SURVEY OF DOWNHILL SPEEDS OF TRUCKS ON MOUNTAIN GRADES

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SYNOPSIS

This report represents a study of the downhill operational speeds of heavily loaded trucks on mountain grades encountered on the highways in Arizona during 1949 and 1950. The object of the survey was to provide basic data to determine just how fast a heavy truck traveled down various rates of grades and what peculiar travel habits were associated with these commercial vehicles. Preliminary study discloses that trucks need little specific consideration on downgrades and generally assume speed characteristics commonly associated with passenger vehicles. Seven typical field locations on transcontinental routes were analyzed with mountain grades ranging from +2 to over +6 per cent. Elevations varied from sea level to 7200 ft. while traffic varied from 1000 to 3000 vehicles per day.

The truck under observation was followed down the mountain grade until a normal operational speed was reached outside of each survey area. Observers in the survey vehicle recorded the speed of the truck with a calibrated speedometer and noted changes in speed in connection with identifying stations on the highway. The various motor horsepowers were determined by observation of the make and type of the truck and by cross reference to the extensive file assembled during the uphill phase of the work. Gross vehicle weights were estimated from observation of the arch of the springs under the load.

Altitude had no apparent effect on downgrade truck speeds. Sight distance was found to be probably the most important factor. Downgrade speeds were higher when a good view of the road and the traffic ahead were available. Some rain was encountered during the survey, however, neither rain nor the resultant wet pavement seemed to cause any appreciable speed variation from average speeds when clear and dry.

Results of this study gave no correlation between downhill truck speeds and either gross vehicle weight or pounds per brake horsepower ratios. There was no evidence found that would associate a particular downhill speed with the percentage of down-grade. Except under congested traffic conditions it may be said that downhill truck speeds are largely controlled by the mental attitude of the driver. This is very much in contrast to uphill speeds which are determined by the hill climbing ability of the truck.

Indicated speeds of up to 74 mph. were encountered during this study. It was found that most trucks move as fast or faster than ordinary passenger cars under the same downhill conditions. No appreciable congestion was caused by downhill speeds of trucks and, at this phase of the project, there appears to be no justification for truck lanes or passing areas on down-grades.

This report represents a study of the downhill operational speeds of heavily loaded trucks on mountain grades as actually encountered on the highways in Arizona during 1949 and 1950. It is believed that the data collected will be of material benefits to highway locating and design engineers, the U. S. Bureau of Public Roads, and to truck manufacturers and operators.

The object of the survey was to provide basic data to determine just how fast a heavy truck traveled down various rates of grades and what peculiar travel habits were associated with these commercial vehicles. It was hoped to determine, from factual data, if there was any degree of correlation between such items as truck weights; percent of downgrade; truck speeds; length of hill; sight distance; mental attitude of the vehicle operator, etc. From these data will come indications as to whether downhill truck lanes, or passing bays, are necessary and, if so, how they can be incorporated in engineering design and planning. Preliminary study discloses that trucks need little special consideration on downgrades and generally assume speed characteristics commonly associated with passenger vehicles.

When this truck speed performance program was started almost four years ago there were three phases to the project. The first was to determine the operational speed characteristics of heavily loaded trucks on upgrades. The second, which is the report presented herewith, had to do with the downhill speeds of trucks and the third will analyze the congestion caused by slow moving vehicles on uphill grades. The uphill speed study for trucks on mountain grades was reported to the Highway Research Board at its 29th Annual Meeting in Washington, D. C. in December of 1949. In that study a composite chart was prepared showing the deceleration rate of speed for various percentages of grades coupled with the distance traveled up the grade. This information has been very valuable to our own highway department as well as to many other states in highway location work in determining when uphill truck lanes become necessary. The third phase of the work is now underway and from it an attempt will be made to show that the congestion caused on certain lengths of various grades with certain traffic volumes, when eliminated, will result in sufficient saving to the motorist to pay for the cost of an uphill truck lane or as an aid, in the construction of passing bays at critical points.

