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Source: *IA. The Journal of the Society for Industrial Archeology*, 1997, Vol. 23, No. 2 (1997), pp. 4-20

Published by: Society for Industrial Archeology

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Figure 1. A 1901 article on structural workers included this illustration of iron workers bolting up a skyscraper framework.
 Frank Leslie's *Popular Monthly* 52 (July 1901): 263.



Figure 2. This four-man crew is field riveting a bridge railing. The man in the foreground operates a forge with a hand-cranked blower to heat the rivets. He tosses the rivets to the man on the far right, who catches them in a special bucket and then places them in the rivet hole. The man on the far side of the railing holds a dolly bar on the already formed head of the rivet, while the man with the hammer shapes the other end of the rivet into a head. The size of the hammer suggests that, as would be expected, the rivets on the railing were relatively small.
 Frank Leslie's *Popular Monthly* 52 (July 1901): 272.



“The Continuous Clatter”: Practical Field Riveting

David A. Simmons

Virtually all types of American structural steel construction in the early-20th century depended on the adoption of an adequate field, as opposed to shop, riveting technique. Hand riveting methods were felt to be inadequate. After experiments with a variety of portable riveting systems, a pneumatic riveting hammer capable of being handled by a single individual was devised in late 1898 by St. Louis-based inventor Joseph A. Boyer. This basic tool is still in use today, although riveting itself is largely a lost art.

Introduction

Throughout the history of American and European iron and steel construction, conflicting schools of theory and practice have existed over connections. The majority of 19th-century American engineers preferred bolts to connect the iron frames of buildings and pin connections for bridges (see figure 1). During the same period in Europe, the rivet was the method of choice for connecting both buildings and bridges. These preferences depended, in part, on the comparative cost of labor on the two continents. The labor-intensive process of riveting was more popular where labor costs were lower. American bridge engineers also justifiably considered riveting done in the field during final assembly inferior to those driven in the shop (see figure 2). A structure whose components were riveted together in the shop and assembled by bolts or pins in the field was felt to function in a superior manner to the same structure connected by field rivets. The attitude of John Harvey, engineer with the Champion Bridge Company in Wilmington, Ohio, was typical. In many riveted connections, Harvey claimed, “calculations of stress are unreliable.” A handful of American engineers, a definite minority, preferred the rigidity of riveted connections to bolts or pins. Nonetheless, railroad specifications, used by American lines in the late-19th and early-20th centuries, essentially penalized the use of hand, field-driven rivets by insisting that the design compensate for the lesser quality of field rivets by increasing their size and number in each connection. Even in England, where field riveting was widely accepted and practiced, engineers conceded that “the greatest care” was necessary whenever designing connections that would ultimately be riveted by hand.¹

Gradually, Americans came to accept the viability of field-riveting structures. Although a number of theoretical considerations went into this transition, one overwhelming practical consideration was at play: it had to wait on the development of a mechanical field-riveting process. In his 1916 volume on *Bridge Engineering*, influential American engineer J. A. L. Waddell identified that mechanical process as pneumatic riveting.² What Waddell recognized, historians have failed to explore, thereby ignoring a fundamental technological event that transformed American structural history. This paper proposes to examine how and by whom pneumatic riveting was created and the reasons for its turn-of-the-century timing.

Some Riveting History

During the 1850s, American builders of iron structures began to use rivets—short, solid bars with heads—to permanently connect the flanges of abutting plates. They adopted a British technology devised and refined more than a decade earlier for, among other things, the construction of iron sea-going vessels. The majority of rivets were driven by large machinery in the shop, at first powered by steam but after 1865 by hydraulic systems. By the last decade of the 19th century, hydraulic power on both sides of the Atlantic was replaced by pneumatic, or compressed air, power. Regardless of the power source, the riveters recognized as doing the best work were those in which the rivets were *upset* (swelled) so as to completely fill the hole. The best rivets also pinched the adjoining segments together and did not loosen through use. Invariably, these top-quality rivets were driven by stationary shop installations. Pieces to be riveted had to be brought to a fixed machine, and work spaces had to accommodate the manipulation of sizable structural components (see figure 3). This created problems in many fabrication situations, such as shipbuilding, and in 1871 a British mechanic named Ralph Tweddell introduced the “portable” hydraulic riveter (see figure 4). Although genuinely moveable, these devices still required some form of crane transport. By the late-19th century, American inventors had succeeded in reducing the size of these machines, even taking them into the field, but their operation still required substantial rigging and a large crew because of their weight and size.³

Figure 3. British mechanic Ralph Tweddell devised a wide range of specialized hydraulic riveters for ship construction. Because of the need for an adequate "bite" to reach the middle of large plates, fixed-shop riveters could be of immense size. Although no scale is provided in the original, the cross-hatched vertical to which the crane is attached represents the wall of a shop high-bay. Wilfrid J. Lineham, *A Text-Book of Mechanical Engineering* (London: Chapman and Hall, 1902): 318.

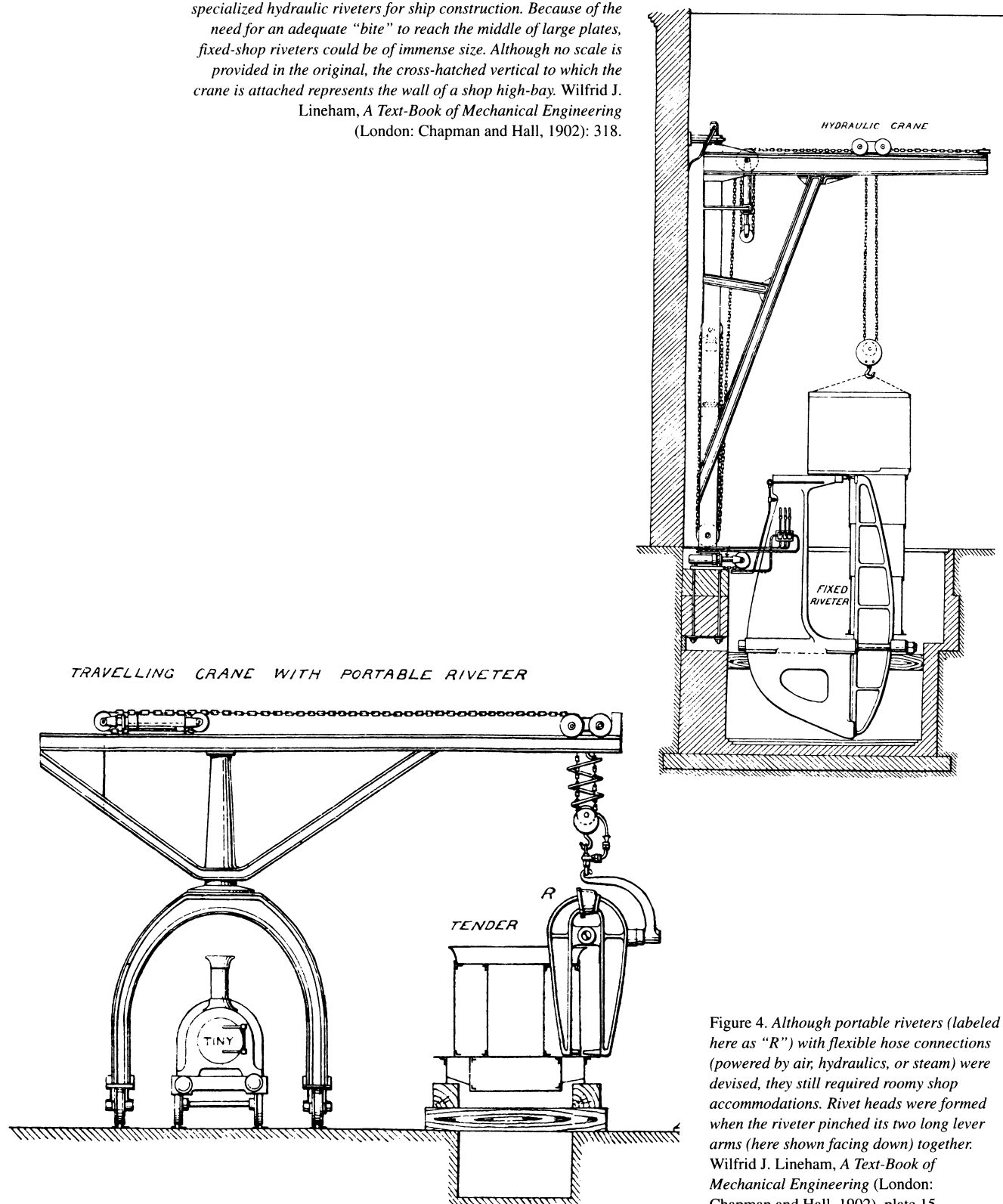


Figure 4. Although portable riveters (labeled here as "R") with flexible hose connections (powered by air, hydraulics, or steam) were devised, they still required roomy shop accommodations. Rivet heads were formed when the riveter pinched its two long lever arms (here shown facing down) together. Wilfrid J. Lineham, *A Text-Book of Mechanical Engineering* (London: Chapman and Hall, 1902), plate 15.

