excerpts Annual Reports of the Graduate School of Engineering from 1943 to 1945

Graduate School of Engineering

To the President of the University:

Sir, — I have the honor to present a report on the Graduate School of Engineering for the academic year from July 1, 1943, to June 30, 1944.

Summary

In the war year 1943–44, as in the two preceding war years, the most extensive activity of the School was the training of Army and Navy personnel in specialized subjects. Thus, during the year, 2,013 officers of the Army, Navy, and Marine Corps were enrolled in the three-to-five-months' full-time courses in electronics and related subjects, serving as pre-training for work with radar devices, and given (since July 1941) under the direction of Professor Chaffee, new classes beginning each month; 999 officers of the Army, Navy, and Marine Corps were enrolled in twelve successive classes in the one-month's or two-months' full-time courses in electricity, magnetism, and alternating currents, pre-training for electronics, given under the direction of Professor Dawes; 187 Army officers were enrolled in seven successive classes in the four-weeks' full-time course in control of soils in military construction, given under the direction of Professor Casagrande; and 63 enlisted men were enrolled in Term 7, and 20 in Term 8, each term 12 weeks, of the Army Specialized Training Program, Specialist Phase, Sanitary Engineering, under the direction of Professor Fair. Great credit goes to Professor Chaffee, Professor Dawes, Professor Casagrande, and Professor Fair and to their associates for the effectiveness with which this important work was organized and has been continued. And recognition again goes to the students in these courses for their intelligent and steadfast performance.

The Faculty participated actively also in other phases of the Army Specialized Training Program, including instruction in Terms 4 and 5, Civil Engineering, and the organization and preparation for Term 6 (which, however, was canceled a few days before it was scheduled to begin); and in the tasks connected with the Navy V–12 program. The responsibilities for instruction in Engineering Sciences in Harvard College remained essentially unchanged. The number of academic students in the Graduate School of Engineering had already dwindled; yet the

demand for graduate instruction remained sufficient to justify the offering of suitable programs in several fields.

Various war research projects were in progress within the School. Some members of the Faculty continued to be on leave for service in the Army or Navy, while others continued in their status of being relieved of regular academic duties in order to devote themselves to war research projects.

Faculty and Staff

On July 1, 1943, two resignations became effective: Leo Leroy Beranek resigned as Faculty Instructor in Physics and Communication Engineering, but remained in the University engaged in war research; and Ralph Eigil Fadum resigned as Faculty Instructor in Civil Engineering to accept an appointment at Purdue University.

Leaves of absence for service in the Armed Forces were continued for the following: Howard Hathaway Aiken, Associate Professor of Applied Mathematics, Commander, U. S. Naval Reserve; William Bollay, Faculty Instructor in Applied Mechanics, Lieutenant, later Lieutenant Commander, U. S. Naval Reserve; John Herbert Hollomon, Instructor in Metallurgy, First Lieutenant, and since April 8, 1944, Captain, Ordnance; and Edward Warren Moore, Associate Professor of Sanitary Chemistry, Major (later Lieutenant Colonel), Sanitary Corps. H. M. Westergaard was absent in two periods, serving on temporary active duty as Commander, CEC, U. S. Naval Reserve; as in the two previous years Professor Albert Haertlein administered the Dean's Office during these absences. James Dillon Cobine, Assistant Professor of Electrical Engineering, Roger Wayne Hickman, Lecturer on Physics and Communication Engineering, and Frederick Vinton Hunt, Associate Professor of Physics and Communication Engineering, were again relieved of regular duties of instruction and research to enable them to devote full time to war research projects within the University.

On February 1, 1944, the Faculty consisted of the President, seven professors, eleven associate professors (including two on leave of absence for service in the Armed Forces), two assistant professors, five lecturers, and three faculty instructors (including one on leave for service in the Navy). In addition, the staff of instruction in academic courses and research, on appointment by the Corporation, included ten lecturers, three research fellows (one of them on leave), one associate, one supervisor, four instructors (one of them on leave), and eight teaching fellows; and the staff appointed by the Corporation to give

instruction in courses for officers of the Armed Forces included, furthermore, twelve lecturers, eighteen instructors, twelve teaching fellows, and one assistant.

Henry Lloyd Smyth, Professor of Mining and Metallurgy, Emeritus, died on April 1, 1944, in his eighty-third year.

The Faculty received with deep regret the report of the death of Mr. Nathan Hayward, Chairman of the Overseers' Committee to Visit the Graduate School of Engineering, which occurred on June 21, 1944. Mr. Hayward had served on that committee as member from 1932 to 1937 and as chairman from 1937 to 1939 and again from 1940 to 1944, until the time of his death. In him the School lost an understanding friend.

Comfort Avery Adams, Abbott and James Lawrence Professor of Engineering and Gordon McKay Professor of Electrical Engineering, Emeritus, delivered, on October 18, 1943, before the American Welding Society the first Annual Honorary Lecture, now known as the Adams Lecture, which was established by that Society in his honor; he served as honorary member of the board of that Society and was engaged in numerous technical activities applying directly to the war effort.

Lionel S. Marks, Gordon McKay Professor of Mechanical Engineering, Emeritus, gave a number of lectures to technical audiences in the United States and Mexico on gas turbines, jet propulsion, rockets, and similar subjects of current war interest; he was selected by the American Society of Mechanical Engineers to initiate its new project of National Lecturers; since then he has served as National Lecturer of that Society.

