Feature

Repair and Working Preservation of Locomotive No. 2109

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Introduction

Modern industrial technologies are usually evolutionary rather than revolutionary—they are the results of small technological advances accumulated over the years. Although people today easily abandon old technologies for new, studying and preserving past achievements can make a great contribution to understanding both the past and the present.

The Museum of Industrial Technology, which is part of the Nippon Institute of Technology in Saitama Prefecture, has a Class 2100 steam locomotive (No. 2109) built by Dübs in 1891. It was donated to the Museum by Oigawa Railway Company in Shizuoka Prefecture. Thanks to the Oigawa Railway's know-how, we have been able to restore the loco to its original working condition.

This article describes what we learned about No. 2109 from its repair and restoration, exhibition, and operation.

Outline of Locomotive No. 2109

Steam locomotive No. 2109 was manufactured by Dübs in 1891 and imported to Japan in the same year. It was the tenth build in the 2100 series and is one of the earliest extant locos of its class. Locomotives of the same design were built not only in Britain (Class 2120) but also in Germany (Class 2400), and in the USA (Class 2500). A total of 534 were ultimately imported from the various builders to Japan.

The first design was drawn by Richard Francis Trevithick (1845–1913) when he was Locomotive Superintendent at the Kobe Works of the Japanese government railways. His original design was based on an existing British locomotive and he sent the drawings to Dübs where they were refined for manufacturing. Table 1 shows the major specifications.

The design proved to have relatively good performance for the period and Class 2100 locomotives were soon being used to haul both passenger and freight trains on steep gradients in Japan's mountainous regions. After long service on main lines, they served out their final days until the 1960s performing shunting in station yards. Interestingly, they were one of the few classes of steam locomotive to use Stephenson's valve gear.

In 1891, No. 2109 was purchased by Nippon Railway and then served on the government railways after Nippon Railway was nationalized in 1906. By 1929, it was being used in the Matsumoto district of the Nagoya Railway Bureau, but was then transferred to Seino Railway, a freight railway company in Gifu Prefecture, where it was used to haul coals until retirement in 1966 after the widespread appearance of diesel locomotives. Seino Railway had completely abandoned No. 2109 by 1970, but public sentiment favoured its preservation so its ownership was taken over by Oigawa Railway to become one of the first steam locomotives in Japan to be preserved in working order. After 6 years, it was downgraded from working order to static preservation and exhibition at Senzu and Kanaya stations on the Oigawa Line. Its life history is summarized in Table 2.

Table 1 Major Specifications of No. 2109

Cylinder diameter	406	mm
Cylinder stroke	610	mm
Boiler pressure	9.8	kg/cm^2
Grate area	1.31	m^2
Heat conduction area	92.2	m^2
Driving wheel diameter	1,245	mm
Water capacity	7.8	m^3
Fuel capacity	1.9	tons
Effective weight	39.5	tons
Working weight	49.2	tons
Overall length	10,439	mm
Overall height	3,810	mm
Overall width	2,438	mm

Restoration History

After taking over ownership of No. 2109 in 1970, Oigawa Railway's steam

Table 2 Life History of Locomotive No. 2109

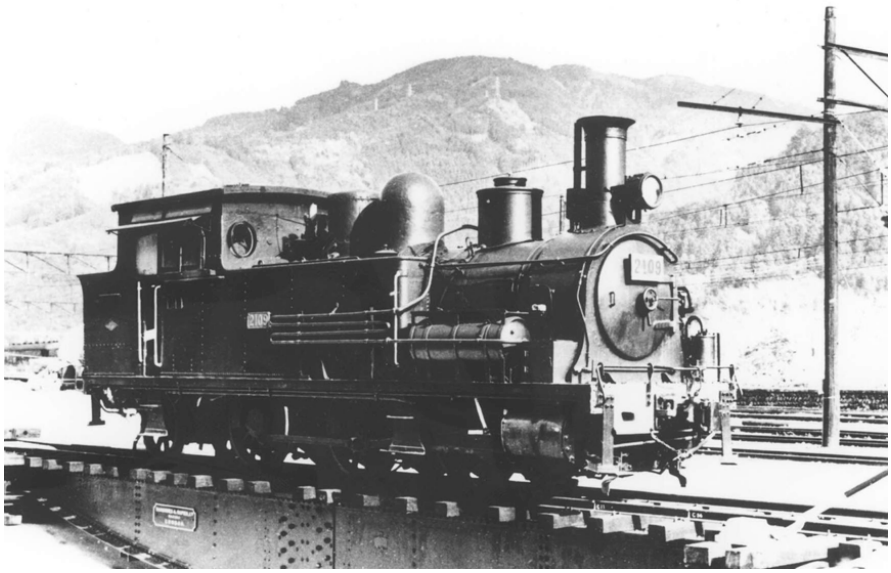
Year	Event
1863	Dübs founded by Henry Dübs
1891	Locomotive No. 2109 manufactured by Dübs and imported by Nippon Railway Company
1906	Nippon Railway nationalized
1925	Oigawa Railway Company founded
1929	No. 2109 decommissioned while in Matsumoto district of Nagoya Railway Bureau and transferred to Seino Railway Company for hauling coals
1966	Seino Railway retired No. 2109 and left abandoned in 1970
1970	Japan Rail-fan Club argued for preserving No. 2109 due to historical value and Oigawa Railway Company took over ownership and working restoration, making No. 2109 one of Japan's first preserved locomotives
1976	Oigawa Railway downgraded working order preservation to static preservation and exhibited locomotive at Senzu and Kanaya stations
1992	Japan Industrial Archaeology Society designated No. 2109 as industrial heritage and Oigawa Railway decided to restore and donate No. 2109 to Nippon Institute of Technology
1993	No. 2109 transported to Museum of Industrial Technology at Nippon Institute of Technology where preserved and exhibited in working order

