MEASURING INVISIBLES

ELECTRICAL WESTON INSTRUMENTS

WESTON ELECTRICAL INSTRUMENT CORPORATION

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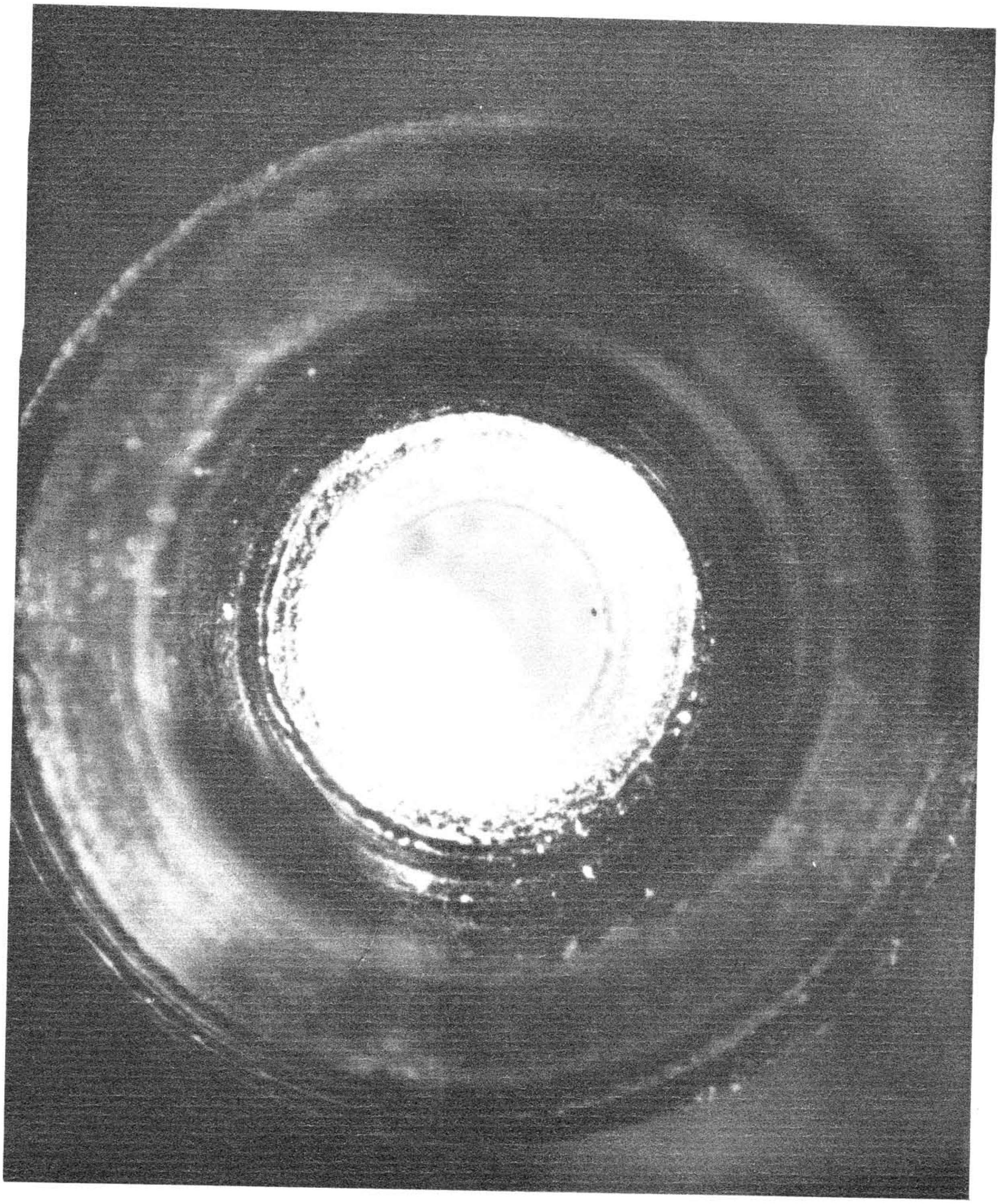
The Fifty-Year Record of the World's
Largest Manufacturer of
Electrical Measuring Instruments

WESTON ELECTRICAL INSTRUMENT CORPORATION
NEWARK · NEW JERSEY



A Weston Movement Stands in a Crater of True Sapphire . . . and with a sister jewel on its head twirls to measure electricity's pressure and flow. The pearly disc of sapphire you see above is a tiny cradle of precious stone in the end of a Weston jewel screw, here enlarged 170 times.

MEASURING INVISIBLES

... has been Weston's business for more than half a century because Edward Weston, a prodigious inventor of electrical visibles, was able to build the world's first practical yardstick for measuring the electrical current he could not see. Today the word Weston may mean Manganin to a physicist, measurement to an engineer, and film speed to a photographer.

IN 1888, a stocky, 38-year-old Englishman, who had run away from the medical career his parents had planned for him in England and who had successfully tried his hand in this country at electroplating, dynamo making, and electric lighting, made his fourth start in business. This time Edward Weston had decided to manufacture indicating electrical measuring instruments, and with three friends who put up most of the cash needed to start things, he formed in Newark, N. J., a company which has become the world's largest company dedicated solely to making such instruments. In its simplest terms, this is what the Weston Electrical Instrument Corporation has celebrated on its Golden Anniversary. As companies go, it cannot boast great size, but in contributions to electrical science in particular and to American industry in general it is among the foremost.

For Edward Weston began a business which is linked to electricity wherever and however it is used, and so automatically embraces just about every industry. His company is not making breakfast cereals or soap or silk stockings or battleships, but a means of determining the value of electrical forces used in these and countless other manufacturing processes and in the electrical trade in general. And it is obvious that without such knowledge you haven't got control, and without control you haven't got electrical power but a phenomenon, interesting, perhaps, but no more useful or reliable than lightning. A measuring instrument does not give control directly, but it will give you knowledge of how electricity performs when it is harnessed in a transformer or a motor or a lamp, and with this knowledge you can take steps to control whatever harnessing apparatus you may happen to be using.

But because measurement is one step removed from actual operation, the layman does not think of it very often. He has come to assume that electrical engineers will control their generators efficiently, that the battery in his car will stay charged, and that his electric-light bill will be right. Yet if the lights in his house flickered continuously, if the motor in his wife's refrigerator or vacuum cleaner burned out from time to time, and his car's ignition system repeatedly went dead, he would be very much aware of what electrical control means and why such things as voltmeters and ammeters and wattmeters are important. Had he taken a physics course in school he would probably remember the simple analogy between electricity and water—that volts corresponded to the pressure of water in a pipe-line and that amperes could be thought of as the rate at which that water was flowing. And he would recall that volts times

Dr. Edward Weston, Father and Founder . . . whose genius and energy envisioned, began, developed and for 36 years personally shaped, and in spirit still shapes, the Weston Electrical Instrument Corporation. Eighty years before this portrait was taken in 1930, he was born an English farm boy; a little over six years after it was taken, he died, having missed his Company's Golden Anniversary by less than two years, but having made a name for himself that no well-informed physicist or engineer or historian will forget.

Edward Faraday Weston, Son and President . . . whose first job was stoking the furnace in his father's High Street Laboratory and whose middle name perpetuates his father's reverence for England's great physicist. After his graduation from Columbia in 1900 he studied company management under his father, succeeding him in 1924 when the Company became a corporation and Dr. Weston retired. Physically, mentally and personally he has continued to grow more and more in the image of his father.

amperes equalled watts, or the amount of power supplied. Even with this meager information, it would not be difficult for him to see why a motor would run unevenly if the voltage feeding it varied continuously, and why, therefore, voltmeters and ammeters and wattmeters are essential tools for controlling the electrical forces of every day use.

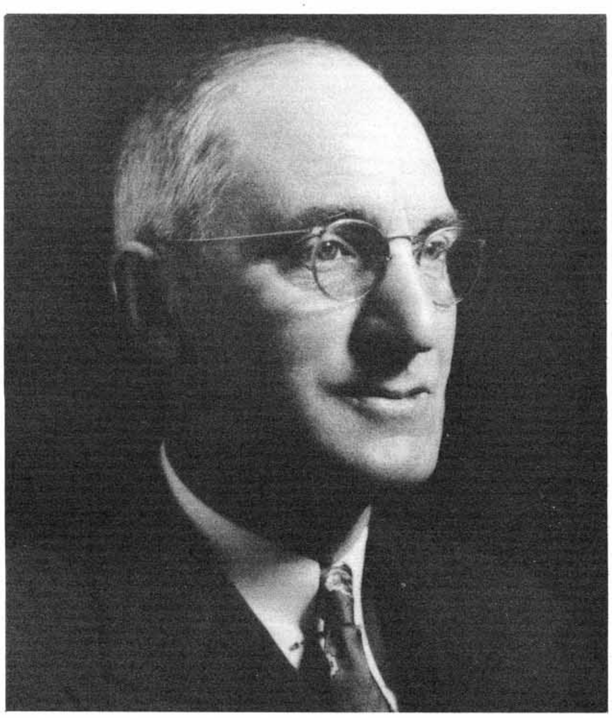
The story of Edward Weston and the company he founded is not, then, the story of huge dynamos or spectacular feats of legerdemain. It has nothing to do with bigness or sensationalism. Weston may be concerned with the measurement of millions of volts or currents as small as one millionth of an ampere or electrical cycles that oscillate a million or more times a second. But the motive prompting Weston's engineers is not simply to produce instruments that will measure these phenomena, but to develop instruments so fine that they will widen and improve the use of electricity. This policy of serving, of helping scientists prove new phenomena, engineers perfect new designs, and manufacturers produce new devices, has guided Weston from the beginning. Obviously such a policy has been profitable, but profit has not been Weston's end and aim by any means. For if it had, Weston would never have undertaken to develop so many instruments, some of which have had very limited uses, while others have been useful for only a short time before new methods and better devices have made them obsolete.

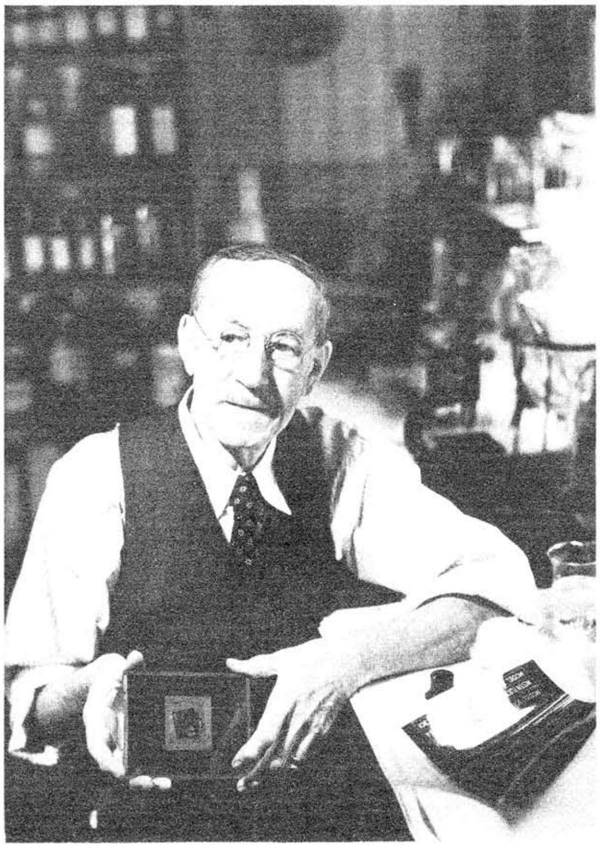
Call it crusading, if you will, but it is still true that this policy has made Weston the most expert and experienced manufacturer of electrical measuring instruments in the world. That is why the story of Weston lies in the story of its instruments and how they have helped industry control its machines by providing more and more accurate means of measuring the electrical forces that operate those machines. In its early days this meant mostly measuring the output of generators and motors. But since then electrical ways have been found to measure practically everything that revolves or gets hot or grows cold. And recently Weston has added light to its list of measurables by means of its Photronic Cell, the "electric eye" which successfully turns light directly back into the kind of power whence it came.

Yet many of Weston's most outstanding contributions to electrical measurement would not have been made at all, had Weston merely improved its instruments whenever the electrical

Vice-President Caxton Brown . . . is the son of the lawyer who protected Edward Weston's first patents on instruments in 1888. A Columbia classmate of "E. F." Weston's, he joined the Company in 1901, becoming successively Inspector in the Repair Department, Manager of the New York Office, and, in 1907, Secretary of the Company. Since that time he has been in charge of the foreign and domestic sales of Weston instruments.

Chief Engineer W. N. Goodwin, Jr. . . . is the man whom Edward Weston picked to head up his engineering staff in 1906, eight years after he joined the Company, when both his Weston record and his record as a scholar at the University of Pennsylvania attracted the founder's attention. Since then, as Director of Research, his scholarship has been reflected in nearly every major Weston contribution to electrical measurement.





William Stevens Can Remember . . . when he used to sit up all night winding armatures with Edward Weston in 1875, the year his father's firm, Stevens, Roberts & Havell, began making Weston's dynamos for electroplating. He has worked for all three Weston companies—dynamo, arc light, and instrument—and today, at 81, still serves in one of Weston's chemical laboratories.

industry improved its machines. Throughout its career, the Company has relied, not simply on supplying industry with fine instruments, but on studying, experimenting with, and introducing new, special instruments that would point the way to better electrical devices. In a word, Weston has relied on advance research. It has been a costly practice, and Weston has had a hard time knowing just when and where to "cast bread upon the waters," but it has given the Company an invaluable asset. For many of these special, new instruments have become standard in the trade, thus raising the whole performance level of electrical devices. And Weston, therefore, by having earned the reputation for pioneering new instruments, has logically become the confidential adviser to whom manufacturers have turned for help on their measurement problems.

Specifically, the results of this advance research have been a bewildering variety of instruments. Weston's catalogue today lists its models by the hundreds, many of which may have as many as 80 to 100 and some as many as 2200 variations, depending on the size or speed or output of what is to be measured. Voltmeters, ammeters, and wattmeters, the common tools for gauging electricity, account for a major part, but not all, of Weston's products. The rest of its large annual crop of instruments goes out to measure quantities as different as the time needed to beat ice cream until it thickens, the density of smoke, the speed of airplane motors, the temperature of drawing rooms or ovens or of steaming chemical vats, the life span of radio tubes, the amount of light required for an exact exposure of camera film, the sound of crashing cymbals in a Toscanini broadcast.

And if this sample assortment of measurables seems confusing to the layman, who has rarely even seen inside the meter in his own basement, the jargon and operations of the instrument maker would be incomprehensible. A glance at the design data for a Weston instrument would bring the novice face to face with algebraic equations a page long and such esoteric terms as damping, hysteresis, magnetic flux, torque, suppressed zero, micro-micro-farads, Foucault currents, lag, air gaps, Peltier effect, coercive force, and Bessel functions of the first and second order. And he would be further appalled at the curious *mélange* of material that goes into the making of a line of instruments. Weston's Purchasing Department must know how to buy many thousands of items, including practically every kind of steel, copper and aluminum made, as well as such unrelated things as sewing needles, sapphires, headless matchsticks and walrus hide, a list ranging in price from platinum iridium strips worth more than three times as much as gold to the coal for Weston's furnaces at a quarter of a cent a pound.

Weston blends all these miscellaneous materials into a line of more than 850 instruments. Although exposure meters are the Weston products now best known to the general public, the Company's reputation stands not on any one instrument so much as on its electrical achievements and contributions to science. In producing the first commercial direct-reading instrument for measuring electricity Edward Weston gave science two alloys, Constantan and Manganin, whose properties upset the existing theory of metals and their reaction to temperature

Weston's Restaurant Serves a 10c, 20c and 30c Lunch . . . to the employees who eat here for 36 minutes every noon. At these tables engineers swap anecdotes with superintendents, officers pass the butter to accountants, and guests are welcomed as one of the family. Because Weston's management thinks so much of these informal noon-time conventions, the restaurant occupies this long, light room which might otherwise have served as ideal space for making instruments.

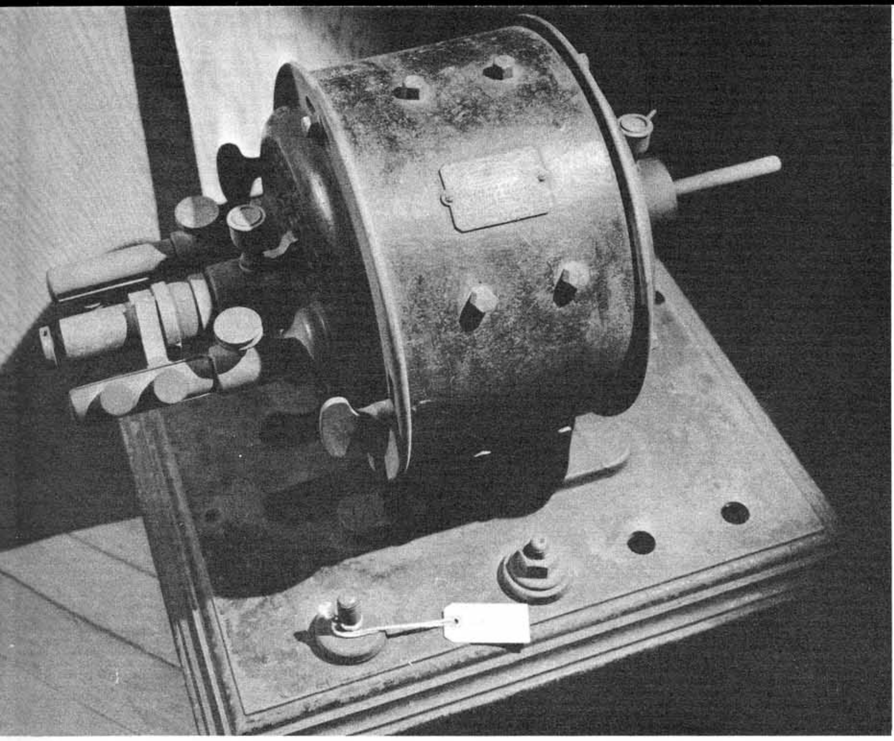
changes; he revolutionized the ideas about the life of magnets, and produced the Weston Cell, which is now the international standard of the volt. For these and countless other improvements and inventions which Weston and the engineers who carried on his work have made in the science of electricity, Weston instruments are honored.

Because its instruments completely cover the indicating instrument field, Weston has, besides the big electrical manufacturers, a large number of smaller companies to compete with, of which only about ten are makers of staple instruments like voltmeters, ammeters and wattmeters. But none of its competitors begins to cover the field as completely, most of them concentrating on a few instruments, generally those most commercially profitable. That Weston has been able to stay out in front is proof of something that doesn't appear in its balance sheet. It is what might vaguely be called the scientific spirit.

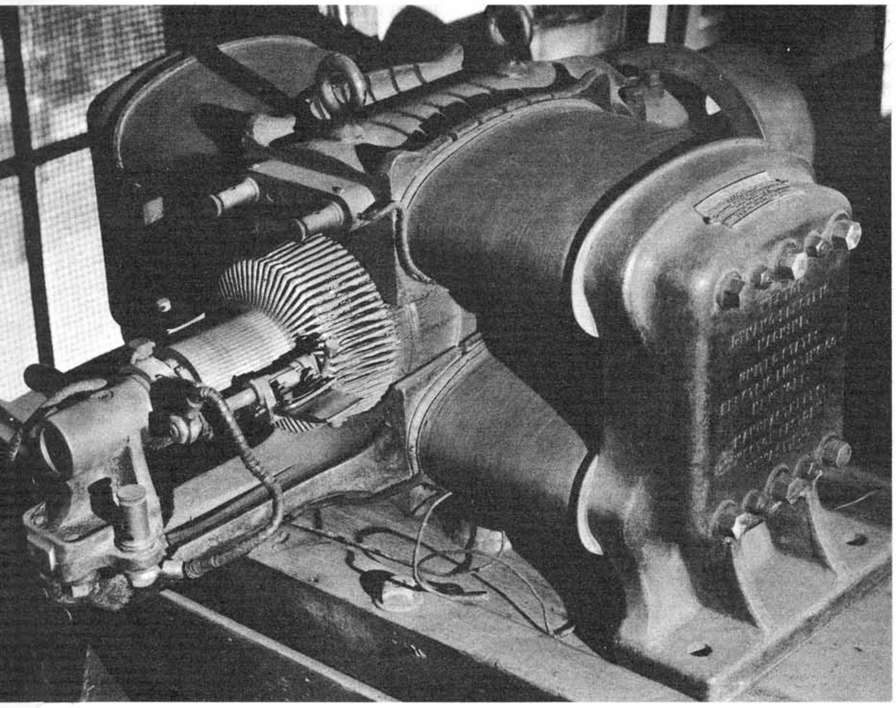
Go into the engineering departments of this Company and you will find men who could not tell you how many instruments Weston sells, or how much such and such a model costs to build, but who could tell you, if they would, for example, why Weston makes much of its own wire, and all its important testing tools; and why the thickness of the springs it makes must be accurate to 1/100,000 of an inch. This care for accuracy, for applying laboratory precision to manufacturing methods, comes close to explaining Weston's position in its field. For it follows naturally that such methods will not only produce superior instruments, but will also attract engineers who are more interested in improving those instruments than in contriving cheaper ones for the sake of the market's demands. In thus glorifying craftsmanship Weston has followed the precepts of its founder who retired from the electric-light business when he saw that the men he was working for were more concerned with profits than with improvements. And both the stability of Weston's earnings and the Company's competitive standing are largely to be accounted for by precisely this fact—that any compromise with perfection undertaken for immediate gain might ultimately impair the sales value of Weston's unique stock in trade.

