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TEXAS TRAFFIC SIGNAL DETECTOR MANUAL

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16. Abstract
A guide to the design and installation of detectors for long life and high reliability. This report contains many suggestions for more rapidly installing loop detectors. It reports on the testing of several innovative loop designs and addresses the special needs of bicycles, MOPED and motorcycles. Special emphasis is given to detector sealants, high speed saw blades and loop wire.

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TEXAS TRAFFIC SIGNAL DETECTOR MANUAL

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Texas Traffic Signal Detector Manual
Evaluation of Loop Detector Installation Procedures and
Preparation of a Texas Traffic Signal Detector Manual
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ABSTRACT

This manual presents the operational basis of induction loop detectors. Installation principles, treatment of commonly encountered field problems, and suggestions to reduce lane down time loop installation are discussed.

The manual is intended for use by field personnel in planning for and installing induction loop detectors. Procedures for high speed dry cutting of asphaltic concrete are presented. Sealants that have proven successful are indicated.

DISCLAIMER

The contents of this report reflect the views of the author who is responsible for the opinions, findings and conclusions presented herein. The contents do not necessarily reflect the official view or policies of the Federal Highway Administration, U.S. Department of Transportation, or of the Texas Department of Transportation. This report does not constitute a standard, specification or regulation. This report is not intended for construction bidding or permit purposes.

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1.0 INTRODUCTION

1.1 Purpose

This traffic signal detector manual is a guide for persons who install detectors. Others may find it to be a good reference manual. The manual presents the following pertinent points:

1. Installation procedures that ensure reliable performance.
2. Suggested practices to reduce loop installation time and maintenance costs.

This chapter details the principles of traffic detection. It also emphasizes the difficulty of detecting all vehicles with one detector layout.

1.2 Detection Principles

Vehicle detection is necessary as traffic demand is different throughout the day. It sometimes varies dramatically over a 5-minute interval. For efficient traffic movement, the actuated signal controller must know the traffic demand. The detection system is the critical element in determining this demand. The detector should be placed in the path of the vehicle. The presence of a vehicle in the detection zone causes the detector (electronic unit) to respond with an output signal. The traffic actuated signal controller logic then adjusts signal timing and phasing to the demand.

Detection is accomplished in one of two basic ways:

1. A magnetic field exists when a current passes through a wire embedded in the pavement. A vehicle passing through this electromagnetic field adsorbs some of the energy in eddy currents in any closed conductive circuits in the vehicle. This takes energy away from the loop detector. A frequency change in the tuned loop circuit results. This change in frequency, if above the established threshold value, is interpreted as the presence of a vehicle in the detection zone.

The size of the change in peak frequency before and after the vehicle is present is the basis for indicating a vehicle detection. This concept is graphically illustrated in Figure 1.1.

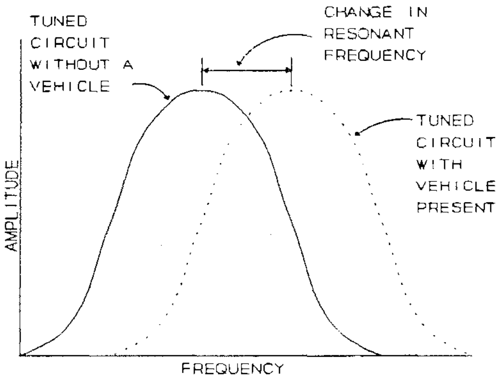


Figure 1.1 Illustration of Changes in Tuned Circuit Measured in ILD's

2. The second measurement method is based on the earth's natural magnetic field. This type of detector is described briefly in Section 8.0.

1.2.1 Pedestrian Detectors

The basic pedestrian detector is the push button. Location of the push button near the crosswalk is essential. The pedestrian pushes the button which activates the pedestrian timing features of the controller. This is a very simple detection unit. Grounding of the pedestrian circuit is necessary to isolate it from the controller cabinet voltage and reduces the power and lightning surge damage to the controller. Isolation is accomplished by using an opto-isolator or a pedestrian isolation card? There is no further reference to pedestrian detectors in this manual.

1.2.2 Typical Application of ILD'S

The typical application of ILD vehicle detection is found at an isolated, signalized intersection. An approaching vehicle passes through the detection zone. The detector unit (electronic unit) responds by sending a signal to the controller. The controller either extends the existing green interval or brings back the green display to that approach as soon as possible.

In other applications, detectors can provide data to store for processing at another time. These data are useful for planning purposes or for the evaluation of traffic control improvements on arterial streets or freeways.

1.2.3 NEMA Definition of a Detector

The National Electrical Manufacturing Association (NEMA) defines a detector as "**a device for showing the presence or passage of vehicles or pedestrians.**"

1.2.4 Presence Mode

A presence detector places a CALL when the vehicle enters the detection zone. A presence detector then holds the CALL until the detection zone is clear. The percentage of the time that the detector is ON determines the lane occupancy rate. Presence detection is particularly useful in left-turn lane vehicle detection. Presence detection also allows estimation of vehicle speed using a single detector by assuming the average vehicle length.

The time duration of detection divided by vehicle length is the approximate vehicle speed. If accurate speed data are needed, use two detectors separated by 10 to 16 feet along the lane.

1.2.5 Pulse Mode

In the pulse mode, the detector serves as a passage detector. A unit CALL goes to the controller when the vehicle first enters the detection area. The vehicle remaining in the detection zone has no further effect on the controller after the first CALL. A square wave signal of approximately 1/10 second duration is all the controller receives. Pulse detection is particularly useful in traffic counting and speed measurement, and for placing calls when presence detection is not required.

1.3 Principles Of Operation

The inductive loop detector's electronic system change with the passage of a vehicle through its electromagnetic field is the basis of detection. The more flux lines cut by the vehicle, the greater the potential change in the electronic circuit. This means there is a better chance of detecting the vehicle. All induction loop detectors have a sensitivity switch. It alters the frequency shift which must exist to show the presence of a vehicle. Two interacting factors control the flux density through which the vehicle will pass. These are (1) the shape of the loop, and (2) the number of turns of wire used in the loop.

Figure 1.2 shows some of the shape effects. Note that a long rectangular loop increases the chance of detecting vehicles in adjacent lanes. This problem may become acute for loops more than 20 feet in length. Long dimensions along the direction of travel also reduce the chance for detecting the presence of small vehicles in the center of the detection area. This is due to relatively low flux density in the center of the loop. The shape of the inductive loop detector (ILD) should increase the flux density in areas of desired detection. It also should reduce the flux density in areas where no detection is desired. This concept is shown in Figure 1.3.

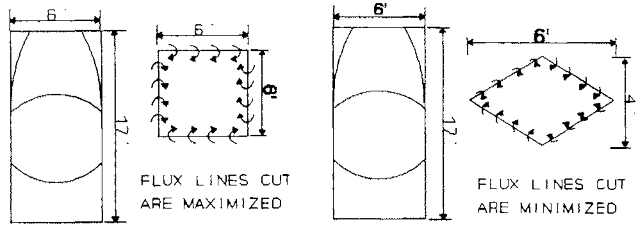


Figure 1.2 Spillover Detection Concept Illustration

A loop of only 6 feet in length can also be critical to detecting smaller vehicles. This is due to the very low number of flux lines cut by the smaller vehicle in crossing the two sides of the loop perpendicular to the line of travel. Figure 1.3 illustrates this concept.

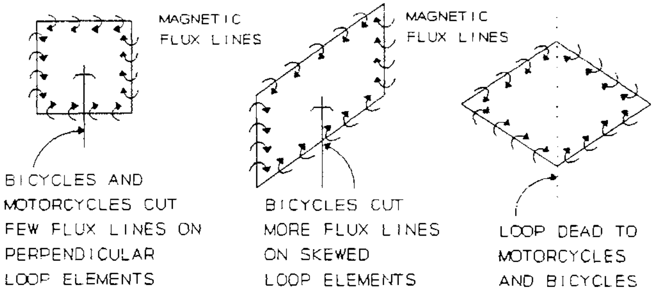


Figure 1.3 Loop Shape Effects on Small Vehicle Detection

1.4 Radar And Sonic Detectors

Radar and Sonic detectors are available. They usually require a very high level of special maintenance capability. For this reason, they are seldom used in modern traffic control strategies.

1.5 The Importance Of Proper Detector Installation

The detection system is the key input to the successful operation of a $50,000 to $100,000 signal installation. The importance of careful location and installation of the detectors cannot be overstressed. Poorly installed detectors are an additional cost to the State of Texas and the motoring public. Do your work with pride. You are responsible for both the safety and efficiency of the best surface transportation network in the world - - The Highways and Streets of Texas.

1.6 Use Of This Manual

The inductive loop detector (ILD) is the primary traffic detection system used in Texas. This manual serves as a ready reference on ILD practices. It does not constitute a standard or specification. This manual is a reference to good practice, and is intended for "**reference only**". The reader is urged to carefully read this manual and implement the suggestions offered. Where the suggested procedures are not practical or fail to perform well, the reader is asked to notify File D-18TE of this fact.

2.0 PRINCIPLES OF DETECTOR OPERATION

2.1 Basic Considerations

The loop consists of one or more turns of wire in a shallow slot sawed in the pavement in a pattern specified by the site plan. The lead wires go to the curb then through or under the curb to a pull box (splice box). No splice is allowed outside the pullbox. In the pull box, the loop lead wire is spliced to the shielded cable used to connect the loop to the detector. If leads from two or more loops must share a common saw cut, it is good practice to twist the leads three to four times per foot to completely nullify the field of the leads. This practice helps to prevent false detection. Where only one pair of leads is involved, twisting the lead wire in the saw cut is not necessary. One pair per slot is recommended.

In the pull box, the two lead wires are carefully connected to a shielded cable which runs to the controller cabinet. Conduit is normally used for all wire runs behind the curb or outside the paved surface. **Splices must be made waterproof.** Twist connectors and plastic tape are not considered to be full waterproofing. The factory twisted wire, shielded cable connects to the detector. This detector energizes the circuit at a radio signal frequency (RF signal) typically in the range of 20 to 200 kHz.

The detector (electronic unit), the lead and loop wire comprise a tuned RF circuit. The loop is the inductive element of the system. A vehicle entering the detection zone will absorb some of the RF signal energy due to the electrical eddy currents created by the closed loop conductive materials of the vehicle chassis and body. This results in a change in the tuned circuit resonant frequency. This change in the tuned circuit, measured as peak frequency change, is interpreted by the detector as a vehicle in the loop detection zone.

2.2 Loop Characteristics

2.2.1 Loop Inductance

A wide range of loop shapes are successfully used. Regardless of the loop shape, the resulting inductance of the loop or loops and the lead wire must fall within the acceptable range of the detector. That is, the loop, lead wire and pullbox to controller cable inductance are all included. The loop system must also be compatible with the operational requirements specified by the designer. The total induction limitation is rarely a problem with modern electronics. The typical range of inductance for commercially available detectors (electronic units) is 20 to 2000 microhenries. Operating loop systems normally fall in the 50 to 300 microhenry range. In addition to determining the loop system inductance, the resistance to ground must also be measured before and after sealing the loop. At 500 VDC, the resistance to ground must be 50 megohms or more.

2.2.2 Determination of Loop System Inductance

Figure 2.1 is a graphical estimate of loop inductance. These are reasonably accurate estimates for simple loops (i.e., no interior wire runs) whose area relative to the spacing of the wire runs is very large. This includes all loop shapes in common use except the quadrapole.