workshop undertook a full working restoration while considering its historical significance in Japan's railway heritage. All the parts required for the restoration were handmade to the original specifications while giving full consideration to working safety.

After 7 years, working preservation became increasingly difficult and Oigawa Railway decided to preserve No. 2109 in static condition. However, in 1992, the Japan Industrial Archaeological Society designated No. 2109 as a valuable industrial heritage, whereupon Oigawa Railway decided to donate it after restoration to the Nippon Institute of Technology. The second round of working-order restoration began at Oigawa Railway on 1 October 1992 and continued for over 1 year until 20 August 1993 when the boiler was put under steam once again to check operation. Table 3 outlines the restoration work.

Characteristics of No. 2109

No. 2109 is a handsome 0-6-2 tank locomotive featuring a riveted boiler, Stephenson's valve gear and other special specifications embodying then state-of-the-art technologies. It has a large water capacity of 7800 liters like other early locomotives, and generates a high tractive power of 310 tons on a gradient of 1:100 (10 per mill) and 155 tons on a gradient of 1:40 (25 per mill) at 32.2 km/h. The valve gear was of the first vertical Stephenson type, featuring both good durability at high speeds and easy serviceability. However, because this type of valve gear is large and heavy it was later replaced by Walschaert's valve gear, explaining why real vertical Stephenson valve gear is hardly ever seen today. However, vertical Stephenson valve gear was the leading technology imported from Britain during the Meiji Era (1867–1912).



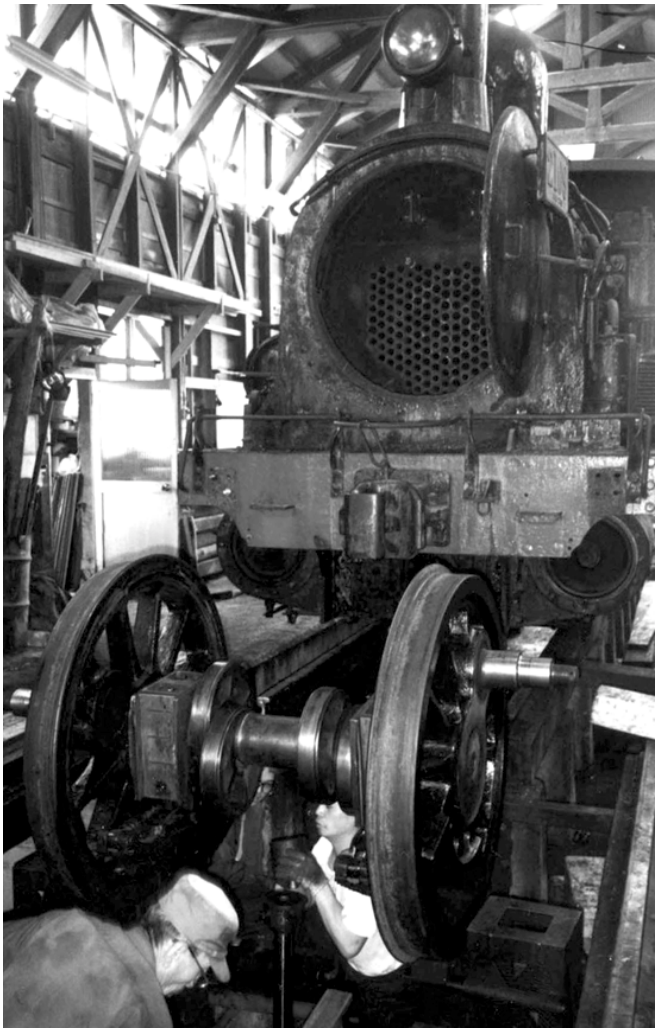
Locomotive No. 2109 working on Oigawa Railway (Authors)

