WESTINGHOUSE Engineer

May, 1941

"Research is seldom wasted, and few developments are ever unnecessary. It is true that today the electrical manufacturing industries are concentrating on the rather grim articles of defense. But we never lose sight of the fact that any new improvement we make in our equipment can and will be applied to the products of peace . . ."

Mr. M. W. Smith, on the AIEE Radio Program
February 18, 1941, over NBC.

Mr. M. W. Smith, as Vice President of Westinghouse, has charge of all engineering activities of the company. He rose to this post by a steady succession of engineering positions that began in 1915 when he graduated from Texas A. & M. On completing the graduate student course at East Pittsburgh, he was given the unusual opportunity of studying special problems under B. G. Lamme's personal direction. Then came advancement in regular, almost rhythmic order. He became Manager, Alternating-Current Generator Section in 1927 and Manager, Alternating-Current Machinery Division in 1930. He was appointed Manager of Engineering for the company in 1936, and in 1938 was named Vice President.

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In This Issue

COVER ILLUSTRATION: *The artist, taking his cue from Pennsylvania's new 160-mile super-highway, has pictured a vapor-lighted highway intersection of the not distant future.*

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The new Harrisburg to Pittsburgh Turnpike gives a preview of the highways of tomorrow. Conspicuous among the innovations is the lighting of the tunnels and interchanges. The seven tunnels, totaling seven miles, are lighted by special 250-watt mercury-vapor lamps.

Westinghouse Engineer

Making Light for Tomorrow

Important new light sources are streaming from the lamp and lighting laboratories at a rate faster than any time in the half century of electric lighting. Incandescent lamps, still the most useful of all, continue an unbroken rise of efficiency and to assume scores of new forms. Mercury-vapor lamps developed within the last ten years are being used in industrial plants, for floodlighting of yards, and for illumination of tunnels. The newcomer, the fluorescent lamp, with its excellent efficiency is again raising our standards for artificial lighting. Other conspicuous developments in lamps include those using the internal-reflector principle, radiant-heat lamps, and the "glamour" lamp of them all, the "black-light" lamp, the radiations of which are nearly confined to the invisible region.

S. G. HIBBEN
Director of Applied Lighting, Westinghouse Lamp Division

NEW ILLUMINANTS and improvements in illuminants have been produced during the last couple of years faster than at any period in lighting history. In this time, progress in illumination has been equivalent to that normally recorded in a decade. The stimulus of the national defense program, education from the great fairs, and a quickened interest in better living have all contributed to the advance. Most credit, however, should go to the world's fairs. Each great exposition has been identified with some new and often radical means of producing light, or at least served to present the new method simultaneously to a large proportion of the population. Each fair has been followed by a steeply accelerated use not alone of the new light sources, but of the older types of lamps as well. Fairs have been tremendously successful in awakening people to the need and possibilities of better lighting.

The Panama-Pacific Exposition of 1915 ushered in tungsten-filament lamps of large wattage for exterior floodlighting, with colored beams from carbon-arc searchlights. In 1926 the Philadelphia Sesqui-Centennial Exposition presented color-coated incandescent-filament lamps with spirally coiled filaments surrounded by the inert nitrogen and argon, in sizes down to and including the commercial 60-watt lamp. High-voltage (10 000-volt range) neon and mercury tubing for architectural decoration, and the high-intensity mercury-vapor lamps received public introduction at the Chicago Century of Progress Exposition in 1933.

Noteworthy above all others, the New York World's Fair of 1939–40 introduced the radically new and efficient fluorescent lamps; new sizes of quartz mercury-vapor lamps for illumination of foliage; the production of short-wave visible colors for underwater fountain lighting; new projector lamps; and the popularly termed "black-light" lamps or long-wave ultraviolet illuminants to give a wide variety of fluorescent effects.

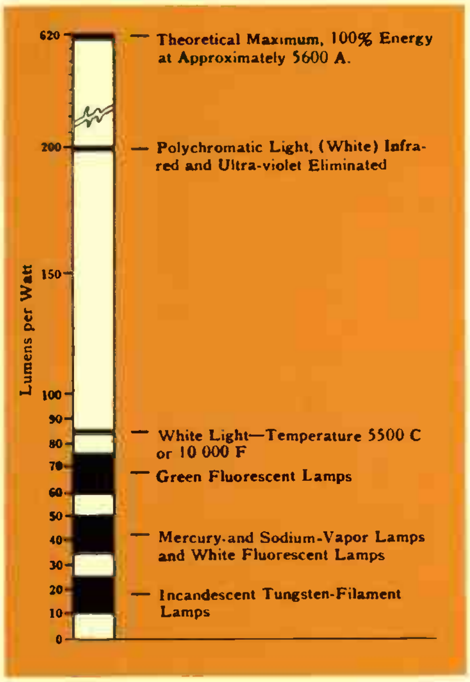
Incandescent Lamps

Whereas attention naturally focuses on the new or unusual illuminants it should not be forgotten that the familiar incandescent lamp is, and for many years to come will be the basic, most commonly used lamp for the seeing job. Some six thousand sizes and types of incandescent lamps are manufactured regularly and the list continues to grow steadily. It is interesting to note that the long-filament lamp known as the Lumiline is growing at a normal rate in spite of the fact that the fluorescent lamp of similar shape and greater efficiency has been introduced since. The field of lighting is so broad and relatively so little developed that in general each new type of lamp exposes more needs than it satisfies; hence, a new light source more often than not simply develops new applications instead of displacing some apparently competitive long-established light source.

The incandescent lamp, not to be left behind by the fascinating developments in metallic-vapor and other lamps, has been moving ahead steadily in two directions: to new forms, and to greater efficiencies of the old stand-by forms. Improvements such as double-coiled Mazda tungsten-filament lamps, and more precise manufacturing methods coupled with lower costs, means that the purchaser obtains two and a half times as much light for the same expenditure as in 1926. The Mazda lamp with drawn tungsten filament still improves as a light source; in 1913 the 60-watt lamp had an output of 560 lumens; today it is 835 lumens—a 47 per cent increase. The rate of improvement has been constant for the last twenty years.

More Concentrated Filament Aids Color Projection

Like the famous line about the chicken and the egg, it is often difficult to tell whether a new lamp results from a need or whether a need is created by the lamp. Such is the case with one of the most interesting of recent incandescent-lamp developments, the concentrated-filament super-incandescent lamp for projection of colored images and pictorial murals. Examples at the New York World's Fair included the cloud images on the Perisphere, the black and white motion murals inside the Perisphere and the projection of the greatly enlarged colored Kodachrome transparencies in the Eastman Kodak Exhibit. All of these uses necessitated the highest possible wattage in the smallest possible bulb. The result is a new lamp, less than a foot long and some three inches in diameter, of superior heat-resisting glass, cooled by air blast. Within is clustered, in a space not more than ½ inch square, several tungsten coils consuming 2500 watts—three horsepower! The filament wire of this new lamp burns at one half the temperature of the sun's atmosphere, or within 200 degrees of its melting point (which is 3390 degrees C.), without squirming or warping. The output of 66 300 lumens is remarkable. It is needed for tomorrow's projection of color pictures.



Comparative efficiencies of light sources.

Bulbs That Are Their Own Reflectors

Another interesting product of lamp evolution is the lamp in which the reflector and light source are combined in one glass bulb. The entire inner surface of this new lamp is mirrored by vaporizing aluminum in a vacuum. Then, by etching with alkali, the thin metallic coating is removed from the end portion of the bulb through which the light is directed.

This internal-reflector lamp has many obvious advantages. A separate reflector is unnecessary. The reflecting surface, being inside the bulb, does not tarnish or get dusty. A reflector and filament built as one fixed unit provide a more precise control of the light beam than does a combination of lamp and separate reflector.

The principle of the internal reflector has spread rapidly to different forms used for a wide variety of purposes. The sealed-beam automobile headlight introduced on almost all of the 1940 cars is perhaps the best known.

Demand for a lamp of very high beam candlepower that could be mounted in a restricted space led to the development of the internal-reflector lamp in several forms. Good beam control is achieved by careful adjustment of the parabolodial bulb contour to a new form of filament mounting that simulates a flattened disk source. The bulb is about five inches in diameter and is used in both 150- and 300-watt sizes. Each size has two beam patterns, spot and flood. To obtain a narrow, concentrated beam for the spot lamp, the section of the bulb in which the light escapes is left almost clear, giving little diffusion of the fairly sharp beam of the silvered parabolic section. The flood or widespread beam is secured by a heavier frosting on the inside of the glass.

These bulbs do not have heat-resisting glass and therefore are restricted to indoor use. They are used extensively in stores for high-lighting displays, for show-window lighting, for illumination of temporary machines and the like.

A companion development is the molded hard-glass bulb, slightly smaller and designated as the projector type. This lamp is principally for outdoor operation. The lamp is made in two forms, to give a narrow-beam spotlight or a wide-beam floodlight, the characteristics dependent upon the configuration of the end section of the glass bulb. Heretofore, glass lamp bulbs had all been blown; these, for greater accuracy of contour, and increased strength, are molded in two sections and fused together. The result is a rugged lamp of closely controlled beam pattern.

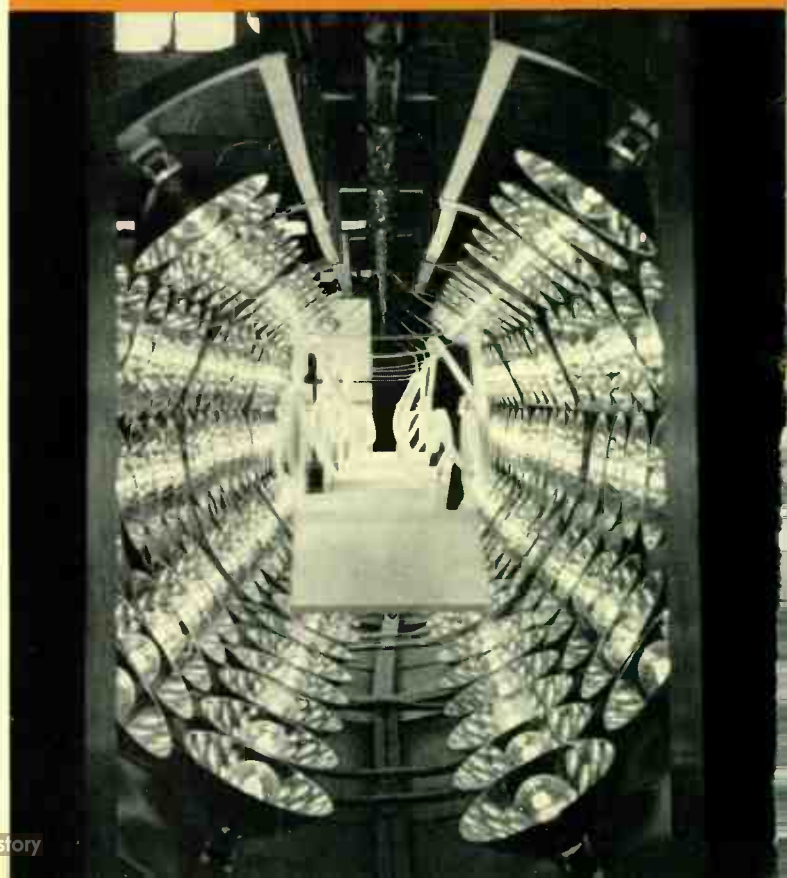
The internal-reflector idea has been applied to photoflood lamps also. This has been a boon to the amateur photographer because it greatly simplifies his paraphernalia for the taking of indoor movies and stills. The internal-reflector principle has also been applied to one form of radiant-heat lamps.

Lamps That Heat Instead of Illuminate

For several decades a major objective of filament-lamp research and engineering has been to reduce heat losses or radiations and to shift more and more of the radiant energy into the shorter wave regions, i.e., into the visible spectrum, making the lamp more efficient. Each year has seen a gain of approximately one per cent in luminous efficiency of tungsten-filament Mazda lamps. Recently, however, a rather curious reversal of this procedure has occurred. A new group of filament lamps has been introduced, the chief objective of which is to emit the maximum amount of their energy as radiant heat and as little as possible as light. Such units become drying lamps or infra-red heaters, applicable to a large number of jobs where ordinary hot-air heat would be much slower and costlier.

There is nothing mysterious about the drying lamp. Radi-

Porcelain-enameled panels, running this gauntlet of radiant-heat lamps, in a production-line tunnel, are completely baked in a few minutes.



ant heat from the sun penetrates the vast distances of sub-zero interstellar space with virtually no absorption. Yet on striking the surface of the earth or other objects, this radiant energy is transformed into sensible heat. For example, a lacquered or varnished surface subjected to radiation of a drying lamp dries from the under-surface outward because all the radiant energy is stopped at the surface of the base material on which the lacquer is applied. Moreover, energy from radiant lamps can be effectively concentrated, reflected, instantly turned on and off. Particularly useful is this control for production-line operations where rapid drying either shortens the production line or the length of time the object is on the line. It may decrease the time interval between successive manufacturing operations.

Applications of radiant lamps are already numerous. They are being widely used for drying lacquers, enamels, paints, photographic negatives and prints, food products, blueprints, photostats, motor and transformer windings, textiles, glue, ink, paste, latex, paper, cardboard, etc.

One fanciful, but not impossible, application of the heat lamp illustrates the principle. Such a lamp with a suitable filter to absorb visible light could be installed in the ceiling above a bed. Because the radiant energy would be absorbed by the bed covers or directly by the body of the occupant, without being wasted on cool winter air, a person could sleep in complete comfort with only the lightest of bed covering.

Where heat without much visible light is desired as in drying porcelain-enameled surfaces, filters can be readily used over the drying lamps. These are 80 per cent or more efficient in transmission of the radiant energy but effectively stop the visible light.

Vapor-Discharge Lamps

Passage of current through a vapor of mercury has turned out to be one of our most useful sources of illumination. Likewise it is one of the most versatile, as demonstrated by the fact that this principle is the basis not only of the present popular high-intensity mercury lamp, but also of the Steri-lamp, the fluorescent lamp, the "black-light" lamp, the sun-lamp, and the sodium lamp.

The mercury-vapor lamp is not new—by a good many years. But it was not until vapor pressure was greatly increased that its full value became apparent. Increasing vapor pressure greatly increases efficiency and improves quality of light output.

The High-Intensity Mercury-Vapor Lamp

A single size of high-intensity mercury lamp, 400-watt, was introduced to the public in 1933 at the Chicago World's fair. It grew, under the impetus of the recent New York fair, to at least a dozen different sizes and types. In sizes larger than 250 watts they light the high bays of industrial plants, and in the lower wattages their most popular use has been to accentuate the crisp green beauty of foliage, or to mix with daylight.

The light source in a mercury-vapor lamp is concentrated in fairly small space. Even in the new 1000-watt, water-cooled unit it is no larger than a cigarette. Thus it lends itself well to good control of the beam, which leads to application for projection or controlled-beam floodlighting, street lighting, etc. Dozens of 400- and 100-watt units were used at the two recent fairs for floodlighting large building surfaces and water displays.

The high-intensity mercury lamp has excellent efficiency, about 50 lumens per watt (incandescent 10 to 20). Its visible output is concentrated into narrow bands in the yellow-green-blue part of the spectrum. For some work this may be objectionable. For many applications, however, color is not as important as high efficiency; for example there are many industrial plants, particularly those air conditioned, in which the lamp losses must be removed by the refrigeration system. Most recent striking application is the use of

Fluorescent lamps have proved a great boon to shops and stores such as this, permitting three times the light without increasing the current consumption directly or by adding to the air-conditioning load.

the 250-watt lamps to light all the seven miles of tunnels on the Pennsylvania Turnpike between Harrisburg and Pittsburgh. In this installation 1000 lamps are mounted in open Alzak reflectors, in the ceiling of the tunnels. Here the principle of lighting by silhouette is used. The cars themselves are not brightly lighted, but are seen as dark objects against a white pavement.

Contributing greatly to the success of the mercury lamp was the development of a method by which the vapor and its discharge are enclosed in an inner quartz chamber only about half as large as the previous glass one. This concentrates the discharge and the lamp thereby gains slightly in as is the case of the heat from incandescent lamps. It is radiated heat that makes a person feel warm. A fluorescent lamp seems, to a person a few feet away, to give off only one fourth as much heat as an incandescent lamp producing the same illumination.

The fluorescent lamp has multitudinous uses, which are increasing rapidly. It made its appearance at the fairs for decoration and illumination, separately and jointly. It is to be found now in scores of offices, drafting rooms, factories, stores, restaurants, night clubs, and is beginning to enter the home for illumination of bathrooms, kitchens, playrooms. Applications have been greatly extended by the recent

Typical new lamps: an internal-reflector lamp, a 100-watt "black-light" lamp, a 1000-watt incandescent lamp, and the 400-watt quartz mercury lamp.

efficiency. Because of the higher pressure and temperature it emits a composite light of whiter color. This is an important advantage likely to influence future designs of high-pressure vapor lamps.

A much larger lamp has been added to the high-intensity mercury group. It is a 1000-watt, water-cooled unit. This was first used at the New York fair for spectacular floodlighting. Other applications, some of them still in the trial stage, include television lighting, blueprinting, sound recording in motion-picture work, photography, and photo-mural work.

Popularity of Fluorescents Rises Rapidly

Of all the children of the mercury-vapor lamp the most promising and the one growing at greatest pace is the fluorescent lamp. It makes use of the fact that certain minerals called phosphors have the remarkable ability to transform energy in the ultraviolet or invisible region into visible energy—and do so with remarkable efficiency. The green fluorescent with highest efficiency of all produces 75 lumens per watt; daylight 45; white 53 (average Mazda, about 15).

These lamps, being long and tubular have a low surface brightness, which is an advantage for most purposes, but their light, of course, cannot be readily focused. Because of the high efficiency losses are low, and the tubes are cool, which is a desirable feature for air-conditioned areas. Of the little heat released most is by conduction instead of radiation increase in sizes available. The six-watt nine-inch lamp is used, for example, for illuminating airplane instruments; the new 100-watt 60-inch by 1⅛-inch to get high illumination levels for industrial plants and over drafting boards.

Even though the fluorescent lamp is only a few years old striking improvements have already been made by developments of better phosphors and better manufacturing methods. Lamp life has been stepped up from 1500 to 2500 hours on standard types. Efficiencies, already high, have been improved: the white lamp by 15 to 20% with an improvement in color; the blue by 20%; gold, 40 to 50%.

The development of the fluorescent lamp has not been without its problems, the severest of which have been solved or are nearing solution. Two of the worst problems, low power-factor and a serious cyclic flicker, received simultaneous and ingenious solution. Early experiences at the 1940 fairs showed that the twin-lamp control unit, that is, a device to burn two lamps on one combination of reactor and capacitor, would reduce the stroboscopic effect to such an extent as to make it negligible in ordinary lighting, provided the lamps composing a pair are close enough together to remain in the central field of view. Correction is not perfect but the stroboscopic effect is no longer noticeable. In addition, the power-factor for the pair of lamps is raised from some 60 to 90–95 per cent. This development started the fluorescent lamp on its real road to success.

"Black Light" Finds New Uses

One important characteristic of high-intensity mercury lamps is radiation in the near ultraviolet region, particularly in the wave lengths of 3654 and 3129 angstrom units. These sources lend themselves to production of "black light" if visible radiation is absorbed by either an accessory filter or a deep-purple glass bulb. One such useful lamp developed in connection with fluorescence was the 100-watt mercury unit enclosed in a bulb of deep-purple glass, which, in a suitable reflector, requires no other filter. The bulb glass has a peak transmission at about 3600 Å; and has very little transmission through the visible spectrum although it possesses a secondary transmission peak around 7000 Å, or in the deep visible red. However, the slight purple visible emission is not objectionable. These lamps now constitute a convenient way of generating radiation required for fluorescence of commercial paints and pigments.

Delineation of road hazards or shelters during blackouts, softly glowing theater carpets, discernment of forgeries and erasures, analysis of minerals, scores of tricks on the theater stage have followed development of these "black-light" lamps. Often the light source itself is invisible and only the object made luminous.

Fluorescent lighting and "black" lighting are not as dissimilar as might be supposed. Each radiation in the ultraviolet region is caused by the passage of current through mercury-vapor and is transformed by some substance into visible light. In the case of the fluorescent lamp the phosphor is a coating inside the tube itself. With "black light" the object to be discerned is coated with the fluorescent or phosphorescent substance. In the studies of this fundamental phenomenon it was found that some pigments are lethargic in their response or have relatively slow rates of decay. In fact some possess quite noticeable phosphorescent characteristics and this brightness requires about a second to decay to half its initial value. This attribute may be put to work, say, to make stair treads in public buildings glow even minutes after a power failure or black-out. An ornament in a bedroom could be made to glow, which would slowly fade after the lights are turned out.

The light-blue phosphor of the commercial Mazda fluorescent lamp emits considerable radiation in the wave lengths at and just below the short-wave end of the visible spectrum, hence for local application of "black light" these could be used in purple glass tubing or cylindrical filters. One service would be to light dials of an airplane, where the observer's eyes should remain "dark-accustomed" but yet able to see instruments.

Where the expense of the mercury-vapor controlling transformer is not justified or where only direct-current is available a substitute "black light" source is available. It is a 250-watt filament lamp in a black glass bulb and burns on either current with a life of 150 hours. By comparison with the 100-watt mercury lamp it provides about half the brightness on the fluorescent target.

Light from Other Vaporized Metals

Instruments for making light in future years will possibly include the cadmium-vapor lamp, both because its output in the red, green, and blue spectrums gives favorable color and because it has a strong emission at a wave length that produces erythema or skin tan. Thus a cadmium lamp may become a companion of the mercury lamp in barber shops, beauty parlors, nurseries, or in places where sunlamps have been used. Efficiency is low, however, from 3 to 20 lumens per watt, depending on pressure inside the bulb.

A modern, fluorescent-lighted drafting room.

