The Westinghouse Automatic Air Brake

A Historic Mechanical Engineering Landmark

George Westinghouse Jr.[1]

George Westinghouse, Jr., was born in 1846 in Central Bridge, New York, just west of Schenectady. His father George Westinghouse, Sr., owned a machine shop and from it George Jr. received an early understanding of machinery and business. At the start of the US Civil War, he enlisted in the New York militia, but since he was only fifteen his parents arranged for him to return home. He re-enlisted when he was seventeen, joining the 16th New York Cavalry. In December 1864 he resigned from the Army to join the Navy, serving as an assistant engineer on gunboat USS *Muscoota* until the war ended. After the war, Westinghouse returned to Schenectady and enrolled at Union College, but dropped out in his first term.

Joining the family business, Westinghouse almost immediately began to apply his creative abilities. He was 19 years old when he created his first invention, a rotary steam engine. He also devised a portable steam-powered engine for use on farms. At age 21 he turned his attention to the railroad business, inventing a device to guide derailed railroad cars back onto the track, and a reversible frog, a device with grooves for wheel flanges that allow a wheel on one rail to cross another rail.

Westinghouse Air Brakes

Reportedly, early in his life, Westinghouse witnessed a train wreck where the two locomotive engineers saw each other's approaching trains, but were unable to stop their trains in time using the existing brakes. Recognizing a need, in 1869 at age 22 Westinghouse invented a railroad braking system using compressed air to actuate the brakes. In 1873, Westinghouse refined his braking system, developing an automatic braking system in which each piece of railroad rolling stock was equipped with an air reservoir and a triple valve, also known as a control valve. Unlike his previous straight air system, the Westinghouse automatic system kept the entire line pressurized and used a reduction in air pressure in the train line to apply the brakes. The Westinghouse system was considered fail safe—any failure in the train line, including a separation ("break-in-two") of the train, caused a loss of brake line pressure, which applied the brakes and stopped the train.

The Westinghouse Air Brake Company was subsequently organized to manufacture and sell Westinghouse's invention. The Westinghouse Automatic Air Brake was eventually adopted by nearly all railways. Modern trains use brakes in various forms based on this design.

Westinghouse also pursued improvements in railway signaling, to further reduce railway accidents. In 1881 he founded the Union Switch and Signal Company to manufacture his signaling and switching inventions.

George Westinghouse went on to pursue many other interests, including important developments in electric power generation and distribution, most notably in promoting alternating current. He had over 400 patents during his career. His Westinghouse Electric Corporation became one of the world's premier manufacturing companies. George Westinghouse also served as the 29th president of the American Society of Mechanical Engineers (1910-1911).

[1] Adopted from "George Westinghouse Jr.," Wikipedia article retrieved September 3, 2018.

The Westinghouse Automatic Air Brake

Early rail locomotives employed rudimentary braking systems, largely limited to cutting or reversing power and using wheel brakes on the locomotive wheels to slow and stop the full train of railcars. This arrangement was acceptable on early railroad trains, because they were generally light-weight with a limited number of cars. However, as locomotives became more powerful and were able to haul more and more railcars the inability to safely, reliably and quickly stop necessitated changes. It became imperative to install brakes on the railcars, in addition to the brakes on the locomotive. Early railcar brakes were activated manually. Rail companies hired brakemen and assigned them to turn manual wheels to actuate railcar brakes. Signaling standards were devised, typically consisting of using the whistle to signal the brakemen.

Reliance on brakemen was easy enough for passenger cars. Passenger trains tended to be shorter and lighter than freight trains, and brakemen could ride in a compartment in the passenger cars and then move from car to car to activate or release the brakes, in addition to performing other job functions like coupling and uncoupling railcars. It was far from a perfect solution, however, and failures abounded.

For freight trains, the situation was far worse. Brakemen rode the exterior of railcars and after applying the brakes on one car, they had to jump to the next to set the brakes there, and then to the next. Given that they needed to jump across the gaps between rail cars while the train was traveling at speed, often during adverse weather conditions and on descending grades, accidents occurred frequently, resulting in severe injuries or loss of life. Moreover, the process of braking a heavy freight train traveling at speed took a significant amount of time. The lengthy stop distances caused numerous crashes between trains and with other rolling stock and structures, with the resulting damage to freight and injury to personnel.

