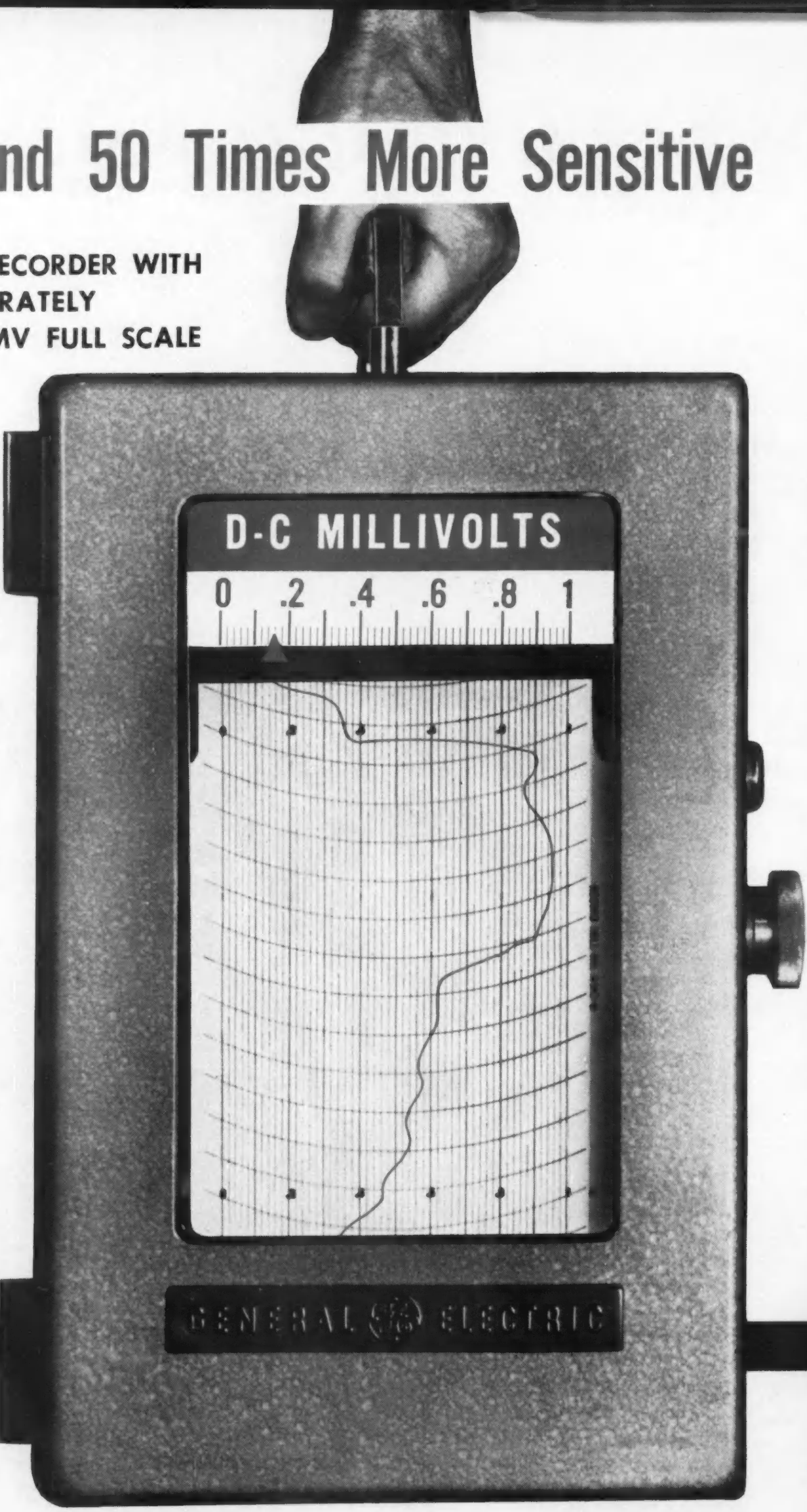
GENERAL ELECTRIC Review

JULY 1957

Measurement of Airborne Particles Speeds Life Tests

PAGE 22

Self-contained and 50 Times More Sensitive



NEW GENERAL ELECTRIC CH RECORDER WITH BUILT-IN D-C AMPLIFIER ACCURATELY RECORDS SIGNALS FROM 0-1 MV FULL SCALE

The General Electric CH recorder with built-in d-c amplifier now offers you for the first time a compact, self-contained, portable instrument with 50 times the sensitivity of the standard recorder. Besides providing accurate measurement of extremely low-voltage signals, this versatile new recorder helps save on instrument investment because you can change ranges merely by inserting different plug-in resistors.

DESIGNED TO MEASURE AND RECORD D-C millivoltage signals as low as 1 mv full scale, the new G-E recorder with built-in amplifier is ideally suited for use in scientific research, pilot-plant studies, laboratory experimentation, and trouble shooting. In addition, it will also operate with various transducers, record the output of thermocouples, and measure low millivoltage signals. The unit is normally supplied with a range of 0-1 millivolt; however, range-changing, plug-in resistors can be furnished for 2, 5, and 10 mv ranges. Other ranges on request.

COMBINING ALL THE ADVANTAGES of the standard model CH recorder by General Electric, the new recorder with self-contained d-c amplifier offers you these important features: 2 percent accuracy of full scale . . . response time of ¾ second . . . critical damping . . . sealed throw-away plastic inkwell . . . and up to 28 different chart speeds from ¼ inch per hour to 2 inches per second.

FOR INFORMATION about the ways your particular operation can benefit from the new General Electric CH recorder with self-contained d-c amplifier, fill out the coupon below as fully as possible and drop it in the mail today.

FILL IN AND MAIL TODAY

General Electric Company
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COMPANY____________________

STREET ADDRESS____________________

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APPLICATION____________________

RANGE____________________ CHART SPEEDS____________________

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GENERAL ELECTRIC

GENERAL ELECTRIC Review

JULY 1957 VOLUME 60 NUMBER 4

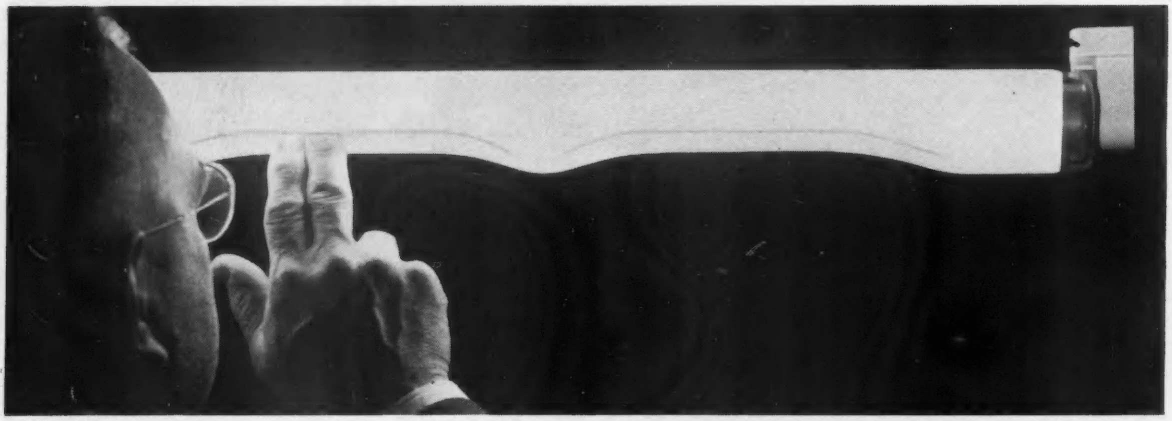
The GENERAL ELECTRIC REVIEW is issued in January, March, May, July, September, and November by the General Electric Company, Schenectady, NY, and is printed in the USA by the Maqua Company. It is distributed to scientists and engineers throughout industrial, consulting, educational, professional society, and government groups, both domestic and foreign. . . . . The GENERAL ELECTRIC REVIEW is copyrighted 1957 by the General Electric Company, and permission for reproduction in any form must be obtained in writing from the Editor. . . . The contents of the GENERAL ELECTRIC REVIEW are analyzed and indexed by the Industrial Arts Index, The Engineering Index, and Science Abstracts and are available on microfilm from University Microfilms, Ann Arbor, Mich. . . . For back copies of the REVIEW—1903 through 1954—contact P. and H. Bliss Co., Middletown, Conn. . . . Six weeks' advance notice and old address as well as new are necessary for change of address. . . . Send communications to Editor, GENERAL ELECTRIC REVIEW, Schenectady 5, NY.

COVER

An engineer at General Electric's General Engineering Laboratory in Schenectady studies an electric arc preparatory to determining the erosion rate of contact materials fitted into electrodes. Air laden with evaporated contact material, sucked through the condensation nuclei meter in the foreground, registers a reading of 70,000 minute particles per cubic centimeter. The article beginning on page 22 relates the significance of particle detection to technology.

For your ***new*** *lighting . . .*

Twice the light for less initial cost . . . with new General Electric "Power-Groove" Lamps . . . now available!



THE GROOVES are the reason you get twice as much light. They bring the phosphors on the inside wall of the tube closer to the ultraviolet radiation thus reducing internal light losses. You get almost twice the light with substantially the same efficiency. Several "Power-Groove" installations are now in the planning stage or nearing completion.

WHEN you're planning new lighting, it'll pay you to check the new G-E "Power-Groove" Lamp, the most powerful G-E fluorescent yet! You'll get almost twice as much light per tube as with High Output fluorescents; over 2½ times as much as with 8-foot Slimlines.

YOU SAVE 5-20% INITIAL COST with General Electric "Power-Groove" Lamps over other fluorescents. There are fewer parts to maintain . . . less than half as many as with Slimlines, 1/6 the number in a 4-foot High Output Rapid Start System. So you save maintenance labor, too.

THEY'RE AVAILABLE! New G-E "Power-Groove" Lamps are now listed in 4-, 6- and 8-foot lengths—and several manufacturers now offer fixtures for them. "Power-Grooves" are not interchangeable in any present fluorescent system. If you'd like more information on this new way to get more light at less cost, call your local G-E Lamp Supplier or write: General Electric Co., Large Lamp Dept. GE-77, Nela Park, Cleveland 12, Ohio.

Progress Is Our Most Important Product

GENERAL ELECTRIC

"I WAS AMAZED . . . ."

Not so long ago an engineering student had his opinion of big business reversed completely.

Robert N. Lee, University of Minnesota, worked in General Electric's Apparatus Sales Division's Minneapolis Office last summer. Before returning to college, he wrote the following letter to his supervisor:

> . . . I entered these offices with a suspicious attitude toward the operation of a company which ranked among the 10 largest in the country. It had been my education in a prejudiced community that led me to believe big business was not to be trusted. Perhaps worse than this was the feeling that the members of a large organization might tend to hold stagnant positions which would confine their imaginations to trivialities.
>
> I was amazed to witness the faith and admiration the employees had in their Company. I watched a young member of the staff make a decision which entailed some amount of money. He considered the facts and forwarded his opinion without fear of rebuttal from high authority. Certainly this indicated that the Company has faith in its employees.
>
> If my experience could be duplicated among more of the young people, I feel certain the progress of General Electric and many other large businesses would be greatly enhanced in the future.
>
> I hope to see you and the other office members in the years to come, whether I finally become a member of the General Electric Company or not.

A letter such as this points up the value of exposing neophyte engineers to the spirit of the engineering profession—and the spirit of a business enterprise—in their formative years. While summer work isn't the only way to accomplish this, it's certainly a proved and effective technique—one that forward-thinking engineering managements can utilize.

Lee's letter is important for another reason. It shows how a routine business action negated certain misconceptions in his mind. Completely shattered was the stereotype of the worker in big business as a stagnant nonentity. In its place, Lee saw the employee accepting responsibility and making decisions, knowing his supervisors would treat his opinions with dignity and respect.

The fact that these misconceptions did exist in the mind of a promising young man and in the minds of his associates, as he indicates in his letter, is a sobering thought to all of us who go to make up a business enterprise. Many share the same illusion that created Lee's preconceptions of how a business operates. Television, movies, plays, and even the comic strips foster such myths. And politicians find business a convenient target. Ludwig von Mises' *The Anti-Capitalistic Mentality* gives a concrete analysis of the attacks on the American business system.

While other forces work hard trying to undermine and ultimately wreck our uniquely successful system of capitalism, American business works with brilliance and energy in supplying good products at fair prices, providing jobs and dividends. But do we devote equal energy in making understood how our free market and free business system operates for the good of all?

Only a few of us have the opportunity to be observed by college undergraduates in our daily work. What can we who make up business today do in our social and civic contacts? As professional people in business, how can we help our fellow citizens gain a better appreciation of the way American business enterprises really work?

We must become far more alert to the social and political currents and undercurrents in our country. We must come to know more about the economic, political, and ethical principles that energize this *people's capitalism.* We must develop a greater feeling for the human considerations that increasingly shape the outcome of all our efforts. We must keep on—and encourage others to keep on—helping all concerned to develop the economic information and political sophistication needed to understand business and intelligently analyze the attacks against business.

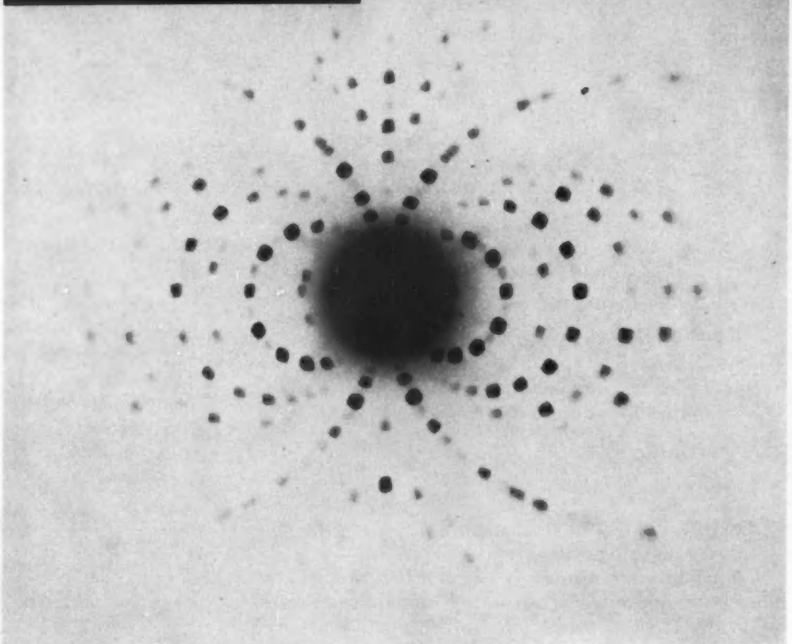
Our fellow citizens expect from us a genuine interest in people and the community. They count on us to keep the human considerations up front, be fair and considerate in our conduct, give our time and money in really dedicated work for charity and other worthwhile causes, fully obey the spirit of the law even when no one is looking, and recognize the importance of other people's opinions.

These are all reasonable expectations. Truly professional people will recognize and fulfill them as their responsibility and contribution to society.

