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Inching toward Modernity: Industrial Standards and the Fate of the Metric System in the United States

That the United States stands almost alone among nations in its failure to adopt the metric system has long been blamed on conservative, reactionary forces. This paper argues against this interpretation, which passes for conventional wisdom in both academic and popular circles. It instead contends that attacks on the metric system in the late nineteenth and twentieth century originated with progressive engineers, entrepreneurs, and industrialists who had taken the lead in setting the nation's first industrial standards. Far from being backward-looking reactionaries, they enjoyed reputations as cutting-edge leaders in the development of the machine-tool industry, the railroads, and the metal-working industries. Many of them pioneered new methods of management that privileged rationality, efficiency, and systemic approaches; indeed, they strongly influenced the development of what became known as scientific management. These individuals deftly advanced their cause through the nation's political institutions, thwarting the metric cause.

Keywords: Metric System, Standards and Standardization, Modernity, Scientific Management, Engineers and Engineering

The metric system is the most ubiquitous, universal method of measurement in human history. Unlike the systems it replaced, which relied on arbitrary benchmarks as eclectic as the width of a man's thumb, the length of a king's forearm, and a certain number of barleycorns laid end to end, the metric system is abstract, universal, and

I wish to thank JoAnne Yates, Craig Murphy, and Walter Friedman for their thoughtful suggestions as well as the three anonymous reviewers who gave invaluable feedback on the initial draft. I also want to express appreciation to the audiences who commented on earlier versions of this paper presented at the annual meetings of the Business History Conference and European Business History Association.

Business History Review 96 (Spring 2022): 47–76. doi:10.1017/S0007680521000751
 ISSN 0007-6805; 2044-768X (Web).

efficient and possesses an internal logic and consistency unmatched by any other system of measurement ever devised. The architects of this "hyper-rational language of measurement," as one historian has described it, sought to sweep away older, "irrational" systems of measurement left over from premodern times.[1] They succeeded: a little over two centuries after its creation, the metric system commands the allegiance of almost every nation in the world. Yet the United States, no stranger to modernity, remains wedded to a hodgepodge of antiquated and arbitrary weights and measures. Why?

Despite a burst of scholarship in recent years on the history of standards and systems of measurement, few academics have attempted to explain this outcome. What little has been written on the subject lays the blame at the feet of artisans, traditionalists, and reactionaries who fought to preserve antiquated methods of measurement. For example, one of the historians to address the question memorably described resistance to the metric system as an attack on "rationalization itself as well as the methods used to secure it."[2] Popular historians and journalists have advanced similar, if less sophisticated versions of this argument, contending that the metric system fell victim to nativist cranks hostile to science, international cooperation, and other cosmopolitan ideals. Some of these writers have gone so far as to portray Americans as innately stubborn and individualistic, unable to accept a more "rational" system. Others contend that American economic hegemony produced this curious outcome: the world's largest economy went its own way simply because it could.[3]

[1] Ken Alder, "A Revolution to Measure: The Political Economy of the Metric System in France," in *The Values of Precision*, ed. M. Norton Wise (Princeton, 1995), 62. On the putative relationship between the metric system, rationality, and modernity, see also Luce Langevin, "The Introduction of the Metric System: The First Example of Scientific Rationalization by Society," *Impact of Science on Society* 11 (1961): 77–95; and J. L. Heilbron, "The Measure of Enlightenment," in *The Quantifying Spirit in the 18th Century*, ed. Tore Frängsmyr, J. L. Heilbron, and Robin E. Rider (Berkeley, 1990), 207–42.

[2] Monte Calvert, *The Mechanical Engineer in America, 1830–1910: Professional Cultures in Conflict* (Baltimore, 1967), 178.

[3] On academic interpretations of this question, see Calvert, *Mechanical Engineer*; and David Noble, *America by Design: Science, Technology, and the Rise of Corporate Capitalism* (New York, 1977), 77. More recently, this argument has been repeated in Hector Vera's otherwise lucid assessment of the engineering community's opposition to the metric system in the early twentieth century; see Vera, "Breaking Global Standards: The Anti-Metric Crusade of American Engineers," in *Technology and Globalisation: Networks of Experts in World History*, ed. David Pretel and Lino Camprubi (New York, 2018), 189–215, esp. 197–98. On popular treatments, see, for example, "Why Hasn't the U.S. Gone Metric?," *Slate*, 6 Oct. 1999; Robert P. Crease, *World in the Balance: The Historic Quest for an Absolute System of Measurement* (New York, 2011), 151; John Bemelmans Marciano, *Whatever Happened to the Metric System? How America Kept Its Feet* (New York, 2014); and Zack Guzman, "Why the US Hasn't Fully Adopted the Metric System," *CNBC*, 4 June 2015.

There is some truth to this narrative, particularly in light of recent history. In the 1970s, the United States embarked on a concerted effort to encourage voluntary adoption of the new units. Though moderately successful at first, this campaign sparked a populist backlash among right-wing politicians, conservative pundits, and libertarians who used the issue to advance a reactionary brand of American exceptionalism that mocked international cooperation and scientific expertise. By the early 1980s, the drive to go metric had stalled—a victim of the so-called Reagan Revolution. Since that time, the metric system has become a perennial target for conservative commentators, who hold it up as irredeemably foreign and dangerous. In a recent, representative exchange, television personality Tucker Carlson assailed "this weird, utopian, inelegant, creepy system that we alone have resisted" and exhorted his followers to continue "fighting against the global tyranny of the metric system." Such rhetoric goes a long way toward explaining why the drive to go metric has stalled in recent years.[4]

But it does not explain earlier, far more consequential episodes of metric resistance. In the late nineteenth and early twentieth centuries, the United States came remarkably close to going metric on several occasions. Each time, a powerful and effective opposition movement arose to defeat the plan. These individuals looked nothing like their contemporary counterparts. Far from being reactionaries, they enjoyed reputations as cutting-edge leaders in the development of the machine-tool industry, the railroads, and the metalworking industries. These progressive engineers, industrialists, and entrepreneurs pioneered new methods of management that privileged rationality, efficiency, and systemic approaches; many of these thinkers would influence the development of what became known as scientific management. Indeed, their ranks included Frederick Winslow Taylor, who played a particularly critical role in defeating the metric system. These self-appointed avatars of modernity cannot be dismissed as conservative cranks, and yet they soundly defeated the metric advocates in the name of preserving and protecting a system of measurement rooted in ancient, arbitrary measures.

This paradox is best resolved by examining the role these same men played in developing the nation's first industry-wide standards: screw threads, for example, and many of the basic building blocks of the emergent industrial order. They did so because they believed that standards

[4] Grace Ellen Watkins and Joel Best, "Successful and Unsuccessful Diffusion of Social Policy: The United States, Canada, and the Metric System," in *How Claims Spread: Cross-National Diffusion of Social Problems*, ed. Joel Best (New York, 2001), 267–81; Marciano, *Whatever Happened*, 242–54; "Can the U.S. Continue to Stand Alone Against the Metric System?," *Tucker Carlson Tonight*, 5 June 2019, Fox News.

could tame what they often described as the "chaos" of industrialization. Yet their quest for order, which proceeded well in advance of comparable efforts in other countries, came at a cost. They built a new system of uniform parts and practices defined exclusively in inches and feet. This was a pragmatic choice; the fate of the metric system remained unclear at the time they made these decisions. In the process, though, they committed the country to a system incompatible with metric units. By the end of the nineteenth century, adoption of metric standards would have meant the destruction of an unparalleled system of industrial standards denominated in the older units.

But there was more to this outcome than a simple matter of what economists call "path dependencies," where choices made in one era constrain future possibilities.[5] Despite the very real costs of going metric, the United States still came remarkably close to making the metric system mandatory at this time. That it did not underscores the political acumen of the industrialists and engineers who ultimately prevailed in this decades-long battle. These individuals proved far more adept at building political alliances. As a consequence, they successfully wrested the mantle of modernity from the educators and scientists who considered the metric system the most sophisticated, modern, and rational system ever devised. In the process, the inch, not the meter, acquired a sacrosanct status in the nation's factories and machine shops, all but guaranteeing that the United States would remain outside the metric fold for the rest of the century.[6]

Machines and the Metric System

Unlike premodern methods of measurement, which typically incorporate disparate, unrelated units, each of the fundamental units of the metric system—the gram, meter, and liter—has a direct, well-defined

[5] On path dependence and history, the work of Paul A. David is most relevant. See, especially, David, "Clio and the Economics of QWERTY," *American Economic Review* 75 (1985): 332–37; and "Why Are Institutions the 'Carriers of History'? Path Dependence and the Evolution of Conventions, Organizations, and Institutions," *Structural Change and Economic Dynamics* 5 (1994): 205–20.

[6] In using the term "modernity" here, I refer not to a single, one-size-fits-all pattern of modernization based on the experience of Western nations. Rather, the term invokes the "multiple modernities" paradigm that has gained currency in recent years. I also build on this interpretation, showing that modernity took different, oppositional forms *within* an advanced industrial nation like the United States. The battle over the metric system is a case study in precisely this dynamic between competing groups of self-appointed modernizers. For more on this debate, see the essays in Shmuel N. Eisenstadt, ed., *Multiple Modernities* (New York, 2017), esp. 1–29; and Johann P. Arnason, "From Occidental Rationalism to Multiple Modernities," in *The Oxford Handbook of Max Weber*, ed. Edith Hanke, Lawrence A. Scaff, and Sam Whimster (New York, 2019), 499–518.

relationship to the others. Metric measures are also unusual in that they are decimal: units can be scaled up or down by powers of ten, making conversion between them extraordinarily simple. There is a reason we call this collection of units the metric *system*: the relationships between the units make it coherent, consistent, and predictable. The whole is greater than the sum of its parts.

