

(Paper No. 2903.)

(Abridged.)

## “The Construction, Equipment and Working of Light Railways.”

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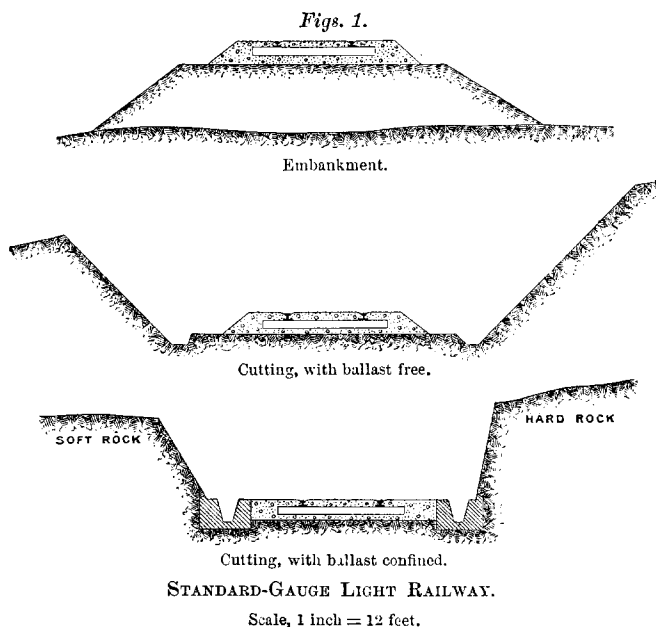
IN the construction of light railways, economy is effected by the reduction of the gauge and of the maximum speed allowed on main lines. With a reduced speed a lighter and therefore cheaper rolling-stock may be adopted, and consequently a lighter permanent way and less solid road-bed. To effect economy, it is, however, not always necessary to reduce the gauge. In a flat country a line of standard gauge may be economically constructed, and it is chiefly in rough mountainous country that, by the use of sharper curves and steeper gradients, thereby avoiding deep cuttings and high banks, a narrow gauge effects considerable saving in the cost of construction. But while in this case the cost of construction is reduced, the sharp curves and steep gradients increase the working expenses, and therefore the cost of working must be considered at the same time as the cost of construction.

Light railways may be divided into four classes:—1. feeders to main lines, in the construction and working of which certain economies may be admitted; 2. subsidiary lines, upon which there is little or no interchange of traffic with the main lines, and to which economies of construction and working may be applied on a larger scale; 3. subsidiary lines, the chief traffic upon which is in goods, and where a lower speed may be adopted; and 4. narrow-gauge lines. The first three classes include railways which, without forming an integral part of the main-line systems, are sufficiently large feeders to them to render a break of gauge inadvisable, and those lines passing through cultivated land of small value where a narrow gauge would effect little economy. These lines should be of the standard gauge but with sharper curves and steeper gradients than on the main lines, where such economy will not weigh too heavily on the working. They must be so constructed as to admit the main-line rolling-stock, except locomotives with long rigid wheel-base, but at a reduced speed. The essential difference

between the three classes is their maximum speed, which in Italy is 25 miles,  $18\frac{1}{2}$  miles and  $12\frac{1}{2}$  miles per hour respectively.

*Class 1.*—Upon Italian railways of the first class the curves may not be of smaller radius than 650 feet, and the gradients may not exceed 1 in  $28\frac{1}{2}$ . The width at formation-level, 16 feet 6 inches, is somewhat less than the main-line standard. *Figs. 1* show sections of the permanent way of such lines on bank and in cutting.

*Class 2.*—To this class belong railways worked at a reduced speed with special lighter rolling-stock, but constructed to admit of the passage of main-line carriages and goods wagons. The permanent



way may consequently be lighter and the road-bed narrower. The minimum radius of curves may be between 500 feet and 330 feet, and the maximum gradient 1 in 20. The construction is similar to that shown in *Figs. 1*, but the width at formation level is reduced to 14 feet 6 inches, and the other dimensions in proportion. Flange-rails are used weighing between 50 lbs. and 60 lbs. per yard.

*Class 3.*—This class comprises lines worked with special rolling-stock, but constructed to allow of the passage of main-line goods wagons. The economies of construction may be still greater than in the second class, the speed being considerably lower. The mini-

imum radius of curves is 330 feet, and the maximum gradient 1 in 20. The construction is also similar to that shown in *Figs. 1*, but the width at formation-level is 13 feet, and the other dimensions in proportion. The flange-rails weigh between 40 lbs. and 50 lbs. per yard.

*Class 4.*—Narrow-gauge lines may be adopted when the amount of traffic is small and where exceptional difficulties of construction are met with. The reduction from standard gauge must not be too small, because while cutting off all the advantages of a similar gauge, it does not effect much economy. Examples of such lines are to be found in Belgium, Switzerland, Sweden and elsewhere.<sup>1</sup> On the other hand it must not be too great, as, except in special cases, a gauge of say 2 feet, while affording considerable reduction in the cost of construction, increases the working expenses. On such a line, with the great overhang of the locomotives, a small amount of oscillation deranges the permanent way, increasing considerably the cost of maintenance, while the too small capacity of the vehicles presents difficulties in the transport of passengers and not a few classes of goods.