An additional 23 microhenries per 100 feet of lead wire must be added to the estimated loop inductance value. Thus, for a 6' x 6' (24-foot loop perimeter) loop made with two turns of wire and assuming 250 feet of lead wire, the inductance is:

$$\begin{aligned} I_{6' \times 6'} &= \text{Loop Inductance} + \text{Lead Wire Inductance} \\ &= 37 \text{ (from curve)} + 23(250/100) \\ &\qquad\qquad\qquad\qquad 23 \text{ h}/100' \ (250'/100) \end{aligned}$$

$$I_{6' \times 6'} = 37 + 58 = 95 \text{ microhenries}$$

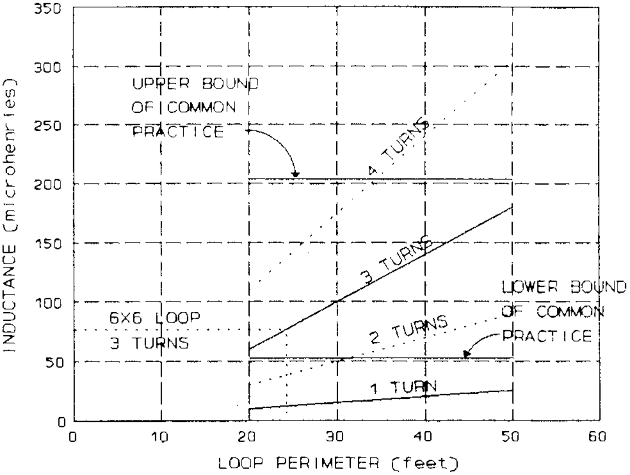


Figure 2.1 Induction Loop Inductance Estimation Curves

This loop is near the limit of good operation. It may be insensitive since a majority of the inductance comes from the lead wire. A three-turn loop of the same dimension (6' x 6') would yield an induction of 76 microhenries and when combined with the 58 microhenries from the lead wire results in a total of 134 microhenries. This would be a far better loop in the field. To have a majority of the inductance coming from the loop is the general guiding principle in designing loop configurations.

When two loops are connected in series, their inductances are added. For example two 124-microhenry loops connected in series would have a system inductance of 248 microhenries. For series connection, the mathematical form of this statement is:

$L = L_1 + L_2$ (Series Connection)

Loops wired in parallel result in an inductance which is the inverse of the sum of the inverses of the individual loop inductances. This is mathematically expressed as:

$$\frac{1}{L} = \frac{1}{L_1} + \frac{1}{L_2} \quad \text{(Parallel Connection)}$$

For two loops connected in parallel, one with an inductance of 76 microhenries and the other with an inductance of 124 microhenries, the resulting system inductance is:

$$\frac{1}{L} = \frac{1}{76} + \frac{1}{124} = \frac{124 + 76}{(76)(124)} = \frac{200}{9424}$$

$$L = \frac{9424}{200} = 47 \text{ microhenries}$$

From the above illustrations, series connection of loops increase the circuit inductance. Parallel connection of loops decreases the circuit inductance. The normal design inductance range is 50 to 300 microhenries. A combination of loop size, number of turns of wire and electrical connection of two or more loops into a system are used to stay within the normal inductance range.

Series connection of loops results in the most sensitive detection system when long lead distances are involved. This is due to the larger value of loop series inductance compared to the lead inductance.

2.2.3 Loop Quality Factor "Q"

The quality factor is a measure of the efficiency of the loop circuit. It is a dimensionless index. If losses in the loop circuit are high, then the quality of detection will be low. No energy loss in the loop circuit would be ideal and the quality factor "Q" should be very high. For acceptable operation, "Q" should be 5 or greater.

The quality factor "Q" is frequency dependent. Therefore the frequency in the tuned RF circuit must be known. These data are available in the manufacturer's technical literature for the detector, or they can be directly measured with a loop tester when the full loop circuit is in place. The quality factor "Q" is expressed as:

$$Q = \frac{\text{Loop Inductive Reactance}}{\text{Loop Electrical Resistance}} = \frac{2 \ f L \pi}{R}$$

Where: f = loop resonant frequency in hertz
L = loop inductance in henries
R = loop resistance in ohms
π = 3.1416, a constant

Typical ranges of tuned frequencies for loop detectors in common use in Texas are between 25,000 and 105,000 hertz. The lower bound is the controlling one. Solving the quality factor equation for an "f" of 25,000, a minimum inductance of 50 microhenries and a minimum "Q" of 5 yields a maximum circuit resistance of about 1.5 ohms. **If the measured loop circuit resistance at the cabinet exceeds 1.5 ohms, the quality of the loop detection circuit will be poor, and a revised design should be considered.** The key point to remember is to measure the loop resistance and the resistance to ground **before** the loop is sealed.

A vehicle passing through the earth's magnetic field warps the field. A circuit tuned to the null position under normal magnetic field strength will sustain an inductance change as a result. This changes the tuned frequency of the circuit. If the change is above the threshold value set on the detector, the presence of a vehicle in the detection zone is indicated.

3.0 ILD'S DESIGN ELEMENTS AND FIELD EXPERIENCE

3.1 Number Of Turns Of Wire Needed In The Induction Loop Detector Sensor

The number of turns of wire required is directly related to the size of the loop detection area and the electrical connection configuration of multiple loops. Table 3.1 presents guidelines that keep the inductance loop above 50 microhenries.

Table 3.1
Recommended Number of Turns for Loop Detectors

LOOP PERIMETER SIZE (FT.)	NUMBER OF TURNS	APPROXIMATE LOOP SIZES INCLUDED
24' or Less	3 or 4	5' x 5', 6' x 4'
25' - 110'	2 or 3	6' x 10' - 6' x 45'*
110' or More	1* or 2	6' x 50' or Longer*

* **A series of short loops used in lieu of the long loop or offsetting the loop within the lane are acceptable methods of reducing to spillover detection problem of long loops. When the offset loop approach is used, the delay feature of the detector must be used to eliminate the problem of opposing through traffic and cross street left-turn traffic actuating the detector.**

* **Loops longer than 10 feet with one wire turn should have a power header.**

Modern detection equipment normally places a call based on a given threshold change in the peak frequency (f, see Figure 1.1) of the tuned loop circuit. Increasing the number of turns of wire increases sensitivity. More flux lines are cut by the vehicle and thus a greater change in resonant frequency results. This also increases the probability of false detection or detection of vehicles in adjacent lanes. Good practice dictates using the minimum number of wire turns required to stay above the 50-microhenry level. Loops with a single wire may allow small vehicles to go undetected. Therefore, it is recommended that a minimum of two turns be used in any typical loop installation or a power header be installed with the single wire long loop.

3.2 Loop Wire

The loop wire is damaged by traffic action if it works to the surface. Also, thin wire insulation can be penetrated by a sharp saw-cut edge. This section discusses selection of wire and sealant to ensure reliable detection.

For electronic reasons, a cross-linked polyethylene insulation is best suited for loop detection applications. The dielectric constant changes are minimal with changes in temperature. A 14 AWG stranded wire of the USE-RHH-RHW-XLPE or XHHW type is recommended.

Consideration of stranded number 12 AWG is justified when the quality of the pavement is questionable or when the site traffic volume is high. Number 12 AWG has a lower resistance that increases the quality factor of the loop. It is also more resistant to breakage due to pavement cracking. The cost difference is small as shown in Table 3.2. The use of number 12 AWG wire may require a wider slot for efficient and effective installation of the wire.

The loop wire is inexpensive compared to the other cost elements in loop installation, especially labor and traffic control. Heavy insulation (0.045 inch) is recommended for all loop installations. The cost ratio for the heavy duty insulation and regular insulation is shown below. The USE-RHA-RHW-XLPE twisted pair may not fit in a 1/4-inch slot.

Table 3.2
Typical Cost of Loop Detector Wire When Purchased in Bulk

WIRE 1989 COST PER 1000 FEET

TYPE	# 12	# 14	INSULATION
XHHW	\$89.78	\$73.81	Cross Linked Polyethylene (0.032" Thick)
USE-RHH-RHW-XLPE	\$111.31	NA	Heavy Duty Cross--Linked Polyethylene (0.045" Thick)

The resulting cost difference for typical loop shapes is:

Condition: Going from #14 AWG to # 12 AWG wire. A wider saw cut may be required.
COST PER FOOT: (89.78-73.81)/1000 = \$0.01597/foot
6 x 6, 4-turn loop ADDED COST = \$1.53/loop
6 x 40, 2-turn loop ADDED COST = \$2.94/loop

Condition: Going from XHHW to USE-RHH-RHW-XLPE stranded wire
COST/FT: (\$111.31-89.78)/1000 = \$0.02153/ft
6 x 6, 4-turn loop ADDED COST = \$2.07/loop
6 x 40, 2-turn loop ADDED COST = \$3.96/loop

Condition: #14 AWG to #12 AWG and XHHW to USE-RHH-RHW-XLPE
COST/FT: \$0.01597 + \$0.02153 = \$0.0375/foot
6 x 6, 4-turn loop ADDED COST = \$3.60/loop
6 x 40, 2-turn loop ADDED COST = \$6.90/loop

Based on this analysis, the added cost of going to #12 AWG wire and/or to the heavier insulation is negligible and the decision to use any wire size or insulation type should be based on operational needs rather than cost alone.

3.3 Loop Sealant And Loop Sealing

A wide variety of sealants are available commercially. Many provide relatively good service under a limited range of environmental exposure. Few, if any, can serve the full range of needs in the field. For example, many come only in 1-quart and 5-gallon containers. Successful application depends upon the department having a unit that will allow placement of the sealant down into the slot. Others are packaged in one-quart cartridges which require only a generic caulking gun, but are more difficult to apply.

Some sealants adhere well to asphaltic concrete but not at all to portland cement concrete. Some are excellent at 75 degrees F but very brittle at a minus 10 degrees F. Curing is slow at 35 degrees for some, while others do not cure at all at 35 degrees F.

Generalization of the loop detector sealant studies is difficult. However, some guidelines are necessary to effectively install loop detectors from which a long functional life can be expected. These general guides are presented below:

3.4 General Observation Of Sealant Performance

1. Almost any sealant that remains pliable within the normal working pavement temperature range will adhere to asphaltic concrete.

2. Very few sealants adhere to portland cement concrete.

3. For portland cement concrete, lightly blast prior to wire placement. The sandblasting is necessary in order to rough up the polished saw-cut face.

4. Fluid sealants at the placement temperature were most easily placed and resulted in the neatest installations. They also tend to flow down the grade when the grade exceeds 2 percent.

5. The sealant must be at least three-fourths of an inch thick to be effective.

6. If tracking is a problem, some type material should be applied to dry the surface of the sealant. Talc, cement and fine sand will dry the sealant surface sufficiently to allow traffic on the loop immediately. It is recommended that the sealant surface be left 1/8 to 1/4 of an inch below the pavement surface to reduce the tracking problem.

7. Even good sealants do not cure well at pavement temperatures below 40 degrees F. Loops should not generally be installed when the pavement temperature is below 40 degrees F. When installation is required, the sealant will not cure until the temperature rises. When installation is required at low temperatures, the normal loop installation procedures are recommended.

8. Asphalt cement does not make a good sealant. The cured asphalt cement may be very brittle at low temperature. Wire failures due to fractures of the pavement being reflected through the brittle asphalt are common under these conditions. Also, the hot asphalt may damage the wire insulation. Cold laid asphaltic concrete can be used in areas not subject to prevent freezing temperatures.

9. Field experience has revealed that epoxy sealant becomes brittle with age and low temperature. A crack in the pavement across the wire run is reflected through the epoxy fracturing the wire. For this reason, epoxy is no longer commonly used to seal detector loops.

Be certain to read the limitation on the use of each sealant prior to using it.

