WESTINGHOUSE

Engineer

MARCH 1949

World Radio History

Man Power for Electric Power

(Editor's Note: In an address before the Edison Electric Institute, Mr. A. C. Monteith, Vice President in Charge of Engineering at Westinghouse, discussed the important problem of the electric-power industry of filling its growing needs for technically trained men and the opportunities these needs offer to engineering-school graduates. Because of the importance of this matter and the practical suggestions contained in this address, a condensation is presented herewith.)

Interviews of 15 000 technically trained students in the last three years disclose an alarming fact. For every one that manifests interest in electric power as a future, two students are interested in electronics and communications. The need is more like ten to one in favor of power. Two factors contribute to this: the prominence given to communication and electronic devices by the war, and second, the glamorizing of electronics as the future key to the solution of practically all problems. Electronics became the hero vocation for many ambitious youths.

The future of electric power? Enormous! Approximately as many kw in generating capacity will be installed in ten years, from 1947 to 1957, as in the total history of practical electricity. This expansion program demands more men—many more—and men of high caliber.

I suggest to the power industry a four-point program for presenting its opportunities to the technical graduate:

First, we must not be backward in telling about what we have to offer. The fact is, electric power is an old and stable industry—and by virtue of that stability has much to attract young men planning their future. Beyond that, the industry has an assured growth not exceeded even by the younger and seemingly more colorful fields. Furthermore, it is overflowing with unsolved problems, new developments, new uses for electric power—all challenges to youth. We are still operating on the straight-line portion of the electric-power opportunity curve.

Second, in this four-point program, the industry should work more closely with the schools. The schools should be encouraged to concentrate on fundamentals. This is even more essential as the industry expands in new directions. Industry should assume the responsibility of orienting the man into its business, of providing the specialized training. If industry accepts this responsibility of specializing the student, the schools can dwell on fundamentals. Also, the industry must be willing to supply some professors of high caliber, who have practical experience and can guide a course in fundamentals to meet our needs. Better contact, too, should be maintained with undergraduates, for example, by summer employment and providing classroom material helpful in teaching a live and timely course. A number of professors spent last summer at Westinghouse, doing specific important work, with mutual benefit. Prominent men in the industry should be encouraged to talk to student bodies, but the material presented must be fundamental and of high caliber.

It is desirable to have good modern equipment in colleges for training purposes. Westinghouse has provided for technical schools some 25 steam laboratories and over 100 electronic sets at a special price.

Summer work for the student following the junior year is valuable. It brings him into contact with the industry and prepares him in a practical way for his final year of formal education. There is one 'must' in this plan. His supervisor must be someone who will see that he gets interesting work. Making him a file clerk or a leg man can easily discourage him with engineering, an attitude that spreads to others. We are encouraging inspection trips through the assembly plants by students during their junior and senior years. This helps the man orient himself.

Third, in our four-point program, we have found that having a definite training agenda for orienting graduate engineers into industry has been a strong selling point. Some might feel that only a large company can afford a training program. However, a program can be set down for a company employing only five men a year as well as for a large company. It would be on a less pretentious scale; but due to the personal contact that would inevitably result between the experienced personnel and the student it could be a better program than when there is a large number of students. One other fact stands out in making a graduate-student training program effective. The most experienced men in the company must understand that they must take time out to work with the embryo engineers. If this is not done, the young men soon pass the fact along to the next year's class and we lose not only these men but the chance of securing more. The personnel people can organize a course, but its success lies with those experienced engineers who must conduct it.

Electrical manufacturers often receive requests from power companies for men with some manufacturing training. The fact is, we expect it and are planning for it with a Utility Training Program. The first was conducted last year and will be repeated this year. Utility companies send men to Westinghouse, where they get production and test assignments and take night classes on advanced circuit theory and methods of system calculations. They then are given a two months' concentrated course on system analysis and planning, and one assignment in a design department. The class has been limited to 25 men so as to provide maximum personal attention by experts in the power field.

Fourth, and last, the young man should not be forgotten by the training department once he has taken a permanent position in the company. The best young men do not have to be told that education is a journey, not a destination. At Westinghouse we have for years had an extensive program that permits and encourages its people to continue their education, particularly in advanced technical fields, with nearby universities. More than 500 of our men registered for such work last year. Some 150 Westinghouse men have taken advanced engineering degrees through this plan.

In following the man after final placement in a permanent job, the last but most important thing is to see that he is placed with an experienced man who has an interest in young men and who will impart to them the challenges in the industry rather than the point of view of the fellow over the hill who is working to eke out an existence. It is inherent in a good man that he wants work with responsibility increasing with his growth in stature. This is the most important point in the development of the young engineers.

The electric industry is great because men have made it so. Because it is great its opportunities for more men and big men are greater than ever.

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On the Side

Nature may soon provide the steam to turn turbine generators in one section of Italy. If present pilot operations are successful engineers will be harnessing high-pressure steam, tapped from water sands near red-hot lava beds, as a source of electric power for nearby industries. When a suitable hot-water sand is struck, engineers believe that hot water will be forced upward under a high pressure. Due to a slight reduction in pressure at the surface the hot water will turn to steam, and can then be utilized to drive turbines.

Drilling operations will be aided initially by equipment designed originally for oil-well use, including two 300-hp mud-pump motors and one 250-hp draw-works motor. Eight other similar units are planned for the project in the future.

Site of these pilot operations is at Larderello, near Milan, in Italy's northern industrial area. The enterprise has a counterpart in California where engineers drilled 650 feet to tap steam pressures up to 275 pounds per square inch.

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Three new tankers, soon to be built for Philadelphia Tankers, Inc., will not only be among the largest afloat, but will also employ special and unusual equipment. The ships themselves will be 625 feet long, and will carry almost ten million gallons of oil, enough to fill a line of tank trucks fifteen miles long. The propulsion unit will be a 16 500-shp, 1000-degree F geared turbine. This temperature rating is about 25 percent larger than that of usual propulsion units, few of which operate at temperatures much in excess of 750 degrees F. Other equipment includes two 750-kw a-c turbine generators, a 700-kw geared generator driven by the main turbine, boiler feed-pump turbines, transformers, switchboards, and motors.

In This Issue

Editor
CHARLES A. SCARLOTT

Editorial Advisers
R. C. BERGVALL
T. FORT

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Progress in Arc Welding

Like Aladdin's princess, who exchanged an old lamp for a new one, the arc-welding industry is now exchanging old concepts for new—but with much better fortune, having gained a genie instead of losing one. The genie appears simultaneously in several forms—alternating-current welding, automatic welding, and inert-gas welding.

C. P. Croco, *Manager, Welding Department, Westinghouse Elec. Corporation, Buffalo, New York*

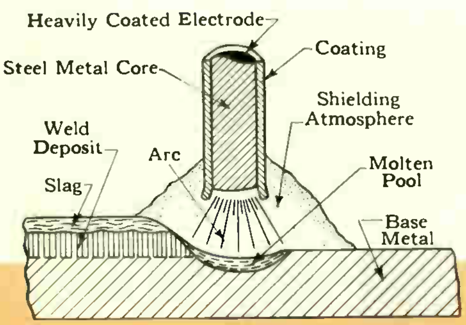
Electric arc welding was born with electricity itself. It dates back to about 1880, when direct current was still in its merest infancy and alternating current, as we know it today, was still unborn.

Electric welding was first successfully accomplished by Bernardos and Demetrus in Russia as a manual process using direct current, a carbon electrode, and a metal filler rod. A few years later, Slavianoff, also in Russia, perfected the technique of using a bare rod as an electrode. In 1907, Kjellberg in Sweden developed the first coated rod, but it was good only for direct current. Arc welding remained in this form for some 30 years, virtually unchanged, although coated electrodes that produced better welds were introduced. But developments of the past decade have produced significant changes that have vastly broadened the flexibility of arc welding. One is the perfection of electrodes and machines for a-c welding, which has greatly increased in popularity, especially since 1940. Second is the perfection of equipments for automatic welding, which, spurred by the rising cost of labor, has replaced manual welding for many tasks. Third is inert-gas welding, and fourth are the multitudes of new electrodes that have greatly increased the number of kinds of things that arc welding can do.

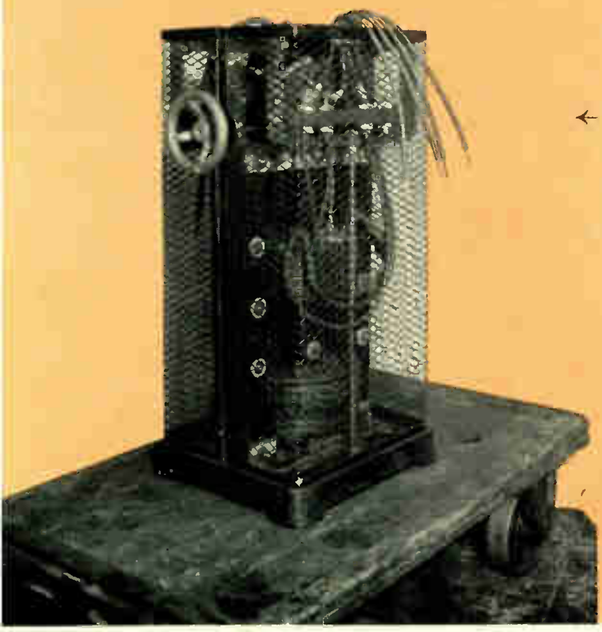
Alternating-Current Welding

As compared to d-c arc welding, the a-c process presents definite advantages, which were early appreciated by many welding manufacturers. These are: (1) absence of arc blow, (2) lower power consumption, and (3) higher power factor.

Arc blow is the "blowing" of the welding arc to one side by the magnetic fields of the direct current flowing through the work and leads. It interferes with speed and continuity of welding and results in a poor deposit. The fundamental characteristics of alternating current—rapid polarity reversals and the resultant eddy currents—reduce the electromagnetic



The action of the electrode coating during arc welding.



The 200-ampere, 125-volt a-c welder built by Westinghouse in 1919. It was of the moving-coil type, made by modifying a constant-current regulator. ←

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The new remote control for a-c arc welders permits the operator to change the current setting and thereby adjust the arc without walking back to his machine. The operator simply presses either the "Raise" or "Lower" pushbutton on the portable station and a small motor moves the core, making the necessary adjustment. The remote control is simply and easily installed by a connection on the primary terminals of a standard welding transformer.

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forces on the arc stream. The absence of arc blow with an alternating arc makes it possible to produce on the average a weld of neater external appearance and better internal quality as compared to one produced with direct current.

Arc blow occurs most frequently when welding in corners and with heavy currents. Under these conditions, particularly, an operator can weld faster with alternating current. The absence of arc blow eliminates the various precautions (such as magnetic shunts to keep the field away from the arc) that must be taken when direct current is used; this frees the operator to deposit more weld metal. Without arc blow, spatter and slag are less, reducing the need for reworking and further increasing production.

Direct current at the voltage required for arc welding (25 to 40 volts) is usually supplied by a motor-generator set; alternating current, by a simple transformer with no moving parts. Direct-current welders, because of their relative complexity (two rotating machines, brushes and brush rigging, etc.) are less efficient and require more maintenance than a-c machines. The principal disadvantage of a-c welders is that they impose a single-phase load on power lines whereas d-c welders provide a three-phase load. However, the unbalance is not large and can be balanced if three or more welders are used.

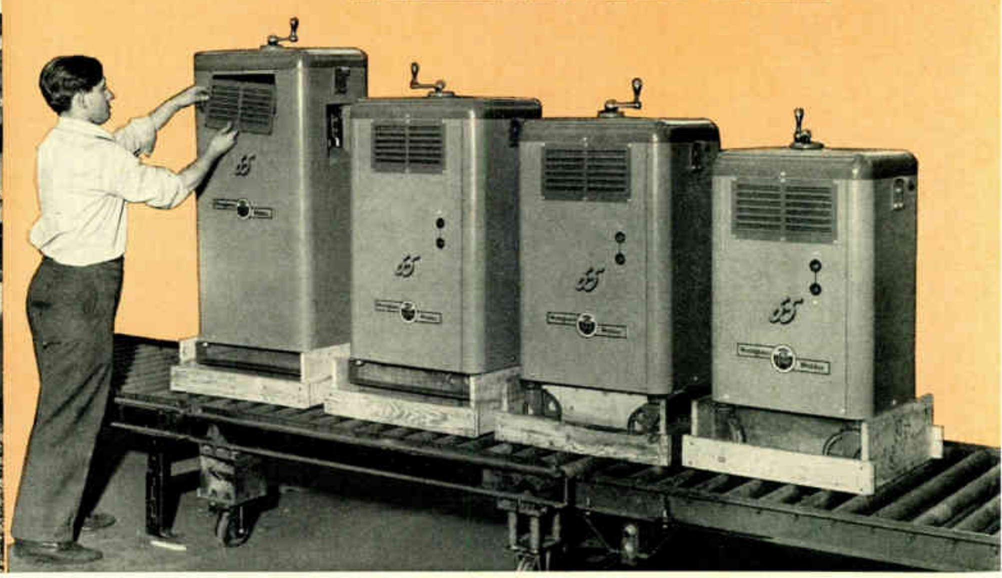
Development of A-C Welding

For all its obvious advantages, the arrival of alternating current on the welding scene was delayed by its inherent alternating form. The current in an a-c arc is zero twice each cycle, and, therefore, if the same voltage and the same bare-wire electrode used for d-c welding were used for a-c, the arc would be extinguished each half cycle and would remain extinguished. It would not be automatically re-established by the resulting open-circuit voltage that exists when no current is flowing. The arc would then have to be continually re-established by the operator, which would make it impossible to obtain a sound weld.

To circumvent this condition when a bare-wire electrode is used, the voltage can be raised. But such electrodes require a high open-circuit voltage (about 150 volts, except with very large rods) to prevent the arc from being permanently extinguished when the current passes through zero and to insure its re-establishment. The hazard of such a high open-circuit voltage prevented widespread use of a-c welding.

Therefore, early attempts to introduce a-c welding failed because of the lack of a suitable electrode—one that would permit welding at a lower open-circuit voltage. Today a continuous arc is obtained with alternating current at low voltage by using an electrode coating, which maintains an ionized atmosphere between the electrode and the work. This ionized layer reduces the open-circuit voltage necessary to re-establish the current when it passes through zero. The coating also performs other functions for it provides an oxygen-reducing protective shield to the arc and controls the fluidity of the weld metal, the penetration, the shape of the beads, and the composition and properties of the deposit—and, ultimately, the quality of the finished weld.

As early as 1919, Westinghouse had built an a-c welder. It was of the moving-coil type and had an open-circuit potential of approximately 125 volts. From tests on this machine, engineers concluded that to build a welding transformer, having a current range of 100 to 200 amperes for use with lightly coated electrodes (the only ones then available), an open-circuit voltage of roughly 125 volts over the entire range would be required to make acceptable welds. This high voltage was unsatisfactory to users of welding equipments.



An early 300-ampere a-c welder (left) on a construction job. The modern "65-line" family, so called because of the low open-circuit voltage, is built in ratings of 200, 300, 400, and 500 amperes (below) and 600 amperes (above) output.

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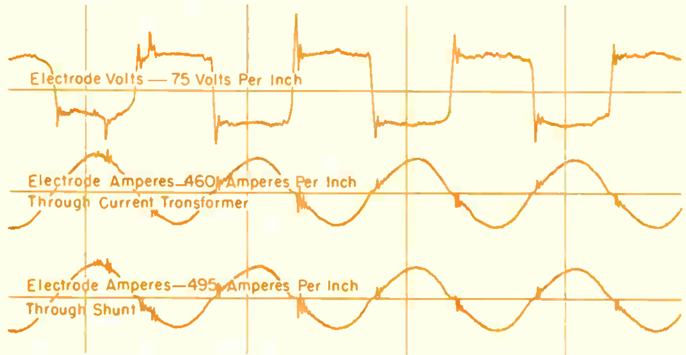
A 300-ampere 65-line welder being assembled. The transformer is already mounted in the frame and the complete reactor is being lowered into position. Hipersil type-C cores are used on both transformer and reactor.



These oscillograms were taken (left) with and (right) without a stabilizing capacitor in parallel with the arc . . . .

Interest in a-c welding was revived some years later. In 1929 another experimental transformer of the tapped-reactor type and rated 1000 amperes, was built. This time, to make it suitable for use with bare wire, a high-frequency (about 200 000 cycles), high-impedance stabilizer was used. Connected in parallel with the 60-cycle circuit, the stabilizer superimposed a voltage of about 3000 volts over the low-frequency voltage. The stabilizer's prime function was to re-establish the 60-cycle arc after its current had passed through zero. Also, the briefer zero-current periods of the high frequency afford less opportunity for gas deionization, thereby reducing the tendency of the arc to go out. The open-circuit voltage of the 60-cycle transformer was about 80 volts, much lower than the high-frequency voltage. The arc-maintaining voltage was provided at high frequency (instead of at 60 cycles) because high voltage at high frequency is not hazardous to personnel.

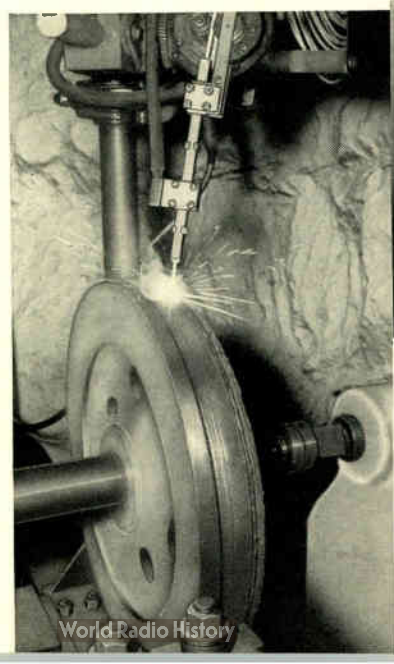
In 1931 this welder was followed by a 50-to-200-ampere, high-frequency-stabilized transformer, also of the tap-changing type. Both these welders were particularly interesting because with high-frequency stabilization, a 60-cycle open-circuit voltage of less than 100 could be used with the bare and lightly coated electrodes then available. These welders were relatively safe to use and, as a result, a-c welding began to find some acceptance in the trade, although it came slowly.

