REPORT OUTLINE

FOR

HISTORICAL STUDY
EDISON NATIONAL HISTORIC SITE
WEST ORANGE, NEW JERSEY

RFP-NARO-4-0044

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Submitted to:

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Note: Footnotes will be found at the end of each section of the report.

SUMMARY OF THE REPORT

This report describes in detail a historical study of the West Orange Laboratory of Thomas A. Edison which is being prepared under contract for the National Park Service (RFP-NARO-4-0044). It is based on research in the secondary literature on Edison, tecnnical and scientific journals from the period, and manuscript collections at Baker Library of Harvard University and the Edison National Historic Site.

This report is divided into three parts. Part I outlines the conceptual framework of the study and suggests now the study will fit into the existing literature on the history of business and technology. In particular, it discusses how the study will focus on the evolution of Edison's business strategy as well as his style and method of invention. This part also includes a narrative overview of Edison's major research projects and the changing relationship of the lab with the Edison business organization. Part II of this report discusses several topics that will be treated extensively in the historical study: the financing of the lab, its accounting systems, and its workforce. The purpose of this part is to indicate what documentary research has been already done and what sort of conclusions will be drawn in the larger study.

Most significantly, it suggests how business and accounting records will be used to describe the changes in the physical plant of the laboratory, to determine the allocation of resources and equipment to different research projects, and to evaluate Edison's effectiveness as a leader of research and development. Part III is concerned with further plans for research in 1985 but it also discusses tentative plans for publication with Rutgers University Press.

CHAPTER OUTLINE FOR STUDY

PROLOGUE

A. Economic and technological context, 1880-1930
B. Sources of technological innovation in mid-1880s
C. West Orange laboratory (WO) as case study for evolving role of research and development (R&D) in American business
D. Case study that reveals how rise of R&D embodies a number of cnanges in sources of innovation

ONE: The Factor Endowment of Innovation, 1886-1887

A. Edison (TAE) in 1886: his successes, personal life, business affairs
B. TAE's previous strategies for labs (Newark and Menlo Park)
C. TAE's plan for WO in 1886
D. Construction and pnysical description of WO; cost of building and running the lab
E. Comparison of WO witn other labs of period (Thomson, Weston)
F. Introduce idea of lab as extension/expression of TAE's personality

TWO: R&D For Hire, 1887-1891

A. WO as "Patent Mill"--developed patentable inventions, sold them quickly; took money on promise to develop products and use it to support lab; sold shares in research projects to provide funds
B. Financial arrangements with Villard, Lippincott, and others
C. TAE as sole leader of R&D; his work habits and managerial style
D. The laboratory workforce; role of specialists and discussion of informal structure
E. Case study: improving the phonograph--example of how lab engaged in product design and refinement
F. Production arrangements with phonograph works at Bloomfield

THREE: The Lab in the Spread of Electric Lighting, 1887-1891

A. Work on electric lignting; role of lab in efforts to spread electric lighting and beat competition

B. AC-DC controversy; investigation of possibility that management of Edison companies was opposed to innovation
C. Formation of Edison General Electric (EGE) as an attempt to rationalize Edison lighting companies and to raise fresh capital
D. TAE disappointed when EGE and then General Electric fail to underwrite a portion of the costs of the lab; impact on work and finances of lab; end of "R&D for hire" strategy

ARTIFACT ANALYSIS: Detailed discussion of one of TAE's inventions from 1886 to 1891, illustrating his personal style and the overall business strategy. Probably one model of the improved phonograph.

FOUR: The Industrial Empire, 1892-1898

A. Following the lack of support from the electric companies, TAE initiated a new business strategy: develop and control whole industries and thus secure autonomy
B. Strategy focused on production rather than research; the inventor became the industrialist
C. TAE's plans for an industrial complex at Silver Lake
D. Ore milling as major example of TAE seeking independence
E. Discussion of possibility of TAE reorganizing phonograph business in order to secure autonomy from outside financiers
F. Relationship between WO and off-site facilities; WO as source of machinery for Ogden ore milling plant
G. TAE fails in ore milling because he lacked experts to help identify technical and marketing problems

PHOTO ESSAY: TAE in the Lab, 1886-1900
A sequence of photos illustrating TAE at work in the West Orange Lab, emphasizing his personal approach to invention

FIVE: Product Diversification and Professionalization, 1895-1911

A. As TAE realized the limitations of ore milling, he began to pursue a new strategy: diversification. Rather than concentrate on a single invention, he chose to protect himself by developing several projects simultaneously.
B. This was the strategy behind development of kinetoscope, x-rays, storage battery, cement, and phonograph--each will be briefly investigated in terms of this strategy
C. The laboratory workforce; in pursuing several projects, TAE relied more on professional engineers and scientists in the lab; role of Miller Reese Hutchinson in directing research

D. TAE organized several production facilities (e.g., Silver Lake Chemical plant and New York film studio); relationship of WO with these facilities
E. Diversification reflected in physical structure and arrangement of WO

SIX: Consolidating the Empire: Thomas A. Edison, Inc., 1911-1915

A. As diversification continued, TAE and his associates decided to centralize control by creating TAE, Inc.; centralization as response to economic factors
B. Role of WO lab in centralization; lab established standard procedures for factories and served as central source of improvements and designs (Engineering Dept.)
C. Discussion of accounting and financial procedures used in centralized organization; impact of procedures on operation of Lab
D. Changes in the physical structure of the lab; lab as part of large industrial complex; effect of the 1914 fire
E. Comparison of WO with labs at GE, AT&T, DuPont, and Kodak in terms of size and mission

ARTIFACT ANALYSIS: How did either the storage battery or the cement house illustrate Edison's style of invention and the new corporate structure of the Edison companies?

SEVEN: Decentralization and World War I, 1915-1919

A. Problems within TAE Inc.; role of S. B. Mambert in applying "efficiency engineering" to these problems; comparison of "efficiency engineering" with practices of Frederick Taylor and others
B. TAE reorganized TAE Inc. into semiautonomous divisions in order to let managers pursue specialized strategies for selling phonographs, chemicals, and movies
C. Divisional strategy led to diffusion of power, reflected partly in creation of smaller divisional labs which competed with WO; lack of cooperation between smaller labs and WO
D. Diffusion of power reinforced by TAE's involvement with the Naval Consulting Board during World War I (WW I)
E. TAE shifted from leader to adviser witnin TAE Inc, from line to staff executive; rise of middle management at TAE Inc.
F. TAE Inc. did well in selling chemicals during WW I

PHOTO ESSAY: TAE and his workers at WO, 1900-1931; TAE as cultural hero and advertising symbol; WO as backdrop for media events

EIGHT: Retrenchment and Reorganization, 1919-1931

A. In response to deflation after WW I, TAE Inc. undergoes reorganization; increased centralized authority over lab and the divisions; new financial controls instituted, reflecting increased power of middle managers; impact of reorganization on lab
B. Firm adopted conservative attitude toward innovation; product lines had been defined, task for WO lab was to come up with minor innovations to improve marketing or manufacture
C. TAE Inc. concentrated on phonograph, Ediphone, consumer appliances
D. The laboratory workforce; further specialization and more formal structure; R & D by committee
E. Lab now sustained business organization rather than business organization serving lab

ARTIFACT ANALYSIS: Disk phonograph or consumer appliances from the 1920s

NINE: An Ironic End: TAE and the Lab in the 1920s
A. TAE was bypassed by management as source of innovation yet for the public TAE and WO were symbols of industrial research
B. TAE and WO as instruments for public relations
C. Rubber research as example of TAE's personal work which was separate from the needs of the company
D. Changes in phyical structure and arrangement of WO
E. Comparison of WO with otner R&D labs in 1920s

TEN: CONCLUSION

A. How effective was TAE as manager of R&D?
B. How did TAE's style of invention change over time? What parts of his style stayed the same?
C. WO as an artifact illustrating the evolution of R&D in American business

PART I:

A CONCEPTUAL OVERVIEW OF THE STUDY

Introduction To The Major Themes

From 1880 to 1930, the American economy underwent a profound and rapid transformation. Frequently, this transformation is described in terms of new consumer products: electric lights, telephones, automobiles, airplanes, and radios. Yet behind these new products were important changes in production and marketing: industrialists pioneered new manufacturing techniques such as the moving assembly line, they developed new large-scale business organizations, and they took advantage of new national markets created by improved transportation and communications. Given the magnitude of these changes in both products and processes, it is not surprising that some historians have labelled this period in American history the "Second Industrial Revolution."(1)

Historians and economists have argued that this revolution was stimulated by a myriad of factors: abundant natural resources, a plentiful supply of capital, new sources and forms of energy (such as petroleum and electricity), the rise of cities, and a growing population of workers and consumers. Yet another key factor contributing to the rapid transformation in America was

that the sources of technological innovation were changing from 1880 to 1930. During these years, American industry shifted from a dependence on independent inventors for new products and processes to a reliance on industrial research facilities located within individual firms. In funding these new laboratories, businessmen came increasingly to regard innovation not as the work of the tinkerer or mechanic, but as the responsibility of the university-trained scientist and engineer. Furthermore, as science-based research provided new products, business leaders came to realize that innovation could be directed to specific corporate goals; instead of being disruptive, businessmen found that new technology could be used to strengthen newly emerging business organizations and to expand or protect markets. Consequently, technological innovation came to be a conspicuous part of American business strategy. As Leonard S. Reich observed in writing about research within AT&T, "Industrial research has changed the way America does business."(2)

This study proposes to explore the development of new sources of technological innovation and their role in the "Second Industrial Revolution" by examining the history of one research and development facility, the West Orange laboratory of Thomas A. Edison. In operation from 1887 until Edison's death in 1931, this laboratory was the site of Edison's work on the phonograph, motion pictures,

x-rays, the storage battery, and other products which altered American life. Consisting of chemical, electrical, and metallurgial laboratories, a scientific library, and a machine shop, West Orange was no ordinary workshop; rather, prior to 1900 it was probably the most extensive research facility in American industry.(3) At West Orange, Edison was hardly the lone, heroic inventor but instead directed teams of professional engineers and scientists assigned to a variety of research projects. Many of the results of the laboratory's research were put into production in the Edison factories located nearby, and as a result the laboratory pursued not only "basic" research but also was responsible for solving production and marketing problems as well.

While there have been numerous studies of Edison, few have analyzed his work at West Orange.(4) Furthermore, those studies that do examine his later years tend to assume that Edison approached the West Orange laboratory in a manner reminiscent of his earlier work at Menlo Park; he needed only a few good-natured assistants, an odd assortment of scientific instruments, and a large junkpile in order to "produce a major invention every six months and a minor patent every ten days."(5) In contrast, in this study we intend to show that Edison and his companies utilized the West Orange lab in a variety of ways over a forty year period. First and foremost, the lab performed a

number of functions: Edison used the laboratory to produce new inventions, but he and his staff also used it for solving production problems, quality control tests, and standardizing manufacturing procedures. More broadly, the laboratory also played different roles in Edison's business strategy and planning. One can argue that through the course of his career Edison not only worked on different inventions but that he pursued them within the framework of larger business strategies. At various stages in his career, Edison saw different ways to make money by inventing and he periodically modified his strategy in order to take advantage of these new opportunities. To pursue new opportunities, Edison often not only introduced new inventions but often he was obliged to develop novel research methods, production techniques, organizational structures, financial arrangements, and marketing plans; taken together, these items can be said to constitute a business strategy. Significantly, each shift in Edison's business strategy affected the operation of the laboratory. As he identified new technical and marketing opportunities, Edison not only employed the lab to develop new products and to perform new tasks but also altered its staff and equipment and found new ways to fund his research. In our study, we shall identify these changes in Edison's business strategy and we shall use them to guide the structure of our narrative.(6)

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Mention of Menlo Park & elec. light in intro.

