Journal of Criminal Law and Criminology
Volume 30
Issue 1 *May-June*
Article 9

Summer 1939

Graphical Method for Rapidly Determining Minimum Vehicle Speeds from Skid Marks

William W. Harper

A GRAPHICAL METHOD FOR RAPIDLY DETERMINING MINIMUM VEHICLE SPEEDS FROM SKID MARKS

WILLIAM W. HARPER†

The traffic accident investigator is frequently required to arrive at a conclusion regarding the minimum speed of a vehicle immediately prior to an accident. In those cases where skid marks remain, reliable methods are available which enable such conclusions to be based upon mathematical calculations.[1] Especially in accidents of the auto-pedestrian type, where the vehicle is undamaged, these calculations can be made with reasonable accuracy. The practical circumstances, however, attending the investigation of the average case are rarely conducive to accurate mathematical treatment. Traffic snarls, bad weather, unwilling witnesses, and combative participants are a few reasons why an accident scene is not an ideal setting for engineering computations. While such computations can be deferred, it is usually desirable to know the minimum vehicle speed at the time of the preliminary investigation, in order that the case may receive the proper disposition.

The purpose of the present paper is to disclose a simple and rapid graphical method of determining vehicle speeds from skid marks. The logarithmic chart, upon which the method is based, enables any one to make such determinations without resorting to even elementary arithmetic. In order that the method will be clear to those unfamiliar with mathematical procedures, the use and application of the chart will be described after reviewing certain basic considerations. A brief account of the underlying mathematics will then be given.

---

† Physicist, Pasadena Police Department, Pasadena, California.

The writer wishes to acknowledge the helpful co-operation of Lieutenant Clarence Morris and the officers of the Traffic Accident Bureau of the Pasadena Police Department, and also the suggestions of Lieutenant Lewis Fuller of the Los Angeles Police Department regarding the manner in which the chart and related data in this paper have been arranged.

1 See Bulletin 120, Iowa Engineering Experiment Station, Iowa State College (Ames, Iowa). This bulletin contains a valuable list of references. Also see "Traffic Accident Investigators Manual" published by the Traffic Safety Institute of Northwestern University, Evanston, Illinois.

Basic Considerations

Although seemingly contrary to everyday experience, the *distance* through which a certain car will skid on a certain street is related in a definite way to the *speed* at which the car was traveling at the instant skidding began. Another way of describing this relationship between skid distance and speed is to say that for a certain car on a certain street only one skid distance can be produced at a particular speed. Thus, in a test, if the speed of a car is 20 miles per hour at the instant of applying the brakes, the car will skid a certain distance, say 17 feet. If the test is repeated at the same speed, then within the limits of error, the skid distance will again be 17 feet. If reasonable precautions are taken to see that the brakes are applied at the same speed in each of a series of tests, and assuming a street with uniform surface characteristics, it is possible to reproduce skid distances with an accuracy of plus or minus 5%.

The mathematical law which relates skid distance to speed is stated thus: *The skid distance is proportional to the square of the speed.* This means that, like the energy of a moving vehicle, the skid distance is quadrupled when the speed is doubled. Thus, if a car skids 30 feet at 30 miles per hour, it will skid 120 feet at 60 miles per hour.

With these considerations in mind, it would at first appear that the investigator of an accident could merely measure the skid mark found at the scene and then make test skids with the car until he found the speed required to lay down a skid as long as that involved in the accident. This, in fact, could be done. But again because of practical circumstances, it is both difficult and dangerous. The more desirable procedure is to make a skid test at some known low speed, such as 20 miles per hour, and note the skid distance produced. From this skid distance and the skid found at the accident, the minimum speed required to produce the accident skid can be calculated. The problem would be one in simple proportion were it not for the squares of the speeds being involved. The actual formula for the solution of the minimum vehicle speed may be written as follows:

$$\text{Minimum Speed in Accident} = \text{Test Speed} \times \sqrt{\frac{\text{Accident Skid}}{\text{Test Skid}}}$$

