Fun Time

Turbine and Diesel Locomotive Development in North America

Last time we explored steam locomotive evolution on North American railroads, so it is only natural to follow that with a discussion of the locomotives that replaced steam, the turbine and Diesel locomotives.

Why Diesel Locomotives?

As you may have noticed, I love steam locomotives. They are huge, powerful, impressive, have their own distinct personality, and they changed the world by making railroads practical. However, they have a number of drawbacks, and if I owned a railroad, that railroad would use Diesel locomotives despite my love of steamers. Why is that?

The most important reason Diesels replaced steam locomotives is economic. First, Diesels need far less maintenance than steam locomotives, which translates into much lower costs due to a far smaller maintenance workforce and smaller facilities. The difference in maintenance costs between steam and Diesel is huge and therefore compelling. Whereas steam locomotives changed the world, Diesel locomotives changed the economics of railroading. In addition to lower maintenance costs, Diesels also do about twice the amount of work as steamers with the same amount of fuel. The difference in fuel cost is very important, especially with today’s oil prices. Of course, steam locomotives could also coal and wood for fuel, something Diesels cannot do.

Another Diesel advantage is that they are easier on the track, reducing track maintenance requirements. There are two reasons for this. First, the unbalanced dynamic forces of the driving mechanism on steam locomotives pounded the track, loosening the spikes and ties. Second, the driving wheels of steam locomotives have a longer wheelbase than Diesels, so when steamers go around curves they try to spread the track apart much more than Diesels do, creating more track wear and more maintenance to do.

Diesels also have some operational advantages over steam locomotives. Diesels are easier and faster to start and get into operation, they don’t need to stop for water or other consumables nearly as often as steamers, and they can have dynamic brakes. As mentioned in an earlier column, dynamic brakes are the ability of the Diesel, when going down grades, to get braking from the Diesel engine. This greatly simplifies and speeds operations in areas with grades.

Finally, and increasingly important, Diesels are cleaner than steamers. Steam locomotives were noted for their heavy smoke pollution, which made them unpopular in cities even before the environment was nearly as big a concern as it is today. Although not pollution-free, Diesels essentially solved this problem.

The Competitive Environment

Diesel engines for locomotives got their start in the 1920s when railroad management was looking for cheap passenger transportation for routes with low ridership. These routes had too few paying passengers to make steam-powered passenger trains economic, and management looked for cheaper ways of addressing this need. Internal combustion engines, first gasoline, later Diesel, were tried in self-propelled passenger cars, and their operational success led to designs for Diesel powered switch engines.

Early Diesel locomotives had neither the power nor sturdiness to replace steam in mainline freight service, but from the 1930s they gradually proved their reliability in switching duties. As locomotive manufacturers and railroads became more experienced with Diesels, more powerful Diesels were developed that were successfully applied to streamlined passenger trains in the late 1930s. By 1940 the Diesel (in the form of the FT series from the Electro-Motive Division of General Motors, formerly the Electro-Motive Corporation) had finally proved itself in mainline freight service, and the writing was on the wall for the future of steam.

However, replacing steam locomotives, especially in heavy freight service, was not easy. By the late 1920s modern steam locomotives were developing more than 6,000 hp. The most powerful steamers ever measured were the 2-6-6-6 Alleghany at 7,500 hp and the Pennsylvania Railroad's 4-4-6-4 Q-2 at 8,000 hp; both were production steamers delivered in the 1940s. The Pennsylvania Railroad's huge 6-4-4-6 S-1 passenger locomotive, exhibited at the 1939/1940 World's Fair in New York, was measured at 7,200 hp and could easily pull a 1,200 ton passenger train at 100 mph. The impressive performance of modern steam locomotives raised the bar for competing Diesels and led many at the time to question whether Diesels would ever demonstrate the toughness and performance to replace steam, especially in heavy freight service.

