MINE TRACKS
THEIR LOCATION AND CONSTRUCTION

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TREATING BRIEFLY ON THE MATERIALS USED AND THE
PRINCIPLES INVOLVED IN THE DESIGN AND INSTALLATION, WITH A SET OF RULES
FOR A STANDARD PRACTICE

BY

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INTRODUCTION

The gradual displacement of animals by mechanical haulage as the motive power in mine transportation, the successive increases in the weight of the locomotives employed and the improvements in car journals and rolling stock, admitting of longer, heavier trains at relatively high velocities, are making imperative a closer attention to the track material used in mines.

Short-radius curves are falling into disuse wherever traffic is at all heavy. These curves are frequently the limiting factor in the length of the trip. The long wheelbase of the motors is not adapted to them, they are the site of continual derailments, the haulage speed must be reduced at their approach, the cars cannot be pushed around them without danger of the bumpers "locking," their maintenance is excessive, and for many other reasons the use of sharp curves is questionable economy.

The introduction of the steel car for mine transportation also demands a higher grade of trackwork than was required for the wooden car; the deficiencies of the roadbed, to which the semi-pliant material of the latter adapted itself, tends to loosen the construction of the more rigid steel car.

With the more progressive mining companies, the old practice of building frogs, switches, etc., at the mine—to suit the conditions as they arose—with the crude facilities of the average smithshop, is being supplanted by the use of better-constructed commercial equipment, to which the curves are standardized. For it is obvious that the highest perfection in the design and quality of the material will accomplish little if this material is improperly installed.

With many mining companies, I have found, that after they are satisfied as to the merit of the equipment, the subject of trackwork is neglected, and the manner of installation and the specific application, the selection of the frogs, switches, etc., goes by default to the foreman or trackman. Generally speaking, no efficient trackwork can be accomplished without some prescribed rules to govern this work.

Moreover, it will be found in endeavoring to compile a standard practice for the guidance of the trackmen, that while most textbooks and handbooks on this subject are replete with data on the standard-gage track, they are curiously lacking when applied to the narrow gages. It is necessary to delve through many topics to find any information at all on the subject, and then often its treatment is intelligible to no one but an engineer.

With the foregoing in mind, the following treatise has been prepared in order to furnish those in charge of the trackwork and the laying out of trackwork with the necessary data in a convenient form, compiled from the usages of several companies where trackwork has been taken up systematically.

The introduction of the rules in the latter part of this book is in line with the policy of the standard-gage roads to standardize practices and material, and fix definitely the responsibility for the various operations. The first part of the book deals briefly with the reasons governing the rules and the mathematical computations involved. The opinion that a mine car will run on any kind of track and that anything is good enough for mine work cannot be too strongly discouraged.

Wellington and other authorities have been quoted. I wish to thank Mr. H. G. Houtz for the preparation of the sketches and Mr. M. B. Gerhard for much valuable assistance.

It is hoped that a consistent application of the practices suggested will result in lengthened trips and lower haulage costs; easier, more economic track maintenance with a minimum of equipment in stock, and, finally, help to reduce delays in transportation ascribable to trackwork.

J. McCrystle.

October, 1917.

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CHAPTER I

RAILS

With the exception of gravity roads on the heavier grades where wood rail is still preferred on account of its higher coefficient of friction, standard tee rail is now in general use for mine tracks. In determining the proper weight or section of steel rail for any work, the type of haulage, the weight of the cars and locomotive, the spacing of the ties, and in some cases the reaction of the acid or sulphur water must be thoroughly considered. The approximate rules heretofore used in the determination of the rail section have usually erred in making the rail section too light. The severity of future as well as present traffic must be considered, since rail once laid is almost invariably utilized as long as the cars will travel over it, regardless of the increase in tonnage both of the trip and locomotive.

In computing the safe load for steel rail laid with 16 ties to the 30-ft. rail, 10 lb. per yard for each 2240 lb. of weight on each wheel is usually taken; this, with an 8-ton four-wheel motor, would mean 2 tons on each wheel, or 20-lb. rail. This weight, while safe, is evidently not enough for any but chamber work—light-weight rail is a costly economy.

The flat wheels common to mine cars, the swaying side motion due to the play of the axles in the boxes and the side slant of the roadbed, the inferior ballast allowing some of the ties to sink and causing the rail to span a number of ties, thus creating greater bending moments, the acid action of the water on the steel, the scrap value of any reclaimed track, the cutting effect on the treads of the locomotive wheels, etc., are too often forgotten in the purchase of rail.

Again, gangways or headings starting out with short mule hauls are converted to motor hauls, and later employed as main haulageways without any improvement in the original track. As a consequence, the rail becomes a series of humps and hollows, the maintenance of the rolling stock and roadbed is excessive, the roadbed is rendered dirty by the car offal, the trips have few cars, frequent derailments occur, and the initial economy in the light weight of the rail is soon overcome.

As Wellington aptly expresses it, in buying rail "we must, unfortunately, use an intelligence somewhat higher than a hay scale." In rail we require: (1) Stiffness, (2) strength and (3) durability, rather than tons of steel. If the strength of various sections is compared, it will be found that these requisites can be purchased at a lower unit rate in the larger sections. In "stiffness" we have that property which allows the rail to span the ties and support the load without deflecting, affording thereby a smooth running surface for the cars; in "strength" we have that quality which bears the load without breaking, while in "durability" we have the ability to resist wear over extended periods of time.

The stiffness varies as the square of the weight, and the strength as the $3/2$ power, while the price per ton is nearly constant. If the unit weight is assumed as being 30 lb. per yard, then the stiffness will increase as follows:

THIRTY POUNDS PER YARD—STIFFNESS = 1

$16\frac{2}{3}$ per cent. increase in weight (35 lb. per yard) stiffness = 1.36 or a 36 per cent. increase.

33⅓ per cent. increase in weight (40 lb. per yard) stiffness = 1.78 or a 78 per cent. increase.

50 per cent. increase in weight (45 lb. per yard) stiffness = 2.25 or a 125 per cent. increase.

66⅔ per cent. increase in weight (50 lb. per yard) stiffness = 2.79 or a 179 per cent. increase.

100 per cent. increase in weight (60 lb. per yard) stiffness = 4.00 or a 300 per cent. increase.

The ultimate strength will increase as follows:

THIRTY POUNDS PER YARD—ULTIMATE STRENGTH = 1

16⅔ per cent. increase in weight (35 lb. per yard) ultimate strength = 1.26 or a 26 per cent. increase.

33⅓ per cent. increase in weight (40 lb. per yard) ultimate strength = 1.54 or a 54 per cent. increase.

50 per cent. increase in weight (45 lb. per yard) ultimate strength = 1.84 or a 84 per cent. increase.

66⅔ per cent. increase in weight (50 lb. per yard) ultimate strength = 2.15 or a 115 per cent. increase.

100 per cent. increase in weight (60 lb. per yard) ultimate strength = 2.83 or a 183 per cent. increase.

The advantages of the heavy section over the light, as regards stiffness and strength, would show a higher comparison as the rail wears or wastes away from any cause whatsoever.

In determining the durability of rail, it is obvious that a great amount of wear cannot be expected if the weight selected conforms closely to the immediate duty it has to perform.

We can assume for practical purposes that half the total weight is in the head, and that about half of this weight, or one-quarter the weight of the rail, can be worn away before the rail is discarded, if a sufficient margin of metal has been allowed; otherwise, the rail will fail before it has attained much more than a high polish.

In mining work, particularly underground, with the trackmen in absolute charge, trackwork, derailments, rail breakage, etc., are taken as part of the day's routine and pass unnoticed, except that part which appears indirectly in the high maintenance charges.

If we assume that a wear of ⅕ the weight of the head is allowed as a safety factor in the lighter rail, then the durability of light and heavy sections will compare as follows:

Weight in lb. per yard	Weight in head only	Available for wear		Left in head after minimum wear	Spare metal in next heaviest rail before head becomes as light	Times increase of wear by adding 5 lb. to section	Increase in weight by adding 5 lb. to section
		Maximum half head	Minimum one-fifth head				
30	15.0	7.5	3.0	12	5.5	1.830	⅙
35	17.5	8.75	3.5	14	6.0	1.710	⅐
40	20.0	10.00	4.0	16	6.5	1.625	⅛
45	22.5	11.25	4.5	18	7.0	1.550	⅑
50	25.0	12.50	5.0	20	7.5	1.500	⅒
55	27.5	13.25	5.5	22	8.0	1.454	1/11
60	30.0	15.00	6.0	24	8.5	1.420	1/12

Or, using 30-lb. rail as a unit, the metal available for wear would compare as follows:

Weight in lb. per yard	Weight in head only	Available for wear before head would become as light		Increase in weight per yard, per cent.
		Maximum lb. per cent.	Minimum lb. per cent.	
30	15	7.5-100	3.0-100	
35	17½	10.0-133⅓	5.5-183⅓	16⅔
40	20	12.5-166⅔	8.0-266⅔	33⅓
45	22½	15.0-200	10.5-350	50
50	25	17.5-233⅓	13.0-433⅓	66⅔
55	27½	20.0-266⅔	15.5-516⅔	83⅓
60	30	22.5-300	18.0-600	100

Briefly, if we were about to build a permanent (so-called) narrow-gage road for mine traffic, for which 30-lb. steel would ordinarily be used, we would gain, by using a 60-lb. section, the economy in maintenance, a more easily operated road with its attendant benefits, fewer ties, fewer derailments and a larger scrap value when the rail was reclaimed. Furthermore, we would have a stiffness 4 times, an ultimate strength 2.83 times and a durability 3 to 6 times as great, for a rail expenditure but double that for 30-lb. steel.

Some concerns, by purchasing "second hand" rail from the railroad companies, obtain the heavier rail for the same price per lineal foot as for new sections ½ to ⅔ their weight. This quality of rail for most mining purposes will serve as well as new sections.

In localities where acid water abounds the corroding of the steel is frequently the limiting factor in the life of the rail. It would be futile to lay heavy section rail in locations where the water would soon destroy it. As the web and edges of the flange are the portions destroyed first, an inspection of the standard dimensions will evidence that, by increasing the weight, we do not secure a proportionate increase in the acid-resisting properties of the rail. Rail weighing 25 lb. per yard has been taken as the basis or unit.

Weight of rail	Increase in weight, per cent.	Web		Ends of flange	
		Thickness	Increase in thickness, per cent.	Thickness	Increase in thickness, per cent.
25	...	19/64	..	11/64	..
30	20	21/64	11	11/64	..
35	40	23/64	21	12/64	9
40	60	25/64	32	14/64	27
45	80	27/64	42	15/64	35
50	100	28/64	47	15/64	36
60	140	31/64	63	18/64	64

In the standard tee rail, adopted by the American Society of Civil Engineers, 42 per cent. of the metal is in the head, 21 per cent. in the web and 37 per cent. in the flange. The top corners are curved to a 5⁄16-in. radius, and the car wheels are designed to give on this as little friction as possible; as the rail due to the wear approaches more closely to the shape of the flange the friction is augmented. The height of the rail is identical with the width of the flange, so if this dimension is measured the weight can be determined.

The table shows the weight of rail per yard corresponding to the height or flange width.

Weight	Width of flange or height, in inches	Weight	Width of flange or height, in inches
25	2¾	45	3 11⁄16
30	3	50	3⅞
35	3¼	60	4¼

LAYING RAIL

In laying rails, the joints should be staggered; that is, the joints of one rail should as nearly as possible come opposite the center of the rail lengths of the opposite rail. Lengths less than 10 ft. should not be used.

In Fig. 1 are shown a number of defective joints exceedingly common in mine-track construction. No. 1 shows what is known as a "dish." This is usually caused by the rolling stock pounding down the joint. In No. 2, two objections will be noticed; first, the ends of the rail are not butted closely together, and second, the rails are on different levels. No. 3 shows two rails which are not in alignment, probably caused by not using joint fastenings. No. 4 is an example of improper curvature, or lack of curvature in bending and laying the rail. The joint should be just as symmetrical and easy running as the remainder of the curve.

When the cars travel over a joint such as No. 1, or a "high joint" (the contrary condition to No. 1, caused by the rail creeping or being improperly laid or ballasted), it

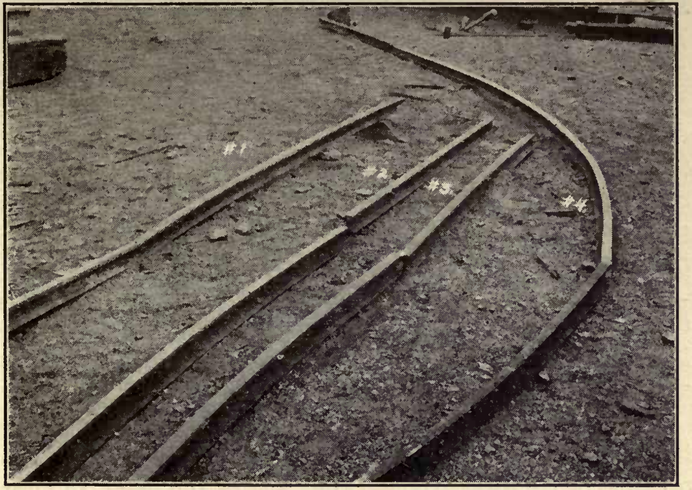


Fig. 1.—Some common faults in rail joints.

necessarily forces one of the wheels to rise above the rail; the consequence is that quite often the flange mounts the rail and the car is thrown off the track. When the trackman seeks to remedy the condition, what often seems the natural thing to do is to elevate the rail which the car has mounted, when really the difficulty is frequently on the opposite rail.

The objection to a joint such as illustrated in No. 2 (Fig. 1) is apparent. While it may not cause a derailment, it sets the entire trip bumping and jogging, racks the rolling stock and loosens all the "topping" on the cars.

The objections to a joint such as is shown in No. 3 are not always as striking as on this figure. The track is apparently not true to gage at the end of one of the rails, and the end of the adjoining rail is probably loose. When no joint fastenings are employed, the rail may spring laterally during the passage of a car and immediately thereafter revert to its natural position. This may derail the car, which, if going at some speed, will travel considerably beyond the defective point and tend to mislead thereby in its detection.

No. 4 (Fig. 1) is the most usual form of bad track. The rail is not curved uniformly, and a swaying motion is imparted to the cars; if the velocity is sufficient, the flange may run directly over the rail.

To be sure, all derailments cannot be ascribed to the track, and in some instances they can be traced directly to the car. However, if the track is in perfect condition the car must be unusually bad before it will leave the track.

All rails should be laid true to the correct gage of the track except where allowance is made for curvature. The practice of slightly reducing the gage of the track to allow for the deficiencies of the gage of the car wheel is questionable, since this expedient impairs the wheel gage of any new cars.

Fig. 2 shows an ordinary rail bender, or "Jim Crow," adapted for bending heavy rails or "dishing" them. The contrivance consists of two eye-bolts, two old sticks of timber, two mine ties and a rail bender. The greater the spacing of the ties, the greater will be the power of the bender.

Rail which has previously been used for locomotive haulage will frequently be found to be brittle and break during bending. This condition is due to the crystallization of the steel from the constant impact of the wheels and does not, as is often erroneously believed, arise from the return passage of electric currents. The effect, if any, of the electricity would be to soften the metal. However, where the bonding of the rails is deficient, the electric current sometimes leaves the rail and runs through the soil, again returning to the rail. This leaving and reëntering the rail causes an electrolytic action, and the rail sometimes disintegrates at the points of exit and entry.

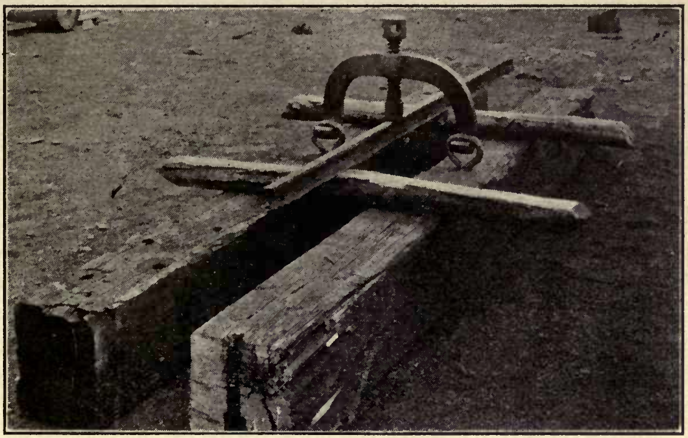


Fig. 2.—Rail bender, adapted for "dishing" rails.

Where the rails have crystallized, or become brittle, they should be either annealed before bending or be bent while hot.

Where rails are laid underground, the small variation in the temperature will not require any allowance at the joints for expansion; when they are laid on the surface, however, the space left for the expansion of 30-ft. rails should be as follows:

Temperature when rail is laid	Space to be allowed for expansion
24 deg. and less	¼ in.
25 deg. to 49 deg.	3⁄16 in.
50 deg. to 74 deg.	⅛ in.
75 deg. to 94 deg.	1⁄16 in.
95 deg. and over	Nothing

On tracks on a heavy grade the rails have a tendency to "creep" or move down the grade. This may be caused either by the braking of the train, or the tractive force of the locomotive, or a combination of both; the effect of the braking being the more appreciable due to the unevenness of its application, and will be more evident in the down track or roads having one way traffic.

The "creep" is caused by a longitudinal thrust, communicated by the wheels to the rail, and is equivalent to 20 per cent. of the weight of the locomotive where the cars are not equipped with brakes, and 20 per cent. of the combined weight of the cars and locomotives on a down grade where the brakes on the cars and locomotive are applied.

This "creep" destroys the alignment of the track and curves, and at sites where it is found impossible to re-align the track without cutting the rail, the excess length should be bent outward and permitted to slide without distorting the track. This is accomplished by inserting a switch point at the bent rail to make a sliding contact instead of the usual unyielding butt connection. Their use at the upper end of the curves will be found advantageous.

WOODEN RAIL

In flat pitch mining, where the car is taken by gravity from the working face, with the wheels spragged to retard the velocity, wood rail is frequently used on account of its higher coefficient of friction, or resistance to sliding. This coefficient for cast iron on steel is 0.20, and for cast iron on oak 0.49, or about 2½ times as great for the wooden rail.

It is problematical whether the use of wood rail is warranted under any conditions. Many mines have discontinued its use without any noticeable inconvenience on their heavier pitching "slants," or chambers. The required friction is obtained by running a plank along the outside of a light tee rail. The tread of the wheel being wider than the head of the rail allows the wheels to slide upon both the plank and the tee rail.

Among the objections to wood rail are: The lack of durability; the rounding of the corners and the splintering of the wearing surface, due to the action of the wheels; the lack of uniformity of the cross-section and the inclination to warp, common to all wood. Owing to these drawbacks and the ease with which the car wheels mount wooden rail, the cars are much more subject to derailments than when steel rail is employed.

Wood rails are usually laid in ties which have been notched to the proper gage and are held in place by the notches and steel spikes. They can be laid almost as rapidly as the light weight steel rail.

The rail is usually ordered about 3 × 5 in. in section and in 12 to 16-ft. lengths of beech, birch, maple, oak or ash. Care should be taken to have such rails sound with square edges, and to have them stored in a manner to prevent warping.

CHAPTER II

TIES

The dimensions of mine ties should be consistent with the rail and spikes used, and the mode of haulage. In order to insure stability, the ties should in no case extend less than 8 in. beyond the web of the rail; nor should they be less than 4½ ft. in length. In addition, the ties should have two parallel faces at least 3½ in. wide. The preferred woods are locust, oak, chestnut, hemlock, ash, ironwood, hickory and hard pine.

