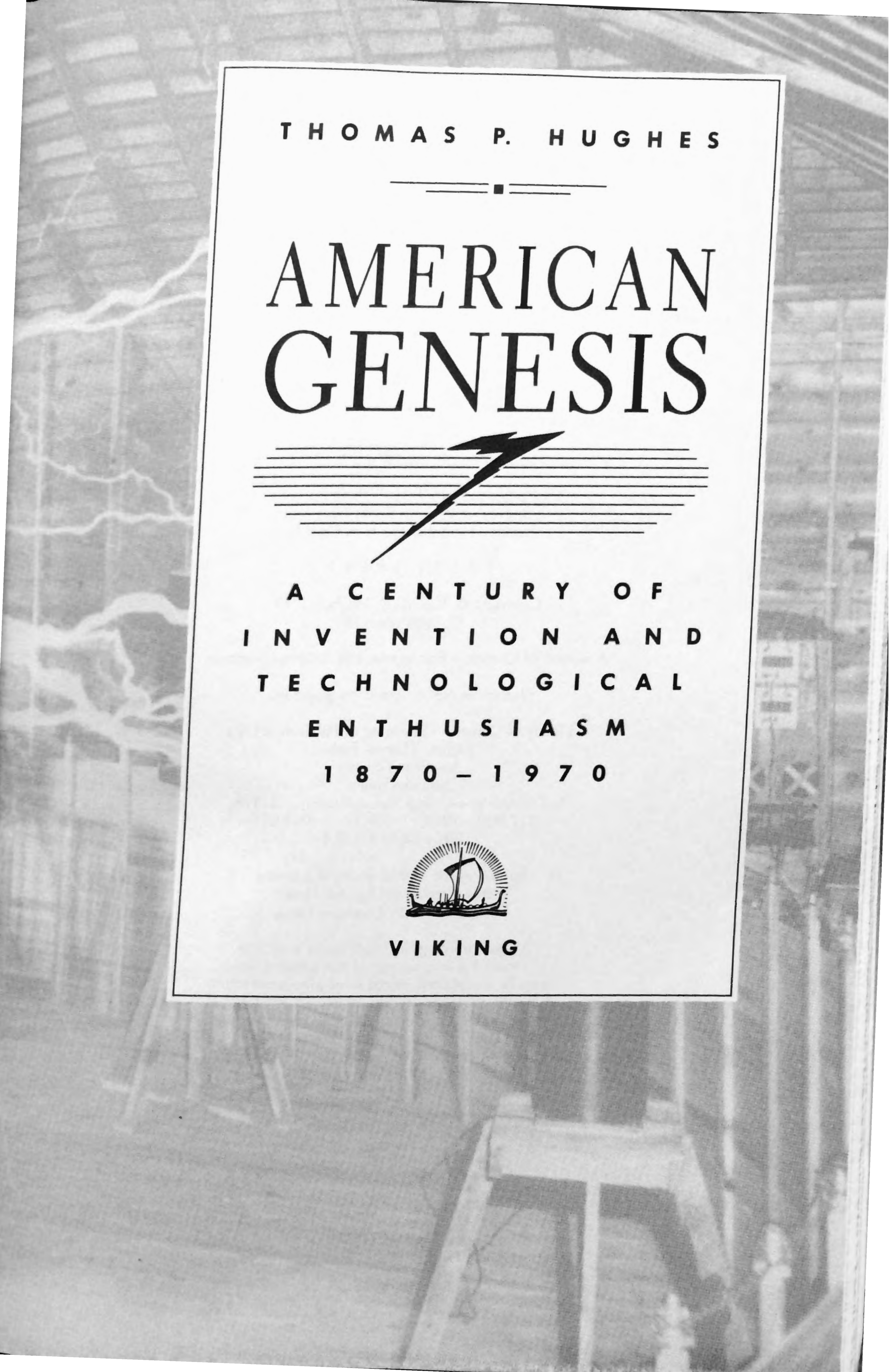

THOMAS P. HUGHES

AMERICAN GENESIS

A CENTURY OF INVENTION AND TECHNOLOGICAL ENTHUSIASM 1870–1970

VIKING

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INTRODUCTION

THE TECHNOLOGICAL TORRENT

This book is about an era of technological enthusiasm in the United States, an era now passing into history. Literary critic and historian Perry Miller provides a marvelous image of Americans exhilarated by the thrill of the technological transformation. They "flung themselves into the technological torrent, how they shouted with glee in the midst of the cataract, and cried to each other as they went headlong down the chute that here was their destiny. . . ."[1] By 1900 they had reached the promised land of the technological world, the world as artifact. In so doing they had acquired traits that have become characteristically American. A nation of machine makers and system builders, they became imbued with a drive for order, system, and control.

Most Americans, however, still see themselves primarily as a democratic people dedicated to the doctrine of free enterprise. They celebrate the founding fathers and argue that the business of America is business. They celebrate technological achievements, too, but they see these as fruits of free enterprise and democratic politics. They commonly assume that Americans are primarily dedicated to money making and business dealing. Americans rarely think of themselves principally as builders, a people whose most notable and character-forming achievement for almost three centuries has been to transform a wilderness into a building site.

A major reason that a nation of builders does not know itself is that most of the history it reads and hears instructs otherwise.

Perceptive foreigners are not so prone to sentimentalize America's founding fathers, frontiersmen, and business moguls. Other peoples have looked to the United States as the land of Thomas Edison, Henry Ford, the Tennessee Valley Authority, and the Manhattan Project. Foreigners have made the second discovery of America, not nature's nation but technology's nation. Foreigners have come to Philadelphia to see Independence Hall, but those who wish to understand the foundations of U.S. power have asked to see Pittsburgh when it was the steel capital of the world, Detroit when most automobiles were made there, the Tennessee Valley Authority when engineering was transforming a poverty-stricken valley into a thriving one, and New York City because its skyscrapers symbolized the technological power of the nation. The Manhattan Project, which produced the atom bomb, reinforced the belief throughout the world that America was the technological giant. Until the space-shuttle disasters and an embarrassing series of launching failures, the National Aeronautics and Space Administration symbolized America's technological creativity.

Americans rightly admire the founding fathers, who displayed extraordinary inventiveness as they conceived the Declaration of Independence and framed the Constitution, but Americans have embodied comparable, if not greater, inventiveness in the material constitution, the technological systems of the nation. Perhaps the myth that they are essentially a political and business people may be emended, if they reflect more on the technological enthusiasm and activity they have displayed throughout their history, but most obviously during the century from about 1870 to 1970. The enthusiasm reached its height during the middle decades of the period, then subsided, especially after World War II. This book, despite its emphasis on invention, development, and technological-system building, is not a history of technology, a work of specialization outside the mainstream of American history. To the contrary, it is mainstream American history, an exploration of the American nation involved in its most characteristic activity. Historians looking back a century from now on the sweep of American history may well decide that the century of technological enthusiasm was the most characteristic and impressively achieving century in the nation's history, an era comparable to the Renaissance in Italian history, the era of Louis XIV in France, or the Victorian period in British history. During the century after 1870, Americans created the modern technological nation; this was the American genesis.[2]

In popular accounts of technology, inventions of the late nineteenth century, such as the incandescent light, the radio, the airplane, and the gasoline-driven automobile, occupy center stage, but these inventions were embedded within technological systems. Such systems involve far more than the so-called hardware, devices, machines and processes, and the transportation, communication, and information networks that interconnect them. Such systems consist also of people and organizations. An electric light-and-power system, for instance, may involve generators, motors, transmission lines, utility companies, manufacturing enterprises, and banks. Even a regulatory body may be co-opted into the system. During the era of technological enthusiasm, the characteristic endeavor was inventing, developing, and organizing large technological systems—production, communication, and military.

The development of massive systems for producing and using automobiles and for generating and utilizing electric power, the making of telephone and wireless networks, and the organization of complex systems for making war reveal the creative drive of inventors, engineers, industrial scientists, managers, and entrepreneurs possessed of the system builder's instincts and mentality. The remarkably prolific inventors of the late nineteenth century, such as Edison, persuaded us that we were involved in a second creation of the world. The system builders, like Ford, led us to believe that we could rationally organize the second creation to serve our ends. Only after World War II did a handful of philosophers and publicists whom we now associate with a counterculture raise doubts about the rationality and controllability of a nation organized into massive military, production, and communication systems. Their doubts increased as the nation's technological pre-eminence waned.

If the nation, then, has been essentially a technological one characterized by a creative spirit manifesting itself in the building of a human-made world patterned by machines, megamachines, and systems, Americans need to fathom the depths of the technological society, to identify currents running more deeply than those conventionally associated with politics and economics. Indeed, many of the forces that Americans need to understand and control in order to shape their destiny, insofar as that is possible, are now not primarily natural or political but technological. We celebrate Charles Darwin for discerning patterns in the natural world; we do not yet sufficiently appreciate the importance of finding patterns in the human-made, or technological, world.[3] The purpose of the understanding is not simply to comprehend the impressively ordered, systematized, and controlled, but to exercise the civic responsibility of shaping those forces that in turn shape our lives so intimately, deeply, and lastingly.

A history stressing the technology of an era of technological enthusiasm should be no more celebratory than a history stressing the politics and business of a gilded age. The tendency of popular histories and of museum exhibits of technology uncritically to unfold a story of problem-free achievement unfortunately leaves readers and viewers naïve about the nature of technological change. When more histories of technology that take the critical stance of the best histories of politics are written, Americans will realize that not only their remarkable achievements but many of their deep and persistent problems arise, in the name of order, system, and control, from the mechanization and systematization of life and from the sacrifice of the organic and the spontaneous.

This history, then, argues that inventors, industrial scientists, engineers, and system builders have been the makers of modern America. The values of order, system, and control that they embedded in machines, devices, processes, and systems have become the values of modern technological culture. These values are embedded in the artifacts, or hardware. Modern inventors, engineers, industrial scientists, and system builders, those who flourished in the century of technological enthusiasm, concerned themselves with the production of goods and services and with preparations for, and the waging of, war. Their influence, however, did not end with these activities. Their numerous and enthusiastic supporters from many levels of society believed their methods and values applicable and beneficial when applied to such other realms of social activity as politics, business, architecture, and art.

This history, however, does not argue technological determinism. The creators of modern technology and the makers of the modern world expressed long-held human values and aspirations. Although the inventors, engineers, industrial scientists, and system builders created order, control, and system, in so doing they responded to a fundamental human longing for a world in which these characteristics prevail. They became the instruments of all those, including themselves, who were uneasy in a seemingly chaotic and purposeless world and who searched for compensatory order. In this sense, technology was, and is, socially constructed. As historian and social critic Lewis Mumford so eloquently insisted decades ago, technology is both a shaper of, and is shaped by, values.[4] It is value-laden.

Despite the drive for order, system, and control among the practitioners and enthusiasts of technology, the history of technology, like the history of politics, is complex and contradictory. Framers of constitutions have also tried to establish timeless, all-embracing systems of checks and balances. Neither they nor the designers of machines, devices, and processes have found the one best solution that pleases everyone and resists change. Contrary to popular myth, technology does not result from a series of searches for the "one best solution" to a problem. This book does not present technology as engineers are taught even today to think about it: as an absolutely one-best-way solution to problems. Instead, it presents practitioners of technology confronting insolvable issues, making mistakes, and causing controversies and failures. It shows the practitioners creating new problems as they solve old ones. This book intends to present the history of modern technology and society in all its vital, messy complexity.

Technology in the age of technological enthusiasm meant then, as now, different things to different people. The efforts of textbook writers notwithstanding, technology can be defined no more easily than politics. Rarely do we ask for a definition of politics. To ask for *the* definition of technology is to be equally innocent of complex reality. For many people, technology is goods and services to be consumed by the affluent, to be longed for by the poor. Others, such as inventors and engineers, see technology as the creation of the means of production for these goods and services. Further up the ladder of power and control, the great system builders, people like Ford, find consumingly interesting the organizing of the material world into great systems of production. Still others analyzing modern technology find rational method, efficiency, order, control, and system to be its essence. Taking into consideration the infinite aspects of technology, the best that I can do is to fall back on a general definition that covers much of the activity described in this book. Technology is the *effort* to organize the world for problem solving so that goods and services can be invented, developed, produced, and used.[5] The reader, however, can accept instead of a definition the historian's traditional approach of naming a subject and defining it by examples of his or her choice.

This book centers less on ideas and more on people, especially American inventors, engineers, system builders, architects, artists, and social critics. The organizations and movements of a modern culture, the institutional frameworks and symbolic structures in which inventors, system builders, and others acted are not, however, neglected. Among the organizations considered are the inventor's workshop, the industrial research laboratory, the business corporation, the government agency, and the military-industrial complex. Among the movements included are the international style in architecture; the Futurists, Constructivists, Dadaists, and Precisionists in art; scientific management and progressivism in production and politics; and the conservationist and counterculture advocates among the social critics. Throughout, references to modern culture refer to the devices, machines, processes, values, organizations, symbols, and forms expressing the order, system, and control of modern technology, and to the thought and behavior mediated by these and their expression.[6]

There is a pattern to this book analogous to that of the growth of the large technological systems about which it is written. The early chapters treat the invention of systems; the middle section deals with the spread of large systems; and the final chapters recount the emergence of a technological culture, of mammoth government systems, and counterculture reaction to systems. The remarkable achievements of independent inventors and industrial research opened and greatly shaped the age of technological enthusiasm. Philosopher Alfred North Whitehead believed that the invention of a method of invention was the greatest invention of the era.[7] Men and women assumed, as never before, that they had the power to create a world of their own design. Independent inventors experienced their heyday during a gilded era after the United States had emerged from the Civil War, and they forged a massive productive enterprise that ended up dominated by giant corporations. The historians Charles and Mary Beard called this the era of "the Second American Revolution," referring to the momentous technological, economic, political, and social changes.[8] Mumford saw it as the beginning of the modern, or neotechnic, era in the history of technology and society.[9] The inventions of the independents provided the foundations for the rise of the industrial giants, especially the newly burgeoning electrical industry. Edison, the Wizard of Menlo Park, became the heroic figure of the era, but there were other independent inventors, such as Elmer Sperry, who were impressively creative and more professional. The inventors continued to flourish as their country competed successfully with the great European powers for industrial supremacy. As World War I approached, the inventors became involved in inventing for the military. The military establishment funded their inventive activity and used their creations to develop new weapons, strategy, and tactics.

By the beginning of World War I, American inventors had helped to establish the United States as the most inventive of all nations. Only Germany, recently united, seemed a competitor for the title. Inspired by German achievements, leading American corporations such as General Electric, Du Pont, General Motors, and Bell Telephone also established industrial research laboratories. Industrial scientists widely criticized the haphazard methods of the independent inventors and claimed that the mantle of creativity had fallen onto their own shoulders. Yet there flowed from the industrial laboratories inventions with a conservative cast improvements rather than dramatic innovations. During World War I in the United States, the scientists, especially those with graduate training in physics, effectively challenged the role of the independent inventors as the source of improvements in military systems. The war-waging nations, dependent on their inventors and scientists, innovated and counterinnovated with the submarine, airplane, tank, and poison gas much as large corporations in peacetime contended for market advantages with innovations. Technology was capable of creating not only a new life-supporting world, but also a deadly environment.

The inventions and discoveries of the inventors and the industrial scientists became part of large systems of production that expanded impressively during the interwar years. These systems were the work of the system builders, whose creative drive surpassed in scope and magnitude that of the inventors. Designing a machine or a power-and-light system that functioned in an orderly, controllable, and predictable way delighted Edison the inventor; designing a technological system made up of machines, chemical and metallurgical processes, mines, manufacturing plants, railway lines, and sales organizations to function rationally and efficiently exhilarated Ford the system builder. The achievements of the system builders help us understand why their contemporaries believed not only that they could create a new world, but that they also knew how to order and control it. Frederick W. Taylor, father of scientific management, became famous, or notorious, throughout the industrial world for his techniques of order and control. Several chapters of this book focus on the American system builders.

American technology, especially its systems of production, fascinated European industrial managers, bureaucrats, social scientists, and social critics. Fordism and Taylorism for them symbolized the essence of the modern American achievement. Fordism and Taylorism spread throughout Europe, much as Japanese managerial techniques would into the United States after World War II. Lenin and other leaders of the Soviet Union displayed even greater enthusiasm for Fordism and Taylorism than the Americans had. When the Soviet Union embarked on a Five-Year Plan that specified mammoth regional systems of technology based on hydroelectric power and prodigiously rich stores of Siberian natural resources, it turned to American consulting engineers and industrial corporations for advice and equipment. The Soviets constructed entire industrial systems modeled on the steel works in Gary, Indiana, and hydroelectric projects on the Mississippi. In Weimar Germany after World War I, many persons believed that Taylor and Ford had the answer not only to production problems but to labor and social unrest as well. They labeled Ford's ideas white socialism, believing this to be an answer to Marxism. Many Europeans, especially Weimar Germans, decided that democracy, American technology, and a new European and modern culture could restore war-devastated Europe and create a good society. In the Soviet Union, Lenin predicted that Soviet politics, Prussian railway management, American technology, and the organizational forms of the trust-building entrepreneurs would bring the new socialist society.[10]

Modern technology was made in America. Even the Germans who developed it so well acknowledged the United States as the prime source. During the interwar years, the industrial world recognized the United States as the pre-eminent technological nation, and the era of technological enthusiasm reached its apogee. Modern technological culture, however, was defined in Europe. The Europeans held up a mirror in which the Americans could see themselves as the raw materials of modernity which the Europeans wanted to fashion into modern culture. European engineers, industrialists, artists, and architects came to America to admire its "plumbing and its bridges"[11] and made, as we have observed, the second discovery of America—the great systems of production.