In stark contrast, early Diesel locomotives were typically rated at 1,500 hp, far less than large steamers. So passenger and freight Diesels were designed from the outset to operate in sets of three, four, or more to deliver the needed power. In essence the Diesel was a modular locomotive; the railroads just hooked together as many as necessary. And they were connected so one engineer controlled the entire set. In contrast, steam locomotives required a separate crew for each locomotive. The most powerful Diesel locomotive ever to see service, the Union Pacific's Centennial series, incorporated two Diesel prime movers (engines) into one chassis and had a total of 6,600 hp. Today's most powerful Diesels develop 6,000 hp with a single engine. Yet even today's Diesels are not as powerful as the steamers of the late 1920s!

The Impact of External Events

The most important external event affecting the steam to Diesel transition in America was World War II. Preparation for the war and the war itself generated ever increasing amounts of railroad traffic just as the Diesel was proving itself in mainline freight service. Some railroads were early adapters of Diesel power and had ordered or already received substantial numbers of freight Diesels by 1941. But Pearl Harbor and America's entry into the war as a direct combatant changed everything. First, traffic immediately soared to new highs, resulting in an extreme demand for motive power. Second, the War Production Board assumed control of locomotive production. With high demand for large Diesel engines from the Navy for submarines and landing craft, very few Diesel locomotives were built for the railroads. The result was a number of railroads that ordered Diesel locomotives during the war, or wanted to do so, were forced to settle for steam locomotives.

With the end of the war, the railroads were exhausted and their locomotives, rolling stock, and track were all suffering from deferred maintenance due to higher wartime priorities for the resources. Many steam locomotives were simply worn out, and many others, having been recalled from retirement when the war started, were obsolete. All these locomotives needed to be replaced, and almost without exception they were replaced with Diesels.

Diesel Evolution

As already noted, the first Diesel locomotives were relatively small, low-powered models for switching duties. These were not intended for use at high speed so were boxy, non-streamlined locomotives with cabs featuring large windows for good all-around visibility in the freight yard environment. Power for these locomotives was typically 900–1200 hp.

The next Diesel locomotives were larger, more powerful models designed to haul streamlined passenger trains. For esthetic and marketing reasons they were streamlined and painted to match the passenger cars. Initially, the same locomotive types, suitably geared down for more pulling power and lower speed, were also used for freight trains. These locomotives were generally of 1,500–1,750 hp, with some as high as 2,250 hp.

The next step in Diesel locomotive fashion was the road-switcher, a type that combined the boxy look and high visibility cab windows of switch engines with the larger size and greater power of passenger and freight Diesels. These locomotives were marketed to the railroads as versatile, dual-purpose locomotives equally suitable for road freight hauling and switching duties. By the end of the 1950s, the greater visibility from the road switcher compared to streamlined Diesels proved decisive, and all new locomotives were essentially designed to be road switchers; streamlined Diesels were no longer being produced.

By the late 1950s Dieselization was complete on major North American railroads, and railroad managements were looking for more powerful Diesels to reduce the number of units they had to purchase and maintain. Developing more powerful prime-movers (as the engine itself is called) was difficult and expensive for the locomotive manufacturers, and they had little incentive to do so and thereby reduce demand for the number of locomotives required. Railroad management was forced to pursue different alternatives.

Union Pacific Railroad decided to turbo-charge some of their Diesels to get more power. Their efforts, with reluctant support from the manufacturer, were successful and the manufacturer started offering new, more powerful turbo-charged locomotives.

After studies indicating that Diesel maintenance costs were essentially independent of the unit's size and power, Union Pacific also specifically requested locomotives from the manufacturers with two engines to create more powerful units. The resulting dual-Diesel locomotives were used for some time by the Union Pacific, but with one exception remained unique to it. Only the Southern Pacific purchased a handful of these dual-engine units for evaluation and did not follow up with more orders.

