Fun Time

Steam Locomotive Development in North America

Last time we explored some practical model railroad issues. If you've looked at model steam locomotives you probably noticed the many different kinds. But why were there all those different types of locomotives? So let's look at locomotive evolution on the real railroads.

How Do We Describe Steam Locomotives?

Before we can talk intelligently about the evolution of steam locomotives, we need to discuss how to describe or classify them. While there are different ways to do that, for the common rod locomotives, the most useful, and thus the most common, is called the Whyte system.

The Whyte system is fairly simple. Starting at the front of the locomotive, count the number of non-powered wheels in the front, or pilot, truck if any. Then count the number of driving wheels. Finally, count the number of non-powered wheels, if any, in the trailing truck behind the driving wheels. For example, a locomotive with four wheels in the pilot truck, six driving wheels, and two wheels in a trailing truck behind the drivers, would be described as a 4-6-2. A locomotive with two wheels on its pilot truck, eight drivers, and four wheels in its trailing truck would be described as a 2-8-4.

In addition to the wheel arrangement, other issues arise. The simplest is whether or not the locomotive has a separate tender for fuel and water. If not, there are water tanks and separate fuel tanks or bunkers on the locomotive; this is indicated by a "T" after the wheel arrangement to indicate *tank* locomotive, meaning no separate tender. An example is a 2-8-2T logging locomotive. Tank locomotives did not have the long range of locomotives with separate tenders, which carried more fuel and water, and were therefore used in short-range operations such as mining, logging, switching, and commuter service.

The above discussion concerns the rod locomotive, the most common design of steam locomotive, in which the driving wheels are moved by rods connected to the steam pistons. However, small, specialized locomotives used gear drive instead of rod drive. These were commonly used for track with sharp curves or steep slopes, such as are found in logging or mining operations. The most common geared locomotive designs are the Shay, Heisler, and Climax, named for their inventors or manufacturers. These are nearly all tank locomotives and are described by their names rather than a Whyte designation since all wheels are driven.

There were many different wheel configurations, and the most popular were even named for convenience when talking about them. But why were there so many? One reason was that railroads ordered steam locomotives custom-built to their specifications, so the variety of steam locomotives was greater than Diesels, which are far more standardized by their manufacturers. But that does not explain all the variations. Steam locomotives were built for different purposes; switching duties, freight hauling, and passenger hauling. Also, locomotive types evolved as operating requirements changed and technology improved.

Switching Steamers

Switch locomotives generally needed to be compact to operate effectively in freight yards. They also needed to have lots of pulling power, called tractive effort. To achieve these conflicting requirements, most had all their weight on their driving wheels, and did not use pilot trucks or trailing trucks. Pilot trucks help locomotives stay on the tracks, but because switch locomotives work at low speeds, they were able to operate safely without pilot trucks. Small switchers had four drivers, medium switchers had six drivers, and large switchers had eight or even ten drivers. These types are written:

0-4-0 0-6-0 0-8-0 0-10-0

The medium 0-6-0 was most common, followed by the 0-8-0. In addition to the locomotives specifically designed for switching duties, older, smaller freight locomotives were also commonly used for switching. This enabled the railroads to avoid buying specially designed switch locomotives and get extra use from their obsolescent small freight locomotives. For example, older 2-8-0 freight locomotives were commonly used for switching, as were, to a lesser extent, 2-6-0 and 2-8-2 locomotives.

Freight Steamers

Steam locomotives designed to haul freight initially had 2-wheel pilot trucks to keep as much weight on the drivers as possible for maximum tractive effort. Due to slow freight speeds, 2-wheel pilot trucks were generally sufficient; 4-wheel pilot trucks were not usually necessary. However, after WWI freight train speeds had to be increased due to competition from trucks, and 4-wheel pilot trucks became more common on freight locomotives for better tracking at those higher speeds. In addition, the 4-10-2 and 4-12-2 type freight locomotives were 3-cylinder designs and needed the larger 4-wheel pilot truck to support the additional weight of a third, center piston and cylinder.

