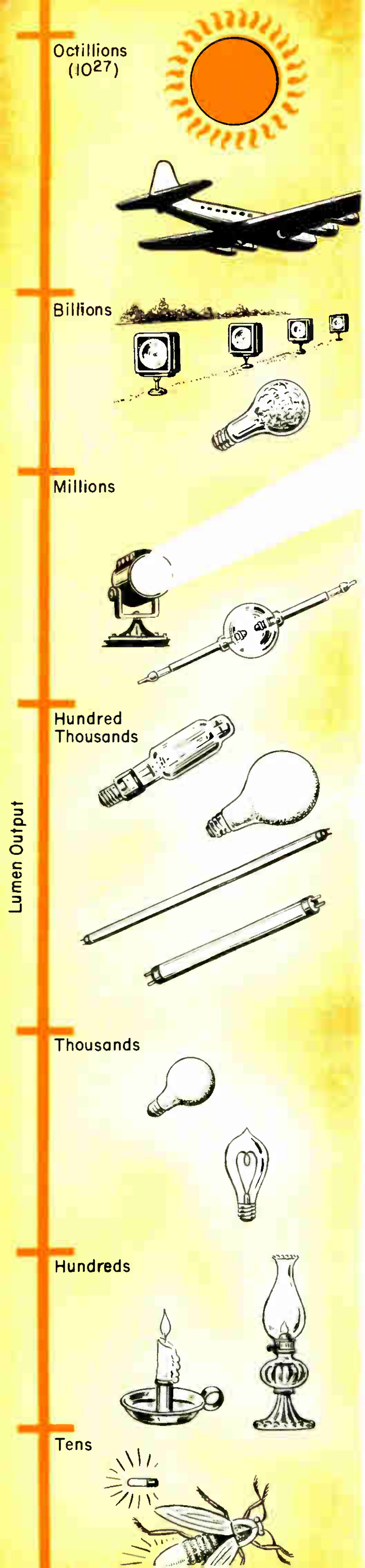
# WESTINGHOUSE Engineer

MARCH 1950



# The Firefly, the Sun, and Modern Lighting

Where light is concerned, engineers consider with astonishment the capabilities of two natural sources that are as different as night and day—the feebly glowing firefly and the blazing sun. The sun is easily the most prolific single source of light in our astronomical neighborhood. Its total lumen output is almost beyond the limits of imagination—about 30 x $10^{27}$ lumens. Compare this with the 60-watt incandescent lamp's 835 lumens, or the 40-watt fluorescent lamp's 2480. The tiny firefly, on the other hand, although a feeble emitter of light, produces it at a luminous efficiency that puts man's best efforts to shame. Expressed in lighting efficiency terms, the firefly's output is estimated at about 500 lumens per watt, more or less. Contrast this with the incandescent lamp's 13.9 and the fluorescent's 62 lumens per watt. Paradoxically enough, nature's largest light source, the sun, and one of the world's smallest natural light sources, the firefly, both surpass man's best efforts to date.

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Despite being overshadowed by the efforts of nature in efficiency and total lumen output, lighting engineers have more than equaled nature in at least one respect—brightness. This is best exemplified by the cigarette-sized krypton flashing lamp used in the Westinghouse All-Weather Approach-Lighting system for airports. This tiny lamp, only a few times larger than the firefly, flashes at a brightness over nine times that of the sun, i.e., its visible light output per unit area is momentarily more than nine times as great. At the peak of the discharge about 3000 kw are being delivered to the gas within the quartz tube and the lumen output is about 50 million. The discharge has a duration of some 20 millionths of a second, long enough to guide—but not blind—the pilot, short enough to avoid tube destruction.

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Considering the fact that man's best efforts in artificial lighting a century and a half ago consisted of the candle and the oil lamp, the progress of artificial lighting seems more impressive. The flickering candle of the 1800's gave off about 12 lumens, the yellow flame of the oil lamp only about three times as much.

In contrast the carbon-filament incandescent lamp by 1905 had an output of over 200 lumens. And today the modern incandescent lamp of comparable rating emits almost four times as much light as its ancestor.

Lighting engineers have also produced lamps of sizable total lumen outputs. The previously mentioned krypton lamp, over nine times as great as the sun in brightness, is the closest approach engineers have made to its total light output, although the 50 million peak lumens of the lamp are still almost infinitesimal compared to the sun's 30 octillion—30 billion, billion, billion lumens. Lesser, but still sizable, outputs include a photoflash lamp at over five million peak lumens, and a sustained carbon-arc searchlight at about half a million lumens. A new experimental short-arc mercury-vapor lamp, described in this issue, has a brightness about one third that of the sun and a lumen output of about half a million.

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Although a lamp that could duplicate the sun's lumen output even momentarily is difficult to conceive, the firefly's efficient production of light might well be within the realm of possibility. But it will not be a refinement of present methods of light production. Incandescent lamps, limited by the melting point of tungsten, cannot reach 50 lumens per watt. And there seems no prospect of a better filament material. Mercury or other discharge lamps have a theoretical maximum efficiency for white light of only about 200 lumens per watt, but to reach this value no energy must be wasted.

Obviously, any great increase in efficiency must be found in new sources of light based on principles other than incandescence or mercury discharge with present phosphors. What these principles may be is a problem that only the future will tell. One thing is certain—the lighting engineer is faced with a huge challenge if he is to match the firefly. According to one source the firefly is about 96 percent efficient in energy conversion to light; the incandescent lamp, on the other hand, is only about 5 to 10 percent efficient in converting electrical energy to visible light. On the basis of overall efficiency, from sun to fossil fuel, to boiler, to generator, to transmission line, to lamp, the energy converted to light in the incandescent lamp is a small fraction of one percent of the original input.

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While lighting engineers may look with respect on the accomplishments of the firefly and the sun, their efforts stand up well in comparison. For though they are sometimes surpassed in individual characteristics by nature, modern lighting is not a matter of achieving one characteristic, such as efficiency, at the expense of all others. Rather, the lighting engineer's task is to achieve a balance of all characteristics in a single light source, a far more difficult problem. For while one factor, such as brightness, may outweigh some others for specific applications, such as motion-picture lighting, it is never all-important. For modern lighting, the efficiency, color, brightness, lumen output, life, and all other lamp features must be carefully weighed in respect to the intended application, and each given its proper value.

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## On the Side

Our artist, Dick Marsh, literally left no stone unturned in doing our current cover on vertical transportation. Deciding that the best way to get a marble-like background effect was to use the real thing, Dick visited a stone-cutting establishment, selected a three-foot-square slab of marble and had it photographed. With the addition of a little color to the print, the result on the cover was obtained. An equal difficulty was the fact that a suitable "crowd" picture was nowhere to be found; the net result was that almost our entire publication staff got into the act—albeit with their backs to the camera.

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Two waterwheel generators, to be built for the TVA's Pickwick Landing Dam, will add 72 000 kw to the network and will bring the total number of machines at this site to six. The new additions, scheduled for completion in 1951, will raise the combined output to 216 000 kw at this location. Each generator will measure 44 feet in diameter and 16 feet in overall height.

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Dredges normally lead a somewhat prosaic life. However, to the Army dredge *Comber* last month came a fleeting glimpse of fame when she was called on to help free the battleship *Missouri* from the mud.

The *Comber* is a 3000-cubic-yard seagoing dredge, all of whose electrical equipment was supplied by Westinghouse.

The contents of the *Westinghouse* ENGINEER are analyzed and indexed in the INDUSTRIAL ARTS INDEX.

## In This Issue

*Editor*
CHARLES A. SCARLOTT

*Editorial Advisers*
R. C. BERGVALL
T. FORT

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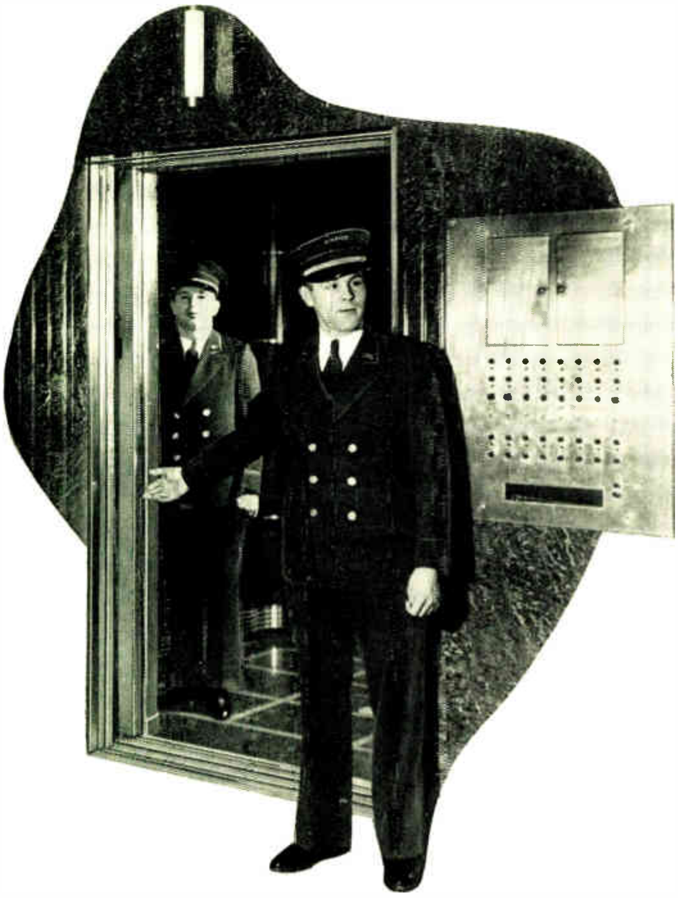
# VERTICAL TRANSPORTATION



**Ask the average person to name the major transportation systems and the chances are that he would omit one of the largest. Vertical transportation, which includes both elevators and electric stairways, is not an eye-catching or outwardly glamorous method of travel. Therefore, few people are aware of its tremendous size, or of the backstage functions that make its operation so convenient. Much hard work and brilliant engineering have gone into the development of what is now one of our most used—but often overlooked—transportation systems.**

IMAGINE a transportation system whose maximum linear speed is slow compared to that of modern horizontal transportation systems—less than 20 mph—yet whose timing is so exact and precise that few potential passengers ever have to wait more than 30 or 40 seconds. A system whose passengers seldom ride more than a few hundred feet, and sometimes as little as a dozen. Whose accident rate is a fantastically low figure, and whose operation is so efficient, smooth, and quiet that its important role in our modern world is thoroughly taken for granted. The basic principle of this system was utilized over 20 centuries ago, yet never applied on a wide scale until the end of the 19th century. Such is one of the most unique and contradictory of all modern transportation systems—vertical transportation.

Still other factors combine to make elevators and electric stairways stand out among the many mass-transportation schemes. Its "vehicles" are privately owned and operated—yet not one penny of fare is collected. Perhaps most important among the numerous distinctions of vertical transportation is the effect it has had in shaping architecture in the United States. In the days when city lots were relatively cheap and time was not of the essence, there was no need for tall buildings. Expansion, when necessary, was horizontal rather than vertical. But the situation changed as the country grew. Lots gradually rose in price; expanding industries and offices needed compactness for efficiency and easy operation. If it was impractical to expand along the ground there was but one direction left—up—and the monumental era of American architecture was born. From this period on, elevator engineers were under constant pressure to keep pace with demands as buildings rose to ever greater heights. The demand was more than met, as engineers designed and built new drive systems, new methods of control, and new safety devices to keep ahead of ever-increasing requirements.

### Early "Elevator" Devices

Loosely speaking, elevators were born when man first devised the simple hoist, the capstan, and the winch. In this respect elevator history dates back at least to 236 B.C. when Archimedes invented a hoisting device operated by manpower, in which power applied to a capstan revolved a drum on which hoisting ropes were wound. Records show that other pioneers built similar "elevators" for the palaces of Nero, Caesar, and Napoleon.

Some of these early hoisting devices showed an insight into elevator problems far beyond their times. For example, a Parisian named Velayer invented a "flying chair," which was mounted on guide rails in a hatch, and raised and lowered by manual power applied to a capstan overhead. This novel device, though later banned because of its dangerous propensities, introduced two features that are still used on the most modern elevators—guide rails, to hold the elevator in place laterally as it rises and falls, and counterbalancing, which compensates for the weight of the car plus part of the load.

Despite these and other experiments with vertical transportation, early elevators were not much of a success. People mistrusted anything designed to get them off the ground, and as yet the real necessity for elevators in the form of high buildings had not been created. Vertical transportation was still in the luxury, not the necessity class.

In the first three fourths of the 19th century the various elevator and hoisting schemes had been considered as interesting novelties but of no practical moment, at least on a wide-scale basis. None was considered suitable for exploitation and development. The picture changed rapidly when the hydraulic elevator was introduced in 1878. Here for the first time was a device that was at least satisfactory in most respects. It was safe, dependable, and smooth in operation. It had inherent characteristics that limit its use today—relatively slow speed, large space requirements, and difficulty in making automatic landings—but in the world of the late 80's these were of little consequence.

With the plunger type of hydraulic elevator, a foot of shaft height for every foot of piston length was required; this had to be sunk vertically beneath the building. In lower buildings this was not a serious difficulty to overcome, but it became an increasing handicap as building heights soared. However, for several decades, the hydraulic elevator ruled unchallenged as the most practical, economic, and safe elevator system. Many passenger hydraulic systems are still in

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Written by Richard W. Dodge, Assistant Editor of the Westinghouse ENGINEER, based on information furnished by the engineering and sales staffs of the Westinghouse Elevator Division and by H. D. James, now engaged in private consulting practice, but who was associated with many early elevator developments.

operation today, but their days are definitely numbered, and they are gradually being replaced by the electric elevator, which far predominates in use.

### The First Electric Elevators

The advent of the d-c electric motor for elevator service in 1884 caused no major stir among either elevator men or the public. In these early electric elevators, power was supplied by a d-c motor, with rheostatic control. Elevator ropes were wound on drums powered by the motor through gearing. A second rope wound on the same drum was attached to a counterweight. When the elevator rope wound up on the drum, the counterweight rope was unwound at the same speed, thus providing partial counterbalancing of the car. As is the case today, the weight of the counterbalance was figured as a percentage (usually about 40 percent) of the full-load capacity of the car, plus the total weight of the car.

The first electric elevators were rough in operation because of the relatively few notches or steps on the rheostat control, and not too dependable; thus they inspired little confidence in passengers. To elevator men of that day the hydraulic elevator seemed the ultimate in smooth, safe operation and minimum maintenance. The electric elevator seemed to have little future unless its problems could be solved.

Because of rheostatic control, stopping and starting were not smooth, especially as compared to the incumbent hydraulic elevator. In tall buildings the drum became long and cumbersome because of the lengthy cables, and made this system unsuitable for extensive use. Common practice was to use the drum-type electric elevator during the first decade of this century only for low buildings; it was seldom applied on rises of more than 150 feet. Contrast this with the exact reverse situation today, where hydraulic elevators are used only on special applications, such as sidewalk lifts.

The motor-driven elevator normally employed dynamic braking for slow-down, but also had a mechanical brake to hold the elevator at the floor. A handrope running through the car gave the operator control of the rheostat. On "high-speed" cars, magnetic contactors were used instead of the rheostat. The drum-type drive had a top speed at this time of about 350 feet per minute.

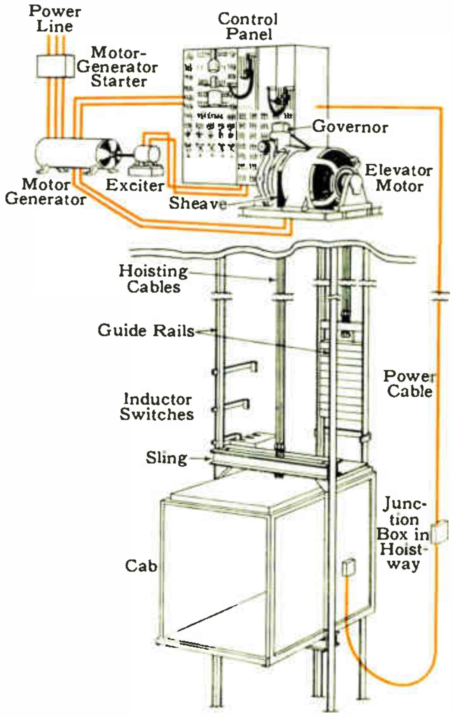
### Traction Drive and Variable-Voltage Control

Elevator engineers had reached what seemed to be an impasse by 1900—both hydraulic and electric elevators were limited in practical height, albeit for different reasons.

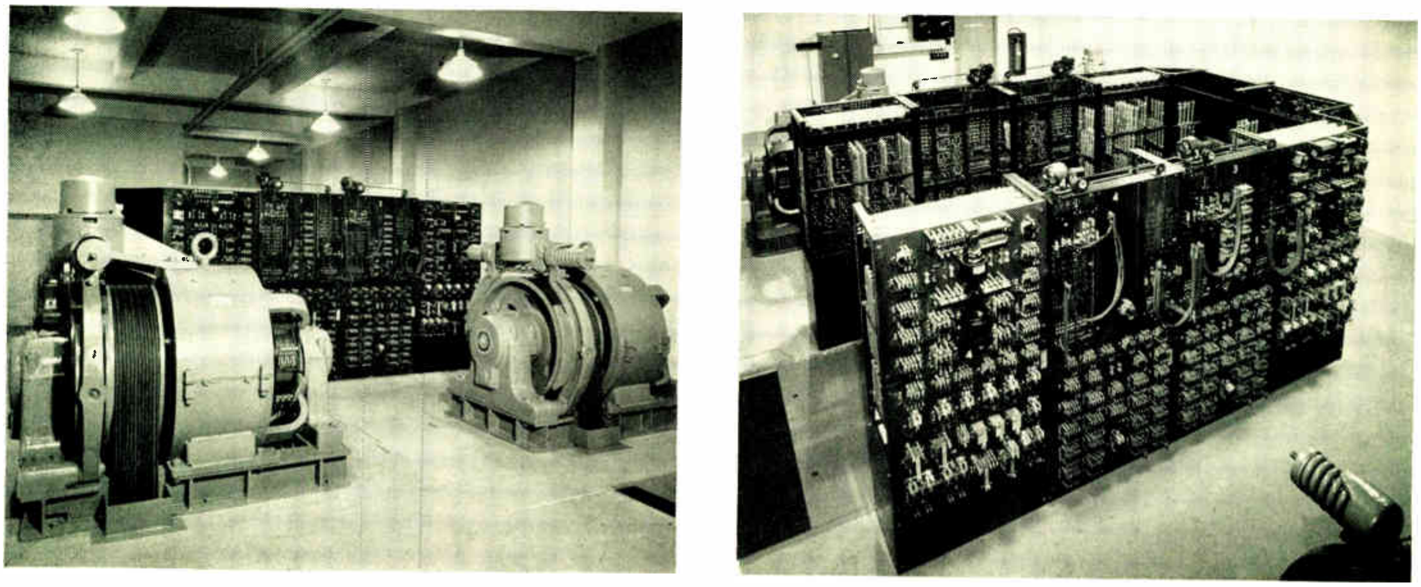
Then in 1905 the gearless traction motor was introduced and vertical transportation was off to new heights. This system consisted of a low-speed d-c motor with a traction sheave, or grooved drum, mounted directly on the motor armature shaft. The cable passed from the elevator cab up to the sheave, which had grooves for the cable, made one or more turns around it, and thence over another sheave and down the shaft to the counterweight. Traction between sheave and cable moved the cab and counterweight.

This traction-type drive eliminated the cumbersome drum on which cables had previously been wound. Instead, all that was required was a much smaller sheave, which did not change in size regardless of the length of cable. Elevator shafts could now be built as high as required. Smoother and more precise control became the major problem.

During this period, Westinghouse, which had been designing and manufacturing motors and controls for electric elevators since before the turn of the century, started full-scale manufacture and installation of complete elevators. In the three decades that the electric elevator had been in use, Westinghouse had introduced many refinements to the rheostatic control, one of which was a reactor (1916) that smoothed out the current peaks caused by switching from one rheostat position to another. This was a substantial contribution to smoother operation.



**A greatly simplified schematic diagram of a variable-voltage traction-type elevator unit. Electrical wiring is in color.**



**Below, left, two of the gearless, traction-type elevator motors in the Prudential Building in San Francisco. Below, controller, selector, relay, and signal panels.**

By about 1920 the electric traction elevator with rheostatic control had—despite its limitations—pulled about even with other types of elevators in service at that time. It was already asserting its inherent advantages for high-speed applications. But elevator engineers, realizing that they had a long way to go before achieving a really good drive, began a search for other methods of control. After considerable experimental work, Westinghouse engineers brought out the now universally used variable-voltage control in 1922, and applied it for the first time in the Chicago Athletic Club. Because here the speed was adjusted by varying the motor's armature voltage (by controlling the generator shunt field) instead of by changing resistance in series with the motor armature, the speed changes were more smoothly made.

Fundamentally there was nothing startling about the principle of variable-voltage control. It had been tried with moderate success in various applications near the turn of the century. For example, Westinghouse installed two of the first variable-voltage controls on mine hoists in Mexico in about 1906. The first practical use of this new elevator system installed in Chicago was an immediate success; before the initial installation was completely tested, orders began to pour in. Its advantage over the previous control systems was immediately obvious.

The hoisting motor of the variable-voltage system is a direct-current machine, supplied by an individual motor-generator set. Speed and direction of travel of the car are controlled by varying the generator field current. Former armature circuit losses are eliminated, and speed, particularly during landing, can be accurately controlled. This system enables the most accurate stops, the most rapid and smooth acceleration and retardation, and power consumption and maintenance are at a minimum. Variable-voltage control with traction drive is the basis for most elevators today, and has served to release high-speed elevators from the limitations imposed by rheostatic control.

Variable-voltage car-switch control improved landing at each floor, but, because of the human element, cars continued to overshoot the floors and much time was lost in releveling. Building heights were not definitely on the increase; building populations were thus increasing and traffic becoming more of a problem. Time consumed by each round trip was becoming more and more important. Any delay, however small which was encountered in releveling, became sizable when multiplied by the number of stops per round trip. Westinghouse engineers solved this problem neatly with the Automatic Landing Control, applied commercially for the first time in 1925 at Huntington, West Virginia. This made possible quick and precise landings and with a consistent accuracy never before achieved.

This landing system consists of magnetic inductor switches mounted on top of the car, and a series of metal plates mounted in the hatchway. As the car approaches the desired floor, under automatic control, the magnetic switch is energized. As each magnet passes its corresponding plate, it is activated. Each time a switch is activated the generator field is reduced by a small degree—through a series of relays—and the elevator is slowed down, and finally brought to a complete and accurate stop at the floor. Since there is no mechanical contact between car and control, there is little or no wear of parts, and the system is essentially noiseless.

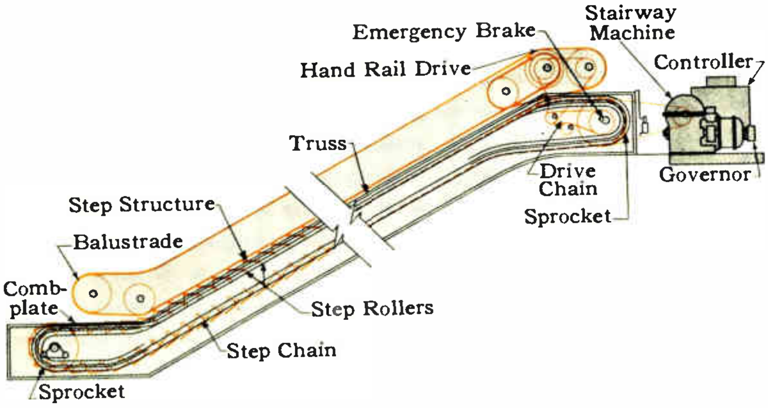
### Traffic Problems Focus

With the major problems of drive and its control well on their way to solution, elevator engineers turned to the matter of handling more traffic. With buildings rising to new heights in the 20's, higher speeds came into use. This in itself was no problem. Variable-voltage control and inductor landings made possible much higher speeds than were actually in use. But except in the express zones of elevators serving top floors, higher speed does little to relieve building traffic congestion. Most trips are short-distance affairs, limiting the advantages of rapid acceleration and fast speed.

Instead, tall buildings brought the matter of traffic control into focus. Up to this time most passenger elevator systems had operated on regular schedules—like street cars—making periodic round trips to the top of the shaft and return, carrying any available passengers in both directions. In rush hours, they were controlled by a dispatcher who tried—often in vain—to maintain a smooth flow of traffic. Plainly, what was needed was an automatic system, in which actions were instigated and controlled by a lightning-fast electrical system,

**Three modern electric stairway installations. Left to right, a lighted-balustrade stairway at Bloomingdale's in New York, a main-floor-to-basement stairway at Toffenetti's in New York, and one group of stairways in the John Hancock Building in Boston.** →

**A simplified phantom view of an electric stairway. To avoid confusion of detail, steps are shown only on the lower half of the unit.**



rather than human reaction. Furthermore, with such a faster control system, it was thoroughly possible that fewer elevators could handle the same amount of traffic.