With usual conditions, the number of cross-ties cannot be too great for service until their closeness to each other impedes tamping, which limit is reached when about 40 per cent. of the rail rests upon the ties. The determination of the tie spacing is dependent on (1) the weight of the rail, (2) the packing and ballast of the ties, and (3) the weight and volume of the traffic

With a tie having a 6-in. face the minimum spacing to allow adequate tamping would, therefore, be 15 in. This, however, is a tie frequency that practically it is almost impossible to obtain under the more usual mining conditions in which the workmen driving the headings or chambers, are also required to extend their own track. With these men, the trackwork being but a secondary consideration, the natural tendency is to give it only enough attention to fulfill their immediate needs and satisfy the none too strict exactions of the mine foremen.

In ascertaining the proper tie spacing or the weight of rail suitable, the following consideration must not be lost sight of.

(1) Allowance should be made for unusual impact stresses caused by the "flat spots" on car wheels. These "flat spots" are quite common on wheels in mines having long grades requiring sprags. The load transferred to a rail by a flat wheel on a car in motion is in the nature of a blow or suddenly applied load, and will therefore be more severe than a smoothly applied moving load.

(2) Consideration should be given to the frequent occurrence of ties that are not adequately supported by the ballast, which may be due not only to improper tamping, but also to the washing out, or disintegration of the ballast. This occurrence will at least double the stipulated span of the rail.

(3) Due thought should be given to the great loss in rail stiffness caused by but a small increase in space between the ties. A failure to observe this will soon be evident in "dishes" in the rail, and the effects on the traffic. It will be recognized readily that if the ties are well packed, any increase in the number of ties used for a given distance will increase the strength and stiffness of the rail. Accordingly, if the rail furnished is too light for the traffic, this deficiency may to a large extent be overcome by the use of more ties. Ties must be well tamped before they can be expected to perform their proper function of supporting the rail and load.

A few concrete examples will perhaps make clear the foregoing considerations in the computation of the weight of rail and tie spacing with various rolling stocks.

Example.—It is desired to establish a safe weight of rail for use with a 4-wheel, 8-ton locomotive, having a 4-ft. wheel base, drawing cars with a maximum gross weight of 7 tons, and having a $2\frac{1}{2}$-ft. wheel base over ties having 6-in. faces and spaced on 24-in. centers.

$$\text{Weight on one locomotive wheel} = \frac{16{,}000}{4} = 4000 \text{ lb.}$$

$$\text{Weight on one car wheel} = \frac{14{,}000}{4} = 3500 \text{ lb.}$$

Since the rail is continuous over the ties, the rail between adjacent ties can be regarded as a beam with fixed ends. The effect of a suddenly applied load is twice that of a stationary load.

The usual allowable stress per square inch in steel shapes used as beams is 16,000 lb., compression or tension, when stationary loads are considered. Hence, the allowable stress in this example will be 8000 lb. per square inch.

Now the maximum bending moment produced on a beam by a single concentrated load $= \frac{1}{8}Pl$ where P = load in pounds and l = space between supports in inches. But the bending moment (M) in any beam also equals $S\frac{I}{c}$, where S equals allowable stress per square inch and $\frac{I}{c}$ = section modulus of the beam.

Hence,

$$S\frac{I}{c} = \frac{1}{8}\text{PL}$$

or

$$8000 \times \frac{I}{c} = \frac{1}{8} \times 4000 \times 18$$

which reduces to

$$\frac{I}{c} = \frac{1 \times 4000 \times 18}{8 \times 8000} = \frac{9}{8} = 1.125.$$

By consulting tables of "T" rail sections in Cambria Steel Company's Handbook, it is seen that:

The section modulus of 16-lb. rail = .75

The section modulus of 20-lb. rail = 1.30.

From the above it is evident that a 16-lb. rail is too light, and therefore the 20-lb. rail, although the section modulus is somewhat higher than required, is used.

In the above illustration, it will be noted that the weight on one locomotive wheel, which is greater than that due to one car wheel, is used, and further that each tie is accepted as doing its full duty.

In the event, however, of a tie failing to contribute its proper support, which is very often the case, the span of the rail would be increased from 18 to 42 in. On this increased span there ordinarily will be space for two car wheels, but only one locomotive wheel, in which case:

Maximum bending moment due to locomotive = $\frac{1}{8}Pl$ as before.

In any condition where the wheel base is more than 0.586 of the span, the bending moment due to two loads, as with the two wheels on the mine car, would not be as great as the bending moment due to the weight on a single wheel in the center of the span. This relation is true regardless of the position of the two wheels.

In the case cited then, in which one tie is not contributing support and the span instead of 18 in. is now 42 in., the greatest weight on one wheel, whether from the locomotive or car wheel, would be used in the preceding formula, $S\frac{I}{c} = \frac{1}{8}Pl$. Substituting the known quantities in the formula and using the weight on one locomotive wheel as an illustration, with the 42-in. span, the following value of 2.625 is obtained for $\frac{I}{c}$. This, by referring to tables of "T" rail sections, is found to indicate 35-lb. rail.

The preceding formulæ show that the bending moment "M," and consequently the section modulus $\frac{I}{c}$, vary directly as the span and the load.

The following tables, based on allowable stress of 8000 lb. per square inch, show the section modulus, with the corresponding weight of rail, and the allowable weight per wheel for the usual tie spacings encountered. The designated weights per wheel, starting at 1000 lb., and varying by successive increments of 1000 lb. up to 10,000 lb., will cover any wheel loads liable to be encountered in mine practice.

TABLES OF RAIL SECTIONS AND TIE SPACING
(Ties with 6-in. faces)

Weight on one wheel	Specified tie centers—24 in.		Resulting span (42 in.) on alternate ties	
	Section modulus	Weight of rail, pounds per yard	Section modulus	Weight of rail, pounds per yard
1,000	0.281	8	0.656	16
2,000	0.562	12	1.312	20
3,000	0.843	16	1.969	30
4,000	1.125	20	2.625	35
5,000	1.406	25	3.281	40
6,000	1.688	25	3.937	45
7,000	1.969	30	4.594	50
8,000	2.250	30	5.250	55
9,000	2.531	35	5.906	55
10,000	2.813	35	6.562	60
	Specified tie centers—21 in.		Resulting span (36 in.) on alternate ties	
1,000	0.234	8	0.562	12
2,000	0.468	12	1.124	20
3,000	0.702	16	1.686	25
4,000	0.936	16	2.250	30
5,000	1.170	20	2.812	35
6,000	1.404	25	3.376	40
7,000	1.638	25	3.938	45
8,000	1.872	30	4.500	50
9,000	2.106	30	5.062	55
10,000	2.340	35	5.626	55

TABLES OF RAIL SECTIONS AND TIE SPACING.—(*Continued*)
(Ties with 6-in. faces.)

Weight on one wheel	Specified tie centers—18-in.		Resulting span (42 in.) on alternate ties	
	Section modulus	Weight of rail, pounds per yard	Section modulus	Weight of rail, pounds per yard
1,000	0.187	8	0.463	12
2,000	0.374	12	0.936	16
3,000	0.561	12	1.404	25
4,000	0.748	16	1.872	30
5,000	0.936	16	2.340	35
6,000	1.123	20	2.808	35
7,000	1.310	20	3.276	40
8,000	1.497	25	3.744	45
9,000	1.684	25	4.212	45
10,000	1.871	30	4.630	50
	Specified tie centers—15 in.		Resulting span (24 in.) on alternate ties	
1,000	0.141	8	0.374	12
2,000	0.281	8	0.748	16
3,000	0.422	12	1.122	20
4,000	0.563	12	1.496	25
5,000	0.703	16	1.872	30
6,000	0.844	16	2.246	30
7,000	0.985	20	2.620	35
8,000	1.125	20	2.994	40
9,000	1.266	20	3.368	40
10,000	1.407	25	3.742	45

NOTE:—Rail sections are American Society of Civil Engineers' standards.

From the preceding table, the weight of rail required for a given tie spacing and weight per wheel, can be taken direct, or if a certain weight of rail has been determined upon, the tie spacing can be fixed to give the required support.

It will be evident to anyone familiar with the ballast, tamping, and drainage around mines, that a different standard of tie spacing and rail will be required for underground as distinct from surface track. Track on the surface will usually be found much superior to track of similar equipment underground.

This is due to a variety of causes, such as inferior alignment, poorer ballast, smaller ties not spaced uniformly, and more exacting drainage conditions. Track frequently considered satisfactory in the mines would not be tolerated on the surface.

Where the ballast and tamping are in good shape and readily open to inspection, as on the surface, the rail sections shown for the specified centers will, I believe, be found satisfactory. For the usual condition underground, the heavier sections shown are recommended as none too heavy.

It is not practical to vary the rail weight to satisfy every condition. The large companies usually adopt a standard for their entire system, as it would entail too much inconvenience and confusion to order rail suitable to specific conditions. The tie spacing, however, is not subject to arbitrary restrictions, and can usually be adapted by the local colliery officials to suit the considerations peculiar to any section.

The greatest attention should be given to selecting the proper weight rail or tie spacing to conform with the other material used, their installation, and the severity of the traffic.

In favor of using heavy rail, the greater durability, stiffness and strength, the fewer ties required with the consequently smaller expense of renewals, the higher scrap value, the easy maintenance of the alignment, the saving in the upkeep on the rolling stock due to the better riding qualities, and the potential ability to meet unforeseen increases in the traffic, must not be forgotten.

You will note that the rail section calculated for 24 in.-tie centers corresponds to the weight as determined by the empirical rule given for well ballasted track in Chapter I, on "Rail."

It might be interesting to note in connection with the tables of rail and tie spacings, what degree of stiffness, as indicated by the deflection, will be obtained.

The maximum allowable deflection or sag under load will evidently be realized when the stresses caused by the wheel load reach the elastic limit of the steel, which for medium steel, referring to "Merriman's Civil Engineer's Pocket Book," is 36,000 lb. Accepting this value and assuming the case of the 8-lb. rail recommended for 24-in. tie centers (18-in. clear span) with a 1000-lb. wheel load, to find the maximum allowable and actual deflection, and the allowable load within this elastic limit, we have the following formulæ:

(1) M (Bending Moment) = S (36,000 lb.) $\times \frac{I}{c}$ (Section Modulus).

(2) M (Bending Moment) = $\frac{1}{8}P$ (Superimposed load) $\times\ l$ (the span).

In formula (1) the section modulus of 8-lb. rail is ascertained, by referring to tables of "T" rail sections, to be 0.31. Substituting, $M = 36{,}000 \times 0.31 = 10{,}850$ in.-lb.

The allowable value of "P" with the given span, and the 8-lb. rail, is determined by substituting in formula (2); where $M = \frac{1}{8}Pl$; transposing, $P = \frac{8M}{l}$; substituting the known values, $P = 8 \times \frac{10{,}850}{8}$ or 4820 lb., which as the stipulated moving load is but 1000 lb. or equivalent to 2000 lbs. static, gives a safety factor of almost 2½ based on the elastic limit.

The maximum allowable deflection or sag is expressed by the formula $D = \frac{Pl^3}{192EI}$; in which P and l are the same as in the preceding formulæ; E is modulus of elasticity 29,000,000; and I, the moment of inertia, obtained from the table of "T" rail sections, being 0.23 for an 8-lb. rail.

Substituting these values to find the maximum allowable deflection, and solving: $D = \frac{4820 \times (18)^3}{192 \times 29{,}000{,}000 \times 0.23} =$ 0.02188 in.

Calculating the deflection for a wheel load of 1000 lb. (moving load 2000 lb. static load); $D = \frac{2000 \times (18)^3}{192 \times 29{,}000{,}000 \times 0.23}$ = 0.0091 inches, which shows that the rail specified is well within the limit of maximum stress.

If it can be accepted that each tie will contribute its full quota of support to the rail, the 8-lb. section will be suitable for the stipulated tie centers of 24 in., but, however, actual experience has proved that this is not to be depended upon, so that some allowance must be made for imperfections in the tie support.

In the tables previously advanced, the rail for the given tie centers, and the rail required for alternate tie centers has been given. The use of the rail for the alternate centers is considered, in the light of actual experience, none too heavy for the specified centers, allowing as it does for the failure of every other tie. Many mining companies consider it economical in the end to go even further than this.

It is difficult to say just where to draw the line, but the assumed condition of alternate ties failing, makes a fair allowance for ordinary roadbed without going to extremes.

With the 8-lb. rail on the 42-in. span, the maximum allowable bending moment is found by the preceding formulæ to be 2065 in.-lb., and the allowable deflection 0.1195 in.

As the moving load of 1000 lb. is equivalent to a static load of 2000 lb., it will be seen that practically no factor of safety is allowed, and the 8-lb. rail is too light for the increased span. The resulting deflection will approach very closely the maximum allowable deflection of 0.1195 in.

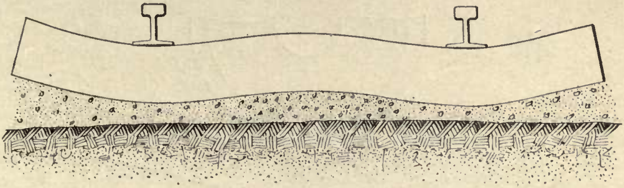


Fig. 3.—Light tie poorly tamped.

As stated before, no fixed rules can be given for determining absolutely the proper rail section to be adopted. The preceding formulæ and illustrations are given in order that the tie spacing and rail can be coördinated for any given conditions at hand or anticipated. Even the tables presented are but a guide to the selection of the most suitable rail and tie spacing.

Each tie should be tamped uniformly and particular attention given to tamping under that portion upon which the rail rests. Fig. 3 illustrates a case of light ties and improper tamping. Fig. 4 shows the effect on the rail of poor tamping or ballast.

Again, referring to Fig. 3, it may be stated that with improper ballast or tamping a tie of excessive length will be distorted more readily than one of proper length. While the long tie justly meets with much favor on account of its greater bearing qualities, there is a limit to which this length can be advantageously utilized. The tie may be considered as inverted, with the rails for the supports, and the pressure on the roadbed due to the weight of traffic acting as a uniformly distributed load on the tie.

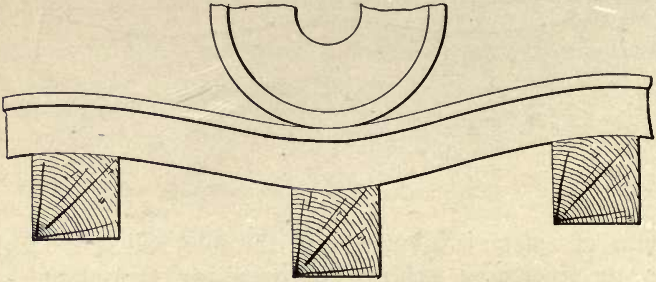


Fig. 4.—Effect of poor tamping on rail.

The portions of the tie outside of the rails are then cantilever beams, and the portion between the rails, a beam with fixed ends.

In order to obtain a tie length in which the overhanging ends will be of the same strength as the center portion, it will be found mathematically that the length of the tie should be 1.8 times the distance between the rail centers. Of course, if the tie is heavier than required, this length can be exceeded within limits. There are so many indeterminate factors entering into the computation of the tie thickness that it is futile to attempt to formulate any definite rules. Experience is the only reliable guide in this matter. However, it may be said that if the rail comports with the traffic and the spike in turn is adapted to the rail, then a tie with a cross-section great enough to carry the spike without splitting and allowing it to protrude below, will be of sufficient strength if its length is not greatly in excess of 1.8 times the gage.

When placing ties at rail joints where angle bars are employed, selected ties of uniform size should be used. These should be so spaced as to give the angle bar sufficient bearing and permit efficient spiking—the rail joint itself to be suspended midway between the ties. The joint should not be directly supported.

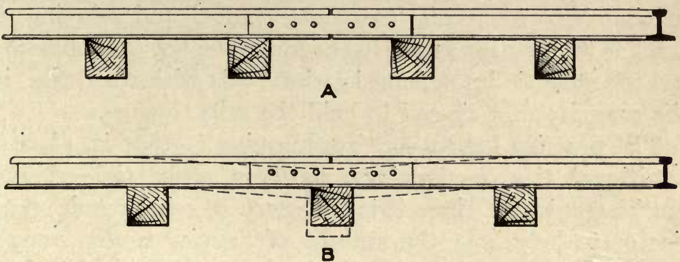


Fig. 5.—A. Proper angle bar support—incorrect fish plate support. B. Proper fish plate support. Incorrect angle bar support.

Where strap plates or fishplates are used, a selected tie should be placed directly under the joint. This also applies where the rails are butted together and not bolted. The ties should be spaced as close as practicable at the rail joint.

The closer tie spacing would seem to be peculiarly adapted to headings where the acid water quickly destroys the rail, the use of the lighter sections with a greater tie frequency recommending itself on account of the low initial cost and the ability to withstand the acid proportionally better than the more heavy rail. There is, of course, also the lesser loss in the event that the rail cannot be reclaimed or is destroyed prematurely.

The use of the steel tie for mine work is generally confined to low veins where height is at a premium. As the usual method is to lay such ties on the floor of the haulageway or chamber without any ballast, the acidity of the water must be given due consideration. If properly placed and taken care of, they will outlast wood ties, especially in chambers where the frequent removal and relaying of track is the limiting factor in the life of the tie. Some mines use the steel tie interspersed at intervals with wood ties, in the capacity of a tie-rod to hold the rails to gage.

The practice known as "corduroying"—that is, placing additional ties, or laggings, between other ties—should not be employed where it is necessary to reinforce decayed ties or to help bear the stresses of heavier traffic, except possibly where mule haulage is the means of transportation. This practice prevents efficient tamping and impairs the drainage of the roadbed.

At switches, many companies are in favor of having the ties in graded lengths, so as to furnish support and hold in alignment both tracks up to and including the frog.

The ties used in conjunction with wood rail are usually made with notches. These are cut to the gage of the track, so as to hold the rails and prevent them from tipping or spreading. While it is not always done, it is better to have the bottom side of the tie faced to prevent the tie from turning and the track from creeping.

It is the general opinion that ties will last longer if the bark is removed, and that the hewed tie is more serviceable than the sawed tie.

HOOK SPIKES

The dimensions of the proper hook spike to be employed should be in accord with the weight of the rail and the cross-section of the tie. The weight of the rolling stock does not require, nor will the general run of mine ties permit the use of as large a spike as is employed on standard-gage track.

Where the ties will stand it, the following sizes of spikes are recommended:

Weight of rail per yard	Size of spike in inches measured under head	Average number per keg of 200 lb.
45 to 70	5½ by 9/16	375
40 to 60	5 by 9/16	400
35 to 40	5 by ½	450
30 to 35	4¼ by ½	530
25 to 35	4 by ½	600
20 to 30	4½ by 7/16	680
16 to 25	4 by ⅜	1,000
16 to 25	3½ by 7/16	900

With such ties as are ordinarily used, however, the 4½ × ½-in. spike will probably be the largest permissible size. In driving the spike, the last blows should be light, to avoid breaking the spike under the head and to make a tighter bind; also, the two inside spikes should be near one side of the tie and the two outside spikes near the opposite side, to prevent tie splitting. If, when a spike is withdrawn, a wooden plug is driven into the spike hole, the life of the tie will be prolonged considerably.

Unless the spikes are known to be in good condition, it is doubtful whether it pays to remove them when track is reclaimed; it is comparatively costly to straighten them, and if they are not in good shape the trackman will probably throw away the poorer ones. Moreover, old spikes are difficult to drive.

Many trackmen, when the ties are to be reused, allow the outer spikes to remain and deliver the ties with these spikes in them to the new location; or when the ties are of no further value, they are burned and the spikes then collected.

There is no doubt that with the majority of mining companies there is a vast waste in the consumption of spikes, and if a check is kept on the amount of track laid this can be readily verified. Usually it will be found more economical to distribute the spikes in a systematic manner than to spend too much time on their reclamation. A good practice is to have someone who is conversant with the needs of the different workmen oversee the distribution of the spikes.

ANGLE BARS AND FISHPLATES

When a locomotive or a trip of cars runs on rails, a wave of elasticity precedes it. The object of the joint fastening should be to make this wave continuous across the joint. The ideal rail joint should have the same strength, stiffness and elasticity, both vertically and laterally, as the rails which it joins.

