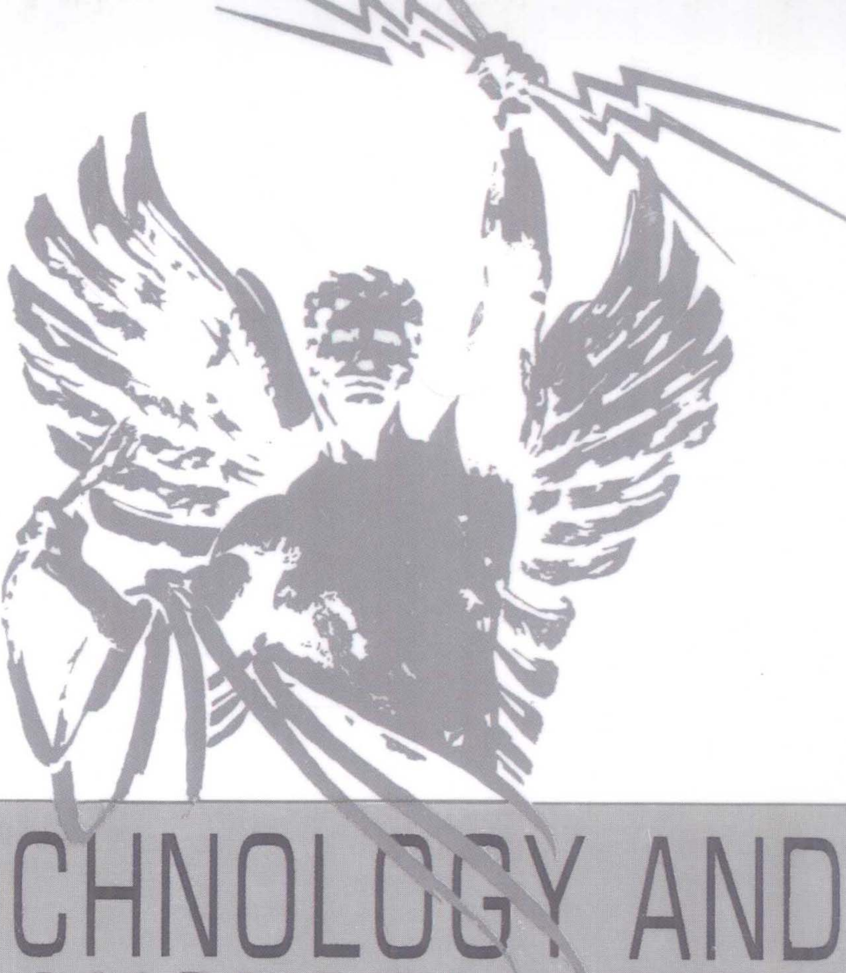

TECHNOLOGY AND TRANSFORMATION IN THE AMERICAN ELECTRIC UTILITY INDUSTRY

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Preface

This book deals with technological stagnation and how it contributes to industrial decline. Focusing on the electric utility industry, the treatise offers a novel interpretation for the industry's woes: it argues that a long and successful history of managing a conventional technology set the stage for the industry's deterioration in the late 1960s and 1970s. After improving steadily for decades, the technology that brought unequalled productivity growth to the industry appeared to stall, making it impossible to mitigate the difficult economic and regulatory assaults of the 1970s. Unfortunately, most managers did not recognize (or did not want to believe) the severity of technological problems, and they dealt instead with financial and public relations issues that appeared more controllable. Partly as a result, the industry found itself in the 1980s challenged by the prospects of deregulation and restructuring.

