America's first high-speed electric locomotive

Old Maude: ^

Parts: Preface | First | Second | Third | Fourth | Fifth | Sixth | Notes

Preface

This is the story of Old Maude, the New York Central Railroad's pioneering high-speed electric locomotive. More than a description of a locomotive, it's the story of an engineering feat brought on ahead of its time in the early 1900s by the need for safety in the smoky tunnel leading into New York City's major train station, the original Grand Central Station.

Clearly electric powered locomotives were seen as the way of the future, even before a tragic event forced the conversion of steam to electricity for trains operating in New York's Manhattan Island. The difficulty was that many variables in the design of electric railways were the subjects of heated discussion among the leading electrical engineers of the time, including Frank J. Sprague and George Westinghouse. The key questions involved the choices of alternating current vs. direct current and all that implied about transmission and distribution of power as well as the final form of the locomotive.

The Baltimore and Ohio Railroad had already demonstrated the enormous pulling power of small electric locomotives in its Howard Street Terminal electrification in Baltimore, but no one had yet designed a high-speed electric locomotive for mainline operation.

The choice of direct current for the system by consulting engineer Sprague was countered by the New Haven Railroad's choice of alternating current for its line outside the confines of New York. The New Haven operated over the Central's New York tracks leading into Grand Central, thus the New Haven had little say on the matter.

More controversial was General Electric design engineer Asa F. Batchelder's selection of the previously tried and failed gearless drive for Old Maude, the project's prototype locomotive.

The design of the entire Grand Central Terminal project, including the new terminal design conceived and guided by the Central's Vice-President and Chief Engineer William J. Wilgus, the system electrification, and the locomotive design has been validated by its long-running success. Grand Central remains today as an important rail center and the electrification remains virtually intact and unchanged since it reached completion in the early 1900s. Old Maude and her 46 siblings continued to provide trouble-free economical service for many years. The last to leave service was number 115, which was retired in 1981.

This article is divided into eight parts:

1. Preface
2. Observations of a young boy
3. Grand Central electrification
4. A bold new locomotive
5. A fatal accident
6. Years of grace
7. Now you know
8. Notes

> This article was originally written in 1992 for Electric Lines magazine. It was completed just as the magazine ceased publication. I've made a few trivial adjustments since then to account for the time gap since I first wrote the article. I've also added a few amplifying sidebars in recognition of the potentially wider audience the Internet affords as compared to the rail enthusiast focus of Electric Lines, but I have not updated any of the research.
>
> Alfred Barten, 1 June 2001.

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Old Maude:^

Observations of a young boy

I grew up watching trains. For one memorable period in my preteens, in the early 1950s, I had one of the best train watching seats in the country. It was Harmon, New York, where the New York Central changed its motive power on all through passenger trains to or from points north of Croton-on-Hudson. Electric locomotives headed trains into and out of New York's Grand Central Terminal to the south, while steam or diesel locomotives powered trains to the north.

S-motor 144 at Harmon, NY, 24 June 1935. Photo by Francis J. Goldsmith, Jr.

My father commuted to New York from Harmon, where my mother and I often met him in the evening upon his return. I had

little difficulty in persuading my habitually early mother to drive us to the station well in advance of his arrival so I could watch the changeovers. Perched on an embankment alongside the tracks, twenty or so feet above the station platforms, I saw a range of the Central's finest steam, diesel, and electric locomotives. For steam there were the omnipresent 4-6-2 Pacifics; the speedy, handsome, classic 4-6-4 Hudsons; the powerful 4-8-2 Mohawks; the occasional Berkshires with their unforgettable 2-8-4 wheel arrangement; and the state-of-the-art 4-8-4 Niagaras. If my father was delayed and took a later train, I saw the big name trains - the Commodore Vanderbilt and the Twentieth Century Limited. These were often spirited to Chicago by A-B lashups of magnificent EMD E7 diesels dressed in the Central's handsome lightning color scheme, a stately combination of grays and white. The E7s' power, speed, and long line afforded them a legendary status in the minds of us boys. We held them in the same esteem as we did that other New York legend, the Yankee Clipper himself, Joe DiMaggio. Looking at the E7s, we saw the future, though with a touch of remorse for the doomed steamers.

Some steam locomotive designations by front-to-back wheel arrangements:
Atlantic, 4-4-2: ooOOo
Pacific, 4-6-2: ooOOOo
Hudson, 4-6-4: ooOOOoo
Mohawk, 4-8-2: ooOOOOo
Berkshire, 2-8-4: oOOOOoo
Niagara, 4-8-4: ooOOOOoo

The following photos are on George Elwood's Erie Lackawanna and other Fallen Flag and Shortline Railroad Photos website:
Pacific, 4-6-2: Harmon, NY, 8/19/1952 (J.R. Quinn photo, Gary Stuebben collection)
Hudson, 4-6-4: Harmon, NY, 7/30/1950 (J.R. Quinn photo, Gary Stuebben collection)
Mohawk, 4-8-2: Buffalo, NY, 1/4/53 (Gary Overfield collection)
Niagara, 4-8-4: Harmon, NY, 05/30/1949 (Gary Stuebben collection)
E-7 diesel: Harmon, NY, 5/18/1957 (David Nyce photo, Gary Stuebben collection)
T-motor: Harmon, NY, 9/17/1954 (Paul L. Dunn photo, Gary Stuebben collection)
P-motor: Harmon, NY, 07/11/1955 (Wm.Curtis photo, Gary Stuebben collection)

The electrics were usually T-class motors, the line's workhorses for nearly four decades until supplanted by the larger P-class motors, which were rebuilt and transferred in 1955 from Cleveland Union Terminal after that branch of the Central was de-electrified. Occasionally a solitary, diminutive S-class motor would arrive with an outbound train in tow and, with little

fanfare, return to New York heading an inbound train. Normally, S-motors could be seen lurking on sidings in and around Grand Central Terminal or in nearby Mott Haven yard. They were the nation's first-ever mainline, high-speed electric locomotives, created at a time when the foundling electric railroad industry was still seeking standards. The first group of S-motors was built in 1906 as part of the Central's pioneering Grand Central Terminal electrification. They gained instant fame when, in 1905, the series' prototype outperformed the Central's newest Pacific-type steam locomotive in trial runs at the General Electric test facilities in Schenectady. After their introduction into regular service in 1906, the S-motors became popular models for toy train manufacturers and thereby introduced a generation of children to the wonders of electric railroading.

