A HISTORY OF THE GENERAL RADIO COMPANY

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BY

ARTHUR E. THIESSEN

WEST CONCORD, MASSACHUSETTS
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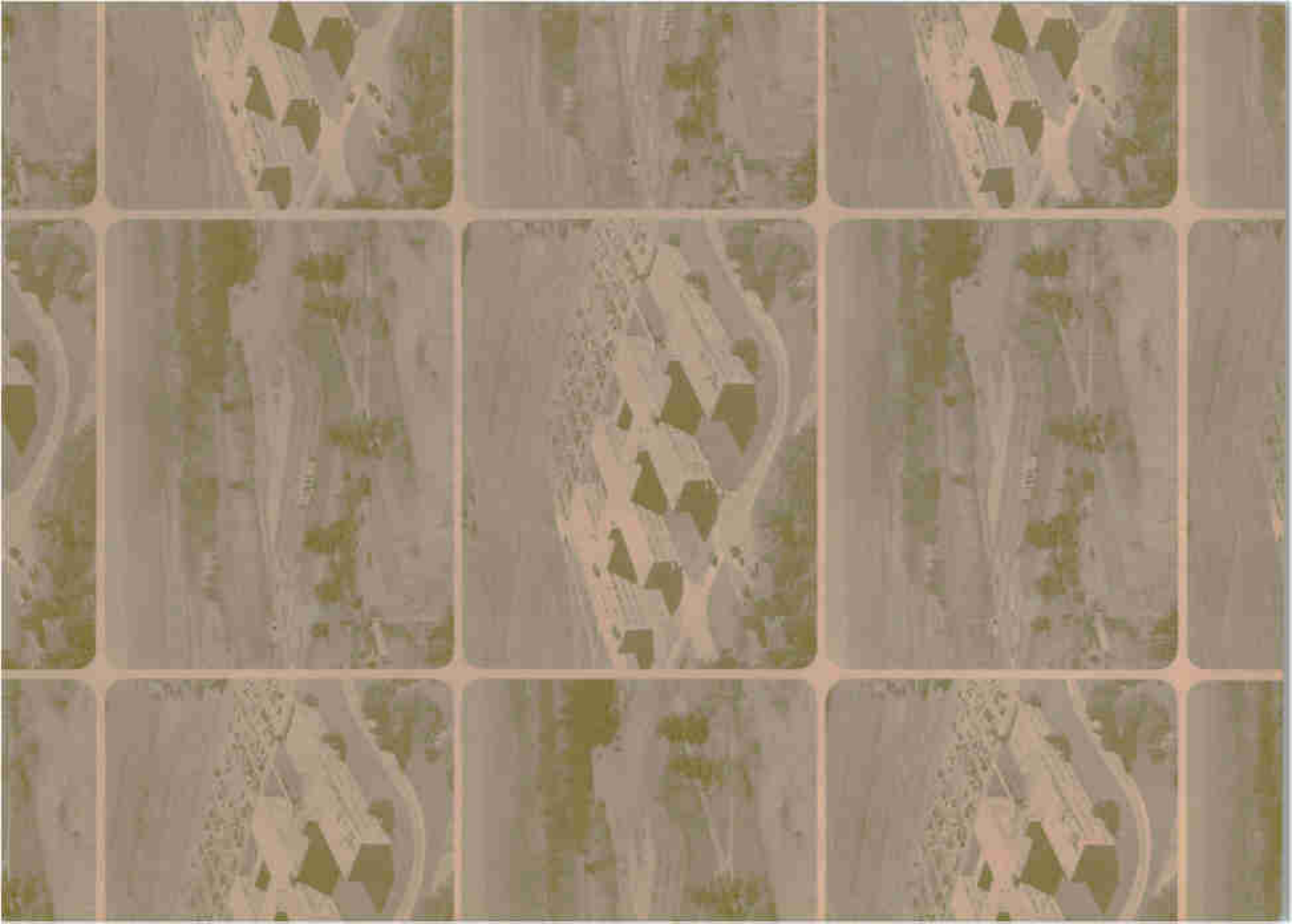

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ACKNOWLEDGMENT

The author gratefully acknowledges the help of all those who so willingly supplied certain of the facts and background for this history, and especially of Frederick T. Van Veen for editing and Veronica A. Krysieniel for preparing the manuscript.

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FOREWORD

THIS is the story of an unusual company and a maker of unusual things. Unavoidably, I am afraid, when one talks about some of them, the language gets rather specialized. If (like my wife) the reader finds those passages to be pretty incomprehensible, they may well be skipped; this story is principally about the company itself and the men who made it.

This history is being published on the fiftieth anniversary of an electronics company. That is a mature age for any organization, but it is more than that in the electronics industry—it is a record. No other electronics manufacturing company in this country, perhaps in the world, has been so long continuously in the business.

But longevity, while interesting, perhaps even commendable, is itself hardly a virtue. It is the future that counts. Unlike people, organizations can renew themselves. We at GR believe that new people, new ideas, and progressive management are the things that will make the future in this fast-moving art even more productive and more interesting than the past.

A. E. T.

March 30, 1965

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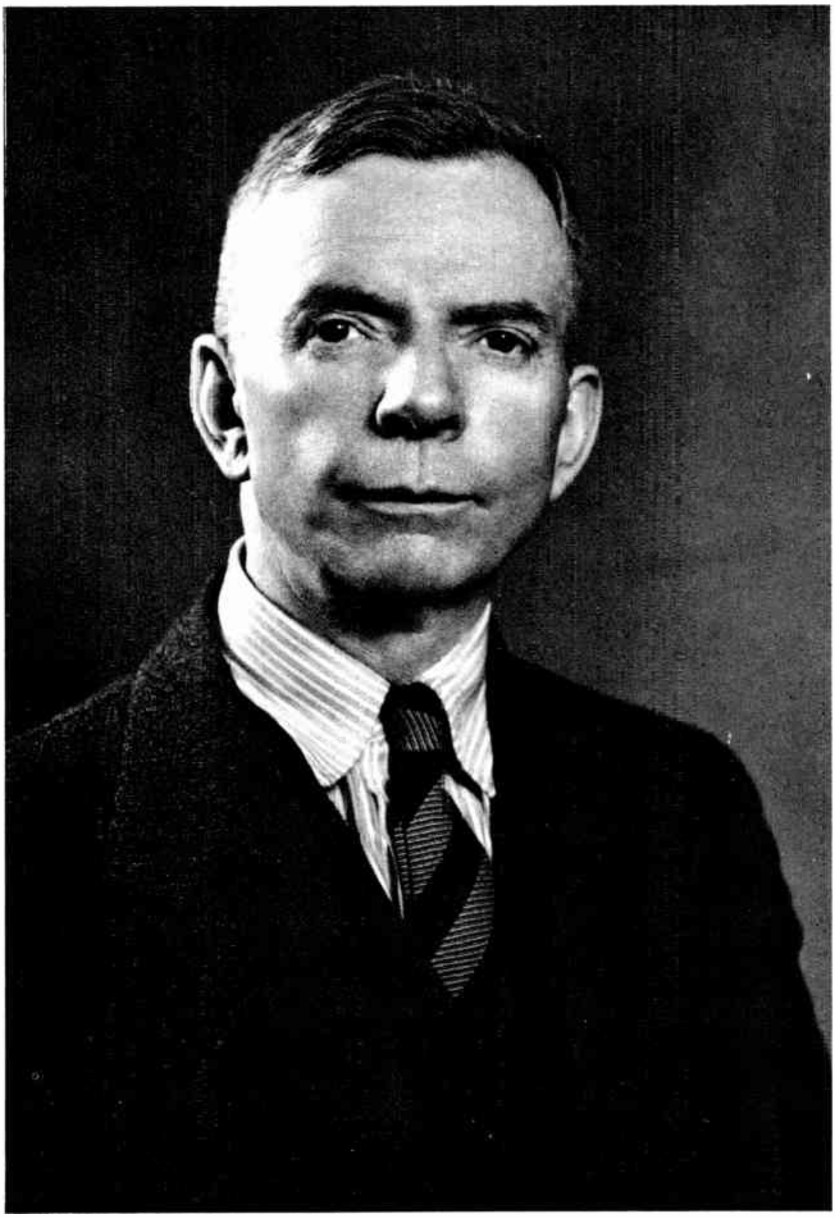


Melville Eastham,
founder of General Radio Company

I

The Early Days

DURING the first two decades of this century the science of communication without wires came out of the laboratory to become a practical art and to grow into a new industry.

Much of the basic scientific work upon which this new industry was founded had been done almost a half century before, in 1864, by the great English mathematician and physicist, James Clerk Maxwell. His brilliant theoretical work, based in part upon the experiments of a still earlier genius, Michael Faraday, mathematically proved that electric waves could and must exist in space. Up to that time their existence had been little more than a suspicion among the world's scientists.

It was the German, Heinrich Hertz, who proved Maxwell's theories by practical experiment about 1890. Many other experimenters contributed both theoretical and practical ideas, including even the idea of communicating intelligence through space without wires, but it remained for the Italian, Guglielmo Marconi, a few years after the publication of Hertz's experiments, to visualize the commercial possibilities. These he pursued with intelligence, vigor, and persistence, so that by 1901 his new British Marconi Company had transmitted the first feeble signal across the Atlantic from England to Newfoundland.

Receiving equipment in those days was so insensitive that to send a signal for any distance required enormous power at the transmitting end. Lee DeForest's invention of the vacuum tube in 1906 was destined to change that. This "greatest single invention," whose value was at first not appreciated even by the inventor, was eventually to revolutionize the radio art and become the foundation of the electronics industry.

During these years many other brilliant inventors were at work, and among them they contributed the practical inventions that gave the new industry the means for the rapid growth that was to follow. For instance, in addition to DeForest and his three-element vacuum tube, Fessenden discovered the heterodyne principle. Lowenstein, Langmuir, and Arnold discovered that the cranky and undependable early vacuum tube could be made reliable by the use of high vacuum inside the tube. Alexanderson developed his high-frequency alternator, and later Armstrong developed both the superregenerative and superheterodyne circuits.

As a practical art, radio communication was used at first principally for communication from ship to shore and ship to ship. Static was a most serious problem and competition from the land telegraph and the telephone hampered the growth of radio except where the land lines could not reach. The Titanic disaster in 1912 dramatically awakened the interest of the general public in this young industry. Two ships were near the Titanic when her first SOS went out. But one ship had no radio, and the other's was not turned on, so it was the S.S. Carpathia, sixty miles away, that received the distress call and dashed to the rescue, to arrive hours after the other two ships could have been there.

Very early in its history, probably like no other industry, radio communications had attracted an unprecedented number of young experimenters, who avidly built and operated their own radio stations. One of these was Melville Eastham. His interest in electricity may have been partly inherited. His father, Edward Lawson Eastham, was one of the pioneers in the utility business, having been instrumental in setting up the first electric power generating system in their home state of Oregon. Eastham was always more interested in the experimental side of radio than in the actual sending and receiving of messages and so would not qualify as the true "ham," as these enthusiastic radio amateurs are called.

Upon the invitation of an acquaintance in the East, Elmer Willyoung, Eastham at the age of twenty came to New York in 1905 and soon went to work for Earle Ovington, an aircraft pioneer who headed the Ovington X-ray Company. Ovington's chief engineer was W. O. Eddy, and one of his sales engineers was J. Emory Clapp. In 1906, Clapp, Eddy, and Eastham decided to go into business for themselves, manufacturing X-ray machines. Clapp financed the venture, and they moved to Clapp's home town, Boston, and started the Clapp, Eddy and Eastham Company at 100 Boylston Street. The next year Eddy left and the firm became known as the Clapp-Eastham Company, continuing with the manufacture of X-ray equipment. The high-voltage spark coils used in those equipments were popular with the radio amateurs for their transmitters. Answering more of the needs of the amateurs, the new company soon was manufacturing variable capacitors, spark gaps, crystal detectors, and many other components used by the hams as well as by the professionals of those days. Gradually, the company drifted out of the X-ray business, and Clapp, whose interests had always been in that area, sold out his interest to O. Kerro Luscomb in 1910. That year the firm moved to Kendall Square in Cambridge, Massachusetts. By this time it was a favorite supplier for radio experimenters and had built up a substantial business and a reputation for the quality of its products, and its customers included most of the men now in radio's hall of fame: R. A. Fessenden, E. H. Armstrong, G. W. Pickard, G. W. Pierce, John Stone Stone, among many others.

While this was a growing and successful business, now moved again to larger quarters in Cambridge, Eastham recognized that one of the great needs of the radio industry was measuring instruments. In the older electrical sciences, excellent and precise instruments were available for the measurement of direct current, voltage, and resistance, and quite good measuring instruments were available in the alternating current power field as well, which was by then rapidly replacing gas for lighting and supplementing steam for power. But at the high frequencies used for radio, very little measuring equipment was available. Recognizing that if the art were to continue to advance, more and better measurements would have to be made, and recognizing that progress would automatically bring greater demands for measuring instruments, Eastham left active participation in Clapp-Eastham to start the General Radio Company in 1915. He and Luscomb agreed that the latter would continue to operate Clapp-Eastham but would have a substantial interest in the new Company.

General Radio's first home was the third floor of this building at the corner of Massachusetts Avenue and Windsor Street, Cambridge.

II

General Radio Gets Its Start

WITH a total of $9,000 in capital, subscribed by three investors, Ralph C. Emery, Ralph C. Watrous, and Cyrus P. Brown, for a half interest, and with Eastham and Luscomb contributing patents, ideas, and their specialized skills, each for a quarter interest, the new Company went to work on the third floor of a small flatiron building that still stands at the corner of Massachusetts Avenue and Windsor Street in Cambridge, Massachusetts. Emery had been in the old Boston shipping firm of John S. Emery and Company, whose history dated back to the days of sailing vessels. Watrous was a prominent citizen of Rhode Island and had been its Lieutenant Governor. Brown was not a New Englander but was a resident of St. Paul, Minnesota, and a friend of Watrous. He did not actively engage in the business. Eastham, Emery, Luscomb, and Watrous were the company's first Board of Directors.

The first entire employment roster at GR included only Eastham and a skilled machinist, Knut Johnson, who had joined Clapp-Eastham two years earlier in 1913. Even for skilled men, jobs were not easy to come by in those days. Johnson recalls that, in answer to an ad in *The Boston Post*, he took the subway to Kendall Square, Cambridge, and found "about 500" already in line for the one machinist's job being offered. Overcoming the initial urge to turn around and go home, he joined the line and was finally interviewed. The interview terminated with a "Don't call us. We'll call you." Johnson remembers receiving on a Friday the 13th the letter offering him a job at a starting wage of 35 or 40 cents an hour.

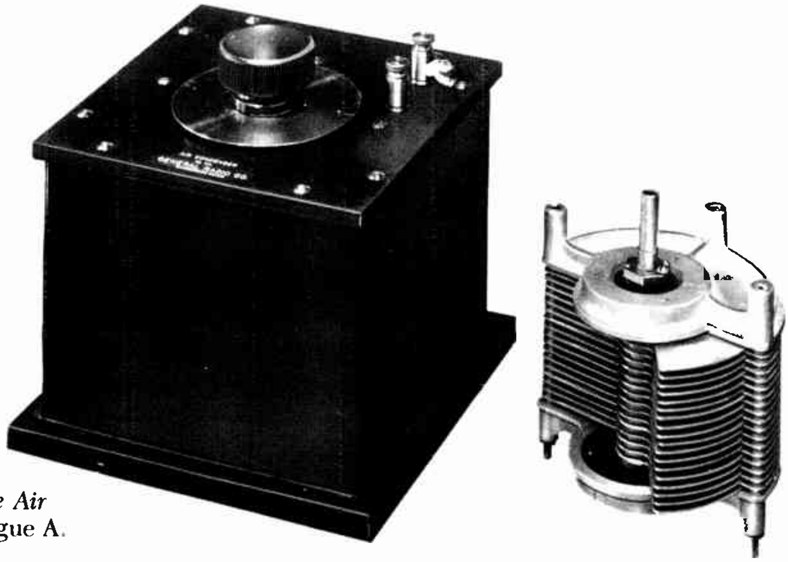
Ashley C. Zwicker, another C-E alumnus, joined General Radio in 1916 and became GR's first foreman. Employment had grown to about thirty by this time.

In 1917, after the Company had been in operation for two years, Eastham exchanged his interest in Clapp-Eastham for Luscomb's interest in GR. Luscomb, GR's first treasurer, was kept occupied with the Clapp-Eastham Company, and so Watrous, previously an inactive partner, had become treasurer in 1916.

Nowadays a question frequently asked is why it is that General Radio doesn't make radios or even radio parts. The answer is that in 1915, when the name was selected, the word "radio" was new and interesting, having lately been coined as a substitute for the more cumbersome "wireless telegraphy." The origins of the word are obscure, but it does appear in German publications as early as 1909, and, when the first professional association of wireless pioneers was organized in this country in 1912, the founders gave it the name of the Institute of Radio Engineers. It was some eight years after the General Radio Company was started that the word "radio" came to mean the instrument that was becoming even more popular than the piano or the Victrola. The Company name by that time was so well established that it could not readily be changed. "Radio" in 1915 was roughly equivalent to "electronics" in 1950.

The Institute of Radio Engineers, probably the first organization in this country to have the word "radio" in its name, quickly became the recognized professional organization, and its journal, *The Proceedings*, has ever since been the bible of the professional radio engineer. In the issue of December, 1914, Elmer E. Mayer, who was chief engineer of a famous radio transmitting station at Tuckerton, New Jersey, wrote, "The efforts of Mr. Eastham deserve the highest credit, and I think that very many members of the profession besides myself would appreciate it if Mr. Eastham would develop his radio-frequency wattmeter to the point of commercial usefulness." Mayer's comment illustrates the profession's need at that time.

Eastham had a number of instruments in mind for the new Company to make, and he promptly started their designs. It took much less time then than it does now to get a new instrument to the market; still it did take time—and money, of which the new Company had very little. Simultaneously with this work, then, and having a solvent customer waiting, General Radio undertook a job to make a nine-phase, synchronous, commutator-type rectifier for the American Telephone and Telegraph Company in New York. This rectifier was to be a part of a significant step forward in the radio communications business, and so the story, connected as it was with the founding of



The Type 101L Variable Air Condenser, from Catalogue A.

General Radio, is worth relating. The time was 1915.

A. T. & T. earlier in the year had successfully completed the first transcontinental telephone call by land lines, a feat made possible by recent improvements in the vacuum tube. The war in Europe threatened to interrupt communications to the Continent, and the Telephone Company wanted to see if transatlantic radio telephone communication would be possible. The French enthusiastically welcomed the idea and set up a receiver on the Eiffel Tower to listen for signals from a powerful transmitter at Arlington, Virginia. The transmitter utilized several hundred vacuum tubes, operating in parallel, and required a very high plate voltage. The General Radio synchronous rectifier was to supply this voltage. As the whole science of radio voice communication was in its earliest beginnings, the experiment was not very successful, but much was learned. It was to be many years before a practical transatlantic telephone was developed.

General Radio published its first catalog of instruments in 1916. Among the products listed were a Precision Variable Air Condenser ($25.00), a Decade Resistance Box ($19.00), a Precision Variable Inductance ($24.00), and an Absorption Wavemeter ($60.00).

In creating the new Company, Eastham wanted to do more than just manufacture quality measuring instruments. It was his concept that a manufacturing company could and should do many things for its employees. It should provide a pleasant environment in which to work; the work week should be as short and the vacation and holiday schedule as liberal as possible, compatible with efficient operation; its growth should be gradual and financed from earnings; for maximum job security there should be no layoffs or shutdowns; profits should be shared among the stockholders, the management, *and the employees.* These were radical concepts in the industrial climate of 1915. How these basic aims were carried out is a part of this story.

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Although these ideas were entirely Eastham's, it happened that there was another company that had in fact been operating for some years closely along the same lines. This was the firm of Carl Zeiss in Jena, Germany. Zeiss, a skilled mechanic, had, since 1846, been manufacturing optical instruments on a small scale in Jena. Although his instruments were built as well as they could be with the knowledge then at hand, Zeiss knew that they could be improved. To that end, in 1866, he persuaded an outstanding scientist, Dr. Ernst Abbe, a professor at the nearby University of Jena, to assist, particularly with the design of microscopes. As time went on, Abbe began to devote his whole time to the business, and when Carl Zeiss died in 1888, Abbe bought out the Zeiss interest and became the sole owner of the business. Soon after, Abbe deeded the whole ownership to a foundation, which he modestly named for his friend, Carl Zeiss.