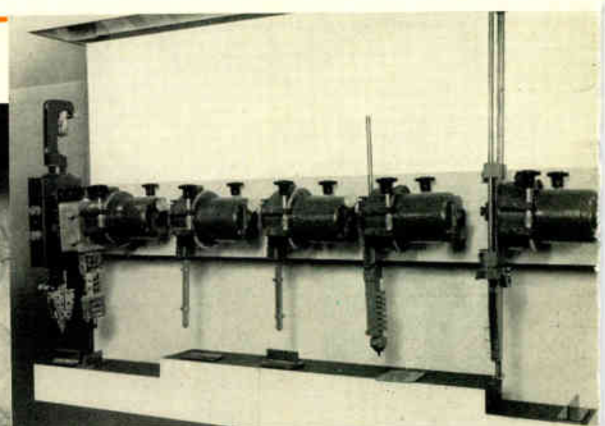
In 1934 two larger welders, rated 750 and 500 amperes and 110 open-circuit volts, were developed. They worked fairly well with the coated electrodes then available. Current control was obtained with a three-legged transformer by adjusting one leg to vary leakage flux. The primary was wound around one leg and the secondary around the same leg and the moving leg; the middle leg had no windings. This arrangement established an adjustable leakage path between the two windings. It was the first attempt to get away from the tapped reactor or the movable coil, which is undesirable because current-carrying parts are moved. However, these welders were objectionable because of high open-circuit voltage, high power input, low power factor, and high weight and cost.

Meanwhile, the heavily coated metallic electrode, which produced excellent welds with open-circuit voltages of about 80 volts, was introduced in America from Europe. This type of rod was approved by the Navy as early as 1932 although it was not until 1936 that the present improved form was made available. Further development has led to what is today the AWS-ASTM class-6020 electrode, now widely applied to a variety of down-hand welding, particularly of mild steel. It operates very satisfactorily and produces excellent welds with open-circuit voltages down to about 75 volts.

While these electrodes were being improved, their success with low open-circuit voltages stimulated development of a new type of a-c welder. These were built in ratings from 300 to 500 amperes at 75 and 80 open-circuit volts. They incorporated the moving-core reactor and were predecessors of modern transformer-type welders.

The modern Westinghouse welder in 200- to 600-ampere ratings employs a unique stabilizing circuit that provides the necessary voltage for re-establishing the current during welding. The stabilizer consists simply of a resistor and capacitor in parallel with the arc. The steady-state open-circuit voltage that exists before the arc is struck (the only time that the operator is subject to electrical shock) is only 65 volts, which is not dangerous. After each half cycle, however, the stabilizer supplies the additional voltage (in excess of the 65 volts at steady-state open-circuit conditions) necessary to re-establish the current and maintenance arc.





The heads for automatic arc welding—coated-electrode (two forms), bare-wire, submerged-melt, carbon-arc, and stick-feed. Rebuilding mine-car wheels by automatic welding (left) and machining.

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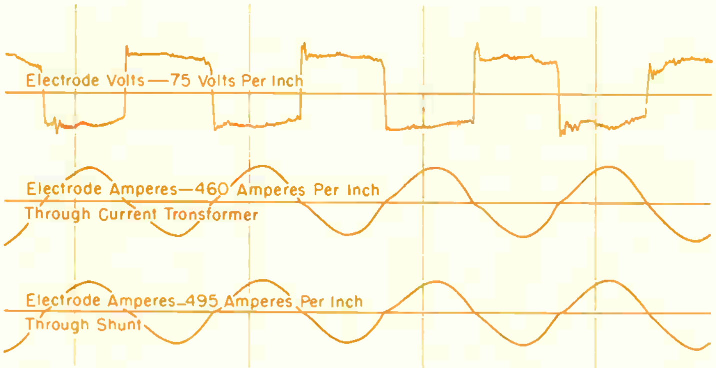
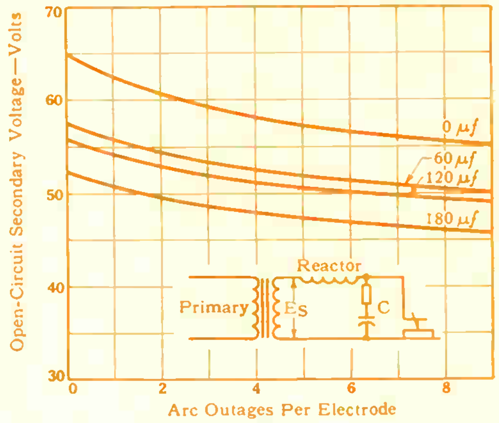


.... **The oscillatory capacitor discharge provides a high voltage when the current is zero and prevents extinction of the arc.**

This series of tests determined that with a 120-microfarad capacitor in the stabilizer circuit, the open-circuit secondary voltage could drop to 55 without causing outages.



Tests on the stabilizer indicate that all types and grades of electrodes can be used with steady-state open-circuit voltages as low as 55 volts. This voltage was made 65 to provide a margin of safety in case of low line voltage.

The reduction of the open-circuit voltage from 80 to 65 volts (which is possible only because of the stabilizer) has other advantages. It reduces the size and rating of the reactor needed to reduce the voltage from the 65 volts required at open circuit to the 25 to 40 volts required for welding; this results in high power factor. This in turn reduces the size and rating of the capacitor needed to raise the power factor to 80 percent at full load. The net result is a reduction in the overall weight of the welder.

Another factor that reduces weight is the Hipersil core. Hipersil is a grain-oriented steel that can carry more flux in one direction than in the other. It is available to the welding industry because the high volume required for distribution transformers brings it within economic reach. The use of Hipersil reduces the weight of the core and hence of the welder. For example, the 300-ampere portable unit weighs only 440 pounds, as compared to 780 pounds for the preceding welder of the same rating.

The use of low-core-loss, transformer-grade steel reduces the core loss and, because smaller coils are required, the copper loss. This increases the welder's efficiency, which approaches that of a transformer of similar kva rating. For example, the efficiency at full load of a 300-ampere welder is 91 percent and that of a 10-kva, 220-to-110-volt transformer is about 98 percent. The built-in capacitors maintain high power factor at all welding loads.

Larger welders, up to 2000 amperes (larger special units have been built), do not have the same stabilizer as smaller units. These larger welders are used principally for automatic welding, in which the transformer primary voltage is cut off when not welding. Hence, a higher open-circuit voltage (80 or 100 volts) can be used without danger to the operator. Stabilization is obtained from the coating on the welding wire or from powdered flux.

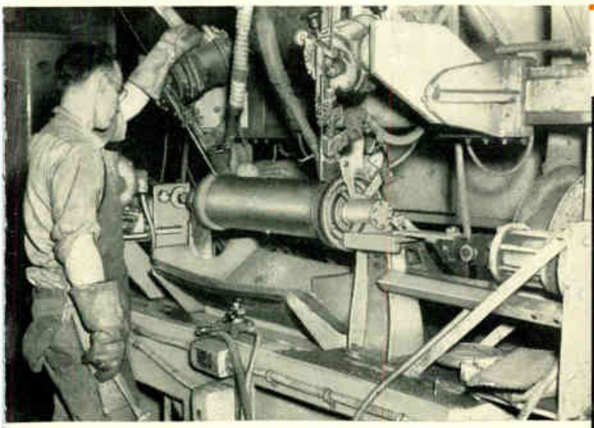
Automatic Arc Welding

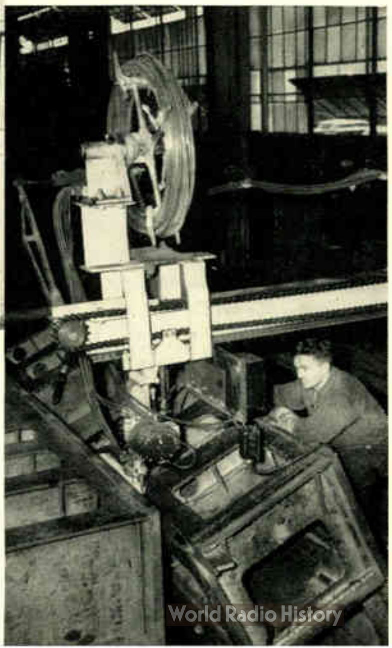
Several new automatic processes of arc welding have been developed during the past decade. These came into prominence during the last war, spurred by their advantages, the shortage of skilled operators, and by the needs of high-quantity repetitive production.

The automatic arc process is essentially the same as manual welding, except that the electrode feed and the relative movement of the arc and the work is accomplished automatically by machine instead of by the operator. Welding current, arc voltage, and wire-feed and work-travel speeds are preset. Either the work or the wire moves, depending on the size of work and type of weld. Welding wire and powdered flux (when required) are fed automatically to weld the seam; at completion, shutdown is automatic.

Five modifications are employed: the submerged-melt, bare-wire, coated-electrode, stick-feed, and carbon-arc. They differ only in the manner by which the welding rod and flux are applied. They use the same equipment with slight modifications to the welding head, except in the case of the stick-feed process.

The most important process is the Unionmelt submerged-melt, developed by the Linde Air Products Company. It uses bare-metal electrode wire and a powdered flux spread over the arc. The functions of this flux are the same as the electrode coating in manual welding. The process is used for mild and low-alloy steels and for some corrosion-resisting steels.





An installation (above) with two automatic heads for simultaneously welding two flanges to the ends of a cylinder. Welding of diesel-engine bases (right).

Photo at right courtesy of The Linde Air Products Co.

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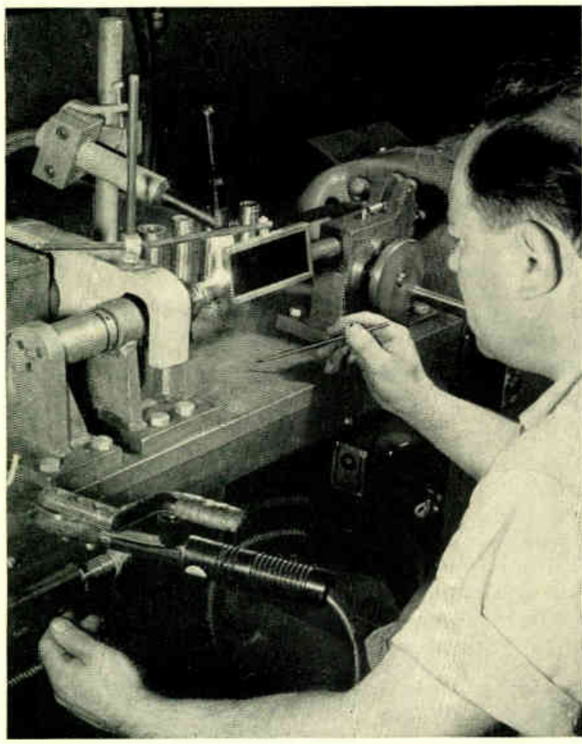
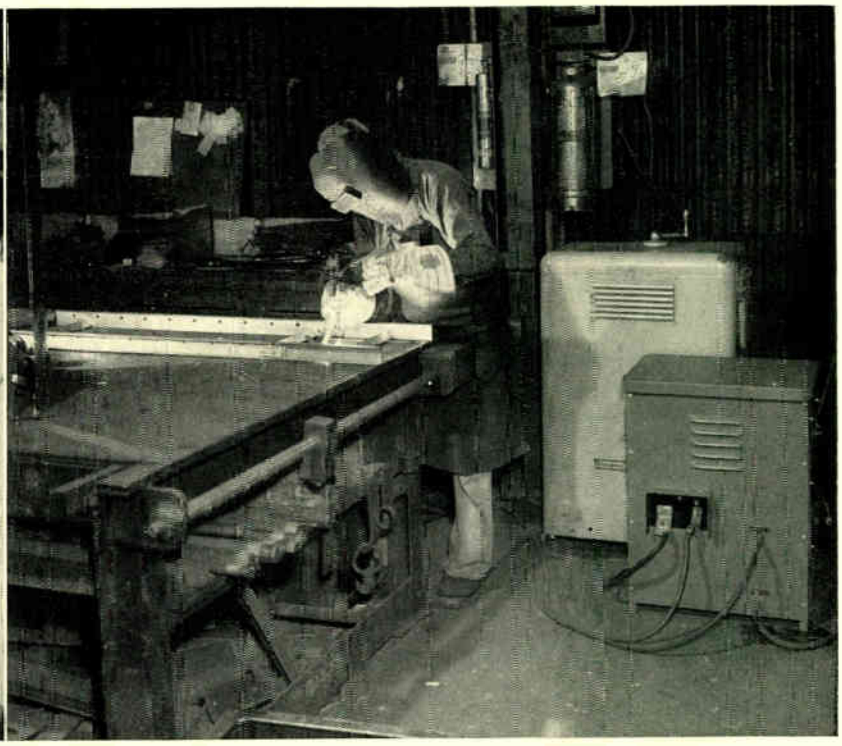

Semi-automatic inert-gas (argon) arc welding of small thin-wall stainless-steel cylinders (left). Manual inert-gas welding of an aluminum conveyor (right) using a 500-ampere, 65-line, a-c welder and a 1000-ampere, high-frequency stabilizer with built-in gas-water controls.
Photo at right courtesy of Mathews Conveyer Company.

The bare-wire process employs only a bare-metal welding wire and no flux. The coated-electrode scheme employs a coated electrode that has a wire wound around it and imbedded in the flux; this wire conducts current to the metal core. The stick-feed (unlike the others which use long reels of welding wire) uses cut lengths of electrode rod, each usually long enough to make one weld. The carbon arc process uses a carbon arc with or without a wire filler rod.

The advantages of automatic welding are as follows:

1—The operator need not be highly skilled since the welding process is automatic.

2—A more steady and uniform arc is maintained, since it is continuous and practically independent of human factors.

3—A higher rate of welding speed is used, increasing production. The submerged-melt process can deposit as much as 125 pounds of electrode per hour as compared to a man's maximum of three to four pounds.

4—Better fusion and stronger welds are produced because current densities as high as 30 000 amperes per square inch of electrode, three times the maximum with manual welding, are used in automatic welding.

5—A continuous reel of wire (except for the stick-feed process) as much as several thousand feet in length, is used, eliminating the waste and expense of stub ends of rod.

The equipment for automatic arc welding consists of a welding transformer (for alternating current) or motor-generator set (for direct current), welding head and its control equipment, operator's panel, work positioner, wire reel, and for submerged-melt operation a flux hopper and flux-recovery unit. All except the electrode wire and flux, which are expendable, are furnished in a complete coordinated package called the Weldomatic.

Direct-current automatic welding seldom uses currents above 600 to 800 amperes. Alternating-current welding, which predominates, uses currents up to 2000 amperes for standard equipments, and larger for specials. Motor-generator sets or transformers are available up to these maximum ratings. Both types are standard equipment, the same as employed for manual welding.

The function of the motor-driven welding head is to strike the arc when the welding process is started and to maintain proper arc length by continuously and accurately feeding the right amount of welding wire as the head progresses along the seam. This is done by the automatic control that adjusts the speed of the welding-head motor so as to maintain a constant preset arc voltage. The welding head of the Weldomatic can handle currents up to 1200 amperes (2000 amperes with special nozzles).

Electrodes up to ¼-inch diameter can be fed at rates up to 75 inches per minute. The arc voltage and work motion are controlled from a compact operator's panel. Provided on the panel are an ammeter and a voltmeter to indicate welding conditions and an inching switch (used for setting up the work) to feed the welding wire up and down without the application of welding voltage.

Motorized work-positioning equipment holds the work and moves it past the arc in a predetermined path according to the shape of seam desired. Weldomatic provides many types of standard, semi-standard, and custom designs for almost any application. Rotating positioners, for example, can be supplied in load capacities from 500 to 2500 pounds. These can rotate the work 360 degrees at any welding speed and can tilt at any angle from horizontal to 45 degrees past the vertical position.

The wire reel can hold 150 pounds of welding wire, the length of which depends on its diameter, for example, about 3500 feet of ⅛-inch size. The flux hopper for the submerged-melt process has a capacity of 25 pounds. If a flux-recovery unit is used, excess flux is reclaimed by suction and returned to the hopper for re-use.

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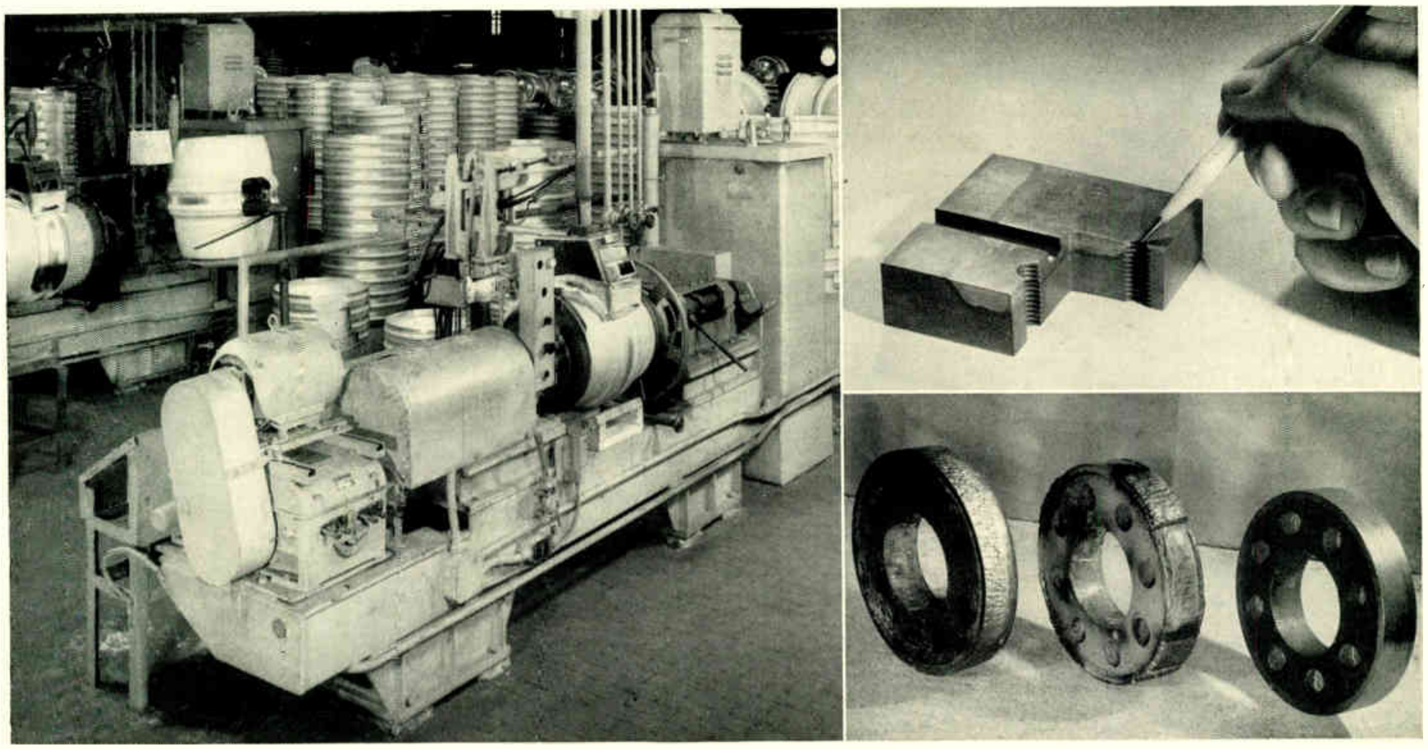

An arrangement for automatic inert-gas welding of aluminum beer barrels (left). This Freemachineweld deposit (upper right) on cast iron was subjected to five machining operations. These wear rings (lower right) of a hydraulic press are rebuilt with Hardentough.
Photo at left courtesy of the Aluminum Company of America.

