phosphor-generated light are inevitable: no fault of the phosphor—just losses of light trying to get out of the bulb. At the present time, this reduces the light output and results in an efficiency of 90 lumens per watt, but some unknown scheme might improve this a percent or so.

25–77

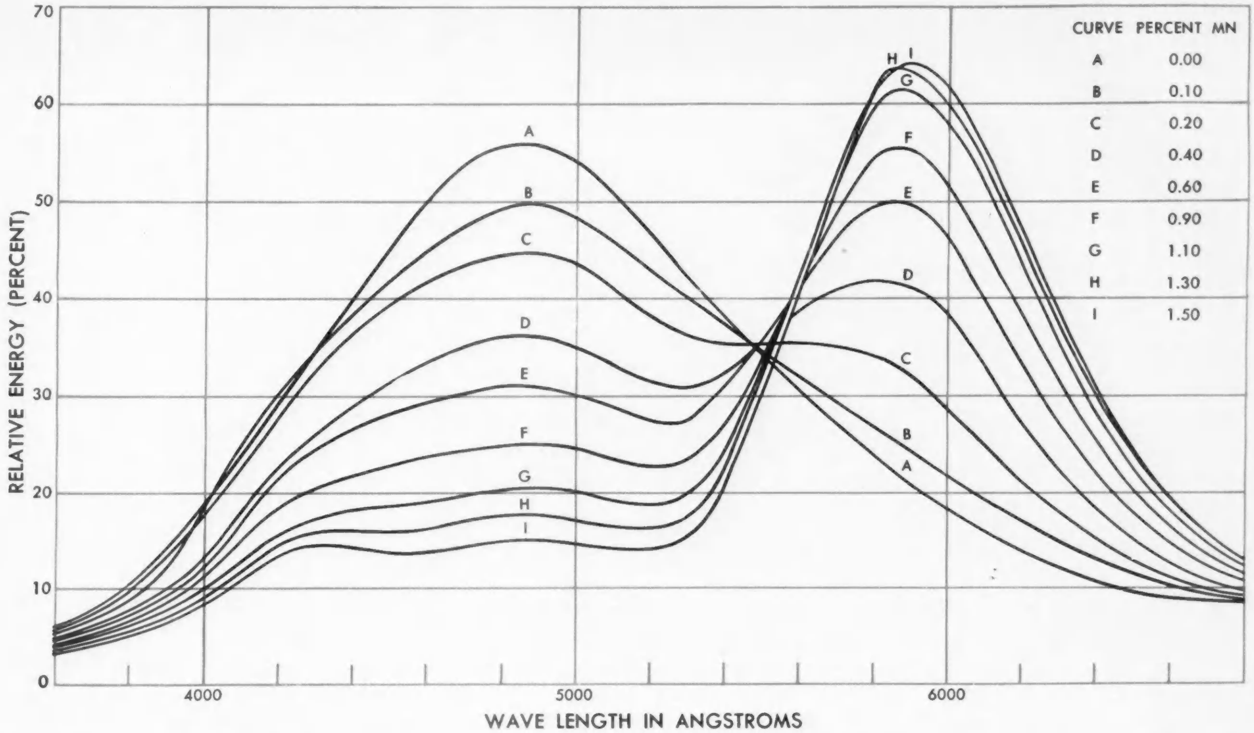
Efficiency ratings for the 96-inch warm-white lamp operated at 120 ma are approximately 77 lumens per watt; for a 4-watt lamp, 25 lumens per watt. If we could disregard limiting factors—lamp watts, lengths, diameters, current loading, and others—this might apply to all various lamp types. Today's phosphors are giving between 80 and 90 percent of their theoretical efficiencies. Possibly this could be improved by screening out imperfect crystals and tuning others more critically so that their energy falls within the visible spectrum. Minor energy losses occur in some reradiation of the ultraviolet and infrared wave lengths that do not, however, produce lumens.

exposed to radiant energy—visible or invisible—have become a significant part of chemistry and chemical analysis. They played an important part in the discovery of x rays in 1895, when radiation from the experimental cathode-ray tube caused some fluorescent materials in an adjoining room to glow. About this time, Edison experimented with a fluorescent lamp, but nothing came of it.

In the 1921 IES *Transactions*, a scientist wrote ". . . unless someone discovers a means of making luminous bodies that are vastly brighter than the best now known, luminescence may be excluded altogether as a factor in artificial lighting." Only 15 years later, fluorescent lamps became a reality. With 10 times the efficiency of Edison's experimental lamp, they also had three times the efficiency of present-day tungsten-filament lamps. And 15 years after their commercial introduction in 1938, the lumen hours generated by fluorescent lamps in the United States exceeded the lumen hours generated by all other artificial light sources.

However, all this did not transpire through development of phosphors, as implied by the scientist just quoted. Actually, the key was the development of an efficient source of activating radiation—a low-pressure mercury-vapor arc lamp. By themselves, such sources generate light at an efficiency of only about five lumens per watt but transform 60 percent of the electric energy entering the lamp to invisible ultraviolet (wave length equivalent: 2537 Angstroms) to which phosphors are tuned (March 1955 REVIEW, page 27).

Prior to the fluorescent lamp, most scientific literature on phosphors related to luminous screens for x-ray machines and for specialized applications of cathode-ray tubes, such as the oscilloscope. A relatively few pounds of laboratory-produced phosphors took care of all commercial requirements. Efficiency, as judged by the lighting engineer, was of secondary importance. Since then, phosphors have become the heart of several great products of industry whose 1955 value exceeds $2 billion: 90-million fluorescent lamps; 7-million or more television picture tubes; plus x-ray, oscilloscope, and radar screens. Today, phosphor production is recorded in tons instead of pounds. Color TV will probably triple phosphor usage for picture tubes and make new precision demands for color balance of phosphor emission.



FOR STANDARDIZED LIGHT, PRECISE AMOUNTS OF MANGANESE ARE ADDED TO CALCIUM-PHOSPHATE PHOSPHOR, REGULATING LUMEN OUTPUT.

In the common celestial-type diagrams, the component electrons are normally pictured as circling the nucleus in a variety of orbits. A large amount of free energy released from an x-ray tube, a cathode-ray gun, or a fluorescent-lamp discharge knocks the electrons out of position. And as these displaced electrons vibrate back to their normal position, they give up their energy by radiation at different frequencies, like a row of piano strings struck by a hammer.

This secondary radiation is at a lower frequency because some of the energy of these activating electrons is lost by contact with the phosphor ions. Thus electrons that are displaced by high-frequency energy—cathode rays or ultraviolet radiation (2537 A in fluorescent lamps)—reradiate energy at a lower frequency to which the eye is receptive. And this we call light. The inherent loss of energy in transferring from the higher frequency radiation (2537 A) to lower frequency visible wave lengths (4000 to 7000 A) is known as the quantum loss. According to physicists today, this quantum loss, or efficiency, is in a fixed ratio for each wave length generated.

Defined Terms

Electronic production of light is luminescence; light produced by heat alone, as in a filament lamp, is incandescence. Under luminescence, phosphorescent materials are regarded as those that persist in light-giving properties for a fraction of a second, a few minutes, or even hours after the source of activation has been discontinued. Some of the electrons are trapped, detaining their return to normal orbits.

Fluorescence, on the other hand, assumes that the radiation of light occurs simultaneously with the exciting radiation. No precise boundary exists between phosphorescence and fluorescence, and perhaps precise differentiation is unnecessary. For slight phosphorescent properties are desirable in fluorescent lamps. They reduce the tendency to flicker and even account for the difference in flicker between lamps using different phosphors or those on circuits of different frequency. Important in television picture tubes, phosphorescent phosphors carry over the picture images for a fraction of a second. The image must not remain more than one thirtieth of a second because the picture tube must be ready to produce new picture responses 30 times a second. Such qualities are the subject of contemporary phosphor research.

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During his 36 years with General Electric, Mr. Weitz—Illuminating Engineer, Lamp Division, Nela Park, Cleveland—has written and edited many widely used lamp and lighting references. He prepared a series of texts used by the International Correspondence Schools as a basis for training lighting men in many parts of the world.

Fluorescent Chemicals

The first modern fluorescent lamps used willemite ore (natural zinc orthosilicate) from mines in Franklin, NJ (July 1954 REVIEW, page 34). Chemical handbooks list the fluorescing properties of thousands of chemicals, both organic and inorganic, but only the latter are used for lamp phosphors. Some of those most commonly used are calcium tungstate (blue), zinc silicate (green), cadmium silicate (yellow-pink), and calcium phosphate (white and color tints).

Although many rocks may fluoresce rather brilliantly in their natural state, the improvements in lamp efficiency due to phosphors have resulted from purifying and processing refinements (photo, page 28). In other words, the natural materials are separated, and each element is reduced to absolute purity and reassembled in varying proportions. Strangely enough, the basic phosphor

CALCIUM CHLORIDE and di ammonium phosphate, two common chemicals used as lamp phosphors, are treated in large glass-lined tanks for solution and purification.

materials demand the utmost in purity, but most of them will not fluoresce until combined with an impurity known as an activator—usually a compound of some metal, such as copper, silver, manganese, antimony, bismuth, or thallium. These impurities not only serve to trigger the excitation but also supply the source of the luminescence. As in TV phosphors, an activator may sometimes assert itself when comprising only one part in 10,000, but most lamp phosphors may be as high as several percent. The electrons in the outer orbits of these activator atoms are the source of the luminescence. The calcium phosphate, for example, that crystallizes the activator is simply an envelope, or housing, to hold the activator, and this structure is ımportant.

A person whose knowledge of chemical formulas is limited to what he learned in a freshman chemistry class may find it difficult to fully understand the chemistry involved in phosphor research or in the complexities of making phosphors. Only inorganic materials are used as lamp phosphors because organic materials break down under high processing temperatures. Of the 3000 or more inorganic phosphor compounds to choose from (the number constantly expands as research continues), only a relatively small number are presently important for lamps and other fluorescent applications. The most important of these use the elements cadmium, calcium, magnesium, strontium, and zinc in the form of sulfides, tungstates, silicates, borates, germanates, or phosphates. The sensitivity of the phosphor compound to 2537 A radiation guides the choice of phosphor materials. The real test comes from examination of its luminous efficiency, spectral distribution, and stability in spectral emission. And its ability to withstand high processing temperatures is essential. Important, too, is the extent of its after-glow characteristics—sometimes desirable, sometimes not.

Phosphor Versatility and Efficiency

Because calcium-phosphate phosphors display a variety of characteristics, they serve as a good example to illustrate phosphor characteristics in general and the major steps in processing. Calcium phosphate, now the basic phosphor structure for the high-demand types of white fluorescent lamps, represents 85 percent or more of phosphor tonnage. Remember, the activator additive does the fluorescing (illustration, page 27).

The family of spectral emission curves shows the differences in the color quality of light that are caused by the amount of manganese added to the basic calcium-phosphate phosphor. The range of these curves extends from no manganese to 1½ percent, indicating just how precise the measurements must be to achieve the spectral quality of light standardized on. And this in turn regulates the lumen output or lumens-per-watt efficiency ratings that lamp and lighting people are most familiar with. That is why phosphor people talk in terms of grams and milligrams and use precision scales.

For deluxe white lamps and for the various colored lamps, other phosphor compounds are used, either as phosphor mixes or as special single components.

The 96-inch warm-white lamp is presently rated at about 71 lumens per watt. Compare this with the theoretical maximum of 105 lumens per watt, theoretically possible if we make no allowances for what we sense as other inevitable losses (Box, page 26). How far we have come in lamp efficiency and how far we must go to reach the theoretical maximum has long been a favorite topic among lighting people.

What Can We Expect in the Future?

Edison's first lamp produced 1.4 lumens per watt; then it rose to 4 for metallized carbon, ranged from 8 to 20 for tungsten, 30 to 65 for mercury, and 25 to 80 for fluorescent—still short of the 200 to 300 or 680 lumens per watt held up as a goal. When people see the wide gap between the theoretical and today's practice, they think that lamp makers should be able to double lamp efficiency any time. Even with the phenomenal fluorescent lamp, physicists and chemists have gone about as far as they can go. But they caution that some discovery might extend present barriers.

Fluorescent lamps of today are considered good so why should we worry about a few more lumens? For a very good reason: At present, people are buying more than a billion dollars worth of fluorescent light each year. If phosphor research could increase efficiency only one percent, the public would acquire $10-million worth of light, minus the cost of such research. An increase of 10 percent would mean not only an extra $100-million worth of light a year at the present rate of usage but also more light every year as demand increased.

New phosphor applications are already appearing: color TV is with us now; electroluminescence is in its infancy; others yet unconceived are inevitable. It will be a long time before the phosphor researcher works himself out of a job. A million or so combinations of variables must still be examined in his effort to dredge the ultimate in phosphor performance for lamps. Ω

AMERICAN SOCIETY OF AGRICULTURAL ENGINEERS

By RALPH A. PALMER

Guidance and aid for productivity in commercial agriculture require aggressive application of engineering and science.

For instance, many energy relationships are involved: sun, wind, chemical, human, animal, mechanical, and electric energy are used in their respective ambient temperature controls and power operations. Much of the product value lies in food energy. But particularly important is efficient use of high-cost human energy.

Structural factors influence the productivity of agriculture's foundation soil and biological building blocks. They are primary in providing basic shelter or more precise and positive environment control for its workers, supplies, equipment, livestock, and some of its operations and finished products.

High-tonnage materials handling—from soil preparation to delivery of a marketable product—requires a variety of complex, precise manipulations and timed sequences of mechanical operations.

Water produces or destroys, depending on its control on the individual farm and agricultural watershed.

In the supply of basic human needs as well as some of life's luxuries, principles of production economics enter the picture too.

Agriculture also challenges engineering with its complex of soil, weather, and biological variables that are subject only to partial control. Even in some of farming's heaviest operations, production machines must be moved to the work.

Considerations of availability of land, capital, labor, and management ability limit adaptation of production units to optimum size for efficient production.

At the same time, farming presents a major opportunity to increase the net productivity and therefore the standard of living by more efficient use of human and natural resources.

Early History

The immensity of these challenges postponed the development of agricultural engineering until the older branches of engineering and agricultural science were well-established.

The terms "agricultural engineer" and "agricultural engineering" occasionally appeared before the turn of the century. Land-grant colleges and experiment stations, developed to promote agriculture and the mechanic arts, fostered a climate partially favorable to the acceptance of these terms. A few early educators and administrators of the agricultural-engineering colleges initiated teaching, research, and agricultural extension as they began to see a natural close relationship between agriculture, the mechanic arts, and physical science.

ASAE Established

By December 1907, several men with a combination of farm background and thorough basic engineering training met at the University of Wisconsin to discuss their mutual interests and problems with a few representatives of industries serving farmers. With foresight and courage, 17 charter members established the American Society of Agricultural Engineers (ASAE).

With identity established and purpose defined, these men set out to improve their work, gain recruits, and build a specialized engineering branch to serve agriculture. Early growth and progress were slow. Many purists—leaders in their respective engineering and agricultural fields—did not welcome the new hybrid agricultural engineer. Some industrial leaders and farmers were still suspicious of book learning.

However, professional unity, technical merit, economic conditions, and the trend of the times were on the side of the agricultural engineers. Farmers who scorned the luxury of implement seats were interested in keeping up with their neighbors in getting work done. Sons who had been cradled in Model Ts were receptive to new mechanical ideas. Farm-equipment manufacturers competing for farm business found that they had to push beyond the blacksmithing stage of production. And it took engineers who knew something about farming to design machines that would satisfy farmers. Agricultural scientists found that their recommendations on tillage, crop production, and pest control had to be "implemented" into farm practice. Agricultural engineers who commanded the respect of other engineers gradually increased in numbers.

Periods of high demand and high prices for farm products, as well as short labor supply, placed a premium on engineered high-capacity farm equipment and methods. Periods of agricultural depression set a premium on engineered means of lowering farm-production costs.

In its early years a large proportion of the Society members were associated with the U.S. Department of Agriculture (USDA) and the state agricultural colleges and experiment stations. Its programs, committee work, and publications reflected their concern with what to teach and how. Members had to develop additional agricultural engineers, teach farm mechanics to college students, and carry their teaching to farmers through the Agricultural Extension Service.

Neither the agricultural sciences nor the older branches of engineering could offer helpful information on how to economically and effectively handle farm operations. To provide the needed information, the Society's Research Committee devoted much attention to defining research, stating and evaluating research problems, refining research techniques and equipment, encouraging support for additional research, and publishing research reports.

Soil and Water

The Society helped farmers, tile suppliers, and irrigation districts combat long-standing problems of drainage in the East, South, and Midwest and irrigation in the West. By the time soil

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Mr. Palmer has been Assistant Secretary of the American Society of Agricultural Engineers since 1927 and for the past 10 years has been in charge of the Society's Personnel Service.

OLD Nineteenth-century steam-powered threshing rig prompted engineers to plan for more efficient farm power.

NEW Most small grains are now combined—harvested, threshed, and cleaned—as the machine moves across field.

conservation was popularized in the early 30's, ASAE had developed a foundation of technical knowledge and literature on the subject. Its Soil and Water Division mobilized existing technical knowledge and trained manpower to refine current practices and develop new approaches.

Division-sponsored programs and papers are emphasizing both basic science—water movement in soil, flow in channels, movement of soil by raindrops, and measurement of water in soils—and practical applications, ranging from ditching with explosives and land clearing to pumping and water distribution in irrigation.

Farm Structures

Farmers were investing a considerable portion of their capital in buildings, constructed by themselves or by rural community builders. Although these buildings, often ornate, satisfied certain basic shelter requirements, neither the rural builder nor the farmer ordinarily had the background and information to create functional design.

