is four times as great on a 5% as on a level ground, and nine times as severe on a 10% as on level grade. Thus if no other factors were to be considered on earth roads alone the cost of upkeep in a very few years would justify the elimination of bad grades;

(10) The condition of the right-of-way and the possible chances for disposition of water and drainage are factors of much importance when considering the maximum grade, because on steeper grades the increasing velocity demands more drainage and greater skill in handling the water, which, if kept on or near the road, will soon destroy it;

(11) The consideration of a grade from the ascension is not the only angle of approach in the location of highway grades because important items enter into the descending grade that should be given as much, if not more, consideration than the ascending direction;

(12) A grade should not be steeper than a horse can descend safely in a trot;

(13) A grade should not be steeper than a team can safely descend with a load that it can handle for ten hours under normal conditions, exerting its normal tractive force;

(14) The amount of time necessary to descend a grade should be considered, making due allowance for the maximum speed that can safely be used on that grade;

(15) The highway engineer of to-day must remember that as time passes the motor traffic requirements of the public highway will be more and more exacting. Experiments as to gasoline consumption and its efficiency on difficult grades and materials are now being conducted near Uniontown, Pennsylvania, by Mr. R. O. Gill, Experimental Engineer for the Chalmers Motor Company of Detroit, Mich. In this connection we have but little data. Some recent experiments made by Mr. H. Kerr Thomas and Mr. D. Ferguson, of Buffalo, N.Y., for the Pierce-Arrow Motor Company, show that the class and kind of surface exert more influence upon the motor-driven truck than the percentage of grade and that it requires practically the same tractive force on a 1% grade in sand and loose stone to handle the same load as it does on a 27% grade on concrete, asphalt, new brick and first-class macadam. But observations lead to the conclusion that grades of any length exceeding 5 or 6% are not as satisfactory and as economical as lighter grades for motor traffic owing to the increased hazard, increased consumption of gasoline, and loss of power due to the resistance to gravity. Observation further concludes that in frozen or icy weather motor traffic is extremely hazardous on grades exceeding 10%, and entirely unsafe on grades exceeding 16%;

(16) Grades crossing a summit should merge into each other by some form of vertical curve. The writer has been accustomed to using the following formula which proves satisfactory and practicable. Take the summit grade at *e* and a grade point 100 feet on each side or any other desirable distance and by use of either one of the following formulas find the elevation at *f*, which will be half-way between *e* and *g*, then by use of the formula find the offset from the tangent at each of the ordinates. This subtracted from the elevation of the ordinate will give the true elevation of the grade.

By reference to Gillespie, whose work contains about all we have upon tractive power of a horse, which embraces the experiments of Sir John McNeil, Sir Henry Parnell, and Mr. Cayffier, some of whose works are quoted by nearly every writer, we find that a horse traveling at the rate of 2½ miles per hour can exert 10% of his weight, and traveling at the rate of 4 miles per hour, can exert 6% of his weight. These observations prior to 1850 and just before the advent of the steam road into our field of engineering embrace about all the experiments we have, excepting the work of Mr. E. B. McCormick, of Kansas State Agricultural College, and the works of Prof. J. H. Waters, of the University of Missouri, and other work by Mr. McCormick is now being done for the Office of Public Roads, at Washington. The writer's personal observations have shown that a horse for a limited period can exert ¼, and sometimes even greater percentage of his weight, this depending in a measure upon the kind of shoes on the horse and the foothold on the grade. A horse on a road material that offers safe footing can be safely trotted down a 5% grade, but cannot be trotted down this heavy a grade for any great length of time without injury by "jamming" or "stoving" him up. Therefore, the ruling grade should not exceed 5%, if for a horse-drawn vehicle over which speed must be made on the descending grade, because the average horse in walking down a grade will not make over 4 miles per hour, while he will trot 12 miles per hour; thus, from this standpoint, we can double the distance of the road and increase the time 33⅓%. The speed of 12 miles

Picking, 5c.; Plowing, 2c.; Steam Plowing, 1.5c. per cu. yd. Hauling by wagon, approximately 35c. per cu. yd. Hauling by trucks and tram, 14c. per cu. yd.

Comparative cost per cubic yard for moving earth with

Distances hauled, feet.	Wheel-barrow.	Drag or slide scraper.	No. 1 wheel scraper.	No. 2 wheel scraper.	1-horse cart.	Wagon.	Tractor and trucks.	Grader.	Casting over bank.
100	$0.057	$0.090	$0.100	$0.100	$0.056	$0.095	$0.080	$0.022	
200	0.114	0.135	0.130	0.125	0.068	0.103	0.080		
300	0.170	0.180	0.160	0.150	0.080	0.111	0.080		
400	0.230	0.225	0.190	0.175	0.090	0.119	0.080		
500	0.285	0.270	0.220	0.200	0.101	0.127	0.080		
600	0.342	0.315	0.250	0.225	0.112	0.135	0.080		
800	0.457	0.405	0.310	0.275	0.135	0.151	0.080		
1000	0.570	0.495	0.370	0.325	0.160	0.167	0.090		
1500	0.857	0.720	0.520	0.450	0.214	0.207	0.090		
2000	1.143	0.945	0.670	0.575	0.271	0.247	0.100		
3000	1.713	1.395	0.970	0.825	0.388	0.327	0.100		
4000	2.286	1.845	1.270	1.075	0.500	0.407	0.100		
				Loading by Hand.					
	$.050	$0.010	$0.010	$0.010	$0.130	$0.130			$0.100
				Loading by Steam Shovel.					
					$0.060	$0.060			$0.060