That the angle bar is much superior to the fishplate in achieving this object will be apparent from a study of the two. The strap plate and the simplest forms of angle bar are the only types employed for mine tracks.

In Fig. 5-A is shown an angle bar properly placed with the rail gap suspended between the ties. By this arrangement the stress at the joint, where there is always more or less pounding from the traffic, is distributed upon two ties instead of one through the bridging action obtained from the shape of the angle bar. The stress at the joint is transmitted to this angle bar in such manner as to produce tension in the lower, or angle, portion of the bar.

If a tie is placed directly under the joint, as in Fig. 5-B, and it becomes depressed or battered, which it will in a short time, the rail is compelled to bridge between the adjoining ties, thereby doubling the span and inviting a long dish in the rail that the angle bar can but poorly prevent, having no support and virtually carrying the tie that should uphold it.

The fishplate lends very little vertical support, so that the tie should be placed as in Fig. 5-B, which you will note is the contrary to the position used for angle bars.

However, the lateral support, or resistance to the side motion or spreading of the rails, which is contributed by both the angle bar and fishplate must not be ignored. The four spikes required for one joint where the rails are butted together, are not only very independable in maintaining the alignment but soon destroy the tie.

While the foregoing may appear to be a needless explanation of self-evident facts, it is none the less true that this matter is often suffered to go by default. At some mines where angle bars are used great pains are taken to insert a tie directly under the joint spanned by the angle bar, and any good effects expected to accrue from the use of this type of rail connection are thereby lost.

TIE-PLATES AND RAIL BRACES

Tie-plates and rail braces have had a restricted use on mine tracks, although there are many locations where they might be employed profitably.

Frequently the flange of the rail wears to a paperedge and the rail must be removed, although the head may be but little worn. This is due to particles of grit which intrude between the rail and the tie. By observing a train of mine cars being drawn by a locomotive, a considerable side motion will be perceived. This side motion tends to force the rails outward as each car passes, the elasticity of the rails returning them to their original position. In time, a groove is worn in the spike, allowing a still greater motion to the rail, and when grit accumulates under the flange the rubbing of the rail on the grit grinds away the flange.

The use of tie-plates, which, in their simplest form, are merely plates provided with spike holes and an offset that resists the lateral thrust of the rail, prevents this motion and consequently the wearing away of the flange. The tie-plate holds the spikes, so that to obtain any side motion it would be necessary to force both spikes, while the offset in the plate prevents cutting the groove in the spike. The tie-plates purchased from a manufacturer are further strengthened by having the bottom cut or serrated so as to resist any sliding motion.

The tie-plate can also be used to advantage on track where the heavy traffic forces the rail into the tie which at intervals compels adzing the tie to give the rail a true bearing. The cutting of the rail into the wood soon destroys the tie.

The amount of labor, taken in conjunction with the cost of the tie, the preservation of the rail achieved and the inconvenience entailed in doing this work, and operating upon a defective support, will afford a figure from which may be judged when and where tie-plates are an economy. It must also be remembered that the plate, properly handled, should last indefinitely.

The application of rail braces should be limited to those curves that are difficult to maintain in gage. The braces prevent the tipping and the spreading of the rails and protect the tie. It should not be necessary to use both tie-plate and rail braces on the one location.

ROADBED AND BALLAST

The best ballast that can be procured will be of little avail if not properly tamped. If a tie is unsupported, it is but an added weight on the rail. The materials in general use for mine-track ballast are cinders, slate or vein refuse, slate from the breakers and broken rock.

The broken rock affords the best drainage and service, but on account of its high cost is little used for ballast around surface mine tracks. In tunnels and rock headings or gangways the smaller rock made when excavating is sometimes thrown to one side to be used as ballast. Any lump should be broken to a size that would pass through a 3-in. ring. Where there is much passage of men and mules, the track should be given a light surfacing of ashes. The material usually employed for ballast is cinders. It is generally procured readily from the colliery boiler plant and affords fair drainage and a fair degree of service. The ashes, if kept in close contact with the rail, will hasten its corrosion.

The refuse from the beds, or veins, is almost without exception of a friable nature and disintegrates rapidly, forming dust or mud. It affords poor drainage and is easily washed from the roadbed. If dry, the passage of the cars swirls the refuse into the journals of the car and dries up the lubrication. It becomes mixed with the coal, and in bituminous mines would be a factor in a dust explosion.

Altogether, it is short-sighted economy to use this material for ballast.

Breaker slate is sometimes used for ballast. It affords a fair roadbed until it disintegrates and becomes dust or mud. Coal is a very expensive and inefficient ballast.

Where practicable, there should be at least 3 in. of ballast beneath the ties; it should be well tamped, particularly under the portion of the tie supporting the rail. The ditch should be sufficiently deep to drain the roadbed and thereby assist in preventing the decay of the ties. The drainage ditch should be driven with the heading, where necessary, and maintained clear of obstructions or accumulations.

As it is quite difficult to secure a good roadbed, or track, where this is a part of the work of the miner driving the opening, and since it is inconvenient to furnish proper ballast to supply his immediate needs as he advances, it will usually be found advisable for the trackman to go over the completed work at intervals.

CHAPTER III

PROJECTION OF HAULAGE ROADS

Where the pitch of coal measures is heavy, the haulageways are driven to follow along either the top or bottom slate of the bed at a grade sufficient to afford good drainage or balance the drawbar pull on the empty and loaded cars. When the pitch is flat, the entire mine is projected and developed along definite lines. In light, rolling pitches, the problem is more complex, compelling a use of both the grade and projection methods, and frequently where there is more than one bed, a close adherence to the lines of any past workings.

As the track must conform to the headings or gangways as they have been driven, some system must be employed in order to have them driven symmetrically.

In the heavy pitching beds, if the top or bottom rock is followed too closely, many irregularities and sharp turns will ensue. To preclude this, a definite minimum radius curve must be adopted and a simple method to attain this established, which the miner can understand and use conveniently.

Where there is "double timber" or props at regular intervals, what is known as the "chord-offset" method will be found useful. The offset or distance in the dark for any set is ascertained by squaring the established distance between the centers of sets of props and dividing by the radius. Let

D = Offset, or distance in the dark in feet;
C = Distance in feet, center to center of props;
R = Radius of the curve;

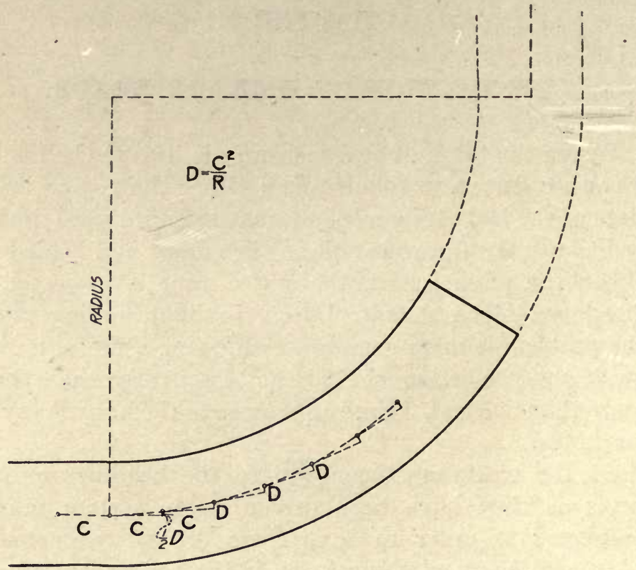


FIG. 6.—Method of driving curves by offsetting.

then

$$D = \frac{C^2}{R} \text{ (see Fig. 6)}$$

In the case of a 40-ft. radius curve, a rib radius of 35 ft. and timber placed 5 ft. between centers, substituting we have

$$D = \frac{25}{35} = \frac{5}{7}\,ft., \text{ or } 8\tfrac{1}{2}\ in.$$

Any two timbers in line on the gangway are then taken, and at a point 5 ft. from the proposed point of curve a prop is placed 4¼ in. (one-half of 8½ in.) out of line of the aforesaid two sets. Then the prop just erected is used to line with the prop at the point of curve, and the

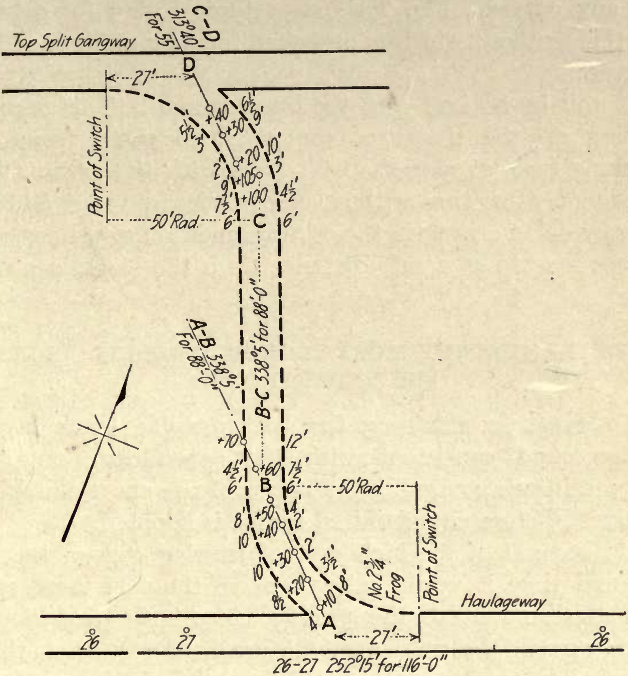


Fig. 7.—Lines of sight and offsets for driving curves.

next is offset 8½ in.; and so on, 8½ in. on all subsequent props until the desired curve is completed.

In the event that no timber is being used, the same results can be attained by driving points on line at definite intervals in the ties or roof, *C* is then made the distance between the points, R is the radius intended, and D is the offset distance, the first offset being but half the regular offset.

Where the headings or tunnels are driven on transit lines, offsets are taken at from 5 to 10 ft. from the line for any curves. Fig. 7 shows a typical plan for driving by this method, which is preferred for long or large radius curves.

It will be noticed that the lines overlap. This permits setting up the transit a convenient distance from the working face, so as not to interfere with the work. The heading is at no time without line. A few days are allowed for any delay arising in the establishment of new lines, and the points are at a safe distance from the blasting at the face.

TO DETERMINE THE MOST ECONOMIC RADIUS CURVE TO USE UNDERGROUND

To assist in attaining the best possible track layout underground consistent with the expenditure entailed, the conditions governing the radius of the curve should be analyzed before any standard radius is adopted.

On account of the high cost of turning curves, the additional time it would take to drive those of large radii and the amount of the product necessarily tied up by large curves, the radii must be much shorter than those permissible on the surface. However, there is no reason in installing the smallest curve that cars will travel around without the bumpers interlocking, merely because the initial cost is low.

An ideal curve would be one with which the sum of (1) the initial cost, (2) the maintenance during the life of the curve and (3) the expense of traffic haulage will be a minimum. The consummation of this ideal can be approached only by assuming curves of various radii and estimating the costs of the several items.

Unless occurring at a site where the roof is poor or the bottom heaves, the shorter the curve the lower will be the initial expenditure. In estimating the cost of curves, certainly, on the shorter ones the cost of the gangway or tunnel required to reach the point attained by the larger curves should be considered, particularly as it is customary to leave considerable pillar each side of a tunnel or main heading. When turning curves of large radii, the wide part of the opening just beyond the frog can sometimes in the heavy pitches be located in solid rock, thereby dispensing with the use of timber and obviating any allowance for maintenance.

As the life of curves is frequently over 30 years, and wood timber has a serviceableness as low as 18 months, the items of labor and material for timber removals, in addition to the risk of a derailed car knocking down the roof supports, with the delays in traffic incident to retimbering, must be thoroughly considered. The use of steel timber will be found advantageous for the long spans encountered at locations where a semipermanent job is required and no "heaving" or "squeezing" is to be expected.

In turning off tunnels where several beds to be worked lie close together, a lower upkeep will be realized by a "wing" tunnel to the outer bed and continuing on the same line to the inner ones, than by having a number of wide areas to maintain from a number of curves off the main haulageway. This also forestalls the cramping of the switchwork and radii, which closely situated veins ordinarily demand.

Viewed solely from the haulage standpoint, the determining factors of the curve radius can be covered under two heads: (1) The cost of resistance due to curvature on the total estimated number of cars to be hauled; (2) the probable number of cars to be hauled in each trip and the rate of travel.

The amount of resistance due to curvature varies with each type of car, and to a lesser degree with each car of a given type. The resistance expressed in terms of grade with curves of from 30- to 100-ft. radius, 42-in. gage, 42-in. wheelbase, will run 0.015 ft. to 0.025 ft. per 100 ft. of track for each degree of curvature. That is, with a 50-ft. radius or a 115-deg. curve, moderately clean track, fair running cars with both wheels keyed to the axle, approximately a 1.8 per cent. grade would be necessary to equal the same drawbar pull as on a tangent. A smaller compensation would be sufficient where the wheels turn loose on the axles and the wheelbase is less.

The value of the radius expressed in degrees can be obtained by dividing 5730 by the radius in feet. This formula will have to be employed especially in small radius curves. The actual arc is used to find the degree, rather than the 100-ft. chord, the practice on standard-gage roads. By using the actual arc, a 50-ft. radius = $\frac{5730}{50}$ = 115-deg. curve. By the use of the 100-ft. chord, a 50-ft. radius = $\frac{50}{sin\ \frac{1}{2}d}$ = 180-deg. curve, showing a disparity of 65 deg.

Assuming a curve with a central angle of 90 deg. on a grade of 0.5 per cent. and allowing the same rate of resistance per degree on a 25-ft. and 50-ft. radius curve, the motor traveling over them would have to mount the sum of the grade and the curve resistance, the equivalent of a 4.5 per cent. grade for 39 ft. and a 2.5 per cent. grade for 78 ft. respectively. From the beginning of the 50-ft. radius to the point of tangency, there would be with the curve resistance the equivalent of 1.96 ft. vertical, while to travel between the same points by way of the 25-ft. radius curve, including the 25 ft. of tangent on each end of the curve to reach the same geographical point, would be a total of 2.02 ft. vertical, or essentially the same vertical rise in both cases.

While actually with the smaller radius curve there would be a lower rate of resistance per degree, this would be more than balanced by the increased resistance due to the slower speed compelled by the sharper curve. If the resistance due to grade and curvature between the similarly located points is accepted as equal, then there remains in favor of the 50-ft. radius the greater speed at which the trip can travel, the reduced danger of cars jumping the track, the greater ease with which the trolley will follow the wire, a haul 11 ft. shorter, and in some cases 11 ft. less of tunnel. With a heading producing six trips per day of twelve 5-ton cars each, this 11 ft. twice per trip would consume enough power to draw one ton 7920 ft. each day, or 375 miles per year.

In estimating the number of cars per trip, the future output, as well as the length of haul, must be considered. The number of cars traveling over a certain haulage road daily may sometimes be trebled by a tunnel to other beds.

This increased output may mean the installation of a larger, or possibly the use of an additional, locomotive. If the curves are too sharp, the larger machine cannot traverse them, and this leaves no choice but the additional motor with its expense for attendance and upkeep.

For obvious reasons no compensation is allowed for curvature underground, and if a locomotive is required to work at its capacity, the additional resistance to be overcome due to curvature may be the factor limiting the length of the trip. With the large curve a locomotive may pull through on its momentum, but on a curve of small radius the velocity must be reduced when the curve is approached.

ALIGNMENT ON THE SURFACE

The general practice in the location of narrow-gage railroads on the surface is to first run a topography survey and then plot this to a suitable scale. If the relative position and elevation of both the beginning and destination of the proposed road are known, it may be found practicable to run a rough grade line between them. Using this as a base, enough of the surface features on each side may be located to permit any desired deviation from the original base line. Sufficient accuracy is usually attained by using circle levels taken with a transit to the objects and ground to be located, and only in special cases need the topography be located with a wye level or Locke level.

When the location has been plotted and any outcroppings of veins and other influencing features shown, the proposed line is laid out on paper and submitted for approval.

This approval, however, in the case of narrow-gage mine roads, is usually permission to use a certain maximum and ruling grade, and the adoption in general of the layout. It is not intended that the layout be adhered to rigidly, and the engineer is permitted to use his judgment in making any minor changes in the grade or route.

It is an infrequent occurrence that the mine track leaves the company's lands, and no right-of-way is required.

These facts and the comparative flexibility of the narrow-gage road, with its almost unlimited allowance in curvature, render the field work for a narrow-gage road a comparatively simple matter.

As this work is usually assigned to the regular mine engineer corps, which frequently is not particularly familiar with it, the customary methods pursued are given.

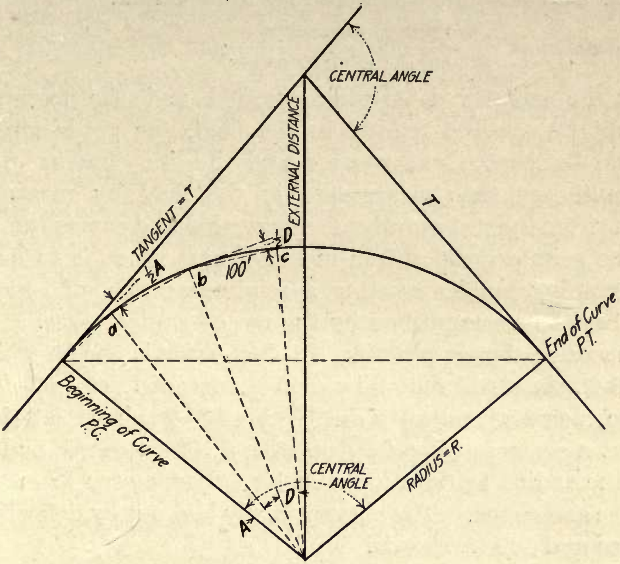


FIG. 8.—Method employed in locating a curve on the surface.

One practice in some use is to scale the location from the plan and then duplicate it in the field. Because of possible inaccuracies in the preliminary survey, the possible divergence of the approved location from the base line, and the errors in scaling it, this method is not to be recommended.

A preferable way is to place stakes on grade at 50- to 100-ft. intervals, depending on the nature of the ground, and then use these stakes as a guide in selecting the straight track or tangents. The radius of a curve is partly determined by establishing the point of intersection and measuring the distance from this point to where it is desired to locate the line of curve (see Fig. 8).

The radius required is found by the formula,

$$\text{Radius} = \frac{\text{Distance measured}}{\text{ext.-sec } \tfrac{1}{2} \text{ central angle}}.$$

If the country is heavily wooded and the tangents cannot be selected readily in the field, the grade stakes should be located and plotted and the line chosen. The tangents are then established in the field by measurements from the stakes and the intersection and curves run in.

The prime consideration in most mine roads is to have the grading and excavating a minimum; this, of course, can best be accomplished by the use of grade stakes.

In standard-gage practice, a 1-deg. curve is one on which a 100-ft. chord will subtend a central angle of 1 deg.; a 2-deg. curve, a central angle of 2 deg. with a 100-ft. chord; a 3-deg. curve, a central angle of 3 deg. with a 100-ft. chord, and so on, the radius being calculated by trigonometry from the degree and chord. The curve is easily laid out by deflection angles and 100-ft. chords.

In computing the various parts of a curve, the following formula will cover most cases (see Fig. 8).

R = Radius of curve,
D = Degree of curve,
T = Tangent distance,
E = External distance,
A = Angle subtending chord or sub-chord,
Δ = Central angle.

(1) External angle = central angle; the external angle is that one measured by the transit upon the intersection of the tangents.

(2) Radius $= \dfrac{E}{ext.\text{-}sec\ of\ \frac{1}{2}\Delta}$, E is found as described above.

(3) Sin $\frac{1}{2}D = \dfrac{50}{R}$, the angle corresponding to sin $\frac{1}{2}D$ can then be found in a table of natural sines and cosines, and doubling this angle will give the degree of the curve. (See pages 43 and 88 for short radii formula.)