Mott Haven Yard

The tracks of the Central's Hudson and Harlem Divisions converge at Mott Haven Junction in the Bronx to begin the aproach to Grand Central Terminal at 42nd Street in Manhattan. Mott Haven Yard, a passenger coach facility, extends north from Mott Haven Junction, at 149th Street, along the Harlem Division. It is still in use today by the MTA Metro-North Railroad, the descendent of the New York Central and New Haven (and other) railroads, but is largely obscured by apartments built in the air space aove the yard.

The sequence of changing outbound locomotives at Harmon was a ritual I quickly learned. Before a given train arrived from Grand Central, the locomotive preparing for the train's real trip - the one from Harmon to Poughkeepsie, Albany, Buffalo, Canada, Cleveland, Toledo, Chicago, or elsewhere - would slowly back over the elevated track leading from the roundhouse or diesel/electric shops on the west (inbound) side to the east (outbound) side. This track, which was just north of the station, crossed over a maze of mainline and secondary tracks below. The elevated track led the locomotive down alongside and, finally, through a ladder of double-slip switches onto the mainline track where its train was to arrive. The locomotive, usually steam, would then pull ahead of the arrival point and wait. Upon arrival, the electric would be uncoupled, run ahead, and switched out of the way. The waiting locomotive would then back up and be coupled to the train. Moments later, amid great clouds of steam and smoke accompanied by resounding blasts of steam escaping the cylinders with each piston stroke, the massive steamer would gradually lurch forward with its heavy train. In one

unforgettable moment, I stood alongside a 4-8-4 Niagara when those 79-inch diameter drivers started. I was astonished to see the wheels skid as that giant piece of machinery, straining under its load, took several strokes to finally gain a foothold. In that moment I felt the magnitude of the forces at work.

The diesels, though less spectacular, created an impressive commotion of their own when their 4000-horsepower's worth of internal combustion engines roared into action.

What could have passed unseen amid this awesome display of power, but didn't, was the unassuming ease with which the electric locomotives delivered their trains to the waiting steam and diesels. Quietly, effortlessly, unceremoniously they arrived and were uncoupled and jockeyed to an inbound track for the return trip to Grand Central. A cartoon equivalent of this incongruous sequence is the bent, gray-haired cleaning woman singlehandedly picking up and moving the champion weightlifter's barbells to dust under them. How these undersized boxes on wheels could outperform their more celebrated steam or diesel counterparts was a mystery. As much a mystery was the electrics' curious shapes that revealed little of their underlying nature and concealed the transformation of electrical energy to mechanical motion.

These were true "black boxes." S-motor number 6000, the Central's 1904 prototype also known as Old Maude, could have been the original "black box," though it wasn't. That title would be more fitting for the tiny four-wheel electric locomotives built in 1890 for the City & South London's deep-tube subway. External appearances left little clue as to how the S-motor worked. With its center cab and biaxial symmetry, there was even doubt as to which way it might move next. There were no side rods connecting its drive wheels to suggest that it could move of its own accord. When it did move, there was little sound from inner activity. There was no steam for propulsion nor smoke nor exhaust from combustion. There were no overhead wires from which to gain electrical energy. The stunted pantographs appeared more like antennae. Only a close observation would reveal the frame-mounted contact shoes which pressed the underside of the energized third rail. Appropriately, the locomotive was painted black; all black save for the gold letters and numbers.

The greater mysteries of the electric locomotive are in its performance - tractive effort, acceleration, speed - and the unseen properties of magnetism and electricity. The principles of steam were known at the start of the nineteenth century. "By the end of the century the basic elements of the steam locomotive and their functions were quite well understood, and very few unsound designs have been built since that time,"[1] wrote Alfred Bruce in his 1952 compendium The Steam Locomotive in America: Its Development in the Twentieth Century. It was not hard to understand or demonstrate the processes of combustion, vaporization, pressure, and conversion to mechanical motion. Even the internal combustion engine at the heart of the diesel-electrics is readily understandable.

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1. Bruce, Alfred W. The Steam Locomotive in America: Its Development in the Twentieth Century. New York: Bonanza Books, 1952; 28.

But grasping the fundamentals of electricity, magnetic induction, and the like still takes a leap of faith for many. The results of the processes are observable. The processes themselves often are not. In his 1890 poem, "The Broomstick Train; or, The Return of the Witches," Oliver Wendell Holmes observed:

> Often you've looked on a rushing train,
> But just what moved it was not so plain.
> It couldn't be those wires above,
> For they could neither pull nor shove....[2]

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2. Holmes, Oliver Wendell. Complete Poetical Works. Ed. Horace E. Scudder. Boston: Houghton, 1895; 301.

If the processes are difficult to "see" today, they were less understood at the start of twentieth the century. When the Central's electrification and accompanying S-motor prototype were designed, virtually every major component of the system and locomotive was a subject for debate. At issue were the type of distribution current and its voltage, the distribution system itself, the locomotive motor(s), and the form of drive. There were "safe" approaches, of course, but would they be best in the long run?

Alfred Barten, 16 January 1993.

This is the first part of an article written in 1992 for Electric Lines magazine, just before it ceased publishing.

