GEORGIA INSTITUTE OF TECHNOLOGY
OFFICE OF CONTRACT ADMINISTRATION
SPONSORED PROJECT INITIATION

Date: June 29, 1978

Project Title: Alexanderson: Biography of an Engineer - Inventor

Project No: G-43-613

Project Director: Dr. James E. Brittain

Sponsor: National Science Foundation, Washington, D.C. 20550

Agreement Period: From 7/1/78 Until 12/31/79*
* Includes 6 month flexibility period

Type Agreement: Grant No. SOC 78-00104

Amount: $22,046 NSF Funds (G-43-613)
758 GIT Contribution (G-43-317)
$22,804 Total

Reports Required: Summary of Completed Project (Form 98A); Final Technical Report

Sponsor Contact Person (s):

Technical Matters

Mr. Ronald J. Overmann
History & Philosophy of Science Program
National Science Foundation
1800 G Street, N.W.
Washington, D.C. 20550
Phone (202) 632-4182

Contractual Matters
(thru OCA)

Ms. Mary Frances O'Connell
Grants Manager - MPE/BBS/SE Branch
National Science Foundation
1800 G Street, N.W.
Washington, D.C. 20550
Phone (202) 632-2858

Defense Priority Rating: N/A

Assigned to: Social Sciences (School/Laboratory)

COPIES TO:

Project Director
Division Chief (EES)
School/Laboratory Director
Dean/Director-EES
Accounting Office
Procurement Office
Security Coordinator (OCA)
Reports Coordinator (OCA)

√Library, Technical Reports Section
EES Information Office
EES Reports & Procedures
Project File (OCA)
Project Code (GTRI)
Other_____

CA-3 (3/76)

G-43-613

GEORGIA INSTITUTE OF TECHNOLOGY
OFFICE OF CONTRACT ADMINISTRATION

SPONSORED PROJECT TERMINATION

Date: 12/17/80

Project Title: Alexanderson: Biography of an Engineer-Inventor

Project No: G-43-613

Project Director: Dr. James E. Brittain

Sponsor: National Science Foundation

Effective Termination Date: 12/31/79

Clearance of Accounting Charges: 12/31/79

Grant/Contract Closeout Actions Remaining:

_ Final Invoice and Closing Documents
X Final Fiscal Report via FCTR
X Final Report of Inventions
_ Govt. Property Inventory & Related Certificate
_ Classified Material Certificate
_ Other _____

Assigned to: Social Sciences (School/Laboratory)

COPIES TO:

Project Director
Division Chief (EES)
School/Laboratory Director
Dean/Director—EES
Accounting Office
Procurement Office
Security Coordinator (OCA)
Reports Coordinator (OCA)

Library, Technical Reports Section
EES Information Office
Project File (OCA)
Project Code (GTRI)
Other C. E. Smith

CA-4 (1/79)

G-43-613

NATIONAL SCIENCE FOUNDATION
Washington, D.C. 20550

FINAL PROJECT REPORT
NSF FORM 98A

PLEASE READ INSTRUCTIONS ON REVERSE BEFORE COMPLETING

PART I–PROJECT IDENTIFICATION INFORMATION

1. Institution and Address	2. NSF Program	3. NSF Award Number
Georgia Institute of Technology Atlanta, GA 30332	History & Philosophy of Science	SOC 78-00104
	4. Award Period From 7/1/78 To 12/31/79	5. Cumulative Award Amount $22,046

6. Project Title
Alexanderson: Biography of an Engineer-Inventor

PART II–SUMMARY OF COMPLETED PROJECT *(FOR PUBLIC USE)*

The project goal was to complete the research and writing of a biography of Ernst F.W.Alexanderson(1878-1975), a brilliant electrical engineer and a prolific inventor of electrical devices,machines and systems. The biography deals with his technical work,the institutional context and his interaction withpatrons and associates during a career of more than fifty years, primarily spent with General Electric and RCA. The study is linked to interpretive themes and issues in the history of 20th century science and technology. Additional research with the Alexanderson Papers at Union College,Schenectady,N.Y. resulted in the discovery of an important new body of manuscripts that had been found after his death and had been added recently to the collection that I had used earlier. New materials were found also in the GE archives, in the Langmuir and Hooper Papers at the Library of Congress and in the R.A.Fessenden Papers in Raleigh,N.C. Additional information was obtained through oral interviews with three of Alexanderson's children and with an early engineering associate of Alexanderson. The research findings were used in the writing of a major interpretive paper entitled "Power Electronics at General Electric:1900-1941" to be published in the fiftieth anniversary volume of Advances in Electronics and Electron Physics in 1980. This paper explores an area of modern science,engineering and invention that has been largely untouched by historians heretofore. The research findings have been used also in writing a major revision of the first five chapters of the biography of Alexanderson. The new evidence enabled a substantial increase in the treatment of his education at the Royal Institute of Technology in Stockholm and at Charlottenberg in Germany before he came to the U.S. in 1901. Greater understanding of his inventive style and the sources of his creativity has been achieved from the research done during the period supported by the NSF. The dialectical exchange between the concepts and perspectives of electrical power engineering and radio-electronics engineering is a constant theme during his entire professional career. Other topics that are explored in depth in the biography are the continuity of corporate design traditions, the protracted "battle"between electric traction systems, the development of the "stentorian" Alexanderson alternator system, and the circumstances that led to the creation of RCA.

