ENGINEERS AS WRITERS

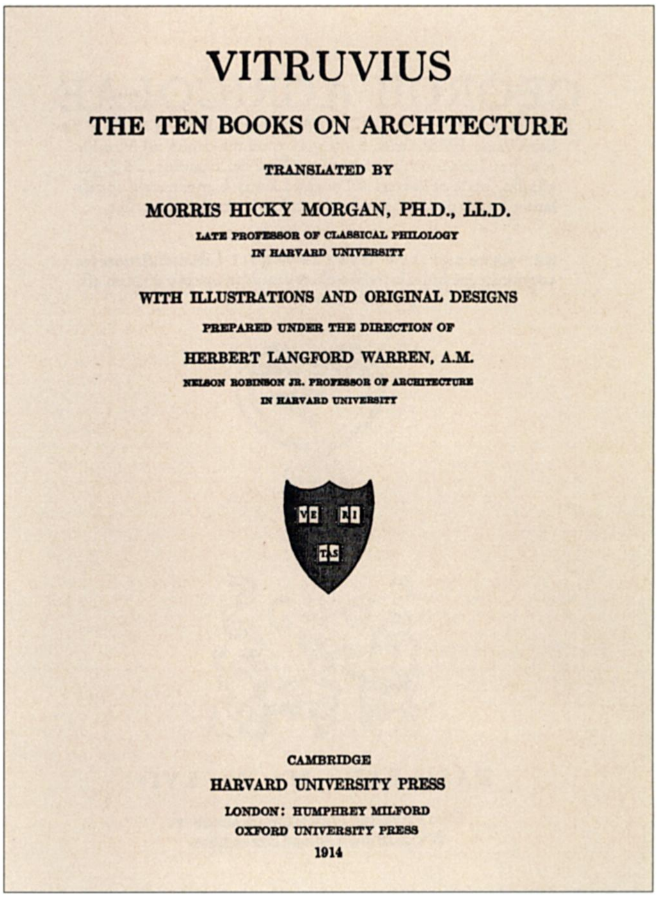
Henry Petroski

According to the conventional wisdom, engineers eschew writing, reading and speaking. But surveys have shown that these activities are not easily avoided in the practice of the profession. A few years ago, two professors in MIT's Technical Communications Group observed the daily routine of 25 staff engineers and scientists, six supervisors and two managers in a corporate research-and-development environment. In describing this study, *Technology Review* (April 1983) reported that "technical professionals typically spend over a third of their work week writing, editing, or preparing oral reports." The results surprised even Richard Miller, the leader of the Exxon Chemical group studied, who summed up the findings as follows: "The managers were reading, the engineers were writing, and the supervisors were doing both."

Things were not much different in ancient Rome. The extensive building that took place during Augustus Caesar's reign in the first century B.C.E. was accompanied by writing about building. Vitruvius, Caesar's *architectus*, or chief engineer and architect, wrote his *Ten Books on Architecture*—a comprehensive summary of the state of the art and a guide to good practice—so that his emperor would have "personal knowledge of the quality both of existing buildings and of those which are yet to be constructed." Although Vitruvius was not a felicitous writer (his style has been compared with that found in specifications and contracts), his work is the oldest surviving treatise on engineering. Like all classics, it remains full of insights for today.

A century or so after Vitruvius flourished, Frontinus was appointed Roman *curator aquarum*, or water-works superintendent. He had extensive experience as a military commander and as governor of Britain. Although not an engineer himself, he regarded engineering as among the empire's greatest achievements, and therefore he was distressed to find the aqueducts in disrepair and the management of the system riddled with corruption. Forty percent of the water supply was being lost or diverted illegally, some by private citizens "for the watering of their gardens." In order to prepare a comprehensive report to

Henry Petroski is the Aleksandar S. Vesic Professor and chairman of the department of civil and environmental engineering at Duke University, Durham, NC 27706.



VITRUVIUS

THE TEN BOOKS ON ARCHITECTURE

TRANSLATED BY

MORRIS HICKY MORGAN, PH.D., LL.D.

LATE PROFESSOR OF CLASSICAL PHILOLOGY
IN HARVARD UNIVERSITY

WITH ILLUSTRATIONS AND ORIGINAL DESIGNS

PREPARED UNDER THE DIRECTION OF

HERBERT LANGFORD WARREN, A.M.