The narrow gauges in most general use are 3 feet 6 inches, 1 metre, and 2 feet 6 inches, of which the mileage at present in operation, together with other particulars of three railways, is shown in Appendix I. While in Italy two gauges, of 3 feet  $1\frac{7}{8}$  inch and 2 feet  $3\frac{9}{16}$  inches respectively, have been fixed for narrow-gauge railways, as yet none have been built to the smaller gauge. According, therefore, to general practice narrow gauge lies between 3 feet 6 inches and 2 feet 6 inches.

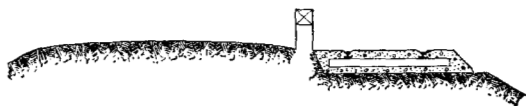
The dimensions and speeds adopted on the Palermo-Corleone Railway, in Sicily, are:—

Gauge, 1 metre centre to centre of rails,	3 feet $1\frac{7}{8}$ inch.
Minimum radius of curves . . . . .	230 "
Maximum gradient . . . . .	1 in 25·64.
Width at formation-level . . . . .	11 feet 6 inches.
Permanent way, steel flange rail . . . .	40 lbs. per yard.
Sleepers (red oak) . . . . .	{ 5 feet 6 inches by 7 inches by $4\frac{1}{2}$ inches.
Minimum depth of ballast under sleepers	4 inches.
Maximum speed on tangent . . . . .	$15\frac{1}{2}$ miles per hour.
" " " " " " " " " " " "	$12\frac{1}{2}$ " " " "
	Hours. Mins. Miles per Hour.
Running time for the whole 42 miles,	{ 3 50 = $9\frac{1}{2}$
including stops . . . . .	
" " " " " " " " " " " "	{ 3 27 = 11
excluding stops. " " " " " " " "	

<sup>1</sup> See also "Light Railways for the Transport of Sugar-cane in Australasia, by C. E. Forster, B.A., Assoc. M. Inst. C.E. Minutes of Proceedings Inst. C.E., vol. cxxii. p. 202.

One of the objections to a break of gauge is the cost of transshipment, but this affects goods only. Goods in baggage and mixed vans are, even in ordinary service, unloaded and reloaded at all junctions with the main line, and sometimes even on the way in order to load the vehicles better. To these goods then, the inconvenience of transshipping on the narrow gauge does not apply. It exists, however, in the case of complete wagon-loads. On the Broelthal Railway in Germany, the cost of transshipping goods is 3*d.* per ton. In Northern Italy the handling of the goods at the stations is in some cases entrusted to contractors for the sum of 5*d.* per ton transshipped. On other Italian lines it costs sometimes more and sometimes less, so that for Italy 5*d.* per ton may be considered a fair average price, the work being heavy, and the staff continuously employed. If this expense for transshipment of 5*d.* per ton is compared with the mean cost of carriage, which is 1*s.* 1.10*d.* per ton-mile, or with the lower charges of 0.80*d.* and 0.64*d.* per ton-mile which full wagon-loads pay, it follows that transshipment is equal to a carriage of 6 miles, and therefore the

Fig. 2.



RAILWAY OF STANDARD GAUGE ON HIGHWAY.

Scale, 1 inch = 12 feet.

distance of carriage and the amount of traffic in full wagon-loads give data to be used in considering the question of narrow gauge.

*Lines laid on Highways.*—Light railways may be laid at the side of highways when these are suitable. In such cases a minimum width of 16 feet 6 inches should be left, and a barrier erected between the rails and the highway, Fig. 2. When, however, the length is short and the speed low, this barrier may be omitted. There are many such examples in Italy under the name of steam-tramways, one of the best being the line from Rome to Tivoli.<sup>1</sup> On the Palermo-Corleone Railway, the first 4 miles from Palermo run alongside and on a level with the highway, separated only by a low stone wall 9 inches to 15 inches high, serving more to mark the boundary of the railway company's property and to maintain the ballast, than as a protection to the road traffic.

<sup>1</sup> Minutes of Proceedings Inst. C.E., vol. cix. p. 344.

Although there is considerable traffic on the highway, both in carts and foot passengers, no difficulty is experienced in working the railway on these 4 miles. The lines in Italy may be laid on the highways, if the rails do not project above the surface, without any barrier, provided that ordinary vehicles can travel without inconvenience, that the line is worked with light rolling-stock, by tramway engines, and at a speed not exceeding 10 miles per hour. Economical railways may cross other railways—even main lines—on the level, provided both lines are protected by safety appliances; and they may join existing lines when necessary between stations, provided the junction is supplied with signals and the necessary automatic safety appliances.

