interdependence, social class, and the influence of science on technology. This is the "systems approach" to the history of technology at its best, a wide-ranging analysis that goes far beyond the single component that is its major focus. Reynolds even attempts cross-cultural comparisons of water power technology in China, Islam, and the West. Although other cultures had early success with water wheels, the West went much further in the use of water power for manufacturing.

The extensive application of water power in the late Middle Ages leads Reynolds to question the standard interpretation of an "industrial revolution" in the late 18th century. Going further than John U. Nef in pushing back the origins of industrialization, Reynolds sees this process under way by 1500. The rapid expansion of water-powered industry in the late medieval period was the "seedbed from which the modern factory system ultimately emerged." Throughout this study, there is an emphasis on continuity as well as change.

For centuries people built vertical water wheels with little understanding of how they produced power or of the relative efficiencies of different wheel types. Reynolds traces the roots of "a science of the vertical water wheel" back to Leonardo da Vinci but finds much theoretical confusion before the hydraulic analysis of Jean Charles Borda in 1767. The quantification of water wheel operation required both theoretical analysis and experimentation. *Stronger than a Hundred Men* covers the reconciliation of theory with practice and the effects of quantification on the design and selection of water wheels in the 19th century. The use of quantified data demonstrated that the gravity wheel was more efficient than the impulse wheel and thus promoted the wide use of breast or overshot types in industry.

Reynolds's most original contribution may be his examination of quantification, but he is also concerned with the physical form of water wheels, with the ways they were built, and with the problems of maintaining them. Looking at wheels from the perspective of the millwright as well as that of the theoretician, he evaluates the strengths and weaknesses of wooden wheels, wood and iron hybrids, and iron suspension wheels. He also discusses the competition from steam engines and water turbines that led to the demise of the vertical water wheel.

Few if any books on the history of technology make better use of illustrations. Each of the many drawings and diagrams has a detailed caption and is placed in close proximity to the textual material it complements. Historical illustrations provide much of the evidence for Reynolds's arguments, particularly in sections dealing with classical or medieval water wheels. Carefully selected graphics, drawn from a wide variety of sources, make complex technical descriptions clear and add a wealth of information.

Stronger than a Hundred Men is an outstanding study of a prime mover that had great technological and cultural significance. Reynolds has a better understanding of hydraulic science and water power engineering than Louis Hunter, whose *Waterpower in the Century of the Steam Engine* is a classic work in the history of American technology. Reynolds breaks new ground with his research and gives the history of the vertical water wheel the thorough analysis it deserves.

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Innovations in Manufacturing

Yankee Enterprise. The Rise of the American System of Manufactures. Papers from a symposium, Washington, D.C. OTTO MAYR and ROBERT C. POST, Eds. Smithsonian Institution Press, Washington, D.C., 1981. xx, 236 pp., illus. Cloth, $19.95; paper, $9.95.

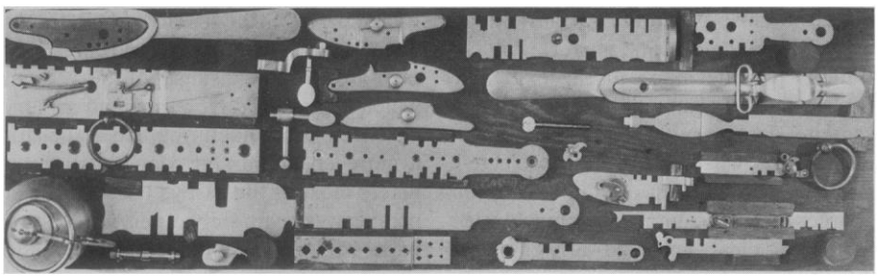
"The American System of Manufactures" is a phrase coined by British observers in the 1850's to characterize what they saw as a manufacturing process readily distinguishable from the methods prevailing in England at the time. As this collection of essays on its causes and consequences makes clear, the precise nature of that system is debatable. The most widely held view is that interchangeability of parts was the important distinguishing feature, but the notions of mechanization and mass production seem noteworthy as well. Related matters are the extent to which this manufacturing system prevailed in the United States at the time of the British visits and the timing and consequences of developments after 1850.

Concern for the exact nature of the system, particularly its distinguishing feature, is important if there is to be any validity to the claim that it is uniquely American, as opposed to a worldwide phenomenon or a more restrictive regional or industrial method. The book's title can be taken to imply that the distinctive methods were confined to New England. And David Hounshell thinks historians have focused too much of their attention on a subset of the system, which he calls the New England armory practice of manufacturing. He argues for a more encompassing view, and fortunately most of the essays take a broader perspective, with only a very interesting paper by Merritt Smith being confined to arms manufacturing.

According to A. E. Musson, the distinctions between American and British manufacturing practices must be carefully drawn if uniqueness is to be claimed for the former. He argues that in the years before 1850 England pioneered the development of some general-purpose machine tools, interchangeable parts, specialization, and the division of labor. The American innovations occurred after 1850, showed up in the form of specialized machine tools, and were confined largely to wood-working and light manufacturing industries. Several authors note that if the system was confined to arms manufacturing then its origins were French. Paul Uselding argues that improved measuring devices were required to assure accuracy and interchangeability, and these were international in origin (as in the case of Joblocks). Clearly, whether American manufacturing was carried on under a unique system of production is ambiguous.

