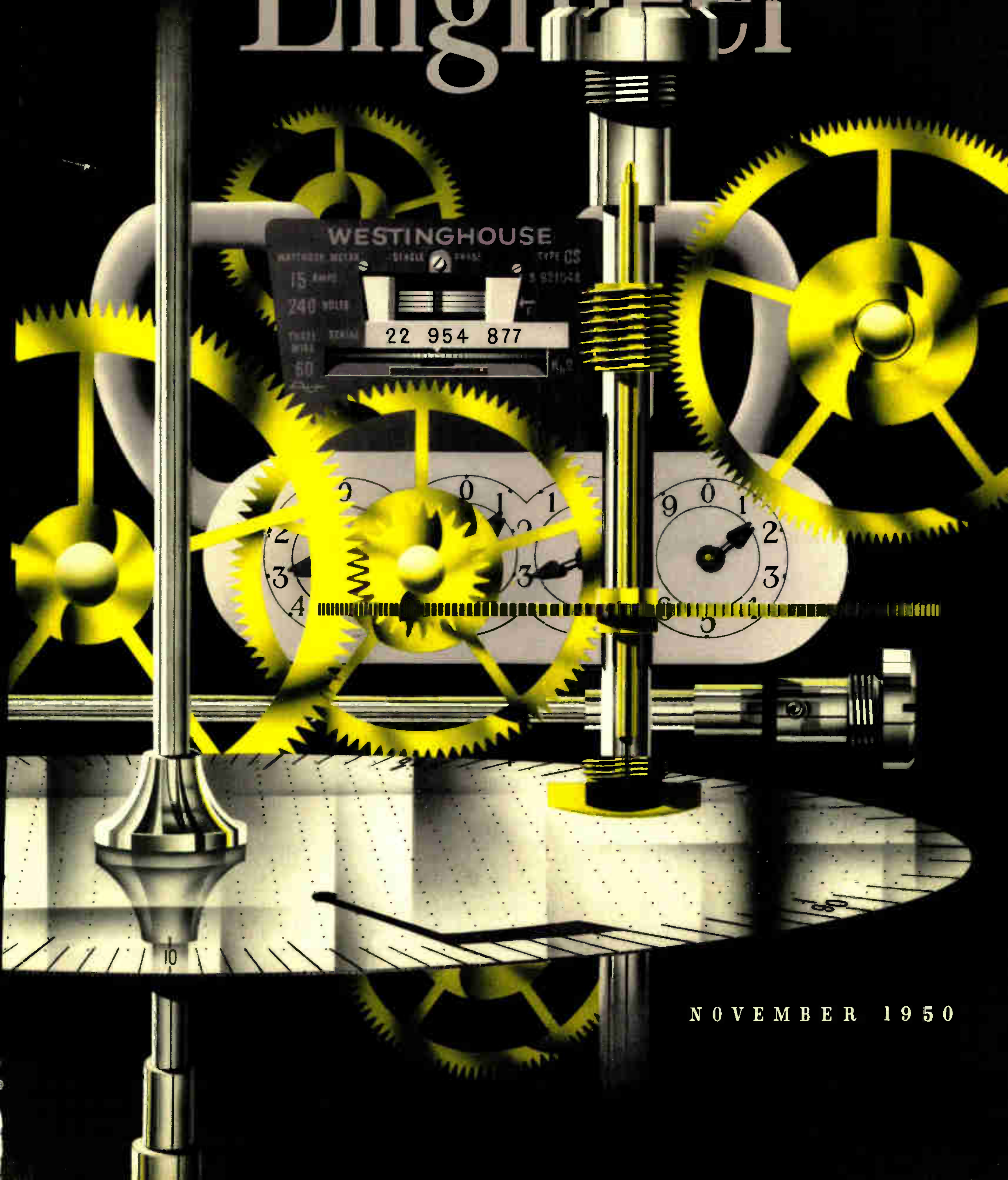
WESTINGHOUSE

Engineer



NOVEMBER 1950

Westinghouse Engineering Education—A New Milestone

Graduate-student training programs commonly operated by large engineering companies are taken for granted. They are an accepted part of the nation's engineering educational system. In fact, it is difficult to conceive how engineering colleges could provide both the general and specialized training now required by a complex industry such as electrical manufacturing. But this has not always been so. Company-sponsored, graduate-student training had to be conceived, promoted, established. And as usual it began with a man.

At the turn of the century, C. F. Scott, Chief Electrician at Westinghouse, was still a young man, but already an engineer of some fame in an industry that itself was only 15 years old. He believed that it was the obligation of large engineering organizations to provide further technical training for their young graduate engineers. He also believed that engineering organizations could and should provide specialized, advanced technical training, which, superimposed on college training, would benefit the student, the company, and the engineering college. The student would have better training. The company would have a man better equipped for its particular field. And the colleges would be spared the impossible obligation of providing both general and many separate specialized trainings.

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By 1902 Scott had "sold" his idea to Westinghouse management. This was not too difficult as Mr. Westinghouse was a great believer in college-trained engineers. In fact Mr. Westinghouse is said to have been one of the first recruiters of graduate engineers for industry. Courses in several phases of the electrical science, with special reference to its bearing on apparatus design, were opened for Westinghouse men in the Casino Building near the big East Pittsburgh plant. The program was an immediate success. Nearly 200 men took these courses, given voluntarily and without pay by the more experienced engineers. The soundness of Scott's idea was quickly demonstrated.

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From the association of men in class work arose sentiment for the organization of a club that could provide social, athletic, and recreational facilities as well as educational. This led to the founding of the Electric Club, later known as the Westinghouse Club. The Electric Club, with E. M. Olin as its first president, was housed in a feed store on Penn Avenue in nearby Wilkinsburg, four miles from the main plant. These quarters served until 1909, when they were moved to a large commercial building on Pennwood Avenue, adjacent the Pennsylvania Railroad in Wilkinsburg. At present, the Graduate Student Club, a social organization, is allowed to use the facilities of the new Educational Center, shown on p. 240.

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The training program for graduate students was then called the Engineering Apprenticeship. It was a two-year program of 5616 hours (56 hours a week) and paid 16 cents per hour the first year and 18 cents the second. (Apprenticeship in those days was no cinch. The following is a quoted complaint taken from the club minutes for September 17, 1903: ". . . After working ten hours a day in the shop most of the men are not prepared to sit and listen to an hour and a half or two hours' talk . . . I would suggest the lectures be absolutely limited to one hour.")

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Meanwhile the educational program grew apace. The training of these students began to be more formalized. New courses of instruction were added as the company grew and as the industry expanded in scope. Under the personal direction of B. G. Lamme, Chief Engineer, specialized training programs were developed, such as the Electrical Design School and the Mechanical Design School. Also, programs were created for those wishing to enter manufacturing and sales departments. All of these training programs were accompanied by "shop" assignments, each of a few weeks' duration, on apparatus test floors, in manufacturing sections, engineering, or sales departments.

Thus was created the general pattern of Westinghouse graduate-student training, which continues today without substantial change in concept. This has since been used as a model by many companies.

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Altogether, in the nearly 50 years this program has been in operation, some 15 000 men have entered the Westinghouse Company through the Graduate Student Training Program. Many have since left Westinghouse for important positions with other companies. Thus the training program has taken on a national significance.

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The student training program has had some interesting offshoots. Soon after the first lectures were given in 1902, a demand arose for them to be made available on paper—for reference by those who heard them and for the benefit of those who were unable to attend or were located in distant plants. Mimeographing was tried and soon proved inadequate. This led, in 1904, to the establishment of a printed publication, *The Electric Club Journal.* This was a pocket-size magazine, without advertising, and provided only for the club membership. The first editor was F. D. Newbury, who was the fourth president of the Club and who is a recently retired vice president of the Westinghouse Company. The name of the publication was changed to the *Electric Journal* in 1905, and the size was changed to standard magazine dimensions in 1914. The publication achieved great popularity and continued as a leading technical journal until 1939, when it was discontinued, to be followed by the present publication, the *Westinghouse* ENGINEER.

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Student training has not been confined to preliminary education for men about to take regular positions in the Company's departments. Engineering education is recognized as a continuing thing, with no real end. Consequently, arrangements are in effect with the University of Pittsburgh by which courses in advanced phases of engineering can be taken for credit applicable to masters' or doctors' degrees. The program has been extended to other cities in which the Company has plants, and now comprises arrangements with 7 universities in 8 plant cities. Hundreds have taken such advanced courses, 223 of them actually achieving 207 master degrees and 16 doctor degrees by this route.

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Industrial-company graduate-student training has become a recognized part of technical education. While it is too much to credit all this to Charlie Scott, certainly it has become a great institution—and assuredly much credit is due to the visionary plan he introduced a half century ago.

WESTINGHOUSE Engineer

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On the Side

The watthour meter that ticks off power consumption day in and day out scarcely ever attracts any attention—except from the meter reader. But inside the plain exterior is a complex array of sparkling gears, bearings, and other essential components. These precise parts, of varying geometric design and shape, are actually the heart of the meter. It is these components that were selected to convey an impression of the watthour meter on this month's cover by Dick Marsh.

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Many principles of the now-familiar streamlined streetcar will be introduced to rapid-transit service in 40 ultra-modern cars to be built for the Metropolitan Transit Authority of Boston, Mass.

Each car will be powered by four 55-hp motors. Special lightweight pantograph trolleys, designed by Westinghouse, will make possible overhead power supply along the right of way; while passing through the East Boston tunnel, cars will draw their power from the third rail. The cars will be built by the St. Louis Car Company; Westinghouse will supply electrical equipment.

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Development of Watthour Meters

Faced with the problem of determining a quantity that could be neither weighed nor measured directly—namely electric power—engineers have come up with some surprisingly ingenious solutions since the first meter was developed. Out of the welter of meter designs developed before the turn of the century, one basic feature has remained—the induction principle—and has since been the basis for meter design.

THOS. D. BARNES, *Watthour Meter Engineering, Westinghouse Electric Corporation, Newark, New Jersey*

PROBABLY most people think of a watthour meter as that device in the basement or on the side of the house that always seems to run too fast! Actually, the modern watthour meter, with its hundreds of detail parts, is a surprisingly accurate, low-priced, and rugged measuring device. Continual development and utilization of the best available materials and techniques have produced a meter of practically unlimited life. Watthour meters are "retired" rather than worn out. This is evidenced by the rulings of many state utility commissions permitting the use of meters up to eight years without again checking their accuracy, and the records of many meters that have required no maintenance for periods of 20, 30, or 40 years! Few other mechanisms can equal such performance.

This situation was achieved, however, only after particularly difficult beginnings. Strange as it may seem, the practical revenue meter was one of the last obstacles to be overcome in the expansion of electric service.

The first patent on an integrating meter in the United States, and probably in the world, was issued in 1872 to Samuel Gardiner of New York City. His device consisted of a spring-driven, air-vane damper that was released whenever any load current passed through a trigger solenoid. A somewhat similar apparatus for alternating-current operation was patented in 1878 by J. B. Fuller of Brooklyn. It involved an electromagnet and polarized armature arranged to vibrate and advance a ratchet wheel connected to a counter. Such lamp-hour devices responded only to the duration of load, and hence were independent of the magnitude of the current.

Commercial use of electricity received a great impetus in 1879 through Edison's invention of the practical incandescent electric lamp. The development of electricity as a commodity, however, depended largely on whether it could be as successfully metered as was its vigorous competitor, gas. Edison himself realized, probably earlier than anyone else of that time, the necessity for a commercial meter. He was one of the first to design a meter that responded not only to duration but also to current rate. The first device (Fig. 1), which he called a "weber meter," was an electrolytic-deposit, amperehour meter that could be read by weighing zinc plates at the beginning and at the end of the billing period. The energy represented could then be calculated from the change in weight. Such a design was, of course, limited to direct-current applications, but found wide use in New York City on the three-wire services also developed by Edison.

Probably the first successful meter to be used in Europe was the Aron pendulum integrator brought out in 1884 (Fig. 2). It was one of the first devices to register energy in watthours. Registration was obtained through the action of a differential placed between two clock-driven pendulums, one of which had its period modified by the mutual attraction between a voltage coil on the pendulum and a fixed current coil. These meters, while complicated and costly, were quite accu-

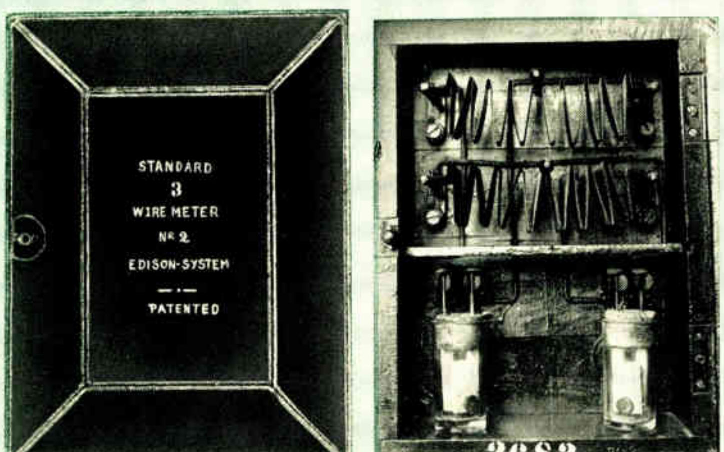


Fig. 1—Edison's "chemical meter" for direct current. A resistance coil or a lamp placed near the zinc plate cells prevented the electrolyte from freezing.

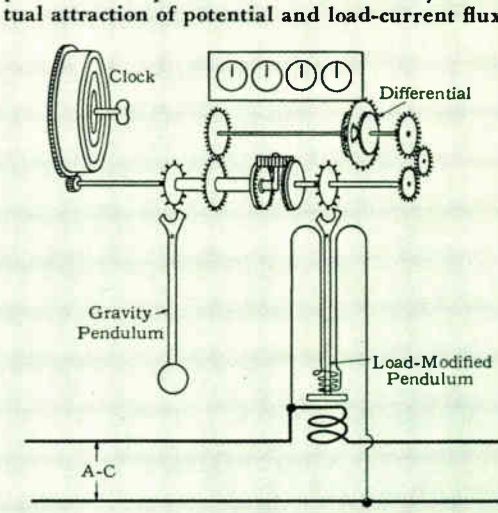


Fig. 2—The Aron differential clock-type meter. The period of one pendulum was modified by the mutual attraction of potential and load-current fluxes.

rate and saw broad service, particularly in Germany, for many years.

One difficulty that worried early investigators was the amount of energy taken to actuate the metering devices. True, these losses, as compared to modern meters, were relatively high, but they were a long way from being as bad as envisaged by the president of the Society of Engineers, England, in 1883, who pessimistically postulated:

"Of course, there are meters which register the current passing at any moment, but when it comes to the question of registering the amount of electricity which has passed through a wire during a given period, it is questionable whether it can be done in a reliable manner, inasmuch as the electrical energy is partially exhausted in the process of registration."[1]

In the early days of alternating-current distribution, in the late 80's, central-station companies felt that a reliable meter had not yet made its appearance. They were justified in this pessimism. Alternators had been developed; the Gaulard and Gibbs transformer invention acquired by Westinghouse had made possible longer transmission distances; and the Tesla inventions, also acquired by Westinghouse, soon provided motors—but still no commercially practical meter could be had. To spur ingenuity, the Paris Council offered a prize of 10 000 francs, which was shared in 1890 by the complicated Aron pendulum meter of Germany and the Thomson-Houston commutator-type meter of this country; but neither provided a fully satisfactory answer. Consequently, energy was generally sold on a flat rate or "per-lamp" basis.

An article written in 1888 in the French technical journal, "La Lumière Eléctrique," presented an interesting corollary:

"One of the best proofs of the importance of distribution of electrical energy is the number of investigations made to produce a meter, the construction of which would include the various qualities that one has a right to expect in an apparatus of this nature . . . the meter of the future has yet to be invented . . . In the meantime, alternating currents present a diversification of phenomena much greater than continuous currents. It is particularly due to the incomplete knowledge of the laws of their reaction that one must attribute this lack of meters."[2]

In 1887, Professor Forbes of London introduced his famous "windmill" ampere-hour meter. It consisted of a coiled resistor, through which passed the load current to be measured, so mounted that the hot convection air currents rising from it would cause rotation of a fan or vane-wheel delicately pivoted above. This meter, first shown before the AIEE in October, 1887, received the Franklin Institute Medal of 1888 in recognition of the inventive ingenuity displayed, but it was never developed commercially.

There was considerable discussion in the early days as to the relative merits of coulomb or ampere-hour meters as compared to true energy or watthour meters. The consensus was that energy could, of course, be measured by watthour or erg meters, but that ampere-hour meters were preferable. The latter, they reasoned, would force the central stations to maintain better voltage regulation. It would be interesting to know to what extent this decision was biased by the industry's inability to build a practical energy meter.

The rapid growth of commercial electricity around the turn of the century and the urgent need for a practical meter were great incentives to inventors in the race for a commercial answer. The first meter, referred to earlier, was patented in 1872, the Shallenberger and Thomson-Houston meters around 1888–89; and by 1891 some 185 patents had been granted.

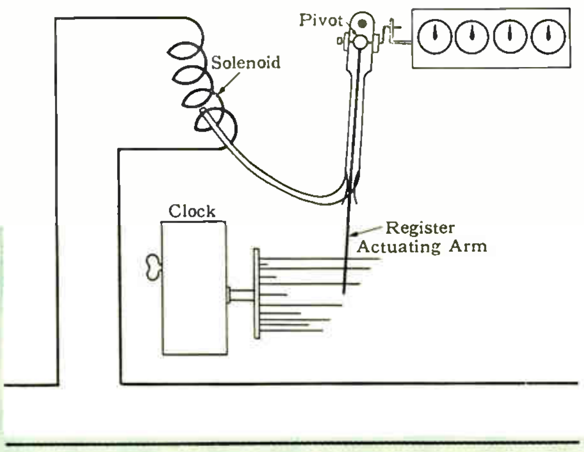
Many of these designs took interesting and sometimes weird forms. One such proposal, Fig. 3, consisted of a pinwheel driven by the repulsion of "exalted potential" sparks between its point and an encircling metal ring. In citing its advantages, the inventor asserted:

". . . the effect is so strong that the breeze from the point is sufficient to extinguish a candle."[3]

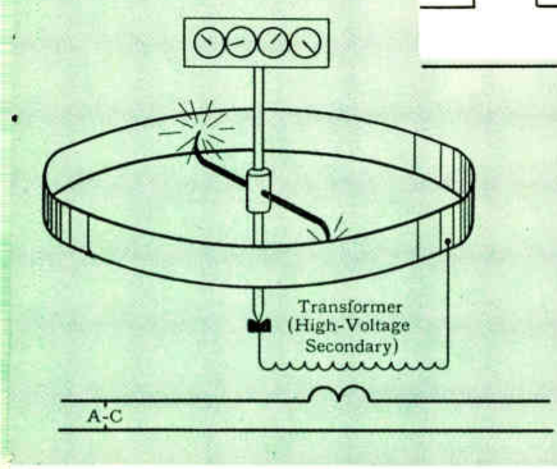
The Pilkington and White meter of 1892 was another interesting design and was used extensively for a time on the Brooklyn d-c system. An increase of load caused a register-actuating arm (see Fig. 4) to engage more pins on the clock-driven disc.

The Blathy meter was the first a-c induction watthour meter to be used commercially in Europe, but it was inaccurate on low power factors and was anticipated by Shallenberger's patent of the previous year.

The Dahl meter of 1889 was based on still another principle, that of change of permeability with temperature of a rotatable

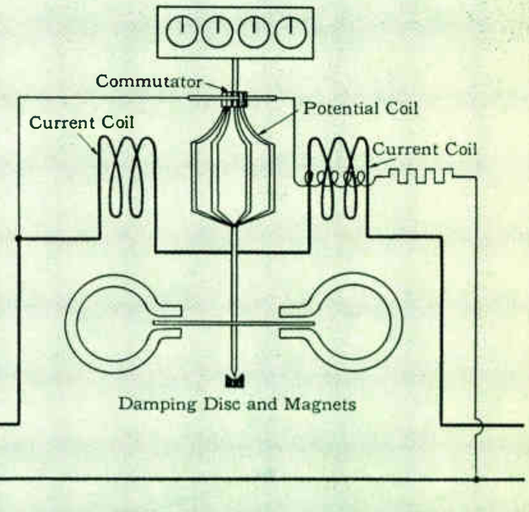


↑ **Fig. 4—The Pilkington and White ampere-hour meter. An increase in load current through the meter's solenoid moved the armature to bring the register-operating arm in contact with a larger number of pins on the clock-driven wheel.**



← **Fig. 3—A proposed "exalted potential" ampere-hour meter. Rotation was produced by the reaction of high-potential sparks between the end of the pinwheel and encircling ring.**

Fig. 5—The Thomson Recording Wattmeter, the first meter with permanent damping magnets.



iron disc. Two heaters, whose responses were proportional to the load current and line voltage, were located under the disc. The disc material directly above and adjacent to the heaters became more magnetic as it was heated and consequently was attracted to the permanent magnets, thus setting up a rotation that was registered on a counter.

Numerous other devices were produced during the early years of metering. To mention a few, there were the well-known Thomson Recording Wattmeter, or TRW, for direct current (Fig. 5); the Walker photographic meter; the Ferranti and Sangamo mercury meters for direct current; the Duncan, Gutmann, Stanley, and Scheefer induction meters; the A.E.G. oscillating meter of Germany; the Siemens-Halske scimitar design, which found wide use commercially in Germany between 1893 and 1904; the Bastian electrolytic ampere-hour meter (whose biggest disadvantage was that it had to be repeatedly filled and, if neglected, was apt to explode!); and the Slattery induction meter, which was probably the first to use overload compensation. Counterbalanced air-vanes were so moved by centrifugal force as to reduce the damping area presented to the air as the speed increased on higher loads.

Early Watthour Meters

Often important discoveries or inventions are independently made by different investigators at about the same time. In the case of the induction principle of meters there were three such discoverers—Professor Ferraris of Italy, Nikola Tesla, and Oliver B. Shallenberger of Westinghouse. As early as the autumn of 1885 Ferraris had demonstrated his conception of a revolving flux field. A replica of his model—the progenitor of all induction watthour meters—is shown in Fig. 6. Unfortunately he carried his work no further, except to publish a paper later (in 1888), and even had this to say regarding the principle he discovered:

"These results confirm the evident *a priore* conclusion that an apparatus founded upon this principle cannot be of any commercial importance as a motor."[4]

Thus he dismissed what is now known to be the basic principle of the induction motor and meter!