George Westinghouse wasn't alone in recognizing a better solution was needed. Several inventors proposed solutions to allow a locomotive engineer to apply brakes the length of a train. Augustine Ambler of Milwaukee patented a system in 1862 that was used on the Aurora Branch of the Chicago, Burlington, and Quincy Railroad. His system used a chain connected to friction brakes on each rail car, and actuated by the locomotive's drive wheel turning a windlass. The chain system worked, but was limited to five cars. It was also a very expensive solution. Other proposed braking systems employed steam or vacuum. A review of early patent filings shows a number devoted to locomotive braking systems. Not much is known about many of these early braking systems, but it is evident that they had little impact upon the safety of the railroad industry.

After viewing Ambler's braking system, Westinghouse looked for ways to improve it. He began exploring ways of extending the Ambler system to longer trains, working on models at his father's shop.[2] He soon abandoned this approach as too costly and cumbersome, and began exploring a different approach.

Westinghouse designed a system, patented in 1869, that employed air pressure supplied by a steam-driven pump on the locomotive. Air hoses fed compressed air generated in the pump to individual rail cars. When the engineer opened a valve, compressed air flowed to the system and activated the brakes on each car of the train. The system is now described as a straight or direct air braking system. It had a significant shortcoming, however. If the hoses leaked or became disconnected, the train lost braking power.

[2] Quentin R. Skrabec, Jr., "*George Westinghouse, Gentle Genius*," Algora Publishing, 2007, p. 41.

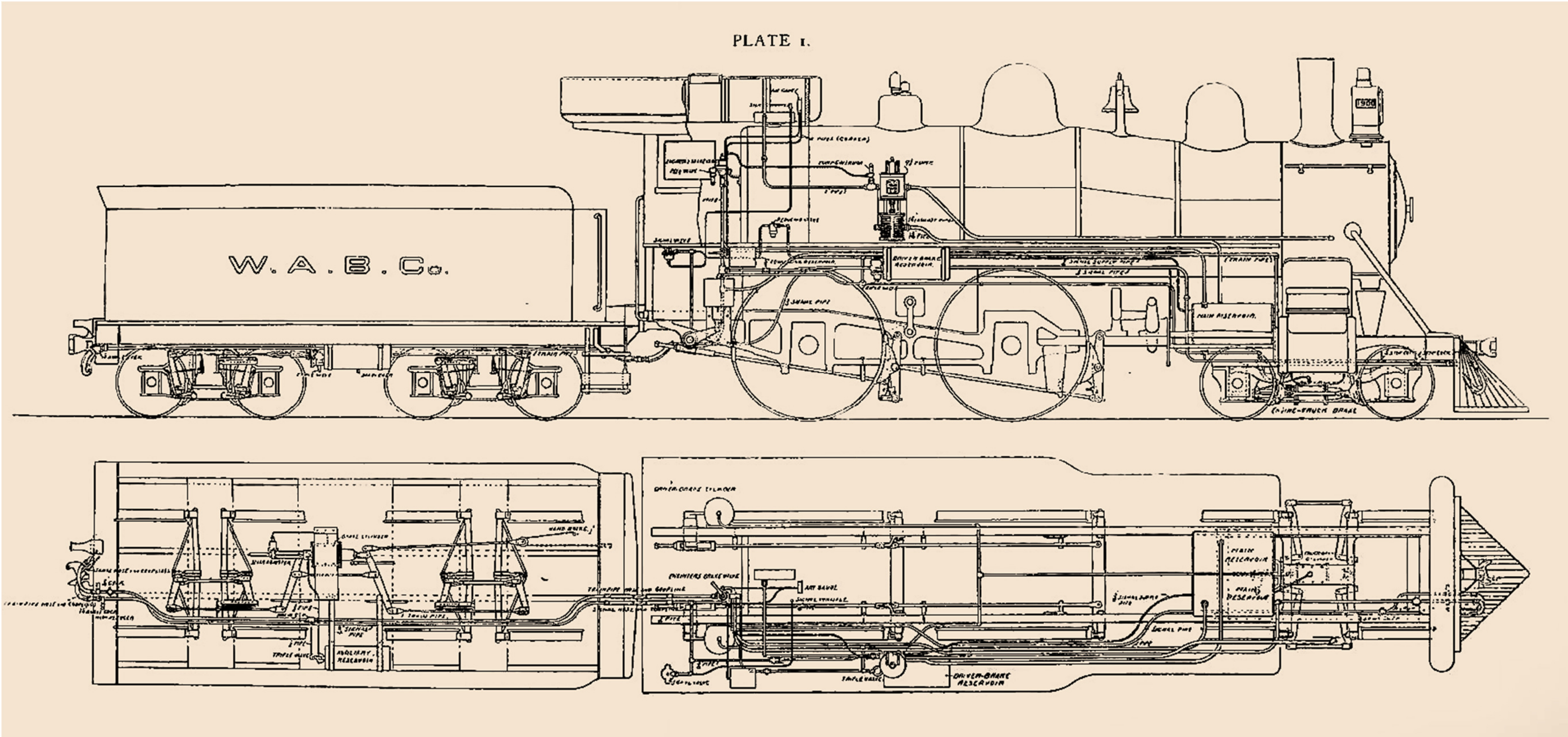
The first locomotive equipped by George Westinghouse with compressed air brakes in 1869 on the Pennsylvania Railroad. The steam driven air pump was installed between the two drive wheels.