These qualities reflect the metric system's origins in European scientific circles, where proposals for a "universal" system of weights and measures first surfaced. These ideas, many of them connected to the larger Enlightenment, came to fruition during the French Revolution, when the National Assembly replaced the confusing diversity of existing weights and measures with a single system designed by the *philosophes*. The revolutionaries, optimistic that the metric system would readily supplant the older units, soon realized that old habits die hard; few people adopted the new system. These frustrations eventually prompted Napoleon to revive some of the old weights and measures, but France subsequently renewed efforts to make the metric system compulsory toward the end of the 1830s. A handful of other European nations followed suit, though resistance to the new methods of measurement meant that it took many decades for metric units to gain widespread acceptance.[7]

The United States stood apart from these developments. Though Thomas Jefferson espoused a more rational, decimal system of weights and measures in the 1790s, his proposals rested on a very different basis than the new metric units—and never gained support. The older system of weights and measures inherited from the British remained in use, even if Congress failed to take steps to give those units legal sanction. The United States limped along on custom alone, which proved far more powerful than any ideas coming out of revolutionary France. By the 1810s, most commentators considered the metric system a failed experiment. One writer in 1813 noted that the French government, despite wielding considerably more power over their own populace than the United States could, nonetheless failed to secure adoption of the metric units. "The new measures . . . are on the counter . . . but the transactions are regulated by the old." In 1819, a House of Representatives committee studying the issue concurred in this assessment, pointing to France's failure to secure widespread adoption of the metric system. Given this, it concluded,

[7] Marcello Maestro, "Going Metric: How It All Started," *Journal of the History of Ideas* 41 (1980): 479–86; Witold Kula, *Measures and Men*, trans. Richard Szreter (Princeton, 1986), 228–79; Heilbron, "Measure of Enlightenment"; Ken Alder, *The Measure of All Things: The Seven-Year Odyssey That Transformed the World* (Boston, 2002).

"whatever benefits uniformity and system [the metric system] may give to posterity . . . the present age must pay no scanty price for them."[8]

This same year, Secretary of State John Quincy Adams released his own report on weights and measures. Adams privately favored the metric system, preferring its simplicity and admiring its promise to transcend older, national systems of measurement. But his report did not offer a full-throated defense of the metric system; instead, it offered a comprehensive history of weights and measures throughout all of history. This disquisition was a model of evenhanded scholarship and artful equivocation, but it offered little direction for ambivalent lawmakers. Adams conceded that the metric system had promise, even detailing its virtues at great length. But he completely undermined this point by offering plenty of evidence that the United States had no ability or will to actually implement the new system. He ultimately counseled patience, prudence, and caution, noting that if there was "one conclusion more clear than another, deducible from the history of mankind, it is the danger of hasty and inconsiderate legislation upon weights and measures." Shortly after entering this 245-page report into the public record, Congress did what it would likely have done anyway: nothing.[9]

Nonetheless, in succeeding decades, the metric system gradually gained adherents in France and, eventually, a handful of smaller European countries as well as former Spanish colonies. This movement drew its strength from the international scientific community and eventually took root in the United States as well. The turning point came in 1863, when the newly created National Academy of Sciences recommended that the United States adopt the metric system. That same year, the United States participated in international congresses on postage and statistics that endorsed the metric system for both scientific and commercial purposes. Rep. John Kasson of Iowa, who attended the postal congress and was now the chairman of the House Committee on

[8] *Journal of the Senate of the Commonwealth of Pennsylvania* (Harrisburg: Christian Gleim, 1814), 13–16; "Weights and Measures," H. Misc. Doc. No. 463, 15th Cong., 2nd Sess. (1819), *American State Papers*, Miscellaneous, vol. 2, 538–41; *Annals of Congress*, 15th Cong., 2nd sess., 755–64.

[9] "Report of the Secretary of State upon Weights and Measures," H. Doc. No. 109, 16th Cong., 2nd Sess. (1821), 6–11, 46–47, 134; "Report of the Select Committee to Which Was Referred, on the 26th of December Last, the Report of the Secretary of State upon the Subject of Weights and Measures," H. Rep. No. 65, 17th Cong., 1st Sess. (1822); *Annals of Congress*, 17th Cong., 1st Sess., 1251–53. It was at precisely the time when Adams wrote his report that Britain embarked on a significant revision of its own weights and measures, simplifying them and otherwise codifying the existing system. This likely weighed on Adams's mind as he prepared his recommendations. See Rebecca J. Adell, "The English Metrological Standardisation Debate, 1758–1824" (MA thesis, Carleton University, 2000); Adell, "The British Metrological Standardization Debate, 1756–1824: The Importance of Parliamentary Sources in Its Reassessment," *Parliamentary History* 22, part 2 (2003): 165–82.

Coinage, Weights, and Measures, capitalized on these developments to introduce legislation in 1866 that legalized the use of the metric system. The law passed with little debate or opposition.[10]

This was a significant step toward "metrication," or the process of going metric. But the law did not make metric measures mandatory. Nor did it specify a date when the metric system would become the exclusive basis of measurement. Senator Charles Sumner, who supported the bill, explained that the metric system would "not be forced into use, but will be left for the present to its own intrinsic merits." He nonetheless predicted that it would soon come into universal use and "become an approved instrument of commerce." A growing number of scientists and educators shared this optimistic outlook. In the 1860s, metric advocates became increasingly hopeful that the new system might eventually become the sole system of measurement in the United States.[11]

Yet this same decade saw a very different development: a small coterie of the nation's most accomplished engineers and industrialists began setting inch-based standards for everything from screw threads to sheet metal to wire and pipe. Many of these standard setters had ties to the machine-tool and metalworking trades. Frustrated by the fact that basic components came in a bewildering diversity of shapes and sizes, a handful of key players pioneered voluntary industrial standards that allowed these items—nuts and bolts, pipes and flanges, and other building blocks of machines—to work together, no matter which company manufactured them. Such standards fostered economies of scale, as many different companies would compete to supply precisely the same components. They also made the construction and repair of the era's machines a simpler, cheaper proposition by dispensing with the skilled labor associated with older, bespoke forms of production. Though engineers and industrialists from around the nation participated in devising these standards, a disproportionate number hailed from Philadelphia. This was understandable; the city

[10] Louis Albert Fischer, "History of the Standard Weights and Measures of the United States," *Bulletin of the Bureau of Standards* 1 (1905): 365–81; Edward Franklin Cox, "A History of the Metric System of Weights and Measures" (PhD diss., Indiana University, 1955), 411–52; JoAnne Yates and Craig N. Murphy, *Engineering Rules: Global Standard Setting since 1880* (Baltimore, 2019), 20–21. Kasson had long been a proponent of international standard setting. See Richard John, "Projecting Power Overseas: U.S. Postal Policy and International Standard-Setting at the 1863 Paris Postal Conference," *Journal of Policy History* 27 (2015): 416–38.

[11] *Cong. Globe*, 39th Cong., 1st Sess. 4219 (1866); Edward Franklin Cox, "The Metric System: A Quarter-Century of Acceptance (1851–1876)," *Osiris* 13 (1958): 358–79; United States Department of Commerce, *A History of the Metric System Controversy in the United States: U.S. Metric Study Interim Report*, National Bureau of Standards Special Publication 345-10 (Washington, DC, 1971), 35–48.

housed the biggest concentration of firms in these industries as well as the Franklin Institute, arguably the nation's most important technical society.[12]

Railroads also gave rise to standards. As a national rail network took shape from the 1860s onward, freight cars began traveling over competitors' lines via the interchange system. The need for so many different companies' rolling stock to work together sparked a drive toward voluntary standards governing everything from screw threads to car couplers, all denominated in inches. Several railroading organizations came to play key roles in these campaigns for standardization, including the Master Car Builders' Association and the American Railway Master Mechanics' Association, which also drew heavily from the machine-tool and metalworking industries. Whatever the focus of their efforts, the individuals who pressed the cause of standardization believed it would advance efficiency, rationality, safety, and order.[13]

As these efforts at standardization gathered momentum, the campaign to go metric also grew in influence, with the famed educator and president of Columbia University, Frederick Barnard, leading the charge. In 1872, Barnard published a well-received book that laid out the case for adoption of the metric system; the following year, he founded the American Metrological Society, an organization dedicated to the same end. Barnard's crusade attracted the interest of elite educators and scientists, though it never became a mass movement. Nonetheless, given developments overseas and the absence of significant opposition at home, it seemed increasingly likely that the United States would follow Europe's lead.[14]

That changed in May 1874, when the American Railway Master Mechanics' Association gathered in Chicago for its annual meeting. The same day that witnessed spirited discussions of standard axle dimensions and standard valve sizes, Coleman Sellers stood up to speak. He was well known, though perhaps less so than his cousin William Sellers, whom the famed British industrialist Joseph Whitworth once described as the "greatest mechanical engineer in the world."[15]

[12] On the conditions that made Philadelphia a center for standard setting, see Andrew Dawson, *Lives of the Philadelphia Engineers: Capital, Class and Revolution, 1830–1890* (Burlington, VT, 2004); and Domenic Vitello, *Engineering Philadelphia: The Sellers Family and the Industrial Metropolis* (Ithaca, 2013).