(4) Tangent $= R \times \tan \frac{1}{2}\Delta$; when the radius is known, before the curve can be staked out, it is necessary to know the p.c. or point where the curve commences. When this is found, the tangent distance is measured from the point of intersection, and will locate the p.c.; measuring the same distance on the line of the other tangent will establish the p.t., the end of curve, or point of tangent.

(5) Radius $= \dfrac{T}{\tan \frac{1}{2}\Delta}$. It frequently happens that the point of curve must be located at a certain definite point, as at the end of a bridge or switch. The tangent distance is then measured and the proper radius of the curve calculated from this formula.

(6) The deflection angle for a 100-ft. chord is one-half the degree of curvature.

(7) If there is no table of external secants convenient, use a table of natural sines and cosines, and divide the cosine of one-half the central angle into 1, and then subtract 1 from the result; this will be the external secant. For example, if one-half the central angle is 18 deg., the cosine is 0.9511; dividing this into 1 gives 1.05146, and subtracting 1, we have 0.05146, the external secant.

(8) When the curve is to be staked out at less than 100-ft. intervals, as is the case in narrow-gage work, sub-chords must be used. The angle for the sub-chord deflection is determined by the formula $\sin \frac{1}{2}A = \frac{\text{sub-chord}}{2R}$. The angle corresponding to $\sin \frac{1}{2}A$ will be found in a table of natural sines.

If the angle is known, as is the case with the last deflection for a curve, the formula becomes, $\frac{1}{2}$ sub-chord $= R \sin \frac{1}{2}A$.

The deflection angle for any chord is always equal to one-half the central angle subtending it. For 100-ft. chords, the deflection angle would be one-half the degree of curve. In formula 8 the angle equivalent to $\sin \frac{1}{2}A$ would be the correct one to turn for the proposed sub-chord.

When the radius of the curve has been determined and the p.c. (point of curve) exactly located, the distance is measured from the last numbered stake to the p.c. The stake here located is numbered, and the transit set up over it. If the p.c. is not at the end of an even chord length, it will be necessary to work out the deflection for the sub-chord, as shown under formula 7.

The p.c. is the point of curve in the direction the survey is being run, and the p.t. (point of tangent) the end of the curve.

The first deflection from the p.c. will be the angle $\frac{1}{2}D$ from the tangent line for the distance of the chord. If the second stake on the curve can be put in from the p.c., the angle required is added to the first angle and turned from the p.c. The distance, however, is measured from the last stake. This process continues as far as can be staked out from the p.c., or until the p.t. is reached. The deflection angles should be added until they equal one-half the central angle, which should intersect the p.t., if the work has been done correctly. The measurements are taken each time from the last stake.

If it is impossible to see from the p.c. to the p.t. and all the intermediate points, the transit can be set on any intermediate stake and the curve continued therefrom. When the transit is set up on the curve, the vernier is set at zero, backsighted on the last place over which the transit was set up and the telescope reversed. By turning the vernier to the last angle turned, the line will be tangent to the curve at the set-up, and deflection angles can again be added until the p.t. is reached. The transit should then be set up on the p.t. and can be again turned tangent by reversing the telescope and turning the last angle. The sum of the deflection angles must equal one-half the central angle, and with the angles turned upon backsighting, equal the total central angle. The chords are always measured from stake to stake, as shown in Fig. 8, from p.c. to *a*, from *a* to *b*, *b* to *c*, etc.

In all American handbooks for standard-gage track, and in formula 3 of the foregoing, all calculations, degrees of curve, etc., are based on the underlying principle that a 100-ft. chord determines the degree of curve.

It is obvious that it is not very convenient to use this 100-ft. chord method with short-radii curves, and it is mathematically impossible to use it with curves of less than 50-ft. radius, as will be seen by formula 3.

Many engineers have resorted to computing short tables for their own use for this class of work, but the majority of such tables are decidedly incomplete.

If we assume, however, for the shorter-radius curve that a 1-deg. curve is one in which a 10-ft. chord subtends a 1-degree central angle, all the numerous labor-saving tables developed in the standard fieldbooks can be adopted and applied to this work by merely moving the decimal point mentally one place.

For example.--A 1-deg. curve would then have a 573-ft. radius instead of a 5730-ft. radius; the long chords, externals, tangent distances, etc., would be one-tenth as great. The angle, of course, would not change.

If a 10-ft. chord was thought too short for use, the long chord for two stations (or three stations, as desired) would be taken from the tables.

Or if no standard fieldbook is at hand, the foregoing formulæ may be used without any change with the exception of formula 3, which would, on the 10-ft. chord basis, be $\sin \frac{1}{2}D = \frac{5}{R}$.

The table entitled "Radii, Degrees of Curve and Ordinates," appearing later, gives degrees of curve on this method for radii from 15 to 200 feet.

It will be found convenient in most cases, when the radius on either the 100-ft. or 10-ft. chord plan corresponds to a fractional degree of curvature, to take the nearest degree and change the radius to agree therewith. For example, if the radius corresponded to 9 deg. 43 min., it will simplify the fieldwork usually to make it a 10-deg. curve, and alter the radius, etc., correspondingly.

CHAPTER IV

GRADES

In railroad work the number of feet of rise or fall per unit of distance is called the grade; the number of feet of rise or fall per 100 ft. horizontal, the per cent. of grade.

On the surface the grade for locomotive traffic is determined, first, by the size of the locomotive and the number of cars it is required to haul; second, by the elevation it is desired to attain in a certain distance; and third, by the topography of the route.

Underground, where the headings are driven on line, the grade follows the pitch of the heading, rope haulage and planes being introduced when the grade becomes too heavy for locomotive traffic.

On the heavier pitching measures the gangways are usually driven on a regular grade, which follows the strike of the bed. In determining this grade, the drainage, haulage, and to a certain extent the loading of the cars, should be considered.

In lightly pitching or rolling measures, before any lines for headings or chambers are adopted, the probable contours of the bed should be shown in advance of the workings, so that an idea of the grade that is likely to be encountered may be formed. A study of the contours and close attention to the grade as the heading advances will serve to forestall using the heavier grades requiring rope haulage or the employment of other forms of haulage than locomotives or mules.

A specific grade cannot be adhered to rigidly in the light pitching or so-called flat measures, but nevertheless more attention should be given to approximating this grade. Too often the workings are projected with very little consideration toward anything other than releasing a certain area of coal, the lines being followed regardless of the grade. This entails high transportation costs. A combination of the line and contour method, while affording a less symmetrical layout, secures a more economic haulage.

A good rule, applicable in many cases where headings are driven by alignment, is to first determine the lines as far as practicable to conform with both the area to be worked and the best possible grade, then to establish a *maximum* grade and give each line with the understanding that this line shall be followed only so long as the inclination of the strata does not compel exceeding this grade. Should this inclination be encountered, further advices can be then given, based on the latest developments, before the heading is continued.

In the determination of a standard gangway grade for the gangways in the heavier pitching beds, the first requisite should be that the grade be sufficient to take care of the drainage and allow the water to maintain its channel free from any accumulations of silt or sediment. Good drainage is a requirement in any type of haulage, and in the maintenance of the ballast and trackwork it is a necessity.

A ditch with a semicircular cross-section will have the greatest carrying capacity, while one with a half-hexagon cross-section is the nearest practical approach thereto for mine work.

The following is an approximation of Cutters' formula for ditches,

$$V = \sqrt{\frac{100{,}000\, r^2 s}{8r + 15}}$$

in which

V = Mean velocity per second;

r = Hydraulic radius; that is, the cross-section of the water in the ditch in feet, divided by the perimeter of the ditch in contact with the water;

s = The slope; that is, the fall divided by the length.

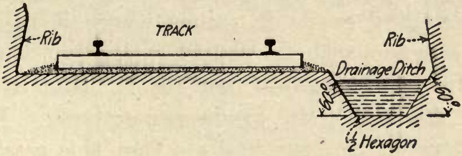


Fig. 9.—Practical drainage ditch.

The following table shows the carrying capacity and mean velocity for a ditch with a half-hexagon cross-section per foot of bottom width. (See Fig. 9.)

Grade per 100 feet	Mean velocity in feet per second	Cubic feet per second	Cubic feet per minute	Gallons per minute
4 in.	1.84	2.39	143.5	1,075
6 in.	2.25	2.92	175.5	1,315
8 in.	2.60	3.38	202.5	1,520
10 in.	2.90	3.78	226.8	1,700
12 in.	3.19	4.14	248.4	1,863

A wide, shallow ditch with the same cross-sectional area and grade will have less current velocity, will carry less water, and will choke up much more easily than one of a narrower and deeper form. The velocity should not be less than 1½ ft. per second, or the suspended particles will be precipitated along the bottom of the ditch.

Where drainage is not the prime consideration, a theoretic grade can be computed, whereby the slope of the road in favor of the loaded cars will compensate for the extra resistance due to the additional weight. In other words, a proper utilization of the grade will allow the drawbar pull on a trip of loaded cars to equal that of an equal number of empty cars. The motor or mules will thus be able to pull as many cars from the face loaded as were brought in empty.

The prevailing grade in mines where it is possible to establish a grade with no consideration but that of haulage runs from 4 in. to 6 in. per 100 ft.; that is, a 0.33 per cent. and 0.5 per cent. grade respectively. Within the last few years it has been realized that this grade is rather too light unless some type of anti-friction bearing is used. Accordingly, many companies have fixed their standard gangway grade at from 6 in. to 10 in. per 100 ft.

It is obvious that the greater the difference in weight between an empty and loaded car, the steeper should be the grade in favor of the load to overcome the greater resistance due to the load.

The amount of track resistance is almost proportional to the weight on the rails, and as the modern practice has been to enlarge the capacities of cars, the grade should likewise be augmented following any increase in car loading; or the additional resistance from the increased load should be overcome by reducing the journal friction by an improvement in the bearings.

The following example will illustrate the usual method of computing the theoretic grade which will equalize the drawbar pull on empty and loaded cars.

Example.—A certain colliery has in use all-steel cars weighing empty 5080 lb. each and loaded with coal an average of 12,230 lb. As the track is dirty and not very well laid, the total frictional resistance will be assumed as 30 lb. per ton for an empty car and 25 lb. per ton on a loaded car; in other words, the coefficient of friction (or ratio of the resistance to the weight) will be 0.015 and 0.0125 respectively. It is desired to find the grade that will equalize the draw-bar pull on an empty car with a loaded car. Let

ϕ = The sine of the angle of the desired grade;
W = Weight of empty car;
W' = Weight of loaded car;
C = Coefficient of friction for empty car;
C' = Coefficient of friction for loaded car;

then

$$(W\ C) + W \sin \phi = (W'\ C') - W' \sin \phi$$

Substituting values in the above case,

$$(5080 \times 0.015) + 5080 \sin \phi = (12{,}230 \times 0.0125) - 12{,}230 \sin \phi.$$

$$76.2 + 5080 \sin \phi = 152.875 - 12{,}230 \sin \phi.$$

$$17{,}310 \sin \phi = 76.675,$$

$$\sin \phi = .00443,$$

which multiplied by 100 will give the rise in 100 ft., which is 0.443 ft., or 5¼ in.

On straight track, with 5¼-in. grade per 100 ft. in favor of the load, a mule would be able to pull as many loaded cars out as it could pull empty cars in the opposite direction.

The preceding formula does not consider the weight of the motor or locomotive, the effective weight of which will also depend on the grade.

If in the foregoing example we wished to use an 8-ton motor having a tractive effort of 3000 lb. on the level, and secure an equal draw-bar pull and maximum loading, the formula will be somewhat different.

Let

M = Weight of motor;
F = Tractive effort of motor.

Then

$$\frac{F + M\,sin\,\phi}{(W'\phi) - W'\,sin\,\phi} = \frac{F - M\,sin\,\phi}{(WC) + W\,sin\,\phi}$$

Solving,

$$\phi = 5\ in.\ per\ 100\ ft.$$

With the same motor compelled to handle cars loaded with rock, the formula in order to make the grade balance the extra resistance of a full trip of rock, the weight of each car being 17,000 lb., would be, letting W'' = weight of a loaded rock car,

$$\frac{F + M\,sin\,\phi}{(W'C') - W''\,sin\,\phi} = \frac{F - M\,sin\,\phi}{(WC) + W\,sin\,\phi}$$

or

$$\phi = 7\ in.\ (almost)\ per\ 100\ ft.$$

The grade on straight track should then be between 5 and 7 in. per 100 ft., and the above motor would be able to pull in about 28 empty cars and the same number out, loaded.

When it is considered that curved track makes up a large portion of every gangway and that the tracks are dirtiest immediately after the cars have been loaded from chutes (all of which has a greater effect on the loaded car), it will be apparent that this theoretic grade should be increased to assist in overcoming these contingencies. Other considerations that would still further increase the grade in favor of the load are the usual methods pursued in panel mining and the loading of the cars.

It is customary in panel mining to drive the coal gangways first, and when they have advanced far enough to begin robbing, to tunnel to a haulage gangway, cutting off the outer section. This frequently increases the length of the tunnels and necessitates a proportionate decrease in the grade of the haulage. As a consequence, where the tunnels are long, the inclination of the haulage road, which by all means should have the best grade, is much reduced, and wet roadbed, choked ditch and small trips naturally result.

Since the installation of mechanical haulage in mines loading from chutes, the loaders are compelled to move the cars at the loading places by their own efforts. Four cars per trip are not infrequently loaded from one chute. On the lighter grades, to move the cars sufficiently to accomplish this loading would require an additional man, and to forestall this expense the foreman resorts to increasing the grades immediately beneath the chutes and inserting an equalizing diminution between them. This expedient facilitates the loading of the cars, but renders the roadbed a succession of flat places and inclines, with pools of water in the "dead spots." It raises the haulage cost, destroys the rolling stock and imparts a bumping and jerking to the cars in motion. It is needless to state that a proper grade would remove the necessity for this distortion.

In the gangways where the grades have been produced by trusting to the judgment of the workmen, the inclination usually is from 8 to 12 in. per 100 ft., and I am inclined to believe that these grades have more to recommend them than the lesser ones.

One objection to the heavier grade is that its first in-

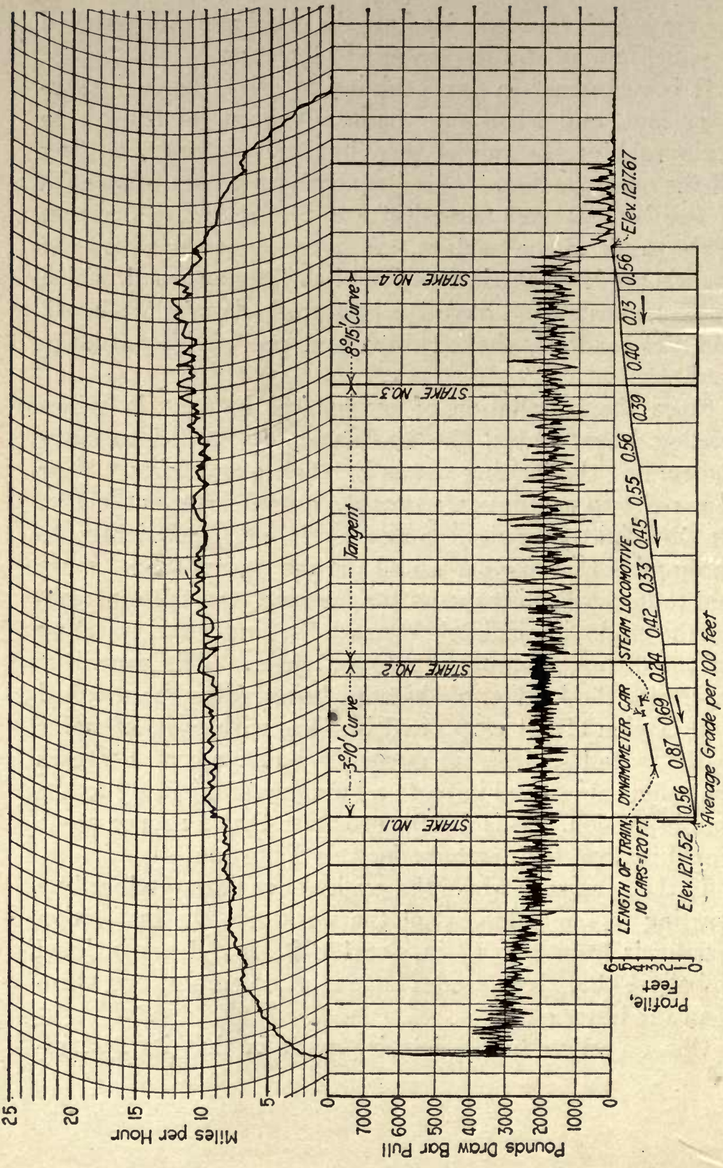


FIG. 10.—Dynamometer record chart of plain-bearing car trip.

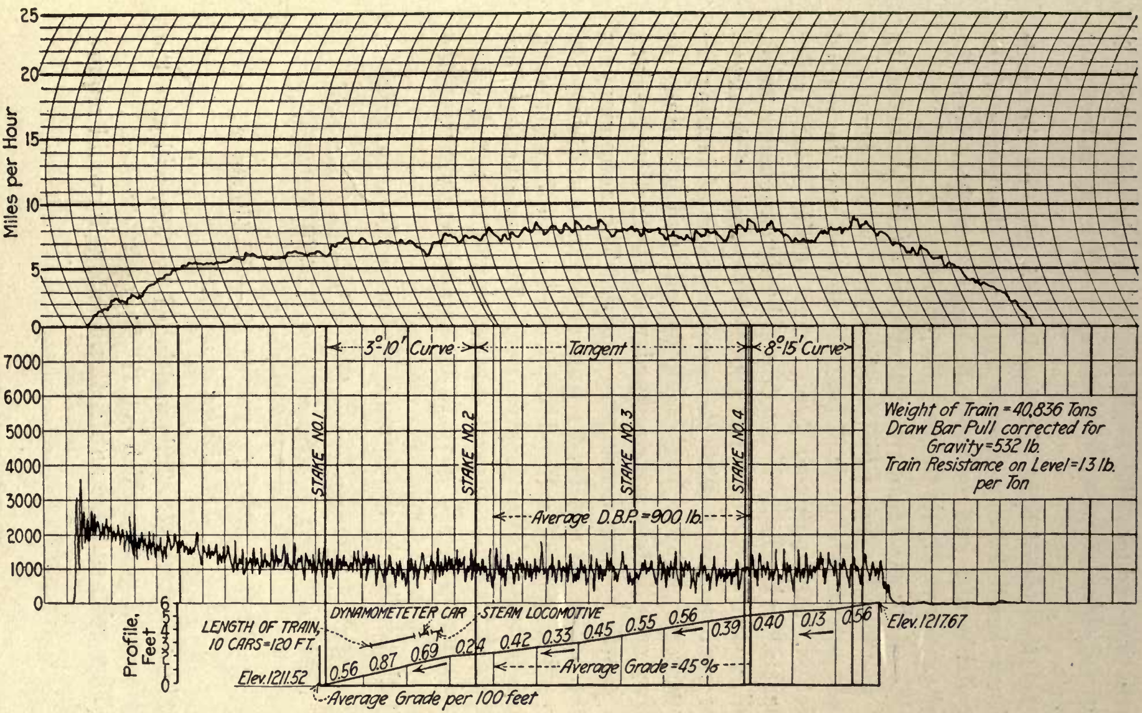


FIG. 11.—Dynamometer record chart of roller-bearing car trip.

stallation reduces the available lift as the gangway advances; this, however, will remedy itself in all subsequent levels.

In the case of light pitching beds, increasing the grade of new headings may mean a too serious shortening of the available lift, and in those headings already driven the flat grades will limit the length of the trip.

