Steam Locomotive Booster Engines on Columbus Railroads –

The Small Device with a Big Kick

by James M. Cavanaugh 2026

Part I

Although Columbus was not on the East Coast to Chicago main lines of the largest railroads during the steam era, and was not among the largest origins or destinations for rail freight, coal and other mineral traffic, many of the most advanced and powerful locomotives of the companies serving Columbus were assigned to the City's roundhouses. The reasons for this as to freight haulage were twofold – Columbus was the key interchange point for a very large share of all U.S. coal movements to Chicago, Detroit and Great Lakes ports, and the long uphill grades north and west from Columbus required the best power the companies could afford to move this tonnage. On the passenger side, the lines through Columbus, although not hosting the premiere national trains of the period, still demanded use of the railroads' top performing locomotives.

At the end of World War I and throughout the 1920s industrial boom that followed, competitive pressure on U.S. railroads to move ever-increasing freight tonnages at faster speeds soared. Volumes of the most challenging high-density cargoes, especially coal, had nearly doubled between the pre-war years and 1918. U.S. coal traffic tons had increased from 212 million in 1900 to 417 million in 1910 and 579 million by 1918. About 15 percent of this surging load moved through Columbus. At the same time, steam locomotives began to reach the railroads' loading gauge limits as to maximum length, height, width and axle weight. The companies could not make engines' boilers, fireboxes or cylinders bigger. Technical innovations of this era such as superheaters, feedwater heaters, improved firebox designs and mechanical stokers could only push locomotives' power so far.

The principal limiting factor for road engines was not horsepower. It was inadequate traction and wheel slippage when starting or working up long uphill grades. This issue arose from lack of enough weight on the driven axles to provide sufficient adhesion between the wheel rim and rail to apply the engine's available power without slipping, especially when the weather was wet. Slow-moving yard and transfer engines could have wheel arrangements with all or nearly all weight on the drivers. But to hold the track at higher speeds, a road engine needed a leading axle or truck to guide the machine around curves. To provide sustained power, the big new engines of this era needed a large fire grate, but this generally required a trailing truck to support the overhanging firebox weight on the frame. These unpowered axles bore 20-35 percent of the locomotive's weight. Starting up or running at slow speed, and sometimes even at high speed, the engine had available steam power to spare, if it could only be converted to pulling force at the drawbar.

Steam passenger engines experienced a slightly different set of wheel slip problems. The most popular models including 4-4-2 Atlantics, 4-6-2 Pacifics and 4-6-4 Hudsons, and advanced designs such as the Pennsylvania Railroad's duplex T1 4-4-4-4s, were designed with a smaller number of driving axles with larger diameter wheels for high speed running. While their boilers generated plenty of steam and high horsepower, these engines often slipped on start-up or during slower-speed hill climbing on certain routes. Some like the T1s also experienced wheel slip at high speeds.

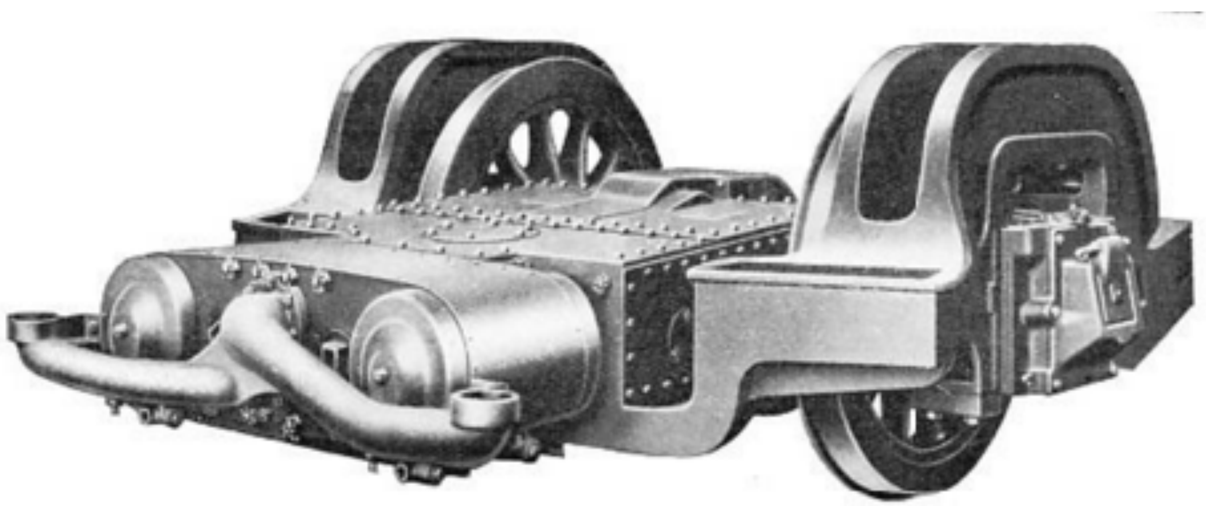
The solution to enable an engine to get more of its energy to the drawbar than its drivers could apply at the point of contact with the rails was a means of delivering steam power to additional axles. European designers had already started experimenting with small steam booster engine designs on additional axles in the 1890s. In the United States, the initial solution was a booster engine powering the locomotive's trailing truck rear axle or the tender axles to provide additional tractive effort.

