Light Railway Construction and Use

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LIGHT railways are not a product of the late war, as is a somewhat accepted belief, but had their beginning, in a small way, some fifty years ago and had well served peace time purposes, as well as limited military needs, prior to 1914.

In the World War, the Germans were first to employ light railways, and with them the system became more extensive and attained an admittedly greater efficiency than with any other of the participants. As a background to this circumstance and to set forth the evolution of the narrow gauge light railway, the subject will be introduced with a brief review of its development.

Despite occasional differing statements as to origin and development, Arthur Koppel, a German, with a small shop in Berlin, originated what is now a standard product known as portable track—a system of steel rails, mounted to gauge, in sections, on steel ties and fastened together with clips and bolts. This system, together with small capacity, man-operated cars, was then intended for industrial purposes, the minor transportation in and about manufactories. In its development, it extended into use for agricultural transportation, serving beet fields and truck farms, and into the mining areas, hauling heavy materials. In this manner the business of Arthur Koppel grew steadily until by 1914, it had an extensive organization of branches and manufacturing plants throughout the world, specializing in light railways.

Through all its progress, much attention was given to military adaptability, and munition and troop cars, ambulance and hospital cars, railway gun carriages and armoured rolling stock were developed. In 1892 the German Military Government adopted a system of light railway which became standardized as army equipment in 1897.

Portable railways were used to some extent, however, by both the Japanese and Russians in Manchuria during the Russo-Japanese war.

Use by the Allies

Great Britain had carried out in late years a development of light railways. However, they apply the term broadly to all railroads other than the Parliament chartered standard railroads, so that the proportion of narrow gauge lines embraced in their light railways is comparatively small. The continental countries, notably France, Belgium, Italy, Austria and Switzerland, gave much more attention to the narrow gauge, both for commercial and military service, and especially in their colonies the narrow gauge light railway made much progress.

The Decauville Company in France was one of the foremost in the design and development of light railways, and it was their product which principally served the French army. The Pechot locomotive, shown in our A. E. F. Manual of Light Railways (designated as Model 1888) is one developed by them and recommended by Colonel Pechot for adoption in artillery supply from railhead to batteries.

In the United States, there has not been the occasion for light railways of the order used abroad. However, we have many in operation, the most interesting of which are the two regularly constituted railroads operating in Maine.

There was no extensive employment of light railways in military engagements prior to the World War. The French had given study to the subject and had installed some light railways which principally served permanent fortifications. The Austrians had adopted a system of light railways before 1880 and use was made of light railways by them.

Germany early instituted the extensive use of light railways in the late war but on the Allied side, other than for incidental lines, it was not until late in 1916 that consideration was given to their utilization. At that time the Commander-in-Chief of the British Forces decided on the adoption of a comprehensive system of light railways for the conveyance of troops, guns, ammunition and supplies from the railheads to the front lines, with the purpose of relieving the highways of traffic, with the excessive consumption of gasoline, in addition to the wear and tear on motor equipment; assisting rapid advance over shell torn areas, useless for travel of motor vehicles and practically useless for horse drawn equipment; conveying material for the rapid repair of roads in the destroyed zone and reducing the manual labor at the front. So satisfactorily did the system develop that they were able eventually to handle almost all heavy material by this means, leaving the roads largely free for light, fast moving traffic.

During 1918 many advances were made in the operation of these roads and the British accomplished material saving in labor employed, due to more scientific organization. During the greater part of 1918 the number of men required on maintenance work averaged approximately five per mile of track operated, being practically one-third of their average through 1917. As to the traffic that developed on the British light railways, the figures show remarkable increase; from an average weekly tonnage in January, 1917, of 10,325 the roads showed an average weekly tonnage in September, 1918, of 210,808, in both cases the haul being an average of from four to five miles. There was, of course, an increase in their equipment also and from 68 locomotives, 27 tractors and 560 cars in January, 1917, they increased to 550 locomotives, 360 tractors and 4,403 cars in September, 1918, and also had some cars especially fitted for the carriage of heavy guns.

The A. E. F. Manual of Light Railways, from which frequent extracts have been made in this article, describes light railways as follows:

> The field of construction and operation of the light railway is primarily that within the field of the enemy's observation and fire.

In simplest form, light railways run perpendicularly to the front, connecting railheads to battery positions and forward distributing points; these main arteries are connected by lateral lines at a reasonably safe distance back, forming a series of loops; the roads are seldom double-tracked, but by short connecting lines, a system of loops is formed, which, permitting continuous one-way travel of a traffic density at least equal to double tracking, has the advantage of alternate routes to critical positions when the line may be broken at any point.

