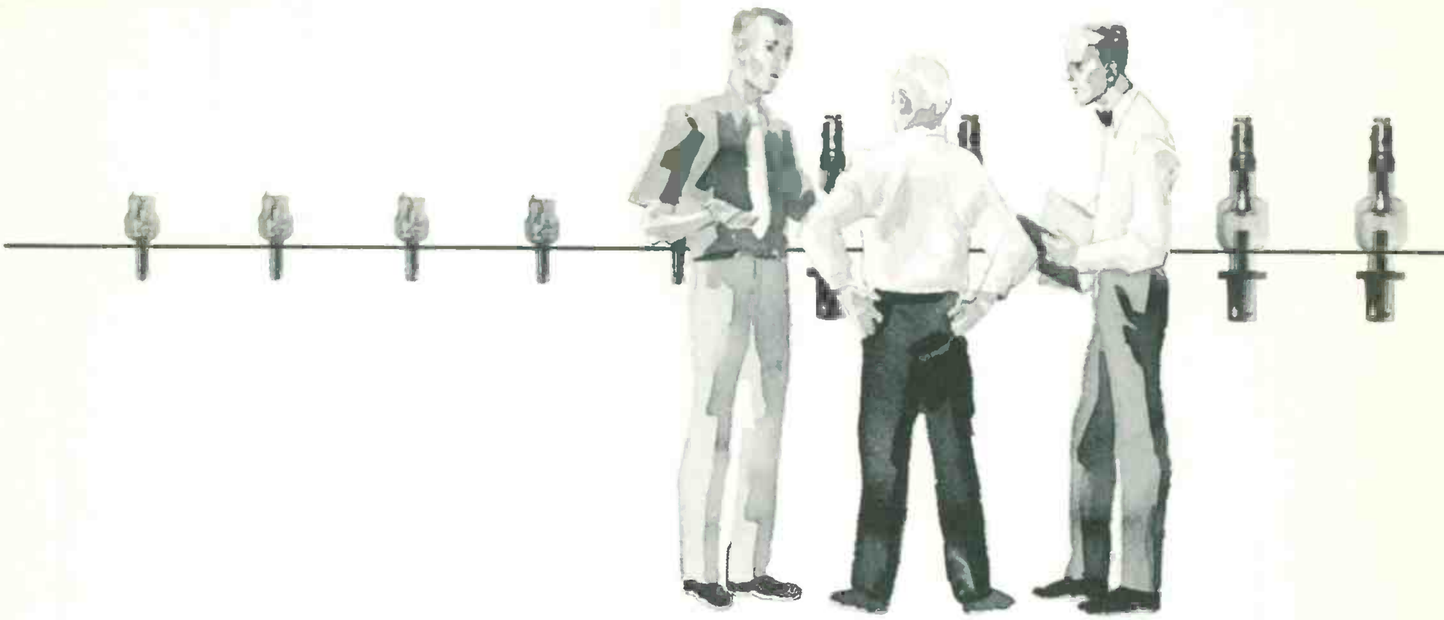
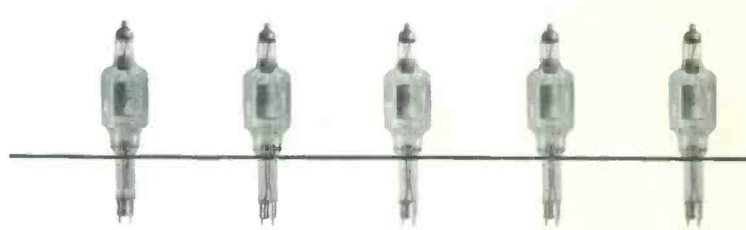
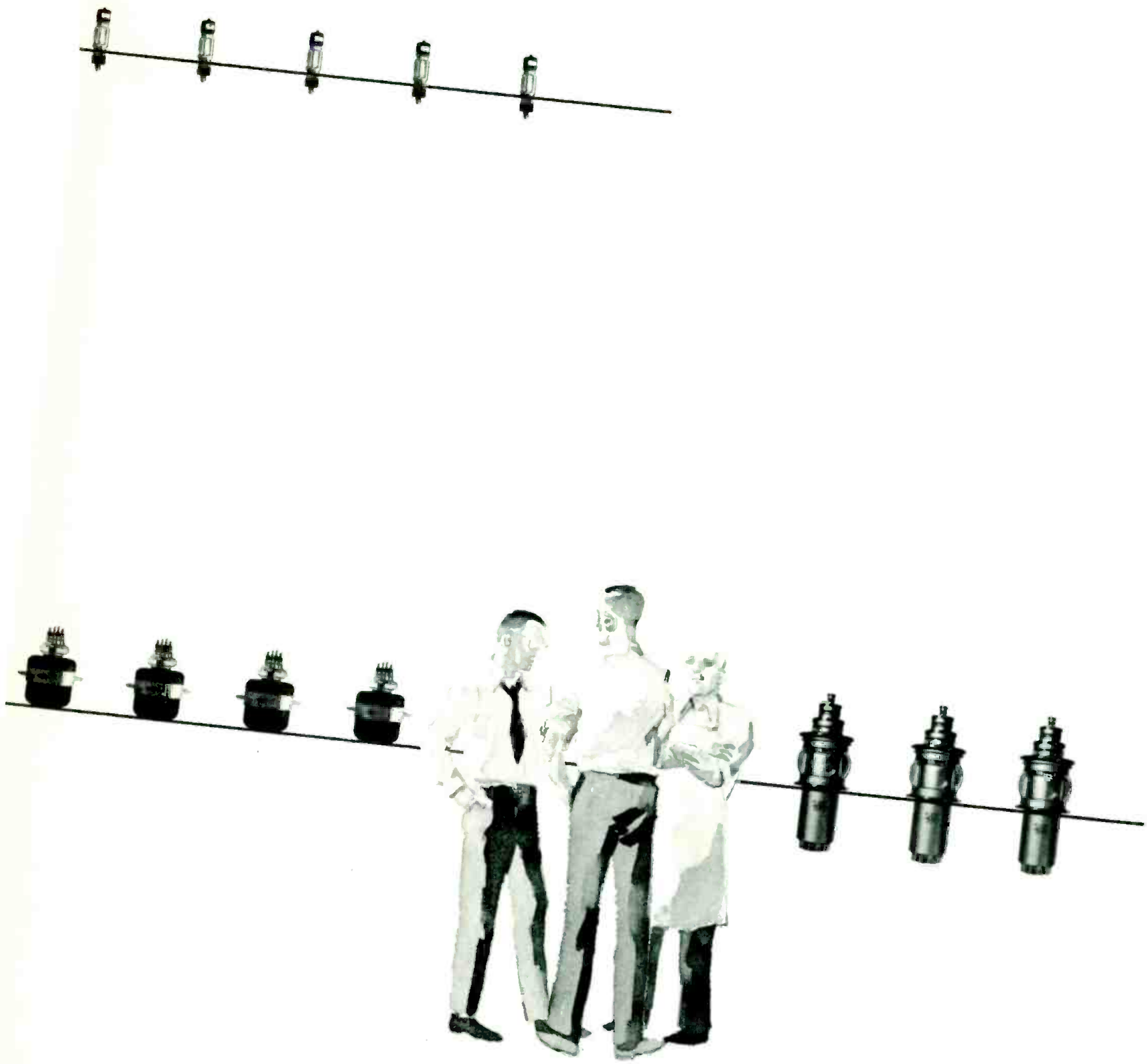
MACHLETT CATHODE PRESS

Memorial Issue







Raymond R. Machlett

1900 - 1955

CATHODE PRESS

Memorial Issue

Written by

Robert Keith Leavitt

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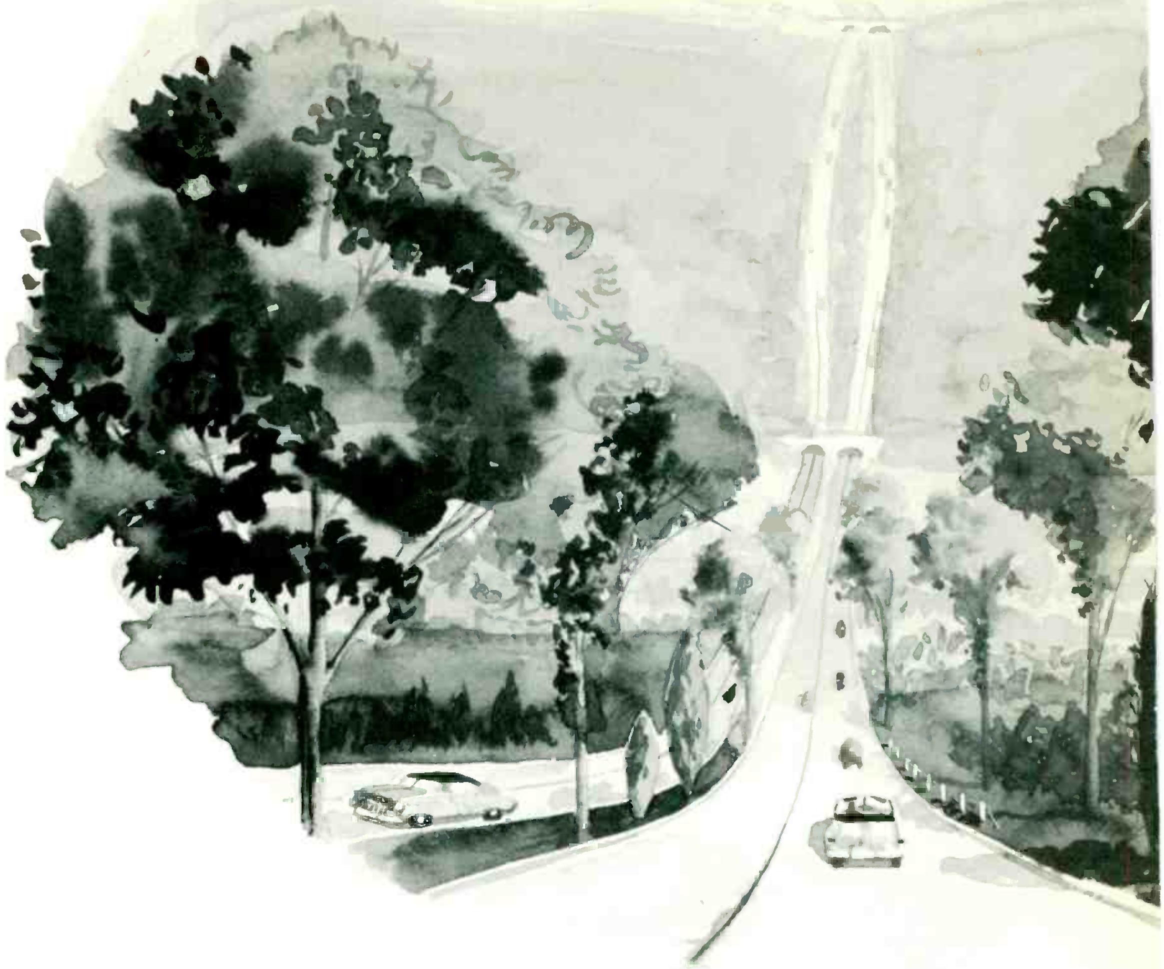
The Case of the Modest Doorway



IT'S pleasant country, out there in Connecticut's Fairfield County, which is the corner nearest New York. Fair and rolling country, luxuriant with trees and open spaces, populous with homes. There is a sea-softness in the air when it drifts in off Long Island Sound, a field-fragrance when the breeze comes from the inland hills. This is old country, and new at the same time. Old as great oaks and Revolutionary houses, new as commuters' estates and electrified industries. It is, and always has been, industrious, prosperous country, with homes and manufacturing plants companionably intermingled. For since earliest times people in this region have made the kind of things in which skill and ingenuity and Yankee conscientiousness counted for more than day-labor and horsepower. So if you were to enter at random almost any manufacturing plant in this area you would likely find it the home of a product known throughout its own industry for some special character or quality nowhere else quite the same. Indeed, in a surprising number of cases you would find very modest-seeming plants with world-reputations in fairly big fields.

Suppose we look at one such company.

YOU turn off the Merritt Parkway north of Stamford and, winding through shaded roads, come soon to the small community of Springdale, which lies on the outskirts of Stamford. It is a small, neat village, typical of a New England area where you find good schools, good stores, good recreational facilities, good building codes, good living. You would be hard put to it, here, to distinguish between the home of a commuter to hour-distant New York and that of a skilled worker in local industry.

At a road junction in the center of the town you come upon a rather widespread brick building, principally of one story in the modern airy, well-windowed style. At its corner is a well-designed, rounded entrance in pleasingly functional architecture. Over its portal, the simple name, MACHLETT LABORATORIES.

You may never even have heard the name, unless your business or profession happens to touch the activities of this concern. So you may not know that this is the largest maker in the world of one vital class of product—x-ray tubes—and among the leaders in the making of another—electron tubes for broadcasting, communications and industrial power. More, it has reached these twin peaks of eminence in a bare quarter of a century from a start (in its present corporate form) so near to scratch as makes no difference. Yet the lineage of its tradition, its craftsmanship and its conscience goes back to the closing years of the last century.

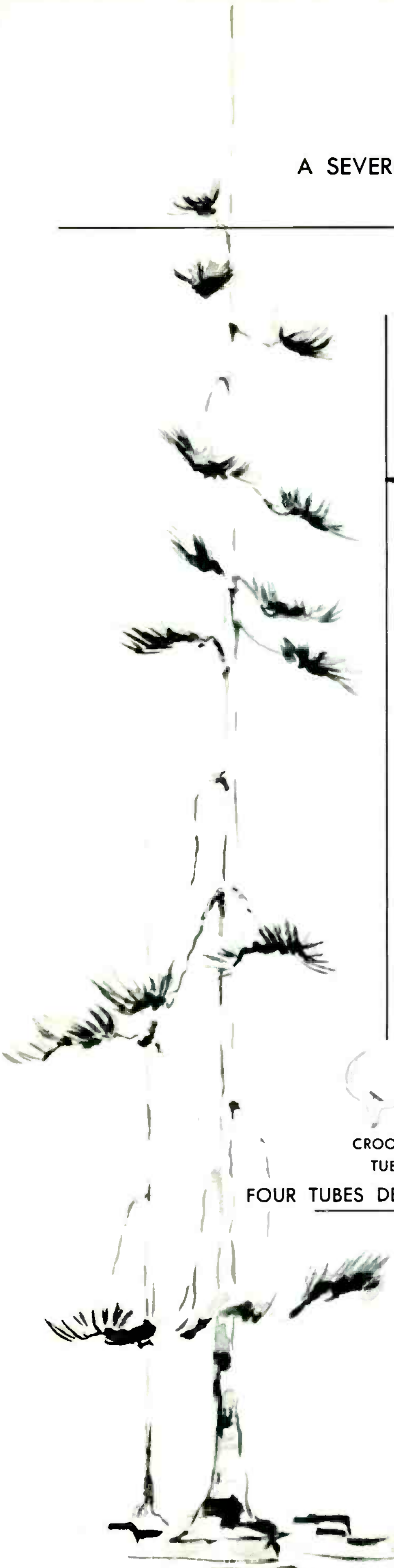
To the outward eye it is just another of those neat, small plants you so often see at the heart of New England towns. Yet behind its unpretentious façade take place fantastic doings with high vacuums, high voltages, high frequencies. . . . The actual buyers of its products would not fill a small ball-park, but practically every one of the nation's 165,000,000 people is a user or a direct beneficiary, one way or another, of some one of its products, and all over the world are professional men, engineers and technologists to whom the name Machlett Laboratories is the familiar, implicitly trusted synonym for a standard in their work.

Perhaps it would interest you, then, to consider this company and its story as a case study of the way a highly technical, highly necessary business can grow in this country of ours; can discern the possibility of a place for itself and make that place by dint of resourcefulness, intelligence, and the willingness to dare anything within the limits of integrity. These we think of—and rightly—as typically American traits. It is worth while to see how they work out in the case of one typically American concern—how they even force the breaks that might otherwise seem luck.

Machlett, then, is a company of some 900 people, making x-ray and power electron tubes in the community of Springdale—a small outlying suburb of the City of Stamford, Connecticut—and selling them for the most part only to makers of the complex equipment of which these tubes are the very heart.

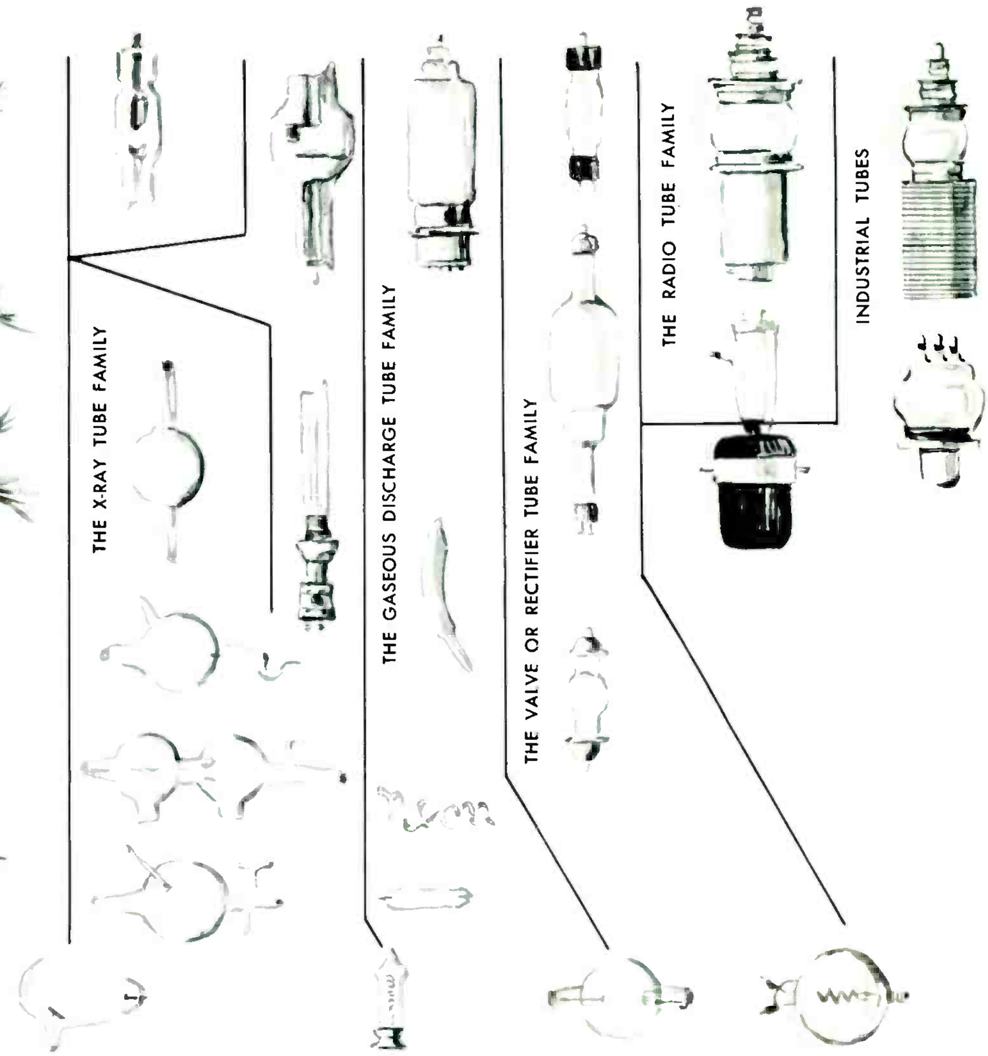
It is important to note this distinction; Machlett does not make the elaborate x-ray equipment that you see, for example, in great hospitals; it makes the tubes which are the vital factor of that equipment, and sells them to the manufacturers of x-ray equipment for medical and industrial use.

Similarly, Machlett does not make broadcasting station equipment or short wave communications equipment, or the equipment for industrial use of high frequencies; it makes the principal tubes for such installations, and sells them to the many highly specialized independent manufacturers



A SEVERELY PRUNED FAMILY TREE

of tubes that figure in Machlett history



FOUR TUBES DEVELOPED FROM 1897 - 1905 FORMED THE BASIS OF FOUR FAMILIES OF TUBES.

Through the 1800's, many experiments and much knowledge. Numerous great experimenters such as Faraday, Henry, Hertz, Maxwell, Zehuder, Edison, Crookes and others made countless experiments, observed many effects, deduced invaluable principles—but the vacuum tube remained mostly a laboratory tool or a scientific curiosity.

About 1740 the first vacuum tube was rigged by the Abbé Nollet, a French experimenter. He found that if electrodes were placed in a glass bulb under a partial vacuum, electrons would flow more easily—in a continuous stream, with luminous effect on the little air that was left.

of equipment, who do not make tubes. Tubes for renewal purposes in these many fields of use are sold through a well-established, closely integrated distribution system. The company also sells to one—and only one—"user." But that is a fairly large one: the United States Government. Both armed forces and civilian agencies use considerable quantities of many Machlett tubes, including particularly those for radar and short wave communication and those for the world-wide Voice of America. To a small extent, too, Machlett makes certain special types of tubes for its tube-making competitors (most of whom also make equipment—x-ray, broadcasting or industrial) and buys from them types of tubes it does not make, for servicing certain of its field requirements.

In general, the kind of tube Machlett makes is a fairly large unit and fairly high priced. An x-ray tube may be as much as three feet long, and cost as much as $5,000, though the norm is somewhere around $750-$1,000. A big high-power electron tube may be a couple of feet long by eight inches in diameter, weighing fifty pounds, and costing some $3,000. At the other end of the scale, a relatively low-power tube, made in quantity for government and civilian short wave communications is small enough to hold in your fist and costs as little as $20. Aside from these, however, the typical price of electron tubes sold for either communications or industrial use is around $400.

Naturally, few of these tubes are needed in what most manufacturers would consider quantities. Yet Machlett's production by 20's or 50's or 100's—or even 2's and 3's in the case of some big tubes—it not a job-shop operation, any more than an airline's flying passengers by the 20 or 50. It is simply the handling of exactly standardized traffic in most efficient-size lots, and the organization and know-how for doing it in this manner are among the most interesting features of this unusual business.

To the layman it may seem that x-ray tubes and military or power tubes are as different from one another as physicians and radio engineers—their typical end-users. Certainly they produce what seem to be widely different effects, and any casual look will show that, inside their glass envelopes they are differently constructed.

Yet they are more alike than the layman realizes. They are—all forms of both of them—descendants of the same family tree of vacuum tubes.

In all of them, the essential principle is the controlled flight of the electron from one electrode to another. In nearly all of them this is flight in a vacuum—and, in the case of tubes in this order of exacting use, a remarkably high vacuum. This consideration, as we shall see, pervades the entire Machlett operation. In many tubes high voltage or high power or high frequency—or all three—are essential to operation and consequently in most of them high operating temperatures have to be foreseen and provided for—again an over-riding factor in all Machlett design and production.

The behavior of metal components inside a glass envelope—and even of the glass itself—at high temperatures, high vacuums and high electrical stresses requires, among other things, a degree of thoroughness in cleaning—including the removal of even the minutest quantities of gas occluded in metal and glass "solids"—which is very high indeed, and is common to both x-ray and power tubes. To design either x-ray or power tubes of the kind Machlett produces requires electronic engineering knowledge and skill of the highest type—and much of this is applicable in common to either kind of tube. Lastly, the making of either requires exactly the same basic skills—for example, in the working of glass, the sealing of glass to metal, the achievement of utter cleanliness and the working with high vacuums, the plant-wide standards for making either type are identical.

Yet an understanding of Machlett Laboratories and of its place in the scientific, social and economic structure cannot be reached by merely taking apart and analyzing its products and operations. The company is an individuality, and a strong one. Its character is even more important than its procedures. The procedures themselves are best understood by seeing how they grew. And the character of the company—like that of a man—can only be appreciated by knowing its background, by seeing it in terms of deeds, not encomiums.

This is the more so because a very great deal of Machlett's character derives from one man. Raymond Robert Machlett, who died in the prime of life at the very beginning of the year 1955, led the building of the company that bears his family name. Like all great builders, he built a thing able and worthy to endure of itself after him. But, again like every truly great leader, he left upon it the impress of his personality, his abilities and his character. To know Machlett Laboratories you must know Ray Machlett. So this is the story both of an organization and of a man.

In fact, as Ray Machlett himself saw it and outlined it in notes made not long before his passing, the story really begins with his father, Robert Herman Machlett. For it was the elder Machlett who first began the making of x-ray tubes more than half a century ago, who made the name Machlett famous in radiology, who transmitted to his son the still-glowing embers of an x-ray business which the son built into a business greater than it had ever been. And he passed on to that son and to those associated with him certain principles and a very positive integrity which are still the heart of the name Machlett.

The Future in the Picture of a Hand

SOME time in the summer of the year 1897, a jovial, florid German-American named Robert H. Machlett did two things, seemingly so small that they interested only himself and his immediate circle, but actually fateful beyond anything he or they could have imagined.

He was a maker of scientific glass apparatus for chemists, university laboratories and medical researchers. He ran a small shop employing three or four people, upstairs in a building on East 23rd Street in New York. In the shop he had put together an apparatus planned partly out of his experience in making difficult glass pieces for electrical experimentation and partly out of the published accounts of similar apparatus in scientific journals, notably those from Germany. The apparatus was a sort of sandwich. Its lower element housed a curiously shaped glass bulb that he had made up—shaped like an overgrown egg with horns out of which sprouted electrical wires. The upper element of the sandwich was a photographic plate in a light-proof holder. There was nothing in between the two parts—until Machlett did the first of the two things that were to lead so far:

He put his left hand into the empty space in the middle of the sandwich and held it there, very still, for a space of minutes.

The second thing he did came perhaps half an hour later when he saw the developed photographic plate. For there on the glass was the shadowy image of his skeletal hand with every bone from carpals to distal phalanges standing out in eerie light. And he said, "Yes. We will make these tubes."

By the first act Robert H. Machlett had unwittingly begun the writing of his own death warrant. But by the second he had started the process of giving to countless people, most of them still unborn, uncountable added years of life. For the photograph was an x-ray negative. And in its picture of Robert Machlett's hand there might have been read, as in a palm, both his own fate from then-unsuspected effects of radiation and, alongside it, the happiness and health of millions of people whom the wonder-ray has helped.

And there was, quite incidentally, fortune to be read in that hand. For by Robert Machlett's entry into x-ray tube manufacturing, he planted the seeds of an enterprise that today supports as many people as in a small town, that indirectly helps thousands of people to earn their livelihood, and that contributes far beyond the proportion of its size to the prosperity and security of a nation.

The egg-shaped bulb that Robert Machlett had made, had tested upon himself, and now offered to his professional clientele was, as far as can be determined, the first x-ray tube to be commercially manufactured[1] in the United States.

[1]The first tubes in the United States capable of producing x-rays were not, of course, originally designed for that purpose. They were Crookes tubes, the invention of Sir William Crookes for the study of electrical discharges through rarefied gas. Roentgen discovered x-rays, experimenting with such a tube in 1895. Almost immediately scientific experimenters started making Crookes tubes to produce x-rays. Among the first of these in America was Dr. Emil A. Grubbé, who made them while still a medical student at the University of Chicago. (Dr. Grubbé was later to become the first among many martyrs to science in the development of x-rays.) But although records definitely establishing manufacturing priority have long since vanished, it appears that both Machlett's professional and business contemporaries recognized him as having been the first U. S. manufacturer to enter the x-ray field. cf. Dr. I. S. Hirsch, himself among the pioneers, writing in Radiology *8:254, 1927, ". . . Machlett . . . succeeded in producing the first [commercially manufactured] x-ray tube in this country. This fact has been recognized and acknowledged by those in position to know of the work done in the early days." Machlett himself was accustomed to testifying to the same effect under oath as a witness in patent suits, and it appears from existing court records that opposing parties did not question this claim.*

Out of it grew, in time, the largest x-ray tube manufacturing company not only in America, but in the world. And out of that company's skill and experience with the high voltages and high vacuum of mid-century x-ray tubes developed another side of the Machlett business—in the big, difficult and costly "power" electron tubes. That is, the tubes used for modern broadcasting and communications, for military purposes and for a multitude of industrial and scientific purposes.

This, to be sure, took more than fifty years of ups and downs, some of which, during the first third of a century, were all but hiatuses. Yet the remarkable growth of the Machlett business during the last quarter century traces back in a very real sense to Robert H. Machlett's pioneering of the x-ray tube as a tool to be made for science by the manufacturer, rather than by the scientist for himself.

ROBERT HERMAN MACHLETT was born in Gehlberg, Germany, on April 22, 1872, the son of Ernst and Caroline (Greiner) Machlett. Gehlberg is in the mountains of Thuringia, a region of central Germany that includes the northern edge of Bavaria and the western edge of Saxony. It is famous for music and for master craftsmanship in the precise arts. Bayreuth and Weimar are there, the great Wagnerian shrines. So is Jena, which was for generations the world center of fine optical glass making. Indeed, craftsmanship in glass working is a proud Thuringian tradition, and no small part of Germany's long-time preeminence in chemical and physical research came from the fine quality of laboratory glass apparatus made by Thuringian artisans.

Ernst Machlett was one of these—a glass blower and an expert on engraving, etching and grinding of glass, as for gauges, stopcocks and valves. In 1880 he executed an extensive contract on laboratory equipment for Eimer & Amend of New York, the now-famous chemists and suppliers of chemists' materials. Eimer was so impressed by the quality of the work that he went to Gehlberg to persuade Ernst Machlett to come to the United States and take charge of a laboratory glassware manufacturing operation for Eimer & Amend.

Machlett, a widower, came to New York in 1883, bringing with him his two youngest children, Clara and Robert. They went to school in New York until 1885, when the boy's father considered him, at 13, ready for apprenticeship in glass working. However, he had come to the conclusion that while America was rich in opportunities to practice a highly skilled craft, it was sadly lacking in facilities to learn one—at least a craft as demanding as precision glass working. So he took the boy back to Germany for two years of combined apprenticeship and attendance at a technical school. At the end of this time they returned to New York and went to work together for Eimer & Amend.

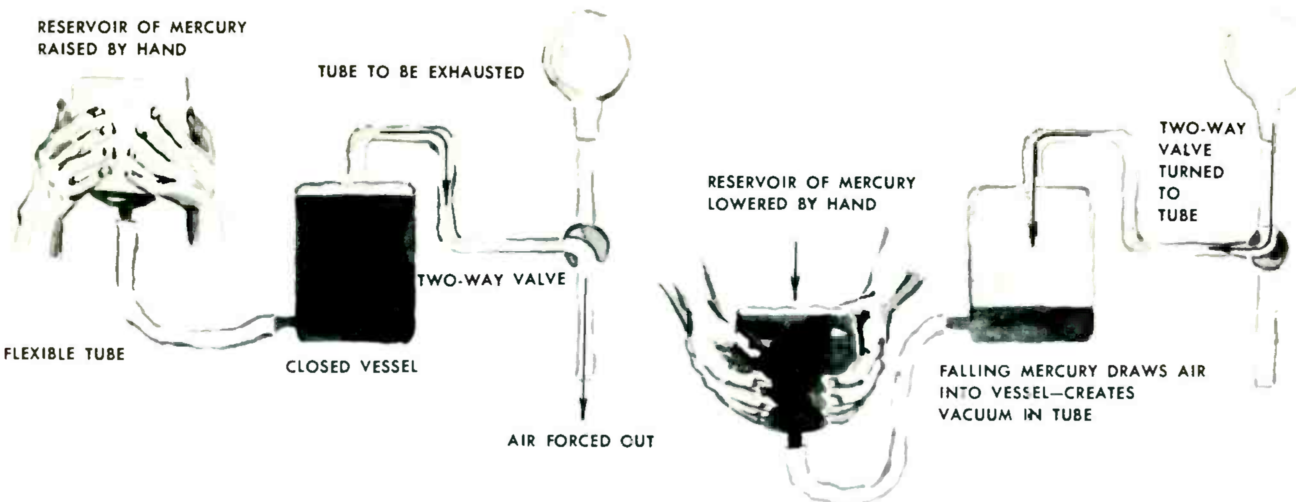
In the course of ten years father and son came largely to specialize in the building of laboratory apparatus to the particular design of professional clients in the research field—doctors from hospitals, Ph.D.'s from universities, independent investigators . . . Robert Machlett had become not only a master maker of glass equipment, but (as customers then and later testified) an uncannily quick perceiver of a client's needs. He was also in a way to become a manager of sorts, with several men under him, including an apprentice, Ernst Zitzmann, to whom he taught the craft of glass blowing as it had been taught to him.

It was a pleasant situation. And in it, probably, the older man would have stayed for a lifetime. But in 1897 Robert Machlett, then 25, persuaded his father to leave with him and set up a business of their own. Eimer & Amend were flatteringly sorry to see them go, but cherished no hard feelings, even when they took the young apprentice Zitzmann with them. Indeed, after a few attempts to hire them back, they gave the young firm a good deal of business in making difficult pieces such as vacuum pumps, and for years Eimer was a frequent and friendly caller at the business establishment of E. Machlett & Son.

That was what they called it, though from the start Robert Machlett was the acknowledged head of the enterprise. (He became its president on its incorporation in 1899.)

They set up business in the second floor of a building at 143-147 East 23rd Street. This was just above the center of gravity of the fashionable business Manhattan of the late 1890's—as though you were to be, today, located in the corresponding block of East 57th Street. In other words, a distinguished location, though the premises were somewhat battered, having been the former quarters of a well-known manufacturer of residence organs.

At first the company had only a front office, a rear office and a small workroom. The quarters were walkup, of course, and only sketchily provided with electric wiring. But even so, the shoestring capital on which father and son had started the business was not enough for electrified machinery. They made do, at the start, with footpower lathes and blowers (some of them contrived out of discarded sewing machines) and when necessary with back and arm power. For example, their first mercury pump for exhausting vacuum tubes of every kind was a homemade adaptation of the 1862 Geissler pump. This was fairly effective, but laborious; it had to be actuated by a husky man alternately raising and lowering a heavy bowl of mercury. This job fell



It took a strong man to operate the Geissler mercury vacuum pump, here shown in schematic diagram.

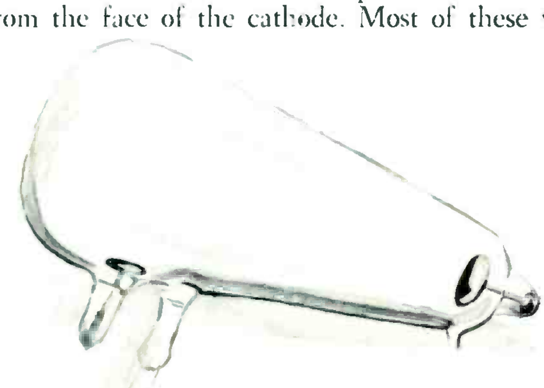
to Zitzmann, since at the outset the entire staff consisted only of the two Machletts, a bookkeeper and Zitzmann himself.

Though the operation was small and its equipment primitive, the reputation of the Machletts' skill brought distinguished customers from the start. Among the first of these was Peter Cooper Hewitt, then merely a wealthy experimenter with quarters a short walk away in the glamorous tower of the old Madison Square Garden. Hewitt was working on a number of inventions, most of which involved vacuum tubes of one kind or another, but notably an adaptation of the Geissler tube idea to use mercury vapor for what he thought of and called "artificial daylight." He would work up sketches at night and bring them over in the morning, often staying to work with Robert Machlett who, alone, was able to translate Hewitt's drawings into tubes. (All his life Machlett had the remarkable facility of being able to study a working drawing for a few minutes and then without a further glance at it and hardly a measurement, to select glass stock of the right size, to blow and fashion the glass parts, to install whatever metal parts were required, and to put the whole together in a faultless finished piece.) Out of this collaboration came the highly successful and still much-used Cooper Hewitt mercury vapor lamp, together with related products such as rectifiers which Hewitt later manufactured on a large scale.

Zitzmann believes it was Hewitt who first suggested the idea of making x-ray tubes to Robert Machlett. This may well have been the case. Yet there were many others among the initial customers of E. Machlett & Son who might as well or even better have done so: research scientists on the faculty of Columbia, of the College of Physicians and Surgeons, of Cornell's Medical School . . . and graduate students at these and other institutions. Several of the New York medical men whose names are associated with the development of roentgenology were among early Machlett customers, though it is impossible to say which were first among a list that eventually included such names as Piffard, Geyser, Cole, Morton, Caldwell, Waite, Titus, Rubin, Hirsch, Besser, Snow and many another—many of them associated with special types of tubes made by Machlett.

At any rate, Machlett had the equipment for making vacuum tubes of the x-ray type, the skill to make these exacting structures and the clientele to make them for, from the minute the business was under way. And very shortly he made, first demonstration models, then others of the same and improved types for sale and use.

Machlett's first x-ray tubes were of the Crookes type: basically a simple pear-shaped glass tube filled with a greatly rarefied gas. In the small end was an aluminum cathode. Inserted through a stem on the side of the tube toward the large end was a platinum anode. Under sufficiently high voltage between electrodes, the gas in the tube became ionized, and a stream of particles we now know as electrons was repelled (i.e. shot away) from the face of the cathode. Most of these were at-



One of the first Machlett x-ray tubes—a simple Crookes type—produced in 1897.

tracted toward the anode, but some of them, flying fast, went by and struck the glass at the big end of the tube. This collision produced a shower of what Roentgen, for want of a better word, had called "x" rays.

At the outset, eager researchers used the Crookes tube, or a modification of it shaped like a truncated cone, called the Monell tube.

Very shortly, however—and no doubt upon the counsel of the numerous New York physician-radiologists who were among his clientele—he was making and improving upon tubes of the type developed in 1896 and known after its English originator as the Jackson or "focus" tube.

This is worth noting since its basic elements were those of fixed-anode x-ray tubes from that day to this, while its special characteristics were the prevailing ones of all x-ray tubes for many years.

Basically the Jackson tube consisted of these elements: (1) A cathode with a concave face so shaped as to focus the stream of electrons impelled from it at one spot—the center of the tube. (2) At this center was placed a target, or anode—its face lying directly in the stream of electrons. (3) This target was set at an angle to direct the shower of x-rays generated on its face toward one side of the tube. (4) The glass envelope of the tube consisted of a fairly large globular or ovoid discharge chamber, at either end of which were tubular extensions through which the leads to anode and cathode entered. It was exhausted to a degree of vacuum optimum for the creation of an electron stream from cathode to anode when these were connected in a circuit of unidirectional current of relatively high voltage.

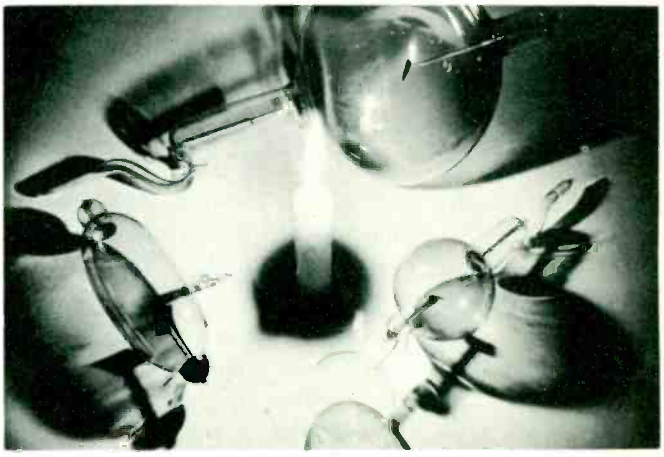
These elements are still basic to the typical fixed-anode x-ray tube.

The Jackson type of tube, however, like all early x-ray tubes, was different from modern tubes in that its vacuum, so called at the time, was filled with a rarefied gas, chosen for its capacity to ionize under readily attainable conditions.

The "gas" tube, standard in one form or another until about 1913, required unidirectional current of relatively high voltage but at first of quite low value. In the early days this was supplied from a static machine, supplying some 1 to 5 milliamperes at 25,000 to 200,000 volts.

With this current supply the gas tube—especially in its early days—was relatively cool in operation. So the cathode face was of aluminum mounted on a light stem, while the target or anode face was a thin plate of platinum similarly mounted on a stem. Neither face had to be heavy, nor did the stems need to be larger than necessary for conduction of current.

For all its relative coolness, however, the gas tube tended to generate sufficient heat so that the metals of the electrodes combined with and absorbed some of the gas in the tube so as to increase or "harden" the vacuum and thus to impair the efficiency of the tube. When this happened it was necessary to release minute amounts of gas in the tube, to restore an optimum gas pressure. This was accomplished by a "regulator," usually housed in a small, hornlike projection from the tube. In this hollow recess was a small amount of any suitable substance which when heated would release a little gas into the tube and thus restore the gas pressure to its proper level. Heat could be applied to the regulator externally (as by a match) or by the passage of an electric current through the gas-releasing substance. As

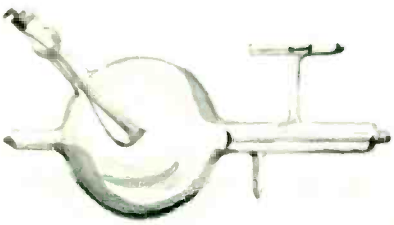


Early Machlett tubes—of the Jackson type. The anode is directly in line with the cathode and bears a target set to receive the full stream of electrons and angled to direct the shower of x-rays to one side. Other protuberances from the tube are incidental to creating or maintaining a vacuum.

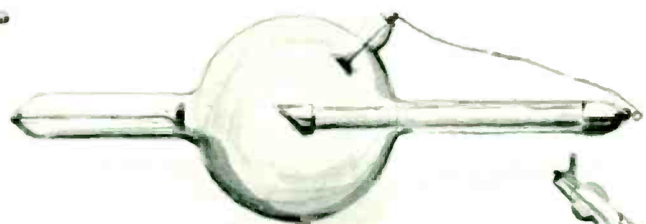
the design of gas tubes evolved, numerous devices were developed to pass such a current automatically whenever the absorption or loss of gas in the tube exceeded a certain point. These, in many forms, can be seen in pictures of any typical gas tube. And these also were the forerunner of the hydrogen reservoirs so essential to modern hydrogen thyratron tubes.

With the rapid progress of radiology even in the very first years, as the medical profession recognized and sought to develop its possibilities, there came a demand for more adequate and reliable current supply than the static machine would provide. This need was filled by induction coils of the Ruhmkorff type. These would produce a largely—but not completely—unidirectional current of higher intensity than that of the static machine. To use such a current it became necessary to strengthen the x-ray tube in certain respects. And to use it to best advantage another type of tube had to be brought into the circuit. Machlett was among the pioneers in both measures. And since both are important in the x-ray field today, it is worth noting the early stages by which they were begun:

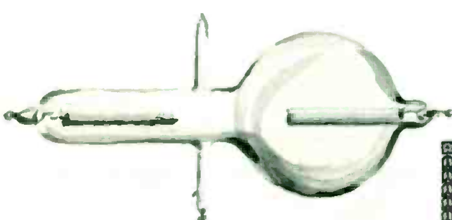
Higher current density meant greater heat in the tube, and particularly on the target face of the anode. This required not only a heavier anode, but means of conducting heat away from it faster than could be provided by the original thin stem on which it was mounted. As early as 1901 Machlett devised and placed on the market a tube with the first liquid cooled anode —in this case water cooled. Not long afterward he offered, first in German importation than in Machlett-made tubes, a heavy copper anode, on the slanting face of which the platinum target was bounded by a drawing process. Both liquid cooling and heavy copper anodes are essential features in some of today's high-powered x-ray tubes.



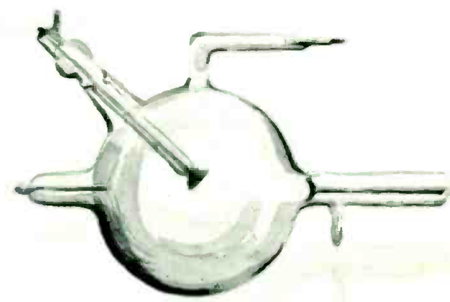
FIRST WATER COOLED X-RAY TUBE



HEAVY COPPER ANODE X-RAY TUBE



EARLY VALVE TUBE



WATER COOLED HEAVY ANODE TUBE

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Special Cancer Treatment Tubes,
Violet Ray Tubes.

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LIST VII, FEB. 1907.

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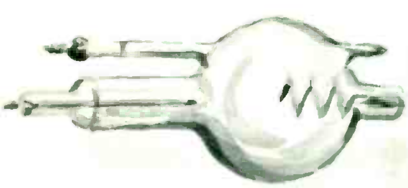
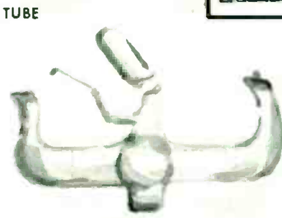
Price List of Standard X-Ray Tubes

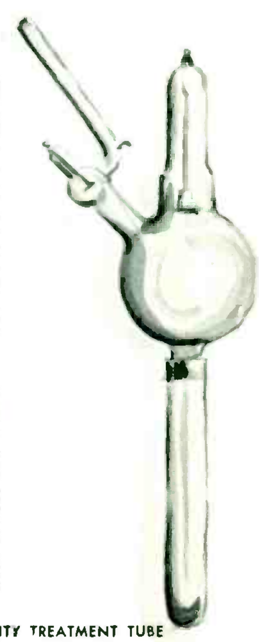
NEW SERIES



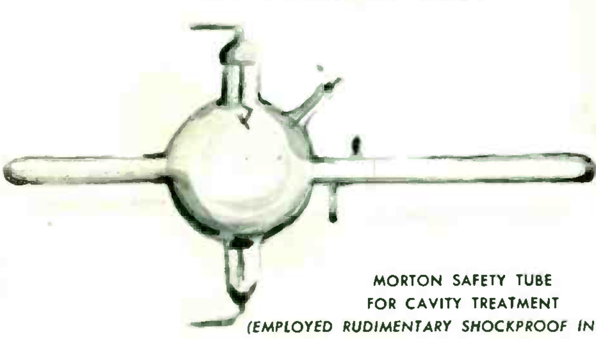
IMPROVED VALVE TUBE



CORNELL PROTECTION X-RAY TUBE

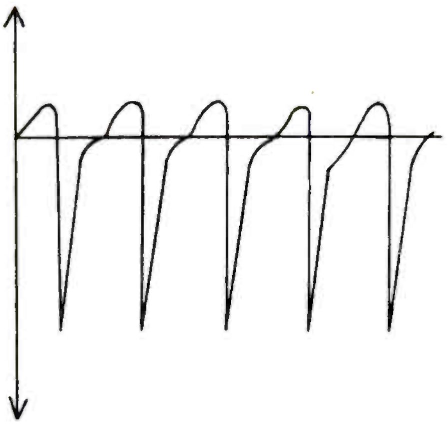


CALDWELL WATER JACKET CAVITY TREATMENT TUBE

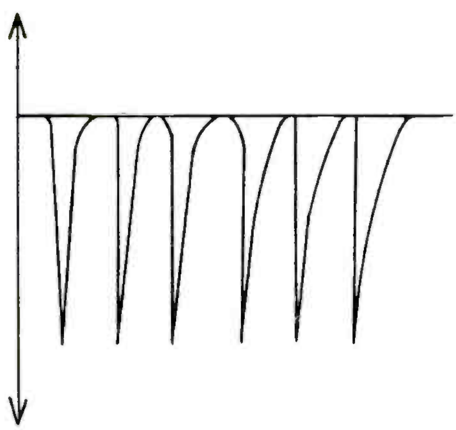


MORTON SAFETY TUBE
FOR CAVITY TREATMENT
(EMPLOYED RUDIMENTARY SHOCKPROOF INSULATION)

Examples of x-ray and valve tubes of the type manufactured by E. Machlett and Sons in the early 1900's.



The current produced by the Ruhmkorff coil.



Effect of valve tubes on Ruhmkorff coil current.

Because of the peculiar characteristics of Ruhmkorff coils, Machlett developed and produced an accessory type of tube the descendants of which were to prove important in Machlett history and to be important today. This was the valve or rectifier tube. The Ruhmkorff coil produced an electric current of the pattern shown at left: strong negative impulses on the "break" cycle, which were essential to x-ray production, followed by weak, positive impulses on the "make" cycle. These so-called "inverse current" impulses were not only useless to the x-ray function of the tube, but tended to impair the x-ray picture and also to shorten the life of the tube. Tube makers, including Machlett, were able to reduce but not altogether to eliminate this inverse current by the use of an external resistance such as spark gap or a resistance wire, built into the tube. To get true unidirectional current, it had to be rectified before reaching the tube.

For this purpose, Machlett made a valve tube, at least as early as 1903, to use in the circuit of an x-ray tube; and eventually made a considerable line of tubes for this purpose.

These valve tubes were simple and crude, but were adequate to suppress the relatively weak inverse impulses that were a feature of Ruhmkorff coil current. So they substantially improved the application of Ruhmkorff coils to x-ray tubes.

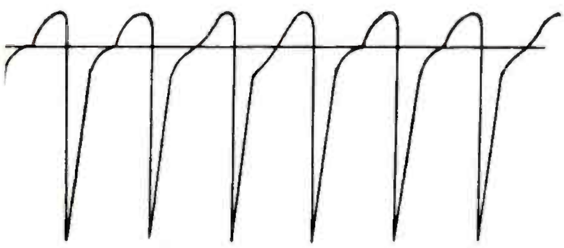
Naturally, the making of tubes to satisfy the increasingly exacting requirements of radiologists called for improved manufacturing equipment, which Machlett was able to install with the increase of his business: notably a power-actuated mercury-fall pump which Machlett himself developed. But then, as now, the quality of tubes derived even more from skill and conscience in manufacture than from mechanical equipment.