3.5 Premature Loop Failures

Field experience indicates that very few premature loop failures occur when the loop has been properly installed. A few guidelines are appropriate to assist in achieving this goal:

1. <u>Do not install loops in a pavement showing signs of</u>

shoving, rutting or bad cracking without first improving the pavement. In surface shoving situations, a loop placed 3 inches deep in the pavement has been successfully used. Another alternative is to use a loop wire which has substantial tensile strength (i.e., Loopduct) or to use conduit for the wire and place it about 12 inches below the surface. Successful tests have been conducted with a four-turn loop 20 inches below the pavement surface.

2. Avoid placing loops across existing pavement joints or wide cracks, if at all possible. Provide slack in the wire when it is required.

3. Do not use sharp edged tools to push the wire down. A flat wooden lathe or paint stirring stick work well.

4. Never allow a splice outside the pullbox. Solder all splices using resin core solder and completely waterproof the finished splice.

5. Check loop continuity before and after sealing.

6. Check loop electrical resistance before and after sealing. A resistance greater than 1.5 ohms measured at the controller cabinet may mean the quality of detection will be too low, and the quality factor should be determined before continuing with the installation.

7. Check loop insulation resistance before and after sealing. Using a Meggar, resistant should be ≥ 50 Megohms @ 500 VDC.

Following these seven guidelines reduces the risk of a premature loop failure to a minimum.

The vast majority of loop replacements which were properly installed come from damage by mechanical equipment. Roto-milling, heater-planer operation, utility cuts, and other contractor equipment are the most frequently cited causes of loop failures. The placement of the loop wire deeper than 1 1/2 inch below the pavement surface minimizes the possibility of the lead wire being damaged during surface maintenance operations.

4.0 SELECTING THE CORRECT LOOP CONFIGURATION

4.1 Introduction

Selecting the best loop configuration for the detection problem at hand is a fundamental part of a high performance, traffic actuated signal system. There are four fundamental questions that must be answered in order to select a loop with a high probability of consistent, reliable detection. These are:

1. What range of vehicle types must be detected?
2. Is presence or pulse mode or a combination of both to be used?
3. Does a special operating environment exist that would adversely affect loop operation?
4. What special limitations exist because of desired geometric or special operational features.

Each of these areas is discussed below. In each case, the loop configuration requirements to achieve and hold the detection in presence mode are provided.

4.2 Design Vehicle Group To Be Detected

All Groups

Width - Minimum 5 feet, maximum 6 feet (Too narrow causes partial cancellation of the flux field, reducing field height. Too wide a loop reduces the probability of detecting small cars and motorcycles.)

Length - Maximum 10 feet, minimum 6 feet (Loops longer than one-half a car length maximize the possibility of spillover detection). The use of multiple loops is preferable where a longer detection area is desired. For left turn lane detection, a long one-turn loop can be used, if a provision is made to accommodate the spillover detection problem.

See Section 4.6 for additional detail.

Group I Design Vehicles - Passenger Cars Only

Shape - Not critical (maintain 5-6 foot nominal dimension)
Turns - Preferably 3, 2 for long loops.
Sensitivity Setting - Low, medium or high are equally reliable.
Lead Length - Up to 1,000 feet; 500 feet or less is desirable.

Group II Design Vehicles - Large High Profile Trucks

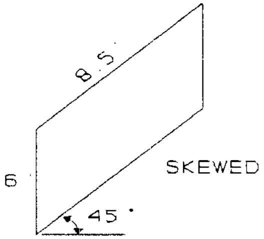
Shape - Not cratical
Turns - At least 3
Sensitivity Setting - Medium or high (height of field may be insufficient when low sensitivity used).
Lead Length - Keep the lead to 1,000 feet or less.

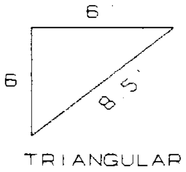
Group III Design Vehicles - Motorcycles

Shape - Avoid long loops without a power header.
Turns - At least 3 turns of wire.
Sensitivity Setting - Medium or high.
Lead Length - 1,000 feet or less.

Group IV Design Vehicles - Bicycles and Mopeds

Shape - A 45-degree slot across the vehicle path with 4 turns. The 6'x 6' loop skewed at 45 degrees or 6'x 6' right triangular loops are recommended (very narrow vehicles require flux lines across the vehicle path);





Turns - At least 4 turns required (Increased flux density required due to narrow vehicle).

Sensitivity Setting - Medium or high (at low sensitivity setting bicycles and MOPEDS missed - i.e., very weak signal).

Lead Length - 1,000 feet or less.

4.3 Type Of Operation Desired

Each loop detector unit has a switch which allows the selection of operating mode. Presence mode and pulse mode are the most commonly used names for these modes. Presence mode operation results in the detector being "on" while the loop area is occupied. Pulse mode, as the name implies, sends a square wave pulse of about 0.1 second duration to the controller. Further occupancy of the loop area by the same vehicle results in no additional action by the detector. Presence mode operation allows the controller to allocate the green time to each phase as demanded by the actual traffic flow pattern. Pulse mode operation usually requires a locking detector memory setting on the traffic detector controller unit.

Presence mode operation of loop detectors is preferred at isolated signal locations and for semiactuated operation. Pulse mode is preferred when the detectors are being used for counting traffic and determining speed. However, it is important to note that either mode can be used in either application. Check the signal plans to be certain of the controller cabinet setup.

The selection of the mode of operation does not affect the loop installation process. It does impact the location decision for loops in the system. A change in the loop location required by a site condition must be carefully considered in light of the operational mode that has been selected for use. Before changing the loop location, check with the designer to be certain that the change is compatible with the operational needs that have been planned into the loop system layout.

When the loop is used for nonsignal traffic engineering functions, it may be located at sites that appear to be strange to field personnel. For example, detectors for traffic adjusted signal systems are commonly placed downstream from an intersection rather than upstream. Counting detectors are usually located well away from intersections. A pair of loops used for speed determination must be at a location where the vehicles are free flowing and not influenced by intersection control systems. The loop layout has assumed many operational parameters. Before relocating the loop for any reason, check back with the office staff to ensure that the change (relocation) will not negate the design function of the system.

4.4 Operating Environment Demands

The presence of high voltage power lines under the pavement, a site with soil having a very high iron content, an unstable surface lift of asphaltic concrete, or undulating intersection pavement surface all have an impact on both the detector type choice and the controller parameter settings. Modern detection equipment has largely overcome the adverse effects of the first two problems. The latter two are normally uncovered in the field investigation phase of the design process. On occasion, these features may be overlooked or a change has occurred since the inspection took place. Therefore, the first step in the field installation process is to review the site to identify any features of the area that would adversely affect loop operation. The reader is referred to the Site Check List included in Section 3.3 of this Manual.

Radio and television transmission facilities normally do not adversely affect loop detector operation. They operate at substantially higher frequencies than do loop detectors. On occasion, harmonics of the basic radio or TV frequency have been reported to impair loop detector operation. It is not clear whether this is the older manual tuning detector units or the modern wide inductance range, self-tuning detectors. Tests within 500 feet of a large area FM radio station and a TV transmission tower revealed no operational problems in the loop frequency range of 20 to 110 kilohertz.

Undulating pavement surface conditions affect loop layout and operational decisions. The problem is the speed reduction necessary to safely drive through the intersection.

Frequently, this condition occurs when a two-way stop controlled intersection is signalized. The drainage along the major street is commonly carried through the intersection. The required stop condition meant that only low-speed operation was possible through the intersection area. When signalized, operation on the green interval places the speed near the posted speed of the facility. The undulating pavement surface radically reduces the vehicle speed, adversely affecting capacity, and increasing the required green and yellow time necessary for safe clearance.

The undulating surface condition should be corrected at the design stage. If it is not, then the signal **should not** be part of a progressive signal system. It should be designed for all vehicles on the rough pavement direction of traffic to stop prior to entering the intersection; that is, semiactuated operation. Desirably, underground drainage should be provided to allow a moderate to high speed surface condition through the intersection area in all directions of travel.

4.5 Dual Mode Operations

Dual mode (or mixed mode) loop operations are commonly used to overcome geometric deficiencies of the intersection. In particular, the lack of a left-turn lane or the existence of right-turn-on-red from a separate right-turn lane. The lack of a left-turn lane creates congestion due to left-turning vehicles blocking through traffic maneuvers. The off-side loop offers a workable solution to this problem. The loop is placed on the left half of the intersection in the path of the left-turning vehicles. The exclusive left-turn interval comes up and is held as long as left-turn traffic is crossing the off-side loop. A gap in left-turning traffic returns the display to the permissive left-turn operational mode.

A second approach to accommodating left turns without a left-turn lane is to operate the left-hand lane detector nearest the intersection of a multiple detector system on presence mode while the remainder of the detectors operate on pulse mode or all loops in the presence mode. When traffic is moving quickly through the intersection, the presence detector acts very much like a pulse mode detector.

A backup due to a delay in making the left turn causes the detector to hold the green time until the queue is cleared or to call in an exclusive lagging left-turn arrow in order to clear the left-turn traffic.

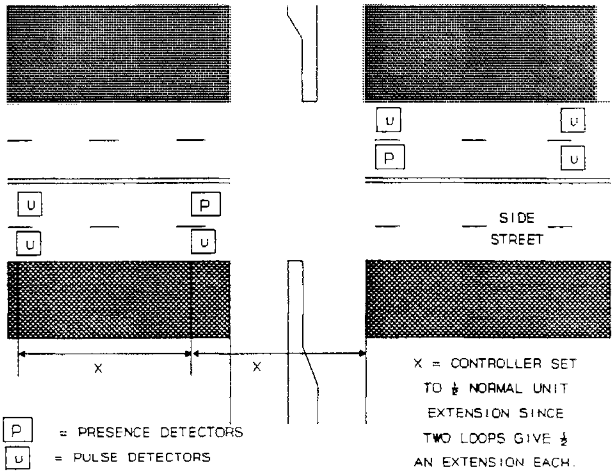


Figure 4.1 Special Left-Turn Mixed Mode Operation Loop Locations

Both of these examples illustrate the wide range of special detector location and operational modes that may be called for in any particular set of traffic signal plans. Mixed mode operation (pulse mode and presence mode) is used to optimize traffic flow at a point on the roadway. If you are unclear as to the appropriateness of the loop location, it is wise to cross-check to be certain that the location in the plans is correct.

4.6 Spillover Detection Control On Left-Turn Presence Loops

The use of a long presence loop for left-turn detection is common. Such installations have a high potential for spillover detection by a vehicle in an adjacent lane. Two methods are successfully used to address this problem. The long loop can be created by using several shorter loops (i.e., 10-foot maximum length). A second equally effective method is to move the long loop laterally in the lane until the nearest long run is 4 feet from the right side lane line of the left-turn lane.

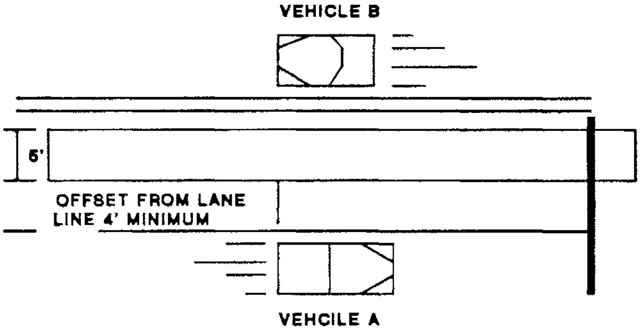


Figure 4.2 Left-Turn Spillover Control

Shifting the left-turn loop to provide a minimum of 4 feet of separation between the lane line and loop edge reduces the spillover detection problem for vehicle A. The loop width may need to be reduced to 5 feet for narrow (10 feet or less) left turn lanes.

