THE CRUFT LABORATORY

To the President of the University: —

Sir, — During the year 1916–17, the ordinary academic activities were pursued up to the time of the entrance of the United States into war. Important researches were made by Dr. Chaffee, Mr. R. F. Field, Mr. Ernest Flammer, Lieutenant Commander Nishizaki, and other students of the University.

The facilities of the Laboratory were also frequently made use of by graduates and former students in connection with commercial undertakings engaged in by them after leaving college. Certain investigations which it was thought might be of use in national defence were also pursued by the instructors and students. Specific accounts of these researches are not advisable at the present time, so that the volume of published material from the Laboratory is smaller than in previous years.

Immediately upon the declaration of war by the United States, all of the activities of the Laboratory were directed toward military ends. The instructors and several advanced students took up special experiments in connection with war problems.

The apparatus of the Laboratory was put into a condition to be used as a signal post if required. The Navy accepted an invitation to establish a Radio Training School at the Laboratory, and later expanded this school to provide training for the radiotelegraphic enlistment of the entire United States.

At about the same time, night and day classes were started for men enlisted and intending to enlist in the Signal Corps of the Army. In these two schools — the Signal Corps School and the Navy School — a considerable number of men were prepared and transferred to active duty, even in the first two or three months of the war.

The Naval Radio School by the end of the summer has grown to more than a thousand men, has equipped many stations with radiotelegraphic personnel, and is still expanding.

Apart from the present service of the Laboratory, it is encouraging to note also that some of the students of former years are now

holding important posts based on special qualifications obtained, to some extent, by study here.

The capacity of the Laboratory to serve even in minor part, in the present emergency, is cause for renewed gratitude to the donors of the building and to the University administration for a generous support.

G. W. PIERCE, *Director.*

THE CRUFT LABORATORY

To the President of the University: —

Sir, — During the year 1917–18, the facilities of the Cruft Laboratory have been devoted almost entirely to Government work. Professor G. W. Pierce, the Director of the Laboratory, has been on leave of absence, being in charge of the experimental work for the Navy at the Naval Experimental Station, New London, Conn. Much research work has been undertaken by Professor E. L. Chaffee and Mr. R. F. Field, in the construction of special radio equipment for the Signal Corps and the Navy, the detailed accounts of which cannot be presented at the present time.

Other researches carried on by them were: Gaseous Detectors; the Hot Cathode Braun Tube; Space Models of Current Amplitudes in Coupled Circuits; the High Frequency Resistance of Coils. During the summer, Mr. B. O'Brien of Yale University investigated the problem of Amplitude Modulation at Telephonic Frequencies.

While the Naval Radio School was growing rapidly in the fall of 1917, the machine and carpentry shops were used by the naval personnel, and day and night watches were maintained by them in the radio receiving station of the laboratory. The building itself was under guard. During the present year, this use of the Laboratory has gradually decreased, as other college buildings were acquired by the Radio School, until now only the towers and connected antennae are at their disposal.

At the request of the Signal Corps in February, an eighteen weeks' course in Advanced Radio Telegraphy was given conjointly by Professor E. L. Chaffee and Mr. R. F. Field at the Laboratory, and Professor A. E. Kennelly at the Institute of Technology, to Seniors in Electrical Engineering or Physics, as the technical preparation for induction into the Signal Corps. Seventeen students entered the course. It was repeated during the summer for ten students, Mr. W. T. Haines giving the work of Professor A. E. Kennelly.

E. L. CHAFFEE, *Acting Director.*
By R. F. FIELD.

THE CRUFT LABORATORY

To the President of the University: —

Sir, — Up to January 1, 1919, the teaching force of the Cruft Laboratory were chiefly engaged in scientific work with the Army and Navy.

Professor E. L. Chaffee, accompanied by Assistant Mechanician Mr. M. W. Carley, was in France and England until the middle of December engaged in demonstrating and testing a new type of radiotelegraphic system that could not be heard or interfered with by the enemy. This apparatus had been developed and partly constructed at the Laboratory by Professor Chaffee and Mr. R. F. Field. At the present time Professor Chaffee and Mr. Field are still engaged on improvements of this system. The work is to be continued in the interest of the American Coast Artillery, who have drawn up a proposal approved by the President of the University for the continuation of the work.