At first, trailing trucks were not needed. However, locomotives became larger and more powerful as the need to haul larger, heavier trains increased. Eventually the firebox on some locomotives became too large to fit in the space between the aft wheels and was often extended behind them. Two-wheel trailing trucks were needed to support the greater weight of the enlarged firebox that often extended behind the driving wheels. In addition, the Santa Fe railroad faced a situation where, in one mountainous location, their 2-10-0 helper locomotives had to back down the mountain for a long distance. To help them move backwards faster without derailing, a 2-wheel trailing truck was added to create a 2-10-2. So while the trailing truck came into use primarily to support larger fireboxes, it also enabled locomotives to run backwards safely at higher speeds.

Initially, the tractive effort of steam locomotives, their pulling power, was the most important criteria because it determined the size of the train they could start and pull. After WWI the need for greater power to move trains faster resulted in a number of innovations, and in particular a new locomotive type with much larger firebox for more power. This larger firebox required a larger, 4-wheel trailing truck for support, and the 2-8-4 type was developed. This was the first of the so-called *super-power* locomotives, and introduced the final development stage in steam locomotives that was soon followed by the 2-10-4, 4-6-4, 4-8-4, and modern articulateds.

Another path of development led to large articulated locomotives. These locomotives had two sets of drivers supporting a single boiler. To enable these huge locomotives to go around curves, the forward set of drivers was articulated, or allowed to turn with respect to the rear set of drivers, that were built solid with the firebox and frame of the locomotive. A typical articulated locomotive would be designated 2-8-8-2, which means the locomotive had a 2-wheel pilot truck, two sets of eight drivers, and a 2-wheel trailing truck.

Technology also improved as engineers worked to improve safety and efficiency. In addition to tractive effort and power, fuel efficiency was critical and two important technical developments were applied in the 1900–1920 timeframe to improve it. First was the feedwater heater, a device to heat the cold water before it was injected into the boiler. The feedwater heater reduced the fuel needed to heat the cold feedwater by heating the feedwater using waste heat before it was injected into the boiler. This also helped the fireman maintain proper steam pressure and water level in the boiler when adding feedwater. The second device was the superheater, which heated the steam to higher temperature than was needed just to produce the steam. The hotter steam was thermodynamically more efficient and also reduced the problem of steam condensing to water after it contacted the pistons. Not only were the feedwater heater and superheater applied to new locomotives, they were also retrofitted to many existing locomotives to increase their fuel efficiency.

Yet another technique applied to steam locomotives to improve their fuel efficiency was compounding. Compounding means running the steam through the pistons more than once. So-called simple steam engines run the steam through the piston once, then it is exhausted to the air. In contrast, a compound steam engine runs the steam at high pressure to the first piston; the exhaust of that high-pressure piston is then run to a larger low-pressure piston to extract additional work from the same steam. While theoretically more fuel efficient, compounding generally resulted in slow-speed locomotives and required much more maintenance than a simple steam locomotive – a very serious problem given that simple steam locomotives already required considerable maintenance. Although compounding was used on a number of steam locomotives, many, perhaps most, compound steam locomotives were eventually converted to simple steam locomotives without loss of efficiency and with a gain in speed and maintainability. Except for a few experiments, no simple steam locomotives were converted to complex locomotives.

The *general* evolution of freight steam locomotive types by wheel arrangement is shown below, with the arrows indicating the direction of development. For example, the 2-10-4 was an enlarged 2-8-4 and was not, as one might suppose, developed from the 2-10-2, which was an earlier design. Although the first 2-10-4 was actually a 2-10-2 modified to have a 4-wheel trailing truck, this was a one-of-a-kind prototype that was not developed further. All other 2-10-4 locomotives were developed from the 2-8-4 type, which was a ‘super-power’ locomotive with larger firebox.

2-6-0 ⇒ 2-6-2

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2-8-0 ⇒ 2-8-2 ⇒ 2-10-2 ⇒ 4-10-2 ⇒ 4-12-2 ⇒ 4-6-6-4 ⇒ 4-8-8-4

⇓ ⇓ (articulated) (articulated)

2-10-0 2-8-4 ⇒ 2-10-4

Articulated Freight Steamers

0-8-8-0 ⇒ 2-8-8-0 ⇒ 2-8-8-2 ⇒ 2-8-8-4

⇓

4-8-8-2 (Cab Forward)

Passenger Steamers

Passenger steam locos usually had 4-wheel pilot trucks for better tracking at the higher speeds used by passenger trains. Furthermore, their driving wheels were larger diameter than those of

freight locomotives to enable higher speeds to be reached. The *general* development of steam locomotives designed for passenger service is shown below.

