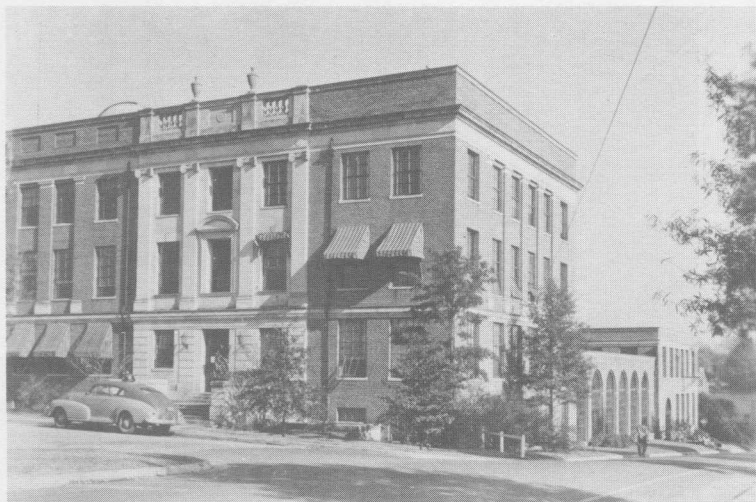


A Brief History
of the
Department of
Electrical and Computer
Engineering



College of Engineering
North Carolina State University

Preface

This work was undertaken at the suggestion of Dr. John Grainger and actively supported by Dr. Tildon H. Glisson, acting Head of the Department of Electrical and Computer Engineering. Dr. Glisson appointed a Committee on History and Memorials consisting of Dr. George B. Hoadley, former head of Electrical Engineering, Prof. Edward G. Manning, and Dr. William J. Barclay, chairman, all retired, with a combined total of over 90 years of active teaching in the ECE department. The first charge was the writing of a history of the Electrical and Computer Engineering Department.

A word of explanation on nomenclature. The name of the University has undergone many changes over the period covered by these notes, as has the Electrical Engineering Department. The most recent change, in 1988, was renaming the School of Engineering the College of Engineering. We will, in general, refer to the university at Raleigh as NC State, and to the Department of Electrical Engineering as either EE or ECE as appropriate at the time.

No history is the work of the authors alone, and this one is no exception. To list all who have contributed their time, talent, and memories would present a formidable task. Note must be taken of a few who have made particular contributions: Dr. Ralph E. Fadum, former Dean of Engineering who made his historical notes available; Maurice S. Toler, University Archivist, for guidance in the use of the University Archives; and Dr. Owens Hand Browne, son of the first head of Electrical Engineering, for his many reminiscences of his father and the department. Particular note should be made of the works of the late William Hand Browne, first head, whose historical writings of 1933 and 1940 tell much of the early days of Electrical Engineering at NC State. Other sources of the early days came from Prof. Edwin W. Winkler, Mrs. Irene Glenn, widow of Prof. Karl B. Glenn, and Mrs. June Fouraker Clark, daughter of the late Professor Raymond S. Fouraker. Professor Manning did much of the research and word processing.

William J. Barclay, Chairman
April 12, 1989

On the Front Cover

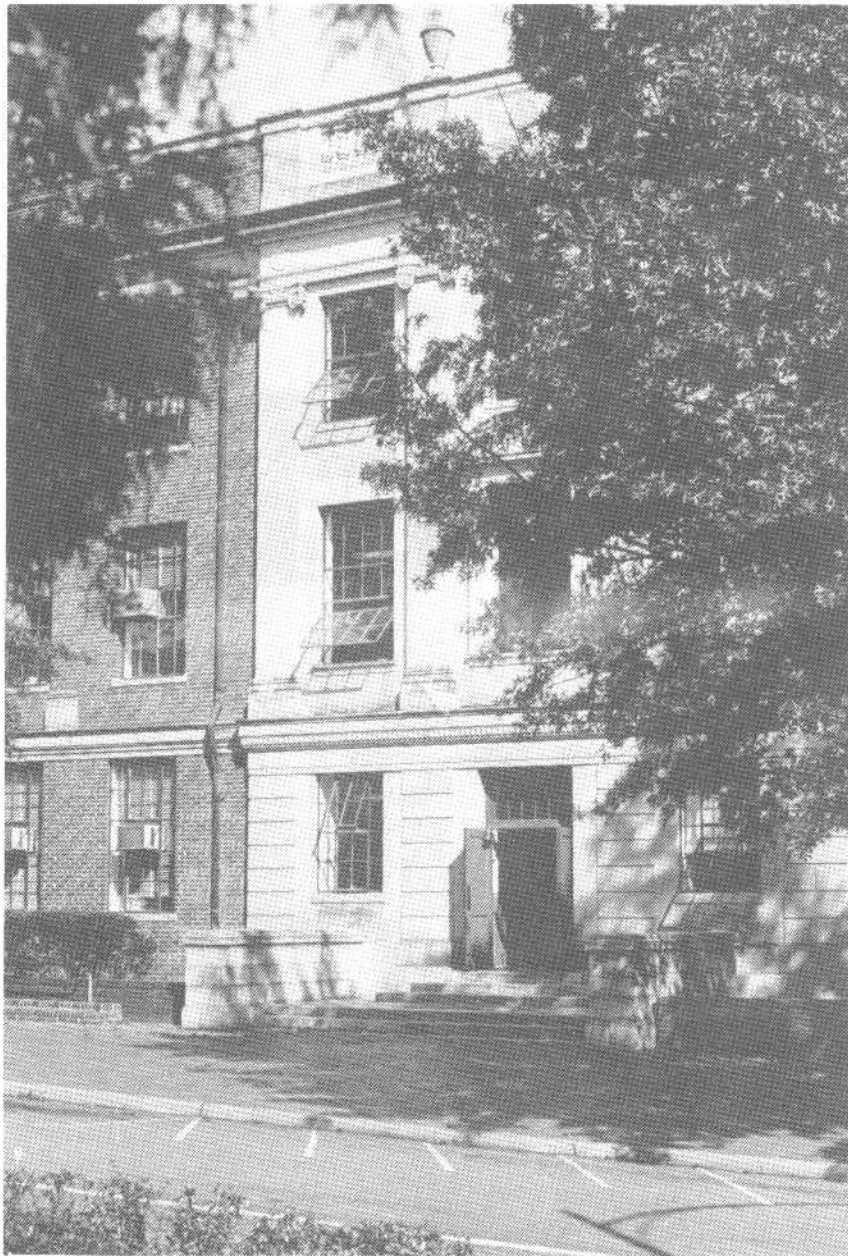
Daniels Hall (1948) as it appeared before the 1951-53 reconstruction. Note the 1 1/2 story connecting link with original two-story Mann Hall. The dome of the observatory atop Daniels Hall is visible over the physics end (west entrance) of the building. The observatory burned in a 1956 fire but was not rebuilt.

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Southwest entrance to
Daniels Hall, Department of
Electrical and Computer Engineering
North Carolina State University

A Brief History of the Department of Electrical and Computer Engineering

Chapter 1 The Early Years

The North Carolina State University of today is a direct outgrowth of the pioneering legislation known as the Morrill Land-Grant Act of 1862. Breaking with tradition, this act opened the doors of higher education to children of the working class and, of greater importance, added applied science and practical technology to earlier curricula dominated by the classical professions of law, medicine, clergy and the liberal arts.

Implementation of the Morrill Act was by a grant of 30,000 acres of public land for each senator and congressman from the state. The states could then sell the land and invest the proceeds. Income from these investments was to be used to establish and endow "...at least one college where the leading object shall be...to teach such branches of learning as are related to agriculture and the mechanic arts...to promote the liberal and practical education of the industrial classes in the several pursuits and professions in life."

For about two decades this procedure was followed with the University at Chapel Hill receiving the interest from the investments. By that time, it was clearly recognized that the program at Chapel Hill did not meet the objectives of the act. After a considerable amount of controversy, agricultural groups, the Commissioner of Agriculture, and certain publications brought enough pressure to bear on the legislature so that on March 7, 1887, the General Assembly passed the act which authorized the establishment of the North Carolina College of Agriculture and Mechanic Arts to carry out the provisions of the Morrill Act.

The cornerstone of A & M College, as it came to be called, was laid in August 1888 near Raleigh primarily because a successful farmer, Richard Stanhope Pullen, gave 62 acres of land for the institution. With a freshman class of 72 students, A&M College opened its doors on October 3, 1889. The first faculty of five professors offered courses in agriculture, horticulture, pure and applied chemistry, English and bookkeeping, mathematics, and practical mechanics. Only 17 of the first class graduated in 1893. However, when the first president of A & M, Alexander Q. Holladay, ended his administration in 1899, resident enrollment had reached 300.

The first catalog of 1889-1890 for North Carolina State College listed a Department of Physics, but it was actually administered by the Head of the Chemistry Department. The first three catalogs listed only general areas of instruction by year and separated the work into Recitation, about 14 hours, and Practice, 12 1/2 hours. The fourth catalog, 1892-1893, listed the courses in tabular form on a three-term, Fall, Winter, and Spring, schedule.

The first course in Electrical Engineering offered at North Carolina State College was given by Lieutenant Richard Henderson of the US Navy, who was appointed professor of Military Tactics and Physics in 1893. This was the first use of the term "engineering" in any course taught at NC State College. No differentiation in the instruction in engineering was offered at that time as the only courses in the college catalog were those in Agriculture and Applied Mechanics. The course given seems to have been largely elementary and the practical work limited to house and bell wiring.

In 1895 the designation of the curriculum was changed from "Applied Mechanics" to "Engineering and Mechanics." Dr. Nathan Hale Barnes, a graduate of the Naval Academy, was secured as professor of Physics and Electrical Engineering and Military Tactics, and the work offered in Electrical Engineering was increased. Nine hours were listed in Electrical Engineering, which was the only specific branch in engineering shown in the 1895-96 catalog. A few machines were secured, and laboratory work was much improved. The classrooms and laboratory were located in the basement of Holladay Hall.

In 1897 Dr. F.A. Weike came to the College as Professor of Physics and Electrical Engineering and secured a slight increase in the time allotted to the Electrical Engineering laboratory.

In 1898 the curriculum was again changed; seniors in engineering were allowed to choose between Civil and Electrical Engineering, and the work in Electrical Engineering was doubled to 18 hours for those who chose the Electrical course.

In 1899 a further differentiation was made; the Senior class was divided into groups: those taking Civil, Mechanical, or Electrical Engineering. The work in Electrical Engineering, however, was still carried by the Department of Physics and Electrical Engineering. The freshman year was common for all students, and the first three years were the same for all engineering students, changes coming only in the senior year.

In the early days the Board of Trustees took a very active part in the management of the College, with frequent concerns about the expenditure of funds. A perennial topic of discussion was the excessive use of coal in the heating and power plant. At a Board meeting in March 1899, it was "Resolved, that in the future, whenever the Head of any department allows expenditures of his department to exceed the amount

annually appropriated to such department, he shall be held personally responsible for such excess, and the amount of such excess shall be deducted from any balance that may be due on his salary." Adopted.

At the Board meeting of May 28, 1901, unauthorized expenditures of \$1,789.70 by Professor Weike were noted. By a vote of 6 to 7, a motion to dismiss him was defeated. A following motion to charge one-half of that amount to his salary was similarly defeated, 6 to 7. This did not end Professor Weike's problems with the Board. At the May 1904 meeting, a committee recommended that the "Chair of Physics and Electrical Engineering be declared vacant." No reason was given. Professor Weike was in the Patent Office in Washington for many years after leaving the College.

In 1900 distinctly separate curricula in the three branches of engineering were listed, and a four-year course leading to the degree of Bachelor of Electrical Engineering was offered. The first known degree in this Electrical Engineering program was awarded to Mr. J.H. Parker, class of 1903. However, the commencement of May 29, 1901, listed three men as graduating with a Bachelor of Engineering in Electrical Engineering and a fourth man, Numa Reid Stansel, with the degree of Electrical Engineer. Mr. Stansel had received his bachelor's degree in 1898 and had served as an instructor in EE from 1898 until 1901. Also in 1900 we find the first mention of a separate Electrical Engineering laboratory. This was really a part of the original Lighting Plant, a building which stood in front of the old dining hall (Leazar).

