Evaluation of Induction Loop Installation Procedures in Flexible Pavements

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EVALUATION OF INDUCTION LOOP INSTALLATION PROCEDURES IN FLEXIBLE PAVEMENTS

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FINAL REPORT

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ABSTRACT

The problems associated with induction loop failures is addressed through the use of a detailed telephone and literature survey. All Washington state DOT districts, and most of the counties and larger cities are covered along with a random sampling of the major geographic areas of the US.

The rates of failures were somewhat simalar throughout the state as well as the country. The major problems associated with loop installation failures were closely related to pavement failures and installation deficiencies. The electronics problems centered around periodic adjustment or alignment procedures which are associated with the type of amplifiers used and with the long term integrity of the loop and lead in wire system. This can be improved by using self aligning amplifiers and by using improved installation techniques.

SUMMARY

The purpose of this research is to identify the types and frequency of induction loop vehicle detector failures and to identify possible solutions. The primary objectives were to find the reasons for loops becoming dislodged, determine the frequency of failure, identify optimum products and construction techniques and to make recommendations as to future research.

A literature search was conducted to identify all possible sources of pertinent information on traffic detectors. Additionally, commercial suppliers of traffic detection systems were solicited for information on their products. The literature was surveyed and a compendium has been developed regarding: 1) Failure rates and modes of different detection systems and 2) Product and construction techniques available for different detection systems.

A state and national telephone survey of traffic engineers was conducted to indentify: 1) What is the frequency of induction loop detector failures, 2) What are the preferred methods of traffic detection 3) What causes are given as the most frequent reasons for failure of induction loop detectors and 4) What techniques for installation have been used and what is preferred.

Since most local and state agencies did not have quantitative

data relating to these questions, the analysis had to be based upon subjective response. Thus, the results of the survey are of a qualitative nature.

It should be pointed out that while much verbage has been written on the theory and operation of induction loops, little effort has been devoted to loop failures.

CHAPTER 1

INTRODUCTION

The specific objective of this research was to determine what problems may be associated with the design, installation and maintenance of induction loop vehicle detectors. Included in this study is the evaluation of current installation procedures and inspection techniques to determine the magnitude of and potential solutions to the problems in placing and maintaining these detectors in the State's highway system.

Some of the existing failures that have been previously identified are associated with the migration of the wires to the surface, resulting in open circuits and with the deterioration associated with what is assumed to be moisture problems. It is also felt that the lack of suitable inspection and quality control techniques using existing installation procedures is a contributing factor in many of the existing loop failures. The primary areas of concern are associated with the techniques used in placing and sealing the wires in the saw cut made in the pavement. For this reason the emphasis of this research is on this problem with special considerations given to alternative sealants and adhesives.

Historically, induction loop detectors have been the most versatile and widely used detectors in traffic signal systems. They have also proven to be troublesome. The problem seems to be failure to hold the loop in the pavement due to pavement

deformation. Due to the large variation in climate and traffic conditions within the state, construction techniques and materials have not been identified that provide satisfactory operation statewide.

Preliminary research indicates that very little quantitative data are available on the exact extent, types and mechanisms associated with loop failures. Also, data are not generally maintained on the frequency of failures associated with different techniques used for installing the loops and how this might correlate with different types or mechanisms of failure.

Because of this lack of quantitative data and because it is felt that a full research effort was not warranted, a detailed agency phone survey, literature review and product survey was undertaken. The major thrust of this effort was focused on an extensive telephone survey of Washington State, county and city agency personnel associated with the installation of these devices and a sampling of other state agencies around the U.S. Private organizations were also solicited for pertinent information.

The topics that are included are a state of the art study of sealants and adhesives, design and configuration of induction loops as they relate to sensitivity, number of windings, wire and insulation type and magnitude of the field strengths and alternative methods of detection. Also the problems associated with the installation of these devices on bridges and bridge approaches is addressed. However, the final evaluation, conclusions and

recommendations are limited to the installation techniques and procedures associated with current loop installation practices.

Ongoing work related to this research is at present(1984) being done at Oregon State, New York State and at the University of Virginia. Also the Traffic Control System Handbook on induction loop sensors is currently under revision. Also the FHWA has developed a course and handbook on induction loops and other traffic detectors.

The four objectives of this study were to:

1) Find the reasons for loops becoming dislodged from the pavement.

2) Ascertain the frequency of loop failures by means of a national and state telephone survey and literature and agency review.

3) Identify products and construction techniques which may minimize or remedy the problem.

4) Make recommendations to the WSDOT regarding future research in this area.

The benefits to be gained from this research are:

1) The establishment of primary modes and frequencies of loop failures.

2) The identification of different materials and procedures to reduce the rate of failure.

3) The recommendation of test plans to try the different materials and procedures.

CHAPTER 2

CONCLUSIONS

Based upon the literature review and agency survey, the following conclusions are made:

1. There are a number of techniques and products used in the construction of induction loops. These techniques and products should be applied in such a manner that the resulting induction loop system will behave as similarly to the pavement as possible.

2. The FHWA has produced two reports on induction loops in particular and one report on vehicle detection in general which should be of help to practicing signal engineers. Additionally, the FHWA sponsors a short course on vehicle detection which received favorable comments from several survey respondents.

3. The literature suggests that induction loops should not be used in bridge decks due to the large amount of ferrous metals in bridges. Instead, induction loops should be placed on bridge approaches or alternative vehicle detectors such as magnetometers or microloops may be used on the bridge structure.

4. Failure rates reported by Washington agencies were much lower than reported by out-of-state DOT's and those found in the literature.

5. The largest single factor contributing to induction loop

failure seemed to be pavement cracking. The next most important factor was utilities construction or repair. Other significant factors included pavement rutting, poor inspection, and sealant failure.

6. A large majority of agencies surveyed were satisfied with the performance of their induction loops using their current practices.

7. Many agencies within Washington rely upon WSDOT specifications for induction loop construction.

8. Amplifier problems are usually caused by the inability of amplifiers to adjust to temperature changes and to moisture or other changes within the loop wire and lead in wire system. This can be cured by purchasing self-tuning amplifiers and by complete encapsulation of the loop wires; do away with the poly rope system.

9. Future developments in vehicle detection methods include selfpowered vehicle detectors and microloops, these should be followed and given further consideration.

CHAPTER 3

RECOMMENDATIONS

3.1 Installation Practices

The following recommendations are made to WSDOT regarding current practices of installing and monitoring induction loops:

1. Saw cuts made to install induction loops should be minimized. This may be done by: 1) using a chipped out or circle cuts at the corners instead of the usual 45 degree angle cut and (See references 11 and 22): 2) installing induction loops in existing surfaces prior to pavement overlays whenever possible.

2. Maintain records of the installation and monitoring of induction loops. Such records would provide valuable information on the expected life of induction loops, failure rates, failure modes, quality and reliability of products, etc.

3. Concern was expressed by WSDOT districts regarding the inspection of induction loop installations. The best remedy for poor inspection is training and experience. Training may be either accomplished on-the-job by assigning new inspectors to more experienced personnel or through formal classes such as the short course offered by the FHWA. Inspectors must remain in their jobs long enough to be effective in the enforcement of specifications.

3.2 Future Research

With Regards to future research, the following recommendations are made:

1. Induction loops behave differently than the pavements in which they are placed. Saw cuts will act as stress risers and the wires and sealant act as inclusions. In order to find an "optimum" induction loop system (one which will behave in a similar manner to the pavement), a theoretical study should be initiated to model pavement-induction loop interactions.

2. Forms and procedures should be developed in order to track induction loop performance.

3. A study should be initiated to find satisfactory vehicle detection methods on bridge decks.

4. Consideration of the development of a hot glue gun type adhesive installation system. This would be analogous to a standard shop type unit used for wood and metal working and other applications. It would consist of a long cylindrical tube (3 to 4 inches in diameter), an electrical heating element, an automatic extrusion mechanism and an application nossle which would fit inside of the saw cut. The device would be lowered into the saw cut against and on top of the electrical lead wires. The gun would be moved through the saw cut by hand, with manual adjustment of speed to insure complete filling of the saw cut with adhesive.

This system would have the following advantages:

a. The wires would be held in place as the adhesive is being applied from the bottom up.

b. The adhesive would begin to harden immediately.

c. The heat would help to dry the saw cut and thus improve adhesion to the pavement and the wire.

d. There would be complete encapsulation of the wire, thus reducing the possibility of moisture getting into the saw cut which can adversely effect the balance of the electronics and the pavement integraty.

e. The adhesive would be in a solid cylindrical stick form and could be handled e of the problems associated
with other techniques.

f. Quality control and the possibility of human errors during installation would be improved considerable.