Direct-Current Welding · · · With a Transformer

Welding with direct current from a transformer or condenser seems contrary to known principles. It is, however, successfully accomplished by the new, stored-energy system of resistance welding. Direct-current energy supplied by an ignitron rectifier is stored at a slow rate in a transformer or condenser circuit, and is released into the weld suddenly instead of being drawn directly from the power lines as needed. The new method is particularly suited for welding aluminum and similar metals and alloys of high thermal conductivity, and offers some metallurgical advantages as well. To the distribution engineer this method of welding is significant because the peak demand on the power-supply system is decreased by three-quarters or more. An equally important improvement results from increasing the power-factor of the primary line to 90 per cent or better.

C. E. SMITH
Control Engineer, Westinghouse Electric & Mfg. Co.

WITH the immediate emphasis on the production of airplanes and other defense implements, a new method of resistance welding assumes special significance. A recent development in resistance welding consists of first storing energy, either electrostatically or electromagnetically, and then discharging it through the two metal parts to be joined. Thus it differs from conventional resistance-welding methods in which alternating-current energy is taken directly from the supply line while the weld is being made. It is particularly suited to welding metals of high thermal conductivity such as aluminum, because extremely high currents are required for very short periods of time if the weld is to be completely formed before the heat can be conducted away from the joint.

One form of electromagnetic stored-energy method of welding is shown schematically in Fig. 1. It consists of a three-phase power supply, an ignitron welding rectifier, a welding transformer, the welding machine, the main direct-current contactor, and suitable control relays. When the welding operator places the metals between the electrodes and pushes the foot switch the electrodes are brought into contact with the work and the circuit through the welding transformer is automatically closed. The ignitron rectifier impresses a direct-current voltage across the transformer primary and the current rises exponentially at a rate determined by resistance and inductance of the transformer, which is the equivalent of an inductance with resistance in series (see Fig. 2). In this manner a charge of energy is stored in the iron core of the transformer for later release as welding energy.

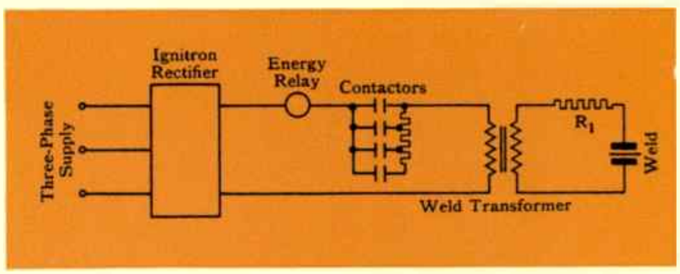
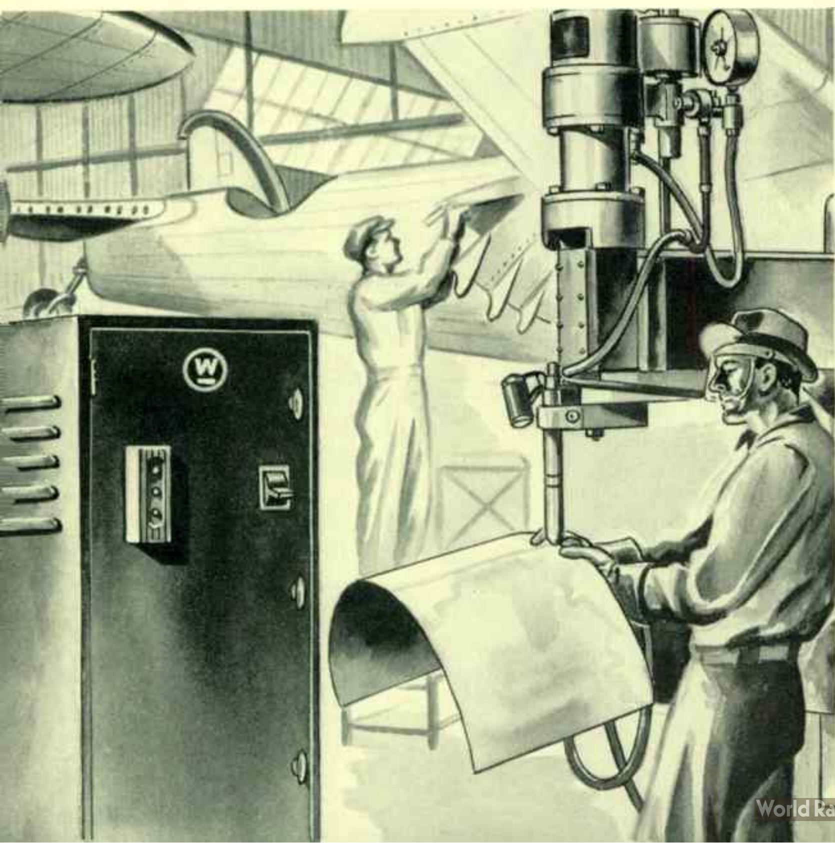


Fig. 1—*How a resistance weld is made with direct current from a transformer. Magnetic energy is stored slowly and released suddenly.*



Since any change of current in the primary of a transformer induces a current in the secondary, a current flows through the work even during charging and serves to preheat the work. This is shown in Fig. 2.

At a preset primary current a current relay causes the contactor to start opening. As the contacts open, one after the other in sequence, more resistance is inserted until finally the last contact opens and ruptures the remaining primary current. The opening of the contactor causes a rapid reduction of primary current.

The rapid change of flux in the iron caused by quick interruption of primary current generates a heavy surge of welding current in the secondary winding and the weld is made. This welding current then decays exponentially to zero as the energy is used up in the weld and in resistance.

Thus, operation of this system is like that of an ignition system in an automobile. The battery is comparable to the ignitron welding rectifier, the timer to the contactor, and the spark coil to the welding transformer. The only difference is that the secondary of the welding transformer is low voltage,

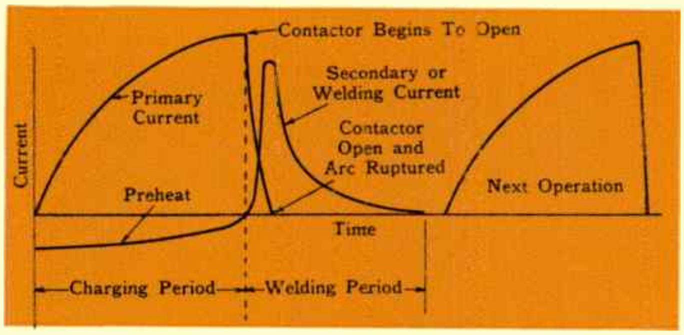


Fig. 2. *The cycle of current flow into the weld.*

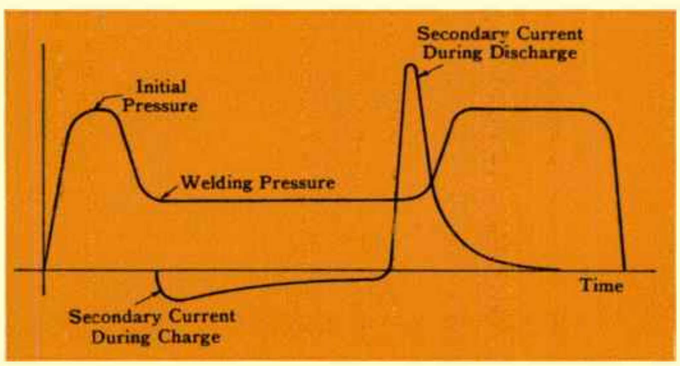
high current, whereas the spark coil secondary is high voltage, low current.

The weld is made in a manner that differs from the usual resistance-welding technique in which the work is simply held under pressure between the electrodes during the current flow. With the stored-energy method pressure on the joined parts is varied during welding operation. As shown in Fig. 3, when the material to be welded is placed between the electrodes the welding machine applies to them a full pressure provided by an air-operated piston behind the upper or moving electrode. This action forces the two metal parts into intimate contact. After this application of initial contact pressure, the electrode pressure is decreased slightly. At the start of this period of pressure retraction the ignitron begins to charge the transformer. During this charging period a small current flows in the secondary, which serves to preheat the junction. When the maximum-current relay de-energizes the main contactor, the secondary current flows. During the fall or decay of secondary current, electrode pressure is suddenly increased. This final compression takes place as the heating period is near completion and after the material has fused. This action causes a mechanical working of the metal, which compensates changes in grain structure of the fused material caused by the heat during fusion. This application of pressure and its variation during welding is controlled by two separate magnetic valves through the action of electrostatic time-delay relays. The desired control of electrode pressure is provided by the action of two contact-making pressure regulators.

Ignitrons and Thyratrons Provide Power Supply

The electromagnetic stored-energy system of welding, like conventional spot-welding schemes, makes use of ignitron tubes, although in a different way. Ordinarily ignitrons are used not as rectifiers but as power switches for a timer, advantage being taken of their timing ability to measure out the required number of cycles of alternating current allowed to flow into the "spot." On the new system, the ignitron is used as a rectifier, but there is no essential difference between the two ignitrons; the only difference is in their control. Both use standard water-cooled sealed metal-tube ignitrons. Two sizes of stored-energy welders are employed; one is used with two 40-kw machines and the other with two 120-kw machines. The rectifiers produce 580 and 850 amperes charging current, respectively, at 130 and 170 volts.

Fig. 3. *The relationship of welding current and electrode pressure.*



The rectifier is three-phase half-wave, using three single-anode ignitron tubes and three firing tubes for control of the ignitrons, connected as indicated in Fig. 4.

The ignitron power supply for the welder is contained in a sheet-steel cabinet that can be located at any convenient spot near the welders. One of these is shown in Fig. 5. Ignitrons are mounted on a common copper busbar below the control panel and in front of the three-phase power transformer. The power transformer has a terminal board with taps by which line voltages can be adjusted within a range of ten per cent above and below normal. The tubes are water cooled and are provided with hose connections to connect their water jackets in series. A thermostatic device is provided to insure sufficient flow of water.

The upper section contains the control and protective panel. It includes a three-pole, manually-operated circuit breaker with thermal and instantaneous trips for the alternating-current power supply. The ignitrons and thyratron tubes, which supply ignition current for the rectifiers, are protected by individual fuses. An *Off* and *On* button station with indicating light is mounted on the front door for opening the direct-current circuit.

Inasmuch as the maximum charging time is approximately one second and since the bulk of a welder operator's time is taken with handling the work, it is economical to operate two welding machines from one rectifier. By electrical interlocking only one welding machine can be loaded on the rectifier at a given instant.

The electrostatic stored-energy system is shown in Fig. 6. Here the power supply consists of a high-voltage multi-phase rectifier of 50 or 60 kva. With the closing of S_1, the capacitor bank, C_1, is charged to a high preset voltage. Then by means of an electronic energy relay the capacitor energy is discharged into the welding transformer. The weld current has one of the wave shapes shown in Figs. 7 and 8. If the circuit is not critically damped the current will tend to oscillate as in Fig. 7. Adequate energy must be supplied in short time to make a good weld and the welding current must decay rapidly to prevent arcing as the electrodes separate. For these reasons an aperiodic secondary current has been found best. However, experiments have shown that with certain thickness of weld material, good welds are obtained even if the secondary current is oscillatory. To prevent unwanted oscillations for a given weld a shunt rectifier tube is connected across the primary of the welding transformer. If the voltage changes polarity the rectifier tube ionizes, absorbing the energy. This reverse action tends to broaden the current wave as

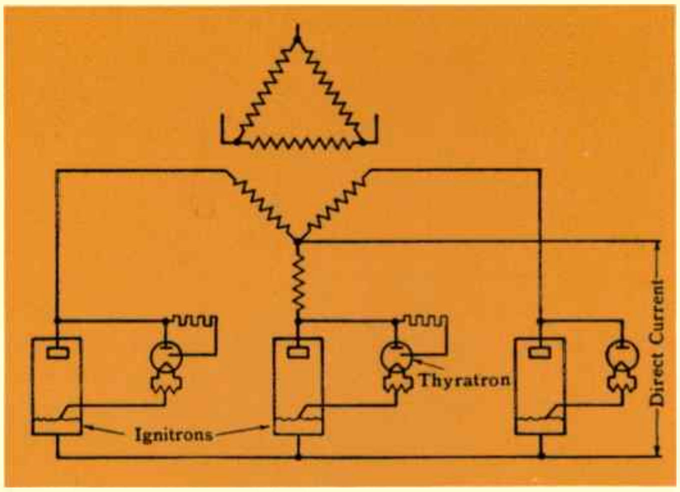


Fig. 4—Three ignitrons, each with its thyratron ignition circuit, are connected to give a direct-current charging voltage from a three-phase power supply. All these devices are mounted in the cabinet shown in Fig. 5.

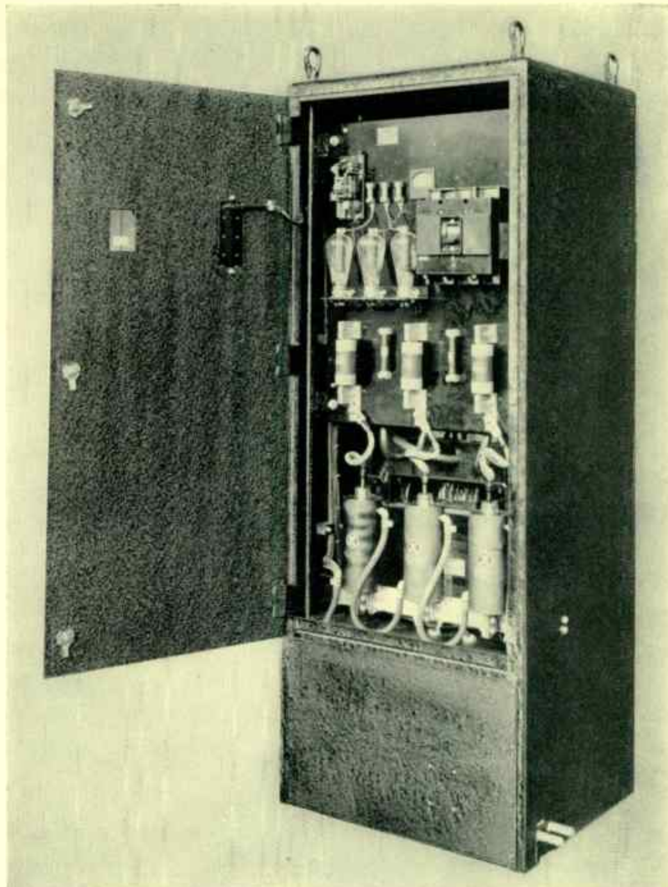


Fig. 5—Power-supply cabinet for an electromagnetic, stored-energy welding system. The water-cooled rectifiers are seen at the bottom.

shown in Fig. 8. It is also possible to change the shape of the wave front by changing the amount of capacitance or the ratio of the welding transformer. Experiments have shown this to be desirable. Other wave forms of current will be found by experiment that are best suited to various welding problems.

The capacitor-discharge type of control is contained in a cabinet similar to that for electromagnetic control, shown in Fig. 5. It contains the bank of capacitors, main rectifier transformer, thyratron tubes, and sequence panels. The charge is preset by a dialed potentiometer and selector switch, controlled from the front of the cabinet. The controls can be set for repeat or non-repeat operation of the welds. A system of interlocks make it impossible for anyone to come in contact with energized parts of the control while there is any high-voltage on the capacitors or charging circuit.

Peak Demand Reduced

An outstanding advantage of either the electromagnetic or electrostatic stored-energy principle of welding is that energy is drawn from the supply lines slowly and discharged quickly. The instantaneous demand is reduced to approximately one-tenth that required by an equivalent alternating-current spot welder and the power-factor is increased almost to unity. Also the load is balanced on the three-phase system, instead of being a peak single-phase load. As a comparison, the instantaneous power demand of an alternating-current spot-welding machine while welding two pieces of 0.080 aluminum is approximately 200 kva at 30 per cent power-factor, single phase. The stored-energy method requires from 40 to 50 kv, on a three-phase balanced line at 100 to 90 per cent power-factor.

A further advantage of the stored-energy system is that normal line-voltage variations do not alter the welding energy because the current relay does not release energy into the weld until the energy storage level established by the preset control has been reached.

Unlike mild steel, aluminum and many other metals and alloys have sharp fusion points; hence a narrow range of current, pressure, and time within which quality welds can be made. The stored-energy system thus broadens the field of resistance welding controls by providing a new and improved method of welding nonferrous metals and alloys that are normally considered difficult to weld.

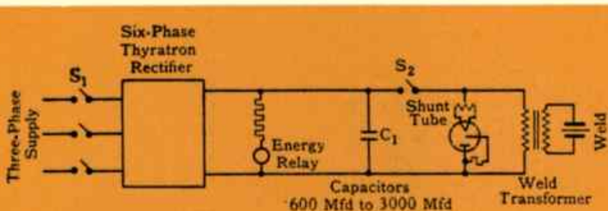
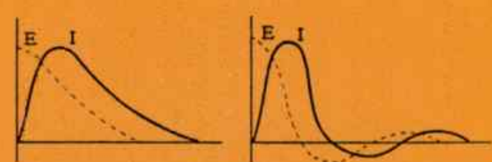


Fig. 6—Circuit for welding with energy stored in a condenser.



Figs. 7 and 8—Possible wave shapes with electrostatic welder.

Suppression of Surges on Arc Furnaces

Severe voltage surges are inherent in the operation of electric-arc furnaces and sometimes result in costly production delays. Evidence of these surges has been found on both sides of the furnace transformer. Unfortunately field data on the surge phenomena has been meager until recently when extensive tests were run on two large furnaces. Of several schemes tried for limiting the rate of rise and magnitude of surge voltages, the use of capacitors connected to the high-voltage side of the furnace transformer proved to be the most effective.

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THE Heroult process of producing alloy steels utilizes the heat of an electric arc for melting and refining operations. The sizes of furnace transformers range from a few hundred to 15 000 kva. Several hundred thousand kva of such furnaces are in service and produce much of the high-grade alloy steel in this country.

The Arc Furnace and Its Operating Cycle

A typical furnace is shown in Fig. 1 and electrical connections are given in Fig. 2. The furnace is a large steel shell lined with refractory material. It is charged with iron, either molten or solid. Most often cold scrap iron is the raw material. Extending into the furnace from above are three graphite electrodes, one for each phase. Power is supplied by a special arc-furnace transformer with each secondary terminal connected to one graphite electrode. The primary winding usually is arranged for both star and delta operation, with a series of taps by which secondary voltage is adjusted as the melt proceeds. Additional reactance is sometimes provided to stabilize the arc. The electrodes are individually movable by automatic controls that maintain equal heat and current in the three arcs.

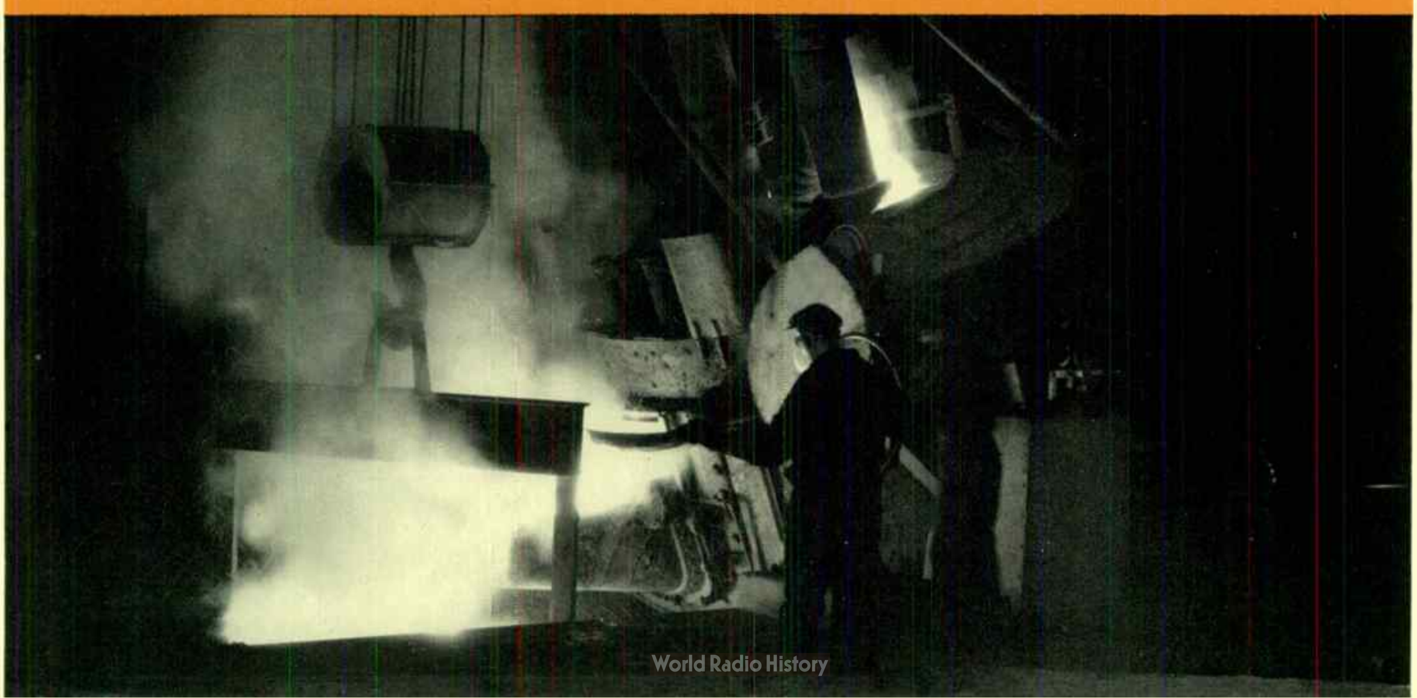
At the start of a melt the taps are set for a fairly high secondary voltage. During the beginning of the melting period the current fluctuates violently, partly because of the changing shape of the mass as it liquefied. Because scrap takes more space than molten metal additional charges of scrap are sometimes added until the furnace is filled to capacity. The arc is quite irregular during the melting period. The arc, during melting, makes a loud crackling noise, indicating its unstable character. Eventually the pool of molten metal becomes well enough defined in level that the arc becomes steadier as the melting proceeds.