The charter, or statute, of this foundation is a remarkable document, explicit in detail and a monument to Abbe, its author. It begins by enumerating the objectives of the foundation, which are stated:

> To cultivate the branches of precise technical industry of Jena (optics and optical glass); to fulfill higher social duties than personal proprietors would permanently guarantee; to take part in organizations and measures designed for the public good; and to provide permanent solicitude for the economic security of the Zeiss Works and particularly for the further development of their industrial labor organization as a source of subsistence for a large number of people, and to better the personal and economic rights of those people.

Paid vacations, sick benefits, retirement income, and the provision that there should be no discrimination because of race, religion, or politics were all part of the charter. It is dated 1905, but Ernst Abbe had the principles in effect in 1896!

But this was in Germany, and the Carl Zeiss Foundation must have been unique in the world. Probably because of Abbe's modestness the foundation was not widely publicized, but Eastham read all that he could find about it and, in the mid 1930's, long after Abbe's death, traveled to Jena for first-hand observation. What he saw reinforced his own beliefs about how an industrial operation should be run and firmed his resolve to continue to guide GR along the path that he had envisaged and which was so similar to Abbe's.

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When the United States entered the First World War in 1917, the demand for General Radio products, as a part of the war effort, rose dramatically, as it was destined to do again during World War II and still later in the Korean conflict.

The possibilities of radio and electronics as weapons of war were not as well understood in 1917 as they were in 1940, but even so, there was urgent need for field communications equipment. Therefore, while the manufacture of laboratory instruments continued all through the war, the company was also called upon to make great quantities of portable wavemeters and crystal sets for communications in trench warfare and to direct artillery fire. To meet emergency production needs, the work force was increased to several times the twenty then employed. Harold O. Erb, one of the skilled electrical technicians who was working on instrument assemblies recalls, "All kinds were hired. We had, for instance, one long bench with twenty to twenty-five Greek young men, most of whom spoke no English. A lad of Irish extraction supervised and instructed them by pantomime. They did minor assembly work. We had some fellows who had been salesmen, clerks, etc., trying to do mechanical work, and it was sometimes pretty pathetic."

Among the first shipments of instruments during that war was a number of precision air capacitors. One of these found its way to an Army laboratory in France, where Lieutenant E. H. Armstrong was experimenting on a new circuit to improve the performance of radio receivers. He appropriated the capacitor, his new circuit was a sensational success, and thus one of the Company's earliest products was incorporated in the first superheterodyne receiver.

The Company's first profit-sharing bonus plan, most unusual in its

Henry S. Shaw and Melville Eastham. These two men, of complementary talents, set General Radio's course in its early years.

day, was begun in October, 1917. Every employee who had been with the Company for more than one year received one week's extra pay twice each year, on June 15 and December 15, or could, if he wished, take one extra week of vacation with pay instead of one of his bonuses. Those with less than a year's service but more than six months' were entitled to one-half a week's pay. The regular paid-vacation period was two weeks—also generous for that time.

A year later, life insurance, with premiums paid by the Company, was placed on all employees. This was surely one of the first of the now common group-insurance plans. The coverage was $1,000.

At about this time the Company was able to finance the purchase of its flatiron building plant at a price of $70,000.

Also in 1917, Henry Southworth Shaw, who was a radio amateur and who had become acquainted with Eastham through his purchases of General Radio equipment for his ham activities, one day asked Eastham if there was something he could do to help with the war effort. He was promptly hired to do design work, but there was more urgent need in the office. Emery, who had been working on the books, but who had many other interests and could devote only part time to the job, arranged for Shaw to take charge of the day-to-day office work, which was then building up rapidly.

At the end of the war, in 1918, there was, of course, a general cancellation of military contracts, and General Radio, along with many other companies, experienced a severe slump. Then came the time of decision. Eastham had founded the Company to make measuring instruments. However, his partners, Emery, Watrous, and Brown, were attracted to the idea that the Company should make high-production parts and components, radio transmitters, and receivers. Eastham opposed this for a number of reasons: His major interest was in instrumentation, and he felt that in the long run it would be more profitable; the patent situation was so confused that he foresaw difficulties ahead for those engaged in radio-set and transmitter production, and most importantly he realized that with the intense competition and the large increase in personnel needed for mass production it would be very difficult to improve further, or even to keep, the kind of working atmosphere that had started so well at General Radio.

Finally the issue was settled by Shaw, a man of independent means, who in 1919 bought out the interests of Emery, Watrous, and Brown for $32,000. This was, practically speaking, the last outside capital ever subscribed in the Company. Thereafter all financing came from earnings, except for minor stock purchases by individual employee-stockholders. Shaw became the GR treasurer, succeeding Watrous, and a director in January, 1918, later became its chairman of the board, which post he held until 1944, and thereafter remained active in GR affairs until his retirement in 1950.

When Emery and Watrous, who had been directors, left the Company, Lawrence Mayo, a prominent businessman and an uncle of Shaw by marriage, was elected as the third director with Shaw and Eastham.

Two years before, in 1917, Homer E. Rawson, Harvard '14, joined the Company and soon became vice president. He left the Company in 1919 to join with Arthur J. Lush to start the Rawson Instrument Company to manufacture sensitive dc meters, similar to those of Paul, a famous English manufacturer, whose U.S. agent Lush had been. Zwicker, the erstwhile foreman, by now GR's superintendent, left a year later to found the Acme Apparatus Company to make transformers, rectifiers, and battery eliminators. With its name later changed to the Delta Manufacturing Company, that company was an important component of the Raytheon Company.

Errol H. Locke, another recent Harvard graduate, joined in 1918. In 1919 Harold B. Richmond joined the Company. Locke was to become vice president in 1920 and Richmond treasurer in 1926.

As the Company struggled out of the postwar depression and resumed the design and manufacture of instruments, it accepted a contract with the Navy Department for the manufacture of hydrophones that had been developed by Professor George Washington Pierce of Harvard. These hydrophones were rubber-covered, carbon-granule microphones placed below the waterline of ships and submarines to detect underwater sounds, particularly from enemy submarines. General Radio, which at that time had about 135 employees, employed H. W. Lamson and P. K. McElroy, both recent Harvard graduates, who were two of Pierce's assistants, to engineer the project, which was highly successful both for the Navy and for the Company. Lamson and McElroy became the first full-time engineers on the payroll and were with the Company until their retirements in 1958 and 1964. Up until their arrival nearly all engineering had been done by Eastham.

Of that time Erb recalls that nearly everyone came to work by streetcar, except a few who came on bicycles. All of the power required for the entire plant was from two 5-horsepower motors operating the machines from jackshafts.

Two important employee benefits were introduced in 1919. A 40-hour work week was established. It had been 44 hours, and the average in industry at that time was 46.3 hours. Also, the annual number of paid holidays was increased to nine. In addition, in the same year, the original bonus plan of two weeks' pay was superseded by a more generous one, but one that was geared directly to the Company's earnings. This plan partially realized one of the more important of Eastham's concepts of business management. This was that the owners, the managers, and the employees should in principle be partners. Profits, as earned, should be shared among those groups; the new bonus plan was designed to implement this by paying generous bonuses to all employees in good times and, conversely, smaller ones or none at all in bad. Many refinements of the manner of distribution have been worked out since then, but the basic principle has never changed.

By 1921, except for the hydrophone project, the Company was entirely back in the business of making instruments. But it was to encounter one more diversion before it was to return permanently to instrument manufacture.

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In 1920 the Westinghouse Electric Company started the first commercial broadcasting station, KDKA, in Pittsburgh, broadcasting returns of the Harding-Cox presidential election. The project was an instantaneous success, and within a year about thirty broadcast stations were in operation. However, there were almost no broadcast-receiving sets except those built by the amateurs. The "ham shacks" thus became the popular rendezvous of the neighbors, thousands of whom promptly decided to build their own radio receivers. Almost overnight a great do-it-yourself craze swept the country, with a corresponding huge demand for receiver parts. The Company, which had been supplying the amateurs, found itself swamped with orders from the neighbors for tens of thousands of components, audio transformers notably, which had been previously produced in hundreds.

This lasted for only three or four years before other manufacturers began to make complete receivers. When these became available at reasonable prices, the do-it-yourself fad died as quickly as it had been born.

This was the beginning of the broadcast receiving-set industry, and these manufacturers, in need of testing instruments, eventually were among GR's best customers. The recognition of the need was not immediate, however. At first the emphasis was on production and sales promotion; design and testing were empirical. But as competition grew and purchasers became more critical, quantitative measurements became increasingly important as a means to reduce manufacturing cost, to improve electrical design, and to ensure the uniformity and quality of performance of the finished sets.

III

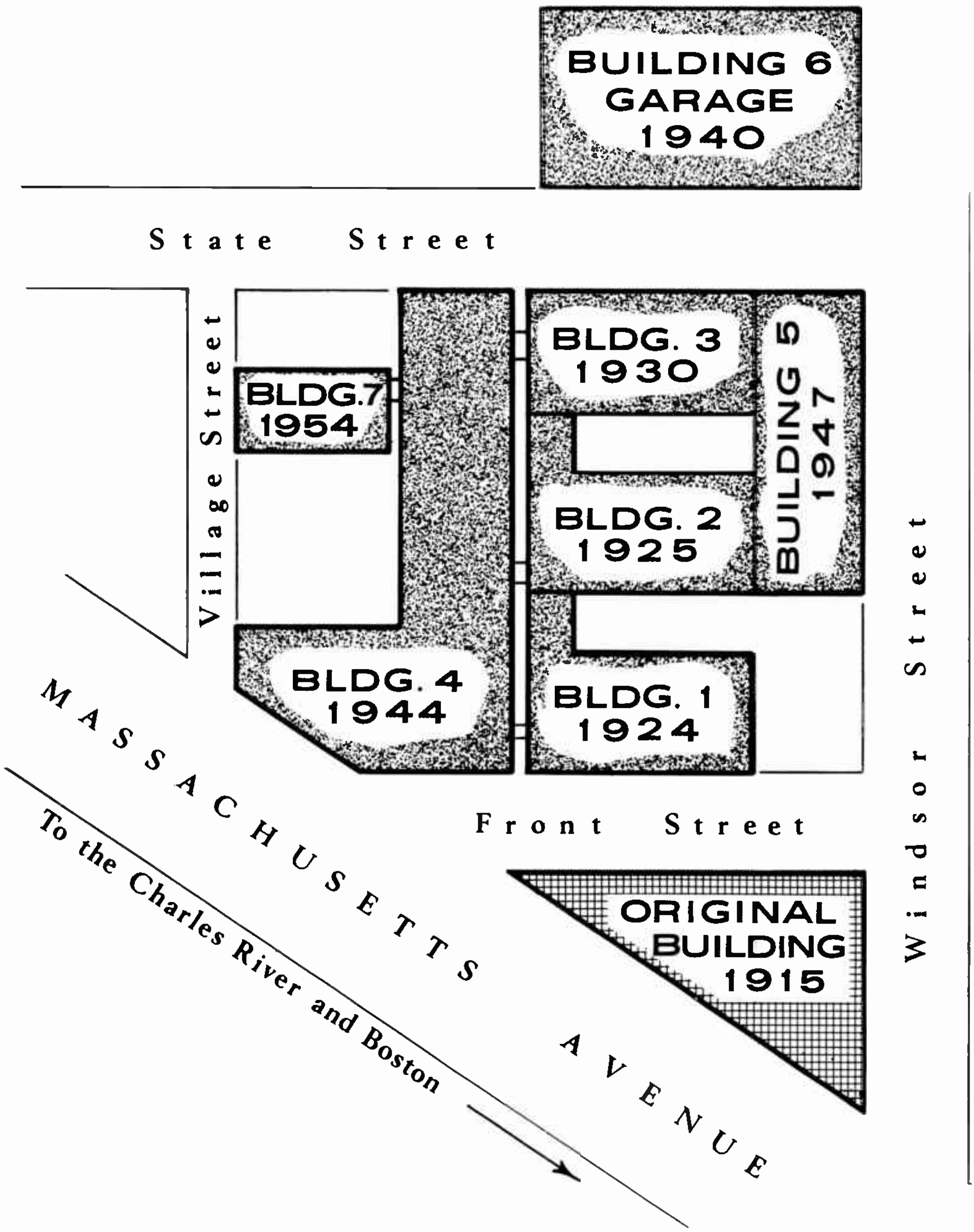
Back to Instruments

IN 1924, GR returned in earnest to the electronic instrument business to develop a long line of products, so many of which were firsts in the field.

The old quarters in the flatiron building had by now become outgrown. A new building across the street on Front Street was erected, and all operations were moved there in 1924.

It was about this time that the direct-sales policy began to evolve. The aim was that eventually the Company would sell only directly to the user, bypassing other distribution channels. During the do-it-yourself era the popular components were sold through distributors and reached the public through the usual retail channels. In this period the Company had built up a considerable sales staff, who, while competent enough in the radio parts business, did not have the kind of qualifications required to sell instruments, the users of which were advanced experimenters, engineers, and scientists. These comprise a sophisticated buying group who need, indeed insist upon, accurate and complete specifications and whose problems with electrical measurements call for the closest liaison with the instrument manufacturer. Now that the Company was firmly launched on a program of making these instruments, sales began to be handled directly. Smaller parts were still available, for convenience, through distributors. By mid-1926 the radio parts sales staff had left and the direct-sales policy was in full effect. In addition to improving communications with customers, this policy had another important advantage: Because there was no longer need for distribution discounts, the Company could and did begin the practice of publishing only net prices. These have ever since been a feature of every piece of sales promotional material so that the prospective buyer always knows the exact price of every instrument, which is, no doubt, as important a specification as any.

Another principle had taken definite form at that time, and that



Plan of Cambridge plant with date of occupation of each building. Buildings 4, 6, and 7 were old structures rebuilt and modernized; the others were new. The original flatiron building of 1915 was vacated in 1924 and subsequently sold.

General Radio's first capacitance bridge, the Type 216 of 1921, was the progenitor of one of General Radio's most successful lines of instruments.

could be called, for want of a better description, the doctrine of "good enough" in its best sense. In developing a new instrument, the conscientious designer has a natural inclination to lavish upon it infinite time and exquisite care. If this were to be done without limit, the cost of the end product could price it out of the market. This is the extreme opposite of mass production, where the emphasis must be on saving the pennies. Although corner-cutting will certainly produce a cheaper product, it will not often produce one of professional grade. Obviously, a compromise between these extremes is necessary to produce instruments of a quality fully good enough to meet the requirements of most users and still priced within reasonable reach. In creating a new instrument, GR engineering has always aimed at developing a design that will do well the job it is intended to do, that can be depended upon for years, and that can be manufactured economically. GR manufacturing was and is aimed at methods of production that are a compromise between expensive one-at-a-time techniques and mass production, maintaining at the same time a standard of quality more than adequate for laboratory needs but free of unnecessary expense.

One of the most successful of the early GR instruments was the Type 216 Capacity Bridge, introduced in 1921. It was, for its time, a sophisticated instrument that permitted accurate measurements of electrical capacitance at low values as well as high. This popular instrument was so well designed that it was not changed for fifteen years, until it was superseded by the Type 716-A Capacitance Bridge. Fifteen years is a long time in this fast-moving industry—in the interval even the word "capacity" had been superseded by the present term "capacitance."

Audio oscillators are so commonplace today that it seems as if they could have had no beginning. Actually, the first commercial low-frequency oscillator (the Type 377) was announced by GR in 1927. It was, of course, battery-operated; the operation of vacuum tubes from alternating-current circuits in those days was not satisfactory because of hum problems. This oscillator was followed in 1928 by a beat-frequency oscillator (the Type 413), also battery-operated. The direct reading of frequency from the controls was unheard of at that time, and the catalog description states that "an approximate calibration giving the settings of the controls at frequency intervals of about 10% for the entire frequency range is provided with each instrument." These two oscillators were, so far as can be determined, the first two of their respective types ever to be made commercially available in the United States, perhaps in the world.

How audio-frequency measurements were made before GR's introduction of audio-frequency oscillators is described by C. T. Burke, who joined the company in 1924, with a Master's degree from M. I. T., in these words: "Mr. Eastham at that time designed the Type 285 Audio Transformer, our first hi-fi component. I was assigned the job of running characteristic curves on them. For a source I used a series of gears mounted on a shaft driven by an adjustable speed motor. A horseshoe magnet with a pickup coil mounted on it could be slid along to each of the gears in turn, giving several frequencies for each shaft speed. The output was fed to a microammeter through a crystal rectifier."

Obviously, in addition to the oscillators, something better than a "microammeter through a crystal rectifier" was needed to measure audio voltage. Therefore, in 1928 GR introduced the Type 426-A Thermionic Voltmeter, the first commercial vacuum-tube voltmeter. The principle of these instruments and other means of voltage measurements had been known for some time, and many experimenters had made their own, following whatever design was convenient, as

Burke had done. The GR instrument was designed to be flexible in operation to meet the needs of most of these experimenters, and it soon replaced many of the homemade rigs.

While, as has been mentioned, catalogs were published frequently, the art was advancing rapidly, and new products and measuring techniques were developing at a fast pace. To announce these advances promptly, the need for some kind of a current periodical was evident. To meet this need, Shaw had the idea of a regular monthly publication, and on the eleventh anniversary of the company, in June, 1926, the first issue of the General Radio *Experimenter* appeared, with Burke and Lamson as part-time editors. Its purpose was set forth on a first-page box: "The *Experimenter* will be published each month for the purpose of supplying unbiased information pertaining to radio apparatus design and application. We aim to treat fairly and thoroughly subjects of interest to experimenters." The publication was to be distributed free of charge to qualified experimenters and so was born the first of the so-called "house organs" in the radio industry. Today, its circulation is about 130,000, still distributed at no charge to a mailing list that is continually revised and updated. The present editor is Charles E. Worthen (M. I. T. '28).

The first issue carried a story about the design of audio frequency amplifiers, and the second described, among other things, a new amateur wavemeter. Quartz crystals, principally used to stabilize oscillator frequency, have now reached such a state of perfection that the following quotation from the third issue of the *Experimenter* sounds quaint indeed: "After many disappointments, due to failure of sources of supply, the General Radio Company is now able to supply quartz plates for amateurs . . . The plates are somewhat irregular in shape from ½ to 1″ in diameter . . . Puncture of the quartz plate due to excessive voltage is a characteristic of the material which cannot be prevented." Amateurs have long been the leaders of many of the advances in the radio communications art. Their interest in quartz crystals came very early and was considerably stimulated by an article by Shaw entitled "Oscillating Crystals," which was published in July, 1924, in *QST*. (His amateur transmitter, constructed early in 1924, is believed to be the first ever to use crystal control.) *QST* is the monthly publication of the American Radio Relay League, the national organization of amateurs, which celebrated its fiftieth anniversary last year. John M. Clayton, who was one of *QST*'s editors, wrote an article in November, 1925, entitled "Make Your Own Crystals." Many amateurs tried this but, because of the skill and complicated equipment required, found it rather impractical and welcomed GR as a source of supply. Clayton, who had left *QST* for the position of secretary of The Institute of Radio Engineers, came to General Radio in 1932, soon to become its advertising manager, a post he held until his retirement in 1963.

The new building on Front Street was soon outgrown, and an addition to it was completed in 1925, with the address of 30 State Street, Cambridge, which more than doubled the size of the plant. By the end of 1926 the Company employed 139, and the plant area was about 42,000 square feet.

IV

Mostly Biographical

THE quadrumvirate consisting of Eastham as president, Shaw as chairman of the board, Locke as vice president, and Richmond as treasurer ran the Company for twenty years and left their imprint so indelibly on it that it is well to pause here for a brief biographical sketch of each.*

The stories of GR and Melville Eastham are so intertwined that, in a way, this history is his biography. The brief sketch that follows contains parts of his story that fit better here than elsewhere in this narrative.

Eastham was born on June 26, 1885, at Oregon City, Oregon. He was a gregarious man of the keenest intellect, a lover of good conversation, and the possessor of an extraordinary range of interests. Of slight build and great energy, he had a huge circle of friends and acquaintances in the industry. He was a notable gadgeteer, skilled mechanical designer, dedicated humanitarian, and keen businessman. So good were his mechanical designs that some are still in current GR production; no one has been able to improve upon them.