Howard Moore Turner, Lecturer on Water Power Engineering, was President of the Boston Society of Civil Engineers. Gordon M. Fair, Abbott and James Lawrence Professor of Engineering and Gordon McKay Professor of Sanitary Engineering, served as Consultant, Office of Inter-American Affairs, Division of Health and Sanitation; as chairman, Committee on Sanitary Engineering Personnel, War Manpower Commission; as member of the National Health Advisory Council of the United States Public Health Service; and as member or chairman of several committees of technical societies. H. M. Westergaard was a member of a temporary committee appointed by Ex-Governor Lehman to make preparatory studies relating to the United Nations Relief and Rehabilitation Administration. Professor Dawes served as chairman of committees of the American Institute of Electrical Engineers, and several other members of the Faculty were likewise active in the affairs of technical societies and agencies of the Government.

The degree of Doctor of Science was conferred on the following:

In March 1944:

HAIM HERSCHEL CHISWIK, A.B. 1937, S.M. IN ENGIN. 1939.
Subject, Physical Metallurgy. *Special field*, Metallography of Steel.
Thesis, "The Effect of Certain Alloying Elements on the Martensite and Intermediate Transformations of Austenite."

YU-YUEH ALVA MAO, B.SC. (*Yenching Univ.*) 1937, S.M. (*Harvard Univ.*) 1941.
Subject, Communication Engineering. *Special field*, Ultra-High Frequencies.
Thesis, "Inductive Output Tube as Amplifier and as Oscillator."

At Commencement:

WAY DONG WOO, B.SC. (*Chiao-Tung Univ.*) 1938, S.M. IN ENGIN. (*Harvard Univ.*) 1939.
Subject, Communication Engineering. *Special field*, Vacuum Tubes.
Thesis, "Effect of the Transit Time on the Impedance of a Cylindrical Diode."

Navy V–12 Program and Army Specialized Training Program

The responsibility of the Faculty of Engineering for instruction in the Department of Engineering Sciences in Harvard College included tasks of giving instruction to fairly large numbers of students in the Navy V–12 program. This responsibility was extended to include instruction in the Army Specialized Training Program, Civil Engineering, Terms 4 and 5. Since these activities were within the jurisdiction of the Faculty of Arts and Sciences, only the following need be reported here: While before the war the usual combined enrollment in the elementary courses in drawing and descriptive geometry, Engineering Sciences 1a and 1b, was less than 200 (less than 100 in each term), in 1943–44 the combined enrollment was 1180 Navy V–12 students and 97 civilians. Grateful acknowledgment is made to Professor Henry A. Frost of the Department of Architecture, who took over during the winter and spring terms (and again during summer of 1944) the complete charge of Engineering Sciences 1a, which was moved to Hunt Hall, and had a combined enrollment of 527 in the winter and spring terms. Instruction in 1b was continued in Pierce Hall under the direction of Mr. Charles J. Walsh. Professor Haertlein was in general charge of instruction in the Army Specialized Training Program, Civil Engineering, Terms 4 and 5, September 13, 1943, to March 4, 1944; 130 enlisted men were enrolled in Term 4, 122 in Term 5.

Instruction in the Army Specialized Training Program, Specialist Phase, Sanitary Engineering, Terms 7 and 8, on the other hand, was entirely an enterprise of the Graduate School of Engineering (this work was continued until December 1944). Professor Fair was in charge. In

trained in this specialty. The report in the next section, on Activities Associated with the Cruft Memorial Laboratory, written by Professor Chaffee, gives further information about the courses in electronics.

Activities Associated with the Cruft Memorial Laboratory

Reported by Professor E. L. Chaffee
Director of the Cruft Memorial Laboratory

"The activities associated with the Cruft Laboratory during the period July 1, 1943, to July 1, 1944, have been principally a continuation of those of the previous year. These activities include the regular courses in Physics and Communication Engineering, researches of the pre-war type including those leading to the Doctor's degree, the pre-Radar war training courses for officers, and the war research projects sponsored by the government.

"A number of the regular staff of the laboratory are on leave and engaged in war activities. Professor Hunt has continued as Director of the Underwater Sound Laboratory located in the Hemenway Gymnasium. Professor Aiken, Commander in the Navy, was on duty at the Mine Warfare School in Yorktown, Virginia, up to May 5, 1944, when he was transferred to the Cruft Laboratory for special duty to be explained presently. Dr. Hickman, who was associated with the Radio Research Laboratory, transferred a large fraction of his time to the Underwater Sound Laboratory in January, 1944. Dr. Beranek resigned as Faculty Instructor in Physics and Communication Engineering but continued as Director of the war project on Sound Control located in the Research Laboratory of Physics. Professors Chaffee, Mimno, and King continued to serve in the war training program and in war research at the laboratory.

"The regular courses in Physics and Communication Engineering have been given during the three terms of the year, the courses being arranged in a cycle of two terms' duration. Fourteen half-courses were given as shown in Table 9; the enrollment in each course is given.

"Researches by members of the staff and by candidates for the Doctor's degree are naturally at a low ebb in these war years when all effort is directed toward the war needs. Notwithstanding the difficult times, fifteen papers have been published by members of the staff; two Doctor's degrees were awarded, and one graduate student has been pursuing his Doctor's research.