The next important step in speeding traffic handling came in 1927, when a system was devised to reverse a car at the highest call automatically, thus eliminating unnecessary trips to the top of the shaft. This system—called the "high-call reversible collective control"—materially speeded elevator service. The following year motor-driven doors were becoming widespread in use. These developments reduced the time spent in loading and unloading passengers, and thus improved the overall efficiency of the system.

By now the tempo of progress was beginning to increase. The latest advancements in the elevator art were incorporated into one system with the installation of a completely automatic bank of three elevators in the Fischer Building in Chicago in 1929. For the first time a bank of elevators could glide operatorless up and down the shaft in response to calls on any floor.

Completely automatic systems now have a definite place among modern elevator systems. Wherever small passenger elevator systems are required, such as those in apartment buildings, these automatic elevators are more than adequate. However in larger elevator systems, where traffic is heavier, they are not generally used because of the time lost, since doors must be slowed to prevent injury and time must be allowed for passengers to push buttons.

Elevator development is full of simple but ingenious solutions to serious problems. A troublesome feature about 1930 was the buckling of elevator guide rails in high buildings as the structure "aged." This was solved permanently for the first time in the Carew Tower in Cincinnati by the simple expedient of fastening the rails to the building in such a manner that the building steel was free to settle with respect to the rails. Thus the rails were not thrown into compression and no damage resulted.

### The Rockefeller Center Installation

Proof that the elevator art had advanced to the point where it was more than capable of handling almost any problems of speed, control, or traffic was dramatically illustrated in 1931 when Westinghouse designed and built the huge elevator system for Rockefeller Center in New York. This installation was unique in many respects. In size alone it eclipsed anything previously attempted—215 cars operate daily, carrying a total of 250 000 car passengers a day.

Of really outstanding moment was the speed at which one bank of express elevators operated—1400 feet per minute. This was a tremendous jump over the standard speeds of 600 to 800 feet per minute then common. It was, in fact, so much of an increase that even today, some 17 years after its completion, this express bank remains the fastest group of passenger elevators in the world.

One control device developed for the Rockefeller Center elevator installation has since carved an important place for itself in a multitude of different and unrelated applications. This is the rotating regulator, now known as the Rototrol. It was the result of elevator engineers' attempts to make the elevator motor follow a predetermined speed pattern under all load conditions, with minimum variation due to temperature changes. The result of these effects was a slight current change and a resultant motor-speed variation. The Rototrol, essentially a small d-c generator, overcomes these variations by making up any small current deficiency in the system. The Rototrol compares speed of the motor with desired speed in terms of voltage. This comparison is made by two differentially connected fields in the Rototrol. Any resultant voltage—caused by generator or elevator-motor deficiency—promotes an output from the Rototrol to supply the current lacking. Since its initial application on elevator systems, the uses of the Rototrol have expanded manyfold. It has since been used to control voltage or speed on such things as sectional papermaking machines, tandem steel mills, electric shovels and hoists, and many other industrial applications.

### Selectomatic Control

Despite the obvious improvement accomplished with various new controls, still better traffic systems were needed if existing elevators were to be used to their fullest extent. Efforts to solve this problem led to the development in 1941 of Selectomatic Control, which is a supervisory system that operates a bank of elevators at the highest possible passenger-

**Some operators in Jordan Marsh's in Boston have private cockpits, which give them an unobstructed view of the entrance, and lead to safer and more efficient service.**

handling efficiency. The operation of this system is controlled by an automatic dispatcher, which, once set by the elevator starter (by merely pressing a button), relieves him of the function of dispatching, allowing him to devote more time to directing traffic.

During the "up-peak" period, when traffic initiates largely on one level—the ground floor—and is carried to all floors, the starter, simply by pressing the "up" button, causes all cars to travel to the highest call and, after delivering their passengers, reverse automatically and return to the ground floor for another load.

When the up traffic dwindles and the interfloor traffic increases the starter changes the method of operation by releasing the "up" button. Automatically all cars in the bank operate on a through-trip basis, with the dispatching interval varying automatically, so that cars are always maintained equally spaced in time throughout the building. Any "bunching" of elevator cars is eliminated by dispatching a car from the terminal ahead of schedule (if the arriving elevator is ahead of schedule) or reversing a late car and returning it to the opposite terminal. In this manner, cars are kept productively occupied at all times.

During the evening hours, when passengers load from various floors and unload at the ground floor, the "down-peak" method of operation is used. At this time, the elevator starter, by pressing the "down" button, causes the dispatcher to automatically divide the elevator bank into two groups—one to serve the lower floors, and one the upper floors. This eliminates a fault common to most controls—the by-passing of passengers on the lower floors because elevators have been filled at upper levels.

But Selectomatic Control has an added feature in down-peak operation. Because traffic originates at many floors, the demand does not remain evenly balanced between upper and lower levels. Instead it comes in surges. Selectomatic allows for these inconsistent patterns by permitting unused or unfilled cars in one zone to travel into the next zone to help out with momentary heavy demands. In effect, the dividing line between high and low zones is allowed to float, according to the demand pattern. In this manner, about the same number of people are brought to the ground floor from the upper part of the building as from the lower part, with the combined number of people brought from both zones in the heaviest five-minute peak of traffic representing the greatest possible percentage of the total population of the building.

### Electric Stairways

Like most vehicles the elevator does not render a perfectly continuous flow of traffic—it must load and unload, and the first passenger in must usually wait for several other passengers to board before the elevator leaves. Similarly, if his destination is, say, the fourth floor, he must often wait while passengers unload at the second and third. Normally this very slight delay is so small as to be inconsequential and unnoticed. However, in such heavy, bi-directional traffic as is found in a department store or railroad station, a continuous flow of traffic is essential to avoid congestion and facilitate the movement of peak loads of large numbers of people. The electric stairway accomplishes this with fast, continuous, comfortable transportation.

The electric stairway, developed initially just before the turn of the century, has found a valuable place in the vertical-transportation field. As well as serving as a supplement to elevator systems in many buildings, it has recently come into its own as a primary transportation system. This was demonstrated by the completion of an eight-story electric-stairway system in the new John Hancock Building in Boston. During the up- and down-peak periods all 16 stairways can be operated in one direction; one-way operation enables the system to move as many as 5000 persons down to the street floor in 15 minutes. During the day the stairways operate half in each direction, speeding the large amount of interfloor traffic in the building.

Basically the electric stairway is not a high-speed device—its standard speed is 90 feet per minute—but the fact that it is continuous leads to rapid transportation. Its application, like that of the elevator, depends to a large extent on the kind and size of traffic.

To the passenger, the primary requisites of an electric stairway system are that it get him to his destination quickly, smoothly, quietly, and safely. To the stairway engineer, satisfying these four major requirements means solving a multitude of complex engineering problems.

Speed, in itself, is no particular difficulty. Electric motors can drive stairways at far faster speeds than would be acceptable to passengers. Standard speed is currently 90 feet per minute, but 125 feet per minute speeds are in use, and are receiving more consideration. The principal problem is a human or psychological, not a technical one. It is getting people accustomed to boarding a platform moving at a higher speed. That this is true is demonstrated by the fact that in the subway systems of London, electric stairways have operated at speeds much faster than our maximum of 125 feet per minute. This maximum speed has been used in the United States; the first installation made by Westinghouse was at Rockefeller Center in 1948.

Drive for Westinghouse electric stairways consists of an a-c induction motor, whose constant speed makes for smooth and safe operation. Speed is geared down to stairway speed. For example, the 32-inch stairway utilizes a 10-hp, 900-rpm induction motor, which is geared down to the standard 90 feet per minute.

Quiet operation of electric stairways is important partially because of its psychological effect on passengers. A jumpy, noisy ride gives the impression of faulty operation, and leaves the passenger uneasy, regardless of whether or not the stairway system is actually in good condition. Westinghouse has contributed several notable efforts toward passenger peace of mind. One innovation was the canvas-covered Micarta roller, which has led to quieter overall operation. Another feature is the concave balustrade. One effect of this design has been to give the passenger more room, which is especially welcome in such places as department stores, where passengers often are laden with bundles.

Smoothness is inherent in stairways using induction motors, because of their constant-speed characteristic, but an added feature is used to eliminate the possibility of overspeed. This is a high-speed, flyball-type governor that prevents overspeed due to any cause, such as an overhauling load, by opening the stopping circuit and applying the brake.

Perhaps most important as a safety consideration are the points of entering and departing from an electric stairway. People are naturally cautious in stepping on or off any moving object. One feature that has simplified boarding the stairway is that of having the first two steps remain level, thus giving the passenger time to secure his balance.

The points at which the steps appear at the lower end, and disappear at the upper end, also represent a potential source of danger. A shoe caught between the moving step and the immobile landing platform, or comb plate, could result in serious injury. This danger is removed by a new step plate and mating comb plate. The new design, developed in the 1930's, has narrow treads, small enough so that even the tiniest heel will not turn or catch. Both step plate and comb plate are built to extremely close tolerances, so that they will mesh accurately as the step passes through the comb.

Because their speed is limited by other than mechanical or electrical problems, electric stairways are not built in a multitude of standard sizes. The passenger-carrying capacity of stairways is a function of their width, as well as their speed. There is, of course, a difference in spacing of floors in different buildings, but accounting for these is mostly a matter of adding (or deducting) a few feet to the basic stairway structure. The Westinghouse standard stairway, the type S, is built in three widths for three capacities—a two-foot width for 4000 passengers per hour, a three-foot width for 6000, and a four-foot width for 8000.

Recently a new "limited budget" stairway was introduced for use where traffic demands do not require the capacity of the larger standard stairway, and where the rise does not exceed 23 feet. This stairway is 32 inches wide and has a capacity of 5000 persons per hour. Engineering design is similar to the larger stairway, but because of the standardization in manufacturing, it is a less expensive device where traffic demands are light.

### The Freight Elevator—Work Horse of Vertical Transportation

Although the high-speed, closely coordinated electric passenger-elevator systems are far more glamorous, the hard-working, rugged electric freight elevator nearly equals it in numbers, and far outdistances it in load carried. There are roughly 80 000 electric freight elevators in use today.

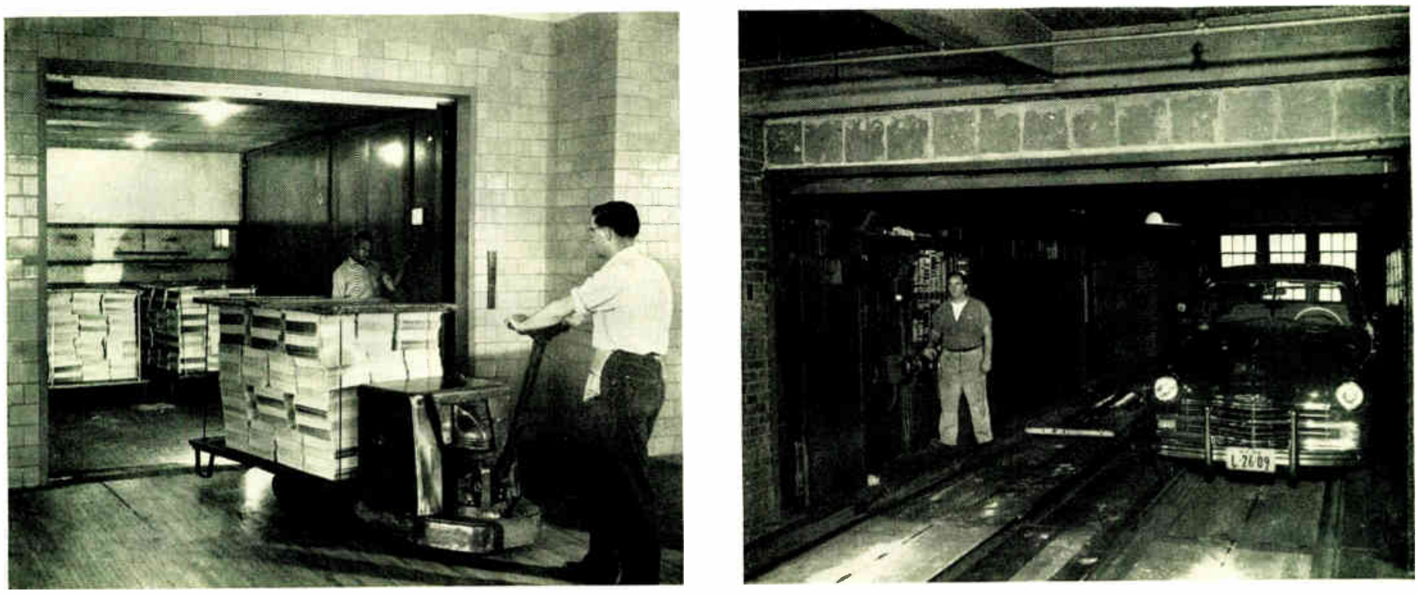
The growth of the freight elevator closely parallels that of its passenger counterpart. However, freight systems are a necessity even for most two- and three-story industrial buildings, because of the large volume of freight that must pass between floors in modern factories, stores, and warehouses.

Although the overall design of freight elevators is similar to that of the passenger elevator, there are several notable differences. Because its speed requirements are usually less than those of passenger elevators, many freight elevators are of the geared type, which proves highly satisfactory up to about 350 feet per minute. Above this speed, gearless machines are often used. All modern freight elevators are of the traction type. For control, the variable-voltage system common in passenger elevators is used for all applications where the elevators are in frequent use. This allows for the most accurate stops, most rapid acceleration and deceleration, and minimum power consumption and maintenance.

A-c motors are often used in the freight elevator, with rheostatic control. Because of the inherent characteristics of any rheostatic control, landing accuracy is not as good with a-c type equipment, necessitating some sort of releveling operation. These are of two kinds—an "inching" operation, which utilizes the main a-c motor, or an automatic releveling operation, which uses the low speed of a two-speed motor and associated control to bring about landing.

The smooth flow of traffic required in any freight-handling system adds several requirements. The elevator door opening

Below, left, a typical freight elevator being loaded . . . at right, a 450-fpm, variable-voltage garage elevator.



must be equal to (or nearly so) the width of the car, in order that maximum use be made of the car floor space.

The sudden load moved onto an elevator platform causes stretching of the elevator cables. The variable-voltage system, informed by the inductor switches, corrects for these minor variations; thus this system is far more desirable where such large weights are to be put on the elevator in one load.

Standard freight elevators are built with platform sizes up to about 12 by 14 feet, with capacities up to about 20 000 pounds. For certain applications, elevators with load capacities of 40 000 pounds and more have been built, but these are usually specially designed. All freight elevators are designed for palletized loading, thus the platform is maintained at floor level despite sudden changes in load.

Freight elevators have become as essential to industrial applications as passenger elevators are to office buildings. With modern mass-production methods, for example, the flow of materials through a plant must be smooth and uninterrupted. In modern factories the production line may extend through several floors, and, especially where heavy equipment is involved, elevators are a vital link. Their place in department stores, hospitals, and office buildings is equally important.

Although the freight elevator is usually considered the work horse of vertical transportation, it, too, has its glamorous side. A notable example is the deck-edge elevator designed for aircraft carriers. This elevator, now used on many modern carriers, enables the ship to carry on most of her normal operations even in the event of damage to the elevator. Previous elevators had been placed smack in the middle of the flight deck; thus while the elevator was at hangar-deck level, there was a gaping hole left in the middle of the flight deck. The deck-edge elevator, hung from one side of the deck, consists of a 73-ton platform capable of lifting 30 000 pounds—all supported on only one side. It operates despite the roll of the ship or the terrific beatings inflicted by stormy seas. And as an added feature the whole structure is collapsible against the side of the ship.

**Future Prospects**

In the few decades of its existence, vertical transportation has undergone significant transitions. It has changed almost completely from hydraulic to electric operation. From almost schedule-less operation to the precise, closely controlled traffic pattern of the Selectomatic. From an inherently inaccurate and rougher rheostatic control to the smooth, accurate landing of the variable-voltage system. Systems have grown in height from two or three stories to the 40, 50, and more, common today. In passenger traffic and in physical size they have reached the point where some 200 000 elevators throughout the country handle more than 25 billion passengers each year, plus vast amounts of freight.

Perhaps of most significance to the future of vertical transportation is the fact that it has grown from the status of a luxury and convenience to that of a necessity. It is now firmly rooted as a part of our everyday modern existence. Without it the whole pattern of our lives would be changed, regardless of whether we actually ride on an elevator daily or not. Without freight elevators, some industries would grind to a halt, and many others would be seriously handicapped.

As with any device, the elevator has practical limitations. For example, although the phenomenally low waiting time of passengers in modern passenger-elevator systems—some 20 or 30 seconds—could always be cut by adding more elevators, a point is reached where returns diminish. For a given-sized building more elevators mean less building space available for occupants, and thus fewer occupants. At some point along this pattern, a number of elevators is reached that can best serve the building population.

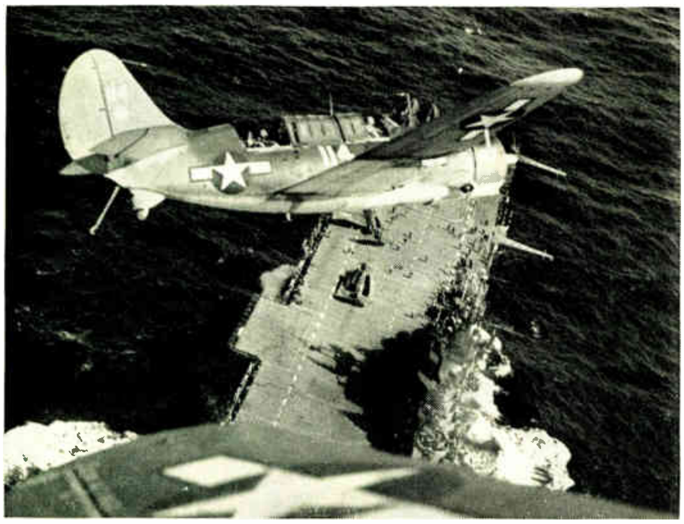
Elevator engineers think the best method of improving present vertical transportation lies in transporting more people with the same basic equipment—utilizing better controls as fast as they can be developed. This would enable the same number of elevators to handle more persons in a shorter time. That this can be done in the future is entirely possible. Witness the tremendous jump in the efficiency of elevator banks when the Selectomatic was introduced.

Much of the emphasis in future elevator developments is likely to be on control. Better and less complicated controls for operation and landings, to promote smoother operation, less lost time, and more accurate floor landings seem likely. And it is entirely possible that the already silent operation of elevators and stairways can be made even more quiet.

As to the speed of elevator systems, any large increases seem unnecessary, at least in the near future. Speed is of the most value in extremely tall buildings; in lower buildings there is insufficient distance for an elevator to accelerate to high speeds at a rate that is comfortable to the passenger. The trend to the monumental-type building of over 50 stories seems at least temporarily over, and unless this trend reverses it is likely that speed increases will be in small jumps, made possible by smoother control of acceleration and retardation. However it is equally possible that no changes in speed will result in the near future. Among other things, the effect of sudden changes in altitude on passengers may limit any further increases in speed. These are facts that will be decided only by future developments and trends. Many variables are involved, and the advantage to be gained is debatable.

The electric elevator is definitely established as the basic system. Its advantages over the hydraulic elevator are so marked that it seems impossible that the trend to the electric elevator should change. One fact makes the future of the electric elevator even more bright. It has grown up side by side with the electrical industry itself, contributing its share to other applications, such as the Rototrol, and drawing from these other uses such methods as are adaptable. As yet the application of the phenomenon of electricity is in its infancy—much has yet to be learned about even its basic concepts. Thus as knowledge of electricity and its applications grows, vertical transportation will likely grow concurrently.

A birds-eye view of the deck-edge elevator.



**Lighting sources continue to get brighter and brighter. Nearly ready for commercial application is a new 10-kw short-arc mercury lamp, which may become a valuable asset in motion-picture studios, searchlights, and similar uses. Its arc length of only 10 millimeters produces a brightness about a third that of the sun. An added feature is a new starting circuit for the short-arc lamp.**

George A. Freeman
*Vapor Lamp Engineering*
*Westinghouse Electric Corporation*
*Bloomfield, New Jersey*

# The Short-Arc Mercury Lamp

When the electrodes of a mercury lamp are brought closer and closer together with the power input maintained, the arc gets brighter and brighter up to the point at which the electrodes touch. Short-arc mercury lamps have now been made in which the electrode spacing has been reduced to less than half an inch and the power input increased up to 10 kilowatts to obtain a new high-brightness, concentrated light source having a real punch in total light output.

In 1936 when fused quartz glass was first applied commercially in high-pressure mercury lamps, in the form of the 85-watt AH3, a desire was kindled for a really high-brightness mercury source. Short-arc lamps were made experimentally at that time although limited by the then available techniques to low power of a few hundred watts. Techniques in making quartz mercury lamps were continually improved during the subsequent decade, as the familiar high-intensity mercury lamps in sizes of 100 to 1000 watts were developed and applied to flood, industrial, and street lighting. These lamps, however, were not considered short-arc lamps, since they had arc lengths between one and five inches. The term "short arc" was coined to apply to high-pressure mercury lamps with arc lengths usually less than a half inch.

In 1947 Westinghouse began the development of a 10-kw, short-arc mercury lamp, the major design problems of which have now been solved. There were four main design problems, namely: bulb, seals, electrodes, and operating circuit.

*Quartz Bulb*—Fused silica was a natural for envelopes as it is the only transparent material thus far tested able to withstand temperatures exceeding 1000 degrees C with the high mechanical strength to contain mercury pressure up to 150 pounds per square inch (10 times atmospheric pressure). The bulb loading is usually 25 to 35 watts per square centimeter of bulb surface. This represents a compromise between deterioration of quartz when the loading is too high, and excessive warming-up time after lamp starting if the loading is too low. This loading is two to three times that used for general-purpose quartz mercury lamps where several thousand hours' life is required. Forced-air cooling permits higher bulb loading but the cooling is often uneven, resulting in bulb strains and failures. Free-air cooling gives more dependable performance.

The bulb for the 10-kilowatt lamp has a spherical shape, four inches in diameter with a heavy $\frac{3}{16}$-inch thick wall. At present, bulbs are hand-made, requiring considerable skill.

*Seal*—The need for providing lead-in conductors capable of carrying currents of 100 amperes or more into the quartz bulb imposed a major problem. The coefficient of thermal expansion of quartz is very low, only a tenth that of tungsten or molybdenum metal used as conductors. A special design is required that will not cause excessive strain when such different materials are hermetically sealed to each other.

The seal used in earlier development work consisted of thin molybdenum ribbons sealed into the annular space between two concentric quartz tubes. The ribbons were only a half-thousandth inch thick in order to set up the least possible strain in the surrounding quartz. Ten ribbons, each three-eighths inch wide, were spaced in the quartz and connected in parallel so that they shared the total current.

Molybdenum ribbon seals are dependable because the only two refractory materials used, quartz and molybdenum, do not deteriorate in time from temperature or electrolysis effects as do softer bead glasses. For short-arc lamps, however, multiple-ribbon seals become increasingly complex and difficult to make as the current-carrying capacity is raised.

The short-arc lamps illustrated on this page employ molybdenum conductors $\frac{1}{4}$ inch in diameter, which extend the current capacity to 300 or 400 amperes. The new design is much more easily adapted to quantity production and can be made larger for still higher current if desired.

*Electrodes*—Concentration of high wattage in a small arc results in a very high temperature at the electrode tips. Tungsten is used because it is the most refractory metal available. However, its melting point of 3370 degrees C is easily exceeded in attempting to obtain maximum arc brightness. This fact puts a ceiling on brightness until a more refractory electrode material is developed.

The merit of a tungsten electrode is determined by its ability to conduct heat away from the electrode tip. Operation of

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This article is a digest of a paper entitled "Short-Arc Mercury Lamps" presented before the Illumination Engineers Society at the National Technical Conference on September 20, 1949.

an electrode at its melting point results in rapid blackening of the quartz envelope from tungsten evaporated from the electrode tips. A compromise either in lower wattage or longer arc length is made in a practical lamp.

Short-arc mercury lamps can be adapted for a-c or d-c operation. Lamps for both types of power have been made. The 10-kilowatt, short-arc d-c lamp has a relatively small cathode and a large anode. At the cathode, the emission of electrons has a cooling effect, making a large mass unnecessary for dissipating heat. The reverse is true at the anode where electron bombardment has a heating effect so that the anode must dissipate about 30 percent of the power input to the lamp as heat. The electrode heat problem in the d-c lamp is eliminated at one of the two electrodes but it is multiplied by a factor of two in the other.

*Characteristics of a Short-Arc Lamp*—The relationship between brightness and arc length, obtained from short-arc lamps operated between five and ten kilowatts on alternating current, is given in Fig. 1. The practical brightness limit at present, considering the rapid bulb blackening should electrodes become melted, is about 500 candles per square millimeter of bulb surface or about one-third the brightness of the sun. At this level the lamp has 50 or more hours useful life.

The color of the light output is similar to other high-pressure mercury lamps, with the usual strong mercury line spectrum and a background of continuous spectrum producing a bluish-white appearance. Cadmium and zinc metals have been added to the mercury content to increase the red output, since both have spectral lines in the red region. Cadmium-mercury lamps with 10 percent of their luminous output in the red region have been tested and found suitable for such uses as motion-picture studio lighting for color photography.