From the turn of the century on, avant-garde European architects and industrial designers searched for ways to combine American modes of mass production and the principles of quality design. In so doing they were inventing the forms and symbols for a modern technological culture. In the 1920s, at the Bauhaus in Dessau, Walter Gropius and his architect and artist associates brought the movement to a climax by contributing greatly to the establishment of the modern or international style of architecture and design. This style expressed in construction methods and in formal design the principles of modern American technology. The dire housing shortage following World War I spurred Gropius and other avant-garde architects to apply the mass-production methods attributed to Ford and the scientific management methods of Taylor. A description of the construction of great housing settlements in Dessau and Berlin makes this clear. In France, Le Corbusier fervently and eloquently articulated the technological age. In his journal *L'Esprit nouveau*, published in the 1920s, he sought to define verbally and visually the modern in art, architecture, and interior and industrial design. He believed that American engineers had found the heart of modern design by joining, in their bridges, ocean steamers, grain silos, and automobiles, a mathematical exactness with rational methods of production and rational design. The architects who adopted the engineers' techniques and infused them with the aesthetics of the artist were, he was convinced, creating the modern style. Le Corbusier was more enamored of order and system than the engineers themselves.

Painters, too, became self-consciously modern. The Italian Futurists, around the turn of the century, saw modern technology as a way of destroying traditional culture in Italy. Social and artistic radicals, they found Italy backward and oppressive. Modern motor cars, not Renaissance museums, held the key to the future for Italians. The Futurists celebrated the dramatic and dynamic artifacts of modern technology—"adventurous steamers that sniff the horizon . . . deep-chested locomotives whose wheels paw the tracks . . . the sleek flight of planes. . . ."[12] After the Russian Revolution of 1917, the Soviet artists of the Constructivist movement, several of whom were graduate engineers, also envisioned art as a means of radically transforming culture, of bringing into being the new Soviet society. Vladimir Tatlin conceived of "machine art" and El Lissitzky of new elements of style from which a modern art and architecture could be created that would influence the character of the new man in the modern social system. In Germany after the war, the artifacts and order of the technological world fascinated the artists of the Neue Sachlichkeit school. Their visual vocabulary included "order," "clarity," and "harmony." They thought these to be the principles of technological rationality and the governing principles of the human-made world.

In 1915 Marcel Duchamp and Francis Picabia came to New York and emboldened a few American artists to look to technological America rather than Europe for the subject matter, forms, and symbols of the modern. The American Precisionists Charles Sheeler and Charles Demuth, and the Russian American Louis Lozowick painted technological landscapes and objects inspired by the development of modern systems of production. Their work was exemplified by Sheeler's series of paintings and photographs of Ford's River Rouge plant.

Leading American architects did not adopt a formal vocabulary characterized by a technological or machine aesthetic until the 1930s, when Gropius, Ludwig Mies van der Rohe, and other avant-garde architects, emigrating from Nazi Germany to the United States, brought with them the international style. The paradox remains that, although modern technology originated in America, modern painting and architecture inspired by it germinated and took root first in Europe.

The Great Depression and the violence and destruction made possible by modern technology during World War II dampened technological enthusiasm, but technological systems entered a new stage in the United States when the government became involved in their cultivation. Franklin Delano Roosevelt inaugurated the Tennessee Valley Authority, a government-funded, -designed, -constructed, and -operated project that systematically developed the resources of an extensive river valley. Once again the United States provided the world a model of modern technology. During World War II, the United States poured unprecedented resources into the Manhattan Project, a technological system of unprecedented size. When President Dwight Eisenhower later warned his nation about the increasing momentum of the military-industrial complex, he referred to the rise of great systems of armament production modeled on the Manhattan Project. The Strategic Defense Initiative, or Starwars, exemplifies the most recent military-industrial (and university) complex.

The dropping of the bombs on Hiroshima and Nagasaki starkly revealed for many the threat of uncontrolled, destructive, technological creativity and the massive size of technological projects and systems in which the government was involved. Subsequent and largely unsuccessful efforts to bring about control of the nuclear arsenal heightened these anxieties. Rachel Carson in *Silent Spring* and others who followed her lead stimulated an increased concern about environmental costs of large-scale production technology. The wasting of Vietnam by military technology brought the growing reaction to a head. A counterculture erupted. Reflective radicals of the 1960s, both in America and abroad, attacked modern technology and the order, system, and control associated with it. The counterculture called for the organic instead of the mechanical; small and beautiful technology, not centralized systems; spontaneity instead of order; and compassion, not efficiency. Paul Goodman, Herbert Marcuse, and other intellectual leaders of the counterculture unerringly aimed their attacks at technological rationality and system. Mumford, whose critical concern about technology and society antedated that of the counterculture, also wrote of megamachines. Jacques Ellul also criticized the technological systems that he and Mumford feared were determining the course of history.

Time has dampened the bitterness and vision of the counterculture. Today technological enthusiasm, although much muted as compared with the 1920s, survives among engineers, managers, system builders, and others with vested interests in technological systems. The systems spawned by that enthusiasm, however, have acquired a momentum—almost a life—of their own. They involve the surviving technological enthusiasts, persons whose income derives from the systems, large corporations, government agencies, and politicians beholden to those with vested interests in the systems. A multitude of persons persuaded that armaments and the producers of them are critical for the nation's defense and survival adds to the momentum of military-industrial systems. The age of technological enthusiasm has passed, but it has left behind a burden of history. Those who know the history and the burden may be able to rid themselves of it or turn it to their ends.[13]

5

THE SYSTEM MUST BE FIRST

Since 1870 inventors, scientists, and system builders have been engaged in creating the technological systems of the modern world. Today most of the industrial world lives in a made environment structured by these systems, not in the natural environment of past centuries. Charles Darwin helped explain the influences of nature; Sigmund Freud tried to comprehend the psychological forces crackling like electrical charges within and all around us; but as yet we reflect too little about the influences and patterns of a world organized into great technological systems. Usually we mistakenly associate modern technology not with systems but with such objects as the electric light, radio and television, the airplane, the automobile, the computer, and nuclear missiles. To associate modern technology solely with individual machines and devices is to overlook deeper currents of modern technology that gathered strength and direction during the half-century after Thomas Edison established his invention factory at Menlo Park. Today machines such as the automobile and the airplane are omnipresent. Because they are mechanical and physical, they are not too difficult to comprehend. Machines like these, however, are usually merely components in highly organized and controlled technological systems. Such systems are difficult to comprehend, because they also include complex components, such as people and organizations, and because they often consist of physical components, such as the chemical and electrical, other than the mechanical. Large systems—energy, production, communication, and transportation—compose the essence of modern technology. As Alan Trachtenberg has pointed out, Americans take the "West" and the "machine" as symbols providing perspectives on their early and recent history.[1] After a century of system building, they might well see the "system" as their hallmark.

Many modern technological systems are extensions of the inventions of Edison, Sperry, Tesla, and other independent inventors. These inventors conceived of technical systems as consisting primarily of mechanical, electrical, and chemical components, such as cams, gears, springs, valves, dynamos, incandescent lamps, antennae, belts, pipes, and transmission lines. The more entrepreneurial among them also integrated organizations into the nascent technological systems. Industrial research scientists have been responsible for many of the extensions or improvement of these systems. About the turn of the century, persons possessing similar system-building drives rose to prominence, but their goals were more complex than those of the inventors and industrial scientists. These system builders have left their mark on modern technological society by creating technological systems of immense size that embody not only technical components but mines, factories, and organizations such as business corporations, banks, and brokerage houses. In addition, system builders established large bureaucracies of labor and white-collar workers to tend the systems. Many of the system builders were trained and gained experience as engineers, managers, and financiers rather than as inventors or industrial scientists. As we shall see, they found that a nation committed to mass consumption, freedom of enterprise, and capitalism particularly suited their goal of technological-system building, whether it was socially benign or destructive. Some were motivated by desire for power and money, but they shared a drive to order, centralize, control, and expand the technological systems over which they presided. In seeking the creators of modern industrial America, we must consider the system builders as well as the independent inventors and the industrial scientists.

Henry Ford's production system remains the best known of the large technological systems maturing in the interwar years. Contemporaries then usually perceived it as a mechanical production system with machine tools and assembly lines. But Ford's system also included blast furnaces to make iron, railroads to convey raw materials, mines from which these came, highly organized factories functioning as if they were a single machine, and highly developed financial, managerial, labor, and sales organizations. Other systems contemporary with his were more advanced than Ford's. But Ford's attracted the attention, because the public was better able to comprehend the mechanical. It was fashionable to say that no one comprehended the ethereal force, electricity—but gears, one could feel and see.

Electrical light-and-power systems, such as those managed and financed by the system-building utility magnate Samuel Insull of Chicago, incorporated not only dynamos, incandescent lamps, and transmission lines, but hydroelectric dams, control or load-dispatching centers, utility companies, consulting-engineering firms, and brokerage houses, as well. When Ford placed a mechanical assembly line in motion, the public was greatly impressed, but electrical systems transmitted their production units too rapidly to perceive: 186,000 miles per second, the speed of light. The concepts motivating and guiding Insull and the other electrical-system builders were more subtle and abstract than those driving Ford and his mechanical engineers. Concepts of electrical circuitry rather than mechanical gadgetry shaped the ways in which builders of electrical systems thought and acted; they manipulated interactions, not the simpler linear relationships of cause and effect. The builders of electric-power and chemical-process plants also envisaged flow rather than the movement of batches of materials and mechanical parts. Instead of being the age of the machine, the interwar years emerged as the apogee of the age of electric power and chemical process. The machine as symbol of an age applies better to the British Industrial Revolution of more than a century earlier.

The wave of system building that crested in the United States during the first half of this century had been building up for decades. As early as the mid-nineteenth century, British engineers and industrialists began to refer to a system of manufacture in the United States characterized by the use of highly specialized machine tools and the arrangement of machines, tools, gauges, and other devices in factories to facilitate the flow of production.[2] The next generation, both British and American, spoke of a unique and fruitful "American System of Manufactures."[3] They realized that the American system involved more than interchangeable parts, special-purpose machine tools, and factories laid out for the smooth flow of work; they understood that the American commitment to an economic democracy as well as to a political one brought a new and unprecedentedly large market for mass-produced goods and services for masses of the population. American values and the market influenced by them were also part of the system.[4] Europeans were well aware of the differing character of their own and the American markets. In the late nineteenth and early twentieth centuries, European products were priced and designed as luxury goods. Europeans expected high unit profits on a small turnover. Insull often showed charts graphically demonstrating that in London the price for each kilowatt hour of electricity was high, the profit margin great, and the kilowatt hours produced low, whereas in Chicago the opposite was true. So he continually lowered prices to increase sales and gross profits. In Germany the electric light-and-power utilities catered far more to industry than to a residential market that could only afford mass-produced low-cost electricity.

Of the American system builders, none took on a more difficult and controversial task than Frederick Winslow Taylor. Ford directed his ordering-and-controlling drive primarily to production machines; Insull focused his on ensuring the large and steady flow of electrical power; Taylor tried to systematize workers as if they were components of machines. Ford's image was of a factory functioning as a machine; Insull envisaged a network or circuit of interacting electrical and organizational components; and Taylor imagined a machine in which the mechanical and human parts were virtually indistinguishable. Idealistic, even eccentric, in his commitment to the proposition that efficiency would benefit all Americans, Taylor proved naïve in his judgments about complex human values and motives. In the history of Taylorism we find an early and highly significant case of people reacting against the system builders and their production systems, a reaction widespread today among those who fear being co-opted by "the system."

TAYLORISM

Taylor was not the first to advocate a so-called scientific approach to management, but the enthusiasm and dedication, bordering on obsession, with which he gave himself to spreading his views on management, his forceful personality, and his highly unusual and erratic career filled with failure as well as success have left a strong, indelible impression on his contemporaries and succeeding generations. More than a half-century after his death, many persons in Europe, the Soviet Union, and the United States continue to label scientific management "Taylorism." Labor-union leaders and radicals then and now find Taylor convenient to attack as a symbol of a despised system of labor organization and control. In the early decades of this century, Europeans and Russians adopted "Taylorism" as the catchword for the much-admired and -imitated American system of industrial management and mass production. The publication in 1911 of Taylor's *Principles of Scientific Management* remains a landmark in the history of management-labor relations. Within two years of publication, it had been translated into French, German, Dutch, Swedish, Russian, Italian, Spanish, and Japanese. In his novel *The Big Money* (1936), John Dos Passos gave a sketch of Taylor, along with ones of Edison, Ford, Insull, and a few others, because he believed that they expressed the spirit of their era. Dos Passos noted that Taylor never smoked or drank tea, coffee, or liquor, but found comparable stimulation in solving problems of efficiency and production. For him, production was the end-all, whether it be armor plate for battleships, or needles, ball bearings, or lightning rods.[5]

Taylor's fundamental concept and guiding principle was to design a system of production involving both men and machines that would be as efficient as a well-designed, well-oiled machine. He said, "in the past, the man has been first; in the future the system must be first,"[6] a remark that did not sit well then with workers and their trade-union leaders and that today still rankles those who feel oppressed by technology. He asked managers to do for the production system as a whole what inventors and engineers had done in the nineteenth century for machines and processes.

Highly efficient machines required highly efficient functionally related labor. When several Taylor disciples, including later U.S. Supreme Court Justice Louis D. Brandeis, sought a name for Taylor's management system, they considered "Functional Management," before deciding on "Scientific Management."[7] Taylor and his followers unfeelingly compared an inefficient worker to a poorly designed machine member.

Taylor developed his principles of management during his work as a machinist and then as a foreman in the Midvale Steel Company of Philadelphia. Son of a well-to-do Philadelphia Quaker family, a graduate of Phillips Exeter Academy, and a U.S. champion doubles player in tennis, Taylor was not the typical machine-shop worker. Without doubt he was the only shop-floor worker at Midvale who was a member of the exclusive Philadelphia Cricket Club. Taylor's physician had recommended manual labor after the deterioration of his eyesight during his last year at the academy precluded his entry into Harvard University. Taylor's father expected his son to follow him into the law profession, but the son chose to remain a blue-collar worker. At Midvale he came under the protective wing of its president, William Sellers, one of the nineteenth century's most influential inventors of machine tools, a mechanical engineer and an industrialist who insisted that every member of a machine designed by him or his associates must be functional, or contribute efficiently to the end for which the machine was intended. Taylor afterward referred to Sellers as "undoubtedly the most noted engineer in this country in his time," "a truly scientific experimenter and a bold innovator," and "a man away beyond his generation in progress."[8] When Taylor moved up the ladder and became a foreman and later chief engineer at Midvale, he deeply depended on Sellers's backing as he experimented with fundamental changes that went against the grain of traditional work practices.

Worker soldiering, variously called "stalling," "quota restriction," "goldbricking" by Americans, *Bremsen* by Germans, and "hanging it out" or "Ca'canny" by the English and Scots, greatly offended Taylor's sense of efficiency. Having concluded that workers, especially the skilled machinists, were the major industrially inefficient enclave remaining after the great wave of nineteenth-century mechanization, Taylor proposed to eliminate "soldiering." He later wrote that "the greater part of systematic soldiering . . . is done by the men with the deliberate object of keeping their employers ignorant of how fast work can be done."[9] The machinists at Midvale, for example, were on a "piecework" schedule, so they were determined that the owners not learn that more pieces could be turned out per hour and therefore demand an increase in the number of pieces required. They did not trust the owners to maintain the piece rate and allow the workers, if they exerted themselves, to take home more pay. The workers believed that the increased effort would become the norm for the owners. We can only conjecture about the natural rhythm and reasonableness of the pace that the workers maintained over the long duration; Taylor believed that they were soldiering. Nevertheless, he also showed that he was determined that the diligent worker be rewarded with a share of the income from more efficient and increased production. To his consternation, he later found that management and the owners also soldiered when it came time to share the increased income. Taylor was no close student of human nature; his approach was, as he described it, scientific.

After being put in charge of the machinists working at the lathes, Taylor set out to end soldiering among them. His friends began to fear for his safety. As Taylor recalled, the men came to him and said, "Now, Fred, you are not going to be a damn piecework hog, are you?" To which he replied, "If you fellows mean you are afraid I am going to try to get a larger output from these lathes," then "Yes; I do propose to get more work out."[10] The piecework fight was on, lasting for three years at Midvale. Friends begged Taylor to stop walking home alone late at night through deserted streets, but he said that they could shoot and be damned and that, if attacked, he would not stick to the rules, but resort to biting, gouging, and brickbats. At congressional hearings in 1912—about thirty years later—he insisted:

> I want to call your attention, gentlemen, to the bitterness that was stirred up in this fight before the men finally gave in, to the meaness of it. . . . I did not have any bitterness against any particular man or men. Practically all of those men were my friends, and many of them are still my friends. . . . My sympathies were with workmen, and my duty lay to the people by whom I was employed.[11]

In his search for the one best way of working, of deciding how and how fast a lathe operator should work, he used a method that he considered scientific. He believed values and opinions of neither workers nor managers influenced his objective, scientific approach. Beginning in 1882, first he, then an assistant began using a stopwatch to do time studies of workers' motions. Timing was not a new practice, but Taylor did not simply time the way the men worked: he broke down complex sequences of motions into what he believed to be the elementary ones and then timed these as performed by workers whom he considered efficient in their movements. Having done this analysis, he synthesized the efficiently executed component motions into a new set of complex sequences that he insisted must become the norm. He added time for unavoidable delays, minor accidents, inexperience, and rest. The result was a detailed set of instructions for the worker and a determination of time required for the work to be efficiently performed. This determined the piecework rate; bonuses were to be paid for faster work, penalties for slower.[12] He thus denied the individual worker the freedom to use his body and his tools as he chose.