The Farm Structures Division of the Society, organized in 1922, serves as the professional forum for technical progress. By supplementing, guiding, and encouraging individual effort, its members have enlarged their service from minor improvements on conventional farm buildings to include the study of functional requirements, measurements of environmental conditions and their effects on the products and animals sheltered, and the integration of farm buildings into the farm as a whole economic production unit. A tangible result of idea exchanges within the Division is the Regional Farm Building Plan Service, developed in several areas having similar building requirements.

Power and Machinery

In the trend toward job-lot and production-line assembly of standardized parts, the farm-equipment industry kept pace with other manufacturers of mechanical goods. Agricultural engineers were needed to design and test new equipment before manufacturers would make major investments in special-production tooling and inventory. They were also needed to help introduce new machines into farm practice and to help farmers over the hump of converting from horse to tractor power.

The Society's Power and Machinery Division helped to improve the application of animal power while it was still a farming factor. Then it helped to refine the tractor from a lumbering land locomotive into today's versatile, maneuverable prime mover that has mechanical, hydraulic, and electric power take-offs for precision control on a variety of jobs. Further, the Division contributed to such developments as the adaptation of the combine for use in humid areas; pneumatic tires for tractors and agricultural implements; the row-crop tractor; improved safety of the tractor power take-off; kinematics and dynamics of the farm tractor; and basic studies in tillage, fertilizer placement, and forage-crop handling.

Rural Electrification

By the early 20's many farmers had lived through the open fireplace, tallow candle, paraffin candle, kerosene and gasoline lamps, and acetylene stages of artificial lighting—each stage having well-known limitations and disadvantages. Some engineers, farmers, and leaders in the electric utility industry dared to think in terms of extending high line power to all farmers and of finding enough profitable farm uses for electricity to overcome the limitation of the number of customers per mile. The problems went beyond the electrical engineer's technical and professional field and the electrician's craftsmanship. A few agricultural engineers manned experimental lines, laboratories, utility services, and research departments of some electric equipment manufacturers. They developed hundreds of new lighting, heating, power, and other farm applications; showed farmers the kind of installations needed to use electric power safely and economically; and promoted the extension of power lines from urban centers to isolated farms.

The Rural Electric Division, organized in 1925, has mobilized the thought and influence of agricultural engineers on the whole range of technical and professional problems, from simple wiring to the need for additional trained personnel to serve in rural electrification work.

In 1927, General Electric helped ASAE and others pioneer the field by establishing a special training course to help young agricultural engineers qualify as rural electric service engineers. GE selected George A. Reitz, a young electrical engineer with a farm background, to organize and teach the course. He continued in the Company's rural electrification work and became an agricultural engineer. Active in the Rural Electric Division of the Society and its broader professional interests, he served as its president in 1947-48.

AGRICULTURAL ENGINEERS RAISE PRODUCTIVITY THROUGH SOIL AND WATER CONSERVATION.

HAYLOFT IS OUTMODED BY ELECTRIFICATION AND IMPROVED FEED STORAGE AND HANDLING.

ASAE Today

ASAE now has about 4300 members mainly located in the United States and Canada, with a few hundred scattered in 40 other countries. Four technical divisions, an Education and Research Division, and 24 geographic sections are primary functional organizations within the Society. It co-operates with more than a dozen engineering, educational, trade, agricultural, scientific, and public service organizations in the following interests: fire prevention and protection, standardization, scientific and agricultural progress, engineering registration, professional standards, and effective use of trained manpower.

Society meetings are a principal means of exchanging information and ideas. Scheduled programs provide the tangible nucleus for a broader professional and technical give-and-take between old and new acquaintances. Section meetings supplement an annual June meeting and a national December meeting.

Standards are adopted when the Society is the only logical body to indicate the technical merit of agreements reached by producers of engineered agricultural products. Sometimes it participates with the American Standards Association, the American Society for Testing Materials, as well as other groups in the development of certain standards.

Publications

Agricultural Engineering—the Society's monthly technical and professional journal—publishes meeting papers and original reports of research and technical developments, plus ASAE news and related engineering activities. It has become the central body of literature in its field, widely referred to in texts, research and extension bulletins, and other special-purpose publications.

The *Agricultural Engineers' Yearbook* presents an annually revised composite of ASAE standards, recommendations, data, organization, and history; constitution, by-laws, and rules; and directories of members and suppliers.

Awards

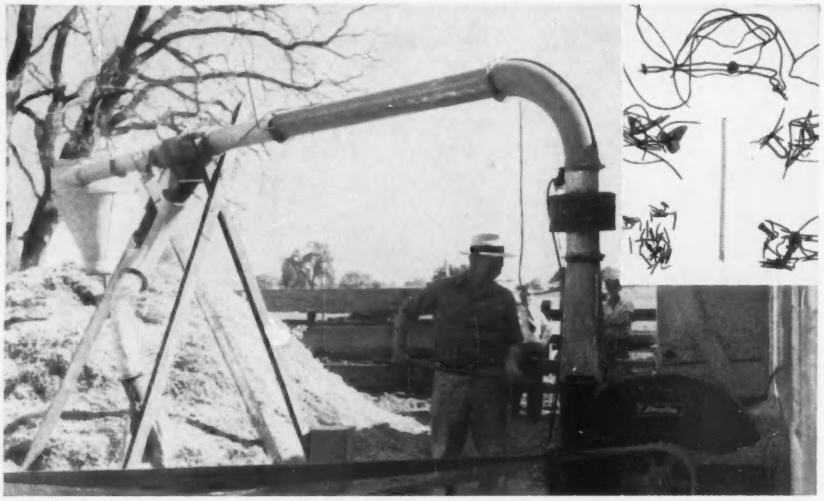
The Jury of Awards, made up of ASAE's seven surviving immediate past presidents, confers two primary awards. The annual Cyrus Hall McCormick Gold Medal—made possible by an endowment memorial to the inventor of the reaper—is awarded "For Exceptional and Meritorious Engineering Achievement in Agriculture." The annual John Deere Gold Medal—a memorial by his descendants to the producer of the first successful all-steel moldboard—recognizes "Distinguished Achievement in the Application of Science and Art to the Soil."

The Council—ASAE's Board of Directors—bestows the special honors of election to the Honorary and Fellow grades of membership.

Pioneers

A. O. Fox, one of the first honorary members and then president of Northern Electrical Manufacturing Co., influenced the eventual formation of the Society perhaps more than any other person. The Society also owes much to the late Dr. Elwood Mead, long-time head of the U.S. Bureau of Reclamation, for his early foresight and leadership in agricultural engineering. His enthusiasm inspired the late Dean O. V. P. Stout, dean of engineering, University of Nebraska, who in turn influenced his students, four of whom became presidents of ASAE—Dr. J. B. Davidson, L. W. Chase, F. A. Wirt, and O. W. Sjogren.

Affectionately recognized as unofficial dean of agricultural engineering, Dr. Davidson over a long period of time has widely influenced sound development of agricultural engineering both in the Society and out. His activities include: Charter Member, Honorary Member, first president of ASAE, and current Chairman of the Society's Committee on ASAE History. Pioneer supporter of rural electrification, he has headed government studies here and abroad.



REMOVAL OF TRAMP-IRON (INSET) SAVES CATTLE FROM INTERNAL INJURY, EVEN DEATH.

Other early Society leaders inseparably linked with the history of rural electrification were E. A. (Doc) White, George W. Kable, Arthur Huntington, and B. D. Moses.

Objectives

The many objectives of the Society include . . .

- Promoting the science and art of engineering in agriculture
- Encouraging original research
- Fostering agricultural engineering education
- Advancing the standards of agricultural engineering
- Promoting the intercourse of agricultural engineers among themselves and with allied technologists
- Encouraging the professional improvement of its members
- Broadening the usefulness of agricultural engineering.

The years have confirmed a belief among many ASAE members that to best serve agriculture they should be both well-qualified in basic engineering and specialized in their appreciation of the engineering requirements and opportunities in agriculture.

ASAE acknowledges and respects its heritage from the older engineering societies and engineering branches. Their "Code of Ethics for Engineers" is embodied in its bylaws. It urges college agricultural-engineering departments to qualify for accrediting by the Engineers' Council for Professional Development (ECPD) and encourages its members to qualify for professional engineers' registration.

Future Challenges

The challenge that faces all scientists, engineers, and their professional society confronts agricultural engineers and their professional society: the opportunity to serve in an environment characterized by a pressure for progress. More people than ever before see the possibility of adding new meaning and fulfillment to life through more effective utilization of human and natural resources. Scientific and engineering progress is opposed less than ever before by self-satisfied stagnation.

In the search for social progress through economic means, agricultural engineers hold the key to one important area for applying engineering methods.

Although the path of progress may not lead directly to push-button farming, we can expect increased agricultural effectiveness that is more sensitive to consumer demand. A more certain supply of food, fibers, and other organic raw materials produced at a lower cost in man-hours per unit will enable people to devote more time and effort to reaching a higher civilization.

Looking Ahead

Rural electrification will undoubtedly progress toward broader and more intensive application of a wider variety of electrical phenomena. The increasing value of human time requires more time-saving automatic controls. In making repeated evaluations of ripeness, moisture, temperature, and other conditions, electric-mechanical instruments not only have proved more accurate than any of man's five senses but also can initiate and direct the required action more precisely than man's mind and hand.

Enough is known about the effect of light on plant and animal development and productivity to demand further attention and refinement as a farm tool.

Farming requires various specific temperatures for air, water, and farm products that invite further application of the heat pump.

Although electric motor power may always remain tethered to the transmission line, its application to farm jobs can still be refined.

Safe control of animals and insects by shock effects merits further development.

Proved effective in removing tramp iron from livestock feed, electromagnetic applications may find other farm uses.

Electronics, presently used in color-grading of some farm products, seems to have unlimited potentialities for farm application.

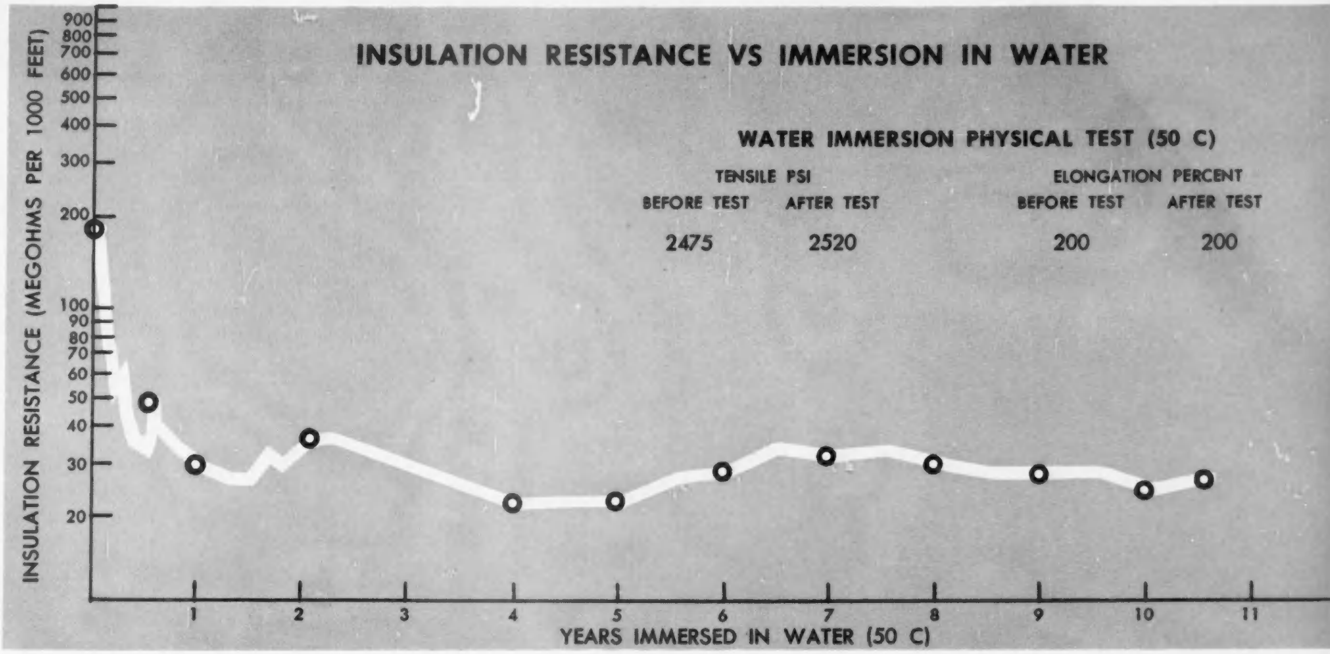
Electrostatics and supersonics show promise in agricultural-engineering research. And we are just beginning to appreciate the electrical phenomena within the productive living-cell unit that some day may be brought under engineering control in the interest of agriculture.

Agricultural-engineering progress in rural electrification will not take the art out of farming but, rather, will enhance it by giving the farmer a higher order of tools than ever before.

The Individual and ASAE

Individual agricultural engineers will contribute to the solution of these myriad problems. The extent to which their efforts will be sparked by their professional society's activities is not directly measurable. However, the creative mind works best in an environment of mutual support, understanding, recognition, appreciation, inspiration, exchange of ideas and information, and visions of new opportunities and challenges. And the agricultural engineers' own technical and professional organization—the American Society of Agricultural Engineers—best provides this environment. The individual agricultural engineer can exert stronger constructive influence through the mass motion of his professional group.

ASAE will continue to prove its worth in engineering service to agriculture; to develop its unity in the special requirements of that service; and to find its strength in the teamwork of its individual members. Ω



INSULATION RESISTANCE OF PLASTICS WIRE REMAINS STABLE AND HAS AN ADEQUATE MARGIN OF SAFETY AFTER HIGHLY ACCELERATED TEST.

Plastics-Insulated Cables Prove Themselves

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

Wire and cable, important components in any electric system or device, represent a three-billion-dollar business. A considerable portion of this business can be attributed to plastics-insulated wire and cables. Their advantages, development, proof of their desirability by test and actual usage, and typical uses will be presented.

Why Plastics?

You may ask what prompted the urge to use plastics-insulated wire and cables, particularly when technology had greatly improved natural-rubber compounds. Natural rubber had approached its limitations, especially with respect to life at high temperatures, being poor in sunlight and oil resistance. Further, natural rubber burns readily and propagates a flame—particularly undesirable when installed in close proximity. This necessitates applying protective coverings, such as weatherproof cotton braids and lead sheaths, for adequate mechanical protection of rubber-insulated wire and cables.

The search for a material that would not have these disadvantages logically led to polyvinylchloride plastics insulations, known to be highly resistant to sunlight, oil, and chemicals. Because the plastics insulation does not require any additional protective covering, the number of components can be reduced. For example, replacing insulation and weather-resisting cotton braid with plastics covering on the simplest single-conductor wire reduced not only the components but also the diameter by 30 mils. The higher dielectric strength of plastics further reduced the wall from 47 to 31 mils, saving approximately another 30 mils. With large conductor sizes, the saving can be as great as 100 mils. This enabled placing a greater number of wires in a given conduit size—important in rewiring old buildings.

Its smooth, shiny appearance turned out to be an advantage, permitting better looking installations. But perhaps the biggest advantage of all may be that plastics-insulated wire neither burns nor propagates a flame.

History and Developments

The first runs of insulated conductors of the polyvinylchloride type were made in 1935. The first commercially produced wire consisted of a conductor, plastics insulation, and a concentric conductor (photo, top left, page 35). Although more costly, the first major use of plastics wire was in machine tools because conventional wires could not withstand exposure to oil and coolants.

Use of polyvinylchloride wire in many industrial and domestic appliances requiring Underwriters' Laboratories approval also necessitated obtaining approval of the new wire. UL's 1938 listing —the first for synthetic-insulated wire —permitted its use in appliances at temperatures not exceeding 80 C or where exposed to oil not exceeding 60 C.

As interest grew in the use of thermoplastic wire, a new listing was needed for use in rewiring raceways and building constructions. This involved a long-time fact-finding test by the Underwriters' Laboratories. Their September 1939 report permitted using plastics wire

WELL-QUALIFIED authorities on cable insulation, both authors are with the Wire and Cable Dept., Construction Materials Division, Bridgeport. With GE 26 years, Mr. McKinley (right) is Manager—Application Engineering. Mr. Seaberg, Supervisor—Solid Dielectric Power Cable Engineering, has 30 years of experience with the Company.

for installation in dry locations in recognized metal raceways. Then the proper current capacity of this new material had to be determined so that Tables could also be included in the 1940 National Electrical Code (NEC). This required extensive testing of plastics wire as well as other types of wire and cable assemblies in air, in conduit, and between partitions. Because of these tests, the 1940 Code carried the correct values not only for the plastics wire but also for other types of wire and cable assemblies based on the temperature limitations of the insulations.

The 1940 Code recognized the plastics wire for rewiring existing raceways in buildings. Early that year, samples were submitted to the Underwriters' Laboratories by several manufacturers, and approval was received.

The Armed Forces became interested in the polyvinylchloride-type plastics wire and cable because it not only had better properties but also could possibly replace the natural rubber supply. During World War II, large quantities of these plastics wire and cables were used by the Armed Forces. Fortunately, much of the development had begun prior to that emergency. In this interval, approval was given in an emergency revision of the NEC to permit the use of plastics wiring in new installations as well as existing raceways. This revision later became permanent.

GE's Wire and Cable Department initiated a long-time test program through the Underwriters' Laboratories for evaluating the possible use of the polyvinylchloride plastics wire in wet locations, such as underground ducts, where the use of moisture-resistant rubber-insulated wire (Type RW) was permitted.