NELSON ROBINSON JR. PROFESSOR OF ARCHITECTURE
IN HARVARD UNIVERSITY

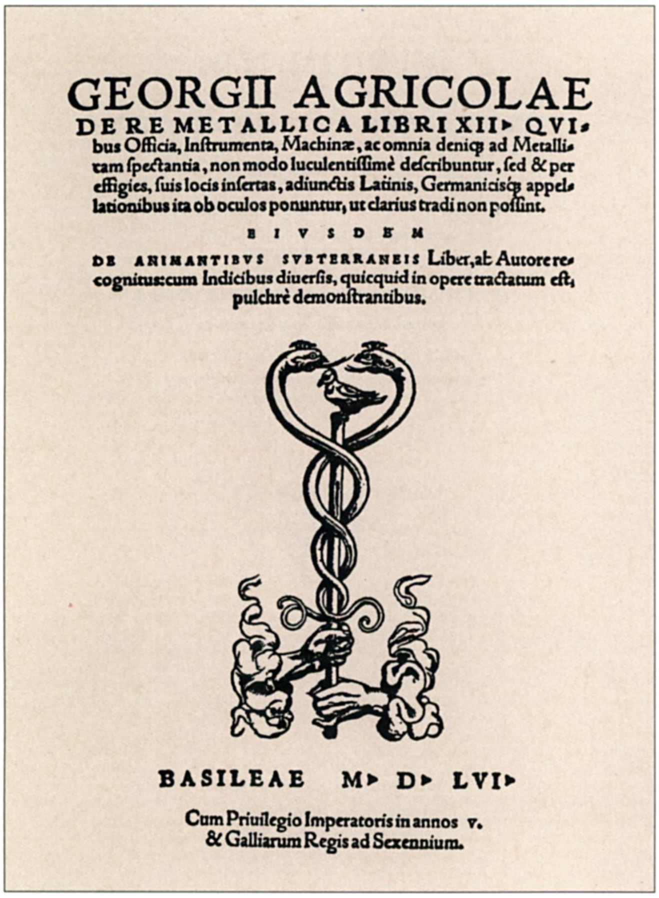
CAMBRIDGE
HARVARD UNIVERSITY PRESS
LONDON: HUMPHREY MILFORD
OXFORD UNIVERSITY PRESS
1914

Figure 1. Title page of Morris Hicky Morgan's 1914 English translation of *The Ten Books on Architecture*, written by Vitruvius in the first century B.C.E.

the emperor on the state of affairs, Frontinus wrote *The Two Books on the Water Supply of the City of Rome*.

Among the issues that Frontinus dealt with in his report were the state and care of the water-supply system's infrastructure. Maintenance, he declared, was "worthy of special care, as it gives the best testimony to the greatness of the Roman Empire." Furthermore, he had delved into the intricacies of the problem not only to be able to advise his emperor and to direct his staff, but also for his own education and edification.

Manuscripts of these writings of Vitruvius and Frontinus disappeared generally after a thousand years or so, but they were the principal works of engineering rediscovered during the Renaissance. Leonardo da Vinci is said to have learned Latin specifically to study Vitruvius, but present-day English-speaking engineers can read him in the classicist Morris Hicky Morgan's 1914 translation. Frontinus's treatise on the water supply was among the first books published after the invention of the printing press. Although many editions of this classic followed, including translations in French and German, an English translation of Frontinus was not made until a modern civil engineer, Clemens Herschel, took up the task in the late 19th century.



GEORGII AGRICOLAE
DE RE METALLICA LIBRI XII. QVIbus Officia, Instrumenta, Machinæ, ac omnia deniq; ad Metallicam spectantia, non modo luculentissimè describuntur, sed & per effigies, suis locis insertas, adiunctis Latinis, Germanicisq; appellationibus ita ob oculos ponuntur, ut clarius tradi non possint.

EIVSDEM

DE ANIMANTIBVS SVBTERRANEIS Liber, ab Autore recognitus: cum Indicibus diuersis, quicquid in opere tractatum est, pulchrè demonstrantibus.

BASILEAE M. D. LVI.

Cum Priuilegio Imperatoris in annos v.
& Galliarum Regis ad Sexennium.

Figure 2. Title page of *De Re Metallica* by Georgius Agricola, published in 1556. (Courtesy of the Rare Books Collection at the University of North Carolina at Chapel Hill.)