Need appropriate title

36 Integration of archit. into text - GOOD! Color coded maps will

p 90 - publication by Rutgers — check once again

Based on our present researcn, we believe that Edison's business strategy changed six times during the years he was at West Orange. Tnese shifts can be summarized in the following way:

Years	Strategy	Inventions
1887-1891	Selling Research	electric lighting phonograph
1892-1898	Autonomy	ore milling
1895-1911	Product Diversification	motion pictures, x-rays, cement, phonograph, and storage battery
1911-1915	Centralization	battery, phonograph
1915-1919	Decentralization and Divisional structure	chemicals
1919-1931	Retrenchment and Reorganization	Ediphone, appliances

Under each business strategy we plan to discuss several of Edison's inventions in detail, and these are listed above. Our goal in describing Edison's inventions will be to provide both the details of the innovation process as well as concrete examples illustrating how Edison brougnt together technical, marketing, and financial considerations while pursuing a particular business strategy. Where possible, we shall discuss both inventions for which Edison is well known (such as electric lighting and the phonograph) and inventions for wnich there has been little previous research (such as x-rays or consumer appliances).

One should also note that we do not believe that Edison snifted sharply from one strategy to another; rather, we see him gradually abandonning and replacing one strategy with another over a number of years. Hence, the years given above snould be regarded as approximate ratner than absolute.

Within the broad framework of Edison's evolving business strategy, we shall explicitly examine now Edison approacned invention and innovation by using two additional concepts or themes. First, in the course of our narrative, we shall describe and assess Edison's style of invention. By style of invention, we are referring to the notion that there are several identifiable features unifying an inventor's work over the course of his career. In particular, under the heading of style, we shall consider the followıng elements of style: design patterns and motifs; general intellectual preferences; and commonalities in marketing.(7)

In its most elementary form, style refers first to the patterns and motifs that recur in the design of Edison's inventions. For example, it is well known that Edison used a combination of the cylinder and stylus in the automatic telegraph, electromotograph, phonograph, and kinetograph. Wherever possible, we snall try to identify similar patterns in his work at West Orange.

In addition to specific design features, however, an

inventor's style often embraces certain general preferences. For instance, Thomas Hughes has observed that Edison had a distinct propensity for building entire tecnnological systems rather than individual machines.(8) Best illustrated by Edison's work on incandescent lighting in the early 1880s, we shall look for examples of "systems thinking" in his later work on ore milling, Portland cement, and the storage battery.

Finally, in investigating Edison's style, we will also consider whetner there are any commonalities in his marketing of different inventions. In creating a new device, an inventor is always thinking about how his creation will be used and sold, and his perceptions of the market often shape the design. For example, at tne present time we believe tnat in tne twentieth century Edison may nave preferred to design his consumer products (such as the phonograph, tne Ediphone, and domestic appliances) so that they appealled to an upper-middle class or wealthy audience.(9)

To complement our discussion of style, we shall also investigate Edison's method of invention. By method, we mean the manner in wnich an inventor goes about designing, developing, and perfecting an invention. Under method, one considers tne patterns shaping the daily routines of the inventor and one seeks to identify those activities that nelped the inventor be creative. To be successful, an

inventor must develop a methodology whereby he can dependably isolate and solve the technical and marketing problems arising in the course of the creative act. [Hughes, SPERRY] In studying Edison, we shall investigate the following aspects of his methodology:

> How did he select his projects? Did he look for "reverse salients" or technological bottlenecks and then pursue them?
>
> In working on a project, did he subdivide it into "critical problems" which he or his staff could solve using their skills and knowledge?
>
> How did Edison use sketches, drawings, and models in his work?
>
> How did Edison make decisions about the staff and equipment that should be applied to a project? How effective was he in allocating resources for research and supervising a staff of professional engineers and scientists?
>
> What role did patenting play in his thinking? Why in some cases (such as electric lighting) did Edison seek broad patent coverage whereas in other projects (such as motion pictures) did he fail to get more than just minimal patent protection?
>
> Within the physical structure of the West Orange Lab, where did Edison perform most of his work? If he changed locations, what does this tell us about his research procedures?

In discussing Edison's method and style we shall be identifying patterns that permeate his work as an inventor. We do not intend to narrate each invention as an individual case study but rather we will investigate different inventions insofar as they help us to characterize Edison's overall strategy at a particular time.

We believe that there are several advantages to using Edison's business strategies to organize our study. First, we shall be able to analyze the connections between Edison's inventions, his business arrangements, and the physical structure of the laboratory. In the course of our research, we intend to examine not only the inner workings of Edison's technical creations but also place them in their organizational and business context. In particular, we shall recount how his inventions were shaped by economic considerations and by the resources he had available at the lab. We shall discuss how Edison organized and reorganized the staff and equipment of his lab in order to take advantage of the marketing opportunities he perceived and to cope with periodic changes in the organization of the Edison companies. To analyze the relationship of these technical, economic, and organizational factors, it is necessary to have a broad yet specific concept, and we believe that the notion of changing business strategies will suit this purpose.

Second, in using business strategies as a theme, we shall be able to strike a balance between Edison "the man" and West Orange "the institution." Our study shall neither be a straightforward biography of a "great man" and his accomplishments nor a dry adminstrative history recounting minor events. Instead, by focusing on business strategy we intend to ask and answer questions such as: how did Edison

succeed in keeping the lab supplied with funds as well as a mission? how did he shape the lab so as to satisfy both his own personal needs and those of the Edison companies? In pursuing questions such as these, we shall be examining Edison's actions within the institutional context of the laboratory.

Third, by discussing business strategies, we shall be able to compare the Edison companies and the West Orange lab with other corporations and research facilities from the same era. We do not intend to treat the West Orange lab as an anomaly but instead seek to show how it is representative of the broader trends occuring in American industry during the late nineteenth and early twentieth centuries. By describing how the Edison business organization shifted from product diversification to centralization to a multidivisional structure, we shall demonstrate that the Edison companies underwent an organizational evolution similar to that experienced by other American corporations during this era. Furthermore, at several points in our story, we shall explicitly compare the West Orange lab with other research facilities. During our discussion of West Orange in the 1880s, we shall contrast it with the workshops of other electrical inventors such as Edward Weston and Elihu Thomson. In the 1900s, we shall attempt to draw parallels between Edison's lab and the early industrial research labs established by

General Electric, AT&T, and Eastman Kodak. Finally, in the 1920s, we shall consider how the West Orange lab functioned much like the labs at General Motors and Dupont. Under the framework of business strategy, then, we anticipate being able to snow how the Edison business organization and the West Orange lab were typical and atypical for their time.(11)

In emphasizing the theme of business strategy, we believe we are breaking new ground. Previous studies of Edison have generally narrated his career as a sequence of inventions and technical projects. Some have shown that their patterns and continuities in his early work but most have had difficulty in making sense of his later accomplishments at West Orange.(12) Furthermore, biographers and scholars of Edison have been unsuccessful in placing him in his business and organizational context. We are confident that by using the concept of business strategy to draw together Edison's inventions, business arrangements, and the physical structure of the West Orange Laboratory, we snall be able to make sense of Edison's later work. By raising our analysis to the level of business stategy we will be able to narrate and analyze Edison's various projects. With the proposed conceptual scheme, we believe that we can do justice to the complexity of Edison's achievments while revealing his unique contribution to America's "Second Industrial Revolution."

Notes

1. Elisha P. Douglass, THE COMING OF AGE OF AMERICAN BUSINESS (Chapel Hill: U. of N. Carolina Press, 1971), 432.

2. Leonard S. Reicn, "Industrial Research and the Pursuit of Corporate Security: The Early Years of Bell Labs," BUSINESS HISTORY REVIEW 54:504-529 (Winter 1980) on 504.

3. Thomas P. Hughes, "Edison's Method" in W.B. Pickett, Ed., TECHNOLOGY AT THE TURNING POINT (San Francisco: San Francisco Press, 1977).

4. According to one recent estimate, Edison has been the subject of at least 62 books, 21 pamphlets, 936 periodical articles, and 3,128 newspaper stories. See Wyn Wachhorst, THOMAS ALVA EDISON: AN AMERICAN MYTH (Cambridge, Mass.: MIT Press, 1981), 225-226.

5. Matthew Josephson, EDISON: A BIOGRAPHY (New York: McGraw-Hill, 1959), 133-134.

6. Our tninking about business strategy has been influenced by Alfred D. Chandler, Jr., THE VISIBLE HAND: THE MANAGERIAL REVOLUTION IN AMERICAN BUSINESS (Cambridge, Mass.: Harvard University Press, 1977); Reese V. Jenkins, IMAGES AND ENTERPRISE: TECHNOLOGY AND THE AMERICAN PHOTOGRAPHIC INDUSTRY, 1839 TO 1925 (Baltimore: Johns Hopkins University Press, 1975); and Jeffrey L. Sturchio, "Chemistry and Corporate Strategy at Du Pont," RESEARCH MANAGEMENT 27 (January-February 1984), 10-18.

7. For a discussion of style of invention, see Thomas P. Hughes, NETWORKS OF POWER: ELECTRIFICATION IN WESTERN SOCIETY, 1880-1930 (Baltimore: Johns Hopkins University Press, 1983), 405 and J.D. Prown, "Style as Evidence," WINTERTHUR PORTFOLIO 15:197-210 (Autumn 1980).

8. Hughes, NETWORKS OF POWER, 18-46.

9. On the theme of the Edison companies preferring to design for a luxury market, see Edward J. Pershey, "Engineering Social Coups: The Design and Marketing of Consumer Goods by Edison Industries, 1929-1931," a paper presented at tne 1983 annual meeting of the Popular Culture Association in Wichita, Kansas.

10. On an inventor's method, see Hughes, "Edison's Method and also his book, ELMER SPERRY: INVENTOR AND ENGINEER (Baltimore: Johns Hopkins University Press, 1971), 63-70).

11. On the workshops of other inventors, see "The Research

Laboratory of Mr. Edward Weston," SCIENTIFIC AMERICAN 57:287 and 290 (5 Nov. 1887) and W. Bernard Carlson, "Invention, Science, and Business: The Professional Career of Elihu Thomson, 1870-1900," Ph.D thesis, History and Sociology of Science, University of Pennsylvania, 1984, 404-430. On the early development of industrial research labs, see George Wise, "A New Role for Professional Scientists in Industry: Industrial Research at General Electric, 1900-1916," TECHNOLOGY AND CULTURE 21:408-429 (July 1980) and Stuart W. Leslie, "When Industrial Research Was Young," RESEARCH MANAGEMENT 25 (Sept.-Oct. 1982), 11-19. For an overview of the historical literature on industrial research, see W. Bernard Carlson, "Industrial Research in America: A Select Guide to Historical Studies," HISTORY OF SCIENCE IN AMERICA: NEWS AND VIEWS 3 (Nov.-Dec. 1984), 2-3.

12. For examples of scholars having difficulty evaluating Edison's later years, see Josephson, EDISON and Robert Conant, A STREAK OF LUCK: THE LIFE AND LEGEND OF THOMAS ALVA EDISON (New York: Seaview, 1979). For a reasonably good treatment of Edison in the twentieth century, see Wachhorst, THOMAS ALVA EDISON.