Inert-Gas Arc Welding

Inert-gas arc welding is a new development. It became prominent during the war as a very successful process of welding magnesium and aluminum and it is now also used for copper, brass, bronze, and stainless steels. At first, inert-gas welding was applied principally to the aircraft industry but it is now used in many other industries. Inert-gas welding is applicable both manually and automatically.

In this welding process, the arc is shielded by an atmosphere of inert gas, usually helium or argon, which is supplied by the welding head or torch. In most cases, the arc is struck between a tungsten electrode and the work, and the heat generated melts a filler rod that is usually of the same composition as the work. The tungsten electrode is gradually consumed but it does not enter the weld. Inert-gas welding requires neither fluxes nor coatings as the weld is protected by the gas.

The equipment used with inert-gas welding is essentially the same as that used in other processes except for the welding head or torch. The use of a high-frequency, high-voltage stabilizer, which establishes the arc without the electrode touching the work, has been found advantageous. Once the arc is started, the high frequency stabilizes it throughout the welding operation. Welders of low rating have this stabilizer built into the same housing as the 60-cycle components. For welding with higher currents, separate stabilizers are built for use with the 60-cycle welders. Larger welders include controls for gas flow and cooling water (to cool the electrode holder).

Developments in Welding Electrodes

During recent years, new electrodes have been coming from the development laboratory with great rapidity. Two of these, Freemachineweld and Castingweld, are for welding cast iron. Freemachineweld deposits metallic nickel to produce soft, readily machined welds in cast iron. It is used to salvage defective castings and incorrectly machined castings, as well as those broken in service. Castingweld deposits high-strength carbon steel. While the deposit is not machineable, due to carbon pickup from the cast iron, its much lower cost recommends it for repairs that do not require machining.

LoH (contraction of low hydrogen) is the outgrowth of wartime research that disclosed hydrogen, dissolved in molten metal and subsequently trapped in the solidified steel, as the cause of underbead cracking in alloy-steel welding. In addition to welding alloy steels satisfactorily, it is also used on high-sulphur and high-carbon steels.

Five hard-surfacing electrodes (Hardentough 250, 350, 440, 550 and W.H.) are effective in rebuilding worn parts and supplying harder surfaces to resist impact and abrasive wear. They derive abrasion resistance from the presence of carbon and chromium as extremely hard chromium carbides. Hardentough 250 (average Brinell hardness of 250) deposits machineable metal for repair of shafts and similar worn parts. Hardentough 350 and 450 are of intermediate hardness. Their deposits are not machineable but they have good resistance to impact and moderate resistance to abrasion. Hardentough 550 is high in alloying ingredients that impart higher hardness and superior abrasion resistance. Hardentough W.H. is moderately hard as welded, but when subjected to severe impact it hardens to over 500 Brinell on the surface. It thus provides a very tough under deposit that will stand severe impact and a hard outer surface for high abrasion resistance.

Twenty-seven grades of stainless-steel electrodes of both the chromium-nickel and straight chromium types have been developed. They are available with two different coatings—a titania-lime coating for both a-c and d-c welding operations, and a lime coating for d-c reverse polarity only. Because some properties of stainless steels differ from those of more common alloys, certain precautions must be taken to insure completely satisfactory welds.

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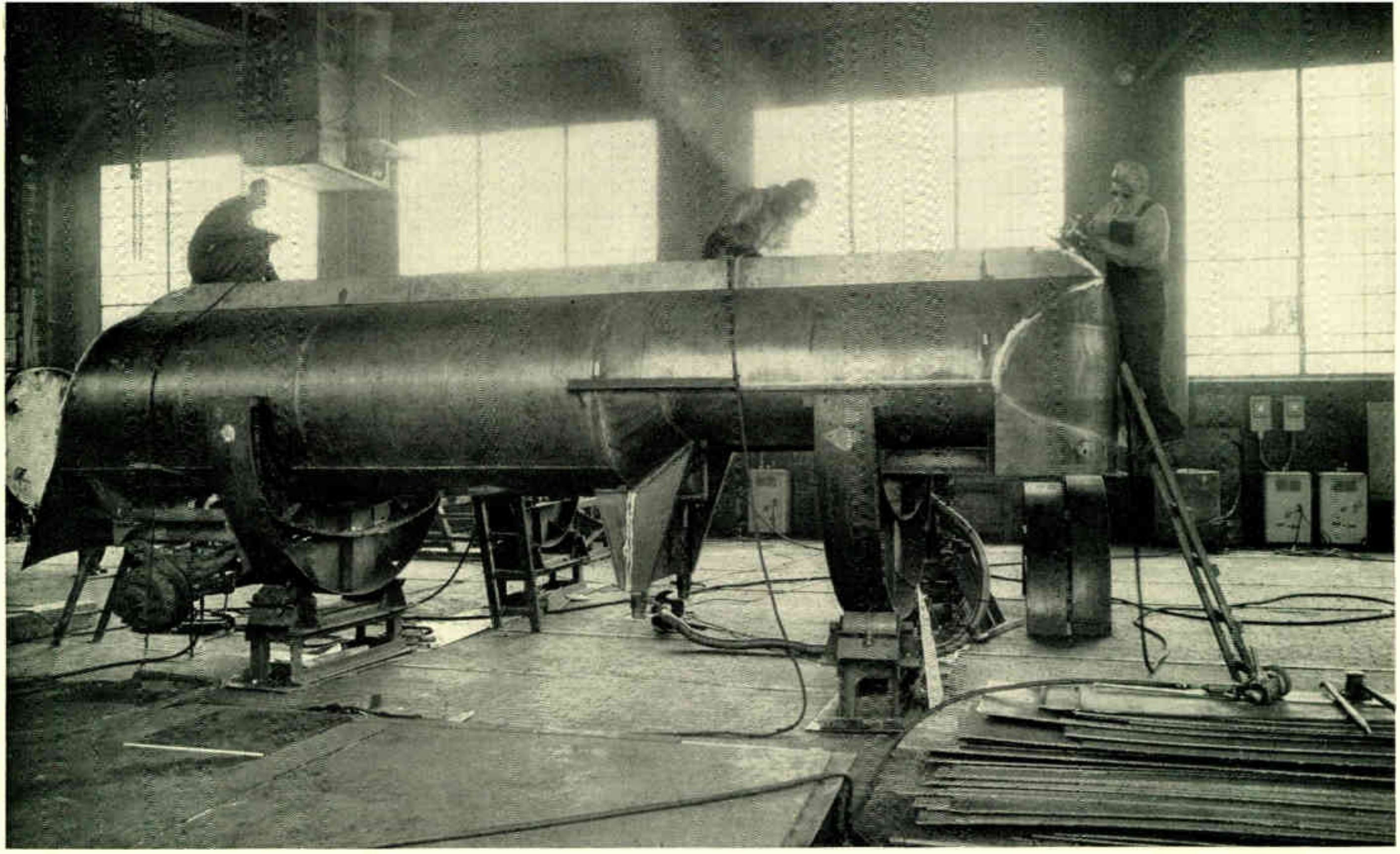

Welding a 3400-gallon semi-trailer at the Kaustine Company. Operators indicate that a-c welding reduces the finish grinding.

Power Analysis of A-C Welders

The reduction in power cost is but one of the savings that results from the use of a-c welders in place of d-c. This reduction is estimated by simple vector analysis of the loads for both types of welding machines.

F. B. MEAD, *District Engineer, Westinghouse Electric Corporation, Buffalo, New York*

In considering the installation of a new arc welder, the economics in almost all cases points indisputably to alternating current. In fact, in many instances the expense of replacing existent welders of the d-c motor-generator type by the a-c transformer type can be economically justified as it will be repaid in 18 to 36 months in power savings alone.

A representative case is that of the Kaustine Company, Perry, New York, whose manufacturing operations include the fabrication and welding of sheet and plate steel. This company employed all d-c motor-generator-type welders and a study was made to determine whether it would be economical to replace some of these by a-c transformer-type welders.

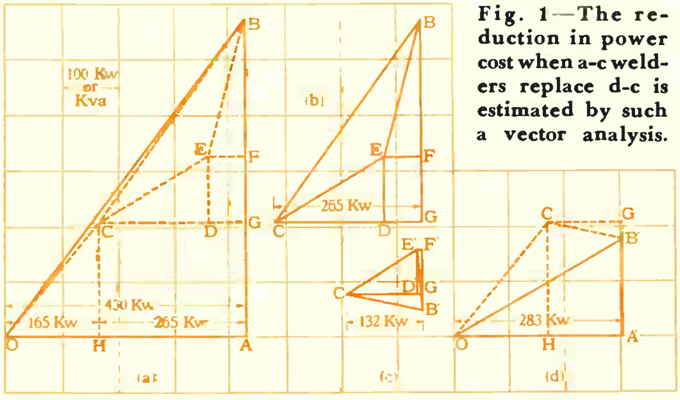

Fig. 1—The reduction in power cost when a-c welders replace d-c is estimated by such a vector analysis.

Based on observations in the plant, a 30-percent duty cycle for welding equipment was assumed, i.e., 30 percent of the welders are fully loaded and the others are running but at no load while the operators are changing position and manipulating parts. The power factor of the entire plant load closely approximated that calculated for a group of m-g sets working at 30-percent duty cycle. Since welding is a predominant portion of the total plant load (over 90 percent), the assumption is justified.

It was proposed to discard 27 m-g sets, consisting of fourteen 300-ampere and thirteen 400-ampere machines, in favor of 27 high-power-factor, high-efficiency a-c welders of the same ratings. The analysis was made and vector diagrams laid out on that basis. These welders represent about 70 percent of the total welders in the shop.

The vector diagram of total plant load is given in Fig. 1 (a). This load, triangle *OAB*, consists of base *OA*, the 430-kw load, and line *OB*, the 715-kva transformer load, resulting from a power factor of approximately 60 percent. The vector diagram of the 27 d-c welders alone at 30-percent duty-cycle operation is given in Fig. 1(b). This diagram is made up of a triangle *CDE* representing 30 percent of these welders working fully loaded (200-kw total at 88-percent power factor) and another triangle *EFB* representing 70 percent of the

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welders idling at no load (65 kw at 24-percent power factor). Using Table I, these values are calculated as follows:

Average power input per welder at full load = 24.7 kw
Total power input to 30 percent of welders at full load
= 24.7 × 27 × 0.30
= 200 kw
Average power input per welder at no load = 3.42 kw
Total power input to 70 percent of welders at no load
= 3.42 × 27 × 0.70
= 65 kw

These two triangles give a total triangle *CGB*, which represents the 27 d-c welders. The load imposed by these machines is 265 kw at a lagging power factor of less than 60 percent. When triangle *CGB* is subtracted from triangle *OAB*, the remainder (*OHC*) represents the load in the plant other than the 27 welders, i.e., the load that would remain if these welders were removed (kw = 430 − 265 = 165).

The vector diagram for the same number and ratings of a-c welders is given in Fig. 1(c). This diagram is also made up of two triangles *C'D'E'* for 30 percent of the welders working at full load (123 kw at 80-percent power factor) and *E'F'B'* representing 70 percent of the welders idling (3.3 kw at 3-percent power factor leading). These two vector diagrams combine to form the total of *C'G'B'*, a load of 132 kw at 97-percent power factor leading. Comparing triangles *CGB* and *C'G'B'* indicates that d-c machines demand approximately double the kilowatts required of a-c welders and add 400 kvar more lagging load.

To determine the overall effect of changing 27 welders on plant load, it is necessary only to subtract triangle *CGB* from triangle *OAB* (leaving *OHC*) and add in its place triangle *C'G'B'*, as is done in Fig. 1(d). The loading is changed from *OAB* to *OA'B'*; in other words, the actual kw load is reduced from 430 to 283 and the power factor is raised from 60 percent to approximately 85 percent.

Furthermore the total load on the transformers supplying the plant has been reduced from 715 to 335 kva, or, in other words, 380 kva of transformer capacity (which in itself has considerable dollar value) has been released for future expansion of plant operations.

Welding a sub-assembly of an oil-fired winter furnace. One of the new transformer welders is visible in the left background.

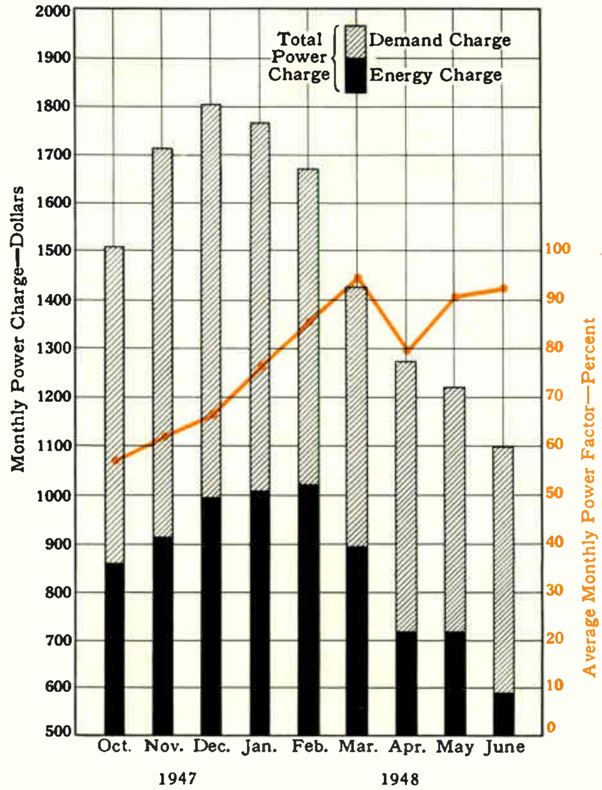

Fig. 2—This is the result of replacing the 27 motor-generator-type welders with the transformer type. The actual bill is somewhat less than the total because the distribution transformers are company owned.

From the reduction in load indicated by the vector diagram, the anticipated saving in power cost was estimated as follows:

Power reduction = 430 − 283 = 147 kw
Cost of electrical energy = 2¢ per kwhr
Saving per month (8-hour day) = 147 × 8 × 0.02 × 30 = $700

The change from d-c welders of the motor-generator type to a-c welders of the transformer type was actually made at the Kaustine Company. The power billing and power factor observed during the change are plotted in Fig. 2. During the first few months, the average monthly reduction in the power cost due to replacing the welders is approximately $450, which is more than sufficient to pay for one 400-ampere welder. This saving alone, which continues to increase, will return the cost of the new welders in about two years.

In comparing the estimated saving ($700) with the actual average saving ($450) it must be remembered that a-c welders increase the production of each operator. This rise in production increases the electrical load and the energy consumed each month. Therefore, the estimated saving is not as high as predicted from the vector diagrams.

TABLE I—CHARACTERISTICS OF STATIONARY-TYPE WELDERS

Rating	300 Amperes		400 Amperes	
	D-C	A-C	D-C	A-C
Full-load input—kw	21.2	12.9	28.2	18.0
Full-load input—kva	24.0	16.1	32.0	22.4
Full-load power factor—percent	88.0	80.0	88.0	80.0
Full-load efficiency—percent	55.0	91.0	55.0	91.0
No-load input—kw	2.8	0.17	4.1	0.18
No-load input—kva	12.0	5.7	16.0	5.8
No-load power factor—percent	23.0	3.0*	25.0	3.0*
Weight—pounds	1361	440	1590	460
Cost—dollars	435	390	500	445

*Leading power factor.

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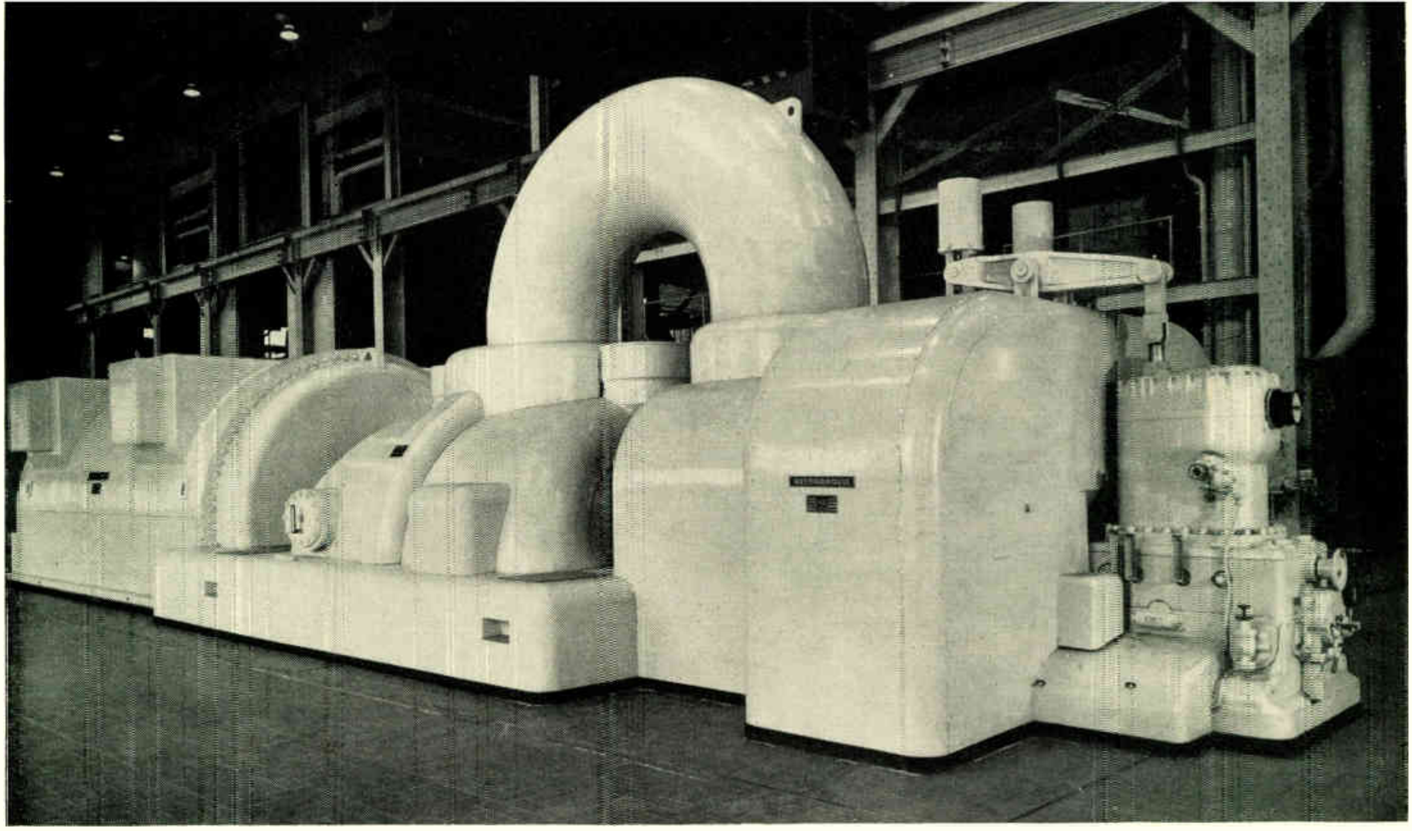

The Hydraulic Steam-Turbine Governor

The governor of a modern large steam turbine must be fantastically sensitive to speed changes, yet must exert tons of pressure on the valves, and must work unfailingly not only to maintain power continuity but also to protect costly apparatus. The modern hydraulic governor for steam turbines, while apparently a complex array of valves, pumps, and oil lines, is fairly simple in principle of construction and operation.

