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GRADE SEPARATION.

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Two bodies cannot occupy the same space. Of two intersecting lines of traffic on the same plane neither can be continuous; each must be intermittent, must stop, or change direction, while the other passes. And while each line may be naturally intermittent, may consist of detached units, if its units pass at variable and unrelated intervals, liability for two units, one on each line, to meet at the point of intersection remains unchecked. If either line is fixed in direction, as on a railway, and cannot turn aside, the danger of interference increases; and increases more if both lines are so fixed.

The fact that the only safe crossing of street or highway and railway, or of railway and railway, is in placing one above the other, and thus giving each a free and unobstructed course, is an axiom. No so-called protected crossing—a grade crossing with gates, signals, derails and other appliances, or any of them, operated by attendants, or automatically—has been found to be ultimately safe. Separation of grades has in addition to safety, the further great advantage of elimination of delay and of maintenance and operating cost.

This paper aims to give existing conditions governing the practicability of grade separation.

The physical laws for grade separation are summed up in two:

1. The structure carrying the upper line of traffic must be sufficiently high above the lower traffic way to clear all objects passing on the latter;

2. The grade on either traffic way, approaching the crossing, must be practicable for the traffic thereon.

The maximum height of loaded vehicles and any objects thereon on city streets or country highways has been accepted as 14 ft. This height is also sufficient to clear regular street railway traffic. While higher objects are moved along roads occasionally, it is properly not considered necessary to endanger the practicability of crossings under railways to accommodate them. With the railway on moderate embankment, undercrossings of roads, subways as they are called, become readily practicable. In many cases it is possible to sufficiently change the grade both of railway and road to meet requirements for a subway. Sometimes a deviation of the road, or change of location for a short distance, is practicable, and greatly simplifies the desired grade separation.

The vertical clearance, top of rail to bridge, required over railway tracks is in most cases much higher than over roads, and this constitutes, in the great majority of cases, the insurmountable obstacle to grade separation. The highest fixed projection on an ordinary railway train is the locomotive smoke stack, and passenger cars project higher than the great bulk of freight cars; but some, comparatively extremely few, special freight cars are higher than either passenger cars or locomotive stacks. The extreme clearance requirement is for height, top of rail to running board, of highest car, height of brakeman added thereto, and a further allowance for contingencies, among which may be height of load of light material on an open car exceeding maximum box car height.

There are, at the present time, on the railways of standard gauge in the United States, Canada, and Mexico,* about 2,377,282 freight cars of all kinds. They classify as to height, rail to running board, as follows:

Under 12 ft. including flat, gondola, and tank cars	63.1	per cent.
12 ft. to 13 ft.	23.4	" "
13 ft. to 13 ft. 6 in. inclusive	11.9	" "
13 ft. 6 in. to 14 ft "	0.65	" "
Over 14 ft.	0.95	" "

Of the total number of freight cars 98.4 per cent. are 13½ ft. high or under, and only 1.6 per cent. are higher than 13½ ft.; and less than one per cent. higher than 14 ft.

*Official Railway Equipment Register.

Considering main trunk lines, the Pennsylvania Railroad, Baltimore and Ohio, Erie, Lehigh Valley, Great Northern, and a number of others, *i.e.*, as far as known, with a small percentage of cars having dimensions not ascertained, among the latter the Grand Trunk and Canadian Pacific Railways, have either none or less than one-quarter of one per cent. of freight cars over 13½ ft. to running board.

The Master Car Builders' Association, whose rules and standards are adopted by railways on the North American continent generally and are recognized by the Board of Railway Commissioners for Canada, has not fixed a standard for box car dimensions, but adopted in 1904, as recommended practice, a height of 12 ft. 9 in. to eaves, equivalent to less than 13 ft. height to running board. High standard cars are such as the Grand Trunk Pacific Series 300000—310824, 13 ft. 4 in., and the Canadian Pacific new steel frame box car Series 130000—132998, 13 ft. 4¾ in. The highest regular Canadian Pacific freight cars are 13 ft. 6 in. to running board and this may be said of most of the main trunk lines of railways. The highest Pennsylvania Railroad freight cars are 13 ft. 4 in.

Limits of car dimensions are fixed by clearance outlines on the various railways. A composite clearance limit diagram for ninety railways,* including all Canadian Trunk lines, has a height of 14 ft. 6 in., limiting "over all" height of cars to this figure and practically limiting height of top of running board of freight cars to 14 ft. In the St. Clair tunnel, Grand Trunk Railway, the clearance height at width of 3 ft. is 14 ft. It is true that on many divisions or branches of the lines considered, the clearance is somewhat greater than shown in the composite diagram referred to, while on the other hand, it is less on a number of main lines, and on many branch lines.

An empty freight car 14 ft. high will on 5 ft. (out to out of rails) transverse base not resist a 30 lb. wind pressure when standing alone.