While Tesla was preparing a paper covering his momentous discoveries on alternating-current motors, for presentation on May 1, 1888 before the Institute of Electrical Engineers, Shallenberger, then chief electrician for Westinghouse, was also making a discovery.

Late in April, while he was examining an alternating-current arc lamp that an associate had just completed, a small coil spring about an inch long dropped out of the mechanism; it lodged on a plate at the top of the coil surrounding a protruding iron core. A co-worker was about to replace the spring when Shallenberger noticed that the spring was slowly turning on its horizontal axis. Immediately perceiving the fundamental principle involved he quickly said, "There's a meter and perhaps a motor in that!" Within about two weeks he had completed a meter design (Fig. 7) that performed so well that it was put in production by August of the same year.

But fortune was to allow Shallenberger the credit and patents for only the meter, as the publication of Tesla's paper on May 1, 1888, and the issue of his patent on the same date were evidence of his anticipation of the induction motor. By coincidence, the Ferraris paper was also published about this time, March 18, 1888, but after Tesla had applied for his patents. Nevertheless, Westinghouse saw fit to acquire from Ferraris the sole rights to his method of electrodynamic rotation as evidenced by the transaction implemented July 15, 1888 with the payment of 5000 francs.[5]

Early induction meters were reasonably accurate on unity power-factor loads but fell off considerably in accuracy on lower power factors because exact quadrature did not exist between the current and voltage fields. Apparently this fact was on Shallenberger's mind, as his solution of employing a secondary winding over the potential pole was rather spontaneous. This is interestingly recounted by Professor Canfield:

"To continue in Lanphier's (R. C. Lanphier of Sangamo Electric Company) own words, 'I have always felt that Shallenberger ranks with Thomson, Edison, Ferraris, and Steinmetz in the electrical art. Shallenberger was failing in health in 1894–1895, culminating in his death a few years later; so that spring, I believe in April, he and Page (patent attorney for Westinghouse) went down to Atlantic City to discuss some matters in that pleasant spot.

"Page told me Shallenberger got around to the subject of meters, and, sitting in the sand, suddenly remarked he had the solution of the true alternating-current watthour meter. With his cane he then drew in the sand the diagram showing the several vector relations, and completing the one due to the secondary winding, said, "There it is!" Page returned to New York at once, prepared the patent application, which was very soon filed, and the patent issued with no references whatever against it, for Shallenberger was, without doubt, the true inventor of this all-important idea.'"[6]

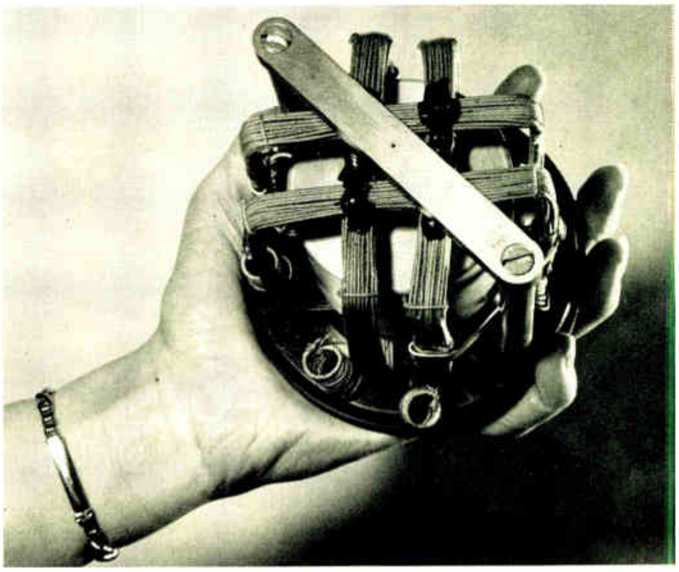
Early energy meters were known as "recording wattmeters," but about 1905 American manufacturers, acknowledging the fallacy of this designation, agreed on the term "integrating wattmeters." A few years later, however, at the suggestion of the United States Bureau of Standards, the term "watthour meter" was adopted.

Development subsequent to these early designs has been one of refinement of the induction principle. Meters operating on other principles have fallen by the wayside.

Shallenberger's successor, Frank Conrad, under the direction of H. P. Davis, was able to decrease meter size considerably by reducing the leakage air gaps and by employing a self-contained lagging method patented by them. This is the basic principle now used universally for obtaining quadrature.

These and other improvements in the efficiencies of electromagnets, mechanical gearing, and damping systems have made possible considerable decreases in meter losses and weight. The first Shallenberger watthour meter of 1894

Fig. 6—A replica of the model used by Ferraris to demonstrate the induction meter principle. The original was built in 1885.



weighed over 41 pounds—some six times that of its modern counterpart (Fig. 7).

One feature making for these reductions was the one-piece electromagnet structure—used by Westinghouse since 1914—containing both the current and potential windings. In fact, the smallest meter ever produced by an American manufacturer was the Westinghouse type OB, brought out in 1924.

Developments since the turn of the century have perhaps been less dramatic but have, nevertheless, been far reaching in establishing the efficient apparatus and metering practices in use in today's electrical systems.

Contributing to long-life accuracy is the ball-and-sapphire lower bearing pioneered by Westinghouse in 1902. Experience with this combination has proved so satisfactory that Westinghouse has used no other. In fact, the rest of the industry adopted it as standard in 1939.

The early years of the 20th century brought about many important improvements in watthour meters, such as glass covers, introduced by Westinghouse, substitution of aluminum discs on the rotor shafts for the heavier copper drums or discs, reduction in internal losses, and the adaptation of meter design to quantity production.

The period since 1925 has been one of many innovations and refinements. Compensations and capacity have been added to maintain accuracies up to and beyond 400-percent rated load. Compensations have also been added to correct the meter's reading for variations of voltage, power factor, and ambient temperature.

One outstanding innovation in the meter art was the detachable or outdoor meter conceived by H. P. Sparkes of Westinghouse and developed in 1928 under the direction of W. M. Bradshaw. The acceptance of the improved design of 1933 became so widespread that arrangements were made in 1934 to allow all other manufacturers in this country to use the construction, which became the standard for the socket or "S" lines. Such a meter is the Westinghouse type CS shown in Fig. 7.

Demagnetization of the permanent magnets by lightning surges has been effectively prevented by using either high coercive-force alnico, or, as in the case of Westinghouse meters, a patented electromagnetic shield of copper plated directly on the chrome-steel magnets.

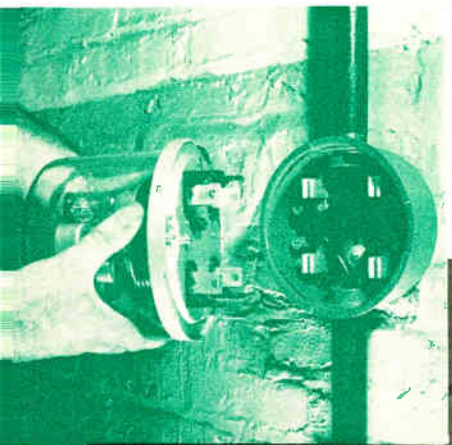
To meet the ever-increasing and diverse customer loads, meters of the past few decades have been built with considerably greater thermal capacity. Improved corrosion resistance makes for long outdoor service and the use of the latest available materials and processes ensures better insulations and accuracy stability.

Particular attention has been paid to the economics and services of the utility customer. Meters have been designed with accurately machined parts for full interchangeability without further adjustments. Calibration adjustments have been simplified. Simplification has been extended to many components, such as registers, magnets, etc., which are interchangeable between lines of apparatus.

Throughout the industry there has also been standardization to the extent that similar meters of different manufacture are physically interchangeable with each other as to mounting means and box trims, and in some cases as to terminal blocks and meter and terminal covers.

Customer testing is facilitated by incorporating stroboscopic indentations on the disc—a feature pioneered by Westinghouse and subsequently made standard.

As for performance, the modern watthour meter has surprising accuracy, measuring, as it does, the combined values of volts, amperes, power factor, and time to within some ± three tenths of one percent at ten-percent load, which, for example, is equivalent to ± 0.03 percent of rated load. In



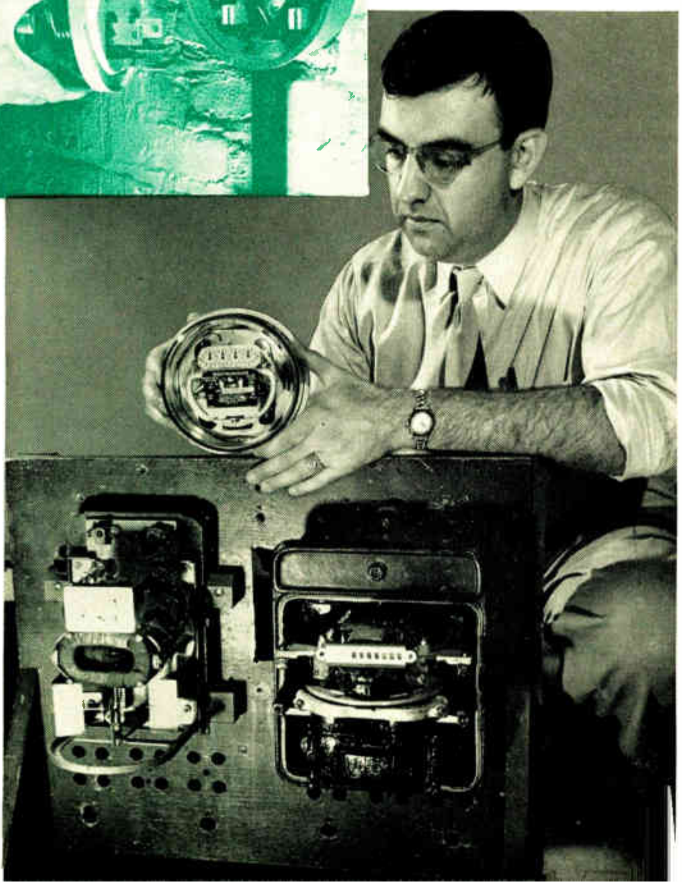


Fig. 7—The first induction meters and their modern successor. Left to right, the Shallenberger ampere-hour meter of 1888, the Shallenberger watthour meter of 1894, and the present meter, the CS. Insert illustrates the detachable feature.

Fig. 8—The manufacturing and assembly department for the Shallenberger ampere-hour meter. This was located in the Garrison Alley Works (Pittsburgh) of the Westinghouse Company. Not until 1900 was manufacture moved to its location at Newark, N. J.

fact, in view of the low value of probable error now obtained with watthour meters as compared with the measurement of other purchased commodities, the modern meter has probably been developed to a point of accuracy where there is little need for further improvement along this line. In future meter development it is reasonable to expect that the emphasis will be on low maintenance, longer periods between tests, and other factors of economic importance.

Polyphase Circuits and Meters

About 1885, electric power was used primarily to operate the telegraph, telephone, and rather limited lighting systems. The d-c system then generally used was doomed, however, as far as general distribution was concerned, because of the rapidly expanding demands of industry. Costs and copper losses would have become prohibitive if attempts had been made to distribute any sizable quantities of energy over other than very short distances at the low voltages involved.

As the advantages of alternating current became known, the polyphase system quickly developed on a large scale in the United States. At first, knowledge of the three-phase system was rather limited. This caused some controversy regarding the relative merits of the two-phase and three-phase systems. This argument was soon quieted, however, by C. F. Scott's invention of the T-connected, two-phase to three-phase transformer interconnection, which served to combine the two systems.

The first polyphase induction meter was the Shallenberger single-disc design of 1896. Because of interference, however, between the fields of the two elements acting on the common disc, this design was abandoned in favor of the multiple-disc meter disclosed in a Davis and Conrad patent in 1898 (Fig. 9). This was the first induction polyphase meter to operate correctly on unbalanced loads.

Demand Meters

As early as 1892, consideration was being given to a dual-rate method of charging for electric service. The utility people realized that fundamentally electricity should be sold on the basis of two factors; first, of course, the customer's actual consumption of energy expressed in kilowatthours, and the second, his demand with respect to his average connected load. In other words, the cost of furnishing electric service was recognized to be proportional not only to the energy delivered but also to the demand upon the system furnishing that service. This second factor covers the fixed charges of interest and depreciation of investment in the equipment necessary to meet the maximum power requirements of the particular customer.

Sometimes, the customer was billed additionally for what was known as an assessed demand, based on percentages of various types of connected loads. Because of the diversity of electric appliances, machinery, and equipment, however, it became increasingly difficult to assess the demand equitably. Thus was born the need for a device that would indicate a "fixed charge" factor consisting of a maximum power demand over a specified period of time. This was the beginning of demand metering.

Demand can be read in terms of kilowatts, kilovolt-amperes, or reactive kilovolt-amperes, and measured instantaneously or averaged over time intervals of different lengths. In the latter, the response can be directly proportional to time

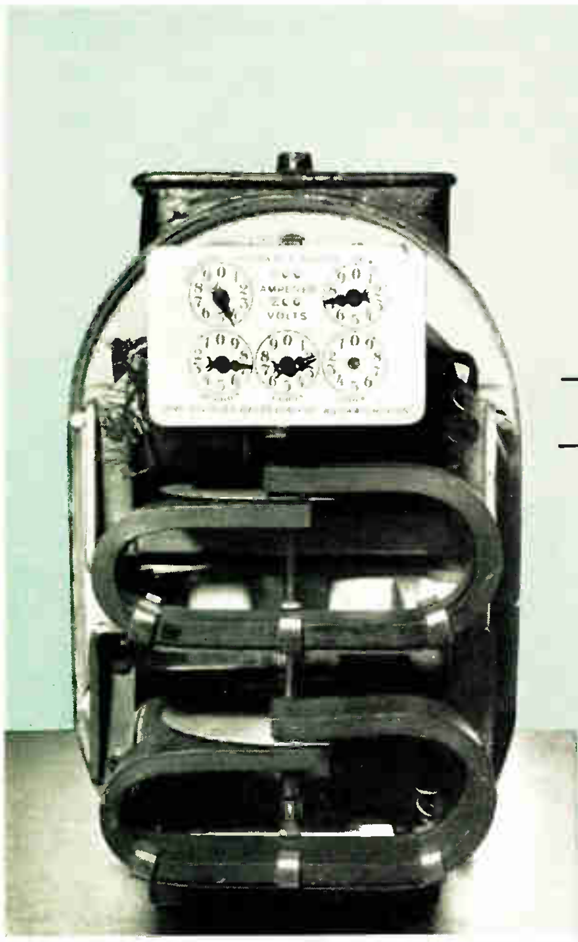


Fig. 9—The Davis-Conrad, two-disc, polyphase watthour meter. This was the first meter to measure correctly unbalanced polyphase loads, or to use separate discs for each element.

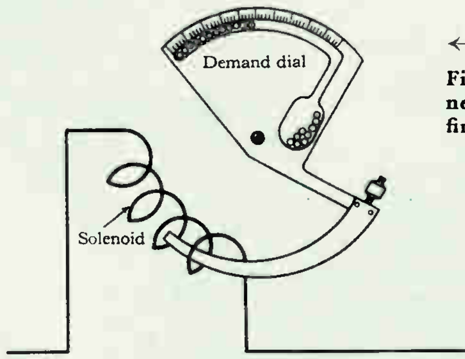


Fig. 10—The Atkinson-Schattner demand device, one of the first forms of demand meter.

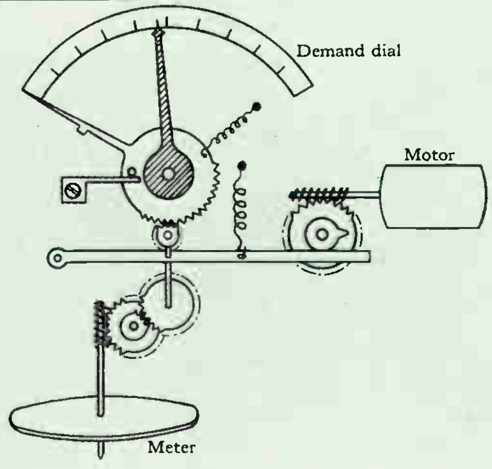


Fig. 11—The Merz demand mechanism. This was the first to employ interval timing on a block-interval principle.

or to a time factor modified by a heating law. As a consequence of all this diversity there exists a wide variety of demand rates and apparatus.

As was the case with meters, early demand devices took some very interesting forms. One such device was the Atkinson-Schattner demand indicator depicted in Fig. 10, wherein the position of the last ball in the tube indicated the amount of ampere demand.

The first demand device to prove commercially successful in this country was the ampere-demand indicator developed by Wright of England and put on the market here in 1896 by the General Electric Company. It was read by noting the height of liquid forced over into a calibrated tube by air pressure. The air was expanded in a bulb by the heat of the load current passing through a surrounding resistor.

The Merz patent of 1903 first made use of the block interval, wherein the demand indication was obtained by integration over a definite time interval. The basic design, which in one form or another is still in wide use today, is shown in Fig. 11. The demand indicator is directly coupled to the integrating meter for a definite timed period, then uncoupled by a timing motor and returned to zero by a restoring spring, after which the cycle is again repeated.

The first commercial demand indicators working on the thermal storage principle were developed by P. M. Lincoln. The use of a divided current circuit, feeding through a voltage-responsive element, made possible indications proportional to energy or watts.

The first device, as patented in 1915, took the form of two metal bellows filled with an expansible liquid such as kerosene. A current proportional to line voltage was circulated by a transformer through the internal heaters. These two currents were additive in one heater and subtractive in the other, giving a difference in heating that resulted in an indication proportional to the watts of the load.

One of the earliest thermal demand meters was the type RH, brought out by Westinghouse in 1920. The bimetal spring type of unit used in this meter (Fig. 12) is now used generally by the industry.

Two basic principles of demand indication have survived the years and are now used widely in greatly improved form —the Merz block interval and the thermal logarithmic interval. An example of the former is the Westinghouse cumulative demand, type RW-2 register shown in Fig. 13. An example of the latter is the combination watthour and thermal watt-demand meter, another Westinghouse development. The detachable, single-phase version of this meter, introduced in 1941, is shown in Fig. 14. There is an increasing trend in demand metering toward the use of thermal meters because of their inherent low maintenance.

The extension of such apparatus to watt demand, ampere demand, and kva demand, both single phase and polyphase, has now been virtually completed by Westinghouse.

Kva Metering

For some time, the measurement of demand in kilowatts was considered adequate to cover the investment component of the cost of supplying service. In recent years, however, the additional effect on costs of the load power factor has

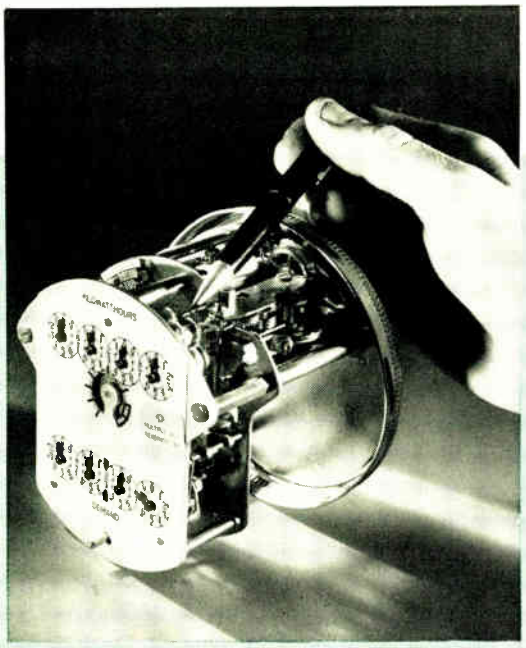


Fig. 13—The type RW-2 cumulative demand register—a modern application of the Merz block interval principle. Integrated watthours are registered on the top dials, and accumulated demand in kilowatts is registered on lower dials.

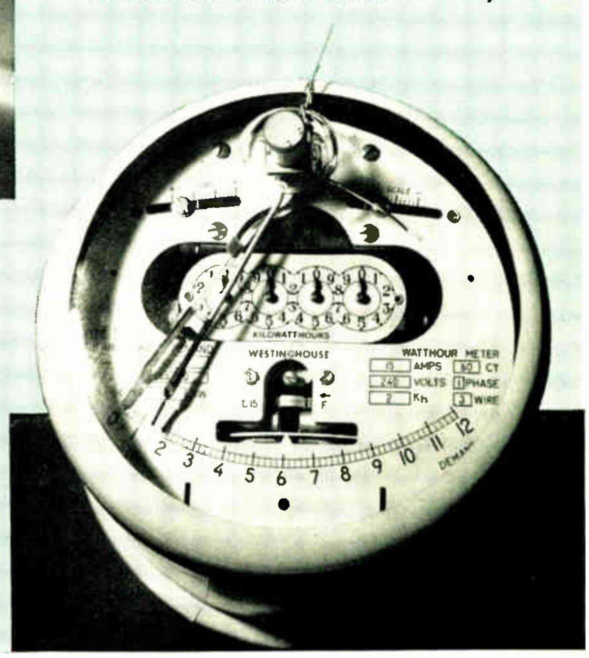


Fig. 14—The type CSH meter, the first combination watthour and thermal watt-demand meter used in the industry.

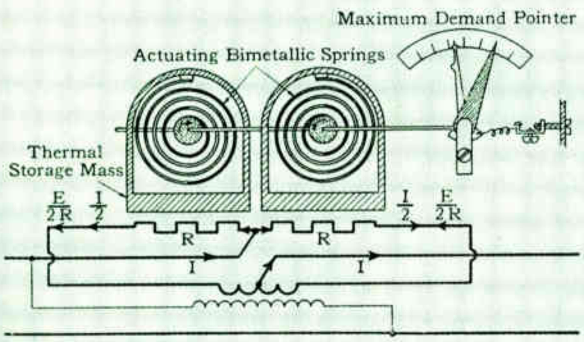


Fig. 12 — The basic thermal demand unit as first proposed by P. M. Lincoln; this was first developed and made by Westinghouse into a combined watthour and demand meter.