It is therefore in Weston's methods and in the instruments themselves that the Company is best appreciated. It is these which both reflect its history and make its present position what it is. They make the story of Weston not merely a narrative of business growth but one of inventing and giving to the world more and more different products. And they tie the early work of Edward Weston to that of Weston's staff of engineers today. It will thus be possible to follow Weston's progress and contribution to industry in terms of the instruments that have come out of its laboratories. Not in a technical description of them—although for those who can grasp their function the picture will be more impressive—but to follow the succession of new instruments as an indication of what Weston is.

But in order to understand the why as well as the what of Weston, we will have to go back to that stocky Englishman who began it all. For 37 years Edward Weston ran his company the way he wanted it run and when he retired in 1924 he left it in charge of a son whom he had been grooming for the job since 1900. In 1936, at the age of 86, he died, having been honored during his life with the Perkins Medal, the Lamme Medal, the Elliott Cresson and

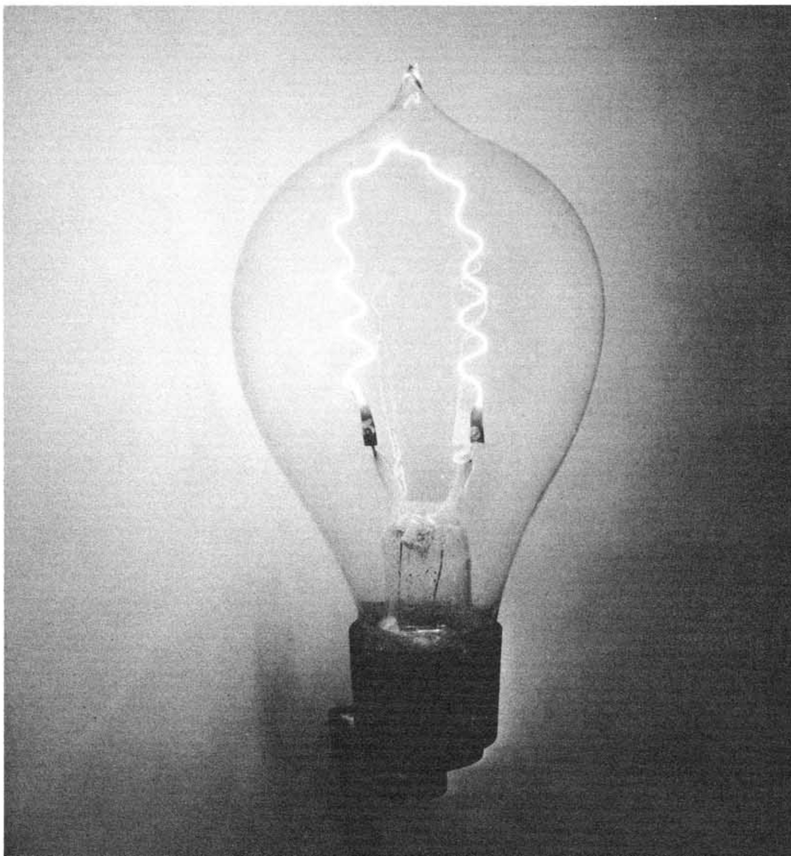


A Plating Dynamo



. . . and a Lighting Dynamo

. . . and a Lamp



. . . were three of Edward Weston's greatest inventions between 1875 and 1886. The first dynamo completely changed the plating industry. The second dynamo helped to make electric arc lighting an industrial reality. And the third invention, the lamp, with Weston's Tamidine filament, made incandescent lighting a practical possibility. (From Tamidine have come both the rayon and cellophane industries.) Together, these three Weston contributions were the prelude to the Weston instrument at the top of the next page.

Model One, Number One . . . This brass encased voltmeter, the first Weston instrument, now rests in the Newark College of Engineering's Weston museum along with the other historical items shown on the previous page. But similar ancient Model Ones are still in use in the laboratories of universities, public utilities and manufacturing plants throughout the world. Prized as historic, many of these early instruments are nevertheless still capable of their original accuracy of ¼ of 1 per cent.

Franklin Medals of Philadelphia's Franklin Institute, and the American Electro-Chemical Society's Medal for his contributions to electrochemistry, as well as with doctorates from Princeton, Stevens, McGill and the University of Pennsylvania. He was a charter member of the American Institute of Electrical Engineers and its President in 1888–89. There are 309 patents filed under his name in the Patent Office at Washington, and at the time of his death he ranked eighth in the list of living American inventors. But to the world at large the name of Weston means little, partly because many of his inventions are too technical to capture the public imagination. Yet many of Weston's contributions to the electrical art—for example, his work on the incandescent lamp filament—are by way of being scientific milestones. And, as a glance at the list on page 15 will readily show, many of Edward Weston's achievements mark him clearly as an electrical pioneer.

FARM BOY TO DOCTOR TO AMERICA

Edward Weston was born on May 9, 1850, in a brick farmhouse near the small town of Oswestry some 150 miles northwest of London. His grandfather was a well-to-do Shropshire farmer and his father was a mechanic who was just beginning to acquire a reputation. To those who like to trace the hereditary traits of great inventors, therefore, Edward Weston's background offers nothing particularly startling. Yet a love of thoroughness and an acute curiosity, the two traits that eventually turned him into an inventor, began to crop out in young Weston shortly after the family moved to Wolverhampton, a typical English manufacturing town, a home of steel and iron companies, foundries and gas works. Here the nine-year-old boy saw things which excited him. And simultaneously he was stirred by what he was learning in school about electricity and the scientists who had worked to define its laws—Ampère the great

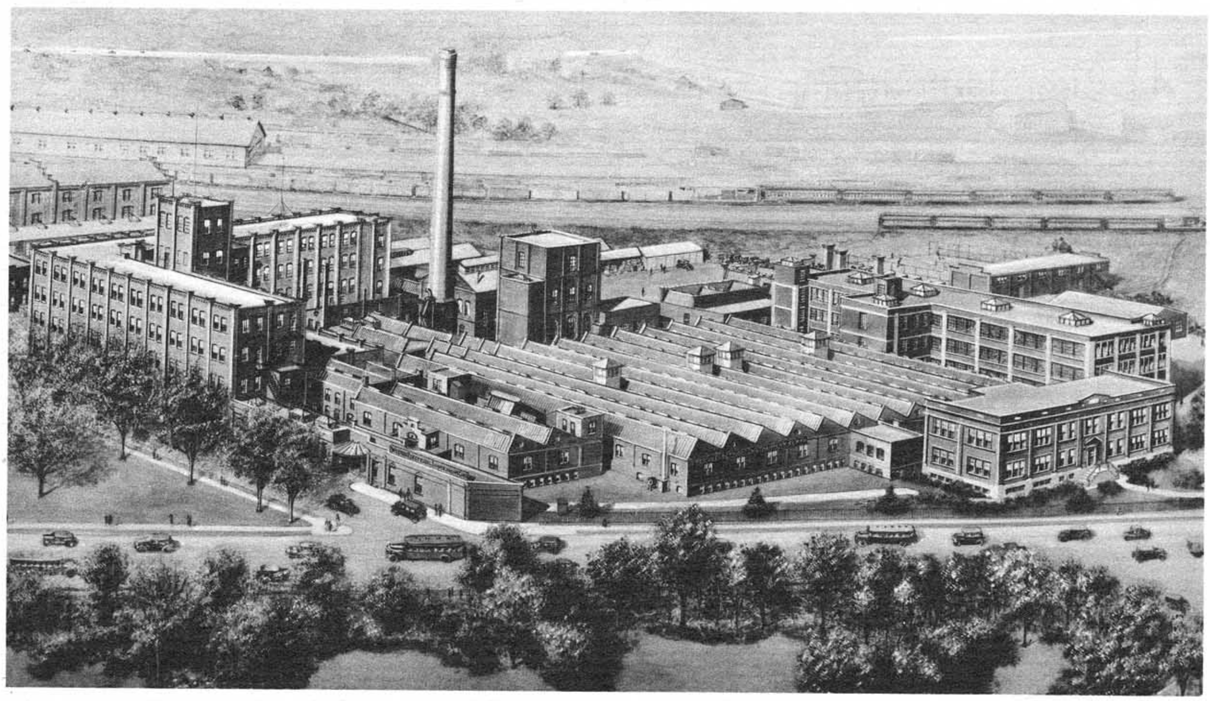
The Birthplace: Weston's High Street Laboratory, 1888-95

William Street Factory: 1895-1900

French physicist, Volta the Italian, Watt the Scotchman, Oersted the Dane, Gauss the German, and England's Faraday.

Faraday excited him the most, for his discoveries appealed both to Weston's curiosity about electricity and his liking for chemistry. Step by step the schoolboy taught himself the reason behind his idol's precepts, carrying out textbook experiments at home with glass jars, sulphuric acid and small pieces of copper and carbon. But in spite of their son's enthusiasm for electricity, Weston's parents placed him in the hands of a local doctor as a medical apprentice. Obediently, Weston stuck it out for three years, and then, convinced that medicine was not an exact science, he left for London where he hoped his chemistry and electricity might be worth something to him.

Going down on the train, however, an American tourist regaled Weston with his story of the wonders of his land, the opportunities which awaited, the fortunes to be made. To the



Weston's Newark Plant Today: 15 Buildings on 12 Acres unsophisticated lad from Wolverhampton, the story made England seem like a nation of thwarted enterprise, and after a few weeks of job hunting in London he was ready to believe it. So he took a chance on the American's advice and promptly spent practically all the money he had left for a steamship ticket for New York.

PLATING TO DYNAMOS TO THE HOT WHITE LIGHTS

Weston landed in New York in May 1870, having just passed his twentieth birthday and with nothing more tangible to go on than some letters of recommendation his friends had given him. One of these got him his first job, which was making up photographic wet plates for Wm. H. Murdock & Company where he learned a good deal about collodion, that thick syrup of dissolved cellulose which was used as a base to hold the light-sensitive salts of the wet plate. But chemistry alone did not satisfy him, and after a few months he succeeded, through the medium of a want-ad, in landing a job with the American Nickel Plating Company.

For most of the next six years Weston was occupied with the problems of electroplating and from the very start he began to give evidence of his inventive abilities. He worked out a plating dip which would remove the scarred film of nickel from old pieces without damaging the original surface of the article; and he devised a method for depositing nickel electrically so that it was malleable afterwards, something no one had been able to accomplish previously. Then in 1872 he formed a nickelplating partnership with a Mr. Harris, which prospered possibly because the claim appearing on the firm's billheads—"We guarantee our nickel not to strip or peel"—was so unusual for the trade.

But the most important outcome of the Harris and Weston tie-up was the machine Weston devised to provide current for electroplating in place of the troublesome, clumsy batteries then in use. The possibility of such dynamo-electric machines as a steady source of electrical current had been demonstrated experimentally by other inventors, notably Siemens and Gramme in Europe. But Weston was among the very first to apply the dynamo to electroplating and he has been recognized as the man who "placed the art of electroplating on a really scientific footing."

By the time he was 26 Weston was a full-fledged inventor with the first patent on the rational construction of dynamos to his credit. At 27 he was running the country's first commercial dynamo factory in an old abandoned Jewish Synagogue on Newark's Washington Street. In addition, in the Spring of 1877, shortly before the Weston Dynamo Electric Machine Company was organized, he had given a demonstrated lecture on the carbon arc light and later had mounted a light at the corner of Newark's Washington and Market Streets, an event which has been recorded as the first public exhibition of an arc light in this country. And shortly thereafter he took the current generated by one dynamo and fed it to a second dynamo

EDWARD WESTON—1850-1936

NO biographer has yet chosen to tell the story of Edward Weston's life and his contributions to electrical science. Like that of many other great inventors his work remains buried in the papers and reports and patents of the 19th century, unknown to a public which for years has read of the careers and findings of such men as Fulton, Marconi, Edison, Westinghouse and the Wright brothers. And no attempt has been made in these pages to do more than sketch in the outline of Weston's life, suggesting his accomplishments rather than fully describing them for the sake of future historians of this country's inventions and inventors. But for those who are interested in scientific pioneers, the following list of 25 Weston achievements will serve to show the originality of the man whose name now appears on 309 patents in the United States Patent Office.

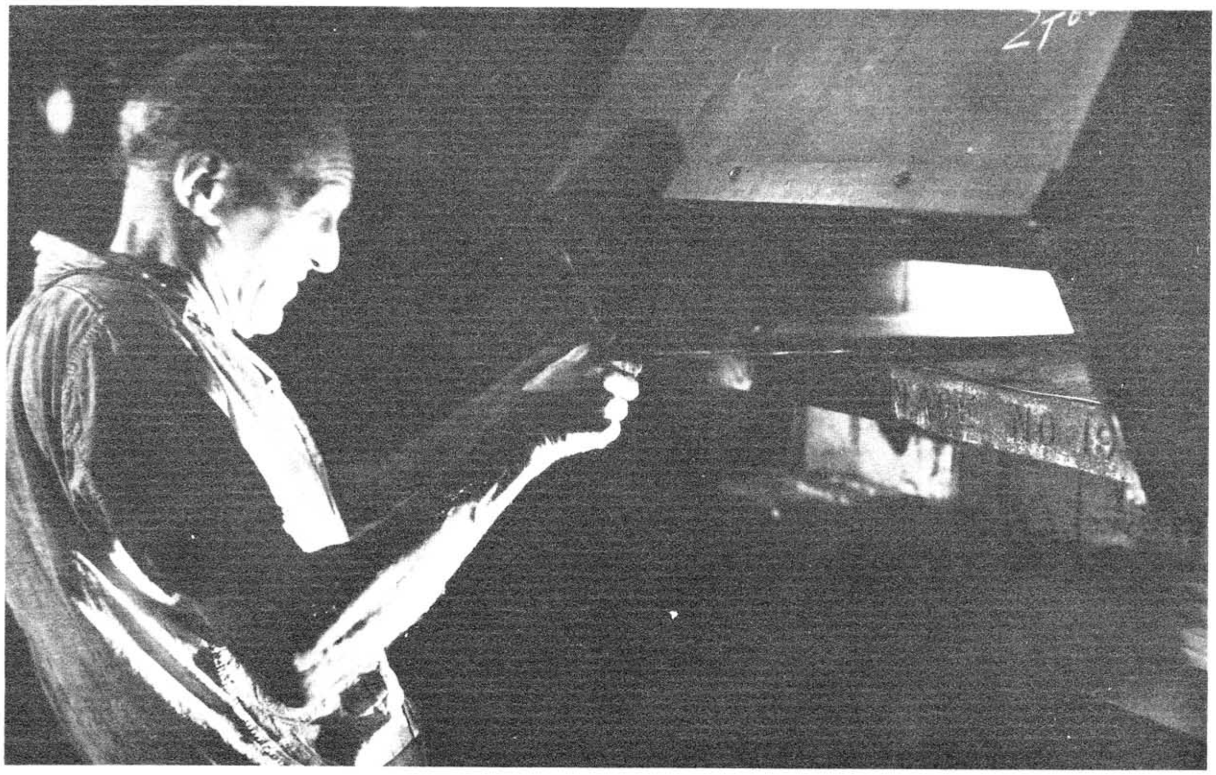
Edward Weston was the man who:

1. Applied the dynamo to electroplating (1872).
2. Patented an anode for making malleable plated nickel (1875).
3. Patented the rational construction of dynamos (1876).
4. Patented laminated pole pieces and cores for dynamos, raising their efficiency from about 45 per cent to 85 per cent (1875).
5. Gave a public exhibition of arc lighting in the United States (1877).
6. Used the arc light for general lighting purposes (1877).
7. Opened a commercial arc light factory in the United States (1880).
8. Used a soft metal core for arc light carbons (1878).
9. Copperplated the ends of arc light carbons (1878).
10. Used an electric arc furnace industrially in the United States (1875).
11. Used the dynamo as an electric motor for industrial purposes (1878).
12. Made a successful homogeneous carbon lamp filament (1885).
13. Cured weak spots in carbon lamp filaments with hydrocarbon flashing process (1885).
14. Made nitrocellulose into pure fiberless cellulose (1885).
15. Made a truly permanent magnet (1887).
16. Compounded a German Silver alloy containing 30 per cent nickel (1887).
17. Made a metal having a negative temperature co-efficient (1887).
18. Made a metal having an extremely low temperature co-efficient (1887).
19. Made an aluminum alloy which could be drawn to very thin tubes (1887).
20. Used a metal frame for damping the motion of moving coils (1887).
21. Made a commercial, direct-reading electrical measuring instrument (1888).
22. Used the shunt circuit (1893).
23. Made a stable cell for use as a secondary standard of the volt (1893).
24. Developed the magnetic drag-type speedometer (1885).
25. Made an ammeter for use with automobile starting batteries (1911).

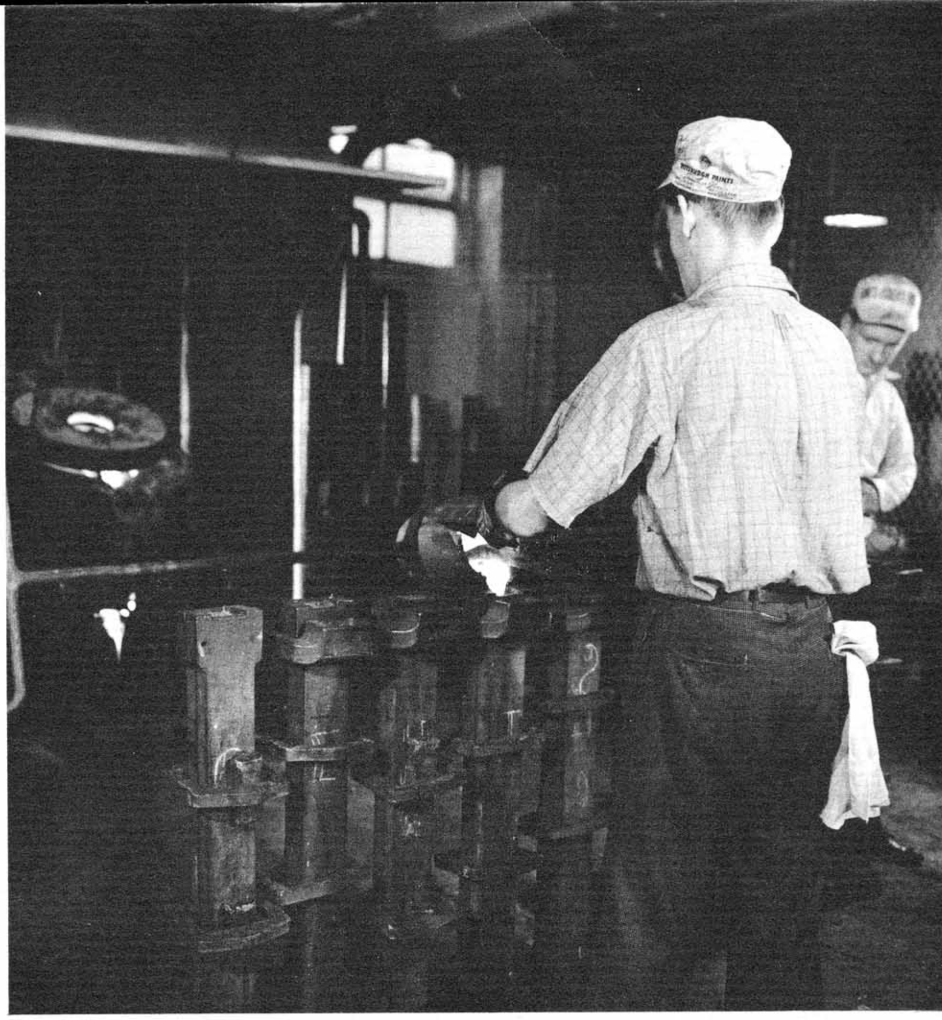
which thereupon became a motor that he used to do some of the work in his shop, thus acquiring another historical honor for himself as possibly the first man to apply the electric current as a means of power for industrial purposes.