PART III–TECHNICAL INFORMATION *(FOR PROGRAM MANAGEMENT USES)*

1. ITEM *(Check appropriate blocks)*	NONE	ATTACHED	PREVIOUSLY FURNISHED	TO BE FURNISHED SEPARATELY TO PROGRAM	
				Check (✓)	Approx. Date
a. Abstracts of Theses	✓				
b. Publication Citations		✓			
c. Data on Scientific Collaborators	✓				
d. Information on Inventions	✓				
e. Technical Description of Project and Results		✓			
f. Other *(specify)*					

2. Principal Investigator/Project Director Name *(Typed)*	3. Principal Investigator/Project Director Signature	4. Date
James E. Brittain	James E Brittain	3/25/80

NSF Form 98A (5-78) Supersedes All Previous Editions

Form Approved OMB No. 99R0011

Publication Citation:

*James E. Brittain," Power Electronics at General Electric: 1900-1941," Advances in Electronics and Electron Physics,vol. 50(1980), pp. 411-447.

* Note: This item is in press and reprints will be forwarded to the Program Officer when available.

FINAL TECHNICAL REPORT TO THE NATIONAL SCIENCE FOUNDATION

PROJECT TITLE: ALEXANDERSON:BIOGRAPHY OF AN ENGINEER-INVENTOR

NSF PROGRAM: HISTORY & PHILOSOPHY OF SCIENCE

NSF AWARD NO: 78-00104

PRINCIPAL INVESTIGATOR: JAMES E. BRITTAIN

DATE: March 25,1980

I. INTRODUCTION:

The principal objective of the project was to complete the research and writing of a book-length biography of Ernst F.W.Alexanderson (1878-1975). Born and educated in Sweden, he completed graduate training in electrical engineering in Germany before coming to the United States in 1901. During a professional career as an engineer and inventor of more than fifty years, his work covered the entire spectrum of power, electronics and communications. Most of his career was spent with the General Electric Company although he was instrumental in the founding of the Radio Corporation of America and was selected to be its first chief electrical engineer in 1919. His interests embraced electrical power, transportation, radio, television, control systems and computers. He received more than 340 patents with the final one being issued in 1973 when he was 95 years old. The Alexanderson radio alternator, the magnetic amplifier and the amplidyne were among his notable innovations. As a protege of Charles P.Steinmetz, Alexanderson was selected as a charter member of Steinmetz's Consulting Engineering Department in 1910. After the death of Steinmetz, he became Director of the Consulting Engineering Laboratory at GE. In addition to his duties as Chief Engineer of RCA, during the 1920s, Alexanderson engaged in pioneering research on facsimile, high-frequency propagation and television. During the 1930s and in WW II, he contributed to the industrial and military applications of high-power electronic tubes and amplidynes including radar and gun-control systems. The biography attempts to deal with both his technical creativity and with the context including the institutional environment in which he worked and his interaction with patrons and associates both inside and outside GE and RCA. The study is linked to interpretive themes in the history of science and technology.

II.DESCRIPTION OF RESEARCH DURING PERIOD SUPPORTED BY THE GRANT:

Additional research completed during the period supported by the NSF Grant included further work with the Alexanderson Papers at Union College in Schenectady, N.Y. An immediate surprise was the discovery that a substantial new body of manuscripts had been found in the Alexanderson home after his death and deposited in the Union College archives as a supplement to the original collection that I had used earlier. The papers in the new gift proved valuable to my research especially for the period before he joined GE and for the period after his retirement. These materials were so extensive that I still have not completed my perusal of all the documents that were generated in the last few years of his life. I was able to obtain xerox copies of a large number of letters written to Alexanderson by his parents soon after he came to America. While in Schenectady, I also visited the archives of the GE Company and obtained copies of several photographs of machines and devices invented by Alexanderson . The GE Historican also provided me with a copy of an oral interview that had been done recently with Howard I. Becker who had been an assistant to Alexanderson during the first World War.