Melting is followed by a refining period in which metallurgical and alloying operations are carried out. Alloying elements are later added. While refining, voltage is reduced by changing transformer taps, because the power required is little more than the loss of heat from the furnaces. Load during refining is fairly steady and is balanced between the three phases. The power-factor is high. Noise from the arcs is more of a hum than the crackling effect during melting.

Source of Overvoltages

Several theories have been advanced to explain surge overvoltages. Conclusive experimental data as to the exact mechanism of overvoltage formation is not yet available. It seems certain, however, that overvoltages are associated with discontinuities of power flow, which occur frequently in electric-furnace operation.

Fig. 1—*Pouring high-quality alloy steel from an electric furnace.*



Each furnace cycle requires several manual operations of the primary circuit breaker for interrupting the circuit to add more metal, change taps, or add alloying elements. In addition, the shifting of solid scrap in the melt may short-circuit the electrodes and cause the breaker to trip. These breaker operations, and the irregular action of the arc, seldom occur at a normal zero point in the wave. Such "forcing of current

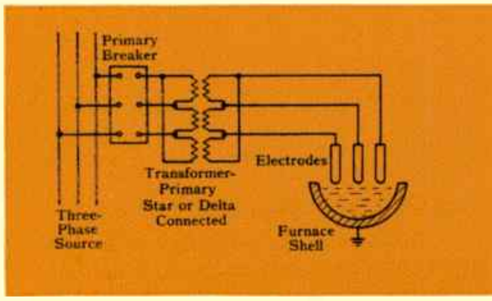


Fig. 2 — The circuit for an arc furnace.

zero" is likely to produce high-voltage surges, because of the discharge of stored magnetic energy in the circuit.

It is likely that overvoltages have other causes, such as collapse of transformer magnetizing flux, and transient surges from unstable arcs.

The Effects of Overvoltages

In many years' experience with a large number of electric furnaces, surge voltages have caused comparatively little damage to equipment. More recently, however, the number of difficulties has increased, a result, no doubt, of increased production loads and attempts to maintain continuous arc-furnace operation. Because of the demand for increased output the expense of delays in production becomes more important than the cost of maintenance or repair. Apparatus failures and difficulties are assuming correspondingly greater importance.

Troubles have developed most frequently on low-voltage buses, between the transformer and the flexible leads to the furnace. These failures have occurred on the average perhaps once in five years, although in some plants flashovers have taken place as frequently as once a month. Failures on the low-voltage bus have not usually caused much loss, either from apparatus damage or interruption of production. Because of their infrequent occurrence no concerted attention was given to their elimination. Failures were usually attributed to collection of dirt on insulation and the remedy was to clean the bus structure. An increase in low-voltage bus insulation has been necessary in some locations. An arrangement of bus-bar insulation that has proved effective is shown in Fig. 4. Failures of apparatus at the transformer supply bus have occurred recently in different plants. The search for causes of these failures pointed to surge voltages and led to the belief that the real cure might lay in reducing the magnitude of these surges rather than in strengthening each part of the circuit exposed to them.

The Sterling, Illinois, Furnace Installation

An opportunity to test the overvoltage theory was provided by the Northwestern Steel and Wire Company at their Sterling, Illinois, plant. Several interruptions of production had occurred as a result of bus and equipment flashovers.

This company operates two electric-arc furnaces having shells 11 feet in diameter and using 14-inch electrodes. The two, three-phase, 7500-kva, 60-cycle transformers have ten taps supplying delta-connected secondary buses. Transformer primaries are either delta or star connected depending upon the desired output voltage. Reactors are built into the transformers. The inherent leakage reactance of the transformers is 4.6 per cent on 7500 kva. Reactors can be used to give 5.9, 12, or 18 per cent additional reactance.

The furnace transformer is supplied over a 13.8-kv three-phase circuit from a 15 000-kva, 132-13.8-kv transformer bank. The 13.8-kv circuit is approximately 1000 feet long. A 20 000-kva condenser operates on the Sterling bus, as shown in Fig. 3 to minimize the voltage fluctuations caused by variations in load.*

Relatively light scrap is used in the furnaces and the melting rate is high. The 30-minute demand from the system has reached 20 000 kw for both furnaces. Overcurrent relays on the breaker ahead of each transformer are set to trip both breakers for an instantaneous inrush of 37 000 kva.

Assembling Overvoltage Data at Sterling

An extensive program of investigation was started to determine the magnitude of the voltage surges and to find means for controlling them. To ascertain the protection afforded by arresters a set was installed on the 13.8-kv bus at the terminals of each transformer. Arresters of high thermal capacity were chosen, having a 60-cycle breakdown of approximately

*The synchronous condenser application, using a reactor in the supply line to cushion the system from excessive current and voltage pulsations, has been described in a paper by T. G. Le Clair, "Power Supply for Arc Furnace Installations," *Electrical Engineering*, April, 1940.

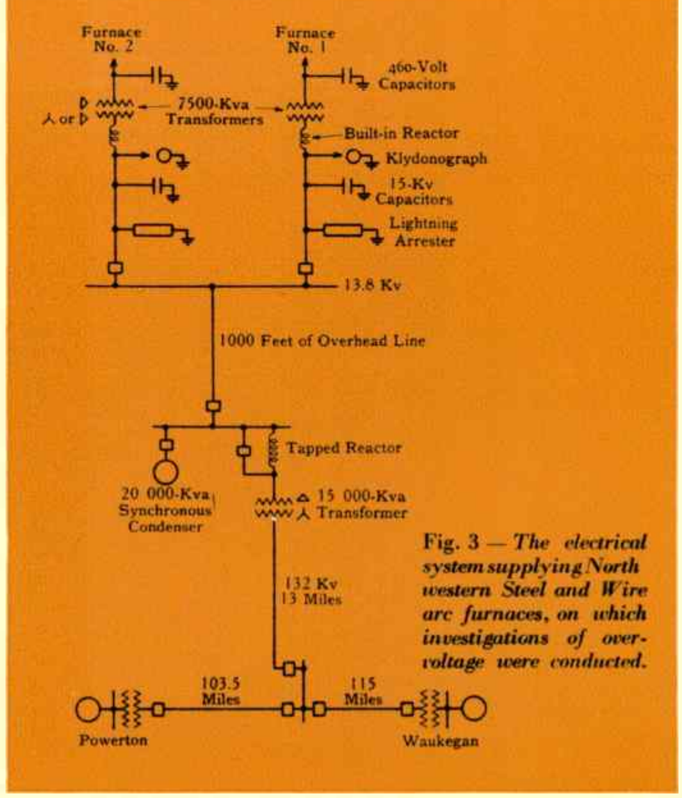


Fig. 3 — The electrical system supplying North western Steel and Wire arc furnaces, on which investigations of overvoltage were conducted.

30 to 35 kv rms, an impulse ratio of unity, and a cut-off voltage of 20 kv rms. Operation indicators were placed in the arrester grounds, and several arrester operations were recorded before other protective devices were added.

A klydonograph as shown in Fig. 6 was used for surge measurement. Altogether, in nine months, more than 70 eight-foot film records were made. Representative sections of records are shown in Fig. 7.

The usual range of surge voltage on the low-voltage side of the furnace transformers was known from previous tests to be less than 3000 volts crest, which is the minimum that can be recorded by a klydonograph. Normal maximum line-to-neutral furnace voltage is about 190 volts. Thus, surges on the low-voltage side of the transformer do not ordinarily exceed 15 times normal. This overvoltage, though large, is insufficient to damage transformer windings or low-voltage bus when properly insulated. However, 3000 volts is sufficient to cause flashovers between low-voltage buses covered with conducting dirt.

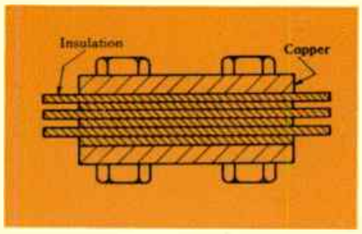


Fig. 4—*Suggested manner of insulating low-voltage bus to an arc furnace.*

Analysis of Data

Numerous changes in experimental setup were made as the tests proceeded so that comparative data was assembled on different protective schemes. Obviously the daily operations of an electric furnace are not truly repetitive. Scrap steel changes in character from time to time, as does the rate of operation. Furnace operation varies with different crews. Each test condition must be observed over a reasonably long period for results to be representative.

Effectiveness of the various protective measures is shown by the data of Table I. The results obtained from one furnace are listed in detail in Table II. The highest surge is of interest, but it is not necessarily a true index because of the random nature of overvoltages. Any furnace might experience its maximum surge on the first day of test. Results may be misleading unless comparison is based on an average of highest surges, therefore attention is particularly directed to column 3 of Table I. The data listed in Table I, obtained under conditions A and B, without surge-protective devices other

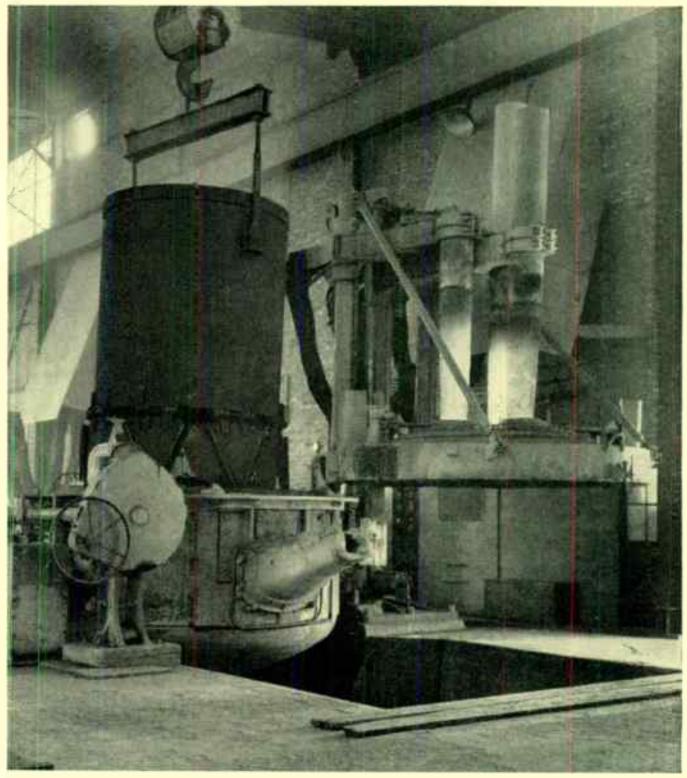


Fig. 5 — *One of the two arc furnaces at Sterling, Illinois.*

TABLE I—SUMMARY OF TEST DATA ON OVERVOLTAGES ON ARC FURNACES
(Northwestern Steel & Wire Co.)

	Circuit Condition	Average Number of Surges Above 20 Kv Line-to-Ground Per Day	Crest Magnitude of Highest Surge in Kv (Line-to-Ground)	Average of Six Highest Surges on Each Film (Kv, Line-to-Ground)	Length of Test Run, Days
A	No Capacitors No Arresters No Reactor	35	68	44	6¼
B	No Capacitors Arresters 5.9% Reactor	10	26	21.9	2[1]
C	LV Capacitors Arresters No Reactor	28	49	38.4	38
D	LV Capacitors Arresters 5.9% Reactor	13	58	31.1	165
E	HV Capacitors Arresters 5.9% Reactor	1	27	22.3	17
F	HV Capacitors LV Capacitors Arresters 5.9% Reactor	3	30	21.6	44
G	HV Capacitors LV Capacitors Arresters No Reactor	5	44	27.6	59
H	HV Capacitors Arresters No Reactor	7	28	23.8	29

[1]Results obtained under Condition B are not significant because the test run was of such short duration.

TABLE II—KLYDONOGRAPH SURGE RECORDS ON 13.8-KV FURNACE No. 2
(Connected equipment shown by o)

	Highest 6 Surges On Film in Kv Crest (Line-to-Ground)						Arresters	LV Capacitors	HV Capacitors	Air Breaker	Oil Breaker	Reactor
A	68	43	39	38	38	38					o	
C	46	39	38	38	37	37		o			o	
	39	36	34	33	33	32	o	o			o	
	41	41	33	31	31	31	o	o			o	
	44	34	34	30	29	28	o	o			o	
D	26	24	24	23	23	22	o	o		o		o
	28	26	26	26	25	24	o	o		o		o
	41	35	34	33	33	33	o	o		o	o	o
	37	37	35	33	31	31	o	o			o	o
	41	37	29	25	23	23	o	o			o	o
	23	22	22	22	20	20	o	o			o	o
	22	22	21	21	20	20	o	o			o	o
	22	20	20	20	20	20	o	o			o	o
B	26	26	25	20	20	20	o				o	o
	26	22	20	20	20	20	o				o	o
	21	21	21				o				o	o
E	20						o		o		o	o
	No surges						o		o		o	o
F	No surges						o	o	o		o	o
	No surges						o	o	o		o	o
E	22	22	22	21	21	21	o		o		o	o
	27	24	22	22	22	22	o		o	o	o	o
F	30	25	24	22	20	20	o	o	o	o		o
	24	23	23	22	20	20	o	o	o	o	o	o
	23	21	21	20	20	20	o	o	o	o	o	o
	22	22	20	20	20	20	o	o	o	o		o
	22	22	21	21	21	21	o	o	o	o		o
	22	22	20	20	20	20	o	o	o	o		o
	23	22	22	22	22	22	o	o	o	o		o
H	27	27	26	25	25	25	o		o	o		
	28	25	24	22	21	21	o		o	o	o	
	26	25	23	23	23	23	o		o		o	
	25	25	24	23	22	22	o		o		o	
	27	27	29	26	26	25	o		o		o	

Fig. 6—*Klydonographs such as this were used to record arc-furnace surges. The device was developed about twenty years ago and played a leading part in the early field studies of lightning. It consists of a grounded metal drum, covered with a Micarta cylinder about 0.1 inch thick. A clockwork mechanism drives the drum and draws a photographic film over it in a fashion similar to a roll-film camera. Insulated metal electrodes bear on the surface of the film and are connected to the points where surge voltage measurements are desired. The surge magnitude is found by measuring the diameter of the familiar Lichtenberg figure.*

than the arresters in condition B, probably do not indicate the highest surges that may occur under these conditions, because of the short length of test. This is particularly true of condition B, because records were obtained for only two days. During only six days, one surge of 68 kv, line-to-ground, was recorded for the unprotected condition (A) with an average of 44 kv for the six highest surges on each film. These voltages serve as a standard of comparison for surges recorded after low-voltage and high-voltage capacitors were connected to the circuit.

Three 15-kva, 460-volt capacitors connected line-to-ground on the low-voltage bus (conditions C and D) reduced surges on the high-voltage bus. Average magnitudes of the six highest surges was reduced from 44 to 38.4 kv.

To reduce the surges further, a 15-kv, 0.125-mf capacitor was connected line-to-ground at the high-voltage terminals of the transformer. Low-voltage capacitors were disconnected, under conditions E and H, to disclose the protective effect of the high-voltage capacitors alone as indicated in Table I. High-voltage capacitors reduced the average magnitude of surge voltages on the high-voltage bus from 44 to 23.8 kv. High-voltage capacitors also reduced the number of significant surges appearing per day, and reduced the crest magnitude of the highest surge to about one-third.

Klydonograph records were also obtained with capacitors installed on both the high and low-voltage buses, as summarized in conditions F and G. Undoubtedly the low-voltage capacitors reduce the surges in the low-voltage bus, although this effect could not be observed during the Sterling tests, because klydonographs were connected only to the high-voltage bus.

Comparison of conditions C and D, E and H, F and G, shows that the transformer reactor reduces the surges on the circuit ahead of the reactor, whether protective devices are used or not. This indicates that surges are originating from the transformer or the arc, and not from the power system.

High-voltage capacitors were installed in May, 1940, and have provided entirely satisfactory protection. To reduce further the surges appearing on the low-voltage bus, low-voltage capacitors have been added. All surges appear to have been reduced to reasonable and safe magnitudes.

Similar field information is being secured from arc-furnace installations of different sizes and voltages in other plants. A laboratory investigation of the surge phenomena, in particular of the origin of the surges, is now in progress.

Conclusions

The type of tests conducted did not permit verification of any theories of the origin of surges. Some correlation of primary breaker operations with surge occurrence was obtained by an induction coil operated by the breaker auxiliary switch and connected to a fourth klydonograph electrode, recording the results on high-speed film. These records indicated, but did not prove conclusively, that the highest surges were attendant with the opening of the breaker.

The following conclusions appear well substantiated by the test results to date:

1—High-voltage surges of at least six times normal in the primary and possibly 10 or more times normal in the secondary may occur in the operation of an electric furnace.

2—Surges occur at random. Moderate overvoltages recur almost continuously during melting. Several surges of high-magnitude may occur within a few minutes of each other.

3—The surges result from operation of the furnace, they do not ordinarily originate in the power system.

4—Capacitors connected from line-to-ground on the high voltage side of the furnace transformer reduce both number and magnitude of surge voltages. They also reduce the slope of the surge wave front. The sloping effect is of value for most insulation, particularly that of transformers.

5—Lightning arresters have not so far proved helpful in reducing surge voltages. They do serve to limit the voltage but, to prevent their destruction by frequent discharges, it is necessary that their breakdown and cut-off voltages be so high as to render them relatively ineffective.

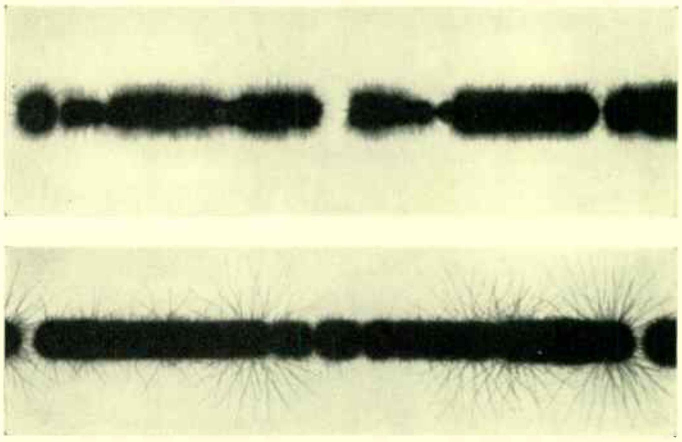


Fig. 7—*Typical klydonograph records of arc-furnace surges. The magnitude of overvoltage is obtained by measuring the radius of rays originating at the point of contact of the electrode. The upper record, of about five hours duration, shows no high-voltage surges, but indicates the almost continuous presence of low-magnitude surges. The lower record shows repeated occurrences of surges of several times normal potential.*

ergy, particularly the opening of new sources of fuel for propulsion of machines and vehicles. But, practical utilization of the trapped stores of power is a mere trifle compared with the potential effects of having some nation unlock the secret of the new knowledge and divert it toward human enslavement instead of human betterment. Certainly it is disturbing to think of world power and atomic power as being kindred terms.

An understanding of the scientific foundation of release and control of atomic energy requires more than a cursory look at the whole business of atom smashing; some fundamentals of nuclear physics need be reviewed briefly.

All matter, from antimony to zirconium, consists mainly of three major basic building blocks: the proton, the neutron, and the electron. The proton and neutron have the same mass, but the proton has a positive electric charge while the neutron has no charge at all, i.e., it is electrically neutral. Protons and neutrons comprise the nucleus of an atom. The electron has a negative charge equal (but opposite) to that of the proton. Relatively the electron is a lightweight, having a mass only 1/1850 that of a neutron or proton, but it makes up in wallop what it lacks in weight.

Scientists occasionally find positively charged electrons, called positrons. Experimental evidence also indicates the existence of a tiny neutral particle, the neutrino, or "little neutron." Positrons and neutrinos have nothing to do with the process of deriving power from uranium. They are mentioned to complete the picture.

The target end of the East Pittsburgh atom smasher.

About Atoms in General

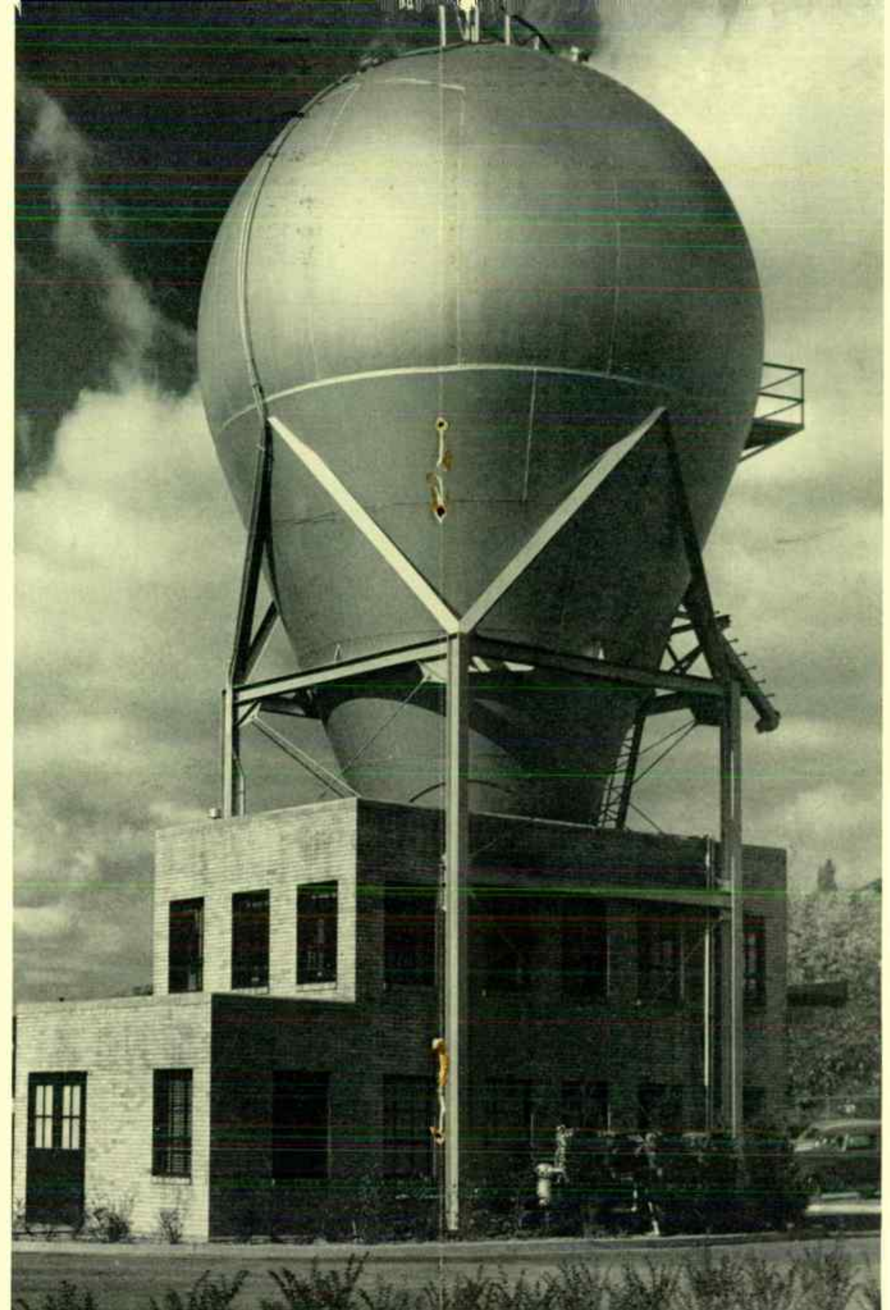
All atoms, according to well-founded theory, are like diminutive solar systems. The atomic nucleus, made up of protons and neutrons corresponds to the sun. In a whirling swarm, electrons spin about the nucleus, and tend to fall into it, just as the earth is attracted by the sun. However, both nucleus and electrons are influenced by other forces that prevent unification; consequently, electrons can neither get to the nucleus nor away from it. They simply race at breakneck pace in orbits about the all-attractive center of their universe. Each proton (positive) in the nucleus, must be balanced electrically by an electron (negative) satellite in the atomic planetary system.