He was a modest man and consistently refused to make public appearances. One story that illustrates his modesty, as well as his own quiet humor, was the occasion, in 1937, when The Institute of Radio Engineers wished to present him with its highest award, the Medal of Honor. While deeply moved and honored by this recognition, he would accept it only if he could be excused from making the customary speech of acceptance at the Award Banquet. This was agreed to, and the award was made by G. A. Campbell at a glittering banquet attended by most of the leading scientists and engineers of the industry. Eastham rose to accept the award with the words "Thank you." Later, when one of his friends congratulated him upon making an acceptance speech of such record brevity, Eastham answered, "My speech was twice too long. All I needed to say was 'thanks.'"

*These biographies are written in the past tense solely for editorial convenience. Messrs. Locke, Richmond, and Shaw are all very much alive.

His primary interest, of course, had always been in electronic instrumentation, but his interests included optics, photography, and machine tools, as well as ancient maps and coins. He owned an outstanding collection of both. He donated the map collection and many of his books to the Library of Congress in Washington. His home workshop was superbly equipped with tools and machines that he had picked up on his extensive travels both in this country and abroad.

Because he left school at an early age, his interest in technical education was perhaps a little surprising, but his main philanthropic interest was the Massachusetts Institute of Technology. He worked with many of M. I. T.'s officers and faculty on wide-ranging problems and was a member of the Visiting Committee from 1936 to 1939. He was active in many other ways to promote technical education. For instance, he, with Richmond, started a co-operative study program with Northeastern University and later M. I. T. Under these programs, selected undergraduates, candidates for engineering degrees, go to college for a period of a few months and work at GR alternate periods. As the student advances in knowledge, the level of his work at the Company rises correspondingly. In this way he learns much from practical experience and he earns good wages in the process. Many of the Company's principal engineers and several of its officers are alumni of these programs.

During the Second World War, as a leader in the Office of Scientific Research and Development, he was instrumental in marshaling the vast engineering and scientific effort of that war and played a principal role in the development of the loran navigational guidance system. For these services to his country he was awarded, in 1948, the United States Medal for Merit, the highest civilian reward. Previously, in 1945, he received the honorary degree of Doctor of Engineering from Oregon State College in his home state. He was a Fellow of The Institute of Electrical and Electronics Engineers, the American Association for the Advancement of Science, the American Academy of Arts and Sciences, and a member of the Acoustical Society of America, the American Physical Society, and the American Meteorological Society.

In keeping with his feeling that responsibility should be continually passed on to younger men, he resigned as GR president in 1944 to take the title of chief engineer (he had often signed his letters that way during his twenty-nine years as president) but remained a director. He retired in 1950 at the mandatory retirement age of sixty-five, in accordance with a rule that he himself had instituted years before.

Throughout his retirement years, Eastham was a frequent visitor at General Radio and maintained his many warm personal associations at the Company.

He died May 7, 1964.

Henry Southworth Shaw was born in Boston, Massachusetts, November 29, 1884. After attending several private schools, including the Volkmann Preparatory School in Boston, he graduated from Harvard in the class of 1906 with an A.B. degree.

Shaw's father was prominent in the textile business as treasurer of Pemberton Company in Lawrence, Massachusetts, and of the Methuen Company and as president of the Saco-Lowell Shops, which then had their main plant in Newton Upper Falls, Massachusetts. After graduation, Shaw went to work with his father because at that time the senior Shaw was rather advanced in years and had turned to his son for assistance in managing his wide business interests. Young Shaw soon became clerk of the Saco-Lowell Shops, where he learned much about corporate procedures; this knowledge was valuable in his later association with General Radio.

Like Eastham, Shaw was one of the early radio amateurs. In 1916 a fellow "ham," Stearns Poor, invited Shaw to a meeting of the Harvard Wireless Club, where Shaw met Bowden Washington, a partner with Fulton Cutting in the then well-known radio transmitter manufacturing firm of Cutting and Washington, of Cambridge. Shaw recalls that he was interested in purchasing a wavemeter for his amateur station and mentioned this to Washington. The latter replied that he thought that he knew where Shaw could get a good one, and so a few days later they went to Cambridge to visit General Radio. Eastham was there that day, and, as Shaw says, "He explained things so clearly and in such a nice way that I was immediately attracted to him."

A year later the U.S. entered World War I, and it was then that Shaw went to see Eastham at General Radio to see if he could help.

Shaw was a quiet, unassuming man, whose donations to scientific

Henry S. Shaw

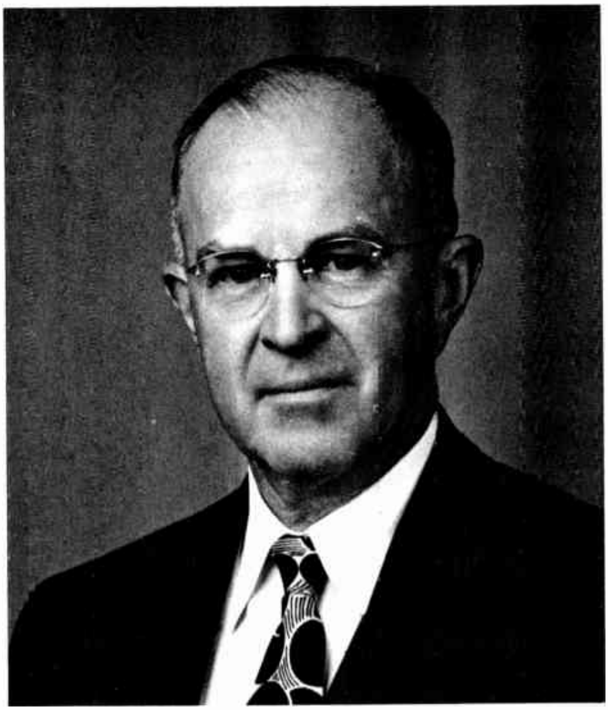
and charitable enterprises were many and almost always anonymous. He had a typical New Englander's distaste for ostentation and lived on a modest scale, but was always exceedingly generous in his support of worthwhile causes and in the gratis distribution of his GR stock to employees to further the employee-ownership principle.

Although his principal interest was, of course, radio, he had many others, including ornithology, music, meteorology, oceanography, and geography and maps. In connection with maps, one of his favorite diversions was taking long hikes over the New England countryside to locate and identify old surveying marks.

He was a Fellow of The Institute of Electrical and Electronics Engineers, Acoustical Society of America, American Academy of Arts and Sciences, and American Association for the Advancement of Science. He was a member of the American Meteorological Society and the American Geophysical Union. He was active in the affairs of the Blue Hill Meteorological Observatory of Harvard University and the Mount Washington Observatory. He was a member of several Audubon societies, of the American Ornithologist's Union, and the Nuttall Ornithological Club of Cambridge. He was for several years a director of the Boston Safe Deposit and Trust Company and a trustee of the Franklin Savings Bank of Boston. He was instrumental in forming the Permanent Science Fund, of which the Boston Safe Deposit and Trust Company is trustee, the income being disbursed by the American Academy of Arts and Sciences.

All through their years of association, Shaw's concept of business philosophy coincided exactly with Eastham's.

Errol Hastings Locke, vice president from 1920 to 1944 and president from 1944 until his retirement in 1955, was born in Lexington, Massachusetts, July 17, 1890, and, after preparatory work also at the Volkmann Preparatory School, attended Harvard, to graduate with an A.B. degree in 1913. After graduation he joined his father, Alonzo E. Locke, in the bond investment business in Boston, which was dissolved early in 1918 following his father's accidental death. During his senior year at Harvard his roommate was a junior, Homer E. Rawson. The latter was GR's vice president in 1918 and that year persuaded Locke to join the Company. Locke's first job was in sales, where he wrote many of the Company's early advertisements and



Errol H. Locke

catalog pages. However, he soon became interested in the manufacturing side of the business and, for most of his thirty-seven years with the Company, devoted much of his time to its management.

He also led the planning for and supervised the construction of the several buildings constructed on the Cambridge site.

Locke was a big, outgoing, friendly man, deeply concerned about the welfare of the Company's employees and, in turn, had their affection and respect. He was a leader in many employee activities and organized, among many other things, the GR Credit Union in 1930 and took the primary responsibility for many of the activities of the Genradco Trust when it was established in 1934.

He was civic-minded and for many years was a member of the Board of Selectmen of his home town, Lexington, and was the Board's chairman for several years. He was treasurer of the Lexington Historical Society, president and treasurer of the Lexington Home for Aged People from 1943 to 1956, and on the boards of two Lexington banks during the same years. He devoted what little spare time he

Harold B. Richmond

had to his hobby of raising prize cattle at his farm in Vermont, to which he turned his full attention after retirement.

Harold Bours Richmond was born in Medford, Massachusetts, in 1892. After graduating from the Massachusetts Institute of Technology in 1914 with a S.B. degree in electrical engineering, he soon joined the teaching staff of that institution. Early in 1917 when this country entered the World War, he was commissioned a lieutenant in the Coast Artillery, and following his return from France early in 1919, had intended to return to M. I. T. As the Institute would not open until September, he took a temporary position on Boston Common placing recently discharged technical military personnel. One day he accidentally encountered Eastham on the Common, and, in the course of conversation, Eastham remarked that General Radio had taken a contract for the manufacture of a new transceiver for the U.S. Army Signal Corps and that the drawings for it were decidedly unclear. Would Richmond, by any chance, be interested in joining the Company as a temporary employee for that summer to help straighten things out? Richmond agreed that he would like to try. Taking an immediate liking to his new job, Richmond resigned from M. I. T., to remain with GR until his retirement in 1957. He once remarked that his status never changed from a "temporary" summer employee, giving him the Company record for tenure in a "temporary" status.

Richmond, like so many at GR, had been a radio amateur, receiving his first amateur license in 1912 with the call letters 1IA. One month later he became a Radio Operator, Commercial First Grade. He still holds an amateur license, now W1CL. He had known Eastham well as a young customer of the Clapp-Eastham Company and at meetings of the pioneer New England Wireless Society, later merged with The Institute of Radio Engineers. In 1962 he received an award in honor of fifty years as a licensed amateur radio operator, which made him one of our country's first.

Richmond became the GR treasurer in 1926 and was chairman of the board and of the Management Committe from 1944 until his retirement in 1957. He was an able administrator, the business manager of the Company, and its sales manager until 1944.

In World War II he again was called to Government service, this time as Chief of the Guided Missile Division of the National Research Defense Committee, of the Office of Scientific Research and Development, for which he was awarded, on the same day as Eastham, the Medal for Merit. A part of the citation that accompanied the award reads, "His unfailing tact and consideration in handling the problems encountered did not lessen the vigor and force of his decisions. He was most successful in a difficult task . . . . His enthusiasm for the broad program was combined with the willingness to expend himself on needed details." Those words might well describe his career at General Radio.

He maintained his interest in education and was a life member of the corporation at M. I. T. and a trustee of Northeastern and Norwich Universities; from the latter he received an honorary Doctor of Engineering degree in 1947. He was a Fellow of The Institute of Electrical and Electronics Engineers and a member of The Newcomen Society and of several social organizations. He was a president of the Radio Manufacturers' Association, now the Electronic Industries Association, and of the Scientific Apparatus Makers Association.

V

Years of Development and Growth

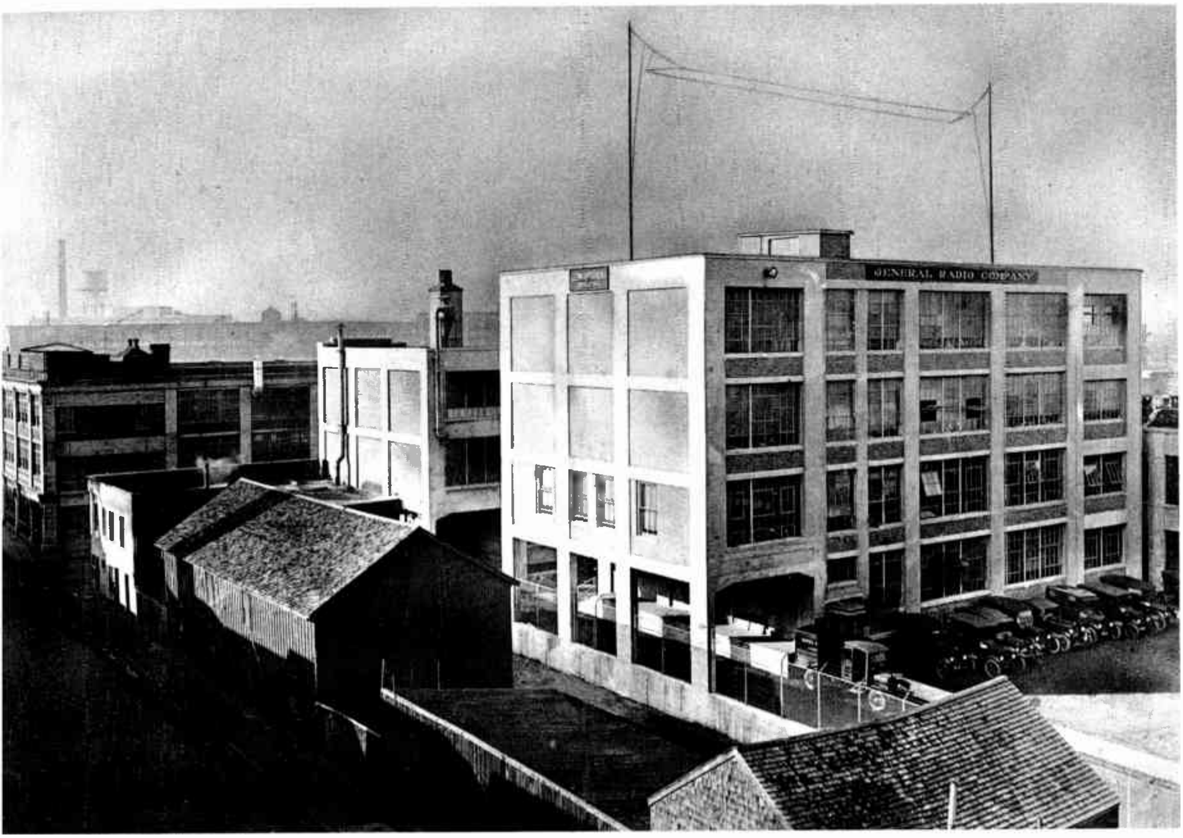
COMPETITION is generally a manufacturer's major marketing problem, but, in the twenties, it was not General Radio's. In those days competition was almost nonexistent, but electronic instrumentation was so new that pioneering the very use of instruments was the major marketing job. There was, of course, a nucleus of experienced scientists, engineers, and advanced amateurs who understood the importance of good measurements, but the field was growing steadily and many came into the business who had yet to be convinced.

The Company felt then, as now, that the way to widen markets was to introduce new instruments to do old jobs better and to do new measuring jobs that previously had been difficult or impossible. In this way, the whole area of radio and audio frequency measurement was expanded and simplified to meet the needs of the established practitioners as well as the newcomers.

As the Company pioneered new instruments and precision components, its reputation soon became worldwide.

In the early twenties there began a trickle of orders from overseas, which steadily grew in volume and which soon led to the appointment in 1922 of the first resident foreign representative, Mr. A. A. Posthumus, a native of Baarn, Holland, for the Netherlands and Belgium. Soon after, representatives were appointed for other countries—Great Britain, Italy, France—and ever since, export has been an important part of the Company's business. Today there are resident representatives in twenty-two countries, including every major country of the free world.

It was in 1928 that the company took another big step forward by the employment of five new engineers in that one year, more than doubling its engineering staff, and J. Warren Horton, a Massachusetts Institute of Technology graduate in 1914, left the Bell Telephone Laboratories to join the company and to become the first one after Eastham to hold the formal title of chief engineer.



General Radio in the middle 20's. The old sheds in the foreground were soon to be razed for additional parking space. The original flatiron building is visible at left background.

There soon followed a number of new instruments, one of the most notable of which was the Type 403 Standard-Signal Generator. This, it is believed, was the first commercial standard-signal generator ever marketed. It was developed by Lewis M. Hull, who was on leave from the Aircraft Radio Laboratories, Boonton, New Jersey, to spend a year with GR. It had a frequency range of 500 to 1,500 kilocycles and an output range from 1 to 200,000 microvolts with 400-cycle internal amplitude modulation and facility for external modulation, both of rather uncertain amount. It operated from external batteries. It was first announced in the Company's *Catalog E* of December, 1928. This pioneer was soon followed in April, 1929, by the world's first commercial primary standard of frequency. This was a monumental development for its day and was largely the work of James K. Clapp (the foster son of J. Emory Clapp), (M. I. T., '24), who joined GR in 1928. It introduced principles which changed little for thirty years. A precision bar of quartz oscillating at 50 kilocycles was housed in an oven to give it a constant-temperature environment. Its frequency, or some multiple of it, was available for comparing with the oscillator under test. To prove that the quartz bar was operating at its correct frequency, its output also operated a synchronous electric clock, the time of which was precisely compared with standard time transmissions, which were being broadcast daily by the U.S. Naval Observatory in Washington. If, in this comparison, the electric clock kept correct time, the crystal was known to be operating at its correct frequency. The time transmissions from the Naval Ob-

The Type C21H Primary Frequency Standard, introduced in 1928, was the most accurate instrument commercially available for the measurement of frequency and thus soon became the reference standard in laboratories throughout the world.

servatory were based upon observations of star transits, and the overall accuracy of the system was within about one part in a million, most remarkable for a commercially available standard in the laboratories of those days. Both the standard-signal generator and the primary standard of frequency were progenitors of long lines of descendants, and today these two classes of instruments are among the most widely used in electronics laboratories.

Catalog E of 1928 was an ambitious publication of 136 pages with descriptions of hundreds of products, among them the vacuum-tube voltmeter, oscillators, and the signal generator already mentioned, as well as what was probably the first instrument ever made to measure accurately the dynamic characteristics of the vacuum tube. That catalog, incidentally, in connection with a description of an attenuation network, featured a detailed description of a new unit of electrical measurement developed by the Bell Telephone Laboratories and called the Transmission Unit, or TU, which, later renamed, became the now well-known decibel.

Eastham's and Shaw's idea had always been that the Company should be, insofar as possible, self-financed. This meant that its stock could be held largely by those active in the Company or by the Company itself. In 1920, Shaw and Eastham, who then owned all of the shares, began to transfer some of their holdings to Locke and Richmond, and later to Horton, as a form of extra compensation or bonus. In December, 1929, this plan of ownership was extended to include seven others. They were C. T. Burke, J. K. Clapp, C. E. Hills, Jr., H. W. Lamson, P. K. McElroy, W. H. Sherwood, and A. E. Thiessen. A year later two more, R. F. Field and H. S. Wilkins, were added, and the number has grown steadily since.

By 1930 the Company had again outgrown its quarters, and a third building was completed, increasing the plant size by about 60 percent for a total of 66,500 square feet. That year employment was 142, divided about as follows: manufacturing 95; office 47. There had been only a small increase in the number employed over the preceding four or five years, but the shift out of radio parts production into instruments necessitated more manufacturing and laboratory space.

The location of this new building in relation to the first two is shown in the plan on page 16.

Although no one at the time recognized them, the economic storm clouds were slowly gathering. The stock market had crashed the year before, but the effect on general industry and on GR had not been too serious. That year, 1929, shipments were $940,000 and in 1930, $850,000. The Company's net worth by the end of 1930 was just $1,000,000. But the great depression was moving in. In 1931 shipments dropped to $600,000, and for the first time since the war order cancellations of 1918, the Company had, instead of a good profit, a loss for the year. It was small, $19,000, but the portents were bad. In the dark economic years of 1932 and 1933, billings hit bottom at $520,000 for 1932 and were only a little better in 1933; by the end of that year net worth had dropped to $786,000, reflecting the losses in the three previous years.

To add to the financial problems, considerable money was tied up in banks that had closed. So were the personal funds of many employees at one neighboring bank, the Central Trust Company. In a typical gesture, feeling that the employees banked there because the Company did and that the Company was therefore in some way responsible, the directors, deeply concerned as they were with GR's own troubles, gave cash to each employee in the amount that he had on deposit. A part of this was eventually recovered by the Company when the bank reopened under new management as the County Bank & Trust Company.

It had long been the Company's feeling that the best way to ride out these business recessions was to adjust the number of hours in the manufacturing work week rather than the number of employees on the payroll. With sales in 1932 and 1933 only a little more than half of what they had been, the production group could be employed little more than half time.

Hard though it was to live on this drastically reduced income, it was a good deal better than walking the streets seeking a job when there were no jobs. Incidentally, all during this period and ever since, the Company has never laid off any employee for lack of work.

