

TRAFFIC COLLISION INVESTIGATION MANUAL FOR PATROL OFFICERS

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ACTAR #38

SECOND EDITION

Introduction

This Traffic Collision Investigation Manual for Patrol Officers is a replacement for a short pamphlet written by the author in 1985 for use at the Central Arizona Regional Law Officers Training Academy (CARLOTA). The original booklet was also used with success for in-service training of police officers.

The new and updated second edition has been expanded to include additional information on vehicle dynamics, speed calculations and equations, and diagramming methods. It is a helpful reference text to any police recruit collision investigation course. The manual is also useful as an entry level introduction to collision investigation for non-police personnel, such as attorneys and insurance investigators.

About the Author

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He is an accredited reconstructionist by the Accreditation Commission on Traffic Accident Reconstruction (ACTAR), and has testified as an expert in accident reconstruction in municipal and superior courts. Luis holds a bachelor of arts degree in management from the University of Phoenix and is currently attending graduate school (Northern Arizona University), working on a Master of Education degree.

SECOND EDITION

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Chapter 1: ANSWERING THE ASSIGNMENT CALL

An officer's responsibility to conduct a motor vehicle collision investigation begins at the time he or she is directed to the collision scene. It is at that precise moment that the officer should begin to obtain as much information as it is available from the radio operator, such as : type of collision, location, extent of injuries, traffic condition, etc¹.

PATROL VEHICLE OPERATION

Most, if not all, law enforcement agencies have in place policies and procedures that determine police response based on the seriousness of the service call. Thus response is generally classified as : routine, urgent, and emergency. In situations that require an emergency response (use of lights and siren), it is imperative that the officer drives to the scene practicing good emergency driving techniques.

Considerable time and effort is currently invested at every police academy towards the goal of producing safe and effective police drivers, yet, police files are full of cases where these safe techniques were either not utilized

¹ This type of advanced planning is useful in avoiding the tunnel vision effect so common when responding to high stress calls.

at all, or applied improperly. The results of these failures are wrecked police and civilian vehicles, painful injuries and, sadly, tragic deaths.

It is of use to no one if a responding police vehicle is itself involved in a traffic collision. A secondary (police involved) crash simply complicates the situation. Many of the collisions involving police vehicles in an emergency response mode can be prevented.

The very first steps an officer should always take during this kind of high stress response is to simply: take a deep breath, remain calm, and recognize that this is nothing out of the ordinary but, in fact, a type of call the officer has been trained for and is quite capable of handling. Self-relaxation techniques, such as deep breathing, are effective and will help any officer when dealing with stressful calls, not just collisions.

The subject of what should be an appropriate driving speed when enroute to an collision is controversial, and difficult to define. Some law enforcement agencies establish strict guidelines on speed limits, others leave that decision up to each individual officer. It would be difficult and purely arbitrary to establish absolute speed limits within the context of this discussion, without consideration to various factors: individual driving skills, equipment, terrain and weather conditions and highway

design. What can be stated without hesitation is that each officer must consider each one of these factors before deciding what a safe speed will be for that particular emergency run.

One of the factors mentioned above is really only known to each officer, that of individual driving skill, and only he/she can decide when those skills are being tasked to their limit. Unfortunately a large part of the "police myth", like the belief that "cops are the best shooters", is the notion that "all cops are Mario Andretti" and can perform driving maneuvers beyond the capabilities of mere mortals. When only civilians believe these things, no real harm is done...when police officers themselves begin to think like that, trouble is not far away.

The bottom line on the speed issue is simple: officers must (a) know the limits of their driving skills, and (b) stay within those limits. The time lost when reducing the response speed by 10 or 15 miles per hour is insignificant in most cases, and can mean the difference in getting there in one piece, or not at all.

SCENE MANAGEMENT

Of course, all of the above discussion can simply be expressed in one phrase: having a plan. A professional

police officer should never fail to plan ahead and have a strategy for action when responding to any call, not just traffic collisions. Since all collision situations are different the officer must also be flexible in the advanced planning and be prepared to adjust or change tactics based on the given scenario.

Upon arriving at the collision scene a primary concern should be preventing the collision from getting worse, that is, effective scene management. Traffic channelization should be used to avoid second and third collisions. Motorists are strongly attracted to collision scenes and "gawking" is the primary cause of a great many secondary collisions.

At the early stages of the process we refer to as scene management, the officer's primary tool to control traffic and to protect those persons injured is the patrol vehicle. It should be parked on the roadway and in such a way as to provide a shield between the crashed vehicles, the injured, the officer, and traffic. Obviously the emergency overhead red-blue lights should be operating and visible to oncoming traffic.

A common mistake after arrival at the collision scene is leaving the patrol car's trunk lid opened after obtaining items from the trunk. A raised trunk lid will obstruct the overhead lights and make them invisible to approaching

traffic. Some departments have addressed this problem by installing a second set of red lights inside the vehicle's trunk lid, they come on automatically whenever the trunk lid is raised. Lacking a system like this one, the best alternative is to always remember to close the trunk lid.

Figure 1 on the preceding page shows the proper positioning of the patrol vehicle at the collision scene in order to provide the best protection to the officer and

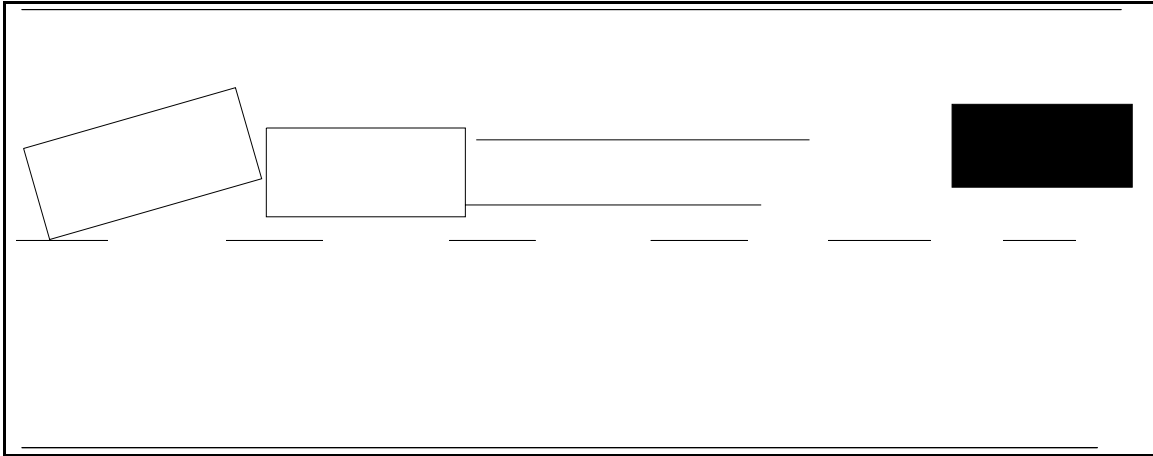


Figure 1- Recommended patrol vehicle position at the collision scene

civilians alike. The police vehicle is depicted in black, the collision vehicles are outlined in white².

Nighttime traffic collision scene management presents an added set of safety factors not present during daylight hours. Visibility is severely restricted and the large number of emergency vehicles at the scene, with overhead lights on, tend to confuse and "hypnotize" approaching drivers. This common phenomena causes the driver visual attention to "home in" on the lights, and thus fail to see other things on the roadway directly ahead (such as police officers diving out of the way). Whenever possible the officer should work while facing the oncoming traffic.

The use of reflectorized safety vests is an absolute must when working nighttime collisions, particularly if an officer's duty uniform is of the dark or black variety. If the law enforcement agency does not issue this type of vest, it is a worthwhile investment for any patrol officer to obtain one of these vests.

On minor traffic collisions (fender-benders) the officer would be well advised to quickly mark (see Chapter 4) the position of the vehicles and remove them from the roadway, restoring traffic flow and enabling the officer to continue his investigation out of harm's way.

2

In this position the police vehicle serves as a shield to protect the officer against drivers not alert, the impact noise of a collision with the patrol car would warn the officer to impending danger.

TRAFFIC CONES/FLARES

Although the patrol vehicle is the first available tool to use in traffic control, devices such as plastic orange traffic cones and flares should not be overlooked. They serve as long range channeling devices when the clearing of the roadway will not be immediate. As soon as the first responding officer has assessed the injuries involved and required medical assistance is on its way, he/she should begin to establish a traffic corridor to divert cars from the scene and avoid a traffic bottleneck at the location.

The orange cones are a useful item to carry in the cruiser's trunk for daylight use, however, their size and bulk limit the number of them that can be carried to no more than 8 to 10 average size cones. Flares, on the other hand, are compact and the average police car can carry 2 boxes with room to spare.

CAUTION- Before igniting any flares the officer must insure that no gasoline leaks or other flammable materials are present. Many tractor-trailers involved in interstate commercial transportation carry flammable and/or toxic materials, exposure to fire could be catastrophic.

When utilizing cones or flares to establish a traffic control pattern, the key thing to remember is: how does the

traffic control devices appear to an approaching motorist ?

Officers sometimes throw a few scattered flares on the roadway and expect oncoming drivers to somehow interpret a pattern and follow a proper path, where there is none. A lane closure requires the placing of flares at evenly spaced distances in a pattern that conveys a message to the motorist, mainly which direction are motorists expected to go...or not to go. This is accomplished by placing the flares lined at an angle leading away from the roadway edge, and in the direction traffic is expected to flow.

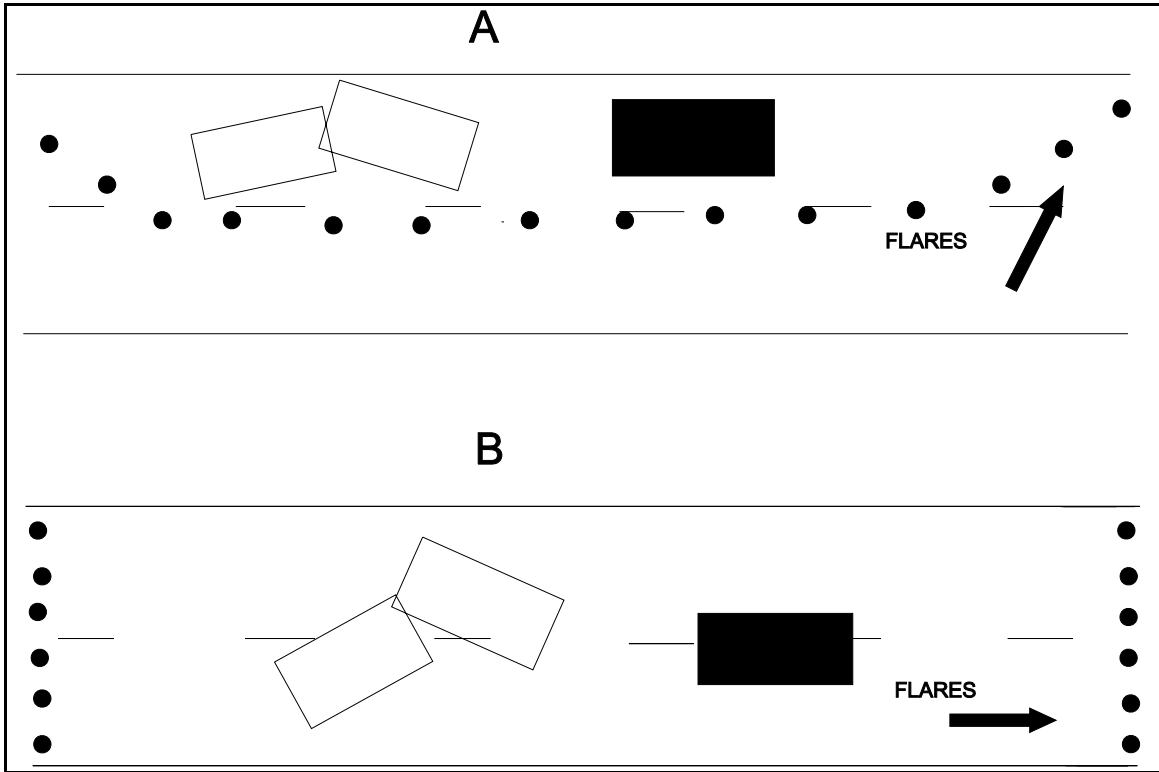


Figure 2- Suggested method to channel vehicular traffic using flares or orange cones, or to block the entire roadway

Figure 2 shows a recommended pattern to use in redirecting traffic flow (A) when the collision is confined to one lane. This will require another officer to control the flow of traffic in each direction. If the complete roadway is obstructed (B) then the officer must close the entire roadway width.

Officers must keep in mind that the distance gap between the first flare or cone positioning and the collision scene is dictated by the speed at which the majority of the traffic is traveling. Motorists must be given a reasonable

amount of time to recognize the problem and react appropriately. Table 1 shows a recommended safe distance for the proper placement of

<u>Speed Limit</u>	<u>1st Cone/Flare</u>
25 mph	68 feet
35	112
45	167
55	227
65	301

Table 1

flares or cones. A motorist should be able to stop before arriving at the collision scene, even if he/she does not see the cone/flare until arriving at the first one. This table is based on the stopping distance of an average passenger vehicle on dry asphalt and using a reaction time of 1 second. Obviously, if the roadway is wet or a driver is

fatigued or under the influence of alcohol the reaction time is going to be longer.

A distance gap of 60 to 70 feet (from first warning device to collision scene) might be adequate in a slow speed zone (25 MPH), 300 to 400 feet may be required on a major state highway or under severe weather conditions. Officers must utilize extreme caution when on a traffic way and always remain alert and facing traffic whenever possible.

If the roadway is wet or iced over, the safe distances above will not be sufficient and a traffic control point manned by an officer 1/4 to 1/2 mile ahead will be necessary. Nighttime collisions, highway curves, and hills present added safety problems during scene management and the officer must consider the visibility problems they create.

The method described above is really only applicable when the colliding vehicles are confined to one lane of traffic on a multi-lane (2 or more lanes) roadway. If the collision scene occupies the entire width of the roadway, channelization will not be effective as there is no place to channel traffic to. In such a case it would be better (and safer) to completely close the roadway to all traffic until the collision scene has been cleared.

INTERVIEWING DRIVERS AND WITNESSES

The immediate purpose of any traffic collision investigation is to obtain the relevant facts about the incident. The level of effectiveness in a criminal investigation is largely dependent upon the investigator's ability to obtain information. In an collision investigation this ability is no less critical. It is important to differentiate, at this point, interviews from interrogations. The balance of this discussion will address the process of interviewing drivers and witnesses in a traffic collision.

It does not cover the interrogation of a driver suspected of a criminal violation, i.e., driving under the influence, and the required legal and constitutional guidelines. The reader is referred to other textbooks on criminal interrogation for such information.

Upon completion of the preliminary traffic control function described above, the patrol officer's next priority is to locate the drivers of the vehicles involved in the collision. They should be located as soon as possible and identified through their driver's licenses, which should be kept by the officer until the investigation is completed. Securing driver licenses safeguards against a driver leaving the scene before the investigation is completed. As an added

method of identification each driver should be asked to point out the other.

Driver interviews must be conducted individually, with each driver given the opportunity to state what happened away from the other driver. This will prevent argumentative behavior, and it will keep the second driver from "developing" defenses while listening to the first driver. During the interview it is important to closely observe each driver for signs of alcohol or drug use, injury, or shock.

Disinterested parties (bystanders) who were not involved in the collision are generally the most effective and reliable eyewitnesses. They should be contacted as soon as possible by the investigating officer, or any other available officer. It should be remembered that bystanders are attracted to the excitement and atmosphere of the scene. Once this begins to dissipate, so will they.

Sometimes managing the scene will take all of the first responding officer's time, with little or no time left for interviewing witnesses and obtaining statements. The investigating officer may have to limit his inquiry to obtaining name and addresses only, and interview these persons at a later date. Injured drivers/passenger may have to be removed from the scene quickly. Follow up interviews may have to be conducted at the hospital or at their homes.

When interviewing witnesses an officer must be particularly careful and very specific. Questions such as: "Did you see what happened"? will only elicit vague or non responsive answers. Be specific: "Where were you standing? Where you looking at the car when it collided with the tree? Was your attention attracted by what you saw..or what you heard? Did you hear the crash first...and then looked"? A good idea when interviewing witnesses and drivers is to have them reenact what they saw, at the actual scene of the collision. If this is not possible, use pen and paper and have them draw what they saw, such as vehicle positions and movement.