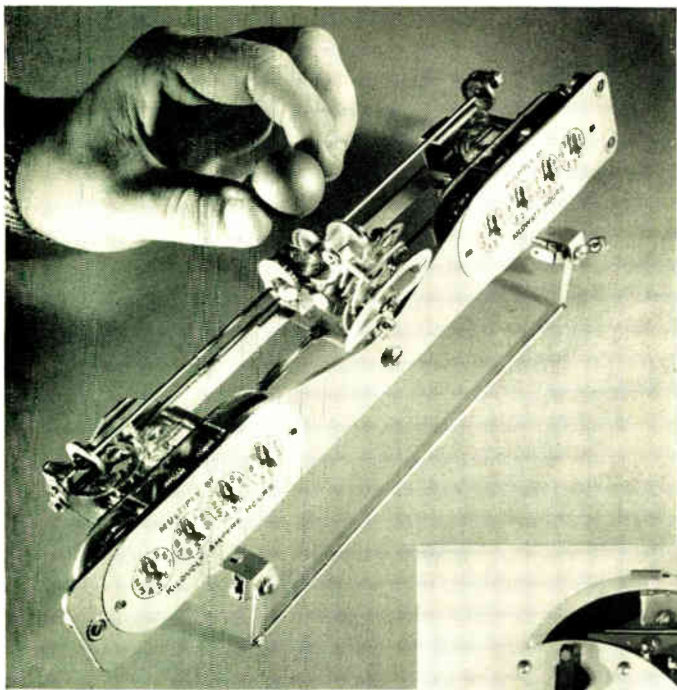


Fig. 15 (above)—The mechanical vector-addition register used on kva-recording demand meters.

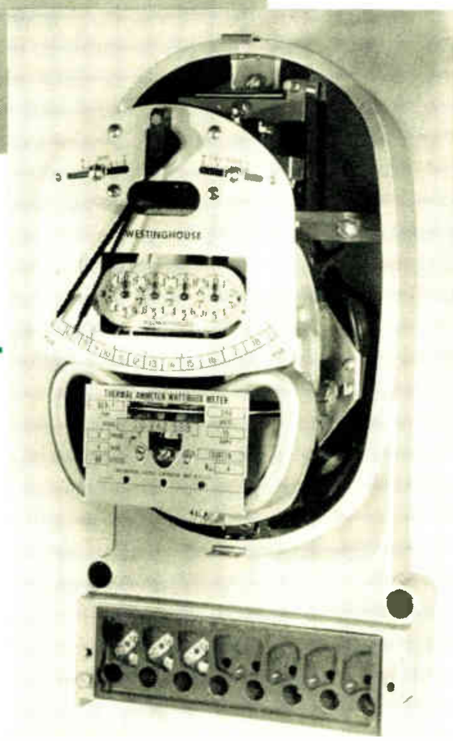


Fig. 16—The type QCA-7 polyphase combination watthour and thermal ampere-demand meter, used for determining kva rates based on an assumed line voltage.

become more generally recognized, particularly because of the higher percentage of low power-factor commercial loads.

To meet such rates, new measuring apparatus was required. There are two basic approaches to kva measurement; one by calculation from kw and kvar registrations, the other by direct reading of kva on a single meter. The former method simply uses two meters, one a watthour or cosine meter, the other calibrated as a reactive or sine meter.

The second approach, that of the direct measurement of kva-hours and/or demand on one meter, has led to some ingenious devices and schemes. However, most of them have proved to be too complicated to be practical. Relatively few have been manufactured and offered to the trade, and still fewer have withstood the requirements of accuracy and economical operation.

One of the early devices was the Trivector meter, built by Landis and Gyr of Switzerland and sold in limited quantities in this country. It consisted of a watthour element and a reactive element acting through five differentials to give an indication proportional to the fastest moving combination. The resulting response approximated a true kva indication at any power factor.

Another early design was the vector-drawing meter built by the Sangamo Company in which an inking pen was moved horizontally across a graphic chart in proportion to kilowatt demand while the chart was advanced vertically at a speed proportional to the kilovars.

One of the most interesting methods of kva measurement, and the one that probably has found the widest application because of its accuracy and dependability, is the mechanical vector-addition device, patented by Innes and acquired by Westinghouse. As illustrated in Fig. 15, the register consists of two discs, one driven by a kw element and the other by a kvar element, surmounted by a ball, which, in turn, drives a caster wheel connected to the indicating mechanism. The sphere, when driven by discs contacting it at points 90 mechanical degrees apart, follows the mathematical law $cos^2 + sin^2 = 1$. Hence the caster wheel, which always rolls on the equatorial or great circle of the ball, responds to the vector sum of the motion of the discs and consequently registers in kva.

Another method of kva measurement is that utilizing phase-shifting transformers, sometimes known as the displaced-voltage principle. In this case a power-factor setting is selected on the meter that approximates that anticipated on the load to be measured. The resulting kva indication will then be accurate at this pre-selected power factor and have acceptable accuracies for considerable divergence in load power factor from the set value.

An ammeter indicates amperes at any and all power factors and is, of course, independent of voltage. Consequently, if the indications are multiplied by a reference voltage, an approximation of kva is obtained. By employing a patented circuit, Westinghouse has been able to obtain an indication on a thermal-demand device that is proportional to true polyphase ampere-demand. A meter using this principle is the combination polyphase watthour and thermal ampere-demand meter, one form of which is the type QCA-7, shown in Fig. 16.

A recent refinement in the Westinghouse kva and thermal-demand meters is the addition of a voltage-responsive element to the polyphase ampere-demand meter. This voltage element, acting through a cosine lever arrangement, so modifies the indication of the current-responsive element as to give a net reading directly in true kva demand. These are identified as the KCA line of combination watthour and thermal kva demand meters.

The advance in meter design is similar to that of much other electrical apparatus. Fundamental principles have changed but little, yet constant refinements have brought forth the highly efficient and accurate meters of today.

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Fosterite Insulation for Small Transformers

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Small transformers get around. In their world traveling, in such things as aircraft service, they meet many unusual operating conditions and climates. Thus their insulation requirements differ widely, necessitating a versatile and tough insulating material. Fosterite compounds, applied in a novel manner, now fill those needs.

SMALL transformers, such as those used on aircraft, must have a versatility undreamed of by their more powerful earthbound counterparts. For example, in an airplane they may perform in a temperate, dry climate, a humid, tropical area, and possibly even a sub-zero, arctic zone—all on a given day. This can play havoc with insulation.

Also, on aircraft as well as communications equipment, high voltages must be handled in small and confined areas. Light weight and small dimensions are, of course, a necessity. And, as if this weren't enough, these transformers must perform dependably despite the incessant vibration and frequent shock common to their applications.

All these requirements add up to a need for an unusual insulation in the form of varnish and impregnation. This is now provided by a new method using Fosterite compounds.

Ordinarily, dried varnish is porous, because its resins must be diluted with about 50-percent solvents that are later driven off in baking. This leaves small holes in the insulation, which provide a path for moisture, dirt, and chemical fumes. Corona may also form in these holes—especially at high altitudes—and thus eventually cause dielectric breakdown. Previously this has necessitated hermetically sealing the transformers in cans, with the attendant additional weight and difficulty in bringing out bushings. Now, with a solventless resin varnish (Fosterite compound), higher operating potentials can be used in a given space, even under conditions of high temperature and humidity. Size reduction, so important in airborne apparatus, is thereby achieved. Or, for a given size, insulation life can be vastly increased. This method applies particularly well to transformers of from one-half ounce to 15 or 20 pounds in weight—the sizes common on aircraft.

Fig. 1—From left to right, in the picture above, are the four stages in treating a small aircraft transformer with Fosterite compounds.

Treatment of Transformers

Fosterite compounds are of two varieties: one, a thin liquid of low viscosity, which penetrates all openings in a coil; and the other, a thick, heavy mixture, which is purposely loaded with inorganic powder to provide a heavy surface coating. This powder also has good dielectric properties.

Dipping a coil in the thin liquid resin is of little value because the resin drains out when the coil is removed from the liquid, leaving air spaces within which moisture can collect and corona can occur. Thus some method of maintaining the low-viscosity compound in the coil is necessary until it is baked. A method for holding this varnish in the coil is shown in Fig. 1 (above).

The untreated transformer is first dipped in the heavier Fosterite compound, thus forming a thick coating on nearly all of the outside of the coils, leaving part of the top uncovered. After baking, this becomes a hard shell or capsule around the outside of the coils to be treated. Obviously the thick outer coating must be prevented from flowing over the top surface or the transformer would be sealed in.

After this baking of the outer coat, the transformer is placed upright (with the uncovered top uppermost) in another container, which is then evacuated (to less than 5 mm of mercury pressure). The low-viscosity resin is then admitted to the container. Vacuum is maintained until the coils are covered, and for 15 minutes afterward to fill any air pockets. The coils are thus completely filled with liquid resin, which is confined by the outer coat, so that the transformer can be lifted from the container without loss of resin, and baked again in an upright position. To give the whole unit a uniform appearance it can be dipped again in the heavy outer coat. A transformer filled in this manner has much smaller dimensions than an encased transformer.

Electrical Characteristics

Ordinarily, dielectric tests of transformers are made by holding a constant voltage for one minute, and are performed on clean, dry surfaces. Dirt and moisture reduce breakdown voltages considerably, so that for untreated surfaces or for ordinary varnish, the tests made under service conditions for dielectric breakdown must be reduced somewhat below the "one-minute hold" voltage. Or, for a given dielectric-strength test, longer creepage paths must be provided within the coil to prevent breakdown.

If corona forms in the vicinity of these creepage paths, the air over them is ionized, and therefore is conducting. Under these conditions, breakdown strength is reduced to a still smaller fraction of the "one-minute hold" value.

If breakdown occurs across organic surfaces, due either to excessive voltage for the spacing involved or to lowering of the surface resistance by dirt or moisture, the organic material may be left relatively non-conducting to partially conducting, depending on the composition of the organic surface, time of arcing, and the current involved. The phenomenon of a material becoming partially conducting after breakdown over its surface is frequently called "tracking." If the partially conducting path is of low enough resistance the insulation is rendered useless and therefore will cause failure of apparatus in which the insulation is used. The powder-filled outer coat of Fosterite composition provides a non-tracking surface, which reduces the likelihood of surface breakdown.

By protecting a coil from the destructive effects of moisture, dirt, and corona, Fosterite compounds make possible a coil that can be tested at a high percentage of the "one-minute hold" voltage. Furthermore, the good dielectric properties of the outer coat prevent deterioration and eventual breakdown across the outer coil surfaces. This exterior coating provides an insulating surface on which terminals can be mounted, with a saving of insulator space—a desirable factor in all electronic equipment. These advantages are particularly applicable to operating voltages up to 20 000 volts.

The ability of Fosterite insulation to reduce the hazards of corona is really a greater improvement than a short-time dielectric test indicates, because corona takes time to break insulation down. A coil may pass the usual one-minute dielectric strength test of twice normal voltage plus 1000 volts and still fail in service due to corona. Insulation reliability is hence greatly improved by Fosterite compounds. These resins also improve the ability of organic insulation to withstand the effects of high temperature. A measure of the improvement is given by a comparison between treated and untreated test samples as shown in table I.

Test potentials of 5000 volts, as used in these tests, represent about 67 percent higher voltage than would be normally used for long insulation-life operation. Since the corona level increased greatly with solvent-type varnish and caused the insulation to deteriorate, while with Fosterite the corona caused no noticeable deterioration, it is evident that solventless varnish permits the use of higher operating potentials in a given space under high temperature and high humidity.

Power factor of Fosterite compounds is approximately one percent at one megacycle frequency, low enough to be masked by most of the solid insulating materials that are impregnated. Fosterite compounds are well adapted to high-frequency transformers because of this low power factor.

Physical Characteristics

The superb moisture resistance of these coils protects fine wire from corrosion in humid atmospheres. Moisture penetration is very slight, and thus small wire sizes have indefinitely long life. Accelerated moisture-penetration tests are made to show this adequacy. Transformers are subjected to 95-percent relative humidity at 65 degrees C and with 100 volts positive direct current applied for two weeks. Then, normal voltage and load are applied for several hours.

With coils treated in ordinary varnish, failure occurs within a few minutes. Fosterite-treated coils survive the test without damage, and can be used with normal life expectancy thereafter. Prior to the advent of Fosterite compounds, encased transformers were necessary to pass this test. This advantage is not impaired by operation in high ambient temperatures, as witness the tests in table I.

Solidity and strength are added to the transformer structure when coils are filled as in Fig. 1. This is an important feature under conditions of heavy vibration or shock, which might otherwise damage the windings. In addition, better heat conduction of the filled coil reduces heating. Because of the better heat dissipation, transformers treated with Fosterite compounds approach silicone-treated transformers in size, especially when fine wire is used.

That this method of treating transformers is practical is testified by the production of thousands for aircraft, communication, and broadcast applications over the past several years. Some achieve difficult electrical performances in small dimensions that are impossible with solvent-type varnishes.

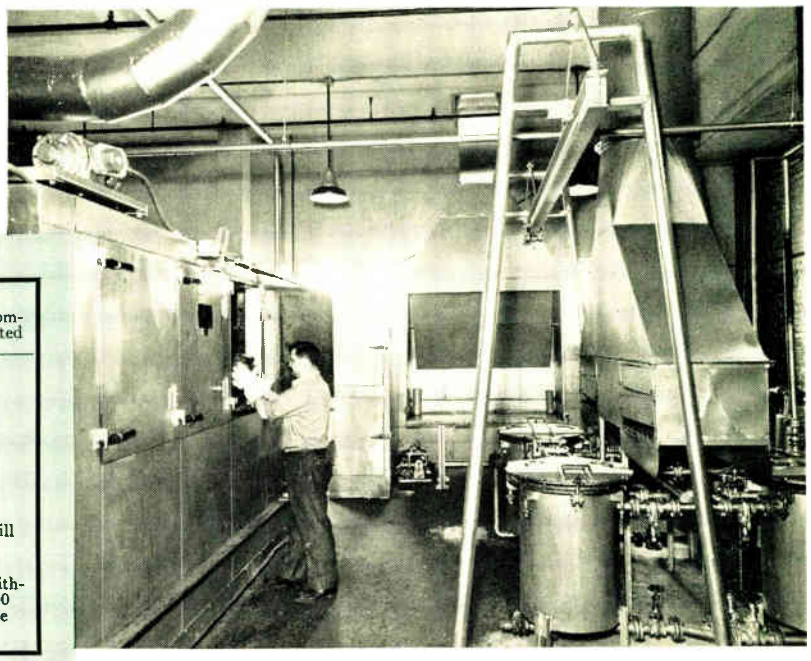

Fig. 2—For large-scale production of solventless-varnish treated transformers, a more elaborate array of tanks and ovens than usual is employed. The tanks at lower right are for evacuating and filling coils with liquid resin. Another tank is used for coating the coils. The oven at left is large enough to provide the high baking temperature evenly throughout its interior with a large amount of air circulation.

TABLE I

Condition	Group A Untreated	Group B Varnish-Treated	Group C Fosterite-Compound-Treated
Initial measurement of corona at 25 degrees C (5000 volts applied).	2500 μV	4500 μV	4000 μV
At 180 degrees C (5000 volts applied).	20 000 μV	20 000 μV	5000 μV
After 40 hours at 180 degrees C (5000 volts applied).	Insulation failed. Test ended.	20 000 μV	4000 μV
After 240 hours at 180 degrees C (5000 volts applied).	———	20 000 μV Insulation charred and brittle.	2500 μV Insulation still solid.
After subsequent immersion in water at 25 degrees C for 64 hours	———	Insulation failed with 500 volts applied.	Insulation withstood 20 000 volts for five minutes.

Note: Three groups of coils were wound alike, and all insulated with 14 layers of Kraft paper (0.005 inch). Group *A* coils were given no treatment, group *B* coils were treated in solvent-type insulating varnish, and group *C* coils were treated in Fosterite compounds. Corona was then measured with 5000 volts (rms) applied across the insulation, according to a standard method.

Analog Computer—New Techniques, New Components

The day of the slide rule, sharp pencil, and numerous sheets of paper—plus, of course, brainwork—has not yet passed for engineering computations. Nevertheless engineers are getting a valuable assist from the analog computer, especially in the solution of long and tedious problems. As experience with the Anacom has grown, new techniques and supplements have been developed.

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Analog computers make possible the solution of problems that formerly took hours, weeks, or even years—in fact, some that were completely incapable of solution by ordinary means. Because of these capabilities, these computers have rapidly become an integral and essential part of science and industry. And their usefulness and capabilities are being increased steadily. A case in point is the Westinghouse Anacom (*ana*log *com*puter).

With the Anacom, new problems have been encountered almost daily, and their solutions have added materially to the storehouse of background information and "know-how." Also, many of these new problems have led to the development of entirely new analog techniques and new computer components. In turn, the new components and techniques have expanded the scope of problems that can be handled, thus giving rise to a cascading or chain-reaction effect.

The Anacom solves problems by use of the principle of analogy or similitude.* Fundamentally, this consists of setting up electric circuits that behave exactly like the original physical system being studied. The proof of the similitude between the actual system and the electric circuits lies in the derivation of the fundamental differential-integral equations that define both the original system and the analogous circuits. Fortunately, the mathematics that define the application of basic physical laws to problems in practically every field of science have their counterpart in the mathematics defining the behavior of electrical circuits. For example, the term for the heat developed in a bearing has the same form as the term for the energy dissipated in a resistor in an electric circuit. Newton's laws of motion, as used in the study of dynamics, have their counterpart in Kirchoff's laws defining the behavior of electric circuits. The one-to-one correspondence between the terms of these various fundamental laws permit the direct measurement of desired solutions in the form of voltages and currents in the analogy of a physical system.

Anacom Components

The Anacom provides facilities for setting up three fundamental requirements necessary to obtain a solution. These are (1) a circuit analogy for the physical system, (2) arbitrary forcing-function generators to simulate the input and initial conditions of the problem, and (3) means for measuring and recording solutions. Use of the Anacom during the past few years has led to many improvements both in methods of attack and equipment used in each of these three requirements.

In early computer work most of the analogs were set up using relatively simple circuits of resistance (R), inductance (L), and capacitance (C), with auxiliary components such as transformers and switches. These are basic, static elements and are always used when they are adequate for the requirements of the analogy. The simplest analogy that satisfies the basic equations of a given problem is invariably the most satisfactory one.

One large category of problems in which the analogy can be handled by these basic elements is that of the transient phenomena in electric-power transmission systems. The distributed constants of the original system are represented by lumped constants in the analogy, connected to give the same operating characteristics as the actual power system. The phenomena under consideration are duplicated in miniature on the Anacom.

New Components and Techniques

A typical problem, for example, is that of determining the transient overvoltages that occur upon de-energizing a long transmission line. Recently, considerable refinement has been made in analysis of problems of this type, particularly in the field of very high-voltage transmission. For example, in one case the effect of corona on the reduction of transient overvoltages was to be determined. Briefly, when the voltage on a wire rises, current is discharged to the space surrounding

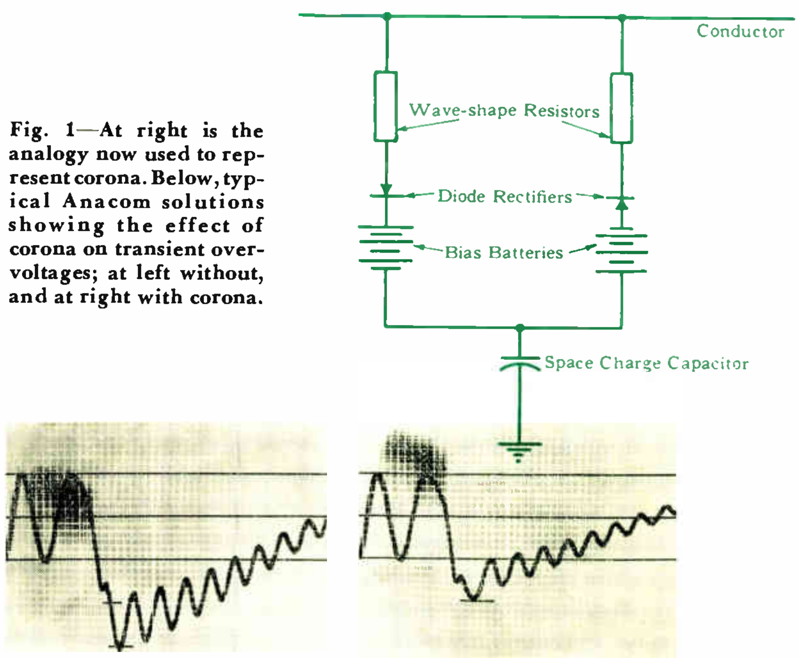
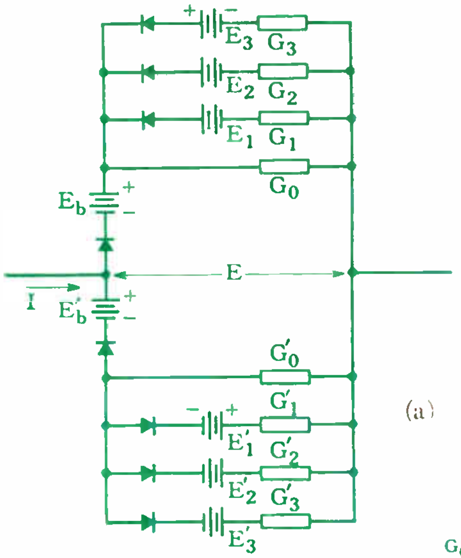


Fig. 1—At right is the analogy now used to represent corona. Below, typical Anacom solutions showing the effect of corona on transient overvoltages; at left without, and at right with corona.

*See "Computer—Mathematical Merlin," by Dr. G. D. McCann and Dr. E. L. Harder, *Westinghouse* Engineer, November, 1948, p. 178.



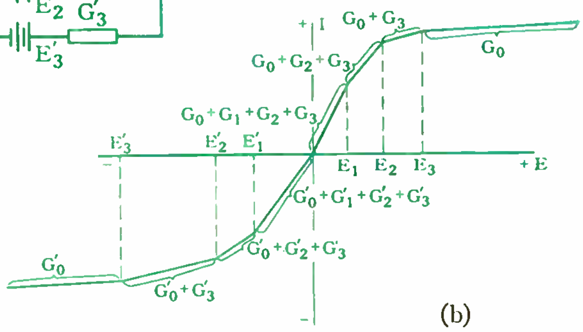


Fig. 2—At left, a circuit used to produce an exponential relationship between voltage and current. Below, the curve obtained with this circuit.

the wire after the critical disruptive voltage is reached. This corona current ceases near the crest voltage. When this point is reached, there is no further current until the voltage swings to twice the critical disruptive value in the negative direction. The discharge of current in the air around the wire produces a space charge about the wire, effectively increasing its radius to the point where the air is no longer stressed above breakdown. The recently devised analogy used to represent corona is shown in Fig. 1. The bias battery is set at the critical disruptive voltage on the computer voltage base. Thus no current exists in the part of the circuit that represents corona until this value of voltage is reached. Small rectifiers, usually crystal diodes, are connected in series with the batteries, blocking current until the potential of the wire exceeds either one or the other of the battery potentials, in the positive or negative direction respectively. The resistors change the wave shape to fit the desired corona pattern. The capacitor simulates the space charge around the wire. Typical solutions demonstrating the effect of corona on transient overvoltages for a specific transmission line are shown in Fig. 1.