The Narrative Outline: The Evolution of Edison's Business Strategy and Style of Invention

Since Edison's business strategies and style of invention will play a prominent role in our study, it is important to describe in some detail how they evolved from the 1880s to the 1920s. Based on our research to date, we believe that Edison built the West Orange lab in 1887 intending to use it the same way he had used his earlier research facilities at Newark and Menlo Park.(1) Initially, he planned to finance the lab by pursuing a variety of research projects. Some of these projects were offered to businessmen such as Henry Villard who in return was expected to supply venture capital.(2) Other inventions were covered by contracts with Edison firms such as the Edison Ore-Milling Company or the Edison General Electric Company in which Edison promised to assign inventions in a particular area to the company in return for an annual fee.(3) Finally, in still other cases, Edison would invent a new device, patent it quickly, and then sell off the rights; in this mode, the West Orange Lab could be called a "Patent Mill."(4) With a range of financial options at his disposal, Edison was free to pursue a variety of inventions and business ventures. Notably, the early years at West Orange were among the most

productive in his career; from 1888 to 1892 Edison received 234 patents, a record succeeded only by his work from 1878 to 1884 when he secured 282 patents.(5)

The key to this first business strategy, though, lay with the research contracts Edison had with the Edison companies; from these, he could rely on regular sums of money to cover the lab's overhead expenses. In particular, Edison assumed that the electric lighting companies would support much of his research and consequently much of the early work at West Orange was devoted to the design and improvement of central station lighting systems. In the early years, Edison appears to have regarded the companies as existing primarily to support the lab; his operation, one could say, was centered on research and innovation. Unfortunately, when the largest of these contracts --the one with Edison General Electric-- failed to provide adequate funding, Edison angrily abandoned this strategy. Feeling that financiers such as Villard and J.P. Morgan had taken advantage of him and had not helped him finance the lab, Edison began to evolve a new strategy in which he would be able to finance the lab on his own.(6)

The new strategy that Edison adopted was one of autonomy through industrialization. Edison would free himself from "the leaden collar" of financier-dominated companies by using his own inventions to create new businesses.(7) At first, he tried to interest businessmen

in creating a new industrial complex at Silver Lake but when this scheme fell through, he decided to utilize his ore milling inventions.(8) Since 1879, Edison had been experimenting with using large electromagnets to recover iron from low-grade magnetic ores and in the late 1880s he concluded that the economic conditions were suitable for undertaking a large-scale venture. At an iron mine in northwestern New Jersey, Edison erected a gigantic plant where he hoped to process 5000 tons of ore daily. Because he was the main investor in this enterprise, Edison was free to design and operate the plant as he saw fit, and consequently, he overlooked a number of key technical and marketing problems. The ore milling venture never produced the revenue that Edison hoped that it would and instead he lost over three million dollars on the project.(9)

Although Edison struggled with his ore milling project until 1898, by 1895 he had begun to sense that he had erred in placing all his financial "eggs" in the ore milling "basket." Autonomy and support for the lab could not be secured through the development of a single invention. In response, Edison initially returned to his old strategy of "research for hire," and he negotiated a contract in 1895 with the General Electric Company under which he was to undertake new experiments for improving the incandescent lamp.(10) However, it soon became clear that GE was not willing to underwrite the entire costs of the lab and his

research; for instance, GE refused to fund Edison's research on x-rays in 1896 and instead supported their own in-house inventor, Elihu Thomson, in developing a line of x-ray equipment.(11)

In the face of rejection by GE, Edison modified his business strategy once again and implemented a policy of product diversification. He would develop and manufacture several inventions simultaneously, assuming that these projects would provide enough work and cash to support the lab. Over time, surely one or more venture would pay off, allowing him to stop worrying about money. Edison began this new program by reorganizing the phonograph company but he also created new companies in order to exploit new inventions such as the kinetoscope, Portland cement, and the storage battery. In following a strategy of product diversification, Edison erected several production facilities (including the Silver Lake chemical works, new phonograph factories in West Orange, and a movie studio in the Bronx). Although his business arrangements in this period (1895-1911) were chaotic and diverse, this strategy generally seems to have worked. With some projects (such as the storage battery), Edison overcame formidable technical problems while in others (especially the phonograph) he struggled with marketing difficulties. In our study we shall investigate how he shaped this strategy and evaluate how well he responded to these challenges.(12)

In 1910 and 1911, as phonograph sales lagged during a short, sharp economic recession, Edison and his business associates decided to reorganize several of the Edison companies into a coherent business organization.(13) Under the leadership of Frank L. Dyer and Charles H. Wilson, the North American Phonograph Company absorbed Edison firms manufacturing primary batteries, kinetoscopes, movies, and dictating equipment. (Not included in the new firm were the Edison Storage Battery and Portland Cement Companies. These companies were absorbed by TAE Inc. after World War I). To capitalize on the "selling power" of Edison's name, the new consolidated company was called Thomas A. Edison, Incorporated (TAE Inc.).(14) In order to secure greater control and efficiency, Edison and his associates organized TAE Inc. along centralized functional lines. Most of the authority in the company was placed in the hands of the president and two vice presidents who were advised by a number of standing committees organized by individual products. Additional functions, such as engineering, legal counsel, purchasing, and finance, were handled by central departments which served the entire organization.(15) Additional coordination and control may have been acquired by having the Silver Lake Chemical Works supply chemicals for the various manufacturing departments. Within TAE Inc. the West Orange Lab appears to have been the "home base" for the Engineering Department which was responsible for

product design and improvements in production machinery. The lab and its staff probably served the goals of centralization by functioning as a clearinghouse for technical and scientific information, by helping to standardize operations in the various factories, and by undertaking routine quality control work.

It is important to note that the new strategy of centralization probably represented a key shift in Edison's thinking; rather than basing his new strategy on technological innovation, he seems to have assumed that organizational innovation would make the difference. Unfortunately, while the centralization scheme looked fine on paper, in practice it appears to have been unwieldly. Although the larger organization provided some economies of scale and coordination, managers and engineers found that the organization hindered the development of marketing plans specifically suited for individual products. What worked well for selling phonographs to a large mass market did not necessarily work well in selling an industrial product such as primary batteries.

Taking advantage of the confusion caused by the 1914 fire in the Orange phonograph factories, Edison reorganized TAE Inc. into several independent divisions. Beginning with the motion picture and primary battery operations, Edison broke the company into separate units, each under a divisional manager who had the authority to make most

decisions regarding the manufacture and marketing of a particular product.(16) Technological innovation was routinized in that an engineer was assigned to each product and charged witn the task of periodically improving its design and operation. To keep control over the entire company, the president and an executive committee retained control over the financing of each division.(17)

Under this arrangement, though, the balance of power shifted clearly for the first time away from Edison and toward the divisional managers and product engineers; although Edison had been gradually losing power to the rising group of professionals, this change in the organization clearly signalled the end of his hegemony over the lab and the manufacturing companies. Under this new strategy, it can be argued that Edison went from being a line executive presiding over the organization to being a staff executive advising the organization on technical matters. To a certain extent, Edison may not have been especially concerned with these changes in his role since his attention after 1915 was focused mainly on the Naval Consulting Board and war-related research.

For the West Orange lab as an institution, however, decentralization meant a loss of a mission and legitimacy. Altnough the divisions were expected to help support the main lab, several divisions created their own labs which conducted their own design work and routine testing.

Anxious to establish their own "turf," professional scientists and engineers in these new, smaller labs were frequently unwilling to cooperate with the main lab.(18)

Like many American manufacturing firms, TAE Inc. prospered during World War I. In particular, the company expanded its chemical operations and earned sizable profits by supplying chemicals for military purposes. Following the war, however, came a period of deflation and the company found itself in difficult straits. Company executives again reorganized the company, this time with an eye toward reducing all costs. Rather than pioneer new inventions, the management became cautious and conservative, choosing to concentrate on perfecting the established product lines. Using new accounting procedures, the executive board gained greater control over the operating divisions. The West Orange lab came under particular scrutiny; before and during the war, the costs of the lab had been covered as part of the overhead of TAE Inc., but the lab had frequently failed to produce the innovations needed by the operating divisions. In the opinion of the divisional managers, the lab was the personal domain of the "old man" and while it was necessary to support it, it was not an essential part of the business organization. Consequently, tight fiscal controls were placed on the expenses of the lab and the managers looked the product engineers for the few design changes that were

required.(19)

By the 1920s, then, the relationship between the lab and the business organization had been reversed from where it had begun in 1887. In the early years, the lab had been the dynamic center of the Edison organization and the business firms had existed to support; now in the last years, the lab served to support the complex business organization. While it had supplied radically new technologies in the beginning, the lab now was left with the task of providing conservative innovations which supported the status quo.(20) To a certain extent, this situation is sad yet ironic, for it was during the 1920s that Edison and the lab came to be symbols for the new order of industrial research. Just as Edison and the lab were losing their role within TAE Inc., they were being celebrated in the company's advertising and in the media generally. Edison and the lab were held up as an example of scientific, team-oriented, and goal-directed research; in reality, though, Edison was out of touch with the company, preferring instead to investigate how to synthesize rubber from domestic plants. In the sixth and final business strategy, Edison and the lab came to play a subordinate role, but in doing so their experience probably parallels the experience of research facilities within other firms which in the 1920s were obliged to closely pursue corporate objectives.(21)

In summary, our study will emphasize how the West Orange laboratory was a vital, dynamic facility that embodied many of the characteristics of modern research and development. The history of Edison and the lab should reveal much about how technological innovation gradually shifted from the domain of the heroic inventor to the function of the industrial research laboratory. In suggesting that West Orange underwent a series of changes in strategy and organization during its forty years of existence, we are attempting to show that the lab was not simply a workshop of a heroic inventor and consequently a nineteenth century remnant hanging on into the twentieth century. Rather, over time, the lab acquired a professional staff of engineers and scientists, a dependency on scientific knowlege and theory, and a range of missions including both basic research and routine testing; in appearance, West Orange came to be like many of the research facilities established by major corporations in the early twentieth century. Edison himself seems to have shifted from being simply a tinkerer or mechanic to being more a manager of research and development. Notably, by periodically adjusting his business strategy, Edison was able to take advantage of new technical, financial, and marketing opportunities and thus keep the laboratory funded for over forty years. Involving a variety of both technological and organizational innovations, we see the

history of West Orange as an exciting story, and one that should contribute to our understanding of how the "Second Industrial Revolution" occurred in America.

Notes

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4. Richard H. Schallenberg, BOTTLED ENERGY: ELECTRICAL ENGINEERING AND THE EVOLUTION OF CHEMICAL ENERGY STORAGE (Philadelphia: American Philosophical Society, 1982), 350-377.

5. Robert Conant, A STREAK OF LUCK: THE LIFE AND LEGEND OF THOMAS ALVA EDISON (New York: Seaview, 1979), 308.

6. Edison to Henry Villard, 8 Feb. 1890, Villard Papers and Abstract of "Laboratory Agreement," 1 Oct. 1890, HFM, ENHS.

7. Edison memo, 1 Apr. 1889, Villard Papers.

8. "Memo as to Proposed Edison Industrial Works," n.d., Villard Papers.

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10. Agreement between GE and Edison, 1 Oct. 1895, HFM, ENHS.

11. J.P. Ord to Edison, 7 Nov. 1896, 1896 Electric Light -- GE Co. File, Document File (hereafter DF), ENHS and W. Bernard Carlson, "Invention, Science, and Business: The

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12. "To the Stockholders of Edison Storage Battery Company," n.d., 1911 Battery, Storage -- Edison Storage Battery Co. -- General 2 of 2 File, DF, ENHS.

13. E.J. Bergrenn to F.L. Dyer, 20 June 1911, 1911 TAE Inc. (2 of 2) File, DF, ENHS.

14. C.H. Wilson to Heads..., 1 Mar. 1911 and F.L. Dyer to T. Graf, 28 Mar. 1911, 20 Mar. 1911, 1911 TAE Inc. (1 of 2) File, DF, ENHS.

15. E.J. Bergrenn to F.L. Dyer, 15 Apr. 1911 1911 TAE Inc. (1 of 2) File and C.H. Wilson, "Key to Office Organization Chart," 16 Dec. 1912, 1912 TAE Inc. File, DF, ENHS.

16. Edison Memo, 25 Feb. 1915, 1915 Battery -- Primary File, DF, ENHS.

17. For the development of multidivisional structure, see Alfred D. Chandler, Jr., STRATEGY AND STRUCTURE: CHAPTERS IN THE HISTORY OF AMERICAN INDUSTRIAL ENTERPRISE (Cambridge, Mass.: MIT Press, 1962).

18. G.E. Clark to J.P. Constable, 16 July 1918, Disk Record Division Minutes, 1916-1919, ENHS.

19. R.W. Kellow to the Executive Committee of the Laboratory of Thomas A. Edison, Personal, 12 May 1920, 1920 West Orange Lab -- Financial -- Monthly Cost of Operations File, DF, ENHS.

20. Thomas P. Hughes, "Conservative and Radical Technologies," in S.B. Lundstedt and E.W. Colglazier, Jr., Eds., MANAGING INNOVATION: THE SOCIAL DIMENSIONS OF CREATIVITY, INVENTION, AND TECHNOLOGY (New York: Pergamon, 1982), 31-44.

21. For an industrial research lab adapted to needs of the corporation see Stuart W. Leslie, BOSS KETTERING (New York: Columbia University Press, 1983).

