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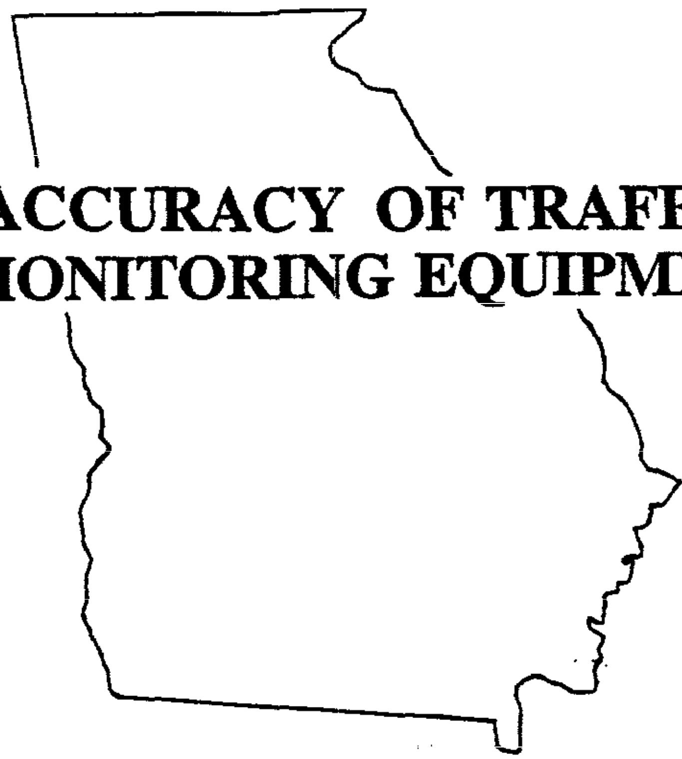
FINAL REPORT

GEORGIA DEPARTMENT OF TRANSPORTATION

ACCURACY OF TRAFFIC MONITORING EQUIPMENT



GEORGIA
INSTITUTE OF TECHNOLOGY

Contract Research
GDOT Research Project 9210
Final Report

ACCURACY OF TRAFFIC MONITORING EQUIPMENT

By:

Bruce A. Harvey
Glenn H. Champion
Steven M. Ritchie
Craig D. Ruby

June 1995

In Cooperation With

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Office of Materials and Research
15 Kennedy Drive
Forrest Park, Georgia 30050

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16. Abstract

A total of 13 sensors and classifier configurations from 10 commercially available equipment vendors were tested to determine their accuracy in classifying vehicles into 13 FHWA vehicle classes, in measuring axle spacings, and in measuring overall vehicle length. A majority of the participating vendors used a P-L-P (piezo-loop-piezo) sensor configuration in the roadway, while the remaining vendors used either a P-P or L-P-L sensor configuration.

Tests provided comparison of the vehicle-by-vehicle data from the classifers with ground truth data obtained from a video tape of the traffic stream in the test lane. Vehicle classes and measurements were obtained from the video tape through the use of a computer-aided data reduction system developed specifically for this project.

Classification accuracies ranged from 78.8% to 96.2%, if class 2 (passenger vehicles) and class 3 (small pickup trucks) are combined. The classification of class 9 vehicles (a majority of the trucks) was very good on most classifers. Classification accuracy, axle spacing measurement errors, and overall length measurement errors appeared to be independent on the sensor configurations.

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PREFACE

Under Contract Number 10-9210-50520, Task Order No. 27, the Georgia Department of Transportation (GaDOT), Office of Materials and Research has tasked the Georgia Tech Research institute (GTRI) to conduct a Federal Highway Administration (FHWA) funded study of the accuracy of automatic vehicle classification equipment. The program was monitored by Mr. Rick Deaver of the GaDOT Office of Materials and Research and Mr. Perry Kent of the FHWA Office of Highway Information Management. Mr. Darrell Elwell and Mr. Scott Knight of the GaDOT Planning Data Services Bureau provided an experienced GaDOT road crew under the supervision of Mr. Bob Creasman to perform the equipment installations described in this report.

This report is authored by the Georgia Tech Research Institute (GTRI) of the Georgia Institute of Technology. The effort was directed by Dr. Bruce Harvey under the general supervision of Mr. Eric Barnhart, Chief of Communications and Networking Division.

EXECUTIVE SUMMARY

In this project, a number of vehicle classifiers were tested to determine their accuracy in classifying vehicles into the 13 FHWA vehicle classes, in measuring axle spacings, and in measuring overall vehicle length. The scope of the project was limited to commercially available equipment that was available in September 1992. The objectives of the project were to:

- Determine the adequacy of vehicle counting devices.
- Determine the adequacy of various types of equipment to correctly sort vehicles into the 13 FHWA vehicle classes (as identified in the FHWA Traffic Monitoring Guide).
- Determine the adequacy of automatic measurement of overall vehicle length.
- Determine how the vehicle and axle sensor technology affects the accuracy of the vehicle classification.
- Determine the effects of vehicle repetitions, heavy axle loadings, and weather on pneumatic tube axle sensors and other types of vehicle and axle sensors.

A total of 13 sensor and classifier configurations from 10 equipment vendors were installed from December 1992 to April 1993 on the west bound side of I-20 near Covington, Georgia (30 mi. east of Atlanta). They were all installed in a single lane for side-by-side comparison.

All of the classifiers tested (excluding the one used for the pneumatic tube tests) used a combination of magnetic loop detectors and piezoelectric axle sensors. Although a wider variety of sensor technologies were desired for the project, none of the vendors using other sensors responded to the FHWA request for participation with commercially available equipment. A majority of the participating vendors used a P-L-P (piezo-loop-piezo) sensor configuration in the roadway, while the remaining vendors used either a P-P or L-P-L sensor configuration.

Three tests were conducted in order to fully characterize the performance of the classification equipment. Two 48-hour tests were conducted on May 5-7, 1993 and September 9-11, 1993. These tests provided comparison of the vehicle-by-vehicle data from the classifiers with ground truth data obtained from a video tape of the traffic stream in the test lane. The classifiers were assessed to determine their classification accuracy, and their ability to accurately measure axle spacings and overall length. The performance of the classifiers was assessed parametrically versus the percentage of vehicle with more than 2 axles, the air temperature, and the pavement temperature.

The third test conducted was a 7-day test performed on September 9-16, 1993 in conjunction with the second 48-hour test. During this test, the classifiers were programmed to bin the data in 15 minute increments. The purpose of the test was to assess the long term performance characteristics of the equipment. The data was compared to determine how accurately the classifiers counted the number of axles, and the number of vehicles in each vehicle class. The 7-day test was also used to assess the performance of the equipment as a function of time in service by comparing the accuracy in the first day of testing with the accuracy in the last day of testing.

An augmented pneumatic tube test was conducted in parallel with the second 48-hour test. This test used a Peek TrafiCOMP III (Peek 241) and four road tubes to monitor the traffic in two lanes. The objective of this test was to assess the ability of road tubes to monitor traffic in multiple lanes. A setup error resulted in the classifier recording all traffic in both lanes into one file. Therefore, the problem of separating the traffic into the two lanes and removing duplications was made much more difficult. Therefore, analysis of this test was postponed until a re-test can be conducted.

Ground truth data for the 48-hour and 7-day tests was obtained from a side-mounted video camera viewing the traffic stream. The vehicle classes and measurements were obtained from the video tape through the use of a computer-aided data reduction system developed specifically for this project. The computer data reduction system was named the Computer Vehicle Classification and Reduction System (CVCRS), and was capable of assisting an operator in the recording of time stamped vehicle classes along with measurements of axle spacings and overall vehicle length.

The classification accuracies resulting from this test ranged from 63.5% to 79.1%. The most common errors occurred between Class 2 (passenger vehicles) and Class 3 (other 2-axle, 4-tire vehicles). A small pickup truck (class 3) is very difficult to distinguish from a large car (class 2) based on length and axle spacing. If class 2 and 3 are combined, then the classification accuracies ranged from 78.8% to 96.2%.

Temperature of the air and pavement was found to have little effect on the performance of the classifiers. However, the range of temperatures was somewhat limited for this test. The percentage of trucks (vehicles with more than 2 axles) tended to have some effect on the classifier accuracies. The classification of class 9 vehicles (a majority of the trucks) was very good on most classifiers, and hence the classification accuracy tended to improve as the percentage of trucks increased. The longer vehicle lengths and axles spacings did, however, result in greater measurement errors as the percentage of trucks increased.

The sensor configuration used by the classifiers did not appear to have a significant effect on the accuracy. Classification accuracy, axle spacing measurement errors, and overall length measurement errors appeared to be independent on the sensor configurations. The primary factor observed in this test to affect the classification accuracy was the performance of the axle sensors. The ability of the equipment to accurately classify vehicles was linearly dependent on the ability of the sensor and classifier to accurately count the number of axles. Therefore, performance of the piezoelectric axle sensor and the interface electronics in the classification equipment are the primary factors effecting the accuracy of the equipment.

A further opportunity has arisen to collect more data concerning the performance of these classification equipments. Road construction is under way at the test site and will result in the sensors in the roadway being overlaid as part of a widening of the road. This presents an opportunity to test the performance of the devices after a pavement overlay. This issue is important to the maintainability of a traffic monitoring site. The results of the overlay tests will be reported in and addendum to this report.

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1. INTRODUCTION AND SCOPE

1.1 Background

There have been significant changes in the sophistication and technological approaches to the gathering of vehicle classification and volume count data since the last major study of vehicle classification accuracy. This has included the use of new types of sensors, such as piezoelectric, the development of programmable classifiers that allow the user to specify the dimensional thresholds for various vehicle types, and the introduction of vehicle classifiers that retain individual vehicle information rather than binning the data. This study addresses the need for controlled testing of the latest Automatic Vehicle Classification (AVC) equipment. The equipment is limited to commercially available devices that provide volume counts and vehicle classifications.

The objectives of the program are to:

- Determine the adequacy of vehicle counting devices.
- Determine the adequacy of various types of equipment to correctly sort vehicles into the 13 FHWA vehicle classes (as identified in the FHWA Traffic Monitoring Guide).
- Determine the adequacy of automatic measurement of overall vehicle length.
- Determine how the vehicle and axle sensor technology affects the accuracy of the vehicle classification.
- Determine the effects of vehicle repetitions, heavy axle loadings, and weather on pneumatic tube axle sensors and other types of vehicle and axle sensors.

Multiple testing sessions are planned over an 18 month period with various AVC accuracy characteristics being analyzed with respect to parameters such as vehicle speed, traffic volume, pavement temperature and others.

1.2 Participating AVC System Vendors

The FHWA provided the Georgia Department of Transportation (GaDOT) with a list of vendors that had indicated a willingness to participate in the assessment project. GaDOT and GTRI contacted each vendor to schedule equipment acquisition and testing. The vendors were asked to specify equipment and sensor selections, configurations, and installation procedures for maximum classification accuracy. Each vendor agreed to provide the equipment to the project on a no-charge loan basis. Permanently installed sensors were purchased by GaDOT directly from the AVC vendor assuring that each vendor was able to select and provide the best sensor for his equipment.

A list of participating vendors (including addresses and points of contact) is included as Appendix A. Table 1 lists the equipment configurations supplied for test by each vendor. In the "Configuration" column, the "P" is a piezoelectric axle sensor, and the "L" is an inductive loop vehicle presence sensor.

Table I. Vendor Classifiers and Configurations Installed

EQUIPMENT VENDOR	MODEL NUMBERS	CONFIGURATION, AXLE SENSOR TYPE
Mikros Systems	TEL-2CM	L-P-L, Philips Vibracoax
Peek Traffic, Inc.	TrafiCOMP III GK-6000	P-L-P, Philips Vibracoax P-P, Philips Vibracoax P-P, Philips Vibracoax
PAT Equipment Corporation, Inc.	AVC-100 AVC-100	P-L-P, Atochem Roadtrax Series 'P' L-P-L, Philips Vibracoax
MITRON Systems Corp.	MSC-3000 DCP	P-P, Autologger MINI
Electronic Control Measure	HESTIA	P-L-P, ECM PB2N33/25
TimeMark, Inc.	Delta II	P-P, Philips Vibracoax
International Road Dynamics, Inc.	TC/C 530-4D/4P/4L	PR-L-PR, Dynax AS-400 (Resistive) P-L-P, Philips Vibracoax
Golden River Traffic	Marksman 660	P-L-P, Traffic 2000
Diamond Traffic Products	TT-2001	P-L-P, Autologger Maxi P-L-P, Philips Vibracoax

2. EQUIPMENT INSTALLATION

2.1 EVALUATION SITE

The objective of this project is to determine various accuracy parameters of classifying equipment under as nearly ideal conditions as practical. An evaluation site was needed that would accommodate installation of the test devices and equipment cabinets, a mobile office for test personnel, and test instrumentation. The site should also have minimal impact on the accuracy of the equipment under test. The GaDOT provided GTRI with a number of candidate sites for testing with characteristics that meet the specifications listed below, and a final selection was made by a consensus of GaDOT, GTRI, and the FHWA.

2.1.1 Evaluation Site Specifications

The specifications for the evaluation site are listed below.

A. Horizontal curvature of the roadway lane for 150 feet in advance of and beyond the sensors shall have a radius of not less than 5,700 feet measured along the centerline of the lane;

B. A longitudinal gradient of the road surface for 150 feet in advance of and beyond the system sensors shall not exceed 2 percent;

C. The cross-slope (lateral slope) of the road surface for 150 feet in advance of and beyond the system sensors shall not exceed 2 percent;

D. The width of the roadway lane or lanes being monitored shall be between 10 and 12 feet;

E. The pavement surface will be relatively smooth and free of rutting and cracking; and

F. The traffic normally operates in a free flow condition of greater than 30 miles per hour and no more than 65 miles per hour.

2.1.2 Site Location and description

The selected site is located on the westbound side of I-20 east of Covington, Georgia (30 miles east of Atlanta). There are two westbound lanes, but the testing is to be conducted only in the outside lane. The roadway is straight; the grade is less than 1% (westbound is uphill); the cross slope is negligible, and the lane width is 11 feet. The speed limit is 65 MPH, and traffic backups rarely occur.

The evaluation site has traffic that includes all 13 of the FHWA classifications except triple trailer units which are illegal in Georgia. The site is also acceptable for conducting the "Extended Pneumatic Tube Testing" called for in Task F of the statement of work.

The expressway was constructed in 1965 and was improved with an overlay in 1986. The pavement condition is fair with no cracking, dips or uneven areas; however, there is some rutting present. The rutting is most severe at the beginning of the test area (the east end of the site) at approximately 1/2 inch and decreases to approximately 1/4 inch at the end of the test area. It was decided that this amount of rutting is fairly typical and should not be a problem.

2.1.3 Test Facilities and Instrumentation

A mobile field office was placed on the site to house personnel and equipment during the tests. Power poles were installed, wires were run, and breaker boxes installed by the local power company. Instrumentation required for the test included a video camera for classification of vehicles (with lights for videotaping at night), a video camera to record lane changes within the test area, air and pavement temperature recording equipment, and a rainfall quantity sensor. The test instrumentation concept is shown in Figure 1.

The classification camera was mounted near the mobile office on a pole which was 69 feet from the outside edge of the test lane. The camera, in its fan-cooled environmental enclosure, was mounted 40' 4" above the level of the highway surface resulting in a pointing angle of 30 degrees down from horizontal. This mounting gave a sufficient angle of view to determine the position of the vehicle within the test lane. The road was marked with reflective tape at ten foot intervals to allow for vehicle length measurement. Two 1 kilowatt metal halide lights were mounted on the same pole approximately 10 feet below the camera for videotaping at night. A VHS video cassette recorder was located in the mobile office. The video was time stamped for correlation with the classifier data and the lane change video.

The lane change camera was enclosed in a traffic control cabinet mounted on the overpass for State Road 81, and the video cassette recorder was located in another cabinet near the overpass. The camera was mounted such that it was directly over the center line of the westbound lanes and viewed the entire test area. The lane change video was also time stamped for correlation with the classification video.

Temperature and rainfall measuring equipment were set up for each test instead of being permanently installed. Temperatures were measured with thermocouple thermometers, and rain was measured with a digital tilt-pan rain gauge.

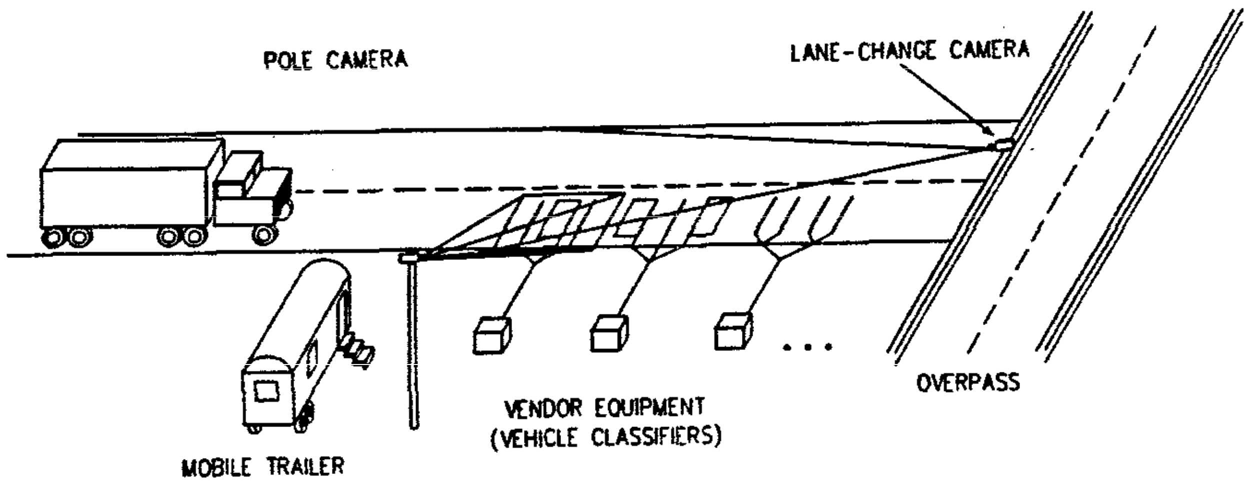


Figure 1. Test Instrumentation Conceptual Drawing

2.2 GENERAL INSTALLATION PROCEDURES

All vendor sensor configurations included in-pavement axle sensors and, in most cases, in-pavement loops. The GaDOT was responsible for providing the equipment, tools, and labor for installing the equipment and was also responsible for traffic control. GTRI monitored and documented the installation process with videotape and written records. The sensors and equipment were installed in strict accordance with the procedures recommended by the vendor, and each vendor sent a representative to supervise the installation. The general procedures presented below were typically followed by each vendor; any exceptions for specific vendors are noted in Section IV.

It was desirable to install the vendor configurations as close together as possible to minimize the overall length of the test area. However, a concern was raised by several vendors about possible electromagnetic crosstalk between their loops the loops of other vendors. Without sufficient separation, a long truck may occupy two vendor's loops simultaneously and induce crosstalk through the truck body. To avoid any potential problems, the spacing between different vendor's loops was maintained at 60 feet or more.

Individual locking equipment cabinets were pole mounted a minimum of thirty feet off the roadway to house each vendor's equipment and protect it from tampering and vandalism. Ground rods were installed at each cabinet, and ground wires were routed into the cabinets for the vendor's use. Cable trenches were dug for the sensor leads. Conduit was supplied for the sensor leads for each vendor who requested it. Some cabinets were supplied with ac power for the classification equipment and for portable computers used for data collection.

The installations were performed mostly during the winter months. Although cold weather installations are not generally desirable, contractual schedule requirements dictated winter installation for this evaluation. Fortunately, Georgia winters are not too severe; the lowest temperature installation was at 38° F, and most were at 50° F or above. The installation procedures included provisions for curing epoxy at low temperatures.

2.2.1 Axle Sensor Installation

The following steps represent a typical installation of an in-pavement axle sensor. These procedures were followed by each vendor except where noted in the detailed installation descriptions of Section IV.

1. Decide on the approximate installation location (leading edge of loop to be situated 60 feet west of the trailing edge of the last vendors loop). Measure the rutting, and adjust the location slightly if necessary.

2. Using a straight edge (10 foot aluminum bar in this case), lay out the sensor configuration and paint guide lines on the pavement. Ensure visually or by measurement that the sensors are perpendicular to the road.

3. Cut each outside edge of the slot with the saw adjusted to the vendor specified depth. Make three or four more cuts inside the previous cuts leaving thin sections of pavement to be removed. Cut a 1/4 slot to the edge of the pavement for the coax cable. To protect the coax from future damage, make the cut deeper near the edge so that the coax will exit the pavement well under ground level.

4. Chip out the excess material using a pneumatic chisel or a hammer and chisel. Use a plywood jig or a ruler to check the depth of the slot. Test fit the sensor to be sure of a proper fit.

5. Wash the slot thoroughly, and blow out any debris using compressed air.

6. Blow out the slot for a few minutes with compressed air to remove any remaining water. Allow the slot to dry thoroughly. Propane torches or torpedo heaters (forced-air, kerosine heaters typically 100,000 BTU) may be necessary depending on conditions. If propane torches are used, do not overheat or melt the asphalt. Torpedo heaters can be utilized more effectively if the hot air is channeled over the slots through tunnels made of cardboard or aluminum sign blanks. In cold conditions, torpedo heaters can also assist in curing of the epoxy by preheating the slot.

7. After the slots are dry, brush all sides with a wire brush to dislodge any dust or dirt that may reduce epoxy adhesion. Blow the slots out a final time with compressed air.

8. Prepare the sensors by attaching leveling bars (typically steel bar stock) to hold it at the right height relative to the pavement surface. The bars are attached using wire or plastic tie-wraps.

9. Form a dam at the coax end of the slot using plumber's putty to prevent the epoxy from flowing out of the sensor slot. Place duct tape along the top of the slot on each side to prevent excess epoxy from adhering to the pavement. Multiple layers of tape can be used to raise the sensor slightly above the road surface by holding the leveling plates slightly higher.

10. Mix the epoxy following the manufacturer's directions. Use a pneumatic or a heavy duty electric drill with a mixing paddle attached. Large paddles of the type used for drywall sealer work very well.

11. Pour the epoxy, and install the sensor. Press the sensor in place, and use a putty knife to remove the excess epoxy or to apply more epoxy to fill any voids around the sensor. Smooth the surface of the epoxy even with the pavement.

12. Place weights on the leveling plates as required to hold the sensor in place.

13. Allow the epoxy to cure in accordance with the manufactures directions. Depending on conditions, torpedo heaters may be necessary to cure the epoxy in the time allowed before the traffic lane must be opened. The same cardboard tunnel arrangement used for drying and preheating can be used for curing.

14. After the epoxy has cured sufficiently, remove the weights and clip the wires or plastic ties holding the leveling plates. Remove the plates by tapping with a hammer. Clip the wires or ties again flush with the epoxy.

15. Route the coax through the coax slot and fill the slot with 3M Loop Sealer. Install the coax in conduit (if used) and route it to the equipment cabinet.

16. Test each sensor using an oscilloscope or by connecting to the classifier.

2.2.2 Loop Installation

The following steps represent a typical installation of an in-pavement loop sensor. These procedures were followed by each vendor with no significant differences except the number of turns of wire as noted in the detailed installation descriptions of Section IV.

1. Locate and mark the loop as in the axle sensor procedure (typically the loop and axle sensor cut lines are all marked at the same time). Chamfer cuts are marked at the corners of each loop to facilitate installing the wire.

2. Make a single cut along each mark using a 1/8 inch saw blade. The cuts should be one inch deep. Cut a slot to the edge of pavement for the lead wires. As for the coax cable, make the cut deeper near the edge so that the wires will exit the pavement well under ground level.

