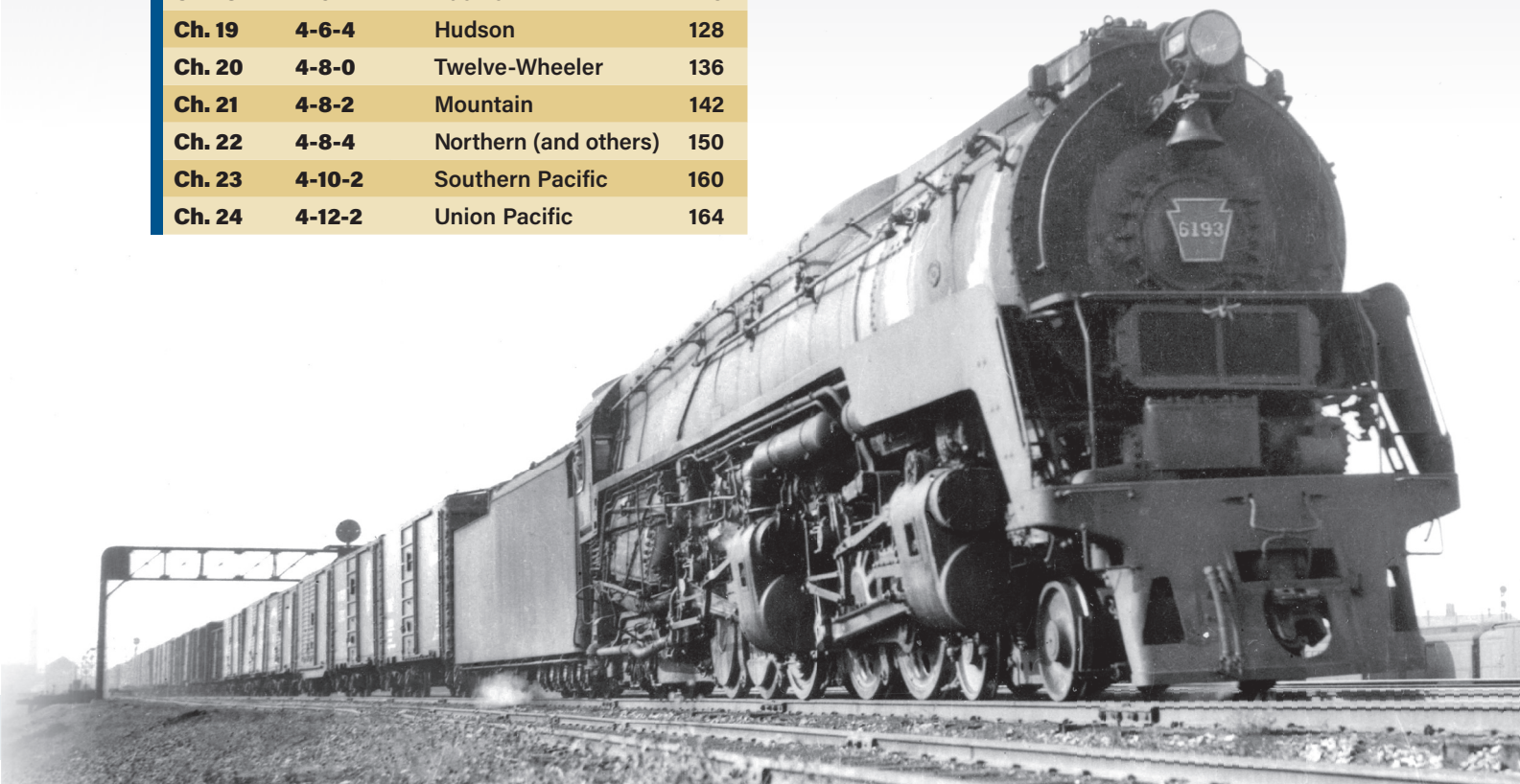


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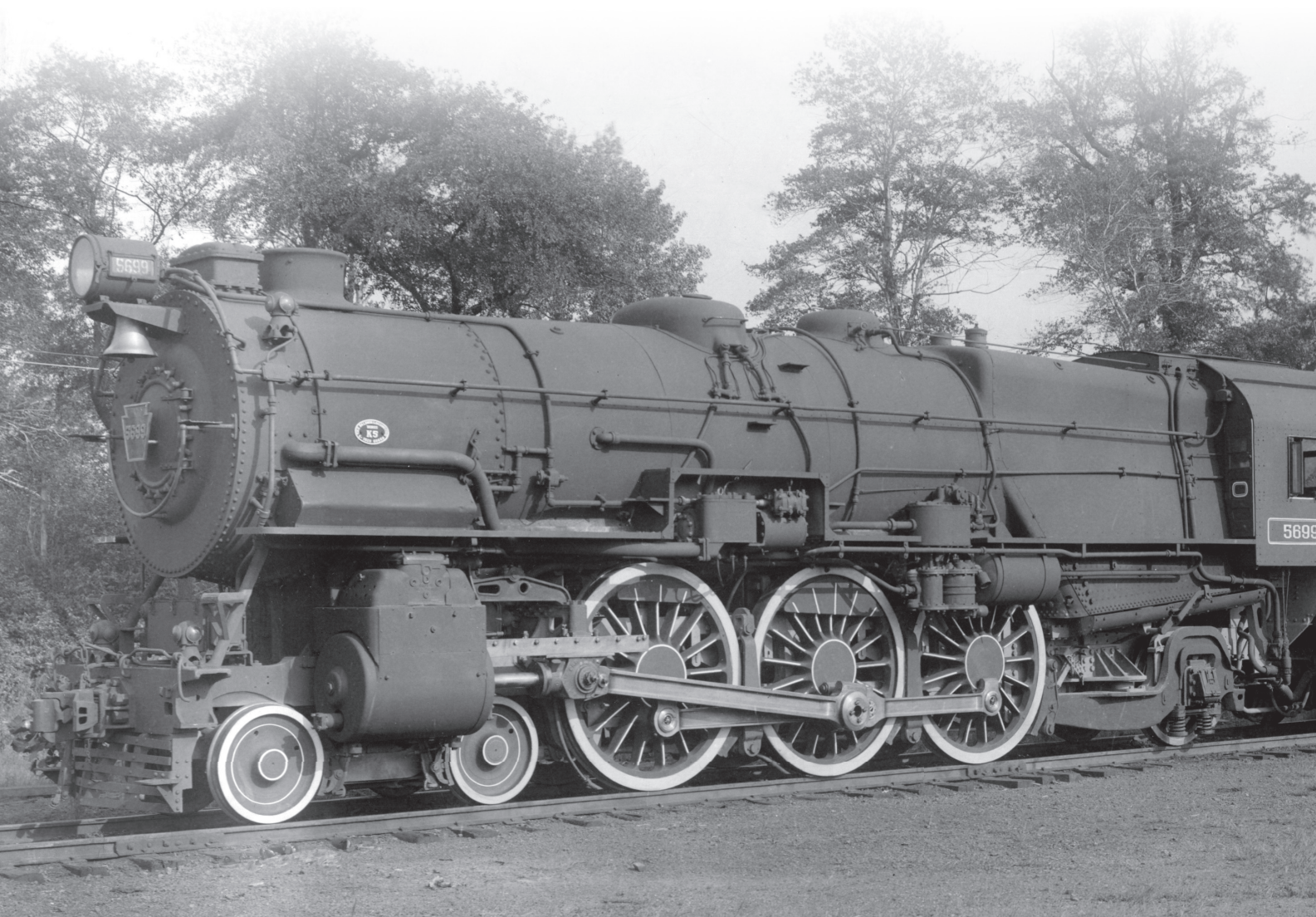
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INTRODUCTION