Because this plastics material was new, the tests were more drastic than those previously applied to rubber insulations. The insulated conductor was immersed in water at 50 C having 600 volts applied continuously for a year. Some formulations were satisfactory, while others fell by the wayside. In September 1943, the Underwriters' Laboratories listed thermoplastic-insulated wire for use in wet locations under exactly the same conditions that Type RW rubber insulation had been approved, making plastics wire the first type of synthetic material approved for such use. Without weatherproof braids that would ultimately rot off, they were smaller in diameter. Approval was timely because the use of natural rubber was practically prohibited in conventional types of wire and cables, being reserved for the Armed Forces. Plastics was the only approved insulation available for use in wet locations without a lead sheath—an important consideration because lead was also in critical supply.

As more and more became known about the polyvinylchloride plastics wire, its use was extended to various fields, one being for railroad signal cable that formerly had been insulated exclusively with rubber. The main advantages in this application were that it did not burn, was smaller in diameter, had a better appearance, and did not require painting to protect the mechanical protective coverings, necessary with cotton-braided wire. Municipalities also became interested in plastics cables for use in fire-alarm and police signal systems.

In power stations, failures occurring in control cable can cause a shutdown of generating equipment. Because of its superior moisture- and flame-resistant properties, single or multiconductor plastics-insulated cable is ideal for this application.

Test and Service

To show how well plastics cables have lived up to expectations, some cables have been removed from installations and tested. The first cable made in 1935 was buried for seven years; and after it was unearthed, tests disclosed its condition to be as good as new. A railway-signal cable lead installed in a relay case for 11 years showed no sign of age when removed.

Another wire was exposed to the elements for more than 15 years in temperature extremes of 0 to 110 F in rain, snow, and fly ash from a nearby power station. Located near the seacoast, it was subjected also to a salt atmosphere. Once again, physical tests showed it to be as good as new. Its tensile strength of 2500 psi and an elongation of 130 percent compared favorably with minimum guaranteed values of 1500 psi and 100 percent when it was new.

One sample of plastics wire was exposed to Florida sunlight for six years along with some natural rubber-insulated wire (photos, lower, next page). Upon seeing the satisfactory appearance and condition of this sample, one customer adopted it for signal cable.

After another sample had been submerged in water for 10½ years at 50 C and subjected to 600 volts, it remained serviceable both physically and electrically (illustration, page 33). Immersion at this temperature constitutes a highly accelerated test. Note that the insulation resistance remains stable and has an adequate margin of safety.

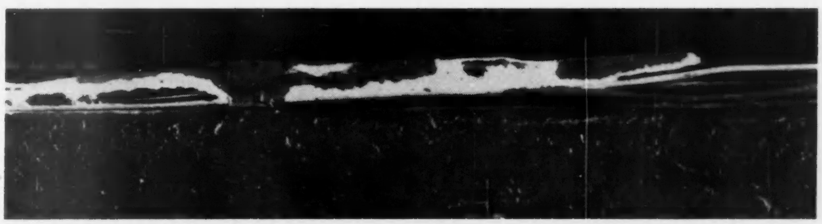
A unique demonstration of plastics versus rubber shows a sample, or what was once a sample, of rubber insulation

FIRST CABLE MADE WAS GOOD AS NEW AFTER SEVEN-YEAR BURIAL.

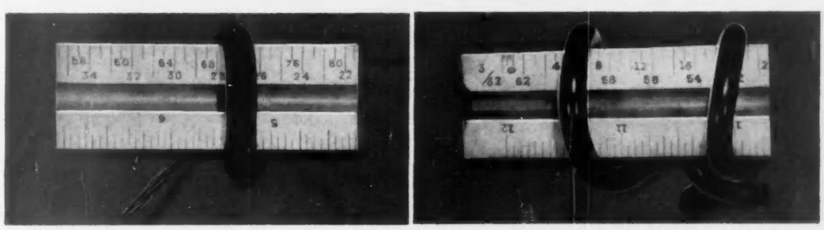
PLASTICS REMAINS FLEXIBLE IN OIL; RUBBER DISINTEGRATES.

and a sample of plastics insulation in transformer oil since 1940 (photo, top, right). The residue, or undissolved, rubber compound has settled to the bottom of the bottle, but the plastics insulations are still flexible and have maintained their bright colors.

A survey of the installation of plastics cables in chemical plants frequently revealed corroded or disintegrated conduit, but the plastics cable remained in good condition (photo, center).



CONDUIT IS CORRODED BUT PLASTICS CABLE UNHARMED IN CHEMICAL-PLANT INSTALLATIONS.



RUBBER- AND PLASTICS-INSULATED WIRES WERE EXPOSED TO FLORIDA SUN FOR SIX YEARS.

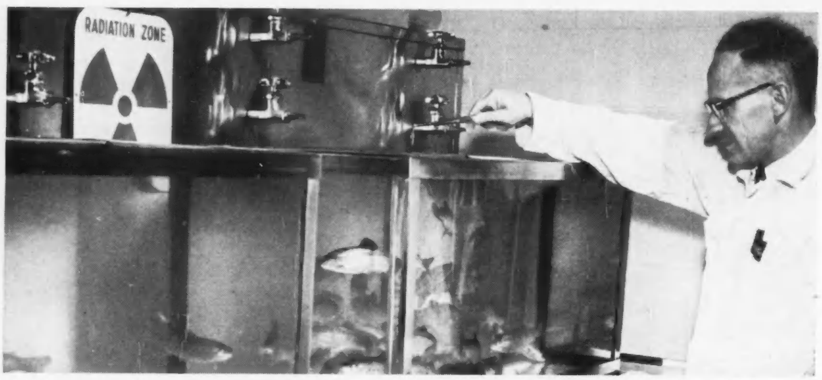
Applications

Some recognition should also be given to the polyethylene type of plastics developed during the war for use in high-frequency cables. Although excellent insulation electrically, it burns and has a lower flow point than polyvinylchloride. Therefore, protection with polyvinylchloride type of sheath is desirable. Polyethylene is principally used for long-distance communication lines because of its lower specific inductive capacity. Polyvinylchloride's advantages make it satisfactory for all general use in communication cable, as well as many other types of varied applications, such as building wire, machine-tool wire, railway signal, and station-control cable. Other uses include radio-hookup wire, aircraft cable, switchboard wire, series-lighting cable up to 5 kv, line wire, flexible cords, and many types of appliance wires. Cables with this insulation can be installed aerially, pulled into ducts or conduits, laid in pans or baskets, or buried.

Many special polyvinylchloride compounds allow a range of maximum operating temperatures from 60 to 105 C. Also, low-temperature compounds pass required bending tests as low as −55 C.

Plastics cables of the polyvinylchloride type have proved themselves in service, as indicated by their increasing use: In branch-circuit wiring, more plastics-insulated wire and cable is used than rubber-insulated cables; and approximately 60-million pounds of polyvinylchloride resin—roughly 16 percent of the total resin production—are annually consumed by the wire and cable industry. Ω

AUTHOR REMOVES YOUNG RAINBOW TROUT THAT HAVE BEEN LIVING IN MIXTURE OF REACTOR COOLANT AND RIVER WATER IN TANK ROOM.



MINNOWS SPIKED WITH RADIOACTIVE MATERIALS ARE FED TO TROUT FOR SPECIAL STUDIES.

Aquatic-Life

A visit to the billion-dollar Hanford Atomic Products Operation near Richland, Wash.—where General Electric produces the nuclear fuel, plutonium, for the Atomic Energy Commission (AEC)—might provoke several questions. Do the large volumes of water used to cool the reactors create any ill effects when returned to the Columbia River? Are the famous salmon runs in any danger from radioactivity? Would a bass or a steelhead trout caught a few miles downstream from the reactors be safe to eat? From the beginning, scientists anticipated these and similar questions and laid careful plans to find the answers.

Although these plans are designed specifically for Hanford, their application is by no means restricted to this site. We are now on the brink of industry-wide construction and operation of power-producing reactors. Because many of these new plants may also have to discharge large volumes of effluent into our waterways, the answers to the questions concerning river life should prove valuable.

SELECT RAINBOW-TROUT STOCK FURNISH EGGS.

"HOT" FINGERLINGS ARE REDUCED TO ASH.

LOCALLY DESIGNED RIG PERMITS STUDY OF ALGAE ON DEEP-WATER ROCKS. GILL NETS ARE MOST PRODUCTIVE MEANS OF OBTAINING SAMPLES.

Studies—Index of Radioactivity Control

By DR. R. F. FOSTER

Fish Laboratory

Soon after the first reactors began operating, tests were started on fish in a fish laboratory—a wooden quonset hut erected near one of the reactors. Young chinook salmon, the most valuable commercial species of the Columbia, were the first to be studied. These magnificent fish grow to about 20 pounds, some even as large as 50. They spend most of their lives in the Pacific Ocean, returning to the stream of their birth at four or five years of age to lay their eggs. The greatest number that enter the Columbia turn off into tributaries below Richland. However, many continue their migration up the main river, a few hundred stopping to dig nests and deposit eggs in the vicinity of the reactors.

Early studies revealed that the radioactivity discharged into the water was too small to directly affect the young salmon. Although some chemicals in the effluent were toxic in strong concentrations, the tremendous dilution occurring in the river dissipated them to below permissible levels.

But as some questions were being answered, new problems were recognized. River organisms were found to be concentrating certain radioisotopes. Juvenile salmon not only moved through the Hanford area on their way to the ocean but also fed extensively in the area. Radioactivity in the river fish originated from the food organisms they ate. How important were particular organisms of the food chain in the passing of radioisotopes along to the fish? Why were some isotopes concentrated thousands of times, others not at all? Why did most organisms show seasonal variations in radioactivity?

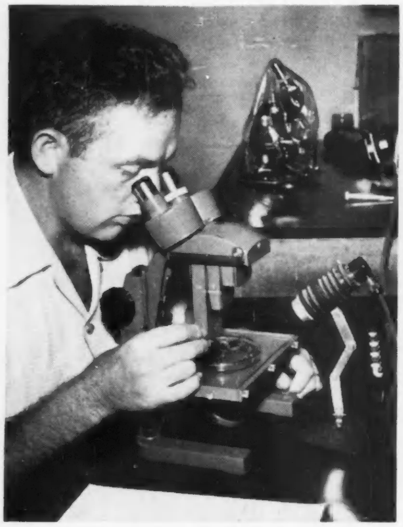
Soon, both the complexity of the problems and the size of the team of biologists studying them outgrew the modest facilities available. A new laboratory constructed in 1952 was occupied that fall in time to experiment with chinook salmon eggs.

Most of the studies were planned to furnish information either on the effects of reactor effluent on aquatic organisms or on how they concentrate radioisotopes from Columbia River water. Continuous biological monitoring of the effluent reveals immediately any undesirable substances entering the river in significant amounts.

Tank Room

Experimental work is carried out in the large tank room (photos, top and center, opposite page) that occupies the entire west side of the new building. The rearing troughs, similar to those in a typical fish hatchery, are fabricated of enameled steel rather than wood so that any radioactive materials adhering to the surfaces can be easily scrubbed off. Glass-fronted tanks, like those in a public aquarium, are used for many special tests.

By simply coupling a hose to the desired supply line, a particular kind of water can be added to many of the troughs and tanks. River water, pumped from the same point that supplies the reactor, is used both for the control fish and for dilution water in experimental mixtures. Just before entering the river, effluent water is pumped from the discharge line and biologically monitored by maintaining stocks of young



INSECT-LARVAE CENSUS determines status of the Columbia's food supply for fish.

DISSECTED WHITEFISH indicates where radioactivity is deposited. The phosphate-rich bone, scales, and liver are generally considerably more radioactive than the flesh.

salmon or trout in troughs with appropriate concentrations. Reactor influent is also supplied to the tank room so that we can compare the reactions of fish held in dilutions of this process water with results obtained with the effluent. Other supply lines originating in the water-preparation room furnish water with special characteristics. Because some tests require effluent cooled to river temperature, refrigeration equipment has been installed. Electric immersion heaters are used where warmer water is required. Sometimes residual chlorine is removed from the influent water by filtration through charcoal.

Many of the experiments call for continuous flow of exact mixtures through the troughs or tanks, requiring careful control of discharge rates. Steady flows are maintained by holding the water pressure constant at a relatively low head (5 psig) and discharging it through orifices. In the tower above the water-preparation room, a tank keeps a constant head on the river-water system, but sensitive pressure-regulating valves are used for the other experimental waters. For ease of adjustment, most orifices are good-quality throttling valves, although glass tubing drawn to a capillary tip is used for flows of less than one gallon a minute. Flow-rate meters assure that desired volumes enter the mixing chambers at the upper ends of the troughs.

Pond Facilities

Besides the tank-room facilities, our studies require a series of small rectangular ponds for exposing large numbers of fingerlings to effluent mixtures. Food organisms—later fed to fish—are also reared in these ponds of radioactive solutions. Such studies not only trace the passage of radioisotopes along food chains but also indicate the mechanism of their concentration in fish. A large circular pond stocked with a community of pond organisms permits us to trace radioisotopes through the many different kinds of aquatic life. Sometimes this unit holds adult salmon that are about to spawn, or it temporarily retains large sturgeon that also live in the Columbia River. A trout fisherman would be especially interested in the large rectangular pond that contains our select brood stock of rainbow trout (photo, lower left, page 36). These fish—many weighing up to four pounds—furnish eggs for experimental studies in the tank room.

Although the numbers of fish raised in the experimental facilities are not large by conventional fish-hatchery standards, they do require substantial amounts of food. Beef liver, fish carcasses, sea-food scraps, and other foods are ground and mixed with protein meals to the desired consistency in the food-preparation room. If all is well, the fish eat with ravenous appetites and grow rapidly. Any retardation of the normal growth rate immediately indicates adverse conditions.

Across the corridor from the tank room are two laboratory rooms where the aquatic plants and animals are processed. Some specimens removed as samples are dissected and examined for abnormalities (photo, right); others are reduced to an ash that contains any radioactive material acquired by the organism (photo, lower right, page 36). A Geiger counter determines the quantity of radioactivity present when the ash is spread on a small stainless-steel plate and inserted in the counter.

The experimental part of our building occupies about half the total floor space. Most of the tests are conducted with solutions containing only small amounts of radioactive materials. However, special studies require spiking with hazardous amount of radioisotopes. For this reason, these facilities are isolated from the lunch room, general offices, and "cold" laboratory rooms. All traffic between the hot and cold sides of the building must go through the change and lavatory rooms at the south end to limit the inadvertent spread of any radioactive materials.

From the first year of reactor operation, biological monitoring of the effluent has been continuous on salmon and

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Dr. Foster—Head of the Aquatic Biology Unit, Radiological Sciences Department, Hanford Atomic Products Operation, Richland, Wash.—began work at Richland in 1945, one year before GE took over the Hanford operation. He carried out the first studies on the effects of reactor effluent on Columbia River life, participated in the resurvey of the Bikini Atoll, and taught a course in fisheries management at the University of Washington.

trout in the delicate stages of life. And at no time have ill effects been detected in concentrations that might exist in the river beyond the immediate vicinity of the discharge pipes. At high concentrations of the effluent—possible only in the laboratory—very young fish suffer some mortality. Similar effects also result from cooling water that has not passed through the piles. This demonstrates that effects are caused by toxic chemicals and not by radioactivity. Considerable work remains to be done on fish other than salmon and on food organisms, but observations indicate that other forms are even more resistant. From our extensive experimental work, we feel confident that the Hanford reactors do not measurably affect fish in the Columbia River.

Although our purpose is to study the fish and not to produce them, surplus salmon are liberated at the termination of each test. The great majority of fingerlings have not been affected by their experiences in the laboratory and contain only insignificant amounts of radioactive materials. Thousands of robust young salmon are therefore planted in the Columbia each spring. These migrate seaward with their brothers who have been fortunate enough to escape their natural enemies and return as adults to be caught by fishermen or to help perpetuate the species.

Field Studies

Although controlled laboratory experiments answer many of the questions arising from discharge of effluent into the river, some information must come from observations made along the river. What kinds of fish and food organisms are present? Are the same forms just as abundant below the reactors as above—or are some forms being wiped out? Do some organisms become more radioactive than others? Where and when is river life most radioactive?

To answer these questions, our aquatic biologists have been collecting river organisms since 1946. Every day, field crews pick up fish and other river life over a 100-mile river distance. In balmy weather they are the envy of office workers, but it's a different matter when the desert sun blazes or subzero winds blow. The collectors use equipment especially adapted for capturing various kinds of aquatic life from the Columbia, a swift and powerful river even in the shallows where most specimens are collected (photo, left, page 37). Conical nets of extremely fine mesh silk strain the diatoms and other minute floating life, or plankton. Bottom-dwelling animals are sampled from shallow water both by allowing the current to sweep dislodged specimens into special sampling apparatus and by brushing and scraping the surfaces of stones. In the middle of the river, where the current may reach five miles an hour, heavy dredges operated from a power boat must be used to sample the bottom forms. Gill nets and small seines capture fish of all kinds and sizes (photo, right, page 37).

For comparative purposes some specimens must be collected upriver from the reactors, where the kinds and quantities of forms are considered normal for this section of the Columbia. Extensive sampling at points immediately downriver from the reactors fails to show differences that would be attributed to the presence of effluent.