3. Use compressed air to blow out the water and any debris in the cut. It is not necessary to dry the cuts.

4. Starting at the equipment cabinet, route the loop wire (14 AWG type MTW or THHN, oil and gasoline resistant) along the trench to the edge of

the pavement and through the slot cut in the paved shoulder. Place the wire into the loop cuts pressing the wire to the bottom of the cut. The GaDOT installation crew used a pavement saw blade mounted to a handle that allowed it to roll freely to roll the wire into the cut. Install the required number of turns then route the wire back to the equipment cabinet. Leave an extra few feet of wire at the cabinet to allow for twisting and routing.

5. Twist the leads by stretching the wire out straight and placing the ends into the chuck of a drill. Operate the drill until the wire has approximately three turns per foot. Route the wires through the conduit (if used) to the box. Whether conduit is used in the trench or not, conduit is always run from the trench up to the equipment box.

6. Fill the cuts with 3M Loop Seal. The sealer can be applied under wet condition without any apparent problems. Cover the top of the cuts with sand or glass beads. Clean up any excess loop sealer or debris.

7. Test each loop using the digital test instrument supplied by the GaDot. The tester measures the inductance of the loop and indicates the loop frequency stability.

2.2.3 System Testing

After the sensors are installed, the equipment is installed in the cabinet and connected to the sensors. When the lane has been opened and the traffic is travelling over the sensors, the classifier is adjusted if necessary and is checked for normal operation. The vendor makes the determination as to whether the classifier is ready for the evaluation.

2.3 AVC SYSTEM INSTALLATIONS

A summary of each vendors's installation configuration and specific installation procedures, where they differ from the general installation procedures of Section III, are presented below. Any problems that occurred with the installation or with the initial system checkout are discussed. An overall view of the installation layout is shown in Figure 2. The station numbers show that the test area extends from approximately station 183 to station 865 for a total length of 682 feet.

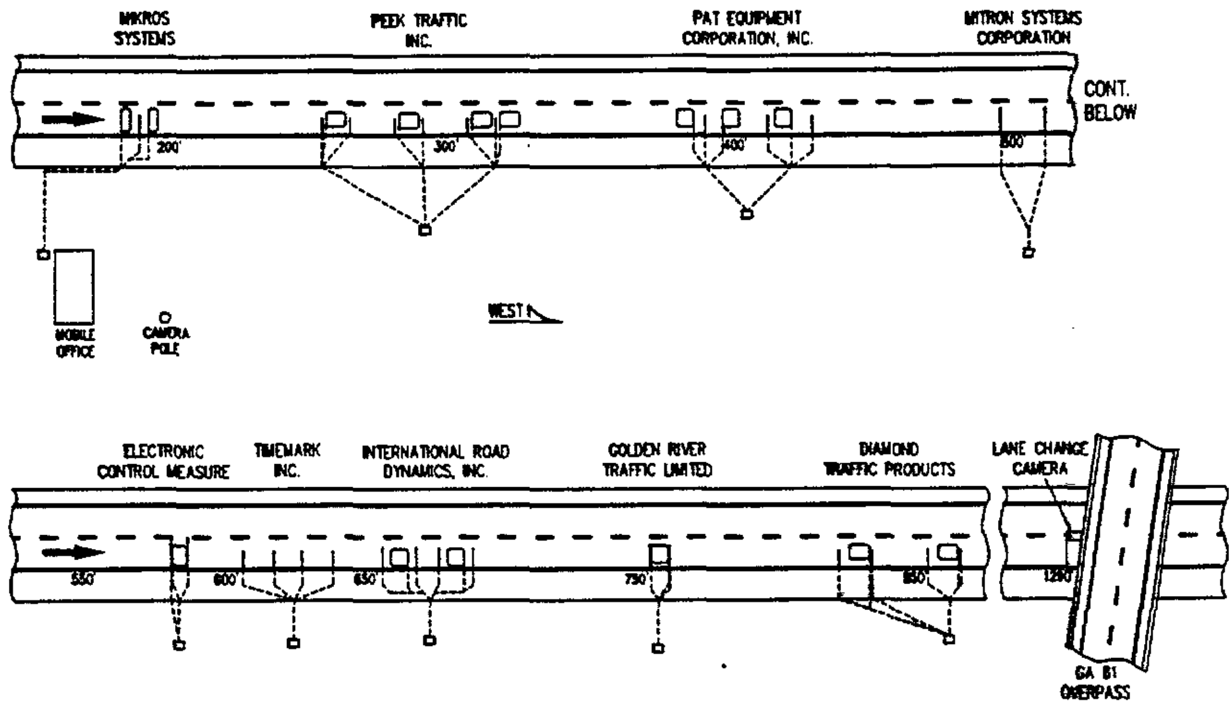


Figure 2. Overall Layout of Evaluation Site

2.3.1 Mikros Systems

Mikros installed a model TEL-2CM classifier with two, three-turn loops and one Philips axle sensor. The sensor layout is shown in Figure 3. The rutting at the location of the axle sensor was 5/32 inch. The installation was performed on 12/3/92. The weather was clear, and the air temperature was 57° F.

The general axle sensor and loop installation procedures were followed. The slots were dried with compressed air, and the epoxy was cured under ambient conditions (no heaters were used). Two layers of duct tape were used along the top of the slot. A strip of duct tape was also used on the top of sensor; it was peeled off after the epoxy cured resulting in a clean sensor surface. The aluminum channel of the sensor was cleaned with solvent prior to installation to insure proper bonding with the epoxy. The epoxy used was Traffic Coil (manufactured by Astor-STAG). The axle sensor was installed using 4 leveling plates.

After the installation was complete, the sensor height profile relative to the pavement surface was measured to determine how well the sensor conforms to the road surface. The measurements were performed by placing a special jig over the sensor with supports resting on the pavement on either side and measuring the height of the sensor surface with a dial caliper. The sensor profile is shown in Figure 4. A sensor height of zero indicates the sensor is flush with the surrounding pavement; negative heights indicate sensor surfaces below pavement level. The rutted area of the road extended from approximately 1.5 feet to 2.5 feet. The plot shows that the sensor was as much as 0.1 inches above the road surface level in the rutted wheel path and was as much as 0.18 inches below the surface at around 3.5 feet.

Initial tests of the axle sensor with oscilloscope verified that it was operational; however, the output levels vary with the position of the vehicle's wheel across the length of the sensor. The sensor performance was determined to be adequate by the vendor. Testing of the loops indicated 89.6 microhenries for loop 1 and 91.2 microhenries for loop 2 with stable frequency readings.

Classifier installation, checkout and training were performed on 12/17/92. The vendor indicated that the classifier was functioning properly and was ready for testing.

The coax and loop leads were broken on 1/28/93 by the power pole installation vehicle. On 1/29/93, the leads were spliced (soldered) and encapsulated inside a six inch section of PVC pipe filled with silicone caulk. The new leads were run in a deeper trench routed away from traffic in the mobile office area. System retests by the vendor indicated that the sensors and classifier were functioning properly.

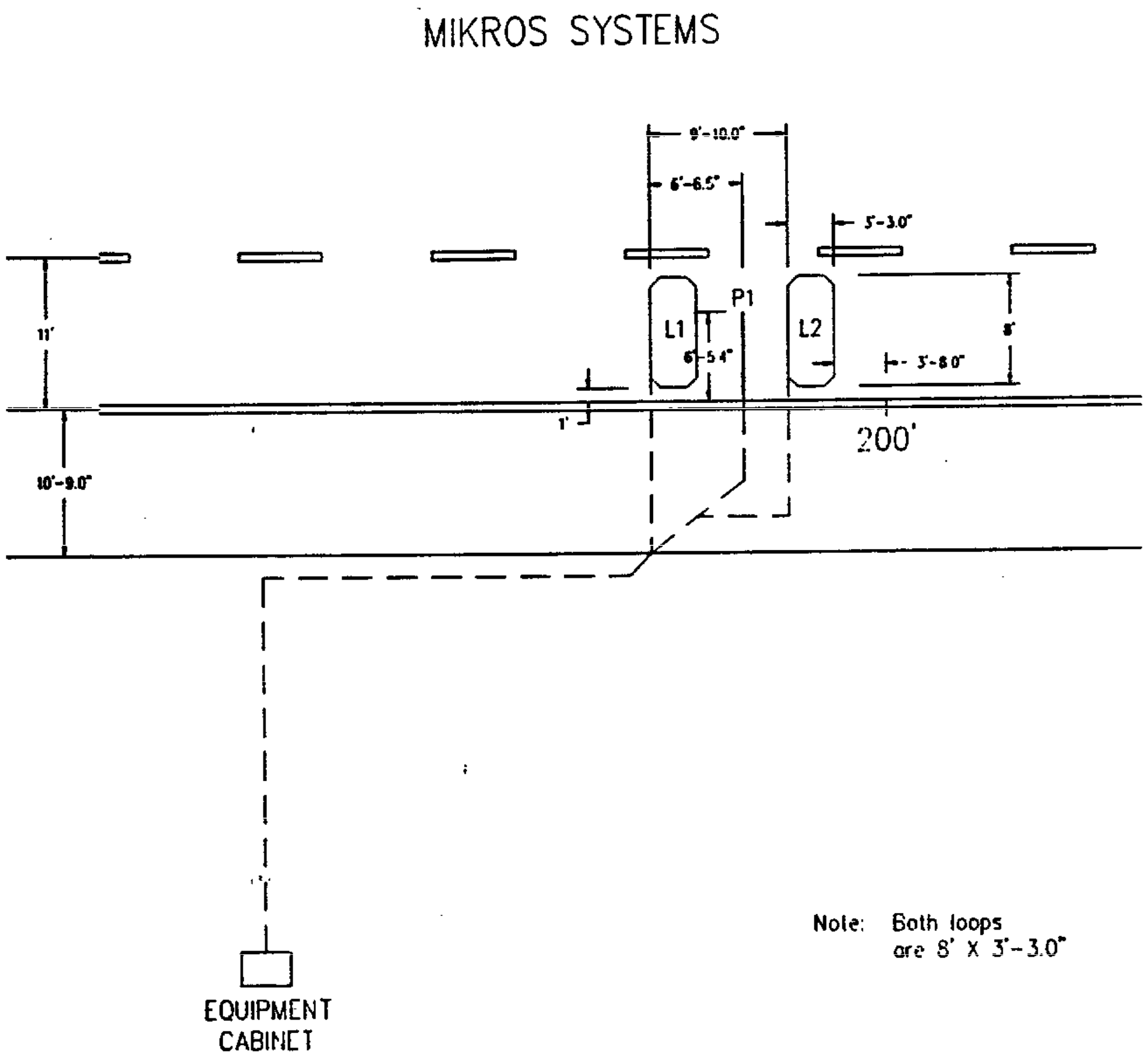


Figure 3. Mikros Installation Configuration Drawing

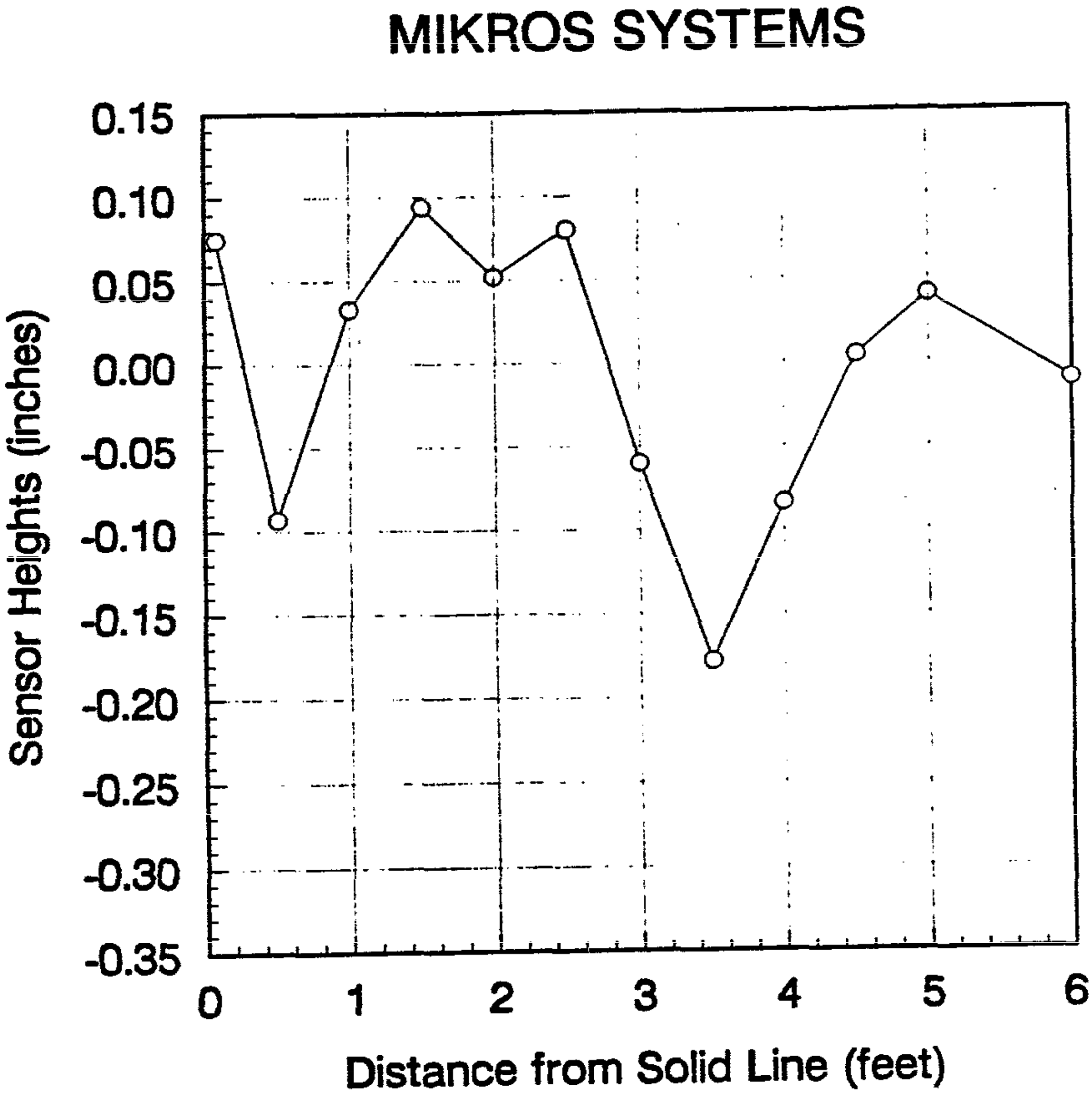


Figure 4. Mikros Axle Sensor Profile

2.3.2 Peek Traffic Inc.

Peek installed a model 241 TrafficComp III classifier with one set of sensors and a model GK 6000 classifier with two sets of sensors configured as two lanes. The sensor layout is shown in Figure 5. The TraffiComp uses two philips piezoelectric axle sensors and one three-turn loop. The GK 6000 uses two philips piezoelectric axle sensors for each configuration (loops were installed for the GK 6000, but were not used during the tests). The rutting at the location of axle sensors 1 through 6 was 14/32, 15/32, 13/32, 14/32, 13/32, 12/32, respectively. The installation was performed on 11/23/92 (axle sensors 1-4 and loops 1-2) and 11/30/92 (axle sensors 5-6 and loops 3-4). The weather was partly cloudy and 59° F on the 23rd, mostly sunny and 55° F on the 30th.

The general axle sensor and loop installation procedures were followed. The slots were dried with compressed air, and the epoxy was cured under ambient conditions (no heaters were used). Three layers of duct tape were used along the top of the slot. A strip of duct tape was also used on the top of sensor; it was peeled off after the epoxy cured resulting in a clean sensor surface. The epoxy used was Traffic Coil. The axle sensors were pre-bent slightly to conform to the local rutting, and were installed using 4 leveling plates. The resulting sensor profiles in Figure 6 show that all of the sensors were close to, or above, the pavement surface level over most of their length. The worst case height variation for any sensor is 0.2 inches (sensor 4).

The axle sensors were tested with an oscilloscope and were all working properly. The loop used for the TraffiComp III (loop 3) measured 140 microhenries and demonstrated good frequency stability. The other loops were functioning properly as well, but were not used during the evaluations.

Classifier installation, checkout and training were performed on 3/24/93. The vendor indicated that both classifiers were functioning properly and were ready for testing. During a subsequent checkout of the TraffiComp III, the processor board latched up several times requiring an internal reset. The vendor supplied a replacement processor board.