Table 3 Donation and Working Restoration

Date	Event
18 June 1992	Oigawa Railway concluded agreement to donate No. 2109 to Nippon Institute of Technology
21 August	No. 2109 transferred to Oigawa steam workshop
1 September	Preparation of drawings started
1 October	Restoration started
22 December	Boiler certification obtained
20 August 1993	Boiler put under steam
25 August	Press release
30 August	No. 2109 exhibited to general public with photograph call
4 September	No. 2109 loaded on trailer
6 September	No. 2109 arrived at Nippon Institute of Technology
10 September	Opening ceremony
11 September	No. 2109 first demonstrated in working order to public

The boiler was formed by hot plate riveting and has no superheater tubes. Instead, it used up to 188 fire tubes. Current Japanese government safety standards do not provide a method for calculating the strength of a hot-riveted boiler, making the boiler restoration a daunting task and requiring studies of old boiler standards.

The main rod is a crucial component that converts the reciprocating motion of the piston to the rotation of the wheels. Notwithstanding its large size, it was formed using hot forged steel. To restore



Restoration in steam workshop (Authors)

Unloading No. 2109 onto track at Nippon Institute of Technology (Authors)

the bearing unit, we took a very complicated approach by soldering babbitt metal to the inside face of the gunmetal to produce a bearing thickness of 10 mm.

The driving wheel unit consists of an axle, wheel centre, tyre, balance weight, and crank pin. The tyre was shrink-fitted onto the wheel centre. However, replicating this process proved very difficult because most of the details and process temperatures for manufacturing a large driving wheel with a diameter of over 1000 mm have been lost. The original builders used a special technique to precisely cast large iron parts. In addition, the driving wheels have very rare, square-section spokes that were used only on the earliest Class-2100 locomotives.

The massive water tanks on both sides of the boiler increase the weight per driving axle, enhancing the adhesion and producing higher tractive power. However, the lack of leading wheels creates a heavier load on the main driving wheels compared to 2-6-2 locomotives. As a consequence, the main driving wheels had a tendency to such high wear that engine drivers tried to drive Class-2100 locomotives backwards as much as possible. However, some reports say that the excessive wheel wear was mostly due to the profile of rails used at the time, as well as to unbalanced axle loads caused by changes in the weight and distribution of water and coal.

Transportation to Nippon Institute of Technology

We decided to move the restored No. 2109 to the Institute without removing any parts. In working order, the locomotive weighs 49.2 tons and is 10.439-m long and 3.8-m high, so we used a large, low trailer with a total length of 27 m and a maximum load capacity of 100 tonnes. Two 100-ton cranes with four 45-mm diameter steel hawsers were used for loading and unloading.

The trailer travelled the distance of 250 km to the Institute by night taking 22 hours at an average speed of 19 km/h.

No. 2109 leaving exhibition hall under steam (Authors)

In exhibition hall over inspection pit (Authors)

Preservation and Exhibition

To preserve and exhibit No. 2109, we prepared a dedicated, one-story, reinforced concrete exhibition hall with a floor area of 170 m^2 designed to resemble a 19th century British brick locomotive shed. For better views of the various features of the locomotive, the building floor has a 1.2-m deep pit as well as a high observation platform to overview the locomotive.

When static, the locomotive's boiler is filled as full as possible with a mixture of water and special chemicals, and the air space is filled with N_2 gas. As a result, initial small signs of corrosion found on the fire tubes have not expanded further. The many friction surfaces are lubricated periodically. After lubrication, the locomotive is drawn by a tractor to fully distribute the lubricants.

The museum puts No. 2019 under steam on a short 120-m section of permanent track at the Institute using both wood and coal to fire the boiler. While running the locomotive, the officers carefully inspect all parts to ensure its performance. To demonstrate the locomotive's technology, we also exhibit related materials, such as technical drawings produced during the restoration and photographs.

During the Age of Steam, locomotives embodied state-of-the-art technologies in mechanics, thermodynamics and hydrodynamics but they still have lessons to teach today while symbolizing part of the history of mechanical tools.

Locomotive No. 2109 is used to teach a popular class on the history of mechanical tools given to third-year students in our Department of Mechanical Engineering. In addition, many people visit the Nippon Institute of Technology just to see No. 2109.

Conclusion

The enthusiasm and support of many related parties have brought a 110-year old British-built steam locomotive back to working condition. The workshop staff of Oigawa Railway are to be commended for their skill and dedication to the restoration of steam locomotive No. 2109, which can now continue to delight future generations of railway engineers and the public with a glance back into rail history. ■

This article was first presented at the international conference 'Slow Train Coming: Heritage Railways in the 21st Century,' held in York in September 2001.

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