Invented by NYC Assistant Vice President Robert Ingersoll in 1918, the standard form of steam locomotive booster in the U.S. was a two-cylinder auxiliary engine delivering additional power to the trailing truck rear axle. Commercial versions of this innovation were soon offered by the Franklin Railway Supply Company of New York City. Franklin later boasted in its advertising that it had sold over 4,000 of these machines. About one-third of the bigger road engines of the major U.S. Eastern railroads eventually had them, including several heavy designs of the New York Central, Pennsylvania, Chesapeake & Ohio and Norfolk & Western stabled in Columbus.

The Franklin booster model C-1 first delivered in 1919 had two double-acting steam cylinders each with a diameter of ten inches and a stroke length of 12 inches, driving a shaft with cranks mounted at 90 degrees apart. These boosters were typically not reversible, and could be operated only in the forward direction. The booster was used at relatively low speeds to provide maximum tractive effort, so there was no need for adjustable valve gear to accommodate steam cut-off. The Franklin design delivered rotary power from the crankshaft to a driven axle of the locomotive's trailing truck via an idler gear engaged by a compressed air piston controlled by the engineer. The C-1 crankshaft to driven axle gear ratio was 36:14, i.e., slightly more than 2.5 turns of the crank for each one revolution of the wheels. The C-1 provided 11,000 –12,000 lbs. of tractive effort, could be activated at speeds up to 15 mph, and could run up to a maximum speed of 25 mph. The idler gear could be set to disengage automatically if the engineer backed down the reversing gear slightly for steam cut-off, or on command from the engineer's controls.

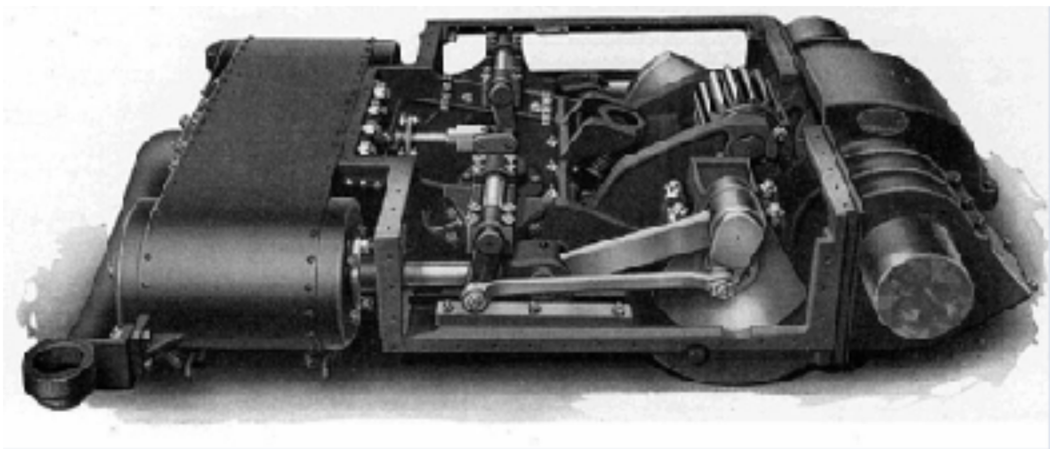
Franklin offered four models, including the C-1 described above, the C-2 which had a slightly lower gear ratio, and the E and E-1, which had slightly larger diameter pistons and lower gear ratios at 2.25 and 2.0, and which could be activated at speeds up to 22 mph and operated at speeds up to 35 mph. Depending on the steam pressure available, these devices could deliver an additional 300-500 horsepower, although the relevant capacity for the railroad was the tractive effort. Bigger Franklin boosters could provide over 15,000 lbs.