Paul R. Heinmiller

EDITOR

QUARTZ CRYSTAL



Long obscure processes, mechanisms, and substances now succumb to identification by x-ray diffraction. This increasingly versatile laboratory technique helps to improve such well-known products as electrical steels, synthetic yarns, concrete, and soils. Minute structures of materials illustrate how . . .

DIFFRACTION PATTERNS SHOW . . .

Molecule Hunting with X Rays

By HOWARD W. PICKETT

If you need thorough understanding of a given substance today, the usual techniques probably won't give you enough information. Beyond the old data—obtained from quantitative and qualitative chemical and metallurgical analyses and tensile, shear, elasticity, compression, and thermal tests—lies an increasingly important measure: crystal structure.

Put yourself in the place of a metallurgist designing steel stator-core laminates for a 200,000-kv power-station generator. To get a precise crystal structure for controlled magnetic characteristics, you're going to anneal those steel sheets. To study vital crystal arrangement, you'll turn to one of man's newest tools for probing nature's mysterious matter: x-ray diffraction.

Suppose you're a university chemist, examining a new explosive for the U.S. Navy. To give the government its money's worth and really perform your duty thoroughly, you must analyze the exact atomic structure of a new, insufficiently understood explosive compound. This task might ordinarily take months or even years to complete. But with the x-ray diffraction technique, you may have your answer in weeks instead of years.

What's X-Ray Diffraction?

X rays scatter, or diffract, when they pass through a solid substance in much the same way as light diffracts in certain optical systems. The direction and intensity of the diffracted beams are dependable and specific for particular atoms in particular crystal arrangements. Modern equipment enables you to quickly measure the results of x-ray bombardment to get the data you need.

These measurements find their basis in a simple natural phenomenon: virtually all solid matter consists of atoms linked together in orderly, periodic patterns. These atoms, each composed of a nucleus with one or more electrons revolving around it, stack up neatly to form crystals. Diffraction data are used to determine the type and number of these atoms and their alignment in all three dimensions—the facts on which the properties of crystalline matter depend.

Analyzing a Sample

To get an x-ray picture or diffraction pattern of that new explosive, you must first mount a small crystal of the explosive on a needle and place it in the path of an x-ray beam. As the needle rotates, the beam hits the crystal at all angles. When the beam careens off planes of atoms in the crystal, it hits and leaves dots on film placed around the crystal. Viewing this film on a light table, you can determine basic data from the intensity of dots and the distances between them. These data enable you to construct a three-dimensional physical model of the steel crystal.

A new, modern arrangement of equipment—a single crystal orienter and diffractometer—allows the observer to read x-ray beam intensities directly, rather than record them on film.

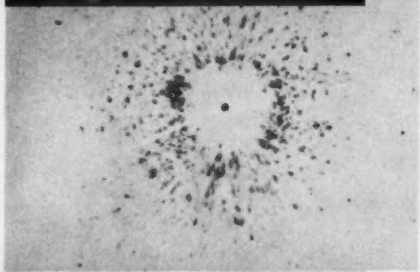
X Rays Work Fast

The diffraction technique sometimes displays this type of result: At the Bayonne, NJ, Research Laboratory of the International Nickel Company, an x-ray emission spectrometer accelerated the analysis of alloys some 40 times. This startled chemists. The analytical chemist's day had normally consisted of careful weighings, filtrations, titrations, and ignitions plus the mathematics and

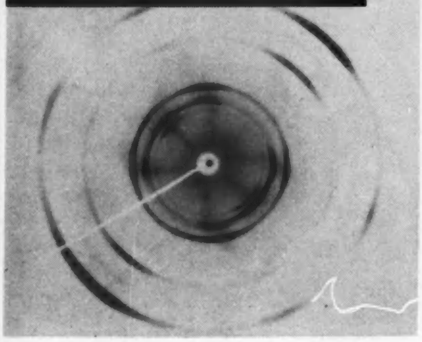
---

Mr. Pickett—Instrument Sales Specialist, X-Ray Department, Milwaukee—one of the nation's leading authorities on x-ray diffraction, emission, and microscopy, began with General Electric 17 years ago. He is presently in charge of x-ray and electron diffraction instruments, x-ray emission spectrometer, and x-ray microscope.

ANNEALED ALUMINUM



HARD-TEMPERED ALUMINUM



LABORATORY-MADE DIAMOND—SINGLE CRYSTAL

NATURAL DIAMOND—SINGLE CRYSTAL

. . . DIFFERENCES . . . . . . OR SIMILARITIES

analytical deductions required for efficient results—slow work.

Wet analysis can be broken down into three major factors—separation, purification, and weighing. In the analysis of complex alloys, the necessity of repeated repurifications becomes an exacting and time-consuming operation, and final weighing involves a most delicate operation. Sometimes standard analytical procedures are difficult or cannot always be followed.

X-ray emission spectrometry, based on diffraction principles, determined platinum in the presence of ruthenium in about 20 minutes; working with wet chemical analytical methods, the same operation took one man two weeks.

And in addition to spectrometry's dramatic speed, the method doesn't destroy the sample. As a result, an analysis can be checked over and over again. Thus a precious metal such as platinum need not be destroyed. This nondestruction of the samples has special application in police investigation where the destruction of the sample might mean loss of vital evidence.

Putting certain routine laboratory analyses virtually on a "hold-the-phone" basis has drastically changed the work of the laboratory chemist when a job that once took two weeks can now be done in 20 minutes. This frees him for more important, more difficult work involving more thinking and less routine. Thus a single scientific principle, translated into an effective machine, has far-reaching human effects: the work of many chemists becomes less tedious, more varied, and more effective. In one laboratory, the average work output per man—formerly 14 analyses per day—jumped to 150 with the help of x-ray spectrometry.

General Electric developed the diffraction technique known as x-ray emission spectrometry—the direct study of the intensities of the x-ray emission spectrum. The method proves approximately 10 times more precise than the optical spectrographs.

The x-ray emission method marks the beginning of a new era in high-speed, routine, quantitative analysis of chemical elements. For while lending itself to analysis for elements of interest in ferrous metallurgy, the method, in general, adapts to all elements except those of very small atomic number.

Diffraction Data's Importance

A piece of steel after proper hardening has the same chemical composition as it had in the soft condition, but the structure has materially changed by the heat treatment. X-ray diffraction will reveal this important change. In a fully annealed condition or in a state of severe cold work, differences appear in diffraction patterns. It may be far more important to know *how* a material is present than to know merely that it *is* present. Because of their atomic structure, graphite and diamond—both made of carbon—possess vast property differences.

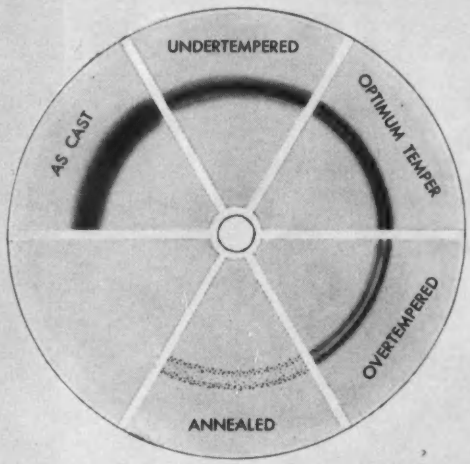
In the past, the microscope has been the metallurgist's principal tool for observing the microstructure of a suitably prepared sample and thus developing a correlation between the chemical composition, the microstructure, and the resulting properties. But the gross structure revealed by the microscope gives no information about the fundamental atomic arrangements that gave rise to the microscopically visible structure. X-ray diffraction has proved an essential complement to microscopic analysis, taking its place as one of the metallurgist's most reliable tools.

The current popularity of x-ray diffraction stems not from new knowledge—for the physical principles have been available for some time—but rather from new equipment, developed by ingenious manufacturers to put the old knowledge to work in an effective way. Exceedingly complex principles of mathematics and physics underlie this equipment, partly accounting for the long delay in developing today's analytical techniques.

In spite of the theory's complexity, the actual use of this equipment does not require personnel trained in either vacuum technique or electronics. Operators must have about the same level of theoretical background as the average

DIRECT RECORDING of diffraction analysis supplements film and direct-reading techniques.

ANALYZING STEEL



DIFFRACTION reveals differing crystal structures in five chemically identical steels.

metallurgist needs to operate the modern metallurgical microscope.

Latest Trends

The outstanding fact about x-ray diffraction today is its increasing versatility in research. At many laboratories, it contributes to well over half the problems investigated and often provides a short cut toward solving them.

Diffraction helps to improve many well-known products. These include electrical insulators of the sheet-mica or power-line-transmission types or spark-plug porcelain. Its tremendously diversified applications in the ceramics field range from the making of electric insulators to the study of solid-state reactions involved in making premium-quality firebrick for lining blast furnaces.

A variety of standard chemical processes with mechanisms that have been obscure for years now succumbs to diffraction studies. Recently the basic lead sulfates involved in the production of standard electric storage batteries were identified by x-ray diffraction. This enables battery manufacturers to control and improve the quality of batteries on the basis of a direct scientific understanding of the process, above and beyond their standard performance tests.

The application of diffraction methods is meeting increasing success in the field of catalytic reactions. There are many mechanisms of catalysis. (A catalyst can be defined as a substance participating in a chemical reaction in such a way that the reaction will proceed at a practical rate.) Whether the catalyst is involved in the production of cracked gasoline with high efficiency or in making hydrogenated edible oils for margarine, the diffraction method remains one of the principal tools for control of the catalyst quality in efficiency and life for reasonable performance.

During the past 20 years the diffraction method has been the primary contributor to the development of metallurgy as a science rather than a well-practiced art.

Electrical Steels

Diffraction controls the processing of electrical steels for transformer cores. The use of modern steels of this type annually saves hundreds of thousands of dollars in energy normally wasted in old-fashioned transformers through hysteresis losses.

Diffraction explains the mechanism of age hardening, work hardening, and other heat-treatment hardening processes. It distinguishes between true alloys and mixtures of metals. (Brass is an alloy, whereas bearing bronze contains lead as a dispersed mixture rather than as an alloy.)

Development of a favorable heat-treatment practice for the machinability of castings has been based on diffraction techniques. And a tremendous variety of other detail has resulted in a true and growing metallurgical science.

Synthetic Yarns

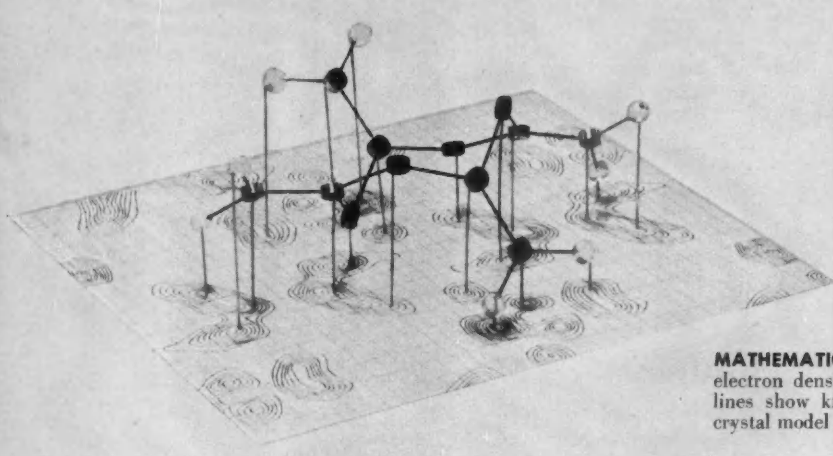
You can also apply the diffraction method to the production control of synthetic yarns. The understanding of the inherent structure necessary in such fibrous materials, demonstrated by diffraction, accounts primarily for the superiority of modern synthetic fabrics that simulate silk and wool. You find that organic chemists tend to extend the use of diffraction from the solution of simple problems such as the fiber structure of gasoline and nylon to biologically complex materials. Evidence of this kind enables the manufacturing chemist to guide himself to the successful production of new materials.

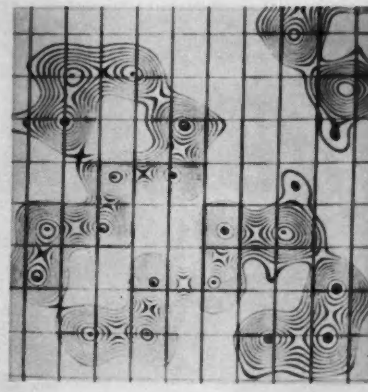
The determination of penicillin's structure by the cooperative efforts of English and U.S. scientists offers a good example. Early in World War II, Dr. Dorothy Crowfoot and her associates in England reported the structure of penicillin. Manufacturers then produced the drug in volume. There is no way of guessing how long it would have taken to determine the structure conventionally and produce the drug synthetically without the diffraction method. But it probably would have required many years and much attention from many chemists.

Better Concrete

Better-quality and lower-cost concrete is the aim of an x-ray diffraction study launched by the Waterways Experiment Station of the Army Corps of Engineers at Jackson, Miss. The study, undertaken for the Chief of Engineers Office, particularly emphasizes the quality and cost of concrete used in the Civil Works Program.

X-RAY DATA SHAPE CRYSTAL MODELS





MATHEMATICAL ANALYSIS of diffraction results yields electron density map. Number and spacing of contour lines show kinds of atoms present. Three-dimensional crystal model (left) is based on map.

Studies by several other agencies indicate that the use of x-ray diffraction methods can be a powerful tool in identifying, classifying, and understanding the properties of materials used in concrete construction.

Foundry Improvements

General Electric's Foundry Department has found that x-ray emission spectrometric techniques provide greater process control along with a rapidly increasing load of chemical analysis.

Increased production in the steel foundry producing low-alloy castings together with expanded output of high-alloy castings for aircraft and turbines had severely overtaxed the personnel and equipment of the chemical laboratory. Even the rapid colorimetric methods employed couldn't satisfy the increased demands for accurate analyses for control and production.

Installing x-ray diffraction equipment to check castings for quantities of chromium, manganese, nickel, vanadium, molybdenum, tungsten, copper, cobalt, columbium, and iron provided a low-expense solution. Routine determinations were made in seconds rather than minutes, with accuracy equal to or better than former wet analysis methods. Savings in cost of nickel alone run $500 per heat by holding within but keeping on the low side of specification.

In-process chemical control of low-alloy and carbon-steel castings has been improved by rapid diffraction analyses. Tests formerly requiring 160 man minutes have been cut to 30, with certain stainless steel analyses cut even more drastically—from hours to minutes.

Along with the advantages of the diffraction technique, the foundry has noted certain limitations. Elements such as carbon, phosphorus, and sulphur don't lend themselves to present x-ray techniques. Experimental work has established that silicon can be determined in steels, but this analysis has not yet been developed to production-line effectiveness.

Better Soils

Under the direction of Professor M. L. Jackson, the Department of Soils of the University of Wisconsin is conducting an intensive research program into the fundamental composition of soils. These studies deal with the analysis of nonquartz crystalline components of soil, paying particular attention to layer silicates that compose clays and the destiny of phosphate fertilizers applied to soils.

Using as a fundamental research tool the new direct-recording x-ray diffraction machine, the department is discovering facts that will help interpret soil tests for farmers, eventually giving the chemical analysis of soils a firmer foundation.