"The pre-Radar Officers' Training program continued, the twentieth course starting July 1, 1943. The courses for the remainder of the year

1943 were in content essentially the same as those for the previous year. Beginning January 1, 1944, the Army and Navy groups were given separate courses. This change was made because the requirements of the two services became so divergent that it was no longer possible to

Table 9. — Registration in Courses in Physics and Communication Engineering

Half-course No.				*Registration*		
Eng'g.	*Physics*	*Title*	*Term*	*Grad. Sch. of Eng'g.*	*Physics*	*Total*
221a	21a	Electric Oscillations and Circuit Analysis	Summer	6	39	45
221a	21a	Same	Winter	3	9	12
221b	21b	Same (second half)	Winter	6	29	35
221b	21b	Same	Spring	2	10	12
222	22	Electronic Devices	Winter	8	25	33
223a	23a	Electric Waves — General Theory	Summer	7	32	39
223a	23a	Same	Spring	5	28	33
224a	24a	Electron Tubes — Fundamental Principles and General Applications	Summer	12	45	57
224b	24b	Electron Tubes — Advanced Theory and Special Applications to Large Tubes	Winter	7	21	28
224c	24c	Vacuum Tube Systems	Spring	5	11	16
225a	25a	Laboratory Course in Electric Oscillations, Electron Tubes, and Acoustics	Winter	4	22	26
225a	25a	Same	Spring	1	2	3
225b	25b	Advanced Laboratory Course in Electric Oscillations and Electron Tubes	Spring	4	1	5
261	61	Electric Circuits and Electronics at Ultra-High Frequencies	Winter	5	13	18
		Courses of Research	Summer	3	4	7
			Winter	2	..	2
			Spring	4	..	4
		Subtotals for individual terms	Summer	28	120	148
			Winter	35	119	154
			Spring	21	52	73
		Totals for whole year		84	291	375

meet these requirements by continuing the combined course. The Army course was extended to a four-month course and was identified as Engineering 272. The Navy course comprised three months on the subjects of electronics and communications, preceded by two preparatory months on mathematics, physics, and alternating currents. These two months of the course were given in Pierce Hall under the direction of Professor Dawes. The new Navy course was identified as Engineering 273.

"Both the Army and Navy requested more emphasis on the treatment of communications. Consequently, a transmitter laboratory, in which were set up service transmitters, was established in Austin Hall.

"The enrollment in the Officers' Training Course has decreased as compared to that of last year as shown by Table 8. Those officers who were detached during their courses because of low grades are not included in the enrollment figures of Table 8.

"The separation of the Army and Navy courses required an enlarged instruction staff for the course notwithstanding the decrease in enrollment. The size and composition of the instructing staff are given in Table 10. The civilian instructors, with the exception of one who was only temporary, were given Corporation appointments.

Table 10.—Instructing Staff of the Officers' Pre-Radar Courses

	Civilians	*Army*	*Navy*
July 1, 1943	39	12	15
October 1, 1943	39	13	13
January 1, 1944	35	11	16
April 1, 1944	41	10	15
July 1, 1944	45	10	16

"The course in Radio Engineering as given to the officers enrolled in the Naval Training School, Communications, by the Staff of the Cruft Laboratory was discontinued on February 1, 1944. The members of the staff for this course were transferred to the staff of the pre-Radar course.

"The war research projects, one directed by Professor Chaffee and located on the top floor of the Research Laboratory of Physics, and the other under the direction of Dr. Leo Beranek located in the basement and first floor of Cruft and the Research Laboratory of Physics, have continued with undiminished intensity. The numbers of employees cannot be revealed in this report, but in general there has been some expansion in size of the staff of both projects.

"On December 1, 1943, Professor Mimno undertook the direction of a research project on Wave propagation sponsored by the U. S. Bureau of Standards. The work required the establishment of a field station in an open location in Lexington and hence made no appreciable demands upon the already overtaxed space of the laboratory.

"The large calculating machine, developed and constructed by the International Business Machines Corporation in coöperation with the University and embodying the ideas of Professor Aiken, was completed and arrived at the Cruft Laboratory February 1, 1944. During the few

months that followed, the machine was installed in the room prepared for it in the basement of the Research Laboratory of Physics. By June 1, 1944, the machine was in operation and ready for a series of shake-down tests which continued through the end of the period covered by this report. In May, the machine was turned over to the Navy under contract to be used for the solution of vital war problems for the government. As stated earlier, Commander Aiken was ordered to the Cruft Laboratory in May to take charge of this new Navy project. (On August 7, 1944, at ceremonies held at the University the machine was

Table 11.—Statistical Summary of Publications and Papers Presented by Members of the School During the Academic Year 1943–44

	Mechanical Eng'g. and Aëronautical Eng'g.	*Electrical Eng'g.*	*Communication Eng'g.*	*Civil Eng'g.*	*Sanitary Eng'g. incl. Industrial Hygiene*	*Totals*
Publications						
Books, edition in Spanish	..	..	..	1	..	1
Book reviews	1	..	1	..	3	5
Original technical papers or articles	2	3	15	4	11	35
Discussions of papers	..	1	..	6	..	7
Chairmanships of technical committees, reports of which were published during the year	..	..	..	..	1	1
Editorships	..	..	..	..	2	2
Technical papers presented at national or regional meetings	1	3	..	8	3	15

presented to the University by Mr. Thomas J. Watson, President, in behalf of the International Business Machines Corporation.)