The effect of transformer saturation can now be simulated easily. This is accomplished by setting up an equivalent circuit for the transformer that has its magnetizing branch represented by a nonlinear element that varies as a function of the applied voltage. In many cases it is sufficiently accurate to represent the saturation curve by two straight lines, intersecting on the knee of the saturation curve. In such cases the analogy becomes quite simple. These auxiliary analogies, such as for corona and saturation, are plugged into the Anacom at the proper points to simulate their counterparts in the actual system under study.

Nonlinear Elements

An increasing number of problems are arising in which the basic linear-resistor computer elements are not applicable. For example, in the field of gas transmission and distribution, analogous electric circuits can be set on the Anacom, with voltage corresponding to gas pressure, current to gas flow (volume per unit time), and charge to the total flow (total volume). But the problem is complicated because flow is not directly proportional to the pressure, whereas in electric circuits the current through a resistor is directly proportional to the applied voltage. That is, doubling the voltage also doubles the current. Thus, to simulate the flow of gas, nonlinear resistors must be used to represent the actual operating conditions.

Resistors are needed that will produce an exponential relationship between the applied voltage and the current. A practical means for securing such a characteristic is demonstrated in Fig. 2. The voltage E_0, across resistor G_0, is adjusted to zero for zero current through the element. Then as the current

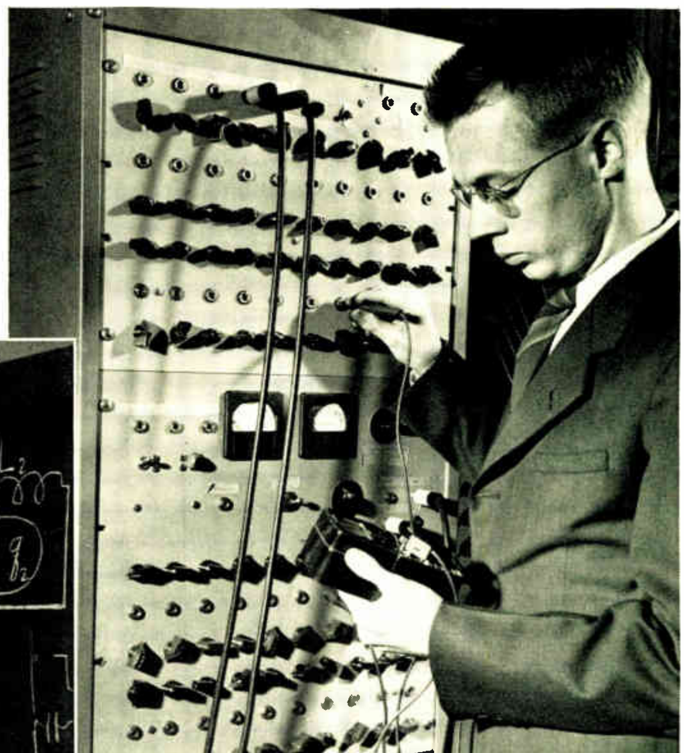


Fig. 3—Above, a typical nonlinear resistor panel. This contains two 20-line-segment units.

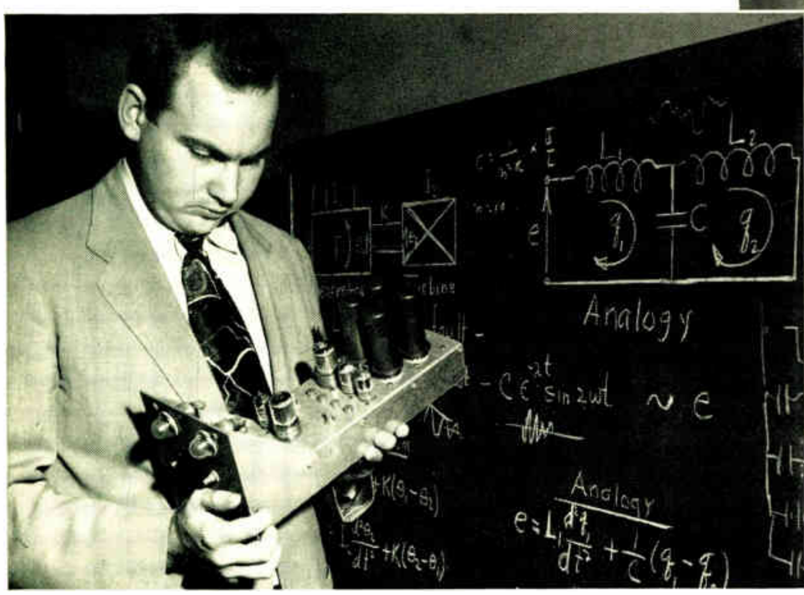


Fig. 4—At left, a Sigma Amplifier. These are useful in performing addition, subtraction, etc.

increases, the bias battery E_1 cuts out G_1 when the voltage reaches E_1, since the diode rectifier prevents reversal of current through G_1. Similarly, G_2 and G_3 are cut out when the voltage rises to E_2 and E_3. This gives a curve of current vs. voltage as shown. By adjusting the voltages E_1, E_2, and E_3 the cutout points are controlled, and by adjustment of the resistors, G_0, G_1, etc., the slope of the I vs. E curve can be controlled. Thus, by a series of straight-line sections a smoother curve can be simulated. For example, a square-law curve can be approximated to within ± five percent by two line sections, to within ± two percent by three line sections, and to within ± one percent by five line sections. A nonlinear resistor panel containing two 20-line-segment units is shown in Fig. 3. In practice, potentiometers are used on the bias batteries and by a simple switching arrangement the resistance of the unit can be made to decrease with voltage, giving a curve of I vs. E of increasing slope rather than decreasing as in the preceding case.

Sigma Amplifier

In contrast to the power-system analogies is the very large field of problems that occur from the expression of the behavior of physical systems by mathematical equations only. Here the Anacom provides solutions to the mathematical expressions irrespective of their origin. It is often helpful, but not essential, that the original system defined by the mathematical expressions be known in order to solve the problem on the Anacom. The computer must be able to perform the basic operations of addition, subtraction, multiplication, division, integration, and differentiation. However, in most problems a direct analogy approach can be used. That is, the computer elements or groups of elements correspond to distinct physical elements in the original system. For example, an inductor can be used to represent the polar moment of inertia of a turbine generator, or a series resistor and shunt capacitor in combination can simulate the time-delay effects in a regulator system.

In the most simple form, addition can be accomplished by passing a current through series-connected resistors. The voltage drop across the combination is equal to the sum of the drops across the individual resistors. Subtraction can be performed in a similar fashion by differentially connecting the resistors. Integration can be done by passing a current into a capacitor, since the voltage across the capacitor is the integral of the current into the capacitor ($e = 1/c\int i\,dt$). Similarly, the voltage across an inductor is equal to the derivative of the current through the inductor ($e = L\,di/dt$), providing a means for differentiation. In many problems, however, it has been found necessary, or more convenient, to use special feedback amplifiers to perform addition, subtraction, integration, and differentiation. The name "Sigma Amplifiers" has been applied to these devices, symbolic of their use in setting up equations. A late model Sigma Amplifier is shown in Fig. 4. These amplifiers are one of the major developments in the analog-computer art. Multiplication is done by a carrier-type electronic multiplier, and division is accomplished by a modification of the multiplier.

The Wave-Form Generator

One of the most recent developments in forcing-function generators is the photoelectric wave-form generator. This device has been adapted for use with the Anacom as an arbitrary function generator. In many problems it is necessary to simulate initial conditions that are made up of complex wave shapes, and consequently a device that can generate any arbitrary wave shape is needed. The essential elements of this device, commonly called a "photoformer," are shown in Fig. 5. As the beam of the oscillograph moves horizontally across the tube, a phototube and servo-circuit force the beam to follow the edge of a template representing the desired function. This device is also used as a nonlinear element in analogies where nonlinear resistors are not applicable.

An additional computer cabinet has been made to house some of the new elements. Fig. 6 shows a front view of this cabinet. At the left top is the photoformer with an oscilloscope alongside. Across the center are jacks that permit the various devices to be connected in any desired position. At the top right are 6 Sigma and 12 preamplifiers. These amplifiers are mounted on draw-out chassis and can be readily removed for servicing. All amplifiers are equipped with signal lights that will indicate saturation and provide a visual check on the proper functioning of the amplifier. The Sigma Amplifiers have standard tube sockets, mounted on their front panels,

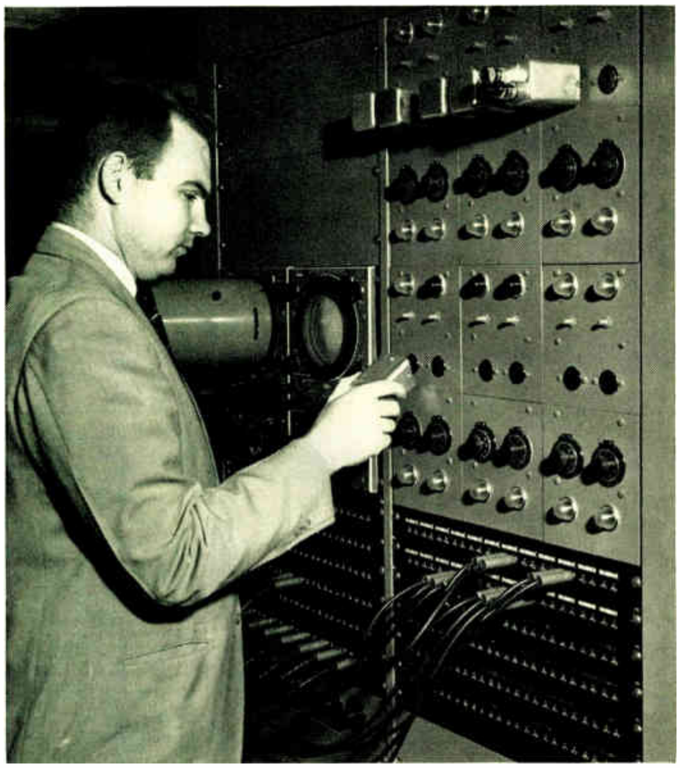


Fig. 6—A front view of a cabinet that houses some of the new Anacom elements. At far left is the photoformer.

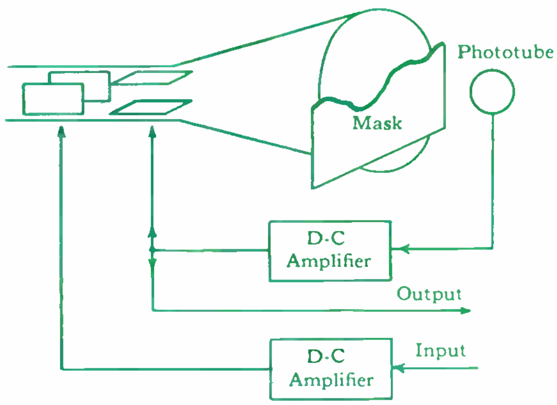


Fig. 5—At right, the photoformer. As the oscillograph beam moves across the tube, a phototube and servo-circuit force the beam to follow a template of the desired function.

that are connected to various points in the amplifier circuit. Through these sockets external circuits, mounted compactly in cans, as shown in the upper right of Fig. 6, can be plugged to make the amplifier perform the desired operations of summation, integration, etc.

Typical New Problems

Many new and interesting problems have been solved during the past several months. Most of these have been rather complex, requiring nonlinear elements for their solution.

Lubrication Systems

One such problem concerned lubrication of modern high-speed diesel engines. The problem was to determine the quantity and pressure of the lubricating oil at various points throughout the lubricating system. This was complicated by the fact that under operating conditions the oil-line frictional coefficients are not constant, requiring the use of nonlinear resistors to simulate the system. The action of the oil pump is analogous to a battery pushing a current through nonlinear resistors; however, superimposed upon this are the simple harmonic forces, caused by the reciprocating motion of the pistons, acting on the oil as it flows out through the crankshaft and up through the connecting rods. This is analogous to a sinusoidal voltage superimposed on the battery voltage. Solutions are obtained by reading voltage and current, corresponding to pressure and flow, at the points of interest. This particular problem could be solved by conventional longhand methods; however, it would be extremely laborious and time consuming. The Anacom obtained a great many solutions at about one hundred times the manual-calculation rate.

Nonlinear Shaft Couplings

A typical problem of the nonlinear type solved recently was the determination of the performance of a clearance-type spline used with a torsionally resilient spindle drive. The typical spline on an automobile drive shaft, or tractor power or other torsionally rigid take-off, is fitted to a very close tolerance circumferentially, but is free to move longitudinally. Thus, for the transmission of torque, the spline acts essentially as a rigid coupling. The close-fit spline performs satisfactorily for this type of service. However, for high-speed engine-driven generators, subject to rapid load fluctuations and also shock excitation, such as engine back-fires or misfires, there is a chance for adverse resonant conditions that would subject the spline and shaft to very high torques. To prevent the build-up of high torques a clearance-type spline (one in which "play" is left between teeth of the spline) is used.

The analog for such a system is similar to that of any spring-connected, two-mass system with the exception that the capacitor, representing the shaft in this case, is connected to a Sigma Amplifier with the proper feedback to represent the nonlinearity caused by the spline clearance. The analogy used and a plot of typical solutions is shown in Fig. 7. An analysis of these plotted solutions demonstrates the nonlinearity of the coupling. Starting at a low value of input or excitation frequency, the shaft twist, which is proportional to torque magnitude, is indicated by the line section labeled *1*. As the frequency increases, the amplitude increases until the spline loses contact between teeth, then jumps to section *2*, and continues along *2* with increasing frequency. With decreasing frequency the amplitude follows back along *2* through *3* and *6* to *1*. If, while operating in section *3*, the engine backfires, or some other shock occurs, the amplitude jumps to curve *4* and remains on *4* as long as the frequency is within that range.

Another problem of somewhat similar nature was recently performed for a large aeronautical laboratory. In this case the shafting for a propeller test stand was being designed. The stand was designed to handle a wide range of propeller designs including the counter-rotating type. The propellers were to be driven inside a wind tunnel with the driving motors outside the tunnel. This required a number of shaft sections, with the last section having one shaft inside the other to handle counter-rotating propellers. Since the propellers were to be tested over a wide range of speeds, excitation frequencies present would coincide with the natural frequencies of the various shaft sections and the connected masses. The torque build-up would be limited only by the losses in the system. Since the normal losses were quite low, it was desired to determine the torque magnitudes with special damper-type couplings in various shafts.

A mass-inductance analogy was used on the Anacom for this job. Inductors represented the polar moments of inertia of the rotating parts, capacitors the inverse spring constants of the shafts, and resistance the various losses of the system. By measuring voltages, which corresponded to torques, the torque of any of the shaft sections could be easily determined for any desired form of excitation.

Reflection of Pulsating Loads through Synchronous Ties

When synchronous machines are connected to each other or

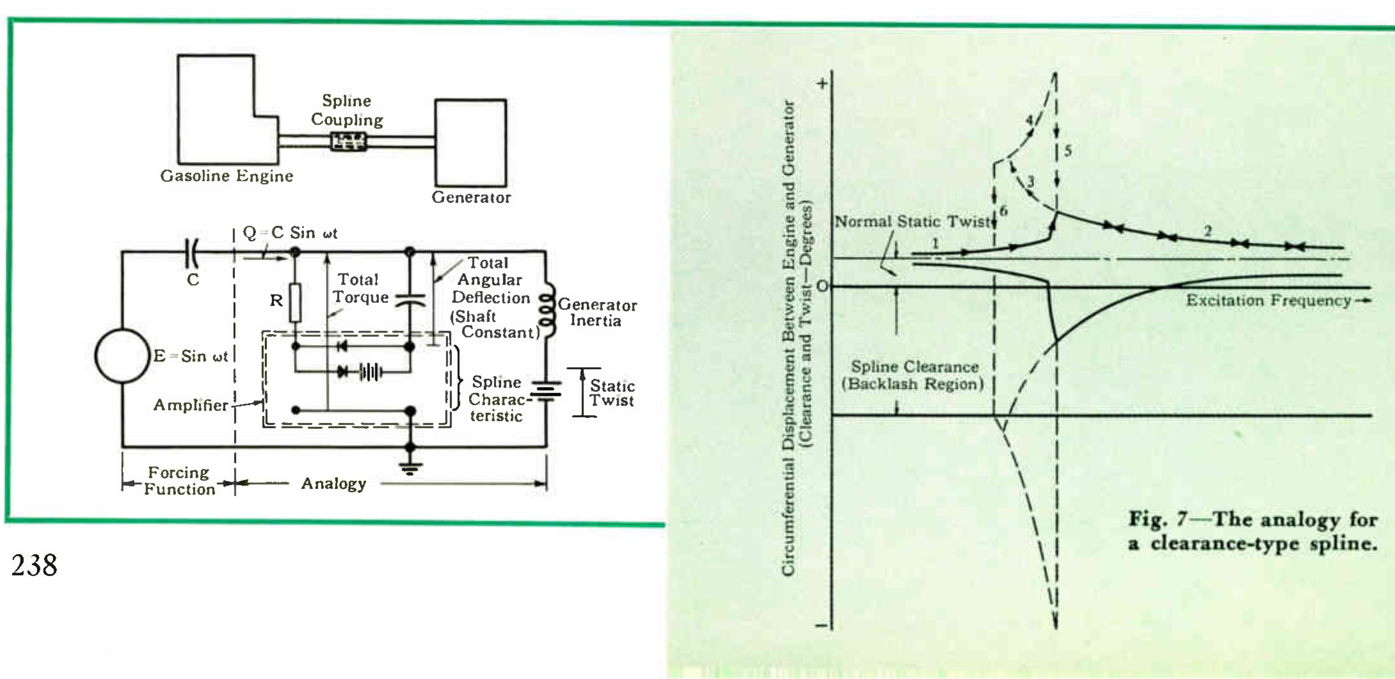


Fig. 7—The analogy for a clearance-type spline.

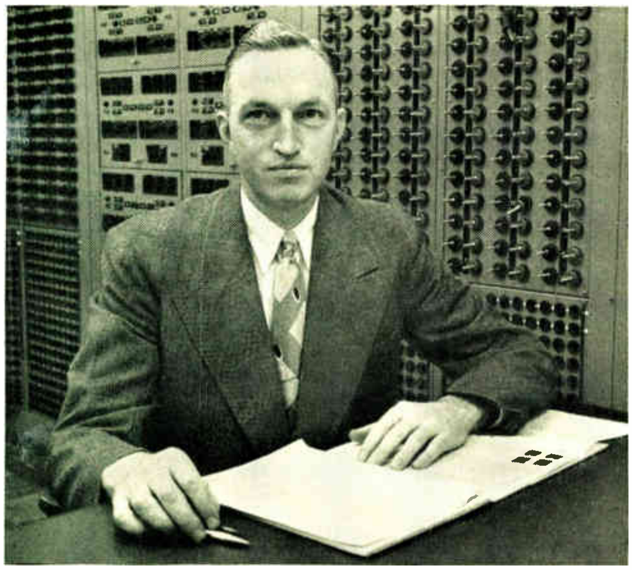
to a system they exhibit electrical torques that are proportional to their angular displacement with respect to each other or the system. The synchronous tie then acts as a spring, i.e., torque proportional to angular displacement. This then immediately leads to a mass-inductance analogy in which a capacitor is used to simulate the synchronous tie. The natural frequency associated with the spring actions and the inertia of the system ranges from one to four cycles per second in typical systems. Any repetitive load variations that occur in this frequency range have the possibility of resonance and thereby cause trouble from excessive current pulsations. This analogy was used recently to determine the current pulsations in a utility power system when a large motor-generator set was to be connected to the system. The load on the motor-generator set consisted of a particle accelerator requiring very high peak power of short duration. The resulting effect upon the system feeding the motor-generator set could be measured directly.

Servomechanism and Regulator Problems

Several problems in the field of regulators and servomechanisms have also been solved. Steel and paper-mill drives have been simulated. Equations of flight can be solved whether they apply to guided missiles or other devices.

The Anacom fills a long-felt need in applying basic physical principles to practical engineering problems that formerly were too complex or time consuming to permit solution.

Personalities IN ENGINEERING



Although engineers are generally adept at mathematics, not many obtain any physical or apparatus concept out of a mathematical expression. But *E. L. Harder* does. Several basic devices now in common use are the result.

In the summer of 1937 Harder was one of a group of engineers working to develop a high-speed, pilot-wire relaying scheme. They had difficulty coordinating the contacts of the essentially conventional relays being tried for the purpose. After two weeks, they stopped one Friday afternoon apparently no nearer the answer than days before. That night Harder pondered the problem and decided to attempt a mathematical solution employing symmetrical components. In the resulting equations he believed he saw the answer. Returning to the laboratory on Saturday, he assembled some relay parts and circuit elements to do the things called for by the symmetrical-component formulas. The next day he ran complete tests on a miniature transmission line. It worked the first time. This system, known as the HCB (high-speed current balance), pilot-wire relay system was subsequently improved by relay specialists and is now in use on dozens of power systems.

Harder has 54 patents in his name, several of which are basic system patents, in addition to the many applying to detail and apparatus improvement. When he is asked to trace his engineering career, he takes from his desk two fat, nicely bound, printed copies of his technical papers. The table of contents lists 51 entries. It is common with men of such engineering accomplishment to look to their childhood for manifestations of unusual technical aptitude. One quickly finds it in Harder's case, in his high school career. Midway through his physics course he took an examination on the entire year's work and passed it, which excused him from further classwork. "Later regretted it, though," he says. Unusual aptitude in mathematics likewise gave early evidence of a theoretical bent.

After high school he went to Cornell University, because he had won a Cornell tuition scholarship as well as a state scholarship good in a New York university. There he studied electrical engineering, he reflects, "probably because that was what my father was." During college summers he sold aluminum. This, he recalls, taught him two things: that he could sell, and that he intensely disliked it. His work at Cornell did, however, give some clue as to what was to come. He took what extra math courses he could, including operational calculus under the famed Karapetoff, and studied the transmission-line stability papers of Wagner and Evans, for whom he later worked.

