The Usui Toge Railway of the Shin-etsu Line, 1893–1997

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Introduction

One Sunday in late May 1995, I found myself in Tokyo with a rest day and a spare day on a weekly all-lines Japan Rail Pass. With a minimum of planning, I set out on a triangular journey (Fig. 1) linking Tokyo, Nagoya, Nagano and Tokyo. I had no particular purpose, other than to relax in the Green (First Class) Cars of Japan's excellent railway system, and to watch the scenery go by on a day of the week when the rail service in the UK varies from terrible to non-existent.

Looking back at the notes I made at the time, I see I departed from my mother-in-law's home in Mishuku, in Setagaya-ku, at 07:30, allowing an hour for the dozen or so kilometers to *Tokyo Eki* (Tokyo Central Station) reached via the Shin Tamagawa subway and the Yamanote Line. In the almost 25 years since I first visited Japan, the journey time for this short distance has not improved, although most train trips have been significantly speeded up. I wonder if our colleagues in Japan will now turn to the integration of transport systems and the improvement of door-to-door times?

On a bill board near *Tokyo Eki*, a British diesel InterCity125, with its distinctive wedge shaped front, was being used to advertise Castor Mild cigarettes; perhaps it is fortunate that the associated logo was not, 'Smoking Clean'! I departed on the *Hikari* 105 shinkansen exactly on schedule at 08:31—all the trains I used departed and arrived exactly on time.

As we pulled out from a brief stop at Shin Yokohama, my Japanese neighbour struck up a conversation, which became animated when I said I came from Sheffield. It turned out that he ran his family's cutlery business, started way back in 1871 soon after the start of Japan's modernization, in the Gifu area by his great grandfather, and helped along by several visits to Sheffield to pick up technical know-how. The company today concentrates on the low-cost mass production end of the market, with British Airways as one of its major customers. His company produces about 25 million stainless steel items a month at about US10¢ a piece of which 40% goes to both the EC and the USA. No manufacturing is now done in Japan, the current production units are in the Philippines and China, with Viet Nam being eyed as the next base. However, all is not lost and I was gratified to see an advertisement for Range Rovers in the on-board copy of *L&G*, JR Central's in-house magazine. The 4.6SH model costing 'only' ¥6.95 million (about £53,000 at the prevailing exchange rate).

With only the one intermediate stop, the 366 km to Nagoya was smoothly accomplished at an average speed of 194.4 km/h, giving me about 30 minutes before my connection on the run to Matsumoto and Nagano by *Shinano* express. This stretch on the Chuo and Shinonoi Lines is over twisting narrow gauge and, sometimes, single track. Motive power was a

Figure 1 The Tokyo-Nagoya-Nagano-Tokyo Journey

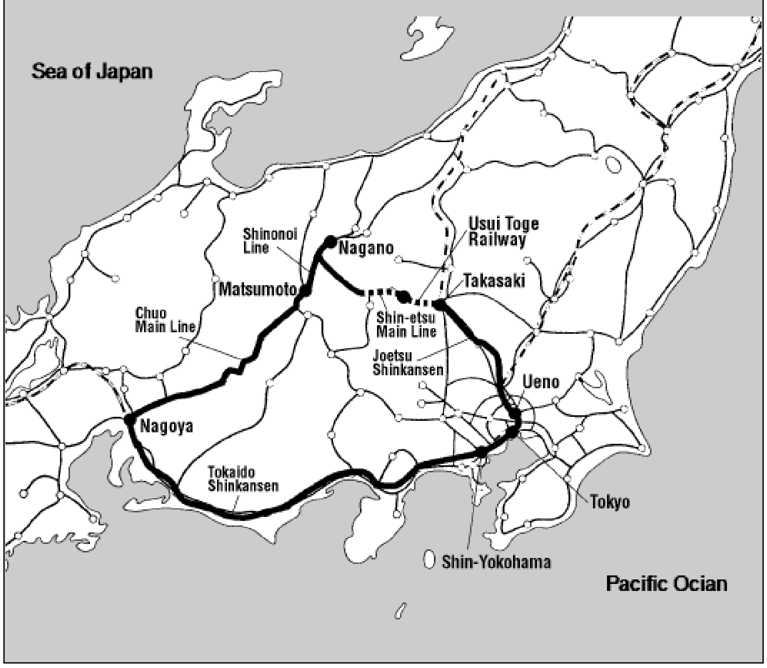


Figure 2 Japanese Railway Map of 1894

Series 381 tilting EMU, which covered the 250.8 km at a very respectable average speed of 84 km/h, including seven intermediate stops.