At the time, however, it was the arc lighting field that looked the most promising, and in 1880 Weston formally organized the Weston Electric Lighting Company, putting himself squarely into a race with a horde of inventors and speculators, all trying to discover and monopolize the best means of selling electric light to the public. Weston lights were installed

Weston's Raw Materials Are Suspect . . . until they have passed the rigid tests Weston puts them to. Most suspect of all are the steels purchased for the magnets that are used in direct current instruments. Here you see some samples being given the permeameter test to discover whether the steel will permanently retain the magnetism it will later receive. But ever since Edward Weston first showed the world in 1888 how to endow a magnet with perpetual life, Weston engineers have worked and sweated over other peculiarities of magnet steels, like coercive force and residual flux, forging them and "aging" them with heat so they would hold their magnetism indefinitely, and testing and grinding and reheating and re-testing for further strength, and certain immortality.



Forging an Instrument's Backbone . . . Once the engineers have approved the steel bars for Weston's magnets, they are furnace-heated to an orange softness, then suddenly bent into flattened horseshoes, semi-circles or U-shapes according to their particular instrumental destinies. But a Weston magnet may also be cast from a mold, or built up in pre-shaped layers stamped from sheets of steel.



Pouring Manganin, Weston's Gift to Science . . . Of the four alloys which Edward Weston compounded in 1887 to make his instruments as nearly errorless as he could get them, Manganin and Constantan astounded physicists the most. Both did something no metal was supposed to do: Constantan actually grew less resistant to current the hotter it got, while Manganin scarcely changed at all with changes in temperature.

in shops, warehouses and factories around New York City, as well as in large resort hotels like the one at Rockaway Beach, Long Island. The Company's high point came in 1883 when it was awarded a contract to string four lines of lights across the newly opened Brooklyn Bridge. Since the Bridge was by far the highest structure in New York at the time, at night its rows of suspended Weston arc lamps were one of the town's spectacles and people would go downtown just to look at them hanging there in the dark sky above the East River.

THE GREAT FILAMENT CASE

By the middle of 1884 Weston had swelled his list of patents to 139, covering a total of fifteen classifications. To those on plating and dynamos and motors he had added 13 patents on arc lights alone within two years, as well as others on underground cables, distributing systems, switches, meters and circuit indicators, air pumps, batteries, incandescent lamps, safety fuses and light fixtures. But Weston's two final inventions in the field of electric lighting marked him as a truly great inventor, one who did a tremendous lot to make the incandescent lamp a workable reality.

For 25 years these two inventions—the hydrocarbon flashing process and the synthetic homogeneous lamp filament—remained the essential principles of incandescent lamp manufacture, and without them, in fact, no successful carbon lamp was ever made. (The tungsten filaments of today's lamps did not arrive until 1911.) Weston made these discoveries while he was the Chief Electrician for the United States Electric Lighting Company, which firm had absorbed the Weston Electric Lighting Company lock, stock and barrel in 1884. The ideas for both inventions came from his memory. He hit upon the hydrocarbon flashing process by recalling Wolverhampton's gas stills in which he had foraged for carbon for his home-made batteries.

The densest carbon, he remembered, had been deposited where the hydrocarbon gas had been the hottest in the stills. As early as 1877 he had taken filaments made from powdered coal, coke or graphite molded and carbonized into fine strips, and had tried heating them in hydrocarbon gas by shooting a high current through them several times. Afterwards he found that they were covered with a shiny film of carbon which was densest just where the filament had been the hottest, *i.e.*, at its weakest spots. The flashing process greatly improved the lamps of the United States Electric Lighting Company, but the filaments themselves, although strengthened, were designed for low voltage currents and could not stand the 110 volts which the new lighting generators were producing. The real problem, therefore—how to make a strong homogeneous carbon filament—remained unsolved.

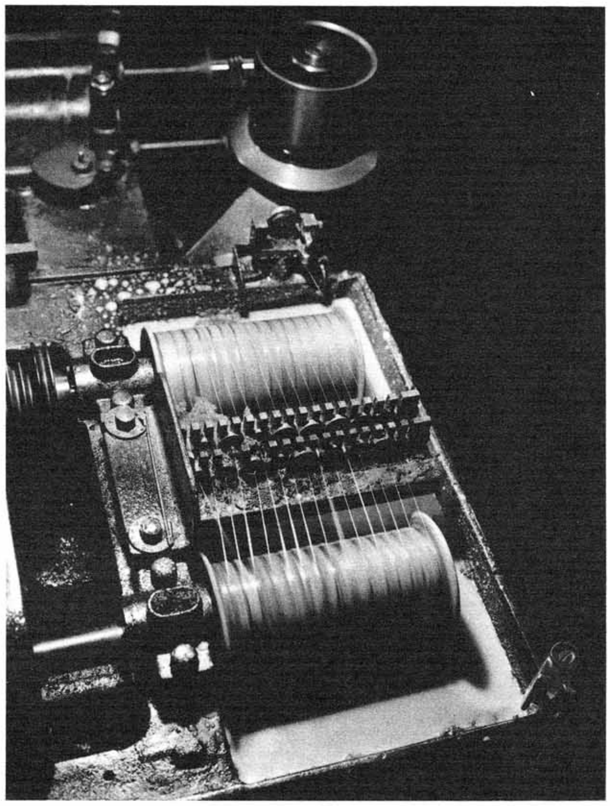
Once more Weston's memory gave him the answer. Fourteen years before, in Murdock's photographic shop, he had used collodion on wet plates, and he now recalled its clear formless characteristics. But from his chemistry he knew he could not carbonize dried strips of collodion because it was nothing more than dissolved nitrocellulose, or guncotton, and the nitrogen and oxygen in it would have burned the strips to nothing when they were pressed and heated in the filament molds. What he wanted—and found—was a chemical process by which to dissolve cellulose fibers and regenerate them into plastic substance less combustible than the nitrocellulose. The result was practically pure slow-burning cellulose which when treated with various oils could be rolled into thin sheets. From these, strips were punched out in a press and carbonized into ductile lamp filaments that were more resistant to electrical current and hence could be made thicker and stronger than other carbon filaments on the market. Whatever slight weaknesses did appear were easily corrected by the flashing process.

Weston called his substance Tamadine, and the process itself later helped to make possible the entire rayon and cellophane industries based upon converting the cellulose in plant life into sheets and filaments. And with the Tamadine filament the United States Electric Lighting Company's lamp soon passed all its competitors. In fact, it was obviously so superior that the two biggest lighting interests, Edison and Westinghouse, went after the United States Electric Lighting Company hammer and tongs. "The Great Filament Case" dragged on for years and before it was decided in 1892 Westinghouse bought out the United States Electric Lighting Company.

FAREWELL TO LAMPS

The quarrel over the incandescent lamp, however, did not occupy Weston for long. By July, 1886, his curiosity about ways of measuring electricity and his dissatisfaction with the United States Electric Lighting Company's purposes had combined and grown to a point where he had to do something about them. What he did was to resign his job as Chief Electrician for the company. That took care of the dissatisfaction. But the curiosity had to wait, for a study of electrical measuring methods required first of all a final decision on his part to devote all his time to it, and second, a much more complete laboratory than any he had yet worked in. Moreover, besides his wife he now had two sons to support and although he had earned enough in these last few years to allow him to buy a good-sized house in Newark, he wasn't yet ready to retire

Control From the Source . . . Weston draws its own special alloy wire on a battery of machines like this that squeeze it down into the thin threads that will later go into Weston's instruments. Other manufacturers could do this for Weston, but if they did Weston would not have the control over the treatment its wire receives, control that goes back to a wire's beginnings and makes sure that as it grows thinner it also acquires the specific texture Weston demands.



to a life of scientific, but profitless, research. Consequently for the next year or so he continued in the lighting industry as a patent expert, selling his advice to several firms for an annual fee.

But one day he went to Philadelphia to test a dynamo at Franklin Institute and when he returned, a week later, he had decided once and for all to do something about measuring electricity. As far as this particular test was concerned, it had not been any harder to complete than usual. But the usual testing routine at that time was precisely what exasperated Weston and made up his mind. He had used the most accurate instrument then available, a tangent galvanometer. But so many things could go wrong in the week it took to prepare for the test that an accurate reading was almost an act of God; even people walking by with steel eyelets in their derbies or hobnails in their shoes could throw readings off. And then the intensity of the earth's magnetism had to be measured, and since this can vary continuously—and very violently during a magnetic storm—the final answer would be wrong unless all readings had been made at approximately the same instant. What with these and many other chances for error, taking a week to measure a dynamo's efficiency was a good average performance for the year 1886.

To Weston, however, the experience was highly annoying, and shortly after he got back to Newark he hired a builder to start putting up a private laboratory in his back yard. When it was finished, this two-story brick structure, stocked with the most up-to-date tools for physical, chemical and metallurgical research, constituted one of the most elaborate private workshops in existence, a laboratory which the *Scientific American*, in its issue of November 5, 1887, hailed as something on the order of a house of wonder.

All that is left today—a small gas engine, some early models and testing apparatus, and Weston's library of scientific manuals—can be seen at the Newark College of Engineering that

Weston helped to found in 1885. The mechanical exhibits, like most historical relics, today seem more interesting than remarkable, but the extensive library is impressive since it illustrates clearly that although there may have been a dearth of instruments in 1887, there were plenty of physicists working in the same field Weston had chosen. Abroad in several countries notable experimental work was being done by a dozen scientists, among whom were: Lord Kelvin, Ayrton, Perry and Cardew; Siemens, Kohlrausch and Hummel; Duprez and D'Arsonval. As we shall see, D'Arsonval, in France, came closest to the solution that Weston discovered, so close indeed that today many of Weston's competitors refer to the D'Arsonval Movement instead of the Weston Movement when discussing the design of Weston instruments.

But neither D'Arsonval nor any of the others had succeeded in making a practical measuring instrument when Weston went to work in his laboratory on Newark's High Street. And to understand what it was that Edward Weston accomplished, it will be necessary to go back for a moment and see what he was working from, and why his discoveries were so important.

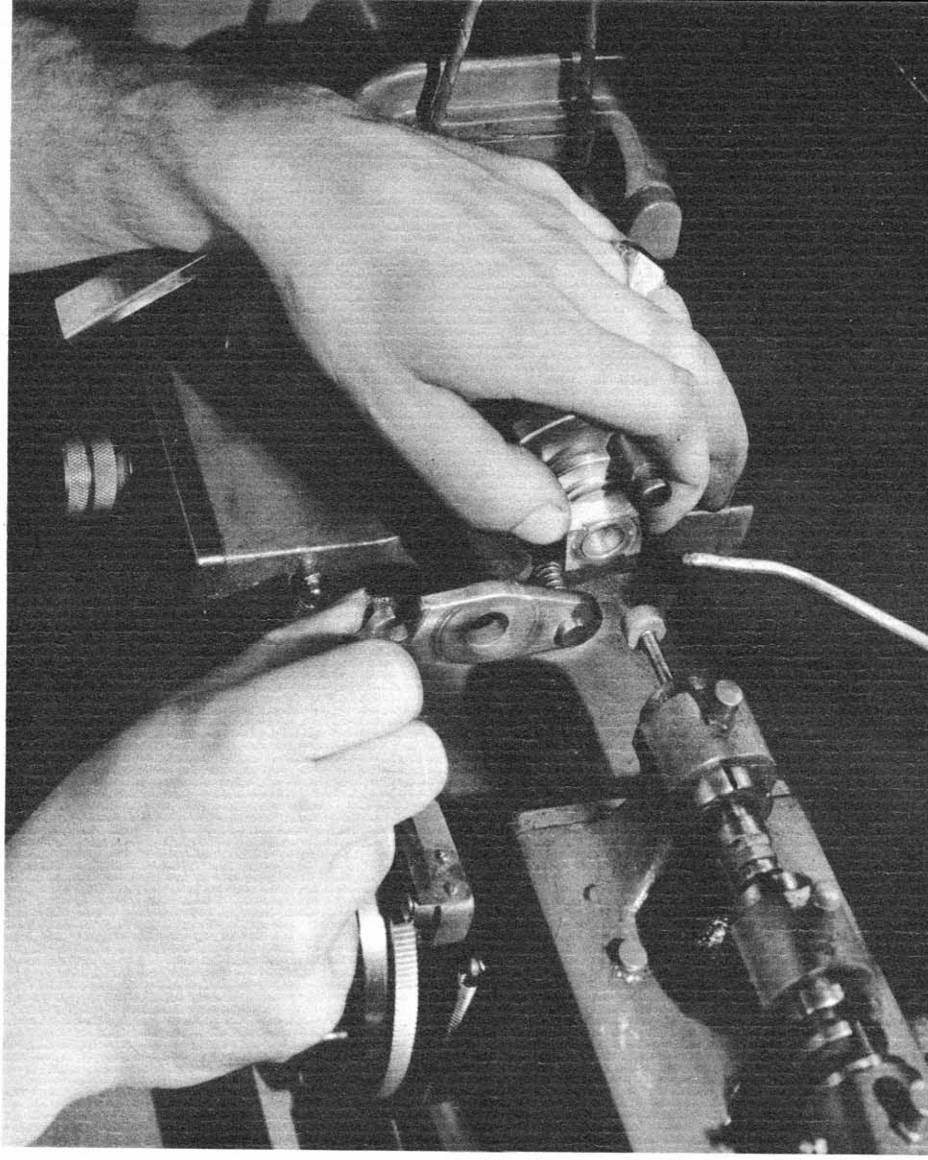
A PERMANENT MAGNET AND A MOVING COIL

In 1819 Hans Christian Oersted, a Danish physicist, had made the basic discovery. It was that a current passing through a wire set up a magnetic field around that wire, and that a magnetized needle, if held over it, would turn aside. Two years later André Ampère, the French physicist, worked out the laws governing the strength of currents. The principles laid down by these two men established the science of measuring electricity by means of magnets, and the men who followed them had struggled to produce instruments that would accurately translate the sensitive and mutual reaction between a current and a magnetic force into readable units.

The mechanical and electrical

The First Piece of Commercial Bakelite . . . in the electrical industry was made in Weston's plant in 1910 shortly after Dr. Baekeland discovered how to mold and press and bake powdered wood pulp and formaldehyde and phenol into a tough, insulating plastic. This man is pouring the powder from a measuring ladle into the shiny, hardened steel molds which in a few minutes will turn it into the bright black exposure meter cases seen in lower right-hand corner of the picture.

Before Weston, Magnets Slowly Died . . . and scientists said a really permanent magnet was impossible. But Edward Weston uncovered the secret of perpetual magnetic life by fitting a small block of soft iron to each of the two prongs of a horseshoe magnet, carving these pole pieces to curve around an iron core. Because they must be curved and smoothed precisely, pole pieces begin as single blocks which are bored, reamed and ground, then numbered and cut into pairs that will narrow the gap between the magnet's jaws, embracing but never quite touching the iron core of Weston's movement.

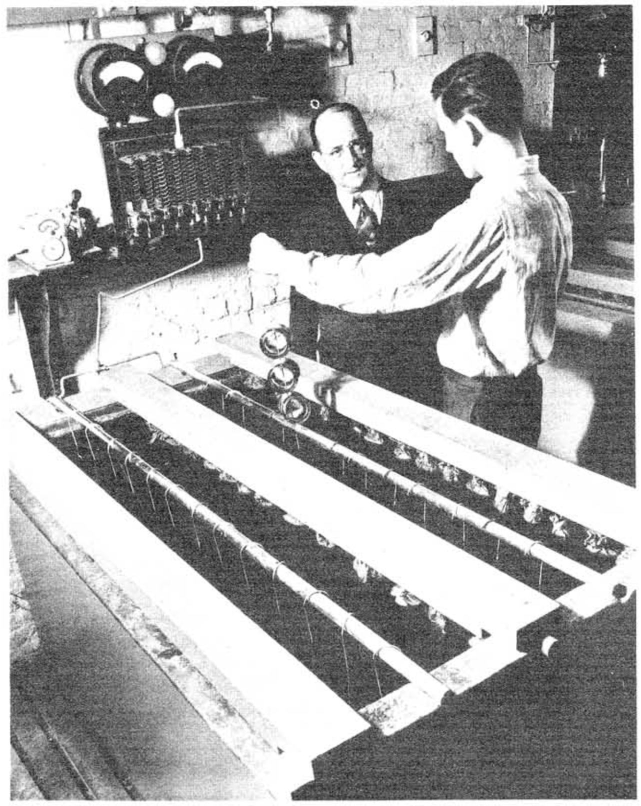


difficulties were enormous and it is impossible to consider them all here. Essentially, however, their chief worry was how to get a magnet that would keep its strength, since with age a magnet grew weaker unless, as every schoolboy knows, a bar of soft iron were placed between its two ends, or poles. Many gave up the search altogether and tried other ways of measuring current; hot-wire types were tried, using the fact that electricity heats up and expands a wire; soft iron types were tried, using the fact that a current going through a coil of wire will so magnetize two bars of iron placed inside the coil that they will tend to move apart.

With these and other methods Weston also experimented, but he at last concluded that the most practical and accurate instrument would be one that used a fixed, permanent magnet and a moving coil of wire which carried the current to be measured. The idea of a permanent magnet was, as we have just seen, considered impossible. But the idea of having the coil of wire move (instead of the magnet) had been advanced, and patented, by D'Arsonval in 1881. This explains why some competitor engineers today say that Weston instruments are of the D Arsonval type. But D'Arsonval's credit for this point is highly disputable for the reason that long before D'Arsonval's patent Weston had developed a moving coil instrument in his laboratory and knew its advantages and disadvantages. And in discussing a paper before the American Institute of Electrical Engineers, in 1893, Weston noted that James Clerk Maxwell, the English physicist, had described a moving coil instrument "very fully and in considerable detail" in the first edition of his work (1875).

But no matter who was responsible for the moving coil principle, Weston alone made it possible to use this type of instrument. For he discovered how to make the magnet permanent. And without a magnet that would retain its power the instrument would never have been

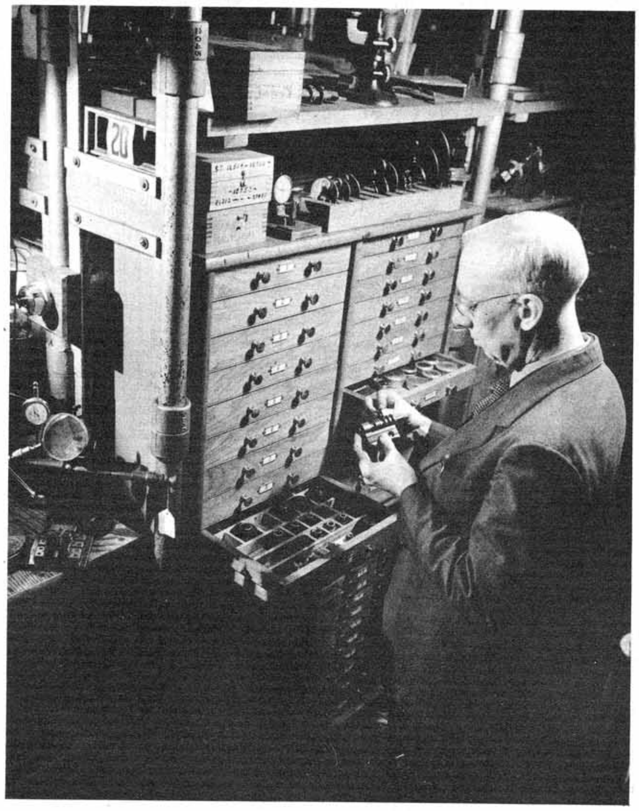
Weston's Electroplating Tradition . . . goes back to 1872 to the time when Founder Weston, at 22, revolutionized the plating industry by using a dynamo instead of wet batteries to supply the necessary current. Today, Weston does gold, silver, copper, tin, cadmium and nickelplating, taking the same care to keep its plating room spick-and-span that Edward Weston took, so that its instrument cases and parts will be sure to emerge with a perfect, even finish, not for looks alone, but for proof against rust and corrosion.



accurate, regardless of the precision of the moving coil. The way he did it was essentially so simple that it is hard to believe no one had tried it before; first he found a steel alloy that held its magnetism best after its molecules were stabilized by heat treatments; and then he made it permanent by narrowing down the gap between the magnet's two prongs. He was able to make the gap so narrow that the magnetic force could flow across it easily without wearing down the magnet's power. In short, he accomplished what a bar of soft iron or "keeper" did when it was placed across the poles, only he did it without closing the gap entirely. Mechanically, his method was to put a small block of soft iron on the inside of each prong, cutting them so that they curved close around a concentrically mounted soft iron cylinder. In this tiny gap—today only five hundredths of an inch wide in the average Weston instrument—the moving coil which carried the current could swing as it obeyed Oersted's law relating current to magnetism.