Recognizing the shortcoming of his direct air braking system, Westinghouse went to work on a more reliable solution. On March 5, 1872 he received a patent for a braking system that incorporated individual compressed air reservoirs on each rail car to provide the force required to apply the brakes. This new Westinghouse braking system was considered fail safe—any failure in the brake line, including a separation (‘break-in-two’) of the train, caused a loss of air pressure and resulted in applying the brakes automatically and bringing the train to a stop, thus preventing a runaway train or runaway railcars.[3] His automatic braking system was first installed in 1872 on a locomotive and railcars operating on the Pennsylvania Railroad. The following year Westinghouse introduced his ‘triple’ valve (so called because it had three operating positions), to simplify the operation of the system.

The American public was increasingly outraged by the number of accidents and concerned about the safety of passenger travel by rail. As a result, the railroad industry warmed to the automatic air brake for its passenger trains. The new Westinghouse automatic air brake was quickly adopted for passenger service. By 1877, most US railroads had outfitted their passenger trains with the Westinghouse system.[4]

[3] While the system was regarded as fail-safe, certain circumstances could deplete the available air supply in the system and result in braking failures. Source: “Railway air brake,” Wikipedia article retrieved April 19, 2017.

[4] Steven Usselman, “Air Brakes for Freight Trains, Technological Innovation in the American Railroad Industry, 1869-1900,” *The Business History Review*, 58:1 (1984): 30–50. JSTOR, www.jstor.org/stable/3114527.



Above: Locomotive and Tender, equipped with a Westinghouse Automatic Air Brake System. The steam-air pump is shown located on the side of the locomotive, above the main drive wheels. A valve in the locomotive cab gave the operator control of the system, which applied brakes to all railcars on the train. From Air Brake Instruction Book of the Westinghouse Air Brake Company, 1901.

However, the situation for freight cars proceeded at a much different pace. While the need for an effective automatic braking system was greater, as evidenced by the loss of life and injury rates of brakemen and the increasing length and weights of freight trains, it wasn't until 1895 that the industry began outfitting freight trains in the United States with air brakes in significant quantities.

A number of factors contributed to this delay:

- The freight railway business was different than the passenger business. Most passenger trains were made up of locomotives and railcars owned and operated by a single company. Acquiring Westinghouse's brake system for passenger trains was relatively straight-forward with few concerns about interchangeability with passenger railcars of competing companies.

Freight railcars, by the nature of their use, needed to pass from one train line to another, as they traveled across the country to their destinations. For a rail braking system to work, all rail cars need to be equipped with compatible equipment. One railcar in the middle of the train not equipped with automatic air brakes would cause the brakes all trailing railcars to be ineffective.
Furthermore, there were no standards. As time went on, competing braking systems were offered by other companies. Railcars equipped with air brakes from one company weren't always compatible with those from another company.
This made it difficult, if not impractical, for most companies to install automatic rail braking systems on their freight cars.
There were a few companies, mainly western companies with extensive systems that didn't often haul railcars from other companies and needed a braking system to allow operation on steep grades in mountainous areas. These adopted Westinghouse's braking system. George Westinghouse designed a retaining valve to be used for systems operating on lines with long descents. When set, retaining valves prevented a complete release of the brakes until they were turned off at the bottom of the grade.[5]