The lamp is operated from a 100- to 120-volt a-c source using a series-connected resistor, or resistor plus reactance ballast. When the lamp is warmed up the arc voltage is between 60 and 75. However, when the mercury arc first starts, the arc voltage is low, usually 10 or 15 volts. If the operating ballast is used for starting, the starting current may be nearly double the operating current. This is desirable since it shortens the warming-up time to five minutes or less. However, the power source and ballast must be capable of supplying the higher starting current. Otherwise, an adjustable ballast can be used if a longer warming-up time is not objectionable.

*Starting Circuit*—During the development of these mercury lamps, circuit difficulties of a special nature arose. The ability to start and restart a hot lamp quickly was considered necessary wherever short-arc mercury lamps might be used. As is well known, a high-pressure mercury lamp will not restart on the usual ballast transformer circuit while it is still hot from previous operation. Various means have been proposed in which high voltage is applied momentarily, but in each case they required a complicated circuit with several relays or other moving parts.

A newly developed circuit (Fig. 2) will start or restart short-arc lamps automatically without relays or other parts that need frequent attention. The circuit consists of a spark-gap oscillator and a pulse transformer to apply a succession of high-frequency pulses to the lamp. The pulse voltage is about 50 kilovolts, which is enough to ionize mercury at high pressure. There is sufficient momentary power to provide the necessary conditions for the arc to start instantly.

The short-arc mercury lamp, characterized by high brightness, is nearly ready for commercial application. In the near future it may become a familiar and valuable asset in the motion-picture studio, in theater spot projection, in searchlights, and similar uses where its full benefits can be realized.

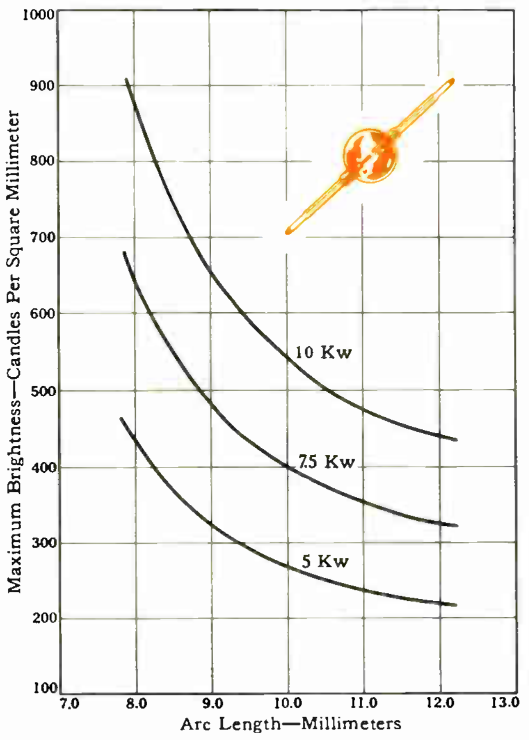


**Fig. 1—Relationship between brightness and arc length of short-arc lamps operated at 5, 7.5, and 10 kw.**

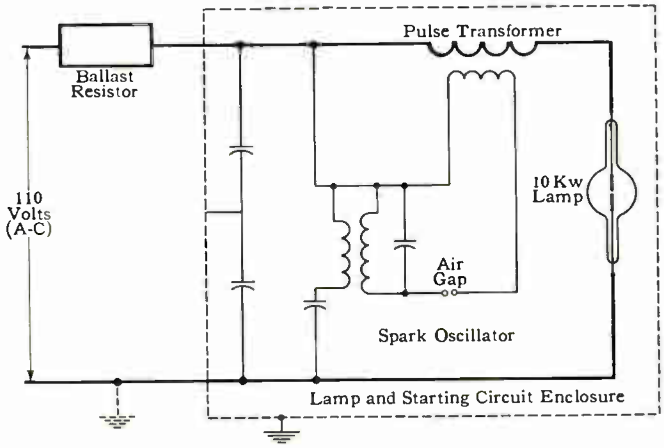
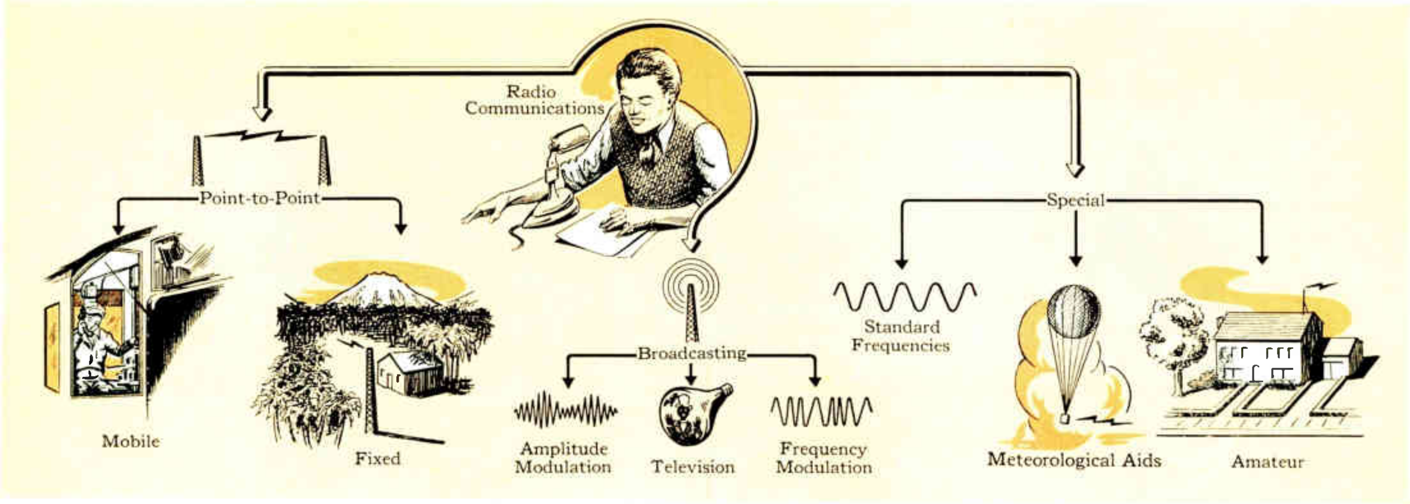


**Fig. 2—The new starting circuit for the 10-kw short-arc lamp. Spark-gap oscillator and pulse transformer apply a succession of pulses to the lamp. Voltage is about 50 kv.**

TABLE I—CHARACTERISTICS OF EXPERIMENTAL 10-KW SHORT-ARC MERCURY LAMPS

| | |
|---|---|
| Wattage | 10 kilowatts |
| Supply | 100–200 volts (a-c) |
| Rated Average Life (hours) | 50 |
| Maximum arc brightness (initial) | 50 candles per sq. mm. |
| Lumens (initial) | 550 000 |
| Arc length (millimeters) | 10 |
| Arc width to half brightness (millimeters) | 5 |
| Bulb diameter (inches) | 4 |
| Maximum overall length (inches) | 20 |
| Arc voltage | 60–75 |
| Arc current (amperes) | 175 |
| Maximum starting current (amperes) | 300 |
| Operating position | Vertical* |

*Other positions with magnetic field or other means to prevent overheating quartz bulb.



# *Point-to-Point* Radio Communication

**In the half century since Marconi first connected a telegraph key to a radio-frequency generator much has been learned about the apparent vagaries of electromagnetic waves. Their reactions under various electrical and atmospheric conditions are now less of a mystery, and, as a result, the application of various types of industrial radio equipment — especially point to point — has moved closer to being an exact science.**

J. R. HECK, *Design Engineer, Westinghouse Electric Corporation, Lansdowne, Maryland*

BECAUSE of the wide popularity of radio broadcasting stations in the United States, the term "broadcasting" is often applied to all types of radio. But, although this form of transmission has grown amazingly in the past few years, its 2700 to 2800 transmitters are far outnumbered by those of other services. Even though seldom brought to public attention, these other services are no less important than broadcasting in our everyday life.

Probably the greatest number of radio stations that can be grouped in a single classification are "point-to-point" stations, which are distinguished from broadcasting stations by their usage, in exactly the way implied by their names. Broadcasting stations transmit a program to the greatest possible number of people, while point-to-point stations transmit to a single receiving station, or a small group of stations.

Radio broadcasting stations are required by federal law to operate always in the public interest, convenience, and necessity. They are prohibited from transmitting material of interest to a single individual, as opposed to programs of interest to the public. Many listeners not acquainted with this requirement have wondered at the consternation of the street interviewer or sports announcer when someone wants to speak to a friend listening at home.

Point-to-point stations, on the other hand, are licensed to transmit messages from one point to another, and most of their transmissions consist of messages directed to a certain individual or group. Federal laws prohibit the use of information received via radio by any person except the one to whom the information is addressed. Because "all-wave" radios are so easily available to persons not familiar with federal radio regulations, some localities have passed further legislation supplementing federal laws. For example, some prohibit car radios capable of tuning to police transmitter frequencies. In some cases this restriction was brought on by the practice of auto-wrecking or towing services using a private message, addressed from a patrol car to police headquarters, for their personal benefit.

Only a few special radio services fall outside of these two classifications. Amateur radio stations resemble point-to-point stations; the majority of the information transmitted is addressed to a particular individual, usually at another amateur station. But an amateur is licensed to transmit or experiment with radio for his personal interest. Such transmitters cannot be used for any commercial purpose. Some special services resemble broadcasting, because they transmit material that can be used by anyone. For example, the United States Bureau of Standards operates a number of stations transmitting standard time signals and standard frequencies; these signals reflect the most precise measurements of these values that are possible.

### Fundamental Principles

Transmission of information by radio is based on a relatively few laws of electrical behavior. Two parallel conductors carry radio-frequency current, with very little radiation, if equal and opposite charges are distributed along the conductors, and if the spacing is not greater than a few percent of the wavelength. With such close spacing the electric field around one wire cancels that around the other, hence no radiation. If, however, the spacing is increased the fields no longer completely cancel; if it is increased to a half wavelength, the fields from the two wires will then add rather than cancel, and

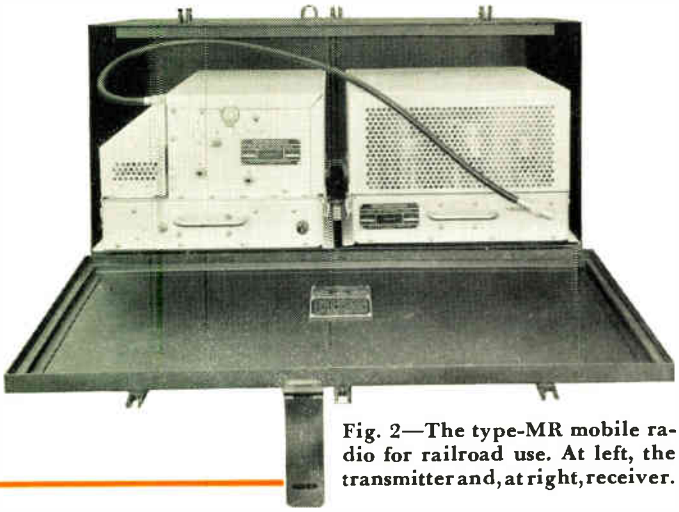


Fig. 2—The type-MR mobile radio for railroad use. At left, the transmitter and, at right, receiver.

radiate quite efficiently. It would be difficult to construct power lines so they would radiate, since a half wavelength for a frequency of 60 cycles would be approximately 1500 miles. However, with a frequency of, say, 800 kc, a half wavelength would be considerably less than an eighth of a mile.

The high-frequency alternating current produced by a transmitter can be radiated directly into space, but until some intelligence is attached to the wave no information can be transmitted. This is accomplished by modulating the generated wave, either as to frequency or amplitude.

### Communication System

A basic radio-communication system consists of a transmitter, a transmission medium, and a receiver. Broadcasting is a simple, basic system of this sort, furnishing one-way communication only.

The transmitter incorporates a radio-frequency generator, a modulator and a radiating system. The receiver consists of an antenna (the counterpart of the transmitter radiating system), a device to discriminate between signals of different radio frequencies, and a demodulator. The demodulator converts the variations of the received signal into the same form as the original modulating intelligence.

These basic parts are used in every communication system, regardless of the service performed, or the frequency used. For example, the antenna for a broadcasting transmitter, using a frequency of 550 to 1500 kilocycles, is often a vertical tower several hundred feet high. The equivalent antenna for a much higher frequency mobile transmitter on a plane may be only a few inches long. A broadcast-receiver antenna may be about the same length, and be contained in the small cabinet, while, on the other hand, the receiving antenna for a transoceanic telephone or telegraph circuit may be made up of miles of wire assembled on high poles.

The exact detail of the communication system components depends on the type of service required, the nature of the intelligence to be transmitted, and on the distance and direction, or directions, that the system must cover. The information to be transmitted can be in any form. The only requirement is that it be convertible to suitable electrical variations needed in the modulator. The frequency of the modulating signal is not restricted except that, in general, the radio-frequency signal must be a minimum of ten times greater than the modulating frequency.

The simplest form of modulation is telegraphy, in which letters of the alphabet are manually converted into the well-known dots and dashes. These dots and dashes (electrical current changes in a telegraph-key circuit) are used by the modulator to vary the amplitude or the frequency of the radio signal. The dots and dashes are interpreted by a listening operator into the original letters. In order to reduce the operating time this process is often speeded up by punching a paper tape with perforations corresponding to the dots and dashes, then running the tape through a transmitter at much higher speed. At the receiving end these characters are automatically marked on a similar tape, which is decoded at a slower rate.

Because its equipment is simple and reliable, telegraphy is widely used for point-to-point communication. In its simplest form, the radio-frequency energy is modulated by changing the amplitude of the signal. In the usual practice, a dot or a dash, called a mark interval, is indicated by a long or short interval of maximum radio-frequency energy. The spaces, or intervals between dots and dashes, are indicated by completely cutting off the signal.

As soon as automatic teletypewriters were developed for use on land telegraph wires, efforts were made to apply them to radio. These efforts did not meet with great success until the development of a modulation system that was less subject to interference, because unlike the human ear the teletypewriter itself cannot distinguish between noise signals and desired signals.

The system now used almost universally for radio teletype is called a frequency-shift system, and is a form of the well-known frequency modulation used by some broadcasting stations. In this system the amplitude of the radio-frequency energy is maintained at a constant level. A mark interval is transmitted on one frequency and a space interval on a slightly different frequency. Although the transmitter and receiver are both somewhat more complicated, the system operates through greater noise levels than amplitude modulation.

The best-known modulation is speech or telephone modulation. Since existing telephone systems operate on a varying electrical current, they can be connected directly to a modulator to vary either the amplitude or frequency of the generator. Because the capacitance of a submarine cable impedes passage of high frequencies, voice cannot be transmitted over a cable of more than moderate length. Radio is the only medium by which international telephone service can be obtained. Wherever ocean barriers, or territory inaccessible because of rough terrain or jungle, prevent construction of a telephone line, radio can be used to bridge the gap.

A type of communication little used in broadcasting, but quite important in point-to-point service, is facsimile—the art of reproducing photographs, or printed matter, at a distance. It differs from television in that the pictures are fixed at both the transmitter and receiver ends. The speed of reproduction is much too slow to reproduce moving images, but the frequencies needed for transmission are low enough that facsimile can be sent over ordinary telephone or telegraph circuits.

The picture is converted into electrical variations by an optical system that systematically traverses the original picture, measuring the amount of light reflected successively from small sections of the picture. At the receiving end of the system a reproducer synchronized with the scanner at the sending end reproduces on paper values of light comparable to those at the same section of the original picture.

News services are probably the largest user of point-to-point facsimile transmission. Radiophoto, or radio facsimiles, has made it possible for a newspaper to print news pictures from half-way around the world within a few hours of some notable occurrence.

Television requires the complete reproduction of a picture by a scanning process similar to facsimile, except that the process must be completed over thousands of full pictures in the same time that the facsimile transmitter completes a single photograph. To reproduce the scanned picture electrically requires frequencies up to 4 or 5 million cycles per second. Ordinary telephone or telegraph lines cannot be used for such high-frequency signals, so special co-axial cables have been developed over which most television networks operate. At points where co-axial lines are not available some television programs are relayed through point-to-point transmitters operating on extremely high frequencies. Television signals cannot be used to modulate radio-frequency signals less than approximately 50 million cycles per second. This makes it impossible to transmit television over distances greater than a few miles at one hop, because of the manner in which radio signals of this frequency travel.

### Antennas and Signal Propagation

The radio-frequency generator is seldom in itself a good radiator, therefore it is generally connected to an antenna system. Often it is impractical to locate the transmitter and antenna at the same point. In such cases a transmission line, which does not radiate, is used to connect the two.

The lowest frequency used for communication is approximately 20 000 cycles per second, or 20 kc. The wavelength of this signal is about nine miles and it is not difficult to construct a two-wire transmission line that has very little radiation. On the other hand, it is hard to construct a system of conductors that is separated enough in distance to give very efficient radiation into space. By using the earth as one conductor and a number of long wires supported high above the earth as the other, sufficient spacing is obtained to transmit and receive this frequency. Radio waves of this frequency travel through space with very uniform attenuation, and with enough power it is possible to transmit over great distances.

Frequencies up to about 500 kc (wavelength about ½ mile) have much the same properties. A very important point in the propagation of signals below 500 kc is that the signals are not affected by atmospheric changes and vary but little from one time to another. Thus radio services that require extreme reliability use frequencies in this low-frequency range. These include navigational radio beacons, and most point-to-point transmissions between ships and shore stations relative to safety at sea.

Radio waves at standard broadcast frequencies (550 to 1600 kc) are attenuated much more than lower frequency waves. At distances beyond a few hundred miles, daytime signals are too weak to be used regardless of how much the transmitter power is raised. At night, however, signals on the same frequency can be heard at distances of several thousand miles.

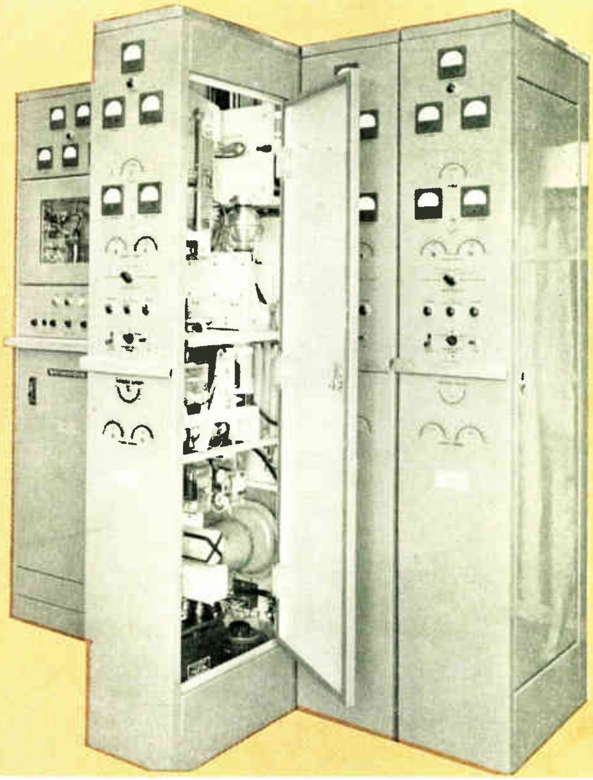
Frequencies between 1500 kc and 24 000 kc, which are used for all long-distance point-to-point communication, exhibit the same tendencies. The higher of these frequencies are attenuated along the ground in just a few miles. Outside this area is a zone—known as the skip zone—where no signal is received. Beyond this space the signal may be received again for many miles.

All long-distance radio communication depends on an important natural phenomenon, namely, that signals are reflected back to earth at some distance from the transmitter.

A number of layers surrounding the earth's stratosphere are ionized by rays from the sun. The heights of these layers vary between 50 and 150 miles above the earth, a region called the ionosphere, and the degree of ionization of each layer varies from time to time. The greatest variations occur between day and night. Changes occur with the seasons of the year, and also follow changes in ultraviolet radiation from the sun in approximately an eleven-year cycle.

When a layer is heavily ionized it sometimes absorbs most of the radio waves reaching it. At other times radio waves are reflected back to the earth, with very little attenuation even at a great distance from the transmitter. In some cases signals are again reflected from the earth, reaching a receiving point

**Fig. 3—Left, the type-FB transmitter and receiver.** ←



→ **Fig. 4—The type-MW point-to-point transmitter. The arrangement shown includes three r-f units at right (one open) and the single modulator at left.**

after two or more hops, or reflections, from the ionosphere.

Let us assume a transmitting station at New York, and a receiving station at Los Angeles. During the daytime hours any frequency between 12 and 20 megacycles may provide satisfactory service. At night possibly none of these frequencies provide a signal that can be heard. At this time frequencies between 4 and 8 mc may be the only satisfactory ones. Thus if constant communication is necessary over this channel the station must operate on a high frequency, say 20 mc at night; at a lower frequency, possibly 6.5 mc during the daytime; and at some other intermediate frequency during the time of change.

If the same transmitter were used to transmit to Brisbane, Australia, the frequencies might be 24 mc, 9 mc and an intermediate frequency. Although Los Angeles falls almost directly on a line between New York and Brisbane, it might be impossible for Los Angeles to receive the same signals, either during the daytime or at night.

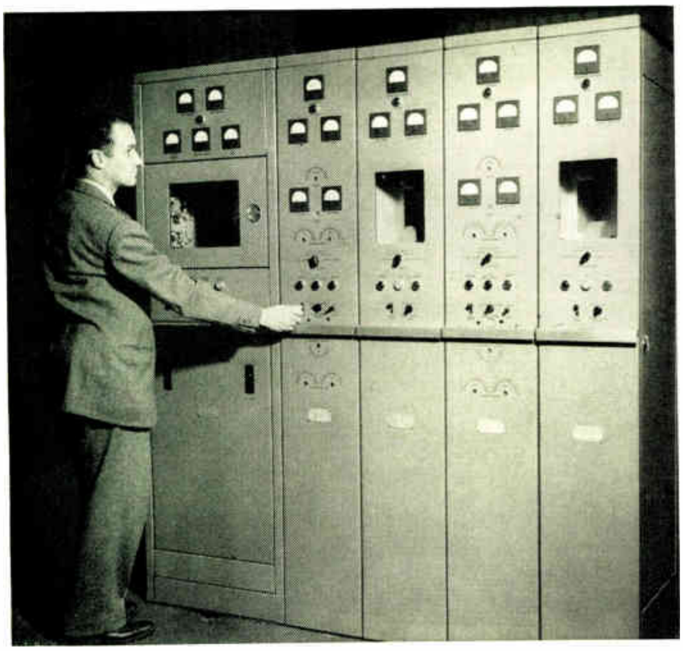
These changes in transmission are not haphazard. During the past several years enough observations have been made of such phenomena to permit the prediction of the optimum frequency for communication between any two points on the globe several weeks in advance.

However, the only way to provide continuous transmission from New York to any widely separated receiving stations is to utilize a transmitter that can operate on a number of different frequencies. Provision for this requirement is one of the major factors in the design of Westinghouse type-MW high-frequency point-to-point transmitters.

At frequencies above 40 or 50 megacycles little or no reflection occurs in the ionosphere. Thus the only signal reception occurs where transmitting and receiving antennas are within line of sight of each other. At these higher frequencies, however, antennas can be completely separated from the earth, and made to transmit or receive very efficiently in a single direction, or in a single plane. A transmitter whose energy is concentrated in a single beam only a few degrees wide can operate over the same distance as a transmitter of a hundred times the power that is radiating power in all directions from the antenna.

Since radio waves are reflected efficiently from a conductor, a metallic sheet or screen can be used to reflect signals. If an antenna is surrounded by a metal parabola the signals are concentrated into a small beam, similar to the way a light beam is focused by the reflector of a spotlight. This type of directivity is obviously impractical for any but the highest frequencies, since the entire antenna radiating system must lie near the focal point of the parabola, and only at the high frequencies can an antenna transmit efficiently and still have small physical dimensions. A useful degree of directivity can be had with reflectors that are only a relatively small section of a parabola. For many uses, a conductor or a number of conductors similar to the antenna furnish reflections of sufficiently large amount.

**Fig. 5—The type-MW transmitter with two modulators, two r-f units, and single power supply.**



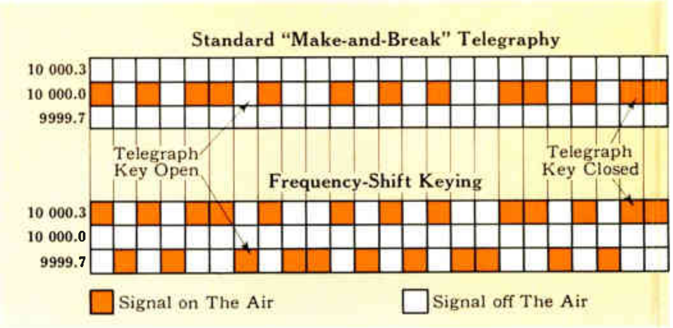


**Fig. 6—The difference between standard and frequency-shift telegraphy is shown.**

### Equipment for Point-to-Point Service

Transmitting equipment for short-distance point-to-point communication is generally of low power because it is limited to line of sight. In many cases the transmitter and receiver are operated from the same antenna to provide two-way communication. Directional antennas are used in some fixed stations. Typical is the Westinghouse type-MR heavy-duty communication equipment, shown in Fig. 2, which is designed to operate on frequencies near 150 megacycles. Such equipment can be installed on a railway locomotive and in a caboose for communication between the ends of a train, or between the train and a wayside station. Equipment for wayside stations is similar except that the transmitter and receiver units are mounted in rack cabinets since heavy shock insulation and protective cover are not required.