"During the period of this report, the laboratory and its facilities have been devoted almost completely to war service. The number of employees on the services-and-wages account has increased from a pre-war strength of six or seven to forty-one. All of the additional employees as well as most of the regular employees were engaged in and paid by the war activities. Consequently, only a small fraction of the normal facilities of the laboratory was available for research and the improvement of the courses of instruction. However, some effort has been devoted to the expansion of Professor King's laboratory in ultra-high-frequency experiments. The photographic facilities under the direction of Mr. Paul Donaldson were considerably expanded."

Productive Scholarship

In a graduate professional school of engineering, research is an essential activity. Without an atmosphere of discovery in the making, the

primary function of professional education would lose vitality. Since research in a University would be lacking in fruitfulness if it were not normally brought to a completion in the form of published work, importance is always attached to the productiveness of members of the Faculty as revealed in published works. Granted that no one would measure the merit of such work by mere numbers of publications, and furthermore that during the war important investigations are normally reported in secret or confidential unpublished documents, the summary in Table 11 will nevertheless serve to give some indication about this phase of the work of the School.

HARALD MALCOLM WESTERGAARD, *Dean*

published in the *Harvard Engineering Society Bulletin,* October, 1941:

At Harvard's Cruft Memorial Laboratory, more than 100 Army officers have recently begun an intensive study of vacuum-tube circuits in order that they may later understand and operate new military devices.

Though the course objective may not be described more explicitly at present, there are two administrative features which may well be emphasized, for they are known to be characteristic of most defense research activities as well as emergency instruction now in progress in universities and technical schools.

First and most important is the fact that this is not merely a local effort of one university but is made possible by the generous coöperation of a number of schools and colleges. Although Cruft normally has a considerable staff, . . . (some) members had already been called to active military service or were so deeply involved in defense research that they could not conceivably assist in the emergency instruction suddenly proposed by the Signal Corps. The other members of the faculty were already carrying an extra load. The proportionate loss of instructors and teaching fellows was even greater. Having made such sacrifices from their own ranks in the interest of national preparedness, the remaining Cruft staff members felt that they could justly appeal to other universities to coöperate by temporarily releasing experienced teachers who had previously received Cruft training, in order that they might participate in the Army program. This mobilization of persons from a number of institutions at centers equipped with special facilities is typical of defense research programs, and will probably be extended in defense instruction.

In spite of the suddenness of the appeal and the inconvenience of the resulting internal readjustment, every institution granted the request. Consequently in addition to Professors E. L. Chaffee, H. R. Mimno and R. W. P. King of the Cruft Laboratory, the emergency teaching staff at present includes Dr. G. R. Tatum, Professor of Physics at Baylor University in Texas, Dr. Robert Sarbacher, Assistant Professor of Electrical Engineering and Communication at the Illinois Institute of Technology, and Dr. C. M. Wallis, Assistant Professor of Electrical Engineering at the University of Missouri. From the Harvard Electrical Engineering Department, Professor J. D. Cobine has been borrowed for special instruction related to his own field. Seven additional instructors assist in the conferences and laboratory sessions. Close coördination has been maintained with the staff of M. I. T. engaged in related activities, and valuable advice has been received from that source.

The second point of interest is the rapidity with which this entire project has been organized by the University and by the Signal Corps. After less than a month of tentative consideration, definite authorization was telegraphed from Washington July 5th. Complete mobilization of staff began less than ten seconds later, as a sheaf of telegrams

went out before releasing the original Western Union 'phone connection. During the next twelve days, although staff and members had to travel from as far as Texas and Chicago, 25 new experiments were set up and 17 others planned and ordered. A new laboratory manual of 109 pages was written, edited, and published. Library, study and laboratory facilities were expanded to meet the new demands and preliminary arrangements were made for housing members of the student group and their families.

Simultaneously the Army selected more than 100 officers with the requisite preliminary training in electrical engineering, drawing them from all parts of the country and practically all branches of the service. Many of the students were en route to Cambridge from points as distant as San Francisco within a few hours after receipt of their first notice. Almost all of them registered in Cruft Laboratory July 16th, were given individual interviews and examinations, assigned to sections and attended classes at 8 A.M., July 17th. Though minor adjustments have been freely made during progress of the course, no serious faults have developed in the organization so quickly assembled.

Productive Scholarship

Professor Lionel S. Marks, who retired on September 1, 1940, came to his office in Pierce Hall with great regularity during the whole year. He achieved the completion of his work as editor of the fourth edition of the "Mechanical Engineers' Handbook," known as "Marks' Handbook," a work of 2,274 printed pages. The first edition of the book was published in 1916; of the first three editions 138,000 copies have been issued; of the new, thoroughly revised fourth edition 10,000 copies were issued in August 1941, and a second printing began shortly after. Professor Marks shares credit for this comprehensive work with many collaborators, including Professor Edward V. Huntington, who prepared the important sections on Mathematical Tables and Mathematics, Professor P. W. Bridgman, who wrote the section on Dimensional Analysis, and various members of the Faculty of Engineering; but a very large share of the credit goes to Professor Marks himself, who assumed responsibility for the completeness of the plan, unity of form, and high standards, and whose influence is seen throughout the book. Professor Marks and his collaborators have performed an important service by bringing out the new up-to-date edition at this time when the national emergency makes the usefulness of the book particularly great.