- Railroad companies found it more cost effective to retain manual brakes with brakemen, than to install costly automatic braking systems. Since few benefits were paid for injuries and loss of life, the calculus came out in favor of retaining manual brakes.
- The general public was not as concerned about safety issues on freight trains, but there was a notable exception. In 1874 an Iowa farmer named Lorenzo Coffin launched a 20-year campaign "to arouse the public to this awful wrong, this butchering of these faithful men who were serving the people at such a fearful risk of life and limb." While Coffin discovered it was not easy to arouse the public, he helped to set the stage for the eventual adoption of a law requiring that automatic braking systems be installed on all freight trains. See sidebar for more information on Lorenzo Coffin.
- Westinghouse's air braking system, as well as competing braking systems, didn't work well with trains containing numerous railcars. It took an excessive amount of time for the pneumatic signal to travel down the line. The brakes on 50^{th} railcar came on about twenty seconds after the brakes were initiated in the locomotive. This led to large shocks as the slack between couplings was taken up and the end cars slammed into the cars ahead in which the brakes had been applied.

The Burlington Brake Trials

It was evident that standardization was essential if automatic brakes were to be employed on most freight trains. In part due to Lorenzo Coffin's persistence, the Master Car-Builders Association (MCBA) agreed to participate in tests conducted on the Chicago, Burlington and Quincy Railroad (the CB&Q). They were held on a steep incline near Burlington in Coffin's home state of Iowa. The Burlington Brake Trials were a seminal event for the industry.[6]

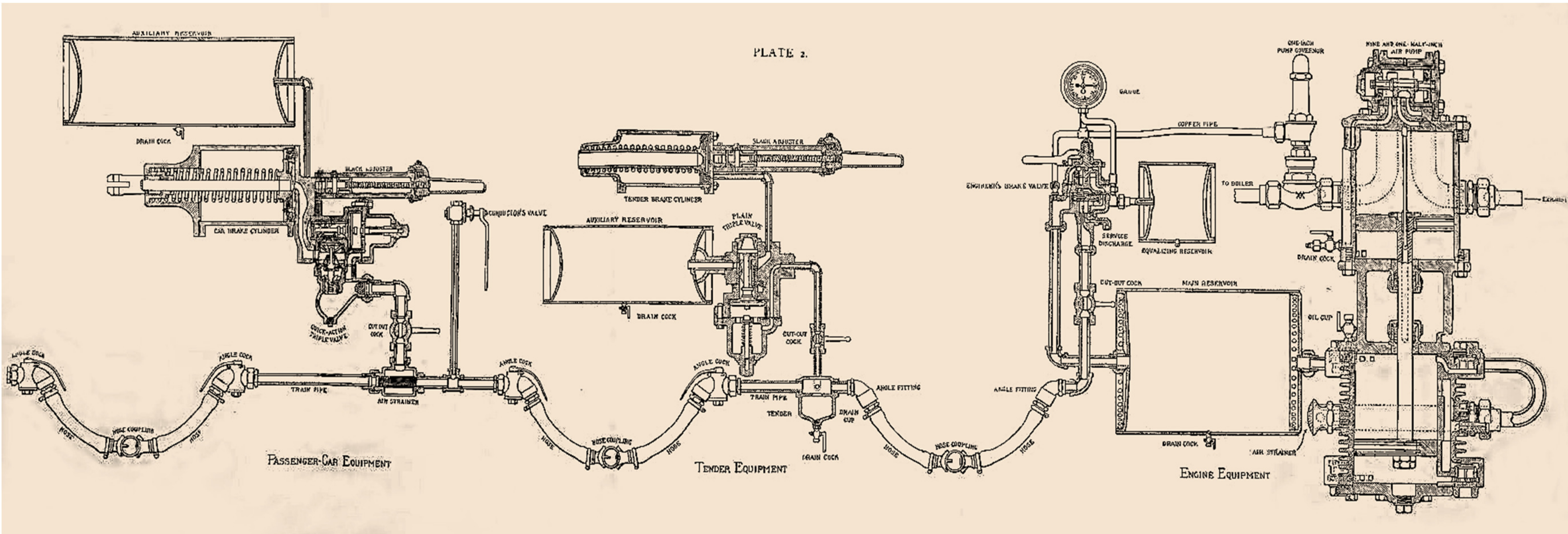
The MCBA was a group of representatives from all major railroad car builders in the United States, as well as from the motive power departments of most railroads. They convened annually to formulate rules regarding the interchange of equipment and set standards for equipment. It had formed a committee on continuous brakes in 1877 and had been studying the issues. In 1884, Godfrey Rhodes of the CB&Q was appointed chairman of the committee. He advocated for trials to determine in the adequacy of automatic brakes for long freight trains and helped to orchestrate the trials. By the