Hand Riveting Techniques

From the very beginning of iron construction in Europe and the United States, there had been structural components requiring rivets where no shop machine could reach. Furthermore, in all types of iron construction, there was always a need for riveting in the field during the final assembly where no machine could be used. Partially for reasons of custom but also because of the lower cost of labor, Europeans tended to be the most adept at the highly rigorous and skilled process of hand riveting. Consequently, some of the best descriptions of the process today can be found in British engineering literature. A London engineering professor explained the process in detail in a volume on structural ironwork in the 1890s.

Rivets were manufactured with one head already formed. They were heated in a small forge with the shanks pointing down through a perforated metal plate, allowing the shanks to be heated red-hot while the heads remained cooler. A *forge boy* oversaw the process, insuring that the rivets were

not overheated or “burnt,” which weakened the metal (see figure 5). The components being riveted were first assembled by a crew of *platers* who installed a few “fitting-up” bolts to temporarily hold the pieces in position and draw them together as tightly as possible. The forge boy picked up one rivet at a time and threw it on the ground to knock off any clinker (see figure 6). He passed it on to a *carrier* who dipped the tip in water, thereby cooling the end in comparison to the stem so that the first hammer blows upset the stem of the rivet. The carrier then ran to the *holder-on* who pushed it through a hole either drilled or punched in two overlapping members. While he held a dolly bar against the already formed head, a pair of riveters first hammered directly on the point of the rivet to upset it and fill the hole. By that time, the heat had crept back to the point and alternate hammer blows formed a head on the rivet. If a button-headed rivet was desired, the riveters then placed a *snap* or cup tool over the newly formed head, which the other struck repeatedly to give the rivet its final configuration (see figure 7). Hand driving a rivet by an experienced crew took about 2½ minutes.⁴



Figure 5. Boilermaking in general but riveting in particular required a highly skilled workforce and was physically demanding. This shop operation used a large hand-powered bellows connected to a very small forge for heating the rivets. The man on the far right holds a bar inside the boiler to back up a rivet, while the two men in foreground with hammers are in position to form the head. Those in the background hold a variety of squares, hammers, and tongs used by riveters. Photo courtesy R. M. Vogel.

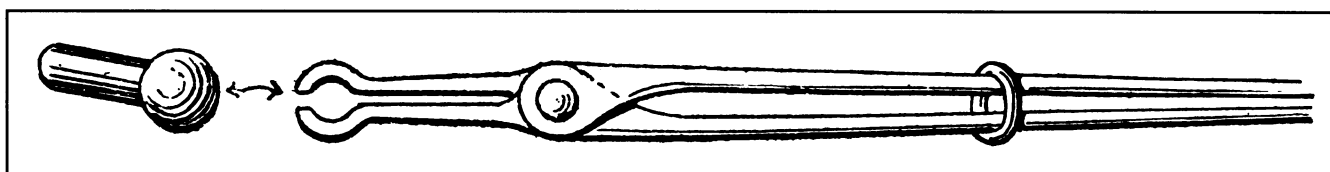
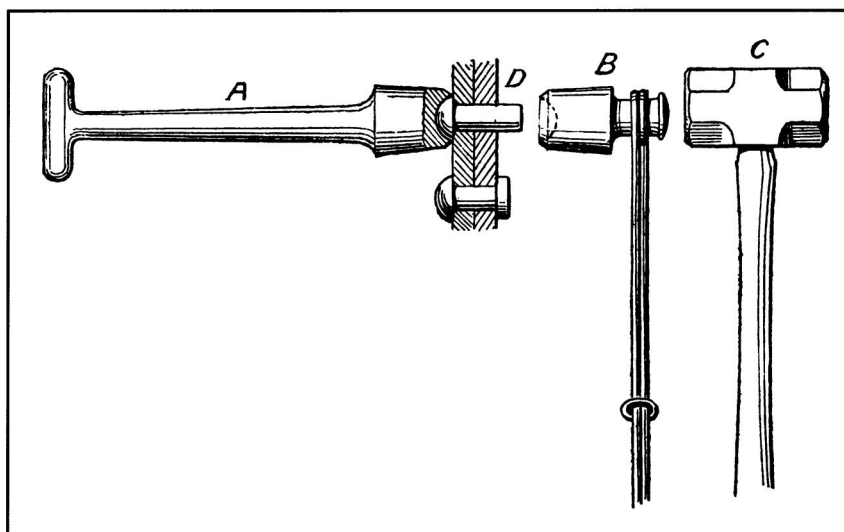


Figure 6. A specially curved pair of tongs was used to handle red-hot rivets. Wilfrid J. Lineham, *A Text-Book of Mechanical Engineering* (London: Chapman and Hall, 1902): 285.

Figure 7. "A" is the dolly bar; "B," the cup;
 "C," the sledge; and "D," the rivet.
 Wilfrid J. Lineham, *A Text-Book of
 Mechanical Engineering*
 (London: Chapman and Hall, 1902): 285.



The hand riveting methods used on both sides of the Atlantic were established out of practical necessity but had technical drawbacks. The process was, according to one American shipbuilder, "the hardest manual labor" in the yard. It required a high level of technical skill, obtained only after an apprenticeship, and was specialized to the extent that a first-class riveter experienced in working on one portion of a ship's framework could not readily transfer to another component. In addition, the increasing thickness of plate at the turn of the century magnified the difficulty in properly upsetting the rivets in the holes.⁵ Comparisons between rivets driven by machine and those done by hand invariably demonstrated the higher technical quality and greater reliability of riveting by machinery. Even in Great Britain, engineers conceded the importance of good quality workmanship and suggested that the most common cause of loose rivets was "indifferent work." It was necessary to search for "practical machinery" as an alternative to the hand methods of field riveting. This was especially true in America where the higher cost of labor effectively decreased the efficiency of hand procedures.⁶

Finding Alternatives to Hand Methods

W. I. Babcock, the manager of the Chicago Shipbuilding Company in the 1890s, identified yet another reason for corporate management to seek alternatives to hand riveting. From an administrator's viewpoint, riveter gangs had—undoubtedly because of their high skill levels and

indispensable nature—become "arrogant and high-handed." They frequently made what were reported as "unreasonable demands" and went on strike. As a consequence, the company sought a riveting system that could be operated by unskilled labor. They were familiar with the portable hydraulic systems used in England but feared the severe winters in Chicago would make them impractical. Compressed air seemed like a reasonable power source, especially since it could be used to power other portable tools. In the company's first experiment in February 1896, a portable compression bow riveter that featured a horse-shoe frame weighing over a ton was used. It proved unsatisfactory due to its ponderous weight. A few months later, the company learned of an experiment where rivets were driven by means of a pneumatic caulking hammer at the Lassig Bridge and Iron Works in Chicago.⁷

In America, tools powered by compressed air, known as pneumatic tools, dated to the late 1860s when rock drills were first used to tunnel through the Hoosac Mountain in Massachusetts. The technology was almost immediately adopted throughout the nation, and pneumatic rock drills became a standard tool for mining and quarrying. During the 1880s, efforts were made to adapt compressed air to light hand tools.⁸ According to an out-of-court settlement for a patent infringement case in November 1899, all pneumatic hammer patents could be traced back to those granted to two late-19th-century inventors and businessmen from St. Louis, Missouri: Joseph A. Boyer and Pierre Chouteau.⁹

Boyer and Chouteau

Although Joseph A. Boyer was born on a farm near Toronto, Canada, in 1848, he always preferred a machinist's shop to agricultural fields (see figure 8). Attracted to the burgeoning farm-tool and implement industries of Oshawa on the north shore of Lake Ontario, he apprenticed in a machine shop when 18 years old. After becoming a journeyman machinist, Boyer was drawn to the opportunities presented in the American West. He took advantage of the new transcontinental railroad and, in 1869, moved to San Francisco. For several years, he worked with a marine engine builder. For an unknown reason, he grew tired of the West Coast and bought a railroad ticket for a destination “as far east as he could get.” That point proved to be St. Louis. Initially he was employed by an ironworks and, later, by a sewing machine company. When the economic depression in the mid-1870s resulted in the failure of the latter, he decided to establish his own machine shop in the defunct company's plant. Bottle molds became one of the principal products of Boyer's small shop, and he eventually received a patent for a cast-iron apparatus for molding glass. It was while working on these in the early 1880s that he first devised a pneumatic hammer of his “own design.”¹⁰

A popular cast-iron bottle mold of this era was made in a two-piece, hinged configuration that featured a cavity into which a slug with individualized lettering could be inserted. Bottle advertising for a variety of companies could thus be produced from a single standardized mold.¹¹ Boyer was using a pneumatic hammer for cleaning or surfacing his bottle-mold castings and, in 1883, received a patent for a “chipping machine” (see figure 9).¹² This was to be his first of 15 patents for pneumatic hand-tool improvements.