The blowing of glass for tubes was an art—and still is. X-ray tubes had to be large, to provide a big vacuum space not liable to quick deterioration; a typical tube would be some 70 cm. or 27½ inches long, with a globular evacuated chamber nearly 12 inches in diameter. The glass had to be strong, of course, to withstand atmospheric pressure, but it also had to be thin to transmit x-rays with a minimum of absorption. "Not over 1/60 inch thick" was a common specification. To make tubes of this size and delicacy; to make them uniform in thickness and geometrically accurate; to position cathode and anode in them with exactness—and to do it all by early hand methods—took skill of the very highest order.

More, it took a vast deal of experienced judgment to determine the correct degree of vacuum in the tube as it was exhausted and finally sealed. This critical responsibility Robert Machlett took on himself. In the final pumping-and-sealing process, the tube was exhausted under both externally applied heat and the heat generated by operating the tube —which of course produced x-rays throughout the process.

As Dr. Percy Brown put it in "American Martyrs to Science," this entailed "careful scrutiny for hours on end, by means of the hand fluoroscope, of the progress of exhaustion of the x-ray tube within its oven. A tedious process . . . having as its sole requital the expert's satisfaction in the knowledge of mechanical work well done."

Perhaps not the sole requital. From very early, Robert Machlett had the enthusiastic applause of radiologists. His mail abounded in enthusiastic letters from medical men who were already becoming famous as pioneers in the use of x-rays for diagnosis, therapy or research. Typically: "With one of your water-cooling tubes I succeeded yesterday in locating kidney stones in a patient weighing 145 pounds. Today I made a picture of a



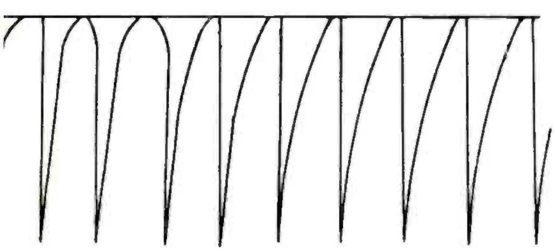
man weighing 187 pounds, in 15 seconds. I made two pictures, one in 30 seconds, the other in 15, and the 15 was the better."

Horseless-buggy performance by today's standards, but in those days something to be reported jubilantly to the maker—and to other radiologists.

Of these, many came to Machlett for tubes of special design, to achieve this or that effect, or to embody their own particular theories. In several instances Machlett made quantities of tubes to the design of one or another specialist. For example, from 1902 he made all the x-ray tubes for Dr. Caldwell and many other tubes for other pioneers in radiology. These included such figures as Drs. Cole (advocate of the very large discharge chamber) and Besser, designer of a high-frequency x-ray tube for close application in therapy.

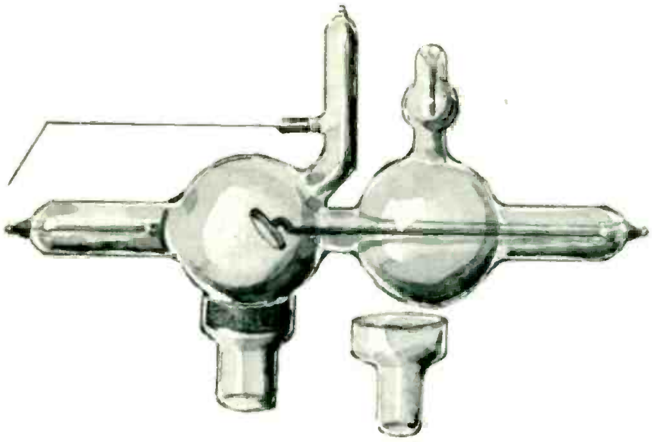
Science was then unaware of the dangers of continued exposure to radiation in small dosages. Machlett was accustomed to exposure not only in the course of making tubes, but in selling them: whenever a professional caller appeared, he would delightedly demonstrate the quality of his tubes by placing a hand behind the fluoroscope screen. True, as early as 1906 he noticed the evidence of multiple hyperkeratosis on the back of his left hand, but he thought so little of it that he pared off the corn-like growths with a sharp knife.

Yet if Machlett, like others of his time, was unaware of the creeping dangers of small exposures, he and everyone else was keenly alive to the danger of severe damage to tissue from exposure in the actual practice of radiology or radiotherapy. Therapy, in fact, had originated in early radiologists' observation of the damaging effect of x-rays on skin and hair; if they would kill useful tissues, would they not by the same token destroy harmful growths? By the turn of the century physicians all over the world were seeking to achieve such results, under control, for beneficent purposes. The tubes they used at first were ordinary Jackson type focus tubes, fitted with special metal screens to exclude x-rays from all but the areas under treatment, and thus to protect patient and operator.



Very shortly, however, leaders in the new field of radiotherapy began suggesting types of tube specially designed for their purpose. They wanted: (1) A tube giving x-rays of an intensity especially adapted to the work of their specialty. (2) A tube with adequate protection against scattered radiation, yet without the bulky shielding that often prevented placing it in effective position for localized therapy. Existing tubes were either dangerous or cumbersome, or both, and many, into the bargain, required the operator to wear lead-lined gloves for safety.

Among the early devisers of tubes to avoid these handicaps was Dr. H. G. Piffard of New York, who in 1904 designed a "safety" tube which, as he later described it (N. Y. Med. Jour. and Phila. Med. Jour. 7/15/05) "should be made from dense flint (lead) glass, opaque to the rays but with a small window of crown glass of low refractive index, through which the rays might emerge. To this end I ordered from an English maker a tube with a six-inch bulb of dense glass, with a one-inch window of transparent glass, the tube to be furnished with a palladium regulator. . . . In reply I was informed that a six-inch bulb was impracticable but that he could furnish one of four inches diameter with a supplementary bulb of the same diameter . . . to aid in steadying the vacuum and in a measure retard the heating of the active bulb . . . In due time [the tube] arrived. A few days later Machlett, a tube maker of this city, having heard of but not seen my tube, brought me one constructed on similar lines." Dr. Piffard's article then goes on to tell in some detail how far



The Piffard tube as Machlett manufactured it for many years. An illustration from the Machlett catalog of 1907.

superior the American-made tube turned out to be—in sturdiness, convenience, ease of handling and—above all—in performance: "A steady radiation with good fluoroscopic definition and no undue heating." These were results which the other tube, for a variety of reasons, including a misfit regulator, would not produce.

The profession immediately gave the Piffard tube the recognition it deserved, and for many years Machlett manufactured and marketed it by arrangement with its inventor. In the tube as it was actually made there was one feature contributed by Machlett, initially to the surprise of Dr. Piffard: the changeable cup shown at the bottom of the catalog illustration. By this means either a large or a small final window could be used at will. According to Frank Farrelly, a Machlett employee at the time and later President of The Green & Bauer X-Ray Tube Company, Robert Machlett added this feature on his own to the pilot model of the Piffard tube. Dr. Piffard, a lanky individual of great vigor in oral expression, blew his top (as the lay expression goes) on seeing what Machlett had done. But Dr. Harry Waite, who happened to be in the office, counseled moderation, pointing out advantages which Dr. Piffard, on calming down, accepted gladly—to the profit of all concerned.

Other safety tubes of ray-proof glass with ray-transparent windows included the famous Cornell Treatment tube, invented by Dr. Alfred C. Geyser and named for the Cornell Clinic where it was introduced. There were also numerous tubes for cavity treatment bearing the names, well known in x-ray history, of Drs. Morton, Cleaves, Tousey and Caldwell.

Concurrent with all this development of x-ray and associated tubes, Machlett was carrying on another kind of work.

THIS was the production of special order scientific apparatus, either as single pieces for researchers and experimenters, or in quantity for educational institutions or practitioners of applied science. On numerous occasions in the early 1900's Machlett made up experimental tubes for Lee DeForest, inventor (1906) of the audion, the first successful three-element electron tube for the amplification of feeble electric currents—the prototype of all radio tubes today. Published drawings of DeForest's original audion show that at the start he worked with a globular form of tube with extensions at either end for leads to grid, plate and filament. This, of course, was a shape of tube for which one would naturally go to an x-ray tube maker such as Machlett. Moreover, Machlett's work for Hewitt had touched incidentally on problems closely allied to those which interested DeForest.

The original DeForest audion tube, forerunner of today's radio tubes. Machlett made experimental tubes of this general type and shape for DeForest. *(Adapted from Encyclopedia Britannica illustration.)*

However much or (very possibly) however little Machlett may have contributed to DeForest's work, early acquaintance with this type of tube and with the problems involved in making it contributed a good deal to Machlett, by adding to the considerable amount he was learning in general about vacuum tubes for the various uses we now call electronic.

We have noted his earlier production of a two-element valve tube. Though he never, during his lifetime, ventured farther into the radio electron tube field, he appears to have picked up a fair working knowledge of it which he passed on to the son who eventually succeeded him at the head of the Machlett business.

Other scientific apparatus with which Machlett was concerned during this period included: mercury vacuum pumps of an improved type devised by Prof. Boltwood of Yale and made for the inventor; Van Slyke apparatus for the analysis of blood, made for its inventor, of the Rockefeller Institute; the Riva Rocci sphygmomanometer, the now familiar, but for many years unappreciated device used by physicians for taking blood pressure. These and a number of other products were produced in quantity and in many cases sold by Machlett as manufacturing agent for their inventors.

Indeed, in one type of electro-therapeutic device Machlett built what eventually became a fairly large business. This was the so-called "electrode"—in reality a gas discharge tube, similar in principle to the Geissler tube, which emitted light rays toward the violet or shorter end of the spectrum, a gentle heat and, in some forms, mild electrical discharges agreeable to the patient. Modern medical opinion holds that such treatment electrodes were at best of debatable value, but for some years they were made in a great variety of shapes for direct contact in external or cavity application, and with electrical characteristics varying according to the theories of their designers. These included many distinguished practitioners of the era. Machlett made electrodes from about 1901 to the designs of (and often bearing the name of) Drs. Snow, Sauer, Mount Bleyer, Titus, Wappler and others.

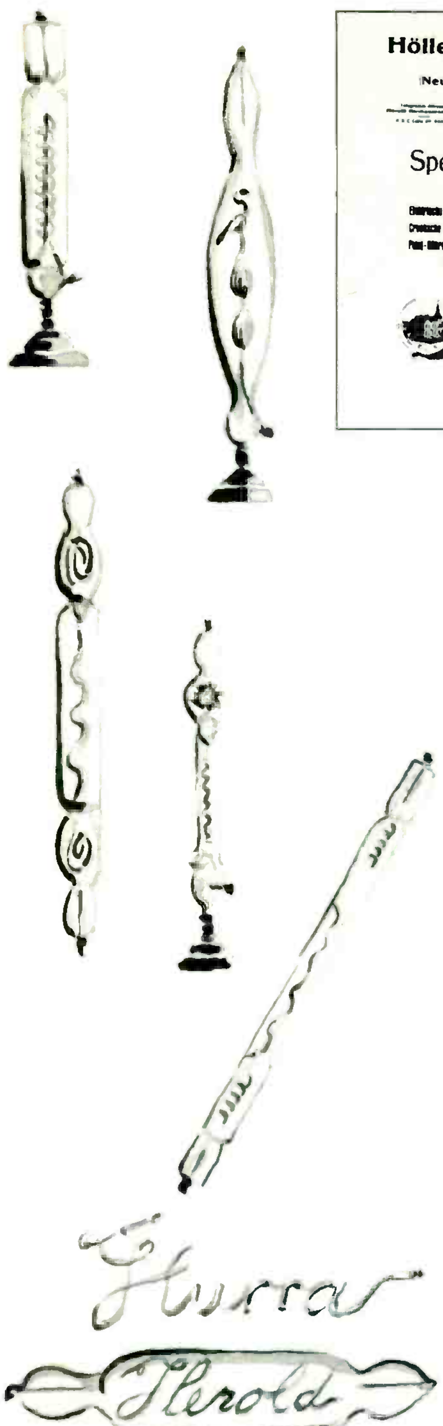
Machlett also built up a fair import business. Of this the mainstay was, of course, German x-ray tubes and x-ray accessories. From 1904 on he went abroad at least every other year, to buy in the German market and to keep touch with German scientific developments. Here he found himself—somewhat to his surprise—an increasingly well-known world figure in radiology. He was taken to meet Roentgen, and at another time introduced to Mme. Curie.

One other item he imported was a small one—a scientific curiosity—a toy, almost. Yet because it fascinated him it had a considerable indirect bearing on his business and on the career of his son.

This was the Geissler tube—a small discharge tube filled with one or another kind of gas which would glow with the passage of electricity between electrodes in either end. The color of the glow depended on the gas used, and the light it emitted was hardly bright enough to be worth much as illumination. But German glassblowers used to amuse themselves and please a mildly fascinated public by making up the Geissler tube in a great variety of fantastically contorted shapes for exhibit in show windows, or for classroom demonstrations.

It is altogether probable that Machlett's interest in the Geissler tube played its part in the development of the Cooper-Hewitt mercury vapor lamp—a discharge tube filled with a different kind of gas and intended for a severely practical purpose. At any rate, Robert Machlett spent a good deal of spare time experimenting with Geissler tubes on his own. And the knowledge of the discharge tube that he thus developed was destined in turn to lead his son up a weird byroad in the field of tube-making.

In the background of all this, Machlett carried on a bread-and-butter production of numerous glass items that could be produced in quantity. These included at one time or another: parts for a type of electric current meter extensively used in the early 1900's, gauge glasses, pipettes,

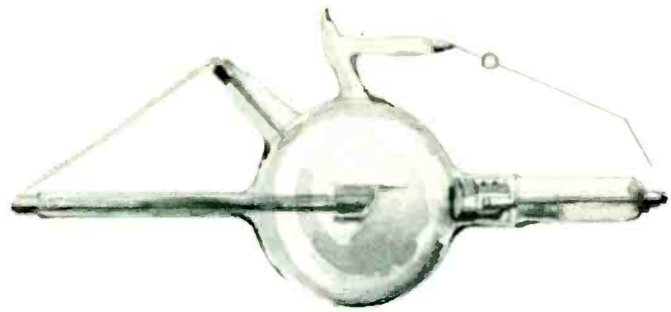


Geissler type tubes from a turn-of-the-century German catalog. These, which glowed with a faint light when electrified, were regarded as scientific curiosities, and were put in show windows as eye-catchers. But apparently some people saw in them a commercial application. Note the final two figures—forerunners, as they turned out, of today's neon advertising signs.

centrifuge tubes, ozone apparatus, vacuum bottle parts, lightning arresters and mercury switches—the latter in an improved, gas-filled design originated by Machlett but never fully exploited by him. He was not much of a promoter.

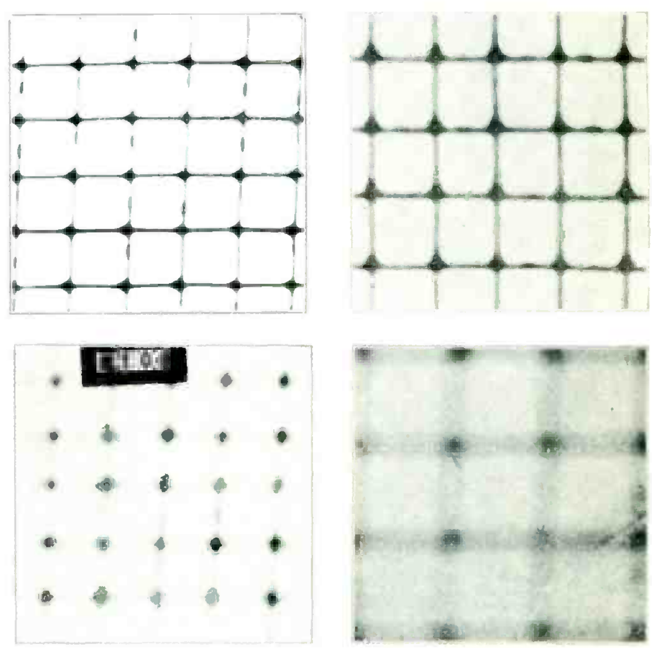
The business, however, grew on its own merits. Machlett rented all the rest of the second floor of the East 23rd Street building, then more upstairs, with an overflow, presently, into adjoining property. And still there was not enough room for his staff of some thirty people, with their equipment and supplies, and for the necessary office and demonstration-room space. In October 1912 he bought a building of his own at 153 East 84th Street—in the Yorktown district of New York, the heart of the comfortable, sociable German district from which so many of his best employees came. It was a homely enough building—an ex-residence with the thunder-and-lightning wallpaper of its earlier occupants still on the walls of some of the workrooms. But it afforded the space needed to make a tube of the type Machlett had now brought to a fine point of development.

This was the so-called Bellevue interrupterless transformer tube. Its origins went back to 1908.



The Bellevue tube for interrupterless transformer current in the form made by Machlett from about 1912—the small spear-point projecting from the face of the anode produced, in some degree, the effect of a valve or rectifier, to suppress some of the inverse impulses necessarily inherent in the alternating current then necessary to produce high voltages in x-ray equipment.

BY 1912 radiologists were demanding still higher voltages and currents than those Ruhmkorff coils provided. These could not then be produced in a unidirectional current by apparatus practicable for use in x-ray installations. Early valve tubes, while adequate for rectifying the slight inverse impulses of the coils, were not up to rectifying a strong alternating current. The only answer was to accept a current, alternating if need be, in the tube itself. An alternating current of sufficient voltage could be produced by the so-called interrupterless transformer—a piece of equipment that could be installed in any radiologist's office. To use this current, x-ray tubes had to be redesigned—with greater ruggedness and heat conductivity to handle higher amperages, and with features to minimize the effect of the alternating inverse impulses on the tube and on the x-ray picture.



Machlett's screen test. The image of a half-inch square of wire screen, 8 inches above the plate and 16 inches below the tube, demonstrated (upper two views) the sharp image produced by the Bellevue tube, as compared with the fuzzy images produced by tubes with more widely diffused target spots.

Machlett's answer to this problem was first worked out about 1912—an anode with a tungsten target (to withstand high temperatures) and with another unusual feature: a sort of spearhead point. This tended to inhibit electron flow during one cycle and increase it during the other. In effect, it was somewhat like a valve within the x-ray tube itself. An imperfect one, to be sure, but the net effect of a higher current through the tube, plus a smaller focal spot on the anode (controlled by better focussing) was to produce sharper negatives in a considerably shorter exposure time.

Indeed, so small and brilliant was the focal spot on the target that negatives made with the Bellevue tube displayed a sharpness of detail hitherto unrealized in radiography. Definition was so clear that Machlett devised (and proudly publicized) a new demonstration to show it—the later widely used screen test for fine detail.

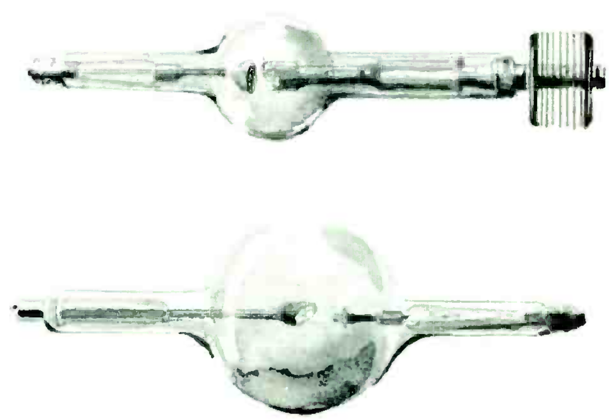
There were other and perhaps more promising developments of these days. For example, the "Hydrex" tube, in which the gas, its rarefication controlled at will, was hydrogen. It was set, for use, in a "safety" bowl of lead glass.

The Machlett "Hydrex" tube, an innovation that had the misfortune to meet the far superior Coolidge tube.

But whether that, or numerous other Machlett variations of the gas tube and its parts, would have led to any great changes in the x-ray tube will never be known. For in 1913 there appeared another type of tube, so formidably different and (in most ways) so much more efficient than the gas tube, that it immediately began to displace tubes of that type and—in the shape of its numerous descendants today—has supplanted them, to all intents and purposes.

Dr. William A. Coolidge, who had left the faculty of Massachusetts Institute of Technology in 1905 to do research work for the General Electric Co. in its Schenectady laboratories, had in 1910 succeeded in making ductile filaments of the very difficult metal, tungsten. This proved the key to making a type of tungsten lamp, introduced in 1911, which is basic in incandescent lamps today. Coolidge thereupon turned his attention to other applications of ductile tungsten, including an x-ray tube brought out in 1913.

In this the cathode was a tungsten filament. The tube, instead of being filled with a rarefied gas, was almost completely evacuated of air. A high voltage (100,000V) potential, applied between anode and cathode, shot streams of electrons out of the tungsten cathode toward the anode. The basic difference between this and the gas tube has been summarized like this: "In the gas filled tube, electrons were liberated from the cold cathode by positive ion bombardment. In the modern type of high vacuum tube, electrons are 'boiled' out of a hot filament cathode. By the use of high vacuum, instability of the tube due to ionization was overcome."



Coolidge tubes handled by Machlett as distributor about the time of World War I. Upper, a diagnostic tube "recommended for fluoroscopy and radiography only. It should never be used for therapy." Lower, "For treatment and general picture work."

The Coolidge tube, since its massive tungsten anode could stand intense heat, was capable of being operated at higher voltage and current than the gas tube. But even more important, it was comparatively very simple to operate, since it did not depend upon a nicely adjusted and maintained rarefication of gas; as long as its high vacuum lasted it would operate satisfactorily.

The Coolidge tube had the added advantage of appearing at about the same time as mechanically operated rectifiers which could transform a high tension alternating current into high tension unidirectional current. (Somewhat later, valve or rectifier tubes were improved to stand this rigorous application.)

The advent of the Coolidge tube did not at once put the gas tube out of business. It takes time for any innovation to take hold. Innumerable x-ray laboratories were equipped with gas tubes, and professional men were accustomed to using them. Many great institutions, such as the Mayo Clinic in Rochester, Minn., had extensive equipment built around Machlett gas tubes, which they replaced only gradually. And although the recognizably greater power, penetration, speed and simplicity of the Coolidge tube were undoubted advantages, many radiological authorities held that for certain uses the gas tube was superior.

During World War I Machlett supplied x-ray tubes at the rate of 2,000 to 3,000 a year, first to the Entente powers in Europe, later to the U. S. armed forces. (During the same war, the company also made large numbers of glass tubular parts for gunsights, and of blood pipettes for the Army Medical Corps.)

With the war's end, however, the Machlett enterprise came upon a period of gradually dwindling prosperity. The Coolidge tube was getting preference for new installations. And since it was controlled under patents assigned to the General Electric Co. there was little other manufacturers like Machlett could do except to handle it—which they did—in the capacity of distributors, and to continue servicing existing installations of gas tubes. (This, incidentally, continued for years, so many were the users of gas tubes and so great their liking for the older type of tube. In fact, as recently as 1940, the 14th Edition of the *Encyclopaedia Britannica*, in an article by Dr. E. V. Pullin—probably written in the mid-1930's—stated that for certain purposes "gas tubes are still in use and have many advantages.")

Robert Herman Machlett

But it was not a competing type of product which slowed Machlett's progress. Robert Machlett was a slowly dying man. The lesions on his hands which had first appeared in 1906 had defied all treatment: minor excisions, fulguration, the application of radium to a particularly persistent area on the middle finger of his left hand. . . . True to the history of radium treatment in radiation lesions of the skin, this area became ulcerative, and gave so much pain that by 1923 the finger had to be amputated. Microscopical examination showed that the process was already malignant.

With his health broken and his vitality gone, with pain his constant companion and unescapable doom his only certainty, Machlett continued cheerful and strangely hopeful. He could give little enough attention to the active management of his business; this he began to turn over to the son who had just come of age. But he could give thought to its future. And for that future he had an idea.

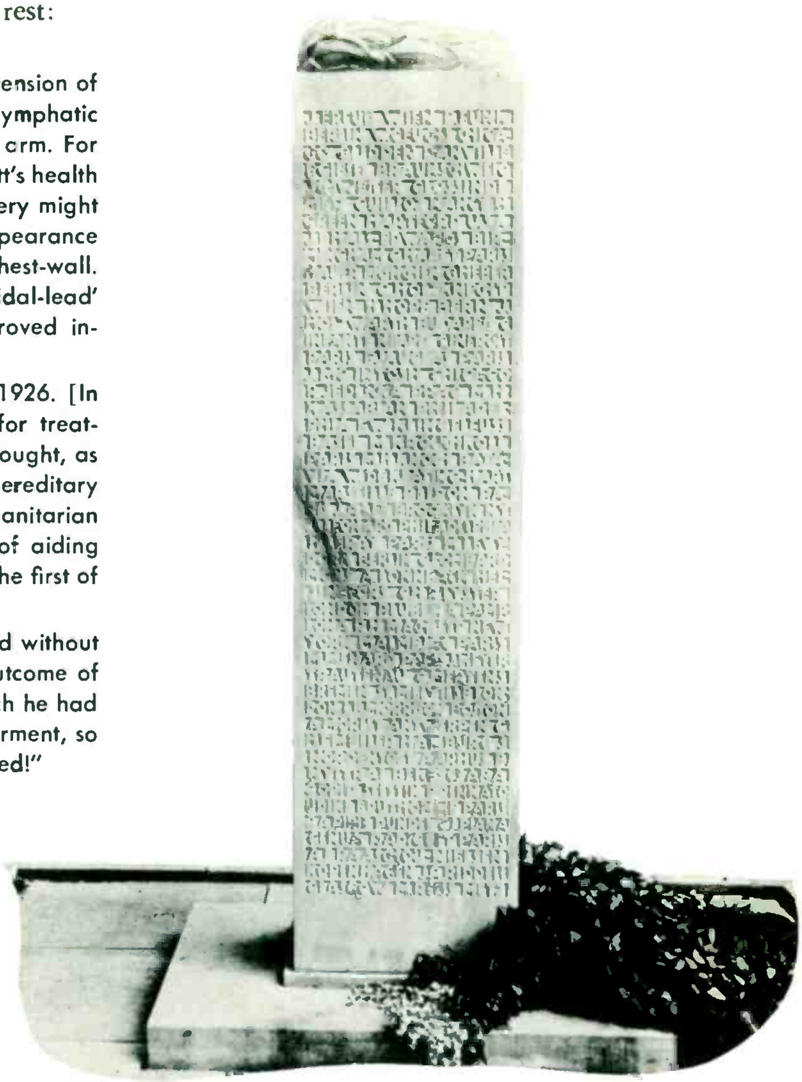
In the Geissler tube, which had so intrigued him from the early days, he saw untold possibilities. If its cool, gentle light could be increased to brilliance, it might become a rival, for illumination, of the incandescent lamp. Again—or perhaps alternatively—the fact that it could be shaped into script or other letters, as the Germans had long ago shown, suggested unlimited possibilities of commercial use.

The working force at E. Machlett & Son in the early 1900's.

He had a hobby-time workshop in his home. And in this, as his days drew in on him, he spent increasing time, experimenting with the little tube that gave so baffling a light.

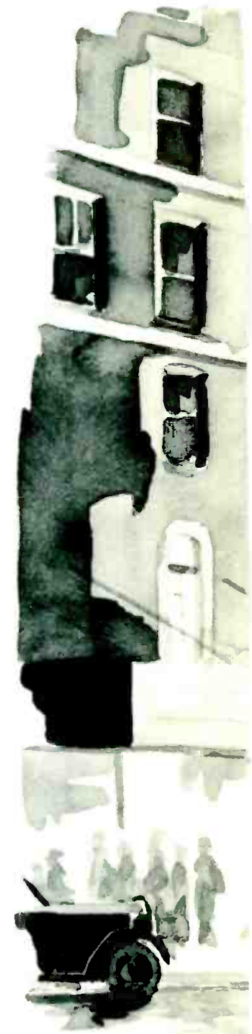
Time was already too short in 1923. Let Percy Brown, in the words of the book already cited, tell the rest:

> "It was during the following year that an extension of the condition was found to occupy the lymphatic glands about the elbow and in the upper arm. For some time after the removal of these Machlett's health improved, but in 1926 the hope that recovery might be thus indicated was destroyed by the reappearance of metastasis in the axilla and also in the chest-wall. In the further search for relief, the 'colloidal-lead' treatment for carcinoma was tried but proved ineffective.
>
> "Robert Machlett died on the first of June, 1926. [In Liverpool, England, where he had gone for treatment.] To the scene of his life's work he brought, as a simple immigrant, a natural talent and hereditary skill. With this endowment and through humanitarian impulse he fashioned an effective means of aiding mankind in the hour of distress and need—the first of his great gifts to the cause of Humanity.
>
> "The second was the gift of life itself, offered without hesitation when it seemed the inevitable outcome of his fruitbearing labors in the pursuit of which he had been disdainful of physical hindrance or torment, so his visions were realized and his aim attained!"



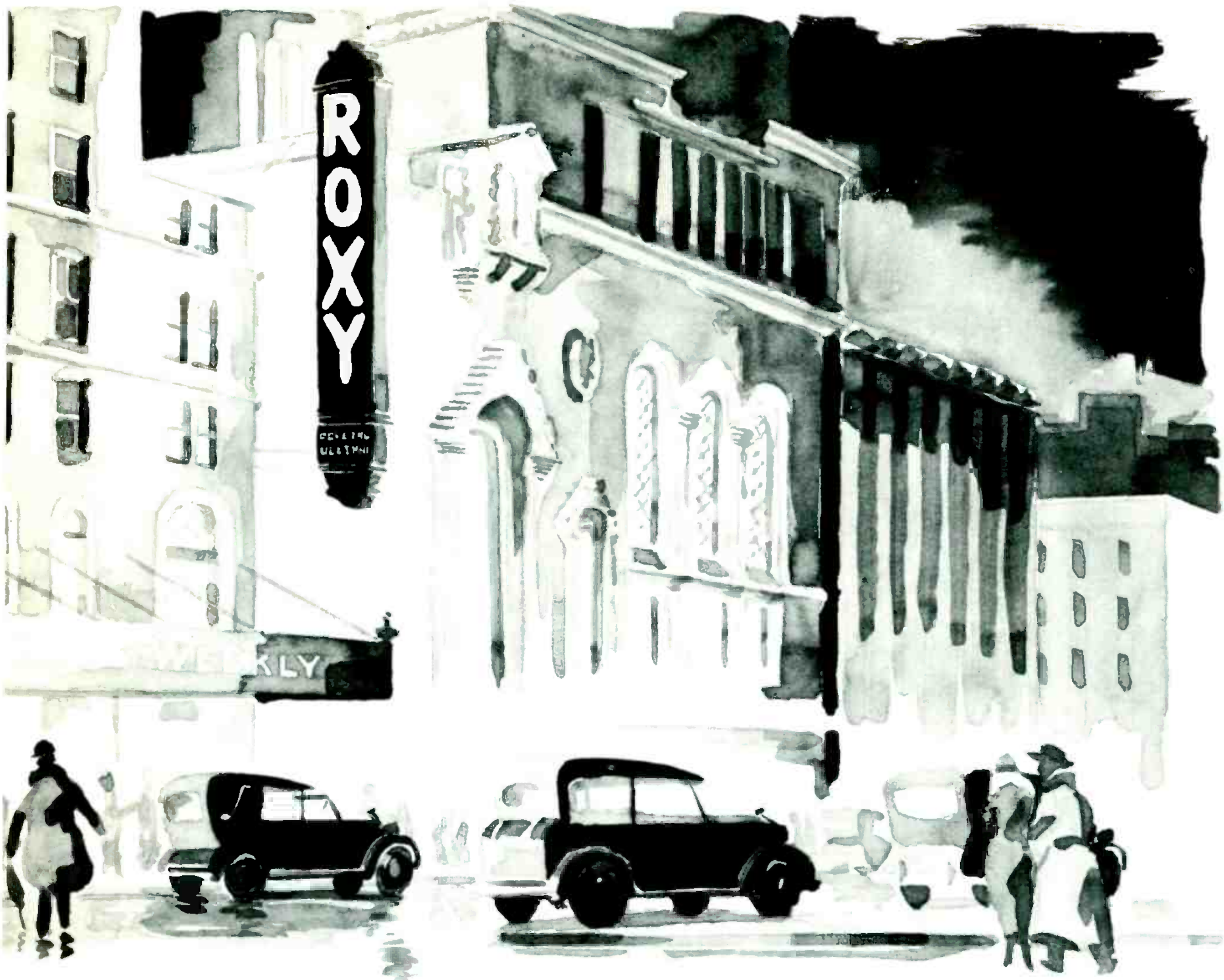
In the lovingly gardened grounds of the Roentgen Institute, at St. George's Hospital, in Hamburg, Germany, there stands a tall, austerely simple, yet movingly eloquent shaft of marble, with a sculptured laurel wreath at its top. Upon the sides of this stone are carved the names and dwelling places of certain men. A hundred and sixty of them there are, from Berne and Berlin and Boston and Brandenburg and Batavia and Basel and Brooklyn . . . from Geneva and Glasgow, from Helsinfors and Hartford . . . wherever men, pushing into the unknown in pursuit of the strange rays they knew could aid mankind, found knowledge—and died for it. Midway down one side, and needing no epitaph more eloquent than inclusion in such company, is the name, "R. H. Machlett, New York."

The Find at the Foot of the Rainbow



ZITZMANN, the only surviving veteran of the early Machlett days, remembers how the shop had always a family air about it. Robert Machlett's sister worked there for a time. His wife, Paula, was a cheerful foster-mother to the shopful of glassblowers and other artisans (she dedicated their first annealing oven by roasting a goose in it for a shop celebration). And very often a man would look up from his work to see, at about the level of his bench top, a pair of direct blue eyes gazing out from under a thatch of blond hair. These belonged to a small boy, of whom all the rest was invisible, below bench-height.

This was Machlett's son Raymond Robert, "a chunky, husky little feller," not even as old as the young business, for he had been born July 31, 1900. He would better have been at Horace Mann School where he belonged, according to his father, who had no intention of making the boy an apprentice glassblower. He was to head for college, and no nonsense. Even in short pants, however, Ray Machlett was inclined to feel that school was something a fellow with strength of character should be able to take or leave alone. He was very good at the structural, scientific or mathematical things that interested him and challenged his curiosity, which was widespread and insatiable. He excelled at drawing, too, and showed a very promising talent for music. But as to the rest of the curriculum, he would as soon be at home experimenting with what was then the absorbing scientific interest of science-minded boys: wireless telegraphy.



He must have been fairly good at this, as well as adequately backed with equipment by his father, for at 14 he was operating a self-assembled set which he later described (in an application for World War I Naval Training) as a "1 KW synchronous set, audion regenerative receiver." Receiving, of course, in that era meant receiving Morse code, at which he could eventually take 28 words per minute—a highly respectable rate.

He got into Naval Training—at 18—in the Princeton radio unit, just about in time to be let out again with the Armistice. Thereafter he entered Cornell's Engineering School, a little behind his class of 1922. Here, as at Horace Mann, he was tremendously absorbed by scientific subjects—particularly physics. This fired his enthusiasm so hotly that he transferred to the academic branch, cheerfully sacrificing his engineering credits, though it cost him his chance for a degree with his class. And, as it happened, for any degree at all, for by the end of spring 1922 his father's disability had become so great that the boy had to go at once into the Machlett business, preparing to take over its active management.

Their pressing problem was to develop a new product to supplement the gas x-ray tube as the firm's mainstay. For a time it seemed they had found this in an electron tube for use as a detector in receiving sets. This was the invention of Dr. Lilienfeld, a German scientist prominent in x-ray tube design who had recently come to the United States and had collaborated with Robert Machlett in the design of a series of high frequency electrode tubes. The new radio tube was christened the

Deflex, and a subsidiary company was organized to manufacture it in the East 84th Street plant. But after a brief flurry of acceptance, in 1923 the Deflex subsided—already outmoded by other tubes.

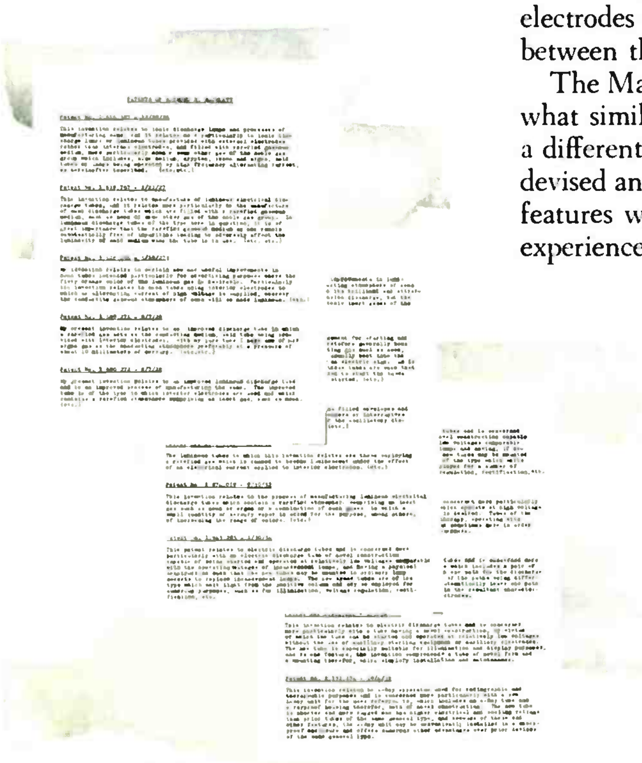
Raymond R. Machlett—1922

Ray Machlett turned then to the project of a luminous discharge tube of the gas-filled type which had so challenged his father. He was 23 now, an intense, energetic young man, compact and muscular, his once-blond hair darkening toward a deep brown. From the Deflex tube experience he had learned a lot about the setting up of a new business and the promotion of a new product, and he was fired with the idea of a great enterprise that might be developed out of a really efficient version of the old Geissler tube.

He had at the time a very special incentive toward this, in the person of Alice Titchener, daughter of Cornell's famous Professor of Psychology, to whom he had become engaged. They planned to be married—and were—in the fall of 1924.

The basic idea of a luminous discharge tube was, of course, nothing new. Geissler had shown how a tube filled with a partially rarefied gaseous medium, such as neon, krypton, helium, xenon or argon, would glow in various colors, upon passage of a high frequency alternating current between electrodes at the ends of the tube. The only difficulties were practical ones of brightness, steadiness, tube life and so on. . . . Others, of course, had worked on these problems: Ramsey and Morris in England, Moore and Hewitt in the United States. A neon light had celebrated Queen Victoria's Diamond Jubilee; Hewitt's mercury vapor lamp (in the development of which Robert Machlett had collaborated) dated from shortly afterward. The Claude patents dated from 1915. But except for Hewitt's highly specialized light, no luminous discharge tube had proved practical for manufacture in quantity.

A few of the patents granted to Ray Machlett as a result of his work with luminous discharge tubes.



Ray Machlett attacked the problem with his father's experience and advice, literally from both ends and the middle: the design of efficient electrodes and the process for producing a rarefied gas of sufficient purity, between them.

The Machlett firm had had long experience in the making of the somewhat similar electro-therapeutic discharge tubes known as electrodes, in a different and less precise sense of the word. Out of this, father and son devised an effective luminous discharge tube, of which the distinguishing features were different and improved electrodes. Out of an even longer experience with processes for producing tubes filled with rarefied gases free from impurities, they devised methods of making luminous tubes that were highly brilliant, and remained so for long periods of useful life. Applying for patents on these* they began to manufacture them in the East 84th Street plant.

The new, brilliantly luminous tube (christened Rainbow on account of the variety of colors in which it could be produced) was an immediate success in the form of signs for store-fronts, store windows and—presently—outdoor advertising. They set up a separate company to make it—Rainbow Light, Inc.—with Raymond Machlett as president.

Immediately they found they needed far more room

* Granted to Raymond R. Machlett in Dec. 1926 and Feb. 1927 and followed by a dozen other patents in the same field over the next six or seven years.

for this new offshoot than the 84th Street plant would afford. For one thing, they needed space for laying out and bending tubes and assembling them into advertising signs. For another, they needed quite a lot of such space, because they began getting considerable numbers of orders. So they took quarters for the new company on 44th Road, Long Island City. This was in late 1925. And because the elder Machlett was by this time almost totally unable to give personal attention to the older concern, they moved it, too, to Long Island City. In new quarters there, a block or two away from the Rainbow business, Ray Machlett could oversee the operations still being carried on by an experienced and loyal staff.

The firm of E. Machlett & Son was there when Robert Machlett left, in the spring of 1926, on the voyage to England for treatment, from which he never returned. And there it remained until 1931, carrying on a modest and very necessary business in the repair, service and (more and more rarely as the years went by) manufacture of gas x-ray tubes. Its other business dwindled, too; treatment electrodes went out of fashion; there were no other products to take their place; Ray Machlett was figuratively—sometimes literally—up to his neck in the Rainbow Light enterprise.

The story of that venture is, strictly speaking, no direct part of Machlett Laboratories' history. Yet it deserves to be told—partly because it is a fantastic tale. But even more, it has a place here because Machlett Laboratories inherited certain very valuable things from the now-vanished Rainbow, much as a young man might inherit from an unfortunate uncle both a set of priceless conclusions about human nature and a matchless collection of rifles and shotguns. Or, to translate analogy into literal fact, Machlett Labortories gained from Ray Machlett's Rainbow experience a dynamic sort of wisdom that was a major factor in making this business what it is today. And it took over from Rainbow, when that firm succumbed to outside manipulation, a number of men of very great value. These were men whom Rainbow had brought in at the height of its prosperity—men such as a more slowly growing firm would scarcely have been able to afford.

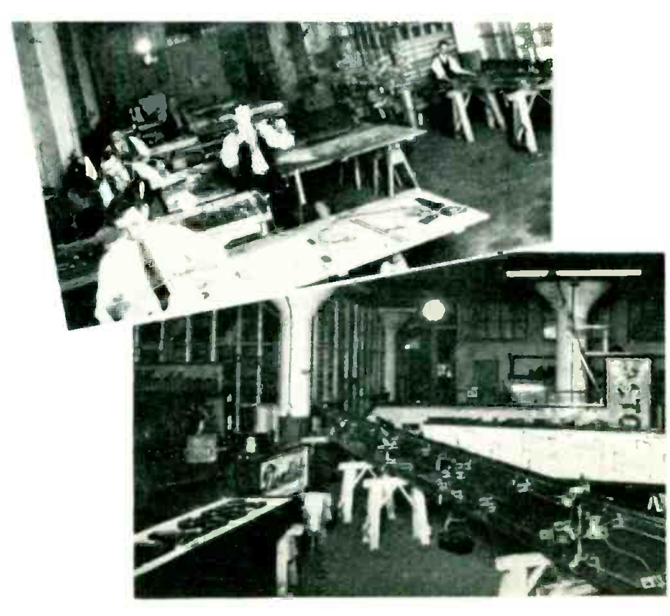
The tale, then, goes like this:

UNDER Ray Machlett the Rainbow business grew, from the start, faster than his and his father's capital would support it. By the spring of 1926, when his father sailed for England in a last, forlorn hope of successful medical treatment, Ray Machlett had created a thriving young business. He had—combined with his technical ingenuity—what soon proved to be a phenomenal sureness in organization and management: an unerring perception of how to set up a manufacturing organization; an instinct for picking men and a gift for directing them; an uncannily accurate feeling for what users of his product would want, even before they began to want it. These were fairly remarkable traits in a boy of 26 without much business experience, and time was to prove how sound and enduring they were. At the moment, however, they were cramped for lack of capital to give them room for action.

Then, unsought and unheralded, capital drove up to Ray Machlett's door. If not in the proverbial hack, then at least in a very large and shiny black limousine. From this debarked a large and insistent man named Bossi. He had seen a Rainbow sign in New York, conceived an idea, made inquiries, and forthwith directed

Deflex tube.

Bending tubes and assembling them into signs required a good deal of space in Rainbow's Long Island City plant.



his chauffeur to Long Island City. Would Ray Machlett sell out to him?

The answer to this being "No," as Bossi may have expected, he offered to put money into the enterprise, and finally persuaded the young president to accept. Starting on this money, the Rainbow business expanded within a year to nationwide scope—with a sales office on Broadway; branches for sales and service (including the forming of tubes into spectacular sign lettering) in Cleveland, Detroit, Pittsburgh, Dallas, Rochester, N. Y., Kansas City and Chicago; and a licensee in Los Angeles. They acquired more space in Long Island City and filled it to bursting with production equipment.

Business came in from all over. Famous places such as the Roxy Theater installed Rainbow signs. The General Outdoor Advertising Company, biggest in the outdoor display field, became a contract customer, with spectacular signs everywhere, including one put up in Times Square as joint publicity for General Outdoor and Rainbow, "BROADWAY WELCOMES YOU TO NEW YORK." Money flowed in—and was promptly invested in added space and added equipment.

More important, Rainbow began getting good men—often on quick decisions Ray Machlett made when good men appeared. For example: In the course of rapid expansion Rainbow, putting in new pieces of equipment almost daily, kept overloading its own wiring system and the power company's transmission lines. The New York & Queens Light and Power Company's ordinary representative was unable to do much about this with the headlong Ray Machlett. So they sent around one of their better men—a young engineer named Stevenson. Stevenson knew his stuff, and while he was tactful enough, he was insistent. Machlett agreed to make the changes Stevenson stipulated—and promptly hired Stevenson for his own organization. Thus entered a man destined to contribute very largely to Machlett Laboratories' achievement of first position in the x-ray field, both by conscientious, meticulous effort and by sound judgment. On which account he is today President of the company.

Today's President of Machlett Laboratories is W. E. Stevenson, one of Ray Machlett's oldest and most trusted associates and a major factor in the growth of the company.

Two other men now in Machlett's top management group came in at about the same time, and almost as much on instant decision by Ray Machlett: J. A. Lambert, who came in as Assistant Treasurer, is now Vice President and Treasurer of the company. And a remarkable young man named Skehan showed up one day—another one-time boy radio fan who had tried to make tubes at the age of 12, who had quit school at 16 and gone back again at 21 to learn electrical engineering, and who now at 24 wanted very much indeed to make tubes of any kind. Ray Machlett, recognizing in him something of the same insatiable curiosity and drive which impelled himself, hired Skehan on the spot. Today, Skehan is Vice President and, as he has been for years, in charge of all Machlett Laboratories production and associated engineering.

Midway of this growth, the new capital supplied by Bossi had all been put into added facilities; profits were being plowed back as fast as they came in; and still the demands of expansion called for more money. At this juncture there appeared (possibly introduced by Bossi, who thence-forward retired into the background) a new investor who could and would supply capital in amounts said to be practically unlimited.

This was the flamboyant and then highly regarded Charles V. Bob. Bob had appeared in New York about 1926 or early 1927 from nobody knew just where, except that it was from mining country. He represented himself as a mining engineer. And since he showed every evidence of having a great deal of money, nobody in the fabulous pre-1929 days asked many questions. He gave big dinners for big-news figures, attended by men of great importance. It didn't matter if he had never met them or they had never heard of him; his name was now bracketed with theirs in the news, and he saw to it that it continued to be. He cultivated figures in the specially newsworthy fields of religion, big business, sports, exploration and aviation. First and last, and legitimately or not, he got himself regarded as the associate of prominent people in all these areas: Aimee Semple McPherson, the Rev. Dr. Christian F. Reisner of Broadway Temple fame, and many other irreproachable New York clergymen; Bernard F. Gimbel, August Hecksher, Otto Kahn, Charles Evans Hughes, Arthur Brisbane, Dr. John H. Finley, Adolph S. Ochs and many another big figure in business or publishing. In sports, he assiduously cultivated fighters and promoters. (Bob claimed to have knocked out Stanley Ketchel in a friendly bout.) Commander (later Rear Admiral) Richard E. Byrd and Clarence Chamberlain, pioneer in aviation, succumbed to his wiles, while only Lindbergh stood him off.

In some such instances the coupling of prominent names with Bob's was an arrant blowing-up of the mere fact that their owners had been fellow members of the same fund-raising or similar group. But in an impressive number of cases these people liked and trusted Bob, for he was a most plausible figure, an agreeable companion and a spectacular giver to worthy projects. Typically, Admiral Byrd, whom Bob backed heavily, believed in Bob so implicitly that he named a mountain range in Antarctica after him, and hailed him at public dinners as "Dear Old Charlie."

It is not surprising, therefore, that 27-year-old Ray Machlett should have been both flattered at the interest of such a man and pleased with the amount of financial backing he brought to Rainbow. He trustingly went along with the Great Man's idea of furnishing this capital through a holding company, Rainbow Luminous Products, Inc., with which he had little to do, and gladly enough consented to Bob's putting in a president ("to take care of executive detail") at Rainbow itself. There were only two things Ray Machlett wanted to do: manage the manufacturing operations of the company and improve its products technically.

Of these products there were two kinds, as he saw it. One was the luminous neon light of commerce, in which Rainbow was doing a tremendous business not only with business-property owners but with the General Outdoor Advertising Co., the biggest figure in the spectacular outdoor display field. The product was good—technically and in every other way. It stopped passers-by; it delighted the firms that showed it; it was well and honestly manufactured; it was promptly and impeccably serviced by a large, efficient field organization. . . .

Vice President and Treasurer J. A. Lambert is an old associate from Rainbow days. He has kept Machlett Laboratories financially on an even keel and a steadily prosperous course since the earliest days.

J. W. Skehan, Vice President in charge of Production and Project Engineering, was Ray Machlett's closest engineering associate in the early days of the company, and perhaps the greatest single contributor to its early technical progress.