But, if it was to stay in business, the Company had to resolve another problem promptly, and that was how to meet the other payroll: the salaries of the engineers and managers. Drastic pay cuts were the order of the day in the other companies, but that solution did not appeal to Shaw and Eastham. Cut pay always seemed somehow hard to restore, and while a cut might be expedient in this emergency, how about the future? Other recessions were presumably inevitable. Also, far from being on short time, the engineers were urgently needed at full time and more to complete new instrument designs whose sales would eventually help to pull the Company out of the depression, and the managers had more than a full-time job to cope with the myriad depression-borne problems.

To solve this, Eastham developed an idea that he had been thinking of for some time, and that came to be known as the "K" pay plan. The basic idea is that the salaries of all who are paid under the plan shall be readily adjustable up or down with the state of business. To make it sensitive to conditions, the adjustment is made each month. "K" is a multiplier by which the regular base salary of each participant is multiplied to determine his actual pay month by month. To set the value of "K," the normal predicted dollar output of the plant working at full time, but with no overtime, is calculated at the beginning of each year (or more frequently if an unusual situation should develop), and the amount is approximately the same as the expected sales rate. This amount, divided by twelve, is the normal monthly business to be expected during the year. At the end of each month the dollar amounts of the actual new orders received and the billings made are averaged, and if that average is the "normal" expected, "K" equals 1.00 for the following month. If the average is higher, "K" is more than 1; if less, it is less than 1.

A part of the idea of the "K" plan is that only those in a position to influence the course of business by their individual efforts should be under it, it being unfair to ask those not in a position to influence "K" to be paid according to its value. The sharing of good times and lean between the Company and its employees, inherent in the plan, was another extension of Eastham's partnership principle.

It has been a remarkably effective incentive system—when "K" is low, all those affected work hard to improve it, and when it does rise, they promptly receive the benefit. In the thirty-three years that it has been in existence, "K" has averaged about 1.24.

It was decided to limit the swing of "K" from 0.5 to 1.5 (if in any month the business figures indicate that "K" should be over 1.5, the surplus is carried forward to the following month). Needless to say, when it first went into effect in 1932, it first value was 0.5, but the next month it rose to 0.6. The plan was immediately accepted by all concerned as a fair solution to a critical problem, and it has been used, with modification only in detail, ever since.

RECOVERY

As has been mentioned, billings were at a low of $520,000 for 1932, but new orders received were much worse at $381,000. They were a little better for 1933, but by 1934 conditions were beginning to brighten. In that year new orders totaled $744,000, and shipments about $700,000, and net worth had climbed from $786,000 back to $804,000.

One of the most notable features of the distribution of sales in the thirties was the rapid climb of the export business. In 1932 about 18 percent of all shipments were made abroad, and by 1937 the percentage of sales made abroad had climbed to its all-time and astonishing peak of 39 percent of the total. It had happened that the development of the radio industry abroad had lagged behind the United States. During the thirties it burgeoned at a time when the Company's reputation had become well established internationally. The largest customers were, in order, Russia, England, France, Holland, and Belgium. Under the Russian Communist regime, then regarded as friendly, great efforts were being made to industrialize that nation, which had consistently lagged behind the rest of Europe. Their large requirements for GR instruments were a reflection of this.

All of these years through 1937 were years of steady growth and were summed up in Richmond's Treasurer's Report for that year:

> "January 31, 1930, with shipments for the twelve months ending on that date totaling $975,000, marked the top of our last boom period. From then on there was a decline of forty months, terminating on May 31, 1933 with twelve months' shipments dropping to $446,000, a decline of 54%. The subsequent rise, the longest in the history of the Company, lasted for fifty-two months and terminated September 30, 1937, with twelve months' shipments totaling

$1,424,000. This rise was 46% above the 1930 peak and became 319% of the low. In the seven years and eight months between peaks, there had taken place one of, if not the most, drastic depressions in the history of the country. It is safe to say that the majority of our radio manufacturing customers failed during that period. Our own expansion of nearly 50% can, therefore, be looked on with considerable gratification. We can also be thankful that we face the current decline with all losses of the previous depression made up, and in general with our physical plant and our personnel organization the best in the history of the Company. Our current finances are sound. In addition to this, the largest bonus in the history of the Company was distributed in 1937."

The "current decline" referred to was a reference to a sharp but brief recession which started late in 1937 and ran through the next year, followed by a good year in 1939.

All during the 1930's the engineering group was very prolific with new ideas, new instruments, and countless refinements on existing products.

It would be impossible even to list all of these developments, but a number of them are of exceptional interest. So far as can be determined, all of those to be described were original with GR. Some, in fact many of them, utilized known principles, but each one, when it was announced, was the first commercial instrument of its kind in the United States and perhaps the world. Although the name of the GR engineer principally responsible for the instrument will be given where possible, it should be remembered that many hands are involved in every development—regrettably, for this history, sometimes anonymously.

In 1929 the idea of combining a miniature copper-oxide rectifier with a sensitive dc meter was conceived, producing for the first time a simple instrument capable of measuring voltage over the wide frequency range of something like 20 to 20,000 cycles. This was incorporated with a voltage divider and called the Type 486 Output Meter. In May, 1932, the Type 583 Output Power Meter, an idea of Horton's and an extension of the use of the original meter, was announced. The Output Power Meter provided a tapped transformer-resistor-meter arrangement so that for the first time small amounts

The Type 559-A Noise Meter of 1933 opened up a new field of measurement, acoustics, in which the company has remained preeminent.

of power from 0.1 to 5,000 milliwatts could be measured directly and quickly over the audio frequency range.

In 1931 Dr. W. Norris Tuttle, (Harvard '24, PhD. '29), developed the first intrument for measuring the percentage of modulation of radio broadcast transmitters, and this led to an instrument, developed by L. B. Arguimbau, by which a broadcast transmitter engineer could read the percentage of modulation of the transmitter directly on an indicating meter. To know this operating characteristic is so important that the Federal Radio Commission (now the Federal Communications Commission) required modulation monitors in all broadcast stations. Needless to say, with that universal requirement, there were soon several competitors in the field.

About the same time, Tuttle developed a meter for measuring audio distortion introduced by broadcast transmitters, which also was further developed by Arguimbau into a direct-reading instrument.

A short time before, the Federal Radio Commission had ordered that the carrier frequency of each broadcasting station must stay very close to the one assigned it to prevent interference among stations, of which there were some 300 then on the air. Each station was required to have an approved instrument, called a frequency monitor, to provide a continuous check that the station was, in fact, staying on channel. With its long experience with stable piezo-electric oscillators, GR was the first to develop and market the instrument that was necessary to permit broadcasters to comply.

The accurate measurement of resistance, capacitance, and inductance at radio frequencies had always been a difficult and time-consuming job, utilizing the voltmeter-ammeter or the so-called substitution methods. Following a long period of development, Robert F. Field (Brown University '06) designed the first radio-frequency bridge, the Type 516-A, which was announced in 1932. This instrument greatly simplified and made much more accurate those previously difficult measurements.

The first sound-level meter, which had been under development by Hermon H. Scott (M. I. T. '30) was announced in 1933. Many investigators had been working in the field of sound and noise measurements, particularly at the Bell Telephone Laboratories and at the Radio Corporation of America, where much basic work had been done. Scott's Type 559-A Noise Meter was the first compact, portable, and relatively inexpensive instrument ever to be marketed in a field which has grown tremendously since that time. Today, greatly refined, the instrument is now always called a sound-level meter, the unit of measurement the decibel. The Type 559-A, like so many other GR instruments, was the forerunner of long lines of instruments, each an improvement over the former and each reflecting the steady advances in the electronics art.

Also in 1933 the Type 650-A Impedance Bridge was announced. This was an instrument of such remarkable flexibility and wide utility that it soon became, and remained for many years, one of the best-selling instruments that the Company had ever introduced. It was a joint development of Horton and Field, based upon an original concept of Shaw's. It combined in one compact instrument measuring capabilities that had hitherto been made by an assortment of separate bridges. Its great flexibility and low price of $175.00 made it an instant success.

The June-July, 1933, issue of the General Radio *Experimenter* was remarkable. In that one issue were described three new products, each, in its own way, a forerunner of major significance in the industry. The most important was the Variac® adjustable autotransformer, which was an invention of Eduard Karplus, a 1923 graduate of the Institute of Technology, Vienna, who joined GR in 1930. It is now so well known that it hardly requires description here. It provided for the first time a means to adjust 115-volt and 230-volt power-line voltages from zero to something above line voltage smoothly in such small steps that the adjustment is, for practical purposes, continuous. The first unit, the Type 200-C, had a current rating of 5 amperes. Later other sizes were manufactured, beginning with a smaller one rated at 2 amperes and a larger one at 20. Tuttle coined its name, "Variac" for "variable ac." It was expected that the Variac autotransformer would first find its greatest use in laboratories, and it did. Later it found its way into many industrial applications, and in this expanded market, many millions are in use today. Not all have been made by GR, as several other companies were licensed to manufacture under the basic Karplus patent.

A second instrument was the Type 535-A Electron Oscillograph. The history of the cathode-ray tube starts with the work of Karl Braun in Germany in 1897. In its modern form, it is, of course, most familiar as "the tube" of the TV set. Following Braun's basic work, many scientists worked upon improving it, with notable advances being made by J. B. Johnson of the Bell Telephone Laboratories. About 1929, reasonably good commercial tubes were available, but aside from the idea that they might someday have application for television if many other technical problems could be solved, they were regarded as being rather more interesting than useful.

One major difficulty was that since no way had been devised to sweep the electron beam across the tube's screen at a constant speed and to hold a repetitive pattern in place, it was impossible to display electric waves in their familiar form. Another was that the spot did not focus well at all parts of the screen. However, with all the drawbacks, cathode-ray tubes did have some useful applications, and, in 1931, GR marketed the first commercial instrument with tubes first obtained from Manfred von Ardenne in Germany, and later from Westinghouse. It was in two parts. The tube was mounted separately on a stand, and the power supply, in a separate cabinet, was connected to it by a cable. By this time Professor Frederick Bedell of Cornell University had invented the so-called linear sweep circuit, which did, at last, provide a means to traverse the spot across the screen at a constant speed and with a steady display. This invention, after the tube itself, was the most important advance up to that time in cathode-ray oscillography. Based upon this invention, GR produced the first commercial linear sweep circuit, called the Type 506-A

Bedell Sweep Circuit. It was housed in a separate cabinet so that a complete oscilloscope consisted of three parts: the tube, the power supply, and the sweep circuit. At first the latter was made under license from Bedell, but later GR purchased the patent, selling the entertainment rights to RCA, who hoped to, and eventually did, apply it to television. GR retained the instrument rights. The Type 535-A Electron Oscillograph combined the tube and its mounting with the power supply, and finally in 1934 GR announced the Type 687-A Electron Oscillograph, which, in addition to the power supply, incorporated the sweep circuit all in one housing. This was the first complete oscilloscope ever marketed. Its design was a joint development of Karplus and Scott. It was followed by the Type 770-A by Dr. Donald B. Sinclair (M. I. T. '31, ScD. '35), an advanced design which included most of the features found in oscilloscopes today. It was never marketed, however, because it was judged to be difficult to manufacture and probably too expensive for the market.

This history would be incomplete without noting that a few years after its introduction of the first cathode-ray oscilloscopes and its development of them up to the Type 770-A, the Company dropped their production. The reason was that the tubes had not been highly developed, and the instrument, unless excessively expensive, was not too suitable for most accurate laboratory work. For that reason it was thought that it would be principally a tool for the radio service technician. This was a field in which the Company did not happen to be interested. Under the impetus of radar development during World War II, the cathode-ray tube was developed to a degree that seemed impossible in the thirties and was then capable of performing excellent work as a laboratory instrument. By this time the Company had been out of the business for several years and had so many other projects afoot that it never re-engineered a new oscilloscope. This was a considerable error in product judgment, as the oscilloscope eventually became one of the most widely used of all laboratory instruments.

The third pioneer instrument of major significance described in that issue of the *Experimenter* was the wave analyzer. This was a development of L. B. Arguimbau. It was a very advanced instrument for its time and provided the means for making accurate, harmonic analyses of wave forms by direct measurements. The best wave analyzers of today still use the principles introduced in that instrument in 1933.

As has been mentioned, it had always been felt that the Company's products, complex and sophisticated as most of them are, could best be sold in the domestic market directly to the users rather than through representatives or distributors. At first the engineers themselves were their products' only salesmen (Eastham was, in the beginning, the archetype of the engineer-salesman), but in fact, the catalogs were the principal sales tool. Gradually, around 1930, a division of responsibility began to emerge, with some engineers devoting most of their time to product development, others to sales. There was an organization-chart recognition of this in 1932, which shows three engineers designated "Engineering Sales" and ten as "Development." Apart from personal preference and different kinds of abilities, a trained engineer functions equally well in either group. These thirteen were the entire technical staff. As the Company grew and its customers multiplied, more engineers transferred into or were employed for the sales function, and by 1934, in order better to reach its greatest concentration of customers, the Company opened its first district sales engineering office in New York, with Myron T. Smith (M. I. T. '30) in charge. This was so successful that a second was opened in Los Angeles in 1937 and a third in Chicago a few years after that.

As far back as 1929 the directors had established the "General Radio Special Fund," the principal and income of which could be used for "the benefit of employees or former employees." The idea of the fund was to provide help for those who, because of serious illness or other personal catastrophies, were in financial difficulties. Shaw had been interested in and concerned with all aspects of employee welfare and in 1934 donated 2,255 of his shares of General Radio stock (there were 9,144 shares outstanding at the time) to this fund, which was named the Genradco Trust. With this generous gift the Trust was able to expand its activities and, in addition to providing emergency financial help, also provided free medical advice for all employees as well as free eyeglasses to those who needed them. One of the activities of Locke was his assumption of the primary responsibility for the operation of this Trust.

Dr. Roy E. Mabrey was engaged in May, 1935, as the medical consultant, and in May, 1938, Dr. Mahlon T. Easton became the ophthalmologist. Both have visited the plant ever since on regular weekly schedules for medical consultations and to provide eyeglass prescriptions.

By 1938 the Company had grown to about 200 employees, and by popular request, another GR publication made its bow—the *General Radio News*, which was first published in November of that year. It was, and is, edited by and for the employees. The first issue records that business had been slow that year, that the Company's net worth was $1,020,681, that several employees had become proud parents, others were ill, and that the Company had purchased 2,400 pounds of solder the year before at a cost of $1,440. The next month's issue contained a stern discourse on the dangers of tobacco by William H. Fish, the affable, nonsmoking foreman of the Assembly Department, and wound up by pointing out that "Uncle Joe" Cannon, who for forty-six years was an energetic member of the House of Representatives, eight years its Speaker, was a confirmed smoker. Twelve to fifteen cigars a day were his ration. The point was that he died at the early age of ninety-one.

Another important employee benefit was introduced in that year, the Blue Cross-Blue Shield plan for the coverage of hospital and medical expenses of all employees. This kind of medical insurance plan is well known today, but in 1938 there were very few sponsored and paid for by employers. Then, and now, GR pays all of the cost for the employee and one-half for the employee's family if the employee elects to have family coverage.

PRODUCTION TECHNIQUES

One of the Company's first complete catalogs, *E*, of 1928, had 168 pages with a different instrument or set of components described on each page. The 1965 Anniversary *Catalog* S, of larger page size, has 272 pages and lists about 125 full-fledged instruments, some with rather complicated auxiliaries, plus hundreds of components and parts. The prices range from a few cents to over $5,000.

Except for a number of the smaller parts and Variac autotransformers, which are sold in larger quantities and can therefore be made on fully or nearly automatic machines, each of these products requires a rather specialized manufacturing technique because its rate of sale does not justify the high-speed in-line assembly processes successfully used, for instance, in the automobile industry.

Both to meet the GR policy of being able to make immediate deliveries from stock and to achieve reasonable production quantities, it has always been standard practice to manufacture in lots or "production runs" for delivery into stock in anticipation of sales.

Before regular production can begin, however, a "trial lot," or a pilot production, of ten or fifteen units is run through. These are made from final drawings and serve three important purposes: (1) to test the correctness of the drawings, (2) to establish methods and tools, (3) to prove performance.

With instruments, individual sales of which are typically between 100 and 1,000 a year, about 25 to 100 are completed at one time from stocks of components previously made or purchased in larger and more economical quantities. Naturally, the cost of carrying the inventory of components and the possibility of obsolescence are important factors in determining those quantities.

In final assembly, therefore, the problem is to find the most efficient means to assemble well over a hundred different instruments several times a year in lots from 25 to 100 with the care and precision that they must have.

The most suitable technique was evolved during the thirties and, except for the refinements gained by experience, is little changed today. Each assembly position consists of two benches, each about 24 feet long, placed side by side with a spacing between them wide enough for the operator to move along them, with the soldering-iron power cord traveling along a trolley overhead. All the parts necessary to assemble a run are conveniently available to the assemblyman's reach. These parts include everything from simple hardware to complex components previously made and tested elsewhere. Rather than the instruments moving past the operator, as in the usual production line, the assemblyman moves from instrument to instrument, performing an identical operation on each, as, for instance, soldering a particular color-coded wire to a terminal. In this way, the speed possible with repetitive operations can be achieved, which is many times faster than one-instrument-at-a-time assembly would be. Because one man

There are no assembly lines at General Radio; the final assembly of an instrument is instead the responsibility of an individual highly skilled in the art.

is responsible for the complete assembly, responsibility for mistakes can be readily traced, but much more important is the quality of work created by the craftsman who is fully responsible for the whole assembly job.

Most of the production operations, including assembly, are paid for on an incentive basis. There is a guaranteed hourly base rate consistent with the performance of the average worker. Piece rates are set so that each worker will earn a premium proportional to his performance above average. Historically, incentive earnings have averaged 20–30 percent above the hourly base rates.

In addition to the production operations, incentive pay plans, which have always been a basic policy of the Company, have been extended to many other, sometimes improbable, areas. For instance, there is a group plan for the Shipping Department which has been in effect for many years and which has proved to be of considerable benefit to both the shippers and the Company. To start it, a historical study was made of the value in dollars of the material shipped per man per year for the preceding five years. This rate per man, reduced to four-week incentive bonus periods, was established as standard. If the same number of shippers exceeded that standard in any subsequent four-week period, they would share in a substantial bonus. If the group fell below the standard, there was no penalty—each man would receive his regular base pay. Two reasonable basic assumptions must be made, which are that the product mix remain essentially the same as it has and that if the value of the material shipped is changed by general selling price adjustments, the incentive bonus may be adjusted accordingly.

It is to be expected that precision products require minute, detailed inspection and test. Beginning with raw materials and simplest parts and ending with final inspection before shipment, inspectors, often with elaborate testing equipment, scrutinize every part and component at various stages of the manufacturing process. The finished instruments, many of them destined to become the standards of other laboratories, must themselves be right.

While it is clear that the control of quality by frequent inspection is important, any inspection process is fallible. Therefore, it is even more important that quality be built in at the beginning. In every step of the manufacturing operation the necessity for careful work is continually stressed, and seeing that all work is, in fact, of the highest grade is a primary concern of all production supervisors.

Except for wartime emergency periods, only men have ever been employed in actual manufacturing. This is not because of any lack of confidence in the skill and competence of the ladies, but rather in recognition of the fact that they do tend to marry and to have family responsibilities which take them out of the factory and into the home. Because so many of GR's operations require skills gained from years of experience, a stable work-force is essential. The Company's long-term employment stability record for men is exceptional, with less than 4 percent turnover per year, excluding retirements.

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Another important engineering development came before the close of the 1940's. A patent was applied for in 1937 and was issued in 1939 to H. H. Scott, and assigned to GR, for what came to be known as an R-C oscillator. This was an important new concept of an oscillator using no inductors, but only resistors and capacitors, and with degenerative feedback, design features that permit substantial reduc-

The Type 1310-A Oscillator, a descendant of GR's original 1938 R-C oscillator.

tions in cost. A license to manufacture under this patent was issued in 1940 to a recently formed partnership in California, Hewlett-Packard. Their first instrument, the Type 200 Oscillator, which eventually became a favorite in the test equipment field, utilized this invention. A number of GR instruments are also based upon that invention, including the current Type 1310-A Unit Oscillator.

The Company was twenty-five years old in 1940. The 215 employees at that time occupied some 75,000 square feet of floor space and designed, produced, and sold about 1.25 million dollars worth of products that year. This size put it in the class of a small manufacturing company, but of a medium-size instrument company. About 20 percent of the personnel had college degrees, most in the electrical engineering field; fully 10 percent of each sales dollar was invested in the development and design of new products.

Although most sales were made directly from the factory, activity was rapidly building up in the two district sales engineering offices, New York and Los Angeles, and the foreign market was strong, accounting for about 30 percent of total sales.