These objections, as well as that arising from the necessity of moving the cars while loading, can be overcome to a great extent by the use of bearings that reduce the journal friction. An improved type, such as the Hyatt roller bearing (as has been demonstrated by dynamometer tests), will require on the level but about 40 per cent. of the draw-bar pull necessary with the common type of bearing, or conversely, on the level a motor will pull 2½ times as many cars if they are equipped with antifriction bearings as it will if plain bearings are used. The accompanying charts, Figs. 10 and 11, are from actual tests and show the draw-bar pull of roller bearing and plain bearing cars. Both tests were over the same run. The low starting effort required for the improved bearing should be noted. The grade formulæ will have to be applied to determine the results for level track.

Substituting in the formula, and using the same weights:

$$(WC) + (W \ \sin \ \phi) = (W' \ C') - (W' \ \sin \ \phi)$$

$$(5080 \times 0.006) + 5080 \sin \phi = (12{,}230 \times 0.005) - 12{,}230 \sin \phi$$

$$30.48 + 5080 \sin \phi = 61.15 - 12{,}230 \sin \phi$$

$$17{,}310 \sin \phi = 30.67$$

Sin $\phi = 0.00177$. This multiplied by 100, will give the per cent. of grade, which is 0.177 ft., or 2⅛ inches.

Thus with suitable antifriction bearings it would require on a grade of 2⅛ in. per 100 ft. the same effort to move a loaded car with the grade as is required for an empty car moving against it.

The antifriction bearing will run several months on one lubrication, thereby eliminating to a great extent the embarrassment of stiff cars and the employment of car oilers. They will be found advantageous in locations where the available elevation for compensating grades is limited and in reducing the elevation required for the car planes in overcoming differences in grade, also on light pitching slopes where the cars are barely able to drag the rope, and in eliminating men required for pushing around dumps, shaft landings, and tipples.

CONSTRUCTING GRADES

Grades on the surface are secured by running levels over stakes set at regular intervals and then marking upon the stakes the cuts or fills required to reach the grade selected, to which the surface is then cut or filled.

In the flat measures underground, the headings are generally driven on line, the grade of the heading being the profile of the bottom rock along the line of heading.

In the gangways or headings which are not driven on line, it is apparent that neither of the methods given can be used; by the first method the heading would have to be already driven before the grades could be run and marked; by the second method a line would have to be given, which, of course, would be impossible in the heavy pitching seams.

Under this last condition, and also for tunnels, the grade is extended by means of a grade board; that is, a board equipped with a spirit level set in its top, or with a plumb-line which hangs from an upright in the center of the board. The grade is carried by having one end of the board higher than the other, this extra height being the amount that the grade in question would rise or fall in the length of the board. This extra height is known as the "toe."

Grade boards are usually cut in fractional lengths of 100 ft., such as 6 1/4 ft., 10 ft., 12 1/2 ft., etc., so that the toe can be readily calculated and the board will be of a length convenient for use. The following table gives the toes to the nearest 1/16 in. for a 10-ft. grade board on grades from 0 per cent. to 10 per cent.:

TOES FOR 10-FT. GRADE-BOARD FROM 0 TO 10 PER CENT. EVERY 1/16 IN.

Per cent.	Toe, in.	Per cent.	Toe, in.	Per cent.	Toe, in.	Per cent.	Toe, in.	Per cent.	Toe, in.
0.00	.....	2.00	2 7/16	4.00	4 13/16	6.00	7 1/4	8.00	9 5/8
0.05	1/16	2.05	2 1/2	4.05	4 7/8	6.05	7 5/16	8.05	9 11/16
0.10	1/8	2.10	2 9/16	4.10	4 15/16	6.10	7 3/8	8.10	9 3/4
0.15	3/16	2.15	2 5/8	4.15	5	6.15	7 7/16	8.15	9 13/16
0.20	1/4	2.20	2 11/16	4.20	5 1/16	6.20	7 1/2	8.20	9 7/8
0.25	5/16	2.25	2 3/4	4.25	5 1/8	6.25	7 9/16	8.25	9 7/8
0.30	3/8	2.30	2 13/16	4.30	5 3/16	6.30	7 5/8	8.30	9 15/16
0.35	7/16	2.35	2 7/8	4.35	5 1/4	6.35	7 11/16	8.35	10
0.40	1/2	2.40	2 7/8	4.40	5 5/16	6.40	7 3/4	8.40	10 1/16
0.45	9/16	2.45	2 15/16	4.45	5 3/8	6.45	7 13/16	8.45	10 1/8
0.50	5/8	2.50	3	4.50	5 7/16	6.50	7 7/8	8.50	10 3/16
0.55	11/16	2.55	3 1/16	4.55	5 1/2	6.55	7 15/16	8.55	10 1/4
0.60	3/4	2.60	3 1/8	4.60	5 9/16	6.60	7 15/16	8.60	10 5/16
0.65	13/16	2.65	3 3/16	4.65	5 5/8	6.65	8	8.65	10 3/8
0.70	7/8	2.70	3 1/4	4.70	5 11/16	6.70	8 1/16	8.70	10 7/16
0.75	15/16	2.75	3 5/16	4.75	5 3/4	6.75	8 1/8	8.75	10 1/2
0.80	1	2.80	3 3/8	4.80	5 13/16	6.80	8 3/16	8.80	10 9/16
0.85	1 1/16	2.85	3 7/16	4.85	5 7/8	6.85	8 1/4	8.85	10 5/8
0.90	1 1/8	2.90	3 1/2	4.90	5 15/16	6.90	8 5/16	8.90	10 11/16
0.95	1 3/16	2.95	3 9/16	4.95	5 15/16	6.95	8 3/8	8.95	10 3/4
1.00	1 1/4	3.00	3 5/8	5.00	6	7.00	8 7/16	9.00	10 13/16

TOES FOR 10-FT. GRADE-BOARD FROM 0 TO 10 PER CENT. EVERY $\frac{1}{16}$ IN.—(*Continued*)

Per cent.	Toe, in.	Per cent.	Toe, in.	Per cent.	Toe, in.	Per cent.	Toe, in.	Per cent.	Toe, in.
1.05	$1\frac{5}{16}$	3.05	$3\frac{11}{16}$	5.05	$6\frac{1}{16}$	7.05	$8\frac{1}{2}$	9.05	$10\frac{7}{8}$
1.10	$1\frac{3}{8}$	3.10	$3\frac{3}{4}$	5.10	$6\frac{1}{8}$	7.10	$8\frac{9}{16}$	9.10	$10\frac{15}{16}$
1.15	$1\frac{7}{16}$	3.15	$3\frac{13}{16}$	5.15	$6\frac{3}{16}$	7.15	$8\frac{5}{8}$	9.15	11
1.20	$1\frac{1}{2}$	3.20	$3\frac{7}{8}$	5.20	$6\frac{1}{4}$	7.20	$8\frac{11}{16}$	9.20	$11\frac{1}{16}$
1.25	$1\frac{9}{16}$	3.25	$3\frac{7}{8}$	5.25	$6\frac{5}{16}$	7.25	$8\frac{3}{4}$	9.25	$11\frac{1}{8}$
1.30	$1\frac{5}{8}$	3.30	$3\frac{15}{16}$	5.30	$6\frac{3}{8}$	7.30	$8\frac{13}{16}$	9.30	$11\frac{3}{16}$
1.35	$1\frac{11}{16}$	3.35	4	5.35	$6\frac{7}{16}$	7.35	$8\frac{7}{8}$	9.35	$11\frac{1}{4}$
1.40	$1\frac{3}{4}$	3.40	$4\frac{1}{16}$	5.40	$6\frac{1}{2}$	7.40	$8\frac{7}{8}$	9.40	$11\frac{5}{16}$
1.45	$1\frac{13}{16}$	3.45	$4\frac{1}{8}$	5.45	$6\frac{9}{16}$	7.45	$8\frac{15}{16}$	9.45	$11\frac{3}{8}$
1.50	$1\frac{7}{8}$	3.50	$4\frac{3}{16}$	5.50	$6\frac{5}{8}$	7.50	9	9.50	$11\frac{7}{16}$
1.55	$1\frac{7}{8}$	3.55	$4\frac{1}{4}$	5.55	$6\frac{11}{16}$	7.55	$9\frac{1}{16}$	9.55	$11\frac{1}{2}$
1.60	$1\frac{15}{16}$	3.60	$4\frac{5}{16}$	5.60	$6\frac{3}{4}$	7.60	$9\frac{1}{8}$	9.60	$11\frac{9}{16}$
1.65	2	3.65	$4\frac{3}{8}$	5.65	$6\frac{13}{16}$	7.65	$9\frac{3}{16}$	9.65	$11\frac{5}{8}$
1.70	$2\frac{1}{16}$	3.70	$4\frac{7}{16}$	5.70	$6\frac{7}{8}$	7.70	$9\frac{1}{4}$	9.70	$11\frac{11}{16}$
1.75	$2\frac{1}{8}$	3.75	$4\frac{1}{2}$	5.75	$6\frac{15}{16}$	7.75	$9\frac{5}{16}$	9.75	$11\frac{3}{4}$
1.80	$2\frac{3}{16}$	3.80	$4\frac{9}{16}$	5.80	7	7.80	$9\frac{3}{8}$	9.80	$11\frac{13}{16}$
1.85	$2\frac{1}{4}$	3.85	$4\frac{5}{8}$	5.85	$7\frac{1}{16}$	7.85	$9\frac{7}{16}$	9.85	$11\frac{7}{8}$
1.90	$2\frac{5}{16}$	3.90	$4\frac{11}{16}$	5.90	$7\frac{1}{8}$	7.90	$9\frac{1}{2}$	9.90	$11\frac{15}{16}$
1.95	$2\frac{3}{8}$	3.95	$4\frac{3}{4}$	5.95	$7\frac{3}{16}$	7.95	$9\frac{9}{16}$	9.95	$11\frac{15}{16}$
2.00	$2\frac{7}{16}$	4.00	$4\frac{13}{16}$	6.00	$7\frac{1}{4}$	8.00	$9\frac{5}{8}$	10.00	12

Another convenient way is to make the level board 100 in. long. The required grade per cent. expressed in feet is then equal to the toe required in inches; the length of the board is to 100 ft. as 1 is to 12, or as 1 ft. is to an inch.

For Example.—On a grade board 100 in. long, if the grade required is 0.75 per cent., the toe is 0.75 in., or $\frac{3}{4}$ in. The toe ends of grade boards are given some distinguishing mark to avoid confusion, particularly in the flatter grades.

Wherever possible, gangways and headings should be driven on a calculated grade, or approach as closely thereto as is practical. This should be done if only for the sake of haulage, but its importance in the event of future developments warranting a tunnel to connect parallel haulages, or in case of panel mining, is inestimable. A system of headings or gangways graded to conform with one another will save many regrets and afford many economic possibilities.

On the surface, especially where the adopted grade is a factor in limiting the length of the trip of cars, the inclination on curves should be reduced; so that the grade allowed on the curves plus the resistance due to curvature will equal the grade on the straight track. The compensation or allowance for curvature is usually spoken of in terms of the grade proportional to the degree of curve as discussed under the most economic radius to use underground, page 34.

For Example.—If the prevailing grade for the road is 2.5 per cent., then on a 100-ft. radius, or 57-deg. curve, the compensation per 100 ft. would be 57×0.010 to 57×0.025, or 0.6 to 1.4 ft. respectively, depending on the particular cars used. The grade on the curve should be 1.9 to 1.1 ft. per 100 ft.

CHAPTER V

GRAVITY GRADES

In the vicinity of shafts, slopes, planes, etc., where cars are required to move without any mechanical aid, it is customary to depend on gravity for their movement. It is impossible to adopt a gravity grade that will work equally well with all the cars; a grade upon which some cars will run smoothly will permit others to run away and will not be sufficient for still others. Most of this difficulty arises from the oiling of the cars, the flat wheels developed in many instances, the nonuniform condition of mine cars in general, and the temperature and the weather.

The grade in the immediate vicinity of a shaft should be sufficiently steep and long enough to permit the car to gain headway quickly, and bump off the car delivered to the landing. If an empty car is to drive a loaded one off the cage, greater allowance should be given than if the reverse was the case.

While no absolute rule can be given, a loaded car on a grade of 5 per cent. for 12 ft. will be found in most instances to work well for removing empties from the cage. When the cage floor is inclined in favor of the car motion, a 2 per cent. to 2.5 per cent. grade with occasional assistance from the cage tender has given satisfactory results.

With the empty car driving off the loaded one, a grade of 5 per cent. for 20 ft. should be allowed; or with occasional help from the foot- or headman, a 2.5 per cent. to 3 per cent. grade.

The grade of the track leaving the cage should be about 2 per cent. to 2.5 per cent. in order to assist the car in leaving the shaft quickly.

It is customary to have about 50 ft. in the vicinity of the shaft, plane or slope landings somewhat steeper than the minimum grade required for the car to start unassisted, so as to expedite handling the cars. The remainder of the turnout grade should run about 1.5 per cent. to 1.7 per cent. for loaded cars and from 1.6 per cent. to 1.9 per cent. for empty cars, on the straight track. A stretch of 50 to 100 ft. should be made level at the end of the turnout to retard motion and prevent the cars from running upon the main track.

When a curve occurs on a gravity grade, the compensation should be reversed; that is, the compensation should be added to the regular grade used for the tangents in order to allow for this curve resistance. The method of computing compensation has been treated previously.

To illustrate: If the grade for straight track was 1.6 per cent. on a 100-ft. radius, or 57-deg. curve, $\left(\frac{5730}{100}\right)$, the compensation should be 0.6 to 1.4 ft. per 100 ft. The grade on the curve would thus be 2.2 to 3 per cent. Experience will determine the proper allowance to use for the cars employed.

Cars with the wheels turning loose on the axles will require a less compensation than those having the wheels keyed to the axle. The curve friction which the compensation is intended to equalize is due to the pressure of the flanges and the sliding, both lateral and longitudinal, of the wheels on the rail head.

In order to secure an easy running curve, three considerations are necessary: First, to elevate the outer rail to allow for the centrifugal force of the moving cars; second, to widen the gage of the track; third, to ease the approaches to the curve.

The elevating of the outer rail is termed the superelevation, and its amount is dependent on the velocity at which the cars are to travel, the radius of the curve, the gage of the track and the weight of the cars. This superelevation may be computed from the formula:

$$\phi = \frac{gV^2}{32.16R}$$

in which

ϕ = Superelevation required, in inches;
V = Velocity at which the cars are to travel, in feet per second;
g = Gage of the track, in inches;
R = Radius of the curve, in feet.

The numeral 32.16 is the force of gravity. By the foregoing formula the superelevation for a velocity of 6 miles per hour (the maximum velocity allowed by law in a number of states for haulages underground) and a 30-in. gage track should be as follows:

For a 40 ft. radius curve	1¾ in.
For a 50 ft. radius curve	1½ in.
For a 60 ft. radius curve	1¼ in.
For a 80 ft. radius curve	1 in.
For a 100 ft. radius curve	¾ in.
For a 150 ft. radius curve	½ in.
For a 200 ft. radius curve	⅜ in.

This superelevation varies directly as the gage, so that if the gage was 40 in., the superelevation would be $^{40}/_{30}$, or 1⅓ times as great; or for 20 in. $^{20}/_{30}$, or ⅔ as great as that shown in the table.

The elevation varies, as will be noted in the formula, as the square of the velocity; that is, if the velocity is 12 miles per hour, instead of the figure for 6 miles per hour, for which the table was computed, the superelevation would be $(\frac{12}{6})^2$ or 4 times as great.

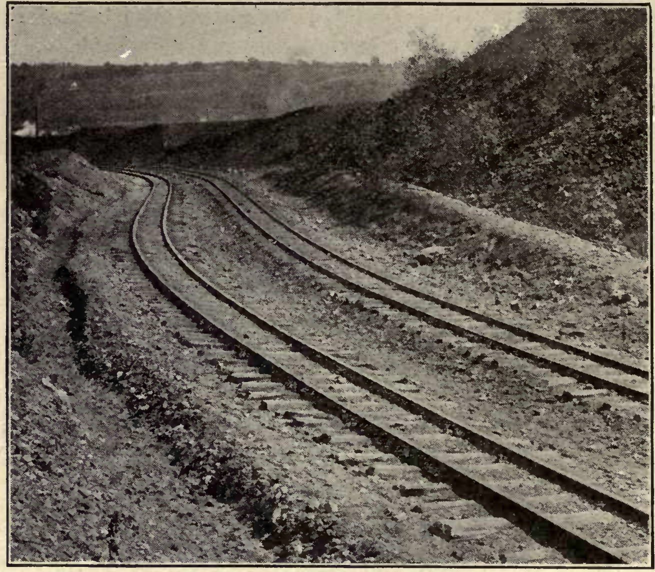


FIG. 12.—Well-laid narrow-gage reverse curve.

For Example.—If the gage was 40 in. and the velocity 12 miles per hour, the superelevation would be $\frac{40}{30} \times (\frac{12}{6})^2 = 1\frac{1}{3} \times 4$, or $5\frac{1}{3}$ times that shown in the table. The maximum superelevation, however, should not exceed about $\frac{1}{7}$ of the gage.

In applying the superelevation the best practice is to start same a distance back along the straight track approaching the curve and give the outer rail the elevation gradually, and at the same time start to gently curve the track, increasing the curvature more and more until when the curve proper is reached it will have the required maximum curvature and full superelevation.

The distance used to reach the full curvature and superelevation will depend largely on the amount of straight track on either approach to the curve; where possible, it is good practice to elevate 1 in. in the length of a rail and apply the curvature in the same distance. To gain a superelevation of 2 in., would mean starting two rail lengths in advance of the nominal curve and achieving the elevation in that distance. When the superelevation and curvature are applied skillfully, there should be no jar to the traffic when the curve is reached.

The maximum speed should be used in figuring the superelevation. This increase in height of the outer rail when within safe bounds tends to reduce the curve resistance. When the cars are moved by rope in both directions over a curve the inner rail should be elevated instead of the outer, as the motive force tends to draw the cars toward the inside of the curve. When they are pulled by rope and allowed to return by gravity, pulling the rope with them, the outer rail should be raised but not to the full superelevation.

INCREASING GAGE OF TRACK ON CURVES

The cars in traveling around a curve do not move concentric to the axis of the curve, as is commonly supposed, but rather in a series of short tangents. Fig. 13 shows the normal position of the wheels in traveling around a curve.

One front wheel hugs the outer rail while the opposite back wheel tends to hold to the inner rail. The friction resulting from the action of the front outer wheel of course cannot be avoided; the flange friction of the hind inner wheel, however, can be reduced or eliminated by widening the gage of the track. The position that the rear axle and wheels will assume when free to move is radial to the curve, so that when the gage of the track is increased sufficiently, no friction will result from the lateral pressure of the rear inner wheel flange against the rail.

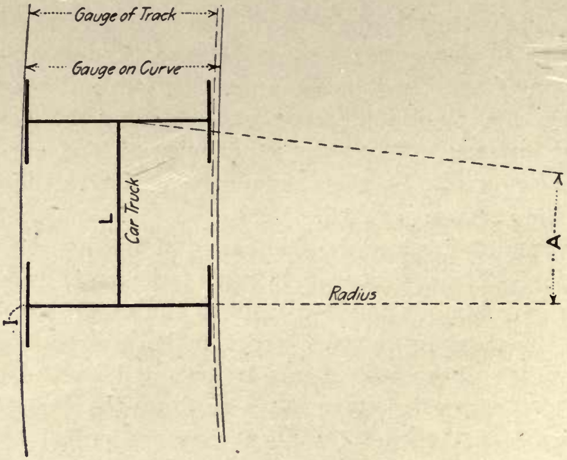


Fig. 13.—Position of car wheels on a curve.

Another reason why the track gage should be increased on curves is that if any advantage is realized from the coning of the tread on the car wheels in consuming the extra length of the outer rail (which is very doubtful, as the position assumed by the rails bears no relation to that required by the coning), it can be better effected by permitting the lateral action necessary.