Franklin also offered two powered axle booster models which could be used as the locomotive trailing truck or as one of the tender trucks. Two powered-axle boosters beneath the firebox were rare, mainly because the space available there was often inadequate to accommodate the necessary apparatus. Bethlehem Steel Co. offered an "Auxiliary Engine" two-axle booster with the axles coupled by a set of external cranking rods, suitable for operation as tender trucks. That arrangement, which does not appear to have ever been used on production model Columbus-based locomotives, usually had the powered truck as the tender's rear wheels under the tank, with the booster steam being exhausted through a vertical pipe at the back of the tender. The under-tender boosters appear to have been far less common than the Franklin C and E models on the locomotive's trailing trucks, but were used on a few big railroads' engines, including Boston & Maine's 2-10-2s. These were more widely deployed on 2-8-0 Consolidations, which of course, had no trailing truck but could utilize their surplus starting steam for extra tractive effort. Some railroads tried two Bethlehem powered trucks under the tender. The Norfolk & Western evaluated use of double powered trucks on the tender of an articulated "Y" class 2-8-8-2, but did not adopt this arrangement for wider use.



Franklin C-1 single axle trailing truck booster, 1942 advertisement.

Franklin exported some of its single-axle and two-axle coupled boosters, with buyers including the London North East Railway (LNER) in England, where they were used on several models of express engines. LNER also fitted its S-1 switching engines with reversible booster units. These were problematic and the reversing linkages were later removed. Franklin sold other units to Australia for the Victoria Railways and South Australian Railways, and to New Zealand. Some 55 of the Canadian Pacific Railway's late-period steam engines were fitted with boosters, including 17 4-6-4s and 36 2-10-4 Selkirks.



Franklin single-axle booster unit with cover removed. Two steam cylinders powered the crank axle, and a movable idler gear moved into and out of the engaged position by a compressed air mechanism controlled by the engineer was engaged the booster engine with the bogie axle at the right.

A few railroads, especially the New York Central and its affiliates, used boosters on a fair number of freight and passenger engine classes. The Central's famed J-class 4-6-4 Hudsons had horsepower to spare but would often slip starting up and maintaining speed on the line's heavyweight trains such as the 18-car Commodore Vanderbilt. Others, such as the Pennsylvania and Chesapeake & Ohio, specified Franklin boosters for limited classes of their new "super-power" models introduced in the 1920s and 1930s, but did not fit them to older classes used over much of their systems' branch lines. Still others such as the Baltimore & Ohio and Norfolk & Western do not appear to have done much with boosters after some initial experimentation. The majority of bigger railroads did not invest in boosters, choosing instead to build progressively larger engines which could throw enormous driven axle tractive effort at their controlling grades without resorting to boosters.

On locomotives with a two-axle trailing truck, the rear axle powered by the booster was fitted with larger wheels than the forward unpowered axle. For example, on the PRR J1s, the booster-powered rear axle wheels were 44 inches in diameter, while the forward axle wheels were 36 inches, the same as the tender's wheels. This larger rear axle wheel diameter is visible on a number of the classes of locomotives with boosters, especially the NYC's Hudsons. The larger powered wheel got better traction on the rails, and the axle rotation speed required was reduced, easing the wear on the bearings and gear arrangement of the booster.

Columbus-Based Locomotives with Boosters

New York Central

The NYC as the pioneering developer of the concept was the first line to deploy boosters, fitting them on its 2-8-2 H-class Mikados and 4-8-2 L-class Mohawks (as this wheel arrangement was called on the Central in lieu of the more common term "Mountain"). A fair number of the NYC's older eastern lines had tighter loading gauges, making the use of ten-coupled or articulated engines impractical. Also, the NYC's main line from the Eastern Seaboard to the Midwest followed its famed "Water Level Route" up the Hudson and Mohawk Valleys and across Western New York State, facing only moderate grades. Accordingly, the NYC stuck with eight-coupled engines, beefing them up with the latest technologies for power and improved steaming ability.