Artifacts, Photographs, and the Physical Plant

To enhance our narrative history of the West Orange Laboratory, we shall make extensive use of artifacts and photographs. Furthermore, where possible, we shall describe and interpret the building and physical structures that comprised the laboratory. We anticipate that these visual materials will make our study more appealing to the reader and tnat they will be especially helpful to those concerned with the preservation and interpretation of the laboratory.

In terms of artifacts, we are planning to include in the study three special sections, each devoted to a single artifact or invention. Each section will describe the artifact in detail, explaining how it operated, now it was designed, what role Edison played in its creation, and how it was manufactured and marketed. Modern and historic photographs, patent drawings, notebook sketches, and advertising materials will be used to illustrate each artifact. Our purpose in including these sections will be to show how the artifact represents Edison's style of invention and how it reflects the prevalent business strategy. Because these sections will require detailed text to be presented alongside illustrations, we have chosen to separate these sections from the main body of the

narrative; they will, however, be inserted between the chapters covering the time period from which the artifact dates.(1)

Photographs will also be used throughout the study. First, analogous to the artifact sections, there will be two photo essays organized thematically. The first of these will come between Chapters Four and Five and will illustrate Edison at work in the lab before 1900. In this section we plan to include historic photographs which reveal how Edison went about the business of invention (or least how he wanted the public to think he pursued invention). A second section will show Edison in the lab after 1900 and will focus on Edison and his research staff. In addition, we will include photographs celebrating Edison as a "statesman of science." We believe that the reader will be able to best appreciate these themes if the photographs are placed together in special sections.

In addition to these sections, photographs will also be placed in the text in order to illustrate the inventions, people, and events being discussed. At the moment, we anticipate that most of these illustrations will be taken from the large collection of historic photographs in the Edison Archives; however, if necessary for clarity of presentation, we will use modern photographs of buildings and artifacts. Similarly, we will make an effort to reproduce some of Edison's notebook entries and sketches

in order to provide something of tne color and flavor of his unique approach to invention.

As a third form of visual material, we shall describe and interpret the buildings and physical structures of the laboratory itself. While it would be possible to have special sections on the architecture and arrangement of the lab, we have decided instead to integrate discussion of the lab directly into the main text. After all, the study is a history of the lab, with a particular focus on how Edison used it in implementing different business strategies. Consequently, in several chapters there will be extended descriptions of the appearance of the lab at different times. Using what sources we find, we shall recount where Edison performed his own research and we shall evaluate how effective was nis allocation of space and equipment to different research projects. We consider the analysis of how Edison used the West Orange Lab to be central to our study since the distribution of space and resources is probably the most revealing evidence that we can cite for changes in business strategy. If possible, we would like to include in the study simplified plans of the lab complex showing by different colors or markings how space was utilized at different times; at least one such would be included for each shift in business strategy.

Notes

1. For examples of how these sections will look, see Exhibit C in the Technical Proposal for this Contract, June 1984 and also "Appendix 2. Singer Sewing Machine Artifactual Analysis" in David A. Hounshell, FROM THE AMERICAN SYSTEM TO MASS PRODUCTION, 1800-1932 (Baltimore: Johns Hopkins University Press, 1984), 337-344.

The Financing of the Lab

Three questions have guided our examination of the accounts records: what are the costs of operating the laboratory, what are the sources of finance, and what strategies did Edison devise to cover the costs of the laboratory? We believe that there are sufficient documents in the Edison National Historic Site to answer these questions, although we are still unable to locate key groups of documents at present. The first part of this essay deals briefly with these three areas and indicates the direction of our research in 1985. The second part reviews the development of Edison's accounting system and the final section looks at the changing role of the laboratory within TAE Inc.

Financing the laboratory was a central issue for Edison and his business organization and thus it is appropriate that this issue forms a part of our study. Financial considerations greatly influenced the direction of the experimental effort; the development of financing and costing were important in establishing the work schedule of the lab and the kind of work that was done. The period under consideration, 1887-1931, covers the evolution of a modern, corporate accounting structure, and the accounts in the archive tell this story. We will use

the evolution of the accounting system as a backdrop to answering more specific questions. In addition to the issue of finance, the accounts records also answer questions related to business strategy, type and pace of work at the lab, and management of the labor force.

The West Orange laboratory was owned and operated by Thomas Edison from its beginning in 1887 until 1930 when Thomas A. Edison Inc. bought the property. The laboratory remained Edison's own business enterprise for the duration. The finance of the laboratory is therefore closely related to Edison's personal finances, for the personal income of Edison formed a major part of the financing of the lab. One indication of the financial involvement of Edison in the laboratory is the name of the key run of laboratory accounts; the general ledgers from 1887 to 1916 are designated "Edison Personal" ledgers. Unfortunately, the bookkeeping of Edison's personal finances is arcane and complex. A clear picture of his personal fortune will probably not emerge until after 1915, when the demands of income tax forced periodic statements of his worth. Even with this information it will be very difficult to divide the laboratory expenses from his personal finances.

Edison used his own money to build the laboratory and provide the supplies and operating capital. His estimates of the initial investment in the laboratory vary from $150,000 to $180,000. These figures are probably accurate:

the accounts records (especially those published in the Historic Structure Reports) and newspaper reports indicate that building and supplying the lab cost around $156,729 by 1887. Further expenditure on testing equipment and transfers of machinery and supplies from other Edison interests could easily account for another $20,000. Documents generated in Edison's plans to raise capital in 1888 (1888 Doc. file, WO Laboratory) indicate that the yearly operating costs of the laboratory were as follows:

Interest on investment	$9,200
Insurance	$1,100
Depreciation	$9,200
Supplies	$7,000
Labor and salaries of assistants	$62,400
This brings total yearly costs to	$88,900

In his dealings with potential investors Edison estimated that his yearly operating costs would be $60,000 to $90,000. The large range between these two estimates is probably due to Edison's inability to estimate (and control) his labor costs--the largest single expense of the laboratory. We know that in 1888 the major element of laboratory costing was labor--that is to say that estimates of the cost of specific experiments normally were based solely on labor costs; overhead, depreciation of equipment, and supplies were not usually included. Edison probably didn't know how much an experiment was going to cost him in

the early days of the lab, and if we take the word of Samuel Insull, probably didn't care. The lack of a coherent R&D strategy in 1887 and the continual changes in the direction of the research effort during the 1890s did not improve this situation. Edison always raised money as he went along--his financial planning was as diverse and chaotic as much of his research.

The first source of finance for the laboratory was Edison's income. This ranges from salary paid from Edison companies to royalties on his inventions. An examination of the 1887-1916 general ledgers shows that funds were taken from Edison "Private" and transferred to Edison "Personal" and this account provided large advances which went into the laboratory's "Experimental" account. Edison "Private" takes in his income from many different sources including his wages from the National Phonograph Company and payments made to him by Henry Ford. Edison "Personal" appears to be the conduit for Edison to pay expenses which are included in the laboratory "Experimental" accounts. (See Chart 1.)

The West Orange laboratory was Edison's own business and it was built to bring his inventions to commercial fruition. The ploughing back of profits from inventions was a central element in the financing of his Newark and Menlo Park laboratories. This continued in the West Orange years, but because of the much larger scale of the WO lab,

and the subsequent higher costs, Edison could no longer support his expenses from income and had to liquidate some of his large investments. For example, during the 1890s Edison began to sell his interest in the electric lighting business to pay for the ore milling project. At least $2,000,000 was involved. Edison was often quoted as saying that he only invented to make enough money to keep on inventing, and he converted assets into experiments throughout his career.

A long and unhappy letter written to financier Henry Villard in 1890, and now in the Villard papers, indicates that Edison did not want to support the laboratory from his own personal finances. He had hoped that he could use other sources of finance to avoid the strains of self-financing that had dogged his years at Newark and Menlo Park. (Villard Papers, Harvard Business School, fol. 473, 8 February 1890.) Unfortunately, his desire for financial security did not materialize.

One customary source of finance for Edison's experiments was the entrepreneurs of Boston and New York. Men like Henry Villard and Jesse Lippincott acted like today's venture capitalist and were willing to finance the development of high tech, high risk products. These men had supported his work in the 1870s and in the 1880s Edison approached businessmen in both cities for financial support. Edison offered Villard half share in a list of

projects in return for a sum approximately half the operating expenses of the lab. The union was never consumated and Edison found it difficult to attract investors in the 1880s and the 1890s. One reason for this was that the development of electric lighting was capital intensive and it had soaked up all the funds from this source. Furthermore, large banking organizations, like Drexel & Morgan, had begun to dominate investment banking and generally took a conservative attitude to research and development. The early history of the electric lighting projects is full of conflict over the banker's control of finance and their reluctance to give Edison free rein for R&D work. One source of finance that Edison deliberately avoided in the West Orange years was the investment banker; the document file is rich in Edison's invective against the like of Drexel & Morgan.

The proposed agreement with Villard anticipated that approximately half the operating costs of the laboratory would be supported by the Edison manufacturing companies; these form an important part of Edison's strategy in building and financing the lab. Edison had established these companies in the early days of the electric light. They included the Lamp Company, the Machine Works, the Edison Electric Light Company, and Bergmann and Company. Samuel Insull provides us with the rationale for establishing the lighting companies : he notes that the

Electric Light Company was "formed for the purpose of supplying Edison with funds for carrying out experiments in connection with the development of an electric lighting system."(Insull's notes in Meadowcroft box 68.) Edison's motivation in forming these separate entities was partly based in operating efficiencies and partly the result of his need to generate funds. Some of these firms were set up as patent holding companies which would provide royalties, while others were to manufacture electrical goods at a profit. Insull states that Edison did not want to get into manufacturing himself so he took part share in these companies and left their operation to his old colleagues at the lab.

The strategy for the lab's work and its financing can be seen in its original physical layout; Building 1 was set up to provide advanced testing and experimental services to the light companies and Edison was proud that no expense was spared in equipping it with the most modern (and costly) equipment. The top floor of the lab was intended for the personal work of Edison and here, too, we find that advanced electrical measuring and testing equipment was installed.(Scientific American, 17 September 1887.) There is little doubt that Edison expected that a lion's share of the lab's activities would be to provide testing and R&D facilites for the electric lighting industry that he had created.

The draft agreement with Villard (1888 Doc. File, WO Lab) gives us an excellent idea of Edison's expectations of yearly financial support from the following :

Lamp Co.	$ 10,000
Edison Electric Light	5,000
Edison Machine Works	6,000
Phonograph Co.	3,000
Ore Milling Co.	3,000

This yearly support of $27,000 is approximately half the laboratory's operating costs as estimated by Edison.

During the early years there was a great deal of interaction between the lab and the various lighting companies with a stream of equipment and ideas passing between the two. Our study will focus on the work of the WO lab in developing the Edison electric lighting system in a competitive market. Although some of the experimental work is billed as commissioned research, it appears that Edison himself decided upon the direction of research and then billed the lighting companies after it had been carried out. The procedure for the first ten years of the lab is to carry out the work, then cost it , and then bill it to the appropriate company. We have found the list (called an "experimental sheet") made up by Edison's assistants in 1890 which assigned all experiments to different companies, except those carried out on the

kinetoscope, bug killer and beef preserver.(Letter Book 03-1-1890, 11 March 1890. The latter three experiments were probably Edison's personal projects and their cost was carried by his personal account.) It appears that the practice of Edison's bookkeepers was to first generate a list of experiments carried out over a fixed time period. Edison, or an assistant, would then indicate to whom the experiment was to be billed. It is significant that all this was done after the event!

This procedure suited Edison; it reflected his style of invention and the bookkeeping heritage from the Menlo Park and Newark years. Not surprisingly, it caused friction between the lab and the lighting companies. The company managers resented the high cost of R&D and their lack of control over it. They frequently asked for explanations of the experimental bills sent to them by the lab. It is evident that the highly detailed costing records produced in the 1890s was not the customary billing procedure of the lab but rather the response to continual complaints from the organizations footing the bill. It could be argued that Edison developed a freewheeling style of invention and accounting in the Newark years and carried it on at the West Orange lab. Yet rather than enrage suppliers and frustrate his customers (as Edison had done in the 1870s), he was now alienating his old comrades in the 1890s. Their growing frustration is evident in the

correspondence in the document file. One note from Insull complained about Edison's practice of buying supplies and then billing the Machine Works and concluded with "we are constantly being asked to pay bills of the laboratory."(1888 Doc. file, Laboratory Bills.)