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Grand central electrification

In 1903, when the Central began planning its Grand Central Terminal electrification, the lure of electric operation was certainly in the air. Trolleys were already taking the country by storm and the first round of electric interurban building was well under way. Chicago had been operating multiple-unit rapid transit trains system-wide since 1900 and the Baltimore & Ohio Railroad had demonstrated the remarkable pulling power of electric locomotives with its Howard Street Tunnel electrification in 1895. The Central had been considering electrification since 1899 but was in no hurry, what with serious questions surrounding the best choice of system.[3] A fatal accident in 1902, however, left no alternative. On January 8 a New York Central morning rush-hour train ran a red light in the smoke-filled Park Avenue tunnel and rear-ended a stopped New Haven train, killing fifteen commuters. The public outcry was so great that the Central moved to action even before the State Legislature, on May 7, 1903, officially banned the use of steam locomotives on the Grand Central line south of the Harlem River after July 1, 1908.

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3. Wilgus, William J. Electrification of the New York Central & Hudson River Railroad in the New York Zone. Street Railway Journal. October 8, 1904; 584.

The Central formed a commission to study the situation and make recommendations as to the general nature of the electrification. The Electric Traction Commission, as it was named, was well-staffed with engineering talent, including two who would play important roles: the Central's Vice-President and

Chief Engineer William J. Wilgus, and reknowned consultant, Frank J. Sprague. The former devised the brilliant two-level scheme for the new Grand Central Terminal while the latter most certainly had a guiding influence (though he downplayed it) in the selection of low-voltage third-rail direct current (d.c.) for the power distribution system. As reported by Wilgus, the group met weekly and set "principles and policies" to be "carried out by a technical corps under the jurisdiction of the electrical engineer."[4]

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4. Wilgus, William J. Electrification of the New York Central & Hudson River Railroad in the New York Zone. Street Railway Journal. October 8, 1904; 584.

To be sure, there were compelling reasons for the Central's selection of 650-volt d.c. over the competing 11,00-volt single-phase alternating current (a.c.). For one thing, d.c. had already been proven in urban and suburban situations, whereas a.c., despite its acknowledged advantages in efficient line distribution, had not been demonstrated in any major installation. There were more convincing arguments in support of d.c. for the Grand Central Terminal electrification, though: 1) the use of a.c. would require lowering tracks to provide clearance beneath overpasses for the overhead distribution wires, and 2) the clincher, a New York City ordinance prohibited the use of unprotected high tension wires (as in overhead distribution systems).

S-motor 133 at Mott Haven Yard, NY, April 1965. Bob's Photo.

Another reason given in support of the low-voltage d.c. installation was the "desirability of harmonizing all of the larger electrical installations in the New York vicinity, such as elevated, surface railways and subways."[5] The intention was to provide "11,000-volt three-phase alternating current for high-pressure transmission between the central power stations and the substations, and 600-volt direct current for the low-pressure conductors and third rail."[6] There was even an intimation that a connection might be made with the rapid transit subway (already using low-voltage d.c.) at 42nd Street, the site of the planned new Grand Central Terminal.[7]

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5. Wilgus, William J. Electrification of the New York Central & Hudson River Railroad in the New York Zone. Street Railway Journal. October 8, 1904; 584.
6. Ibid; 585.
7. Ibid; 584.

The Central's commitment to d.c. extended to its suburban electrification, which included radiating lines to Yonkers and North White Plains in addition to the mainline Hudson Division as far as Croton-on-Hudson. Whereas the New Haven Railroad, which shared Grand Central Terminal facilities and approaches with the Central, chose to use 11,000-volt single-phase catenary a.c. once outside the city and on its own right-of-way (and put

itself at the cutting edge of railroad electrification technology), the Central planned instead to eventually extend its Hudson Division electrification as far north as Albany with low-voltage d.c. (The superiority of a.c. as a distribution system ultimately discouraged any serious expansion of the Central's electrification. The New Haven, after experiencing early difficulties to the point of nearly abandoning its a.c. system, extended its electrification to New Haven and set the standard to be followed decades later by the Pennsylvania Railroad in its electrification of what is now Amtrak's Northeast Corridor. As of this writing, that system is expected to be extended all the way to Boston.)

S-motor 110 at North White Plains, NY, 13 November 1966. Photo by Francis J. Goldsmith, Jr.

A paper presented by Sprague at a meeting of the American Institute of Electrical Engineers on May 21, 1907, provides some insight into the Central's choice of system and the design of the S-motors, so integral a part of the overall plan. What is interesting is that by 1907 many of the claimed advantages of d.c. over a.c. were discounted by at least some engineers, as was evident by the comments of those attending the meeting. Yet Sprague's approach to electrification remained unchanged.

Foremost in Sprague's approach was the assertion that the locomotive's motor (Sprague's forte) is the starting point, the key element, the first variable in the design process to be fixed. For Sprague, this pointed to the d.c. motor because of its

greater simplicity, efficiency, and reliability. Building on these three factors, the remaining components fall into place: Specifically, the use of third-rail distribution, with its proven reliability, to provide the carrying capacity required by the low voltage; and the design of a locomotive that would exploit the theme of simplicity, efficiency, and reliability to the fullest extent possible. (In support of Sprague's position, the d.c. traction motor has until recently been the de facto standard for today's electric and diesel-electric locomotives.)

These above considerations are of paramount importance in any electrification because of the need to write off the project's large initial investment. This was especially true of low-voltage d.c. (with its expensive distribution system), which Sprague characterized as the unequivocal choice for high-density traffic. "The present hope of usefulness of the single-phase system," he said, "is on roads of considerable extent which operate an irregular and sparse traffic, and where only a moderately expensive, or what may be called second-class overhead construction which will keep down the ratio of line investment to that of the balance of the equipment, is tolerable."[8] If Sprague's remark, made in his May 1907 presentation, didn't ruffle a few a.c. feathers, a subsequent remark must certainly have:

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8. Sprague, Frank J. Some Facts and Problems Bearing on Electric Trunk-Line Operation. Street Railway Journal. May 25, 1907; 907.