Taylor stressed that the time studies, with their accompanying analysis and synthesis, did not alone constitute scientific management. He realized and insisted that, for the work to be efficiently performed, the conditions of work had to be reorganized. He called for better-designed tools and became known for his near-fixation about the design of shovels. He ordered the planning and careful management of materials handling so that workers would have the materials at hand where and when needed. Often, he found, men and machines stood idle because of bottlenecks in complex manufacturing processes. Taylor even attended to lighting, heating, and toilet facilities. Seeing inanimate machines and men together as a single machine, he also looked for ways in which the inanimate ones failed. Believing that machine tools could also be driven faster, he invented a new chromium-tungsten steel for cutting tools that greatly increased their speed. As we would expect, he did not leave decisions about even the cutting speed of the machine tool or the depth of the cut to the subjective judgment of the machinist. In his book *On the Art of Cutting Metals* (New York, 1907), he described his thousands of experiments that extended over twenty-six years.

FREDERICK W. TAYLOR INSPECTING CONSTRUCTION

As a system builder seeking control and order, Taylor was not content to redesign machines, men, and their relationship; he was set upon the reorganization of the entire workplace or factory as a machine for production. Stimulated by his example, individuals with special education, training, and skill contributed to the establishment of "the new factory system."[13] To understand this achievement, we need to consider the way in which the work process was carried out in many machine shops, engineering works, and factories before Taylor's reforms. After the concern received an order, copies specifying the product and quantity to be made were sent to the foremen. They carried most of the responsibility for the production process. Once draftsmen had prepared detailed drawings, foremen in the machine shop, the foundry, pattern-making shop, and forge determined the various component parts needed, ordered the raw materials, and wrote out job cards for the machinists. The machinists then collected drawings, raw materials, and tools, and planned the way in which the job for a particular component part would be done. When the machinists had completed the particular job, they reported to the foreman for another. The foremen had overall supervision, but there was little scheduling and, therefore, little planned coordination of the various jobs. Components sometimes reached the assembly point, or erecting shop, haphazardly. Because of lack of planning, scheduling, and close monitoring of the progress of work, raw materials were often not on hand. How the workmen might then use their time is not clear, but proponents of Taylorism leave the impression that they were idle.

Taylor found the disorder and lack of control unbearably inefficient and declared war on traditional methods responsible for these. His reform specified that an engineering division take away from the foremen overall responsibility for the preparation of drawings, the specification of components, and the ordering of raw materials. Upwardly mobile young graduates from the rising engineering schools were soon displacing their "fathers," the foremen. The planning department in the engineering division coordinated deliveries of materials, and the sequence in which component parts would be made. The planning department prepared detailed instructions about which machines would be used, the way in which machinists, pattern makers, and other workmen would make each part, and how long the job should take. Careful records were kept of the progress being made in the manufacture of each part, including materials used and time consumed. Unskilled workers moved materials and parts around shops so that they would be on hand where and when needed. By an elaborate set of instruction cards and reports, the planning department had an overall picture of the flow of parts throughout the shops, a flow that prevented the congestion of the work at particular machines and the idleness of other machines and workmen. The reports of worker time and materials consumed greatly facilitated cost accounting.

The complexity and holism of Taylor's approach was often ignored because of the widespread publicity given to some of his simplest and most easily reported and understood successes. Taylor often referred to the "story of Schmidt," who worked with the pig-iron gang at the Bethlehem Steel Corporation in Pennsylvania. When Taylor and his associates came to Bethlehem in 1897 to introduce their management techniques and piecework, they found the pig-iron gang moving on the average about twelve and a half tons per day. Each man had repeatedly to lift ninetytwo pounds of iron and carry it up an inclined plank onto a railroad car. After careful inquiry into the character, habits, and ambition of each of the gang of seventy-five men, Taylor singled out a "little Pennsylvanian Dutchman who had been observed to trot backhome for a mile or so after his work in the evening about as fresh as he was when he came trotting down to work in the morning."[14] After work he was building a little house for himself on a small plot of ground he had "succeeded" in buying. Taylor also found out that tlie "Dutchman" Henry Noll, whom Taylor identified as Schmidt, was exceedingly "close," or one who placed "very high value on the dollar." The Taylorites had found their man.

Taylor recalled the way he and Schmidt talked, a story that tells us more of Taylor's attitudes than of what actually transpired:

> "Schmidt, are you a high-priced man? . . . What I want to find out is whether you want to earn $1.85 a day or whether you are satisfied with $1.15, just the same as all those cheap fellows are getting?"
>
> "Did I vant $1.85 a day? Vas dot a high-priced man? Vell, yes, I vas a high-priced man."
>
> ". . . Well, if you are a high-priced man, you will load that pig iron on that car to-morrow for $1.85. You will do exactly as this man tells you to-morrow, from morning till night. When he tells you to pick up a pig, and walk, you pick it up and you walk, and when he tells you to sit down and rest, you sit down. . . . And what's more, no back talk."[15]

Taylor found it prudent to add:

> This seems to be rather rough talk. And indeed it would be if applied to an educated mechanic or even intelligent laborer. With a man of the mentally sluggish type of Schmidt it is appropriate and not unkind, since it is effective in fixing his attention on high wages which he wants. . . .[16]

Perhaps Taylor, the upper-middle-class Philadelphian, forgot that the Pennsylvania Dutchman was not so mentally sluggish that he could not save for land and build a house. Schmidt moved the forty-seven tons of pig that the Taylorites had decided should be the norm, instead of the former twelve and a half tons, and soon all the gang was moving the same and receiving sixty percent more pay than other workmen around them. We are not told whether Schmidt was still able to trot home and work on his house.

Numerous other examples of Taylor's methods increasing worker output and production abound, but there is also abundant evidence of failures. Ultimately his efforts at Bethlehem Steel exhausted him, and the head of the company summarily dismissed him. Taylor had come to the steel company with the full support of Joseph Wharton, a wealthy Philadelphian into whose hands the company had passed. Wharton wanted a piecework system installed in the six-thousand-man enterprise. Taylor warned that his system would be strongly opposed by all of the workmen, most of the foremen, and even a majority of the superintendents. Bold and determined, he forged relentlessly ahead, introducing a planning department and new administrative roles for the foremen. Instructions for routine were codified with time cards, work sheets, order slips, and so on. As worker resistance stiffened over several years, Taylor became rigid, even arbitrary, in dealing with labor and management. His achievements were impressive, but "as time went on, he exhibited a fighting spirit of an intensity almost pathological," an admirer wrote.[17] Taylor's communications to the Bethlehem president were tactless and peremptory (he believed Wharton would shelter him). He complained of poor health and nervous strain. He thought that some of the major stockholders opposed him because he was cutting the labor force, and they were losing rents on the workers' houses. The curt note dismissing him came in April 1901.

Many workers were unwilling, especially the skilled ones, to give control of their bodies and their tools to the scientific managers, or, in short, to become components in a well-planned system. An increase in pay often did not compensate for their feeling of loss of autonomy. Taylor's scientific analysis did not take into account worker independence and pride in artful craftsmanship—even artful soldiering. Perhaps this was because Taylor, despite his years of experience on the shop floor, did not come from a blue-collar worker culture.

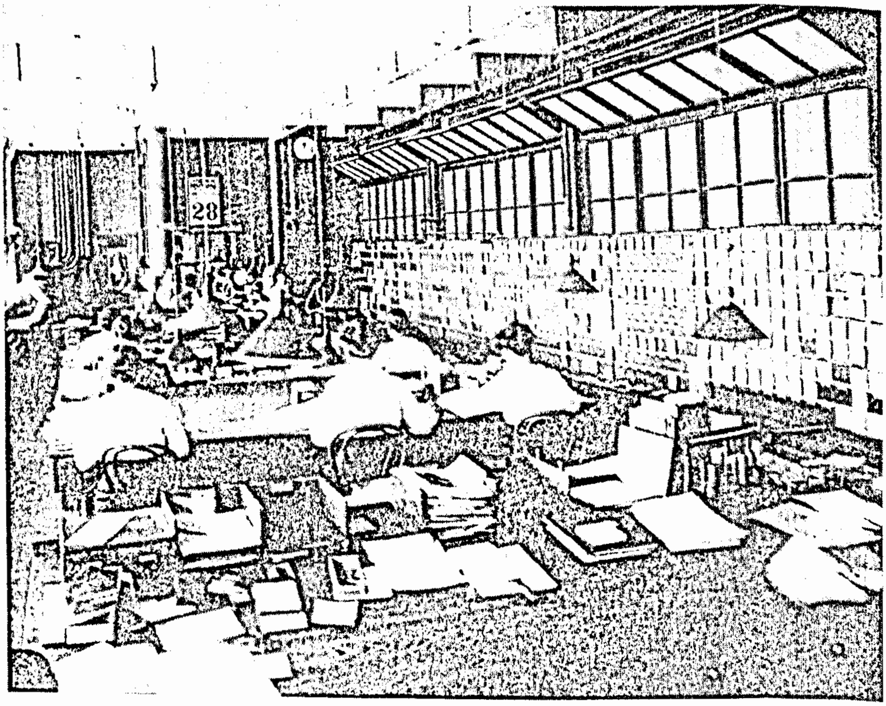
HENRY NOLL, WHOM TAYLOR MADE FAMOUS AS "SCHMIDT"

Samuel Gompers, a labor leader, said of Taylorism and similar philosophies of management:

> So, there you are, wage-workers in general, mere machines—considered industrially, of course. Hence, why should you not be standardized and your motion-power brought up to the highest possible perfection in all respects, including speeds? Not only your length, breadth, and thickness as a machine, but your grade of hardness, malleability, tractability, and general serviceability, can be ascertained, registered, and then employed as desirable. Science would thus get the most out of you before you are sent to the junkpile.[18]

One of the most publicized setbacks for Taylorism took place at the Watertown Arsenal when Carl G. Barth, a prominent Taylor follower and a consultant on scientific management, tried to introduce the Taylor system. Serious trouble started in the foundry when one of Barth's associates began stopwatch-timing the men's work procedures. The skilled workers in the shop discovered that the man carrying out the study knew little about foundry practice. The foundrymen secretly made their own time study of the same work process and complained that the time specified by the "expert" was uninformed and represented an unrealistic speed-up. The Watertown project was also flawed because Taylor's practice was to reorganize and standardize a shop before doing time-and-motion studies, and this had not been carried out at Watertown Arsenal. On the evening after the initiation of the stopwatch studies, the workers met informally and in a petition to the commanding officer of the arsenal they stated:

> The very unsatisfactory conditions which have prevailed in the foundry among the molders for the past week or more reached an acute stage this afternoon when a man was seen to use a stop watch on one of the molders. This we believe to be the limit of our endurance. It is humiliating to us, who have always tried to give to the government the best that was in us. This method is un-American in principle, and we most respectfully request that you have it discontinued at once.[19]



A TAYLOR PLANNING DEPARTMENT RATIONALIZED THE WORK PLACE AND PROCESS.

When stopwatch timing continued, the molders walked out on 11 August 1911.

Promised an investigation of the "unsatisfactory conditions," the molders returned to work after a week, but the publicity given a strike against the U.S. government intensified, fermenting union opposition to scientific management, specifically Taylorism, at Watertown and at another U.S. arsenal, at Rock Island, Illinois. August brought the formation of a special congressional committee of three to investigate scientific management in government establishments. The committee took extensive testimony from Taylor, among others. He became so exercised by hostile questions that his remarks had to be removed from the record. The report of the committee did not immediately call for any legislation. In 1914, however, Congress attached to appropriations bills the proviso that no time studies or related incentive payments should be carried out in government establishments, a prohibition that survived for over thirty years. Yet Taylorism involved, as we have seen, more than time studies and incentive payments, so work processes in government establishments continued to be systematically studied, analyzed, and changed in ways believed by management experts to be scientific.[20]

Worn down by the never-ending opposition and conflict, Taylor moved in 1902 to a handsome house in the Chestnut Hill area of Philadelphia. He no longer accepted employment or consulting fees but announced that he was ready to advise freely those interested in Taylorism. When he had serious inquiries from influential persons, he often invited them to his home, Boxly, lectured to them, often for an hour or two, and then arranged for them to visit several plants in Philadelphia. Among the plants was the Link-Belt Company, where the Taylor system had been successfully implemented. He might also show a particularly welcome guest his success at Boxly in the use of systematically organized labor—including his own—to landscape the grounds, or the specially designed golf clubs that he used on the local course.

Free from the confrontations in the workplace, Taylor dedicated himself to showing that his philosophy of management would ultimately promote harmony between management and labor. He argued that increasing production would increase wages and raise the national standard of living. His principles of scientific management struck responsive chords in a nation intent on ensuring economic democracy, or mass consumption, through mass production and also on conserving its natural resources. Taylor wrote that maximum prosperity could exist only as a result of maximum productivity. He believed that the elimination of wasted time and energy among workers would do more than socialism to diminish poverty and alleviate suffering.

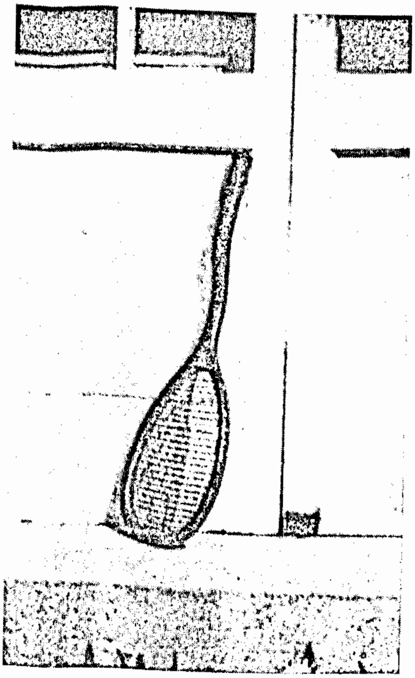
Because of his firm belief that his method was objective, or scientific, he never fully comprehended the hostile opposition of aggressive, collective-bargaining labor-union leaders. He found the unions mostly standing "for war, for enmity," in contrast to scientific management, which stood for "peace and friendship."[21] Nor could he countenance unenlightened and "hoggish" employers who either found his approach and his college-educated young followers unrealistic or were unwilling to share wholeheartedly with the workers the increased profits arising from scientific management. He considered the National Manufacturers Association a "fighting association," so he urged his friends in scientific management to cut all connections with it and its aggressive attitudes toward labor unions. Firmly persuaded that conflict and interest-group confrontations were unnatural, he awaited, not too patiently, the day when management and labor would realize, as he, that where the goal was increased productivity there were discoverable and applicable scientific laws governing work and workplace. Scientific managers were the experts who would apply the laws. He wrote:

> I cannot agree with you that there is a conflict in the interests of capital and labor. I firmly believe that their interests are strictly mutual, and that it is practicable to settle by careful scientific investigation the proper award that labor should receive for the work it renders.[22]

Their interest was not only a mutual but a national one—production and democracy. Production and Democracy. Taylor's times were not ones of affluence for workers, so his means to the end of mass production, thereby raising living standards of the masses, seemed in accord with democratic principle. Within a few years, Vladimir Lenin argued that Taylor principles accorded with socialism, as well.

Taylor became nationally known when Brandeis, the Boston "people's lawyer," argued in 1911 that scientific management, especially Taylorism, could save the nation's railroads so much money that the increased rates that the railroads were requesting from the Interstate Commerce Commission would not be needed. Since the rate hearings were well publicized, writers from newspapers and magazines descended on Taylor to find out about his system and then, at his suggestion, visited Philadelphia plants to see firsthand Taylorism in practice. The favorable publicity induced Taylor to write that "the interest now taken in scientific management is almost comparable to that which was aroused in the conservation of our natural resources by Roosevelt."[23]

Taylor rightly associated his scientific management with the broader conservation movement that had attracted national interest and support



TAYLOR INVENTED A TENNIS RACQUET THAT WAS UNDOUBTEDLY LABOR-SAVING.

during Theodore Roosevelt's terms as president, 1901–08. This progressive program for conservation focused on the preservation and efficient utilization of lands and resources. Like scientific management, it advocated that decisions about conservation be made scientifically by experts. Like Taylor, the progressive conservationists did not countenance as inevitable conflict of interests among ranchers, farmers, lumbermen, utilities, manufacturers, and others. To the contrary, they believed that such conflict was regressive, that it must be displaced by a scientific approach expected to bring harmonious and rational compromises in the general interest. This approach expressed a technological spirit spread by engineers, professional managers, and appliers of science, a belief that there was one best way. College-educated foresters, hydraulic engineers, agronomists should be, the progressives argued, the decision makers about resources; professional managers about the workplace.