In the 1903-04 catalog, "Electrical Engineering (laboratory)" appears in the junior year, and a course in alternating currents was first listed in the senior year. In 1904 Professor Elery B. Paine succeeded Dr. Weike as professor of Physics and Electrical Engineering, and from this time rapid development took place in the work offered in Electrical Engineering. Professor Paine stayed three years. He was succeeded by Prof. Wm. James Moore who stayed but one year.

Note: Much of the above material is taken from documents dated July 1, 1933, and February 6, 1940, located in the University Archives. There is some reason to think that the first was written in preparation for the consolidation of engineering work from Chapel Hill to NC State and the second were notes attached to a letter from Dean Blake R. van Leer to Dr. Frank P. Graham, President of the Consolidated University of North Carolina. Although unsigned, they were probably both prepared by Professor William Hand Browne, Jr., who was head of the Electrical Engineering Department.



William Hand Browne, Jr.

Head
Physics and Electrical Engineering
1908-1916

Head, Electrical Engineering
1917-1944

Chapter 2 The Early Browne Era, 1908-1931

Professor William Hand Browne, Jr., came to NC State from Johns Hopkins in 1908 as head of Physics and Electrical Engineering. The story of Professor Browne is best told in a letter from his son, Dr. Owens Hand Browne, now living in his father's old home in Hymettus Woods at the corner of Wade Avenue and Dixie Trail.

"My father came to A&M from Johns Hopkins in a round-about way. I don't know just what he studied at Hopkins, where his father was Librarian and Professor of Anglo-Saxon. He married Linda Mary Whitaker on June 6, 1898. He taught at Nebraska U. and then at the University of Illinois at Urbana. Circa 1902, he became Technical Editor of the *Electrical Review* in New York City, commuting from Wycoff, NJ.

"In 1908 he came to A&M. At that time the Department of P. and E. occupied an office, a laboratory and a store room in the south end of Holladay Hall basement. For a classroom, Dad had to look around the campus to find one not in use. He complained so much to President Hill that finally he was assigned the task of preparing the class program or "schedule" for the entire college and for some years spent most of his vacations and Christmas recesses at the task. When completed, the program was displayed on an enormous board on the wall of Holladay Hall.

"On coming to Raleigh, Dad purchased the old Boylan mansion, 'Montfort Hall,' and I remember that his assistant, John W. Dorsey, roomed with us. Shortly after coming to Raleigh, he became ill. Dad's illness lasted from fall until the following summer, during which time he was in a sanitarium in Virginia. But in the short time he had taught, he had made such a good impression that the position was held for him and he returned the following fall.

"On returning after his illness, he took a house on Glenwood Avenue at the end of the street car line and opposite the Methodist Orphanage, and Dad used to walk through the orphanage grounds on the way to college. It was his custom to carry a hickory stick so for Christmas the students presented him with a gold-handled cane such as would befit a governor.

"Originally the Prof. of EE had charge of the building which furnished heat and light for the campus. It was the responsibility of the fireman to blow the whistle which signaled class periods. Eventually a new heating plant was built and the old building was taken over by the Department of Ceramics.

"One night during my early days at State (about 1916, ed.), I went with Dad to his office. He had a gadget called a 'cat whisker detector,' which he adjusted by means of a muffled buzzer in his desk drawer. At ten minutes before ten, he handed me one side of a head set and I heard the Naval Observatory clock ticking off the seconds, all the way from Arlington, Virginia, and no wires! At exactly ten, Dad set his watch. Later, a P.A. system called a 'Magnavox' was displayed at a local

record shop. This was borrowed by the Department. Dad taped his headset to the microphone and KDKA could be heard all over the room! This may have been the first 'loud speaker' in Raleigh. When we entered WW I in 1917, the wireless equipment had to be dismantled.

"An annual event in the Department was an electrical show which many local citizens attended. Among the features demonstrated by the students were the telautograph, Geisler tubes, an 'organ' consisting of a set of tuned electric bells, cooking over ice by microwaves and the Tesla Coil.

"Dad used a homemade device for teaching alternating currents, which are represented graphically by the sine curve. It consisted of a frame of vertical plywood vanes and a number of sine curves of different frequencies cut out of plyboard. With this device it is possible to add mechanically three sine curves. The vanes are allowed to settle onto one of the curves. A second curve is used to draw a chalk line on the vanes. Then they are allowed to settle onto a third curve.

"This reminds me of a story. Before the development of the thief-proof lock, students had the general run of a college campus. Late one night during examination week, I surprised one student who had broken into Dad's office. I was told that once a student thought he had found on Dad's desk what he was looking for, but inside the folder was not a copy of the next day's examination but a note from Dad saying: 'Sorry boys! Better luck next time!'

"Dad retired in 1946, after a tenure of thirty-eight years. Not many years later, I went with him to call on his successor. He stopped to examine the directory in the hall and then commented to me, 'Twenty-two on the staff! All they ever let me have was seven!'"

Professor Browne and his assistant, John Dorsey, who roomed with him in the Boylan mansion, constituted with Prof. William J. Walter the entire department of Physics and Electrical Engineering, with Professor Browne handling most of the Electrical Engineering and the assistant covering the Physics.

Charles M. Heck was appointed professor of Physics in 1913 during the presidency of Daniel Harvey Hill, 1908-1916, and became head of Physics when it was separated from Electrical Engineering in 1917. Professor Browne continued as head of Electrical Engineering until 1944.

Professor Browne lived in a succession of houses: on Glenwood Avenue from which he walked to the College, at 1413 Hillsboro Street, then in Cameron Park, then a house which he built on Van Dyke Avenue about 1915, and finally the house he built in the middle of what is now known as Hymettus Woods, and now occupied by Owens Browne. Two well known secretaries in the EE Department during his tenure were the Bledsoe sisters, Mary and Elizabeth. Elizabeth built a house across from the Van Dyke home of Professor Browne.

There is a story of how Van Dyke Avenue got its name. It started out as a driveway along the side of the house. A developer then carried it on through to Brooks Avenue and beyond. The city fathers wanted to call it Browne Street, but Professor Browne was quite self-effacing and demurred. He told his wife about it, and she said "Why not call it after your beard?" And it came to pass that Professor Browne's Van Dyke beard was honored by having a street named for it.

In 1908 the College built a new power house, and the original power house became the Electrical Engineering laboratory. (The 1908 power house in later years housed the Department of Ceramic Engineering and was demolished in 1971 to make way for Poe Hall.) Laboratory work was given in the old power house until 1911 when the Department of Electrical Engineering was moved to a new building, Winston Hall, completed in 1910 at a cost of \$52,647. Electrical Engineering was housed in the basement and first floor on the west end, Civil Engineering was similarly housed in the east end, and Chemical Engineering occupied the second floor. This building for many years was known as the "Engineering Building." Electrical Engineering was still administratively combined with Physics although the courses in Physics were conducted in the basement of Holladay Hall. This arrangement continued until 1916-17 when the Department of Physics and Electrical Engineering were separated. However, the School of Engineering was not formally organized until February 27, 1924, with former president of NC State College, Wallace Carl Riddick, as the first Dean, who served until 1937.

The 1913-1914 catalog lists the College as being on the semester system. The catalog of 1918-19 shows that elementary work in Electrical Engineering, previously given in the junior year, was now to be given in the sophomore year, reflecting the need to allow more time for proper understanding of the applied sciences. Beginning with the twenty-eighth catalog, 1916-1917, alternate elective courses are listed for both the junior and senior years. Previously, no electives were listed.

A student and later Assistant Professor, George C. Cox, is credited with initiating the first radio station both on the campus and in North Carolina, WATC, in the basement of Winston Hall. He later went on to develop a method of magnesium electrolysis useful in de-barnacled ships. He is also suspected of a prank played on Professor Henry Knox (Buzz) McIntyre (1911-1925). In those days, Professor McIntyre drove a horse-drawn station wagon. One day the students switched the large rear wheels with the smaller front wheels so the wagon appeared to be going up hill. Finally Professor McIntyre pleaded, "Boys, please put the wheels back."

The 1917 budget for the School of Engineering listed only two members of the Electrical Engineering faculty: Professor Browne at \$2,500 and Associate Professor McIntyre at \$1,700. The two-man staff prevailed from 1917 until George C. Cox was added in 1921 and Robert J. Pearsall was added in 1922. Professor

Browne, in correspondence dated September 1920, listed problems of accommodating large classes, 35 juniors, 49 sophomores and 70 freshmen.

Professor McIntyre died in 1925 and was succeeded by Professor Raymond Spivey Fouraker from Texas in 1928. Professor Fouraker had a twin brother, Roy, who taught Electrical Engineering at Texas A & M. The two were identical, even to the same Texas drawl, to the extent that at least one student was completely fooled when Roy visited Ray in the late 1940s.

Professor Karl Browning Glenn joined the faculty in 1928 at a salary of \$2,000 per year. Professor Browne noted in an appeal for increases in faculty salaries that the \$2,000 represented a substantial cut from Professor Glenn's previous salary in industry, but in 1930 he was forced to cancel the appointment of an additional faculty member because of budget cuts.

An Electrical Meter School for the public utilities was established in the winter of 1923 by the Extension Division of the College and taught by the Electrical Engineering staff. Edward W. (Ed) Ruggles was a member of the EE staff and later headed the Extension Division. The Meter School, under the direct supervision of the Electrical Engineering Department, continued to be taught on campus during the early spring until after World War II when it was moved to the coast in order that the attendees could combine the School with a vacation at the beach.

In 1925 a new building was planned, and for a time it was undecided which departments should be moved. The Departments of Physics and Electrical Engineering, which had been separated for fourteen years, offered to come together again and share the same building, later named Daniels Hall. In 1927-28 two additional floors were added to the structure. The first three floors were shared by the two departments. Most of the fourth floor housed the Department of Architectural Engineering. Adjoining on the east side was Mann Hall with two



Raymond Spivey Fouraker
Acting Head, Electrical Engineering
1944-1945

floors, the quarters of the Department of Civil Engineering and the Engineering Experiment Station. A one and one-half story structure linked Daniels Hall with Mann Hall. In 1933, EE classroom space was listed at 14,000 square feet and laboratories at 11,000 square feet. The EE faculty numbered six: two full professors and four assistant professors. Five faculty members held both the bachelor's and master's degrees. In 1930-31, the School of Engineering enrollment reached 791 students.

On the front page of the January 9, 1930, edition of the *New York Herald Tribune* appeared the following story:

***Professor Off to Pray
For Class Rated at 12 1/2 %***

RALEIGH, N.C. Jan. 8 (UP)—
Professor William H. Brown, Jr. passed today in "humiliation and prayer," hoping it would bring up the scholastic average of his engineering class. The North Carolina State College students who make up Professor Brown's class in electrical engineering averaged 12 1/2 per cent in an examination. When they appeared for class today they found this notice on the door:

"The papers from this class are the poorest I ever got in twenty years of teaching. . . . It would be wise not to bother me for the rest of the week, which I must pass in humiliation and prayer.

"WILLIAM H. BROWN"

Note the error in spelling Prof. Browne's name. It should also be noted that he later defended his 12 1/2 percent students by offering to stack them up against any other "87 1/2 percent" students from any other school in the country!