This equipment is designed to be phase modulated by voice or telephone signals. Quartz-crystal oscillators are used to generate stable radio-frequency energy in both the transmitter and receiver. Frequency multipliers and amplifiers provide about 25 watts from the transmitter at the output frequency. In most installations a number of receivers and transmitters are tuned to a single frequency, with all receivers adjusted to hear any transmitter and a loudspeaker signaling system connected to each receiver. Transmitters are made operative by a switch on the microphone or telephone handset. Establishing communication is a matter of simply pressing the switch and talking into the microphone.

The ultra-high-frequency equipment illustrated in Fig. 3, type-FB microwave relaying equipment*, operates at fre-

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*For a complete description of this equipment see "The Principles and Prospects of Microwave Communication," by F. S. Mabry, *Westinghouse* ENGINEER, May, 1949.

quencies of approximately 950 megacycles. In contrast to the type MR, it is not intended for mobile use, and has a highly directional radiating antenna, not readily movable. Such equipment can transmit more than a single voice message and is therefore used to communicate between two fixed locations where a considerable amount of information is conveyed.

By using the multiplexing systems common in telephone practice a number of different communication channels can be combined in one radio-frequency signal, and broken down into the original channels at the receiving station. Thus one transmitter can send as many as seven simultaneous telephone signals. Or one of the telephone channels can be replaced by a number of telegraph channels. The number of telegraph channels is determined by the keying speed required.

Since at these frequencies the transmitter antenna must be within line of sight of the receiver antenna, type-FB equipment is generally used to furnish multiple-channel communication over short distances where it is impossible or impracticable to construct or maintain reliable telephone lines.

For long-distance communication a somewhat different construction is employed in transmitters. Since a number of frequencies must be used to maintain constant communication throughout the day and night, transmitters are built so that the output frequency can be changed quickly. One of the best ways to accomplish this is to separate the radio-frequency generating system from the power supply and modulator. In this way the radio-frequency unit can be designed for highest efficiency on some particular frequency and left tuned at that point. When it becomes necessary to go to a higher or lower frequency an entirely separate frequency unit is switched into operation with the same power supply and modulator. The radio-frequency unit contains all the equipment required to generate a stable signal at the desired operating point, with amplifiers, control circuits and protective circuits.

By separating the power supply, the generator, and the modulator into separate units, a transmitter can be arranged to operate with amplitude or frequency-shift keying for manual or automatic telegraphy, for frequency-shift keying for teletypewriter operation, or for amplitude modulation for voice communication. If more than one frequency is required the modulation system need not be duplicated for each frequency or transmission channel. In most systems maintaining constant long-distance communication, two or three frequencies are required.

Typical transmitter line-ups for a communication system using the Westinghouse type-MW equipment are shown in Figs. 4 and 5. The single power supply and two radio-frequency units in Fig. 4 will establish a telegraph or teletype channel providing a day and a night frequency. Or, if desired, the two units can be operated simultaneously, providing channels to any two points for which the frequencies are suited. The transmitter in Fig. 5 includes a modulator unit that provides high-level amplitude modulation of one radio-frequency unit. This combination will provide, simultaneously, one telephone channel and two telegraph or teletype channels. Or, if desired, the combination can be used for a single telephone or telegraph channel, with either of three frequencies available for instant use.

For long-distance communication, directional antennas are commonly used, beaming the radio-frequency energy efficiently toward the intended receiving station. The radio-frequency generator need not, therefore, have as much power as is required for some other radio services. The high-frequency units illustrated have a power output of three kilowatts on any radio frequency between 2 and 24 megacycles. This is adequate for long-distance point-to-point service and yet the unit occupies a minimum of space. The type-MW low-frequency unit is similar in appearance and identical in size. This furnishes up to 4.5 kilowatts of power at frequencies between 265 and 500 kilocycles. Provision is made within a single unit for the use of two frequencies, or more, for telegraph service.

Radio-frequency units and modulators are constructed in lightweight aluminum cabinets mounted on casters. These units can be rolled out of line for servicing, as shown in Fig. 4.

The unit type of construction lends itself well to the use of communication companies, where several channels are necessary or where many different frequencies are used. In order to have sufficient space for the antenna systems required for a number of transmitters, transmitting stations are usually constructed in open country. Likewise, receiving equipment for a long-distance communication system is located in a remote area free from electrical interferences common in a city.

Telephone lines, very high frequency, or microwave multichannel links usually connect the receiver station and the transmitter station to a central communications office, where messages originate and are dispatched. This office, in a typical long-distance communication network, can choose, often automatically, the proper transmitter units at the sending station for transmission to the required destination. In a typical international communications transmitter station, a number of type-MW units are available for immediate use. Each radio-frequency unit is tuned to a different frequency. Through such transmitting equipment travels international correspondence of all kinds.

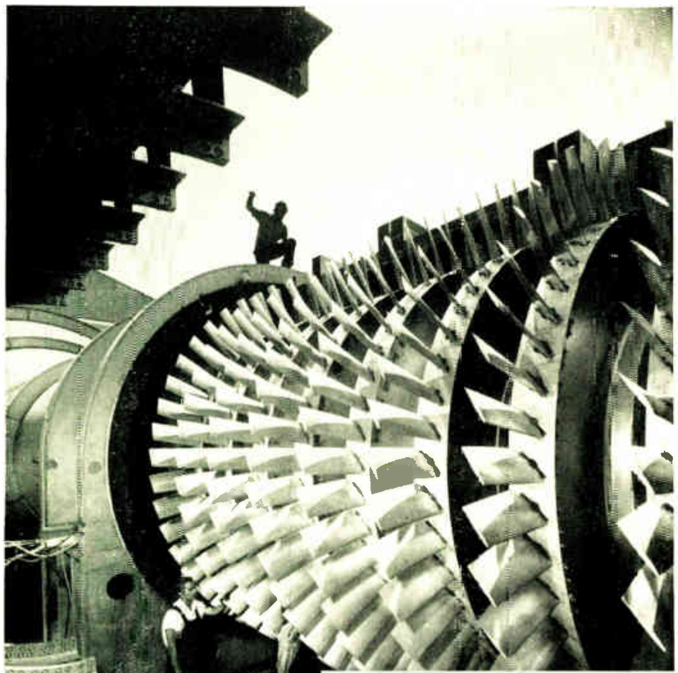
In the slightly more than 50 years since Marconi first connected a telegraph key and an antenna to a radio-frequency generator, tremendous technical developments have been achieved. Radio frequencies are now being used by thousands of different services. The constantly growing demand for radio facilities continues to spur technical advance. Methods of making more efficient use of available frequencies continue to occupy many engineers. The past few years of military development have made it possible to use frequencies higher by many times than were used before the war. The development of new techniques and new equipments for radio-frequency generation and handling will undoubtedly continue the expansion and more efficient utilization of the present radio-frequency spectrum.

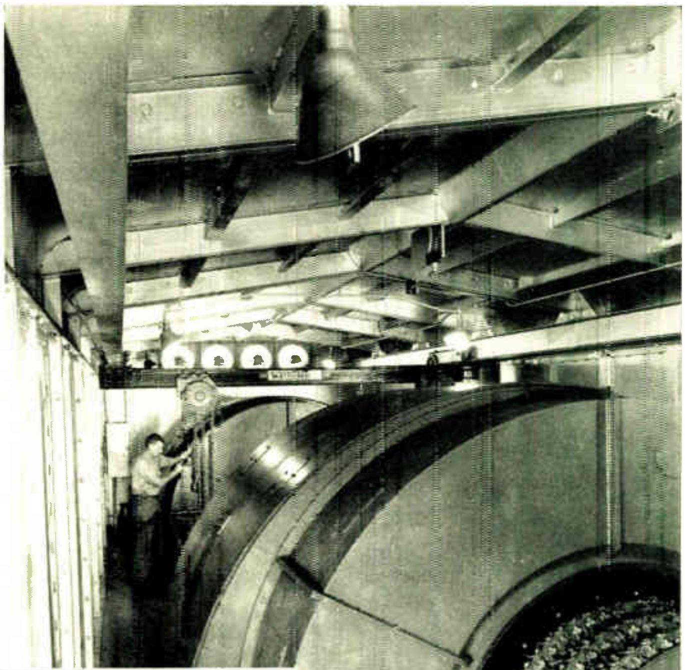
## Larderello—Utility Utopia

The closest thing to perpetual motion in the power-generation field is a fuel-less plant in Larderello, Italy, where engineers utilize a constant supply of steam from natural deposits far underground to operate steam turbines.

This integrated operation has been in existence for some time, providing electric power for much of the nearby industrial area. However, retreating Germans destroyed virtually the whole plant in 1944 and the entire structure is now being replaced. Before the war the plant produced about 900 million kwhrs yearly; so far, about 150 000 kw of installed capacity have been replaced, and more equipment is planned.

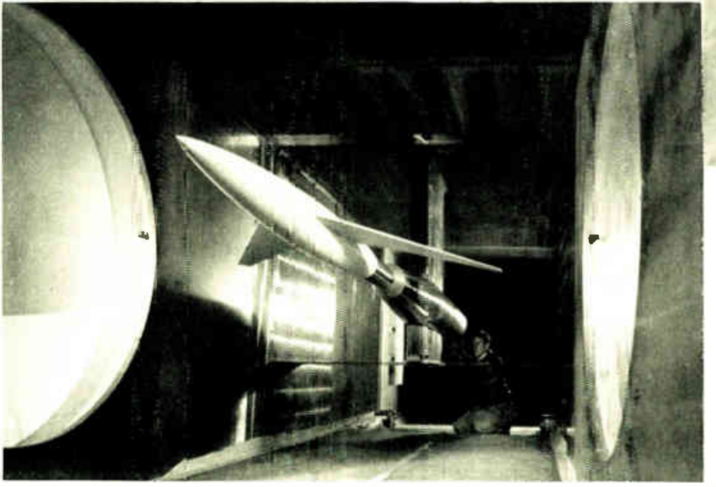
The biggest job ahead is that of drilling for new steam sources. Steam lies in beds far below the earth, and due to the pressure (up to 390 psi) and temperature (up to 400 degrees F) offers difficult problems. Two new rotary drilling machines to tap these beds will be equipped with Westinghouse motors, and will reach steam cracks 6500 feet deep, with an initial diameter of 27 inches. Similar electrical equipment for other drills will be supplied by Marelli and Company, Westinghouse licensees in Italy.





**Left above:** Workmen make final adjustments on the eight-stage Westinghouse compressor.

**Right above:** The two 25 000-hp main driving motors are coupled in tandem directly to the single eight-stage air compressor.



**Right:** A supersonic model mounted in the test section of the new wind tunnel is shown between the observation windows. The location of this test section is indicated on the artist's sketch, p. 113.

# 50 000-Hp for a *Supersonic* Wind Tunnel

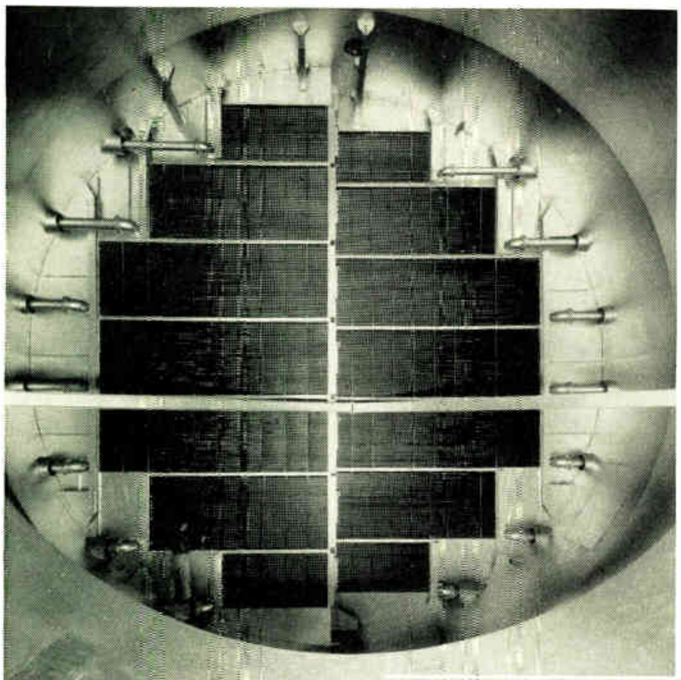
S. L. Lindbeck
*Atomic Power Division*
*Westinghouse Electric Corporation*
*Pittsburgh, Pennsylvania*

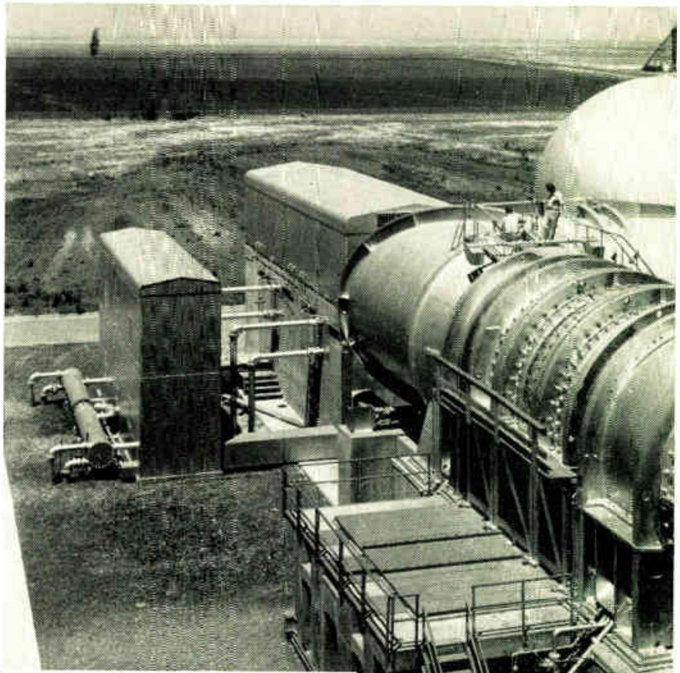
**Two factors are becoming increasingly important in proving the validity of the aircraft designer's ideas and in augmenting his theoretical knowledge. The first is a forceful imagination in devising test methods that approach or are analogous to the actual flight conditions to be encountered. The other is the sheer brute force necessary for conducting these tests. While the imaginative function can come only from the human mind, such tools as the new 50 000-hp Moffett Field wind tunnel are supplying the tremendous force necessary for testing.**

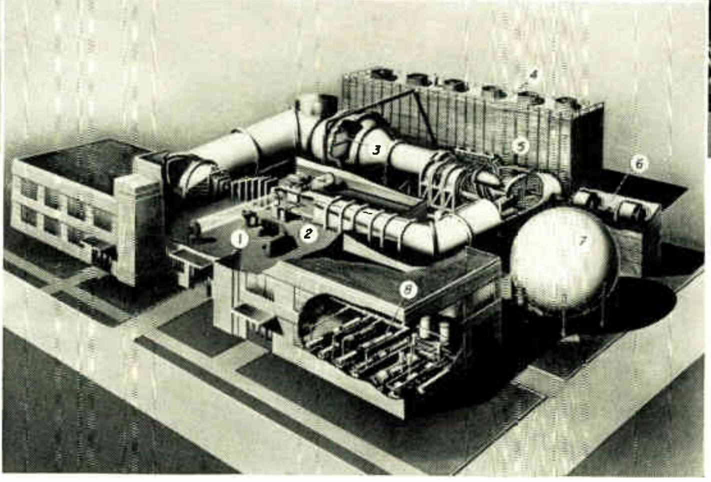
SUPERSONIC planes are requiring super-power engines and the wind tunnels for research on these planes are requiring super-power drives. The single-motor, 40 000-hp wind-tunnel drive at Wright Field has been surpassed in power by a new 50 000-hp two-motor drive. This unit powers the 6- by 6-foot closed-circuit-type supersonic tunnel of the NACA at Ames Aeronautical Laboratory, Moffett Field, California.

The main components of the drive equipment for this tunnel are the two 25 000-hp motors, which are connected in tandem and coupled directly to the axial-flow air compressor. These are wound-rotor induction motors utilizing liquid-rheostat speed control.

The drive requirements for a supersonic wind tunnel differ greatly from those of a tunnel operating below sonic speed. Air velocities for testing below the speed of sound can be attained most easily by varying the speed of the compressor or fans. However, when the critical condition of sonic speed is reached at the most narrow section of the tunnel, further increase of compressor speed does not increase the air velocity.







**Left above: This "king-sized" radiator dissipates the heat energy from the giant compressor.**

**Right above: One corner of the 6- by 6-foot wind tunnel. Motor housing is beyond tunnel elbow, rheostat enclosure at left.**

**Left: An artist's sketch of the wind tunnel showing (1) control panel, (2) test section, (3) cooling coils, (4) cooling towers, (5) compressor, (6) drive motors, (7) dry-air storage tank, (8) auxiliaries.**

It results only in the dissipation of the additional energy in a "shock wave." To obtain controlled air speed above the sonic point, the shape of the test section must be changed. When this method of speed control is used, the compressor need be run at a speed only high enough to maintain a pressure that is somewhat greater than the minimum critical pressure required for proper air-flow conditions. As the exact compressor speed required cannot be predicted before the tunnel is built and tested, it is desirable to provide a small amount of speed adjustment in the drive equipment.

The wound-rotor motor with liquid-rheostat speed control has the characteristics necessary for proper operation of the supersonic tunnel and also for coordination with the power system. As all large wind tunnels operate on systems of definite and more or less limited capacity, this is an important consideration in selection of the drive. To minimize adverse influence on the distribution network, starting current should be a minimum and the rate of load increase must not exceed the ability of the system to assume load.

When starting the drive, the liquid rheostats are set for maximum resistance and only one of the two motors is placed on the line. This holds the starting power demand to a minimum. After a short delay the second motor is energized, producing an additional load increment. With both motors on the line, the rheostat electrode spacing is decreased at a rate that results in nearly constant rate of load increase. This starting sequence, performed automatically, brings the speed of the motor to the operating range, then transfers control to the operator's manual switch. The tunnel operator can then adjust the liquid rheostat to obtain the desired speed.

As the drive motors are in tandem, the six electrode assemblies—two separate, three-phase elements—operate on a single mechanism. Each assembly consists of a vertically positioned insulating tube, which contains the electrolyte, and two electrodes; one is a fixed electrode, which is the tube bottom, and is connected to the motor secondary. The other is grounded and moves vertically within the tube to vary the effective length of the electrolyte, and thus the resistance of the secondary.

Electrolyte is pumped from the sump below into a heat exchanger, from which it flows into a header and passes down insulating pipes to the bottom of each electrode cylinder. The electrodes are perforated with a large number of holes. This permits the electrolyte to pass over the entire area of the plates, preventing the formation of local hot spots that would produce undesired steam. The electrolyte, after passing through the space between the two electrodes, flows into a manifold at the cylinder top and drains into the sump below.

An adjustable-voltage d-c drive for the electrodes obtains the wide speed range necessary to give the desired uniform rate of change of power. When the electrode spacing is a maximum, electrode speed is high; at small electrode separations the drive operates slowly. The motor-generator set for the electrode drive is located in the liquid-rheostat enclosure, which is a separate outdoor weatherproof steel housing.

The two 25 000-hp motors are mounted on a concrete structure 17 feet above ground level. A steel weatherproof enclosure similar to the rheostat housing provides protection and also supports a three-ton crane used for maintenance operations. To permit access to the rotors and stators for maintenance, the center bearings and supports can be removed and either stator shifted to the center.

An exhaust fan at the tunnel end of this housing is started automatically when the temperature within the enclosure becomes excessive. The motors are cooled by a recirculating air ventilating system. Air is taken from the space below the motor by axial-flow blowers and discharged into each end bell of the motor. After passing through the machine, the cooling air is discharged from the bottom of the frame into an air cooler and then returned to the compartment below the motor. Also, automatic temperature-control equipment is provided to energize space heaters in the motor and rheostat enclosures when the temperature drops below a given level, or if the difference between inside and outside temperatures is sufficient to cause condensation on the equipment.

A magnetic brake on the outboard end of the shaft reduces the time required to bring the drive to rest. In decelerating from full speed, the compressor load slows the drive to the given low velocity at which a speed-sensitive switch operates to apply the friction brake and bring the motors to rest. This speed-limit switch greatly decreases the total energy absorbed by the brake in stopping, thus reducing the brake size.

The turning gear located at the end of the motor shaft is used to rotate the shaft for inspection of the motor. This turning gear consists of a motor that drives a low-speed pinion through a two-stage worm-type speed reducer. A sliding idler gear accomplishes the mesh between the idler and the shaft gear when the turning gear is used. A position interlock on this moving idler prevents application of power when the turning gear is energized.

The bearings of both the motors and the compressor are equipped with individual oil-lift and oil-circulating pumps. The oil-lift pumps are operated during starting as well as when the turning gear is in use. When the motor circuit breakers close, the oil-lift pumps are de-energized.

The drive can be started and controlled either from the switchgear location or from a control desk at the tunnel operating position. Under normal operation the compressor will be started and brought up to speed under full automatic control. All auxiliary equipment is started automatically in proper sequence and checked by interlock circuits before the motor circuit breakers are closed and the drive is brought up to speed.

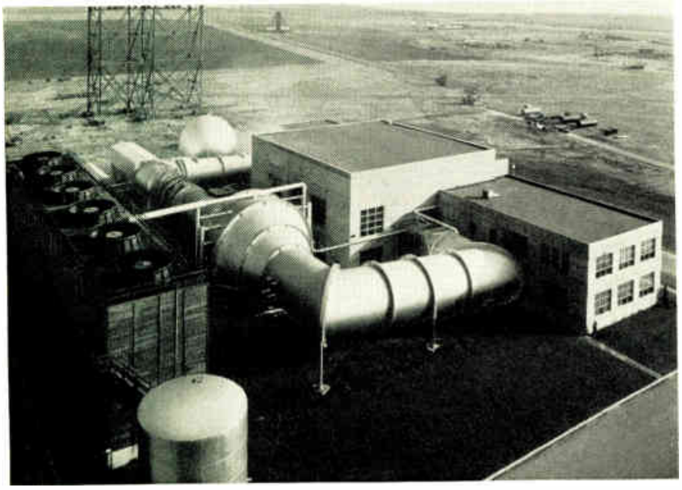
The normal automatic shutdown sequence reduces the speed of the drive so as to produce uniform rate of load decrement. When the motor has stopped, the auxiliary pumps and blowers are de-energized. Under emergency conditions the motor circuit breaker can be tripped without the usual delay for reduction of power at the normal rate.

Protective features of the drive indicate the location of trouble on an annunciator panel and initiate shutdown. The protective devices are divided into two groups: those that initiate shutdown in emergency sequence and those that shut down in normal sequence. Emergency shutdown is caused by: motor overcurrent, motor differential current, phase current unbalance, substation-transformer differential current. Also thermostatic fire detectors are provided to actuate the $CO_2$ fire-extinguisher system at the motor. Normal shutdown is initiated by: overtemperature of the motor, compressor or auxiliary equipment bearings; overtemperature of motor stator, electrolyte, cooling-tower water, or tunnel air; low oil level in compressor bearings; low rheostat electrolyte level; and undervoltage of d-c control bus.

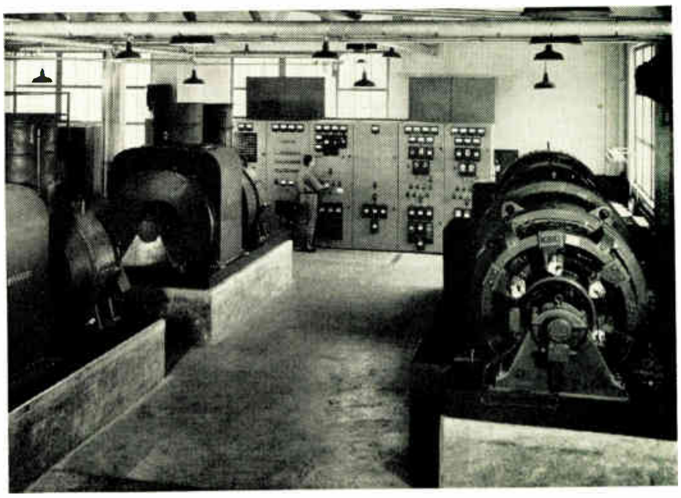
The enormous amount of energy poured into the circulating air by the giant compressor is dissipated by a large circular radiator installed in the path of the air. An evaporative water-cooling tower is provided to extract heat from the cooling water of this radiator, the electrolyte heat exchanger, and the main-motor air cooler.

The entire plant, its construction coordinated from the contract stage through design, fabrication, and erection, is compact and closely integrated for doing its assigned job. It is an excellent example of the efforts being made to improve our leadership in the air. Today, more money, more power, more energy, and more thought are being poured into the task of producing faster, better, and safer aircraft. The benefits from things learned today will be with us for many years to come.