In offering this view of the industry's problems, this book differs markedly from other works in history or business policy. This difference should also make the book of interest to several audiences. To historians, for example, this study provides a contrasting perspective to those that examine undaunted technological progress as a central theme in American history. Americans appear to have taken as a fundamental belief – even a faith – that technology always improves and makes their standard of living among the world's highest. Though impossible to quantify its contribution precisely, technological innovation is credited for much of America's tremendous increase in productivity during the last century. Advances in power machinery, transportation, and communications – to name a few – have increased the amount and quality of goods and services enjoyed by people.[1] The natural assumption made after examining this orthodox history is that technological progress will continue unabated and that it will enable further material advances in the future. It was a view accepted by engineers, managers, the general public, and even historians.[2]

Of course, progress does not continue forever. But rarely is this aspect of technological development discussed in the scholarly literature. In the few instances in which limits to technical advance are examined, they serve as the backdrop against which technological revolutions and other improvements are viewed. For example, in his rightly acclaimed book, *The Origins of the Turbojet Revolution*,[3] Edward Constant considers how scientific knowledge can offer a means by which stagnation is avoided and progress continued. His concept of "presumptive anomaly" helps explain how engineers employed scientific analyses to "predict" the most rapid speed that could be attained by propeller-driven aircraft. The studies spurred attempts to invent a different propulsion system – the jet engine – for overcoming this limit.

But technologies do not always undergo conveniently timed revolutions. Besides the electric utility industry, the automotive, steel, petrochemical refining, and rubber industries have watched productivity growth rates decay partly because they lost their ability to produce incremental improvements in existing process technologies or to develop revolutionary technologies as substitutes.[4] Even the "high tech" telecommunications industry has reached a point where new transmission technologies offer few cost advantages for the entire network.[5] In other words, the nature of technological or business enterprises does not necessarily guarantee that innovations will occur when they are needed most. Put still another way, not all technological problems are soluble. While some academics who deal with economic history believe that a free and efficient market exists for technological "progress" and that technological choices can be explained simply in neoclassical market terms, this may not always be the case. Some industries may have to wait years for needed technical advances. Others may be radically transformed before they arrive.

For readers interested in the history of business strategy, this book has policy implications simply because it focuses on a socially and economically significant industry. The electric utility industry provides the most versatile and desirable form of energy available. Its inability to produce abundant electricity at decreasing unit costs (as it had before the late 1960s) affects millions of people who developed a lifestyle dependent on this energy source. Cheap and available electricity, in other words, contributed to the material way of life that helped make Americans the "people of plenty."[6] Electricity's loss of these features has therefore had a major impact on the way people live. And because electricity propels hundreds of industries, trends in the utility industry are reflected in others. When the industry's productivity declines, the entire economy feels the repercussions.

Perhaps more importantly, the book examines one of the central problems in managing technology, namely, the difficulty of projecting accurately the direction and magnitude of future technological change. Several studies have focused on technological discontinuities and on the revolutionary innovations that created them.[7] This book, however, probes the unfamiliar but equally critical phenomenon of technological stability. It should therefore have practical and theoretical significance, providing a basis for business policy implementation by extending discussions on the creation of technological knowledge. While suggesting that technological stagnation need not be a permanent condition and that "rejuvenation" may be possible, the book's greatest use may be to sensitize business managers to technological standstill and to ways it can be avoided.

Students of business management may discover other interesting discussions as well. For example, the book offers a case example of how professional traditions, culture, and history affected the way technically trained managers directed a large technology-based industry. When running electric utilities, engineers often made decisions based on considerations of technological sophistication rather than on "simple" financial concerns such as profitability. Economic considerations, in other words, did not always rank prominently in the minds of engineer-managers, whereas technological prowess (as evidenced by deployment of the biggest and most technically efficient equipment) sometimes did. In short, utility managers often pursued goals that differed from those sought by accountants and other people who had more traditional backgrounds in business and finance.

Finally, the book suggests some business "lessons" for restructuring a technology-based industry. In early stages of a technological enterprise, a novel set of problems commonly gives rise to a "manager-entrepreneur" who can exploit features of a new technology and "rationalize" or make order of an industry. The solution to one problem, however, often leads to others in the form of financial constraints, later to be solved by "financier-entrepreneurs."[8] But the recent period in which technological stagnation has occurred in the utility industry calls for new people – certainly not the same type of people who organized a growing and incrementally improving technological system. Rather, they must be managers who can rerationalize the industry by comprehending technological barriers, social concerns, political realities, economic forces, and – perhaps most importantly – their own history.