4-4-0 ⇒ 4-4-2 ⇒ 4-4-4

⇓ ⇓

4-6-0 ⇒ 4-6-2 ⇒ 4-8-2 ⇒ 4-8-4

⇓

4-6-4

The 4-6-4 was used for high-speed passenger service on routes with shorter trains or that were nearly level. In the West the passenger trains were fewer and longer than in the East, requiring more powerful locomotives to handle larger trains over mountains. The larger, more powerful 4-8-4 became the ultimate passenger steamer and was also powerful enough for use as a fast freight locomotive.

Although early articulated locomotives were usually too slow for passenger service, there were at least two notable exceptions among modern articulated locomotives. The Union Pacific Railroad designed their Challenger type 4-6-6-4 for dual service, and this type was so successful it was purchased by a number of other railroads. And newer versions of the Southern Pacific's unique Cab Forward articulated locomotives had 4-wheel pilot trucks and were capable of the higher speeds required by passenger trains. The mighty Cab Forwards were used in passenger service over mountain routes.

In addition to the dual-service articulated locomotives noted above, some other locomotives, mostly 4-8-4 types, were designed with both freight and passenger service in mind. Finally, passenger trains were often pulled by steam locos designed for freight service when passenger locomotives were not available.

Southern Pacific's Unique Cab Forwards

Due to the extensive length of snow tunnels on the Southern Pacific's difficult route over the Sierra Nevada Mountains (Donner Pass), the SP found that the smoke and fumes from the large 2-8-8-2 articulated locomotives they attempted to use over this route asphyxiated the locomotive's crew. The unorthodox solution was to run the locomotive in reverse; the crew went through the tunnel before the smokestack and thus were able to breathe. This was possible because the SP had already moved to heavy bunker oil instead of coal to power most of their locomotives. SP then ordered a very successful series of Cab Forward locomotives that eventually totaled 256 engines. There were a number of series and types as described below.

Class AM-2: Ordered for fast passenger service, these 2-6-6-2 locomotives were quickly converted to 4-6-6-2 configuration for better tracking after derailments due to their 2-wheel pilot trucks early in their career. Originally MM-2 compound locomotives, they were converted to simple locomotives and re-designated class AM-2. Used as freight locomotives for most of their lives, they were retired in 1948.

Classes AC-1, -2, and -3: Slow but powerful 2-8-8-2 compound locomotives ordered for freight service, they were originally designated classes MC-4 and MC-6 but were re-designated classes AC-1, -2, and –3 when converted to simple locomotives. Despite their slow speed, these were often used for passenger service over the steep, difficult Donner Pass, where no locomotive was very fast. Three production batches of essentially identical locomotives; the last were retired in 1948. All subsequent AC classes were designed and built as simple locomotives for higher speed and reduced maintenance.

Classes AC-4, -5, and -6: Powerful, fairly fast 4-8-8-2 locomotives ordered for fast freight service, they were distinctly more modern than the earlier AC classes in all respects. The AC-6 batch differed in steam pressure and minor details from the AC-4 and AC-5 batches. Much faster than earlier Cab Forwards and used in passenger service in the mountains, all lasted until the end of steam.

Classes AC-7, -8, 10, 11, and -12: Powerful, fairly fast 4-8-8-2 locomotives ordered for fast freight service and also used in passenger service in the mountains. These were five batches of essentially identical locomotives that lasted until the end of steam. The very last built, AC-12 #4294, rests in the California Railroad Museum in Sacramento; it is the only surviving Cab Forward.

Class AC-9: Conventional (cab aft) 2-8-8-4 locomotives ordered for fast freight service. These were coal-burning locomotives intended for use in the desert where there were no snow tunnels, so the cab forward configuration was not needed. Designed to the same technical specifications as the late Cab Forwards, they were converted to oil burners in the early 1950s and lasted until 1955.

American Steam Locomotive Wheel Arrangements

Here is a summary of the most common American steam locomotive types. With few exceptions, such as the 2-8-8-2, common wheel arrangements were named.