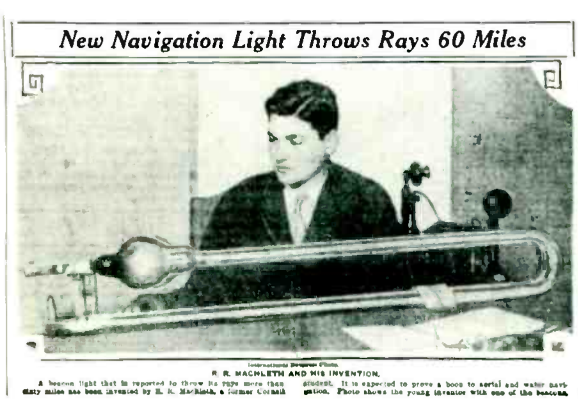
There seemed every reason to expect of it a great and lasting success.

The other kind of product that interested Ray Machlett was a neon light for brilliant illumination. So far, this was not a manufacturing reality, but he had developed a number of forms of it including one, shaped like an enormous contorted hairpin with a bulb at each end, which gave promise as an airfield beacon. The longer wave-length of its light had a somewhat greater ability to penetrate haze than ordinary lights of equal intensity. At least so pilots reported after homing on an experimental beacon set up at Hadley Field.

Bob turned his publicity talents loose on this, and shortly Ray Machlett found himself appearing in newspapers and magazines as the "young Cornell scientist" holding his "new 10,000 candlepower light for aviation." All well and good, and literally enough true, but the pictures show him looking uncomfortable. He found himself shaking hands, for the photographer, with Aimee Semple McPherson, to whom Bob had promised a beacon for her tabernacle. Soon he began reading, in some disquiet, that his light would do things he himself had never suspected and would not have claimed. Pilots' reports of a 50-mile visibility in haze and 20 in light mist were blown up to be 60 in mist and 40 in fog—and finally 100 in pea-soup fog. Bob laughed off his demurrers as naive, and pointed to the fact that beacons were being put in at Roosevelt, Curtiss and McCook Fields—with the presumed approval of the National Bureau of Standards. He got Assistant Secretary of War Davison to be photographed with Ray Machlett. He got a beacon put up in the S. S. Leviathan—navigation laws forbade its use at sea, but it received wide publicity, especially when Chamberlain took off from the ship in a fog and flew back to Long Island. Bob took his young protege to Roosevelt Field, introduced him to the equally young Lindbergh, then waiting to take off for Paris, and had pictures made of the two standing at the nose of the Spirit of St. Louis. Neither looked particularly happy about it.

One of numerous photographs industriously broadcast to the press by Bob's high-powered publicity experts showed Ray Machlett with an experimental form of the Rainbow airfield beacon tube.

(In fact, by the night before Lindbergh took off, Ray Machlett was beginning to have enough of publicity, so he went home instead of to the nearby Roosevelt Field. But Stevenson and a couple of others who had been concerned with the Roosevelt Field beacon went there and, hearing rumors and seeing lights in the Lindbergh hangar, stayed on through that showery night. So they were among the few to see, in the murk of the next dawn, the lumbering, splashing, perilous takeoff across the mud, the agonizingly slow lift of the heavy-laden plane, its bare clearing of the treetops, its vanishing into the dimness, Paris bound.)



New Navigation Light Throws Rays 60 Miles

International Newsreel Photo.

R. R. MACHLETH AND HIS INVENTION.

A beacon light that is reported to throw its rays more than sixty miles has been invented by R. R. Machleth, a former Cornell student. It is expected to prove a boon to aerial and water navigation. Photo shows the young inventor with one of the beacons.

There was much other publicity, all engineered by Bob. The fund-raising campaign for Dr. Reisner's Broadway Temple (the famous "Skyscraper Church") was topped off by a $100,000 gift—or promise of it—from Charles V. Bob: It was to be in the form of a great Rainbow Light cross atop the church structure, and it was to be called the Commander Byrd Beacon—visible for *150* miles in a pea-soup fog! The promise was gratefully accepted, at a big dinner, by municipal and religious leaders of New York, and reported in papers all over the nation.

All this time there had been going on a series of patent suits at law among various firms in the neon light field.

Of these, the two largest were Rainbow and Claude Neon Lights, Inc. As is normal in so many fields where long and widespread research and experimentation have at last produced a number of practical and competing products, the numerous patents granted to one or another of the competitors were being contested in the courts. In the various suits, Rainbow had maintained its position, and the probabilities are that if the general situation had been what it is in most industries, an amicable agreement would have been reached among all principal parties, with benefit to all.

"Neither looked particularly happy" in the publicity photographs that Bob had taken of Lindbergh and Ray Machlett, and distributed widely to the press in May 1927.

But the situation was not normal. Neither Bob nor the principals on the other side were willing compromisers. And Bob, at least, was a free-for-all fighter of the barroom school. In 1929 he caused two of the principals of Claude to be arrested, handcuffed and thrown into jail before a battery of news photographers, on charges of publishing false and misleading statements. It only made matters worse that they were shortly released, since the charges were plainly groundless, and worse still that Bob bedeviled the courts to have them incarcerated again. After this there was no chance of an amicable or even a sensible settlement.

Even so, Rainbow might have survived as an active and successful competitor within the scope of patents upheld in court decisions. Those patents covered adequate ground. The company's standing in the outdoor industry was tops, its organization efficient, its financial position strong. But it was shortly to suffer a blow from which no concern could entirely recover.

In October 1930 the vastly distended reputation of Charles V. Bob blew up in a series of spectacular bangs that began with a mysterious disappearance headlined from coast to coast, proceeded at once into thunderous investigations by the District Attorney's and other offices, and went therefrom into a thunder-roll of sensational disclosures, charges, indictments and eventual conviction with a jail sentence for fraud.

Bob, it appeared, had been conducting operations in which he was involved hardly at all as an investor, but very much as a manipulator. The State contended—and made the charge stick, though it took three trials—that in the course of these operations of his own Bob had appropriated to himself very large sums of money entrusted to him by the credulous citizenry.

His fraudulent operations did not, of course, involve Rainbow, with which he had had little to do except in investment (which was genuine enough) and in publicity (which stopped with exaggeration of a degree then common in very many businesses). Indeed, to give the devil his due, it should be said that Bob had allowed the Rainbow Light management to run its business operations and its own finances, according to its own standards—which were high—without any interference at all. As far as its people, its suppliers and its customers went, there might never have been any Charles V. Bob at all. Whatever his influence in the holding corporation, he had taken care to exercise none whatever in the manufacturing, selling and servicing company. So the authorities, after a careful look at Rainbow, along with other concerns in which Bob had interested himself, shook their heads in wonder and waved Ray Machlett and his associates to pass on, along with Admiral Byrd and uncounted similar victims of the super confidence man.

In 1930 the Rainbow business—impaired more by the association of Bob with its name than if it had lost a dozen patent suits—passed into control of the Heckshers, from whom Bob had borrowed extensively. Ray Machlett, understandably sick at heart, would have cut free at once and entirely, to follow another line in which he perceived the opening-up of great possibilities. But the new owners of Rainbow persuaded him to continue at least in an advisory connection with the firm, which he did for about a year.

From the Rainbow experience he had gained a chastening and abiding distrust for the promoter type of business man. He had got a lifelong distaste for exaggeration. He had acquired a wariness of any control in a business organization not wielded by those actively concerned with its operating management.

But as against these caveats he had gained a great deal more on the positive side: experience in the building of a business; seasoned knowledge in the handling of men; and a group of tried and true associates.

These included, besides those already mentioned, several others who are important in later Machlett history: Bror Magnuson, an exceedingly valuable engineer, Miles Pennybacker, who at a highly critical juncture was in immediate charge of launching one of Machlett's largest steps in expansion, and—in the office—Mrs. E. A. Henrickson, who became Ray Machlett's secretary in 1927 and is now Secretary of the company. And on the board is a man who has possibly played as significant a part at certain critical moments in Machlett history as any one of the others, though he has never been among the company's operating executives:

In 1928 Rainbow was engaged in a patent suit in Los Angeles. The company sent Ray Machlett west as its principal witness and, almost as

Mrs. E. A. Henrickson, Secretary of the company, probably knows more of its history than any other single person. She was "right hand man" to Ray Machlett in the Rainbow days, and served as his secretary through the entire development of Machlett Laboratories.

an after-thought, an eastern attorney named Dean S. Edmonds, to collaborate with its California counsel. Almost at once it developed that the local attorney had so imperfect a grasp of the case that even Edmonds, who was new to it, could see that the suit was as good as lost if something was not done, literally overnight. He sought out Ray Machlett, whom he had barely met; the two sat up till dawn and prepared a new approach to the case which they introduced—to the astonishment of all concerned—the next day. Eventually they won, but what was more to the point, they discovered in one another a kinship of spirit, an equal quickness of grasp, a likeness of outlook and matched driving force, together with just enough differences in experience and knowledge to complement one another when they worked together. Edmonds was a somewhat older man, already at the top of his profession, while Ray Machlett was roughly twenty years his junior. But the two became inseparable friends. And out of that friendship was to arise, in time, a collaboration of far-reaching effect.

One other sort of thing Ray Machlett had derived from Rainbow. In the technical side of his work, which was both intensive and extensive, he had added substantially to his knowledge of what happens inside an evacuated tube and of how to make tubes of exacting types. For while much of the work in building a luminous sign involved merely glass bending and shop fabrication, the basic efficiency of the Rainbow tube came from a very accurate knowledge of rarefied gases (i.e. of precisely regulated partial vacuums) and of vacuum processing.

These, put all together, amounted to very considerable gains from the Rainbow experience, even though his financial gains had been very largely on paper and so mostly wiped out. But he took what he had, put it together with the idea that had begun to possess him, and started preparations for a new venture. This one, he was resolved, should Go. And it did.

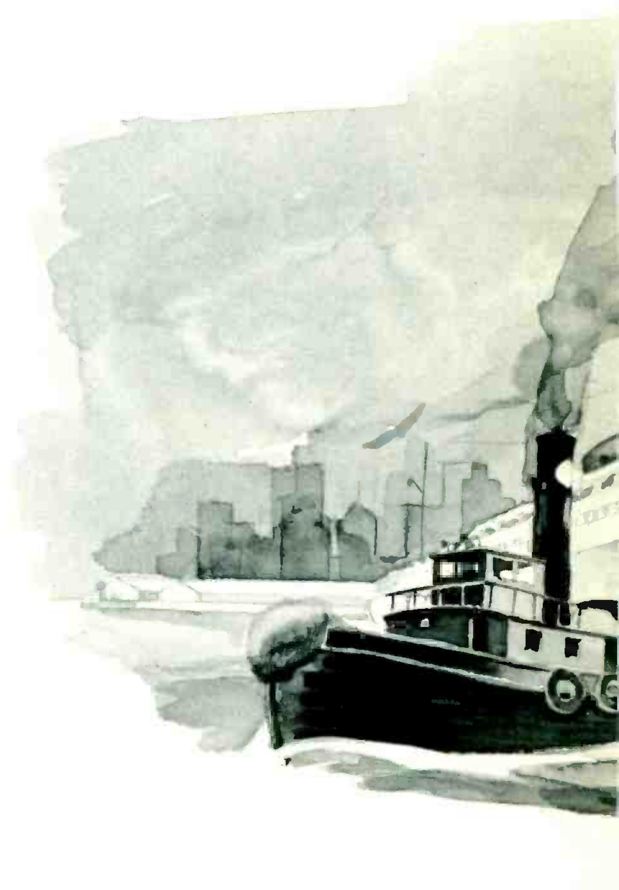
Chairman of the Board Dean S. Edmonds is a combination godfather and elder statesman to Machlett Laboratories. Here he sits at the head of the table in the Board Room at Springdale.

The Care and Feeding of Ideas

THE idea that took possession of Ray Machlett in 1930 was all the more compelling because it was both old and new. It was the perception that in an established field for which he was uniquely fitted by experience, by equipment and by the reputation of his name, there was about to open up a boundless new opportunity.

Within a year, when the Coolidge patents were due to expire, the x-ray tube field would be wide open for an independent manufacturer. At the moment such independents as were still holding on—including E. Machlett & Son—were limited to the area of gas-filled tubes, which had shrunk almost to the vanishing point. But the x-ray field as a whole was immense—bigger than ever before. In this field there was a very genuine need for the independent manufacturer. The first concern to meet that need would have a tremendous advantage; and if it could introduce improvements in the x-ray and related tubes (for which Ray Machlett already had ideas) it could go far indeed.

In the fifteen years since the hot cathode tube had appeared, great advances had taken place in the medical profession's use of x-rays for diagnosis and for therapy. There were also scattered but noteworthy uses of radiography for industrial purposes. The technical implements for this work fell into two classes: X-ray tubes



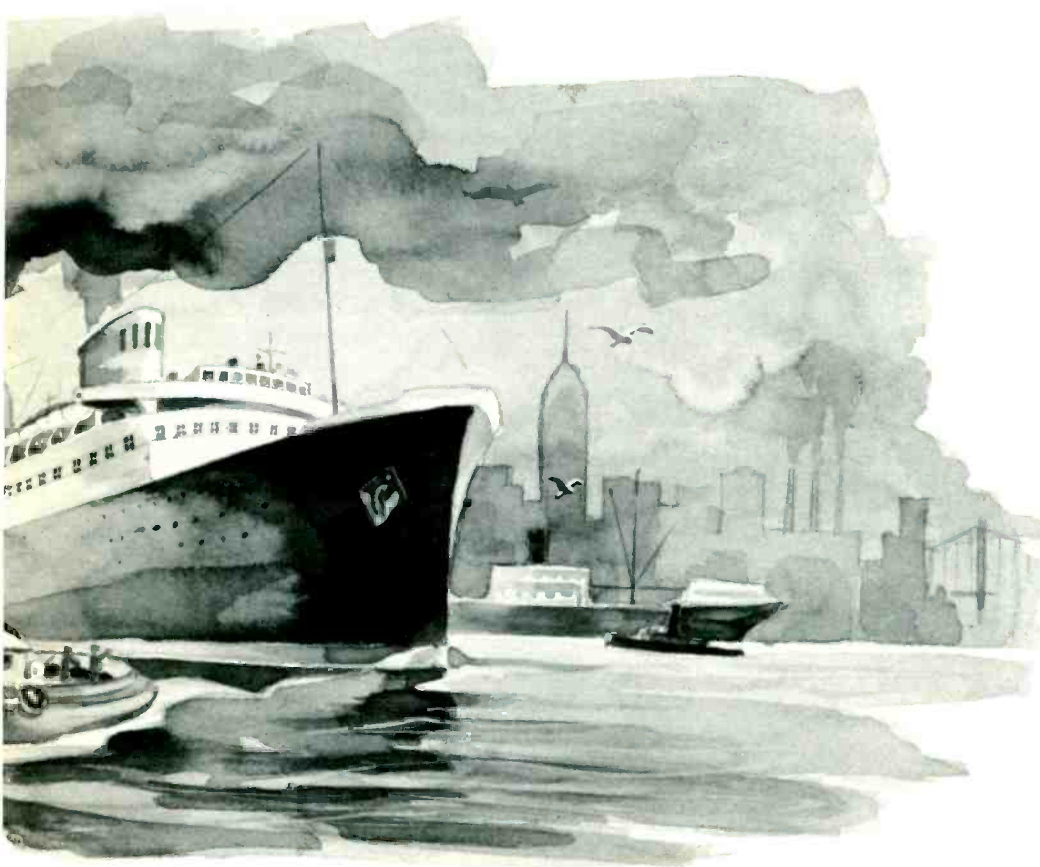
proper and the professional accessory equipment for putting them to one or another special use. Modern x-ray tubes were made in this country only by General Electric, owner of the Coolidge patents. Equipment was made by a number of concerns of very high repute among professional men. Their only existing sources of hot cathode high vacuum tubes were European manufacturers (chiefly German or Dutch), or General Electric. But G-E was also a manufacturer of equipment as well as tubes, so that firms like Waite & Bartlett (now Picker-Waite), Kelley-Koett and Standard had, in effect, to buy the heart of their equipment from their largest competitor.

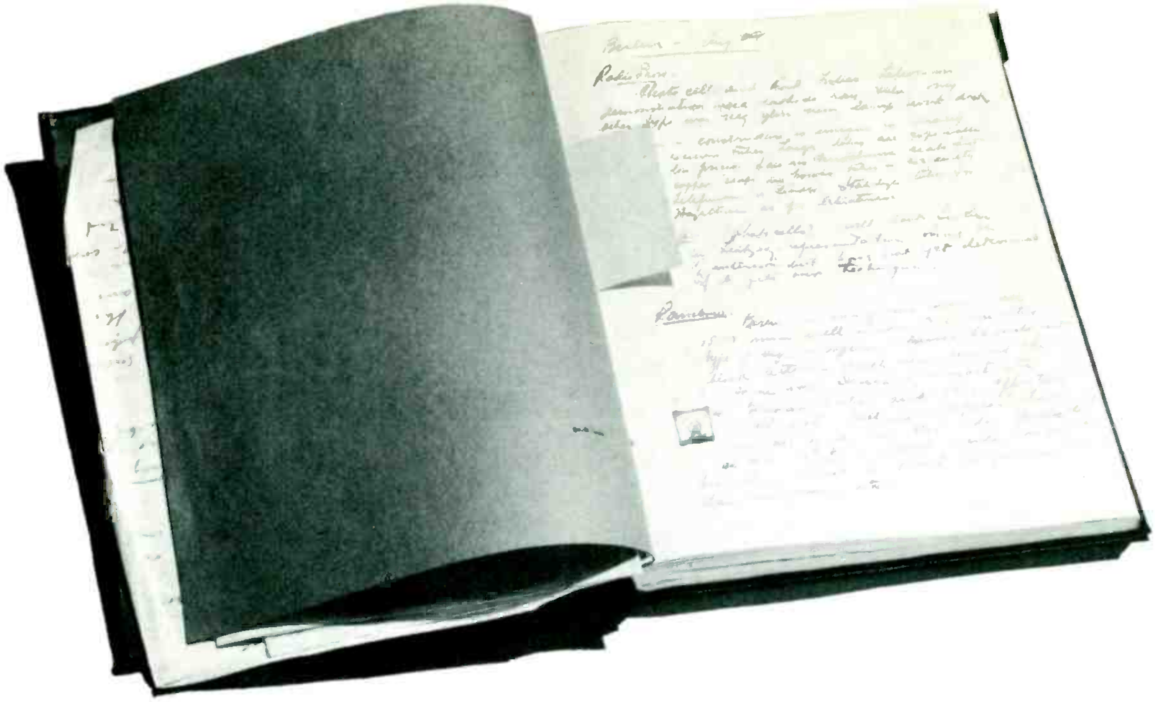
To this they had no objections on purely business grounds, for they were treated with scrupulous and broad-minded fairness. But G-E very naturally tended to give its main attention to designing and making the types of tubes best adapted to its own equipment. And the equipment manufacturers felt that competition was the life not only of trade but of technological advance.

Ray Machlett, who had never lost touch with the x-ray field in which his father had pioneered, saw the general outlines of the picture with great clarity—an outstanding gift of his, remarkable throughout his career. He was confirmed in it by the advice of old friends in the equipment-manufacturing industry, notably the younger Dr. Harry Waite, son of one of the great pioneers in radiology and until recently a principal in the Waite & Bartlett division of Picker X-Ray Co. Particularly, Waite spoke at considerable length of German and Dutch advances in the technology of the x-ray tube. He also received excellent guidance from outstanding x-ray apparatus engineers, such as Wilbur Werner and Edwin Goldfield.

With characteristic promptness, Ray Machlett made his decision, and his first step in implementing it was strictly personal, except for the confidential knowledge of a few associates such as Stevenson, Skehan and Edmonds. He went abroad in 1930 to study the latest developments in x-ray tube engineering and manufacture in Germany and Holland. Here the still-warm remembrance of his father gained him entree which would have been difficult if not impossible for another. He had, of course, a fair working knowledge of x-ray tubes and their use to start with, plus an intensive personal experience in the technique of making air-exhausted glass tubes. But even more, he had a remarkable facility for swiftly grasping exceedingly difficult subjects—a facility perhaps all the greater because he was not in the academic sense an engineer.

He returned from Europe at the end of the year with a great stock of the latest technical information, a few professional secrets and a ferment of ideas. Now he had to start a firm of his own in order to put his ideas into





In a bulky manuscript journal, Ray Machlett noted all he saw, and all he learned, in Europe.

effect. The old family firm of E. Machlett & Son still existed—but only barely, after difficulties in the late 20's which his own preoccupation with Rainbow had not helped. It was now being rescued by his brother-in-law, Richard Schnier, and started back on the road toward prosperity as a manufacturer and distributor of scientific laboratory glass equipment—a field in which it is today outstanding. In 1931 it had a small residual business in x-ray tubes, which it would be more than glad to hand over to a new Machlett concern willing and able to carry on the Machlett name in the x-ray field and to handle that exacting type of work.

SO RAY MACHLETT set up, on October 9, 1931, Machlett Labortories, Inc., a New York corporation, with somewhat small quarters in the Long Island City building with E. Machlett & Son. He put the greater part of his savings into first-class equipment, which came high, and staked all the rest in working capital, principally to pay a few good men, who came gladly out of affection for Ray Machlett and confidence in a future allied with him.

Among the first of these were the resourceful Skehan, to help solve exceedingly difficult technical problems in making the tubes that Ray Machlett had in mind; the skilled Zitzmann, to work glass (and train others to do it) in the way that only a great craftsman can; and a short time later the energetic Stevenson, to sell tubes and thus bring in the money to keep them—and a handful of other operatives—alive.

Their first products were therapy tubes of the accepted Coolidge design. To these they shortly added a line of valve or rectifier tubes, also following accepted designs which had been brought to a fairly advanced stage by electronics engineers in the radio field. These, together with a small increment of repair and service business in gas-filled tubes carried over from the predecessor company, E. Machlett & Son, served as the meager bread-and-butter of a small business getting under way.

It would have been simple, though not easy, to follow along such lines, relying for business on the good will naturally accruing to the first independent manufacturer in the x-ray field as it had newly opened up. But Ray Machlett had set his sights on a higher mark.

For one thing, he wanted to make radiographic tubes of higher rating and performance characteristics than any hitherto available. This would mean, among other things, a smaller and brighter focal spot. To get it smaller Machlett Laboratories adopted the line-focus cathode, until then not in general use in this country.

To help get the focal spot brighter they wanted a heavier copper-backed anode. They needed massiveness to conduct intense heat away from the target, which would otherwise quickly burn out—tungsten though it was. They were unable to buy massive copper castings of the unusual characteristics needed, and they didn't know precisely how to cast them for themselves. But they undertook experiments, which for some time didn't quite work.

Finally, Skehan and Ray Machlett devised a plan to cast calcium-deoxidized copper in a vacuum, by high frequency induction heating. They built a temporary rig for this purpose, improvising most of its parts, and were all ready to try it out when a holiday intervened—Washington's Birthday, 1932. Skehan, however, could not wait. He went down to the shop alone that morning, hooked up the apparatus, set it in operation—and by noon realized, with the thrill only a solitary explorer can know, that Machlett Laboratories were In: the process worked.

As they had been confident, the new copper-backed anodes, when put into tubes designed for them and embodying the line-focus principle, made possible radiographic performance of a new and advanced order. They immediately put in production two tubes along these lines—MR50 and MR100. These won instant acceptance by the profession, since they outperformed any competing tubes of that time. To the young company this acceptance seemed—as it was—a jewel beyond price, and they took care to guard it with considerable diligence, both in the service of orders and in a field follow-up to make sure that the performance of tubes continued exceptional in use.

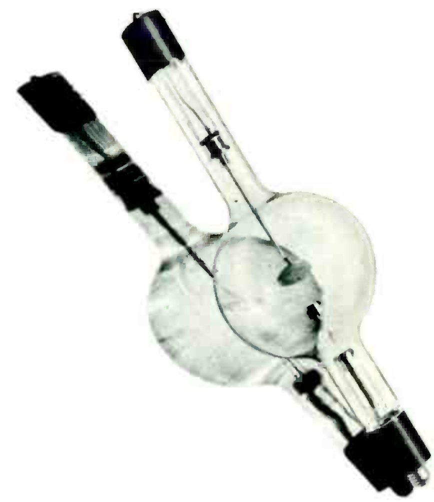
The success of this combination of design and conscience disposed once and for all of any fears that they might have to compete in the industry solely on a price basis. From then on it was basic policy to design and make tubes that would sell on the principal basis of superiority in performance—with everything else if possible, but everything else secondary.

In this era—and for a considerable time afterward—Machlett Laboratories also made tubes custom-fashion, to the designs of several of the leading equipment makers.

The new Machlett tubes put the company on firm footing and in a potential position of real prominence in the industry. But to make that possibility come true while the time was still favorable they needed capital—for more space, more equipment, more people, more materials . . . Ray Machlett undertook to find the money.

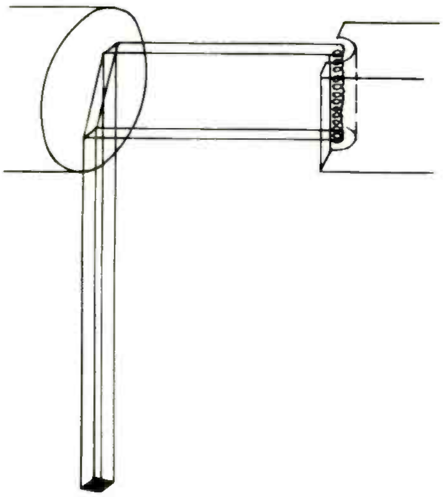
From Rainbow days, of course, he knew a lot of people with money, but only one with whom he felt he would like to be in business again. This was Edmonds, the New York lawyer, who was continuing to serve the Rainbow interests as patent counsel.

Edmonds was living in Fairfield, Connecticut. On an evening in early fall of 1933, Ray Machlett dropped in on him, as he often did, and as was their habit, they sat on the porch and talked.



A therapy x-ray tube of the Coolidge type made by Machlett in the early 1930's. Note the light target, supported on a slender stem. Heavy copper anodes were yet to come.

An early Machlett Laboratories rectifier tube, the ML-20 of about 1932.



In the line-focus principle, the filament (right) emits a stream of electrons which is focused by the shaped walls surrounding it into a beam that is broad yet thin, like a board standing on its edge. This thin beam strikes a target set at an angle of about 20°. So the spot on the target is foreshortened, as seen from outside the tube, into a very small square. This square is the "focal spot" of the x-rays that emerge from the tube. The smaller it can be made, the sharper the x-ray picture.

Machlett's first tubes with the heavy copper-backed anodes made possible by the working out of induction casting in a vacuum: the MR 50 and MR 100 tubes.

"We know now," said Machlett, "that there is a place for us in the x-ray tube field. A good deal bigger one than we now hold, if we can move up and take it."

"Why don't you?" asked the older man.

"Well, to put it baldly, after we've paid the rent and met the payroll and bought the materials we need—more of them all the time—there isn't much left for expansion. If we have to grow out of earnings, we'll grow, but slowly. If we had a little cash, we could grow a great deal faster."

"How much do you need?" asked Edmonds, and reached for his checkbook.

Ten thousand, it appeared, would do for a start, but they might need more later. So within a day or two—on Sept. 18, 1933 to be exact—Edmonds became owner of stock to that amount in Machlett Laboratories, Inc.

They could expand, now, to meet the growing demand for their improved tubes, and to try their hands at still other advances in tube types. The first of these became the first Machlett ray-proof tube.

Intensities of x-ray tubes in use by the 1930's were beyond those that could be safely contained within a lead glass tube itself, such as the Piffard tube. Customarily, tubes were either set in a heavy lead glass bowl or installed in an elaborate structure of lead shields for protection of patient and operator. These safeguards were part of the accessory equipment, but not of the tube. Recently, however, European designers had brought out tubes fitted with ray-proof shields as complete units. In the United States, both Machlett and G-E took up the idea at once. Machlett's version was the "Conex" (so-called from structural features in its design), housed in a combination lead-impregnated Bakelite and metallic-lead shield. This was brought out in 1933. It was moderately successful, but it produced something of far greater value to the company than its own sales: Equipment manufacturers and professional users alike made suggestions for certain improvements, starting from their good impression of this version of a ray-proof tube. Taken all together and analyzed, these suggestions pointed to new types of tube that Machlett and Skehan felt sure they could make. But to do so they needed still more space and equipment. And, it might be, more money.

On Edmonds' first financing they had spread out into all the readily obtainable space in Long Island City, but there was now barely enough to hold their working force of 28 people and their constantly growing outfit of equipment. If they were not going to lose business that was plainly within their grasp, they would need bigger facilities.

They started scouting around separately, in pairs and in a group, on the winter weekends of early 1934, exploring generally up into Westchester County, New York and nearby suburban Connecticut. Edmonds, as a much interested party, with every prospect of becoming more so, helped with the search. Their choices soon narrowed down to two, both in the Stamford area: the former Telephone Company building in the city itself and a small but fairly new building in the outlying village of Springdale, two or three miles north-by-east of Stamford. The latter building had been one of the plants of a corporation making luggage locks, whose president wanted to sell the property subject to a lease of its top floor to a tenant already there, with several months to go. At first they thought less of this than of the city property, but somehow, suddenly, all found they had changed their minds and preferred Springdale—more for its future possibilities than its present.

Among all the friends Ray Machlett (left) had, there was none on whom he depended more for counsel and support and friendship than Dean S. Edmonds.

Edmonds and Ray Machlett went to see the locksmith at his New York office, listened dourly to an offer to sell for $75,000 and rose to take their departure. Pressed by the locksmith for an explanation, Edmonds said, "One: we haven't got $75,000. Two: if we had we wouldn't pay it. Three: we have $5,000. If you will take that, plus a mortgage for $30,000, we can talk." They bowed and left the locksmith sputtering, but within twenty-four hours they got a telephone call, and the property was theirs for $35,000—6/7 of it on notes. As a postscript, it might be added that several months later the locksmith was in pressing need of cash again and offered the mortgage for sale at a steadily decreasing price which ultimately reached $20,000. At that time, Edmonds bought the mortgage and told Machlett that the company could buy the mortgage from him at the price he paid for it whenever it wanted to. Later on, when the company purchased the mortgage and cancelled it, title to the property became complete.

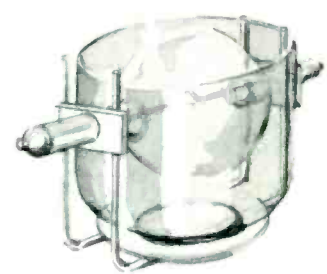
Machlett Laboratories, Inc. was organized as a Connecticut corporation on March 23, 1934. Original officers of the corporation were:

President	Raymond R. Machlett
Vice President	J. A. Lambert
Treasurer	J. A. Lambert
Secretary	Richard Schnier
Assistant Secretary	E. A. Henrickson

The company's General Counsel was Creswell Micou, who did a great deal for the organization as Counsel and as a Director from May 1938 until his death in December of 1945.

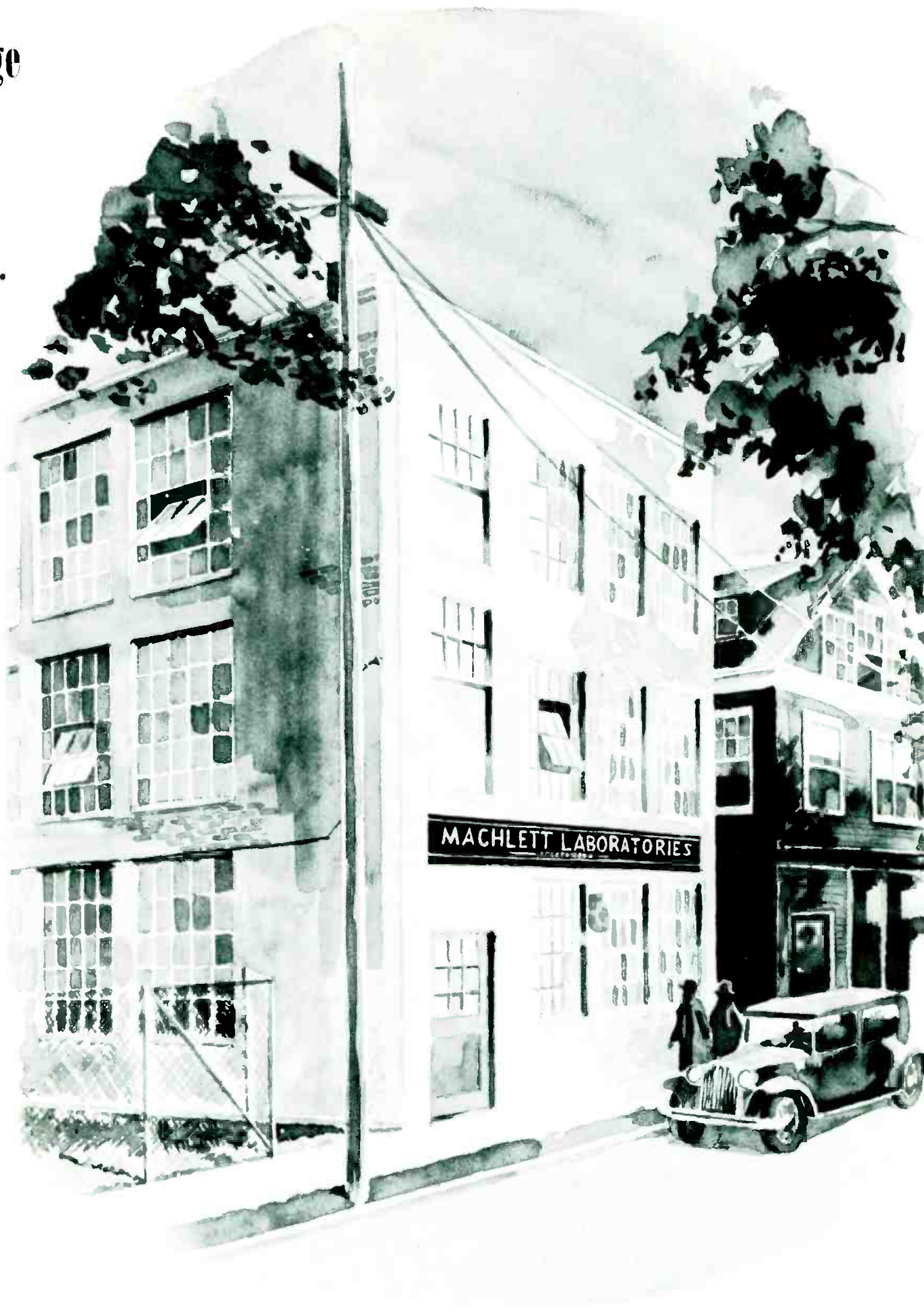
Machlett Laboratories moved into its new quarters at the time of its Connecticut incorporation. From that move dates an almost unchecked growth to top position in the x-ray tube field and to a position as a major factor in the development and production of power electron tubes for a wide variety of increasingly essential uses.

Ray-proofing adequate for some of the early x-ray tubes had been achieved by setting the tube in a heavy lead-glass bowl.



Machlett's first version of a ray-proof tube was the "Conex" of 1933.

At the Average Age of 27 . . .



THE Springdale building was a long, narrow structure, at 1063 Hope Street. Now surrounded by much larger additions, it is identifiable as the three-story section next the present trailer delivery yard. Machlett Laboratories at first occupied only the two lower floors. In the top story, the existing tenant was a manufacturer of preparations high in spirituous content. It soon appeared that this firm's operations were also spirited, and that splashed alcohol was apt to come seeping through the Machlett ceilings from above, at unexpected times and places. This caused Machlett people a good deal of consternation, since one of the prime necessities of their exacting operation, drilled into everybody from the start, was meticulous cleanliness. They counted the days till the upstairs tenant's lease expired, and breathed a unanimous sigh of relief when they got the whole building to themselves.

They had set about creating an improved ray-proof tube, to be not only a high performance diagnostic unit in a ray-proof lead-Bakelite housing, but to be rugged, portable, small, light and compact, so that it could be positioned wherever professional use required. The result, brought out early in 1934, was the CYR, a tube that strikingly exemplified for the first time what has since become well known as a basic and readily recognizable characteristic of Machlett tubes: utmost compactness of exceptionally rugged parts, to take every advantage of what has been called "geometry of design." That is, (1) getting into a smaller-than usual space elements that are heavier-than-usual wherever massiveness will mean extra performance (as, in this case, a very heavy copper-backed anode). (2) Combining elements in such a way that each adds to the other, and all to the strength of the whole (as, in this case, the heavy copper anode carries the weight of the tube. In previous tubes the glass tube carried the weight of the anode. Again, the Bakelite housing is not merely a shield but a structural member, supporting the tube and so eliminating the need of end-caps on the tube.) (3) Good design geometry, too, employs to the greatest possible advantage the inherently great strength of cylindrical forms—if possible coaxial with one another.

The small, compact CYR was greeted with considerable enthusiasm in the radiographic profession, many of whose most eminent practitioners had counseled with Ray Machlett and Skehan during the course of its design and experimental construction.

The CYR was a ray-proof tube. But it was not proof against a secondary hazard in the practice of radiology—a hazard which had been growing with the increase in voltages:

Since the earliest days of x-ray practice, the danger of shock from high voltages had been recognized as second only to that of injury from radiation. Early practitioners were accustomed to suspending their tubes from any convenient lighting or plumbing fixture—often hitching the patients to the same installations for additional safety. Later, the tube—and sometimes the transformer as well—was mounted in a grounded enclosure. Such installations were bulky indeed, and even if expensively made, with ingenious pivoting and careful counterbalancing, they could not be conveniently positioned for certain uses. To overcome such difficulties Machlett devised a relatively compact, air-insulated, shockproof shield for the CYR tube. This was a grounded metallic enclosure to which high voltage was supplied through well-insulated flexible cables. The CYR had, moreover, another feature: the tube could be readily inserted or withdrawn for replacement.

Machlett's CYR tube of 1934 was the first ray-proof x-ray tube, compact and light for easy positioning. It achieved these advantages by using what has since become widely known as "geometry of design"—a hallmark of Machlett engineering.

One of the earliest types of "shockproof" apparatus.

Machlett's Thermax tube had an oil-insulated housing which made it safely shockproof, though it was a tube of unusually high voltage for its day.

Existing shockproof units were not only too bulky for efficient positioning, but their shockproofing depended upon insulation by a filling of dielectric oil. Whenever a tube had to be replaced in such an installation, the whole business had to be shipped back to the equipment maker, or the old tube had to be taken out of its oil bath and replaced, either in the doctor's office or in the dealer's shop. This was an annoying interruption at best, and likely to be a messy one as well.

The shockproof CYR achieved so promising a degree of success that Machlett followed it immediately with a substantially similar tube in an oil insulated housing, for considerably higher voltages—the Thermax. This, too, succeeded so well that they set about designing a tube which should combine the advanced features of both the CYR and the Thermax.

They saw a great place for a tube that would be in itself a complete rayproof, shockproof, quickly installable-and-removable unit, oil insulated within its own housing. One that would be, moreover, so light and compact that, with flexible shockproof cables designed to go with it, it could readily be positioned for all common diagnostic applications.

It was not easy to design a tube of these characteristics. There were those, indeed, who said it could not be done. The illustrious Coolidge himself was reported to be skeptical whether Machlett's people could successfully achieve so much in so small a space.

There were, as well, practical problems in manufacture, to make a theoretically superior tube actually superior in use and in life. These included not only problems to which Machlett was accustomed in the making of high-vacuum, high-voltage tubes, but additional ones such as the treatment of oil to avoid possibility of its insulating properties being broken down by exposure to air during assembly or by deterioration under the effects of heat and electrical stress while in use.

Solution of these problems involved among other steps: treatment of the copper anode chemically to retard its catalytic effect on hot oil; filling the shockproof enclosures under vacuum; and immediate hermetic sealing. The whole amounted to a process that was Machlett's own by virtue of discovery.

The new CYS tube—half the size of the tube-and-housing heads in previous shockproof equipment—Went to Town. There is no other phrase to describe its reception by the radiological profession. It not only met existing needs in a way that no tube had up to that time, but it opened up whole new areas in diagnostic radiology by making possible new applications, new techniques. For example, the taking of a stereoscopic pair of negatives, hitherto exceedingly difficult, was simple with this small, movable, rayproof and shockproof tube.

In bringing out the CYS Machlett added another advantage, almost as attractive to the professional user as any inherent feature of the tube itself: They sold the unit as a whole, but under an agreement that it could be returned as a whole when the insert tube was finally used up in service, for essentially full credit on the housing. So, in effect, the x-ray user paid only for the insert tube. (The housing would normally be in perfectly good condition for refinishing and use with another unit.) This practice is now standard in the x-ray tube business, but at the time Machlett introduced it, it was an innovation almost as startling as the tube itself.

Among them, all these compact tubes opened further what had been only a very small chink into a big potential field for x-ray use. A few industrial firms were already using radiography for non-destructive testing of fabricated parts or assemblies. But their number was limited to those

The CYS tube was an innovation in design —half the size of previous ray- and shockproof tubes. It had the added advantage that the insert could be readily changed.

that could bring pieces for testing to a fixed x-ray installation. The portable tube could be brought to work in process and used on several parts of it in quick succession. Thus Machlett entered a field where great numbers of its tubes are now in daily use.

The number of such uses, both medical and industrial, was again greatly increased by a tube Machlett brought out in 1939—the Aeromax, for radiography, fluoroscopy and therapy. In essence this was the CYS in a housing with integral forced-air cooling. It was the first air-cooled, oil immersed, shockproof tube unit of modern small size and light weight designed for continuous operation.

In developing these tubes and others, both x-ray and valve, which accompanied them, Machlett had necessarily to master increasingly difficult techniques. By the time of the CYS, for example, voltages up to 100,000V were accepted as common in diagnostic radiology. Heavy currents at high voltage in a high vacuum produce effects that impose problems of extraordinary difficulty in manufacture.

Few laymen realize, for example, that glass is actually a fluid substance. It contains absorbed gases, and in a vacuum at high heat, it gives up those gases somewhat the way a warm bottle of soda water fizzes when the cap is removed—though of course so minutely that only very sensitive instruments can detect this "out-gassing." But even the minutest quantities of gas can impair the quality of vacuum needed for a high voltage tube. Metals, too, give up gases under heat and vacuum, especially if there are impurities in them. And the least amount of oil or grease on either glass or metal—as from the lightest touch of a fingertip—can completely ruin the quality of a vacuum. These and scores of other things that can happen inside a hot, highly charged vacuum, called for a new order of purity in materials, of faultlessness in cleaning, of thoroughness in pumping, of strength and flawlessness in sealing, of care in testing.

It was during this period that Machlett worked out many of the techniques and procedures that are now fundamental and distinctive in its making of big, high voltage and high power electron tubes: the vacuum casting of copper anodes; the final pumping, aging and severe testing of tubes at currents, voltages and temperatures far higher than those encountered in service conditions; and the use of Kovar Alloy*, a composition of iron, nickel, cobalt and manganese, at the point where molten glass is sealed to metal. Kovar has very nearly the same coefficient of expansion as a special glass made by Corning Glass Works. When used together the two form a seal that is not only proof against expansion flexure, but heavy and rugged as well.

"We put a fan on the CYR," says Skehan, "and the result was the Aeromax."—The first oil-immersed, shockproof, rayproof tube to be cooled by integral forced-air circulation.

MEANWHILE, Machlett Laboratories were building a very effective system to service equipment manufacturers, dealers and users, both in the field and at Springdale. At first, of course, they did it in simple prudence, as a means of making sure their tubes gave good and lengthy service. Later, they had the added incentive of gratitude to the industrial and professional friends who had helped them to so good a start. And now they were very happily impelled to continue it on a more extensive scale

* Kovar Alloy was developed by Howard Scott, an engineer of Westinghouse Electric & Manufacturing Co. Originally patented and trademarked by Westinghouse, it is now fabricated and distributed by the Stupakoff Division of The Carborundum Company.

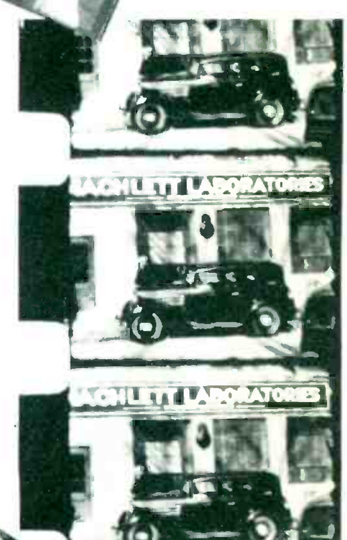
by the sheer volume of business that had become theirs in the late 1930's.

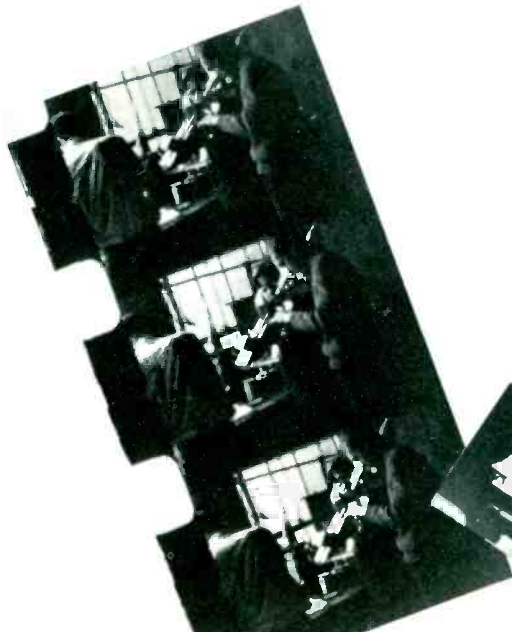
For long before that decade was over Machlett Laboratories found themselves in the position of being the suppliers of the great bulk of all x-ray and valve tubes bought by all manufacturers of radiological equipment who were not themselves makers of tubes. And since these supplied equipment for the majority of users, this meant that Machlett Laboratories had become the largest x-ray tube manufacturer in the United States. It was not bad going for a firm which barely seven years before had branched off from its predecessor company to specialize in this technologically difficult field.

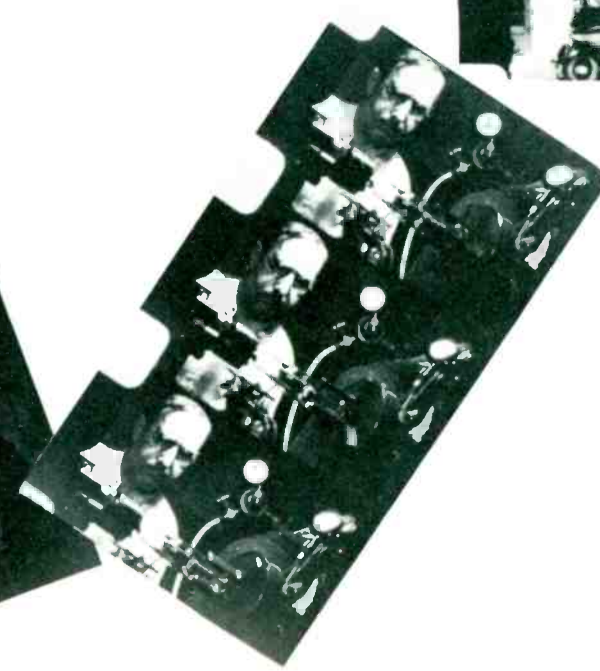
Of course this growth in technical competence and in business had not been achieved without a corresponding growth in equipment and personnel. By 1937 they had outgrown the first Springdale building and were negotiating the purchase of one just behind and at right angles to it—the present machine shop. They bought it in 1938. In that year the total number of Machlett people had reached approximately 250.

Most of these, of course, were shop people, and at that time practically all of those, outside the office, were men. It was not until the World War II era that Machlett was able to go into a type of production in which women could figure to any large extent. In fact, the work of the early years —like the bulk of it today—was not "production work" in the sense that the term is used to describe the output of large, mass production concerns. Big, costly tubes of exacting characteristics are not so much assembled as built—in relatively small lots, in which each part is an expert's personal responsibility, and even assembly is a shop constructor's job rather than a factory quantity-lot operation. This is still markedly true today, but in the early 1930's it was more so, since quantities were smaller and much of the way had to be found by intelligence, resourcefulness and care, rather than by accumulated and recorded experience.

Hence, the IQ level of Machlett people was even then of a high order.



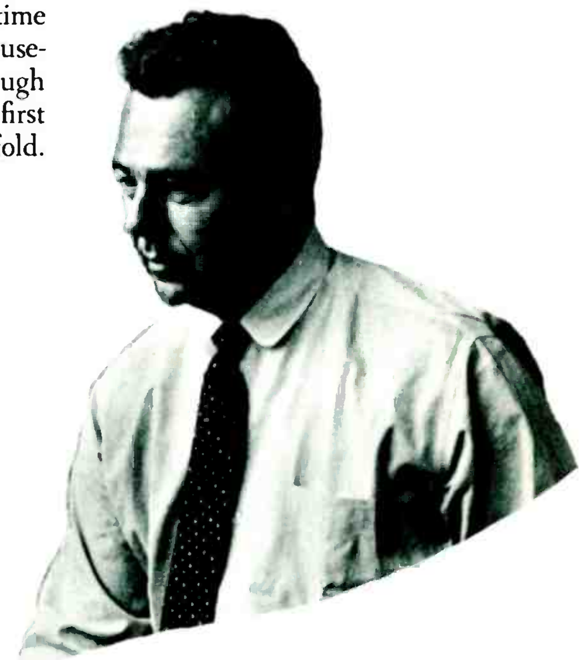




The average education-level was high-school-graduate or better, and in a great many cases shop people, encouraged by management, were taking spare-time extension courses in engineering and related subjects. Numbers of these are among Machlett's present-day key executives. Take, for example, a youth named Lester Crabb, who came to work, fresh out of Stamford High School, in the fall of 1934. An amateur motion picture film of the period taken in the plant by a fellow beginner, shows Crabb as a seemingly carefree kid of (17). Yet he was already a shift foreman in the pump room, of which he shortly became foreman. Today he is head of a substantial portion of Machlett's production operations (and of its Quality Control operations as well) and a member of the company's Operating Committee. A fellow beginner, the gifted Wally Steen, who had come as a boy with those who moved up from Long Island City, is among the company's more important project engineers.

