most chapters are very competent reviews, and in the nine chapter bibliographies sampled the latest dates were 1958, 1960 (three chapters), 1963, 1964 (two chapters), 1966, 1967. Did the editors adequately define and limit the field to be covered? Yes; the inclusion of fiber-glass-plastic composites, which might be questioned because these substances melt so readily, is justified by emphasis on their ablation properties. Did they subdivide logically, and avoid overlapping? Yes and no; the subdivision of the major sections (Chemistry, Materials, Methods, and Measurements) is reasonable, but overlapping and repetition between some chapters (for example, "High-temperature thermodynamics" and "High-temperature reactions," "Selection of materials," and "Oxide ceramics") is slightly annoying. Did they standardize in editorial matters such as form, units, and terminology? No; I found it particularly disconcerting to jump from °C to °F and back, or from cal/(sec cm²)(°C/cm) to "BTU/(hr/ft²)(°F/in)." Did they require definitions or references for esoteric terms? Not always; "Refrasil," which has at least two commercial meanings, went unexplained, and that old misnomer "quartz" for a type of vitreous silica went uncorrected. Were the bibliography and indexes well done? No; the duplication inherent in chapter-by-chapter bibliographies could surely be avoided in this day of clerical automation; the author index is undependable; and the subject index should be much improved for the uninitiated, to whom the book is addressed in the preface.

The editors disclaim the intention of providing a handbook, and state their judgment that further revision of the individual authors' contributions was not necessary or desirable. To argue that judgment might be unfair, but it is true that the lack of unification and the imperfect indexing make for a poor reference work. On the other hand, an individual chapter may thereby have more value when used textbook-fashion, to orient a stranger in the field or compensate for past neglect of the journals and the meetings. The editors deserve thanks for assembling a well-organized collection of reviews of the important aspects of high-temperature materials technology. Most workers in this field would find profit at some point in its reading.

FRED ORDWAY

Melpar, Inc.,
Falls Church, Virginia

History of a Machine

American Locomotives. An Engineering History, 1830–1880. JOHN H. WHITE, JR. Johns Hopkins Press, Baltimore, 1968. xxiv + 504 pp., illus. $20.

The steam locomotive enjoyed an active life, in Europe and America, of 125 years: it appeared as a useful and reliable machine between 1825 and 1830; its manufacture in the United States ceased in 1949, and it disappeared from productive service in the following decade. Its development during this long period was remarkably stable, perhaps to a degree unparalleled for machines invented in the modern industrial period. All the essential elements persisted in form and in working relations throughout its history: firebox, boiler, smokebox, cylinders, driving and truck wheels, driving mechanism, and valve gear appeared in their fundamental character at the beginning and remained to the end. This orthogenetic evolution offers the historian a built-in conceptual and organizational scheme, but mechanical and thermodynamic complexities, as well as the scanty source material, have discouraged him from trying his hand.

White's impressive work takes off from the second level, so to speak, and makes few concessions to the uninitiated. He assumes an understanding of the basic processes, uses the technical vocabulary of locomotive design and operation, and offers little explanation of the more complex thermal and mechanical elements. His treatment is analytical to an extreme degree, not only in the care with which he examines the requirements, the solutions, their successes and failures, but also in his method of splitting the subject into its separate aspects, pursuing each one through its entire chronological development before turning to the next. The result is that the major components of the locomotive are exhaustively described with respect to their function, design, changing form, and operating relation to other working elements, the descriptions set forth in a series of parallel subdivisions. This approach makes it possible to organize a mass of details into a logical pattern, but it places a burden on the reader, who must try to keep an image of the whole machine in mind as he moves from firebox, boiler, and smokebox to driving wheels, trucks, running gear, suspension systems, and the like, until he finally reaches the tender. In this respect, of course, he is helped by the generous illustrative material, but nothing is quite so helpful as a previous knowledge of how locomotives look and how they operate.

American Locomotives is divided into three main parts followed by eight appendices, of which the last is a chronological table summarizing the history of rail motive power to 1875. Part 1, Era of Fundamental Locomotive Design, is introductory, concerned with the first British imports and the British background to American design, native builders, materials, performance characteristics (treatment of which is particularly valuable, being rare in books on the subject), and locomotive types classified according to the familiar system of wheel arrangement invented by Fredric Whyte. With respect to the last subdivision, it is surprising to learn that for nearly the first half of its active life the locomotive was restricted to only eight different types, of which three were truckless engines (0-4-0, 0-6-0, and 0-8-0), whereas its subsequent development revealed a wide-ranging adaptive radiation into an additional 16 reciprocating types, a figure that I have arrived at by placing all Mallet articulated locomotives (of which there are 12 wheel arrangements alone), the Pennsylvania Railroad's late oddities, Forney tank engines, and steam turbine forms in only four separate categories.

Part 2 of White's volume, designated simply as Components, is the heart of the work and reveals the author's unparalleled mastery of his subject. He examines in detail 41 major parts, described in separate sections running from 3 to 15 pages in length. These subdivisions are grouped into three broad categories respectively designated "Boilers and boiler accessories," "Running gears," and "Miscellaneous" (cowcatchers, headlights, bells, whistles, and other components not essential to the operation of the machine). Here the analytical method reaches its fullest development. For each component White begins with the initial invention, which he takes as the fundamental form or standard and which serves as the basis for the analysis of the mechanical or thermal problem, and continues with the variation on the standard, the mode of operation of each one, the successes and the failures, all presented with numerous concrete examples. He is particularly effective in analyzing failure and inadequate operation, as in the cases, for example, of feed-water pumps and steam pressure gages, which offered peculiar problems because of the con-

ditions under which most engines operated and because of difficulties arising from the operation of other working components expressly designed to meet these conditions.