Some national defense research projects under contract with the Government were begun; it is hoped that there will be more of

Appendix to the Report on the Graduate School of Engineering

Report of Activities Associated with the Cruft Laboratory during the Period from July 1, 1945 to June 30, 1946

This report covers the principal activities directly associated with the Cruft Laboratory and its staff during the period from July 1, 1945 to June 30, 1946. The staff of the Cruft Laboratory is identified as the group of professors and instructors which offers courses in electronics and communication engineering listed under both the Faculty of Arts and Sciences and the Faculty of the Graduate School of Engineering. As the activities of this staff normally extend beyond the walls of the Cruft Laboratory into the north half of the Research Laboratory of Physics and, during the war, have expanded into other buildings of the University, this report, as in former years, includes reference to the activities in those other areas.

The period covered by this report has been a period of transition from war to peace-time activities. Most of the war research contracts were terminated and members of the staff engaged in these researches returned to take up the educational and research work at the Laboratory. The war training courses ended. The regular courses of instruction were continued with increased enrollment during this period with little change. These courses were offered jointly by the Faculty of Arts and Sciences and by the Graduate School of Engineering. July 1, 1946, however, marks the end of the joint administration of the Cruft Laboratory by the Graduate School of Engineering and the Faculty of Arts and Sciences and the joint offering of courses by the two faculties.

In July 1945 four war-time research projects were in progress and used many of the facilities of Cruft Laboratory and adjoining areas. The Electro-Acoustic Research under Division 17 of the National Defense Research Committee and directed by Dr. Leo Beranek, occupied the Anechoic Chamber and many rooms in the basement and first floor of the Research Laboratory of Physics; research on Infrared Detection (Division 16, NDRC) under the direction of Professor E. L. Chaffee, occupied the fourth floor of the Research Laboratory of Physics; the Central Communications Research (Division 13, NDRC) under the direction of Professor Chaffee, was principally located in Austin Hall and the Hemenway Gymnasium with its connecting, temporary building (formerly occupied by Underwater Sound) but occupied also many rooms and offices within the Cruft Laboratory area; and the Computation Research Project under contracts with the Bureau of Ships and the Bureau of Ordnance of the Navy and directed by Commander Aiken, occupied much of the basement of the Research Laboratory of Physics.

The Electro-Acoustic Project began a reduction of activities shortly after

V-J day in August, 1945, and by February, 1946, had freed most of the space in the Research Laboratory of Physics although it still occupied some rooms outside the Anechoic Chamber for report writing. The rooms used by this project were returned to use by the laboratory in much better condition than when they were taken over by the Project. Some improvements, such as installation of benches, altered partitions, better ventilation and heating were accepted by the laboratory with appropriate adjustments with the Government.

Experimental work under the contract in infrared research ceased December 31, 1945, and several rooms were immediately released for graduate research, for which there was a pressing demand. Four rooms, however, were retained for report writing and for storage of equipment and files pending final disposition of Government property.

Experimental work of Central Communications Research officially ended October 15, 1945, although some of the experimental work was continued under the auspices of a new Navy contract. This experimental work was carried on in the Library of Austin Hall and in the Hemenway Gymnasium and the adjoining building. However, final report writing and termination of details of administration required continued occupation of some of the space in the Research Laboratory of Physics for several months.

The Computation Laboratory contracts continued essentially unchanged except for some details. Its facilities, including the I.B.M. Sequence Controlled Calculating Machine, were used for Government work throughout the period.

During the war a number of the Cruft Laboratory staff were engaged wholly or in part by war activities. With the termination of these activities, some of these members were able to devote more time to normal teaching and research activities in the Laboratory. Professor Hunt during the spring term was able to devote half-time to educational activities and offered one-half course. Professors Chaffee, Mimno, and King continued to offer courses as they had throughout the war. Dr. Hickman, who, during the summer of 1945, devoted his entire time to Underwater Sound, returned to help out in the teaching activity during the fall term. He gave the lectures in two half-courses and took over some of the administrative work in connection with the Physics Laboratories. Dr. Aiken continued to devote full-time to the research contracts under his direction.

Because the full strength of the Cruft Laboratory staff was not adequate for the increased enrollment of students, the assistance of Dr. Philipps LeCorbeiller, Dr. Sherwood Githens, and Mr. Walter J. Cunningham was required. Dr. LeCorbeiller and Dr. Githens were former members of the war training staff, and Mr. Cunningham was an advanced graduate student.

Almost a full quota of regular courses in Physics and Communication Engineering was offered during the fall and spring term because of the increased demand for them by returning veterans and those specializing in

electronics. No courses were given during the summer term of 1945, as was true in other departments. The numbers of students enrolled in these courses is given in Table I.

A total of 22 half-courses was offered during the two terms, with a total student course enrollment of 452. This may be compared with the 253 student course enrollment of the previous year which included a summer term.