It is obvious that Edison's billing activites were less and less tolerated by the managers of the various companies in the 1890s. These men had once been colleagues of Edison but now they were responsible for large operations and had to exercise the financial restraint that was alien to him. The move to a more formal structure of the Edison lighting companies (Edison General Electric in 1889 , General Electric in 1892) in turn made the financial relationships with the laboratory more formal. The financial control of the investment bankers was increased and this made it much harder for Edison to carry out research with the same freedom. We know that by 1890 he was disturbed by the reluctance of the lighting companies to pay for his research. In a letter to Villard in 1890 he complained about the financial stringency of the lighting companies and alleged that he had to carry the cost of R&D vital to the competitive position of the Edison lighting system. A handwritten note attached to the letter is most revealing : "As the Genl Co were morally bound to take advantage of the costly facilities erected primarily for the very purpose and as they did not do so but left me for

three years and over to pay the whole expenses of the same."(Villard Papers, Harvard Business School, Fol 473, 8 February 1890.) This marks an important event in the financing of the lab; this source of funds was not as easily accessed as Edison had hoped and in the 1890s the work done for the lighting companies by the lab was formal and commissioned. Documents in the Henry Miller file indicate that Edison entered into several contracts with the lighting companies to carry out research for fixed sums over pre-determined periods of time. Financial control was in the hands of the lighting companies and they exercised it.

The financial support of the laboratory may be divided into three classes: research that Edison initiated and then billed to an appropriate company, long-term agreements between Edison and companies which cover blanket R&D activities, and contracts for specific research projects. One major project for 1985 will be to identify and trace these three types of work and find out how the proportion of each class in the total activity of the lab changed over time. We have plenty of evidence for the first class. An example of the second class of work is the relationship between the Edison and the Ore Milling Company. This was established by a prior agreement which left Edison to initiate research and bill it from an agreed upon reserve. The reserve in the Ore Milling agreement was $25,000 and

Edison carried out research and billed the company "for experiments carried out by me.....as contemplated in my agreement with you." (Letter Book LB 03-1-1890.)

The lab's relationship with the Phonograph Company illustrates all three classes of financial support. The lab had a close relationship with the phonograph works and during the first decade of its operation often carried out manufacturing for the works. Thus in the list of experimental accounts of 1 January 1890 (Doc. file, Lab Experimental) there is a charge for 41 "duplicating machines" manufactured at the lab. This was billed to the works who then complained about the high price! (The lab's labor charges were higher because their labor force was more skilled and therefore more expensive.) An experimental account was set up between the lab and the Phonograph Company to cover blanket research, testing, and production engineering carried out by the lab. There are also some examples of specific pieces of work commissioned by the Phonograph Company. The movement between these classes of financial support underlines the changing relationship of the lab to the phonograph companies. We think that by 1900 the management of the phonograph works had developed priorities for research which differed significantly from those held by Edison. We intend to test the hypothesis that the manufacturing division leaned towards new products which could be mass produced--thereby

reducing unit costs and increasing profits. On the other hand, the watchword of the Edison laboratory was "Quality First" and this could have led them into the direction of high quality, high price products which they did not want to be manufactured in the "Quantity Mode." (Laboratory Blue Book, 1917.)

One final source of business for the laboratory was the work contracted by outside companies. Many of these companies had bought or franchised Edison patents and relied on the WO laboratory for R&D support. Among the early customers of the new lab was A.B. Dick who purchased the rights to manufacture the mimeograph. Other companies required the services of Thomas Edison for specific research projects and made contracts with him that were carried out by the lab. The $12,000,000 project to develop a battery for the Ford Motor Co. is an example of this. The contract research will be fleshed out of the general ledgers which normally record these accounts. We will also plot the percentage of total research activity which falls into this category to see when contract research reaches a peak and when it declines.

The Development of the Accounting System.

The West Orange Laboratory used the same accounting system that was set up at Menlo Park and Newark. This system reflects Edison's lack of concern with bookkeeping

and his reliance on other people, such as Insull, to organize the day-to-day financing of the lab. The general financial affairs of the laboratory are recorded in general ledgers, which contain accounts payable and receivable, and profit and loss accounts. The daily transactions of the lab are recorded in day books and journals. The raw materials which provide information for these account books are bills, receipts, and vouchers.

We have found a long run of general ledgers which provide a solid core of accounting records from 1887-1919. Our central focus will be on the "experimental" accounts because these record the cost of research and show to whom it was billed. We will first examine and correlate the "experimental" accounts, also looking,if neccessary, at the general ledgers of the companies billed. We can then work backwards from the ledgers to day books and journals and get a clearer, more exact, picture of the type of work done by the lab. Working forwards from the general ledgers we can find out who was billed for the work and how unbilled and overhead costs were assigned to the "experimental" line of profit and loss accounts.

One priority of our research plan will be to work backwards from the general ledgers into Edison "personal" and then Edison "private" to find out where funds came from to balance the experimental account. By reconstructing these transactions and evaluating the profit and loss

accounts of the larger organization we will uncover a major source of the lab's finance. We plan to follow the costs of major experimental projects like the storage battery 1900-1912, and the rubber experiments of the 1920s, and find out how exactly costs were determined, to whom billed, and the sources of funds which balanced these accounts in the general ledgers.

Another goal of our research in 1985 is to document and analyze the increasing sophistication of costing experimental work. In the beginning this was done on the basis of labor cost alone, but over time considerations of overhead lead to a more exact and sophisticated system. In the nineteenth century Edison knew that he had the personal resources to support years of unprofitable experimentation and didn't let his ignorance about the cost deter him. This situation changes when the Edison companies begin to move towards large scale manufacturing. Failure to properly estimate cost had fatal consequences in twentieth century manufacturing. Inflation increased costs rapidly; and in the case of motion pictures, costs quickly outstripped profits. One view of this situation is given in an overview of the lab's operations written in 1919: "we were forced to discontinue the Motion Picture business largely on account of costs, faulty at best and never correctly analyzed from a manufacturing point of view." (1919 Doc. file, TAE Inc Organization.)

In the twentieth century more financial controls were placed on the lab by the manufacturing companies. Edison was working with a tighter budget and his ungrateful customers wanted a more detailed analysis of the cost of the work done for them. This involved a move to a costing system that better suited the needs of manufacturing. The advent of mass production demanded more exact cost analysis. For example, the manufacture of phonograph wax blanks meant that experimental and testing costs were distributed over 1 million units in 1919. The decision to increase production to 2 million units meant that costs had to be estimated very exactly per disc. Edison's business managers were measuring costs per disc in units of ten thousandths of a cent!(Laboratory Blue Book, Memo of John Constable, 27 August 1919.) Like Edison's managers, we too are concerned with finding the cost of experiments, and it remains to be seen if we have better luck than they did in getting the numbers out of the laboratory's accounts.

The bookkeeping procedures that Edison inherited from Menlo Park and Newark were based on a mercantile system of accounts which is focused towards outside transactions. This system suited the business dealings of Edison which involved many different outside suppliers and customers. The general ledger system allows for flexibility in billing and new accounts can be added or amended easily. The strategy of contract research for many customers meant that

Edison needed an accounting system of open architecture--changes needed to be made on a continual basis. But when the Edison companies moved to a more rational structure beginning in 1911, the accounts system also had to change. The major need was for a more precise method of internal billing between divisions, which would replace the haphazard and informal procedures of the first decade of the lab. The system had to be focused toward the internal transactions which begin to dominate the accounts of the lab.

The increased size and structure of TAE Inc. inevitably led to the creation of many more documents. Communications between lab and manufacturing divisions, and divisions with the central administration, became more formal and travelled along established channels. The annual and monthly reports of the division managers will be an important summary of the activities of the divsions and their relations with the laboratory. The minutes of several key committees, such as the laboratory executive committee, will provide valuable insights into the operation of the lab. The development of "R&D by committee" naturally involved many forms, minutes, reports, and the other paraphernalia of bureaucratic control. Edison's hand-written notes on scraps of paper were replaced by shop orders, product improvement forms and the reports of the product engineer (Form 1217)--which contain

a great deal more information and are easier to comprehend. The weight of the bureaucracy bore heavily on Edison's laboratory work force, but it could end up to be a godsend for us if we can locate some of the documents generated. One source could be the reserve records microfilm mentioned in Mr. DeGraaf's report.

The development of Edison's accounting system involved the creation of separate records like purchase and shop orders, and along with vouchers and lists of disbursements, they appear in the accounts records in great numbers around 1900. Edison's bookkeepers recorded more information and it is placed on a separate document, thus freeing space in the day books and journals where this information was kept in the 1870s and 1880s. The problem for us is to locate the shop orders and vouchers and then assign them to accounts. These type of records are probably all in vault 33, but the enormous number of documents generated in this fashion makes it highly unlikely that enough will be recovered to make up long runs of information. What we can do is to use these kind of documents to provide a detailed glimspse into the day-to-day activities of the lab.

The formation of TAE Inc. did not bring a sudden change in accounting practices for an examination of the post 1911 accounts indicate that the change was gradual. A rational corporate accounting system probably did not

emerge until 1916 when a policy was begun to standardize the accounting practices of different TAE divisions. In 1916 the auditing process was standardized and standard general ledger accounts were set up for all TAE interests.

Role of the Laboratory in TAE Inc.

The creation of TAE Incorporated in 1911 grouped several Edison enterprises around the National Phonograph Company. Each line of business: phonograph, primary battery, motion pictures, Bates Manufacturing and chemicals was maintained in a separate division. There were still several enterprises owned or managed by Edison which were outside the new corporate structure, such as the Storage Battery Company and the Portland Cement Company. These were all potentially important customers for the services of the lab, and along with the private research projects of Thomas Edison, their business had to be incorporated into the accounting system. The laboratory was still centrally operated and served the whole of the Edison interests, both inside and outside TAE Inc.

The Edison laboratory of the 1880s and 1890s had provided the leadership of the company through its development of new technology. The considerations of marketing and manufacturing had been tailored to the technology being developed. The story of the lab covers the transition of the laboratory as the center of the stage

of Edison's activities to the point where it is split between supporting the manufacturing interests on one hand and the private laboratory of its founder on the other.

The new company formed in 1911 comprised of sales divisions organized by product and managed by a central administration. This was probably done to obtain increased efficiency by centralizing the administrative and purchasing services. The process of rationalization spread to other services like auditing and legal and continued up until the mid 1920s. Initially divisions were under the control of the central management but over time the divisions grew larger and more autonomous and by 1917 they enjoyed a great deal of independence. One document talked about the division structure like the federal government: the central administration was the federal government and the division managers governed the states.(Cylinder Record Division Blue Book, letter of division manager, 21 April 1917.) In 1917 each division had a manufacturing, sales, and engineering arm. This reflects a new management policy that divisions should stand by themselves. The division was operated as a profit-making enterprise and the division managers were gradually given the financial control to do this.

The laboratory billed each division for the work done on its behalf. This involved the creation of purchase orders for work ordered and shop orders for the work

carried out by the lab. The shop orders gave an idea of the work of the lab but we know that initially they are of a very general nature: labor and supplies are billed on separate orders. This made it difficult for managers to keep track of R&D expenditures.

The laboratory created by Edison in 1887 did not fit the needs of a large corporate structure that was primarily concerned with maintaining market share in an established group of products. The primary goal of the divisions was in manufacturing and selling existing lines. The work of the lab, as envisaged by Edison, was to develop completely new products. The central lab that had been the moving force of the Edison companies in the nineteenth century assumed a different role in the twentieth. The pressing concerns of making and selling products drew the laboratory more into supporting the manufacturing effort. Testing, quality control and production engineering had always been a part of the lab's work, for we can see these functions in the very early days of the phonograph company. Yet as time went by and the Edison divisions found themselves in a more competitive market, the imperative to provide an engineering support for the manufacturing branch grew more powerful.