Whenever possible, the use of written statements is preferred over notes taken by the officer. After obtaining written statements, the officer should read them and clarify any issues not clear. Do not overlook the value of interviews in traffic collision investigation.

NOTES

NOTES

Chapter 2: WHAT THE ROAD SHOWS

The investigation of a traffic collision, whether it is a property damage-only collision, one involving many injuries, or the dreaded fatal, is pretty much like investigating any crime. Some officers who spend hours and spare no resource to assess and process a crime scene will attempt to "speed" through an collision scene investigation, with disastrous results. Unfortunately this is not realized until six months or a year later, when issues arise concerning the investigation. It is then that a hapless, overpaid (civilian) or underpaid (police) reconstructionist is handed an incomplete report, with important roadway evidence missing, and asked: "Tell me what happened !" One of the author's career long objective and teaching goal has been to put forth a strong but simple message to police recruits: traffic collisions involving injuries/fatalities are crimes, in the strictest definition, and should always be treated as such.

Some police personnel have chosen the position that collision reports are only of benefit to attorneys and insurance companies and they are not "real police work". Nothing could be further from reality. The primary mission of any law enforcement agency worth its title is to serve and protect the public. Collision investigation and

collision reconstruction certainly fall under the "to protect" definition. If third parties gain some benefit from our investigation, incidental to our primary purpose, then so be it.

Police investigators do not normally approach a crime scene expecting the victim(s), particularly if he/she is deceased, to tell them much of anything. The traffic collision investigator should approach the collision scene in the same manner. This is not to imply that witness testimony is not important (see Chapter 1) but to underscore a point: sometimes there are no witnesses and the victims are in no position (or disposition) to provide any useful information as to what occurred.

In such a situation the evidence left on the roadway, and the officer's interpretation of said evidence, become crucial in the final determination of exactly what happened.

Roadway evidence can provide the investigating officer useful information, when located and properly interpreted. This physical evidence from a crash can be used to confirm the final resting location of each vehicle, the direction to which each vehicle faced at final rest, and the path the vehicle followed from impact to rest. Final resting locations are generally classified as controlled and uncontrolled.

Controlled final resting locations are those which a vehicle reached with direct human intervention after the initial impact. An example of this would be a driver who, after exiting his vehicle to ascertain the extent of the damage, reenters the vehicle and parks it at the edge of the curb of the road to wait for the police. This type of controlled final resting location means little to the final determination of collision angles and post-collision paths and is of little significance to an collision investigator.

An uncontrolled final rest location is that which a vehicle (or a pedestrian) reaches without direct human intervention, that is, human control is deemed to cease at the instant of collision. A pedestrian struck by a car who is vaulted a certain distance, lands and does not move again by his own volition is a good example of an uncontrolled final rest (no pun intended!) location. It is this type of positioning that is most significant to the investigator and reconstructionist in determining departure paths and post-collision velocities.

The roadway evidence helpful in determining vehicle positioning and paths consist of : tire marks, roadway scars (scrapes, gouges), debris, markings that suggest the vehicle went airborne, and markings to other objects on or near the roadway. Whenever possible, and always in collisions involving death or serious injury, photographs of all

roadway evidence should be obtained. Photographs should be taken prior to the placement of marks on the roadway (chalk or crayon).

TIRE MARKS

Tire marks and roadway evidence are extremely important in determining how vehicles moved in to the impact point, and from impact to final resting locations. In collision investigation tire marks are the equivalent of a fingerprint in a criminal investigation, and just as important.

Before we can properly analyze tire marks we must first understand how they are made and the braking mechanism involved. The majority of the passenger cars on the road today still use the standard hydraulic braking systems for their primary braking systems, and mechanically activated brakes for their parking brakes.

When brakes are applied the vehicle has a tendency to shift forward, this results in a weight transfer from the rear wheels to the front wheels. Typically, 55% - 60% of the total weight of the vehicle rests on the front wheels during braking, leaving 45% - 40% weight applied to the rear

wheels. There are complex weight-shift equations that can provide an exact percentage of weight shift for a given vehicle, however, they are a bit more complex and beyond the scope of this handbook.

When the brakes are applied, the kinetic energy of motion (as a result of the vehicle's mass times velocity) is transformed into heat by friction. If the brakes are applied strongly enough the tire itself will lock. This is sometimes referred to as 100% slip. The kinetic energy, or energy of motion, is then dissipated between the tires and the roadway surface in the form of heat.

It is this heat that dissolves, or melts, the tars and oils on the roadway surface, thus creating the distinctive dark smear we commonly refer to as a tire mark, or in this case, a skid mark. Although some small particles of tire rubber do separate from the tire itself, the skid mark is primarily composed of asphalt tar.

On concrete surfaced roads skid marks are lighter in color. They are made by the rough concrete surface actually "grounding up" the tire, or melting it. Sometimes the "squeegee" effect of the tire will actually clean the dirty road surface, resulting in a skid mark lighter in color than the surrounding surface. When a vehicle travels with its tires locked (sliding) through a soft or loose surface it

will plow through the loose material, pushing it out to the sides and ahead of the tire.

SKID MARKS

This skid mark is created by a tire that is locked, that is, sliding and not rolling. Skid marks tend to be straight, although they can exhibit some curvature due to asymmetrical braking (not all brake pads locking simultaneously) or due to the crown of the road. This can make the vehicle depart from a straight-ahead path. Front tire skid marks tend to be darker than rear tire marks (remember weight shift) and the outside edges of the mark may be darker than the inside area, due to over deflection of the tire (weight shift, again). The tire grooves are generally visible and easy to see in a skid mark. Rear tire skid marks tend to be even in appearance, that is, no dark outside edges.

Skid marks are an extremely important piece of physical evidence to the collision investigator. They can be used to determine speed (see Chapter 5) and to establish the path of the vehicle while skidding. Unfortunately, tire mark evidence has a life span. They are affected by weather, sunlight, and traffic.

Tire marks can be obscured by movement of other vehicles at the collision scene (very common on gravel roads), and destroyed by the ever present evidence eradication team, sometimes known as the fire department! Therefore, it is most important that tire marks be located, measured, and properly documented before their disappearance.

When looking for skid marks it is of extreme importance to determine the point where the skid mark begins. This beginning point of the skid mark is a relatively faint mark, as compared to the rest of the dark tire mark. During initial brake application there is a short time delay between the time the braking system/tire combination locks the wheel, and the point at which the tire heats up sufficiently to begin leaving a mark.

This faint beginning is called the skid mark *shadow*. To locate this shadow the investigator must kneel or bend down to the roadway level, 20 to 30 feet ahead of the mark, and look towards the apparent beginning of the skid mark. A second person is required to assist the investigator in marking the beginning point of the shadow with a crayon or paint.

The location and inclusion of this faint beginning of the skid mark is extremely important for future use in speed determination. Testing by the author shows that as much as

10 percent of a skid mark can be in this shadow, overlooking it can underestimate the speed of the skidding vehicle considerably.

Curved skid marks indicate that the vehicle that made them is rotating while simultaneously skidding. When this happens all four tire marks can be observed. This rotation during a skid can be initiated by the driver beginning a turning maneuver as wheels are locked in braking, the vehicle then continues in rotation.

Curved skid marks can also be indicators of unequal braking. If left side tires are braking with greater force than right side tires, the vehicle will tend to rotate counterclockwise in the direction offering the higher resistance.

Skid marks that are curved can also be indicative of a half spin, this is a rotation of the vehicle 180° from its original direction of travel. This is caused by the rear tires locking up before the front wheels. A vehicle is less stable in terms of directional control when rear tires are locked up before the front ones. Rear tires will then lose the necessary lateral forces which are essential to directional control of the vehicle. When this happens the vehicle will "switch ends."

If there is a question as to the operational status of all or any brakes, an examination of every tire should be

conducted. This will reveal the presence, or absence, of abraded areas at the road/tire interface, also known as skid patches.

SKIP SKIDS

When skid marks are not continuous but are intermittent, they may have been made by a vehicle bouncing along on the roadway. In this situation the length of the skid mark and the length of the space between them is uniform and consistent, and less than 3 to 4 feet apart. This condition can result when the wheel strikes a pothole, or bump on the roadway, which starts the vehicle bouncing.

Skip skids should be measured for total length so that the gaps are included in the finished measurement. These gaps are considered to be a part of the overall skid mark. Vehicle braking is not reduced during the skip portion of the skid by virtue of the wheels being off the ground for such short distances.

While actual braking does not occur during these short intervals when the wheel leaves the ground, heavier braking does occur when it returns back to the ground to compensate for the missing distance. This effect has a tendency to average the energy lost and results in valid speed estimations from skip skids. Skip skids, like any tire mark,

should be documented accurately as well as photographed for further evaluation of the skid mark.

GAP SKIDS

Many times skid marks are observed in which there is a gap between the termination of the skid marks on the roadway and a re-initiation of the skid mark some distance down the roadway. This is the result of the driver applying the brakes, and subsequent release and re-application. Sometime the driver may momentarily release the brakes because he/she believes that the collision conflict situation ahead, in which a collision appears imminent, has passed, only to re-apply them again when he/she realizes that the initial judgement was incorrect.

This is a typical situation in collisions with pedestrians or bicyclists, where the slower movement of the person or bicycle can change suddenly from that which the driver anticipates. Unlike skip skids above, such gaps in skid marks are not included in the overall measurement of the skid mark. Gap skids are measured separately, as if they were made by two separate vehicles. A combined speed approach is then utilized in calculating a speed. The chapter on speed calculations presents the mathematical approach for this situation.

ACCELERATION MARKS

Often, tire marks that look like skid marks are really acceleration marks. These marks are created when a vehicle is accelerated rapidly from a stopped position or when moving at a slow speed, so as to make dark tire marks. These acceleration marks closely approximate skid marks in their appearance. They begin as heavy dark marks and slowly disappear as the rotational velocity of the tire begins to approach the linear velocity of the vehicle.

One characteristic common to acceleration marks is their linearity. When rapidly accelerating a vehicle under forward maximum acceleration, some steering is necessary to maintain the path straight. This is because the torque from each wheel may not be equal at each rear tire because of road-tire interface differences³. This small difference must then be corrected by steering. This results in a curved or "wavy" appearance.

TIRE TREAD PRINT

An imprint of the tire tread pattern indicates that the wheel was rolling and not skidding. The effect thus created

³

For front wheel drive vehicles this would then be true of the front drive wheels.

is much like an ink stamp, in which the pattern of rubber is imprinted on a flat surface without smearing. The print may be the result of loose matter picked up by the tire as it rolled on the roadway.

Tire prints are different from skid marks in that they convey the tire tread pattern of the tire without any of the slick or smoothly worn features characteristic of a skid mark. In addition, the print pattern is uniform in contrast and noticeably similar to other print marks left by tires on other wheels of the same vehicle.

SCUFF MARKS

Scuff marks, also known as yaw marks or critical speed scuffs, are tire marks left on the roadway by wheels that are sliding and rolling simultaneously. The wheel is rolling and slipping sideways at the same time.

When a vehicle "spins out" or "slips out" while cornering, or is oriented in a direction different from its direction of travel, scuff marks will be deposited. Often they are in the form of light parallel grooves, referred to as striations or hash marks, which run straight but are diagonal to the outline of the continuous scuff mark. They are made by the sidewall or rib of the tire.

One of the most important bits of information one can obtain from scuff marks is that the vehicle is taking a turn at a critical cornering speed. Critical cornering speed is the speed at which the vehicle is on the threshold of spinning out or slipping laterally.

Tire scuff marks which occur under these circumstances are critical speed scuffs made by tires sliding as the vehicle traverses the curve, and are made by the outside edges of the tires. The scuff mark left by the rear tire will fall outside the scuff mark made by the front tire for that side of the vehicle tending to slip off the roadway as a result of centrifugal force.

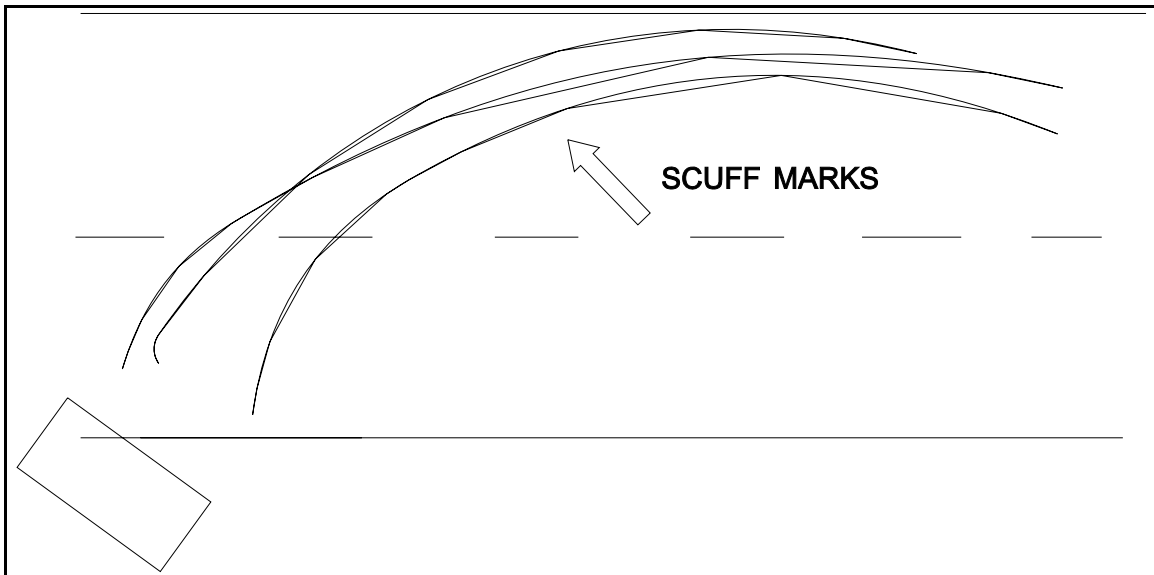


Figure 3- Typical curved scuff mark appearance

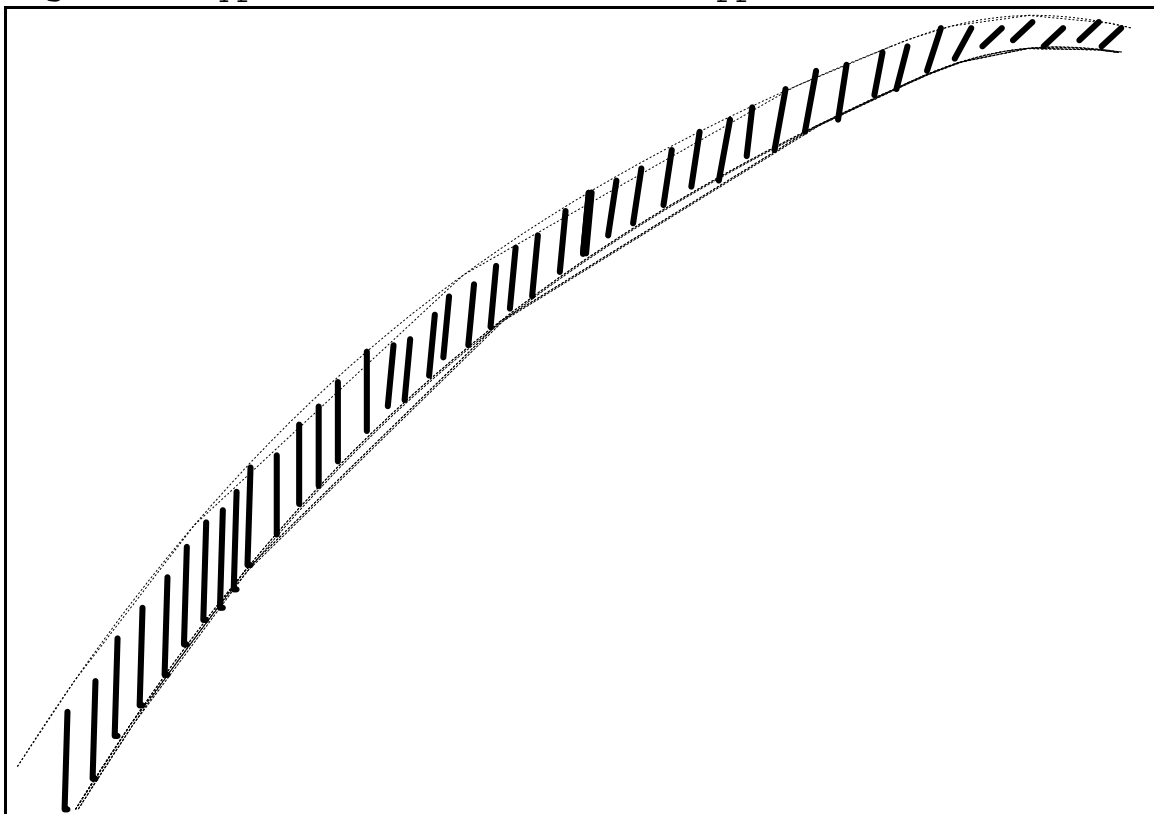


Figure 4- Close-up view of scuff mark, showing the striations

It is important to remember that scuff marks are made by steering, or rather over-steering, as opposed to skid marks which are made by braking. Two important characteristics to look for when examining scuff marks are their curved path and the striations (see pages 28 & 29).

