MISSION: STOP A

A TRAIN

How inventor George Westinghouse Jr., investors, railroad officials, and test trains helped put the brakes on the wheels 150 years ago

by Ronald Olsen

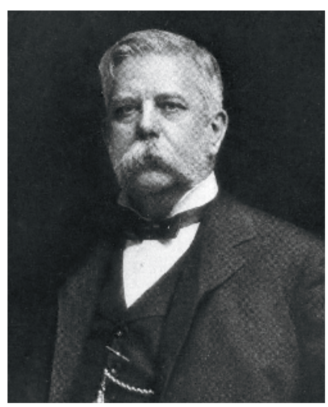
On the 150th anniversary of the creation of the air brake, the story of how George Westinghouse Jr. developed this transformational technology is worth recounting. It's also a saga that launched a major American industry that, with the merger of Wabtec and GE Transportation earlier this year, is ongoing. The story began in 1866, when two men began to inspect a new Chicago, Burlington & Quincy Railroad Aurora local passenger train in Chicago.

The older man, Augustine I. Ambler, an inventor from Milwaukee, explains how he has designed and installed a braking system on the coaches. A windlass, which is revolved by pressing a grooved wheel against the driving wheel of the locomotive, winds up a chain, which runs the length of the train, transmitting a force to a series of levers connected to brakeshoes, which press up against the wheels, and provide power to stop the train. The younger man, also an accomplished inventor, takes great interest and says he's been working on a brake, too. Ambler claims his setup is the only feasible plan and is protected by a patent dating to 1862. Undaunted, the young man leaves determined to come up with something better. His name was George Westinghouse Jr.

Burlington Junction Railway's Brad Holtmeyer steps in between the locomotive and lead car of a 27-car freight train to attach air lines in Quincy, Ill. Steve Smedley

Westinghouse grew up working in his father's machine shop in Schenectady, N.Y. His father, George Westinghouse Sr., made and sold farm implements and had a number of inventions and patents. At an early age, young George learned about machining, forging, and casting metals, and became an excellent engineering draftsman. While working for his father, he traveled by train, made visits to suppliers, and sold to customers in the East. But he longed to strike out on his own.

In the 1860s, railroad accidents were not uncommon. Westinghouse had been a passenger on a train between Schenectady and Troy, N.Y., when he was delayed several hours due to a collision between two freight trains. From this event, the idea to devise some sort of power brake was firmly planted in his mind.



George Westinghouse Jr.

Inventors had been trying to come up with a workable system to stop railed vehicles even before locomotives were invented. By 1869, about 650 patents were granted for contrivances to stop trains in England, and another 305 in America. In the 1830s, George Stephenson invented a steam brake for locomotives, and by the 1850s, some U.S. locomotives were equipped with them, but they were hardly a solution. Cold weather in North America froze pipes and cylinders, making maintenance difficult.

AIRING OUT THE ISSUES

The vacuum brake showed promise in the 1860s. An ejector on the locomotive pumps air out of the brakepipe to power this system, but the vacuum was far from perfect. While 14.7 pounds was the theoretical maximum pressure, 8 or 9 pounds was a more realistic pressure gradient for the system. It needed huge cylinders and mechanical advantages in the linkages to supply enough force to effectively brake the train. Vacuum brakes also lost power as atmospheric pressure dropped with a rise in altitude, making them impractical for mountain roads, exactly where the need for a power brake was most acute. Several U.S. manufacturers had commercial success producing them, most notably the Eames Co., which produced vacuum brakes for the entire New York elevated railroad system.

Handbrakes and sturdy brakemen were the main way that trains were brought to a stop in the mid-1800s. Upon hearing a single, long blast from the whistle (also known as the "down brakes" signal), the brakemen would spring to the brake wheels as fast as possible. However, it took time to wind up the slack in the chains, and if it took the crew just 10 seconds to do it, a train traveling at 30 mph would have already moved 440 feet. Up until mid-century, most cars didn't even have both trucks braked.

In the 1850s, double-acting brake foundations came into general use, which helped, but using human muscle was still a slow and uncoordinated way of putting the brakes on the wheels. A brakeman's pay was low, and it was a dangerous job. Thousands of them died each year, many from falling off the tops of railcars.

While at his father's shop, Westinghouse read in a monthly newspaper about a tunnel being driven through Mont Cenis in France. Instead of using manual labor, workers sent compressed air at 90 psi through 3,000 feet of pipes to a pneumatic drill. This account convinced him of the feasibility of using air to power brakes on a train.

MORE INVENTIONS

In the mid-1860s, Westinghouse came up with two devices: a "car replacer" that helped rerail cars and a steel railroad frog for diverging trains at switches. Westinghouse travelled the country promoting them, and in the course of doing so made many connections with railroad executives. Soon after he sold his first frog to the CB&Q, Superintendent A.J. Towne invited him to look at the braking system on the Aurora local passenger train.