Newest Diffraction Apparatus

A newly developed diffraction instrument permits rapid analysis with high accuracy, thanks to the use of a high-speed proportional counter and preamplifier that free x-ray diffraction techniques from dependence on conventional Geiger counters. Result: A laboratory scientist can now perform a greater amount of work in a shorter time and still be assured of accuracy in analyzing unknown materials. Additionally, the proportional counter's life span becomes at least 1000 times longer than that of Geiger counters.

Another feature of this instrument—a single-crystal orienting device—now makes possible a routine identification of unknown organic or inorganic single crystals of matter. This not only represents an important advance in the science of x-ray diffraction but also permits scientists to analyze fibers and wires and to study preferred orientations by the reflection method.

The portion of the diffraction instrument used for x-ray emission spectrometry utilizes a helium-tunnel assembly, greatly extending the range of application for this new technique. It increases the sensitivity and permits for the first time routine, accurate, quantitative analysis of such widely present elements as aluminum, silicon, phosphorus, sulphur, chlorine, potassium, and calcium.

A helium atmosphere is substituted for air in the path of soft x rays emitted by small-atomic-number elements. This not only broadens the scope of the method but also achieves greater counting efficiency and saves time.

With the diffraction instrument—a powerful research weapon—scientists have greatly extended their ability to probe the nature of matter, to develop better materials, and to analyze unknown substances. Ω

Before

The large, bulky ducts of this old-fashioned basement installation fail to distribute air properly or efficiently in the house.

After

This well-designed installation distributes air evenly to all parts of the house for your family's healthy, comfortable living.

How Proper Air Distribution Aids Your Comfort

By W. R. YEARY

Whether for heating or cooling, you can't possibly air-condition your home in the technical sense without air movement and distribution.

Neither can you do it by opening doors and windows nor by running a ventilating fan. Good fresh air and ventilation, though important, still don't substitute for air conditioning. Fans give you some relief on a hot, stuffy day, but they obviously can't reduce indoor temperature below that of the outdoors.

True air conditioning, like most of industry's technological developments, has a scientific base. Its simplest definition: A process of controlling the air's heat and moisture content; introducing fresh air; and, finally, cleansing out foreign irritants—all to your direct benefit.

Because scientific heating and cooling of homes has taken on such significance in America—year-round air conditioning being economically within reach of the average homeowner—you will want to understand some basic facts.

More Than Comfort

Man learned early in his existence that he needed movement of air for personal comfort. To keep comfortable on hot days, he broke branches from trees and fanned himself with them. And as time passed, he progressed through various stages—leaf fans, flutter wheels, air shafts, and other crude devices—to the basic designs of present-day air-moving devices. All this evolved because he enjoyed the pleasing effect of air movement.

Today, scientists know that for comfortable living you must be able to control not only the air's movement but also its temperature, moisture content, and quality.

In your home you can control temperature simply by adding or removing heat from recirculated air. But to control moisture content—dependent on both temperature and humidity—you have two choices: either increase or lessen the air's moisture content. In other words, you humidify or dehumidify. Personal preferences vary; but for summer comfort, temperatures in your home should range from 75 to 80 F, with 45 to 55 percent relative humidity.

By removing dust, dirt, pollen, smoke, and odor, you improve the quality of air in the home. Various types of filters and air cleaners that attach to summer and winter air conditioners will do this for you automatically. Dust filters, in fact, come as standard accessories on today's air conditioners, installed so that air must pass through them before it's heated or cooled.

During winter operation, these filters effectively destroy odors that result from hot or burning particles in the air stream. Also, they prevent the particles from clogging coils, ducts, and grilles and impeding a unit's full-rated delivery of air.

What about the freshness of air? As an individual you daily consume the oxygen from 34 pounds of air. Thus the absence of a fresh supply in your home can, and often does, lead to illness.

Mr. Yeary—Supervisor, Application Engineering, Home Heating and Cooling Department, Tyler, Texas—handles application engineering for the department. He first became associated with General Electric in 1944 and since then has written several manuals as well as articles for trade publications.

MINIMUM ARRANGEMENT FOR GOOD AIR DISTRIBUTION IN YOUR HOME

Check this list against your present air system or the plans for the house you are building or intend to build. If they don't match these minimum specifications, you don't have optimum performance and satisfaction.

- **One supply register per room**
  All registers adjustable to provide variation in volume of air and its discharge pattern
  High wall registers situated on inside walls discharging toward outside walls
  Low wall registers situated on outside walls
  Ceiling outlets near center of ceiling.
- **One return grille in each room, except baths and kitchen**
  Grilles sized to return same quantity of air supplied to room except where fresh air is introduced through the unit or where infiltration of outside air is excessive
  Dampers behind grille or in duct to allow adjustment of return air.
  ***Alternate:* Minimum of three central returns with one in center of house and one in each extreme end.**
- **Ducts**
  Properly sized to deliver required air quantity at correct velocity. For supply and return ducts located in the attic, minimum of 3 to 4 inches of duct insulation in south and north areas, 2 inches in central areas.
- **Introduce at least 7 cfm of fresh air per person mechanically or through natural infiltration.**
- **Sufficient air cleansing**
  Glass fibers, or the equivalent, in return side of unit, or electrostatic air cleaner in return air duct.
- **Properly balanced system to provide smooth, comfortable heating or cooling in each room.**
- **Adjustable fan speed to compensate for difference in air requirements at the beginning of cooling and heating seasons.**

Introducing fresh outdoor air is the only way to replace the oxygen you consume —no amount of filtering, cleaning, or cooling will do it.

Accordingly, if your home is tightly constructed, approximately 7 to 15 cubic feet per minute (cfm) of fresh outdoor air should be introduced for each member of your family. A healthy atmosphere depends on this mixture of recirculated and fresh air. Many homes acquire a sufficient amount of fresh air by natural leakage, or infiltration, through doors and windows. Perhaps yours is one.

Controlling Distribution

Effective temperature and moisture control plus quality of the air rests on *movement* and *distribution*. In the absence of these two factors, you can't maintain a healthy indoor condition.

Hot air will move by convection. Yet really efficient distribution calls for a fan. For example, take a gravity flow furnace (photo, left, opposite page). It operates on the principle that hot air rises naturally, and as it rises the cooler air drops down to occupy the vacated space. This sets up a continuous current that gives movement to air in the adjacent areas.

Distant rooms or spaces may receive none of this heat, however. For the hot air moves primarily in a vertical rotating flow in the immediate vicinity of the gravity furnace: it has little sideways movement. If you blow the air away from the furnace with a fan, more of the area can be heated. But because of the fan's limited power to distribute air properly, the entire house may not be heated. Velocity of the air diminishes a few feet from the open fan, and the resultant rapid decrease in air temperature creates a downdraft.

Now, if you enclose this same furnace and fan in a sheet metal cabinet and install a duct system to channel heated air into each room, you will attain overall heating. Each room has an outlet, or supply register, sized to deliver only a portion of total air being moved by the fan. Air being measured in cfm, fan capacity is likewise rated in the same unit of measurement.

Heating vs Cooling

Usually you determine the cfm requirement of air for any house on the basis of heat loss per room—heat loss being measured in British thermal units per hour (Btuh). You need this amount of heat per hour to balance or exceed the quantity lost or dissipated from the house to the outdoors. It's the quantity necessary to maintain the average room temperature you wish.

As an example, assume that a particular room in your house has a heat loss of 6850 Btuh. Temperature of the hot air from the furnace as it enters the room is 140 F. You desire a room temperature of 75 F. By substitution in an appropriate formula, you calculate that 98 cfm of 140 F air will heat the room to the desired 75 F.

If yours is an average residential application, you then select a supply register, or grille, to deliver 98 cfm of air at a velocity of about 500 fpm. The register you select should spread the air evenly and uniformly over and into the area being heated. How well the register performs will depend on its type and location.

At first it might seem strange that you need more air for summer cooling than for winter heating. But you do and for a sound reason: the smaller difference between room temperature and that of the entering cooled air.

To clarify this statement, consider that comfortable room air temperature in the summer can generally be assumed at 80 F, with air entering from the cooling unit at 60 F. Heat gain of the room divides into two types: sensible and latent. Sensible heat, appropriately named, causes the mercury column in a thermometer to rise or fall; you can feel its effects. Latent heat, on the other

". . . a good system requires return ducts as well as supply ducts."

hand, doesn't register on the thermometer, nor can you feel it by touch. It evaporates water in the air and accounts for humidity—or lack of it.

When calculating cfm requirements for cooling, you consider only the sensible portion of heat gain. Thus if heat gain were 6850 Btuh as in the preceding example and 4915 Btuh of this were sensible heat, 214 cfm of 60 F cooling air would maintain the room at 80 F in summer.

Actually then, cooling your home requires a greater quantity of air than does heating it. Engineers have factored this into the design of year-round air conditioning systems, sizing all ducts according to summer flow requirements.

Proper Delivery Essential

Supply registers play an important part in the proper movement and distribution of air. You can situate them high or low on walls, in the ceiling, or in the floor.

How well you select and place the registers, however, will determine how well they'll deliver the air, whether for summer cooling or winter heating. Situated at the right height with the proper angle of deflection, the registers keep air from dropping into the head zone—five or six feet above the floor—at too great a velocity or at temperatures too extreme for comfort. If your registers will be high on a wall, select them to deliver air directly to the opposite wall without a pronounced rise or fall along the way. This will help prevent uncomfortable cold drafts, hot blasts, and alternate cold and hot layers of stratified air.

Each of your rooms should have one or more supply outlets. Their total number depends on the quantity and velocity of air delivered plus the size of ducts and registers used. For high-volume delivery, it's often more desirable to use two or more registers of low air capacity than to use a single large high-volume register. On the other hand, one register is better than two for low-volume delivery.

As a rule, the home owner selects a furnace or air conditioner to provide the necessary heating or cooling capacity: its air delivery is loosely fixed by the size and speed of a self-contained fan. For example, a General Electric home furnace (photo, right, preceding pages) delivers 1 cfm of air per 88 Btu's of heat output; a cooling unit delivers one cfm of air per 30 Btu's.

Once you know the cfm requirements of your house and the heat loss or gain per room, you can determine the proper duct size. Length of any duct depends on the distance between the heating or cooling unit and the register—or between the main duct and the register.

How large a duct, in cross-sectional area, should you have? That depends on: the quantity of air to be delivered; the duct's length and its resistance to airflow; and the air pressure at the outlet of the heating or cooling unit.

For simplicity in layout, duct systems —or air distribution pipes, if you prefer —come in several different sections. Each type is assigned a range of recommended air velocities that will produce the most satisfactory results. In order of decreasing size, they are variously called plenums, trunk or main duct, branch duct, laterals, risers, and registers. You can find their rated air velocities in heating-and-ventilating handbooks.

Balancing Air Flows

For a good residential air-distribution system, you must have return ducts as well as supply ducts. Otherwise, there wouldn't be sufficient air at the conditioning unit to provide the needed recirculation. Neither would you obtain the recommended temperature rise in a furnace nor the necessary temperature drop in a cooling unit. Unsatisfactory performance would result in either instance.

As in the supply system, you should have one or more return grilles for each room. Exceptions: In kitchens and bathrooms the return system is usually omitted. Over-all size of return grilles should be such that the same volume of air that is supplied to the room will be returned to the unit.

If your house has high or excessive infiltration of outside air, you should introduce fresh air through the unit and return less room air. This effectively prevents infiltration by introducing a slight positive pressure inside your house, tending to create a condition of "exfiltration." Thus you achieve a balance between supply and return air. (The volume dampers in the ducts or behind grilles of your present installation are useful for this purpose.)

A current trend, however, promotes a single central return grille for most residential applications. Not because fewer grilles are necessary, but because some builders and installers encourage it as a cost-cutting practice. It doesn't render individual room returns obsolete nor any less desirable.

In fact, few single centralized return installations perform as well as those utilizing individual room returns: the larger your house, the more unsatisfactory they become. You can readily appreciate why. With a single grille, it's difficult to get satisfactory air return in distant spaces or portions of homes containing 1100 or more square feet of area on one floor—as in the average three-bedroom ranch-type house. In two-story homes, it's even more difficult.

If you plan to build, you might keep this in mind and insist on a minimum of three returns: one near the center of the house and one at each end. Remember that the return system is as important as the supply. (Be sure your contractor thinks so, too.) Rooms with two or more walls exposed to the northeast, north, or northwest should have an individual return for adequate heating. Any rooms with south, southwest, or west exposures need individual returns for adequate cooling. And, if you build in a windy area, all rooms directly exposed to cold winter winds should have individual returns.

When calculating the capacity of a heating or cooling unit, failure to consider the excessive infiltration will very often result in unsatisfactory conditions.

And you can see why: Any air that infiltrates into your house reduces the conditioning unit's capacity to heat or cool the space by the *same* number of Btu's required to heat or cool the renegade air. This can seriously alter winter or summer design temperatures. For the infiltrated air is *not* heated or cooled by the conditioning unit but by the air within your home.

Accordingly, in estimating the unit's over-all load, you must calculate the Btu's required for infiltrated air and add this amount to the total. In effect, then, you need additional heating or cooling capacity to handle infiltrated air. Unless it's excessive, though, you shouldn't consider infiltration a renegade. Actually, for reasons mentioned earlier, infiltrated air in reasonable quantity offers a blessing in disguise—a welcome source of fresh outdoor air.

CONCLUDED ON PAGE 29

Primarily a design analysis tool, electronic computers—such as the author operates—serve as invaluable engineering timesavers. But before engineers can accomplish complete synthesis with computers, many problems must be solved.

Let's Really Put the Computer to Work

Engineers need larger computers to handle the entire design process—all engineering areas, plus manufacturing and financial considerations.

By D. D. McCRACKEN

Today, engineers accept electronic computers as commonplace tools in their design work. But a computer's potential exceeds its use. For so far, these machines do only a part of the job. The design of any system—whether a missile, an atomic reactor, a steam turbine, or a jet engine—involves two distinct phases: analysis and synthesis.

Analysis of various parts, singly or in combination, determines how a system would perform. For instance, in a high-fidelity record-playing system, you might want to know the frequency responses of the pickup, amplifier, and speaker. Further, how would the response be changed if another stage of amplification were added to get more power?

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Synthesis, the second design phase, produces the final system from the best combination of the variables, determined from a set of specifications as well as the initial analysis. An engineer might be assigned the task of designing a hi-fi system with a 5-watt output, flat response from 50 to 10,000 cps, and a crystal pickup—using standard components and achieving the lowest possible cost.

So far, computers have been used extensively only in design analysis. (For examples, see "Electronic Computers—Engineering Timesavers," May–July 1956 REVIEW and "Solving Problems with the SEMAC II" July 1954 REVIEW.) Let's look at current design synthesis and its potential and study the problems to be overcome before complete synthesis can be accomplished with computers. To illustrate the principles, you could find many examples in your own field, whether it be petroleum refining, bridge building, or designing light bulbs. But for present purposes, let's use these two examples: a complex jet engine and a simple geometrical model.