For the survey of downhill speeds of trucks on mountain grades, seven typical field locations were chosen to cover grades from 2 to over 6 percent. These sites were in general on transcontinental routes such as U. S. 60; U. S. 66; U. S. 70; U. S. 80; U. S. 89 and were at elevations ranging from a few hundred feet to seven thousand feet. The volume of traffic varied from less than a thousand, upward to about 3,000 vehicles per day with approximately 22 percent of the total consisting of trucks. Only trucks of a capacity of 1½ tons or greater were considered in this project. The highway in all cases was of the two lane type. The individual sections had roadway widths ranging from 40 to 22 ft. with 12- to 10-ft. traffic lanes. A number of gross vehicle weights of 80,000 lb. were noted during the course of the field work and one 3-3 tanker with a gross weight of over 90,000 lb. was found. The locations included in this study were the same ones used in the uphill survey and ten different directional sections were reported upon. The direction of traffic was the reverse to that observed during the uphill project.

Each truck under observation was followed at a safe distance down the mountain grade until a normal operational speed was reached outside of the survey area. Two observers in the survey vehicle recorded the speed of the truck with a calibrated speedometer and noted changes in speed in connection with identifying stations on the highway. The subject vehicles were not stopped nor weighed. The various motor horsepowers were determined by observation of the make and type of the truck and by cross reference to the extensive file assembled during the uphill phase of the work. Gross vehicle weights were estimated from observation of the arch of the springs under the load. Two of the key personnel employed on the uphill survey, where the trucks were weighed, also conducted the downhill survey and were thoroughly familiar with all makes and weights of trucks. It is felt that the gross vehicle weight estimates were on the conservative side.

Speed and time observations were recorded during the survey, for each truck at 0.1- and 0.2-mi. intervals. This corresponds roughly to 500 and 1000 ft. respectively. As the survey progressed, additional recording points were sometimes added if several of the observed trucks showed decided speed changes at any common point on the highway other than at the regular time and distance intervals. In order to obtain accurate data an unmarked state automobile with ordinary passenger car license plates was used. This was done so that the truck driver would not alter his usual driving habits for fear of being followed and perhaps arrested by a State Highway Patrol Officer.

Prior to starting the first observations, the survey car, a 1947 Chevrolet sedan equipped with safety type tubes was driven over the speedometer test section near Phoenix on U. S. 60-70-89. This section of highway was accurately chained, with temperature corrections applied, and marked by signs at one-mile intervals on a nearly level gradient for a distance of ten miles. Stop watch timed test runs were made from 20 to 70 mph. in five-mile increments. This operation was repeated after completing the field survey and average tables of corrections were prepared and used on all computations and charts appearing in the final report. The speedometer readings were found to vary from 3 to 12 percent above the actual time distance rate. The speed rates in this report are therefore less than generally observed by most motorists on the highway. The odometer readings were found to vary from $1\frac{1}{2}$ to $2\frac{1}{2}$ percent from the measured distance and an average 2 percent correction factor was applied in the analysis.

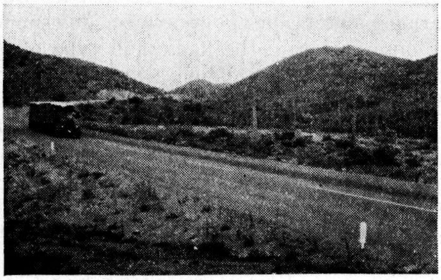

Figure 1. Unladen 2-S-1-2 Diesel Powered Van Entering 2.5-Percent Grade from 4.07-Percent Grade, Sta. 2-E, Gonzales Pass—40-Ft. Mix. Bit. Surface on 40-Ft. Roadway—1947 Construction—Average Traffic 1700 V.P.D.

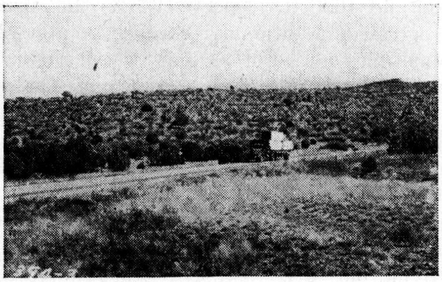

Figure. 2. Heavily Loaded 2-S-1 Lumber Truck Traveling Down Short 4-Percent Grade at Foot of Ash Fork Hill, Sta. 3—Entering 2-Mi. Tangent with Rolling Grades.