The limit of grade, approaching crossings, can for railways be taken as between 0.5 of one per cent. and 1 per cent. For city streets a grade of 5 per cent. is in most cases extreme and it should be so for main country highways. A preferable maximum grade for roads is 4 per cent., and 3 per cent. is materially better. This works out as follows:

Five per cent. grade 20x2=40 ft. length of approaches for every vertical foot of clearance.

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*Railroad Age Gazette.

Four per cent. grade 25x2=50 ft. length of approaches for every vertical foot of clearance.

Three per cent. grade 33 ft. 4 in. x 2=66 ft. 8 in. length of approaches for every vertical foot of clearance.

Any gain, by curtailment of vertical clearance requirement, or by change of railway grade, or by both, means corresponding shortening of road approaches, at the high ends. Such a gain of one foot may greatly reduce the cost of a given grade separation, making it practicable when it would not otherwise be so. A vertical gain of two feet would mean a very large addition to the number of practicable grade separations.

The extreme allowance that should be made for brakemen on a car must not exceed 7 ft. 6 ft. 6 in. will clear any brakeman unless he should be over 6 ft. tall, and 6 ft. brakemen are not common, to say the least. What is to be said for the contention, seriously made, that the brakeman on the running board of highest known car, should be allowed room to swing his lantern over his head ? The necessity for brakemen on the tops of cars is becoming less and less, and has in many cases disappeared, rules and regulations of railway companies to the contrary notwithstanding. The air brake is now universally used in train control. In Canada the orders of the Board of Railway Commissioners, in force since December 1908, provide that no regular freight train shall be allowed to proceed on its journey unless at least three-quarters of the cars comprising it are equipped with air brakes in good working order; also that every freight car built shall be equipped with air brakes and with operating levers on both sides of the end.

A stage is reached in the traffic of railways when grade crossings become intolerable, and when the risk and interruption due to them becomes more expensive than their elimination. In Europe, grade crossings, in any considerable centres of population are the exception, and this may soon be said also of main trunk line railways in the older parts of the United States. The Pennsylvania Railroad makes it a rule to avoid all grade crossings on new work, and has within the last nine or ten years eliminated over 50 per cent. of all its grade crossings on main lines. To do this clearance must be made as low as possible. Overhead bridges are as low as 16 ft. 6 in. above top of rail, while many are 18 ft. 6 in. and less. Twenty-one ft., the standard for signal bridges, is recognized as the highest clearance for which there can be any need. In New York State many overhead bridges are only 18 ft. above the top of rail, and this is the case also in Massachusetts and in other States. The New York Central and Hudson River

Railroad has asked for 16 ft. or 16½ ft. clearance for all overhead bridges within the electric zone, extending 16 miles from the Grand Central Station, in the City of New York.

Electric traction within limits for such large centres of traffic as Montreal and Toronto, with hydro-electric energy, abundant or soon to be, is easily within the range of probability in the not distant future. Smoke abatement alone points in this direction. The vexed question of grade separation would at once assume an entirely different aspect if these conditions were accompanied by a cutting down of the vertical clearance requirement to 17 feet, or even to 18 feet.

It is submitted that with conditions as they are and more so with regard to the future, 20 ft. (13½ ft. for car and 6½ ft. for man), is a reasonable vertical clearance. It has been shown that 13½ ft. covers the height to running board of all but a very small percentage of freight cars now in use, and that cars higher than 14 ft. to running board, *i.e.*, higher than 14 ft. 6 in. "over all," or to top of brake rod, can only to a limited extent traverse beyond their home railways. That higher cars will be economical or practicable is as little probable as that the gauge of railways will be widened or their entire structure changed. For a vertical clearance requirement greater than 21 ft. (14 ft. plus 7 ft.), there can, in any event, be no conceivable rational need.

In the United States there is no federal law fixing vertical clearance for bridges over railways. A number of States deal with the question. In Massachusetts there is a special Grade Crossing Commission. The minimum clearance required by this Commission is in general 18 ft. Connecticut and Rhode Island also specify 18 ft. In New York the Public Service Commission has charge of grade crossing regulations. While this Commission requires 21 ft. clearance where practicable, many lower bridges are built throughout the State, some, as already stated, are as low as 16½ ft. New Hampshire, Ohio, and Indiana require 21 ft. The only States requiring more are Illinois and Vermont, where 22 ft. is specified, but exception is made where this height is not practicable. In all other States there is no statute or regulation, as far as has been ascertained, and heights of overhead bridges vary from 16 or 18 ft. to 22 ft.

In Canada the Dominion Railway Act of 1904 specifies a minimum clearance of 22 ft. 6 in. above rail top for bridges over railways, with no deviation except by leave of the Board of Railway Commissioners; and this board has hitherto not allowed a deviation in any case.