[13] On the railroads and standardization, see Steven W. Usselman, *Regulating Railroad Innovation: Business, Technology, and Politics in America, 1840–1920* (Cambridge, U.K., 2002). On the general embrace of standardization at this time, see Andrew L. Russell, *Open Standards and the Digital Age: History, Ideology, and Networks* (Cambridge, U.K., 2014), 25–57; and Yates and Murphy, *Engineering Rules*, 19–51.

[14] Frederick A. P. Barnard, *The Metric System of Weights and Measures* (New York, 1872); Cox, "History of the Metric System," 452–81; U.S. Department of Commerce, *History*, 51–58, 63–68.

[15] Joseph Whitworth, "William Sellers," *Journal of the Franklin Institute* 159 (May 1905): 381.

The two men operated the William Sellers Company of Philadelphia; Coleman served as chief engineer, William as president. The firm was the most important and efficient manufacturer of machine tools in the country, a place where standardization proceeded faster and farther than almost any other factory in the country, transforming everything from paint colors to shop drawings. William Sellers even created the first and most consequential industrial standard of the era: a system of screw threads that had gained many adherents by the time Coleman delivered his talk. The Sellers name was synonymous with standardization. And the metric system was the ultimate standard.[16]

Yet Sellers had come to bury the metric system, not to praise it. He began by pointing out that earlier in the century the United States had led the rest of the world in developing interchangeable parts. More recently, this obsession with uniformity had given rise to the first industry-wide standards, creating a system of interoperable parts that could work in any machine made by any manufacturer. "Separate and distinct manufacturing establishments have come to use the same standards and to make their production interchange one part with another," he noted. But there was a catch: "what has been done in this direction, and what is being done now, is founded on the inch as the unit of measurement in the machine shops." This put the two imperatives—a universal system of metric measures and a universal system of standard parts—on a collision course. "While French savants were laboring to build up this decimal system of interchangeable measures," observed Sellers, "the better class of American mechanics were solving the problem of making machinery with interchangeable parts." These very different approaches to standardization could not be reconciled without immense cost.[17]

In this paper as well as in expanded versions delivered over the rest of the decade, Sellers asked his listeners to consider the cost of going metric by examining the tools his firm used to produce components in the standard size of 1¼ inch. He counted 129 sets of articles: drills, reamers, gauges, cutters, taps and dies, mandrels, and many other implements. These pieces, he observed, "tally with and belong to the dimension marked 1¼ in many thousand places on drawings, which have been accumulating for years, to patterns loading down our pattern lofts to gear wheels interchangeable over a continent." These

[16] John K. Brown, "When Machines Became Gray and Drawings Black and White: William Sellers and the Rationalization of Mechanical Engineering," *Journal of the Society for Industrial Archaeology* 25 (1999): 29–54.

[17] Coleman Sellers, "The Metric System in Our Work-Shops: Will Its Value in Practice Be an Equivalent for the Cost of Its Introduction?," *Journal of the Franklin Institute* 97 (1874): 385–86. Sellers would soon advance these arguments in several other venues. See, for example, Sellers, "On the Metric System of Weights and Measures," *Transactions of the American Society of Civil Engineers* 5 (1876): 364–67.

could not be replaced without creating an entirely new set of patterns, taps and dies, gauges, and all the other equipment necessary to go metric. At the same time, the old system would have to be maintained: all the equipment already in existence would need to be serviced and repaired for many years, requiring that two sets of every tool, old and new, would become necessary.[18]

In theory, every industrial establishment could convert existing units to their metric counterparts. Sellers argued that this solution, which metric advocates proposed, was better in theory than practice. Instead of a binary system in which everything was divisible by two—1 inch, ½ inch, ¼ inch, ⅛ inch, and so forth—a rather ungainly sequence of numbers would take their place: 2.54 cm, 1.27 cm, 0.635 cm, 0.3175 cm, 0.15875 cm, 0.079375 cm, each becoming significantly more cumbersome than the last. The same was true with larger components: boilers, for example, came in 36 inches, 42 inches, and 48 inches; when translated into the metric system, these tidy, divisible numbers, each of which shared multiple factors, became 91.44 cm, 106.68 cm, and 121.92 cm. The existing whole numbers made intuitive sense to mechanics, never mind the buyers of this equipment; their metric translations did not. The only way to clean up this problem was to change the actual dimensions, but this meant retooling at considerable expense.[19]

Sellers and the growing number of engineers and industrialists who came to oppose the metric system had little sentimental attachment to other customary measures in use. They did not care whether people continued to measure their wheat in bushels or their milk in gallons. Only the inch and the standards derived from it mattered. That this humble unit could so thoroughly thwart the metric cause is understandable. Unlike the grab bag of unrelated measures still used in the United States, the metric system's appeal lay in the perfect, predictable interdependence of its units. Any country that adopted some metric units but not others undermined the conceptual foundations of the entire system, making full adoption extraordinarily difficult. Yet this was the path the United States followed, legalizing the metric system without making it the exclusive system of measurement. The result was a hybrid system, where metric measures became customary in medicine and science even as engineers made older units like the inch increasingly integral to the organization of industry.

[18] Coleman Sellers, "The Metric System—Is It Wise to Introduce It into Our Machine Shops?" *Transactions of the American Society of Mechanical Engineers* 1 (1880), 1–19, quote on p. 7.

[19] Sellers, "Metric System in Our Work-Shops"; "Is It Wise to Introduce." Metric equivalents are calculated on the basis of the figures supplied by Sellers.

https://doi.org/10.1017/S0007680521000751 Published online by Cambridge University Press

Metric proponents, fearful of precisely this outcome, began organizing campaigns to make the metric system mandatory. In 1876, a new group known as the American Metric Bureau opened its doors, funded in part by Barnard's existing organization. Lead by the educator and librarian Melvil Dewey—who consistently ordered the world along decimal lines—the new group focused its efforts on schoolteachers and children, publishing tracts that explained the operations of the metric system, its advantages, and its growing use outside of the United States. Dewey hoped that the American Metric Bureau could create a groundswell of popular support that would ultimately lead to national legislation making the metric system the exclusive system of weights and measures. But as metric advocates marshaled their forces, a more coherent opposition coalesced within two very different organizations connected to the larger engineering community.[20]

The first was the American Society of Mechanical Engineers (ASME), founded in 1880 by a number of the nation's leading technical minds. Many of the founding generation shared an obsession with standardization, and in the coming years, the ASME would play a key role in coaxing industry to adopt a growing number of voluntary standards, even if it rarely formulated those standards itself. It was only appropriate, then, that attendees at the first annual meeting listened to papers on standard screw threads and the dangers of the metric system. The latter, given by founding member Coleman Sellers, proved even more influential than his first foray into the subject. It explicitly joined the campaigns of industrial standardization with a critique of the metric system, arguing that it was too late—and too costly—for the country to consider going metric. The inch had been enshrined in the industrial base; it would not be dislodged. Sellers repeated the warning he had offered earlier that decade: "America," he wrote, "has for the last half century, been striving in its own way toward equalization of its standard sizes. The immense railroad industries demand this."[21]

The central role of the ASME in defeating the metric system was overshadowed by the rise of another group known as the International Institute for Preserving and Protecting Weights and Measures (hereafter, the Institute). This organization, founded in 1879, launched a very visible, if eccentric, campaign against the metric system. It promoted what became known as "Great Pyramid metrology," a belief that the

[20] U.S. Department of Commerce, *History*, 62–73; Wayne A. Wiegand, *Irrepressible Reformer: A Biography of Melvil Dewey* (Chicago, 1996), 28, 49–50; Hector Vera, "The Social Life of Measures: Metrication in the United States and Mexico, 1789–2004" (PhD diss., New School for Social Research, 2011), 330–40.

[21] Sellers, "Is It Wise to Introduce," 14–15. See also Bruce Sinclair, *A Centennial History of the American Society of Mechanical Engineers, 1880–1980* (Toronto, 1980), 46–60.

Egyptians had inscribed the inch as a sacred unit of measurement in the design of their famed structures. The movement gained numerous adherents in both the United States and England at this time, including many distinguished scientists. Like earlier generations of otherwise respectable thinkers who dabbled in astrology or alchemy, the intellectuals drawn to this movement did not see any contradiction. Over the 1870s and 1880s, pyramid metrology channeled much of the opposition to the metric system in the United States, eliciting furious rebuttals by Barnard and other metric proponents.[22]

The rise of pyramid metrology would seem to underscore the alleged irrationality and provincialism of the anti-metric movement. But the story is more complicated. Both the leadership and the rank-and-file membership of the Institute included an extraordinary number of engineers; many of them had close ties to the railroads, metalworking trades, and other industries where standardization had taken root. The founder of the Institute, Charles Latimer, may have dabbled in mesmerism and divining rods, but he was best known for being the longtime chief engineer of the Atlantic and Great Western Railway. A proponent of developing standard practices in the maintenance of rail lines, he pioneered what *Railway Age* would later describe as the "correct principles and . . . good practice in railway track work," turning what had been one of the more chaotic, poorly maintained lines in the country to one of the safest and most reliable.[23]

Many members had comparable professional profiles. In a typical update on membership from 1883, the Institute's journal noted that it had elected six new members at its recent meeting, "most of them engineers." This particular cohort included Edward Wellman Serrell, a well-known civil engineer who had worked on railroads and bridges; and Charles G. Roebling, the famed engineer, wire manufacturer, and builder of the Brooklyn Bridge. Eventually, the membership would encompass many more high-placed engineers, including John B. Jervis, the railroad and public works engineer; and William H. Searles, a civil engineer who wrote the principal textbook on railroad surveying. Though it is impossible to know why, precisely, so many of these men—civil engineers, iron foundry owners, and others—came to embrace a belief in the mystical origins of the inch, it

[22] Edward F. Cox, "The International Institute: First Organized Opposition to the Metric System," *Ohio Historical Quarterly* 68 (1959): 54–83; Eric Michael Reisenauer, "'The Battle of the Standards': Great Pyramid Metrology and British Identity, 1859–1890," *Historian* 65 (2003): 931–78.