* * *

My ideas about the technology employed in the electric utility industry began developing in 1979, when I served as chair of a citizens' committee overseeing rate "reform" for the Gainesville, Florida, municipal power system. The utility had just completed construction of a new power plant, and now the customers had to start paying for it. The elected politicians recognized an unpopular issue when they saw one, but they also had the wisdom to seek public input into the decision-making process. In my position as committee chair, I needed to learn quickly about power technology and utility economics. Then I realized the need to forge a consensus among committee members and public activists, some of whom desired low rates for commercial and industrial customers (to encourage business activity) and others who wanted high rates for all customers (to discourage waste). We eventually succeeded in developing an "inverted" block rate structure and an experimental time-of-day rate that all felt was reasonable and equitable. In gaining this education, I need to thank the patient staff of the Gainesville Regional Utilities system and Barney L. Capehart, professor of industrial and systems engineering at the University of Florida. Besides helping me understand the business, Barney provided a wonderful example of how engineers can solve social problems without reverting to technological "fixes."

Virginia Polytechnic Institute and State University (Virginia Tech) served as the next breeding ground for ideas. Through grants offered by the university's Center for the Study of Science in Society and the Virginia Center for Coal and Energy Research, I had the opportunity to design novel rate structures with physicist Samuel P. Bowen and learn more about the utility industry. Other Virginia Tech colleagues who helped me in formulating ideas and who read portions of my manuscript included Arthur L. Donovan, Rachel Laudan, Harold C. Livesay, Gary L. Downey, Saifur Rahman, Marjorie J. Norton, and Albert E. Moyer, the last of whom often coached me on style and content as we jogged along Blacksburg's wooded running trails.

A happy and unexpected course of events next brought me to the Harvard Business School, where I served for two years as a research fellow with Richard S. Rosenbloom. Through Dick's special form of tutelage, I learned much about the business management of technology. I know this book would have taken a very different form had I not become sensitized to business issues, and I am grateful to Dick and several of his colleagues at the "B-School" who generously helped me. These people include Thomas K. McCraw (who first brought my name to the attention of others at the school), Alfred D. Chandler, Jr., Richard K. Vietor, David A. Garvin, Robert H. Hayes, Roger E. Bohn, George C. Lodge, E. Raymond Corey, Robert D. Cuff, Kenneth A. Merchant, and Leslie R. Porter (another running partner who offered an abundance of good ideas).

While in Boston, I received an invitation from Professor Earl R. Mac-

Cormac of Davidson College in North Carolina to participate in a conference concerning electric power technology and values. The meeting with Earl began a solid professional and personal relationship that has benefited both of us. We bounced around ideas and tested new concepts, often while bouncing around a rubber ball in the squash court. (Earl usually beat me!) I gratefully acknowledge his enthusiasm for my work and his careful reading of all too many versions of this manuscript.

Thanks are due to many other people at various institutions. They include Warren D. Devine (Oak Ridge Associated Universities); David R. Nevius (North American Electric Reliability Council); Thomas J. Grahame (Department of Energy); Ronald R. Kline, Anne C. Benson, and Joyce Bedi (Institute of Electrical and Electronic Engineers); Spencer W. Weart (American Institute of Physics); Sam H. Schurr (Electric Power Research Institute); David K. Smith (Middlebury College); Herman Koenig (Michigan State University); George Wise (General Electric Company); and the staff of the Edison Electric Institute Library in Washington, DC. Extremely useful comments and suggestions also came from some of the leading members of the history of technology community, such as Thomas P. Hughes, Eugene S. Ferguson, Edward W. Constant, II, and Alex Roland. At the same time, I owe much to Ronald J. Overmann and Margaret W. Rossiter of the National Science Foundation and David E. Wright of the National Endowment for the Humanities, who encouraged my efforts and helped pay for an academic year of pure research. I also gratefully appreciate the time and effort expended by the managers, engineers, and regulatory officials who talked with me and who offered valuable insights into the history and management of the utility industry. (See the Bibliographic Note.) These people provided the source material from which I wove together many of my arguments and conclusions.