Several night studies were attempted to ascertain whether there was speed differences between day and night operations. This practice was soon given up because it was found unsafe and the type of truck and estimated weight were difficult to observe. Sufficient data were obtained, however, to show that there were no appreciable speed differences between day and night truck driving practices. Additional data were assembled relative to passing opportunities and accidents to be used in Phase 3 of the investigation.

After the basic speed data were gathered in the field, they were processed and analyzed in the office. The first chart drawn was a speed profile for each of the seven different locations. These drawings were made on standard highway plan and profile sheets where the alignment is shown above and the highway profile is shown below. The speed profiles were shown in two different ways. The first was by a high, medium and low speed group arrangement and the second was by an A, B, C, D grouping having to do with gross vehicle weight; brake horsepower and average pounds per brake horsepower. Group A went to 199 pounds per brake horsepower; group B from 200 to 299; group C from 300 to 399 and group D over 400 pounds per brake horsepower. Information about the age of the highway section, the roadway width and pavement width was shown on the drawing for each section. The percentage of each change in grade was shown and was identified with the usual highway station arrangement for showing horizontal distances. These many sheets were studied individually and collectively with a search being made for something that would correlate the speed downgrade with the percentage of grade. This endeavor was unsuccessful and the analysis gave no means of identifying any downhill speed with either gross vehicle weight or pounds per brake horsepower. Neither was any evidence found that would associate a particular downhill speed with the percentage of downgrade.

Speeds generally were not as high as expected, considering some very excellent alignment, weather and pavement conditions. The State Highway Patrol had been conducting a very effective statewide speed enforcement program and had issued citations of 80 to 85 mph. During the course of this study, however, an indicated speed of 74 mph. was the highest encountered. This was an actual speed of 70.6 mph. on a 6 percent downgrade. It occurred on the lower end of a 2.5-mi. hill on U. S. 66 near Flagstaff, Arizona, at an elevation of 7200 ft. The highway was constructed in 1940 with a 22-ft. surface width of portland cement concrete and a total roadway width of 38 ft. The horizontal alignment was practically straight and the sight distance was nearly up to present day standards. The truck operating at this high speed was a type 3S2 with a G.V.W. of 50–55,000 lb., powered by a 200 HP Diesel motor at approximately 250 pounds per brake horsepower. The truck was owned by a firm which operates over this section as a part of their regular route between Los Angeles and Albuquerque. About halfway down the hill the road is visible for three miles ahead and any possible congestion can be seen well in advance. This condition undoubtedly accounts for the accelerations and high speeds noted at the end of this section. The Arizona Highway Sufficiency Rating for this section for 1950 was 90 points, a very excellent highway for the 1773 vehicles per day that it carries.

It might be that the survey car trailing the subject vehicle caused some drivers to reduce their speeds and certainly the Patrol program had its effect, but, all in all, the recorded downhill speeds were not of the fantastic magnitude we had heard about before the survey began.

Study of the speed profiles for Station 1-W on U. S. 80 known as the Telegraph Pass section near Yuma, Arizona, gave some clues on downhill speed performance. This particular section had about a mile and a half of −6 percent and then went progressively to shorter sections of −2.4 percent; −3.61 percent and down to −1.45 percent. Here it was indicated that when a truck had accelerated to its probable top speed, the rate of further descending grade did not greatly influence the speed thereafter. Ensuing accelerations and decelerations then became a function of sight distance, road conditions and congestion of the visible traffic, ahead of the subject vehicle. This performance was generally found at each station and became, more or less, one of the axioms of this report. Notes were made relative to the type of braking control used and this was observed in four different categories as follows:

1. Intermittent heavy brake application in a rather high gear.
2. Continuous light or feathering application in a rather high gear.
3. Low gear and compression only, with the service brake reserved for emergency stops.
4. Neutral gear coasting with brakes applied at more or less regular intervals in a fanning manner.

The legal speed law for Arizona states that the day speed shall be reasonable and prudent while the night speed is limited to 50 mph. Speed zones are established by the Arizona Highway Commission on the recommendation of the Traffic Safety Engineer and the Engineering Division. They are usually based on inventory of the road condition plus frequent 85 percentile radar speed machine surveys, tempered by studies of the accident rate. Most open highways, however, are speed zoned for 60 mph.