After a 20-minute break in Nagano, I boarded the 14:19 *Asama* express EMU bound for Ueno Station in Tokyo. The departure was enlivened by a large party bidding farewell to a honeymoon couple. The noisy crowd produced a mixture of tears and cheers before the obviously embarrassed and tired couple were allowed to sink into their seats. Soon after our departure, signs of the construction of a new adjacent railway were apparent—suddenly I understood. The new line was the Hokuriku Shinkansen being built for the 1998 Nagano Winter Olympics. In my hastily drawn-up plan, I had not realized I would be travelling on the famous Usui Toge Railway, under threat of closure on the completion of the new shinkansen. The line is famous for its very steep gradients on the descent to Yokokawa (sometimes pronounced Yokogawa), and sure enough at Karuizawa, two locomotives were added at the front of our train to provide additional braking power. The next 11.2 km took 27 minutes, the average of 25 km/h being significantly slower than the morning's run on the Tokaido Shinkansen. As we passed between two tunnels, I glimpsed a large brick-built viaduct on an abandoned line on the right hand side. Such a structure is most unusual in Japan, and again my memory was jogged back to articles I had read of early Japanese railway history.

However, to complete my triangle first. At the bottom of the steeply-inclined section, the locomotives were removed at Yokokawa Station, where the noodle and popular *kamameshi bento* (rice, vegetables and meat steamed in a pottery crock) sellers lined up on the platform edge and bowed to our train as we departed. I continued as far as Takasaki where I transferred to the Joetsu Shinkansen for a swift return to Ueno Station in Tokyo. From there I completed an anti-clockwise circuit of the Yamanote Line to Shibuya and arrived back in Mishuku at about 18:45, after a trip of approximately 860 km lasting 10 hours and 45 minutes.

My experience of the Shin-etsu Line stimulated me to sift through piles of papers back in Sheffield until I located two half-remembered items; an article by S. Kikkawa (also known as S. Yoshikawa) from *Engineering* of 19 October 1894, and a paper from the *Minutes of the Proceedings of the Institution of Civil Engineers*, 1894–95 by C. A. W. Pownell. What follows is culled largely from these two sources.