As the great-grandson of the founder of St. Louis, Pierre Chouteau was a member of the city's elite (see figure 10). He was educated at St. Louis University and took classes at the Royal School of Arts, Mines, and Manufactures at Leige, Belgium. Returning to St. Louis in 1874 with aspirations of becoming a mining engineer, he helped organize the Missouri Mining Company in 1877 to exploit the state's lead and coal resources. In 1888, he established the Chouteau Manufacturing Company in St. Louis to produce both steam and pneumatic tools. In the meantime, his father, Charles, was heavily involved in the city's iron industry. The father insisted that the aspiring tool manufacturer devote more energy to overseeing the family's real-estate investments. In



Figure 8. Joseph Boyer, a Canadian by birth, developed his pneumatic tools while laboring in St. Louis. He later moved to Detroit where he gained fame as the president of the Burroughs Adding Machine Company. He died in 1930. Photo courtesy of the Burton Historical Collection, Detroit Public Library.

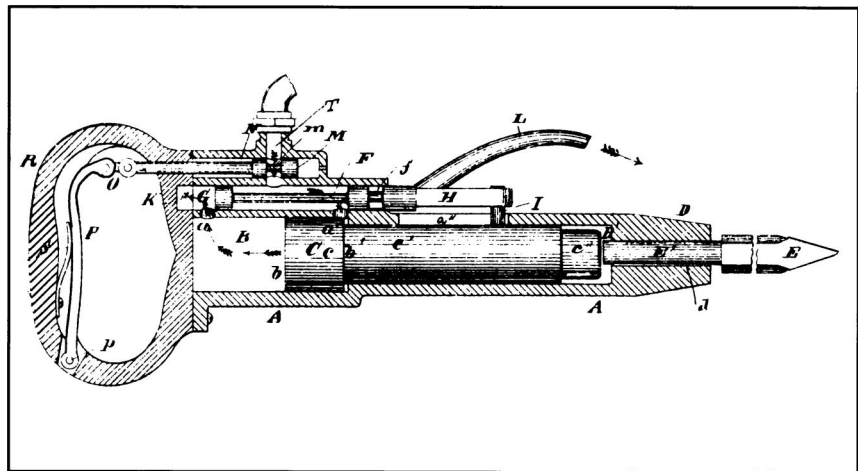


Figure 9. Boyer's 1883 patent for a “chipping machine” was the first practical pneumatic hand tool for shop use. The rear dimension of the reciprocating piston (C) was larger so that the forward stroke would have more force than the reverse, thereby reducing the amount of “kick” to the operator. The use of both a throttle valve (M) operated by a lever (P) in the handle and a slide-valve (F) to control the air flow in and out of the cylinder (A) created a convenient one-handed tool. The exhaust air was directed at the working surface through a blowpipe (L). Photo courtesy of the Ohio Historical Society.



Figure 10. *Pierre Chouteau, a member of the privileged class in St. Louis, was educated at St. Louis University and the Royal school of Arts, Mines, and Manufactures at Leige, Belgium. In the late 1880s, he became interested in pneumatic tools for mining use. Photo courtesy of the Missouri Historical Society.*

1906, the senior Chouteau's advancing age and the additional business responsibilities that it placed on the son required the closing of the tool company.¹³

Chouteau's tack to his inventive creations was different from Boyer's working-class approach. The firms producing pneumatic hand tools seem to have been especially litigious, although probably no more so than their turn-of-the-century counterparts. Companies were mindful of the need to acquire patent rights or compensate their owners, and it is in this context that the importance of Chouteau to our story becomes clear. As a wealthy capitalist, Chouteau had the resources to exercise a strong hand in developing and refining workable pneumatic hand tools. His patent history reflects that role. In the late 1880s, Chouteau was granted rights from a co-worker for a dozen patents for mechanical mining devices powered either by steam or air, including several rock drills and their carriages. He personally received a patent in August 1890 for some improvements on the company's first direct-acting pneumatic hammer, intended to simplify manufacture and produce a more durable tool (see figure 11). Through the remainder of the decade, the patents obtained by Chouteau or assigned to

him and/or his company followed a similar pattern. They encompassed improvements and refinements on virtually all components of the tool; the handle and its attachment, lubrication, valve design, placement and design of air ports, and the method of attaching the working tool were typical developments endorsed by the patent examiners. Twenty-one patents followed the initial design. Chouteau's personal interest in the tools seems to have waned after the middle of 1897, resulting in his selling the company's patents to the Standard Pneumatic Tool Company of Chicago. The various improvements credited to Chouteau and his company, nonetheless, remained a potent force in the business at the turn of the century.¹⁴

Air Hammer Artifacts

Two air hammers featuring Boyer and Chouteau patents are in the Missouri Historical Society's collections. Both are examples of "Little Giant" hammers produced by the Standard Pneumatic Tool Company of Chicago and date approximately to the turn of the century. The largest is made of a ferrous metal and measures about 11 inches in length and weighs over 8 pounds (see figure 13). The other smaller tool, which can be screwed apart to view the internal piston, appears to be of bronze and weighs a little over 5 pounds (see figures 12, 13). Such hammers were either made with or without valves to control the inlet and exhaust of the compressed air. Both types used a rapidly reciprocating piston within a cylinder or sleeve to deliver blows upon a tool fixed to the end. These specific tools ranged between 20 and 33 blows a second.¹⁵ Others ranged as low as 12 and as high as 90 per second. In valveless hammers, the piston itself acted as the controlling valve. Little Giants were valved hammers and, therefore, had a longer stroke than those lacking this component. Standard Pneumatic Tool, the builder of these tools and the purchaser of the Chouteau patents, was headed by Henry Kimman of Chicago, himself the recipient of pneumatic tool patents. The firm began using either a midget or child in their advertisements in 1900 to emphasize the lightness of their tools. Despite their longer stroke, these specific tools were too small to deliver blows heavy enough for any but the smallest rivets, having been designed for lighter work, such as chipping or caulking (see figure 14).¹⁶

Chicago Experiments

Predictably, the initial attempt to use these hammers by the Chicago Shipbuilding Company was problematic. The hammer's action was severe on the operator. The holder-on's dolly bar was jarred off the head of the rivet by the



Figure 11. A pair of pneumatic hammers was donated to the Missouri Historical Society in 1929 by a local patent attorney as examples of “very early pneumatic hammers.” They are believed to be the oldest extant in the country. Photo by author.



Figure 12. “Little Giant” hammers like these were produced in Chicago by the Standard Pneumatic Tool Company. This bronze example (figure 11), which can still be easily screwed apart to view the valve and piston, bears patent dates ranging from 1883 (Boyer’s original patent) to 1900. Photo by author.



Figure 13. Although the iron hammer is the heaviest of the two, its weight, a little more than 8 lbs., places it in the chipping tool category. The screw on the upper portion of the handle was connected to a bushing that regulated the volume of air entering the hammer. The force of a blow on a hammer without this feature could only be regulated by the degree that the trigger was depressed. This example from the Missouri Historical Society’s collections matches the hammer shown in an 1899 announcement by Standard. Photo by author.