5 Usselman, 37.

6 Usselman's "Air Brakes for Freight Trains" does an excellent job of explaining the events leading to the Burlington Trials, including the efforts of Harlan B. Stone, Godfrey Rhodes, and vice president T.J. Potter—all of the Chicago, Quincy and Burlington Railroad to adopt the air brake for freight train use.

late 1880s, Westinghouse's patents were beginning to expire and a number of companies were designing continuous braking systems. As a result, six brake companies entered the contest, each of which outfitted fifty rail cars. CB&Q provided the locomotives and the use of its repair shops.[7]

The first series of tests, in July 1886, was a failure. The tests used trains of 50 rail cars traveling down a steep grade and applied brakes at 40 mph. The railcar braking systems for all six manufacturers subjected the rear railcars to severe jolts and several cars were damaged. Rhodes called a stop to the trials and the parties agreed to reconvene for additional tests, using the time to modify their systems to address the problems experienced.



Above: Illustration of Westinghouse Automatic Air Brake System. The steam-air pump is shown at right, along with the control equipment located in the locomotive. At middle is the typical equipment installed in the tender, and at left the breaking equipment installed in each passenger car. From *Air Brake Instruction Book of the Westinghouse Air Brake Company*, 1901.

The second set of trials in May 1887 was more successful. All manufacturers added electric wires that traversed the train to ensure that the brakes on all railcars were activated quickly. Westinghouse, however, criticized the use of electric signals, claiming that adding a second system resulted in complications, and that they would not function reliably in everyday use. He stated that he would be introducing an air brake that would eliminate shocks without the use of electric signals. Later that summer, a third set of trials was held. Westinghouse employed his recently introduced 'quick-action' air brake. The new 'quick-action' air brake employed larger air brake piping and redesigned triple valves on each rail car. Upon application, a

[7] Usselman, 44.

shock wave was rapidly transmitted the entire length of the train through the larger pipe. This more quickly triggered the triple valves and caused the brakes to apply faster.[8]

In the trials using the quick-action Westinghouse braking system, a train of 50 cars traveling down a steep incline at 40 miles per hour was stopped in 695 feet—about a third of the distance previous tests with air brakes using the electric signals—with scarcely a jar and no damage.[9]

Based largely upon the results of the tests, the MCBA adopted brake standards for freight trains that only Westinghouse's quick-action air brake could meet. As a result, any railroad wishing to interchange freight cars with automatic air brakes would need to purchase brake systems from Westinghouse Air Brake.

Railroads were slow to adopt the new standard.[10] The public, in part due to Lorenzo Coffin's efforts, became increasingly vocal about the issue. Coffin drafted proposed regulations and several states considered adopting the law to require continuous brakes be installed on all railroad trains. In 1890, the Federal Government began holdings hearings on the subject. Candidates from both parties in the 1892 presidential election advocated for new safety legislation. Finally, in 1893, President Benjamin Harrison signed the Railroad Safety Appliance Act, requiring all American railroads to adopt air brakes and automatic couplers.

The Railroad Safety Appliance Act of 1893 required that all rail lines conducting interstate commerce must employ power braking systems that could control the speed of the train without a brakeman to do so, and also mandated that all such rail lines use cars that coupled and uncoupled without manual assistance of a worker standing between cars. A seven-year grace period allowed railway companies time to comply with the new law. The effect of the changes was marked by the dramatic reduction of injury and death to brakemen.

George Westinghouse traveled throughout the country on a specially outfitted train to demonstrate his quick-acting air brake system. He also continued to innovate; refining his automatic braking system and designing solutions for even longer trains and addressing specific applications.[11] The company worked closely with the MCBA to ensure that its products met all safety standards. Westinghouse's invention and development of the automatic railroad air brake significantly improved the safety of rail travel for passengers and freight, dramatically reduced the accidents suffered by brakemen and other railroad workers, and allowed the safe adoption of longer trains and higher speeds. As a result, the innovation greatly contributed to the economies of the United States and foreign countries.