The shift to the left may allow opposing traffic (vehicle B) to activate the left turn lane detector. The "DELAY" feature of the detector may provide a solution to this problem. The appropriate "DELAY" setting is a function of the loop length. Suggested settings are:

Long Loop Length (feet)	Suggested Delay Setting (seconds)
Up to 40'	2
40' to 80'	3
Over 80'	4

Two successive vehicles occupying the opposing traffic lane adjacent to the left turn lane may be detected even with the delay settings suggested above. This situation usually occurs when the cross street protected left turn phase is operating. Use of the pin J "power on" setting to inhibit any detection from the left turn detector during this phase may eliminate this problem.

A second method of reducing the spillover detection problem is a series of short loops to simulate a long loop. The individual loop may be separated up to 20 feet without appreciable impact on the operation of the presence mode detection system. The loop width should be reduced to five feet for narrow left turn lanes.

4.7 Preventing Crosstalk When Multiple Lane Detectors Are Used At A Point On The Roadway

Several detector lead pairs may run in a single bundle to the controller. When the frequencies are all similar, crosstalk between loops is common. One method of addressing this problem is to add a capacitor or inductor to the detector circuit to reduce or increase the frequency. This provides the essential separation of the individual loop circuit frequencies and permanently eliminates any possibility of crosstalk regardless of the detector setting. The detector setting can provide such a separation. However, if the detector frequency setting is ever changed, the crosstalk can return. The use of capacitors and/or inductors is the best permanent solution to the problem. Capacitors in the range of 0.001 to 0.06 microfarads are recommended. Inductors of 680, 820, and 1,000 microhenries are commonly used.

Where many lead pairs run together into the controller, this method should be used to insure a permanent separation of the operating frequency of each loop.

Several closely spaced detectors can create the same problem. For example, with one detector loop in each of five lanes of a freeway, there is not enough difference in lead length to provide a significant change in loop frequency. Combining a variable number of turns of wire with carefully selected application of capacitors or inductors can insure satisfactory operations without crosstalk. The pattern shown below is one such plan. The inductors used in this application should be 680, 820 or 1000 microhenries and be a minimum of 1 watt to reduce the problem of lightening spikes. Capacitors used in series with the loop should be between 0.001 and 0.06 microfarads.

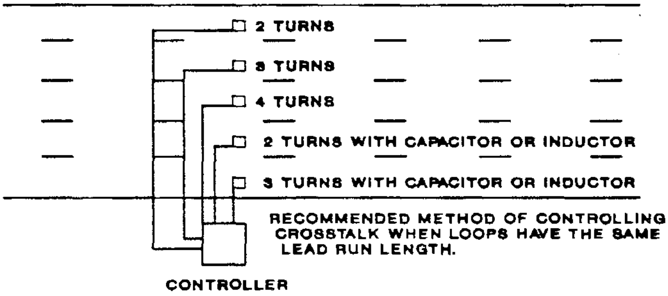
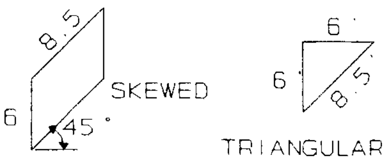


Figure 4.3 Crosstalk Control On Multilane Freeway Detectors

4.8 Loop Detector Recommendations

The summary below incorporates all of the basic loop detection principles previously discussed in a readily usable form.

DESIGN VEHICLE	RECOMMENDED LOOP
Passenger Cars Only	6' x 6' rectangular loop with 2 to 4 turns of wire. Use multiple loops for larger detection areas. Maximum lead length 1,000 feet. Use low, medium, or high sensitivity setting.
High Profile Truck	6' x 6' rectangular loop or 6' x 6' skewed loop @ 45 degrees to the flow of traffic with 4 turns of wire. Use multiple loops for larger detection areas. A 1,000-foot or less maximum lead length should be used.

Motorcycles	6’ x 6’ skewed loop at 45 degrees across the traffic lane or 6’ x 6’ right triangular loop with 3 or 4 turns of wire. A 1,000-foot maximum lead length. **Use medium sensitivity setting.** 
Bicycles and Mopeds	6’ x 6’ loop skewed 45 degrees across the traffic lane or 6’ x 6’ right triangular loop with 4 turns of wire. A 1,000-foot maximum lead length. **Use medium sensitivity setting.**

5.0 INSTALLATION PROCEDURE

5.1 Preliminary Planning

The success and efficiency of loop detector installation is directly related to the preplanning for that installation. A plan sheet is usually available from which the basic layout dimensions are determined. The planning steps include selecting the equipment and supplies that are required; knowing what traffic control devices are needed and making certain they are on the field truck; determining the equipment necessary to completely check out the field installation and having it available on the field truck; and knowing the time required to complete each task, selecting an installation time-of-day that will minimize the impact on the motoring public. The last item not only saves the public and the agency time and money but also provides the maximum possible safety for the field installation personnel.

This chapter includes a section on each of these areas. Additionally, several critical installation items are discussed.

5.2 Preplanning For The Job

The preplanning tasks begin by reviewing in detail the plan sheet for the loop installation. The following questions should each be answered affirmatively:

1. Are the loop locations referenced to at least two well-defined points?

2. Are dimensions for all loop sides shown on the plan sheet?

3. Does the lead plan provide at least 12 inches between the lead saw cuts at every point as they extend across the pavement surface?

4. Is the loop wiring pattern (turn direction) shown on the plan sheet?

5. Are the numbers of turns of wire shown?

6. Is the depth of cut for the saw cut specified?

7. Is a detail showing the treatment of the loop corner provided?

8. Is a detail showing the approved curb and gutter treatment shown?

9. Is a North Arrow provided on the plan sheet?

10. Is shielded cable called for? If so, is a sufficient continuous run available?

11. Are specific lightning protection units called for and are there enough of them?

12. Are there special grounding requirements? Are there sufficient ground rods?

13. Is the intersection sketch the same as the field conditions?

14. Is the detector limited to a single traffic lane?

Remember, there should be no unresolved questions when you go into the field.

The following questions may be answered either "yes" or "no." When the positive response occurs, be sure the needed supplies are available.

1. Are wire holddowns called for? If so, How many are required and are they available?

2. Is a particular type of loop wire called for?

3. Is a special type of sealant required?

4. Can the work area be shut down for an hour or more? If "Yes," plan for closure based on approach speed (i.e.,

MUTCD). If "No," consider alternative techniques for installation under continuing traffic movement (i.e., flagging and no closure).

5. Does the plan sheet call for identifying the lead end (L) and the tail end (T) of each loop wire at the pull box?

6. Is the pavement portland cement concrete? A different saw blade and cutting technique is required in PC (wet cutting) as compared to AC. Also a source of water is required for wet cutting.

7. Does this site require "high speed" loop installation? If "Yes," are you prepared with the larger saw (65 horsepower) and special blade (Diamond Blade)? Do you have at least 100 pounds of dead weight to hold the saw down?

8. Is the pull box to controller cable to be run (also see question 10 in the section above)?

9. Does the plan call for concrete under and/or around the pull box? If "yes," is premix concrete available on the truck?

The preplanning task reduces unproductive time during field installation as well as motorist delay. This task is an essential step in loop installation.

5.3 Field Site Visit

Desirably, a supervisor should visit the site prior to sending the field crew out. In some instances, the travel time to the site may make this prohibitive. In this situation, the field site review is the first step in the installation process. Even before any traffic control has been set out. The check list below should guide the field site review.

CHECK LIST OF POTENTIAL SPECIAL SITE PROBLEMS
TRAFFIC DETECTOR LOOP INSTALLATION

1. Condition of Pavement at Planned Loop Location

___ Sound - No Noticeable Problems --> Continue installation process
___ Rutted Noticeable --> Advise Supervisor
___ Alligator Cracking --> Advise Supervisor
___ Pavement Joint Crossed --> Advise Supervisor
___ Sizable Pavement Crack Crossed --> Advise Supervisor
___ Thin Pavement or Unpaved Road -->
  a. Check plans to see if noted
  b. If no, advise supervisor
  If yes, continue installation
___ Utility Work or Unexpected Construction Work in the Area --> Advise Supervisor

NOTE: DO NOT PROCEED UNTIL YOU ARE CERTAIN OF THE SITUATION.

2. Are Locations of Existing Utilities Identified or Their Absence so Stated on the Plans?

Water
___ Yes --> Continue Installation
___ No --> Contact Utility and/or Advise Supervisor

Natural Gas
___ Yes --> Continue Installation
___ No --> Contact Utility and/or Advise Supervisor

Telephone or Cable TV Trunk Lines
___ Yes --> Continue Installation
___ No --> Contact Company and/or Advise Supervisor

Electrical
___ Yes --> Continue Installation
___ No --> Contact Utility and/or Advise Supervisor

Sanitary Sewers
___ Yes --> Continue Installation
___ No --> Contact City Public Works Department for Clarification

High Pressure Gas Lines
___ Yes --> Continue Installation
___ No or Unknown --> Check with Gas Company and/or Advise Supervisor

3. Special Situation That Will Make Loop Installation Questionable; (manhole, bridge deck, drainage inlet, etc.)

___ Yes --> Reason:______________________________
--> Advise Supervisor
___ No --> Continue Installation

4. Proposed Lead Runs to Controller Will be Difficult or are Closer Together Than 12 Inches.

___ Yes --> Reason ______________________________
--> Advise Supervisor
___ No --> Continue Installation

5. Proposed Pull/Splice Box Site at Low Point (May Flood) or in a Sidewalk.

___ Yes --> Relocate Pull Box and/or Advise Supervisor
___ No --> Continue Installation

6. Is the Pavement at the Proposed Loop Location Covered with Dirt, Mud, etc.?

___ Yes --> Clean Pavement Before Installation
Is a large sweeper required?
    ___ Yes --> Advise Supervisor
    ___ No --> Clean Manually
___ No --> Continue Installation

A traffic control plan (TCP) is available with the signal plans. During the site review, mentally locate each device called for and note any conflict that is apparent. Plan a way to avoid the conflict and submit the revised traffic control plan for approval. For installation on a local street approach, bypassing the traffic to another street during the installation is often the best alternative.

5.4 Manpower Estimates

The field site review should provide sufficient information to allow estimation of the time required to install the detectors. Table 5.1 contains suggested task times to assist in this process.

Table 5.1
Tasks in Installing Loop Detectors

Based on one 6' x 6' Loop With Four Turns of Wire
and 20 Feet of Lead Slot to Curb From Detection Point

REQUIRED ACTIVITY	REQUIRED PERSONNEL	TIME
1. Check for Special Site Problems	1	5 Min.
2. Set up Traffic Control		
Normal Speed Cutting	3	20-35 Min.
High Speed Cutting		10 Min.
3. Trace Loop Pattern on Roadway	2	5-10 Min.
4. Make Final Check of Location for Accuracy	2	2 Min.
5. Cut Loop and Lead Slots (high speed sawing)	2	6 Min.
(normal speed cutting or PC)	2	30 Min.
6. Remove Sharp Edges at Slot Intersections (chisel)	1	2 Min.
" " " (corner cut)	2	10 Min.
" " " (core corner)	1	15 Min.
7. Clean Loop and Lead Slots	2	
Dry Cut		5 Min.
Wet Cut		10 Min.

Table 5.1
Tasks in Installing Loop Detectors (Continued)

REQUIRED ACTIVITY	REQUIRED PERSONNEL	TIME
8. Install Loop Wire in the Slot	2	5 Min.
9. Test Loop for Continuity	2	5 Min.
10. Prepare Curb and Gutter For Conduit	2	10 Min.
11. Seal Loop into the Pavement/Curb and Gutter	2	15 Min.
12. Clean up the Pavement at Site	2	5 Min.
13. Remove Traffic Control	3	10 Min.
14. Dig Hole for Pull/Splice Box	1	15 Min.
15. Install Pull/Splice Box, Set Concrete and Backfill	1	2 Hours 30 Min.
16. Install Conduit and Lead to Controller	2	30 Min.
17. Splice Loop Leads and Waterproof at Pullbox	1	30 Min.
18. Ground Shielded Cable at Pull Box	1	10 Min.
19. Clean up Site	2	15 Min.