> But whatever may be the future of single-phase operation under the conditions stated, any present claim for it as preferable equipment for congested service demanding high schedules and great capacity is not worth a moment's thought, for in this field, at least, it cannot touch the direct-current system.[9]

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9. Sprague, Frank J. Some Facts and Problems Bearing on Electric Trunk-Line Operation. Street Railway Journal. May 25, 1907; 915.

The success, if not also the ultimate validity, of Sprague's approach has been borne out by the durability of the Central's electrification and the S-motors in particular. The installation is

still in operation and the last of the S-motors survived till the early eighties, after nearly eight decades of virtually trouble-free day-in and day-out service.

Alfred Barten, 16 January 1993.

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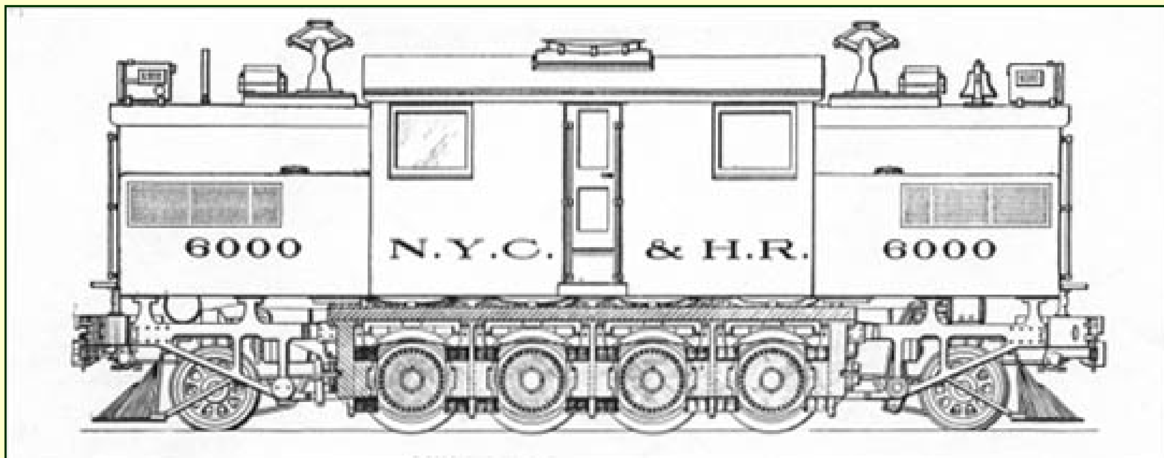
A BOLD NEW LOCOMOTIVE

For all the apparent conservatism in the selection of d.c. as the system of choice, the S-motor design was a bold departure from earlier electric locomotives. It was primarily the work of General Electric's Asa F. Batchelder, who patented four of the design's features. Most significant was a Batchelder innovation that produced the first successful use of bipolar gearless motors.



Sectional elevation of Old Maude. Street Railway Journal, 1904.

The lure of the gearless motor is the absence of gears, which by their very nature introduce friction (with its loss of operating efficiency) and require maintenance. In practice a gearless motor design is achieved by wrapping the motor armature around the driving wheel axle. This has the drawback of adding dead weight to the axle, which in turn lowers the locomotive's center of gravity, a detriment to good tracking. In an age of early motor design, placing the armature on the axle also limited the capacity of a motor by restricting its size to the space available between the wheels. Previous gearless designs usually placed the armature in a hollow quill that surrounded but did not contact the axle.

The motor's fields were placed in the motor casing, which surrounded the quill and was attached to the locomotive frame. The quill ends were fastened to the drive wheels via springs or rubber to allow a flexible connection that reduced the unsprung weight of the motor and mitigated some of the stresses of starting and accelerating on the wheels and motors.

The B&O used a gearless quill drive in its historic locomotives of 1895 but chose geared drives instead for its second generation of locomotives in 1903. The New Haven also used gearless quills in its initial a.c. locomotive fleet of 1907 and likewise turned to geared quill drives for subsequent designs.

But Batchelder chose a gearless drive that omitted the quills altogether. Such an attempt had only been tried on an "important" installation once before.[10] That was on the locomotives for the 1890 deep-tube electrification of the City & South London Railway in England. The C&SL attempt was a disappointment, though, and the locomotives' pounding of the rails soon led to the use of multiple-unit motor cars in place of the locomotive-drawn trains. Thus Batchelder's initiative drew a good deal of attention throughout the industry.

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10. High-Speed Electric Locomotive for the New York Central & Hudson River Railroad. Street Railway Journal, November 19, 1904; 901.

There were two significant differences between the C&SL attempt and the Central's. First, the London installation was said to be very light, and the vibrations from running were readily "transmitted to and propogated in the surrounding soil of London clay in a way which could not be possible on a roadbed of the character of the New York Central."[11] Second, in the C&SL design the entire motor was axle-mounted, which produced a relatively greater unsprung weight, a large contributor to rail-pounding. In the Batchelder design only the motor armature was mounted on the axle. The pole pieces were mounted on the truck frame. The resulting 11,000-lb dead weight of each axle, drive wheels and armature included, was "somewhat less than is customary with steam locomotives."[12] Since the most problematic element of the steam locomotive as regards wear on the track is the "impossibility of properly balancing the reciprocating motion of connecting and driving rods"[13]

(completely absent in gearless designs), the concern for pounding the rails was heavily discounted. Engineers expected a twenty to thirty percent reduction in wear from that of a comparable steam locomotive.[14]