From a weight standpoint the maximum allowable single axle load is 18,000 lb. while a tandem axle load may reach 32,000 lb. The total combination length is limited to 65 ft. and the maximum legal gross load for this length is 76,800 lb.

SPEED GRAPHS

Graphs A, B, C in Figure 3 are of the usual speed distribution type with speed in miles per hour shown on the horizontal axis and the percentage of trucks descending grades at or below various speeds indicated on the vertical axis. The curves themselves are the speed performances plotted for various grades from 2 to 6 percent.

Graph A shows the speed curves of all observed trucks without regard to road type or posted limits. These data are broken down in Graph B to show how trucks performed on an old 2-lane pavement 18–20 ft. wide, in a zone posted for 50 mph. Graph C shows a situation for a two lane pavement in good condition and signed for 60 mph.

The 85 percentile speeds conformed closely to the posted limits and the average speed for all combinations was in a very narrow range of about 7 mph. The lines are not only parallel but they are almost on top of each other. The graphs therefore indicate that regardless of percent of downgrade the average speeds are about the same and the distribution of speeds of all trucks on each grade follows the same pattern.

AVERAGE SPEEDS

On Charts 1 and 2 (Figure 4) the average speeds from the previous chart have been plotted in combination with speeds on a level highway for a distance of approximately one mile. Chart 1 shows an arrangement by brake horsepower grouping while Chart 2 is for the same vehicles by gross vehicle weight (g.v.w.).

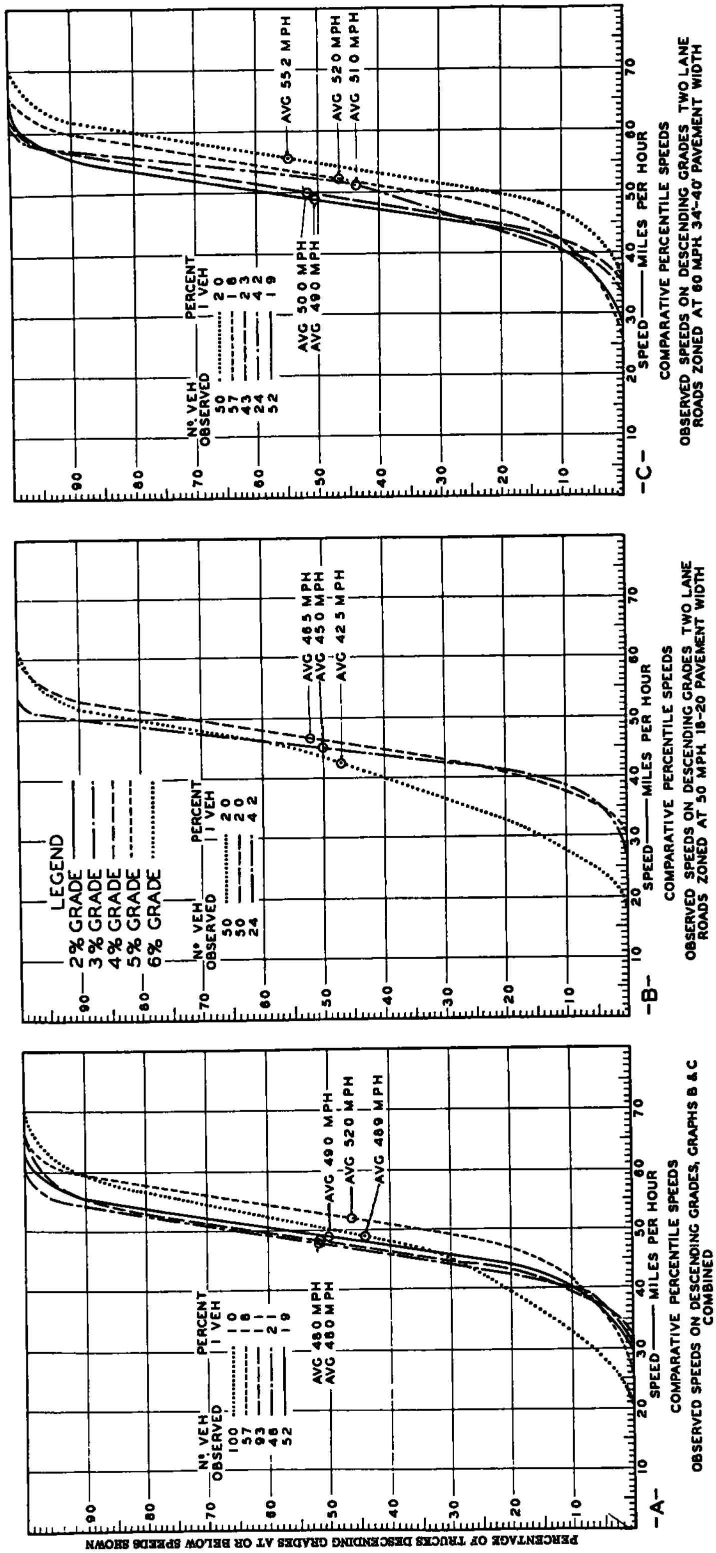
PERCENTAGE OF TRUCKS DESCENDING GRADES AT OR BELOW SPEEDS SHOWN
LEGEND
2% GRADE
3% GRADE
4% GRADE
5% GRADE
6% GRADE
Nº VEH OBSERVED
PERCENT 1 VEH
AVG 48.0 MPH
AVG 48.0 MPH
AVG 49.0 MPH
AVG 52.0 MPH
AVG 48.9 MPH
SPEED —— MILES PER HOUR
COMPARATIVE PERCENTILE SPEEDS
OBSERVED SPEEDS ON DESCENDING GRADES, GRAPHS B & C COMBINED
-A-
AVG 46.5 MPH
AVG 45.0 MPH
AVG 42.5 MPH
OBSERVED SPEEDS ON DESCENDING GRADES TWO LANE ROADS ZONED AT 50 MPH. 18-20 PAVEMENT WIDTH
-B-
AVG 50.0 MPH
AVG 49.0 MPH
AVG 55.2 MPH
AVG 52.0 MPH
AVG 51.0 MPH
OBSERVED SPEEDS ON DESCENDING GRADES TWO LANE ROADS ZONED AT 60 MPH. 34'-40' PAVEMENT WIDTH
-C-