The third part, entitled Representative American Locomotives, is composed of descriptions of 27 locomotives built between 1829 and 1870, each section divided between text and numerous illustrations, chiefly drawings of elevations, sections, and details supplemented by photographs of the later engines. This part of the book alone represents a heroic undertaking because of the small quantity of reliable source material on early locomotive history. The engines in White's selection include famous machines, among them the British-built *Stourbridge Lion,* which enjoyed the distinction of being the first locomotive operated in the United States when the Delaware and Hudson Company gave it a trial run on 8 August 1829, and the *Consolidation,* which was built for the Lehigh and Mahanoy (later Lehigh Valley) Railroad in 1866 and which gave its name to the 2-8-0 type, the most popular of all American freight locomotives. Others are less well known but equally important, such as the four locomotives built for the Hudson River Railroad (later New York Central) in 1849–1854 which were the first high-driver, high-speed passenger engines in the United States.

Two major themes emerge from White's history, which we might designate respectively as ontological and historical. The first is associated with the distinguishing characteristics of the rail network in the United States and ultimately with the economy itself. The chief problem in the design of American locomotives was the need to develop adequate power in a light, flexible machine able to maintain adhesion on uneven, tortuous, unreliable, cheaply built track. The successful solution came primarily through carefully designed running gear, frames, and suspension systems. John B. Jervis' invention of the leading truck played an important role because it not only prevented derailments as the result of movement through sharp curves but eventually made possible the high-speed passenger locomotive. Underlying the whole development was the pragmatic and empirical spirit that American technology exhibited through much of the 19th century. Ingenuity and gross experience were the main factors in the builder's process of adapting his constructions to the exigencies imposed by the American economy and physiography. The spirit was essentially unscientific, antitheoretical, and conservative, with the consequence that many basic inventions and the scientific foundation on which they increasingly came to rest were of European origin. The American mechanic, with his passion for practicality and simplicity, could produce a machine able to work effectively under the most forbidding conditions, and at the same time exhibit an irrational obstinacy in clinging to old forms in the face of the obvious advantages offered by new inventions. He refused, for example, to adopt the Worthington steam-operated feed-water pump even though it was superior to the common crosshead pump, simply because the former was unfamiliar to him. More extreme was the rejection of the feed-water heater and the superheater, in spite of the fuel economy they offered, in favor of extremely complex valve gear. Thus, ironically enough, the spirit that produced a workable locomotive in the first place often inhibited the progress that changing conditions and increased traffic demanded.

The second theme of the book is that early locomotive development was divided into two stages covering periods of almost identical length. The earlier, extending from 1830 to about 1855, was the pioneer phase, when trial-and-error experimentation with British models was the rule until the builder grasped the conditions he had to deal with and arrived at the successful archetypal solutions. The later period, 1855 to 1880, brought the advent of what White regards as the modern locomotive. The fundamental innovations that marked this transition were the wagon-top boiler, spread truck, link valve motion, coal-burning firebox, and boiler pressures at or above 100 pounds per square inch. The trailing truck, superheater, feed-water heater, and stoker, as standard components, were to come shortly before or after the turn of the century, but the basic form was largely established in the immediate post-Civil-War period.

The publication of White's encyclopedic book inevitably leads the historian to reflect on the state of literature in the field, which has certain interesting characteristics not shared by other areas of technological history. The only book comparable to White's is Alfred W. Bruce's *The Steam Locomotive in America,* but in spite of the broad title it is restricted to the period of 1910 to 1950. Moreover, it suffers from serious omissions, is unreliable on antecedents, and contains no documentation. The 30 years from 1880 to 1910 remain largely untouched, and the evolution of electric and diesel-electric power has yet to be examined. The books that treat the subject, such as those by Walter A. Lucas, are descriptive surveys rather than histories.

The small quantity of mature work is not unusual in the history of technology; what is perhaps unique, however, is the steady outpouring of big expensive volumes prepared by and for the railroad buff. About a hundred of them have appeared since 1938, when the late Lucius Beebe brought out the first of his pictorial albums of trains past and present, and the end is certainly not in sight. Among these volumes at least 16 are devoted exclusively to the motive power of individual railroads, most of them restricted to the 20th century but several, notably those on the New York Central and the Baltimore and Ohio, surveying the entire history of motive power development. These books constitute what we might call naive vernacular history: the texts range from the barely literate to the overblown and hackneyed; the illustrations are endlessly repetitive, more than a dozen sometimes devoted to identical engines of the same class, while true historical evolution always seems to elude the authors. Yet the books cannot be dismissed as the happy obsessions of the hobbyist. First of all, they represent a psychological reaction to a phase of material history that has no exact counterpart elsewhere and for this reason deserves some attention from the cultural historians, who might explore this popular response to the railroad as Alan Trachtenberg examined the reaction to a great structural work in his *Brooklyn Bridge.* Second, whatever its defects, the buff literature constitutes a not always reliable but extensive repository of undigested locomotive facts, photographs, drawings and confused miscellaneous information. Critical examination of this mass of material might pay off for the historian, but there are few with the patience and the competence to undertake the job. Meanwhile, White's book will very likely stand as a model of locomotive engineering history for a long time to come.

CARL W. CONDIT
Departments of Art and *History of Science, Northwestern University, Evanston, Illinois*