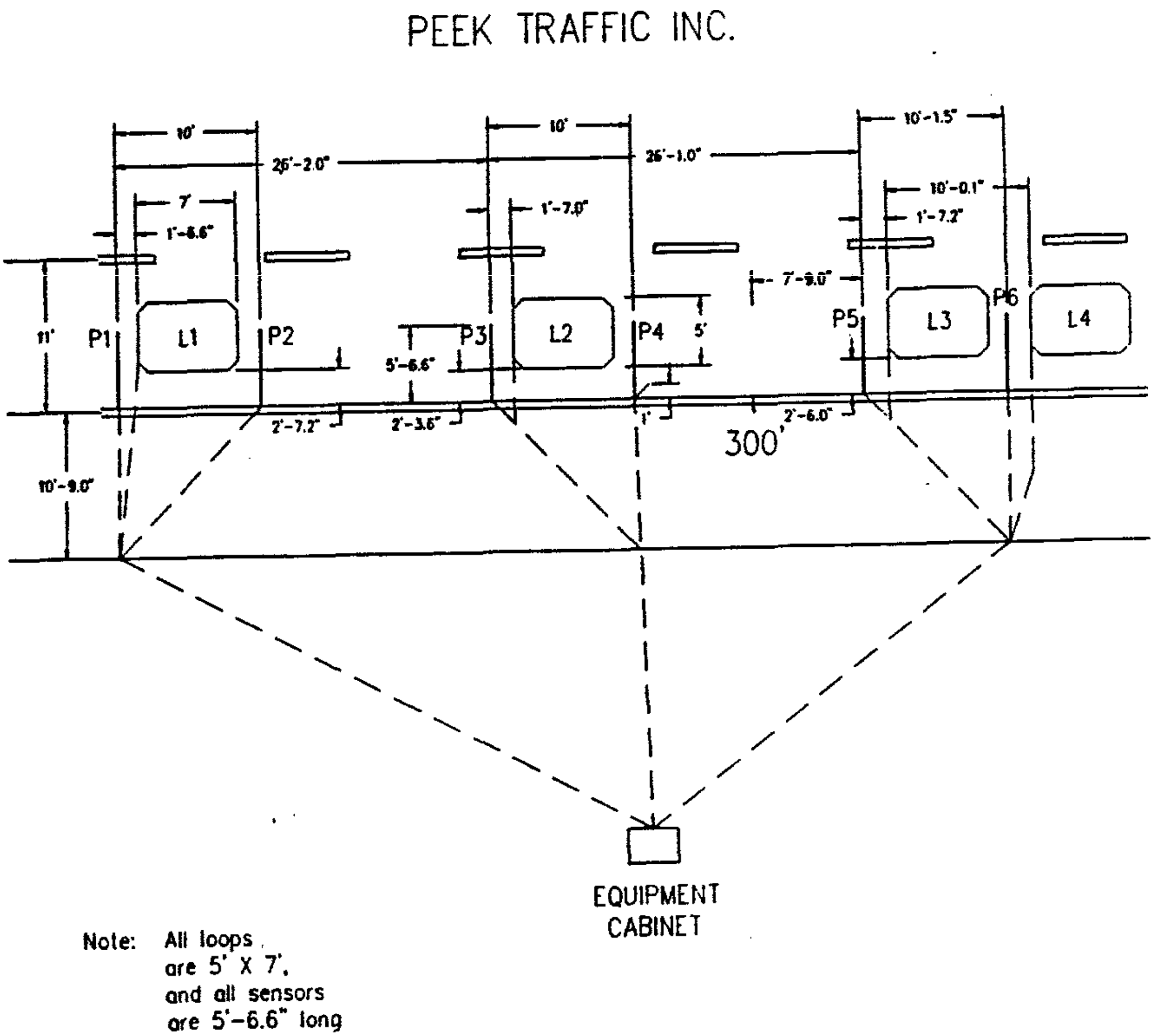


Figure 5. Peek Installation Configuration Drawing

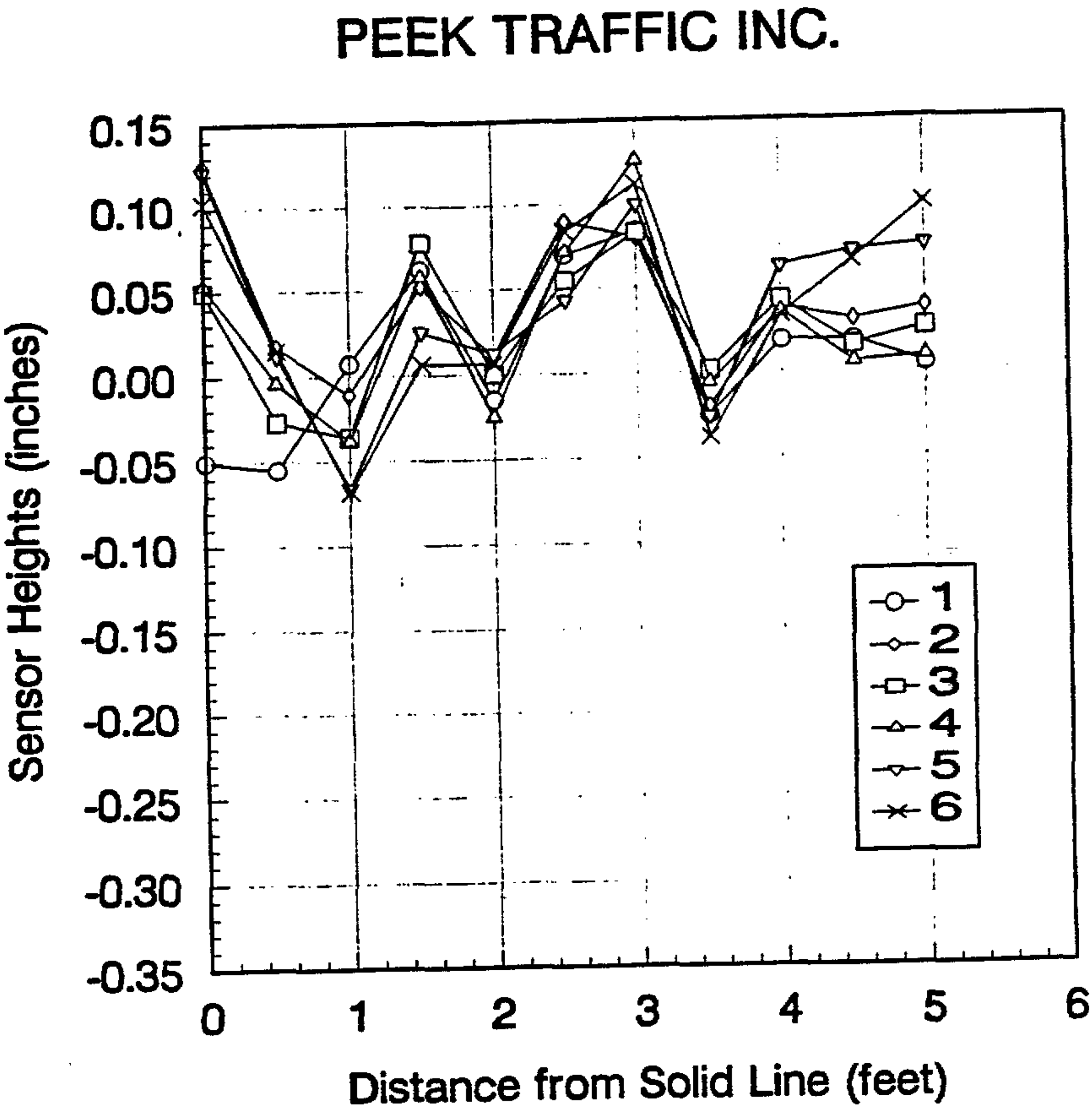


Figure 6. Peek Axle Sensor Profiles

2.3.3 PAT Equipment Corporation

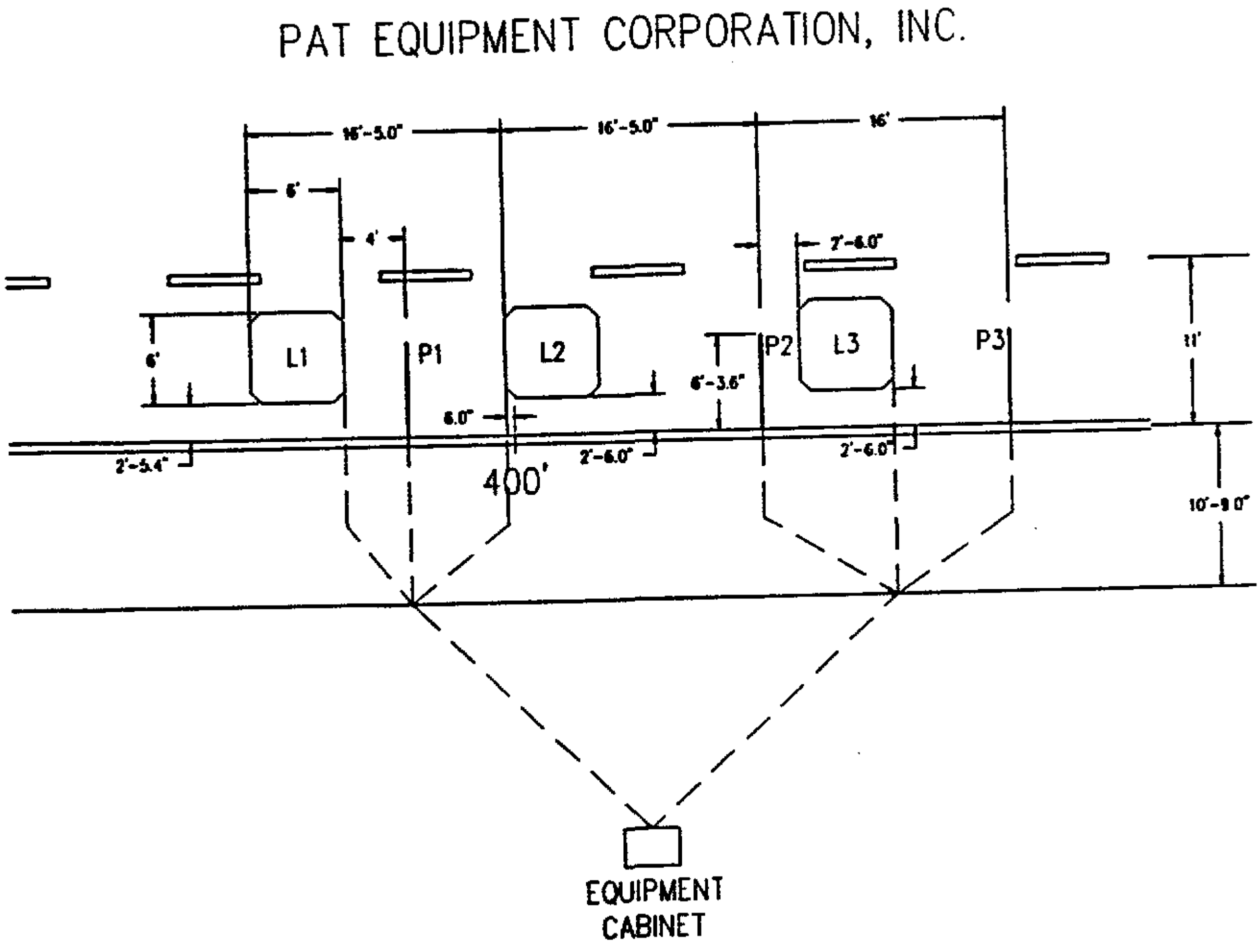
PAT installed two AVC-100 classifiers each with one set of sensors. The sensor layout is shown in Figure 7. The first unit uses one Philips piezoelectric axle sensor and two four-turn loops. The second unit uses two Atochem piezoelectric axle sensors and one four-turn loop. The rutting at the location of axle sensors 1 through 3 was 11/32, 12/32, 11/32, respectively. The installation was performed on 12/9/92. The sky was overcast, and the air temperature was 38° F.

The general axle sensor and loop installation procedures were followed. The slots were dried and preheated using kerosine "torpedo" heaters. No duct tape was used along the top of the slot or on the sensor. Care was taken to scrape off any epoxy on the pavement surface, and epoxy on top of the sensors was smoothed off flush with the road surface. The epoxy used was E-Bond G-100. The Atochem axle sensors were pre-bent slightly to conform to the local rutting, and were installed using only two leveling plates. The philips sensor was not pre-bent; it was installed to be flush in the rut, and the low spots were covered with epoxy. Since the ambient temperature (38° F) was too low for efficient curing of the epoxy, all three sensors were cured using torpedo heaters.

The sensor profile in Figure 8 shows that the number one sensor is flush with the pavement in the wheelpath as intended, and is below the pavement everywhere else. The number two sensor is very low (-0.3 inches) near the solid line, but is near or only slightly below the pavement in the wheelpath and beyond. The number three sensor is at -0.05 to -0.13 inches from the solid line out to well beyond the wheelpath.

Axle sensors were tested with an oscilloscope and were all working properly. Loops 1 through three measured 143, 146, and 145 microhenries, respectively, and demonstrated good frequency stability.

The classifiers were installed in the cabinets and were tested. The vendor indicated that one classifier was not working and that the other classifier was functional but missed too many axles. The vendor returned on 5/5/93, repaired the classifier, and added an enhanced printed circuit card. The axle sensor signals were too low and variable. In order to get acceptable signals, strips of bituthane tape approximately one inch wide were placed over the low ares of each sensor to build them up to pavement level. Both classifiers were then approved by the vendor for testing.



Note: All loops
are 6' X 6',
and all sensors
are 6'-3.6" long

Figure 7. PAT Installation Configuration Drawing

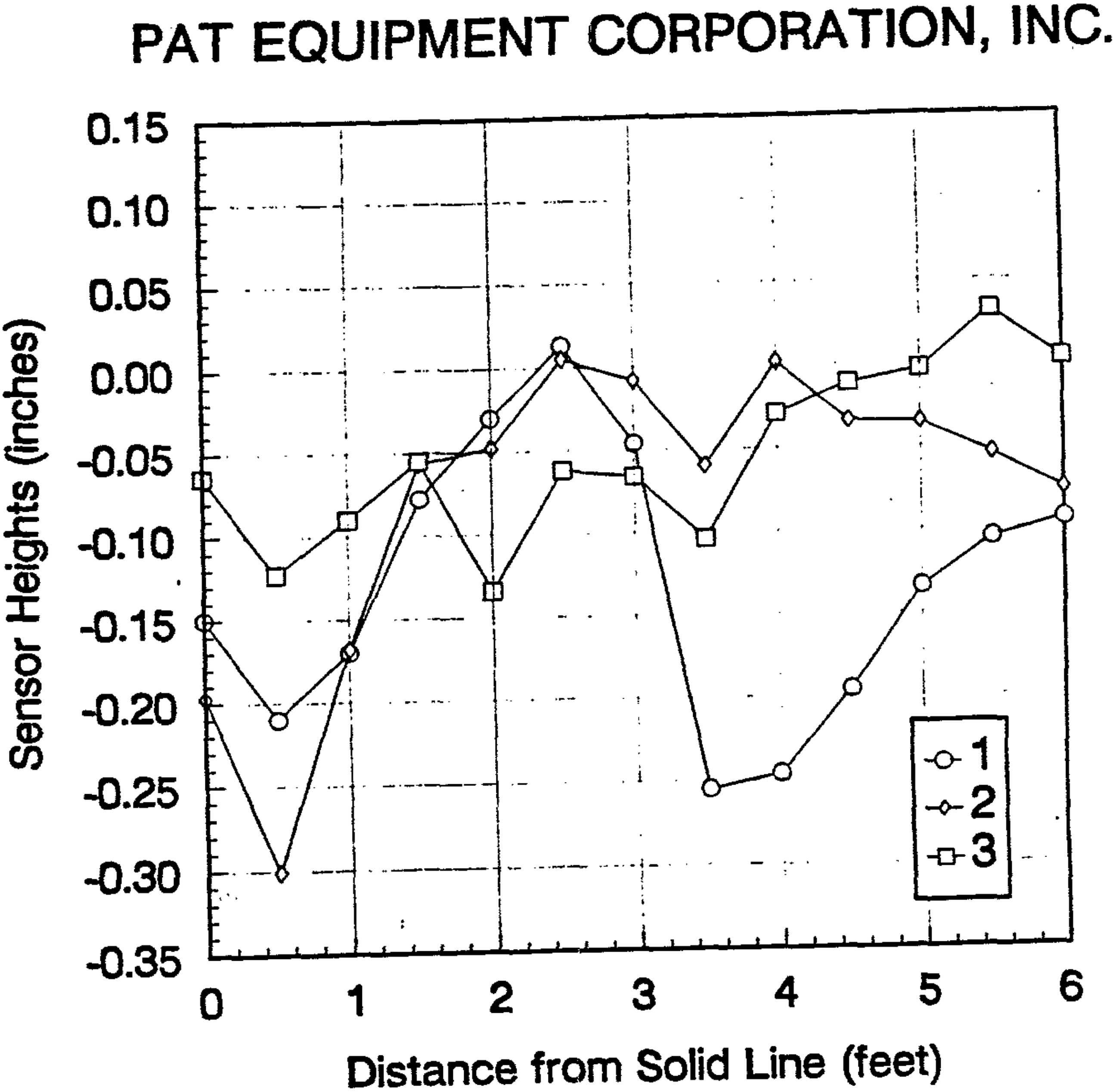


Figure 8. PAT Axle Sensor Profiles

2.3.4 MITRON Systems Corporation

Mitron installed a model MSC 3000, single lane classifier with two Autologger-Gates piezo cable Mini Replaceable axle sensors. These sensors consist of a channel which is epoxied into the road and a replaceable sensor element. The channel has a short section of copper conduit on one end to which 3/4" plastic tubing is attached to form a conduit from the channel to the edge of pavement for the coax cable. The sensor layout is shown in Figure 9. The rutting at the location of both axle sensors was 9/32 inch. The installation was performed on 12/7-8/92. The weather conditions were: overcast, light rain (in the morning), and 42° F on the 7th; partly cloudy and 43° F on the 8th.

The channel was installed much like a typical piezoelectric sensor, and the general axle sensor installation procedures were followed. In order to get the maximum cure time, the slots were cut one day then filled with sand. The next morning the slots were cleaned then dried and preheated with torpedo heaters. Two layers of duct tape was used along the top of the slot. A strip of duct tape was also used on the top of channel to keep epoxy out. The epoxy used was E-Bond G-100. The channels were installed using 16 leveling plates, and since the channels were slightly flexible, good conformity to the rutting profile was achieved. Epoxy was poured to fill the slot approximately half full. The channel was placed in the slot and seated so that the leveling plates were in contact with the pavement. A new empty caulk tube was filled with epoxy, and using a manual caulk gun, the voids along the sides of the channel were filled. The epoxy was then smoothed with a putty knife. Since the ambient temperature (43° F) was too low for efficient curing of the epoxy, the sensor channels were cured using torpedo heaters.

The next day, the sensor element was installed in the channel. The protective tape is removed and the channel is thoroughly cleaned of any debris. The sensor element is laid out along the channel, and the coax is fed through the conduit. Each end and the middle of the sensor element is initially seated in the channel then the element is hammered in place with a rubber mallet. The sensor is very tight in the channel, but several screws are used to ensure the element is held in place. The screws are countersunk in the channel and the heads are covered with caulk.

Initial tests of the axle sensor with oscilloscope indicated outputs slightly lower than desired by the vendor. The first set of elements were damaged by snow plows as well, and were replaced on 2/11/93. The replacement procedure involved removing the screws and pulling up the sensor element then installing a new one as before. The coax on one of the replacements was very difficult to feed through the conduit, which probably should have been a little larger.

Classifier installation, checkout and training were completed on 2/11/93. The vendor indicated that the classifier was functioning properly but the new sensor output levels were still too low for accurate operation. Thin shims were placed under both sensors to raise them higher above the road surface. The vendor verified that the system was ready for evaluation. The installed sensor element profile in Figure 10 shows that the elements protrude above the channel slightly (+0.05 to +0.14 inches) and conform fairly well to the road surface.

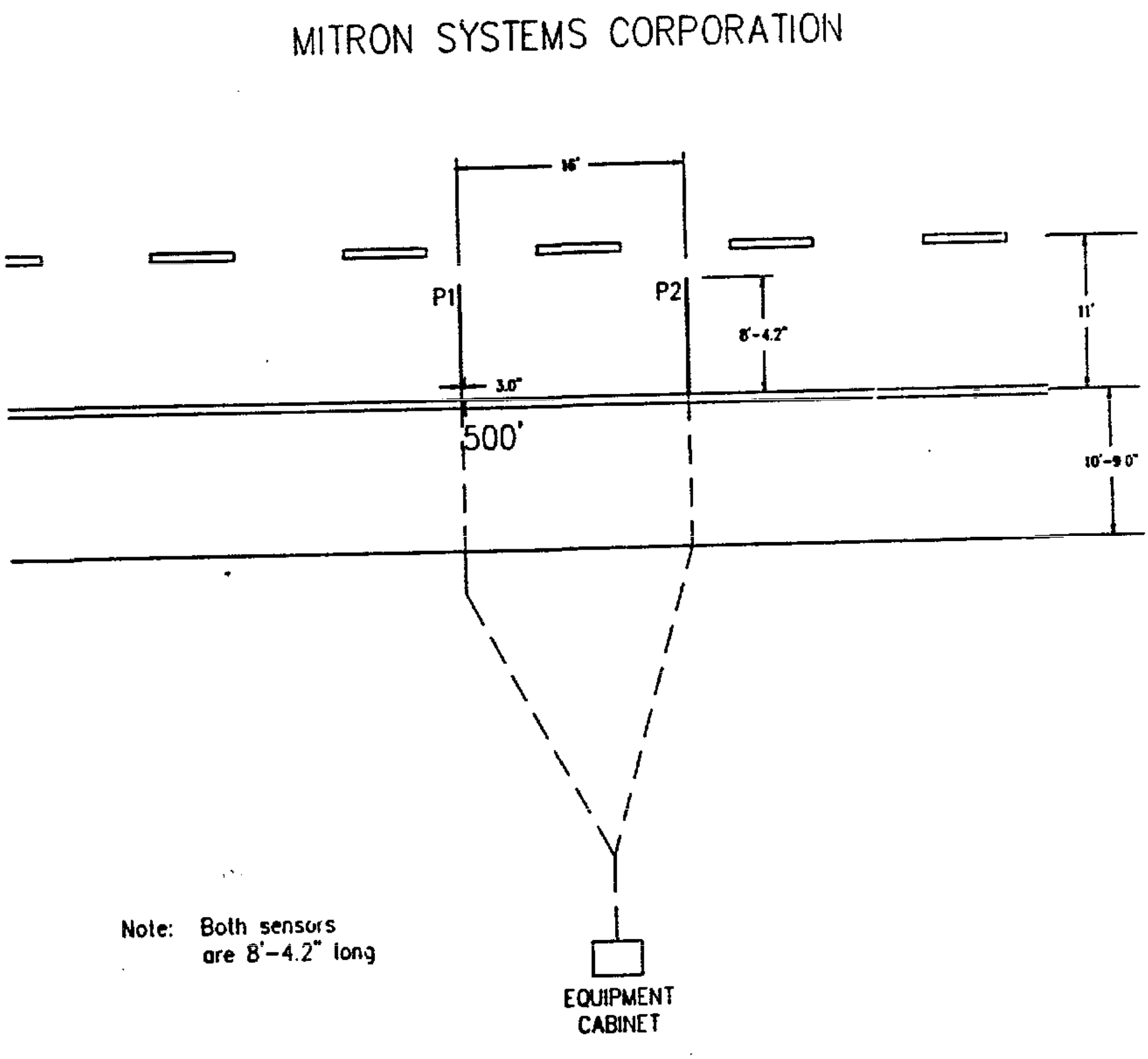


Figure 9. Mitron Installation Configuration Drawing

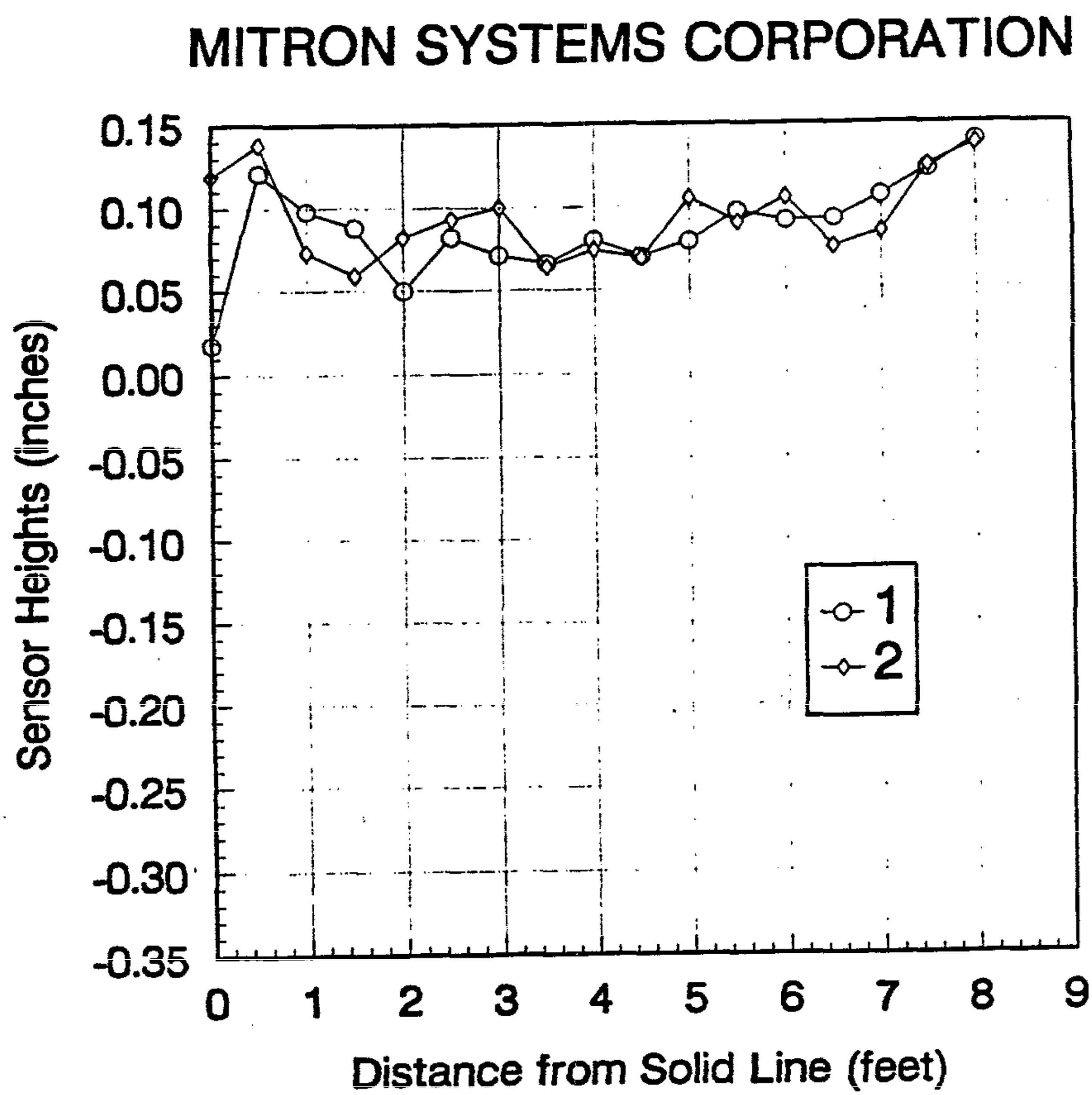


Figure 10. Mitron Axle Sensor Profiles

2.3.5 Electronic Control Measure

ECM installed a model HESTIA classifier with ECM piezoelectric axle sensors (part number PB2N33/25). The sensor layout is shown in Figure 11. The rutting at the location of both axle sensors was 6/32 inch. The installation was performed on 12/10-11/92. It was lightly raining and 47° F on the morning of the 10th; the asphalt cutting was done that afternoon after the rain stopped. On the 11th, when the sensor was installed, it was partly cloudy, 47° F, and windy.

The general axle sensor installation procedures were followed. The slots were cut one day, but because of the rain, the installation could not be completed. The slots were filled with sand and one turn of loop wire was installed in the loop cuts to protect them. The next day the loop wire was pulled from the cuts to clean out any debris, and the sand was cleaned out of the sensor slots. The slots were washed out, dried and preheated with torpedo heaters. Two layers of duct tape was used along the top of the slot. The epoxy used was ECM proprietary. The sensors were installed using 11 leveling plates, and since the sensors were flexible, good conformity to the rutting profile was achieved. Because of their flexibility, the sensors are always kept in an aluminum channel to protect them from bending and possible damage until they are installed. Sufficient epoxy was poured such that when the sensor was placed in the slot, epoxy was forced out. The epoxy was then smoothed with a putty knife. Weights were placed on the plates to hold the sensor in place until the epoxy starts to harden. The plates were then removed, and the epoxy was heated using torpedo heaters and a full length cardboard tunnel until completely cured. The installed sensor element profiles in Figure 12 show that these sensors are nearly level with the pavement and conform very well to the rutting.

Loop measurements indicated 139 microhenries and good stability. Initial tests of the axle sensors with an oscilloscope indicated outputs slightly lower than desired by the vendor and somewhat erratic for one sensor. The number one sensor frequently gave negative output voltages, low voltages, and occasionally missed axles completely. The number two sensor output was low but fairly consistent. Sensor number one was later replaced. The replacement procedure involved cutting the old sensor out with multiple passes of the asphalt saw. All of the sensor was removed and most of the old epoxy. The same installation procedure was used for the new sensor. The new sensor was slightly different in that it was manufactured with molded-in metallic strips to limit the flexibility and protect the sensor from bending damage.

After the sensor replacement, the classifier was functional but missed too many vehicle axles due to low sensor output levels. In order to get acceptable signals, strips of bituthane tape approximately one inch wide were placed over the entire length of both sensors. The classifier was then approved by the vendor for testing.