ESTIMATED TOTAL INSTALLATION

TIME	LANE BLOCKED	TOTAL
Normal Speed Cutting or P.C.	- 1 Hr. 23 Mins	4 Hrs. 33 Mins.
High Speed Cutting	- Periodically	3 Hrs. 50 Mins.

Assumptions:

1. Flag person used during all on-the-pavement operations
2. Two persons required when sawing slots
3. Three-person crew required
4. Some activities not requiring all three persons can be scheduled simultaneously.

5.5 Equipment Required For Loop Installation

5.5.1 The Saw - Wet vs. Dry

Wet cutting is necessary in portland cement concrete and may be desirable in asphaltic concrete. In each instance, the water must be blown from the slot prior to continuing installation of the loop. Wet cutting increases the life of the diamond saw blade. A good practical way to avoid problems with wet cut installation is to require at least one day delay between sawing and installation of the loop wire. Asphaltic concrete can be successfully dry cut at high speed, but only at the expense of blade life. Wet cutting in AC will result in blade life near 30,000 inch-feet (1 foot long and 1 inch deep). Cutting dry will reduce the life of the blade. No data are available from which to definitively estimate the blade life reduction. Experience suggests that a one-third reduction in blade life should be expected when cutting dry, if the blade is not overheated. Dust control may be a problem when dry cutting; thus, wet cutting is desirable.

A high speed router has also been successfully used to prepare a slot for the loop wire. The resulting 3/8-inch wide slot is sealed with cold laid asphaltic type FF ACP concrete.

5.5.2 Saw and Blade Selection for High Speed Loop Slot Cutting

In selecting the concrete saw and diamond saw blade for high speed saw cutting, some essential points are:

1. The saw must be large enough to provide all the power necessary to keep the blade from "bogging" down. The largest commercially available concrete saw is the 65 horsepower unit. **For high speed dry cutting, a 65 horsepower unit should always be used.** Just having a 65 horsepower saw does not guarantee successful high speed cutting. It must be capable of delivering 65 horsepower. Old saws often run poorly and thus fail to deliver sufficient power.

When cutting at high speed, the blade tends to ride up out of the slot, resulting in a substantial variation in the depth of cut. A difference of up to 1/2 inch is common. Adding 50 to 100 pounds of dead weight directly over the blade drive shaft will correct this problem. In the cutting speed range of 25 to 30 inch-feet per minute, the added weight significantly reduces the variability of saw slot cut depth. On a 6-foot long cut at 30 inch-feet per minute, the entire cut takes 12 seconds. There is no time to make cutting depth adjustments.

2. Diamond blade design is a specialized area of expertise. Generalization about the best blade to use is difficult due to the variation of aggregate across the state. The best blade for the job is one that matches the cutting requirements (speed and pavement hardness) and the specifics of the saw. In general, diamond quality and quantity must match the specific material being cut. The diamonds are set in a matrix which is laser welded to the blade blank. The principles guiding the design process are:

a) Maximize blade life
b) Expose new diamond cutting edges only after the surface ones are rounded to the point that they are no longer efficient in cutting.

The requirement to cut faster means exposing new diamonds more quickly. This, in turn, means a reduction in the life of the blade. The matrix used to hold the diamonds must be matched to the speed of the saw. The centrifugal force throws the diamonds out after a time sufficient to round the diamond cutting edges. By making the matrix softer, the cutting diamonds are released sooner and a faster cutting rate is possible. Increasing or decreasing the power of the saw will, by necessity, force a change to a blade that is better suited for the saw and pavement type.

5.5.3 Indicators of an Underpowered Saw

In addition to the "bogging down" of the saw under load, other indicators of an underpowered saw or improper match of blade to the saw and/or the pavement are useful.

1. A white or blue smoke is emitted in front of the saw. This is an indication that the blade is excessively hot. Using water to reduce the blade temperature or selecting a more appropriate saw blade are the best treatments. Failure to recognize and correct this problem may cause excessive diamond chip loss and short blade life.

2. Blue to black discoloration of the blade core just below the cutting edges is another indicator of excessive heat in cutting. Follow the guidelines in 1 above.

3. Breakup of part or complete loss of the cutting edge units indicates excessive pressure on the blade during cutting. Diamond loss is usually preceded by one or both of the indicators described in 1 and 2. Reduction in cutting speed with the same type of blade, adding water to cool the saw blade, or selection of a blade better suited to the job are the best alternatives in this situation.

Simply adding water does not necessarily mean that the problem is solved. The water jets must direct the water to strike the blade near the center of the core. Centrifugal force then throws it out to the edge.

The placement of the water is accomplished such that the water arrives at the cutting edge of the blade about the time the edge point in question goes down into the pavement. This maximizes cooling and lubrication. A poor water distribution system on the saw can be nearly as bad a situation as dry cutting. Check the saw water distribution system each time wet cutting is used to ensure that water is being directed onto the blade near its center.

5.5.4 Other Equipment Requirements

In addition to the selection of the proper saw and blade, several other field equipment requirements exist:

1. Power Saw - A self-propelled power saw equipped with a water valve, a depth of cut gauge, and an alignment guide is essential.

2. Water Supply - A water supply sufficient for one day's operations should be available on the field truck.

3. Compressed Air - An air compressor of sufficient capacity to provide at least 50 psi at 2 cfs is needed. Air is required for the jack-hammer or core drill and to clean the saw cuts.

4. Jackhammer or core drill for boring holes through or under concrete curbs, when called for. Going under the curb and gutter section is the preferred treatment.

5. A 1 1/2-inch wide cold chisel and large hammer for removing the sharp edges of the loop corners.

6. A blunt wooden stick (such as a paint stirring stick or wooden lathe) for seating the wire in the slot.

7. A wire pair twister system. A pair of wooden sticks will suffice. This device is used to provide a uniform twist over the length of the leads when two or more loop leads run in the same saw cut. Also a minimum 3/8-inch wide slot is required. Running loop leads in separate saw cuts is preferred.

8. Traffic control devices as required to satisfy the traffic control plan for the site. Be certain to use the complete traffic control plan as specified in the TCP.

9. An adjustable template or straight edge (carpenter's chalk line acceptable) for drawing loop outlines on the pavement. Spray painting over a tight line is also a good way to provide a straight alinement.

10. Small trenching machine for burying cable.

11. Electricians fish tape for pulling cable through conduit.

12. A portable 110 volt AC gasoline generator, if required, to provide power for making solder connections and to provide a source of light for night work.

13. A 50 megohm meggar for checking the loop resistance to ground.

14. A loop analyzer to check for electrical continuity and to measure the inductance of the finished loop.

15. A loop finder to permit identification of dead loops in a series of loops connected in parallel.

16. A soldering iron rated for open air use (either butane or electrical) or a soldering gun.

17. A flexible measuring tape at least 100 feet in length.

5.6 Material Requirements

The final planning phase item is to be certain that sufficient materials to finish the job are available prior to leaving the shop. These include:

1. Loop wire - Remember no splices are allowed in the pavement surface,
2. Lead-in shielded cable,
3. Pull boxes (splice boxes) as required for the job,
4. Loop sealant sufficient to seal all loop slots, lead slots and the hole(s) through or under the curb should be available,
5. Splice kits for waterproofing pull box splices,
6. Conduit for the curb to pull box run and pull box to controller run.
7. Power supply surge protectors,
8. Rosin core solder,
9. Spray paint or chalk for outlining loop, and
10. Wire lubricant for electrical wire lubrication during pulling.

5.7 Installation Phase

5.7.1 Loop Layout and Sawing the Slots

The loop will be laid out on the pavement prior to sawing. Check the location to be absolutely certain that it

is correct before beginning the sawing. The layout of the loop should then be checked with that required on the plans. Finally, the layout on the pavement surface must allow for guidance of the saw in a straight path until a full overlap with the intersecting saw cut is obtained. This eliminates the sharp edge at the bottom of the saw cut.

Cutting at normal speed will result in the lane being closed during the installation. **For high speed sawing,** traffic needs only to be stopped for a few seconds. Therefore, a flagger is used to hold traffic while the in-the-roadway operations take place for lower speed roadways.

The #14 loop wire is about 0.2 inches in diameter. Using a guideline of about 1 1/2 inches minimum cover to reduce surface maintenance damage problems, a saw-cut depth of 2 inches is used for one or two turns of wire. When three or four turns of wire are used, a cut depth of 2 inches to 2 1/2 inches is recommended. Avoid cutting too deep as excessive pavement damage will result. These recommendations assume a 1/4-inch saw-cut width. The following table summarizes the saw-cut depth recommendations.

Table 5.2 Saw Cut Depth Recommendations
3/8" to 1/4" Slot

Number of Turns of Wire	Recommended Minimum Slot Depth
1 or 2	2"
3 or 4	2" to 2-1/2"

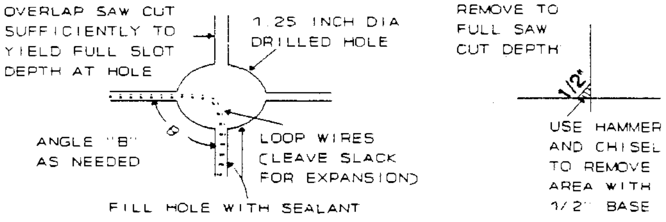
5.7.2 Loop Corner Treatment

The sharp edges at the corner may need to be treated to reduce the wire installation time. Three methods are in common use: core drilling, punching with a jackhammer, and trimming with a hammer and cold chisel. A source of compressed air should always be available at the site. A jackhammer will be needed to punch through or under the curb and gutter section. Field experience indicates that the hammer and cold chisel requires the least time. The object is to provide space for the fingers when adjusting the wire at the corner. When bending the corner, the wire by necessity comes up out of the slot on the down stream wire run. This allows the wire to rest high up in the slot at the corner. A slight tension is required to place the wire. Pushing the wire down after it has been firmly set at the corner can damage the loop wire insulation.

A heavy hammer with a 1/2-inch wide cold chisel, when placed diagonally across the corner such that the chisel edges correspond with the inner edges of the saw cut, allows sufficient space to easily accomplish the wire installation task. About 10 seconds per corner is required for this treatment. A small flat blade screw driver or pocket knife will be needed to clean out the slot. **The screw driver or pocket knife MUST NEVER be used in seating the wire in the slot.** A flat piece of wood such as a paint stirring stick or a piece of wooden lathe should be used to push the wire down.

Placing a hold down on each side of the corner is an effective way to avoid damage to the wire in placement. This takes more time than the chisel method but, when carefully done, is equally effective. When holddowns are not used, someone should precede the person doing the sealing to push the wire gently to the bottom of the slot.

On long loops, the hammer and cold chisel method may not provide sufficient slack to ensure space for temperature expansion. A 1 1/4-inch drilled or punched hole is recommended for long loops. This method is illustrated in Figure 5.1.