Brief History of the Usui Toge Railway

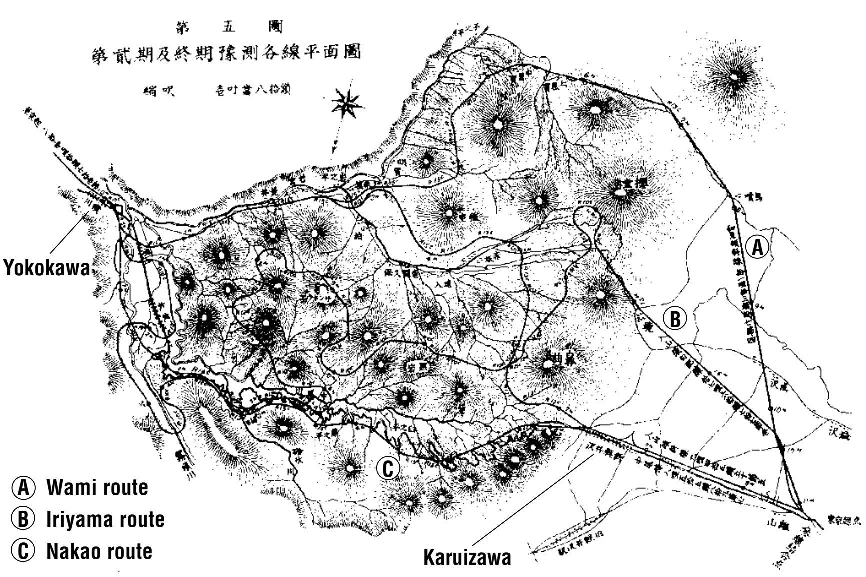
The problem

Figure 2 shows the railway map of Japan in 1894. The section we are concerned with, the so-called Usui Toge Railway, was built to fill a difficult gap in the main line from Tokyo to the north-coast seaport of Naoetsu. The railway joined Yokokawa, on the Tokyo side, with Karuizawa on the Naoetsu side, both places being terminal stations before the link was built. The Usui Toge (Usui Pass) between these two places had long been considered as the greatest natural barrier in Japan, although it was crossed by the Nakasendo route between Tokyo and Kyoto. It consisted entirely of high hills rising one above the other. Yokokawa is 384 m (1260 ft) above sea level, while Karuizawa is on a plain at 939 m (3080 ft). The problem to be solved was to connect these two points, which are only 9.3 km (5.75 miles) apart in a direct line.

Possible routes

From 1885, various surveys were made of proposed routes relying on adhesion, and naturally these involved long detours to limit the gradients. In 1889, W. A. C. Pownell, an English *yatoi*, or hired government foreign employee, and then Principal Engineer to the Japanese Imperial Government Railways, suggested a line limited to 1 in 40, some 15.25 miles long

Figure 3 Proposed Routes for Usui Toge



and estimated to cost some ¥2 million or about £300,000 at the old exchange rate. In the following year, Messrs M. Sengoku and S. Kikkawa were sent to Europe to investigate the various traction systems used on mountain railways. They were particularly impressed by the Abt rack-and-pinion system used on the then recently-opened (1885) Harz Mountain Railway in Germany, which would permit steeper gradients and therefore a more direct route. Various alternative schemes were investigated.

The first, the Wami route was the most southern of the three principal contenders. It left the Karuizawa Plain via the Wami Pass, then linked the villages of Onga, Akahama and Arai before reaching Yokokawa. The length was 12.3 km with more than half at a 1 in 15 (6.7%) incline and with 17 tunnels totalling 3.7 km. The central Iriyama route left Karuizawa via Mt Manacho, and then dropped down to Yokokawa via Akahama. This route was slightly shorter than the first, but had more tunnels occupying a shorter total length. The northerly Nakao route followed the Nakasendo road, in those years little more than a track, down the Nakao valley from Karuizawa, thence via Sakamoto to Yokokawa. This was the shortest route at 11.2 km, but with 26 tunnels totalling 4.6 km (Fig. 3).

These alternatives were referred to T. R. Shewinton, consulting Engineer in London to the Japanese Imperial Government Railways. After resurveys, the Nakao route was eventually chosen due to the several advantages it offered in the alignment of the tunnels, the reduction in the lengths of required viaducts and its proximity to the Nakasendo road which allowed access for the engineers and materials.

Construction

Construction, began in June 1891 under the direction of Mr E. Honma, with Mr S. Kikkawa as assistant. Altogether 26 tunnels and 18 viaducts were needed, the largest being the impressive Usui Viaduct (Fig. 4), consisting of four spans of 60-ft arches, the highest being 106 ft above the river bed. Some 2,300,000 bricks were needed to build this large viaduct. The piers were designed to resist an earthquake acceleration of 4 ft/s^2, according to the formulas of Prof. John Milne, the so-called Father of Japanese earthquake engineering. This was estimated as 50% higher than the accelerations that destroyed the Kiso Bridge during the great earthquake of 1891; but at 0.125 gal, it seems small compared to the horizontal accelerations of 0.83 gal measured during the 1995 Great Hanshin Earthquake in Kobe.

The inclined 1-in-15 sections of track, 2.45- and 2.41-miles long, were laid with rack rails on cross steel sleepers, with a passing point about halfway up the otherwise single line of 7-miles length. The cost, was almost exactly the same as Pownell's original estimate of £300,000, perhaps £15 million at present prices. This total included the purchase of four special engines and rolling stock at £63,000, the expensive Abt rack (Fig. 5) at £3000 per mile and the cost of the tunnelling at £113,000. The works were largely completed by the end of 1892.