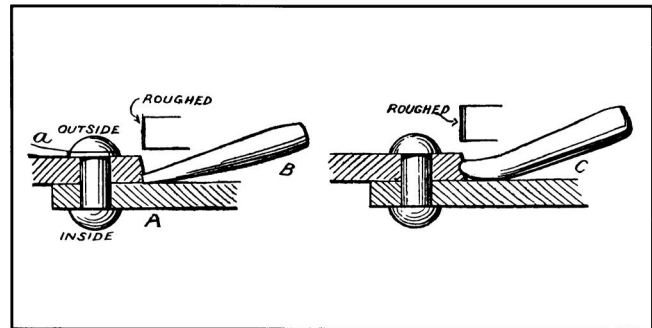


Figure 14. Workmen used a pneumatic hammer with a chisel-like tool to push plate edges together, thereby helping ensure watertight joints. This procedure was known as caulking. Wilfrid J. Lineham, *A Text-Book of Mechanical Engineering* (London: Chapman and Hall, 1902), fig. 281.

hammer. The solution to both these problems was to attach the hammer and a company-devised “pneumatic holder-on” (essentially a cup tool backed by a simple cylinder that could be filled with compressed air) to a horseshoe frame to create a single machine. Eventually these bow or yoke-type riveters became a standard tool in the industry. Both hammer and holder-on were equipped with a single trigger to completely unify their action (see figure 15). A yoke riveter was fine for edge work, but to reach rivets in the middle of plates, bows with a deeper reach were required, in this case made of wrought-iron pipe. These tools ranged in weight from 83 to 220 to as much as 400 pounds and were, therefore, not easy to manhandle. Their operation required at least two men or even an overhead framework equipped with block and tackle (see figure 16). Furthermore, there was initially no way to clamp down on the work to ensure the pieces fit tightly before the rivet was driven. Another fundamental limitation was the depth or reach of the yoke itself, since there were bound to be situations where the distance was inadequate.¹⁷

These riveters could, however, be operated by unskilled labor, the original goal of the Chicago Shipbuilding Company. As soon as one of the firm’s distinctive riveters was introduced in the yard in 1898, every hand riveter walked out and stayed on strike for nearly three months. The company responded by putting together a dozen more machines and continuing the work. Their only regret was the impact that breaking in the new men had on the cost of the particular ship they were building at the time.¹⁸

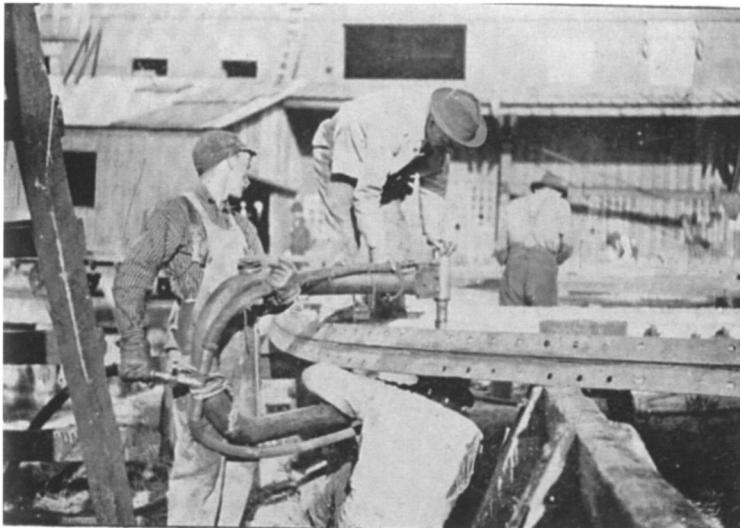


Figure 15. *The Chicago Shipbuilding Company was attracted to yoke riveters in 1898 because they required a relatively low skill level. But manhandling a yoke riveter large enough to reach rivets not on the edge of plates was a major physical challenge. W. I. Babcock, "Portable Pneumatic Riveters in Shipbuilding," Transactions, Society of Naval Architects and Marine Engineers 6 (1898), plate 49.*



Figure 16. *Ultimately the work required yoke riveters large enough to necessitate, even in the context of a shipyard, a special A-frame and rigging to handle and operate them. The yoke riveter is parallel to the X-bracing of the A-frames. The lighter bow frame above it is part of the rigging hanging from the rail between the A-frames. W. I. Babcock, "Portable Pneumatic Riveters in Shipbuilding," Transactions, Society of Naval Architects and Marine Engineers 6 (1898), plate 46.*

Timing

The building trades were known for their labor disputes, so it was not simply a recalcitrant work force that explains the willingness of companies to adopt the pneumatic hammer at the turn of the century. Instead, it was a convenient convergence of theoretical and practical matters.¹⁹

American engineers had been moving towards the acceptance of riveted connections during the last decade of the 19th century. A small but largely isolated group of American railway engineers had promoted riveted, iron lattice-truss bridges from the mid-century. But the majority remained wedded to their old pin-connected ways. A prime catalyst that began to move North Americans away from this emphasis was the construction of the Firth of Forth Bridge in Scotland during the 1880s, a project that

received extensive coverage in American technical journals. The Forth bridge, of unprecedented scale and size, was an all-riveted tubular steel structure. In 1886 and 1887, articles that examined the technical basis for the materials and connections used in the bridge, written by bridge designer Sir Benjamin Baker, appeared in American journals. The opening of the bridge in 1890 was an international news event.²⁰ Almost simultaneously, government-supported experiments and testing at U.S. Military Academy, West Point, and the Watertown Arsenal in Massachusetts confirmed the theoretical viability of riveted connections. Finally, the opening of the Leffert-Buck designed, all-riveted railway arch over the Niagara Gorge in 1897 provided a first-hand demonstration of the practicality of these connections. American theory had finally confirmed the need for a practical field riveting method.²¹

Boyer Long-Stroke Hammer

The need for a pneumatic tool comfortably handled by a single individual and yet powerful enough to drive the largest rivets then in use was finally filled by inventor Joseph Boyer in October 1898.²² To strengthen the blow without making the tool cumbersome, Boyer reduced both the diameter of the tool's cylinder and the size of the reciprocating piston but increased the length of the piston stroke. The impact of each blow was greater, but, with a longer distance to travel, the rate was dropped to as few as 10 per second, making it easier for a workman to hold.

Boyer steadily refined his new tool over the next year and, eventually, settled on a design. The piston moved a total of 9 inches through two valves, one near the front and the other at the rear, that acted in tandem via connecting rods and that controlled the air flow in and out of the cylinder. Labeled a “Boyer long-stroke riveting hammer,” the most powerful version was about 20 inches long and weighed 25 pounds (see figure 17). Simple to use, an official from the B & O Railroad suggested that “an intelligent helper” could be trained to use a Boyer hammer in a single day (see figure 18). Boyers were manufactured by the Chicago Pneumatic

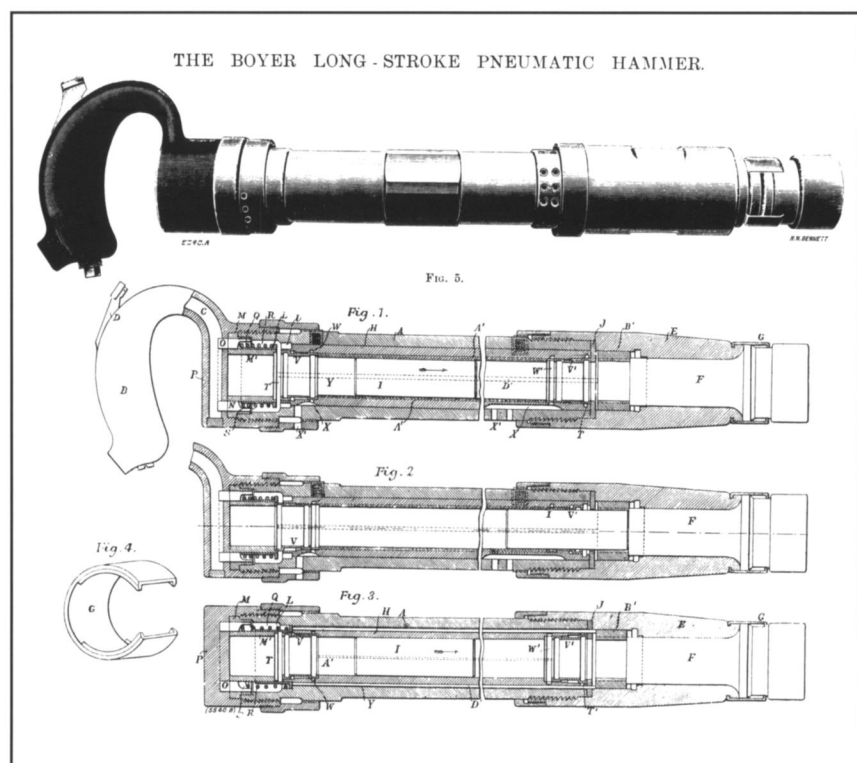
Tool Company, which by 1904 had consolidated with enough rival firms, including Boyer's own St. Louis operation, to become the nation's largest pneumatic tool maker.²³