Much of the work of the laboratory was consolidated into central departments after the formation of TAE Inc. Functions like drafting and pattern-making services were

standardized and reestablished in separate service departments, and by 1916 they served not only the product divisions but also the experimental work of Edison. The latter had become increasingly separated from the engineering services of the lab at this time. The division of the R&D effort between Edison and the laboratory engineering department was formalized with the creation of the product engineer.

The product engineer was a specialist who devoted his time to a single product, such as disc phonographs or motion pictures. The product engineer was expected to remain in close contact with the manufacturing and sales departments of his product, and initially this was the rationale behind the creation of the job. A memo of 1917 specified the duties of the product engineer in: experimental, development, manufacture, and sales. The emphasis at first, however, was on the latter two categories, and especially stressed was the engineer's duty "to keep your product one jump ahead of the sales requirements."(Lab Blue Book, memo of 11 September 1917.)

Initially the product engineer was to have a foot in both camps; he carried out experimental and development work to improve the product or to create new ones, at the same time he kept a close watch on problems in manufacture and feedback coming from sales. All his work was billed to the relevant divison managers, and he was supervised by the

chief engineer who ran the engineering service of the laboratory.

Over time we believe that the manufacturing arm of Edison industries began to exert more financial and management control over the work of the lab, and this is especially clear in the development of the product engineer. The divison managers 'considered the work of the product engineer vital to their success in the market place and naturally stressed the sales and manufacturing parts of his job over the experimental and development duties. We have found some significant correspondence in which division managers argue for complete control over their product engineers. A letter from the division manager of primary batteries to C.H.Wilson, vice president of TAE Inc., in 1918 included the following: "the foundation stone of our success is the engineering division...it must be reorganized...The development (product) engineer must be placed under my jurisdiction and I must govern his research and development activities and control expenditures. He is working exclusively on articles whose sales I control." (Primary Battery Division Blue Book, memo of 28 June 1918.)

The control exercised by division managers was primarily financial: they wanted to know how much of their money was being spent, and on what. By 1918 the division managers had achieved financial control over their product engineers, and by doing this had also restricted the purely

experimental work done by the engineers. They paid for the engineer's salary and the overhead for running his lab in their operating premises. A memo sent from John Constable (the head of the engineering service of the lab) indicates that the division manager, through his manufacturing committee, had close control over the direction and costs of development work carried out on his product by the product engineer.(Lab Blue Book, 21 March 1918.) The manufacturing committee was chaired by the division manager and comprised of several representatives of the manufacturing division (management, planning and production), and the product engineer. It is clear from the documents we have found that "R&D by committee" put the important decisions into the hands of managers rather than engineers.

The structure of the laboratory changed in parallel with changes in corporate structure. The work of the lab became increasingly divided between production engineering on one hand and research and development on the other. In addition, the growing emphasis on production engineering resulted in the creation of satellite laboratories in manufacturing sites.

The primary use of these separated labs was quality control and testing. This was especially important in phonograph and storage battery manufacture, where a rapid response was needed to demands coming from the market place

and problems in quality control. Testing and quality control played an important part in the successful manufacture and marketing of the product. This point was not wasted on the top management of the Edison concern nor on its testing workers, one of whom stated that " the importance of the work here, as related to the marketing of the product, is to my mind unquestionable." (Blue Books, Employment Ratings, 1917-1918, Storage Battery Test dept.Memo of R.C. Mitchell, head of research dept. Edison Storage Battery Co.) The functions of testing and quality control had to be close to the point of manufacturing to be effective. Separate test departments were quickly set up in storage batteries operations. A chemical lab was established at the Silver Lake site to ensure better quality control for the manufacture of raw materials for phonographs. This process eventually led to a number of competing laboratories within TAE Inc. which had the facilities to do the same kind of work. We intend to find out more about the relationship of the main laboratory with its satellite labs.

The central issue between the laboratory and the manufacturing divisions was who was going to decide, and pay for, experimental and development work. For much of the work of the laboratory, billing, and in turn financing, was not much of a problem. Testing, tool making, pattern making, drafting and other engineering support of the

manufacturing branch were clearly identified and accounted for. It was the more general basic research that was harder to finance. This involved high risk research, perhaps to develop a totally new product or to find out new ways of making a better product. It demanded a long-term commitment of funds and resources, and in a tighter corporate structure in which division managers had to watch their costs very closely, it was sometimes hard to justify the expense of experimental work.

The changing structure of the laboratory after 1911 created a division between the short-term engineering services and the long-term experimental and development work carried out by the lab. Edison carried out basic research that did not have an immediate payoff and division managers were often reluctant to support this. At question was the relationship between expenditures on R&D work and the benefits that accrued to the manufacturing divisions. According to division managers, the benefits were frequently out of proportion to the costs.

Edison often carried out research under blanket orders which were different from shop and purchase orders. Open "blanket" orders, like those with the phonograph works, gave Edison the freedom to continue R&D without need to refer to the division's financial or technological needs. These open orders appear to have caused problems in the 1917-1919 period, and by 1918 division managers were

refusing to pay for Edison's experiments on new types of storage batteries and phonographs. Consequently, the development of new primary batteries and dictating phonographs was supported by the financial reserves of the laboratory. It was estimated that unbilled experimental work was running at $3,500 a month in 1920 and this sum was supported through Edison's personal finances and the capital of the laboratory.

The financial executives were alarmed at the steep cost of R&D; a letter written by S.B. Mambert of 21 May 1918 commented that from 1917-1918 about $100,000 had been spent on experiments carried out by the lab without proper authorization from the central administration.(1918 Doc. file, TAE Inc Organization.) The lowest estimate for the monthly expenditure on R&D is $10,000 in 1919 and the highest is $29,000 in 1920. Statistics produced for the financial executive (1919,1920 Doc. file, TAE Inc Organization) indicate that from January to August 1919 $72,698 worth of experiments were billed to the divisions and $13,527 was carried by the lab.

The increased financial stringency brought on by the high price of capital in the early 1920s, accelerated by a postwar depression, led to important changes both in the structure and the financing of the lab. Changing economic conditions meant that the Edison organization had "to get the most out of every dollar we spend", especially in

experimental work.(1920 Doc. file,TAE Inc. Organization, financial statement.) Another pressing consideration was to develop the system of financing the laboratory which would support experimental work and at the same time impose financial discipline on experimental expenditures. A measure of the status of the lab in 1920 is revealed in the following comments made by Edison's secretary, R.W. Kellow,: "the Laboratory has been quite popularly conceived to be a place where sundry mysterious experiments are carried on by Mr. Edison and charged to other Edison functions arbitrarily without any corresponding advantage to them." (Doc. File, WO Lab Financial.)

A scheme to rationalize the laboratory was undertaken in 1920. The work of each department of the lab was divided into four main classes:

A self-supporting engineering work.

B general engineering and research.

C Edison personal activities.

D daily engineering support of the phonograph works.

The self-supporting engineering work included work carried out by the machine shop, pattern shop, and photographic department. Class D work was carried out by the Edison Phonograph Engineering department. The experimental and development work was classified in classes B and C, the former being directed by the chief engineer at

the request of the divisions and the latter was under the personal direction of Thomas Edison. Class C work was further divided into three departments: Music Room, Chemical Laboratory, and Experimental.(1920 Doc. file, TAE Inc Organization.)

The major distinction betwen clases A & D and B & C is that the former is short-term work in which the product can be clearly identified and billed, such as the work of the machine shop. Class C work was personally initiated by Edison and carried out by him, often without the knowledge, approval, or financial support of the relevant division.

The restructuring of the lab operations in 1920 was done to give management tighter control over the operations of this central facility and to ease the cost of financing basic R&D. The plan was to make a profit with the first two engineering classes and divert this profit to a laboratory reserve. Also the overhead on specific jobs was to be enlarged to cover some of the basic costs of the central laboratory. In 1920 several options were being considered to support the basic long-term R&D carried out by Edison himself. One plan was to levy a fixed charge from those divisions expected to gain from the experiments carried out by Edison. Another option was for the Board of Directors to appropriate a large sum and for the Lab to charge against this experimental reserve. (1920 Doc. file, Financial and TAE Inc Organization.) This follows a policy

of making the organization itself support some of the experimental work of Edison. According to an accounting chart of 1916 experimental costs were deducted from profit and loss as loss. This means that some of the burden of R&D was carried by the organization as a whole. The development and rationale of this form of support will be a subject of further investigation.

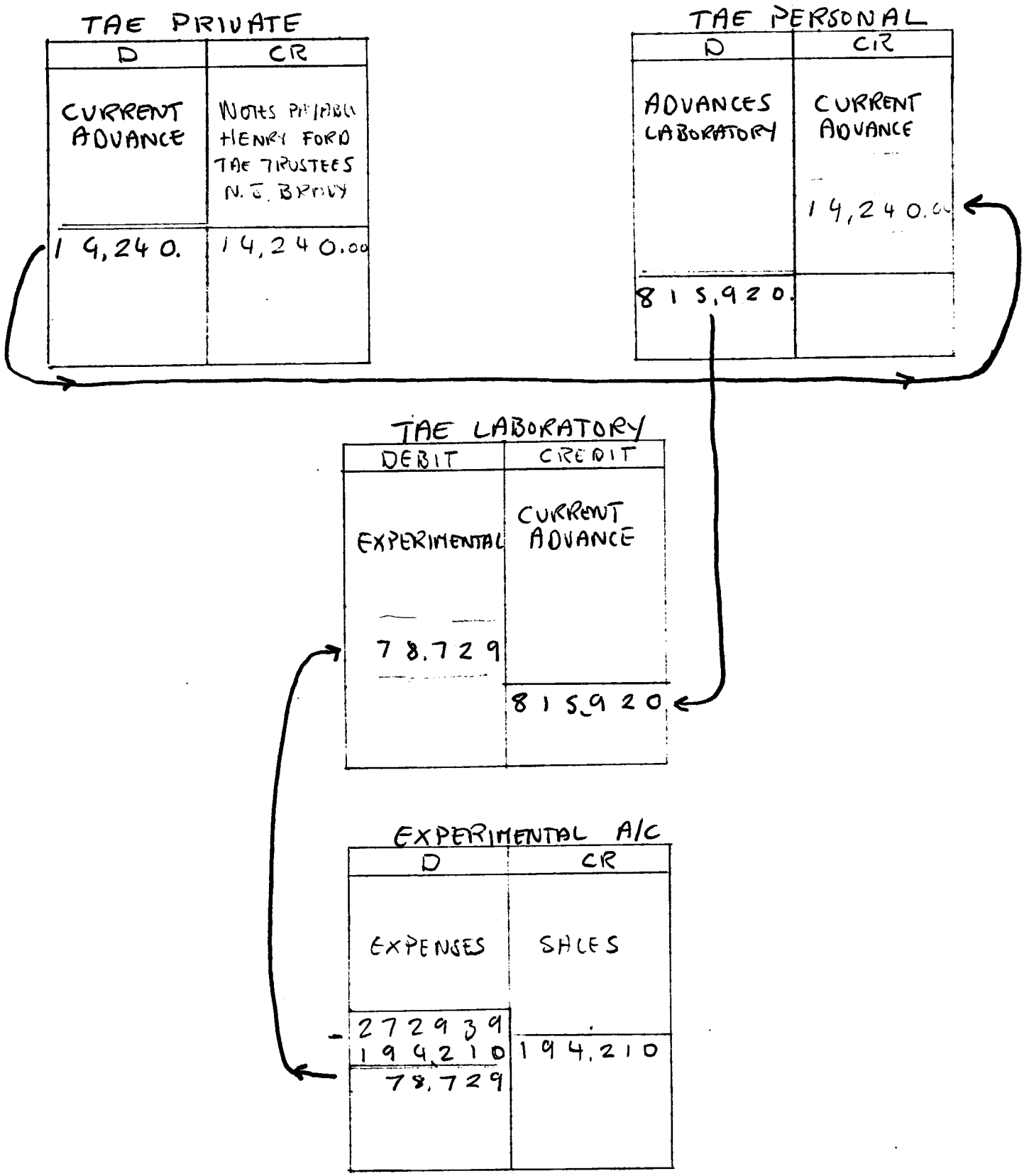
The new system introduced in the 1920s gives a much more formal and closed structure to laboratory finance. One standardized shop order system was used by which the managers of the lab could bill work ranging from experimenting, research and supervison to the more easily billed activities of tool making, drafting and blueprinting. The laboratory was described as the "Experimental and Development Engineering Service" and is classified as a division of TAE Inc. Instead of being an integral part of the lab, the research activity of Thomas Edison was a small and seperate part of the laboratory. His work is classified under "The Laboratory of Thomas A Edison, Personal." We will investigate the budget and billing procedures used at the lab to establish the exact relationship between its parts. We expect to find a division of function and finance between the "Experimental and Development" and the "Engineering Service" of TAE Inc.