Also, as the hind lateral pressure is reduced, there is less force tending to narrow the wheel gage and produce an excess play on the axles, which trouble is quite common where the wheels revolve on the axle.

The distance which the gage of the rails can be increased is small, depending on the widths of the wheel treads, the condition of the wheel gage and the radius of the curve; one in. is about the maximum with ordinary rolling stock.

The distance which the rear outer wheel stands from the outer rail on a curve, is the theoretic distance that the gage should be widened, and is equal to the versed sine of the chord subtended by twice the length of wheelbase.

Expressing this relation as a formula:

Let

I = Theoretic distance in feet that the gage should be increased beyond the gage of the car wheels;
L = Length of wheelbase of the cars, in feet;
R = Radius of curve, in feet;
A = Angle subtended by the wheelbase.

$$\sin A = \frac{L}{R}$$

Then

$$I = R \operatorname{vers} \sin A.$$

For Example.—If the car has a 5-ft. wheelbase, the theoretic distance the gage should be increased on a 1-deg. curve is:

$$\sin A = \frac{5}{5730}. \quad A = 0 \text{ degrees } 3 \text{ minutes.}$$

$$I = 5730 \, vers \, sin \, A = 0.0022 \, ft.;$$

in which $5730'$ = radius of a 1-deg. curve,
and $1 - \cos A = \operatorname{vers} \sin A$.

This increase in gage should be applied gradually, as explained under superelevation. The theoretic distance required in excess of the wheel gage is as follows:

Radius, ft.	Wheelbase 2½ ft.	Wheelbase 3 ft.	Wheelbase 3½ ft.	Wheelbase 4 ft.
40	⅞ in.	1⅜ in.	1⅞ in.	2⅜ in.
50	¾ in.	1⅛ in.	1½ in.	2 in.
60	⅝ in.	⅞ in.	1¼ in.	1⅝ in.
75	½ in.	¾ in.	1 in.	1¼ in.
100	⅜ in.	9⁄16 in.	¾ in.	1 in.
150	¼ in.	⅜ in.	½ in.	⅝ in.
200	3⁄16 in.	5⁄16 in.	⅜ in.	½ in.

The foregoing distances apply to the wheel gage, not the track gage, and as mentioned before the increase above the track gage will hardly be permitted to exceed 1 in., unless the treads are unusually wide.

Taking the case of a 50-ft. radius curve with a 3½-ft. wheelbase, the track gage being ½ in. greater than the gage of the wheels, the theoretic increase is 1½ in., which, as there is ½ in. allowance between the track gage and the wheel gage, and the treads of the wheels permit another inch, the full increase can be given.

With a 4-ft. wheelbase and ½-in. play between the gages on a 40-ft. radius curve, if 1 in. above track gage is allowed, there will be ⅞-in. deficiency. This deficiency will have a resisting effect equal to the force required to move the weight on the hind wheels ⅞ in. over the length of the curve.

GUARD RAILS

When guard rails are necessary on curves they should be placed parallel to and at such a distance from the inner rail that they will restrain the flange of the front wheel from running over the head of the outer rail.

Where the wheels are not true to gage, as is often the case with loose wheels, the guards in this position are not very effective. Placing the guard at a distance equal to the tread of the wheels on the outer side of the outer rail and about 1 in. higher is often resorted to.

With rope haulage, the guard should be placed at a distance equal to the width of the tread outside the inner rail. At the bottoms of slopes and similar places, since the force is contrary in hoisting and lowering, the guard should be placed outside of both rails.

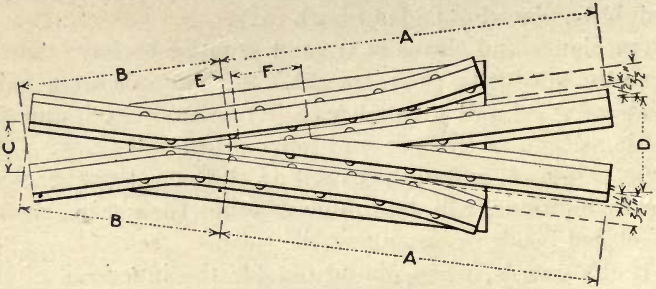
On planes and slopes it is good practice to have guards even though the track is straight. Such guards are usually made of wood and covered with flat or angle iron, and are made as high as the axle and journal box will allow. The type of journal and oil-box used on the cars, together with local conditions, will determine whether the guards should be placed inside or outside of the rails.

If the guards, when placed outside the inner rail of the curve, are made of "T" rail, and are spiked to ties distinct from those supporting the main rails, they can be more readily brought back to the tread distance as they wear or are forced out of alignment. If the same or a lesser weight rail is used for the guard rail, than for the main rails, the requisite elevation above the main rails is usually obtained by notching the guard rail ties directly under the one main rail.

CHAPTER VI

FROGS AND SWITCHES

The standardization of turnout equipment furnishes a fertile field for improvement; both time and equipment can be economized and at the same time better results obtained.



FROG NO.	FROG ANGLE	A	B	C	D	E	F
3.	19°-12'	3'-0"	2'-0"	8"	12"	¾"	6⅜"
4	14°-22'	3'-9"	2'-0"	6"	11 3/16"	1"	8½"
6	9°-30'	5'-0"	2'-6"	5"	10"	½"	12¾"

Fig. 14.—Typical plate frog of uniform length for varying weights of rail.

In the preparation of standards, every effort should be made to achieve simplicity—the adoption of three or four different numbered frogs with possibly two switches of different lengths that can be installed to suit most conditions, if a little forethought is used in laying out the work, will be found ample.

The use of a frog of a certain number for chamber work, another for general cases other than the chambers, and a third for locations subject to heavy traffic and high velocity will be sufficient except for special cases.

Plate frogs should be designed so they can be made, should the necessity arise, at the colliery blacksmith shop, although ordinarily it will be found advisable to purchase such frogs from a manufacturer who specializes in this kind of equipment. The reasons for this latter choice are, of course, obvious.

If the mine employs various weights of rail, by designing a certain number of frogs the same length for the different weights, the one turnout standard will apply. This will also permit in an emergency the replacing or temporary installation of any frog of a certain number with rail of different weights. With this idea in view, a No. 4 frog would be the same length, whether made of 30-, 40- or 60-lb. rail.

Fig. 14 shows a typical frog design for a No. 3, 4 or 6 frog to be used with any weight rail up to and including 60 lb. per yard. The length of the frog must be sufficient to permit the easy application of the angle bars.

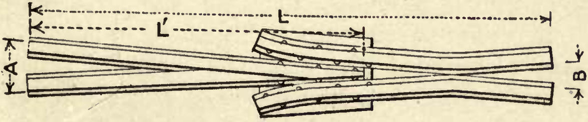


Fig. 15.

While frogs are sometimes lettered or numbered arbitrarily, the generally accepted practice is to designate the frog by the number found by dividing the length by the spread; that is, the frog number is the ratio of the length to the spread. Thus, referring to Fig. 15:

Let

L = Double or entire length of the frog;

A = Spread between gage side of rails at one end of the frog;

B = Spread between gage side of rails at the other end of the frog.

Then the frog number equals $\frac{L}{A + B}$, or the frog number equals $\frac{L'}{A}$.

If L is measured in inches, then A and B should be in inches; and similarly, if L is in feet, A and B should be in feet.

The use of the cast frog is not to be recommended with locomotive haulage, and even with mule haulage and light rail it should be restricted to chamber or room work. While the initial cost of the cast frog is less than for the built-up frog, it will not wear as well; the point breaks off or wears down in a short time; it does not permit an efficient connection with the rails; it wears down quickly and contributes to many derailments.

Many companies require the face of such frogs to be chilled in order to increase the wearing qualities. Fig. 16 shows a shrouded cast frog; the shrouded type being found much superior to the ordinary casting in the prevention of derailments. The shroud precludes the possibility of the flange hitting the frog point or taking the wrong flange channel when passing from the throat of the frog. It will be noted that the shroud is cast about 1 in. higher than the frog, and at such a distance from the gage lines that the shroud engages the outside of the wheel tread a short distance before the point is reached.

The use of the usual guard rail on the inner side of

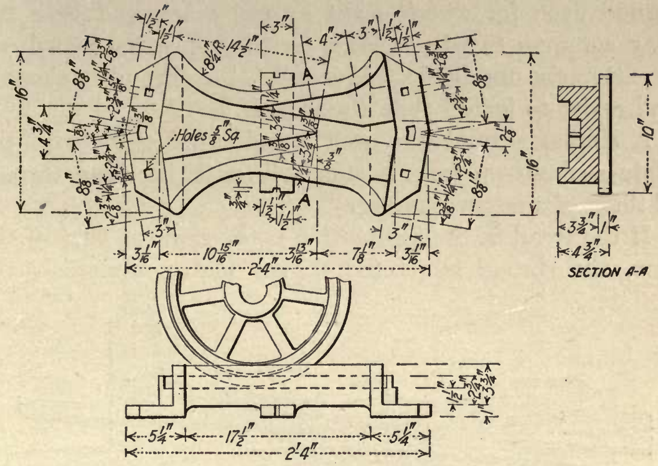


Fig. 16.—Plan of shrouded cast frog.

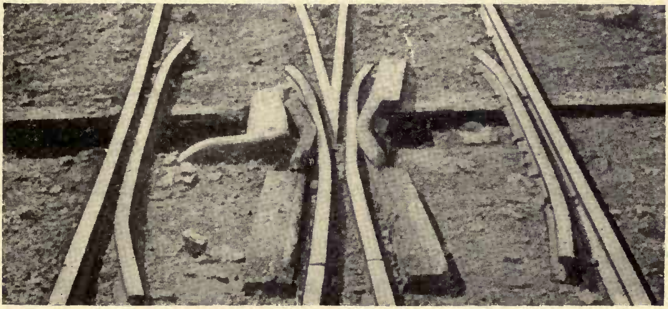


Fig. 17.—Tee rail shroud with spring.

the opposite rail is not so positive in its action as the shroud even for wheels tight on the axles, and with the play common to wheels loose on the axles, the guard rail is extremely unreliable. Moreover, the shroud is cheaper and easier to install than the guards.

A similar shroud has been found satisfactory with the plate or built-up frog, particularly with the long throats of those of a larger number.

If the tread of the locomotive is the same as that of the cars, the shroud is riveted to the plate; otherwise, the shroud is held in the position required for the cars by a spring, which the locomotive pushes back when passing. It will be noted that one spring will serve for either a single or double shroud (see Fig. 17).

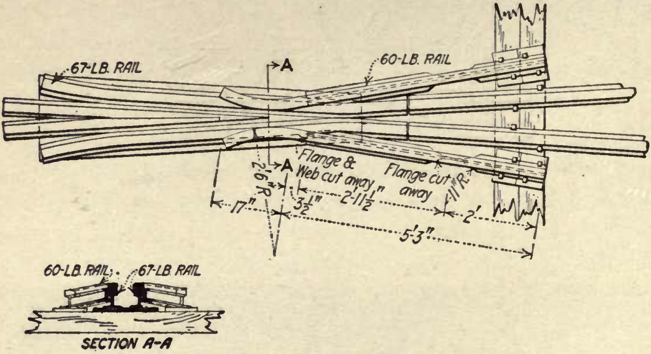


Fig. 17A.—Plan of spring-rail shroud frog.

Fig. 17*A* is a plan of a shroud built of ordinary tee rail, the elasticity of the rail constituting the shroud maintaining it in position.

In designing either plate or cast frogs, the flange channels should be made as narrow as the flanges of the wheels will permit. There are two objections to a wide flangeway: First, the diameter of the wheels of mine cars is comparatively small, so that instead of spanning the gap between the point and the wing they drop partly into it, jarring the cars and wearing out the frog; second, the wider the flangeway the longer will be the "throat" of the frog—that is, the distance between the point and the "wing"—and the wheels in traveling over the throat, especially of the frogs of large number, are more liable to depart from their proper course and derail the car by striking the frog point or by taking the wrong flangeway. As stated before, the guard rail placed near the opposite rail cannot be depended upon when the cars have loose wheels. The short length of mine frogs does not adapt them for having one wing on a spring, as may be the case on standard-gage tracks; and furthermore, wheels loose on the axle would not operate a spring frog.

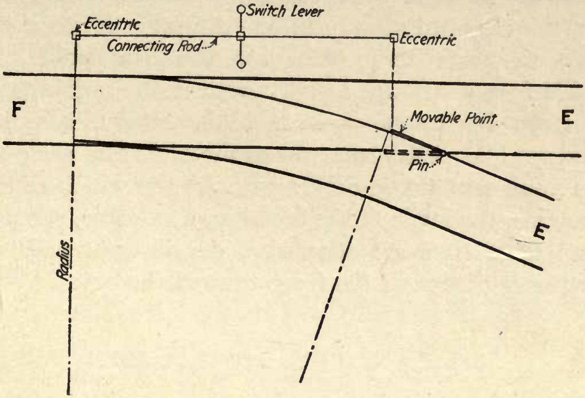


FIG. 18.

Fig. 18 shows a form of frog built to avoid the gap in the usual type. It is generally connected with the switch lever, so that whichever way the switch is set the frog will be in proper relation. The tongue is held by a pin which allows it to swing to fit either of the rails. About 3 in. are left between the ends of the rails—the tongue is made sufficiently long to reach from the frog point and make a close joint with the ends of the rails.

This arrangement has been found to work well in preventing derailments where cars are pushed. On switches where the cars run always in one direction (*E* to *F* in the figure), the cars themselves set the frog point. This movable frog point will usually outlast the ordinary type.

In frogs for crossings over other tracks, the flangeways should be made as narrow as the mine cars will permit. If the mine cars are equipped with wheels which run loose on the axle, the angle of the crossing, if possible, should not be less than 10 deg.; otherwise, derailments may occur when passing through the frogs toward the point.

SPLIT SWITCHES AND LATCHES

The length of the switch point should be in conformity with the radius of the turnout curve and the speed and character of the traffic.

The tapered end of the switch is known as the point; the blunt end, the heel. The switch made of tee rail is termed a split switch; that made of a bar of iron which turns on a pin near its heel is known as a latch. Switch points are designated right and left hand and are not interchangeable, the right and left hand being determined by standing at the switch point and facing toward the frog. When ordering a single switch point, its position, right or left, must be given. No distinction is necessary with latches as they can be reversed and used for either side.

Split switches for mine work should be straight, not curved, so that any pair of mated switch points can be used on a right- or left-hand turnout. When light rail switch points are curved, they frequently break a short distance from the point.

The split switch is usually longer than the latch and is operated by a lever. It thereby makes a more efficient bearing against the rail and affords a smoother haulage than does the latch. It is known as a rigid split switch when used without a spring, and as a spring switch when a spring is employed. The spring makes the switch automatic and is profitably used at turnouts when the traffic is in one direction. For ordinary use underground, the spring, if not properly cared for, clogs with mud and is no better than the rigid switch. The bolts attaching the rods connecting the switch points should be sufficiently low so that when the treads of the motor wheels are well worn the flanges will not cut the bolts. It is often advisable to attach the connecting-rods to the flange of the switch points rather than to the web.

The latches in general use on mine tracks run from 2 to 5 ft. in length and the split switches from 5 to 10 ft. Due to its easy and cheap installation, the latch is much used for mule haulage and chamber work.

The use of the stub switch has been limited around mines. It is assumed that it is a simple curve from the point of the stub to the point of frog; the lead being found by multiplying twice the gage by the number of the frog and the radius by multiplying twice the gage by the frog number squared. For example: If the frog is a No. 3 and the gage 3½ ft., the lead is 21 ft. and the radius 63 ft.

The following table gives the angles corresponding to the various length switches and frogs:

Frog no.	Frog angle		Split switch lengths, ft.	Switch angle for 5-in. throw; switch, ¼ in. at point	
	Deg.	Min.		Deg.	Min.
1¾	33	12	5	4	32
2	28	56	5½	4	08
2½	23	04	6	3	47
3	19	12	6½	3	27
3½	16	25	7	3	15
4	14	22	7½	3	01
4½	12	46	8	2	50
5	11	30	9	2	31
5½	10	26	10	2	16
6	9	34	. .	. .	. .
7	8	10	. .	. .	. .
8	7	09	. .	. .	. .

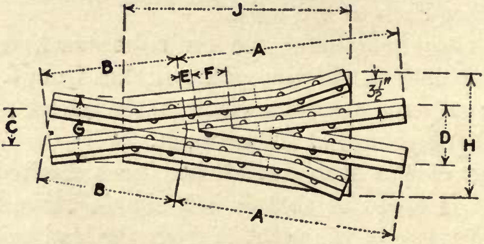


Fig. 19.—Dimensions of plate frog of 25- to 60-lb. rail.

The accompanying tables give dimensions for frogs from No. 3 to 5½ for rail from 25- to 60-lb. weight per yard:

STANDARD RIVETED PLATE FROGS FOR 25-LB. RAIL

Frog no.	Frog angle		Space between heads of rail	Diameter of rivets	General Dimensions												Plate thickness
					A		B	C	D	E	F	G	H	J			
	Deg.	Min.	In.	In.	Ft.	In.	In.	In.	In.	In.	In.	In.	In.	Ft.	In.		In.
3	19	12	1¾	½	0	21	15	5	7	¾	3¾	9	16	0	24		⅜
3½	16	25	1¾	½	0	24	15	4 9/32	6 27/32	⅞	4⅜	9	16	0	24		⅜
4	14	22	1¾	½	2	3	18	4½	6¾	1	5	9	16	2	6		⅜
4½	12	46	1¾	½	2	3	18	4	6	1⅛	5⅝	9	16	2	6		⅜
5	11	30	1¾	½	2	6	18	3⅝	6	1¼	6¼	9	16	3	0		⅜
5½	10	26	1¾	½	2	9	21	3 13/16	6	1⅜	6⅞	9	16	3	6		⅜

STANDARD RIVETED PLATE FROGS FOR 30-LB. RAIL

Frog no.	Frog angle		Space between heads of rail	Diameter of rivets	General Dimensions												Plate thickness
					A		B	C	D	E	F	G	H	J			
	Deg.	Min.	In.	In.	Ft.	In.	In.	In.	In.	In.	In.	In.	In.	Ft.	In.		In.
3	19	12	1¾	½	2	3	18	6	9	¾	4⅛	9	16	0	24		⅜
3½	16	25	1¾	½	2	6	21	6	8 9/16	⅞	4¾	9	16	0	24		⅜
4	14	22	1¾	½	2	9	21	5¼	8¼	1	5½	9	16	2	6		⅜
4½	12	46	1¾	½	3	0	24	5⅜	8	1⅛	6⅛	9	16	2	6		⅜
5	11	30	1¾	½	3	3	24	4 13/16	7 13/16	1¼	6⅞	9	16	3	0		⅜
5½	10	26	1¾	½	3	6	24	4⅜	7⅝	1⅜	7½	9	16	3	6		⅜

STANDARD RIVETED PLATE FROGS FOR 40-LB. RAIL

Frog No.	Frog angle		Space between heads of rail	Diameter of rivets	General Dimensions												Plate thickness
					A		B		C	D	E	F	G	H	J		
	Deg.	Min.	In.	In.	Ft.	In.	Ft.	In.	In.	In.	In.	In.	In.	In.	Ft.	In.	In.
3	19	12	1¾	½	2	9	0	21	7	11	¾	4⅞	9	16	0	24	½
3½	16	25	1¾	½	3	0	0	24	6²⁷⁄₃₂	10¼	⅞	5¾	9	16	0	24	½
4	14	22	1¾	½	3	3	0	24	6	9¾	1	6½	9	16	2	6	½
4½	12	46	1¾	½	3	6	2	3	6	9⁵⁄₁₆	1⅛	7¼	9	16	2	6	½
5	11	30	1¾	½	3	9	2	3	5⅜	9	1¼	8⅛	9	16	3	0	½
5½	10	26	1¾	½	4	0	2	3	4¹⁵⁄₁₆	8¾	1⅜	9	9	16	3	6	½