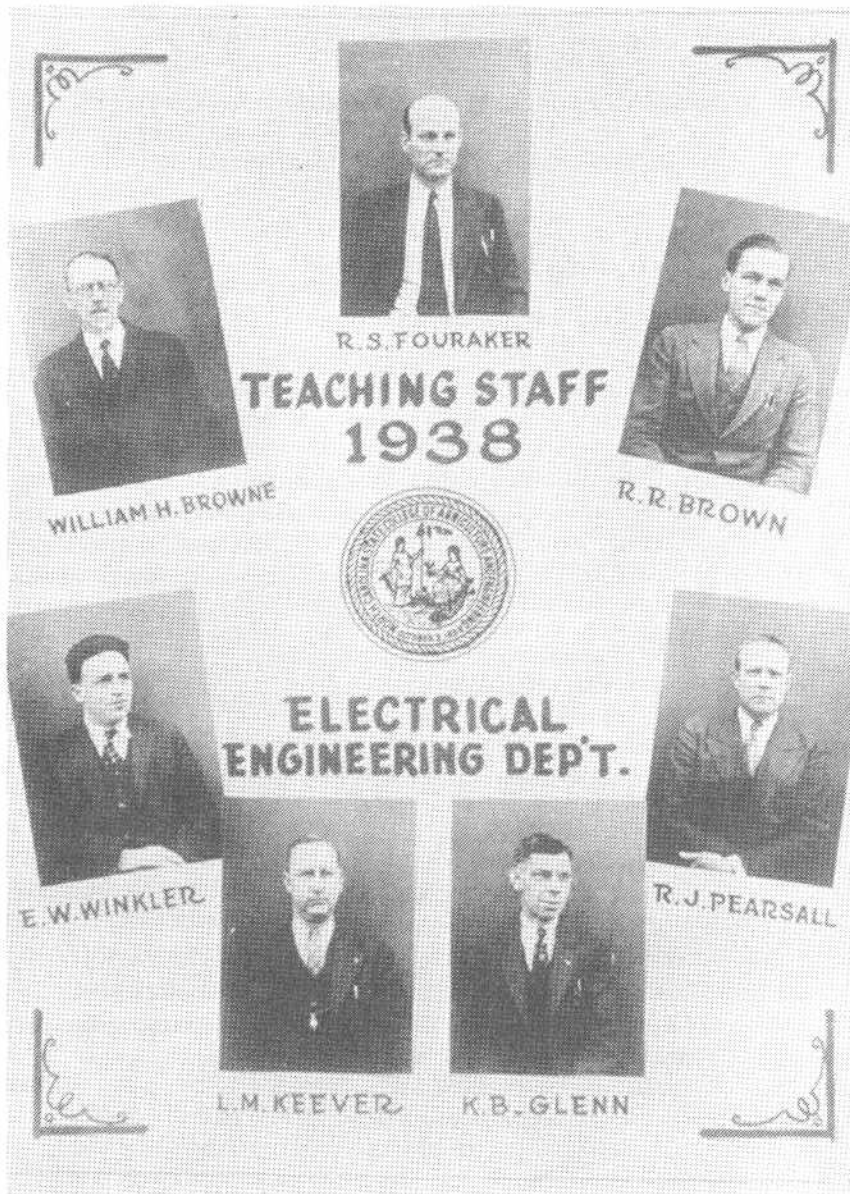
Chapter 3 Consolidation to World War II

Leaders in North Carolina had long been concerned about the limited resources of the State and had considered the idea of consolidating the University of North Carolina at Chapel Hill, the North Carolina College for Women at Greensboro, and North Carolina State College of Agriculture and Engineering at Raleigh. Upon taking office in 1929, Governor O. Max Gardner retained the services of the Brookings Institution to study North Carolina's government and to recommend how it might operate more efficiently. Among the recommendations presented in 1930 was the consolidation of these three major public institutions of higher learning. A Consolidation Commission was appointed in 1931 to review the Brookings Institution report.

The Schools of Business and the Schools of Engineering were duplicated on the Raleigh and Chapel Hill campuses. The Consolidation Commission report of 1932 proposed that Business and Engineering be moved to Chapel Hill and the Raleigh campus be reduced to a two-year institution. The Trustees rejected this report and left the decision to the new president of the Consolidated University, Dr. Frank Porter Graham. This created considerable apprehension among the supporters of NC State, fearful of Dr. Graham's background in the classics and his ties to the University at Chapel Hill. But Dr. Graham turned out to be a fair-minded friend and appointed a study commission which, by a six to five vote, recommended that all technical education be conducted at the Raleigh unit of the University. Amid much controversy, the final decision was made in 1936 to affirm the consolidation of Engineering at NC State. Prof. Winkler in his personal memoirs relates that in preparation for the move to State, Prof. Lear prepared a list of all the equipment in the EE Department at Chapel Hill. Knowing that Chapel Hill departments would have first pick, he listed all the minor items first and buried all the "goodies" in the last pages.

The 1934 *NC State Catalog* listed 36 faculty members in the School of Engineering, 5 of whom held the doctorate.

In 1936, Engineering was consolidated on the NC State campus with \$40,000 of equipment from Chapel Hill. Col. Blake R. van Leer, former Dean of Engineering at Florida, was named Dean of Engineering in 1937 succeeding Dr. Riddick. The last engineering class at Chapel Hill was graduated in 1938, and all engineering instruction was transferred to the NC State campus effective July 1, 1938. All remaining laboratory facilities and staff formerly at Chapel Hill were transferred to Raleigh. The curriculum in Electrical Engineering was strengthened in the fundamental sciences, and a course in differential equations was added to the junior year.



Teaching Staff — 1938

Chapter 4 Early Postwar Years

A constitution and by-laws for the Engineering School were approved by the Engineering faculty on November 21, 1938, outlining powers and responsibilities of the dean, department heads and faculty, requirements for tenure, and the time—six years—during which instructors and assistant professors were expected to have either moved up in rank or have left. The School of Engineering comprised 12 departments: Architectural, Ceramic, Chemical, Civil, Electrical, Geological, Industrial, and Mechanical Engineering; the Engineering Experiment Station; Engineering Mechanics; Mathematics; and Physics.

The Engineers' Council for Professional Development (ECPD) in 1938 accredited the Electrical, Mechanical, Civil, and Ceramic engineering curricula. In the same year a petition for a chapter of Eta Kappa Nu honor society was approved. Professor Edwin W. Winkler, who had come over from Chapel Hill in 1937, prepared the petition and included a picture of the Electrical Engineering faculty, Professor and Head William Hand Browne, Jr., professors Raymond S. Fouraker, Robert R. Brown, Karl B. Glenn, LeRoy M. Keever, Edwin W. Winkler, and Robert J. Pearsall. Professor John Lear joined the EE faculty in 1938 in the last wave of instructors to transfer from Chapel Hill. Professor Stainback had taught electrical engineering in Chapel Hill, but he joined the Physics department at NC State after one year on the EE faculty.

An intriguing episode began with the hiring of John H. Nichols as a laboratory assistant in 1939, in which position he continued until the catalog of 1942 when he was listed as an assistant professor and taught some classes. The following year he was listed as an instructor then dropped back to lab assistant in 1945, in which position he continued until he was replaced by Alan N. Harris as shop technician in 1947.

World War II brought changes. War time training programs were established, and in July 1941, EDT, Engineering Defense Training, was changed to Engineering, Science, and Management Defense Training (ESMDT). That same year, the Electrical Engineering Department became one of 40 such college units conducting courses in radio communications for the Army and Navy personnel. It was reputed to be one of the largest in the country. Professor Raymond Spivey Fouraker, who had been a radio officer in WWI, and Professor Robert R. Brown taught the course. When war was declared, the name was changed to Engineering, Science, and Management War Training.

Professor Browne stepped down as head of the department in 1944, and retired in 1946. Professor Fouraker took over as acting head for a year. Col. Blake R. Van Leer also retired as Dean of Engineering in 1944.

In preparation for expanding and enhancing the national stature of the NC State School of Engineering, the Engineering Foundation was established in 1944, by leaders of North Carolina industry. Mr. David Clark of Charlotte was a prime mover and had seen his earlier work in forming the Textile Foundation become very successful. The Foundation was incorporated on September 29, 1944, with 49 representative engineers and executives on the Board of Directors. The first President of the Foundation was the Honorable J. Melville Broughton, then Governor of the State of North Carolina, and the first meeting of the Executive Committee was held in his office in the State Capitol Building. Other well-known leaders forming the Executive Committee were both David Clark and his brother, John, James M. Peden and C. A. Dillon of Raleigh, William Muirhead of Durham, and K. Clyde Council of Wannish, NC.

Prof. Lillian Lee Vaughn became the acting Dean of Engineering for one year and actively promoted planning by the engineering departments for the post-war period. A first priority listed by all of the departments was "cover the railroad," which runs through the middle of the campus, or somehow remove the tracks to another location. Second was an addition to the Daniels-Mann Hall complex. Track removal did not happen, though it was a regularly proposed activity for many years. The addition to Daniels-Mann did become a reality beginning in 1951 when two stories were added to Mann Hall and a four-story link between Mann Hall and Daniels Hall was constructed.

In accordance with the plan of the Engineering Foundation, the first action was to appropriate \$3,000 a year for five years as a supplement to attract a top-notch Dean of Engineering, and similarly \$2,200 per year to supplement salaries for new heads of Electrical Engineering and Chemical Engineering. Dr. John Harold Lampe came April 1, 1945, as Professor of Electrical Engineering and Dean of Engineering. New heads of Electrical Engineering, Dr. Cornelius Godfrey Brennecke, and Chemical Engineering, Dr. Edward M. Schoenborn, were appointed. Dr. Brennecke held AB, BS, and EE degrees from Columbia and a PhD in physics from NYU. He came to NC State from Lehigh University in Bethlehem, Pennsylvania, in September 1945, and remained as department head until his death in August 1954. He was an accomplished musician and member of the American Guild of Organists.

A prime objective of Dr. Brennecke was to add faculty holding the doctorate, not an easy task, for engineering doctorates were rare. Early additions were Dr. Victor S. Carson, Dr. George B. Hoadley, both in 1948, Dr. Arthur R. Eckels in 1949, and Dr. Wilhelm F. Gauster in 1950. In the professional area, Dr. Brennecke organized the NC-VA section of the Institute of Radio Engineers (IRE) and served as vice-chairman and chairman in 1946-48, and also as chairman of the NC Section of the American Institute of Electrical Engineers (AIEE). Prof. William D. Stevenson, Jr., served as secretary-treasurer of AIEE during the same period.

In April of 1948, Dr. Hoadley, having been recruited by Dr. Brennecke the previous fall, sent his wife, Mary, down to inspect a piece of property on Leadmine Road just south of Lynn Road, about seven miles from the State Capitol. She returned to inform him, "I've bought 92 acres." At that time it was so far out in the country that not only were no houses visible, there was not even a church steeple on the horizon. Nonetheless, he traded a one and one-half to two-hour commute in Brooklyn for a 20-minute travel time in Raleigh.



Cornelius Godfrey Brennecke
Head, Electrical Engineering
1945-1954



George Burnham Hoadley
Head, Electrical Engineering
1954-1974

During this period of time, the Daniels-Mann Hall complex consisted of a four-story west wing, a two-story east wing, and a one and one-half story south wing connecting the ends. Daniels Hall on the west housed the Physics department on the north end of the ground, first and second floors.

Electrical Engineering had a shop and storerooms plus two sophomore labs at the south end of the ground floor. The first floor housed three interconnecting offices and four classrooms, the second floor had a three-man office, the departmental office, and a classroom. Two electronics labs were on the top floor. Also occupying most of the top floor were offices and labs for the School of Design. In the connecting link were the main machine lab and, on the balcony, the machine lab for the non-EEs, two offices, and the radio club.

The East wing, or Mann Hall, housed Civil Engineering, Engineering Mechanics, and the Office of the Dean of Engineering. Two telephone lines served the entire EE department, one of them being reserved for the department head. Some classes were taught in two-story barracks in the area now occupied by the Burlington Nuclear Reactor building, or in Quonset huts located in the Court of North Carolina north of Poe Hall.



Main Machine Laboratory, 1948, 115 Daniels Hall

One feature of the old Daniels Hall is now missing. The astronomical observatory on the roof was used to store paint during one of the renovations, about 1957. A fire got started somehow, and the firemen were frustrated in reaching the roof since the door onto the roof was locked and no key was readily available. Extension ladders were used instead. The observatory was totally demolished and only the platform remained.

The Electric Meter School, begun in 1923, continued after the war, with Dr. Brennecke as director and faculty members as instructors in the "Basic" and "Polyphase" courses. Men from industry and the utilities took over the "Advanced" course. Initially the courses were taught on campus but were moved to Morehead City at the Camp Glenn Elementary School in the early '50s. A gold-plated meter and plaque was presented to the Camp Glenn School in 1956 in memory of Dr. Brennecke. This meter and plaque was returned to Mrs. Brennecke in December of 1988. Dr. Hoadley continued active participation in the school for a number of years, bringing in Prof. Bell in 1959. The School was moved to Wilmington College, now UNC-W, in 1964 and through 1989 has been held at the Wilmington Hilton Hotel.

