AFD Ep 417 Links and Notes - Westinghouse Air Brakes [Bill/Rachel] - Recording Mar 15, 2022

- [Intro] This week we return with another episode of industrial technology history that focuses on something relatively specific and narrow in application that had significant results for commerce, workplace safety, and more. 150 years ago this month, on March 5, 1872, George Westinghouse, later known as an electric power innovator, patented his triple valve automatic air brake system for railroad equipment. This triple-valve design is known as the Westinghouse Air Brake. It proved to be a critical development in basic railroad safety for passengers and workers and vital to growing the nation's rail capacity, and it was a crucial improvement on his 1869 air brake design. His and other people's earlier air brake designs had caused problems when rapidly stopping trains (i.e. telescoping cars through each other) or had left trains vulnerable to sudden total brake failure across the entire train set. The vital change in design in 1872 was that Westinghouse flipped the notion of using air to apply pressure onto the brakes (known now as "straight" air brakes) and instead used air valves to keep the brakes *inactive*; that way, instead of a system or component failure resulting in the loss of brakes, a failure would actually apply the brakes by quickly bleeding off the air pressure that had been preventing brake application. The triple valve would take in air to a reservoir, apply the brakes when needed, and then finally release the brakes when ready. In most situations, this is effectively an automatic fail-safe. The only times it could result in a runaway situation is when the brakes have to be used maximally in quick succession without sufficient time to restore air pressure in the system after being depleted or vented, but usually a parallel and unaffected emergency air braking system can be deployed with its own air reserves at that point. The Westinghouse Air Brake Company founded in 1869 can still be found today as the Wabtec division of GE, manufacturing locomotives and train cars, and featuring a logo based on a stylization of a mechanical brake valve. (Boise had a plant for 50 years, closing in September of 2019.) https://en.wikipedia.org/wiki/Westinghouse_Air_Brake_Company#The_plain_automatic_air_brake https://en.wikipedia.org/wiki/Wabtec https://en.wikipedia.org/wiki/Railway_air_brake
- Unfortunately, despite the effectiveness of air brake technology, railroads dragged their heels for decades on implementing them widely and it would eventually take federal legislative mandates to make substantial progress on adopting air brakes on train equipment and train sets. So, let's talk on this week's episode about what it meant for safety and why it took so long to develop the technology and then almost as long to use it broadly. Our main source this week will be the 1993 book "The American Railroad Freight Car" by John H. White Jr., one of the foremost experts on rail equipment history in the US, published by Johns Hopkins University Press. The book has a whole section on the historical development of train brakes in the United States (pages 527-546)
- [Rachel] Pp.527-30 – The No-Brakes and Hand-Brakes Era: The early railroads faced some pressure to improve brake safety on passenger trains because horrific mass-casualty accidents were very bad press, but with freight trains (which early on were basically just sets of box cars) they were much more willing to roll the dice because most cargo was either recoverable or replaceable if it went flying every which way in a crash and railroad workers (unlike passengers) were viewed as completely expendable. The job was dangerous and that was viewed as simply to be expected. The private investors financing the railroads were eager to make their money back or earn dividends and with low profits during the various rate wars between railroads, it was easy for executives to treat brake technology improvements as nice-to-haves that were too expensive to adopt. As late as the 1850s, some railroads just refused altogether to pay for brakes of any kind on their freight cars, let alone brakes that were really effective and