The Boyer long-stroke hammer proved highly durable and sped up the process of driving rivets to a mere six to seven seconds. They could be driven faster, in fact, than hot rivets could be inserted in the holes. The gang size was reduced to two men and a heater, and, more importantly, there was no longer a need for an expert riveter (see figure 19). Equally significant from a theoretical point of view, the quality of the rivets driven by this tool compared very favorably with other machine-driven rivets. Still, using pneumatic riveters required a certain level of care (see figure 20). One observer suggested that in the hands of “an incompetent or lazy workman,” a hand riveter could produce lopsided rivet heads.²⁴

American Reaction

Whether out of a lack of competence or a genuine fear of the new technology, American workmen were initially wary of pneumatic riveters. Their fear that they or a co-

Figure 17. *The Chicago Pneumatic Tool Company introduced the Boyer long-stroke hammer in 1898. Boyer continued to refine the design, finally receiving a patent for it in 1901. Air enters the hammer through the handle (B) and is controlled by the thumb lever (D). Admission of the air into the cylinder (A) is managed by the bushing (M). Valves V and V' at the rear and front of the piston are connected by wires to operate simultaneously and control the input and exhaust of the air, thereby moving the piston (I) backward and forward against the riveting tool (F). “The Boyer Long-Stroke Pneumatic Hammer,” *Engineering* 70 (14 December 1900): 767.*



worker would be displaced by the tool fueled their reluctance to deal with the recoil or kick of the hammer and encouraged claims of injury due to the vibration. This was especially true with the earliest tools. Later, hammer designs incorporated a way of cushioning the blows by either the entering or exhausting air. The suspicion remained, however, and in addressing a convention of foundry men late in 1897, one Philadelphia manufacturer of pneumatic tools recommended that the tools be put in the hands of “young men” who tended to be more “ambitious” and who could be enticed into giving it a fair trial with an offer of a modest pay raise. One turn-of-the-century shipbuilder observed that the primary drawback he had found to the use of pneumatic tools was “the infernal

racket” they produced and the effect the noise had on the neighborhood and adjacent workers. W. I. Babcock, manager of Chicago Shipbuilding, conceded that the noise was sometimes objectionable, but that, given the benefits, it had never been bad enough for them to stop riveting! One wonders how heartily the workers shared that point of view.



Figure 18. Lewis W. Hine photographed a riveter working on the Empire State Building in 1931. The force of repeated blows on the riveting cup tool necessitated ad hoc ways of keeping it on the end of the hammer. This man used a simple rope. Photo courtesy of the George Eastman House.



Figure 19. Hine's photographs of the Empire State Building construction included this view of a three-man riveting crew. The man on the left caught the red-hot rivet in his special bucket and placed it in the hole with his tongs; the next man held it in place, in this case with a pneumatic holder-on; and the third man operated the riveting hammer. Photo courtesy of the George Eastman House.



Figure 20. A rivet tester followed along after the riveting crews and used a special hammer to check for loose or dull-sounding rivets. Photo courtesy R. M. Vogel.

But with this kind of pressure from administrators, it is not surprising that pneumatic riveters were quickly adopted in the United States.²⁵

Economics was, of course, the real reason for the rapid acceptance of the new technology by American builders. A study conducted in 1900 by a committee of the Association of Railway Superintendents of Bridges and Buildings

(headed by A. B. Manning of the Missouri, Kansas & Texas Railroad) confirmed that hand riveting took twice as long and was, thereby, double the expense of pneumatic riveters. Besides the greater speed, there were savings in personnel costs associated with the reduction in the riveting crew size. A study that same year by a railroad shop executive reported a cost savings of 67 percent when using pneumatic riveting hammers instead of hand work for locomotive repair.²⁶

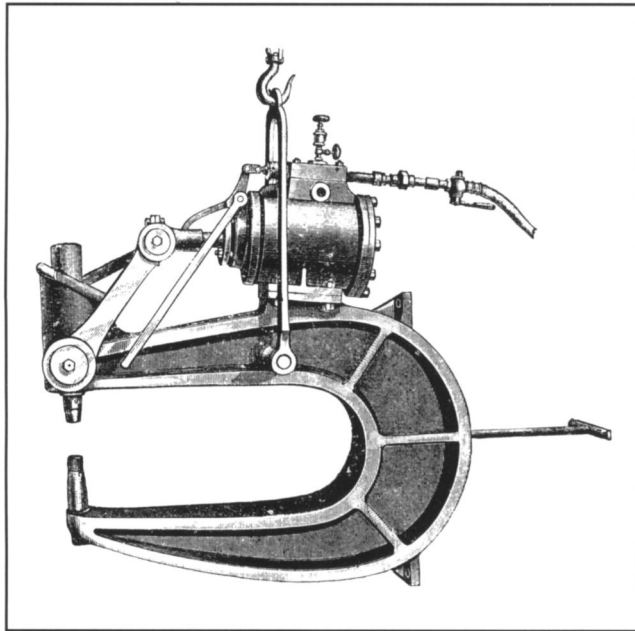


Figure 21. Jaw riveters like this version manufactured by the John F. Allen Company in New York remained popular in Europe long after the turn of the century. They could be rigged for field use but were much more cumbersome than pneumatic hammers. G. Barkhausen, “Mitteilungen von einer Studienreise nach et den Vereinigten Staaten von Nordamerika,” *Zeitschrift des Vereines Deutscher Ingenieure* 37 (1893): 1513.

European Reaction

The European reaction to the Boyer hammer was mixed. While the Russian navy immediately adopted Boyer tools, opposition to them persisted within most European labor organizations. When interviewed in June 1901, two chief engineers at German foundries were still objecting to the repetitive vibration and shock of pneumatic hammers. Traditional hand-riveting methods, in which the worker himself controlled the impact, remained popular overseas. Many Europeans also seemed to mistrust lighter-weight pneumatic hammers, preferring to use heavy mechanized riveters that required rigging to operate (see figure 21). The influential British volume *Practical Shipbuilding* by Campbell Holms, first published in 1904 and reprinted four years later, treated hand techniques as the primary method of riveting, although acknowledging that pneumatic tools were gaining favor for lighter work such as caulking. Eventually Europeans saw themselves as bucking a world-wide acceptance of labor-saving devices (see figure 22). W. L. Saunders, editor of the trade magazine *Compressed Air*, reported that the most “progressive” firms gradually adopted the tools. Pneumatic hammers eventually acquired the nickname “pom-pom” in England, presumably because of their distinctive sound.²⁷



Figure 22. If the construction of the Peterborough Lift Lock in 1902 on the Trent-Severn Waterway in Ontario is any indication, pneumatic riveting hammers were much more readily adopted in Canada than in Europe. Photo courtesy of Parks Canada.

Ancillary Tools

Another component critical to the successful operation of Boyer's pneumatic riveter was a portable compressor. As early as 1899, pioneer engine-builder Fairbanks, Morse & Company was producing a combination air compressor and gasoline engine. It came complete with two water tanks for cooling both the engine and compressor and was mounted on a small truck with steel-spoked wheels. The Christensen Engineering Company of Milwaukee made an electric-powered portable compressor, weighing 1,400 pounds, the same year. Within a couple of years, portable compressors powered by kerosene or even steam were being manufactured. Railroads soon began to equip "portable plants" on rail cars to supply their field work. An important component of all these plants were receiving tanks that stored the compressed air but also cushioned the supply line from the pulsation of the compressor and collected condensation that accumulated in the lines. Workmen also continued to experiment with holder-on devices, since an individual had difficulty holding even a heavy hammer against the rivet while a pneumatic riveter formed the opposite head (see figure 23). An adjustable or spring-loaded dolly bar was sometimes inserted between the rivet and an adjacent member. In lieu of that, individual pneumatic holder-ons were devised on the shop floor and several versions were sold by tool manufacturers.²⁸

Boyer's Popularity

Boyer submitted his patent application for a "pneumatic hammer" in May 1899 but did not receive it until February

1901, almost two years later. Boyer had trouble convincing the patent office examiner of the unique merits of the valve design of his invention. The industry had no such doubts. They recognized its value within a matter of months. As early as January 1899, the Pencoyd Iron Works in Philadelphia, Elmira Bridge Company in Elmira, New York, and railroads that included the Illinois Central, Louisville & Nashville, and Erie were using the hammer for bridge work in the field. The cover story of the December 1899 issue of *Compressed Air* illustrated the "new long-stroke pneumatic hammer" in use at a railroad car works in Pittsburgh. Over the succeeding months, the trade literature is filled with examples of Boyer's tool in use by foundries, boiler shops, shipyards, railroad car shops, bridge erectors, and those fabricating high-rise building frames (see figure 24). The *Railroad Gazette* asserted that in less than a year after its introduction, the long-stroke hammer had been used to drive enough rivets to circumvent the world several times over.²⁹

Much credit for the rapid adoption of the tool must go to an aggressive promotional campaign initiated by the Chicago Pneumatic Tool Company. Representatives of the firm performed demonstrations and set up exhibits at numerous mechanical technical associations throughout 1900. A special catalog in English, French, and German was prepared for the Paris Exposition that year. In fact, the company was awarded a gold medal for its displays and demonstrations of pneumatic riveting tools in Paris, and Boyer himself was given a medal as inventor of the hammer (see figure 25).³⁰



Figure 23. A turn-of-the-century Ingersoll-Rand Company catalog showed pneumatic hammers in use on the construction of the Trinity Building in New York. It also illustrated a variety of holders-on, some more or less devised on the job. The second man from the left uses a heavy sledge and his foot wedged between the flanges of the column as a holder-on, while the man on the right holds a piece of pipe whose end has been bent to allow alignment with the end of the rivet. The forge boy or heater, surrounded by barrels of rivets, stands ready to toss the next hot rivet to one of the riveting gangs.