MORE BENEFITS FOR EMPLOYEES

It was in 1940 that the regular two-week vacation period was extended to three weeks for all office employees, and the shop group, while remaining on the two-week schedule, received an extra week's pay instead.

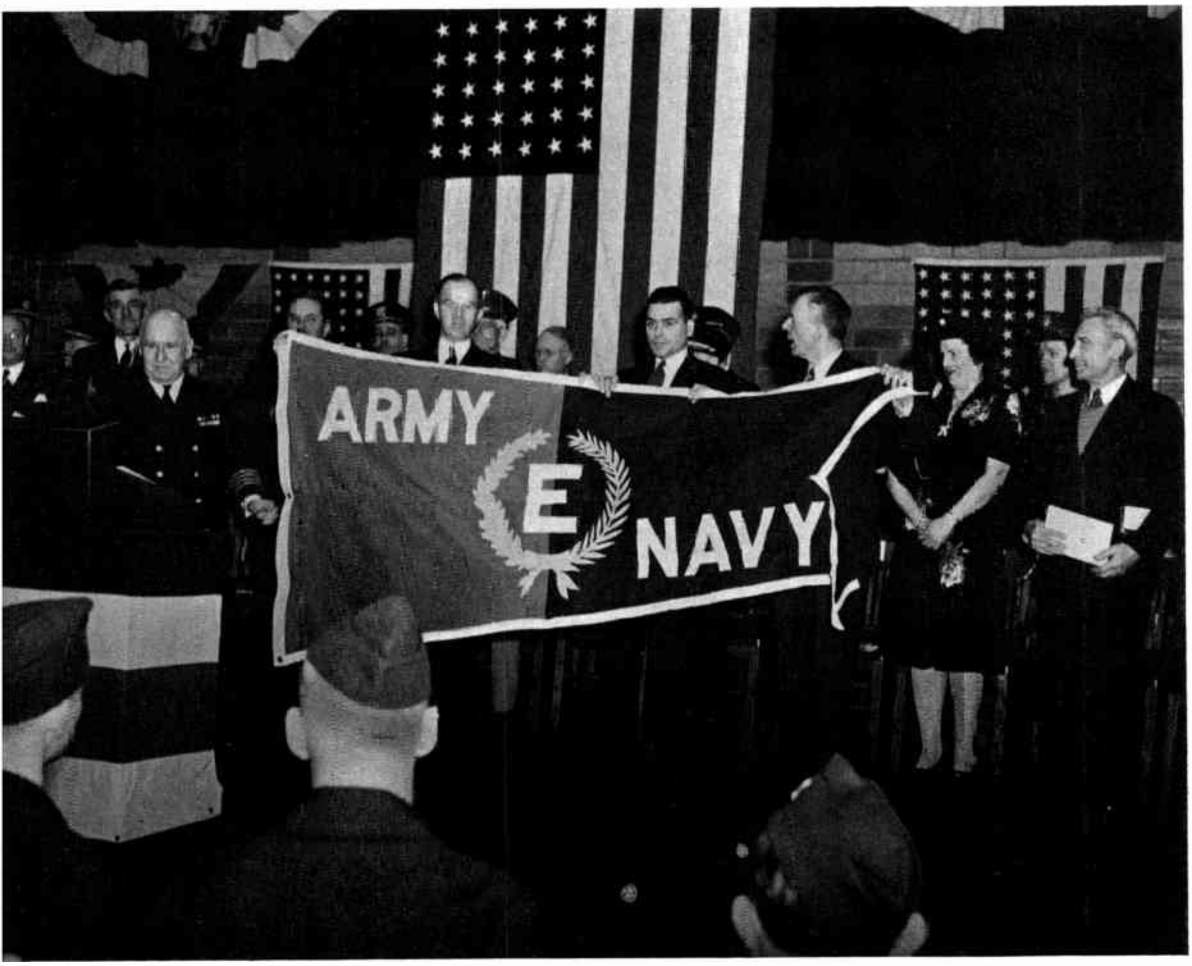
A year later, in December, 1941, a pension plan for retiring employees was worked out with the John Hancock Mutual Life Insurance Company. The plan provides that the employee, if he elects to join, contributes 1 percent of his pay, which is matched by a 3 percent contribution by the Company, up to a pay level of $3,000 a year.

Above that the contributions are 2 percent and 6 percent. Upon retirement, the employee receives a monthly check from the insurance company, its size being dependent upon the length of time he has been covered and his average pay during that time. In practice, the plan has provided a substantial supplement to Social Security income.

A further, more important retirement benefit became possible when the Congress passed Public Law No. 729 in 1942. This act amended the income tax laws so that an employer, like GR, can give, tax-free, some portion of its annual profit (when there is a profit) to an irrevocable trust for the benefit of all its employees, pro rata with the yearly pay of each. The employer's contribution each year is a percentage of the total payroll but may not exceed 15 percent. When an employee leaves his job by retirement or for any other reason, his nest egg in the trust is payable to him or, if by death, to his estate, subject, if in a lump sum, only to capital gains tax. The trust fund may never revert to the employer, although the employer is the sole contributor to it.

GR was among the first to form a profit-sharing trust under this law. There are many formulas by which the exact portion of the employer's annual contribution may be calculated, but, to be valid, any plan must have the prior approval of the Federal tax collectors.

The General Radio Profit-sharing Trust came into existence in December, 1943. The agreed-upon formula is that each year, out of profit before taxes, an amount is first set aside for the stockholders of the Company sufficient to equal, after Federal taxes, 6 percent of the stockholders' equity. Fifty percent of the balance remaining is paid into the trust for the accounts of the eligible employees (those with two years or more of service) up to the limit of 15 percent of payroll.



Presentation of Army-Navy E Award to General Radio in 1943. Holding pennant are (left to right) Errol H. Locke, Charles H. Riemer, and Melville Eastham. Knut Johnson, GR's first employee, stands far right.

VI

The Great War

THE above discussion of the several employee benefits introduced in the early forties is a little ahead of the chronology of this story. The progress of the war in Europe had been the cause of much concern in this country but had not, in 1940, had much impact upon U. S. industry nor upon GR. Some material was being shipped abroad under the Lend-Lease plan, but it was a small part of the total production of the nation and of GR.

But the "day of infamy" at Pearl Harbor, December 7, 1941, was to change that almost overnight. The entire apparatus of national production was transformed, insofar as it could be, into a massive effort to supply the country's military needs and those of our allies, at the same time maintaining civilian production at the level of the necessities.

For some manufacturers this transformation was radical: automobiles to tanks, refrigerators to machine guns, fertilizers to gunpowder. General Radio was faced with problems of another sort, just as difficult, but different. The first was to resist the urging of military production planners to plunge into the production of large quantity "primary" electronic requirements—military radio sets, radar (then highly secret), and the like. The Company argued, and rightly, as it turned out, that there was much capacity for that kind of production in the country in plants practiced in quantity production, but that without adequate instrumentation they would be badly handicapped —and so would the laboratories striving to improve and more fully to utilize electronic devices and techniques to win the war. Those plants and laboratories, both military and civilian, soon called for instruments in unprecedented quantities, and still more were required for field maintenance of the military electronics gear which, as the war progressed, became ever more complex and sophisticated.

A second problem that caused more than a little concern was the so-called priorities system. Recognizing long before the war that a shortage of basic materials, especially metals, was a certainty in case of war, government planners had devised a priority system whereby the makers of primary implements of war—guns, tanks, aircraft, and the like—would by first priority, receive a sufficient supply of needed raw materials. Others would have to wait. What the planners overlooked was that no gun could be fired, no airplane fly, without its auxiliary equipment, much of which was electronic, and the makers of electronic equipment could not design, test, or calibrate the performance of those complicated devices without instruments. GR, not being a primary producer, had no way, under the system, to get the relatively small amount of raw materials it had to have, while at the same time the demands for instruments reached almost panic proportions. Finally, following months of frantic conferring between GR and others in related industries and the U. S. War Production Board, the problem was understood in Washington, and corrective steps to amend the priority system were taken.

When this was done and materials began to flow again, GR was in a position to cope with the huge backlog of orders, all of which were directly associated with the war effort and many of which had the highest emergency priority rating.

As the mobilization of American industry for war became almost complete and the requirements for electronic equipment in the military services skyrocketed above every prior estimate, it became obvious that the Company could meet the demand for its instruments only by taking fast and drastic action to expand its output. A vigorous program of subcontracting was started, in which dozens of outside suppliers were provided with manufacturing drawings and know-how to make the subassemblies, leaving the critical operations of final assembly and calibration and test to the practiced GR personnel. Many of the less complex instruments were farmed out completely.

Multiple-shift operation was not practical because one bottleneck was the shortage of skilled personnel, but, by working long hours (the 48-hour week was standard) and by the most efficient use of its craftsmen and technicians, the Company was able to achieve a remarkable increase in output, which was sufficient to meet the urgent demands and almost enough to meet all of the military requirements.

One of the civilian shortages that developed early in the war was sugar. While this was a major inconvenience to housewives, it was disastrous to candy manufacturers. The plant of one of the largest, the New England Confectionery Company, famous for its Necco Wafers, was located directly across Massachusetts Avenue from GR. It was practically closed down, when it occurred to GR that a reservoir of skill existed there that might well be utilized. The girls who make candy develop a high degree of manual dexterity, and it was thought, correctly as it turned out, that they could be quickly trained to a new skill of assembling simpler electronic equipment. An arrangement was promptly made for GR to lease a floor of the Necco plant to be staffed by a group of selected girls who were to remain on the Necco payroll. Under the supervision of Charles E. Rice, George Flint, and George E. Bickell, the operation was a quick success, and soon good production was built up there, principally of Strobotac® electronic stroboscopes. About 100 girls were employed.

The combined result of extensive subcontracting and leasing of facilities and help was a more than four-fold increase in output, from an annual level of $1,200,000 in 1940 to $5,300,000 during the peak year of 1944. This was accomplished by an increase in permanent staff from about 220 to 440, an achievement which made it possible, when the emergency was over, for the Company to hold to its firm policy of not laying off personnel for lack of work.

In February of 1943 the Company received the first of five Army-Navy "E" awards for excellence in the production of war materials. At an impressive ceremony the award was presented by ranking officers of the Army and the Navy and was accepted for the Company by Richmond and for the employees in an eloquent speech by Charles H. Riemer.

The space problem had been difficult and became critical about this time, and finally negotiations were completed for the purchase of a large garage adjoining the GR plant on the north. This garage was in very poor condition and had to be completely rebuilt, a difficult process because of acute wartime shortages of materials and labor, before it could be occupied in May, 1944.

The offices, engineering laboratories, and experimental shop were moved into this reconstructed building, and the Company's address was changed from 30 State Street to 275 Massachusetts Avenue, Cambridge, the address of the old garage.

While GR equipment was used by almost every branch of the armed services (for instance, the GR-made Model LR Frequency Meters, several thousand in all, were installed in almost every fighting ship of the Navy), much of it went into highly secret development projects. One example of this was the now famous "Manhattan" project, the cover name for the development of the atom bomb. Large amounts of instruments were shipped to the laboratories of project "Manhattan," but the security was so airtight that no one at GR had the slightest idea what this giant "Manhattan" was that was consuming such quantities of equipment.

During this period, and at the peak of the war activities, Eastham had been drafted to help direct the operation of the famous Radiation Laboratory at M. I. T. This occupied a great deal of his time, and in 1944 he and Shaw decided that it would be a good time to put into effect a realignment of Company officers that they had been considering for some time. Shaw, who had been chairman of the board, resigned this office but remained as a director; Eastham, who was president, also resigned the office but remained a director and chief engineer; Richmond, who had been treasurer and a director, became chairman of the board; Locke, who had been vice president and a director, became president; Frank L. Tucker, from the University of Texas and the Harvard Business School, who had been with the Company since 1934 and comptroller since 1937, became secretary and treasurer and a director; Charles C. Carey, who came with the Company in 1927, became vice president for manufacturing; and Arthur E. Thiessen, (Johns Hopkins '26) became vice president for sales. At the same time Charles E. Hills, Jr., Northeastern University, '22, who came with the Company that year and had been commercial manager since 1929, became assistant secretary and assistant treasurer.

VII

The Postwar Years

AFTER the war ended in August, 1945, GR welcomed back its forty-six employees who had been with the armed services and rapidly reorganized its affairs for a return to a peacetime economy.

All during the war years everything the Company produced was used directly in the war effort. At the end of the war the expected order cancellations arrived in a flood, creating a monumental clerical load; but it was also expected, and correctly, that the expanded electronics industry, once converted to meet civilian demands, would provide a market comparable almost to that of the war.

Re-establishment of the export business was an urgent need. During the war contact with GR sales representatives abroad was cut off almost completely, but when communications were again restored, it was found, with pleasure, that practically all were still in business and eager to take up from where they had been cut off five or six years before. This led to rapid restoration of the export market, which soon returned to its prewar level in spite of severe dollar shortages overseas.

In October, 1945, the Company reduced its basic work week for all employees from 40 hours to 35 hours, a remarkable move at a time when the industry average was 41.4 hours. The long-time policy of paying time-and-a-half for time worked over the basic work week was continued. At that time the offices began working an average 37.5 hours a week and the shops about 40.

During the short interval between the end of the war and before civilian production could start again, there was the expected sharp drop in business to a low of $2,400,000 a year in May, 1946, but by 1948 the Company and industry had reoriented themselves to a peacetime economy, and business for the next two years leveled off at about $4,000,000 annually.

These years in the late forties were devoted to the steady, balanced growth of the organization, to the introduction of new and improved instruments, and to the expansion of marketing activities to cover the

General Radio's final Cambridge plant. Building in foreground, a converted garage, housed administrative, engineering, and sales offices.

broader fields of instrumentation which had been the outgrowth of wartime developments. As has been mentioned, the success of electronics in warfare, notably for radar, loran, fire control, and communication, had been the cause of forced-draft investigation and development of all facets of the electronics science which resulted, as a matter of course, in broadening the base of the entire electronics industry. As was noted in the June, 1945, issue of the *Experimenter*, "The accelerated research of wartime compresses into a short period advances that normally would require several times as long to achieve. The experience gained by General Radio engineers through war work will be reflected in new and better instruments in the postwar period," and, in amplification, the article goes on, "Circuits developed for military equipment have obvious applications in industrial instruments. New parts and materials have shown the engineer how to get better overall performance from a given circuit or to extend the ranges over which acceptable performance can be maintained. New techniques of measurement lead to entirely new instruments and improved methods of construction can mean more economical designs, greater convenience of operation, easier maintenance, or longer life."

One of the many technically interesting devices to emerge was the so-called butterfly circuit, invented by Karplus with added refinements by Arnold P. G. Peterson (University of Toledo '34, Sc.D., M. I. T. '41). In this device, which is an odd-appearing variable air capacitor, both circuit inductance and capacitance vary up or down simultaneously, without the use of sliding contacts. When used in a rf oscillator circuit, this design permitted wide variations in frequency with a single turn of the control knob. One of the first instruments to use it was the Type 720-A Heterodyne Frequency Meter, introduced in 1945, which was followed by a long series of useful instruments utilizing the same basic butterfly design.

Although business volume had remained level at about $4,000,000 a year during the late forties, the existing facilities were somewhat crowded and there was certainly little room for further expansion. So in 1947 work was completed on still another addition to the plant. It was a four-story, 30,000 square-foot structure designed to match in appearance and construction the earlier buildings on the site. It brought the total plant space to 145,000 square feet. With it the last available building space was used up in the city block then occupied by the Company. This, naturally, aggravated the parking problem, which was solved, in part, by purchasing and razing, one at a time, several condemned tenement buildings across Windsor Street and by leasing, and later purchasing, a one-story garage opposite Building 3 on State Street. During this period (1947–1948) average employment was around 430, and parking for about 200 cars was to remain a major problem as long as the plant was to remain in the city.

But for how long could that be? Early in 1948, as a few months earlier had been urged by Shaw, it was decided to begin a search for land for a future building site away from an urban center. There were several basic considerations for new land: There should be plenty of it, not only to solve the perennial parking problem and to allow room for plant expansion, but to have the exurban advantage of plenty of fresh air and quiet; although employees' homes were scattered in many towns in the greater Boston area, the center of GR population was around Watertown, so the indicated direction was west of Cambridge to keep down the average commuting distance; the land should be flat to minimize the amount of earth-moving necessary for building; some reasonable sort of public transportation should be available; and the land should be on or near good roads for trucking. After a search of several months, the land where the West Concord plant now stands was located and purchased. A 66-acre tract, it met all of the requirements, and a couple of years later an 18-acre adjoining piece became available and was also purchased to make the present 84-acre, almost square property, bounded by Route 2 on the north, Baker Avenue on the east, and by the Assabet River on the south and west.

At the time that the search for land was going on, another employee benefit was instituted. It was to increase the regular three-week vacation to four weeks for those with twenty-five years or more of service. It is interesting that, although in 1948 the Company was only thirty-three years old, thirty-four employees had been with the Company at least twenty-five of those thirty-three years, thereby qualifying for the added vacation.

Soon to reach the mandatory retirement age of sixty-five, Eastham, feeling that GR directors should be active in the business, declined to stand for reelection as a director at the stockholders' meeting in February, 1950. Shaw, who had already passed retirement age, also declined, so Carey and Thiessen were elected in their places. The board then consisted of them with Locke, Tucker, and Richmond as chairman. They, together with Burke, director of planning, and Sinclair, who had recently succeeded Eastham as chief engineer, comprised the Management Committee. That Committee, since its formation in 1939, has been responsible to the directors for the over-all operation of the Company.

Eastham, whose wise counsel had guided the Company from its beginnings and by whom so many of its basic policies were developed, formally retired in June, 1950.

INTO THE COUNTRY

All during that year political and military events in the far-off peninsula of Korea were leading toward the armed intervention of the United States. That intervention, when it came in July, had an effect upon the Company similar to that experienced at the beginning of World War II. The vital importance of electronics in warfare had been thoroughly established, and the essential military requirements for all kinds of electronic equipment, including instruments, again skyrocketed.

To meet its part of these requirements, the Company was able almost to double its production within one and one-half years to an annual level of over $7,000,000 by the end of 1951. As the Cambridge plant was already operating near to capacity, it was evident early in 1951 that it was essential to acquire more space, so it was decided to build the first structure on the recently purchased land in West Concord. Plans were drawn, the necessary permits obtained, and construction was started in July. The building, completed in April, 1952, added about 72,000 square feet of space to the 145,000 square feet in Cambridge. In accordance with plan, ample parking space was provided and particular care was taken with landscaping to give the new plant an attractive appearance in harmony with its natural setting.

The coil winding, transformer assembly, parts assembly, and Variac autotransformer manufacturing departments moved to Concord and were in full operation by the end of June, and in October an Open

House was held. Over 1,000 Cambridge employees, their families and friends, and residents of Concord came to see the new plant in actual operation.

Of the Company's total employment of 592 at the end of 1952, 443 were in Cambridge, 14 in the three district sales engineering offices, and 135 in Concord. Among the latter, A. W. Cleveland (Northeastern '34), who had been purchasing agent in Cambridge, and Charles E. Rice, production engineer, were transferred to Concord to take charge of the new operation.

Much care had been taken with the layout of the new plant to ensure maximum operating efficiency, and equal pains had been taken to make it a pleasant place to work. Needless to say, there were plenty of applicants for transfer to the country from the traffic and noise of Cambridge. P. K. McElroy, writing in the September, 1952, issue of the *News*, had this to say:

> "The plant has this wonderful look of scrubbed-up neatness, and there seems to have gone with it a concomitant cleaning out by the men of their mental cobwebs. A day's work seems so much less of a cross out there in the open, and there is always the chance to go fishing in the Assabet River at noontime, which I gather a number of men actually do. Don't tell me that fishing will ever replace poker!
>
> "One of the most interesting sidelights concerns some negotiations that were going on between one of the men in the Cost Department and a workman in the shop. This friendly difference of opinion over the alleged inadequacies of a piece rate had begun in Cambridge, and the cost man had agreed to look into the matter preparatory to making a decision. Shortly after things settled down in Concord, the cost man went out to see the shop man, with the conversation going something like this:
>
> 'About that rate you were discussing with me in Cambridge.'
>
> 'What rate?'
>
> 'You remember the one you wanted raised. You felt it was not fairly set.'
>
> 'Did I say that?'
>
> 'Yes.'
>
> 'Oh well, that was back in Cambridge. Forget about it. Isn't it a beautiful day outside?' "

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In December, 1952, the Serendib Foundation was started to handle most of the Company's contributions to education and to charity. It had always been the practice to contribute generously to those charities, like hospitals, that might in some way or some time be beneficial to employees, or to the families of deceased or disabled employees. Also financial support of educational institutions, particularly those to which the Company would be likely to turn for its trained personnel, had long been regarded as most important. Obviously, the amounts that could be given each year depended upon earnings and thus were likely to vary widely. In order to smooth the flow of contributions, many of which were continued from year to year, the Foundation was established. The Company then could make its contributions to the Foundation large in good years, less in lean ones, and from the pool of funds thus established the trustees might make disbursements at a suitable, uniform rate.