**An overall view of the Ames Wind Tunnel, Moffett Field, California. Cooling towers are at left.**



**Control room, with 800-cycle frequency changers at left and motor-generator sets at right.**



# *Power* for Atom Smashers

L. A. KILGORE
*Assistant Manager*
*A-C Generator Engineering*

J. L. BOYER
*A-C Generator Engineering*

C. S. HAGUE
*Industrial Department*

*Westinghouse Electric Corporation*
*East Pittsburgh, Pennsylvania*

**In the days of pre-Columbus navigators, the unknown was feared and seldom delved into. Today, however, aided and abetted by the dynamic technology of our great industrial economy, scientists are probing into one of the great unknowns, the atomic nucleus. Providing the means for carrying out these researches is the task of such tools as the large systems that supply power for the latest nuclear accelerator, the proton synchrotron.**

SINCE that fateful day in August of 1945 when Hiroshima was shattered by a terrifying new force just harnessed by man, much has been written about atomic energy. Although most comment has been concerned with the impact of this development in its military light, in smaller print we have learned that the Atomic Energy Commission is sponsoring a program to expand facilities for fundamental research on the structure of atomic nuclei. Indeed, it may well be that these new research programs should be given the headlines, for we must look to them to determine how man can use this new force in a constructive manner rather than a destructive one.

In truth, nuclear research—the term the scientists prefer—is a big and continually expanding business, demanding larger and larger physical facilities and capabilities. For several years various universities and national research centers throughout the country, such as the Brookhaven National Laboratory on Long Island, the Argonne National Laboratory in Chicago, the Knolls Atomic Power Laboratory in Schenectady, the Mound Laboratory in Ohio, the Radiation Laboratory of the University of California, and the Westinghouse Research Laboratories, have been utilizing atom smashers. Their tools of nuclear research have been the Van de Graaff electrostatic generator, the linear accelerator, the cyclotron, the betatron, and the synchrotron.

### The Proton Synchrotron

Recently a new and tremendously powerful atomic accelerator—the proton synchrotron—has been designed and two of these machines are currently being constructed, one at Brookhaven National Laboratory and the other at the University of California Radiation Laboratory. The Berkeley proton synchrotron, called a "bevatron" from the abbreviation "bev" for billion electron volts, will accelerate protons (positively charged nuclear particles) from their initial injection energy level of about 10 million electron volts to an energy level as high as six billion electron volts. The Brookhaven machine, called a "cosmotron," will accelerate protons to over three billion electron volts. These are new highs in energy levels when compared with the few hundred million electron volts previously obtainable.

One function of the proton synchrotron will be to facilitate further study of mesons, the short-lived particles seen in cosmic rays. Mesons are now produced by synchro-cyclotrons at Berkeley and at Rochester, but the high-energy level of the proton synchrotron should greatly increase meson yields and thus advance knowledge of these key particles. In the billion-volt energy region one may expect nuclear reactions not obtainable in the laboratory with accelerators now operating. Also there is speculation on the possibility of producing heavy nuclear particles, such as proton pairs (positive and negative protons), which is analogous to the production of electron pairs at lower energies.

Basically the proton synchrotron is a giant doughnut-shaped iron magnet—110 feet in diameter, weighing upwards

## *The Meson*

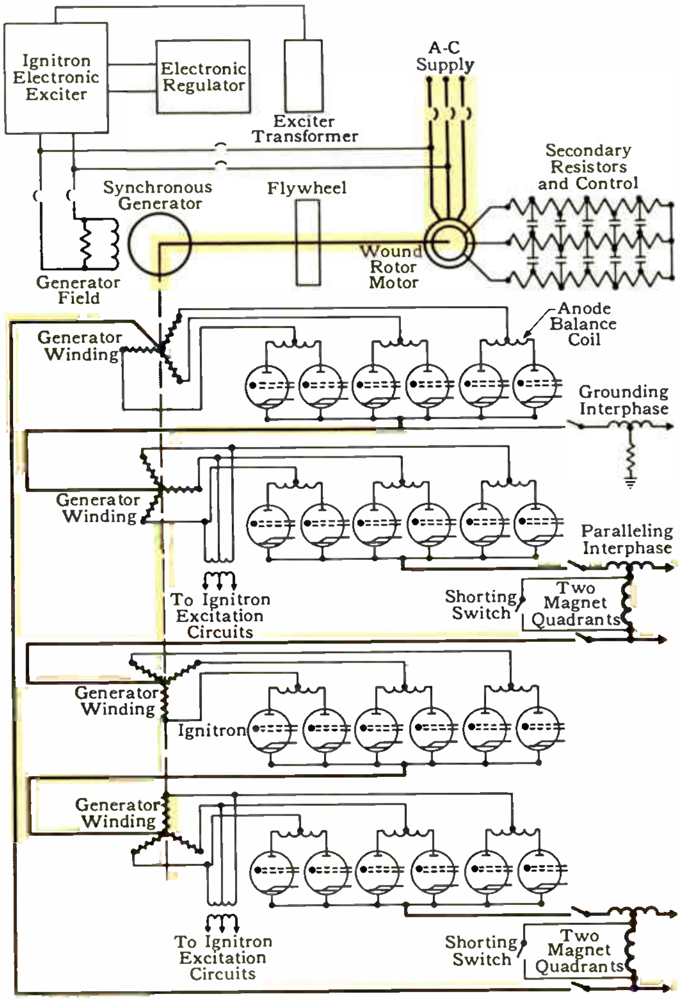
The meson is one of the lesser known atomic particles that has mystified scientists since its discovery in 1936—which mystery may be solved by use of the super-power synchrotrons. Originally observed as a part of cosmic radiation, it is now known that the mesons falling to the earth are actually secondary particles resulting from the collision of cosmic-ray protons from outer space with the atomic nuclei of elements in the atmosphere. These collisions release mesons in such a quantity that mesons comprise three-fourths of observed cosmic radiation at the earth's surface. These secondary particles, mesons, have velocities almost as great as that of the primary proton itself, and have penetrated as much as a mile into the earth's crust, having been observed at that level in mines. Artificially produced mesons were first observed at the 184-inch cyclotron of the University of California Radiation Laboratory. However, these mesons were of low velocities and did not compare with high-energy mesons of cosmic radiation.

Two types of mesons are known to exist: the pi ($\pi$) meson having a mass 276 times that of the electron and the mu ($\mu$) meson having a mass of 210, but some other mesons have been observed having a smaller mass. Also, each type meson can be positive, negative, or neutral, and the charge, whether positive or negative, is equal in magnitude to that on the electron. It has been observed that the negative mesons are readily captured by the nuclei of certain heavier substances, while the positive mesons wander through both heavy and light substances and are not so readily captured. On the other hand, very little is definitely known about the actions of either the positive or negative meson. The mean lifetime of the mu ($\mu$) meson—positive and negative—has generally been pegged at from two to four microseconds (micro=one-millionth). The pi ($\pi$) meson has been observed to live about 1/100 of this time. While mesons are thought to exist statically within the nucleus in the field between a proton and a neutron, this, along with most everything else about the meson, is bafflingly complicated. Attempts to explain the meson can be described as groping approximations and scientists therefore welcome means of producing high-energy mesons for future experimentation.

of 10 000 tons—the inside of which is an evacuated chamber into which the protons are injected. The protons are accelerated around this void by oscillator-governed electrodes and their path is controlled by the field of the magnet. The particles make a few million revolutions and travel about 300 000 miles in the 1.9 seconds required to attain the velocity desired for bombardment of the target. Upon reaching this high energy level, the closely grouped protons are made to strike a target placed at the edge of the vacuum chamber. Here these "bullets" of energy will cause transmutation or atomic disintegration of the targets at which they are aimed. Nuclear particles will be knocked out of target atoms struck by these projectiles, and thus one can expect a secondary beam of neutrons from the target, which, since neutrons bear no charge, will emerge tangentially from the vacuum chamber. At a later date, the proton beam may be brought out of the machine to bombard external targets directly.

Of prime importance to the proper functioning of the proton synchrotron is the precise control of the magnetic field needed to maintain the protons in their orbit. As the higher velocities are reached, the radius of the circular path of the accelerating protons changes because of the changing mass of the protons themselves. Control of this orbital path is obtained by increasing the field strength of the magnet as the particle velocity is raised. But, because the field strength does vary, the particles can be accelerated only in groups and not in a continuous stream as in the cyclotron.

**Fig. 1—Simplified circuit diagram of the main units in one half of the magnet power supply. No attempt is made to show the full wiring diagram. The portion shown is half of the complete system; an identical section is tied in where the arrows indicate (on the right side) to complete the bevatron magnet power supply.**



To avoid complications in frequency tracking and to insure a gradual increase in energy gain per turn, it is desirable to increase the field in a uniform manner from zero at the beginning of each accelerating impulse to a peak value just as the protons are deflected from the chamber. The current build-up time is roughly 1.9 seconds. Following this, to reset the magnet for the next proton-accelerating period, it is desirable to have the current decay period as short as possible. But to reduce the current to zero against the tremendous inductance of this magnet, the polarity of the d-c supply must be reversed.

Two systems are available for supplying such power requirements. One involves d-c generators driven by a-c motors, with generator-field reversal utilized to change polarity. The other uses ignitrons, supplied by an a-c motor driving an a-c generator. The ignitrons are fired as rectifiers during the period of current build-up and as inverters during the period of current decay.

The system utilizing ignitrons has many advantages. Of foremost importance is the fact that the initial expense is less than for massive d-c generators of the required capacity. Furthermore, the polarity of the ignitron system can be reversed within 1/120 second, whereas a much longer period and a highly complex regulating system would be required to reverse the field of the d-c generator.

Complete systems for supplying magnet power for two new proton synchrotrons are being built. The larger of these units requires a peak direct current of 8333 amperes at 12 000 volts, with the power peak occurring at a maximum rate slightly more than 11 times a minute. To allow operation of the proton synchrotron at full capacity and also at one-half capacity, two parallel power-supply units are provided.

## Direct-Current Supply

The flow of power can be visualized from Fig. 1 by following the heavy lines from the a-c supply line to the wound-rotor motor that drives a flywheel and a 12-phase synchronous generator. Each three-phase group of generator windings is connected through anode balance coils to six continuously evacuated ignitrons. The four ignitron groups are connected in series with the two sections of the magnet coil, which is divided into two parts to reduce maximum voltage to ground.

During the period of proton acceleration, the ignitrons are fired on the positive half of the voltage wave to act as rectifiers. In drawing current for the magnet coils from the a-c generator, the motor-generator-flywheel set is slowed down. The flywheel gives up energy, as the rotational velocity decreases, to maintain speed drop within the required limits. Upon completion of the accelerating period, the firing point of the ignitrons is shifted to the negative half of the voltage wave and they act as inverters to transfer the stored energy in the magnet inductance through the generator to the flywheel, where it is absorbed to return the shaft speed to normal. Also, during this period, power is being drawn from the line to return the m-g set to normal speed in readiness for the next accelerating impulse. The motor secondary resistance is controlled in such a way as to limit the motor current to reasonable values as the flywheel changes speed.

Although appreciable voltage regulation in the d-c supply is permissible, it is important that the voltage wave shape for each succeeding impulse be identical to maintain the relationship between the magnet field force and the frequency modulation of the driving oscillator. To accomplish this, the field of the generator is supplied by a small sealed-tube ignitron

A basic physical law states that a charged particle moving in a plane perpendicular to a uniform magnetic field describes a circular orbit at constant angular velocity, regardless of its speed. This fact is important because it provides the basis for the design and operation of our most powerful atom smashers. Although the paths of the accelerating particles are different in the cyclotron, betatron, and synchrotron, the forces of a magnetic field are used to balance the centrifugal force inherent in whirling masses. Hence, to maintain control of the particle in these machines, the particle is in equilibrium between two balanced primary forces. One, the centripetal force ($F_c$) is caused by the magnetic field and is the product of $H$, the magnet field strength, $e$, the charge of the particle, and $v$, the linear velocity of the particle. The other is the centrifugal force ($F_g$) of the particle and is equal to its kinetic energy divided by the radius of the orbit, $mv^2/r$. As these two are balanced, $F_c=F_g$ and $Hev=mv^2/r$. Rearranging the equation gives $He/m=v/r$.

From this equation ($He/m=v/r$) we can see that if the field $H$ is held constant, an increase in velocity (by an external accelerating force) would be accompanied by an increase in the radius of the particle's orbit. Hence, when the particle velocity is raised to the tremendous values—approaching the speed of light—required in nuclear research the radius would increase beyond the dimensions of any practical-sized machine. But another factor enters the picture at this point. According to Einstein's Theory of Relativity, which equates mass and energy, as a particle approaches the speed of light the mass increases; the law of constant angular velocity breaks down. Therefore, to compensate for this mass change and to maintain the angular velocity ($v/r$) constant we must increase the field $H$.

rectifier. The output of this rectifier is controlled by an electronic regulator acting on the firing point of the sealed ignitrons and receiving its intelligence from instrument transformers in the output circuits of the generator. This arrangement allows a variation of only one half of one percent for any point on succeeding voltage waves.

If allowed to coast, the m-g set would take several hours to come to rest. However, under certain emergency conditions the machine can be stopped within five minutes. For such emergencies a switching arrangement is provided whereby the motor primary is disconnected from the supply line, the generator-field circuit breaker is opened, and the d-c output from the electronic exciter is impressed across one phase of the motor primary. In this way the energy of the rotating parts is absorbed in the secondary resistance.

As two flywheel-motor-generator units are operated in parallel, the instantaneous voltages of the a-c outputs may not be the same because of phase displacement of one generator with respect to another. Therefore, paralleling interphase transformers are required at each point where the magnet coil is connected to the rectifier units, ensuring equal load division. Another interphase transformer is provided to block circulating currents at the point where the two units are connected to a common ground.

These power supplies are composed of specially designed units containing several unique features because of the problems posed by the design and performance requirements. The a-c generator, the ignitron tubes, and design of the necessary control circuits are of signal importance.

## Ignitron Rectifiers

These specially designed ignitron tubes are required to handle a heavy direct current at a high voltage (18 000) and be reliable on both rectification and inversion. The period of rectification is about 1.9 seconds and the peak current for each six-tube rectifier is 4167 amperes. At the start of the pulse the output voltage of each rectifier is 4500 volts direct current, and at the peak load the d-c voltage is 3000 volts. Pumped ignitrons meet these requirements more satisfactorily than sealed ignitrons on these applications because the tubes are more rugged, the ratio of peak current to average current is higher, and they do not require replacement.

The grid circuit of the firing thyratron is the major control circuit. On this grid circuit, one peaking transformer is phased for rectifier operation and another for inverter operation; and by changing the bias value, either the rectifier or the inverter firing pulses can be made effective. When proper phase relationship releases the thyratron for firing, a capacitor is discharged through an insulating transformer to fire the ignitor.

The excitation circuit allows one half of the converters (ignitron units that operate as both rectifiers and inverters) in series to change from rectifier to inverter operation at one time, and, after a given time interval, allows the other half of the converters to change. A small commutator on the motor-generator shaft governs the rectifier-to-inverter change by removing the positive bias on the grids of the firing thyra-

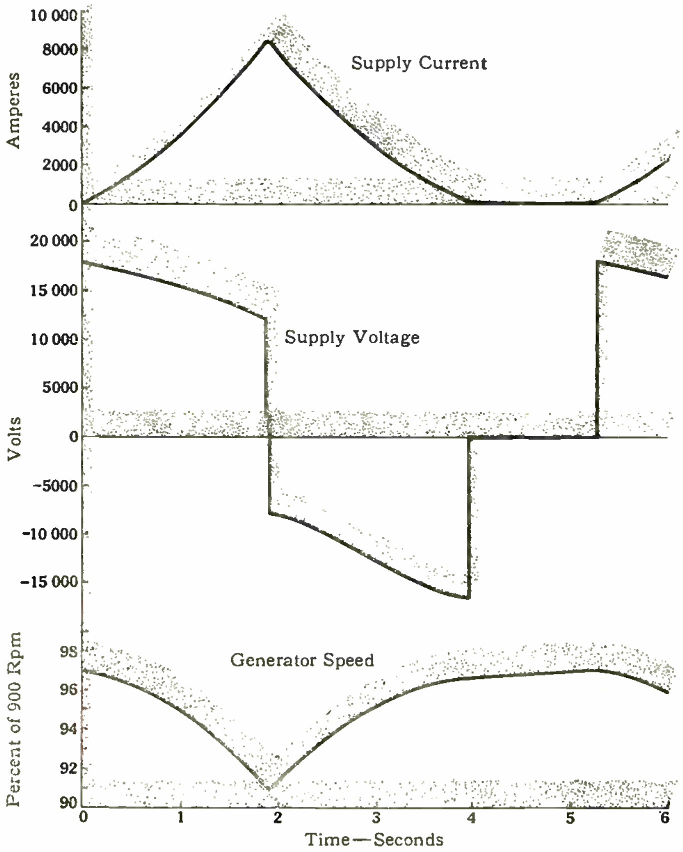


**Fig. 2**—The current curve shows the variation in amperage that generates the desired inductance in the main magnets. The voltage curve indicates the change in d-c voltage through the ignitron units. The notch in this curve is caused by the shifting of each ignitron half-section from rectifier to inverter operation. The speed curve shows the small drop in speed of the flywheel m-g sets.

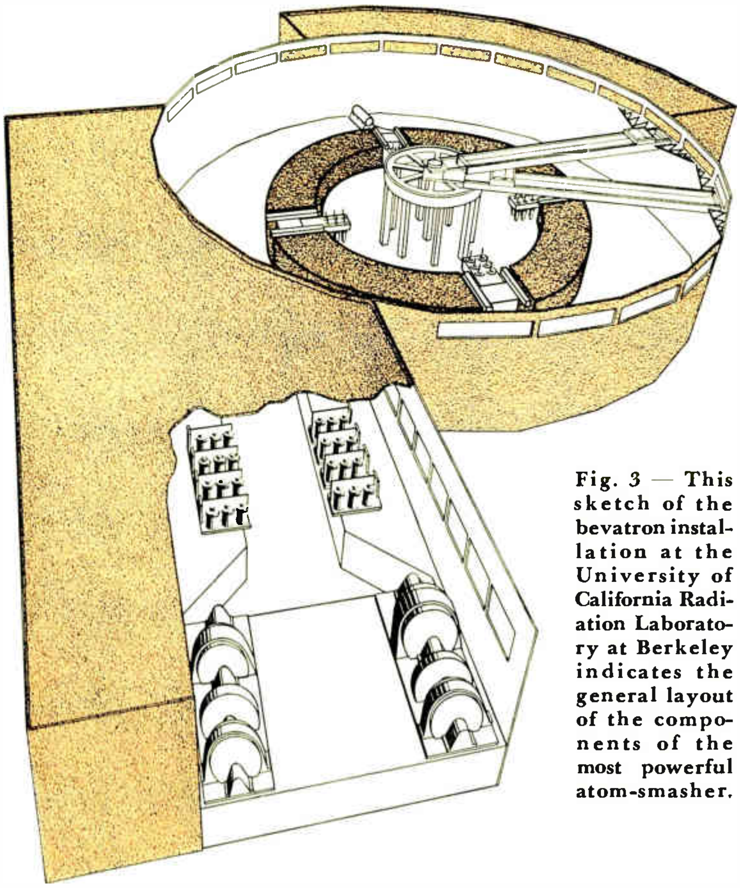


**Fig. 3 — This sketch of the bevatron installation at the University of California Radiation Laboratory at Berkeley indicates the general layout of the components of the most powerful atom-smasher.**

trons. Proper timing minimizes any torsional vibrations in the motor-generator shaft.

The rectifying portion of the current pulse is the most critical because the particles are accelerated during that period. The d-c voltage magnitude and harmonics must be held to definite limits to prevent losing the protons at the start of the pulse. Voltage regulation is held to 0.5 percent by electronic regulators and electronic exciters that control the field of the main generator. As the magnitude of the d-c harmonics would otherwise be increased, no delay in rectifier firing is used; a 12-phase output voltage ripple is satisfactory.

The normal d-c voltage regulation of the motor-generator set with rectifier gives, basically, the desired characteristics. When the rectifier load increases, the voltage regulator does not attempt to hold a constant voltage as it is current compensated to hold the correct voltage for a constant flux in the generators. Because of the machine reactance, the d-c voltage drops almost the desired amount, and only a small change in the field is required to give the proper regulation.

The change from rectifier to inverter operation is a critical step, and the power circuits must be specially designed to operate correctly. When the firing direction is changed, each conducting tube must continue firing for about double the normal angle. The voltage on each interphase transformer increases severalfold because the difference in phase position of the windings in the paralleled wyes of the two generators causes a larger difference in voltage between the two rectifier groups. The interphase exciting current under this condition must be low to prevent an unbalance that would cause inverter faults.

At the peak load, inverter firing is considerably advanced to permit commutation with a large margin angle. The magnitude of the d-c voltage is not critical during the inverter portion of the pulse. The inverter counter-voltage should be as high as possible to bring the current to zero in a minimum time and thus reduce the current loading on the equipment.

As current decreases, the ignition delay angle is increased to hold the margin angle approximately constant. Both this ignition change and the increase of the machine voltage with reduced load causes the d-c voltage to increase as the load decreases. When the load becomes zero the ignition angle must be greater than 150 degrees to prevent a small positive voltage from causing current pulses in the magnet windings.

The problem of protecting the equipment in case of an ignitron fault or system short circuit is serious because it is not possible to interrupt load current in the tremendously inductive circuit of the large magnet. The peak stored energy of the magnet is about 80 million watt-seconds, therefore it is always desirable to invert the current to zero before the operation of the equipment is stopped. However, when a serious fault occurs it is necessary to stop immediately. The ignitors on all ignitrons are blocked so they do not fire and the tubes attempt to quench the arc of the fault current. If this fails to correct the fault, the main magnet is short circuited and the generator excitation is removed. The magnet current must then decay according to the RL characteristics.

In the rectifier period of the pulse, an arc-back requires an arc suppression that causes disturbances in the output d-c voltage, but this lasts for only a portion of one pulse. Arc-throughs (passage of current when tube is supposedly nonconducting) during the inverter period can be corrected in one cycle without any change in excitation, because the magnet current does not increase. Unless the unbalance between groups becomes too great, the current in each wye should be commutated when the correct phase comes up the second time. If the fault is not corrected the back-up protection of short circuiting the magnet will go into effect.

### Flywheel-Motor-Generator Sets

The generators were designed especially for direct connection to the rectifier tubes, which eliminates the reactive drop of the transformers. The elimination of the transformer caused the extra complication of generator windings having four wyes brought out for a 12-phase rectifier connection. A special winding, adequate for carrying the d-c component and arranged to minimize adverse effects on the rotor, was developed. It also gives a minimum commutating reactance that limits the voltage drop of the generator at the peak load. The resulting high-fault currents necessitated extra bracing for the end windings.

The m-g sets have eight-pole generators and an eight-pole wound-rotor motor running just below 900 rpm at 60 cycles. The speed was chosen as high as practical to give a minimum reactance for suitable regulation.

The inertia characteristics of the flywheel allow about a six-percent speed drop with a corresponding reduction in voltage. It might appear that a smaller flywheel would be more economical, but with a limit to the overall voltage drop a wider tolerance in speed requirements would have demanded a major reduction in reactance and an increase in generator size. Whereas the peak power input to the magnet is 100 000 kw, the average power input to the generators does not exceed 3600 hp on each of the two motors. To minimize the voltage dip, the pulsation in kva is limited to 3000. To meet these limitations the wound-rotor motors are provided with several values of secondary resistance. Then the secondary resistance and the resulting torque-slip characteristics are changed by contactors that open and close in a certain sequence as the motors slow down or accelerate.

The experience obtained from these units in the next few years will give valuable engineering data on the performance of high-voltage rectifiers and large flywheel-motor-generator sets. Thus, in providing an instrument for advanced research, advances in engineering experience are also obtained.

# Stories of RESEARCH

## The Phosphor—Wavelength Transformer

SOMETIME last year, research engineers at the Westinghouse Lamp Division built their own private sun. By now there are dozens of them scattered throughout the various offices; sunrise and sunset are accomplished by the simple flipping of a switch. These "suns" are the new fluorescent sun lamps.

The secret of this new lamp is largely wrapped up in a recently discovered phosphor, one that transforms the ultraviolet radiation given off by a low-pressure mercury discharge into radiations in the erythemal or sun-tanning region.

Engineers have long known that the low-pressure mercury discharge was one of the most efficient means of converting electrical energy into very short ultraviolet radiations. However, some means of transforming these short wavelengths into longer ultraviolet rays in the sun-tanning region had to be found before a lamp could be built to utilize them.

Reduced to its barest essentials, the problem was this. A mercury discharge gives off radiations with a characteristic wavelength of 2537 A (Angstroms). On the other hand, the peak sun-tanning effect of ultraviolet radiations occurs at 2967 A, although the sun-tanning band covers a range of frequencies from about 2800 to 3500 A. The task, then, was to find a phosphor that would receive ultraviolet at 2537 A and transform it to 2967 A or thereabouts.

