vative processes on important competitive fronts (a main contention, for example, of David Noble's work, *America By Design: Science, Technology, and the Rise of Corporate Capitalism*, 1979).

The narrowest of the three books is Neil Wasserman's, a work of only 125 pages of main text that offers a detailed treatment of both the invention and the implementation of coil loading, the invention at the turn of the century that made high-quality, long-distance voice transmission possible. Wasserman considers the basic scientific contributions of the British physicist James Clerk Maxwell and others, and, at greatest length, the contribution of AT&T's own George A. Campbell, who lost out in the race for a patent so that AT&T was left with no choice but to purchase the coil-loading patent from Michael Pupin at a price that was handsome even by modern Silicon Valley (or Hollywood) royalties standards. A key to why AT&T stumbled, ironically enough, was poor advice from its lawyers, who were so adept at other things, when it came to patent strategies and requirements.

Wasserman has in common with Garnet a keen eye for the role of happenstance and contingency in historical development of both technology and business organization and marketing. He is at pains particularly first to set out in neat diagrammatic form a "process of innovation" flow chart that he then uses as his straw man, modifying it to reflect the complexities, switchbacks, and turnarounds that the real-world history of implementation involved once AT&T sought to apply loading technology in its operations.

The book closes with the assertion that the company's experience with the loading coil "strongly influenced the way AT&T, and, indirectly, the way other large corporations have dealt with science, technology, and the management of change in the twentieth century." The suggestion, though intriguing, is undeveloped here; readers interested in that problem will need to consult the new historical studies on industrial research by Leonard Reich and older work by Kendall Birr and others.

None of these three books, withal, has the comprehensiveness or theoretical importance for historical analysis of technological change in relation to science, law, public policy, and market competition of Hugh G. J. Aitken's truly brilliant tour de force on the parallel and intersecting developments in radio technology and American business. But all three works are of distinct value to students of American science, with Garnet's in particular transcending specialists' concerns to provide a complex, though only partial, portrait of a fascinating industry in an epoch that seems far removed in time but startlingly similar in some of its competitive dimensions to today's brave new world of communications.

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Labors at Menlo Park

Edison's Electric Light. Biography of an Invention. ROBERT FRIEDEL and PAUL ISRAEL. With Bernard S. Finn. Rutgers University Press, New Brunswick, NJ, 1986. xvi, 263 pp., illus. $35; until 1 July 1986, $27.95.

Mention the name of Thomas A. Edison to almost any American and he or she will probably think of his most famous invention, the incandescent electric light. So persuasive and enduring is Edison's electric light as a symbol of invention and creativity that a light bulb coming on over the head serves as a conventional way of representing a good idea. Nearly everyone is familiar with the basic story of how Edison invented the electric light in 1879, and the story is regularly used to celebrate how American virtues such as ingenuity and perseverance can lead to technological progress.

Yet beyond the symbolism and myth, what do we really know about the history of this invention? Not much, according to Robert Friedel and Paul Israel, and what little we know is based "more on hearsay and foggy memory than on historical evidence" (p. xii). Drawing on a wealth of manuscript material at the Edison National Historic Site in West Orange, New Jersey, the authors set out to retell the making of the incandescent lamp. For them the story is an exciting one, filled with insight into the personal and human aspects of creativity.

In narrating how Edison invented his system of incandescent lighting, Friedel and Israel surpass the earlier Edison biographies by providing a clear description of the technical challenges faced by Edison at each step in the innovation process. Their understanding of the technology is based on their masterly analysis of over 250 laboratory notebooks. Friedel and Israel are the first scholars to study the notebooks in their entirety, and through them they have secured a complete overview of the events in the Menlo Park laboratory from 1878 to 1882. Because their narrative is close to the records, it comes across as fresh and stimulating, with the reader sharing in every breakthrough and false lead. This sense of intimacy with the creative act is further enhanced by the extensive use of illustrations from the notebooks, which provide a rich visual record of how Edison worked.