Finally, I owe much to my parents, sister, and grandmother for their intellectual and emotional support throughout the years. As the first academic in the family, I probably posed an enigma to them, since I worked in a strange field that crossed disciplinary boundaries (history and management of technology) and that was undoubtedly difficult for them to explain to friends and relatives. (If I wanted to be a professor, why couldn't I work in economics or physics – fields that people can relate to?) And to my beautiful new bride, Margene (who turned out to be my greatest "discovery" when I was on research leave at Harvard), I offer my thanks for abundant patience and understanding as I pursued this project. With good, common sense, she ordered me to stop building a room in our basement and complete my manuscript. She also gave me the "space" and comfort I needed, especially when working on one of those especially troublesome paragraphs or chapters. To her and the rest of my family – my original and newly extended family – I dedicate this book.

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Contents

Introduction

In 1965, electric utility managers celebrated the eighty-third year of their industry's existence. No one held any "jubilee" festivities for this uneven anniversary, but signs of pride, confidence, and vitality could be seen everywhere: managers justifiably rejoiced as their power-generating technology recorded new heights in technical performance, contributing to the industry's unequalled productivity growth rate since the beginning of the century. They also congratulated themselves for managing a technology that supplied increasing amounts of electricity at declining unit prices, providing for higher standards of living during a period of general price inflation. Meanwhile, utility executives watched happily as investors bid up the share prices of their companies to new post-Depression highs, reflecting the view that previous trends in technology and business management would continue unabated.

By 1975, however, many of the same utility managers lamented their industry's condition. Instead of continued improvement, electric power technology appeared to have reached barriers that could not be breached. As a result, productivity gains disappeared, and the industry became susceptible to the same economic forces that disabled the overall economy. As the industry turned away from a pattern of declining unit costs, regulators abandoned their permissive role and became more activist, trying to represent cost-conscious consumers who ceased to view power technology as safe and benign. At the same time, utility managers encountered culture shock as they discovered that trends in electricity consumption had reversed themselves, and that "growth" no longer meant improved economic well-being for their companies or customers. Finally, investors forsook the electric utility industry as some firms approached uncomfortably close to bankruptcy. In short, the electric utility industry had been radically transformed in just ten years.

This book details the transformation of the electric utility industry. It focuses on the importance of technological progress in the industry's history and the business management principles that evolved to take advantage of improved hardware. But this book does not tell a success story. While providing a background glimpse of early accomplishments, it argues that the electric *utility* industry (which must be distinguished from the electrical equipment *manufacturing* industry) underwent a fundamental reorientation when the basic generating technology reached a pair of performance plateaus. Crippling the industry's productivity growth pattern, these consisted of barriers to thermal-efficiency improvements and to increases in scale economies. Experienced chiefly *before* the 1973 oil embargo, these limits contributed to the end of electricity's traditional features of cheapness and consistent availability. By concentrating on fundamental technological problems, this book therefore challenges the commonly held assertion that the industry's predicament stemmed *exclusively* from disruptions in energy supplies, financial market difficulties, environmentalism, inflation, and overzealous regulation.[1] Though not discounting these serious problems, this book simply argues that "traditional" studies do not paint a complete portrait. Inflation, for example, dogged the utility industry for decades, but it only became a heightened concern when manufacturers could no longer deliver new productivity-enhancing technology to mitigate it. In short, improving technology had always been a primary contributor to the industry's success and high productivity growth rate. When the technology reached apparent limits to improvement, it exacerbated an already decaying financial, economic, and regulatory situation.

To explain the causes of technological stagnation and decline in the electric utility industry, this book introduces the concept of "technological stasis." Stasis is the cessation of technical advances in an industrial process technology. Incremental improvements no longer are made, and the technology appears to have reached its limits. Stasis is not the same as what some people call technological "maturity," though it is related. A mature technology, according to some definitions, is one in which the basic design components of a process technology (or the products it creates) are well-defined. In the utility industry, for example, the design and successful use of steam turbines in the early 1900s set the agenda for further innovations.