reliable like the later ones we'll be talking about. In those situations, with no car brakes, they would just use brakes at the front and rear of the train and hope that was enough. You might think this was only practiced on eastern railroads with very flat tracks, but some companies didn't really care if there were hills and no brakes, as long as it wasn't a mountain. Before the development of air brakes, in the best case scenario, train crews had to literally run along the top of the trains while they were moving and tighten up manual brakes one at a time, gradually slowing the train quite inefficiently and inconsistently. Brakemen were employed at varying ratios depending on the railroad, but it would have been fairly common to have one brakeman responsible for applying the brakes to five, eight, or even 15 cars. They ideally didn't fully apply each brake because that would cause friction damage, skidding, telescoping, or other dangerous problems; so, they would instead partially apply the hand-brake and run to the next one, slowing the train enough for the locomotive to stop it in place. But in practice, they tended to do a rougher job of applying the brakes as quickly as they could humanly manage, and (as we'll circle back to in a moment) they often didn't have enough brakemen on board to actually apply all the brakes before the train had stopped anyway. Freight trains also had the complicating factor of uneven cargo distribution making different cars heavier or lighter throughout a train set, unlike the more consistent passenger train weight distributions. (This is noted in the 1900 training textbook Bill skimmed on the topic.) Anyway, after running along setting the brakes while in motion, the brakemen would then repeat the process in reverse on a stationary train to get the brakes released – or they would further tighten the brakes and chock the wheels to keep the train from running away while parked. The manual brakes had a range of operational systems from rooftop foot pedals to long arm levers (like a stagecoach brake) to hand-crank wheels, popularized by 1850. If the train (or part of it) had come across from a different railroad, it might be a total jumble of whether or not the cars even had manual brakes to set, let alone the same type. These brakes could be quite primitive in the early years, including wooden brake shoes that would burn away from the friction of being applied. Cast iron brakes didn't come into default status until 1860 or so. The brakes on the cars that did have brakes often tended to only be connected to one set of wheels, or even just half of one set of wheels, meaning very little braking power on the entire car and even more damage to the brakes when applied. Wheels also were originally spoked, unlike today's much more solid wheels on rail equipment. It's important to remember in the early days of railroads that a lot of the equipment was much lighter and smaller across the board and the trains themselves tended to be much lighter, shorter, and slower than even trains of the late 19th century, to say nothing of the super-long, super-heavy freight trains of today. For example, 30 miles per hour for a mid-19th century train would have been fairly fast, and manual brakes could be applied at that speed over a stopping distance of several hundred to a thousand-plus feet to bring it to a successful halt, assuming nothing went wrong and depending on the length and weight of the train, as well as the number of brakemen employed. So again, from the executives' point of view, they felt for quite some time they could simply get away with running short light freight trains on relatively flat routes with very strong-armed brakemen and a few brakes here and there and not need to worry too much about runaway trains, with the occasional catastrophic failure as the cost of doing business. The job of the mid-19th century brakeman was awful because they were generally understaffed, underpaid, working 16-hour shifts, and assigned to run along the top of trains moving 10, 20, or 30 miles per hour in all weather and conditions, frequently slipping or even blowing off to their deaths. The men just kind of hung out on top of the trains a lot of the time when not actively applying or releasing brakes, in case they were suddenly needed, and there was no shelter, not only from weather but also the choking smoke of the locomotive ahead. The railroads would hang little overhead physical warnings, kind of like beaded curtains or dangling ropes, called "tell-tales" to brush against the brakemen if they were about to cross under a bridge or enter a tunnel so they could hit the roof deck and not get obliterated. Brakemen crews would not be reduced to a small, mostly indoor team until after Westinghouse air brakes became widespread, and even then, they still sometimes had to apply manual brakes, especially in train yards. And you have to admit that from a labor perspective it was probably for the best to eliminate as much as possible the horrific rooftop manual brakeman job through that mechanization and automation, much in the same way that it's good that late 19th century glassblowing mechanization and automation ended horrid child labor in that industry, as we discussed in episode 391 in August 2021.