The last war training course given to Army enlisted men of the Weather Wing started April 1, 1945, and finished at the end of July. The staff for this war training course during July numbered eight civilians and four Army officers. At the termination, some of the civilian staff members were absorbed in the research projects while others left to take positions elsewhere.

Research activities have been largely confined to work under government contracts, and little has been published individually. Four volumes by the Computation Laboratory of Harvard University have been published by the Harvard University Press: Vol. I "A Manual of Operation for the Automatic Sequence Controlled Calculator"; Vol. II, "Tables of the Modified Hankel Functions of Order One-third and of their Derivatives"; Vol. III, "Tables of Bessel Functions of the First Kind of Orders Zero and One"; and Vol. IV, "Tables of Bessel Functions of the First Kind of Orders Two and Three." Five technical papers have been published by Cruft staff and graduate students.

Effective October 16, 1945, Project I under a Navy contract between the Office of Research and Inventions and Harvard University, carried an appropriation of $200,000 up to July 1, 1946, to be used for basic research in electronics. This research project was under the direction of Professor E. L. Chaffee.

Table I. — Courses in Physics and Communication Engineering Fall Term, 1945

Chaffee	Physics 21a	4	
	Engineering 221a	24	28
King and LeCorbeiller	Physics 21b	5	
	Engineering 221b	29	34
King	Physics 23a	10	
	Engineering 223a	29	39
Hickman	Physics 24a	5	
	Engineering 224a	17	22
Githens	Physics 25a	2	
	Engineering 225a	11	13
Cunningham	Physics 26a	3	
	Engineering 226a	12	15
King	Physics 20Q	1	
	Engineering 292	6	7
Chaffee	Engineering 294	5	5
Mimno	Engineering 296	1	1

Spring Term, 1945

LeCorbeiller	Physics 23a	20	
	Engineering 223a	20	40
King	Physics 23b	4	
	Engineering 223b	27	31
Chaffee	Physics 24b	9	
	Engineering 224b	35	44
Mimno and LeCorbeiller	Physics 24c	6	
	Engineering 224c	44	50
Githens	Physics 25a	3	
	Engineering 225a	2	
	Radcliffe	1	6
Githens	Physics 25b	3	
	Engineering 225b	10	13
Hunt	Physics 27a	6	
	Engineering 227a	17	23
Purcell	Physics 28a	17	
	Engineering 228a	22	
	Radcliffe	1	40
King	Physics 61b	3	
	Engineering 261b	22	25
Chaffee	Engineering 294	6	6
King	Engineering 292	7	7
Mimno	Engineering 296	2	2
Hunt	Engineering 299	1	1

During the latter part of 1945 and early 1946 research work was well under way at Hemenway Gymnasium and the second floor of Austin Hall, but around June 1 the research groups were forced to move in order to free Hemenway and Austin for reconversion. The second floor and a portion of the first floor of the temporary building adjacent to the Biological Laboratory and formerly used by Radio Research Laboratory were allocated for the use of Navy Research Project I. This laboratory is now unofficially known as the Electronics Research Laboratory. By July 1 most of their moving into these new quarters was completed.

A considerable amount of equipment for the electronic research groups was transferred to Navy custody from various wartime researches, such as Radiation Laboratory, Radio Research Laboratory, Central Communications Research, Underwater Sound, and the Infrared Research Project. A very considerable amount of components and Navy equipment was thus obtained and first stocked in the Hemenway Gymnasium, but by June 1 this stock of equipment was transferred to a large stockroom on the first floor of the Electronics Research Laboratory.

One of the principles underlying the new project is that it be, as far as possible, integrated with the research activities of the Cruft Laboratory. By this arrangement it is possible to use under the Navy contract, graduate

students who are doing research for their Doctor's degree. It is also possible to employ in these research programs a number of younger graduate students who need experience and financial help during their graduate training.

With the termination of war activities and the suspension of course work during the summer of 1945, a good opportunity was furnished for a considerable amount of repainting and alteration of Cruft Laboratory, the first since its construction in 1914. The walls of halls and of the rooms throughout the second and third floors were painted. A partition was removed which had separated two rooms, in order to establish a stockroom to accommodate the large amount of added equipment obtained during the war training courses and now available for laboratory instruction and research. A technician was established in the quarters to maintain the equipment. An iron stairway made unnecessary when the Research Laboratory of Physics was attached to the Cruft Laboratory, was removed providing a usable increment of much needed additional space on the second and third floors. A partition was erected through the main laboratory in order to separate the passageway from the laboratory space proper. These changes have been made in order to increase the amount of space needed for laboratory instruction.

Although these changes were necessary for instruction purposes, they result in a reduction of space for research. Practically the only space now available in Cruft Laboratory for research by Doctor's degree candidates comprises three rooms in the basement and a less desirable area in the generator room. A few Doctor's researches can still be accommodated in a portion of the basement and fourth floor of the Research Laboratory of Physics, and a few in the Electronics Laboratory. These extra, and possibly temporary spaces for research will be inadequate in a very short time, in view of the increase in numbers of Doctor's degree candidates. This need for increased research space has been repeatedly emphasized and will be a very critical problem in the near future.