Figure 3

It may be noted that the average speed lines are generally parallel, or even criss-cross, and that the variance from the mean is very small. In other words there was no correlation found between speed, weight, or percent of grade. The average downhill speed under conditions of modern road design for all types of trucks was estimated to be around 55 mph. for long grades. This is slightly higher than the 53 mph. determined by a study on the Pennsylvania Turnpike on a 3 percent grade; however, in the west the volume of traffic is not so great while the steep grades are longer which would indicate a somewhat higher speed. It is also higher than the 51 mph. average found during this study but our intermediate grades were too short to allow a higher speed average to be attained.

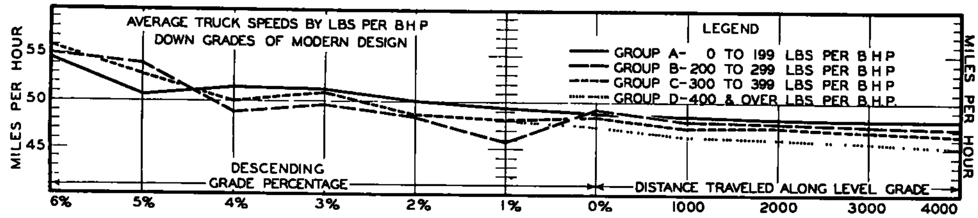

CHART 1
BRAKE HORSE POWER

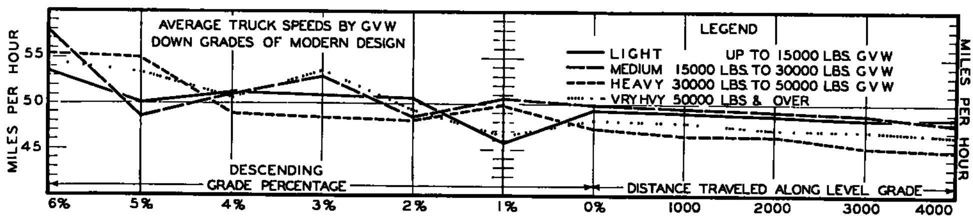

CHART 2
GROSS VEHICLE WEIGHT

Figure 4

SPEED INCREASE

Charts 3, 4, 5 (Figure 5) show the relation between speed increases and distance down the grade in feet. Chart 3 illustrates the findings on a 2 percent grade. The nearly horizontal lines show speed characteristics for various truck weight groupings together with the speed range from 500 ft. beyond the top of the hill for an additional distance of 1500 ft.