Evolution of wheel arrangements



Throughout this book, I examine the development, design and application of dozens of American steam locomotive types. I've organized the presentation by wheel arrangement as described in the Whyte system (see the chart below). This standard numerical method of describing locomotive types — “by the numbers,” as it were — was devised by Frederick M. Whyte, a mechanical engineer working for New York Central System. The Whyte system — which is simple, easy

In 1929, the Pennsylvania Railroad built a pair of heavy Pacifics (Nos. 5698, 5699) with larger cylinders and 6,000 pounds more weight on drivers than its well-regarded K4s 4-6-2s. The resulting K5 design proved slippery and was not repeated, but represents railroads' never-ending quest to improve locomotive design. *Trains* magazine collection



to understand, and became widely accepted — largely replaced a host of earlier methods for categorizing steam locomotives.

The Whyte system divides wheels into groups each defined by function and separated by hyphens: The first digit is the number of leading (pilot) wheels, followed by the number of driving wheels, and then the number of trailing wheels. When a locomotive type lacks leading or trailing wheels, a “0” is used. For example, a six-wheel

switcher with all wheels powered and connected (six-coupled), having neither leading wheels nor trailing wheels, is an 0-6-0; a locomotive with two leading wheels, six drivers, and no trailing wheels is a 2-6-0. Locomotives with more than one group of drivers have a separate number for each set, thus a 2-6-6-2 is an articulated locomotive with two sets of drivers, two leading wheels, and two trailing wheels. Locomotives are assumed to have a separate coupled tender for

COMMON WHYTE LOCOMOTIVE CLASSIFICATIONS

0-4-0	Four-wheel switcher	<00
0-6-0	Six-wheel switcher	<000
0-8-0	Eight-wheel switcher	<0000
0-10-2	Union	<00000o
2-4-2	Columbia	<o00o
2-6-0	Mogul	<o000
2-6-2	Prairie	<o000o
2-8-0	Consolidation	<o0000
2-8-2	Mikado	<o0000o
2-8-4	Berkshire	<o0000oo
2-10-0	Decapod	<o00000
2-10-2	Santa Fe	<o00000o
2-10-4	Texas	<o00000oo
2-6-6-6	Allegheny	<o000 000 ooo
2-8-8-4	Yellowstone	<o0000 0000oo
4-4-0	American	<oo00
4-4-2	Atlantic	<oo00o
4-4-4	Jubilee	<oo00oo
4-6-0	Ten-Wheeler	<oo000
4-6-2	Pacific	<oo000o
4-6-4	Hudson	<oo000oo
4-8-0	Twelve-Wheeler	<oo0000
4-8-2	Mountain	<oo0000o
4-8-4	Northern, Dixie, Niagara	<oo0000oo
4-10-0	Mastadon	<oo00000
4-10-2	Southern Pacific	<oo00000o
4-12-2	Union Pacific	<oo000000o
4-6-6-4	Challenger	<oo000 000oo
4-8-8-4	Big Boy	<oo0000 0000oo

fuel and water; locomotives that lack tenders and instead carry the fuel in a rear bunker and the water in a tank (generally around the boiler) are indicated by a letter “T” suffix (for “tank”).

WHAT'S IN A NAME?

The industry adopted common names for most individual locomotive types and wheel arrangements. Some are descriptive, such as the 4-6-0 being known as a “Ten-Wheeler,” while others commemorated an early buyer, such as “Pacific” for the 4-6-2, which was first ordered by Missouri Pacific. This book also references secondary names, as railroads sometimes didn't follow standard names. For example, the 4-8-2 was commonly known as a Mountain, but the New York Central called them Mohawks. The use of names can cause confusion when perusing a century of railroad trade literature. In the mid-19th century, for example, the term “Mogul” was used to describe any large (for the period) locomotive, but eventually was specifically applied to the 2-6-0.

The progression of locomotive development tended to result in gradually larger designs with more wheels, as railroads sought new locomotives that were faster and/or more powerful. However, the introduction of each wheel arrangement does not follow a strict linear numerical progression; for example, the 4-4-0 was introduced decades before the 2-8-0. To improve organization, chapters are grouped first by locomotives lacking lead and trail trucks (mainly switchers, but some early road locomotives), followed by locomotives with two-wheel (single-axle) leading trucks, then those with four-wheel (two-axle) leading trucks. Following this is a section on articulated locomotives, both compound and simple designs.

There are separate chapters for the late-era Duplex types that applied two complete sets of drivers and running gear under a rigid frame (differentiating them from articulated locomotives), for geared engines (Shay, Climax, and Heisler), and tenderless designs such as Forney locomotives. All of the locomotives in this book represent reciprocating steam locomotives — those using cylinders with double-acting pistons coupled to driving wheels. Steam turbine locomotives are not covered (their design could warrant a separate book!), and the focus for all types is on North American practice.