Photo courtesy of Northwest Architectural Archives, University of Minnesota.

“THE CONTINUOUS CLATTER”: PRACTICAL FIELD RIVETING

Figure 24. This illustration of the assembly department in the Chicago Pneumatic Tool Company's Philadelphia works is suggestive of a line approach. "The Philadelphia Works of the Chicago Pneumatic Tool Co.," *The Railroad Gazette* 32 (12 October 1900): 671.

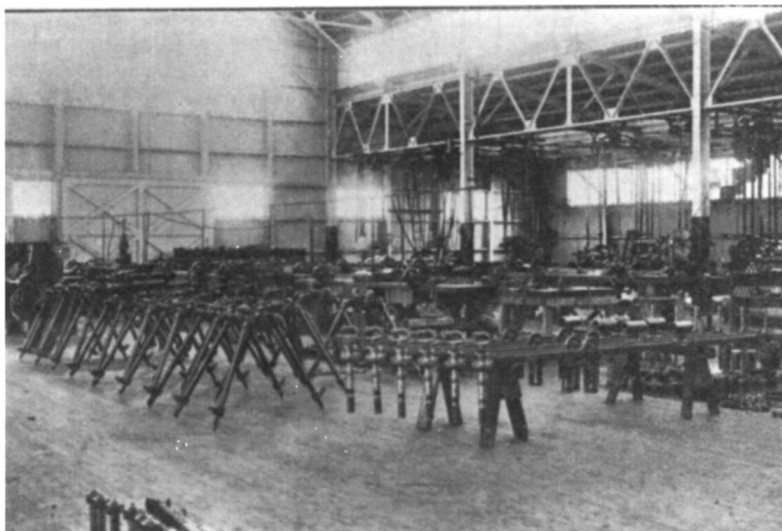


Figure 25. *Chicago Pneumatic Tool Company proudly advertised the success of the Boyer hammer at the Paris Exposition in 1900. The Railroad Gazette 32 (28 December 1900): iv.*

[illegible]

Most telling, perhaps, was the begrudging prominence given to Boyer's hammer in a report delivered in May 1900 by Chester Albree, a rival tool manufacturer, to the Engineers' Society of Western Pennsylvania. A few months later, the British journal *Engineering* published an in-depth treatment of the tool, complete with detailed drawings, describing it as a "labour-saving appliance" that had been "very largely adopted." Soon "a long-stroke" was a standard part of the trade lexicon, identifying a powerful riveting hammer. A practical means of pneumatic field riveting was finally in place. As one shipbuilder remarked, "the continuous clatter of air riveters" was now a common workplace phenomenon.³¹

Epilogue

The basic Boyer hammer has had a remarkable longevity as a tool. Ironworkers still use them, although riveting is a thing of the past, and the Chicago Pneumatic Tool Company continues to sell them. While they were not stock items, the 1975 catalog listed a “Boyer Heavy Riveting Hammer” with a 10-inch stroke that weighed 25 pounds. The Boyer name was dropped from the 1991 catalog, but a hammer with an 11-inch stroke was listed that looked amazingly like a turn-of-the-century model. Hammers, which are adapted to split or shear off rivet heads instead of forming them, are now viewed as demolition tools or “busters.” Among some ironworkers, the hammers are labeled “helldogs.”³²

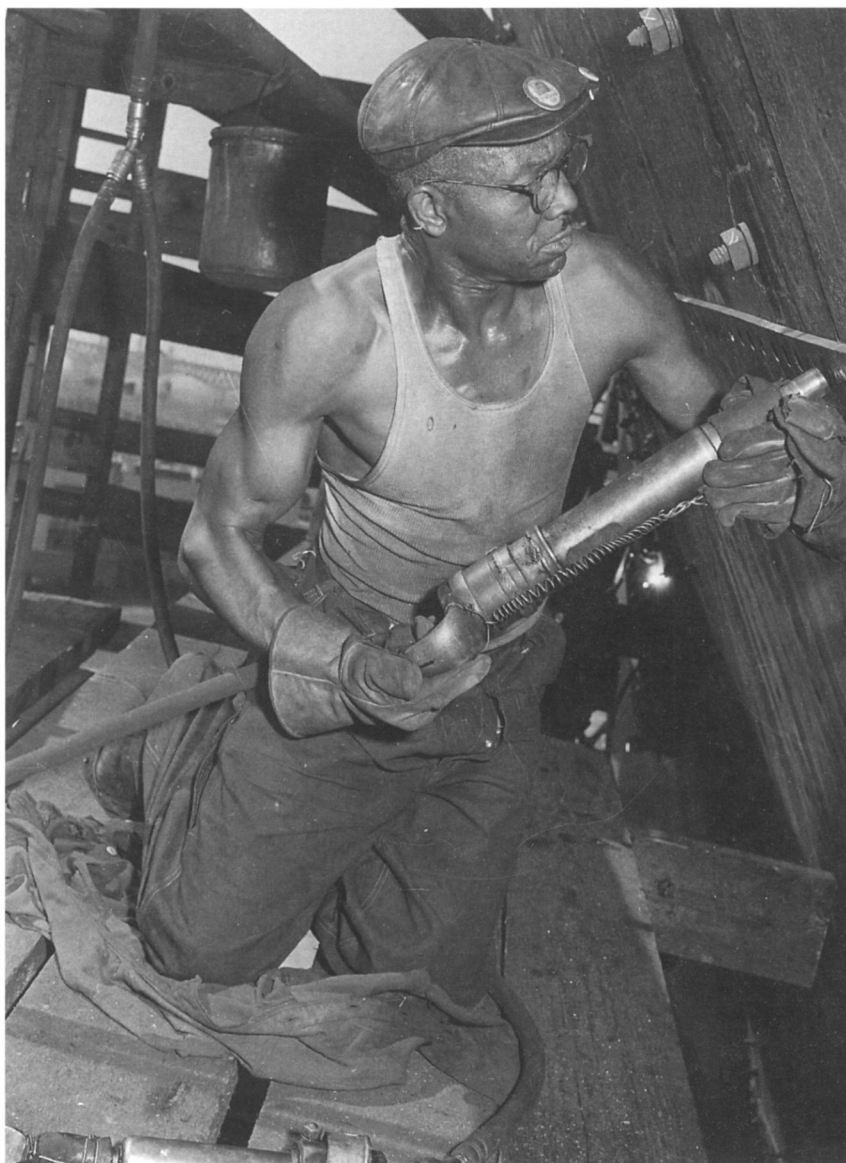


Figure 26. Federal Office of Emergency Management photographer Howard Liberman documented a veteran riveter in an eastern shipyard in May 1942. A leather sleeve and heavy gloves were necessary to cushion the impact of the hammer's blows on the operator. A wye in the air supply hose can be seen behind the riveter, the second hose leading to a chipper laying at his knees. Photo courtesy of the Library of Congress.

These company catalogs would suggest the tools were in use for actual riveting well into the 1970s. Contract riveting crews could reportedly be found operating in the Great Lakes to repair older vessels as late as the 1980s. One of the last U.S. Navy vessels built with any riveted components (if not the last) was the USS *Sacramento*, a combat support ship built at the Puget Sound Naval Shipyard in the early 1960s.³³

Ironically, the men who operated riveting hammers, considered higher-skilled workmen than *chippers* who simply cleaned castings, gradually took on some of the attitudes that had so alarmed shipbuilders in turn-of-the-century Chicago. Every workplace develops its own social hierar-

chy, and the constant percussive strain and strength required to individually manhandle a hammer placed these modern riveters near the top (see figure 26). So while the tools may have changed, the workplace itself retained a certain continuity. Riveting was hard work regardless of the tools and methods.