METAL SCARS

When a moving vehicle is damaged in such a way that metal parts come in contact with the roadway surface, scars or scratches are left. Scars are helpful in indicating the direction of movement of the vehicle on impact. When they are correlated with the parts of the vehicle which made the scars they can also confirm the position of the vehicle on the roadway at impact.

Scars resulting from rollovers may indicate where the vehicle initiated its rollover movement. A vehicle sliding along the pavement on its side, or top, leaves distinctive scratches made by sharp sheetmetal edges or other protruding parts. Scars may also indicate the direction of impact as well as the relative force of the impact. This is true when the scar can be matched with the undercarriage portion of the vehicle (engine, frame, transmission, differential, etc.) that made the scar.

There are also some instances in which scratches on pavement prior to impact are indicative of a failure of some vehicle component. An example of this is when scratches occur from the rim of a wheel which sustained a flat tire before the crash. This can be confirmed by the distinctive pattern of a wobbly flat tire as it moves across the pavement.

Gouges may be distinguished from scratches in that they are much deeper and wider, and tend to chip or chop chunks of road surface material. Examination of the undercarriage of the vehicle can indicate abraded areas which may have gouged the pavement. Deep gouges are characteristic of severe head-on collisions, where the front end of one or both vehicles are driven down into the road surface with tremendous force. These deep road gouges are good indicators of the point of impact, or area of collision.

DEBRIS

Debris is not necessarily related to surface effects made by the vehicle directly in contact with the surface over which it is moving. However, inasmuch as debris

associated with the collision is physical evidence similar in importance to other crash evidence, it should be considered with the same careful attention. Debris are any large or small vehicle parts or pieces separated from the vehicle as well as undercarriage dirt and mud which drops onto the roadway, rust from metal parts which is shaken loose, paint, various vehicle fluids (radiator coolant, engine oil, brake fluid, battery acid, etc.), and similar materials. debris may also consist of portions of the roadway which are scooped up and spread in the collision area.

In severe injury producing crashes, debris may include human fluids and other matter, as well as portions of human bodies. Blood is perhaps the most common here, but may also be accompanied by other human matter. Pools of blood can show where an injured person lay or crawled to or was moved to after the crash.

Material carried by the vehicle, or within its passenger compartment, trunk or cargo area, is often dispersed about the crash site. This is an important consideration when attempting to interpret debris associated with only one crashed vehicle. Fluids are of particular significance. When a fluid container bursts, the fluid is dispersed with the same velocity as the vehicle. This

results in fluid patterns which can help determine vehicle movement at impact.

Debris in the form of fractured parts which separate at impact are deposited in a pattern consistent with the dynamics of the crash. This can be helpful in understanding the collision. Some parts can travel great distances, due to their relatively light mass and great initial velocity. In head-on collisions, for example, parts from each vehicle can be propelled forward a considerable distance from the impact point.

OTHER SIGNS OF IMPACT

Damage to fixed objects, such as bent and broken guardrails, posts, trees, and other fixed objects can give some idea of the speed and position of the vehicle striking them. Such damage is best described by photographs. When matched with damage or marks on the vehicle they can fix its position at a specific point in the chain of events. Sometimes particles of paint in the scraped area will help distinguish which of the vehicle involved in the collision came in contact with that object.

The term fall is used to describe a vehicle which has left the ground for a short time, while falling or flipping. Signs of this are found at the beginning and particularly at

the end of the fall, in the shape of marks on the ground itself. Flips or vaults occur when the moving vehicle strikes an obstruction that suddenly stops the wheels. The vehicle then pivots upward and leaves the ground, usually landing bottom up. The signs of tire marks at the take-off and landing points should be carefully located. If the vehicle was sliding in soft material the tires will dig a furrow, this is a distinctive spot and very easy to locate. A vault is an endwise flip.

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Chapter 3: WHAT THE VEHICLE SHOWS

Now that the road markings and the information they can reveal have been discussed, we can turn our attention to the technical examination of the vehicle.

Final position of the vehicles is usually the most important observation to make on all collisions. A quick glance at all traffic units involved upon the officer's arrival can give a general idea as to final positions. This, of course, should be followed by efforts directed at locating the vehicles by measurement.

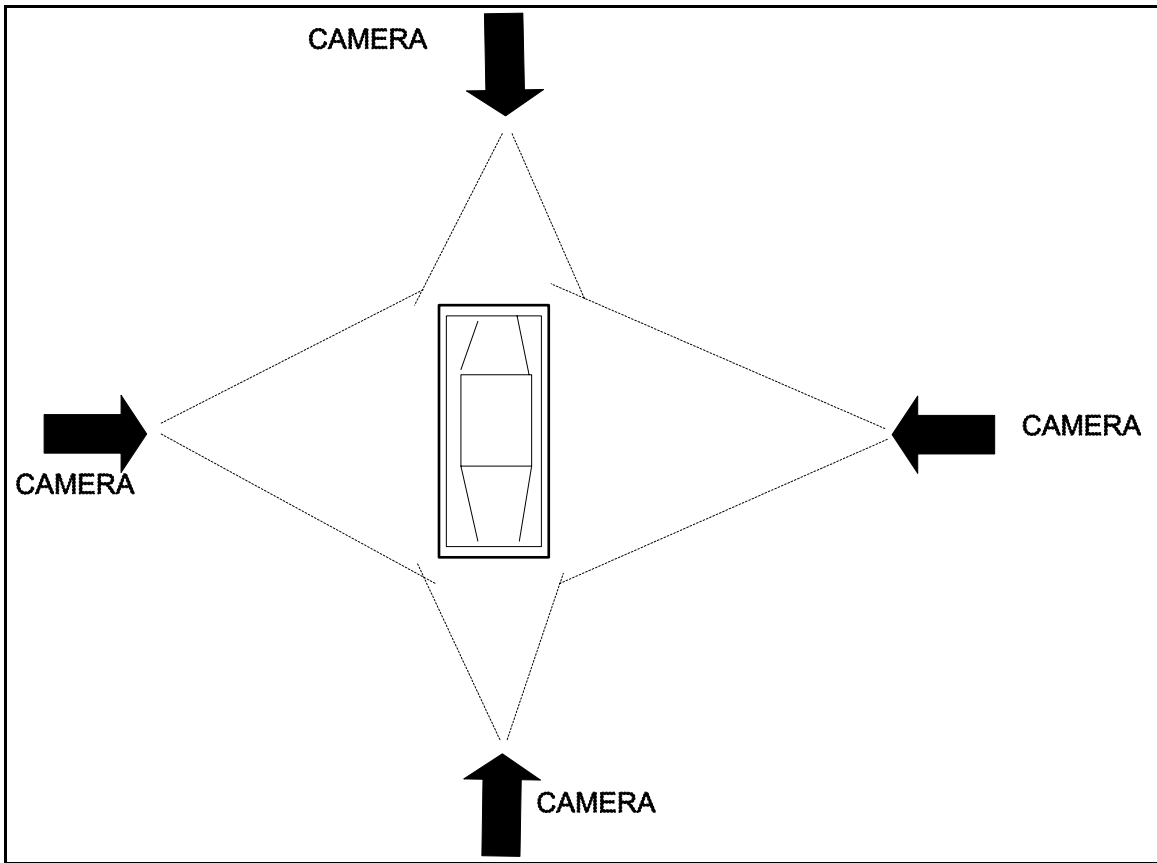


Figure 5- Standard photographic record (4-view) of vehicle damage

If photos are to be taken, the basic four view sequence of photographs should be taken before allowing vehicle removal (page 37). Additional photos should be obtained showing closeup or detailed areas of damage, matching damage parts of two vehicle showing how they came in contact, and any other item on the vehicle that can help explain the collision.

CONTACT AND INDUCED DAMAGE

Before any discussion on vehicle examination can begin, an explanation of the terms contact and induced damage is in order. Contact damage is damage to any part of the vehicle caused by direct contact with some other object. This object can be another vehicle, a pedestrian, a fixed object, or even the road surface itself.

External contact damage is shown by rubbed-off paint (paint transfer), crumpled vehicle skin, tire rubber, road material, tree bark, and even human tissue or clothing. It is also indicated by imprints of headlight housings, wheel rims, bumpers, door handles, poles, and other fixed objects.

Induced damage is damage to any part of the vehicle caused by the forces of the collision. Damage to the

differential or universal joints, for example, is induced damage because these parts are not broken by direct contact.

Contact damage to vehicle glass has specific effects depending on which type of glass is involved. On the safety, or laminated, glass used in the front windshield contact damage leaves fracture lines radiating away from the contact point. These circular lines formed what has been described as a "spiderweb" pattern. Parallel fractures (checkerboard pattern) on a front windshield are indicative of induced damage. Tempered glass, used in side and rear windows, display no pattern when subjected to either contact or induced damage, it simply shatters.

EXTERIOR DAMAGE ASSESSMENT

The second step taken by the investigator, after assessing final positions of the vehicles, should be to determine if the damage present is consistent with his/her understanding of the crash in terms of vehicle orientation and dynamics. Many collisions which are listed as single impacts will actually involve more than one impact, i.e., the vehicle bounce after impact into a fixed object, or vehicles may rotate quickly after impact and contact each other a second time. Crash damage to the vehicle is helpful

in determining how the object was struck. This is most easily observed on impacts with narrow objects.

In vehicle-to-vehicle impacts the investigator should look for damage that matches both vehicles. This can be like a jigsaw puzzle, in which the contour of one piece must fit the contour of another. Ejection avenues should be noted and listed in the report. These may be any opening in the vehicle through which a human body may pass (side glass openings, windshield openings, opened doors, etc.). These ejection portals may not be large, the human body is very pliable and can take various shapes and postures.

Gross vehicle failures in crashes should also be noted. These could be in the form of a large rupture, such as separation of the roof, doors, and other structural damage which renders the passenger compartment useless as a secure area for occupants.

Damage to wheels and tires of vehicles also require careful examination. Many times a driver will claim tire failure as being the cause of the loss of control leading to the collision. The investigator should attempt to determine tire damage caused by the crash, as opposed to damage existing prior to the crash or while the vehicle was being removed for the collision scene. Roadway tire marks often indicate tire failure prior to the crash. This can be seen in the form of flat tire or wobble scuff marks. These scuffs

indicate that the deflated tire was being distorted between the road and the rim as it rolled flat along the roadway.

Blowouts which precipitate a crash exhibit unique and distinctive characteristics. They are indicated by those features of the tire which appear to have been caused by the explosive deflation of the tire. Ruptured cord fiber ends are frayed and fuzzy, as if torn apart by a great force. A blowout may occur before impact, during impact, or after impact. Fresh cuts or slits in the tire are associated with crash damage resulting from sharp metal edges coming in contact with the tire.

VEHICLE IMPACT ORIENTATIONS

There are many variations to the impact orientation of vehicles involved in collisions. Head-on collisions where frontal areas of both vehicles are brought into contact with one another may be offset by varying degrees and may be at various angles rather than linear. During the author's 17 years in the field, with involvement in the investigation of over 1,000 motor vehicle collisions, he has seen only one head-on collision where the involved vehicles met perfectly head-on, or "headlight-to-headlight."⁴

⁴ This crash involved a pickup truck and a small subcompact. Due to the truck's larger weight and higher impact speed it pushed the smaller vehicle back in a straight line.

Most head-on crashes involve less than 100% overlap and occur at offset angles to one another. Override occurs when the frame of one vehicle does not meet the frame of the other. The damage characteristics will determine which vehicle overrode or underrode the other one. Motor vehicles do not behave either as solid objects nor as elastic ones, they behave somewhere in between. Making predictions of how vehicles move against each other at impact, after impact, and away from each other can be less than precise.

Head-on collisions in which one corner of the vehicle impacts a similar corner on the other vehicle also occur. The left front corner or left front corner orientation is most common because vehicles travel on the right hand side of the roadway in the United States. These crashes always result in rotation to one or both vehicles. Each vehicle is deflected from the point of impact towards its own side of the road while rotating counterclockwise. For right front impacts rotation is clockwise (as seen from above).

Side impacts between vehicle encompass a wide variety of crash orientations and vehicle surface areas. The investigator should attempt to determine whether the vehicles remained engaged through part of the crash phase, and where disengagement occurred. Engagement occurs where the vehicles remain locked together momentarily and behave as a single body before separating to their final rest

positions. At-crash and post crash movements can be determined by tire scuff marks since wheels may be forced to move laterally.

Rear-end impacts should also be similarly examined if an override or underide condition existed between the two vehicles. Fuel system integrity takes greater importance in rear-end crashes since any failure of the system can result in large amounts of fuel spillage, with accompanying fire risk. Examination of the fuel tank, its mountings and attachments, takes on greater importance in rear end collisions.

ROLLOVERS

Unlike other crash orientations, such as head-on, side or rear, rollovers usually consist of a series of distributed impacts as the vehicle contacts the ground with its sides, top, front, rear, and corner surfaces as it rolls over. It is important to note and record the number of impacts to which the vehicle was subjected in a rollover so as to best determine its rollover pattern and trajectory.

Impact areas on the vehicle help determine what the vehicle came into contact with. Often this is not the soil but stumps, large rocks, or other irregular surface features. In rollover configuration where the vehicle is

"tripped" by a curb, or other surface feature while moving forward and yawing, or sideslipping, the roof and "A" pillar is often subjected to the greatest impact forces. This can be a clue to vehicle orientation as it began to rollover.

VEHICLE INTERIOR EXAMINATION

The vehicle interior can provide evidence as to how occupants moved, what they contacted, and what damage resulted from this contact. Contact areas may be distinguished by tissue deposits, hair, fabric transfer, skin oils, cosmetics, imprint of occupant features, as well as by the deformation characteristics of contacted areas.

Occupant contact with the vehicle controls is indicated by damage to those controls. A deformed steering wheel, bent shift lever, or distorted dash panel control knobs indicate occupant impact. Knowledge of the injuries sustained by the occupants prior to examining the interior should be obtained whenever possible. This will assist the investigator in knowing where to look and what to look for.

Examination of the seat belts and their location can also be helpful to the investigator. Upon examination of the occupants physical evidence due to seat belt injuries might be present (abrasions, bruises).

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Chapter 4: MEASURING AND DIAGRAMING THE COLLISION SCENE

A collision scene diagram is of the highest importance, as it assists the reader of the report in the visualization of what the scene looked like. A good diagram helps the investigating officer in testifying in court with precision and confidence. A diagram also helps in the reconstruction of the collision, if it becomes necessary at a later date. Finally, collision diagrams assist in supporting probable cause for any traffic citations or criminal charges arising out of the collision.

WHAT TO MARK AND MEASURE

After the initial response, arrival, and scene management responsibilities are carried out, the next step of the investigative process is to decide what items of physical evidence must be located, marked, and documented. The following list is presented as a guide but it is not, by all means, all inclusive:

1. final rest positions of vehicles and bodies; this includes cars, trucks, bicycles, pedestrians, etc.

2. tire marks on the pavement or anywhere if they are related to the collision; skid marks, scuff marks or tire prints.
3. gouges and scratches on the road surface.
4. debris of any type, such as undercarriage, vehicle parts, or liquids.
5. any items which were scarred or marked as a result of the collision.

After the decision is made on what items are going to be marked and recorded in the collision diagram, the issue of how many marks or spots on the road surface must be addressed. Generally, police agencies issue common spray paint and/or lumber crayons to their officers for marking purposes.