Dr. Hoadley left the Meter School in 1974 after more than 21 years. In 1981, a celebration of the 50th Meter School included the establishment of a Meter Museum and a Hall of Fame. Faculty members recognized by the Hall of Fame include Dr. G.B. Hoadley, Prof. N. R. Bell, and Prof. E. W. Winkler. The Meter School is still sponsored by the College of Engineering and Department of

Electrical and Computer Engineering, but it is now administered by Continuing Education out of McKimmon Center with guidance by a committee composed of representatives from Carolina Power & Light, Duke Power, and Virginia Electric Power, plus vendors of electric power instrumentation and equipment.

ECPD continued the departmental accreditation in 1949, and it was stated that in 1950 only Harvard and MIT had more accredited engineering programs. Dr. Carson had been appointed to chair a committee to develop a doctoral program for the School of Engineering. At that time, all graduate degrees were under the control of the Graduate Dean at Chapel Hill so the proposal was prepared with that in mind. The report to establish the engineering doctoral program was approved in 1949, and the first engineering PhD graduate was Ralph Marshall McGehee in Electrical Engineering in 1953. He was followed by Robert L. Ramey in 1954 and in 1955 by John S. Mayo and Edwin H. Tompkins, Jr.

The great influx of returning veterans following the war overwhelmed the facilities of the School of Engineering. To ease the impact, particularly on laboratory space, the Engineering-General program was instituted in the fall of 1947, which allowed the departments to select the top students to continue into the junior year as departmental majors. The remainder went into the Engineering-General program where students received lecture-type course work but few labs. In the fall of 1947, out of approximately 270 who successfully completed the sophomore work in Electrical Engineering, 100 were allowed to become juniors in EE. To broaden the cultural background of engineering students, the Humanities Program featuring current events and social studies was added to the required engineering coursework.

Student activities included the 1947 revival of the EE Honor Society, Eta Kappa Nu, along with active student branches both of the AIEE and the IRE, between which there was considerable rivalry. Papers were presented by the students and were frequently of high quality. Mr. Fred R. Willard, an instructor in the department, was instrumental in establishing a carrier current student radio station with the call letters WVWP, or the Voice of the Wolf Pack. It turned out that there was a licensed broadcast station in West Virginia with the same call letters and the call letters had to be changed, eventually to WKNC. Studios were in the old Publications building on the site now occupied by Brooks Hall. Programming included remote broadcasts of football and basketball games.

Amateur radio activity with call letters W4ATC was popular during the post-war years, with many field trips and Moon Bounce experiments. The club was housed for many years on the top floor of the 1911 Building and then occupied added space on the top floor of Daniels Hall for the conduct of high frequency experiments. A large antenna array was mounted on top of the freight elevator penthouse of Daniels Hall for this purpose. Radio Club activity continued until the late 1970s but is now moribund.

A brief recession in early 1950 found many promised engineering jobs withdrawn by commencement time. The Engineering Manpower Report issued

that same year predicting a surplus of engineers brought a sharp drop in enrollment and the threat of staff curtailment. The Korean "Police Action" brought a quick turnaround in jobs, but the reduced enrollment continued for several years.

A major \$778,000 building renovation and addition took place between 1951 and 1953. Actually there were two contracts, one for Mann Hall and one for Daniels Hall. After some persuasion by Dr. Brennecke of EE and Dr. Fadum of CE, the two were combined into one contract. The one and one-half story link between Daniels and Mann Halls was torn down to be replaced by a four-story structure joined to the existing buildings plus two additional stories on top of the old Mann Hall, making a U-shaped building. During this period, the machine laboratories and several offices were moved back to Winston Hall where the department had been in bygone years.

Dr. W. F. Gauster was interested in high-voltage phenomena and in 1952 was able to install a high-voltage laboratory in the lower level of the southwest corner of Riddick Laboratory. This was later moved to the high-bay area of Riddick. Some years later when the insulating oil used in high-voltage experiments and equipment was to be disposed of, it was realized that it contained PCBs, complicating its disposal.

The year 1952 also saw the admission of the first black student—Robert Lee Clemons. An honor graduate of A & T College in Greensboro, he was admitted as a graduate student in electrical engineering with—it must be said—considerable trepidation. The willingness of Dr. George B. Hoadley to accept him as a graduate student was a major factor in his admission. All fears proved groundless and the student body was remarkably receptive, with one student volunteering to be his lab partner. It might be noted that by the fall of 1978, 44 or 6 percent of the EE enrollment was black, and in 1985 the numbers had risen to 187 and 11.8 percent. In 1987, 25.7 percent of the EE undergraduates were in minority categories, including Hispanics and Orientals.

The first regular female student, Lucille Thomson, enrolled at NC State in electrical engineering in 1921. She completed only two years of her program. The first degrees to be conferred on women did not come until 1927 when three were awarded. Immediately after World War II, women represented only about one percent of the student body, being for the most part registered in Textiles and the School of Design. A few women registered in Electrical Engineering beginning in the 1950s, but it was not until the mid 1970s that any reached the junior year. From then on, progress was rapid. Women became very active in the student branch of IEEE and sometimes filled all four elective positions. The count rose from zero women in EE in 1952 to 268 in 1985, or 17 percent of the EE student body. That level has fallen slightly to 14.4 percent.

Another activity was the Spring Senior Industrial Trip, generally to the New York City area to visit a variety of industrial plants, including Consolidated Edison, Federal Radio and Telephone, and Weston Instruments in the New York area; IBM in Poughkeepsie; the GE Switchgear plant in Philadelphia; and the Naval Research

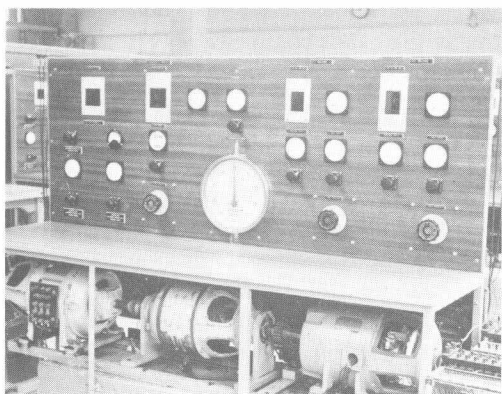
Chapter 5 Growth of Graduate Studies

Laboratory in Washington, DC. In addition to the industrial exposure and recruiting that the students encountered, there were more cultural events, visits to the United Nations, radio broadcasts and adventures in good eating. The cost per student was \$50.00 for the week and included transportation, hotel accommodations, and insurance. There was even a small refund at the end! What started out as busloads of individual students returned to Raleigh as a Senior Class.

Dr. Brennecke fell seriously ill in the spring of 1954 and died later that year. Dr. George B. Hoadley was appointed Department Head to succeed him.

A study of student retention in the School of Engineering was made in 1954. It showed that 50 percent of entering freshmen would still be enrolled in Engineering at the beginning of their fourth year; 26 percent would graduate in four years plus an additional 13 percent at the end of five years. The University had been on the quarter system since before the war but, in 1954, went back to the semester system with graduation requirements in some departments in excess of 150 semester credit hours, placing the engineering school at a competitive disadvantage to liberal arts schools requiring as few as 115 credit hours. After some attempts to scale the engineering requirements down towards 125 semester credit hours, the current level has stabilized at 135 semester credit hours.

Although not a direct part of Electrical Engineering, the Burlington Nuclear Reactor, the first nuclear reactor not a part of the Federal government, was loaded with nuclear fuel on September 5, 1953. This had been a long-term project of Dr. Clifford Beck, Head of the Physics Department, who had come to NC State in 1949. EE Instructor George N. Webb had worked on the instrumentation for the reactor, of necessity inventing several instrumentation systems, for none were commercially available; there was little guidance from the Nuclear Regulatory Agency.



Electromechanical Lab Station, 1966

Designed by A.J. Goetze, originally in Room 115 Daniels

Only eight known MS degrees in EE were awarded prior to WW II. Two were to become faculty members, Leroy M. Keever, MS in 1927, and Karl B. Glenn in 1933. Beginning in 1948 with the awarding of an MSEE to Paul E. Green, Jr., the son of the famous Chapel Hill playwright, the graduate program expanded rapidly, averaging five MS degrees per year in the decade 1950-1960. Both John Mayo and Paul Green, Jr., have since been recognized as Outstanding Engineers by the NCSU School of Engineering.

As industry based on electrical technology developed in North Carolina, the EE graduate program began to grow. One example was the activity of the Western Electric Company and Bell Telephone Laboratories. At the invitation of Western Electric-Bell Labs, the department began offering two graduate-level courses at Greensboro. In addition a program was developed to send selected employees either to Duke University or NC State University to engage in studies leading to the master's degree. Usually these students were part-time at the university and part-time on their jobs. This was the beginning of a continuing off-campus graduate program, now carried on largely by videotape through the Video-Based Engineering Education program (VBEE) or TV.

The increase in the number of students in the master's program created a dearth of faculty for thesis supervision. Consequently, for each part-time student who was working on an engineering project for his employer, the department considered his supervisor at his company as his thesis advisor. A qualified member of the faculty read and discussed the thesis and passed on its acceptability.

A large analog computer (GEDA) was installed in Riddick Building on loan from the US Government for use by Dr. John W. Cell of the Mathematics Department on a research project for Redstone Arsenal dealing with rocket trajectories. Several EE graduate students were employed to operate and maintain the machine. Maintenance included replacing about a bushel basket of vacuum tubes a month. The GEDA computer was instrumental not only in replacing a roomful of Marchant calculators, but in finding better algorithms for solving trajectories.

The School of Engineering budget for the 1952-53 year totaled \$1,161,802. Included in this amount was a State appropriation of \$90,264 for research and \$191,800 of contract money. The teaching budget was \$725,792, and equipment was \$23,270. The staff had 180 full-time-equivalent people, including 27 in Mathematics.

In the early 1950s Dr. Victor S. Carson won a contract from the US Bureau of Ships to analyze strip chart data on long-wave radio propagation. The project, known as GRANPA, used a photoelectric pickup to scan the strip charts and input

it into multiple seven-foot racks of vacuum tubes for analysis. Each rack had a 90-ampere filament transformer mounted at the base, and no room heating was required even on the coldest days.

Although the point-contact transistor was invented in 1947 and explored in a master's thesis by Howard Hamer in 1949, transistors did not become part of the electronics coursework until 1955, when it was introduced by Drs. Carson and Barclay for EE majors and Prof. Manning for non-EE majors.

In July 1955, as part of the Atoms for Peace Project, a Point Four program was initiated and called the International School of Nuclear Science and Engineering, ISNSE. Scientists and engineers from all over the world were brought either to NC State or Pennsylvania State for 16 weeks to be "brought up to speed" in the area of nuclear energy. Following that they would spend up to two years at one of the nuclear installations such as Oak Ridge. Some of the countries represented were not always on the friendliest of terms, but relations remained cordial. As an example, the Suez Canal War might have caused a crisis between an Israeli and an Egyptian scientist, but they were personal friends and all was peaceful. The families later toured together on their way to the Argonne National Laboratory near Chicago. Electrical Engineering instructors included Drs. Hoadley, Gauster, Barclay and Prof. Manning in the areas of circuits, power, and instrumentation. The ASEE-AEC also offered Summer Institutes in 1959-61 in the area of nuclear energy with participation by professors William J. Barclay, Norman R. Bell, Wilbur C. Peterson, and William D. Stevenson.

The middle '50s also brought a series of spring dinner meetings of the faculty and seniors in Eta Kappa Nu during which departmental and curricular problems were discussed. Representatives of other departments were sometimes invited, including English and Mechanical Engineering. It was a form of student evaluation, with the advantage that the discussion could be a two-way street. On one occasion, Mechanical Engineering Prof. Jesse Doolittle, an authority on thermodynamics, even expanded on the student complaints about the course in Thermodynamics!

Prof. Alan B. MacIntyre, son of Prof. Henry "Buzz" McIntyre, had considerable experience in broadcast engineering and was named the chief engineer for the developing WUNC-TV. The first broadcast was a basketball game between UNC-CH and Wake Forest on January 8, 1955. Alan was to bring a number of technical innovations to the art, generally with a maximum of ingenuity and a minimum of expenditure of funds.