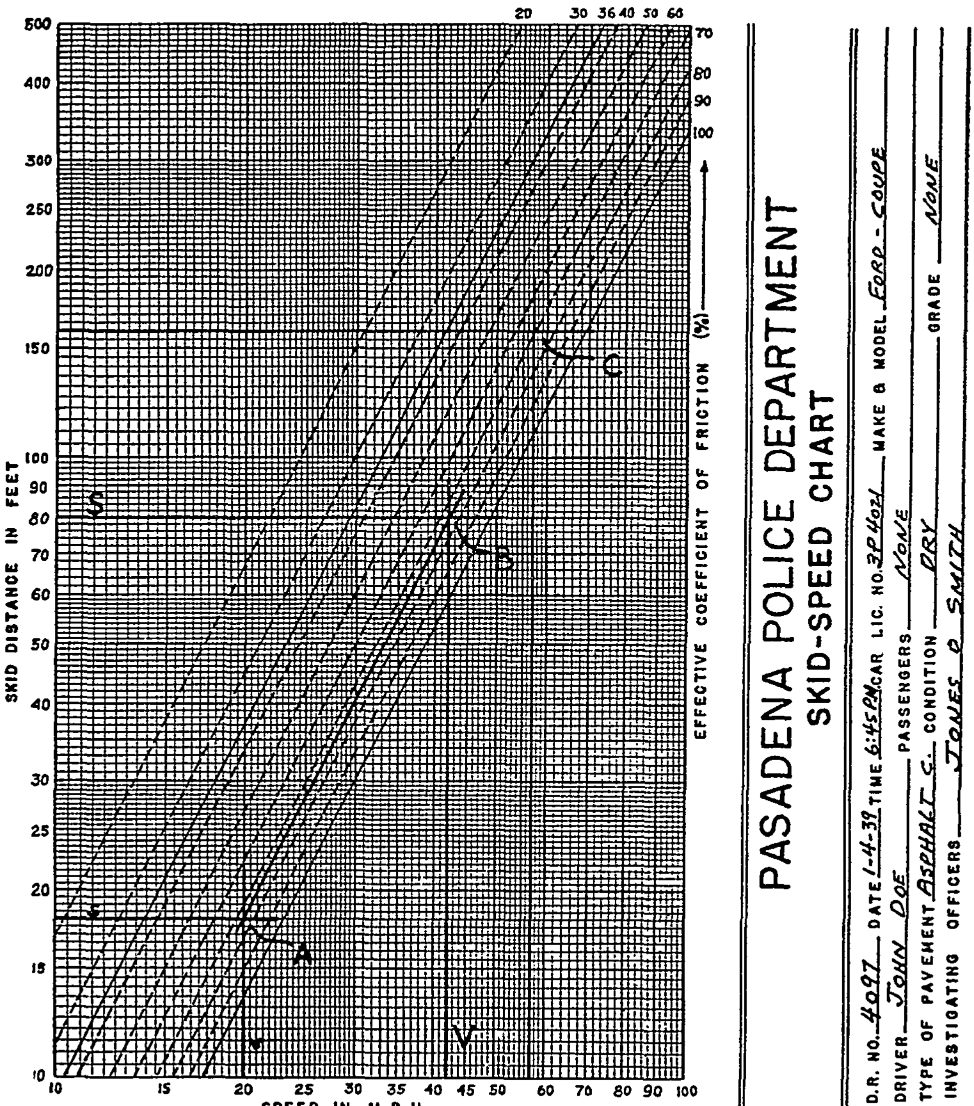
This formula may be worked out in three different fashions: (1) by long hand arithmetic, (2) by means of a slide rule, and (3) graphically, by means of a logarithmic chart. The first method is definitely unsuited to the adverse conditions under which accidents are investigated; not to mention the fact that many investigators in the police service are not adept at square root extraction. The second method, while more rapid than the first, unfortunately requires that investigators be proficient in the operation of the slide rule. The third method has none of the disadvantages of the first two and in addition has a great many advantages. The logarithmic chart eliminates the necessity of any knowledge of either arithmetic or slide rules. A problem may be solved very rapidly. Several different types of problems may be solved, non-arithmetically, by means of the chart. In addition, unlike the slide rule, a permanent record of each problem (or case) is available for later presentation in court.