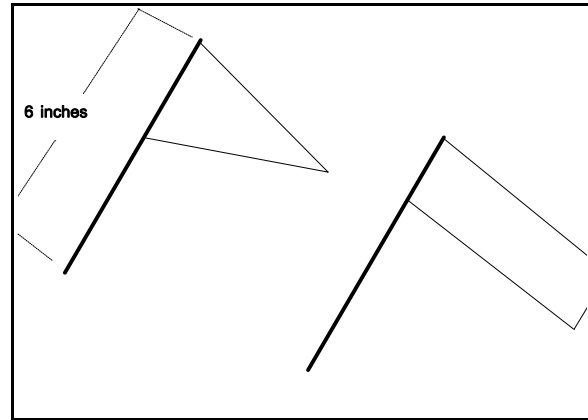
Bright orange or yellow paint is the most common color as it is easily visible and located for subsequent measuring. In the case of paint, less is usually best. There is no need to deface the roadway with colorful "art", a simple paint dot to locate an item is sufficient. Paint is of little use on unpaved or dirt roadways.

An alternative method on these surfaces is the use of small flags or streamers.

These are small (4 to 6 inches) pieces of wire to which bright streamers or flags are attached. Coat

wire hangers and engineering

tape (found at large hardware stores) are handy materials to make these flags. They are used at every spot where paint would ordinarily be used and are easy to locate later, particularly across rough or uneven fields.



Officers must remember that a discussion on marking tools and devices is academic if they are not carried in the police vehicle at the time they are needed. It is the responsibility of each patrol officer to insure that all supplies needed are in the police car at the beginning of each shift. A professional police officer always knows what equipment he/she has at all times.

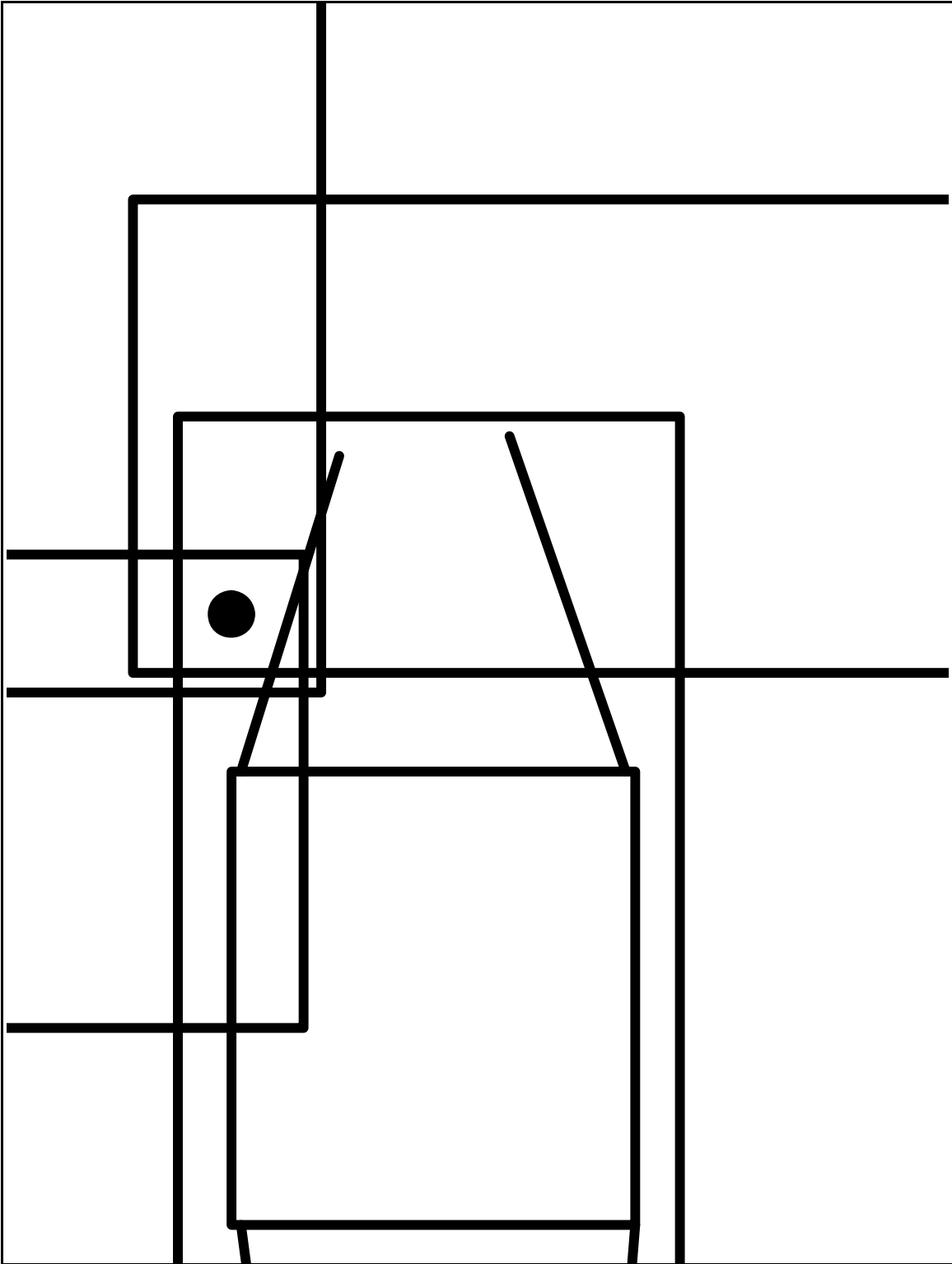


Figure 7- Location and heading of a vehicle can not be established with only one measurement (left front tire, in this case)

After deciding what items the investigating officer is going to want to measure, a decision has to be made on how many marks or spots are going to be used for each item. For vehicles, bodies, long tire marks, or large debris areas one mark is insufficient. As an example, figure 7 shows how one mark will not locate a vehicle's specific location and heading as it can be facing in any direction if a single mark is used.

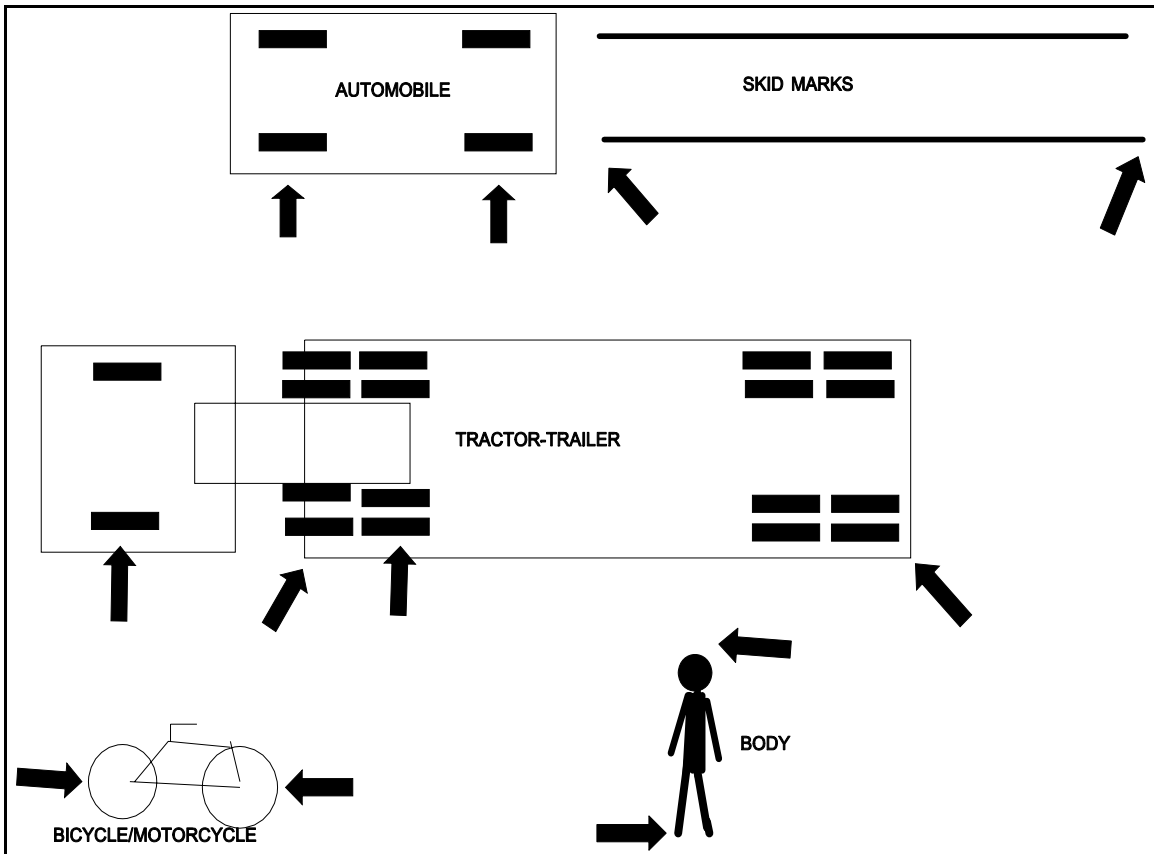


Figure 8- Examples of how to mark different vehicles and other items at the collision scene

Two or more points or marks are needed for such items as: vehicles, bodies, skid or scuff marks, and large areas of debris. A marking on the front and rear tire (same side) of an automobile is usually sufficient. In the case of an articulated vehicle, such as a tractor trailer rig, they are marked as if they were two separate vehicles. The tractor is marked as if it was a car, so is the trailer. One mark at the head of a body and one at the feet is sufficient to locate it.

Straight skid marks are marked by a single spot at each end of the skid, this is repeated for every skid mark. A two-wheel vehicle such as a bicycle or motorcycle is marked by placing a paint or crayon spot at each wheel as shown by the arrows in figure 8.

On small objects, such as gouges, small scuff marks, or small debris areas less than three feet in diameter, a single mark or spot to the center of the object is sufficient. On curved tire marks such as yaw marks, locate stations along the mark at 5, 10, 15, or 20 foot intervals, depending on the length and sharpness (radius) of the mark. Large debris areas can be located by placing marks along its perimeter, between 4 and 8 marks are usually sufficient.

If the collision is of such severity that a specialized unit or investigator is going to respond to the scene, it is best not to mark any items. The officer's role in that case

is to secure the scene and insure no vehicles or other evidence are moved until the investigator arrives. This assists the investigator in taking photographs of the evidence in an unmarked, or "as found" condition for court presentation.

DIAGRAMMING THE SCENE

Several methods of diagramming traffic collision scenes have been developed over the years and are in widespread use. Some of these techniques are simple to learn and use, while others are somewhat complex and require considerable amounts of training.

There is very little doubt that traffic collision investigation is, by its nature, a technical task. However, the majority of on-scene investigative work is carried out by regular patrol officers; this is particularly so in small law enforcement agencies. This chapter is primarily addressed to that group, although personnel in larger agencies may find it useful.

With the above in mind it is easy to see why a large number of police organizations find it necessary to teach their officers simple yet effective collision mapping techniques. Two of these methods are the coordinates and

triangulation techniques. The following discussion presents each method, with accompanying examples.

COORDINATES

The coordinate system is based on locating any specific spot by means of distances from a fixed reference point (RP), along a reference line (RL). In using this method a vital ingredient to accurate measurements is the selection of a good reference point.

If future reconstruction of the collision is necessary, the reference point becomes the key from which the scene is mapped. Some examples of a good reference point are: highways mileposts or mile markers, utility poles, fire hydrants, culverts and bridges, intersections of roadways, and any other manmade or natural point of a permanent nature.

When selecting a reference point keep in mind that if the RP is destroyed, then surveyor plans, street maps, engineering drawings, etc., should be available which will enable the reconstructionist to "place" the RP back at its original location. Remember that the reference point is the keystone from which the entire collision is measured and drawn. A bad RP selection would make exact reconstruction of

the collision at a later date difficult, if not impossible, to the degree of accuracy required.

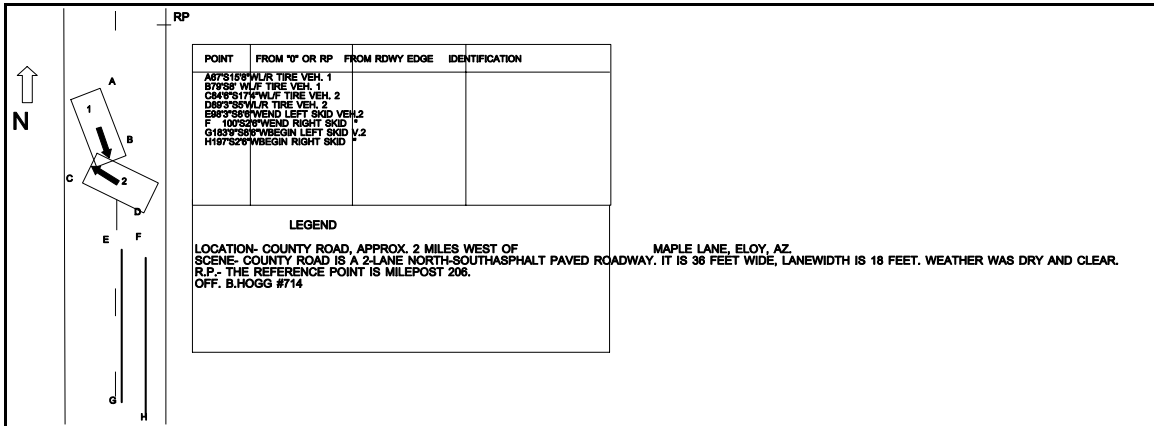


Figure 9- An example of a simple field sketch using the coordinate method, with accompanying measurements table

To use the coordinate method, as with any other technique, the collision investigator first prepares a field sketch of the scene, showing all significant items. Once the field sketch is prepared, the investigator assigns each significant item a letter of the alphabet starting with 'A'. After this, the investigator draws a table where all measurements will be recorded. This table can be next to the field sketch or on a separate page.

The table will include a legend and it should include the following information: geographical location of the collision, scene, weather, roadway width, complete description of the reference point, and the investigating officer's name and badge number. The date the diagram was prepared and an explanation of any non-standard symbols used can also be included here. Figure 9 shows a simple collision scene sketch, including a measurements table and legend.

On the space above or below the legend the table will show the collision measurement data broken down in four separate columns: point, from '0' or RP, from roadway edge, and an identifying description of each item or point. The first column is simply the alphabetical listing of all significant items marked at the collision scene. After reaching the letter 'Z' the investigator may go on to 'AA', 'BB', etc., or an alphanumerical system such as 'A-1', 'A-2', etc., may be used.

The next column (From "0" or RP) will show the distance from the reference point along the reference line to a point abreast or perpendicular to each significant item. At each point the investigator places a mark (paint, crayon) and continues to measure up to the next point, without resetting the rollatape. The '0' designation is used when the RP does not lay directly on the reference line, such as when using a telephone pole as the RP.

This is commonly referred to as "bringing" the RP to the roadway edge by measurement. This distance is not part of the table itself, but it should be shown in the legend. It should be noted that the coordinate method should not be used when significant items are more than 35-40 feet from the roadway edge, as accuracy begin to suffer beyond this distance. In such a situation a triangulation-based method (see below) should be used.

After this process has been completed the investigator then measures the distance from the roadway edge out to each significant item. This information is recorded under the "From Roadway Edge" column, next to its respective letter. Thus, a set of measurements, or coordinates, is established for each significant item. The last column, "Identification", is simply a short description of each item in the diagram.

Equipped with this information the investigator is now ready to prepare a post-collision, or final position, diagram. If the diagram is to be to scale then he will need additional information such as radii of any curves, etc.

TRIANGULATION

Many times the final rest positions of vehicles involved in collisions, particularly in rollovers, are too far from any convenient roadway edge reference lines, rendering the coordinate method somewhat inaccurate when distances beyond 30-40 feet from roadway edge are involved. This is a common occurrence along county and state highways, where the high velocities involved sometimes cause the crashed vehicle to arrive at its final rest at a considerable distance from the roadway.

This inability to determine right angle straight lines out to an object is due to parallax error, an apparent change in position of an object when viewed from two or more positions not exactly in line with the object. The greater the distance the greater the margin of error.