NYC H-10 Mikado No. 2156, pre-1940 photo, fitted with a Franklin booster on the rear axle. The flexible steam coupling for the booster is visible just below the "5" on the cab. https://www.railarchive.net/nyccollection/nyc2156_grabill.htm

The Central's H-10 Mikados, delivered from 1922 onward, were the main workhorses of the company's Columbus lines. These were especially high-performing brawny engines with all the latest innovative steam technologies, providing 66,640 lbs. of tractive effort on the drivers, plus an additional 10,700 lbs. with their boosters on the trailing truck axle. NYC's L-2 Mohawks built in 1925-30 at Schenectady, also deployed on the Big Four line in Columbus, offered 60,000 lbs. of tractive effort from the drivers and 12,700 lbs. from the booster. The line's L-3 Mohawks delivered in 1940-3 from Schenectady and Lima were dual-service designs, used mostly on passenger trains and manifest freight. The L-3s provided 60,100 lbs. on the drivers and 13,900 lbs. from their boosters. The NYC removed freight engine boosters in 1948, due to high maintenance costs and collective bargaining agreements which paid higher wages to engine crews based on locomotive tractive effort ratings, whether or not the booster was in use.

The NYC's signature passenger engines for elite service trains over its entire system, including the Big Four line through Columbus, were its J-class 4-6-4 Hudsons. These had Franklin boosters on their rear axles, which notably had larger wheel diameters than the forward trailing truck axle. Delivered from 1927 onward by ALCO Schenectady, the Hudsons provided 42,300 lbs. of tractive effort on the drivers and a further 10.900 lbs. from the booster.

The Central's main power for other passenger trains, including those on the Toledo & Ohio Central branches and some on the Big Four, were its K-class 4-6-2 Pacifics, delivered in 1912-27 by Baldwin, Brooks and Schenectady. The K-5s offered 37,650 lbs. on the drivers and the booster provided an additional 9,700 lbs.

The NYC's ultimate steam engines, the storied Niagara class 4-8-4s built by ALCO in 1945, were also used in Columbus on crack Big Four trains such as the Cincinnati Mercury. However, these 6,000-horsepower giants did not have boosters.

Pennsylvania Railroad

The PRR was the most prolific user of multiple engine designs, stabling no fewer than 12 different wheel arrangements at its two roundhouses in Columbus to serve its five lines entering the City. But only one, the J1 2-10-4 Texas types which began to appear in Ohio in 1943, featured boosters. These were Franklin models providing 15,000 lbs. of tractive effort in addition to the J1's main drivers' 93,750 lbs. The PRR's 125 J1s were the much-admired "War Babies" built in 1942-44 from C&O plans. They were used on the Sandusky Branch, hauling 125-car 10,000 ton coal drags from Grogan or Pennor Yards up to the Sandusky Coal Docks, double heading as far as Lewis Center, or sprinting west on the Panhandle Bradford Line toward Logansport and Chicago and to the east between Dennison and Columbus. Interestingly, the 12 much-photographed 2-10-4s the PRR leased in from the Santa Fe Railroad during a 1956 coal traffic overload did not have boosters.

Note from comparing photos of the PRR J1s and the Santa Fe engines that the booster-mounted trailing trucks of the J1s have a larger rear wheel, characteristic of the booster arrangement, while the wheels both axles of the rear trucks on the Santa Fe engines are the same size. The telltale signs of boosters on engines also include the steam and exhaust piping around the firebox, and on two-axle rear trucks, the slightly higher bearing box on the rear axle to accommodate the larger driven wheel.

None of the PRR passenger engines assigned to Columbus trains featured boosters. However, observers have commented that PRR's Raymond Loewy-designed shark nose high-performance duplex-drive 4-4-4-4 T1s, which were notorious for wheel slip both on starting and at speed, certainly could have used boosters. Reportedly, when the T1s were being introduced in the early 1940s, one unit was fitted with a Franklin booster on the rear truck, but the results were unsatisfactory and the idea was scrapped. The last class of steam engines ordered by the PRR while the road's dieselization was already underway, the T1s' problems were numerous, including difficulties with its poppet valves and throttle control and various maintenance issues. These exotic late-steam era models were withdrawn by 1950.

PRR J1 No. 6474. https://www.rrpicturearchives.net/locoPicture.aspx?id=226178

Chesapeake & Ohio

The C&O did not use boosters widely on its extensive system, but at least four classes of engines used in Columbus had them. The most famous these were the C&O's iconic T-1 2-10-4 Texas types introduced in 1930 and operated until the end of the steam era in 1952-3, used for lugging 135-car coal drags up from Russell, Kentucky through

Parsons Yard and to Toledo and the Lake Erie coal docks. These were fitted with Franklin boosters providing 15,275 lbs. of added tractive effort on top of the engines' 93,350 lbs. available from the drivers. The Lima-built T-1s and their "War Baby" cousins on the PRR built from the same plans were by some measures, the largest two-cylinder locomotives ever built.