5. Consideration should be given to the use of teflon coated wire. This would propable require special odering and would only be feasible if a large quantity were purchased. This coating is by far superior to any other type of insulation in terms of moisture resistance and in strength and resistance to abrasion. One draw back to teflon, however, is that it is difficult to make a good seal to the teflon when splicing.

6. Self sealing heat shrink tubing, which is manufactured by several companies should be considered for splicing wires. It is used quite successfully in the marine industry in relatively deep underwater applications and adds extra strength and abrasion resistance to the area of the splice. Heat guns with fixed temperature heads should be used with the temperature chosen so as to eliminate damage to the wire coating.

CHAPTER 4

REVIEW OF PREVIOUS WORK

4.1 Introduction

DeLaski (1) cites over 50 years of use of traffic detectors. It was apparently in the 1920's when fixed-time signals replaced manually controlled signals. Among the first vehicle detection systems was a horn-actuated device developed by Charles Alder and installed at an intersection in Baltimore during 1928 (2). The principle of this device was that a microphone received a signal from the sounding of a car horn and transmitted the signal to a switch controlling the intersection.

At about the same time, a pressure-sensitive detector invented by Harry A Haugh was installed in New Haven, Connecticut (3). This detector works on the principle of a load (vehicle wheels) forcing two electrical contacts (plates encased in rubber) together. This device remained in popular use for forty years.

The use of magnetic detectors began in the 1930's. These devices are noted for their durability and reliability (1). They are generally used for passage detection since they are limited to vehicles moving at speeds greater than 3 to 5 miles per hour. Magnetic detectors sense a change in the earth's magnetic field due to the iron content in passing vehicles. This change in magnetic flux causes a voltage to be induced and transmitted to

an amplifier which controls the counter.

A photocell traffic detector was developed by the Bureau of Public Roads in the 1930's (3). Problems with environmental interference prevented any widespread use of this type of device.

During the 1950's, radar began being used in traffic detection (1). In this system, microwaves are directed toward the traffic and the type of reflected signal indicates the presence of traffic. The limitation on radar is that vehicles must be moving greater than three miles per hour. These devices were popular since they could be installed with a minimum of traffic disruption and no saw cuts were required in the pavement. However, FCC regulations and the cost of these units precluded their continued popularity.

Sonic detectors for both passage and presence detection were introduced in the 1950's (1). They operate by emitting a sound which is reflected to a receiver. Changes in the reflection indicates a vehicle. As with radar units, sonic devices are expensive but easy to install. Additional disadvantages include requirements for extensive maintenance, theft of components, and false calls on such objects as parked cars and snowdrifts.

The use of infrared systems began in the 1950's (1). These devices have very specialized uses due to the narrow field of influence produced by the beams. Most recently they have been used to detect vehicles following too closely.

Induction loop detectors such as the one illustrated in

Figure 1 began being used in the early 1960's (1). An electromagnetic field is created around the loop area in the 20 to 200 KHz frequency range. Vehicles in the area absorb some of the energy which increases the resonant frequency of the loop. Electronics in the control circuitry sense the change in phase, frequency, or impedance and actuate the signal or counter. DeLaski (1) noted that these systems are very flexible and dependable. They are currently the most widely used detection systems.

The 1960's also saw the advent of the magnetometer detector (1). This device is different from the magnetic detector. The magnetometer operates by sensing a concentration in flux lines of the earth's magnetic field. This concentration occurs because the iron in the vehicle bodies is more permeable to the magnetic field than air. The magnetic flux lines will bend to pass through the vehicle. Magnetometers are used primarily for passage detection.

4.2 Current Developments

Although induction loops are currently the most widely used detector systems, other detectors which may offer advantages are currently being investigated (1). These include: 1) self-powered vehicle detector (SPVD), 2) passive bus detectors, and 3) the microloop.

As the name implies, the SPVD has a self-contained power

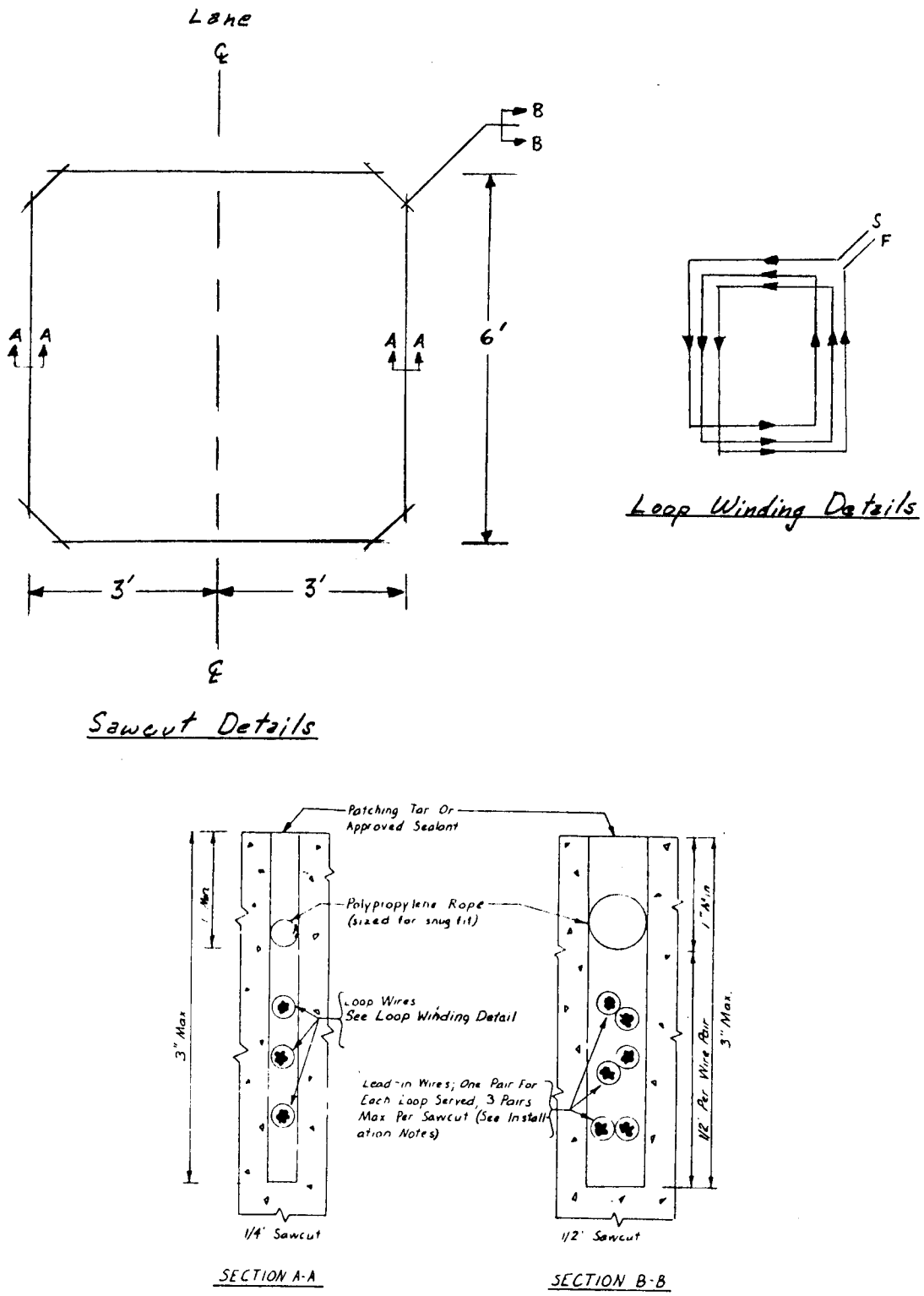


Figure 1. Example of Induction Loop Details.

source. It also has a transducer and an RF transmitter with antenna. The dimensions of the cylindrical unit are 4.5 inches in diameter by 14.5 inches in length. The six-volt battery is expected to last for one year. The Federal Highway Administration began development of this device in 1973 (3). The detector operates on the principle of a magnetometer. When a change in the earth's magnetic field is sensed, a signal is transmitted to receiver located within 500 feet of the detector and a signal or a counter may be activated. A study in Kettering, Ohio (4) showed that although electronic problems existed in experimental models, reduced installation and maintenance costs make this device attractive for further development.

The passive bus detector is a system especially developed to distinguish buses from other vehicles (5,6). It does this by identifying the particular waveform profile on buses as they pass over induction loops. This can be used to prioritize flow at signalized intersections.

The microloops, developed by the 3M Company, show great promise in vehicle detection on bridge decks and unsurfaced roads as well as on normal asphalt and concrete roads (7). The microloop consists of small (1 inch diameter by 3.5 inch long) probes which are connected by a single wire to an amplifier. This device is suitable for point detection and can be installed with a minimum of disturbance of the pavement surface.