FOUR MORE FUNDAMENTALS

But having discovered how to make a permanent magnet, Weston did not by any means have a current measuring instrument. The magnet was to be sure the *sine qua non;* but he had four more essential things to work on: 1) The wire carrying the current to the moving coil; 2) The wire spring that controlled the moving coil; 3) The moving coil itself; and 4) The amount of current which passed through the instrument. And before he achieved the instrument he was after he had to turn metallurgist and discover four new alloys, one of which completely shattered the physicists' definition of the difference between metal and non-metal. The first of these alloys, although not directly concerned with the five fundamental problems Weston faced, nevertheless greatly improved his instrument. This was an aluminum alloy for his instrument's



One Weston Instrument May Have 1,000 Parts . . . and in 50 years Weston has accumulated an almost infinite variety of tools and gauges for cutting and bending and boring and punching an almost infinite variety of parts for some 850 models. The tool vault's most precious collection lies in the drawers of gauges shown in this picture.

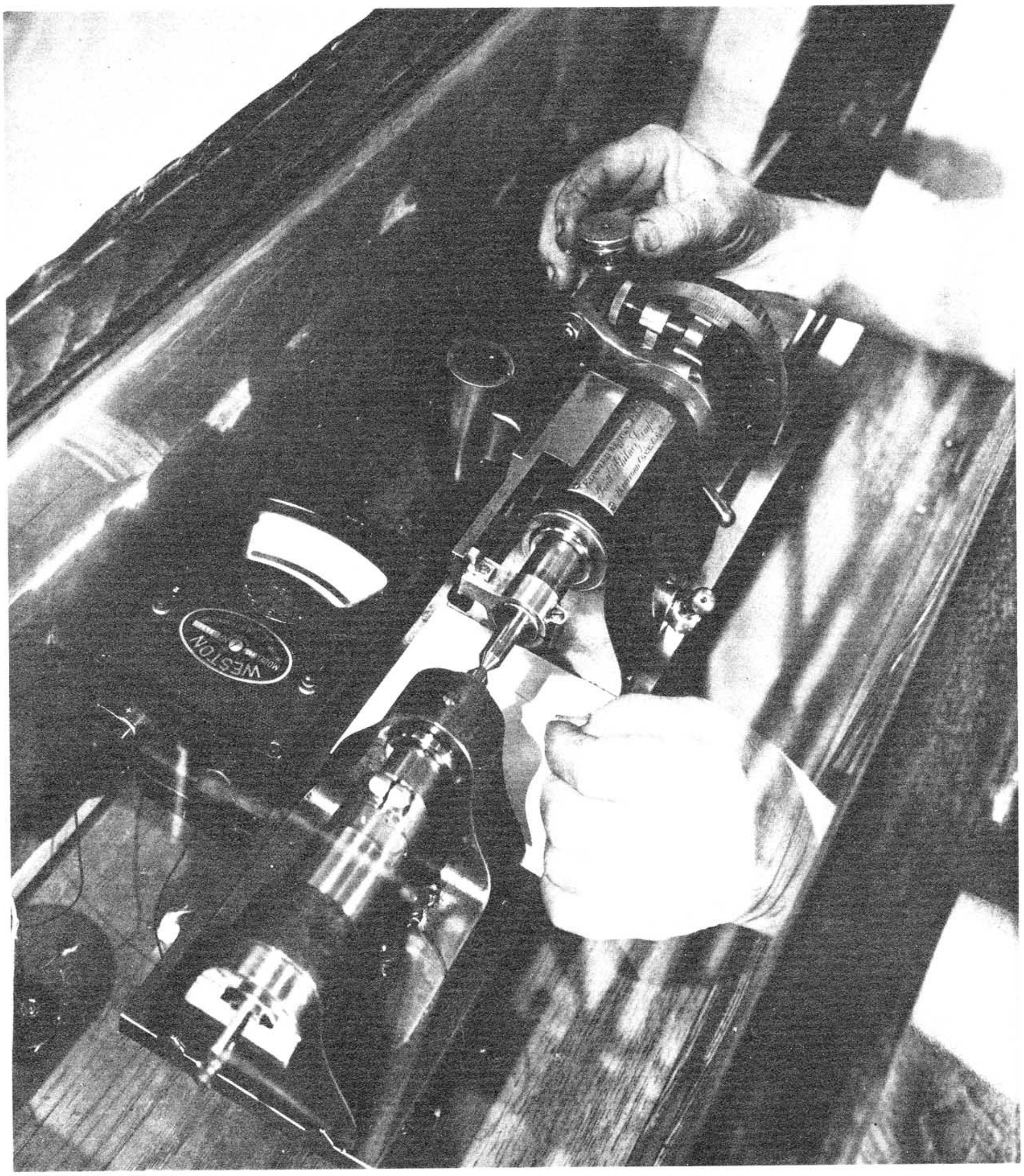
pointer; aluminum in those days could not be drawn into the lightweight, minutely hollow tube he wanted and he therefore compounded an alloy that could be drawn, calling it Alloy No. 1.

Similarly, consider his contributions to the four essentials listed above:

1. The wire carrying the current to the moving coil: Until Weston disproved it, one of the prevailing definitions of a metal was a substance which, as its temperature increased, resisted the flow of current more and more. Since a change in the resistance of an instrument would affect the instrument's readings, he looked for a metal which showed this reaction to temperature changes the least. He experimented with German Silver and was the first to produce this alloy with more than 18 per cent nickel. But this was not good enough, and after testing over 1,000 different alloys, he struck one of copper and nickel that actually grew less resistant to current as its temperature rose. He called this his Alloy No. 2, but the German wire manufacturer who made it for him (American wire makers couldn't draw it fine enough) called it Constantan.

Constantan, however, had one serious defect as far as its use in instruments was concerned: when connected to a copper terminal, a change in temperature would arouse "parasitic" currents between the two metals, which thermo-electric effect was more than enough to offset Constantan's great virtue of becoming less resistant with higher temperatures. Therefore, Weston sought—and found—another alloy, this one of copper, manganese and nickel, whose resistance to the current hardly changed at all with a rise in temperature, and which showed almost no thermo-electric effect against copper. This alloy he used, naming it Alloy No. 3, the Germans re-christening it Manganin.

2. The wire springs that controlled the moving coil: These coiled strips of wire do the actual measuring job, for they oppose the twisting motion of the coil produced by the current



A Human Hair is Six Times as Thick . . . as some of the flattened wire this micrometer must measure for the springs in Weston's instruments. As the small name plate points out, Pratt & Whitney made this gauge specially for Dr. Weston whose engineers later provided it with a sensitive electric touch. With it, Weston's spring wire is continuously checked and re-checked to the correct 1/100,000 of an inch by the 78-year-old ex-surgical-instrument maker whose hands you see in this picture. The coarsest wire he draws is but 0.0105 inch thick; the finest, an incredibly slim 0.0005 inch.

flowing through it. Since the springs' tension, by just balancing the coil's twist, serves as the true measure of the current, springs are in fact the essence of any moving coil instrument. Weston rejected the idea of steel springs which the other meter makers were using in their instruments and experimented until he found an alloy of copper, which was non-magnetic (unlike steel) and had fine elastic qualities as well as low resistance to current. This was Alloy No. 4 and since Weston could make it himself, the Germans didn't get a chance to name it.

3. The moving coil: The rotating coil of D'Arsonval's galvanometer was, before Weston's time, wound into a rectangular coil and stiffened into shape with glue or varnish so it could pivot around the iron cylinder between the magnet's prongs. Weston devised a light copper frame (later aluminum) to hold the coiled wire; this not only did away with the crude stiffening methods; it also performed an important electrical function by inducing Foucault currents in itself as it swung with the coil through the magnet's field. Without these currents to absorb energy from the moving system, the delicately pivoted coil will swing the pointer first above, then below, the true reading many times before it oscillates to a stop. By checking this swing of the coil, these Foucault currents "damped" this tendency of the pointer to shiver, thus giving a quick reading.

4. The amount of current which passed through the instrument: The voltage of a circuit, *i.e.*, its electrical pressure, can be measured without much danger of hurting the thin wires of the moving coil, since only a minute current passes through the instrument, this amount being kept at a minimum by means of the highly resistant Manganin wire leading to the moving coil. But in order to measure the strength of a current, *i.e.*, its amperage, most of the current flowing would have to be diverted, since only a small fraction of it could pass harmlessly through the instrument's delicate coil. Before the advent of Weston's moving coil ammeter, it was necessary to lead the full current output of a generator to the instrument through thick, costly bars of copper. But in 1893 Weston invented the shunt to eliminate this expensive drawback. The shunt (British for railroad siding) was simply a metal sidetrack which took most of the current *around* the instrument, only an infinitesimal proportional part going *through* it. Weston had the ideal shunt material in his own Manganin and by doing away with the need for long copper bus bars leading to the instrument he greatly reduced the cost of measuring current.

"HORSE-AND-BUGGY" INSTRUMENTS

So much for how Edward Weston managed to make the first practical direct-reading measuring instrument for electrical current. There were, of course, other improvements, such as balancing the pointer by threading tiny nuts onto the three non-pointing ends of its cross-shaped balance arm. But the permanent magnet plus the four revolutionary changes just described established the fundamental characteristics of all direct-reading instruments used for measuring direct current.

By the spring of 1888 these improvements (excepting, of course, the shunt which came five years later) were perfect enough to convince Weston that he was ready to take his instrument to market. And the market was unquestionably ready for his instrument. In the five and a half years which had passed since the opening of the country's first central lighting station in New York City, the need for an accurate instrument had grown steadily more acute. Edison had started in 1882 by using a shingle nail hung up beside one of the heavy wires feeding current to his customers' lights; whenever the current got strong enough to draw the nail close to the wire he would adjust his generators until the lamps seemed to him to be burning "about right."

But by 1888 such primitive methods had been pretty well superseded by a varied assortment of relatively crude galvanometers, ammeters, and voltmeters, and engineers were hotly discussing their refinements and defects. The *Electrical World* carried a total of fourteen articles on these electrical measuring instruments during 1888, many of them bearing English names. This, then, was the competition which Weston faced when he decided to enter the instrument business. And since he knew his instrument was better than any other on the market, he had no doubts about being able to sell it. The only possible hitch might be to find enough customers.

For in spite of the fever of invention which had swept over physicists and engineers since 1875, there were pitifully few ways in which electricity was actually being used. The telegraph was going strong, but New York City still had only 8,200 telephones, and London, with three times its population, only about half that many. Factories got what power they needed from steam engines geared to shafts and leather belts; the trolley car was just emerging, and most people were pulled around in horse cars, or steam-driven cable cars if they lived in a big enough city; in his home a man did his night reading by gas or oil lamps and his food was cooked on a coal range; after dark he might walk home from the local trocadero by the light of an arc lamp, but except in the bank or the main store he wouldn't be apt to see one of the new incandescent bulbs. It was, in short, the original "horse-and-buggy" era.

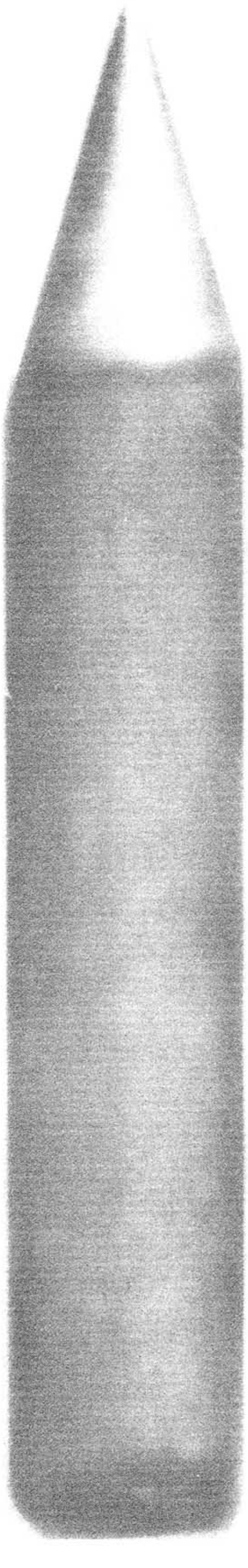
Yet the largest market for electricity, and hence electrical instruments, was curiously enough just where there were the most buggies and horses—in the small towns. The big towns could afford to install a central gas plant and thereafter benefit from cheap gas rates in their lighting systems. But the small town took the cheaper generators and gave their citizens the luxury of electric lights. As a result, small central lighting plants were scattered all across the country while New York socialites had to hire storage batteries to enjoy electric illumination at their parties. And even then such a display was rare enough; the elder Mr. Ogden Mills, the New York banker, apparently started the practice on January 16, 1888, when he had the New York Isolated Accumulator Company set up batteries and sixty 16-candlepower lamps for a ball and housewarming in his Fifth Avenue home.

THE BUSINESS BEGINS

From the way the use of electricity had been increasing, though, Weston thought that the demand for instruments would be likely to grow into a nice steady business. And besides the lighting industry there were the school and college laboratories which would certainly grasp at an accurate, dependable instrument. He had what they wanted, but since the expense

The Springs Are Sorted . . . by means of this torque tester which tells the twisting strength of every spring. Since Weston's specifications cover 115 different sizes of springs, and from 10 to 15 different strengths, or torques, the total number of stock combinations of size and strength lies somewhere between 1350 and 1400. Most of Weston's instruments use two springs, and their combined strengths must be perfectly equal to the total torque called for in the engineering specification.

The Touch of a Finger . . . can render a perfect spring useless, so sensitive are many of the delicate spirals to mechanical strain or the chemical corrosion caused by a moist fingerprint. Hence the inspector here is careful to use tweezers as she examines the procession of springs passing in final review before her under a projection microscope that enlarges them 25 times, revealing whether they be truly concentric and their tails and terminals properly aligned.



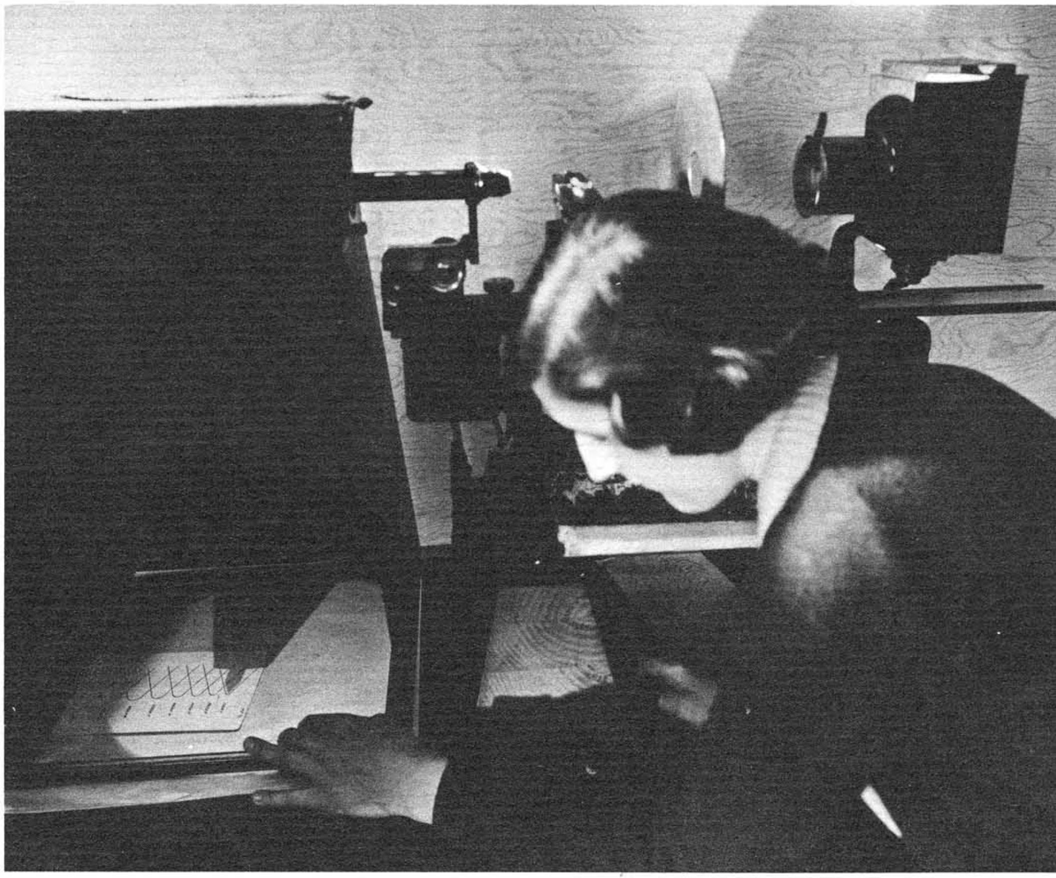
of his laboratory had eaten up whatever extra cash he had saved from his fees as a patent expert, he needed first of all some money to start things going. He therefore began looking around for a backer, and with his instrument as a definite, clinching argument soon managed to persuade not one but three of his friends to act as godfathers for the venture. Two of them were father and son, W. E. and E. E. Quimby, patent solicitors; the third was Franz O. Matthiessen, who owned the sugar refinery in Jersey City where Weston had installed some of his first arc lights nine years before.

On March 31, 1888, this four-man alliance became a corporate reality with sufficient cash invested to pay for the tools and materials and hire the employees Weston needed to begin turning out his instruments. And since the laboratory was to be the factory there was no rent to worry about. The company's greatest asset, of course, was Weston's patents which were at once entered on the books as worth $58,000, representing 580 of the 1,000 shares of stock in the firm's portfolio.

Thus was Weston's fourth and last company born. Like the three which preceded it—his nickelplating business, his dynamo business, and his arc light business—this company was concerned with making, improving, and selling a new kind of electrical apparatus. But in one very important respect it was different from the other three. For this time Edward Weston had started in a business that had to deal with the whole field of electricity and not just one corner of it. His problems from now on were not confined to dynamos or lights or electrolysis; he had to follow every electrical improvement

The Pivot: A Crucial Point . . . in the life of Weston's moving coil instruments. For although the coil it will support may weigh only 1/140 of an ounce the weight will be concentrated on so small a spot that the pivot (here enlarged 115 times) will be straining under a normal pressure equal to 1½ or more tons per square inch. Actually there are two pivots between which the coil rides as it swings in answer to the current passing through the instrument, and if they are to bear up under their enormous burden critical accuracy of point is essential. Each year Weston makes hundreds of thousands of these little pointed cylinders, cutting them in ¼-inch lengths from high carbon steel rods 15 thousandths of an inch thick, then beveling, hardening with heat, grinding to a sharp point, hardening again, and finally rounding off the point to an exact radius so it will spin smoothly in its sapphire socket (see frontispiece).

The Most Expensive Small Part . . . in a Weston meter is the little hand-picked sapphire crater whose nadir is a precisely ground cup in which rests the pivot's point. Each one must be examined under a microscope to make sure it has no flaws that might later, under the pivot's insistent pressure, roughen the polished hollow of the jewel.



The Silhouette . . . of Weston's pivots is here inspected to make sure the points are running true. This projection microscope can enlarge a pivot's shadow 400 times and reveal at once how far, if at all, its point is off center.

A Bent Tube Will Do the Pointing . . . on most Weston instruments, although Weston makes 100 different kinds of pointers. The tube being bent may originally have been a small aluminum pipe 2 inches long before it was drawn down until it was a foot long and its walls were less than two-thousandths of an inch thick. Later, the hollow ends of its two arms will slip over the solid arms of a trussed balance cross, and its V-shaped neck will slip into a flat finger of hair-thin aluminum, making a featherweight, vibration-proof pointer.

An Oblong Coil Will Do the Twisting . . . when the current to be measured races around its turns, in electrical opposition to the magnetic stream flowing between the magnet's prongs. Weston winds some of its special, heavier coils by hand, as shown, but the wire for most of its standard coils is rapidly wrapped up on the row of oblong frames by machine. Of the more than 300 kinds of wire Weston buys each year, some 70 go into coils, the finest of all being wire 0.001 inch thick, one pound of which would span some sixty miles.

that came along and find some way to measure it efficiently. That is the chief significance behind the founding of the Weston Electrical Instrument Company in 1888. It meant that the 38-year-old inventor had finally reached the life he was looking for, a life spent in constantly devising and discovering new mechanisms that satisfied him scientifically.