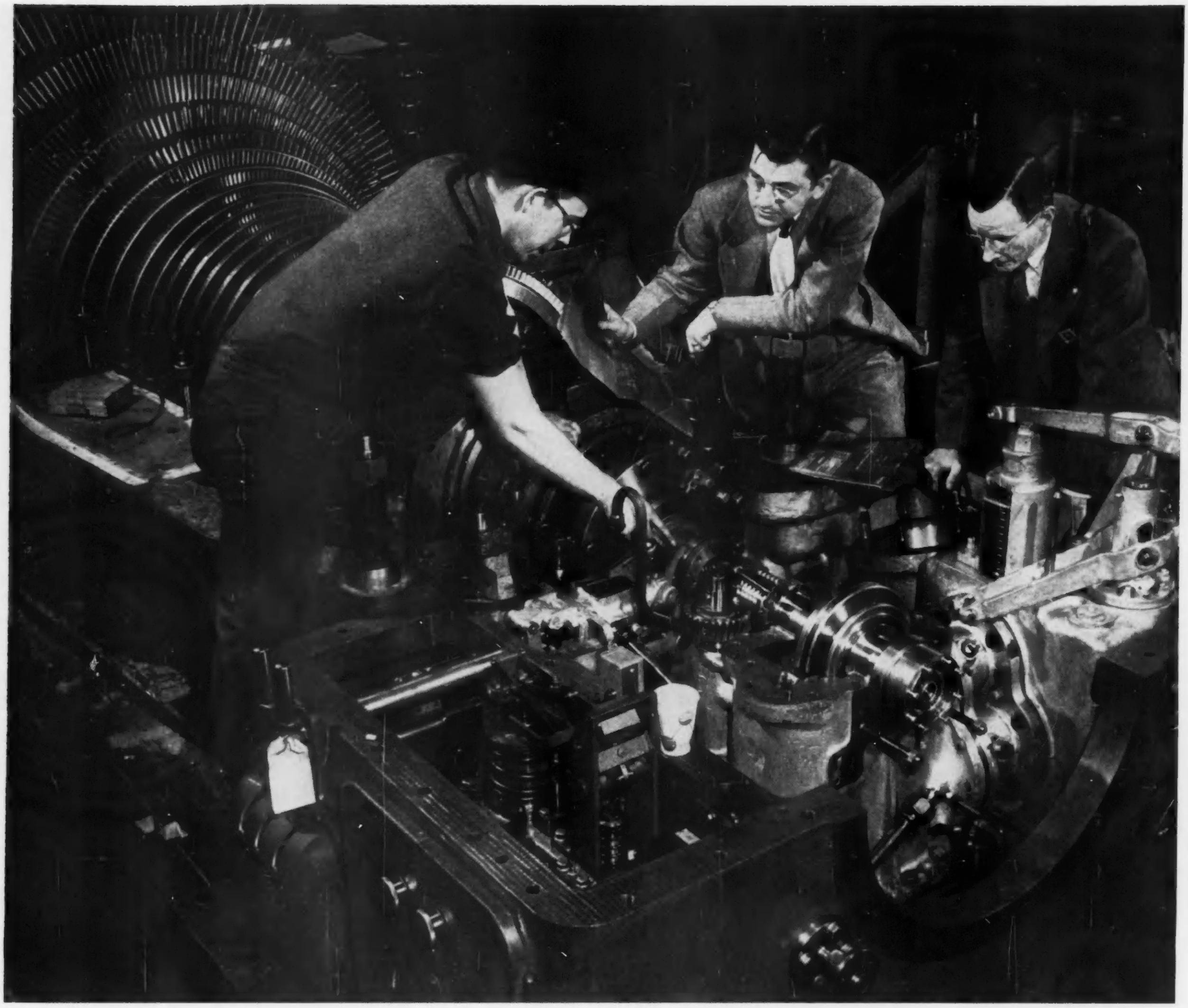
The samples are processed in facilities on the cold side of the Aquatic Biology Laboratory. The processing rooms contain equipment typical of biology laboratories, such as microscopes (photo, left), dissecting instruments, and centrifuges. They also have chemistry-type work benches and hoods for reducing specimens to inorganic ash. The hundreds of specimens processed each month require mass-production methods and business-type record keeping, using punch cards. Electronic computers greatly speed computation of specimens' radioactivity densities.

From the first samples counted, it was apparent that river organisms contained considerably more radioactive material than equivalent volumes of river water. The relative amounts of the several isotopes found in the organisms differed from their occurrence in the water. Certain biologically important isotopes were concentrated thousands of times, others not at all. Generally, the single-celled diatoms floating in the water were not only more radioactive than other forms of life but also contained a greater variety of isotopes. Because this plant life uses dissolved nutrient to grow and multiply, it is one of the basic forms that removes the radioisotopes from solutions and binds them into biological compounds. Many kinds of aquatic animals eat the simple plant life and subsequently become radioactive. Through a chain of organisms, one feeding on another, the radioactive isotopes eventually reach carnivorous fish. Some of the short-lived isotopes decay before the chain is completed. Of the large variety of isotopes initially present in the reactor effluent, only radiophosphorus persists through the food chain and is deposited in fish tissues in significant amounts. This explains why phosphorus-rich tissues—bone, scales, and liver—are more radioactive than phosphorus-poor tissues, such as the flesh.

The concentration of radioisotopes in the water is greater during the winter when the Columbia's flow is lowest. However, our samples show that river animals are most radioactive when temperatures are highest, because the body processes of these cold-blooded animals function in direct relationship to temperature. During the winter months, they are sluggish and eat sparingly, but as temperatures rise, consumption of radioisotope-bearing food increases. Although fish caught in the vicinity of the reactors show measurable amounts of radioactivity, they are safe to eat. An ardent fish eater could not possibly consume enough of these fish to exceed the permissible quantity of radiophosphorus. The radioactivity of aquatic life diminishes rapidly downriver from the reactors so that fish near Richland are less than half as radioactive as those close to the reactors.

Studies Will Continue

Several of the basic questions have been at least partially answered—for present operating conditions. Although no evidence has been found that the effluent is harmful to the river life or that it creates a hazard to humans, we cannot terminate our efforts now. Production capacity has been expanded rapidly at Hanford during the past decade, and additional plants are still under construction. As technological advances are made, processes change. For assurance that no future hazards are developing, to understand how hazards might develop, and to avoid construction of costly and unnecessary protective devices, studies at the Aquatic Biology Laboratory must keep pace with and even anticipate changes in plutonium plant design and operation. Ω



TO PREPARE ACCURATE INFORMATION FOR INSTRUCTION BOOKS, A COPYWRITER FREQUENTLY VERIFIES HIS FACTS IN THE FACTORY.

What Makes the Good Instruction Book?

By WARREN H. DECK

The good instruction book is a tool, both for your company and for your customer. It aids your customer in properly installing, operating, and maintaining the equipment he has purchased. And if it is a good tool for him, then it will be an even better tool for your salesman. Your customer will never be satisfied with equipment that he cannot properly operate and keep operating.

The instruction book basically eliminates complaint expense. When it teaches the customer well, the need to call in engineering and sales personnel diminishes. If the equipment satisfies your customer, the first sale may initiate succeeding sales.

Instruction books need not be fancy exhibits of artistic imagination or typographical achievement. But the well-designed book reflects the standards of quality inherent in your products. Written in sympathy with the man who will use it, the books should contain adequate information in an easily understood well-organized form.

To meet the user's needs, present the information from his viewpoint. And prepare the text with full recognition of its function as a tool for the engineer, maintenance man, and operator. To these men the instruction book can be as important as any mechanical tool.

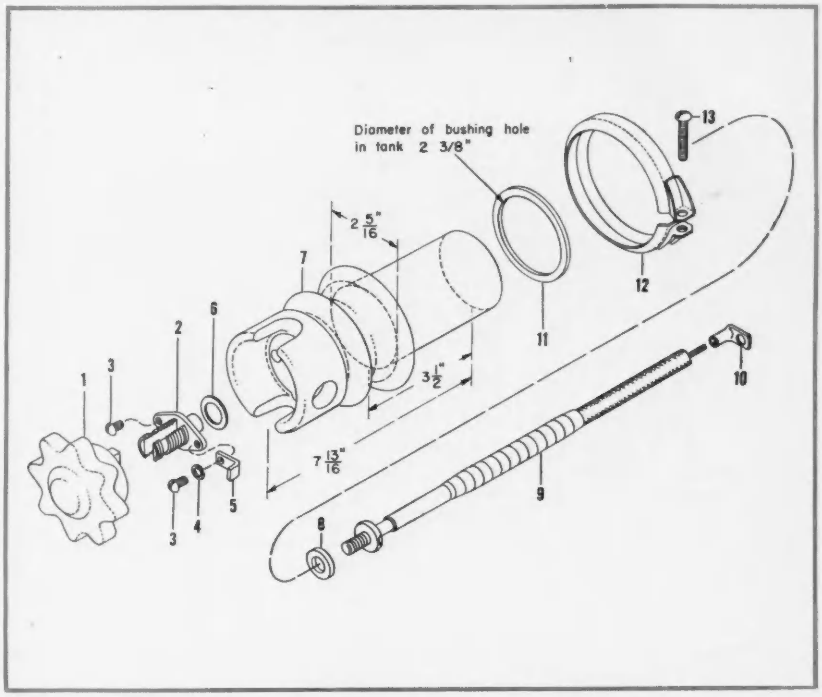
Even though instruction books do not always reach the proportions of a book, we use the term as a general description. Often the instruction appears on a sticker, tag, card, or leaflet of relatively few pages. Description, operation, and maintenance of a motor starter may fit on one page, but the same information about a photoelectric web scanner may require 16 pages of text and illustrations. And the instructions for a turbine-generator set for a powerhouse may fill 150 pages. But regardless of its size, the instruction book must do its specific task well.

Who Reads Instruction Books?

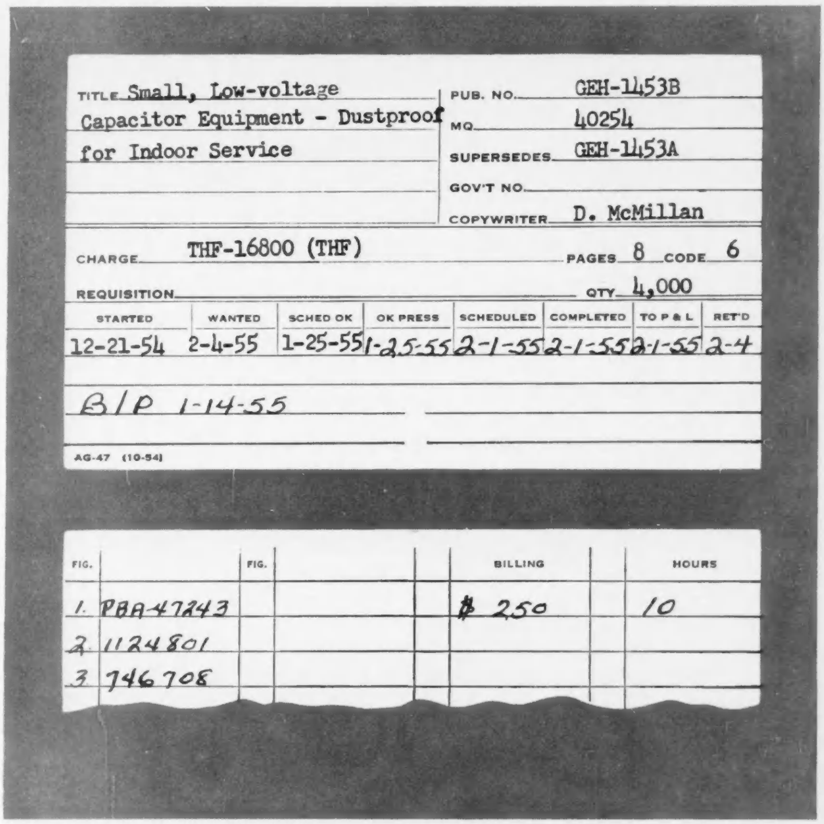
The specific task of your instruction book determines its audience. As you gather material for most instruction books, you may discover the difficulty of determining this audience. Special installation, maintenance, or shipping instructions have obvious readers. But the audience for the instruction book written to cover the installation, operation, and maintenance of a particular piece of equipment is probably as general as that of *The Saturday Evening Post* or *Life*.

This audience may consist of installation men who initially install the equipment; operators who daily use it and possibly make periodic checks; maintenance men who repair and service it; engineers who determine the proper use of the apparatus and its relationship to other equipment; and company executives who are interested in the general characteristics of equipment they are purchasing or approving for use by their company.

With such a varied audience, you can see how difficult it can be to give full satisfaction with one book. Your description of the operating principles of the equipment might be self-evident to an engineer and at the same time be too advanced for the customer's maintenance man and operator. Recognizing this, is it impossible to write a good instruction book? Will you be constantly hamstrung by supplying the semitechnical man with material not too complete yet giving the engineer the information he needs to recommend the equipment for use—a use that will give his company peak operating performance and satisfaction? An instruction book that completely satisfies each person who picks it up exists only in theory. But everyday, good instruction books are produced—good because the engineer-artist-copywriter team recognized and worked toward the primary use of the book, remembering that it would serve a number of subsidiary tasks.



EXPLODED VIEWS of your product will aid the instruction-book reader by simultaneously showing both disassembly instructions and renewal-parts information.



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B/P 1-14-55

AG-47 (10-54)

FIG.		FIG.			BILLING	HOURS
1.	PBA-47243				$ 250	10
2	1124801					
3	746708					

PERMANENT RECORD CARD provides on its face a concise history of each instruction-book job. The reverse side of the card contains data useful for reprinting purposes.

HERE'S AN OUTLINE FOR A TYPICAL INSTRUCTION BOOK

Cover
Title page
Contents
Introduction
Receiving, handling, storage
Description
Installation
- Location
- Mounting
- Connections
- Adjustments and tests

Operation
- Operating limits
- Initial operation
- Operating procedure

Principles of operation (for unfamiliar complex equipment)
Maintenance
- Inspection
- Servicing
- Lubrication
- Repair and replacement

Trouble-shooting
Overhaul
- Special tools
- Disassembly
- Cleaning
- Inspection
- Testing
- Repair
- Replacement
- Lubrication
- Reassembly

Renewal Parts (in a separate book for complex equipment)

For specific components, such as a motor starter, an abridged outline can be used . . .

Description
- Magnetic contactor
- Overload relay

Installation
- Remove packing
- Clean magnet surfaces
- Select heater size
- Check movement of armature
- Mounting
- Connections

Maintenance
- Cleanliness
- Removal of coil
- Removal of contacts
- Changing contacts from normally open to normally closed
- Replacing stationary contact support

Content and Organization

The primary job of an instruction book varies not only with the equipment it covers but also with the specific reader it aims to reach. Will your customer need to know more about using the equipment or about maintaining it? Can he or will he overhaul it? Will he install it, or will you? These and other factors must be considered before organizing an instruction book, for the basic problem is one of content and organization.

You cannot organize a book to satisfy all its readers. But you can organize it so that the customer will be satisfied with the operation of the apparatus—and this should be your aim. At the same time, you can present the material in a style and manner that will neither insult any reader by writing down to him nor baffle another by using terms that are over his head.

There's more to starting an instruction book than having someone sit at a typewriter and bang out the first sentence. Information must be gathered, equipment studied, an outline made, and illustrations planned. By gathering the information before starting the book, you'll save delay and rewriting later. Then plan your illustrations while you plan your text. This way, you can integrate the two and let each carry its share of the burden.

Illustrations need not be fancy or expensive to do the job. Simple wiring diagrams, for instance, may be more helpful than many lines of text. Photographs not only add believability and provide excellent product-recognition reproductions but also logically describe such operations as the steps in disassembly. Color illustrations are expensive; use them sparingly and functionally—never decoratively. Try to make your point some other way.

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Mr. Deck came with GE on the Test Course 14 years ago, spending most of his career working on technical publications. Supervisor, Instruction Books, Apparatus Sales Division, Schenectady, he is responsible for producing most of the Company's instruction books on producer's goods, setting standards for arrangement, content, and appearance.

"...follow fundamental rules...simple, exact, concise, and coherent."

Many instruction books originate in a sales contract. The contract may call for equipment and technical information necessary to operate and maintain it. And the instruction book or parts catalog furnishes this information. Often your customer will not pay in full until he receives the information; thus it's important to know what is required and when.

If you are writing the book, make an outline (Box, page 42). If you are editing only, outline the required production steps, noting estimated dates, quality, and quantity.

The copywriter with his visualizer and engineer should plan the artwork. Their different viewpoints can contribute to an attractive well-organized book. Set up the records so that you can keep a finger on all stages of the production to avoid any bottlenecks.

Your copywriter acts as a clearinghouse for all material in the book, so don't let him waste time working out things that the engineer or artist can do.

Because products discussed in instruction books cover such a broad field of design and application, the contents and organization of each instruction book vary, and one outline will not cover all types of books. Just remember that your presentation should best fit your situation.

Writing Style

A style of writing is second to content and organization in the production of instruction books, for an adept literary style will not make an incomplete or poorly organized book acceptable. On the other hand, a garbled, ambiguous, and hard-to-understand presentation can make a book containing correct and complete information completely worthless. Remember that no instruction book has a captive audience: when a man reads an instruction book, he looks for information. If you do not give it to him so that it is quickly and easily understood, he might work at reading your book, but he won't like it. More likely he'll throw it aside and start experimenting with the equipment. This may cause trouble for him, his employer, and you.

Essentially, the style must follow fundamental rules. Keep it simple, exact, concise, and coherent. To do these simultaneously is not always an easy task. For the most difficult writing to conceive often seems the simplest when read. And the time and thought spent in the preparation of a book is apparent when it reads as if it had written itself. Short sentences, short paragraphs, and plenty of subheads will help your reader. But you must still use plain talk.

When confronted with a certain term that might cause some of your readers trouble, forget it. Talk around it if you have to. Or, if you must use it, define it in conversational language. If possible, illustrate it with a reference that you're sure your audience is familiar with. For example, few people understand how a capacitor stores electric energy, but every reader can be expected to understand the action of a compressed spring. But make sure that he'll understand your analogy. Don't compound the confusion.