Harder came to Westinghouse in 1926. After finishing the student-training course he elected central-station engineering, where he assisted on railway-electrification and relay problems. Soon, however, the depression arrived and his work on railway power supply was transferred to the Switchgear Division. The Wilmington-to-Washington electrification of the Pennsylvania Railroad was about to get underway. He was placed at work on its relaying problems.

Later came work on the above-mentioned carrier current, the development of the linear coupler, and association with "Doc" Travers on relay applications and developments. Harder returned to the central-station application section in 1938 and was made Consulting Transmission Engineer in 1946. He developed the servo-analyzer, now an integral part of the Anacom (electric analog computer), of which he now is technical director, supervised field studies of lightning, promoted microwave communication, and helped coordinate magnetic-amplifier developments.

Somewhere in all this Harder has found time for advanced engineering study at the University of Pittsburgh, obtaining an M.S. in 1931 and a Ph.D. in 1946. He also has taught many classes on mathematics and circuit theory.

Harder is tall, angular, and sober of mien but possesses a keen sense of humor. His interests, he admits, are his engineering work, a retreat on Crooked Creek near Pittsburgh, and his family, which comprises his wife and four boys. "Looks like the two older boys are going to be mechanical engineers," he says.

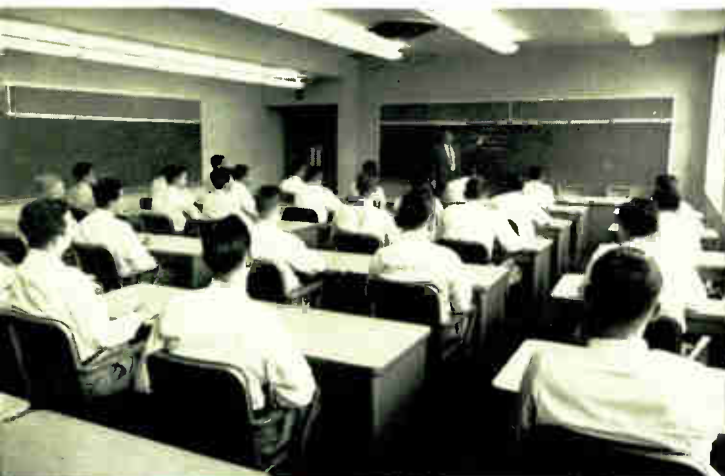
Education IN INDUS

THE advanced courses taught engineering graduates by industry fifty years ago are part of the undergraduate curriculum of today's schools. Now, advanced courses have soared into fields and sciences that in some cases were unknown a half century ago. The physical plants in which these courses are taught have kept pace with this progress. Witness the new Westinghouse Educational Center depicted here.

The first location for the Graduate Student Training program was—as pointed out in the inside-front cover of this issue—a single room over a store. A marked contrast indeed to the spacious, modern facilities shown here.

In this building engineering students from all over the country are introduced to their new employer, and are given a good, close look at its numerous products and broad activities. The first class they attend is an orientation course, which lasts about a week and gives a general, overall picture of the Company. Then they get down to finer points in Product Engineering Conferences, studying the wide variety of devices manufactured by Westinghouse. These last six weeks. Here the student engineer obtains not only an "inside" picture of the Company's products, but also an insight into the interrelation of the various activities of a large organization. This phase of the course is called "Basic Training" and includes several work assignments in various of the

Right—The Center's auditorium is shown with a Product Engineering Conference in session. Below—Discussion-type classwork in one of the Center's classrooms.



Right—The Snack Bar on the lower floor of the Center offers noontime meals to students and staff, and serves as a refreshment stand at other times.

TRY

Company's plants to supplement the usual classroom work.

After four to five months of Basic Training, each student segregates to a major field, such as engineering, sales, or manufacturing. His training is then pointed toward placement in a permanent job within that field. The training again consists of appropriate work assignments and a period of classroom work. This classroom work is also held at the Educational Center.

In all phases of instruction at the Center, full use is made of both the lecture-type class—utilizing such teaching aids as movies, slides, models, and demonstrations—and the smaller, more informal, group-discussion sessions.

The Center's facilities are also used for the Graduate Study Program, conducted evenings in cooperation with the University of Pittsburgh. Here any employe in search of more knowledge is given the opportunity to take further work, and can earn advanced degrees in many fields.

All work and no play have the well-known results—so the personal side of the program is abetted by a separate, self-sustaining organization known as the Graduate Student Club. The facilities of the Center are made available to this club for recreational purposes.

The Westinghouse Educational Center is located in Wilkinsburg, Pennsylvania, about four miles from the Westinghouse main plant at East Pittsburgh.

Students relax between class sessions in the main lounge (left) and in the downstairs lounge (below). A library and reading room adjoin the main lounge.

Left—Here the student makes initial contact with the Company—the main offices of the Educational Department on the second floor of the Center.

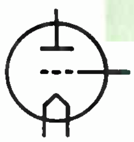
Reliability in *Electronics*

Electronics has been hailed as the "wonder" science. And it justly deserves such a title. But the art is yet a young one, whose basic fundamentals are not even completely understood. In every new application, the usual engineering factors of dependability, cost, and maintenance should be carefully weighed in the choice of electronic apparatus. This frank appraisal of the situation makes it clear that electronics for electronics' sake should never influence the decision.

D. D. KNOWLES, *Manager, Electronics Engineering Department, Westinghouse Electric Corporation, Bloomfield, New Jersey*

ELECTRONICS, a young, progressive, and occasionally brash branch of engineering, has achieved its stature quickly. And for the most part it has been a resounding success. Witness its widespread use in industry—not only in the familiar radio, television, and telephone, but in hundreds of instances where it serves to make products better and cheaper than can be done by other methods. Sometimes it makes possible things that could not otherwise be achieved. For example, x-ray machines, used to diagnose and treat human ailments; diathermy and other apparatus used extensively in medicine. Modern warfare is also dependent on electronic apparatus for all kinds of detecting and measuring devices and for automatic control of planes, ships, rockets, etc.

Yet, in spite of all this use of electronic schemes, the fact remains that electronic apparatus has still not matured—it is not yet as reliable as it should be. For electronics to attain its rightful place in the sun, this situation must be corrected. It will not be corrected, however, unless the importance of reliability is recognized, and then only if all concerned spend the necessary effort and money toward this end. It requires the best efforts of the tube designer and manufacturer to make better tubes, and the equipment designer and manufacturer to make better equipment, and an educational program to teach the user how to maintain and utilize such electronic equipment and tubes in his plant.



"Probably the greatest threat to reliability in electronic equipment is the continual pressure from users and equipment designers to increase the ratings 'just a little bit' . . . Very rare indeed is the question: 'How much will tube life and reliability be increased if I use the tube below its ratings?' "

The electron tube itself is a common denominator in all electronic apparatus. Undeniably, electron tubes are not as reliable as motors, transformers, resistors, etc.—not because the tube manufacturer wants it that way, but because too little is yet realized about their application (or for that matter their basic principles). To gain a better understanding of this situation, let us analyze the various factors that contribute to electron-tube operation, especially those that affect reliability.

Cathodes

Every tube has a cathode of some kind whose duty is to emit electrons. Sometimes they do and sometimes they don't. In spite of the widespread use of cathodes the exact detail mechanism of electron emission is still a matter of argument.

Except for pure metal filaments, most cathodes are complicated composite materials, such as oxide coatings, deposited on metal cores; or they can be some form of metal impregnated with other materials, as, for example, thoriated tungsten. Their operation depends on a fine balance between diffusing a sufficient amount of emissive element to the surface as opposed to evaporating too much of the emissive element. Cathodes are sensitive to contaminations by minute impurities, which can come from other elements of the tube, from the glass, or from chemicals that have been used to clean tube parts. These composite cathodes must be run close to their rated temperatures in order to get satisfactory operation. This imposes a hardship on the equipment designer because he may have to supply voltage regulators or take the consequence of impaired operation and life if he omits the necessary voltage control.

Vacuum Tightness

All electron tubes must be vacuum-tight in order to continue operation. At least they must be essentially vacuum-tight. Any tube manufacturer has, much to his dismay, a certain amount of "shrinkage" because some tubes leak sufficiently fast that they are caught at inspection and rejected. Undoubtedly a certain number of tubes are shipped that leak so slowly as to defy detection. As a matter of fact, it was recently stated that probably no one has yet made a really vacuum-tight tube. Those tubes that are called "vacuum-tight" simply leak so slowly that they may last for many years without becoming too gassy and give trouble.

Gas Content

Other electronic tubes, such as gas-filled thyratrons, depend upon the maintenance of a specific gas pressure throughout their operating life. In electron tubes two mechanisms occur—namely, the gradual evolution of gas from certain metal parts due to temperature and electron bombardment; and the gradual absorption, or clean-up, of gas by other surfaces in the tube. In the high-vacuum type of tube it is fortunate that this gas clean-up mechanism exists. Without it, large high-vacuum power tubes might not be practical. Here the satisfactory maintenance of high vacuum depends in part upon the mechanism of gas clean-up by certain electrodes keeping pace with the gas evolution from other electrodes. Fortunately, in this case there cannot be too much gas clean-up, since the better the vacuum the better the condition. Failure from this cause results only when gas evolution exceeds gas clean-up.

With gas-filled thyratrons, however, this balance is more delicate and even with the best-known techniques, gas clean-up eventually develops too low a gas pressure for satisfactory operation and the tube ceases to function.

Grid Emission

Many tubes, such as triodes, tetrodes, and thyratrons, have grids that control the current between cathode and anode. For the control characteristics of the tube to remain constant, the primary emission (due to temperature), the secondary emission (due to electron bombardment), and the current collected or intercepted by the grid must all remain constant throughout the life of the tube. Both the primary and secondary emissions are sensitive to minute traces of impurities deposited on the grid metal. Since cathodes invariably vaporize a certain amount of active material, a grid material must be used that remains constant in its characteristics regardless of contaminations. This is necessary as long as no method is known for making cathodes that do not vaporize.

Mechanical Design

In the manufacture of electron tubes, as in a radio receiver for example, many connections or joints must be made by either welding, soldering, brazing, riveting, or clamping. If a connection fails in a receiver the repair man can fix it. If it happens to a tube it cannot be repaired and the tube has to be scrapped. Making reliable connections is complicated by the necessity, for other reasons, of using and joining widely dissimilar materials that operate at widely differing temperatures. The choice of joining methods is further limited by the necessity of avoiding any flux or other material that will make the tube become gassy, or any material that will evaporate at operating temperatures and contaminate other tube parts or bridge over insulators.

Another common factor in all tube designs is the problem of insulating the various elements of the tube from one another. These insulating sections may be glass, mica, or ceramic. In most cases they form all or a part of the vacuum-tight envelope and also become a part of the mechanical support for the tube elements. Both glass and ceramic materials are brittle, will withstand only a limited thermal shock, and match more or less imperfectly the metals to which they must be sealed. The insulating sections should be long to improve insulation and short to improve mechanical strength. The designer thus has to compromise between these two requirements, depending upon the application. He has to balance insulating reliability against mechanical ruggedness. The insulating material must be vacuum-tight, relatively free of gas content or easily outgassed, and must have a temperature coefficient of expansion, matching as closely as possible one of the metals to which it is joined. The choice of insulating material is further limited by the fact that it must be suitable for forming vacuum-tight seals.

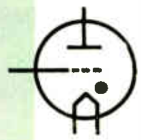
So much for the major factors that contribute to the reliability or unreliability of electron tubes. These factors should bring about a broader understanding of the problems involved in developing dependable tubes. Some of these problems require intensive research and engineering, but there is no doubt that they can be solved if sufficient effort is put forth.

Reliability in Electronics

Probably electron tubes depend for their operation on more little-understood factors than any other product in mass production. Tube people believe that they are making good tubes, but also that they will gradually find out how to make them better. In the meantime, immediate steps can be taken to utilize better the present qualities of tubes.

Many field troubles with electronic tubes come under one or more of the following categories: (1) the use of tubes when some other device would be more suitable, (2) failure to select the best tube for the job, (3) failure to operate the tube at or below its ratings, and (4) actual engineering errors in the design of the circuit and inadequate protective devices.

"In a democracy an individual is considered innocent until he is proven guilty. In electronics the tube is considered guilty until it proves itself innocent."



Thus equipment engineers can do much to improve reliability of electronic devices. The first questions to ask are: "Is a tube needed and if so, why? What will be the consequences of a tube failure?" In the case of radio or television, the answer is easy because tubes are essential. A tube failure in a radio receiver is an inconvenience, but does no real damage. Also it doesn't ruin the refrigerator or the oil burner.

On the other hand, the use of a tube where failure can mean actual loss of property or life is an entirely different matter. This does not rule out the use of a tube, but it does call for serious consideration of alternate methods and the selection of the most reliable solution. Many graduations exist between these two extremes. Electronic devices are used in certain railway signalling systems where life and property are at stake. However, the devices are designed such that any conceivable type of tube fault results in a "safe" failure.

Electronic apparatus is used for rectification, spot and seam welding, induction and dielectric heating, and other manufacturing processes where it is in competition with other methods. The consequences of a failure are usually no greater than the interruption of production that occurs during shutdown. In deciding the economics of the various methods, the frequency and duration of shutdown must be considered to decide intelligently whether to use tubes or not. This involves tube life, ease of replacement, and other circuit design and maintenance considerations.

Tubes, of course, eventually fail and in the long run the rate of failure follows the usual probability curve. Most failures occur close to the average life expectancy but a certain percentage happens before or after that time, and some tubes fail early in life. If the consequences of failures are serious, then tubes should not be used if there is a more reliable way.

The selection of the best tube is important and far from easy. It requires the cooperation of the user, the commercial man who knows the requirements, the equipment designer, who provides the method, and a tube engineer who knows his tubes thoroughly.

Commercial warranties are not an indication of life expectancy any more than a 90-day guarantee on an automobile. The technical data sheet alone is not enough because, of several tube types possessing approximately the same ratings, one may be designed for 500 hours' average life, another for 5000 or perhaps 10 000 hours. Tube manufacturers are naturally loath to commit themselves on tube-life expectancy without knowing in considerable detail how the tube is to be used, what the circuit conditions are, and what grade of maintenance the equipment will get. This is because tube life may be as dependent on these factors as on the design or quality of the tube itself. Good life cannot be obtained from a bad tube, but there have been some outstanding instances in which bad life has been obtained from a good tube.

> ***"If electronic tubes ever form a union, the first thing they will do is put in a grievance charging discrimination, speed-up, and hazardous working conditions."***

In his attempt to select the best tube for the job, the equipment designer often consults, directly or indirectly, different tube manufacturers—and gets conflicting answers. These conflicting answers may reflect a varying eagerness to sell tubes, an honest difference of opinion as to what will happen under given circumstances, or, as is often the case, a varying appreciation of the rigid requirements of industrial applications as contrasted to a less exacting sphere of use. In this situation the designer has to decide for himself whose judgment to accept and should make careful tests to determine his choice.

Probably the greatest threat to reliability in electronic equipment is the continual pressure from users and equipment designers to increase the ratings "just a little bit." Hardly a week passes that a tube manufacturer does not get a request to raise the rating on a given tube. Very rare indeed is the question: "How much will tube life and reliability be increased if I use the tube below its ratings?"

The trend is completely contrary to the desire for greater reliability. The telephone system gets long life and maximum reliability by using tubes at low ratings. Until better tubes are made the same should hold for industrial apparatus.

Often laboratory tests must be made to determine if tubes are actually being used within ratings. For example, several cases are on record where the designer thought a tube was being used within its voltage ratings because the transformers could not supply more than the peak voltage ratings. However, oscillographic tests showed that transient oscillations superimposed on the normal voltage nearly doubled the actual voltage applied to the tube. Another common occurrence is that two or more tubes do not divide the load properly, so that one tube is underloaded and the other overloaded. This is especially likely to happen with gas-filled tubes, which do not parallel well unless specific means are provided in the circuit for this purpose.

Considerable benefit can be gained by using tubes under their ratings, and by making actual tests to prove that conditions in a circuit are as they appear to be. Complete tests on a finished model with oscillograms to show transient conditions will also catch many design errors that would otherwise go unnoticed.

Inadequate protective devices are often a costly factor. Tubes do not as a general rule have the factor of safety inherent in other components, so the elimination of a good protective device usually results in the tube acting as a fuse and being destroyed or damaged every time a fault occurs anywhere in the circuit. In a democracy an individual is considered innocent until he is proved guilty. In electronics the tube is considered guilty until it proves itself innocent. If electronic tubes ever form a union, the first thing they will do is put in a grievance charging discrimination, speed-up, and hazardous working conditions.

Another frequent cause of trouble is the failure of the equipment designer to take into account the extent to which characteristics vary from tube to tube and with life. Equipment engineers can help by trying several tubes in the set instead of one complement, and by consultation with the tube supplier. This should eliminate many cases where replacement tubes do not operate satisfactorily either because there is not enough adjustment in the apparatus to accommodate the variation in characteristics, or because of the need for closely matched tubes, which may have accidentally occurred in the first complement tried.

There are numerous examples of things that have been done wrong or could have been done better. However, four things will help eliminate many of the problems in the future. First, intensive research and development must be conducted, aimed at improving reliability and life of electronic tubes. If both cannot be done this should take preference over the invention of new and more exciting types of tubes that would probably still have the same "uncertainty factors." Secondly, greater effort must be put forth on the part of the equipment designer to build reliability into the apparatus and thus get the most out of the tubes as they are today. Third, there must be more consideration of reliability, even where it means a higher initial cost. Last of all, an educational effort must be conducted to improve maintenance of electronic equipment. Without extensive training, an automobile mechanic—no matter how highly skilled—would certainly not be placed in charge of maintaining expensive telephone-system equipment; neither should electronic apparatus be maintained by men without a thorough background of training and experience in electrical circuits, and electronics in particular.

Much research and effort have gone into making tubes rugged and adaptable to industry. Continuing developments, both in tubes themselves and in their application, will improve these devices toward even greater reliability.

Waste "Gas" Turbines

Engineers of the Arabian American Oil Company (Aramco) are operating conventional mechanical-drive turbines by utilizing the kinetic energy of presently "unusable" combustible gases. These gases, which would otherwise be burned as waste, drive eight turbines delivering more than 6000 hp to centrifugal pumps at the initial stage of a pipeline.

These turbines operate non-combusting on the expansion of the great quantities of natural gas, which is separated from the oil-gas mixture that comes from the wells, and expands through the turbine exactly as does steam. Power is developed from thermal energy as it passes through the turbine from initial conditions of 450 psig and 300 degrees F to 8 psig and 100 degrees F at exhaust. (The natural gas is heated from its normal temperature of about 160 degrees F to prevent freezing at the reduced exhaust pressure.)

As the oil-gas mixture comes from the wells, it passes through a series of traps that separate the two, the oil flowing to the storage tank from where it is pumped, the gas passing through the heaters and to the turbines. The exhaust from the turbine is then flared (burned in the atmosphere).

Pipeline pumping, accomplished in this manner, requires only a bare minimum of equipment—steam generators, condensers, feed pumps, etc., are eliminated. Only the traps and heaters are needed. Wherever there is excess gas, the use of gas-expansion turbines can be a practical and economical solution.

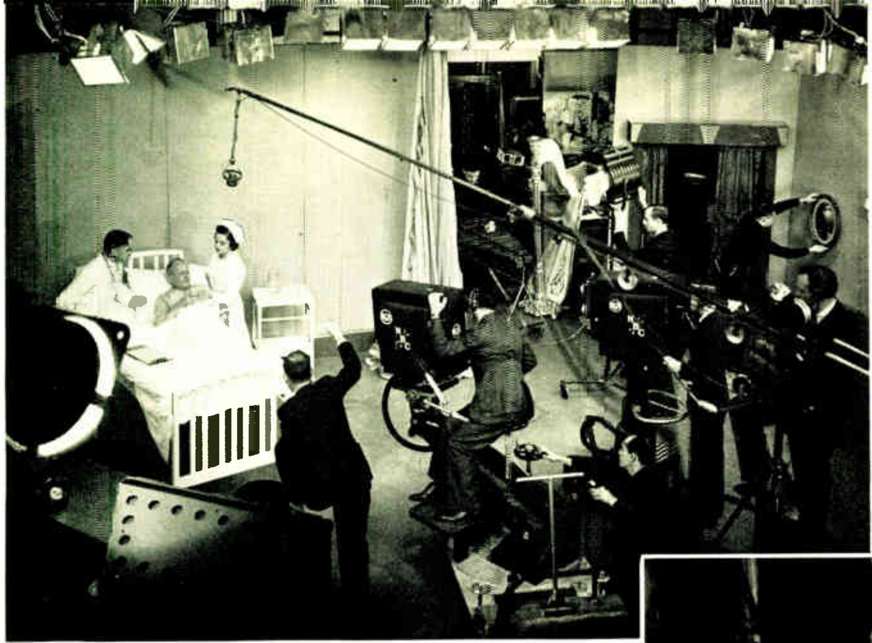


Fig. 1—Early TV lighting techniques were borrowed from movie-studio practice. Floor areas were cluttered with cables and lighting equipment; little room was left for camera movements.

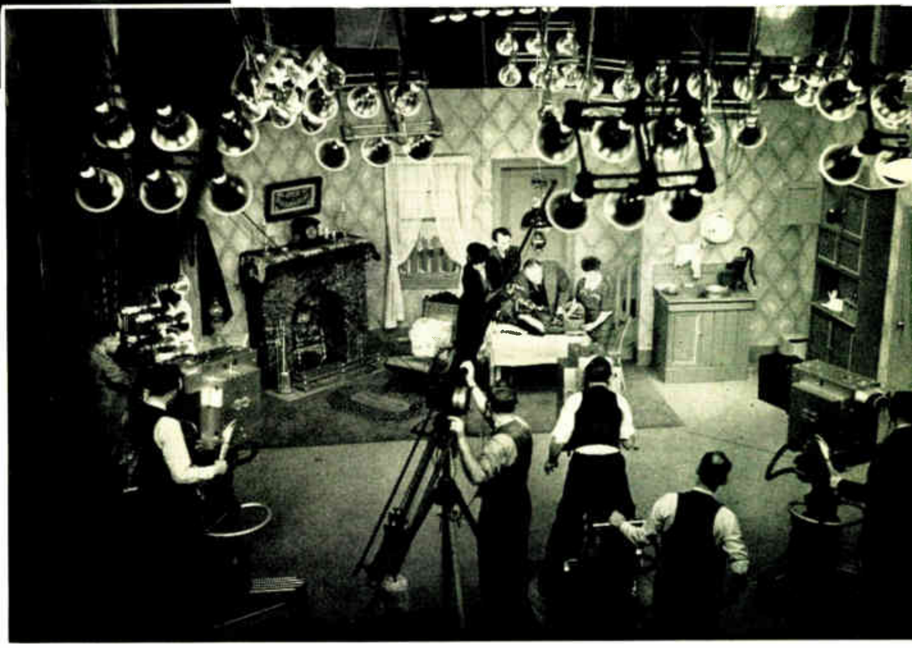


Fig. 2—To clear the floor of cables and lighting equipment, clusters of reflector lamps in special fixtures were suspended over the studio.