Until January, 1919, the Director of the Laboratory was at New London, Conn., engaged on Submarine Detection Devices and Aids to Navigation. He developed a type of electric search gear used as standard on all American Submarine Chasers; also a method of electric compensation for determining the direction of submarine sounds. This latter instrument is a part of a system of submarine sound reception which is used in conjunction with devices invented by Professor Max Mason of Wisconsin University and Professor H. C. Hayes, a Harvard Ph.D., to form an equipment that has proved to be of importance as an aid to navigation in time of peace. The system has been installed upon a number of transports and naval vessels and will probably come into general use to enable vessels to hear each other under water so as to prevent collision in fogs, and to hear also certain underwater signals installed at ports so as to permit a correction of the course on entering harbors. These listening devices permit a very accurate determination of direction of the source of sound.

Mr. R. F. Field, Instructor of Physics, gave at the Laboratory from September to December, 1918, part of a course on Radio Telegraphy to men enlisted in the Signal Corps.

Mr. Y. C. Wen, a Graduate Student, carried on a research on Measurements of Antenna Resistance and Standardization of

Wavemeters. Mr. Field has continued his work on Resistance Losses in Inductances and Condensers. Professor Chaffee has continued work on Gaseous Detectors. Professor Pierce has finished the writing of a book on the mathematical theory of Electric Oscillations and Electric Waves, which is now in press.

In the opinion of the Director the proposal of the Signal Corps of the Army to establish a unit here should be approved so that the Laboratory may keep in touch with matters of practical importance in this field of communication engineering.

In order to meet the strong competition of other educational institutions in applied physics, the equipment and facilities of the Laboratory should be considerably increased. The annual appropriation to the Laboratory, which has heretofore seemed to be as large as we should expect, has not permitted material additions to our equipment; so that the need of additional resources has come to be pressingly felt.

G. W. PIERCE, *Director.*

THE CRUFT LABORATORY

To the President of the University: —

Sir, — During the year 1919–20 the activities of the Cruft Laboratory were directed to coöperation directly and indirectly with the Army and Navy, to the establishment of a standardized four-year program on Electrical Communication Engineering in the Engineering School, and to teaching and research in those branches of physics and engineering that pertain to oscillatory-current and electric-wave phenomena.

The problems pertaining to the Army and Navy work have dealt with systems of secret signaling by radiotelegraphy, with apparatus for the remote control of torpedoes by electric waves, and with devices for submarine sound detection to be used in coast defence and in aid of navigation. Two army officers, Captains Seeds and Muir, were detailed to the laboratory as students in connection with the army work; and four naval officers, Lieutenant Commanders Fenn, Lavender, Ruble and Starkey, were detailed by the Navy to the laboratory during the summer of 1920 and the year 1920–21 to pursue work in radiotelegraphy and allied subjects.

The program in Electric Communication Engineering adopted by the Engineering School, to begin in September, 1920, provides for systematic study of telegraphy, telephony and radiotelegraphy and for the training of men for research and invention in this important branch of engineering. This program is based partly on courses previously offered by the Engineering School and the departments of Physics and Mathematics, but requires in addition the offering of several new courses by the teaching staff of the Cruft Laboratory. Among these new subjects, a half-course on hydrophone engineering, which is concerned with the study of the propagation of sound through water, with methods of producing, detecting and directing sounds in water, and with methods of determination of the direction of sources of sound in water, constitutes the beginning of university instruction in a new scientific aid to navigation.

During the year the enrolment of students in courses given at the laboratory was considerably larger than in previous years.

Although the work at the laboratory as designated in the titles of courses might appear to treat only a narrow field of science, atten-

tion might be called to the fact that the theories, methods, and apparatus in this restricted field have a broad application to engineering processes and to general research in physics and allied sciences. As examples of such applications, I may mention that Professor E. L. Chaffee of the Laboratory, and Professor W. T. Bovie of the Medical School, have made a highly successful application of the amplification methods of radiotelegraphy to the determination of the electric phenomena associated with the response of the retina of the eye to light. Also Dr. Alexander Forbes of the Medical School has utilized similar apparatus in the diagnosis of irregularities of heart action.

The usefulnesss of the laboratory could be increased by additions to its equipment.

G. W. PIERCE, *Director.*

THE CRUFT LABORATORY

To the President of the University: —

Sir, — During the year 1920–1921, there were 94 registrations in courses given at the Cruft Laboratory. These registrations included the names of 36 different students, about half of whom were in the School of Arts and Sciences and half in the School of Engineering. In both schools about 25 were graduate students, among whom were one Army officer and four Naval officers detailed by the U. S. Government.