Translating Agricola

Another significant work was a 16th-century treatise on mining engineering that remained the definitive work for 200 years. In the course of practicing medicine in a German mining town, George Bauer noted that the miners had stores of knowledge about metals and engineering not recorded in any book. He took it upon himself over many years to collect and master this knowledge, and his *De Re Metallica* was published posthumously in 1556 under his Latinized name, Georgius Agricola. Although *De Re Metallica* was said to have been chained to church altars and translated between religious services by priests serving the mining camps of Spanish South America, it was considered "untranslatable" by Latin scholars because Agricola had coined many technical terms to describe minerals and mining practices that had been discovered long after Latin as a spoken language had died.

It remained for a leading mining engineer and his wife, Herbert Hoover and Lou Henry Hoover, to prepare the first English translation. Over five years they "lugged the manuscript all over the world for odd moments that would be available for work on it," and they were satisfied with the result only after four complete revisions. The Hoovers's translation of *De Re Metallica* was published in 1912, in an edition made to look as much like the original as possible. Before translating Agricola, Hoover had written a standard textbook on mining, would go on to write many public documents, and would eventually publish his memoirs in three volumes.

Waddell's Wisdom

In the early part of the present century, when engineers were extremely conscious of their increasing professionalism, an obligation to the written word was a point of special concern. Harwood Frost's *Good Engineering Literature*, published in 1911, opened its chapter on "literary expression" with the assertion that, "The professional engineer is naturally looked upon as an educated man." While the exclusive male pronoun is no longer appropriate, the chapter's conclusion is: "Literary expression should, therefore, be considered as one of the most practical problems with which the engineer has to deal."

One engineer who agreed especially with Frost was John Alexander Low Waddell, who was born in Ontario, Canada, in 1854. He graduated from Rensselaer Polytechnic Institute in 1875 and occupied the chair of civil engineering in the Imperial University of Tokyo in the mid-1880s. Waddell became a prolific writer. His engineering books included an encyclopedic handbook on bridge construction entitled, in the Roman tradition, *De Pontibus*, and the two-volume, million-word magnum opus *Bridge Engineering*, published in 1916. It was not uncommon to find discussions of report writing in engineering textbooks and treatises of the time, and chapter 70