For lines of different gauges a third rail may be laid between those of standard gauge to give access to a station, and a third rail may be so used where the main-line road-bed can also serve for a narrow-gauge line. Continuous fencing is required only at dangerous places, such as the close proximity of a road or pasture fields. Level-crossing watchmen, distant signals, and the electric telegraph may be dispensed with when trains do not run at high speed or at night. Station buildings for both standard and narrow-gauge lines should be as simple as possible, adapted to the special requirements of the place and to the importance of each station. In all intermediate stations of little importance a single room for use as an office will suffice, the tickets in such cases being sold by the train-conductor. Goods sheds should be attached to the station-building with a communication between them. Platforms may be dispensed with or considerably modified on all lines, except those where carriages of the main-line type are used. Except in special cases, level crossings may be left unguarded, a warning notice to the public being sufficient. Where the line crosses roads of much traffic, or where the nature of the country precludes an uninterrupted view of the line, some simple form of barrier should be erected. Distant signals may be dispensed with, and home signals provided only at those stations where trains cross. Metal bed-plates should be inserted between the rails and sleepers to increase the life of the latter and to maintain the correct gauge on sharp curves. On the Palermo-Corleone Railway they were at first laid only on joint sleepers and on some of the sleepers in the sharpest curves; this number being found insufficient, it was increased. At first the bed-plates were pierced for three spikes; but this was afterwards reduced to two, as so many spike-holes were found to be injurious to the sleepers.

*Gradients.*—To determine the gradients on a light railway, the

nature of the traffic, details of the proposed working, and the profile of the line, must be known. The amount of traffic has no effect upon the extra expenses of lowering gradients, while the increased cost of working from adopting the maximum gradient is proportional to the traffic. On lines with small traffic it is advisable to adopt the maximum gradient, when thereby a considerable saving in cost of construction may be effected, while on lines with the prospect of a good traffic, it is well to make some sacrifice in first cost of construction, avoiding as much as possible the maximum gradient, so that when the traffic is fully developed, it may be worked economically. On the Porto Empedocle-Termini Railway, in Sicily, with gradients of 1 in 33·33, the consumption of coal, for the same amount of traffic, is double that on Italian railways with medium gradients, and other locomotive charges follow the same rule. On railways in the province of Calabria, with a traffic of £5 per mile per week, or £257 per mile per annum, the additional working-expenses from economical construction were £1 5s. per mile per week (£65 per mile per annum), or one-fourth.

In his work on "*Les Pentes Économiques*," Mr. de Freycinet states that, "In very rough country, with special locomotives and by doubling up trains, if the traffic is less than on the six great French railways, the most economical gradient will be 1 in 25, and even more on lines of small importance. When the rough portions are smaller, but repeated over the whole line, if the length of line on gradient equals that on the level, the most economical gradient for lines of moderate traffic will be 1 in 55, and therefore more if the length on gradient is greater."

The limiting gradients on Italian railways are :—On lines worked with main-line rolling-stock  $3\frac{1}{2}$  per cent., and on other lines 5 per cent. In tunnels the maximum gradient should be reduced because of the lower adhesion.

*Curves.*—On lines of the first class, the limiting radius of curves for Italian railways is 650 feet on ordinary gradients, and 800 feet on steep gradients. On the South-Western of Venezuela Railway, a 2-foot gauge railway, the limiting radius is 150 feet on 3 per cent. gradients, and 200 feet on  $3\frac{1}{2}$  per cent. gradients. On the La Guaira and Caracas Railway in Venezuela, of 3-foot gauge, there are curves of 140 feet radius on gradients of  $3\frac{1}{2}$  per cent. This should be considered an extreme case. In Italian practice the minimum radius of curvature is 650 feet, 500 feet to 330 feet, and 330 feet on railways of the first, second, and third classes respectively. For a gauge of 3 feet  $1\frac{7}{8}$  inch it is 230 feet, and of 2 feet  $3\frac{1}{8}$  inches 130 feet. Where bogie trucks are adopted for the

rolling-stock, these limits may be further reduced. Curves of similar direction should be joined by a compound curve and not by a tangent; this has considerable effect on the smoothness of running of a train on a mountain line, where the curves are numerous and of small radius. When curves occur on maximum gradients, they should be compensated for by reducing the gradient so as to offer no greater resistance than the adjoining tangents. This amount of compensation varies in practice between 0·03 foot and 0·05 foot per 100 feet per degree of curve ( $1^\circ = 5,730$  feet radius) for standard gauge. On the Rocky Mountain section of the Canadian Pacific Railway, with minimum curves of  $10^\circ$  (573 feet radius) on a maximum gradient of 4·5, per cent., the equation used was 0·03 foot per degree of curve;<sup>1</sup> while on the Rocky Mountain section of the Great Northern Railway, U.S.A., with the same minimum curves of  $10^\circ$  the equation used was 0·04 foot per degree of curve. On the Palermo-Corleone Railway, the minimum distance between reverse curves is 50 feet, the length of the longest train ascending gradients being 142 feet. This, therefore, allows, on each portion of reverse curves in ascending trains, 46 feet. No trouble was experienced with these reverse curves, the trains running safely at all speeds. On the South-Western of Venezuela Railway of 2-foot gauge, the minimum distance between reverse curves is 21 feet. The length of the longest train ascending gradients is 140 feet, which therefore allows on each portion of reverse curves 59 feet. The setting out of this line would have been easier had a shorter tangent between reverse curves been admitted; but further experience on this point is necessary to state whether a shorter tangent would have been admissible.