A. F. Schwendner, *Advisory Engineer*
J. R. Carlson, *Manager, Application Engineering*
Steam Turbine Div., Westinghouse Electric Corporation, South Philadelphia, Pa.

Prime movers, generating power, must be provided with some mechanism that can adjust the rate of energy input to be commensurate with load. Such a mechanism or governor, as it is called, was originated by James Watt. It may range in complexity from a simple manually operated mechanism to highly sensitive, powerful, and reliable governors used on high-speed rotating engines.

The most widely used and largest energy converter is the steam turbine. Because of its high rotative speed, it packs tremendous power in a light machine. The inertia of its rotating parts, in relation to the power developed, is low; therefore, it has a tremendous ability to accelerate rapidly following loss of load. Furthermore, turbines connected to electric generators must provide for accurate control of frequency as well as varied electrical output to suit customers' demands. Turbines, consequently, require governors of great sensitivity and reliability.

Early turbine governors generally consisted of a vertical spindle rotated by means of a worm wheel and gear, Figs. 1 and 1(a). Flyweights were attached to the vertical spindle in a manner that permitted them to move with changes in speed. Outward movement of the flyweights, caused by centrifugal force, is opposed by a spring. Normally the strength of the spring, ratio of the lever attachments, and mass of the flyballs are such that the centrifugal force of the weights starts to compress the spring just before the turbine reaches normal speed. At the normal working range of the governor, the centrifugal force of the flyweights and the opposing force of the spring balance exactly—not an ounce of force is left over for positioning or controlling the steam-admission valves. Only by having a change in the speed with no movement of the flyweights and the movable collar does force become available to position the valves. A change in speed of the governor spindle with free movement of the movable collar permits the spring force and centrifugal force of the weights to balance each other perfectly.

The "power," or the ability of the governor to perform a useful job, is defined as that force exerted by the rotating flyweights in a position corresponding to full load, for a one-percent speed change but without radial movement of the governor weights. For example, if the governor collar were restrained from movement and a one-percent change in speed occurred, the magnitude of the collar restraint would represent the power the governor develops for movement of the

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valve. An average governor may, for example, produce a force of ten pounds for a one-percent speed change. Then for a 2-percent speed change it will be 20 pounds; 4-percent speed change, 80 pounds; and so on.

Steam-admission valves are of two types: balanced or unbalanced. Balanced valves, Fig. 1, are constructed so as to make the net steam forces acting upon them almost zero. The slight unbalanced forces usually act to keep the valve closed but as the valve is opened, the force may reverse and tend to open the steam valve.

Steam-admission valves for large turbines generally are of the unbalanced type because of their better relation between valve lift and steam flow, which means steam flow versus kw load. These valves controlling the flow of high-pressure steam may require a pull of five tons to open them.

A direct-acting governor would require tremendous change in speed before it would develop enough force to position unbalanced valves. Consequently they are most frequently used on small balanced valves. Heavier weights and stronger springs could be used to make a stronger governor. That solution is not practical as it would entail larger bearings and greater internal friction.

Because direct-acting governors require large changes in speed before they develop much power, some other method must be used. What is really needed is a powerful and obedient giant that will open and close the valves, when ordered to do so, by the lightest touch or impulse. Such an obedient and powerful mechanical servant can be obtained by building a hydraulic operating mechanism or "servomotor." The servomotor used is a large cylinder containing a movable piston. The fluid that moves the piston can be air, water, steam, or oil. For steam turbines, oil is the most desirable as it is noncorrosive and is a lubricant.

High-pressure oil acting upon the servomotor piston forms the powerful mechanism for positioning the valves. All the governor now has to do is position a relay that admits high-pressure oil to either the top or the bottom of the servomotor piston. The force required to operate the valves comes from the oil pump; the governor only directs it.

High-pressure oil for use in the servomotor is provided by an oil pump often driven by an extension of the vertical governor shaft. The addition of the oil pump

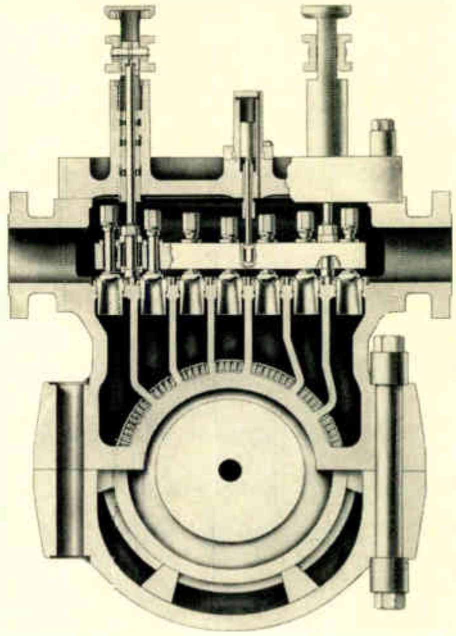

Fig. 2—The multi-valve steam chest of a turbine. Unbalanced valves are employed here.

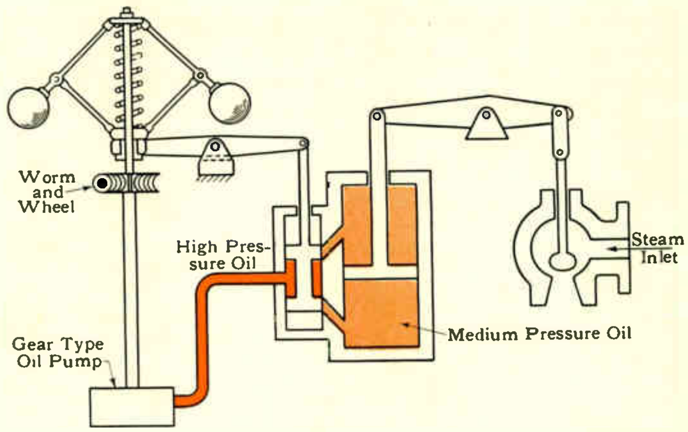

Fig. 3—Geared flyball governor with geared oil pump servomotor and unbalanced type of steam valve.

Fig. 1 (a)—Mechanism of early type flyball, gear-driven governor with oil pump mounted on a turbine shaft extension.

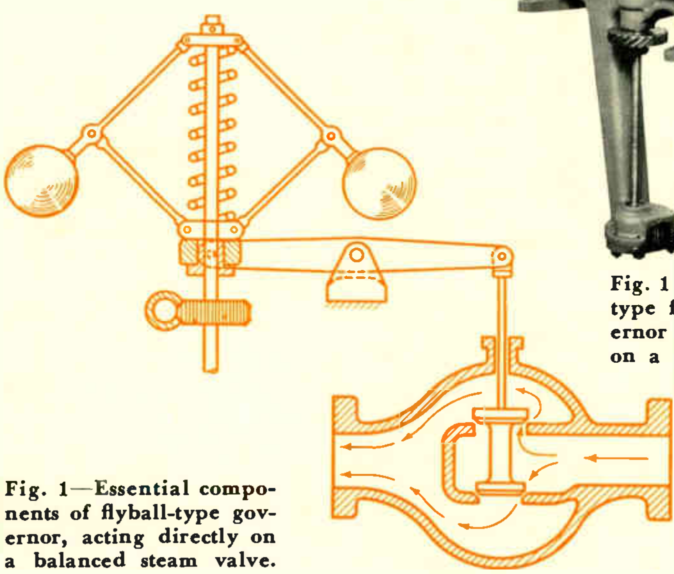

Fig. 1—Essential components of flyball-type governor, acting directly on a balanced steam valve.

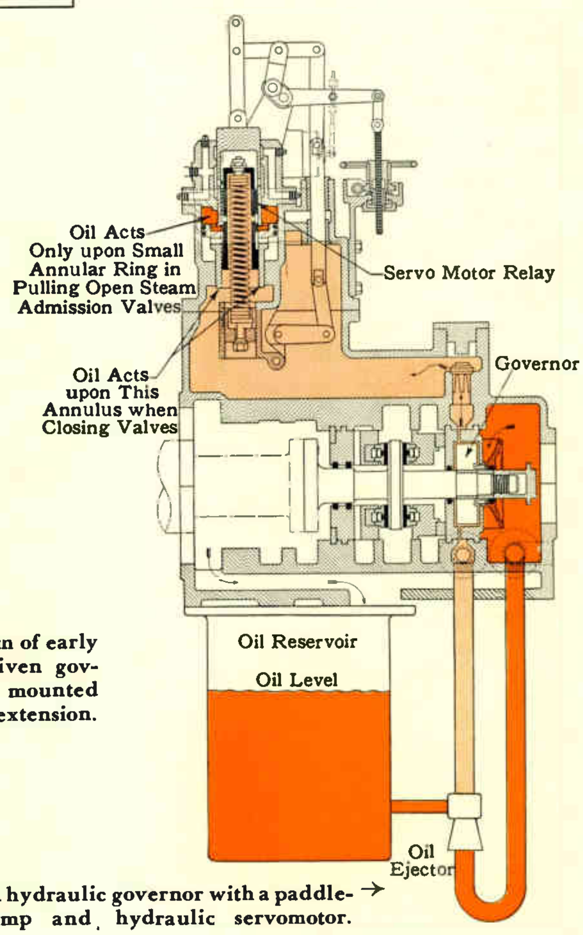

Fig. 4—A hydraulic governor with a paddle-type pump and hydraulic servomotor.

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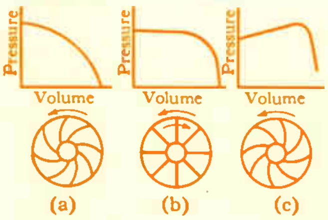


Fig. 5—Performance characteristics of centrifugal pumps with different blade angles.

increases greatly the power the worm and wheel must transmit to the vertical governor shaft. On large turbines, as much as 200 hp may be required. A completely reliable satisfactory worm and wheel drive is practically impossible to obtain.

That was the way governors were designed, until about 25 years ago, when Westinghouse engineers introduced a new and radical idea. There were compelling reasons for inventing a new control system. Repeated difficulties with oil pump and governor and governor gears made it desirable to eliminate them if at all possible.

Why not mount the oil pump directly on the turbine shaft? No one had dared to do this as it was considered absolutely imperative that the main oil pump be submerged in oil to guard against any possible loss of suction. Mounting the main oil pump directly upon the turbine shaft meant that the pump had to be primed by a method that was at least as reliable as the submerged suction.

One piece of power apparatus particularly free of trouble is an ejector, a device completely devoid of moving parts. Why not make the pump self-priming or provide oil for its own suction supply, by taking a small portion of the high-pressure oil and passing it through an oil ejector? The ejector in turn would gather a larger quantity of oil from the oil reservoir and deliver it to the pump at a positive suction pressure, thus providing a positive suction supply. That was done. In more than 25 years of service no cases of oil failure chargeable to the oil ejector are known.

The oil ejector made it possible to mount the high-pressure oil pump directly on the main turbine shaft with safety. Mounting the main oil pump on the shaft reduced greatly the power transmitted through the "governor gears." But why not go even further and eliminate these gears altogether?

The pressure-volume characteristics of various types of centrifugal pump runners are shown in Fig. 5. With vanes curved backwards the pressure diminishes with increased flow. With vanes curved forward the pressure tends to increase with flow. With radial vanes the pressure remains practically constant with varying flow. By selecting a pump with radial vanes the oil pump can be made to serve a dual purpose, that of measuring the turbine speed and providing oil for control purposes. A centrifugal pump runner for governor purposes should have as nearly as possible a flat line characteristic independent of the flow over the range through which it must operate. Experience has shown that a straight radial vane pump, designed for a sufficiently large capacity to care for full movement of the servomotor piston, will have a pressure-volume characteristic sufficiently flat as not to interfere with governing. The pressure delivered by a centrifugal pump varies directly as the square of the turbine speed or, in exactly the same manner, the force varies for rotating flyweights. However, with hydraulic forces it is possible to transmit them directly to the relay of the servomotor without mechanical linkages. In this manner the friction and lost motion of linkages are eliminated.

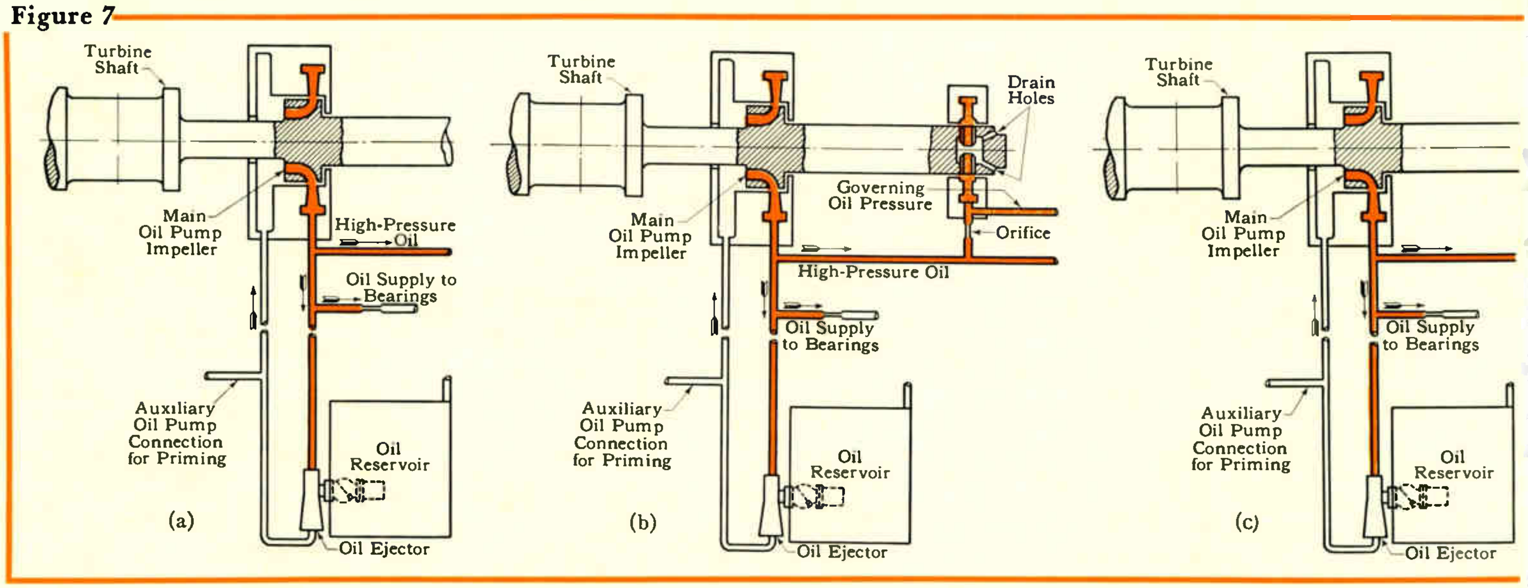
The oil ejector made it possible to locate the main oil pump directly on the turbine shaft; but by making the oil pump serve a dual purpose of measuring the turbine speed as well as supplying high-pressure oil, flyweights, knife edges, linkages, and gears are all eliminated.

This form of governor was used with great success until 1932. It was stable in operation and its reliability was of the highest order. But, it did have certain limitations. The pressure delivered by the main oil pump was low, only about 70 pounds, and the effective area of the piston of the servomotor was rather limited because of the use of an internal relay, thus limiting its force. As a result, its use was confined to turbine-generator units of moderate capacity.

Beginning in about 1932 large-capacity superposition turbines were constructed. These machines have very large power output combined with low inertia of rotating parts. They required governors of superior sensitivity, powerful in action and of utmost reliability.

Furthermore, larger turbines were being constructed for higher steam pressures, requiring more powerful servomotors than ever to position the valves. The best way to obtain more powerful action was to increase the oil pressure and to enlarge the area of the operating piston in the servomotor. Increasing the size of the main oil pump and doubling its discharge pressure meant that more power was required than

Figure 7



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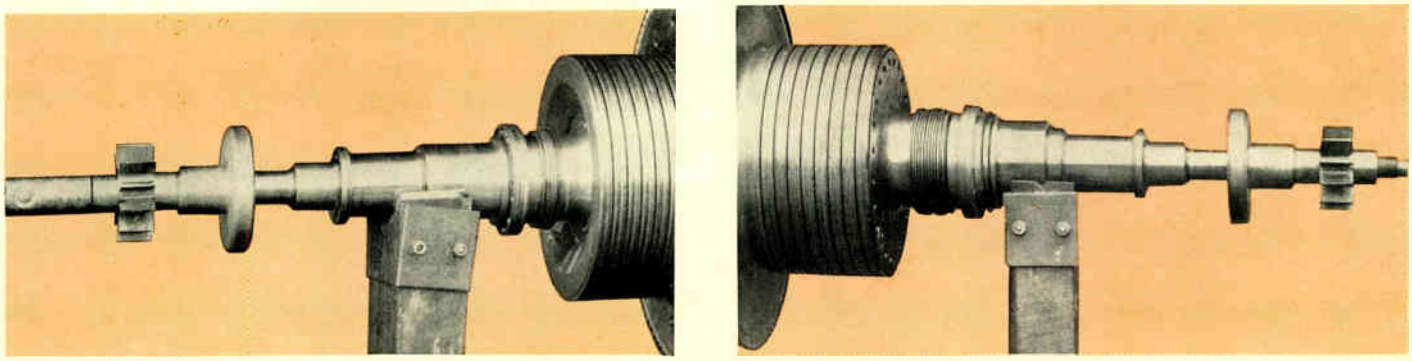

Fig. 6—Examples of early, paddle-type governor pumps.

before to drive it. Consequently the principle of the shaft-mounted pump was more desirable than before. However, a single pump designed for the dual purpose of pumping high-pressure oil and measuring turbine speed sacrifices something in efficiency.