I did further research in Washington,D.C. using the Langmuir Papers and the Stafford Hooper Papers at the Library of Congress. Langmuir was a close friend and associate of Alexanderson at GE whose work on high-vacuum tubes at the GE Research Laboratory is well known to historians of science. The Langmuir Papers proved indispensable to my work on a paper on the history of power electronics at GE that has subsequently been completed. I am also incorporating some of my findings in the Alexanderson biography. Hooper was a key figure in radio history during and after WWI and was instrumental in the founding of RCA and as a patron of some of Alexanderson's work. His Papers have proved quite illuminating on the political aspects of the Alexanderson radio system. A second visit to the R.A.Fessenden Papers at the N.C. State Archives in Raleigh,N.C. provided further helpful sources for my research. Fessenden was an early patron of Alexanderson's work on the high-

frequency radio alternator. Fessenden was also much involved in radio politics and Alexanderson learned much of value from him.

During the period of the Grant, I was able to interview three of Alexandeson's children, Amelie, Edith and Verner. Mrs. Amelie Wallace shared some reminiscences of her father and also provided access to some family correspondence and information on her mother, Alexanderson's first wife, who died at the time of Edith's birth in 1912. Mrs. Edith Nordlander recounted several anecdotes about her father and his personality and character traits. Mr. Verner Alexanderson gave me a very useful copy of the family tree of E.F.W. Alexanderson and copies of several family photographs. While on Long Island to interview Mrs. Wallace, I was also fortunate to be able to talk with Mr. Edward D. Sabin, another early engineering associate of Alexanderson. Mr. Sabin kindly gave me a photograph album containing 133 photographs of three of the RCA stations that employed the Alexanderson system during the 1920s.

Additional research has been done in the engineering journal literature and in patent records . Most of this work has been done in the excellent collection of the Georgia Tech Library supplemented by a brief visit to the Engineering Societies Library in N.Y.City.

New information that was discovered during the grant period has been and is still being used in a revised version of the manuscript. Thus far approximately 200 manuscript pages have been revised (five chapters). Revision of the remaining chapters is still in progress.

III. RESULTS:

A substantial amount of information uncovered during the period supported by the NSF Grant was used in the writing of a paper entitled "Power Electronics at General Electric: 1900-1941" that is to be published this year in Advances in Electronics and Electron Physics, vol. 50(1980), pp. 411-447. This will be a

special fiftieth anniversary issue devoted to papers in the history of electronics. I have received very favorable comments on the paper from two colleagues in the history of technology who received pre-print copies of the paper. The paper was divided into four sections: 1) "The Prehistory of Electronics at GE" 2) "Vacuum Tube Electronics: 1913-1930" 3)"Gas Tube Electronics:1922-1930" 4)"Industrial and Military Electronics: 1930-1941". In the paper I argued that " the history of power electronics at G.E. is almost a paradigm case of modern science,engineering and invention. It was marked by a dialectical exchange of ideas and information on techniques at several levels including lamps,gas and vacuum tubes;electrical power and radio communication; glass and metal containers;theory and experiment;science and engineering;competitive and noncompetitive applications." I found that "much of the dynamism in power electronics at G.E. was derived from the creation of an environment that tended to encourage both creative science and engineering and that maintained a strong linkage between them. " In addition to the contributions of Alexanderson,I examined the work of W.R.Whitney,W.D.Coolidge,Irving Langmuir,W.C.White,Saul Dushman and Albert Hull. In a 1920 paper Alexanderson credited the successful creation of a transoceanic radio communications system to the cooperative effort of two groups of engineers and a group of scientists at GE. One group of engineers had the perspective of power engineering while the other had the perspective of radio. He stated that the scientists had been "brought into contact"with the engineering problems andhad given it a new impetus. Alexanderson's method of developing systems that was manifest repeatedly in the period covered by the paper was in stages with each at a higher level of complexity taking advantage of experience gained from sinpler stages. In the paper I believe that I have opened a new area of historiography that is appropriate to the problems encountered in the study of the history of technology in the 20th century.