*Rolling-stock.*—While the tractive power required on curves for bogie trucks shows a decided reduction over that required for stock with a rigid wheel-base, considerable improvement is to be made in the ratio of dead-weight to load. The Author is of opinion that the cost of traction may be substantially reduced by the use of roller bearings and a satisfactory form of flexible wheel-base, combined with independent wheel rotation.

The permanent way being lighter and the curves sharper than on the main lines, special types of locomotives are necessary with a shorter rigid wheel-base, using all their weight for adhesion,

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<sup>1</sup> See "On the Construction of the Canadian Pacific Railway (Rocky Mountain Division) during the Season of 1884," by G. C. Cunningham, M. Inst. C.E., Minutes of Proceedings Inst. C.E., vol. lxxxv. p. 105.

and with less weight on each axle. The following dimensions have been adopted in Italian practice.<sup>1</sup>

Six Wheels Coupled.	Class 2.	Class 3.	Class 4.	
	Ft. Ins.	Ft. Ins.	Ft. Ins.	Ft. Ins.
Diameter of driving-wheels . . . .	3 3	2 7	3 3	2 7
Rigid wheel-base . . . . .	8 6	6 6	6 0	5 0
Maximum weight per axle . . tons	10	8	6	5

Railways of the first class have carriages of the same type as the main lines. Those in the second and third classes should be of the American or Swiss type, with a longitudinal passage along the centre, and end platforms with communication between. When bogie underframes are not adopted, the rigid wheel-base on Italian railways does not exceed 9 feet 10 inches and 8 feet 3 inches, and the weight is such as to allow six passengers and a little more than six per tare ton in the second and third classes respectively. For narrow-gauge lines the weight of the carriages per axle must be greater than that of the locomotives; the former should have a central coupling and buffer, as each line may require different types and dimensions. On economical railways of whatever gauge, excluding those of the first class, it is most desirable there should be only two classes for passengers, for the economical working of the line.

In Italy, when bogie underframes are not adopted, the wheel-base does not exceed 8 feet 3 inches and 7 feet 4½ inches in the second and third classes respectively. The weight of the wagon in each case must not exceed half the load. For covered or box-wagons one type only is recommended, while for open wagons there should be as few types as possible. On the Palermo-Corleone Railway four-wheeled wagons, having a rigid wheel-base of 5 feet 11 inches, caused great trouble owing to frequent derailments. Trains composed of this stock required good driving and very careful braking. Upon additional wagons being required, Mr. W. Shelford, the Company's consulting engineer, adopted bogie trucks and wagons with a rigid wheel-base of 4 feet and bogies 18 feet centre to centre, which gave complete satisfaction. The tractive-power required on curves to haul two bogie-wagons was equal to that required for three four-wheeled wagons.

<sup>1</sup> See also Minutes of Proceedings Inst. C.E., vol. cxx. pp. 35-42, and Appendix I, *post*.



The weights of the rolling-stock on the Palermo-Corleone Railway are :—

	Empty.	Full.
Carriages :—	Tons.	Tons.
1st class, 16 seats (longitudinal) . . . . .	3	5
2nd „ „ „ . . . . .	3	5
3rd „ 32 seats (transverse) . . . . .	3	7
Baggage vans . . . . .	3	5
Wagons :—		
Four-wheeled (complete wagon-load) . . . . .	3	9
„ (loaded with general goods) . . . . .	3	6
Bogies, eight-wheeled (complete wagon-load) . . . . .	6	18
„ „ (loaded with general goods) . . . . .	6	9

The following Table shows the engine-loads used in making up trains :—

Railway.	Length of Continuous Inclines.	Maximum Ascending Gradient.	Summer.		Winter.	
			Two Axles Coupled.	Three Axles Coupled.	Two Axles Coupled.	Three Axles Coupled.
	Miles.	Per Cent.	Tons.	Tons.	Tons.	Tons.
Palermo-Ficuzza . . . . .	2½ and 3	3·9	47	50	42	45
Ficuzza-Donna Beatrice . . . . .	..	..	100	105	95	100
Donna Beatrice-Corleone . . . . .	3	3·9	47	50	42	45

*Working.*—The expenses upon coal, repairs to locomotives, and renewal of rails form about one-fourth the total working-expenses on Italian railways. They may be considered proportional to the velocity of the traffic travelling over the line. In Italy the speed of omnibus, passenger and mixed trains, varies between 15 miles and 18½ miles per hour, including stops, and between 9 miles and 12½ miles per hour for goods trains. A reduction of the speed by one-third would reduce the total working expenses by about 8 per cent. The number of trains should be reduced to meet only immediate needs ; for stations a hut must suffice, tickets must be sold by conductors, and on short lines the trains should be worked by one locomotive, thereby rendering the telegraph unnecessary. The trains must be suited to the requirements of the district, but in view of the fact that a night service increases the cost of running a train. Excluding this, and reducing the speed, the patrolling of the road will be easier and less costly,

since it will be sufficient to examine it once a day, and only necessary to signal obstructions.

