speeds". The former gives an integrated acceleration-pattern recording. The apparatus is portable and stable in operation and has shown consistency in performance. It would appear that there are several uses for this equipment in the field of traffic research. The apparatus has been used to record acceleration patterns of motorists when approaching narrow bridges, curves, stop signs, speed zone signs, and vehicle performance on hills. It has been used as an economical and accurate means to measure "spot speeds". Many other driver reactions could be studied.

THE USE OF SPEED-RECORDEE EQUIPMENT

Robert E. Frost,
Research Assistant, Joint Highway Research Project,
Purdue University

The Photo-Velaxometer is designed to measure and record small time intervals and sequences of small time intervals so as to give an acceleration pattern of a moving vehicle as it progresses through a measured distance.

The immediate application of this instrument to highway engineering is its use in studying the following types of traffic problems:

1. To find the maximum, minimum, and average speeds of vehicles at any location on the open highway for speed-limit determinations.
2. To make speed determinations on city streets and in semi-residential areas to discover driver obedience to speed-limit signs.
3. To record both positive and negative acceleration of vehicles approaching and leaving various highway warning signs to determine the effect of the signs on motorists.
4. To discover the effect that highway hazards have on motorists, by measuring positive and negative acceleration of vehicles approaching and leaving highway hazards, such as narrow bridges, sharp curves, steep hills, sudden dips, and highway junctions.
5. To discover differences in driving characteristics on wet, dry, and icy pavements.

These types of highway problems can be further analyzed by obtaining other pertinent data, such as state license, sex of driver, number of passengers, type of vehicle, weather, condition of pavement, and any surrounding characteristics of the location that may influence the driver's reactions.

Since the completion of the Photo-Velaxometer, five studies have been made on some of the above suggested types of traffic problems. These studies are as follows:
1. The effect of a narrow bridge on highway traffic.
2. A spot-speed study in a 50 m.p.h. speed zone on State Road 67 at Mars Hill, Indiana.
3. A speed study on State Road 67 at Valley Mills, Indiana.
4. A study of traffic speeds on State Road 100, commonly called the Municipal Airport Road, at Indianapolis.
5. Speed study on the U. S. 52 Lafayette By-Pass Hill.

An additional study is now in progress that further illustrates the uses of the Photo-Velaxometer. Its purpose is to compare vehicular speeds on wet, dry, and icy pavements.

**Speed Study on U. S. 52 Lafayette By-Pass Hill**

This paper reviews a preliminary study presenting conditions as they were during the time of the survey.

This study was made on a steep hill near the Wabash River on U. S. 52 near Lafayette, Indiana, commonly known as the Lafayette By-Pass Hill. The location studied was 2,800 feet of the By-Pass hill, extending from the west end of the Wabash River bridge to the top of the hill. The lower section consists of about 300 feet of 2\(\frac{1}{2}\) per cent grade, while the upper section has about 2,500 feet of 6 per cent grade. The magnitude of this grade is a serious factor affecting the speed of north-bound trucks. The resultant reduction in the speed of trucks presents a hazard to the other traffic on the hill. It is not an uncommon sight to see several cars trailing one or two very slowly moving trucks (Fig. 1). The shoulder near the top of the hill has been worn smooth, thus indicating that passing "on the right"
is quite frequent. In addition, many motorists disregard the yellow line and pass on the left, thus violating the law and endangering all traffic in that location.

Since the construction of the Lafayette By-Pass (about three years) there have been nine reported accidents on the hill alone (between the bridge and the top of the hill). There were 13 injuries but no fatalities. Most of these accidents were at night. In general, these accidents involved cars in passing movements.

The purpose of this study was to find the effect of the hill on traffic flow. This can be illustrated by listing several questions about this type of highway situation. They are as follows:

1. Does the presence of a steep hill affect vehicular speeds?
2. How much are truck speeds reduced?
3. What part of the hill seems to be critical to truck speeds, or where does the most gear shifting occur?
4. What is the maximum speed differential between trucks and cars, and where does it occur?
5. Is there much violation of the no-passing zone?

Since the Photo-Velaxometer can accommodate only 700 feet of roadway at a time, it was decided to divide the 2,800-foot hill into four sections and make the survey in four days. Speeds were recorded in 100-foot intervals over 700-foot speed traps, on each of the four days; each succeeding day’s speed trap started where the preceding day’s trap ended. This plan was followed in traversing the entire hill. It was believed that if enough records could be obtained, there would be little or no breaks in the average speeds at the beginning and end of two adjacent speed traps. Assuming this to be true, a complete acceleration pattern for the entire hill was plotted, showing the effect of the hill on vehicular speed (Fig. 2).

Examination of the speed chart for the entire hill (Fig. 2) shows that the presence of the hill alone does not cause any great change in the speeds of automobiles. It appears that drivers maintain a nearly constant speed throughout the entire hill, unless, of course, they are forced to a slower speed because of a truck. The average loss in speed of automobiles for the
entire hill was about six m.p.h. (from about 52 to 46 m.p.h.). This condition is changed greatly by the presence of slowly-moving trucks. Many trucks near the top of the hill are moving from five to 15 m.p.h. On the entire hill, the maximum single truck speed was 57.78 m.p.h. and the minimum, 3.57 m.p.h. The maximum single automobile speed was 80.21 and the minimum, 12.29 m.p.h.

It might be pointed out that this was not the fastest speed on the hill during the survey. One instance in particular deserves some mention. While the speed recorder was being used in the first 700 feet of the hill, a very fast car was observed coming down the hill. As the Photo-Velaxometer was in operation on the northbound or uphill lane, it was necessary to use a stop watch to obtain the speed of this car. The watch was started the instant the first road cable was crossed and stopped the instant the last road cable was crossed. The distance of 700 feet was covered in 4.5 seconds—a speed of 106 m.p.h. A little later, two more very fast cars raced down the hill, and their speeds were found to be 96 m.p.h.

The critical part of the hill for trucks seemed to be between Stations 7+00 and 11+00 (between about 600 and 1,100 feet from the bridge). This was evidenced by the fact that the speed started to drop suddenly between Stations 6+00 and 7+00. The greatest number of truck gear changes or shifts occurred between Stations 7+00 and 11+00.

The largest number of separate shifts on an observed section was 162; however, the number of probable shifts on the hill would be four times this, since only one fourth of the hill was observed each day. Of the 297 trucks seen, 256 were forced to shift gears. The record of truck shifts and their frequency

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**Fig. 3.** Frequency and location of truck "shifts" on U. S. 52 By-Pass Hill, Lafayette.
distribution by stations can best be studied by examining Figs. 3 and 4. Figure 4 shows the frequency distribution between stations, and Fig. 3 shows the actual number of shifts in any 100 feet of the hill.

It is planned to continue this study of the By-Pass on beyond the top of the hill by determining the rate of increase in speeds of trucks after they have traversed the hill and are on level highway.

Since the development of the Photo-Velaxometer, sufficient data have been obtained to show that the machine can be operated accurately, efficiently, and economically.

Fig. 4. Accumulated truck gear shifts by stations on U. S. 52 By-Pass Hill, Lafayette.

TRAFFIC STUDIES IN METROPOLITAN AREAS
William J. Mortimer,
Assistant to the Superintendent, Cook County Highway Department, Chicago, Illinois

Many traffic counts have been made in the metropolitan area of Chicago by the separate road-building agencies. They have been taken with a high degree of accuracy and have proved of great value in the design, construction, and location