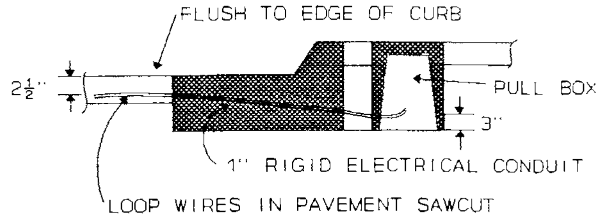
DRILLED HOLE CHISELED HOLE

Figure 5.1 Alternative Corner Treatments

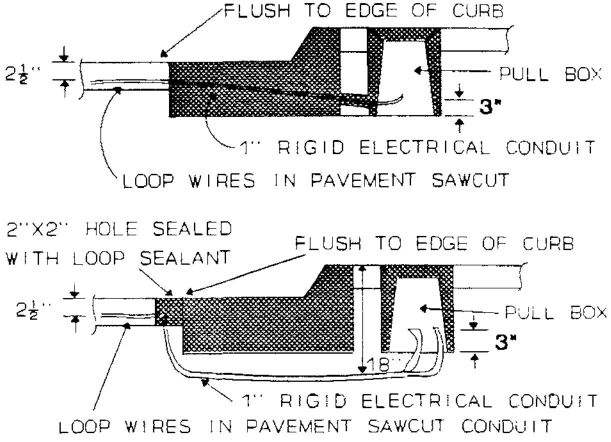
5.7.3 Curb and Gutter Treatments

The curb and gutter sections of urban facilities must be traversed without excessive curb damage. Also, no path allowing water to enter the subgrade can be permitted. This is accomplished by passing the conduit under the curb and gutter. Another commonly used procedure is to punch a 1-inch diameter hole through the curb and gutter section with a jackhammer. The hole begins at the base of the curb face and is sloped downward at about 45 degrees. The conduit fits up into the hole and runs to the pull box. Both ends are securely sealed so as to be watertight. Conduit running under the curb and gutter section is the preferred treatment. Details of these two treatments are presented in Figure 5.2 below.

An alternative to the jackhammer curb and gutter treatment is core drilling rather than punching the hole through the curb. This reduces the possibility of curb section damage. Saw cutting across the curb and gutter section has also been used to reduce the damage to the curb section. When this latter method is used, a flange should be attached to the back face of the curb to begin the conduit run or the pull box set immediately behind the curb. The major disadvantages of sawing the curb is the requirement for wet cutting P.C. concrete, the requirement of a 30-inch saw blade, and the susceptibility to damage due to roto-milling operations to restore the drainage path. These three alternative treatments are illustrated in Figure 5.2.



PUNCHED OR DRILLED



TAKEN UNDER (PREFERRED)

Figure 5.2 Alternative Treatments for the Curb and Gutter Section

5.7.4 Crossing Pavement Cracks or Joints

The loop layout should, to the maximum degree possible, avoid crossing pavement cracks or joints. When crossing of a crack or joint is necessary, a provision for joint movement must be provided. One common method is to saw the crossing an inch deeper than the slot. This is accomplished by adjusting the saw gradually as the crossing is approached. If the wire is then pushed down to the bottom of the slot, sufficient expansion slack will exist in the wire. Unfortunately, pulling the wire during downstream placement tends to pull out the slack. There is no easy way to check to be certain that the slack is provided short of measuring the depth to the wire. For this reason, alternative treatments have been developed. **It is important to recall that crossing the crack or joint should be avoided.** Several short loops rather than one long loop can keep the necessary crack crossings to a minimum.

The alternative treatment for crack or joint crossings is to punch or drill a 1 1/2 inch diameter hole or to saw cut a 1 1/2 inch hole at the crossing, as shown in the sketch below. This allows a "Z" to be placed in the wire at the crack. Visual checking of the hole then reveals if the necessary slack has been provided. Figure 5.3 illustrates these concepts.

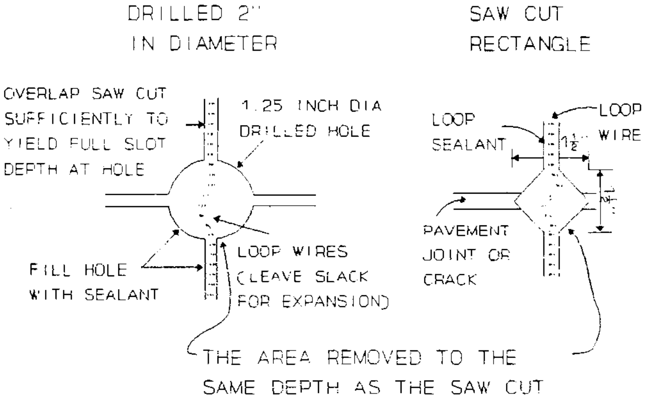


Figure 5.3 **Recommended Treatment at Pavement Cracks and Joints When Crossing is Required**

5.7.5 Conduit and Pull (Splice Box) Installation

All connections and splices in the loop wire are made in the pull box. A rigid conduit must run from the curb and gutter to the pull box except when the pull box is set immediately behind the curb. The preferred installation is for the loop ends to enter the pull box at the bottom. The pull box may be set directly behind the curb in the absence of a sidewalk, in the outer separator when the sidewalk is away from the curb, or beyond the sidewalk when the sidewalk is adjacent to the curb. The pull box should not be located within the sidewalk area unless it is required.

It is good practice to cast a concrete bottom for the pull box. For stability reasons, many agencies use a concrete collar around the top of the pull box as well.

5.7.6 Placing the Wire

The direction of current flow in the loop is important. The lead and tail ends of the wire are identified in the pull box. Beginning at the pull box, use a tab with the letter "L", for lead. On the return to the pull box, place a tab on the wire with the letter "T", for tail, on the wire. **REMEMBER**, no splices are allowed in the loop wire run. These tabs allow the direction of current flow in the loops to be used to increase or decrease the sensitivity in the area between the loops. This procedure, along with the right hand rule is presented in Figure 5.4.

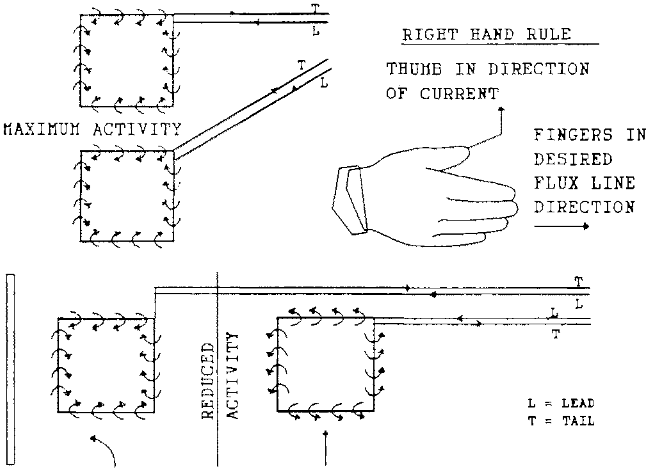


Figure 5.4 Current Flow to Optimize the Detection Objectives

The continuity of the loop, insulation resistance, and loop resistance should be checked and recorded before sealing the loop. Continuity must exist and the resistance to ground should exceed 50 megohms at 500 VDC. Failing either of these tests calls for rewiring the loop. Loop resistance should be less than 1.5 ohms. Exceeding 1.5 ohms suggests that the loop quality will be low. This should be checked to be certain "Q" is 5 or more, and any problems are resolved before sealing the loop begins.

Finally, cross-check the plan sheet to be certain that the loop location, layout, number of wire turns and other special plan requirements have been satisfied. Only then should the loop saw cut be sealed.

5.7.7 Electrical Grounding of the Shielded Cable

Electrical grounding of the cable shield on the pull box to controller run is not necessary or desirable in the pull box. The drain wire should be left floating and waterproofed. Grounding is normally accomplished at the controller cabinet end. If the system, grounded at the cabinet, continues to be an operational problem, request assistance from D-18TE.

5.7.8 Sealing the Loop

Sealing the loop serves two essential functions. First, the wire is held down below the surface level, reducing the possibility of traffic damage. Second, the sealant reduces the accessibility of water to the loop. Epoxy and hot asphalt were widely used to seal loops in the past. Hot asphalt often damaged the wire insulation. A brittle sealer such as epoxy or asphaltic cement, reflects any pavement cracks and often fractures the loop wire. This is a major contributor to premature loop failures, forcing a change to a more pliable sealing material. Extensive laboratory testing and limited controlled field studies revealed six sealants which can provide the pliability required. Table 5.3 summarizes the recommendations of the sealant study.

To enhance the bond to the polished cut face of the concrete, a light sandblasting is recommended. None of the products tested adhered well to portland cement concrete without sandblasting. Sandblasting is a commonly used installation procedure in building construction.

If slots are overfilled with sealant, dusting the sealed loop surface may be necessary when the lane is to be opened to traffic immediately. Cement, talc, or fine sand work well in dusting the surface.

5.7.9 Wire Splices

All splices are to be made in the pull (splice) box. Each splice must be watertight. **Plastic electrical tape or twist on wire nuts are not considered to be a watertight seal.**

Table 5.3
Recommended Sealants for Loop Detectors

Manufacturer	Product Name	Comments
3M Company	3M Loop Sealant	Very easy to use. Good bond to pavement.
Preco	One-Part	Very easy to use. Relatively long curing time.
Ruscoe Highway Products	Permanent Sealer 974	Very good pliability; more difficult to apply than those above.

The Type FF ACP cold mix asphaltic has proven to be successful in the non-freezing areas of the State. When a wider slot (3/8 inch or more) is being used and the location is outside the freezing zone as defined above, the Type FF ACP cold mix may be a suitable alternative sealant. Liquid asphalt (cutback asphalt or emulsified asphalt) is typically too brittle at low temperature to use for sealing loops for extended life reliability.

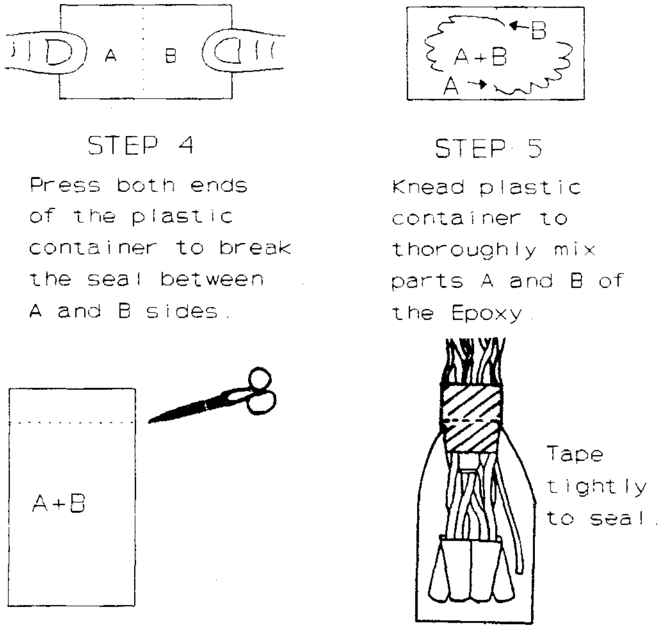
5.7.10 Water Proofing the Pullbox Splices

A commonly used method of providing a permanent watertight splice include the use of epoxy with a specially designed two-part plastic container. The two-sections are squeezed to break the seal between the sections. The two components are then fully mixed by kneading the plastic container. The wire group are taped securely together making certain that the drain wire is isolated. The end of the plastic packet is trimmed off, the bundle placed into the semi-fluid epoxy. The cut end is taped to the wire bundle above the bare wire sections of the splice. This system is illustrated in Figure 6.5. It is critical that every wire splice be made water tight to prevent shorting out of the loop circuit during periods of wet weather.

STEP 1. Use electrical tape or wire nuts to insulate each splice joint.

STEP 2. Cluster all splices to be sealed leaving the drain wire floating.

STEP 3. Tape all splices into a tight bundle being certain that the drain wire is left floating.



STEP 4

Press both ends of the plastic container to break the seal between A and B sides.

STEP 5

Knead plastic container to thoroughly mix parts A and B of the Epoxy.