On the Palermo-Corleone Railway there are nine women employed at the level crossings, at a monthly salary ranging between 5*s.* and 9*s.* They perform their work admirably, not only protecting the level crossings, but also signalling the trains.

The station expenses per mile on Italian railways are:—

Main lines . . . . .	£ 296 per mile.
„ (Sicily) . . . . .	125 „
Light railways . . . . .	74 „
Narrow gauge . . . . .	40 „
Palermo-Corleone (metre gauge) . . . . .	36 „

The train service may be much simplified, if the line is short, by making the trains cross at fixed points, and by the use of the train staff, which dispenses with the use of the telegraph, or at least very considerably reduces it. Experience on the Continent has shown that the administration should be decentralized and local, and that whenever possible the working of economical railways should be separated from that of the main line. In Appendix II are given particulars relating to the Sicilian and Palermo-Corleone Railways, and in Appendix III an account of the working of the Bavarian economical railways.

To construct and work economically new lines of railway, before reducing the gauge the speed should be reduced, and consequently the diameter of the locomotive driving-wheels, as well as the rigid wheel-base. Economy will therefore be effected in the construction, because the ordinary roads may be utilized, and in every case sharper curves, steeper gradients, and lighter bridges may be adopted. For the rolling-stock and permanent way also, a lighter type, yet always well suited to its work, may be adopted; and in working economy will result, because the useful load of a train compared with its dead load will be greater, the wear of the permanent way, locomotives and rolling-stock less, the consumption of fuel and supplies will be smaller, as also the repairs to rolling-stock, and the staff required along the line and in the stations will be diminished. When all these sources of economy do not suffice to render a railway financially successful, then, and not till then, should the question of reducing the gauge be considered.

The Paper is accompanied by three sheets of tracings, from a selection of which the *Figs.* in the text have been prepared.

## APPENDIXES.

## APPENDIX I.

NARROW-GAUGE RAILWAYS AT PRESENT IN OPERATION.<sup>1</sup>

	2 feet 5½ inches and 2 feet 6 inches.	3 feet, 0·95 metre and 1 metre.	3 feet 6 inches.
	Miles.	Miles.	Miles.
Africa, S. . . . .	..	..	2,570
America, U.S. . . . .	..	5,291	91
Argentina . . . . .	..	2,597	
Australia . . . . .	..	..	4,766
Bolivia . . . . .	574		
Bosnia . . . . .	261		
Brazil . . . . .	406	5,139	336
Canada . . . . .	..	..	212
France . . . . .	..	1,880	
„ (African Colonies)	..	..	479
Germany . . . . .	302	482	
India . . . . .	188	7,637	
Italy . . . . .	..	463	
Mexico (approximate) .	..	1,976	
New Zealand . . . . .	..	..	2,036
Newfoundland . . . . .	..	..	346
	1,731	25,465	10,836

<sup>1</sup> For reference to further information on the subject, see "A Catalogue of Books, Reports, Papers, and Articles relating to Light Railways," compiled by Corrie L. Thompson. London, 1895.

TABLE OF PARTICULARS RELATING TO THREE NARROW-GAUGE RAILWAYS.

	Palermo-Corleone Railway.	South Western Venezuela Railway.	South Western Venezuela Railway.	Quebrada Railway, Venezuela.	Quebrada Railway, Venezuela.
System . . . .	Adhesion	Adhesion	Adhesion	Adhesion	Adhesion
Gauge . . . .	Metre	2-feet	2-feet	2-feet	2-feet
Sharpest curve feet	230—328	150—200	150—200	150—200	150—200
Steepest gradient .	1 in 25	1 in 28½	1 in 28½	1 in 19	1 in 19
Length of incline .	Various	Various	Various	1 mile	1 mile
Type of locomotive .	Tank	Tank	Tank	Tank	Fairlie
Diameter of cylinders } inches	12½	13	10½	12	9
Stroke " . . . .	18	18	18	18	14
Axles . . . . .	{ 3 coupled 1 pony	{ 3 coupled 1 pony	{ 2 coupled 2 bogie	{ 3 coupled 2 bogie	{ 6 in 2 sets 3 coupled
Rigid wheel-base .	6 feet	{ 5 feet 10 inches	5 feet 10 inches	9 feet 10 inches	6 feet
Diameter of wheels .	{ 2 feet 10½ inches 2 feet	{ 2 feet 6 inches 2 feet	2 feet 3 feet 2 feet	{ 2 feet 6½ inches 1 foot 6 inches	.. 2 feet 6 inches
Heating-surface } square feet	495	489	363	421	785
Weight of loaded locomotive . . . .	{ 24 tons 6 cwt.	23 tons	17 tons 10 cwt.	22 tons 5 cwt.	29 tons 10 cwt.
Greatest weight on an axle . . . . .	{ 6 tons 4 cwt.	6 tons 10 cwt.	6 tons 5 cwt.	5 tons 16 cwt.	4 tons 18 cwt.
Gross load hauled up incline . . . .	50 tons	64 tons	30 tons	63 tons	61 tons
Builders of locomotives . . . .	Hawthorn, Leslie & Co.	Kitson & Co.	Falcon Engine Co.	Dübs & Co.	Hawthorn, Leslie & Co.