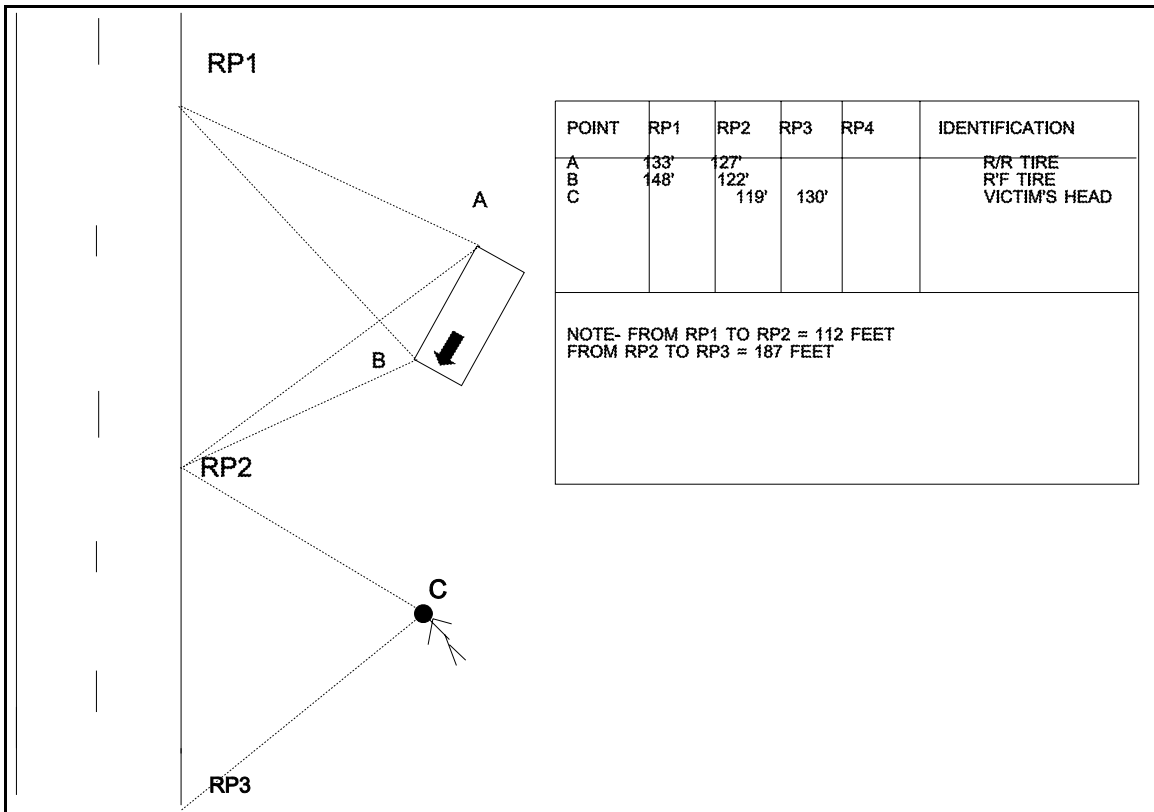


Figure 10- Triangulation method, commonly used when evidence is at a significant distance from the roadway edge

At these times the triangulation method presents a much more accurate alternative. When using triangulation each significant item is located by establishing fixed distances from two reference points along a reference line. In the example given on page 52 point 'A' is established by: (1) measuring the distance from the first reference point (RP 1) to 'A', (2) measuring the distance from RP 1 to RP 2, and finally (3) measuring the distance from RP 2 to 'A'.

The investigator can use as many RP's as necessary. The only criteria to keep in mind is to select RP's that will maintain an evenly spaced or equilateral triangle.

Each of these steps is repeated for every significant item in the diagram. The accompanying table shows the recommended method of documenting these measurements. Two measurements must be obtained for each significant item.

To draw the diagram to scale a common compass, which has been previously adjusted to the distance required using the scale on the template, is used to draw an arc⁵ from each of the RP's. The point at which they intersect is the location of the significant item.

The methods explained above are simple, easy to learn, and do not require a large amount of equipment or time to use. They are accurate and will cover every collision diagramming problem officers are called on, with minor

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An arc is a portion of a circle, or the part between two points on a curve.

modifications. The coordinate method is easier to use and can be applied to about 90 percent of all collision scenes, and the triangulation system is available for those few times it is required.

DRAWING THE SCALE DIAGRAM

The last step in the measuring and diagraming process is to prepare a scale diagram. This is a representation of the collision scene which is proportionate to the actual scene, based on a given scale. In reality, most collisions investigated by patrol officers will require no more than a simple, not-to-scale, diagram showing vehicle final positions and other physical evidence.

Scale scene diagrams are time consuming and not necessary for most collisions, department policy and local practices will generally dictate when a scale diagram will be prepared. Most law enforcement agencies only require their patrol officers to prepare a scale diagram on fatal collisions, other require them in collisions involving deaths and serious injury.

In order to draw an accurate and technically acceptable scale collision diagram, the following is needed:

1. field sketch
2. field notes

3. table of measurements and legend information
4. state-issued diagram form, or plain paper
5. template, with 1=10 & 1=20 scales
6. compass
7. fine point pencil

The first step in drawing a scale diagram is to decide what items are going to be included. It would be technically possible but extremely time consuming to attempt to include every single item at the collision scene, such as sidewalks, poles, street signs, bushes, and other items commonly found on or near the scene. The rule to remember is to include those items in the diagram which are relevant to the collision.

All roadway evidence, such as skid marks, must be included in the drawing. The final positions of the vehicles is of course critical to an understanding of the collision and are also shown. The roadways involved are shown but sidewalks and gutters are not included unless they are of relevance, i.e., in a case of a vehicle jumping a curb and striking a pedestrian on a sidewalk.

In drawing the diagram a template designed for collision mapping is essential. Two templates commonly used by investigators are the TRAFFIC TEMPLATE AND CALCULATOR from the Traffic Institute, and the BLUE BLITZ from IPTM⁶.

⁶

The Traffic Institute, Northwestern University, P.O. Box 1409, Evanston, IL 60204
Institute of Police Technology and Management, University of North Florida. 4567 St. Johns Bluff Rd, Jacksonville, FL 32216.

Both templates are made out of plastic, have a nomograph for speed calculations, include special cut-outs for drawing cars and trucks, and have the two most commonly used scales: 1 inch = 10 feet, and 1 inch = 20 feet, or 1=10 / 1=20. These scales are printed on either edge of the template.

The selection of scale to be used in the diagram will determine how large the final product will be. A standard 8½ by 11 in. Arizona Traffic Accident Report Diagram form will accommodate a collision scene of approximately 160 feet by 135 feet on a 1=20 scale, and 81 feet by 68 feet on a 1=10 scale. If a larger diagram is necessary then additional sheets can be taped together, or a smaller scale must be used⁷.

In drawing the diagram it is a good idea to show North towards the top of the page, this is an accepted rule in map making and should be complied with whenever possible. In order to show intersection curves, or other roadway curves to scale, certain measurements have to be obtained at the scene:

1. Chord - straight line intersecting a curve at two points (tangent).
2. Middle Ordinate (M.O.) - shortest distance from the center of a chord out to a point on its perimeter.

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As an example, if a 1=20 scale is not small enough to keep the diagram manageable, a 1=40 scale can be used. In this case the same 1=20 side of the template can be used but all measurements are divided by 2 before using the template.

3. Radius - the distance from the center of a circle to a point on its perimeter.

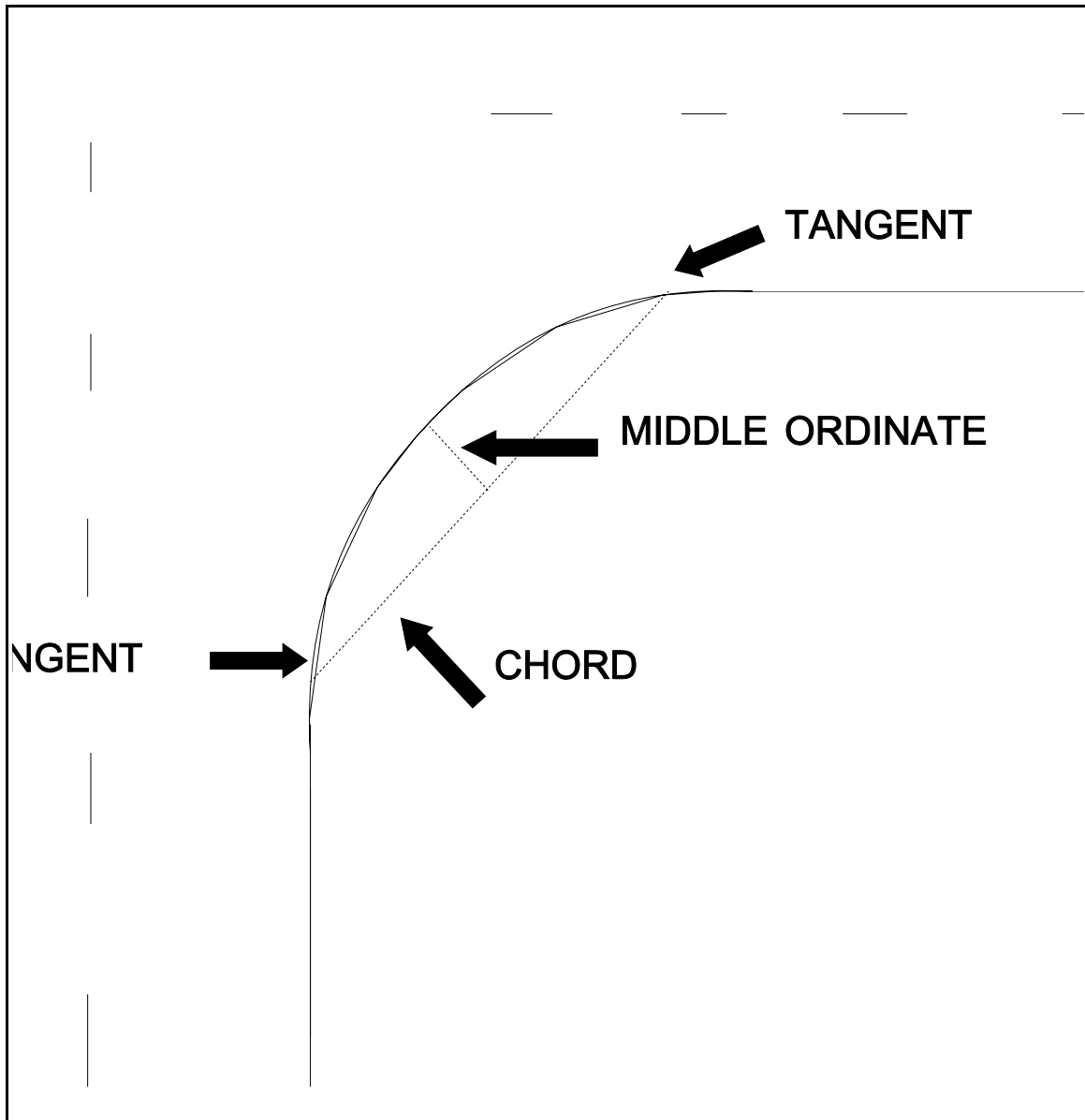


Figure 11- Intersection curve diagram showing the location of the chord line, middle ordinate, and tangent points

The first step in calculating the radius of a curve is to measure its chord line. This is done by stretching a 100 foot tape from tangent point to tangent point (see figure 11). At the midpoint the middle ordinate is then measured out to the curve. As an example, if the curve chord measurement was 50 feet then the middle ordinate measurement would be taken at the 25 foot mark.

Once the chord and middle ordinate measurements are recorded, and roadway width measurements are also taken, then all necessary information is available to go to the next step in the process. A mathematical calculation, using the radius of a curve equation, has to be completed before using a compass to draw the curve. The equation is:

$$R = \frac{C^2}{8M} + \frac{M}{2}$$

Where R= the radius of the curve

C= the chord measurement

M= the middle ordinate measurement

8 & 2= are constants; in a mathematical equation a constant is a value that never changes its value; i.e., in this equation 8 and 2 are always used as such.

As an example, the next series of steps will show how the equation is worked out, using a value of 50 feet for our hypothetical roadway curve, and 7 feet for the middle ordinate. The final result of the equation is a radius of the curve of 48.14 feet. In actuality, one tenth of a foot

is a little over one inch, which is impossible to discern in a 1=10 or 1=20 scale diagram, so we can safely round down to an even 48 feet.

$$R = \frac{C^2}{8M} + \frac{M}{2}$$

$$R = \frac{50^2}{(8)(7)} + \frac{7}{2}$$

$$R = \frac{2500}{56} + 3.5$$

$$R = 44.64 + 3.5$$

$$R = 48.14 \text{ feet}$$

The next step in the process of drawing the curve, now that we know the radius, is accomplished using the template and a common drawing compass.

Start by drawing two straight, intersecting lines as shown in figure 12 (step #1). The "cross" should be on the side of the page or paper that the curve is to be. This is a

trial-and-error process sometimes, and the investigator will improve this skill with practice.

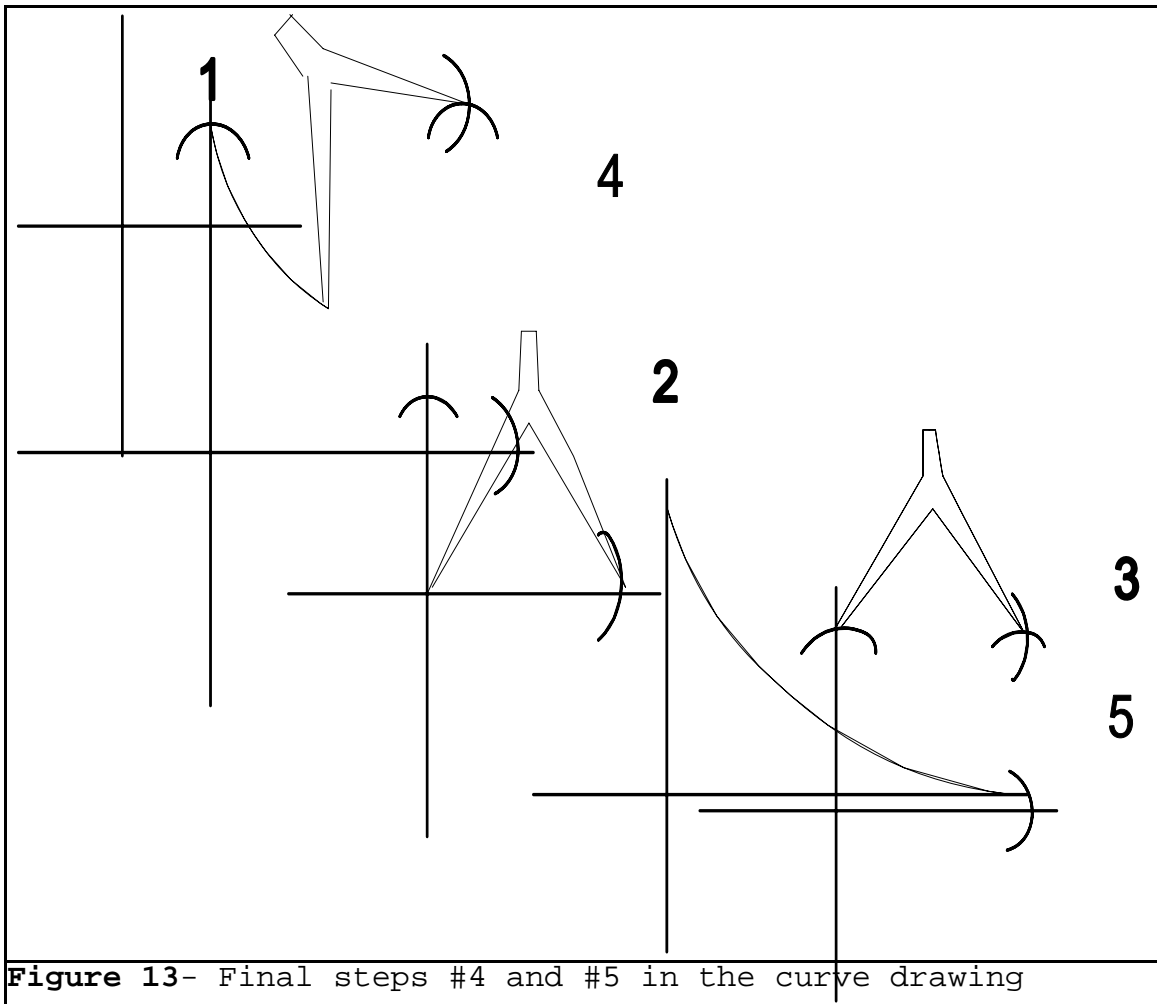


Figure 13- Final steps #4 and #5 in the curve drawing process

Figure 12- Steps #1 through #3 used in drawing the intersection curves to scale

After deciding what scale is to be used in the diagram (1=20 for most diagrams), the compass gap is then adjusted to the distance calculated in the radius of a curve equation using the template, in this case it would be adjusted to 48 feet. The sharp metal point of the compass is then placed at the intersection of the two lines and two short arcs are drawn, intersection each line as shown in step #2.