[23] A. M. Wellington, "Charles Latimer," *Proceedings of the American Society of Civil Engineers* 15 (1889): 137–40; The American Railway Engineering and Maintenance of Way Association," *Railway Age* 43 (1907): 370; Cox, "International Institute," 62–63.

likely affirmed the central place this unit had in their work lives, governing everything from the components used to build bridges and tunnels to the scale of the blueprints and surveys that structured their plans.[24]

Mechanical engineers did not join the Institute in the same numbers, but their embrace of standards did far more to halt the progress of the metric system. In the 1870s and 1880s, engineers promoting a uniform system of screw threads ran up against what seemed like an insurmountable obstacle when they discovered that the underlying unit—the inch—could not be accurately reproduced because the United States lacked an accurate reference standard. Ultimately, George Bond, a mechanical engineer connected with Pratt & Whitney, the nation's premier manufacturer of reference gauges, solved the problem with the help of William Rogers, a Harvard professor of astronomy, instrument maker—and longtime member of the Institute. The duo devised a "comparator," which enabled them to build the most accurate inch-based gauges ever built. These supplied the metrological benchmarks used to define standards governing everything from the gauge of wire to the pitch of a screw to the thickness of iron plate.[25]

By the 1880s, the engineering profession had largely won the first battle over metric conversion. While a handful of historians have noted the signal contribution of engineers in this consequential struggle, they have struggled to explain it. Following the interpretive lead of Monte Calvert, David Noble and others claimed that the debate over the metric system exposed a longstanding divide between an anti-metric "shop culture," consisting of practical, self-educated men who owned and operated small machine shops, and a pro-metric "school culture" of progressive, professional, college-educated engineers and academics. According to this interpretation, the older "shop culture" engineers feared the metric system because it would make it easier to calculate measurements on the factory floor, thereby depriving them of their esoteric knowledge. As Calvert wrote, "What could be more of a boost to the status of the college-trained engineer than for him to possess a new and arbitrarily determined system of measurement?

[24] "Transactions of the Ohio Auxiliary Society of the International Institute," *International Standard* 1 (1883): 402; "Monthly Receipts from Subscribers to the International Standard," *International Standard* 2 (1884): 189–92. On the history of civil engineering at this time, see Bernard G. Dennis Jr., Robert J. Kapsch, Robert LoConte, Bruce W. Mattheiss, and Steven M. Pennington, eds., *American Civil Engineering History: The Pioneering Years* (Washington, DC, 2002).

[25] George M. Bond, "Standards of Length and Their Subdivision," *Journal of the Franklin Institute* 117 (May 1884): 357–86; Bond, *Standards of Length and Their Practical Application* (Hartford, CT, 1887), 71; "George Meade Bond, M.E.," *Stevens Indicator* 38 (July 1921): 220–21; Bruce Sinclair, "At the Turn of the Screw: William Sellers, the Franklin Institute, and a Standard American Thread," *Technology and Culture* 10 (1969): 20–34.

What could better assure his ascendence over the boy from the shop? Knowledge of the metric system could become, like calculus, a badge of the formally trained." In this reading, conservative, self-educated traditionalists defeated the metric system in order to protect old-fashioned, high-skill forms of production.[26]

This interpretation has no basis in reality. Metric opponents William and Coleman Sellers presided over a vast industrial empire that included Sellers and Company, one of the largest manufacturers of machine tools in the world; Edge Moor Iron Company, the world's largest fabricator of iron and steel components for bridges and other structures; and most famous of all, the Midvale Steel Company, a company one historian has aptly described as "the leading scientific steelmaker in America."[27] Neither man wanted to preserve autonomy on the shop floor. Coleman Sellers once wrote that "the attention of engineers is constantly directed to so perfect machine tools so as to utilize unskilled labor."[28] An industry journal likewise described him as "writing from the plane of experience of the practical mechanic, and yet he is a school man, too. He is the advocate of system at any cost."[29] Toward that end, Coleman and William Sellers hired university-trained engineers to wrest control from the shop floor. The most dramatic of these interventions took place at Midvale Steel, site of Frederick Winslow Taylor's experiments in scientific management; recent scholarship suggests that many of Taylor's concepts originated with William Sellers and his deputies. None of this comports with the idea that these men wished to protect antiquated shop-floor traditions from university-trained managers.[30]

Moreover, university-trained managers and engineers came to dominate the anti-metric cause. Consider George Bond. He studied mechanical engineering at the Stevens Institute before joining Pratt & Whitney and becoming head of the company's standards and gauge department; he authored a number of scientific papers on the problems of precision measurement and inch-based standards. He was the antithesis of the older shop culture—and yet he became a strident foe of the metric system. For example, when a dissident group of railroad engineers in

[26] Calvert, *Mechanical Engineer*, 184, 186; Noble: *America by Design*, 77. This argument resurfaces in Vera, "Breaking Global Standards."

[27] Vitello, *Engineering Philadelphia*, 136.

[28] Coleman Sellers, "Theory and Construction of the Self-Acting Slide Lathe," *Journal of the Franklin Institute* 94 (1872), 106.

[29] "Defending Our Standard Unit of Measurement," *National Car and Locomotive Builder*, Mar. 1889, 44.

[30] "William Sellers," 365–81; Thomas J. Misa, *A Nation of Steel: The Making of Modern America, 1865–1925* (Baltimore, 1995), 180–82; Geoffrey W. Clark, "Machine-Shop Engineering Roots of Taylorism: The Efficiency of Machine-Tools and Machinists, 1865–1884," in *Scientific Management: Frederick Winslow Taylor's Gift to the World?*, ed. J.-C. Spender and Hugo J. Kijne (Boston, 1996), 93–110; Vitello, *Engineering Philadelphia*, 136, 146–47.

New England had the temerity to recommend that the Master Car Builders' Association study the question of adopting the metric system, Bond, like other high-placed, university-trained mechanical engineers, dismissed the idea out of hand on the grounds that it would derail standardization. The mere act of discussing the metric system, Bond warned in 1889, would "inspire a feeling of cautious hesitancy on the part of those who may be willing and even anxious to adopt a standard of whatever system may be officially recognized."[31]

This particular attack came at a critical phase in the metric battle. Barnard died a month after this editorial appeared, depriving the metric system of its most forceful advocate in the United States; Dewey's Metric Bureau went defunct around the same time. Though a handful of scientists carried on the campaign, engineers and managers hostile to the metric system outnumbered them. This was a logical consequence of the proliferation of inch-based standards among railroads, machine-tool manufacturers, and metalworking trades. The gradual embrace of standard sizes proceeded with little fanfare or notice—yet it proved decisive in what became the most important battle over the country's system of measurement.[32]

The Revolt of the Engineers

In 1896, the House of Representatives considered a bill that mandated the immediate, exclusive use of the metric system in the federal government, with the rest of the country to follow suit a few years later. The sudden interest in the issue had grown out of the fact that the Republican Party now controlled both the House and the Senate for the first time since 1873. Charles Stone, a pro-metric educator from Pennsylvania, became the new chairman of the House Committee on Coinage, Weights, and Measures. Stone, eager to push a pet issue, summoned sympathetic witnesses for hearings; all dutifully praised the metric system for its simplicity and consistency, as did academics and

[31] The request to consider the metric system came from the New England Railroad Club, which represented some of the smaller companies in the Northeast. The group had a history of opposing standard sizes of components favored by competitors in other parts of the country. Their flirtation with the metric system may also have reflected the metric movement's outsized sway in this area of the country. See "Metric Measurements in Railroad Shops"; Bond, "The Metric System of Measurement;" and "Defending Our Standard Unit of Measurement," all in *National Car and Locomotive Builder* 20 (1889): 28, 41, 44. On Bond, see "George Meade Bond, M.E.," 220–21.