The Southern Pacific, faced with problems similar to those experienced by the Union Pacific, finally went to foreign manufacturers for more powerful Diesels. The SP imported some German units with 4,000 hp engines at the time when 2,400 hp was about the best American manufacturers offered. This was intended not only to get more powerful locomotives for the SP, but also to put pressure on American manufacturers to offer more powerful locomotives.

In addition to their greater power, these German units had another innovation. Most Diesel locomotives use Diesel-electric drive. This means the Diesel engine powers an electrical generator, and the current from that generator is used to power traction motors on each driving axle of the locomotive. The problem was that traction motors of the time were limited to 500 hp, limiting the power per axle. The German locomotives were hydraulic drive; their Diesel engine drove a hydraulic pump that powered hydraulic motors in the trucks. This eliminated the power per axle limitation of the traction motors. While successful in Europe, hydraulic drive was less successful in American operating conditions. There were several reasons for this, including that American railroaders were used to traction motors and the hydraulic drive Diesels were therefore viewed as an odd, foreign innovation at a time, the early 1960s, when things American were definitely preferred to things foreign on the railroads.

The net result of the pressure from the railroads – especially UP and SP – for more powerful Diesel locomotives was that American locomotive manufacturers decided they had better develop more powerful locomotives or risk losing their market. Soon more powerful locomotives using a single, more powerful prime-mover and more powerful traction motors were being offered by the manufacturers and eagerly purchased by the railroads.

Steam Turbine Tangent

Although Diesel locomotives have dominated the discussion to this point, Diesels were not the only new type of power investigated to replace conventional steamers. Two different types of turbine engine, the steam turbine and the gas turbine, were also tried.

By the late 1930s steam turbines had been in use in ships and stationary power plants for many years. This successful experience, coupled with the familiarity of steam, lead to steam turbines being tried in locomotives. The first steam turbine locomotive was made by General Electric Company for the Union Pacific in 1938 for hauling a streamlined passenger train. The two units built worked, but, like all new technology, had teething troubles. After six months of testing the units were withdrawn from service.

The Pennsylvania Railroad, the Chesapeake & Ohio, and the Norfolk & Western railroads all tried their own versions of steam turbine locomotives. Pennsy received one coal-burning steam turbine locomotive in 1944. Using a gear drive from the turbine, it was a fast, powerful, 6,900 hp locomotive that could out-pull anything on rails at the time and was used in passenger service. Unfortunately, at low speeds it used enormous amounts of coal and water, and eventually it was scrapped in favor of Diesel locomotives.

The C&O built three coal-burning steam turbines in 1947 and 1948 using turbine-electric drive. These huge units were simply too complex and unreliable; by the middle of 1948 the C&O decided to Dieselize. The final steam turbine locomotive was delivered to the N&W in 1954. Like the C&O steam turbines, it was coal-burning and used turbine-electric drive. It was smaller and less complex than the C&O turbines and much more successful, but still was scrapped in 1958 in favor of Diesels.

Locomotives are much less benign operating environments than ships and power plants. They vibrate more, are subject to much more mechanical shock, and constantly change speeds. Furthermore, the need for a compact design to fit on the rails makes it more difficult to keep coal dust out of the rest of the mechanism, especially the traction motors and other electrical components. While these problems are solvable with time and effort, the Diesel was, by this time, a readily-available, proven solution. Railroad management had many other demands for their attention and investment, and Diesels were the easy choice.

Gas Turbines – the Big Blow

While the steam turbine locomotive was quickly discarded in favor of the Diesel, the gas turbine locomotive was more successful.