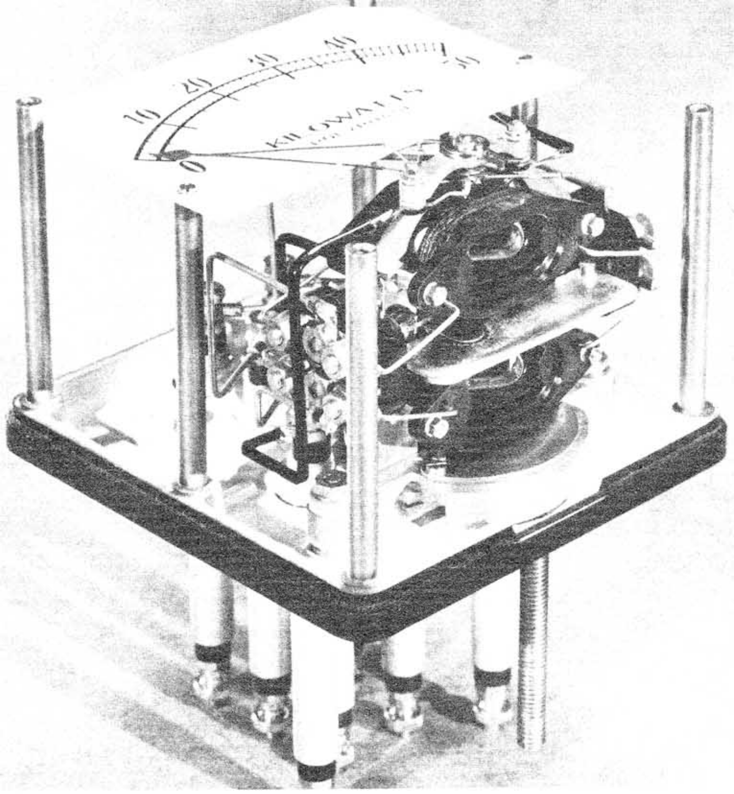
And because Weston had this purpose in mind when he went into the instrument business, the story of his company falls very naturally into a recital of the contributions which Weston and the engineers who followed him have made both to industry and to electrical science. But in presenting the Company's historical record, no attempt can here be made to explain its instruments technically. It will be possible only to highlight those which show most clearly how Weston and his engineers anticipated and answered the demands of the electrical industry.

UP FROM MODEL ONE

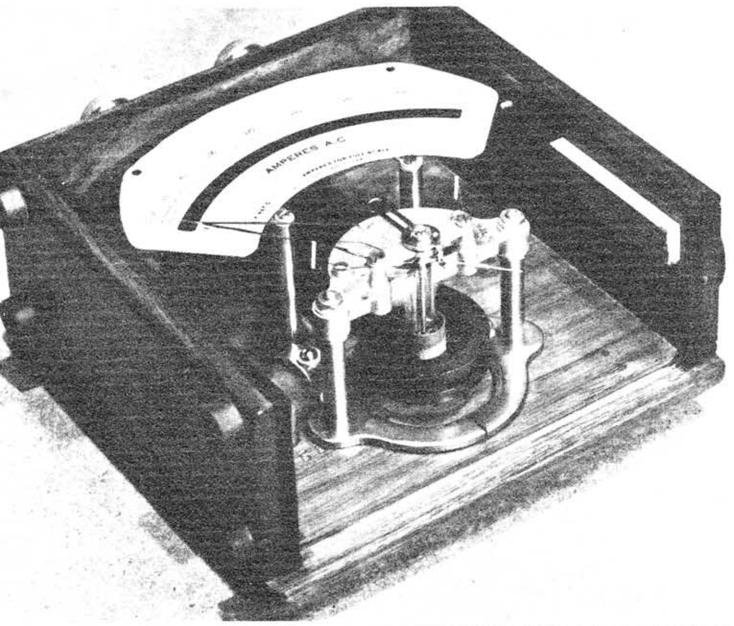
As Weston had predicted, his measuring instrument with the permanent magnet and the moving coil proved to be much better than anything then on the market. His Model One voltmeter became (and with refinements has remained) the commonly accepted means for measuring direct-current voltage, and, as he had also foreseen, schools and colleges were his best customers in the beginning. They bought his Model One because it was not only very accurate but also portable and could be carried around the laboratory from one experiment to another.

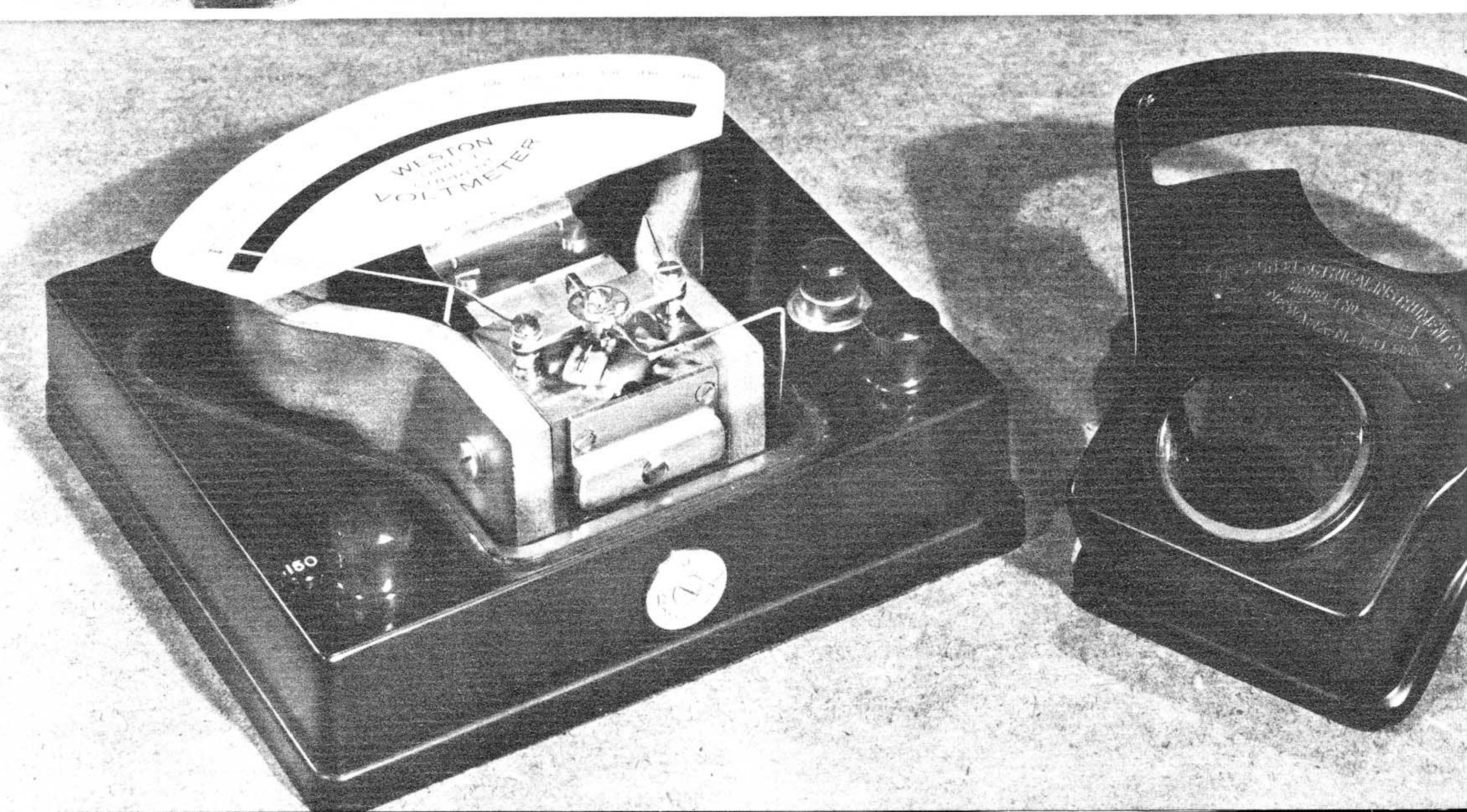
But the growing light and power industry was to be the main market for Weston's instruments and he lost little time in adding other types of measuring instruments needed in this industry. By 1892 he could offer electrical engineers a line of portable voltmeters not only for direct current but for alternating current which had arrived commercially in 1886. In addition he had introduced a line of direct-current voltmeters and ammeters for use in the small individual power plants which engineers were then installing in the belief that they were more economical for the customer than buying power from a central generating station. Then in 1893 Weston gave the electrical world his shunt by means of which his ammeters became the most accurate as well as the most economical instrument for measuring amperage.

The Shunt Takes the Brunt . . . of a current's amperes. The shunt being tested here can sidetrack 8000 amperes, only a small fraction—three-hundredths of an ampere—passing through the wires seen leading from the shunt to the ammeter. Actually, the instrument is a millivoltmeter, calibrated to read in amperes, that measures the definite drop in voltage introduced by the shunt. Because the shunt's resistance to the current must be unvarying it is made from ventilated leaves of Manganin, the alloy which, like the shunt idea itself, Edward Weston gave to the electrical world.

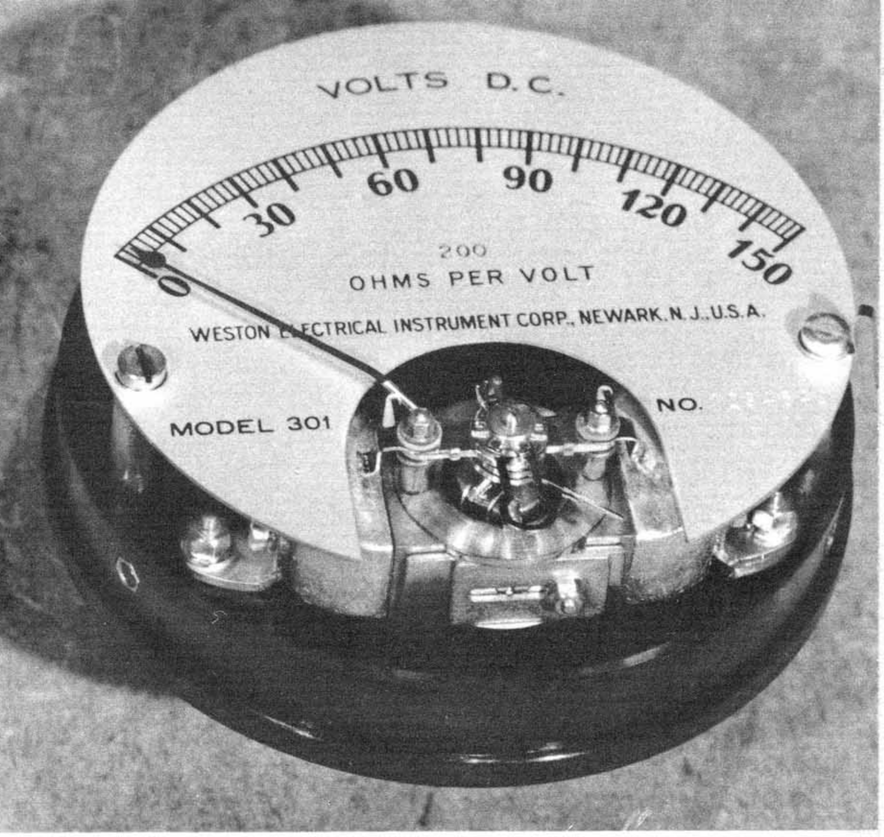


Weston Has No Yearly Models . . . and Weston engineers may spend years developing a new instrument. But when they have finished, they will have arrived at a design that in all probability will remain unchanged for years. On this page you see Weston's interpretation of the three basic types of electrical measuring instruments: the moving coil type (below), the dynamometer type (top), and the movable iron type (center). Each has its own separate and important function, and to those who know what an electrical measuring instrument should be, each has precisely the pattern that means the difference between the ordinary and the optimum in instruments. For proof of which Weston has but to point to Model One below, the lineal descendant of the instrument shown on page 12. Ever since 1888 when Edward Weston drew its pattern, this instrument has been the accepted standard of direct current instruments. Details have been refined as chemists and metallurgists have contributed new materials, but not one change has been made in its fundamental design. The relatively long magnet, the hyper-accurate air gap, the sapphire jewels, the use of control springs to convey current to the moving coil—all the electrical essentials of Weston's moving coil system can be found in the original specification. For a highly technical product, a design that can live so long is an almost unheard-of engineering rarity. Similarly, the design of the other two instruments on this page has remained the same for years. In the polyphase wattmeter at the top—the most complicated member of a group of identically encased switchboard instruments—Weston had to fit all the necessarily complicated elements into a restricted space, allowing for reasonable clearances, yet at the same time being sure that this pair of electrically independent electrodynamometer wattmeters were sufficiently shielded from each other. How balanced the design and how nice the assembly, adjustment and calibration must be are evident from the fact that, in conjunction with Weston instrument transformers, this model's pointer may one day indicate the total power of a Boulder Dam. Conversely, because of its very simplicity, the movable iron instrument shown below it—the simplest type for measuring alternating current—demands just as great care in its design, in the proper shaping of its iron vanes, for example, and the delicate adjustment of the featherweight, tray-like piston which, fastened to the pointer's shaft, controls the oscillation of its moving system.





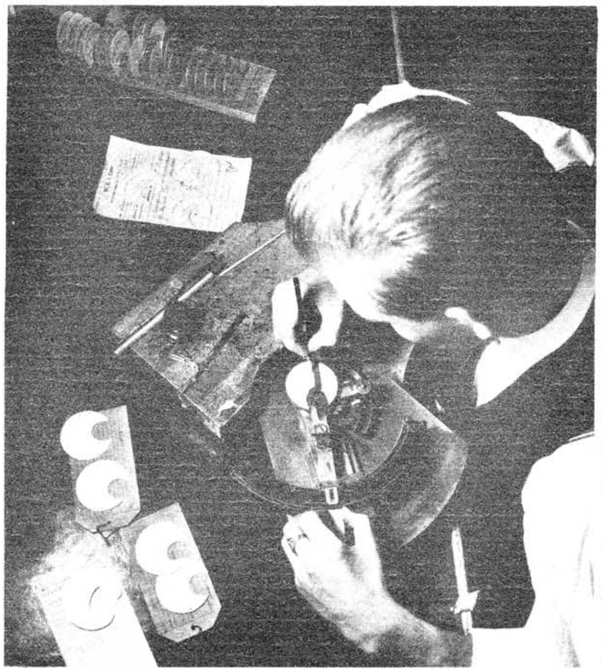
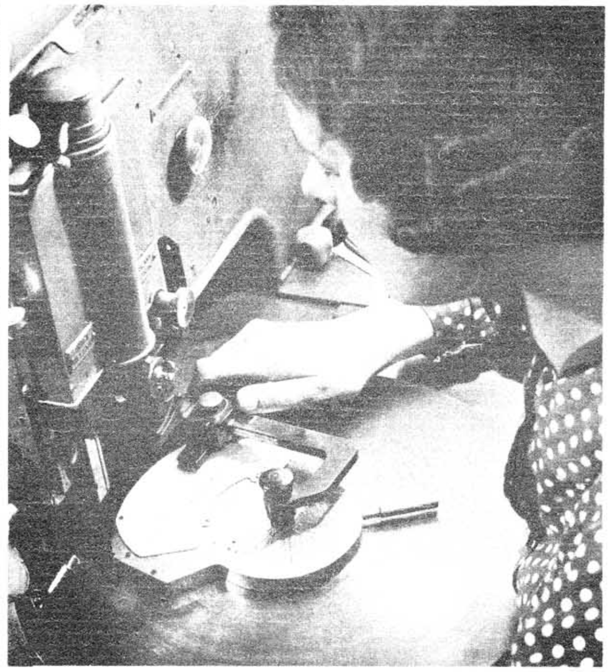
Weston's Miniatures . . . are the diminished counterparts of those larger instruments used in laboratories, power plants and schools. Since they are to be found at work on a myriad of manufactured products, they outnumber their bigger duplicates by many times. Yet in making them by the thousand, Weston has not sacrificed a single element in their clean design. Compare this Model 301, here, originally designed in 1911, with the Model One on the opposite page; even though Weston has made more than a million copies of this miniature model, its design has remained as just as that of its full-sized twin.



That same year he also finished developing the Weston Normal Cell which was the first stable standard for the volt, the basic unit of electromotive force. It is obvious that such a standard is essential in order to determine whether or not an instrument is measuring the voltage accurately, and the Clark Cell, which had been the standard unit up to that time, lacked the very important quality of being steady in its voltage output. At 15 degrees centigrade, this cell, the electrodes of which were zinc and mercury immersed in the sulphates of these two metals, would supply a constant voltage of 1.4322 volts, but this would vary slightly with a rise or drop in temperature. Weston substituted cadmium and cadmium sulphate for the zinc elements of the Clark Cell and succeeded in producing a cell whose output of 1.0183 volts was not only steadier but less affected by changes of temperature. By 1908 Weston's Normal Cell had become so thoroughly accepted that the International Conference on Electrical Units and Standards held that year made it the international standard of electromotive force. Whereupon Weston waived his patent rights on the cell so that others could make it.

For everyday use, however, Weston's Normal Cell was still too sensitive to temperature, and it was not long before he introduced a cell that could be used as a working standard in the standardizing laboratories of the world. The voltage output of this cell, containing a less than saturated solution of cadmium sulphate, was slightly higher than that of Weston's Normal Cell, but its greater immunity to the effects of heat and cold has made it a practical and commercially useful tool for checking the performance of current measuring instruments. Actually, the unsaturated Standard Cell is a secondary standard of the volt, each one standardized against the Normal Cell, with which the electrical world has permanently linked the name of Weston.

The Weston Standard Cell was followed in 1894 by a line of laboratory standard instruments against which engineers could check their portable and switchboard instruments and so standardize their equipment. These reference standards in turn were followed by the first

An Instrument's Dial May be Hand-Drawn . . . or Inked-In by Machine . . . or it may be printed on Weston's own presses. It usually depends on how close a measuring job the instrument will have to do. For example, some dials can be printed when a reading that is accurate to within two per cent is all that is necessary. But scales for big switchboard instruments which must register 99 per cent accuracy, and scales for portable precision testing instruments whose performance must be true to within ¼ or ½ of 1 per cent, must be marked off on the machine to allow for the individual eccentricities of each instrument. As a rule, hand-drawing is reserved for laboratory standard instruments whose indications cannot be off more than 1/10 of 1 per cent.

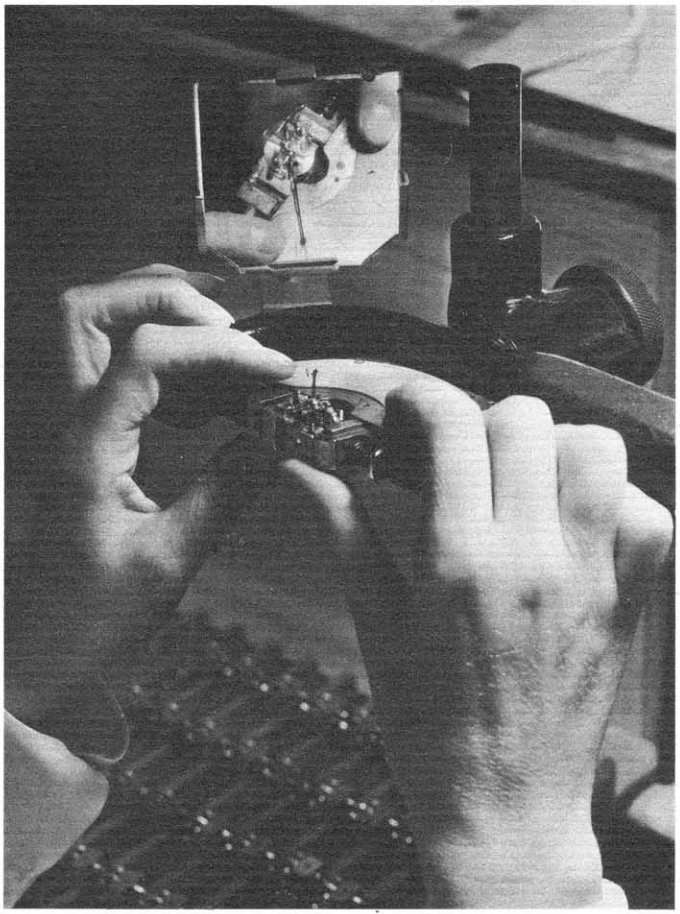
direct-reading, portable voltmeters and wattmeters for alternating and direct current. And in the next three years a line of sensitive portable galvanometers was developed which, unlike the galvanometers Weston used in 1886 when he took his memorable trip to Philadelphia, were adapted to commercial use. At the same time Weston went to work on switchboard instruments, introducing in 1898 the first edgewise type of alternating current voltmeters and wattmeters.