In step #3 the sharp point of the compass is placed at the intersection of each arc made in step #2 above, and two additional arcs are drawn towards the side the final roadway curve will be. Step #4 consists of placing the sharp point of the compass at the intersection of the last two arcs drawn, then drawing the curve from one side to the other (step #5). The straight lines are now erased, leaving a perfect, to scale, roadway curve.

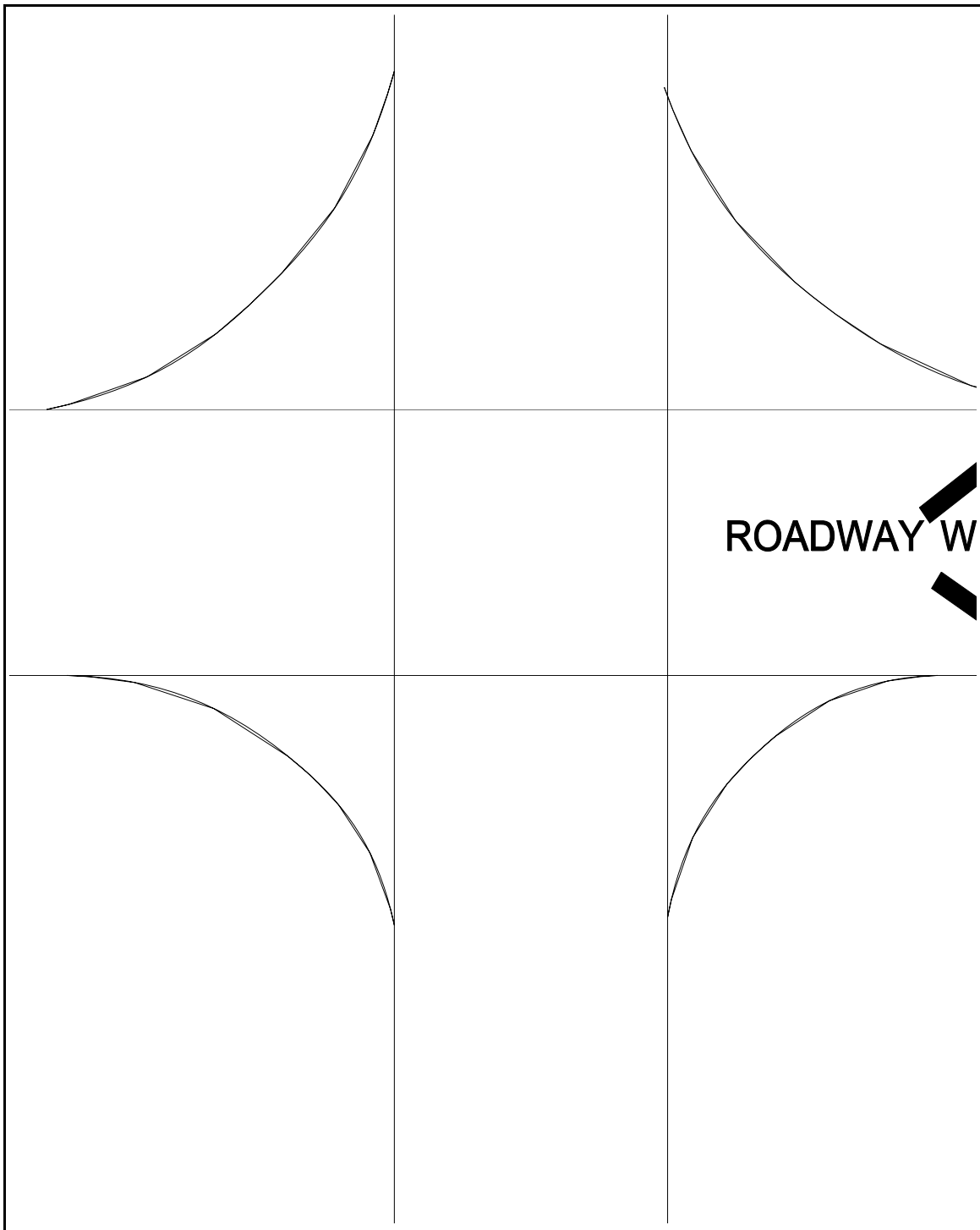
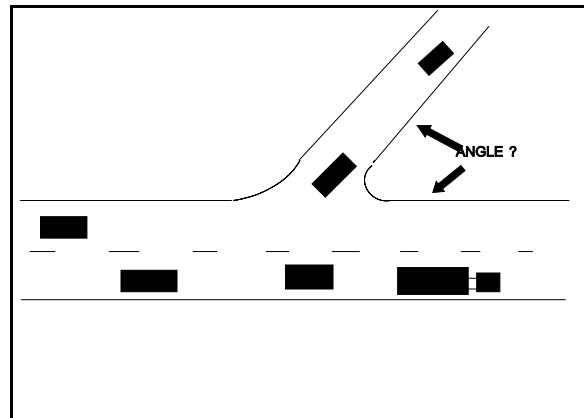


Figure 14- A four-way intersection with all curves drawn to scale, prior to erasure of roadway edge lines

The process is completed by extending all lines and measuring the space between the lines with the template, to match the roadway widths at the collision scene (figure 14). Once the curve drawing procedure is carried out three more times, a four-way scaled intersection is finished.

Investigator should keep in mind that, although all four curves at an intersection are generally of the same radius, this is not always so. Measure each curve to be sure.

Of course, not all intersections are 4-ways or T-bones, meaning they do not all meet at nice, easy to draw 90° angles on a piece of paper without thought given to measuring actual angles. Many roadways join at acute or obtuse angles⁸, such as the one depicted on the figure at the right. If the investigator simply guesses and draws free-hand the intersection on the paper, it is no longer a scale diagram. The investigator must first determine the angle at which one roadway meets the other.



8

An acute angle is any angle less than 90° , an obtuse angle is any angle greater than 90° .

In order to do this, the investigator first visually extends the roadway edges and marks the point at which the

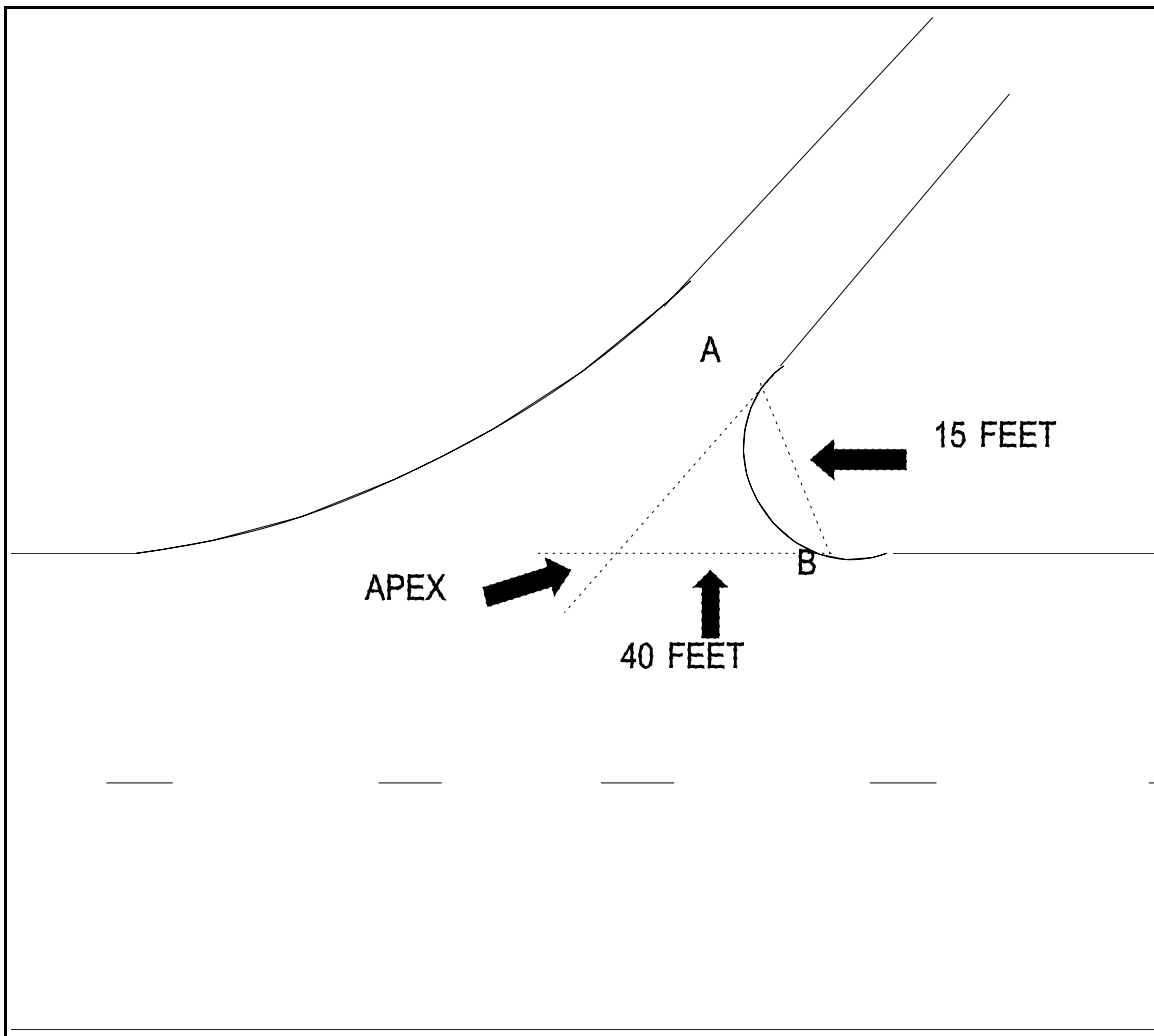


Figure 16- To measure the intersection angle, establish the apex and mark off a point along each side

two meet (apex). Once this is done then an arbitrary but equal distance is measured and marked from the apex along each roadway edge (A and B in figure 16). The distance between A & B is recorded, along with the first distance measured.

As an example, lets assume that the first distance was 40 feet and the second was 15 feet. On the diagram paper the investigator begins by drawing a straight line across the page, keeping in mind where the intersection is going to come in at.

Using a compass/template and adjusting the gap to the first distance (40 feet in this example), the investigator then draws an arc with the sharp point of the compass at the apex. The arc will cross the first line drawn, as shown in figure 17 (step #1). The compass is then removed and adjusted to the second measurement (15 feet), the sharp point is now placed at the intersection of the straight line and the arc. A second arc is now drawn intersecting the first arc (step #2).

The next step is to connect the apex and the intersection of the two arcs using a straight edge, this

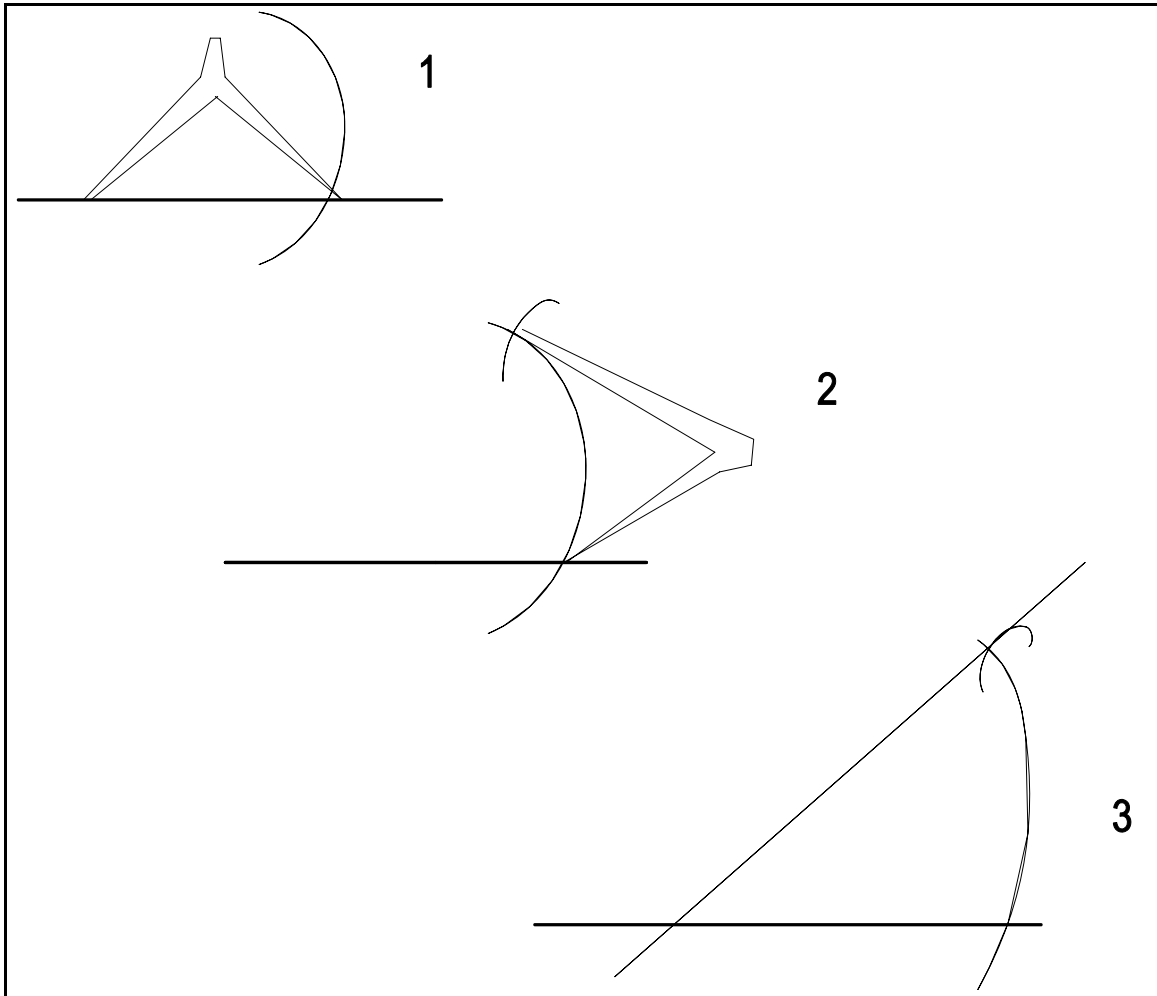


Figure 17- Steps to draw the angled intersection to scale

will provide the angle of the intersection. To complete the drawing the other two roadway edges have to be added, in accordance with the actual roadway width measurements. A last step required is to draw the radius of each curve. The mathematical equation is the same one used for 90° intersections, but the process to draw the curves is slightly different.

Once the angle intersections has been drawn to scale, then the radius of each curve is added. To do this, measure two parallel lines, one on each side of the angle and to the distance of the radius obtained from the equation. Where these lines cross, place the sharp point of the compass and draw the curve.

This process is then repeated for the opposite curve, using the radius calculated for that curve. Figure 18 shows how to complete these steps.