CHAPTER 5

PROCEDURES

Elements of the work plan are described below in the sequence in which they were accomplished:

A literature search was conducted to identify all possible sources of pertinent information on traffic detectors. Additionally, commercial suppliers of traffic detection systems were solicited for information on their products. The literature was surveyed and a compendium was developed regarding: 1) Failure rates and modes of different detection systems and 2) Products and construction techniques available for different detection systems.

A state and national telephone survey of traffic engineers was conducted to identify: 1) What is the frequency of induction loop detector failures, 2) What are the preferred methods of traffic detection 3) What causes are given as the most frequent reasons for failure of induction loop detectors and 4) What techniques for installation have been used and what is preferred.

Since most local and state agencies did not have quantitative data relating to these questions, the analysis had to be based upon subjective responses. Thus, the results of the survey are of a qualitative nature.

The compilation of the results is essentially the data

analysis phase of the work in which the results of the literature review and telephone survey are compared to ascertain if there are significant differences between results. Additionally, such variables as mode and frequency of induction loop failures and geographic location are evaluated to see if correlations exist.

CHAPTER 6

LITERATURE REVIEW

6.1 Introduction

There are three references (1, 3, 8) cited in this report which are recommended reading for the practicing signal engineer or technician. These reports and implementation packages provide comprehensive discussions on the theoretical and practical aspects of induction loops. Useful information may be obtained on the design, construction, and maintenance of induction loops.

De Laski (1) developed an extensive handbook and short course on many aspects of traffic detectors for the FHWA. subjects covered in this implementation package include:

1. Purpose and History of Detectors
2. Detector Theory and Hardware
3. Detector Applications
4. Installation Procedures
5. Detector Maintenance
6. Detector Selection and Specification

This handbook discusses induction loop detectors, magnetometer, and magnetic detectors.

Dorsey (3) conducted a survey on vehicle detector and induction loop installation procedures. Additionally he provided a list of induction loop product manufacturers. Doresy discussed induction loop construction, electronics, problems and research.

Pinell, et al. (8) developed an implementation package on induction loops for the FHWA. The purpose of this package was to

provide guidance in the design, installation, and testing of induction loops. This report provides a very convenient method for trouble-shooting faulty loop systems.

6.2 Induction Loop Failures

Very little is published regarding induction loop failures and failure rates. This is most probably due to the fact that very few agencies document repairs performed on traffic signals. Such documentation could provide valuable information for planning and research.

Parsonson and Tarnoff (9,10) conducted a survey on a wide variety of traffic control issues. They gathered data from 10 state and local agencies having documentation on repair rates and costs. Although most of the data pertained to types of controllers, some agencies gave additional information on detector types. One district of the Minnesota Department of Highways reported an annual loop detector failure rate of 24 percent per year. The annual failure rate for loop detectors in Cincinnati, Ohio was found to be 29 percent per year. Washington, D.C. reported a failure rate of about 13 percent per year which was about evenly divided between electronics failures and utility excavations. Pinell, et al. (8) noted that in the city of Los Angeles, 70 percent of the loop failures were the result of construction and repair work on utilities or the street. The second most common cause of loop failures in Los Angeles was insulation wear.

The Minnesota DOT conducted a study similar to the one presented in this report (11). That effort entailed a literature review and a survey of agencies in the snowbelt. The survey queried these agencies on the causes of loop detector failures and the installation procedures and specifications in use. Responses as to the causes of loop failures included:

1. Wire Breakage
2. Wire Insulation Deterioration
3. Pavement Distress
4. Moisture in Splices
5. Amplifier Tuning
6. Improper Loop Sealing

Within the Minnesota DOT, it was found that:

1. There was inadequate attention given to detail during the initial installation.

2. There was poor inspection of installations.

3. Repair procedures were inconsistent, and inadequately planned.

6.3 Installation Procedures

There are a variety of methods and materials used in the installation of induction loops. The general sequence of installation is:

1. Mark loop location on pavement.
2. Saw cut slots in pavement.
3. Clean saw cuts.
4. Place loop wire in slot.
5. Seal slot.

There is very little variation in the way that the first three steps are performed. However, the placement and sealing of loop wires can be done in a number of ways. Loop wires may be given no protection other than their insulation or may be placed

inside of a rigid PVC conduct or a flexible polyethylene tubing. Sealing may be done with either a rigid or flexible sealant and in such a manner as to give total or partial encapsulation of the loop wire.

(a) <u>Loop Placement and Saw Cutting.</u>

Pinell, et al. (8) recommended that joints and cracks in the existing pavement should be avoided if possible. However, if joints cannot be avoided, there are three methods which may be used to negotiate joints as shown in Figure 2a,2b, and 2c. These methods are all designed to minimize the stress on the loop wire during pavement expansion and contraction and to waterproof loops in the vicinity of joints.

Hale (11) cited problems with corner cutting the loop slots. The triangle formed by saw cuts creates increased stress concentration in these areas of the pavement. The pavement within these triangle are stressed to failure much sooner than the surrounding pavement. To alleviate this, it was suggested that two inch diameter holes be drilled at the corners and the radii of the holes be chiseled out to form rounded corners for the wire. This is illustrated in Figure 3. Hale (11) also noted the importance of having slack in the wire at corners to accommodate pavement movement.

A subject which is not addressed in the literature is the effect of saw cuts on a pavement. By saw cutting a pavement, the geometry of a relatively continuous pavement layer is drastically

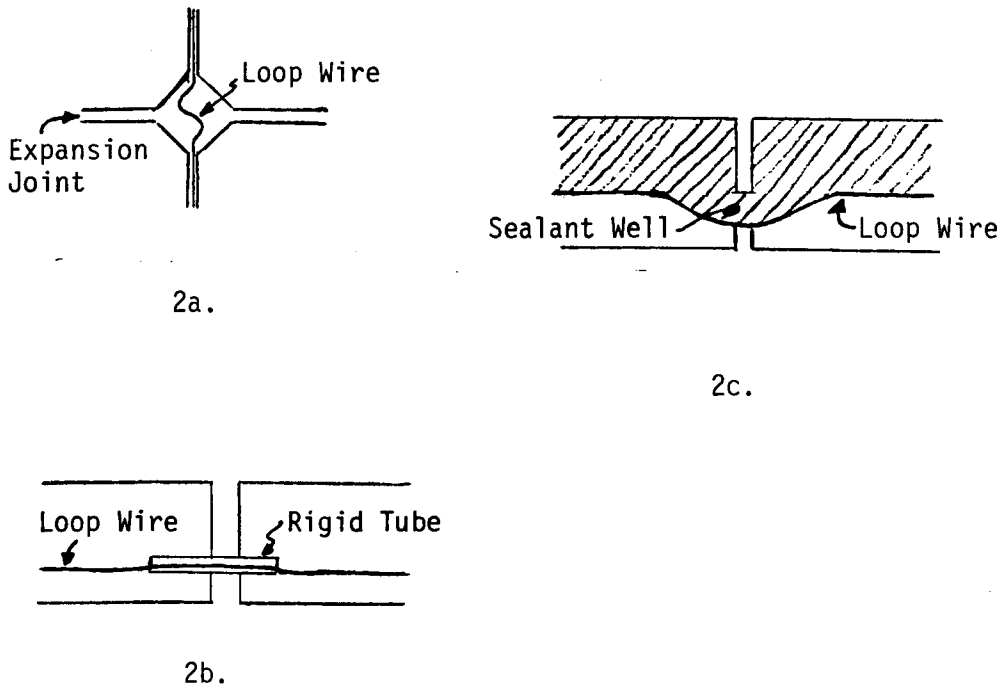


Figure 2. Methods of Negotiating Expansion Joints.

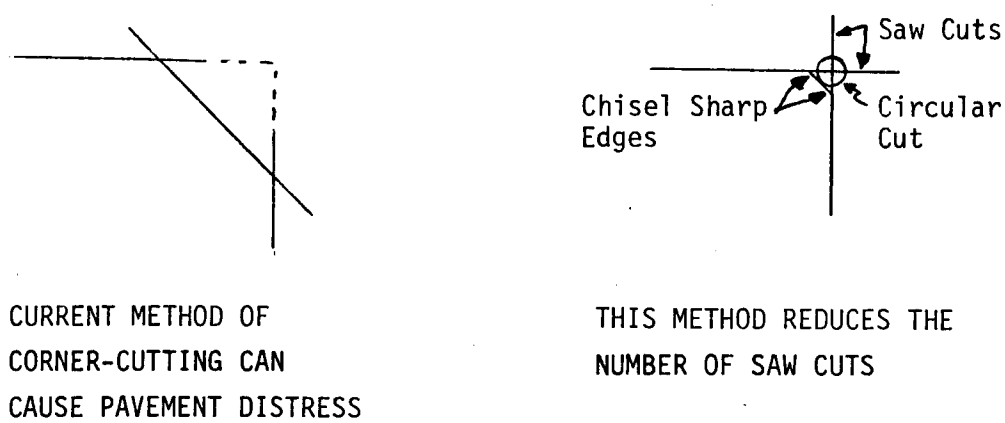


Figure 3. Method to Reduce Stress Concentrations at Corners.