Researches were carried on by graduate students as follows: E. J. Baldes, radio filters and compensators; P. P. Coggins, mercury-tube oscillators; L. M. Hull, vacuum power-tube oscillators; Phillip Machanik, construction and study of an artificial line equivalent to 1000 miles of South African Telephone conductor; D. P. Randall, vacuum-tube detectors and amplifiers; Captain E. C. Seeds, U. S. A., researches in connection with coast defence and secret radiotelegraphy; H. J. McLeod, resistance of condensers.

Among these researches, that of Mr. H. J. McLeod, who is Professor of Physics at the University of Alberta and who was on leave of absence for study at Harvard, constituted the basis of his thesis for a Ph.D. degree that was awarded in June. The work of Mr. Machanik, a telephone engineer of the Union Government of South Africa on leave, was also successful in yielding important information that may be applied directly to the telephone systems of his government.

The researches of Professor Chaffee, in coöperation with Professor Bovie of the Harvard Medical School, have yielded interesting results as to the response of the eye to optical and electrical stimulus, and have been embodied in various reports before scientific societies. The work is still under way. Professor Chaffee has also continued researches on vacuum-tube phenomena, and, in coöperation with Mr. R. F. Field and others, has made important progress in the field of secret radiotelegraphy.

Professor Pierce has completed designs of a government hydrophone station, which is now being installed, and has made modifications in electric compensators for use as a part of the

hydrophone equipment on Naval vessels. His book on "Electric Oscillations and Electric Waves" has been published and is used as a text in Physics 4*a*, 4*b*, and 4*c*, and in Engineering 226.

The new four year program in Electric Communication Engineering in the Engineering School was initiated at the beginning of the year, and seems to conform to the needs of a serious body of students, and to an active demand for men grounded in mathematical physics and the principles of electric communication to engage in telegraph, telephone and electric wave development. This program required the addition to the curriculum of three new half courses, Engineering 224, 225, and 226, which were taken by a considerable number of students.

G. W. PIERCE, *Director*.

THE CRUFT LABORATORY

To the President of the University:

Sir, — The following table gives the registrations in courses at the Cruft Laboratory in recent years and shows a small decrease in the year 1928–29:

	No. of half-courses Registrations	No. students engaged principally in research	Theses completed for Doctor's Degree
1925–26	151	5	2
1926–27	187	9	1
1927–28	295	20	0
1928–29	242	21	3

About 82 per cent of the enrollments above given were graduate students. Two research men, Messrs. A. R. Frey and W. N. Tuttle, were awarded the Ph.D. degree in June. Another doctor's thesis was completed but the degree has not yet been awarded.

The results of researches were published as follows:

P. S. Bauer: Discussion of Paper and Symposium on Electrical Shielding, *Transactions of the American Institute of Electrical Engineers.*

P. S. Bauer: The Condition of Self-Oscillation of a General Triode System, *Proceedings of the National Academy of Sciences*, January 1929.

E. L. Chaffee: Equivalent Circuits of an Electron Triode and the Equivalent Input and Output Admittances, *Proceedings of the Institute of Radio Engineers*, Vol. 17, No. 9, September 1929.

C. E. Keeler, Evelyn Sutcliffe and E. L. Chaffee: A Description of the Ontogenetic Development of Retinal Action Currents in the House Mouse, *Proceedings of the National Academy of Sciences*, Vol. 14, No. 12, December 1928.

G. W. Pierce: Magnetostriction Oscillators, *Proceedings of The Institute of Radio Engineers*, Vol. 17, No. 1, January 1929.

G. W. Pierce: Awarded Patents as follows:

Country	Serial Number	Subject
Mexico	27,894	Vibradores "Magnetostrictive"
Cuba	16,798	" "
Spain	105,829	Vibrador perfeccionado
France	649,796	Dispositif et appareil, etc.
Gt. Britain	283,116	Magnetostrictive Vibrator
" "	314,891	" "
" "	313,031	" "
" "	311,004	Magnetostrictive and Piezo-Electric Vibratory Systems.

Eight officers of the U. S. Navy were detailed here for study in Communication Engineering, and after completing their year's work at the laboratory have been assigned to duties as Communication Officers in the Fleet.

At the end of the year Dr. K. C. Black, who has been an instructor at the laboratory for several years, terminated his connection with the University in order to take up a position as research engineer with the Radio Frequency Laboratories at Boonton, New Jersey.

Also, Dr. Frey has severed his connection with the laboratory and with the department of Physics, in which he has been an instructor, to become Assistant Professor of Physics at Lehigh University.

G. W. PIERCE, *Director.*