A better solution of the problem was obtained by providing two pumps, Fig. 8. One of them is designed as an efficient centrifugal pump and its sole purpose is to deliver a varying quantity of oil under high pressure. This pump would have backward curve vanes so as to give a flat "pressure-volume" curve. Thus the pump can provide large quantities of oil when the need arises, without appreciable pressure drop. The second impeller can now be designed to measure accurately the turbine speed.

The improved hydraulic governor works as follows: A portion of the high-pressure oil is passed through an oil ejector mounted in a separately located oil reservoir, Fig. 7(a). The oil ejector draws a larger quantity of oil from the reservoir and discharges it at about 15 pounds to the suction of the main oil pump, thus establishing a self-priming system. This part of the system supplies the oil that is used in the hydraulic servomotor governor and the bearings.

The component of the governing system that measures the turbine speed—by producing a hydraulic pressure that is a function of the turbine speed—is a governor oil impeller also mounted upon the turbine shaft. This addition is shown in Fig. 7(b). This oil impeller replaces gear-driven rotating weights commonly used.

A small quantity of the oil from the high-pressure main pump is supplied to the outer periphery of the governor impeller through a fixed orifice. Inasmuch as the governor oil impeller is capable of developing a normal pressure of about 30 pounds and the main oil pump a pressure of 150 pounds, the flow of oil is always through the pressure-reducing orifice and through, in the reverse direction, the governor impeller. However, the higher the speed of the turbine shaft the greater is the resistance to oil flow in the reverse direction and consequently the higher the governor impeller pressure. What the impeller really does is to produce hydraulic pressure that is an accurate measure of turbine speed. Having done this the next step is to transmit that relatively weak impulse to the powerful servomotor. However, all servomotor relays require a sizable force to move them. The trick is to build up or magnify the initial governing impulse without loss through friction or distortion in intermediate relays. This is accomplished by multiplying the primary governing force in a frictionless pressure change magnifier, added to the previous two elements in Fig 7 (c). This magnifier consists of a bellows to which is attached a spring and a cup valve. The cup valve controls the oil pressure in the chamber above it. The main pump supplies oil to this chamber through an orifice. If the cup valve seats tightly, the oil pressure becomes 150 pounds. If the cup valve is withdrawn the oil pressure in the chamber drops to zero.

Because the area of the end of the bellows is several times the area of the cup valve—normally about five times—a

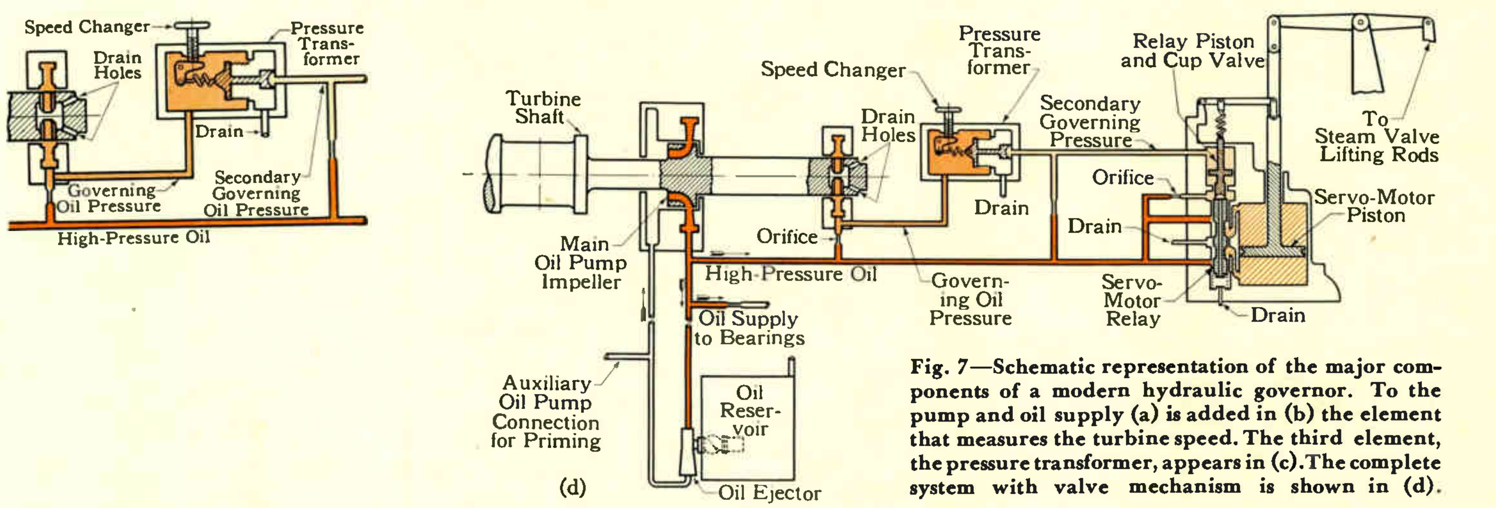

Fig. 7—Schematic representation of the major components of a modern hydraulic governor. To the pump and oil supply (a) is added in (b) the element that measures the turbine speed. The third element, the pressure transformer, appears in (c). The complete system with valve mechanism is shown in (d).

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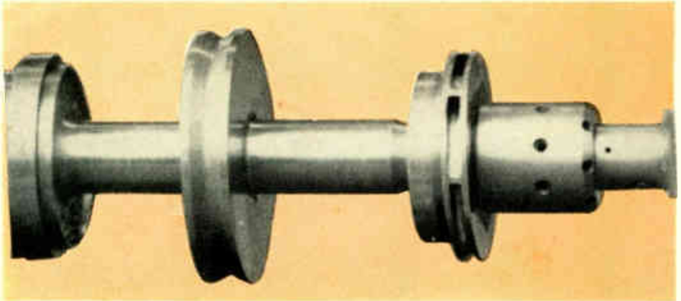

Fig. 8—The shaft end of a modern 15 000-kw powerhouse-type steam turbine shows the pump and governor.

pressure change acting upon the bellows causes the cup valve to restrict the flow of oil escaping past it until the oil pressure change above the cup valve is five times as great as the initial governing impeller pressure change. The bellows with attached cup valve moves only several thousandths of an inch and the only friction required to move the multiplier is the internal molecular friction of the spring and bellows.

These multiplied or secondary governor oil pressures are transmitted hydraulically to a small oil relay, which again, by differences of areas—large piston area and small cup-valve area— build up a larger hydraulic force by restricting the flow of oil past the relay piston valve. This easily positions the servomotor relay and admits high-pressure oil above or below the servomotor piston, which in turn positions the valves. The complete system is shown in Fig. 7 (d).

The whole problem of good governing can be summarized thus: First, accurately measure the turbine speed; then, by means of a series of relays, multiply, without distortion, the initial governing forces to a point where it accurately actuates

BOUND VOLUMES . . . INDEXES
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a servomotor. The servomotor must be able to exert, in some cases, a force of five tons.

Practically everyone shares the benefits of better turbine governing. Greater continuity of electric service is accomplished by many public utilities by tying their utility systems together with miles of transmission lines. Therefore, they can share increased load caused by a loss of a generating unit or by sudden overloads. Accurate and stable governors permit a smooth interchange of electric power between huge generating stations.

Automatic frequency regulators in combination with sensitive and stable governors regulate electric-system frequencies so accurately that electric clocks in homes are the accepted accurate timepiece. Bank clerks, machinists, postmen, and teachers are awakened by electric timepieces, which are regulated by the frequency of the electric generating systems—the number of revolutions of the steam turbine.

Accurate speed control of turbines installed in industrial plants provides a better and more uniform grade of paper or steel or a host of products.

The requirements of industry are becoming more exacting, necessitating higher quality turbine control. Hydraulic governors can be built in sizes to accommodate the largest turbine generator unit contemplated. Governors have already been designed that will meet the most exacting regulation requirements of specialized industry.

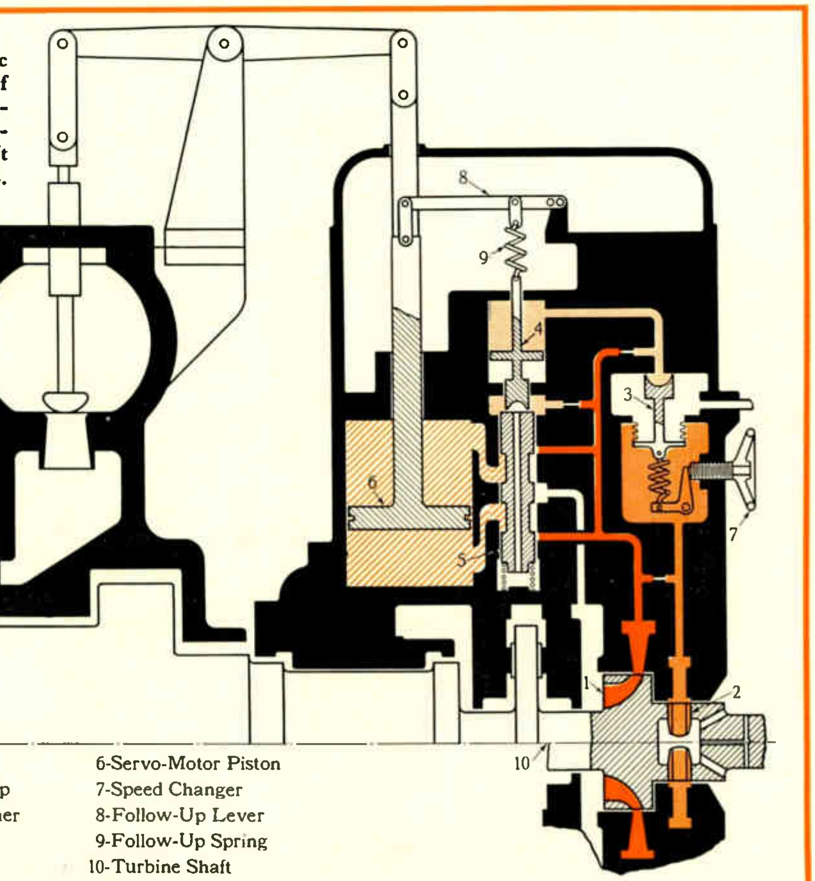

Fig. 9—Schematic representation of the complete governor for the turbine whose shaft end is in Fig. 8.

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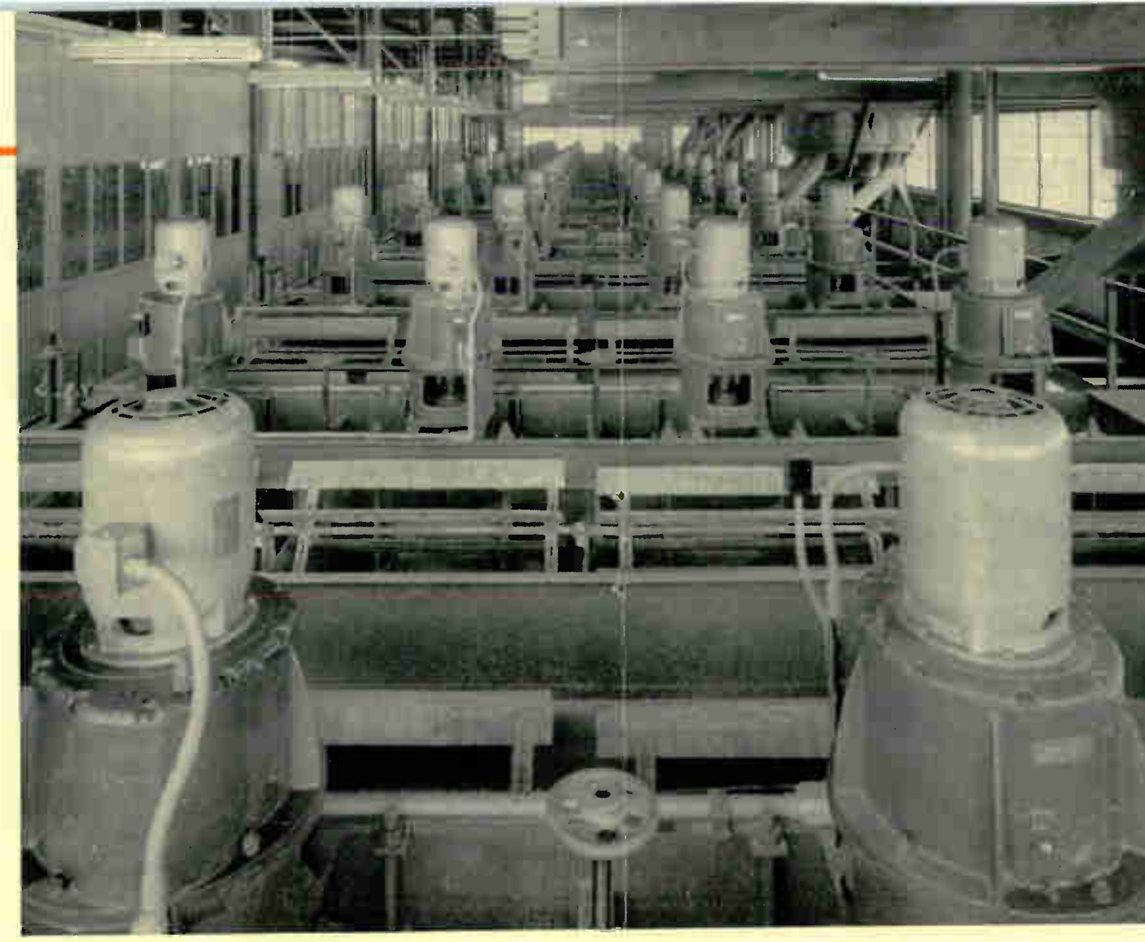
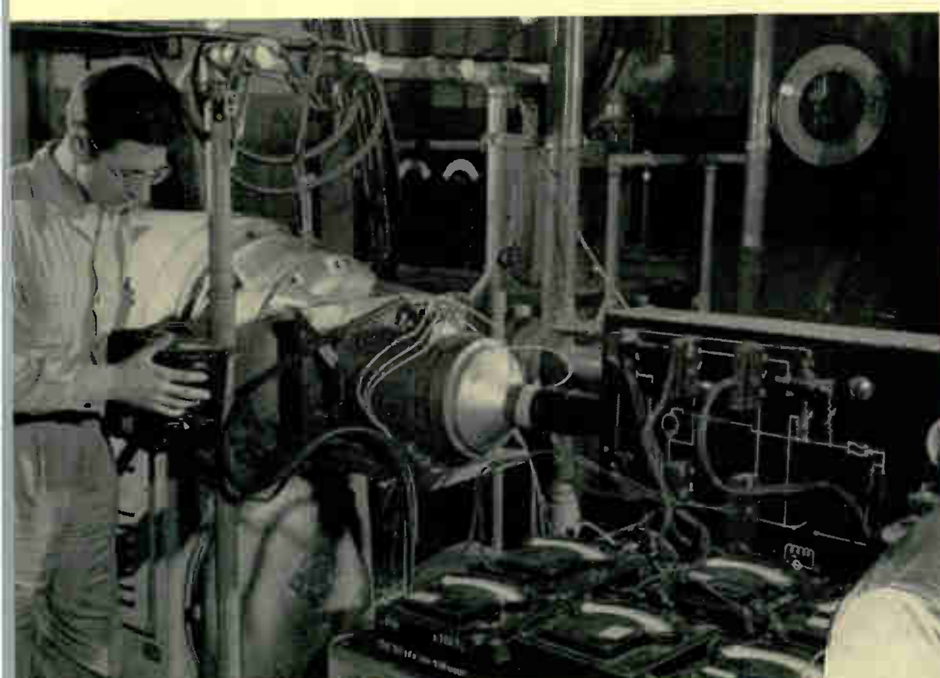
What's New!

THIS portable shunt capacitor, rated 1080 kvar at 2400 volts delta or 4160 volts wye, is used by Pennsylvania Power and Light Company to boost useful capacity during temporary emergencies or overloads and to study the effectiveness of proposed installations. Any one of six ratings (in steps of 180 kvar each) can be used. Automatic control is provided to add capacitor kilovars to the line as the voltage drops, and vice versa. Time-delayed operation prevents capacitors switching in response to changes in line voltage of short duration.



THIS battalion of 119 vertical gearmotors drives flotation cells and reagent mixers at the world's largest phosphate mining development, the Noralyn Mine of the International Minerals and Chemical Corporation. The gearmotors must carry a high thrust load and, being subject to moisture, are totally enclosed, fan cooled.

EQUIPMENTS such as these high-frequency transmitters are providing radio-communication services between widely separated, fixed points. This installation is one of a system of 21 stations owned and operated by Tropical Radio Telegraph Company to provide both public-service and plantation communications throughout Central America and into the United States. The type-MW equipment incorporates many new features that contribute to smaller physical size and better protection against heat, humidity, and high altitudes.



A PRE-PRODUCTION model (rated 30 kw) of the largest 120-volt d-c aircraft generator is put through its paces in the laboratory. The machine can supply 250 amperes continuously over its entire speed range of 3000 to 9000 rpm. Its weight is 130 to 140 pounds for various mechanical modifications or only 4½ pounds per kw. This is about two thirds the weight of the largest commercial (9-kw) 30-volt, 3000-to-9000-rpm aircraft generator and only one sixth that of a land-bound, 30-kw, 125-volt, 3600-rpm, d-c generator. Having pole-face compensating windings and scientifically proportional interpoles, the machine gives excellent commutation over the entire speed range at altitudes up to 40 000 feet and can supply instantaneous demands exceeding 1000 amperes. Prototype aircraft using the 120-volt system, intended for large military planes, are being built.

THE freshness of an egg need no longer be a subject of controversy until the shell is broken. Its condition can be determined by the invisible ultraviolet rays of black light (below), which cause a fresh egg to fluoresce scarlet and an old egg, purple. The color switch is presumably due to oxidation of the protein covering the shell. The protein is undisturbed when eggs are washed in clean warm water. Blacklight inspection supplements candling, which is primarily to disclose any blood spots.

THE new electronically controlled exhaust arrangement removes the damaging and deadly by-products of fire—super-heated air, toxic gases, and smoke. The cloud of smoke being generated at left is detected by a photocell that opens the fresh air intake, opens the collection ducts on the floor involved and closes all other floor dampers. The downdraft of air through the stairwell confines smoke to the floor where it was detected. This effect is shown at right.