In 1866, Westinghouse went to Pittsburgh to seek out a new foundry to produce his inventions. Pittsburgh was then a growing industrial center, producing coke, glass, iron, and steel. In a fortuitous meeting, Westinghouse befriended wealthy industrialist Ralph Baggaley, who became enthusiastic about the air brake and raised capital for it. In 1868, Baggaley helped Westinghouse set up a small factory at Liberty Avenue and 25th Street in Pittsburgh, just three blocks away from Pennsylvania Railroad's 28th Street roundhouse.

Westinghouse started working on an apparatus consisting of a converted Worthington air pump, an air reservoir tank, and four or five cylinders that would be installed on the cars, along with all the necessary piping needed to make the system work. Steam from a boiler powered the air pump, which compressed air to 70 psi in a reservoir. When a brake application was desired, a three-way cock in the cab was opened that released the air from the tank, which flowed through a pipe to the brake cylinders on the locomotive, tender, and cars. The air pressure exerted a push on the brake-cylinder pistons, which were connected through linkages to the brakeshoes, and these were pushed against the wheels to slow the train.

The system could easily put several times as much pressure against the brakeshoes as a brakeman did winding on a hand brake. The apparatus was first set up by late summer 1868, and railroad officials from the Pennsylvania Railroad and the Pittsburgh, Cincinnati, Chicago, & St. Louis were invited to inspect it. W.W. Card, superintendent of the PCC&StL, offered to let Westinghouse install the equipment in the Steubenville passenger trainset, which consisted of 4-4-0 No. 23 and four cars. It made a test run in September 1868.

Westinghouse remarked: "Upon its first run after the apparatus was attached to the train, the engineer, Dan Tate, on emerging from the tunnel near the Union Station in Pittsburgh, saw a horse and wagon standing upon the track. The instantaneous application of the air brakes prevented what might have been a serious accident, and the value of this invention was thus quickly proven and the air brake started upon a most useful and successful career."

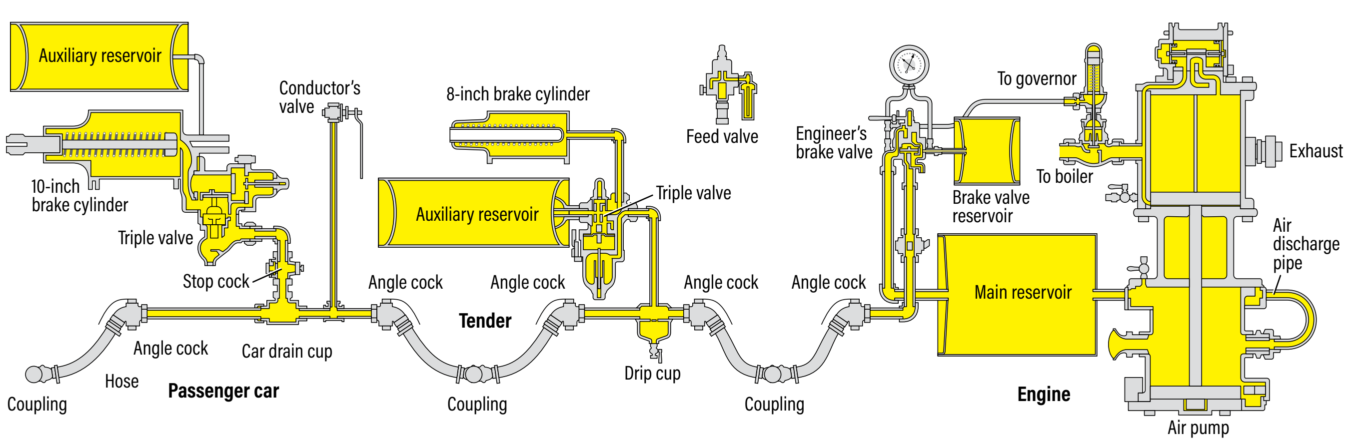
His patent, No. 88929, was issued on April 13, 1869, and the state of Pennsylvania granted the Westinghouse Air Brake Co. its charter on Sept. 28. After the success of the apparatus, Robert Pitcairn, superintendent of the Pennsy's Pittsburgh Division, invited Westinghouse to fit a six-car train with the new brake