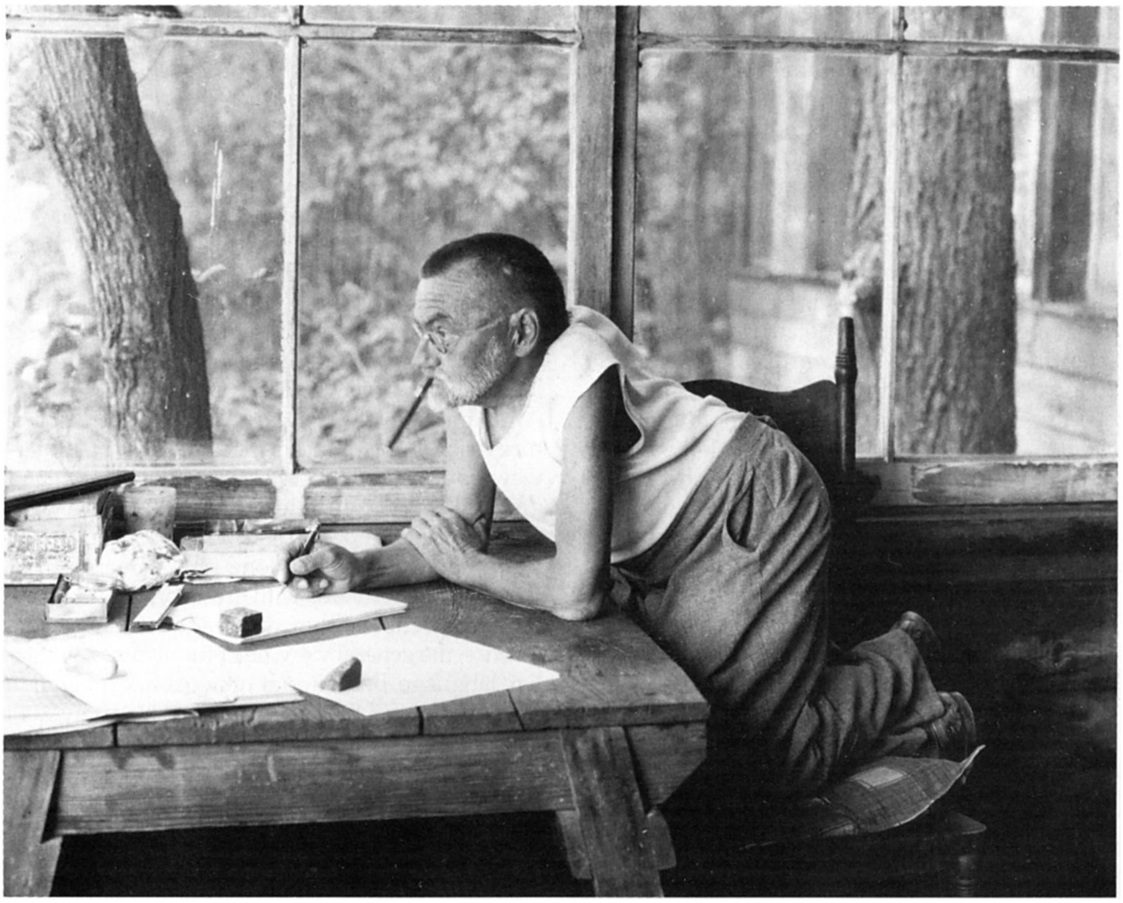


Figure 3. Charles Steinmetz said that engineering reports should include sections that are accessible to a wide audience.

of *Bridge Engineering* opened as follows: "The preparation of reports, like that of estimates, is one of the most important and responsible classes of work that an engineer is called upon to perform. It involves not only a wide engineering experience but also sound judgement based upon a practical knowledge of business affairs; and no inexperienced engineer need expect to be entrusted with the making of reports of any great consequence."

Later, in a vocational guidebook to the engineering profession that Waddell participated in editing, he approvingly quoted a further admonition: "Whenever an engineer learns something new in technics, it is his bounden duty to put it in writing and see that it is published where it will reach the eyes of his confrères and be always available to them. It is absolutely a crime for any man to die possessed of useful knowledge in which nobody shares." Waddell also believed the profession had an obligation to communicate engineering to the public: "Every established practicing engineer should also, on occasions, contribute to magazines or the daily press timely descriptions, discussions, or statements of local or important engineering projects or constructions, clearly showing to the layman the vital features, advantages, disadvantages, and probable or possible results." There was more than a tinge of professional self-interest attached to such statements, and effective communication was also seen as a means of helping the profession of engineering "attain and maintain its proper recognition, influence, and eminence."

A System for Reporting

Charles Steinmetz, who was discussed here in July–August 1991, also had something to say about engineering reports. The preface to the third edition of his *Engineering Mathematics* noted three significant additions to the text, including a section on engineering reports, which discusses "the different purposes for which engineering reports are made, and the corresponding character and nature of the report, in its bearing on the success and recognition of the engineer's work." According to Steinmetz, "Engineering investigations evidently are of no value, unless they can be communicated to those to whom they are of interest."

Steinmetz recognized three classes of reports: the scientific record of the investigation, a generally lengthy and technically detailed document "read by very few" and meant "essentially for record and file"; the general engineering report, a shorter document, a summary of results "in as plain language as possible," intended for administrative engineers "interested only in results"; and the general report, "materially shorter," addressed to non-engineers, the "administrative heads of the organization," omitting all details, and merely dealing with "the general problem, purpose and solution."

Steinmetz's acknowledgment that not every reader of a report would bring the same ability or interest to it was in the long tradition of engineering writing. Nearly 2,000 years before, in Frontinus's treatise on the Roman water-supply system, he advised readers: "Those who will be satisfied with knowing the main facts, can skip the details."

In *Engineering Mathematics*, Steinmetz advised that his three kinds of reports be combined, in order of increasing technical detail. If only a lengthy scientific report were submitted, according to Steinmetz, "as a rule it will be referred to the engineering department, and the general engineer, even if he could wade through the lengthy report, rarely has immediate time to do so, thus lays it aside to study sometime at his leisure—and very often this time never comes, and the entire matter drops, for lack of proper presentation."

Although Steinmetz had in mind the kinds of reports that are directed principally to a corporate organization like his own General Electric, his advice remains sound for a variety of contexts. Civil-engineering projects, because of their size and common interest, have been the subject of documents that are often more widely read than company reports or the archival literature. For example, the many reports of the great 19th-century bridge builder John Roebling might well have served as models for Steinmetz's hierarchical structure, and those of the 20th-century engineer Othmar Ammann, who designed the George Washington Bridge, might serve as examples of evolutionary applications.