A problem arose in the 1950s in that US students wishing to continue their education as graduate students did so at a substantial financial sacrifice, and there was a corresponding increase in foreign nationals at the graduate level. Their use as teaching assistants posed problems, both because of the language barrier and their limited laboratory experience. Prof. William D. Stevenson, Jr., graduate

administrator and acting associate department head for the EE department, became very selective, beginning in 1956, in admitting offshore students. This was also a time of sharply declining interest in the power sequence both at NC State and countrywide. The course in Electron Tubes became Electronics, and solid state was coming into prominence.

Professor W. D. Stevenson, Jr., was active in the recruitment of industries to establish research facilities in the new Research Triangle Park. It soon developed that some of the research scientists sought some connection with a major university and so was born the position of Adjunct Professor. Dr. Gerhart Megla of Corning Glass and Erich Christian of ITT Telecommunications were among the first, followed by many others over the years. Both men were active in the department for many years, Dr. Christian retiring in 1987.

The year 1959 saw the institution of an English proficiency test to be given to EE juniors with remedial work to be taken if necessary. The Joint Student Branch, AIEE-IRE, received special commendation from the National AIEE for their excellent chapter record. A proposal for a master's degree in EE without thesis or language requirement was submitted in 1962. The Freshman Engineering Division was installed July 1, 1963. The relationship between the NC State School of Engineering and Kabul (Afghanistan) University School of Engineering was established under the direction of Dr. Robert G. Carson, Associate Dean of the School of Engineering. Dr. Arthur R. Eckels was to represent the EE Department there between 1969 and 1971 as head of a combined department of Mathematics, Physics, and Electrical Engineering.

There was great excitement in the EE Department when the legislature in 1959 appropriated \$1,000,000 for an 80,000 sq. ft. Electrical Engineering building. But problems soon arose. Since the \$1,000,000 was to cover structure, equipment, and services, it became apparent that 80,000 sq. ft. of building could not be built without severe compromises. By December 1959, the decision was made that Civil, not Electrical Engineering, would get the new building, partly on the grounds that EE had a substantial investment in Standard Electric Time facilities built into Daniels Hall during the 1951-53 building and renovation. Dean Lampe in January 1960 advanced a proposal that EE get \$300,000 to develop old Mann Hall for EE. New Mann Hall was built, and Civil Engineering moved to their new building.

Before the renovation of old Mann Hall could be completed, Pullen Hall was destroyed by fire set by an arsonist. Occupation of the renovated quarters by Electrical Engineering was delayed so that departments burned out by the Pullen Hall fire could be accommodated on a temporary basis in the space vacated by Civil Engineering. State expenditures for the renovation came to \$325,000 with an additional NSF matching grant of \$67,000. The work was essentially completed in 1966.

The US Navy sponsored the Naval Enlisted Scientific Educational Program (NESEP) beginning in 1961 to make the best use of enlisted personnel, who, with additional education in science and engineering, could qualify as officer material. NC State's program in electronics and nuclear engineering made it especially attractive to the Navy. At the initial site visit, Dr. Hoadley was asked a series of questions of the form "can you do 'such and such'." Each time he could answer, "Yes, no problem." At the end of the session, the Navy representative relaxed in her chair and said, "This is the first conference I have ever been in where there were no problems." NC State was only one of four institutions around the country chosen for this program, and it brought some excellent students to NC State for up to four years. One student who insisted on carrying 65 percent above a normal load was still able to maintain a nearly "A" average. The NESEP students took the regular courses and often became leaders in student activities.

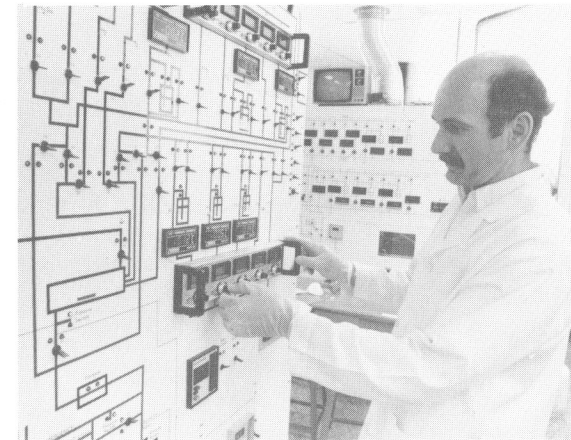
The first NESEP class graduating in 1965 produced 15 BS degrees, and in the same group there were four professional and five master's degrees. Navy supervision of the NESEP group was by a lieutenant and a yeoman stationed in the EE Department. The goal for many of the NESEP students was entry into the Nuclear Submarine Navy. To enter it meant the toughest examination of all, a face-to-face interview with Rear Admiral Hyman Rickover.

Dean Lampe retired as Dean of Engineering, and Dr. Ralph E. Fadum, Head of Civil Engineering, replaced him on July 1, 1962. Shortly after Dean Lampe retired, it was reported that 70 percent, 95 out of 136 professional staff, held the doctorate. North Carolina with 2 percent of the US population was graduating 1.5 percent of the 4-year graduates in engineering, 0.7 percent of the master's and 1 percent of the doctorates. Fifty-nine percent of the 1965 entering class in Engineering came from the top one-fifth of their class with average Verbal Scholastic Aptitude Test (SAT-V) scores of 495 and Math Scholastic Aptitude Test (SAT-M) scores of 585, each out of a possible 800. Effective September 1963, graduation requirements for the School of Engineering were reduced to 140 credit hours.

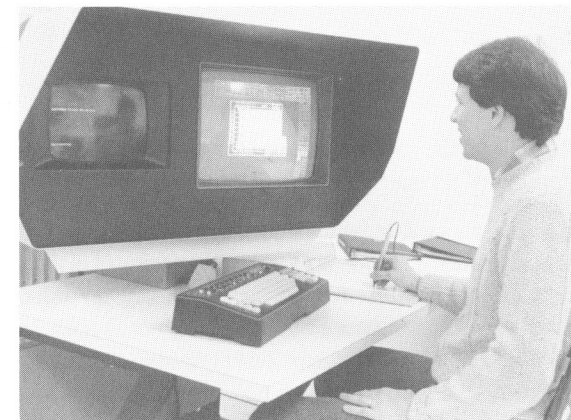
Dr. Arthur R. Eckels spent a year in Japan as a Visiting Professor at the Japan National Defense University, 1964-65. He was later to spend two years, 1969-71, at the Kabul, Afghanistan, University School of Engineering as head of a combined Department of Mathematics, Physics, and Electrical Engineering. In 1981 he was on leave as Adjunct Professor of Physics at NC Central University at Durham.

Although the research program known as GRANPA under the direction of Dr. Victor S. Carson for the Bureau of Ships had been underway since the early 1950s, a major shift to sponsored research began with the hiring of Dr. Robert E. Lade in 1962 in solid state with a start-up grant of \$20,000. Later faculty additions in solid state were Drs. John R. Hauser, Larry K. Monteith, and N.F.J. "Sy" Matthews. From a small beginning in a laboratory originally designated for vacuum

tube research and fabrication, the Solid State Laboratory with adjunct offices has grown to include the top floor of the south and east wings of Daniels Hall. Major facilities include Molecular Beam Epitaxy (MBE) and Organo-Metallic Chemical Vapor Deposition (OM-CVD). The Solid State Laboratory is not only the oldest major research operation in the ECE department, but the largest. The establishment of the Solid State Laboratory initiated rapid growth in the production of graduate students as well as growth in research facilities.



Organo Metallic Chemical Vapor Deposition (OM-CVD) system used to grow thin epitaxial layers of Group III-Group V semiconductors, e.g. gallium arsenide. Designed and built by Dr. John Hauser of the Solid State Laboratory.



CALMA station used in the layout of solid state integrated circuit chips.

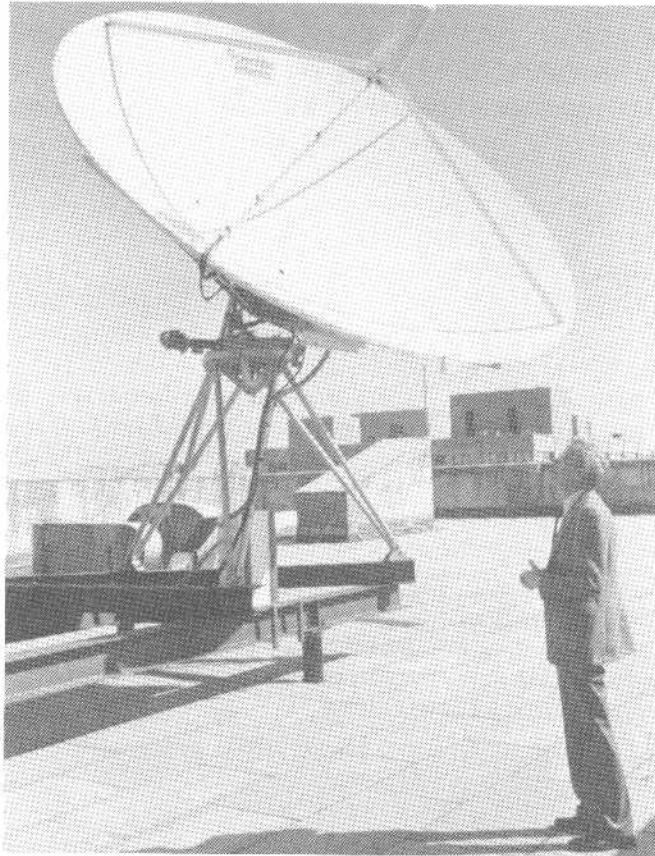
Chapter 6 Growth of Research

In communications Dr. J. Benjamin O'Neal won a major THEMIS research grant in 1969, step-funded over three years for "A Study of Digital Encoding Systems." The award was for \$392,000, a generous amount for those days. The success of the venture can be judged from the contents of a 1976 IEEE Press Book entitled *Waveform Quantization and Coding*, which surveyed research in this area. The book of reprints contained more papers by authors from NCSU than from any other organization.

Dr. Carson taught the graduate students working on GRANPA some digital logic systems, but the first digital logic course was EE 520, taught in 1959 by Prof. Norman R. Bell. In 1963, he and Dr. Ralph Stacey of Physiology went to MIT to work on the LINK computer. Shortly afterwards, the University acquired a DEC PDP-5 computer based on the LINK, followed by a PDP-8 for the Electrical Engineering Department. These computers used discrete solid state components and were programmed primarily in machine language. Plug-in modules, AND, OR, etc gates were in the \$6 to \$15 range. Machine costs were \$16,000 to \$18,000. In 1966, the Triangle Universities Computing Center, TUCC, was getting underway at the Research Triangle Park, supplementing the IBM 1620 leased by the School of Engineering in October 1964.

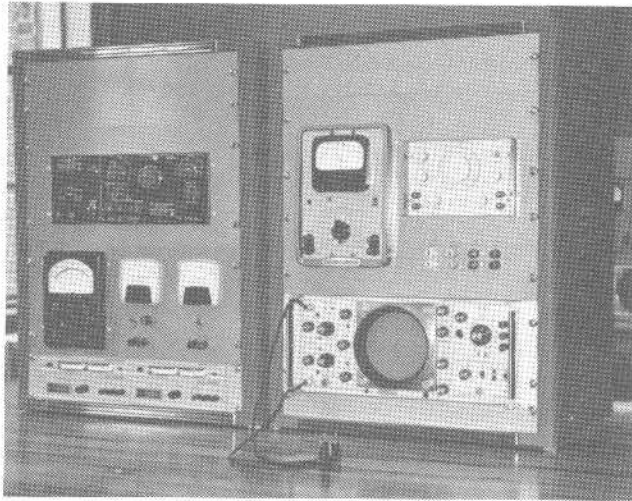
Later Dr. John Staudhammer was able to obtain funding for the AGT-10 Graphics Computer, which was later upgraded to an AGT-30. It was a very fast machine for its time using discrete germanium transistors which were very temperature sensitive. Therefore a major part of its installation was the requirement for close temperature control. Pioneering research in computer graphics was done on this machine, and at least one start-up company, IKONAS Graphic Systems, headed by Nick England and his wife Mary Whitten, evolved directly from this work. By 1969, major areas of research and graduate study included solid state (five faculty), electromagnetics and communication (six faculty), information engineering (six faculty), and systems engineering (three faculty).