On the entrance of the United States into the war, a commission was formed to make a study of the light railways as then in operation and to determine upon a general plan and organization for all American light railways. This commission determined upon the weights and types of trackage, locomotives, tractors and cars and departed very materially from the practice of the British and the French.

As to the general ground plan of the system, the experience of the British served as a guide in determining upon the establishment and location of a Light Railway Central Shop and particular consideration and study was given to the selection of a proper site for such shops. The site selected was Abainville, Meuse, and the determining factors were, first, its location with reference to the expected activities, with recognition of the need that it should be sufficiently close to serve effectively the systems that were dependent upon it, yet well enough removed from the fire and observation of the enemy as to be reasonably secure. The second factor was the necessity of ample incoming transportation facilities of main line railroads, adequate highways and canal shipment. Abainville met these several requirements, although its location presented some physical difficulties in the matter of location of the main artery to connect the shops with the general operating system of the railway, as the French authorities had made particular provision that there were to be no grade crossings over their main line railroads, nor any interference with traffic through their canals. The line, Abainville to Sorcy, known as the A-S Line, constituted this main connection and was one of the three major divisions of the American light railways, the other two being the light railway system of the Verdun division and the Toul district. The A-S line, which was put into operation August 22, 1918, was 28.5 k.m. long and proved to be a vital element in affording access to the primary supply and repair center, and was an important and well constructed piece of light railway.

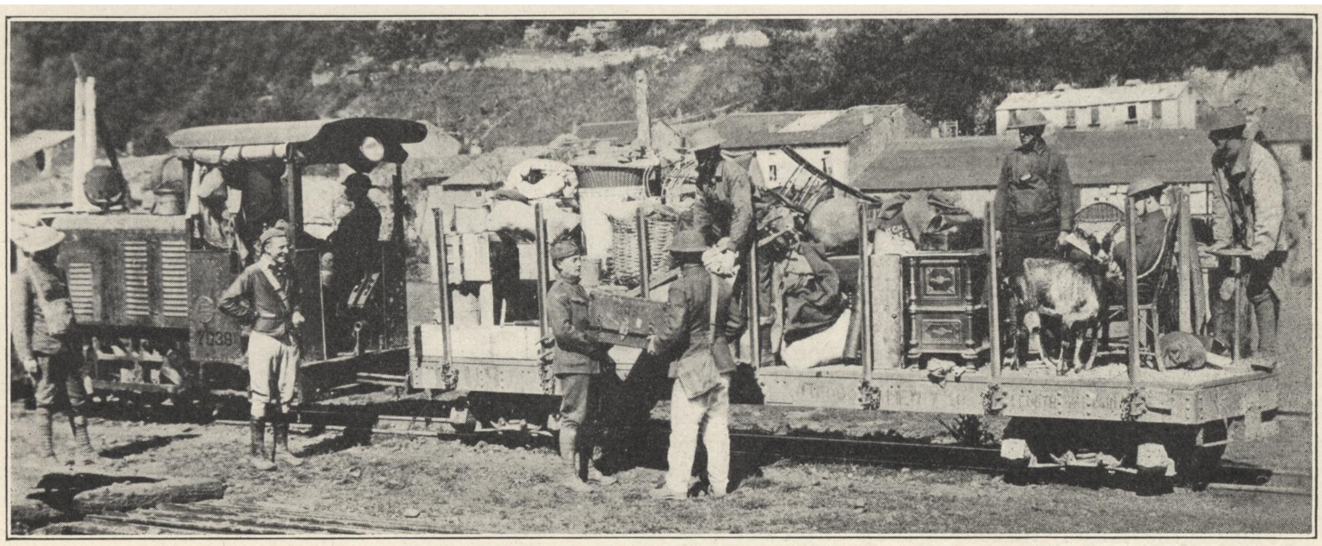
As to the weight of rail to be used, the recommendations of the commission determined upon 25-pound section, wherein we differed from the practice of the British with a 20-pound section and the French with a section weighing 9.5 k.g. per meter (approximately 18 pounds), which was also the German standard.

The British used a large proportion of assembled steel tie track together with some trackage laid on wood ties; the French used almost entirely steel tie track of the Decauville system with the rails riveted to closed end pressed steel ties, which they transported and laid in these assembled units. The Germans, on the other hand, used steel tie sectional track almost entirely, but fastened the rails to the several different types of steel ties by means of clips and bolts. The German standards called for ten cross ties, 7 inches wide by 4 feet 5 inches long, to the 5-meter section. However, under the exigencies of war, they departed materially from these standards as necessary.