George Westinghouse's legacy continues to this day. His early innovations for railroad brakes provide the foundation upon which most rail braking systems continue to be developed.

8 *Railroad Gazette* 19 (October 17. 1887): 653: and 19 (November 11, 1887): 729, 734.

9 Usselman, "Air Brakes for Freight Trains, Technological Innovation in the American Railroad Industry, 1869-1900," 45.

10 In 1893, six years after the MCBA standards were adopted, almost 90 percent of freight railcars still employed manual brakes. Source: *Interstate Commerce Commission Reports,* 1893, and *Railroad Gazette* 20 (October 12, 1888): 671; and 22 (March 21, 1890): 197.

11 George Westinghouse Jr. had at least 35 US patents related to refinements to his air brake system, and the company strongly contested patent infringement.

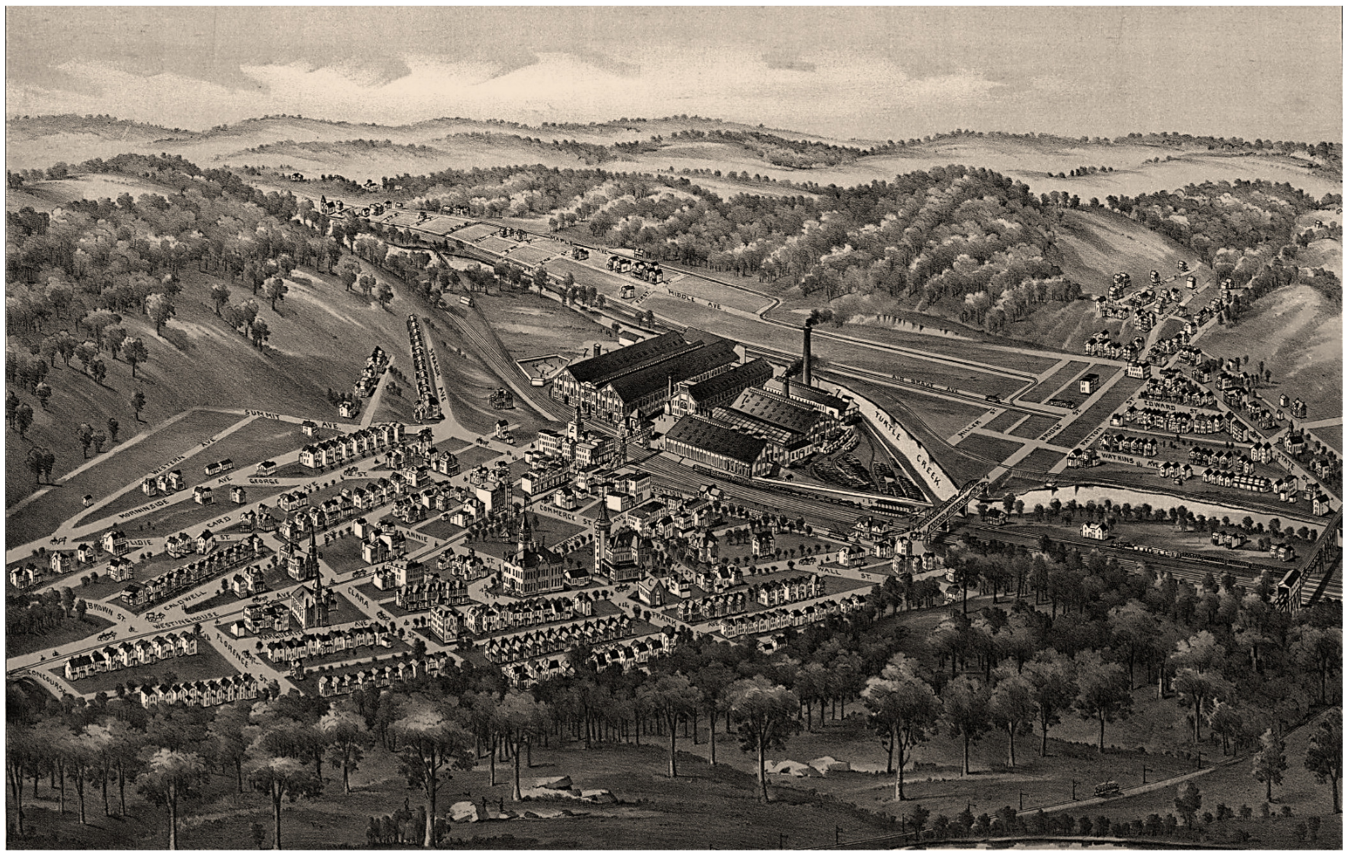
Westinghouse Air Brake Company and the Wilmerding Factory