It's frequently good practice to define a word twice: when you first use it and later in a different way, to strengthen the reader's confidence in his own understanding of the word. When technical descriptions can't be expressed in more familiar terms, leave them out if you can. Tell the reader what to do for specific results. He won't be interested in why it happens and probably won't even question your omission. However, don't let simplicity get in the way of presenting important information—your audience will not be overwhelmed with a great amount of information if it is understandable. Rarely can you give too much information; the danger lies in not giving enough.

Be sure that you interpret and express meanings correctly. A reader must get only one meaning—the correct meaning. When editing technical material, some phrase or sentence inversions can make statements totally inaccurate. And a sentence entirely satisfactory to its author, already familiar with the subject, can be completely ambiguous to someone seeking information.

Speak directly to the reader as though you were instructing him in person. Use the word "you" frequently and give commands as you would in personal teaching, but help him to carry out your command. Rather than merely "Check brushes," say something like this: "Check brushes. Replace any less than three-eighths inch long." The pitfall of ambiguous command appears most common in trouble-shooting and maintenance charts. Indicate the sources of possible trouble as well as the nature of the trouble.

All of this presupposes, of course, that you are confident of the text's technical accuracy. Naturally, the copywriter expects the engineer to supply him with accurate material, but the engineer must check it again before final printing.

Your Book—An Instructor

The saying "If you can't be right, be consistent" does not apply to instruction books. In their production, you *must* be right, and you *ought* to be consistent. If a tool has several names, decide on the best and use it throughout the book. Make sure your nomenclature on the illustrations coincides with the terms in the text. If you refer the reader to a "jumper" in a photograph, don't confuse him by labeling it "resistance tap" on related diagrammatic illustrations.

Carry your consistency further. Tell your reader all that he should know without weighing him down with unnecessary theory of operation. But give him the fundamentals needed to efficiently operate and maintain the equipment. Don't burden the reader with information concerning irrelevant procedures or tools and set-ups that he may neither have nor know how to use.

Even though we've been talking largely about commercial instruction books, the same techniques in some degree apply when writing books for equipment purchased by the government. The outline and contents will probably be determined by a government publication specification, but the exact specification will vary, depending on the equipment and the service purchasing it. However, you'll have little opportunity for deviation. The government knows who will use the book and how. Although you may sometimes not wholly comply with the specification, any radical changes must be taken up with the government agency concerned to avoid doing much of the work over.

Remember that your book is the reader's instructor. He has come to the book seeking information. Don't let him go away confused or dissatisfied with your book, your equipment, or your company. What he wants to know should be easy to find and easy to read.Ω

SAKS FIFTH AVENUE, New York City, requires high-level surface illumination to compete with brightness of nearby advertising and display lighting.

What Every Engineer Should Know

ACCENTUATING HEIGHT of Kansas City Power and Light Co. building in Missouri, illumination gradually tapers off at upper surface of each level. Suburban buildings (right) are easiest to illuminate because floodlights can be mounted at ground level and concealed by shrubbery.

BORDER HEDGES on lawn (right) conceal floodlights—a 30-year-old lighting installation—that illuminate Boston's famous State House on Beacon Street, resolving a difficult problem. In some instances, low-level ground lighting might be aesthetically undesirable because daytime shadows of the building are reversed or eliminated altogether.

NICHES AND OFFSETS of Sun Life Assurance building in Montreal, Canada, are brightly illuminated and building columns effectively silhouetted.

About Architectural Floodlighting

By H. N. McINTYRE

Ever since the blackouts of World War II darkened American cities, architectural floodlighting has lain practically dormant. Today, however, it seems likely to be revived on a larger scale than ever before (photos).

Sooner or later almost every engineer is exposed to a lighting problem of one kind or another, but seldom is he called on to floodlight a building for display purposes. Perhaps this is unfortunate, for good architectural floodlighting requires considerable imagination and creativity. Rarely are standard lighting methods used because floodlighting tools have many and varied characteristics. Each is designed to do a specific job just like the individual wrenches in an auto mechanic's tool kit.

As architectural floodlighting again arises in importance, the engineer will probably be expected to understand many things about it.

What Is a Floodlight . . .

Little basic difference exists between the lighting fixture for architectural illumination (photo, page 47) and the industrial or commercial fixture for interior lighting. Both use reflectors more efficiently to utilize the available light flux from the source. Floodlight reflectors, however, provide considerably more accurate beam patterns. They project light from a relatively great distance into or on the area requiring illumination. So that the engineer can be sufficiently sure of the accuracy of his calculations, he must know that the beam patterns will be carefully controlled. In architectural lighting there are no walls or ceilings to catch stray light and bounce it back. Misdirected light is irretrievable. The engineer must know not only where to put the light but also how much of it will get there.

Because most architectural floodlights are outdoor installations, they must be completely weatherproof to protect the inner lamp and reflector. As an example of just how weatherproof they are, an installation of G-E heavy-duty floodlights made 30 years ago to illuminate the Boston State House (photos, lower, opposite page) still operates efficiently.

. . . and How Is It Applied?

Floodlighting is the foremost method for illuminating a structure. Festoon lighting—strings of bare lamp bulbs suspended near and frequently outlining the lighted surface—is another method employed today that can also be used to

LIGHT from fluorescent lamps and mercury searchlights transforms the G-E building, New York City, into a 50-story candle.

PASSERS-BY experience no glare from floodlights that illuminate modern buildings; ornamental fixtures atop street-lighting standards completely conceal the lights.

light ground-level areas. Sign tubing, similarly employed, creates a carnival effect instead of enhancing a building's normal dignity. But when concealed from view, this method illuminates much like conventional floodlighting.

Although decorative, festoon lighting not only draws attention away from the building itself but also produces an uncomfortable glare. Further, the electric power distribution is clumsy, inefficient, and uneconomical. On the other hand, banks of floodlights in concealed positions enhance rather than detract from a building's appearance. And they are easily supplied with power. The building—not the lights themselves—attracts interest.

However, whether a building can be floodlighted depends mainly on the reflectance and brightness of the surround—lighting in close proximity to a building (Table).

Reflectance refers to the color and texture of the building's surface. Obviously, an older building constructed with dark facing material might need large, impractical quantities of light to provide the striking appearance considered essential for successful architectural floodlighting. Should its surface be hard and glossy—such as highly polished marble, stainless steel, aluminum, or glass—useful illumination is difficult to achieve because the shiny surface acts as a mirror.

Most building floodlights are mounted near the lower boundary of the surface that requires illumination. Floodlights, therefore, project light upward toward the building, and a mirror-like surface reflects most of the light up into the air. Little of it reaches an observer's eye. Fortunately, however, the majority of buildings have fairly rough, or diffusing, surfaces. Some component of light always reflects back, unless the surface is too dirty or dark.

Brightness of the surround simply refers to the amount of advertising or display lighting near a building. In some downtown areas, streets are lighted at relatively high levels. So bright is the profusion of neon signs, shop windows, and the many displays employing bare lamps that a building surface must be lighted to high levels for sufficient contrast. For this reason, you sometimes see lower stories of tall buildings left unlighted. Only the upper reaches are "painted with light"—these being visible for many miles without any interference whatever from the local bright surround.

Because of their dark surround, buildings located in isolated areas need relatively little light for effective display.

Concealing Floodlights

Usually floodlights are mounted on a platform. Care should be taken to shield the floodlights from view, protecting the observer from uncomfortable glare. This isn't too much of a problem because, as mentioned before, floodlights usually project their light upward against a building's surface.

A highly convenient location for low-mounted floodlights is atop a marquee, or canopy, and in many instances roofs of low, adjacent buildings serve well. Also utilized are cornices, ledges, and parapets of the building itself—particularly useful for fluorescent floodlighting. Where lighting equipment cannot be concealed, straight, shallow fluorescent fixtures do not detract from a building's architectural appearance. The frequent necessity of mounting the units close to a building's surface has the advantage of maximum utilization of light. As the lighting engineer familiarizes himself with the techniques and advantages of fluorescent floodlighting, he will put it to greater use.

Lacking a convenient place to locate floodlights, technicians often install crossarms at the top of street-lighting poles near the building. Some of the older ornamental street lights can be converted completely to conceal the floodlight (photo). (Light is directed downward to the street by an auxiliary lamp.)

The problem of locating floodlights to illuminate factories, office buildings, hospitals, civic memorials, and other buildings in a noncommercial environment is easily solved. Usually mounted at ground level, the floodlights can be shielded from direct view by shrubbery.

Painting with Light

Only imagination limits the unusual and interesting effects that you can achieve by properly projecting light. The arithmetic of floodlighting is simple. Any engineer who will accept the few basic premises of light production and utilization can quickly calculate an installation. The handy relationship "foot-

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A nationally recognized authority on outdoor lighting, Mr. McIntyre—Senior Application Engineer, Outdoor Lighting Dept., River Works, West Lynn, Mass. —came with the General Electric Company in 1947. He completely designed the lighting installation at the new Kansas City Athletic's Stadium.

candles equal lumens per square foot" helps to find the proper type and required number of floodlights. Recommended lighting levels are listed in readily available publications, such as the Illuminating Engineering Society's (IES) *Lighting Handbook.*

But many times, uniform illumination of a complete building surface isn't enough, for such uniformity can be undesirable. To attractively light a continuous building surface, for example, sometimes the floodlights should be so arranged that the illumination level is highest on the lower portion of the surface. As the lighting level tapers off toward the upper portion, it pleasingly accentuates a building's height.

Suppose a tall building has many levels. Each successive level could be lighted in exactly the same manner, and the average amount of illumination increased slightly on each upward step. By thus complementing a building's height and proportion, spectacular effects are frequently achieved.

Shadow effects need careful attention in architectural floodlighting. Most architects have a good idea of the appearance of their building in daylight. In fact, they may have planned certain aspects with daylight shadows in mind. Floodlighting, usually done from low levels, frequently reverses or eliminates these shadows altogether. Sometimes this may be undesirable, and so it might be necessary to consult an architect.

Silhouetting columns and illuminating niches and offsets to a high level are other effective uses of light. They, too, provide great aesthetic appeal to the observer.

Without question, color is becoming more prevalent in architectural lighting, particularly with the development of colored fluorescent floodlights. Many of these floodlights employ fluorescent lamps whose phosphors convert radiant energy to colored light with high efficiency. Thus light and electric power aren't wasted as when colored filters are used with conventional filament-lamp floodlights. (A red filter, for example, passes only the red component of light, absorbing all the other colors.) Blue-green, amber, and red floodlighting are produced directly by mercury-vapor, sodium, and neon light sources without phosphor conversion.

FLOODLAMPS—tungsten, mercury, and fluorescent—fill a specific need in architectural lighting. Using reflectors in fixtures concentrates the light in definite beam patterns.

RECOMMENDED ILLUMINATION LEVELS FOR FLOODLIGHTING

Surface Material	Reflectance (Percent)	Surround Bright (Footcandles)	Surround Dark (Footcandles)
Light marble, white or cream terra cotta, white plaster	70 to 85	15	5
Concrete, tinted stucco, light gray and buff limestone, buff face brick	45 to 70	20	10
Medium-gray limestone, common tan brick, sandstone	20 to 45	30	15
Common red brick, brownstone, stained wood shingles, dark gray brick	10 to 20*	50	20
Poster panel and bulletin board	Light	50	20
	Dark	100	50

* Buildings or areas of materials having a reflectance of less than 20 percent usually cannot be floodlighted economically unless they carry a large amount of high-reflectance trim.

These data appear in IES *Lighting Handbook*.

An Undeveloped Art

The tools used for floodlighting have progressed a long way from the arc searchlight and festoons of bare lamps used in the early 1900's. High-efficiency light sources and well-designed outdoor equipment are commonplace today. But even so, the field of architectural floodlighting has been touched on only slightly.

Floodlighting a building is a subtle, economical way to advertise. Yearly cost of electric power, even for the most elaborate installations, totals only a fraction of a company's advertising budget. Utilized after business hours, this electric load is welcomed by power companies. They, too, are providing added incentive for a return to this neglected phase of illumination. Ω

ROOM AIR CONDITIONERS designed for high power factor benefit the home owner by providing greatly increased operating efficiency and reduced current and power consumption.

How Higher Power Factor Improves Room Air Conditioners

By R. J. LEHNEN

The high-power-factor design of today's room air conditioner guarantees lower operating expense, less costly installations, and more reliable service. Traditionally a low-power-factor device, the room air conditioner (photo) has made a tremendous impact on the comfort-conscious public, finding almost universal acceptance. Such terms as exhaust capacity, ¾ hp, Btu, and cfm are becoming part of our everyday language. Where horsepower and fuel consumption are considered standard measures of quality in the automotive industry, power factor is rapidly becoming the index in exceptional room-air-conditioner performance, playing an important role in public acceptance.

High and Low Power Factor

The closer the power factor approaches 100 percent the more the home owner and the electric utility benefit. Appliances such as irons, toasters, and hot-water heaters—all operating on the resistance principle—have power factors of 100 percent. Unfortunately, power factors of motors range upward from 40 percent. Low power factor means that the device draws more current, thus imposing more of a load on the home owner's circuits as well as on the electric utility.

Utilities' New Problems

The difference in current demand between the high- and the low-power-factor load increases the demands on the country's electric utilities. This is of particular concern when the load increases peak demand because of the additional generation and distribution capacity that is brought into use.

Summer air conditioning has increased the load on utilities' systems, often raising system peak demands. For many years, the peak demand occurred during the winter months, but today peak loads appear on many systems during the summer months, particularly in the South.

The consumer of electric power pays the utility according to the figure registered on his meter. However, a watthour meter connected to a low-power-factor load doesn't spin any faster than a meter connected to an identical load of high power factor. Thus, although the utility must provide more current to supply the low-power-factor load, it receives no more money from the consumer.

When large quantities of low-power-factor load are connected on the system, both the user and the power company are confronted with other difficulties: overloaded house circuits, increased fuse blowing, expensive rewiring, excessive voltage drop, increased line losses, and overloaded generators and transformers.

Domestic vs Commercial Loads

Industry was the first to use large amounts of low-power-factor connected load. The power companies soon realized that some distinction between a domestic load and a commercial load must be made. Thus the volt-ampere-hour meters or penalty rates for low-power-factor load were established to recognize the difference in investment necessary to supply the various power-factor loads.

For many years, domestic load was mainly comprised of high-power-factor devices such as lights, water heaters, and electric ranges. However, with the ever-increasing numbers of refrigerators, fans, disposal units, oil burners, automatic washers, and home workshops, the domestic circuits began to feel the impact of low-power-factor devices. At first, the effect of room air conditioners was negligible because by 1946 yearly sales totaled less than 30,000 for the entire country.

Room Air Conditioners

Power companies, aware of this changing complexion in the domestic load, were planning for increased facilities to handle these load-building devices. Then in 1950, the room-air-conditioner business suddenly came alive, surpassing the most optimistic predictions. By 1953, room air conditioners, not only low in power factor but also high in current consumption, were

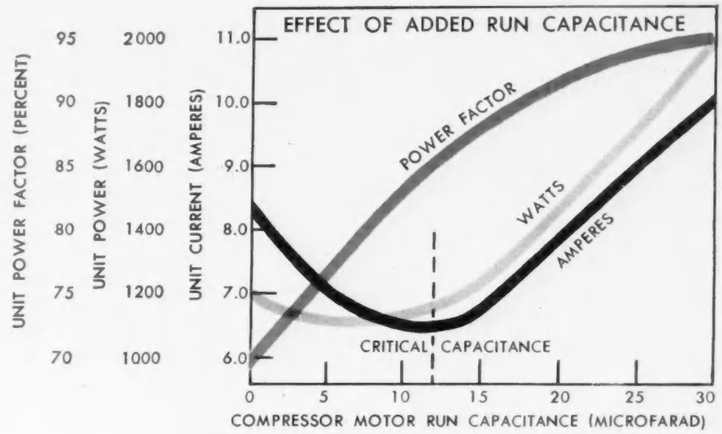
HOW CAPACITANCE HELPED POWER FACTOR—TO A POINT

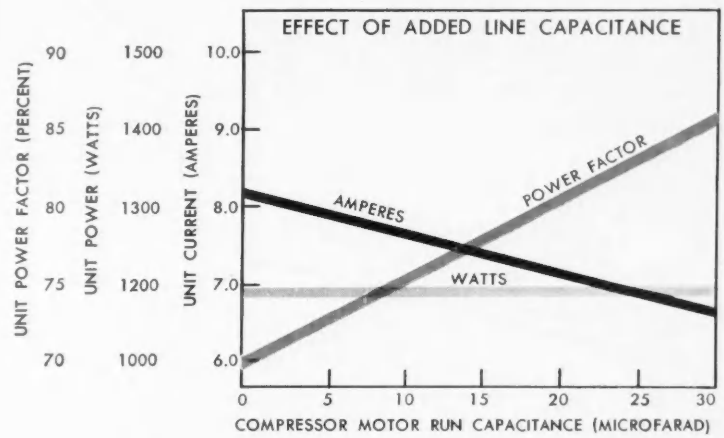
To determine the effect of added capacitance on existing 1954 room-air-conditioner designs, many tests were conducted. The effect of motor-run capacitance and line capacitance was studied. Similar tests were conducted using various combinations of motor-run capacitance and line capacitance.