STANDARD RIVETED PLATE FROGS FOR 45-LB. RAIL

Frog No.	Frog angle		Space between heads of rail	Diameter of rivets	General Dimensions												Plate thickness
					A		B		C	D	E	F	G	H	J		
	Deg.	Min.	In.	In.	Ft.	In.	Ft.	In.	In.	In.	In.	In.	In.	In.	Ft.	In.	In.
3	19	12	1¾	⅝	2	9	0	24	8	11	¾	5¼	10	18	2	6	½
3½	16	25	1¾	⅝	3	0	0	24	6⅞	10¼	⅞	6⅛	10	18	2	6	½
4	14	22	1¾	⅝	3	6	0	24	6	10½	1	7	10	18	3	0	½
4½	12	46	1¾	⅝	3	9	2	3	6	10	1⅛	7⅞	10	18	3	6	½
5	11	30	1¾	⅝	4	0	2	3	5⁷⁄₁₆	9⁹⁄₁₆	1¼	8¾	10	18	3	6	½
5½	10	26	1¾	⅝	4	3	2	3	4¹⁵⁄₁₆	9¼	1⅜	9⅝	10	18	4	0	½

Standard Riveted Plate Frogs for 50-lb. Rail

Frog No.	Frog angle		Space between heads of rail	Diameter of rivets	General Dimensions												Plate thickness
					A		B		C	D	E	F	G	H	J		
	Deg.	Min.	In.	In.	Ft.	In.	Ft.	In.	In.	In.	In.	In.	In.	In.	Ft.	In.	In.
3	19	12	1 7/8	5/8	3	0	0	24	8	12	3/4	5 5/8	10	20	2	6	1/2
3 1/2	16	25	1 7/8	5/8	3	3	0	24	6 7/8	11 1/8	7/8	6 1/2	10	20	2	6	1/2
4	14	22	1 7/8	5/8	3	6	0	24	6	10 1/2	1	7 1/2	10	20	3	0	1/2
4 1/2	12	46	1 7/8	5/8	3	9	2	3	6	10	1 1/8	8 3/8	10	20	3	6	1/2
5	11	30	1 7/8	5/8	4	0	2	3	5 7/16	9 9/16	1 1/4	9 3/8	10	20	3	6	1/2
5 1/2	10	26	1 7/8	5/8	4	3	2	3	4 15/16	9 1/4	1 3/8	10 1/4	10	20	4	0	1/2

Standard Riveted Plate Frogs for 60-lb. Rail

Frog No.	Frog angle		Space between heads of rail	Diameter of rivets	General Dimensions												Plate thickness
					A		B		C	D	E	F	G	H	J		
	Deg.	Min.	In.	In.	Ft.	In.	Ft.	In.	In.	In.	In.	In.	In.	In.	Ft.	In.	In.
3	19	12	2	5/8	3	0	0	24	8	12	3/4	6 3/8	10	20	2	6	5/8
3 1/2	16	25	2	5/8	3	6	0	24	6 7/8	12	7/8	7 3/8	10	20	2	6	5/8
4	14	22	2	5/8	3	9	0	24	6	11 3/16	1	8 1/2	10	20	3	0	5/8
4 1/2	12	46	2	5/8	4	0	2	3	6	10 5/8	1 1/8	9 1/2	10	20	3	6	5/8
5	11	30	2	5/8	4	3	2	3	5 7/16	10 3/8	1 1/4	10 5/8	10	20	3	6	5/8
5 1/2	10	26	2	5/8	4	9	2	6	5 7/16	10 3/16	1 3/8	11 5/8	10	20	4	0	5/8

Note.—Rivets to be countersunk on bottom side of bottom plate; frogs to be drilled for standard splice bars.

The assumption that a turnout is a simple curve from the point of switch to the point of frog is no longer tenable. By the simple curve theory, the lead was found by multiplying twice the gage by the number of the frog; the radius of the curve by multiplying twice the gage by the square of the number. The above, of course, ignores the fact that the frog is straight and not curved, and the switch points are, especially for mine work, also straight.

In standardizing the switch design, the frog numbers to be used and the length of switch point to accompany each frog should first be determined. The design of each frog and switch proposed should be gone into thoroughly and the types adopted rigidly adhered to. Local conditions will determine the frog angles and switch points most suitable.

Companies purchasing their equipment from manufacturers will find it advisable to state the frogs and switches they propose to use and have the builders of such equipment furnish designs of the entire turnout. For the convenience of the companies who make their own frogs and switches, the following formulæ are given. Referring to Fig. 20:

Let

ϕ = Angle of switch points;
F = Angle of frog;
G = Gage of track;
B = Length of wing rail;
C = Chord of connecting rail arc;
S = Length of switch;
L = Length of lead;
R = Radius of center line of turnout curve;
H = Connecting rail length;
D = Distance from theoretical to actual frog point.

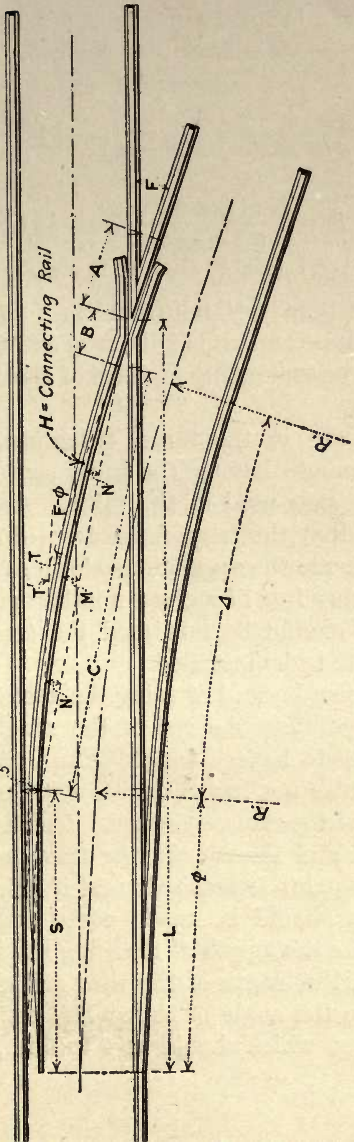


Fig. 20.

Then

$$C = \frac{G - B \sin F - S \sin \phi}{\sin \frac{1}{2} (F + \phi)}$$

$$R = \frac{C}{2 \sin \frac{1}{2} (F - \phi)} - \frac{1}{2} G$$

Or

$$R = \frac{G - B \sin F - H}{\cos \phi - \cos F} - \frac{1}{2} G$$

$$L = (R + \tfrac{1}{2}G)\ (\sin F - \phi) + B \cos F + S + DC.$$

Table I has been worked from the foregoing formulæ—the actual shape and size of the frog and switch are used—a simple curve connecting the heel of the switch with the end of the frog.

The dimensions in the table, of course, are only applicable to turnouts having the same switch lengths and the same wing rails used in the table. As stated before, to a certain extent the frogs made from different weights of rail can be made the same dimensions, so that one turnout design for any frog of a given number will be sufficient. Similar tables should be furnished the trackman for the various turnouts to be installed.

Some trackmen, instead of using the actual length of the frog from the point to the end of the wing rail (B in the formula), prefer to have a tangent from the point of the frog for a distance not less than a few inches greater than the wheelbase of the mine cars used. This is done in order that both wheels of the car may be traveling in a straight line before the point is reached; and if this is desired, B in the formula should be made equal to this distance. Naturally, where the length of the wing rail is greater than the wheel-base, the length of the wing rail should be used.

To determine the angle of the switch points or latches, the heel distance which should be 4 to 5 in., is divided by

TABLE 1.—DIMENSIONS OF TURNOUT LAYOUTS

Frog No.	Frog angle		Frog bluntness	Wing rail		Switch length	Switch angle			Chord		Lead		Radius		Middle ordinate	Connecting rail		F — φ Angle	
	F		D	B		S	φ			C		L		R		M	H			
	Deg.	Min.	In.	Ft.	In.	Ft.	Deg.	Min.	Sec.	Ft.	In.	Ft.	In.	Ft.	In.	In.	Ft.	In.	Deg.	Min.
24-In. Gage																				
1¾	31	53	7/16	1	0¾	5	4	32	12	3	4	9	0½	6	0¾	2 13/32	3	4 7/16	27	21
2	28	04	½	1	0¾	5	4	32	12	3	11 3/16	9	8⅛	8	7¾	2 7/16	3	11 17/32	23	32
2½	22	38	⅝	1	0¾	5	4	32	12	5	1 1/16	10	10¾	15	2⅛	2 13/32	5	1 5/16	18	06
3	18	55	¾	1	3	5	4	32	12	5	10 13/16	11	11 1/16	22	6⅞	2 7/32	5	11	14	23
3½	16	16	⅞	1	3	5	4	32	12	6	11⅜	13	0⅛	32	11¾	2⅛	6	11 17/32	11	44
4	14	15	1	1	5	5	4	32	12	7	8 5/16	13	11 1/16	44	5½	1 31/32	7	8 7/16	9	43
5	11	25	1¼	1	9¼	7½	3	1	27	9	11¾	19	0 29/32	67	1 19/32	2 3/16	9	11 27/32	8	24
6	9	31	1½	2	1½	7½	3	1	27	11	5 23/32	20	11 5/32	100	2 23/32	1 31/32	11	5 13/16	6	30
30-In. Gage																				
1¾	31	53	7/16	1	0¾	5	4	32	12	4	11¼	10	6¾	9	2¼	3 9/16	4	11 13/16	27	21
2	28	04	½	1	0¾	5	4	32	12	5	8 9/16	11	4⅝	12	9⅛	3 17/32	5	9 1/16	23	32
2½	22	38	⅝	1	0¾	5	4	32	12	7	2⅝	12	11 9/16	21	8¼	3 7/16	7	3 1/16	18	06
3	18	55	¾	1	3	5	4	32	12	8	4⅜	14	6¼	32	1 11/16	3 5/32	8	4¾	14	23
3½	16	16	⅞	1	3	5	4	32	12	9	8⅝	15	8 9/16	46	3⅜	3	9	8 15/16	11	44
4	14	15	1	1	5	7½	3	1	27	11	8 5/16	20	4 9/16	58	6	3 7/16	11	8 9/16	11	14
5	11	25	1¼	1	9¼	7½	3	1	27	13	11 17/32	23	0 5/16	94	0⅝	3 1/16	13	11 23/32	8	24
6	9	31	1½	2	1½	10	2	16	07	17	0 15/16	29	0 1/16	133	9 11/16	3¼	17	1 1/16	7	15

TABLE 1.—DIMENSIONS OF TURNOUT LAYOUTS.—(*Continued*)

Frog No.	Frog angle		Frog bluntness	Wing rail		Switch length	Switch angle			Chord		Lead		Radius		Middle ordinate	Connecting rail		F — ϕ Angle	
	F		D	B		S	ϕ			C		L		R		M	H			
	Deg.	Min.	In.	Ft.	In.	Ft.	Deg.	Min.	Sec.	Ft.	In.	Ft.	In.	Ft.	In.	In.	Ft.	In.	Deg.	Min.
36-In. Gage																				
1 3/4	31	53	7/16	1	0 3/4	5	4	32	12	6	6 7/16	12	1	12	3 15/16	4 11/16	6	7 3/16	27	21
2	28	04	1/2	1	0 3/4	5	4	32	12	7	5 15/16	13	1 1/8	16	10 9/16	4 5/8	7	6 19/32	23	32
2 1/2	22	38	5/8	1	0 3/4	5	4	32	12	9	4 1/8	15	0 3/8	28	2 3/8	4 7/16	9	4 11/16	18	06
3	18	55	3/4	1	3	5	4	32	12	10	9 7/8	16	8 7/8	41	8 5/8	4 3/32	10	10 11/32	14	23
3 1/2	16	16	7/8	1	3	5	4	32	12	12	5 7/8	18	5 3/8	59	7	3 27/32	12	6 1/4	11	44
4	14	15	1	1	5	7 1/2	3	1	27	15	0 5/16	23	8 3/32	75	3 1/8	4 13/32	15	0 9/16	11	14
5	11	25	1 1/4	1	9 1/4	10	2	16	07	18	11 1/32	30	5 13/32	117	1 1/8	4 17/32	18	11 1/4	9	09
6	9	31	1 1/2	2	1 1/2	10	2	16	07	21	11 13/32	33	10 3/16	172	1 1/32	4 5/32	21	11 9/16	7	15
42-In. Gage																				
1 3/4	31	53	7/16	1	0 3/4	5	4	32	12	8	1 5/8	13	7 1/4	15	5 3/8	5 7/8	8	2 5/8	27	21
2	28	04	1/2	1	0 3/4	5	4	32	12	9	3 5/16	14	9 3/4	21	0	5 3/4	9	4 3/16	23	32
2 1/2	22	38	5/8	1	0 3/4	5	4	32	12	11	5 3/4	17	1 1/4	34	8 3/4	5 7/16	11	6 1/2	18	06
3	18	55	3/4	1	3	7 1/2	3	1	27	14	2 1/8	22	3 3/4	49	6	5 29/32	14	2 3/4	15	54
3 1/2	16	16	7/8	1	3	7 1/2	3	1	27	16	5 1/4	24	9 3/4	69	6 1/8	5 11/16	16	5 3/4	13	15
4	14	15	1	1	5	7 1/2	3	1	27	18	4 1/4	26	11 5/8	92	0 3/8	5 13/32	18	4 5/8	11	14
5	11	25	1 1/4	1	9 1/4	10	2	16	7	23	1 13/32	34	7 13/32	143	1 3/4	5 17/32	23	1 11/16	9	09
6	9	31	1 1/2	2	1 1/2	10	2	16	7	26	9 27/32	38	8 11/32	210	4 9/32	5 3/32	26	10 1/16	7	15

TABLE 1.—DIMENSIONS OF TURNOUT LAYOUTS.—(*Concluded*)

48-In. Gage

Frog No.	Frog angle F		Frog bluntness D	Wing rail B		Switch length S	Switch angle φ			Chord C		Lead L		Radius R		Middle ordinate M	Connecting rail H		F — φ Angle	
	Deg.	Min.	In.	Ft.	In.	Ft.	Deg.	Min.	Sec.	Ft.	In.	Ft.	In.	Ft.	In.	In.	Ft.	In.	Deg.	Min.
1¾	31	53	7/16	1	0¾	5	4	32	12	9	8⅞	15	1½	18	7⅛	7	9	10	27	21
2	28	04	½	1	0¾	5	4	32	12	11	0¾	16	6¼	25	1⅜	6 27/32	11	1 11/16	23	32
2½	22	38	⅝	1	0¾	5	4	32	12	13	7¼	19	2 1/16	41	3	6 7/16	13	8 1/16	18	06
3	18	55	¾	1	3	7½	3	1	27	16	9⅝	25	1¾	58	9	7	16	10 5/16	15	54
3½	16	16	⅞	1	3	7½	3	1	27	19	5⅛	27	9	82	2 7/16	6¾	19	5 11/16	13	15
4	14	15	1	1	5	7½	3	1	27	21	8¼	30	3⅛	108	9 9/16	6⅜	21	8 11/16	11	14
5	11	25	1¼	1	9¼	10	2	16	07	27	3¾	38	9 13/32	169	2 7/16	6 17/32	27	4 3/32	9	09
6	9	31	1½	2	1½	10	2	16	07	31	8 5/16	43	6½	248	7 9/16	6	31	8 9/16	7	15

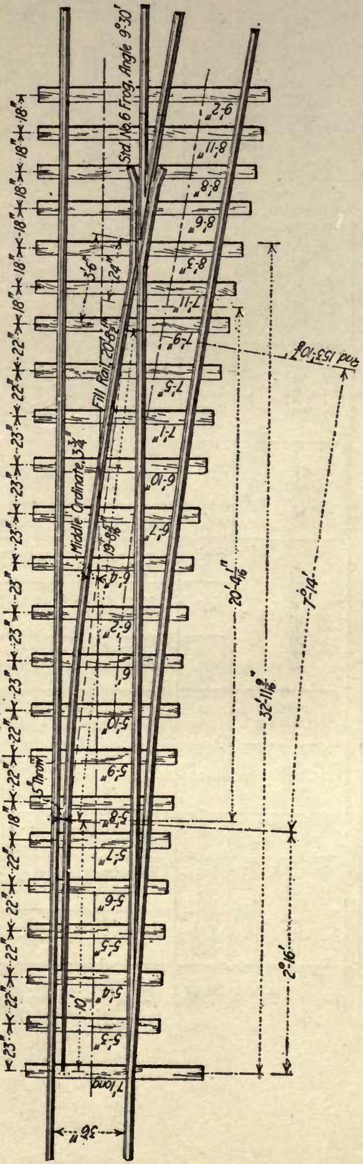

Std. No. 6 Frog, Angle 9°30'
Fill Rail 20'-8½"
Middle Ordinate 3¼"
19'-8 5/16"
3'-6"
24"
5" Throw
10'
7' long
36"
20'-4 1/16"
32'-11 9/16"
7°14'
2°16'
Rad. 153'-10½"
18"
18"
18"
18"
18"
18"
22"
22"
23"
23"
23"
23"
23"
23"
22"
22"
18"
22"
22"
22"
22"
23"
9'-2"
8'-11"
8'-8"
8'-6"
8'-3"
7'-11"
7'-9"
7'-5"
7'-1"
6'-10"
6'-7"
6'-4"
6'-2"
6'
5'-10"
5'-9"
5'-8"
5'-7"
5'-6"
5'-5"
5'-4"
5'-3"

FIG. 21.

the length of the points; the result is the sine of the switch angle. The less the angle the less the shock to the motion of the cars, and consequently the greater speed and safety with which the rolling stock will travel over the switch.

There are locations, however, where the amount of room is limited, and shorter frogs or switch points, or both, must be resorted to; and the extreme to which this can be carried will be governed by the radius *R* of the lead curve, combined with practical experience.

When the frog and switch standardization has been decided upon, and the designs for the complete turnouts have been made, the various parts of the turnout, including the frogs, switches, points, the middle rail curved to the proper radius and drilled, and all the other parts, should be carried in stock, so that when it is desired to install a turnout, all that will be necessary is to specify the frog number desired and the entire equipment can be delivered to the site desired and will require a minimum of labor to install. The ties for the turnout should be in graded lengths to carry both the main and turnout curve as far as the end of the frog. Such ties would be delivered with the rest of the turnout equipment.

It is obvious that by having this equipment standard, and thereby interchangeable, great economy can be achieved in both the original installation and renewals.

TURNOUTS OFF CURVES

For all practical purposes, the lead of a turnout off a curve, whether from the inside or outside of the curve, is the same as the lead off a straight track. The radius of the curve connecting the frog and switch points, however, will increase or decrease, depending on whether the turnout is to the outside or the inside of the main curve.