Though "mature" as early as the 1920s or 1930s, power technology advanced in small, incremental steps for the next several decades. But during the 1960s and 1970s, barriers to improvement emerged in thermal efficiency and economies of scale. Now even the slow but steady progress ended, leading to industrial deterioration. Stasis therefore describes a condition that occurs in a technology that has already matured.

Stasis comprehends more than a hardware problem, however. It constitutes a technical condition that occurs within a social *system* of engineers, business managers, regulators, financiers, and the general public. Each set of participants (or "stakeholders" – people who have a direct interest in the operations of utilities) has different goals and agendas, and when they conflict, they can make a technology appear moribund. For the first half of the twentieth century, the engineer-managers of the equipment manufacturing firms and utilities developed technology that served all participants well. During the 1960s and 1970s, however, some players (utilities and manufacturers) tried unsuccessfully to speed up development of large-scale technology while others (consumers and regulators) began to distrust the actions of elitist technical managers. The resulting conflict exacerbated technical decay and seriously affected the industry's more obvious financial and regulatory woes. In short, this book uses the concept of technological stasis as a way to emphasize the social dimension of technical development. As such, the book offers a "sociotechnical" explanation for the recent decline of the electric utility industry. (See Appendix A for a more detailed discussion of stasis within the context of technology life-cycle models.)

As upsetting as it was, stasis did not occur throughout the world's electric utility systems. Rather, it remained an American phenomenon. Several factors account for this localization. For one, the United States constituted the world's largest market for power equipment – in 1969, it contained 43% of the noncommunist world's installed capacity – and it traditionally produced the greatest demand for new technology.[2] And because of an unusual form of competition between utilities (described in Chapter 5), American companies sought technology that continuously offered greater fuel efficiency and larger scale. If practical limits in technological advance were to be encountered, then they would show up first in the United States, where technically aggressive utility managers ordered large quantities of state-of-the-art equipment earlier than their counterparts in other countries.[3] In addition, the United States sported a decentralized and pluralistic utility industry consisting of hundreds of independent power companies, largely financed through free-market mechanisms and governed loosely by state and federal regulatory bodies. As a result, the American system could be affected by a variety of participants that contributed to the onset of stasis in a way that could not be easily duplicated in many other countries. For these reasons, the account that follows describes events occurring in the United States.

A few simple graphs will clarify the problem addressed in this book.

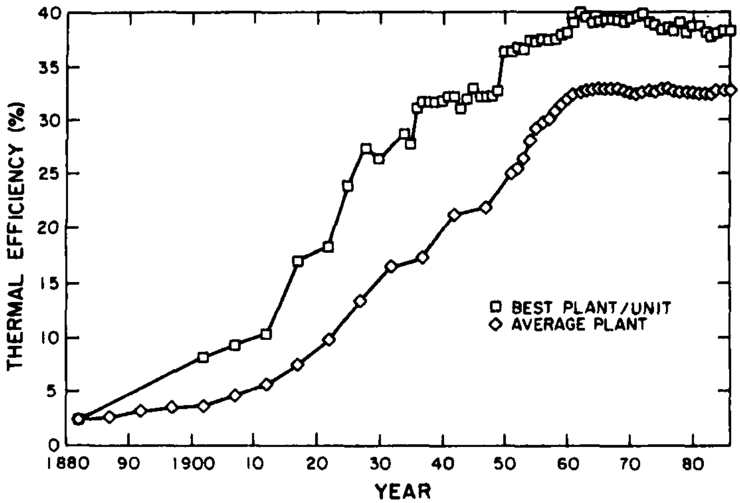

Figure 1. Thermal efficiency of generating units, 1880–1986. Thermal efficiency of power units increased gradually throughout the industry's history, plateauing in the 1960s. For the years after 1965, the data on the top curve relate to the most efficient *unit*. Before 1965, the data relate to the best plant – a combination of units. Data are from Federal Power Commission publications and annual reports of best thermal efficiency in *Power Engineering* magazine.