Television-Studio Lighting

H. M. GURIN
National Broadcasting Company
New York, New York

R. L. ZAHOUR
Lamp Division
Westinghouse Electric Corporation
Bloomfield, New Jersey

Television has been taking some giant strides in the past few years. To maintain this pace, illumination engineers are providing good studio lighting. Fortunately, a few problems are similar to those of movie studios; however, most are unique to television and thus require special consideration and design.

TELEVISION, whose growth has rivalled that of Jack's beanstalk, has progressed so rapidly that its present equipment and methods bear little resemblance to those in use only a few years ago. Many of these advances—in new studio equipment, transmission and receiving apparatus—are interdependent, i.e., advances in one element necessitate or allow changes in others. Such is true in the case of television-studio lighting.

Much success has been achieved in the development of highly sensitive camera pickup tubes. This has brought about many changes in television-studio techniques and transmission. However, because the results obtained with these new tubes are dependent upon the lighting, advances in studio illumination have gone hand in hand.

In the early days of television experimentation, about 1936, many television techniques were borrowed from the motion-picture industry (Fig. 1). In many respects, the problems were the same. However, dissimilarities in the two applications soon appeared, and it became obvious that much of the equipment would have to be radically altered for television use.

Factors to Consider

Lighting of television studios has been complicated by several factors. One is the need for uninterrupted action, which means instantaneous transferal from one field of view to another. Action on the set cannot be halted (as might be done in a movie studio) while camera positions are reset, lenses adjusted for different depths of field, lights rearranged, etc. This requires multiple sets. Instantaneous switching from one scene to another without mutual interference of lights adds to the complexity of the operation.

Another problem is the extremely crowded space, often converted broadcast studios, in which operations are carried out. Often sets must be torn down and rearranged quickly, all in a limited area. As a result, the physical factors of size, weight of equipment, ease of manipulation, and general handling are important considerations.

In addition, the problem of dissipating heat from the lamps cannot be ignored. The early camera pickup tube, the iconoscope, was much less sensitive than those now used. It required the use of a tremendous amount of light—about 1000

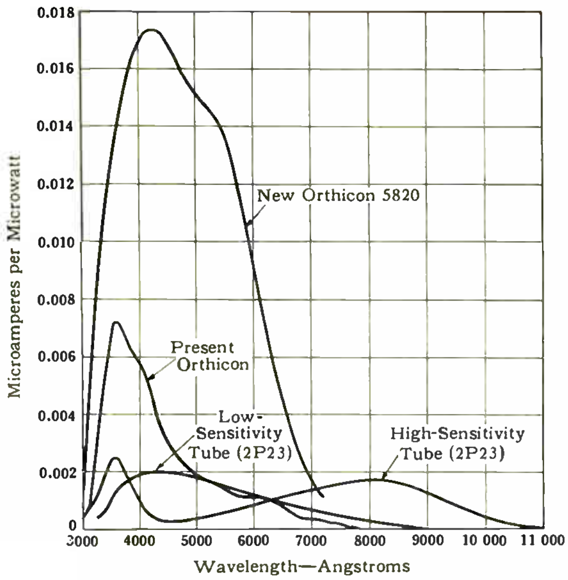


Fig. 3—The spectral characteristics of several different image-orthicon pickup tubes. (The term "Present Orthicon" refers to the 5655 orthicon tube.)

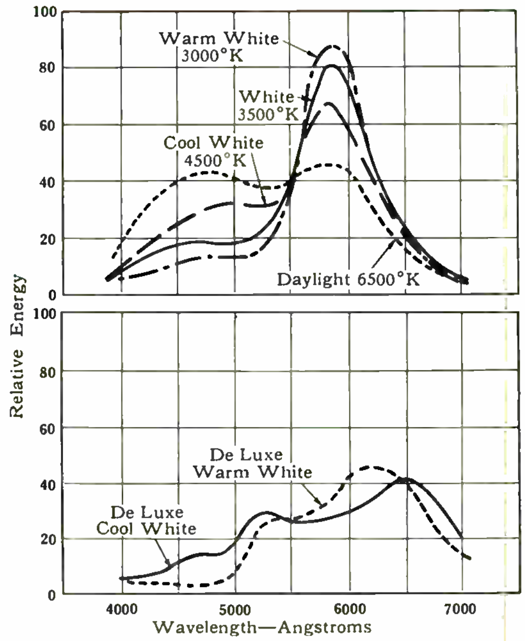


Fig. 4—The energy distribution curves of six fluorescent lamps.

to 2000 footcandles incident. As a result, large, cumbersome units, radiating an uncomfortable amount of heat, were replaced by clusters of smaller reflector lamps mounted in special fixtures (Fig. 2). This led to much greater flexibility in manipulating the light sources, and in clearing the floor for greater camera freedom. It also provided broad, diffuse light—but it did not solve the problem of heat. A further difficulty existed in obtaining a satisfactory degree of modeling light, because of the high foundation light necessary to obtain an adequate picture.

One problem common to both motion-picture and television studios is the need for selecting the proper quality of light for a given camera pickup characteristic, in order to obtain a satisfactory rendition of colors in a suitable gray scale for black and white pictures. The solution of this difficulty will permit the widespread use of color in scenery and costuming with its associated favorable psychological effect on television performers.

The development of the present image-orthicon camera tube has been a major step in obtaining the excellent results now common in some of the large cities. The actual amount of light used with this tube is about one-sixth that required in a normal motion-picture studio. Obviously, however, the most sensitive tube is of little use unless the proper lighting is employed. Thus, much careful engineering planning has been devoted to studio illumination to assure the maximum use of the advantages of new tubes and other equipment.

Even with the advent of the image-orthicon tube the problems of correct illumination have not been completely solved—but definite strides to acceptable solutions have been made. For example, a light source should have spectral characteristics correctly related to those of the camera pickup tube used, and psychologically suited to the performers. The spectral characteristics of several different image-orthicon tubes are illustrated in Fig. 3. The spectral characteristics of several fluorescent and incandescent lamps, sunlight, and the average eye response are shown in Figs. 4 and 5.

When the various light sources are used in conjunction with an image orthicon (No. 5820), the pickup tube now being rapidly accepted for studio use, an overall photographic response can be plotted. This group of curves shows the photographic effectiveness of various light sources on the image orthicon tube (Fig. 6). It is found by multiplying the relative sensitivities of the pickup tube by the relative energy of the light source used.

These curves yield some interesting results. For example, when an incandescent source is used, the combination leads to a curve that approaches the response curve of the average eye. This is significant, since it leads to a tonal rendition in the gray scale that can be readily reconciled to the actual colors used in the scene. This objective can also be attained with fluorescent light if a filter (Wratten 6) is used at the camera. Because of these fortunate circumstances, fluorescent lights can be mixed with incandescent to excellent advantage. Incandescent sources, in general, are preferred because of their simple construction, ease of handling and installation, and because they allow better control of beam pattern. However, fluorescent lamps can be used where flexibility in adjustments is not as important, and where air-conditioning limitations restrict the heat load. No light source, of course, however well matched with the pickup tube, can be efficiently utilized without a good reflector and housing.

Types of Studios

Thus far, studios can be classified into three main types, which have different lighting requirements. The first, which requires the greatest degree of flexibility, is the general-purpose or workshop studio. In this studio originates a wide variety of dramatic performances, commercial sequences, and almost any type of small musical or speech grouping. Here maximum mobility in scenery changes and camera movements are essential. As a result, the lighting system must be capable of matching these requirements in both physical manipulation and in beam pattern and intensity control. This type of studio is illustrated in Figs. 7 and 8.

The second type of studio frequently used for television programming is one in which an audience is present, and which is chiefly used for theatrical presentations, as in a

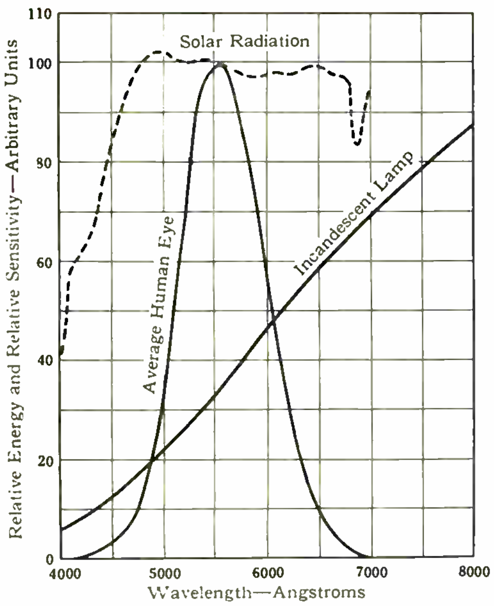
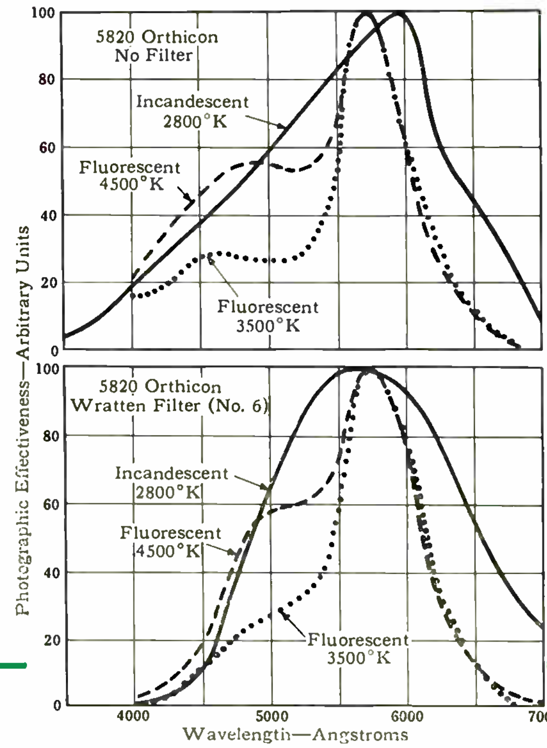


Fig. 5—Spectral characteristics of solar radiation, incandescent lamps, and the response of the average eye. ←

→ **Fig. 6—The photographic response curves of the No. 5820 image orthicon for white fluorescent lamps, and an incandescent source.**



variety show of the Texaco "Star Theatre" type. Here the television point of view is that of an observer in the theatre, and varies primarily not so much from different angles, as from the area of view between a close-up and a long shot.

The lighting problems are consequently not as complicated as in the workshop studio, but results sometimes suffer from inadequate fill light. Footlights are used only to a limited extent because of the unnatural effects produced. Follow spots have been found to be satisfactory for long shots, but usually fail to improve the appearance of the principal characters on close-ups because the sharp beam creates harsh shadows and lines around the eyes, nose, and mouth. Color gelatines, frequently used in theatres to create pleasing color tones to the theatre audience, are almost completely lost to the television audience, and also introduce an undesirable change in the gray scale.

Most of the lighting fixtures are supported above the stage. Lower angle lighting is created by the use of standards located in the wings or on the sides of the theatre, as shown in Figs. 9 and 10. Lighting effects as produced in the NBC studio at the International Theatre in New York are shown in the photo of Fig. 12.

The third type of studio is one in which the set is essentially fixed in position and the program material is repetitive. The lighting can be fixed, if desired, once the original plan is set. Under such conditions desirable artistic effects can be

Figs. 7 and 8—Two different NBC general-purpose or workshop studios; various kinds of programs originate in such studios, requiring considerable flexibility in lighting arrangements.

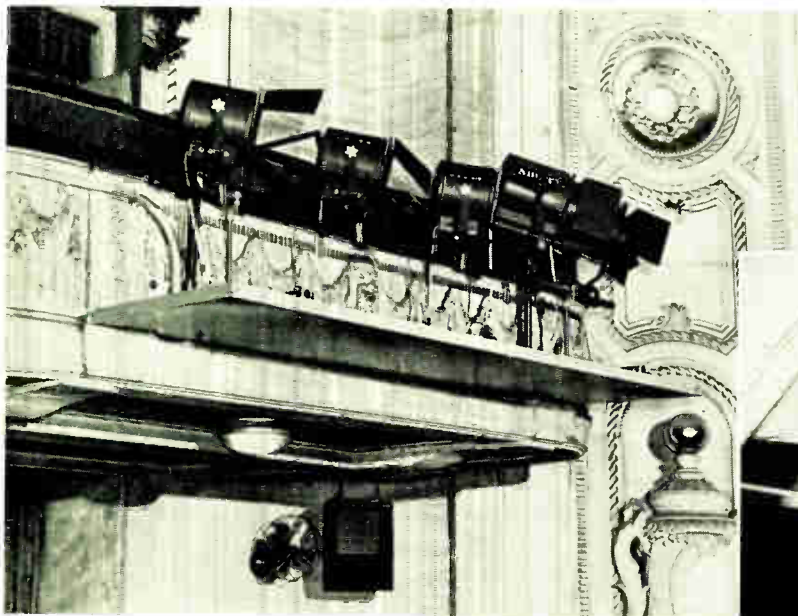
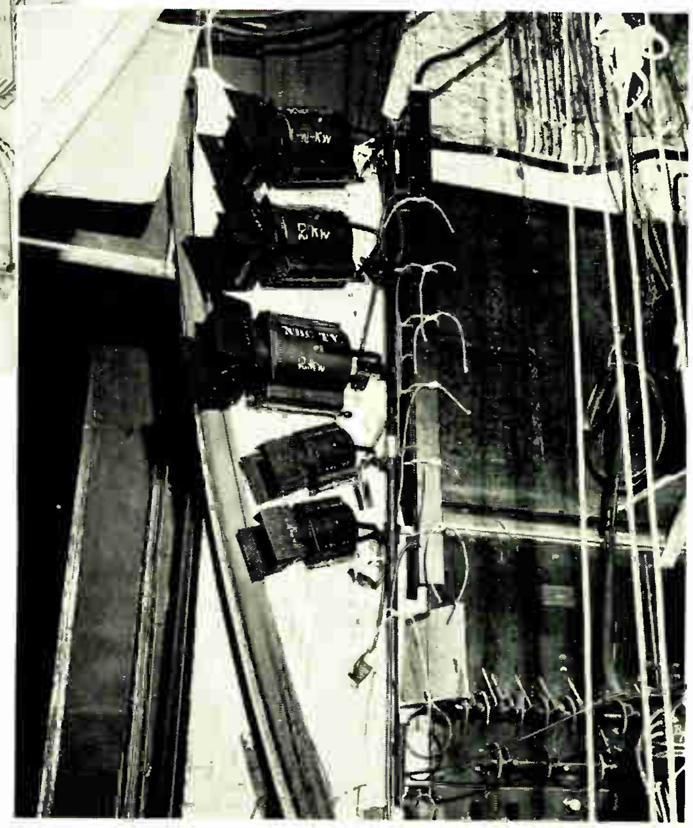


Fig. 9—Spotlights for accent lighting are mounted on a platform on a balcony loge in this television theatre.

Fig. 10—Spotlights with barn doors provide lower angle modeling light. These are usually located in the theatre wings.



achieved with spotlights for backlighting and accents, together with floodlights for fill and base lighting, since they add a great deal to the pictorial quality. Such a studio can be used, for example, for newscasting, interviews, quiz programs, kitchen demonstrations, etc.

Lighting Equipment

Television-studio lighting equipment can be classified into four types: (1) floodlights, (2) spotlights, (3) strip lights, and (4) effects lighting.

Floodlights can be either incandescent or fluorescent. The incandescent floods usually contain lamps of from 250 to 2000 watts, and are useful in providing a wide-angle distribution of uniform, moderate intensity illumination. A typical fluorescent floodlight unit (42- to 64-inch slimline, 4500 or 3500 degrees K) has a wide, uniform distribution curve.

Spotlights (500 watts up to 5 kw) usually assume the form of a cylindrical-ventilated metal housing, similar to those used in conventional photographic work. Some have a built-in iris, which permits a variation of sharply defined beam spreads of high intensity for creating artistic effects.

A *strip light* (150–300-watt reflector lamps), as its name implies, is a metal, trough-like fixture, which houses a series of similar incandescent sources. These produce general shadowless illumination of low intensities, and provide a uniform light on backgrounds, walls, and similar places.

Effects lighting is often produced by a projector equipped with a motor-driven "effects disk" painted to create scenes such as moving clouds, moonlit water ripple, rising fire or smoke, falling leaves, ocean waves, and many others. Television, unlike radio, utilizes "sight effects" as well as sound effects.

Good television practice favors the installation of lights on a permanent scaffolding or grid system, constructed of iron pipe hung from the ceiling. However, when the occasion demands, the system can be temporary by supporting the grid structure with heavy vertical pipes. In some television studios, catwalks above or around the grid are used for making adjustments, hanging scenery, etc., but they take valuable space needed for overhead utilities.

A good practice, proved by experience, is to suspend lighting equipment on pantograph devices fastened to the grid structure. This allows raising and lowering the lighting units, a highly desirable feature in crowded television studios.

Studio Lighting Technique

For general illumination over a working area, intensities ranging from 2 to 150 footcandles can be used, depending upon the nature of the scene. This general illumination or incident light is measured with the color-corrected, light-sensitive surface of the meter facing the camera lens and perpendicular to the lens axis. This method leads to a close approximation of the amount of light "seen" by the camera pickup tube.

In general, the average footcandles of incident light required for a type 5820-orthicon tube ranges from 32 to 64 (with a lens opening of f:8). Lens stops normally used to give sufficient depth of field lie between f5:6 and f:8. The inherent characteristics of the pickup tube limit the highlight-to-shadow or contrast ratio for an average scene to approximately 30 to 1.

Lighting technique for television studios can be broken down into three general types: (1) base or general lighting, (2) accent lighting, and (3) effects lighting.

Base lighting is a uniform, wide distribution of low-intensity illumination that covers the entire set. This can be provided by either incandescent floodlights, or fluorescent lamps with some reduction in radiant heat. When fluorescent lamps are used to provide a considerable portion of the total illumination, a filter (Wratten 6) is used to correct for tonal rendition.

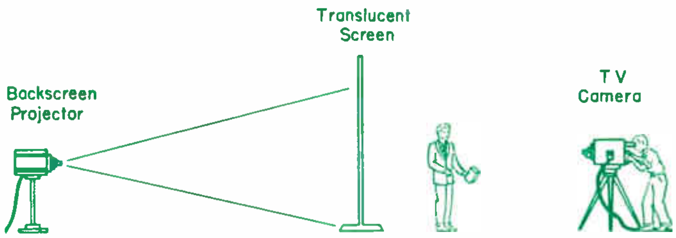


Fig. 11—A simplified schematic showing the essentials of rear-screen projection for television.

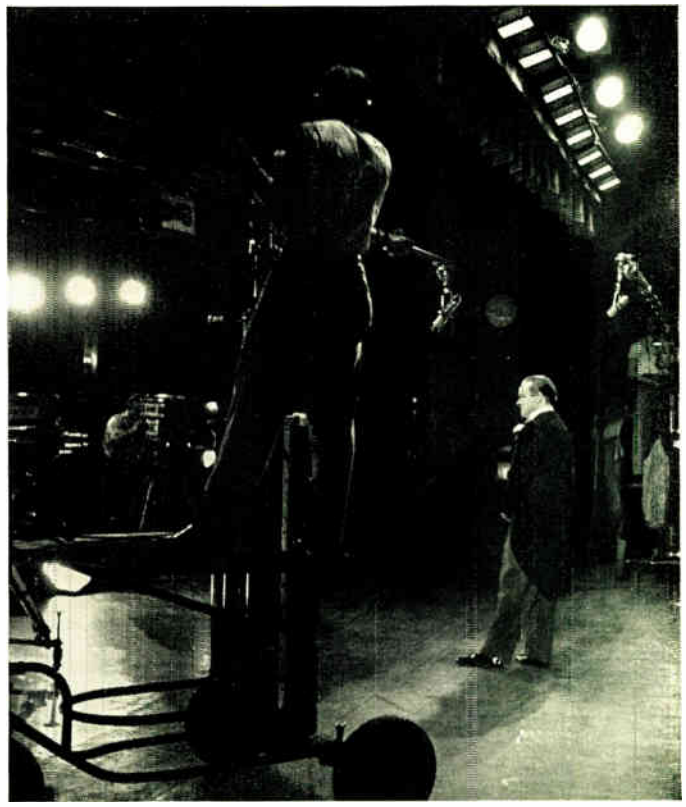


Fig. 12—Floodlights and spotlights are suspended over the front of the stage area and concealed by drop curtains in this television theatre.

Accent lighting is principal illumination that falls on a subject from light coming through a window, an open door, or a fire-place, or at any point where action takes place. Spotlights with accessories and effects lighting devices are used to produce these key lights, and are kept between one and a half and two times the base light intensity.

Modeling lights are used to enhance the appearance of any subject, and for creating artistic effects. Fresnel lens spotlights are commonly used for this purpose.

Back light is used to create the illusion of separation between the subject and the background, and to produce effects such as highlights on the hair. Spotlights are again used, equipped with "barn doors" to control spill light or shape the beam pattern.

Fill light, as its name implies, is used to fill in where too much contrast exists. It can be used to add more light to portions of the subject or set to bring out more detail by adding diffused light on the face of the subject opposite the key light source, and never exceeds the base light.

Effects lighting is used to simulate realistic scenes. For example, firelight, cloud effects, and window light are created by such lighting. Recently, a technique was borrowed from the motion-picture studios in simulating backgrounds and moving scenery, as from a moving-train window, the back of a car, etc., by using rear-screen projection as shown in Fig. 12. This involves several problems. First, care must be taken with regard to perspective. Also, distance between the screen and the live subject must be correct, so that unwanted shadows are not created. And, more difficult, the amount of front light must be carefully adjusted so that the projected picture is not washed out.

