the curve is so sharp or the truck so long as to render this impossible, when the rear inner wheel flange will also jam against the rail. This, however, will not happen with a 5-foot American truck on any ordinary curve. Wheels are still made with a modified coning (see chapter on track), but this is intended only to provide for future wear, as it is proven that it does not aid in passing around curves by the whole truck moving to the outside, as was formerly supposed to happen.

In passing around a curve the wheels slip in two directions, besides flange friction: (1) Longitudinal, due to the inner and outer rails being of different lengths; (2), lateral, due to a continuous sidewise movement in changing direction. This latter is confined to the front axle, as the rear one keeps radial always to the curve. The amount of these slippages are calculated, if necessary, as fol.ows: (See Fig. 5.)

(1) Longitudinal slippage $= \frac{\text{gauge}}{\text{radius}} \times$ distance travelled.

(2) Lateral slippage = sin. angle a × distance travelled for 5-foot American truck, sin. a = .00087, and lateral slip = .00087 d.

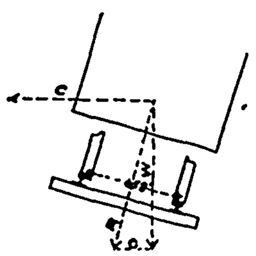

Fig. 3.

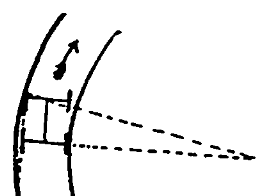

Fig. 4.

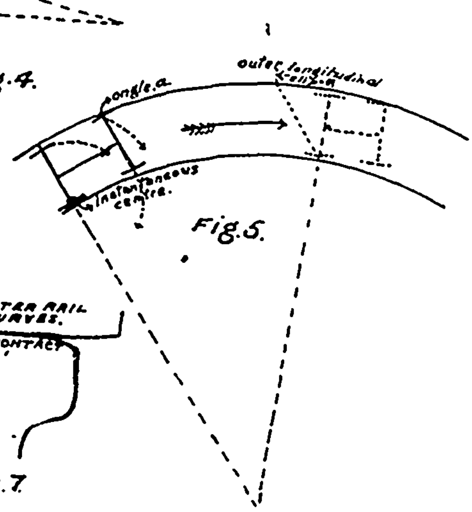

Fig. 5.

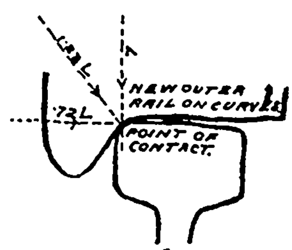

Fig. 6.

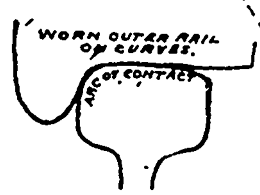

Fig. 7.

It will be seen by Fig. 5 that the truck is turning continually around the inner rear wheel as a centre, and the aggregate slippages are as follows:

(1) Rear inner wheel does not slip at all.
(2) Rear outer wheel slips longitudinally.
(3) Front inner wheel slips laterally.
(4) Front outer wheel slips laterally and longitudinally.

TABLE VIII.

	1° Curve Ft.	5° Curve. Ft.	10° Curve. Ft.	20° Curve. Ft.
Average slippage per wheel, per foot	.00073	00363	.00730	.0145
Average velocity of slippage (in feet per second), train going at 30 miles per hour	.043	.21	.43	.86
Ditto (miles per hour)	.029	.145	.29	.54

It is noticeable that the slipping is at a very low rate, being for ordinary curves and speeds only a fraction of one mile per hour, and which ever wheel starts slipping, whether inner or outer, will continue to do so around any particular curve; but this is immaterial.

Now, the coefficient of sliding friction between steel tires and steel rails under different velocities is about as follows:

0+	miles per hour	.242
7	" "	.088
13	" "	.072
34	" "	.065
52	" "	040

And as anything in the above table is nearly at zero miles per hour, we can be safe in assuming a coefficient for this slippage at from .24 to .20, with a tendency to get less as the curve gets sharper (contrary to earlier notions on curve resistances.)

In addition to these slippages we have flange friction (see Fig. 6). When the rail is new the line of pressure is nearly a point; the two forces acting on the front outer wheel are the load on the wheel and a lateral horizontal force sufficient to cause the slippages to take place, which have already been mentioned. If we take the coefficient of friction at .24, then there will be a total force of .72 ∠. This is combined with the vertical force ∠ to give a resultant force 1.23 ∠, acting as shown in Fig. 6. This causes the radius of the outer wheel at its line of bearing to be ⅛ inch to ¼ inch larger than the inner one, and a consequent slippage takes place which is constant for all curves. The amount of friction caused by this increases rapidly as the rail becomes worn and the surface of contact increases. (See Fig. 7). So that any estimate of its actual amount will be useless unless we know the exact condition of the rail head and wheel flange.

Wellington estimates it to be 1 lb. per ton for new rails, with a considerable addition as rails become worn. This will not vary with the curvature, and is to be added to the amount calculated from Table VIII., which, taking the coefficient of friction at .24, amounts to .35 lbs. per ton per degree. The results of experiments confirm the theory that the total amount varies from ½ to ⅝ lbs. per ton per degree, increasing as the condition of the rail becomes worse, and the surface of contact, for flange friction, greater. The total curve resistance does not increase quite as fast as the curvature when the rails are new, but as the rails become worn the opposite is the case; and as the rails on curves become worn more quickly the sharper the curve, it is probably safe, as an average, for ordinary use, to assume that curve resistance varies with the curvature, and equals ½ lb. per ton per degree. Referring back to grade and level tangent resistances, we see that—

6 lbs. per ton = resistance on 12° curve.
= resistance on $\frac{3}{10}$% grade.
= level tangent resistance at low speed.