Besides the research activities within the Cruft Laboratory, several field stations have been established for ionospheric work under Professor Mimno's direction, which afford some facilities for Doctor's researches. A field station established in Weston in 1934 was discontinued in September, 1945, and transferred to Framingham on rent-free land held by the State Guard. A direction-finding field station is located in Lexington on land belonging to the City of Arlington. At this station, work was done under Central Communications Research and is continued under the Navy contract. Also work is being done at this station under a special contract established in 1943 with the Central Propagation Laboratory at the Bureau of Standards. In Lexington another ionospheric station is maintained on property partly occupied by Professor Mimno's residence. This field station was established in 1939 and is used for work under the Navy contract.

Course	*Instructor*	*Graduate Engineers*	*Others*	*Total*
Sanitary				
Water Purification and Sewage Treatment Works, 400b	Professor Fair	19		19
Principles of Sanitary Chemistry — Physical and Colloidal, 412b	Dr. Morris	3		3
Aquatic Biology, 413a	Dr. Renn	2	2	4
Sanitary Parasitology, 413b	Dr. Chang	4		4
Theory of Water Purification and Sewage Treatment, 430b	Assistant Professor Thomas	18		18
Field and Laboratory Work in Water Purification and Sewage Treatment, 431b	Associate Professor Whipple and Assistant Professor Thomas	12		12
Industrial Air Analysis, 470b	Professor Drinker and Dr. Silverman	2		2
Industrial Hygiene, 472b	Professor Drinker and Associates	2		2
Research, 492	Professor Drinker	1		1
Metallurgy				
Research, 690	Professor Berry	1		1

The degree of Doctor of Science was conferred on the following student: In March 1945:

LIANG-SHENG CHEN, B.SC. (*Chiao-Tung Univ.*) 1938, S.M. (*Harvard Univ.*) 1942. *Subject*, Civil Engineering. *Special field*, Soil Mechanics. *Thesis*, "Stress-Deformation and Strength Characteristics of Cohesionless Soils."

Activities Associated with the Cruft Memorial Laboratory

Reported by Professor E. L. CHAFFEE
Director of the Cruft Memorial Laboratory

"The activities associated with the Cruft Laboratory during the period from July 1, 1944 to July 1, 1945, have been much the same as those of the previous year because of the continuation of the war. The principal activities include instruction in the regular university courses in the field of electronics and communication, special war-training courses given under contract with the Army and Navy, war researches carried on under contracts with the National Defense Research Committee and with the Navy, and a very small amount of pre-doctorate research.

"The Cruft Laboratory staff suffered from war-time disruption. Professor Hunt continued on leave of absence as Director of the Underwater Sound Laboratory. Commander Aiken, also on leave of absence, directed the work carried on for the Navy in the Computation Laboratory. Dr. Hickman, who was on leave of absence, was Special Research Associate at Underwater Sound Laboratory and

Consultant at Radio Research Laboratory. Professors Chaffee, Mimno, and King continued in their regular role with the University though devoting much of their time to war projects, as will be explained later.

"The regular courses in physics and communication engineering were offered during the three terms to a decreased but very substantial enrollment of both undergraduate and graduate students. Although in previous years, the engineering students outnumbered the physics students, during this period the enrollment in physics was larger than in the Engineering School.

"A total of twenty-six half-courses was given during the year with a total student course enrollment of 253. The instruction in these courses was given by Professors Chaffee, Mimno, and King, aided by Dr. P. LeCorbeiller, Dr. Orin Cornett, Mr. W. J. Cunningham, and Mr. B. C. Dunn, who were members of the pre-radar training staff.

"A book on 'Electromagnetic Engineering' was published by Professor R. W. P. King. A book on 'Transmission Lines, Antennas, and Wave Guides', written by Professors King, Mimno, and Dr. Wing, was published by McGraw-Hill. This latter book is a portion of the notes used in the pre-radar training courses, somewhat revised. The other portion of the notes is in process of publication. Nine papers have been published by staff members and graduate students associated with Cruft Laboratory.

"The pre-radar training courses given to officers of the Army and Navy continued with but slight diminution in enrollment until December 1st, when the last class entered. As the course was of four months' duration, the pre-radar training ended with the last graduation on March 30th. A special training program for enlisted men from the Weather Wing of the Army was started on September 1, 1944. This program comprised eight courses, each of four months' duration and attended by approximately 45 men. The last of this series of courses began on April 1, 1945 and ended the last of July. This concluded all special war training courses given at Cruft Laboratory.

"The staff of the pre-radar training courses was maintained at substantially constant level up to January, 1945, when a gradual decrease was necessitated because of the decrease in student enrollment. Most of the staff members were transferred to other activities within the Cruft Laboratory, as will be explained later. In December there were 42 civilian staff members and 33 Army and Navy officers serving as instructors in the courses. By July, the civilian staff had dropped to 8, and the service staff members, to 4.

"A few data summarizing the war training activities are given below.

Number of courses given July 1, 1941–July 1945:	57
Total students enrolled	6,254
Total student hours	4,450,000
Total cost	$966,886.21
Average cost per student per month	$40.38
Average cost per student per hour	21.6 cents

"The pre-radar training program during its operation continued to use the sub-basement of the Littauer Building, a considerable portion of Langdell Hall, and three portable Army houses set up behind Austin Hall, as well as Austin Hall. Four additional portable Army houses and one specially built house were erected behind Jefferson Laboratory to accommodate the direction-finding equipment used in the enlisted men's training course.