Because the mass of an electron is so small compared with that of a proton or neutron, virtually all of an atom's weight is concentrated in the nucleus. A hydrogen atom, simplest and lightest of all, has a nucleus consisting of one proton and no neutron, around which revolves a single electron. Approximately, then, the atomic weight of hydrogen is one, the weight of a proton. The nuclei of more complex atoms have both protons and neutrons. The numerical sum of their weights represents almost exactly the atomic weight of the substance.

The Uranium Atom

Uranium has three forms or isotopes, as chemists call them. These have identical chemical properties. Each has 92 protons in the nucleus and 92 revolving electrons. But the number of neutrons varies in the three isotopes, and therefore their atomic weights differ slightly from one another. The lightest has 142 neutrons, making its atomic weight 234, hence its name—U-234. The other two isotopes, which have 143 and 146 neutrons respectively, are similarly called U-235 and U-238.

These swarming particles contain a lot of energy. To release such energy the atom must be broken apart, or must disintegrate of its own accord. Radium, for example, disintegrates slowly without any external stimulus, giving off energy steadily. A pellet of radium still has one third of the energy it had 2000 years ago.



The four-million-volt atom smasher at East Pittsburgh.

Shooting at Atoms

Several kinds of atoms have been broken apart in the Westinghouse atom smasher at East Pittsburgh by bombardment with minute particles, usually these are protons or neutrons traveling at terrific speeds of 10 000 miles or more a second. When the nucleus of an atom is hit by a high-velocity particle the structure of the atom is changed, and an actual transmutation of the element takes place, the very thing the alchemists of old were trying to do. But, a stable atomic structure cannot be disrupted without some change in its latent energy. Many of the synthetic or analytic elements created by transmutation become short-lived radioactive substances that emit radiant energy essentially sim[illegible] that given off by radium. As the energy is spent, t[illegible]cial substance may change to another element.

Sometimes the energy extracted from such a reaction is greater than the energy invested in the high-speed particle making the hit. But, don't forget that the nucleus of an atom is a bewilderingly small thing—less than a trillionth of an inch in diameter—and a bull's eye is pretty hard to make. In fact, the odds against a direct hit are about a million to one, hence the proportion of bullets that go astray is large. Power generation from most elements probably will not be practical.

In this respect uranium is different, especially the isotope U-235. A direct hit on the nucleus of the uranium atom causes the element to split into two other distinct elements, usually radioactive, each having about half the atomic weight of uranium. These two main fragments of the collision release a huge amount of energy. Furthermore as by-products of this atomic split (which physicists called "fission" because it resembles the progenitive process of several of the primary animal cells) two or three neutrons—remnants—surge out of the cataclysm at tremendous speeds. Each of these by-product neutrons has far more energy than the particle originally used for bombardment. So, kicked out of their own colony, they fly berserk at neighboring atoms, perhaps smashing them in the process. When this happens more energy and more neutrons are released to disintegrate other atoms. Here, then is a possibility of continuous or chain reactions, which, once initiated, will proceed without further external assistance, meanwhile liberating a flood of usable energy.

Uranium 238 differs from its isotope U-235 in two important ways. First, it can be split only by a high-speed particle. This means that the energy put into the reaction is fairly large compared with that gained. Second, for some inexplicable reason the U-238 atom occasionally absorbs a bom[illegible]g neutron without fission. The neutron is wasted, as[illegible] nergy liberation is concerned.

[illegible] strangely enough, is split much easier by a slow-moving particle than by a fast one. One reason for this strange behavior is that the U-235 nucleus is mor[illegible]table so that a soft blow smashes it more surely than a hard one. Probably more important, a "slow ball" is easier for the nucleus to "field." Explanations are speculative anyway; the important thing is that a beam of slow-moving particles is more effective on U-235 than fast ones. The "effective" area of the U-235 nucleus is estimated to be about 500 times as large as that of the U-238 nucleus; or it is 500 times easier to score a productive hit.

Bombarding a U-235 atom with a neutron is not the only way it can be disintegrated. Research at East Pittsburgh has shown that it can be accomplished with gamma rays or hard X-rays, which are streams of energy and not particles at all. Little is known about the fundamentals, but it is conceivable that this method of "photofission" will start a new trend in the search for atomic power.

U-235 is Hard to Get

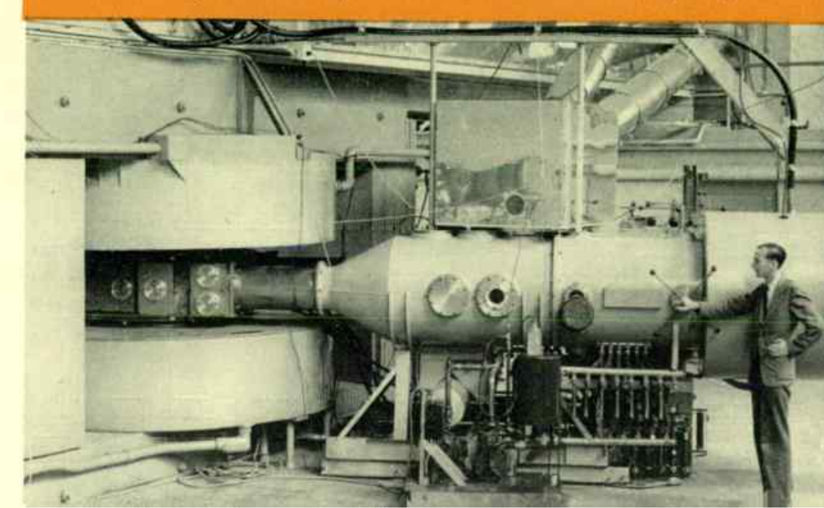
One of the first and most stubborn problems is obtaining a sizable quantity of U-235. Of U-238 there is plenty, obtainable from pitchblende deposits of Colorado, Ontario, and Czechoslovakia. However, very little of it is U-235. A ton of commercial uranium, were it available, would contain about 14 pounds of U-235, less than 2 ounces of U-234, and the remaining 1985 pounds, U-238. Several separation methods have been tried, none successful thus far on a commercial scale.

The principal obstacle to separating the isotopes is in the fact that U-238 and U-235 are chemically identical. They, therefore, cannot be isolated by chemical means. There is only the small difference in atomic weights by which they can be distinguished.

At the University of Minnesota mass spectrographs have isolated minute quantities, measured in billionths of an ounce. This is not enough even for satisfactory experimentation with atomic power. Since the mass spectrograph requires a large transfer of electricity to carry a small amount of matter, its use for separating uranium isotopes will probably never be practical.

Research scientists are examining all proposed methods of uranium separation, and have experimented with some untried ways. One of the best bets appears to be a device called the ultracentrifuge. Fundamentally it works just like a cream separator used on the farm. U-238 particles are thrown toward the outside of a rotating cylinder and the slightly lighter U-235 particles tend to accumulate near the axis.

The 60-inch cyclotron built by Dr. Lawrence at the University of California



ATOM SMASHERS ARE OF TWO KINDS

The cyclotron and the belt-type electrostatic or Van de Graaff generator are the two most important types of machines for cracking the atom. They differ both in principle and in work they do. Each has an important place in the nuclear-research program.

The cyclotron was invented in 1930 by Dr. E. O. Lawrence of the University of California. In this device protons, deuterons (heavy-hydrogen ions), and other atomic bullets are accelerated to high velocity by sending them in an expanding spiral path and giving them a carefully timed impulse or kick twice each revolution. Energies up to 10 million electron volts (mev) are obtained in the larger cyclotrons, and Dr. Lawrence has a giant one under way with which he hopes to attain 200 mev. The cyclotron produces not only the highest voltage but also the heaviest current of any high-voltage generator. It is the Big Bertha of the atom smashers, and is more effective of the two types for producing artificial radioactive elements. Several cyclotrons are being worked on a 24-hour-a-day schedule to manufacture radioactive materials.

For more exact work, where critical measurements must be made, the belt-type generator is superior for several reasons. Its beam voltage, though lower than obtainable in the cyclotron, can be more accurately controlled and it is more homogeneous, that is, the "bullets" comprising the beam are all moving at the same speed. This enables the nuclear research worker to know exactly at what voltage a certain atomic change occurs, as the curve in Fig. 2 shows. Furthermore, the beam of atoms can, in the electrostatic generator, be focussed on small targets more accurately.

The generator at Massachusetts Institute of Technology (built by the inventor, R. J. Van de Graaff), the one at the Carnegie Institution of Washington, and the Westinghouse machine, are the outstanding large belt-type generators. Some of these can be operated under pressure, the Carnegie machine up to 60 pounds, and the Westinghouse one up to 120 pounds per square inch. Raising the pressure increases the obtainable voltage for a given machine, because it increases the dielectric strength of the insulating air.

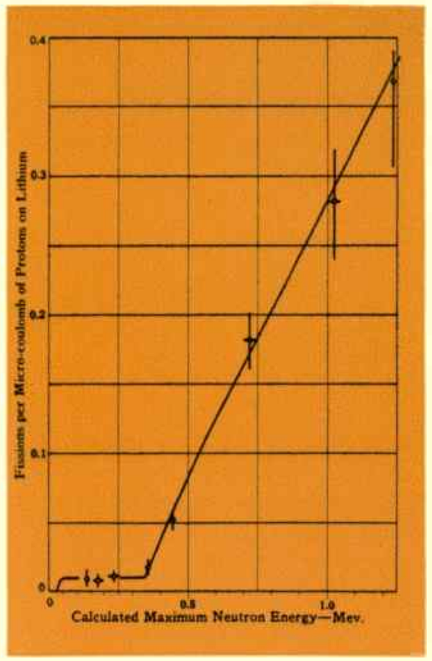


Fig. 2—*A curve obtained during early experiments to determine the threshold of uranium fission with fast neutrons. It shows the critical voltage necessary for fission.*

Already much has been learned about uranium and its possible utilization for power, but many of the things discovered merely hint at the complexity of the problem.

For example, since neutrons released from the U-235 nucleus are high-speed particles, how are they to be made useful in breaking up other U-235 atoms, a job that requires slower particles? Obviously the by-product neutrons, which are too fast, must be slowed up in some way. Surrounding

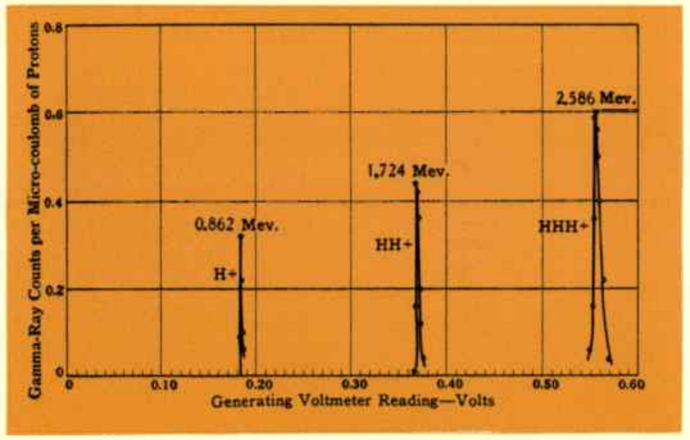


Fig. 1—*The atom-smasher voltage scale is determined by measuring the gamma rays produced when fluorine atoms are struck by different kinds of particles. The sharpness of the peaks indicates the steadiness and homogeneity of the high-voltage beam, essential for precise measurement.*

the uranium mass with water, paraffin or some other substance rich in hydrogen may do the job, the theory being that the rampaging neutrons will collide with the hydrogen atoms, lose part of their energy and bounce off at velocities more suitable for smashing uranium atoms. Energy imparted to the hydrogen can be converted into usable heat.

Just how much energy is required to split the U-235 atom is not known, but it can be accomplished with a particle moving no faster than an air molecule moving at random in a room of average temperature (about 1000 feet a second). The relative efficiencies of bombardment by neutrons and gamma radiation are being studied. Another unknown is the nature of the two elements produced by the fission process. It is probable that uranium atoms are split by bombardment and by gamma radiation in different ways and create different chemical elements. This in itself will possibly constitute an intensely interesting chapter in the unfinished story of uranium research.

No one yet knows whether U-235 needs be highly purified for use as a power source. Nobody has had enough of it to experiment with different degrees of purity.

These and kindred problems are being vigorously attacked. It is interesting to note that more than 500 active research workers attended the first Conference on Applied Nuclear Physics last October at Boston, Mass.

What Lies Ahead?

Most of the story of uranium power has been sketched. Nothing has been said about U-234, which remains unobserved in the background. Perhaps U-234 is an even more promising source of atomic power. Difficulties of research with U-234 would be of thousand-fold complexity as compared with those offered by U-235, if only because it is many times harder to get. The thorium atom, too, splits like uranium, but must be bombarded with high-speed particles, like U-238. Perhaps, too, there are other elements, that behave like U-235.

When scientists know all these secrets locked within the atoms, the day of atomic power will dawn . . . perhaps.

Progress in Atom Smashing*

The release of atomic energy has been theoretically anticipated for several decades and has actually been accomplished in a limited way for a dozen years. Two years ago atomic physicists made the surprising discovery that an atom of one form of uranium can be split with comparative ease and that there is released in the process nearly twenty times as much energy as had previously been obtained by atom cracking. The energy is equivalent to more than two million times that obtainable from coal. Revolutionary as this discovery is, its practical realization awaits the solution of many stubborn problems, not the least of which is how to obtain the necessary form of uranium in more than microgram quantities.

ONE of the most imagination-stirring scientific advances of the last decade—perhaps even of the last century—is the discovery that leashed in the atom of uranium, nature's heaviest element, lies 2½ million times as much energy as is contained in an equivalent amount of coal. Even more intriguing is the realization that the world may be standing upon the threshold of practical utilization of atomic power.

What does this mean to the average person? Immediately, nothing. Ten, twenty, or fifty years from now it may mean that an entire winter's fuel supply for an average home may be packaged in a container no bigger than a vitamin pill. A lump of uranium no larger than a walnut contains as much potential energy as about 1250 tons of good bituminous coal.

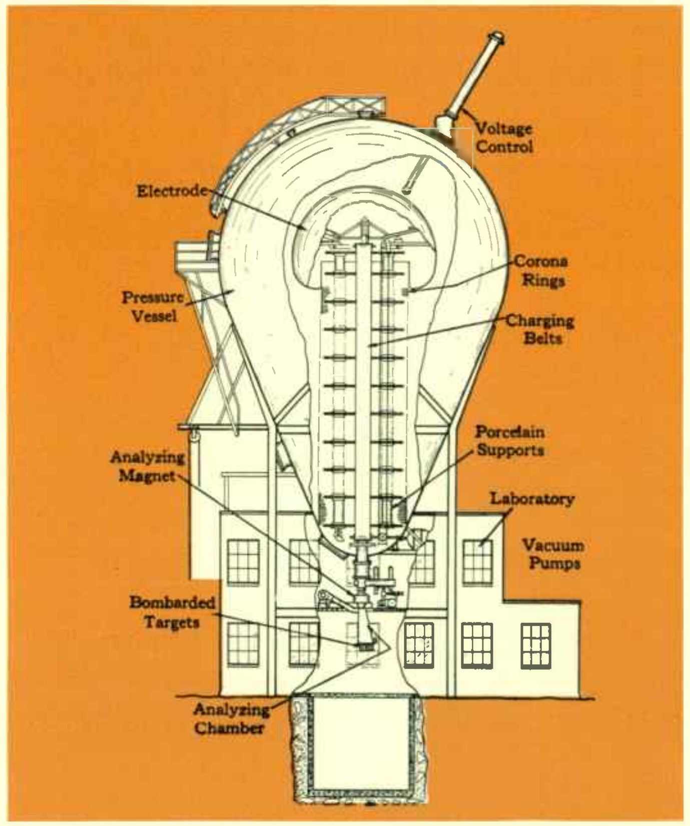
Such a piece of uranium, if the energy could be extracted and utilized, could produce some 2¾ million kilowatt-hours of electrical energy even at present efficiencies of steam and generating apparatus. This is enough to supply power for a city of 100,000 inhabitants for a month. The ocean liner of the future may have no coal bunkers or oil-storage tanks. Space and handling equipment for fuel may not amount to much in power plants a few decades from now.

The amount of energy that would be released if any matter could be broken into elements of lower atomic weight could have been predicted with exactness by theoretical physicists more than twenty years ago. It has remained for experimental physicists in atom-smashing laboratories to accomplish the actual splitting of atoms with the attendant release of the predictable energy. This has been done many times in several laboratories of the world, but only with atoms releasing negligible energy.

Then, like a bombshell, came the report early in 1939 that a uranium atom had been split into almost two equal parts, releasing in the process nearly 200 million electron volts of energy instead of the 10 or 15 million commonly obtained. This dozen to twenty-fold increase in liberated energy is a tremendous step forward to practical control of atomic power.

The practical implications of this discovery have stirred every man who understands the possibilities of nuclear en-

*Based on an article by R. E. Williams, Editorial Service Department, Westinghouse, from facts supplied by Dr. E. U. Condon, Westinghouse Research Laboratories.



THE MACHINE FOR SMASHING ATOMS

The atom smasher at East Pittsburgh is of the pressure electrostatic type. In the steel "pear" or pressure tank is located the apparatus for making and firing the nuclear "bullets," while in the two-story brick building at the base are the auxiliary devices, the targets, the measuring, and the recording devices. Electric charge is carried from a generator at the base of the tank by two belts running up to the electrode at the top where the charge accumulates on its outer surface, creating a high potential between electrode and ground. In the electrode an arc discharge is maintained in hydrogen. This produces hydrogen ions, i.e., hydrogen atoms minus their electrons, and deuterons, which are double-weight hydrogen atoms minus electrons. These ions—the prospective bullets—start on their trip down the vacuum tube, which stands in the center behind a charging belt. Directed at the targets at the bottom of the tube, the ions are accelerated en route by the electric field created by the high voltage.

Such a source always produces a mixture of several kinds of ions, so the beam is passed between the poles of an analyzing magnet. Here the lightweight ions are deflected more than the heavy ions and the kind that is sought comes out of one of the portholes in the analyzing chamber. Here they strike the targets, and here the atom smashing occurs.

Tomorrow's Transformer Today

The truly fireproof and explosion-proof transformer is here; it is cooled with a natural flow of air without the use of oil or liquids of any kind. Already available in all needed sizes up to 1000 kva and 15 000 volts, it is at work in office buildings and apartment centers, hospitals and stores, industrial plants, generating stations, and in tunnels and mines. With a three-year record of flawless performance, it asks no quarter from other types of transformers—and it gives none. It cannot catch fire or explode, hence it need not be isolated in separate rooms or by partitions, and it can demand favorable insurance rates. Its short-time overload capacity is unusually great, its operating efficiency excellent. As to regulation, reactance, and other electrical characteristics it is comparable to conventional types. It is no larger than a liquid-filled transformer, weighs even less, has a lower installed cost, and pays dividends because of its safety and reliability. It requires no maintenance, except occasional dusting.

H. V. PUTMAN
Manager, Transformer Division, Westinghouse Electric & Mfg. Co.

THE NEW air-cooled transformer is a practical fulfillment of that long-sought objective—a unit that is both fireproof and explosion-proof. Hazards of this kind have been eliminated by its design and construction. With it, power supplies for new machinery and new equipment can be provided in the plant in the safest and most convenient way. The transformer places no restrictions on the distribution system. Main distribution feeders throughout the plant can be run at fairly high voltage, from 2.4 to 13.8 kv, with the transformers placed conveniently at the principal load centers. Because they are fireproof and explosion-proof, transformers of this kind can be located safely right on the factory floor near the motors, furnaces, or other apparatus they serve. They can be placed in the basement of a building, out in the open in any convenient space with other equipment; no space-consuming, complicating special vaults are required. Safety and convenience are cardinal virtues of these new transformers.