Designing a Jet Engine

The basic idea of jet-engine operation is simple: Air entering the engine through ducting in the airplane is compressed to high temperature and pressure by the compressor and then mixed with fuel in the combustion chambers where it burns with high efficiency. The resultant gases furnish enough energy to not only power the turbine that drives the compressor but also provide thrust for pushing the engine and airplane.

However simple the basic principle of operation, the design of a complete engine from performance objectives isn't at all simple. For a large number of design variables must be considered, balanced against each other, and combined to give the best operation.

Some of these variables include 1) compressor pressure ratio, 2) air flow, 3) design of combustion chambers, 4) number of stages in compressor and turbine, 5) speed of the gas leaving the turbine, 6) number of bearings supporting the shaft, 7) the weight of the entire engine, 8) whether to include burning after the turbine, or a reheat operation, 9) shape of blades in compressor, 10) method of removing heat from the lubricating system, 11) schedule of fuel flow at different operating conditions, and 12) design of control system for translating throttle position at different operating conditions into engine operation.

Moreover, many of these variables conflict with each other. For instance, a high compressor pressure ratio improves thermodynamic efficiency but complicates the compressor design.

To illustrate the design process geometrically, suppose you're outside a room containing a scale model of a mountain laid out on a system of coordinates. You can specify any spot on the mountain but cannot see into the room. Your task: Find the coordinates of the peak when you can measure only with a pair of x and y coordinates requested of a man inside who calls back the height of the mountain at that point.

You can divide each coordinate into small intervals—making a meshwork over the area—and try all combinations. Once you have located the point where the mountain shows the greatest height, you can reduce the mesh size and look for a more accurate answer in that region. Although accurate and foolproof, this costly procedure requires taking a large number of measurements and too much time looking at the wrong part of the map.

A more practical method: Take readings at several points in the same region and look for the gradient, or the direction of steepest slope—a much quicker procedure, if it works. However, most mountainous areas—and engineering systems—have foothills, and the gradient method may lead you to the top of an adjacent ridge much lower than the peak you really want. Or if two peaks of approximately the same height stand fairly close together, you may get to the lower one without ever knowing about the other.

In design work the height of the mountain may be the efficiency, cost, thrust, or whatever you want to reduce to the optimum. The x and y coordinates represent design variables, although in design you must consider many more. Measuring the height of the mountain corresponds to testing the optimity of a particular set of variables by either building a model and experimenting or trying the design inside a big computer.

This geometrical model points up several facts. First, you cannot choose to optimize the design of 5 out of 20 variables and let the next chap take over and optimize the others. For this would correspond to looking at one cross section that you hope cuts through the peak in the two-dimensional model. On the other hand, varying all 20 design variables at once while looking for the optimum may be impractical, because you would have to break up the process into groups and suboptimize repeatedly. Returning to the geometrical model, you might guess which plane contains the peak and then find the highest point in that cross section. Finally, you could select the highest point in several adjacent cross sections, and the highest one would be the peak.

Examining all engineering areas simultaneously being impossible, you can find several compartments and suboptimize each, as in current practice. Thus the thermodynamic designers of jet engines make their best guess about what the mechanical and aerodynamic people can do and then find the best thermodynamic design while holding these other variables constant.

When the mechanicals receive the design, they hold the other two areas constant at the guessed and calculated values and optimize the mechanical design. The resulting best mechanical design might not be the one assumed in deciding the thermodynamic cycle; so the thermodynamic work must be redone.

This inevitable process does not indicate lack of foresight or bad judgment by any of the groups.

What Computers Are Doing

Computers have found extensive use within all the engineering areas. An IBM 701 has been used literally thousands of hours in calculating thermodynamic performance of jet engines and to a similar extent in reactor physics, steam turbines, thermodynamic design, air-frame structures, and air-frame aerodynamics. But nearly always the calculations have included only one engineering area, with but a single exception—where both the aerodynamic and mechanical design of a device is being investigated in one computer program.

Usually, the performance of a system or some part of a system is analyzed from one viewpoint under one set of assumed design variables. For instance, in the system having 20 variables, perhaps 13 are assumed constant because they are outside the particular field being investigated. Six of the remaining seven are specified to the program, and the computer finds the last. You must play a complicated guessing game, because it's usually impractical or impossible to write out formulas giving the last variable as an explicit function of the others.

The game amounts to assuming an answer and seeing if that answer is consistent with the specified variables. For the engineer repeatedly runs into situations where he needs to know the answer to calculate some other quantity in the system. These situations often occur right within the loop of the major guessing game. Some programs guess successively at a half dozen different quantities in the course of finding the one number that represents the answer. For this reason, systems calculations frequently consume a great deal of time even with computers that do thousands of operations a second.

Remember that this process gives the performance of the system from one engineering viewpoint for only one set of variables. The whole job must be repeated many times to show how the system operation depends on the several design variables. A bundle of performance data at hundreds or even thousands of combinations of design variables typically comes of the computer's efforts. After these data are plotted to make them intelligible, the engineer optimizes the areas—an occult task, frequently said to be outside the capabilities of a mere computer. This is true in some areas.

With only one engineering area optimized so far, you must repeat the process on those remaining—and the juggling begins. The engine might be much too heavy; so you must redesign the compressor with two fewer stages, necessitating at least a partial change in the thermodynamic design. Then because the mechanical designers predict large vibrations due to the length

...present computer knowledge, require improved facilities and methods."

of the compressor blades, something else has to be changed.

This shuffling and balancing of requirements may continue for some months. And apparently, if the mathematical model proposed earlier holds any validity, suboptimization will always require juggling and reoptimization; and time must be allowed for it in setting the design cycle.

The Optimum

Ideally, a large computer would carry out the entire design optimization process not of just a jet engine, for instance, but the system of engine, air frame, armament, and mission. Further, the program would consist of all the smaller engineering programs now used plus manufacturing and financial considerations. A master computer program would then carry on the suboptimization necessary to find the best design.

Business programs such as population trends and past company performance would, in their complexity, transcend present computer knowledge. And these new areas will require both improved facilities and methods.

Computer Facilities

Presently available computers are too small by a factor of thousands in speed and memory size to handle this new problem approach. Too much time would be required to not only do each engineering design separately but also combine them intc one computer program. For sometimes such a program must calculate more points than if human intervention were involved. In the past the attempt to absorb one more variable in the suboptimization of a system like a jet engine has required a new generation of computers, involving two or three years and a factor of 10 in speed and memory size.

Even worse, the number of variables in designing jet engines is increasing at a rate faster than the development of new computers so that computer people are actually falling behind in their ability to handle such an approach. However, the computers available in 5 to 10 years will certainly provide the necessary facilities.

Objectives Defined

A major problem in designing optimization, whether done inside or outside a computer, involves the setting of objectives, particularly the relative importance of the objectives that must be optimized jointly. For instance, the original specifications for a jet engine may ask for the lowest fuel-consumption rate and at the same time the smallest total engine weight—hardly a helpful description of what the balance should be. Which is the more important: an extra 100 pounds of fuel an hour or 20 pounds in the total weight of the production engine?

For each objective, the designer would like to have exact specifications of mathematical weights showing its relative importance—a difficult but not impossible task. In other words, future computers will function in matters of judgment. Even now, computers in business applications not only provide data on which decisions can be based but also actually make routine decisions.

Mathematical Techniques

As the mathematical model of design procedure indicated, finding the best combination of 20 variables is not a simple task, even after establishing a usable definition of *best*. For instance, the brute-force approach of trying all possible combinations, using only four or five values of each variable, would involve literally billions of combinations.

Consequently, some way must be found to hunt systematically for the optimum. Linear programming—once computer personnel learn how to apply the method to over-all system design—might help systematize the approach.

Different Component Arrangements

Design synthesis involves two levels of complexity. First, with a fixed arrangement of all the components of the system, the optimization procedure finds the proper values of the design parameters—a problem now done on computers for some simple systems.

The second level of complexity requires the computer program to try many different component arrangements, optimizing each and arriving at the best design. Although computers now assist extensively in this process, none has solved completely this level of complexity in design synthesis.

A good engineering design cannot be created apart from engineering, manufacturing, and financial considerations. To represent these in a form that can be fed into a computer will require much imaginative hard work. But the past successes of computer applications indicate its feasibility.

Organization and Personnel

Finding the right people to do the job presents one of the most serious obstacles in carrying out such an approach. Only team effort can develop a computer program that will find the best design from engineering, manufacturing, and finance standpoints.

But once acquired, how should the team be trained? should experienced engineers learn computing and computing people learn engineering? or should the engineers define the program and the computing people transcribe it into computer language? The team will probably consist of several topnotch engineers who have learned computing and possibly a cost accountant and a manufacturing specialist plus several highly trained and experienced mathematical computing specialists.

The Future

Present computers can often be more effectively used in the optimization process. This may mean simply revising computer programs to consider more variables at once to permit more complete suboptimization. And the engineering areas not using any electronic computers could improve their optimization process with computers.

Rethinking the whole design procedure in terms of the fundamental nature of the suboptimization process as described in the jet-engine example and the mathematical model can also be profitable. Often, finding a systematic method rather than using cut-and-try means reduces the amount of labor in optimizing a design.

Finally, some product areas could now feasibly include financial or manufacturing considerations in the computer design of a unique product by either nibbling at the edges—adding a little cost information here and there in a conventional approach—or completely reorganizing the design and manufacturing control procedures to do an integrated job. If the right product area can be found, this integrated process might well be the next major step in improving the design process by means of computers. Ω

Edison and Steinmetz—both electrical giants—made many contributions to the field. But to General Electric, Steinmetz was most valuable as a consultant—a Supreme Court to whom engineers with difficult problems came for advice.

Steinmetz Revisited: The Myth and the Man

A mathematical and electrical wizard, he feared electricity, owned six cars but drove none, spent his happiest moments in role of Granddaddy.

By CLYDE D. WAGONER

Who was the Steinmetz I knew? a self-satisfied electrical wizard? a twisted hard-bitten man, isolated from his fellow man? Although a common stereotyped image, this is not the Steinmetz I knew.

The man who created artificial lightning was deathly afraid of electricity; the slightest shock from a harmless low-voltage circuit made him jump with alarm; yet this same man, who could not swim a stroke, spent a major portion of his summer days paddling and drifting on the Mohawk River in a 12-foot tippy canoe with no apparent fear.

These were some of the peculiarities of Dr. Charles Proteus Steinmetz, world-famed electrical wizard, who spent a lifetime investigating the various ramifications and mysteries of electricity. So far as we know, he never experienced any narrow escapes in his experiments. His knowledge of electricity's dangers probably created the fear. Rain or shine, he always wore thick-soled rubbers when working in his laboratory. He never explained why, but his associates thought he wore them as an insulator should he accidentally come into contact with an electric circuit.

On the other hand, he liked the solitude of the water. It afforded him the opportunity to read or work out a mathematical problem unmolested. He frequently explained, "It is so quiet and peaceful on the water." And there he solved many of his important mathematical problems.

This great electrical wizard, deformed from birth and little more than four feet in height, had other peculiarities. Fond of pets, he generally surrounded himself with them—but not the ordinary variety, as you will see.

Steinmetz's Zoo

Steinmetz's menagerie included a nest of owls, several alligators, a raccoon, two black crows, and a temperamental Gila monster that frequently had to be hand-fed by his master.

He also loved plants and flowers that, with one exception, weren't of the ordinary variety either. His spacious conservatory, lighted by mercury lamps, was filled with rare and prickly cacti. He spent hours sitting among these plants, puffing on a cigar, and looking into space just daydreaming. Some say he enjoyed befriending plants avoided by others be-

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Mr. Wagoner—pioneer industrial publicist—retired from General Electric in 1954, after 35 years' service. An organizer of the Company's news bureau, he headed it for 25 years. Then he devoted full time to directing General Electric's broadcasting and television and special events. Admiral Byrd named Mount Clyde D. Wagoner after him in honor of his part in the radio-mail service to the explorer's South Pole expeditions. Prominent among the notables he associated with during his career was Steinmetz—who became an intimate friend.

cause in his early years people sometimes avoided him.

Orchids represented the one exception to his odd collection. In a separate and smaller conservatory, with a small fountain and pool in the center, hundreds of them hung. He never disturbed them from their natural environment for a table bouquet or a gift. He grew no other flowers. His only explanation for the orchids: rare, beautiful, and hard to grow.

A Friendly Acquaintance Begins

As a newspaperman in Schenectady, I knew Steinmetz. But our long acquaintance really began when I became a publicity man for General Electric. There Steinmetz was chief consulting engineer and often referred to as the Supreme Court of the Company. I had been with the Company only a few months when my boss called me into his office. He explained that he had a page-one story: The Company had just sold the largest turbine ever undertaken—a 60,000-kw machine for the Commonwealth Edison Company in Chicago.

I left the boss's office thoroughly bewildered, wondering how the big news could get more than a paragraph or two on the financial pages of the newspapers. I thought: There's nothing glamorous about a turbine. Steam goes into one end and electricity comes out the other. You see no action, no wheels turning, nothing but a huge metal casing emitting a low humming sound.

Electricity is something most people take for granted. Only the technically educated minority knows or cares what constitutes a kilowatt of electricity. I was among the vast majority ignorant of the term.

My problem: Write the story with popular appeal. An engineer friend suggested I see Steinmetz. In my newspaper days I had heard how this great man thrilled neighborhood children with explanations of what made the stars appear to twinkle, what made the wind blow, what made flowers bloom. But I had no occasion to consult him on a personal problem. Now with some fear and concern, I made my way to his office. There kneeling on a leather-padded stool, elbows resting on his desk, this shaggy-bearded hunchback with a twinkle in his eyes greeted me with, "Hello, what's new?"

I explained my problem and shall never forget how quickly he sensed my predicament—and how quickly he came up with an answer. Without a moment's hesitation, he jotted down some figures on his pad, explaining them as he progressed.

"One kilowatt of electricity equals 1.34 hp. So 60,000 kw would be equivalent to about 80,000 hp. And one horsepower is equivalent to the muscle work of 22½ men," Steinmetz remarked, looking up from his pad to see if I understood his explanation. "To carry it further, 80,000 hp would equal the muscle power of 1,800,000 men. But a turbine requires no rest; it works 24 hours a day, three 8-hour shifts. And so we multiply the 1,800,000 by three, and what do we get? Energy equivalent to the muscle work of 5,400,000 men. That's greater than the combined muscle power of all the slaves in the United States before the Civil War."

His quick, clear explanation amazed me. In jotting down these figures he had used no reference books. I thought he might be wrong on the slave population angle; and after leaving his office, I checked the figure, only to find that the slave population in 1860 was 4,700,000. Armed with his simple explanation, I fulfilled my boss's request for a page-one story.

That interview began a friendly acquaintanceship that continued until his death, 34 years ago. I visited him frequently at his home and his summer camp as well as at his office. His ability as a mathematician was uncanny. He could multiply and divide huge numbers between cigar puffs as readily as I could add two and two. For instance, one day an associate, thinking he might trick Steinmetz, put this problem to him:

"If you bore a hole two inches in diameter through a circular solid rod two inches in diameter, how much material is removed?"

Again, without hesitation, jotting a few figures on his pad, he came up with the answer:

"Exactly 5.333 cubic inches."