STEP 6

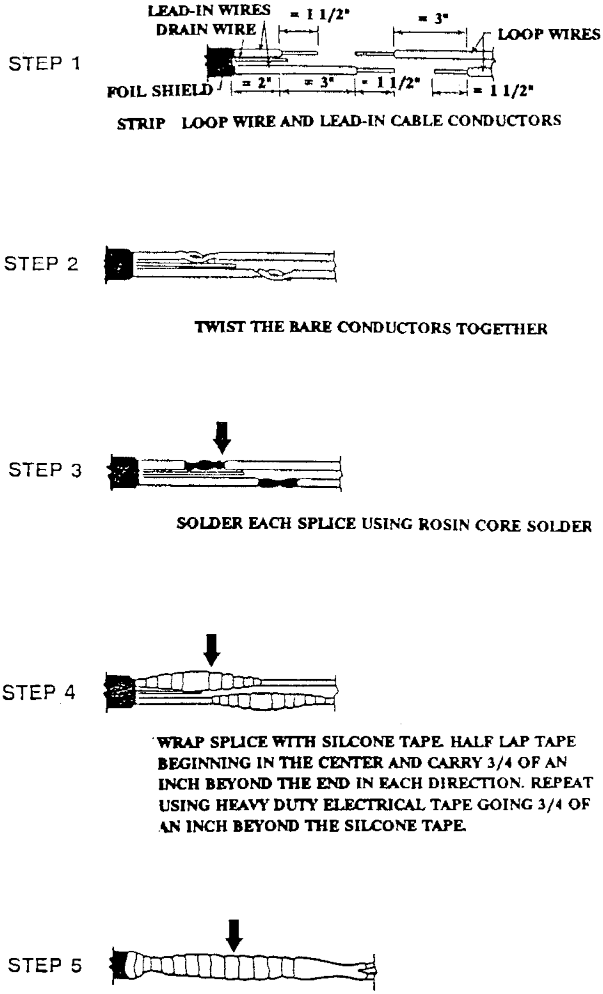
Cut off the end of the plastic container

STEP 7

Place wire bundle into epoxy container and tightly tape the open end around the bundle to seal the container

Figure 5.5 Two-Component Epoxy Splice Seal

Two other watertight seals are available. The first involves a heat shrink tubing. The steps in using the heat shrink seal is illustrated in Figure 5.6. Figure 5.7 illustrates a somewhat less costly method of forming a watertight splice seal. It uses a small paper cup and loop sealant. Both of these methods are being used very successfully in field applications.



STRIP LOOP WIRE AND LEAD-IN CABLE CONDUCTORS

TWIST THE BARE CONDUCTORS TOGETHER

SOLDER EACH SPLICE USING ROSIN CORE SOLDER

WRAP SPLICE WITH SILCONE TAPE. HALF LAP TAPE BEGINNING IN THE CENTER AND CARRY 3/4 OF AN INCH BEYOND THE END IN EACH DIRECTION. REPEAT USING HEAVY DUTY ELECTRICAL TAPE GOING 3/4 OF AN INCH BEYOND THE SILCONE TAPE.

HALF LAP THE TWO SPLICES TOGETHER USING ALL WEATHER HEAVY DUTY ELECTRICAL TAPE. TAPE TO LAP 1 INCH BEYOND THE LEAD-IN CABLE COVER.

Figure 5.6 Heat Shrink Tubing Watertight Seal for Wire Splices

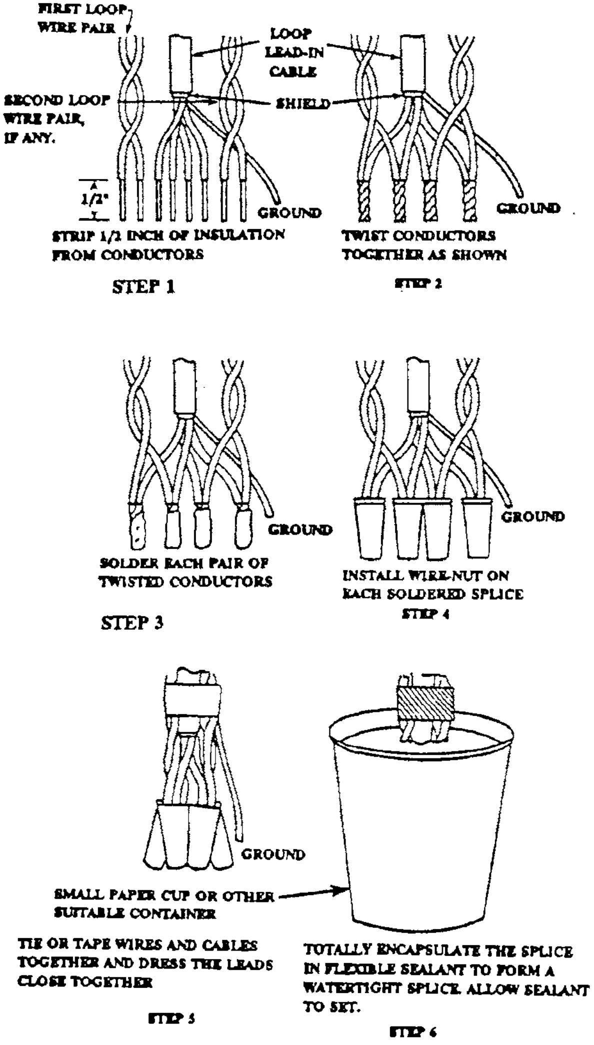


Figure 5.7 Paper Water Cup Watertight Seal Installation Procedure

5.7.11 Installing Lightning Overload Protection

Lightning protection elements are sometimes added to loop detector circuits in areas where lightning storms are common. These will normally go in the controller cabinet. However, the plans should be carefully reviewed to determine if special devices are called for in the pull box.

5.7.12 Loop Installation Tips

1. Splices SHOULD be soldered by hot iron, pouring or dipping (no flames) with rosin core solder.

2. Splices ONLY allowed in pull boxes.

3. Splices MUST be insulated and waterproofed.

4. Loop corners MAY be cored, chiseled or diagonally cut to eliminate sharp edges. Coring or chiseling are preferred.

5. Loop lead-in saw cuts SHOULD be at least 12 inches from any adjacent loop lead in wires.

6. Saw cuts MUST be deep enough to provide for 1 inch minimum coverage by sealant over uppermost wire, preferably 1 1/2 inches.

7. Loop wire size SHOULD be selected to allow sealant to fully encapsulate the wires. In a 1/4 inch saw cut, number 14 AWG wire is a suitable choice.

8. Loop wire MUST have high quality polyethylene insulation and be a stranded wire. USE-RHH-RHW-XLPE or XHHW is an acceptable loop wire type.

9. Loop wires MUST be laid out in the saw cut in the rotation (clockwise or counterclockwise) as specified on the layout and tagged to indicate lead (L) or tail (T) in the pullbox. This facilitates series splicing with alternate polarity connections (See item 16 below).

10. Loops SHOULD have a minimum of two turns of wire in any saw cut. When long presence loops are used, one turn with a two-turn 6' x 6' power header is acceptable. A special provision must be made to reduce the spillover detection problem when long loops are used. See section 4.6.

11. When two sets of loop lead-in wires must share a common saw cut, they SHOULD be twisted a full 360 degrees three times per foot as a minimum.

13. Loop lead-in wire in conduit, pull boxes and cabinets MUST be twisted through a full 360 degrees a minimum of three times per foot. Shielded multiconductor cables are so twisted in manufacturing.

14. Loop leads in pull boxes SHOULD be checked for continuity with an ohmmeter immediately after the wire installation has been completed, prior to placement of the sealant.

15. Loop leads in pull boxes SHOULD be checked with a 500 VDC megger to confirm that the insulation resistance to ground exceeds 50 megohms, prior to and after placement of the sealant.

16. Multiple loops connected to the same detector or loops side by side SHOULD be connected to enhance the detection function; usually this is accomplished by connecting every other loop's current flow in opposite directions when maximum sensitivity between the loops is desired, and in the same direction when it is desired to reduce the sensitivity between the loops.

Coding the lead ends "L" for LEAD and "T" for TAIL makes this connection pattern easy to accomplish.

17. Loop pull box to controller cable splices MUST be soldered, insulated and made waterproof.

18. Loop pull box to controller cables SHOULD have a crossed-linked polyethylene jacket.

19. Loop pull box to controller cables MUST be twisted a minimum of three complete 360 degree turns per foot of run, or shielded multiconductor cable must be used.

20. Loop pull box to controller cables SHOULD be shielded.

6.0 RECOMMENDED LOOP LAYOUTS

The recommended loop layout proven successful in various locations around the state is shown in Figure 6.1.

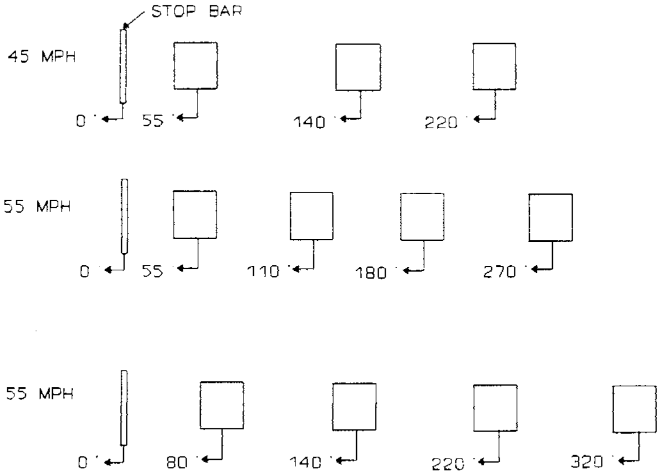


Figure 6.1 Recommended Loop Layouts

Controller Data for 45 to 55 mph:

Detector Memory Setting - Locking Mode

Detector Operation - Presence Mode

Minimum Green 8-14 seconds, depending on traffic volume, speed and number of trucks.

Passage Interval 1-1.2 seconds

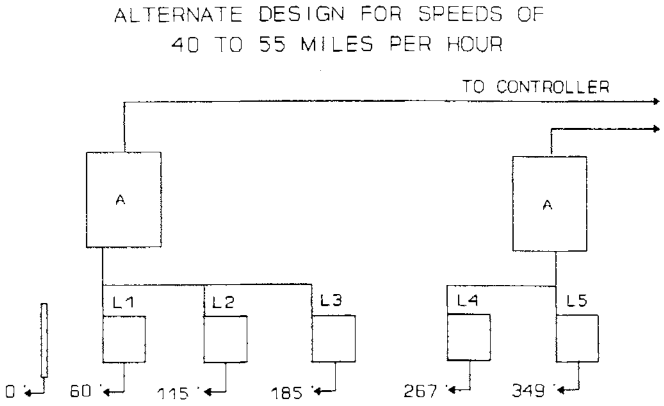


Figure 6.2 Alternate Loop Layout

CODES: A - Detector Units (amplifiers)

NOTES: Separate detector units (amplifiers) must be used for each loop group (Group A: loops 1 through 3 and Group B: loops 4 and 5).

CONTROLLER DATA:

- # Detector Memory Setting - Locking Mode
- # Detector Operation - Presence Mode
- # Minimum Green - 8 to 14 seconds, depending on the volume of traffic speed and number of trucks
- # Passage Interval - 1.0 second
- # Inhibit detector after "GAP" setting has been reached. This is a standard software feature on some modern traffic signal controllers.

Note: Some controllers have "loop drop" feature built-in.

7.0 EXTEND CALL AND DELAY CALL (EC/DC) FEATURE

7.1 Delayed Call

Delayed call is normally used when there is a chance that the detector will be activated by traffic in the wrong direction or when detection of traffic in the desired direction is not immediately needed in the control system. Specifically delayed call is used when:

1. The left turn detector could be activated by adjacent traffic moving in the opposite direction.

2. The left turn detector could be activated by the left turning traffic from the cross street. This is particularly acute for vehicles arriving near the end of the left turn phase and proceeding through on a relatively high speed, sweeping left turn through the intersection.