Figure 4 The Usui Viaduct under Construction *(Transportation Museum)*

Steam Traction

Four engines were initially ordered from the Esslingen company in Germany. The 0-6-0 coupled side tank locomotives (Fig. 6) of the Abt combination type were shipped to Tokyo where they were assembled at the Shimbashi Works and delivered to the line in January 1893. The ordering, delivery and testing of these locomotives was carried out under the direction of Francis H. Trevithick, grandson of Richard Trevithick of Cornwall, who had come to Japan in 1876 and was appointed Superintendent of the Tokyo Shimbashi Works in 1878. After many trials, the line was opened to the public on 1 April 1893.

The performance of the locomotives was initially somewhat disappointing. Their small heating surfaces limited the loads they could haul up the incline to about 65% of what had been expected. The best that could be achieved was 60 to 70 tons at 4.7 miles per hour. Furthermore, inefficient combustion, combined with the slow speed, caused a smoke problem, particularly in the tunnels. To decrease this, some of the locomotives were converted to burn a mixture of oil and coal. Three more-powerful locomotives were ordered from the same manufacturer, but there are reports that they were eventually replaced by locomotives from Beyer Peacock in Britain. The line continued to be steam worked until 1912. In this year, the line was electrified with electric locomotives imported again from AEG/Esslingen in Germany.

Figure 5 The Abt Rack System

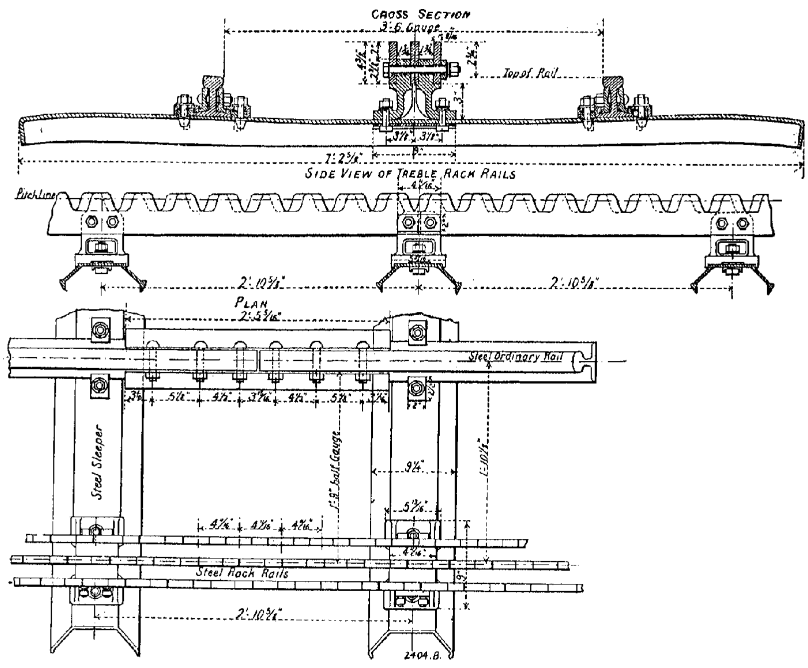
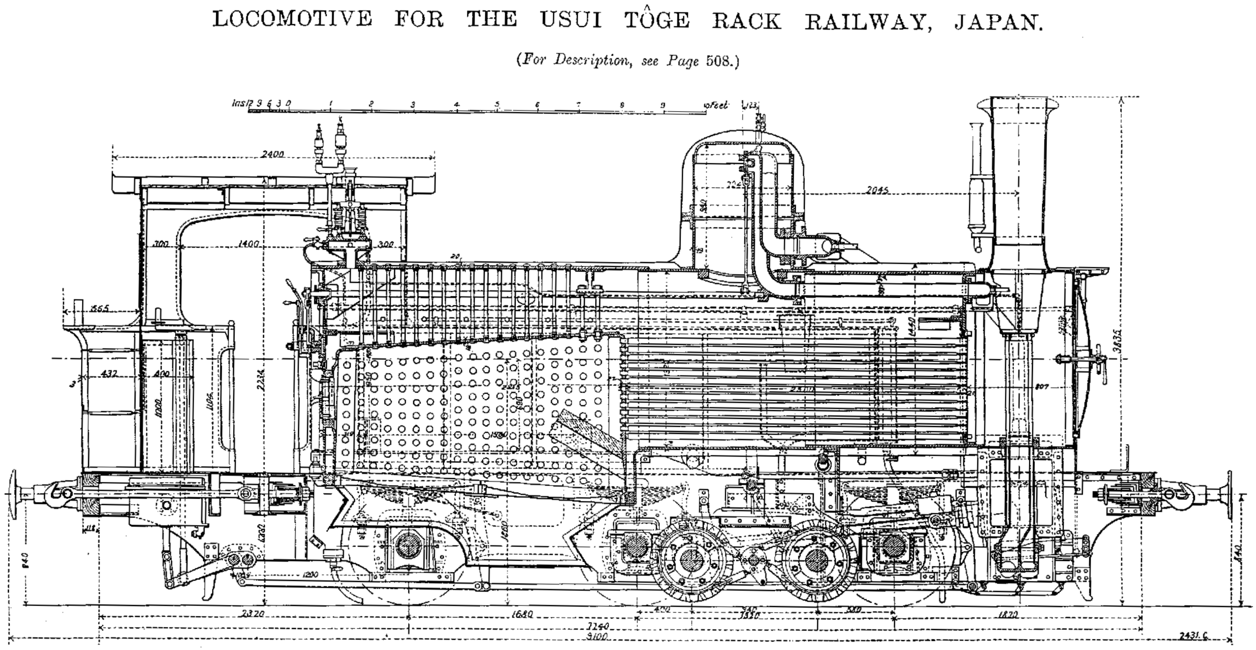