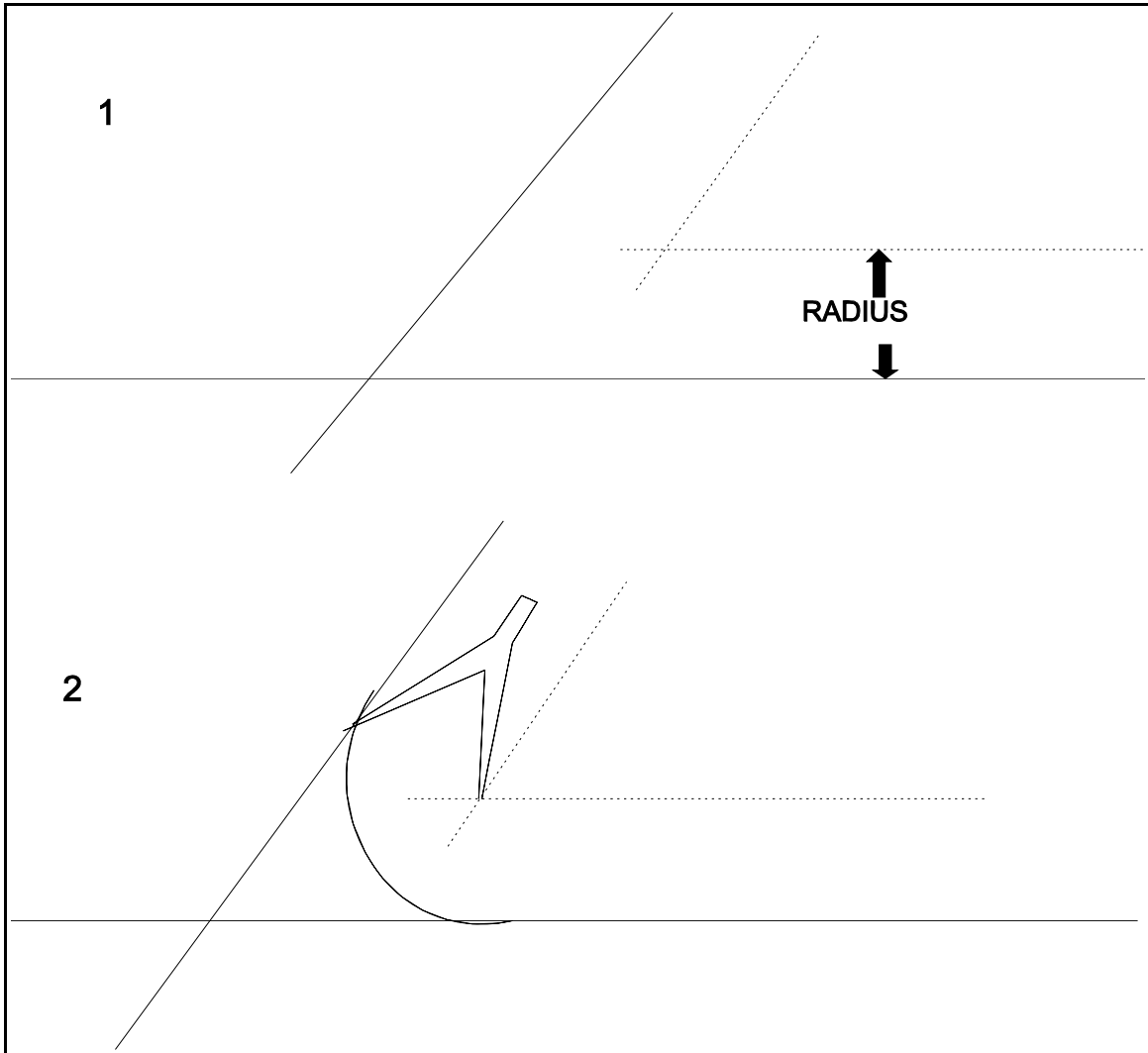


Figure 18- Drawing the curve radius, to scale, of an angled intersection

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Chapter 5: ESTIMATING SPEED FROM TIRE MARKS

Tire marks are one of the most important pieces of evidence among all of the physical evidence found at the crash site. They can not only be used to establish the precrash path and orientation of the vehicles, point of impact and postcrash travel, but they can be of great help in estimating vehicle speed prior to skidding. Identifying tire marks at the crash site is fundamental to the crash investigation.

SKID MARKS

Estimating speed from skid marks is one area that has perhaps been most written about, and is of primary concern to collision investigators where law enforcement considerations in crashes must be considered. Since skid marks are solid physical evidence of the crash, they can be used to estimate the speed of the vehicle at impact as well as its speed prior to skidding.

It is unfortunate, at times, that police investigators will clearly neglect or ignore skid marks as a source of probable cause for speed violations. This is usually due to poor training and lack of awareness of the speed determination process, which is actually quite simple.

Any moving body possesses a certain amount of kinetic⁹ energy by virtue of its motion. How much kinetic energy is involved is dependent on two factors: the mass of the body and its velocity. The mathematical equation for kinetic energy is:

$$Ke = \frac{1}{2}mv^2$$

Where Ke= kinetic energy
 m= mass of the body
 v= velocity

Through a process called formula derivation the basic kinetic energy formula or equation above serves as the basis for the speed-from-skid formula. A moving vehicle's work energy is determined by multiplying the weight of the vehicle times the drag factor¹⁰ of the road surface times the distance it will slide over while stopping.

$$WfD = \frac{1}{2}MV^2$$

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The word "kinetic" is from a Greek word meaning "motion".

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Throughout this discussion the term "drag factor" will be used, even when referring to coefficient of friction, for simplicity. They are not the same but their differences are only of importance to reconstructionists.

Mass is the same as the weight of an object divided by the acceleration of gravity, or W/g . If we change M to W/g and divide out W , it leaves:

$$fD = \frac{1}{2g} V^2$$

To get V^2 alone, both sides are multiplied by $2g$:

$$V^2 = 2g fD$$

In the next step of the derivation process, the g (gravity) is changed to its actual value of 32.2 feet per second². This 32.2 is multiplied by the 2 next to it, which becomes 64.4:

$$V^2 = 64.4 fD$$

The next step is to change V^2 to the more conventional and familiar miles-per-hour. There are 5280 feet in a mile, and 3600 seconds in an hour. By dividing 5280/3600 the conversion factor of 1.466666667, or 1.466, is obtained:

$$(S \times 1.466)^2 = 64.4 fD$$

Carrying out the square function of 1.466 yields 2.15, this value is then divided out to leave S^2 by itself:

$$\frac{S^2 \times 2.15}{2.15} = \frac{64.4 fD}{2.15}$$

$$S^2 = 30 fD$$

The last step is to extract the square root from both sides of the equal sign (squaring a number is the inverse of the square root):

$$S = \sqrt{30 D f}$$

Where S= speed
 f= drag factor
 30= constant
 D= distance vehicle skidded

This is the basic speed formula commonly taught and used in determining speed from skid marks. Although it is not necessary that the collision investigator be proficient in the derivation process, it is always a good idea to be able to explain, or at least have an understanding, of the scientific origins of the basic speed-from-skid equation.

As can be seen from the equation above, in order to determine the speed of the vehicle at the time braking was initiated, the investigator needs two pieces of information: the distance the vehicle slid and the drag factor¹¹.

There are a couple of different approaches to the drag factor question. The investigator can refer to one of many published tables showing a sampling of drag factors for

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A number representing the acceleration or deceleration of a vehicle as a decimal fraction of the acceleration of gravity; a dimension-less number representing how slippery the road-tire combination is.

different surfaces (more on this later) or he/she can conduct a skid test to obtain one.

TEST SKIDS

To obtain a drag factor from a test skid, ideally the vehicle that was involved in the collision should be used. Since this is highly impractical, a police vehicle is an acceptable substitution.

The test skid should be made at or near the same location and with the same surface conditions. For maximum safety a second police officer should be present to monitor traffic and block the roadway while the test is being conducted. A good, safe speed for skid tests is 35 miles per hour. Speeds beyond this increase the safety risk and do not yield substantially better results. If possible, a radar unit should be used during testing to prevent errors caused by defective speedometers.

To do the test, the police vehicle is accelerated to 40 miles per hour and the driver steps of the gas pedal, allowing the vehicle to coast down to 35 mph. Upon reaching 35 mph the driver applies the brakes HARD (panic stop) until

the vehicle slides to a stop. The longest skid mark should be measured and recorded, and a second test conducted. If the second test yield a distance close to or similar to the first (within 10 percent), then the test is valid.

If the collision occurred on a roadway which is sloped at a significant grade, and the test skid was conducted on the same surface and in the same direction, then the grade is already accounted for.

However, if no test skid was conducted and a drag factor table is to be used, then the percentage of grade has to be factored into the selected drag factor.

Figure 19 shows how to obtain the road grade using a common carpenter's level. One end of the level is place on the roadway surface and the opposite end is placed directly down-grade from the end that is on the road. Insuring the bubble is level, a measurement is taken (in inches and tenths) from the road to the bottom edge of the level. In the example above, the **run** is 18 inches and the **rise** is 1 inch. Dividing 1 by 18 yields a grade of .05 percent.

To use this grade on the selected drag factor, if the sliding vehicle was going uphill, the grade is added. As an

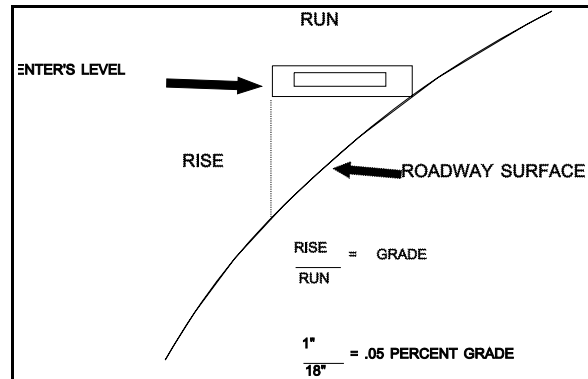


Figure 19

example; if the selected drag factor is .7 and the grade is .05 percent, then $.7 + .05 = .75$ for drag factor. If the vehicle was sliding while traveling downhill, the grade is subtracted.

Once the test skid data is obtained, this information can be used in the drag factor equation:

$$f = \frac{S^2}{30d}$$

Where f= drag factor
 S^2 = test speed squared
 30= constant
 d= distance test vehicle skidded

As an example, assume that a test skid yielded a skid distance of 55 feet with a test speed of 35 miles per hour:

$$f = \frac{35^2}{30 \times 55} \quad f = \frac{1225}{1650} \quad f = .74$$

The drag factor for that surface, with all wheels locked and sliding, is .74, this would be the value used as "f" in the speed formula discussed earlier. Lets assume that the collision vehicle skidded for 66 feet. Using the drag factor calculated above:

$$S = \sqrt{30 \times 66 \times .74} \quad S = \sqrt{1465.2} \quad S = 38\text{mph}$$

The collision vehicle was traveling at **no less than** 38 miles per hour at the beginning of the skid. Why do we say "no less than" ? Simple, the vehicle collided with another one (or an object) before coming to rest. If it had not, the skid marks would have been longer.

It is important to remember that the speed calculated from the speed equation is the true speed of the vehicle **only** if it slides to a stop, that is, all energy is dissipated sliding to rest. When it is not, that is, some energy is dissipated doing crush damage then this energy is not accounted for in the speed equation. This is why we refer to speed from skids as a **minimum speed**.

DRAG FACTORS FROM PUBLISHED TABLES

There are various sources of sample drag factors for different surfaces, to be used when the investigator is precluded from doing a test skid. Most law enforcement agencies do not allow police officers to conduct test skids on anything but serious injury or fatal collision. Some agencies do not permit test skids at all.

Under these circumstances the investigator can still make a speed determination with the careful use of a sample drag factor from a published table. The Northwestern University Traffic Template & Calculator instructions booklet includes a table of drag factors, and there are many other sources found among collision investigation & reconstruction manuals.

Average Sliding Drag Factors for Passenger Car Tires	
Surface	Drag Factor
Asphalt	
Concrete, dry	.65 - .90

Asphalt	
Concrete, wet	.45 - .70

Gravel	
loose to packed	.45 - .70

Road, w/ snow	.30

Ice	.15

Table 2

Table 2 shows a sample of common drag factor ranges found among the many tables. Since using a table involves a range of values, it is always better to conduct a skid test if possible.

A last note on speed from skid marks: if the collision vehicle was braking at less than 100% efficiency (less than all four wheels braking), an adjustment has to be made to the drag factor before it is used in the speed equation. A discussion on this topic is beyond the scope of this manual. Investigators suspecting less than all four tire braking

should consult with someone with advanced training, preferably a collision reconstructionist, for assistance.

THE TEMPLATE NOMOGRAPH

A quick way to calculate speed from skid distance, without utilizing the mathematical equation, is available using either the Northwestern template or IPTM's Blue Blitz template. Both templates have a set of scales printed down the center of each instrument.

To use nomograph to calculate speed; first a drag factor is selected. The example on figure 20 uses a .7 for drag factor and 60 feet for the distance of the skid. Using a straight edge and connecting the drag

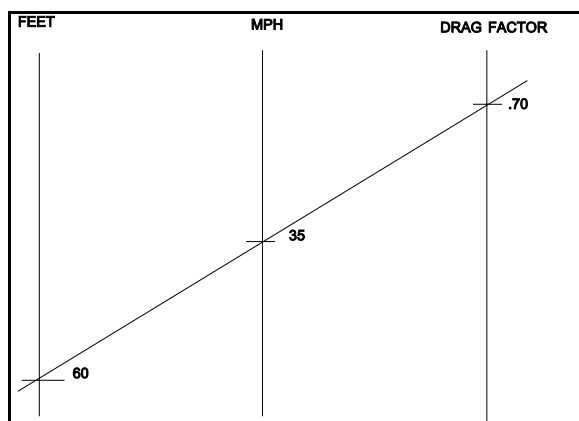


Figure 20

factor scale (right scale) with the distance scale (left scale) yields a speed of approximately 35 mph (center scale). The nomograph is an easy to use instrument and very helpful to those investigators who have difficulty with the equation. It can also serve as a "quick and dirty" speed estimation method at the collision scene.

CRITICAL SPEED (YAW) MARKS

In Chapter 2 a discussion of critical speed marks and their value to collision investigation was presented. Critical speed marks, or yaw marks, are tire marks left on the roadway by wheels that are sliding and rolling at the same time. They are made by the tire sidewall and are a result of the driver oversteering the vehicle.

A common occurrence where yaw marks are found is in rollovers involving drunk drivers. The intoxicated driver falls asleep and allows the vehicle to drift off the roadway. When the driver suddenly awakens he/she jerks the wheel to the left, launching the vehicle into a sideslipping maneuver. This brings the vehicle across opposite lane of traffic, off the shoulder and completely off the roadway, usually flipping in the process. The telltale yaw marks can be used to estimate the vehicle speed at the beginning of the maneuver.

In order to calculate the speed at which the vehicle began to sideslip, the investigator must first know the drag factor (from skid test or table) and the radius of the curve followed by the vehicle. The mathematical equation used in calculating the radius has already been discussed in Chapter 4. Figure 21 shows how to obtain the chord and middle ordinate (m.o.) of the yaw mark.

When measuring the chord, the beginning of the tape measure is placed at the beginning of the yaw mark, and a

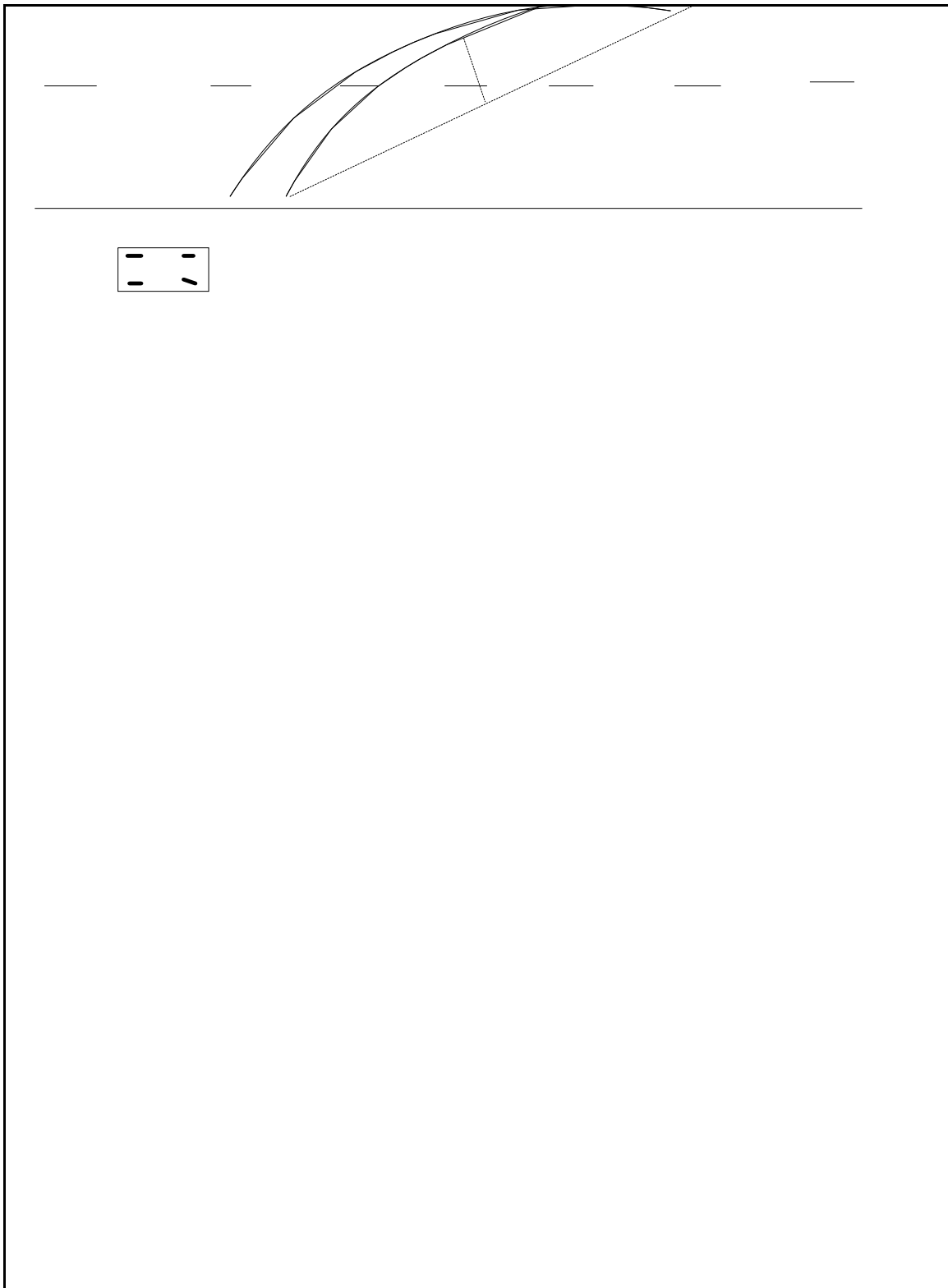


Figure 21- How to obtain the chord and middle ordinate (M.O.) measurements from a yaw mark

chord of 100 feet is generally used. When measuring the middle ordinate particular attention must be given to obtaining a precise measurement, as the equation is extremely sensitive to middle ordinate changes.