Whyte	Common Name	Notes
0-4-0	Four-coupled	Switch engine
0-4-4T	Forney four-coupled	Industrial use
0-6-0	Six-coupled	Switcher
0-6-4T	Forney six-coupled	Industrial use
0-6-6-0	none	First articulated Mallet in USA
0-8-0	Eight-coupled	Switcher
0-8-8-0	Angus	Low speed helper locomotive
0-10-0	Ten-coupled	Heavy switcher
0-10-2	Union	Heavy switcher; 5 built for Union RR, Pittsburg
2-4-4-2	none	Smallest articulated, used for logging
2-6-0	Mogul	Freight
2-6-2	Prairie	Dual use
2-6-4T	none	Suburban passenger service
2-6-6-2	none	Freight
2-6-6-4	none	Freight
2-6-6-6	Allegheny	Freight
2-6-8-0	none	Freight, used by GN and Southern
2-8-0	Consolidation	Freight
2-8-2	Mikado	Freight
2-8-4	Berkshire	Freight, first *super-power* locomotive
2-8-8-0	Bull Moose	Freight
2-8-8-2	none	Freight
2-8-8-4	Yellowstone	Freight
2-8-8-8-2	Triplex	Freight (one 2-8-8-8-4 was built)
2-10-0	Decapod	Freight
2-10-2	Santa Fe	Freight, Santa Fe RR was first user
2-10-4	Texas	Freight, Texas & Pacific RR was first user

2-10-10-2	none	Freight, used by Santa Fe and Virginian railroads
4-2-2	Bicycle	Dual purpose
4-4-0	American	Dual purpose, widely used early type
4-4-2	Atlantic	Passenger
4-4-4	Jubilee	Passenger
4-6-0	Ten-wheeler	Passenger
4-6-2	Pacific	Passenger
4-4-4-4	Duplex	Passenger
4-4-6-2	none	Passenger
4-4-6-4	Duplex	Freight
4-6-6-2	Cab Forward	Passenger
4-6-6-4	Challenger	Dual purpose
4-8-0	Twelve-wheeler	Freight, also called Mastodon
4-8-2	Mountain	Passenger, NYC called theirs Mohawk
4-8-4	Northern	Passenger, Northern Pacific was first to use, some railroads used other names
4-8-8-2	Cab Forward	Dual purpose
4-8-8-4	Big Boy	Freight
4-10-0	Mastodon	Freight, one built for Central Pacific
4-10-2	Southern Pacific	Freight, Southern Pacific was first to use
4-12-2	Union Pacific	Freight, Union Pacific was first to use
6-4-4-6	The Big Engine	Passenger, one built for PRR
6-8-6	none	Dual purpose, one built for PRR

Summary

You now have a basic overview of steam locomotive development, with a special look at the Southern Pacific's unique Cab Forwards. For further information, check the books and other resources below.

Resources

Railroad Books & Videos:

- If you want more information on steam locomotives, this is probably the first book to read: *Guide to North American Steam Locomotives* by George H. Drury, Kalmbach Publishing Company (December 1993), ISBN-10: 0890242062
- *American Steam Locomotive* by Brian Solomon, MBI (May 23, 1998), ISBN-10: 0760303363
- *Cab-Forward: The Story of Southern Pacific Articulated Locomotives* by Robert J. Church, Central Valley Railroad Publications; Revised Edition edition (1982), ASIN: B0006EDVP6
- *Perfecting the American Steam Locomotive* by J. Parker Lamb, Indiana University Press (June 2003), ISBN-10: 0253342198
- *Model Railroader Cyclopedia: Steam Locomotives* by Linn Westcott, Kalmbach Publishing Company (June 1980), ISBN-10: 0890240019

Websites and Online:

- Steam locomotive site: www.steamlocomotive.com

- Extreme steam locomotives; unusual variations on the steam locomotive: www.dself.dsl.pipex.com/MUSEUM/LOCOLOCO/locoloco.htm
- Yahoo groups on prototype railroads and model railroading, such as:
    - Southern Pacific Railroad: Espee@yahoogroups.com
    - Union Pacific Railroad: up_modelers@yahoogroups.com