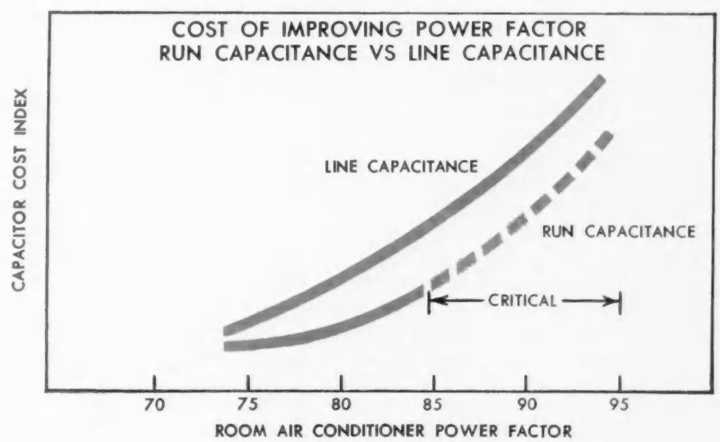
These tests indicated that the addition of compressor motor-run capacitance improved compressor motor performance—but only to a point. Beyond that, any additional increase caused a serious deterioration of performance. Power factor improved over the entire range (illustration, top). However, any increase beyond a critical capacitance resulted in a serious increase in power and current, thereby negating all the advantages of high power factor. This critical value of run capacitance depends on the design of the particular motor under investigation.

Capacitance added directly across the line had a different effect on unit performance (illustration, center). The current was reduced in direct proportion to the increase in line capacitance. The power stayed constant, while the power factor increased linearly with line capacitance but at a much lower rate than with a comparable value of run capacitance.

Let's look at the relative cost of improving the power factor by using either additional run capacitance or line capacitance (illustration, lower). The rapid rate of increased cost not only made this approach uneconomical but also presented serious engineering problems. Therefore, the final answer had to come from an entirely new electrical design that integrated properly applied capacitance with the improved compressor motors and fan motors.







PRODUCT DESIGN ENGINEER, Room Air Conditioner Department, Erie. Mr. Lehnen coordinated and incorporated the power-factor-correction advancements in the 1955 room air conditioner. Joining GE on the Test Course in 1949, he aided in the administration of the Test Program and later directed statistical quality-control procedures for food freezers.

being added to the circuits at a rate of over a million a year.

Because of its growth rate, this new load immediately caused concern to the electric utilities, and it appeared that power-factor correction was one way of minimizing the problems involved. Early in 1954, some major utilities considered establishing specific minimum power-factor requirements—usually 90 percent—for room air conditioners.

The Edison Electric Institute (EEI) had already gone on record recommending that a 90 percent operating power factor be required on all room air conditioners. Manufacturers, immediately concerned, felt that this increase would result in excessive price increases at the consumer level. And, even if reasonably economical means of increasing power factor could be found, no time was being allowed for engineering development and manufacturing.

The manufacturers were facing cold facts. The compressor motors and fan motors included in their current designs were basically low-power-factor devices. By the addition of motor-running capacitance and capacitors directly across the line, some improvement could be achieved—but only as a partial step toward the 90 percent power-factor goal set by EEI. The real solution lay in the hands of compressor- and fan-motor designers and capacitor manufacturers, for these devices could be redesigned to closely approach the 90 percent power factor desired.

A series of informal discussions between room-air-conditioner manufacturers and the electric utility industry improved understanding of their mutual problems. In the spring of 1954, as a result of these meetings, a joint recommendation by EEI and Air Conditioning and Refrigeration Institute (ARI) suggested that operating power factors effective on 1956 model room air conditioners would be 75 percent on ⅓-hp units, 80 on ½-hp, and 85 on ¾-hp and larger.

Some Important Factors . . .

Let's see how far industry in general had come in providing room air conditioners with higher power factor. A survey of 1952 room air conditioners of various manufacturers disclosed operating power factors from 60 to 80 percent. A similar survey of 1953 units indicated power factors of 65 to 83 percent, with more and more units operating in the 70 to 75 percent region. Most 1954 models operated in the 70 to 82 percent range. These new goals presented a real challenge to the entire room-air-conditioner industry. For G-E engineers the challenge was even greater because they were charged with meeting the 1956 goals on 1955 units even though designs were in the final stages.

Three important events helped GE incorporate high power factor into their 1955 designs a year ahead of the industry's recommendations: an early 1954 survey investigated all possible ways of improving power factor while using existing compressor and fan motors, new high-power-factor compressor motors were introduced, and much higher power factor fan motors became available. In brief, the survey showed that just adding more capacitance to existing designs was not the answer (Discussion, page 49). However, the unusually high power factor of the new compressor motors—many exceeding 90 percent—was an important contribution and resulted from the optimum use of motor-run capacitance in the basic motor design.

The new fan motors, while more costly, were a major step forward. Shaded-pole motors with power factors of 48 to 58 percent were being used. A permanent-split capacitor motor was designed that, when operated with a separate capacitance or in conjunction with the compressor motor-run capacitance, obtained a power factor of 95 percent. It was much more efficient, too. Then a new "extended winding" shaded-pole fan motor was developed with an 80 percent power factor.

. . . and Their Results

All these factors helped General Electric achieve the goal of "equal or better 1956 power-factor goals for 1955 model room air conditioners." For instance, in the ½-hp 115-volt model, the 1956 goal was 80 percent, the G-E realization, 90 percent. All other 1955 models range between 85 and 91 percent and are above the industry's goals.

The home owner benefits in many ways when he buys a room air conditioner designed for high power factor. Operating efficiency is greatly increased. Current and power consumption are significantly reduced (in the ½-hp 115-volt model, the current is reduced 40 percent, and the power, 20 percent). A ½-hp model can be plugged into any multiple-outlet 15-amp branch circuit (in accordance with the National Electrical Code) because the full load current is only 7½ amp—less than a flatiron or toaster. This eliminates expensive rewiring. Excessive fuse blowing and voltage drop are things of the past.

Electric utilities benefit by more efficient utilization of system components. The use of capacitors to maintain system power factor is reduced, and peak demand becomes less severe.

The benefits of high-power-factor room air conditioners have touched a wide segment of the electricity-conscious public, as well as the many electric utilities serving this public. Ω

THE ENGINEERS' COUNCIL FOR PROFESSIONAL DEVELOPMENT (ECPD) MAKES LISTS OF THEIR PUBLICATIONS AVAILABLE TO ENGINEERS.

HOW INDUSTRY, ENGINEERING SOCIETIES, AND COLLEGES CAN CO-ORDINATE A . . .

Community Project in Professional Development

By J. S. ALFORD and PROF. C. WANDMACHER

A group of active engineers—occupied in their own fields of endeavor but wanting to help the rising generation attain their full professional stature—took time six years ago to study the problems that confront young engineers.

This resulted in a comprehensive report published by the Engineers' Council for Professional Development (ECPD) under the title, "The First Five Years of Professional Development." In addition to a recommended six-point plan for such development, this report emphasized the need for concerted action by industry, engineering societies, and colleges in the community where the young engineer begins his professional practice.

Next the group attempted implementation of the recommended professional development program for young graduate engineers in a typical American industrial community—Cincinnati, Ohio, and vicinity.

In the fall of 1952 an industrial Sponsor Group was formed in that area to foster and promote the Professional Training Program of ECPD. Nine industries were represented in the original group . . .

- Cincinnati Gas & Electric Company
- Champion Paper & Fibre Company
- Cincinnati & Suburban Bell Telephone Company
- Procter & Gamble Company
- Cincinnati Milling Machine Company
- Armco Steel Corporation
- American Telephone & Telegraph Company, Long Lines Division
- Williamson Heater Company
- General Electric Company

Recently, several additional local industries have been brought into the group to comprise the local Industry Committee that totals 15 members.

E. S. Fields, Vice President and General Manager, Cincinnati Gas & Electric Company, is chairman of the Sponsoring Group with Professor Cornelius Wandmacher serving as the representative of ECPD's Professional Training Committee—the team undertaking leadership of this community project.

The local Industry Committee has attempted to establish a favorable climate encouraging the optimum growth of young engineers by following the six-point plan . . .

- Continued education after graduation
- Orientation and training in industry
- Integration into the community
- Professional identification
- Personal appraisal
- Selected reading

To make the greatest initial progress, the Industry Committee concentrated its efforts where the needs seemed most acute—continued education, orientation and training, and integration into the community.

Continuing Education

Today, the rapidly enlarging scientific base for engineering progress requires a broader engineering background for engineering leaders. They must become well schooled in the advanced aspects of fundamental principles, and the analytical and experimental methods of engineering sciences, such as dynamics, elasticity, fluid flow, and metallurgy. If the present trends continue, in 15 years the managers of engineering activities, as well as the technical specialists, will be drawn largely from the ranks of men with advanced engineering training. Because many organizations employ young engineers directly after graduation, it is important to provide locally adequate opportunities for part-time graduate study in engineering.

The local Industry Committee decided that each industry should be responsible for training within the Company to meet its own specialized needs. Also the University of Cincinnati was requested to introduce at advanced levels a number of fundamental courses related to several fields of engineering activity.

To insure substantial class groups at regular intervals in all courses, making the program self-supporting, all participating industries agreed to jointly support a selected group of courses each year. And announcing a definite cycle of rotation allowed everyone to make future plans.

Through the local committee, executive officers and engineers of co-operating companies were interviewed. The interviews resulted in a proposal for a basic group of courses that most nearly suited the needs of this industrial community.

With the approval of the University, the local Industry Committee published a brochure describing the courses. Accompanied by a letter from a management source, most companies circulated the brochure to all engineering personnel.

As a result of this co-ordinated planning and promotion, 285 students enrolled in the nine selected University courses of the first year: advanced engineering mathematics, advanced strength of materials, advanced dynamics, modern atomic and nuclear physics, engineering analysis, advanced circuit analysis, advanced physical chemistry, advanced analytical chemistry, and advanced unit operations in chemical engineering.

Not one of these courses fell short of necessary class size to be self-sustaining financially; three courses required additional class sections; and six sections closed at maximum enrollments.

Much thought went into the problem of a logical division between the courses that should be offered at established graduate schools, such as at the University of Cincinnati, and those given at the plants of the local industrial groups. For the University courses, the major emphasis is being placed on the advanced study of fundamentals and principles rather than on current engineering practices. Through such re-examination of fundamentals, engineers acquire the increased versatility demanded in the rapidly changing technologies of today's engineering. These courses will expose the student to comprehensive problems of increasing novelty and difficulty and then encourage him to carry through the analysis and solution completely on his own.

Specialized technical courses are prepared and sponsored by the various industries to meet their own specific needs. Courses at GE's Aircraft Gas Turbine Division, Evendale, Ohio, deal primarily with gas turbine fundamentals; systems, especially complete accessory systems used on aircraft gas turbines; mechanical design, including specialized problems in vibration, mechanisms, and process technology; and specialized problems in installation aerodynamics.

These four courses, intended for engineers in aircraft gas-turbine design, are too specialized to be of general interest to other members of industry in Cincinnati. Having these courses taught by the best specialists in the Aircraft Gas Turbine Division makes them effective. At the present time, 350 engineers—about one third of all technical engineers—are enrolled in the technical courses given at Evendale.

Industry always faces the necessity of giving vocational-type training for many jobs. Here, the course must provide an adequate kit of educational tools to do a certain job. The University Graduate Program, not concerned with this type of vocational training, aims rather at advanced study of fundamental basic principles of Engineering.

Orientation and Training

Late in October 1954, a series of presentations and panel discussions, held in Cincinnati on the subject of orientation and training in industry, indicated a trend toward making training programs more flexible in subject matter, duration, and type of experience for each trainee. Usually, experienced training supervisors are employed to carefully consider what is best for each individual. Although wide differences existed in the types of industries represented, participating companies generally agreed that the assignments in any training plan should be selected on the basis of five objectives . . .

- Bring the young engineer in close association with a mature engineer of genuine professional interests and accomplishments.
- Give each trainee a distinct sense of responsibility.
- Help the young man feel that at the outset he is really making a contribution in his job.
- Provide for measuring a man not only on his technical understanding but also by his ability to get things done and to accept responsibility.
- Provide various types of experience so that the individual can decide on the type of work he desires as a career.

Community Integration

Each year the Professional Activities Committee of the Engineering Society of Cincinnati (ESC) arranges a Newcomers' Night, welcoming all engineers new to the community. The letter of invitation includes data on all 24 of the societies participating in the Technical and Scientific Societies Council of Cincinnati.

During the past year, an ESC committee prepared a community orientation booklet titled "Cincinnati—From

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Joining GE on the Test Course 21 years ago, Mr. Alford—Mechanical Engineer, Jet Engine Department, Evendale, Ohio—completed the Advanced Engineering Program and served on engine development and design review. Holder of 12 patents and a previous contributor to the REVIEW, *he was co-author of "Turbojets for Supersonic Flight," November 1954 issue. Professor Wandmacher has spent 18 years in teaching and administrative posts of engineering education. Currently Head of the Department of Civil Engineering, University of Cincinnati, he has served as National Chairman of ECPD's Professional Training Committee for the past two years.*

an Engineer's Point of View," covering professional, cultural, and religious activities; educational opportunities; civic information; and recreational facilities. Its initial printing of 1000 copies was immediately followed by 2000 more for distribution through the Engineering Society of Cincinnati and the co-operating industries.

Professional Identification

As a result of recent discussions in Cincinnati, Professional Identification has now been established as Point 4 of the ECPD's program. This concept of a broad base in professional activity emphasizes the fundamental steps for the young engineer's identification as a professional man: 1) to become actively associated with an engineering group—national or local society and 2) to qualify for professional registration.

For encouragement of professional group activities at the Evendale Plant, a "Know Your Technical Society Week" was also conducted last October and received a hearty response. Many applications were submitted, and a noticeable increase in participation in technical society activity has been apparent.

Some of the activities during the week included: prominently displaying promotional posters; publicizing this event through the Plant newspaper; making Society application blanks and literature available; sending all engineers a letter from the president of the Evendale Engineer's Association, endorsing the week; and distributing bulletins on Society honors and awards, plus calendars of national and local events.

Within the Plant a bulletin titled "Professional Societies Information" is published each month. It furnishes the dates and general agenda of the forthcoming meetings, lists of Division personnel who will attend the meetings, announcement of papers to be presented by General Electric employees, committee membership held by Division personnel, and summaries of reports by engineers attending meetings. In addition, the weekly Plant news often summarizes the talks made to technical societies and frequently announces forthcoming papers to be presented.

To prepare students for taking the State of Ohio engineering examination, the Evening College of the University of Cincinnati regularly offers refresher courses. Repetition of these courses for a number of semesters demonstrates the interest and need for them. Many engineers new to Ohio have successfully completed these examinations as evidenced by the large and growing number of Professional Engineer certificates. An engineer who has taken one of the two steps toward becoming identified as a professional man will likely take the other.

READING LIST FOR ENGINEERS INCLUDES GENERAL, TECHNICAL, AND PROFESSIONAL BOOKS.

Personal Appraisal

Currently 300 young engineers in the Cincinnati area are participating in an evaluation study of the present ECPD Personal Appraisal Form. Designed to aid a young man in making a personal inventory, this appraisal outline helps him capitalize not only on his technical training but also on his best personal characteristics. A long-term objective of the ECPD program is to make the young man recognize that technical competence is necessary but not the only requirement for becoming a professional engineer.

Selected Reading

As an aid to stimulate the selected reading program, the Cincinnati and Hamilton County Library furnished the Engineering Society of Cincinnati Headquarters with a loan collection of 80 books from the "Reading List for Engineers." Synopses of these books have been written by the Library Committee and published serially in the *Engineer and Scientist*—a weekly bulletin circulated to all Society members in the city.

Discussion of reading habits by ESC groups disclosed three essential parts to a reading program: General reading—biography, travel, history, economics, philosophy, literature, and others; technical reading—listed in ECPD's *Selected Bibliography of Engineering Subjects;* professional reading—periodicals of the national societies and industry.

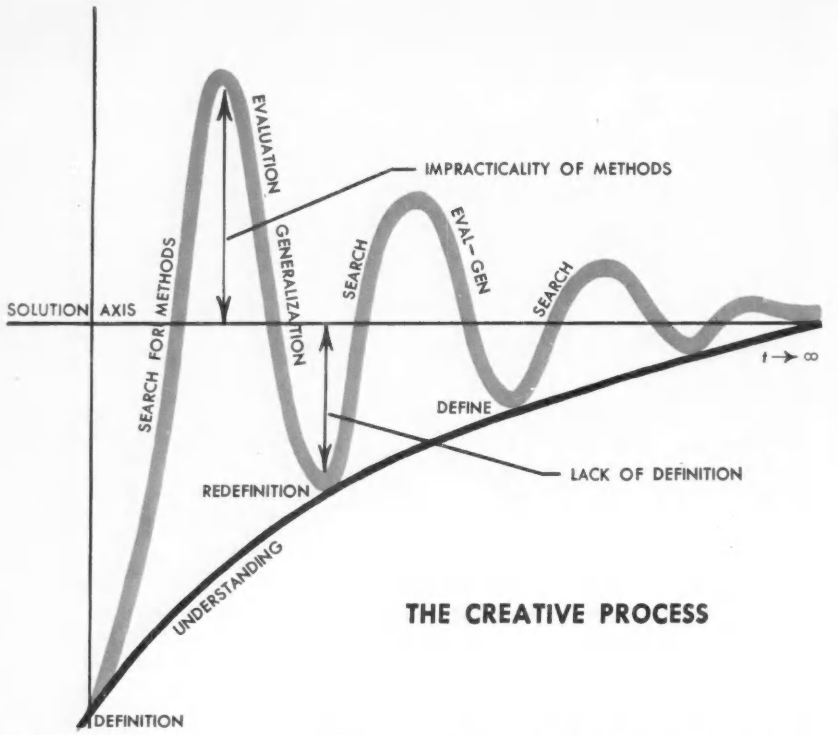
Results of Studies

The pilot-plant studies of the ECPD's Professional Training Program in the Cincinnati area indicate several conclusions . . .