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"Incandescent" Fluorescent Lamp

PEOPLE who prefer the warm, homelike atmosphere of the incandescent lamp, but are attracted by the coolness, comfort, and economy of the fluorescent, can now have all these qualities in one lamp—the new "Warm White" fluorescent lamp.

A new phosphor mix has a color approximating that of a black body at about 3000 degrees K, which provides a spectrum much closer to that of customary artificial light. Because of its color quality, the lamp gives a pleasing effect when used in combination with ordinary incandescent lamps. The Warm White lamp is very adaptable to stores where mixed light is often used, and also suitable for homes, where a warm atmosphere is desired.

The Warm White supplements the Soft White lamp, used where an especially flattering color is needed, and the Standard White (3500 degrees K), 4500 White, and Daylight (6500 degrees K) lamps, which give a cooler, whiter light, more similar to natural daylight.

The Warm White lamp operates in standard fixtures and has the same life performance as other standard colors. It is the most efficient, giving about 7 percent more lumens per watt than the Standard White lamp.

Trends in Series Capacitors

THE series capacitor does not "beat around the bush." It neutralizes the source of trouble—reactance—directly. In one case, that of four 10 000-kva electric-arc furnaces on 66-kv lines of the Duquesne Light Company, a record-size 10 000-kvar series capacitor neutralizes line reactance, thereby reducing sudden voltage variations. In other applications, series capacitors neutralize reactance in resistance welding transformers, reducing instantaneous kva demand by as much as 50 percent. This application has recently been gaining in importance because utilities are tending to consider instantaneous demand as well as 15-minute demand in setting rates.

Series capacitors are also used with electric graphitizing furnaces, where some 60 000 kvar are in service. Here their principal function is to cancel the reactance of feeders during steady-state conditions. Full-load currents are from 50 000 to 100 000 amperes (at about 200 volts). Hence circuit reactance, however small, causes a large voltage drop and poor power factor. Until about a decade ago, graphitizing furnaces were operated on 25 cycles to reduce these effects. Since then, however, series capacitors have made it possible to employ 60 cycles, at the same time maintaining unity power factor (it would otherwise be about 50 percent) and reducing the cost of transformers.

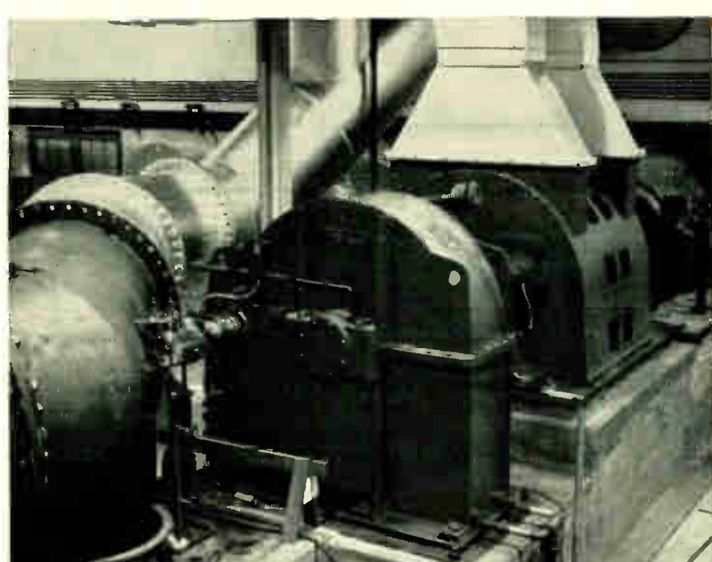
The average rating of series capacitors for graphitizing furnaces is about 3000 kvar. But now being designed are 6 banks, each rated 15 000 kvar, 50 percent more than the present maximum. The banks will employ the newly developed indoor-type, 25-kvar capacitor units in forced-ventilated, weatherproof housings. These units, as compared to the older 15-kvar rating, reduce floor-space requirements some 40 percent. Each 15 000-kvar bank will be connected to the line through a current transformer that steps up the reactive voltage of 300 volts to the more convenient rating of 2400 volts. Such a transformer "coupling" permits utilization of 2400-volt capacitors, which are much less costly than low-voltage units.

Series capacitors are being considered for improving the operating characteristics of long high-voltage lines that transmit large blocks of power, again by neutralizing line reactance. Here, too, the purpose is to reduce voltage drop during steady-state conditions, thereby raising overall level and making it possible to transmit more power with greater efficiency and greater system stability. As yet no capacitors for such applications have been placed in service.

Lighting Fixtures for Outdoors and In

LIGHTING engineers generally strive to place the light source at the focus, or at least symmetrically, with respect to the optical system. But not always. The problem of lighting the large area of a service station uniformly has found solution by deliberately placing the lamp off center in the symmetrical reflector. The lighting unit, which is now completely enclosed for better protection against the weather, achieves a long throw of light in which the greatest candlepower is about 35 degrees above the apparent center of the beam. This means that the brightest part of the beam is aimed at the more distant points and the floodlight thus achieves uniform lighting from 10 or 12 feet behind the pole base out to about 70 feet in front of the pole. There is almost no loss upward to the night sky (or into someone's bedroom).

Two new indoor-type fluorescent luminaires, types CD-80 and CD-160, provide either two- or four-lamp fluorescent illumination for schools and offices. They are available with either a steel-louvered bottom for direct-indirect lighting or with a translucent plastic bottom for semi-indirect illumination. The louvered bottom is recommended for general offices and classrooms, as dirt and chalk dust cannot collect on its vertical surfaces; this reduces maintenance. The translucent bottom is recommended for drafting rooms and accounting departments, where a maximum shielding and diffusion of light is required for critical, prolonged visual tasks. The units can be suspension mounted by single- or twin-stem hangers. Louvered units can be mounted on ceiling brackets.



***Flexible Wind-Tunnel Drive*—Not only model airplanes are tested in wind tunnels. One of the newest supersonic tunnels, at the Packard Motor Car Company's Gas-Turbine Division, is being used to develop the most efficient shapes of blades and air and gas passages for jet engines.**

The drive is one of the most flexible ever employed for a wind tunnel. Three arrangements are possible, an unusual feature made necessary by the desire to utilize an existing 600-hp, 2000-rpm d-c dynamometer. For maximum power the dynamometer is used as an adjustable-speed motor in tandem with a Westinghouse 3500-hp, 1170-rpm wound-rotor, liquid-rheostat-controlled, main-drive motor. When the dynamometer is not available, the motor is used alone. At low power only the dynamometer is needed. Speeds are increased to either 10 100 or 12 800 rpm (maximum) by two gear units.

The controls must be able to handle all three arrangements. When below sonic, the air velocity in the tunnel fluctuates with changes in motor speed. To maintain air velocity accurately, an electronic regulator controls the d-c voltage of the dynamometer and the liquid rheostat of the wound-rotor motor.

What's New!

FM Radio Becomes a Tool for Industry

"YARDMASTER calling engine 207."

"This is 207."

"When you finish your shifting, go over to the stockhouse, pick up two empties, and spot them on track 7 at the warehouse. Call me when you're through. We have another job near-by."

"O.K."

This conversation is representative of scores that are taking place over short-distance, two-way, FM radios in industrial railroad yards. These radios are also being used between plantations, tugboats, construction sets, shovels in open-pit mines, and on main-line railroads between engine and caboose and between signal points and passing trains. They provide reliable communication where stringing telephone lines is impractical.

FM radios reduce operational costs, in many cases to the extent that the investment in communications is returned within a few months. In railroad yards, for example, radios reduce waste motion, speed dispatching and refueling, and overcome bottlenecks caused by inclement weather. In everyday switching and moving service, the radio relieves the engineer of traveling to a telephone to call the yardmaster each time he completes a task or if breakdown occurs. In weighing trains, radios prevent bottlenecks during foggy weather, when accurate spotting of cars on scales is hampered by poor visibility of hand signals. Radios have been found effective by the Weirton Steel Company in helping to coordinate the operation of eight diesel locomotives that move 23 000 cars each month over 36 miles of company track.

Practically identical radio equipments are used for all applications. The radios meet the requirements of the Federal Communications Commission and many recommendations of the Association of American Railroads. Minimum rated output is 25 watts at a radio frequency of 152 to 162 megacycles. Fixed and mobile equipments are identical and of heavy-duty construction in a weatherproof housing, if need be, which minimizes maintenance and interruptions of communication. Should the transmitter, receiver, rotary inverter, or other major component be found faulty, it is immediately replaced by another. Mobile radios can be tested while the carrier is in operation.

Making Smoke Exit Gracefully

SPRINKLER systems in modern buildings have reduced the danger of fire to a large degree. In fact they have reduced it to such an extent that smoke is now a bigger problem. For one thing, smoke spreads faster. Along with the smoke there are usually super-heated air and toxic gases, and of course the terrifying by-product of fire and smoke—panic. These factors are the principal killing agents of fire, and in addition cause millions of dollars of damage to property yearly.

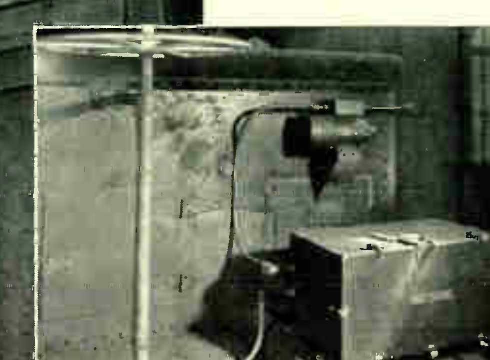
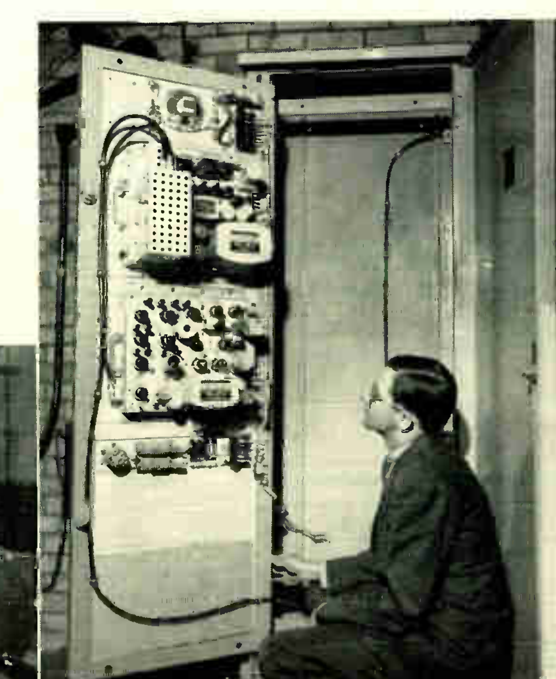
Now a new electronically controlled exhaust arrangement for preventing the chimney action of smoke and gases in stairwells has been devised. Installed in the Sage-Allen Department Store in Hartford, Connecticut, it uses an exhaust system in conjunction with an electronic smoke-detection unit.

The system, devised from an exhaust water spray system developed by Westinghouse, Otis Elevator, and Grinnell, consists of collection ducts located around the stairwells; these ducts lead to a centrifugal-type exhaust fan on the roof that draws out sufficient air from the floor where a fire occurs to create a downdraft in the stairwell. This confines the smoke to the floor on which the fire is located.

The exhaust fan is driven by a 2-speed, 25-hp motor, which at low speed (900 rpm) serves as a ventilator, and at high speed (1200 rpm) as a protective motor. In the roof directly over the stairwell are louvers through which fresh air is drawn.

Each floor has an independent detection unit. Developed by the Walter Kidde Company, it consists of a photocell, activated by a lamp, under whose surveillance pass samples of air drawn from the room. The slightest amount of smoke present causes the light reaching the photocell to be diminished. At a certain critical value of light the photocell actuates a relay; this stops the electric stairways, rings an alarm in the boiler room, and starts the exhaust system.

This scheme is not intended to replace the conventional overhead sprinkler system but merely to supplement it. Used with a sprinkler system it provides an outstanding method of smoke control, thereby increasing safety as well as decreasing potential property loss due to smoke and heat.

For some applications it is desirable to operate the equipment from a knee switch (left). The rotary inverter and other equipment can be mounted outdoors (center). A rear view of the panel (right).

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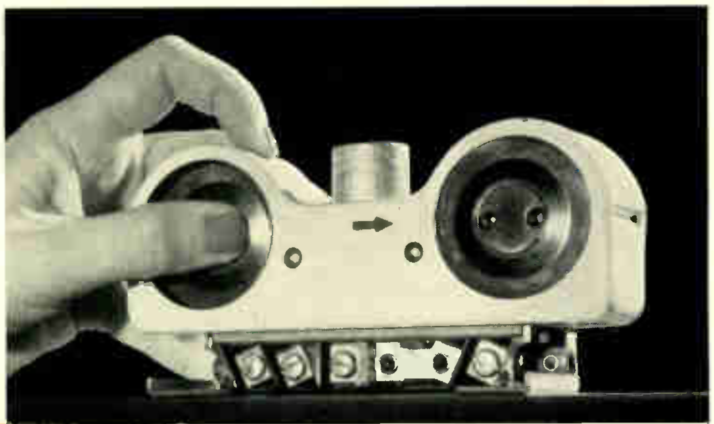
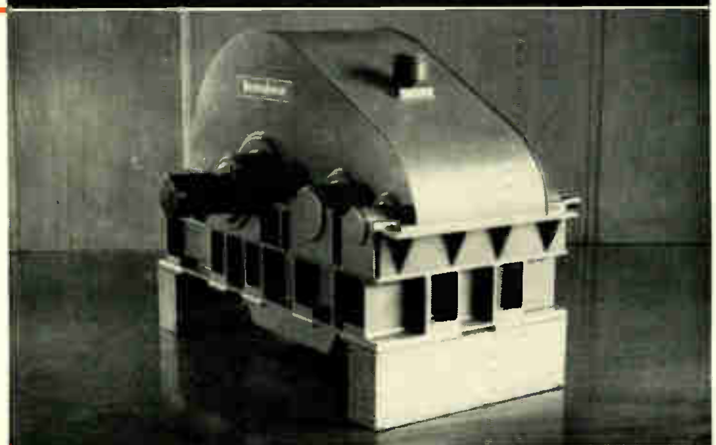
New Lampholder—A new heavy-duty steel-housed lampholder brings several improvements to fluorescent-lamp fixtures. The pin terminals of the lamp are received by a new type of receptacle flexibly positioned by springs instead of rigidly held, as is usual. Installation of the lamp is simplified and the lamp itself is positively held by lateral spring pressure instead of resting solely on the small pins. Lamps cannot fall out of the fixture. Slight variations in spacing between lampholders at opposite ends of the lamp are adjusted for by the springs and are hence no longer serious. Lampholder breakage is greatly reduced. Because the starter socket is built into and permanently wired as part of the lamp socket, installation wiring is reduced—in a typical case from 12 to 8 connection points. The possibility of electrical trouble is reduced by positive-action wiping contacts with lamp pins.



Giant Speed Reducers—At right is a model of one of four sizes of giant speed reducers for driving large conveyors, dredge cutters, ball mills, tumblers, and similar equipment. The development of these speed reducers parallels the growth of heavy-duty industrial machinery. The units are to have a range of output torques from 6800 to 15 540 pound-feet with gear ratios of 11.5 to 70.5:1, and are for use with motors rated from 200 to 1600 hp depending upon the ratio, speed, and type of duty. An important feature is the housing, which will be fabricated from beams and steel plate, resulting in smaller size and weight as compared to cast construction.

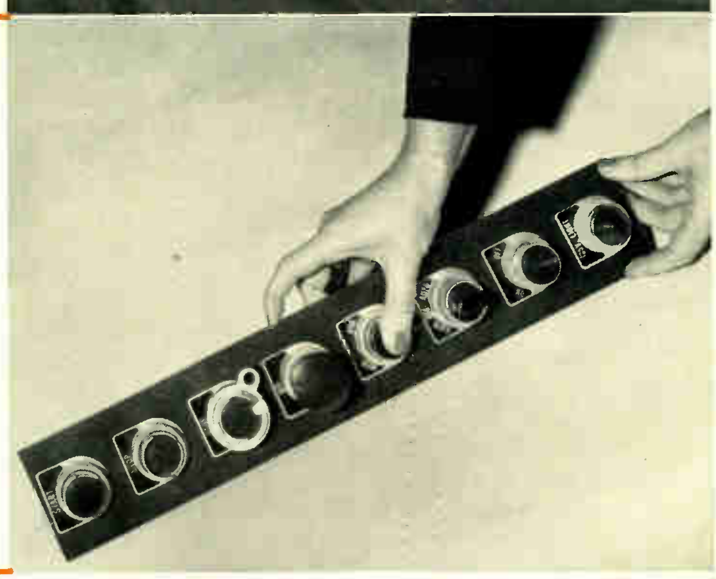


Silicone Motor—These two polyphase motors are identical in rating and construction—with a single exception: insulation. Both are rated 5 hp, 1750 rpm, totally enclosed, non-ventilated, continuous duty, and operate with comparable torque, power factor, and efficiency. The larger one, built in a size-326 frame with class-A insulation, operates at a 55-degree-C temperature rise and weighs 250 pounds. The smaller, built in a size-254 frame with Fiberglas, mica, and silicone-resin insulation and silicone bearing grease, operates at a 120-degree-C rise and weighs 145 pounds, 40 percent less. The silicone motor is used where a small, non-ventilated unit is desirable. It is built in frame sizes from 203 to 326 and is rated from ¾ to 15 hp at various speeds.

Keep Out the Oil!—Oil, coolants, cutting compounds, and water suspended in air create an undesirable atmosphere—but one in which pushbutton stations often function. Such a condition exists near machine tools, particularly high-speed grinders, lathes, and drills, where rapid motion of the grinding wheel, tool, or work throws a constant spray into the air. The pushbutton station, on which the entire operation depends, must be located near the work so that the operator can easily and quickly adjust his machine.

To prevent malfunctioning of a pushbutton due to oil, a family of heavy-duty oil-tight units has been developed. The line provides different combinations of four types of contact blocks, five types of operators, two types of operating attachments, and eight sequence cams for selector switches.

Features of the Oil-Tite pushbuttons include a rawhide seal, solid silver contacts, and accurate, die-cast, heavy-duty parts. Interchangeability and standardization have been utilized to the maximum degree, so that a relatively small number of parts are required to assemble a multiplicity of different pushbuttons. The buttons meet specifications of a committee of the automotive and machine-tool industries.