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By 1953 business had reached an annual volume of almost $10,-000,000, and the need for better sales coverage in the field became urgent. On the twentieth anniversary of the opening of the first district sales engineering office in New York (followed later by Los Angeles and Chicago), the fourth district office was opened in Silver Spring, Maryland, a suburb of Washington, D. C., in 1954, with William R. Saylor (M. I. T. '36) in charge. This was followed a year later by the Philadelphia office under Kipling Adams.

In the decade between the end of World War II and 1955, the Engineering Department had been very busy, and an important series of new instruments and improvements on old flowed into the Production Departments and eventually into use in laboratories and industries with widely diverse fields of interest both in this country and abroad.

As these new or improved instruments were being introduced at a rate of almost one a month, it is possible to mention only a few of more-than-usual interest.

A major new entry into the electronics industry, and one that immediately stirred enormous public interest, was commercial tele-

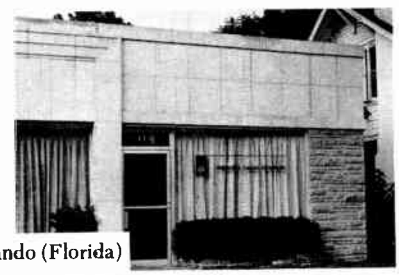
Cleveland

San Francisco

Los Angeles

Philadelphia

Dallas



Orlando (Florida)

Toronto

Washington, D.C.

Chicago

New York

General Radio's Sales Engineering Offices. (Not shown: the Montreal and Syracuse offices.)

vision. The idea of transmitting pictures by electrical means was by no means new. As early as 1884 a Russian, Nipkow, conceived the basic principle which eventually made TV possible; that was to divide the picture to be sent into hundreds, or thousands, of tiny components, then sequentially and rapidly to transmit the components to a receiver which would reconstruct and display the picture by shades of light and dark just as it was picked up by the transmitter. The persistence of vision of the human eye was relied upon to hold sight of the first components of the picture for the split second until the last was received. Nipkow's method of scanning the picture was by mechanical means and was never satisfactory. In 1929 the British Broadcasting Company was regularly scheduling TV broadcasts, using a system invented by John L. Baird, but it, too, was unsuccessful, owing to the poor quality of the received pictures.

The first TV broadcasts using a cathode-ray tube, the "picture tube," for the display at the receiving end, were conducted experimentally in Great Britain in the mid '30s; the first such broadcasts in this country were made by the National Broadcasting Company in 1939. A year later several competing systems were available, but the Federal Communications Commission would license none to go on the air until one could be selected as the standard. This was because the several systems were incompatible, each requiring a different kind of receiving set. Finally standards were accepted in 1941, but war intervened so that no new transmitting stations or receivers could be built. Immediately after the war there was a further two-year delay while the FCC investigated whether the standard system could not be for color rather than black and white. The latter system was finally selected in 1947, as the equipment for color was found to be both tricky and expensive, and about 100 transmitting stations were licensed.

Just as there had been with broadcast transmitters years before, there was a problem of holding TV transmitters precisely on their assigned channels. Unlike the manufacture of TV transmitters or receivers, a mass production operation, this was again an instrument problem. In 1947 and 1948 GR introduced its TV monitors, designed by Charles A. Cady. They were the first in the field.

Also, in 1948, after field tests and demonstrations lasting two years, the unique Type 874 coaxial connectors were announced. These were a joint development by Karplus, Harold M. Wilson (M. I. T. '31), and William R. Thurston (M. I. T. '43). A feature of the unique design is that any two connectors fit smoothly together without the usual complication of matching male and female assemblies. This feature, together with excellent electrical and mechanical performance, made them an immediate success. It is not known exactly how many of them are in use today in all their forms, but the number is in the millions.

Later that year, recognizing the need for simple, wide-range, basic, laboratory instruments, particularly, for instance, in schools and colleges, GR introduced the so-called Unit line, a concept of Eastham, developed by Karplus. Precision laboratory instruments are rather costly, especially in terms of college teaching budgets, but by the careful use of cost-cutting design and manufacturing procedures, good instruments adequate for many purposes can be produced. The first of a long line of Unit instruments made with these considerations in mind were a wide-range oscillator and an amplifier. The power supply for them was a separate unit, suitable for either, so that one supply could be purchased to power either of them and, later, many other Unit designs for a variety of uses.

Several new standard-signal generators were introduced, notably the Type 1001-A in September, 1949, a development of Arthur G. Bousquet and Karplus, and the Type 1021 series in March, 1950, a joint development of Karplus and Ervin E. Gross; the latter was among the many instruments that used the "butterfly" tuner.

Countless improvements to update and modernize basic products were made as the progress of the art made them possible. Among these, an interesting one was an improvement in the Variac variable autotransformer design that virtually eliminated a serious burn-out problem, except from gross overloading. Like so many inventions, the solution, when found, was simple enough, but the finding was difficult, the solution elusive. The problem began when Variac autotransformers became widely used in all sorts of industrial applications. Complaints, not numerous at first, were received that some units were, under normal electrical load conditions, inexplicably burning out. These burn-outs always occurred in the wires at the point where the carbon brush was in contact with them and seemed to happen mostly when the brush had not been moved for some time. At first, heat from the brush was suspected, and radiators to remove the heat were tried. That did little good, and as time went on, the trickle of complaints grew to alarming numbers.

Gilbert Smiley (M. I. T. '28), who had been responsible for recent improvements in variable autotransformers, then devoted his full time to tracking down the trouble. He eventually discovered that, although the brown oxide of copper, called cuprous oxide, which forms on all exposed copper under usual atmospheric conditions, was harmless to autotransformer performance, it would, when subject to heat, as under the carbon brush, gradually turn into cupric oxide, which has high electrical resistance. The formation of a little cupric oxide, would cause more resistance under the brush, more heat, more oxide, and so on in a vicious circle to the eventual destruction of the copper wire.

With the trouble discovered, the solution was simpler. It was to electroplate the entire brush track with some material that would not form an oxide subject to such destructive breakdown. Several materials were found to work well, among them silver. When the problem was understood and the solution found, all Variac autotransformers made thereafter had silver-plated brush tracks; thereupon, the problem disappeared. Adams invented the word "Duratrak®," which became GR's trade name for this improvement.

Although the answer had been found in 1951, it took time to prove it thoroughly in the field and to get the new process into production. The Duratrak-treated brush track was announced early in 1953.

The foregoing account is given in such detail to illustrate the sorts of problems and methods of solution so often encountered in the design of General Radio's products.

The trend toward making measurements by automatic means was becoming evident during that decade. This trend was one of the derivative results of the explosive growth of the whole electonics field following World War II. There was a continuing shortage of trained engineers and technicians, and as their valuable time had to be used most efficiently, many measuring jobs once done by hand were gradually delegated to machines.

GR introduced a number of devices to support that trend. There was, for instance, a series of motor drives that could be readily connected to the frequency control dial of an oscillator to turn it at various speeds automatically, leaving the operator free to read, observe, or record the measurement desired. Another, more versatile drive, the Type 1750-A, turns an instrument control knob forward and backward with a reciprocating motion over any predetermined arc and at speeds from one-half to five times a second. This completely frees the engineer to observe, typically on an oscilloscope, the phenomenon under investigation.

One semiautomatic instrument was the comparison bridge, designed by Malcolm C. Holtje (M. I. T. '49), which can compare, at high speed, a bin of capacitors with a standard to find whether their capacitance values are high or low and by how much. It was a short step to associate the bridge with an automatic sorter to drop the capacitors into three bins according to their measured values.

This trend toward instruments that provide the maximum ease and speed of use, coupled with rapidly increasing sophistication of design made possible by advances in art, were to form important segments of the pattern for instruments of the future.

VIII

The Past Decade

IN December, 1955, Locke, who had been GR's president since 1944, retired, and early the next year the directors elected Carey to succeed him. The board at that time consisted of Carey, Richmond, Sinclair, Thiessen, and Tucker. Tucker, who was also treasurer, resigned at the end of 1956, and Lawrence H. Pexton, who, like Tucker, was a Harvard Business School graduate and who had been comptroller, was elected to succeed him.

In the meantime, sales had climbed close to $11,500,000 a year in 1956 and employment to over 650. Even with a sizable group in West Concord, parking remained a major problem, and mounting city traffic made getting to work more and more a chore. To cope with the parking problem, the Company had, in addition to securing the garage and the spaces on which the old tenements had stood, leased several scattered vacant lots. They were not all near the plant; it was a question of renting what was available. To decide who parked where, a regular bumping system was devised. The newest employees, presumably the spryest, were assigned to the most remote lot and, with seniority, moved nearer to the plant. The graybearded seniors occupied the garage.

While transportation and parking were minor irritants that no doubt had their influence on corporate thinking, business had been growing at a brisk rate after the brief 1954 recession and was, by the close of 1956, at a level that made necessary an early decision about expanding the West Concord plant.

Management opinion was divided as whether approximately to double the West Concord space by adding a second unit to the one already there or to build three more units and move out of Cambridge entirely. It was finally decided to build only the second unit, which would add about 80,000 square feet of space to the existing 72,000-square-foot unit.

In order to provide adequate financing, a $2,500,000, five-year

General Radio's plants at Concord (above) and Bolton (below) are both set amid the pleasant surroundings of the New England countryside.

rotating credit agreement was executed with The National Shawmut Bank of Boston, and building was begun early in 1957.

Harold B. Richmond, after thirty-eight years with the Company, retired in June. The remaining directors, Carey, Sinclair, and Thiessen, decided to leave his office of chairman of the board open for the time being.

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Two new sales engineering offices were started that year, one in the San Francisco area, with James G. Hussey (University of California, '49) manager, and the other, the Company's first office in another country, in Canada. Toronto was the city selected, and Arthur Kingsnorth was named manager.

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A couple of years earlier, in 1955, an interesting instrument had been developed that took GR, in one leap, into the jet age.* The measuring problem this time had to do with the fuel gauges in aircraft.

Until about 1943 fuel in the tanks of all planes was measured, as it still is in automobiles, by a float gauge. A float in each tank actuated a rheostat, and as it moved, the current through the rheostat changed. This varying current was read by a meter with a dial calibrated in the amount of fuel, usually by pounds rather than gallons in airplanes.

In search for greater reliability and accuracy, a null-type device was developed by fuel-gauge manufacturers and in final form employed a servo-balanced capacitance bridge of great durability and with minimum weight. Two shaped flat metal plates, parallel to each other and closely spaced, and of a length about equal to the depth of the tank, are located at the deepest part of the fuel tank. As the fuel, with its relatively high dielectric constant, rises and falls, the electrical capacitance between the plates varies accordingly; thus capacitance is a measure of the height of fuel in the tank. The setting (indicated by a dial in the cockpit calibrated in pounds) of a self-balancing bridge then indicates fuel level accurately. The metal plates are shaped to suit the shape of the tank so that even with the most odd-shaped wing tanks the capacitance change is approximately linear with the amount of fuel.

The problem of adjusting these fuel gauges when installed in the

*The author is indebted to an article by P. K. McElroy in the September, 1955, *Experimenter* for this story.

could be so much more efficiently laid out that there was a marked increase in usable space.

It is interesting to note that because the direction of the move had been known for several years and because employees who, for personal reasons wished to change their residences, usually moved toward Concord, not a single male employee was lost because of the move. A few secretaries understandably preferred to remain in the city, and those were left behind with regret; otherwise, the organization remained intact.

While these building plans were in progress, the Engineering Department continued to be busy with new product development. Several new designs of Variac autotransformers were introduced to

Aerial view of General Radio's main plant. The village of West Concord, in background, and the plant are politically in the town of Concord.

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planes and periodically checking their accuracy was an instrumentation problem, which resulted in GR's development of the MD-1 Field Variable Capacitance Tester.

Prior to the MD-1, a simpler testing device was satisfactory for propeller-driven planes that used only gasoline for fuel. The composition of aviation gasoline, and consequently its dielectric constant, is essentially uniform, and it happens that the expansion in volume on heating is just balanced by the reduction in dielectric constant. Thus a given weight of fuel gives the same capacitance reading and balance regardless of temperature.

The coming of jet planes complicated matters.

Jet fuel is not a homogeneous, approximately single, chemical compound, but almost any sort of a combustible mixture, depending upon where and when it was refined. It exhibits broad variations in dielectric constant. Hence jet fuel gauges had to include an added sensing element in each tank to introduce an appropriate correction into the bridge circuit.

The MD-1 was developed to adjust and calibrate these more complex devices. Several thousand are in use in military and civilian maintenance hangars all over the world wherever jet planes are flown.

So critical and important is the accuracy of fuel gauges, that subsequently a laboratory instrument of ever greater precision was developed to make periodic checks of the MD-1—a checker to check the checker!

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The new building addition was completed late in 1957, and the various groups began the move to West Concord between November 15 and the end of January, 1958. Among those were the entire development engineering department—86 strong—the purchasing department, the calibration laboratory, all the final assembly departments. After the move, 267 remained in Cambridge, 461 were in West Concord, and 43 staffed the seven sales engineering offices.

Wilson, who had joined the Company in 1945, had recently been appointed manufacturing manager and took charge of the expanded West Concord plant. His assistants were Rice, who had supervised the Necco operation during World War II, as plant production manager, and Robert W. Patterson as production office manager.

A. W. Cleveland, at the same time, pioneered a new activity for the Company as industrial relations manager. To that office was delegated the responsibility of maintaining the Company's contacts with outside municipal and business-oriented groups as well as the responsibility for personnel relations in the shops.

It had been expected that there would be a communications problem with the Company divided and its parts separated by some eighteen miles, but it developed that the problem was considerably more serious than had been foreseen. Although the division had been carefully planned to keep together those departments that obviously needed to be in close touch, it was soon found that there was a great deal more necessary interdepartmental communication than anyone had realized.

Although there were eight telephone tie lines between the two plants, the lack of person-to-person contact led to some inefficiencies, as, for instance, time lost in travel between plants. The sentiment soon developed that the whole Company should be in West Concord. This feeling was no doubt strengthened by the mild envy of the city workers for their more fortunate country cousins.

Therefore, building plans for further additions at Concord were continued during 1958 and the marketability of the old Cambridge complex was explored tentatively.

Soon, an unexpected offer to purchase the property for $800,000 was received from Epsco, a relative newcomer in the electronics field. The price was considered to be satisfactory, even though the property was not actually on the market. But the fact of the offer did make the possibility of the move even more attractive, and about midyear 1958 the decision was made to move the whole plant to Concord as soon as the buildings could be finished.

The move was completed during the first half of 1959, and for a good omen, the year set many new business records. Orders went up to $14,700,000 from $11,460,000 the year before, shipments to $13,400,000 from $12,000,000, and employment to 843 from 791. The new buildings made available a total of about 300,000 square feet of space, and, as had been expected, efficiency, as well as morale, improved greatly. Actually, in the previous Cambridge-Concord plants there were about 297,000 square feet, but the new all-Concord plant could be so much more efficiently laid out that there was a marked increase in usable space.

It is interesting to note that because the direction of the move had been known for several years and because employees who, for personal reasons wished to change their residences, usually moved toward Concord, not a single male employee was lost because of the move. A few secretaries understandably preferred to remain in the city, and those were left behind with regret; otherwise, the organization remained intact.

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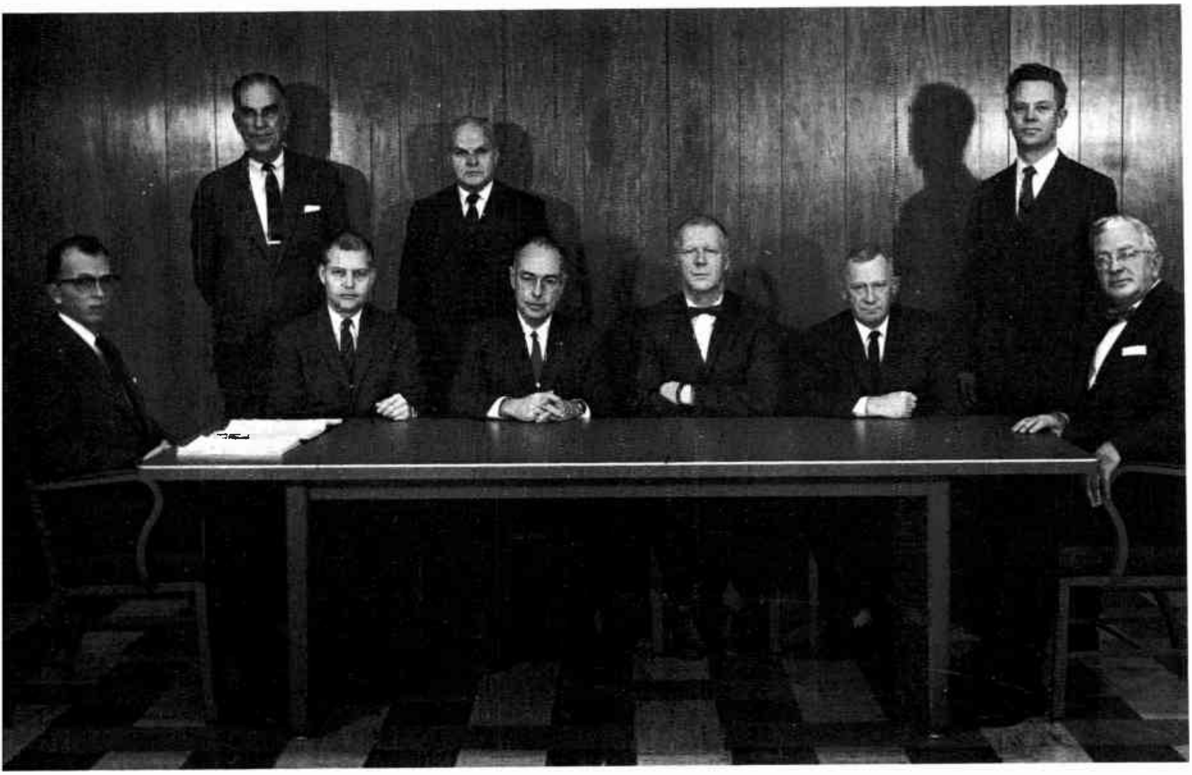
Aerial view of General Radio's main plant. The village of West Concord, in background, and the plant are politically in the town of Concord.

Two popular GR impedance bridges: the modern Type 1650-A and its predecessor, the Type 650-A of 1934.

augment a line that continued to contribute the largest dollar volume of sales of any in the GR catalog.

Transistors, the revolutionary new devices that had been developed in 1948 by W. Shockley, J. Bardeen, and W. H. Brattain of the Bell Telephone Laboratories, and for which these men won the Nobel Prize of 1956, were beginning rapidly to supplant the vacuum tube as they became commercially available. Because of their low power requirements and small size, and as their reliability and uniformity were steadily improved by the manufacturers, they were gradually introduced into GR instruments. One of the first was a small test oscillator, the Type 1307-A, and the designs of several other instruments under development were radically changed to convert them from vacuum tubes to transistors.

The need to measure accurately the electrical operating characteristics of transistors at vhf and uhf led in 1958 to the development by William R. Thurston and Robert A. Soderman of a transfer-function meter (the Type 1607-A) that was to become an unofficial industry standard. And in 1959 the longest-lived of any GR instrument, the famous sloping-panel Type 650-A Impedance Bridge, introduced just a quarter-century before, was superseded by the up-to-minute Type 1650-A, designed by Henry P. Hall (Williams '49). Illustrative of the



GR's Management Committee in 1960. Left to right: L. H. Pexton, A. E. Thiessen, J. D. Quackenbos, C. T. Burke, M. T. Smith, I. G. Easton, H. M. Wilson, D. B. Sinclair, and C. C. Carey.

growth of the electronics industry over those years is the comparison of the sales of these two equivalent instruments, each quite advanced for its time and each priced about the same in dollars of the same vintage. About 1,600 of the Type 1650-A's of 1959 were sold in the first year of its life; it took eight years for the sales of the Type 650-A of 1934 to reach that figure.