The inquiring friend returned to his office and spent almost an hour figuring out that Steinmetz was correct.

Maker of Lightning

He made numerous worthwhile contributions to the electrical field yet is undoubtedly best known to the public as the first man to create artificial lightning. His gnome-like appearance suggested the type of person one might imagine as the hurler of man-made thunderbolts. But why make lightning when nature supplies far more than the average person likes?

Before he perfected his Jovian machine so that electric equipment could be laboratory tested and made to withstand the destructive forces of natural lightning, homes were often thrown into darkness during a thunderstorm. No one knew how to make electric equipment withstand a lightning stroke. You just built it as well as you knew how, placed it in service, and hoped for the best during a thunderstorm.

Steinmetz closely duplicated nature in producing his artificial lightning. For thunderclouds, which store up the electric energy of the raindrops, he coated several glass plates with metal foil. These were arranged on wooden racks that acted as insulators. When voltage was applied, each plate stored up energy until it could retain no more. Then an instant discharge, a quick flash, and simultaneously the plates discharged their energy.

Steinmetz figured that the destructive force of such flashes represented one-million horsepower during the hundred-thousandth second of their duration. It was sufficient to shatter huge blocks of wood, heavy porcelain insulators, or whatever was desired in testing equipment against the natural forces of lightning. His lightning, though not equivalent to natural lightning, proved most useful. Later, General Electric built what has become one of the world's best-known lightning laboratories, where flashes extending more than 50 feet and carrying 15-million volts are produced.

His Human Side

Although best known as an electrical wizard, Steinmetz had a human side—equally as interesting though little-known. He loved to play cards, calling his poker club the Society for the Equalization and Distribution of Wealth. In pinochle he remembered every card until the last one was played.

Though careful not to hurt people's feelings, he enjoyed outwitting them. He once talked the president and board of trustees of Union College in Schenectady into granting his fraternity permission to build a new home on the most coveted spot on the college campus. And later he helped them to have the only private tennis court on the college grounds. During 10 of his years at General Electric, Steinmetz also served as professor of electrical engineering at Union.

By custom, some fraternities had members of the faculty as members. Steinmetz readily accepted an invitation

His Home, Hobbies, and Camp

Steinmetz's home—representative of his character—contained the unusual. In the study besides the customary desk, you were likely to find stuffed animals—relics of former pets. Orchids flourished in

to join Phi Gamma Delta. Enjoying the companionship of young people, he seldom missed a meeting, often joining the students at dinner and remaining to take part in early evening discussions.

When the question of a new fraternity house came up, Steinmetz suggested that it might be well to ask for more than the group wanted and then arbitrate. The site desired was near the gymnasium and athletic field. At that time the college was shifting fraternity houses to a far end of the grounds.

"Let's in all apparent sincerity ask for a site right next to the president's home. I am sure the board will oppose it and probably suggest that we locate where the other fraternities have been permitted to build."

That's exactly what happened. Steinmetz suggested they arbitrate, each give in part way, and thus Phi Gamma Delta got the site it wanted. The fraternity wanted a tennis court adjoining their new home, but no fraternity had ever been granted that permission. So Steinmetz told the trustees he was thinking of building a new home and asked the college to deed him a lot adjoining the fraternity house where he spent so much of his time. The request was granted. Steinmetz never built, and in a year or two deeded the lot to the fraternity. It became the first and only private tennis court on the campus.

Early in life Steinmetz decided never to marry. He realized that children shunned him—perhaps fearing him because of his deformed body. And since he was the third generation of hunchbacks in his family, he believed that the deformity might well be hereditary. It was a difficult decision to make, for deprived of a normal child life and its pleasures in Germany, he loved nothing more than children and a home graced with them. But to be the father of more hunchbacks, to frighten more children, was too great a price to pay.

Family Life

However, Steinmetz showed himself a wizard in solving this difficult personal problem, just as he had done so many times with perplexing electrical or mathematical questions. He had a spacious three-story home, a large yard, and every facility for rearing a family. A young engineer at General Electric, who had worked closely with Steinmetz and often remained overnight when experiments occupied their time until the early hours of the morning, married and started housekeeping in a small apartment nearby.

Steinmetz was a frequent visitor to dinner, and on one of these occasions he suggested to the young couple that they leave their crowded apartment and live with him. They consented and his hopes that they might rear a family of normal, healthy children soon came true. Two boys and one girl were born. I doubt that Steinmetz could have loved those children more if they had been his own. Constant companions, they called him Granddaddy. Each night Steinmetz tucked them into bed and told them a story. He often interrupted a business conference to perform this fatherly function.

In the late afternoon or early evening, you generally found him participating in the children's games in the spacious yard. No father showed greater attention to his own children. It was Granddaddy this and Granddaddy that from morning until evening. His deformed body, disheveled hair, and broad, shaggy beard struck no terror in their hearts. Associated with him since their cradle days, they grew up to see nothing scary in his appearance.

Added to the happiness the children brought into his home, the mother assumed a real daughter's interest in Steinmetz's welfare. She would see that his favorite dishes were served, that his clothes were in order, that he didn't sneak out mornings with a soiled shirt minus a necktie. A woman was interested in his home, in his welfare. And it brought great pleasure to his life.

Steinmetz had a laboratory in his home where he spent as much time as at General Electric. It was well equipped; the Company gave him anything he needed to carry on his work.

Pet Problems

Of all his queer pets, his alligators caused the greatest commotion in Schenectady. He had seven. One day they escaped and took refuge in the Erie Canal, which then passed through the center of Schenectady. For hours people thronged canal banks watching the rescue operations. Eventually six were recovered. A passing canalboat crew probably picked up the seventh.

Steinmetz had other pet problems: His two crows brought home all sorts of shiny articles—often pieces of jewelry—that he was forever trying to return. He also had trouble with his owls. He didn't realize they were of the cannibalistic species until one morning he discovered all his baby owls missing and the plump mother owl sitting on a limb, feathers still protruding from her mouth.

a special conservatory, adjoining another where cacti grew. And his butterfly collection was often admired by the neighborhood children. But his deepest concentration was accomplished in the solitude of his camp on the Mohawk.

Later his pet raccoon evened the score by eating the mother owl!

His reputation as a keeper and friend of strange animals was far-reaching, as evidenced by an exchange of greetings when Marconi visited Schenectady a year before he died. His first question to Steinmetz was:

"Doctor, how's that Gila monster of yours?"

"Oh, he got too lazy to eat and died," Steinmetz replied. Then he told how he tried to force raw eggs and other food down its throat, but in vain.

Summer Solitude

When he sought solitude, he would go to his crudely built summer camp, hidden from view along the Mohawk River, about eight miles from Schenectady. It had few conveniences other than electric lights operating from a large storage battery that was recharged at the laboratory about once a week. When at camp, his office secretary reported him out-of-town to visitors, unless she thought it important enough to disturb him. Today this camp occupies an honored spot in Henry Ford's Greenfield Village, Dearborn, Mich.

He spent much of his time while at camp in his floating office—a canoe with a couple of boards stretched across the gunwales as a desk, an old tin box as the receptacle for his pencils and slide rule, and a cushion to kneel on. But he was not always engaged in working on some technical problem. I remember my last visit to his camp, a few months before he died. I found him in his canoe, stripped down to a sweat shirt and shorts, with elbows resting on his improvised desk, reading a book.

"What are you reading today, Doctor?"

"It's called *The Lunatic at Large*."

"Who wrote it?"

"I don't know. The first eight pages have been torn out."

In this way he relaxed his busy mind. However, his camp wasn't just a place to escape work. Here he wrote his entire series of electrical textbooks, still considered among the best fundamental authorities in teaching modern electrical engineering at many colleges.

An event at his camp prompted his investigations of lightning. On a summer afternoon in 1920, lightning struck his camp, shattering timbers, fusing wires, burning out his storage battery, and breaking a large mirror in his bedroom into hundreds of small pieces. He carefully reassembled the broken glass, studied the path of the lightning on the silver coating, remarking "Just the evidence needed to begin some laboratory investigations." A year later he had built his artificial lightning generator at General Electric.

Practical Jokes

Steinmetz enjoyed his pranks even at camp. One day he had a friend in his canoe. When a few feet from shore, he deliberately tipped it over, throwing both men into the water. In the commotion, Steinmetz disappeared from sight. Although not a swimmer, he could hold his breath a long time under water. On this occasion he sank to the bottom, crawled to shore under water, and hid in the underbrush until excitement reached a high pitch.

Another time, when I had made an appointment to bring a newspaper friend for an interview, I found him apparently swimming with a lighted cigar in his mouth. Actually, he was crouched in the shallow water, moving about on his hands and knees in hopes of creating comment and laughter.

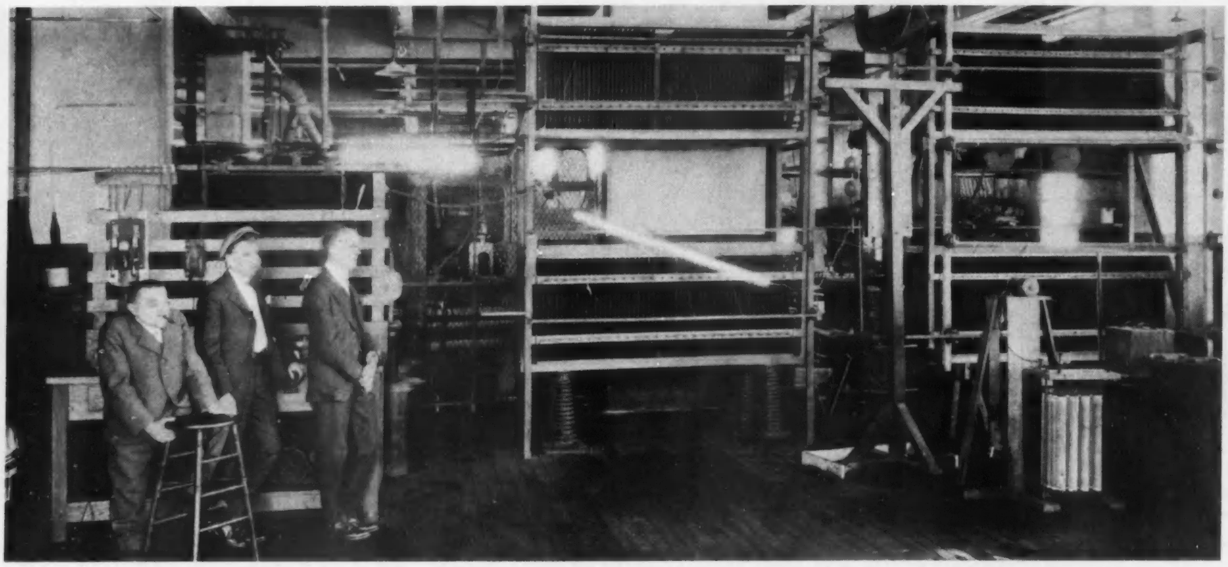
Steinmetz enjoyed cooking and prepared most of the meals on a small alcohol stove. When some particular guest was present at camp, he would prepare a chicken or steak, serving vegetables from cans. Another favorite dish was *eier kuchen*, or egg pancakes. I never learned their ingredients, but they tasted good.

He never liked to wash dishes, generally allowing them to pile up until he had some friend at camp with whom he would bargain: "I'll cook the meal, if you'll wash the dishes." He would then slip in his accumulation of dirty dishes with those used for the meal.

Exploding Some Myths

Many stories are told about Steinmetz. Perhaps the best known is the "No smoking, no Steinmetz." To meet an insurance regulation, General Electric posted "No Smoking" signs. As the story goes, when Steinmetz saw the signs, he left the plant and was absent three or four days. Found at home, he explained between puffs on his cigar that if he couldn't smoke, he couldn't work. It's almost too good a story to refute. The truth is Steinmetz never paid any attention to the signs but kept on smoking; no one ever stopped him.

Another anecdote, also without foundation, claims that Steinmetz never drew a salary from General Electric. According to the story, he was given a Company check book, wrote whatever



MAN-MADE LIGHTNING, a valuable contribution, enabled engineers to laboratory test resistance of electric equipment to lightning.

checks he wanted, and the Company paid them. Actually, Steinmetz received a definite salary, just as every other employee of General Electric. Being a socialist, money was never too great an object with Steinmetz so long as he could have all the necessary tools to work with, and these the Company readily supplied without cost.

Although owner of six different automobiles and coorganizer of the Steinmetz Electric Motor Car Corporation, Steinmetz drove a car only once in his life. When he died, he owned a Lincoln and a Detroit Electric but relied on his friends to do the driving. The Electric was arranged so that he could sit in the front seat, in what appeared to be the driver's seat, while a man in the rear seat operated the car.

Steinmetz seldom resorted to dictation in answering his mail. Instead he wrote replies across the face of letters, using his own peculiar style of shorthand, a sort of German script and Pitman combined. Only his secretary and one or two others closely associated with him could transcribe it. I once asked him why he used this peculiar style. He had a reason and to me it seemed a good one. He went to his files, picked up some of his shorthand written at least 20 years previously, transcribed it as readily and easily as though reading from a daily newspaper. "Show me the stenographer who can pick up 20-year-old notes and do the same," he said.

On one occasion our conversation drifted to remembering names of people.

"Do you have that trouble?" I asked.

"No, I don't have that trouble because I don't try to remember names," was his ready response. "I remember people as the one who said this or that or the man who did something worthwhile. That's all that counts."

Personal Philosophy

On another occasion, when I was seeking information for a story on his advice to young people, he made this remarkable statement that seems as sound today as when he gave it more than 30 years ago:

"If a young man goes at his work as a means of making money only, I am not interested in him. However, I am interested if he seems to do his work for the work's sake, for the satisfaction he gets out of doing it.

"If I were able to bequeath one virtue to every young man, I would give him the spirit of divine discontent, for without it the world would stand still. The man hard to satisfy moves forward. The man satisfied with what he has done moves backward."

Although Steinmetz didn't belong to any church and had often been accused of being an atheist, this wasn't true. He may not have believed in the Supreme Being, since he once asked me, "What evidence do you have for one?" Yet he did believe some supernatural force governed the world. Roger Babson, well-known economist, asked him: "What line of research will see the greatest development during the next 50 years?" With a moment's careful thought he replied:

"I think the greatest discovery will be made along spiritual lines. Here is a force which history clearly teaches has been the greatest power in the development of man and history. Yet we have been merely playing with it and never seriously studying it as we have physical forces.

"Someday, people will learn that material things do not bring happiness and are of little use in making men and women creative and powerful. Then the scientists will turn their laboratories over to the study of God and prayer and the spiritual forces which, as yet, have hardly been scratched. When this day comes, the world will see more advancement in one generation than it has in the last four."

Civic Interests

In addition to his engineering achievements, Steinmetz took an active interest in the civic life of Schenectady. He was president of the Board of Education and also president of the Board of Aldermen. He quickly appreciated the opportunities offered by this country, becoming a citizen as quickly as possible. He told me that this country afforded a freedom to do things not possible under government regulations in the old country. To him America was truly the land of opportunity.