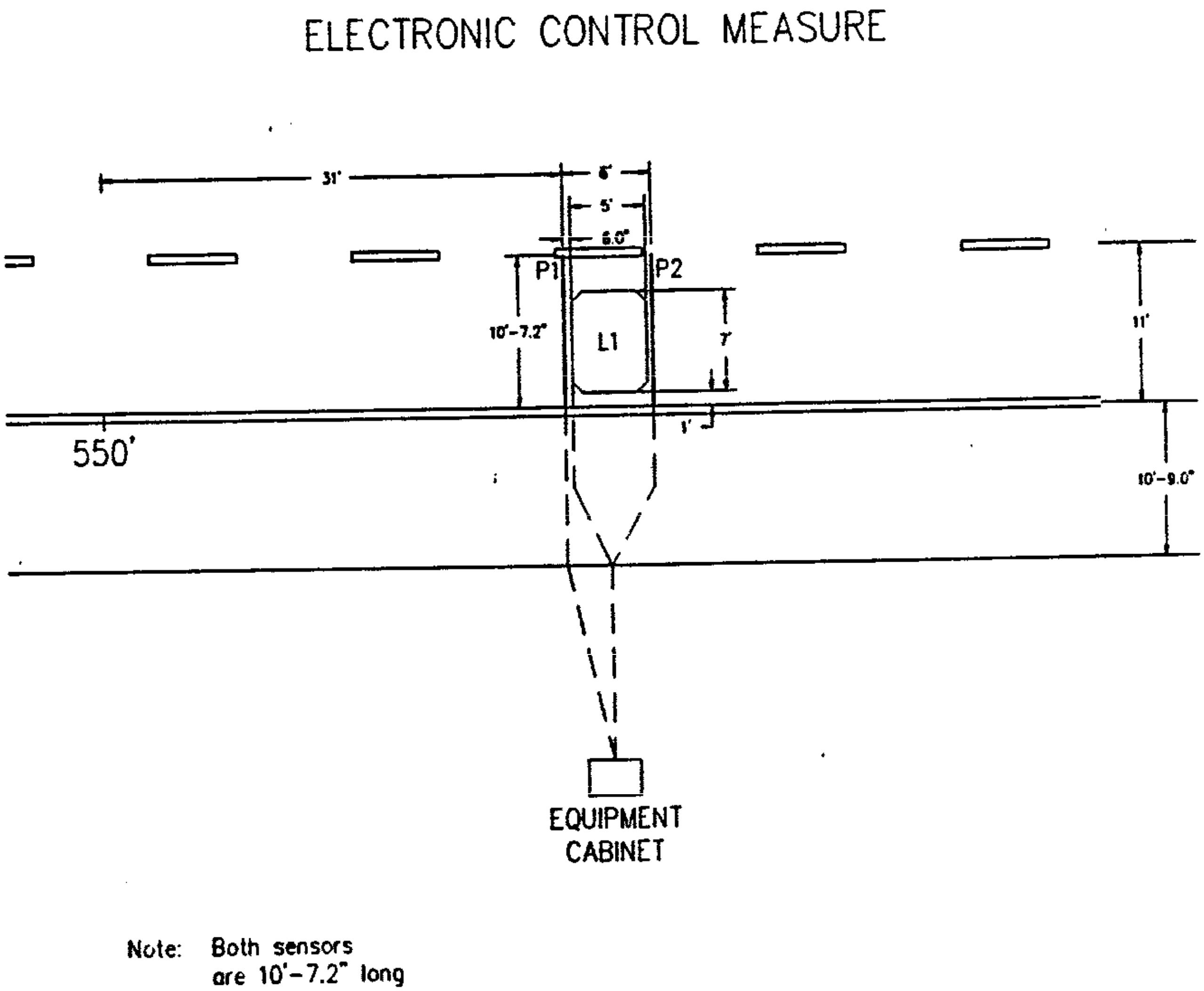


Figure 11. ECM Installation Configuration Drawing

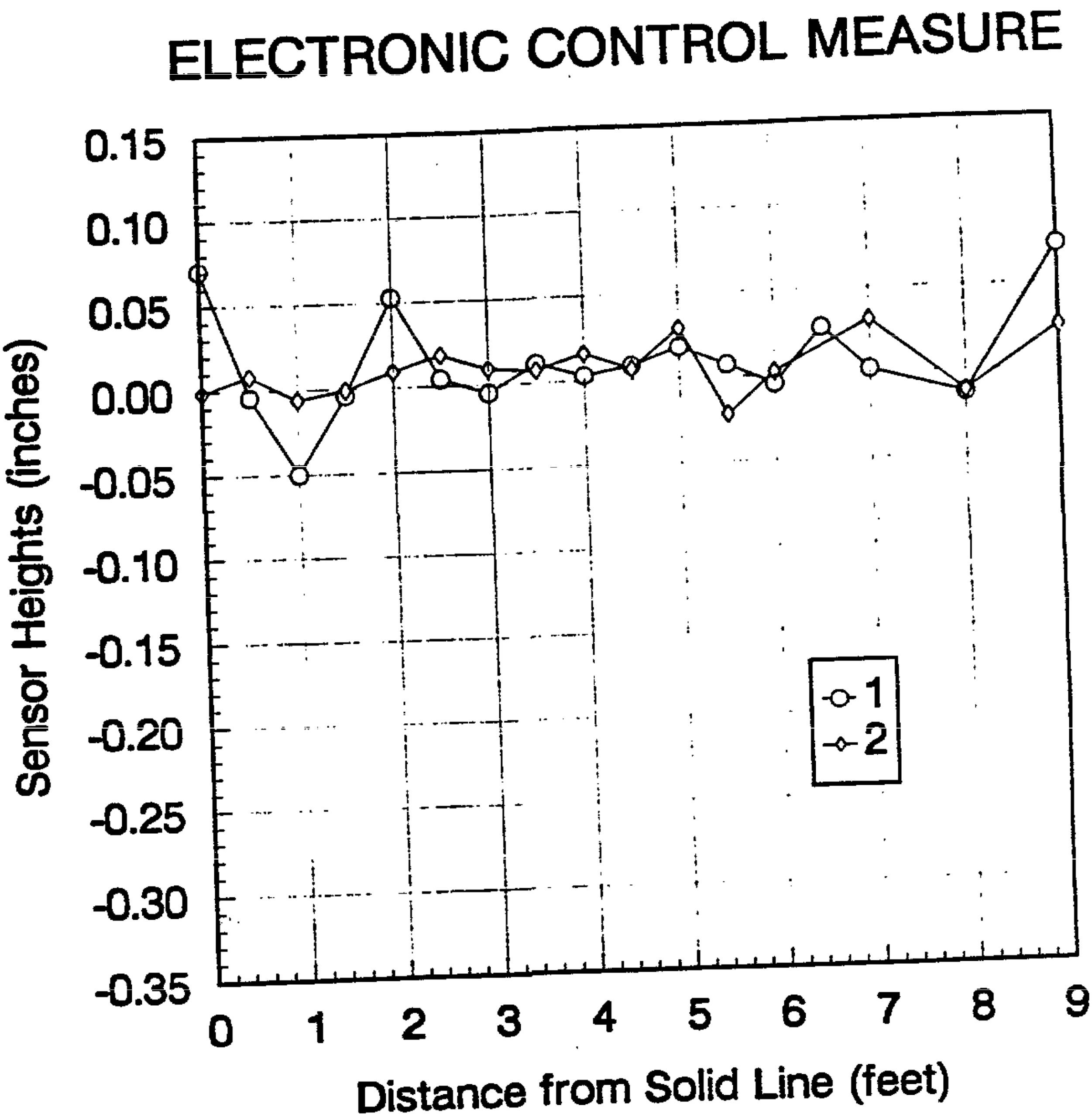


Figure 12. ECM Axle Sensor Profiles

2.3.6 TimeMark

TimeMark installed two classifiers (DELTA I and DELTA II) each with one set of two Philips piezoelectric axle sensors. The sensor layout is shown in Figure 13. The rutting at the location of axle sensors 1 through 4 was 6/32, 5/32, 6/32, and 6/32 inch, respectively. The installation was performed on 12/14/92. The weather was mostly cloudy with an air temperature of 50° F.

The general axle sensor installation procedures were followed. The sensor slots were dried using hand held propane torch being careful not to overheat the pavement. Two layers of duct tape were used along the top of the slot. The epoxy used was Schul International Ready-Set pavement grout (a technical bulletin is included in Appendix A). Schul had a technical representative on site for the installation. The sensors were installed using four leveling plates. Some difficulty was encountered in mixing the epoxy. One batch cured too fast and did not allow time to completely fill the slot and smooth the epoxy, and another batch cured in the bucket before adding the sand and had to be discarded. The last batch was mixed for a shorter time before adding sand. This batch had a better working time allowing for a smooth installation, and was used to top off and smooth the other sensors. However, it also took much longer to cure, and about 2 hours before the lane opened, a torpedo heater was placed on the sensor to speed curing. When the lane had to be opened, that epoxy was still slightly soft. The sensor profiles in Figure 14 show that in the wheelpath the sensors were all slightly high (up to +0.1 inches) and outside the wheelpath they were all slightly low (up to -0.07 inches).

The axle sensors were tested with an oscilloscope. The outputs from sensors 2 and 3 were acceptable, but the output from sensors 1 and 4 were very low. After failing to get sufficient output levels from sensors 1 and 4, it was decided by the vendor to abandon them and only use sensors 2 and 3. The Delta I was withdrawn from the evaluation, and the Delta II was connected to sensors 2 and 3.

The Delta II experienced an oscillation problem (continuous axle counts with no vehicles present) and was repaired at the vendors facility. In order to get more consistent signals for vehicles outside the wheelpath, bituthane tape was placed over the low spots on both sensors. The classifier was then approved by the vendor for evaluation.

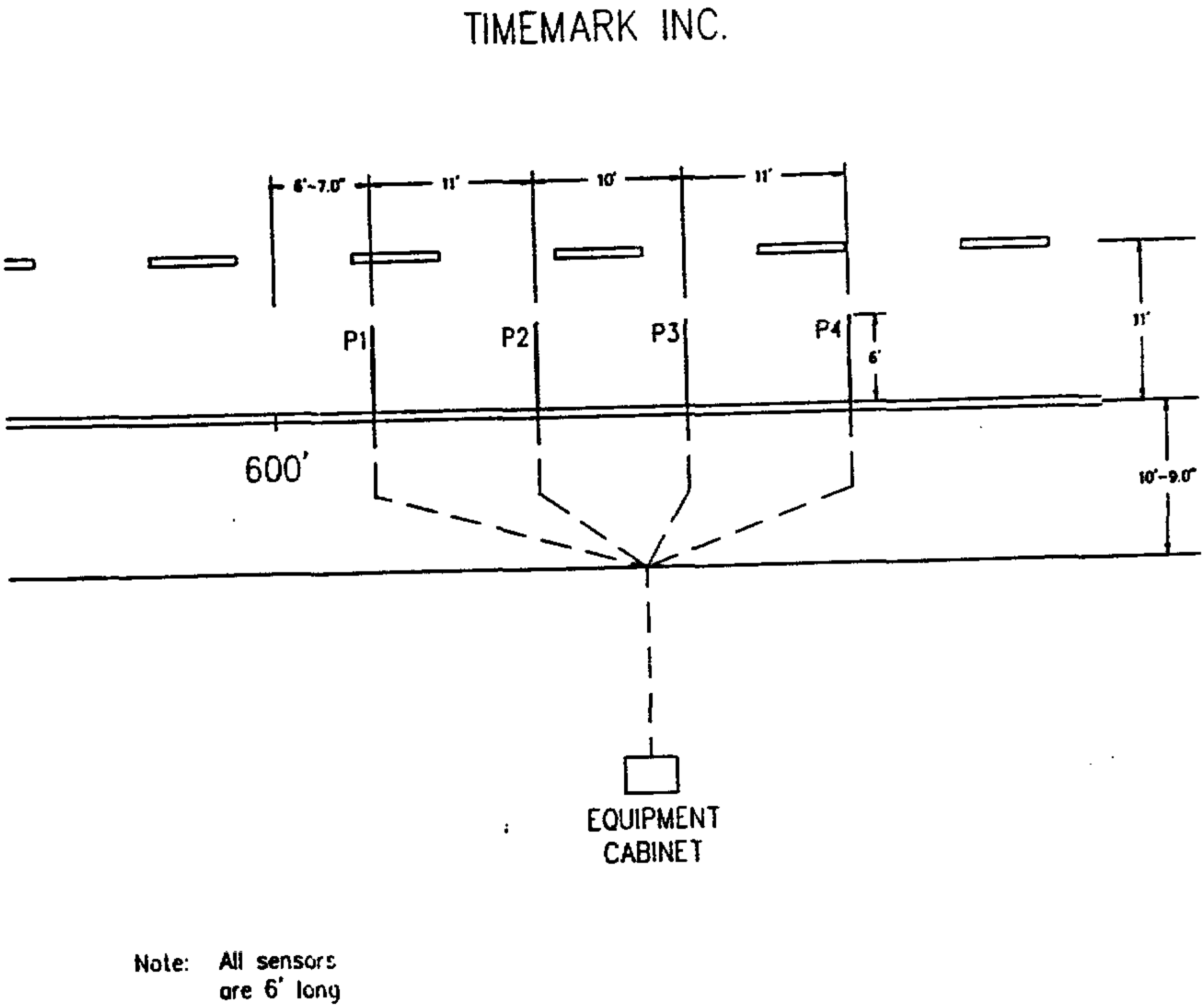


Figure 13. TimeMark Installation Configuration Drawing

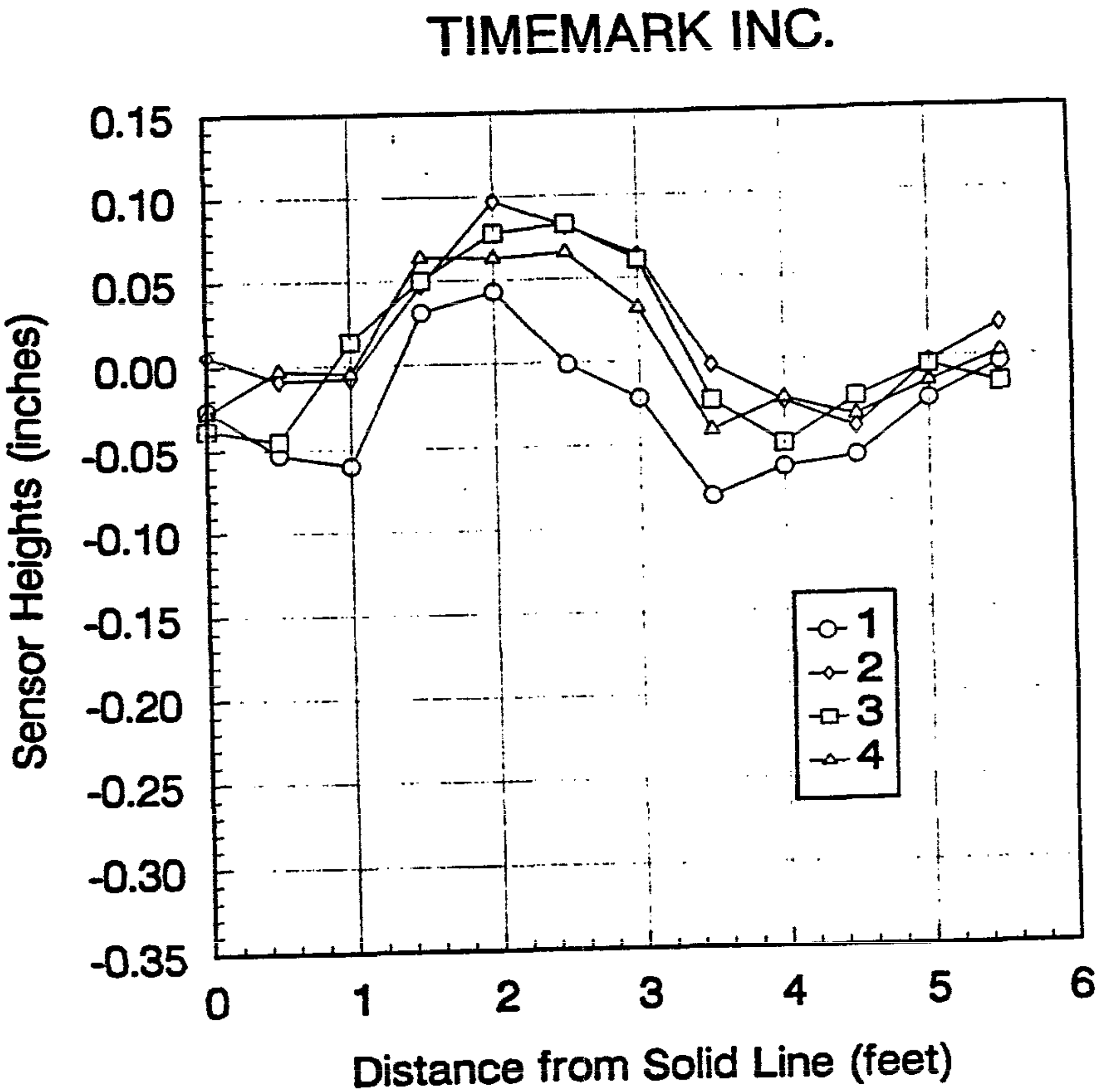


Figure 14. TimeMark Axle Sensor Profiles

2.3.7 International Road Dynamics

IRD installed a model TC/C 530 classifier with two sets of sensors configured as two lanes. The sensor layout is shown in Figure 15. The first sensor configuration uses two IRD DYNAX AS400 resistive axle sensors and one four-turn loop. The second sensor configuration uses two Philips piezoelectric axle sensors one four-turn loop. The rutting at the location of axle sensors 1 through 4 was 6/32, 5/32, 5/32, and 4/32, respectively. The installation was performed on 12/17-18/92. The weather conditions were: cloudy, rain (in the morning), and 59° F on the 17th; clear and 58° F on the 18th.

The general axle sensor and loop installation procedures were followed. The slots were cut on the afternoon of the 12/17/93, but because of the rain delay in the morning, there was not sufficient time to completed the installation. Before opening the lane, the slots were filled with sand to protect them from damage by vehicles. The next day the sand was cleaned out of the sensor slots using compressed air and the slots were dried with hand held propane torch being careful not to overheat the asphalt. Two layers of duct tape were used along the top of the slot. The epoxy used was IRD System 400 for the Philips sensor and Dural International Corporation 331 LV epoxy for the DYNAX sensors. The DYNAX sensors were flexible and conformed well to the local rutting, and were installed using 5 special leveling plates. The plates have a slight hump in the center to allow the raised surface of the DYNAX sensor to come up over the road surface slightly (approx 1/32). The Philips sensors were installed using 7 special leveling plates that were drilled and tapped in the center for a 1/4 inch bolt. The bolt is adjusted and the plate is tie wrapped to the sensor such that the sensor is held down 3/16 inch below the road surface.

The DYNAX sensor procedure is to pour enough epoxy such that excess material extrudes around the sensor. The excess is troweled off and smoothed using a putty knife. Weights are placed on the leveling plates and the epoxy is allowed to cure under ambient conditions.

The Philips sensor procedure is to pour 1/2 the required epoxy, place the sensor in the slot and apply weights to hold it in place, let the epoxy partially set up then remove the weights. After both sensors were installed, another batch of epoxy was mixed to top off the slots flush with road surface. The epoxy is smoothed with a putty knife and allowed to cure under ambient conditions. Sensor 3 had voids underneath due to insufficient epoxy on the first pour and had to be pulled up so more epoxy could be poured in the slot. The epoxy had started to harden and the sensor could not be pressed down fully below the road surface.

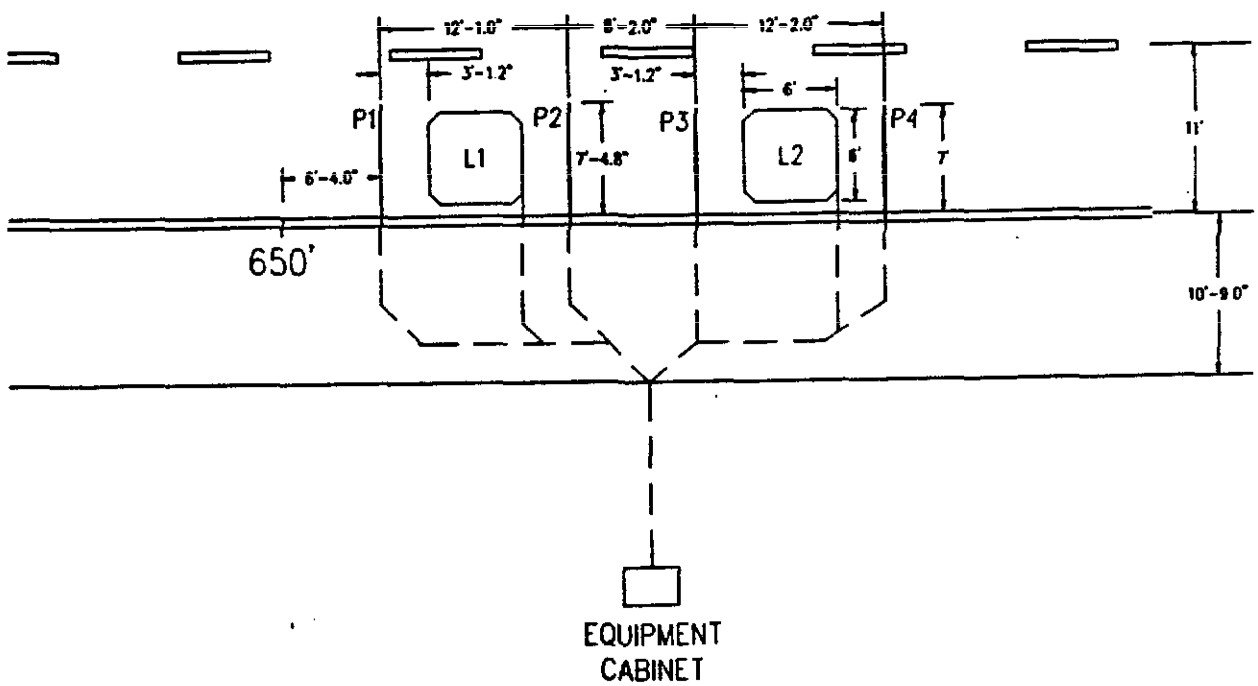
The DYNAX resistive sensor operation was verified using an ohmmeter. The Philips sensors were tested with an oscilloscope and were both working properly. The loops measured 152 microhenries for the Dynax configuration and 154 microhenries for the Philips configuration; both loops demonstrated good frequency stability. The sensor profile in

Figure 16 shows fairly good conformity to the road surface with the highest point at 0.09 inches and the lowest at -0.05 inches.

On initial system installation and checkout on 1/18/93, the classifier would not recognize the DYNAX sensors. The IRD representative found a loose connector inside the classifier, and after repairing it, the classifier worked well with the Dynax sensors. As a normal part of setting up a new installation, the sensitivity of the piezoelectric sensor circuits were adjusted internally for optimum detection.

Sensor number three started to break out of pavement after approximately one month. The epoxy was chipping away at the end of the sensor and in the wheel path. IRD patched the sensor by making saw cuts along the chipping areas, removing the loose epoxy, and applying more epoxy of the same type. The epoxy failure may have been because of the difficulty encountered with its installation as discussed above. After the repair of the sensor, the system was rechecked and readjusted for optimum performance. The classifier was then approved by the vendor for testing.

INTERNATIONAL ROAD DYNAMICS, INC.