To provide an idea of the popularity of each type, at the top of each chapter is a summary of the total number built. This is easier to determine for some types than others: exactly 25 Big Boys (4-8-8-4s) were built, but understand that even the best estimate of the number of 4-4-0s is still a guess (somewhere around 25,000), with dozens of builders supplying hundreds of railroads in the 19th century. The totals come from several of what I consider to be the most reliable sources, including George H. Drury's *Guide to North American Steam Locomotives, Revised Edition*, Alfred W. Bruce's *The Steam Locomotive in America*, Robert A. LeMassena and Harold K. Vollrath's *Age of the Decapods*, and John H. White's *A History of the American Locomotive — Its Development: 1830-1880*.

THINGS AREN'T ALWAYS WHAT THEY SEEM

There are numerous instances where an individual wheel arrangement did not follow direct progression, where early examples did not have appreciable influence on later development. The 0-8-0 is case study: between

the 1840s and 1860s, locomotives using eight-coupled drivers without leading or trailing wheels were developed by several builders for heavy road freight service. By the mid-1860s the 0-8-0 fell out favor — it was strictly a slow-speed engine — and the type wasn't built again for several decades. However, the arrangement re-emerged in the early 20th century, becoming popular as a heavy switching locomotive. Technologically, the 0-8-0 switcher was an outgrowth of the 0-6-0 switcher, and in many respects did not follow a direct evolutionary line from early 0-8-0 road locomotives.

In other instances, trailing or leading wheels may have simply been added to an existing locomotive type, often to improve guidance or to reduce average axle weight, but these changes did not necessarily reflect the development of a new type. The Lehigh Valley, for example, experimentally applied trailing wheels to an early 2-8-0. While this technically created a 2-8-2, the experiment was unrelated to the advancement and technology of the “true” 2-8-2 Mikado decades later. To avoid confusion, each section mentions early examples that were a prelude to a type, but these are clearly distinguished from later technological development. Each type has also undergone significant evolution; thus an early light 2-8-2 may have a completely different appearance (and operating characteristics) compared to a bigger, heavier, late-era 2-8-2.

CLASSES AND RAILROAD DIFFERENCES

Although most railroads distinguished their fleets of steam locomotives by wheel arrangement, this method of categorization only hints at

USRA STANDARD DESIGNS

The swell of freight and passenger traffic on the eve of American military involvement in World War I, combined with other factors, caused the railroad network to congeal. Massive delays and backlogs of traffic had become so severe that by 1917 the congestion threatened America's industrial capacity and the nation's ability to supply its military in an efficient and timely manner.

In an effort to untangle this transportation quagmire, the U.S. government under President Woodrow Wilson effectively nationalized the railroad network by placing it under authority of the United States Railroad Administration (USRA). The goal was to improve traffic flow by streamlining interchanges, eliminating operational bottlenecks, and coordinating operations.

Among the challenges facing railroads had been individualistic approaches



The USRA in 1919 assigned 10 light 4-8-2s to New Haven. The railroad liked them enough to order 39 additional copies during the 1920s. Alco

toward motive power. The USRA established an engineering committee that included representatives from the three major locomotive manufacturers — Alco, Baldwin, and Lima — as well as key people from mechanical departments of major railroads, in an effort to introduce standard designs that would improve efficiency in production and maintenance.

Initially there had been discussion of selecting and promoting the most effective existing designs, but instead the engineering committee opted to draft a dozen new designs. These drew from the best ideas, minimized individ-

ual railroads' specialized engineering solutions, and created new designs for existing types that embraced simple, straightforward engineering principles that could be applied across all designs. Designs assumed a minimum capacity of least 50,000 pounds axle weight, while designing both "light" (type A) and "heavy" (type B) variations of four key types. The chart below lists the designs, which were introduced in 1918.

Locomotives were assigned to railroads by the USRA based on need — sometimes regardless of whether railroads agreed.