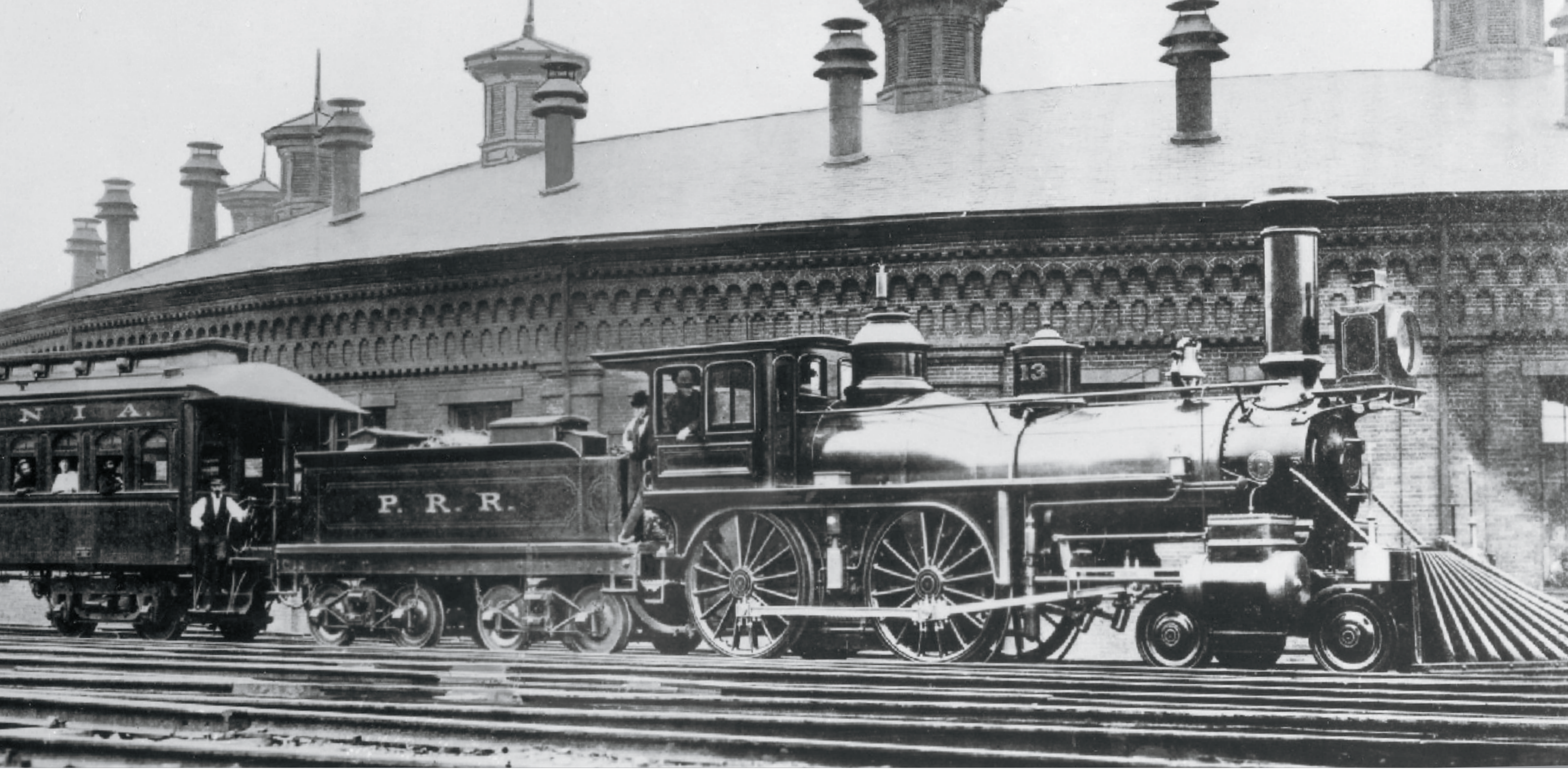
system, and it was demonstrated in front of the Association Of Master Mechanics in September 1869, which was meeting in Pittsburgh. The train ran without incident to Altoona on the eastern slope of the Alleghenies. Stops were deliberately made on the steepest portions of the line in short distances to demonstrate that compressed air could be successfully used to control the brakes on a train, even in mountainous terrain. Card and Pitcairn used Pennsy money to help Westinghouse fine-tune his equipment.

TESTING, TESTING

In November 1869, a set of air brakes was installed on a

WESTINGHOUSE QUICK ACTION AUTOMATIC BRAKE, 1887





The first locomotive, Pennsylvania Railroad 4-4-0 No. 13, equipped by Westinghouse with compressed air power brakes in 1869. Wabco

longer, 10-car Pennsy train, and it was taken to Philadelphia to show company officials. The Pennsylvania had been using a chain brake on its passenger trains, but it was not satisfactory. George L. Dunlap, president of the Chicago & North Western, took great interest in it. He invited Westinghouse to Chicago to demonstrate the brake to other railroad people and to members of the press. The apparatus was transferred to a new locomotive and six new cars, and it ran over the Fort Wayne Railroad to Chicago. During one demonstration, the train, moving at 30 mph, stopped in 19 seconds, in a distance of just 380 feet, far shorter than a team of brakeman could do it.

C&NW and Michigan Central ordered air-brake sets immediately, and shortly after Union Pacific, Boston & Providence, and Old Colony lines did as well. In 1870, the Pennsy decided that the Westinghouse brake would be the standard equipment for its passenger trains. Then in February 1871, New York Central Railroad suffered a spectacular, fiery wreck near Poughkeepsie, N.Y., involving one of its crack trains, the *Pacific Express,* in which 30 people were killed and a bridge destroyed. In 1872, NYC equipped all of its passenger trains with the Westinghouse brake, and a flood of orders from other railroads followed.