Notes

1. Dario Gasparini and David Simmons, *American Truss Bridge Connections in the Nineteenth Century: Part II, 1850–1900* (Washington, DC: American Society of Civil Engineers, 1997), 9–14; John Harvey, "Iron Bridge Connections," *Fifth Annual Report of the Ohio Society of Surveyors and Civil Engineers* (Columbus: Society, 1884), 125; Theodore Cooper, *General Specifications for Iron and Steel Railroad*

- Bridges and Viaducts* (New York: Engineering News, 1888), 462; W. H. Thorpe, “Riveted Connections,” *Engineering* 79 (27 January 1905): 103–5.
2. J. A. L. Waddell, *Bridge Engineering* (New York: John Wiley & Sons, 1916), 747–50.
3. David A. Simmons, “Bridges and Boilers: Americans Discover the Wrought-Iron Tubular Bowstring Bridge,” *IA* 19, no. 2 (1993): 63–79; George Drysdale Dempsey, *Tubular and Other Iron Girder Bridges* (London: John Weale, 1850); L. T. C. Rolt, *Isambard Kingdom Brunel* (Middlesex, England: Penguin Books, 1957); William Fairbairn, *On the Application of Cast and Wrought Iron to Building Purposes* (New York: John Wiley, 1854): 107–12; Wilfrid J. Lineham, *A Text-Book of Mechanical Engineering* (London: Chapman and Hall, 1902), 313. Lineham includes numerous fold-out plates of turn-of-the-century British equipment and practices.
4. Henry Adams, *The Practical Designing of Structural Ironwork* (London: E. & F. N. Spon, 1894), 36. Adams was a professor of engineering at the City of London College. Similar descriptions can be found many decades earlier. See E. J. Reed, *Shipbuilding in Iron and Steel* (London: John Murray, 1869), 340–1. For a turn-of-the-century description, see A. Campbell Holms, *Practical Shipbuilding I* (London: Longmans, Green, and Co., 1908), 302. Speed of riveting comes from “Field Riveting by Power,” *Engineering Record* 42 (27 October 1900): 385.
5. J. H. Linnard, “Naval Practice in Ship Rivets and Riveting,” *Transactions of the Society of Naval Architects and Marine Engineers* 4 (1896): 33; C. Schofield, “Pneumatic Tools as Applied to Ship Construction,” *Mechanical Engineer* (9 December 1905): 845.
6. Ewart C. Amos, “Portable Pneumatic Tools,” *Compressed Air* 6 (April 1901): 1268–70; Thorpe, “Riveted Connections” (see n. 1); “Field-Riveting Abroad,” *Engineering Record* 32 (10 August 1895): 182.
7. W. I. Babcock, “Portable Pneumatic Riveters in Shipbuilding,” *Transactions of the Society of Naval Architects and Marine Engineers* 6 (1898): 29–35. Caulking was a routine procedure for boilermakers and shipbuilders that ordinarily followed riveting. A pneumatic hammer with a blunt-ended tool was used to drive or smash together the edges of the recently joined plates in an effort to prevent leakage. See Charles A. Hirschberg, *Compressed Air for the Metal Worker* (New York: Clark Book Co., 1917), 243–7; and J. D. MacBride, *A Handbook of Practical Shipbuilding* (New York: D. Van Nostrand Co., 1918), 46–50.
8. Robert M. Vogel, *Tunnel Engineering—A Museum Treatment*, U.S. National Museum Bulletin 240 (Washington DC: Smithsonian Institution, 1964): 210–12; “The Influence of Portable Tools on Workshop Practice,” *Compressed Air* 6 (June 1901), 1380; Hirschberg, *Compressed Air*, 4–5 (see n. 7).
9. “Pneumatic Tools,” *Compressed Air* 5 (December 1899): 810. See also American Pneumatic Tool Company vs. Bigelow Company, *Federal Reporter* 100 (9 Nov. 1899): 467–75. Because Boyer and Chouteau were both from St. Louis, it is tempting to speculate about their possible collaboration. Unfortunately, no documentation of such cooperation exists. Hugh Wagner, a St. Louis patent attorney who knew both men, made no reference to such joint efforts when donating to the Missouri Historical Society a pair of pneumatic hammers that incorporated inventions by both men. Apart from their mutual interest in pneumatic tools, Chouteau and Boyer had little in common; the former was an individual of wealth and influence, the other a member of the working class. See Hugh K. Wagner to Nettie Beauregard, 19 March 1929, Missouri Historical Society Collections Center, no. 29.14.1–2.
10. Clarence M. Burton, *The City of Detroit, Michigan, 1701–1922* (Detroit: S. J. Clarke Pub. Co., 1922), 3: 20–1; “How Two Huge Corporations Started in Little Shop Here,” *St. Louis Post-Dispatch*, (26 October 1930); *The Canadian Encyclopedia* (Edmonton: Hurtig Pub., 1985), 2: 1340. U.S. patent no. 428,712 for an “apparatus for making glass bottles” was issued to Joseph Boyer on 27 May 1890.
11. Gay LeCleire Taylor, *Out of the Mold* (Millville, N. J.: Museum of American Glass, 1990), 5, 12.
12. A U.S. patent for a “chipping machine” was issued to Joseph Boyer on 15 May 1883. He applied for the patent in April 1882 but was rejected by the examiner because of prior claims issued for steam pumps, dental devices, and an 1878 rock drill. It took over a year and five amendments to overcome the objections. See Patent file no. 277,448, RG 241, National Archives II, College Park, Maryland.
13. “Pierre Chouteau Dies,” Necrology File IIC, Missouri Historical Society Library, St. Louis; *Encyclopedia of the History of St. Louis*, ed. William Hyde and Howard L. Conard (New York: Southern History Co., 1899), 365; various Gould’s *St. Louis Directory* (St. Louis: Gould’s Directory Co., 1888–1901); “Articles of Association of the Missouri Mining Company,” Missouri State Archives, Secretary of State, Jefferson City, Mo.; “Articles of Association of the St. Louis Steam and Pneumatic Engine Manufacturing Company,” Missouri State Archives, Secretary of State, Jefferson City, Mo. Chouteau patent no. 519,147 for an “engine” on 1 May 1894 is the earliest of those identified by Hugh Wagner as critical in the development of the pneumatic hammer in Wagner to Beauregard (see n. 9). Chouteau’s obituary in the necrology file is the source for his association with the Missouri Mining Company. Unfortunately, he does not appear among the incorporators of the firm. Perhaps he was a silent partner, but his money certainly made him a desirable associate for the mining company, and his interest in the firm’s work was long standing. See also “The Pneumatic Tool Litigation,” *The Railroad Gazette* 31 (24 November 1899): 812–13.
14. The liberality of patent examiners in approving even minor improvements to these tools left a confusing mass of claims and counterclaims that could only be resolved through court cases. So many companies were bringing suit for patent infringements in 1899 that the Q and C Company of Chicago advertised that their tools were not involved in any court challenge and could be purchased without fear of legal action; see *Railroad Gazette* 31 (8 December 1899). Rival Chicago tool makers, Chicago Pneumatic (manufacturers of Boyer’s tools) and Standard Pneumatic (owners of Chouteau’s patents) filed suit and countersuit in late 1899. Initial notice that Joseph Boyer was filing an infringement suit in a Philadelphia U.S. Court against National Pneumatic Tool Company appeared in *The Railroad Gazette* 31 (19 May 1899): 356. Additional notices of patent litigation appear in the *Gazette* for 17 November 1899, 24 November 1899, and 18 May 1900. Chouteau is listed as a “capitalist” in the population schedule for the 1900 St. Louis census, a copy of which was provided thanks to Missouri State Archivist Patricia Luebbert. Chouteau’s first relevant patent was U.S. patent no. 384,186 issued to co-worker Gustav Barth on 5 June 1888. His last, U.S. patent no. 578,603, was granted to Thomas R. Hill of Philadelphia and assigned to Chouteau on 9 March 1897.
15. The hammers are no. 29.14.1 and 29.14.2 at the Missouri Historical Society Collections Center; “Gives 2 Chouteau Air Hammers to State Society,” *St. Louis Times*, 29 March 1929. The “Little Giant” advertisement on p. 815 of the December 1899 issue of *Compressed Air* 5 includes an illustration very reminiscent of the Missouri examples. Dates listed on the smaller, bronze hammer include Boyer’s original 1883 patent and 1895 patent to Chouteau and Fred Cornwall, dealing with the handle design and attachment; another 1895 Cornwall patent for a valve design and 1896 patent to Frank Rinsche for a piston and hammer head design (both assigned to Chouteau); an 1898 patent to