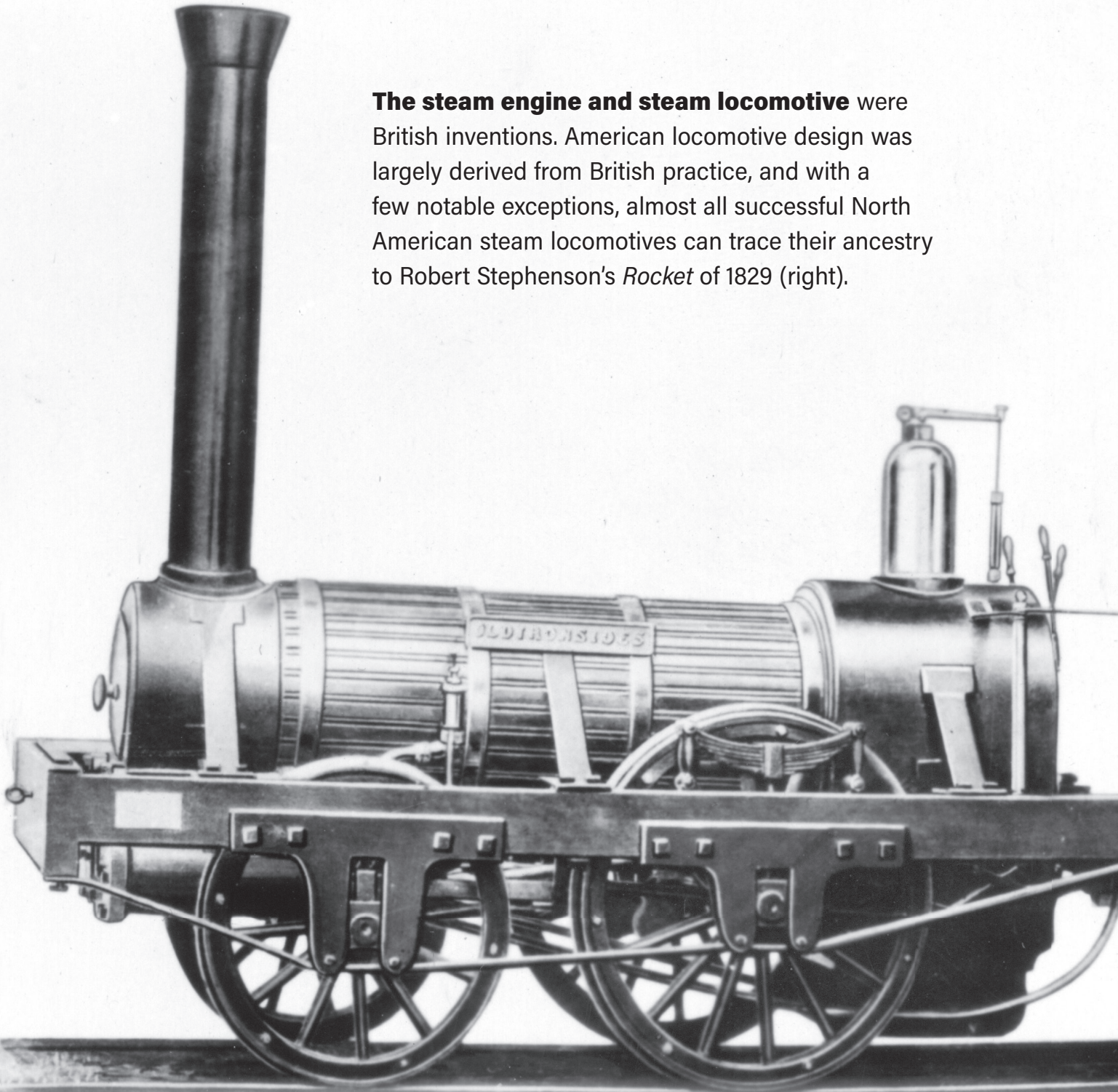
USRA TYPE	DRIVER DIA.	CYLINDERS (inches)	TOTAL ENGINE WEIGHT (lbs.)	WEIGHT ON DRIVERS (lbs.)	RATED TRACTIVE EFFORT (lbs.)	NUMBER BUILT
0-6-0	51"	21x28	163,000	163,000	39,100	255
0-8-0	51"	25x28	214,000	214,000	51,000	175
2-8-2 (light)	63"	26x30	292,000	220,000	54,700	625
2-8-2 (heavy)	63"	27x32	320,000	239,000	60,000	233
2-10-2 (light)	57"	27x32	352,000	276,000	69,600	94
2-10-2 (heavy)	63"	30x32	380,000	293,000	73,800	175
4-6-2 (light)	73"	25x28	277,000	162,000	40,700	81
4-6-2 (heavy)	79"	27x28	306,000	197,000	43,900	20
4-8-2 (light)	69"	27x30	327,000	224,000	53,900	47
4-8-2 (heavy)	69"	28x30	352,000	243,000	58,200	15
2-6-6-2 Mallet	57"	23, 35x32	448,000	358,000	80,000	30
2-8-8-2 Mallet	57"	25, 39x32	531,000	474,000	101,300	106

Figures from Drury, *Guide to North American Steam Locomotives, Revised Edition*

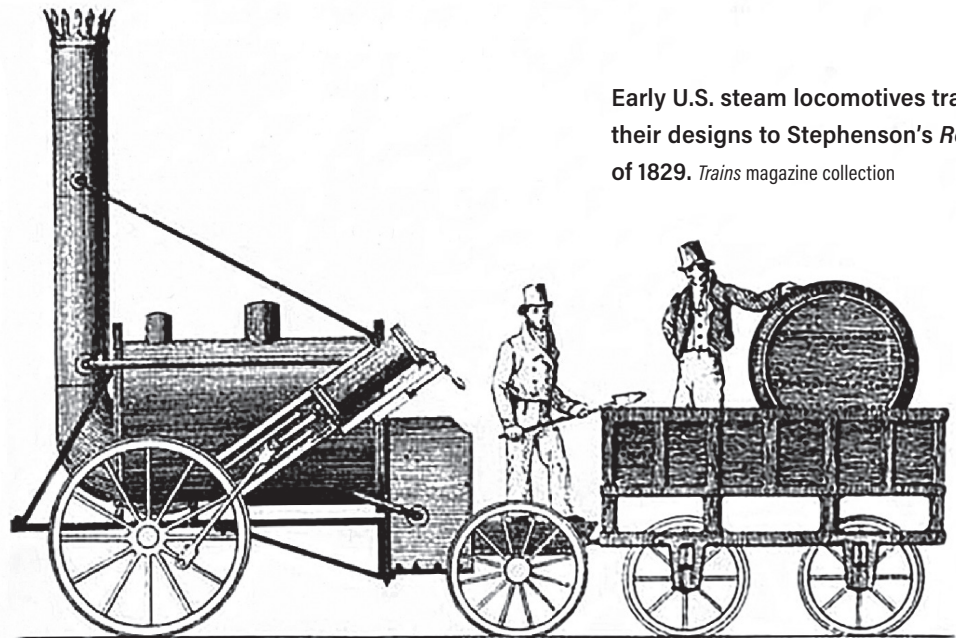
USRA control of American railroads continued for 26 months, with operations returned to the owning companies in 1920. By this time, 1,856 USRA standard locomotives had been built by Alco and Baldwin. Most numerous was the Light (Type A) 2-8-2 with 625 engines constructed. The USRA Standard plans didn't result in industry-wide locomotive standardization, and many railroads returned to the practice of custom-engineering locomotives for their specific needs; however, many railroads continued to order locomotives based on the USRA designs, which had a significant influence on new locomotives in the 1920s. Notably, the USRA 0-8-0 set the pattern for engines of this wheel arrangement built from 1920 onward, with at least 1,200 copies built to that design over the following three decades.

Early locomotive

The steam engine and steam locomotive were British inventions. American locomotive design was largely derived from British practice, and with a few notable exceptions, almost all successful North American steam locomotives can trace their ancestry to Robert Stephenson's *Rocket* of 1829 (right).