The position of Extension Specialist was created in the fall of 1967. Mr. Ron Ingle was hired by IES, the Industrial Extension Service, on September 1, and assigned to Electrical Engineering. His purpose was to promote industry/university interaction through various methods: providing fast answers to simple technical problems for industry, finding information for technical references, finding faculty and students to work on industry problems, teaching short courses/workshops on technical topics, speaking, serving on university/industry committees, and doing research. He filled this position until October 1969 when he left to enter industry. The position of Extension Specialist remained unfilled until August 1986 when Dr. John Sutton joined NCSU with joint appointment with IES and as lecturer in the ECE department. He was instrumental in forming the local chapter of the IEEE Computer Society and in promoting symposia on artificial intelligence.



Satellite dish on the roof of Daniels Hall used in the distribution and reception of advanced engineering courses by the National Technological University.

The 1960s was a time when funding for equipment became easier to obtain. In 1965, Prof. E. G. Manning was able to obtain a federal matching grant of \$15,000 supplemented by State money for a total of \$42,000 to completely rebuild the Junior Electronics laboratory. Other grants followed for sophomore and senior laboratories. Prof. A. J. Goetze was successful in modernizing the machine and control laboratories. By the mid '70s the undergraduate laboratories were close to the state of the art. In 1973, long-time shop technician, Alan N. Harris, who had started in 1946, was retired on disability. Gone were his favorite sayings, "...if the good Lord's willing and the creek don't rise" and "...if it won't go, don't force it; get a bigger hammer."

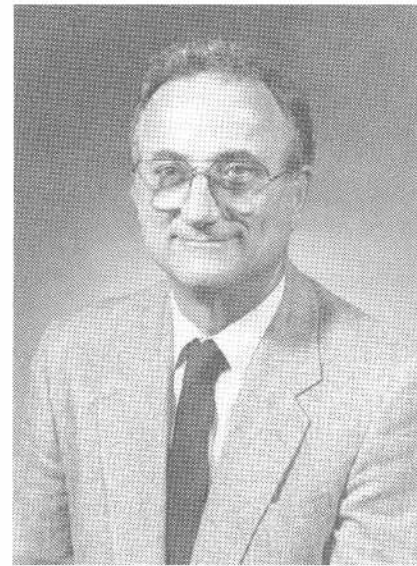


Junior Electronics Laboratory Station, one of eight, 1967

For a number of years, Prof. Goetze had been interested in the digital control of machines, attracting considerable interest in educational circles. In 1980, he obtained grants of \$30,000 from both Alcoa and NSF to support this work and build a laboratory. This has grown to become a major activity in the department, both for instruction and graduate research.

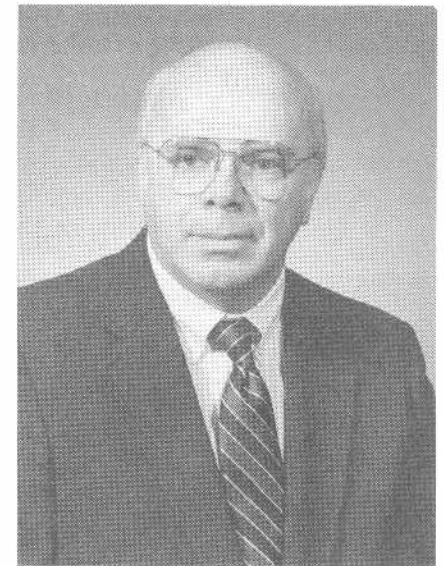
Dr. Ralph Fadum of Civil Engineering succeeded Dean J. H. Lampe in 1962 as Dean of Engineering and was in turn followed in 1978 by Dr. Larry King Monteith, head of the Electrical Engineering Department. To replace Dr. Monteith as head of EE, Dr. Nino A. Masnari, an authority on high frequency solid state devices and Director of the Electron Physics Laboratory of the University of Michigan, was appointed in 1979. He continued the aggressive campaign to strengthen the research program in the EE department, particularly in solid state. Dr. Frank Kauffman was acting department head during 1978-79.

The Microelectronics Center of North Carolina (MCNC) had its 1982 origins in planning by Drs. John Hauser, Michael Littlejohn, and Nino Masnari. The old Machinery Lab in the basement of Daniels Hall was gutted and a silicon microelectronics clean-room facility installed. Most of the initial design and engineering work was done by Dr. Hauser, who served as acting Vice President for MCNC from 1981 to 1982. This served as a temporary facility until the present MCNC lab was completed in the Research Triangle Park.



Larry King Monteith

Head: Electrical Engineering
1974-1978



James Frank Kauffman

Acting Head: Electrical Engineering
1978-1979

In 1987 the ECE Department took over the sole operation of the Daniels Hall MCNC laboratory. At this time there are about 50 graduate students using the facility in Daniels Hall, including Mechanical, Materials, and Chemical engineers, Physics and Chemistry majors, as well as students from UNC-Chapel Hill and Duke University.

Prof. Norman R. Bell was appointed department executive officer in 1959. He was followed by Prof. Wayland P. Seagraves, who took over the position of Undergraduate Administrator and acting assistant head of the department shortly

after he came in 1964. He was very popular with the students, and his picture hangs in the student lounge. He insisted that he never broke any university rules, but he found many ways to bend them to the benefit of all concerned. The position of Undergraduate Administrator and Associate Department Head was established in January 1980 when Prof. William T. Easter returned to the EE department from the Engineering Operations department, which he had headed and which he continued to administer for the spring semester. Prof. Easter's responsibilities took on a much wider scope than those of either of his predecessors.

Upon the retirement of Prof. William D. Stevenson, Jr., as Graduate Administrator and acting Associate Department Head in 1978, Dr. N. F. J. (Sy) Matthews took over. He in turn was succeeded by Dr. Jimmie Wortman in 1981, Dr. Frank J. Kauffman in 1982, and Dr. Tildon H. Glisson in 1986. When Dr. Nino Masnari was named to direct the new ERC Center for Advanced Electronic Materials Processing on August 1, 1988, Dr. Glisson became Acting Department Head and Dr. Glenn Edgington took over the graduate position on a part-time basis.



Nino A. Masnari

Head: Electrical and Computer
Engineering
1979-1988



Tildon H. Glisson

Acting Head: Electrical and Computer
Engineering
1988-1989

Chapter 7 The Department of Electrical and Computer Engineering

Other operational changes in the EE department had taken place over the years. The departmental designation was changed to Electrical and Computer Engineering in 1981. Initially, the student advising was shared by all members of the department with 20 to 35 students per faculty member. Two approaches were tried, either for a faculty member always to advise, for example, sophomores or else to follow a group of students from the beginning to the end of their college career. The variety of rule changes, differing requirements for succeeding classes, and the interest of the faculty member all combined to make either approach a less than satisfactory system. In January 1983, the position of advisor for all undergraduates in the department was created with Mr. Ron Ingle in charge, assisted by other faculty members during pre-registration periods.

When Mr. Ingle left again for private industry in early September, Prof. Manning substituted for six months. He was followed in February of 1984 by Mrs. Joan Larson, BSEE Purdue, 1948, who established a model program. The increasing sophistication and computerization of the advising program has made the position of a dedicated advisor more important than ever, and the increased burden has involved the addition of a secretary to handle record keeping.

Approval was received for the BS in Computer Engineering (BSCPE) to be implemented with the incoming class in the fall of 1983. The MS and PhD programs in Computer Engineering were also approved. That same year, enrollment of black students reached 136, over 10 percent of the undergraduate students.

The School of Engineering adopted a restriction on students entering the engineering program by requiring a minimum of a "C" in certain freshman mathematics, English and physics courses. This became known as the "C-Wall." Later, to better control the flow of students into the sophomore engineering courses, the categorization "Engineering Undesignated" has since been applied to incoming freshman. To matriculate into the engineering program, a student must meet a somewhat modified set of requirements, adding a chemistry and a social science course. Students could indicate a preference for a particular curriculum, but could neither be designated as ECE without matriculation, nor take any engineering courses. Graduation requirements include at least a 2.0 overall average and a 2.0 or better average in all technical coursework.

The continuing popularity of the electrical engineering program led to the imposition of quotas on entering and transfer students. Since the early 1980s this quota has been filled early by entering students with University Predicted Grade Point Averages, UPGA, greater than 2.6 and SAT scores exceeding 1100. Transfer students had to meet a Grade Point Average, GPA, of 2.8. Even so, by 1985-86,

students had to meet a Grade Point Average, GPA, of 2.8. Even so, by 1985-86, enrollment had risen to 1522 and EE graduates represented 28.2 percent of the School of Engineering BS graduates. This rose to 30.4 percent in 1988.

In 1982 members of the EE faculty served as editors or reviewers of 27 professional journals, published 44 papers, were consultants to 29 agencies and companies, and served on many national, regional, and local committees. In 1983, the ECE Department listed 14 Professors, 10 Associate Professors, and 9 Assistant Professors, but teaching loads were very heavy. The year 1984 saw an allocation of 35.6 faculty positions with 5 vacancies. To match the School of Engineering average teaching loads, 8 positions would be required on top of the 35.6 allocated.

With the rise in sponsored research, the position of Instructor has been replaced, for the most part, by the Teaching Assistant. The departmental directory of 1958 shows 6 Instructors and 7 Teaching Assistants and 11 faculty of professorial rank. In the fall of 1988 there were 1 half-time Instructor, 3 Visiting Instructors, 89 Teaching Assistants, as well as 154 Research Assistants, plus 45 of professorial rank. Instructors have not been listed under the departments in the University catalog since 1970.

Mr. William M. Cates, a 1932 graduate, bequeathed the residue of his estate, \$300,000, to establish a scholarship fund for an Electrical Engineering student. An amendment to the will was obtained permitting multiple scholarships to be awarded, and, in 1984, 21 Cates scholarships of \$1,200 dollars each were awarded. The William D. Stevenson, Jr., Scholarship of \$1,200 was also awarded, along with two smaller ones.

A major development in the ECE department has been the growth of research centers supported by continuing "memberships" of industrial organizations. Dr. J. Benjamin O'Neal established and headed the first one, the Center for Communications and Signal Processing, CCSP, on July 1, 1982, with initial funding of \$575,000. This was followed by the Electric Power Research Center, EPRC, under Dr. John Grainger in 1985. The two centers were sponsored by the National Science Foundation program, dedicated to fostering cooperation between NCSU and industry and which provides industry the opportunity to assist in defining and developing the University's research mission. The NSF furnished seed money to establish the centers and will gradually reduce funding over a five-year period.

In 1988 the CCSP had industrial membership which included AT&T, IBM, DEC, CP&L, Westinghouse, General Electric, Northern Telecom, and Bell South. That same year the Electric Power Research Center included support by CP&L, VEPCO, and Duke Power. These programs have produced a number of master's and doctoral degrees. For example, two PhD and four MS degrees have already been granted under the EPRC program.

In contrast to these is the NSF ERC Center for Advanced Electronic Materials Processing headed by Dr. Nino Masnari which began in July 1988. The Center is 1 of 18 NSF Engineering Research Centers that have been established in the country over the past 4 years. It is headquartered temporarily in Daniels Hall but will occupy space on the NCSU Centennial Campus. It is a collaborative effort with UNC-Chapel Hill, UNC-Charlotte, NC A&T University, Duke University, the Microelectronics Center of North Carolina (MCNC) and the Research Triangle Institute (RTI). Funding is provided by NSF (\$1.6M in year 1), industry (approximately \$1.5M in year 1), and NCSU (\$800K in year 1). The NSF award is for a total of \$12.8M over 5 years with the possibility of continuing funding for a total of 11 years.

The overall objective of the Engineering Research Center is to develop the processing technology and equipment needed to permit the realization of atomic-level engineering of advanced electronic materials. At the present time there are 20 faculty members and approximately 35 graduate students involved in the Center.