Americans Have Long Haul

While both the French and the British sought to maintain their railhead seven to ten miles back of the front line, the American railheads were more distant. The average haul for the entire American operations was 15.3 k.m., and in the Toul sector there were regular movements, from railhead to battery or company positions, of 48 k.m. for munitions; of 55 k.m. for rations and water, and 43 k.m. for personnel. During the Meuse-Argonne offensive, extreme hauls were made in deliveries from Abainville that were the longest on record, notably from Abainville to Grand Pré, a distance of 175 k.m. This condition made necessary the use of better constructed lines, that is, rails laid on wood ties, except for the forward operations, which continued to use the steel tie track.

The final organization of the American light rail-



Light Railways Moved Everything, Including the Kitchen Stove and the Family Goat *Signal Corps Photo.*

ways was designated the Division of Light Railways and Roads, under the Chief Engineer of the A. E. F. From May, 1918, to the end of the war, the light railway organization carried out its work in liaison with the Chief Engineer, A. E. F., and the Fourth Section, G. S., GHQ, and with the Chief Engineers,

Signal Corps Photo.
German 60-Centimeter Track Damaged by Bombs, Lancon, Ardennes, January 25, 1919

Armies, and the Fourth Section of Army Staffs, with whose work its operations were connected. The organization consisted of Manager, Light Railways; Deputy Manager, Light Railways; Chief Engineer, General Superintendent of Motor Power, General Superintendent of Construction; and Supply Officer.

The light railway central shops at Abainville, embracing ten buildings, were equipped to make heavy repairs, to manufacture special equipment, and, generally, to supply every mechanical need to the operation of the light railway system.

When American troops first went into the line at the St. Mihiel sector the base of their supplies was Toul, but with the French troops immediately to the east using Toul as a base, there followed a congestion, resulting in the establishment of the Sorcy railroad. The facilities for the handling and transportation of supplies at Sorcy were thoroughly complete and well met the objections advanced against the labor and loss of time in transferring supplies from the standard to the narrow gauge, although the permanent character of this railhead, which permitted of these conditions, would not be practical in a war of movement.

Factors in Light Railway Location

As a general principle of light railway construction in France, the clearance of right-of-way was governed by the intention to transport guns with a width of 9.5 feet over hubs, so that provision was required for this dimension as a minimum. Loads were figured to the basis of three tons per axle. The location of lines was determined by the suitability for distribution of ammunition, road material, rations, engineer material, etc., and possible means of access to objectives within the enemy's lines.

One of the major values of the light railway is adaptability to the actual physical condition of the country it traverses and facility for avoiding costly and time consuming construction, avoiding, with a very flexible alignment, such obstructions as may be encountered; so that, with the railhead determined upon, the survey is carried forward with a view to securing, first, the lightest gradients and curvature which the topography of the country affords and with a minimum of grading; second, cover from enemy observation, with the site of the line as inconspicuous as possible. In wooded areas the clearing should be of a width reduced to the minimum, and so far as possible leaving the overhead foliage undisturbed. Where grading is necessary, the line should be laid so as to give the shallowest possible cuts and fills consistent with proper drainage; third, in the location of the line, it is desirable to avoid using streets or highways, first, to eliminate the obstruction it would offer to other traffic and, second, to separate distinctly in point of enemy destruction, the two lines of communication.

The general characteristics of good construction prescribed that the alignment should not have curves sharper than 50-meter radius (35½ degrees) and with no short curves at the foot of long steep grades. Curves in the opposite direction should have a 50-foot tangent between them. Grades were limited, as far as possible, to 3 per cent, with compensation for grades on curves at the rate of .02 per cent per degree; road-bed on embankments with a 9-foot crown and in cuts, 14-foot, at subgrade with 2-foot 6-inch ditches on each side, leaving a finished road-bed of 9 feet.

In clearing the right-of-way, all vegetation was thrown to one side, available for covering fresh excavations. When encountering large trees, cutting generally was avoided by curving around them. In ballasting, not less than 6 inches was required under ties, with an extension of 6 inches beyond ends of ties and of the available ballast in France there were, in order of superiority; crushed rock, slag, gravel, brick-bats, cinders, chalk, sand. The desired clear-

Signal Corps Photo.
Narrow Gauge Railway in the Bois de Forest

ances of the right-of-way were 5 feet 6 inches from the center of the track, although, as stated, the minimum clearance required was set at 9 feet 5 inches, over-all. The vertical clearance was 15 feet from the top of the rail.