Since the turn of the century new Weston Models have followed thick and fast upon each other. Numerically, the increase has been startling: In 1900 there were 28 models and four years later there were ten times that number. At the close of the war, Weston's catalogue showed more than 400 different instruments and a hundred-odd more were added by 1929. Since then the list has mushroomed to more than 850, growing faster than it ever had before.

To explain and account for all these instruments would require a history of the growth of the electrical industry since 1900, a history it is obviously impossible to include here. But by selecting some of those outstanding Weston contributions and setting them down beside the historical events and industrial developments of those years it will be possible to show

how Weston has both kept pace with and anticipated the nation's electrical requirements. Those requirements have come chiefly from five directions: the electrical industry itself; the communications industry, including broadcasting; the transportation industry; the motion picture industry; and the Government. And in that order they can be considered.

The Electrical Industry: Weston has consistently answered the demands of light and power companies and those electrical engineers who handle the privately-owned power stations. Practically all of the developments mentioned above went to benefit this group. In 1905 Weston introduced a line of special measuring instruments including potentiometers, pyrometers, galvanometers and standard resistances, all of precision standard; and



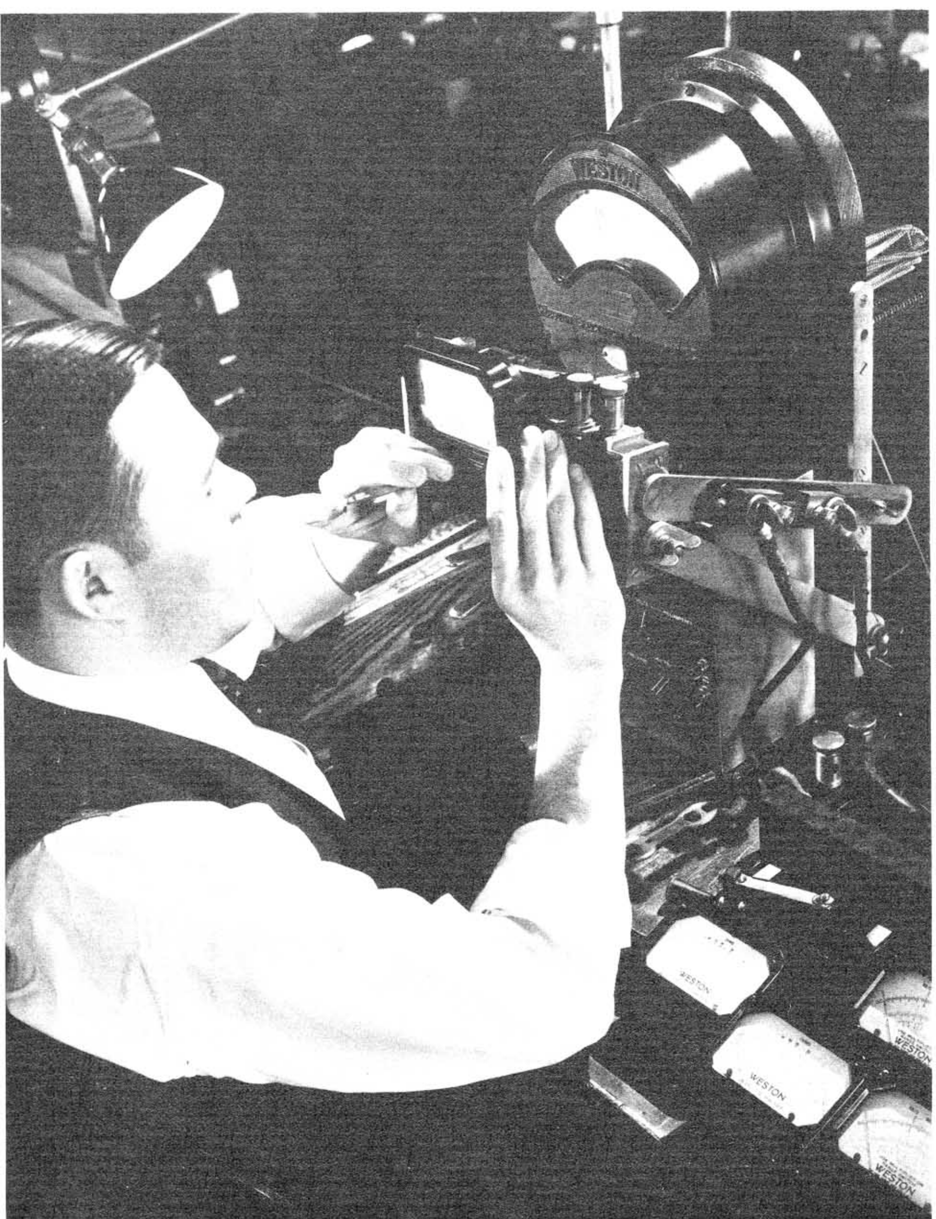
So Far, Only a Mechanism . . . Here on this "lazy sue" table, the magnet, its jaws already packed tight with some 67 sensitively adjusted parts, gets its bakelite pedestal and a face. But although it arrived at this point in its own compartment in the flat wooden case, and will depart under a temporary glass-windowed shield, it is still no more than a precise assemblage of parts.

A Pointer Floats in Air . . . Attached to the stem of an aluminum balance cross whose arms bear counterweights, the pointer must be perfectly balanced and leveled (above) before it will hang suspended over the instrument's dial. Sometimes the counterweights are little coils of bronze, sometimes they are nuts working on a thread so fine that they must be turned 500 times before they will move an inch along the cross arm.

two years later he brought out a series of soft-iron direct-current instruments in response to the demand for a less expensive type of switchboard instrument. Then in 1911 the Company contributed a complete line of alternating-current switchboard instruments operating on the dynamometer principle, an achievement that was praised by the entire electrical industry. The following year Weston shrank its permanent magnet and moving coil movement down until it had a line of miniature instruments suited to the small switchboard panels that manufacturers were beginning to include as standard equipment on industrial electrical machinery. That year also a group of small multi-range portable instruments appeared which could be used either commercially or in the laboratories of schools and colleges.

Since 1912 Weston has steadily refused to let well enough alone but has continuously changed the size and shape and electrical characteristics of its instruments in response to the needs of the electrical industry. Sometimes the arrival of a new material—as, for example, the appearance of high intensity magnetic steels in 1929 and 1934—has meant bettering an instrument already established in Weston's line. And sometimes a new instrument has resulted from the wedding of two Weston models, as, for example, the contacting instruments introduced in 1938 which combine the controlling characteristics of Weston's Sensitrol Relay (see page 46) with the indicating characteristics of Weston's ammeters, voltmeters, frequency meters, wattmeters and power factor meters.

An Instrument is Born . . . the moment this man has made its pointer agree with that of the big mother instrument behind it. Henceforth, only a final inspection and a careful wrapping stand between this instrument and its shipment from Weston's plant to Weston's customer.



The Communications Industry: From the very beginning Weston's instruments have been essential tools in the telegraph and telephone industries. Indeed, one of the first special-purpose instruments ever made was a voltmeter for telephone wire chiefs who were anxious to secure an instrument that could be used to test a line without interrupting the circuit. Since Weston's instrument was sensitive to a current as small as four ten-thousandths of an ampere, tests could be carried on all day long without disturbing any conversations on the line, an achievement that was then remarkable for a commercial instrument, although today some of Weston's instruments are eighty times as sensitive, registering currents so minute as to give a full-scale reading with five microamperes — *i.e.*

five millionths of an ampere. Then in 1910 Weston developed a differential milliammeter which shortly became a standard tool for balancing the country's telegraph circuits.

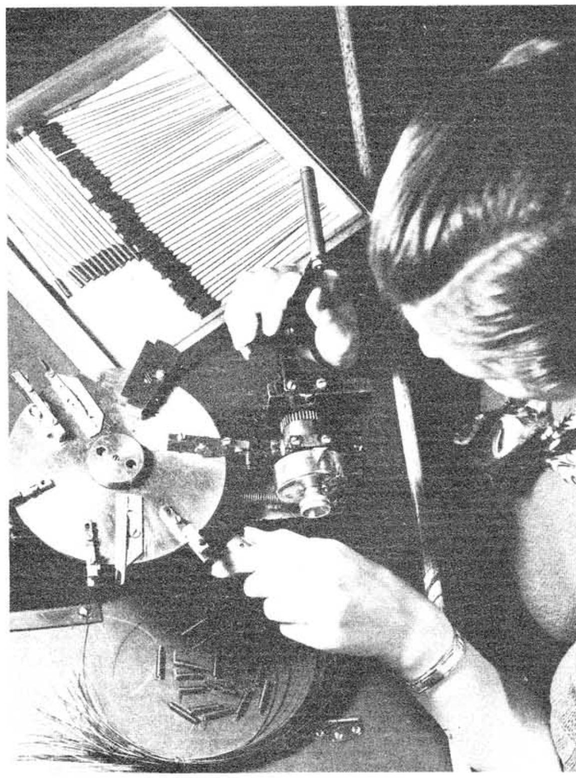
During the war Weston brought out a group of instruments for measuring the high-frequency radio currents required for transmitters, currents oscillating so fast that no ordinary ammeter was able to measure them; they would frequently leap across a coil rather than race around it. Weston engineers helped to solve this difficulty by devising the thermoammeter which measures not these high-frequency currents directly, but the current they set up in passing through and heating a junction of two different strips of metal, *i.e.*, a thermocouple.

In 1919 the country's first commercial broadcasting stations opened the field for the radio receiver and Weston's first contribution was a small instrument that would reflect the battery charge used by these early battery-operated receivers. For a while Weston contemplated the idea of making a radio loudspeaker, and although the idea was abandoned, the experience was later turned to excellent account, resulting in the development of an instrument for measuring noise, translating the loudspeaker's current into decibels, the unit of sound. An instrument adapted to the panels of radio sets followed in 1925, and in 1926 Weston gave the industry its first radio testing set, from which has since grown a long line of servicing instruments, including tubecheckers, voltmilliammeters, oscillators, and a supersensitive analyzer for testing receivers, transmitters, television sets, amplifiers, cathode ray apparatus, telephone and telegraph relay circuits. Each year Weston has improved the design of its radio service instruments, adding refinements and frequently discovering new principles of measurement that have helped the industry along the road toward better equipment.

Following the war, the science of telephony broadened, and the new science of broadcasting rapidly grew up, requiring supersensitive instruments for measuring extremely small voice currents. Weston's contribution was to perfect in 1927 a rectifier instrument which had been developed for use in Weston's laboratory many years before. This instrument changed alternating current into direct current, the translation making it possible to measure, in terms of direct current, much weaker alternating currents than were possible with the common soft iron, thermal, or dynamometer types of A.C. instrument. And it is because of Weston's early experiments with this current-translating instrument that Weston engineers can lay claim to being the first to use electrical measuring instruments for measuring sound. From the rectifier instrument sprang a line of instruments for measuring the energy in voice-frequency circuits, variously called output meters, decibel meters, volume-control instruments and volume-level indicators. And, as any electrical engineer will tell you, without the control made possible by such instruments, such scientific conveniences as ship-to-shore and plane-to-ground telephones and public address systems would never have reached their present practical state.

As in other fields, however, Weston's work only began with the introduction of a new type of instrument. Since 1927 the Company's developmental work for the telephone and broadcasting industries has gone steadily ahead. To cite but one example, Weston improved its volume level indicators in 1938 by devising one that had definitely specified characteristics, both as to its electrical properties and as to its dynamics, *i.e.*, the way the pointer responded. Because it has the qualities the telephone and broadcasting engineers are looking for, this instrument promises to become an electrical standard for this type of service.

The Transportation Industry: By virtue of the fact that an electrical instrument can be made to read in terms of speeds and temperatures as well as electrical power, Weston has been able to help solve transportation problems on land, at sea, and in the air.



A Thermometer's Tail Gets Its Final Twist . . .

ON LAND: As early as 1895 Edward Weston had invented a magnetic drag-type speedometer whose principle was later used by speedometer manufacturers when the motor car finally arrived. And in 1900 Weston voltammeters were installed in the early electric pleasure cars to let the owner know how strong his batteries were. Then in 1911 Charles Kettering, the inventor of the self starter, came to Weston for an ammeter that was sturdy enough to stand the jolts and shudders of the early gasoline buggy and still tell the driver whether the battery that operated his starter was discharging or being charged in preparation for the next groaning start. Kettering and Weston engineers climbed into a gaunt old Cadillac and pounded over the frozen fields near Dayton again and again that winter before they finally had an instrument that stood up under the treatment. Weston's first models, introduced in 1914, were fan-shaped, but small round types were soon developed, and this style became standard for the industry.

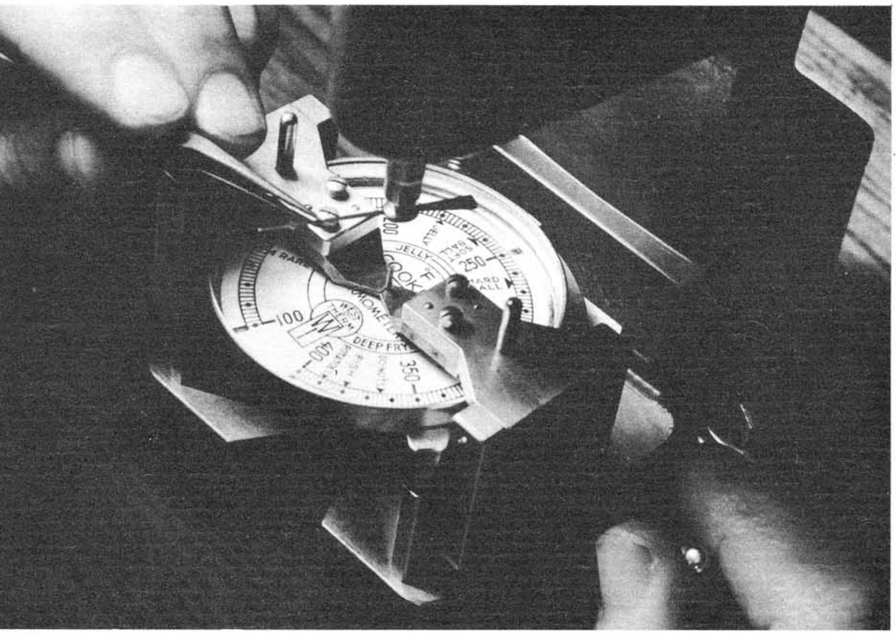
Likewise Weston has helped railroad transportation. Before 1900 Weston instruments were used in checking and maintaining the delicate communication and signal circuits that have done much to make trains so safe a means of travel. Since these original circuits were operated by direct current, more or less conventional Weston models could be used, but with the arrival of alternating current systems, Weston was called upon to produce a line of more sensitive instruments. In 1913 Weston engineers responded with a variation of the dynamometer type instrument in multi-range compact form which could be operated on these A.C. circuits without affecting this critical service.

In 1921 Weston introduced a train speedometer developed from the tachometer that Edward Weston had devised in 1897. From the face of this speedometer, hermetically sealed against its daily shower of steam, engineers can tell at once the speed with which they are passing through a signal block, giving them a positive measurement of something they had formerly guessed at from the sound of the engine's clanking rods.

With the arrival of automatic train control in 1926, the railroads again looked to Weston for instruments to solve the measurement problems raised by this new step toward accident-proof operation. And again Weston, by revamping certain of its instruments to meet the requirements, gave them what they wanted.

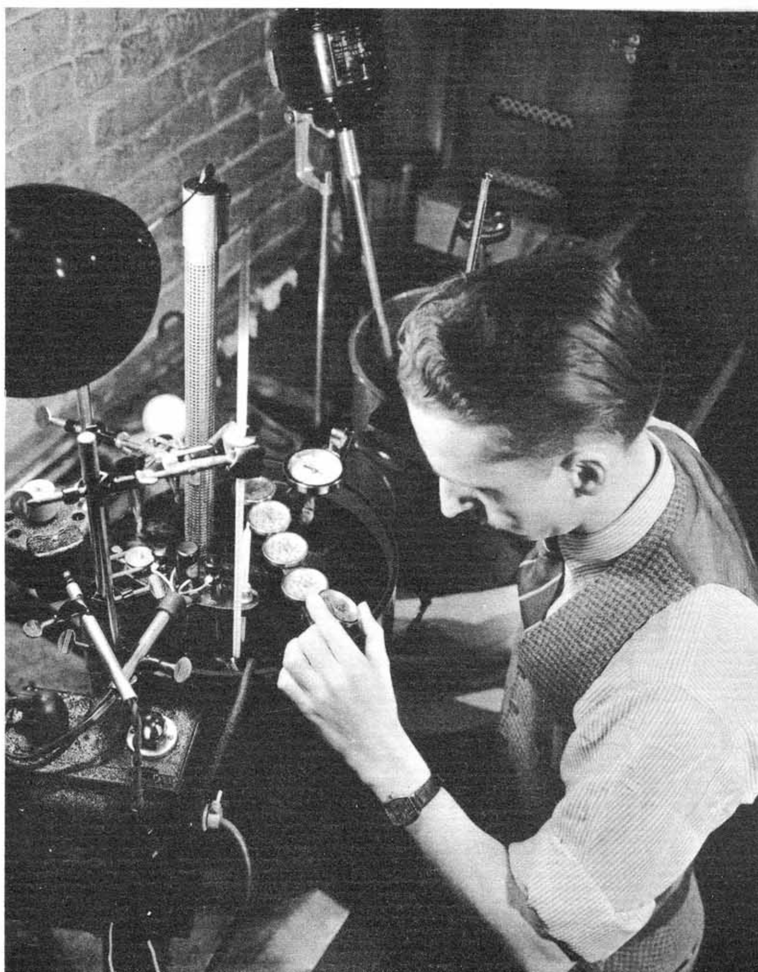
AT SEA: For modern liners Weston has devised instruments that measure the speed of whirling turbine blades, translating their revolutions into knots for the captain on the bridge and the men in the engine room. Other Weston instruments measure the voltage and frequency of currents used by electrical sounding devices whose tones, sent out from a diaphragm on the ship's bottom, are reflected back from the channel bed, the time consumed between sending and receiving the signal tone being an accurate indication of water depth.

And Weston relays stand ready to ring a warning bell in case a ship's SOS alarm recorder fails to work. Unless its supply of voltage remains between certain fixed limits, an alarm recorder cannot "hear" the coded signal of distress flashing from a ship foundering within its listening range. But Weston's relays, by guarding the operating condition of these alarm recorders, make sure that no SOS appeal will go unheard, even though the operator may be absent.



... and a Pointer Punched Onto Its Shaft ...

Curleycue Thermometers ... Since 1935 Weston has been making the coiled elements for its line of temperature gauges on the ingenious tool shown above, left. A laminated strip of two temperature-sensitive metals is fed successively to each of six positions on the revolvable tool table, the result being three concentric bimetal helices which with heat and cold will expand and contract so as to turn the gauge's pointer around a temperature dial. To check the accuracy of its thermometers, Weston maintains a separate and complete temperature laboratory (right).