Current funding for these three centers is about \$6 million per year. Total research funding for the department as a whole is now on the order of \$8 million per year. In contrast, the 1949 School of Engineering research budget had reached the heady level of \$141,000, up from \$52,000 the year before.

The growth and improvement of the undergraduate laboratories has not been neglected. In 1984, Dean Monteith promised funding of up to \$1 million for renovation of the undergraduate laboratories over five years with the understanding that the department would seek to match that amount through grants, gifts of equipment, and discounts on purchases. By 1987, \$500,258 in School of Engineering funds had been expended with matching funds of \$917,530 for a total of \$1,487,530. The program was nearly complete in 1988.

The growth in both student body and the graduate-research program has created severe space and staffing problems, particularly for technicians. Many space adjustments and moves have been made. The old Dynamo Lab which had Room 115 Daniels for many years was consolidated and moved upstairs to join with the non-EE lab and has now been replaced with a more specialized machine laboratory using bench-top sized machines. The Junior Electronics Lab has been moved four times and now occupies a former classroom and shares facilities with the senior electronics course. MCNC took over the space formerly occupied by the Dynamo Lab and the two sophomore labs. Several millions of dollars of equipment have been installed throughout the department. Space in other buildings has been used to house graduate students, generally two to a desk, and in laboratory spaces. In 1985, plans for a \$2 million addition on the north end of Daniels Hall were developed with hopes for occupancy by the fall of 1987. In the meantime, some small relief was obtained by recovering from University Administration five offices and a large room for a computer research laboratory on the 200-level floor of Daniels Hall.

In the fall of 1988, after nearly two years of construction, the EE Department was able to occupy an award-winning new addition to Daniels Hall with about 18,000 square feet of floor space. Although air conditioning had been added to about half of Daniels Hall over the years, the new addition has central heating and air-conditioning. The addition provides primarily new office and laboratory space.

Over the years the ECE faculty has received a number of honors. Between 1971 and 1986, four faculty members have been recipients of NCSU Outstanding Teacher Awards: Littlejohn (twice), Kauffman, Matthews, and Rhodes (twice). In addition, 15 other awards were made to members of the ECE department. In 1987, three were elected as IEEE Fellows, D.P. Agrawal, W. Chou, and J.R. Hauser. M.B. Steer was chosen as an NSF Presidential Young Investigator, a new Analog Devices Career Development Professorship was awarded to R.S. Gyurcsik, and S.T. Alexander received the Conference of Southern Graduate Schools Achievement Award for New Scholars. A Sigma Xi Research Award went to S.A. Rajala and an Alcoa Foundation Distinguished Engineering Research Award to S.M. Bedair.

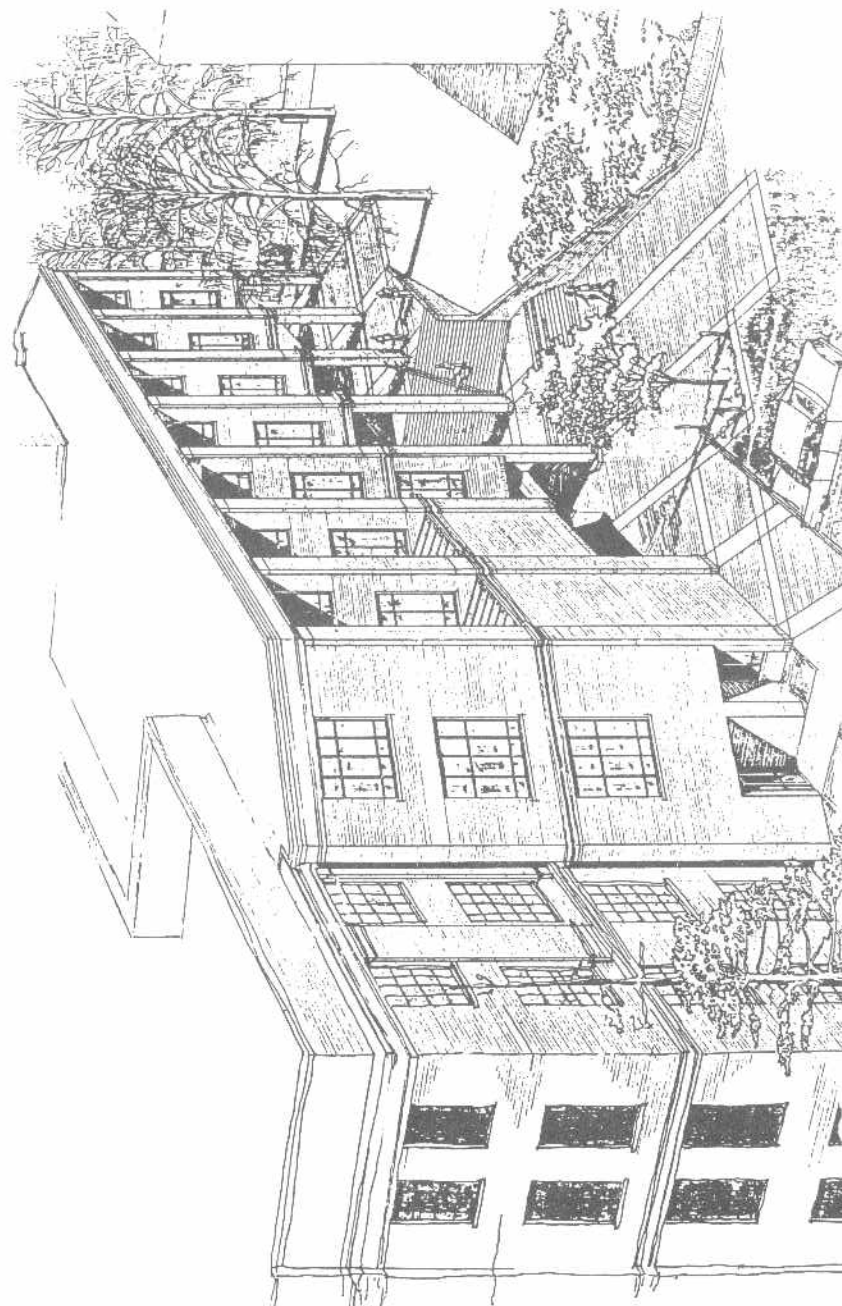
Two IEEE Fellows were awarded in 1988 to J. J. Grainger and A. Reisman. Previous IEEE Fellow awards made to department members include Dean Harold Lampe in 1948, C. G. Brennecke in 1951, Victor Carson in 1955, G. B. Hoadley, F.W. Tischer, and W. D. Stevenson in 1962, W. F. Gauster in 1965, Gerhard Megla in 1968, and Homer Brown in 1976.

In 1989 George Abbott was elected Executive Vice President of IEEE and H. T. Nagle Vice President for Technical Affairs. Also in 1989, two former EE students received IEEE Gold Medals. Eugene Sakshaug, class of 1952, received the Lamme Medal, and Billy B. Oliver, class of 1954, received the Alexander Graham Bell Medal, Sakshaug for work in power systems and Oliver in long distance communications. This same year Umesh Mishra received the NSF Presidential Young Investigator award.

ECE students have also done well, with 94 students holding merit scholarships and accounting for 3 of the 7 valedictorians of the class of 1988, i.e., those with a perfect 4.0 average.

Now that the first class of Computer Engineering, CPE, students have graduated, the department is awaiting an ABET accreditation visit in the fall of 1989. The BSEE curriculum was accredited in August 1987 for a full six years, or until September 30, 1993.

Over the past 10 years the ECE Department has graduated 1,817 BS students or 21.9 percent of the Engineering degrees awarded. Corresponding numbers for the master's program are 414 or 25.7 percent, and PhDs are 71 or 19.0 percent. Beginning in 1988, the School of Engineering became the College of Engineering.



Artist's Rendering of Daniels Hall from Northeast showing 1988 addition

APPENDIX A

NCSU COLLEGE OF ENGINEERING DATA 1987-88

1. 9 Departments offering 15 BS, 10 MS & 10 PhD degrees
2. 8th in the nation in undergraduate degrees
3. Enrollment:
5,285 undergraduate students (19% women; 10% blacks)
1,072 graduate students (12% women; 4% blacks)
4. Degrees awarded:

1987-88	908 Undergraduate
	237 MS
	69 PhD
	2 Professional
5. Faculty

Faculty	908
Adjunct Faculty	237
Visiting Faculty	41
Teaching/Research	316
Industrial Extension	34
6. Papers and books

Papers and books	558
Teaching load	357 student credit hours
7. Average Faculty Member:

Advised 27 undergraduates
Supervised 5.4 graduate students
Supervised 11/2 grants
Generated \$79,800 in research funding
Submitted 1.7 proposals
Won 1.1 grants
Published 3 papers

APPENDIX B

ECE DATES

DEAN, College of Engineering:

1923-1937	Wallace Carl Riddick, former President of NC State A&M
1937-1944	Col. Blake R. Van Leer
1942-1945	Lillian Lee Vaughn, Acting Dean
1945-1962	John Harold Lampe
1962-1978	Ralph Egil Fadum
1978-date	Larry King Monteith

HEAD, Department of Electrical Engineering:

1908-1916	William Hand Browne, Jr., Physics & Electrical Engineering
1917-1944	William Hand Browne, Jr., (retired, 1946)
1944-1945	Raymond Spivey Fouraker, Acting Head
1945-1954	Cornelius Godfrey Brennecke (died, Aug.2,1954)
1954-1974	George Burnham Hoadley
1974-1978	Larry King Monteith
1978-1979	James Frank Kauffman, Acting Head
1979-1988	Nino A. Masnari
1988-date	Tildon H. Glisson, Acting Head

Distinguished Engineering Alumnus Awards

1977	John S. Mayo, Vice President, Bell Laboratories
1983	Paul E. Green, Jr., Staff Member, IBM Corporate Technical Committee
1985	William F. Troxler, President, Troxler Electronic Labs, Inc.

APPENDIX C

ELECTRICAL ENGINEERING FACULTY

Abbott	George	1987	—	Visit. Lec.
Adams	Winfred Morse	1903	1908	Instructor
Agrawal	Dharma Prakash	1982	—	Professor
Alexander	Winsor E.	1982	—	Professor
Alexander	S. Thomas	1980	—	Associate
Andrews	J. Edward	1983	Adj. Asst.
Arbuckle	James Stewart	1927	1928	Assistant
Ardalan	Sasan Houston	178	—	Assistant
Baliga	B. Jayant	1988	—	Professor
Barclay	William John	1954	1980	Professor
Barnes	Nathan Hale	1895	1897	Professor
Beaver	Jacob Lynford	1953	1957	Vis. Prof.
Bedair	Salah M.	1977	—	Professor
Beilman	Don	1982	1988	Adj. Professor
Beil	Norman Robert	1958	1982	Associate
Bilbro	Griff L.	1984	—	Res. Assoc.
Bland	George F.	1976	—	Associate
Bledsoe	Miss Mary	1912	1944	Stenograph
Bledsoe	Miss Elizabeth	1933	1942	Secretary
Brand	J.C.	1981	1983	
Brennecke	Cornelius Godfrey	1945	1954	Professor
Brown	Robert Roderick	1927	1947	Professor
Brown	Homer	1975	1983	Adj. Prof.
Brown	Harry S.	1984	1985	Adj. Instr.
Browne	William Hand, Jr.	1908	1946	Professor
Campbell	I.S.	1949	1950	Associate
Carley	William Sutton	1945	1948	Assistant
Carson	Victor S.	1948	1957	Professor
Chitsaz	Sirus	1983	1987	Associate
Chou	Wushow	1976	—	Professor
Chow	Mo-yuen	1987	—	Vis. Asst.
Christian	Erich	1964	1987	Adj. Prof.
Civinlar	Mehemt	1984	1985	Res. Assoc.
Cockrell	Henry H.	1986	—	Vis. Lect.
Colby	Roy Stephen	1987	—	Assistant
Cox	George Chandler	1921	1926	Assistant
Davis	W.K., Jr.	1895	1896	Assistant
Diehl	Sherra	1982	1987	Associate
Dorsey	John Worthington	1908	1909	Instructor
Easter	William Taylor	1963	—	Associate
Eckels	Arthur R.	1962	1983	Professor