Note: The first two sensors have lengths of 7'-4.8", and the last two sensors have lengths of 7'

Figure 15. IRD Installation Configuration Drawing

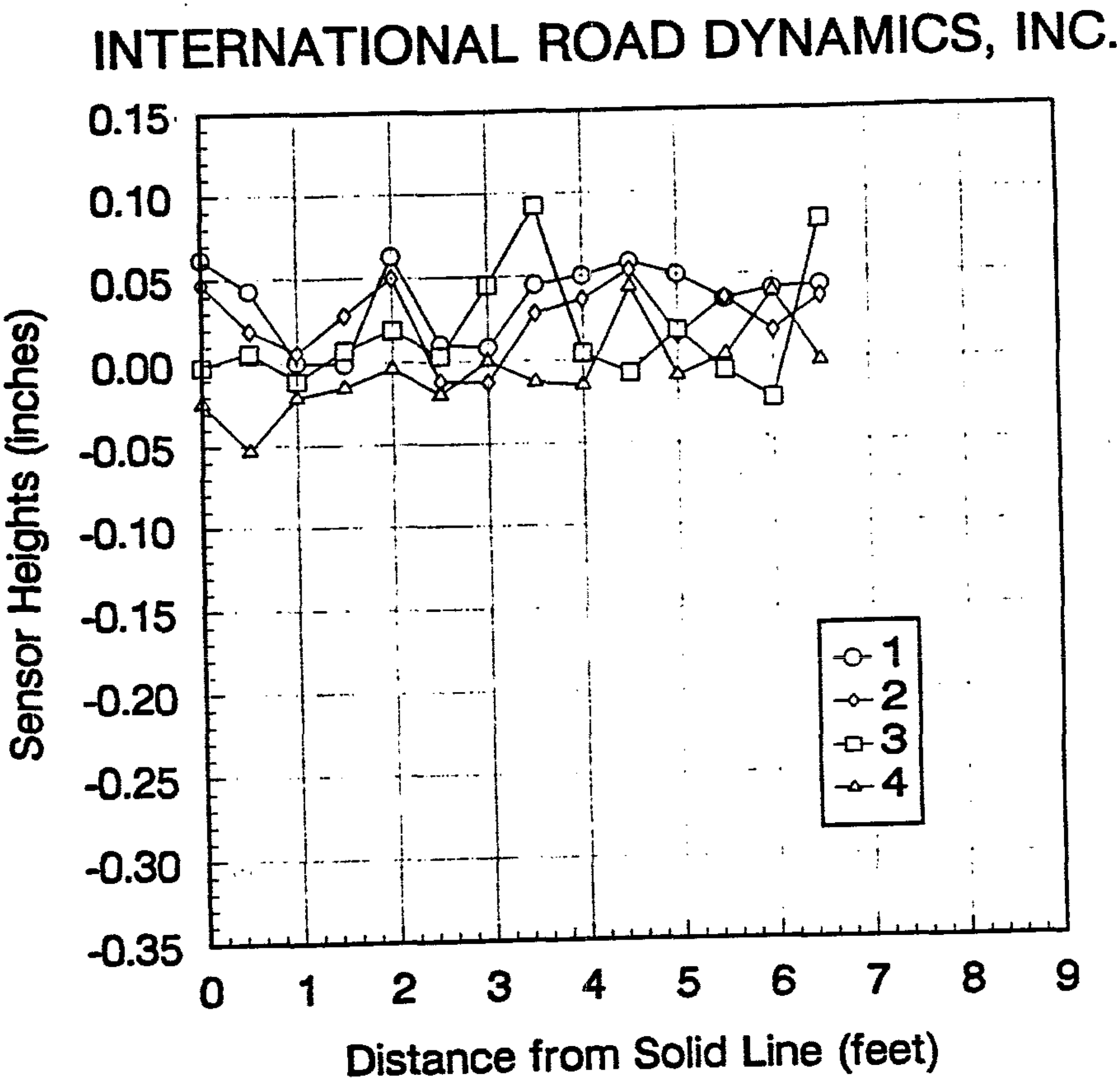


Figure 16. IRD Axle Sensor Profiles

2.3.8 Golden River Limited

GRI installed a Marksman 660 classifier with Traffic 2000 (14 mm width version) piezoelectric axle sensors and one four-turn loop. The axle sensors are a domed type that extends slightly above the road surface. The sensor layout is shown in Figure 17. The rutting was 5/32 inch at the location of sensors 1 and 6/32 at the location of sensor 2. The installation was performed on 1/13-14/93. The weather was partly cloudy and 58° F on the 13th, partly cloudy and 47° F on the 14th.

The general axle sensor installation procedures were followed. The sensor slot was cut for snug fit (1mm clearance on each side of the sensor) using ganged blades on the asphalt saw. Each end of the cut was made a little wider and deeper to protect the ends of the installed sensor. The slots were cleaned then dried and preheated with torpedo heaters. One layer of duct tape was placed along the top of the slot leaving approximately 1/4 inch of pavement next to the slot uncovered because of the domed sensor construction. The epoxy used was Traffic Coil which was poured in sufficient quantity such that excess material extrudes around the sensor. The excess is trowelled off, and the sensor surface is cleaned with acetone. No weights are required for this type of sensor, it is simply pressed down until the domed portion is touching the pavement. The epoxy had been preheated in a heated truck cab for two hours before mixing, and cured very quickly under ambient conditions. The vendor replaced the leading sensor the next day because it was decided that better performance would be achieved with the axle sensor much nearer to the loop than first installed.

The installed sensor element profile shown in Figure 18 shows that the domed portion of the sensor extended above the road surface approximately 0.12 inches. Since the sensors were flexible, good conformity to the rutting profile was achieved.

Loop measurements indicated 136 microhenries and good stability. Initial tests of the axle sensor with oscilloscope indicated outputs slightly lower than desired by the vendor and somewhat erratic. Both sensors were replaced on 3/11/93 (55° F and partly cloudy) using the same installation procedures. The sensor output was better, but the classifier was not giving consistent results. The equipment was returned for checkout and repair, but was not working properly in time for the first evaluation. The equipment was then returned to GRI in Great Britain for checkout and repair, and was functioning properly for the second evaluation.

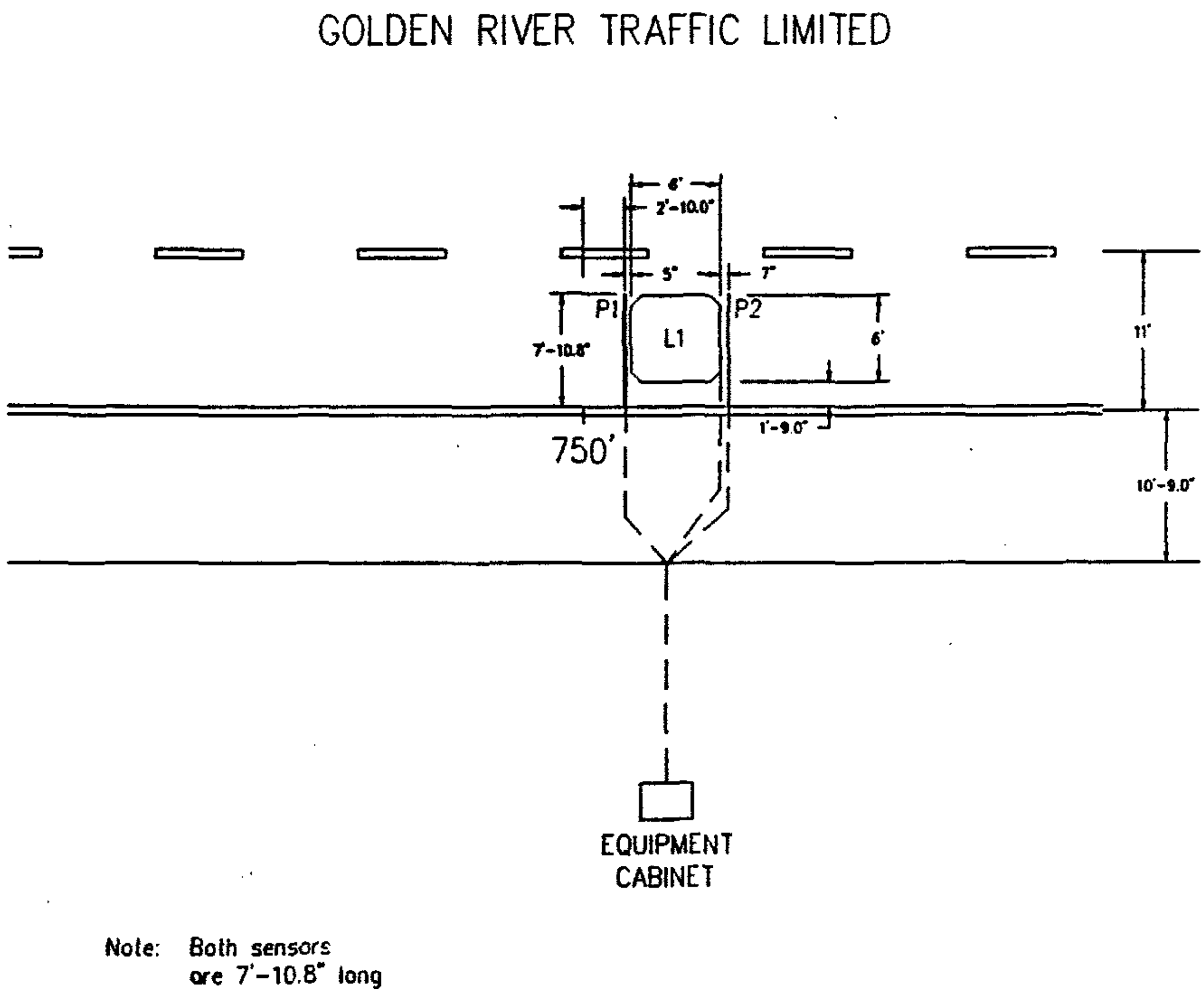


Figure 17. GRI Installation Configuration Drawing

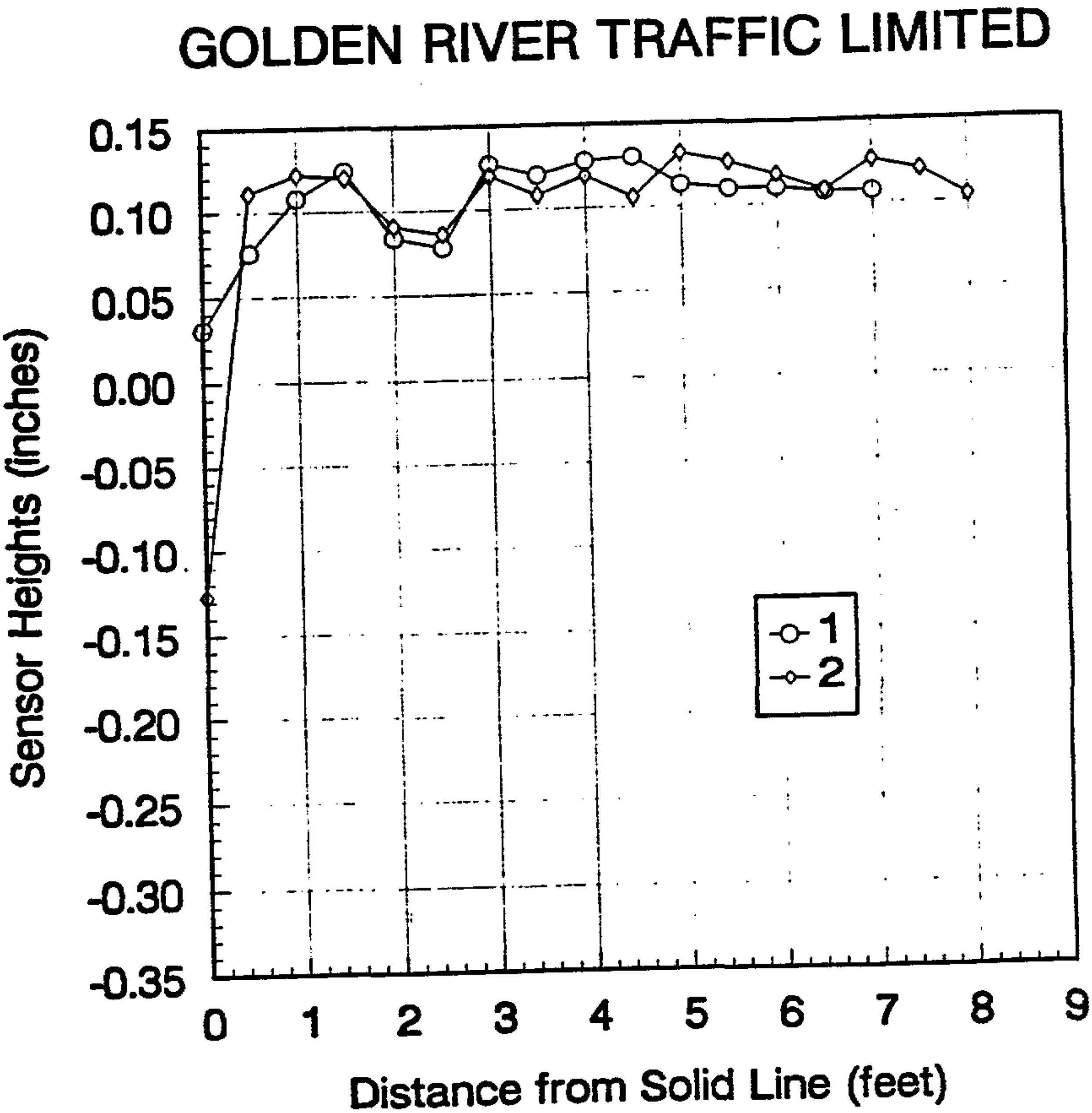


Figure 18. GRI Axle Sensor Profiles

2.3.9 Diamond Traffic Products

Diamond installed a model 2001 multi-lane classification unit with two sets of sensors configured as two lanes. The sensor layout is shown in Figure 19. The first sensor configuration uses two Autologger-Gates, piezo cable, class 2, Maxi replaceable flush fitting design axle sensors and one three-turn loop. The axle sensors consist of channels which are epoxied into the road and replaceable sensor elements. The channel has 3/4" plastic tubing is attached to form a conduit from the channel to the edge of pavement for the coax cable. The second sensor configuration uses two Philips piezoelectric axle sensors one three-turn loop. The rutting at the location of axle sensors 1 through 4 was 4/32, 5/32, 5/32, and 6/32, respectively. Installation began on 1/19/93 and was finished on 1/29/93.

The slots for the Philips were cut on the morning of 1/19/93, but because of rain that began around noon, the installation could not be completed. The slots were filled with sand until the weather cleared and the installation crew could be rescheduled. On 1/26/93 (49° F and partly cloudy) the slots were cleaned then dried and preheated with torpedo heaters. There was no pavement cracking or other noticeable effects on the slot after the seven day delay. Two layers of duct tape were used along the top of the slot. The sensor had five leveling plates installed with tie wraps. The epoxy used was E-Bond G-100. Enough epoxy was poured such that excess material extrudes around the sensor then the excess was trowelled off and smoothed using a putty knife. Weights were placed on the leveling plates and the epoxy was cured using the torpedo heaters.

The Autologger channel was installed much like a typical piezoelectric sensor, and the general axle sensor installation procedures were followed with some extra steps. On 1/27/93 (58° F and clear), the slots were cut and cleaned then dried and preheated with torpedo heaters. Two layers of duct tape was used along the top of the slot. A strip of duct tape was also used on the top of channel to keep epoxy out. The epoxy used was E-Bond G-100. The channels were installed using eight tie-wrapped leveling plates, and since the channels were slightly flexible, good conformity to the rutting profile was achieved. Before installation, the channels were thoroughly cleaned with acetone for better epoxy adhesion. Sufficient epoxy was poured in the slot such that it extruded out when the channel was placed in the slot and seated. The excess epoxy was removed and the surface was then smoothed with a putty knife. The epoxy was allowed to cure under ambient conditions. On 1/29/93 (61° F and partly cloudy), the protective tape was removed, the channel was thoroughly cleaned of any debris, and the sensor element was installed using the same procedure as for the mini-replaceable (Section 3.3, MITRON).

All axle sensors were tested with an oscilloscope and were working properly. The loops measured 152 microhenries for the Autologger configuration and 154 microhenries for the Philips configuration; both loops demonstrated good frequency stability. The sensor profile in Figure 20 shows that all four sensors conform well to the road surface with the maximum height variation of 0.1 inches. The lowest point is -0.08 inches.

The classifier was installed in the cabinet and the sensors were connected. After making the normal internal adjustment of sensor threshold for a new installation, the system was working properly and was approved for evaluation. On a later visit, the vendor replaced the EPROM with updated version and readjusted the sensor threshold.

DIAMOND TRAFFIC PRODUCTS

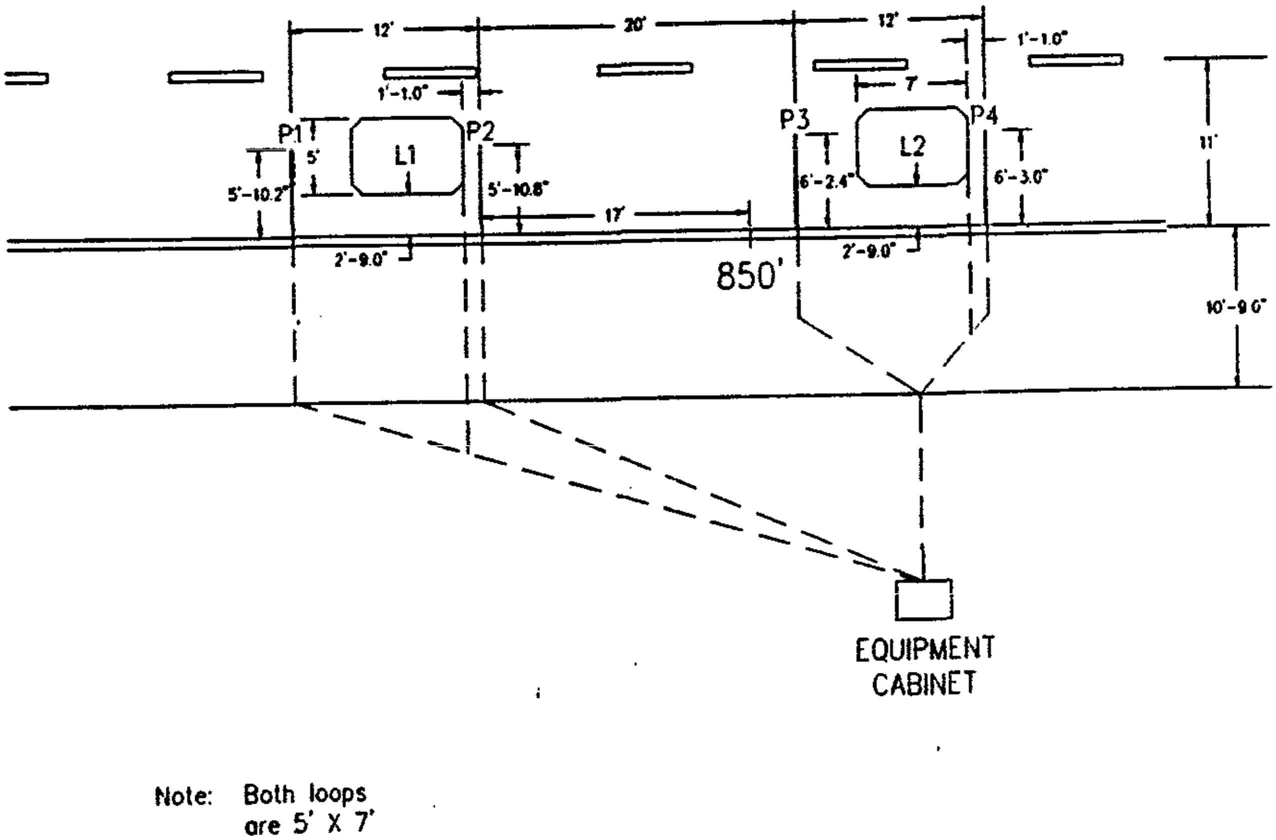


Figure 19. Diamond Installation Configuration Drawing

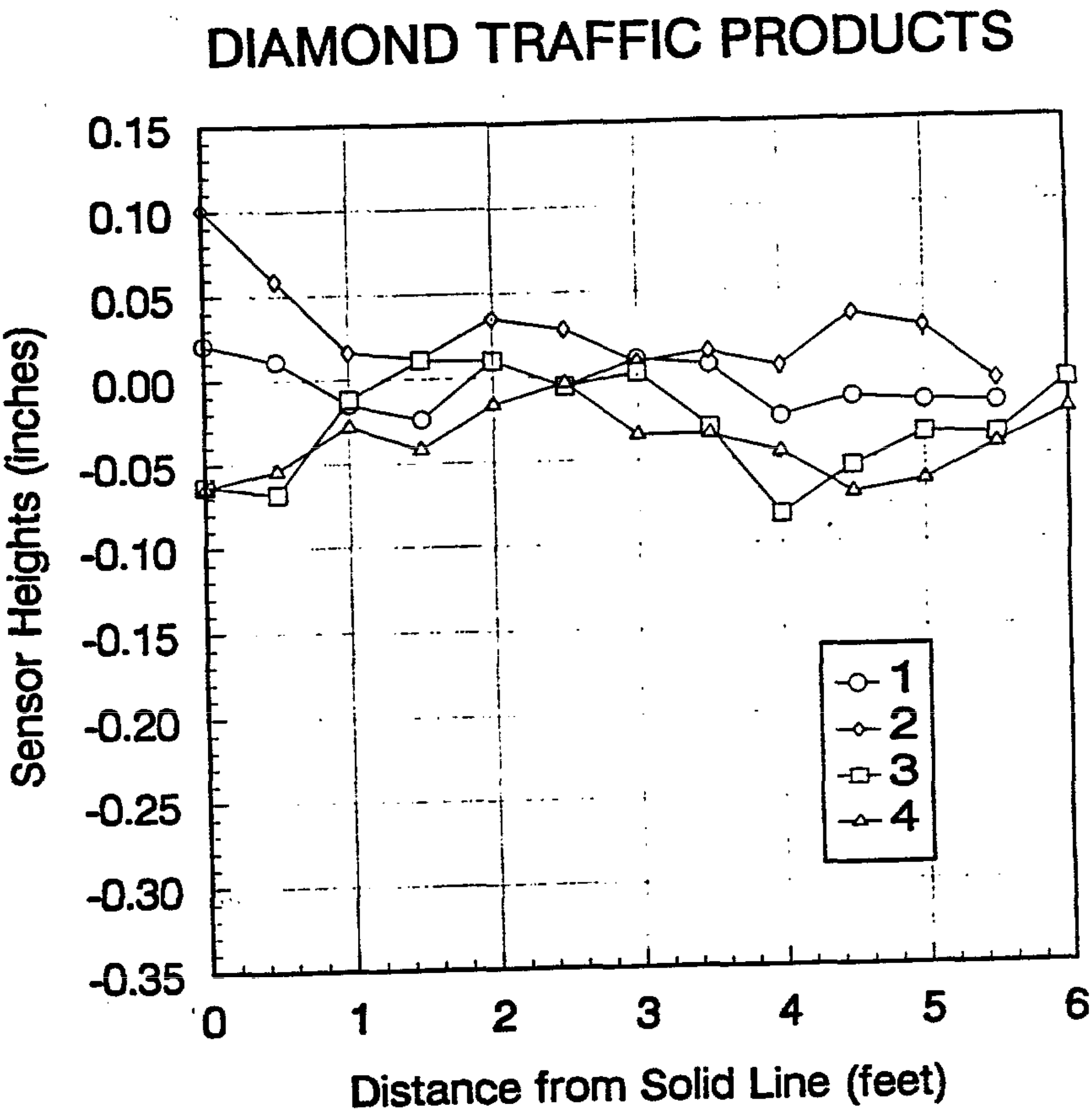


Figure 20. Diamond Axle Sensor Profiles

2.4 INSTALLATION SUMMARY AND CONCLUSIONS

Over the period of November 1992 to March 1993 eleven classifiers from nine vendors were installed using fifteen test sensor configurations. Fifteen loops and twenty-eight axle sensors were originally installed. Six axle sensors were replaced and two were abandoned for a total of thirty-four installed and twenty-six functioning. Six different types of axle sensors were installed using five different types of epoxy. The procedures used by each vendor for sensor installations were the same except for a few minor details. The only significant difference in installation procedures was for the Autologger replaceable type which required some special procedures.

There were no problems encountered with any loop installations; however, there were quite a few problems encountered with the axle sensors. The biggest problem was low output levels and large differences in output levels across the length of the sensor. Some of the variation could be caused by manufacturing variations, but most is caused by the height profile of the installed sensor. Areas of the sensor below pavement level have a lower output voltage causing classifier sensitivity problems; areas above pavement level have a higher output level but subject the sensor to possible damage.

When larger signals are presented to the classifier, overshoot and undershoot of the signal will cause extra axle counts if the detection threshold level is set too low. The threshold level must be set low enough to detect small cars but high enough to avoid extra axle counts. Variation of the output level along the length of the sensor, due to installation or manufacturing, make this setting more difficult. The field repair for the sensor profile problem, bituthane tape over the low spots, had to be employed for thirteen of the twenty-six functioning sensors to achieve good classifier performance. Most of the difficulty with sensor profile can be attributed to the rutting present at the site. Even though the rutting was not too severe, the rigid sensors could not be made to conform well to it.

Other problems encountered with axle sensors included snow plow damage of the Autologger mini-replaceable (which extended over the pavement level), cracking and chipping of epoxy on one of the IRD Philips sensors requiring repair, and poor coax connections to classifiers. The one epoxy failure was probably due to a premature epoxy cure not allowing the sensor to be installed below the road surface as designed.