Of course Machlett had to hire some great, hulking graybeards of 23 or 24 or so when it needed men with university or technical school degrees in science and experience in electronic work. Among the first of these were T. H. Rogers, now at the head of all Machlett engineering, who came to Machlett, with experience obtained at Bell Telephone Laboratories, in August 1934, and H. S. Cooke, a young engineer out of Syracuse who arrived the following year, and who now heads x-ray sales.

It may amuse present-day degree holders in scientific and engineering subjects to learn that in those days, with a world-wide depression afflicting all industry, a young technologist was not exactly courted by manufacturers with offers of employment. In fact Rogers, with a B.S. and all the work completed for his Master's degree, was constrained for a time to take up painting in order to keep body and soul together. House-painting, that is. And he remembers the day when the M.S. came through with particular appreciation, because it was the day he completed his first contract and got his first check for wielding a 5″ paintbrush on a scaffold.



T. H. Rogers, first of Machlett's scientists, and a recognized authority in the field of x-rays, still has responsibility for design engineering in that field, and has in addition, general charge of the company's engineering organization.

Machlett Laboratories was, you see, a youthful organization. The average age of all its people at the middle 1930's was only 27, counting all experienced machinists and glass workers (such as Zitzmann) and the men at the top like Skehan, Stevenson, Lambert and Ray Machlett. These heads of the biggest U. S. business of its kind were only in their mid-thirties.

Perhaps it would be more accurate to say that at this period there was one head, Ray Machlett himself. For he was then only creating what would become a corporate organization, bigger than any one man, and the process of creation necessarily had to be one man's work.

He was in the prime of life—a burly, compact, fast-moving man with broad shoulders, direct eyes and, across a fine forehead, a sweep of hair that had gone dark brown—almost black. His outstanding characteristic was vitality: aliveness, interestedness, quickness of comprehension, whether of a technical or a human problem, energy in decision and action, joy in living and in the work of life. He had a remarkable faculty of seeing; he could walk fast through the plant and see things that others even on a slow, careful inspection, missed. He had boundless energy and unlimited interest; he could participate equally in one man's preoccupation with a problem in hand manipulation, another's puzzle with the functioning of a machine, a third man's wrestling with equations in physics, a fourth man's absorption in statistics and the difficulties of a fifth to make a sixth understand him. He could get enthusiastic about any of these things—and infect others with his enthusiasm. He saw quickly to the essence of any problem, and as unerringly as though he had worked out its data with a slide-rule and graphed them in a logarithmic curve. And it did not matter whether this problem concerned a balance in

At the Average Age of 27


R. R. Machlett


W. E. Stevenson


J. W. Skehan


T. H. Rogers


J. A. Lambert

electronic characteristics or one in dollars-and-cents.

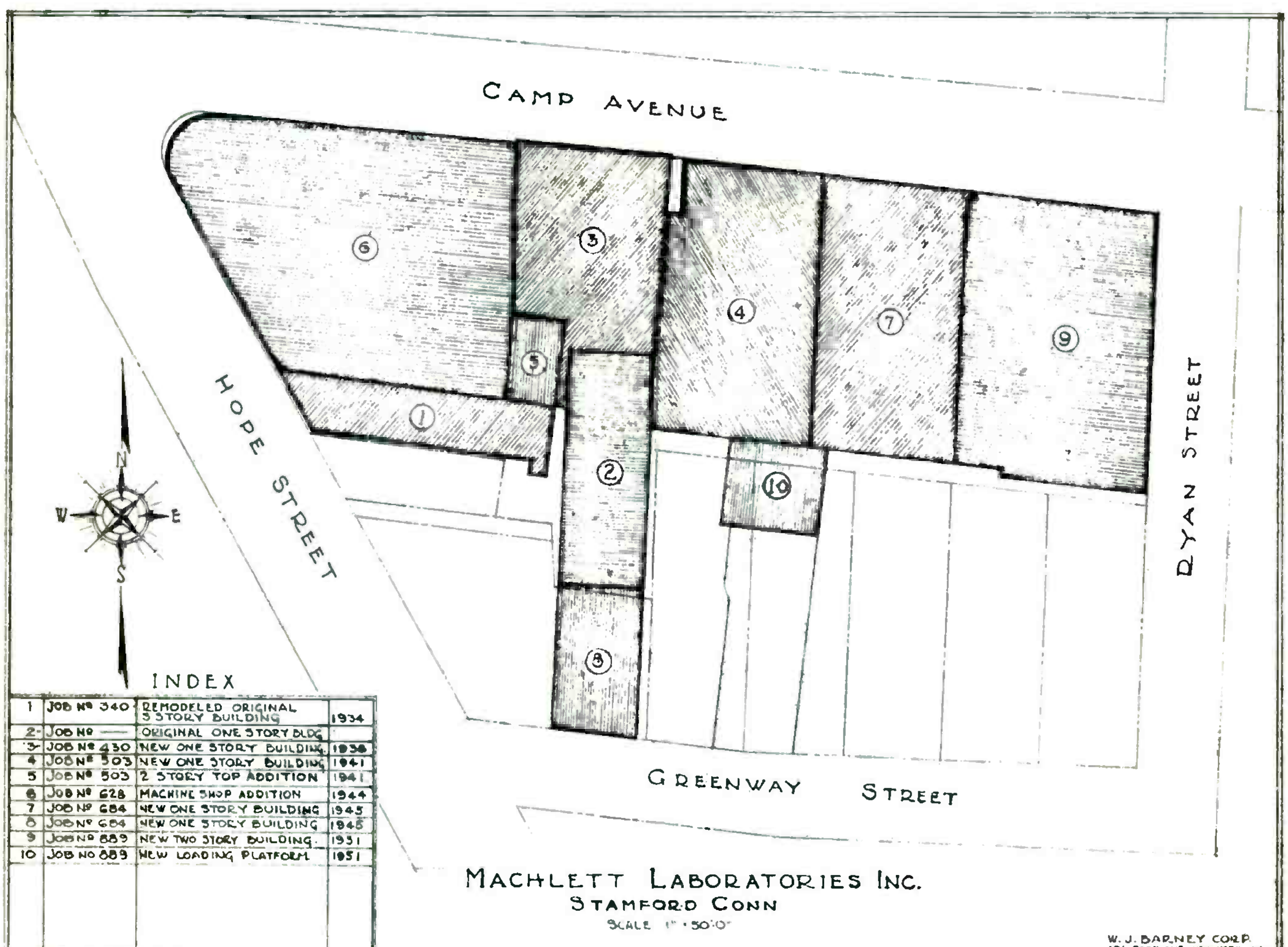
On what he saw, he could decide, and stick with that decision until it clearly proved right or wrong—and it was usually right. To carry out these decisions he gave people material support and authority—with responsibility for results. He gave "loyalty down" and got unstinted loyalty in return. He expected much of others, but demanded even more of himself. He was unsparing in credit where it was earned, and in criticism when it was deserved. (But they say this of him: that he could criticize more penetratingly and accurately than any other man, yet be liked for it by the men he criticized. It takes an extraordinarily honest man, and one of unquestioned sincerity and good will, to do that.)

He was a superb and unpretentious mixer, as much at home under a bench in the shop as across the desk in another man's office; and in his own office he was at home, without distinction and without affectation, to anyone who walked in. He had an unfailing tact in dealing with people, a sure knowledge of whom to jolly along and whom to draw out with grave encouragement; he knew all manner of men, instinctively. He was that rare phenomenon: an extrovert intellectual. Because so many different things and so many kinds of people interested him, he took an immense joy in life. He was as fond of good play as of good work; good food, good song, good companionship, good talk. It is singularly revealing that his best friends were all friends with whom he shared his work.

No wonder, then, that in seven years of the 1930's he built a business from nothing to unquestioned leadership in its field; that he built from a group of individuals an organization now extending that leadership beyond anything he may have dreamed.

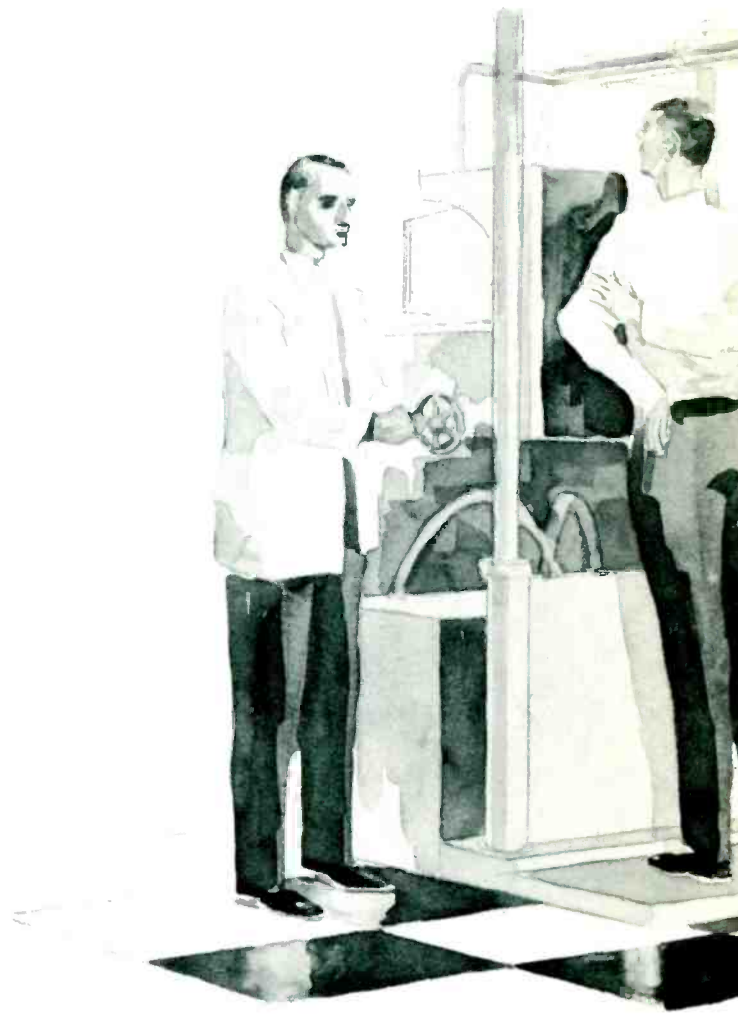
Their first step was already in the making.

Ground plan of principal buildings in Machlett's Springdale plant, showing how they grew. Note the additions made in 1938-1941.



A Spin for Fortune's Wheel

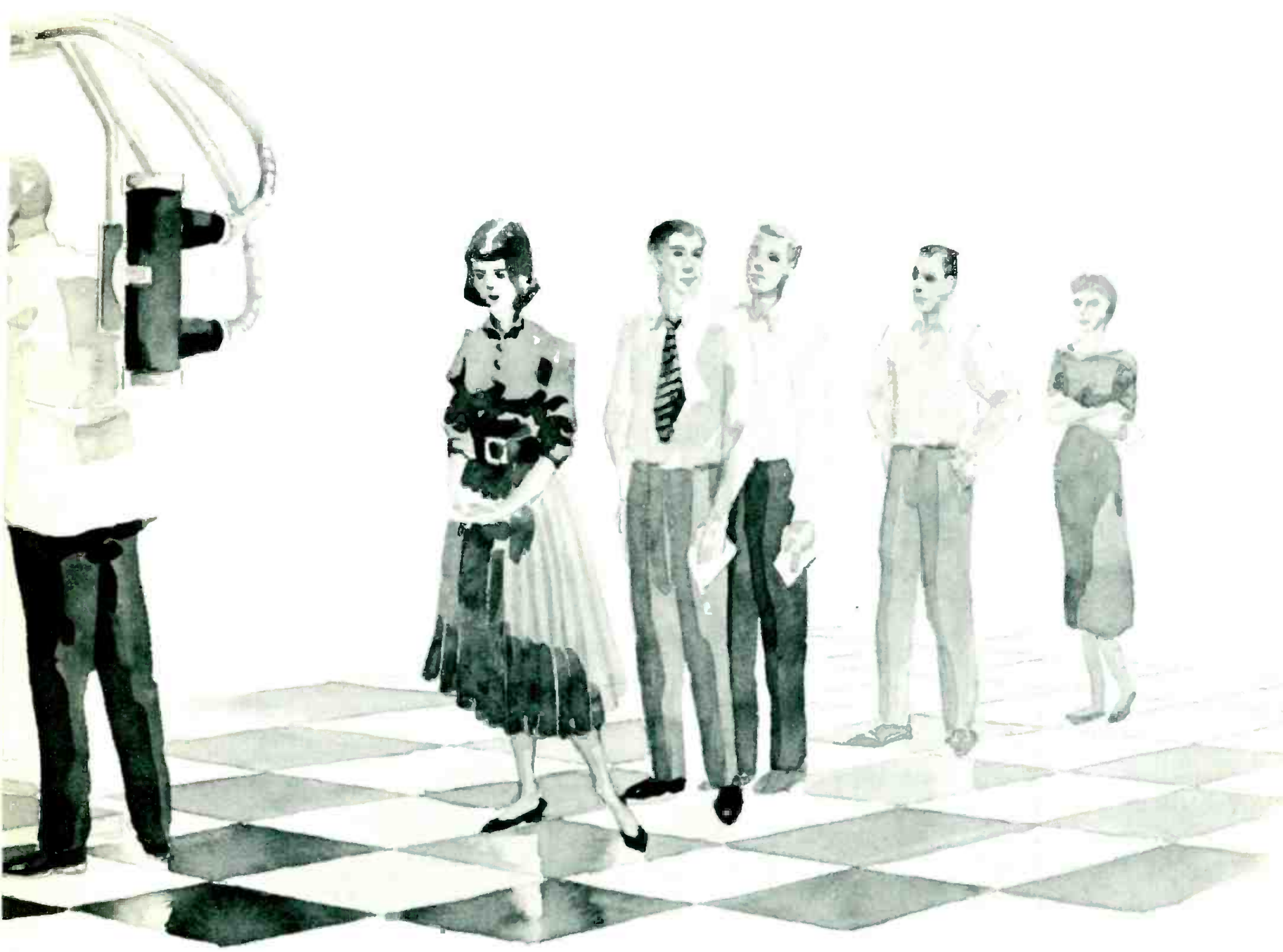
SINCE 1931 there had been great advances in the art of making x-ray tubes, many of them stemming directly from Machlett innovations. Each advance had opened new fields in the science of radiology. Yet the cumulative effect of these was to spur new demands for even better tubes. Primarily the profession wanted a finer, brighter focal spot to make possible still shorter exposures through greater anatomical sections, and with sharper detail in the resulting negative. But they wanted this without sacrificing tube life and—if possible—with longer life.



The basic idea for achieving these two mutually opposing results was not new. If the target, instead of being one small, stationary piece of metal, was a large, rapidly spinning disc, then the effect of intense heat at the focal spot would be spread, much as the effect of a fast skater's weight is spread out along thin ice by his speed. The skater at high speed can cross ice which would instantly break under his weight if he were standing still. So radiologists had long recognized that an intensely hot focal spot could safely "skate" over a rapidly spinning tungsten surface that would quickly fuse under its heat if it were stationary.

The only difficulty had been how to do it.

Theoretically, all you had to do was to enclose an electric motor in a high-vacuum tube, and on the end of its shaft mount a disc of tungsten with its edge beveled at the same angle as the stationary anode. Spin a large enough disc at high enough speed, and your problem would be solved. Some years before, Philips of Holland, utilizing this well-known principle, had brought out the "Rotalix" tube, which was satisfactory within its designed limits. Those limits were kept low, to minimize heat, yet even so, the life of the tube was only a few thousand exposures before the rotating mechanism gave out.



In 1937 Machlett Laboratories set itself to the problem of producing a really practicable, high intensity, rotating anode tube with long life—small, compact, capable of being operated in any position in a shockproof, rayproof housing. In this there were innumerable difficult problems of detail. But two major problems—or groups of them—were most important:

1. To construct a bearing arrangement capable of operating at about 3600 r.p.m. at temperatures up to 1000°F, in any position, and *without the aid of conventional lubrication*. In a high vacuum all then-known lubricants would give off gases or vapors ruinous to the functioning of an x-ray tube—and into the bargain most of them would break down as lubricants under high heat.

2. To use a rotating tungsten target disc that did *not* require a heavy, massive copper backing to dissipate its heat. This in the interest of lightness for instant starting as well as of reliability. (Tungsten facing, bonded to copper massive enough to conduct away the great heat of high-power operation, would sometimes peel off under loading.)

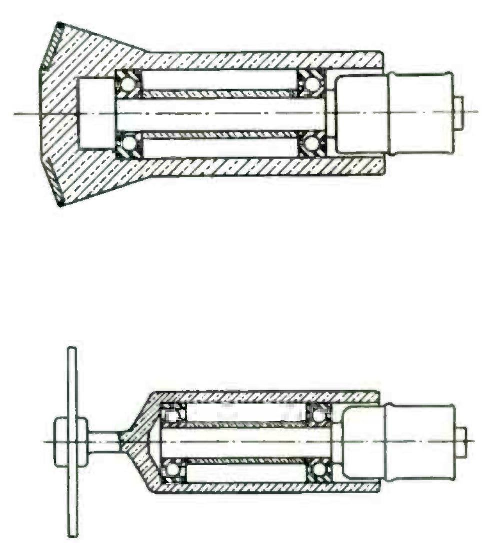
Other problems were less only in comparison. They included: the design of an induction motor of which the rotor would operate inside the tube under high vacuum and high temperature, and which could be degassed (also at high temperature) along with the other parts of the tube; problems of dynamic balance in all positions and at all temperatures; problems involved in wide temperature changes; problems of design for utmost compactness; problems of de-gassing and exhausting . . . and many others.

On one or another of these, practically every engineer and machinist at Machlett worked at one time or another, but the principal driving forces were Ray Machlett and Joe Skehan.

Of the two major problems, they came nearer to solving the second one first—the problem of getting heat away from the rotating anode. They solved it by dissipating heat, not by conduction, but by radiation. Fundamentally, they accomplished this by mounting the rotating disc on a thin stem of metal, through which relatively little of its heat escaped to the rotor and bearings, while most of the heat was backed up to seek its escape by radiation. In accordance with a well-known law of physics, the radiation efficiency of the disc was thereby increased with the "fourth power of the temperature." The hotter the disc got, the faster it tended to radiate away its heat. This basic principle, promisingly effective from the first, was improved step by step in its operation. Another important step came in 1942, worked out by Ray Machlett and Rogers: an improved design, of which the outstanding feature was a surface treatment of the rotor which housed the bearing so as to increase radiation of heat from it. This kept the bearing system cooler with still heavier thermal loadings of the target disc.

Meanwhile, practically everyone was working on the problem of a bearing that would work without conventional lubricants. It had to be a ball bearing, of course, and various forms of unlubricated ball bearings were hopefully tried—with results that were scientifically fascinating as to what happens to tool steel ball bearings

In early models, the rotating anode had a target backed with heavy copper (top). This arrangement gave trouble; the tungsten shell peeled away from the copper under severe heat. But a rotor of solid tungsten (bottom) could stand such severe overloading that its surface became molten without breaking down.



in a vacuum, but seemingly not at all helpful in the search for a successful bearing device.

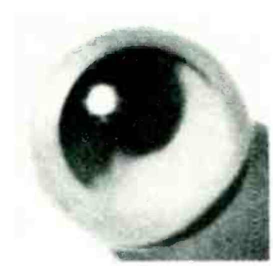
Finally, in 1938 George J. Agule, then a tube assembly superintendent, now one of Machlett's outstanding project engineers, came in with a suggestion that silver coating on steel bearing balls would act as a lubricant. They tried it, and were instantly rewarded with success. By October of that year Machlett had produced its first practicable rotating anode tube, christened it "Dynamax" and started testing its load-bearing capacity and its life.

These tests, however, showed that first methods of silvering bearing balls were not entirely satisfactory. Neither plating nor coating by tumbling produced a silver coat that would stand up in prolonged service of the order they wanted. Then in 1939 Agule came up with a suggestion based on a curious thing they had found while experimenting with uncoated steel balls: after being out-gassed in a vacuum, these balls developed an affinity for other metals. They tended to stick instead of rolling, and to pick up minute particles of other metals. This interesting phenomenon had ruled out unlubricated steel balls as bearings. But recollection of it suggested to Agule that perhaps it was the key to coating balls with silver: out-gas them and then mechanically apply a coating of silver which they would grip on account of the very phenomenal affinity that had earlier seemed so undesirable. Machlett promptly did this—and from that moment the problem of a lasting lubricant was licked. Microphotographs showed that balls silver-coated by the new process were glassy-smooth after hundreds of hours in operation.

George Agule (right) and Bill Fengler, both among the oldest and most valued Project Engineers, confer with each other on specifications for a Super-Dynamax tube.

(To be sure, the improvement of mechanisms to utilize these silver-coated ball bearings continued over a period of years, but the discovery of a successful method of coating them was second in importance only to the idea of using silver as a lubricant.)

The Dynamax tube appeared on the market in 1939. It embodied literally scores of ingeniously designed elements, such as the motor, which Machlett had had to work out in special form. It was housed in a rayproof, shockproof, oil-filled housing, sealed at the factory. By virtue of design and redesign over the long period of its development, it was light and compact—less than 16″ in length. Its manufacture involved many entirely new processes. Yet it was by far the most efficient tube for general radiographic and diagnostic use developed up to that time—capable of the highest instantaneous exposures for a long time in operation, on an extremely fine focus. And its life was to prove, in time, phenomenal. Whereas a life of 5,000 exposures had been considered a fair performance for fixed anode tubes of high rating, and a maximal life of 10,000 had been news, the rotating anode tube went so far beyond these limits that eventually it became commonplace to hear from delighted users that their tubes had exceeded 200,000 exposures.



Above: a steel ball bearing silver coated by the process worked out by Machlett, after 500 hours of continuous operation at intense heat in high vacuum shows no sign of wear or of breakdown in the lubricating coat of silver. Below: an uncoated steel ball bearing after the same test shows serious deterioration.

The Dynamax tube could hardly have appeared at a more propitious time than 1939. The profession welcomed it with enthusiasm and proceeded in the immediately ensuing years to apply it to new uses which seemed almost to have been awaiting this tube—to advanced work in angiography, serial spot filming and cinematography at 60 exposures per second, as well as to difficult tasks in the radiography of cranial, abdominal and other dense or heavy-section anatomical subjects. Hospitals, clinics and similar busy institutions found they could use it, if necessary, all day long for extended periods. Without any other help than the reputation the new tube gained in such circles, it would have made its way rapidly and far.

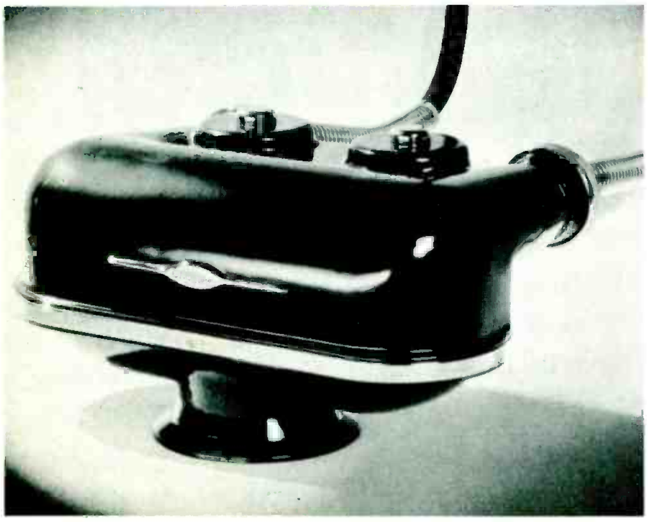
Yet beginning in the fall of that year there came an added demand for this—and all other Machlett x-ray tubes. War broke out in Europe. German tubes practically vanished from the world market. England and France began calling on the United States for x-ray tubes, both for civilian and armed forces needs. Machlett became the chief supplier of these countries. Within another year Holland was overrun by the Germans and English x-ray plants were threatened with obliteration by bombing. Business came to Machlett from all points of the world outside the limits of Axis conquest. And the United States itself, with war looming on the horizon, started equipping for combat and drafting an army. Each of these had a tremendous effect on Machlett x-ray tube operations—and as will be told, an even more profound effect in the applications of Machlett's experience and techniques to tubes for military communications and radar purposes.

Government requirements for the equipment of potential base and field hospitals alone were enough, when taken with the flood of business from abroad, to tax Machlett capacity and necessitate the building of new structures in 1941, adding substantially to floor space. But this was only the beginning.

As 1941 swept into 1942 and 1942 into war, the armed forces called in men by the millions. Each call meant a physical examination, including chest fluoroscopy—a mass operation, even when spread among scores of induction stations, involving tens of millions of examinations as fast as all the available physicians with radiological training could make them, working all day long and all through the greater part of five pre-war and war years. For this kind of sustained work the new rotating anode tube proved so far superior that the armed forces eventually used it in practically all installations where great numbers of men had to be examined.

This meant, of course, a further great surge in Machlett's production activity, undertaken gladly, not only as "new business" but also as a responsibility in the national interest. But it meant, too, quite incidentally, a great deal more to Machlett's future than to the company's immediate present. For the widespread use of the rotating anode tube both in mass physical examinations and in active service hospital use, served to acquaint literally thousands of physicians, temporarily in uniform, with the Dynamax, and so with Machlett x-ray tubes of all kinds.

But in effect this was only the first of two wartime introductions by which the emergency molded Machlett's future.



Early Dynamax model which appeared on the market in 1939 and was to prove the most efficient tube for general radiographic applications.

1 — Typical modern Dynamax rotating anode tubes.

2 — Rayproof linings are installed inside welded aluminum shockproof housings of x-ray tubes.

3 — Assembly of the Dynamax rotating anode x-ray tube requires skill and trained judgment of a high order.

4 — Completed, inspected and tested rotor assemblies for the Dynamax tube are sealed into their glass envelopes by expert workers.

5 — The final seal-in of the Dynamax tube requires a combination of precise machine tool equipment with the experienced craftsman's skill.

6 — The Dynamax tube insert is assembled to its supporting parts, preparatory to being installed in its shockproof housing.

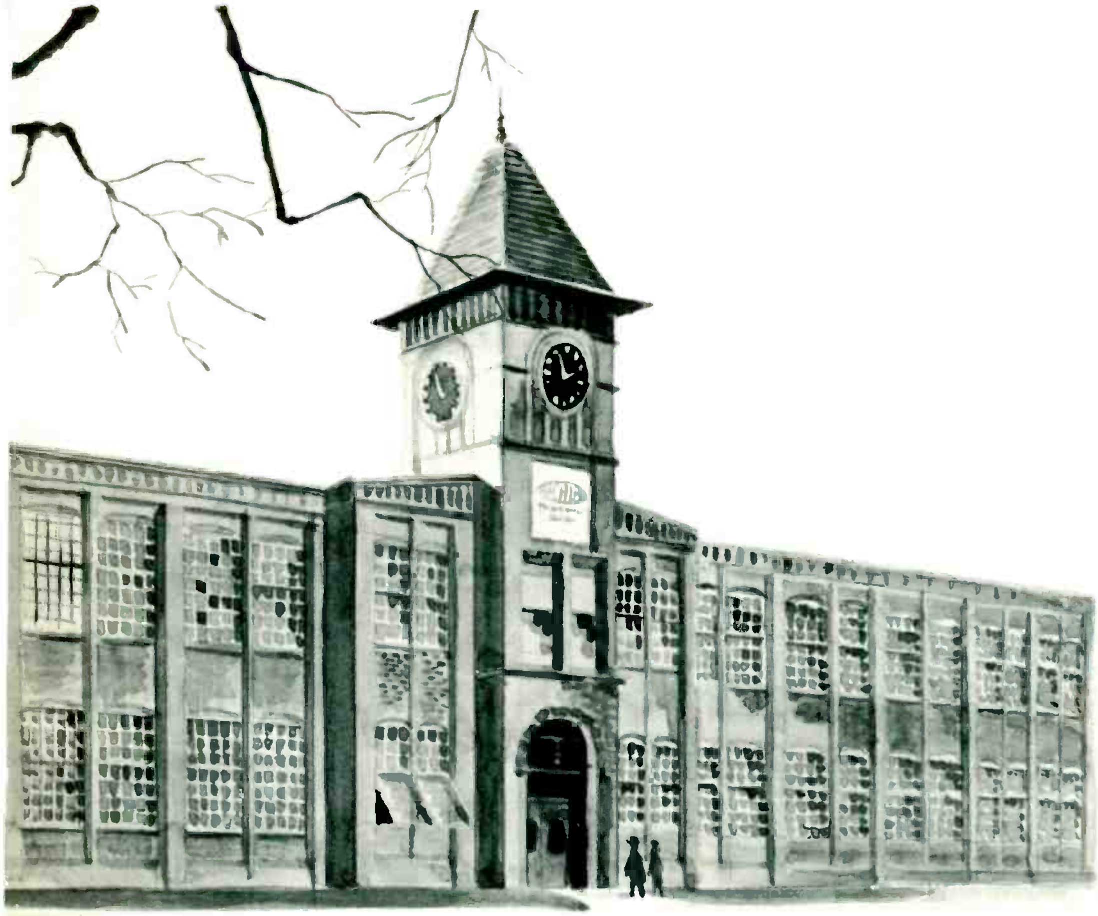
7 — Here Dynamax inserts are being assembled ready to go into shockproof housings like the one the two men are working on.

The Willing--
and Ready--
Conscript

AT THE start of World War II Machlett Laboratories was suddenly and of necessity—but willingly—drawn into the making of a whole class of tubes new to its experience: electron tubes for radar, radio broadcasting, radio communication and allied uses. Such tubes, broadly termed "power tubes" to distinguish them from x-ray tubes, became for a time the biggest part of Machlett's operation. And they remain today a substantial and growing half of the company's business.

The story really begins years before a second world war loomed on the horizon.

From its start in 1931, the company had made valve or rectifier tubes of a type not greatly different from those required in broadcasting. But, more to the point, it had built those tubes to the same standards as its x-ray tubes. Since x-ray tubes normally operate at voltages far in excess of power tubes, making them had always—and increasingly—meant unusually faultless vacuum: high



vacuum both quantitatively as expressed in millimeters of mercury and qualitatively as expressed in perfect cleanliness and extremes of out-gassing. And to maintain such a vacuum x-ray tubes had to be far more precisely and flawlessly built. High voltage requirements had also necessitated a precision of alignment and positioning of elements in the x-ray tube far beyond that needed for satisfactory operation of the power tubes of those days. To make tubes to such standards took specially developed equipment and procedures, painfully-acquired know-how, and implicit acceptance of a rigid code of perfection by everybody from top to bottom of the organization.

These factors, as much as leadership in design progress, had earned Machlett an enviable reputation among users of x-ray tubes. But that reputation did more than establish Machlett firmly in the x-ray field; it led, in a curious but very direct way, to Machlett's entry into the power tube field:

In the mid-1930's Westinghouse, which had gone into making both x-ray equipment and x-ray tubes about 1931, was seeking—like Machlett and everybody else—to improve its tubes both in design and quality. Its field representatives kept reporting to headquarters the glowing comments of users of Machlett tubes. And headquarters executives—after the manner of executives everywhere—kept crisply relaying these comments to Henry J. Hoffman, head of the division that made Westinghouse x-ray tubes at Bloomfield, N. J. Hoffman, a trained electronics engineer and a manufacturing executive of considerable experience, knew that in making any kind of tube all the backing and resources in the world cannot take the place of the thousand-and-one intangibles of know-how accumulated over the years by a successful manufacturer. So with the approval of his superiors, he gathered up his two principal engineering and manufacturing managers and went to Springdale to visit Ray Machlett.

He had heard of Machlett, of course—everybody in the industry had—but had never met him. Accordingly he was bowled off his feet by the warmth of his reception and the freedom with which Ray Machlett took him and his associates through the plant and answered any and all questions without reserve. The Westinghouse men went back to Bloomfield with full notebooks, a swarm of ideas and a profound awe for Machlett Laboratories' procedures—particularly those of cleanliness, thoroughness in achieving a vacuum and unremitting precision in fabrication.

For a time the only tangible return Westinghouse could make was limited to the purchase from Machlett of several types of valve tube to supplement its own line. (In this industry, as in many others, the leading concerns follow this practice. Today Machlett supplies certain tubes to its friendly competitors and buys other types from them.) In the course of these transactions the acquaintanceship between Hoffman, Ray Machlett, Stevenson and Skehan ripened into a cordial friendship.

Then in 1939 Westinghouse was presented with an opportunity to show its appreciation on a very substantial scale. The company got, among its rapidly growing defense assignments, an order to produce a large quantity of an external-anode rectifier tube that Westinghouse had designed. Quantity and time factors indicated sub-contracting. So Hoffman called Ray Machlett to inquire if he wanted to try his hand at such a tube—in quantity. The answer was, characteristically, "Why not?"—and Machlett Laboratories found itself with the largest single order it had ever received from anybody.

Volume-wise it was no small job to produce tubes by the thousands where before hundreds had been large lots. But qualitatively it was no problem at all; Machlett simply turned out a rectifier tube to its x-ray tube standards.

Results filtered back in the form of many reports from technicians of the military services—all to the effect that this run of tube performed far beyond expectation or requirement.

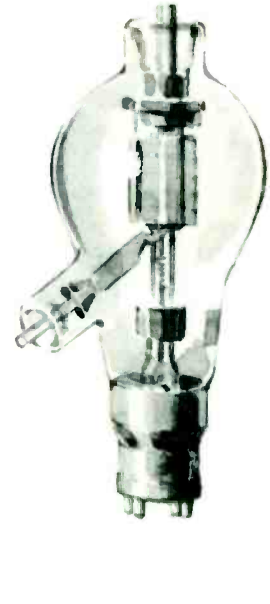
So in 1941, when Westinghouse was presented with a staggering order for equipment and tubes urgently required in early-warning radar installations, there was one obvious place to turn for sub-contract help. The order was of exceptional size—and required the production of many thousands of a special triode modulator known as 6C21. Specifications were exacting; among other requirements was that of absolute uniformity with similar tubes made by G-E and Eimac. Westinghouse immediately started building a special plant to make as many of the 6C21 as it could. And once again Hoffman called in Machlett—this time with an urgent invitation to take up some 40% of the task.

Ray Machlett was more than willing, but at a loss to know how to begin on an assignment so far beyond any capacity of the Springdale plant. Hoffman, who had had some experience with the Defense Plant Corporation, set him on the right track and almost before you could say "triode modulator" Machlett had leased the greater part of a vacant hat factory ten miles away in Norwalk, Connecticut.

The structure had to be practically rebuilt inside—for cleanliness as well as for straight-line production. New equipment had to be set up—much of it designed and built from scratch. A cadre of experienced Machlett operatives had to be trained not merely in making the new kind of tube but in teaching others to make it and in directing them at work. It was a job to challenge every resource of management, of production engineering and of personnel direction.

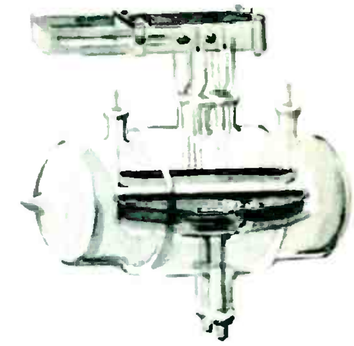
Here Ray Machlett's unusual gifts found full expression: his versatility;

VT-141 high voltage rectifier for early-warning radar sets was another tube made in great quantities by Machlett during World War II.



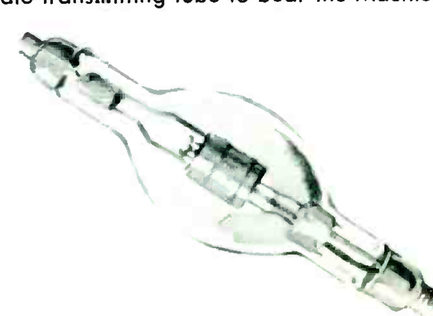
The 6C21 pulse modulator tube, heart of the transmitter in early-warning and gun-laying radar systems, was Machlett's first big assignment in defense production work.

In the modern form of the straight-line exhaust system, tubes are mounted on moving dollies equipped with mechanical and diffusion pumps which keep the tubes under continuous high vacuum as they progress through the final stages of exhaust and seal-off.



The VT 158 tube, made to Signal Corps designs as a compact, light source of UHF energy for a portable radar system was a complex assembly in a glass envelope of unusual shape. Yet Machlett Laboratories trained people, previously untrained in assembly or in glass-blowing, to make this difficult tube in large quantities.

The ML 880 tube was made during the war at Norwalk for the armed forces which used it as a transmitter tube for overseas radio communications and for high power radar jamming. Later it became the cornerstone in the development of Machlett's power tube line—the first high-power radio transmitting tube to bear the Machlett name.



A high-vacuum rectifier made for the British Air Ministry during the war, the VU 504 was extensively used in British radar installations.

his instant perception of the essentials of any problems, however new; his combination of a layman's mastery of engineering with an engineer's mastery of management; his untiring vitality . . .

He had, of course, invaluable assistance: Skehan, willing and able to tackle anything technical; Stevenson, equally resourceful in management; and a considerable staff of highly skilled engineers and managers. Of these, two rate special mention, though all deserve it:

Miles Pennybacker, a veteran of Rainbow days, became General Manager of the Norwalk Power Tube Division. He had great capacity for management, especially in improvising measures to meet new situations, and in quickly creating an organization out of new people.

H. Sherwood Cooke (whose arrival among the earliest of Machlett's engineers has already been noted) was assigned the task of developing all plans and specifying or designing all equipment for the Norwalk plant —in a hurry. Perhaps it might be sufficient to say that the factory—of which he became Chief Engineer on its completion in November 1942—proved adequate to handle not only the enormous initial undertaking of the 6C21 tube but the later production of upward of a dozen other comparable power tubes, all in considerable quantity and all of extremely exacting type. That statement alone implies prodigies of foresight, of ingenuity and of able management. But one particular contribution of Cooke's needs special description for two reasons: it was a vitally important factor in the efficiency of the Norwalk Power Tube Division and it is today an equally vital part of Machlett Laboratories' production of all tubes, both x-ray and power.

This was the mobile exhaust system, together with its patented equipment. Until this invention of Cooke's, tubes had to stay in one place—right on or near the pump—while they were processed for out-gassing and related procedures, and for final sealing-off. Thus, any thorough processing of tubes under vacuum was an expensive and time-consuming operation. In the mobile exhaust system, tubes previously exhausted for preliminary processing are mounted on wheeled vacuum pumps—that is, on moving dollies each of which carries a high-power, high-efficiency vacuum pump, capable of exhausting the tube to a vacuum of 10^{-7} millimeters of mercury. When this high vacuum has been reached, the whole business—tubes, dolly and all—moves through the successive furnaces and other processing stations with the pumps continuously at work, maintaining the vacuum and drawing out any vestigial gases liberated by heat, external or internal, with the tube operating under a power overload. So the tube moves right up to its final sealing-off under the maximum operationally-obtainable vacuum.

Cooke devised this system not merely to expedite the processing of tubes that had to be produced in quantity, but to produce them to the high-vacuum and high-purity standards that Machlett had always maintained in x-ray tubes. Significantly, these standards had always been maintained above those stipulated, even in government specifications. So far beyond even the best power-tube requirements are those for making a really first-class x-ray tube that Machlett was in one sense coming down in the world rather than up, in making the supposedly difficult triode for Westinghouse sub-contract and the other, militarily essential tubes that followed it.

H. S. Cooke, inventor of Machlett's mobile exhaust system, and now Manager of X-ray Sales, talks over new Dynapulse tube with Design Engineer Gordon Bavor. The Dynapulse is a fast-action switch tube for use with high-speed radiographic tubes.

Of course not even the most ingenious and efficient equipment could have met the challenge of the 6C21 tube if it had not been for people. Eventually Machlett had 800 of them in Norwalk—largely women and girls and practically all of them from the regional area. These people—twice as many as had ever worked for Machlett before—had to learn difficult arts, such as glass blowing, and to master techniques of extreme accuracy. To teach them and to lead them when they had learned, was the job of a cadre of some 50 of Springdale's best people. While none of these had had any prior experience with triodes, there is a great deal less difference than the layman might expect between such tubes and the x-ray and valve tubes to which Springdale people were accustomed. Especially, there was no change in the stringency of the company's requirements for conscientious, skillful and thorough work on its power tube line.

It speaks volumes for the teamwork planners, managers, engineers, supervisors and operators, both new and old, that Machlett got into qualification-approved production on the 6C21 before any of the larger firms concerned in the contract. And it speaks a whole library that the performance of this tube in service gained Machlett a reputation among Signal Corps and other service electronics engineers that lasts to this day.

As a natural consequence, contracts for other tubes followed. These included rectifiers, hydrogen thyratrons and triodes for a wide variety of uses. Many of the most spectacular successes of radar in target detection, in identification and in fire control were achieved with sets designed around tubes of types made at Norwalk. At the outset, of course, these were tubes in which Machlett's function was strictly that of a manufacturer, not a contributor to design. But since design is to some extent a function of manufacturing requirements, Machlett engineers entered more and more into this phase, in consultation with Signal Corps engineers and with civilian scientists in government service at such installations as the Radiation Laboratory at Massachusetts Institute of Technology. And in at least one instance—a rectifier of unique construction and exceptionally low loss—Machlett was able to make a substantial contribution of its own. Large numbers of this tube were used in the atomic energy program. In this, as in many other government research projects large and small, Machlett engineers necessarily had to share secrets of the gravest import. Such work, with the contacts it established among leading scientists in government service and in advanced research centers like M.I.T., was destined to have a profound effect on Machlett Laboratories' later development.

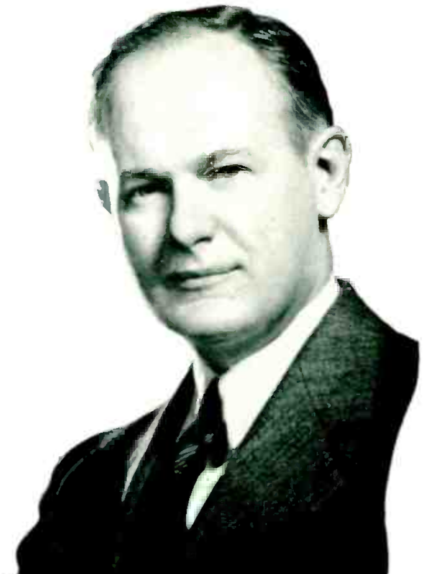
For example, in 1943 Dr. John G. Trump, of M.I.T.'s Radiation Laboratory and at that time Secretary of the Micro-wave Committee of the Office of Scientific Research and Development, was working on the problem of a high-power magnetron. The magnetron, a British invention, is a type of transmitter tube specially designed for micro-wave-frequency work at the very high powers needed in pin-point accuracy radar installations. Trump was hopeful of developing a magnetron capable of working at a peak of 5 to 10 million watts (as compared with the 2 megawatts already achieved in megatrons. In this work several of the largest companies in the U. S. electronics industry were cooperating. Dr. Trump knew of Machlett Laboratories through his associate, Dr. R. J. Van de Graaff, who had worked with Ray Machlett, Skehan and their organization on another extremely important wartime undertaking (which we shall examine presently) that involved very high voltages and very difficult manufacturing problems. He invited Machlett to join in this work. It was the beginning of a remarkable association.

Trump, an advanced scientist, found in Ray Machlett a degree of quick, intuitive understanding utterly surprising in one who—academically—barely qualified as a scientist at all. (Surprising to Trump, that is, though it would hardly have surprised Edmonds the lawyer or Stevenson the sales engineer or Lambert the treasurer or any of the factory craftsmen and others who knew Ray Machlett's gift for comprehending the other man's specialty almost as though he too had spent a lifetime at it.)

Trump found, moreover, a thing that had already impressed Van de Graaff and other scientists accustomed to dealing with industrialists on behalf of the government's research projects: an enthusiasm and willingness to enter whole-heartedly into a new undertaking that was unusual among industrial executives. They are always an overburdened class of men and in wartime they were so hard-driven that few of them could spare a great deal of time—much less enthusiasm—for any one scientific project. Ray Machlett had, somehow, the ability to be as interested in each of several entirely different vital activities as though it were the only thing in his life. A warm and intimate friendship grew up between these two, as it had between Ray Machlett and so many other men of such widely different kinds.

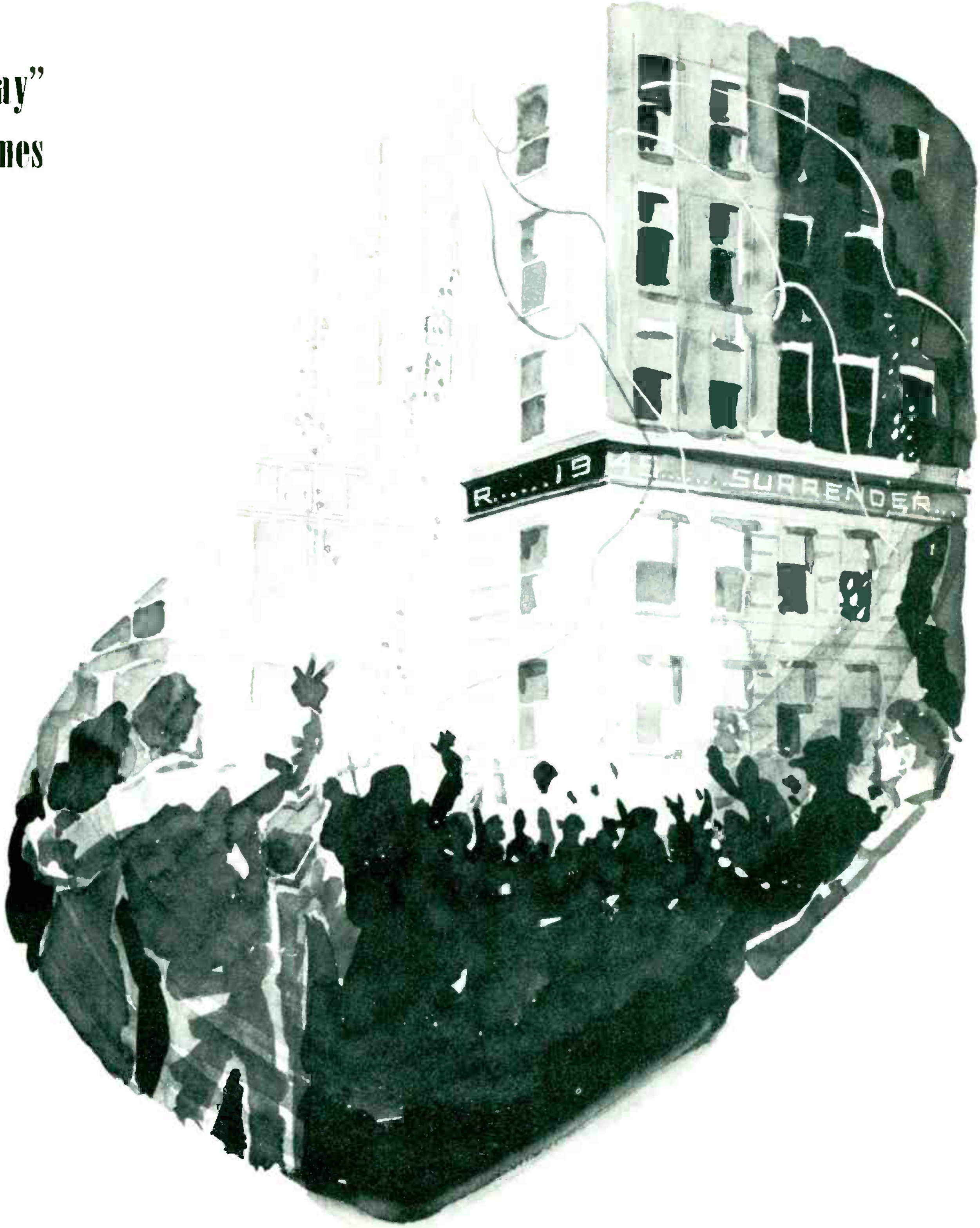
The magnetron project was not finished by the war's end (indeed, the magnetron is still in process of perfection by laboratories in advanced electronics here and abroad). But it, with other high-voltage, high-frequency tubes for wartime communications and allied uses, gave Machlett invaluable experience and certain ideas that are today basic in the company's power tube operation. Ever-higher frequencies mean ever-smaller distances between the plate, grid and filament of a tube; high powers mean large dimensions in those elements; as frequencies and powers increase, dimensional tolerances decrease—in the elements themselves and in the spacing between elements. And every other characteristic of a tube becomes more and more critical: the quality of its vacuum, the perfection of its metal-to-glass seals, the purity of its elements, the completeness of its out-gassing, the strength of its envelope and of elements in it, not only against shock but against electrostatic tensions and heat. . . .

In such things Machlett wartime experience with communications and power tubes was an intensive education. Along with it there were innumerable minor problems in the handling of special glasses and difficult metals, in putting together intricate and precise assemblies, in processes and procedures. Yet nothing in the power tube operation involved problems of a new order. They were simply problems on the same high level of standards where Machlett Laboratories had been operating as a matter of course for many years in the making of x-ray tubes.