Taylor and the growing number of his followers wrote books, published articles, gave lectures, and acted as consultants. He authorized C. G. Barth, H. K. Hathaway, Morris L. Cooke, and Henry L. Gantt to teach

LILLIAN GILBRETH (1878–1972)

his system of management: "All others were operating on their own."[24] Frank Gilbreth, among those who operated "on their own," became well known for his *A Primer of Scientific Management* (1914) and for the use he and his wife, Lillian Gilbreth, made of the motion-picture camera to prepare time-and-motion studies. Her contribution to scientific management has yet to be generally acknowledged. She, not her husband, had a Ph.D. degree in psychology (Brown University, 1915). Perhaps because of her study of psychology, she sensitively took into account complex worker characteristics. The Gilbreths' articles on scientific management show the influence of her concern that the worker should not be seen simply as a component in a Taylor system. After her husband's death, she continued her consulting work and served as a professor of industrial management at Purdue University.[25]

FORDISM

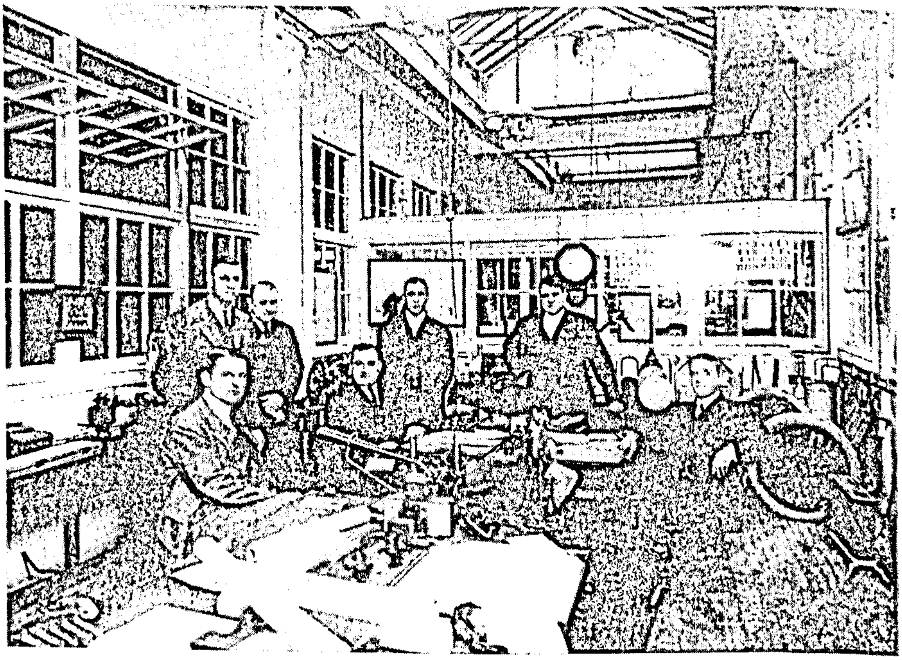
Ford denied that Taylor and his disciples had inspired him when he presided over the creation of a massive system of production. Flow characterized his automobile system, too, but moving assembly lines, conveyor belts, gravity feeds, and railroads, not workers and foremen, constituted the materials-handling network. Ford, unlike Taylor, did not need detailed schedules and routing instructions to direct the movements of materials and work across the shop floor. Ford and a few like-visioned mechanics and self-educated engineers created at his Highland Park plant a system of mass production unlike any the world had ever before seen. They established a finely directed, controlled, and steady flow of energy and materials on a scale then unprecedented. At Highland Park, from about 1910 to 1913, Ford experienced spontaneous teamwork and brilliant *ad hoc* innovation. He displayed the unconscious and inspiring leadership that he longed later—in vain—to recapture. The few years when Ford and a band of enthusiasts, sure-handed, keen-eyed, and ingenious, created the assembly line recall the similar creative exhilaration of Edison and his men at Menlo Park.

Historians and biographers have offered countless explanations for the remarkable achievement of Ford and his men at Highland Park. Siegfried

Giedion, the historian of mechanization, attributes Ford's introduction of the moving assembly line—the best-known component of his mass-production system—to an analogy that Ford drew with the moving disassembly lines of Chicago meat packers. Others believe that he knew about the moving-line production used in the manufacture of tin cans. Some conclude that Ford must have been aware of the various types of moving conveyors, such as the gravity slides used for centuries in flour mills, when he introduced conveyor systems to feed the moving assembly lines. The critical idea of the layout of machine tools to facilitate the flow of production through the factory may have come to Ford first through persons familiar with the best practices in New England machine shops. His insistence on interchangeable parts continued in a long tradition reaching back early in the nineteenth century in the United States to manufacturing at army arsenals.

The list of likely precedents and stimuli can be extended but, unaccountably, the Ford historians have overlooked another likely explanation for Ford's fixation on the flow of production. From 1891 until 1899 he worked for the Edison Illuminating Company of Detroit, becoming the chief engineer of the company's Washington Boulevard electric-power station. Even though Ford's job gave him responsibility for technical, not organization and economic, problems, as a notably alert and curious man he probably absorbed the fundamentals governing the production and consumption of electricity. From Alex Dow, who headed the utility company after 1896, Ford could have learned much, for Dow was destined to be recognized as one of the most innovative U.S. utility managers. Ford learned, perhaps by osmosis, that electricity continuously flows and cannot be stored. For this reason it was essential that demand and supply move hand in hand. (Later he insisted that dealers take his cars as they moved off the assembly lines.) He also saw that electricity supply involved a seamless network, or system, of interconnected machines, transmission, and communication facilities. Electrical engineers usually referred to their "systems." Progressive utility managers advocated the economies of large-scale production machines and power plants, low prices to encourage mass consumption, the cultivation of a widespread market, and continuous flow of production to reduce costs.[26] When Ford spokesmen reflected on the production system that evolved at Highland Park and River Rouge, a system that also depended on constant flow, mass demand, and mass supply, they said that Ford's guiding principles were power, accuracy, economy, system, continuity, and speed.[27] A newsman describing the new Ford plant at Highland Park about 1914 spoke for other reflective observers when he identified its salient feature as "System, system, system."[28] The Ford and electric-utility approaches are too much alike to ignore the strong possibility that he absorbed some of the electric-utility style of production when he was an engineer at the Edison company in Detroit. The search, however, for priority and key individuals becomes less important if we remember that mass-production and mass-consumption principles permeated the American industrial and social environment about the turn of the century.

From about 1909 through 1913, Ford and his mostly young assistants engaged intensively in designing the Model T and the system for producing it. Afterward the inventive process of improvement, especially in the system of production, continued. Because so many writers have studied and written Ford history, we can identify the contributions of some of his mechanics and engineers and need not fall into the error of portraying Ford as a heroic figure leading but not learning from others. Ford had an uncommon gift for, or was simply lucky in, attracting mechanics who considered creative work play. Charles "Cast-iron Charlie" Sorensen had been a foundryman and brought ingenious ideas from that experience; Walter E. Flanders, a machine-tool salesman whom Sorensen believed to be a "roistering genius," brought to Ford the lore and craft of the Yankee mechanic thoroughly familiar with machine tools, the critical components in the manufacturing process. Flanders, who as a machine-tool salesman had acted as something of a cross pollinator in moving from company to company, taught Ford that the essence of the motorcar business should be the fusion of the art of buying materials, the art of production, and the art of selling.[29] When Ford purchased the Keim company to acquire its labor-saving techniques involving stamping instead of casting parts, he also acquired the services of William Smith, its superintendent and part owner of the company. For a time William Knudsen, who later became head of General Motors, helped design the

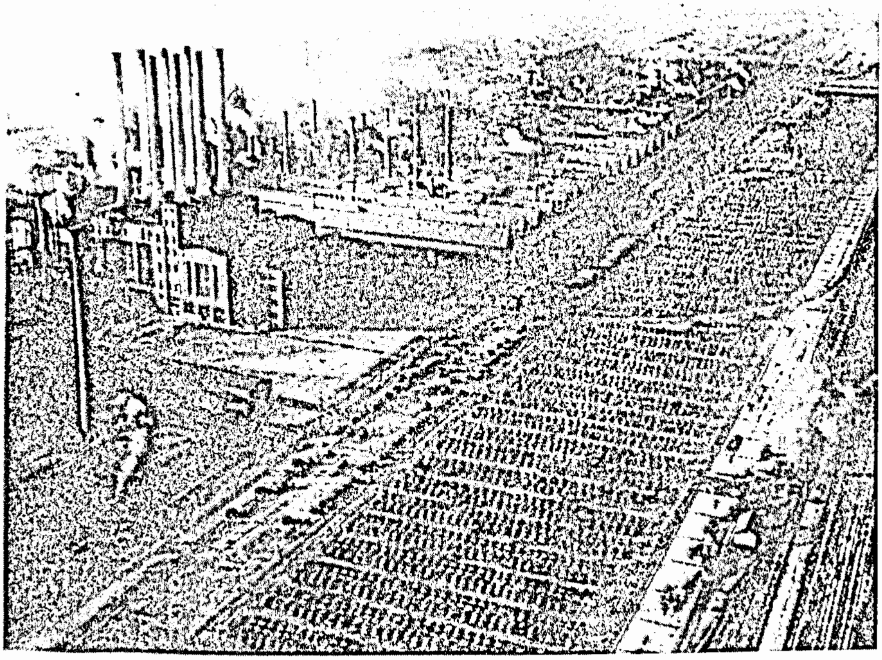


SOME OF THE CREATORS OF THE FORD ASSEMBLY LINE, 1913. CHARLES SORENSEN IS SEATED AT FAR LEFT.

Ford system of production. The list is long, and the men on it changed as other companies wishing to learn Ford methods hired them away.

HIGHLAND PARK AND RIVER ROUGE

The design and layout of the Highland Park plant, which first produced the Model T, has attracted more general interest than the designing of the car itself. Albert Kahn, who became the most noted factory architect of the day, designed the plant that came to be known as the Crystal Palace because of its great expanse of windows. Ford, his engineers, and his mechanics laid out the machinery. Memoirs of participants tell us that they had no hard-and-fast responsibilities, no well-defined chain of com-

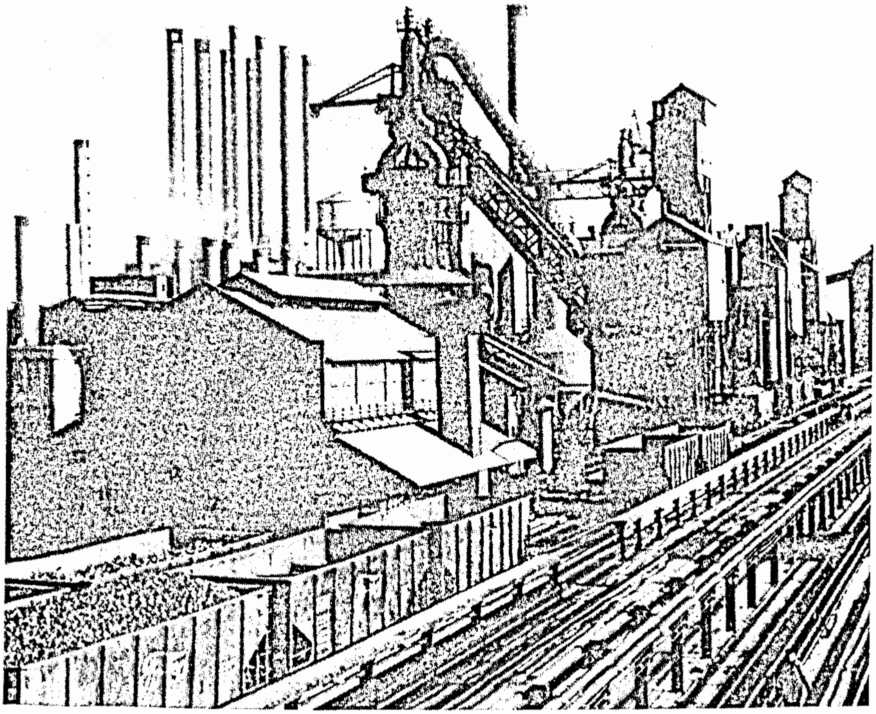


RIVER ROUGE PLANT

mand, no painstakingly worked-out set of instructions—they simply threw themselves wholeheartedly into solving the problems of production. Ford was the leader in the sense that he, much more than any other automobile manufacturer in Detroit or in the world, possessed the unswerving and overarching commitment to the mass production of an automobile for mass consumption. The Ford men became known for designing the best special-purpose machines in the world, laying them out along with their materials-handling network for a smooth flow of parts through the plant. In 1913, *annus mirabilis,* the dramatic step forward in production technique came when Ford and his associates introduced moving assembly lines for magnetos, engines, and transmissions. By early 1914 the chassis was also moving along complex assembly lines. With various conveyor systems carrying subcomponents to the assembly lines, with railroad lines constantly moving materials into the plant, and with dealers throughout the country supplying eagerly waiting Americans, the Ford system could be portrayed metaphorically as a great flowing tide of production.

In planning the great River Rouge plant, which displaced Highland Park in the 1920s as the heart of the Ford system, Ford again fulfilled his near-fixation on flow. He worked once more with Kahn the architect, and with Sorensen, Knudsen, and others of his lieutenants. Ford, no verbal or blueprint man, insisted on having scale models of machine tools, conveyors, windows, pillars, and floor space, so that these could be moved around to test ideas about production.[30] Today this can be done with complex computer models that reveal where there will be obstructions to flow. Between 1922 and 1926 Kahn designed and had constructed at the Rouge site a coke-oven plant, a foundry, a cement plant, an open-hearth steel plant, a motor-assembly building, and several other plants. Not only for its engineering aspects, but also for its aesthetic inspiration, River Rouge was the most important industrial complex of its day.[31]

The massive array of facilities at Highland Park and River Rouge existed because of Henry Ford's determination to sell his Model T to average Americans, especially to millions of farmers. Without warning, one morning in 1909 Ford announced that in the future his Ford Motor Company would build only the Model T. In the five succeeding years of increasing production efficiency and savings, he cut the price of the basic car from $900 to $440, well below the price of the nearest comparable automobile. The average monthly total of unfilled orders swelled to almost sixty thousand.[32] In 1921 the Ford company had a fifty-five-percent share of the automobile market. Production of the Model T climbed to its peak in 1923 with production of two million cars and trucks. Before changing over to the Model A in 1927, the Ford company had produced more than fifteen million Model T's. At the start, production took twelve and a half hours for one car; by 1925 cars rolled off the assembly line at half-minute intervals. Allan Nevins and Frank Hill, authors of the seminal work on Ford and the company, wrote:



RIVER ROUGE BLAST FURNACE

. . . by 1926 the entire productive activity of the company had been impressively developed. Raw materials were now flowing from the iron mines and lumber mills of the Upper Peninsula, from Ford coal mines in Kentucky and West Virginia, and from Ford glass plants in Pennsylvania and Minnesota, much of the product traveling on Ford ships or over Ford-owned rails. Ford manufacture of parts had been ex-

> panded—starter and generators, batteries, tires, artificial leather, cloth, and wire had been manufactured by the company in increasing quantities. The Rouge was producing coke, iron, steel, bodies, castings, engines, and other elements for Highland Park and the assembly plants, and also manufacturing the full quota of Fordsons [tractors].[33]

When he and his band of bright young mechanics and engineers were designing and redesigning the legendary Model T and creating the famed production system, Ford flourished as a visionary and a problem solver. In the 1920s, after the mammoth River Rouge plant had been placed in operation and while the Model T continued to be produced year after year, Ford became part of the management problem rather than of the solution. Even though he had an instinctive grasp of the fundamentals of mass production and mass consumption in a capitalistic society, he did not understand or appreciate managerial organization and the essential managerial practice of cost accounting. He even reduced the administrative staff needed for information and control of a large organization. As a result, production and sales were poorly coordinated. He made annual decisions about the price of the Model T on crude estimates of profits. The myth persists that the decimated accounting staff estimated costs by sorting bills into broad cost categories, estimating the average amount of each bill in the category, or pile, and then measuring the height of the pile to get a total. An aging Ford was trying to lead an aging bureaucracy manufacturing an aging automobile as if it were a team of enthusiastic mechanics and engineers solving the problems of a rapidly evolving system of mass production to bring a new automobile into the world.

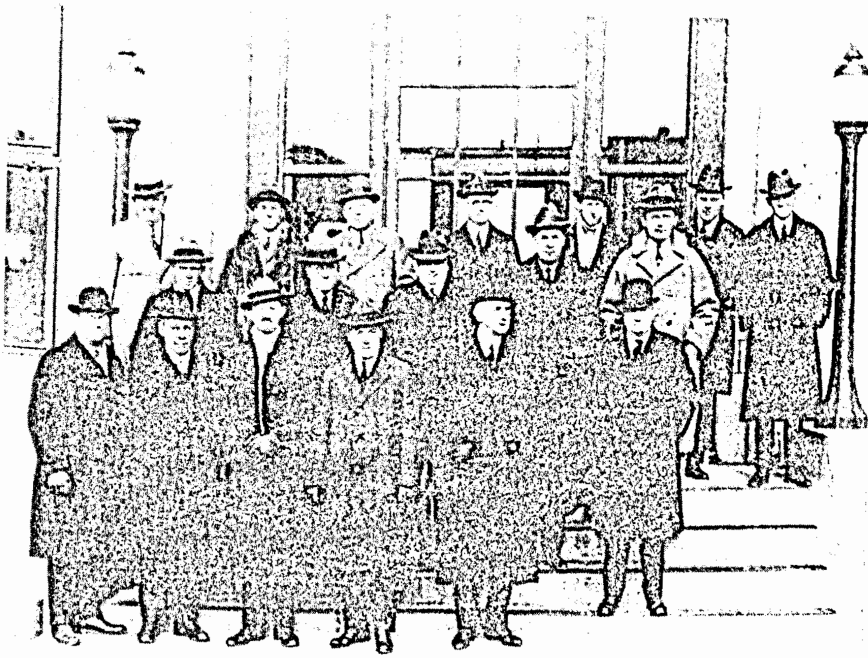
In recent years historians and biographers have found Ford and his company in decline as interesting as Ford on the rise. His reluctance to abandon the Model T from 1908 to 1927 has become part of the legend of Ford "the destroyer"[34] and despotic obsessive.[35] By the time he accepted the changeover to the Model A, the Ford share of the automobile market had dropped to thirty percent. Anecdotes abound about his ossifying and then deteriorating personality, and about the chaotic managerial policies

ASSEMBLY-LINE WORKERS, RIVER ROUGE

he tolerated, even encouraged, in the name of flexibility but exploited in the spirit of an authoritarian figure who intervened at will in the absence of a managerial structure and routine. William Knudsen, considered one of the ablest production men in the company, discussed with Ford's son

Edsel possible improvements in the Model T. Learning of this, the infuriated Henry Ford regularly countermanded Knudsen's orders and humiliated him. Knudsen resigned in 1921 and moved to General Motors, where he quickly took over the Chevrolet division that within a few years took the major market share from Ford. Later, when Edsel Ford and the company's chief engineer had designed and built a model of a six-cylinder engine as a needed replacement for the Ford four-cylinder, Henry Ford requested the chief engineer to accompany him to see a new scrap-conveyor. Riding on the conveyor, destined for destruction, was the new engine. Also cited as an example of Ford's irrational behavior was his dismissal of experts. He wrote in *My Life and Work* (1922), "We have most unfortunately found it necessary to get rid of a man as soon as he thinks himself an expert—because no one ever considers himself expert if he really knows his job."[36] Sorensen, who echoed Ford's state of mind, said, "When one man began to fancy himself an expert, we had to get rid of him. The minute a man thinks himself an expert, he gets an expert's state of mind, and too many things become impossible."[37] Another Ford company executive recalled that if Henry Ford wanted a job done right he would always choose the man who knew nothing about it.[38] One after another the able men left, until, in the 1930s, Henry Ford was reduced to relying on Sorensen, who was unwilling to counter Ford's obvious mistakes, and Harry Bennett, a one-time prizefighter who used bullies to control the plant and keep out the union.[39]

Despite Henry Ford's behavior tactics, Edsel, a mild-mannered and intelligent man experienced in the automobile industry, and many of those who had worked with Henry Ford in the exhilarating days when the Model T and Highland Park were created, remained loyal as long as they could to him and to the legend. In 1926 Ernest Kanzler, a talented Ford production chief and brother-in-law of Edsel, tried tact, flattery, adulation, and reason to persuade Henry Ford to consider the manufacture of the six-cylinder engine. In a seven-page memorandum to him cautiously proposing changes, Kanzler expressed concern that even to suggest change might affect "your feeling for me, and that you may think me unsympathetic." He added diplomatically, "Please, Mr. Ford, understand that I realize fully that you have built up this whole business



FORD EXECUTIVES, C. 1925: E. C. KANZLER (FRONT ROW, THIRD FROM LEFT), SORENSEN (SECOND ROW, FIFTH FROM LEFT), EDSEL FORD (THIRD ROW, SECOND FROM LEFT), HENRY FORD (THIRD ROW, SEVENTH FROM LEFT)

. . . that all the company's successes . . . will really be your personal accomplishment . . . even after your lifetime." Kanzler then risked mentioning that among most of "the bigger men in the organization there is a growing uneasiness. . . . They feel our position weakening and our grip slipping." "The buoyant spirit of confident expansion is lacking." Not long after, Henry Ford fired Kanzler.[40] In the same year, the Ford company share of the market had fallen to about one-third. The fabled Model T, despite changes, no longer fulfilled the dreams of a car-hungry public. Ford jokes about the Model T took a less tolerant form:

> The Ford is my auto / I shall not want another.
>
> It maketh me to lie down beneath it, / It soureth my soul.