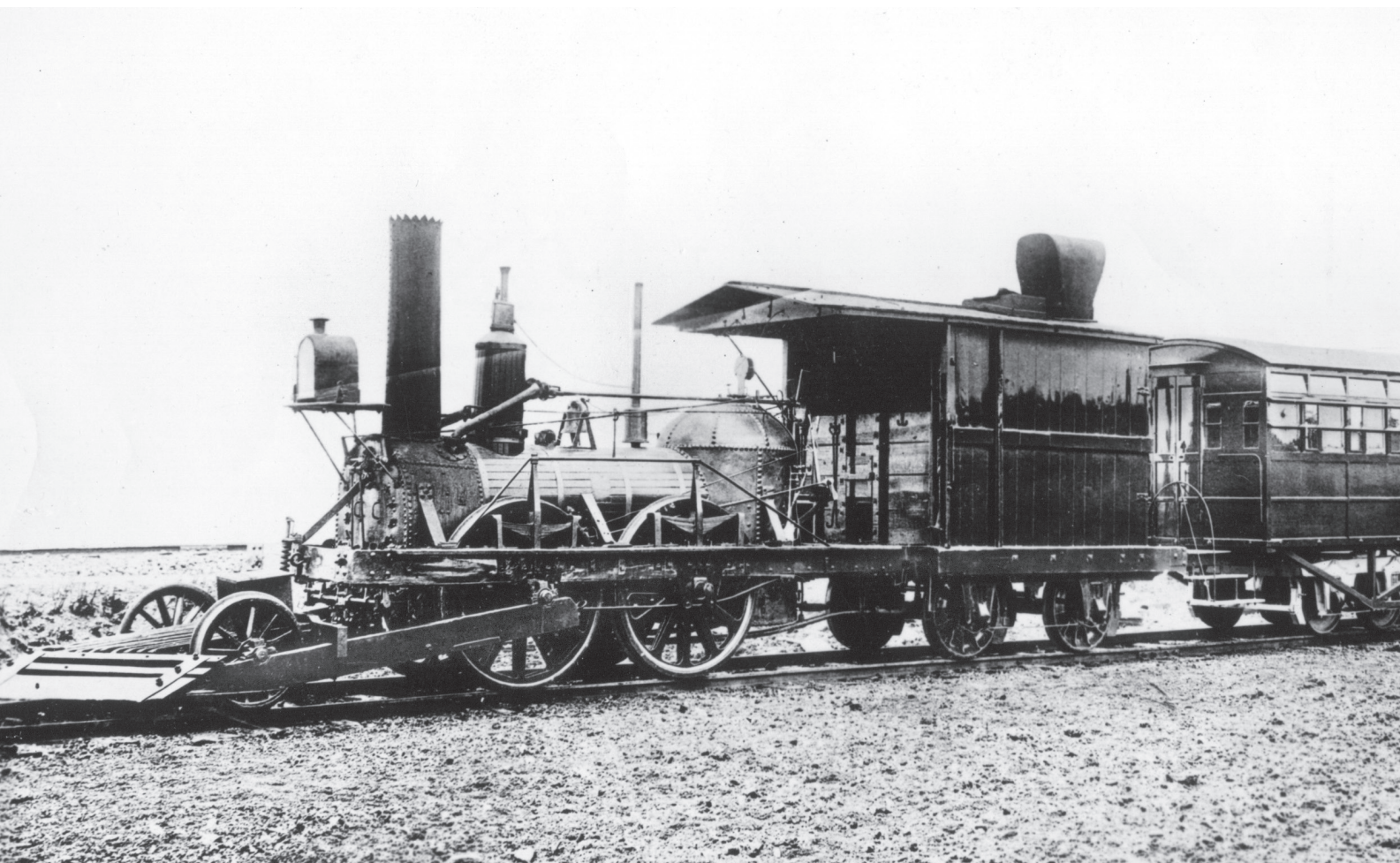
types



Early U.S. steam locomotives trace their designs to Stephenson's *Rocket* of 1829. *Trains* magazine collection



Old Ironsides, designed and built by Matthias Baldwin, made its first run in 1832 on the Philadelphia, Germantown & Norristown Railroad. The 5-ton locomotive was among the first steam locomotives built in the United States, and the first built by Baldwin. The rear (54" diameter) driving wheels powered the engine, which was technically a 2-2-0 under the Whyte system. *Trains* magazine collection



The British-built *John Bull*, constructed by Robert Stephenson and Co., first ran in the U.S. in September 1831 on the Camden & Amboy Railroad in New Jersey. The locomotive has been preserved and is on display at the Smithsonian Institution.

Trains magazine collection

The *Rocket* was the winner of the famous Rainhill Trials contest conducted by Britain's Liverpool & Manchester in October 1829. This milestone locomotive hit a top speed of 29 mph while demonstrating consistently reliable operation. More significantly, it was the first to blend three key elements common to most of the world's successful steam locomotives: a multi-flue fire-tube boiler, forced draft from cylinder exhaust, and direct rod connections between the pistons and driving wheels without using gears or other complicated mechanisms.

Rocket's equipment was arranged in reverse of later practice, with steeply angled cylinders engaging drive wheels from behind using an 0-2-2 wheel arrangement.

Stephenson soon refined this design, reversing the arrangement to produce a reliable 2-2-0 type known as a "Planet." These were built in large numbers during the early days of railroading, and many of the type were sold to railroads in the United States. Stephenson's 0-4-0 Sampson type was another early arrangement bought by American lines or emulated for domestic production in the 1830s and 1840s.

During the first several decades of railroad operation, American locomotive designers tried a variety of innovative, sometimes bizarre arrangements. Horatio Allen, who studied British railways and was involved importing Delaware & Hudson Canal Company's early engines from Britain (see Chapter 2, 0-4-0s), devised several