Dr. John G. Trump who became a friend of Ray Machlett's and Machlett Laboratories' in 1943 through collaboration on the problem of high power magnetron; is today one of the company's directors as well as an active and valued consultant in the field of advanced electronics.

The X in "X-Ray" Becomes X^n



WHILE all this had been taking place in Machlett's Norwalk Power Tube Division, the Springdale plant had been equally busy with a vastly stepped-up program in the production of x-ray tubes. Not only was there a tremendous demand for diagnostic and therapy tubes for military and civilian uses, but the needs of industry had greatly increased the use of x-ray tubes for the examination of munitions and other manufactured products in process. Non-destructive testing had long been among the uses of radiography, and equipment for it used several types of Machlett tube. Now industry wanted x-ray tubes with certain characteristics especially useful in the examination of other-than biological substances. Machlett Laboratories did much work along this line during the war, and produced two tubes which were altogether remarkable.

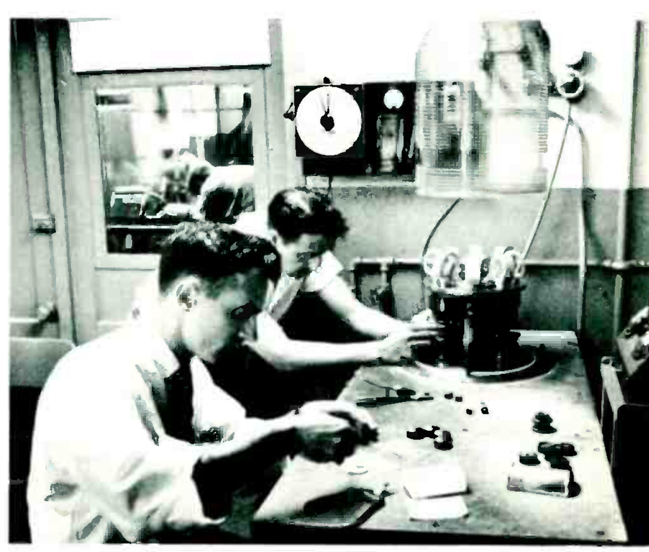
One was a tube with a beryllium window. Beryllium, with the lowest atomic weight of all stable metals, is the most transparent to x-rays. Thus it was recognized as an ideal material of which to make a window in a tube, to pass x-rays, especially those of relatively greater wave length (i.e. lower penetration). But beryllium was an exceedingly difficult, brittle metal to work—and incapable of being rolled into thin sheets or machined satisfactorily. Nobody knew how to make a thin, strong beryllium window. The metal was extensively used in the making of fluorescent lamps and as an alloy for other metals. But metallurgists were still seeking ways to make it malleable in itself. Among companies most determined to solve the problem was Machlett Laboratories.

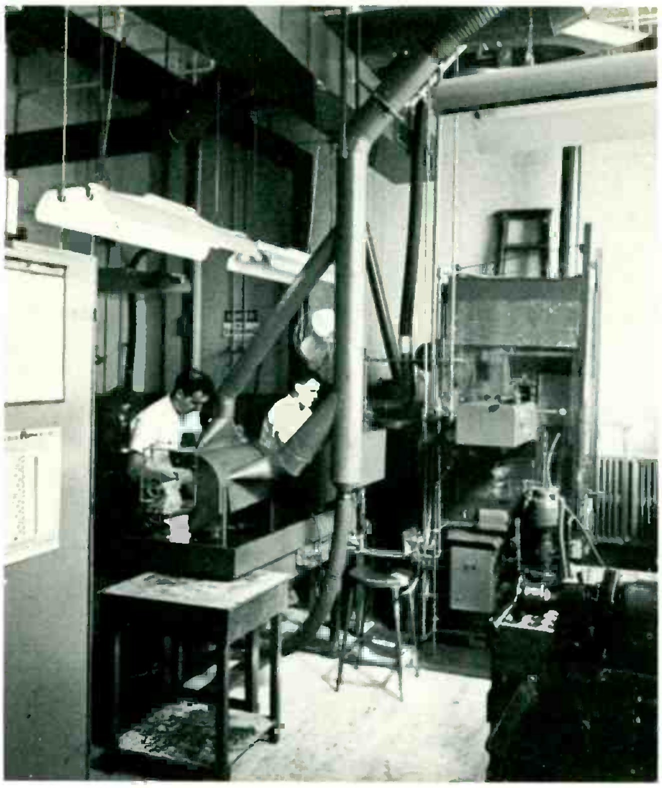
Machlett succeeded, in large measure, as early as 1942, though at an unforeseeable price. G. E. Claussen, metallurgist, working with Skehan, started with an adaptation of Machlett's induction casting in vacuum, and alloyed the molten beryllium with minute quantities of titanium. This process resulted in a metal which could be hot-rolled to .020″ thickness. In this form it made exceedingly efficient vacuum tight windows for long-wave-length x-rays. Machlett metallurgists were also able to solve certain puzzling difficulties of setting these windows into x-ray tubes. Many tubes of this construction found use in vital wartime industries.

It was not until years later that American industry, including Machlett Laboratories, had its first intimation that beryllium processing can produce altogether unsuspected cumulative pulmonary effects on workers unless it is safeguarded by very special precautionary measures. Until 1947 neither ordinary observation nor experience had indicated anything hazardous in the atmosphere where beryllium was worked. But in that year some 400 cases of beryllium poisoning were discovered in the United States. Most of them were in ore processing and fluorescent lamp manufacture, but a few were in industries using beryllium as a metal. Some of these, including one at Machlett, proved fatal. Elaborate precautionary measures were taken at once: all beryllium-working operations were segregated in a room with many protective devices, including thorough and separate exhaust ventilating equipment for the room and for each machine in it. Present day beryllium working is as safe as the working of countless other substances that industry uses day in and day out with appropriate safeguards.

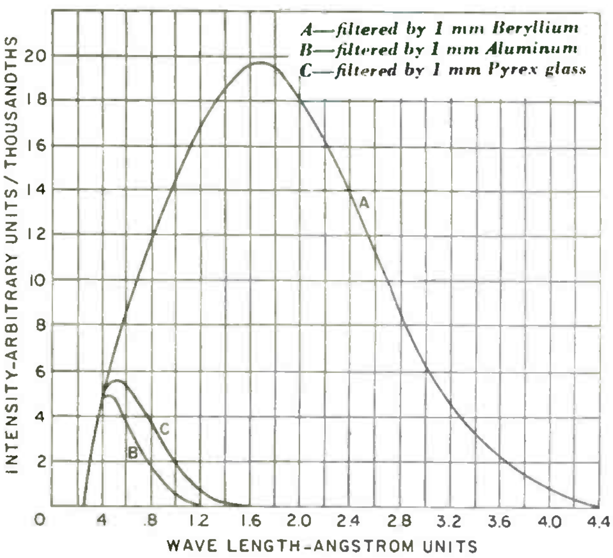
When it became certain that tubes with thin

One of the most critical and important operations in the making of a beryllium-window tube is the sealing of the window itself into the envelope of the tube.





In modern beryllium processing every operation is surrounded with every possible safeguard. Here in this closed, air conditioned room, special suction tubes, like giant vacuum cleaners, draw every particle of dust away from every point where the metal is worked.



Beryllium transmits a far greater intensity of x-radiation at longer wave-lengths than other practicable materials. Curve A shows intensity transmitted by 1 mm. thickness of Beryllium. Curve B, 1 mm. of Aluminum; Curve C, 1 mm. of Pyrex Glass.

beryllium windows could be manufactured, Rogers worked out, by painstaking mathematical analysis based on underlying physical considerations, the characteristics and properties of radiation obtainable from such tubes—factors which could not be adequately measured with instrumentation available at that time. He made these findings available to his good friend Prof. G. L. Clark, prominent x-ray scientist at the University of Illinois, who made the first public announcement of them in an address on the 50th anniversary of Roentgen's discovery of x-rays, predicting many of the extremely valuable applications that have since come to pass. His appraisal was based on the indicated quantitative and qualitative properties of x-radiation through beryllium, as calculated by Rogers. Rogers subsequently published his calculations, together with numerous applications, predicted and actual, based on them, in a series of technical articles which have become the basis for an ever-widening field of uses for the thin-beryllium window x-ray tube.

In medicine the beryllium window tube is widely used for certain work in radiography, fluoroscopy and superficial therapy where no other x-ray tube will do as well. In medical research it has played important parts in microradiography and historadiography, in genetics, bacteriology, pathology and many other fields of investigation. In the physical and chemical sciences (which serve medicine, too) it is important in chemical analysis, photochemical research, metallurgy and crystallography, to name only a few of its applications.

THE second major field of x-ray development in which Machlett played a vital part was also directly connected with the non-destructive examination of materials—but far more searchingly and at the time far more imperatively. Like the beryllium window, this contributed, in time, to even more valuable results in medical and allied sciences. Technologically it was a more difficult problem. And happily, it was one in which the dangers were all well known and could be avoided. This was the development of the first 2-million-volt "super x-ray" tube using the constant potential linear accelerator principle.

During the immediate pre-war years when the United States was rushing an extensive program of naval, air and ground rearmament, ordnance and construction engineers of all the services called for x-ray tubes of unprecedented penetration for the radiographic examination of massive metal pieces: armor plates, sternpost castings and forgings for ships of war, welded frames, big-calibre guns—all pieces in which freedom from flaws was a matter of life and death and perhaps of victory or defeat.

Some of these pieces were so big that no known x-rays would penetrate them; others could be x-rayed only by exposures unduly long for a time of emergency. Then, when war broke there were calls of the utmost urgency for x-ray equipment to examine the mechanisms of captured enemy munitions—such as shells, bombs or mines—deadly gadget-puzzles that had to be solved quickly, yet could not safely be taken apart by guesswork.

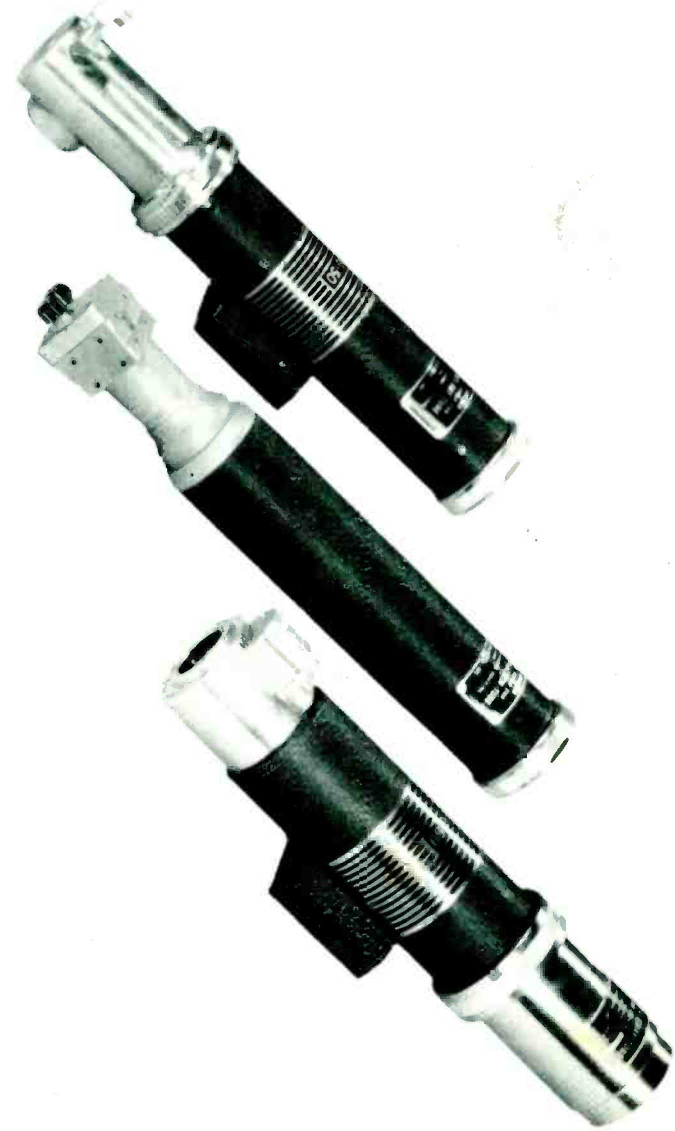
To work out x-ray equipment for such purposes the Office of Scientific Research and Development of the National Defense Research Committee called in Dr. R. J. Van de Graaff of M.I.T., a scientist already famous as inventor of the Van de Graaff electrostatic generator—one of the most important tools of research in the electrical, electronic and allied fields (including nucleonics) of recent years. Briefly, the Van de Graaff generator is a relatively simple device capable of generating a constant electrical potential of millions of volts.

Now high voltage is one—but only one—factor in creating x-rays of high penetrating power. The higher the voltage, the greater the speed at which electrons are shot from cathode to anode. And the greater this speed, the greater the penetrating power of the x-rays shot from the anode. But there is an upper limit to the electron-speed which can practically be achieved by the use of high voltage alone.

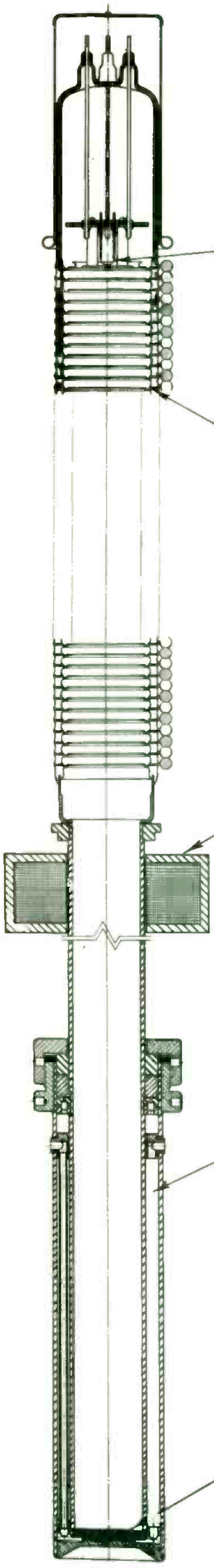
Quite early, various inventors had devised ways to accelerate electrons in flight by giving them a series of pushes. The idea was in a way analogous to the acceleration of the German "buzz bomb" or any other rocket type of projectile—except, of course, that the electrons could not carry their own flutter jet engines. The series of accelerating pushes was supplied by a succession of electric fields through which the electrons passed.

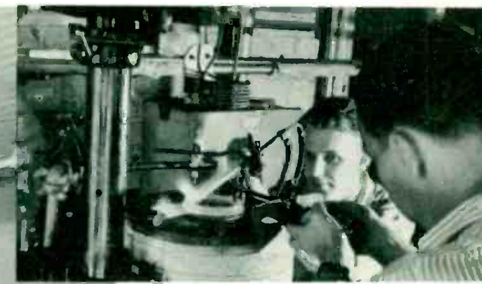
One such device had been worked out about 1913 by Lilienfeld, the German friend of Robert H. Machlett and inventor of the Deflex tube which Ray Machlett briefly manufactured. His x-ray tube embraced the principle of acceleration of electrons toward the anode through a series of charged metal rings. It chanced to appear at about the same time as the Coolidge hot cathode tube, which proved more efficient for production of x-rays of the intensities needed at that time. Another line- or column-accelerating device for use with x-rays was later patented by Coolidge himself. But until the necessities of World War II, no x-ray tube had required the acceleration which Van de Graaff now proposed to utilize.

The basic principles were well enough understood. Potentials on the order of 2 million volts were not too difficult to achieve. But an x-ray tube to put this high voltage to work was an entirely new problem. As conceived by Van de Graaff, it must shoot an accelerated



Typical beryllium-window x-ray tubes of the present day. Upper and lower tubes (Types OE6-50 and OE6-60) are oil-immersed, hermetically sealed, shockproof tubes for medical, research, and industrial uses. Middle tube (Type A-2) is a type expressly made for crystal analysis and other applications of x-ray diffraction phenomena.





It was a task of unprecedented difficulty to make a long column of glass-to-metal seals, every one perfect.

Ray Machlett was rightly proud of his company's achieving the hitherto-impossible through new techniques.

Schematic cross-section of the two-million-volt x-ray tube. Electrons are shot downward, accelerated in flight through the column, and produce x-rays when they hit the gold target at the foot of the tube.

stream of electrons along a precisely controlled straight path, at and through an exceptionally rugged target, producing x-rays in passage. It must embody a 57″ precisely aligned column made of 180 alternating metal and glass rings, each accurately sealed to its neighbors with a seal that would stand the extremely high vacuum of 10^{-6} mm. of mercury, not merely in atmospheric pressure, but inside a generator casing filled with gas at a pressure of at least 200 lb. per square inch. (There were plenty of other difficult requirements, too, but space forbids mentioning them all.)

It was right after Pearl Harbor that Van de Graaff started several experimental operations to seek these results. Two projects undertaken at M.I.T. laboratories involved glass-to-metal bonds, made with plastic or lead-and-plastic seals. The third he commissioned to Machlett Laboratories in the hope that they could work out a successful tube sealed-off with Kovar-to-glass sealing, for which they were well known. They did, while M.I.T.'s laboratories were still trying to overcome other difficulties. But it was a long, tough job.

"I knew Machlett Laboratories were the largest and most successful makers of x-ray tubes in the world," says Van de Graaff, "and I had heard a lot about Ray Machlett, though I had never met him. I called him one afternoon from a phone in the NDRC office, and the next morning he and Skehan were right on my doorstep. But what impressed me was not this promptness—common enough among wartime industrialists—but the wholehearted way in which they tackled this problem when they had so much else on their minds. Perhaps only a small concern would have done as much, certainly nobody could have done more. They were in the project from the start of design discussions and stayed to the finish through innumerable practical difficulties, discouragements and triumphs."

The biggest single problem was that of getting 180 perfect seals of 3" diameter metal and glass rings. With old techniques perhaps 4 or 5 seals in every 100 might prove less than perfect. So the chances against getting 180 perfect seals in succession were astronomically high. New and failure-proof techniques had to be developed. These involved such things as combined gas and electric induction heating, and sealing with carbon forming tools on a specially built vertical lathe which fed the finished sections (still on the lathe mandrel) right into an electrically heated annealing furnace. And much else beside that involved starting all over again a dozen times, to overcome difficulties in production or in operation, before the first 2-million-volt tube was finished for testing at M.I.T. and for use at a naval ordnance installation.

Machlett made five of these tubes in all. "I do not believe," says Van de Graaff, "that anyone, even at Machlett Laboratories, realized how important those were to the nation in its prosecution of a war."

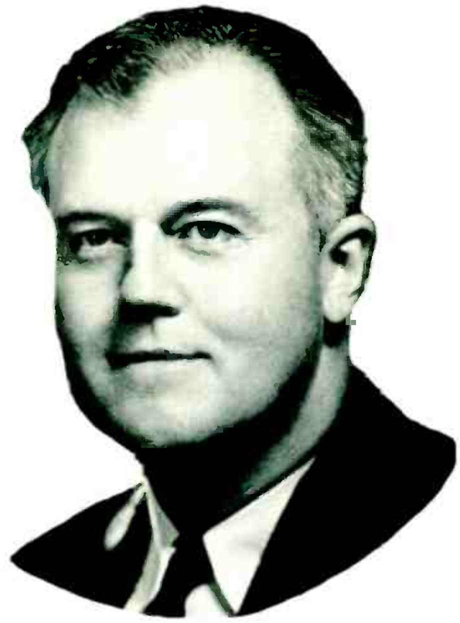
"With one of these 2-million-volt accelerator type x-ray tubes naval ordnance was able to x-ray great steel pieces of armor plate some 14" thick—in a matter of mere hours—something you couldn't have done previously if you had been able to combine all the x-rays in all the years since Roentgen, plus all the radium ever used for radiography." In effect, the "X" in "X-ray" had been increased by an exponential factor, to what might be called "X^n."

"These tubes played an important part in discovering the hidden 'bugs' in torpedo design that had caused an appallingly high percentage of 'failure to explode' in the early days of the war. They saved great ships and lives by the thousand, in spotting defective castings or frames or shafts before those ships were ever launched, and in locating damage to ships that had come in from combat. They solved the mysteries of enemy mines, bombs and shells. And much else. . . . All of this they did quickly and faultlessly. Just recently I heard that the very first one is working admirably at the Bremerton Navy Yard, out on the coast."

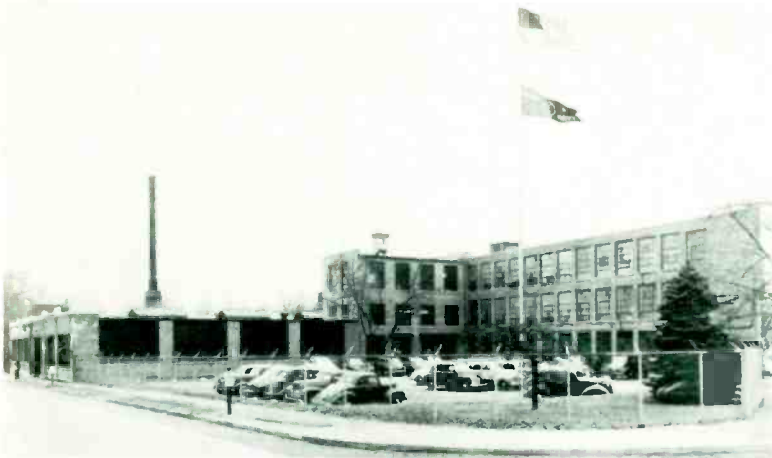
"And you might add," says Dr. Van de Graaff, "that Machlett built them at a very substantial net loss to itself, running well up into five figures."

That is true enough in a way. But two things should be said: First, if Machlett had chosen to continue after the war in making this type of tube, the expense of development might well have been regained in time. It is that way with most major products that take long to work out. For various reasons, however, Machlett chose to leave this type of tube to concerns specializing in this particular field, of which the leader today is the High Voltage Engineering Corporation of Cambridge, Mass.—the post-war enterprise of Drs. Trump and Van de Graaff. (HVEC tubes of similar design are now performing incalculably valuable service in deep therapy, both at M.I.T.'s Radiation Laboratory and at large hospitals and clinics all across the nation.)

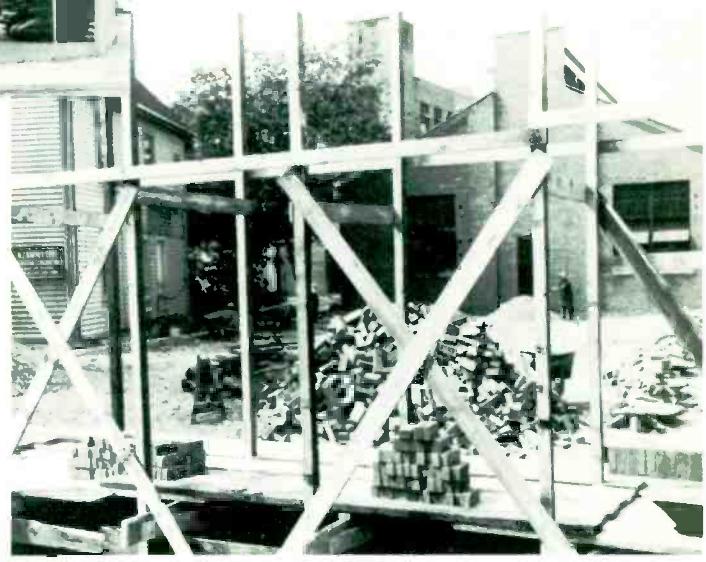
Second, in a business of this type, everything you learn in developing

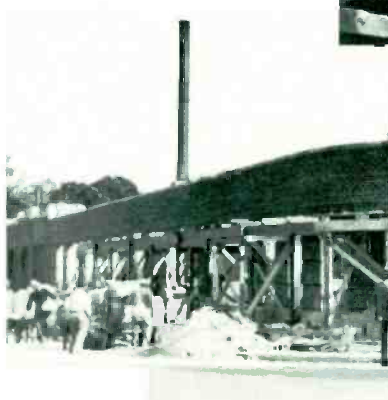


Dr. R. J. Van de Graaff, inventor of the high voltage generator that bears his name, was a prime mover in the development by Machlett of the two-million-volt x-ray tube.



The plant as it looked before urgently-needed new construction was undertaken in 1944.





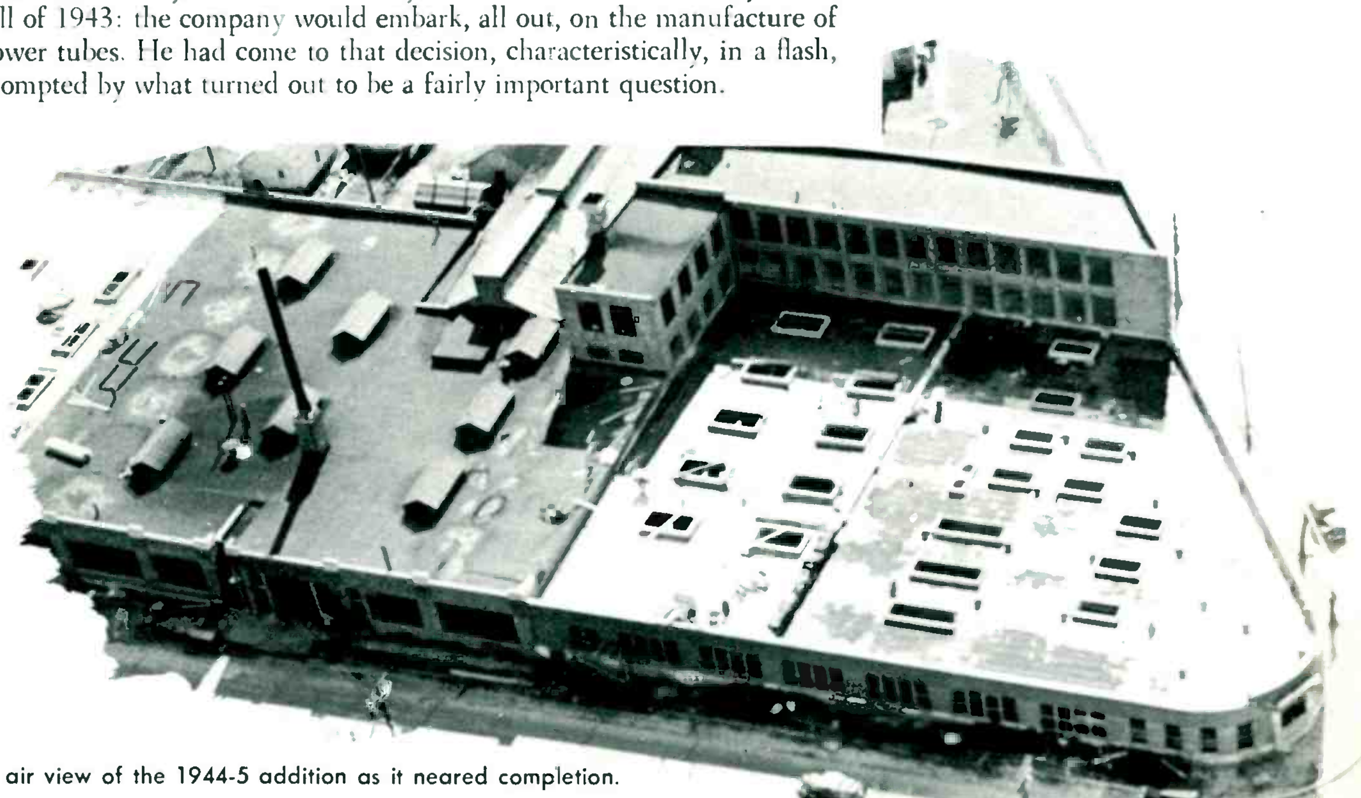
On October 4, 1945, Ray Machlett placed in the cornerstone of the new building a "time capsule" containing a Machlett tube, catalogs, letters of commendation from government authorities, and issues of Cathode Press.

one difficult product has some application in making other products better. There may be little apparent similarity between a 2-million-volt column accelerator type x-ray tube and a big triode for high power communications or industrial use, but experience shows that the latter are inevitably better for the lessons learned in making the first successful super-voltage x-ray tubes.

All these activities had, of course, taxed the capacity of the Springdale plant to the limit. By 1944 enlargement was imperative in the sheer interest of service to national defense. Some 650 people were working at Springdale on the x-ray tube program, and they urgently needed more room. So in that year construction was started on three additions which, when the last of them was completed in 1945, nearly doubled existing floor space. Of these, the most important was that on the corner lot which now, with its main entrance and offices, presents Machlett's face to the visitor. It was barely approaching completion when the war ended in 1945.

Even before that the government had been able to start terminating contracts for all types of war equipment—including x-ray and power tubes. In both these fields, however, there was still much work that must be carried on. Less, of course, than would require two whole plants, but probably enough in total to fill the newly enlarged Springdale plant. And certainly, in a future of which they were confident, enough to make them want to keep on the payroll as many as possible of the good people who had come to work in both plants during the emergency. There were many people, naturally, who wanted to stop working, once the emergency was over. But there were many others who had showed a serious interest in electron tube making and a fine aptitude for that exacting work. Machlett kept the Norwalk people busy ("by the skin of our teeth," as Crabb recalls, reminiscently) until October, when all operations were concentrated at Springdale.

Behind this lay a decision that Ray Machlett had taken as early as the fall of 1943: the company would embark, all out, on the manufacture of power tubes. He had come to that decision, characteristically, in a flash, prompted by what turned out to be a fairly important question.



An air view of the 1944-5 addition as it neared completion.

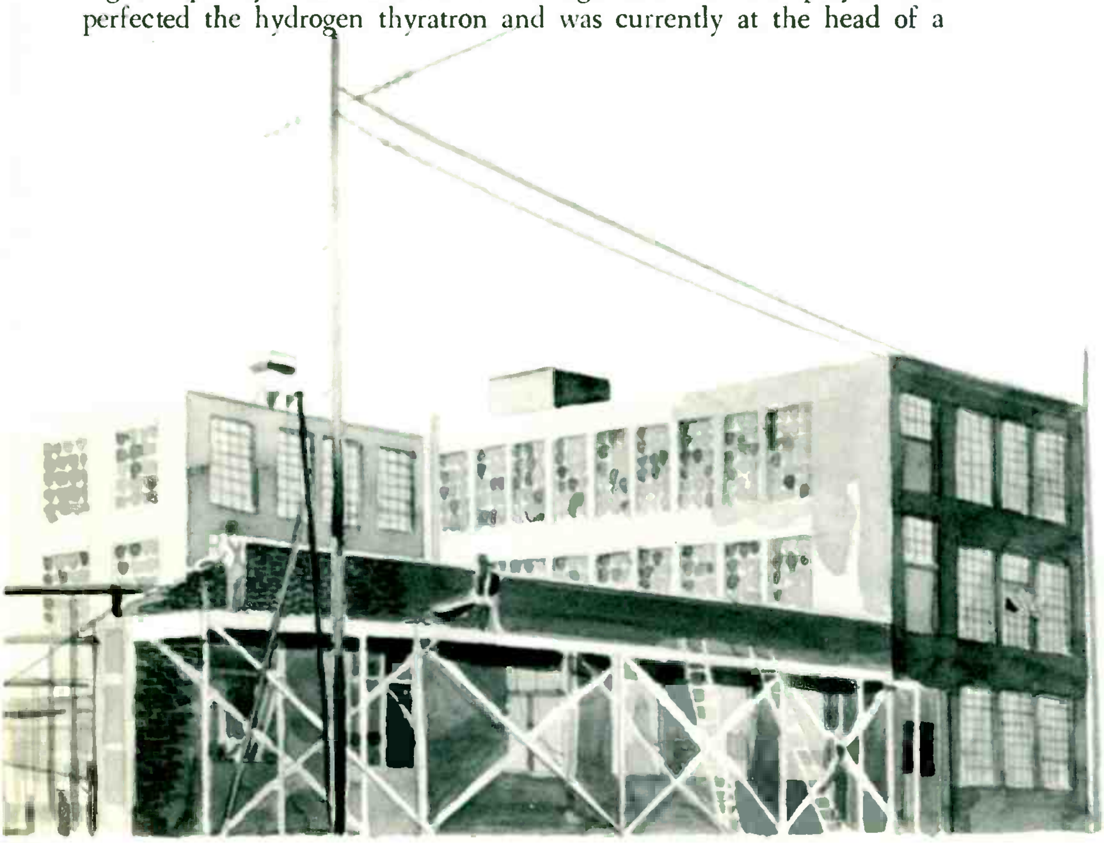
Hanging Up a Hat

QUITE naturally, Machlett Laboratories' success in the making of communications and power tubes for the government had raised the question whether the company should stay in that field after the war and seek to build for itself a market in privately owned industry.

The war years and the period immediately following had made it evident that Machlett had certain of the makings of success in an expansion along those lines: a know-how in manufacturing, founded upon years of experience in the exacting x-ray tube field and now proved in the making of power tubes; a plant which would be ample for the purpose; and a working force well trained in the production of tubes that were either identical with or very similar to tubes that would be required by a peacetime market.

During this period the company had acquired numbers of very valuable people in management and sales as well as in direct production work. These included E. J. Gannon, an experienced industrial engineer with a flair for production control; and A. J. Foster, an experienced export man with a considerable knowledge of European and other countries. Two other men whose previous experience lay in other specialties developed unusual abilities at Machlett and came to fill extremely important posts: J. A. Miller who became Purchasing Agent; and Gordon Hamblen who as the company's Personnel Director is also a member of its operating committee.

Ray Machlett had also noted and marked down in his own mind a number of men in government and other work outstanding in the development and engineering of communications and power tubes. Of these, the one he wanted most was Dr. H. D. Doolittle, of M.I.T.'s Radiation Laboratory. Doolittle, recognized as one of the foremost men in high frequency work, had been in charge of the M.I.T. project that perfected the hydrogen thyratron and was currently at the head of a



group working on pulse modulators. He was also identified with magnetron development and with many other projects of similar importance. Of course a man of this calibre would not be available until the war's end, but Ray Machlett was determined that when that time came he wanted Doolittle, to head Machlett engineering of power tubes—as opposite number to Rogers in x-ray tubes.

There remained, however, one other and absolutely essential slot that had to be filled if a power tube operation were going to be a business success as well as a technological and production success. It was one thing to fill orders placed by the government as fast as the plant could handle them; it would be something else again to sell tubes in a competitive peacetime market where Machlett knew few of the big users and distributors and—more to the point—was known by fewer still.

In the x-ray field Machlett—as a firm—was practically Mr. X-Ray Tube. And not merely because of the firm's history or technical accomplishments or of Ray Machlett's personal fame. A very large part of its standing had been created by Stevenson, who in the course of years as head of Machlett sales and as Machlett's representative in x-ray industrial and professional associations had probably a wider personal acquaintance than most men in the industry and certainly as high a reputation as any.

If Machlett wanted to go places in the electron tube field in its broadest sense, the company would need a man with a standing in that field comparable to Stevenson's in the field of x-ray tubes.

The one man, as Ray Machlett saw it, who came nearest to filling this bill was Hoffman, then at the head of Westinghouse's electron tube operation. Hoffman had not only the technical and managerial background that this would imply but also a very considerable reputation in the industry, since his responsibility included sales as well as engineering and production, and since he had been a leading figure, as representative of his company, in the principal associations of the radio, electronics and allied fields.

Reflections on these points were occupying a good deal of Ray Machlett's mind in August 1943, when he got a telephone call from Hoffman. "Are you," asked Hoffman, "planning to continue in the power tube business after the war?"

Whether Ray Machlett sensed in this question a trial balloon of Hoffman's, or whether he was thinking only of his own problems, there is, of course, no way of knowing. But he answered,

"If you're interested in coming in with us, we are."

"I am," said Hoffman, or words to that effect. And from that moment Machlett Laboratories were in the power tube business to stay.

Hoffman joined the company on January 1, 1944, but they were not able to get Doolittle until after the end of hostilities in 1945. Shortly thereafter—in October of that year—they finally consolidated all operations in the enlarged plant at Springdale, with a nucleus of 600 people for both x-ray and power tube production.

In working out the organizational structure of this consolidation the company had to make one all-important basic decision: whether to set up under one roof two entirely separate and distinct divisions, or to conduct the making of x-ray and power tubes as intermingled

Dr. H. D. Doolittle, formerly of M.I.T.'s Radiation Laboratory, heads Machlett's Design Engineering and Research in the electron tube field. He has been responsible for many of Machlett's contributions in this field.

Henry J. Hoffman, mainspring of Machlett's rapidly growing electron tube activity. A well-known industry figure, he has been a top executive of Machlett Laboratories since 1944. Now, as Vice President in Charge of Sales, he is a member of the four-man Executive Committee which guides all Machlett's operations.

activities of the same organization. Obviously, many of the operations (such as parts fabrication or testing, to name only two) were completely different for each type of tube, and every operation of that kind would require its own group of people, working with its own specialized equipment. There was much to be said—economy-wise—for separating such operations, and for providing the power tube division with separate facilities of its own. After all, the requirements for vacuum and for certain other characteristics in the power tubes of 1945 were not as exacting as those for x-ray tubes. It was a great temptation to build an operation planned for the highly efficient meeting of power tube standards and no others.

But on exactly this point the company decided not to separate operations. There should be one set of standards for all Machlett tubes, and it should be the higher one. In so far as keeping operations together would help hold all production up to x-ray standards they would be kept together. Some operations along the way would necessarily have to be separate—possibly large groups of them. Possibly in time all power and x-ray tube making might have to be physically separated. But there could not and would not be two separate sets of standards in Machlett Laboratories.

It was a decision that seemed at first as needlessly trying and profitless as a smoker's swearing off cigarettes. But within three years it paid off in a spectacular way. In order to see how it did, we can set over for a later chapter the story of several important developments in x-ray tubes during the same period, and follow Machlett activity in power tubes alone up to 1948.

There was, to begin with, a comfortable backlog of continuing production of certain tubes for the government. Of these the largest was for the 2C39A, a low power transmitter tube of the planar triode type, originally designed for ultra-high frequency communication among air, naval or ground units in the armed services, as well as for air navigation systems, micro-wave relaying and radar use. Other peacetime uses were many, and actually increased as, over the years, Machlett worked out many improvements in the construction of this competent tube and in its adaptability for use at frequencies up to 2500 megacycles.

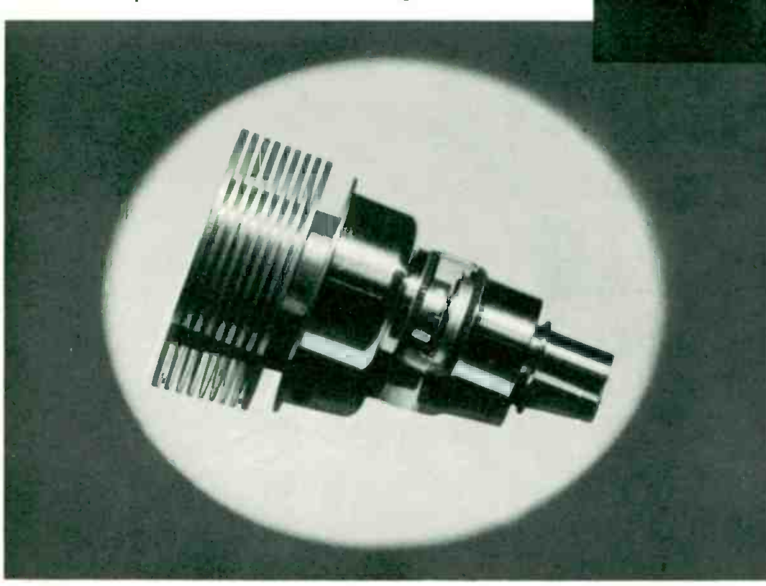
There were also a number of other tubes originally made as part of the war program which had substantial peacetime uses. Among these was the hydrogen thyratron first developed for radar and now finding other uses, such as short-circuit protection in high-power transmitting equipment. Again, there were several high-power, high-voltage rectifiers of types first designed for the atomic bomb program. Adaptations of the latter brought out in 1946, found immediate and growing uses in particle precipitation equipment for industrial plants: the cleaning of gases, the recovery of valuable solids (such as catalysts) from stack discharges, the abatement of smoke and fly-ash nuisances. . . . These particular rectifiers owed a good deal of their efficiency to a catenary form of filament developed by Machlett engineers.

In addition to these, and of prime importance to Machlett's post-war commercial program, was a series of high-frequency oscillators specially designed for use in industrial induction and dielectric heating equipment. Machlett's development of special tubes for these hard-service purposes

In this typical air-conditioned area, precision parts for the 2C39A tube are assembled to very close tolerances.

All-but-automatic exhaust apparatus for the 2C39A tube requires only general supervision —but it has to be very intelligent supervision.

The 2C39A planar triode is the smallest in size but the largest in numbers made by Machlett Laboratories. Reason: it is the key tube for great numbers of military and commercial low power mobile transmitting sets.



produced not merely a number of profitable and still-growing additions to the company's line, but indirectly led to far-reaching changes in the character of all Machlett power tubes and ultimately in that of most power tubes made throughout the industry:

In the first rapid growth of induction and dielectric heating during and just after the war, most equipment used oscillators of the exact type then made for broadcasting stations; there were no others available.

That type was adequate for broadcasting use, in which it got careful handling by trained radio engineers; it was operated at constantly supervised and rigidly controlled voltages and currents, in immaculate, quiet, shock-and-vibration-free buildings.

Consequently the typical oscillator of 1946 was not only laboratory-designed but was built laboratory-style for uses scarcely more severe—except in continuity—than those of the laboratory.

Specifically, it had, among others, certain features of construction that were a good deal better adapted to the broadcasting station than to the factory:

—The glass envelope was large; it was shaped in whatever form was convenient to surround the elements it had to enclose, and it was not particularly heavy or strong.

—The envelope was sealed to its base by the well-known and long-established Housekeeper seal (named after its inventor)—that is, the rim of the glass was beaded onto a thin feather-edge of copper. Copper has a different coefficient of expansion from that of glass, but the thinness and feathered cross section of the copper—a ductile metal—allowed it to conform to variations of glass under heat or cooling. This necessarily light construction, to be sure, meant that a tube required respectful treatment when in place and careful handling whenever it was changed, but in radio stations that could be expected, even if it meant, as in some cases, that only one trusted employee was allowed to replace tubes.

—Within the tube, elements were customarily fabricated out of numerous pieces of sheet metal and wire, shaped and formed as might be required, and then welded together into a sometimes quite complex structure. In broadcasting service such a structure did not have to stand appreciable shock or vibration, and while some radio engineers felt it could be improved for better dissipation of heat and resistance to electrostatic strains, it was a good deal less costly kind of assembly than, say, the cast-and-machined metal elements in an x-ray tube.

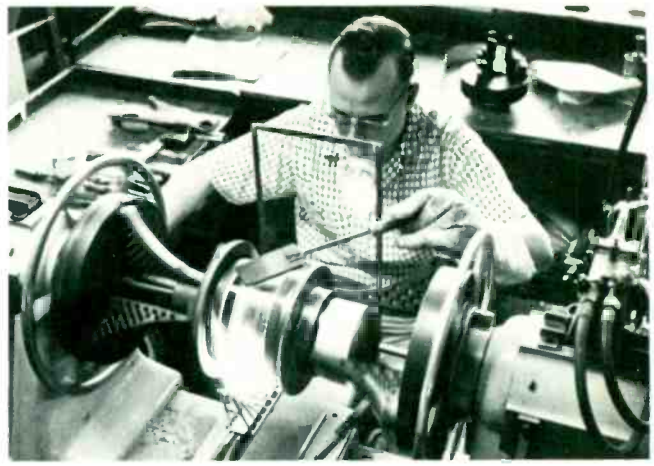
—Since heavy overloads need not be expected in a carefully run broadcasting station, no elements were any heavier than a moderate margin of safety required.

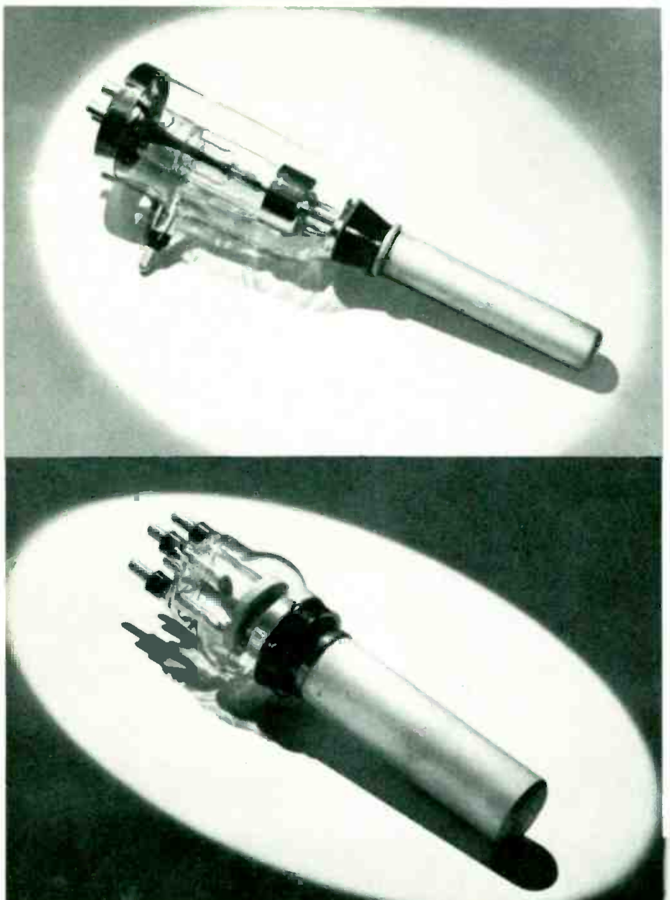
But in a foundry, or a machine shop, or a furniture factory, or a plastics molding establishment, all these and some others were points of weakness.

Machlett engineers set out to design a line of tubes of the same general electronic characteristics, but with considerably larger safety factors, both electrical and thermal, and with a great deal more structural strength.

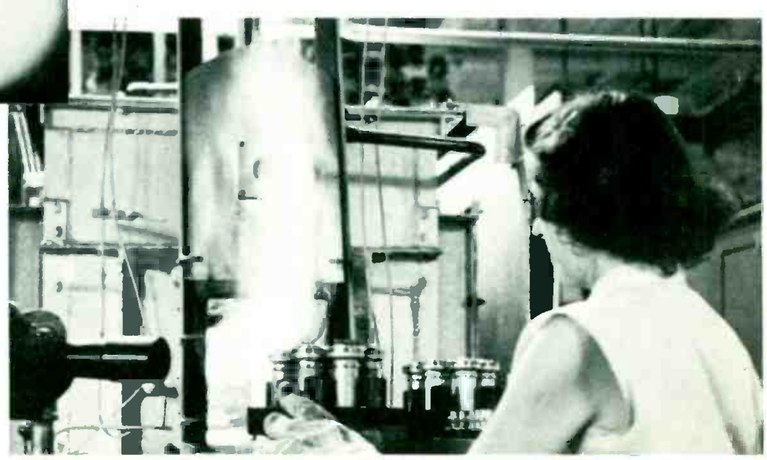
Their immediate object was to make an oscillator that would stand up in hard service, with only moderately trained operators and even under occasional unwitting but heavy overloads, in any industrial plant that could profitably use induction or dielectric heating. If they produced a tube that would do such things—they shrewdly suspected—not only would Machlett get a substantial lead in the industrial power tube field, but it would not be long before broadcast and communications users, too, began to recognize the advantages of a more rugged, longer-lived, mishap-resistant

Right, the making of a Kovar-to-glass seal is an expert's job, requiring extraordinary care in the case of big tubes.





The redesign of a tube of conventional broadcast transmitter type (upper) into a rugged form (lower) which is not only suitable for gruelling industrial applications, but at the same time better for broadcast use. Its basic electronic characteristics remain the same.



The hydrogen furnace plays an important part in making big "power" tubes. Its extreme heat is measured for precise control by optical instruments.

tube for radio and television stations. The fact that this came about has had a tremendous bearing on the entire Machlett business today—to say nothing of the effect that it has had on the design of most tubes for broadcast, communications and power uses made anywhere at the present time.

These are the basic structural principles that Machlett introduced into power tube design as early as 1946. They are now conspicuous in practically all power tubes the company makes—and most of them have been adopted throughout the industry:

—Tubes are as compact and sturdy as design and re-design can make them.

—There is a minimum area of glass in the envelope, and that glass is of a type specially produced for this use, of substantial thickness and of a shape engineered with extreme care for maximum strength combined with optimum electronic efficiency.

—The seals, in all cases, are Kovar-to-glass, designed for ruggedness under any conditions and in long operation.

—The design of electrodes, grid and all other elements makes for maximum heat dissipation and minimum distortion by electrostatic or other stresses.

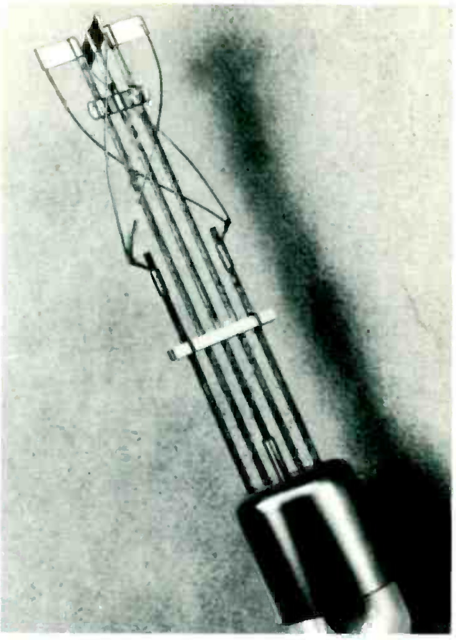
—Wherever electrical, thermal or structural considerations indicate, metal parts of tubes are machined from solid stock or from castings, rather than fabricated from sheet metal by spinning, stamping, etc.