In America the gas turbine locomotive was a joint development of GE and the Union Pacific, last seen together in 1938 trying a steam turbine without great success. However, during World War II GE was given a prototype jet airplane engine developed in Britain and was asked to manufacture it in America for warplanes. GE went on to become a major jet engine manufacturer. Post war, GE wanted to expand their jet engine market and UP wanted more powerful locomotives than the 1,500 hp Diesels then on offer. The result was a gas turbine locomotive of 4,500 hp. The prototype was demonstrated to several railroads but only UP ordered production models in three distinct production batches and variations. Delivery of the 4,500 hp production model started in 1952; the final version, initially rated at 8,500 hp and later up-rated to 10,000 hp, was delivered from 1958 and remains the most powerful locomotive in history. Like Diesels, these gas-turbine locomotives used generators and traction motors to power their wheels.

The gas turbine locomotives had much more power than competing Diesels, which was a key advantage for the Union Pacific. Used for hauling heavy freight trains over long distances, the turbines were initially very useful to UP. The turbines used heavy oil that was relatively cheap at first, but later became more expensive as more uses were found for it. The turbines were reasonably efficient at full power, where they were intended to operate, but guzzled fuel at rest and low power. In addition, like any jet engine they were noisy, a characteristic that gave the final model their nickname of the “Big Blow”. While the noise could be tolerated on much of UP’s route system over the Great Plains, it was not acceptable in heavily-populated areas.

Union Pacific’s turbine story would not be complete without mention of their prototype coal turbine. Unlike earlier coal-burning turbines, which burned the coal to produce steam that then powered the turbine, this prototype burned powdered coal in the turbine itself. In contrast, conventional gas turbines burned liquid fuel in the turbine. This locomotive was built in 1962 by the UP in conjunction with GE and Alco (American Locomotive Company) and tested in revenue service for some time. Along with coal particles causing problems with the electrical components, as experienced earlier by the C&O and N&W prototypes, the powdered coal eroded the turbine blades too quickly and the experiment was eventually dropped.

Although a few specifically-designed turbine-powered passenger train sets were active into the 1980s, high fuel consumption and noise spelled the end of the gas turbine locomotive in general service.

Summary

You now have a basic overview of Diesel and turbine locomotive development. While turbines offer some advantages, continued development of the Diesel provided a practical and economic solution to the railroads without the time, effort, and resources required to bring the turbine to a comparable state of practical development. For now, the Diesel locomotive reigns supreme. However, as petroleum becomes more expensive and harder to find, might the coal turbine and coal-steam turbine be investigated again?

For further information, check the books and other resources below.

Resources

Railroad Books & Videos:

- For much more information on development of both steam and Diesel locomotives on one of America's most famous railroads, read: *Santa Fe Locomotive Development* by Larry E. Brasher, Signature Press (2006), ISBN: 978-1-930013-20-9
- For information on Union Pacific's turbine locomotives and dual-Diesel locomotives, read: *Giants of the West: A Pictorial Presentation of Union Pacific's Super Powered Locos* by George R. Cockle, Overland Publications (1981), ISBN-10: 0-916160-12-2
- For more information on Union Pacific's turbine locomotives, read: *Union Pacific's Turbine Era* by A. J. Wolff, Withers Publishing (2001), ISBN-10: 1-881411-30-3
- Another useful book on Union Pacific's turbine locomotives is: *Turbines Westward* by Thos. R. Lee, T. Lee Publications (1975), ISBN-10: 0-9162-44-01-6
- *Model Railroader Cyclopedia: Diesel Locomotives* by Bob Hayden, Kalmbach Publishing Company (June 1980), ISBN-10: 0890245479

Websites and Online:

- EMD Diesel locomotive site: en.wikipedia.org/wiki/Template:EMD_diesels
- GE Diesel locomotive site: en.wikipedia.org/wiki/List_of_GE_locomotives
- List of ALCO diesel locomotives: en.wikipedia.org/wiki/List_of_ALCO_diesel_locomotives
- Gas turbine-electric locomotive site: en.wikipedia.org/wiki/Gas_turbine-electric_locomotive
- Steam turbine locomotive site: en.wikipedia.org/wiki/Steam_turbine_locomotive
- Yahoo groups on prototype railroads and model railroading.