- An effective community program for promoting the development of engineers should embrace a well-rounded basic program such as represented by ECPD's first-five-year program.
- Industrial leaders need to take the initiative in providing the favorable climate for continuing professional development of the young engineer.
- Industry benefits by providing plans for encouraging engineers to participate in technical-society activities.
- Opportunities for part-time graduate study in engineering are essential for both those who seek advanced degrees and those who desire particular subjects.
- The need continues for refresher courses to help prepare the engineers who desire to take the State Board Examination required for professional registration.
- Many present demands on educational institutions to prepare the student for specialized fields will be met in the future by expanding programs for continuing growth after graduation.
- Industry and the engineering societies will increase their co-operation with the colleges and universities of the community where the young engineer begins his professional practice. Ω

Understanding the Creative Process

By E. K. VON FANGE



CREATIVE ABILITY improves not only as you practice your facility for grouping knowledge into new combinations but also as you study to enlarge your capacity for understanding.

Literature on the subject of creativity reveals some confusion and uncertainty as to its meaning. Few writers say whether creativity is a product of heredity or environment, usually giving a ratio of one line of statement to 20 lines of qualification.

Creative men in the past are usually portrayed as receiving some mysterious illumination, or inspiration—sometimes referred to as a "flash of genius"—to climax their creative search, often appearing to them in the dead of night. Thus from study and practice, a novice might expect to be suddenly awakened by a flood of illumination and, in a brilliant flash of genius, spout forth his first creation.

With creative ability placed on such a high pedestal, it may now disturb people to see it also applied to homemaking, gardening, art, and other areas. And so let's ask such basic questions as: Who is creative? is it the man who proposed the basic idea or the people who carried through the development and design and made it practical? was the end device even a creation? if so, were the contributors each partially creative, ingenious, or not creative at all?

Today's student of creativity is appalled when an experienced engineer coldly and logically proposes four or five ways to solve a creative problem. He asks: Were those ideas creative? The experienced man was clever, but where was the flash of genius? Upon reflection he may honestly say to himself, "If I had originated those ideas, I certainly would have thought I was being creative."

To dispel the mystery and confusion surrounding the creative process, we will present the factors that comprise successful creative engineering.

Common Denominator

Although the dictionary defines create "as causing to be or to come into existence," interpretations vary. For instance, when notable contributors to progress are eulogized, some people say the contributor was creative, ingenious, resourceful, brilliant, imaginative, original, an artful contriver, clever, or all of these. Others may label him imitative, fanciful, lucky, far-fetched, a good guesser, a daydreamer, or unconventional. The various shades of meaning in these words, although useful in semantics, offer little understanding of the creative process. But before an understanding can be obtained, we must achieve a common but specific definition.

Creativity is not limited to any one group of people, being applicable to those in research or development, design or product engineering, the arts or sciences, and other areas. To achieve something new or different, a person must discover a new combination or application previously unknown to him. This combination might include an existing device, mechanism, linkage, fundamental law, effect, or change in attribute such as size, shape, or color.

For example, the first automobile was a buggy modified by an electric motor. Because a horse no longer turned the front wheels, a shaft and handle were extended upward, permitting the driver to steer the vehicle. Still another whole industry emerged with the application of the electric motor and heater strip to the home-appliance field.

Creativity, then, is the obtaining of a combination of things or attributes that

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Mr. Von Fange joined General Electric in 1950. Graduating from the Creative Engineering Program in 1953, he is currently Second Year Supervisor, Creative Engineering Program, Engineering Training and Education Section, Engineering Services, Schenectady.

are new to the creator. Thus, when a person does something for the first time by himself, without specific previous knowledge of the technique or process, he is being creative.

Who Is Creative?

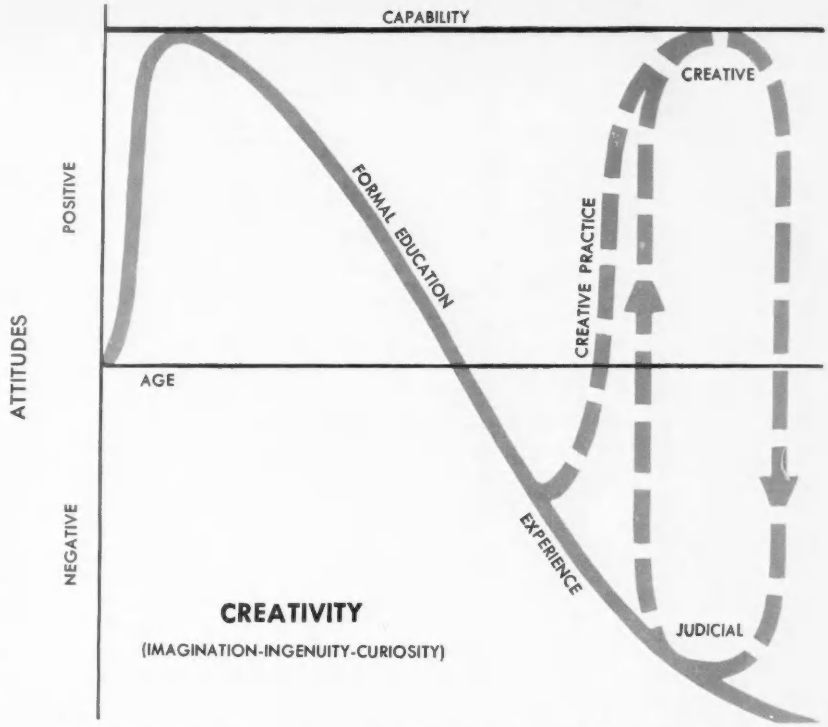
Pioneers with a minimum of equipment settled in undeveloped areas and created a successful livelihood from the natural materials at hand. More recently the Seabees earned immortal fame by their ability to build airstrips and other war needs under great adversity. Theater productions have often been presented on a shoestring budget. And in spite of inadequate equipment, the answers to many laboratory experiments are still achieved. Creativity in all these areas is synonymous with the art of improvising.

Another area of creative activity comes under the general heading of rationalization. An individual may be so engaged when justifying his job, asking for a raise, devising methods of coping with unexpected trouble, worrying about an imaginary evil, and building dream castles in the air. A person who lives in a housing development, where every house on the block is the same, exercises a rather simple creative process by giving an individual appearance to his home. To achieve this difference, he can select from a wide variety of color combinations, choose various types of landscaping, or add a porch, storm shutters, or a decorative fence. By presenting a variety of menus and table settings to her family, a housewife also displays creativity.

A student, apprentice, or any beginner must be creative to accomplish a problem or task that he has not been specifically instructed in. For example, problems at the end of a chapter of any mathematics textbook usually do not reveal the steps to solution. Only by carefully searching the chapter contents and combining bits of knowledge can the student finally arrive at the right combination.

Small children illustrate outstanding examples of creativity in the form of imagination and curiosity. To a child, a stick is his trusty rifle or his prancing stallion: a mound of sand is an impenetrable fortress or, a moment later, a towering cliff to tunnel. And his curiosity is just as active. Everything he sees merits an inquisitive tug or close inspection.

We may conclude, then, that everyone can be creative through the use of imagination, logic, chance, mechanical methods, or in other ways.



SUBJUGATION to closely directed well-disciplined activity from kindergarten through the college years tends to encourage conformity and smother creative expression and curiosity.

What Stifles Creativity?

With creativity not confined to a select few, let's look at the reasons why useful creativity is not universally utilized.

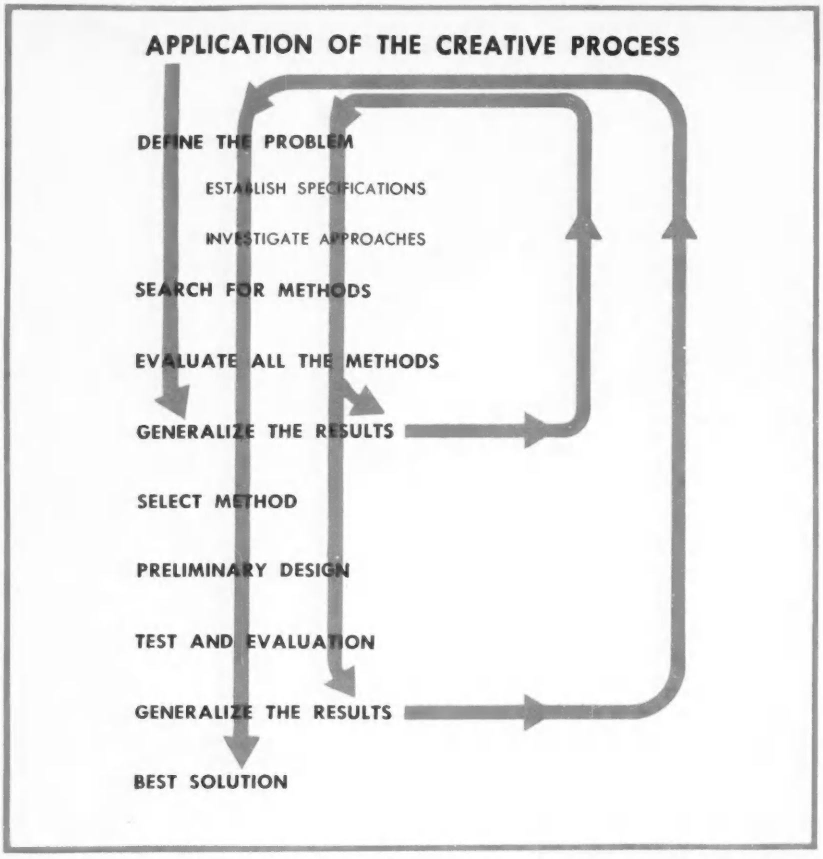
Although naturally creative, a child lacks judgment (illustration). As a result, most of his creative expressions are suppressed with choruses of "don't," "no," "stop that," and "just wait until I get you home." Similarly, from grammar school through college, emphasis is placed on subjugation to fixed and well-explained text assignments, closely directed laboratory experiments, and well-disciplined study periods. Now, this in itself isn't bad except that it provides little outlet for creative expression. Consequently, creativity and curiosity dwindle and lie dormant through sheer lack of exercise.

Other factors also contribute to submerging creative expression. If a child's physical characteristics or clothing differ from his associates, he is often a subject of laughter and derision. With such bitter object lessons in conformity, it is no wonder that a child's creativity is stifled. A twofold damaging effect results: a feeling that they lack opportunity to apply creativity to solve their problems and the desire to actually resist change.

College training also has adverse effects on creativity. For example, the assignments given in a typical engineering institution could be likened to a footbridge across a wide, deep chasm. The bridge represents the problem with the solution at the other end. Such factors as the detailed definition, boundary conditions, and applicable formulas or procedures given in the text form strong and sturdy guide rails.

As the student progresses, he crosses longer bridges with little difficulty because each is still protected by guard rails. Then comes graduation with a sheepskin instead of guard rails. Small wonder that new engineers are hesitant and indecisive about what to do and how to begin. They have learned to use the safely guarded bridges and refuse to cross a creative bridge when they see it, simply because it has no guard rails to lead and guide them.

After working problems that have only one approach, one method, and one answer, with all the working knowledge in the written material immediately preceding the problem, you can easily see why most engineers readily accept the conventional approach. Any automobile



CREATIVE EXPRESSION to be efficient and successful must be planned and scheduled, and recommended procedures followed either consciously or subconsciously.

design is all right as long as it keeps the horsepower up front like grandpa's buggy. It must have four wheels, hinged doors, and roll-down windows—like the old stagecoaches—even though this may not be the most economical or practical design. The same is true with a refrigerator design, as long as it looks like an icebox. Any electric or gas range is equally satisfactory if it closely resembles the old wood stove.

Because of this educational background, many engineers and other people fail to realize that many approaches can be used to solve the problems they are responsible for. Not only that, but the methods for applying each of these approaches are numerous.

A recent article said, in effect, that the basic radio circuit has been simplified or perfected to such an extent that no further improvement is to be expected. Someone, some day, will take that as a challenge. He will look for and find a new approach, and a new radio circuit will be created.

Another example of how education can limit people's vision and their thinking is the often-heard story of the United States Patent Office Director who resigned in the late 19th century because he felt that everything had undoubtedly been invented and that his job had absolutely no future.

Another factor tends to stifle creative expression. As the standard of living progressively increases, individuals become more self-satisfied with the status quo; and self-satisfaction, or contentment with what one has, is the very enemy of creativity. The individual who first observed that the dead live in us summed the situation neatly. Too often, progress and growth are impeded because judicial thought processes depose instead of dispose a creative contribution. And so, even though industry may recognize and create a more efficient automobile, refrigerator, or range, customers will not buy if the product is too different.

But perhaps the biggest stifler of useful creativity stems from its definition. Inherently, the entire span of the creative bridge is initially untested—full of unknowns and possible dangers. Sometimes the creative process can be successful only through a fierce determination to succeed. When notable inventors finally overcome the last obstacle in their creative process, we can easily understand why their elation is so vividly recorded. The same thrill exists in any situation where a person sets himself a challenge and is victorious. But pathetically few have enjoyed this thrill. Time and time again, creative bridges can be and have been safely crossed by the strong-willed few who dared. And anyone can safely dare if he will merely practice.

For example, the apprentice carpenter or construction man first relies on overadequate railings on his scaffolds. Then as he becomes accustomed to walking and working high above the ground, he works confidently on a bare scaffold.

A similar approach should be used in any course in college or elsewhere to develop creativity. The problems or situations first presented should be well defined, with solutions or methods readily apparent to one familiar with the creative process. As the student's confidence increases, progressively more difficult problems without obvious solution can be given until the student has the confidence necessary to tackle any creative situation that presents itself.

A strong desire to create is essential in the useful creative process. All too often in engineering, this desire has come only when competition or other factors have forced the discarding of the old blueprints or techniques.

In spite of a strong desire and competence on the part of the individual to achieve new combinations, a successful result is not assured. Understanding in the area where he wishes to create must also be present.

How to Acquire Understanding

An individual may exhibit creativity regardless of his level of understanding a problem. The usefulness, however, of the ideas generated is strictly a function of his understanding of the fundamental concepts involved. The quality of his ideas will become higher as his understanding of the problem becomes greater. Initial ideas are often discarded after additional effort is expended. And as understanding increases, the additional idea combinations that evolve will better satisfy the real needs.

Further, understanding increases with frequency of exposure to a concept or to a situation. For example, each time a new theorem is presented in a mathematics course, the student achieves understanding by successively solving more difficult and different problems, applying the theorem in their solution. His understanding increases still more when he applies this learning to other areas where the theorem would be useful.

Thus, when a situation presents itself, it should first be defined as basically as initial understanding permits. This should be followed by investigating the various approaches that could solve the problem and by searching for the specific methods to accomplish each approach (illustration, opposite). Evaluating each method by asking "how could this be made to accomplish the problem definition" permits a generalization of the results, leading to a better understanding of how best to solve. To further improve understanding, the problem definition is reviewed and the entire procedure repeated.

At this point, the understanding could be called two-dimensional—a paper solution. Far from complete, this solution must first be transformed into a preliminary design—a working three-dimensional model. Testing and evaluating this model, as well as generalizing on the results, may reveal an incompleteness of understanding. And so, once again, the definition is reviewed, and the entire procedure repeated until complete three-dimensional understanding is achieved.

As in other activities, the fourth-dimensional unit—time—nearly always affects the final results attained in an engineering problem. Thus the result used best fits the problem requirements in the budgeted time, even though understanding would increase and a better solution would be obtained if more time were available—still another reason why so much opportunity for creativity exists today.

Once thought of, the best ideas are often amazingly simple; and in retrospect the embryonic solutions seem ridiculous when compared with the simple result. However, they were essential steps in achieving an understanding of how best to solve the problem. It becomes obvious, then, that people trained throughout all their educational experience in the one-problem one-solution philosophy experience difficulty in achieving this understanding. By typically accepting the first method that occurs to them, they encounter unforeseen stumbling blocks from factors they neglected to consider. And instead of attempting to evaluate their mistakes, achieve new understanding as a result, and rework the problem, they continue on, ending with a top-heavy device difficult to manufacture and even more difficult to market. This tendency of engineers allows the competitor to enter the picture, do a little more investigating, create a much better solution, and offer a more saleable product.

To find the gem, or pearl, of an idea that will give undisputed product leadership is the practical application of the creative process. How does the pearl fisherman find his pearl? Suppose on a given day, he is told to go out in his boat, obtain one pearl, and be back at the shore within a specified time. He will be paid an amount proportional to the value of his pearl.

Now, some fishermen of narrow viewpoint will dash out, find a pearl, and race back for their commission. But the majority will realize that they stand to gain if, on the way out, they will estimate the return time, probable number of oysters, and the breaking and evaluating time. Thus they know the maximum time they can spend in the water actively searching for and accumulating oysters. By this efficient system the fishermen not only obtain a larger quantity of oysters but also are smart enough to break open all of the oysters after their search. The results can then be carefully and judiciously examined, and the largest and most perfect pearl selected, giving both the employer and the divers the greatest return on their investment of time and money.

Besides showing the value of searching for many methods and soundly evaluating all of them, this analogy shows how the planning and scheduling of creative activity is normally accomplished (illustration, page 54).

Theoretically and practically, complete understanding occurs at infinite time, for the true definition places in proper perspective all the factors of quality, cost, and customer needs. Difficult to place in absolute perspective, they change with advances as new materials and processes become available to the designer and as consumers' likes and dislikes vary. Consequently, the creative process, although limited by the economics of time and money available during any given period, always affords the opportunity for achieving a better solution.