By the early 1880s, Westinghouse had succeeded in putting his brakes on most of the wheels of the U.S. passenger-car fleet.

Several factors explain why the straight air brake was quickly adopted. Public outcry for the need for safety was ever-increasing, and travelers were becoming more discerning when it came to trains which they considered "safe" (having air brakes) vs. "unsafe" (those without). Each company also looked for a competitive advantage over the others. Traffic volume and speeds had increased markedly, so there was a real need for reliable brakes.

In July 1871, Westinghouse made his first trip to Europe to introduce his invention, but at first, he was not successful. In an attempt to make some headway, Westinghouse made contact with James Dredge Jr., the editor of Engineering, an English journal. After several interviews, Dredge gave Westinghouse a paper he was about to publish on the general subject of air brakes.

Several of the requirements he outlined had already been met by Westinghouse's straight-air brake, but at least two of them were not: "If a part of the train breaks loose from the rest, the brakes must come automatically into play; the failure of the brake apparatus on one or more carriages must not interfere with the action of the brakes on the rest of the train."

While the straight air brake was a commercial success, it did have two major shortcomings. It was not a fail-safe brake. If a hose burst (a common occurrence, as a high-grade of air hose was not available at the time), or if the train broke in two, the air would rush out and no braking power would ensue. Westinghouse's partial solution was to invent an automatic check valve that was installed in the coupling hoses; if the train came apart while the brakes were applied, the check valve would retain the brake pressure in the train line in both halves.

If the train was going uphill, and the brakes had not been applied, however, the rear half would have to have its hand brakes wound up by the brakemen to prevent it from running away back downhill.

WORKING OUT THE KINKS

Even during the early years of its success, Westinghouse knew the system was far from perfect. The propagation of air just took too much time to travel from the front of the train to the rear, which made it less practical for longer trains (more than six-10 cars). What was needed was a system that would work on a train of any length, and put the brakes on automatically in case of a break-in-two.

THE SYSTEM COULD EASILY PUT SEVERAL TIMES AS MUCH PRESSURE AGAINST THE BRAKESHOES AS A BRAKEMAN DID WINDING ON A HAND BRAKE.

The solution he came up with was the reverse of the straight-air system; instead of using air to apply the brakes, he would use it to keep the brakes off. He added two components to make this happen.

First was an air tank on each car, called the auxiliary reservoir. This put the air closer to the brake cylinder, where it could be supplied quickly, rather than having to travel from the locomotive to apply

HOW AIR BRAKES WORK

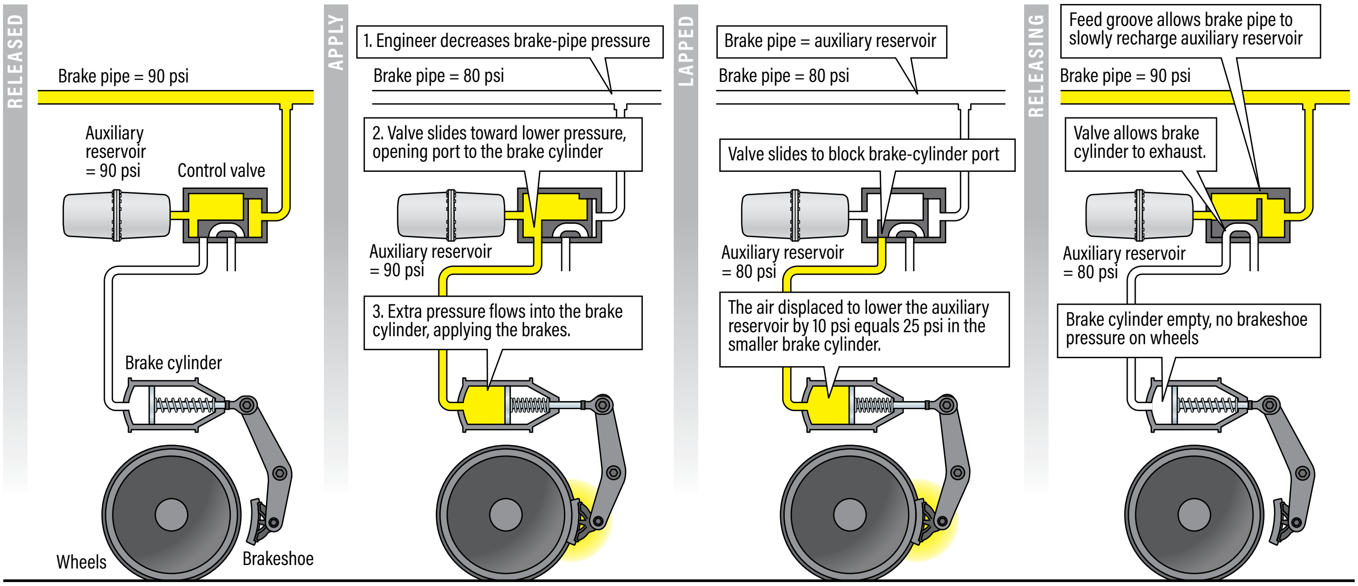


Illustration by Rick Johnson

the brakes. The second was a triple valve to control the three states of the braking system: charge, apply, and release. One was mounted on each car, and it controlled the system by being connected to the brake pipe, auxiliary reservoir, and brake cylinder.

