surely, the method of science will help to make life more intelligent, toil more cheerful, fear and hatred, pain and tears less prevalent in our lives. If in any place or time the blind fury of hatred of our brethren and the insane violence of war render the pursuit of science impossible, and the scientific method submerged and forgotten, it will be rediscovered, in better days, by better men.

CONTRIBUTIONS TO SCIENCE BY THE RESEARCH LABORATORY OF THE GENERAL ELECTRIC COMPANY[1]

By Dr. KARL T. COMPTON

PRESIDENT OF THE MASSACHUSETTS INSTITUTE OF TECHNOLOGY

ON this program in celebration of the fortieth anniversary of the Research Laboratory of the General Electric Company, I am privileged to represent the thousands of scientists in every field of research whose work has been significantly aided by the generous cooperation of the members of the staff of this laboratory, and who have been stimulated by the fundamental scientific discoveries that have come out of it in continuous succession. A typical example, of hundreds of similar situations, was my first contact with this laboratory just thirty years ago.

As a graduate student in Princeton University I was working under O. W. Richardson, the distinguished British physicist who first understood the true nature of thermionic emission—the emission of electrons from hot metals which is the basic performance of filaments in radio tubes and x-ray tubes. Richardson's experiments had led him to conclude that this emission was really an evaporation of electrons out of the hot metal, but another school of thought held that the phenomenon was due to chemical action on the filament by residual gases in the enclosing evacuated tube.

At that time Richardson visited the laboratory in Schenectady. He learned from Langmuir that what scientists had theretofore called "high vacua" were really very crude vacua indeed, and that by prolonged heating of the glass tube nearly to its melting point and by even more vigorous heating of the metallic electrodes contained within it, the amount of residual gas could be reduced a thousand-fold below the amounts in the best vacua hitherto realized by scientists. This new high vacuum art having been disclosed to Richardson, he was able to return to Princeton and prove by conclusive experiments the fallacy of the chemical theory of thermionic emission.

At the same time Langmuir, who had even then been pioneering in the properties of surfaces, showed that thermionic properties which Richardson had thought characteristic of tungsten were really due to layers of thorium, not over one atom thick, which formed on the tungsten surface by diffusion of this impurity to the surface of the hot tungsten filament and which for many purposes greatly improved its ability to emit electrons.

This incident recalls a whole group of scientific investigations and their practical applications which have been main lines of continuous study in this laboratory. Coolidge's discovery of a way to make ductile tungsten, and hence tungsten filaments, revolutionized the incandescent lamp industry. It, and the high vacuum studies, led to the Coolidge x-ray tube now in practically universal use. These, with Langmuir's work on surfaces and diffusion, led to improved radio tubes and hydrogen arc welding. Langmuir's studies of surfaces have contributed much to our knowledge of chemical reactions and are now opening up new vistas for the physiologist in his study of biological actions at membranes and cell boundaries in living organisms. As by-products of the x-ray, and to a considerable extent through the work of Hull in this laboratory, has come our modern knowledge of the arrangement of atoms in crystals. Using thermionic emission as a tool and making new applications of the kinetic theory of gases, Langmuir and Tonks have made the most notable contributions of the past twenty years to our knowledge of the complex, but highly interesting, important, and often spectacular, phenomena of ionization and electrical conduction through gases. By his scholarly exposition of such diverse subjects as magnetism, quantum theory and atomic structure, and by his able direction of research efforts, Saul Dushman has been a worthy collaborator in this highly individualized but well coordinated group.

If time permitted I should like to mention other scientific achievements of this laboratory, and other able contributors to its program, for they are many. I have only mentioned a few of the high spots by way of suggestion of the scientific work which has gone forward in what the public has come to think of as the "House of Magic"; but whose "magic" is in reality the logical outcome of systematic, orderly hard

[1] Fortieth anniversary celebration of the Research Laboratory of the General Electric Company, Schenectady, December 17, 1940.

work following with painstaking detail, step by step, the testing and development of ideas—always aiming first at a full understanding of materials and their behavior and with faith that, once these things are really understood, they can be used more advantageously. But let me close with a more general comment.

More significant than the specific discoveries on the programs of research in this laboratory has been the fundamental philosophy of its operation, and this is the great pioneering achievement of the man who directed and guided it from its beginning, Dr. Willis R. Whitney. He had supreme faith in science and in men. He conceived of a great industrial research laboratory, not as a place where mediocre men would carry on routine tests to help production men with their week-to-week problems or as a place to make inventions whose financial value to the company would show in black ink on the cost accountant's books at the end of the year or as a storehouse of industrial secrets. He thought of it as a center for the advancement of knowledge and art in all things pertainng to electricity and for the stimulation of such knowledge and art everywhere for the benefit of mankind. He realized that, in the long run, his company would benefit more from a general advance in knowledge and use of electricity than from the selfish accumulation of a lot of trade secrets. He furthermore had great faith in men; having selected men of brilliant ability and high character and loyalty to the enterprise, he gave them every possible encouragement and support, and protected their freedom to explore the unknown. At the same time, Dr. Whitney saw to it that the laboratory was alert, as opportunity arose, to the possibilities for reducing to practical applications the scientific discoveries which ensued. In all this he was ably aided and abetted by that prince of executive engineers, Larry Hawkins.

These basic policies are now being continued by Dr. Whitney's successor, Dr. Coolidge. They have stood the test of time and have been an inspiration to scientific men everywhere. I can express no greater hope, on this happy occasion, than that they will continue to receive the farsighted support of the officers of this great company.

Some one has remarked that, in every era of history, the stage of civilization has been limited by the tools at man's disposal. Tools and men with ideas—these have been the great contributions to our era from the Research Laboratory of the General Electric Company.

THE RESEARCH LABORATORY OF THE GENERAL ELECTRIC COMPANY

By L. A. HAWKINS

EXECUTIVE ENGINEER, RESEARCH LABORATORY, GENERAL ELECTRIC COMPANY

THE fortieth anniversary of the founding of the Research Laboratory of the General Electric Company was celebrated on December 17, 1940.

Research in General Electric had its beginnings long before 1900. It may be said to have started with the scientific investigations by Professor Elihu Thomson in the 70's of the last century, while he was a teacher in a Philadelphia high school, for those investigations and the developments consequent upon them laid the foundations on which the beginnings of General Electric were built. Thomson continued his scientific studies throughout his long and fruitful life. He was the first great industrial scientist in America. That fact was fittingly recognized at the Research Laboratory's birthday party by the unveiling of a plaque in his memory.

But it was in 1900 that the present Research Laboratory had its small beginnings.

In December of that year a young professor of chemistry from M. I. T., Dr. Willis R. Whitney, came to Schenectady to give half his time to research in the electrical field. The half-time arrangement had been made because Whitney doubted if enough worth-while problems could be found to occupy him fully. He began his work in a barn then used by Dr. C. P. Steinmetz as a laboratory, sharing the services of Steinmetz's single laboratory assistant. Two or three weeks later the barn burned down, and a small building was made available in the Schenectady Works, into which Whitney and his assistant moved. In June, 1901, five M. I. T. graduates were brought to Schenectady, and the growth of the laboratory was begun.

The purpose of the Research Laboratory was made clear in the following extract from the annual report of E. W. Rice, Jr., third vice-president, to President Coffin:

> Although our engineers have always been liberally supplied with every facility for the development of new and original designs and improvement of existing standards, it has been deemed wise during the past year to establish a laboratory to be devoted exclusively to research. It is hoped by this means that many profitable fields may be discovered.

It did not take long for Whitney to perceive that there were more than enough worth-while problems in the company's field to occupy the full time of himself