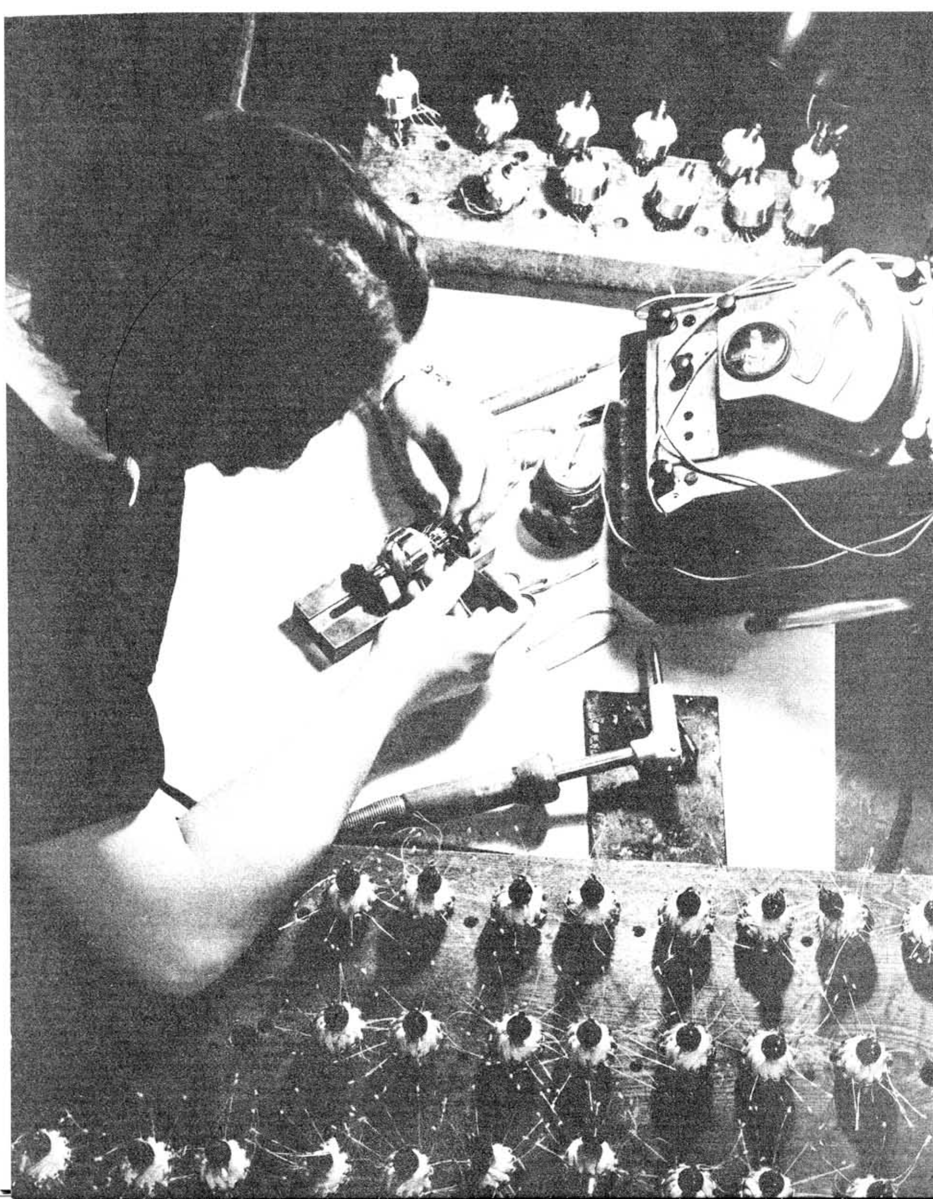


... But It May End Up in the Laboratory

In the Air: To a very large extent the pilots on today's airliners put their faith in the cluster of black-faced instruments on the cowl before them and, except for the compass and altimeter, most of those instruments reflect the state of the ship's motors, specifically their speeds and temperatures. Weston tachometers developed for aircraft in 1928 report the speed of wing-suspended engines, translating the spin of the shaft into current that can be read as r.p.m. Another Weston instrument developed in 1931 reports the temperatures of motor cylinders by means of a thermocouple which can react electrically to temperatures that may approach 600 degrees F. And with the help of resistance bulbs, these Weston instruments report the heat of engine oil (up to 230 degrees F.), and the temperatures of air fed to carburetors (to 160 degrees F.), air in the passenger cabin (to 120 degrees F.), and air outside the fuselage (from —20 to 120 degrees F.).

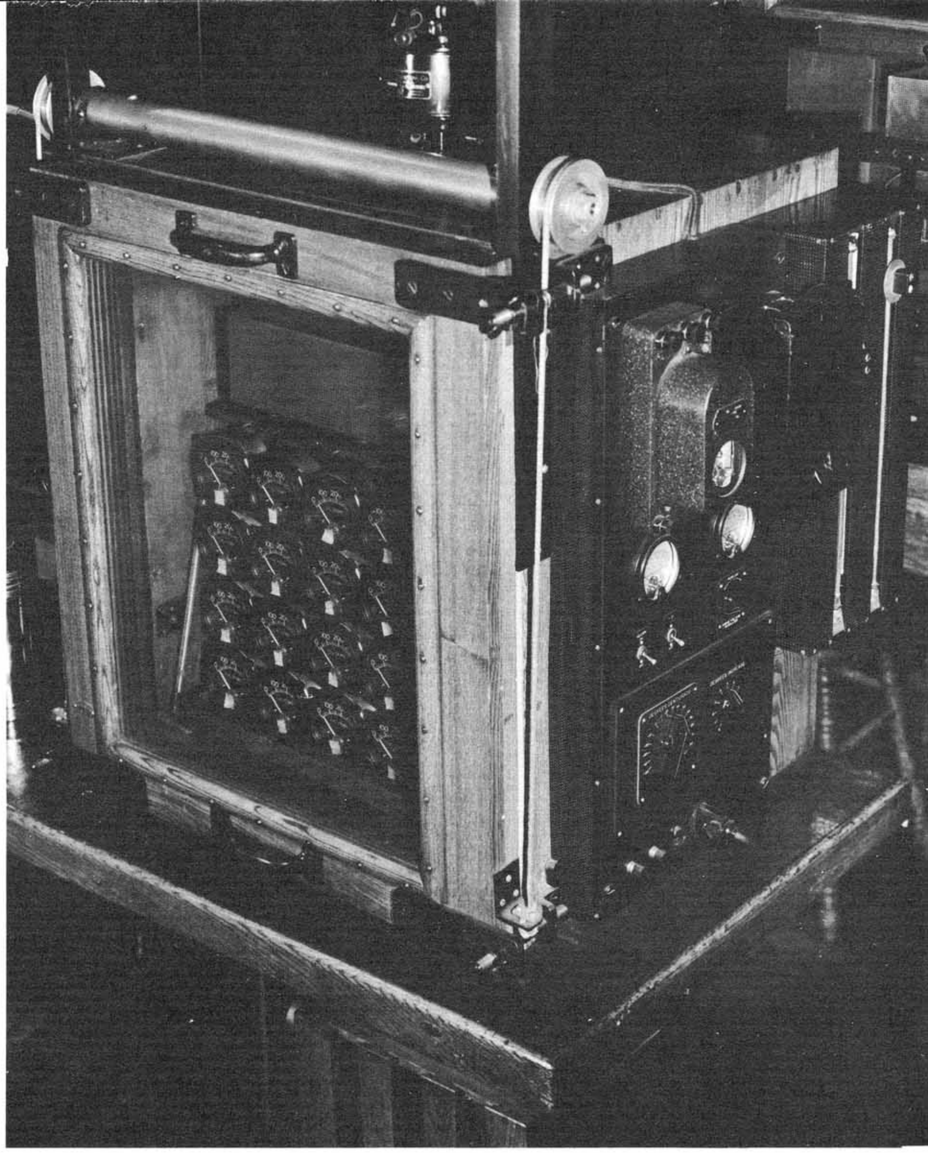
In 1933 Weston introduced a cross-pointer instrument for blind landing. From its face the pilot can read at once his position with respect to the radio directional beam that guides him to a safe blind landing at the airport. But because the science of aeronautics is by no means standardized as yet, Weston continuously faces new problems, some of which are much more difficult to solve than would be the invention of a wholly new instrument. The new super-airliners must carry their own separate generating plants for which standard instruments must be specially re-designed. And often it is a mechanical or metallurgical rather than an electrical problem that arises when faster and bigger planes are built; stronger steels, for example, were required in Weston's tachometer shafts in order to withstand the terrific starting acceleration of today's engines.

The Motion Picture Industry: With the arrival of sound pictures in 1928, Weston was called upon to develop a whole line of new and varied instruments. By helping sound film engineers control the complex circuits required in this equipment, Weston contributed



Revolution Into Electricity . . . To measure the speed of spinning shafts, Weston must first convert rotation into current by means of its miniature magnetos which, attached to the shaft, generate more and more current the faster they are whirled. Here you see some of Weston's baby magneto armatures being prepared for a life most probably to be spent coupled to the shaft of a bus or airplane motor. Historically, these little magnetos are the direct descendants of Edward Weston's electroplating and arc lighting dynamos of 1872 and 1876. Note the soldering iron: Weston has designed a different model for each particular job.

This Icebox-Oven Toughens Instruments . . . Since Weston cannot foresee what the future environment of its instruments may be, those which are apt to lead a changing life, airplane instruments especially, go into this calorimeter. These sixteen black-faced oil temperature gauges for airplane motors, trapped behind six panes of glass, are suffering a change from arctic cold to tropic heat, a possible swing in weather from 50 degrees Fahrenheit below zero to 120 degrees above. They must be both mechanically and electrically indifferent to such extremes of weather if they are to report the truth about motor cylinder temperatures up to 600 degrees Fahrenheit.



directly to the development of the modulated, coördinated talking film of to-day.

The Government: With the outbreak of the World War Weston's instruments and Weston's engineering staff were enlisted by the Allies, and by the time the United States entered the war, the Company had acquired considerable experience in devising instruments to measure the operation of modern electrical weapons. For two years, therefore, Weston worked principally for the United States Government; most of the new instruments developed were special, like switchboard instruments for the Navy's spark-type radio transmitters and relays for exploding submarine mines. But there were also a great many instruments in this war-time crop that subsequently became industrially important, such as frequency meters, power-factor meters, phase-angle meters, synchroscopes, and ohmmeters. And it was on the Government's Liberty Motors that Weston installed the first of its line of aviation instruments, developed from its earlier work with the automotive industry.

"ELECTRIC EYES"

Weston's achievements since 1930 have included an electrical wonder that has continued to fascinate scientists as well as Sunday Supplement editors. This is the photoelectric cell, or "electric eye," whose potential uses have piqued men's imaginations for the last sixty years or so.

Although even now scientists do not know exactly what happens in photoelectricity, the phenomenon is beautifully simple. Light falls on certain substances and a current is produced. Edmund Becquerel, a French scientist, first noticed this fact in 1839 when he discovered that light increased the output of the voltaic cells he was working on when it fell on the cell's

An Exposure Meter's Nervous System . . . is here being assembled. In her hand this girl holds the meter's round flat electric eye which, when properly sandwiched and clamped between lens, grid, electrode, gasket, and terminals, will become a Weston Photronic Cell, capable of translating the light that strikes it into current which it will shoot through its wire tail into the Weston movement later to stand beside it on the oblong bakelite base. And camera fans, watching the movement's pointer, will know how wide their lenses should be opened and how fast their shutters should be clicked.

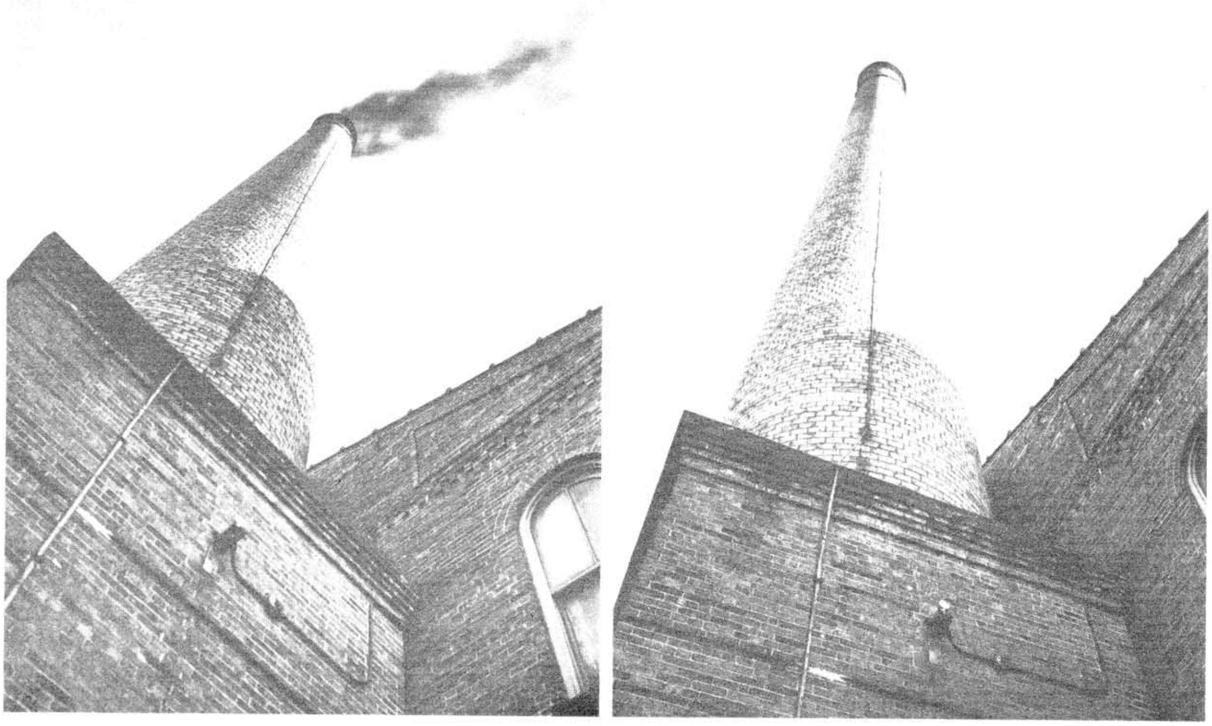
platinum electrodes. Then, in 1873, Willoughby Smith, a telegrapher in the Azores, noticed that the selenium in his line-testing instrument changed its resistance to current when light struck it. In 1887, Heinrich Hertz, a German, first discovered that substances shot off electrically charged particles, now known as electrons, in the presence of ultra-violet rays. These three discoveries, and the experiments that followed them, established the three ways in which photoelectricity operated, *i.e.*, the photo-voltaic, the photo-conductive, and the photo-emissive effects, as they are now called.

Although a photo-voltaic liquid type of cell did not appear on the market until 1930, experimenters had brought out both photo-conductive and photo-emissive cells by 1928 when Weston first got actively interested in cells. The photo-conductive types generally used a small glass disc covered with fine lines of platinum which were separated by lines of selenium; the platinum lines were really interlocking electrodes charged with current and when light fell on the selenium, reducing its resistance, the current flowed between them. The photo-emissive types, however, were like radio tubes, with their inside surface coated with light sensitive material; light struck this surface and released electrons which were picked up by a charged wire standing in the center of the tube. But the currents produced by both types were so minute that they needed to be stepped up with batteries and amplifiers so that they would be strong enough to operate even the most sensitive device for opening and closing a power circuit which would do the actual work. It was these devices, called relays, that experimenters originally sought from Weston, and in time Weston engineers grew curious about the photoelectric cell as a possible means of measuring light.

But all the commercial cells Weston bought and tested were either too weak or too short-lived or too unstable. The selenium resistor types needed an outside source of current and the selenium itself was too unreliable, changing with temperature, moisture and light intensity. The tube types, besides needing batteries and amplifiers, were apt to burn out if the sun struck them. And experiments with the liquid type showed that they were apt to explode or go dead. So in 1928 Weston's engineers set out to make a cell of their own.

For their model they took a fourth type of cell whose photoelectric effect scientists had observed since 1876 and which seemed to fall somewhere between the photo-voltaic and the photo-emissive type. In this cell, called the barrier-layer type, light set up an electronic reaction resulting in a current that was prevented from flowing in any but one general direction, supposedly by some kind of layer in the cell. As early as 1883 Fritts, an early American experimenter, had made such a cell with selenium and noted that it generated small currents in itself when light touched it. And a cell of this type, using copper oxide instead of selenium, reached the market in Germany in 1930. But it was neither very stable nor did it retain its original characteristics for long. Weston engineers, however, tried one combination of light sensitive materials after another, and in 1931, after trying for three years, they produced a cell that was stable, apparently permanent, and capable of sending out a light-generated current stronger than any other cell then known.

The secret was not so much in the ingredients—a mixture of iron, selenium, cadmium, nickel and other alloys—as in their blending. Spread on an iron disc, rimmed top and bottom with two current-collecting bronze rings, Weston's photoelectric blend became the first



A Fireman May Not See the Smoke . . . But a Photronic Cell Will Warn Him . . . Since bad combustion is liable to begin at home, Weston has put its smoke alarm device on its own chimney (above). From its perch at the base of the chimney a Photronic Cell peers through a hole straight into a light beam coming from the other side of the chimney. When smoke impairs the cell's vision, cutting down the current it is producing, a sensitive switch snaps shut, starting a series of events that will either warn the fireman or automatically correct combustion, or do both.

practical, stable, self-operating light cell in the scientific world. Or, in other words, it was the first apparently permanent device for converting light directly back into power, since the energy of the light waves in some mysterious way was transformed within the cell into electric current that was strong enough to operate a Weston moving coil instrument. Weston named it the Photronic Cell. It was, and still is, ridiculously inefficient, translating into power only a few tenths of one per cent of light's potential energy. But since it would operate a Weston movement, it gave Weston engineers the means of making the light-measuring instrument they originally had set out to make.

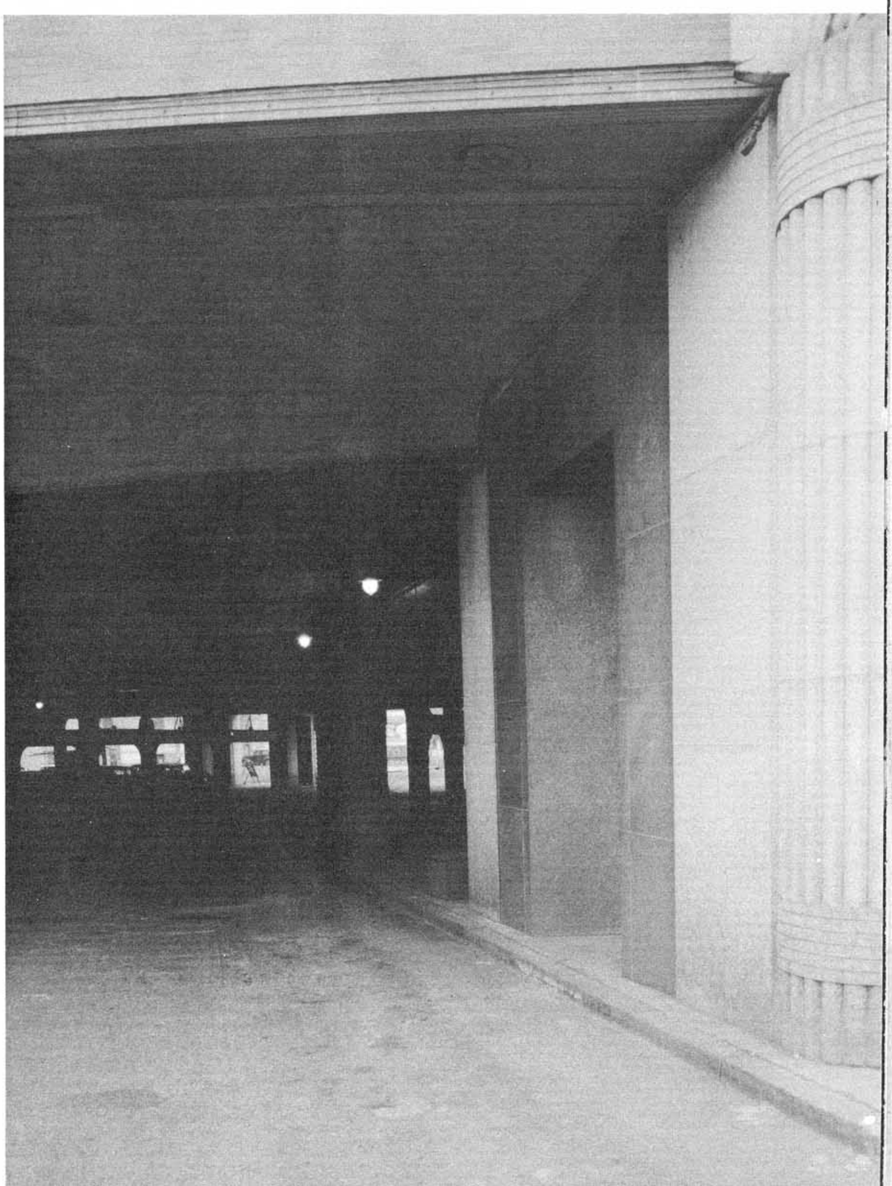
When the instrument came out in 1932, the lighting companies at once seized upon it as the instrument for measuring the efficiency of their lamps and street lighting installations. And because it gave them a direct reading in light values it wasn't long before it had replaced more complicated light-measuring devices based upon comparisons by eye of the light to be measured against standard tube-enclosed light. Weston soon followed this professional instrument giving readings in foot-candles with a Sight-Meter Light Indicator which had its dial marked off according to the light required for different kinds of work—for sewing, reading large and fine print, and severe visual work for long periods.

But the most successful adaptation of the cell was the exposure meter evolved in 1932. For years serious amateur photographers had calculated the exposure of their films with the aid of voluminous tables giving the average light intensity for every day in the year. When the cell came along, making it possible to measure light exactly, Weston saw that all this work of figuring out exposures could be done instantly if a calculator could be devised that would combine data on lens openings, film speeds, and exposure times with the light values the cell supplied.

Such a calculator was devised, but first Weston had to work out a new system for rating the emulsion speeds of films, since neither of the older systems—H & D and Scheiner—supplied the exact information Weston decided was necessary. The development of these Weston film speeds, which have already generally superseded the older systems, particularly in the United States, is a striking and very typical example of the thorough way Weston has gone about solving the measuring problems it has faced. And combined with the Photronic Cell, these speeds made Weston's exposure meter the first really accurate device for calculating camera exposures. For although it was not the first photoelectric exposure meter on the market, it was the first that possessed a self-generating cell which required no batteries.