It leadeth me in the path of ridicule, / For its name sake.

Yea, though I ride through the valleys, / I am towed up the hills, / For I fear much evil.

Thy rods and thine engines discomfort me.

I anoint my tires with patches; / My radiator runneth over.

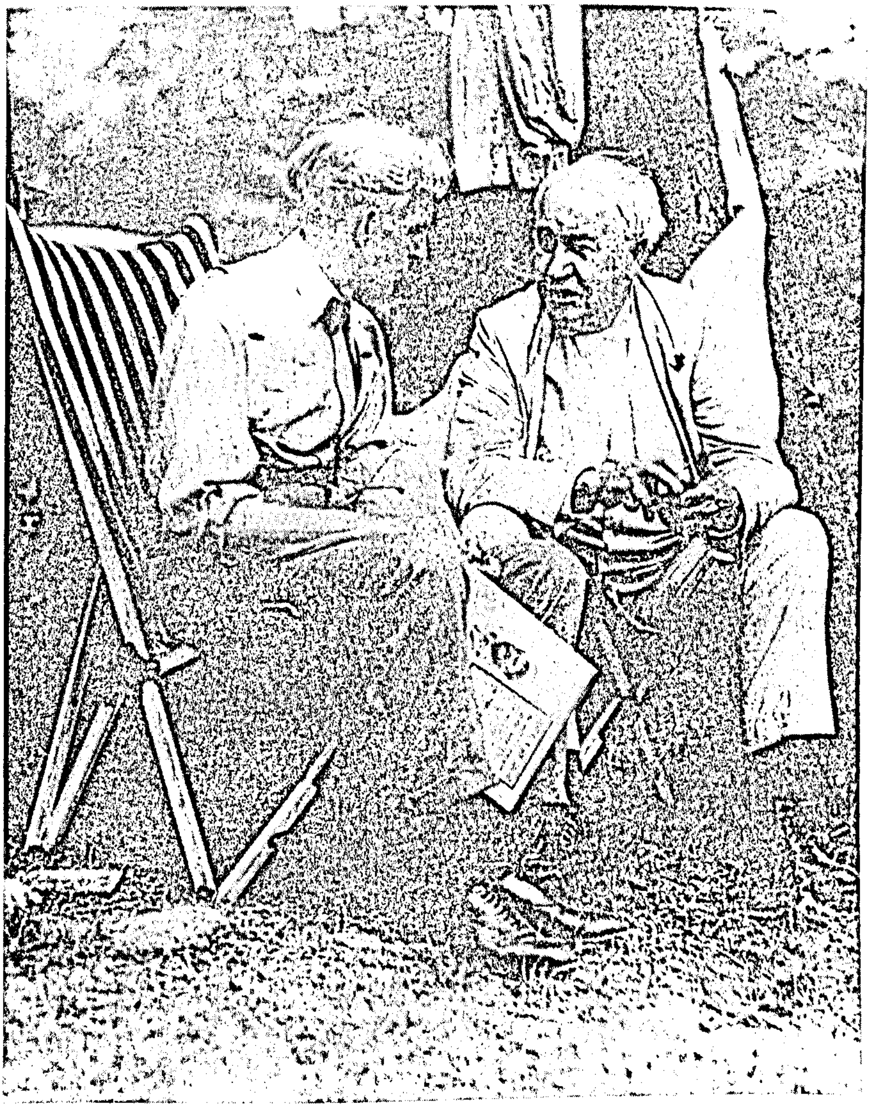
I repair blowouts in the presence of mine enemies.

Surely, if this thing followeth me all the days of my life

I shall dwell in the bug-house forever.[41]

A few of the widely told anecdotes about Henry Ford also took on derogatory twists that suggested lack of learning and eccentricity of intellect. Ford, for example, told reporters he believed in reincarnation, and as evidence noted that chickens had once run into the paths of oncoming automobiles but more recently had stayed by the side of the road. He explained that the roadwise chicken "had been hit in the ass in a previous life."[42]

His growing eccentricity and gradual transformation from inspired system builder to arbitrary, mean-minded, and ineffectual manager offer a major explanation for the decline of his company.[43] In fact, the change was not so much in Ford's personality as in the company problems he faced: not in the man, but in his environment. His solutions were for past problems. Ford's autocratic behavior and his dismissal of experts can be seen, on the one hand, as indicating the increasing rigidity and domineering nature of an aging man. Another explanation, however, reveals his longing for the exhilaration of creative activity and problem solving that he had known earlier as an inventor and a system builder. When he and his team were creating the Model T and the Ford system of production, there were no lines of authority, routine procedures, or experts. Theirs was a resourceful, ingenious, hunt-and-try probing into the unknown future. Edison, whom Ford revered and with whom he enjoyed a close friendship, also rejected experts, especially those with university



HENRY FORD AND THOMAS EDISON

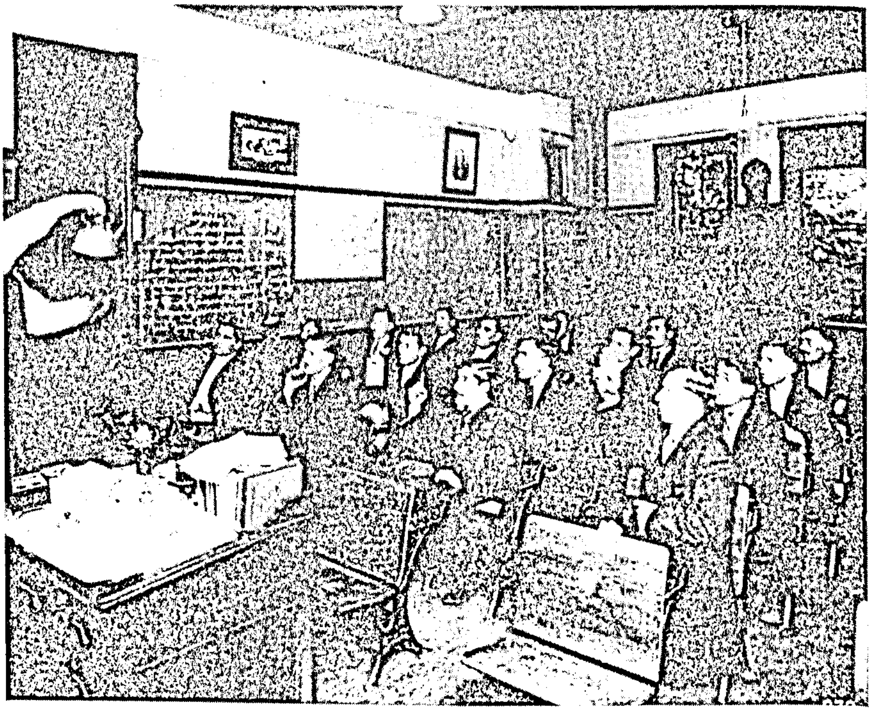
degrees. Edison associated them with inappropriate theories drawn from past experiences. Ford and Edison understood that there were no experts about the unknown; no theories, only hypotheses or metaphorical insights, about the uninvented. Edison even withheld information about prior work on a problem from his assistants, fearing that sharing such information would move them into a particular track and close their minds. He subjected his expert assistants with advance degrees to crude ridicule, hoping to destroy what he considered their smug and unwarranted self-assurance. In common in Ford and Edison's attitudes, we find prejudice and ignorance but also a shrewd understanding of the freewheeling nature of invention and innovation. Unfortunately for Ford and his company, he continued to advocate a leadership style suited for times of invention and great change long after the Ford company had become an extremely large and a relatively stable managerial and technical system with high inertia. Ford would not, or could not, make the transition in leadership style from the inventive stage to the managerial. His attack on a bureaucracy was, in the context of a bureaucracy, irrational behavior. For the company, it would have been a blessing if he had resigned after the Highland Park system of production had stabilized around 1915. Elmer Sperry, on the other hand, regularly left the companies he had helped to found with his inventions. Perhaps Ford sensed his incapacity, even distaste, for management when he considered selling the Ford Motor Company three times between 1908 and 1916. In the style of the inventor, he spoke of entirely new ventures he would undertake if he were relieved of the burden of routine.[44] He found himself bored and constrained by the very system of production he had enthusiastically created. His lack of self-awareness is ironic in view of what he wrote in *My Life and Work*: "Business men go down with their businesses because they like the old way so well they cannot bring themselves to change."[45] He could not understand that he, too, was resisting change from his own old way, invention and innovation, to an appropriate style of management dependent not on radical invention and innovation, but on incremental, slow-paced improvement, growth, and systematization.

Ford's unwillingness to make substantial changes in the Model T can be better understood if we remember that for years he held the large share of the market by regularly reducing the cost of production and the price of the automobile. To reduce costs, his policy was to introduce changes in the mode of production rather than in the product. He wrote:

> Our big changes have been in methods of manufacturing. They never stand still. I believe that there is hardly a single operation in the making of our car that is the same as when we made our first car of the present model. That is why we make them so cheaply. The few changes that have been made in the car have been in the direction of convenience . . . [or] added strength.[46]

He believed that a change such as a six-cylinder engine would force price increases. Ford also confessed that "one idea at a time is about as much as any one can handle." The Model T with a four-cylinder engine was his idea, one that he intended to perfect.[47] Despite his unwillingness to make Model T changes, his longing for the creative experience was demonstrated by other ventures on which he embarked after 1913. Ford the system builder flourished again when he, with Sorensen at his side, planned and constructed the River Rouge plant after World War I. He also revealed his imagination and foresight when he tried, in the early 1920s, to create an industrial complex in the Mississippi Valley and a decentralized system of production at waterpower sites outside of Detroit. The contradictions and complexities in Ford's behavior can be better understood only if we perceive the irony of the creative person engaged in system building. Thomas Mann, in his novel *Doctor Faustus*, captured the ironical essence when he had his protagonist Adrian Leverkühn, creator of a twelve-tone musical system, express a longing for a method of composition. This was a request to which Mephistopheles eagerly assented, for the composer would create a system that would then become an iron cage preventing his further free expression.

Henry Ford's relations with labor as well as with his managers deteriorated in the later years. Like other system builders of his era, he insisted on control, order, and system for workers while fighting it off for himself. For machines he designed, this was no emotional, psychological burden. For men, especially the workers, it was different. Men tending the machine tools and on the assembly line had to conform to the rhythm and logic of machine production. Ford, like Taylor, saw them as components in the system of production, but, also like Taylor, he believed that a well-functioning worker should receive some part of the cost savings for



WORKERS AT FORD COMPANY LEARNING ENGLISH

which he was responsible. Ford wanted to spread the national income among the grass roots, and he also wanted workers to stimulate the market for automobiles and other mass-produced goods. When possible, however, he and his engineers replaced the workers with more easily directed machines. Machines, unlike men, could be designed especially for the function to be performed. They did not strike, and independent thinking did not lead them to vary their work methods from those prescribed by production engineers and planning departments. On the other hand, Ford had to consider that the workers could be laid off in a recession but investment in machines was fixed. Creative and skilled work was done by a relatively few engineers and tool-and-pattern makers; the mass of Ford labor was unskilled and included thousands of newly immigrated Hungarians, Poles, Serbians, Armenians, Bohemians, Russians, Rumanians, Bulgarians, and Italians. A touching photograph from the early years at Ford shows workers diligently studying elementary English during their lunch period. They learned their simplified, routine, and highly specialized tasks in several days, and they, like the parts of the Model T, were easily replaceable.

The workers, however, found the mechanized system of production in place at Highland Park by 1913 so wearing and depersonalizing that the turnover reached 380 percent. If the company wished to add a hundred workers, 963 had to be hired. Signs of unionism alarmed Ford and his staff. The flow of production was adversely affected. In 1914 Ford, disturbed not only by the labor turnover and unionism but also by the great discrepancy in spread between the salaries of his executives and the wages of the workers, decided on an unprecedentedly high five-dollar-a day wage. Job applicants lined up before the factory gates. An anonymous wife of a Ford worker wrote to him:

> The chain system you have is a slave driver. My God!, Mr. Ford. My husband has come home & thrown himself down & won't eat his supper—so done out! Can't it be remedied? . . . That $5 a day is a blessing—a bigger one than you know but oh they earn it.[48]

The decline of the Ford company cannot be attributed solely to Henry Ford. The company's decline was relative to that of other automobile manufacturers, especially the General Motors Corporation under the leadership of Alfred Sloan. By 1927 General Motors had forty-five percent, the leading share of the automobile market, which it did not relinquish. In 1931 the Ford market share had dropped to twenty-six percent, with losses amounting to more than $50 million.[49] Sloan, president of General Motors, introduced consumer credit in 1919, used-car trade-ins, a closed car, and an annual model.[50] (Ford dismissed the costly annual model change with thinly veiled contempt, recalling that earlier it had been common among bicycle manufacturers.[51]) General Motors also depended on general-purpose instead of special-purpose machine tools, thereby facilitating basic model changes such as the replacement of a four- by a six-cylinder engine. Additionally, Sloan, following managerial practice at the Du Pont Company, installed a multidivisional, decentralized management structure that was becoming a model for large industrial firms. Sloan carried Ford's policy of low inventories to a much higher stage of managerial expertise when he introduced control of factory flows. These flows were based on statistical feedback derived from dealer information sent every ten days about orders, deliveries, and new and used cars on hand. General Motors also developed the art and science of long-range forecasting of sales and of allocation of resources.

AUTOMOBILE PRODUCTION AND USE SYSTEM: PETROLEUM REFINING

At the peak of his powers, Ford controlled a highly complex system of automobile manufacture that spread throughout the United States and into other regions of the world. Despite the extent of its holdings, Ford's motor company was only a component in a greater production system, or network, that involved an even larger array of organizational, production, supply, and service activities.[52] Besides the automobiles, this automobile production-and-use system involved physical components like the automobile, roads, and service stations, as well as people and organizations like automobile manufacturers, the suppliers of raw materials and components to the manufacturers, the unions organizing the automobile workers, the dealers selling the automobiles, the suppliers of gasoline, the operators of a network of service stations, the public authorities constructing highways, the organizations financing car purchases, and numerous other organizations such as advertising agencies stimulating the market. No individual or organization could centrally organize and control the automobile production-and-use system, but in diverse and complex ways a level of coordination was achieved. Ford's visible hand coordinated the system he created; the invisible hand of the market, along with a variety of informal institutional and personal ties, coordinated automobile manufacture and petroleum refining.

Karl Marx in *Capital* showed how increased production by weavers during the British Industrial Revolution stimulated an increased output of spinners and how, in turn, technical improvements and output in spinning forced the development of weaving. The systematic interaction followed from the overarching goal of cloth production that inextricably linked spinning and weaving. The increased production of cloth also put pressure on the British chemical industry to find ways to improve the quality and to increase the quantity of bleaches and dyes. Similarly, in the twentieth century, automobile production has been inextricably interwoven with the refining of gasoline. In both cases, the concepts of mass production and flow dominated the producers.

During the nineteenth century kerosene for lamps was the chief product of the petroleum refiners. The gasoline fraction, or component, of petroleum was a waste product. The dramatic rise in automobile use after the turn of the century brought a dramatic change—the refiners needed to find ways to increase the yield of gasoline, the lighter fraction of petroleum. Between 1909 and 1913 Dr. William M. Burton, a Ph.D. in chemistry from The Johns Hopkins University and refinery superintendent with Standard Oil Company (Indiana), developed the process of thermal cracking. In contrast to an earlier distilling technique that involved heating petroleum in open vessels to drive off the various fractions, beginning with the lighter ones and proceeding to the heavier, Burton heated the raw petroleum in a closed vessel. The pressure that built up in the vessel broke down, or cracked, the heavier molecules of the heavier fraction—once used for kerosene—into lighter, or gasoline, molecules. When he received the Perkin Medal in 1921, Burton recalled that his success in almost doubling the yield of gasoline from a barrel of crude came from his foolishness in heating oil under pressure despite the obvious danger of an explosion. By 1920 other cracking processes stimulated by Burton's success rendered his obsolete, but the Burton process brought Standard Oil of Indiana profits of $150 million.[53] This success also brought other refiners to invest in chemists and chemical engineers. (When young Burton had first arrived at Standard Oil of Indiana with his Ph.D., his superintendent asked him where his tools were.)