Chart 4 is the same as 3 except that it depicts a 6 percent downgrade instead of a 2 percent downgrade. Here the crossing lines indicate that there is no constant factor in the various weight groupings.

Chart 5 is on the same base as 3 and 4 and is a composite picture of increase in speeds by various rates of grades. The non-uniformity of lines and the crossing of lines shows again, in a different sort of way, that there is no correlation between truck speed, weight and grade.

An increase of about 15 mph. in 1500 ft. of downgrade was the average speed increase observed on any rate of grade and for various average entrance speeds. The greatest rate of increase was 19 mph. down 1500 ft. of a 3 percent grade 500 ft. below the summit. Therefore we conclude that from a psychological standpoint the complaint that most drivers have about following a truck down a grade is not the lack of acceleration of the truck but rather is a combination of other factors. The passenger car is too close to the truck to allow a good field of vision ahead; the passing sight distance built into the highway is too short or the driver is fearful of using the full accelerating ability of his car to make the passing movement. These factors are difficult to analyze so most mountain drivers seem to be satisfied to blame the trucks and let it go at that.

It has been said many times in scientific research that it is just as important to find out that something doesn't happen as it is to find out that it does. In the uphill performance study it was found that there was a firm relationship between the uphill speed, the weight and horsepower of the truck, and the percentage of upgrade. The findings of the downhill study, however, were just the opposite and from the charts it is evident that there was no correlation between the various known elements. No constant or identifiable variable was found in any combination of data that was tried.

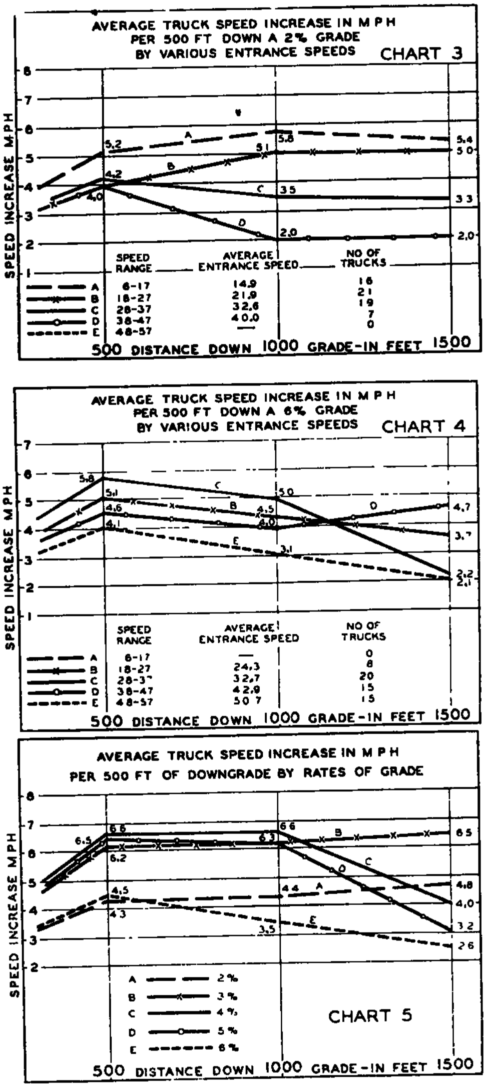

Figure 5

In summarizing the results it would be well to repeat the premise which brought about the project. The primary object of the previously published report on uphill speed characteristics was to determine the extent to which an extra uphill lane should be provided for slow moving trucks. Results of this first study definitely indicated the desirability of providing an extra uphill lane for slow moving vehicles under certain conditions of roadway and traffic. It had been evident for some time that dangerous passing maneuvers often resulted when motorists, having followed a slow moving truck up a grade, found themselves unable to pass this truck safely on the following descent. It was decided that it might be of equal importance therefore to consider what happens when the slow moving uphill truck descends the same or a similar grade.