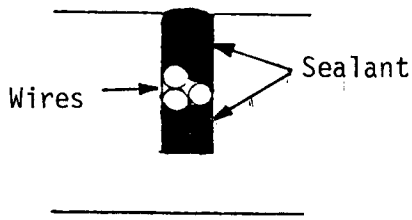
altered. This gives rise to stress concentration at the point of discontinuity (saw cut). Thus, the installation of induction loops may cause pavement failures which are blamed for the induction loop failures. An appropriate analogy might be to saw a structural beam through 3/4 of its thickness from the top and expecting it to hold the design load. In instances where an induction loop is to be installed in conjunction with a pavement overlay, the induction loop should be placed and sealed in the existing surface prior to the application of the overlay.

(b) <u>Loop Sealant</u>.

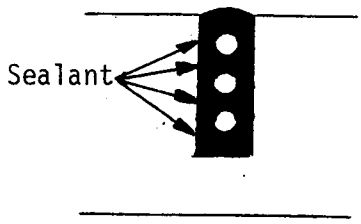
The success or failure of an induction loop system is largely dependent upon the method and material used to hold the loop in place. There are three general methods used to hold loop wires in place: 1) partial encapsulation, 2) total encapsulation, and 3) the conduit method. These are illustrated in Figure 4. The current WSDOT procedure calls for using the conduit method. De Laski (1) does not recommend the use of the conduct method although no evidence was presented to show that it was any worse than the other methods. Instead, he favors the encapsulation of loop wires because of the "tough-but-rubbery" nature of recently developed loop sealers.

Although De Laski (1) did not define "tough-but-rubbery", he did outline the following criteria for loop sealants:

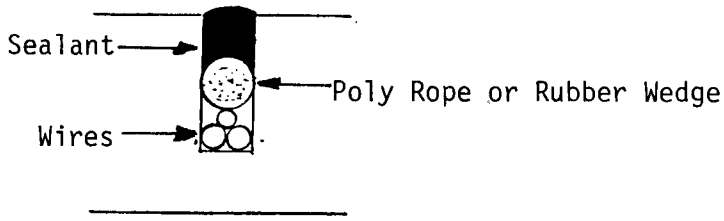
1. Penetration resistance to debris.
2. Ability to conform to changes in the pavement surface.
3. Good adhesion to asphalt and concrete surfaces.
4. Rapid curing time.
5. Ease of preparation and placement.



4a. Partial Encapsulation.



4b. Total Encapsulation.



4c. Conduit Method

Figure 4. Methods of Sealant Application.

6. Environmental durability.
7. Corrosion or degradation resistance.
8. Proper viscosity.

Hale (11) stated that loop sealants should "maintain adhesion to the sides of a saw slot during its expansion, withstand compression when the slot contracted, and yet be of the right viscosity to be poured into the slot but not run out if the slot was on an incline."

In 1982, the Virginia Department of Highways and Transportation decided to perform a field trial using six types of sealants which would not have met their specification (12). These researchers rated the loop sealants according to the ease of mixing and application, the quantity required. pot life, cure time, and clean-up. the results of their findings are listed in Table 1, they gave the best ratings to Sealex, a compliant two-component material, and Gold Label Flex, a moderately hard polyester system. No conclusions were reached regarding the performance of any of the sealants. Epoxy sealants were rated as the most difficult in installation.

(c) <u>Wiring and Splicing</u>.

Dorsey (3) found that there were two popular types of lead-in cables: 1) Beldon 8720 and 2) Underground feeder cable. The Beldon 8720 was the most popular type. This wire consists of two No. 14 stranded conductors, shielded with aluminum, insulated with vinyl. Agencies using underground feeder cable specify either AWG gauges 12 or 14. Table 2 lists the relative advantages and disadvantages of the two types of lead-in cables,

Table 1. Results of Virginia Sealant Test (12).

Loop No.	Sealant	Ease of Mixing	Quantity Mixed	Ease of Application	Pot Life	Cure Time	Clean-up
2	Bondo P-606	N	S	S	S	S	S
3	Sealex	E	S	S	S	S	S
4	E-Bond 1260 w/ Saunders sand	N	S	N	N	N	S
5	Gold Label Flex	S	S	S	S	S	S
6	MagnoLoop I w/ play sand	S	S	S	S	N	S
7	MagnoLoop I w/ Saunders sand	N	S	N	N	N	N
8	E-Bond 1260 w/ glass beads	S	S	S	S	N	S
9	3M	N/A	N/A	N	S	S	S

KEY: N = not satisfactory (below average)

S = satisfactory (average)

E = excellent (above average)

Table 2. Comparison of Beldon 8720 and Underground Feeder Cable (3).

CABLE TYPE	FAVORABLE CHARACTERISTICS	UNFAVORABLE CHARACTERISTICS
Beldon 8720	a) it offers EMI/RFI protection b) it minimizes cross-talk c) stranded conductor	a) its capacitance can change due to water penetrating jacket b) jacket can tear in pulling through conduit
UF Cable	a) can be run in conduit or direct burial b) has a tough molded cable jacket that will prevent water penetration	a) does not have EMI/RFI protection b) it is a solid conductor cable and cannot withstand as much flexing as a stranded cable

De Laski (1) states that some agencies have encountered problems with the jacket of the Beldon 8720 tearing as it is being pulled through the conduit. He reports that this might be remedied by the use of nylon armor or high-density polyethylene jackets.

The Minnesota DOT (11) found that broken loop wires and deteriorated loop wire insulation were mostly associated with concrete pavement joints, pavement cracks and curb or shoulder interfaces. This finding stresses the importance of properly locating loop wires.

Hale (11) found that splices most often fail due to inadequate sealing or poor splicing methods. Dorsey (3) list two general methods for sealing splices.

1. Alternate layers of sealant and electrical tape are applied to the splice. Sealing is considered complete after several layers have been applied.

2. The use of an epoxy sealing kit. Resin and hardner are mixed and poured into a mold which is set over the splice.

Hale (11) favors the latter method of splice sealing. He also found that most agencies prefer soldering splices to simply crimping them.

(d) <u>Loop Casings and Preformed Loops</u>.

The Illinois DOT (14) uses a vinyl plastic tubing for encasing loop wires. Originally intended to allow the wires to shift with pavement faulting, it was found that the tubing also protected the wire upon exposure to traffic. De Laski (1) reports that one detector manufacturer has produced a loop system in

which the wire is encased in a thick-walled PVC pipe. The loop is easily shipped and assembled and may be installed in surfaced or unsurfaced pavements.

The Virginia Department of Highways and Transportation (12) conducted field trials in which 7/8 inch o.d. PVC conduit and 0.23 inch O.D. vinyl tubing were used as loop casings. It was speculated that the vinyl tubing would protect the wire while allowing it to move with the shifting pavement. The PVC conduit was thought to provide greater physical protection for loops by virtue of its rigidity. A four-inch wide saw cut was required for the PVC system while a 1/2 inch saw cut was used for the vinyl casing. Although conclusions regarding the performance of the loop casings could not be made at the time of the report, certain observations were made:

1. A four-inch wide saw cut for the PVC loop was too large. The saw cut should only have been slightly larger than the outside diameter of the conduit.
2. Lead-in wires should be protected in the same manner as the loop wires.
3. The loop sealer should be of a type that is easily mixed and applied under field conditions.

Utah (15) uses a preformed induction loop which is manufactured in their DOT shops. The loop is formed into the desired configuration, wrapped with a fiberglass fabric, and sealed in a hard-setting resin. These loops are well suited for use in new pavements or overlays where they can be placed on an existing surface prior to the application of the surface course. They can also be placed in an existing pavement by saw-cutting

slots in the pavement surface. The Utah DOT has estimated a savings of 75 percent over the conventional method of loop installation. This is mostly due to the elimination of saw cutting and sealing slots.

California (16) has developed a loop detector which can be placed on a pavement surface. This loop uses two turns of U.S. Army Communications wire encased in polyurethane rubber. The loop is two inches in width with a thickness of 3/8 of an inches at the center and tapered at the edges. It is reported that these detectors can withstand 1,000,000 axle repetitions and cost about 47 dollars each.

6.4 Electronics

The principle by which an induction loop detects vehicles is that the body of a vehicle causes a decrease in loop inductance when the vehicle is in the vicinity of the loop's electromagnetic field. Most available electronics detect the inductance change by either a frequency or phase shift (3). Once the frequency or phase shift is present, a difference in the signal from the comparator circuitry causes a relay closure.