APPENDIX C

ELECTRICAL ENGINEERING FACULTY, continued

Eckels	Arthur R.	1949	1955	Associate
Edgington	Glenn	1987	—	Visit. Lec.
Ejigu	T.	1976	1977	
Elbulik	Malik E.	1986	—	V. Asst.
Etzel	Howard	1981	—	Vis. Prof.
Figueroa	L.	1981	1982	
Flood	Walter A.	1967	1981	Professor
Fouraker	Raymond Spivey	1927	1958	Professor
Franzon	Paul D.	1988	—	V. Asst.
Gault	James W.	1969	1988	Professor
Gauster	William F.	1951	1958	Professor
Gehringer	Edward Francis	1984	—	Assistant
Girgis	Adly A.	1981	1985	Assistant
Glenn	Karl Browning	1927	1962	Associate
Glisson	Tildon H.	1969	—	Professor
Glomb	Walter L.	1985	—	Adj. Prof.
Goetze	Alfred John	1956	1986	Professor
Grainger	John Joseph	1977	—	Professor
Gruver	William A.	1974	1980	Assistant
Gyurcsik	Ronald S.	1986	—	Professor
Hampikian	A.K.	1964	1965	Adj. Prof.
Harris	Alan N.	1947	—	Shop Techn.
Harrison	James W.	1981	—	Adj. Assoc.
Hauser	John Reid	1966	—	Professor
Henderson	Richard	1893	1895	Professor
Herman	Luther R.	1967	1982	Assistant
Hoadley	George Burnham	1948	1974	Professor
Hutchby	James A.	1981	—	Adj. Prof.
Hutchison	Paul T.	1982	1988	Lecturer
Itoh	Makato	1962	1971	Vis. Prof.
Jeffers	George Linwood	1926	1927	Instructor
Johnson	William Duffie	1928	1929	Assistant
Karam	Nasser H.	1985	1988	Res. Assoc.
Kauffman	James Frank	1970	—	Associate
Keever	LeRoy Monroe	1924	1947	Associate
Kelley	Arthur Woodfin	1987	—	Assistant
Khorram	Siamak	1982	—	Professor
Kim	Ki Wook	1988	—	V. Asst.
Kolbas	Robert M.	1985	—	Associate
Krowne	Cliff L.	1977	1982	Assistant
Kuehn	Richard T.	1982	—	

APPENDIX C

ELECTRICAL ENGINEERING FACULTY, continued

Lade	Robert	1962	1967	Associate
Laidig	Wyn D.	1981	1985	Associate
Lampe	John Harold	1945	1962	Professor
Lear	John Emery	1938	1948	Professor
Lee	Sun L.	1980	1983	Adj. Assoc.
LeFevre	H.	1981	1982	
Littlejohn	Michael A.	1966	—	Professor
Liu	Wentai	1983	—	Assistant
Lubkeman	David L.	1983	—	Assistant
Luo	Ren Chyuan	1984	—	Associate
Manning	Edward George	1947	1982	Associate
Maracas	G.N.	1982	1984	Assistant
Masnari	Nino A.	1979	1988	Professor
Matthews	Neely F.J. (Sy)	1964	—	Professor
McIntyre	Henry Knox	1909	1925	Professor
Megla	Gerhart K.	1964	1971	Adj. Prof.
Mehrota	Ravi	1984	1988	Assistant
Miller	Thomas K., III	1982	—	Associate
Mink	James W.	1981	—	Adj. Assoc.
Mishra	Umesh K.	1988	—	Assistant
Monteith	Larry King	1967	—	Professor
Nagle	H. Troy	1984	—	Professor
Nash	Thomas Lewis	1937	1939	Instructor
Nichols	John H.	1939	1946	Lab Technician
Nilsson	Arne A.	1978	—	Professor
O'Neal	J. Benjamin, Jr.	1967	—	Professor
Osburn	Carlton M.	1983	—	Professor
Ozguz	Volkan	1986	1988	
Ozturk	Mehmet	1988	—	
Patt	Yale N.	1969	—	Visit Assoc.
Paulos	John James	1984	—	Assistant
Pearsall	Robert J.	1921	1960	Assistant
Peterson	Wilbur C.	1958	?1980	Associate
Pimmel	Russell L.	1976	1981	
Rajala	Sarah A.	1979	—	Associate
Rastgoufard	Parviz	1983	1987	Lecturer
Reeves	G. George	1968	1977	
Reeves	Douglas R.	1987	—	Assistant
Reisman	Arnold	1982	—	Professor
Rhodes	Donald Robert	1966	—	Professor
Ruggles	Gary A.	1986	—	Assistant

APPENDIX C

ELECTRICAL ENGINEERING FACULTY, continued

Ruggles	Ed	1925	1927	Instructor
Rynders	Raymond	1984	—	Vis. Lect.
Schafer	George E.	1962	1964	Professor
Seagraves	Wayland P.	1962	1976	Associate
Sherman	John	1947	1950	Assistant
Sindoris	Arthur Richard	1978	1979	Visit Assoc.
Smith	P.G.	1964	—	Adj Prof.
Snyder	Wesley E.	1976	—	Associate
Spoon	L'Roy Page	1926	1927	Instructor
Stainback	Raymond Franklin	1939	1940	Instructor
Stancil	D.D.	1981	1986	Assistant
Stansel	Numa Reid	1898	1901	Assistant
Staudhammer	John	1967	1980	Professor
Steer	Michael Bernard	1983	—	Assistant
Stevenson	William D., Jr.	1946	1977	Professor
Stroh	Ray W.	1969	1979	Associate
Suttle	Jimmie	1971	—	Adj. Prof.
Sutton	John	1986	—	Lect. Spec.
Thanikachal	A.	1981	—	Adj. Assoc.
Thurstone	Frederick L.	1958	1964?	Assistant
Tischer	Fred J.	1965	1968	Professor
Toma	C.	1973	1974	Vis. Prof.
Tompkins,	E. Harry, Jr.	1958	1961	Assistant
Townes	Stephen A.	1981	—	Vis. Asst.
Townsend	Keith	1988	—	
Townsend	J. Keith	1988	—	Assistant
Trew	Robert J.	1977	—	Professor
Trussell	Henry Joel	1980	—	Professor
Vanden Bout	David B.	1987	—	Assistant
Vanderlugt	Anthony	1986	—	Professor
Viniotis	Ionnis	1988	—	V. Asst.
Walter	Henry C.	1901	1903	Instructor
Walter	William James	1908	1909	Actg. Prof.
Weihe	Frederick Augustu	1897	1904	Professor
White	Mark W.	1986	—	Associate
Whitted	L.R.	1896	1897	Assistant
Willard	Fred R.	1946	1955	Assistant
Williams	C. Kenneth	1977	1985	Adj. Asst.
Winkler	Edwin Weems	1937	1972	Associate
Wittman	Horst R.	1981	—	Adj. Assoc.
Wortman	Jimmie J.	1969	—	Professor
Zaalouk	Mohamed G.	1980	1981	Adj. Assoc.

APPENDIX D

BOOKS WRITTEN BY ECE FACULTY WHILE ON THE STAFF OF NCSU

ALEXANDER, S. T.

Adaptive Signal Processing: Theory and Applications, Springer-Verlag, New York, 1986

CHRISTIAN, Erich

- (1) *Filter Design Table & Graphs*, J. Wiley, 1966, with E. Eisenmann
- (2) *Introduction to Design of Transmission Networks*, Self, 1975
- (3) *L-C Filter Design, Testing, and Manufacturing*, J. Wiley, 1983

GAULT, J. W. & PIMMEL, R.

Introduction to Microcomputer-Based Digital Systems, McGraw-Hill, 1982

GEHRINGER, E. F.

- (1) *Parallel Processing: The Cm* Experience*, Digital Express, 1987 (with D. P. Siewiorek & Z. Z. Segall)
- (2) *Capability Architectures and Small Objects*, UMI Research Press, 1982

GLISSON, T. H.

Introduction to System Analysis, McGraw-Hill, 1985

HAUSER, J. R.

- (1) *Bipolar Transistors*, Chapter I in *Fundamentals of Silicon Integrated Device Technology*, Vol. II, Edited by Burger & Donovan, Prentice Hall, 1968
- (2) *Unipolar Transistors*, Chapter II in *Fundamentals of Silicon Interated Device Technology*, Vol. II, Edited by Burger & Donovan, Prentice Hall, 1968

HOADLEY, George B.

Principles of Electrical Engineering, J. Wiley, Timbie, Bush & Hoadley, 1951, 4th Edition

(2) *Basic Theory of Space Communicatons*, Van Nostrand, 1965

RHODES, D. W.

(1) *Introduction to Monopulse*, McGraw-Hill, 1959

(2) *Synthesis of Planar Antenna Sources*, Oxford University Press, 1974

SNYDER, W. E.

Computer Interfacing and Control of Industrial Robots, Prentice-Hall, August, 1984

STEVENSON, W. D., Jr.

Elements of Power Analysis, McGraw-Hill, 1982, 4th edition

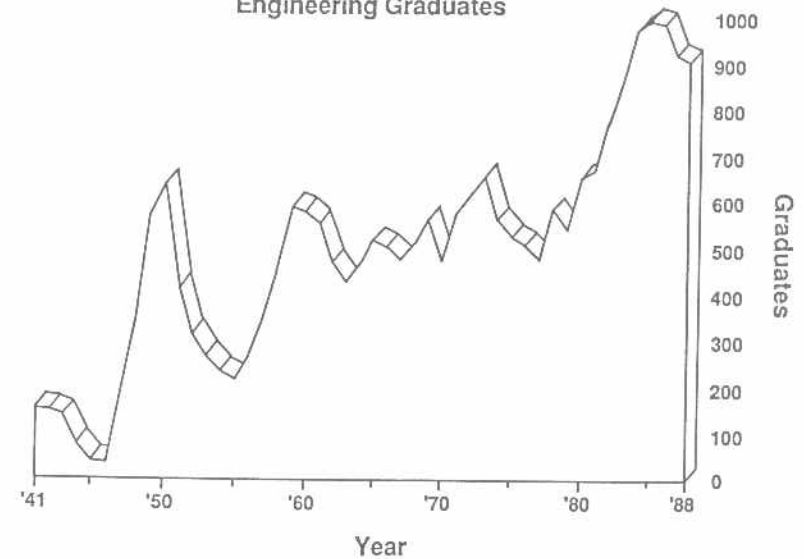
TISCHER, Fred

(1) *Microwave Measurements*, Springer Book Co. 1958

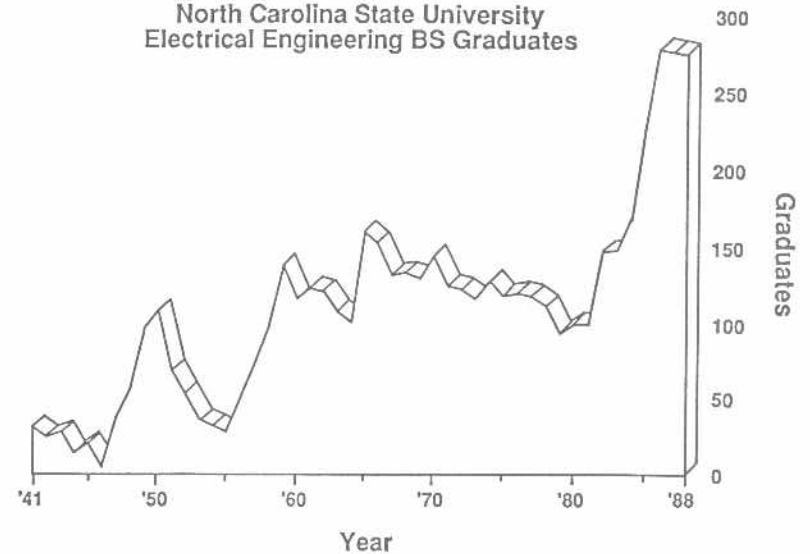
APPENDIX E

GRADUATE AND RESEARCH DATA

North Carolina State University
Engineering Graduates



North Carolina State University
Electrical Engineering BS Graduates



APPENDIX E

GRADUATE AND RESEARCH DATA, continued