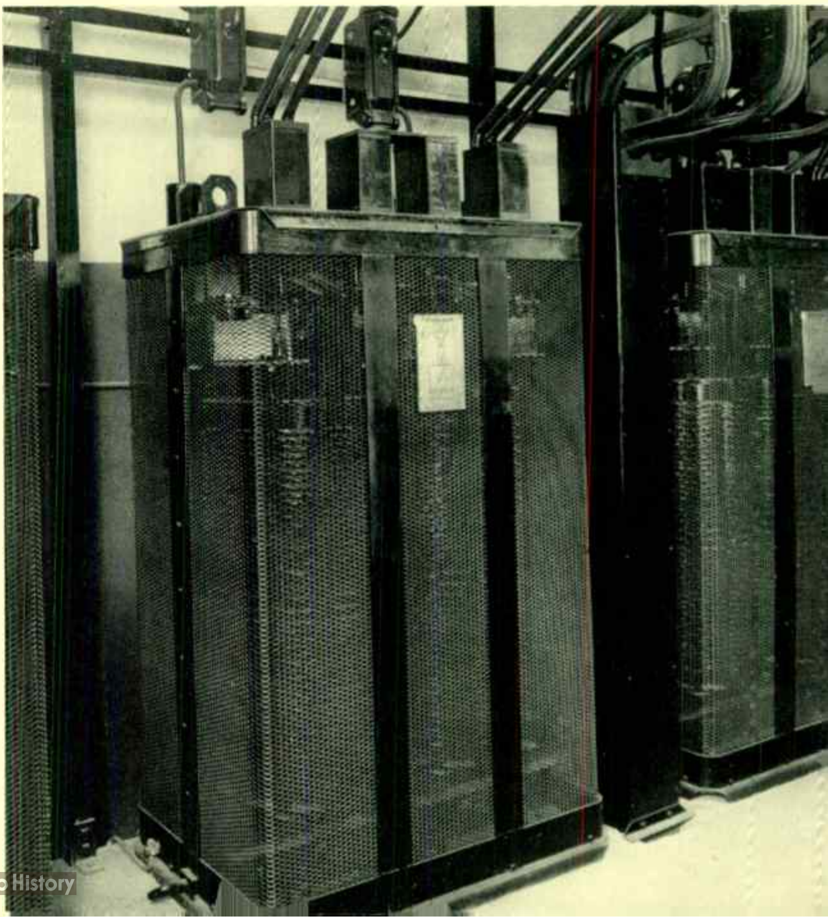
Organic Insulation Eliminated

Immunity to fires and explosions is obtained primarily by elimination of almost all organic insulating material, including even the transformer oil. The principal insulations of the transformer are porcelain and air. The windings are supported on porcelain pillars. Porcelain spacers separate the coils. Between the high-voltage and low-voltage windings is an entirely clear vertical cylindrical space filled only with air, and acting as a natural-draft chimney. There are no creepage surfaces between windings on which dirt might collect and eventually cause a breakdown. Dirt falling between high- and low-voltage windings simply drops through to the bottom of the transformer.

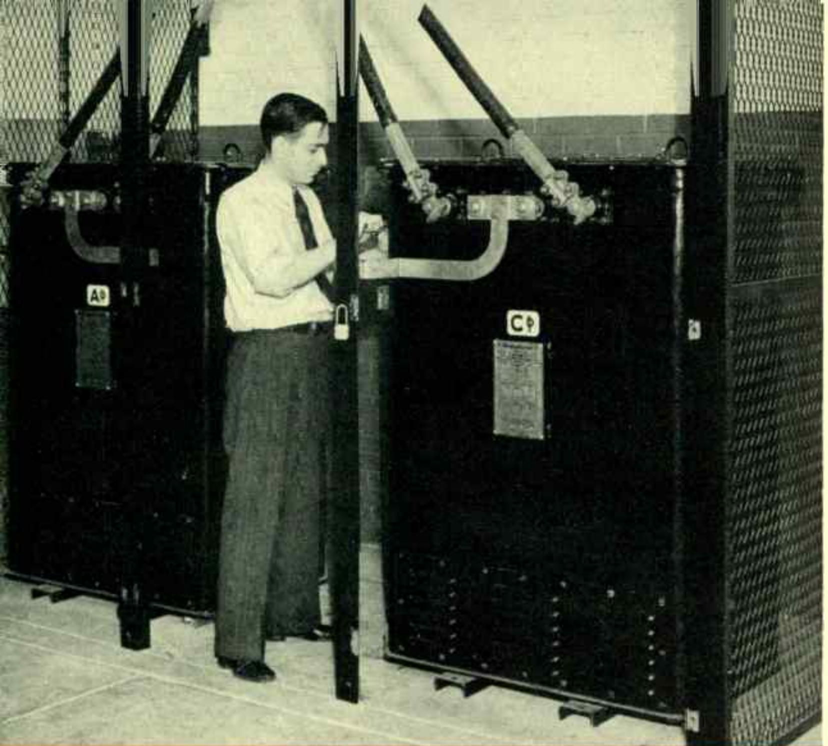
Even a major flashover between terminals inside this air-cooled open-type transformer can cause no explosion. It would resemble, rather, an insulator flashover. This is an important advantage because any liquid-filled transformer, regardless of the liquid, would be severely distressed by such a major flashover as a result of the sudden generation of gas in a confined space.

It is true, of course, that air cooling itself does not give complete assurance against fires and explosions because solid insulating materials generally used in transformers are not fireproof. They can give off gases that would be explosive when mixed with air. The assurance lies in the use, on the coils themselves of inorganic materials that neither burn nor generate explosive gases when exposed to an electric arc.

It may seem surprising that air alone, without forced circulation of any kind, can be used to cool a transformer as



Installed in the open basement, these 500-kva, single-phase, air-insulated transformers furnish the power for a large department store.



The power for 240-volt auxiliaries in the Schuylkill Station of the Philadelphia Electric Company is supplied by these air-cooled transformers, rated at 150-kva, 2400 to 120/240 volts. These transformers were among the first to be applied and use the sheet-metal construction for the tank walls.

large as 1000 kva. However, consider that oil-insulated transformers of these sizes are cooled eventually by a natural circulation of air around the tank wall and other cooling surfaces. The oil serves simply as a medium for transferring heat from its source to the air-cooled tank walls. Therefore, for air cooling, it is necessary only to design the windings so that they present approximately the same surface to air as the walls and tubes of the oil type, and to arrange the windings so that air can freely circulate through them. Because the insulation is fireproof, the transformers are designed for a normal temperature rise of 75°C. corresponding to the A.I.E.E. temperature limit for Class B materials.

Use of air as the major insulation naturally increases the electrical clearances required. It is worth-while to examine the effect of these increased clearances on over-all dimensions, losses, and overload capacity of the transformers. Except in the smallest sizes, 150 kva both single and three-phase, the air-cooled unit is smaller in height, width, and depth than the corresponding liquid-filled transformer, as the data in the table show. In the largest size, 1000 kva, three-phase, the cubical content of the air-cooled unit is slightly less than half as great. The saving in headroom, which is considerable in the larger sizes, is sometimes a great advantage in commercial installations as it permits locating the transformers on or under balconies.

Electrical Characteristics Good

The total losses of air- and oil-insulated transformers do not differ greatly. However, the relative proportions of the component losses, iron and copper, are quite different. The iron loss is slightly higher and the copper loss lower in the air-cooled units.

The reason for lowering the ratio of copper loss to iron loss for the air-cooled transformer lies in the increased clearances between high- and low-voltage windings. The greater spacing increases the permeance of leakage paths; to maintain the same reactance, the number of turns in the windings must be reduced and the cross-section of the iron circuit correspondingly increased. The core is therefore larger and windings have fewer turns but of heavier copper. Thus full-load efficiencies of the two types of transformers are almost identical. At light load the liquid-cooled transformer has slightly superior efficiency, because its iron losses, which are independent of load, are lower. At overload the air-cooled transformer has some advantage.

This difference in ratio of losses results in a greater overload capacity for the air-cooled transformer. Initially, following an increase in load, the increased heat losses are stored in the copper. Thus the air-cooled transformer, with a larger copper cross-section and without any insulation that can char, has an advantage over the conventional unit on overloads of a few minutes. Even in network applications where transformers are required to burn off cable faults, the air-cooled design is not handicapped.

The air-cooled transformer is designed to have a reactance equivalent to the liquid-filled transformer of the same rating. Voltage regulation characteristics are virtually identical, with perhaps a slight advantage for the air-cooled unit on loads of high-power factor, again because of its larger copper.

Excellent Service Record

While these air-cooled, fire- and explosion-proof transformers are said to be "new," actually they have been through three years of field experience with a perfect operating record. One early unit destined for network service after undergoing a series of particularly severe field tests has been in operation over three years without requiring any maintenance attention except dusting. Others have been in service for shorter periods in powerhouses and different types of factories. They have replaced liquid-filled transformers as the power supply in the basements of several large department stores.

COMPARISON OF WEIGHTS AND DIMENSIONS OF AIR-COOLED AND LIQUID-FILLED TRANSFORMERS

Kva	Air-Cooled				Liquid-Filled			
	Single-Phase							
	Ht.	Wdth. Inches	Dpth.	Weight Pounds	Ht.	Wdth. Inches	Dpth.	Weight Pounds
150	75	37	35	3100	74	33	35	3100
200	78	38	35	3500	74	37	37	3780
250	80	48	36	3900	88	50	41	4650
333	83	50	36	4450	88	56	46	5400
500	87	51	36	5400	94	59	48	6850
	Three-Phase							
150	70	69	33	3900	66	50	35	3500
200	74	71	34	4600	80	50	35	4500
300	78	74	35	5800	94	67	37	6350
450	83	76	35	7200	94	71	47	8000
600	87	78	36	8500	111	73	54	9350
750	90	80	37	9600	111	82	54	10050
1000	94	81	37	11300	123	86	57	12400

Many minor improvements have been made in the design and in manufacturing methods. For example, early transformers had tanks with solid walls in which louvers were cut top and bottom to provide for circulation of air. Tanks now are of open-mesh expanded metal, which greatly facilitates cooling. The walls can be removed horizontally without lifting the units out of their tanks. This, incidentally, greatly reduces the headroom required, since, if necessary, one could get at the core and coils simply by removing the mesh sides; coils do not have to be lifted out of a tank.

Effects of moisture on these transformers have been investigated with a 500-kva, 13 800-volt unit. A sixteen-day outdoor rain test was made with the transformer subjected to a precipitation of two-tenths of an inch of water per minute. The transformer carried no load but was excited at normal voltage two-thirds of the time. During the periods without excitation, the rain test was continued. On one occasion the transformer was also subjected to a natural, three-day rainstorm with light rain falling about half the time. Later heavy rain fell for about an hour.

After these extreme tests, lasting sixteen days altogether, the transformer was again subjected to its regular dielectric tests with no signs of distress whatever. While these transformers are intended only for indoor applications where moisture is not likely to be present, these results are reassuring when condensation or the effects of rain during transportation and installation are considered.

Nothing in the service experienced with these air-cooled transformers to date indicates that maintenance of any kind is required. There is, of course, no oil to be checked and serviced. Dust will accumulate on the coils and it is desirable to blow it off perhaps once a year with an air hose directed against the open tank wall. Dust will not weaken the major insulation because there are no horizontal surfaces between windings for it to rest upon. Two of these transformers were located next to a building where demolition of an old foundation created an excessive amount of dust. An examination of these units was made to determine whether dust had accumulated as a result of electrostatic charges, but no evidence of such was found.

THE ORIGIN OF THE AIR-COOLED TRANSFORMER

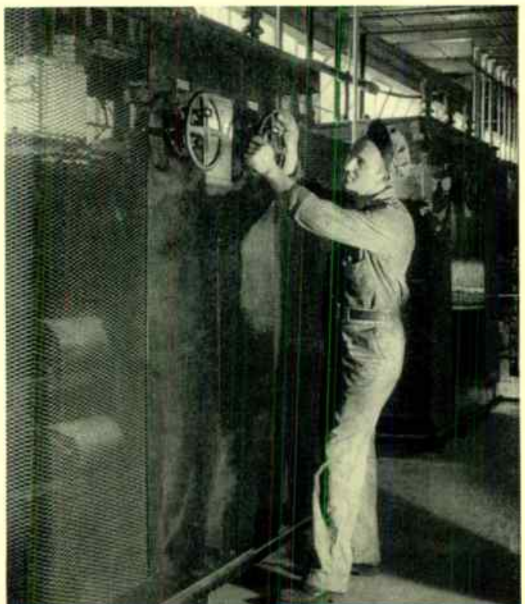
The air-cooled transformer, like most new electrical apparatus, did not spring from a single sudden discovery. The need for a liquidless transformer has been apparent for a long time, but it was not until the late 20's that the demand for a truly fireproof transformer became emphatic. One answer came in the form of new fireproof cooling liquids of the Inerteen type. A contemporary development of a transformer with no liquid or combustible insulation was started—and the present air-cooled transformer is the result. It is the product of a multiplicity of developments. A long series of designs, experiments, and actual trials were made before a physical form was found for the active elements that would give the necessary mechanical characteristics of adequate cooling, freedom from dirt accumulations, etc., without sacrificing any desirable electrical features. New insulating materials were demanded. After extensive development, they were forthcoming. These include new and much improved asbestos insulation, glass tape, special porcelains, asbestos-Micarta tubes, and new high-temperature, extremely hard and durable varnish for the coils.

The Future

Air-cooled transformers have been built in the common sizes up to 500 kva single-phase, and 1000 kva three-phase. These are the most common sizes of indoor transformers. There is no fundamental engineering reason why somewhat larger kva ratings could not be built if necessary. Eventually a limit would be reached because the surfaces exposed to the cooling air do not increase at the same rate as the kva rating. Thus, for large sizes of transformers probably it would be necessary to resort to forced draft. However, for large transformers air blast is less objectionable.

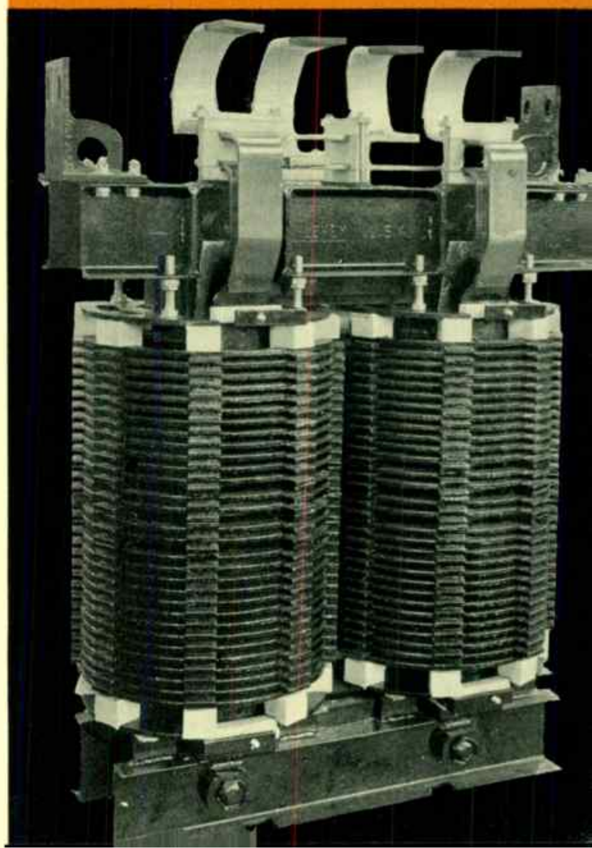
A maximum voltage rating of 15 kv appears to be a practical limit. Since reliance is placed on air as the dielectric, spacings at higher voltage become unduly large.

The air-cooled transformer unquestionably has a great future. It has clearly passed the laboratory and field-test stage. It has a large field of application in office buildings, stores, industrial plants, and powerhouses. Because of their simple foundation requirements and because they can be quickly relocated to keep them near changing load centers, air-cooled transformers have an important place in the present expansion of old plants and building of new ones. They are playing an important part in the national defense program.



These air-cooled transformers stand under a balcony beside the electric furnaces they serve in a manufacturing plant. Each is a 350-kva, three-phase, 6900/115-volt unit.

The windings are supported on porcelain pillars with porcelain spacers between coils. A clear cylinder of air separates the windings.



Models Help Determine Pipe Stresses

Steam pipes as they try to expand with temperature may exert excessive forces and turning moments on the boiler headers, turbine casings, or other apparatus to which they are bolted. To determine the magnitude of these forces and moments and the resulting pipe stresses entirely by calculation is laborious, open to error, and often virtually impossible. By tests on models, the forces and moments can be found quickly and accurately for any type of pipe system. The merits of this method become particularly conspicuous when the system is complicated by one or more branches. The best location for struts, braces, tie-rods, and rollers can be quickly determined.

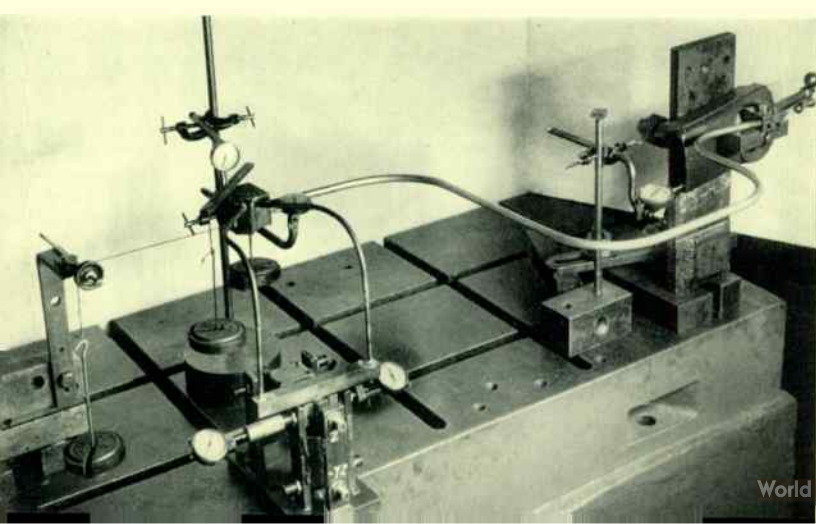
JOSEPH D. CONRAD
Mechanical Engineer, Turbine Division, Westinghouse Electric & Mfg. Co.

IN THE modern power station, pipes experience temperature cycles from ordinary room temperature to as high as 950 degrees F. In doing so they expand; the ends try to move and rotate under tremendous forces and turning moments. The end of a steam pipe from a high-temperature boiler header to a turbine if unrestrained would move in some cases as much as six or eight inches. However, since the end is bolted fast it may exert sufficient force and turning moment seriously to distort the turbine casing, open its own joints, or rupture its walls unless made with sufficient flexibility to absorb this expansion within safe limits of end reactions and stresses.

The determination of stresses in pipes is a relatively easy task, once we have determined the end reactions and moments. The predetermination of these end reactions and moments presents a real problem. If the pipe lies in one plane and there are no branch lines or intermediate restraints the solution is not difficult mathematically. A three-dimensional pipe line supported only at the ends also can be calculated, although the work is more involved than in the single-plane pipe. As soon as one starts to add branch lines, intermediate partial restraints, heavy valves with spring supports, etc., the calculation becomes more and more difficult and on the more intricate systems practically hopeless.

The problem can be solved by making a model of the pipe line in question and measuring forces and moments on a rigidly fastened end when the free end or ends are moved mechanically to the calculated location. It is then a simple matter to interpret the data into the forces and torques present when the full-size pipe experiences a temperature change. This method has the merit that it is all done at room temperature with small, easily changed replicas of the pipe, and with small forces and moments. Models are made of seamless steel tubing, which is available in a wide variety of sizes and wall thicknesses.

The steam line from the boiler to a turbine is represented in this model, the right end being figuratively at the boiler and the left end at the throttle valve. Extending forward from the "throttle valve" are two downward curving pipes representing a double line from throttle valve to steam chest—which greatly complicates any attempt at mathematical solution.



Even in the comparatively less complicated three-dimensional system, solution by a model is more satisfactory than by mathematics even though the time required to make the model and run the test is as great as performing the calculation. The possibility of error is far less in model testing than in any mathematical method; it is not only faster but a better method.

A typical pipe-model system is shown in the illustration. It is a lead from a boiler header to a steam turbine. The pipe line from the boiler header to the throttle valve is not complicated in this case. However, the use of a double line from the throttle valve to the turbine steam chest and the weight of the twenty-thousand pound throttle valve on springs complicates the problem. These springs constitute an intermediate restraint in the line; also horizontal tie rods near the throttle valve were proposed as a means of reducing lateral forces on turbine connections. With the model a test can be made readily for end reactions and moments, first omitting the effect of throttle-valve support springs and horizontal restraints. The test can then be repeated applying pure forces at these points. By applying the simple rules of superposition the combined reactions and moments including these intermediate effects are quickly determined.

As in the above case various types of struts, tie rods, stops, rollers and other devices are often applied to pipe lines to reduce reactions on turbines or associated apparatus. Too often one can only guess at or hope for benefits from such devices. With a model test the actual effect can be determined at once. In one case such a proposed device actually aggravated rather than alleviated the situation. In the system illustrated, a real benefit was found by properly locating the horizontal rods. Another feature of model testing is the ease with which the movement of the pipe line at any point can be determined. This information is desirable in designing and locating pipe hangers.

Induction Motor with 5 to 1 Speed Range

Unusual speed ranges can be obtained from an alternating-current drive by using a wound-rotor induction motor connected to a small series generator. Stable operation and high torques are obtained at all speeds.

C. W. DRAKE
Industrial Application Engineer, Westinghouse Electric & Mfg. Co.

Occasions arise when no standard motor possesses all of the desired speed-torque characteristics. An outstanding example is the drive for the complicated and intricate full-fashioned hosiery machine that manufactures a dozen or more stockings at one time.

A hosiery machine motor must have a wide range of speed for knitting various portions of the stocking. Also, it is necessary to change speed quickly from any operating speed to a predetermined speed with braking effect for the narrowing operation, followed immediately by a quick return to the previous high-speed setting. Generally, the knitting operation on a full-fashioned stocking is done at some constant high speed. Slower speeds are required for welt turning, that is, when the top of the stocking is turned over, and for narrowing, when the machine must be slowed down to allow the needles to reset for a different length of row. For instance, machines that automatically turn the welt or the double-thickness top of the stocking require a speed of about one-sixth of the maximum for a short time with a high torque to overcome the varying torque of the cams and a reasonably good speed regulation.