[32] Cox, "History of the Metric System," 551–52; U.S. Department of Commerce, *History*, 96. Thomas Corwin Mendenhall, who became superintendent of the United States Coast and Geodetic Survey, emerged as the most visible proponent of metrication in the 1890s. See, for example, T. C. Mendenhall, "Fundamental Units of Measure," *Transactions of the American Society of Civil Engineers* 30 (1893): 120–34.

scientists who wrote in support of the legislation. The bill attracted little attention until it was sent to the floor for full consideration. It might well have passed, but growing concern that changing weights and measures in an election year might cost votes prompted legislators to send it back to the committee for further consideration.[33]

Despite its defeat, the bill sparked a backlash among engineers and industrialists, none of whom had been consulted on the proposed change. Later that year, the ASME created a committee charged with preparing "such material as may be necessary, which may be used in opposition to legislation seeking to make the Metric System and its use compulsory in the United States." The members of this committee included George Bond and Coleman Sellers, but it also welcomed several other members, including John Sweet, a mechanic turned professor of engineering at Cornell University who had devised some of the first—and most accurate—standard gauges ever manufactured in the United States. These engineers, like most who opposed the metric system, had a significant professional stake in the existing system of standards denominated in the inch.[34]

They would soon be overshadowed by a younger group of college-educated engineers, most of whom had close ties to the first generation of metric foes and shared their obsession with standardization. Henry Towne was typical of the new face of the opposition. The son of one of the partners of the Southwark Foundry in Philadelphia, Towne attended the University of Pennsylvania and later studied at the Sorbonne. He worked in Philadelphia with many key proponents of industrial standards, including Coleman and William Sellers and Robert Briggs, the famed engineer who developed a system of uniform pipe threads still in use today. Towne contributed to the development of standard systems of belts and pulleys before pioneering the mass production of locks at several factories in Connecticut; he eventually became the biggest such manufacturer in the world. Like others in this circle, Towne was obsessed with increasing efficiency and rationalizing the shop floor. In 1886 he presented a now famous paper at the annual meeting of the ASME entitled "The Engineer as an Economist," which inaugurated the new "science" of management. The connection between Towne and Taylor was well known nearly a century ago. As one of Frederick Winslow Taylor's earliest, most sympathetic biographers conceded in 1923, "if Taylor was great, Towne was his prophet." The historian David Noble has echoed that assessment, noting that

[33] U.S. Department of Commerce, *History*, 102–9.

[34] House Committee on Coinage, Weights, and Measures, *Hearings on H.R. 2758*, 54th Cong., 1st Sess., 1896; *Cong. Globe*, 54th Cong., 1st Sess. 3688–98 (1896); *ASME Transactions* 18 (1896): 10; U.S. Department of Commerce, *History*, 569–84.

Towne's pathbreaking paper "is generally considered to be the first significant articulation of the scientific-management movement."[35]

Towne's career highlights another quality found in the new generation of metric opponents: their shared enthusiasm for the constellation of ideas that sought to bring order and "system" to the management of factory floors. These thinkers marched under various banners, from "shop management" to "systematic management" and, eventually, "scientific management."[36] Taylor himself would play a pivotal role in the decisive defeat of the metric system. So, too, would another like-minded figure: Frederick Halsey. Like Towne, Halsey boasted a formal education; he attended Cornell, becoming a protégé of John Sweet. A consummate modernizer, Halsey developed cutting-edge machine tools; he also helped pioneer "systematic management," developing a detailed "premium plan" that gave laborers carefully calculated incentives to increase productivity. Though overshadowed by Taylor's efficiency studies, Halsey's plan was adopted in some version by more factories. Halsey achieved considerable fame in economics and engineering, becoming one of the leading figures in the quest to make factories more efficient. He went on to become associate editor at the *American Machinist*, arguably the most influential industry journal in the United States. A gifted propagandist and relentless self-promoter, he was well positioned to lead the attack on the metric advocates.[37]

Advocates of standardization and "scientific" approaches to management emerged as the most vocal and effective critics of the metric system because these thinkers shared a common belief in the transformative power of inch-based standards, both within the walls of individual factories and across the larger economy. They had a preoccupation—one

[35] Henry R. Towne, "The Engineer as an Economist," *ASME Transactions* 7 (1886): 428–32; "Henry R. Towne," *Railway Age Gazette* 89 (1915): 207; Frank Barkley Copley, *Frederick W. Taylor: Father of Scientific Management*, vol. 1 (New York, 1923), 400; Noble, *America by Design*, 267; Daniel Nelson, *Frederick W. Taylor and the Rise of Scientific Management* (Madison, WI, 1980); Sinclair, *Centennial History*, 57–59; JoAnne Yates, *Control through Communication: The Rise of System in American Management* (Baltimore, 1993), 85; Daniel R. Nelson, *Managers and Workers: Origins of the Twentieth-Century Factory System in the United States, 1880–1920* (Madison, WI, 1996), 52–53; Yehouda Shenhav, *Manufacturing Rationality: The Engineering Foundations of the Managerial Revolution* (New York, 1999), 75–76; Fred Carstensen, "Towne, Henry Robinson," in *American National Biography*, vol. 21, ed. John Arthur Garraty and Mark Christopher Carnes (New York, 1999), 780–81.

[36] The tangled intellectual relationship between these different self-appointed modernizers is summarized well in Shenhav, *Manufacturing Rationality*, 102–21; Nelson, *Managers and Workers*, 49–55; and Noble, *America by Design*, 266–68.

[37] Nelson, *Managers and Workers*, 53–55; Robert R. Jenks, "Halsey, Frederick Arthur," in *American National Biography*, vol. 9, ed. John Arthur Garraty and Mark Christopher Carnes (New York, 1999), 888–89; Robert Kanigel, *The One Best Way: Frederick Winslow Taylor and the Enigma of Efficiency* (Cambridge, MA, 2005), 282–84; Morgen Witzel, *A History of Management Thought* (New York, 2017), 112–14.

might say obsession—with uniformity, imposing it on everything from nuts and bolts to the most mundane movements of a worker's body. In a typical expression of this world view, Taylor counseled "the adoption and maintenance of standard tools, fixtures, and appliances down to the smallest item throughout the works and office, as well as the adoption of standard methods of doing all operations." Or, as he put the matter more succinctly, "It is uniformity that is required." Whatever their particular investment in standards, such uniformity was inevitably defined in inches. The metric system threatened to destroy not only the hard-fought system of standards governing the actual machines but also the performance standards that Taylor and others had spent years developing.[38]

The battle against the metric system, then, was waged by a technical elite of industrialists and engineers closely connected with both the standardization movement and scientific management. This argument, which goes against conventional wisdom and the academic literature, underscores that the metric debate was not a battle between pro-metric progressives and rear-guard reactionaries but between two distinct communities of self-appointed modernizers. In the end, the standards setters and scientific managers proved far better organized and more persuasive. They would triumph in what became the decisive clash over the metric system waged in the opening years of the twentieth century.

The catalyst was the creation of a new federal bureaucracy known as the Bureau of Standards. This institution, modeled on Germany's famed Physikalisch-Technische Reichsanstalt, would pursue scientific and technological research in optics, electricity, mechanics, metallurgy, and chemistry. It would simultaneously set the standards used to define these fields; it would also validate and certify the advanced instruments necessary to conduct such research. This was imperative: the swift, chaotic growth of new industries proceeded without any agreement on standards used to measure and meter electricity. As a consequence, companies—and even the federal government—sent equipment and measuring devices overseas for calibration and verification. Frustrated by these restrictions, a coterie of scientists, electrical engineers, chemists, and others associated with new technical fields pushed for a new standards bureau.

The most important player in these efforts was an electrical engineer and physicist named Samuel Stratton. A professor at the University of

[38] Frederick Winslow Taylor, *Shop Management* (New York, 1911), 116, 124; David Montgomery, *Workers' Control in America: Studies in the History of Work, Technology, and Labor Struggles* (Cambridge, U.K., 1980), 113–38; Tom Korver, "Standards and the Development of an Internal Labor Market," in Spender and Kijne, *Scientific Management*, 93–110.

Chicago, Stratton's real talent lay in playing politics and building bureaucracies, and he shepherded the legislation through Congress. Though Stratton and his allies favored making the metric system the exclusive system of measurement in the United States, they understood that yoking the fate of the Bureau of Standards to the metric cause would derail their fragile political coalition. As Stratton later noted in private correspondence, "a great many would have opposed [the bill] had it been understood that the Bureau was favorable to the adoption of the metric system." Witnesses therefore studiously avoided any mention of it in their pleas for the Bureau's creation, and pro-metric legislators steered clear of the issue as well. This defused the issue and President McKinley signed legislation creating the Bureau of Standards in the spring of 1901 and installed Stratton as its head. Over the next twenty years, Stratton would turn the Bureau into the largest national laboratory in the world.[39]

Stratton tackled the metric question as soon as he became director. He corresponded closely with Thomas Corwin Mendenhall, president of the pro-metric American Metrological Society, and addressed the organization in person; he also began working closely with Rep. Henry Southard, a metric advocate who now chaired the House Committee on Coinage, Weights, and Measures. Southard oversaw the introduction of two largely identical bills that would make the metric system the legal, and exclusive, system of weights and measures for the United States. In 1901, Stratton began a campaign aimed at building support for the legislation. That summer, he privately noted that "Mr. Southard and myself have been preparing the work for the next session. I have secured the cooperation of many large manufacturers." Stratton rattled off a number of big firms he believed would go on record in support of the metric system. He predicted that the metric system would soon become the law of the land.[40]

Despite Stratton's confidence that manufacturers would support the legislation, few appeared before the committee. Instead, most of the support came from scientists, electrical engineers, educators, and instrument makers—valuable allies, to be sure, but hardly qualified to speak about the potential cost of retooling the nation's heavy industry along

[39] House Committee on Coinage, Weights, and Measures, *Hearing on House Doc. No. 625*, 56th Cong., 1st Sess., 1900, 7–8; Samuel W. Stratton to E. E. Corthell, 16 Aug. 1901, folder MS 1901–1911, box 20, "IWL-MS," in Records of the NBS, RG 167, NARA; David Cahan, *An Institute for an Empire: The Physikalisch-Technische Reichanstalt, 1871–1918* (Cambridge, U.K., 1989).