—Since spacing between elements of high-frequency tubes is necessarily close, design is as important as care in fabrication, to insure unfailing dimensional accuracy even under the severest operating conditions. Internal electrodes are adequately but very accurately spaced from one another, and are rigidly supported by the whole design of the tube.

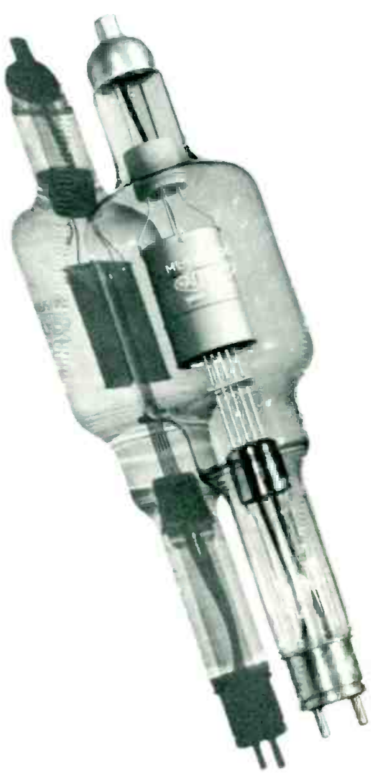
—Since power is high, with heavy overloads probable in industrial use and always possible in other uses, thicknesses and other lateral dimensions of electrodes are more than ample. For example, the walls of copper anodes once customarily 1/16" thick now measure at least 1/4" and in large tubes as much as 1/2".

—The whole geometry of the tubes' over-all design combines to embody every basic principle of strength and rigidity with economy of mass and bulk. In present-day tubes this finds fullest expression in coaxial arrangement of all elements, utilizing to the utmost the great natural strength of the cylinder as a geometric form.

Obviously, it cost more to make tubes designed to these structural principles, and they had to justify higher prices. Industrial users, however, were quick to realize that the cost of such tubes in terms of watt output per dollar—and in terms of useful life in hard service—was measurably lower than the cost of earlier type tubes. So it was not long before Machlett led in this rapidly growing industrial field. A few broadcasting stations, too, began to recognize that it was worth while to use tubes with a material margin of dependability, and Machlett found itself modestly and at first on a limited scale established in this field as well.

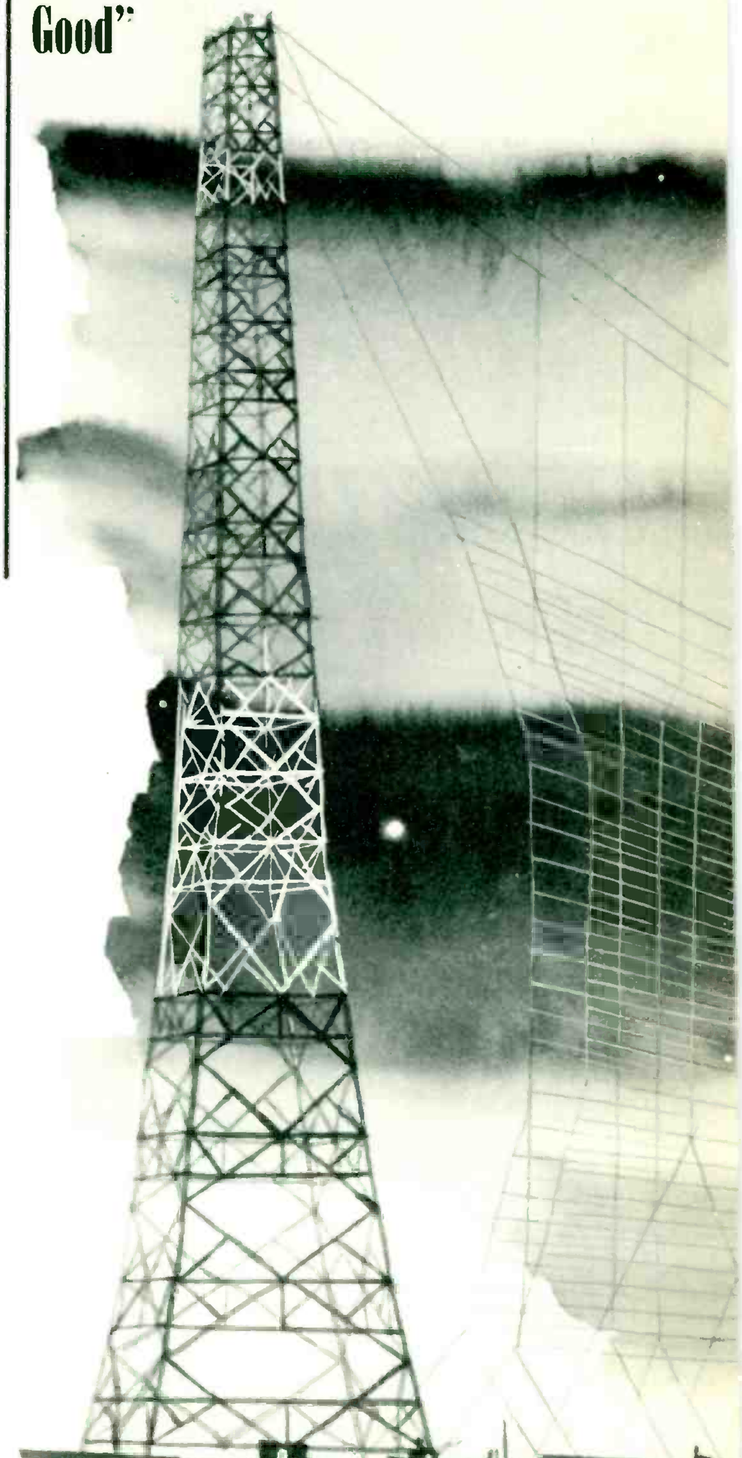


The catenary type of filament developed at Machlett for low voltage drop and greater structural rigidity under the severest operating conditions.



A modern, high-power rectifier tube, typical of those used in many industrial installations.

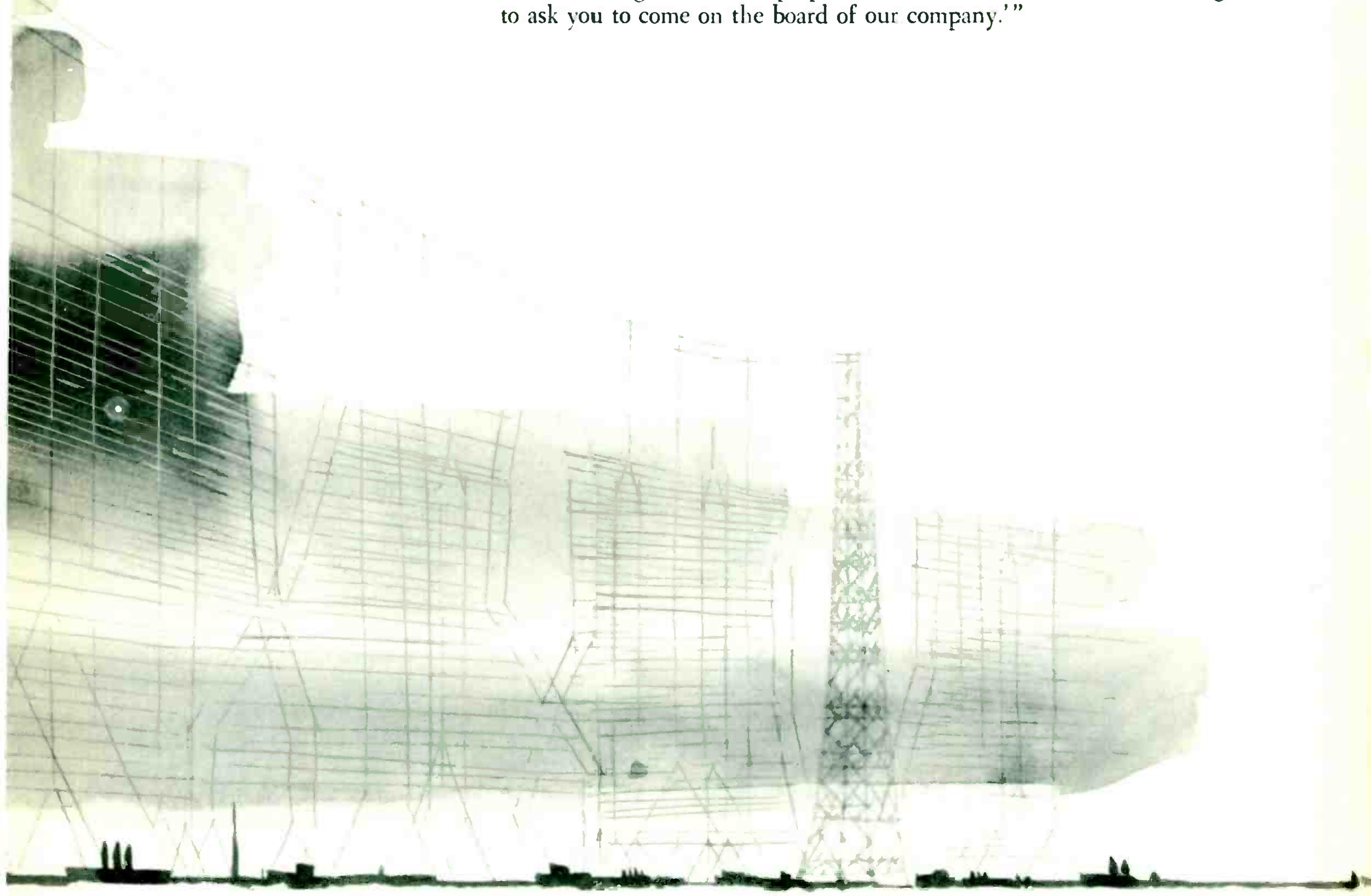
"What Is Good Stays Good"



MANY other things were happening, in these post-war years, to effect a gradual, over-all change in Machlett Laboratories —a transition from the essentially small enterprise of a small group of men to an organization larger than any of the men in it—even Ray Machlett. Larger not so much by virtue of size as by virtue of a body of beliefs, a code of practice and a corporate point of view that unified many individuals' widely differing gifts. Symbolizing this broader outlook was the coming on the board of Dr. John G. Trump, in 1946.

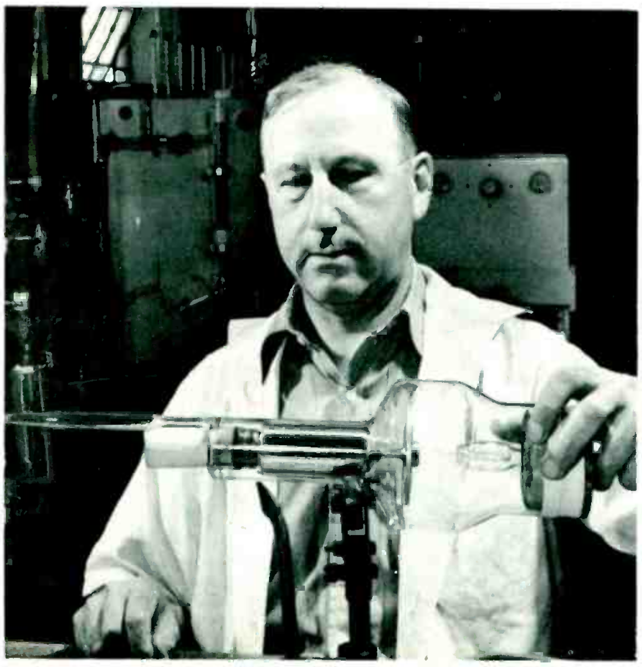
Ever since their first acquaintance in wartime work on high-voltage, high-frequency tubes, he and Ray Machlett had belonged to a mutual admiration society of two members. Its meetings had been interrupted during the latter part of the war when Dr. Trump went overseas as Director of the British Branch of M.I.T.'s Radiation Laboratory. Now he was back in Cambridge as Associate Professor of Electrical Engineering, and on the side as co-founder (with Dr. Van de Graaff) of the High Voltage Engineering Corporation.

"It was funny how that directorship happened," he remembers with a smile. "Van de Graaff and I had been wondering if we could get Ray Machlett to come on the board of our infant company. And so one day when Ray appeared in Cambridge, ostensibly on some technical business or other, I worked up the nerve to ask him. He looked at me and burst into a broad grin. 'This is preposterous,' he said. 'I came to Cambridge to ask you to come on the board of our company.' "



Dr. John G. Trump, Director and Technical Advisor, pays one of his regular visits to Machlett Laboratories, where he finds Joe Skehan and Henry Hoffman deep in discussion of some minute but vitally important detail of a tube part.

Ernst Zitzmann, retired mastercraftsman in glass, loved nothing better than to work with this difficult material, whether with the traditional glassblower's tools or with modern equipment such as the glass-working lathe.



(For the record, each took the other up. Ray Machlett served on the High Voltage Engineering Corporation board until 1951; Dr. Trump is still a director—and a very active one, as well as a valued technical consultant—of Machlett Laboratories.)

If Dr. Trump's joining in 1946 struck a new note in Machlett history, there came early in the following year an answering note to mark the passing of the old. Ernst Zitzmann, sometime apprentice glassblower to Robert Machlett and later, for many years, master craftsman in glass and trainer of scores of other masters in that difficult art for Machlett Laboratories, retired in March 1947. Unlike so many Old Timers who in fond remembrance of the past can see nothing good in the present, Zitzmann had a five-word philosophy that joined the two. It was a philosophy that had first of all expressed the honest craftsman's faith in the enduring quality of all honest work. But as the years went by, Zitzmann began applying it to everything that was solid and enduring about the Machlett business in its growth from a small artisan's shop to a big technological organization. He said it to people who asked him if he regretted the passing of old hand-craftsmanship; he said it to lamenters for the Good Old Days; he said it to those who asked him whether science could ever take the place of art. And by that time everybody in the shop knew Zitzmann's maxim: "What is good stays good."

The biggest and conclusive mark of Machlett's transition came in 1948. A great competitor handed over all its manufacturing of communications and power tubes to Machlett Laboratories.

Western Electric, the manufacturing member of the Bell Telephone group of companies, had made tubes of this type since radio broadcasting began.

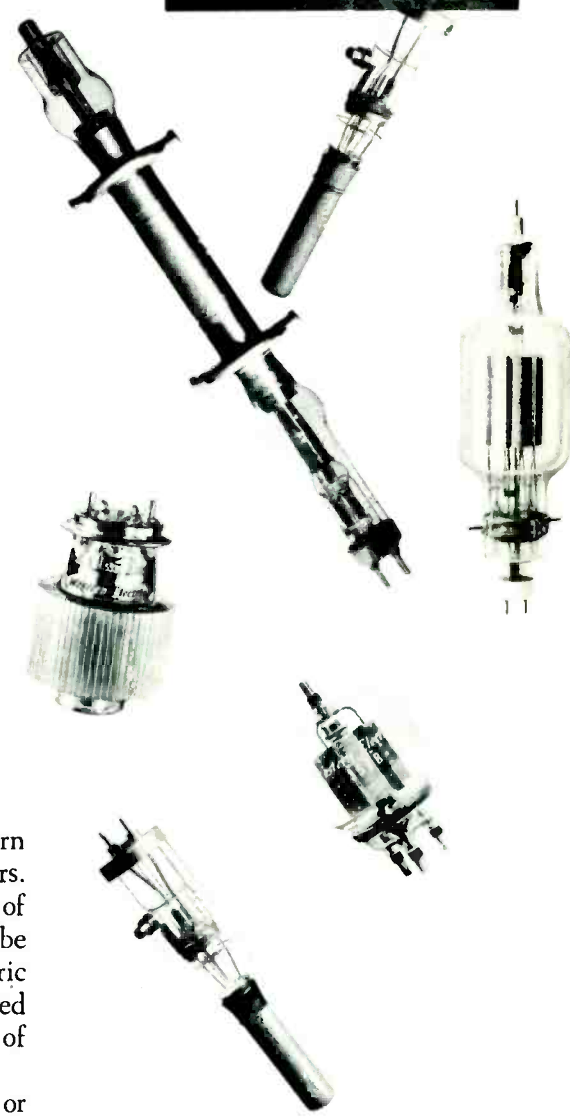
The tubes, engineered by Bell Telephone Laboratories, were made both for Bell System applications and for sale to broadcasting and other users through the Graybar Electric Company. Western Electric was a leader in this field and its products so successful that by 1948 it was faced with the necessity of finding a great deal of new manufacturing capacity quickly, if it wanted to meet the demands of a vastly growing market. For reasons connected with over-all corporate policy, Western Electric decided that instead of buying or building this production capacity it would turn over its entire business in high power tubes for broadcast and allied applications to a selected company, if it could find one to meet its requirements: The company must be capable of continuing the manufacture of tubes to standards equalling those Western Electric had always maintained and it must be able and willing to service Western Electric equipment anywhere, in the measure and to the extent that the Bell System required.

Western Electric surveyed the entire electron tube industry before making its choice—and picked Machlett Laboratories. There seems to have been no hesitation on Western Electric's part in making this decision, but the first intimation Machlett had of its selection was a phone call from Fred Lack, Vice President of Western Electric, to Hoffman in the spring of 1948. The conferences that followed were swift and to the point, and an announcement was made to the industry by the larger company in a statement that included several significant phrases:

"The Western Electric Company is proud that the outstanding skill, the engineering ingenuity and the high integrity of Machlett Laboratories will be utilized in the manufacture of Western Electric high power electron tubes . . . It was decided that . . . strictest maintenance of quality standards could best be obtained by . . . the highly specialized skills of Machlett Laboratories . . . [resulting] from its position as the world's largest producer of x-ray tubes, and from extensive development of tubes for r-f heating and other industrial applications . . . requiring the highest standards of ruggedness, performance and quality . . . Machlett has made numerous contributions both as to design and manufacturing methods for x-ray tubes and industrial heating tubes . . . X-ray tube production is basically like that of electron tubes for communications use . . . An x-ray tube is essentially a diode [except for] very much higher anode voltages . . . the necessity for sharp focussing of electron beams . . . and other related differences make the manufacture and testing techniques for x-ray tubes and the control of quality for long life and proper performance in general more difficult than corresponding techniques for communications tubes.

Machlett['s] . . . recent production of high power tubes for r-f heating and for high power transmitters . . . has . . . established a flow of techniques from . . . x-ray . . . into the related . . . field of tubes for communications uses.

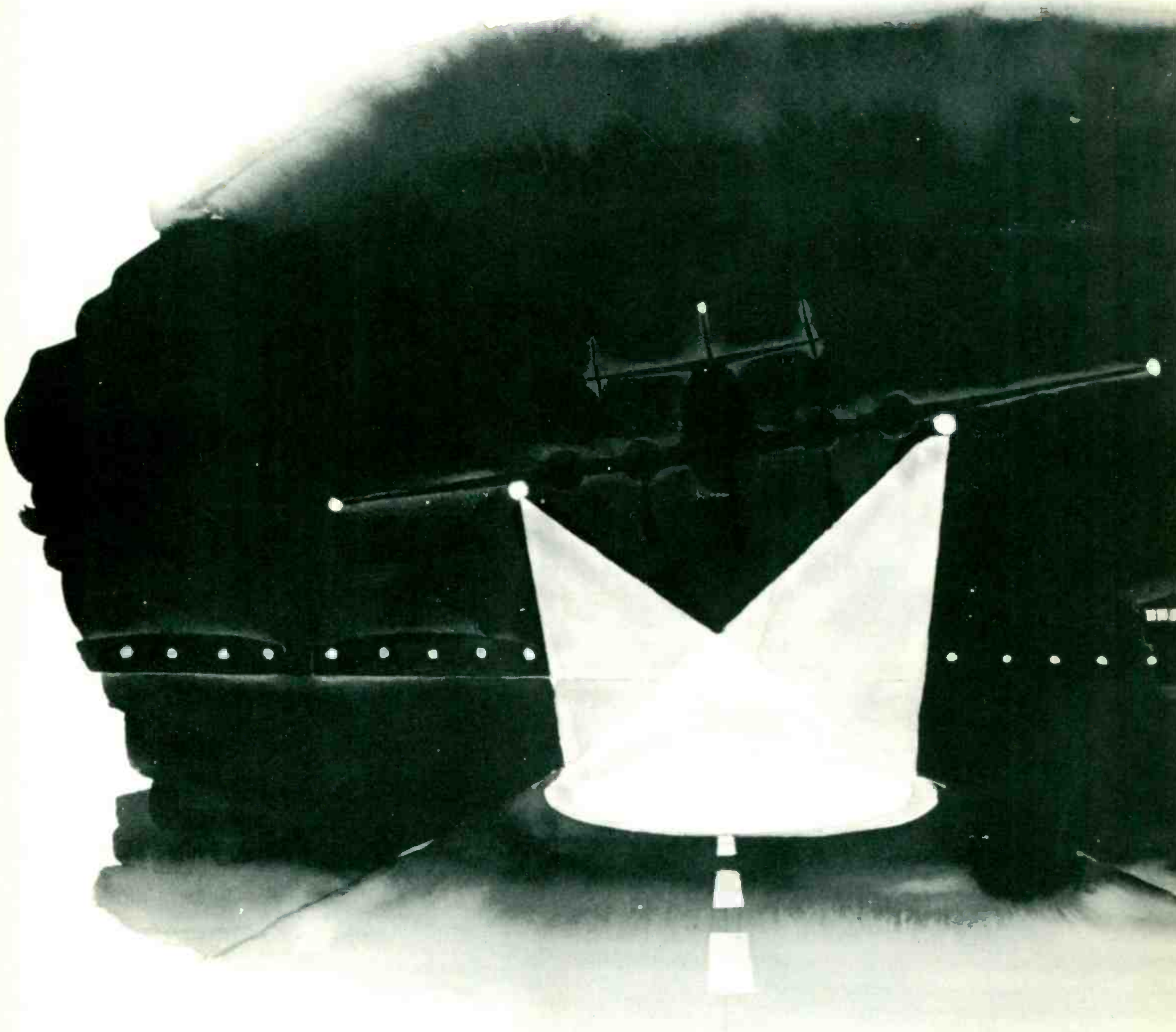
The Machlett . . . organization . . . is uniquely adapted to meet the requirements of high power, high voltage electron tube development and manufacture . . . Development and design engineering groups . . . function in . . . closest coordination with quality control and production . . . Quality control division is more extensive in size and scope than is customary in the tube industry . . . 100 per cent inspection . . . is rigidly adhered to . . . throughout the plant . . ."



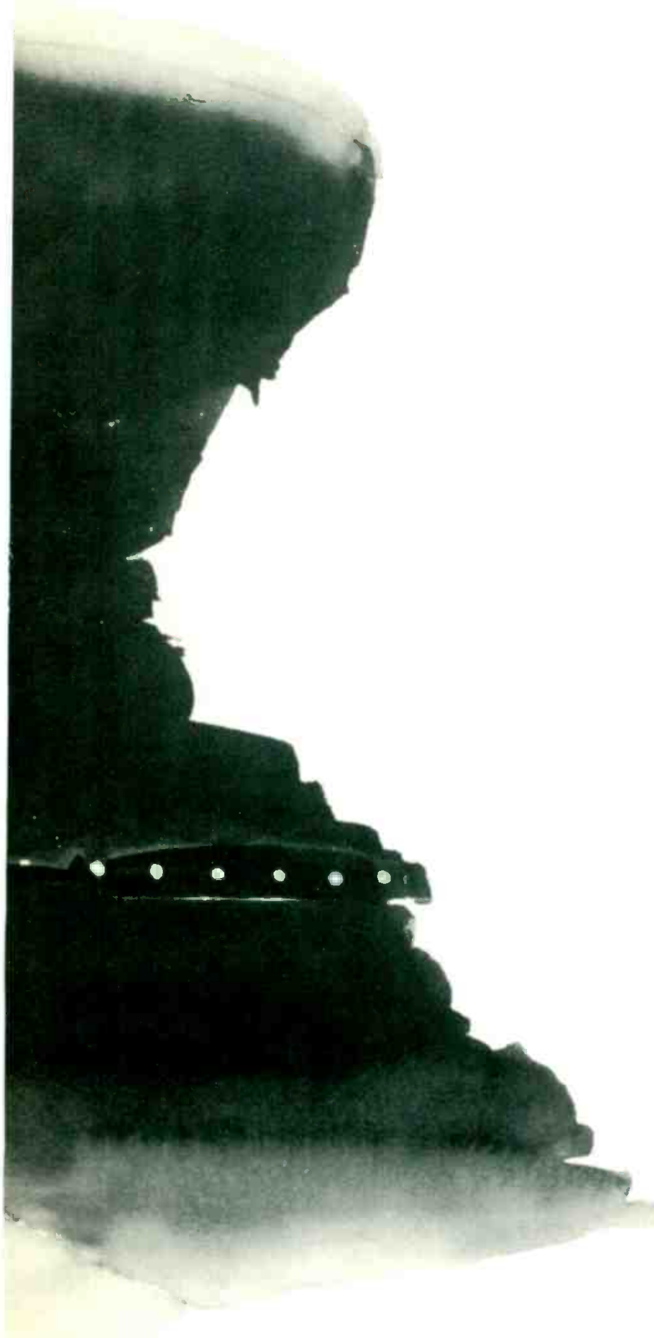
The arrangement was that Machlett would manufacture for Western Electric its line of 28 high power transmitting tubes: triodes and rectifiers. These tubes would be made to Bell Laboratories designs, with full use of production techniques developed by Western Electric. They would be labeled, "Manufactured by Machlett Laboratories for Western Electric Company." They would be sold for use by the Bell System and distributed through more than 100 nation-wide offices of Graybar as a supplier of tubes for broadcasting and other commercial applications.

In one sense it was a windfall, for Machlett had not sought it, or worked to bring it about. Yet, as Western Electric's carefully chosen phrases showed, it was in another sense an award—for twenty years of the hardest and most consistent kind of work. It was more than a mark of the completeness of Bell System recognition; it was a sign and seal for all to see of the reliability, the permanence of Machlett Laboratories as a major factor in the big electron tube field.

Some of the many types of tube produced by Machlett Laboratories for Western Electric, as the latter company shows them in an announcement in its magazine, *The Oscillator*, for November, 1948.



Meanwhile, Overseas . . .



AS we have seen, three things, happening by chance at about the same time, had combined to drop into Machlett's lap a very large volume of overseas business in x-ray tubes during World War II: The war had destroyed or disrupted most British and West European manufacturing facilities; it had vastly increased the need for x-ray tubes in diagnosis and treatment; and Machlett had introduced new and greatly improved tube types, culminating in the rotating anode Dynamax.

With the war's end, demand actually increased: lessened military requirements were replaced by civilian needs that were all the greater for being so long pent-up. Denmark, in dire need of x-ray tubes for a public health program, including mass chest x-rays, approached Machlett Laboratories in early 1946 through its consular representatives in the United States. Machlett hastily made A. J. Foster its export manager and—with red-tape-cutting assistance from Washington—put him aboard a transatlantic plane with a load of Dynamax tubes for Denmark, Sweden and Norway. He was back in a month, only to take off again for Holland, Italy, Spain and Portugal. These were the first of trips which within two years covered practically all Continental Europe east of the Iron Curtain and within the next two years established distribution in much of the Near East and practically all of Latin America.

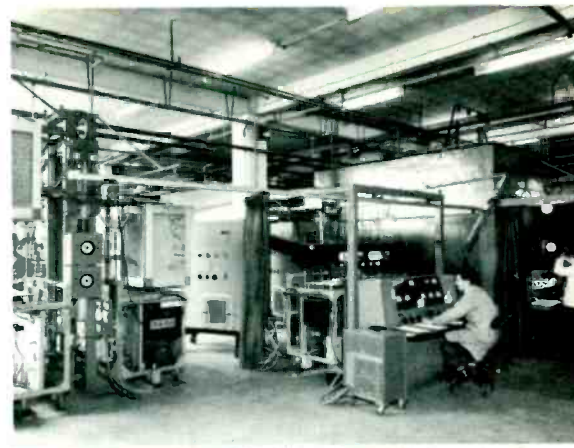
In the English market, Machlett had been supplying British Isles requirements since 1938 through Watson & Sons, Ltd., the x-ray manufacturing subsidiary of British General Electric Company (no relation to the U. S. company of the same name). By the war's end this activity had developed a cordial relationship with British GE's Chairman Leslie Gammage and with Watson's Managing Director A. J. Minns.

War-crippled Britain could obviously not afford for long to import 85% of its x-ray tube supply, so in early fall 1946 Ray Machlett went to England to work out

Andy Foster, (left) Export Manager, shows the plant to two visiting Swedish radiographic experts.

with Gammage and Minns an arrangement of the type later known as Point Four cooperation between the United States and a sister nation: Machlett furnished know-how and technological assistance to aid in establishing a British x-ray tube manufacturing operation, and in return became part owner with British GEC in a subsidiary: Machlett X-Ray Tubes, Ltd. of Great Britain. Specifically, Machlett contributed patent rights to products and processes, complete access to a great accumulation of scientific and technical data, machinery, instruction at Springdale of key British personnel and on-the-spot consultation at Wembley, where Machlett X-Ray Tubes, Ltd. built an entire new plant. That construction project, incidentally, got one of the earliest post-war building authorizations in a Britain where all construction was subject to rigid priorities. At the start of this manufacturing operation, too, Machlett furnished some tube inserts and parts. Now the British plant, entirely self-sufficient as to supplies, employs some 150 people and makes x-ray tubes not only for the British Isles but for a large part of the world's sterling-exchange area.

In similar manner Machlett has contributed—by limited licensing and by the supply of tube inserts or critical parts—to the establishment of x-ray tube manufacturing in Switzerland, Italy and elsewhere. For the most part, however, Machlett x-ray tubes for other countries are exported from the United States, though devaluation and foreign exchange restrictions combine to restrict the volume of this business, as they restrict the export business of so many American manufacturers. The effect of devaluation is lessening as wages and income rise in other countries; the very real need of many nations for x-ray tubes helps get certain trade restrictions relaxed; international trade seems headed gradually toward



The home of Machlett X-Ray Tubes, Ltd., at Wembley, England. It was built under high priorities from the British government, equipped and set in operation largely with the help of Machlett experts sent from the U.S. Now entirely self sufficient, it is the outstanding maker of x-ray tubes, not only for Britain but for most of the world's sterling-exchange area.

normal exchange of products; and there appears every prospect that Machlett will continue to be, as it is, the world's largest supplier of x-ray tubes.

Meanwhile, the Western Electric arrangement, including its working alliance with the great Graybar distributing organization, has opened a world market for Machlett tubes in communications, broadcast and industrial power uses. Westrex Corporation, the overseas selling member of the Bell Telephone family, maintains more than 100 offices, with 1300 people working in or from them, on every continent in the world and in practically every country outside the Iron Curtain where electricity and electronics play a significant part in the social and economic life of the nation. In Canada corresponding associated companies of the Bell System—the Northern Electric Co. and Dominion Sound—serve our closest sister nation as thoroughly as Graybar does the United States.

Naturally, in the field of power and communications tubes, Machlett has not yet achieved anything like its dominance in the x-ray field. Yet there are significant facts: During the last war, the United States as a whole made advances in the development of tubes for power and communications which left the rest of the world with tubes obsolete or soon to become so. Other nations are now catching up and modernizing their installations. As they do, they tend to choose the more advanced designs of new tubes and those, especially, in which design is one factor in higher performance and longer life. Machlett, as the originator of many of these designs, and as the maker of all electron tubes to x-ray tube standards, has shown a tendency to gain an increasing share—though still a modest one—in the world market.

New Job Horizons--for X-rays

PROVERBIALLY, ancient wars left behind them—if nothing else—a lot of swords that could be beaten into plowshares. The equivalent legacy of modern war consists of an enormous abundance of new techniques—mostly developed at appalling expense—which can be adapted to effective peacetime use. That, of course, is the situation we see throughout American life today, in everything from atomic power to insecticides, from jet propulsion to artificial fabrics.

Naturally, then, the story of post-war use of x-ray tubes is almost altogether the story of applying to peacetime purposes the lessons learned at great expense during the war. Particularly it is a story that revolves around two war-year advances—the beryllium window, made possible by the costly development of malleable beryllium, and the techniques of producing ultra-high-energy x-rays by multiple acceleration of electrons before they hit the target.

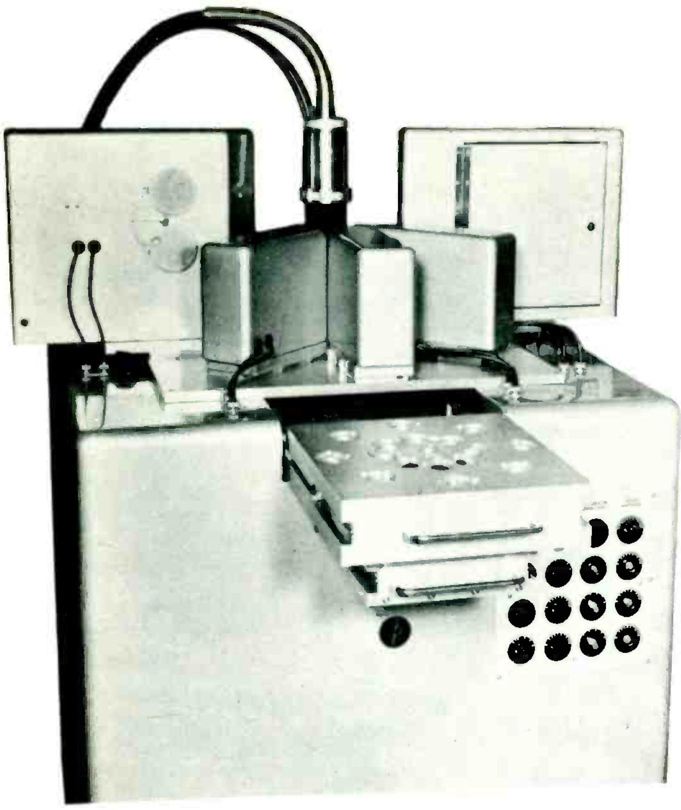
This is not to say that there have not been constant improvements in the more conventional forms of x-ray tubes—of both fixed and rotating anode types. But those improvements have been essentially much like improvements in the motor car over the same period: tubes are more powerful, faster, more compact, safer, easier to use, longer-lived. . . . And many of the advanced medical uses of x-rays for diagnosis are analogous to driving a more powerful car faster and under better control: better negatives, faster (up to cinema speed) and sharper (down to microscopic detail).

The most striking new uses of x-rays have been in the field of industry. And many of these depend upon the beryllium window or upon principles of particle acceleration—or both.

Like medicine, industry started to use x-rays in two ways: "diagnostic" and "therapeutic." That is, to examine opaque-to-light substances, or to change them in one way or another by bombardment with x-rays. Out of each kind of use have grown many interesting variations.

The war gave a great impetus to non-destructive testing. And the beryllium window tube, with its far greater transmission of long wave lengths, made possible useful intensities at relatively low voltages. So, in confirmation of Rogers' theoretical predictions, the post-war years have seen a very wide use of this tube for such purposes as the examination of light substances—e.g. thin metal sheets (often spot-welded to one another) or non-metallic substances all the way from plastics to paintings. Museum and other fine-arts authorities discover primitives under not-so-old pictures on the same canvas. They detect fakes and identify genuine old masters with equal ease and sureness by x-ray examination. There are a multitude of more prosaic but equally valuable uses of low-voltage x-rays; for example, the detection of weevil infestation in samples of stored wheat. . . . And industry is taking to them the more rapidly because the beryllium window tube, operating at relatively low voltages, is safer for operation by moderately trained industrial personnel, and is structurally a good deal more rugged than glass-window tubes.

But there are many industrial uses for other x-ray tubes—particularly in the examination of metals such as castings or welds or assembled mechanisms that cannot be visually inspected after assembly. Most of these uses are radiographic, especially where sections are too heavy for fluoroscopy, but also—in some cases—where it is important to preserve a photographic record of the piece for permanent files. Equipment makers have created a variety of ingenious installations to take x-ray negatives



Applied Research Laboratories' x-ray spectrometer utilizing Machlett beryllium window tube.

of work in process. In one device, for example, an x-ray tube can be sent crawling through a mile or more of pipeline to x-ray every welded joint along the way. Another portable piece of equipment can x-ray every joint as the plates are welded in place on a steel ship under construction. And still another can take flash x-rays of such things as projectiles in a gun barrel, with exposures of 1/1,000,000 of a second.

For magnification of small detail, industry makes use of techniques developed in medical research: fluoroscopic examination of an enlarged image projected by a very fine focal spot.

But x-rays can show up more than structural details in a substance under examination. They can, for example, reveal a number of vital facts about the characteristics of any substance (such as a metal) that has a crystalline structure. For x-rays are diffracted in passage through crystals, and the diffraction of x-rays of carefully controlled wave lengths, from specially constructed tubes, can be exactly measured and interpreted as indications of hardness or state of stress and strain in metals. Or, for that matter, a wide variety of physical properties of many kinds of materials.

Two other characteristics of matter under an x-ray beam make possible chemical analyses of certain substances: (1) Each chemical element has a "mass absorption coefficient:" it is transparent or opaque to x-rays in its own degree for any given wave length of radiation. (2) Elements exposed to x-rays become to a small extent x-ray emitters themselves, each again to its own degree. So, just as it is possible to analyze substances spectroscopically by visible light, so it is possible to analyze them by x-rays—using, of course, very specialized equipment for the purpose. Indeed, x-ray spectroscopy can make qualitative analyses of many specimens that cannot be examined conveniently—if at all—by light spectrometry; for example, liquids or gases in transmission through pipelines, metals moving in a process-industry plant. On a finer scale—though relying upon the same characteristics of matter—research scientists (including those in industry) employ x-rays for histochemical and microchemical analysis of laboratory specimens.

The fact that materials absorb and emit x-rays is the basis of another rapidly spreading industrial use of x-ray equipment: thickness gauging. Typically, a moving sheet of metal passing at high speed through a rolling mill passes under an x-ray beam and absorbs radiation in proportion to its thickness. This radiation, being measured by an electronic pick-up device just beyond, instantly indicates the thickness of the metal—for immediate correction, if necessary, in the setting of rolls. A somewhat similar kind of x-ray gauge measures the thickness of coating on tin plate.

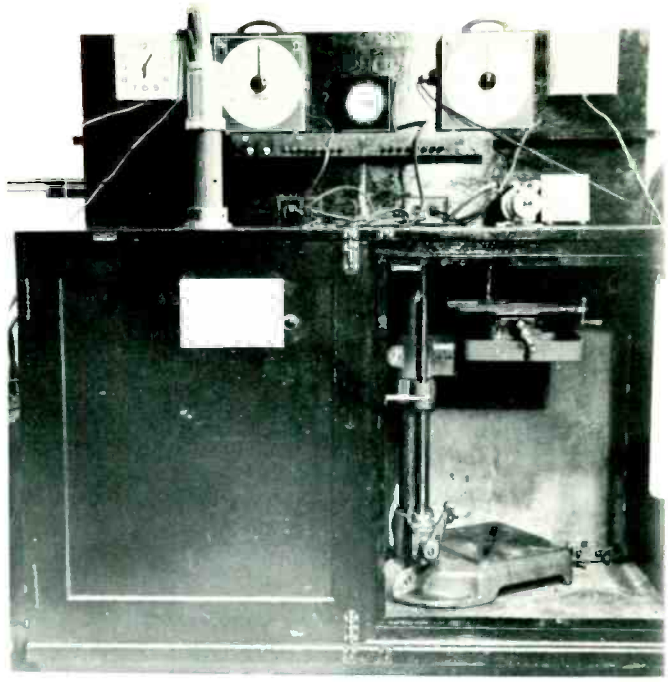
Almost all electronic thickness gauging equipment designed to handle moving metal up to 1/10″ thickness, uses Machlett beryllium window tubes.

Industry's most direct "therapeutic" use of x-rays is a borrowing from medicine: the destruction of harmful living organisms by radiation. In other words, sterilization. "Soft" x-rays—such as those made possible by the beryllium window—are readily absorbed by foodstuffs, for example, without material damage to them but with efficient destruction of harmful microorganisms. So x-ray sterilization is ideal for certain heat-sensitive foods and pharmaceutical products. They can be treated in the course of production or even afterward in certain types of package. The cost of sterilization is low per unit treated. Equipment is relatively inexpensive; it is rugged so that it can be used in industrial plants; and it does not require highly trained operators.

A whole other class of industrial applications of x-rays to change the characteristics of substances may be just over the horizon. It had long been known that x-ray bombardment would affect the colors of certain crystals. Experiments with the beryllium window tube to produce this and allied phenomena have been conducted by Rogers in collaboration with F. H. Pough, prominent geologist, and have yielded results both popularly spectacular and scientifically promising. They produced startling—though temporary—changes in the color of many semi-precious gems. Other, more important, changes are also producible in other substances which can be altered in such characteristics as, for example, electrical conductivity: certain insulators become semiconductors.

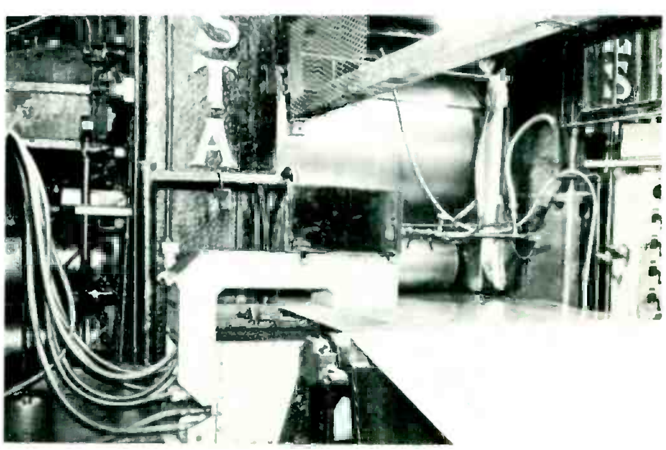
Here, of course, x-ray research barely touches upon fields much farther explored by physicists working with particles accelerated by linear-accelerators, cyclotrons and synchrotrons. Even at this elementary level, it is significant that Dr. Trump, using his linear-accelerator to produce not x-rays but streams of electrons, reports possibilities of electron sterilization in many ways very similar to those of x-ray sterilization, while other M.I.T. scientists are studying effects of electron bombardment upon crystalline structures of the same general type as those produced with x-rays by Rogers and Pough.

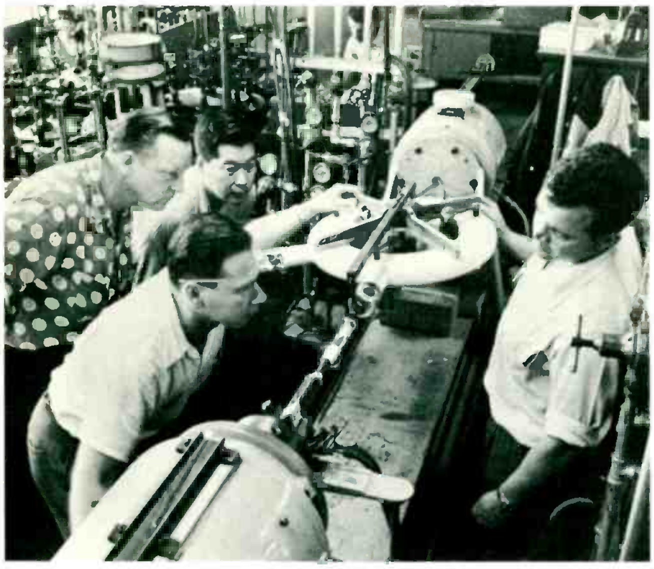
(It may be remarked in passing that Machlett power tubes play a very considerable part in several of the great accelerators popularly known as "atom smashers:" 2½ billion electron volt proton accelerators at Brookhaven National Laboratories and at the University of California; Columbia's Nevis Cyclotron, the Collins Cyclotron at the Argonne National Laboratories; the University of Washington's 60″ cyclotron and others are among these. "The heart of a cyclotron," says Prof. F. H. Schmidt of Washington University, "is its r.f. oscillator," which not only has an all-important job to



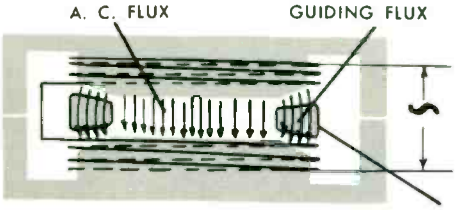
Installation for biological experiments using soft x-rays from Machlett beryllium window tubes at Battelle Memorial Institute.

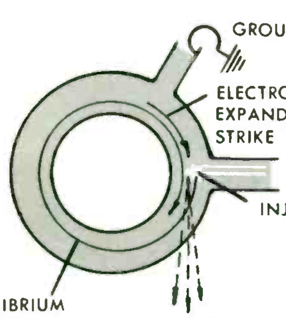
X-ray thickness gauge installed on a sheet steel rolling mill. This gauge employs Machlett 50 kv beryllium window x-ray tubes.





The sealing-in of a Betatron Donut is a critical procedure that rivets the attention of engineers, as well as of expert operators.





Schematic diagram of the Betatron. The upper diagram, shows the Donut, in cross section, between the upper and lower halves of the transformer. Below, a simplified plan of the Donut itself shows the circular path in which electrons are whirled to accelerated speed, and the track they follow when released, to strike the target and produce x-rays.

do in controlling the great machine's build-up of particle velocities, but often has pretty rough going to perform it—operating at very high power (60 kw or more) and subject to continual severe overloads caused by sparking which is "very vicious indeed" (says Dr. Schmidt). This is, as he and others point out, a good deal harder service than oscillators have to perform in high power radio transmission.

All of which brings us to consider another remarkable x-ray tube of recent years—the 22-million-volt betatron "donut."

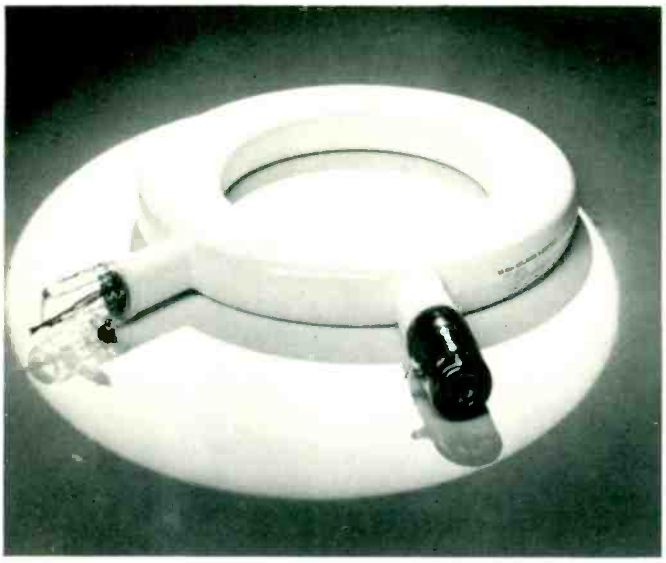
The betatron is an accelerator designed to impart very great velocities to electrons for the purpose of producing x-rays of exceedingly high penetrating power. Like all circular-path accelerators, the betatron steps up velocities by whirling electrons in an orbit much in the manner of the biblical David twirling his sling. And—again like David—when the betatron has got its missile going fast enough, it lets it fly out of its orbit at a target. In this case the target is platinum and the results are x-rays capable of penetrating not merely a giant's forehead but up to 20 inches of steel.

Specifically (but over-simply), the betatron consists of a high-power transformer with its primary winding in two halves, upper and lower. Between them, in place of a secondary winding, is a hollow-ring, dough-nut-shaped chamber. Electrons fed into this are accelerated in a guided path as they would be in a copper wire secondary. They are whirled around some 350,000 times in 1/720 second, covering 250 miles, gaining about 70 volts energy at each turn, and reaching a velocity very nearly that of light. At their peak velocity they are "peeled off" out of their orbit and shot at a platinum target, where they produce a beam of x-rays.

The betatron was first conceived as far back as 1922, was first successfully built by D. W. Kerst at the University of Illinois in 1940, to operate at 2.3 million volts, and was further developed by him in wartime in collaboration with the Allis Chalmers Mfg. Co. under sponsorship of the Office of Scientific Research and Development, for armed forces ordnance radiography. Its operating energy for that purpose is in the range of 20-25 million volts.

The heart of the betatron is its "donut," for if this functions less than perfectly, all the current in the world will not produce high-speed electrons. The donuts in early betatrons were assembled glass chambers, kept under vacuum by constant pumping. But in reducing the betatron to production as a commercial item, Allis Chalmers came to Machlett Laboratories for a sealed-off donut of true x-ray tube characteristics. They wanted not only Machlett Laboratories' advice in details of tube design for high performance and long life, but a special Machlett know-how in the design and manufacture of a beryllium window assembly, since this would be an important factor in transmitting a high-energy electron beam output as well as x-rays from such a tube.