Though they do not substantially change the general outline of how Edison invented the electric light, Friedel and Israel give the story a number of new twists. From the outset, they tell us much about Edison's associates and the role they played in the project. Other historians have identified the important contributions made by Francis Upton, Charles Batchelor, and John Kruesi, but Friedel and Israel in addition discuss how Charles Deane, Wilson Howell, and Ludwig Boehm helped create the incandescent light. Curiously, at times the authors tell us much more about the work of these men than they do of Edison; for instance, they reveal that it was not Edison but Upton and Batchelor who performed the crucial experiments with carbon filaments on 22 October 1879. Edison's apparent absence may be the result of the fact that Upton and Batchelor kept records of their work that day and Edison did not, but the authors do not speculate on this point.

Another novel feature of the book is that the authors provide a detailed analysis of the craft aspects of invention. During the early months of 1879, for instance, we learn how Edison used a microscope to observe that the platinum filaments in his lamps were not melting but oxidizing. On the basis of these experiments, Edison and his staff decided to enclose the filament in a vacuum. Friedel and Israel then recount how the Menlo Park team designed an improved vacuum pump, building upon the work of Geissler and Sprengel. In later chapters, the authors provide additional examples of the craft of invention by describing the intricacies of fashioning miniature clamps for the filament, designing large-scale dynamos, and perfecting insulation for the underground conductors. Throughout their narrative, the authors emphasize that Edison succeeded with the incandescent lamp not so much because he had a profound theoretical understanding of the light as because he and his staff were able to attend to all the requisite details.

Friedel and Israel also examine Edison's relationship with the press. Earlier accounts of the electric light have mentioned how Edison received a great deal of coverage in the New York daily newspapers. In this study the authors consider this publicity as both an asset and a liability. For example, in the fall of 1878, Edison skillfully elicited extensive press coverage in order to stimulate investment in the Edison Electric Light Company. At other times, however, he found it difficult to restrain the press. In the fall of 1879, as the carbon filament lamp

neared perfection, Edison tried to keep the news of his achievement out of the newspapers until he was certain that he had a commercially feasible lamp. Having made earlier premature announcements of success, Edison knew that a flop would discourage his financial backers from investing further in his invention. Through their discussion of Edison and the media, Friedel and Israel reveal Edison's ability in handling non-technical matters while at the same time they show the limitations of his control over the larger environmental forces that affected his inventions.

Though the strength of this study is that it is based heavily on the laboratory notebooks, the reliance on this limited base of evidence also creates difficulties. The authors are not always able to place Edison's work in a larger technical or economic context. Failing to compare Edison's designs with those of other inventors, Friedel and Israel find it difficult to explain certain aspects of the electric lighting project. For instance, they seem especially puzzled as to why Edison retained a cumbersome electromechanical regulator on his platinum lamp for some months after he had discovered that he could protect the filament from oxidation by placing it in a vacuum. I would argue that one explanation for the puzzle of the regulator can be obtained from comparing Edison's lamp with the arc lights of other inventors. Nearly every arc light in the 1870's employed some type of regulator, not just to feed the carbon electrodes but to maintain each lamp at a standard resistance. At a standard resistance, each lamp was a stable portion of the load, thus allowing a single generator to power several lamps at once. This was a solution to the problem of "subdividing the electric light," and until the summer of 1879 Edison probably assumed that he needed a regulator on his lamp not to protect the filament but to ensure the stability of his system. Had Friedel and Israel compared the information in Edison's notebooks with secondary sources such as electrical engineering texts and journals, they could have probably resolved this and other technical anomalies. Furthermore, through a few judicious comparisons of Edison with other inventors, they could have sharpened their remarks about just how unique and original was Edison's work.