The axle sensor replacements included, two of MITRON's Autologger Mini replaceable sensors (for low output levels), three of GRI's Traffic 2000 sensors (one to relocate closer to the loop and two for low output), and one ECM sensor (for low and erratic output). The abandoned sensors were two of TimeMark's Philips sensors.

In addition to the axle sensor problems, several problems were encountered with initial setup of the classifiers. Some problems were actually sensor related (such as difficulty in compensating for low or variable axle sensor output) and some were faulty electronics or bad internal wiring connections. Of the eleven classifiers installed, five were malfunctioning; three were repaired on-site and two were returned to the vendor facility for repair.

The overall conclusion, based on these installations, is that generally a classifier will require some internal adjustment, repair, or sensor compensation when first installed. The problems are usually minor and can be easily corrected by a technically qualified installer. Each system installed for this evaluation was in accordance with the vendor's specification. Before the first evaluation was performed, proper operation of each classifier was achieved and was verified by each vendor.

3. TEST SESSIONS

3.1 OVERVIEW OF TEST PROCEDURES

Each test was conducted using the following basic steps:

1. Camera/video installation,
2. AVC equipment installation,
3. AVC equipment start-up,
4. Video start-up,
5. Monitor video and AVC equipment, and record weather conditions,
6. Test shut-down,

and 7. Remove and store AVC equipment.

Camera and video installation involved placement of the video cameras and recorders for traffic stream video and lane-change monitoring. The traffic stream camera (pole camera) was mounted in a metal box at the top of a utility pole near the mobile office. It was angled to monitor the traffic stream in a test area marked with a 40 foot long test area. The video output was connected to a VCR in the mobile office for recording the video. The camera was set to display time and date on the video output. Standard speed recording was used for the detailed (48-hour) test periods and extended play recording speed was used for the long term (7-day) test.

The lane-change monitoring camera was mounted in a modified traffic control box located on the overpass at the end of the test area. It was angled to look directly between the two westbound lanes and covering the entire test area. The video output was connected to a VCR in a traffic control cabinet at the end of the overpass. This camera did not have the capability to display time and date, so a time/date generator was installed between the camera and the VCR. In this manner, the video was time stamped for use in the data reduction. Extended play recording speed was used for all tests.

The AVC equipment installation involved the placement of each of the classifiers in the appropriate traffic control box, connection of sensor leads, and check-out of operation. Some of the classifiers required the use of a personal computer (PC) in order to record detailed vehicle-by-vehicle information. Others required occasional downloads of information to a PC during the tests to avoid overflowing the internal memory of the classifiers. The PCs needed by vendors were connected to the classifiers during the equipment installation. The following is a list of the classifiers which required connection to a PC during the detailed testing sessions:

Mikros Systems TEL-2CM - Connected to a PC running a monitoring program provided with the classifier. The monitoring program logged the vehicle-by-vehicle information and stored it on the PC's hard disk.

Peek Traffic TrafiCOMP III - The vendor supplied a modified instruction set on an EPROM which transmitted the vehicle-by-vehicle data (the screen display) to a serial prot on the unit. The serial port was connected to a portable PC running a terminal emulator program. Data was stored by using the logging capability of the terminal emulator.

PAT Equipment AVC-100 - One of the PAT units (PAT 2) did not have the internal memory to store the vehicle-by-vehicle data. This unit was connected to a PC running a monitoring program supplied by the vendor. The program stored the data using a logging function.

The following is a list of the classifiers which, due to memory limitations, had to have data downloaded to a PC during the detailed testing sessions:

- Peek GK-6000,
- Electronic Control Measure HESTIA,
- International Road Dynamics TC/C 530-4D/4P/4L,
- Golden River Traffic Marksman 660, and
- Diamond Traffic Products TT-2001.

The remaining classifiers had sufficient internal memory to store the vehicle-by-vehicle data for the entire 48 hours of the detailed testing sessions.

Once the equipment was installed and checked out, the AVC equipment was turned on and recording of the traffic begun. The internal clocks of the classifiers and the video recorders were then synchronized. Each classifiers was checked to ensure proper operation.

The video recorders for the lane-change camera and the pole camera were started once all the classifiers were operational. The starting of both camera marked the official start of the test.

The test site was manned continually during the detailed (48-hour) testing periods. The person manning the site changed the video tapes as needed, and downloaded the data from the classifiers which required storage on the PC to avoid overflowing the internal memory of the classifier. During the first 48-hour test, the air and pavement temperature were measured manually, and the precipitation and wet/dry pavement conditions observed on a 15-minute interval. During the second 48-hour test, the temperatures and rainfall amounts were recorded using a PC interfaced to temperature sensors and a rain gauge.

At the end of the first 48-hour test, the classifiers, computers and video equipment were stopped. Data was downloaded from the classifiers using a PC if needed and the power was turned off to the equipment. All of the equipment was removed and returned to storage where batteries were connected to chargers as needed.

At the end of the second 48-hour test, the classifiers were reconfigured to record binned data on 15 minute intervals for the long-term (7-day test). The pole camera video recorder was also switched to the extended play recording speed. The first two days of the 7-day test were the same two days used for the second 48-hour test, and the remaining 5 days were those immediately following the detailed test. The site was not continually manned during the remaining five days of the 7-day test. Every approximately 5.5 hours, the video tapes for the pole and lane-change cameras were changed. Temperature and rainfall monitoring continued for the five days as well.

3.2 DETAILS OF INDIVIDUAL TESTS

3.2.1 First 48-Hour Detailed Test

3.2.1.1 Test Date and Conditions

The first detailed test session was conducted May 5 - 7, 1993. The air temperature during the test ranged from 55 degrees F to 86 degrees F. The pavement temperature ranged from 63 degrees F to 118 degrees F. The weather was sunny and clear and there was no precipitation during the test. This test was intended to be conducted under good weather conditions as the a baseline for the remaining tests.

The traffic during the test was typical weekday traffic for the site. There was no traffic congestion during the test and the average speed of traffic was typically near 65 MPH. The average daily traffic (ADT) in the test lane (as determined from the video data reduction) was approximately 9700 vehicles.

3.2.1.2 Participating Vendors

The vendors and classifiers that participated in the first 48-hour test included all of those listed in Table I except the Golden River Traffic Marksman 660. The Golden River equipment was sent back to the vendor for repair and was not returned in time to be included in this test. The Mitron Systems TEL-2CM was included in this detailed test, but the Mitron equipment provided binned data rather than vehicle-by-vehicle output. All of the remaining equipment either recorded individual vehicle records internally or were capable of transmitting these records to a PC for storage.

3.2.1.3 Problems and Exceptions to Test Procedures

There were no significant problems with the test equipment encountered during the first test. The air and pavement temperatures were recorded manually every 15 minutes using a thermocouple and hand-held meter.

The problems experienced with the participating vendor's equipment during the first 48-hour test are as follows:

- Mikros Systems TEL-2CM - This systems had a software bug in the TELCOM software used to download data to the PC. The download utility skipped the data stored in certain portions of the classifier memory when downloading to the PC. This resulted in gaps averaging one gap every 2 hours that ranged in time from 16 minutes to over 2 hours. This problem was fixed after this test with a TELCOM software upgrade from the vendor.

- Peek TrafiCOMP III - Twice during the test, the classifier's processor halted and the equipment stopped classifying vehicles. The gaps totalled about 3 hours and 26 minutes. To restart the processor, the cover of the unit had to be removed and the processor reset.

- Peek GK-6000 - This classifier required periodic downloads to a PC to store data. During these downloads, the classifier didn't record traffic data. The downloads took generally greater than 15 minutes.

- Electronic Control Measure HESTIA - New PC software received from the vendor prior to the first 48-hour test was incompatible with the firmware installed in the classifier. The classifier could not be set up at the beginning of the test with the new software. The vendor sent the old software by express courier and the classifier was started approximately a day late. The system also locked up once during the test and lost about 8 hours of data. A full reset was required to restart the equipment.

- TimeMark Delta II - A 1 MB memory card installed in the classifier was not recognized by the unit. The unit continued to classifier until the internal memory was full and then stopped recording vehicles. The result was that the final 18 hours of the first test were not recorded by the unit.

- International Road Dynamics TC/C 530-4D/4P/4L - The processor in the classifier seemed to lock up occasionally. Some time the unit returned to normal operation on its own, but other times the unit had to be stopped and restarted in order to correct the problem. The data showed gaps in the lane 1 record only corresponding to these down times. The vendor updated the firmware (ROMs) in the unit after this test to correct the problem.

- Diamond Traffic Products TT-2001 - The memory in this unit filled more quickly than expected in the early part of this test. Approximately 24 minutes of data collection was lost when the memory filled up before it could be downloaded to a PC. The download cycle was shortened from 4 to 3 hours to avoid this problem for the rest of the test.

3.2.2 Second 48-Hour Detailed Test

3.2.2.1 Test Date and Conditions

The second 48-hour test was conducted September 9 - 11, 1993. The air temperature during the test ranged from 62 degrees F to 84 degrees F. The pavement temperature ranged from 61 degrees F to 110 degrees F. The weather was partly cloudy and there was no precipitation during the test. This test was scheduled in the hopes of rainfall, but the only rain was a brief sprinkle which did not register on the rain gauge or significantly moisten the pavement.

The traffic during the test was typical weekday traffic for the site. There was no traffic congestion during the test and the average speed of traffic was typically near 65 MPH. The ADT in the test lane (as determined from the video data reduction) was approximately 10,600 vehicles. The ADT was higher during second 48-hour test because it was near the Labor Day holiday.

3.2.2.2 Participating Vendors

All of the classification equipment listed in Table I was included in the second 48-hour test except the Mitron Systems MSC-3000. Failures in the piezoelectric sensors used by the Mitron classifier resulting in the vendor electing to withdraw from the remaining tests. The Golden River Traffic Marksman 660 was repaired and participated in this test. The Diamond Traffic Products TT-2001 received a software upgrade (new ROMs) between the first and the second tests. The upgrade had a bug in the data recording algorithm which resulted in errors in the data file stored by the unit. All of the remaining classifiers were operated in the same way as they did in the first 48-hour test.

The augmented road tube test was conducted in parallel with the second 48-hour test. Two road tubes were installed across the outside lane of the highway and two were installed across both lanes of the highway. The classifier used for this test was a Peek TrafiCOMP III (Peek 241) supplied by the Georgia DOT. The intent of the test was to determine how accurately the road tubes could monitor traffic in multiple lanes, particularly in heavy traffic.

3.2.2.3 Problems and Exceptions to Test Procedures

During the second 48-hour test, the main problem was an incorrect configuration of the lane-change camera and recorder. The camera used for recording lane changes did not

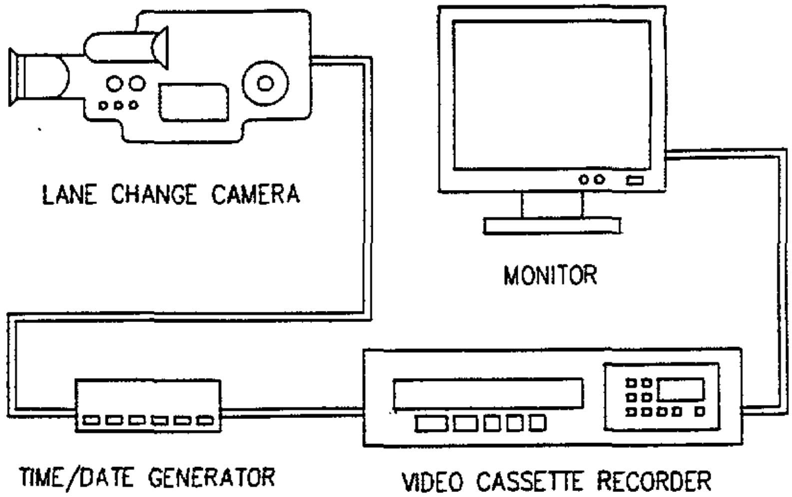


Figure 21. Correct Configuration of the Lane-Change Camera, Time/Date Generator and VCR

have the capability to imprint time and date on the video. A time/date generator was added in the line between the camera and the VCR to add the time and date to the video image before being recorded. This configuration is shown in Figure 21. During the second test, the VCR and time/date generator were accidently swapped in the configuration. Thus the time and date was displayed on the local monitor during the test, but was not recorded by the VCR for use during data reduction. Careful use of the VCR's tape time counter and manual time synchronization with the pole camera was required to match vehicles that change lanes with the appropriate vehicles in the ground truth data. This problem did not affect the results of the test.

The road tube test appeared during testing to be working properly. During data reduction, however, it was found that the classifier had been set up to sum the traffic in both lanes and not record the traffic counts in individual lanes. This would have made it very difficult to separate the traffic to determine errors in the count due to 2 or more vehicle in different lanes passing over the sensors at the same time. The data is still being reviewed, but the initial assessment indicates that the test will need to be repeated in order to obtain accurate data. Currently, the plans are to repeat the test in parallel with a follow-on test. The results will likely be available for the final version of this report.

The problems experienced with the participating vendor's equipment during the second 48-hour test are as follows:

- Peek GK-6000 - This classifier required periodic downloads to a PC to store data. During these downloads, the classifier didn't record traffic data. The downloads took generally greater than 15 minutes. The data also inexplicably ended in one file 6 hours before the end of one of the downloaded files.

- PAT Equipment Corporation AVC-100 (P-L-P) - This classifier appeared to operate correctly most of the time during the test, but the reporting software required to convert the binary data files into readable text files could not convert the data files. The problem is still under discussion with the vendor. The classifier also appeared to be having classification problems a couple of times. These were checked out using the other AVC-100.

- PAT Equipment Corporation AVC-100 (L-P-L) - Two small gaps (less than 15 minutes) occurred when the equipment was intentionally disconnected to check out an apparent problem with the other AVC-100.

- Diamond Traffic Products TT-2001 - The last 16 hours of data were lost when the internal battery in the classifier malfunctioned. The unit would not operate even when the charger was connected to the unit. An external battery was used during the remaining 5 days of the 7-day test.

3.2.3 Seven-Day Test

3.2.3.1 Test Date and Conditions

The 7-day test was conducted September 9 - 16, 1993 in conjunction with the second 48-hour test. The air temperature during the test ranged from 50 degrees F to 86 degrees F. The pavement temperature ranged from 61 degrees F to 117 degrees F. The weather was partly cloudy and there was no precipitation during the test. Like the second 48-hour test, this test was scheduled in the hopes of rainfall, but the only rain was a brief sprinkle which did not register on the rain gauge or significantly moisten the pavement.

The traffic during the test was typical traffic for the site. There was no traffic congestion during the test and the average speed of traffic was typically near 65 MPH. The average daily traffic in the test lane (as determined from the video data reduction) was approximately 10,100 vehicles.

3.2.3.2 Participating Vendors

The participating vendors for the 7-day test are the same as those for the second 48-hour test. The road tubes used for the augmented tube test did not last the entire 7 days, but did last through one full day of the detailed recording period (48-hour test).

3.2.3.3 Problems and Exceptions to Test Procedures

No notable problems with the test procedure occurred during the remaining 5 days of the 7-day test (after the second 48-hour test). The classifiers where converted to a binning mode (rather than vehicle-by-vehicle mode), and the pole and lane change video recorders were switched to the extended play recording speed (tape changes required every 6 hours).

The problems experienced with the participating vendor's equipment during the second 48-hour test are as follows:

- Mikros Systems TEL-2CM - Approximately 3 days of data was lost due to an error by the test personnel. The unit was not configured to record binned data after the 48-hour detailed test was complete causing the internal memory of the unit to fill up. This was not a problem with the classifier, but a setup error.

- Peek GK-6000 - Problems occurred while trying to set up the classifier to collect binned data. The vendor assisted in the conversion, but the classifier missed approximately 2 days of data collection. The unit also failed to record one 30 minute period at the end of one day.

- PAT Equipment Corporation AVC-100 (P-L-P) - This classifier appeared to operate correctly during the test, but the reporting software required to convert the binary data files into readable text files could not convert the data files. The problem is still under discussion with the vendor.

- TimeMark Delta II - Gaps in the classification data occurred during the periods of time when the data was being downloaded to a PC. These gaps were 20 and 11 minutes in length. Most of the last day of data was lost due to data being corrupted in the memory of the classifier. Attempts were made to recover the data by the vendor, but they were unsuccessful.

- Diamond Traffic Products TT-2001 - An external battery was required to operate the unit. The battery was installed approximately 8 hours after the start of the 5-day binning period.

4. DATA REDUCTION AND ANALYSIS

4.1 THE COMPUTER VEHICLE CLASSIFICATION AND REDUCTION SYSTEM (CVCRS)

The CVCRS is a PC-based system designed to assist in the collection of detailed vehicle classification, length and axle spacing from video tapes of the traffic stream. The video tape of the traffic stream taken from the utility pole off the side of the roadway (the pole camera - see Figure 21) is displayed on a second monitor connected to a video processor card in the PC. The video is paused by the user when a vehicle enters the test area. The locations of the front and back bumpers, and the axles are then entered using the mouse on the PC and a crosshair displayed on the monitor. The software calculates the overall length of the vehicle and the axle spacings, and then makes an initial estimate of the vehicle's classification. The user has the option of accepting or modifying the classification of the vehicle based on the FHWA guidelines for vehicle classes. The CVCRS also reads the time recorded on the videotape and time stamps the vehicle recorded for comparison with the data from the vendor's classifiers. Calibration of the CVCRS system length measurements is done using a 40 foot box marked on the pavement and a calibration routine in software which accounts for the camera angle and distance.

4.1.1 Hardware

The CVCRS hardware includes a video cassette recorder (VCR), a personal computer with mouse (PC), a Data Translation DT3851A-1 Flexible Frame Processor (PC video card), and a second VGA monitor. A picture of the CVCRS hardware is shown in Figure 22. The PC video card is installed in the PC and receives input from the VCR (lower right). The PC video card displays the video on the second VGA monitor (right of the PC) along with a crosshair cursor used to make measurements. Use of the video card allows the overlay of the crosshair cursor and automatic measurement of vehicle lengths and spacings by simply pointing and clicking with the mouse. The software required to operate the video card and record the vehicle data is installed an run on the PC.

The monitor and VCR shown on the left in Figure 22 is used for monitoring lane changes within the test site. The process used to handle vehicles which change lanes within the test site will be discussed below in Section 4.2.

4.1.2 Software

Custom software was written to setup and operate the CVCRS hardware. The primary purposes of the software were to operate the Data Translation PC video card, calibrate the length measurements, assist in the measurement of vehicle lengths and axle spacings, record the time at which the vehicle entered the test site, and make an initial guess of the vehicle class. The software ("CVCRS.c") was written using the C language and the Microsoft C compiler.

Figure 22. The CVCRS System

As the data reduction proceeded continual modifications were made to the software to improve its efficiency. For instance, a character recognition algorithm was added to the software after the data reduction from the first 48-hour test. The character recognition algorithm records time directly from the time displayed on the video screen saving the user the effort to increment (or enter) the time. This saved the user approximately 20-25% of the time required to enter each vehicle. Also, the five days of the second test not used for detailed vehicle-by-vehicle comparison did not need measurement of vehicle lengths and axle spacings. Therefore, a second version of the program ("CVCRS2.c") was made which simply recorded the time from the video, and saved the vehicle class and number of axles entered by the user. The second version of the software allowed the user to record vehicle data at nearly twice the rate of the original software.

The typical steps required to operate the CVCRS for detailed vehicle-by-vehicle data reduction are as follows:

1. Turn on the PC, change to the data reduction directory, and type "CVCRS <return>". Enter the file name for storing the data at the prompt "Enter Work File Name:".

2. Turn on the VCR and second monitor, insert a pole camera tape, and hit PLAY on the VCR.

3. When the CVCRS reaches the main screen (showing menu options at the top of the screen and vehicle data at the bottom), hit PAUSE on the VCR.

4. Select "Calibrate" on the CVCRS main screen. Follow the instructions to enter the four corners of the calibration box on the pavement, and enter the length of the calibration box (40 feet in this test).

5. Record each vehicle using the following steps:

   a. Advance VCR tape and PAUSE when a vehicle is on screen.

   b. Click the right mouse button to make a crosshair cursor appear on the second VGA monitor superimposed on the video image.

   c. Align the vertical bar of the crosshair with the front of the vehicle and click the left mouse button (position of the horizontal bar is unimportant).

   d. Align the crosshair vertical bar with the center of the first axle, align the horizontal crossbar with the bottom of the tire, and click the left mouse button. Repeat this step for each successive axle.

   e. Align the vertical bar of the crosshair of the rear of the vehicle and click the left mouse button.

   f. Click the right mouse button to exit the vehicle data entry and return the cursor to the main CVCRS screen. The program will automatically read the time from the tape.

6. If an error is made in the vehicle entry, exit the data entry screen (click right mouse button), select "Re-Enter Vehicle" from the main menu, and repeat step 5.

7. If the vehicle is longer than a full screen, then use the following steps:

   a. Pause the tape with the front bumper and at least half the vehicle displayed on the monitor.

b. Enter all of the points described in step 5 that are displayed on the screen, but DO NOT exit the data entry screen.

c. Choose a distinct vehicle feature (mark, reflector, axle, etc.) behind the middle of the vehicle, align the vertical bar of the crosshair with the selected feature, and hit "r" on the keyboard.

d. Advance the VCR tape and pause it such that the rear of the vehicle and the feature chosen in step 7c are both on the screen.

e. Align the vertical bar of the crosshair with the feature selected in step 7c and again hit "r" on the keyboard.

f. Finish entering axles and the rear of the vehicle as described in step 5.

8. Upon returning to the main menu, the user verifies the vehicle classification guess made by the program and the time recorded from the video. Either of these items can be changed by clicking on the appropriate selection in the middle of the main screen.

9. The data is saved using the "Save Data" option at the top of the main menu.

The steps required to operate the CVCRS2 program for less detailed data analysis are similar, but less complicated than those required to run the CVCRS program. Steps 1 through 3 and 9 are identical, but steps 4 through 8 are replaced by:

4. Advance the tape until the vehicle is centered on the screen.

5. Enter the vehicle class and number of axles using the keyboard.

6. Select "Re-enter Vehicle" on the main menu if an error is made, and repeat steps 4 and 5.

7. Verify time recorded by the program and edit if necessary.

8. Hit <Enter> or <Return> on the keyboard to start next vehicle.

4.2 HANDLING LANE CHANGES

The use of the long (600 foot) test site meant that a significant number of vehicles changed lanes within the site. A vehicle changing lanes will only be recorded by classifiers over which it passed, and can cause errors in those classifiers which it passed over while changing lanes. Also, if the vehicle entered the test lane after passing the pole camera, it would not appear in the ground truth data. Therefore, all vehicles that changed lanes within the test site were removed from the ground truth data for detailed vehicle-by-vehicle comparison (48-hour tests). Those which entered the test site after the pole camera were already not included in the ground truth data. The program for aligning and comparing ground truth data to classifier data ignored all vehicles in the classifier's data which did not have an appropriate match (in time) in the ground truth data.

The vehicles which changed lanes were identified using the video tapes from the lane change camera located on the overpass at the end of the test site. The tapes were viewed on a VCR and monitor (left side of Figure 22) an the time and class of each vehicle that changed lanes was manually recorded. The classifier over which the vehicle began and ended its lane change, and the direction of the lane change (in, out, both) was also recorded. Lines were drawn on the monitor screen to identify the locations of the classifier's sensors to enable the user to locate the classifier locations when viewing night time footage of the video tapes. The vehicles identified as leaving the test lane after the video monitoring area (pole camera) were manually removed from the ground truth data for the detailed analysis of the 48-hour test data.

For the long term statistics of the 7-day test, the lane changes were ignored. It was impractical to try to identify and remove lane changing vehicles from the classifier's binned data. The problems with removing the vehicles included identifying the particular classifiers for which the vehicle needed to be removed, and determining the effects of vehicle which had partially changed lane when passing over the classifier's sensors.