When the brake-pipe pressure is charged up before the train starts or after the brakes are released by the engineer after an application, the triple valve opens a passage to the auxiliary reservoir, filling it with pressurized air, while the brake cylinder is opened to the atmosphere. If the brake-pipe pressure is reduced by the engineer, or by a hose coming uncoupled, or a conductor's valve being pulled, the triple valve sends air from the auxiliary reservoir to the brake cylinder, and applies the brakes.

The triple valve had a lap feature, which would allow the engineer to make several small brake applications, but it could not be partially released like the straight-air system could. For this reason, until the 1880s on some Western lines, both systems were used in tandem (some narrow gauge railroads in the U.S. still use a dual system).

On standard gauge railroads, the main reservoirs on the locomotive had two pipes running into the cab and through two cocks in front of the engineer. At the back of the tender, the automatic brake pipe would come from the engineer's side (just as it does today) and cross under the coupler to connect to a hose on the fireman's side of the passenger car. The straight-air brake pipe would do just the opposite.

To make sure that a brakeman wouldn't mix them up, the straight air used a type-H gladhand while the automatic side used a type F, and the two could not physically make a connection. The two systems connected at the car's brake cylinder at a "T" junction (downstream from the triple valve on the automatic side). A shuttle valve flipped to allow air to the cylinder, depending on which side had the greater pressure. This arrangement allowed fine control, using the straight-air brake side for light braking, but allowed a quicker emergency response if needed from the automatic side.

The first triple valves of 1871 had soft rubber diaphragms that were too sensitive and reacted inconsistently to pressure changes. Westinghouse also tried leather, but finally settled on a piston with brass rings by 1874, which became the first practical triple valve to withstand rigorous railroad service.

FINE-TUNING THE FINE-TUNING

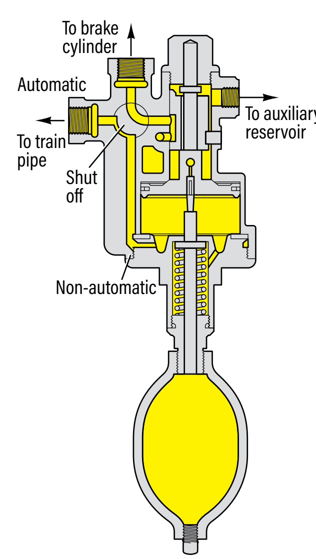
Westinghouse took out 10 patents for hose couplings between 1867-1874. One of the problems with the early ones was that they had male and female ends. This meant that two hoses were needed on each end of the car, so that opposites could couple to each other. In 1874, however, when the automatic brake came into use, Westinghouse made a revolutionary change when he turned the air passage 90 degrees, and the gladhand took the form that is essentially used today.

In 1878-79, the Galton-Westinghouse tests were performed on the London, Brighton & South Coast Railway in England, and much was learned about coefficients of friction between rail and wheel, and wheel and brake blocks. It had long been assumed that locking and sliding the wheels was the most effective way to stop a train. However, testing proved that clamping down with brakeshoes just short of doing so provided the shortest stops. The stopping effect of sliding wheels is less than one-third of the stopping effect of wheels that revolve.

While most railroads had installed air brakes on their passenger-car fleets by 1877, comparatively few were using them on freight trains at that time. To try to entice them to buy, Westinghouse offered a 20% discount to any railroad buying air brakes to equip all of its freight cars, and in 1883, most of the major Western roads, including the Central Pacific, Union Pacific, Santa Fe, and Northern Pacific, took advantage of his offer. Some railroad executives, however, did not like the growing near-monopoly that Westinghouse was enjoying. When a rival company started to make headway on a working system, Westinghouse would buy out the patents if he could.

Also, cost was a factor. By 1885, about 800,000 freight

TRIPLE VALVE



cars were in service around the country, and the cost to convert them all was enormous. The CB&Q, for example, had about 15,000 freight cars. Westinghouse was selling freight air-brake sets for about $40 a car (passenger cars cost up to $100), with installation costing about the same, so the total cost for conversion of the entire fleet was more than $1 million. New cars cost around $400, so adding air brakes was a significant added expense.