Westinghouse founded the Westinghouse Air Brake Company on September 28, 1869, in Pittsburgh Pennsylvania to manufacture his braking systems. After manufacturing brake systems in Pittsburgh for a number of years, Westinghouse purchased land in the Turtle Creek Valley of Pennsylvania in Wilmerding, a few miles east of Pittsburgh, to manufacture his air brake system. In 1889, Westinghouse Air Brake Company moved its brake manufacturing and related facilities there.

Wilmerding quickly became a ‘company town’ in which the majority of its citizens were employed by Westinghouse Air Brake. In the early 1900s, the company purchased additional land and began building housing for its employees. It also offered educational and cultural activities through the local YMCA.

Westinghouse Air Brake was one of the first companies to institute a 9-hour work day and a 55-hour work week, as opposed the 60+ hour work week that was more typical at the time. The company also initiated a series of welfare options to better the working and living conditions of company employees.

By 1905 over 2,000,000 freight, passenger, mail, baggage, and express cars and 89,000 locomotives had been equipped with the Westinghouse Air Brakes.[12]



Illustrated Map of Wilmerding, Pennsylvania, showing the Westinghouse Air Brake Factory. Created/Published by T. M. Fowler and James B. Moyer, Morrisville, PA, 1897. From the Library of Congress

12 Westinghouse Air Brake Company article, Wikipedia, retrieved September 9 , 2018.

Lorenzo Coffin[13]

In 1874 an Iowa farmer named Lorenzo Coffin watched the train he was riding hook on to a freight car. A brakeman stood between the car and the train, ready to couple them. He miscalculated, and Coffin saw the man fall to the ground shrieking, two fingers sheared from his right hand. Anyone would have been disturbed by that brutal vignette, but Coffin was more than disturbed; the brakeman's misfortune changed the course of his life and, in time, saved the lives of thousands.

He started talking to railroad men, and learned that the accident he had seen was hardly unique. The railroads used link-and-pin couplers, savage devices which were locked by a brakeman dropping a pin between two iron loops as they came together. It was easy enough for a brakeman, darting between approaching cars, to lose his fingers, his hand, his life. Moreover, when the trainmen weren't coupling cars, they were on top of them, bucking along unsteadily above the roadbed, setting hand brakes. In fact, a trainman had one of the most hazardous peacetime occupations on earth; twenty to thirty thousand were maimed or killed each year.

Coffin, appalled, persisted: Were there no safety devices available to the railroads? Yes. Eli Janney had already patented an automatic coupler that locked like two hands clasping, and George Westinghouse had developed a workable air brake that could stop a train from controls in the locomotive.

Why weren't these in use? The railroad officials' bland, obdurate answer was that their installation was "impracticable"—that is to say, expensive. The dollar and fifty cents a day that the trainman earned made him responsible for his own injuries. Air brakes and automatic couplers cost the lines money; maimed railroad men cost nothing.

As Coffin asked his questions, his interest grew into fanaticism. At fifty-one years of age, he started off on a twenty-year crusade. The public was not, he found, easily aroused. Coffin appeared in railroad offices, only to be thrown out. In an age when railroads could buy senators, they had little time to spare for a scrawny, bearded do-gooder. Coffin wrote to newspapers, but his stories were rarely printed. Religious and farming periodicals were the only platforms he could find, and there his vivid harangues appeared, in between essays on sheep dipping and accounts of parish goings on.

Coffin kept on the move, traveling around the state, telling horror stories. In 1883 he managed to get himself appointed Iowa's first railroad commissioner. The commissioner wrote thousands of letters, and attended every gathering of railroad officials that did not forcibly eject him. The railroad managers knew him as the "Air-Brake Fanatic."