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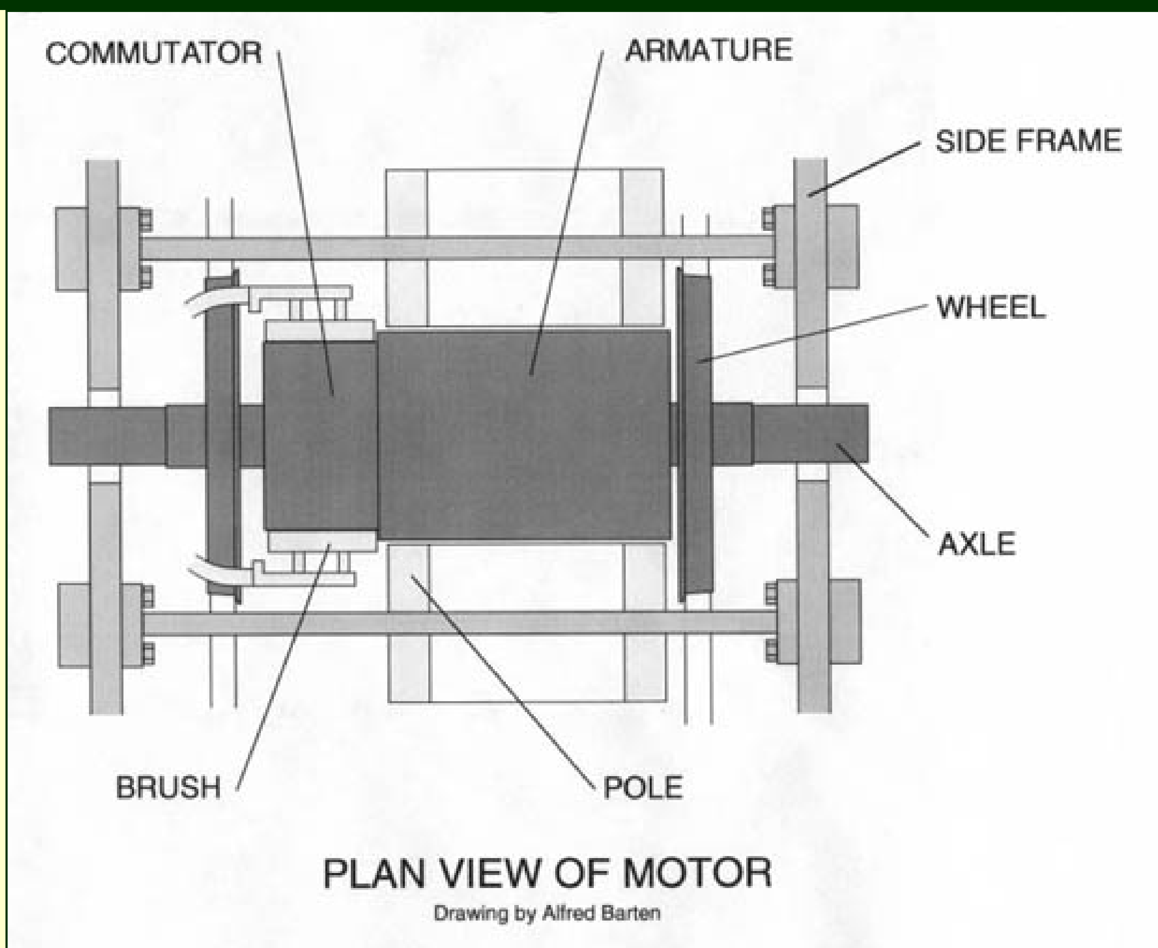
11. High-Speed Electric Locomotive for the New York Central & Hudson River Railroad. Street Railway Journal, November 19, 1904; 901.
12. Ibid; 901.
13. Ibid; 901.
14. Ibid; 901.

Batchelder's innovation lay principally with his solution to the problem of maintaining a nearly fixed relationship between the frame-mounted field poles and axle-mounted armatures while permitting relative vertical movement of the axle. Batchelder solved the problem by providing only two field poles for each motor instead of the four customary in d.c. traction motors. This enabled him to place nearly-flat-faced iron pole pieces opposite each other in vertical planes parallel to the axle. The axle then was free to move up and down while the locomotive was moving. It also allowed the axle, drive wheels, and armature to be easily removed as a single unit when maintenance was needed.



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Electrically, the magnetic flux was continuous from one end of the truck to the other, i.e., the fields were arranged in tandem so that the flux passed through all poles and armatures in series and then returned via the cast-steel side frames and two iron bars between the frames. The design, called "entirely novel" by the Street Railway Journal, effectively permitted each motor to act independently while remaining in circuit with the main flux.[15]

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15. High-Speed Electric Locomotive for the New York Central & Hudson River Railroad. Street Railway Journal, November 19, 1904; 902.

Structurally, the Batchelder locomotive consisted of three components: 1) the main truck, 2) the pony trucks pivoted from each end of the main truck, and 3) the locomotive main frame and superstructure supported from below by the main truck and the pony trucks.

The main truck included the four driving axles, motor armatures,

and field poles. Each end of the truck frame was extended to provide a mounting for the coupler. A system of half-elliptic springs and equalizing levers suspended the locomotive main frame and superstructure, effectively providing cross equalization and three-point support for the load.

The two pony trucks were single-axle, radial type, connected to and pivoted from each end of the main truck by a radius bar. An arrangement of linkages enabled these trucks to support the portion of the locomotive frame above them while retaining the ability to swing about their own centers. On straight track they also were self-centering. The design was reported by the Street Railway Journal to be "the standard construction adopted" by the Central for its steam locomotives.[16]

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16. High-Speed Electric Locomotive for the New York Central & Hudson River Railroad. Street Railway Journal, November 19, 1904; 903.

With the motors placed around rather than above the axles, where they would encroach upon the superstructure, the designers were able to provide a roomy center cab for the engineer and train crew, as well as a center-aisle walk-through space from end to end of the locomotive. Contactors, rheostats, reversers, and such were placed in fireproofed steel boxes adjacent to the aisles. Since this equipment was small, the enclosure height could be kept low to afford the engineer excellent forward/backward visibility from the cab. The outer shape of the locomotive formed a neat, straightforward representation of the spatial arrangement within.