Some encouragement was offered in the fact that several phosphors had been found to convert the radiations from a mercury discharge to visible light (3800 to 7600 A), a considerably greater step than was needed in this case. But these phosphors themselves were not suitable for the smaller conversion. Other phosphors in existence came closer to the desired transformation—enough so they could conceivably be used in a sun lamp. But Dr. R. Nagy and Robert Wollentin wanted a better one.

Most of the available phosphors failed in one of three respects. Either they were not efficient enough, failing to produce a high percentage of the radiations, or they were not stable enough to operate in a fluorescent-type lamp, or their peak radiation was not close to the maximum erythemal peak. For example, calcium silicate activated by thallium, although stable and efficient, had its peak emission at 3350 A.

After a careful study of the available phosphor types, Nagy and Wollentin selected calcium-phosphate compounds as the most promising. Then came the long and arduous process of substituting small amounts of other substances for some of the calcium to see what effect they might have in producing a more suitable transformation. Thirty-five different elements were tried. The most promising was zinc. Increasing amounts of zinc were added. Each increment pushed the emitted wavelength closer to 2967 A. Finally the point was reached where more zinc failed to have any further effect. This phosphor contained eight percent zinc phosphate and 92 percent calcium phosphate. Its peak was found to be 3110 A, closer than any other man-made source of ultraviolet to the ideal of 2967 A. Furthermore, its erythemal distribution curve—the curve showing its scope of wavelengths—corresponded closely to that of an ideal erythemal distribution. Research engineers had thus achieved a new peak in sun-tanning effectiveness.

This new phosphor made possible a fluorescent sun lamp with all the best features of fluorescent lighting. Cool operation, low power consumption, and long life—inherent in fluorescent lighting—became available in a sun lamp. Such a lamp was quickly constructed. Thus this newly discovered phosphor, in effect a miniature frequency transformer for electromagnetic energy, has made possible a lamp that approximates the sun-tanning effects of the sun more closely than any other known artificial source of ultraviolet.

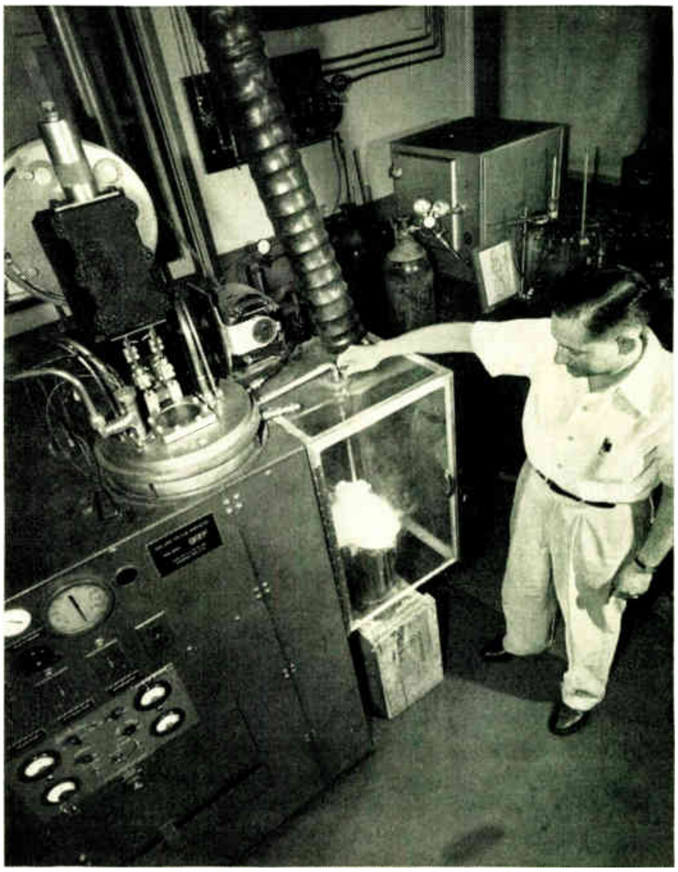
## Temperatures Go Down

AT TEMPERATURES nearing absolute zero (-452.7 degrees F) some of nature's laws seem to go haywire. For example, liquid helium flows uphill. Perhaps of more practical significance is the phenomenon of superconductivity. An electrical circuit immersed in liquid helium—at about -452 degrees F—will continue to carry current even when the power supply is removed, i.e., under these temperature conditions the circuit loses its electrical resistance. This and other low-temperature phenomena are under intensive study in the Westinghouse Research Laboratories.

Only certain metals exhibit the property of superconductivity, among the more important of these are columbium, tantalum, vanadium, and their alloys—these become superconducting at fairly "high" temperatures. For example, pure columbium conducts current without resistance at about 17 degrees F above absolute zero, its nitride at about 29 degrees above absolute zero.

To produce the super-cold temperatures, Westinghouse scientists are utilizing a new cryostat, which converts helium gas to a liquid form. Ultra-pure helium is first raised to about 200 psi by a four-stage compressor system, then put to work driving a piston engine. The energy used in accomplishing this work is lost as heat and the temperature of the gas drops to about 75 degrees K. Work on a second engine lowers it still further, to about 12 degrees, and the gas is then throttled through a tiny orifice and drops to four degrees K, and subsequently condenses to a liquid state. By drawing a vacuum above the liquid helium, evaporation is hastened and the temperature can be reduced still further to about one degree K.

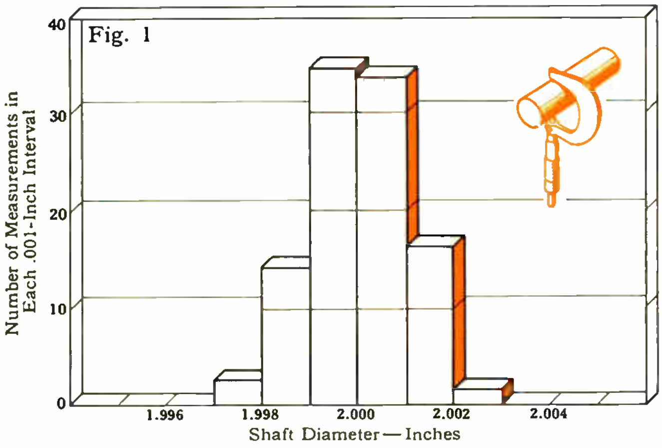
**Below, Dr. Aaron Wexler draws liquid helium at —452 degrees F from the cryostat for use in experiments.**



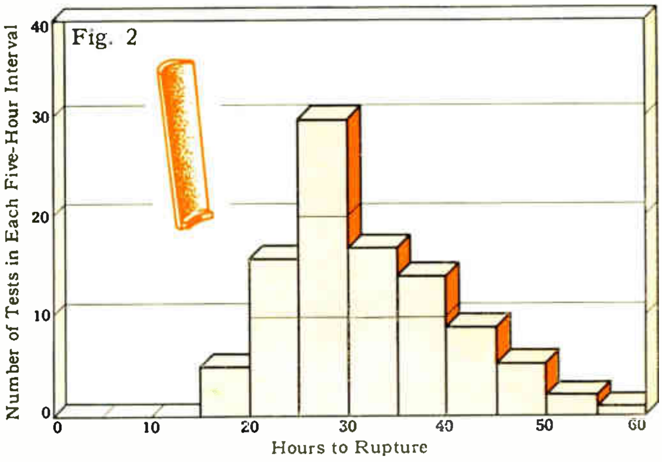
# Graphical Statistics—
## An Engineering Approach

**Nearly every engineer is familiar with the testing procedures that apply to his particular field. Trouble is, the data collected is usually meaningless as facts and figures—its interpretation is what counts. Methods of evaluating information vary from the use of "engineering intuition" to laborious and painstaking mathematical procedures. Somewhere between these extremes lies a relatively simple and timesaving, but often overlooked, tool—statistical analysis. With the knowledge of only a few basic rules, engineers can easily master this useful method.**

L. R. Hill and P. L. Schmidt
*Materials Engineering Department*
*Westinghouse Electric Corporation*
*East Pittsburgh, Pennsylvania*



**Above, a histogram of shaft-diameter measurements. Here the values cluster almost symmetrically about the center point. Below, a skewed distribution showing the number of hours required to rupture a high-temperature alloy. The logarithms of these numbers assume a symmetrical distribution. Below right, another skewed distribution of the breakdown voltages of thin capacitor paper.**



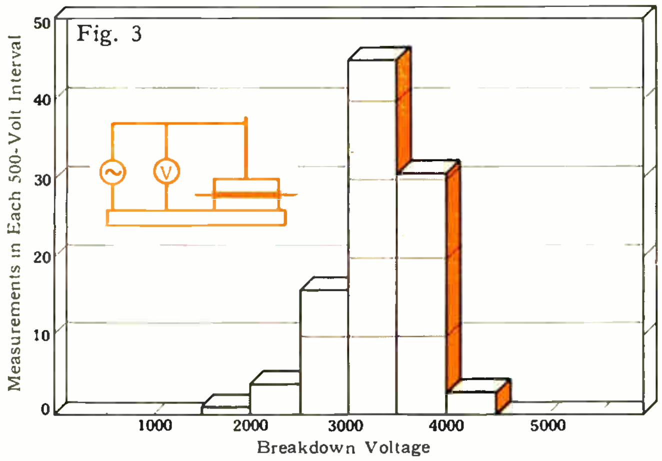
Each day thousands of seemingly identical products roll from each of the many mass-production factories in this country. Endless rows of automobiles, light bulbs, and motors pour off production lines—each unit essentially a mate to the one in front of it and the one behind it. Perhaps even more amazing is the fact that each of these finished products is made up of hundreds, even thousands, of parts, and each of these parts is similarly a mate to its counterparts in other products in the line. Yet despite the amazing accuracy achieved by engineers in controlling these individual processes, obviously no two finished products are exactly alike. Neither man nor nature has ever achieved this miracle.

Depending upon their magnitude these individual differences or variations may be either of major importance or of none at all. But, regardless, the manufacturer must have some way of expressing these variations—so that he may determine means of improving his process, and also so that the user may have precise information on the product he buys. A perplexing problem in any manufacturing process is determining how accurate a device or method can be made before the law of diminishing returns takes effect; there is obviously little use in making a device more accurate than its application demands. A faithful analysis of the variations of the product from its design standards can thus be invaluable.

Since no two products can be exactly alike, most manufacturers establish limits or ranges within which the characteristics vary when the device is used under a given set of conditions. For example, the temperature rise of a motor is often given as no greater than 55 degrees C when operated at full load; or the minimum life of an incandescent lamp is given as, say, 1000 hours.

Since it is the variation in individual properties that determines such factors as "average," "maximum," and "minimum" values, a generally recognized and relatively simple method for describing variations is extremely useful in engineering and manufacturing.

One widely used scheme of expressing variation states the approximate maximum and minimum values that a variable may have. For example, a photocell is sometimes rated as having a maximum output of, say, 4.5 microamperes per foot-



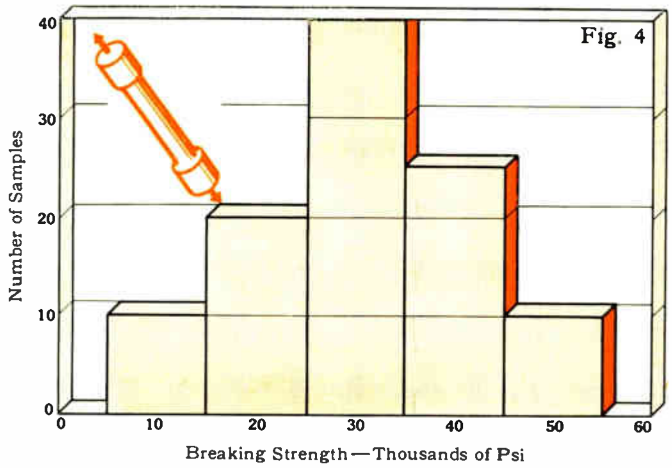


Fig. 4

**Above and at right are the progressive steps in developing a straight-line distribution curve showing the number of cast-iron samples breaking in each of the strength intervals.**

candle and a minimum output of perhaps 2.5 microamperes per footcandle. Another method gives the average difference between the individual values and the numerical average. For example, the average deviation of precision resistors from a nominal value of 1000 ohms might be specified as 0.01 ohm.

The most widely used method, however, defines the variation as the root mean square of the individual deviations from average. This factor is called the standard deviation* of the values from the average, and is represented by the Greek letter sigma ($\sigma$). This method is preferred because it furnishes a basis for predicting the number of values found between two specified limits, and for an accurate estimate of the error involved in inspecting only a small part of the total production.

Although the variations of any process can be calculated by arithmetic methods, a graphical solution is sufficiently accurate for nearly any engineering problem, and is far less time consuming. It also lends itself to relatively simple analysis.

The graphical method of solving statistical problems has other inherent advantages. For example, no matter how much data is collected on a particular manufacturing operation, or any other activity, it is at best merely a sample. The information that can be obtained from this sample is limited in exactness due to sampling error. This error may exist because there is a real chance of choosing a sample that is not representative of the total production, but the information becomes more accurate as the size of the sample is increased. However, contrary to what might be expected, the accuracy is not proportional to the size of the sample. It varies as the square root of the number of observations. Thus 36 observations will not give 9 times as much accuracy as 4 observations, but only 3 times. However, the use of graphical analysis makes possible quick and easy determination of the probable error between the sample taken and the true condition. It also makes clear whether further sampling would give a worthwhile increase in accuracy of the result.

Many common and closely allied engineering problems can be studied using graphical methods rather than the more laborious analytical statistical methods. One such problem is that of determining whether two or more samples differ because of their sampling error, or because they are actually

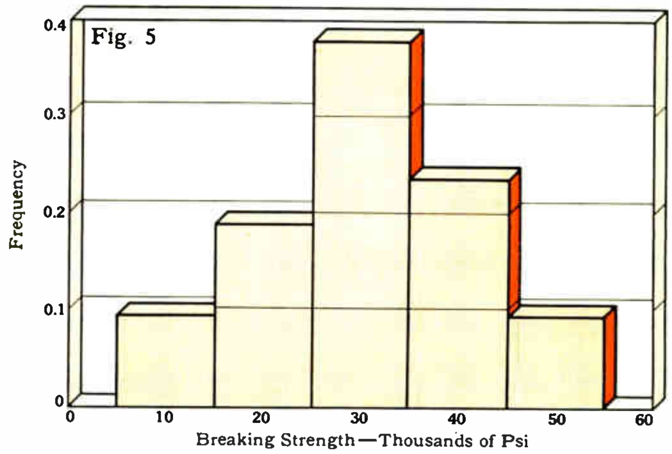


Fig. 5

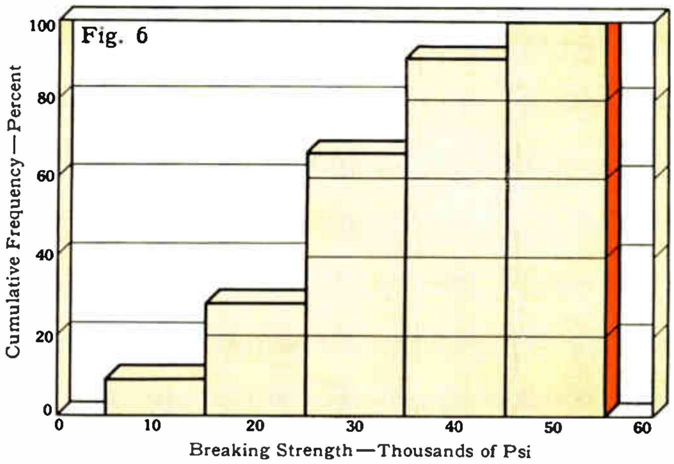


Fig. 6

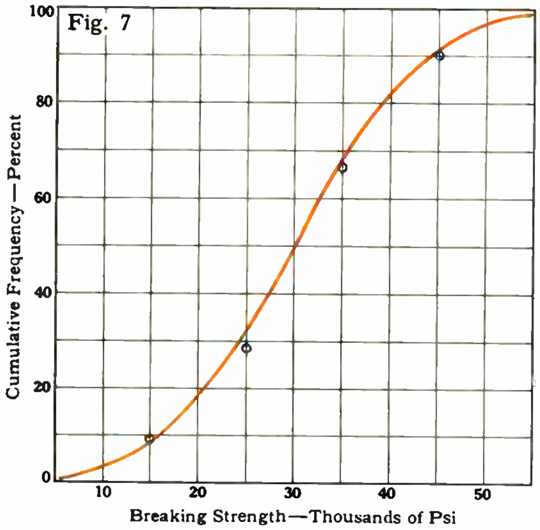


Fig. 7

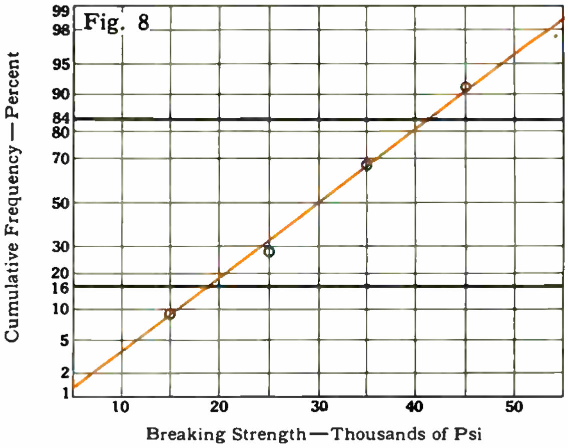


Fig. 8

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*Standard deviation is defined mathematically as,

$$\sigma = \sqrt{\frac{\Sigma\,(X_i - \overline{X})^2}{n}}$$

where $\overline{X}$ is the average value, the $X_i$'s the individual measurements, and $n$ the total number of values.

physically different. This question often arises when an attempt is made to improve a manufacturing process by changing one of its variables. For example, consider the process of impregnating high-voltage coils with varnish. There are several variables in this process—pressure during impregnation, temperature during baking, time of baking, and others—all of which affect the quality of the coil as measured by insulation breakdown strength.

Suppose the effect of changing the baking temperature is to be studied. Two sets of data are obtained—one of breakdown voltages before the change, and one after. Invariably these values will be different, but the question remains as to whether the differences were caused by sampling error, either human or mechanical, or whether the process has actually been improved. Since a great deal may depend upon a change in baking temperature—both cost-wise and quality-wise—the question becomes important. Thus the ability to determine, with any desired degree of accuracy, whether or not a real change has been made is of vital interest. Graphical analysis enables the solution of this problem.

### Basic Ideas

Consider a group of measurements taken of the diameter of a shaft machined on an automatic lathe. If the maximum and minimum measurements are noted and the interval between them divided into equal segments, or test intervals, then the number of measurements occurring in each of these test intervals can be plotted against the interval, as shown in Fig. 1. In the case of these particular measurements the resulting graph, or histogram, shows that the values cluster about a central point. The majority of these fall within the interval of the middle bar. If a large enough sample had been taken these values would have been perfectly symmetrical about the center, and the number of values in each interval would obey a definite law. This mathematical oddity—called the Normal Law—is invaluable in statistical analysis.

The most useful distribution is that resulting when the measurement or occurrence depends upon a large number of unrelated factors that are equally likely to affect it. Such a distribution, as in Fig. 1, is known as a normal distribution, and can be used to describe most engineering data.

Normal distribution is defined by two factors—the average value of the data ($\bar{X}$), and a measure of the spread of the data, or the standard deviation ($\sigma$) from average value. The normal distribution, as well as other distributions, are simply mathematical models. However, many sets of data collected fit one of these models. This is fortunate, in that if a particular set of measurements fits the model, all the mathematical facts known to be true about the model can also be applied to the data. For example, it can be mathematically proved that in a normal distribution approximately 68 percent of the values lie within plus or minus one standard deviation from the average. Thus if a set of data forms a normal distribution curve, approximately 68 percent of the values can be assumed to lie within plus or minus one standard deviation from average. Many other facts are known about normal distributions, all of them functions of the average value $\bar{X}$ and the standard deviation $\sigma$, which makes the analysis of any data by graphical means a relatively simple matter.

Although all groups of measurements do not assume such symmetrical regularity, most follow some definite pattern. For example, the values of Figs. 2 and 3 are skewed, respectively, toward the lower and higher values. But the values in Fig. 2, which represent data on the number of hours required to rupture a high-temperature alloy at elevated temperatures, do assume a symmetrical distribution when their logarithms are plotted instead of the actual numbers. And in Fig. 3, which represents the breakdown voltages of a thin capacitor paper, the number of values in each breakdown interval obeys another distribution law.

### The Basis of Probability Paper

Although the bar graph, or histogram, represents clearly the results of any measurements, such a form is not the simplest in which to obtain a measure of the spread of the data or to compare two or more results. Thus the data is usually reduced to a more convenient form.

Take, for example, the histogram of Fig. 4, which gives the number of cast-iron samples breaking in each 10 000-psi strength interval. If, instead of plotting the actual number of samples versus the interval, the ratio of the number of samples in each interval to the total number is plotted versus each interval, the result will be as shown in Fig. 5. This has a definite purpose. By plotting the ratio instead of the actual number, the curve becomes more general, since it is not dependent on the number of observations. Since it makes the information essentially independent of the number of observations, a basis is provided for comparison with other sets of data from the same total distribution.

If now the ratio of samples breaking in any one interval and below the interval are plotted against the total number of samples, on a cumulative basis, Fig. 6 is obtained. With a large enough number of samples the size of the interval could be reduced sufficiently to represent the data by a smooth curve, as in Fig. 7. This gives the percentage of samples that break below any given strength. For example, referring to Fig. 7, 20 percent of the samples broke below 20 500 psi.

If the percentage axis is now expanded in a symmetrical but nonlinear manner about the 50-percent line, at some point Fig. 7 will become the straight line of Fig. 8. The coordinate system that achieves this straight-line relationship, developed in 1914 by Hazen, is one of the most valuable tools of graphical statistical analysis.

All normally distributed curves plot as straight lines on this probability paper, thus how close a given set of data approaches a normal distribution can be observed immediately by noting how nearly its points approximate a straight line. On probability paper the average value is that which falls at the 50-percent ordinate. The standard deviation is the difference between 50-percent ordinate and either the 16- or the 84-percent ordinate intersections with the curve. These facts can be proved mathematically. Obviously, probability paper greatly simplifies the discovery of both standard deviation and average values since they can be read directly from the probability curve. In Fig. 8, for example, standard deviation is 12 000 psi, average value is 30 000 psi.

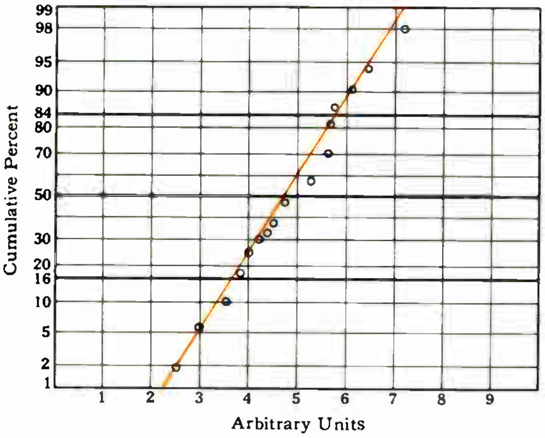
### Methods of Plotting Probability Curves

In general there are two methods of using probability paper, depending upon the number of samples or measurements available. When the number of observations is small—about 30 or less—each value is plotted as a separate point. When the number of values is high, they are grouped in equal-sized intervals and plotted against the top of the interval. In both cases cumulative percentages at or below a given value are plotted against that value. These methods are shown on p. 123.

In a subsequent issue, probability paper will be put to other uses, such as determining the confidence limits of the average value and standard deviation, and determining whether two sets of data are significantly different.