Mills (17) provides a mutual coupling formula for computing the inductance of loops. De Laski (1) presented a table (Table 3) computed from this formula for easily estimating the loop inductance based upon the loop perimeters and the number of wire turns. De Laski prefers this method to less accurate "rules of thumb."

Dorsey (3) indentified three basic types of induction loop electronics: fixed frequency, self-timing, and self-tracking. The fixed frequency type was the earliest to be developed. This type is rarely specified any more for new installations because semi-annual or annual retuning was required and because expensive crystals had to be changed in order to repair the units. Self-tuning electronics can automatically compensate for loop and lead-in geometry. Both analog and digital models are available for self-tuning electronics. Each of these types of self-tuning electronics have their disadvantages (3). The most popular electronics are the self-tracking type. These can adjust to temperature and loop changes within certain tolerances and require no manual tuning beyond the initial installation.

6.5 Special Considerations

(a) Bridge Decks.

De Laski (1) concluded that induction loops should not be used in the vicinity of structures having a significant amount of iron such as bridge decks. Steel reinforcing bars in the concrete can reduce the sensitivity of the detector. This conclusion is supported by the findings of two studies (18, 19). In addition, the presence of saw cuts and intrusions in a bridge deck may have a significant impact on its structural integrity.

Magnetometers can be used under bridge decks that are either concrete or steel (20). However, caution must be exercised in

Table 3. Loop Inductances Calculated by Mill's Formula (1).

Loop Size (Feet)	1 Turn	2 Turn	3 Turn	4 Turn	5 Turn	6 Turn	7 Turn
5 x 5	9	30	62	104	155		
6 x 6	10	37	76	129	194	269	355
6 x 10	14	51	107	181			
6 x 15	19	69	147	249			
6 x 20	24	88	187	320			
6 x 22	26	96	204	349			
6 x 25	29	107	229	392			
6 x 30	34	126	272	461			
6 x 35	39	146	315	542			
6 x 40	43	165	359	618			
6 x 45	48	185	402	695			
6 x 50	53	205	447	773			
6 x 55	58	225	492	853			
6 x 60	63	245	537	932			
6 x 65	67	265	583	1012			
6 x 70	72	286	628	1092			

Spacing between loop conductors: 150 MIL center to center
NOTE: Boundaries show the designs recommended for normal use.

their placement since steel cross-members will distort the earth's magnetic field and may reduce the magnetometer's effectiveness. These detectors should be located at a maximum possible distance from the steel cross-members as shown in Figure 5. It has also been reported that the 3M Company's microloop will perform satisfactorily in bridge decks (7).

(b) **Bicycle Detection**.

WSDOT (21) conducted field tests to ascertain the effectiveness of various induction loop configurations in detecting bicycles. Their conclusion was that the quadrupole configuration was sufficient to detect bicycles consistently and reliably. This has been taken a step further in Adelaide, Australia (22) where special lane markings are used to channel bicycles into the most sensitive sections of the induction loops. A similar program is currently being tried in Lynnwood, Washington.

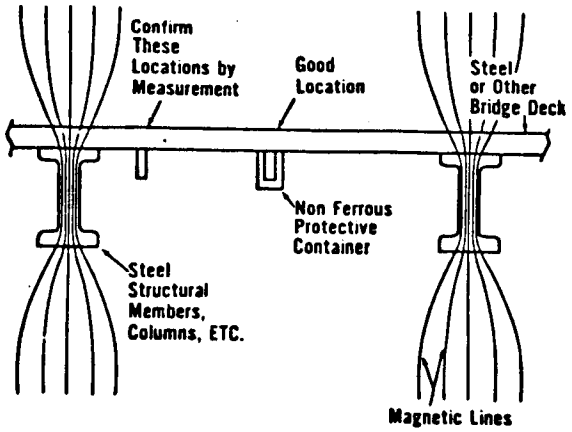


Figure 5. Magnetometer Placement for Bridge Deck Detection. (1).

CHAPTER 7

REVIEW OF END USER SURVEY(Aug 84)

7.1 Introduction

The questionnaire developed for this survey was designed such that either verbal or written responses could be accommodated. Respondents were asked questions pertaining to four areas of interest.

1. General Information,
2. Construction Techniques,
3. Induction Loop Failures, and
4. Additional Information or comments.

If the respondent did not have the exact answer to a question, an estimate was requested. In some cases, even estimates were not given due to a lack of information. Thus the results of the survey should be treated as qualitative. The survey form is included in Appendix A.

The survey form began by listing information on the individual and agency responding to the questions. This was followed by general questions regarding traffic detection methods. Respondents are asked to provide information on: 1) the number and types of traffic detection devices, 2) the associated repair rates for the devices, and 3) how the traffic detection installations were monitored.

The next part of the form inquired about the construction techniques and specifications used by the agency in placing loop detectors. Information was obtained on the percentages of loops installed by contractors and in-house personnel as well as preferences on the time of the year for installations. The respondents were asked about the types of loop configurations they used and to rate them for sensitivity and reliability. Regarding the placement of the loops, questions were asked regarding:

1. The dimensions of sawcuts,
2. Methods for cleaning sawcuts,
3. Sealants used for the loop,
4. Sealants used for splices,
5. Types of wire used for loops and feeder cables, and
6. Casings used for loop wires and feeder cables.

Additionally, information was obtained about amplifiers.

The various agencies were asked about the modes of loop failures and failure detection. The first question in this part asked what percentage of loop failures was detected in-house and what percentage was called-in by an outside source. The next question asked if the engineer considered the annual number of loop failures to be excessive. The responses to this question play a major role in conclusions reached later in this report. The engineer was asked which components of the pavement-induction loop system were responsible for loop failures. The questionnaire also asked if the failure could be attributed to normal traffic

wear and tear or environmental factors. Respondents were also asked to give a description of the loop failures as well as provide cost estimates on the repair and installation of the induction loops.

Finally, the individual was asked to list any additional sources of information on induction loops as well as any comments regarding induction loops or comments on the survey.

The total number of surveyed agencies was 45. This included 23 Washington cities, 7 Washington counties, 6 WSDOT Districts, and 9 other state DOT's. The participants are listed in Table 4. It was considered important to concentrate on Washington agencies since these would have similar construction techniques and environments. Thus solutions offered for various problems can be addressed in the same context.

Washington Cities

Bellingham	Lynnwood	Seattle
Bellevue	Moses Lake	Spokane
Bremerton	Olympia	Tacoma
Edmonds	Pasco	Vancouver
Everett	Port Angeles	Walla Walla
Kennewick	Pullman	Wenatchee
Kent	Renton	Yakima
Longview	Richland	

Washington Counties

Clark	Spokane
Franklin	Thurston
King	Yakima
Pierce	

Washington DOT

District 1	District 4
District 2	District 5
District 3	District 6

Other State DOT's

Arizona	Illinois	North Carolina
Florida	Mississippi	Pennsylvania
Georgia	Nebraska	Texas

Table 4. List of Survey Participants.

7.2 Results of Survey

(a) General

1. Number of Loops and Failure Rates

		No. of Loops	Failure Rate, % per yr.
Cities:			
	Mean	477	4.1
	Median	300	2.4
	Range	1724	11.7
Counties:			
	Mean	646	3.4
	Median	300	1.7
	Range	2090	9.5
WSDOT:			
	Mean	1255	3.8
	Median	525	3.0
	Range	4070	9.0
Out-of-State:			
	Mean	*	11.3
	Median	*	9
	Range	*	34.5

Comments:

Washington cities and counties had the same median for the number of loops. The counties had a slightly greater range for the number of loops which contributed to a higher average. WSDOT districts had a much greater mean, median, and range for the number of loops than either the cities or counties. Almost all out-of-state respondents did not give estimates on the number of induction loops within their jurisdiction.

County officials reported the lowest incidence of induction loop failures while WSDOT districts and the cities seem to have comparable failure rates. Out-of-state respondents indicated

higher failure rates than those found in Washington. It should be noted that two of the nine state DOT's did not give estimates on failure rates.

2. Methods of Monitoring Induction Loops

	Periodic Inspection	Wait for Complaint	Cont. Monitor. & Periodic Inspect.	Cont. Monitor. & Complaints
Cities:	12	5	3	3
Counties:	4	3	0	0
WSDOT:	4	0	2	0
Out-Of-State:*	4	2	0	0

* 3 States indicated that induction loops were not maintained by the state DOT.

Comments:

The favorite method of monitoring induction loops was through periodic inspections which were carried out by various agencies from one to 25 times per year per installation. WSDOT districts averaged approximately 12 inspections per year per installation which was greater than any of the other categories in the survey. A few agencies had continuous monitoring on some installations. Continuous monitoring is usually used in areas of high congestion in order to optimize traffic flow.