- Henry Breitenstein of Laramie, Wyoming, for control and cushioning of the hammer without additional air ports or valves; and a 1900 patent to Henry Kimman for a throttle-valve design.
16. Ewart C. Amos, "Portable Pneumatic Tools," *Engineering* 69 (2 March 1900): 304, 336; Max H. Wickhorst, "Air Motors and Air Hammers," *Transactions of the American Society of Mechanical Engineers* 25 (December 1903): 116. One of Standard Pneumatic's advertisements with a midget or child appears on p. 920 of the April 1900 issue of *Compressed Air*. The Paris Exposition catalog for the Standard Pneumatic Tool Company (Chicago, 1900): 41, indicates that a Little Giant hammer weighing nine pounds was still considered a chipping tool.
 17. Babcock, "Portable Pneumatic Riveters," 30–1 (see n. 7); Amos, "Portable Pneumatic Tools," 335–6 (see n. 16); "Air for Ship Building," *Compressed Air* (June 1897): 234; "A Pneumatic Yoke Riveter," *The Railroad Gazette* 32 (6 July 1900): 469. See also *Chicago Pneumatic Tool Company* catalog for 1904, 14.
 18. Babcock "Portable Pneumatic Riveters," 38 (see n. 7). A Philadelphia shipbuilder reported the breaking of a 7,000-man strike with pneumatic riveters the following year. See "Pneumatic Tools at Home and Abroad," *The Railroad Gazette* 32 (27 April 1900): 282.
 19. Sidney Fine, "Without Blare of Trumpets," *Walter Drew, the National Erectors' Association, and the Open Shop Movement, 1903–57* (Ann Arbor: Univ. of Michigan Press, 1995), 12–14. William Haber, *Industrial Relations in the Building Industry* (Cambridge: Harvard Univ. Press, 1930), 161–9.
 20. Gasparini and Simmons, *American Truss Bridge Connections*, 139 (see n. 1); Sheila Mackay, *The Forth Bridge: A Picture History* (Edinburgh, Scotland: Moubay House, 1990); Benjamin Baker, "Some Notes on the Working Stress of Iron and Steel," *Transactions of the American Society of Mechanical Engineers* 8 (1886): 157–81.
 21. Harry F. Hodges, *Rivets, Riveted Joints, and Pin Connected Joints* (West Point: U.S. Military Academy Press, 1891); A. E. Richard de Jonge, *Riveted Joints* (New York: American Society of Mechanical Engineers, 1945), 20; R. S. Buck, "The Niagara Railway Arch," *Transactions of the American Society of Civil Engineers* 40 (December 1898): 125–50.
 22. "A Large Pneumatic Hammer," *Railroad Gazette* 30 (14 October 1898): 746.
 23. "Boyer Long-Stroke Hammer," *Engineering* 70 (14 December 1900): 767–8; Chester B. Albree, "An Inertia Valve Percussive Tool," *Proceedings of the Engineers' Society of Western Pennsylvania* 16 (May 1900): 134–5; patent file no. 667,863 granted to Joseph Boyer on 12 February 1901, RG 241, National Archives II; "Notes," *Compressed Air* 5 (November 1900): 1100; George M. Andrews, "Compressed Air—Its Use and Advantages," *Compressed Air* 6 (December 1901): 1631–2; *Chicago Pneumatic* catalog, 7 (see n. 16). Boyer's St. Louis operation moved to Detroit early in 1900. See *The Railroad Gazette* 32 (12 January 1900): 24.
 24. "Pneumatic Tools," *Compressed Air* 4 (October 1899): 771; *Compressed Air Information: A Cyclopedic Containing Practical Papers on the Production, Transmission and Use of Compressed Air*, ed. W. L. Saunders (New York: Compressed Air, 1903), 182–3; Amos, "Portable Pneumatic Tools," 335 (see n. 16).
 25. George H. Robbins, "Improved Pneumatic Tools for Foundry Use," *Iron Age* 61 (13 January 1898): 7; Amos "Portable Pneumatic Tools," 306 (see n. 16); Babcock, "Portable Pneumatic Riveters," 37–8 (see n. 7). The issue of noise was raised by a U.S. naval "constructor."
 26. "Pneumatic Field Riveting in Railway Bridge Work," *Engineering Record* 42 (27 October 1900): 393–4; Edward C. Schmidt, "Applications of Compressed Air in Railroad Shop Practice," *Compressed Air* 5 (July 1900), 971–3. See also "Hand vs. Pneumatic Riveting," *American Engineer and Railroad Journal* 74 (December 1900), 386, in which a Boyer long-stroke hammer was used for the test. The study by the Manning committee is summarized in *The Railroad Gazette* 32 (16 October 1900): 700.
 27. "Pneumatic Tools," *Compressed Air* 4 (February 1900), 863; *The Railroad Gazette* 32 (2 March 1900): 140; "Ipswich Engineering Society—Compressed Air and Pneumatic Tools," *Compressed Air* 5 (April 1900): 909–11; Holms, *Practical Shipbuilding*, 298–9 (see n. 4); Editorial, *Compressed Air* 6 (June 1901), 1362. The 1924 British text *Constructional Steelwork* by Harry Atkin (London: Chapman and Hall, 1924), 154–5, describes the "pom-pom" or pneumatic hammer in detail but only after a lengthy discussion of hand-riveting procedures. Comparisons between American and European technologies are, admittedly, more complex than this brief paragraph suggests. See, for example, Eda F. Kranakis, "Technological Styles in American and France in the Early Nineteenth Century: The Case of the Suspension Bridge" (PhD dissertation, Univ. of Minnesota, 1982).
 28. "Portable Air Compressing Outfit," *Compressed Air* 4 (March 1899): 603–4; "Portable Air Compressing Apparatus," *The Railroad Gazette* 31 (23 June 1899): 456; Andrews, "Compressed Air," 1630–2 (see n. 23); *Compressed Air* 6 (January 1902); *Air Compressors* (Chicago: Chicago Pneumatic Tool Company, c.1903); *Chicago Pneumatic* catalog, 17 (see n. 16); C. Schofield, "Pneumatic Tools as Applied to Ship Construction," *Mechanical Engineer* (9 December 1905): 845; "Special Tools in the Missouri Pacific Shops," *The Railroad Gazette* 29 (5 November 1897): 778.
 29. Boyer patent (see n. 12); William Burlington, "Experiences with Compressed Air in Shipbuilding and Ship-Yard Work," *Compressed Air* 3 (October 1898), 511–17; "Pneumatic Riveting Tools for Bridge Work," *The Railroad Gazette* 31 (10 February 1899): 100; "Pneumatic Tools," *Compressed Air* 4 (December 1899): 811.
 30. "Chicago Pneumatic Tool Company's Exhibit," *American Engineer and Railroad Journal* 74 (November 1900): 359–60; *The Railroad Gazette* 32 (8 June 1900): 373–4. The exhibit at the Master Car Builder's Association in Saratoga, New York, was said to be the largest ever done by the firm. See "Exhibits at the Convention," *The Railroad Gazette* 32 (22 June 1900): 416, 431. An illustration of the exhibit itself appeared in "Chicago Pneumatic Tool Company's Exhibit, Paris Exposition," *American Engineer and Railroad Journal* 74 (November 1900): 359.
 31. Albree "Inertia Valve," 134–5 (see n. 23); "Boyer Long-Stroke" (see n. 23); *Compressed Air* 6 (August 1901): 1475.
 32. Barb Peters, Chicago Pneumatic Construction Division, facsimile to author, 13 January 1997; Bill Vermes, HNTB, telephone call to author, 12 January 1997. I learned from Bill Vermes, inspector for Howard, Needles, Tammen, and Bergendoff on the Detroit-Superior Bridge rehabilitation project in Cleveland, that "helldogs" were being used to remove rivets on this project. While visiting the site on 18 September 1997, the foreman for A.B. Dick Contractors, Mark Gelofsack, invited me to operate one of the tools along with another ironworker. The distinctive sound, and overpowering "rat-a-tat-tat," was my first impression. I was soon made aware of the need for bracing the back of the tool against a leg or midsection, much as I had seen on historic photos (see figures 18 and 19). And finally, it was apparent that strength was not the prime criterion for success. A large amount of finesse and skill was involved that would require more time than my brief stint behind the tool.
 33. Jack L. Schmidt, Bechtel, e-mail to author, 11 and 30 December 1996.