When he was elected to the Board of Education, some 3000 students in the public schools didn't have seats. Playgrounds and facilities for retarded children, the blind, or the tubercular were lacking. During his term, eight new schools were built, special classes for retarded children established, and playgrounds inaugurated. He also brought in physicians and trained nurses as a regular part of the school system.

Steinmetz—born in 1865 in Breslau, Germany, of ordinary parents—was reared by his *grossmutter*, or grandmother. His mother had died soon after his birth. His crippled body prevented participation in games with other children, who gradually shunned him.

When he reached college age, he had largely overcome, through his brilliant mind, the feeling of others against him. He knew the answers when other students didn't, so naturally they turned to him for assistance. His socialistic tendencies at college forced him to flee to Switzerland in his senior year to escape imprisonment. He entered the Zurich Polytechnical School and while there met a fellow student who persuaded him to join him on his return trip to America.

Arriving at Castle Garden with practically no knowledge of the English language, he possessed no visible means of support. A bad cold had caused his face to swell, adding to his deformed appearance. Immigration officials first decided to refuse him admission to this country. Only when his friend produced a roll of bills, declaring "half belongs to Steinmetz," and guaranteeing, "he will not become a public charge," did they change their minds.

First U.S. Job

Steinmetz had heard and read much about Thomas Edison. He felt that if he could get a job in Edison's plant, he would be afforded the opportunities he sought. But he got no further than a short interview with the chief engineer. Downhearted but not discouraged, Steinmetz went to Yonkers the next day. He had a letter of introduction to Rudolph Eickemeyer, a manufacturer of hatmaking machinery and electric devices.

Eickemeyer, like Steinmetz, was a German. Speaking their native language, Eickemeyer quickly realized that here was a top-flight engineer and mathematician. He told Steinmetz to report for work as a draftsman the next morning for $12 a week. Before long Eickemeyer transferred him to electrical research work. Here, at last, he was in his element. He soon designed a new streetcar motor, a marked improvement on any motor then available.

While with Eickemeyer, Steinmetz assumed what he termed a good American name. He had been christened Karl August Rudolph Steinmetz. Learning that Charles was English for Karl, he started using it. Then one day an old German friend—a man who had attended school with him—dropped in to see him.

"Well, if it isn't Proteus!" exclaimed the former classmate.

It was the nickname conferred upon Steinmetz by one of the student societies. At the time he didn't like it. He knew the *Odyssey* from beginning to end; Proteus was the old man of the sea. If you caught him, he'd change in your hands to a hurricane, to a fire, or to a sea serpent. If you kept a firm hold on him, he would change back to his real shape, a wrinkled old deformed person, and tell you all the secrets of the world.

But now he felt differently. He had assumed no middle name and felt that all Americans required one. As names, he liked neither August nor Rudolph; both were too German. His friend's greeting gave him an idea. He picked up his pencil and wrote, "Charles Proteus Steinmetz."

"There, that's a good American name," he said—and used it ever after.

Joins General Electric

Steinmetz's work at the Eickemeyer factory attracted wide attention. One day he had a most distinguished visitor, Edwin Wilbur Rice, chief engineer and later president of General Electric. Rice offered him a job. But Steinmetz was reluctant to leave his good friend Eickemeyer. Then General Electric purchased a part of the Eickemeyer business that included Steinmetz.

Four weeks after Steinmetz had reported for work at General Electric, a friend noticed he didn't appear too well. He asked if anything was the matter. With some hesitation, Steinmetz replied that he hadn't been paid since he joined the Company, that his funds were low. As a result he had not eaten too regularly. When asked why he had not said something, he explained that he had hesitated for "fear that maybe General Electric thought the experience he was getting was enough—without pay." Nothing had been said about salary in his talk with Mr. Rice. The Company quickly rectified the mistake. A clerk had neglected to add his name to the payroll.

His Achievements

Steinmetz was not a great inventor. His discoveries carried no popular understanding and appeal as did Edison's. Perhaps his greatest contribution to the electrical art during his 30 years with General Electric was his formula on the laws of alternating current, which made possible a much wider use of alternating current. The formula solved hundreds of problems that had puzzled engineers for years in the designing of transformers, motors, generators and in the distribution of electricity for far greater distances at higher voltages.

His artificial lightning machine made possible the development of dependable lightning arresters, protectors of transmission lines, and electric equipment that withstood the ravages of natural lightning. To General Electric he was probably most valuable as chief consulting engineer, the Supreme Court to whom all engineers with difficult problems came for advice. The Company had implicit confidence in his decisions.

Steinmetz's death at the age of 58 came suddenly and unexpectedly. Only a week earlier he had returned from a combination vacation and business trip to the Pacific Coast. He had enjoyed his first visit to Hollywood where he met his favorite movie actor, Douglas Fairbanks, Sr. He even drove an ostrich cart at the Los Angeles Ostrich Farm and asked that a photograph be taken for his scrapbook. He enjoyed retelling this unique experience.

The exertion of the trip apparently was too great. Returning to Schenectady, Steinmetz's doctor advised him to remain at home resting for two weeks. On the morning of October 26, 1923, he awoke at the usual hour, cheerful as ever, and ordered his breakfast. But when the tray was brought to his room a few minutes later, he had passed on, as quietly as an electric motor stops when it ceases to receive electric current.

Who was the Steinmetz I knew? Not a hard-bitten man of science, but a patient friend to mankind. Not a self-satisfied man of fame, but a friend to the underdog. Having pulled himself up to the height of giants, he paused to give mankind and science a lift.

Two men summed up this dual devotion to man and science . . .

"He always wanted to help everybody."

—ALFRED E. SMITH

"Mathematics to Steinmetz was muscular strength and long walks over the hills and the kiss of a girl in love and big evenings spent swilling beer with your friends."

—"Proteus," *USA*, by JOHN DOS PASSOS

Condensation Nuclei Offer Technology a New

Airborne particles have many sources—from the ocean's spray to an arcing electric contact. Detecting them gives a direct indication of a material's erosion.

***Review* STAFF REPORT**

The long-standing problem of measuring minute particles still excites the scientific mind. But few phases present the complications and frustrations encountered in the submicroscopic airborne particles.

Engineers are only now beginning to understand the techniques for particle measurement. "Correctly evaluated," says Consulting Engineer T. A. Rich of General Electric's General Engineering Laboratory in Schenectady, "the myriad benefits to mankind of particle measurement range all the way from better air-conditioning equipment and control of air pollution in cities to development of better electric control devices." Rich should know. One of the more than 70 patents he has thus far accumulated in his engineering career is for the measuring instrument shown in the photo, left, opposite page. He has spent many years investigating airborne particles.

What They Are

From childhood you have known about the existence of airborne particles—the dancing motes in a sunbeam or, to be more prosaic, the dust particles that settle upon a surface. Such particles don't truly represent the whole, however, because they're only the portion visible in the atmosphere. Invisible particles—some so small you can't see them under a microscope—are much more numerous.

One such group is called *condensation nuclei.* Upon these particles, whether solid or liquid in nature, moisture condenses to form water droplets. These in turn produce a variety of effects: highway fog, for example. At the center of each fog droplet, you will find a condensation nucleus.

Scientists more than a century ago realized that without these airborne particles, rain as man knows it wouldn't occur. Without particles to serve as nuclei, air over lowlands would become supersaturated with moisture, discharging torrents of water when it contacted mountains. The result: vast areas of semidesert and rapidly eroding hills.

What are the sources of such condensation nuclei? Combustion, mainly, both natural and man-made, according to F. W. Van Luik, Jr. (cover and photo, left, opposite page), a specialist in engineering physics and analysis associated with Rich. Other sources, Van Luik says, such as dust storms and salt spray from the oceans contribute small amounts, too. But with the exception of this general knowledge, until comparatively recently there was little practical understanding of condensation nuclei. Both Rich and Van Luik attribute this lack of interest to these reasons: preoccupation of scientists in other fields and the experimental difficulties caused by the extremely small size and transient nature of the particles.

So tiny is the average condensation nucleus that it bears the same size relationship to a grain of sand as the head of a pin bears to a three-story house. What's more, all attempts to study nuclei had their own peculiar frustrations for the scientists. In their investigations of airborne particles, they couldn't depend on the reproducible experiment—the cornerstone of true scientific study. For they simply couldn't duplicate test conditions in the laboratory from one experiment to the next.

Difficult Task

Studying condensation nuclei involves the basic principle of encouraging water to form upon particles in a given sample

Comprising haze that overhangs industrial complex (left) are airborne particles that Van Luik and Rich (above) measure with a portable condensation nuclei meter. Engineers (right) determine erosion rate of motor-starter contacts in test chamber.

Yardstick

of air. Moisture, pressure, and character, or source, of the nuclei all profoundly affect results.

Moisture and pressure are reflected in a special condition of relative humidity, also called *supersaturation*—the ratio of actual moisture the air retains under specific conditions of temperature and pressure to the moisture contained at saturation. The size of nuclei upon which water vapor condenses depends on the degree of relative humidity.

For example, at a relative humidity of 112 percent, condensation takes place on particles 1/50 the size of those visible in cigarette smoke. At a relative humidity of 400 percent—equivalent to a supersaturation of four—water drops form on a charged particle as small as a single molecule. But if you raise relative humidity to 800 percent, a moisture cloud appears even in the absence of any nuclei. Why this phenomenon? It occurred because several molecules collided to form, in effect, their own nuclei.

Character of the particles is the final factor over which researchers must maintain control for accurate investigations. Unfortunately, they often find it impossible to know the source of the particles being measured. Difficulty in interpreting results arises because hygroscopic, or water-seeking, particles have different characteristics than other types of nuclei.

Evolution of Instruments

For producing such conditions in the laboratory and counting the condensation nuclei present, engineers have devised many forms of instrumentation that readily detect nuclei in the ratio of 1 to 100 trillion parts of air by weight. Fundamental to most is bringing the air under test to a condition of 100 percent relative humidity.

By using this principle, you can draw a sample of air containing condensation nuclei into a test chamber and raise the relative humidity to 100 percent. If you then expand the air adiabatically—that is, rapidly enough to prevent heat from flowing to the gas—the resulting decrease in temperature instantaneously elevates relative humidity to a figure greater than 100 percent. Now the air holds more moisture than it normally could. In this unstable condition, the moisture condenses upon any nuclei present.

Such condensation takes place rapidly. Within a few milliseconds the submicroscopic nuclei grow into a fine fog droplet. You can then count them with some optical system.

In a type of instrumentation once widely used, an investigator would expand the water-saturated air sample with a hand-operated pump. Then, when the air cooled, the water droplets that formed would settle onto a squared slide where they could be counted.

Another device utilizes a long wet-blotter-lined tube, traversed by a beam of light. The investigator pressurizes the sample air until it holds all the moisture it's exposed to, called *humidity equilibrium*, and then he suddenly releases the pressure. Accordingly, the fog thus formed attenuates the light beam. And this attenuation gives investigators a reliable measure of the numbers of nuclei originally present in the air sample.

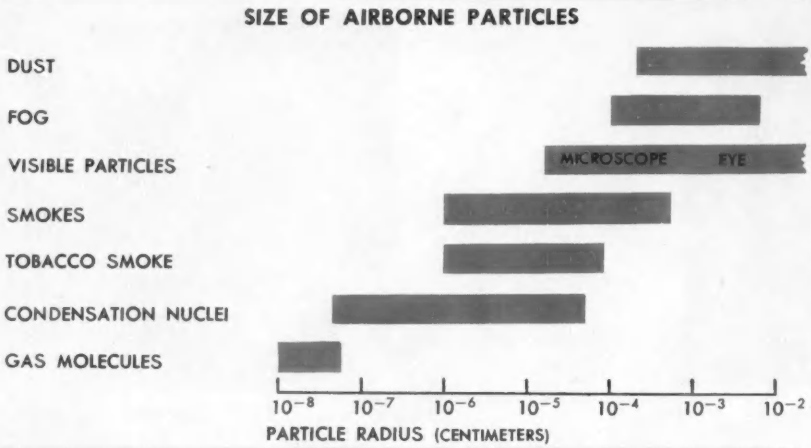
In both devices the wet blotter has a function: bringing the air to 100 percent saturation before it expands. After expansion, the blotter serves as a reservoir of additional moisture. As a result, droplets persist much longer.

This characteristic of persistence, coupled with the ability to reproduce similar conditions, has made possible the development of a modern condensation nuclei detector (photo, left). Suitable for field use, it has an excellent degree of repeatability. With this instrument or similar detectors, you can not only measure the *numbers* of condensation nuclei present but also obtain a rough estimate of their *size* distribution as well by using appropriate techniques.

Air Pollution

Already, measurements of airborne particles now possible with modern detectors have opened new avenues of investigation. More and more types of problems lend themselves to study. Take, for example, the field of air pollution. How submicroscopic particles affect your health and visibility is becoming increasingly apparent.

In rural northeastern United States, an average nuclei count would be



approximately 5000 particles per cubic centimeter of air. In a small industrial town, it would rise to about 50,000 per cubic centimeter. And over a super-highway or major industrial complex, the count might go as high as 500,000.

It isn't sufficient, however, to determine only the number of particles discharged into the air. For their size (illustration) relative to the mass of the pollutants is extremely important with respect to visibility.

If submicroscopic particles comprise the mass, your ability to see through the atmosphere remains almost unaffected. But if the pollutants' mass is contained in particles with a size in the range of the wave length of light, a readily visible plume is likely to form. If the mass were contained in still larger particles, a less visible plume would result. Thus air that appears clean to you may contain considerable pollution. The need to detect and evaluate this condition has been met in a large degree by these instruments.

Practical Application

Benefits are already apparent in the field of air filtration. Because engineers can now rapidly measure and count particles in the air stream, development of filters is proceeding at a rate not previously possible. Thus the air distribution systems of your home and office may one day discharge truly clean air. (For the importance of proper air distribution and filtration in your home, see article on page 12).

But even broader technological implications hold promise in another field of application: electrical development. Here the age-old problem has been the contact erosion that results from electric arcing.

Arcing between contacts (cover) produces large quantities of condensation nuclei. When you make or break an electric current, you produce extremely high temperatures. Contact material literally evaporates. As the evaporated material passes out of the arcing region, it cools and condenses into small particles.

For example, interrupting a typical relay contact that carries current of 5 amp at 115 volts produces 100 trillion minute particles. Because of their high concentration and thermal activity, the particles immediately begin to combine with one another. The vaporized contact materials quickly move away from the arcing region. And shortly, the accumulations grow to comprise about 1000 molecules. This is, of course, still extremely small—less than 1/500 the size of a nucleus in cigarette smoke. Nonetheless, the total number of particles — probably metallic oxides — is sufficiently reduced.

By sampling the air adjacent to the arc, you can measure the particles with a nuclei condensation meter. With this information plus knowing the contact's cycling rate and flow of air around it, you can calculate the number of nuclei produced by an arc.

What is the significance of this? Tests show a high degree of correlation between the *number* of nuclei and *degree* of arcing. Thus by measuring condensation nuclei in the vicinity of an arc, you readily determine the degree of contact erosion. Presently, the greatest value of this application lies in finding the best operating conditions for a specific type of contact. Almost equally valuable, you can determine the best materials to use for a given set of operating conditions.