By the 1920s it is the manufacturing divisions which provided direction for the lab and Edison. One major theme

which we will attempt to follow is when and how did Edison relinquish leadership of the company through the lab. In 1908 we know that Edison was still taking a leadership role in the lab, overseeing several crucial research projects. By 1916 there is reason to conclude that he was drawing away from leading the company from his laboratory and occupying himself with more personal research endeavours. A memo sent by Edison's secretary in 1919 informed company executives that "communications about laboratory operations should be sent to J.P. Constable, Division Manager of the Laboratory" and not to Edison. (1920 Doc. file, TAE Inc Organization.) At what point did the majority of the lab's work originate not from Edison personally, but from the hierarchy of professional managers? The laboratory accounts will give us important information to assess the changing situation.

CHART 1

General Ledger #15, 1908-1916



The Laboratory Workforce

The examination of the labor records in the accounts series will not only furnish us with important information about the workforce, it will also help us understand some of the larger issues we have addressed in the chapter outline. The composition and size of the workforce at the lab reflects the changing nature of R&D and the role of the lab in the Edison companies.

The lab built by Edison in 1887 was to continue the work his previous laboratories in Newark and Menlo Park--but on a much larger scale. It was set up much like the early labs; it was flexible, informal and unstructured. There was little specialization or gradation of work in the Edison lab of 1887. Like his other laboratories it comprised (as far as we know) of Edison, in sole charge; his lieutenants like Batchelor who assumed a supervisory role; a small band of experimenters, like the Ott brothers; a large number of laborers with varying levels of skills and the ubiquitous "boys" who played an important role in the everyday activities of the lab.

In 1887 there were few college trained experimenters working in the lab. We know that the development of electrical technology brought a need for skilled and specialized workers and college trained men joined the lab at Menlo Park. One of our projects for 1985 will be to

trace the increase in highly educated and technically skilled workers in the laboratory. Although we will concentrate our search in the West Orange archives, there are several secondary sources, especially those written by ex-lab employees, which will be used.

In the early days of the lab most of the workforce was concentrated in the machine shop of Building 5. The lab did in fact operate as a manufacturing extension of the phonograph works and this seems to have continued for some time onwards. The physical set-up of the lab represented an initial division of function. Building 1 contained electrical test equipment and a small skilled staff. Building 2 was the chemical lab where Edison and a few helpers conducted experiments. The pattern shop was established in Building 3 and Building 4 contained a metallurgical laboratory and a blacksmith's shop.

There does not appear to have been a formal structure to the lab and men were moved about a great deal. The loose organization allowed Edison maximum flexibility to shift labor around as he needed it. A payroll for the Machine shop in 1889 has the notation on it from Edison "give me one(man)for....."(1889 Doc. file, WO Lab employees.) The payroll records show that the workforce was constantly being altered to meet the changing experimental and production loads. The low skill level of his workers and the lack of highly specialized functions

gave Edison the flexibility needed to staff his "R&D for hire strategy" 1887-1891.

The records show that the laboratory workers are hired and fired on a daily basis. Edison was not averse to closing down parts of his experimental activities when they did not offer adequate return. This meant firing experimenters as well as laborers. Several memos in 1889 and 1890 attest to the closure of the chemical room at the West Orange lab.(Doc. file, WO Lab, Personnel.) This involved the firing of a Dr Wuntz (an indication of the growing educational and scientific attainment of some of Edison's employees), Reginald Fessenden and other experimenters. Some of the skilled workforce of the chemical department was moved to the Ore milling operation. The reason for closing down the chemical room was because Edison perceived that its work was not bringing profitable results. His memo about Wuntz expressed the sentiment that "I can't make his work pay me"(1889 Doc. file, WO Lab Employees.)

We have good payroll records for short periods of time and from these we can estimate the number of workers and the kinds of jobs they were doing at one fixed point in time. There appears to be a broad range of different wage rates for all types of employees under Edison's control. Experimenters wages move from $2 to $8 per week in the nineteenth century, and there are many different rates used

to compile the wages of the machine shop employees. The complex wage structure at WO indicates a growing specialization of task and the use of wage increases as incentives. A memo written by Edison to Batchelor in 1888 lists some workers and instructs Batchelor to raise their wages for "these are good men." Included in this list of fast-rising Edison employees are Fred Ott and Jonas Aylesworth.(Doc file, WO Lab General.)

Edison's employees tended to be faithful and stayed with him for long periods of time. These men were often promoted through the system and assumed more and more powerful, and perhaps managerial, positions within the company. We can examine the rise of many of Edison's lieutenants from their own recollections. We also have found some good labor records which show changing wage rates and which can be used to reconstruct the careers of several key workers within the Edison organization. For example, we have found summaries of employee work histories which were used to compute pay raises. These show men joining the lab as unskilled workers, rising through the testing departments to finally managing research and development for a separate division.

Edison took complete control of the lab's activities in the early years. He decided on the direction of research and he gave his leading experimenters whole projects on which to work. The records of his important

lieutenants,like Batchelor,and their correspondence in the archives indicate that his chief experimenters enjoyed a great deal of autonomy. We will explore these sources of information to find out exactly how much leeway and decision making they were allowed in their projects. Each built up a specialization: Dickson with the movies, Aylesworth with phonograph chemistry,for example. We expect that their growing specialization enabled them to work with less supervision of their daily activities. How Edison supervised his chief lieutenants is surely the key to understanding the management of innovation at the lab.

The early records of the lab indicate that Edison kept a close watch on the activities of his lieutenants. When he was away from the lab he received reports from his chief experimenters every two or three days. This might indicate a tight control over their work. Other pieces of evidence indicate that the absence of Edison had an impact on the direction and pace of research. While he was away in 1889, a letter to his secretary A.O.Tate noted that everything was going on in a "hum drum kind of way" and expected that the lack of attention to experimental work would change when Edison returned from Europe to "take things in hand."(Doc. file, WO Lab General.) Edison's absences from the lab might provide a valuable test case to evaluate his leadership of experiments and the growing initiative of his lieutenants.

One important research goal we have is to follow the process of Edison as sole leader of the laboratory, and sole setter of laboratory research goals, to the time that professional manangement is in control of the experimental arm of the Edison interest. The control of the labor force is an important element in this analysis. Who assigns labor to specific jobs, and who determines the level of staffing for each project? Over time a layer of middle management is established in the lab--taking the place of the old "gang" system. We will look at the timing and origins of "R&D by committee" and describe its impact of the work of the lab.

Edison's control and treatment of the workforce is also going to be examined, considering his reputation as a poor labor manager. Edison always worked his men hard and there are plenty of pieces of evidence which attest to this. One report to Edison on the work of the lab mentions in 1888 that "the men are working night and day." An article in the Newark Leader of 8 September 1917 accused Edison of exploiting his workforce at the lab. It was alleged that he paid them lower rates than other comparable institutions, gave them less vacation time, and made them work a longer week. The only way to substantiate these charges would be to compare his labor rates with other laboratories. We will be looking at the newspaper articles and the management reports for the strike of 1903. We hope

to uncover the changing origins of the West Orange workforce and identify, wherever possible, the waves of immigrants who provided the unskilled and semi-skilled workforce. Our final report will give the flavour of work in the nineteenth and twentieth centuries, mentioning some common practices such as the January lay-offs.

The West Orange laboratory was in a process of constant change during its first twenty years of operation. A series of different projects and different strategies for R&D led to changes in the size and composition of the workforce. It also led to changes in the physical structure of the lab. Edison often built temporary structures for specific experiments which were later taken down. A tantalizing comment in the Edison Phonograph Monthly of August 1906 noted that several old frame buildings in the factory yard, "relics of the early days of the factory, or buildings formerly used for experimental purposes by Mr. Edison" were being torn down. Edison also changed the interiors of his buildings to suit new functions. We know, for example, that the demands of ore milling greatly changed the physical setup and personnel of the lab. Building 4 was set up to do mechanical testing of ore samples around 1890 but only remained in this function while ore milling was the center of Edison's attention. The Historic Structure Report indicates that Building 4 was used for phonograph, rubber, and consumer durable work.

Different projects could have decreased or increased the size of the lab. One direction of our research will be to chart the increasing size and diverse activities of the workforce of the lab. We hope to determine the size of the labor force at different times, and find out where they were working on different products. Charting the changing physical shape of the laboratory and the changing workforce will not be an easy task; the documentation is dispersed and hard to get out. We hope that by mid summer we will have covered enough ground to begin pulling the numbers together. The photographs of the lab will provide very important evidence about what is being done and where.

This information will then be compared with what we already know about the changing pace of innovative activity at WO. There were periods of intense research activity and periods when most effort was placed on production and sales. Information about the size and dispersal of the workforce will be used to support evidence coming from other quarters, such as account records. We know from Edison's accountants that the period before the World War was characterized by concentration on research and development. After the War was over, it appears that the main emphasis turned to manufacturing and marketing perfected products.(1920 Doc. file, TAE Inc Organization, letter from financial executive to IRS, 1 October 1920.) One way of keeping track of these changes will be to

estimate the size and function of the workforce.

The total number of employees in the laboratory rose from about 40 in 1887 to 203 in 1920. In comparison with the situation in 1887, when about 4 or 5 men worked there, the chemical laboratory employed 11 men under the supervision of John Ott and remaining under Edison's personal control. The number of employees working in the pattern shop went from 2 in 1887 to 8 men and a foreman in 1920. Hand in hand with the growth of the lab is the increased structure of the lab's work and workforce. This period in U.S. economic history is the time when professionalization of skilled workers occurs, and we can follow and document the increasing specialization of the workforce. By 1920 the lab had 17 different hourly paid occupations and 30 different weekly paid occupations. This latter group included the old "experimenters" and "office boys" but also included chemical engineers, product engineers, and a catalogue librarian.

There are some very detailed "work in hand" accounts which give an exact report of the various research and engineering tasks being carried out by the lab, so we can show what the lab was doing at fixed points in time. We have already found excellent records for the periods: 1888-1890, 1908, 1912, 1916-1920. We plan to insert these descriptions of the lab's work at strategic points in the text. This will chronicle the changing types of work

carried out by the lab and the increase in its workload.

The laboratory went through a major structural change after the formation of TAE Inc. It was broken down into different departments, and the experimental work of Thomas Edison was structurally (and maybe physically) separated from the daily engineering work of the lab. By 1920 the laboratory consisted of the "Experimental and Development Engineering Service" which was headed by a chief engineer aided by an assistant who was also the foreman of the two floors of machine shops. The chief engineer was responsible for supervising all the experimental and development work carried out by the engineering service, which was separate from Edison's personal work. The engineering service was physically based on the third floor of the lab building although several of its departments, like pattern making and blueprint services, were situated in other buildings.

The division of function at the lab is a central part of our story; it marks the shift of leadership of R&D and begins the rationalization of the lab's organization which makes it a modern industrial research laboratory. The general R&D functions that had once been carried out by Edison and his assistants in the lab were taken over by product engineers and the engineering service. The labor records will provide important evidence in documenting and analyzing this shift. We will find out which lab

experimenters remained under the control of Edison and which ones were absorbed in the new corporate laboratory structure. The changing functions and specialization of lab workers will also provide clues to a changing structure of R&D. The physical layout of the lab will also give us some very important information about the structure of the lab and the affiliation of its various parts.