2-8-2

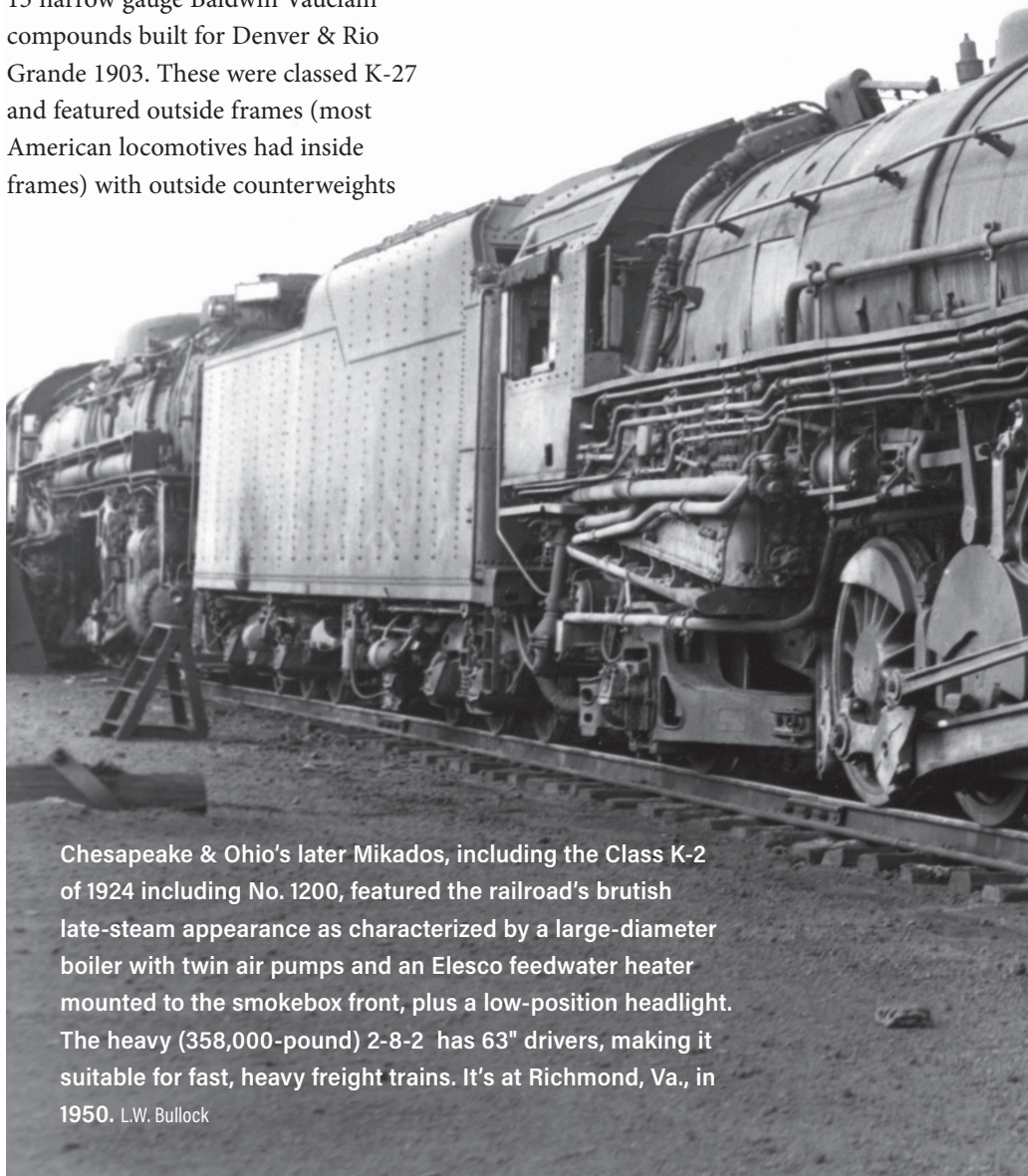
MIKADO

When the 2-8-2 type emerged in the early 20th century as a powerful machine, it ultimately supplanted the common 2-8-0 as America's preferred road freight locomotive. The Mikado eventually became by far the most common freight engine of the late steam era.

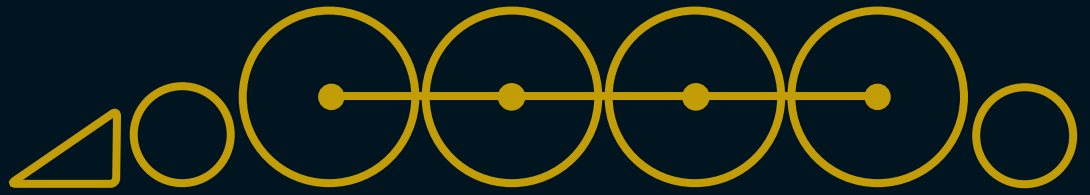
The 2-8-2 was a well-balanced design. Its evolutionary period straddled the advent of superheating, and the Mikado made great developmental strides with the advent of efficient modern appliances and advances in metallurgy. The great versatility of the 2-8-2 wheel arrangement saw many of the type survive in regular revenue traffic longer than many of the larger, more powerful, and more technologically advanced machines that superseded the 2-8-2.

The earliest known examples of the 2-8-2 are believed to be a pair of engines rebuilt by Lehigh Valley from unsuccessful 2-10-0s in the 1860s. These were a curiosity, and had little effect on later development. In the 1890s, Baldwin adopted the 2-8-2 wheel arrangement for export applications, first on some locomotives to Mexico, then more famously a batch to Japan in 1897. The great popularity of Gilbert and Sullivan's comic opera *The Mikado*, combined with the fascination with Japanese culture, led to adoption of the 2-8-2's common name. In 1902-1903, Baldwin built 15 2-8-2 Vaucain compounds for Santa Fe to work as helpers on Raton Pass; they were described as Mikados in period literature.

Also among the earliest domestic applications of the 2-8-2 were 15 narrow gauge Baldwin Vaucain compounds built for Denver & Rio Grande 1903. These were classed K-27 and featured outside frames (most American locomotives had inside frames) with outside counterweights