Inside the cab, master controllers for multiple-unit operation and other equipment to be manipulated by the operator were provided at each end. The control system permitted three running connections: 1) four motors in parallel, 2) two groups of two motors in parallel-series, and 3) all motors in series. A motor-driven air compressor and, later, a small boiler to provide a limited amount of steam on passenger runs, were also placed in the cab.

Multiple-unit, or M-U, operation refers to a Frank J. Sprague invention that enables more than one motor car (or locomotive) to be operated simultaneously from a single controller in one of the cars. This form of control was first used in elevated

and subway rapid transit operations but subsequently found use in trains of trolley cars and multiple units of electric and diesel-electric locomotives.

On the roof, a small pantograph known as a dc shoe was placed near each end. These enabled the locomotive to receive power from overhead conductors to be installed where complicated trackwork, as in Grand Central, would result in excessively long gaps in the third rail. In operation the dc shoe was extended to the overhead rail and held there by the engineer's pressing and holding the DC SHOE UP button. Upon release of the button, gravity would return the dc shoe to its down position.

The first formal testing of the prototype for the Central's new electric locomotive took place on November 12, 1904. The event, which was open in the morning to railway officials and in the afternoon to the press, and locomotive number 6000, the object of everyone's attention, were well covered by the Street Railway Journal in its November 19 issue the following week. Appropriately, the testing took place on an experimental six-mile electrified section of track in nearly the same location that the early steam trials had been conducted by DeWitt Clinton some seventy years before.

Commenting on number 6000's design, the Journal noted:

> Considerable discussion has been raised ... as is natural when so decided a departure is taken from previous lines of construction. The elimination of gearing and the bold step of mounting the armature directly upon the axle without an intermediate spring supported quill has caused comment, which has not all been favorable to the designing engineers.[17]

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17. Test of New York Central Locomotive. Street Railway Journal, November 19, 1904; 897.

The Journal observed that in spite of any effect the dead weight of the motor on the axle might have on the roadbed, there was none to be felt while riding in the cab. Moreover, it said:

> The reduction in gear wear and in space occupied, and

> the increase in efficiency tend largely to offset any objection to the greater dead weight per axle imposed by the gearless over the geared motor. Compared with the steam locomotive, there is every reason to expect a great reduction in the wear and tear on the track, due to the following, among other reasons: (1) Less total weight on axle, due to four driving pairs instead two; (2) uniform torque, hence a reduction of slipping effect; (3) absence of reciprocating parts with their necessary counterbalances.[18]

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18. Test of New York Central Locomotive. Street Railway Journal, November 19, 1904; 897.

The Journal also compared the recent acceleration test of number 6000 with that of a steam locomotive two years earlier. The steam locomotive had been designed specifically to achieve high acceleration for suburban use. Both locomotives pulled 265-ton trains, locomotive and tender weights included, in the tests. The startling results recorded the new electric locomotive and train as reaching 30 mph in 37.5 seconds versus 55 seconds for its competitor.

In its description of number 6000, the Journal noted that the "total rated capacity of the locomotive is 2200 hp, although for short periods, a considerably greater power may be developed, making it more powerful than the largest steam locomotive in existence."[19] The Journal noted also that with its multiple-unit control, the locomotive could be operated simultaneously with additional units to increase the effective pulling capacity:

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19. High-Speed Electric Locomotive for the New York Central & Hudson River Railroad. Street Railway Journal, November 19, 1904; 900.

> A single electric locomotive will be able to maintain a schedule of from 60 to 65 m.p.h. with a 450-ton train, and two locomotives will be coupled together for heavier trains, some of which in the New York Central service reach 875 tons in weight.[20]

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20. High-Speed Electric Locomotive for the New York Central & Hudson River Railroad. Street Railway Journal, November 19, 1904; 900.

In its competition with other forms of motive power, electric locomotives are particulary good at starting and accelerating heavy train loads. In heavily trafficked trunk lines, the electrics can handle longer trains and maintain shorter operating schedules than steam or even diesel-electric. They can literally save a railroad from having to install additional track where traffic would otherwise require it.

The secret of the electrics lies 1) in their ability to exert a steady tractive force through their drivers, as opposed to the steam locomotive's intermittent traction-defeating bursts, 2) in the inherent characteristics of electric motors, and 3) in their effective use and placement of on-board equipment to achieve maximum power-to-traction efficiency.

One distinguishing characteristic of the electric motor is its ability to deliver maximum torque at zero rpm (exactly the opposite of the internal combustion engine). Another is the electric motor's ability to deliver greater-than-normal horsepower for short durations. Electric motors rise to the demand, that is, they deliver the power called for until they overheat, at which time their insulation melts and their wires short or burn out. Electric motor horsepower ratings are thus given as functions of time, usually as one-hour and continuous. A rating for one-hour may be 50 to 60 percent higher than for continuous, and a rating for several minutes may be many times higher than that.

The limit to an electric locomotive's starting a large load, then, is not so much the horsepower rating as the limits of adhesion between drive wheels and rail. Here again the electric locomotive has an advantage because a greater percentage of its weight can be carried by drive wheels than for a steam locomotive, which normally carries its fuel supply in a tender. By not having to generate its own power, the electric locomotive, unlike the steam or diesel-electric, can have every piece of apparatus on board used to direct power supplied from a distant power plant to the motors.

In 1906, with testing of number 6000 completed, the Central

ordered 34 more identical locomotives and took delivery later in the year. The new locomotives were numbered 3401 through 3434. Number 6000, the prototype, was renumbered 3400 and all were designated by the Central as Class T motors. In December electric operations from Grand Central began, thus concluding the first step of the project brought on by that fateful Park Avenue tunnel accident nearly five years earlier.