(b) <u>Construction of Loop Detector System</u>

1. Who Installed the Induction Loops.

	in-house	contractor
Cites:	14%	86%
Counties:	4%	96%
WSDOT:	6%	94%
Out-of-State:	20%	80%

Comment:

Washington counties and WSDOT districts were more inclined to use contractors for the installation of loops than the cities or out-of-state respondents. One state DOT indicated that approximately 98 percent of its loop installations are accomplished by in-house personnel.

2. Preference for Time of Year for Installation.

	Summer	Fall	Spring	Fall/ Spring	All Year
Cities:	12	1	3	2	5
Counties:	3	0	0	1	3
WSDOT:	2	0	1	2	1
Out-of-State:	4	0	0	1	4

Comment:

Most agencies seem to prefer installing induction loops in the summer although many indicated that the primary concern was for installations in dry conditions. Thus there seems to be little concern regarding the difference between thermal behavior for induction loops and pavement as related to installation.

3. Loop Configurations and Ratings. (See figure or appendix)

a. Sensitivity

	Rect.	Sq.	Quad.	Rec./dia	Diamond loop	other
Cities:	9	18	15	4	1	0
Good	3	9	12	2	1	0
Fair	4	5	2	2	0	0
Poor	2	2	1	0	0	0
No Op.	0	2	0	0	0	0
Counties:	4	4	5	0	1	0
Good	2	3	4	0	1	0
Fair	1	0	0	0	0	0
Poor	0	0	0	0	0	0
No Op.	1	1	1	0	0	0
WSDOT:	0	2	6	1	0	0
Good	0	2	6	0	0	0
Fair	0	0	0	1	0	0
Poor	0	0	0	0	0	0
No Op.	0	0	0	0	0	0
Out-of-State:	9	6	7	1	0	1
Good	5	4	5	1	0	0
Fair	3	1	1	0	0	0
Poor	0	0	0	0	0	0
No Op.	1	1	1	0	0	1

b. Reliability

Cities:	9	18	15	4	1	0
Good	7	13	13	3	1	0
Fair	0	2	2	1	0	0
Poor	2	1	0	0	0	0
No Op.	1	1	1	0	0	0
Counties:	4	4	5	0	1	0
Good	2	3	3	0	0	0
Fair	1	0	1	0	1	0
Poor	0	0	0	0	0	0
No Op.	1	1	1	0	0	0
WSDOT:	0	2	6	1	0	0
Good	0	2	5	1	0	0
Fair	0	0	1	0	0	0
Poor	0	0	0	0	0	0
No Op.	0	0	0	0	0	0
Out-of-State:	9	6	7	1	0	1
Good	6	3	5	1	0	0
Fair	2	2	1	0	0	0
Poor	0	0	0	0	0	0
No Op.	1	1	1	0	0	1

Comments:

The most popular loop configuration for the cities was the square loop followed by the quadrupole and rectangular loops. The counties and WSDOT districts were more inclined to use quadrupole. No WSDOT districts used rectangle or diamond loops. Only one WSDOT district used a rectangle with a diamond head. Other state DOT's preferred the rectangular loop followed by the quadrupole and square configurations. One state DOT used a variety of other configurations such as the chevron loops.

The quadrupole was given the highest ratings for sensitivity and reliability. Square and rectangular configurations were not given high sensitivity ratings but most agencies felt that they were fairly reliable. Most sensitivity problems were associated with vehicles having a high ground clearance such as certain four-wheel drive trucks and logging trucks. All agencies except one city and one WSDOT district expressed concern for the detection of light vehicles such as bicycles and small motorcycles.

4. Pavement Saw Cuts

Cities:

Nine cities directly cited WSDOT specifications for saw cut dimensions in the placement of loops. Others had minimum depths ranging from 0.625 inches to four inches and widths ranging from 0.375 inches to 0.625 inches for the feeder cable.

Counties:

Four out of the seven counties directly cited WSDOT specifications. Others used minimum depths ranging from one to two inches with no maximum depths specified. All used a 0.25 inch cut width for loops and 0.375 inch cut width for feeder cables.

WSDOT:

All Washington districts used WSDOT specifications.

Out-of-State:

Other state DOT's used minimum depths ranging from one to three inches. In three cases, the minimum depth was 0.5 inches less for loops in Portland cement concrete than asphalt cement concrete. None of the other states had specifications regarding the maximum depth of placement. Cut widths ranged from 0.25 inches to 0.375 inches for loops and from 0.25 inches to 0.5 inches for feeder cables.

5. Method of Cleaning Saw Cuts

Cities:

Pressurized Air	22
Pressurized Water followed by Pressurized Air	0
No Response	1

Counties:

Pressurized Air	7
Pressurized Water followed by Pressurized air	0
No Response	0

WSDOT:

Pressurized Air	4
Pressurized Water followed by Pressurized Air	2
No Response	0

Out-of-State:

Pressurized Air	8
Pressurized Water followed by Pressurized Air	1
No Response	0

Comment:

By far, the most popular method of cleaning saw cuts is pressurized air. Some respondents used pressurized water prior to pressurized air to ensure the removal of all debris from the cuts. All stressed the need for the cuts to be dry prior to wire placement.

6. Sealants for Loops and Splices

a. Loop Sealants

Cities:

Ten of the 23 Washington cities directly cited the WSDOT specifications for loop sealants. Two other cities used a

variation of WSDOT specifications. One of these used polypropelene rope on the top and bottom of the wire with 0.25-inch gravel broomed over the top rope to prevent the wire from floating to the surface. The application of asphalt followed the aggregate placement. Another city used cotton rope instead of polypropylene rope. The rationale for this was that the polypropylene deformed when hot asphalt was applied causing the rope to be forced out of the groove.

Counties:

Three of the seven counties directly cited WSDOT specifications. One county which no longer uses the WSDOT method stated that the state's method did not adquately hold the loops in place.

WSDOT:

Three districts in WSDOT use the state specifications with no variance. One district is using the current method along with trying other types of sealers. Another district uses Type 2 or 3 roofing asphalt with the polypropylene rope or rubberized asphalt. The remaining district uses roofing asphalt or a joint sealer with polypropylene rope.

Out-of-State:

Most of the other state DOT's contacted use a variety of products and methods for loop sealing. None of those contacted

indicated the use of rope in the sealing process. The products used were usually subjected to some sort of approval process prior to their general use.

Comments:

Manufacturers and products which were mentioned by the respondents are listed below. These are given without preference to the manufacturers.

Preco	Bondo
Magnolia	3-M
Euclid	Goldflex

Other generic loop sealer systems given by the respondents included:

Two-part Epoxy
50/50 Roofing Asphalt and AR-4000 Asphalt
Roofing Asphalt with strips of Scrap Rubber
High-strength Grout (PCC pavements)
Asphalt
Asphalt and Sand

b. Splice Sealants

Cities

All of the cities use WSDOT's recommended method of splice sealing. Very few cities allowed splicing outside of the controller boxes and these allowed for emergency splicing only.

Counties:

Only two counties cited WSDOT specifications directly. Others counties used 3-M kits, heat shrink tubing with bee wax.

WSDOT:

All districts cited state specifications in splice sealing.

Out-of-State:

The majority of other state DOT's used 3-M kits. Other sealing systems mentions included:

Magnolia
Heat Shrink Tubing with silicone Sealer
Epoxy
Loop Sealant

7. Electrical Wires

a. Loop Wire

Cities:

Sixteen of the cities contacted use WSDOT's specification of No. 14 AWG wire with RHH-RHW insulation for induction loops. Other cities used No. 12 gage wire with THHN or THW insulation. One city uses a product marketed under the name Detect-a-Duct in which the loop wire is encased in a polyethylene tube.

Counties:

Four of the counties use the state specifications. The others use No. 12 AWG wire.

WSDOT:

All WSDOT districts use No. 14 gage wire,with RHH-RHW insulation.

Out-of-State:

The following types of electrical wires have been used in other states:

No. 12 THHN, THHWN, THWN XHHW
No. 14 THHN, THHWN, TWWN, THWN, XHHW

b. Feeder Cable

Cities:

Fifteen cities use the same type of lead-in cable as that recommended by the state. Others use twisted paired, Shielded wires of No. 10, No, 12, or No. 16 gage. One city uses lead-in cable supplied by the controller manufacturer.

Counties:

Six of the counties use WSDOT specifications for feeder cable. The remaining county uses No. 18 or No. 19 twisted paired, shielded cable.

WSDOT:

All of the districts use the state specification of No. 14 twisted paired, shielded wire.

Out-of-State:

Six of the other state DOT's use No. 14 twisted paired, shielded wire for lead-in. One state uses a No. 18 guage wire and another cited controller manufacturers recommendations. One state did not respond to this question.