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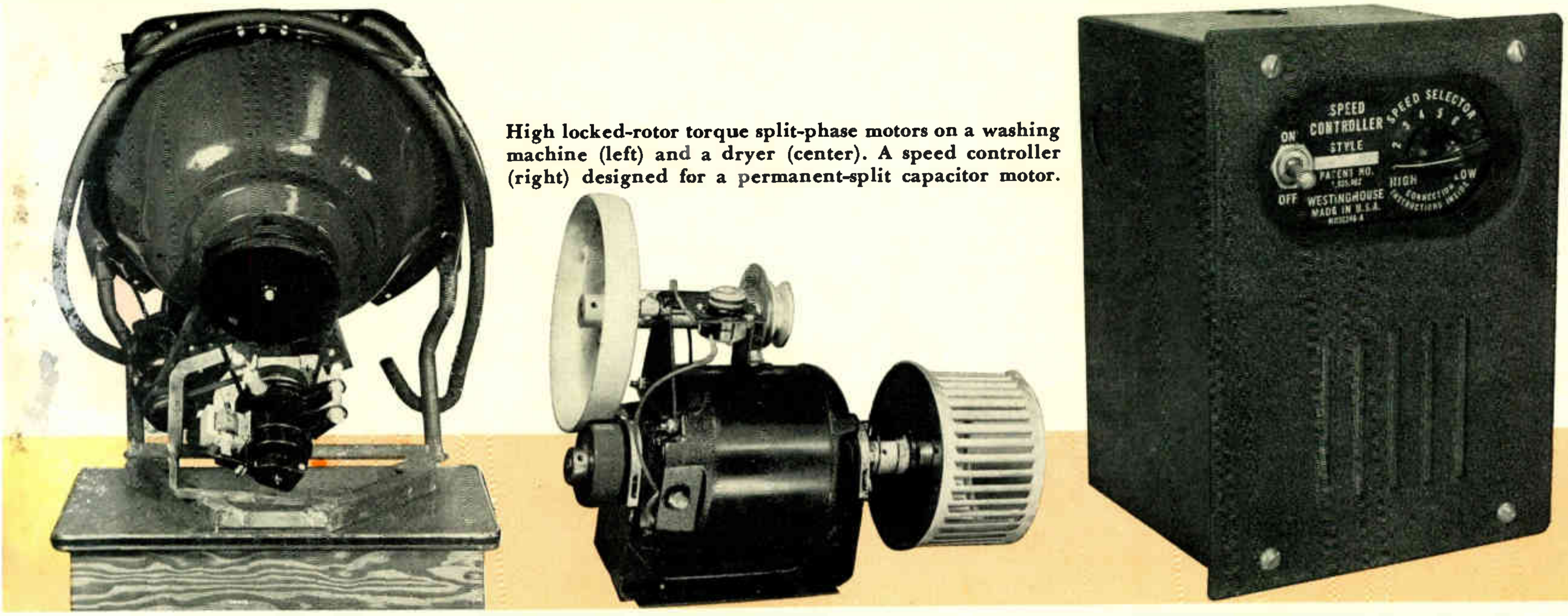

High locked-rotor torque split-phase motors on a washing machine (left) and a dryer (center). A speed controller (right) designed for a permanent-split capacitor motor.

Application of Small Motors

From the neck down, the hourly work output of the average man is worth about two cents —approximately the cost of operating an equivalent fractional-horsepower motor. Recognizing this, man's specialization has increased—he is using his brain more, and his back less. To drive the ten thousand and one machines that require only a modicum of power, a variety of types of fractional-horsepower motors are available, each best fitted for certain fields of applications.

T. E. M. Carville, *Manager, Industrial Small Motor Engineering, Westinghouse Elec. Corp., Lima, Ohio*

Industrialists point with pride to the increased mechanization of their plants, as indicated by the increase in horsepower per worker from 0.106 in 1899 to 6.25 in 1946. But a companion increase has occurred in the horsepower per housewife and per office worker as well. While the motors employed in industry are principally in integral-horsepower sizes, those in the home and office are generally in fractional or subfractional sizes. Millions of these motors are in use today, driving such machines as fans, oil burners, food mixers, washing machines, vacuum cleaners, typewriters, office machines, and many more. Each of these represents a problem in application engineering to select the smallest and least expensive motor capable of fulfilling the requirements, consistent with good engineering practice.

Factors in Application Engineering

The factors to be considered in selecting a motor for a certain application include the power supply, horsepower rating, torque requirements, limitations of locked-rotor current, overload protection, and the type of mounting and other mechanical features. These factors must be weighed carefully. By matching the requirements of the machine with the characteristics of available motors, the best and most economical drive can be easily selected.

The *power supply* generally depends on the location of the machine, as determined by its market. For small machines, the most common is 115-volt (or 115/230-volt), single-phase, 60-cycle current. Market requirements may dictate the use of universal (a-c or d-c) motors.

The *horsepower rating* depends on the torque required to drive the load, not only under normal operating conditions but also under momentary overloads. Duty cycle and frequency of starting (which may cause dangerous overheating) must be considered.

The motor must be capable of driving the machine without excessive temperature rise. Most open induction motors are rated for a 40-degree-C rise on a 40-degree-C ambient temperature. However, the nameplate may indicate a service factor, which is the percent rated load that can be carried continuously without exceeding a 50-degree rise. This service factor allows the maximum safe output to be obtained from the motor where operating conditions are fully known. Peak loads, even above the service-factor rating, can be carried for short periods if they are offset by loads below rated so that the average heating is under the 50-degree maximum. Service factor is dependent on the motor rating and is generally higher for motors of smaller ratings. In applying a motor to run at any overload, the duty cycle should be checked with the motor manufacturer.

The torque required by the appliance or machine at normal load is not the only torque to be considered. Both the locked-rotor and breakdown torques play important roles. Locked-rotor torque of the motor is the turning effort produced at the instant of starting. Direct-connected fans, for example, require very little torque to start as compared with the torque at normal speed, but compressors, on the other hand, may require a starting torque above 200-percent full-load torque. Starting torque is often the determining factor in choosing a

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cycle frequency is arbitrarily selected as the reference. The loudness level of a pure tone (in phons) equals the intensity level (in decibels) of a 1000-cycle tone that sounds equally loud. Consequently, the 72-decibel, 40-cycle note, the 30-decibel, 1000-cycle note, and the 27-decibel, 4000-cycle note all have a loudness level of 30 phons.

The phon simply defines sounds of equal loudness levels. While the phon is useful in this respect, it does not, however, indicate in any way the proportionate effect of these levels on the ear. A sound of 60-phon loudness level is not twice as loud to the ear as a sound of 30 phons nor three times as loud as a sound of 20 phons.

The relation (established by test) between loudness level in phons and proportionate loudness sensation in *loudness units* is given in Fig. 2. Loudness units are directly proportional to the response of the ear to pure tones. A sound of 100 units appears to the ear to be twice as loud as one of 50 units and ten times as loud as one of 10 units. The loudness unit is defined as the loudness sensation corresponding to a loudness level of zero phons (zero decibels at 1000 cycles).

The procedure in determining the loudness sensation of the ear to a *pure tone* of given frequency is therefore:

1—Measure intensity level in decibels.
2—Convert the decibels to phons to Fig. 1.
3—Convert from phons to loudness units by Fig. 2.

Thus, a pure 8000-cycle tone of 82-decibel intensity level has a loudness level of 70 phons and causes an ear response of 7800 loudness units. Another pure 8000-cycle note but of half the intensity level (41 decibels) has a loudness level of 30 phons and causes an ear response of 360 loudness units; thus it appears to the ear to be less than one twentieth as loud as the 82-decibel note.

If the components of a complex sound are widely separated in frequency, the ear response is proportional to the sum of the loudness units of the components. In general, however, a phenomenon known as masking is encountered to some degree. Masking is the reduction of the ear's ability to distinguish one frequency in the presence of another. The magnitude of the effect, which depends on loudness level, frequency, and frequency separation of components, is unfortunately too complex to be introduced into commercial testing equipment. Consequently, if masking is to be considered, the reading of the sound-level meter must be corrected to account for the effect of masking in reducing ear response. This correction is accomplished by multiplying the loudness units of each component by a masking coefficient, equal to or less than unity. The corrected loudness units are then added to obtain the total, which is, of course, less than if masking is neglected. The masking correction is ordinarily used only in the laboratory and not in general industrial tests where measurements need not be quite as precise as those made in laboratories due to the different nature of their use.

Glossary of Acoustical Terms

Intensity—A measure of sound energy (watts per square centimeter).

Intensity Level—A logarithmic expression of intensity relative to 10^{-16} watts per square centimeter (decibels).

Loudness Unit—A unit proportional to the response of the ear.

Sound Level—The measurement of a sound-level meter. It is a modification of intensity level made in an attempt to approximate the loudness level response of the ear to a complex sound (decibels).

Differential Sensitivity—The minimum change in intensity level perceptible to the ear (decibels).

Sound-Level Meter

The sound-level meter is the principal instrument employed in industry for measuring sound. The meters available from different manufacturers conform to standards of the American Standards Association and are practically uniform.

The sound-level meter consists essentially of a microphone, an amplifier, a variable attenuator, weighting networks, and an indicating meter calibrated directly in decibels. The microphone is usually of the nondirectional piezoelectric (crystal) type and converts the minute pressure variations of the sound wave into equivalent voltage variations. The meter range is usually 100 decibels in 10-decibel steps, which corresponds to an intensity ratio of 10 billion to 1. This is sufficient to measure most of the intensities encountered by the ear, whose range is a trillion to one.

When pure tones are measured, the curves of Figs. 1 and 2 can be employed to correlate the meter reading with ear response. This method of correlation, however, cannot be employed with a complex sound as the meter does not indicate the intensity level of each frequency separately but rather the total level of the sound. Hence, the measured intensity level of a complex sound must be correlated to ear response in another manner. This is accomplished approximately by weighting networks in the sound-level meter.

Without weighting networks the reading of the sound-level meter depends only on sound pressure or intensity and is prac-

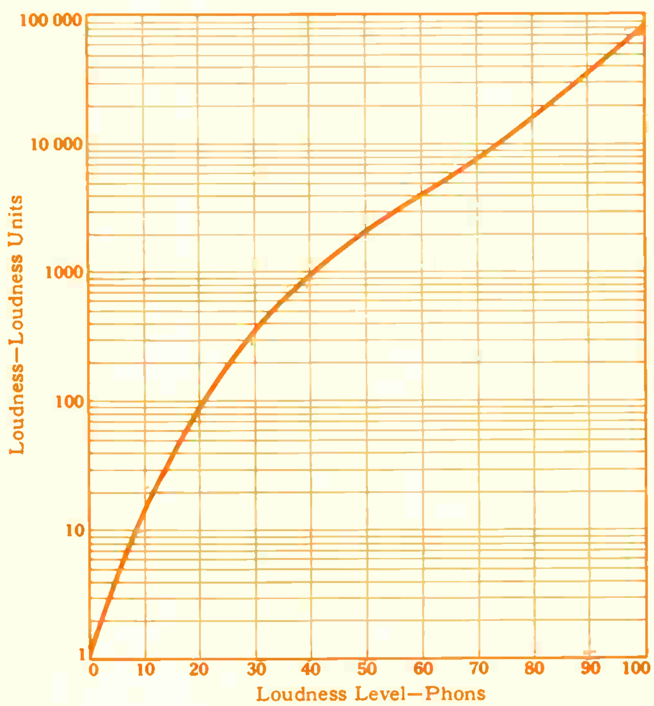

Fig. 2—This relation was determined by psychological tests.

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TABLE I—APPROXIMATE SOUND LEVELS OF FAMILIAR SOUNDS

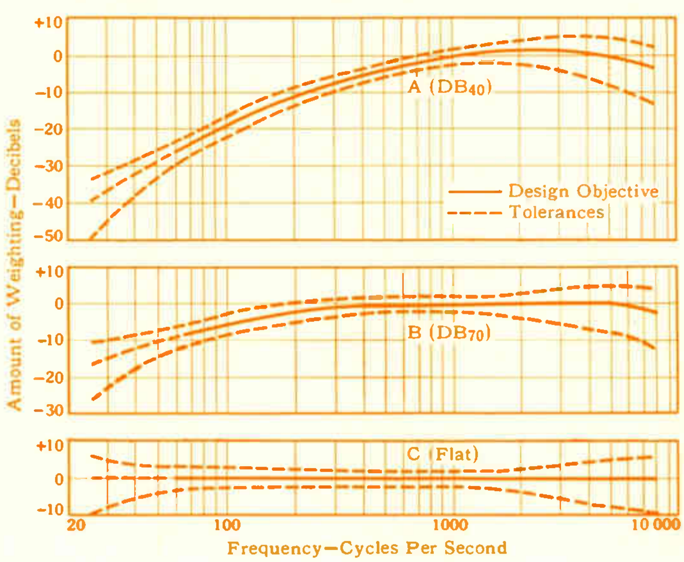
(Level db)	Sound
120	Nearby thunder
110	Boiler factory
100	Noisy factory
90	Heavy street traffic
80	Average street noise
70	Average factory
60	Department store
50	Quiet residential street
40	Quiet office
30	Quiet home
20	Quiet garden
10	Rustle of leaves

tically independent of frequency. However, ear response is very much dependent on frequency as well as intensity level, as Fig. 1 indicates. Hence, component frequencies of a complex sound are "weighted" so as to cause a meter reading equivalent to ear response. A frequency of 1000 cycles is chosen as reference. Thus, a 68-decibel, 50-cycle note (which causes the same loudness on the ear as a 30-decibel, 1000-cycle note) should be reduced in intensity from 68 to 30 decibels, or weighted −38 decibels. If such weighting networks were not used, the reading of the sound-level meter would be more than twice as great for a 68-decibel sound as for a 30-decibel sound, regardless of frequency, which is dissimilar to the response of the ear.

The amount of weighting required varies as the response of the ear—with the frequency and intensity level of each component of a complex sound. Therefore, a 50-cycle note of 68 decibels must be reduced 38 decibels, whereas a 50-cycle note of 126 decibels need be reduced only 6 decibels and a 160-cycle note of 68 decibels must be reduced 8 decibels. If weighting networks made such corrections exactly for all frequencies and intensities, the meter would indicate the exact loudness level in phons of a pure tone. However, such corrections would require an infinite number of networks, one for each intensity level at each frequency. Such an instrument would be impractical to build.

As a practical compromise, two circuits having "A" and "B" weighting networks have been standardized. These attenuate different frequencies by amounts shown in Fig. 3. The weighting curves are approximations of the 40-phon and 70-phon equal-loudness contours of Fig. 1. They have permissible manufacturing tolerances as shown by the dashed lines. Curve "C" represents the uniform or flat network of the meter and provides a minimum of weighting. For this network, zero change is ideal but some occurs because of components in the circuit other than weighting networks. Readings for the flat response correspond approximately to the actual unweighted intensity level. Pure tones can be measured on the flat circuit and then "weighted" for relative response of the ear by using Figs. 1 and 2. The "C" circuit is flat as the weighting corresponding to high levels is approximately zero. For example, the 100-phon contour in Fig. 1 does not differ materially from a straight line over a considerable portion of the frequency range.

Fig. 3—Weighting provided by the three standard networks.



The reading of the sound-level meter, Fig. 4, is neither intensity level nor loudness level. The reading is called *sound level* (decibels), which is a modification of intensity level made in an attempt to approximate ear response. It is very difficult to convert sound level of a complex sound into equivalent loudness level (phons) or loudness (loudness units) as this requires a complete analysis of each component. Such an analysis is unnecessary for most industrial work as sound level itself is a good relative indication of the amount of noise caused by a piece of equipment.

The reading of a sound-level meter depends on the weighting network used in the measurement. Hence, readings are referred to as "DB_{40}," "DB_{70}," or "Flat" to identify the weighting. The network used in a measurement is determined by standards for the type of equipment under test or selected by the operator if a standard has not been set.

When sounds occur simultaneously, their decibel values, because of their logarithmic relationship, are not added, but rather their intensities. For example, the level resulting from the addition of a 99-decibel sound to a 100-decibel sound is not 199 decibels. The corresponding intensities of the two sounds are 0.75 and 1.0 microwatt per square centimeter. These, when added, give 1.75 microwatts, which corresponds to a level of 102.5 decibels. Consequently, the addition of a 99-decibel component to an existing 100-decibel component produces an increase of 2.5 decibels. The decibels to be added to the component of higher level are plotted in Fig. 5 as a function of the decibel difference between the two levels. The sound-level meter performs this addition automatically and gives a resultant intensity level in decibels.

The problem of adding loudness levels (phons) is somewhat more complex. The meter cannot do it. Addition must be performed in terms of loudness units rather than intensities. The

Fig. 4—A typical sound-level meter for industrial measurements. Courtesy of General Radio Company.

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overall loudness level of two sounds can be obtained only by converting each component frequency into loudness units, multiplying by masking coefficients if necessary, adding, and converting the total loudness units to phons.

Significance of Sound-Level Measurements

Sound-level measurements furnish an objective basis for the comparison of apparatus noise. Although they are only approximations to loudness levels (from which proportionate loudness units can be determined), these measurements are consistent within practical limits and give as accurate an indication of relative loudness as can be obtained without the use of extremely complicated apparatus. Increasing the intensity of any or all components of a complex sound increases the weighted sound level, but the original and final readings may not be exactly proportional to the true loudness levels.

However, exact correlation between sound levels and loudness levels is unnecessary because standards are used as a basis for comparison. For example, consider a hypothetical sound source that produces a fixed group of frequencies whose intensities bear fixed ratios to each other. If the intensity of this complex sound is raised (maintaining the frequencies and ratios) in a series of steps and the sound level (on the DB_{40} network, for instance) and true loudness level are evaluated, a curve of sound level versus true loudness level can be plotted. To formulate a standard for a type of equipment producing such a complex sound, both true loudness level and sound level could be employed with equally effective results. For the same sound, the two standards would give different numerical values, related by the curve, but they would correspond to exactly the same loudness. In commercial practice, only one standard is necessary, and sound level is chosen because it is much easier to measure. A fixed frequency spectrum in which the ratios of intensities remain constant as the sound level increases thus represents an ideal condition for comparisons of sound levels. Fortunately such a condition is approached when two equipments of the same type are compared; for example, transformers with transformers, motors with motors, and turbines with turbines.

The tendency in standardizing sound levels of apparatus has been to choose the one weighting network that is most suitable for the specific type of equipment. This permits a continuous scale of comparison, which is not obtained if abrupt changes are introduced by changing weighting networks. For example, DB_{40} weighting, which is most suitable for moderate sound levels, has been selected as a standard for transformers.

Sound-level measurements of apparatus are made to permit comparison with established standards or with similar apparatus. In making such comparisons two questions are frequently encountered: one, what is the minimum change in sound level perceptible to the ear (*differential sensitivity*); and two, what is the relation between a change in sound level and the resultant change in loudness sensation of the ear. Sound levels in the DB_{40} range occur frequently in industry and hence are selected for answering these questions.