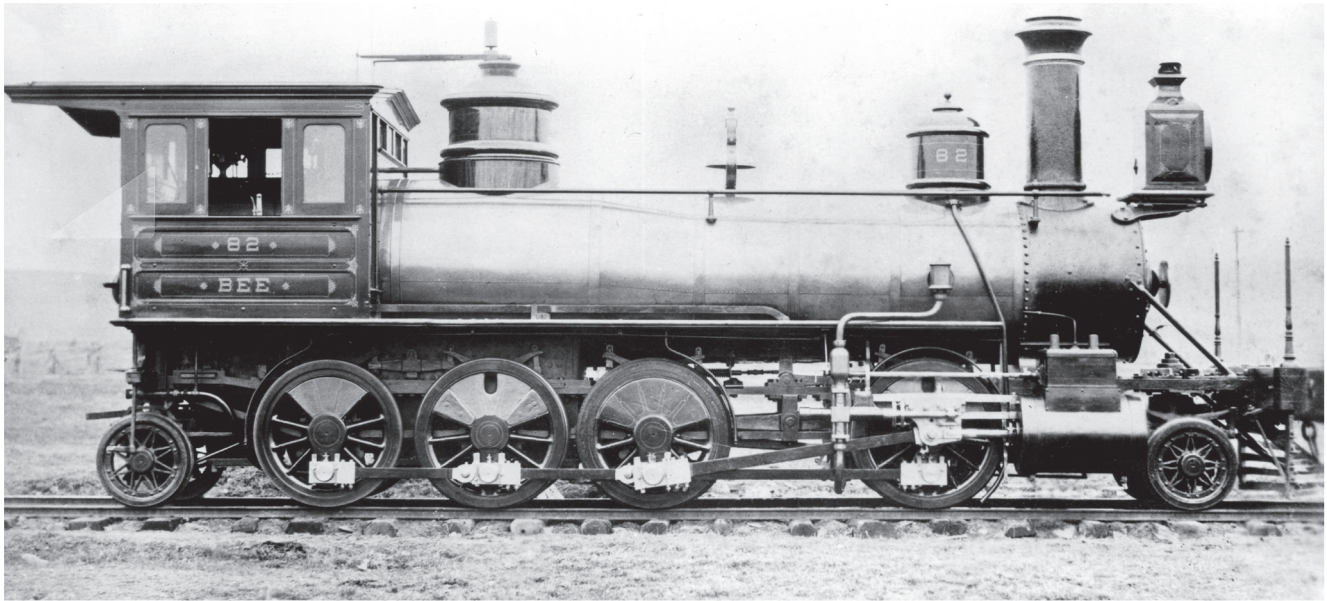
Chesapeake & Ohio's later Mikados, including the Class K-2 of 1924 including No. 1200, featured the railroad's brutish late-steam appearance as characterized by a large-diameter boiler with twin air pumps and an Elesco feedwater heater mounted to the smokebox front, plus a low-position headlight. The heavy (358,000-pound) 2-8-2 has 63" drivers, making it suitable for fast, heavy freight trains. It's at Richmond, Va., in 1950. L.W. Bullock



Total built: 21,000



2-8-2



Lehigh Valley 2-8-2 Bee is an evolutionary anomaly that predated the development of the 2-8-2 as a main-line engine by many years. Originally, this was one of Alexander Mitchell's pioneering 2-10-0s, built by Lancaster Locomotive Works in 1867. Lehigh Valley rebuilt it as America's first 2-8-2 in 1883, but the engine had little connection to the more refined 2-8-2 types developed in the early 1900s.

W.A. Lucas collection; general photo collection, Railroad Museum of Pennsylvania (PHMC)

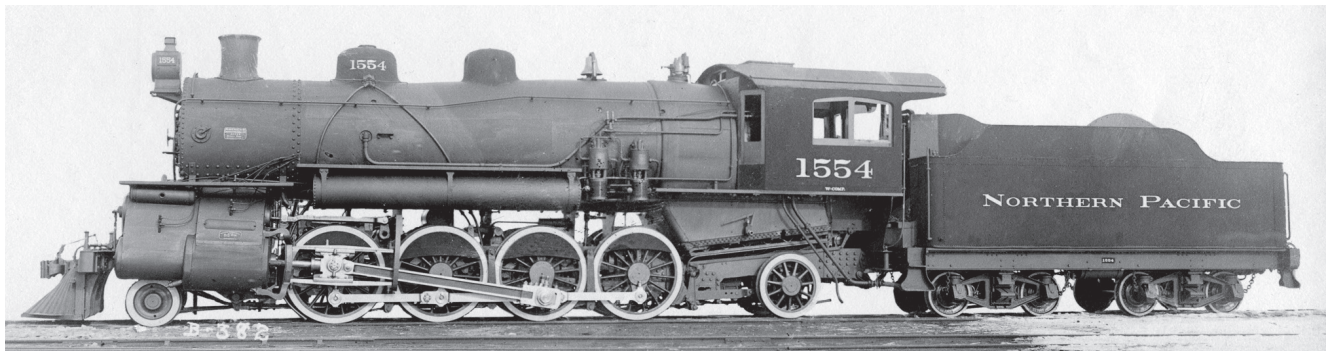
and crankpins. In their early days, Rio Grande's 2-8-2s were called "Monsters" because they were so much larger than typical narrow gauge power of the day (they were later known colloquially as "Mudhens").

Other early adaptations of the 2-8-2 wheel arrangement were engines built for small industrial railways, including timber-hauling lines, where weight distributed over four axles — with guiding wheels fore and aft — made for a flexible, bidirectional, lightweight machine that provided relatively high tractive effort on lightly built track.

The origin of the 2-8-2 as a main-line freight hauler was in 1903, when Baldwin built a pair Mikados for the obscure Bismarck, Washburn & Great Falls Railway. Undoubtedly, Northern Pacific was inspired by these engines, and in 1905 the NP placed a significant order with Alco's Brooks Works for large 2-8-2s. The NP, like railroads across the country, was experiencing a traffic surge, and the 2-8-2 with its larger boiler offered an economical means of moving greater tonnage.

Although a few of NP's early 2-8-2s were built as four-cylinder tandem compounds, most were conventional two-cylinder simple locomotives. These were built before the popular advent of superheating and are considered by some authorities as the zenith in saturated (non-superheated) steam freight locomotive development. The NP was impressed with the performance of its 2-8-2s and placed successive orders for the type, acquiring 160 of them between 1905 and 1907; it continued to order 2-8-2s for freight service, with some of the original engines serving the railroad for nearly half a century.

The 2-8-2 as a mainline engine offered several significant advantages over the 2-8-0, which had been America's standard heavy freight engine for a quarter century. Mainline Mikados were typically divided into two categories, light and heavy. Light Mikados weighed less than 300,000 pounds and were often the product of standard plans. These were well-suited for fast freight service in level



or lightly graded territory and for passenger work as well. In *The American Steam Locomotive, Vol. 1: Evolution*, Frank M. Swengel summed up the type by saying, “There are few locomotive designs that have remained as useful and undergone as little change as the light Mikados.” While interest in light Mikados is often overshadowed by the more impressive statistics of their heavy cousins, light 2-8-2s were more useful and more versatile, and for this reason tended to survive in road service longer. After they were displaced from their primary mainline duties by more modern engines, many light Mikados lasted to the end of steam in secondary service.