How to obtain such characteristics with an alternating-current motor has long been a question. Speeds from 1150 to 1700 as obtained with a wound-rotor motor with secondary resistance control are ordinarily considered satisfactory for continuous knitting operations. A speed of 850, however, with resistance control would have no slowing down or braking effect as required by narrowing, and a speed of 275 by resistance control is entirely impracticable because of the poor speed regulation and, even worse, the low stalling torque obtained.

One solution is to use a wound-rotor induction motor and a direct-connected series generator of special design. The series generator acts to load the motor artificially at the lower speeds. Although individually the characteristics of both machines are well known, the combination of the two working at various speeds and with different resistances in the circuits of both machines is quite difficult to calculate. Proper design of both machines and the correct choice of resistances are necessary to produce the desired speed-torque characteristics. The fundamental circuit is as shown in Fig. 1, consisting of a series generator direct connected to, or integral with, the wound-rotor motor and with adjustable, interlocked resistors in both circuits. Maximum speed is obtained with the rotor resistances short-circuited, and with the maximum amount of resistance in the series-generator armature circuit. Very little current then flows through the series generator circuit, hence it has practically no loading or braking effect on the main motor. However, if the rheostat arm is moved to the right, inserting resistance in the motor and decreasing the resistance in the series generator, more current will flow in the direct-current circuit. With suitable resistances, contactors, and control relays, various preset speed combinations are possible. For example, a definite high torque can be obtained with automatic transfer to any operating speed. Although ordinarily used only at the lower speed, the generator or regulating unit can, with suitable control, be used at any speed. This results in improved speed regulation but necessarily somewhat higher losses. Since approximately two-thirds of the knitting operations are performed at the higher speeds, the resistor and generator losses at reduced speeds have a comparatively small effect on the average efficiency.

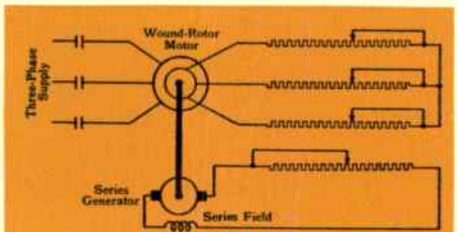


Fig. 1

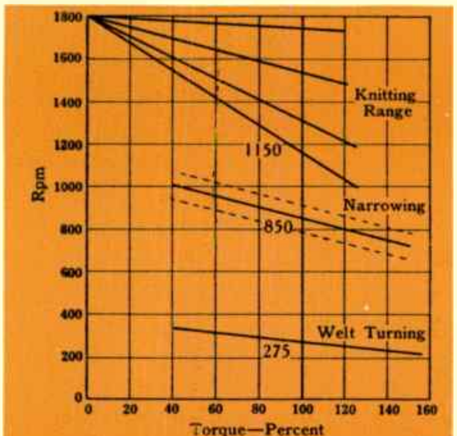


Fig. 2

In Fig. 2 are shown the characteristic speed-torque curves obtained for the arrangement as described above. However, if the regulating generator is used at all times, for knitting speeds as well as for work requiring lower speeds, adjustable speed characteristics with good regulation can be obtained over practically the entire range.

The method by which the speed of the wound-rotor motor is stabilized and the regulation improved by artificial loading is unlike that obtained by a mechanical brake or similar device. The torque developed by the series generator with a definite resistance varies widely with changes in speed (approximately as the square) and the results obtained are somewhat analogous to the stable operation of series motors on fans or loads of a centrifugal nature. For any load condition, the intersection of the speed-torque curve of the motor and load gives a stable operating point.

New Applications for Secondary Networks

The alternating-current network system has in fifteen years firmly established itself as the ace method of supplying power to heavily-loaded city areas and to skyscrapers. Powerhouses, industrial plants, army posts and ocean liners, with their concentrated loads, have essentially similar electrical requirements. The merits of the secondary network for these applications have been overlooked. The network has three basic features: reliability, maximum adaptability to meet changing load conditions, and a lower installed cost. One or more of these advantages is available to each job of concentrated power distribution.

JOHN S. PARSONS
Central-Station Engineer, Westinghouse Electric & Mfg. Co.

During the last 15 years the alternating-current secondary-network system has been installed for general distribution of power in the business sections of cities at an average rate of ten cities yearly. The network system is not inherently restricted in its application to metropolitan power distribution. Its features of reliability, flexibility, and economy have been so outstanding in that service that it demands consideration for other jobs of high load density.

The system offers the first two features—reliability and flexibility—to all applications. The secondary-network system provides greater reliability of service than any other alternating-current system. It is also the system best adapted to take care of changing load conditions. In addition to these two important features, the secondary network is often the most economical to install and operate in areas of high load density. This is particularly true if the cost comparison is made over a period of at least five years and if system losses are evaluated. Because of the necessity for reliability, secondary networks are also used in areas of lower load density, where a radial system would cost less.

The third desirable feature of the secondary-network system—maximum economy—is not present in all applications. The network system is likely to show a saving in cost where the competing system must provide relatively high reliability of service, where it must cope with rapidly growing or shifting loads, or where it must serve highly concentrated loads with good regulation and a minimum of voltage fluctuation. One or more of these requirements is present in systems for supplying powerhouse auxiliaries and many industrial plants. Here, as before, the secondary-network system is often the least expensive to install and operate.

"... The system has been installed in the majority of skyscrapers built in the last ten years."

Perhaps one of the chief reasons for the slow acceptance of the secondary-network for these other services is the fact that it is not generally appreciated that a network system can be satisfactorily operated at 460 volts. It has been possible for many years to operate spot networks at 460 volts. A spot network is a bus that is supplied through two or more network transformers and protectors over at least two primary feeders. The load is fed from the bus or spot secondary over radial circuits. Since 250 volts is about as high a voltage as can safely be used on a network designed to be self-clearing of secondary faults, it was not feasible to operate distributed or grid-type secondary networks at 460 volts, until after the "limiter" was developed. The only other alternative has been to use expensive sectionalizing breakers at both ends of all secondary mains.

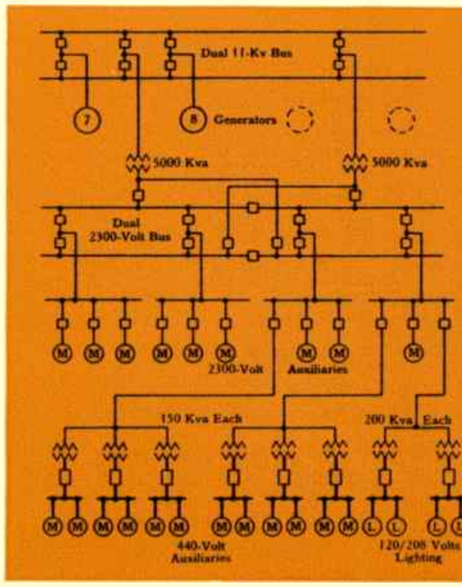
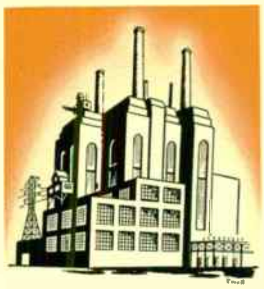


Fig. 1. The double-bus radial power supply to the station auxiliaries of a proposed new power-generating station.

The purpose of current limiters or protective fuses, which are placed in each end of each secondary conductor, is to remove short-circuits from the secondary grid that would not otherwise burn themselves clear, and to limit the extent of damage to secondary cable on those faults that would take an abnormally long time to clear themselves. The current limiters are built to open before the cable insulation can be damaged by heating resulting from the fault current. Four years' experience with limiters has shown that, properly applied, they are satisfactory.

Now that there are no reasons why the secondary network cannot be operated at any voltage up to about 500 volts without the use of sectionalizing breakers in the secondary mains, the system should receive widespread acceptance for supplying power-house auxiliaries, industrial plants, army posts, air fields, and ships.



". . . The system should be considered for new power-plants, of any size."

Powerhouse Auxiliaries

Power usually is supplied to powerhouse auxiliaries by a radial system, sometimes with throw-over schemes and at other times by a loop or a duplicate feeder. Unquestionably a secondary network is as reliable as the most expensive system used in powerhouses heretofore and is certainly more reliable than the great majority of systems now in operation. The system should be considered for all new power stations, regardless of size. The system may be difficult to justify economically where extremely large units are used or where boiler pressures are high, which necessitates large high-speed boiler feed pumps. Such stations may have several large motors uneconomical to build or serve at a low voltage, such as 208 or 460. The smaller auxiliaries in such stations, however, might well be supplied with power from a network, probably at 208 volts.

Stations that have single units up to about 50 000 kw and operating at moderate pressures are most promising for the secondary network system. For such stations its use should be carefully analyzed. Such an analysis usually requires a calculating-board setup of the network system to determine the most satisfactory layout. Every powerhouse is a tailor-made job, and it is necessary to study the problem of auxiliary power supply for each station individually to determine whether the network system offers an economic advantage.

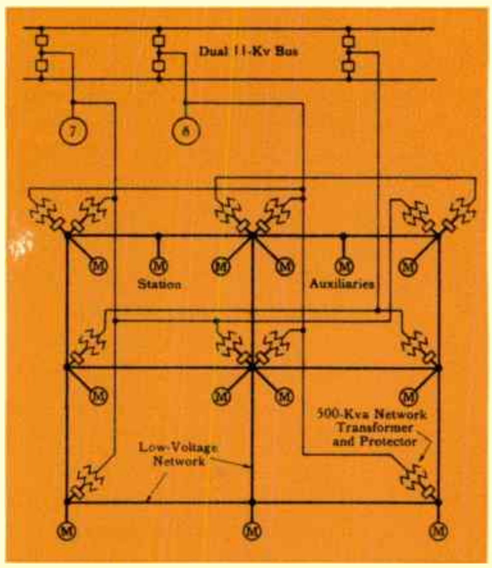


Fig. 2. *How the auxiliaries of the station in Fig. 1 could be fed by a low-voltage network.*

A rough analysis was made recently for a station having an initial installation of two 35 000-kw units and an ultimate of two more, which indicates the possibilities of the secondary network. The station is being built using 2300- and 400-volt auxiliaries supplied as shown in Fig. 1. The equipment portion of the cost of the auxiliary supply system shown in Fig. 1 is about $230 000. To supply the auxiliaries from a 440-volt secondary network shown in Fig. 2 would entail an equipment cost of only $165 000. Neglecting the cable and bus cost, which would probably favor the network, the network system of Fig. 2 is roughly $65 000 cheaper than the radial system of Fig. 1 for the initial layout, and more than twice this amount for the ultimate layout contemplated. The reliability of the network system is superior to that of the double-bus double-breaker system of Fig. 1. This appears to be an ideal application for the secondary network.

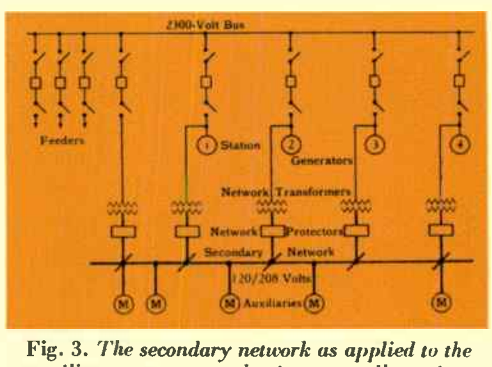


Fig. 3. *The secondary network as applied to the auxiliary power supply in a small station.*

Even if the 2300-volt supply bus did not use the double-bus, double-breaker scheme to obtain reliability, but, instead, used a simple radial scheme with single buses and single breakers, the cost of the system of Fig. 1 would still be higher than that of the network system; and certainly the reliability would be far from comparable. The cost of the system of Fig. 1 could be reduced by taking a part of the auxiliary supply from the terminals of one of the main units as is done in the network system of Fig. 2. This would save one main bus position in the initial layout and a total of two main bus positions in the ultimate layout. Even if this were done, the network system would cost less.

About two years ago a station of two 3500-kw generators was rebuilt and equipped with a network system, shown in Fig. 3, which has been satisfactory. Although a radial system would have been cheaper, it was felt that the greater reliability of the secondary network system fully justified the difference in the installation cost.

The grid, as initially installed, is sufficient for the ultimate layout and as units are added it is necessary only to add one primary cable and one network transformer and protector per unit to the auxiliary-supply system, as shown in Fig. 4. Thus additions to the system to accommodate increased station capacity can be made more easily, quickly, and usually at less cost than with a radial system.

In the small station of Fig. 3 the secondary grid is 120/208 volts and was designed to burn off secondary faults. In the larger stations, such as the 70 000-kw station discussed above, it is less expensive to use a 440- or 460-volt secondary grid. At these higher voltages the network system cannot be designed so that all faults will definitely be self-clearing; each end of each cable should be protected by limiters. Limiters can be used also in the 208-volt grids to clear faults that would not burn themselves free because of insufficient current. It is possible to design the network system so that a fault on the low-voltage mains will not cause any loss of load; care should be taken to do this, using limiters if necessary.

Equipment for a power-plant secondary network should be selected with the idea of minimizing fire and explosion hazards. Secondary network transformers should be either Inerteen filled or of the new air-cooled type, which are of about equal cost. The new dry-type transformer uses class B insulation and depends on natural air circulation for cooling. Either of these two transformers can be placed at the most desirable locations in the plant without enclosing them in vaults. The dry-type transformer is preferable.

". . . The industrial plant, with its changing load, makes the flexibility of the network very welcome."

Network protectors should be of the submersible type to protect the relays and mechanisms from dirt. They can be standard in all respects except for a simple interlock with the main breaker. This interlock opens the protectors when their associated main-unit breaker opens, and prevents their reclosing automatically until the unit breaker is closed so as to eliminate the possibility of trying to synchronize a main generating unit through the network system.

Industrial Plants

Industrial plants offer a much wider variation in the service requirements than do power plants. In general, service reliability is less important than savings in installation. Operating and maintenance costs are more important in industrial plants than in power stations. This means that the network system usually has to show an economic advantage over any competitive system. The greater flexibility of the network system, which can be converted into a cash saving should a major rearrangement of manufacturing methods and plant load take place, is more likely to command a premium over competing systems than is its greater reliability. Once installed, the secondary grid rarely will require change unless the load area is extended, in which case it is necessary only to enlarge the grid. The fact that the system can be operated with any one primary feeder out of service facilitates extensions and rearrangements of primary cables without interruption to service. The relatively small, self-contained network units, each consisting of a three-phase network transformer with a network protector mounted on it, can be readily added or relocated adjacent to other utilization centers if load changes require it. The only extensive rearrangement that is likely to be required to take care of major load changes is in the radial circuits from the utilization centers to the loads. Such load changes, when using a radial system, often require revamping of the entire system from the main step-down transformers to the loads, and much or all of the plant load has to be dropped while the work is being done.

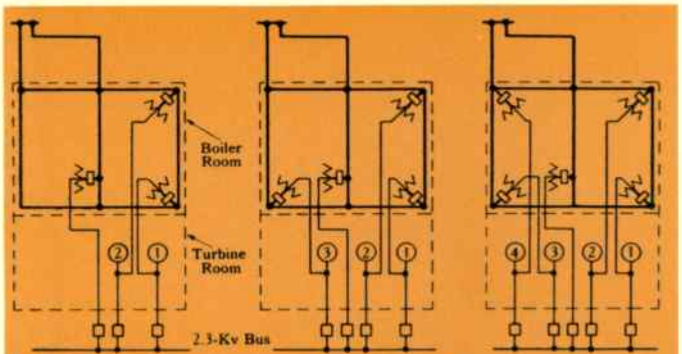


Fig. 4. *Progressive steps in applying a secondary-network system to the power supply for auxiliaries in a power-station as units are added.*

A well-designed secondary-network system will usually have considerably lower losses and better regulation than the radial distribution system. These factors are of economic importance to the industrial plant and should be weighed along with the initial investment when a distribution-system study is made.

The utilization voltage of the network and the competing system are frequently the same. This, plus the considerable diversity between the plant loads, are factors favoring the network system economically in industrial plants and are usually not present in power-station applications.

An alternating-current secondary-network system for an industrial plant can take either of two major forms. A spot-network system, as shown in Fig. 5, consisting of one or more spot networks whose buses (42) are operated independently or connected together through tie circuits (62), can be used. This system with its radial feeders (61) from the major distribution bus or buses (42) to the utilization centers or buses (7) is similar in layout and arrangement of its secondary buses and circuits to the ordinary radial distribution systems.

The system of Fig. 5 is, of course, designed so that no part of it will be seriously overloaded when any one of its primary circuits is out of service. Its advantages over the usual radial system are: better regulation, lower losses, greater convenience in operation and maintenance, and greater reliability of service. A fault anywhere on a primary feeder, such as feeder (1), or in one of its associated network transformers (3) will not cause any interruption to service. Such a fault is disconnected from the system by the tripping of the circuit breaker at the supply end of feeder (1) and the opening of its associated network protectors (9). Obviously, faults on buses (42) or radial circuits (61) result in some service interruption, just as on a radial system.

The preferred form of secondary-network system having a distributed secondary grid, as shown in Fig. 6, will give greater service reliability and flexibility than any other distribution system. It will also often be the least expensive, particularly for serving dense load areas where the loads are fairly uniformly distributed and the total load is relatively large. The utilization centers or buses (7) are connected by the secondary mains to form the network grid, and the network transformers (3) are located immediately adjacent to certain of the buses (7) and connected to them through network protectors (9). This arrangement gives a two- to four-way feed to all utilization buses, and minimum transmission distances at the secondary voltage, which results in exceptionally good voltage regulation, low losses, and minimum voltage fluctuation during the starting of large motors. The radial cable circuits (61) and their associated secondary breakers (51) of Fig. 5 have been eliminated, resulting in a saving in breaker cost and often in the total cable cost, although the amount of primary cable has been increased.

As the plant load grows, usually all that is necessary is to

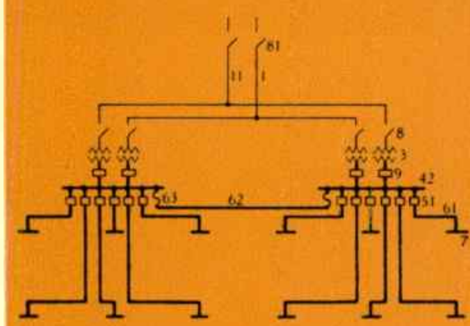


Fig. 5. *A spot-network system as applied to an average industrial plant.*

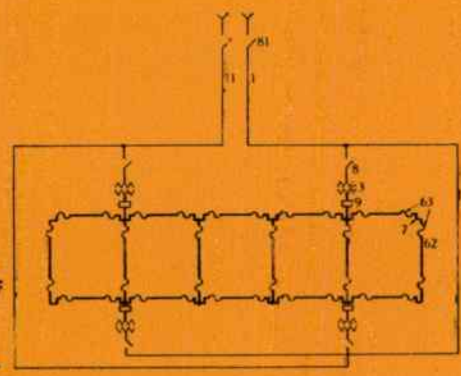


Fig. 6. *A distributed secondary grid is preferred to that of the system of Fig. 5.*

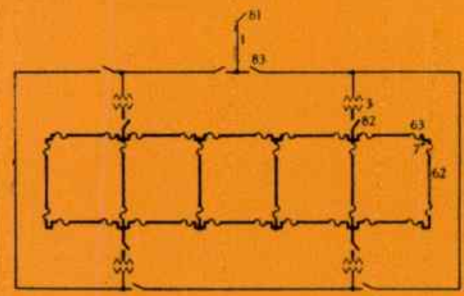


Fig. 7. *A modified radial system offering some of the advantages of the network system.*

add network transformers and protectors at the proper utilization buses 7 and connect them to the existing primary feeders. Rarely is any change in the secondary grid necessary unless the load area is extended, in which case the grid may have to be enlarged. Should radical changes in the locations of the existing loads be made within the load area covered by the grid, it will be necessary only to move the network units, each consisting of a three-phase transformer with a network protector mounted on it, to the proper utilization points as dictated by the load changes.

It is questionable whether appreciable additional expense can be justified to obtain the reliability of a network system unless the plant is served by at least two primary feeders, either of which is capable of carrying the entire plant load. A network system can be installed in a plant served by a single primary feeder, however, by dividing the feeder and installing two circuit breakers in the two branches where the supply feeder enters the plant property. From there the system could take the form shown in Fig. 5 or Fig. 6.

For plants supplied by a single primary feeder, where service interruptions of short duration are not serious, a desirable and economical form of radial distribution system is shown in Fig. 7. While its service reliability is not as good as that of a network system, it has some of the advantages of the network system, such as flexibility, good regulation, and low losses, at a lower cost. There is a saving in investment in primary cable, network protectors, and usually in transformers; although the secondary grid in some cases may cost more. This system is often the most economical, and it has the further great advantage of permitting changeover to the distributed type of secondary network at a minimum cost when load growth or the necessity for more reliable service makes a second primary feeder available.

This possibility of changing to a secondary network should be kept in mind when purchasing equipment and installing the system. The use of the primary disconnecting switches (83) and secondary disconnecting switches (82) makes possible the quick restoration of service after a fault anywhere in the primary loop or in any transformer. The entire system will be de-energized when such a fault occurs. However, the faulty section can be isolated readily by opening its associated disconnects 82 and 83. The system can then be re-energized in a relatively short time by reclosing the breaker at the supply end of feeder 1. This form of system, where all transformers are connected to the same primary circuit and are paralleled on the secondary side, is generally known as a banked transformer system. It should be designed so that full load can be carried without overloading when one transformer and its associated section of primary cable is out of service.