The Logarithmic Chart

The use of the chart, which is shown in the accompanying illustration, will now be explained. Along the horizontal axis is a scale of vehicle speed in miles per hour, while the vertical scale represents skid distance in feet.[2] Ten diagonal lines (all but two are dotted) correspond to the various values of the over-all braking efficiency which vehicles may exhibit during a skidding stop. These lines cover braking efficiencies from 20% to 100% and the different values are indicated on the chart by the term "Effective Coefficient of Friction."

Let us apply the chart to an actual case. Assume that a car struck a pedestrian and skidded for a distance of 80 feet. The investigators wish to know the minimum speed at which the car was traveling at the time it went into the long skid. In such a case four skid tests may be performed with the car, all at 20 miles per hour and under road conditions similar to those involved in the accident itself. The skid distances obtained in these four tests are then recorded. The tests indicate that the longest skid distance obtained was 18 feet. In order that the driver of the car be given the benefit of the doubt the longest test skid is chosen as the basis for the unknown speed determination. We now proceed as follows: Draw a vertical line, **v**, from the speed scale at 20 miles per hour, and a horizontal line, s, from the skid distance at 18 feet.

[2] From 10 to 30 along the skid distance scale each division is 0.5 foot; from 30 to 60 each division is 1.0 foot; from 60 to 100 each division is 2.0 feet; from 100 to 300 each division is 5.0 feet; and from 300 to 500 each division is 10 feet. Similar values for the divisions also exist along the speed scale.



ACCIDENT SKID LENGTH 80 STRAIGHT ✓ SIDE. SPEEDOMETER CORRECTION 0

SKID TEST	M.P.H.	FEET	DRIVER	PASSENGERS
1.	20	17.0	OFFICER SMITH	NONE
2.	20	18.0	" "	"
3.	20	17.5	" "	"
4.	20	17.0	" "	"

TEST NO. 2 USED FOR COMPUTATION. MINIMUM SPEED FROM CHART 42.0 M.P.H.

REMARKS CAR WAS GOING AT LEAST 40 M.P.H AT TIME OF ACCIDENT

The symbols **v** and **s** correspond respectively to the test speed and the test skid. It will be seen that the lines we have drawn intersect at point **A**. Now a second horizontal line, **S**, corresponding to the accident skid of 80 feet is drawn from the skid distance scale. For convenience this line may be drawn until it reaches the solid diagonal line representing the 100% effective coefficient of friction. A fourth line is now drawn from the intersection **A**, parallel with the diagonal lines, until it intersects the line **S** (at point **B**). This intersection gives the answer required, for by dropping a fifth line vertically from the intersection **B** until it crosses the speed scale the minimum speed of the vehicle is indicated. This is represented by the symbol **V** and its value as determined by the chart is 42 miles per hour. The investigator, in such a case, would be justified in maintaining that the car was going at least 40 miles per hour prior to the accident.

It may be of interest to point out that in performing the skid tests we have determined the braking efficiency of the car on the street in quesion. The value of this braking efficiency is given by the location of the intersection **A** with respect to the diagonal lines. In the case shown in the chart the braking efficiency is roughly 72%. The chart thus enables one to get an approximate answer to a problem in which it is desired to determine the braking efficiency if the skid distance corresponding to a certain speed is known.

The chart is frequently helpful even in those cases where skid tests cannot be made. As an example, assume that a two-car collision has occurred on a level and dry asphaltic concrete road. One driver states that he was traveling 25 miles per hour. His car deposited skid marks from all four tires for a distance of 160 feet, leading to the point of impact. Through previous tests it is known that the minimum effective coefficient of friction for this surface (dry) with new tires is 70%. Referring to the chart, a horizontal line extending from a skid distance of 160 feet intersects the 70% effective coefficient of friction line at point **C**. This corresponds to a speed of 57 rather than 35 miles per hour. Since much of the energy of the car may have been dissipated in the impact, the investigator is justified in reaching the conclusion that the car was going at least 57 miles per hour.

Clearly, where skid tests can be made, the grade of the road can be ignored. This assumes that the skid tests are made in a region where the grade is the same as that where the accident occurred. Where skid tests cannot be made, a correction for grade can be included in the effective coefficient of friction. This correction amounts to 1.0% for each per cent of grade. The sign of the correction depends upon whether the skid has been ascending or descending; being plus where the skid is ascending and negative where descending.