Having introduced its exposure meter, Weston proceeded to improve upon it with the result that new models followed each other in quick succession. The first long rectangular model was superseded by an oval-shaped type in 1933, which in turn was superseded by a small rectangular model in 1935. Then in 1938 Weston provided a simplified instrument for amateurs who had little use for all the precise readings required by professionals and miniature camera fans.

Weston's other variations on its Photronic Cell are not instruments at all, but triggers. Almost from the first the dream has been to put the light-into-power phenomena to work, but no cell yet has been able to turn out much more power than it



Putting the Shades of Night to Work . . . These lights happen to be under the Pennsylvania Station in Newark, N. J., but Weston's Photronic lighting apparatus controls street lights in many towns. In this picture, what appears to be a snake issuing from the upper right-hand corner of the arch is a Photronic Cell in its round bull's-eye holder at the end of a cable that leads back to the light switch. Hanging there outside the tunnel, the cell generates less and less current in itself as the daylight fades, eventually allowing the switch to snap on the lights. But with sunrise, or after rainclouds have passed away, its current strengthens, opening the switch and dousing the lights.

Eyes Alone Cannot Measure Light Exactly . . . because no two pairs of eyes are exactly the same. But with a Bar Photometer Weston can check the electrical output of its Photronic Cells against the luminous output of Standard Lamps. Streaming through the row of little doorways which keep the lamp's beam uncontaminated by any other light rays, the standardized light falls on the cell that stands beside the meter which this man is reading, telling him whether the cell's current output is what it should be.

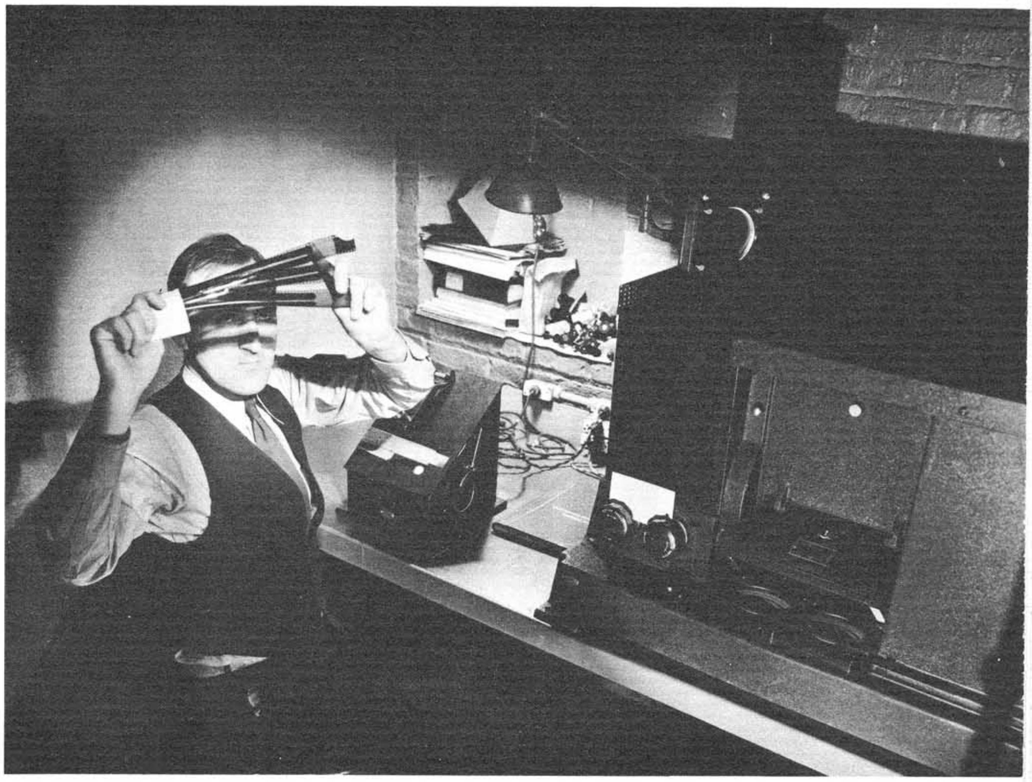
would take to lift a fly. Besides operating sensitive instruments, the only immediate use for such niggardly power has been as an automatic starter or stopper, having the cell's current set off a device that was cocked and ready to do the actual job. The device was a relay that closed or opened a circuit and, as we have seen, Weston got into the photoelectric cell field by making these relays for other cell experimenters.

As soon as the light-measuring instruments were well launched, Weston's engineers again got busy on the relay and in 1935 came out with the Sensitrol Model. It worked just like any other relay of this type, *i.e.*, when light generated current in the cell, the pointer on the Weston movement swung up to record its intensity; but if the light were interrupted or grew stronger or weaker, the pointer would move up or down until it struck a small contact standing in its path, thus completing a circuit which in turn usually set off another relay, closing still another circuit that was strong enough to do some mechanical job like running a motor or ringing a bell. Because the Sensitrol relay's little fixed contacts were magnetized, they would draw and tightly clamp the iron "rider" contact mounted on the pointer whenever it swung near, making a more dependable circuit for the controlled current.

Together, this relay and the cell with a beam of light focussed on it combined to form a hypersensitive trigger, and Weston now has several standard models of such light triggers in its Photronic Control line. One applies to industrial operations like counting, cutting, sorting and weighing. Here the beam of light may point at the cell across an endless conveyor belt on which cardboard boxes, say, are marching by in single file; every time a box cuts through the light beam, the relay will snap shut, then open, setting off an electrical impulse that will operate a counting meter, a sliding knife, a sorting or weighing device. Another model, the smoke alarm relay, responds when the smoke in a chimney gets dense enough to cut down the light beam focussed on the cell across the inside of the stack, making a bell ring or a light flash

Testing Testing Testing Instruments . . . Or, testing instruments that are used to test instruments that are used to test Weston's instruments. In this laboratory Weston makes sure that its instruments will agree with the primary standards of electrical measurement, those universally accepted combinations of metals and chemicals that define by international agreement, for example, what an ohm, a volt, or an ampere really is.

Photographers Have Accepted . . . Weston's system of rating film speeds, *i.e.*, how fast a film's emulsion reacts when exposed to light. Since 1932, when Weston introduced its camera exposure meter, camera addicts have come to refer to Weston speeds more often than they do to those older ratings, H & D and Scheiner. Weston tests its film samples in the big sensitometer and small densitometer shown here. Here Weston's film expert is examining the double track of exposed film which the sensitometer has left on three samples; from the way these tracks increase in density he can tell how fast the film will react to light and how much light it should receive in the camera to produce a perfect negative.



Since 1908 the Weston Normal Cell . . . has been the international standard of the volt. To provide a working standard of the volt, as well as a purely reference standard, Edward Weston developed in 1893 the Weston Standard Cell. These little glass jars, filled with mercury, cadmium and their sulphates, will generate an unbelievably steady voltage throughout their lives. Each cell going out from this laboratory gets a Weston certificate, and, if required, also one from the United States Bureau of Standards.

Weston's Basic Tube Tester . . . From the nine dials on the sloping face of this behemoth tube tester, Weston's engineers read the inner life of those radio tubes which are used as reference standards to test Weston's line of commercial radio tube checkers. Here a tube checker is being checked with a tube from Weston's rack of standards, which has, in turn, previously been checked on the giant master tester against the data established by agreement among manufacturers as bogie for this type of tube.

down in the fireman's room, so warning him that his fire needs looking after. And passengers rushing for trains through New York's Pennsylvania Station have seen another form of Photronic Control when the doors they expected to push open suddenly flew open ahead of them; they had walked through a beam of light streaming between two brass posts outside the door and focussing on the photoelectric trigger that set off an electric door-opening device.

Weston's third model of Photronic Control uses daylight instead of a focussed light beam and turns street lights on and off for local lighting companies. Perched high on a pole, a Photronic Cell will deliver enough current to the Sensitrol Relay to shut a city's lights off when the sun rises and turn them on when the sun sets or when clouds darken the sky during a storm.

A DEPARTURE

In 1935 Weston stepped outside the field of electrical measurement for the first time. That year it devised, in collaboration with its associates, a new instrument for measuring temperature. It was a mechanical thermometer based on the familiar bimetal principle found in thermostats used in heating systems, electric irons, aircraft instruments, etc. The bimetal principle is simply an application of the fact that metals expand and contract differently with heat and cold; if two metal strips are joined together, wound into a spiral and a pointer fastened at the center, a change of temperature will make the spiral twist, moving the pointer in an arc.

Instead of coiling the laminated strip of temperature-sensitive metals into one flat spiral, however, it was made into a nest of helical springs, one around the other, producing a unit that corrected the sag and sidesway errors often found in common bimetal thermometers. Each of the helices in the unit counterbalanced the distorting forces of the ones next to it so that the pointer always gave a true reading. This stainless steel encased instrument has no glass tube to break or explode if overheated. And in addition these new temperature gauges are as easily read as the face of a clock. Because of these characteristics, Weston's thermometers are today being used in many places where the job of reading temperatures has long been costly and difficult.

CONTROL

Thus ends the recital of representative outstanding Weston developments in the fifty years that have followed the debut of Edward Weston's Model One meter. As developments they are a remarkably clear reflection of the kind of painstaking work which the Company's founder lavished on his first instrument. And commercially they were responsible for Weston's moving first from the High Street Laboratory into a four-story building on Newark's William Street in 1895; and then, when these quarters became too small in 1900, to a spot in the country about three miles out from Newark's business center on the road to Elizabeth where the plant was settled for good in a 12-acre field and a group of five red brick buildings which has since grown to fifteen.

The final credit for Weston's showing, of course, must be given to the instruments themselves. But behind those instruments lies the all-important fact that Weston's mechanical and electrical developments have gone hand in hand with its advance in manufacturing methods. If you walked through Weston's plant today you would see hundreds of employees hard at work, but you would find it difficult to see how the thousands of parts and masses of wire and steel and copper they are working on manage to pass through the shop without cluttering up the floors and aisles and benches. Most of the orders being filled in Weston's shop are for stock models whose manufacture can be carried out with clocklike routine, but some 30 per cent will be for special instruments each designed for one particular use or customer. To keep them all flowing steadily, Weston depends on its efficient production control, a system involving punched tabulating cards and perpetual inventory cards for each part which does away with "stock chasers" and allows Weston's orders to move through to completion on orderly schedule.

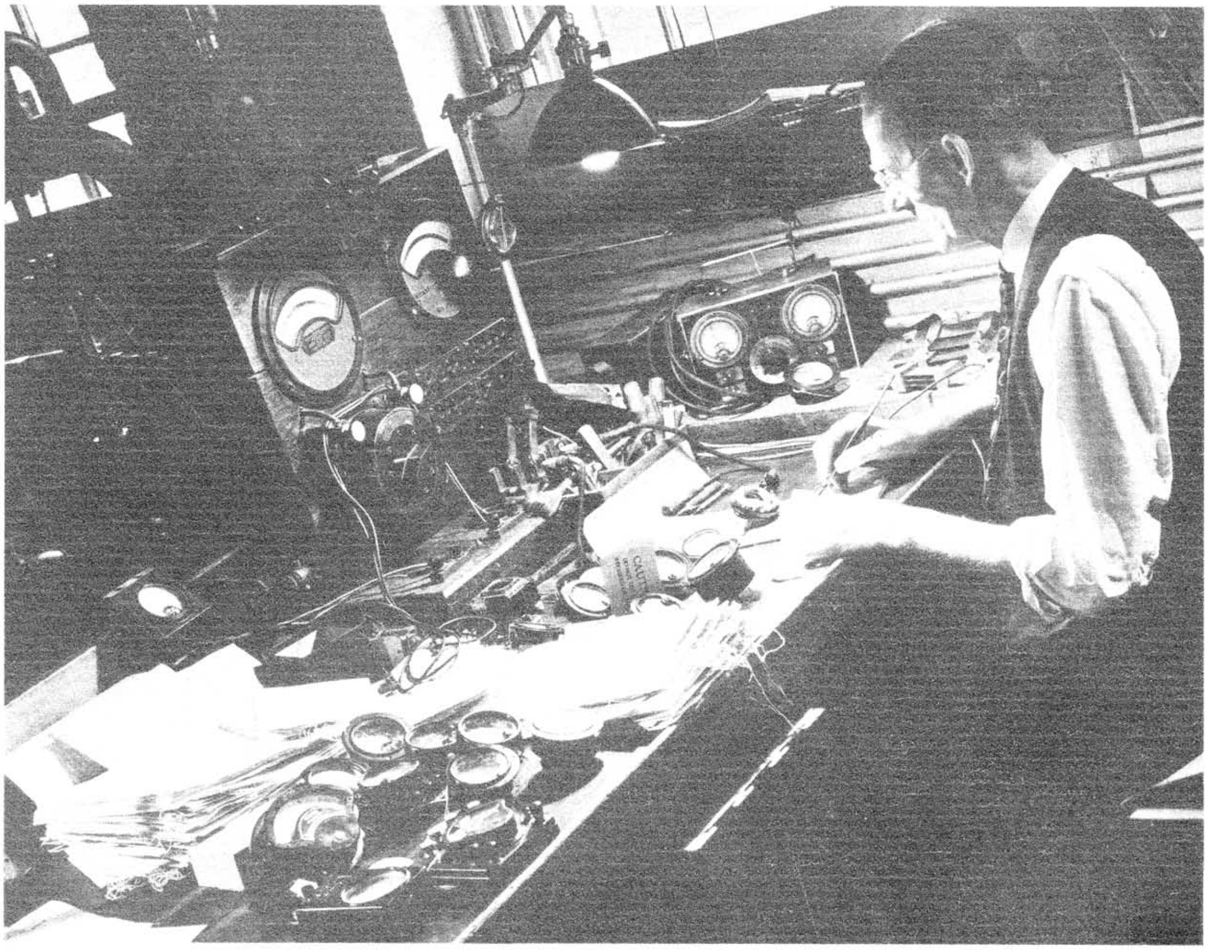
SALES

Since 1888 Weston has seen its selling job change from one of letting the instruments sell themselves to one involving the services of specialized agencies scattered across the country and throughout the world. Its two branch offices—New York and Chicago—are Weston-manned, but most of its sales come through twenty or more domestic and some forty-five foreign agencies handling, besides Weston's models, a complex line including transformers, central station equipment, controls, high tension fuses and switches. Weston's agents, therefore, know what the electrical trade wants since they are also selling from two to five or more other allied products.

As for the foreign market, Weston has been competing with foreign instrument makers since 1895 when it established a plant in Germany. When the war broke out the German Government took it over and Weston hasn't gone back to manufacture there, but a Weston plant has been operating in England since 1904.

AN OLD FORMULA FOR THE FUTURE

But wherever Weston sells its instruments, in Tokyo or London or San Francisco or New York, it has steadfastly refused to lower quality to cheaper competitive levels, although, to be sure, it may simplify some of them to bring them within the range of popular use. And Weston has had



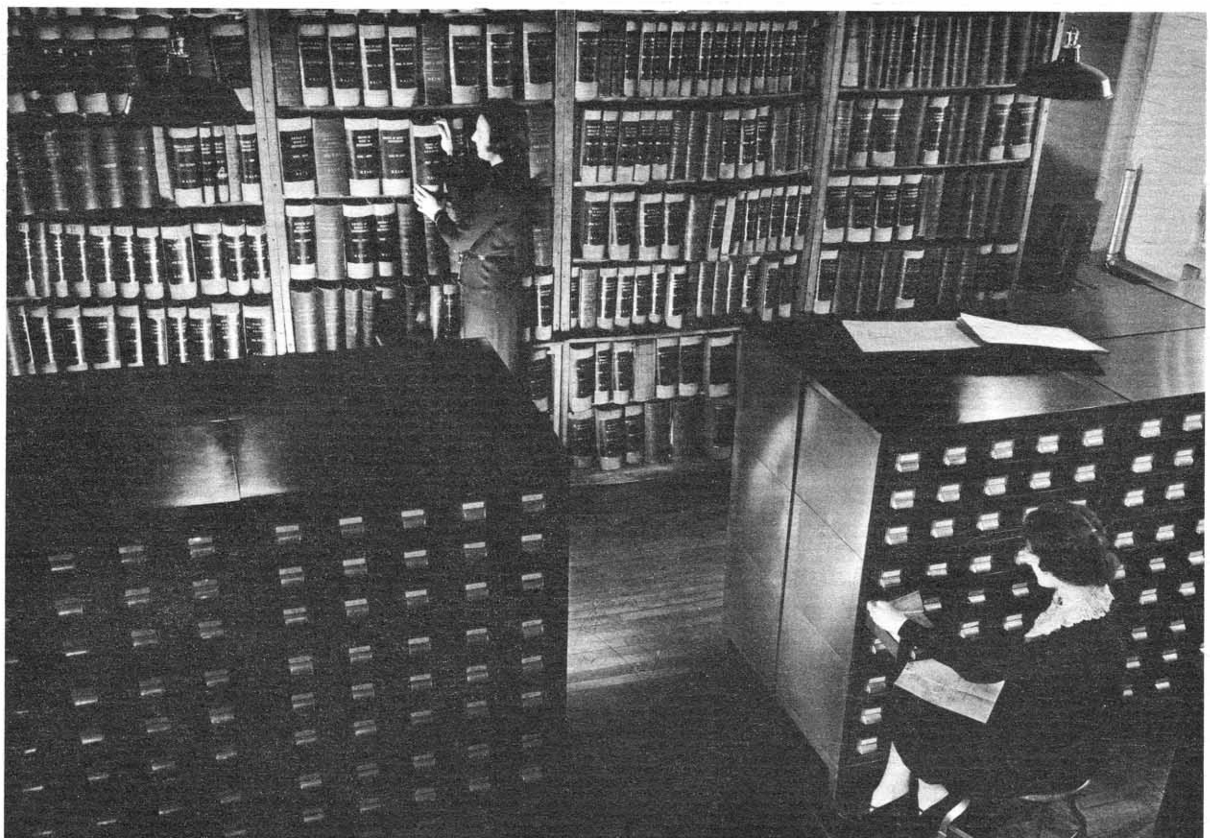
Weston's Base Hospital for Crippled Instruments . . . handles some hundreds of new cases a week, many of them coming to the Newark plant from halfway around the world. This inspector diagnoses the symptoms and determines whether mistreatment, accident, defective manufacture, or acts of God have caused the damage. Since many parts made today will fit in models made forty or more years ago, and since most instruments are rebuilt rather than repaired, new Weston movements replacing the damaged ones, an instrument is rarely too obsolete to go through Weston's ordinary repair routine.

excellent reasons for following this policy for fifty years, since it is based upon a craftsmanship, a penchant for perfecting little details, that has obviously made Weston instruments what they are. Admittedly it is an expensive way to do things. And if huge profits were the immediate short-range aim and end of the business, it could not be justified. But in the long run the very precision of Weston instruments, costly though it is, is the guarantee that the Company will prosper and endure as it has during its first fifty years.

For, come good times or bad, fine instruments remain a necessity in this mechanized world. Progress toward new technologies is based upon smaller and smaller tolerances, finer and finer measurements, before it becomes translated into larger and larger bulk and production. The output of steel, and of automobiles and radios may tumble periodically during economic cycles, and the market for mass-produced instruments may slump with them. But the precision behind all production has an existence almost independent of economics. There are always new problems of measurement to be solved in the laboratory rather than the stockroom. There are always new industries rising, as did the automobile, the airplane and the radio. There are always new refinements being achieved within established industries. And at their core, in some form, is an electrical current which must be measured. So Weston's uncompromising care is logical.

Not only logical but inevitable. For it is a direct inheritance from Edward Weston, who was never satisfied until he had found the best material to use and the best way of using it. He spent most of his life between his laboratory and the workbench, changing this, discarding that, improving this, and he was very careful to surround himself with men who felt the same restless urge about making instruments. That urge has been going on now since 1888. It is at once the explanation and the practical justification of the Weston Electrical Instrument Corporation.

The Biographies of Thousands of Instruments . . . can be read in these volumes and on the filing cards Weston now uses to keep track of special instruments whose individual peculiarities must be remembered if and when they return for repair. The first entry in the oldest book gives the career of a voltmeter shipped to Johns Hopkins University on May 6, 1889; in 49 years of service it came back five times for overhauling.



PLANNED AND WRITTEN BY
F. LAWRENCE BABCOCK ASSOCIATES, NEW YORK

PHOTOGRAPHS BY
RUSSELL C. AIKINS

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JENKINS & GUILLO, INC., NEW YORK AND
H. G. POTTER, NEWARK, N. J.

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