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Several organization changes were made in 1960. A. E. Thiessen was named chairman of the board, C. C. Carey continued as president, and D. B. Sinclair became executive vice president and technical director; Ivan G. Easton (Northeastern '38) and Harold M. Wilson were newly appointed vice presidents for engineering and manufacturing, respectively. The other officers were L. H. Pexton (University of Colorado '38) treasurer; J. D. Quackenbos (Colgate '37) secretary;

E. D. Hurlbut (St. Olaf's '43) controller; and C. E. Hills, Jr.; assistant treasurer and assistant secretary. The directors were Carey, Sinclair, and Thiessen; and the members of the Management Committee were Burke, Carey (chairman), Easton, Pexton, Quackenbos, Sinclair, Smith, Thiessen, and Wilson.

EXPANSION OVERSEAS

The Company's export business continued its steady growth after it could be resumed in 1946 following World War II, in spite of rather serious Governmental restrictions. In order to stop as far as possible the re-exportation of certain strategic materials to Iron Curtain countries, the U. S. Department of Commerce was authorized under the Export Control Act of 1949 to control all U. S. exports by a licensing procedure. This meant that prior to the shipment of any item designated "strategic," the exporter had to obtain a license from the Department, accompanied by a certification from the buyer abroad that the item will not be re-exported. Of course, shipment direct to any Iron Curtain country was prohibited entirely.

Many questioned whether this procedure was, for the long run, a wise one, for, while the shortage of imported strategic materials, including electronic test instruments, might temporarily slow the build-up of industrial and military potential in the proscribed countries, the lack was certain to accelerate the development of local industries to supply the shortages. There is ample evidence today that this is just what happened—there are many producers of quite satisfactory electronic instruments in several Iron Curtain countries, where there were virtually none before.

At first, individual export licenses were required for nearly every GR instrument sold abroad, although later the list was gradually shortened to a more reasonable length.

Notwithstanding all the burdensome red tape involved for the buyers as well as the seller, the Company's export business continued to thrive, not only because of the performance and utility of the products themselves but also because of the sales efforts of GR's export group and the representatives abroad. In order to give the latter all possible support, it was decided early in 1960 to set up what was to be, in effect, a GR branch office in Europe. Complete stocks would be carried there for quick deliveries, and factory-trained personnel would be available for convenient consultation on technical problems and to interpret specialized European needs back to headquarters; also, the export licensing procedures would be slightly simplified.

The first question was where to locate. Many countries would have been suitable, and all were investigated. Finally Zurich, Switzerland, was selected because of its central location geographically, the excellent air, rail, banking, and communication facilities it provided, and because the language problem was not likely to be serious in a country where English was so widely understood.

The next question was how the new branch should be organized. It could have been set up as a district sales engineering office similar to the many already operating in the United States and Canada, but it was decided to make it a Swiss corporation, wholly owned by GR. The legal requirements were soon completed, and the General Radio Company (Overseas) came into being in April, 1961. Peter J. Macalka, a 1952 graduate of the Austrian State School for Engineers who had joined GR in 1954, was appointed its manager, reporting to Stephen W. DeBlois (Cornell '36), GR's export manager. Jürg Keller and Hans Rahm were, with Macalka, the first Board of Directors of the new subsidiary. Keller was the managing director and Rahm the commercial manager of Seyffer and Company of Zurich, GR's sales representatives for Switzerland since 1940.

An extension of direct sales activity overseas was the formation of General Radio Company (U.K.) Limited in January, 1964, with its offices located in Bourne End, some thirty miles west of London. This wholly owned corporation gradually took over GR sales in Great Britain from the representative there, who had become principally interested in manufacturing.

THE CHANGING BUSINESS SCENE

The decade from 1950 to 1960 was marked by the almost explosive growth of competition and by the continuing trend in instrument design toward automatic or at least highly simplified operation.

Earlier in this history it was mentioned that competition, prior to 1940, was not a serious marketing problem. GR's problem in those days was to pioneer the very use of measuring instruments. World

War II and the events that followed were to change that dramatically. The growth of the electronics industry, spurred on by the advent of television, by broadly expanded radio communications, and by the use of electronics in data processing, was immensely accelerated by the huge needs of the Department of Defense for military programs. As the electronics industry grew correspondingly, so did the instrument segment of it, the necessity for good measuring equipment having long since been well established. The Company shared well in this growth; its shipments grew from $4,450,000 in 1949 to $16,000,000 in 1960. The growth would have been much greater had the Company elected to participate on a broader scale in numerous Department of Defense procurements of its own highly specialized requirements. However, the Company wisely adhered to its policy of self-financed, controlled growth, leaving most of the larger Government contracts to others, of which there was no lack.

Immediately following World War II and the temporary slowdown of Government-financed research, hundreds of business-minded engineers and scientists decided to go into business for themselves. Many of these ventures were successful, and they were often the contractors for Government procurements. Because of vigorous competition in bidding, because of the risk of extremely wide swings in volume with changes in the direction and funding of defense work, and because the allowed profit under Government contracts was generally quite low, these manufacturers soon sought business in the industrial field. One result was that the electronics business in general and the instrument business in particular became one of the most highly competitive of all in the intrinsically competitive U.S. economy. Of course, by no means all competition came about in this way. There were a number of well-established manufacturers prior to 1946, some of high competence, and these today make up the strongest competitive elements.

The trend toward speedy and simplified means of measurements to conserve engineering time continued strongly and all GR's engineering designs were made with those requirements in mind. Development was started by Robert G. Fulks (M. I. T. '59), for instance, on one instrument, the Type 1680-A Automatic Capacitance Bridge, that will measure both the capacitance and dissipation factor of a wide range of capacitors completely automatically. All that the operator does is to connect the capacitor under test to the Bridge, and almost immediately the answer is presented in illuminated numerals. The whole operation requires only a fraction of a second to make a measurement that previously would require at least a minute, usually more.

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In 1961 two more sales engineering offices were opened, one in Orlando, Florida, to be near the new industries and Government laboratories there, with John C. Held (George Washington '52) as manager, the other in Syracuse, New York, under Leo J. Chamberlain (Cornell '52).

Toward the end of that year, with employment approaching 1,000, it seemed probable that an addition to the West Concord plant would be needed within a few years. Therefore, in accordance with the long-standing practice of anticipating space requirements so that new space would be available before overcrowding, with the resultant loss of efficiency, occurred, planning for the addition was started.

Ample land was available for added wings on the existing building; a separate building on the same site was another possibility. Both these alternatives were attractive, but there were certain drawbacks. Traffic congestion on the Concord roads was one. Already policemen were necessary at closing time to control traffic flow. Another, more important one, was that the traditional GR atmosphere of a well-acquainted, well-knit group was tending to be lost with so large a number under one roof. Also, having in mind the lessons learned from the Cambridge-Concord separation, management believed that in a separate plant, complete within itself, more efficient overall operation could be achieved.

A year earlier, in 1960, GR had purchased a 100-acre tract of land in the town of Bolton, eleven miles west of West Concord, partly because it was felt that it might some day be useful and partly as an investment.* The land, originally a farm, was located most attractively on an important state highway (Route No. 117), backed on Great Brook, a trout stream that had once been dammed to create a sizable pond for water power, and surrounded by large pine trees.

*The Concord land, and most good land in the area, had increased tenfold in value in the twenty years that GR had owned it.

General Radio's Bolton plant, opened in 1963.

Thus, already having the land, and with the other factors in its favor, the Company decided in mid-1962 to go ahead with the new facility.

Three-story, brick-faced, concrete construction very similar to the West Concord pattern was used. The T-shaped building, designed so that other T's could be readily added, provided 80,000 square feet of space. The dam was repaired to remake the pond to add to the rural attractiveness of the site.

Planning for the Bolton operation was undertaken with much care. It was (and is) a smaller version of the West Concord plant with complete, self-contained manufacturing facilities, including its own machine shops, assembly, laboratory and test departments, and supporting functions, such as a purchasing department. The engineering department was also planned to be self-sufficient with its associated drafting department and experimental shop.

The only functions that were not moved in part to Bolton were sales engineering and corporate administrative functions, which remained centralized at West Concord.

In order to get it off to a good start, several rapidly growing product lines were assigned there, including uhf coaxial equipment, signal generators, and frequency synthesizers.

The new plant, on divisional status, went into operation in February, 1963, with Robert A. Soderman (Stanford '40) as engineering manager, reporting to Easton, vice president for engineering, and Philip W. Powers (Harvard '50) as manufacturing manager, reporting to Wilson, vice president for manufacturing.

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A year earlier, in 1962, Easton and Wilson were elected directors so that the board was then Thiessen (chairman), Carey, Easton, Sinclair, and Wilson.

That same year, another district office was opened in Dallas, Texas, with Edward F. Sutherland (Cornell '55) in charge, and in 1963 still another in Cleveland, Ohio, under L. C. (Tom) Fricke (University of Illinois '57).

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At Sales Week, development engineers brief sales engineers on new instruments and measuring techniques.

In October, 1963, Charles C. Carey died following an operation. Carey had occupied the office of president with distinction since his election in 1956. In all of the moves, from Cambridge to Concord and Concord to Bolton, he had been leading proponent. He was a man of high intelligence and broad-ranging interests. His knowledge of GR's operations was great, as was his acquaintance with GR people, all of whom mourned his untimely death at the age of fifty-eight.

Sinclair, who had been executive vice president, was elected to succeed him as president and Thiessen as chairman of the Management Committee.

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Communications, person to person and group to group, within the Company have always been considered of primary importance, which is one reason for the committee form of management. Two stockholders' meetings are held each year, supplemented by three financial reports, to keep stockholders fully informed about the Company's business, its present and future plans. To communicate information, in detail, to the sales engineers in the field about the new products, a week-long gathering of the entire field force is held each year at headquarters. This development of the last decade, called Sales Week, is one of intense activity in which the development engineers responsible for the new instruments give detailed technical talks about them in the mornings, and in the afternoons the sales engineers familiarize themselves with the instruments by working with them in "workshop" sessions. The last event of the week is the stockholders' meeting, held at that time so that it may conveniently be attended by the many sales engineers who are stockholders.

Another similar activity is the biennial International Sales Seminar. These are the same in format as the Sales Week meetings, and various GR representatives abroad have graciously been hosts. All export representatives and their sales engineers are invited, and between forty and fifty attend, representing at least a dozen countries. The first host organization was Groenpol in Amsterdam, followed by Radiophon in Paris and Belotti in Italy. GR was the fourth host on the occasion of its fiftieth anniversary.

General Radio's overseas representatives gather for International Sales Seminars at Milan in 1963 (above) and at Amsterdam in 1959 (below).

Today, GR directly employs over 1,000 people, distributed as follows: about 750 in the main plant at West Concord, 175 in the Bolton plant, 95 in the twelve district sales engineering offices in the United States and Canada, and three overseas in Switzerland and England. Indirectly employed are ten in the overseas operations.

Thus, the Company is small by the usual industry standards but of medium size in the instrument field. It is presently geared to an annual manufacturing and sales rate of about $20,000,000. Of the total shipments in recent years, about 17 percent have gone abroad and about 15 percent to the largest domestic customer, the U. S. Government.

In accord with the principle laid down by Eastham and Shaw some thirty years ago, the Company is owned wholly by its employees except for a small block of stock owned by the Massachusetts Institute of Technology, which received it as a gift from Eastham shortly before his retirement, and another by the Genradco Trust, the employee-benefit fund established by Shaw.

Today there are about 150 employee-stockholders, who together represent the active ownership of the Company. M. I. T. and the Genradco Trust each owns just over 5 percent. The direct holdings of the employees, together with those of Genradco and M. I. T., are a little more than 60 percent of the total. The balance is owned by the General Radio Profit-sharing Trust, in which every GR employee with over two years' service has a direct beneficial interest. By these means almost every employee is directly or indirectly a stockholder with a financial stake in the Company's welfare.

Employee-stockholders acquire their stock as year-end bonuses. It has been mentioned that twice each year, in May and November, profit-sharing bonuses are paid, when profits justify, to all regular employees. Again with the reservation that the profitability be adequate to support it, this third bonus is paid to the stockholder group in shares of stock. Each year new stockholders are added, and, of course, old stockholders leave, usually by retirement. It is a requirement that departing stockholders may not take their stock with them but first must offer it for sale back to the Company. The Company may, at its option, either purchase the stock back for cash or give in exchange for it nonvoting 5 percent cumulative preferred stock. The exchange option has rarely been used, but it could be if, for instance, a large cash purchase were to come at a financially inconvenient time. Employee-stockholders may, if they wish, purchase moderate amounts of stock with their own funds, and many have.

Because the stock has no public market, and thus no market price, all stock transactions have traditionally been made at book value.

All three bonuses mentioned above are of the so-called "discretionary" sort, which means that no employee is ever promised a bonus; each is paid at the discretion of the directors, who must decide for each bonus period whether profits justify one. It has been a fortunate circumstance that none has been missed since the depression years of 1932 and 1933. They have, of course, varied greatly in amount but together generally make an important addition to pay; 5 to 20 percent would be typical figures except at upper management levels, where the swings can be higher.

There are about the same number of stockholders in the three major divisions of the Company—engineering, manufacturing, and marketing—with a lesser number in the smaller administrative area. Stockholders are selected key employees with jobs at the organization-chart level of shop foremen, experienced engineers, and higher.

The growth of a self-financed company is naturally limited by the rate at which its after-tax profits can be put to work in the business. This, of itself, could put a limitation on GR's rate of growth. But the growth rate is limited by other factors too. An important one is the time it takes to find and train new people. With its policy of seeking only above-average people, who the Company hopes will become permanent employees, selection and training in this specialized business are not likely to be a rapid process.

Internal ownership also tends to reduce flexibility in matters of possible acquisitions of or mergers with other companies. These possibilities are not automatically foreclosed, but they are more complicated. However, such considerations have been more theoretical than real, as the Company has never seriously considered either a major acquisition or merger.

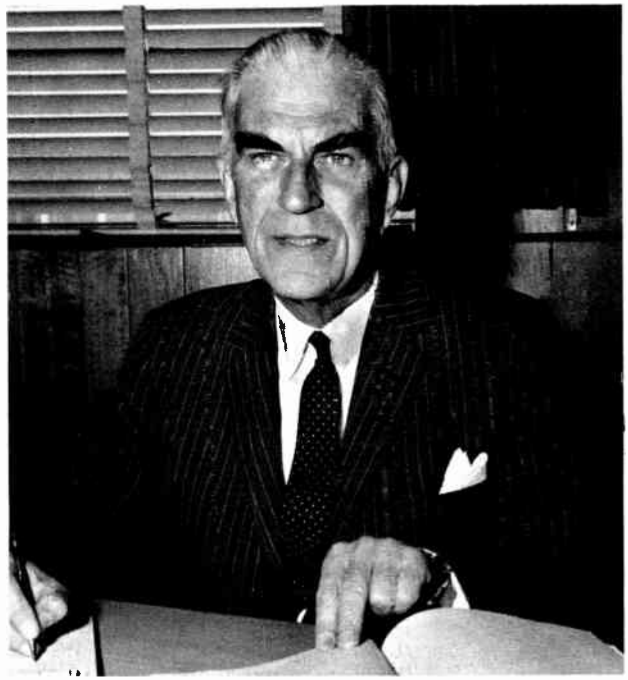
While the limitations are real enough, internal ownership, when spread among the employees who are in the key positions that directly influence the Company's work, and extended indirectly to all personnel, provides the incentive, the feeling of participation, and the day-to-day concern that has contributed much to the Company's progress.

GR has almost from the beginning been a strong believer in the committee form of management. Management experts sometimes argue that committees are cumbersome, slow-moving, and time-wasters. The counter-argument is that a committee decision, although possibly slower to reach, is likely to be a sounder one, combining as it does a number of informed viewpoints. Committees do not have to be wasteful of time if the members are experienced in committee work, with working with each other, and if they understand the job that the committee is intended to do. As a means of communication, these groups perform an excellent, almost unbeatable service.

At GR, committees perform no administrative tasks; these are the jobs of individuals, but the functions of the committees are to co-ordinate action and to make general decisions, which are followed by the individuals, and to provide the ready means by which individual actions are communicated to interested colleagues.

Of the several committees, formal, informal, and ad hoc, that function at General Radio, the standing formal committees that should have special mention because of their impact on company affairs are the Management, New Products, Development, Pricing, and Patent Committees.

The Management Committee, made up of the directors and the heads of functional operating groups, is the direct representative of the directors and is responsible for the operation of the Company. It is the primary duty of the Management Committee to carry out the general policies formulated by the directors and to see that the several operating areas of the Company are properly co-ordinated to provide for unified, balanced operation of the Company as a whole. This includes the allocating of responsibilities among the various departments and guarding against work overlap among them. The various members of this committee are directly responsible for the administration of their departments, but they are not free to make changes that would materially affect the overall operation of the Company without the prior approval of the committee. It also approves all titles of



Arthur E. Thiessen

individuals except those of the officers, which are, as in most corporations, the responsibility of the directors. Its weekly meetings provide a place where members may announce proposed actions to be taken by them so that such actions may be properly co-ordinated with the activities of other groups or with Company administration as a whole. At this time (1965) the Committee has eight members, and five alternates who sit in for various members in their absence.

The New Products Committee determines what products the Company will offer for sale. It receives from any source available to it suggestions for new products or for improving existing ones. It authorizes the opening of engineering product development assignments, establishes the order of priority of these, decides upon the maximum amount of money that may be spent on a development together with general product specifications, expected completion date, approximate selling price, and any special features that are regarded as necessary for the market success of the product. It has the further duty of determining which products are to be listed in general catalogs and which items are to be deleted. The Development Engineering Department may expend reasonable sums for preliminary investigations in order to obtain essential technical background information, but the development of a major new product is undertaken only on the authority of the New Products Committee. This Committee has six members, including the heads of the Engineering, Sales, and Marketing Research Departments.

The Development Committee is responsible for the execution of product development assignments authorized by the New Products Committee and, in general, for the conduct of the research and development program of the Company. It carries through the development work until detailed drafting has been completed, models have been made, and the product is ready for tooling and manufacturing. It currently has ten members, including the leaders of the several development and design engineering groups.

The Pricing Committee determines, based upon cost information supplied to it, what the selling prices of new products shall be. It regularly reviews the cost-price relationship of items already listed and makes price changes when appropriate. It is also responsible for approving quotations for bids on large special jobs, that is, for products and services not included in regular catalog price lists. It has four members.

The Personnel Committee administers the Company's personnel program. It carries out personnel policies as determined by the Management Committee in such matters as hours of work, total number of employees, and the various benefit plans of the Company. It handles all matters pertaining to pay scales and, with the assistance of a subcommittee, reviews the rates of pay of all employees at least four times a year. It also approves the transfer of personnel between the principal divisions of the Company. No employee may be discharged without the prior approval of this Committee. It has five members, including four executive officers and the personnel manager.

The Patent Committee co-ordinates all activities dealing with licenses, trademarks, and patents of the Company. It initiates and supervises action related to the securing of patents and trademarks and negotiates for license agreements under patents held by others. It also draws up and issues license agreements under GR's own patents and trademarks.

All the committees are appointed by the Board of Directors, and their membership is made up of individuals who are closest to and most knowledgeable in the work that the several committees are concerned with. The current membership of the committees is given in the appendix.

In the consideration of a new product, several criteria are of primary concern to the New Products and Development Committees, the groups chiefly responsible. The two most important are that the proposed new instrument shall make an important contribution to the art of electrical measurements and that it should have a good chance of becoming a commercial success. Actually, these two considerations are likely to be compatible because a new instrument that meets a real need and solves an important measuring problem will probably find a good market.

There are about sixty engineers in the design and development engineering organization, all holders of degrees in science or engineering and many with advanced degrees, including six with doctorates.

More than 10 percent of each sales dollar is invested in the research and development program. This percentage has been almost constant for many years and has resulted in a new instrument or a substantially improved old instrument at the rate of about one a month.

The Company's direct-sales method of selling in the domestic market, begun almost forty years ago, has remained substantially unchanged. The only minor exception is that Variac autotransformers, which are sold to a rather wider market than are most instruments, are available through a number of carefully selected distributors as well as through the Company's direct sales offices.

The twelve sales engineering offices in the United States and Canada, including the home office, are staffed by about fifty-five sales engineers with suitable clerical assistance. Like development engineers, all sales engineers hold degrees in electrical engineering or have the equivalent in technical experience.