- [Bill] PP.530-33; 539-41; 545 – The need for change: By the 1870s, Westinghouse had developed not only air brakes but safe air brakes, but it was by no means an instantaneous process to get them adopted. The same corporate pressures against adopting them were still around. But as we've alluded to, freight trains were getting heavier and longer than their pre-Civil War predecessors, and this was starting to create countervailing pressures even for the most hardened executive who didn't care about safety. A manually-braked 60-car train in the late 1870s, substantially longer than many 1850s freight trains (often a half-dozen, dozen, or 30 cars) and with now much heavier equipment for each car, might take about a minute and a half to stop, even when traveling just 10 miles per hour. And faster speeds, when track conditions even allowed it if the railroad was bothering to invest in track condition maintenance, were often unsafe to attempt under manual braking. That kind of operational slowness and routine uneven braking damage to the equipment, as well as the growing risk of heavy parked cars rolling away or catastrophically telescoping, was costly enough to force some consideration of full-train automatic air braking systems and all-wheel braking. Passenger trains adopted them first because of the public pressure for passenger safety, but freight operations still lagged – not least because the ratio of freight cars to passenger cars on big railroads could be something like 50,000 vs a few hundred (p.539). Upgrading a whole company's fleet of equipment on a major railroad would have run well into the millions in 1870s dollars, to say nothing of hundreds of thousands of dollars in annual maintenance costs on brake systems that now featured about 150 parts. The Westinghouse patent was for the brake technology, but not how exactly to implement it on train cars, which were made by many different companies according to their own and their client's preferences and service needs, so it was also not even a matter of plugging in a uniform new Westinghouse brake system to every railcar in America, and other companies came up with specific designs for deploying the technology on existing or new equipment. The steam locomotive crews (i.e. the engineers and firemen) were also not thrilled about having to deal with operating and tending to the new air pump systems being grafted onto existing locomotives, when previously braking had mostly been up to somebody else in the crew to deal with. They did often try to negotiate for pay bumps for the new responsibility, made possible by the reduction in brakemen per train. It took over a decade for Westinghouse to secure a significant railroad's conversion to triple-valve air brakes for its freight car fleet, not just its passenger cars, and he had to offer a 20% cost discount to get it: Over the course of 1883 to 1884, the Central Pacific outfitted more than 6,600 freight cars and – satisfied with the results – had completed around 20,000 upgrades in just a couple more years. Unsurprisingly, the Central Pacific was a mountainous railroad with a much more pressing need for serious and fail-safe braking systems. Several other western railroads operating across or through the Rocky Mountains quickly followed suit. Other railroads began upgrading their locomotives by the thousands as a minimum interim step, but still hesitated on the capital costs of upgrading the freight car fleets. However, the need to increase safe operational traffic speeds on dense eastern lines just to allow more freight trains to run per day even on flat lines continued to build pressure on the railroads to bite the bullet and install fail-safe Westinghouse brakes on freight car fleets. 10 mile per hour runs weren't going to cut it anymore on main lines and the triple-valve air brakes could get trains to run safely at 25. The Pennsylvania Railroad decided its toe in the water on these equipment conversions would be installing them on cattle cars, which were a much worse scenario cargo for abrupt braking or runaway train accidents than say a coal train or grain train. The railroads also began making the calculation that larger and heavier cars, while creating some challenges for braking, also hauled more cargo and thus trains could either be made up of fewer cars or kept at the same number but more profitable per unit, but either way it would be more cost-effective to upgrade braking systems than it had been a decade prior. In 1886 and 1887, Westinghouse made some significant improvements upon his 1872 design to try to deal with braking in longer train sets so that it wasn't so herky-jerky from the system firing one car at a time in sequence. By this time as well other companies were releasing variants of fail-safe air brakes incorporating additional features like electric control and so on.

    - [Rachel] PP.539-on & https://en.wikipedia.org/wiki/Railway_brake#Air_versus_vacuum_brakes – As mentioned previously, Westinghouse's triple-valve brakes relied on generating and maintaining high air pressure relative to atmospheric air pressure, releasing air pressure to engage the brakes. To do this, train cars needed to be outfitted with air compressors. Since train cars weren't standardized, one challenge in getting railroads to adopt this system was the difficulty in retrofitting the cars with these parts. Another challenge was the fact that Westinghouse's design was complex and made up of many parts, parts which could fail. One of the biggest competitors of the triple-valve brakes was the Eames vacuum brake system. The vacuum system worked off of low pressure relative to atmospheric air pressure, which could be achieved with a steam-powered ejector with no moving parts. A vacuum is maintained in a line that runs down the length of the car. When air is let into the line, it puts force on brake shoes which act on the treads of the wheels. Britain adopted vacuum brakes, largely shunning air brakes.
    - Air brakes had two major advantages. Air brakes can be made much more effective than vacuum brakes for a given size of brake cylinder.Therefore, an air brake system can use a much smaller brake cylinder than a vacuum system to generate the same braking force. Also, this advantage of air brakes increases at high altitude because of the greater pressure difference, making them the better choice for those lines that operated in the mountains.
- [Bill] P.546 – Forcing change: Despite growing adoption of the technology, it was still not being implemented fast enough. By 1888, Westinghouse was selling thousands upon thousands of his new and improved 1887 design, refining his 1872 triple-valve patent, and a demonstration train showed it off around the country to prove it to railroad executives. Nearly 85,000 freight cars had been outfitted with air brakes by 1889, but there were over a million freight cars in service. The financial pressures discouraging a total adoption across the country were still there. A couple years later, a fifth of all fleets had been upgraded, but this was still taking too long, and air brakes remained very heavily concentrated in the Mountain West. Some companies were being old-fashioned or just cheapskates but others were genuinely really struggling with capital costs on their systems in general after years or decades of financial mismanagement and excessive returns to investors. Mixed trains with some air-braked cars and some hand-braked cars began creating a great deal of operational chaos. Congress finally stepped in with the Safety Appliance Act of 1893 to pass a federal mandate requiring the standardized