[40] Thomas Corwin Mendenhall to Samuel W. Stratton, 15 Mar. 1901 and 17 May 1901, both in Samuel W. Stratton Papers, MC 8, box 2, folder 17, Massachusetts Institute of Technology, Institute Archives and Special Collections, Cambridge, MA; "Uniformity of Measures," *Washington Post*, 20 Apr. 1901, 9; Stratton to Corthell, NARA.

metric lines. When the committee began to question individuals outside of Stratton's circle, the hearings became acrimonious. The rear admiral in charge of the U.S. Navy's Bureau of Steam Engineering predicted that going metric would cause a "great deal of confusion," undoing the Herculean efforts to standardize nuts, bolts, and other fasteners that had begun with the work of William Sellers in the 1860s. Other witnesses, most notably Pratt & Whitney's George Bond, seconded this point. Like many in the field, Bond predicted that compulsory adoption of the metric system would impose "great hardship" and necessarily "involve more expense than we would care to assume." Though Stratton could have ignored these dissenting voices, he jumped into the fray, accusing Bond of misrepresenting the cost and inconvenience of the proposed conversion. "As far as your product is concerned," Stratton lectured, "I am quite sure you could turn it out in the metric system."[41]

Stratton's blithe dismissal of Bond awakened the resistance. Shortly after Bond had delivered his testimony, the Franklin Institute met to hear from a committee it had appointed the previous year to report on the advisability of adopting the metric system. Unsurprisingly, the committee—which included several of the pro-metric witnesses whom Stratton had tapped—embraced the idea. But when the report came up for discussion among the larger membership, Bond, fresh from his clash with Stratton, openly attacked the committee's findings. But his real target was the metric legislation under consideration in Congress. He questioned the propriety of the hearings, noting that it had been his understanding that manufacturers would be well represented on the roster of witnesses. "I was surprised to find myself the only one, except for one gentleman," he complained. Bond, who had played such a critical role in defining the inch and the standards linked to it, made an impassioned case against the metric system. After considerable debate, the Franklin Institute narrowly endorsed the committee's pro-metric report.[42]

But Bond and his allies would not be deterred, and in the succeeding months, a movement against the metric system took shape within a loose community of machine-tool manufacturers and firms in allied industries

[41] House Committee on Coinage, Weights, and Measures, *Metric System of Weights and Measures: Hearings on H.R. 2054*, 57th Cong., 1st Sess., 1902, 33–40, 52–56, 63–70, 88–102, 109–20, 151–62. On the Navy's interest in standards, see *Report of the Board to Recommend a Standard Gauge for Bolts, Nuts, and Screw-Threads for the United States Navy* (Washington, DC, 1880).

[42] "The Metric System of Weights and Measures," *Journal of the Franklin Institute* 153 (1902): 405; "The Metric System of Weights and Measures," *Journal of the Franklin Institute* 154 (1902): 59–72; "The Metric System of Weights and Measures," *Journal of the Franklin Institute* 154 (1902): 107–20; "The Metric System of Weights and Measures," *Journal of the Franklin Institute* 154 (1902): 171–91.

along with organizations like the National Association of Manufacturers, founded in 1895. Veterans of the first metric battle took part, including Coleman Sellers, but the movement acquired a new face: the mechanical engineer Frederick Halsey. At the turn of the century, Halsey had emerged as the leader of a band of younger engineers within the ASME. As Halsey's standing grew, he gained outsized influence within the organization, and he likely had a hand in the decision to devote most of the annual meeting in 1902 to the "metric question." Initially, the meeting was set to hear a formal report submitted by a committee on the subject, but Halsey took matters into his own hands, writing and distributing a voluminous study in advance of the meeting. This document closely resembled a legal brief, buttressing its claims with copious "exhibits." Though Halsey echoed many of the earlier arguments voiced by Coleman Sellers and others, he went much farther, actively seeking to demolish the metric system's pretensions of superiority. Halsey would soon publish this report as a book, pointedly titled *The Metric Fallacy*.[43]

Much of Halsey's argument centered on a key claim: every nation that made the metric system mandatory failed to abandon older units of measurements. "The fatal mistake of the metric advocates and the weakness of their case," he wrote, "lies in their assumption that the statute book is an index of the practice of the people." Halsey offered considerable evidence demonstrating that ostensible models of metric adoption like France were still trying to stamp out older standards. This was a devastating line of attack: Halsey knew that the metric system's popular appeal lay in the promise that it would supplant other standards entirely and immediately. By painting a picture of countries caught awkwardly between old and new standards, Halsey effectively undercut the metric system's claims to bring order to chaos. He predicted that the United States would be no different, noting that existing gas pipes alone "would keep the old system alive for fifty years." So long as the dead hand of the past exercised its influence, Halsey argued, many of the alleged benefits of going metric would prove elusive.

Halsey also assailed the widely circulated belief that conversion to the metric system would help the United States gain an edge in overseas markets. He pointed out that the Europeans used inch-based screw thread standards and that foreign businesses and governments bought American machine tools denominated in inches because the benefits—low prices, interchangeable parts, and the interoperability of vital

[43] Nelson, *Managers and Workers*, 53–55; Jenks, "Halsey, Frederick Arthur," 888–89; Kanigel, *One Best Way*, 282–84; Witzel, *History of Management Thought*, 112–14; Frederick A. Halsey, *The Metric Fallacy* (New York, 1904).

components like nuts and bolts—far outweighed this liability. If the United States already dominated these overseas markets, going metric offered few benefits and might even undercut this advantage. Halsey assembled testimonials from foreign buyers, including a French industrialist who reported that he knew of "no case where the fact of the machines being built to English measures affected their saleability." And as Halsey noted, in those rare instances where foreign customers demanded metric components, American manufacturers readily produced these as well, even if such requests remained a rarity.[44]

The debate over Halsey's manifesto defined the annual meeting and marked a significant new front in the battle. The ASME gave Halsey top billing, letting him deliver his report to the assembled members; it also asked several metric advocates to offer a rebuttal, including Stratton and Southard. This was only fair: Halsey had attacked both men by name in his report. Both appeared, not anticipating the trap that Halsey had set for them. When Stratton offered a generic defense of the metric system, Halsey adopted the air of a vengeful prosecutor, accusing the Bureau of Standards' new head of being "the prime-mover of the present pro-metric movement." Stratton, who disliked public speaking, struggled to answer, eventually conceding a key point: that older units would persist for decades. Southard fared even worse. When he dismissed practical obstacles to conversion, some members of the audience, likely coached by Halsey, interrogated Southard on obscure provisions in the proposed bill, asking questions that he could not answer. And when Southard claimed he had invited anti-metric activists like Coleman Sellers to testify about the legislation, Halsey dramatically produced a letter from Sellers alleging that no such thing had happened. Halsey then reclaimed the floor to give his closing arguments. His performance won plaudits in the press, emboldening metric foes.[45]

In addition to Halsey's report, the committee charged with weighing in on the issue also released its own recommendations. While it was far more evenhanded, it sided with Halsey on a key point: that Congress should not, under any circumstances, make the metric system compulsory. Even the pro-metric members of the committee agreed that this

[44] Frederick A. Halsey, "The Metric System," *ASME Transactions* 24 (1903): 397–629, esp. 434, 455; Halsey, *Metric Fallacy*. On the formal report of the ASME, see "Report of the Committee Appointed to Discuss the Arguments in Favor of and Against the Metric System," *ASME Transactions* 24 (1903): 630–712. On Halsey's role in the power struggles within the ASME, see Sinclair, *Centennial History*, 67–71, 76–81; and Jenks, "Halsey, Frederick Arthur," 888–89.

[45] Halsey, "Metric System," 460, 517, 592–629; "Engineers Divided over Metric System," *New York Times*, 4 Dec. 1902, 2; "Metric System Discussed," *New-York Tribune*, 4 Dec. 1902, 6; "The New York Meeting of the American Society of Mechanical Engineers," *Engineering News* 48 (1902): 509.

was hardly practical, with the report asserting that "such legislation could not be enforced . . . so far as transactions between private individuals are concerned." And this, as much as the relative merits of the two systems, helped forge a consensus against the proposed legislation. Indeed, when the ASME polled its members in early 1903, it found that 78 percent of respondents opposed the bills under consideration, and 67 percent objected to *any* legislation designed to promote the metric system. These results cannot be taken as representative of the entire membership, given that only a fifth of the members responded. But for members who cared about the issue, it was clear that a critical plurality had become more militant in their opposition. As signs of opposition grew, Southard and Stratton made an ignominious retreat, shelving the bills two months after their disastrous appearance at the ASME meeting.[46]

Over the next few years, opponents of the metric system launched other campaigns to sway public opinion on the subject. The National Association of Manufacturers, which had initially adopted a more neutral stance toward the issue in the late 1890s, registered its opposition to making the metric system compulsory as early as 1902. A year later, it moved more firmly into the anti-metric camp after releasing a poll of its members that showed they opposed going metric by a margin of three to one. This poll, which William Sellers helped administer, was misleading: only a small fraction of the membership bothered to vote—a fact that metric opponents conveniently overlooked when reporting the results. Nonetheless, it reflected a genuine shift in the organization's leadership, which became increasingly hostile to metric bills pending before Congress. Over the next few years, the group went on the offensive, lining up witnesses who could offer credible testimony about the costs of retooling the nation's industrial base along metric lines. Its powerful secretary, Marshall Cushing, forged close personal connections with many proponents of industrial standards, eventually appointing Halsey to serve as its official representative before Congress on metric matters.[47]

[46] "Manufacturers' Meeting," *New York Times*, 26 Jan. 1898, 5; "Manufacturers and the Metric System," *New York Times*, 25 Apr. 1902, 8; "Report of the Committee," 630–712; "The Metric System," *American Machinist* 25 (1902): 1796; "The Meaning of the Action of the A.S.M.E. on the Metric Question," *American Machinist* 25 (1902): 1804–5; "The Metric System Bill Withdrawn," *Iron Age* 71 (1903): 29; U.S. Department of Commerce, *History*, 134–36.