## APPENDIX II.

## SICILIAN RAILWAYS—MAIN LINES, STANDARD GAUGE.

	Kilometres.
Length of line on level . . . . .	118 or 20 per cent.
" " gradient of 1 in 200 or less . .	123 " 20 " "
" " " " 1 in 66 . . . . .	235 " 39 " "
" " " " over 1 in 66 . . . . .	129 " 21 " "
Total . . . . .	605
Length of straight line . . . . .	303 or 50 per cent.
On curves over 500 metres (1,640 feet) . .	122 " 20 " "
" " of 500 metres radius or less . . .	160 " 30 " "
Maximum gradient . . . . .	1 in 31·5
Minimum radius of curves . . . . .	492 feet.

ALLOWANCE FOR LOCOMOTIVES.		Kilogram.	(reduced to 0.26 kilog. during months May- October.
Coal—			
For each axle-kilometre . . . . .		0.27	

NOTE.—Locomotives hauling express trains receive 30 kilograms extra. Each hour standing in steam is equivalent to 2 locomotive kilometres, and each hour shunting trains to 5 train kilometres.

Oil—			
Four-coupled locomotive . . . . .		0.028	per kilometre.
Six- " " . . . . .		0.030	" "
Eight- " " (special mountain locomotive) . . . . .		0.035	" "

NOTE.—Express trains with four- and six-coupled locomotives receive 0.010 kilogram and 0.015 kilogram extra respectively.

Shunting trains at stations, four-coupled locomotives . . . . .	0.075	per hour.
" " " other locomotives . . . . .	0.100	" "

#### PALERMO-CORLEONE RAILWAY—METRE GAUGE.

		Kilometres.	
Length of line on level . . . . .		7.7	or 12 per cent.
" " gradient of 1 in 200 or less . . . . .		9.4	" 14 " "
" " " 1 in 66 . . . . .		9.5	" 14 " "
" " " " over 1 in 66 . . . . .		40.8	" 60 " "
Total . . . . .		67.4	
Length of straight line . . . . .		37.2	" 55 " "
Curved line over 500 metres radius (1,640 feet) . . . . .		2.0	" 3 " "
" " 500 metres radius or less . . . . .		28.0	" 42 " "
Maximum gradient . . . . .		1	in 25.6
Minimum radius of curves . . . . .		230	feet.

ALLOWANCE FOR LOCOMOTIVES.		Kilograms.
Coal—		
For each locomotive kilometre . . . . .		4.00
" hour in reserve shunting . . . . .		30.00
" " standing in steam without shunting . . . . .		15.00
" lighting up . . . . .		60.00
" carriage kilometre . . . . .		0.60
" loaded wagon (two axles) kilometre . . . . .		0.70
" " (four axles) " . . . . .		1.40
" empty wagon (two axles) " . . . . .		0.35
" " (four axles) " . . . . .		0.70
Each hour shunting = 4 locomotive kilometres.		

Oil—			
For each six-coupled locomotive kilometre . . . . .		0.040	
" four-coupled " " . . . . .		0.035	
" hour shunting . . . . .		0.100	

NOTES.—100 kilograms of wood = 50 kilograms of coal.

Every ton of coal saved gains 5.00 lire (4s. 2d.).

" kilogram of oil saved gains 0.50 lire (5d.).

" ton of coal burnt extra costs 7.00 lire (5s. 10d.).

" kilogram of oil used extra costs 0.70 lire (7d.).

The drivers generally saved on the above coal allowance, but used between 3 kilograms and 25 kilograms of oil in excess of above allowance.

## APPENDIX III.

## BAVARIAN GOVERNMENT RAILWAYS.

The Bavarian Government light railways are all of standard gauge, 4 feet 8½ inches, to allow of the passage over them of main-line goods wagons, but are under entirely separate management. The service is under the direction of the general manager, and on each branch or local railway an official is appointed who reports to a special department of the Director General of Railways' Office. The receipts vary between £2 and £12 10s. per mile per week (£100-£650 per mile per annum), of which on an average two-thirds are from goods and one-third from passenger traffic. On these lines there are a large number of stopping-places, which are divided into two classes, called principal and secondary. There is only one station, situated at the terminus of each line, where the branch manager resides. Of the one hundred stopping-places on branch lines fifty-one are principal and forty secondary, and there are nine stations. As the tickets are distributed on the trains, the machinery at the stopping-places is limited and reduced to the least possible amount. Frequently there is only a waiting-shed, and sometimes only a platform with a tablet showing the name of the stopping-place. There are no signals except at the entrances to junctions. Stations and stopping-places on lines where trains are worked by the staff are connected by telephone, and on these lines there is no fencing, and the level crossings are unguarded.