Railroads were also uncertain how much the new equipment would cost to maintain, and what financial benefits it would bring. The CB&Q did equip a freight train with air brakes and ran it between Chicago and Denver, and employees had good things to say about it:

"I believe the cost of the brakes would soon be paid for in the reduction in the number of wrecks, with this loss of life and property; the reduction in the number of flat wheels; and in the additional mileage we would get out of our Engines, Cars, and Crews in a given time. Any larger road which adopts this brake will have an advantage over its competition that they will sooner or later be compelled to adopt it." — Yours Truly, William Forsyth M.E. (letter to Godfrey Rhodes, superintendent of motive power, May 31, 1884).

By the late 1800s, the country had adopted a standard gauge of track, and unlike passenger cars, which stayed on their host road, freight cars were now being shipped long distances over several roads without having to transfer the goods from one car to another. Managers were not enthusiastic about spending money to equip all their cars with air brakes, only to see them disappear among competing railroads.

A group of New York-based railroad managers created the Master Car-Builders' Association in the 1860s to facilitate interchange of cars between their lines. By the 1880s, the association included representatives from all major carbuilders and railroads, and formulated recommendations for standardization of equipment. While the group had no formal power, the founders hoped to create a venue where ideas could be exchanged, an agreement could be reached, and its recommendations followed voluntarily.

However, as the group grew into a national organization, it often had difficulty reaching a consensus. In 1884, the CB&Q's superintendent of motive power, Godfrey Rhodes, became the carbuilders' association chairman, and quickly went to work on railroads' air-brake dilemma.

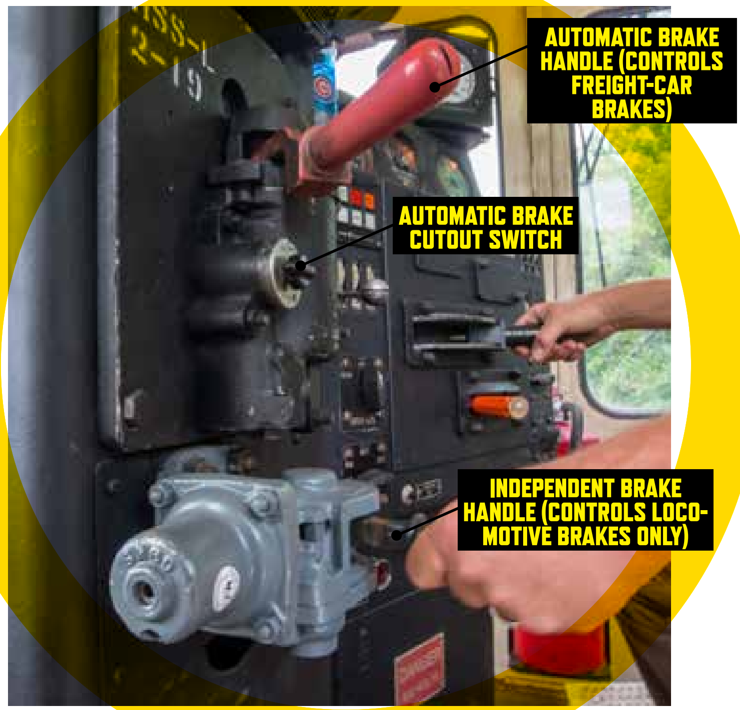
In October 1885, the carbuilders' association arranged for trials with 50-car blocks to be held the following summer on CB&Q at West Burlington, Iowa. Five companies took part in the trials: Rote Brake, American Brake, Widdifield and Button Brake, Eames Vacuum Brake, and Westinghouse Air Brake. The first three were of the direct- or friction-buffer type, and worked by compression. When the engineer applied the locomotive brake, the slack on the cars ran in and the drawbars compressed, exerting pressure on connected devices and levers down to the brakeshoes.

None of the five companies had ever investigated what would happen if their brakes were used on long trains, and during the trials, all brake types experienced large shocks at the rear. The sliding movements of toolboxes inspired the idea of rigging up a "slideometer" to measure the degree of the shocks in the last car. Movements of 12-20 inches on this device were enough to shift loads through the ends of the wooden freight cars.

THE COMPETITION

The American Brake Co. had the best performance in holding the speed uniform during the downhill run, but while things weren't too bad in the dynamometer car (which measured speed and resistance) in the middle of the train, on the rear car, shock after shock was being experienced in rapid succession. Results showed 28 large blows

● **LEFT GAUGE** **Red: main reservoir pressure, White: equalizing reservoir pressure. MIDDLE GAUGE Red: brake-cylinder pressure (locomotive), White: brake-pipe pressure (locomotive and cars). RIGHT GAUGE Air-flow indicator (not on all locomotives).**