Other refiners burdened by license fees for the Burton process turned to engineers and research scientists for alternative ways of responding to the steadily rising demand for gasoline. Because of dire predictions in the early 1920s of an early exhaustion of the world's supplies of crude oil, the need to increase the amount of gasoline from a barrel of crude appeared critical. In Germany scientists and engineers sought ways to derive gasoline from coal. Authorities estimated that petroleum supplies would be exhausted within fifteen years. Others saw a good possibility for improving the yield from the Burton process by increasing the rate of flow of materials through the refinery. Petroleum refiners, emulating Ford and Taylor, became obsessed with the need to systematize and increase the flow of production. Burton's was a batch process, in contrast to continuous flow. Petroleum was statically contained in tanks, or stills, as it was processed. Afterward refinery workers removed the products and recharged the still with another batch. As had been the case with the steam engine before James Watt introduced his separate condenser, the cylinder—or still, in the case of the Burton process—had to be alternately heated and cooled, with attendant wastes. The answer to the static nature of the batch process was one of continuous flow, in which petroleum passed through a stage where various transformations, or unit operations, occurred because of heating, cooling, and so on. Similarly, Ford had moved the evolving automobile past workers at fixed stations, where they carried out particular functions. No wonder that an American engineer visiting China about this time thought the principal differences between the two countries were that in the United States everything and everyone was in motion.

The Universal Oil Products Company introduced the continuous cracking process of a young inventor named Carbon Petroleum Dubbs. (Jesse Dubbs, a Massachusetts Institute of Technology graduate and also a pioneer in the petroleum industry, had given his son this name.) J. Ogden Armour, whose family fortune had been made in meat packing, invested in the Dubbs process because he saw a parallel between the earlier introduction of a cost-saving continuous disassembly line in the abattoir and continuous cracking in the petroleum industry.[54] The Dubbs process involved a number of stations in sequence. Heat and pressure remained constant at each station as the oil passed through and the products of the cracking process were sequentially removed. Having proved more economical than the Burton process, by 1924 the Dubbs process was displacing it throughout the industry. With an increasing allocation of money for research and development throughout the petroleum industry, the Burton and Dubbs processes proved to be only the beginning of a series of improvements resulting in greatly increased gasoline yield from the stock of crude oil.[55]

Before 1930 the oil refiners and their chemists and engineers, worried about an energy crisis, concentrated on increasing the yield rather than the quality of gasoline. But after the discovery in late 1930 of the rich East Texas oil fields, their emphasis shifted to quality. The East Texas fields had more than three thousand producing wells by December 1931. Greater production kept the ever-increasing number of automobiles on the road, but improved quality allowed higher-compression engines to move the autos down the highways faster and more efficiently. Even before the bountiful oil of East Texas solved the oil shortage, however, Charles Kettering and his gifted associate Thomas Midgley, Jr., cooperated with the automobile manufacturers to reduce engine knock and allow higher engine compression. During World War I Kettering, whom we last encountered watching his flying bomb soar out of control to dizzy heights, had also tried to improve the quality of gasoline for airplane engines and thereby to reduce knocking—a sharp ringing sound also familiar to early automobile owners when their engines were working hard.[56] Not only annoying and an indication of inefficient combustion, knocking could become physically destructive. Employed by Kettering, who headed an independent research lab, Midgley, a mechanical-engineering graduate of Cornell University, soon after the war took the lead in the search for a gasoline additive to reduce knocking. The resulting search, which continued after Kettering became head of the newly formed research-and-development division of General Motors in 1919, provides an insight into the combination of empirical method and systematic research common in the industrial laboratories of the day. Midgley attributed his eventual success "in part to luck and religion, as well as to the application of science."[57]

Probing the unknown, Midgley and Kettering assumed that the fuel's low volatility caused the knocking. Then Midgley invented by analogy. He remembered that one of the first-blooming spring flowers was trailing arbutus, which had red-backed leaves, and he assumed that the early blooming resulted from red's absorption of the early-spring heat. So he tried dyeing gasoline red with iodine, the only red coloring substance in his storeroom. He hoped that this would increase volatility and reduce knocking. Iodine reduced knocking, but not because of its red color. It also, as Midgley observed, had a "slight" drawback: iodine changed the cylinder into a salt factory, with the cylinder walls as the raw material. Over several years Midgley tried more than thirty-three thousand compounds in his search for an antiknock additive. He called this hunt-and-try an Edisonian approach, a misnomer common among research scientists who did not know that Edison's approach at Menlo Park often involved a theory-based systematic approach as well as hunt-and-try. Then, by chance, Kettering read a newspaper article reporting a universal solvent, which, he and Midgley noted with amusement, was delivered in a glass bottle. Interested in the inflated claims and open to the slightest leads, they tried selenium compound, the solvent, and found that it did reduce knock. Used as a gasoline additive, however, selenium had an extremely unpleasant odor. He found that, after a day in the lab experimenting with the selenium compound, he had to forgo family, friends, and the evening movie.

Next he resorted to what he called applied science. He made a pegboard of the chemist's periodic table of the elements and began testing various soluble compounds of other elements in the table in the vicinity of selenium. In the board he inserted wooden pegs of a length corresponding to their antiknock properties.[58] Midgley said that he had turned a wild-goose chase into a "scientific fox hunt."[59] The hunt ended with tetraethyl lead, which worked perfectly after a few additives were found to prevent harmful deposits. Developing and producing leaded gasoline in quantity required a complex system involving universities, chemical companies, automobile manufacturers, and petroleum refiners, among them the Dow Chemical Company, General Motors Corporation, Du Pont Chemical Company, Standard Oil Company of New Jersey, Brown University, and the Massachusetts Institute of Technology. A newly formed enterprise, Ethyl Gasoline Corporation, a company formed by General Motors and Standard Oil of New Jersey, marketed the leaded gasoline.[60]

With production, the specter of lead poisoning then arose, and a number of physicians warned of the risk. In 1924 the U.S. Bureau of Mines experimented for months by exposing animals several hours each day to exhaust from an engine running on leaded gasoline. They found "no indication of plumbism in any of the animals used."[61] Then, however, forty-five persons handling the concentrated tetraethyl lead at a pilot plant fell ill, and four died from lead poisoning. In 1925 sales were halted. The U.S. surgeon general appointed a committee to investigate the potential hazard. Chemical authorities decided that, when the distribution and use were controlled by proper safeguards, there was no hazard from gasoline containing tetraethyl lead.[62] "Ethyl" no-knock gasoline then became common at service stations. Decades later the additive was targeted as an environmental hazard.

In the 1930s a French independent inventor working outside the mainstream of petroleum technology developed another major improvement in the quality of gasoline. Eugène Jules Houdry, born near Paris in 1892, received a technical education at the Paris Conservatoire National des Arts et Métier. Auto racing fascinated this son of a wealthy steel manufacturer, and in 1922, when he attended the five-hundred-mile Memorial Day Race at Indianapolis and inspected Ford's plant in Detroit, he concluded that American automobiles were of excellent construction but that the gasoline used was of poor quality. He then realized that advances in automotive-engine design depended on simultaneous advances in petroleum refining.[63] In 1925, drawing on his own and his wife's inherited wealth, he began the search, not for an additive like lead, but for a new way of refining petroleum that would produce a gasoline of high quality. After thousands of experiments, he and his associates found in 1927 that using activated clay as a catalytic agent during the refining process produced such a gasoline. Technical problems remained, but Houdry approached the Standard Oil Company of New Jersey. Finding the Houdry process technically unrefined, the Standard Oil engineers turned down the outside inventor's process. They probably did not know that there was a long history of industrial labs' buying crude devices, like de Forest's three-element tube or Pupin's loading coil, and then greatly improving their technical and economic efficiency. Turning to other

U.S. refiners, Houdry ultimately secured support from the Vacuum Oil Company, and from Sun Oil Company, a relatively small firm known for its innovative spirit. By 1936 Houdry-process gasoline was in the service stations. Then, in 1938, Standard Oil of New Jersey, in alliance with Standard Oil of Indiana, the giant German chemical company I. G. Farben, and M. W. Kellogg Company, a U.S. engineering-construction firm, responded with the formation of Catalytic Research Associates, whose goal it was to improve on the Houdry process without infringing its patents and without paying license fees. A landmark event then, though it is almost forgotten now, the formation of Catalytic Research Associates probably represented the largest *ad hoc*, or single-purpose, concentration of scientific and engineering manpower in the world prior to the establishment of the Manhattan Project. Four hundred engineers and scientists were involved at Standard Oil of New Jersey, and six hundred in other companies.[64] In 1941 the crash program brought forth the "fluidized catalytic cracking process" that exploited the principle of continuous flow more fully than the Houdry process and produced a gasoline of high quality.

INSULL THE SYSTEM BUILDER

Petroleum refiners and automobile manufacturers managed smoothly flowing processes of production, but their products and rates of production did not compare in subtlety and velocity with that of an electric light-and-power system. The latter's product, the moving electron, traveled at the speed of light. An automobile-production system loosely linked countless machines and processes by clanking conveyors, flapping belts, and heavy, traveling cranes. An electrical-supply system was a seamless web of whirring machines and humming transmission lines. Insull, as a master system builder, presided over one of the world's largest and most complex power systems. Ford, his mechanics, and engineers had to allow for the irrational and unmanageable nature of thousands of workers; Insull and his associates felt omnipotent as they manipulated pliable machines and processes in great power plants attended by only a man or two. Insull and other heads of major urban and regional electric light-and-power utilities created systems of mass energy production that preceded the better-known Ford system and anticipated its essential characteristics. Throughout the world, Insull and Commonwealth Edison of Chicago, his principal utility, were respected as setters of standards of efficiency and growth, until Insull's utility holding companies began to collapse during the Great Depression. In the presidential campaign of 1932 Franklin Delano Roosevelt, aware that Insull had become a symbol of financial manipulation to the public, delivered a long attack on him and electric-utility holding companies. He spoke of the "lone wolf, the unethical competitor, the reckless promoter, the Ishmael or Insull whose hand is against every man's. . . ."[65] With reason, Insull's biographer, historian Forrest McDonald, characterizes him as "America's most powerful businessman of the twenties—and its most publicized business villain in the early thirties."[66] Today a respected historian refers to him, because of his financial manipulations, as a "notorious crook."[67] Yet Insull was found not guilty of the charges of financial chicanery for which he was indicted. Before his fall he was an impressively accomplished technological-system builder. In 1934, when he was on trial for using the mails to defraud in connection with his bankrupt holding company, Insull denied that he was a predatory holding-company tycoon, insisting that he, like Edison his hero, was a creative man enthusiastically committed to managing an expanding and productive technology.[68]

Insull learned system building in the Edison school. Edison, he said, "grounded me in the fundamentals. . . . No one could have had a more considerate and fascinating teacher."[69] From a middle-class, dissenting-Protestant background, Insull had emigrated from England, where he had been secretary to Colonel George E. Gouraud, Edison's business representative. On arriving in the United States in 1881, when he was twenty-one, Insull became Edison's personal secretary. From then until 1892, when he became manager of the Edison General Electric plant in Schenectady, New York, Insull witnessed and took part in the formative years of the electric utility and manufacturing industry. He closely observed Edison and helped him create his electric-light system, build the path-breaking electric central station on Pearl Street in New York, and

SAMUEL INSULL, 1885

establish the various plants to build incandescent lamps, electric generators, and distribution cables. Insull sat in on countless meetings where engineers, mechanics, business entrepreneurs, financiers, managers, and others pooled their knowledge and resources to solve the problems of expanding electric light-and-power systems. He absorbed the creative, problem-solving, systematizing, and expansionistic approach of the system builder. He learned from Edison how to solve problems by weaving a web of ideas, artifacts, and people. Insull pleased Edison, and would have Ford, because he was no expert, no specialist. If he had attended an engineering school and been trained as a specialist grounded in science, as was increasingly the case in the expanding engineering colleges of his day, he might never have absorbed the problem-solving approach of an Edison or a Ford. None of the three rigidly sought a mechanical, electrical, or chemical solution. Instead, all ranged widely for answers without respecting disciplinary boundaries. If a technical response did not work, they resourcefully turned to one commonly labeled political or economic.

In 1892, after the Edison company merged with the Thomson-Houston Electric Company, Insull left the newly formed General Electric Company to head the Chicago Edison Company, a small Chicago electric-supply utility. He accepted the challenge of building the system, but with certain conditions. He would not be involved in financing the company, and the directors and stockholders would supply sufficient capital at all times; in addition, the company would build a new power plant and pay for it by issuing $250,000 in stock, all of which would be sold to him. (He borrowed the entire amount from the wealthy Chicago merchant Marshall Field.[70])

Within three decades he had absorbed about twenty other Chicago electric utilities to form the Commonwealth Edison Company, which monopolized the Chicago market and became known as early as 1910 as the world's leading utility. By the 1920s he had interconnected the Chicago system with others in urban and rural areas to create a regional electric-supply network. Then he established the Middle West Utilities Company, a holding company with electric-supply properties throughout the nation. This holding company brought him to the attention of Roosevelt and others campaigning against private utility holding companies. Like other system builders, Insull strove to merge, couple, link, centralize, and control all of the institutions and artifacts that he needed to solve the problems of supplying electricity at low cost to a mass market. To create the electrical empire that he managed in the 1920s, he combined or coordinated physical artifacts, such as electric generators, transformers, and transmission lines, with organizations like utility companies, investment banks, and state regulatory agencies. He saw to it that all of these components interacted effectively, he insisted, to produce electricity efficiently. His critics saw him as creating a monopoly primarily to produce profits. He countered with statistics showing that his companies followed the best American practice and took small unit profits on massive sales of kilowatt hours, while others took large profits on small sales.[71]

Insull's policies show how he simultaneously manipulated a broad range of technical, economic, and political factors. With the technical advice of Sargent & Lundy, a forward-looking firm of consulting engineers, Insull and his staff pioneered in the introduction of steam turbines to replace reciprocating steam engines in central stations. Because turbines represented much larger concentrations of power than the reciprocating steam engines they replaced, Insull and his engineers had to extend the area served by a single massive central station. To do this, he used his considerable political power in Chicago to bring about the enlargement of the franchise held by his company. He also had the imagination to call for state, rather than city and county, regulation of electric supply. This allowed him to extend the area served by his growing electric-supply system to the borders of the state, not simply to the borders of the political jurisdiction of Chicago. Having drawn on his technical and political resources, he then turned to the Chicago stock-and-bond market. The Chicago investment-and-brokerage firm of Halsey, Stuart and Company became a part of the Insull empire. Because of Insull's reputation for management, and because of the profits and expansion of his company, its securities could be sold at lower interest rates. Lower interest rates, in turn, meant lower-cost electricity. He thrived before the onset of the Great Depression, for financing seemed always available, markets insatiable, and cost reductions through improved technology unending.

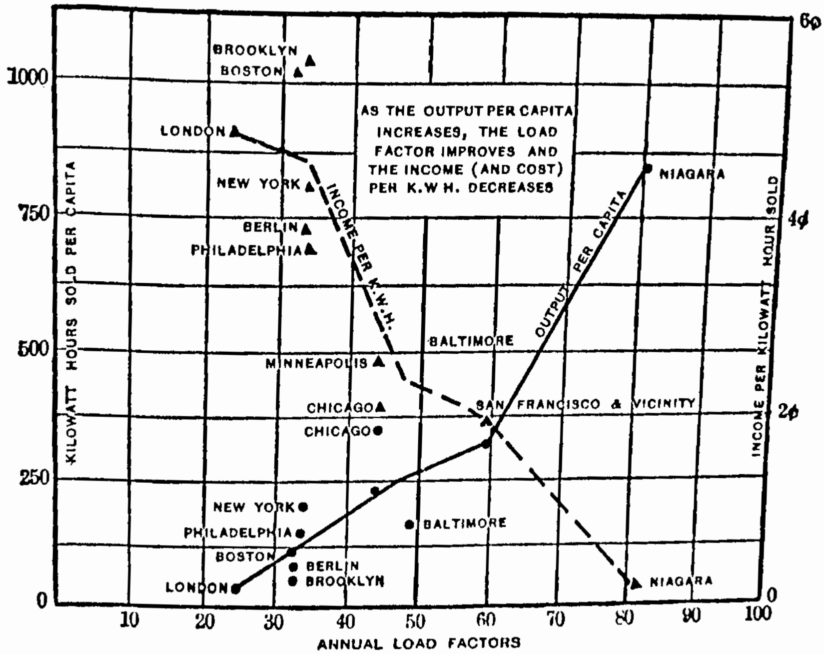
By the mid-1920s his electricity-and-gas-supplying system—his empire—consisted of Commonwealth Edison, a $400-million company serving electricity in Chicago; Peoples' Gas, a $175-million Chicago gas utility; Public Service of Northern Illinois, a $200-million company supplying gas and electricity in three hundred communities around Chicago; Middle West, a holding company with several hundred subsidiaries representing an investment of $1.2 billion supplying electricity and gas in five thousand communities spread over thirty-two states; and Midland, another holding company, representing an investment of $300 million, supplying gas and electricity in Indiana communities. These and several other enterprises that he controlled and managed amounted to nearly $3 billion in utility properties, with six hundred thousand stockholders and about five hundred thousand bondholders supplying about four million customers with about one-eighth the electricity and gas consumed in the

United States. Insull's personal stock and bond holdings in this empire, however, were not impressive by the standards of his day: his net worth in 1926 at age sixty-seven was about $5 million. "His friends and enemies would have been shocked that it was so little; he could easily have made twenty times that, had he been willing to work for the sake of acquiring it, but since 1912—by which time he had a million pounds sterling—he had simply not been interested in accumulating money."[72] Manipulating and controlling an immense system of things, institutions, and people may have filled his psychological needs more fully than money making.