The passenger coaches and locomotives are of special types, lighter than those on the main line, and in order to reduce the number of vehicles there are only two classes. The carriages are of the Swiss or American type, with a central passage and communication with the baggage-car, and weigh about 6 tons each. On trains carrying the mail the baggage-car has a small compartment fitted up for the post-office official. The carriages are either heated by steam from the engine, or in mixed trains by a vertical boiler in the baggage-van. Lighting is effected by petroleum lamps. The "Heberlein" brake is used, and the rolling-stock is also provided with ordinary screw-brakes for use in case of need. There are two types of locomotives. Those for use only on lines having gradients not exceeding 1 in 150 have two axles coupled, and weigh about 18 tons in working order, and those for lines with gradients up to 1 in 40 have three axles coupled, and weigh about 26 tons loaded. On gradients of 1 in 100 the former have to take a load of 93 tons at a speed of 7½ miles per hour, and the latter 165 tons at a speed of 9 miles per hour.

The method of working these lines is of considerable interest, as on many of them the receipts, although very small, are sufficient to cover the working expenses. In 1893 the total receipts on the Bavarian Light and Roth-Greding Railways were £106,601 and £3,842, or £5 and £3 per mile per week respectively. The total expenditures were £55,588 and £2,636, or 50·26 per cent. and 68·61 per cent.

The branch manager is responsible for the due maintenance of the property as well as the working of his branch. He reports direct to the general manager through the office of Economical Railways. He has to take charge of the station where he resides, all the employees are under his orders, and in his office are kept the accounts of the branch. In case of an interruption to the working of the line he must, after despatching assistance, himself ascertain the cause on the spot. He controls the conductors and checks their accounts. Having the care of all the company's property he must pass over his branch on foot at least once a week, and satisfy himself that the points, permanent way and crossing places

are in good working order, making provision for renewals or repairs where necessary. He is also responsible for the proper maintenance of the road-bed and structures. He has to see that the locomotives are in charge of men well qualified to drive them, that the rolling-stock is properly distributed, in good condition, clean, and properly lubricated and lighted. He provides for all payments relating to his branch out of the traffic receipts. Every ten days he checks the balance of his cash office. The share of his branch in the expense of rolling-stock repair is furnished him monthly from the central-workshop returns, and every month he balances his books and sends a balance-sheet to the Director General of Railways.

The management of each train on the branch lines is entrusted to a conductor, who is responsible for the safety of the goods while on the train. He distributes the tickets during the journey, superintends the shunting at private sidings, and sees that all the train-hands assist. When at the terminal station he must, if required by the manager, assist by working in the office. The conductor is provided with a book of tickets containing stub and file so arranged as to show, by means of holes punched in them, the stations from and to which the passenger is travelling and the amount paid. By this method a simple and complete check is kept on these transactions. In the baggage-van are schedules showing the amount to be charged for the different classes and journeys for passengers, baggage and goods. Baggage is weighed by a weighing-machine in the baggage-van. Tickets in duplicate show the station from and to which the goods are being carried and the amount paid, one being given to consignor. Labels with a number corresponding to that on the ticket are attached to the goods, which are given up on arrival at their destination in return for the ticket. On arrival at a junction passengers and baggage are re-booked. For goods "carriage paid" at the junction the conductor acts as consignor, paying the freight for carriage on the main line and retaining that due for carriage on the branch out of the sum received when the goods were loaded on the train. At the end of the day the conductor makes out a report giving in detail all his transactions, which, together with the money received, counterfoils of tickets issued and checks withdrawn, he consigns to be checked by the branch manager, who then and there checks their accuracy. The conductor, besides performing all the duties inherent to the movement and safety of the train and care of goods consigned to him, provides directly for the distribution of passengers' tickets, receipt, taxing, and delivery of baggage and dogs, of goods and animals despatched between stations on the branch, exacting the amount due and compiling a complete account relative to such transport. The wages of a conductor are £50 per year, with an allowance for mileage.

The work at the stopping-places may be performed by men either employed or not employed by the Company. To the former are given between 3 miles and 4 miles of line to patrol. The man in charge provides for the receipt and delivery of goods, and assists in the shunting, loading and unloading of goods. These operations are facilitated and expedited by stopping the train so that the goods wagon is opposite the goods shed; and by means of planks the goods are wheeled on trucks from one to the other to avoid lifting. At stopping-places in charge of a man not in the Company's employ he is obliged to be at his post only half an hour before the train is due, to receive the goods to be forwarded or those coming by train. These men are authorized to charge consignors and consignees, according to a tariff fixed by the Company, for loading and unloading goods, the Company guaranteeing them between £15 and £20 a year of such charge. They receive whatever excess they make above that amount, and in this way are to a certain extent co-interested in the prosperity

of the railway. They give a small security as guarantee of their obligations. The receipt and delivery of goods are limited to certain hours in the day, having regard to local requirements, to allow the agent in charge of the stopping-place to perform his other duties for the receipt of trains and patrolling the length of line assigned to him.