Heavy Mikados were certainly the most impressive of the type. These engines straddled the transition from strictly hand-fired engines to stoker-equipped locomotives. These were among the first locomotives where the stoker became a necessary improve-

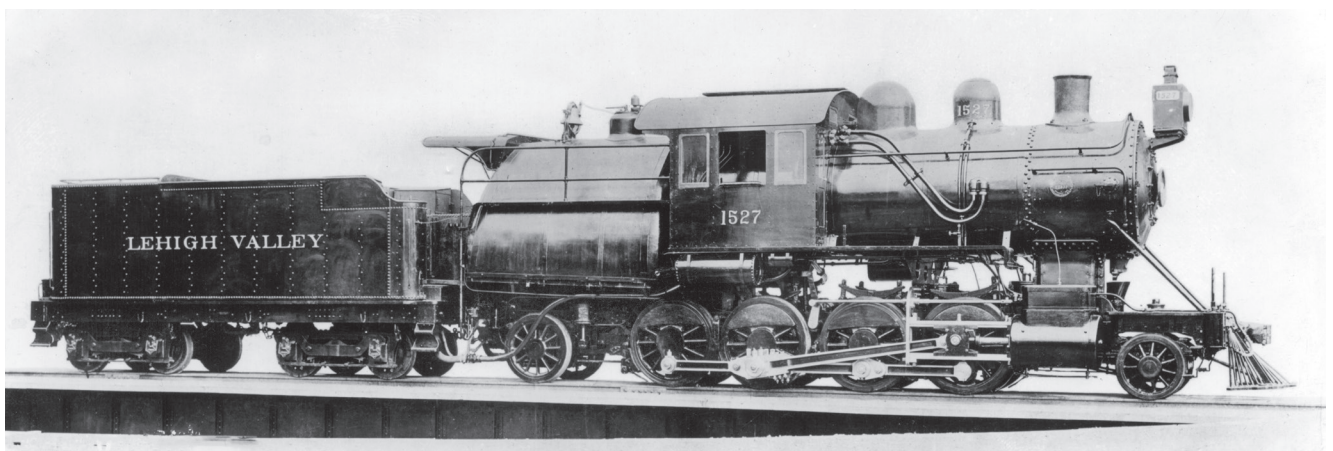
ment, required to maximize the potential of its voracious firebox capacity (as opposed to a luxury that simply made the fireman’s job easier). Although it wasn’t the first to use the type, Northern Pacific was the first railroad to place large orders for 2-8-2s. Initially, it bought 160 Class W engines built by Alco-Brooks between 1904 and 1907. This included about 20 engines, such as 1554, built as four-cylinder tandem compounds with 30x30-inch low-pressure cylinders situated behind 19x30-inch high-pressure cylinders. W.A. Lucas collection; general photo collection, Railroad Museum of Pennsylvania (PHMC)

Railroads developing heavy 2-8-2s included Chesapeake & Ohio, Erie, Lackawanna, Lehigh Valley, Missouri-Kansas-Texas, and Western Pacific. Among the most noteworthy fleets were the Pennsylvania’s L1s, which it developed in 1914 as a standard design in tandem with its K4s Pacific. The two locomotives shared many common components, including a high-capacity Belpaire boiler, much later

than other railroads. The PRR took delivery of 574 L1s Mikados between 1914 and 1919, many of which were built at the railroad’s Juniata Shops in Altoona; the remainder were built by Baldwin and Lima. Both light and heavy Mikados emerged as designs by the World War I-era United States Railroad Administration, whose designers produced exemplary patterns for these engines. The USRA’s “A-series 2-8-2” was its light Mikado (weighing about 293,000 pounds). It was a well-proportioned, well-balanced design that

Among the most unusual interpretations of the 2-8-2 were Lehigh Valley’s anthracite-burning Camelback Mikados. No. 1527 was built by Baldwin in the first decade of the 20th century. *Trains* magazine collection

Among the most unusual interpretations of the 2-8-2 were Lehigh Valley’s anthracite-burning Camelback Mikados. No. 1527 was built by Baldwin in the first decade of the 20th century. *Trains* magazine collection





On May 3, 1936, East Broad Top Baldwin-built 2-8-2 No. 12 leads a passenger train out of the 1,138-foot Wrays Hill Tunnel near Coles, Pa. The three-foot gauge EBT purchased six new 2-8-2s between 1911 and 1920. The first and smallest was No. 12. Although the railroad ceased common-carrier operation in 1956, portions of its line and its Mikados were preserved and since the 1960s have been a popular tourist attraction. Brian Solomon collection

Swengel praised for matching capacities of boiler and firebox with running gear. It was, in fact, so admired by American railroads that it was adopted as the basis for many notable locomotive designs after the war.

The USRA's B-series heavy Mikado employed a larger boiler and cylinders (27 x 32-inch compared to 26 x 30-inch) and used Baker valve gear in place of the Walschaerts employed on the A-series. Tractive effort for the heavy increased to 60,000 pounds, compared to 54,700 pounds for the light version.

In the 1920s, heavy 2-8-2 design was the focus of significant advanced development aiming to increase output, improve efficiency, and build a more reliable, more capable locomotive without adding unnecessary complexity. Most significant was the development of New York Central's Class H-10, built by Lima Locomotive Works under the direction of William Woodard. He started with the Central's already excellent H-7 Mikado of 1912, of which 120 were in service by the early 1920s. Woodard refined the design to obtain significant improve-



Minneapolis & St. Louis 2-8-2 No. 604 rests at Peoria, Ill., on Oct. 12, 1947. Between 1915 and 1921, M&StL bought 35 unusually light Mikados from Alco. They weighed between 252,500 and 259,000 pounds with 20x30-inch cylinders and 59" drivers. John E. Pickett collection



An Erie 2-8-2 leads Extra No. 3156 West out of Marion, Ohio. No. 3156 is one of 40 Class N-3 Mikes (Nos. 3155-3194) built by Baldwin for the Erie in 1923. They were retired around 1950. H. W. Pontin photo