If motion pictures are used, the problem of synchronizing the frame frequency of the projector to the television camera must also be overcome. This problem has now been solved by a specially built film projector, so that simulated moving backgrounds can be quickly and economically reproduced. Stationary backgrounds require only a variety of slides, and still projection can be satisfactorily employed.

Final Results Depend on Skill and Imagination

With the results of several years of experience and a good knowledge of the requirements, television-studio lighting has reached the point where definitely planned schemes and practices can be recommended to produce artistic effects and good pictures. However, television practices are by no means static; the best results can be obtained only through imagination and originality in applying the principles already learned.

One fact regarding television lighting is worth bearing in mind—the final appraisal cannot be based solely on the results obtained with home receivers; too many factors enter into the final result—including properly functioning transmission facilities, and a good quality and correctly adjusted home receiver. Good pictures are the result of efforts on the part of all the chain of facilities that link the studio scene to the home receiver. Studio lighting is but one part of this link.

• • •

Inhibitors Lengthen Life of Transformer Oil

Oxygen is a major enemy of transformer oils. Numerous schemes have been tried—including several very successful ones—to minimize or prevent the oxidation of oils in large transformers. Now a method is being applied to distribution transformers—the use of oxidation inhibitors in the oils—and promises unusual and profitable results.

J. G. Ford, *Manager, and* T. K. Sloat, *Manufacturing Engineering Dept., Westinghouse Elec. Corporation, Sharon, Pa.*

Distribution transformers are now built and shipped with inhibited insulating oil as standard. Extensive studies made for a number of years indicate that this will lengthen the useful life of the oil by at least three times.

Oxidation inhibitors are being commonly used in commercial products, such as mineral oils used for lubricating and cooling purposes, animal and vegetable fats and oils, waxes, and rubber. An outstanding example is their use in rubber, which provides a consequent large extension of the life of automobile tires.

Oxidation, with the formation of acids, esters, peroxides, moisture, and sludge, is largely responsible for the deterioration of insulating oils. The rate of oxidation is influenced by temperature and various catalytic materials, most important of which are copper and steel. Both are used in transformers. Some impurities in fabricated insulations also affect the deterioration rate. These compounds are complex in nature and may vary widely in amount and composition, depending upon the source of raw materials. Their effects are not very well established except in a very general way. Although careful consideration is given to the preparation of solid insulating materials entering into transformer construction, it is practically impossible to eliminate completely small amounts of impurities, which in some cases may catalyze the oil oxidation, and in others may actually retard it. Different manufacturers use highly divergent materials of construction. The problem is further complicated by the fact that oils of different degrees of refinement and from different crudes may be used in transformers of various manufacture. Installations throughout this and other countries are subject to practically every conceivable condition of weather, temperature, and atmosphere. Thus the problem is highly complex. It permits only generalization on the behavior of insulating oil in transformers.

In recent years oil deterioration has been given greater consideration due to higher loading and reduction in size of transformers, with the corresponding reduction in oil volume. While the size has been materially reduced, the major insulation has not been reduced in the same proportion. Thus an increase in rate of deterioration would be expected. However, this has been offset by better purification of materials and exclusion of air from contact with the oil. Several successful systems have been devised to limit the oxidation of oils in power transformers. All of them have been based on the idea of preventing or minimizing the contact of oxygen with the oil. One of the first of these was an expansion tank connected to the main tank and arranged so that only a small amount of the oil was in contact with air at any time. This scheme increased the life of oil by a factor of about two over the conventional free-breathing type. In the early 20's, it was recognized that oxygen must be eliminated from the system if the life of transformer oil was to be fully preserved. This led to the development of the Inertaire transformer, which, in the present form, uses nitrogen under low pressure fed to the air space above the oil through a regulating valve. This type of construction is still used extensively. Twenty-five years' experience with this system has proved it excellent. Some of the original Inertaire transformers are still in service and the oil characteristics remain good. In some cases transformers have been hermetically sealed to prevent in-breathing of air, but there are definite limitations on the size of transformers that can be completely sealed, based on the economics of tank construction. Tests have demonstrated that in sealed transformers, oil deterioration is not a problem. The general conclusion can be drawn that it is practical to eliminate oxygen as a source of contamination in power transformers, and that under such conditions, with proper attention, the oil is good for the life of the transformer.

It is hard to keep distribution transformers sealed against oxygen. Also the use of an inert-gas equipment with them is not practical. These are the pole-mounted transformers, in the range of 1½ through 100 kva, where gasketed covers and bushings are used and means are provided for changing taps through a small handhole cover. While considerable progress has been made in the design of tanks and covers to make them tight, these distribution transformers in some cases breathe air due to operating conditions. For example, when covers are replaced after changing taps, a tight seal is not always obtained. It would appear, therefore, that distribution transformers are ones that can benefit most from the use of inhibited oil. It is this line of transformers that Westinghouse now supplies with inhibited oil as standard equipment.

Many compounds have been studied for use as inhibitors in lubricating, turbine, and insulating oils, as evidenced by the voluminous literature on the subject, including hundreds of patents. While in general all of them restrict oxidation of hydrocarbon oils, not all are suitable for use in insulating oils because of side effects on the electrical properties of the oil. Only compounds that do not adversely affect power factor, interfacial tension, and dielectric strength are applicable. Such other characteristics as hot and cold solubility, removal by filtering agents, toxicity, availability, and cost must also be given proper consideration.

Mineral oils as refined generally contain small amounts of certain compounds that act as natural oxidation inhibitors. The amounts and effectiveness of such compounds are related to the degree of refinement of the oil. Unfortunately, as oils are more and more highly refined to remove the more unstable constituents, the natural inhibitors are likewise removed. Therefore, the more highly refined products are practically free from natural inhibitors. If it were possible to remove objectionable compounds without at the same time removing natural inhibitors, there would be little need for the subsequent addition of synthetic inhibitors.

Synthetic inhibitors appear to work best in highly refined oils. However, too high refinement is undesirable because of the rapid deterioration once the inhibitor has been exhausted. There is one significant difference in the behavior of oils refined to leave sufficient natural inhibitor and those that have been highly refined and synthetic inhibitor added. In a moderately refined oil containing some natural inhibitor the accumulation of oxidation products is consistent and gradual. In the case of highly refined oil with added inhibitor, there is a period in which deterioration is negligible followed by a sharp break with accelerated accumulation of oxidation products. From the standpoint of use in transformers, the latter is quite objectionable.

The question immediately arises—if inhibitors are to be used in insulating oils, what should be the initial degree of refinement? A hard and fast answer is impossible, first because of the variance in crudes and, second, the many types of refinement. It can be answered only in terms of oils that have been in commercial use and with which a great amount of experience has been obtained. These oils have generally come from certain common sources and have been refined by essentially the same methods. In order to be sure of the behavior of transformers with inhibited oil, it is necessary that we continue using such oils as have been used in the past. Otherwise, a great deal more information must be obtained about the subject.

Considering the experience with present-day oil used for transformers, we believe that if inhibited oils are used, and if the dangers of over-refinement associated with the consumption of the inhibitor are to be avoided, then moderately refined oils, properly inhibited, would be most practical. In other words, conventional, moderately refined oil with properly selected inhibitors added in proper amounts is the best immediate practical solution to the problem. With further study on inhibitors and methods of refinement, it is entirely possible that at some future time suitable inhibitors will be found for use with so-called over-refined oils.

As pointed out above, the transformers in which inhibited oils can be used most effectively are the pole-type distribution. But the question naturally arises—would there be any advantage in using inhibited oil in the larger distribution and power transformers? The answer to this question is strictly one of economics. Inhibitors increase the cost of oil. Some slight advantages from the use of inhibited oil in such transformers would be possible, such as additional protection of the oil against oxidation in case of leaks in the system. Some slight reduction in the rate of cellulose deterioration would also result. In general, however, the relative improvement arising from the use of inhibited oil in this line of transformers as compared to tightly sealed tanks and the use of inert gases is rather small. It is simply a matter of opinion as to whether the additional cost of the oil can be justified in view of the relatively small improvements in performance.

Associated with the use of inhibitors, many questions naturally arise:

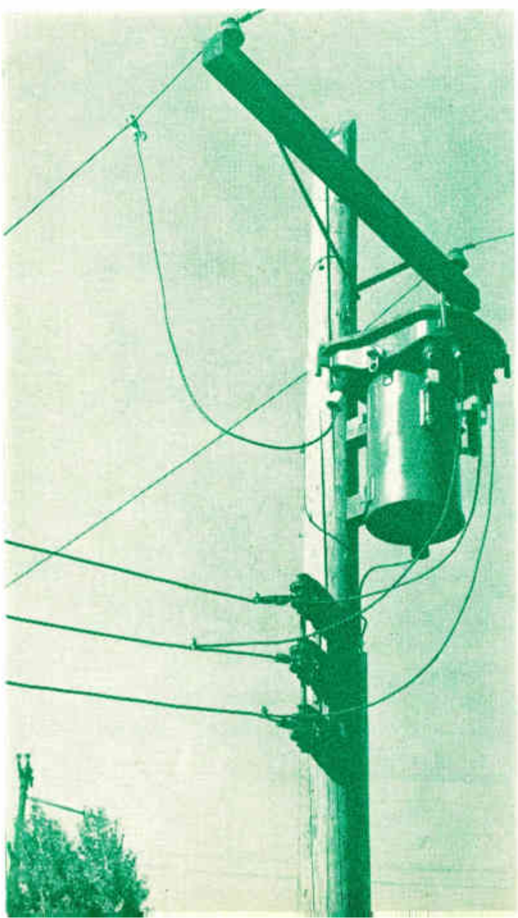
1. *If various manufacturers resort to different inhibitors, what could be expected from the mixing of the various oils?* A conclusive answer cannot be given to this question at present. However, it can be stated that all available data indicate that no difficulties arise as a result of mixing, and that the inhibiting effect of the various inhibitors contained in the mixture is about the average expected from such combinations. This is based on the assumption that the inhibitors have been properly selected and tested and have been shown to perform satisfactorily in the individual oils.

2. *What would happen if the inhibited oil were mixed with used oil?* Again, sufficient experience has not been gained to give a conclusive answer. Experience indicates that the used oil would be slightly inhibited by virtue of the inhibitor in the new oil. Naturally, the life of the new oil would be decreased by the presence of the used oil, as a result of oxidation products already present and by the dilution of the inhibitor. The effectiveness of the inhibitor in such mixtures would depend upon the relative proportions of new and used oil in the transformer.

3. *Are inhibitors detrimental to the electrical properties of the aged oil and do they have deleterious effects on the solid insulation?* Numerous inhibitors are available today that do not adversely affect the quality of the oil electrically either new or as used, and that do not deteriorate solid insulation. In fact, by virtue of extending the life of the oil and retarding the accumulation of oxidation products, the most damaging of which is peroxide, the inhibitor generally extends the life of solid insulation.

4. *Are inhibitors removed by filtration through such agents as activated carbon, clay, alumina or silica gel and, if so, what could be expected of the subsequent behavior of the oil?* Some inhibitors are not readily removed by filtration unless excessive quantities of activated filtering materials are used. Assuming the oil to be of the highly refined type and the inhibitor largely removed by filtration, the oil, of course, would subsequently deteriorate quite rapidly. However, with the conventional inhibited oil, this rapid deterioration would be less likely. This again is a sound argument for inhibition of conventional oil rather than the over-refined.

5. *What is the expected increase in life of the oil in distribution transformers when Westinghouse inhibited oil is used?* The average expected increase in life of inhibited Wemco-C oil over conventional Wemco-C oil will be roughly three times in free-breathing transformers. For restricted breathing, it is



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Inhibitors are now used in distribution transformers such as this pole type.

difficult to anticipate what the relative increase would be since the character of oil oxidation can change depending upon the availability of oxygen. Were tanks to remain absolutely tight in service, the inhibitor would add little to the oil life.

Conclusion

Modern transformers in general are constructed to be air-tight or properly protected against atmospheric oxygen by the use of protective atmospheres. The line of transformers most difficult to seal and keep free of oxygen are the pole-type distribution. Inhibited oil can be used in this line of transformers to greatest advantage. The most practical oil for such transformers is properly inhibited and selected conventional transformer oil. The life of such oils in transformers of this type would be materially extended at a minimum cost and internal corrosion resulting from moisture and oxidation products would be greatly reduced. No dangers arising from mixing inhibited oil with uninhibited oil and mixtures of different inhibitors are anticipated and, with the proper selection, it is probable that the inhibitor will not be removed by reconditioning processes, particularly filtration.

No attempt has been made to deal with the subject of use of inhibitors in used oils, and no reference has been made to the use of new inhibited oils in the older type of transformers. Much has already been written by other authors on the subject of inhibitors in recovered oils and some work has been done on the use of inhibited oils in the older designs of transformers. There seems to be some justification for both; however, these are not within the scope of this article.

Similarly, the use of inhibited oils in circuit breakers has not been touched upon, since factors other than these for transformer use alone are involved. The effect of inhibitors upon arc interruption and the subsequent settling of the products of arcing in oil have not yet been fully determined.

What's NEW .... in Products

A Pocket-Sized Reflector Photoflood Lamp

Photographers, both amateur and professional, often find themselves burdened with more equipment than they can carry. A new medium-beam, reflector photoflood lamp, suitable for both color and black-and-white photography, will relieve part of their burden—it is small enough to carry in a coat pocket.

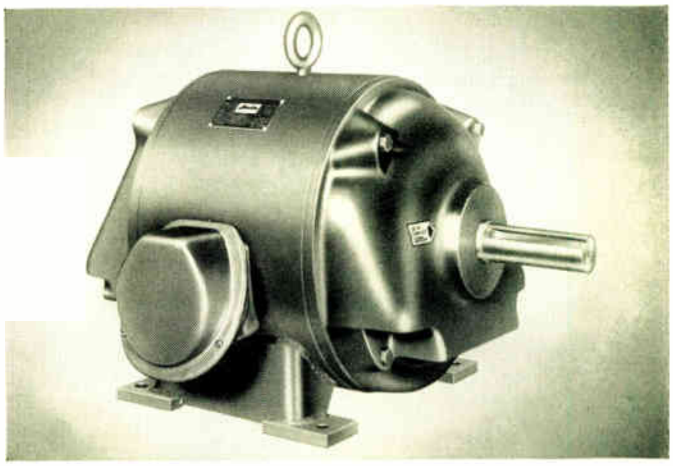
This new reflector photoflood is only 5½ inches long overall, and but 3¾ inches in diameter. In spite of its small size it is an excellent picture-taking lamp. A 300-watt device, it has a maximum life of four hours, and a beam width of 40 degrees. Its color temperature is 3400 K, making the lamp suitable for use with type-A indoor color film without a filter on the camera.

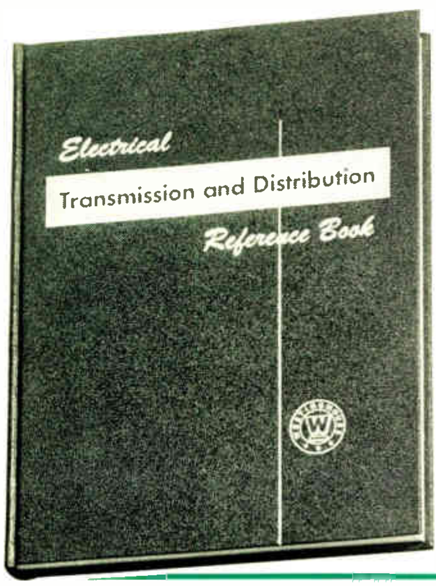
The lamp is suitable for all photographic purposes, but is especially valuable for home-movie fans who have a camera mounted on a hand-held lighting unit that holds several lamps.

The small size of this new lamp is made possible by a different filament design—a three-legged arrangement instead of the more common semi-circular shape—which gives greater filament concentration. Also a new gas fill, with a higher percentage of nitrogen in the argon-nitrogen mixture, lessens the possibility of arcing in the more compactly coiled filament.

New Splashproof Motor

Splashing liquids can play havoc with electric motors. As a result, special motors are required for such industries as food processing, and for chemical plants and refineries; these are protected from splashing by a partially enclosed, solid rolled-steel





Electrical Transmission and Distribution Reference Book

In 1942, "—to consolidate the past twenty years' advances—" in transmission and distribution of electric power, the first *Transmission and Distribution Reference Book* was prepared. Now this useful engineering tool, which has become a handbook in the industry, has been revised and brought abreast of the developments of the last ten years. The new book, again prepared by central station engineers of the Westinghouse Electric Corporation, presents information gained in consulting with utilities and aiding in the solution of their transmission and distribution problems.

In addition to bringing up to date the material previously presented, new chapters on Excitation Systems, Application of Capacitors to Power Systems, and Power-Line Carrier Applications are included. In this volume, which now totals over 800 pages, the tables and curves are again large enough to be readily legible.

The price of a single copy is $6.00. All orders should be addressed to *Westinghouse* Engineer, 306 Fourth Avenue, P. O. Box 1017, Pittsburgh 30, Pennsylvania.

frame construction, and baffles to divert water where ventilation openings are necessary in the enclosure.

The Life-Line splashproof motor has recently been designed for a wider range of ratings, to permit more flexibility in the use of this type of motor. They are now made in horsepower ratings from 7½ to 100; in voltage ratings of 208, 220, 440, 550, and 2300; also for frequencies of 60, 50 and 25 cycles. Frame sizes 364 through 445 are included. All have prelubricated bearings.

New Sealed-Beam Bicycle Headlight

Bicycle headlights have seldom been more powerful than a small flashlight, which is not adequate for nighttime cycling. A new light, patterned after the regular sealed-beam automobile headlight, throws a powerful shaft of light of some 5000 beam candlepower. This provides three times the visibility of the average flashlight. The lamp is 2½ inches smaller than an automobile headlight.

This headlight operates from either three or six ordinary flashlight batteries. Because the aluminized reflector is hermetically sealed to the lens, the reflector remains bright and enables the headlight to burn at peak intensity throughout its 50-hour life.

Home Precipitron Redesigned

Cleaning the air of your home now requires less power than is utilized by a 60-watt bulb. A new home model of the Precipitron electronic air cleaner embodies several engineering changes that not only reduce the power consumption from 80 watts to slightly under 60, but also make for a smaller, more compact unit. And the unit has the same air-cleaning capacity as the preceding model—1200 to 1500 cubic feet per minute.

These results were brought about by several design changes. The new unit utilizes straight-through air flow, as contrasted with the older unit, in which air entered the top, was redirected by an air-turn baffle and passed out through the side of the unit. Elimination of this baffle simplifies duct connections, and leads to a smaller overall dimension.

Two new water nozzles have been added to the washing mechanism to provide for improved ionizer washing. And the whole process of washing has simplified to the extent that the user now need only flip a switch to initiate the washing cycle. A new timer clock then takes over and completes the washing and draining sequence and returns the unit to normal air-cleaning operation—all in a matter of 25 minutes.

Any inquiries relating to specific products mentioned in this section should be addressed to the *Westinghouse* Engineer, 306 Fourth Avenue, P. O. Box 1017, Pittsburgh 30, Pa.

Simplification of the washing control cycle, and replacement of a six-watt incandescent pilot light by two one-fourth-watt neon lamps, has resulted in the cut in power consumption of about 20 watts.

The new home Precipitron air cleaner is a complete packaged unit. No field assembly is required.

Higher Average Lumens for Sports Lamps

Most lamps for sports lighting are burned at overvoltage, a practice that gives increased light but increases power consumption. Also, the light output of an incandescent lamp is

reduced by bulb blackening caused by the evaporation of the tungsten filament. The particles of tungsten are deposited by convection currents on the inner surface of the light globe, resulting in a steady decrease in the amount of light passed by the glass.

A new sports lamp contains a nickel, cone-shaped screen that traps most of the vagrant tungsten particles and retains them, thus minimizing the blackening effect. This lamp is rated at 1800 watts and is designed to operate at 117 volts, as stamped on the bulb. The initial light output of the lamp is 44 900 lumens, and, in combination with conventional equipment, its beam lumens at the end of life only depreciate to 81 percent of initial output. This compares with 59 percent for the conventional 1500-watt lamp when operated at 10 percent overvoltage. In size and dimensions this new lamp is identical with the 1500-watt lamp; it can be used in the same fixtures, and has a rated life of 300 hours.

Because this new sports lamp retains, throughout its life, a higher proportion of its initial lumen output than any other incandescent lamp designed for outdoor sports, the lighting of baseball and football fields where it is used will remain more nearly constant all season long.

Airport Runway Light

PROGRESS often involves design simplification of a previous unit. So it is with the new bi-directional, high-intensity runway light for airports. Previous designs consisted of a large metal housing containing two or more lens and panels to obtain the required light distribution throughout the full 360 degrees. The new light complies with specifications of the CAA (L-819), the USAF (M-2), and the Port of New York Authority specification on this type light. It consists of a one-piece glass lens enclosing the lamp and a light-weight aluminum mounting assembly that houses the socket and the leveling and adjusting arrangement.

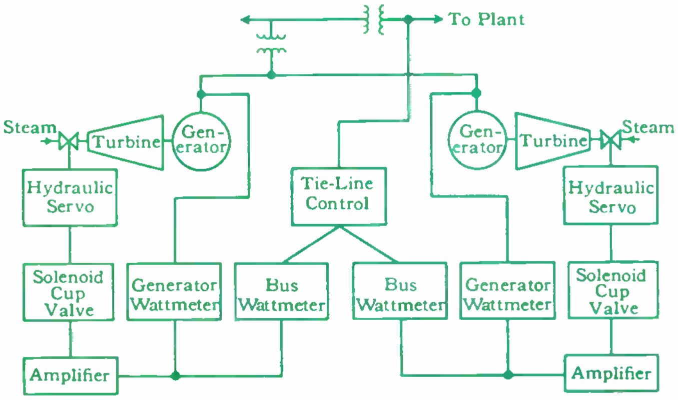
This light provides the necessary photometric maximums and minimums for the rigid requirements of high-intensity runway lighting. Main beams of high candlepower are projected up and down the airport runway to outline the strip to the incoming pilot. Light projecting onto the runway between the two main beams is limited to a value that will not distract or interfere with the pilot's vision as he passes the unit. Light projected in the direction away from the runway is of high intensity, especially in the area three to eight degrees above the horizontal, to indicate to circling pilots the direction and orientation of the runway. The new one-piece lens, which is in the form of a globe with flat bull's-eye sections on two sides to project the main beams, gives this required photometric pattern when used with the standard 200-watt, 6.6-ampere lamp.