"Space in Cruft Laboratory and in the Research Laboratory of Physics continued to be occupied by the several war researches. Research under Division 17 of NDRC, directed by Dr. Leo Beranek, continued to occupy a large portion of the basement of Cruft Laboratory and the Research Laboratory of Physics and a considerable portion of the first floor of the Research Laboratory of Physics. This work was largely concerned with problems in acoustics and was associated also with the work being done in the Psycho-Acoustic Laboratory under the direction of Dr. S. S. Stevens.

"The installation of the IBM Automatic Sequence Controlled Calculating Machine, installed in 1943 in the basement of the Research Laboratory of Physics, was described in last year's report. The Navy contracted for the sole use of this calculating machine from July, 1944, to July, 1945. This work is directed by Commander Aiken and is supported by a staff of civilian and Naval personnel.

"The research project under Division 16, directed by Professor E. L. Chaffee, continued unabated on the fourth floor of the Research Laboratory of Physics.

"Early in January, Division 13 of NDRC concerned with communication problems, initiated arrangements to set up a Central Communications Laboratory at the Cruft Laboratory with Professor E. L. Chaffee as Director and Professor H. R. Mimno as Associate Director. The contract was signed in March, 1945, retroactive to January 1st, and active research began in February. The establishment of this new research program engaged the services of many of the civilian staff members released from the training courses.

"Most of the work in this project was conducted in Austin Hall, making use of space released by the training courses. The large room on the second floor of Austin, formerly used as the library of the Law School, furnished ideal quarters for conducting problems on antenna research because of the absence of metal in the structure. A classified document room was set up in the Research Laboratory of Physics, and various rooms were used as offices for members of the Division 13 staff. It was anticipated that the increasing intensity of the work would be accommodated in the Underwater Sound Laboratory, as the work in that project tapered off.

"The facilities of the Cruft Laboratory were used to a considerable extent by the several research projects mentioned above. For example, the stockrooms and machine shops were used almost exclusively by these projects. The photographic and printing facilities were also heavily taxed by the demands of the researches.

"Throughout the war, lack of space has been an especially difficult problem. Even though some space will be liberated by the termination of NDRC projects, the additional space will be insufficient to supply the needs resulting from the expansion in the field of electronics and the larger number of students pursuing work for the doctorate. Cruft Laboratory was crowded before the war, but in the postwar period, space will be all the more urgent a problem."

Navy V-12 Program

The Faculty of Engineering gave instruction in the Engineering Sciences in Harvard College during each of the three terms. The enrollment in these courses consisted largely of Navy V-12 students. Professors Berry, Dawes and Haertlein also gave the special courses in engineering prescribed by the Navy V-12 program, namely Elementary Heat Power, Elementary Electrical Engineering, and Analytical Mechanics. Some of these courses were repeated in each of the three terms.

"*Engineering, Science, and Management War Training*"

The School continued to participate in the program of Engineering, Science, and Management War Training, or ESMWT, sponsored by the United States Office of Education. This program has been in progress since 1941 when it was known as Engineering Defense Training and subsequently as Engineering, Science and Management Defense Training until 1942. Between 1941 and 1943 our participation in this program included not only training for civilians but also the training of officers

of the Army and Navy. Since the summer of 1943 the program has included only the training of civilians. Professor Dawes has served as Institutional Representative, that is, as liaison officer of the University with the United States Office of Education.

Table 7 shows the students, instructors, and courses offered during the year. The total number of civilians who have received training in the program is 1,560. The United States Office of Education has terminated the program as of June 30, 1945.

Table 7. — Courses, Part-time, not for Academic Credit, for Civilians, in the Program of Engineering, Science, and Management War Training, Sponsored by the United States Office of Education

Class No.	Course	Began	Ended	Number Enrolled	Completed Course Satisfactorily
7	Alternating Currents, Engineering 261, evening course, Assoc. Prof. Dawes in charge	*1944* Oct. 2	*1944* Dec. 22	37	20
8	Same	*1945* Jan. 3	*1945* Mar. 26	24*	14
	Totals			61	34
6	Vacuum Tubes and Radio Circuits, Engineering 262, evening course, Prof. Chaffee in charge	*1944* Oct. 2	*1944* Dec. 22	42†	17
7	Same	*1945* Jan. 3	*1945* Mar. 26	38‡	19
8	Same	Apr. 2	June 22	19	8
	Totals			99	44
4	Mathematics for Teachers, Assoc. Prof. Beatley in charge	*1944* Nov. 4	*1945* May 26	34	6
5	Physics for Teachers, Asst. Prof. Kemble in charge	*1944* July 3	*1944* Aug. 11	16	10
6	Same	Nov. 4	*1945* Feb. 24	13	9
	Totals			29	19
	Totals for all courses			223	103

* Including one member of the Armed Services.
† Including four members of the Armed Services.
‡ Including one member of the Armed Services.

Full-time Courses for Officers of the Armed Forces

The students enrolled in these courses were officers of the Army, Navy and Marine Corps assigned to the University for training in Pre-Radar. Since the summer of 1941 when this training was begun, there have been 5,533 Army, 3,122 Navy, and 734 Marine Corps officers enrolled in these courses. The last class under this program was graduated on March 30, 1945. Table 8 gives the enrollment figures for these courses between July 1, 1944 and March 30, 1945.