The approximate weight of material, excluding ballast, per mile of single track equals 100 tons. With six inches of ballast under wood ties, there is required per mile of single track 1,026 cubic yards; with six inches under steel ties, 520 cubic yards. The American practice, except in work at the front, was

Signal Corps Photo.
22d Engineers, Laying Track to Connect with Captured German Road, Vauquois Mountain, October 2, 1918

to use 25-pound rails of 30-foot length, spiked on wood ties 4 inches by 6 inches by 4 feet 6 inches long, spaced 24-inch centers.

The speed with which construction was carried out is indicated by figures taken from various reports. In 1917, the British constructed one mile, including ballasting, with 2,100 man-days of labor. The 1918 French Manual of Light Railways places their average of construction at the rate of three-quarter meters per man per day, which is equivalent to 2,146 man-days per mile. On the A-S line which, as stated, was the best constructed light railway in France, the Americans averaged a speed of construction at the rate of 2,640 man-days per mile.

The Sorcy-Corneville line aggregated 2,344 man-days per mile. The Hamonville and Raulecourt lines, which were front line work, with light grades and sectional track, as distinguished from the Sorcy-Corneville line which was on wood ties, averaged from 1,024 to 1,169 man-days per mile.

Construction Data

The matter of ballast was a serious problem, as the light railways were badly choked at times with ballast trains, the tonnage of ballast hauled varying from one-tenth to one-quarter of the total tonnage handled. Number of men employed in light railway work:

Period	*Number of Men*
Prior to August 10	2,470
August 11 to September 14	4,715
September 15 to November 9	10,435
November 10 to January 18	11,300

The proportions, in segregation, being, during the heaviest period, 53 per cent construction, including rehabilitation of captured lines, taking up and storing track, etc.; 20 per cent maintenance; 22 per cent operation and 5 per cent shop.

Besides extensive reconstruction of systems taken over from the French and captured from the Germans, the American light railway forces completed:

Location	*K.M. of Main Line and Sidings*
Meuse-Argonne sector	25.4
Rattantout district	8.5
Toul sector	95.2
A-S Line	57.1
Baccarat sector	14.3
Total	200.5

From the commencement of American light railway operations in the week ending March 28, 1918, at which time there were 46 k.m. of main line and sidings in operation, handling 2,092 tons of material, to the week ending November 9, 1918, with 721 k.m. of main line and sidings in operation, handling 45,157 tons of material, including personnel and rations, there was handled over the entire period a total of 860,652 tons, the larger tonnages consisting of:

Munitions	166,202 tons
Light railway ballast	160,360 "
Rations	77,901 "
Road material	98,857 "

The total figure of 860,652 tons represents a ton mileage of 8,106,700, which is equivalent to more than 280,000 loads for a 3-ton motor truck.

The equipment available in the various operating districts for the handling of the above tonnages consisted of: 104 steam engines; 61 gas tractors and 1,695 20-foot cars. The personnel consisted of 55 officers and 2,585 men.

A number of heavy troop movements were handled by light railways. By November 1 the lines were well connected up and were operating smoothly. As the combatant troops advanced in November for the final phase, more light railway troops and materials were made available so that for a few days it was

Signal Corps Photo.
Tractors and Steam Locomotive of 21st Engineers (Light Railway), Cheppy, Meuse, October 30, 1918

possible to maintain contact with the advancing infantry, although by November 11 the infantry had advanced so far that the line of supplies had almost collapsed.

In the Meuse-Argonne offensive on November 11 supplies were being hauled on one line for a distance of 55 k.m. and on another for a distance of 60 k.m., both lines handling approximately 1,000 tons per day of rations and ammunitions.

At the end of the war there were, under American control, 2,240 k. m. of light railway, of which 300 k. m. had originally been constructed by the French but rehabilitated by the Americans; 200 k.m. constructed outright by the Americans and 1,740 k.m. which had been taken from the Germans, the latter figure comprising 900 k.m. south of the battle line of November 11 and 840 k.m. just in front of it.

The equipment of the American light railways consisted of motive power of 2-6-2 steam locomotives and 35 H. P. and 50 H. P. 4-cylinder geared gas locomotives. The rolling stock included box, gondola, flat, dump and artillery cars, together with some miscellaneous cars, cranes and general equipment types.

Major repairs were cared for at the light railway central shops but, additional to this, running repairs were made at small shops in each operating district and there was an equipment of shop trains, both for standard gauge and for narrow gauge, each equipped with dynamos, drills, power saws, lighting plants, compressors, blacksmith outfits, power hammers and general tools. Also, there were the regularly established wrecking trains for services needed.