Fortunately, from a broader perspective, uniqueness and the exact distinctive features are not crucial. Regardless of where improved measuring devices or the notion of interchangeable parts originated, or how limited the scope of the system's use in the 1850's, American manufacturing became a behemoth of production in the years thereafter, turning out volumes of standardized merchandise via large-scale, capital-intensive methods and influencing life styles and living standards around the world. In Eugene Ferguson's view this American conquest is one of the "great historical movements that have changed forever the conditions under which human beings live." Most of the essays are concerned with these broader implications rather than with the narrow topic of the definition of the American System.

Several authors hint at an explanation for the development of such a system, but only Nathan Rosenberg provides a coherent view of the process. He argues that its development was shaped by demand pressures, such as population growth and a standardization of tastes, and a supply condition of resource abundance. These factors pushed inventive



Inspection gauges for U.S. Rifle Model 1841. In 1826, "with the aid of over sixty-three inspection gauges and an impressive stable of machinery," John H. Hall "conclusively demonstrated that his rifles could be made with interchangeable parts. . . . Eight years later Simeon North . . . from Middletown, Connecticut, . . . adopted Hall's gauges and succeeded in making rifles with parts that could be exchanged with those made by Hall at Harper's Ferry." What Hall and North had done was achieved "in a larger, more efficient manner . . . in the mid-1840s when the national armories and private contractors began to produce the Model 1841 percussion rifle and the Model 1842 percussion musket. These were the first fully interchangeable firearms to be made in large numbers anywhere, one of the great technological achievements of the modern era." [M. R. Smith, in *Yankee Enterprise*; gauges from the collections of the Division of Military History, National Museum of American History]

efforts in a certain direction that just happened to be a fruitful one. The core of this fortunate technological dynamism was a capital goods industry that transferred technology and knowledge to new industries and whose own productivity improvements lowered the costs of new technologies and helped diffuse them throughout the economy. Interestingly enough, Rosenberg's explanation does not require that the American System was unique or that it originated in America, only that the mechanized type of production processes flowered more widely and pronouncedly in the United States.

The consequences and concomitant developments of these production methods are covered well in this collection. Uselding examines the development of improved measuring devices; Chandler reports on improved factory and corporate management techniques; and Nelson provides an assessment of working conditions in factories using the American System and their implication for labor unrest and unionization. One consequence that had previously been neglected is the change in buying habits necessary to consume the large volume of products, which Neil Harris terms the rise of an American System of Consumption. He explores this phenomenon through the use of descriptions of consumption patterns and life-styles found in novels, juxtaposed with the known changes in retailing strategies. One theme found in early 20th-century novels was the consumers' need to cope with the standardization of mass-produced goods.

This is an interesting collection of essays presented originally at a Smithsonian Institution symposium by a diverse group of the top scholars in the field. There is a certain amount of repetition of earlier work by a few authors, but for the most part this appears to be fresh material. The scope of its coverage is hinted at by references to Babbage as well as *Babbitt*. Alphabetically these may not cover much ground, but intellectually they encompass the applied sciences and the humanities. The book should, however, have its widest appeal among social scientists of many different persuasions and disciplines. Whatever one's primary focus, all the essays should be readily accessible, written for any intelligent reader, not just specialists.

If there is a drawback, it is that there is no essay putting the topic in the perspective of previous research. Though such literature reviews can easily lose the interest of non-specialists, more might have been done to indicate at least the conventional wisdom concerning the subjects. A certain amount of this comes through in the individual essays, as well as from the combination, but each author typically specifies his view of things, focusing narrowly on one aspect of the topic. Fortunately, there is an excellent bibliography to direct the interested reader elsewhere.

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Forging shop, Singer factory, 1880. An illustration of the factory published in 1854 "shows relatively few machine tools compared to the army of workmen at the bench with files in hand." In 1880 "an excellent series of illustrations appeared in a Singer-supported book, *Genius Rewarded; or the Story of the Sewing Machine*. These engravings show quite clearly the transformation that had occurred in Singer manufacturing technology. Whereas most parts of the Singer machine had formerly been cast iron, [the factory] relied increasingly on drop forging and fabrication from bar stock." After 1863 "Singer acquired ever-larger numbers of special-purpose machine tools." Singer's superintendent reported in 1885 that "by the addition of machinery the same number of employees will produce double the number of [machines] they would ten years ago." [D. Hounshell, in *Yankee Enterprise*; illustration reprinted from *Genius Rewarded*]

A 19th-Century Material

Pioneer Plastic. The Making and Selling of Celluloid. ROBERT FRIEDEL. University of Wisconsin Press, Madison, 1983. xxii, 154 pp., illus. $19.95.

Celluloid was the first plastic. John Wesley Hyatt invented it in Albany, New York, in 1869 in the course of a long and unsuccessful search for a replacement for ivory in billiard balls. These bare facts are well known by historians