The inscription reads: "First experimental trip leaving High Bridge." This was the return leg of the journey started at Grand Central. Number 3406 is shown here, whereas number 3405 led the first leg. 30 September 1906. From Alfred Barten collection.

Alfred Barten, 16 January 1993.

This is the third part of an article written in 1992 for Electric Lines magazine, just before it ceased publishing.

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A FATAL ACCIDENT

If the Central had any thought of resting on its laurels, it was soon to be disappointed. The new electrics, conceived as part of a monumental response to a tragic accident, soon became - along with their creators, owners, and operators - embroiled in an accident that produced a public outcry of even greater proportion than its predecessor. On February 16, 1907, an evening rush-hour commuter train headed by a pair of the new electrics derailed on a curve near 205th Street in Woodlawn. The last four of the train's five wooden coaches left the tracks completely and overturned, leaving twenty-three dead and another one-hundred fifty injured.

The flames of public discontent with railroads needed little fanning from the press, though it received plenty. The New York Times, for example, carried one or more articles on the accident almost daily for the next three weeks. The great struggle by governmental and other reformers to reign in the freewheeling railroads on such matters as unregulated shipping rates and general disregard for public and worker safety had already been given much ink for several years. Barely a month before the Woodlawn accident, the Interstate Commerce Commisssion had launched a hearing on the subject of railroad safety. On January 17 the Times reported that 1276 people had died in New York State alone during the previous fiscal year in train and street railway accidents. Two of the Central's crack passenger trains, the Twentieth Century Limited and the Pacific Express had crashed in 1906. The Century, always on the cutting edge of new speed records, had crashed in 1905 as well. On January 22, 1907, another Central passenger train crashed near Albany, killing

seven. The previous November, Central's management had been accused of diffidence in its apparent lack of concern for three track workers killed and mutilated by a passing train. Thus a February 3, 1907, article in the Times would seem in retrospect almost comical for its absurdity were it not for the tragic circumstances. The article carried Central Vice-President W.C. Brown's denunciation of public criticism of railroads as being "a menace to national economy."[21]

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21. The New York Times, February 3, 1907; pt 5, 13:1.

Given the setting, the investigations into the circumstances surrounding the Woodlawn accident and the subsequent accusations and indictments of people in high places are not surprising. Investigators at the site found broken locomotive wheels, broken rails, and sheared rail spikes along the outer flange of the curve's outer rail. They determined - at least preliminarily - that the locomotive had left the rails before the rest of the train. The rails could be seen to have been pushed from their fastenings, and since the track had been repaired only a week before the accident, the general opinion was that the train was traveling too fast and/or the locomotive was exerting more pressure on the rails than expected.

A member of the train crew reportedly estimated the train to be traveling in excess of seventy miles an hour. Further investigation pointed out the crew's need to estimate speeds for lack of a speedometer.

In short, the New York Central and its management were held to blame by many for a variety of reasons, including improper training of motormen, improper posting of speeds, faulty design, and so forth. Fingers were pointed at the Electric Traction Commission, the company's board of directors, and other people in senior management. A New York City Grand Jury on March 27 handed down indictments against the railroad company, Vice-President A.H. Smith, and General Superintendent I.A. McCormack. The three were charged with manslaughter in the second degree. As reported in the Street Railway Journal on April 6:

> The presentment states that the disaster was

> undoubtedly due to the excessive speed. It refers to the fact that the electric locomotives run with greater smoothness than steam locomotives, and consequently men not experienced with them almost invariably underestimate their speed. The jury believed that the engineer of the wrecked train had not received sufficient instruction to enable him to form a judgment of any value as to the speed at which he was running his train.[22]

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22. The New York Central Accident, Street Railway Journal, April 6 , 1907; 621.

Meanwhile, more scientific investigations were made into the effect the new electrics were actually having on the rails. The Journal published abstracts of several studies, all of which found that even at seventy miles an hour (a speed in excess of the limits at the accident site), the worst-case scenario left the spikes with a factor of safety of four just to reach yield stress, approximately seventy percent of their ultimate failure stress. Moreover, subsequent trial runs of a similar train at the Schenectady facilities could find no fault with the locomotive design.

The most detailed of the published abstracts was one made by the General Electric Company (GE) and its locomotive-building partner, the American Locomotive Company (Alco).[23] In this study, the engineers compared the new electric locomotive with an Atlantic-type steam locomotive (4-4-2 wheel arrangement) whose single trailing-wheel axle was pedestal-mounted in the locomotive frame. (Radial trailing trucks were not yet in use.) This gave the steam locomotive a rigid wheelbase similar to but somewhat longer than the electric's. In analyzing the stresses on the track a number of variables come into play, such as the speed, the degree of track curvature, the superelevation of the outer rail, the lateral play in the second drive axle with regard to the locomotive frame, the locomotive center of gravity, and the pressure of the pony truck against the outer rail. Calculations were made for all the scenarios that one could reasonably expect. Generally speaking, the calculated stresses on the track were similar for both locomotives, though the electric's lower center of gravity was seen to produce a somewhat greater

shearing force on the outer rail. (The higher center of gravity at lower speeds has a tendency to produce a greater downward but lesser outward force on a superelevated outer rail.) As the speed was increased, however, and centrifugal force became the dominant force, the difference became less, then reverse, and finally moot because the steamer would have toppled.[24]

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23. The New York Central Accident, Street Railway Journal, March 16 , 1907; 461.
24. Ibid; 461.

One paragraph in the report is particularly noteworthy in light of eventual developments:

> The maximum shear on the spikes is not necessarily caused, however, by the driving wheels of the locomotives, but at certain speeds may exist at the leading wheel of the guiding truck. Although the pressure of the guiding truck wheel against the rail may be actually less than that of the driver, the weight upon the rail of the guiding wheel is so much less that the resultant shear on the spikes is consequently greater.[25]

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25. The New York Central Accident, Street Railway Journal, March 16 , 1907; 461.