3. On narrow two-lane intersecting streets when the sweeping right turns from the major street pass over the cross street detectors.

4. When no left turn lane is provided and a detector is placed in the intersection area to extend the protected left turn green time.

5. Where a heavy right-turn-on-red exists and the signal on the minor roadway and the signal is set to dwell-in-green on the major street. If the right turning traffic clears on the red interval, a green interval on the cross street may not be needed, particularly when a multilane approach is involved.

6. Where a permissive/protected interval is used for the left turning traffic, the protected portion of the phase may be needed. The vehicle must be able to clear on the leading green permissive interval provided by the primary through traffic phase.

7.2 Extended Call

Extended call is used to overcome operational problems resulting from poor detector location and to adapt operations for loop failures. Specifically, Extended Call is used when:

1. The spacing between the stop bar detector and the next detector upstream will not allow the queue of vehicles to begin to move over the upstream detector until after the green interval has been terminated. This situation also occurs when a single detector is placed upstream from the stop bar.

2. One detector of a multiple detector system fails, the extended call can allow for reasonably normal operation until the failed detector can be replaced.

3. Fine tuning a signal system that may be experiencing premature gap-out on one or more lanes, but where it is desired to provide an overall reasonably short gap time.

4. When a single detector is located upstream from the stop bar.

The extended call feature can be used with either pulse mode of presence mode operation.

The DELAY/EXTEND features may be on the controller, on the detector or on both. Each system must be carefully checked and carefully set on to insure that the desired operation is achieved. Turning the power on pin "J" inhibits both the EXTEND and DELAY for that detector.

Modern controllers sometime come with power on pin "J." Always check the status of pin "J" to be certain it is consistent with the plans for the signal operation.

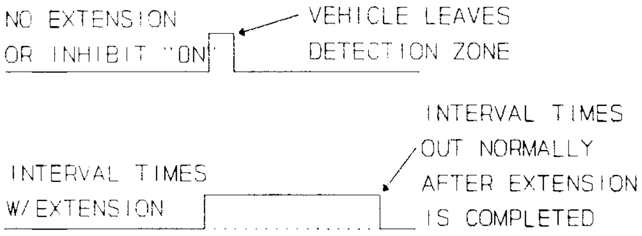


Figure 7.1 Illustration of Extension Call Feature

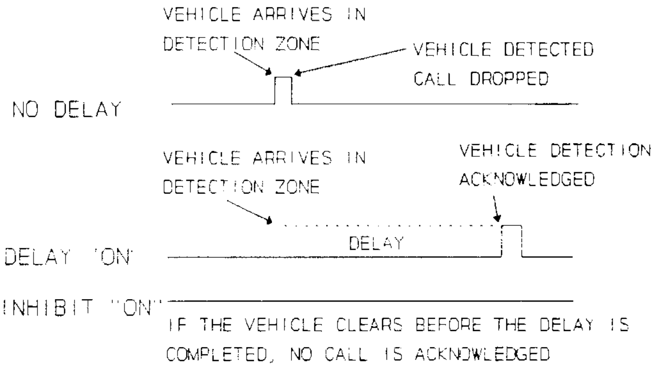


Figure 7.2 Illustration of the Delay Call Feature

8.0 THE MICROLOOP

8.1 Introduction

The microloop is a passive sensing system based on the earth's magnetic field. The passage of a vehicle through the detection area temporarily distorts the field. This localized change in the earth's magnetic field strength creates an electrical circuit change in the especially designed circuit of the microloop. This change indicates the passage of a vehicle. The microloop is fundamentally different from induction loop detectors in two ways:

1) The circuit is passive rather than active. No current flow is required in order to operate. The microloop basically tunes itself to the null condition. A change in the circuit above the threshold value set results in a detection.

2) The frequency of operation is extremely low. Typically in the 10 to 100 Khz range. Optimum operation is near 40 Khz; however, the sensitivity of the microloop decreases with increasing frequency.

The reason for addressing the microloop is it's application in situations when the induction loop detector is impractical.

The Microloop

The microloop uses the second detection concept. It senses the magnetic field strength of the earth and nulls out the ambient induction. A vehicle passing through the detection area distorts the earth's magnetic field. This alters the system inductance by concentrating more of the earth's magnetic field flux lines through the microloop probe. This changes the inductance and frequency of operation in the system. This change is the basis of detection in the microloop.

The microloop operates at very low frequencies in comparison to induction loop detectors. The common frequency range used is from 10 to 100 kiloHertz. This causes some problems in the field. The microloop will operate with any loop detector. Experience indicates the detector units, other than those of the microloop manufacturer, often yield erratic behavior. This is probably the result of the very low operating frequency of the microloop. Placing two or more microloops in series can usually solve this problem.

Microloops have several distinct advantages. They are placed well below the pavement surface. This allows them to be used with poor pavement conditions, which precludes the use of induction loop detectors. Also they can be used in high iron environments. This includes areas under bridge decks between steel girders. The microloop can be installed very quickly. Basic installation, excluding the lead wire, is accomplished in about 10 minutes in the traffic lane. The microloop has no practical limit on the lead length. This feature makes it's application in freeway control attractive.

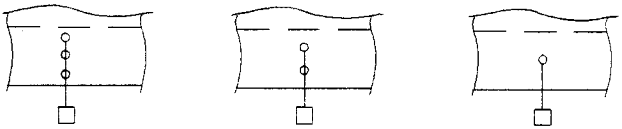
The microloop also has one distinct disadvantage. It operates only in the pulse mode. Presence detection is not possible. This limitation, combined with the higher cost, limits the use of the microloop in typical traffic signal detection applications. Installation of the microloop is critical. The Microloop sensor must be placed about 18 inches below the pavement surface and kept within + or - 5 degrees of vertical. Failure to locate the microloop sensor at the proper depth results in erratic detection. Failure to locate it properly in the vertical plane reduces the microloop's sensitivity to a vehicle. Section 5.0 presents the installation details to ensure high performance from the microloop sensor.

8.2 Limitations And Disadvantages Of The Microloop

The microloop has been demonstrated to be a potential problem near high wattage radio transmission stations. Likewise, locations near power transmission lines may be a problem. By far the most commonly cited field problem was the incompatibility of the microloop with detectors other than those of the manufacturer. The problem is the low frequency of operation. Below 50 Khz, the operation of many detector units is questionable. For this reason, it is recommended that the decision to use the microloop include the manufacturer's detector units as well. This ensures compatibility of the microloop and the detector unit. An alternative is to use a series of microloops to obtain a system inductance over 50 microhenries.

A more serious limitation to microloop use is the fact that it is not recommended for presence detection. Where counting vehicles is the primary problem or the induction loop detector is not suitable to the environment and operation in the pulse mode is acceptable, the microloop is a viable detector alternative.

The effective width of microloop field is a relatively narrow inverted cone. In a single lane, one microloop effectively detects cars and trucks. It is very marginal with bicycles and motorcycles. For this reason, two or even three microloops in series may be needed to ensure full lane coverage for all traffic. Figure 8.1 below illustrates the recommended installation setup for several typical cases.



PASSAGE
DETECTION
FOR ALL DESIGN
VEHICLES

PASSAGE
DETECTION
FOR CARS, TRUCKS
AND MOTORCYCLES

PASSAGE
DETECTION
FOR CARS
AND TRUCKS

Figure 8.1 Suggested Microloop Installation Patterns

8.3 Microloop Advantages

The primary advantages of the microloop are the speed of installation, installation below the pavement level, and the lack of a constraint on the lead length. These situations are normally found in freeway information electronic systems.

Microloops are also very attractive in high iron or steel concentration areas, such as bridges. Saw cuts in the bridge deck are undesirable. The microloop can be placed below the bridge deck between the steel girders and operate successfully. Figure 5.2 illustrates this application.

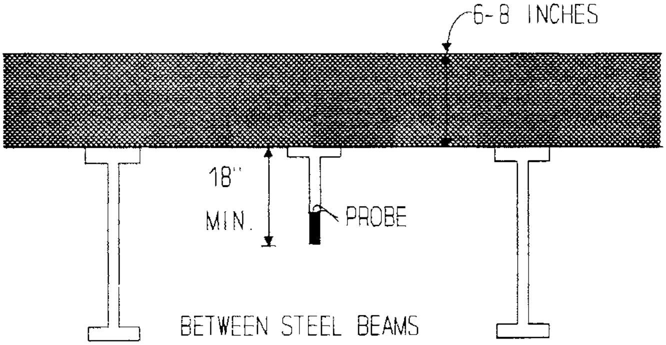


Figure 8.2 Application of the Microloop Under a Bridge Deck

The fact that the microloop is not installed in the pavement, but rather in the subgrade, is a another advantage. They can be installed prior to paving on new construction and at any time prior to an overlay. When it is installed just prior to an overlay, consideration should be given to using pavement crack water-proofing material to cover the lead wire rather than saw cutting the pavement. Pavement marking waterproofing is a pliable, self-adhesive, cold laid crack sealing material. It is designed to place over pavement cracks prior to an asphaltic overlay. Experience indicates that it can be used to temporarily replace a loop for a short period of time prior to the overlay (i.e., 30 to 60 days).

8.4 Microloop Placement

The placement of the microloop is very different from the installation of an induction loop detector. Place the bottom of the probe 18 inches below the pavement surface.

Placing the microloop closer to the surface results in multiple actuations. A 1-inch diameter hole is needed. Using a jackhammer, this hole can be punched in an asphaltic concrete pavement in about one minute per microloop. The lead saw cuts must be made to the roadway surface exit point. Table 8.1 summarizes the time requirement for the lead cut work.

Table 8.1
Time Estimates to Saw Lead Slots for the Microloop

NUMBER OF LANES	LINEAR FEET OF SAW CUT	TIME @ 20 FT./MIN.	TIME @ 6 FT./MIN.
1	6 feet	18 seconds	1 minute
2	18 feet	54 seconds	3 minutes
3	30 feet	1 minute & 30 seconds	5 minutes

The total time for installation of one microloop in the traffic lane is 10 to 15 minutes.

Microloops tend to move out of the vertical plane over time. It is recommended that a 1-inch diameter, schedule 40 PVC pipe 18-inches long be used to prevent movement out of the vertical plane. The PVC pipe must be driven below the pavement level, or the saw cut must pass through it, to allow the lead wire to pass from the vertical to the horizontal plane below the surface level. The saw cut should allow for a minimum of 1 1/2 inches of sealant over the wire. Desirably, two to 2 1/2 inches of sealant cover can be provided. Roto-Mill operations usually cut 1 inch or so off the surface. An inch and one-half of cover assists in ensuring a minimum of damage during the preparation for and overlaying of the roadway. Movement of the pavement surface can result in Roto-Mill cuts in excess of 1 1/2 inches. Figure 8.3 depicts the installation details for the microloop.

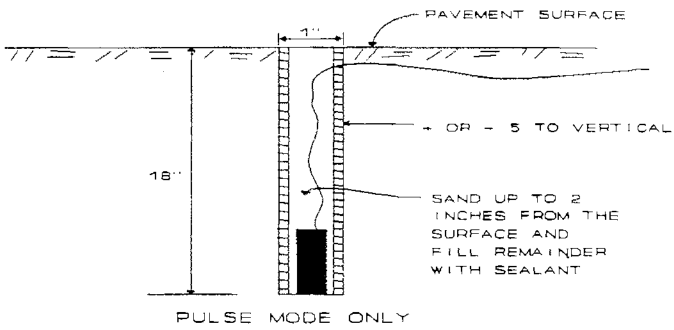


Figure 8.3 Installation Details for the Microloop

The critical installation dimension of the Microloop is the depth of the probe. **Do not compromise on the 18-inch minimum probe depth requirement!** It is better to be too deep than too shallow with the probe.