8. Loop Wire Casing

Cities:

Six on the Washington cities use some kind of protective casing for loop wires in pavement. Two of these cited specification ISMA 51-5-1984 PVC tubing. Duct tubing and preformed wire in polyethylene casing were also mentioned. Two cities stated that loop casings were only used at concrete pavement joints or broken asphalt concrete.

Counties:

Only one county used PVC casing for loop wires.

WSDOT:

None of the districts use any sort of protective loop wire casing.

Out-of-State:

Five of the nine other state DOT's use loop wire casings. Most notably, these states are in the midwestern and northern areas of the country. One state uses polyvinyl sleeving at pavement joints and cracks only. The others use polyethylene or PVC to protect the whole loop wire.

9. Amplifiers

A variety of commercial brand amplifiers are in use throughout the state and nation. Those mentioned by the respondents include:

Canoga
Detector System
Sarasota
ICE
Eagle
Safety Signal
Econolite
Micro Delta
Digital
Streetramett
Golden River

Some brands were more widely used than others and the degree of satisfaction for particular brands varied.

(c) **Induction Loop Failures**

1. How Induction Loop Failures are Detected.

	In house, %	Called-in, %
Cities:		
Average	39	61
Median	50	60
Range	99	99
Counties:		
Average	77	23
Median	92	8
Range	75	75
WSDOT:		
Average	73	27
Median	75	25
Range	40	40
Out-of-State:		
Average	20	80
Median	20	80
Range	40	40

Comment:

For Washington cities, the primary method of detecting induction loop failures is by means of notification to the traffic departments from other individuals (general public, police, etc.). County agencies and WSDOT districts believe that more of the failures are discovered by their own personnel. The other state DOT's indicated that loop failures are more frequently found by sources outside of their agencies. Three cities, one county, and three out-of-state DOT's did not respond to this question.

2. Are the Number of Induction Loop Failures Excessive?

	Yes	No
Cities:	1	22
Counties:	2	5
WSDOT:	1	5
Out-of-State:	2	5

Comment:

The results of this question show that most agencies, including WSDOT districts, are satisfied with the current performance of their induction loop systems. Those indicating excessive failures thought that current repair procedures were too costly or that the performance of loops could be improved. Two state DOT's did not respond to this question.

3. Component Failure

a. Pavement Failure

	Cracking	Permanent Def.	Both
Cities:	10	4	3
Counties:	3	2	1
WSDOT:	3	1	2
Out-of State:	2	2	3

Comment:

Among Washington agencies which listed pavement failure as a reason for loop failures, most listed cracking as the primary

mode of pavement distress. Others found that permanent deformation (rutting and shoving) or a combination of this with cracking was responsible for loop failures.

b. Wire Failure

	Fraying	Breaking	Other
Cities:	1	1	1
Counties:	0	1	1
WSDOT:	0	1	0
Out-of-State:	0	1	0

Comment:

Some agencies believed that wire failures were primary problems. Of those that gave wire failures as a reason, most indicated that the wires tended to break. Two agencies said that on certain occasions, they have had incomplete circuits in the loops with no apparent fraying or breaking.

c. Sealant Failure

	Debonding	Cracking	Out of Grove
Cities:	2	0	5
Counties:	2	1	2
WSDOT:	1	0	1
Out-of-State:	1	0	1

Comments:

Agencies which stated that sealants were being forced out of the groove generally used sealants which were very flexible (asphalts, certain special chemical compounds, etc). These

materials will behave differently that the surrounding pavement. They should have greater thermal coefficients and deformation under applied loads. Debonding apparently occurs in situations when the sealant is incompatible with the pavement material (coal tar) or the sealant is very rigid (certain epoxies).

d. Amplifier Failures

Cities:	6
Counties:	1
WSDOT:	2
Out-of-State:	1

Comment:

Amplifier failures as defined by the respondents ranged from having to constantly retune amplifiers to adjust for temperature changes to lightening damage. Others indicated that while retuning was occasionally necessary, it was not what they considered to be a failure.

4. Causes of Failures

a. Traffic Wear

Cities:	11
Counties:	2
WSDOT:	2
Out-of-State	3

Comments:

These respondents believed that the normal application of traffic loads was responsible for induction loop failures. The cities and out-of-state agencies were more inclined to list this as a reason that the counties or WSDOT districts.

b. Environment

	Water Infiltration	Temperature Change
Cities:	4	6
Counties:	1	1
WSDOT:	2	1
Out-of-State:	0	3

Comment:

Temperature change seemed to be the greater factor under environmental causes of induction loop failures. One agency indicated that ice forms in the conduct from the lead-in to the controller. One Washington county stated that frost heave in the pavement was the biggest problems with induction loops.

c. Other Causes of Failures

	Poor Installation/Inspection	Utility Trench Digging
Cities:	4	6
Counties:	1	2
WSDOT:	4	0
Out-of-State:	1	1

Comments:

These problems seem to be as important as environmental and traffic induced failures. Many of the cities and counties said they were not informed about the installation of utility lines prior to their construction. Some counties and cities cited a lack of manpower for inspection of loop installations. Within

WSDOT, the districts believed that inspector should be given more training and not so readily transferred out their positions. One WSDOT district has instituted an on-the-job training program to educate new inspectors and this has apparently been beneficial.

5. Cost per single Induction Loop

	Cost per Repair	Cost per New Installation
Cities:		
Average	$300	$1060
Median	110	510
Range	980	6925
Counties:		
Average	880	360
Median	630	340
Range	2200	600
WSDOT:		
Average	800	990
Median	600	1000
Range	1875	1100
Out-of-State:		
Average	350	380
Median	400	400
Range	200	400

Comment:

The median values for the cost of new installations and repairs are probably more meaningful than the averages due to extreme answers given in some instances. For example, one city reported a cost of 75 dollars for new loop installation while another estimated 7000 dollars. Respondents were asked to base their estimates on a quadrupole configuration. WSDOT districts reported higher costs than the other state DOT's.

(d) Summary

Although largely subjective, the important results of this survey show that:

1. A large majority of the agencies contacted are satisfied with the performance of induction loops using their current practices.

2. Agencies in Washington state reported much lower induction loop failure rates that other state DOT's.

3. Induction loop failures often occur in conjunction with pavement failures; especially pavement cracking.

4. Some WSDOT districts expressed a need for better training of inspection personnel as well as policies which allow inspectors to remain in their positions longer.

APPLICATIONS

The effective products of the study were the results of the literature review and telephone survey as well as the subsequent recommendations contained in the report.

REFERENCES

1. De Laski, A.B. , "Traffic Detectors: Handbook," Implementation Package FHWA-IP-83-2, Federal Highway Administration, Washington, D.C., 1983.

2. Sessions, G.M., "Traffic Devices: Historical Aspects Thereof,: Institute of Traffic Engineers, Washington, D.C., 1971, page 133.

3. Dorsey, W.F., "Status Report on Vehicle Detectors," Report No. FHWA-RD-77-137, Federal Highway Administration, Washington, D.C., November 1976.

4. Oaks, R.L. "Test of Self-Powered Vehicle Detectors," city of Kettering, Ohio, C. August 1980.

5. Tarnoff, P.J., "The Results of FHWA Urban Traffic Control Research: An Interim Report," Traffic Engineering, Vol. 45, April 1975, pp. 27-35.

6. Honeywell, Inc.. "Vehicle Detector, Phase III: Passive Bus Detection/Intersection Priority System Development," Vols. I-III, Report No. FHWA-RD-76-66 to 68, Federal Highway Administration, Washington, D.C., December 1975.

7. 3M Company, Conoga Laboratory, "Operation Manual for the Model 701 3M Brand Microloops Probe," conoga Park, California, March 1981.

8. Pinell, et al., "Inductive Loop Detectors: Theory and Practice, "Report No. FHWA-RD-IMP-76-2, Federal Highway Administration, Washington, D.C. , January 1976.

9. Parsonson, P.S. and Farnoff, P.J.,"Maintenance and Costs of Traffic Signals," Traffic Control Devices, Geometrics, Visibility and Route Guidance, Transportation Research Record No. 737, Transportation Research Record No. 737, Transportation Research board, Washington d.C., 1979.

10. Turnoff, P.J. and Parsonson, P.s., "Selecting Traffic Signal Control at Individual Intersections, "NCHRP report no. 233, Transportation Research board, Washington, D.C., June 1981.

11. Hale, J., "Study of Traffic Loop Failures,: Report No. FHWA/MN/RC-84/04, Minnesota Department of Transportation, St. Paul, July, 1984.