TABLE I

| Obs. No. | Available Number of Observations | | | | | | | | | | | | | | | | | | | | | Obs. No. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 | 25 | 26 | 27 | 28 | 29 | 30 | |
| 1 | 5 | 4.5 | 4.2 | 3.8 | 3.6 | 3.3 | 3.1 | 2.9 | 2.8 | 2.6 | 2.5 | 2.4 | 2.3 | 2.2 | 2.1 | 2.0 | 1.9 | 1.9 | 1.8 | 1.7 | 1.7 | 1 |
| 2 | 15 | 13.6 | 12.5 | 11.5 | 10.7 | 10.0 | 9.4 | 8.8 | 8.3 | 7.9 | 7.5 | 7.1 | 6.8 | 6.5 | 6.25 | 6.0 | 5.8 | 5.6 | 5.4 | 5.2 | 5.0 | 2 |
| 3 | 25 | 22.7 | 20.8 | 19.2 | 17.8 | 16.7 | 15.6 | 14.7 | 13.9 | 13.2 | 12.5 | 11.9 | 11.4 | 10.9 | 10.4 | 10.0 | 9.6 | 9.3 | 8.9 | 8.6 | 8.3 | 3 |
| 4 | 35 | 31.8 | 29.2 | 26.9 | 25.0 | 23.3 | 21.9 | 20.6 | 19.4 | 18.4 | 17.5 | 16.7 | 15.9 | 15.2 | 14.6 | 14.0 | 13.5 | 13.0 | 12.5 | 12.1 | 11.7 | 4 |
| 5 | 45 | 40.9 | 37.5 | 34.6 | 32.1 | 30.0 | 28.1 | 26.4 | 25.0 | 23.7 | 22.5 | 21.4 | 20.4 | 19.6 | 18.75 | 18.0 | 17.3 | 16.7 | 16.1 | 15.5 | 15.0 | 5 |
| 6 | 55 | 50.0 | 45.8 | 42.3 | 39.2 | 36.7 | 34.4 | 32.3 | 30.6 | 29.0 | 27.5 | 26.2 | 25.0 | 23.9 | 22.9 | 22.0 | 21.2 | 20.4 | 19.6 | 19.0 | 18.3 | 6 |
| 7 | 65 | 59.1 | 54.2 | 50.0 | 46.4 | 43.3 | 40.6 | 38.2 | 36.1 | 34.2 | 32.5 | 30.9 | 29.6 | 28.3 | 27.1 | 26.0 | 25.0 | 24.1 | 23.2 | 22.4 | 21.7 | 7 |
| 8 | 75 | 68.2 | 62.5 | 57.7 | 53.5 | 50.0 | 46.9 | 44.1 | 41.7 | 39.5 | 37.5 | 35.7 | 34.1 | 32.6 | 31.25 | 30.0 | 28.9 | 27.8 | 26.8 | 25.9 | 25.0 | 8 |
| 9 | 85 | 77.3 | 70.8 | 65.4 | 60.7 | 56.7 | 53.1 | 50.0 | 47.2 | 44.8 | 42.5 | 40.5 | 38.7 | 37.0 | 35.4 | 34.0 | 32.7 | 31.5 | 30.4 | 29.3 | 28.3 | 9 |
| 10 | 95 | 86.4 | 79.2 | 73.1 | 67.8 | 63.3 | 59.4 | 55.9 | 52.8 | 50.0 | 47.5 | 45.2 | 43.2 | 41.3 | 39.6 | 38.0 | 36.6 | 35.2 | 33.9 | 32.8 | 31.7 | 10 |
| 11 | | 95.5 | 87.5 | 80.8 | 75.0 | 70.0 | 65.6 | 61.8 | 58.4 | 55.3 | 52.5 | 50.0 | 47.7 | 45.7 | 43.75 | 42.0 | 40.4 | 38.9 | 37.5 | 36.2 | 35.0 | 11 |
| 12 | | | 95.8 | 88.5 | 82.1 | 76.7 | 71.9 | 67.7 | 63.9 | 60.6 | 57.5 | 54.7 | 52.2 | 50.0 | 47.9 | 46.0 | 44.2 | 42.6 | 41.1 | 39.7 | 38.3 | 12 |
| 13 | | | | 96.2 | 89.2 | 83.3 | 78.1 | 73.6 | 69.4 | 65.8 | 62.5 | 59.5 | 56.8 | 54.4 | 52.1 | 50.0 | 48.1 | 46.3 | 44.6 | 43.1 | 41.7 | 13 |
| 14 | | | | | 96.4 | 90.0 | 84.4 | 79.5 | 75.0 | 71.1 | 67.5 | 64.4 | 61.4 | 58.7 | 56.25 | 54.0 | 51.9 | 50.0 | 48.2 | 46.6 | 45.0 | 14 |
| 15 | | | | | | 96.7 | 90.6 | 85.4 | 80.6 | 76.4 | 72.5 | 69.1 | 66.0 | 63.1 | 60.4 | 58.0 | 55.8 | 53.7 | 51.8 | 50.0 | 48.3 | 15 |
| 16 | | | | | | | 96.9 | 91.2 | 86.1 | 81.6 | 77.5 | 73.8 | 70.5 | 67.4 | 64.6 | 62.0 | 59.6 | 57.4 | 55.4 | 53.5 | 51.7 | 16 |
| 17 | | | | | | | | 97.1 | 91.7 | 86.9 | 82.5 | 78.6 | 75.0 | 71.8 | 68.75 | 66.0 | 63.5 | 61.1 | 58.9 | 56.9 | 55.0 | 17 |
| 18 | | | | | | | | | 97.2 | 92.2 | 87.5 | 83.4 | 79.6 | 76.1 | 72.9 | 70.0 | 67.3 | 64.8 | 62.5 | 60.4 | 58.3 | 18 |
| 19 | | | | | | | | | | 97.4 | 92.5 | 88.1 | 84.1 | 80.5 | 77.1 | 74.0 | 71.2 | 68.5 | 66.1 | 63.8 | 61.7 | 19 |
| 20 | | | | | | | | | | | 97.5 | 93.0 | 88.6 | 84.8 | 81.25 | 78.0 | 75.0 | 72.2 | 69.6 | 67.3 | 65.0 | 20 |
| 21 | | | | | | | | | | | | 97.7 | 93.2 | 89.2 | 85.4 | 82.0 | 78.8 | 75.9 | 73.2 | 70.7 | 68.3 | 21 |
| 22 | | | | | | | | | | | | | 97.7 | 93.5 | 89.6 | 86.0 | 82.7 | 79.6 | 76.8 | 74.2 | 71.7 | 22 |
| 23 | | | | | | | | | | | | | | 97.9 | 93.75 | 90.0 | 86.5 | 83.3 | 80.4 | 77.6 | 75.0 | 23 |
| 24 | | | | | | | | | | | | | | | 97.9 | 94.0 | 90.4 | 87.0 | 83.9 | 81.1 | 78.3 | 24 |
| 25 | | | | | | | | | | | | | | | | 98.0 | 94.2 | 90.7 | 87.5 | 84.5 | 81.7 | 25 |
| 26 | | | | | | | | | | | | | | | | | 98.1 | 94.4 | 91.1 | 88.0 | 85.0 | 26 |
| 27 | | | | | | | | | | | | | | | | | | 98.1 | 94.6 | 91.4 | 88.3 | 27 |
| 28 | | | | | | | | | | | | | | | | | | | 98.2 | 94.9 | 91.7 | 28 |
| 29 | | | | | | | | | | | | | | | | | | | | 98.3 | 95.0 | 29 |
| 30 | | | | | | | | | | | | | | | | | | | | | 98.3 | 30 |



*Method I*—Where approximately 30 or less measured values are involved, the following steps are taken:

(1) Arrange the data in order of increasing magnitude.

(2) Give each observation a cumulative percentage value from table I.

(3) Choose a proper scale, and plot each different value as the abscissa, and the cumulative percent as the corresponding ordinate.

*Example*—Suppose the values in table II were obtained by 25 observations. These have been listed in order of increasing magnitude and given a cumulative percent from table I. Note that the lowest value is not given a cumulative percent of 4 percent, although one observation is obviously 4 percent of the total number of observations (25). Instead it is plotted at 2 percent. If a large number of observations were taken, approximately 4 percent would center around the value 2.4, half lying above and half below. Each succeeding percentage is found by adding 4 percent to the preceding value.

Also note that in the data there are three observations at 3.8, four at 4.8, and five at 5.6. Instead of plotting points that would have the same abscissa and lie in the same vertical line, the value is plotted against the midpoint of the percentage values assigned to it. For example, 3.8 is plotted at 18 percent, 4.8 at 48 percent, and 5.6 at 70 percent.

The probability curve for these values is shown above. Note that these points approximate a straight line closely, indicating that the data is normally distributed. This graphical method yields an average value, $\bar{X}$, of 4.8, found by the intersection of the curve with the 50-percent line. The average value calculated arithmetically from the data is 4.84.

TABLE II

| Observed Value | Cumulative Percent from Table I |
|---|---|
| 2.4 | 2 |
| 3.0 | 6 |
| 3.5 | 10 |
| 3.8 | 14 |
| 3.8 | 18 |
| 3.8 | 22 |
| 4.0 | 26 |
| 4.1 | 30 |
| 4.4 | 34 |
| 4.5 | 38 |
| 4.8 | 42 |
| 4.8 | 46 |
| 4.8 | 50 |
| 4.8 | 54 |
| 5.3 | 58 |
| 5.6 | 62 |
| 5.6 | 66 |
| 5.6 | 70 |
| 5.6 | 74 |
| 5.6 | 78 |
| 5.7 | 82 |
| 5.8 | 86 |
| 6.1 | 90 |
| 6.4 | 94 |
| 7.2 | 98 |

The standard deviation, $\sigma$, is found to be 1.1 by subtracting the abscissa of the curve at 50 percent from the abscissa at 84 percent, or $5.9-4.8=1.1$. By arithmetic calculation 1.05 would be obtained.

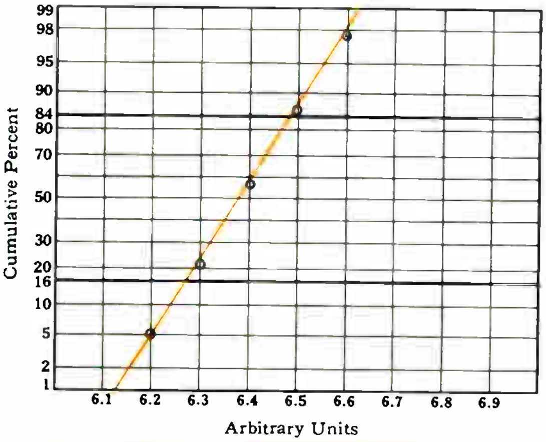
*Method II*—When a large number of observations are available, the process of plotting individual values is too lengthy. Thus, the following procedure is used:

(1) Tabulate the number of observations that lie in chosen equal-sized intervals. The interval should be at least 10 times the last significant figure to which the values are measured.

(2) Calculate the percentage of observations in each interval and the cumulative percentage in and below the interval.

(3) Plot the cumulative percent on the probability scale against the top of the interval on the abscissa.

*Example*—From 200 observations the information was tabulated as in table III, with their calculated percentages.



The probability curve for this data, shown at left, was constructed by plotting the top of each interval against the cumulative percent value associated with that interval. Note that the last point cannot be plotted because 100 percent is theoretically at infinity on this scale.

The average value and the standard deviations are found as in Method I; average is thus 6.38, standard deviation 0.11. Calculated values are 6.382 for average value, and 0.114 for standard deviation.

TABLE III

| Interval in Arbitrary Units | Number of Observations in Each Interval | Percent of Observations in Each Interval | Cumulative Percent |
|---|---|---|---|
| 6.01-6.10 | 1 | 0.5 | 0.5 |
| 6.11-6.20 | 9 | 4.5 | 5.0 |
| 6.21-6.30 | 36 | 18.0 | 23.0 |
| 6.31-6.40 | 68 | 34.0 | 57.0 |
| 6.41-6.50 | 57 | 28.5 | 85.5 |
| 6.51-6.60 | 24 | 12.0 | 97.5 |
| 6.61-6.70 | 4 | 2.0 | 99.5 |
| 6.71-6.80 | 1 | 0.5 | 100.0 |

# What's NEW!

## "Gas Turbines for Aircraft"

The aviation gas turbine and its application are given a thorough coverage in a new book co-authored by F. W. Godsey, Jr., of Westinghouse, and L. A. Young of The Rand Corporation. This book, entitled "Gas Turbines for Aircraft," includes three introductory chapters covering basic aerodynamics, aircraft propulsion and gas flow, and eight other well-illustrated chapters dealing with such things as gas-turbine components and cycles, controls and accessories, and the performance of aircraft powered by gas turbines.

The second volume in the "Westinghouse-McGraw-Hill Books for Industry," this book is written at the college level and is primarily for the use of design and application engineers rather than those involved in research and production.

## No "Soup" Too Thick

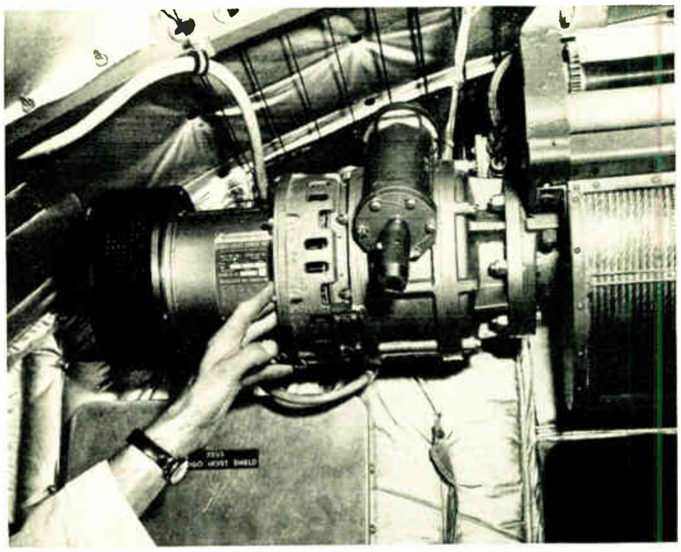
Air-cargo pilots on the Newark to Cleveland run—eastern leg of many cross-country routes—now take bad weather more or less in stride. Not that flying this route in soupy weather is as yet a "milk run," but bad atmospheric conditions at the Cleveland terminal are now more of a nuisance than a hazard. Recently dedicated at the Cleveland Municipal Airport was an extensive system of bad-weather landing aids that is expected to make possible a new record in commercial flight completions.

A major part of this landing-aids system is the 1650-foot row of the world's brightest lights, the sun-rivaling krypton lamps. Neon blaze units are alternately spaced with these krypton lamps in the long row, to allow variation in light intensities for different weather conditions. The 11 krypton units flash 40 times per minute with a brilliance of over three-billion candlepower each. Timed to flash in sequence, their effect is such as to point out the runway with a brilliant stroke of lightning.

At full intensity, this system penetrates at least 1000 feet of fog, but for less soupy weather the neon blaze units, which can operate at candlepower outputs up to 10 000 000, can be softened to about 100 candlepower.

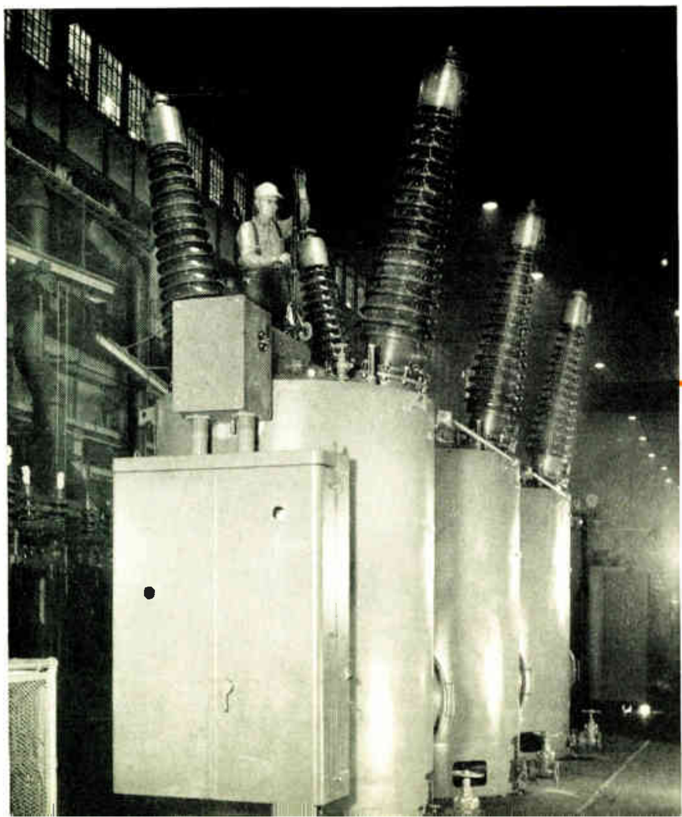
This system of flashing lights works in conjunction with an Instrument Landing System. The ILS guides the pilot to the runway approach on radio beams; from there the row of lights takes over and directs the pilot to a safe landing.

With the completion of the installation of these landing systems, the Cleveland Municipal Airport becomes one of the most advanced centers of modern landing aids. Experience gained here with air-freight service is expected to benefit passenger service and lead to more flight completions in bad weather.



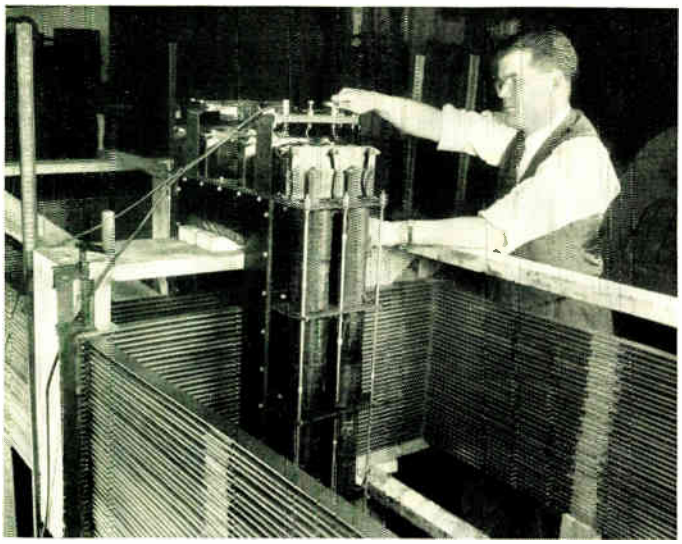
**The "strong arm" of the latest cargo planes is this new hoist, shown installed in the Army's C-97A. Rated at 15 000 pound-inches at 12 rpm, it can lift a one-ton load at almost 50 feet per minute. The complete hoist consists of a 26-volt d-c motor, a magnetic brake, a friction-type overspeed device, a torque-limiting clutch, a gear train, and a worm wheel for manual operation in case of electrical failure. The overspeed device, operated by centrifugal force, prevents rotating speeds of over 14 000 rpm at the motor or 24 rpm at the output shaft. Such overspeeds might be caused by either a heavy overhauling load, or the "running away" of the series motor because of light load. Reduction of speed by the gear train is 582 to 1, accomplished by a triple-stage planetary arrangement.**

**An important feature of this new cargo hoist is its explosion-proof construction. Specially designed flame quenchers let 150 cubic feet of air per minute pass over the commutator and windings.**



## 10-Million-Kva Breakers

**These giant three-phase circuit breakers have the highest interrupting capacity of any breaker built to date—10 000 000 kva. This far exceeds the previous high of 3 500 000 kva. Only one twentieth of a second (three cycles) is required for operation. The tripping function, the separation of the contacts, and the extinction of the arc take place in the interval required for a freely falling body to move three eighths of an inch. Also, the breakers will interrupt the total 10 000 000 kva twice within an interval of but 20 cycles, if necessary. Each section (tank and bushing) of the three-phase, 230-kv unit, to be used on the Grand Coulee project, is over 20 feet high; the complete assembly is 34 feet long.**



**This current transductor, undergoing tests (above), is rated at 75 000 amps—the largest ever built in this country. Sometimes called a "d-c transformer," this device will facilitate metering of high direct current. This current (in the primary winding of the transductor) sets up a magnetic field. The field varies the inductance of the secondary winding, which is energized from a 440-volt, 60-cycle, a-c supply. The secondary a-c exciting current is proportional to the direct current in the primary; a current reading in the secondary therefore becomes a direct measure of the direct current in the primary. Prime advantage of this system of metering is that the secondary is electrically isolated from the primary. The ratio of currents does not vary appreciably over the whole current range up to the rated value. Similar current transductors in ratings from 1000 to 100 000 amps will be available.**

## Bigger Wing Muscles for Naval Aircraft

Just as humans need arm muscles to flex their arms, carrier-based naval aircraft need wing muscles to raise and lower their wings. One of these muscles, which are called wing-fold actuators, is needed for each wing.

Wing fuel tanks were recently added to the McDonnell "Banshee," the Navy's fighter, which uses two Westinghouse jet engines. Operation of these heavier wings and the desire to double the speed of operation have necessitated a new, more powerful wing-fold actuator. The actuator can exert a force of 15 000 pounds through a lever mechanism to fold the wing against a 60-knot wind in a maximum of 17 seconds. The actuator unfolds the wing (an overhauling load) in 10 to 14 seconds. The actuator has successfully withstood the required life test of 3000 duty cycles, each consisting of moving a simulated wing load from unfolded to folded position and back every 10 minutes. Operation is started by controls in the pilot's cockpit and stopped by limit switches on the wing structure.

The new "muscle" consists of a thermally protected motor, a brake, a torque limiter, a gearbox, and a ball-bearing screw jack. The motor is a 26-volt, intermittent-duty, explosion-proof d-c unit capable of delivering 2.25 horsepower, and has temperature rise of 90 degrees C when operated at its rated duty cycle. The brake is of the disc type and is rated 25 pound-inches. It will stop the motion of the wing in $\frac{1}{5}$ to $\frac{1}{30}$ of a second, according to position. The torque limiter prevents overloading of structural elements of the plane. The maximum torque it can transmit is equivalent to a load of 19 000 pounds.

The gearbox combines spur and planetary gearing to give an overall speed ratio of 43 to 1, which reduces the motor speed of 9800 rpm to 230 rpm. The gearbox has a hand release that is used in case of power failure to permit raising and lowering the wings by hydraulic jack. The actuator, with its extendable screw jack, forms a part of the wing-folding linkage.

## Air-Conditioned Plants

Most plant life takes what nature dishes out in the way of weather, favorable or otherwise. Not so the plant specimens in Harvard University's Biological Laboratories, where plant life is studied under optimum conditions of temperature and humidity, rigidly controlled by a precise air-conditioning system. The object here is not to imitate different climates, but to grow plants under controlled conditions so that scientists can learn what conditions affect such things as pigmentation and flowering.

From an air-conditioning standpoint the requirements were exacting. Temperature and humidity variations were limited to less than one degree and one percent, respectively. Control was further complicated by the artificial "sun," a 2600-watt battery of fluorescent and incandescent lamps that causes a considerable cooling load variation when lights go on and off.

The portion of the laboratory involved consists of three separate cubicles and a connecting corridor. Each cubicle contains a plant platform, which can be raised or lowered, and the artificial "sun." Plants are mounted on the adjustable platform, just below the lights; the intensity is adjusted by raising or lowering this platform with respect to the "sun." For example, when a new group of seedlings is being mounted, the platform is moved close to the light; then, as the plants grow, the distance to the tips of the plants is kept uniform by lowering the shelf.

Two compressor condensing units (type CLS-110), with a heat-absorption rate of 36 000 Btu per hour, are used to satisfy the rigid temperature and humidity requirements. One fan system carries heat away from the lamp enclosure; another controls conditions in the rest of the room. A specially designed water spray-chamber system, designed by Carrier-Mandell, Inc., humidifies or dehumidifies the air as necessary. Four Rexvane fans propel air through the system at a rate of 1100 cubic feet per minute. The perforated metal ceiling of the cubicle is used as the inlet for conditioned air, which then passes through the room, past the plants, and flows out through a metal wall similar to the ceiling. Baffles assure that all air passes through the plant area.

This installation provides for temperature settings at any point between 66 and 86 degrees F, and relative humidity variation between 60 and 90 percent. This range covers the optimum for the majority of all known plants. Despite the extremely rigid requirements for this air-conditioned laboratory, all equipment, with the exception of air-washing equipment, is standard.

# What's NEW!

## Simpler Control for Wide-Speed-Range Motor

Adjustable speed of wide range is the order of the day for industrial drives. One means of fulfilling this requirement is the wide-speed-range d-c motor,* which gives an adjustment as high as eight to one by field control alone. The method of regulating this motor has recently been simplified.

With the original scheme, both field windings were adjusted in strength (one field being reversed), which necessitated two rheostats. In the new system, only one winding is varied, using a single potentiometer-type rheostat, which simplifies the control equipment of the motor.

The speed range of a standard shunt motor is generally limited to four to one, a limitation imposed by the effects of residual magnetism, distortion and demagnetization of the main field by the armature, and increased reactance voltage. These factors contribute to instability and poor commutation when the field of the motor is weakened beyond about one-fourth maximum.

However, the speed range can be extended by minimizing these limitations. This has been accomplished in the wide-speed-range motor by using two independent field windings, each having an independent coil on each of the four poles. One of the field windings is connected in the standard manner, producing alternate polarity poles. The second winding is connected with the coils on the upper pair of poles cumulative to the first winding, and the coils on the lower pair of poles differential to the coils of the first field winding.

The first winding is adjusted by the rheostat but the second is kept at constant potential. At base (minimum) speed, both windings receive full excitation. At twice base speed, the top two poles are at approximately 80-percent flux and the bottom two at 20-percent flux. At four times base speed, the upper pair of poles is at about 65 percent and the bottom, 15 percent. At eight times base speed, the upper pair is at 60 percent strength and the bottom pair at minus 35 percent. (The variable field is de-energized at maximum speed.)

Thus, by maintaining stronger field strengths and by reversing two poles, the effective flux is reduced, increasing the maximum speed and hence the speed range. More flux per pole is provided at high speeds, improving the speed regulation and consistency of operation. The effects that limit the speed range of conventional motors have been minimized partly by cancellation, because at higher speeds one pair of poles opposes the other.

The eight-to-one motor is adaptable to almost any equipment requiring a wide speed range. Because this motor, like all shunt motors, has a constant-horsepower characteristic, it is particularly suitable where high torque is required at low speed. Because a two-circuit armature is used, the motor can be built only in ratings of relatively low horsepower.