Two other classes of C&O freight engines working in Columbus also had boosters: C&O's 2-8-2 K-2 Mikados' boosters provided 11,250 lbs, of tractive effort, and its 2-8-4 Kanawhas had 14,400 lbs. boosters assisting their 69,350 lbs. available from the drivers.

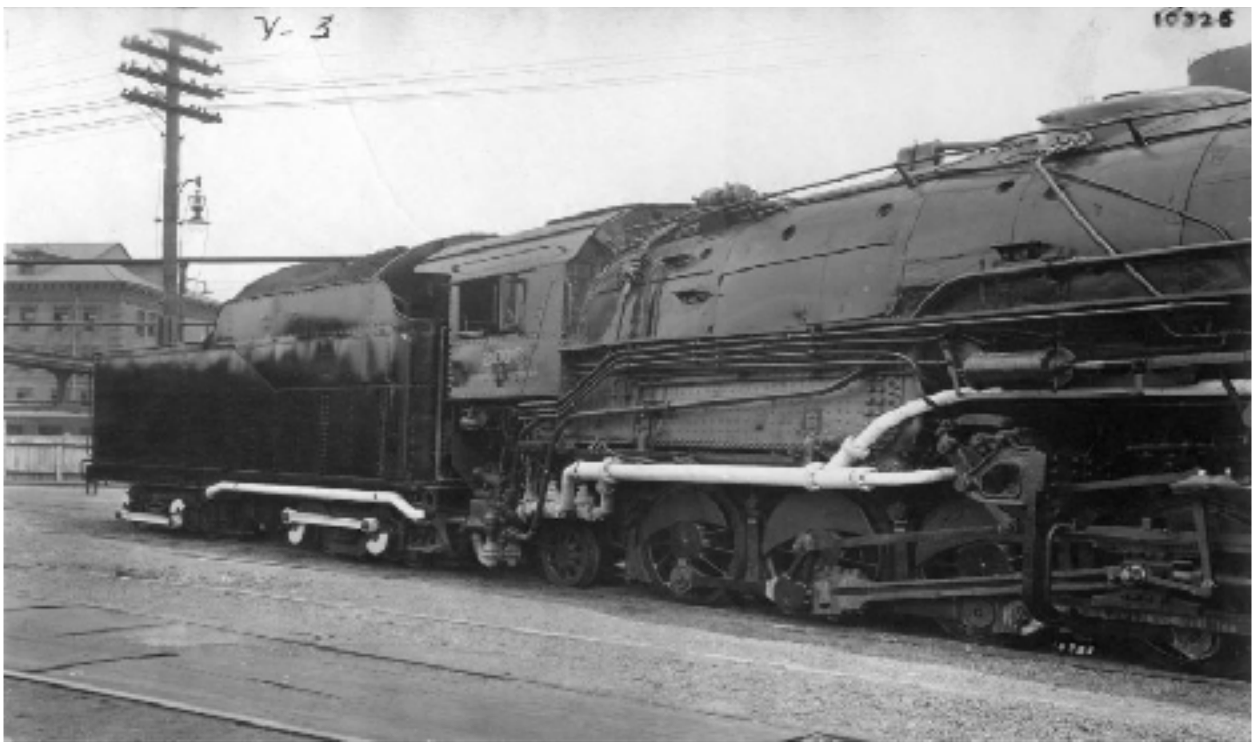
C&O's 4-8-4 J-3 Greenbrier class passenger engines had several booster models offering 12,400 or 14,355 lbs. of tractive effort to supplement their 66,350 lbs. provided by the drivers.

Franklin trailing truck booster unit fitted to C&O locomotive No. 2705, a 2-8-4 Kanawha-class 2-8-4 delivered by Alco's Schenectady Works in 1943.

Norfolk & Western

The N&W, whose line terminated at Columbus until its 1964 acquisition of the PRR's Sandusky Branch, was nevertheless the biggest coal hauler into Columbus from the

1950s on, due to its main line routes through the Pocahontas and Thacker coalfields in West Virginia and Virginia. With its Roanoke Shops designers and engineers always focused on getting every ounce of performance from its heavy haulage equipment, the N&W tried boosters out when first introduced. These included two-axle boosters with exterior cranks and connecting rods on both trucks under the tenders of 2-8-8-2 “Y” class articulated engines. This would have possibly contributed another 20,000 lbs. of tractive effort to this monstrous engine’s 166,000 lb. provided by its eight driven axles when operated in the “simplex” mode with high pressure steam delivered to all four cylinders. Apparently the results were not sufficiently impressive compared with the massive tractive effort ratings of the drivers on line’s newest and last lines of big articulated engines.