12. Arnold, E.D. and Munn, G.L. "Installation Report-State Demonstration Project: Loop Detectors,: Report No. VHTRC-83-R15, Virginia Highway and Transportation Research council, charlottesvill, Virginia, October, 1982.

13. Everall, P.F., "Urban Freeway Surveillance and control: The State of the Art,: Appendix 2, Federal Highway Administration, Washington, D.C. November 1972.

14. Burmeister, D.L. and Parsonson, P.S., "Installation Innovation for Environmental Protection of Inductive loops," Compendium of Technical papers, Institute of Transportation Engineers 49th Annual Meeting, Toronto, September 23-27, 1979.

15. Leathan, J.L., "Preformed Inductive Loops," Implementation Package VDOT-IMP 77-1, Research and Development Unit, Utah Department of Transportation, May 1977.

16. California Department of Transportation, "Portable Disposable Traffic Detector Loop, "Division of Structures and Engineering Services, FHWA No. C-1-2, TL No. 636346, March 1976.

17. Mills, M.K. "Self Inductance Formulas for Multi-turn Rectangular Loops with Vehicle Detector, "Proceedings, 33rd IEEE Vehicular Technology conference, May 25-27, 1983. Tronto.

18. Blikkern, W.A., "The Adjustable Diamond Loop for Vehicle Detection," Michigan Department of Transportation, Detroit Freeways Operations Unit, 1979.

19. Ingram, J.W. "Detection Devices to Optimize Computerized Traffic Control, "Report No FHWA-CA-TL-79-12, California Department of Transportation, 1979.

20. Conoga Controls Corporation, "Manual for Proximeter II-S, Magnetometer Vehicle Detector System,: August, 1975.

21. Intra-Departmental communication, "Quadrupole Loop Test Results," Washington State Department of Transportation, Olympia, December 3, 1980.

22. Urban Transportation Abroad, Summer 1984, pp. 5-6.

23. Bikowitz, E.W., Ross, S.P. "Evaluation and Improvement of Inductive-Loop Detectors," Engineering Research and Development Bureau, New York State Department of Transportation, Research Report 119, February, 1985.

APPENDIX A

Questionaire Forms

TRAFFIC DETECTION QUESTIONAIRE

AGENCY: _____ DATE: _____

NAME: _____ PHONE: _____

TITLE: _____

ADDRESS: _____

_____

I. GENERAL

1. How many loop detectors are used by your agency?

2. Do you:

_____have any type of real time (continuous) monitoring system?

_____monitor your installations periodically?

_____wait until you get a complaint about a traffic signal before making a visit?

II. CONSTRUCTION TECHNIQUES FOR LOOP DETECTORS

1. Your induction loop systems are installed by:

_____in-house personnel.

_____contractors.

_____both.

_____% in-house

_____% contractors

2. Installation is done primarily in the

_____summer

_____fall

_____winter

_____spring

3. What type of loop configuration do you prefer to install?

_____

Are you concerned with bicycle or other light vehicle detection?

_____Yes

_____No

4. What is your minimum specified depth for placement of induction loops?_____ in. Maximum?_____ in. Width of cut?_____ in.

5. What types of sealants do you usually use?

_____Epoxy

_____Asphalt Joint Sealer with Polyester Rope

_____Grout

_____Other_____

Brand Names:_____

Which is used most?_____

What do you think of its performance?

_____Good

_____Fair

_____Poor

6. What type of wire insulation does your agency specify?

_____

7. Do you specify any type of casing for the loop wire?

_____Yes
_____No

If yes, what type of casing?_____

Do you think it helps?

_____Yes

_____No

III. INDUCTION LOOP FAILURES

1. What is your estimate of the yearly average number of loop detector failures?

_____Detected by in-house personnel

_____Phoned-in by the public

_____Total

Do you think the total number is excessive?

_____Yes

_____No

2. Induction loop failures are generally associated with: (if more than one, please indicate)

_____Pavement Failure

_____cracking

_____rutting

_____shoving

_____Electronics Failure

_____Wire failure without pavement failure

_____fraying

_____breaking

_____Sealant Failure

_____debonding

_____cracking

_____forced out of groove

_____Other_____

3. These failures occur because of:

_____Normal mechanical wear and tear

_____Normal electronics wear and tear

_____Environment

_____water infiltration

_____temperature change

_____other_____

_____Vandalism

_____Other_____

4. How do these failures generally look?

_____Wire forced out of pavement with no pavement deformation

_____Wire forced out of pavement with pavement deformation

_____Sealant cracked with no pavement deformation

_____Sealant cracked with pavement deformation

_____Other_____

5. What is your estimate for the average yearly cost per repair call on induction loops?

_____

IV. ADDITIONAL INFORMATION

If you know of additional sources of information which might be of assistance to us, please list them below. Also, if you have any comments regarding this questionaire or this study, please make them below. Your assistance is greatly appreciated.

I (would) (would not) like a copy of the results of this survey.

TRAFFIC DETECTION QUESTIONNAIRE

AGENCY: _____ DATE: _____

NAME: _____ PHONE: _____

TITLE: _____

ADDRESS: _____

_____

TRAFFIC DETECTION QUESTIONNAIRE

AGENCY: _____ DATE: _____

NAME: _____ PHONE: _____

TITLE: _____

ADDRESS: _____

_____

I. GENERAL

1. How many of each type of the following traffic detectors are used by your agency? Please rank each type and estimate the average number of yearly repairs per type.

	Rank	Avg. no. Repairs per Year	Comments
_____Induction Loop	____	_____	_____
_____Magnetometer	____	_____	_____
_____Other_____			
_____Other_____			
_____TOTAL			

2. Do you:

_____have any type of real time (continuous) monitoring system? (Such as a Multisonics Video Monitoring System)

_____monitor your installations periodically?

_____wait until you get a complaint about a traffic signal before making a visit?

II. CONSTRUCTION TECHNIQUES FOR LOOP DETECTORS

1. What percentage of your induction loop systems are installed by:

in-house personnel_____%

contractors_____%

2. Installation is done primarily in the

_____summer _____fall _____spring

3. How many of each type of loop configuration are used by your agency and how would you rate the sensiivity and reliability of the electronics? (See attached sketches)

	Sensitivity	Reliability
_____Rectangle	Good Fair Poor	Good Fair Poor
_____Square	Good Fair Poor	Good Fair Poor
_____Quadrupole	Good Fair Poor	Good Fair Poor
_____Rectangle with Diamond Head	Good Fair Poor	Good Fair Poor
_____Diamond Loop	Good Fair Poor	Good Fair Poor
_____Other_____	Good Fair Poor	Good Fair Poor
_____Other_____	Good Fair Poor	Good Fair Poor

Please sketch those listed as "Other" above.

Are you concerned with bicycle or other light vehicle detection?

_____Yes _____No

4. What is your minimum specified depth for placement of induction loops?_____ in. Maximum?_____ in. Width of cut?_____ in.

5. How do you clean the sawcuts?

_____Pressurized Water

_____Pressurized Air

_____Other_____

6. What types of sealants or sealant systems do you use (please include manufacturers' names and designations)

For the loop wire?_____

_____

For splices?_____

_____

7. What type of wire is used (please include applicable government or industry/manufacturers designation)

For the loop wire?_____

For the feeder cable?_____

8. Do you specify any type of casing for the loop wire or feeder cable?

_____Yes _____No

If yes, what type of casing?_____

9. What type of amplifiers do you use?

Brand Name	Model	Govt/Ind Specs	Comments

III. INDUCTION LOOP FAILURES

1. What is your estimate of the yearly average number of loop detector failures?

   _____Detected by in-house personnel

   _____Phoned-in by the public

   _____Total

   Do you think the total number is excessive?

   _____Yes _____No

2. Induction loop failures are generally associated with: (if more than one, please indicate)

   _____Pavement Failure

   _____cracking

   _____rutting

   _____shoving

   _____Wire failure without pavement failure

   _____fraying

   _____breaking

   _____Sealant Failure

   _____debonding

   _____cracking

   _____forced out of groove

   _____Amplifier Failure

   _____Other_____

3. These failures occur because of:

   _____Normal wear and tear

   _____Environment

   _____water infiltration

   _____temperature change

   _____Other_____

4. How do these failures generally look?

_____Wire forced out of pavement with no pavement deformation

_____Wire forced out of pavement with pavement deformation

_____Sealant cracked with no pavement deformation

_____Sealant cracked with pavement deformation

_____No visible damage

_____Other_____

_____

5. What is your estimate for the average yearly cost per repair call on induction loops and total average cost per unit for original installation?

$_____per repair $_____per initial installation

IV. ADDITIONAL INFORMATION

If you know of additional sources of information which might be of assistance to us, please list them below. Also, if you have any comments regarding this questionnaire, please make them below. Your assistance is greatly appreciated.

I (would) (would not) like a copy of the results of this survey.