Where test skids have been made at several different speeds (which may result from the inability of the driver to apply the brakes each time at, say, 20 miles per hour) it is difficult to choose by inspection that test which favors the driver. The chart enables the investigator to immediately make such a selection without computation. As an example, say that four skid tests gave the following data:

Test	Speed (M.P.H.)	Skid (Feet)	f (Approximate)
1	20	22.0	60%
2	18	21.0	50%
3	25	35.0	59%
4	20	23.0	56%

The intersection **A** for the second test may therefore be selected as the basis for a minimum speed determination, since this test most favors the driver. The longer the test skid produced for a given speed, the lower will be the minimum vehicle speed **V**.

The logarithmic chart has been arranged with proper spaces for recording pertinent data. This further facilitates its use at the accident scene as well as in court. A separate chart is used for each accident in which skidding is involved. The chart is attached to the accident report at the completion of the investigation.

It will be noted that a line is given for an effective coefficient of friction of 36%. This defines the maximum stopping distances permitted by the California Vehicle Code. In other jurisdictions this line could be changed to conform with the local code. Legal brakes in California therefore lie between the 36% and the 100% lines of the effective coefficient of friction. Braking efficiencies greater than 100% are not realized with tires and paving materials now in existence. This is perhaps a fortunate circumstance, since even with the 80% braking efficiency of many modern cars, passengers would have to wear safety belts to avoid injury during emergency stops.

Mathematical Derivation

The stopping distance (not including reaction time distance) may be derived in the following manner: In order that a moving vehicle will stop, its kinetic energy must be reduced to zero by the work done during braking, hence,

$$\frac{Wv^2}{64.4} - fWs = 0 \ldots\ldots\ldots\ldots (1)$$

Where W—weight of car in pounds
v —speed in feet per second
f —average effective coefficient of friction
s —stopping distance in feet

Solving for s,

$$s = \frac{v^2}{64.4f} \ldots\ldots\ldots\ldots\ldots\ldots (2)$$

To determine the minimum speed in an accident from a skid mark found at the scene, tests are made with the vehicle in question in order to find the maximum skid distance for a definite speed. The vehicle, after being "clocked" to determine the accuracy of the speedometer, is driven at a known low speed such as 20 miles per hour and the brakes suddenly and forcefully applied. The skid thus produced is measured and recorded. The test is made three or more times, all at the same speed. The test speed is designated as **v** and the *maximum* skid distance obtainable at this speed is designated as s. If we call the unknown minimum speed prior to the accident **V** and the skid mark involved in the accident **S**, we have

$$\frac{S}{s} = \frac{\dfrac{V^2}{64.4f}}{\dfrac{v^2}{64.4f}} \ldots\ldots\ldots\ldots\ldots (3)$$

Since the test skid is produced under identical conditions as the accident skid, f will be substantially the same in each case and may therefore be cancelled.

Solving (3) for **V** we obtain,

$$V = v\sqrt{\frac{S}{s}} \ldots\ldots\ldots (4)$$

Where **V** and **v** are in miles per hour. Equation (4) is the same as that for the "minimum speed in accident" previously given. Referring now to equation (2), it will be evident that this may be written,

$$\log s = 2 \log v - \log (64.4f) \ldots\ldots\ldots (5)$$

This is the equation of a straight line. By taking f as a parameter, we may plot on logarithmic paper a family of straight lines which show stopping distance as a function of speed for various values of f. Such a family of lines is shown in the accompanying illustration. These lines so plotted on logarithmic paper provide a computing chart upon which equation (4) may be rapidly solved as previously shown.

Conclusion

The skid-speed chart has been in use for the past several months by both the Pasadena and Los Angeles Police Departments. It has been extremely helpful to the police investigators in numerous major accident cases during this period. Because of its simplicity and the fact that no arithmetical computations are required, its use and application are easily mastered. In several major cases arrests have been made and convictions obtained largely on the information gained from the chart.

[Journal readers may obtain copies of the chart described by Mr. Harper in this article by writing to the Pasadena Police Department.]