A review of the number of lane changes in a typical day (in the first 48-hour test) revealed the following:

1. Number of vehicles leaving the test lane = 384.

2. Number of vehicles entering the test lane = 408.

3. Number of vehicles which both entered and left the test lane = 90.

The number of vehicles entering and leaving the test lane are nearly equal, and the number of vehicle entering and leaving the test lane was relatively small. The ADT for the first test was approximately 9700 vehicles and the total number of vehicles which changed lanes was 882. Therefore, the percentage of vehicles which changed lanes was approximately 9.2%.

4.3 THE STANDARD DATA FORMAT

To reduce the number of programs required to handle the different storage formats of the classifier vendors, the detailed vehicle-by-vehicle classification and measurement data was converted to a standard format. Simple conversion programs were written by GTRI for each vendor data format which would convert it to the standard data format. The ground truth data was also converted to the standard format. The standard format files were used as the input for the "Binned" and "Analyze" programs described in the next two sections.

```
Line Format:

MM-DD-YY__HHMMSS_CC_B_VVV.V_LL.LL_AA.AA__X_aa.aa_bb.bb_cc.cc_...

where     MM-DD-YY  = date (month - day - year),
          HHMMSS    = vehicle time where
               HH   = hour (24 hour clock),
               MM   = minute and
               SS   = second,
          CC        = vehicle class (13 FHWA classes),
          B         = vehicle subclass,
          VVV.V     = vehicle speed in MPH,
          LL.LL     = overall vehicle length in feet,
          AA.AA     = vehicle wheelbase in feet,
          X         = number of axles,
          aa.aa     = axle spacing between axles 1 and 2 in feet,
          bb.bb     = axle spacing between axles 2 and 3 in feet,
          cc.cc     = axle spacing between axles 3 and 4 in feet,
               .
               .
               .
```

Figure 23. The Standard Data Format

The standard data format is shown in Figure 23. Note that not all vendors have all the information required for the standard format, and the ground truth (or tape) data does not include vehicle speed. A pound symbol ("#") was used in those fields in the standard data format for which there was no data. For the case where the data for a particular field is normally provided by the classifier, but due to an error or other cause is not provided for a particular vehicle, a dollar symbol ("$") is used as a place holder. Vehicle subclass refers to the configuration of the axles on the trailer units within a vehicle class. Vehicle subclass was not used in the analysis of the data for this effort.

4.4 THE "BINNED" PROGRAM

The program "BINNED.c" was written in C, and is designed to transform vehicle-by-vehicle data files in the standard format to files in which the vehicle classes and axles are summed over a given interval (bin). Typically, the bin size is 15 minutes. The output of the BINNED program is a file showing the number of vehicles, the number of axles, and the number of vehicles in each vehicle class for each interval. Also, the program outputs the percentage of vehicles with greater than 2 axles in each interval and daily summaries.

When run, the program prompts the user for the name of the input file (in the standard format), the output file name and the time interval over which to bin the data.

The program then informs the user of the start time of the input file and prompts the user to input the time to start the binning. The start time input by the user is primarily used to get the program to bin at even times such as every quarter hour. The start time is assumed to be for the same day. If the user enters a start time before the input file start time, the output file will contain all zeros for those intervals before the interval containing the first vehicle in the input file.

The BINNED program was the primary analysis software for comparing the long term statistics of the data from the 7-day test.

4.5 THE "ANALYZE" PROGRAM

The ANALYZE program was the primary tool for analyzing the detailed performance of the vendor classifiers on a vehicle-by-vehicle basis. This program contained an algorithm which matched the vehicles from the tape data (ground truth data) to those from the vendor files. After matching the vehicles, the program collected statistics of classification accuracy, overall length measurements, axle spacing measurements and wheelbase measurements. The output of the program is a set of files containing tables of results and examples of suspected splits or combinations of vehicles by the classifiers. A split occurs when a classifier classifies a single vehicle as two separate, smaller vehicles. a combination occurs when two vehicles are classified a single larger vehicle by the classifier.

The ANALYZE program looks at the data from three vehicles from the ground truth file and three from the vendor classifier file at a time. The input files are assumed to be in the standard format and the clocks are assumed to be synchronized. If the clocks are not synchronized, then differences must be determined manually and adjustments made to the vendor data file. The program will attempt to find the best match between the ground truth vehicle and one of the vendor vehicles. The best match is made based on time and number of axles. A flow chart of the vehicle matching algorithm of the ANALYZE program is shown in Appendix C.

The user can set a maximum time differential to be used when determining that a ground truth vehicle and a vendor data vehicle match. For this project, the maximum time differential was set at 2 seconds. If no unmatched vendor vehicle was within the maximum time differential of an unmatched ground truth vehicle, then that ground truth vehicle was declared to be a Missing vehicle (missing from the vendor file). If no unmatched ground truth vehicle was within the maximum time differential of an unmatched vendor vehicle, then the vendor vehicle was declared to be an Extra vehicle. Missing and Extra vehicles most often occurred when vehicles changed lanes, or when the vendor equipment or the pole camera was not operating for a short period of time.

The ANALYZE program was designed to give the vendor classifier the benefit of the doubt when performing vehicle matching. The program seeks a match where the time difference is minimized and the number of axles is the same. If the number of axles differs between the vendor vehicle and the ground truth vehicle, the program searches for splits and combinations of vehicles. If no splits or combinations are found then the program declares this a Sensor Error. The misclassification is recorded, but no length or axle spacings measurements are used in the statistics for the device. Only a match in time and number of axles is used in calculating the length and axle spacing statistics.

When ANALYZE is run, the user is prompted to enter the "Real" (ground truth) data file name and the "Vendor" (classifier) data file name. These files are expected to be in the standard format. The program then prompts the user to enter the start time for the analysis (must be in the starting day of the ground truth data). Finally, the user is asked to enter the "Time Interval" (maximum time differential).

The outputs of ANALYZE are the following seven files:

TABLE.OUT - The file containing a classification matrix depicting the classification accuracy of the vendor classifier. It also contains the mean and standard deviation of the vehicle length, wheelbase and axle spacing measurements as a function of the speed of the vehicle.

MAIN.OUT - The file contains the vehicle data from the ground truth and the vendor data files for every vehicle which was not matched in time and number of axles.

EXTRAV.OUT - This file contains the data from the ground truth vehicles for which there were no matching vehicle in the vendor data file.

MISSINGV.OUT - This file contains data from the vendor vehicle for which there were no matching vehicle in the ground truth data file.

SENSORER.OUT- This file contains the vehicle data from the vendor and ground truth data files for vehicles which matched in time, but had different number of axles (declared a Sensor Error).

MISTYPED.OUT - This file contains the vehicle data from the vendor and ground truth data files for vehicles which matched in time and number of axles, but had different classifications.

SPLT-CMB.OUT - This file contains the vehicle data from the vendor and ground truth data files for vehicles which the vendor classifier either split into two vehicles, or combined two vehicles into one.

The TABLE.OUT file contains the primary results of the ANALYZE program. The other files, particularly SPLT-CMB.OUT, are used to check the classification errors detected by the program for accuracy. Certain combinations of lane changes, sensor errors, and dense traffic caused the program to determine the splits or combinations occurred when, in fact, there were none. These types of errors were few and far between, and did not significantly impact the results.

4.6 TYPICAL ANALYSIS OUTPUTS

Figure 24 is an example of the output of the BINNED program. The first line is the input file name (standard formatted file). Then the date is shown followed by the binned data for that day. The first two columns are the start and stop time for the bin given as HHMMSS, where HH is the hour (24 hour clock), MM is the minute and SS is the second. The next two columns show the total axle and vehicle count for the bin. The next fifteen columns show the vehicle count in the 13 FHWA vehicle classes, the class 14 (which is unused by all the classifiers), and class 15 (usually used for unknown vehicle types). The remaining three columns list average speed in MPH (if given by the classifier), the number of vehicles with greater than two axles, and the percentage of vehicles with greater then two axles. Daily totals are provided, and 7-day totals are calculated for the long-term test.

Figure 25 shows and example of the ANALYZE programs output to the TABLE.OUT file. This file contains a classification matrix, and statistical summaries of the axle spacing, wheelbase, and overall length measurements. The first line contains the filename for the vendor classifier data, and the second line contains the time interval (maximum delta time allowed) used for the ANALYZE matching algorithm. The first matrix depicts the total vehicles as classified by the vendor classifier and the ground truth data. The vendor classes are numbered at the top of the columns, and the ground truth classification is numbered at the left of the rows. In other words, the number in the column C and row R is the total number of class R vehicles (as determined from the CVCRS) that were classified as class C by the vendor classifier.

The second matrix in the TABLE.OUT file is identical to the first, except the totals are expressed as percentages of the total vehicles in the class (ground truth). Following the matrices are the totals of the real (ground truth) vehicles, the vendor vehicles classified, the number of mistyped vehicles, the number of sensor errors detected (miscounted axles), the number of extra vendor vehicle not in the ground truth data, the number of missing vehicles not in the classifier's data file, and the number of correctly classified vehicles. Also totalled is the number of split and combined vehicles suspected by the ANALYZE program. The file of split and combined vehicles detected by the ANALYZE program was manually reviewed to determine the actual split and combination count for the classifier.

Following the totals are summaries of the length measurement statistics for the classifier. The statistics on the accuracy of axle spacing, wheelbase and overall vehicle length measurements are summarized as a function of speed. The speed bins are 5 MPH wide from 30 to 80 MPH. The mean and standard deviation of the measurement, and the total number of vehicles in the speed bin are listed. For the axle spacing measurements, the total axle spacings (i.e. 4 axle spacings are on a 5-axle truck) for each speed bin are also

Date: 9-12-93

Class----------		Axl---	Veh	1	2	3	4	5	6	7	8	9	10	11	12	13	15
0	1500	102	46	0	29	13	0	0	1	0	0	3	0	0	0	0	0
1500	3000	76	36	1	17	16	1	0	0	0	0	1	0	0	0	0	0
3000	4500	84	36	0	21	10	0	2	1	0	0	2	0	0	0	0	0
4500	10000	88	36	0	20	11	0	0	0	0	1	4	0	0	0	0	0
10000	11500	90	36	0	22	7	0	2	0	0	1	4	0	0	0	0	0
11500	13000	72	32	1	18	11	0	0	0	0	0	2	0	0	0	0	0
13000	14500	57	22	0	12	4	1	1	0	0	0	3	0	0	1	0	0
14500	20000	59	25	0	15	7	0	0	0	0	0	3	0	0	0	0	0
20000	21500	73	32	0	19	9	0	1	0	0	0	3	0	0	0	0	0
21500	23000	66	24	0	12	6	0	0	0	0	0	6	0	0	0	0	0
23000	24500	42	16	0	6	6	1	0.	1	0	0	2	0	0	0	0	0
24500	30000	55	19	0	7	6	0	1	0	0	0	5	0	0	0	0	0
30000	31500	23	11	0	7	3	0	1	0	0	0	0	0	0	0	0	0
31500	33000	43	14	0	4	5	0	0	0	0	0	5	0	0	0	0	0
33000	34500	35	15	0	8	4	0	2	1	0	0	0	0	0	0	0	0
34500	40000	37	14	0	6	3	1	0	1	0	1	2	0	0	0	0	0
40000	41500	68	29	0	17	7	1	1	0	0	0	3	0	0	0	0	0
41500	43000	53	20	1	5	7	4	0	0	0	0	3	0	0	0	0	0
43000	44500	61	24	0	12	7	0	0	1	0	0	4	0	0	0	0	0
44500	50000	53	20	0	6	9	3	0	0	0	0	2	0	0	0	0	0
50000	51500	30	12	0	3	5	3	0	0	0	0	1	0	0	0	0	0
51500	53000	66	26	0	13	8	0	0	1	0	0	4	0	0	0	0	0
53000	54500	52	23	0	17	4	0	0	0	0	0	2	0	0	0	0	0
54500	60000	58	24	0	15	5	0	1	0	0	0	3	0	0	0	0	0
60000	61500	46	20	0	9	9	0	0	0	0	0	2	0	0	0	0	0
61500	63000	68	26	0	10	11	0	1	0	0	0	4	0	0	0	0	0
63000	64500	64	25	0	10	10	0	1	0	0	0	4	0	0	0	0	0
64500	70000	57	24	0	10	11	0	0	0	0	0	3	0	0	0	0	0
.																	
.																	
.																	
.																	
.																	
184500	190000	381	179	0	100	71	0	3	1	0	0	4	0	0	0	0	0
190000	191500	386	175	1	98	63	0	4	0	0	0	9	0	0	0	0	0
191500	193000	396	180	0	116	54	0	2	0	0	0	7	0	1	0	0	0
193000	194500	365	164	0	104	51	0	0	0	0	1	8	0	0	0	0	0
194500	200000	366	160	0	99	48	0	3	1	0	0	9	0	0	0	0	0
200000	201500	335	150	0	79	60	0	2	1	0	0	7	0	1	0	0	0
201500	203000	327	148	0	100	38	1	0	0	0	0	9	0	0	0	0	0
203000	204500	344	157	1	102	43	0	4	0	0	0	7	0	0	0	0	0
204500	210000	299	130	0	72	46	0	1	0	0	0	9	0	1	1	0	0
210000	211500	281	128	0	82	37	0	2	0	0	0	5	0	2	0	0	0
211500	213000	268	116	0	77	29	0	0	1	0	1	5	0	3	0	0	0
213000	214500	281	116	0	63	36	0	2	0	0	0	15	0	0	0	0	0
214500	220000	243	101	0	64	24	0	3	0	0	0	10	0	0	0	0	0
220000	221500	233	102	0	66	26	0	1	1	0	0	6	0	2	0	0	0
221500	223000	200	81	0	46	22	0	0	0	0	3	10	0	0	0	0	0
223000	224500	211	85	0	52	19	0	0	1	0	0	13	0	0	0	0	0
224500	230000	198	78	1	34	29	0	0	0	0	0	14	0	0	0	0	0
230000	231500	169	68	0	40	17	0	2	0	0	0	9	0	0	0	0	0
231500	233000	166	66	0	34	22	0	1	0	0	0	9	0	0	0	0	0
233000	234500	115	47	1	28	10	0	1	0	0	0	7	0	0	0	0	0
234500	0	98	38	0	21	9	0	1	0	0	0	7	0	0	0	0	0
TOTALS:		21651	9657	23	5522	3319	34	169	36	1	21	516	2	12	2	0	0

Figure 24. Example Output of the BINNED Program

Time interval: 2

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	15	1	0	0	0	0	0	0	0	0	0	0	0	0	0
2	3	8565	135	0	4	1	0	12	5	3	1	0	1	0	0
3	1	3503	1881	0	40	1	0	66	6	1	0	0	2	0	0
4	0	0	3	5	21	13	2	0	0	0	0	0	1	0	0
5	0	11	135	4	182	0	1	32	0	0	0	0	2	0	0
6	0	1	7	2	0	164	3	5	7	0	0	0	3	0	0
7	0	0	0	0	0	1	0	1	0	0	0	0	0	0	0
8	2	19	5	0	0	0	2	228	3	0	1	0	1	0	0
9	2	20	12	0	5	2	0	22	2229	507	49	2	34	0	0
10	0	2	1	0	0	0	0	2	2	17	1	0	1	0	0
11	0	1	0	0	0	0	0	0	1	0	80	2	1	0	0
12	0	0	0	0	0	0	0	0	0	0	0	27	1	0	0
13	0	0	0	0	0	0	0	1	0	4	0	0	0	0	0
14	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
15	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	93.8	6.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2	0.0	98.1	1.5	0.0	0.0	0.0	0.0	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0
3	0.0	63.7	34.2	0.0	0.7	0.0	0.0	1.2	0.1	0.0	0.0	0.0	0.0	0.0	0.0
4	0.0	0.0	6.7	11.1	46.7	28.9	4.4	0.0	0.0	0.0	0.0	0.0	2.2	0.0	0.0
5	0.0	3.0	36.8	1.1	49.6	0.0	0.3	8.7	0.0	0.0	0.0	0.0	0.5	0.0	0.0
6	0.0	0.5	3.6	1.0	0.0	85.4	1.6	2.6	3.6	0.0	0.0	0.0	1.6	0.0	0.0
7	0.0	0.0	0.0	0.0	0.0	50.0	0.0	50.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
8	0.8	7.3	1.9	0.0	0.0	0.0	0.8	87.4	1.1	0.0	0.4	0.0	0.4	0.0	0.0
9	0.1	0.7	0.4	0.0	0.2	0.1	0.0	0.8	77.3	17.6	1.7	0.1	1.2	0.0	0.0
10	0.0	7.7	3.8	0.0	0.0	0.0	0.0	7.7	7.7	65.4	3.8	0.0	3.8	0.0	0.0
11	0.0	1.2	0.0	0.0	0.0	0.0	0.0	0.0	1.2	0.0	94.1	2.4	1.2	0.0	0.0
12	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	96.4	3.6	0.0	0.0
13	0.0	0.0	0.0	0.0	0.0	0.0	0.0	20.0	0.0	80.0	0.0	0.0	0.0	0.0	0.0
14	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
15	0.0	0.0	0.0	0.0	0.0	0.0	0.0	100.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

#Real:	19091
#Vendor:	19186
#mistyped:	4751
#sensor err:	793
#extra Vend:	927
#Missing Vend:	864
#Correct:	13393
#Splits:	49
#Combinations:	17

Figure 25. Example Output of the ANALYZE Program

listed. The overall (independent of speed) mean, standard deviation and vehicle totals are listed for each measurement. If applicable or existing information is available, the following statistics are calculated and listed in the file TABLE.OUT:

- Axle Spacing - True (ground truth) length less the measured length (classifier) in feet,
- Wheelbase - True length minus measured length in feet,
- Overall Length - True length minus measured length in feet,
- Overall Length Percentage - True length times 100 and divided by the measured length.

5. CLASSIFIER RESULTS

5.1 OVERVIEW OF GENERAL RESULTS

In Section 5.2, the results of the comparison of the individual vehicle-by-vehicle classifier outputs to the ground truth (from videotape) data are presented and discussed. The results will be discussed for each of the two 48-hour testing sessions. The results presented here include classification, axle spacing measurement, wheelbase measurement, and overall length measurement accuracy. The results for the whole tests as well as the parametric results versus percent trucks, air temperature, and pavement temperature are presented for each classifier.

In Section 5.3, the parametric results versus percent trucks, air temperature, and pavement temperature are summarized for all the classifiers and tests. General trends of performance are presented and discussed.

5.2 TEST RESULTS FROM INDIVIDUAL CLASSIFIERS

The results of each classifier model and sensor configuration for each of the two 48-hour tests are presented in the following subsections. The overall classification matrix for each is depicted as well as table demonstrating the parametric results.

5.2.1 Mikros Systems TEL-2CM

The Mikros Systems model TEL-2CM classifier used an L-P-L sensor configuration and Philips Vibracoax piezoelectric axle sensors. The results for the individual tests are presented below.

5.2.1.1 First 48-Hour Test

The classification matrix for the first 48 hour test and the summary of number of vehicles (real and vendor), mistyped vehicles, sensor errors, extra vendor vehicles, missing vendor vehicles, correctly classified vehicles, suspected splits and suspected combinations are presented in Figure 26. The classification matrix is presented in both absolute numbers, and percentages. The classifier correctly classified 70.3% of the vehicles (82.5% if class 2-3 errors not included). The number of vehicle axles was miscounted 13.91% (percent sensor errors) of the time. Less than 1.0% of the vehicles classified by the Mikros equipment were suspected to be the result of a split or combination of an actual vehicle.

The measurement accuracy of the classifier as a function of vehicle speed is depicted in Figure 27. The Mikros classifier measures axles spacings, wheelbase and overall vehicle length. The measurement error statistics (mean and deviation) for all measurements, and the overall length percentile statistics are included in the figure as a function of measured vehicle speed (mph). Note that all measurements are in feet.

Table II contains a summary of the results of the classification accuracy as a function of percent vehicles with greater than two axles, air temperature and pavement temperature.

Time interval: 2

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
2	0	3318	15	0	142	0	0	0	0	0	0	0	0	0	0
3	7	953	319	1	893	1	0	34	1	0	0	0	0	0	0
4	0	0	0	13	10	6	0	0	0	0	0	0	0	0	0
5	0	9	9	4	273	3	0	6	5	0	0	0	0	0	0
6	0	1	1	2	0	166	8	2	4	3	0	0	0	0	0
7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
8	0	3	0	2	2	0	0	115	4	0	0	0	0	0	0
9	0	3	0	0	0	0	0	3	1329	153	0	0	8	0	0
10	0	0	0	0	0	0	0	0	5	10	0	0	1	0	0
11	0	0	0	0	0	0	0	1	1	0	49	0	0	0	0
12	0	0	0	0	0	0	0	0	0	12	0	0	0	0	0
13	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
14	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
15	0	1	1	0	0	0	0	11	1	0	0	0	0	0	0

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	0.0	100.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2	0.0	95.5	0.4	0.0	4.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
3	0.3	43.1	14.4	0.0	40.4	0.0	0.0	1.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0
4	0.0	0.0	0.0	44.8	34.5	20.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
5	0.0	2.9	2.9	1.3	88.3	1.0	0.0	1.9	1.6	0.0	0.0	0.0	0.0	0.0	0.0
6	0.0	0.5	0.5	1.1	0.0	88.8	4.3	1.1	2.1	1.6	0.0	0.0	0.0	0.0	0.0
7	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
8	0.0	2.4	0.0	1.6	1.6	0.0	0.0	91.3	3.2	0.0	0.0	0.0	0.0	0.0	0.0
9	0.0	0.2	0.0	0.0	0.0	0.0	0.0	0.2	88.8	10.2	0.0	0.0	0.5	0.0	0.0
10	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	31.2	62.5	0.0	0.0	6.2	0.0	0.0
11	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.0	2.0	0.0	96.1	0.0	0.0	0.0	0.0
12	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	100.0	0.0	0.0	0.0	0.0	0.0
13	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
14	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
15	0.0	7.1	7.1	0.0	0.0	0.0	0.0	78.6	7.1	0.0	0.0	0.0	0.0	0.0	0.0

#Real:	18299
#Vendor:	8476
#mistyped:	2357
#sensor err:	1106
#extra Vend:	402
#Missing Vend:	10283
#Correct:	5592
#Splits:	61
#Combinations:	3

Figure 26. Classification Matrix for Mikros Systems TEL-2CM 1st 48-Hour Test

Axles Spacing Statistics

Speeds	Mean	STD	Veh	Axle_Spacings
<30	10.818	11.181	6	18
30.0-34.9	0.000	0.000	0	0
35.0-39.9	0.513	0.496	3	4
40.0-44.9	0.441	0.799	11	23
45.0-49.9	0.180	0.441	12	25
50.0-54.9	0.159	0.568	206	482
55.0-59.9	0.143	1.162	710	1577
60.0-64.9	0.083	0.988	1735	3777
65.0-69.9	0.045	0.706	1530	2661
70.0-74.9	0.009	0.526	631	872
75.0-79.9	0.030	0.299	152	168
>80	-0.130	0.578	18	19
Overall	0.099	1.113	5014	9626

Length Statistics

Speeds	Mean	STD	Vehicles
<30	39.353	27.719	6
30.0-34.9	0.000	0.000	0
35.0-39.9	3.787	2.020	3
40.0-44.9	3.344	2.570	11
45.0-49.9	3.053	1.725	12
50.0-54.9	3.253	1.989	206
55.0-59.9	2.764	2.225	710
60.0-64.9	2.329	1.979	1735
65.0-69.9	1.701	1.669	1530
70.0-74.9	1.186	1.868	631
75.0-79.9	0.925	1.074	152
>80	0.477	0.673	18
Overall	2.093	2.549	5014