This consideration probably more than any resulted in the replacement by GE of the single-axle pony trucks with heavier, better tracking double-axle ones (as used in the Atlantic design). It must certainly have led also to GE's use of articulated-frame wheel arrangements in subsequent mainline electrics, including the Central's T-class locomotives of 1913 and their B-B+B-B wheel arrangement. (The original T-class locomotives were redesignated S-class when their pony trucks were converted.)

GE's adherence to articulated frames continued with the famous Milwaukee Road 1-B-D-D-B-1 bipolars, and a string of 2-C+C-2 designs beginning with the New York Central subsidiary Cleveland Union Terminal's P-class motors and continuing through the New Haven Railroad's EP3-class, and the Pennsylvania Railroad's famed GG1's.

Interestingly, Bruce, writing in 1952, comments on the use of single- and double-axle pony trucks for steam locomotives as follows:

> Two-wheel leading trucks were - and still are - applied to freight locomotives in moderate-speed service. They were also applied to some passenger locomotives from 1901 to 1907 without accident traceable to the two-wheel truck, but it was thought that the four-wheel truck offered better insurance against accident and possible loss of human life.[26]

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26. Bruce, Alfred W. The Steam Locomotive in America: Its Development in the Twentieth Century. New York: Bonanza Books, 1952; 238.

Bruce had forty-five years of locomotive-building experience behind him and had been assistant vice-president in charge of engineering and director of steam locomotive engineering at Alco. He must certainly have been aware of the Woodlawn accident and its implications, though he does not refer to it by name. (Note the specific date of 1907 in his comment.) In a nutshell, his statement summarizes the outcome of the accident and its investigation: Nothing was ever proven, charges were eventually dropped, and locomotive designers quickly turned away from single-axle lead trucks for high-speed service.

S-motor 110 hustles an 8-car passenger train toward Harmon, NY. Photo at Spuyten Duyvil by Francis J. Goldsmith, Jr.

Alfred Barten, 16 January 1993.

This is the fourth part of an article written in 1992 for Electric Lines magazine, just before it ceased publishing.

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Years of grace

In 1908 twelve more S-class motors, numbered 3235 through 3246, were ordered from GE and added to the roster in 1908-9. They were slightly longer and heavier than the earlier group and given the more specific designation of S-3. The original motor, Old 6000 or Maude as it came to be known, was designated S-1 and renumbered 3200, while the remainder of the first group were designated S-2 and renumbered 3201 through 3234. Thereafter, existence for the S-motors was routine, punctuated mainly by changes in numbering and ownership.

In 1917, the S-motors were renumbered 1100 through 1146; in 1936 100 through 146; and in 1969, those still around had 4600 added to their numbers to put them in new owner Conrail's 4700-series numbering system for electrics. Before Conrail, of course, Penn Central took a turn at owning the S-motors from 1968 to 1975.

S-motor 1115 backs a string of empty passenger cars from Grand Central Terminal to Mott Haven Yard, 29 June 1926. Kevin T. Farrell collection.

Few stories about the S-motors have made it to print, but one from the early days bears retelling. Track workers along the elevated mainline approach to Grand Central, near 125th Street, one day dropped their tools in place as they stepped away from a passing train headed by S-motors. When the train had passed, their tools were nowhere to be found. Upon the train's arrival at Grand Central, and the shutting off of its power, the clatter of picks and crowbars falling to the ground solved the riddle. The engine's intense magnetism near the track had snatched and held the tools. The problem was solved by adding steel plates to limit the scope of the magnetic pull.[27]

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27. Night Ride. Trains, February, 1944; 35, 36 (Reprinted from The Monogram, General Electric Company).

In 1913 the Central's need for greater hauling power to meet a growing demand for service led to the building that year of a larger, more powerful class of locomotives. These were assigned the Class T designation vacated earlier when the original T's

were redesignated S. This was the same year that the new Grand Central Terminal was finally completed, a full decade after the great electrification project was begun. The S-motors were thereafter relegated to yard duty and light or occasional suburban use. Their durability has become legend, as has that of the T-motors, which also used the Batchelder bipolar motors.

As long-haul passenger business declined into the dark years of the '60s and '70s, and the New York Central was merged into the Penn Central before dying, the entire electric fleet began to disappear. Most New York area passenger business on the former New York Central lines is now handled by Metro North multiple-unit cars in place of locomotive-drawn trains. The few longer-distance trains in and out of New York are usually handled by Amtrak's French-built turboliners or rebuilt former New Haven FL9s. Both are diesel-electrics equipped for third-rail pickup. By 1955 all the S-3 motors had been retired and scrapped. Old 6000 was retired in 1965 to the Mohawk & Hudson Chapter of the National Railway Historical Society, where it is now stored. The S-2s were gradually retired and scrapped, with number 115, the last, retired in 1981. This was the same year the Northeast Rail Services Act of 1981 was passed permitting Conrail to shed commuter service at the end of 1982. Former number 111 is preserved at the Illinois Railway Museum in Union, Illinois, with its last number, 4715. It has been equipped with a South Shore pantograph for operation with the museum's overhead distribution system. Another S-2, number 113, resides at the National Museum of Transport, in St. Louis.

Alfred Barten, 16 January 1993.

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Now you know

It's been forty years now since this boy watched the changing of locomotives at Harmon and posed unspoken questions about the nature of electrics. As I sit here recalling those moments, I can hear the words of Holmes's rhyme on the evening breeze:

> Often you've looked on a rushing train,
> But just what moved it was not so plain.
> It couldn't be those wires above,
> For they could neither pull nor shove;
> Where was the motor that made it go
> You couldn't guess, but now you know.[28]

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28. Holmes, Oliver Wendell. Complete Poetical Works. Ed. Horace E. Scudder. Boston: Houghton, 1895; 301.

Number 121 at Mott Haven Yard, June 1963. Bob's Photo.

Alfred Barten, 16 January 1993.

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