It was not an easy task; the porcelain tube was a difficult shape, in which certain elements—themselves exacting in specifications—had to be placed with great accuracy. Exhaust and high vacuum problems were not lessened by the fact that the tube had to be coated, inside, with a micro-thin film of palladium, and the beryllium window assembly was most difficult of all: a thin section of hard-to-work low-density metal that

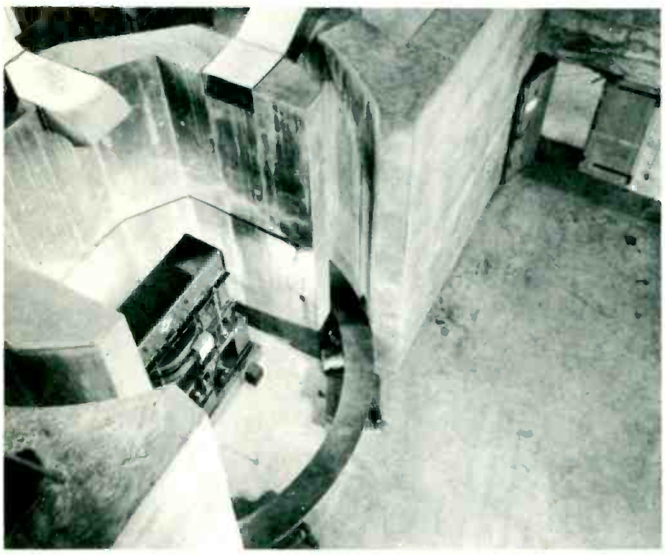


The Betatron Donut is a simple-seeming but actually very difficult tube to make.

must be permanently sealed into the donut, vacuum-tight against the high temperatures required for perfect out-gassing. But to Machlett it was a fine, engrossing problem, of the kind that gives zest to an engineer's life in somewhat the same way a tough Sunday-paper puzzle challenges the week-ender. In the end, Allis Chalmers officials credited Machlett with "perfecting" the donut tube which doubled the output of radiation from the betatron and which increased tube life several-fold.

One of the betatron's great peacetime uses, of course, is in the treatment of deep-seated malignancies. Its maximum dose is realized at some 12 cm. below body surface, so that with modern equipment and techniques of revolving the patient, effects of radiation can be focussed on a given area without danger to other tissue. Among great institutions for the treatment of cancer now using the betatron are:

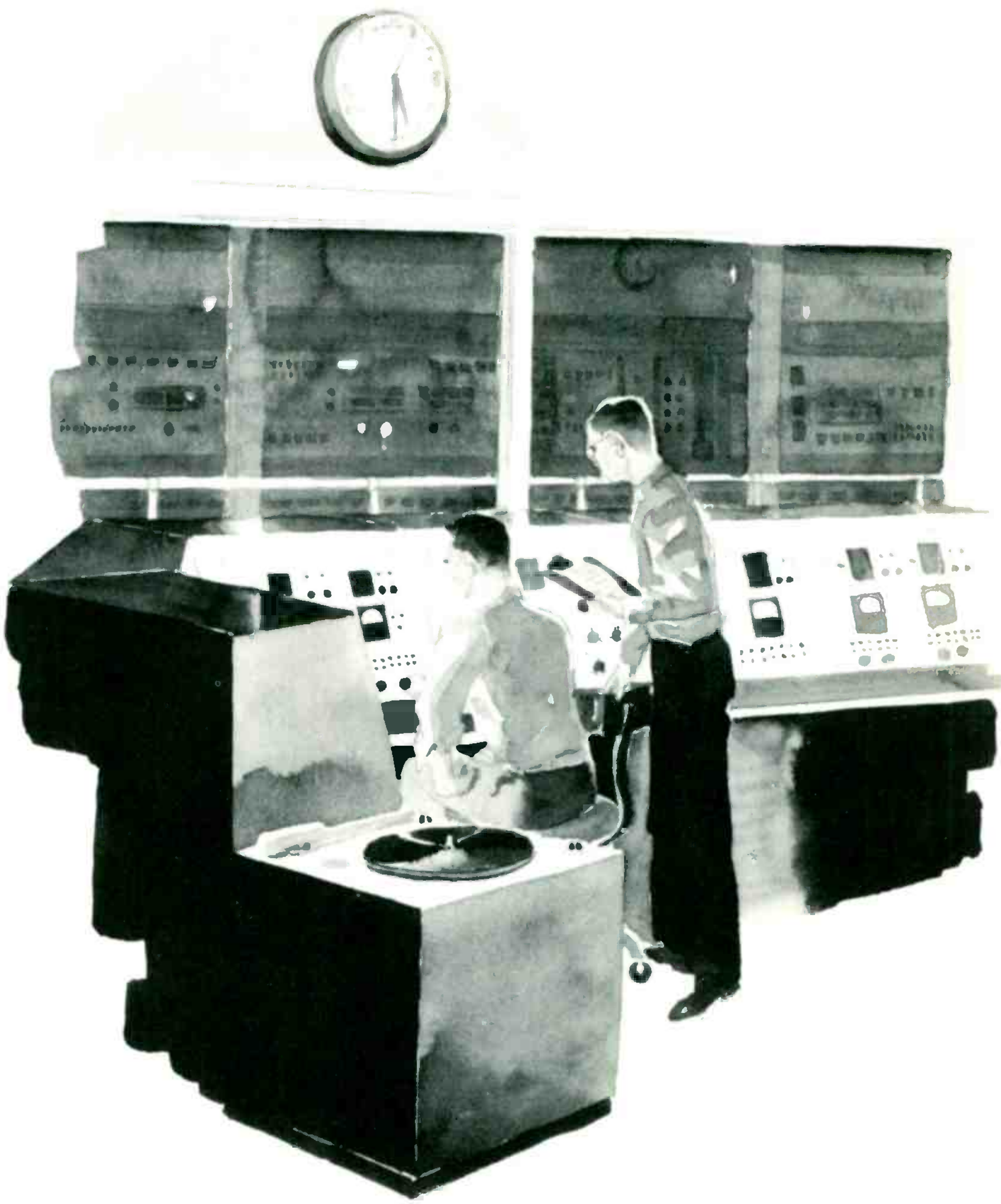
University of Saskatchewan	Saskatoon, Saskatchewan
University of Illinois Medical College	Chicago, Illinois
Memorial Hospital	New York, New York
French Ministry of Health	Paris, France
Anderson Hospital	Houston, Texas
Washington University Medical School	St. Louis, Missouri
Columbia - Presbyterian Medical Center	New York, New York



A Betatron in position, surrounded by great shielding walls of concrete to guard against uncontrolled radiation. The Donut is between the two curved-edge parts at left center of the apparatus.

Patients are wheeled into position right by the Betatron, for deep x-ray treatments made possible by the accurately localized dosage produced by this remarkable apparatus.

Steps Add Up to Miles



WHILE all this was going on in its x-ray activities, a good deal more, proportionately, had been taking place in Machlett's power tube operations.

It was no light task to step into Western Electric's shoes as manufacturer of 28 highly reputed tubes for broadcast, communications and power uses. Quality-wise, the responsibility was enormous; Machlett had two reputations to uphold—its own and Western Electric's—and there could be no chance-taking with either. Nor could there be any shortcoming in quantity, since important equipment makers and users (including the Bell System) depended upon these tubes. It was, for a year or so, an anxious time.

There was this, however: "Quantity" meant steadiness of manufacture of numerous types of tubes in small lots, not large-lot production. And Machlett was all but literally geared to this kind of operation—by long experience, by size, by equipment and layout of plant, by management set-up, by habituation of production personnel and by established engineering procedures. It was nothing new to make the most exacting kinds of tube in 50's or 20's or even 10's; the company had been doing just that ever since it started in the x-ray tube business.

And as a consequence Machlett Laboratories had developed a unique characteristic: the ability to engineer design improvements and put them into effect without a break in pace. You cannot readily do this if you are a big production-line manufacturer; any change in design means a halt in the flow of retooling, rescheduling, perhaps retraining. So large companies, in the interest of efficiency, tend to make design changes at convenient periods, in greater or less degree, the way the automotive industry does. Machlett, however, had—and has—a mobility that comes right out of the very fact that production goes in small lots for practically any tube, while remaining steady over-all. So it is possible to make design changes in a tube and—once they are proved sound by thorough in-plant and field tests—to incorporate them in the very next lot of that tube that goes through the plant.

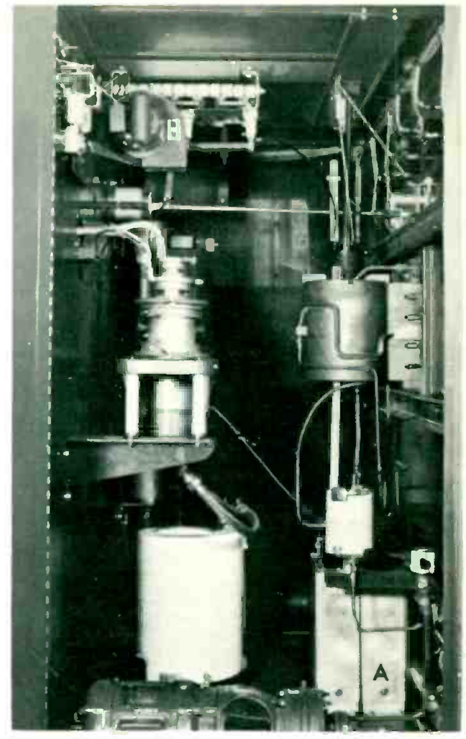
Typically, the popular tube type 880, widely used in short wave broadcasting and military equipment, was first "ruggedized" by structural design changes, retaining complete interchangeability for all existing installations. A year later it was further improved by incorporating a thoriated tungsten filament. The cumulative effect of these changes was to double the service life of the tube. Its success among users led to a very wide acceptance of the basic principles of structural design in which Machlett had set the pace, notably the smaller, sturdier glass envelope; the use of Kovar-to-glass seals in place of the feather-edge Housekeeper type; the heavier-wall anode and other thicker-section elements; and the over-all employment of geometry in design for the mutual support of all elements.

Typical, too, but also exceptional, was the cooperation of Machlett engineers with those of Western Electric and Bell Telephone Laboratories in bringing to completion a tube of unusual size and power which Western Electric had had in development at the time of the transfer.

This was a 50kw triode to operate at 110 megacycles for FM broadcasting. Into this Machlett put all its experience in design for high-frequency and high-power use. The result was the present

The well-known and widely used type 880 tube (sketched above) was "ruggedized" by repeated small but effective changes in design and construction, into the type 5658—a tube which replaces the 880 in existing equipment and gives superior performance.

widely-known type 5681, used in Voice of America broadcasting, in powerful radio stations like Cincinnati's 50kw WLW, in many major television transmitters such as CBS's Channel 2 in New York and in large numbers of other installations. It is a tube of such scale and importance in use that it warranted incorporation of every known refinement in design and manufacture regardless of cost.

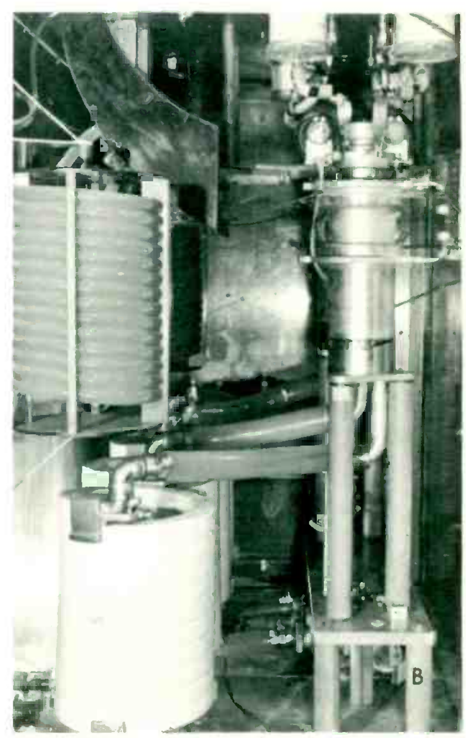


The 5681 would be unique in its field except for one thing: Its success prompted engineers designing equipment for the State Department's million-watt VOA transmitting stations to ask for a still higher power version of the same tube. This, known as type 5682, is noted for better than 300kw input up through 50 megacycles. 18 of them in a Voice of America megawatt transmitter deliver a broadcast signal of over 4 million watts peak power.

Together, the two big triodes 5681 and 5682 have come to stand for Machlett Laboratories in the same sense that Cadillac stands for General Motors: they exemplify the best the company makes, regardless of cost, and they are widely recognized as typifying the best anybody can make in this top class of tube.

Long before these developments were complete, Western Electric and Machlett Laboratories announced a final step in the change-over from one to the other: From September 1950 all tubes, including those developed out of Western Electric types, were designated straight-out "Machlett Laboratories" tubes. This was not merely because by that time they were well on the way to becoming distinctively Machlett products by virtue of redesign. It had been Western Electric's intention from the start to step entirely out of the picture as soon as it became clear that Machlett performance was all the bigger company had expected when it made its selection. Two years had shown this beyond all question.

And they had shown it in certain respects that were as important, in their way, as competence in engineering and conscience in manufacture. Among these was personal service to customers—in the filling of orders and in the follow-up procedure to see that tubes were satisfactory in service.



As we have seen, it was largely with this in mind that Western Electric—one member of a keenly public-relations-conscious organization—had selected a relatively small company to take over its operation in a kind of product that needed a highly personalized service to purchasers. Machlett had built its x-ray business from scratch, in a field hitherto dominated by big corporations, largely because as a small and very human outfit it gave a degree of personal attention to order-filling and order-follow-up that a big manufacturing company rarely does—because it doesn't have to. And when this helped move the company up through the field to world-leadership in x-ray tube manufacture, Machlett was bright enough to see that personalized service belonged for good, and to organize it so it would keep working.

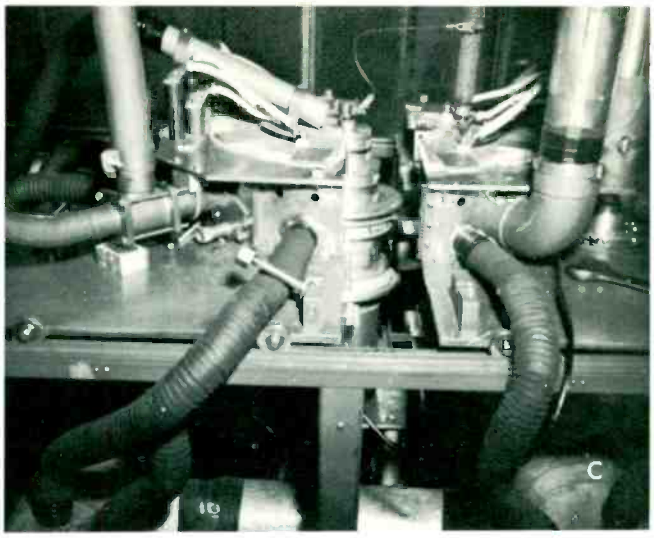
Perhaps "organize" is the wrong word if it conveys an impression of framed charts on which people are penned in ruled rectangles sharply separating their functions, and connected by lines showing authority. Actually, orders reach Machlett in practically every way, formal or informal, and many of the biggest ones come in by phone to Cooke, who handles x-ray sales, or to R. E. Nelson, his opposite number in power tubes. Others land on the same desks by mail direct from customers, or come in from the company's four field representatives

IN INDUSTRY

A A 5681 tube (left center) in the oscillator compartment of a Lindberg 50 kW induction heater.

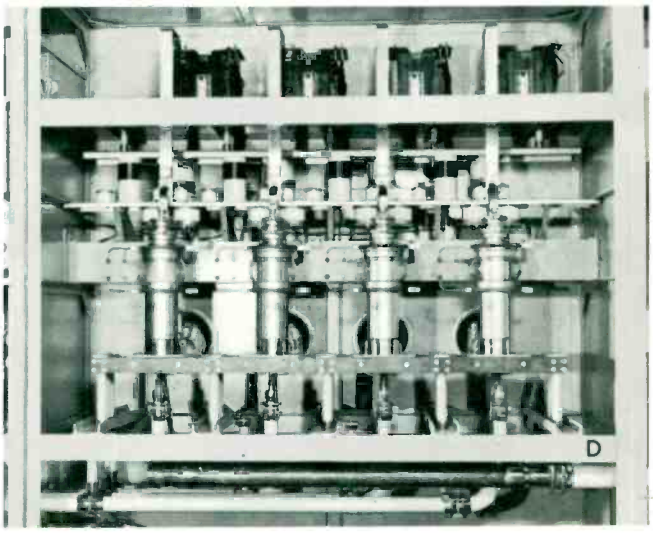
IN RESEARCH

B Here two 5681's—one visible at upper right—form part of the power amplifier for the 2.5 BEV proton accelerator at Brookhaven National Laboratories, Upton, Long Island, New York.



ML-5681

ML-5682

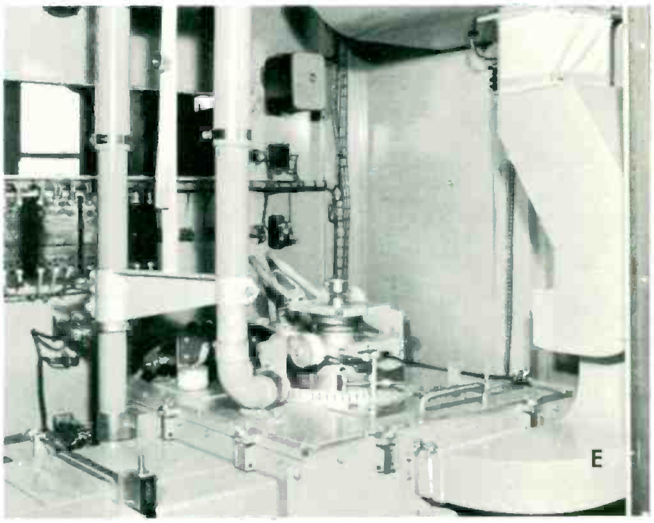


IN BROADCAST TRANSMISSION

C A 5681 tube at the heart of the final amplifier stage at Major E. H. Armstrong's FM Radio Station K E 2 X C C, at Alpine, New Jersey.

D Four of the eighteen 5682 tubes in the megawatt super-power transmitter, developed and built by Continental Manufacturing Company for International Broadcast Service.

E In many TV installations, the big Machlett tubes are vital elements. Here, a 5681 (of which the top shows at right center) appears in the video cavity of a General Electric TV amplifier putting out a 35 kW peak visual signal. The sound section of the same station equipment also uses a 5681 tube.



Dave Frankel, who headquarters in Chicago, is Machlett's liaison man with customers throughout the Midwest — a territory whose extent is exceeded only by its importance.

George Taylor, working out of Los Angeles, covers the Mountain and Coast states for Machlett. Like Dave Frankel, he does so largely by fast airline transportation.

D. S. Frankel, G. J. Taylor, E. H. Gilbert, and G. W. Whitney (even these are not salesmen, since they cover no set routes and take orders, when they do, only in the course of engineering service to the customers on whom they call). To be sure, all these orders pass through an Order Service Department, but this is better characterized than described: it is the department of which the head gets up at 4 A.M. to drive a tube to the airport so it will make an outgoing plane to the customer who phoned for it at midnight. And orders get followed up, after they are delivered, by the field representatives plus, if necessary, a Service and Adjustment Department, which is one that has not yet learned of the invention of form letters.

The net effect of thus personalizing Machlett's operating relations with its customers—and, in fact, with many users—is to make relative smallness an asset rather than a handicap in the competition for business. And just as it proved its worth in x-ray tubes, so it produced results in broadcast, communications and industrial power tubes. In this considerably greater field Machlett had become by 1954 a modestly prominent organization. For this achievement the personal touch deserves a good deal of credit, along with leadership in engineering and integrity in manufacturing.

Perhaps another factor, too, should be given credit: the very existence of the company's x-ray business alongside of and interacting with that in power tubes.

Without its background in x-ray tube design and manufacture, painfully learned over years of meeting ever more rigorous requirements, Machlett could not have succeeded so quickly and unquestionably in the making of other types of electron tubes. Nor would Machlett broadcast and power tubes be quite so good except for the self-imposed discipline of building up to x-ray tube standards. Conversely, though perhaps not so noticeably, Machlett x-ray tubes have also gained from association with the design and manufacture of power tubes. The accession of top-flight electron-tube engineers; the manifold experience in wartime production of rigidly specified communications and radar tubes; the lessons of designing and making power tubes for industrial installations (so much more stringent in physical requirements than the radiologist's laboratory); the experience in ultra-high-frequency electronics; and above all, perhaps, the contact with design and operating engineers in the ever-broadening field of electronics—all these things have contributed to refinements in the design and manufacturing techniques of all Machlett tubes—including those for x-ray use.

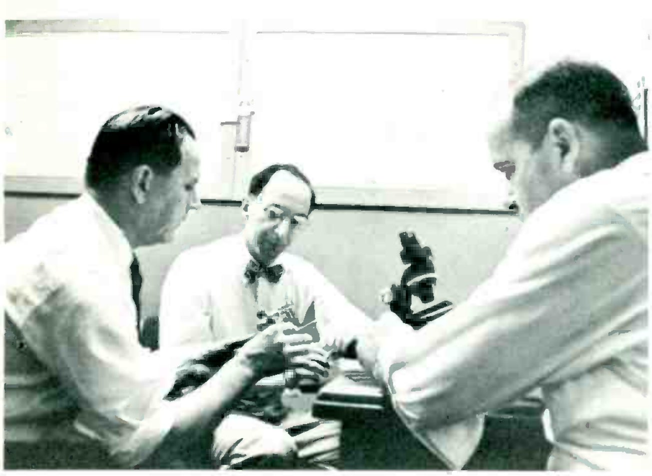
Rod Nelson, Manager, Power Tube Sales, has a tremendous field to cover, what with broadcasting, communications, industrial heating, military applications and many other fields of which the electron tube is the heart.

Key men of the Order Service Department talk over the never-ending problem of keeping production, delivery and service up to—and just ahead of demand. Left to right: Neil Perone, Manager Al Martel, Bob Lahey, Dick Parlette, Rem Toner.

Harold A. Murphy is in charge of Machlett's Patent Department, a responsibility that requires not only legal training but a comprehensive grasp of engineering.

Ed Gilbert is opposite number to Frankel and Taylor in the east, working out of the home office in Springdale.

Their watchfulness ranges from world-wide to microscope-close; W. A. Rousseau, Manager (center) with two of his aides in Service and Adjustment, Harry Townsend and Ken Cornell.



Sales Engineer G. W. Whitney is a specialist in the problems of broadcasting and communication networks. He carries other important assignments as well, including responsibility for Canadian sales activity and contact with fellow manufacturers in the electron tube field.

A Chapter That Had to Be Written

INEVITABLY Machlett Laboratories, dealing on an ever-increasing scale with complex sciences and technologies, became an organization of men rather than a man's organization. In the early 1930's gifted men like Ray Machlett and Skehan could solve difficult problems in x-ray tube design or manufacture with a mere assist from engineers with university degrees. By the 1950's the shoe was on the other foot; the burden of applying advanced science had now to be carried principally by men with advanced technical training; the support function fell to such as Ray Machlett, Skehan and others. In the early 1930's Ray Machlett could be—and was—the active managing director of every operation, with able assistance from a crowd of young comers. By the 1950's it had to be the comers (now arrived) who did the active management of operations with support—but only over-all direction—from the head of the business.

This gave Ray Machlett fuller opportunity, of course, to exercise his unusual gifts for understanding and encouraging other men. It gave him more freedom to apply his unique, instinctive flair for the successful guidance of a business. And it gave him the first taste of the creative man's richest satisfaction: sitting back now and then, to watch his creation run itself. It is a reward that comes all the more gratefully to any man in proportion as he has labored in the building of something that works—whether it is a boyish radio set or a youthful hot-rod or an adult hobbyist's workshop project—or a born organizer's team of human beings functioning smoothly and powerfully in the work of the world. Ray Machlett was too much interested in his creation ever to stand off and watch it for very long;

he enjoyed the fun of sitting at the controls. But he could see that it was a sweet machine, capable, if necessary, of going far and true on its own.

He had time, too, to enjoy some of the simple luxuries that were the only kind he cared for. He was indifferent to most of the things that attract men who have made money to spend. Characteristically, he didn't care about yachts, though he liked sailing and lived near Long Island Sound. He had no yen for big, shiny motor cars and would, indeed, buy a new car only when urged to it— except for a small imported sports car—a "bug," he called it—that gave him a good deal of hilarious amusement. His only sizable purchase (though a modest enough one for a man of his means) was a summer vacation estate along the shores of a lake in nearby Brewster. This he called in typically irrepressible irreverence, "Helgramite Hollow," but with an equally typical touch of sentiment, he caused to be lettered on a beam of its pleasant porch the quotation:

> "God save some silent places still
> Apart from those where man forever goes."

He had an open-air fireplace there, where he loved to give barbecues for groups of friends who also loved good eating, good song, good cheer. Most of these were associates in business. It was at the lake, too, that he indulged his one hobby—the raising of Brittany spaniels. Even in this he found his chief pleasure was friendship. Shortly after the war he commissioned Foster, on a European trip, to find and bring back the best dog France had of that remarkable breed. Foster managed it, with considerable and enthusiastic French help. Arriving in New York he introduced Ray Machlett and Wippy de la Vallée Bourrault, champion of his breed and, as it turned out, a character among canines for quickness, intelligence and devotion. Dog and man took to each other from the first instant of their meeting on the pier and from that moment were inseparable companions.

Ray Machlett, in mid-1953, was in the prime of life, with everything to be proud of and everything to live for: a successful lifework now able to stand on its own feet; a family at that best of all ages when at last all are companionable adults together; a host of friends who loved him because he was above all other things the most lovable of men.

And then ironical fate stepped in.

In June of that year a bothersome lung irritation suddenly became acute. Doctors gravely showed him the first x-ray negatives—there never was any holding-back of anything from Ray Machlett. He recognized very well what the spot on the negatives probably meant,

Laughter brightened every corner of Helgramite Hollow whenever granddaughters Bonnie and Meg, children of son Bob, came to visit Alice and Ray Machlett.

since so much of his life-work had been in the making of tubes for the medical profession's diagnosis and treatment of cancer, and he consented to go into a hospital in New York for some days of thorough diagnosis. Here there was a great deal more radiography, which he followed with a professionally severe eye. And when at the end of it the surgeons proposed to operate "tomorrow morning," he just as positively told them they would do no such thing, put on his clothes, signed himself out and went home. He wanted first to consult specialists in the advanced treatment of cancer by radiation—notably Dr. Trump in his capacity as Director of M.I.T.'s Radiation Laboratory, and Dr. Hugh Hare, of the Leahy Clinic.

Experience, of which he knew, showed that x-ray therapy had been successful in cases considerably more advanced than he believed his own to be. On examination, Drs. Trump and Hare and others concurred in this view. There seemed a strong probability of success with x-ray therapy alone, and in any event, a preparatory sterilization of the area by radiation would make surgery—if it came to that—more likely to succeed. Accordingly, a series of x-ray treatments were begun at Cambridge, to cover five weeks, with five sessions a week.

Here another irony of fate developed. It turned out that Ray Machlett, who had been intimate, so to speak, with x-rays all his life, was in some unforeseeable and unexplainable way unduly sensitive to their effect. He suffered marked exhaustion under treatment, and disturbing secondary after-effects. Nevertheless, it appeared by the summer's end that radiation had been successful in destroying the malignancy, and he went back to his home and his work. The doctors would have to watch, of course—and perhaps for a long time—before they could know that the cure had been permanent, but there seemed every indication that in this, as in so many worse cases, radiology had won over cancer.

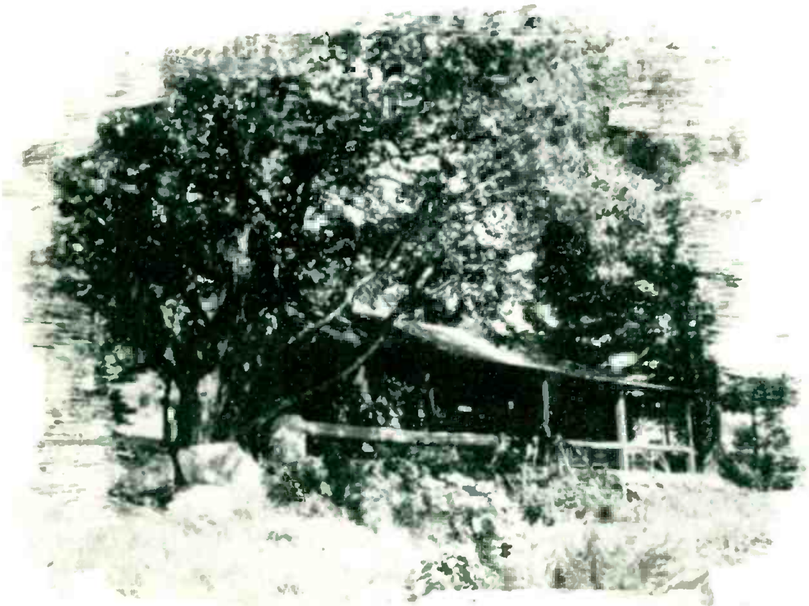
For a year, then, Ray Machlett led very much his usual life. If he consented, now and then, to abate the spending of energy afoot, he made up for it by the vigor and liveliness of his mind. People remember of him in that last year a tremendous interest in learning what they were doing, and in finding ways to help them do it. He had the knack of ribbing people constructively, and the capacity to accept as well as to deal out informality. But he was always the boss. Totally without affectation or sham dignity, he had nevertheless a tremendous self-respect. He would put up with anything that did not matter, but in what counted, he was never put upon. That, and the courage with which he maintained it in all things great and small, and the fact that he was usually right, were the things that combined to give other people their utter confidence in him.

"A family at that best of all ages when all are companionable adults together." Two of Ray Machlett's three children entered the business with their father. Raymond R. Jr., better known as "Bob" is active all across the board in the work of many departments. Alice, as Advertising Manager, heads all the company's public relations and sales promotion activities, including Cathode Press, its prize winning company magazine.

Younger daughter Paula, with her husband and a Brittany spaniel friend, on their place at Helgramite Hollow.

They were becoming confident of his health, too, when in September 1954 discouraging news came from Cambridge. Analyses of sputum samples showed for the first time that the malignancy had not gone. They rushed him to Cambridge, of course, for immediate x-rays, and these showed all too clearly a spot in the old area. More, examination showed that surgery would now be perilous. The only thing left was a resumption of x-ray therapy, but it was hoped that this could be effective in fewer treatments, smaller dosages than before. Unfortunately the old susceptibility was back, too, and so markedly that they suspended the treatments for a while to let their patient regain strength.

He must have lost more than anybody knew, for on the Tuesday before Thanksgiving he suddenly collapsed in his office with a violent chill. The alarmed doctors at the hospital to which he was rushed diagnosed half a dozen simultaneous infections, beginning with pneumonia and trailing off into pleurisy. Yet he rallied so quickly that within a week



he demanded to go home and, being refused (on the paltry ground that his temperature was 103°), signed himself out and went anyway. It gave him a hugely amused satisfaction to demonstrate on arrival that the bothersome temperature was back to normal again.

Nevertheless, from that time on he consented to regular medical care. No hospitals, thank you, but he got more than reconciled to a nurse in his home and cultivated what he described as quite a taste for oxygen.

If he knew all these things were too late—and being a perceiving man, he must have—he did not show it. He was never a man to live in the past and he deplored that quality in others. His tremendous capacity for the full enjoyment of life never left him, and when toward the end he couldn't talk very much, he would grin confidently and affectionately at those around him. His death came quietly and mercifully early Friday morning, January 7, 1955.

"Look Around You"

Over a doorway in St. Paul's Cathedral, London, is carved the epitaph of Sir Christopher Wren, architect of that great building: SI MONUMENTUM REQUIRIS CIRCUMSPICE: *If you seek his monument, look around you.*

PERHAPS this is the time to look at the work of which Ray Machlett was so rightly proud, the organization that he and the others erected so well and truly that it became a living, enduring, dynamic, growing thing—Machlett Laboratories as it is today.

To the eye, it is interesting, and at many points fascinating. Yet the things that make it vitally alive are not those that first strike the eye. Some of them are the standards and working practices and ideals we have already seen as they grew. Another—and a very big one, important to understand—is the principle of close-knit integration. This is not a "compartmented" organization; few of its people do simple repetitive or limited jobs; its operations are interwoven with one another to an unusual degree, made necessary by the unusual character of its business.

An example occurs on your very first step into the Machlett plant, though you may not be aware of it. In the reception room where you comply with the formalities necessary at any plant doing government work, you will note that careful, considerate courtesy which is the mark of all progressive modern corporations. What you may not know is that at Machlett all the very able and friendly reception and telephone people are part of the purchasing department! The company thinks of purchasing not only as an integrated part of manufacturing —which it is—but also as an instrument of good will and hence of sales. This concept is the heritage of a past in which earned friendship was as important as proved competence. It is symbolic of a present in which practically all responsibilities have to transcend the customary bounds.

You find this in the main office, which you enter from the reception room. Outwardly it is the usual assemblage of personable young people at desks and files. The executive offices which it serves, and which open onto it, are occupied by men of well-designated functions. Yet you are apt to find sales being made in a design engineer's office, and design being discussed around the desks of sales engineers. Step in to the order-service department—primarily charged with seeing that purchasers get exactly what they want exactly when they want it—and you find them drawing up requirement schedules that are in effect mandates to the production departments. All these and infinite other crossings of conventional lines are not so much complexities as tight integrations, rising out of the way the company grew and the imperatives of its business.

This cannot help but strike you forcibly when you pass (directly through a short passage) into the production departments.

Organically, these are laid out with complete logic and clarity. Physically, that functional orderliness is hard, at first, to perceive, so closely woven is the whole production structure.

It is, in concept, somewhat like that of a many-tracked railroad system over which pass in the course of a day many different trains of widely differing types. Some trains stop at certain stations but pass through or far around others. Some trains are daily-scheduled flyers or fast freights; others are specials dispatched as the traffic requires. Some multi-track stretches of the system serve virtually all trains, and numbers of trains can pass along these at the same time; others are single-track by-passes or sidings or what-not, for this or that special kind of train, and these may be used, perhaps, only now and then.

The "tracks" and "stations" in Machlett production are the various processes, each with its equipment and people and techniques, through which any given tube must pass on its way to completion. The "trains" are tubes of one kind or another—some 200 kinds in all—in the two main classifications of x-ray and power tubes. Both classifications pass over the same general system.

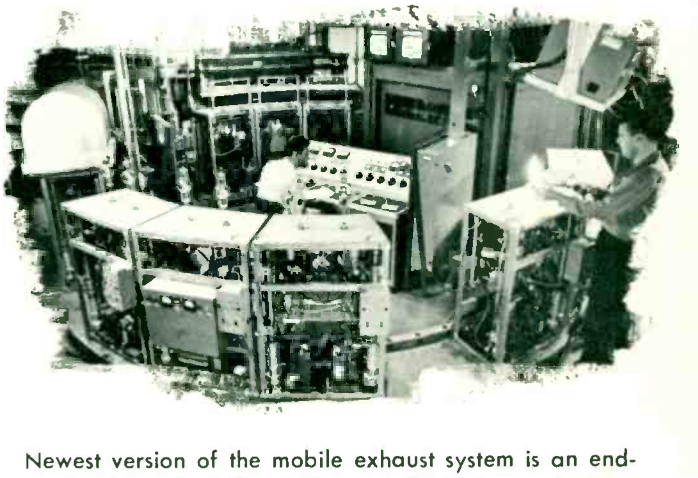
The reason for this is twofold: First, as we have noted, the company's basic policy is to preserve one standard for both x-ray and power tubes—the higher one. It helps preserve this standard, to produce both kinds of tube in operations that use as far as possible the same "track system." But this is a minor reason; uniformity of standard could, if necessary, be maintained even if the two kinds of products were totally separated in production.

More important is the fact that with one exception, Machlett tubes are produced in small quantities which can and should travel successively through the same general channels of flow. Only a few types of tube are made daily: rotating anode x-ray tubes, rectifying valves and the 2C39A planar triode, and of these only the latter in such quantity that it can justify a separate manufacturing unit of its own. Certain of the very large power tubes are made at a steady rate, but the quantity of these is small. Most other tubes are made in lots of 75, 100, 150 or whatever other size may be dictated by operating efficiency, and these lots are variously scheduled to meet —on the nose—precisely forecast requirements compiled from sales records and from carefully maintained contact with equipment manufacturers, distributors and users in the field.

Hence it is difficult for the outsider to distinguish

The Machine Shop looks typical of modern industry—but actually works with some extremely difficult metals.

X-ray tubes are tested under high voltage in an oil-immersion tank.



Newest version of the mobile exhaust system is an endless-track circuit. Tubes being sealed into pump—bearing dollies at right, progress through outgassing stages accurately controlled from the instrument board at center.

A power tube, at left, glows behind safety glass as it is put through gruelling, instrument-recorded tests.

The chemical cleaning of tube parts looks—and is—as thorough as in a research laboratory.

In the Model Shop expert machinists and glass workers fabricate pre-production tube components.

visually the process of flow, as he might readily follow it in a plant devoted to the day-in-and-day-out quantity manufacture of the same product or group of products. Through any one department, and often through any one point in a department, there must pass in the course of a day many different kinds of tubes. So more or less any point may have to be equipped to perform a far greater variety of operations than if it were functioning always on the same model of tube, production-line fashion.

There is an added reason why you find it visually hard to follow an uninterrupted production-line flow: the company's business has grown during the last fifteen years faster than its constantly increased manufacturing space. So production facilities are physically fitted together in some cases jigsaw-puzzle fashion, to get the utmost out of available space.

Nevertheless, there is at Machlett Laboratories a very neat, orderly, systematic and precise production-flow. But it is not a mechanical one of conveyor-belts. Rather it is an administrative one of schedules. An elaborate and efficient system of records is interlocked at one end with user needs and at the other with every parts bin, fabricating machine, assembly installation and testing station in the whole plant. The moving parts of this system are rapidly changing figures and fast-working people: its effect is to make one smoothly-moving machine out of what seems at first glance to be a bewildering complexity of equipment.

And this equipment is complex by the very nature of the many highly intricate, precise and rigid-specification products on which it must function. Materials alone are unusual. You cannot choose them for easy workability; you have to work with metals, for example, whose inherent characteristics mean difficult machining; tungsten, beryllium, unusual alloys of copper, pure nickel, platinum, gold, silver. . . . You have to work with glasses chosen for unusual coefficients of expansion combined with strength, not for ease of forming. You have to employ a variety of gases: oxygen, nitrogen, hydrogen, argon and helium—not to mention enough illuminating gas each month to supply the ordinary household for a generation. You have to work, at one extreme with tolerances expressed to ten-thousandths of an inch of dimension or milligrams of weight, and at the other with vacuums many times as great as are customary in the manufacture of ordinary receiving-set tubes, and with voltages over a thousand times as high as in the ordinary household.

Furthermore—and most importantly—in the making of big tubes in relatively small quantities, you have to manufacture an unusually large percentage of all parts on the spot. Customarily, in volume-production American industry, large percentages of a finished product

Personnel Manager Gordon Hamblen drops in to visit with Plant Nurse Amy Salley.

It takes a special gift for care and unfailing accuracy, to inspect electrodes for any kind of Machlett tube, prior to sealing-in.

An optical comparator is used to inspect the machined head of an x-ray tube cathode. This instrument not only shows an enormously magnified silhouette of a small metal part, but by means of a projected scale enables the operator to measure the part with ten-thousandth-of-an-inch accuracy.

are composed of parts or assemblies manufactured by independent suppliers. (Something like two-thirds of your motor car is purchased in finished parts by its manufacturer, from makers of frames or axle assemblies and so on, down to hardware.) But in the making of x-ray and power electron tubes, requirements for most parts are so particular and quantities so small that there do not exist subcontractors capable of making them. So, for example, where the makers of a household appliance can buy electric motors, Machlett, needing a very special type of motor for rotating anode tubes, not only makes the rotor (the all-important anode itself) but winds the unusual stator.

The "railway system" of production for Machlett begins with purchasing, receiving, inspection and storage of materials. After that it is divided, as a railway is, into two "divisions," each with its group of successive operations. Those in the first division put a tube all together and seal it under what would ordinarily be considered a respectable vacuum. Those in the second are concerned with perfecting that vacuum, testing tubes under conditions more severe than service requirements, and finally finishing them for shipment.

Operations in the first series, under Gannon, include every variety of parts-forming by machine-shop operations, vacuum casting, brazing, welding, soldering, plastic molding and other processes. Parts—and assemblies of them—are exhaustively cleansed by mechanical, detergent, chemical and firing methods; are then assembled and "glassed in"; and are finally sealed off much as though they were actually completed products. Indeed, this amounts to more than the whole sequence of completing tubes of the home receiver type.

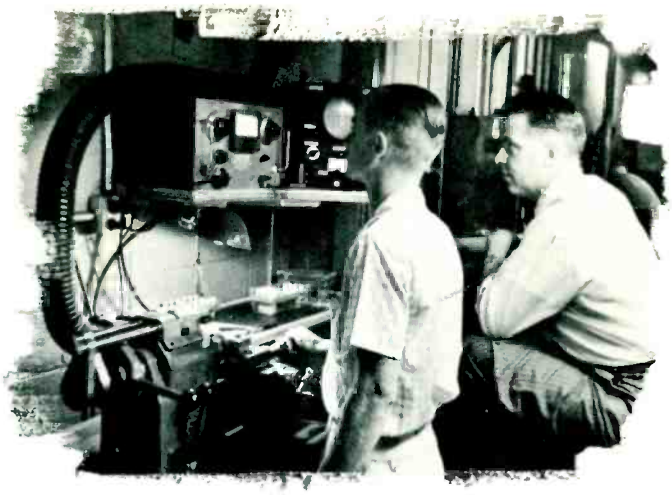
The second series of operations, under Crabb, is what makes big tubes "big." It starts at the pump room, the heart of Machlett Laboratories production operations. Here tubes are sealed to high-vacuum pumps mounted on moving dollies. On those—with the pumps continuously at work—they travel for 4 to 36 hours (depending on the type of tube) through intense-heat baking ovens and other installations to perfect the out-gassing of glass and metal components. They are then sealed off and operated—both for "run-in" and test purposes—under severe overload conditions with elaborate recordings of their performance in every respect and at every stage. Naturally, these procedures differ according to whether the tubes are x-ray or power tubes, but the objective is the same: to produce a tube known and recorded by every possible test to be well above the highest user-specifications and with a life expectancy, as far as it can be determined, considerably above the accepted norm. Records of each tube's tests are permanently filed for reference, if need be, years later. In the case of many tubes—especially the larger power tubes—these records include an x-ray negative by which the alignment of all elements has been checked as one step in quality control.

Only after such tests do tubes go on for final assembly, which includes, in the case of x-ray tubes, such operations as encasing in oil filled shockproof housings.

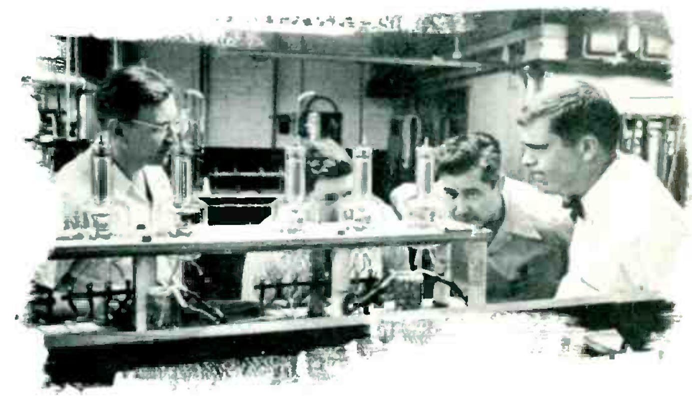
Through all these processes, from beginning to end, runs quality control. It is, of course, unusually thorough, in view of the nature, the importance and the high unit value of the product. Quality control takes place at stations before and after every operation in the preliminary sequence. For initial tests—of materials and simple parts as received from suppliers—statistical sampling according to the most modern techniques is sufficient. But all testing of finished parts and assemblies is a 100% check at every point. And obviously, all examination of tubes as a whole is a repeated 100% testing. Quality control is under Crabb's direction.

The 2C39A planar triode is the only Machlett tube manufactured in what would be regarded elsewhere as quantity production. So it is made in a separate manufacturing unit of its own. Since it is dimensionally smaller than any other Machlett tube, the operations in its manufacture are on a spatially smaller scale. But it is made to the same scale of quality and, within its design limits, tested to the same scale of requirements. Significantly, Machlett's 2C39A operation was the first to qualify under the Signal Corps RIQAP (Reduced Inspection Quality Approval Plan) by which the Army is able materially to reduce its own time-consuming inspection of certain products in manufacture by relying upon demonstrated and approved procedures of manufacturers with whom it has had sufficient experience.

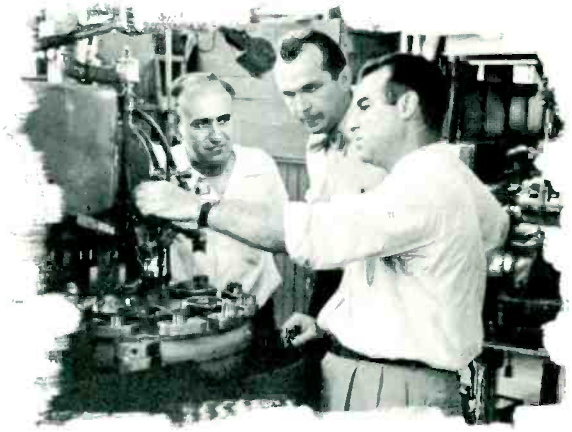
Perhaps as important as quality control, and certainly a good deal more unusual, is another all-pervading factor you become aware of in Machlett Laboratories—cleanliness. It is not the showy kind of immaculateness that smacks you in the eye—white-tile fashion—though certain of the sealing-in rooms are neat and white as hospital wards. Rather it is the kind of tidiness you see aboard a lovingly-tended yacht. You realize that a lot of surfaces are—seemingly without imperative necessity—varnished, and that the varnish has very evidently just been swabbed down and polished. Floors are dustless where you might expect it, and so are walls and ceilings, where you might not. A good many more people wear white cotton gloves than you would normally see—and it turns out that this is not to protect hands but to guard against getting even the touch of a fingertip on anything about to go into the inside of a tube. Above all, there is the incessant cleansing, firing and pumping-out of tubes, repeated again and again, to remove everything—gross contamination and all—down to one molecule in seven-and-a-half billion.



An unusual piece of equipment, delicate and precise far beyond the ordinary, insures parallelism of electrodes in an assembly destined for a high-vacuum triode.



Like umpires calling a close play, a group of Quality Control Engineers watch a new test devised for rotating anode tubes in the Tube Exhaust Department.



Production Manager Ed Gannon (right) is responsible for all production scheduling, and for manufacturing operations through the first half of Machlett's processing. Here he confers with Machine-Shop Foreman Anthony D'Acunto and Methods Engineer Al Fengler.

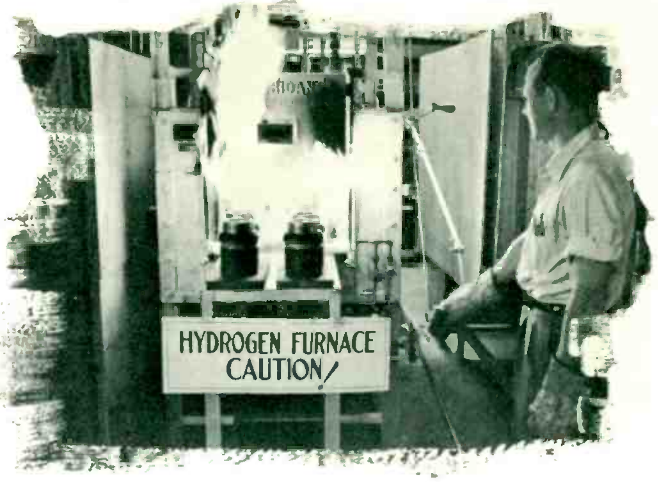
This is not so much a formalized procedure as it is the visible evidence of a trait of character. Inherent in the Machlett consciousness is the realization that the company achieved its success in making tubes better not by blueprint but by extraordinary care. When you have got something good, you hold onto it. Which is one reason why, as Zitzmann was so fond of saying, "What is good stays good."

Another trait of Machlett character impresses itself upon you as you walk through the shop: this is a place of intelligent people. You see quick-looking people, meet understanding-looking eyes. It is no surprise to learn that the educational level of hourly-paid people here is still, as it was at the start, that of the high school graduate. It is no surprise to discover that Skehan, who gets out an occasional mimeographed letter to all employees, is apt as not to lead off with a quotation from Arnold Bennett and wind up by recommending a book on nuclear physics.

Of course, a high order of intelligence is a function of both Machlett's past and its present. The firm made its way by the exercise of a very lively resourcefulness. All its early puzzles tended to bring out the best intelligence of the men, and their successful solution tended to put such men in positions of authority—where they in turn tend now to pick people of like quickness. In the daily work of the company it takes intelligent, resourceful people to change quickly from one type of product to another, and to make all of them well. It takes an intelligent kind of conscience-in-work to make a product as exacting as the x-ray tube or its cousin, the big power tube—priced at $3,000 or so for a cylinder of glass and metal you could easily cradle in one arm.

