American Collegiate Populations vastly improves the numerical record and exposes some of the ahistorical norms of earlier accounts. It is not light reading, but it has many interesting discussions. There is a bit of overkill in the attack on Whig history, and the very end of the book is marred by the mysterious appearance of two tables containing recent student test scores that are not discussed in the text. But these distractions are outweighed by the fact that Burke makes his main points persuasively as the book unfolds. Scholars in a variety of fields will want to read it and know it as a reference work.

Burke's picture of antebellum colleges contributes to the rediscovery in social history of viable, local, voluntary, independent institutions in the early years of the republic. While it would be ahistorical and naïve to claim they are a model for the present, it was equally ahistorical for earlier historians to condemn them as dysfunctional and unprogressive. This book escapes both forms of presentism. In addition to setting the numerical record straight, Burke has added to a mounting reinterpretation of early-19th-century institutions on their own terms.

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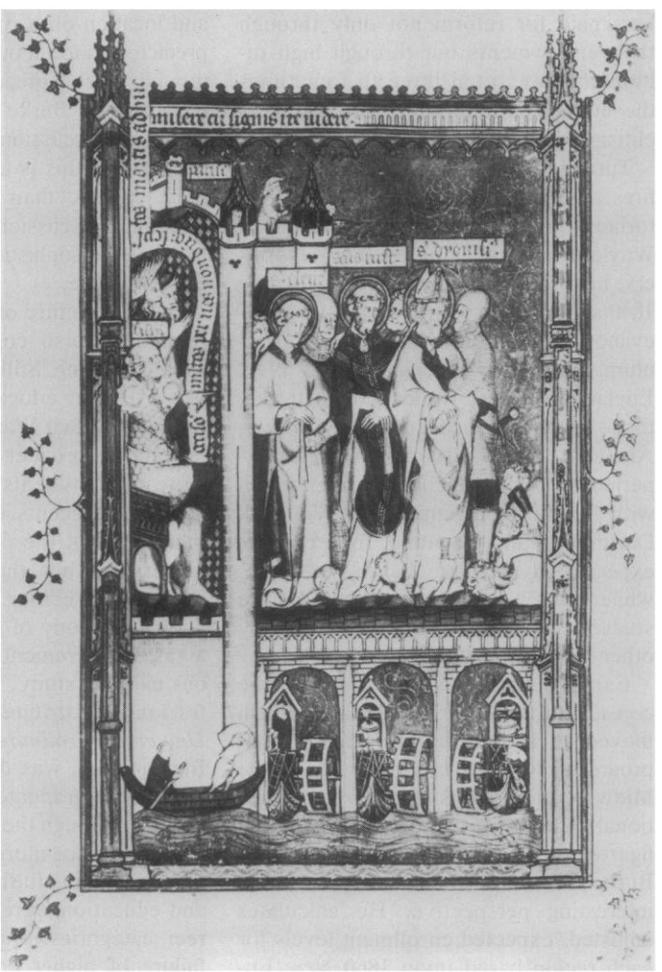
A Power Source in Its Context

Stronger than a Hundred Men. A History of the Vertical Water Wheel. TERRY S. REYNOLDS. Johns Hopkins University Press, Baltimore, 1983. xviii, 454 pp., illus. $35. Johns Hopkins Studies in the History of Technology, new series, no. 7.

The vertical water wheel was one of the most important developments in the history of technology. Terry S. Reynolds traces the ancient origins of this prime mover, or producer of power, and shows how it became the "mainstay" of Western power technology from the medieval period well into the 19th century. His lucid, technically precise, and comprehensive study of this key element in the evolution of Western society is a major scholarly contribution. It is also an extremely interesting and readable book that should appeal to anyone with an interest in energy, machinery, or innovation.

Reynolds is not one of the technological determinists who believe that energy usage is the one key factor in establishing the level of culture. He makes only the most reasonable claims for the role of energy and for the influence of the vertical water wheel. This particular prime mover had a tremendous effect on social and economic development, but Reynolds takes care to recognize the complex nature of culture and the diversity of forces that shape it. The vertical water wheel did reduce the amount of labor involved in many technical processes. It often allowed great increases in industrial productivity, and it made possible things that could not be done with existing power sources.

In order to explain the development and diffusion of the vertical water wheel, Reynolds has had to delve into such sujbects as geography, feudalism, monasticism, urbanization, technological



"Bridge mills under the Grand Pont in Paris, from a French manuscript of 1317." [Bibliothèque Nationale, MS franç 2092, fol. 37v, reprinted in *Stronger than a Hundred Men* from H. M. R. Martin, *Légende de Saint Denis* (Champion, Paris, 1908), courtesy of Honoré Champion and the Bibliothèque Nationale]

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