Additional to this, however, many other applications of nuclei measuring instruments have already been made. Some show promise of unearthing new technical knowledge and design techniques.

A typical problem engineers encounter in developing electric equipment is the "bounce" of contacts that close. They must for instance evaluate in advance of design the amount of bounce, or springback, of a closing relay. Many factors affect this characteristic: mass of the contacts and their supporting arms; natural frequency of the structure; and force, velocity, and accelerations involved in closing.

To evaluate each factor, a designer would have to build various sample configurations of the relay for life testing. And you can appreciate what a time-consuming process that would turn out to be.

By using the nuclei-measuring technique, however, the designer builds each of these configurations and operates them in a test chamber (photo, right, page 23) under identical load conditions. He merely compares the number of nuclei produced by each and in a single day can test many configurations. What's more, improvement of a design or material as determined by nuclei count is *statistically* more significant than a conventional life test. (From just such an investigation data were obtained that actually more than doubled the life of a contact.)

Tests conducted in other areas may also bring significant results. One is the commutation of a d-c motor or generator. Engineers can now measure commutator arcing, quickly calculating the relative amount at each brush. They can examine individual brushholders or determine the average value of arcing for all.

Improvements Ahead

Knowledge of condensation nuclei provides data of definite, positive value in many ways. While its ultimate use cannot now be foreseen, you can be certain that knowledge of these particles will be of importance to the engineer who designs electric equipment.

It will also result in better filters, fog and smoke detection devices, and more efficient control of industrial and social hazards resulting from air pollution.

Interesting and valuable as the data have been to date, you can best interpret them as the bases of more useful information in the future. Ω

From the housewife's familiar iron, General Electric industrial designers borrowed many concepts, adapting them to create a new mixer—one facet of the story behind how . . .

The Electric Portable Mixer Revived a Market

By E. D. HOWELL

What's wrong when you find your product sales lagging behind an expanding national economy? is the market saturated? or does it demand a different type of product?

This situation faced food-mixer manufacturers in the late 40's. Prior to 1940, the traditional stand-mounted mixer enjoyed a steady but slowly increasing business. However, by 1948 its future growth looked sad compared to the blossoming economy. Management saw the mixer industry drifting into a staid, unexpanding market of $45 to $50 million annually, with sales leveling off at 1½-million mixers a year.

Marketing research professionals in General Electric's Portable Appliance Department viewed market saturation as doubtful. For statistics didn't confirm the saturation theory. That a section of the market was seeking a different or similar product at lower price presented a more likely reason for the leveling off of standard mixer sales. Clearly the growth rate of the industry in standard mixers couldn't match the national growth rate. The answer: Meet the challenge by conceiving a new product—the modern electric portable mixer.

This involved two major steps: changing the consumer's traditional visual conception of a mixer and mass-producing a small, lightweight, inexpensive electric hand mixer.

Appearance Radically Changed

Industrial designers at General Electric decided that the new design must be a radical deviation from the public's conception of mixers. One hazard of this approach rested in the highly competitive market where the design would be accepted or rejected. For to the housewife a mixer should look like a mixer; if it didn't she would not consider it a mixer and would not buy it. The average consumer believed that a mixer looked like a rocket ship with a handle on top and beaters protruding from the bottom. Because the rocket ship was anchored to a stand, she assumed that mixers weren't really supposed to be portable although they could be used that way.

General Electric's new mixer introduced in 1952 bore no resemblance to any mixer on the market. In fact, it vaguely resembled an iron with its iron-like handle and soleplate. Further, the power line entered its case in about the same place as an iron's cordset; the switch appeared at approximately the

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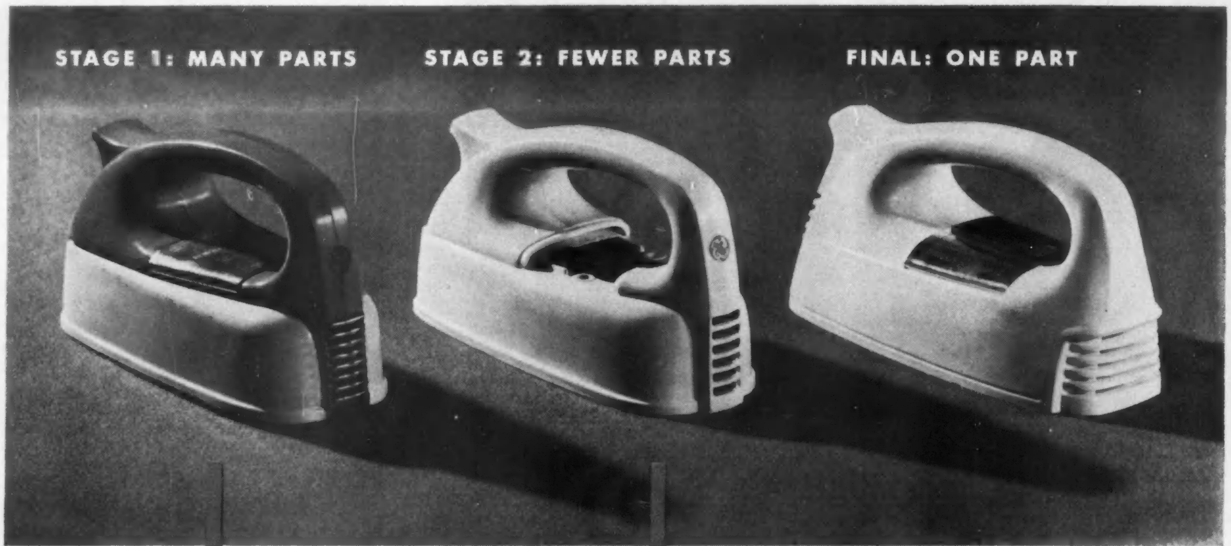
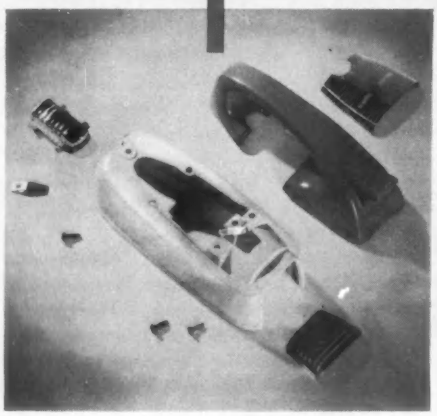
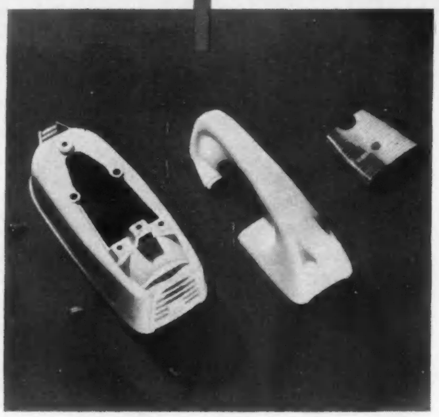
Mr. Howell—Development Engineer, Portable Appliance Department, Brockport, NY—joined General Electric on the Test Course in 1953. Presently developing new motorized portable appliances, he was formerly design engineer on the all-purpose mixer which appeared on the market in 1955.







Progress in Mixer Design

The original case (top, left) consisted of many parts and weighed about a pound—one third of the total mixer weight. The first improvement integrated the grills and case, changed the handle material, and eliminated one assembly screw (top, center). Final design resulted in a one-piece plastics case and handle, weighing only 9 ounces.

same location; the lines of the design were clean and simple; and when not in use it also stood on its heel. One vestige of mixerhood remained—the beaters (photo, center page 25).

Why did industrial designers borrow from the iron? To insure the appeal of the new mixer, they adapted the familiar features of an accepted appliance—the iron, the only truly portable domestic appliance. Transferring these attributes to the new mixer became the designer's task.

To make the advantages of the new appliance obvious to the housewife, the industrial designers recognized two requirements: the device would have to appear easy to use; and storage, both while in and out of use, would have to seem simple and handy.

Appearing easy to use meant that the mixer's operation must be evident. The design should suggest to the customer how to grasp and operate the device. The *comfortable* iron-like handle and a self-explanatory switch—marked with mixing jobs and speeds instead of fabrics and temperatures—satisfied this requirement. Beaters, protruding from the soleplate, clearly indicated the business end of the machine.

To fulfill the other requirement—ease of storage—the mixer had to have both *permanent* and *in-process* storage.

Permanent storage entailed putting the device away when not in use. To meet this requirement, the new mixer design outdid the iron. A screw with a ball head, supplied with the mixer, made any wall a potential storage area. By slipping the keyhole slot—cut in the mixer's soleplate—over the screw, the mixer could hang neatly against the wall instead of standing in a cabinet or knocking about in a drawer.

In-process storage meant putting the machine down between jobs without allowing the sticky beaters to rest on the counter top dripping messily. Here, in-process storage was identical to the iron's. With its heel on the table and nose in the air, its beaters didn't rest on any surface. Batter drip no longer meant a problem because a bowl or saucer could easily be placed under the beaters.

Thus, a new appliance was conceived —designed to change the consumer's visual conception of a mixer. Similarity in design between it and the iron made the mixer's advantages potentially apparent to the consumer. Its market acceptance could indeed change the public's concept of a mixer.

Mass-Production Problems . . .

The second major step involved a manufacturing problem—mass-producing a portable mixer.

By changing the consumer's visual idea of how a mixer should look, the designers did come up with a truly portable device. But other traditions about mixers had to be discounted before the mass market could be thoroughly sold

"As small as an iron . . . half the weight and cost of larger mixers."

on the advantages of a portable mixer.

For one thing, mixers—formerly larger than irons—often weighed five pounds or more. Portability was not one of their strong features. Also, a fruit juicer, meat grinder, and other useful kitchen attachments supplemented most mixers. These accessories needed more power than the average minimum mixing requirements. For homemakers who wanted attachments for heavy mixing tasks, the existing mixers were excellent.

But certain factors tended to diminish this trend. Many housewives undergoing the revolution in today's kitchens needed a mixer with only enough power to mash potatoes and mix cookie batter. The kneading of heavy bread dough, for example, has become a less frequent mixer chore. Power attachments, stands, and bowls didn't interest many housewives. They wanted a lighter, purely portable mixer, and they wanted to pay for mixing power only.

As small as an iron and almost half the weight and cost of the larger mixers, the new General Electric mixer filled the bill. Reducing the power requirements helped to accomplish some savings, but the reduction to the final dimensions resulted from the design.

. . . the Internal Components . . .

Basically, the new mixer consisted of a small universal-series motor perched on a die-cast aluminum chassis (photo, page 28). Changing the number of coils in the circuit, thus altering the strength of the magnetic field, varied the speed of the tapped field motor. A simple switch connected or disconnected these coils. The worm gear on the motor shaft, which drove a pair of helical gears, supplied the power. The gear spindles, enclosed in a case with a handle, were adapted to receive and hold the beater shafts. And a rubber gasket, mounted around the motor base, separated the case from the base.

The greatest dimensional reductions and value improvements occurred in the design of the motor and case. Because of motor design, each component justified its existence by performing as many chores as possible. Bosses and cavities in the die-case base served as fastening and locating devices for the motor, brushes, switch, bearing, and gears. The switch plate doubled as a thrust plate for gear shafts and as a gear grease retainer.

The gasket acted as a heat barrier, a sound dampener, a resilient mounting, and a continuous nonscuffing shoe. As a heat barrier, the gasket prevented heat escaping from the chassis to the case—a vital function. For a hot case would alarm the housewife into thinking that her mixer was overheating.

As a sound dampener, the gasket absorbed motor-chassis vibrations before they reached the case. As a resilient mounting, the gasket reduced the need for critical tolerance fitting of the case to the base. Finally, as a continuous nonscuffing shoe, the gasket gave the mixer a soft pad that prevented counter-surface scratching and wall marring and that enabled the device to rest gently on the rim of a bowl or pan while mixing.

This multipurpose design greatly reduced the number of parts in the mixer, making way for a reduction in both volume and consumer cost. The use of aluminum and plastics in the motor components allowed a reduction both in mass and cost.

But the principle of motor construction provided the greatest value improvement of all. Previously, tradition dictated round motors. Following custom, the chassis was an integral part of a round envelope to improve coolant air flow, conserve volume, and preserve the rocket-ship contour. The new mixer, on the other hand, took a radically different form. A square motor mounted on top of a flat chassis afforded far easier access to the motor and its components leading to simpler, less costly manufacture.

Thus the motor met the second part of the basic challenge in size, weight, and cost. But the case still presented a problem.

. . . and the External Components

The original case consisted of 10 parts, 8 different and purchased from 5 sources (photo, lower left, page 26). It weighed almost a pound—one third of the total mixer weight. Manufacture involved two plating and painting operations. And the cost to handle and assemble these parts was high. Though the first version met the design requirements of size, the weight and cost of manufacture still left much to be desired.

During a short preproduction run, a value-improvement program was instituted to simplify the enclosure without losing the quality and basic features of the original design. This program involved two phases: first, the integration of some parts in a single die casting instead of in three and a manufacturing change in the handle; second, the integration of all parts within a single plastics molding.

The first value-improvement phase integrated the grills and case, changed the handle material, and eliminated one of the assembly screws (photo, lower right, page 26). Integration of the grills and case eliminated both the grill spring and the need for plating and, incidentally, removed some dirt-catching cracks that made the device hard to clean. Changing the handle material from a phenolic thermosetting compression-molded plastics to a cellulosic injection-molded thermoplastic resulted in the elimination of a painting operation as well as a reduction in weight and manufacturing cost. The over-all effect afforded a substantial reduction in assembly labor plus some savings in material.

Thus with an improvement in performance and quality, the case more closely satisfied the economic requirements of the design. However, disadvantages still existed, and they proved hard to live with. Some of the difficulties: Matching the color of the painted case and plastics handle and insuring that they would always match as the colors changed with age; reducing the variations in the fit between case and handle—these parts were supplied by different vendors who used multiple-cavity molds; and further reducing weight though it had improved slightly—from 14 to 12 ounces. The total mixer still weighed three pounds.

Perfecting the Design

The second redesign phase was a long-range affair. Drawbacks remaining in the first improvement couldn't be tolerated for long by marketing and manufacturing. Of the many approaches, molding a one-piece plastics case and handle was the most attractive but baffling (photo, top page 26).

While the industrial designers proceeded to design the case for one-piece injection molding, engineers consulted the custom molders. Only one of those approached felt that it had even a 50 percent chance of success. Most molders seemed to be inhibited by the traditional fears of heavy, rapidly changing cross sections because such factors can make good molding difficult.

However, a preconceived notion that the Underwriters' Laboratories would not approve a thermoplastic motor enclosure offered the greatest stumbling block of all. Although thermoplastics had a history of flammability problems, technological advancements in the plastics industry had developed flame-inhibited materials that eliminated such problems.

The requirements of a plastics motor encasement made a formidable list. The Underwriters' Laboratories required that the finished molding withstand: a specified open flame without supporting combustion; a 7-hour exposure to 212 F without the potential hazards of cracking or softening in the case; a burnout of the motor without emitting a flame; and three 3-foot drops on a hardwood floor of the assembled mixer without live electrical or mechanical hazards.