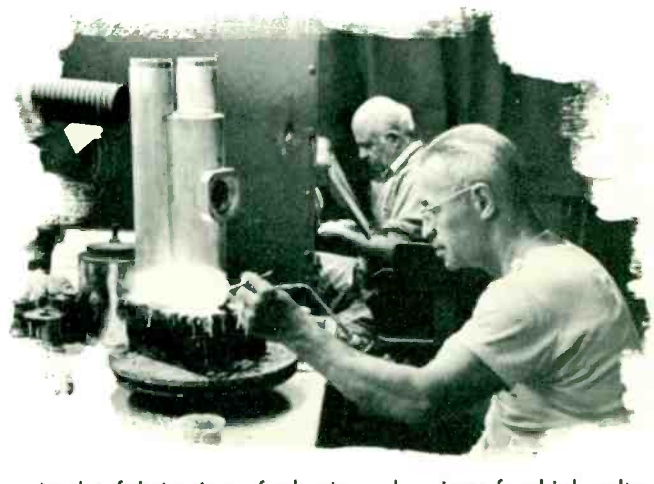
Perhaps this explains in large part Machlett's unusually happy employee relations. It is true that the company pays its people well—and that it administers its pay plan intelligently, with careful job evaluation, systematic review of performance and regular raises within each job class. Incentive pay for quantity being obviously out of place in work where quality means all, the company has a unique and highly successful attendance bonus which has all but eliminated absenteeism.

Naturally Machlett has the vacation-with-pay plan and other fringe emoluments common in advanced employment practice, and it underwrites in full perhaps more than the usual in "benefits" such as insurance, hospitalization plans and the like. An Employees' Benefit Trust Fund, established in 1941, gives each employee of three years or more an equity in the business which increases with the length of his employment, without requiring any contribution from him. He gets his entire share on retirement (or his heirs get it if he dies) and if he leaves before retirement he gets that percentage of his share which has matured with the length of his



Metal parts are brazed in the intense heat of hydrogen flames.

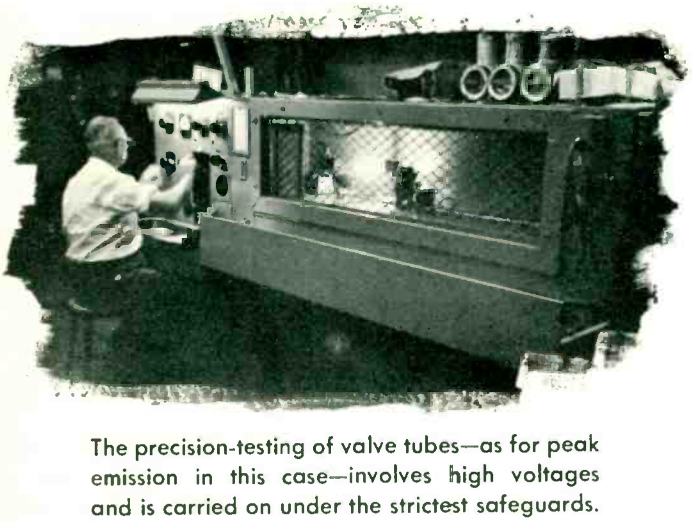
Believe it or not, this is a foundry! The personable young lady in the dainty apron is overseeing the high-vacuum induction casting of copper anodes—a process developed by Machlett Laboratories and unique to Machlett Laboratories.



In the fabrication of aluminum housings for high-voltage x-ray tubes, shown here, operators take unremitting care to achieve an absolutely sound bond between aluminum components and shockproof housings.

The human element is vitally important. People who work well and with loving care are as important to finishing big electron and x-ray tubes as the most advanced high-vacuum, high temperature, high-voltage equipment used along the way.

Purchased parts are inspected on receipt and tested with micrometers and other precision measuring equipment before being put into stock.



The precision-testing of valve tubes—as for peak emission in this case—involves high voltages and is carried on under the strictest safeguards.

employment. The company maintains an excellent canteen for its employees, encourages the usual recreational activities, and last year held a singularly successful Open House for employees' families.

But none of these things explains altogether the high degree of confidence and liking between management and employees at Machlett. Machine shop, tool room and maintenance department employees are represented by the International Association of Machinists (A. F. of L.). The balance of the plant employees deal with management through elected representatives of their own. But this is purely incidental; the catalyst of good relations between management and employees is the very simple but relatively uncommon one of intelligent good sense combined with complete, unpretentious sincerity on both sides.

As you might expect in view of the nature of its business, a rather high proportion of Machlett people (some 8%) are engineers. Currently, among them they represent 45 universities, colleges and institutes of technology —including the Ivy League, all the top rated technical schools, West Point and institutions of higher learning in Switzerland, Germany, Sweden, Canada and India.

Machlett's engineering structure is severely functional—organized with the clear perception that tube making is both a technology and a business, and that it cannot afford ever to lose sight of one function in preoccupation with the other. True, this is a business which exists to serve science, but it is always applied science, in medicine, in research, in communications, in industry and in the national defense. Moreover, Machlett can exist for this service only by operating as a business—that is, by making a profit to live on. Hence Machlett engineering is primarily developmental—concerned chiefly with solving problems that originate in one or another of many fields of product use, and solving them in the form of practical manufacturing operations.

All research is under general direction of a Research and Development Committee, consisting of Stevenson, Hoffman, Skehan, Rogers, Doolittle, Gannon and Crabb —that is, of the principal executives in sales, research and manufacturing. Subject to the general direction of this committee, Machlett engineering is divided into three functional parts:

Design engineering, under Rogers, with Doolittle as associate in the power tube and high-frequency field and with a group of younger associates, is responsible for basic design origination. It must on the one hand maintain a continuously moving acquaintance with developments in pure and applied science and on the other hand work in close liaison with users of x-ray and power tubes both directly and through the company's sales organization. Its job is to know both possibilities as they develop and needs as they occur—often in widely separate places

Lester Crabb, one-time boy-Foreman of the vital Pump Room, is now in charge of half of Machlett's production, head of Quality Control, and a member of the Operating Committee.

The Wage and Salary Committee consists of Gordon Hamblen (left) Personnel Director, Lester Crabb and Ed Gannon.

In Machlett's operations the Importance of capable intelligent Foremen is equalled only by the need for closest teamwork among them. Here Ed Gannon presides over one of their regular and frequent conferences.

—and then to bring the two together for the working-out of a design that uses the possibility to meet the need. For any given problem, design engineering defines the objective in both technical and economic terms, specifies comprehensively and definitely what the characteristics of a tube must be to solve the problem, together with all dimensions, spacings, etc. that are essential to achieving those characteristics. On the basis of these, design engineering prepares a prospectus for the approval of the Research and Development Committee. When approved and given an appropriation, this becomes a "project."

Project engineering is under general direction of Skehan, and is now closely integrated under Rogers with design engineering. With twelve senior and a score of assistant project engineers, it is concerned only with solving the specific problems that come to it as approved projects. Generally, but only very generally, project engineering is structural as contrasted to the theoretical function of design engineering. It develops specific designs both for tubes and for the special equipment, if any, needed to test them. To these designs it builds models, working out as it does so further details of any special equipment that may be needed in manufacture. These models are tested and evaluated in collaboration with design engineering and if satisfactory from every standpoint are put into pilot production. From this, manufacturing specifications, costs and other data are accurately determined. When all these are known, the entire project is evaluated by the Research and Development Committee, whose final approval sends it as a completely engineered product to the company's production organization.

(Lest you think Machlett is afflicted with hardening of the committee arteries, it should be said that all principal committees are pretty much interlocking directorates. The Production Committee includes the Research and Development Committee members, plus manufacturing, scheduling and quality control specialists. And the company's over-all Operating Committee includes them, too, plus the corporation's Secretary, Treasurer and Personnel Director.)

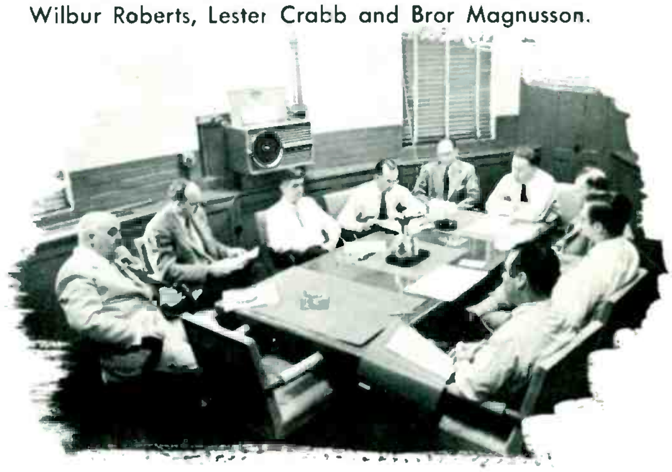
Quality control engineering, under Crabb, is called after its most important function—the devising and maintenance of procedures and equipment for inspecting and for testing tubes in process and occasionally outside in the field. But among its score of technologists it also includes methods engineering and factory engineering specialists. Important as these are, the fact that they are technically subordinate to the concept of quality control is a significant one in the over-all Machlett picture.

Naturally, engineering in the Machlett operation is not and cannot be confined to the formally established engineering organization. The work of the company's headquarters and field sales organization is principally with engineers among equipment manufacturers and users and is, in fact, far more largely of a technical than of a selling nature. Conversely, both design and project engineers are continually being called into contact with customers and users and exercising, whether they realize it or not, a very real sales function. The company has never been, nor is it likely ever to be, a manufacturer of equipment for putting tubes to specific uses. It does not, except in its government business, sell direct to the user. Yet in the course of nearly a quarter-century of supplying x-ray tubes and some 15 years of making communications and power tubes, it has had to learn a very great deal about how to help users not merely with better tubes but with better ways to get the best results in using them.

In the making of x-ray and power electron tubes there is a curious paradox. It is the same paradox you find in the case of so many other complex and exact things: the more nearly perfect they have to be, the less can perfection be achieved by formula alone—by equations and blueprints and precision machinery. You can make a perfect spectacle lens by formula and machine, but to make the 200-inch reflecting telescope for the Mount Palomar observatory took a world of engineering calculations plus the "feel" of great glass manufacturers for their material, the "feel" of expert optical scientists for the grinding and polishing of a mirror, the "feel" of experienced engineers for the design and building of a great mechanism. It is so in simpler things: you can make a very good rifle by rigid adherence to manufacturing specifications, but for gilt-edge accuracy you have got to have not only the utmost in carefully figured specifications, together with equipment to execute them, but at every stage from design to final finishing of the barrel the people concerned must have a certain experienced "feel" for the complex relationships of materials and forces that make a super-fine gun.

It is very much that way when you work in tubes that have to operate at high voltages or high frequencies, high powers, high temperatures, high vacuums. . . . You work with a dozen or a score of different materials. You can know all about any one of them alone, even to its peculiar behavior under weird extremes of temperature or vacuum or current or voltage and all the rest. But when you go to put them together in a complex structure where they all interact with one another and in constantly varying extents as voltage, current, temperature and vacuum change—when you set out to produce with this combination a tool that will precisely control for the use of professional men the lightning-fast flight of the electron—and when you seek to endow that tool with a life-expectancy that you can safely predict in spite of all variables—then you have bitten off a problem

Project Engineering problems are reviewed by a group under the direction of Joe Skehan (nearest the camera). Clockwise around the table from him: Ken Spitzer, Walt Stahl, Bob Machlett, Sam Yanagisawa, Wilbur Roberts, Lester Crabb and Bror Magnusson.



This is a sales meeting. But of the departments represented only three are directly charged with selling: X-ray Tube Sales, Power Tube Sales, and Export. Also present, and equally important in Machlett's view of "Sales" are Quality Control, Order Service, Marketing and Production.

Production Planning is a vital job, in which plant people at Machlett take a major part. Left to right around the table: Sal Del Vecchio, Al De Carlo, Angelo Roscillo, Bill Henry, Bob Scott, Frank Tropsa, Rita Lane, Frank Iliff, and Gene Journalist.

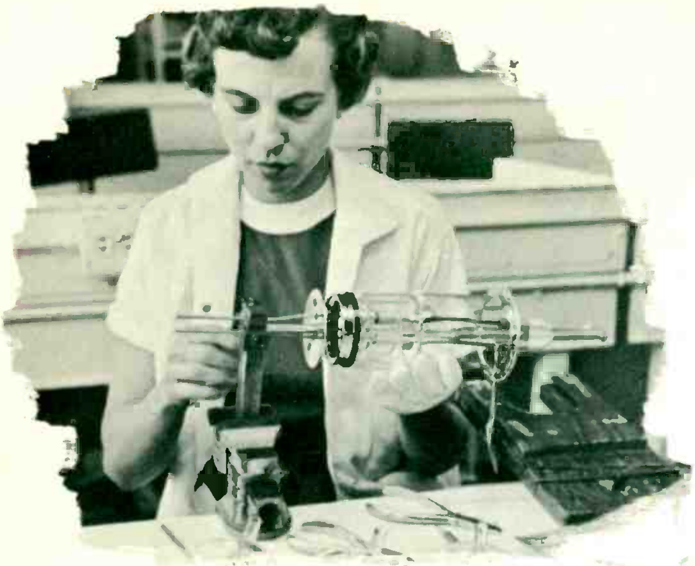
that cannot be solved merely by differential calculus, specifications to the milligram and watching dials as machines produce.

From start to finish in the making of x-ray and power tubes, people need a subtle, undefinable sensitivity to the materials with which they work and the results those materials produce in combination. Production operators must have it, of course; there is no instrument so sensitive and so precise in its reactions to multiple combinations as the trained human intelligence. Even engineers must have it, else their most laborious computations will run off the track by following a straight line when experience shows there is a subtle and incalculable curve. More, an organization must have it as a whole, since its members influence one another consciously or unconsciously in everything they do. They modify one another's individual tendencies, supplement one another's special fields of knowledge. Any organization reaches its highest function not as an aggregation of individuals but as a body of men with a group character all its own. There is a morale in manufacturing, just as there is in fighting or teaching or publishing or anything else, and it is perhaps that morale, finding its expression in refinements beyond those obtainable by formula and precision, that makes the essential difference at Machlett Laboratories.

Purchasing Agent J. A. Miller has a big responsibility and a big department. Four of his principal aides are shown here. Left to right: Bud Dunn, Ass't P. A.; John Hilder and Don Rith, Buyers, and Stan Brown, Ass't P. A.

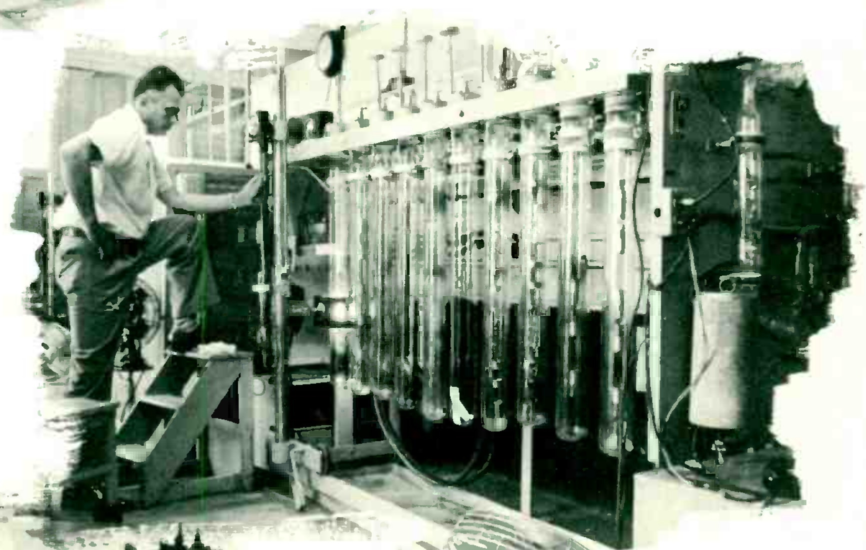
It takes these draftsmen and still more in other drafting rooms—to keep up with the need for working drawings as Machlett tubes and production equipment are constantly being improved.

Walt Wilson, in general charge of all Machlett Accounting, pauses for a moment at the desk of Pete Gwizdak, Chief Cost Accountant.



A typical tube assembly operation. Machlett people are careful, intelligent builders of complex and important electronic structures.

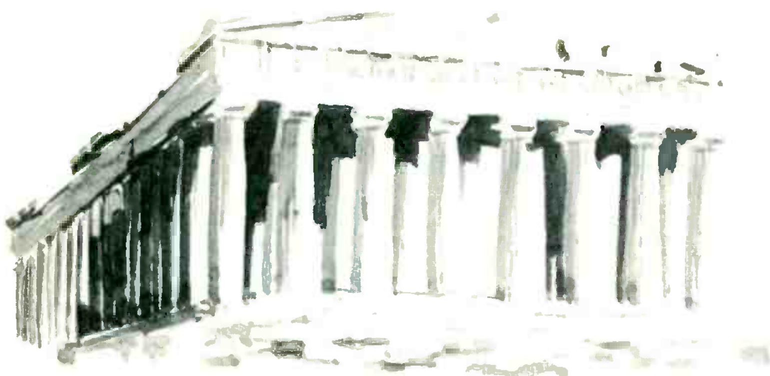
"Furnacing" tube components in high vacuum and under intense induction heating removes every last trace of impurity, creates a degree of cleanliness that results in long life for finished tubes.

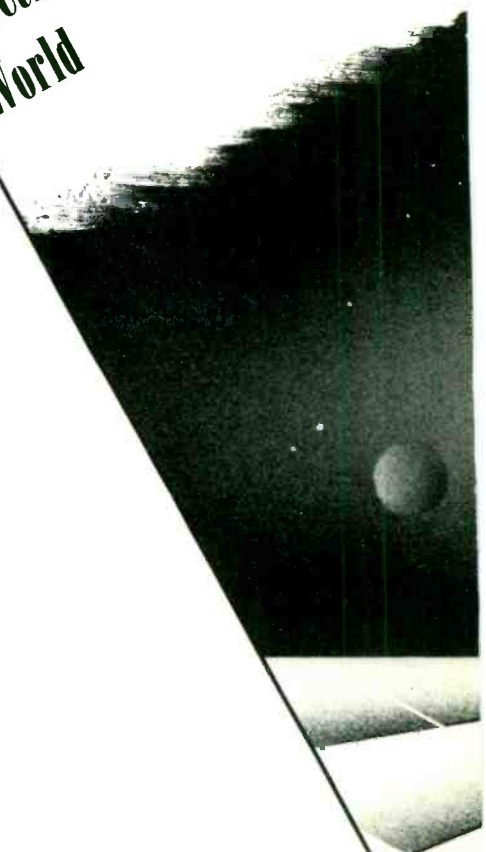


Beyond a certain-stage, parts destined for the inside of a tube are never touched with ungloved hands. Work goes on in surroundings hospital-clean.

Here skilled glassworkers are fabricating small glass parts, and making glass-to-metal seals in the time-honored gas flame known as "the glass blower's fire."

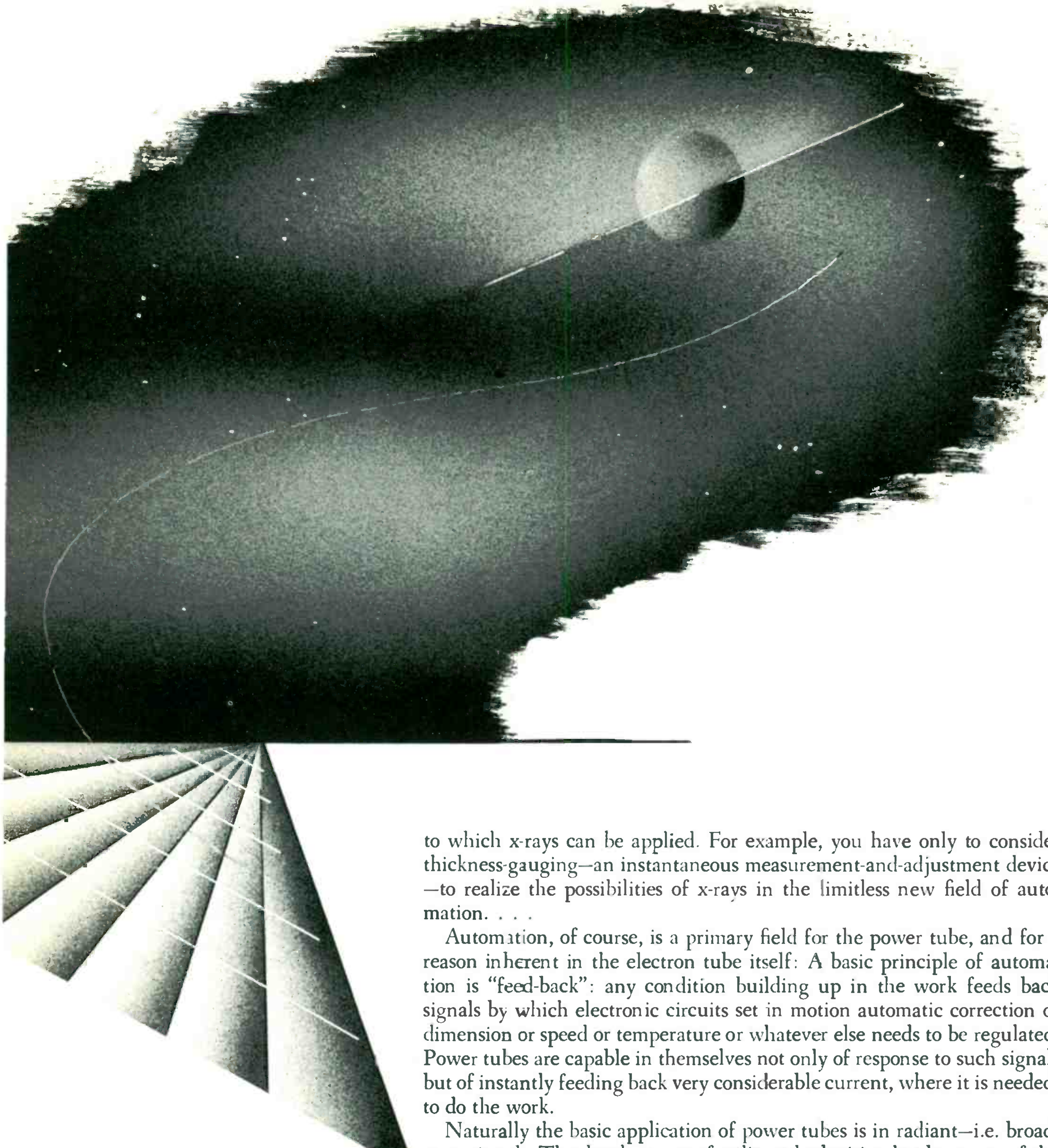
At the Threshold of An Electronic World





WHAT, then, of the future? The present is the best indication. And in the present, the most impressive fact is that the use of each type of tube Machlett makes is at once solid and dynamic. Both x-ray and power tubes are necessary products, serving vitally important purposes in such fields as public health, basic research, communications, transportation, local and national security and essential industry. And in every one of them, these employments are increasing daily.

We have seen how the applications of x-ray tubes expand repeatedly with broadening use and with new developments in tubes that put new powers in the hands of medical and other sciences and—more and more—in the hands of industry. Far as medicine has gone in applying x-rays, whole great fields remain and are certain to be occupied as medicine and its x-ray equipment continue to advance. Other sciences, including physics and chemistry, are very evidently only on the threshold of their knowledge of uses of radiation. And if industry were merely to use existing, recognized applications of x-rays for such purposes as non-destructive examination and thickness-gauging, there would still be a quantitatively enormous potential market for x-ray tubes. But there is every reason to believe that in the infinite variety of industrial operations there are countless other uses



to which x-rays can be applied. For example, you have only to consider thickness-gauging—an instantaneous measurement-and-adjustment device —to realize the possibilities of x-rays in the limitless new field of automation. . . .

Automation, of course, is a primary field for the power tube, and for a reason inherent in the electron tube itself: A basic principle of automation is "feed-back": any condition building up in the work feeds back signals by which electronic circuits set in motion automatic correction of dimension or speed or temperature or whatever else needs to be regulated. Power tubes are capable in themselves not only of response to such signals but of instantly feeding back very considerable current, where it is needed, to do the work.

Naturally the basic application of power tubes is in radiant—i.e. broadcast—signals. The development of radio and television has been one of the great economic and social phenomena of the past generation—and it is still increasing. In this field alone Machlett has won a secure place. You cannot twirl your dial or flip your channel-selector switch without the probability (varying, of course, with your location) that you will hear and see something that has come to you across space, out of Machlett broadcast-station tubes. You cannot tune your all-wave receiver to any of the numerous

Voice of America frequencies without overhearing a message beamed to one quarter of the globe or another with the help of similar Machlett tubes. You cannot telephone overseas, or to a ship at sea, without the probability that your voice will go through Machlett tubes. Send a radiogram, and your message will very likely be dot-dashed, literally "on the beam," to your overseas correspondent through Machlett tubes in transmitting stations. . . . Call a taxicab and your message will probably reach a cruising driver through the agency of Machlett 2C39A tubes. Or for that matter call a cop. . . . Nowadays fire departments, forest rangers, railway dispatchers and a good many people who serve you in ways you never suspect—such as offshore fishermen, cattle ranchers on the plains, manufacturers with big, many-acre plants, operators of the pipelines that bring you oil and gas—minister to your daily needs with the help of two-way communication that depends on this smallest of tubes made at Springdale.

Obviously, these—and other uses of broadcast communication which have been growing so rapidly in number over the past years—will continue to increase and to multiply for years to come. And on a conservative appraisal of Machlett's prospects, based upon its gains in this field since 1949, it would seem that the company was headed for a larger share of a far bigger market.

But broadcasting is only one way in which the electron tube has entered our lives. Many others are less evident. Perhaps you think radar is an armed-forces instrument. Of course it is. Our whole national security against air attack depends on a great radar network, still in process of being woven wider and tighter. Ground and naval forces would be comparatively blind, as today's combat is waged, without radar. But radar is far more widely used for civilian purposes than most people are aware. It guides your passenger plane on any trip at night or in clouds; it safeguards you if you travel, even coastwise, by steamer; it helps the Weather Bureau warn you of storms; it is a vital part of the traffic control that keeps great modern highways unblocked and open for your motor travel. . . . And any of these services it may very likely perform with the aid of one Machlett tube or another.

Just so, other Machlett tubes developed originally for communications or defense are going to work at even more commonplace tasks. It was the oscillator of broadcast type that first made industrial electronic heating equipment practicable—either of the induction or the dielectric type. Now special tubes are made just for these purposes—to stand rough usage both electrically and mechanically. Machlett was the first to design and produce these for the uses of industry.

Induction heating is quick; it heats metals in seconds to temperatures that would take as many minutes to achieve by flame. So it saves labor time, both in work and in waiting. It is neat; it requires no stack, emits no smoke or gas. It is compact; it takes far less room than a furnace. It can melt down metals—for casting, as in the case of Machlett's own copper anodes—or for purifying, as in the case of the germanium used for transistors. It can localize heat in one part of a metal piece, as for the cutting edge of a tool to be tempered or the teeth of a gear to be hardened. It can be applied to light metal pieces as well as to heavy ones, so it is widely used for soldering and brazing such pieces as automobile radiators, domestic appliances, business machines. . . . In literally hundreds of shops and factories induction heating equipment embodying Machlett tubes is already in use. Yet these are only a small fraction of the places where industry can—and will—use this time-, labor- and space-saving process in manufacture.

Dielectric heating is even more widespread in use—and faster spreading. It is ideal for the light industry which would—and should—dispense with fired heating. You find it extensively in woodworking plants—for veneering, for edge-gluing of panels or for securing the joints of furniture, kitchen cabinets and the like. It enters into the making of everything from tennis rackets to yachts—and does a far better job than old-type heating, since in a matter of minutes, using modern quick-setting adhesives, it will make a bond stronger than the adjoining wood.

The plastics industry, too, uses dielectric heating—and increasingly as more things are made of more new kinds of plastic material. Chances are that pretty much any solid plastic piece you see may have been molded under dielectric heat: a phone base, a radio or TV cabinet, an appliance handle, an electric cord plug. . . . Flexible plastics are increasingly being cured by the same process, and those of them that are heat-joined (like plastic raincoats, or billfolds, or inflatable toys, or beach articles, to name only a few out of hundreds) are usually seamed under dielectric heat. The fact that plastic packages can be quickly and economically sealed this way is one reason why more and more different kinds of items are being packed in tough, watertight, transparent or translucent plastic—as a glance at the open display counters will show you in your grocery or drug or hardware or variety store.

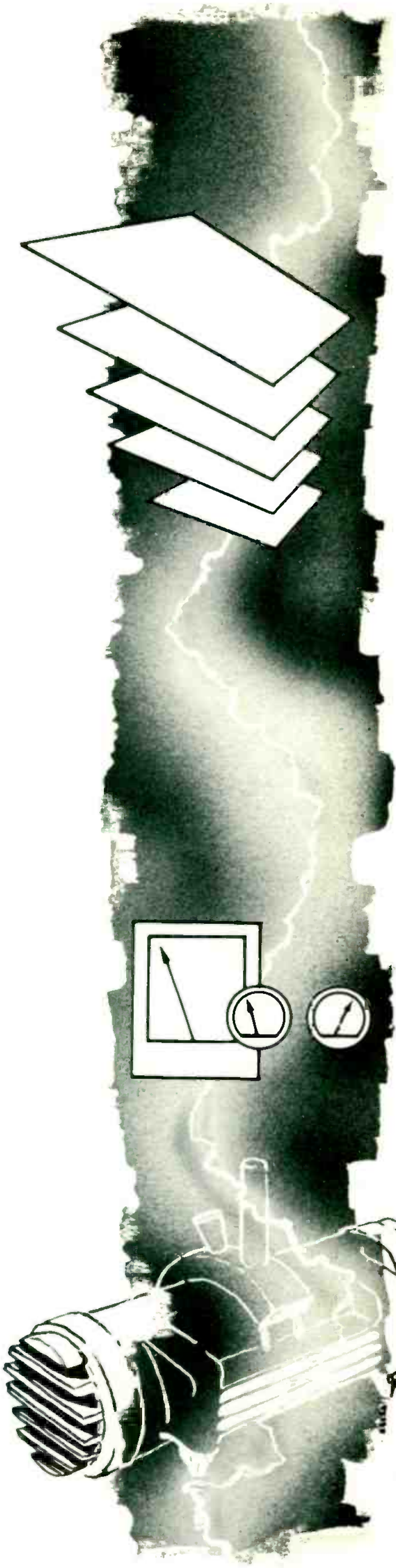
Industry can dry out things, too, under dielectric heat. For example, cereals to be crisped or tobacco to be cured or sand foundry-cores to be baked for the quantity production of cast metal articles. In such fields, perhaps, may lie the largest potential increase of all for dielectric heating.

Another kind of tube—also one in which Machlett led the way in producing rugged models for industrial use—is the high voltage rectifier, for producing what amounts to DC out of AC with low loss. The most widespread industrial use of this is in electrostatic particle precipitation equipment for the cleaning of gases in big processing plants. You may want to take the fly ash out of gas or smoke merely to abate a public nuisance, and many power stations and factories use it for just that purpose. Or the "dust" may be in itself richly worth catching and keeping, as in a smelter or a cement or chemical plant. It takes only a few tons of sulphur trioxide or sodium carbonate at a paper mill to make gas cleaning worth while. In petroleum refineries recovery of high-priced catalysts can become a very profitable operation indeed.

Just as electrostatic forces can separate particles in air, so they can separate them in liquid. Certain flotation processes in mining and metallurgy depend for their efficiency upon power passed through rectifier tubes.

A somewhat similar use of electrostatic force to collect finely divided particles is only beginning—and may well become even bigger. This is spray-painting metal products as they move through an electrostatic field —a far more efficient way to spray-coat than mere squirting, since it wastes considerably less of the fine modern enamels. Machlett tubes were among the first used in equipment devised and made for this purpose. When you consider the great number of quantity-manufactured products which are now spray-coated by ordinary methods, it is apparent what a tremendous new potential there is in this field alone.

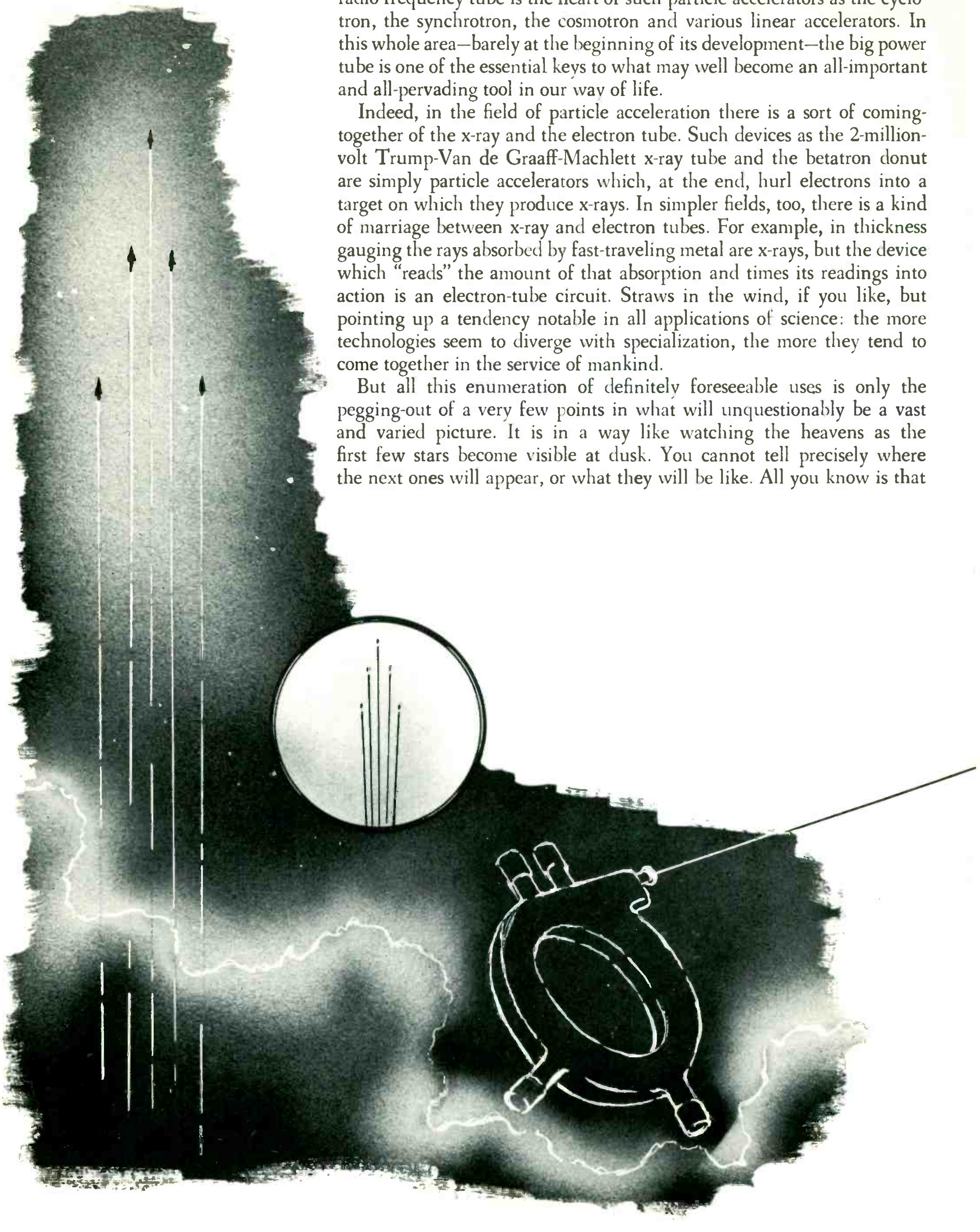
Another whole territory in which the high-power tube is a vital factor is that growing out of nuclear physics. As we have seen, the high-power



radio-frequency tube is the heart of such particle accelerators as the cyclotron, the synchrotron, the cosmotron and various linear accelerators. In this whole area—barely at the beginning of its development—the big power tube is one of the essential keys to what may well become an all-important and all-pervading tool in our way of life.

Indeed, in the field of particle acceleration there is a sort of coming-together of the x-ray and the electron tube. Such devices as the 2-million-volt Trump-Van de Graaff-Machlett x-ray tube and the betatron donut are simply particle accelerators which, at the end, hurl electrons into a target on which they produce x-rays. In simpler fields, too, there is a kind of marriage between x-ray and electron tubes. For example, in thickness gauging the rays absorbed by fast-traveling metal are x-rays, but the device which "reads" the amount of that absorption and times its readings into action is an electron-tube circuit. Straws in the wind, if you like, but pointing up a tendency notable in all applications of science: the more technologies seem to diverge with specialization, the more they tend to come together in the service of mankind.

But all this enumeration of definitely foreseeable uses is only the pegging-out of a very few points in what will unquestionably be a vast and varied picture. It is in a way like watching the heavens as the first few stars become visible at dusk. You cannot tell precisely where the next ones will appear, or what they will be like. All you know is that

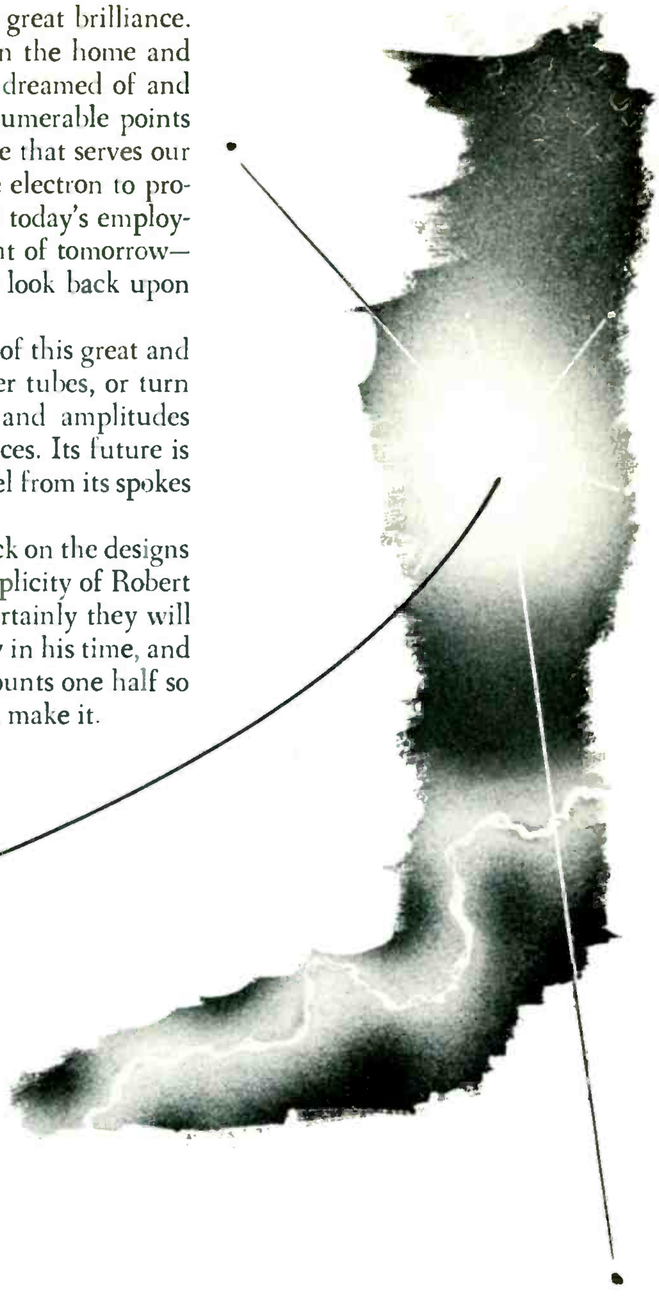


they will appear in great numbers—and some of them in great brilliance.

For this is the electronic age. Already we are served in the home and at our places of work by devices our grandfathers never dreamed of and our fathers only hoped for. Already we are served at innumerable points beyond our seeing—out in the complex economic structure that serves our needs—by great numbers of mechanisms that employ the electron to produce or to control results essential to our way of life. But today's employment of electronics will seem primitive indeed in the light of tomorrow—as simple as 1897's uses of electricity itself, now that we look back upon them.

Machlett is in the happy position of sitting at the heart of this great and growing activity—as maker of the tubes that actuate lesser tubes, or turn crude current into the precise forms and frequencies and amplitudes needed for putting the electron to work in uncounted places. Its future is as inseparable from that of electronics as the hub of a wheel from its spokes and tires.

Naturally, people at the end of this century will look back on the designs of today's tubes as indulgently as we look back on the simplicity of Robert Machlett's x-ray tubes at the century's beginning. But certainly they will know then as we know now, and as Robert Machlett knew in his time, and his son Ray after him, that it is not what you make that counts one half so much as the care and skill and conscience with which you make it.



Begun in 1955, this latest addition, of approximately 30,000 sq. ft., to the buildings comprising the Machlett Plant in Springdale, Connecticut, will provide fully air-conditioned manufacturing space for Machlett's expansion into the field of Photosensitive Devices. It will also provide for expansion of the Companies' Engineering Laboratories.

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Author's Afterword

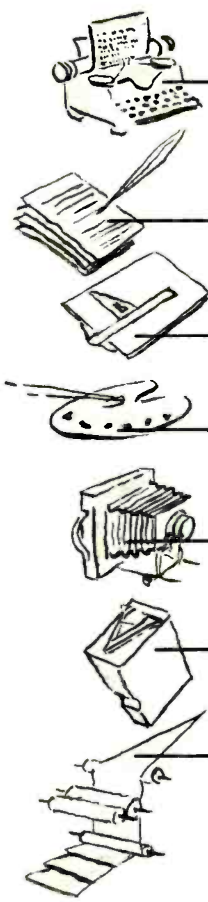
THERE'S a great deal in this story which you will have perceived, if at all, only between the lines. To Machlett Laboratories management belongs credit for certain very important factors: the over-all concept of the story, its scope, character and purpose; the unreserved completeness of information made available to the writer in his gathering of facts; the utter freedom accorded him to interpret those facts as they seemed to him and to tell the story drawn from them in his own way. Machlett's management went to infinite pains to make sure that facts were accurate as far as they could be ascertained, but they left to the writer the way he should present those facts, the conclusion he drew from them and the way he chose to narrate the story, even though it was in part their very own story.

To numberless people in the Machlett organization must go credit for generosity with time and for infinite patience in helping the writer to assemble and to understand (sufficently, at least to write a layman's account) a highly technical and exceedingly complex business.

Last, but by no means least, credit should go the Machlett's advertising people who gave the "dress" to this story in format, type and illustration. If this story has proved readable, that is largely due to their contribution of creative ingenuitey with intelligent understanding. There are so many of these people that I cannot name them all, but two ought surely to be mentioned: Ed (Edward J.) Bulger, whose function was art, layout and design, and Allie (Alice F.) Machlett, who acted as Editor-in-chief.

Allie, a compact, clear-eyed, forthright, dynamic gal with a fine hearty sense of humor is, of course, Ray Machlett's daughter. But it's sheer ability that has earned her place as Machlett Laboratories Advertising Manager and Editor of Cathode Press. She not only carried all the responsibility for organizing and directing this endless detail of publication, but acted as a singularly understanding and helpful Editor of the story itself.

Credits



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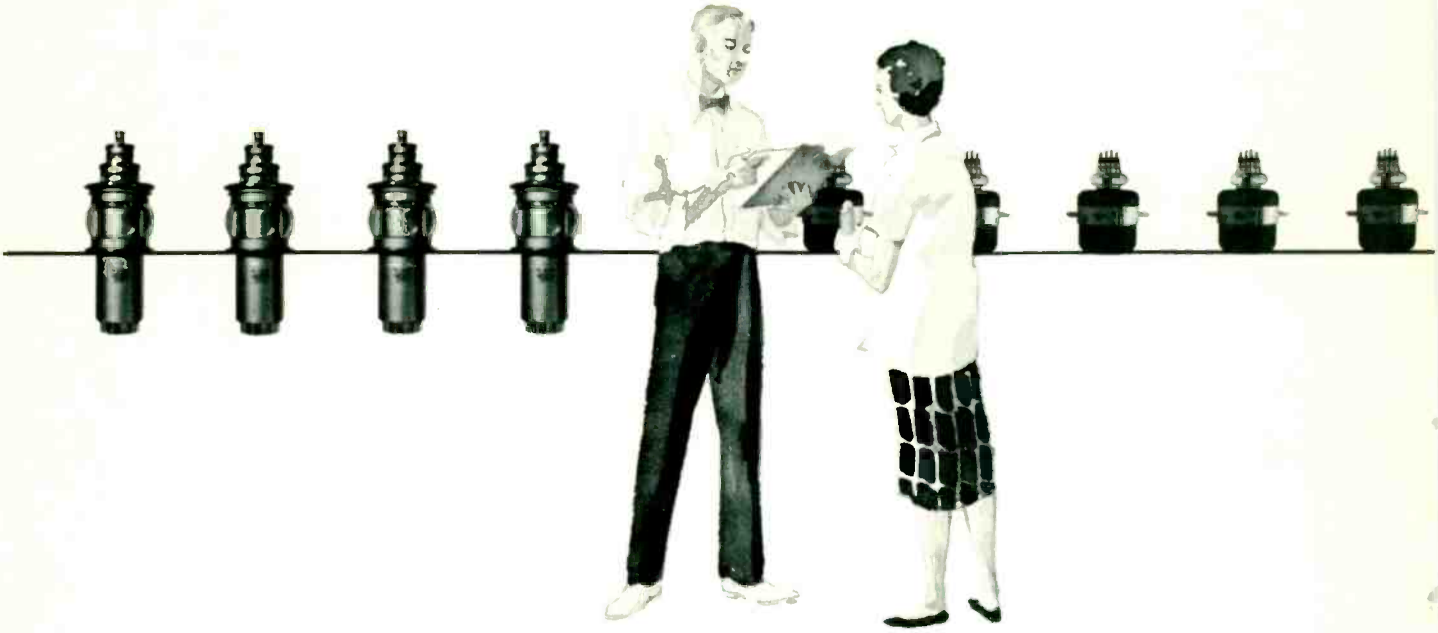

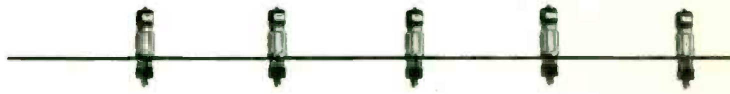

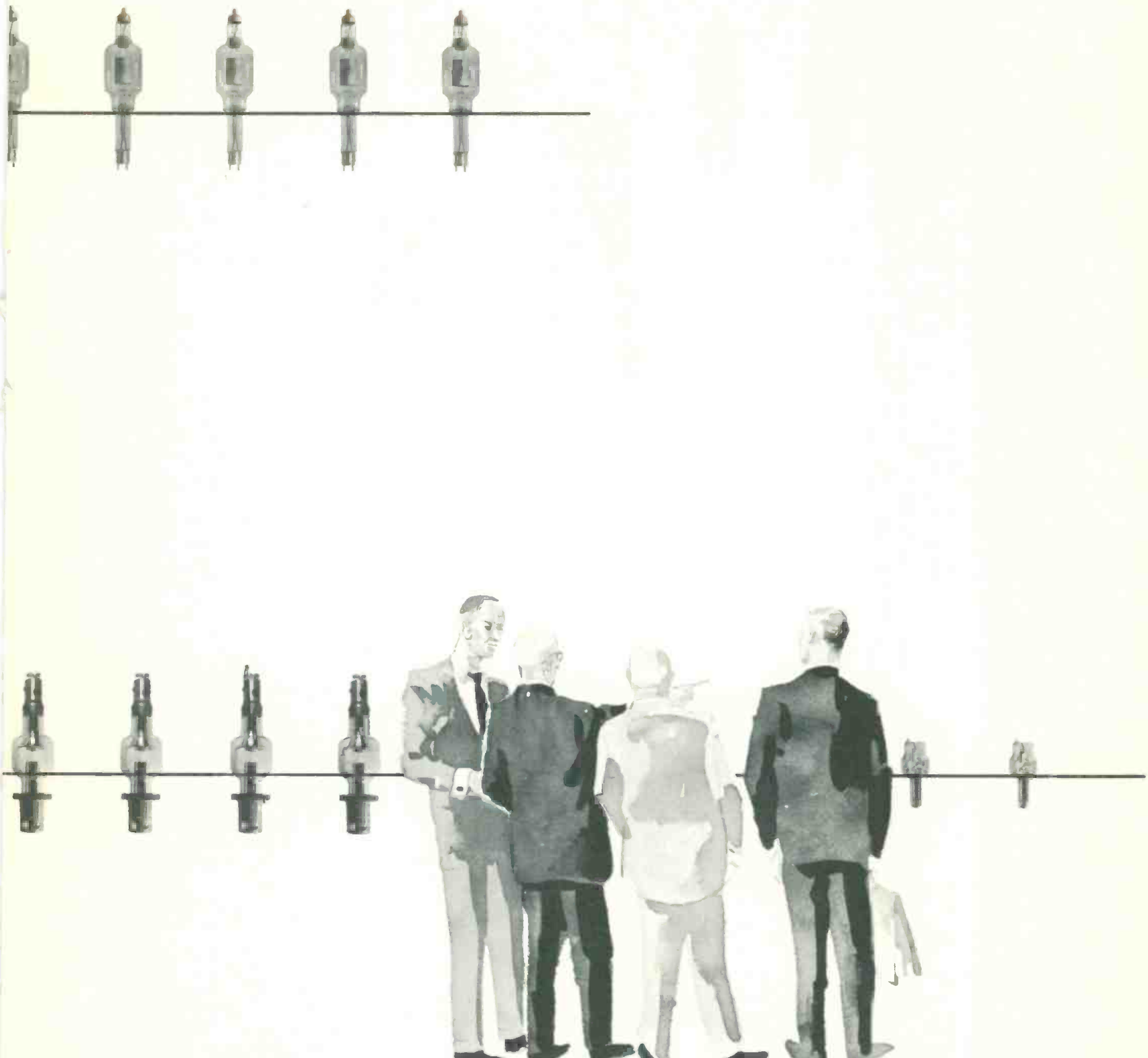

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