Thus to improve creative ability, one needs to expand his accumulation of knowledge and sources for reference, improve through practice his facility for grouping knowledge into new combinations, and improve through study his capability for understanding.

By following consciously or subconsciously the recommended procedures, one can successfully create; but to create efficiently on a repeatable and predictable basis, one must plan and schedule this activity.

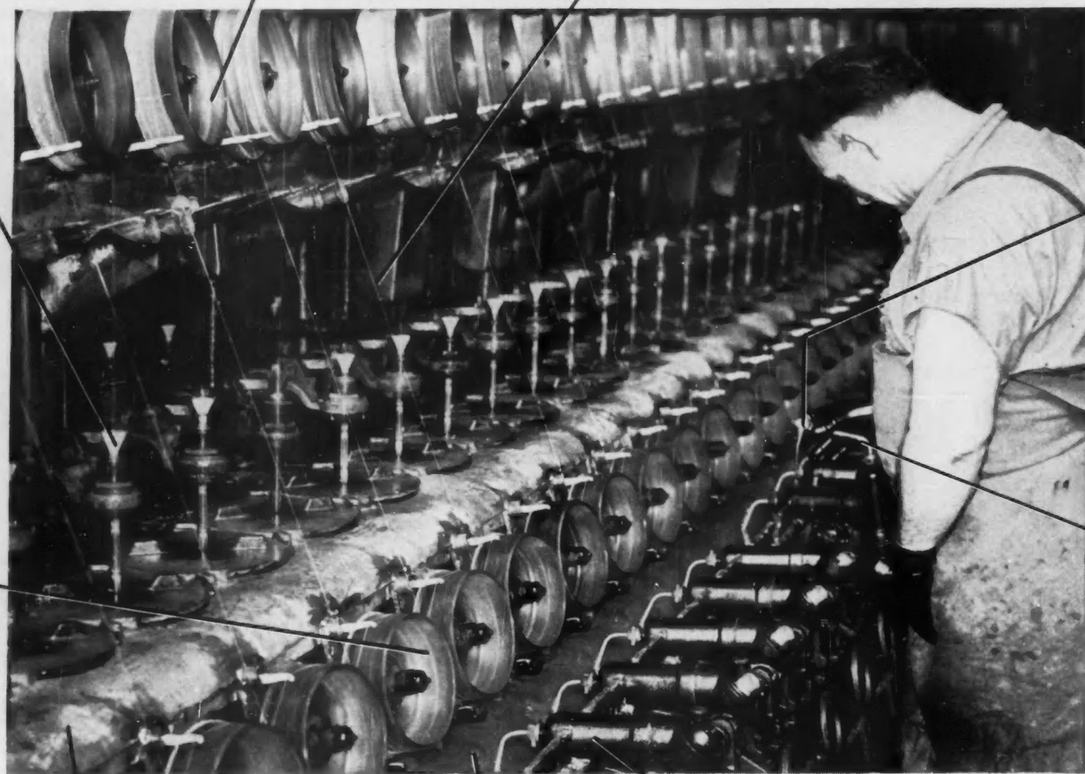
Using the steps in the creative process has one objective—achieving problem understanding so that the best method will be obvious.

Initial problems should be relatively simple and taken from areas familiar to the student, such as the home or the automobile. To facilitate understanding, time should be scheduled for generalizing and projecting any specific knowledge into other uses and useful tools should be provided. Ideally, training should include model shop construction activity to give experience in three-dimensional understanding. The instructor should take adequate time to lead the hesitant over their first creative hurdles, but his counseling should progressively decrease.

Today's Opportunities

Man's progress continues as a function of the existing quantity of separate thoughts and things, the intercommunication between tribes or nations, and the permissive atmosphere of his environment. Look, then, at the tremendous opportunities for creative expression today! Each new idea becomes in itself an additional building block to be combined with any of the already existent blocks. Thus creativity is not degenerative; the patent office need never close because everything has been invented. Rather, creativity is a regenerative process with each new contribution permitting a whole series of additional combinations or creations as does each discovery of a new effect or property.

Several factors stimulate the need for creative processes: Every design is a compromise achieving only the best possible solution within a given time; new effects, new materials, and manufacturing processes are continuously being discovered and developed; and, of course, customer desires are constantly changing. Thus creative opportunity exists and always will exist in every phase of engineering activity.Ω



EARLY VISCOSE PROCESS OF SPINNING RAYON NOW PRODUCES THE MAJOR PORTION OF TODAY'S FIBER OUTPUT WITH HIGH-SPEED MOTORS.

Man-Made Fibers Challenge the Motor Industry

By C. L. HAMM

The ingenuity and persistence of engineers are largely responsible for the success of the synthetic fiber industry. Through the engineer's efforts in designing the necessary special equipment, synthetic fibers and yarns are being used commercially.

Early Experimenting

Count Hilaire de Chardonnet first experimented in 1889 with producing a practical synthetic yarn made by the nitrocellulose process. At about this time, English and German scientists also made artificial fibers. But Chardonnet actually produced the first commercial rayon at his plant near Besancon, France, his home town, where regular small-scale production began a year later. Lacking a better method, the spindles at this plant were driven mechanically. Breakdowns were frequent and costly, resulting in almost as high a cost for the "artificial" silk as for the real silk that it replaced.

Despite these difficulties the new product attracted widespread attention. Several other European countries hurried along their developments for making similar fibers. In England, Stearn, Bevoir, and Cross invented the viscose process, destined to become the major portion of today's rayon production. Although it greatly improved the manufacture and cost of making rayon fiber, this process left unsolved the mechanical problems of running spindles at high speeds in wet and acid conditions with loads not in dynamic balance.

Producing Synthetic Fibers

Everyone today is delighted with the many new fabrics made from such synthetic fibers as rayon, nylon, dacron, acrilan, and others. Although well aware of their advantages and beauty, most of us know little about their manufacture or the equipment used in the process. The majority of man-made fibers start out as liquids that pass through many chemical processes before they are extruded through fixtures and eventually drawn into fibers. Processes and chemistry vary so widely that it is impossible to discuss them all.

Let's begin with viscose rayon—by far the most common fiber. Cellulose, mainly from wood pulp or cotton linters, is treated with caustic soda and carbon bisulfide that breaks it down into a golden liquid that looks much like honey. Referred to as viscose solution, it ages a certain length of time while being carefully filtered to remove any impurities or solids; it is then pumped through lead pipes to the spinning machine (photo, opposite page). Then the viscose, after flowing into accurate metering pumps, passes through a glass tube and spinnerette and then into an acid bath directly in front of the pumps.

Attached to the end of the glass tube is the spinnerette—a platinum thimble-shaped device with 30 to 60 holes about 0.001 to 0.004 inch in diameter. The spinnerette extrudes the strongly alkaline viscose from the acid bath that solidifies it into rayon fibers, or filaments. These fibers are picked up by the lower godet wheels that pass them to an upper godet wheel and down through a glass funnel into a revolving rayon bucket below, where the fibers accumulate in the form of a cake.

As the extruded fibers—still not small enough—leave the spinnerette, they are stretched between the godet wheels to the proper size by merely running the upper wheels faster than the lower ones. This stretching also increases the strength of the fibers.

The rayon buckets and the special motors that drive them (photo) run at the high speed of 6000 to 10,800 rpm so that the yarn leaving the lower end of the funnel is drawn out, winding around the inside surface of the bucket. The bucket accumulating the rayon is a strong cylindrically shaped piece of reinforced plastics or metal. Attached to the shaft of the vertical spindle motor, these buckets must be sufficiently strong to withstand the high speed, as well as the chemical corrosion of the acid and alkalis present in the yarn. Because the filaments are so small and vary in size, from 1 to 20 hours are required to fill a bucket, even at speeds as high as 10,800 rpm.

HOLDING NINE PATENTS in his field, Mr. Hamm began his G-E career on the test course 35 years ago. Placed in charge of rayon spindle-motor design in 1939, he was more recently responsible for design of all textile motors. In March, he transferred to the Aircraft Gas Turbine Division, Small Aircraft Engine Department, West Lynn, Mass., and now works primarily on the mechanical application of bearings and seals.

After the buckets are filled, the rayon is removed in cakes—resembling angel-food cakes—that are carefully washed to remove chemicals and then dried. From this point, the rayon goes to textile twisters to be formed into yarn in the same manner as all other textile yarns. Usually, plants sell rayon on cones, or beams, for conventional use by textile mills.

Machines and Methods

As the synthetic industry grew in size, improvements were largely confined to solving urgent basic problems of operation and to controlling the quality and chemistry of the process. Once these were under control, more effort was concentrated on the machines and methods for reducing product cost. Of the machine problems, the most serious were chemical corrosion and high-speed bucket spinning of yarn for desired rate of fiber output.

That the yarn in the bucket was never in dynamic balance imposed serious unbalanced forces on the machines, particularly the spindles, resulting in frequent and costly interruptions of production. Further, this caused a serious loss of rayon chemicals, for the solution once mixed had to be used or it would spoil. Such problems were new in the textile field and no one could offer a remedy. But gradually engineers and machinery makers recognized the need for better machines with simplified mechanisms. They turned to electric control and equipment—it could be sealed against corrosion—to accurately control product variations and to increase reliability.

Electric Spindle Motor

Steps toward electrification began in 1908 when a limited quantity of enclosed vertical electric spindle motors were tried experimentally. These small three-phase induction motors were designed to drive relatively small spinning buckets at about 5000 rpm—a high spindle speed at that time. Thought to be a great advance over existing mechanical methods, these first motors had low power output and contained few of the refinements of today's standard. But their improvement over existing mechanical drives attracted wide attention and caused a concerted demand for more.

Aware of this trend, Copson and Crewdson of the newly formed Viscose Company of America approached the General Electric Company in Lynn, Mass., to obtain a few samples of a motor similar to European types. If General Electric could build a satisfactory spindle motor, they might buy as many as 5000—a figure regarded as

FROM THE FIRST ELECTRIC SPINDLES, MOTORS DELIVERING 3 HP HAVE EVOLVED TO DRIVE 16-INCH BUCKETS AT SPEEDS OF 10,000 RPM.

fantastic optimism by GE, for such a quantity of motors of any design was unheard of then. However, 10 samples were built, tested, and found to be satisfactory. And after several months of trials, the Viscose Company was ready to construct what was then thought to be a large plant at Marcus Hook, Pa., using these motors.

By 1916, about 1000 electric spindle motors were operating in America. These 3-phase 30-volt 90-cycle induction motors, small by present standards, operated a shallow five-inch-diameter bucket at speeds up to 5000 rpm, developing 0.07 hp at their maximum speed. Of stiff-shaft construction like their European counterpart, the motors handled moderate unbalances only by virtue of their ruggedness, for little was known about vibration absorbing systems at that time. And they could be bolted to a mounting rail—an improvement over existing European designs.

Some of these motors, including the first American electric spindle motor, identified as Design No. 1 (photo), are still in commercial use after 38 years of 24-hour-a-day operation, 7 days a week. Many have been rebuilt with larger electric output so that they can drive 6- and 7-inch-diameter buckets at speeds up to 7000 rpm.

By 1930, spindle-motor requirements had increased so much that design No. 2 was developed. With three times the output of design No. 1 and rated 0.2 hp at 7200 rpm, it was intended to drive 6- and 7-inch-diameter buckets. These motors incorporated the first attempt at vibration absorption by placing resilient washers between the motor and the mounting rail.

Improved Motor Design

From this point on, the industry's needs grew rapidly. The appeal of larger buckets, larger cakes, and higher speeds prompted the development and production of Design No. 3. Essentially the same as Design No. 2 except larger and heavier, the new motor was rated 0.35 hp at 9000 rpm. Improvements in the oil-pump lubrication and larger resilient washers at the bottom of the motor resulted in better operation. This motor was able to drive 7-inch-inside-diameter by 6-inch-deep buckets with six-pound cakes of rayon at speeds up to 8500 rpm. The design proved so popular that it soon became the standard of the industry, being widely used by many companies and copied both here and abroad. Because so many thousands were made, it still predominates in the industry in numbers of units.

As pressure for a more reliable smoother-performing motor grew, engineers soon realized the need for a new approach. Unbalanced forces had become so large that it was difficult to make bearings and shafts to withstand the severe stresses. Design engineers accepted the challenge to produce a new motor that would absorb and dissipate the excessive unbalanced forces so that vibration would not affect the yarn, and yet keep shaft, bearing, and motor size reasonable. This presented a new problem to the motor industry because most high-speed motors were carefully balanced to prevent vibration.

To accomplish this, Design No. 3 was modified to incorporate a flexible shaft and counterweighted adapter. But this was soon abandoned because the motor-frame proportions and general design

DESIGN OF THE NEWEST ELECTRIC SPINNING MOTOR

Instead of the former rigid, heavy construction, the new motor (illustration) was built light in weight and flexible so that it would readily deflect under stress. A gyroscopic adapter automatically compensates for bucket unbalance and tends to always keep the bucket and rayon cake running on center of rotation. This action is aided by the flexible shaft.

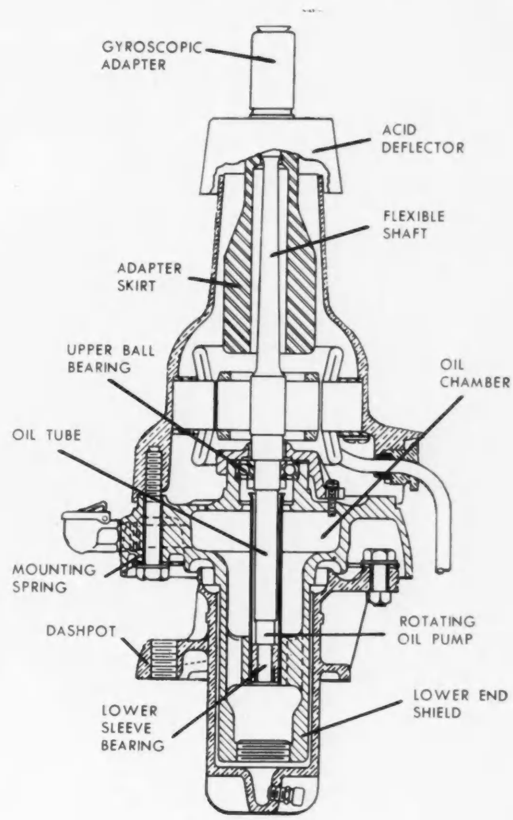
The mechanical design proportions are such that the shaft always runs above the first natural critical vibration. A nodal vibration point occurs in the shaft about 3½ inches below the top end, allowing the shaft to bend about midway between the adapter weighted skirt and the bucket. This results in maximum effectiveness for correcting unbalance and centering of the load.

The entire motor frame is flexibly mounted on three points of a flat disc-type mounting spring. Three other points of the mounting spring midway between the motor frame mounts are bolted or dashpot. This flexible construction would be useless without an adequate damping system.

Damping is provided by a large oil-filled dashpot formed by the cylindrical surface of the lower end shields and located at the bottom of the motor. This dashpot not only restricts horizontal vibrations of the motor frame but also protects the bearings from the vertical shock of dropping on buckets. The outer casting is about 0.125 inches larger than the inside, and this space is filled with heavy dashpot oil.

Because the oil chamber is entirely separate from the lubricating oil, the heavy viscosity does not affect lubrication and permits ample damping without moving parts other than the oil. The result: an accurate and permanent hydraulic damping system that does not change with wear—an important feature when the vibration rate (360 cps) is so high.

The exceptionally large (280 cc) lubricating oil chamber not only helps to maintain low lubricating oil temperatures but also allows runs of many months between lubrications. The lower sleeve bearing runs directly in the oil bath so that it is always cooled and thoroughly lubricated. The upper ball bearing is oil-mist lubricated by oil pumped up the inside of the oil tube surrounding the shaft—the pumping action obtained by a rotating shoulder on the shaft.



Because all the moving oil is within the oil tube, little or no turbulence results in the main oil chamber in spite of the high motor speeds.

did not provide the necessary low center of gravity that was needed.

Today's Bucket Spinning Motor

Early in 1936, the first General Electric samples of autodamped Design No. 4 motors were installed in several rayon plants. An entirely new concept, these bucket spinning motors handled large unbalanced loads with less bearing load than any of the previous smaller stiff-shaft motors. Even when unbalanced they operated smoothly, resulting in better-formed rayon cakes.

This motor has established a new standard of smooth, reliable performance (box). Originally designed to drive 7-inch diameter buckets up to 10,000 rpm, many motors now drive 8- to 8½-inch-diameter buckets up to 8000 rpm. At first, these motors delivered the same power as design No. 3, but recent requirements have increased this to approximately 0.5 hp.

Two autodamped bucket-spinning and extracting motors of much larger size are exemplified by Designs No. 5 and No. 6. Capable of delivering 1½ hp and 3 hp respectively at 10,000 rpm, they are designed to drive 12-inch-diameter and 16-inch-diameter buckets. These extremely large motors are principally used in the production of such heavy-denier yarns as tire cord.

Plainly, the history of bucket spinning motors and the rayon industry has been closely allied—one more example in the constant striving for more goods for more people at less cost. And in the accomplishment we recognize the necessity for the combined efforts of all the specialized engineering skills. Ω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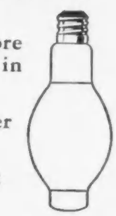
• Light on the work equal or greater in most equipment • Adds color balance • Less maintenance 	• Delivers 10-20% more light on the work in most equipment • Has somewhat better color balance • Lower cost of light 	• 35% more light on the work in most equipment • Has good color balance • Lower cost of light 

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