N&W No. 2006, a Class “Y” 2-8-8-2 with a tender with booster engines on both trucks. https://www.modelrailroading.nl/collection/Y3/images/ns0965.jpg

Baltimore & Ohio

The B&O’s Midland line south from Columbus to Cincinnati was not heavily built and could only accommodate the company’s Q-3 and Q-4 2-8-2 Mikados, which did not have boosters. The B&O also used these Mikados for freight haulage over the jointly-owned B&O-PRR C&N Division between Columbus and Newark, which was upgraded to the heaviest PRR main line standards. The B&O’s lines radiating north, east and south of Newark were generally laid with 100 lb. rail and could only handle the line's smaller engines.

B&O used P-6a and P-7 4-6-2 Pacifics for its relatively few passenger trains through Columbus. These did not feature boosters.

Part II

Technical Issues and Other Interesting Background About Boosters

Tractive Effort

Generally a locomotive's potential tractive effort, expressed in "pound/ft." but usually stated just as "lbs.," or sometimes as "lbf," is measured separately for starting drawbar pull, maximum pull or continuous pull. Starting drawbar pull for each cylinder connected to the drivers on a steam locomotive is calculated by the following formula:

t = (c x P x d2 x s) / D, where:

• t is tractive effort

• c is a constant representing losses in pressure and friction; normally an Association of American Railroads figure of 0.85 is used

• P is the boiler pressure in psi

• d is the piston diameter (bore) in inches

• s is the piston stroke in inches

• D is the driving wheel diameter in inches

Alternatively, calculation of booster tractive effort per piston is determined with the following formula:

t=cd2sprw,

*w*here:

- *t* is tractive effort in pound-force
- *c* is the coefficient representing mean effective pressure, normally set to 0.80
- *d* is the piston diameter in inches (bore)
- *s* is the piston stroke in inches

- *p* is the steam working pressure in pounds per square inch
- *r* is the booster gear ratio
- *w* is the diameter of the trailing wheels to which the booster is geared in inches

The reasons for the differences, such as using an AAR coefficient 0.85 for the drivers and 0.80 for the booster, or multiplication by the wheel diameter instead of dividing by that figure, are not apparent, but are discussed in AAR engineering literature. The differences due to the booster having a geared mechanism seem clear.

Shortly after introduction of the Franklin boosters, the leading technical publication in the industry, Railway Mechanical Engineering, published comprehensive engineering test results for the device in its October 1922 edition. In tests run at Poole Engineering & Machine Co.'s Baltimore shops, the Franklin C-1 demonstrated 316 horsepower at 200 psi, and a capability of adding 11,000 lbs. of starting tractive effort. This article also provides some good photo images of the booster mechanism, including a top view with the housing cover removed. https://archive.org/details/sim_railway-locomotives-and-cars_1922-10_96_10/page/562/mode/2up

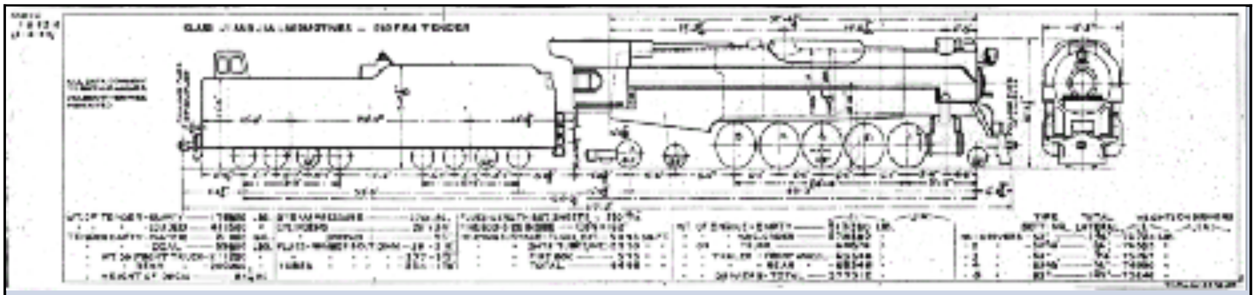
Booster Problems and Solutions:

Mounted on the trailing truck of the locomotive, the most popular Franklin single-axle booster unit had to be placed beneath the firebox and ash pan, where its mechanism was exposed to extensive heat and grit. Any heavy overhaul required the removal of the bogie from the locomotive.