The secondary network appears to offer the greatest economic promise where two or more primary feeders are available for serving the plant and where load density in the plant and total plant load is large. Utilization voltage of the secondary-network system should be either about 216 or 460 volts, although spot networks have been used at 2300 volts.

Office Buildings, Ocean Liners, etc.

Secondary-network systems, both of the spot and distributed types, have definitely proved economical for serving large office buildings. These networks are sometimes of the vertical form where some of the network transformers and associated protectors are located on one or more of the upper floors of the buildings as well as in the basements, and the primary feeders and secondary cables are run vertically up into the buildings. In buildings that are not very tall but have a large ground area, the network takes the more customary horizontal form. Load conditions and requirements in large commercial buildings are no more favorable to the economic use of the secondary-network system than they are in powerhouses and many industrial plants, yet in the first case the system has been used quite extensively and in the latter cases very little.

". . . The suitability of the secondary-network system for the large vessels seems to have been overlooked."

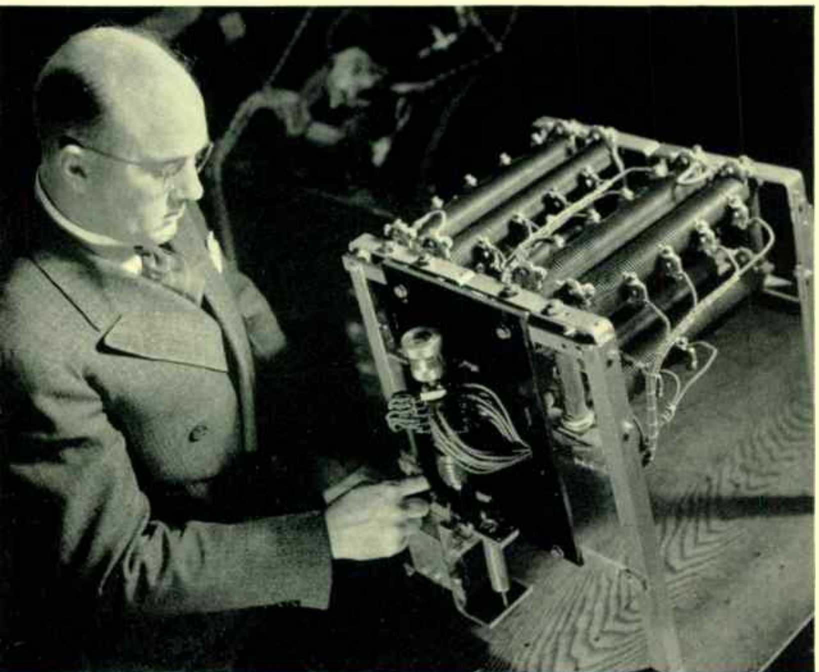
Large ships, navy yards, air fields, and army posts, are typical of places that could make good use of the system. A study of their requirements will greatly extend the field of usefulness of the secondary-network system.

STORIES OF RESEARCH

Mercury, a New Boss of Speed or Voltage

A NARROW column of mercury standing in a slender glass tube is one of man's oldest and simplest devices. It has long been a standard way to measure temperature or atmospheric pressure. Because it is so simple the idea would seem to have no radically different use. But a research engineer, K. A. Oplinger, has seen in it something more, much more. Out of that perception has come a device that may well turn out to be a basis for one of the most versatile schemes for regulating speed of a motor or voltage of a generator.

Instead of using a glass bulb below the column, to act as a mercury reservoir, Mr. Oplinger uses a stainless-steel bellows. Sealed into the column rising above it are electrical contacts, spaced roughly a sixteenth of an inch apart. When the bellows is compressed the mercury rises and successively short circuits the contacts, forming thus a series of mercury switches. Because of the large ratio of bellows area to the cross section of the capillary, only a slight compression of the bellows is necessary to raise the mercury the full height of the tube. In fact,



K. A. Oplinger at his educated column of mercury. With contacts sealed in a tube in which mercury rises and falls as a steel bellows is moved, he is able to obtain a power amplification of one hundred thousand with a total bellows motion of only fifteen thousandths of an inch.

in the experimental model only fifteen thousandths' of an inch movement of the bellows is required to cover or uncover the forty contacts, a ratio of about 150 to 1. The bellows can be actuated by a mechanical driver, as a cam or lever. Thus it may well be a speed-control device, the contacts in the tube controlling a motor rheostat; or an electromagnetic element can make it respond to changes in voltage or current.

The device is, in effect, an amplifier. The full mercury column can be raised by 0.05 watt change in the coil driving the bellows. The change in power controlled may be five kilowatts. Thus the power amplification is one hundred thousand.

Because of the low voltage between adjacent contacts and because the contacts are sealed in a hydrogen atmosphere, relatively high currents can be handled. The device was tried on a 220-volt direct-current circuit, the current being varied from 12 to 30 amperes. After five million operations the contacts showed no sign of wear.

Although the mercury column has long been used as a thermometer or barometer, the new control scheme is insensitive to either changes in temperature or pressure.

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Radium Hound

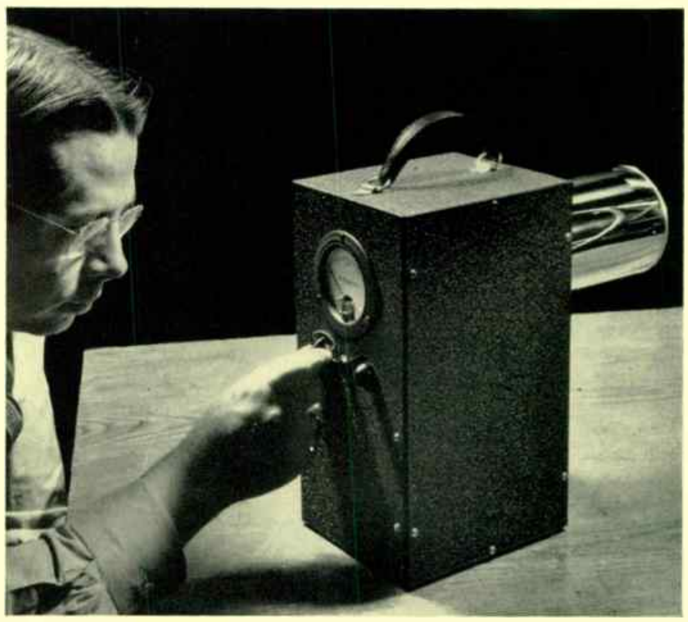
AN OUNCE of radium is about as big as a large pea, and is worth more than $700 000, so a few thousand dollars' worth of the stuff is fairly easy to misplace. That is, it would be if it weren't radioactive.

Dr. W. E. Shoupp recently rigged up a device he calls a "radium hound" which is so sensitive it can detect the radioactive emanations from as little as four quadrillionths of an ounce of radium, which would be the merest speck of it, and worth only a few cents. This dramatic use of the radium hound may not turn out to be its most important, though. Few laboratories and hospitals can afford enough radium for therapeutic use, but high-voltage X-rays are being used more and more for the treatment of cancer. These "hard" X-rays are highly penetrating and must be controlled carefully to avoid killing normal, healthy tissue.

Shoupp's radium hound will be ideal for determining safe therapeutic dosage for a given quantity of radium, radon, or X radiation. Compact, weighing only 15 pounds, it can be carried like an overnight bag quickly from place to place as it is needed. It has the further advantage of being a direct-reading instrument, which is a radical improvement over the Geiger counter normally used for this purpose.

The astonishing thing about the radium hound is its simplicity. The heart of the device is a cylinder made of wire screen. Between this screen and a metal rod along the axis of the cylinder is connected a dry battery. Assume the positive terminal to be connected to the screen and the negative to the rod. X-rays or radium emanations produce gaseous ions; positive ions are attracted to the negative rod and negative ions leap to the positively charged screen cylinder.

Actually the number of ions thus collected is not very great, for only an extremely feeble electric current flows through a resistor connected between the two elements. It amounts to something like a ten-



This little box with a shiny "nose" sniffs out lost radium or measures intensities of X radiations. Weighing only 15 pounds, it can be easily carried to track down as little as 4 quadrillionths of an ounce of radium.

billionth (0.000 000 000 1) of an ampere, or five hundred-millionths as much current as used by the lamp in one of those fountain-pen flashlights. This tiny current is fed into an amplifier, thence to an indicating instrument calibrated in *r* units (1/10 of an *r* unit is the maximum dose of X radiation that can be endured by an average person for 8 hours without detrimental effect).

The screen cylinder is surrounded by a solid metal shield, which prevents abnormal electrostatic disturbances from giving false readings.

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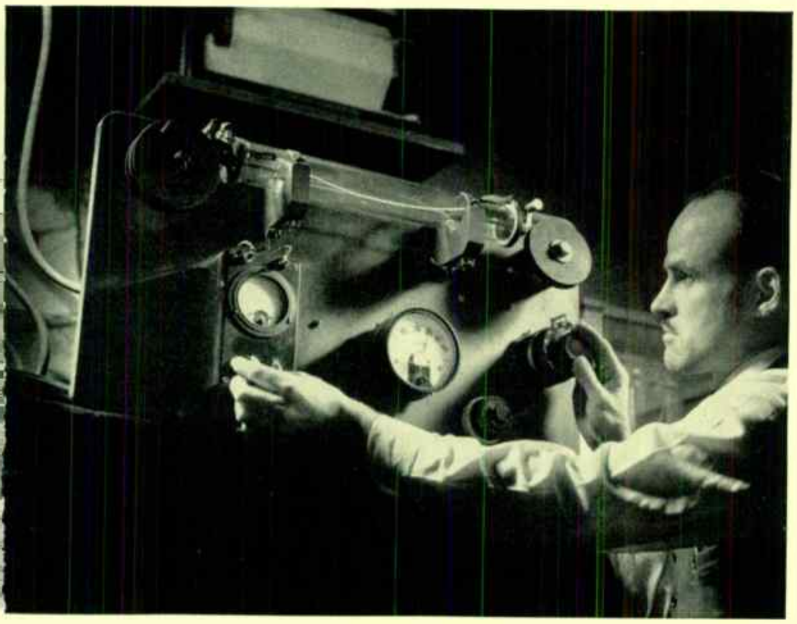
Wisp of Wire Controls Steel Quality

A STRANGE chemical tug of war goes on when a piece of steel is heat-treated in an atmosphere of protective gas. Normally the gas contains some carbon, which it tries to inject into the steel. But the hot steel may have no appetite for carbon, so it generously shares its store of that element with the gas.

Usually the metallurgist wants a stalemate between the two actions. He starts with a steel having the right amount of carbon for a given purpose, and he wants to keep it that way. It seems simple enough, until he starts to select a gas to do the job. The process is devious, because the most accurate chemical analysis of a gas does not reveal what effect it will have on steel. And so the metallurgist usually must try one gas after another, varying its carbon-introducing capacity (or



A hot wire has been used to measure electric current; one is being used here to measure the amount of carbon in a heat-treating gas. The wire while hot absorbs carbon, which changes the resistance of the copper.

"carburizing potential," to use the technical term) until he finds one that produces precisely the right physical properties in the finished steel part.

J. R. Gier recently built an instrument—ingenious because it is simple—that banishes all this empirical fuss, and for the first time substitutes exact scientific control of carburization. A fine iron wire, of known carbon content, is suspended in an airtight glass tube and heated by an electric current at a predetermined power input. The wire reaches a temperature of about 1800 degrees F., and a stream of the test gas is passed through the tube.

After ten minutes the electric current is shut off. Because the wire is so small it "quenches" by normal cooling, thus freezing the carbon in solution. Gier then measures the electrical resistance of the treated section, which gives a precise, direct indication of the amount of carbon in the wire. Precision comes from a peculiar electrical characteristic of steel. Normal carbon content varies from zero to about 2¼ per cent in commercial steels, but this slight chemical variation produces a change of more than 300 per cent in electrical resistivity of the metal. The amount of carbon in the wire can be determined within 0.05 per cent by this method.

In practice the wire is heated, and the gas is varied until the resistance of the wire corresponds to the desired carbon content of the steel; then no further change in gas is necessary.

As a check on the accuracy of his method, Gier heat-treated two pieces of steel—one carbon-free, the other with a known carbon content—in a gas of unknown carburizing potential. From calibration curves of the hot-wire instrument he computed the percentage of carbon in the treated steel. Precise chemical analysis verified the computation within 0.01 per cent.

The hot-filament instrument will be particularly valuable in these days of high-speed metal fabrication. Its original use was for control of atmospheres for steel-hardening furnaces, but it can be used also for controlling special atmospheres, as in sintering metal powders.

• • •

Cure for Mechanical Jitters

SOMETIMES beneath the solution of a whole group of complex practical problems lies a single simple scientific principle that works time after time. When research Engineer C. R. Hanna was asked to seek a remedy for excessive vibration in a modern high-speed turbo-generator, he employed the simple expedient of damping with small particles. To Hanna's practiced eye it was apparent that the turbine housing was vibrating in resonance with the natural mechanical frequency of the turbine. So he had the housing removed; inside it he welded steel pockets and filled them with common sand. Energy of the mechanical vibration was absorbed by movement of the sand particles over each other, and the turbine settled down to a normal level of vibration. The same fundamental idea has been used by Westinghouse relay engineers for making contacts that do not bounce.

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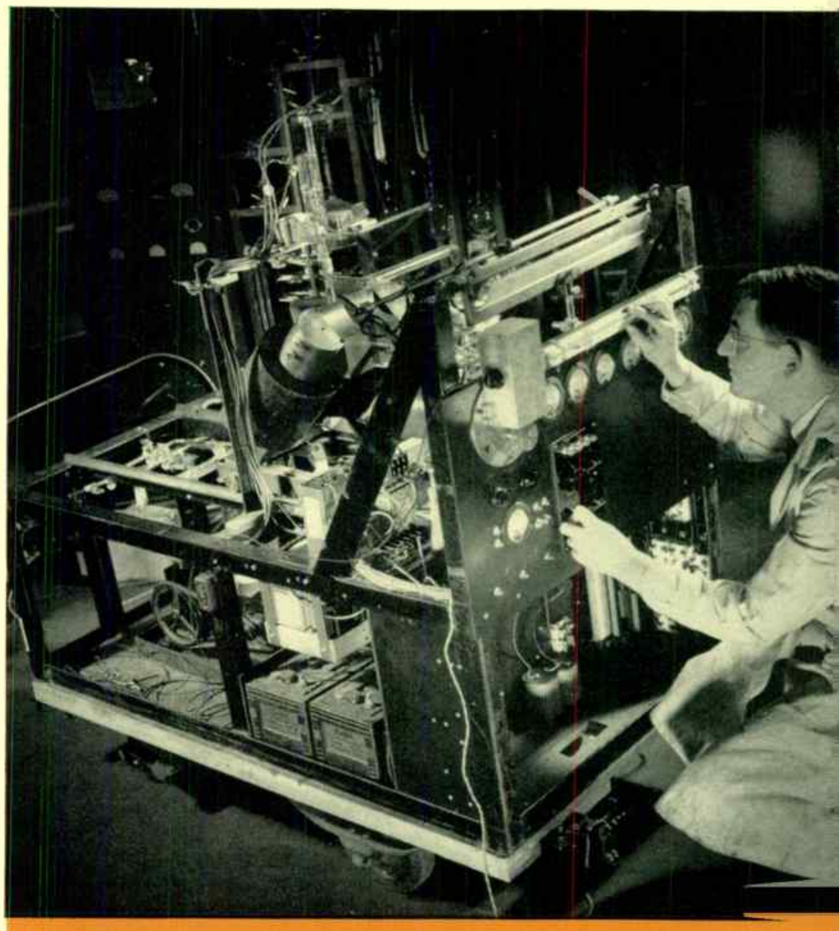


The mass spectrograph has gone from fields of pure research to the "production line." This one, developed by Dr. John A. Hipple, can be rolled to a controlled-atmosphere annealing furnace, for example, and provide continuous indications of the gases present. The device separates molecules according to their charged masses. It is capable of detecting a substance if present only one part in 100 000.

What's New!

Transformer History Repeats Itself

Transformer history, from the days of George Westinghouse's first transformer in 1890 has made progress through important periodic developments. The first core material available was just ordinary iron sheets, which deteriorated electrically with age. As methods of using it were learned, transformers steadily improved, until transformer design reached an almost static level. Then, about 1906, a new material appeared, silicon iron, that was far superior electrically to the previous "stovepipe" iron. Engineers found it necessary to recast their designs to utilize the full advantages of the new sheet. Following this, there came a period when transformers were pushed little by little to new levels of excellence, until the middle 20's when the work of research metallurgist, Dr. T. D. Yensen, showing the adverse effects of impurities, resulted in a greatly improved silicon iron; a new cycle of transformer betterment began.

Today, another new and greatly superior transformer material has appeared, Hipersil. Succinctly stated, Hipersil has about one-third more flux-carrying capacity than the best grade of hot-rolled silicon steel without increased energy loss. This means again a major revolution in transformer practice.

Research metallurgists learned some time ago that an iron crystal is much more readily magnetized along its face than along any diagonal through it. Thus if the crystals are oriented so that all or most of them face in one direction, the steel will have much higher magnetic permeability in that one direction than an iron with crystals pointed at random. For the same reason the permeability in any cross direction will be poorer. Also, the energy loss when the direction of flux is reversed is reduced. All this is due to an orientation of the iron crystals.

Rolls of Hipersil ready for slitting into ribbons, which are wound into transformer cores. Hipersil is a new material that has one third more flux carrying capacity than the best grade of hot-rolled silicon steel.

Advantage can be taken of Hipersil's greater permeability in any of several ways. A Hipersil transformer could be roughly twenty per cent smaller and lighter than a conventional transformer of the same electrical rating. Or, built to the same physical size, the losses could be considerably less or the load carrying capacity considerably greater. Hipersil makes possible modern transformers, more closely adjusted to present demands of power and distribution systems.

In the smaller sizes of distribution transformers, 1½ to 15 kva, to which Hipersil has been applied to date, the gain shows up in increased short-time overload capacity, in better regulation, in lower weights and dimensions and in less oil. With distribution systems more fully loaded than a few years ago, higher short-time overload capacity is to be preferred to minimum losses at rated capacity. This has been accomplished by changing the ratio of iron to copper. By properly proportioning the iron and copper, the iron losses, even in spite of the superior iron, are allowed to increase slightly but the copper losses are reduced. The sum total of the losses remains about the same in these lower ratings, but the lower copper losses permit higher loads to be carried for short periods.

The regulation of Hipersil distribution transformers is better than in previous transformers. This is true at both high and low power-factors. At high power-factor, it results from the lower copper losses. With Hipersil worked to about one-third higher densities than ordinary silicon iron, fewer turns are required for the same voltage. This, plus longer leakage paths, improves regulation at low power-factors.

Hipersil offers to larger distribution transformers and to power transformers the same advantages it does to the small distribution transformers already available. The advantages can be utilized, however, in different ways as seem expedient for each class. Plans under way will make these larger transformers available in the near future.

Hipersil ushers in a new era in transformer history. This is because Hipersil, by virtue of its grain orientation, is a basically new transformer iron, not just hot-rolled silicon iron of higher permeability. At present, it is far superior to previous transformer irons. As processes for making and handling it improve and as designers learn how to take fullest advantage of it, transformers will continue to improve; simultaneous development work on the material itself can be expected to advance still further the performance of this remarkable magnetic material.

Frequency Meter—Slide-Rule Size

What the thermometer is to a doctor, a new type of frequency indicator is to the engineer seeking the cause and cure of troublesome vibration. This new instrument built on the old vibrating-reed principle is no larger than an engineer's slide rule and weighs but eight ounces, yet it will disclose just what frequencies between 10 and 3500 cycles per second are present in a vibrating body.

The meter consists of a thin steel reed clamped between rollers and extending from them as a cantilever. Rotation of one of these rollers by means of a thumb nut lengthens or shortens the free end of the reed with a resulting decrease or increase respectively of the resonant or natural frequency of the reed. The frequency, which depends on the position of the reed with respect to the frame of the instrument, is given by a pointer fastened to the reed and a calibrated frequency scale on the frame.

To measure the frequency of vibration, the head of the device is held against the vibrating body. Adjustment is made until the reed vibrates at maximum amplitude and the corresponding frequency is then read opposite the pointer. If more than one frequency exists there will be a corresponding maximum reading of vibration for each frequency present. Vibration in different planes can be determined.

The success of a reed-type meter of this sort depends largely on how the reed is clamped. The requirements are severe: the length of the reed is to be adjustable; the reed should be held rigidly with the least possible damping, and the response of the reed to vibration should

Vibrating-reed frequency indicator.

not change with wear of the clamp. By an ingenious mechanical structure these stipulations are satisfied simultaneously.

The reed is held clamped between two pairs of rollers. Three of these rollers are actually ball bearings and the fourth is used to move the reed in or out by turning a thumb nut which is an integral part of the roller. The rollers, which hold the reed, obtain their clamping action through stiff springs which are integral with, and machined out of, the head. These springs support the rollers and give practically constant clamping load on the reed, even after some wear of the rollers. The calibration therefore remains constant.