We required that the case be not only light, inexpensive, and easily molded, with good color and finish but also nonstaining, sound deadening, free of obnoxious odors, nontoxic, and mechanically and chemically stable after years of use. Above all else, the less it looked, felt, and sounded like any low-quality plastics products on the market, the better.

The field narrowed rapidly to cellulose acetate with a flame-inhibited additive. The first samples proved disappointing. Cold-weld seams disfigured the mold where the chilled plastics had collided without fusing. Scorch marks appeared where hot spots in the mold had burned the plastics, and deep sink marks showed where the cooling plastics had shrunk away from the sides of the mold. But eventually, the technological knowledge applied by the molder and material supplier resulted in an acceptable, finished case.

Suppliers Cooperated

During the preceding operations, all groups involved—designers, engineers, part molders, and raw-material producer—worked in close cooperation. Compromise characterized the numerous conferences held by two or more of the groups. The teamwork between a large-scale business enterprise and the specialized skills of small businesses, such as the part molder and the raw-material producer, resulted in a better product for the public and a profitable business opportunity for the suppliers. This relationship with suppliers combined not only our talents but also the skills and ingenuity of the part molder and the raw-material supplier. The final product offered the housewife the greatest value for her money.

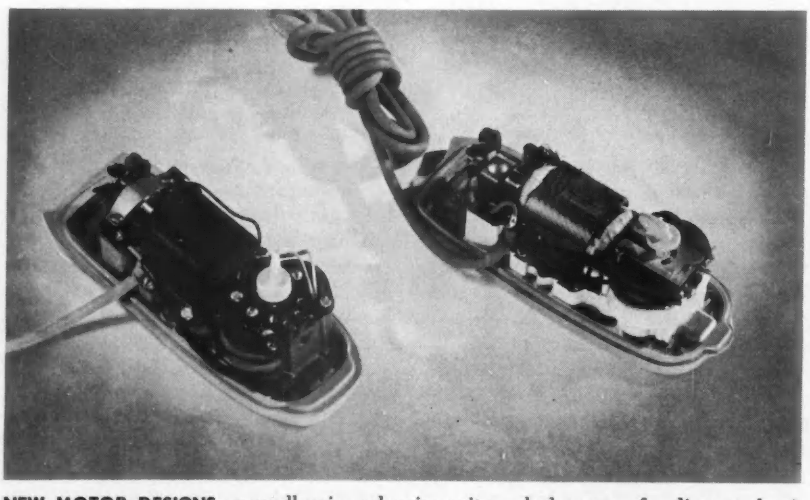
The completed second redesign phase of the case had succeeded in meeting the requirements of weight and cost. The case now weighed nine ounces, almost half its original weight, and cost only a fraction of the original version. It passed the Underwriters' Laboratories tests and more than satisfied the design requirements.

The less expensive cellulose-acetate case offered two unexpected benefits. Integral color made mix-or-match colored mixers a simple proposition, and the acoustically dead plastics material seemed to have a quieting effect on the appliance. The former metal case transmitted if not amplified the motor sounds in spite of the inclusion of a sound-dampening gasket.

The Challenge Met

Thus General Electric's new portable satisfied the mixer industry's challenge to produce a small, lightweight, inexpensive electric hand mixer whose acceptance on the market place would change the consumers' traditional visual conception of a mixer. A modern electric portable mixer had evolved. The favorable position in the market which the mixer enjoys indicates its acceptance and success in meeting the current challenge.

Today's portable mixers have captured the mixer-market spotlight. Mixer industry sales figures show that the present annual portable mixer volume of 1½-million mixers already equals the stand-mixer volume. The portable mixer market, worth about $31½ million, is about half the present value of the stand-mixer market. Consumers appreciate the value of portable mixers as a gift item; low price makes them a good impulse buy. The rapidly expanding market indicates no apparent lag for food mixers. You can be sure that future portables will have additional features with a scope limited only by the imagination of the engineer and the designer. Ω



NEW MOTOR DESIGNS—a small universal-series unit perched on top of a die-cast aluminum chassis—resulted in both reduced dimensions and value improvements.

CREDITS

Page	Source
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23 (left)	Burns Photography, Inc.
25 (right)	National News and Illustration Service, Inc. New York City

Proper Air Distribution—
(*Continued from page 12*)

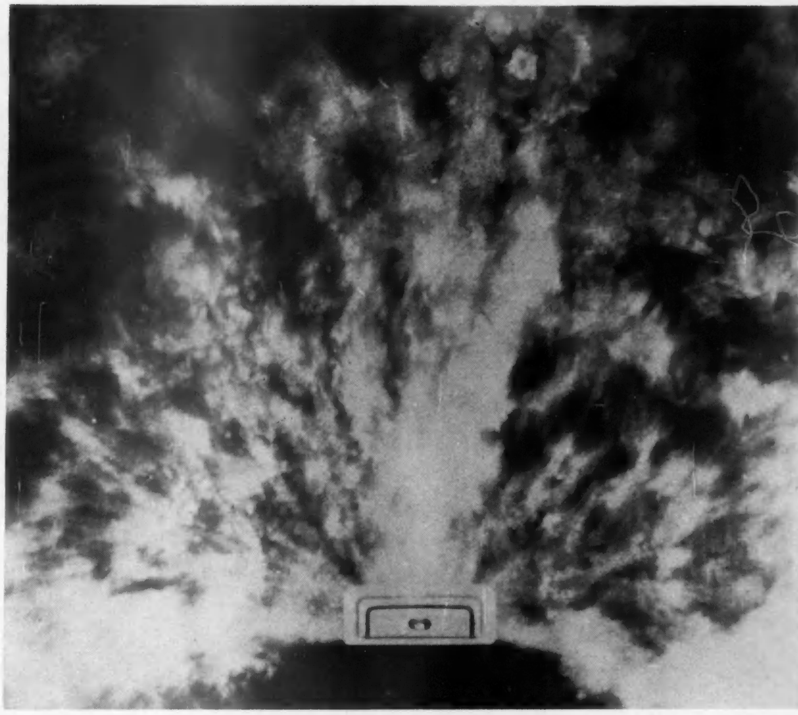
Cheaper in the End

After all, your primary interest in a heating or cooling system centers around its feature product—comfort. And you can best obtain this with a conditioning unit and air-distribution system that fulfills the heating or cooling requirements in every room of your house.

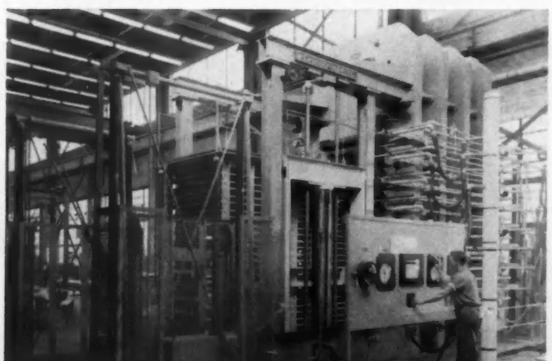
Naturally, this type of distribution costs somewhat more than a less perfect one. But the increased comfort and satisfaction you get balances out the extra cost. What's more, your operating expense—the fuel or electric bills—may well be less because of full utilization and even distribution of the conditioning unit's output.

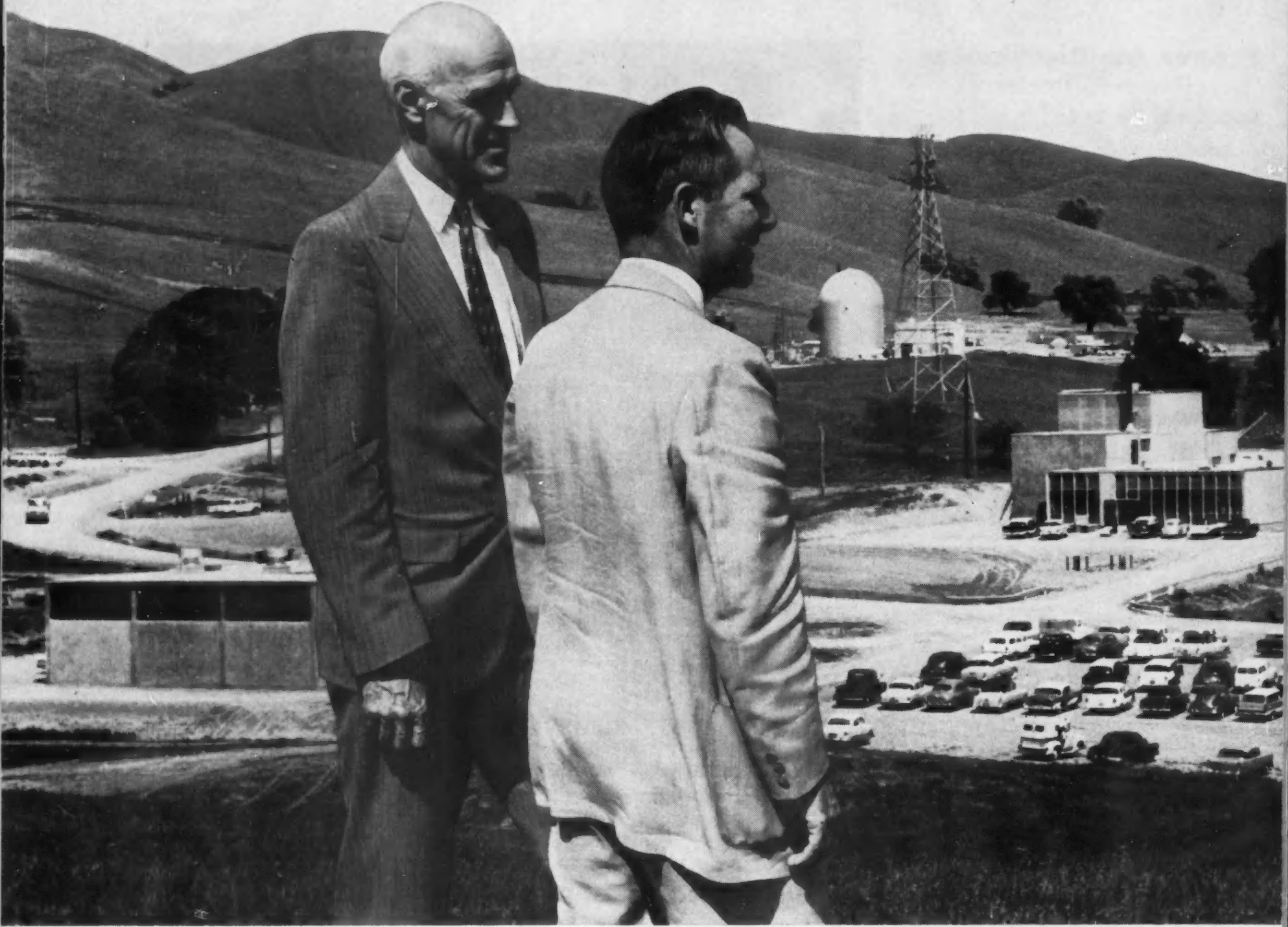
More important to you as head of a household, though, is that good air distribution aids in maintaining your family's health the year round.

How well is your present system designed? Check it against the minimum arrangement for good air distribution in your home (Box, page 13), and see how it stacks up. Ω



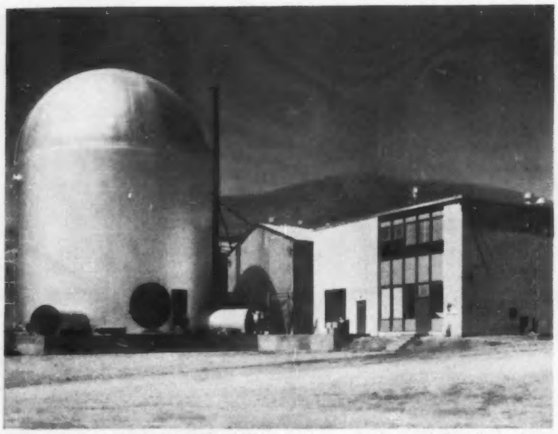
SMOKE TEST reveals how warm air hugs the wall closely and prevents cold air from spilling down to create drafts; floor level air drawn to register blends with the warm air.



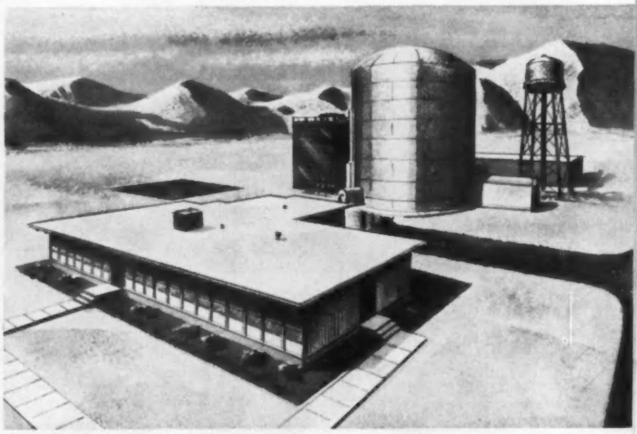


DR. R. D. BENNETT, Vallecitos Atomic Laboratory Manager (left), and **E. P. LEE,** Manager of Plant Operation, view Lab-

General Electric Vallecitos Atomic Laboratory



PURPOSE OF EXPERIMENTS to be conducted in Developmental Boiling Water Reactor is to develop economic nuclear power. Facility will furnish steam to 5000-kw turbine-generator, owned and operated by Pacific Gas & Electric Company.



GENERAL ELECTRIC TEST REACTOR, planned for completion in 1958, is a new concept in reactor design developed by General Electric. This 30,000-kw test reactor combines features of tank and pool reactor types.

oratory's facilities: Radioactive Materials Laboratory (right), Experimental Physics Laboratory (center), Developmental Boiling Water Reactor (rear). New General Electric Test Reactor (not shown) will be completed in 1958.

will help speed economic nuclear power

LABORATORY IS NATION'S LARGEST PRIVATE NUCLEAR RESEARCH FACILITY

Progress in private industry's determination to reduce the cost of nuclear power was made May 22 when the new General Electric Vallecitos Atomic Laboratory at Pleasanton, Calif. was dedicated.

At Vallecitos, advanced research and development facilities will be utilized to help accelerate the practical application of atomic energy.

The Radioactive Materials Laboratory will be used to study irradiation effects on reactor fuels, components and structural materials. These studies will lead to improved reactor technology.

The Experimental Physics Laboratory contains a critical assembly which will be used to study reactor core configurations and fuel loadings. A Nuclear Test Reactor will also be used for general physics experiments and calibration.

The Developmental Boiling-Water Reactor, to be completed later this year, will be used to develop important research data on power reactor systems.

A General Electric Test Reactor (GETR) will be added next year to test materials and components for the Company's nuclear projects.

The multi-million dollar Vallecitos Atomic Laboratory represents another significant step taken by private industry in developing practical applications of atomic energy. Atomic Power Equipment Dept., General Electric Co., San Jose, California.

197-5

Progress Is Our Most Important Product

GENERAL ELECTRIC

World's first large generator with liquid-cooled stator windings shown prior to shipment to The Cleveland Electric Illuminating Company's Eastlake Plant.