Figure 4. Othmar Ammann's reports included logical subdivisions of the topic and the use of common language. (Photograph courtesy of Margot Ammann.)

Ammann's Advice

In an interview on his report style, Ammann revealed his method: "In my reports I usually start off with a summary and a statement of conclusions. Then I use logical subdivisions of the subject, and try to develop my basic material in language the layman can understand." This is not to say that Ammann's "well-designed" reports were structured rigidly or phrased mechanically. His interviewers described his style as generally "rapid and graceful," and continued their description with some more-than-pedestrian writing of their own: "[Ammann] uses many long-span sentences, but they carry heavy loads with great spring and verve. Since he believes that the reader must get the essence, the general view, he naturally uses qualitative language, but without unnecessary ornament. He does not feel that his 'scientific objectivity' will be compromised if he translates quantity into quality ('intolerable traffic situation') or views a fact through a feeling ('charming landscape'). He accepts the professional man's responsibility not only to specialize, but to generalize."

Ammann's writing style was described in a 1934 *New Yorker* profile as possessing a "grace and fluency surprising among scientific men." As with many writers, however, Ammann's graceful and fluent results often came only after much arduous and lengthy work. "I usually have to take my reports home and work on them until two in the morning," he admitted. During the course of his career, which spanned more than half a century, Ammann wrote more than 100 full-length reports. They were no easier to design than bridges, he once confessed, and each report no doubt had idiosyncratic premises and problems as varied as those of the individual bridges discussed. When asked how he had trained himself to write his reports, he replied: "Logic taught me how to structure my writing. Literature gives me an understanding of the importance of style."

Builders Who Were Bards

Engineers who have kept one foot in the world of literature have often achieved an admirable report style. Thomas Telford, the first president of the Institution of Civil Engineers, has been described as a virtuoso of large-scale projects. He also wrote poetry that was said to have been admired by his contemporary, Robert Burns, and his classic *Edinburgh Encyclopedia* article on bridges has been described by David Billington as "the first treatise by an engineer on structural art." A number of other engineers whose writings have survived as models of style also appear to have felt as comfortable writing about non-technical matters.

John Roebling, who studied philosophy under the great Hegel in Berlin, kept a diary on his voyage to America and attempted philosophical essays before turning to bridge building and the attendant report writing. Steinmetz wrote books on his socialist views. David Steinman, a contemporary and sometimes an adversary of Ammann, wrote eloquently on professionalism in engineering and later wrote several books of poetry. Joseph Strauss was class poet when he graduated from the University of Cincinnati with an engineering degree in 1892, and his wonderfully readable final report as chief engineer of the Golden Gate Bridge was recently reissued to celebrate the structure's 50th anniversary.

When a near-octogenarian, the notoriously shy Ammann identified the "engineer's number one problem" as the need for an ability to "communicate more easily—both with his colleagues and with the public." The problem might be addressed, Ammann allowed, by more attention to language: "Teach the student engineer how to write reports, or how to explain something to somebody without stumbling all over the English language in doing it."

Although writing has been described as the engineer's "invisible activity," it clearly has a long and honorable, even if generally unacknowledged, tradition. Some of the most accomplished engineers of all time have paid as much attention to their words as to their numbers, to their sentences as to their equations, and to their reports as to their designs. These engineers of the past have left much sound advice and many excellent models of writing for today's engineer, whether he or she is preparing a technical treatise or writing a report for a broad class of readers.

Bibliography

Frontinus. 97. *The Two Books on the Water Supply of the City of Rome*. Translated by Clemens Herschel. 1913. Second Edition. New York: Longmans, Green.

Frost, Harwood. 1911. *Good Engineering Literature: What to Read and How to Write, with Suggestive Information on Allied Topics*. Chicago: published by the author.

Miller, Walter J., and Leo E. A. Saidla. 1953. *Engineers as Writers: Growth of a Literature*. New York: Van Nostrand.

Steinmetz, Charles P. 1917. *Engineering Mathematics: A Series of Lectures Delivered at Union College*. Third Edition. New York: McGraw-Hill.

Vitruvius. 1st century B.C.E. *The Ten Books on Architecture*. Translated by Morris Hicky Morgan. 1960. New York: Dover.

Waddell, J. A. L. 1916. *Bridge Engineering*. Two volumes. New York: John Wiley and Sons.

American Association of Engineers (ed.) 1933. *Vocational Guidance in Engineering Lines*. Easton, PA: Mack Printing Co.