Two-axle booster units mounted as the leading or trailing truck under the tender required long piping runs from the boiler dome, compromising thermal efficiency. The under-tender units also lost tractive efficiency as the tender's load of coal and water was consumed, reducing the weight upon the driven axles. The axle-connecting side rods on two-axle booster units also reportedly were difficult to balance adequately with crank counterweights, resulting in rougher running at higher speeds.

Both the high-pressure steam piping from the boiler dome to the valve chambers and exhaust stem piping from the booster to the smokebox at the front of the locomotive had to be flexible, because the trailing truck was mounted on a pivot and moved from side-to-side on curved track. Flexible steam couplings were common equipment on articulated locomotives of the era, but tended to leak and required frequent attention. Use of superheated steam for boosters did not materially improve performance, and in any case, it would have been difficult to deliver it back to the boosters.

The gear mechanism of the booster had to be engaged at very low speeds, generally 10-15 mph for Franklin C units. It also had to be disengaged at a relatively low maximum speed, generally not above 25 mph.



General arrangements diagram of the PRR J1 locomotive design. Note the booster shown as extending from the rear trailing truck axle. For a full-size version of this drawing see: http://prr.railfan.net/diagrams/PRRdiagrams.html?diag=j1_j1a.gif&sel=ste&sz=sm&fr

Boosters should be distinguished from other steam locomotive arrangements which featured a full additional set of full of mid-sized cylinders and medium-diameter (48-50 inch) driving wheels under the tender. Apparently not ever deployed in Central Ohio, these included the Erie Railroad's "triplex" 2-8-8-8-2 articulated design, and a similar design tried by the Virginian Railway. Both of these were limited to a single prototype, and were abandoned principally because the boilers were inadequate to supply sufficient steam for all six big cylinders on a sustained basis. Like the alternative concept of tender-mounted booster trucks, these arrangements suffered from diminished adhesion once the tender's coal and water was consumed, and it was not feasible to apply sand directly to the rails back under the tender to reduce driver slippage.

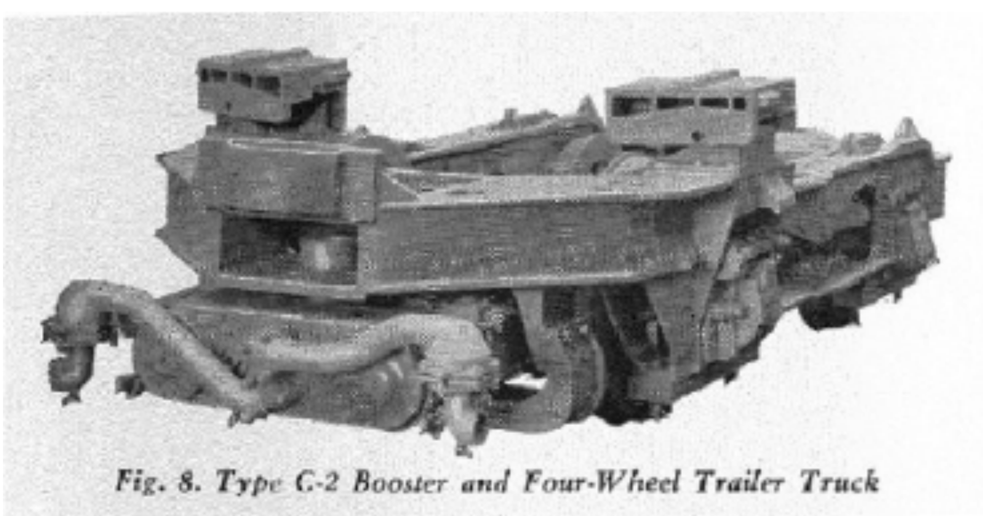
Beginning in 1915, the Southern Railway ordered seven M-class 2-8-2 "Duplex Mikados" with a second engine with a 2-6-0 or 2-8-0 arrangement under the tender. Beset by steam inadequacy and tender unit wheel-slip issues, Southern abandoned these in just a few years. Between 1918 and 1926, Southern also ordered a 2-10-2 duplex locomotive from Baldwin with a 2-6-2 second steam engine beneath the tender (it is unclear if Baldwin installed the tender engine or if Southern retrofitted it later). This locomotive fared better, working on Southern's infamous 4.9 percent Saluda Grade in North Carolina until 1952.