Characteristics of Motive Power

The steam locomotives used on the light railways were intended for work as far forward as was permissible on account of their noise, smoke and steam, from which point the gasoline tractors furnished motive power. They weighed totally 34,500 pounds, of which 23,500 pounds were on the drive wheels, with a tractive effort of 6,225 pounds, capable of taking curves of a minimum radius of 20 meters (about 66 feet). These locomotives were 21 feet 7 inches long, 6 feet 5 inches wide, with a total wheel base of 15 feet 7 inches. The 50 h. p. gas tractors were of 4-wheel type with a draw-bar pull with low gear of 3,000 pounds or with high gear of 1,500 pounds. Their length was 15 feet, their width 5 feet 2 inches, weight 7 tons, and wheel base 4 feet. The 35 h. p. gas tractors had a draw-bar pull in low gear of 1,500 pounds, in high gear of 650 pounds. They weighed 4 tons each and had a wheel base of 3 feet; they were 10 feet 9 inches long and 4 feet 7½ inches wide.

Of the car equipment, the box, gondola and flat cars were of 22,000-pound capacity, with a length of 24 feet 1¼ inches, mounted on double trucks, with wheels 15¾ inches in diameter. The floor height was 2 feet 4¼ inches and their weight was:

Box cars	10,900 pounds
Gondolas	9,000 "
Flats	8,000 "

The inside dimensions of the box cars were:

Length	19 feet 10 inches
Width	5 " 5 "
Height	5 " 8 "

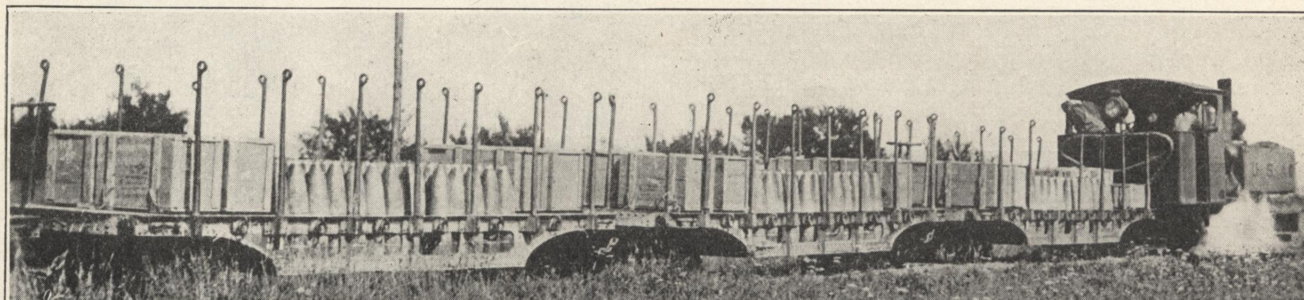
These steam locomotives were of the manufacture of the Baldwin Locomotive Works and were capable of handling 60 tons of freight on maximum grades of 3 per cent.

The fuel consumption of the locomotives and tractors averaged respectively 48 pounds of coal and .35 gallon of gasoline per locomotive-mile.

In our operation of the light railways we met with a great many troubles of derailment due to the high center of gravity of equipment, rigidity of construction of equipment and to poor road-bed. Our steam locomotives were notoriously unstable, of insufficient steam capacity, and not well adapted to the coal in use in France. The spring suspension was poor and only 68 per cent of the weight of the locomotives was on the drivers. The over-all length was too great in proportion to the rigid wheel base, causing the rear drivers to pull off of the rail when hauling heavy trains on sharp curves. The gasoline locomotives were better for staying on the track but developed mechanical troubles, particularly with the clutch and gear case. The spring suspension was poor and this, with the large overhung weight, caused considerable jumping when moving at a high rate of speed and resulted in frequent derailment.

Contrasted with this, the German equipment was of exceedingly low center of gravity; their steam locomotive was particularly adapted to the narrow gauge and the rough and poorly laid track which it needed to travel. The German type of locomotive was designed with an underslung water tank which was the principal means of accomplishing low center of gravity. All of their equipment was likewise brought as close to the ground as possible.

Without a great deal of question, narrow gauge railways have their place in army equipment and, while the engagements of movement may pass beyond the efficiency of such equipment, it is to be strongly advocated that preparation for light railways continue, and that a study of the deficiencies of our own system be made and steps be taken to complete improved designs and establish fixed standards.



Signal Corps Photo.

12th Engineers, Ammunition Train Loaded with 9-inch Shell between Baccarat and Azerailles, August 12, 1918