Changing his tactics slightly, Coffin started badgering the Master Car-Builders Association to test the air brakes on a freight train. Finally, in 1886, the trials were initiated. Three trails were eventually held before successful. In witnessing the final test of the Westinghouse Air Brake, the gaunt old fighter stood watching it with tears on his face. "I am the happiest man in all Creation," he said. He helped draft the first railroad safety appliance act. In 1893, a bill requiring all American railroads to adopt air brakes and automatic couplers came before President Benjamin Harrison. The President signed it into law and gave the pen to Coffin.

[13] *Lorenzo Coffin*, Extracted and adapted from *American Heritage Magazine* 1979, 30:6, Written by Richard F. Snow.

HISTORIC MECHANICAL ENGINEERING LANDMARK

WESTINGHOUSE AUTOMATIC AIR BRAKE

1869, 1872

IN 1869, GEORGE WESTINGHOUSE, JR., PATENTED A SYSTEM THAT USED AIR PRESSURE TO STOP TRAINS. THIS LED TO HIS DEVELOPMENT IN 1872 OF THE FIRST AUTOMATIC AIR BRAKE SYSTEM FOR RAILROADS. IT HAD A BUILT-IN SAFEGUARD TO APPLY THE BRAKES ON THE ENTIRE TRAIN SHOULD IT SEPARATE OR IF AIR PRESSURE WAS LOST IN THE PIPE(S) CARRYING AIR TO THE RAILROAD CARS. THE WESTINGHOUSE BRAKING SYSTEM MADE POSSIBLE LONGER AND FASTER TRAINS AND IMPROVED THE SAFETY OF RAIL TRANSPORTATION. IN VARIOUS FORMS, WESTINGHOUSE'S AIR BRAKE SYSTEM HAS BEEN NEARLY UNIVERSALLY ADOPTED.

THE AMERICAN SOCIETY OF MECHANICAL ENGINEERS—2019

Wabtec Corporation Today

Wabtec is a diversified, global leader in equipment, components, services, software and systems for the transportation industry. Drawing on nearly four centuries of collective experience across Wabtec, GE Transportation and Faiveley Transport, the company is paving the way in safety, efficiency, reliability and productivity.

As an integrated solutions provider, Wabtec accelerates lifecycle solutions for the transportation industry by improving interoperability, efficiency and competitiveness for customers. With more than 23,000 locomotives in our global installed base, and components on many of the locomotives, freight cars and transit cars around the world, we are the movers and shakers of tomorrow's logistics and transit solutions.

Our digital solutions, combined with Positive Train Control (PTC) and electronics capabilities, unlock significant productivity improvements — saving billions of dollars for rail customers and operators, all while creating pathways to advanced automated operations. These digital technology solutions improve safety and efficiency for the transportation industry, helping address the growing demand for improved rail performance.

The History and Heritage Program of ASME

Since the invention of the wheel, mechanical innovation has critically influenced the development of civilization and industry as well as public welfare, safety and comfort. Through its History and Heritage program, the American Society of Mechanical Engineers (ASME) encourages public understanding of mechanical engineering, fosters the preservation of this heritage and helps engineers become more involved in all aspects of history.

In 1971 ASME formed a History and Heritage Committee composed of mechanical engineers and historians of technology. This Committee is charged with examining, recording and acknowledging mechanical engineering achievements of particular significance. For further information, please visit http://www.asme.org

LANDMARK DESIGNATIONS

There are many aspects of ASME's History and Heritage activities, one of which is the landmarks program. Since the History and Heritage Program began, 272 artifacts have been designated throughout the world as historic mechanical engineering landmarks, heritage collections or heritage sites. Each represents a progressive step in the evolution of mechanical engineering and its significance to society in general.

The Landmarks Program illuminates our technological heritage and encourages the preservation of historically important works. It provides an annotated roster for engineers, students, educators, historians and travelers. It also provides reminders of where we have been and where we are going along the divergent paths of discovery.

ASME helps the global engineering community develop solutions to real world challenges. ASME, founded in 1880, is a not-for-profit professional organization that enables collaboration, knowledge sharing and skill development across all engineering disciplines, while promoting the vital role of the engineer in society. ASME codes and standards, publications, conferences, continuing education and professional development programs provide a foundation for advancing technical knowledge and a safer world.

Cover photograph, courtesy of Douglas Van Bossuyt, showing a pair of Westinghouse cross-compound air pumps on a large steam locomotive.

ASME
SETTING THE STANDARD