The first chapter of the biography of Alexanderson concerns his heritage and education from the year of his birth in 1878 in Uppsala ,Sweden until he joined the Engineering Department at GE in 1904. Research findings during the months of the NSF support expanded my understanding of his studies at the Royal Institute of Technology in Stockholm and the importance of two summers with the ASEA,a leading Swedish electrical company. I discovered also some exciting new documentary evidence of his year of graduate work at the technical university in Berlin including student notebooks. I was able to fix precisely his discovery of the analytic method of Steinmetz in May 1901. I also found new evidence of his first encounter with Thomas Edison and concerning his six-month tenure at the C&C Electric Company before going with GE. New evidence also led to a substantial revision of my treatment of his first several months at GE, and of the circumstances surrounding his first patented inventions. I found also that he began work on the theory of high-speed rotary discs of the type later used in his famous alternator much earlier than previously known.

The second chapter develops the theme of creativity in engineering and invention as illustrated by Alexanderson's work from 1904 to 1907. The stimulating effect of being able to deal simultaneously with problems in traction engineering and wireless engineering seems to have been very important. The tensions produced by having both an external patron,Feesenden, and an internal patron,GE are considered also. I stress the importance of his remarkable ability"to visualize and analyze spacial and temporal relationships of rotating magnetic fields as a function of multiple variables of design and load conditions." I asserted further that "his fundamental understanding of the principles of AC power remained a touchstone throughout his career even when he was dealing with radio and electronic systems." I contrast Alexanderson as a corporate inventor with earlier independent inventors or inventor-entrepreneurs and why he was relatively content to be a "captive inventor." In this chapter I examine in detail the first stage of development of the Alexanderson high-frequency

alternator, a machine that was employed in an historic radio broadcast in December 1906 by R.A.Fessenden. In the same chapter I have examined a "battle of traction systems" that involved not only Westinghouse vs. GE but also two groups of engineers at GE. This is an important story that is comparatively unknown to historians of technology.Alexanderson achieved a synthesis of the series and repulsion motors in the context of this battle of systems despite the fact that GE came to favor high-voltage DC traction. The continuity of corporate traditions exerted a surprisingly strong influence on the types of motors and systems preferred by the engineers responsible for innovation. I suggest that these are comparable to the petsistence of Kuhnian paradigms in science.

The third chapter of the biography deals primarily with the second stage of development of the Alexanderson radio alternator from 1907 to 1910. I suggest that he had not yet acquired the broad perspective of a system engineer but was designing an element to be used in a system conceived by his outside patron, Fessenden. However his association with Fessenden during these years helped to educate him about wireless systems and about the role of government and the military "as patron,consumer and regulator of the new technology." The important role of a temporary interest of A.T.& T. in the alternator is examined also. In the long run it was Alexanderson's personal friendship with Fessenden that kept his project alive and csused a competing one to be abandoned. By 1909 a 2kw-100kc alternator had reached the commercial stage of development at GE. It opened many new doors of opportunity for Alexanderson.

The fourth chapter begins with Alexanderson's transfer to the Consulting Engineering Department headed by C.P.Steinmetz and ends with the start of the first World War in Europe. In this chapter I compare the CE dept. and the GE Researh Lab to illuminate the nature of modern science and technology and their interaction.

I examine in detail Alexanderson's important investigations of the high-frequency properties of iron and dielectric materials using the alternator as a scientific tool. His invention of the magnetic amplifier followed and he soon became interested in the de Forest audion and brought it to his friends at the GERL for improvement. The important contributions of Langmuir on the theory of thermionic vacuum tubes followed. along with Alexanderson's invention of multi-stage tuned amplifiers for radio receivers. In the same chapter I discuss the invention of the phase converter as a technique to enable the use of polyphase motors from a single-phase source. In this invention he clearly used concepts drawn from his radio experience. The role of the Alexanderson split-phase locomotive in the battle of traction systems is also explored. By 1914 the system based on the Alexanderson radio alternator had attracted the attention of the British Marconi Company as a solution to their goals of a world chain of powerful radio stations.

In the fifth chapter of the biography, I have examined the process by which Alexanderson became a system engineer and how he orchestrated the development of a successful transoceanic radio system using 50 kw and later 200kw alternators. This chapter covers the period 1915-1918 and I also consider the extent to which the exigencies of war hindered or accelerated developments in radio. The role of the innovator as a promoter of technological change through behind-the scences activities that contributed to formulation of corporate and national policy is examined from the perspective of Alexanderson. The chapter documents an exciting period in radio history as the Alexanderson system was used at New Brunswick for regular communication with Europe and finally to re-establish communication between the U.S. and Germany in the final stages of the War. Once again, several inventions by Alexanderson such as the multiple-tuned antenna and barrage receiver illustrate a creative exchange between power and radio technology. Finally I discuss Alexanderson's role in the pioneering effort to introduce electric propulsion of ships.