The differential sensitivity for pure tones is a function of intensity, frequency, and the rate of change of the two sounds being compared. Experimental data, some of which is plotted in Fig. 6, indicates that differential sensitivity is a minimum (smallest variation in intensity is perceptible) when intensity is changed three times a second. However, although the three-

Fig. 5—Intensity levels of sounds cannot be added.

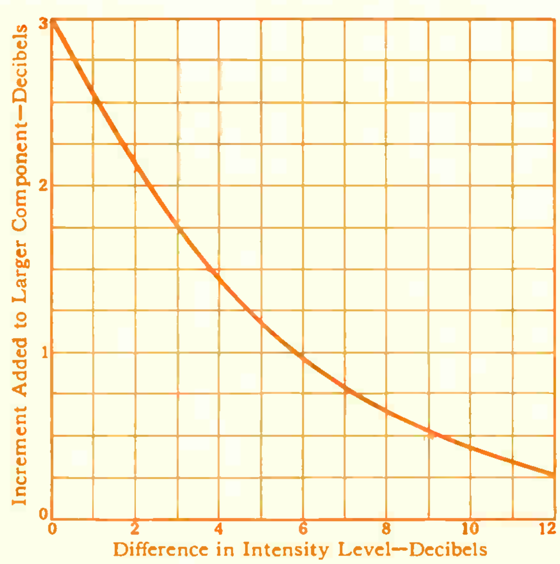


Fig. 6—Results of tests on differential sensitivity.

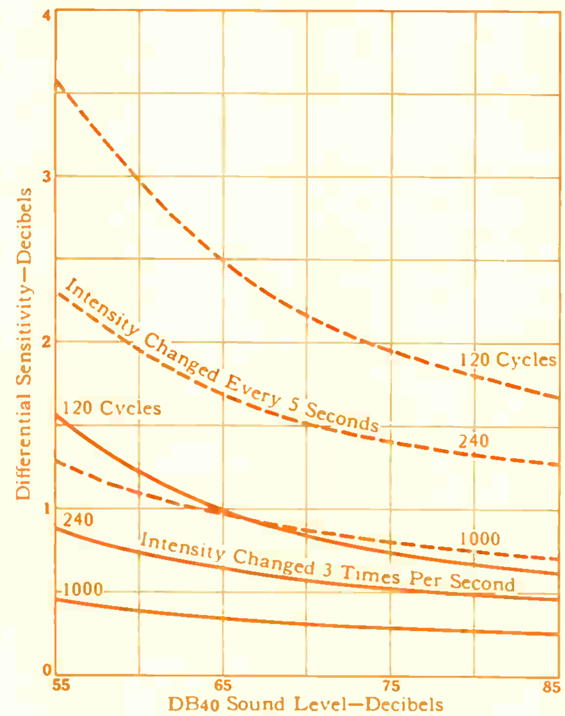
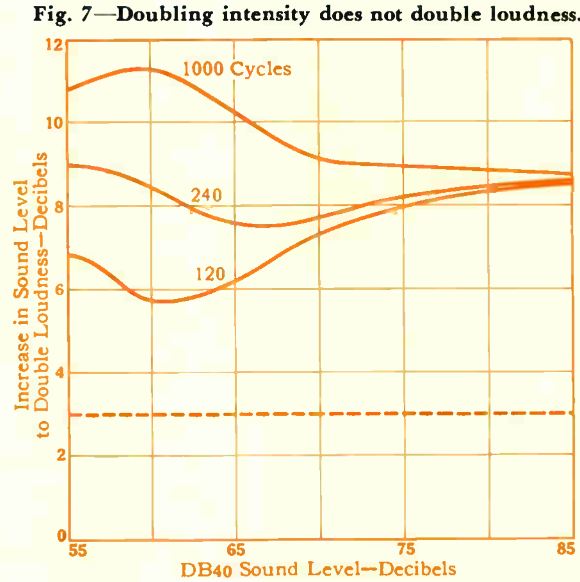


Fig. 7—Doubling intensity does not double loudness.



times-per-second variation gives information of theoretical importance, this rate of change is much too rapid to serve as a guide for practical comparisons.

In the field, comparisons of sounds of two pieces of equipment are made by switching power from one to the other or by moving from the location of one to the other. Consequently, time of change is usually between a few seconds and several minutes rather than one third of a second. Hence, similar studies were made with sound level changed every five seconds. They indicate that when intensity of a 1000-cycle note is alternated every five seconds instead of every one-third second, differential sensitivity increases roughly three times, i.e., a larger change in intensity is required for the observer to note the difference. The dashed lines in Fig. 6 are based on this approximate ratio and give some indication of the differential sensitivities that might be encountered in practical field testing. It should be noted that under usual field conditions a change in intensity of a fraction of a decibel is probably not detected by the ear.

The second question involves determination of a relation between a change in intensity level and the corresponding change in loudness sensation. An indication of this relation is the change in decibels necessary to double loudness. This information is obtained from Figs. 1 and 2, and is plotted in Fig. 7. For example, to determine the number of decibels necessary to double the loudness sensation of a 65-decibel, 1000-cycle sound, the intensity level is first converted, using Fig. 1, to phons (65). From Fig. 2, this loudness level is converted to loudness units (5900). To obtain double the loudness sensation, the number of loudness units must be doubled. This number is 11 800, which is equivalent to 75 phons or 75 decibels. Consequently, to double a 65-decibel, 1000-cycle sound, the intensity level must be increased 10 decibels. The curves of Fig. 7 indicate that at the lower sound levels of the DB_{40} range the increase necessary to double the loudness varies from approximately 7 to 11 decibels depending on frequency, but at the higher levels the increase is about 9 decibels and is practically independent of frequency. Incidentally, an increase of ten in the intensity level is equivalent to an increase of ten times in intensity itself.

The fallacy of the common assumption that loudness sensation is proportional to intensity is clearly indicated by the curves of Fig. 7. The change in intensity level caused by doubling a sound intensity is $10 \log (2I/10^{-16}) - 10 \log (I/10^{-16})$, which equals 10 log 2, or 3. Hence, if this assumption were true, loudness should be doubled by an increase in sound level of three decibels as indicated by the dashed line of Fig. 6. This is definitely not the case; a much greater increase is required to double loudness.

The relation between a change in intensity and the corresponding change in intensity level is given in Fig. 8, which is a simple logarithmic curve. If the intensity is doubled the level increases three decibels. An increase of seven decibels in the intensity level indicates that the intensity itself has been quintupled.

Conclusion

A clear understanding of the physics and psychology of sound helps clarify the concepts of sound analysis and to understand the true significance of test results. It is important to understand that the sensation of the ear is proportional to neither intensity nor intensity level.

Sound levels are an index of relative rather than absolute loudness. The sound meter is used principally to compare two similar pieces of industrial or commercial apparatus. Fortunately, the equipments usually have the same frequency components, which enhances the accuracy of the comparison.

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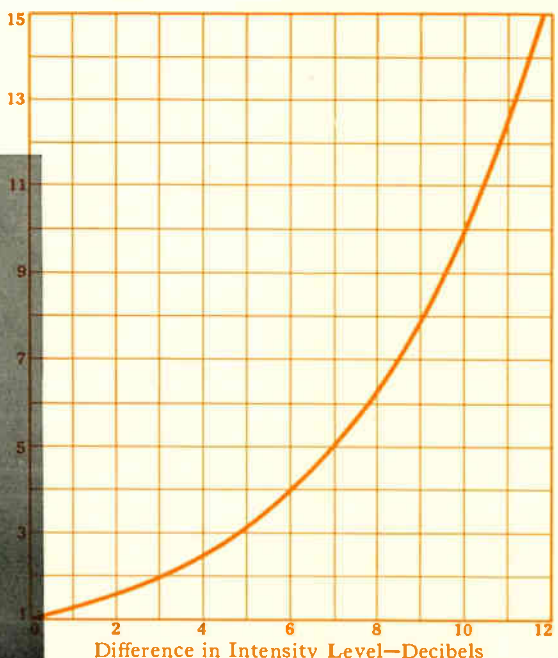

Fig. 8—The logarithmic relation between intensity ratio and intensity level.

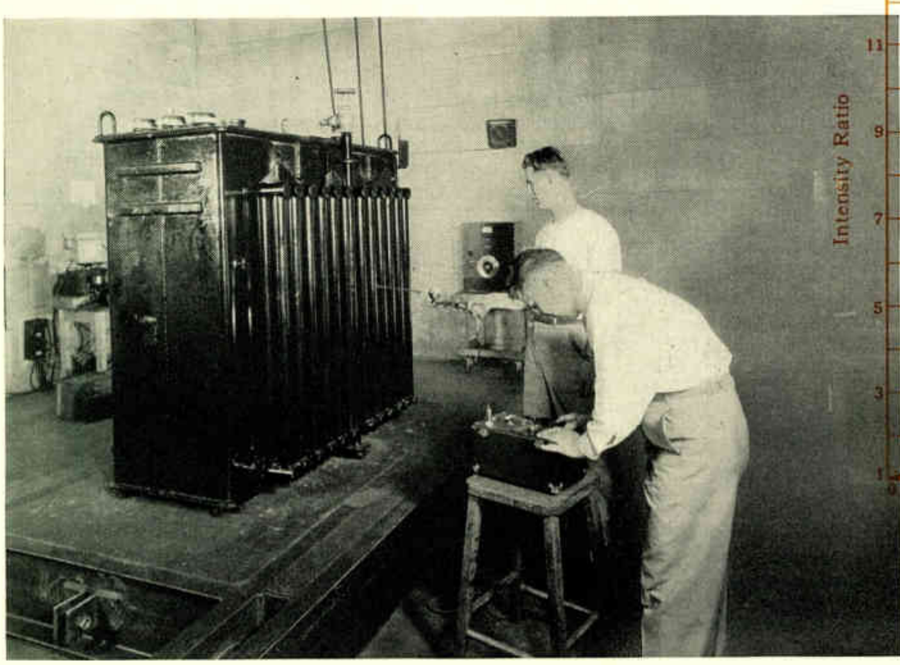

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Fig. 9—A sound-level test on a transformer.

World Radio History

Personality Profiles

A former table-tennis champion of the Lima Works team, *T. E. M. Carville* has doubled as pitcher of a baseball team and member of the YMCA volley-ball team. This athletic ability stood him in good stead a few years ago during an office picnic. The main event was chasing a greased pig, which Carville caught—not once, but twice—the second time after it escaped from its crate.

Carville graduated from the University of Maine in 1924 with a degree in electrical engineering and then joined Westinghouse. After student training he became a design engineer in the Small Motor Engineering Department, then at East Springfield, Massachusetts. In 1937 the Small Motor Division moved to Lima and in 1941 Carville became an assistant section engineer. Since then he has progressed to his present position as manager of the Industrial Small Motor Engineering Department, which he assumed in 1944.

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The engineering career of *F. B. Mead* began at an early age, 18, when he was an undergraduate at Syracuse University. He spent one summer as a plant engineer, operating and maintaining boilers and steam engines. Subsequent summers spent at other technical tasks laid a firm groundwork of engineering experience.

After graduating with a degree in electrical engineering, Mead was employed as chief draftsman and designer of a mechanical transmission company. He then joined the Canadian Westinghouse Company as a test engineer and was transferred after 18 months to the Buffalo Office as district engineer. His work since then has been a never-ending variety of application engineering problems, which have taken him to all branch offices in New York State.

• • •

Associates of *C. P. Croco* recall that when he graduated from the University of California and joined Westinghouse at East Pittsburgh in 1925, he considered the East only a stop before returning—and that he became so fascinated by the steel industry and its problems he could not leave.

Croco started in the student training course and after its completion spent two years designing large d-c motors. He transferred to the steel-mill section and then to the Pittsburgh Office as application engineer. There he served for about ten years, during which he became a recognized authority on steel-mill electrification. Croco was instrumental in speeding up rolling processes and, in 1939, helped engineer a 2500-fpm skin-pass mill, at that time a record speed. In 1943, he left Westinghouse, but returned after a year's absence as manager of the Welding Department, the position he now holds.

• • •

"Quiet, please!" has been the watchword of *S. Bennon* since he left the University of Pennsylvania in 1937 with an M.E. E. The Transformer Division grabbed him before the ink on his diploma was dry and set him to putting the mum on the mumbles of transformers. These activities were interrupted by the war when Bennon was needed to design Naval torpedoes, a task that carried him to Pearl Harbor and resulted in a new type of electric torpedo. For this, Westinghouse awarded him a silver "W," the award for outstanding accomplishment. When the war ended, Bennon returned to reducing noise levels, a project linked with his efforts at home to reduce the noise level of his two-year-old daughter. "Compared to Lois Ann," he says, "transformers are a cinch."

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As far as *John Carlson* is concerned his office in the Steam Engineering Department at South Philadelphia is little more than a place to pick up mail as he stops in between consultations on turbine applications. Our last appointment with him was sandwiched in one morning between returning from St. Louis and leaving for Jacksonville.

He has several qualifications that suit him well for his occupation. He is apparently immune to that occupational disease of the traveling man, "Pullmanitis." He loves people; he has the personality that wins friends, and he knows turbines "like a book."

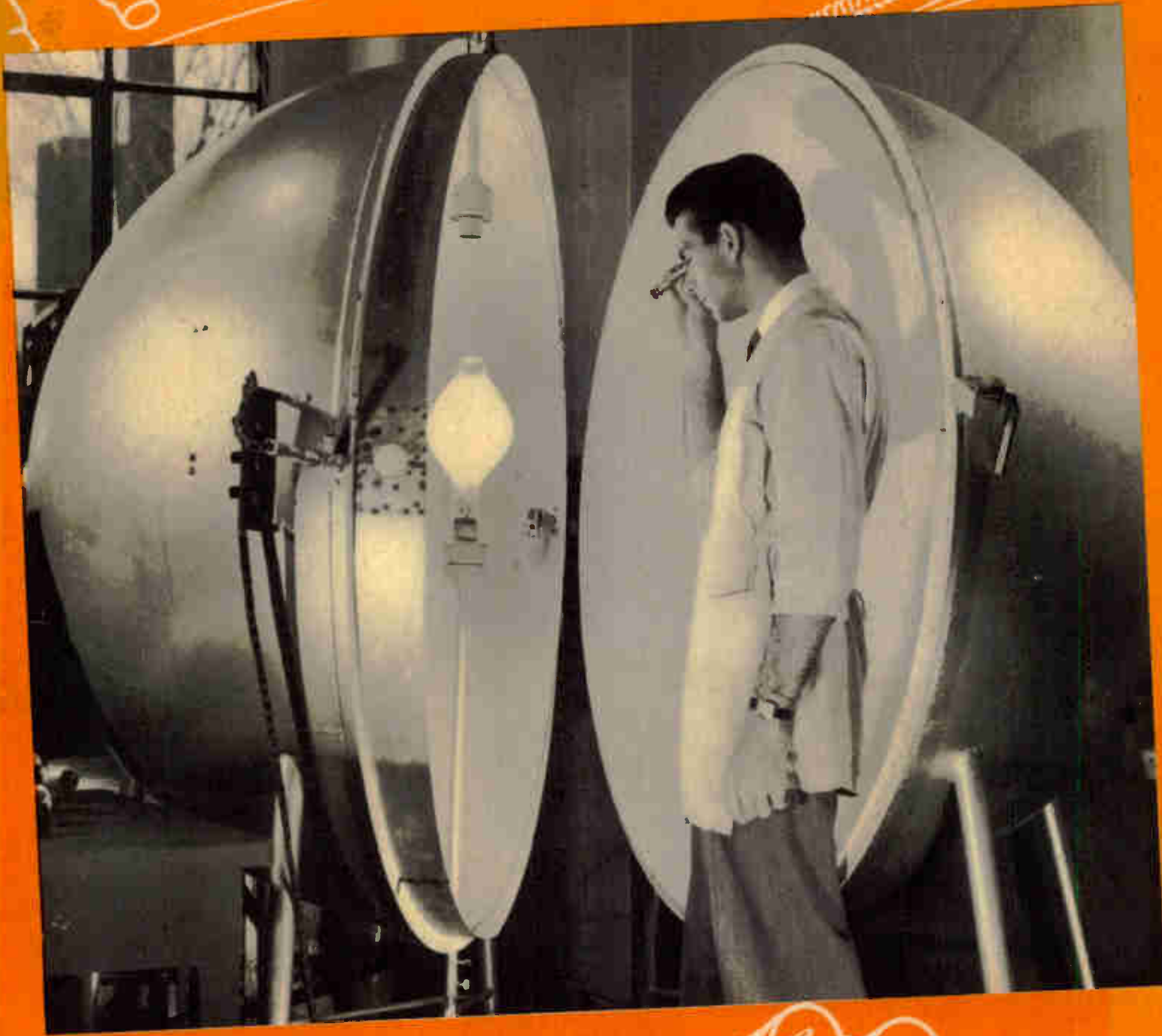
A native of Nebraska, Carlson fitted himself for his profession by studying mechanical engineering at the University of Nebraska. He remained at his alma mater another year to pick up a second degree, B.S. in Commercial Engineering, before coming to Westinghouse in 1926. His shop-training course was followed by a year and a half on electrical equipments before entering the field that has become his specialty—steam turbines. He worked first on application of small turbines and then, after 1929, on large ones. In 1947 he became manager of the Steam Division application engineering section. Carlson is well known from coast to coast for his ability to explain turbines and their performance.

• • •

The story of *A. F. Schwendner* is a little like that of the "man who came to dinner." After completing his technical education in Budapest, Hungary, he decided to obtain training in American manufacturing methods. He arrived in the United States during the depression of 1913. In 1915, after a succession of jobs that kept the "wolf" from his door, he joined Westinghouse as a tool-room machinist. During World War I he was transferred to tool design and later made foreman in a shell-manufacturing department. After that war Schwendner was put in charge of tool design in the Transformer and Large Circuit Breaker Department. By then he had decided to remain and, over 30 years later, is still actively engaged in engineering on this side of the Atlantic.

In 1920 he was transferred to the Steam Division as a designer. This gradually developed into specializing in turbine control. He showed considerable inventive capacity and before long was handling central-station turbine-control systems completely; later, he was in charge of such work for all turbine applications. At present Schwendner is an advisory engineer majoring in steam- and gas-turbine control problems.

World Radio History



MORE LIGHT, BETTER LIGHT

The new color-corrected mercury-vapor lamp is inspected for color quality with a spectroscope. A special phosphor on the pear-shaped bulb changes some of the ultraviolet to red without sacrifice of lamp efficiency. This 400-watt experimental model will also be tested in the sphere, which measures light intensity.

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