TABLE 2.—RADII, DEGREES OF CURVE AND ORDINATES BASED ON A 10-FT. CHORD

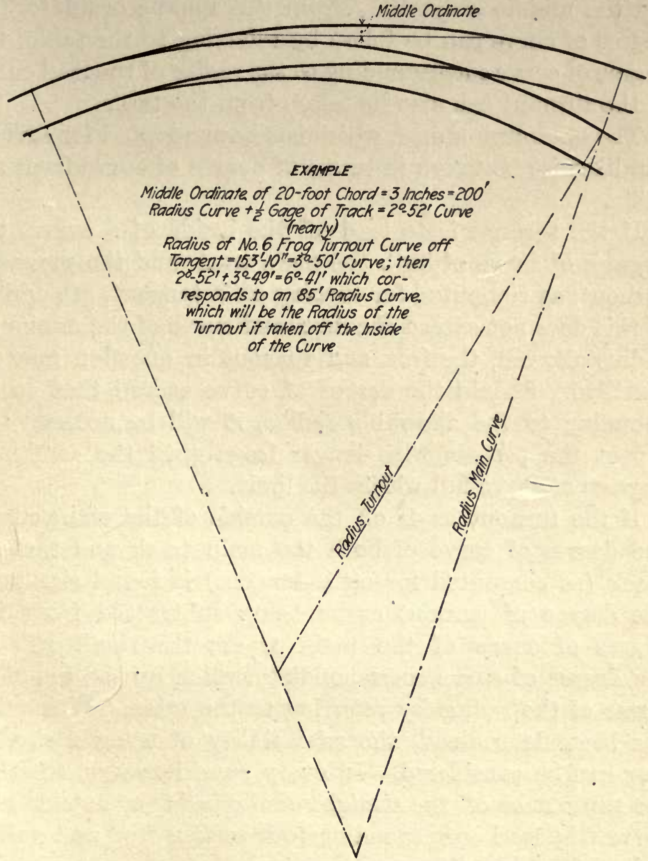
Radius, ft.	Degree of curve		Middle ordinate of 10-ft. chord		Radius, ft.	Degree of curve		Middle ordinate of 10-ft. chord	
	Deg.	Min.	Ft.	In.		Deg.	Min.	Ft.	In.
15	39	00	3	9⅞	18	32	20	3	0⅜
20	29	00	2	8⅛	22	26	20	2	4¾
24	24	00	2	2⅛	26	22	10	2	0
28	20	30	1	10¼	30	19	12	1	8½
32	17	58	1	7¼	34	16	54	1	6
36	15	58	1	5	38	15	08	1	3
40	14	22	1	3	42	13	40	1	2¼
44	13	2	1	1⅝	46	12	28	1	1⅛
48	11	58	1	½	50	11	28	1	0
52	11	2	0	11½	54	10	38	0	11⅛
56	10	14	0	10⅝	58	9	53	0	10¼
60	9	34	0	10	62	9	15	0	9⅝
64	8	58	0	9⅜	66	8	41	0	9⅛
68	8	26	0	8⅞	70	8	12	0	8⅝
72	7	58	0	8⅜	74	7	45	0	8⅛
76	7	33	0	7⅞	78	7	21	0	7⅝
80	7	10	0	7½	85	6	45	0	7
90	6	22	0	6⅝	92	6	14	0	6½
95	6	2	0	6¼	100	5	44	0	6
105	5	28	0	5¾	110	5	13	0	5½
115	4	59	0	5¼	120	4	47	0	5
130	4	25	0	4⅝	140	4	6	0	4¼
150	3	49	0	4	160	3	35	0	3¾
170	3	22	0	3½	180	3	11	0	3¼
190	3	1	0	3⅛	200	2	52	0	3

$$\text{Degree of curve} = \frac{573}{\text{radius}} \ldots \text{(approximate)}$$

Ordinates midway between middle ordinate and end of chord equal three-quarters of the middle ordinate.

$$\text{Radius} = \frac{5.0}{\sin \tfrac{1}{2} \text{ deg. of curve}}$$

Table 2, which is based on the assumption that the degree of curve is the angle subtending a 10-ft. chord, is but a modification decimally of the standard practice for expressing the degree of curvature, and is more fully discussed under "Alignment on the Surface."



EXAMPLE

Middle Ordinate of 20-foot Chord = 3 Inches = 200′
Radius Curve + ½ Gage of Track = 2°-52′ Curve
(nearly)
Radius of No. 6 Frog Turnout Curve off
Tangent = 153′-10″ = 3°-50′ Curve; then
2°-52′ + 3°-49′ = 6°-41′ which corresponds to an 85′ Radius Curve.
which will be the Radius of the
Turnout if taken off the Inside
of the Curve

FIG. 22.—Turnout off a curve.

The degree of the main curve may be found by stretching a tape or string along one of the rails and then measuring the middle ordinate. From this middle ordinate, the degree of curve can be taken by referring to the table; the degree of curve corresponding to the radius of the lead curve of the turnout can also be taken from the table.

The minimum radius, which has been adopted for curves, can likewise be taken in terms of degree of curve from the table.

If the turnout is to lead off the inside of a curve, the degrees of curve of both the main track and the proposed turnout, as computed for turning off a tangent, are added. If this does not exceed the degree of curve of the minimum radius allowed, the frog and turnout in question may be installed. Should the degree of curve exceed that corresponding to the allowable radius, it will be necessary to repeat the process with longer frogs until the combined degrees of curve fall within the limit.

If the turnout leads off the outside of the main curve, the degree of curve of both the main track and turnout track (as computed for on a tangent) is found similarly, the degree of turnout curve being subtracted from the degree of curve of the main track; the result will be the degree of curve corresponding, which can be found in terms of the radius by referring to the table. When this has been determined, the advisability of using a shorter frog can be considered. In every case, however, whether the turnout be off the straight or the inside or outside of a curve, the lead corresponding to a certain frog and switch points should be the same.

CHAPTER VII

LOCATING THE TURNOUT

When the site for either the frog or switch has been decided upon, the rest of the turnout location can be taken from a standard plan. Within certain limits it will often be found advisable to place the frog at the nearest rail joint, taking care, however, that the switch points do not also come at a rail joint.

If no standards are available the location of the point of either the frog or switch should be determined. The other point can then be moved along the rail, at all times keeping it in position until the tangent distance from the point of frog to the point of intersection of the line of frog and switch will equal the distance from the point of intersection to the heel of the switch.

Referring to Fig. 20, either the frog or switch must be shifted until the distance T equals the distance T^1. This plan is applicable, whether the frog is on a curve or a tangent.

While an experienced trackman will usually be able to lay a fair turnout under varying conditions, this cannot always be depended upon. Particularly in the case of a new trackman, some governing and easily learned rules should be given.

If it is found in laying a switch point off a curve that there will not be sufficient clearance at the heel of the switch and the adjacent rail, as may occur in turning off the inside of a curve, it is well to leave a proper distance on the lead or middle rail unspiked so that when the switch is set for either track sufficient clearance will be obtained.

The switch points are sometimes bent, to accommodate this clearance, but this expedient for light rail frequently results in having the points break after a little wear at the place where the rail bender has been applied.

LADDER TRACKS

A ladder track is one from which a number of parallel tracks branch, the frogs being located at intervals, dependent upon the centers required between tracks and the frog number used. In Fig. 23, *A* is the ladder track, and *B*, *C* and *D* are the branches.

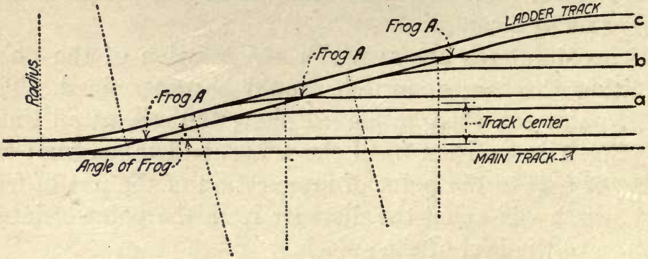


Fig. 23.—Ladder tracks.

The distance required between frog points is found by dividing the distance desired between track centers by the sine of the frog angle. The ladder track should be on an angle to the main tracks, equal to the frog angle to be used.

The ladder track makes a better and more symmetrical layout where several turnout tracks are to be laid, than having each turnout track branch off the one adjacent, the usual method used around mines.

CHAPTER VIII

BOOK OF RULES

It is obvious that in order to secure any high degree of perfection in the standardization and installation of track it will be imperative to have definite instructions and plans to govern and guide the workman in its construction.

The instructions should be concise and easily understood; the routine work should be covered fully; and the duties of the trackman, and those indirectly concerned, clearly specified. This will preclude any evasion of responsibility; and, on the other hand, by prescribing the course to be pursued under different conditions, remove to a great extent the burden of decision from the workman. This policy will help to develop more quickly young and inexperienced trackmen and tend to conserve material and time with the more efficient. Able trackmen are not produced over night, and there is a vast waste of time and many inferior layouts made before any great proficiency is acquired.

Those concerned in any way with the track installation and the preliminary work on which it is to a great extent dependent, should be furnished with copies of the rules, plans and all information in reference to them, and care taken to insure that they are thoroughly familiar with these instructions. It will be conceded that more efficient and uniform results will be obtained if such a course is pursued than if the workmen are all left to depend upon their own judgment.

The engineering department should lay out the work in a manner that will utilize the standard equipment supplied to the trackman. The curves should be of a radius to correspond to the regulation frog to be used, so that the turnout can be installed with the frog fitting the curve and requiring no compromising in its installation. To do this, a radius that will be tangent to the end of the frog that joins the curve, and at the same time conform to the portion between the switch and the frog, should be used.

The mine foreman, or his assistants, should see that their work is symmetrical and conforms to the plans. A failure on the part of either will compel a distortion of the trackwork.

The following book of rules is here given as a skeleton or model around which the many rules demanded by local conditions can be built. This plan is an adaptation of the practice of many standard-gage roads that regulate their maintenance-of-way employees with instructions governing their various duties. Some of the rules have been carried to a refinement which it is realized will be impossible to obtain in actual practice; however, they furnish a standard which experience will determine how close it is required to approach.

The underlying reason for the rules should be explained to those concerned, and meetings held at intervals where any suggestions or revisions can be discussed. This policy will instill enthusiasm and a spirit of rivalry among the trackmen, which if fostered should be productive of the most beneficial results.

It may be pertinent to state here that, to produce the most efficient transportation, careful attention must be likewise given to improving the running parts of the rolling stock, so that the results to be expected from well-installed track may not be nullified by poor cars.

There are many ways of performing almost any task. Scientific management (so-called) has shown the advantages to be derived in selecting and perfecting one method and performing in their logical sequence the various operations involved.

The considerations or formulæ which determine the following rules will be found in the preceding articles.

In conclusion I would say that even though the best practice may not be achieved in the first set of rules, an inferior practice well carried out will accomplish more than a good system indifferently followed.

(A) General Rules

1. The foreman of each colliery must supply copies of these rules and standards to the trackmen and repairmen; and the assistant foreman must enforce obedience to them and report to the district superintendent all violations and the action taken thereon. Every employee with duties in any way prescribed by these rules must be conversant with them.

2. The fact that any person enters or remains in the service of the company will be considered assurance of willingness to obey its rules.

3. In the event of any doubt as to the meaning of any plan, or if additional data is required, application should be made to the ——————.[1]

4. Meetings will be held at least once every 3 months by the ——————, where a review will be taken of the various

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[1] Where blanks occur in these rules they should be filled with the title of the proper official, or necessary data, in this case probably the division engineer.

rules, and suggestions for alterations, improvements or additions to the existing standards received.

5. Safety is of prime importance in the performance of any duty; every precaution must be taken to avoid accident to the workmen themselves or others.

6. Workmen are responsible for the care and condition of their tools.

7. All work must be left in a safe condition.

8. Any work that interferes with the safe passage of trips at their normal speed is an obstruction, and except in emergencies should be attempted only after working hours.

9. Material must not be piled along the sides of haulageways.

10. Only such an amount of material must be stored inside as is required for immediate use, and care must be taken to place this so as to permit free passage on the ditch side of the gangway.

11. Tools and special material must be kept under lock and key and not given out or loaned without proper authority.

(B) ROADBED

1. The roadbed on all new work, or wherever roadbed is renewed, should conform to the standard plan.

2. The drainage ditch should be driven full width and depth at the same time as the heading or tunnel, and maintained clear within 25 ft. of the face by the party driving same.

3. The ——————— will determine what material shall be used for roadbed, and see that same is adhered to. Ballast is graded as follows: (1) Broken stone, excellent. (2) Ashes, good. (3) Breaker slate, fair. (4) Coal and refuse, poor.

4. Where rock is used for ballast, it must be broken to a size that will pass through a 3-in. ring.

5. All main haulage roads should have at least 2 in. of ballast beneath the tie, wherever possible.

(C) TIES

1. Ties must be laid 16 to a 30-ft. rail and 18 to a 33-ft. rail. They must be placed at right angles to the rail and properly and evenly spaced.

2. Whether or not ties are of uniform lengths, the ends of the ties on the ditch side of the track should be aligned at an even distance from the rail.

3. Selected ties should be used on all main haulageways.

4. The standard square ties in graded lengths, conforming with both the turnout and main tracks, should be used at all turnouts and switches.

5. Joint ties should be selected and be as near the same size as possible.

6. When a spike is drawn from a tie, the hole should be plugged before a spike is again driven in this tie.

7. As ties become unfit for service, they should be removed in the manner known as "spotting" and not in continuous sections.

8. Ties removed that cannot be used for any other purpose should be loaded and taken out of the mine at once.

9. All ties must be well tamped and particular attention given to tamping under the rail.

10. On account of drainage and tamping considerations, the practice known as corduroying—that is, inserting new ties between those partially rotted without removing the rotten ties—must not be employed except in cases where mule haulage only is in service.

11. Steel ties alone should only be used in locations where the roof is low and no acid water abounds.

12. Where fishplates are used, a selected tie should be placed directly under the rail joint.

13. Where angle bars are employed, the rail joint should be suspended with a selected tie under the angle bar on each side of the joint so as to give the angle bar a good and sufficient bearing.

14. Ties not up to specifications should not be laid until the foreman's attention has been called to them and his instructions received.

15. Tie Specifications:

(*a*) Mine ties,—ft. long, must be first-class sound timber and stock well manufactured, not less than — nor over — in. thick, with not less than — in. faces at small end. Such ties may be of either oak, chestnut, hemlock, ash, soft maple, ironwood, locust, hickory or pitch pine. They must be hewed or sawed on two parallel faces.

(*b*) Outside ties, — ft. long, must be first-class sound timber and stock well manufactured, — to — in. thick, with not less than — in. faces at small end, and be of either oak, chestnut, locust or pitch pine, and hewed or sawed on two parallel faces.

(*c*) Notched ties, — ft. long, must be not less than — in. in diameter under bark at small end, and of the same kinds of timber as (*a*) mine ties.

16. (*a*) Mine ties (*a*) should be used for general work inside. (*b*) Ties — ft. long should be used for outside work. (*c*) Notched ties may be used only for chamber work where wood rail is in service.

(D) RAIL AND SPIKES

1. Rails must be laid with broken joints; that is, the joints of one line should be as nearly opposite as is practicable the centers of the rails on the opposite line.

2. Short rails are only advisable for temporary work. No rail under 10 ft. in length is permitted on main-haulage roads.

3. Rails must be spiked in full and each spike driven home perpendicularly with full hold on the rail. The last blow should be a light one, to avoid breaking the spike under the head.

4. The ———————— shall see that not more than enough spikes to last — days are given out at one time to any workman.

5. Spikes should be staggered; that is, the outside spikes of both rails must be toward the same side of the tie and the inside spikes toward the opposite side.

6. Rails should be laid true to gage. No deviation from this rule may be made except on curves as shown.

7. The gage on all curves whose radius is less than — ft. should be widened 1 in.

The gage on all curves whose radius is 200 ft. should be increased — in.; for 250-ft. radius, — in.; for 300-ft. radius, — in., etc.

8. On straight track both rails must be on the same level, except on approaches to curves, where the proper elevation must be given the outer rail.

9. The superelevation for the outer rail for maximum speed allowed must be:

	Gage	
	Underground, in.	On the surface, in.
For a 30-ft. radius curve.............	....	....
For a 40-ft. radius curve.............	....	....
For a 50-ft. radius curve.............	....	....
For a 60-ft. radius curve.............	....	....
For a 80-ft. radius curve.............	....	....
For a 100-ft. radius curve.............	....	....
For a 150-ft. radius curve.............	....	....
For a 200-ft. radius curve.............	....	....

10. The track level should be tested frequently and always used when surfacing track.

11. (*a*) — lb. rail shall be the lightest rail laid and be used only for buggy work. (*b*) — lb. rail shall be the lightest rail used where the regular mine cars run. (*c*) — lb. rail shall be the lightest rail used where locomotive haulage is employed. (*d*) — to — lb. rail may be used on main-haulage roads, and for heavy outside traffic by special arrangement.

12. "Dead" steel rail—that is, old rail unfit for regular haulage—shall be used wherever possible for chamber work.

13. Wood rail shall be used only for heavy pitching chambers and slants where the "dead" rail cannot be utilized.

14. Wood rail not conforming to specifications should not be used until the foreman's attention has been called to its defects and his permission to lay it obtained.

15. Specifications for wood rail: Wood rail should be first-class sound timber and stock well manufactured and sawed — by — in. and in — to — ft. lengths; it must be square edged and sound, of beech, birch, maple, oak or ash.

16. Steel rail must not be dropped from the sides of railroad cars.

17. The size of spikes should be for — ties — inches.

18. The size of spikes should be for — ties — inches.

19. The track gage must be placed square with the track, and the rail held tight against it, until the spikes are driven.

20. The locomotive engineer or driver shall report the location of any poor roadbed, and all derailments and the cause thereof to the ————————.

21. Spikes in abandoned ties or track must be reclaimed by ————————.

(E) CURVES

1. Lines will be given by the engineers for all tunnels and rock curves, and no tunnel or curve shall be started without such a line.

2. It is the duty of the mine foreman to see that all lines are rigidly adhered to.

3. A — ft. radius curve is the minimum curve allowed.

4. When curves are necessary in following the irregularities of a bed, the curve offset for a — chord should not be greater than — ft.

(F) ANGLE BARS, TIE-PLATES AND RAIL BRACES

1. All rail 25 lb. or over should be laid with joint fastenings.

2. All rail joints where mechanical haulage is in service should be laid with angle bars.

3. All joint fastenings must be applied with the full number of bolts, washers and nuts, screwed up and kept tight.

4. The ties at joint fastenings should be laid as indicated in Rules C 13 and C 14.

5. Where heavy locomotives are in service and the flange of the rail cuts the tie, requiring frequent notching, tie-plates may be used by permission of the ————————.

6. Tie-plates may be used where the traffic wears out the flange of the rail before the head has given full service, and where the rail cuts the spikes by applying to the ————————.

7. Rail braces may be used on curves where it is hard to maintain the gage by applying to the ————————.

8. Rail braces, when used, should be applied to both rails.

9. Rail braces must not be applied where tie-plates are used.

(G) FROGS AND SWITCHES

1. A No. — ———————— cast frog shall be used on all new chamber switches of — lb. rail.

2. A No. — builtup frog shall be used on all new chamber switches of — lb. rail or over.

3. A No. — ———————— frog shall be used for general use.

4. A No. — ———————— frog may be used in cases where the traffic is fast and heavy.

5. A No. — ———————— frog may be used outside by special arrangement where the locomotives are large and the traffic is unusually fast and heavy.

6. A — ft. tongue switch should be used with the cast frog.

7. A — ft. split switch should be used with the No. — and No. — builtup frogs.

8. A — ft. split switch should be used with the No. — and No. — frogs.

9. Frogs inside the mine must be placed to conform to the ribs of the curve and not the nearest rail joint.

10. The lead of a frog to be located on a curve should be the same as the number of frog adopted calls for—that is, no difference should be made in the lead whether the turnout is off a tangent or a curve.

11. When the frog is located on a curve, the sum of the degree of curve of the main track and the degree of curve corresponding to the frog should not exceed — deg. The degree of curve of the main track may be found by measuring the ordinate of a 10-ft. chord and referring to Table —, page ——. The degree of curve corresponding to the turnout radius may also be taken from the same table.

12. The rail connecting the frog and the heel of the switch should conform to the length shown on the standard layout drawings. One rail should be bent to the required radius and should be drilled, and a supply kept constantly in stock.

13. The distance from the switch to the frog must agree with the standards, so as to make the connecting rails interchangeable.

14. Where possible, the switch lever should be placed on the ditch side of the gangway, or heading.

15. Switch stands must be used at all switches where mechanical haulage is employed.

16. The switch with spring should be used at all main switches; for general use, the type without the spring must be employed.

17. The switch and spring must be kept clean and well oiled.

18. When a turnout is to be laid, a complete set of parts should be delivered to the proper location in ample time.

19. Bills of material for each turnout design used are as follows:

These bills of material to be prepared for standard turnout installations. The standards adopted, of course, will be peculiar to each mine or company.

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