Figure 6 Longitudinal Section of 0-6-0 Tank Locomotive for Usui Toge Railway



Electrification

Dwindling coal supplies, the promise of cheap hydro-electric power and general technical achievement, led to several experiments on electrification early this century in Japan. Therefore, it is not surprising that the poor performance of steam locomotives on the Usui Toge Railway prompted thoughts on the improvements that electric traction might bring. Government contracts were placed with AEG Maschinenfabrik, Esslingen, Germany, to provide twelve 40-ton electric locomotives, rated at 630 hp and capable of negotiating the line at speeds of up to 16 km/h, thus reducing transit times to 40 minutes. Power supplies came from Curtiss-GE of the USA, who constructed a power plant housing a 3-phase 1000-kW steam turbine. Power was supplied to the locomotives via a third rail at 600 volts DC, after transformation and rectification by equipment also supplied by AEG. Batteries were housed at each end of the line in case of power failures, and steam locomotives remained on stand-by. The system was completed in 1912, but the results were very disappointing. More powerful Brown Boveri locomotives were ordered and interesting attempts were made to build locomotives in Japan. Copies of the AEG locomotives were assembled at the Government Railway Works at Omiya in northern Tokyo, using controllers imported from AEG, pumps from GE and ancilliary motors from English Electric. Local input was provided by Shibaura Engineering. By 1919, fourteen of these locomotives had been supplied, capable of producing 630 hp, but with the weight increased to 61 tons.

Once again, performance proved to be less than anticipated. Operating costs were very high, hauled loads were small (77 tons) and severe wear on the driving pinions and rack, meant that both had to be replaced at frequent intervals. It was reported that as much as 20 mm was worn from the pinion teeth in seven months of service. The system was reappraised in view of these weaknesses and in the light of the success of 1500-volt systems then in use in the coastal regions of Japan. Electric traction was also proving to be very successful overseas; in Switzerland, single units of up to 1200 hp, supplied by high-voltage overhead equipment, had no difficulty in hauling loads of up to 300 tons over very mountainous terrain. However, the existing civil engineering works on the Usui Toge Railway, seemed to preclude the use of overhead high-tension wires, and efforts were concentrated on using more powerful locomotives as much as possible.

After much discussion, in 1924, Brown Boveri was instructed to build two locomotives capable of hauling loads of up to 160 tons up the rack at 15.5 km/h, with a tractive effort of 12,000 kg, adhesion to be shared 2/3 on the rails and 1/3 on the rack. Interestingly, these locomotives used a dual-current collection system, the third rail being replaced by overhead wires in areas posing no safety hazard.