But more important than being able to explain technical puzzles, Friedel and Israel may have been overzealous in their determination to let the notebooks "speak for themselves." The authors do not invoke any models of technological change and scrupulously avoid drawing any generalizations about the innovation process. But they do not hesitate to criticize other scholars who have studied Edison and detected a method of invention. In particular, they question the work of Thomas P. Hughes and his claim that Edison was a systems thinker who conceived of a complete lighting system from the outset and then proceeded to solve each problem related to the system in a logical sequence. In their study of the notebooks Friedel and Israel found no evidence of a grand scheme or systems thinking but only specific sketches, calculations, and descriptions. Consequently, they conclude that Edison only gradually arrived at his notion of a lighting system, that he was guided by no larger intellectual plan, and that he worked on various aspects of the project in a piecemeal and random fashion. In my opinion, Friedel and Israel arrive at this position by failing to consider adequately the nature and purpose of the laboratory notebooks. For Edison as for other inventors, notebooks were a tool or heuristic used in the course of visualizing and working out an invention. Generally they were neither planning nor historical documents, and they were not intended to provide a broad overview of the invention process. Informal, day-to-day records should not be expected to yield explicit descriptions of overall method or strategy. It is the task of the historian to view such material as a whole and to extrapolate from it a larger pattern or sense of process. Though Friedel and Israel are probably right not to "read" anything into the notebooks, they have been far too timid in not considering how the notebooks reveal the cognitive patterns that informed Edison's creativity.

Nevertheless, Friedel and Israel have swept away the legends and myths surrounding the invention of the electric light and have replaced them with an accurate and exciting narrative. Despite the limitations stemming from its narrow focus this book should be the standard source on Edison's greatest invention for years to come.

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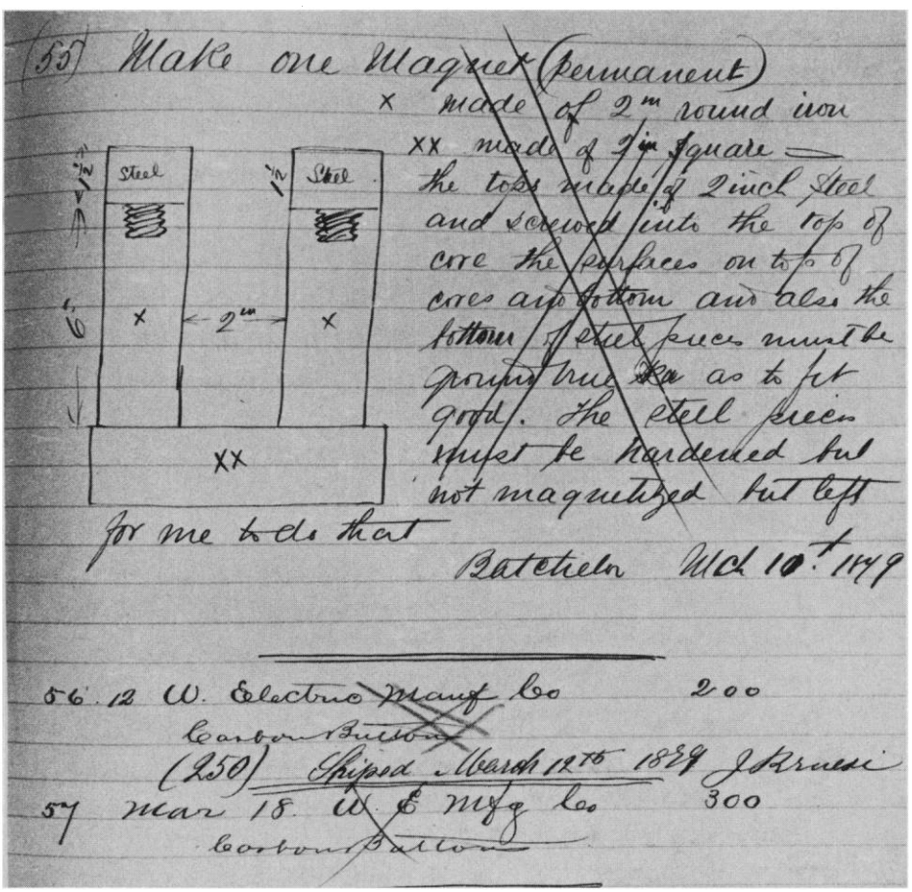
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Orders from Edison to his machine shop for the design of large dynamo field magnets, 10 March 1879. "The development of Edison's bipolar dynamo owed little to theoretical understanding and much to the ability of Menlo Park mechanics to execute modification after modification, as is evident from this book of orders. However, an underlying theoretical foundation can be discerned in the design of the large field magnets. Edison, like most others, relies on Faraday's half-century-old conception of cutting magnetic lines of force with a conductor; the more lines of force crossed in the most direct manner, the more productive the generator." [From *Edison's Electric Light*]