The technical intricacies and organizational complexities of Insull's creation were too abstract for the public and press to comprehend or to visualize, as they could Henry Ford's automobile empire. Therefore Ford, not Insull, became the world-famous system builder, and he remains so today. The public could see the assembly lines moving, the blast furnaces pouring forth metal, the machine tools cutting, shaping, and turning at Ford's River Rouge plant, but the electricity flowing out of Insull's central stations over thousands of miles of transmission lines to power countless motors driving factories and railroads remained too ephemeral for the public to envisage. Not only did Insull and his lieutenants create a system for mass-producing energy, but they also articulated the concepts of mass production more subtly, more extensively. Today Ford's mechanistic concepts seem familiar, fairly simple, and bear the patina of the era; Insull's remain vital, complex, and applicable in an era that remains essentially electrical. Before the Ford system of mass production was analyzed and widely publicized by Horace Arnold, a technical writer, in *Engineering Magazine* (1914)[73] and more than a decade before the *Encyclopedia Britannica* (1926) published a widely quoted article attributed to Henry Ford on "Mass Production,"[74] Insull summarized his ideas of mass production in a series of public addresses (1897–1914).[75] Other thoughtful utility managers in the United States simultaneously grasped many essential principles of electricity supply and learned from one another, but Insull, with the help of his accounting and planning staff, articulated these principles, so that he became a spokesman for his peers in the United States and abroad. (In the 1920s the British government asked him to preside over the planning of their national electric supply grid.)

By the turn of the century Insull had absorbed the spirit driving the rapid industrialization—a second industrial revolution—in his adopted country. He believed in mass production and mass consumption, and accepted the conditions of capitalism. Translating these into utility policy, he created a dynamic system of production in which flow was the cardinal principle, flow of production from raw materials such as coal to the consumption of kilowatt hours by various consumers. Unlike European utility magnates, he stressed, in a democratic spirit, the supplying of electricity to masses of people in Chicago in the form of light, transportation, and home appliances. In Germany, by contrast, the Berlin utility stressed supply to large industrial enterprises and transportation, but was relatively indifferent to domestic supply to the lower-income groups. In London, utilities supplied at a high profit luxury light to hotels, public buildings, and wealthy consumers.[76] Fully aware that the cost of supplying electricity stemmed more from investment in equipment than from labor costs, Insull concentrated on spreading the equipment costs, or interest charges, over as many kilowatt hours, or units of production, as possible. Much as Ford later pushed the evolving Model T through his production plants as rapidly as possible, Insull processed energy as quickly as possible in his power plants. During the time in plant, the product was absorbing the cost of capital—interest charges. Smooth flow became a fixation for Ford, Insull, their managers and engineers. Flow was smoothest when the means of production were coordinated systematically.

Because electricity could not be economically stored, Insull and the electrical-utility managers felt especially keenly the pressure of maintaining flow of production and consumption. In the case of most manufacturing industries, the product could be stored, or stockpiled, when consumption fell, and products could be fed out from storage when consumption increased. In the case of electricity, customer demand had to be met instantly. When darkness fell on a cold December day while the factories and the transportation system were running at capacity, Commonwealth Edison had to respond. The company had to have elec-

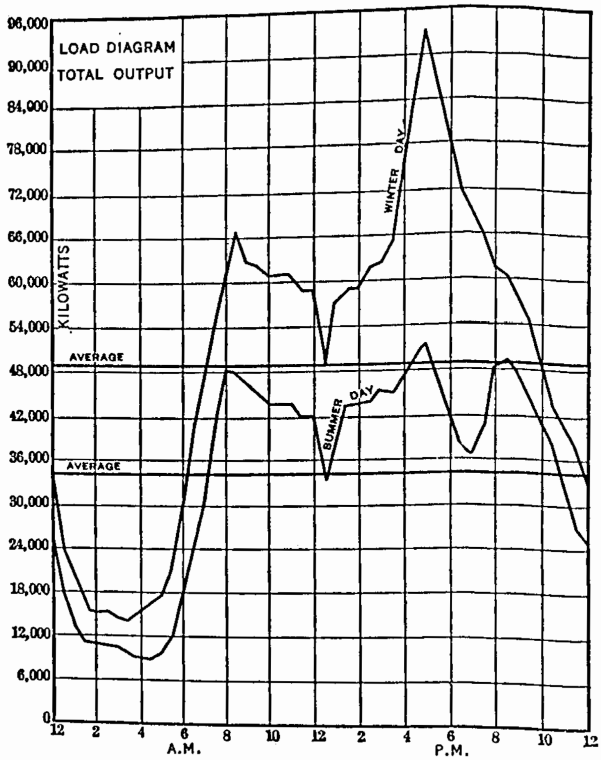


INSULL'S UTILITY ECONOMICS

tric generators with sufficient capacity to meet this peak, even though for the remainder of the twenty-four hours the consumption was lower—in the late evening and early morning hours, much lower. Production and consumption had to be coordinated.

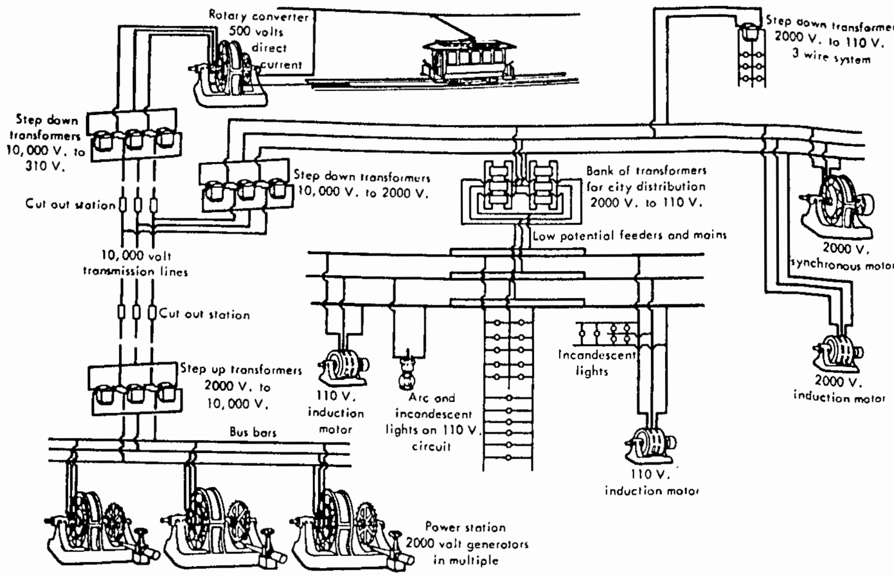
It became customary in the utility industry to draw a curve showing the variation, throughout a twenty-four-hour period, of production of kilowatts of energy. Insull often showed these in his lectures and articles. The "load curve" graphically showed the valleys of low electricity demand and the peaks of high. More generally, Insull and others in the electrical industry realized that the load curve portrayed graphically one of the cardinal realities of a capitalistic society: the relationship between investment and the utilization of investment. In the case of an electrical utility, the curve usually displays a valley in the early morning, before the waking hours, and peaks in the early evening, when business and industry use power, homeowners turn on lights, and commuters increase

COMMONWEALTH AND EDISON COMPANY LOAD DIAGRAMS, 1907–1908



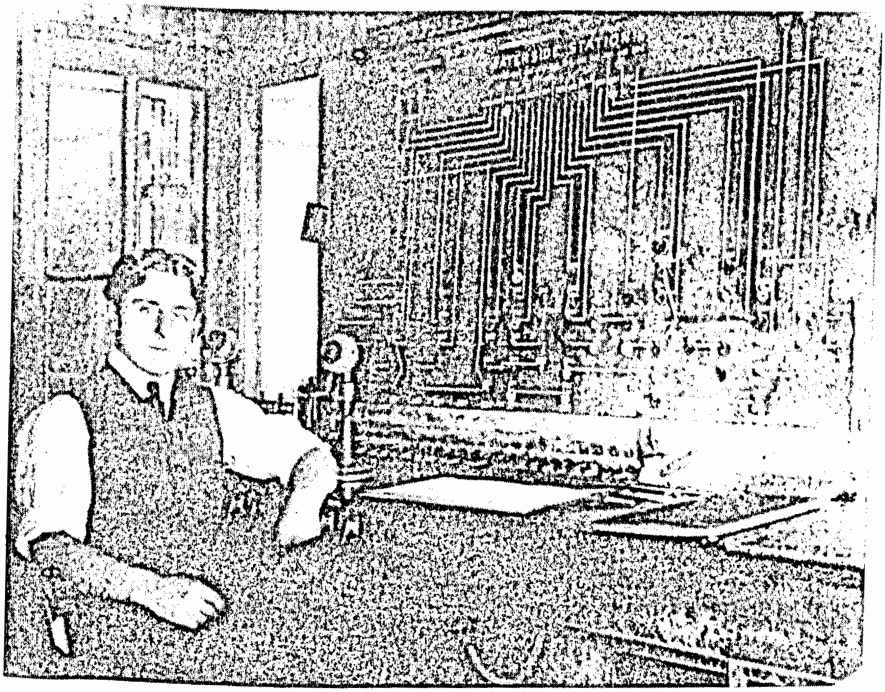
their use of electrified conveyances. Showing graphically the maximum capacity of the generator, power plant, or utility—which had to be greater than the highest demand—and tracing the load curve with its peaks and valleys, starkly revealed the utilization of capacity, or investment. With this information, Insull and his associates then did everything possible to fill the valleys. In this way the interest charges arising from the equipment installed to meet the peak load could be spread over many units and lower the cost of each kilowatt. The goal was simple and obvious, but the means to obtain it were complex, and the result for society momentous. As costs in other modern technological systems, such as the commercial airlines, computer networks, and communications, have become increasingly dependent on the cost of capital (interest), load-factor problems have also loomed larger and larger for them. Today the bewildering variety of rates devised to encourage us to fly and telephone during hours of low traffic are one indication of the pervasiveness of load-factor considerations and of load management. Utility managers realized this by the turn of the century and began to introduce rates according to time-of-day usage.[77] This is one more example of how we live our lives in a human-made time and space filled by the forces unleashed by technological systems.[78]

To fill the valleys in the load, or demand, curve, Insull resorted to a policy that came to be known as "load management." It was also social manipulation. Through expansion, variations in the charges for electricity, and advertising, Insull manipulated consumers of electricity. By expanding the service area of Commonwealth Edison and other progressive utilities in the United States, he exploited diversity of consumption. Expansion to achieve diversity is an infrequently recognized but major explanation of the inexorable growth of technological systems. Often the uninformed and suspicious simplistically attribute the expansion of systems only to greed and the drive for monopoly and control. All other circumstances being the same, a utility is more likely to find in a large area, rather than a small, a diversity of consumers, some of whom would use electricity during the valley—rather than the peak—hours of consumption. Then the utility attracts them by favorable rates. Chemical plants filled the valleys well, because their nearly labor-free processes could be carried on throughout a twenty-four-hour period. Through advertising, utility salesmen also pushed the sale of home appliances such as irons, fans, vacuum cleaners, refrigerators, and, later, air conditioners. After World War II the sale of air conditioners ironically created a new and undesirable peak of consumption on hot summer days. Insull pioneered in load management through appliances by establishing in 1909 an "Electric Shop." The ground floor emphasized domestic appliances; on the floor below, an Industrial Power Room displayed a wide variety of electric-motor-driven machines. Australians on an observation tour of North American utilities found the Electric Shop a remarkably effective marketing scheme. Chicagoans, they decided, did not hustle more than others elsewhere in the world, but their hustling was more organized. Insull was pleased. American consumers also seemed pleased by load management and manipulation when it meant shiny new gadgets.



AN EARLY ELECTRIC LIGHT AND POWER SYSTEM

Behind the scenes, in places like load-dispatching centers and power plants about which American consumers were only dimly aware, Insull and other utility magnates and engineers pulled the strings of control even more deftly. They organized and systematized to achieve an "economic mix." Managing a mixture of interconnected power plants, some old, some new, some efficient, some inefficient, some using coal as fuel, others using waterpower, the utility engineers combined the output of the different plants to achieve the most efficient "economic mix." Sitting in a control center that was the esoteric high technology of the 1920s, the load dispatcher had before him a mass of indicator lights, diagrams, and switches that allowed him to keep the most efficient power plants in the system "on line" continuously and to switch in and out the less efficient plants to meet peaks of demand. To anticipate the rapid-fire switching necessary, the load dispatcher had information about the peaks and valleys on the same day of the previous year. Few better examples can be found of the direct applicability of history. The intellectual attraction—the elegant puzzle-solving aspect—that load factor, economic



A LOAD DISPATCHER, 1902

mix, and load management had for Insull the system builder and for the engineer-managers of rapidly expanding electric-power systems becomes understandable. This is not to deny the drive for power and profit, but to acknowledge human delight in "sweet" problem solving.

By the mid-1920s the far-flung Insull empire incorporated diversity and economic mix. To use the jargon of the day, it was a utility with a "good load curve." Not only were diverse customers interconnected by high-tension transmission lines carried on the great towers that symbolized modernity, but power plants in waterpower regions were connected to those in coal-rich regions hundreds of miles distant. These technical systems demanded organizational innovations. One of the most inventive organizational responses was the utility holding companies of the 1920s. Holding companies had a long history, extending back at least as far as those designed for railroad empires in the nineteenth century, but the

INSULL IN HIS PRIME

holistic subtlety of the electric-utility holding companies was unprecedented. Insull organized Middle West Utilities Company in 1912. Like others mushrooming in the United States about the same time, Middle West acquired the securities of far-flung small electrical utilities in exchange for its own stock and cash. The holding company also sold its stocks and bonds to the public. In this way the holding company gained control of a large number of utilities, and if these were physically contiguous they were often physically interconnected with high-voltage transmission lines, with the resultant benefits of diversity, economic mix, and higher load factors. Holding companies not only financed the technical and organizational improvements in the numerous companies under their control, but often constructed the new facilities and managed the small companies. Well-conceived and -managed holding companies efficiently integrated the financial, engineering, and management aspects. Others became the settings for financial chicanery and the watering, the ballooning, and the pyramiding of holding-company stock.

The heyday of the holding company came in a later stage of the evolution of electric light-and-power systems. In the opening stage, inventor-entrepreneurs like Edison solved the major technical problems. In the following stage, Insull and other manager-entrepreneurs presided over the organizational innovations facilitating growth. During the next stage, financiers took over the leading role. They had the capability to solve the critical problem of raising the immense amount of money needed by holding companies to form regional networks of power. During the 1920s Insull, essentially a manager-entrepreneur, began to fear that he would lose control of his utility empire to financiers, especially to the New York ones whom he as a Chicagoan found especially rapacious.

In 1928 he saw the major threat coming not from New York, however, but from Cyrus S. Eaton, a creative Cleveland capitalist who had also built utilities from the ground up. Despite this, he had a reputation as a "financial buccaneer" whom many saw as swimming sharklike in "the big leagues of utility operations."[79] Insull observed with concern that Eaton was quietly buying large blocks of stock in Commonwealth Edison, Middle West, and other Insull companies. Insull the manager-entrepreneur, like Elmer Sperry the inventor-entrepreneur, believed that he, like a shoemaker, should stick to his last. But he violated this rule to enter the unfamiliar world of high finance in an effort to thwart the raid he expected from Eaton. Insull decided to pyramid in order to transform his control of his utilities from that of manager to that of proprietor. In 1928 he established Insull Utility Investments (IUI), an investment trust, the controlling stock of which he and his friends acquired in exchange for the utility stock they owned. Utility Investments then raised money to acquire control of the various Insull utilities.[80] In 1930 Insull took the fateful step of removing the Eaton threat by having Insull Utility Investments and the Corporation Securities Company, another newly formed Insull investment trust known as "Corp," purchase for $56 million the Eaton holdings in the Insull empire. Because Chicago bankers could only partly finance the purchase, Insull had to borrow a substantial part of the money from New York financiers and give as collateral IUI and Corp stock. If the value of these stocks fell, Insull would have to increase the amount of stock correspondingly.