In installation along the sides of a runway, the new unit is mounted on a conventional base plate and mounting base, which houses the 200-watt insulating transformer. A breakable coupling is installed between the column supporting the unit and the base plate. This coupling will fracture if the unit is struck by a taxiing plane or other vehicle, thus minimizing possible damage to both the vehicle and the unit.

. . . . in Engineering

Isolation Ward for Load Peaks

ONE utility recently felt the need for an isolation ward—not for personnel, but for load peaks on one section of their interconnected system. Following the installation of a large rolling mill, sudden load peaks affected the transmission system when the huge mill rolls "bit" into the metal billets. The large amount of energy needed was drained proportionally from the connecting tie lines to other power plants on the system and was felt as a surge throughout.



To prevent disturbances in the system, it was desired to absorb these peak loads solely from a generating station near the mill. But on an "infinite bus" system the conventional turbine generators react to carry a given small percentage of the total system load and, therefore, only the same percentage of the tie-line load peaks. A really fast-acting tie-line regulator was required; one that would respond to the local load change and cause the turbine to meet the surge before it could be felt throughout the remainder of the system.

Electronic wattmeters combined with a solenoid-operated cup valve developed by the Special Products Development Division of Westinghouse, provided the solution. The wattmeters receive inputs from current and potential transformers on the line to be measured, and put out a d-c voltage proportional to any power change within a few microseconds of that change. One electronic wattmeter measures the demand of the rolling mill and others measure the output of each of two generators in the station.

The voltage from each of the two generator wattmeters is compared with a predetermined share of the d-c voltage from the bus (rolling mill) wattmeter.

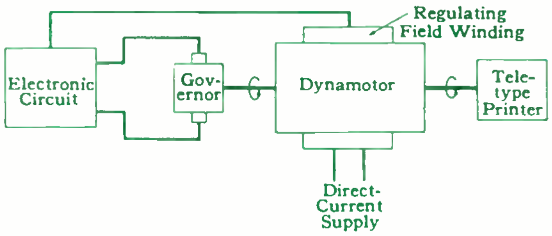
During steady-state operation these two voltages are equal. But when a surge occurs, the bus starts to draw additional power from the entire tie-line system. This unbalances the voltages between the tie-line wattmeter and the generator wattmeter. The difference is amplified to energize a solenoid-operated cup valve that in turn controls a hydraulic servo that opens the turbine steam valve. The generator takes the surge, and the wattmeter-output voltages again become balanced.

The hydraulic servos are mechanically restricted to prevent each turbine from taking more than an 8000-kw swing. Otherwise these turbines might be forced to swing through their entire range, some 40 000 kw, in the event of circuit failures. The moving elements of the solenoid cup valve are light in weight to minimize inertia, thereby increasing the speed of response.

The portion of the surge that each generator supplies is regulated by adjusting the fraction of bus-wattmeter voltage to which each generator-wattmeter voltage is compared. The control equipment can also adjust the base load on each machine, and the amount of surge to be taken in proportion to other generators in the station.

Dynamotor for Aircraft Teletype Printer

In airplanes, manpower, as well as space and weight, are at a premium. To ease the load on radio operators, an aircraft teletypewriter is being installed on some military and commercial planes. This will provide radio reception at all times,



even when unattended. In addition to being small, light, and automatic in operation, the aircraft teletypewriter must synchronize the speed of the mechanical printer to the steady incoming radio signal despite variations in the voltage supply of the aircraft electrical system. To do this, close regulation of a constant-speed-drive dynamotor is required.

A novel application of a small d-c dynamotor serves the purpose. Its output is a combination of electrical and mechanical load. A special regulating field winding, in conjunction with a governor and an external electronic circuit, serves to maintain the speed of the printer constant during normal voltage swings.

Operating through system voltage changes from 22 to 29 volts, the motor speed is kept constant by the action of a governor on the armature shaft. Brushes on this governor supply a voltage to the external circuit that is proportional to motor speed. The circuit detects these voltage changes and varies the excitation in the regulating field winding to maintain the speed constant.

This dynamotor is $6\frac{1}{2}$ inches long, $2\frac{3}{4}$ inches in diameter and has a starting torque of seven ounce-inches and a running torque of four ounce-inches to drive the printer.

"Feeding" a Furnace

Charging an open-hearth furnace by the conventional method is somewhat akin to requiring one waitress to serve several tables—without perfect timing someone will have to wait. Scrap iron and other charge materials are trundled in on rails on a string of buggies, past the several furnace doors, and each furnace is charged as required. While the cars are stopped to charge one furnace, no cars can pass to reach those farther down the line. Unlike restaurant patrons, furnaces can't complain about poor service, and the inevitable tie-ups that can result are expensive of both furnace and manpower time.

A new system of flow eliminates this possibility by allowing individual charging of any furnace at any time. This method is being installed in a plant of the Armco Steel Company, where four special hydraulic hoists will serve three open-hearth furnaces. Each furnace will have a hoist on either side of its furnace doors. The hoist platforms, some 10 by 20 feet in size, will be loaded with one charge buggy per elevator on the yard level. Due to the plant layout involved the elevator will rotate 90 degrees on its way up to the furnace floor level (about 20 feet above yard level), so that the buggy can be unloaded in line with the furnace doors. All buggies will, of course, run on tracks throughout the length of their journey.

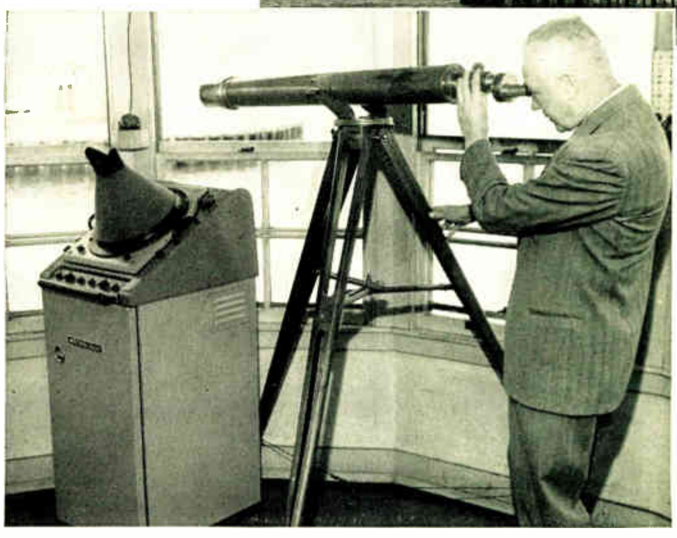
The hoists to accomplish this will be designed to lift a 45 000-pound load in 30 seconds, or a maximum of 60 000 pounds in 38 seconds. With the flexibility and speed that this system will allow, charging time for one furnace will be cut from $3\frac{1}{2}$ to $1\frac{1}{2}$ hours, i.e., a furnace will be charged with its 150-ton load in less than half the usual time.

Radar Keeps Tabs on Ship Arrivals

A long glass (see photo) has been used since 1901 to spot and identify ships entering and leaving San Francisco Bay. And in good weather it has served its purpose well. But a new radar set (type MU-1) alongside it will provide an accurate and reliable determination of the position of any object within range, regardless of fog, rain, or darkness.

This radar set, located in the Marine Exchange lookout station, provides valuable information about a ship location and movement, to expedite work in the harbor during periods of bad weather. Docking orders and mail can be dispatched swiftly to incoming vessels by the Marine Exchange launch, and information about ships can be transmitted more rapidly to owners, operators, suppliers, shipyards, governmental, and numerous other agencies.

With its antenna located in a weatherproof radome on top of the lookout station—about 40 feet above water—the radar equipment (see photo) can "see" vessels outside the Golden Gate as well as in the harbor.



A-C Lighting for Subways

The complexity of the track layout of the huge New York subway system is such that numerous gaps in the third-rail system are necessary for crossovers. Thus power to each car is interrupted frequently—about 35 times per operating hour. To the operation of the car this has little consequence; but it does cause erratic and annoying interruptions in the lighting circuit, as well as having an adverse effect on the life of fluorescent lamps if they are operated directly from the d-c third-rail voltage of the subway system.

In a new experimental train placed in service last year by the New York City Board of Transportation, a-c lighting is used, made possible by a special 600-volt, d-c driven, 60-cycle motor-alternator mounted under each car. This not only furnishes constant power to the lighting system, but also allows close control of voltage and frequency. The inertia of a flywheel provides energy to keep the lamps lighted across even the longest gaps in the third-rail system.

Experimental work on this new system was begun in 1947. Tests had revealed that there was a wide variance in the number and duration of the third-rail interruptions of the system. The average time was less than a second, but on a few occasions power was interrupted for as long as 10 seconds. A 142-pound flywheel on the new motor-alternator set stores sufficient energy to keep the lights on for about 25 seconds.

Several other problems were also solved with this motor-alternator set. One involved the wide range in voltage on these subway systems. Nominal d-c voltage is 600 volts, but this sometimes drops to as low as 400 volts and rises to as high as 750. This, of course, results in variations in light output of the lamps, whether incandescent or fluorescent. With the new alternator the output volts and the frequency are closely controlled, resulting in an almost constant light level in the cars.

This a-c system also makes possible the relief of another situation. Railroad lamps must, of course, light at all times, regardless of the ambient temperature. With incandescent lamps no difficulty is encountered, but fluorescent lamps are somewhat more sensitive. While the d-c potential available for starting is limited to that available for traction, an a-c generator has been devised to provide normal potential even with a low traction voltage. Also the peaks of the a-c waves aid fluorescent lamp starting, so with alternating current the low-temperature starting problems are fundamentally less than with direct current.

The new alternator also supplies the 118-volt, 60-cycle current for other apparatus in the car, but loads other than lights are dropped after one second of gap operation to conserve the flywheel's energy.

With this alternating-current system available, standard fluorescent lamps and equipment can provide a relatively constant lighting level and give the same excellent operation found in ordinary industrial lighting service.

Corrosion Protection—Defense in Depth

From the time that an iron or steel structure is completed—or even before—corrosion begins to tear it down. Moisture, acids, and alkalies all attack incessantly; even sunlight, i.e., its ultraviolet component, lends a hand with photochemical reactions. Trouble is, there's no single best shield or coat to prevent corrosion indefinitely, because of the many ways in which it can be brought about. A new paint system, developed by Westinghouse transformer engineers for distribution transformers, provides a "defense in depth"—three separate and different layers of paint, each designed to stop one primary cause of corrosion, but prepared to handle them all.

Painted surfaces in general are nothing more than tough "skins" designed to obstruct the passage of unwanted and harmful elements. Unlike the human skin, however, they should not be porous—nothing should be allowed to pass through them, or their effect is nullified. Moisture, for example, that infiltrates a porous painted surface (as they often are) combines with the metal, generally forming the hydroxide and liberating hydrogen, which forms "bubbles" under the surface of the paint. These eventually rupture and expose a larger area to moisture or other corrosive elements.

By using three different paint layers on distribution transformers—each one a specialist—engineers have provided triple insurance against the conditions in which these devices are often forced to work. The vehicle of the prime coat, next to the metal, is a combination of modified phenolic and alkyd resins, and contains one of the best rust-inhibiting pigments; it not only protects the metal against moisture but resists acids, alkalies, and numerous other chemical compounds.

The second or middle coat is the most unusual. It also contains as a vehicle a mixture of phenolic and alkyd resins (of slightly different composition from the first coat). The main difference from the prime coat, however, is in the pigment used—fine mica flakes. The mica particles are closely interwoven with each other within the film and are arranged physically so that they act like a "shingled roof"; they fend off moisture and prevent it from filtering through to the prime coat and metal.

The final or finish coat consists of a modified alkyd resin vehicle properly pigmented to give the best weather resistance and the desired color. One of its main functions is to filter out sunlight, and particularly ultraviolet, for the protection of the underneath coats.

None of these three coats is unilateral in action. Each to a large degree provides protection against all the various factors that cause corrosion; but since each has a special function, protection is triply assured.

The resultant paint "skin" is remarkably tough and durable. The particular combination of ingredients fulfills many desirable functions. The combination of phenolics and alkyds used as a vehicle leads to toughness, but with flexibility enough to withstand the dimensional changes of the metal with temperature. The paint vehicles are especially chosen for abrasion resistance. The mica used in the middle coat is an inert material chemically and is not readily attacked by the elements. Tests show that the life of the paint at elevated temperatures is as much as ten times that of many standard finishes. The ingredients used have excellent adhesion properties and produce a surface free of pinholes, the downfall of most painted surfaces. Moisture and other corrosive substances readily penetrate pinholes, and once inside they corrode the metal surface rapidly.

The new paint system was developed specifically for distribution transformers. It is applied in the same fashion as standard finishes; in production it is baked for speed. A modification of the finish air dries, and thus can be used to patch a transformer in the field, should the surfaces be damaged.

Since the system was developed to meet the requirements of distribution transformers, the exact composition used is most suited to their requirements. The process has flexibility, however, and it is possible that a similar system, with ingredients slightly changed to fit other requirements, could be used on many other surfaces. Possibly even as an undercoating on automobiles, or in the innumerable other places where corrosion is a difficult problem. These possibilities have not yet been explored, although engineers are now investigating the practicality of this system for other transformers. If the ingredients can be properly balanced to fit the needs, many other applications may, in time, arise.

Personality Profiles

In the summer of 1927, *D. D. Knowles* was conducting life tests on a new type of voltage-regulator, vapor-discharge tube in the Westinghouse Research Laboratories. He was getting erratic results. Some tubes were failing and then restarting for no apparent reason. Knowles observed that the tubes that happened to be in the sunlight were behaving queerly—they started in the light, and went out in the dark. This led to discovery of the photo-glow tube.

About the same time, Knowles invented the grid-glow tube that carries his name. This tube, so sensitive that it could be triggered simply by bringing one's hand near it, has been used for hundreds of purposes, some prosaic, others more dramatic, such as the "glass-ball" over which President Hoover in the White House waved his hand to start the first big generator at Hoover Dam. It was a forerunner of the modern thyratron.

Although more than 70 patents have been granted Knowles for tube and circuit inventions, his contributions to electronics have not been confined to development work. He has, by an intimate knowledge of research, of manufacturing problems, of product design, and product application, developed a broad view of the electronics field and has achieved an electronics philosophy that has been influential in helping guide the directors of the electronic industry.

Knowles is a graduate of Baldwin-Wallace College and Purdue University. He came to Westinghouse in 1923, as a member of the research staff. Later (in 1930), he headed the Gaseous Conduction Section and the Electronics Section (1935) of the Research Laboratories. In 1939 Knowles joined the Lamp Division and since 1941 has been manager of Electronics Engineering.

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Personal enthusiasm for your subject is a much-to-be-desired attribute for an author. *Reuben Lee*, who wrote the current article on Fosterite insulation for transformers, left no doubt in our minds on this score. After enumerating a heavy list of work and spare-time activities, he ended his letter as follows, "And at any hour, day or night, I'll take time out to talk about Fosterite compounds. The stuff's good!"

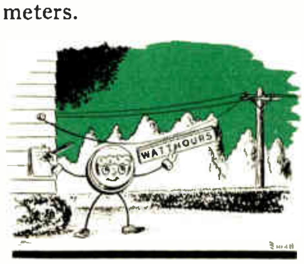
Lee has been with Westinghouse since his graduation from West Virginia University in 1924 (B.S. in E.E.). After completing the graduate student course, he joined the Control Engineering Department, where he helped design machine-tool and printing-press controllers. In 1928 he switched to radio engineering, where he gained experience in the design of radio transmitters. The development and design of inductive components for electronic apparatus next became his work (in 1932), and in 1945 he was appointed Advisory Engineer.

Lee is one of the many engineers who realize that technical pursuits alone do not lead to a full life. Thus he devotes much of his spare time to non-engineering interests—among them religion, sociology, and literature.

• • •

When we last talked to *Thos. D. Barnes*, he had just completed two major construction jobs—one the historical article on meters that appears in this issue, the other a small cottage for his summer use. We haven't seen the cottage, but if its structure is as sound as that of his article, it must be a fine building indeed.

For his meter story Barnes had plentiful material from which to draw. In addition to an extensive historical file on the subject, he had his own experiences with meter development. Barnes joined Westinghouse in 1926—after graduating from Bliss Electrical School with highest honors—as a technical assistant in the meter section at East Pittsburgh. In 1928, he packed up and moved with the rest of the Meter Division to its present location at Newark, N.J. Here he became a junior engineer, and later a design engineer for watthour meters. In 1934, he was selected to go to England for a few months to help an English licensee set up production on a new meter designed by Westinghouse. Since 1940, Barnes has been manager of the Watthour Meter Engineering Section. Among other things he has played a large part in the design of the type-OC meter and subsequent types, including, particularly, the electromagnets for both the single-phase and polyphase meters.



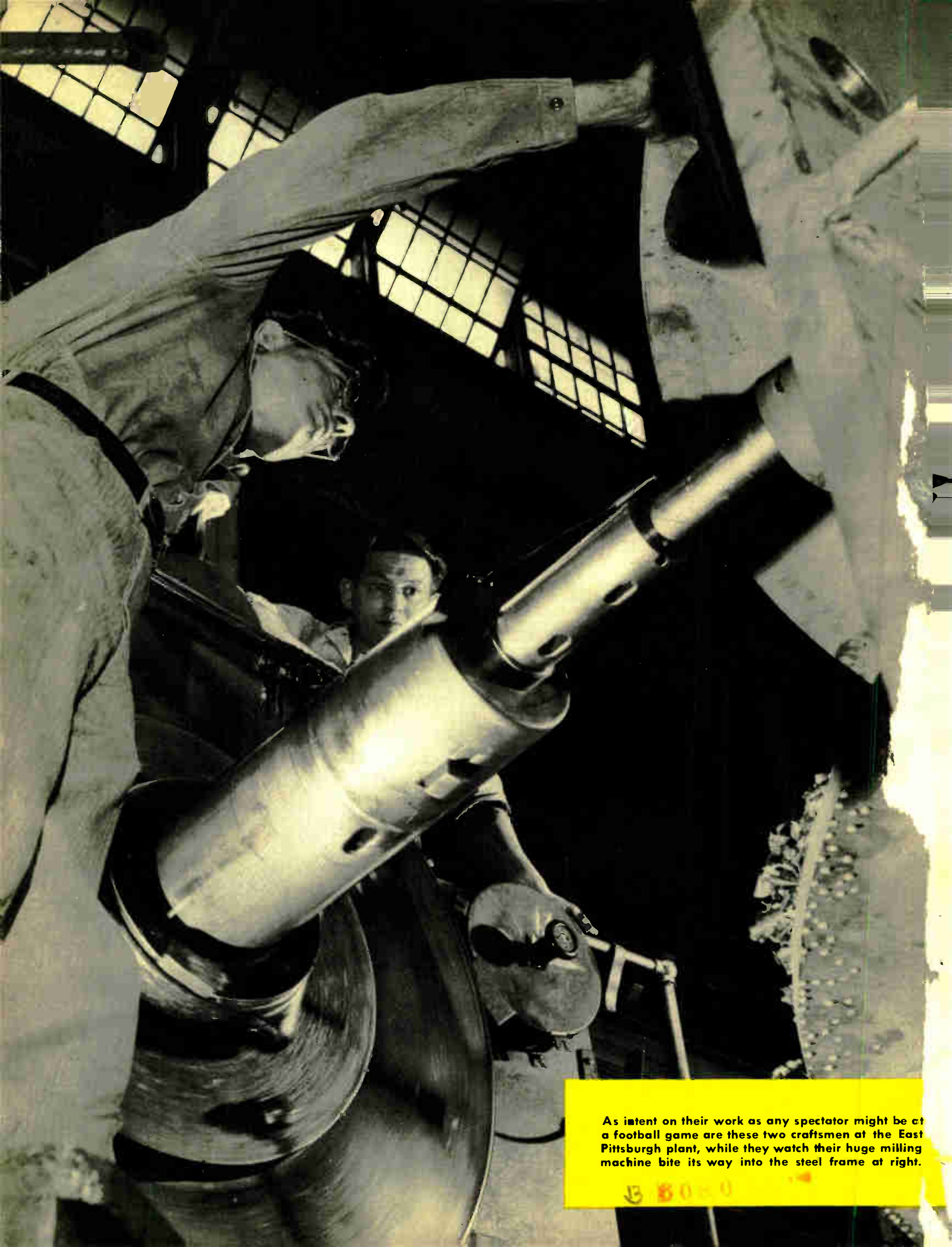
Television studio design and satisfactory lighting are inseparable; each must be guided by the requirements of the other. Thus the team of *H. M. Gurin*, of the National Broadcasting Company, and

R. L. Zahour, of the Westinghouse Lamp Division—experts in their fields—speaks with authority on studio lighting.

Gurin, a member of the NBC Development Laboratory Group, is currently concerned, among other activities, with the development of television lighting systems. He joined NBC in 1934, and has since become associated primarily with television. He received his B.S. in Mechanical Engineering from New York University in 1936, and in 1938 joined the development group during the early stages of experimental television operation. In 1940 he was assigned to the studio group, but left for duty with the Navy shortly thereafter. While in the service he was engaged in a research and development program on acoustics, shock, and vibration. Upon his return to NBC in 1945 he rejoined the Development Laboratory to assist in acoustical studies, and broadcast and television studio design. He is now a Development Administrative Assistant.

Zahour has been a lighting engineer ever since his graduation from Case Institute of Technology in 1923, where he received a B.S. in Electrical Engineering. He joined Westinghouse as a lighting engineer in 1923, and for a number of years was active in conducting special lighting schools, and in supervising research for new lighting applications. In 1930 he received his Master's degree at Case for a thesis on a special lighting project. In 1935 he left Westinghouse to take charge of lighting and rural electrification promotion for the Connecticut Light and Power Company. Before returning to Westinghouse in 1949 he was associated with the North American Philips Company. Since his return he has handled many special lamp applications.

Zahour is a registered Professional Engineer in Connecticut, New York, and New Jersey; he now heads the Illuminating Engineering Section of the Commercial Engineering Department at the Lamp Division in Bloomfield, N. J.



As intent on their work as any spectator might be at a football game are these two craftsmen at the East Pittsburgh plant, while they watch their huge milling machine bite its way into the steel frame at right.