Five of the sales engineering offices, New York, Washington, Chicago, Los Angeles, and Toronto, have complete service and repair facilities to carry into the field in the major electronics centers of the continent the fast repair services available at the main service facility at the factory.

All GR products carry an unconditional two-year warranty except for vacuum tubes and batteries, which sometimes, under heavy use, have a shorter life but which are readily replaced by the user. Unless there are clear evidences of abuse (for instance, if an instrument were dropped on a concrete floor from a high shelf), repairs are made immediately and at no charge within the two-year period. After that repairs are made approximately at cost. It is policy to carry repair parts in stock for old instruments for at least five years after they have been discontinued.

A GR sales engineer must be primarily an expert in electronics measurements, but he also requires some facility in many other fields. This is because electronics methods and tools are being used more and more in such diverse fields as medical research, psychology, agricultural research, steel production, and sister engineering fields, like petroleum and chemistry. Practitioners in these nonelectronics fields are often not experienced in the possibilities of electronics measurements and thus may receive considerable help from sales engineers.

Customer needs, as reported back from the engineers in the field, are a fruitful source of ideas for new or improved instruments. The continuing study of customer needs is a full-time job for the marketing research group. By means of extensive field trips and with the co-operation of instrument users, many of whom willingly answer questionnaires about their uses of GR instruments, the marketing researchers continually accumulate much valuable information about needed improvements and desirable new instruments.

In the export market, which is almost one-fifth of the total, most of the sales are handled by resident representatives in all major countries outside of the Iron Curtain. Most of these have represented the Company for a great many years. After the appointment of the Netherlands representative in 1922, there followed appointments in Great Britain in 1924, in Italy in 1931, in France in 1934, and so on to the present total of twenty-two.

To speed the handling of incoming orders and to insure the greatest possible accuracy in filling them, the order-handling process is largely automated. Orders received one day are usually shipped the next; in fact, about one-quarter are shipped the day received.

Some of the methods used to produce and test the 125 instruments in the Company's current line have already been described. In addition, many hundreds of different kinds of smaller components, coaxial connectors, plugs, jacks, potentiometers, precision capacitors, resistors, and connectors, are in regular production and, like instruments, are expected to be available in stock, ready for immediate delivery. To keep all these flowing smoothly through the various manufacturing departments is obviously a major scheduling problem. The mechanics of controlling and guiding this flow are also automated, as are many of the details of inventory-keeping and cost accounting.

The maintenance of high quality remains a major concern of the manufacturing departments. Frequent inspection points are the rule, with about sixty-five people directly concerned with quality control. Nevertheless, the emphasis remains on having the products made correctly in the first place.

Secure employment, under pleasant working conditions, with adequate financial security, both while employed and after retirement, the partnership principle, and concern for the progress and welfare of all who work at GR are basic aims today as they were when first proposed years ago.

One of the more important reasons for the move from Cambridge to the country was to provide a more pleasant place to work. The new plants are laid out so that, insofar as possible, every work place is near a window (almost every work place is identified by the employee's name). Meals are provided at cost by the Company-run cafeterias; good housekeeping is emphasized; commuting to work is, for most, an easy drive through the country.

It has always been GR policy to have base rates of pay at least equal to the going rates for similar jobs in the community and to augment these by many opportunities for incentive pay and by the profit-sharing bonuses. Good pay and no layoffs provide the desired financial security for the employee, and his family is protected by Company-paid group life insurance with coverage on a scale that varies with length of service and as the surviving family's needs are likely to vary. Coverage starts at one times annual base pay for service from six months up to two years, one and one-half times between two and five years, and twice annual pay after five years of service. As the children grow up, the emergency financial needs of the average family tend to decrease, so the two-times-pay coverage after five years gradually drops after age fifty until it reaches one-times-pay from age sixty to retirement at sixty-five. After retirement, all employees are insured for $1,000.

In cases of illness, all employees are covered by a Company-paid medical and hospitalization insurance plan, and the employee's family may be included, if desired, with the employee and the Company sharing the cost fifty-fifty. Both active and retired employees who are faced with unusual sickness, accidents, and other emergencies may receive help from the Genradco Trust, which, the reader will recall, was set up by Shaw in 1934. The Trust, by the way, also makes donations to outside charitable and scientific organizations with projects that are in keeping with the purposes of the Trust.

Financial security after retirement is assured by the retirement income plan, by the employee's share in the Profit-Sharing Trust, and for stockholders, by the proceeds from the sale of their stock back to the Company. Naturally, the benefits that accrue from these plans will vary with length of service and earnings while employed, but with the low turnover, the benefit is usually substantial.

A Medical Department is available to all employees, where nurses are on hand for first aid and minor ills and where the doctor is available on a regular schedule for medical advice. The services of an ophthalmologist are also provided for eye examinations and for eyeglass prescriptions. All these services are free, including the eyeglasses.

Because every employee with more than two years of service has a financial interest in the Company, either directly as a stockholder or indirectly through the GR Profit-Sharing Trust, because a substantial part of the earnings each year are distributed to all employees as bonuses, and because in lean times or boom the work is shared among all, with the "K" plan operating so that monthly and hourly take-home pay varies in close relationship, it is clear that the partnership idea is a keystone of operating philosophy.

Promotion from within is another basic policy. Virtually without exception, all jobs in the managerial and supervisory hierarchy are filled by the advancement of talented understudies, most of whom will have had several years of experience in a subordinate but closely allied position before advancement. In order best to utilize all available skills, job openings in the shops are posted on bulletin boards, and any who are interested and feel qualified are invited to make their interest known to appropriate supervisors or more usually the Personnel Department. By means of these discussions, even though a transfer to the new job may not be indicated, a catalog of available skills for future promotions is built up by the Department.

The basic work week, in 1965, is seven hours a day for the five-day period, Monday through Friday. All employees are entitled to three weeks' vacation after one year's service, four weeks' after twenty years', and five weeks' after thirty years' or at the age of sixty, whichever comes first. With forty years of service and after age sixty, the vacation is six weeks. The Company observes ten holidays, and if any should fall on a Saturday or Sunday, the day off is observed on some other work day, usually a Monday or Friday.

The Company sponsors a tuition-refund program that is designed to help develop and improve skills. To anyone who elects to take a course related to his work, the Company will reimburse 75 percent of the tuition providing the course is satisfactorily completed. There is no obligation that the employee remain with the Company after the completion of a course of study, but nearly all do.

Employees with five years or more of service may borrow from the Company for college tuition for their children. These loans are interest-free for the two- or four-year college term and after graduation are paid back at the rate of 20 percent per year with interest beginning then at 5 percent on the unpaid balance.

A Credit Union was established under the statutes of the Commonwealth of Massachusetts in 1930. The By-Laws define its purpose as ". . . wholly cooperative, organized . . . for the promotion of thrift among its members by the accumulation of their savings . . . and the loaning of such accumulation to its members for provident purposes . . . ." Today it has 850 members and assets over $1,000,000. Because of lower overhead expenses (the Company pays the clerical staff and donates the facilities), it aims to pay slightly higher dividends and charge lower interest rates than are possible for regular savings banks.

Junior Achievement, a nationwide youth activity, has been sponsored by GR for sixteen years. Its purpose is to give high school juniors and seniors practical experience in the ways of business. GR is identified among the pioneers of the program in the Boston area, and many GR people have contributed much time to make the program the success it is. Another Company-sponsored activity for young people is an Explorer Post of the Boy Scouts. A group, usually about thirty, of Boy Scouts meets at the plant after hours on a biweekly schedule and, under the tutelage of GR engineers, learn about electrical engineering. The program is career-oriented and practical. Groups have constructed all sorts of equipment, even including a working digital computer.

OF THE FUTURE

Electronics is a big industry, reputedly the third largest in the nation today. To have been a part of it almost from its beginnings has been a rich experience for the Company and an absorbing and challenging one for those who have worked for it. Every day new advances in the art are made in scientific laboratories all over the world. These advances, or discoveries, some in small ways and some in large, continually broaden the already immense field of electronics and make it ever more useful to mankind. And in all of this progress, scientific and material, men strive by means of measurements to assign numbers to those phenomena that they observe and use. Those numbers are essential to the scientific and technological processes. They are the invaluable means of communication for the exchange of knowledge among the practitioners; and they are the links from the scientist to the engineer to the production line to the market.

As the art advances, so does the need for better, more accurate, faster, and more sophisticated measuring instruments. It will be General Radio's job for the future, as it has been in the past, to make available those instruments for progress. In so doing, the Company and the men and women associated with it will know an ever more promising and exciting future.

APPENDIX

Following is a list of the people and the organizational structure of General Radio as of April, 1965:

Directors

A. E. THIESSEN, *Chairman*
I. G. EASTON
D. B. SINCLAIR
H. M. WILSON

Officers

A. E. THIESSEN, *Chairman of the Board*
D. B. SINCLAIR, *President*
I. G. EASTON, *Vice President for Engineering*
H. M. WILSON, *Vice President for Manufacturing*
MYRON T. SMITH, *Vice President for Sales*
L. H. PEXTON, *Treasurer*
J. D. QUACKENBOS, *Secretary and Clerk*
E. D. HURLBUT, *Controller*
LELAH A. SULLIVAN, *Acting Secretary*

Management Committee

A. E. THIESSEN, Chairman
I. G. EASTON
C. J. HORNE
L. H. PEXTON, *Secretary*
J. D. QUACKENBOS
D. B. SINCLAIR
M. T. SMITH
H. M. WILSON
E. D. HURLBUT, *Alternate*
A. T. JONES, *Alternate*
W. R. SAYLOR, *Alternate*
R. A. SODERMAN, *Alternate*
W. R. THURSTON, *Alternate*

Continued next page

COMMITTEES

Personnel

I. G. Easton
D. B. Sinclair
A. E. Thiessen
H. M. Wilson
J. D. Quackenbos, *Secretary*

New Products

D. B. Sinclair, *Chairman*
I. G. Easton
L. J. Chamberlain
A. E. Thiessen
W. R. Thurston, Jr., *Secretary*
W. N. Tuttle

Development

I. G. Easton, *Chairman*
R. A. Soderman, *Vice Chairman*
M. J. Fitzmorris, *Secretary*
R. W. Frank
H. P. Hall
M. C. Holtje
H. C. Littlejohn
A. Noyes, Jr.
A. P. G. Peterson
W. R. Thurston

Pricing

A. E. Thiessen, *Chairman*
D. B. Sinclair
W. R. Thurston, *Secretary*
H. M. Wilson

Bolton Administrative

D. B. Sinclair, *Chairman*
H. M. Wilson, *Vice Chairman*
I. G. Easton
P. W. Powers, *Secretary*
R. A. Soderman
ex officio members
Chairman of the Board of Directors
Secretary
Treasurer

Patent

D. B. Sinclair, *Chairman*
M. C. Holtje
M. Nacey
A. E. Thiessen

Data Processing

E. D. Hurlbut, *Chairman*
D. C. Beedy
M. J. Fitzmorris
F. C. Heinemann, *Secretary*
E. Hutchinson
A. T. Jones
R. E. Wilson
D. B. Sinclair, *Advisor*

TRUSTS

General Radio Profit-Sharing

Trustees
L. H. Pexton
J. D. Quackenbos
D. B. Sinclair
L. A. Sullivan
A. E. Thiessen

Genradco

Trustees
I. G. Easton
A. T. Jones
J. D. Quackenbos
C. H. Riemer
M. T. Smith
L. A. Sullivan, *Secretary*

ADMINISTRATION

Donald B. Sinclair, *President*
Lawrence H. Pexton, *Treasurer*
John D. Quackenbos,
Secretary and Clerk
Lelah A. Sullivan,
Assistant to President
Michael Nacey,
Assistant to Secretary
Catherine A. Brown
Lillian H. Colford
Thelma O. Mattson
Loretta E. Tobin

Accounting Department

Edwin D. Hurlbut, *Controller*
Walter D. Hill,
Assistant Controller;
Credit Manager
Winona C. Hary,
Administrative Assistant
M. Glenna Bradley
Marjorie E. Ching
Patricia F. Dwinells
Edith L. Hodsdon
Myra R. Jennings
Madelein J. Lemay
Elizabeth W. Lowe
Carla E. Montague
Carol M. Ricard
Marilyn A. Small
Phillis Trebendis

Data Processing Department

Edwin D. Hurlbut, *Controller*
Franklin C. Heinemann,
Assistant to Controller
Richard E. Wilson,
Supervisor, Data Processing
Thaddeus S. Kosciuszek,
Assistant Supervisor
Arthur W. Callbeck
Marjorie M. Cevolani
Paul A. Duddy
Frederick H. Hanna, Jr.
Robert J. Lettieri
Edith S. Tyler

Personnel Department

John D. Quackenbos, *Manager*
Michael Nacey, *Assistant Manager*
Marilyn B. Kent,
Personnel Assistant
Norman F. Swanson,
Personnel Assistant
Ann F. Hildreth
Barbara L. Norris
Ann J. Poulson
Carole A. Westphalen

Medical Department—Concord

Dr. Mahlon T. Easton
Dr. Roy E. Mabrey
Frances E. Hannah, RN
Bessie McLellan, RN
James V. Robinson

Medical Department—Bolton

Dr. Charles S. Keevil, jr.
M. Louise S. Damon, RN
Nina E. McLaren, RN

Cafeteria—Concord

Charles H. Riemer, *Supervisor*
Robert E. Sheehan,
Assistant Supervisor
Robert C. Kent
Philip H. Lozier
Helena M. McDonald
Walter T. Michaels
Russell N. Moser
Ralph L. Phipps, jr.
Stanley J. Wasiuk

Cafeteria—Bolton

William F. Lucas,
Assistant Supervisor
Helen L. Dudley
Richard D. Powderly

Activities

Charles H. Riemer, *Chairman*
Jeanne E. McGrail

GR Credit Union—Concord

Josephine A. Donato, *Treasurer*
Carole Cardoza
Lorraine C. Perkins

GR Credit Union—Bolton

Mary G. Enneguess

ENGINEERING

Ivan G. Easton, *Vice President*
Michael J. Fitzmorris, Jr., *Assistant to Vice President*
W. Norris Tuttle, *Engineering Consultant*
Lawrence H. Mounce, *Supervisor, Special Projects*
Rita M. Leary, *Administrative Assistant*
Claudia J. Chabot
Catherine A. Donato
Joan P. Hansen
Marie A. Oliva

Audio Group

Arnold P. G. Peterson, *Group Leader*
Basil A. Bonk, *Development Engineer*
Arthur G. Bousquet, *Development Engineer*
James J. Faran, Jr., *Development Engineer*
Ervin E. Gross, Jr., *Development Engineer*
Warren R. Kundert, *Development Engineer*
Robert J. Ruplenas, *Engineering Assistant*
Carlton A. Woodward, Jr., *Development Engineer*

Frequency Group

Richard W. Frank, *Group Leader*
Steen Bentzen, *Development Engineer*
Albert M. Eames, Jr., *Engineering Assistant*
Dale O. Fisher, *Development Engineer*
Harold T. McAleer, *Development Engineer*
David S. Nixon, Jr., *Development Engineer*
Gordon R. Partridge, *Development Engineer*
William J. Riley, Jr., *Development Engineer*
James K. Skilling, *Development Engineer*
Herbert P. Stratemeyer, *Development Engineer*
Albert M. Wentworth, *Engineering Assistant*
Norman L. Westlake, Jr., *Development Engineer*

Impedance Group

Henry P. Hall, *Group Leader*
Walther J. Bastanier, *Development Engineer*
Dudley H. Chute, *Engineering Assistant*
Robert G. Fulks, *Development Engineer*
John F. Hersh, *Development Engineer*
Robert K. Leong, *Development Engineer*
Robert W. Orr, *Development Engineer*
Robert E. Owen, *Development Engineer*
Richard F. Sette, *Development Engineer*

Industrial Group

Malcolm C. Holtje, *Group Leader*
Ralph P. Anderson, *Development Engineer*
K. George Balekdjian, *Development Engineer*
Martin W. Basch, *Development Engineer*
Costa G. Chitouras, *Development Engineer*

Charles E. Miller,
Development Engineer
Gilbert Smiley,
Development Engineer

Mechanical Design Group

Henry C. Littlejohn,
Group Leader
Marshall G. Bibber,
Engineering Assistant
George Cromidas
Paul d'Entremont,
Industrial Engineer
James O. Esselstyn,
Design Engineer
J. Edward Hunter, Jr.,
Design Engineer
Harold C. Jensen,
Engineering Assistant
William A. Montague
George E. Neagle,
Design Engineer
James H. Nye, *Design Engineer*
Charles A. Tashjian,
Design Engineer

Drafting

Melville R. MacIntosh, *Manager*
Carl F. Uhlendorff,
Assistant to Manager
Carter C. Hollis,
Assistant to Manager
George C. Oliver, *Designer*
Henry G. Stirling, *Designer*
Gertrude A. Beaudoin
Ronald J. Beaudoin
Mabel E. Beliveau
David K. Bitzer
Robert Bross
Andrew A. Corcoran
Leonard J. Cummings
Rosemary Dentino
Robert F. Duffy
Chauncey W. Erickson
Arthur R. Gagnon
Salvatore D. Giliberto
Richard A. Goucher
Ernest M. Gray, Jr.
John W. Hagerty
Robert E. Hall, Jr.
Ernest C. Hiscoe
Jon E. Hunt
Charles S. Kennedy
Leroy W. Kizina
Michael M. Lonigro
Paul L. Meuse
Diane L. Nedza
Robert E. Parsons
Carolyn F. Perkin
Raymond T. Schofield
Mabel C. Taylor
Robert E. Votapka

Experimental Shop

Edgar I. Pasho, *Manager*
Paul E. DeMille, *Supervisor*
Charles S. Carbary
David W. Carey
R. Bruce Donovan
Harold Hansen, Jr.
Russell A. Hubbard
Russell N. Kimball
Vinal W. Kundert
John P. Littlefield
Clifton J. MacDonald
Bruce D. MacLeod
Otis G. Manchester
Richard D. Manning
Paul Mohler
John P. Morey
Daniel E. Paine
Lawrence M. Pierce
Robert M. Rich
Stephen G. Sheridan
Lee D. Smith
Alfred Stierli

ENGINEERING—BOLTON

Robert A. Soderman,
Engineering Manager
Mary L. Mullaney
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Lillian F. Kensley
Conrad W. Masson
Jane S. Putnam

Photography

Rudolph F. Recke, *Photographer*
Francis E. Bolieau
Victor P. Johnson

Marketing Research and Statistical

William R. Thurston, Jr., *Manager, Marketing Research & Statistical*
Eleanora Hutchinson, *Manager, Statistical*
Robert A. Boole, *Engineer, Marketing Research*
H. Albert Webb, *Supervisor, Statistical*
June King, *Administrative Assistant, Statistical*
Nancy H. Bancroft
Shirley A. Blood
Nancy Hallowell
Jeanne L. Jackins
Barbara R. Morrison
Marcia K. Perry
Helen W. Smith
Susan H. Spangler

Co-operative Students

Cornell

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Bruce R. Carpenter
John H. James
Robert M. Sprague

MIT

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Matthew L. Fichtenbaum
Paul L. Kebabian
Karl B. Kehler
Robert Ochis
Arthur R. Sindoris
David H. Slosberg
Wayne P. Stevens
James L. Sweeney
Robert T. Szpila
John J. Vencill
Peter V. Young

Northeastern

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William A. Clark
William J. Connolly
Thomas J. Coughlin
Belford E. Cross, Jr.
John C. Donohue
Jon A. Ebacher
David Fecitt
Albert J. Grubis
James F. Hashem
Bruce J. Jay
David A. Johnson
Neal H. Kleinberg
F. Nils Krook III
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Douglas G. MacDonald
Dominic P. Marro
Donald E. Moodie
James F. Morrow III
Charles T. Namur III
David R. O'Brien
Theodore J. Oldakowski, Jr.
Frederick A. Otto
Frank Perillo
Robert G. Petersen
Peter A. Previte
David F. Rivers
William D. Sparks
Jeffrey L. Struthers
Phillip A. Szathmary
Gary L. Tater
William F. Wyman, Jr.

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Jerry W. Anderson
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Charles T. Burke
Carmine Carbone
Alvah W. Chase
Finn I. Christensen
Edward T. Clarke
John M. Clayton
Adrian W. Cleveland
Albert W. Clisbee
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Errol H. Locke
John J. Lydon, Sr.
C. Henry MacIntosh
David D. MacLean
Paul K. McElroy
Emil Mohler
Sarah F. O'Connell
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William T. Regan
Jerome A. Reinhalter
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Harold S. Wilkins
Frederick W. Williams
Louis Zolot

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