adoption of certain railroad safety technologies, among them fail-safe air brakes, which hastened the process enough that they were in place across the country's freight fleets by 1900. This legislation (pp.517-518) was a Progressive Era reform spearheaded by an Iowa activist/preacher who had happened to witness a brakeman lose his last few fingers in a mishap with a coupler, the other big technology that railroads in the 1880s were very slow to upgrade even after the technology was proven. The Safety Appliance Act of 1893 was also a crucial test of the powers of the federal government, instead of the state governments alone, to legislate on and regulate the operations of railroads after the passage of the Interstate Commerce Act of 1887. As we have discussed in past episodes, the early prevailing model of railroads like many other corporations had been that they were chartered by a state government and existed only within the bounds of that state. But the 1870s rise of interstate corporate combinations like Standard Oil and the personal-union corporate conglomerate model of the New York Central and its partner railroads under the personal control of Cornelius Vanderbilt had created a role for significant federal intervention in the industry beyond just land-granting transcontinental route constructions. It was signed into law as one of the final lame-duck actions of outgoing President Benjamin Harrison. The 1893 law had set a 5 year time horizon for adopting fail-safe air brakes and safety couplers, but an extension was granted twice with a much firmer final mandate that it would be completely illegal to operate non-compliant rail cars across state lines after August 1, 1900.

- PP.533-38 – The momentum brakes scam: Air brakes were quite an expensive add-on feature (around $50 per freight car in money of the day, plus $42 to install, plus $500 in locomotive modifications [p.539]), and there was kind of a boom in the late 19th century version of "tech disruptors" who were convinced they could invent a cheaper automatic brake based on the kinetic power of the train's own momentum. They were promising somehow to deliver a whole new (yet to be invented!) technology across an entire industry for a mere $8 million instead of the projected $40 million in industry-wide air brake installation cost projections (p.539). Even Westinghouse's own brother, an executive at Westinghouse Air Brake Company, was an evangelist for non-existent momentum brakes for at least a couple decades, sort of like today's tech futurists obsessed with self-driving vehicle technology or hyperloop nonsense that is supposedly always just around the corner and totally feasible and real-world conditions. Momentum brakes were the white whale of the railroad equipment inventor field from almost the beginning of US railroads, in the 1830s. Prototypes sometimes worked in test conditions, but that was about it. The media tended to print wild claims of success uncritically, not totally unlike today. In 1886, a trade association group representing and creating industry standards for rail car manufacturers, conducted very serious tests of a number of different designs of purportedly functional momentum brake systems and exposed them all as defective if not outright frauds. 1887 follow-up tests supposedly meant to show improvements and lessons learned found the same result. Even the emergence of electricity technologies and experiments with electromagnetism could not save the doomed momentum brake concept from the realization that the humble Westinghouse triple-valve air brakes of 1872 and 1887 were the only functional game in town for modern train braking and should have been widely adopted and refined all along instead of wasting time waiting for something better.

Additional points:

- Despite the inherent safety advantages of Westinghouse air brakes, there have still been some braking accidents involving trains using triple-valve air brakes, but these are sometimes due to crew errors during setup and failures to test and check equipment properly before getting under way. You can hear more about an accident where the equipment itself bumped against something and sealed itself off from functioning in the episode of Well There's Your Problem on the Pennsylvania Railroad's little non-fatal woopsy-daisy in 1953 in Washington DC that put a train from Boston through the floor inside Union Station. Starting at the end of the 1960s, trains were eventually equipped with an End-of-Train-Device or Flashing Rear-End Device (aka FRED) that both act as a tail light for the back of a train in the dark and as an automated monitor (linked to the locomotive crew) to ensure that air brakes are properly connected across the entire length of the train set and not interrupted somewhere in the middle as in the 1953 accident. As with the effect of triple-valve air brake systems reducing the need for crew to run along the tops of trains operating hand brakes, these end-of-train devices (and trackside automated defect detectors) by the 1980s had the unfortunate effect of putting a lot of unionized train crew members out of work by eliminating the need for a caboose on the back end of trains carrying personnel to do work on the back of the trains.

- [Rachel] Air brakes are used on large vehicles such as buses, tractor-trailers, semis, etc. for their superior braking power vs. hydraulic brakes that are used on personal vehicles. Hydraulic brakes would be easily overpowered by the momentum of heavy vehicles. Air brakes have other advantages: The supply of air is unlimited, so the brake system can never run out of its operating fluid, as hydraulic brakes can. Minor leaks do not result in brake failures; air brakes are effective even with considerable leakage, so an air-brake system can be designed with sufficient "fail-safe" capacity to stop the vehicle safely even when leaking. Air line couplings are easier to attach and detach than hydraulic lines; the risk of air getting into hydraulic fluid is eliminated, as is the need to bleed brakes when they are serviced. Air-brake circuits on trailers can be easily attached and removed. The main disadvantages of air brakes are the expense, the specialized knowledge of how to operate air brakes, and the noise associated with them. Some towns and cities ban the operation of air brakes in heavily-populated areas because of the noise pollution of their use. They can be as loud as 115-120 db, able to cause immediate damage to hearing.