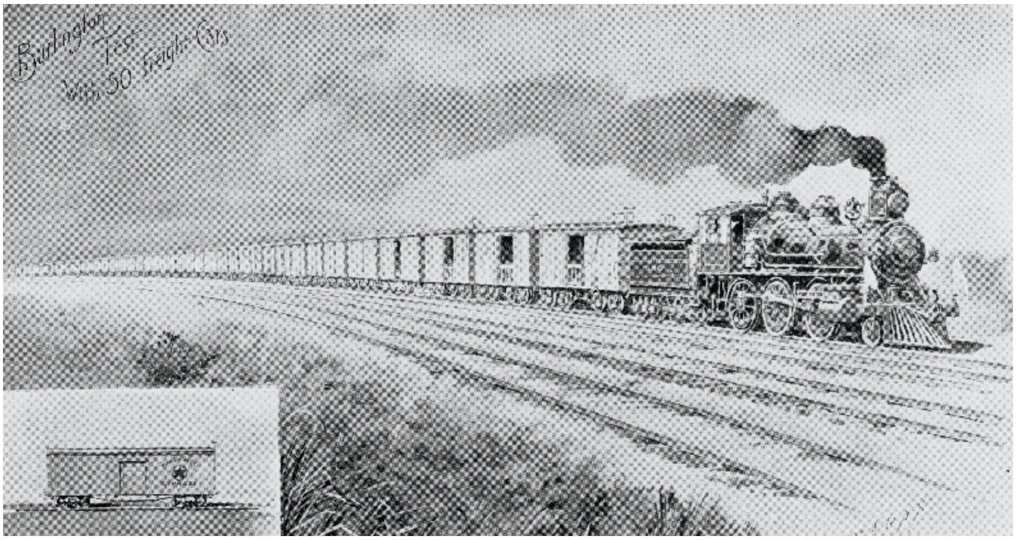


● **Parts of the air-brake system: Air gauges, levers, and switches, aboard Burlington Junction MK1500D No. 9630, along with the engineer work together to stop the train.** Two photos, Steve Smedley

"THE COST OF THE BRAKES WOULD SOON BE PAID FOR IN THE REDUCTION IN THE NUMBER OF WRECKS, WITH THIS LOSS OF LIFE AND PROPERTY; THE REDUCTION IN THE NUMBER OF FLAT WHEELS; AND IN THE ADDITIONAL MILEAGE WE WOULD GET OUT OF OUR ENGINES, CARS, AND CREWS IN A GIVEN TIME." - WILLIAM FORSYTH M.E.

measured in one run of only 11.5 minutes, culminating in a massive 63-inch shock at the end, which threw people at the rear the length of the car and broke the train in two.

An examination of the train after the stop revealed that nine of the rear cars had their ends broken and bulged out by the shifting of the loads. Tests with the buffer-brake systems were halted both for the safety of the observers and so that the cars would not be damaged and rendered unfit for service.



CB&Q hosted an air-brake trial with 50-car blocks in West Burlington, Iowa, in 1886. The inset shows a boxcar outfitted with a "slideometer" to measure shocks experienced in the last car. Eleutherian Mills Historical Library

The train with Westinghouse air brakes had the most severe shocks of all during emergency stops, registering up to 120 inches on the slideometer, and the train would break in two upon an emergency application at any speed greater than 25 mph.

Toward the end of the trials both the Eames and Westinghouse trains were limited to service stops only. During the tests, it was apparent that the amount of slack would have a great influence on increasing the severity of any shock.

To try to reduce this, some scrap steel was inserted into the coupler links of the Westinghouse train to make a snugger fit. This was found to make a decisive improvement. While the Master Car-Builders' Association was content with the performance of the service portion of the air brake, the emergency function was unsatisfactory.

TRY, TRY AGAIN

The results of the 1886 trials were disappointing. The Master Car-Builders' Association called for new trials in May 1887. This time, three new competitors, Hanscom Air Brake, Card Electric Brake, and Carpenter Automatic Electro Air Brake joined Eames and Westinghouse, although the first two dropped out early. Westinghouse had improved his equipment, and came up with something called the quick-action triple valve. For a service application, there was no change from the previous version. However, when an emergency application was made, instead of exhausting air from the brakepipe to the atmosphere, the new valve sent it directly into the brake cylinder, facilitating a quicker application.

The first sharp reduction in air activated the triple valve nearest the engine, and the air that it drew activated the next triple, and so on to the last car, a process called serial venting. Whereas before on a 50-car train the rear brakes started to apply 20 seconds after the ones in front, the new valve applied them in only 6 seconds.

When word reached the company that J. Fairfield Carpenter had entered the 1887 trials, Westinghouse also installed electrically operated vent valves on his test train, connected by wires to a battery in the locomotive. Just three or four of these devices in a 50-car train provided substantial uniformity for emergency applications, whereas the Carpenter system used 50.

The 1886 trials had shown clearly that quick application of the brakes was needed to avoid the shocks in the rear of the trains, and all the competitors remaining had electrical apparatus to apply them. The Carpenter system relied on electricity implicitly, while the Eames and Westinghouse systems used them as auxiliaries; if an electrical connection failed, the vacuum or air system would still operate the brakes.