According to Forrest McDonald, "The New York financial club, abristle with excitement at the prospect of giving Insull his comeuppance, at last, and atremble at the prospect . . . of all those millions," moved in to take over from the once-independent and still-defiant Chicagoan.[81] It was 1931, the country was sunk in the Great Depression, and in September Britain abandoned the gold standard and stock prices plunged. Increasing amounts of IUI and Corp securities had to be put up as collateral against the Insull bank loans. By mid-December the combined portfolios of the two investment trusts fell into the hands of the bank creditors. "Coolly and with finesse, the Morgan group moved in for the kill. The kill took about six months, for though the House of Morgan could be devastatingly predatory, it was never impatient and it was never messy."[82]

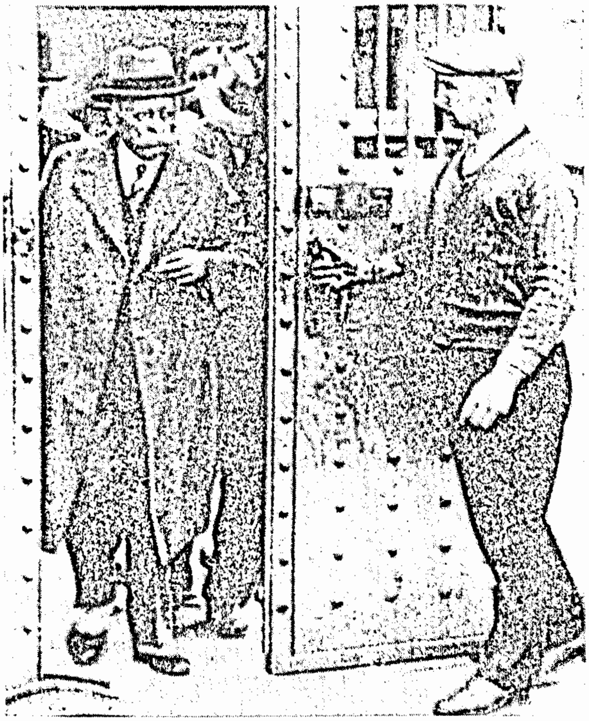
Ostensibly seeking a solution to the plight of the Insull companies, the bankers called for an audit of Insull books and incidentally a report on any improper transactions. After the auditors changed the mode of calculating depreciation to an industrial one, rather than the one used by Insull and most utilities, they could then declare the Middle West holding company insolvent, a situation that the auditors maintained was concealed before by improper bookkeeping. The auditors also found a number of corporate indiscretions, so rumors began to circulate about the plight of the Insull empire, and hints were even dropped about fraud and embezzlement. Insull worked furiously to save Middle West, for the utilities it controlled were in good economic condition, but in April 1932, at an afternoon meeting in New York, the bankers told Insull that no one would put up more money for Middle West and that it was in receivership.

For the seventy-three-year-old Insull, the end then came quickly. In June, Stanley Field, a trusted friend of Insull's and like him a generous Chicago philanthropist, carried the message, not only from New York bankers but from Chicago bankers and business leaders as well, that they wanted his resignations from all of his companies. They argued that, because of the failure and suspicion now surrounding him, the remaining credit of the companies would vanish unless he complied. Insull uncharacteristically acquiesced without a struggle, and signed resignations from sixty-odd corporations. He and his wife, Gladys, then sailed for

Europe, to live in Paris in relative obscurity until the politicians decided that from the Insull collapse they could make political capital. In September, John Swanson, state's attorney for Cook County (Chicago), told Insull's son-in-law, "You know Sam Insull is the greatest man I've ever known. No one has ever done more for Chicago, and I know he has never taken a dishonest dollar. But Insull knows politics, and he will understand . . . I've got to do it."[83] Swanson then announced that he would launch an investigation of the scandals involved in the collapse of Insull's empire.[84] On the initiative of Swanson, a Cook County grand jury indicted Insull and his associates for embezzlement and larceny. Newspapers headlined the investigation, and local politicians throughout the country played on the resentments of stockholders in the far-flung Insull companies. Insull, persuaded that he would be subject to a political lynching by angry stockholders led by publicity-seeking politicians, sailed to Greece, where he believed he could avoid extradition until the tempest had passed. One anonymous note to his wife said, "You can get ready to buy a cemetery lot as the gang will send you your crooked boys head. you will pay as we have paid our good money. that has been stolen by the dirty yellow crooked Insulls Jews. . . ."[85] The Roosevelt administration succeeded in having him extradited, so in October 1934 Insull and his associates stood trial in Illinois for using the mails to defraud in the sale of the "worthless" stock of the corporation.

The prosecution rested its case on a mass of evidence taken from the records of the Insull companies. The defense, led by Floyd Thompson, a brilliant trial lawyer, succeeded in showing that critical prosecution arguments depended on the interpretations—not illegality—of accounting methods. For instance, a key prosecution witness testified that the Insull company had improperly treated certain expenses, but then, under cross-examination, had to admit that the system used by Insull was used by the government itself. The defense built its case on a sentimental account of Insull's life story that he had been persuaded to organize into autobiographical reminiscences while he was awaiting trial. On the stand, Insull told a story of the rise of a young immigrant to a position of wealth and power. He stressed his long association with the legendary Edison and the build-up of the utility industry through technical and organi-

INSULL RELEASED FROM JAIL, CHICAGO, 1934



zational changes. The jury was fascinated, and even the prosecuting attorney half-said, half-inquired, privately to Insull's son, "Say, you fellows were legitimate businessmen."[86] The jury, impressed by Insull's system building and persuaded that a crooked business would not have exposed all of its crimes in its books as, in effect, the prosecution was maintaining it had, quickly returned with a verdict of not guilty. Insull was also found not guilty on other charges in other trials. In 1938, having retired with his wife to Paris, Insull died of a heart attack in a subway. McDonald has pointed out that all of the operating electric and gas utilities Insull had managed survived him—and the Depression—and ultimately the personal collateral Insull gave his creditors in 1932 became worth $10–15 million more than the debts. Only about one-fifth of the Insull securities in public hands in 1932 were forfeited in any way, in contrast to a figure of close to forty percent for the securities of all American corporations.[87]

Insull's legacy, however, remains unclear. Despite his acquittal by the courts, a leading historian recently referred to him as a crook. At the bar of history, pronouncements about Insull's legacy will depend much on whether he is judged as a financier or as a system builder. As an organizer and a financier of holding companies he was, in comparison to a J. Pierpont Morgan, inept. As a system builder, he carried on in the tradition of Edison by bringing the urban utility system he invented and organized to the next-higher stage of development. Insull was an inventor, too, but his creations were coordinated organizations instead of integrated electrical circuits.

TENDERS OF TECHNOLOGICAL SYSTEMS

As electric light and power, automobile production and use, and numerous other production systems spread, not only system builders and financiers but also trained technicians and managers were needed. They provided a rank and file for operation and maintenance. For centuries expanding production systems had absorbed countless workers, but in the new era of system building, tens of thousands of persons, almost exclusively men with training in scientific engineering and management, were needed as well. As a result, there was an enormous increase in the number of university- or college-trained engineers who knew how to use engineering science and apply economic principles in solving the day-to-day problems of production. Earlier, the majority of engineers had constructed canals, roads, railroads, buildings, and bridges. Most learned engineering by apprenticing with leading engineers engaged in construction projects or in the supervision of machine shops associated with manufacturing plants. In 1862 the U.S. Congress, through the Morrill Act, appropriated funds to the states to support colleges of agriculture and mechanical arts. By 1917 there were 126 engineering schools on the college or university level. Between 1870 and the outbreak of World War I the number of engineering graduates leaped from 100 to 4300 annually. In 1900 there were 45,000 engineers; by 1930 there were 230,000. By 1928 the enrollment in electrical-engineering courses exceeded that of the older civil- and mechanical-engineering courses by fifty percent, and chemical engineering, the newest branch, was already half the size of mechanical engineering.[88] College training for managers followed in the wake of the boom in engineering education. Among the institutions establishing courses in management were the University of Pennsylvania, New York University, the Massachusetts Institute of Technology, Columbia University, Dartmouth College, and Purdue University. Engineering colleges also gave courses in scientific management.

Electrical- and chemical-engineering departments in engineering schools and the corresponding professional engineering societies did not exist in the United States until after 1880. From the beginning, most of the electrical and chemical engineers found employment as salaried employees with the rapidly increasing number of electrical and chemical manufacturers. No tradition of professional independence such as that known by the mechanical and civil, or construction, engineers in the earlier decades of the nineteenth century delayed the adaptation of the electricals and chemicals to corporate employers. In 1930 a study of the engineering profession reported that "the independent private practice of engineering [was] distinctly on the decrease and . . . engineers to a greater extent [were] going into the employ of corporate organizations, particularly of the large industries."[89]

During the first two decades of this century there was a short-lived and minor "revolt of the engineers," who in the name of professionalism insisted that the first responsibility of the engineer was to society. Morris Cooke, Taylor's disciple and a progressive engineer, wielded enough influence by 1919 in the American Society of Mechanical Engineers to have a society committee recommend a code of ethics stating that the first professional obligation of the engineer was to the standards of the profession, not to his employer. Yet the overwhelming pressures and the definition of problems, standards, and tasks continued to come from the corporations.[90] The engineers were the tenders of the technological systems.

The large corporations encouraged their engineer employees to join their respective professional organizations, such as the American Society of Mechanical Engineers (founded 1880), American Institute of Electrical Engineers (1884), and the American Institute of Chemical Engineers

(1908), and to take active roles in the Society for the Promotion of Engineering Education (1894). Through their employees in these organizations, the corporations could influence the formation of professional-society committees to define technical problems of common interest and to design engineering-school curricula. The corporations also greatly influenced the engineering schools by hiring faculty as part-time consultants, providing them equipment for their laboratories, and generally bringing them and their students to study and carry out experiments on problems of interest to industry. After 1900 cooperative plans between university and industry permitted students to work part-time for large manufacturers while pursuing their studies in engineering schools. The president of the American Society of Civil Engineers (formed 1852), with its longer tradition of professional independence, warned in 1909 that the engineer was becoming "the tool of those whose aim it is to control men and to profit by their knowledge."[91] In 1928 a professor of chemical engineering at the University of Michigan could write, in the *Transactions of the American Institute of Chemical Engineers*, that:

> There is some analogy between the college and the manufacturing plant which receives partially fabricated metal, shapes it and refines it somewhat, and turns it over to some other agency for further fabrication. The college receives raw material. . . . It must turn out a product which is saleable. . . . The type of curriculum is in the last analysis not set by the college but by the employer of the college graduate.[92]

The salable product brought to the employer an ability to solve routine technical problems using organized information about the natural sciences, management, and engineering practice. The corporations quickly heightened the young engineer's sensitivity to economics. Henry Towne, a leading American engineer whose ideas greatly influenced Taylor, wrote in 1886, "the symbol for our monetary unit, the dollar is almost as frequently conjoined to the figures of an engineer's calculations as are the symbols indicating feet, minutes, pounds, or gallons." In 1896 the president of the Stevens Institute Alumni Association told the students, "The financial side of engineering is always the most important. . . .

[The young engineer] must always be subservient to those who represent the money invested in the enterprise."[93]

Engineers entering the corporate world often aspired to move, after a stint of engineering work, into the ranks of corporate management. The career patterns of engineering graduates from 1884 to 1924 showed "a healthy progression through technical work toward the responsibilities of management."[94] Within fifteen years after finishing college, about two-thirds of the graduates had become managers. In the 1920s the chief executives of General Electric, Du Pont, General Motors, and Goodyear had been classmates at the Massachusetts Institute of Technology.[95] They had risen from the ranks of system tenders into the heady atmosphere of system builders.

VEBLEN'S SOVIET OF ENGINEERS

An inordinate appreciation of order, centralization, systematization, and control spread from the realms of the system builders, the scientific managers, and engineers throughout American society and culture. The engineering societies, the American Society of Mechanical Engineers among them, widely publicized the gospel of efficiency. The ASME even elected Taylor, an atypical member, president in 1906. As the technological spirit spread in the United States before World War I, it found a warm reception with the Progressives, an ill-defined political and social movement given impetus by the election of Theodore Roosevelt, a self-styled Progressive, to the presidency. Roosevelt ran for president in 1912 as a third-party Progressive. This party was not content that experts bring order, control, system, and efficiency only to resources and work; they wanted social scientists—also "scientific experts—to direct their reforming zeal to city, state, and federal government."[96] Those who applied the technological spirit to such diverse realms of society came to be known to the public as "efficiency experts." Among this group fell Taylor's scientific managers.[97] He encouraged the spread of his doctrines beyond industry when he wrote:

> . . . the same principles [of scientific management] can be applied with equal force to all social activities; to the management of our homes; the management of our farms; the management of the business of our tradesmen large and small; of our churches, our philanthropic institutions, our universities, and our government departments.[98]

In 1919 one of the country's most original and eccentric economists took the rise of the technological spirit, the Progressive movement, Taylorism, large technological systems, and wartime efforts to organize and plan the economy as signals that society was on the verge of a dramatic transformation. Because of an indifferent teaching style, a hostility toward bureaucratic authority, and amatory relations that college campuses considered scandalous at the time, Thorstein Veblen never found a permanent niche in the academic hierarchy.[99] His unorthodox books, *The Theory of the Leisure Class* (1899) and *The Theory of Business Enterprise* (1904), however, attracted attention. In 1919 he set down his views on the coming transformation in a series of articles, first published in a new radical journal, *The Dial;* in 1921 they appeared as a book, *The Engineers and the Price System.* In the meantime, the *Dial* essays were widely read, *The Theory of the Leisure Class* reissued, and an essay on Veblen by the widely read H. L. Mencken published in the magazine *Smart Set.* When *Vanity Fair,* the journal of the sophisticates, spoke approvingly of him, he became required reading among intellectuals.[100] "Veblenism was shining in full brilliance. There were Veblenists, Veblen clubs, Veblen remedies, for all the sorrows of the world."[101]

Veblen pursued the logic of the technological spirit and system building to its rational conclusion: the entire industrial system of the country should be under the systematic control of "industrial experts, skilled technologists, who may be called 'production engineers.' " He believed the nation's industry to be "a system of interlocking mechanical processes." In writing about the industrial system, he gave a fundamental definition of a system, "an inclusive organization of many and diverse interlocking mechanical processes, interdependent and balanced among themselves in such a way that the due working of any part of it is conditioned on the due working of all the rest." Veblen conceived of a national industrial system, a great productive machine, that would dwarf Ford's and Insull's. Veblen's interlocking system, or "network," of processes and exchanges of materials included "transport and communication; the production and industrial use of coal, oil, electricity and water power; the production of steel and other metals; of wood pulp, lumber, cement and other building materials; of textiles and rubber; as also grain-milling and much of the grain-growing, together with meat-packing and a good share of the stock-raising industry."[102]

Borrowing terminology from the Russian revolutionaries of 1917, Veblen called for soviets, or governing committees, of experts to take the management of the nation's industrial system away from parasitic financiers and inexpert entrepreneurs who were wasting the resources and manpower of the country through their counterproductive greed for profits and their competitive instincts. Veblen was of the opinion that, because of its highly technical nature, the interlocking industrial system had already drifted into the keeping of the corps of production specialists who would become members of the industrial soviets. He numbered inventors, designers, chemists, mineralogists, soil experts, production managers, and engineers as suitable members of organizing and controlling soviets to displace the "captains of finance" who had wastefully commercialized and exploited the experts.[103]

Veblen mistakenly believed engineers like Taylor, Gantt, Cooke, and the radical-minded engineers who followed Cooke in the American Society of Mechanical Engineers to be the tip of an iceberg. He erroneously assumed that a wartime commitment to the rational planning of the industrial economy would extend beyond the emergency into years of normalcy. He badly erred in not seeing that most of the engineers from whom he would draw the members of the soviets were salaried employees of the great industrial corporations, infused with corporate values, and content to move up the ladder of engineering and management in organizations often controlled by the "captains of finance."

NOTES

INTRODUCTION ■ THE TECHNOLOGICAL TORRENT

1. Perry Miller, "The Responsibility of Mind in a Civilization of Machines," *The American Scholar*, XXXI (Winter 1961–1962), 51–69.
2. I am indebted to Elaine Scarry of the University of Pennsylvania for the notion of the invention of the nation's "material constitution" and to Jaroslav Pelikan of Yale University for reminding me of the Genesis story as "Urmythus," of God as the first to practice technology (Genesis III: 21), and of Cain bearing the curse of work and creation (Genesis III: 23).
3. Thomas P. Hughes, "The Order of the Technological World," *History of Technology*, V (1980), 1–16.
4. Casey Blake, "Lewis Mumford: Values over Technique," *Democracy* (Spring 1983), pp. 125–37.
5. Martin Heidegger, *The Question Concerning Technology and Other Essays*, trans. W. Lovitt (New York: Harper & Row, 1977), p. 19. In *American Genesis* I have concentrated on the means of production, especially the mechanical and electrical. Also of surpassing importance during the age of technological enthusiasm were the great works of civil engineering. See, for instance, David McCullough, *The Great Bridge* (New York: Simon & Schuster, 1972), and McCullough, *The Path Between the Seas: The Creation of the Panama Canal, 1870–1914* (New York: Simon & Schuster, 1977).
6. Sidney W. Mintz, "Culture: An Anthropological View," *The Yale Review*, 71 (1982), 499–512.

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12. F. T. Marinetti, "The Founding and Manifesto of Futurism 1909," in *Futurist Manifestos*, ed. and intro. by Umbro Apollonio (London: Thames and Hudson, 1973), p. 22.
13. C. Vann Woodward, *The Burden of Southern History* (Baton Rouge: Louisiana State University Press, 1968), pp. 187–211.

1 ■ A GIGANTIC TIDAL WAVE OF HUMAN INGENUITY

1. Edward W. Byrn, "The Progress of Invention During the Past Fifty Years," *Scientific American*, 75 (25 July 1896), 82–83. Earlier I have written on invention and independent inventors in "The Era of Independent Inventors," *Science in Reflection: The Israel Colloquium: Studies in History, Philosophy, and Sociology of Science* III, ed. Edna Ullmann-Margalit (Dordrecht: Kluwer Academic Publishers, 1988), 151–68.
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3. W. S. Woytinsky and E. S. Woytinsky, *World Population and Production: Trends and Outlook* (New York: Twentieth-Century Fund, 1953), pp. 868–

Research: The Du Pont Company, 1902–1980," paper presented at the Second International Conference on the History of Enterprise, Terni, Italy, 2 October 1987, p. 11.

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62. Hounshell, "Continuity and Change," p. 14.
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5 ■ THE SYSTEM MUST BE FIRST

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nology (*Shifting Gears: Technology, Literature, Culture in Modernist America* [Chapel Hill: University of North Carolina Press, 1987], p. xii).

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3. David A. Hounshell, *From the American System to Mass Production: The Development of Manufacturing Technology in the United States* (Baltimore: Johns Hopkins University Press, 1984), pp. 331–36.
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11. Taylor, *Testimony*, pp. 8, 115.
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6 ■ TAYLORISMUS + FORDISMUS = AMERIKANISMUS

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