Summarizing the highlights of the project it was found that:

1. The largest number of observations in this study were in the 50,000-lb. gross vehicle weight and medium (MS) speed class.
2. Traffic congestion on narrow 2-lane roads was an important cause of reduced truck speeds on downhill grades.
3. Modern speed design, which provides adequate sight distance, facilitates and encourages faster downgrade truck speeds.
4. Except under congested traffic conditions it may be said that downhill truck speeds are largely controlled by the mental attitude of the driver. This is in contrast to uphill speeds which are determined by the hill climbing ability of the truck.
5. Altitude did not seem to affect speeds of trucks on downhill grades.
6. Results of this study gave no indication of any correlation between downhill truck speeds and either gross vehicle weight or pounds per brake horsepower ratios.
7. There was no indication of any correlation between downhill truck speeds and percentages of downgrade.
8. The small amount of rain encountered during this study did not cause any appreciable speed reduction of trucks on downgrades.

9. In the previously published study on uphill speeds, the truck crawl speeds could be easily ascertained since the gradients imposed limits which the trucks could not exceed. However, in this downhill study, the speeds encountered were apparently those which the individual driver considered proper.

10. It was found that acceleration rates of trucks on downhill grades seldom approach the maximum acceleration inherent in a truck.

11. The average truck speeds on downgrades and level road are nearly the same and are approximately equal to the national average speed of free moving vehicles traveling level 2-lane roads of modern design. No appreciable delay was caused the average passenger vehicle following the truck.

12. If a separate lane for passing trucks on the upgrade is provided when necessary, the problem should be solved, since speeds observed in this study indicated no justification for an extra lane for trucks on downgrades. The exception to this is the idea that it might be well to continue the uphill truck lane over the crest of the hill to a point where the truck reaches a speed of say 50 mph. From data collected in this report the distance required to do this is roughly 0.4 mi. beyond the summit.

ACKNOWLEDGEMENT

Photographs were taken by Mr. Norman G. Wallace, Chief Locating Engineer, Arizona Highway Department, Mr. John M. Nutter and Mr. H. D. Sines of the Arizona Highway Department and Mr. Eddie Deuel, Photographer, Phoenix, Arizona. Mr. J. W. Dewey was project chief in charge of field operations.

REFERENCES

There seems to be almost no published material on this type of a study. However, considerable use was made of the following works during the period of processing the field data.

Highway Research Board
  Highway Capacity Manual 1950
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Commercial Car Journal, Chilton Co., Inc., Philadelphia 39, Pa.

SPEEDS ON RURAL HIGHWAYS, PAST AND PRESENT

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SYNOPSIS

Of the many respects in which automotive vehicles have been improved in the past 50 years, none has affected our lives so profoundly as the tremendous increase in speeds. The record for the fastest mile has risen from 39 mph. in 1898 to 394 mph. at the present time, while even the cheapest of the standard American cars can now be driven faster than 80 mph.

The speeds at which people drive on the highways are important for at least three reasons: (1) speed is what makes automobiles useful, and anything which reduces actual driving speeds takes away a part of their usefulness; (2) speeds are related to accidents, making it essential that safety officials pay attention to speed trends: (3) driving speeds are important to the designers of new highways, whose job it is to satisfy the desires of most drivers without going to unnecessary expense.

Continuous records of speed trends before World War II are scarce. A number of states made "one-shot" speed surveys of a fairly intensive character during the depression years of the 1930's, but these studies were not repeated in a way which would have permitted year-to-year comparisons. It was only in 1942, with the restrictions on gasoline and rubber, that the states began to make continuing large-scale speed studies.

The earliest usable speed-trend information comes from Rhode Island, where the average speed showed a steady increase from 22 mph. in 1925 to 34 mph. in in 1934. A second state where pre-1940 figures can be used is New York, in which seven of the locations studied intensively by the Bureau of Public Roads in 1935 were restudied in 1950. The results show a slight drop in the average speed,