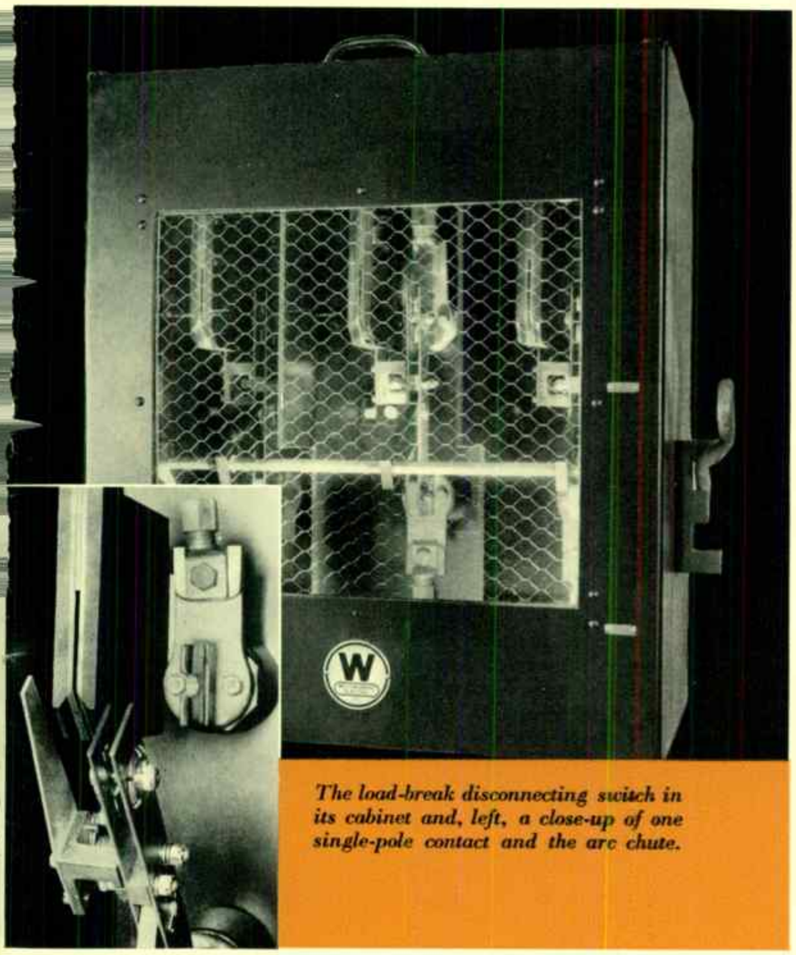
The device is sensitive. It will indicate the presence of a vibration of any frequency within its rating whose double amplitude of vibration is about one ten-thousandth inch or greater.

The Disconnecting Switch Goes De-ion

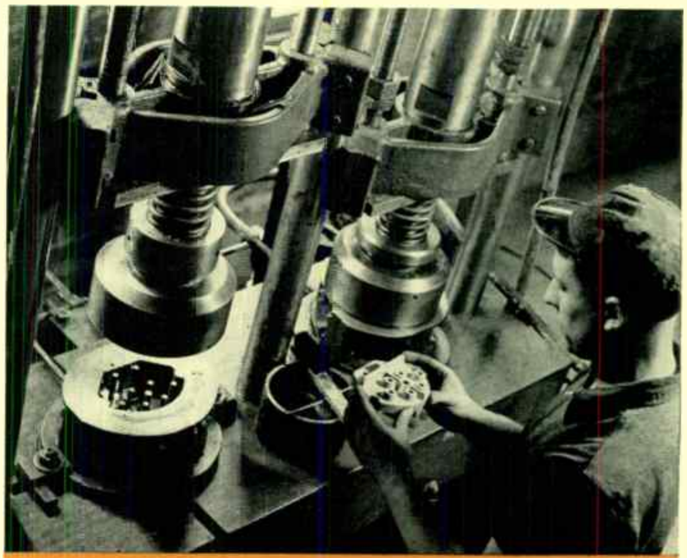
THE OLDEST circuit-opening device known to the industry—the familiar knife-blade or disconnecting switch—has become thoroughly modern by its adoption of one of the newest principles of arc interruption—the drawing of an arc in a narrow, fiber-walled slot. This marriage results in a switch capable of performing important new duties—that of serving in indoor installations as a non-automatic switch interrupting full-load (but not short-circuit) current without hazard to the operator, without external flame and with little noise.

Basically the device consists of a standard single-pole switch paralleled by an auxiliary De-ion arc chute. When closed, the conventional disconnecting-switch elements carry the load current. When the switch opens the main disconnecting blade opens first, shunting the current through the blade and contacts in the arc chute. When the main blade has moved away far enough that an arc cannot strike to it, the contacts in the arc chute separate with a sudden, snap action. As the quick-break blade retreats within the narrow walls the hot arc vaporizes some of the fiber, creating a blast of cooling, de-ionizing gases that accelerate the arc extinction; because the arc life is held to one cycle or less, the wear on contacts and walls is kept extremely low.

The switch has been built in single-pole and three-pole forms and for voltages up to 15 000 and for load currents up to 400 amperes.



The load-break disconnecting switch in its cabinet and, left, a close-up of one single-pole contact and the arc chute.



Prestite, a porcelain made by a new method, possesses the superb electrical qualities of wet-process porcelain and the dimensional fidelity of that made by dry process.

A Radical Change in an Ancient Art

MANUFACTURE of porcelain is unique in the electrical industry. A handicraft as old as civilization itself, the manufacture of porcelain became an important part of the electrical industry at the very beginning, and has retained many artisan practices to this day. A new method of making porcelain makes it much more of a mechanized procedure and, what is more important, results in a product that combines the good features of porcelain made by the two common processes, wet and dry, without their objectionable points.

Prestite, as the new porcelain is known, has the excellent electrical strengths of wet-process porcelain and good adherence to physical dimensions obtainable in the complicated forms only with the dry-process method.

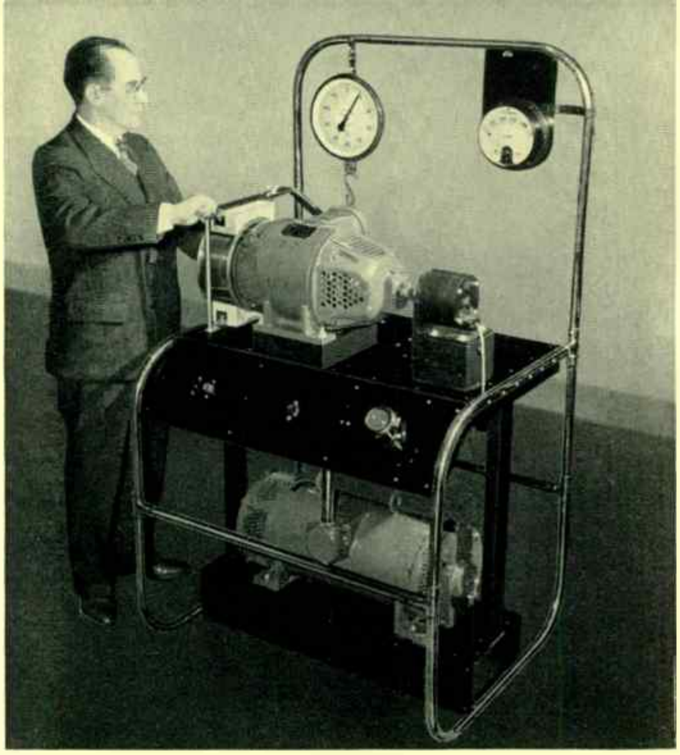
Insulators, bushings, and other symmetrical objects requiring high-dielectric strength have been made by mixing the ingredients of clay, feldspar, and flint with water to the consistency of a paste and forming the product by extrusion and turning, molding, or casting. The result of this wet-process is a hard, non-porous porcelain of high dielectric strength. Because it has to be dried of much moisture the shrinkage is large. Dimensions cannot be held closer than to plus or minus three per cent. The surface must be subsequently finished by trimming.

To produce irregular shapes of high dimensional fidelity, the constituents are mixed, dampened slightly and pressed into shape. This is dry-process porcelain. Unfortunately it is porous and absorbs moisture readily. Thus it is unsuitable for high-voltage work. Dry-process porcelain is more of a spacing material than an electrical insulator.

Prestite is wholly impervious to moisture, has the same dielectric strength as wet-process porcelain, and is its equal or better in mechanical strength including resistance to shear, compression, impact, and tension. Both electrically and mechanically Prestite is the equal of the best porcelain previously obtainable and is far superior to that available by the dry-process, the only kind heretofore used for irregular shapes of accurate dimensions. Prestite can be held to as close dimensions as the dry-type porcelain, an advantage when a shape having bosses, ribs, or recesses is required.

Several refinements in processing are responsible for the improved qualities of the new material. The mix is similar to that for dry-process, but of somewhat finer grain. Molding pressures are considerably higher, in some cases up to 60 tons. These and other mechanical pressing operations result in a far more compact porcelain than ever obtained by dry-pressing. Furthermore the processing time is reduced to about one-eightieth that taken by casting wet-process porcelain. Drying time is reduced from about four days to thirty-six hours.

At present Prestite is being used for fuse boxes, tap-changer plates, bus supports, and third-rail insulators. However, it holds promise of supplanting wet-process porcelain for many other applications. When designers are able to impart full advantage of its high-dielectric strength to irregular shapes it may lead to a reduction in size of many electrical devices.



The simplified variable-voltage drive is here set up for demonstration. The alternating-current motor and series generator are combined into one unit underneath the stand. The series drive motor is on the table.

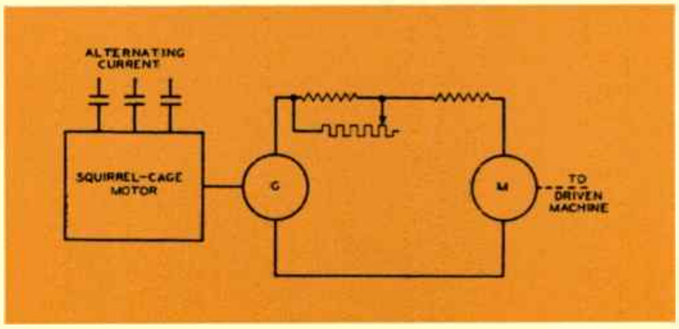
Wide Speed Range Without Complexity

You can't beat an alternating-current system for distribution; you can't improve on a direct-current motor for speed variation. As a result, the variable-voltage drive, which combines the two, is without peer for drives requiring accurate speed control over a wide range. In the conventional scheme a squirrel-cage motor is used to drive a direct-current generator that feeds the motor to be controlled. Both direct-current machines are separately excited by an auxiliary generator. By varying the excitation, hence the voltage of the generator, the speed of the motor is controllable over a wide range.

The whole method has been drastically "streamlined" in a new and simplified version of the variable-voltage system. Series machines are used instead of separately excited ones. Only three machines are required, instead of four, and the circuit is correspondingly simpler. The induction motor and series generator are combined into a single frame. The output of this unit supplies the series motor driving the load. By diverting part of the generator field current to a variable rheostat of low resistance the voltage, and therefore the speed of the motor, can be varied continuously over a wide range.

The series motor gives the drive high starting torque. Fluctuations in load do not cause great changes in speed because any increase in load current of the motor is accompanied automatically by a rise in the generator voltage. The series motor thus has practically flat speed response, similar to that of a shunt machine.

The drive is not intended to replace conventional applications where fast reversals, regenerative braking, or accurate stoppings are required. However, ratings from 1 to 15 hp and a 10-1 speed range from 1750 to 175 rpm (which can be extended to 20-1 for short-time operations) make this drive applicable to a wide variety of industrial tasks, particularly where the more expensive scheme is not justified. Typical applications are a 10-hp unit on a printing press, a 10-hp lathe drive, and a 1½-hp unit driving a bottle-making machine. Dynamic braking and inching can be incorporated in the unit when desired.



Circuit diagram of the simplified variable-voltage system.

Demand for Geiger counters, created by increasing usefulness of artificially radioactive substances, has resulted in factory-made units no larger than a table radio.

New Style Atom Counter

Do you have any atoms to count? It is not impossible that you do, or will soon. With the availability of artificially radioactive substances from atom-smashing laboratories, the usefulness of these as "tracers" is becoming apparent in many fields of engineering and science, from steel mills to medicine. To meet a growing demand for a means of detecting and following these tracer substances the familiar Geiger counter of research laboratories has become a factory-made device. Because Geiger counters have been limited to laboratory work they have been tailor-made, bulky, and complex to operate. The new models are no larger than a mantelpiece radio, and just as easy to use. They combine the good points of many former designs, are reliable, and easily portable.

The primary function of a Geiger counter is to receive the electromagnetic waves emitted by radioactive atoms and record them on a counting device. The most important application is to pick out and follow a small sample of artificially radioactive atoms mixed with millions of others. With a Geiger counter it is possible to determine the thickness of an extremely thin film, to unravel such mysteries as how growing plants make sugar, how far atoms wander, and where such food elements as calcium and sodium go in the human body.

For example, to follow the path of sodium in a patient's organism, the physician mixes a little radioactive sodium with the salt in the subject's food. By detecting and counting the radioactive sodium atoms in the various parts of the alimentary tract, the progress of the salt can be traced through the human body.

The instrument is also valuable in many phases of technical and metallurgical work for instance in the study of the diffusion of silver, i.e., the manner in which silver atoms wander inside the metal. A layer of radioactive silver is plated on a block of ordinary silver. After the radioactive atoms have had a chance to wander into the body of the metal, thin layers of the block—about three-thousandths of an inch thick—are sliced off and held up to the Geiger counter. The number of radioactive atoms in each layer indicates to what extent and depth the atoms of the plating metal have penetrated.

P E R S O N A L I T Y   P R O F I L E S

C. E. SMITH arrived at his present position as an authority on electronic subjects by an unusual and devious route. When the movies were first learning to "talk" he was designing sound reproducers for theaters. Which probably accounts for his spending his week ends while vacationing in Michigan this summer installing public-address systems as a pastime (and for profit, we dare say). After a time as instrument engineer for the Follansbee Bros. Co., steel makers, he came to Westinghouse some five years ago as electronics service engineer. Since moving into the engineering department in 1939 he has specialized in welding timers, although the newest form of pinhole detector used in the new high-speed tin mills is his creation. In case the diplomats fail to get our international affairs smoothed out and Uncle Sam must call on his defenses, Mr. Smith will be ready—maybe as boss of a battleship—what with his training at Culver Military Academy, and four years at the Naval Academy from which he was graduated in 1931.

SAMUEL G. HIBBEN entered the lighting business early and has been at it ever since. At the age of six he smashed burned-out carbon-filament lamps to salvage the platinum leads, making as much as five dollars in a summer. Even as Director of Applied Lighting of the Westinghouse Lamp Division he is not content merely to take a leading position in designing the lighting of the Chicago and the New York fairs, the Holland Vehicular Tunnel, the Statue of Liberty, and scores of other outstanding jobs, but, at his home, he plays with lighting. Tulips bloom in his basement in winter under the artificial suns he has provided. He likes to experiment with "mood lighting," and on one occasion as a practical joke served an excellent dinner to his friends in a light filtered so that the expensive steaks looked so ghastly none could touch them. Hibben has had considerable experience as a public speaker, which, with his thorough knowledge of electric lighting in all its phases, enables him to "put across" a lecture or demonstration on lighting with equal success before a critical audience of lighting experts or a lay audience at luncheon, both of which he has done scores of times. Alumnus of Case School of Applied Science ('10) he has served as Illumination Engineer with MacBeth-Evans Glass Company, has been in consulting work, has seen service in France as a captain of Engineers on sound ranging, and since the first world war, has been associated with Westinghouse in its lighting activities, having been appointed to his present position in 1933. He functions as ambassador-at-large on all lighting activities, keeping in touch with new developments and following them through to final application.

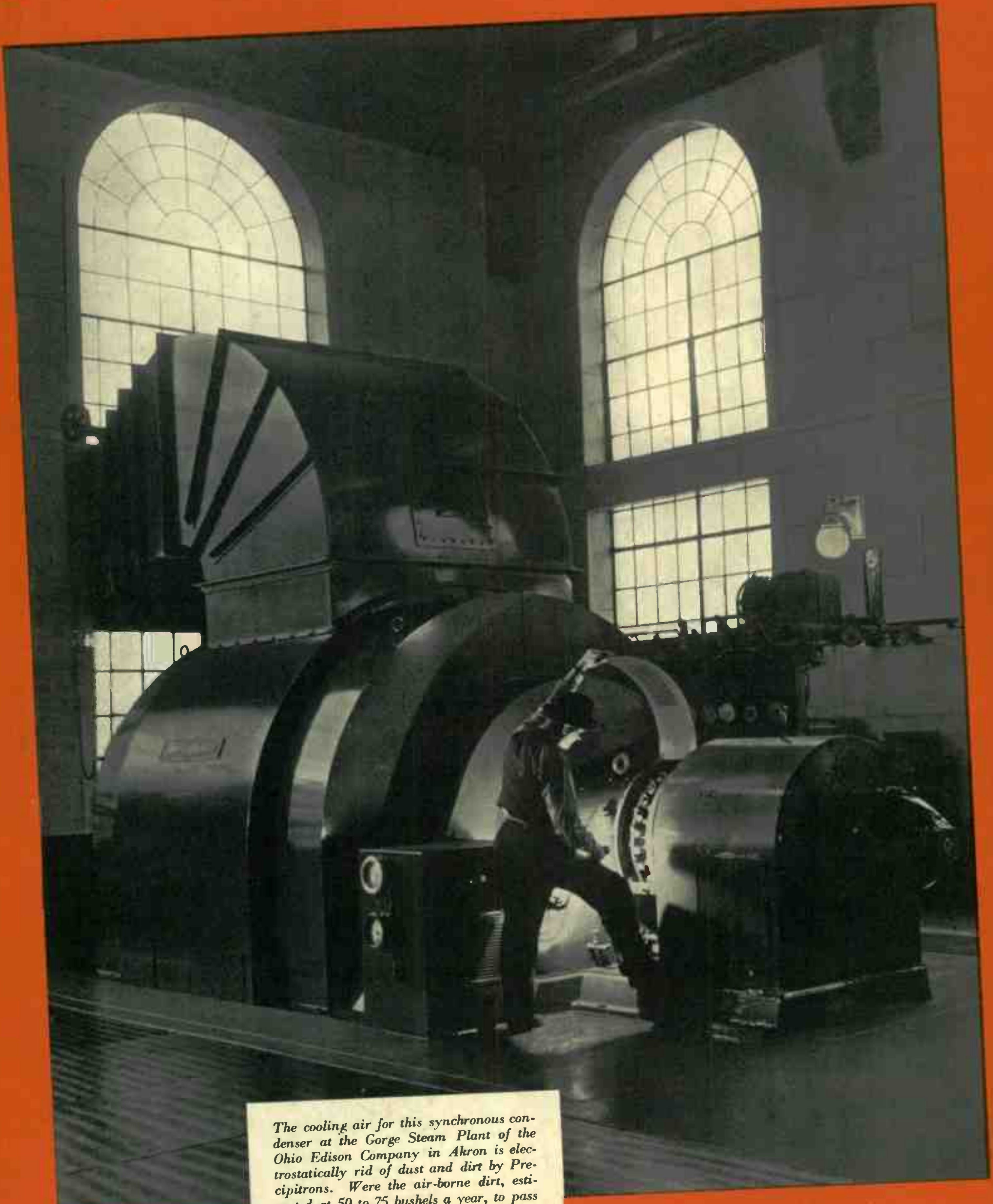
Intricate, involved mathematics do not trouble *J. D. CONRAD.* He has in fact made it his business, having been in charge of the calculating group in the Mechanical Division of the Turbine Engineering Dept. at Westinghouse since 1931. However, like the true engineer, to him the end must justify the means, so he takes any possible detours around long and devious calculation. Thus he has been a leader in developing the use of models to predetermine pipe stresses for modern power stations. Conrad comes from North Carolina, graduating from its State College in 1927 as Mechanical Engineer.

One fifth of the 150 patents on network distribution systems granted by the United States Patent Office are held by one man—*JOHN S. PARSONS.* He got in on the ground floor of this network business at the very beginning. He was present back in 1922 when the basic idea was conceived by New York utility men as a solution to their trying load problems. Not only did he design the first three-phase network relay but he also devised the pump-proof network protector, plus some thirty other important improvements. Following his technical training at the U. S. Naval Academy and Georgia Tech ('21), he came to Westinghouse, working in the relay engineering division of which he later took charge. In 1930, he moved to the central-station division, specializing in problems of power distribution, a field in which he is now recognized as pre-eminent. His company honored him in 1931 with an Award of Merit, given outstanding people within the company's ranks for distinctive work.

An abrupt shift from one branch of engineering to another is a fundamental test of a man as an engineer. *H. V. PUTMAN* passed such a test with eminent success, when, in 1930 he left a position in charge of the design of synchronous motors at East Pittsburgh to become Assistant Engineering Manager of the Transformer Division at Sharon, Pa., and to become, a year later, the Engineering Manager. Just recently he has been appointed Manager of the Transformer Division. He promoted the building of the high-voltage laboratory for impulse testing and lightning studies. He encouraged the development of surge-proof construction, and the famous CSP transformers, and holds several patents on both. The air-cooled transformer grew out of a conversation between him and the chief engineer of the United Electric Light & Power Co., Arthur Kehoe, and he has continuously led in its development. He has also been instrumental in bringing Hipersil to practical application. Putman received his electrical engineering training at Union College, Schenectady, and following his graduation in 1920 he spent three years in post graduate work and two years as Assistant Chief Engineer of the Ideal Electric Company, coming to Westinghouse in 1925.

Nothing delights *C. W. DRAKE* more than to solve some tough industrial problem by the ingenious use of standard devices. It pleases him more to "get more out of what we have" than to devise something totally new. And few engineers are more skilled at this sort of thing than he. He has been working at it for the thirty-five years since coming to Westinghouse from Worcester Polytechnic Institute. For some time he has been in charge of the Application Engineering Division solving the problems of the paper, textile, rubber, cement, glass, lumber, and kindred industries. It was he, for instance, who devised in 1910 the first sectional paper-mill drive using synchronized direct-current motors. The equipment of that first installation ran 25 years with the original regulators. He has been conspicuously associated with such important developments as the synchro-tie; holds many patents (including one just granted on the scheme described on page 23); has traveled uncounted thousands of miles in solving, on the job, electrical problems in almost every type of industrial plant in the United States except mining and steel. A desk drawer is crowded with copies of his engineering articles that have been published in many different journals. Lately he has concerned himself in his spare time with educational work of various kinds.

New tasks FOR ELECTRICITY



The cooling air for this synchronous condenser at the Gorge Steam Plant of the Ohio Edison Company in Akron is electrostatically rid of dust and dirt by Precipitrons. Were the air-borne dirt, estimated at 50 to 75 bushels a year, to pass through the machine, periodic shut-downs would be necessary for cleaning it by hand.