[47] *Proceedings of the National Association of Manufacturers* 7 (1903): 181–94; "Report of a Committee of the National Association of Manufacturers on the Metric Question," *American Machinist* 26 (1903): 594–95; "Marshall Cushing," *Shop Review* 12 (1915): 277; Vera, "Breaking Global Standards," 191–97; Jennifer A. Delton, *The Industrialists: How the National Association of Manufacturers Shaped American Capitalism* (Princeton, 2020), 30–33.

A number of other professional and trade organizations followed the group's lead, passing anti-metric resolutions and lobbying Congress. These included the Railway Master Mechanics and the Master Car Builders' Association; business groups such as the National Carriage Builders' Association, the National Metal Trades Association, and the Engine Builders' Association; and smaller professional organizations like the American Society of Heating and Ventilation Engineers. The opposition of these groups sprang from the simple fact that most of them designed, manufactured, or sold standardized goods denominated in inches and feet. When confronted with the prospect of being forced to go metric—and spending the money to retool—most became converts to the cause. That many engineers who opposed the metric system belonged to more than one of these organizations made it far easier to steer these groups toward the same end. Halsey again played a key role in these efforts, visiting annual meetings, delivering talks, and urging members to adopt resolutions condemning the proposed legislation in Congress.[48]

Though Halsey could take significant credit for the groundswell of opposition, so too could Samuel S. Dale. Like Halsey, Dale was an editor, helming several key trade magazines in the textile business. Much like the machine-tool industry, the textile business had forged standards denominated in inches; while archaic and confusing to outsiders, these had acquired an almost sacrosanct status with the industry. The debate in Congress had awakened fears that all of this would be undone by government fiat. Dale threw himself into the anti-metric cause, helping Halsey compile the data that went into the report to the ASME. But he also authored a tract of his own that showcased the dangers that metric conversion posed for the textile industry. Dale had an obsession with facts and figures and wielded these to great effect, forcing opponents like Stratton into answering lengthy interrogatories on obscure topics. Inevitably, his opponents would misstate some minor point and Dale would pounce on the error as evidence of a nefarious conspiracy. Though a zealot, he was also a puckish, mischievous figure. The journalist Ida Tarbell described him as a "wonderful truth seeker" who had "fun" provoking powerful figures. "The rout which truth is sure to make," she wrote, "is the joy to life for him."[49]

[48] "The Railway Master Mechanics on the Metric System," *American Machinist* 26 (1903): 994; "The Metric System Again," *Engineering News* 50 (1903): 482; "The Metric System in Relation to Shipbuilding," *Transactions of the Society of Naval Architects and Marine Engineers* 11 (1904): 167–88; "The American Society of Heating and Ventilation Engineers on the Metric System," *American Machinist* 27 (1904): 169; "American Industries and the Metric System," *Electrical World and Engineer* 43 (1904): 847; Frederick Halsey, "The Metric Fallacy," *Canadian Engineer* 12 (1905): 133–35.

[49] On Dale, see Ida M. Tarbell, "A Wonderful Truth Seeker," *American Magazine*, Dec. 1914, 60–63; Samuel S. Dale, *The Metric Failure in the Textile Industry* (New York, 1904);

In 1904, Congress held hearings on yet another metric bill, similar to the one introduced two years earlier. The first witness was Halsey, representing the National Association of Manufacturers; Dale followed him. Both men went on the offensive, attacking the metric system as a pet project of visionaries and cranks that ran counter to the will of the country's engineers and entrepreneurs. Halsey spoke with disarming certainty. "There is no intelligent man in the machine shops," he averred, "who will for a minute contemplate the retirement of our standards for this system." Dale opened a new offensive, arguing that whatever the merits of the metric system for scientific work, it was profoundly ill suited for the textile business. Dale walked the legislators through the arcane field of textile standards. He explained how the world's manufacturers had gradually embraced an idiosyncratic, but eminently logical, set of standards. "Unification of the world's textile standards by the English system is in sight, almost within reach," Dale testified. "By the metric system it is an impossibility." In Halsey's and Dale's testimony, the metric system—long billed as bringing order to a chaotic world—would instead sow confusion, disorder, and danger in its wake.[50]

Other witnesses lined up to corroborate their claims: several prominent mechanical engineers; representatives of powerful trade groups including the Metal Trades Association, the Machine Tool Builders' Association, and the American Iron and Steel Association; and a parade of legendary industrialists who came armed with facts and figures, offering real-world examples of what it would mean to forcibly retool the nation's industrial base along metric lines. Many of these arguments focused on cost and convenience, but an equal number described the threat posed to the carefully constructed system of standards that now structured the entire industrial base. William Sellers rhapsodized about how "the screw bolts and nuts which enter into the construction of every machine, and which unite the rails on more than 100,000 miles of roads in this country, are interchangeable, so that a nut made in Maine will screw upon a bolt made in Texas." Sellers extolled the efficiency and savings made possible by the decades-long drive toward standardization, arguing that "we have attained . . . a system superior to any other the world affords, and we are now threatened

and U.S. Department of Commerce, *History*, 136–38. On the complicated, centuries-old history of textile standards, see David J. Jeremy, "British and American Yarn Count Systems: An Historical Analysis," *Business History Review* 45 (1971): 336–68; David M. Higgins and Aashish Velkar, "'Spinning a Yarn': Institutions, Law, and Standards c. 1880–1914," *Enterprise & Society* 18 (2017): 591–631.

[50] U.S. Department of Commerce, *History*, 144; House Committee on Coinage, Weights, and Measures, *The Metric System: Hearings on H.R. 93, H.R. 2054, and H.R. 8988*, 58th Cong., 2nd Sess., 1904, 1–56, quotes on pp. 25 and 42.

with a law, which, if adopted, will make it necessary to abandon all that we have accomplished." This became a constant refrain in the testimony. A witness from Brown and Sharpe, the maker of machine tools, gauges, and precision instruments, emphasized that the expense of going metric was not the primary reason for his opposition: "I would again emphasize the fact that it is not alone the first cost of changing standards and gauges that is the greatest objection. This, though important, is insignificant compared with the greater evil of breaking away from our standards and interchangeable system." Or as an engineer with the Southern Railway put the matter more bluntly, "the use of the metric system will for the time, at least, destroy all present existing standards."[51]

The National Association of Manufacturers helped organize this critical testimony, much as it did when Congress resumed hearings two years later, in the spring of 1906. What correspondence survives from this period indicates a concerted campaign to defeat the metric bills that relied heavily on the efforts of a handful of engineers and industrialists, all closely connected with standards setting and the promotion of efficiency on factory floors. Cushing tapped Towne and other familiar names to provide testimony, but he also reached out to Taylor, now president of the ASME. The two men carried on an extensive correspondence rooted in their shared antipathy toward the metric system. As Cushing confided to Taylor in one typical missive, "You know better than I do how resolute all the metric cranks will be, and how necessary it will be for all of us who are interested in this cause to double our efforts in every way."[52]

Taylor's appearance before Congress proved a turning point. He readily conceded that the metric system was preferable for scientific work. He also steered clear of the usual arguments about the cost of retooling, focusing instead on how the proposed change would burden ordinary workers. The inch and its fractions, Taylor testified, was "one of the most important facts of their lives. They live with it. It is a language to them. They talk and think more in inches than in words while at work, and they are doing that all their lives long." Taylor claimed that because the inch had become so thoroughly embedded in the nation's machines—and by extension, in the consciousness of the men who tended them—skilled workers could measure and make parts without recourse to gauges or rulers. Taylor, who had spent his life watching workers,

[51] U.S. Department of Commerce, *History*, 145; House Committee on Coinage, Weights, and Measures, *The Metric System*: *Hearings on H.R. 93, H.R. 2054, and H.R. 8988*, 58th Cong., 2nd sess., 1904, 68–76, 91–132, 138–84, 208–13.