Once the radius of the curve has been calculated then this value can be used in the critical speed equation:

$$S = \sqrt{15 R f}$$

Where S= speed
 15= constant
 R= radius
 f= drag factor

As an example, if a critical speed yaw mark left by a vehicle that subsequently ran off the roadway and overturned had a radius of 335 feet, and the drag factor was .7 for that road surface:

$$S = \sqrt{15 \times 335 \times .7} \quad S = \sqrt{3517.5} \quad S = 59mph$$

The speed of the vehicle when it began to sideslip was 59 miles per hour.

COMBINED SPEEDS

Sometimes vehicles skid across two different surfaces before stopping or colliding with another vehicle or object. Using the same drag factor for both distances is a common approach, it is also wrong. To approach this problem the total distance of the slide must be divided and each segment must be calculated using the basic speed equation.

Upon completion of the step the investigator will have two different and separate speeds. They are not added ! These speeds, speed #1 and speed #2 must now be used in the combined speed equation:

$$S_c = \sqrt{S_1^2 + S_2^2}$$

Where S_c = combined speed
 S_1^2 = speed #1 squared
 S_2^2 = speed #2 squared

As an example, if the two speed calculations resulted in 40 mph for speed #1 and 60 mph for speed #2:

$$S_c = \sqrt{40^2 + 60^2} \quad S_c = \sqrt{1600 + 3600} \quad S_c = 72 \text{ mph}$$

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Chapter 6: THE COLLISION REPORT NARRATIVE

The report narrative segment of the police traffic collision investigation is the final topic of this manual. Forms used for reporting collisions are covered in other manuals so they will not be discussed here. The collision report narrative is where the investigator reports the results of the investigation, his observations and findings, and arrives at a conclusion on cause and contributing factors in the collision.

The author of this manual has seen numerous collision investigation report narrative formats, some are better than others, but there is no one format that is always best. The selection of narrative style is usually left to the department employing the officer, so extensive discussions on which format is best are somewhat academic.

For those officers whose agencies do not regulate report narrative format and style, two different styles will be presented as examples. Neither is truly "better" than the other, but they are different. Investigators should look at both and use whichever styles suits them.

EXAMPLE #1

FACTS:

On 10/9/XX at 1640 hours I was dispatched to the intersection of 11th street and Palo Verde street, regarding an injury collision. Myself and Officer Jones arrived at 1643 hours. I saw a young boy, later known to me as Jimmy Smith (7 y.o.a.), laying on the roadway at the intersection. He was being treated by paramedics. I also saw a 1987 Dodge Coupe (AZ Lic. ABC-123) stopped on the roadway approximately 45 feet south of the boy. There was a red boy's bicycle under the Dodge (see attached diagram). I secured the scene by blocking the intersection with traffic cones.

I located the driver of the Dodge, Mary Maple, standing on the sidewalk near the scene. Mrs. Maple provided me with her Arizona driver's license, and I interviewed her regarding the collision (see STATEMENTS). I also met witness J. Leno, who also provided a statement.

At approximately 1650 hours the victim was transported to General Hospital by Arizona Ambulance. I took photographs of both vehicles and all roadway evidence. Mary Maple was allowed to drive her vehicle home, and the bicycle was turned over to Jimmy Smith's father, John Smith.

I continued with my investigation by marking several roadway scrapes, skid marks, and the final position of the victim and the Dodge. I took all required measurements with assistance of Officer Jones and cleared from the scene at approximately 1730 hours.

LOCATION:

11th Street and Palo Verde, Cactus Cove, AZ

SCENE:

Day time, weather was dry and clear, 11th street is an asphalt paved roadway in a north-south alignment, two lanes with stripped centerline, there is a stop sign for all traffic approaching 11th street on Palo Verde. There was a small (2 x 3 inch) red paint scraping near the left front corner of the Dodge bumper, no other damage visible.

EVIDENCE:

Driver/witness statements
Officer's Observations

STATEMENTS:

Mr. J. Leno told me he was watering his lawn at 1234 Palo Verde (southwest corner of intersection) when he saw the Smith boy ride his bicycle into the intersection without stopping. Leno then heard the car's brakes and suddenly the car appeared, striking the boy. He estimated the car's speed at approximately 25 mph (statement attached).

Mrs. Maple told me she was southbound on 11th street, at approximately 25-30 miles per hours. She stated she is always cautious in this area as there are always children playing and riding bikes. She said that the Smith boy darted into the intersection and she didn't have time to stop(statement attached).

INJURIES:

The victim sustained a broken left leg, deep lacerations to the forehead, minor contusions, and a possible concussion. He was admitted to General Hospital.

OPINIONS/CONCLUSIONS:

The Dodge left skid marks for a distance of 67 feet, starting approximately 20 feet prior to impact. Using a drag factor of .7 yields a speed of approximately 37 miles per hour, in a 25 mph posted zone. The bicycle rider is obligated, by law, to stop at the sign prior to entering the intersection. Based on available evidence it is my opinion that the collision was caused by the pedalcyclist's failure to yield to the Dodge. The Dodge was exceeding the posted speed limit by 17 mph, this was a contributing factor to the severity of the injuries.

RECOMMENDATIONS:

The driver of the Dodge was cited for speed.

EXAMPLE #2

INITIAL OBSERVATION

Upon arrival at the scene, I observed a vehicle (traffic unit #1) stopped on the south side shoulder of the on-ramp to I-40 milepost 289G. A pedestrian was lying in the middle of the roadway being attended by local ambulance personnel at that location. there were several items of personal apparel in the roadway prior to the pedestrian as well as some under-carriage debris.

ENVIRONMENTAL AND ROAD FACTORS

The location of the collision is a one-way on-ramp eastbound at milepost 289G. The roadway is constructed of asphalt surface and was full of defects.

TRAFFIC UNIT INFORMATION

Traffic unit #1 sustained contact damage to the grill, hood and windshield that was consistent with collision with a pedestrian. Several pieces of fabric were observed in the grill that appeared consistent with clothing worn by traffic unit #2.

Traffic unit #2 is a pedestrian that sustained major trauma to the head, neck, and both legs. he was transported to Jim's Hospital by the rural ambulance company.

WITNESS INFORMATION

There were no known witnesses to the collision.

INVESTIGATION

Investigation revealed that traffic unit #1 was eastbound on the on-ramp to I-40 at milepost 289G accelerating onto the interstate. The driver stated that as he reached the top of the ramp, he observed a pedestrian walking in the roadway. He attempted to stop his vehicle by applying his brakes but was unable to do so. His vehicle struck the pedestrian from the rear. The pedestrian rotated onto the hood of vehicle #1 and then into the windshield.

Evidence at the scene was consistent with the driver of traffic unit #1's statement and is documented on the attached diagram.

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Appendix

EQUATIONS FOR THE TRAFFIC COLLISION INVESTIGATOR

DEFINITIONS

a = acceleration or deceleration rate, in feet per second
per second (fps²)

C = chord

D = distance

f = acceleration or deceleration factor, drag factor or
coefficient of friction

g = Acceleration due to gravity (32.2 feet per second²)

M = middle ordinate

R = radius of a curve

S = speed, in miles per hour

t = time, in seconds

V = Velocity, in feet per second

Velocity to travel a known distance in a known time:

$$V = \frac{D}{t}$$

Distance traveled at a constant velocity and a known time:

$$D = V \cdot t$$

Time to travel a known distance at a constant velocity:

$$t = \frac{D}{V}$$

Acceleration or deceleration factor when speed and distance are known:

$$f = \frac{S^2}{30 _ D}$$

Acceleration or deceleration rate when acceleration/deceleration factor is known:

$$a = g _ f$$

Basic speed formula, decelerating to a stop when distance and drag factor are known:

$$S = \sqrt{30 _ D _ f}$$

Combined speed:

$$S = \sqrt{S_1^2 + S_2^2 + S_3^2 \dots}$$

Converting speed (MPH) to velocity (FPS):

$$V = S _ 1.47$$

Converting velocity (FPS) to speed (MPH):

$$S = \frac{V}{1.47}$$

Critical speed of curve, or path of center of mass when radius and drag factor are known:

$$S = \sqrt{15 \cdot R \cdot f}$$

Distance to accelerate or decelerate to a or from a stop,
when speed and acceleration/deceleration factor are known:

$$D = \frac{S^2}{30 \cdot f}$$

Radius of a curve when chord and middle ordinate are known:

$$R = \frac{C^2}{8 \cdot M} + \frac{M}{2}$$

TRAFFIC COLLISION TERMINOLOGY

ACCELERATION: time rate of change of velocity; change of velocity divided by time; a vector quantity measured in feet per second per second (fps^2) or expressed as a decimal fraction of the acceleration of gravity (32.2 fps^2).

ACCIDENT (COLLISION): occurrence in a sequence of events that usually produces unintended death, injury, or property damage. The term 'collision' has gained wider acceptance as a more accurate term for what used to be referred to as an accident.

APEX: the point at which two sides of an angle meet or cross.

AREA OF IMPACT: the place on the roadway or ground closest to the first contact between colliding objects.

ARC: part of a curve; especially part of a circle, between two points on a curve.

BERM: see shoulder.

BRAKING DISTANCE: the distance through which brakes are applied to slow a vehicle; the shortest distance in which a particular vehicle can be stopped by braking from a specified speed on a particular surface; the distance from brake application to collision.

BRAKING SKID MARK: see skid mark.

CENTRIFUGAL FORCE: the force of a body in motion which tends to keep it continuing in the same direction rather than following a curved path.

CHORD: a straight line connecting the ends of an arc or two points on a curve.

COEFFICIENT OF FRICTION: a dimension-less number representing the resistance to sliding of two surfaces in contact; the drag factor of a vehicle or other object sliding on a roadway or other surface which is level.

CONTACT DAMAGE: damage to a vehicle resulting from direct pressure of some foreign object in a collision or rollover. It is usually indicated by striations, rub-off of material, or puncture. Compare with induced damage.

CONTROLLED FINAL POSITION: a final position reached because of conscious effort of some person to modify the motion of a traffic unit after a collision.

COORDINATE: a method of locating a spot in an area by measurements along and at right angles to a reference line or by measurements of the shortest distances to each of two intercepting reference lines. Compare with triangulation.

CRITICAL SPEED: the speed at which centrifugal force of a vehicle following a specific curve exceeds the traction force of the tires on the surface; a velocity above which a particular highway curve could not be negotiated by a vehicle without yaw.

CRITICAL SPEED MARKS: see yaw marks.

CROOK: an abrupt change of direction of a tire mark due to collision forces. See offset.

DEBRIS: loose material strewn about the road as the result of a traffic collision; dirt, liquids, vehicle parts, and other materials from the involved traffic units.

DECELERATION: rate of slowing; negative acceleration.

DISENGAGEMENT: see last contact.

DRAG FACTOR: a number representing the acceleration or deceleration of a vehicle or other body as a decimal fraction of the acceleration of gravity. When a vehicle slides with all wheels locked, the drag factor is the same as the coefficient of friction.

ENERGY: ability to do work or produce an effect such as damage; a unit of force operating through a unit of distance; half the mass or weight times velocity squared; measured in foot-pounds (ft-lb).

FINAL POSITION: the location of a vehicle or body when it comes to rest after a collision; final positions may be controlled or uncontrolled.

FIRST CONTACT: the initial touching of objects in a collision; the place on the road or ground where this touching occurs.

FIRST HARMFUL EVENT: the first occurrence in a traffic collision that results in appreciable damage or injury.

FLIP: the movement of a vehicle, without touching the ground, from a place where its forward velocity is suddenly stopped by an object such as a curb or furrow-in below its center of mass with the result that the ensuing rotation lifts the vehicle off the ground. A flip is usually sidewise but if it is endwise, it is a vault.

FOGLINE: the solid white line that separates the drive lanes from the shoulder/berm area.

FURROW: a channel in loose or soft material, such as soil or dirt, made by a skidding or scuffing tire or some other part of a moving vehicle.

GAP SKID: a braking skid mark which is interrupted by release and reapplication of brakes or which terminates by release of brakes before collision. Compare with skip skid.

GOUGE: a pavement scar deep enough to be easily felt with the fingers.

GRADE: the change in elevation in unit distance in a specified direction along the center line of a roadway or the path of a vehicle; the difference in level of two points divided by the level distance between the points.

HIGHWAY: the entire width between the boundary lines of every way publicly maintained when any part thereof is open to the use of the public for purposes of vehicular travel.

IMPRINT: a mark on the road made without sliding by a rolling tire.

INDUCED DAMAGE: damage to a vehicle other than contact damage, often indicated by bending, braking, and distortion. Compare with contact damage.

INTERSECTION: when two or more roadways cross or connect, the area contained within the extension of curb lines, or, if none then the lateral roadway boundary lines is defined as the intersection.

KINETIC ENERGY: the amount of energy represented by a moving body; half of the mass times the square of the velocity.

LAST CONTACT: the final touching of objects in a collision before separation.

MAXIMUM ENGAGEMENT: greatest penetration of one body, such as a vehicle, by another during collision; moment of greatest force between objects in a collision.

MIDDLE ORDINATE: the perpendicular distance between an arc and its chord at the middle of the chord.

NOMOGRAPH: a graph on which three or more scales are arranged so that a straight line drawn through values on any two will cross the third at a corresponding value.

OFFSET: see crook.

RADIUS: the distance from the center of a circle to a point on its perimeter (circumference); the distance from a point on an arc to the center of the circle of which the arc is part.

REFERENCE LINE: a line, often the edge of a roadway, from which measurements are made to locate spots, especially spots along a roadway.

REFERENCE POINT: a point from which measurements are made to locate spots in an area; sometime the intercept of two reference line; RP.

ROAD: the part of a trafficway which includes both the roadway, which is the traveled part, and any shoulder or berm along the roadway.

ROADWAY: that portion of the highway improved, designed, or ordinarily used for vehicular travel, exclusive of the berm and shoulder.

ROLLOVER: a situation where the vehicle rolls at least 90 degrees. The term rollover is also sometimes used to describe a pitchover (vault).

SCRAPE: a broad area of a hard surface covered with many scratches or striations made by a sliding metal part without great pressure.

SCUFF MARK: a friction mark on a pavement made by a tire which is both rotating and slipping.

SHOULDER: that portion of the road contiguous with the roadway for accommodation of stopped vehicles, for emergency use, and for lateral support of the roadway structure.

SKID MARK: a friction mark made on a pavement by a tire that is sliding without rotation.

SKIP SKID: a braking skid mark interrupted at frequent regular intervals; the skid mark made by a bouncing wheel on which brakes keep the wheel from turning.

TRAFFIC: pedestrians, ridden or herded animals, vehicles, street cars, and other conveyances either singly or together while using any highway for purposes of travel.

TRAFFIC UNIT: an element of traffic; a person using a trafficway for travel or transportation; vehicle, pedalcycle, pedestrian.

TRAFFICWAY: see highway.

TRIANGULATION: a method of locating a spot in an area by measurements from two or more reference points, the locations of which are identified for future reference.

UNCONTROLLED FINAL POSITION: a final position reached by a traffic unit after a collision without conscious human intervention.

VAULT: an endwise flip.

VEHICLE: every device in, upon, or by which any person or property is or may be transported or drawn upon the highway, excepting devices moved by human power or used exclusively upon stationary rails or tracks.

VELOCITY: time rate of change of position in which direction as well as rapidity is an element; distance divided by time if velocity is constant.

YAW MARK: see scuff mark