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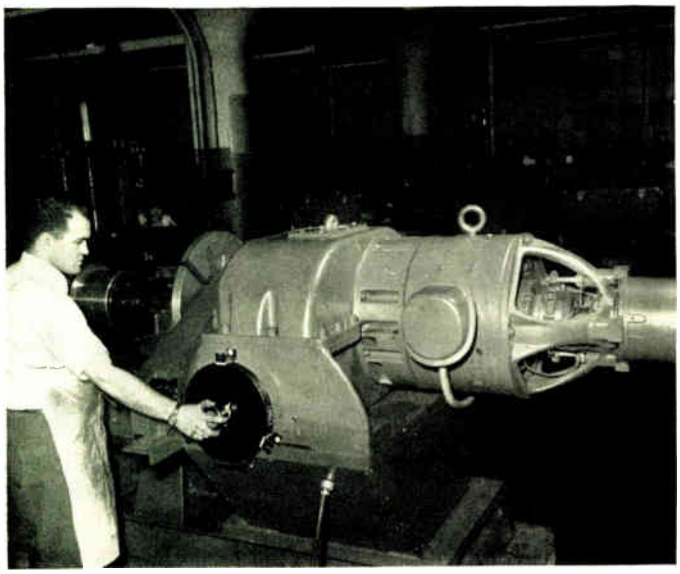
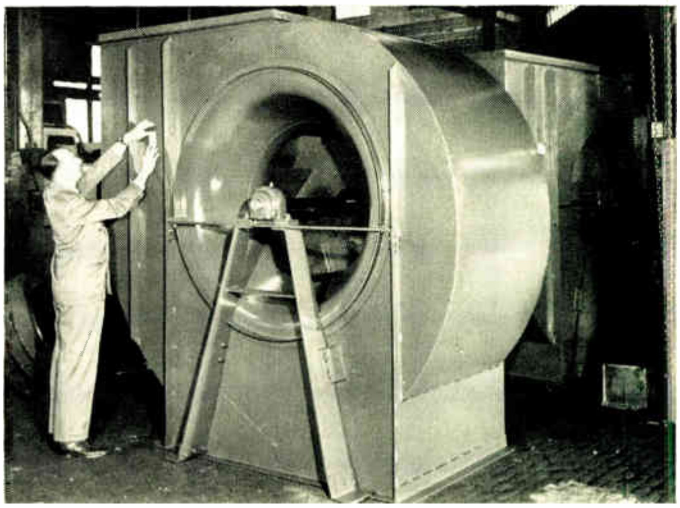
*The principles of the wide-speed-range motor are discussed in the article "Eight-to-One Range Adjustable-Speed D-C Motor," by R. W. Moore, *Westinghouse* Engineer, November, 1947, p. 184.

**The wide-speed-range motor with simplified control.**





**The Silentvane Design 10 fan.**

## Efficient Wind

Two newly designed partners in air handling—the Silentvane 10 and the Turbovane 10—boast the highest static efficiencies of any commercially known centrifugal fans.

The Silentvane 10, for use in heating, ventilating, and air conditioning of commercial and industrial buildings, reaches a static efficiency of about 80 percent. This represents an increase in efficiency of about two percent over previous models. This gain was brought about by design changes in the blading, wheel, inlet, back plate, and scroll of the fan. The most significant of these changes is in the scroll, the spiral housing that surrounds the revolving blades. The conventional scroll design somewhat obstructs the flow of air through the system; the new design eliminates this, with improved performance and quieter operation the result. The Silentvane 10 is available in 23 different wheel diameters, the largest of which stands 18 feet high in its housing, and will have a capacity of 480 000 cubic feet per minute.

The heavy-duty partner of the Silentvane is the new Turbovane 10. Basically the design of this fan is similar to the Silentvane, but since it is built for higher pressures, and thus greater tip speeds, the construction must be heavier to add strength. This fan also is available in 23 wheel diameters, and capacities from 2000 to 500 000 cubic feet per minute. Its principal application is in supplying forced-draft air for combustion purposes, although it is also used for air-supply purposes in a number of other heavy industrial applications.

One prime difference between these two designs is in the pressures they develop. Applications such as ventilation and air conditioning require pressures considerably below 6.75 inches, which is the Silentvane's maximum. Forced draft and some dust collecting operations require the higher pressures of the Turbovane.

The use of these highly efficient fans can cut thousands of dollars from the power bills of large users of fans. A forced-draft fan that costs $7000 may run up a power bill of $20 000 in a year's time. Increased efficiency pays off not only in better performance but in dollars and cents.

## Relay Questions? Here's the Answer

The popular book on protective relays, "Silent Sentinels," is again available. This book began its illustrious career in 1924 as a pamphlet produced by Westinghouse as an educational service to engineers on relaying matters. It achieved instant popularity both with practicing engineers and with students, resulting in the use of many thousands of copies of the several reprints and editions. Because the book contains so much practical information relating to power-system faults, short-circuit voltage and current calculations, bus and circuit protection, and related matters, it has rightfully achieved the status of a textbook. The fact that the discussions are written in language as simple as the subject will allow has greatly widened its appeal.

The new edition is enlarged and extensively revised. By comparison with the last revision (1940) the text is about one fifth larger and contains one entirely new chapter, "Protection of Multi-Terminal Lines."

The price of a single copy, postpaid, is $3.00; in quantities of 20 or more shipped to a single address, $2.70 per copy. To educational institutions the price of 1 to 9 copies is $3.00 each, postpaid, or for 10 or more copies, $2.00 each. All orders should be sent to the *Westinghouse* ENGINEER, 306 Fourth Avenue, P. O. Box 1017, Pittsburgh 30, Pennsylvania.

## Propulsion Turbines Are Not Far Behind

The maximum operating temperature of central-station steam power plants has recently risen to 1050 degrees F, a noteworthy achievement.* Of equal significance is the increase in operating temperature—to 1000 degrees at 600 pounds steam pressure—of ship-propulsion plants. (Usual steam conditions for new construction on this size plant are 850 degrees at 600 pounds.) Three tankers, the first to use this new high temperature, are being built for Philadelphia Tankers, Inc. They will be completed this year by the New York Shipbuilding Corporation.

The geared-turbine propulsion equipments are being built by Westinghouse, together with the turbine generators and switchboards for the vessels' electrical service and the many auxiliary motors and controls. The main propulsion equipment, consisting of cross-compound turbine, reduction gears, condenser, air ejectors, and lubricating oil system, will be built as a "package" unit mounted on a single foundation built into the ship.

The electrical system, which will be 450-volt, 3-phase, 60-cycle, is also unique. Each tanker will have, in addition to two 750-kw turbine generators, a third generator rated 700 kw, driven from the second reduction pinion of the propulsion gear. When the vessel is running at constant speed near its maximum rating, as is usual, this geared generator can be manually switched to the auxiliary bus and will supply all auxiliary power to the ship. This scheme takes advantage of the high operating economy of the 18 000-hp propulsion turbine, as compared to that of a smaller 750-kw turbine. During steady running conditions, the attached generator will also supply power to one of the 750-kw turbine generators, operating it as a motor. This drives an auxiliary d-c generator and the exciter that supplies excitation to both the attached generator and the 750-kw turbine generator. If for any reason the ship must slow down, reducing the speed of the geared generator to below the equivalent of 53 cycles, the auxiliary turbine generator automatically picks up the load and the geared generator is disconnected from the bus.

Considerable study and experience have resulted in the owners selecting steam conditions of 600 psi and 1000 degrees F total temperature. The choice of steam conditions together with the unique electrical scheme will make these tankers extremely economical in operation.

The application of the high-temperature package power plant to ship propulsion is a development fostered by engineers of Philadelphia Tankers, Inc. and Westinghouse.

## R-F Speeds TV-Tube Production

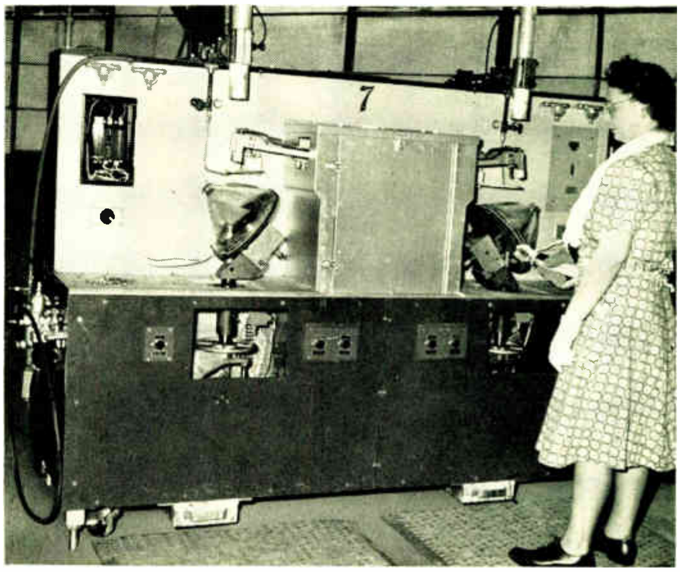
Radio-frequency heating is helping to set new production records in the manufacture of television viewing tubes. The assembly of these tubes is a difficult operation, involving many different components.

The Kimble Glass Division of Owens-Illinois Glass Company, a glass-bulb manufacturer, is using r-f heating to seal a metal anode contact button into the side wall of the bulb cone. To prevent thermal shock, the glass cone is preheated and then placed in a stationary fixture having strip heaters to maintain its temperature. The anode contact button and a cup-shaped facsimile of the button (but of slightly smaller diameter) are held by two hollow magnetic rods. First, the facsimile is lowered by air pressure through an induction-heating coil, which brings it to white heat in a few seconds. The white-hot facsimile then pushes its way through the glass wall, leaving an opening. Meanwhile, the rod holding the facsimile has passed through the coil, where it is heated, losing its magnetism as a consequence. The rod, aided by air pressure in its hollow center, loses its hold on the facsimile, which falls free into the cone interior, from which it is removed. The rod is automatically withdrawn through the opening without touching the glass.

An arm indexes automatically, bringing the real anode button into position. It, too, is heated by the same induction coil and lowered into the opening a fixed distance, after which a limit switch cuts off the r-f power. When the glass cools, the rim of the opening seals the anode button firmly into the glass, completing the operation. The r-f power is switched to another work position, thus enabling one 5-kw generator to serve a second fixture while the first is being reloaded with another bulb cone, anode button, and facsimile.

The rate of production is two tubes per minute per r-f generator (one tube per fixture), several times that possible with previous methods of heating. Eight generators serving sixteen fixtures are in operation at the Kimble plant.

**The picture below shows TV-tube production at the Kimble Glass Division of Owens-Illinois Glass Company. The r-f generator is located directly behind the machine shown. The use of r-f heating has enabled a sizable increase in production over other methods.**



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*"Sewaren Station—Pioneer Power Plant," *Westinghouse* ENGINEER, September 1949, p. 142.

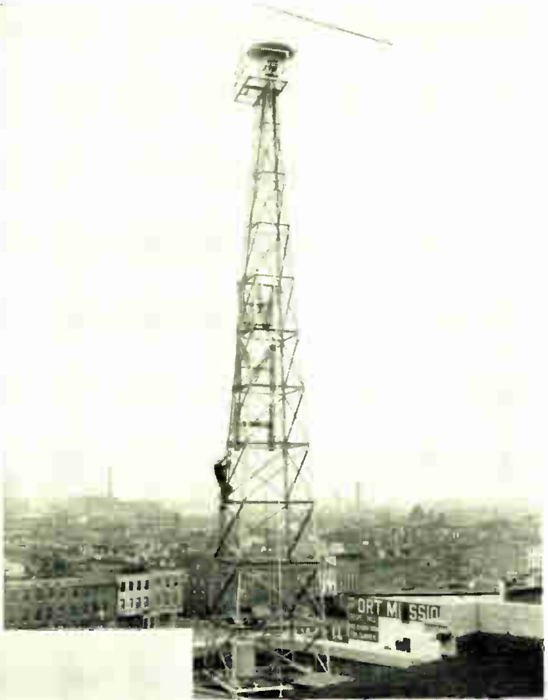
# Radar Guides Harbor Traffic

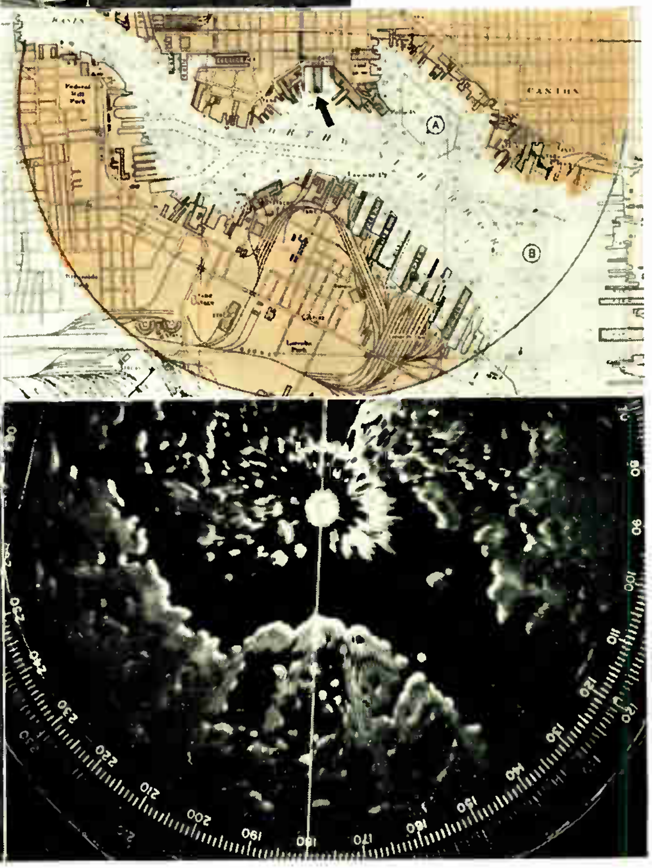
THE VIGILANT eye of marine radar now surveys ship traffic in Baltimore harbor in fog and bad weather. The third major port in the world to institute such a harbor radar system, Baltimore is using its equipment as part of a navigation-aid research program designed not only to assist ships entering and leaving the harbor in bad weather, but also to provide continuous observation of shipping and give immediate information on the location of shipping casualties in the harbor.

The console of the radar set (below) is located in the radio control room, close to the transmitting facilities of the ship-to-shore voice and code services, so that messages can be given immediately to ships in the harbor. The Westinghouse radar set (type MU-1) has a 12½-inch screen and shows the movement of shipping at ranges from 80 yards to 40 miles. The radar antenna (shown at right) is located on one of the radio towers, some 140 feet above the water. The transmitter is located at the bottom of the same tower.

An idea of the ability of this harbor scheme is given by the map and radar-scope scene shown below. Land areas, ships, and other objects show as light areas on the end of the tube, water areas as black. With an "electronic ruler"—an adjustable circle on the radar scope—distance of objects from the pier can be measured with an accuracy better than one tenth of a mile. In addition, the radar observer can reference the position of the vessel to the radar presentation of buoys and prominent landmarks.

Although the feasibility of this scheme has been demonstrated, a period of experimentation will precede the actual use of the system during poor visibility. During this period pilots will be made familiar with procedure, operators will receive additional training, and the harbor will be checked for possible blind spots where harbor installations block the path of the straight-line radar waves.





**With the radar unit set at the one-mile range, the operator observes the bottom picture on his scope, compares it to the same area on the chart above. White spot in the center of the scope is the pier where the set is located; arrow shows its position on the chart of the harbor.**

# Personality Profiles

In the early days of radio, men with enough knowledge to tackle the strange innards of a transmitter or receiver were few and far between. *J. R. Heck's* father was one of these then-rare individuals, and was operating spark transmitters about ten years before commercial broadcasting began. Thus at an age when most children are still trying to get started on their ABC's, Heck and his older brother were sending messages to each other by telegraph over buzzers set up in different parts of the house.

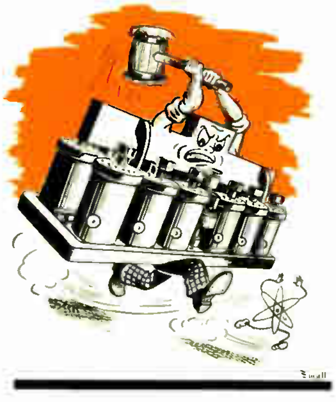
With this auspicious start Heck's career seemed fairly well set, and it was. In the next decade or so he picked up a wide background of communication and radio knowledge by repairing and experimenting with receivers and transmitters.

From 1934 to 1942 Heck concentrated on the broadcasting end of radio, serving the last four of these years as chief engineer of Station WMMN in Fairmont, West Virginia. He joined Westinghouse in 1942, and in the following two years played a part in the development of magnetrons, klystrons, and other tubes. Since January, 1944, Heck has been a design engineer at the Industrial Electronics Division, and has worked on numerous projects, including power-line carrier, railroad radio, and marine radar.

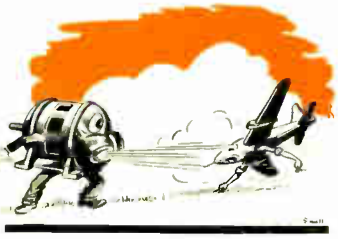
* * *

*L. A. Kilgore*, seen twice previously in these pages with wind-tunnel drives as his subject, brings a story of a-c application to another field—nuclear research. As assistant manager of A-C Generator Engineering, Kilgore has continual supervision of the design of large motors, generators, and ignitron rectifiers.

Teaming up with Kilgore are *C. S. Hague* and *J. L. Boyer*. Hague, currently with the Petroleum and Chemical Section of the Industrial Sales Department, obtained his B.S. in E. E. from Johns Hopkins in 1940. From there he came to the Westinghouse Student Training Course. He was with the Steel Mill and Electronics Sections of the Industry Engineering Department until 1947 when he came to his present position.



J. L. Boyer graduated from Rice Institute in 1942 with a B.S. in E. E., and came directly to the Westinghouse Student Training Course. After this he became design engineer in the A-C Engineering Department and later manager of the Rectifier Development Section, which position he now holds.



It seems that boats are playing an increasingly large part in *S. L. Lindbeck's* life, both career-wise and leisure-wise. This could have been expected, though, because he was born in the San Francisco Bay area and ships and boats were an early interest. The war years, spent in marine-engineering work with Westinghouse, brought cruises off the East Coast and to Cuba on Navy transport-ship trials that whetted his appetite for salt air. He is now to continue his experience with things nautical. Lindbeck has joined the Atomic Power Division where he will work with the revolutionary application of atomic power to ship propulsion.

Receiving a B.S. in E. E. from the University of California in 1941, Lindbeck immediately came to the Westinghouse Student Training Course and subsequently joined the Marine and Aviation Section of the Industry Engineering Department. In 1944 he received an M.S. from the University of Pittsburgh.

While Lindbeck has appeared in our pages but three times, his present assignment may make further appearances difficult. However we maintain hope that eventually he will be able to unfold some part of this new story to us.

* * *

The high-intensity short-arc lamps described in this issue by *George Freeman* make some of the previous lamps he has worked on pale to insignificance, but only as far as brightness is concerned.

Most of Freeman's career has been spent on vapor-discharge light sources, although immediately after his graduation from Brown University (B.S. in E. E.) in 1933, he helped develop the coiled-coil filament for incandescent lamps. In 1935 he started work on the then-new mercury-vapor lamps. He helped devise the first 250- and 400-watt mercury lamps made of glass, which are still standard. He later developed more compact mercury lamps using quartz glass. These lamps are also still standard, having had their spectacular debut at the New York World's Fair.

Freeman also played a large part in the development of the RS sun lamp, the first such lamp to be complete in itself, with no external auxiliary equipment.

Freeman's special forte has been the development of suitable seals for various kinds of vapor lamps, a task in which he has been eminently successful.

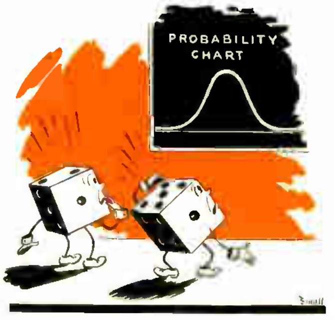
He is now section engineer in charge of vapor-lamp development, which includes, among others, Sterilamps, sun lamps, photochemical lamps, and many varieties of mercury lamps.

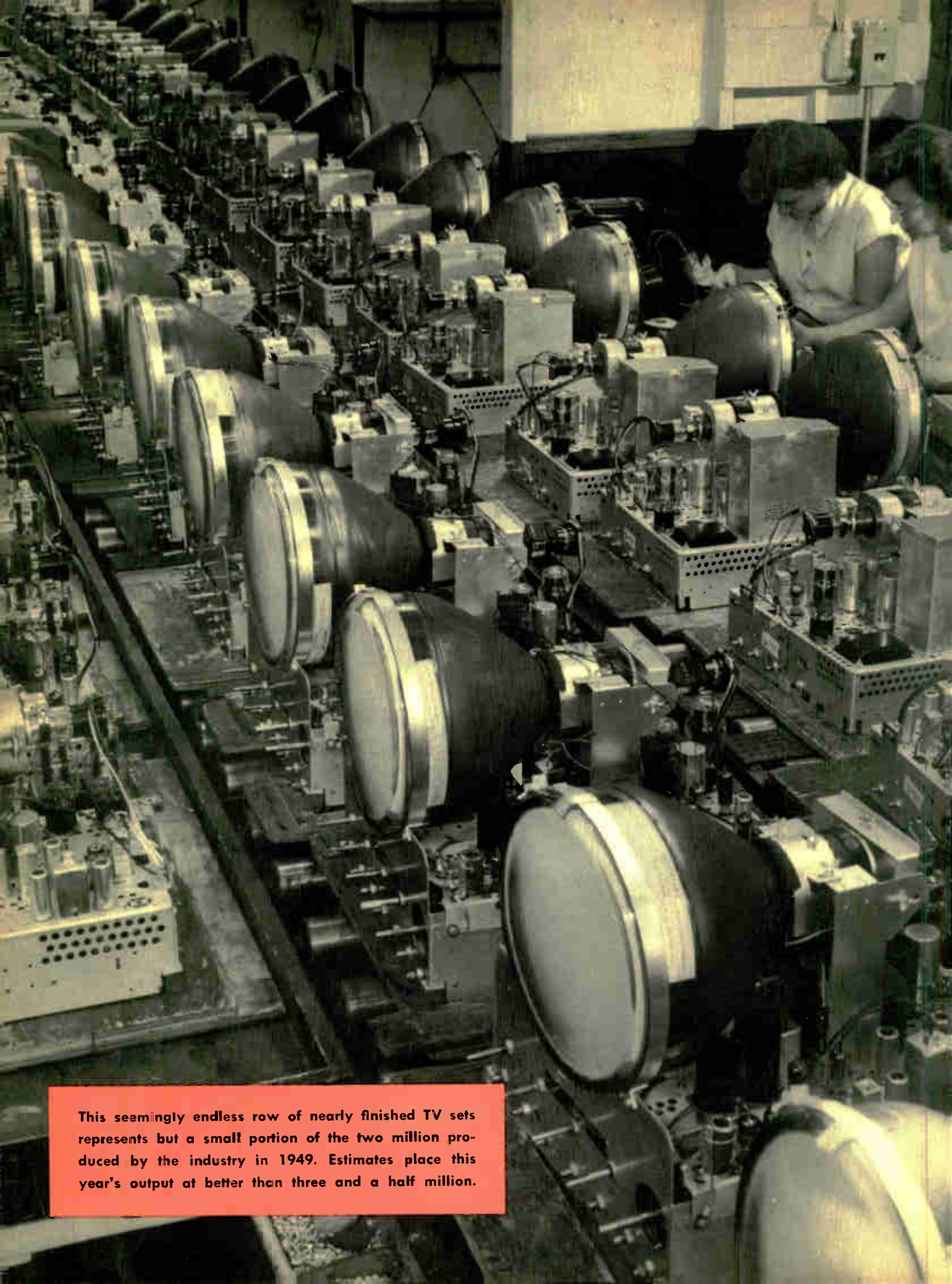
* * *

Some time ago *L. R. Hill* and *P. L. Schmidt* tackled a sizable task—that of simplifying statistical methods to make them a more useful tool to engineers in their department. Their results were such that we felt their adaptations would be of value to all engineers.

Strictly speaking, neither Hill nor Schmidt is a mathematician, at least in the theoretical sense. Hill, who is now assistant manager of the Materials Engineering Department, got his B.S. in Chemistry at West Virginia University in 1935; he followed this with an M.S. in Physics in 1936. After a brief stint with the West Virginia Pulp and Paper Company, Hill joined Westinghouse in 1938, where his work has covered a wide range of materials and processing problems.

Schmidt received his A.B. degree from Capital University in Columbus, Ohio, in 1939, and went on to get his Master's degree in Physics at Ohio University in 1941. After graduation he taught high-school subjects in Pennsylvania; when he came to Westinghouse in 1943 for summer work he was offered and accepted a position in the Materials Engineering Department. Since then he has worked on various projects, among them the job of developing surface coatings for electrical steel to provide interlaminar resistance. This problem introduced Schmidt to the practical application of statistics.





This seemingly endless row of nearly finished TV sets represents but a small portion of the two million produced by the industry in 1949. Estimates place this year's output at better than three and a half million.