Unfortunately, there had been no time to test the new Westinghouse valves on a 50-car train before the second trial, and while the train stopped in a shorter distance when operated by air-only, the shocks in the rear car were worse than before. Observers were again thrown the length of the car, with at least one leg broken, and some quite cross officials.

The increased efficiency of each brake overpowered the effect of the serial venting. When activated by electricity, however, all the entrants in the 1887 trials were notable for making much smoother stops. In the end, the committee recommended that the best type of freight brake was one operated by air and actuated by electricity. But could an electrical system be made reliable enough to work in everyday railroad service?

Westinghouse didn't think so. The Carpenter apparatus was ideal when it worked, but a broken wire in the last test caused a brake failure. Westinghouse had actually been granted one of the first patents for electro-pneumatic brakes in 1883, but decided to make improvements to the quick-action triple valve, while activating it by air alone.

The test train was left in Iowa, while he tinkered with the new triple valves in Pittsburgh. By increasing the size of the brake pipe from 1 inch to 1¼ inches (an increase in cross-section of 56%), and using larger ports and more sensitive valves inside the mechanism, he was able to reduce the application time from 6 seconds to less than 3 seconds on the rear of a 50-car train. By fall, he had a working system, and in October, November, and December 1887, Westinghouse sent the train on a tour of the U.S., inviting prominent citizens, railroad officials, the press, members of government, and professors and students in technical schools to attend. Some observers in the rear noted that when the whistle was blown by the engineer at the same time as making an application, the brakes came on before the sound was heard, indicating the air pressure wave had travelled supersonically (not quite, but close). The new brake was able to stop a train travelling at 40 mph in less than 700 feet, on

The air hoses connect between freight cars as part of the air-brake system to slow or stop a train. Steve Smedley a 1% grade, exerted in excess of 7,600 hp worth of stopping power, and dissipating the energy as heat in the brakeshoes and wheels. From 20 mph, the train could be stopped in 176 feet.

So pronounced was the success of this tour that in June 1888, the Master Car-Builders' Association revisited the issue of brakes. The group did not specifically recommend the Westinghouse product (although they did recommend that all brake equipment should couple with the Westinghouse hose coupling), but they set down a list of requirements for brakes that only the quick-action air brake could fulfill.

THE WESTINGHOUSE ENDURANCE

While some larger railroads like CB&Q, Pennsylvania, and NYC equipped nearly all of their freight cars with quick-action brakes, others did not. From 1887-1893, about 180,000 freight cars nationwide had been fitted, a number which nearly matched the number of new cars being constructed. Westinghouse built a factory in Wilmerding, Pa., in 1890 that could produce one new air-brake set per minute, or 250,000 per year (limited only by the foundry's capacity). But by 1893, only about 10% of the freight cars in the country had them.

Railroads were both expanding and transforming themselves during this time, and it took a tremendous amount of capital to do so. As locomotives got bigger, there was a need to replace iron rail with heavier, expensive steel ones. The railroads also bought thousands of new, larger-capacity freight cars. These produced returns on investment, which pleased stockholders, whereas benefits from things like Westinghouse air brakes and Janney couplers were harder to quantify.

Starting in the late 1880s though, forces outside the railroad boardrooms started to have an effect. The public had voiced their outcry earlier for reliable passenger-train brakes, but so far had done less for their installation on freight cars (a wreck which kills 12 people makes headlines, while 12 dead brakemen in separate incidents does not). This started to change, however.

Also, in late spring 1889, the newly formed Brotherhood Of Railroad Brakemen petitioned the federal Interstate Commerce Commission to adopt the air brake and Janney coupler. Most railroads opposed any compulsory legislation, even the ones who had already bought air brakes for their freight-car fleets. But in the 1892 presidential election, it became a campaign issue, and in 1893, the Safety Appliance Act became law, requiring the railroads to install air brakes and automatic couplers per Master Car-Builders' Association standards by 1898. When this wasn't met, Congress did grant a two-year extension, but petitions for a second extension were denied. By 1900, after 30 years of hard work, legislation was in place to put air brakes on the wheels of all the nation's freight cars.

The results were longer trains running at higher speeds, a marked drop in rail freight rates, and greater safety.

It was largely due to George Westinghouse's inventive genius, determination, and perseverance that produced a product that not only worked, but has endured. He once said, "If someday they say of me that in my work I have contributed something to the welfare and happiness of my fellow man, I shall be satisfied."

Amen, Mr. Westinghouse. ■

The author would like to thank Wabtec/GE, Tim Bader, Ray Betler, Rich Bonadio, and Roger Lewis for helping with this story.

SOME OBSERVERS IN THE REAR NOTED THAT WHEN THE WHISTLE WAS BLOWN BY THE ENGINEER AT THE SAME TIME AS MAKING AN APPLICATION, THE BRAKES CAME ON BEFORE THE SOUND WAS HEARD, INDICATING THAT THE AIR PRESSURE WAVE HAD TRAVELLED SUPERSONICALLY (NOT QUITE, BUT CLOSE).