They also outline its basic themes about technological stasis. Consider, for instance, a graph of thermal efficiencies of power plants (Figure 1). Rising steadily throughout the first eighty years of the electric utility industry's history, the curve flattens out in the early 1960s and remains unimproved into the 1970s, showing that utilities could no longer economically coax more electricity out of a pound of coal or a barrel of oil.[4] Meanwhile, other graphs demonstrate that the capacity of new power units had also leveled off, this time in the 1970s (Figures 2, 3, and 4). Since the increasing output of units generally provided economies of scale that helped reduce unit costs, the flat curve in the 1970s meant bad news. Together, the end of thermal efficiency and scale improvements contributed to the reversal of a trend toward productivity improvements – improvements that previously made electric utilities the marvel of American industry.

These graphs do not necessarily prove a correlation between technological stagnation and industrial decay. But because they demonstrate that significant trends in the industry had begun to change well before 1973, they prompted an examination beyond the common interpretation of the electric utility industry's decline. That is, they encouraged a look beyond energy-supply distortions and economic, financial, and regulatory problems. This book is a result of that examination. Its first part, "Progress and Culture," provides the technical and social background for the utility indus-

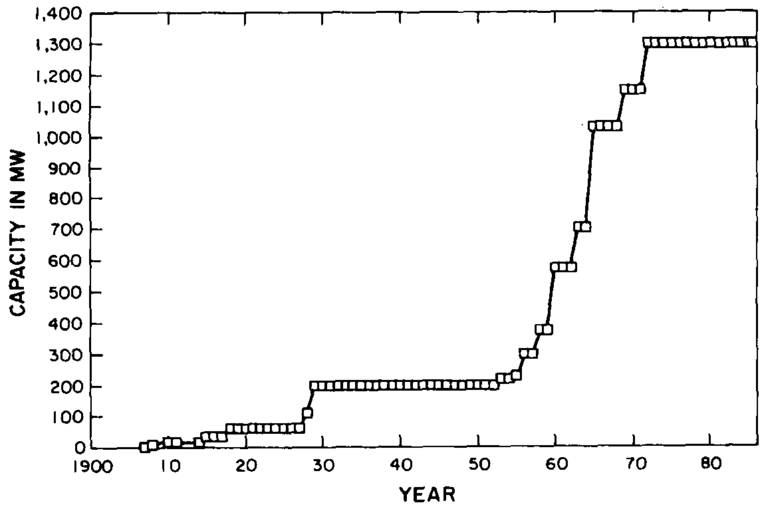

Figure 2. Maximum capacity of extant power units, 1900–86. The output of the largest steam-turbine generator grew dramatically in the period before the Great Depression and after World War II. A "unit" is defined as a "tandem-compound" or "cross-compound" turbine generator. Data are from U.S. Department of Energy, Generating Unit Reference File.

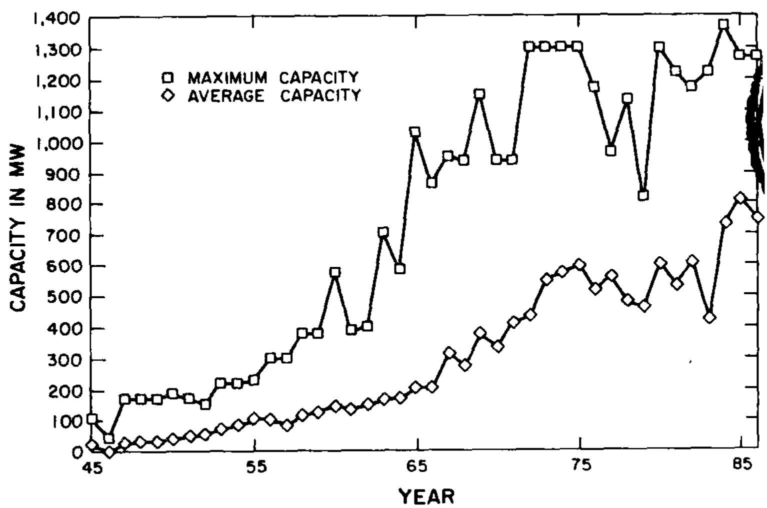

Figure 3. Maximum and average capacity of new units, 1945–86. The output of newly installed fossil-fueled and nuclear units increased until the early 1970s. Data are from U.S. Department of Energy, Generating Unit Reference File.