Stopping-places are provided with tariffs showing the rates between points on that branch. For the cumulative service, or with other lines of the Bavarian railways system, the terminal station, where the branch manager lives, is provided with a complete set of tariffs. When the man in charge of a stopping-place has to despatch goods "carriage paid" to other lines, he finds from the terminal station by telephone the rate from the junction to the destination, and adds it to the rate for freight on the branch, which he has already ascertained from his tariff. In these cases the junction station acts as the intermediary, and, as described above, the work of the branch line is complete when it has handed over the goods and the amount received for freight from the junction to the destination. Men in charge of stopping-places send daily reports, which are compared and checked with those of the train-conductors. The terminal station then makes up its account and communicates with the junction station by telephone to ascertain whether they agree.

The driver must be capable of driving and maintaining his engine in good order, and of making such repairs as the appliances at the branch line's running shed admit. The locomotive and repair shops are situated at the headquarters of each division. He has to keep the record book of the respective engines, in which he notes all repairs executed and washings out. In addition to the duties incident to his office, he must, with the help of his fireman, before the departure of the train, and at intermediate points when necessary, examine and oil the carriages and wagons. The driver and fireman are enjoined to pay attention to defects in the road, and to immediately notify the branch manager of them, so that he, having at his disposal a limited number of platelayers, can send them to those points where they are most required. The cleaning of the carriages and preparation of the lamps is also carried out by the locomotive staff.

The fireman at the station and stopping-places must assist in loading and unloading goods, and act as pointsman. He must, in the absence of the brakeman, light the carriage-lamps, and light and extinguish the tail lamps of the train.

The duties of brakeman are performed by a porter from the junction or terminal station, who is employed when the train is longer than usual. Under the orders of the station-master or conductor, the brakeman must assist in shunting, attaching or detaching vehicles from the train, loading and unloading baggage and goods, and everything that the requirements of the service demand of them.

It is thus possible to perform the service in stations where there is only one employee, and provide in the ordinary cases for loading and unloading goods, and all the operations pertaining to the arrival and departure of trains. When the station-master, the conductor, fireman and brakeman all assist at these operations, the whole of the staff is equally employed and the service is economically performed. To show the actual results of such economical working, statistics of the Roth-Greding line are appended.

#### ROTH-GREDING RAILWAY. (Gauge 4 ft. 9 inch.)

This line is 24·38 miles long, and was opened in 1883. Its construction cost £2,858, and its rolling-stock £269 per mile, the total cost being £3,127 per mile.



The permanent way consists of steel flange-rails, 29 feet 6 inches long, weighing 38·3 lbs. per yard between Roth and Eysolden, 13·6 miles, where they are laid on iron sleepers, and 44·3 lbs. per yard between Eysolden and Greding, 10·7 miles, where they are laid on iron longitudinals. This change of permanent way is due to the scarcity of material suitable for ballast, which in the first length consists of clean sand, and in the second of sand and clay mixed. This last arrangement allows a minimum quantity of ballast, while affording a firm bearing for the permanent way. The railway runs close to an ordinary road, and its levels follow as closely as possible the natural surface of the ground. The steepest gradient is 1 in 40, and the minimum radius of curve 650 feet, with the exception of a curve of 590 feet at the exit from Roth Station. The masonry works are few in number and of small size, constructed for the most part of rough stone. For carrying off the water cement pipes are extensively used, of circular section up to 2 feet diameter, and of oval section for larger openings.

The stopping-places are laid out as simply and economically as possible. There are no platelayers' huts, and the fencing both along the line and at all level crossings is entirely suppressed. The stopping-places and the station of Greding are connected by telephone. Between Roth and Greding there are seven principal and seven secondary stopping-places; generally they are placed close to a level crossing, and at those where there is no building a small wooden shed is erected to accommodate passengers waiting for the trains.

The rolling-stock assigned to this line consists of three Krauss locomotives with six wheels coupled; eight passenger carriages, of which three are second and third class mixed, and five are third class; three baggage-vans, with a compartment for the post-office; and two goods wagons. This rolling-stock forms three complete trains, of which two are in service and one in reserve. When, owing to heavy traffic of passengers or goods, other vehicles are required, they are borrowed from the main line.

The speed of the train is between 12 miles and 15 miles per hour. There are three trains each way in summer and two in winter.

The staff on this line consists of the branch manager, who is also station-master at Greding, an assistant and two clerks. The rest of the station staff consists of one pointsman at Roth, who, besides patrolling a length of the road, helps in the running-shed, lighting the fire in the locomotives, and filling the water-tank; and one pointsman at Greding, who assists in loading and unloading goods, cleaning the office and patrolling a length of road.

Three of the intermediate stopping-places are worked by employees of the Company, the others being served by men not in the Company's employ.

The staff of each train ordinarily consists of three men, the driver, fireman and conductor, unless the number of vehicles, owing to the gradients, require the assistance of one or two brakemen. Generally the trains consist of only two passenger carriages, one of second and third class mixed, and two of third class. The conductors have leave once every eight days, when their place is filled by one of the two office clerks. The whole line is therefore worked by thirty men, or 1·23 per mile of railway.

For the particulars respecting the Bavarian railways the Author is indebted to a report by the late Commendatore Biglia, and information supplied by the Director General of Bavarian Railways.