Duplex Mikado operated by Southern Railway, 1915. *https://locomotive.fandom.com/wiki/Southern_Railway_Class_Ms*

For more detail and photos showing duplex and triplex engine arrangements see: http://douglas-self.com/MUSEUM/LOCOLOCO/steamtender/steamtender.htm#mk

A more widely successful duplex type arrangement was the Beyer-Garratt locomotive, which featured a pair of 4-6-2 or 4-8-2 engines under two separate tenders (one being the water tank and the other the coal bunker) with a large boiler on a long frame between the two, pivoted at either end such that the boiler's weight was transferred to the wheels beneath the tenders. These wheel arrangements, usually expressed in the form 4-6-2+2-6-4 or 4-8-2+2-8-4, distributed the engine weight over more axles for use on lighter-gauge track, often narrower gauges, throughout Africa and Australia. Some are still running even now in places like Eritrea.

Franklin two-axle booster unit with outside cranks and rods used in England.



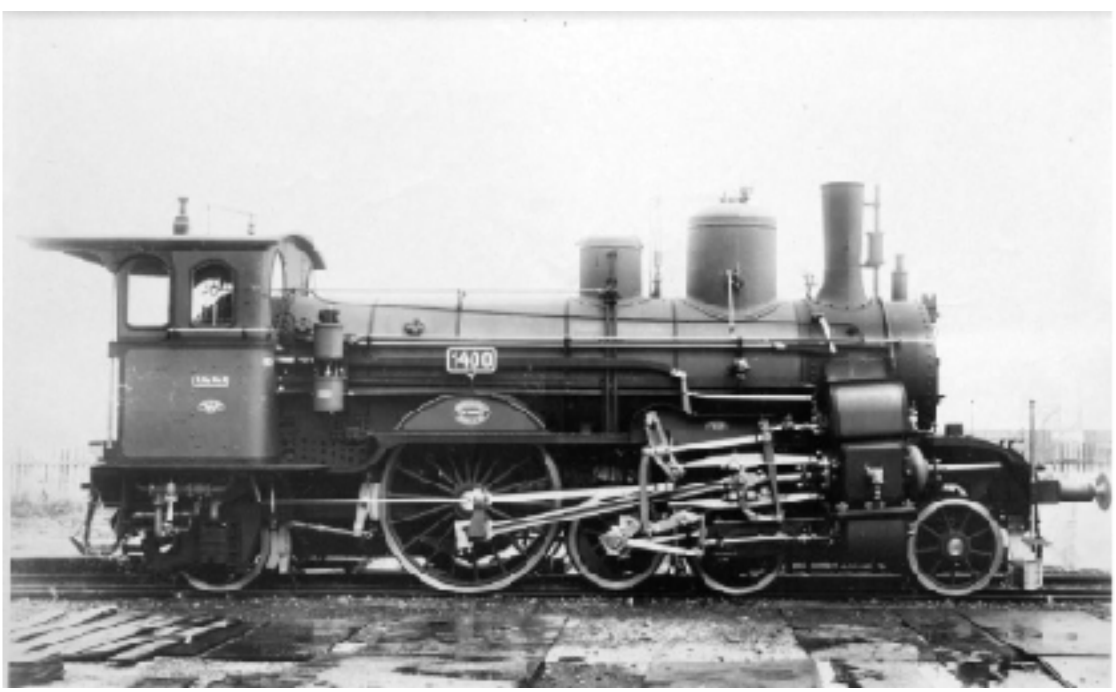
Franklin C-2 booster unit, 1942.

Other Resources:

See a YouTube Video, in-cab view of Reading & Northern 2102 4-8-4 in operation, with the crew cutting in the booster around 4:00. Note the steam valve for the booster is on the upper left portion of the firebox shell. https://www.youtube.com/watch?v=_VGe7-LYqiiE&t=80s

Other Booster Designs

Various railroads around the world experimented with widely-differing booster designs. The most exotic were in Europe. In 1896, Krauss Locomotive Works built No. 1400, a 4-2-2-2 engine for Royal Bavarian State Railways featuring a single axle with 6 foot 1-5/8" drivers powered by the main set of pistons, with a "dolly axle" with small wheels the same diameter as the leading truck, driven by a smaller set of pistons mounted below the main pair. When not engaged, the booster wheels were raised 1.5 inches above the rail. When activated, the booster wheels were lowered by a steam piston to contact the rails. This arrangement required a complicated double set of rods and valves. This design appears not to have been widely used, but the 1400 remained in service with some modifications until 1933. Bavarian Railways also tried a second booster design, with the dolly axle between the leading truck axles with external small booster engine pistons, and with the main pistons moved inside the frames.



http://douglas-self.com/MUSEUM/LOCOLOCO/booster/booster.htm and https://en.wikipedia.org/wiki/Bavarian_AA_I