The re-organization of the lab in the first two decades of the twentieth century marked the creation of several new jobs which had a direct relation to the changing work of the laboratory. The new position of product engineer came from the increasing emphasis on production engineering which began after 1915. His job was to handle the production and marketing aspects of a product as well as research and development. The changing corporate strategies for R&D will be covered in the company organization sections, but where these men came from, what their changing duties were, and their subsequent rise in the organization forms an important part of our material on labor.

One reason for creating the position of product engineer was to try and control the work of production engineering. This had previously been in the hands of the works foreman who had often acted autonomously in making design and production changes. An informal, and at present anonymous, history of the lab written in 1919 noted that in

1914 "it was customary for each foreman, and sometimes production hands, to change processes, designs etc....there was no central development man, excepting Mr. Edison, who was rarely consulted." (1919 Doc. file, TAE Inc Organization.)

One goal of product engineers was to assist in the standardizing of production engineering. By 1919, the lab had turned full circle. Once the experimental arm of the heroic inventor, it was now a part of a corporate organization and its experimental engineers were expected to act like corporate employees. It appears, however, that the personality of the product engineer still played an important role in the direction of the lab's work. The origins and work habits of the product engineers are well worth finding and documenting; they are carrying out major R&D work in the laboratory of TAE Inc.

For example, several product engineers came out of the ranks of the sales force and we might find them leaning towards the goals of manufacturing. After spending some time as sales engineer for primary batteries, E.E.Hudson went on to become its product engineer. He rose to be division manager by 1916 and later defected to the Waterbury Battery Co. which gave Edison strong competition.(Primary Battery Division Blue Books.)

On the other hand, there were product engineers who kept close relationships with Edison. Although Edison was

fast withdrawing from active leadership of the lab in the 1920s, his influence was still present in those product engineers who had served their apprenticeship with him, such as disc record product engineer, W.W. Dinwiddie, who was his "mucker." Dinwiddie noted in a letter that although Edison was not devoting the same time and energy to developing the product he "still keeps in very close touch with the work and is constantly suggesting experiments." Dinwiddie concluded "I still lean very heavily on Mr. Edison for his vast experience in developing all the processes used in making records." (Disc Records Blue Books, letter of 21 April 1917.) Dinwiddie served as division manager of disc records but was removed from this position "to carry out research of a very special nature" in 1918. (Doc. file, TAE Inc Organization.) We will attempt to chronicle the rise of product engineers and show how some individuals exerted an influence on the conduct and strategies of R&D.

Research Performed by Leonard DeGraaf

In order to obtain additional information about the Edison Archives for the preparation of this report, we employed Leonard DeGraaf as a research consultant. Mr. DeGraaf is a member of the editorial staff of the Edison Papers and during the month of November 1984 he devoted approximately forty hours to research for our project. We asked Mr. DeGraaf to investigate two matters for us: first, we wanted him to identify and key groups of documents in the Edison Archives and second, we requested him to collect specific information about Edison inventions during the period of product diversification (1895-1911). We were very pleased that Mr. DeGraaf found a number of important and unusual groups of records and we intend to examine these materials in our next visit to the Archives. Because these record groups indicate the type of materials we plan to utilize in our research, we have included a list of them in this section of the report. As to the specific data found by Mr. DeGraaf, it too was very useful and we have incorporated it in the Narrative Outline and other sections of this report.

LIST OF DOCUMENTS OR GROUPS OF DOCUMENTS FOUND IN THE EDISON ARCHIVES

1. Vault 12--cab. 113(inner vault)--shelf 1. Photo album entitled "The Laboratory of TAE," dated 2/11/17. This album contains photographs of the various rooms and departments in the lab. Each photo has a caption which identifies the name or function of the room. There are also group photos of lab personnel. The dedication of this album states: ". . . it has been our endeavor to arrange a series of photographs which will visualize your great laboratory as it is organized today, show its vast resources and its purposes in connection with your varied interests."

2. Vault 12--cab. 114(inner vault)--shelf 9. Maps of Edison interests (property)--1915-1920.

3. Vault 12--cab. 113(inner vault)--shelf 1. Inventory and appraisal of machinery, tools and equipment in Bldgs. 3 and 5, dated 8/15/20, prepared by the New York Appraisal Co. There are floor plans in this report for the first and second floor machine shops, giving details of the layout of tools and machinery.

4. Vault 12-2 safe E4813 cat. 290 shelf 3. TAE--private--insurance Service Dept. Records. Monthly statements of payments of insurance premiums for W. Orange lab. This group was not found.

5. Vault 12-2. File folders of misc. drawings of floor plans, foundations, beam specifications, framework for Accumulator Bldg., dates: 12/14-1/15; 7/19, 4/14, 5/17. This group not found.

6. Vault 12--cab. 520--shelf 4. Series of ledger account books for the lab for the period 8/90-5/06.

7. Vault 12--cab. 518--shelf 3. Black ledger W. Orange lab--supplies, E4294, dated 11/24/87. 41 pp. This ledger contains lists of chemicals, supplies and equipment purchased for the lab. There are also a number of pages which discuss the layout of various rooms in the lab, the equipment which went into these rooms and brief notations describing each room. Pages 34-38 are pencil sketches of lab floor plans, page 35 is a sketch of the third floor of Bldg. 5. Most of this book is in Edison's hand.

8. Top of cab. 50783. Three large bound volumes of organizational charts for Edison companies and for the lab for the years 1916-1921. Included are charts for the Edison Storage

Battery Co., Cylinder Record Mfg. Div., TAE Inc., Edison Phonograph Works, Musical Phonograph Co., Wisconsin Cabinet & Panel Co., Primary Battery Co., and Bates Mfg. Co. There is also a chart for standard journal entries of TAE interests in manufacturing and selling.

9. Kellow File--safe E2547. This file is a series of envelopes which contain various legal documents, mostly for the post-1900 period. Included are tax records, deeds, leases, contracts between Edison, members of Edison's family and the Edison companies; as well as powers of attorney and patent assignments. This file can be easily checked because the contents of each envelope are clearly marked on the outside. Of particular interest is a report in envelope 13, sent to the New Jersey Dept. of Labor in 1918. This report states the main function of the lab, the number of male and female workers, the average number of weekly and daily operating hours and the average wages.

10. Reserve Records Microfilm. This is a collection Edison company records filmed during World War II. Most of these records were generated after Edison's death, but the following reels contain pre-1931 records which may be of interest: RR-67 (Minute Books-TAE Inc. vol 2, 3, 11/29/16 to 5/28/23); RR-68 (Minute Books-TAE Inc. vol 5, 9, 6/7/23 to 12/16/24 and 10/24/29 to 1/3/31); RR-69 (Minute Books-Edison Portland Cement Co. vol 1 to 6, 6/9/99 to 5/31/27); RR-70 (Minute Books-Edison Portland Cement Co., vol 6, 7, 6/27/27 to 11/16/31). These four reels are in the Papers Office.

11. The following laboratory notebooks, listed in chronological order, contain specific information about the West Orange lab: 87-06-00 (Charles Batchelor-machinery and tools ordered for new lab), 87-11-15 (TAE notes on dimensions of new lab and work plan), 87-12-07 (lab fitting up), 88-01-07, 88-01-14 (lab fitting up), 88-03-20.1 (employment applications), 91-01-14 (time reports for lab employees), 91-05-15 (time reports for lab employees), 12-07-05 (record of daily meal expenses), 12-10-10 (lab equipment), 12-11-04 (L. F. Ott-Chem lab account book), 13-02-27 (M. R. Hutchinson-status of experiments), 14-12-15 (notes by TAE after December fire about work in various departments and lab, see also loose sheets next to this notebook), 20-06-16 (capacity of water still), 21-02-03 (lab shop orders), 29-00-00.3 (list of equipment wanted).

12. The document file contains financial expense distribution breakdowns for the West Orange and Silver Lake labs for the years 1918 to 1921, in folders entitled "TAE Inc-Financial-Expense Distribution-Laboratory." For 1920 there is also a cost analysis for lab operations for October, November and December and a report by R. W. Kellow dated May 12

discussing the lab as part of the business organization. (West Orange Lab-Financial-Cost of Monthly Operations). See also TAE Inc.-Financial-Recapitulation sheets for August, 1918.

13. 1912 Document File. Report dated June 12, 1912 outlining the organization of TAE Inc. by division and discussing accounting procedures. (TAE Inc.-Organizations-positions and Departments). See also folder TAE Inc., part 2, for an organizational chart of TAE Inc. and a report outlining the responsibilities of officers within the organization.

14. In the 1918 Document file I found a letter from R. W. Kellow to J. P. Constable dated July 19, 1918, discussing the replacement of drawings of the drafting service dept. in the event of a fire. According to Kellow, the drawings were kept in a Mr. Olson's office on the third floor of the lab bldg.

15. C. H. Wilson Memos, Vault 12-cab. 514-shelf 2. Bound volume of memos from C. H. Wilson, general manager of TAE Inc. to various departments and divisions from October, 1916 to December, 1918.

Research in Spring and Summer of 1884

We intend to keep to the timetable and workplan established in our original proposal, with the following modifications:

1) Mindful of the staffing problems at E.N.H.S., we plan to stagger our research in 1985 to avoid an overload of the facilities at West Orange in the summer. We would rather pursue a steady research schedule than try to cram it all in during the summer months. In this way, we hope to:
a) carry out more research trips in the spring and fall of 1985.
b) concentrate on the secondary research in the spring, before we both arrive in West Orange in May/June.
c) perfect our data communication system before the summer and carry out sufficient testing at West Orange
d) change our plans for summer interns.
2) We are re-evaluating our plan to hire a full time summer intern. We have been able to contact some well-qualified candidates, but we are experiencing problems in attracting them to West Orange for a summer of low-pay archival work. We are concerned that much of our time this summer will be spent training and supervising a newcomer to the E.N.H.S. Consequently we are thinking about hiring experienced

people who have an "Edison expertise" for short periods of time. We will do this on a contract basis for specific projects and this will not only provide direction for their projects but also make it easier for us to incorporate their work in our study. Among the "experts" we have contacted and are considering: Joyce Bedi (Photographs), Anne Jordan (Chemical lab) and Jane Morley (Portland Cement).

3) One priority for the winter and spring is to invest in a data communications system and to upgrade and standardize our microcomputor hardware and software. We want to buy and install modem and model 100 communications and iron out the bugs before the spring. We plan to use model 100 portable computors in the archives in the spring and train our research assistant to use them and transmit data to the micros. We are also working on backup systems which will minimize the damage of a breakdown.

Tentative Plans with Rutgers University Press

In planning the historical study, we have begun to investigate the possibility of having it published. In particular, we are interested in having the study published by a university press and we were pleased to learn at our August 1984 meeting that both the contracting officer and the project officer felt that this would serve the best interests of the Park Service. We were all in agreement that a published version of the study would be a wonderful way to celebrate the centennial of the laboratory in November 1987.

Consequently, in November 1984 at the annual meeting of the Society for the History of Technology, we met with Karen Reeds, science editor for Rutgers University Press. She was extremely interested in our study since Rutgers will be publishing Robert Friedel and Paul Israel's history of the electric lamp, an earlier historical study funded by the Park Service. She emphasized, however, that publication would require a strong conceptual framework which analyzed Edison's work and placed him in a broad historical context. To provide Dr. Reeds with additional information, we sent her a copy of the technical proposal for the study. Dr. Reeds has since written us and requested that we submit a formal prospectus for the study.

We presently are planning to revise a portion of this report to serve as our prospectus. We expect to submit the prospectus to Rutgers University Press in January 1985, and Dr. Reeds has indicated that the press should be able to give us a decision by the early spring.

To assist in securing a tentative contract for publication, we believe it would be most helpful if the National Park Service could provide the following:

> One, information clarifying the matter of copyright and who may enter into contractual arrangements with the press concerning this study;
>
> Two, information concerning the possibility of the book being marketed and distributed at the Edison National Historic Site and through the Eastern National Monument Association; and
>
> Three, letters from the Regional Office and the Edison National Historic Site indicating approval for publication of the study by Rutgers Unversity Press.

We believe that if this information and these letters can be presented at the same time we submit our prospectus, then our chances for publication with Rutgers University Press will be greatly enhanced.