Class 10,000 AEG/Esslingen electric locomotive on Usui Toge Railway *(Transportation Museum)*

End of Abt rack system

Various improvements were made to the traction equipment over the years, but operations remained slow; by the early 1960s, the Usui Toge was one of the few remaining trunk lines in the world using the Abt rack system. Rather than making more incremental improvement, radical reconstruction was undertaken. Alternative routes were examined again but the 14-km increase in length required to ease the gradient to 1 in 40 was too expensive. A new adhesion line was built almost following the original alignment and this opened in 1963. It operated at speeds of up to 35 km/h attained by new EF 63 electric locomotives and rolling stock. Double-tracking was finally achieved in 1966 by mostly rebuilding the original alignment.

Accidents

The line operated safely throughout the years but there were several accidents attributable to the steep gradient and the mountainous terrain that the line passed through. In one of the most noteworthy, on 13 July 1902, a mixed-traffic train was ascending the inclined section when a steam explosion occurred, probably due to a faulty weld. The locomotive footplate was blasted by steam, blowing the two firemen off the train. The driver struggled to apply the emergency brakes, but the train started to roll back down the slope, gathering momentum. The passengers included Baron Mori, President and Technical Director of the private Japan Railway Company, together with his son. The Baron, from his knowledge of the line, anticipated immediate disaster, and urged his fellow passengers to jump from the train. Most were paralyzed by fear and refused to move. The Baron jumped, but fell under the wheels and was killed; his son smashed into the portal of a tunnel and was also killed. One passenger survived jumping from the train without serious injury and managed to walk back to Karuizawa Station. Meanwhile, the driver had stayed at his post and succeeded in operating the brake. After the train had rolled back some 2 km, it eventually stopped, much to the relief of the remaining passengers.

A much worse disaster happened in 1950. During the late evening of 8 June, a large landslide occurred, burying part of the line. A large gang of men was assembled at the site and cleanup operations started. Early the following morning, a much larger slip, estimated at a volume of about 7000 m^3 of earth and rocks, engulfed 73 people, not only members of the emergency gang, but also occupants of eight company houses adjacent to the site. Some of these people were rescued, but the eventual death toll reached 50 with 29 people seriously injured.

Conclusion

The Usui Toge Railway has always been more than a tourist attraction. In its early days, it established an important link with the northern regions, from which rice was exported, while imported and locally manufactured goods travelled to the provinces in the opposite direction.

The Nagano Winter Olympic Games are due to be held in February 1998, and many people from all over the world will travel north west from Tokyo to reach the various sports sites. This is a challenge too many for the Usui Toge. Over the last few years, a second substitute line, north of the original route has been built, in the form of the Hokuriku Shinkansen. Test runs have been made on long 1-in-33 gradients, much less than the original Abt rack, but the steepest of any shinkansen line built so far. *Asama* E2 Series shinkansen will replace the narrow-gauge line services on the Shin-etsu Line between Tokyo Ueno and Nagano. Journey times between these points will be halved to 80 minutes and the book will finally close on the famous Usui Toge Railway, which will be replaced by a bus service. JR East will continue to operate commuter trains from Takasaki to Yokokawa, while the section between Karuizawa and Shinonoi will be transferred to a semi-public company called the Shinano Railway Co.

On 14 May 1993, the four-span brick arch of the Usui Viaduct was recommended by the Japanese Council for the Protection of Cultural Properties to the Minister of Education, Science and Culture, as an important cultural asset of historical significance. This viaduct, which would easily blend in with English railway landscape, reminds us of the role played at the beginning of this project by British engineers, in particular, C. A. W. Pownell and Francis Trevithick. The line was built in the period of transition from the dependence on imported *yatoi* know-how to reliance on indigenous skills. In 1893, Richard F. Trevithick, the brother of Francis, supervised the building of the first steam locomotive in Japan, at Kobe Works. He also trained many Japanese engineers who became leading figures in Japan's railways.

The Usui Toge Railway was one of the last major projects in Japan in which foreign engineers were directly employed, before the great flowering of Japanese railway technology which has produced so many fine achievements in the latter half of this century. ■

Acknowledgements

I would like to thank Yayoi Yamanoi Smith for translating the original Japanese texts on which some of this article is based.

Figure notes

Figs. 2,5,6 Reproduced from *Engineering*, Vol. LVIII, July/Dec., 1894

Fig. 3 Reproduced from *Bulletin of Japan Transportation Association*, Vol. 9, No. 5, 1908

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