[52] See, for example, M. Cushing to F. W. Taylor, 1 Mar. 1906, and M. Cushing to F. W. Taylor, 16 Mar. 1906, both in box 148, Frederick Winslow Taylor Collection, Samuel C. Williams Library, Stevens Institute of Technology, Hoboken, NJ.

described in minute, almost loving detail how the inch structured every step of the manufacturing process. He predicted that if Congress tried to impose the metric system on the workmen, it would invite a rebellion that he half-jokingly predicted would sweep the committee members from office. This was a clever bit of theater, but Taylor's concern lay less with the workers than with the fact that he had built his career on finding what he liked to call "the one best way": that is, standards that banished difference and promoted efficiency. The idea of introducing an entirely new system of measurement to the nation's factory floors would be deeply inefficient, at least in the short term—and perhaps in the longer term as well. In his testimony, Taylor predicted that introduction of the metric units would likely lead to the worst of all worlds. Instead of assuming the financial burden of genuinely adopting the millimeter as the basic unit for manufacturing—something that would require new patterns, gauges, dies, and machines on a massive scale—manufacturers would simply stick to the inch, but camouflage it with metric equivalents. One inch would become 25.54 millimeters; three-fourths of an inch would be 19.05 millimeters. This awkward workaround meant that workmen would constantly toggle between the two systems. "Owing to this tomfoolery," said Taylor, "the workman's time is wasted." And for Taylor, the man with the stopwatch, nothing was more precious than time. His arguments, echoed in an encore performance by Towne on the final day of the hearing, sealed the fate of the legislation; after the committee finished deliberating, it shelved the bill entirely.[53]

In retrospect, the hearing was the high-water mark in the metric campaign. Though metric advocates continued to press for legislation, and Stratton intermittently sought to advance the metric cause, industrialists and engineers proved far more capable at shaping public opinion. In 1916, these efforts culminated in the creation of a new anti-metric organization known as the American Institute of Weights and Measures. It featured veterans of the metric wars: Halsey, Bond, Dale, Towne, and others. But it also counted many newer faces among its members: presidents of engineering societies; leaders of prominent firms in the metalworking and machine-tool businesses as well as the railroads; pioneers in industrial standardization like Henry Leland, president of the Cadillac Motor Car Company; and educators such as Alexander Crombie Humphreys, president of the Stevens Institute. Over the next decade, this organization waged a running battle against the metric system, repeating

[53] House Committee on Coinage, Weights, and Measures, *The Metric System: Hearings on H.R. 8988*, 59th Cong., 1st sess., 1906, 111; U.S. Department of Commerce, *History*, 152–53.

the arguments that had worked so well in the climactic struggle that took place in the opening years of the twentieth century.[54]

Much of its success can be attributed to a sophisticated public relations campaign. It placed advertisements and editorials in industry journals; successfully lobbied hundreds of trade associations, chambers of commerce, and technical societies to go on the record condemning mandatory use of the metric system; and obsessively monitored legislation on the local, state, and national levels. When the group identified a bill that endorsed mandatory metric conversion—or merely contained clauses that opened the door to greater reliance on the metric system—it mobilized hundreds of industrialists, engineers, and managers to defeat the legislation with letters, testimony, and editorials. By the 1920s, its membership rolls included many of the most important firms in the nation as well as presidents of the National Association of Manufacturers, the Association of American Steel Manufacturers, the American Railroad Association, and other national organizations. These organizations had a stake in standardization, actively joining government-sponsored efforts to bring further uniformity to the nation's economy over the course of the 1920s. As inch-based standards governing everything from automobile tires to pads of paper became the norm, the prospects for going metric became ever more remote. Only in scattered pockets of the business community—the electrical field, for example, and pharmaceuticals—did the metric system become dominant.[55]

The individuals behind the American Institute of Weights and Measures understood that the battle over the metric system went beyond the borders of the United States. Though manufacturers of machine tools and other precision products occasionally made products for the export market denominated in metric units, most foreign buyers in metric countries purchased the less expensive, more ubiquitous products defined in increments of the inch. In effect, the United States exported its

[54] "Take Warning!," *American Machinist* 44 (1916): 563; Henry R. Towne, "Metric System in Export Trade," *American Machinist* 44 (1916): 825–26; "American Institute of Weights and Measures," *American Machinist* 45 (1916): 1100; "American Institute of Weights and Measures," *American Machinist* 46 (1917): 378; *Bulletin of the American Institute of Weights and Measures*, 1 Apr. 1920.

[55] Henry R. Towne, "Adoption of the Metric System Would Do Untold Damage," *Industrial Management* 59 (1920): 473–74; Lawrence Busch, "Herbert Hoover and the Construction of Modernity," *Journal of Innovation Economics and Management* 22 (2017): 29–55; Colleen A. Dunlavy, "The Unnaturalness of Mass Production: The 'Gospel of Simplification' in World War I and the 1920s" (unpublished paper delivered at the Business History Conference in Miami, FL, 26 June 2015). For a representative sampling of the institute's activities, see the *Bulletin of the American Institute of Weights and Measures* for July 1920, October 1920, January 1921, July 1921, April 1922, January 1923, and October 1923. On the metric system in medicine and electrical engineering, see Spencer M. Vawter and Ralph E. De Forest, "The International Metric System and Medicine," *Journal of the American Medical Association* 218 (1971): 723–26; Cox, "Metric System," 358–79.

inch-based standards, building significant markets in metric countries in Europe and Latin America. The new group promoted these efforts, but it also took the fight to international organizations that might threaten the American position. These efforts, which often involved both British and American anti-metric activists, built on earlier campaigns in the textile industry, where individuals like Dale had worked closely with British firms to defeat attempts to replace inch-based standards with new metric units. In 1921, for example, the organization sent delegates to the International Chamber of Commerce in order to defeat a pro-metric resolution; it did the same with meetings of the Pan American Standardization Conference over the course of the 1920s, working to ensure that the United States did not join the larger hemispheric embrace of the metric system.[56]

The American Institute of Weights aand Measures would disappear by the 1930s, but by then the die was cast. As one government-sponsored assessment would later observe, "by that time it had done its job so well that there was really no further need for it." The path dependencies begot by hundreds, and eventually thousands, of standards created an iron cage no less rational and restrictive than the more figurative cage devised by theorists of modernity. As Walter Ingalls, a mining engineer and president of the Institute, declared in 1921, "The names of things may be changed, but the things themselves, i.e., the standards that have been developed by industry," could not be readily altered. "What engineer" he asked, "would conceive the folly of attempting to change our standards of screw threads, pipe sizes, board measures, the dimensions of structural steel, etc.?" Ingalls, like many others, could not countenance the destruction of a carefully constructed system of standards woven into the nation's industrial infrastructure.[57]

[56] See, for example, Frederick A Halsey, "Pan-Americanism in Weights and Measures," *American Machinist*, 8 Apr. 1920, 784–86; "President's Foreword," *Bulletin of the American Institute of Weights and Measures*, 1 July 1920, 2; "Metric Activities," *Bulletin of the American Institute of Weights and Measures*, 1 Oct. 1920, 6–7; "International Chamber of Commerce," *Bulletin of the American Institute of Weights and Measures*, 1 Oct. 1921, 7; Vera, "Breaking Global Standards," 204–9. On textile standards, see Norman Biggs, "A Tale Untangled: Measuring the Fineness of Yarn," *Textile History* 35 (2004), 120–29.

[57] W. R. Ingalls, "Why the Metric System Should Not Be Adopted," *Mining and Metallurgy*, May 1921, 15–16; U.S. Department of Commerce, *History*, 169. The language of the "iron cage" owes as much to Talcott Parsons as it does to Max Weber. Whether a mistranslation or not, it has become a powerful metaphor for modernity. See Weber, *The Protestant Ethic and the Spirit of Capitalism*, trans. Talcott Parsons (New York, 1958), 103–4; Peter Baehr, "The 'Iron Cage' and the 'Shell as Hard as Steel': Parsons, Weber, and the *Stahlhartes Gehäuse* Metaphor in the *Protestant Ethic and the Spirit of Capitalism*," *History and Theory* 40 (2001): 153–69.

Conclusion

In the opening years of the twentieth century, Stratton described the coalition opposing the metric system as a "coterie of ultra-conservatives" who would inevitably give way to the inexorable advance of a more rational, scientific system of measurement. This view of the clash, which survives in scholarly and popular histories of the episode, is deeply misleading. In fact, opposition to the metric system enjoyed broad-based support. Advocates of the existing system of measurement built a complex political campaign that enlisted professional societies, business leaders, and management theorists, all of them associated in some way or another with the latest, most "scientific" and systematic approach to bringing order to the industrial economy. They proved remarkably adept at using modern political tactics to achieve their ends, deploying expert testimony, mounting elaborate public relations campaigns, and otherwise operating as a modern interest group.

Far from being a collision between tradition and progress, then, the battle over the metric system was fundamentally a fight over different definitions of modernity. On the one side stood a group of sophisticated engineers and manufacturers who developed standards governing everything from screw threads to the rhythm and pace of industrial labor. These modernizers, who labored to bring order to the machine shop and factory floor, viewed metric measurements as destroying the profitable, efficient systems they had built. They could legitimately claim the mantle of modernity—yet their adversaries could as well. Stratton and his allies embraced a different vision of modernity, one rooted in scientific inquiry, not scientific management. They arrived too late in the United States. By the early twentieth century, engineers, managers, and workers had built the industrial base around the imperfect, but well-nigh immovable, inch. We live in the world they built.[58]

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[58] Stratton quoted in U.S. Department of Commerce, *History*, 131.

https://doi.org/10.1017/S0007680521000751 Published online by Cambridge University Press