Wheelbase Statistics

Speeds	Mean	STD	Vehicles
<30	32.455	23.527	6
30.0-34.9	0.000	0.000	0
35.0-39.9	0.683	0.489	3
40.0-44.9	0.921	1.323	11
45.0-49.9	0.376	0.371	12
50.0-54.9	0.372	0.874	206
55.0-59.9	0.316	0.921	710
60.0-64.9	0.180	1.025	1735
65.0-69.9	0.079	0.787	1530
70.0-74.9	0.012	0.585	631
75.0-79.9	0.033	0.376	152
>80	-0.137	0.714	18
Overall	0.191	1.637	5014

Length Percentile Statistics

Speeds	Mean	STD	Vehicles
<30	707.43	432.02	6
30.0-34.9	0.000	0.000	0
35.0-39.9	118.802	8.723	3
40.0-44.9	113.416	14.954	11
45.0-49.9	111.109	7.331	12
50.0-54.9	111.339	7.713	206
55.0-59.9	109.764	11.145	710
60.0-64.9	107.675	5.616	1735
65.0-69.9	107.137	6.382	1530
70.0-74.9	106.106	7.773	631
75.0-79.9	105.907	7.457	152
>80	103.09	4.32	18
Overall	108.43	26.62	5014

Figure 27. Measurement Accuracy Versus Speed (MPH)
Mikros TEL-2CM - 1st 48-Hour Test

Table II. Accuracy Summary for Mikros Systems TEL-2CM
1st 48-Hour Test

	Sensor Errors	Correct	Correct (no 2,3)	Axle Mean	Axle S.D.	Length Mean	Length S.D.	%L Mean	%L S.D.
Total	13.91	70.3	82.5	0.099	1.113	2.093	2.549	108.43	26.62
% Trucks									
0-20	13.57	67.4	82.5	0.099	1.035	1.716	1.657	107.84	7.05
20-40	13.93	70.8	82.1	0.101	1.204	2.121	2.811	108.80	31.73
40-60	14.86	77.6	86.8	0.091	0.672	2.679	2.027	107.04	5.684
60-80	12.09	78.0	83.5	0.129	0.634	3.351	1.990	107.63	5.838
Air Temp									
50-59	14.87	66.9	83.7	0.117	0.767	2.172	2.418	108.84	26.77
60-69	15.45	71.2	82.6	0.115	0.985	2.403	2.916	108.34	29.81
70-79	13.14	72.7	83.1	0.101	1.322	2.140	2.864	108.42	33.04
80-89	13.25	70.1	81.5	0.080	1.181	1.918	2.240	108.30	20.61
Pav Temp									
60- 69	13.63	69.8	84.6	0.084	0.512	2.421	1.906	108.32	6.63
70- 79	15.94	70.6	82.6	0.112	0.992	2.342	2.965	108.40	31.53
80- 89	12.83	72.6	83.1	0.131	1.338	2.238	3.360	109.36	41.40
90- 99	11.78	71.9	81.8	0.084	1.002	2.187	2.651	108.95	32.37
100-109	12.38	72.9	83.9	0.091	2.033	1.791	1.719	107.71	7.109
110-119	14.29	69.2	81.0	0.061	0.993	1.813	1.966	107.64	6.97

5.2.1.2 Second 48-Hour Test

The classification matrix for the second 48 hour test and the summary of number of vehicles (real and vendor), mistyped vehicles, sensor errors, extra vendor vehicles, missing vendor vehicles, correctly classified vehicles, suspected splits and suspected combinations are presented in Figure 28. The classification matrix is presented in both absolute numbers, and percentages. The classifier correctly classified 63.5% of the vehicles (78.8% if class 2-3 errors not included). The number of vehicle axles was miscounted 4.81% (percent sensor errors) of the time. Approximately 1.7% of the vehicles classified by the Mikros equipment were suspected to be the result of a split or combination of an actual vehicle.

The measurement accuracy of the classifier as a function of vehicle speed is depicted in Figure 29. The Mikros classifier measures axles spacings, wheelbase and overall vehicle length. The measurement error statistics (mean and deviation) for all measurements, and the overall length percentile statistics are included in the figure as a function of measured vehicle speed (mph). Note that all measurements are in feet.

Table III contains a summary of the results of the classification accuracy as a function of percent vehicles with greater than two axles, air temperature and pavement temperature.

Time interval: 2

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	1	7	0	0	0	0	0	1	0	0	0	0	0	0	0
2	1	3381	46	4	324	4	0	19	55	2	0	0	0	0	0
3	0	1074	286	9	799	6	0	57	44	3	0	0	0	0	0
4	0	4	0	14	0	3	0	0	0	0	0	0	0	0	0
5	0	17	5	17	79	1	0	7	8	1	0	0	0	0	0
6	0	11	1	0	3	20	0	0	2	0	0	0	0	0	0
7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
8	0	8	1	0	3	0	0	39	3	0	0	0	0	0	0
9	0	71	5	1	16	0	0	1	800	13	1	0	0	0	0
10	0	0	0	0	0	0	0	0	0	1	0	0	1	0	0
11	0	2	0	0	0	0	0	0	0	0	27	0	0	0	0
12	0	0	0	0	0	0	0	0	0	8	0	0	0	0	0
13	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0
14	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
15	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	11.1	77.8	0.0	0.0	0.0	0.0	0.0	11.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2	0.0	88.1	1.2	0.1	8.4	0.1	0.0	0.5	1.4	0.1	0.0	0.0	0.0	0.0	0.0
3	0.0	47.1	12.6	0.4	35.1	0.3	0.0	2.5	1.9	0.1	0.0	0.0	0.0	0.0	0.0
4	0.0	19.0	0.0	66.7	0.0	14.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
5	0.0	12.6	3.7	12.6	58.5	0.7	0.0	5.2	5.9	0.7	0.0	0.0	0.0	0.0	0.0
6	0.0	29.7	2.7	0.0	8.1	54.1	0.0	0.0	5.4	0.0	0.0	0.0	0.0	0.0	0.0
7	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
8	0.0	14.8	1.9	0.0	5.6	0.0	0.0	72.2	5.6	0.0	0.0	0.0	0.0	0.0	0.0
9	0.0	7.8	0.6	0.1	1.8	0.0	0.0	0.1	88.1	1.4	0.1	0.0	0.0	0.0	0.0
10	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	50.0	0.0	0.0	50.0	0.0	0.0
11	0.0	6.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	93.1	0.0	0.0	0.0	0.0
12	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	100.0	0.0	0.0	0.0	0.0	0.0
13	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	100.0	0.0	0.0	0.0	0.0	0.0
14	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
15	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A

#Real:	20107
#Vendor:	9076
#mistyped:	2676
#sensor err:	352
#extra Vend:	1611
#Missing Vend:	12546
#Correct:	4648
#Splits:	15
#Combinations:	111

Figure 28. Classification Matrix for Mikros Systems TEL-2CM 2nd 48-Hour Test

Axles Spacing Statistics

Speeds	Mean	STD	Veh	Axle_Spacings
<30	11.359	9.308	3	12
30.0-34.9	0.070	0.000	1	1
35.0-39.9	0.000	0.000	0	0
40.0-44.9	-0.030	0.000	1	1
45.0-49.9	0.038	0.250	14	17
50.0-54.9	0.103	0.621	176	342
55.0-59.9	0.108	0.777	541	1043
60.0-64.9	-0.016	0.895	1277	2265
65.0-69.9	-0.093	0.744	1477	2208
70.0-74.9	-0.144	0.550	807	1004
75.0-79.9	-0.132	0.874	274	305
>80	-0.414	1.309	46	49
Overall	-0.022	0.988	4617	7247

Length Statistics

Speeds	Mean	STD	Vehicles
<30	52.643	3.020	3
30.0-34.9	-3.240	0.000	1
35.0-39.9	0.000	0.000	0
40.0-44.9	-0.420	0.000	1
45.0-49.9	-1.651	2.395	14
50.0-54.9	-2.497	3.907	176
55.0-59.9	-1.938	3.407	541
60.0-64.9	-2.142	3.931	1277
65.0-69.9	-2.334	3.249	1477
70.0-74.9	-2.165	4.382	807
75.0-79.9	-2.186	4.410	274
>80	-2.647	3.827	46
Overall	-2.167	4.031	4617

Wheelbase Statistics

Speeds	Mean	STD	Vehicles
<30	45.440	3.691	3
30.0-34.9	0.070	0.000	1
35.0-39.9	0.000	0.000	0
40.0-44.9	-0.030	0.000	1
45.0-49.9	0.047	0.237	14
50.0-54.9	0.199	0.857	176
55.0-59.9	0.208	1.176	541
60.0-64.9	-0.029	1.166	1277
65.0-69.9	-0.138	1.065	1477
70.0-74.9	-0.179	0.739	807
75.0-79.9	-0.147	1.001	274
>80	-0.441	2.098	46
Overall	-0.035	1.581	4617

Length Percentile Statistics

Speeds	Mean	STD	Vehicles
<30	797.02	174.35	3
30.0-34.9	84.571	0.022	1
35.0-39.9	0.000	0.000	0
40.0-44.9	97.375	0.000	1
45.0-49.9	91.924	11.376	14
50.0-54.9	90.844	13.006	176
55.0-59.9	92.207	11.494	541
60.0-64.9	91.828	25.673	1277
65.0-69.9	89.888	12.344	1477
70.0-74.9	90.659	31.711	807
75.0-79.9	89.547	21.132	274
>80	88.01	12.46	46
Overall	91.29	28.32	4617

Figure 29. Measurement Accuracy Versus Speed (MPH) MIKROS TEL-2CM - 2nd 48-Hour Test

Table III. Accuracy Summary for Mikros Systems TEL-2CM 2nd 48-Hour Test

	Sensor Errors	Correct	Correct (no 2,3)	Axle Mean	Axle S.D.	Length Mean	Length S.D.	%L Mean	%L S.D.
Total	4.81	63.5	78.8	-0.022	0.988	-2.167	4.031	91.29	28.32
% Trucks									
0-20	4.06	62.7	78.7	-0.002	0.995	-2.277	3.872	90.46	27.95
20-40	7.62	65.2	78.5	-0.065	0.999	-1.837	4.524	93.77	29.97
40-60	0.00	78.9	84.6	-0.116	0.432	-0.717	1.594	98.09	06.09
Air Temp									
60-69	2.32	66.5	80.4	-0.033	0.887	-1.955	3.925	92.72	29.24
70-79	7.30	60.5	77.0	-0.024	1.020	-2.305	4.156	90.29	24.36
80-89	1.62	65.7	81.2	0.046	1.400	-2.392	3.770	90.22	42.90
Pav Temp									
60- 69	00.83	67.6	79.5	-0.049	1.023	-1.28	4.332	96.63	42.44
70- 79	03.50	67.3	81.5	-0.028	1.014	-2.004	4.652	92.95	30.77
80- 89	08.63	60.9	77.7	0.003	0.857	-2.441	4.193	89.99	18.38
90- 99	12.46	53.9	73.6	-0.025	1.263	-2.719	3.613	87.83	13.33
100-109	05.21	62.3	78.2	-0.033	0.605	-2.362	3.008	89.09	12.03
110-119	00.96	65.2	79.9	0.011	1.034	-2.502	3.389	88.87	29.16

5.2.1.3 Seven-Day Test

The results of the 7-day test to determine long-term statistics on classification accuracy, vehicle count and axle count are summarized in Table IV. The totals for the entire seven days for the vendor and classifier are listed. Also, the difference (ground truth minus vendor) and the percent difference (ground truth * 100 / classifier) are listed. To assess the change inaccuracy over the seven days, the percent difference is calculated for the first and last full days recorded of the seven days.

Table IV. Long-Term Count/Classification Accuracy Mikros Systems TEL-2CM

	Total Grnd Truth	Total *Classifier*	Total *Difference*	Total *Percent*	1st Day Percent	Last Day Percent
Vehicles	26995	23717	3278	113.82	108.23	113.59
Axles	65759	57450	8309	114.46	109.02	114.65
Class 1	53	6	47	883.33	700.00	550.00
Class 2	13919	14533	-614	95.78	91.02	95.04
Class 3	8645	1168	7477	740.15	660.45	989.27
Class 4	75	161	-86	46.58	59.57	21.54
Class 5	671	4263	-3592	15.74	12.05	25.66
Class 6	196	163	33	120.25	125.64	117.89
Class 7	2	0	2	--	--	--
Class 8	220	530	-310	41.51	45.45	84.87
Class 9	3073	2679	394	114.71	110.12	116.27
Class 10	27	140	-113	19.29	18.60	23.81
Class 11	88	69	19	127.54	117.24	129.41
Class 12	26	0	26	--	--	--
Class 13	0	5	-5	0.00	0.00	0.00
Class 15	0	0	0	--	--	--

5.2.2 Peek Traffic Inc. TrafiCOMP III

The Peek Traffic Inc. model TrafiCOMP III classifier used a P-L-P sensor configuration and Philips Vibracoax piezoelectric axle sensors. The results of the individual tests are presented below.

5.2.2.1 First 48-Hour Test

The classification matrix for the first 48 hour test and the summary of number of vehicles (real and vendor), mistyped vehicles, sensor errors, extra vendor vehicles, missing vendor vehicles, correctly classified vehicles, suspected splits and suspected combinations are presented in Figure 30. The classification matrix is presented in both absolute numbers, and percentages. The classifier correctly classified 75.3% of the vehicles (93.0% if class 2-3 errors not included). The number of vehicle axles was miscounted 3.71% (percent sensor errors) of the time. Note that the TrafiCOMP III output was not time stamped with seconds and manual aligning of the data was required. Therefore, identification of splits and combinations could not be accomplished.

The measurement accuracy of the classifier as a function of vehicle speed is depicted in Figure 31. The TrafiCOMP III classifier measures axles spacings and wheelbase length. The measurement error statistics (mean and deviation) for all measurements are included in the figure as a function of measured vehicle speed (mph). Note that all measurements are in feet.

Table V contains a summary of the results of the classification accuracy as a function of percent vehicles with greater than two axles, air temperature and pavement temperature.

Time interval: 0

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	2	0	0	0	0	0	0	0	0	0	0	0	0	0	3
2	10	6682	31	0	3	1	0	5	0	0	0	0	0	0	58
3	8	2826	1550	0	29	0	0	79	1	0	0	0	0	0	41
4	0	0	2	47	9	6	0	1	0	0	0	0	0	0	0
5	2	26	173	60	331	0	0	40	0	0	0	0	0	0	15
6	0	0	2	4	5	415	0	3	8	0	0	0	0	0	2
7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
8	0	0	2	0	0	0	0	280	1	0	0	0	0	0	3
9	1	0	1	1	0	4	0	349	2673	0	0	0	0	0	133
10	0	0	0	0	0	0	0	1	9	20	0	0	0	0	3
11	0	0	0	0	0	0	0	0	1	0	84	0	0	0	2
12	0	0	0	0	0	0	0	0	0	0	0	27	0	0	0
13	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0
14	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
15	0	1	2	0	0	1	0	4	4	0	0	1	0	0	21

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	40.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	60.0
2	0.1	98.4	0.5	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.9
3	0.2	62.3	34.2	0.0	0.6	0.0	0.0	1.7	0.0	0.0	0.0	0.0	0.0	0.0	0.9
4	0.0	0.0	3.1	72.3	13.8	9.2	0.0	1.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0
5	0.3	4.0	26.7	9.3	51.2	0.0	0.0	6.2	0.0	0.0	0.0	0.0	0.0	0.0	2.3
6	0.0	0.0	0.5	0.9	1.1	94.5	0.0	0.7	1.8	0.0	0.0	0.0	0.0	0.0	0.5
7	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
8	0.0	0.0	0.7	0.0	0.0	0.0	0.0	97.9	0.3	0.0	0.0	0.0	0.0	0.0	1.0
9	0.0	0.0	0.0	0.0	0.0	0.1	0.0	11.0	84.5	0.0	0.0	0.0	0.0	0.0	4.2
10	0.0	0.0	0.0	0.0	0.0	0.0	0.0	3.0	27.3	60.6	0.0	0.0	0.0	0.0	9.1
11	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.1	0.0	96.6	0.0	0.0	0.0	2.3
12	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	100.0	0.0	0.0	0.0
13	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	100.0	0.0	0.0	0.0
14	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
15	0.0	2.9	5.9	0.0	0.0	2.9	0.0	11.8	11.8	0.0	0.0	2.9	0.0	0.0	61.8

#Real:	16120
#Vendor:	16120
#mistyped:	3987
#sensor err:	598
#extra Vend:	0
#Missing Vend:	0
#Correct:	12133
#Splits:	0
#Combinations:	0

Figure 30. Classification Matrix for Peek TrafiCOMP III 1st 48-Hour Test

Axles Spacing Statistics

Speeds	Mean	STD	Veh	Axle_Spacings
<30	7.506	7.256	4	5
30.0-34.9	0.140	0.100	2	2
35.0-39.9	0.203	0.160	6	11
40.0-44.9	0.260	0.303	18	36
45.0-49.9	0.175	0.246	68	132
50.0-54.9	0.166	0.291	427	897
55.0-59.9	0.193	0.371	1646	3494
60.0-64.9	0.164	0.432	4867	10307
65.0-69.9	0.162	0.270	3366	4965
70.0-74.9	0.186	0.150	1295	1316
75.0-79.9	0.191	0.144	321	321
>80	0.170	0.101	34	34
Overall	0.172	0.399	12054	21520

Wheelbase Statistics

Speeds	Mean	STD	Vehicles
<30	9.382	16.119	4
30.0-34.9	0.140	0.100	2
35.0-39.9	0.372	0.144	6
40.0-44.9	0.519	0.380	18
45.0-49.9	0.340	0.310	68
50.0-54.9	0.349	0.408	427
55.0-59.9	0.409	0.569	1646
60.0-64.9	0.347	0.628	4867
65.0-69.9	0.238	0.320	3366
70.0-74.9	0.189	0.149	1295
75.0-79.9	0.191	0.144	321
>80	0.170	0.101	34
Overall	0.307	0.601	12054

Figure 31. Measurement Accuracy Versus Speed (MPH) Peek TrafiCOMP III - 1st 48-Hour Test

Table V. Accuracy Summary for Peek TrafiCOMP III 1st 48-Hour Test

	Sensor Errors	Correct	Correct (no 2,3)	Axle Mean	Axle S.D.	Length Mean	Length S.D.	%L Mean	%L S.D.
Total	3.71	75.3	93.0	0.172	0.399	*	*	*	*
% Trucks						*	*	*	*
0-20	2.58	72.8	93.6	0.195	0.469				
20-40	3.74	75.4	93.1	0.166	0.394				
40-60	5.46	80.4	90.9	0.159	0.327				
60-80	8.04	79.1	88.2	0.194	0.337				
Air Temp						*	*	*	*
50-59	3.54	69.6	91.9	0.151	0.466				
60-69	4.93	76.8	91.8	0.175	0.387				
70-79	3.88	76.0	92.8	0.181	0.299				
80-89	3.20	76.4	94.0	0.172	0.419				
Pav Temp						*	*	*	*
60- 69	4.72	71.6	91.3	0.148	0.483				
70- 79	4.19	77.5	92.8	0.171	0.380				
80- 89	3.96	77.1	93.8	0.174	0.373				
90- 99	3.66	75.3	92.6	0.161	0.248				
100-109	2.39	76.0	95.0	0.181	0.296				
110-119	3.52	76.7	93.4	0.177	0.508				

* - Does Not Measure Overall Vehicle Length

5.2.2.2 Second 48-Hour Test

The classification matrix for the second 48 hour test and the summary of number of vehicles (real and vendor), mistyped vehicles, sensor errors, extra vendor vehicles, missing vendor vehicles, correctly classified vehicles, suspected splits and suspected combinations are presented in Figure 32. The classification matrix is presented in both absolute numbers, and percentages. The classifier correctly classified 74.8% of the vehicles (93.2% if class 2-3 errors not included). The number of vehicle axles was miscounted 3.53% (percent sensor errors) of the time. Note that the TrafiCOMP III output was not time stamped with seconds and manual aligning of the data was required. Therefore, identification of splits and combinations could not be accomplished.

The measurement accuracy of the classifier as a function of vehicle speed is depicted in Figure 33. The TrafiCOMP III classifier measures axles spacings and wheelbase length. The measurement error statistics (mean and deviation) for all measurements are included in the figure as a function of measured vehicle speed (mph). Note that all measurements are in feet.

Table VI contains a summary of the results of the classification accuracy as a function of percent vehicles with greater than two axles, air temperature and pavement temperature.

Time interval: 0

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	3	3	0	0	0	0	0	0	0	0	0	0	0	0	0
2	93	7438	45	0	2	2	0	3	6	1	1	0	0	0	34
3	59	2926	1483	0	136	4	0	61	2	0	0	0	1	0	45
4	0	0	2	30	5	7	0	0	0	0	0	0	0	0	1
5	3	7	45	48	161	1	0	37	0	1	0	0	0	0	10
6	0	0	2	3	1	182	0	4	3	0	0	0	0	0	0
7	0	0	0	0	0	1	0	0	0	0	0	0	0	0	2
8	1	1	1	1	0	1	0	261	0	0	0	0	0	0	7
9	0	5	1	2	3	2	0	286	2398	3	2	0	0	0	134
10	0	0	1	0	0	1	0	1	1	16	0	0	0	0	2
11	1	0	0	0	0	0	0	0	0	0	85	0	0	0	2
12	0	0	0	0	0	0	0	0	0	0	0	27	0	0	0
13	0	0	0	0	0	0	0	0	0	4	0	0	0	0	0
14	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
15	0	1	0	0	0	0	0	0	0	0	0	0	0	0	1

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	50.0	50.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2	1.2	97.5	0.6	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.4
3	1.3	62.0	31.4	0.0	2.9	0.1	0.0	1.3	0.0	0.0	0.0	0.0	0.0	0.0	1.0
4	0.0	0.0	4.4	66.7	11.1	15.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.2
5	1.0	2.2	14.4	15.3	51.4	0.3	0.0	11.8	0.0	0.3	0.0	0.0	0.0	0.0	3.2
6	0.0	0.0	1.0	1.5	0.5	93.3	0.0	2.1	1.5	0.0	0.0	0.0	0.0	0.0	0.0
7	0.0	0.0	0.0	0.0	0.0	33.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	66.7
8	0.4	0.4	0.4	0.4	0.0	0.4	0.0	95.6	0.0	0.0	0.0	0.0	0.0	0.0	2.6
9	0.0	0.2	0.0	0.1	0.1	0.1	0.0	10.1	84.6	0.1	0.1	0.0	0.0	0.0	4.7
10	0.0	0.0	4.5	0.0	0.0	4.5	0.0	4.5	4.5	72.7	0.0	0.0	0.0	0.0	9.1
11	1.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	96.6	0.0	0.0	0.0	2.3
12	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	100.0	0.0	0.0	0.0
13	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	100.0	0.0	0.0	0.0	0.0	0.0
14	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
15	0.0	50.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	50.0

#Real:	16158
#Vendor:	16158
#mistyped:	4072
#sensor err:	571
#extra Vend:	0
#Missing Vend:	0
#Correct:	12086
#Splits:	0
#Combinations:	0

Figure 32. Classification Matrix for Peek TrafiCOMP III 2nd 48-Hour Test

Axles Spacing Statistics

Speeds	Mean	STD	Veh	Axle_Spacings
<30	-0.000	0.000	1	1
30.0-34.9	-0.067	0.178	3	3
35.0-39.9	0.074	0.378	4	7
40.0-44.9	0.055	0.373	23	36
45.0-49.9	0.119	0.343	107	172
50.0-54.9	0.077	0.349	530	1000
55.0-59.9	0.073	0.381	1719	3313
60.0-64.9	0.063	0.381	4747	9383
65.0-69.9	0.053	0.326	3300	4766
70.0-74.9	0.067	0.226	1264	1297
75.0-79.9	0.098	0.191	298	298
>80	0.113	0.217	24	24
Overall	0.064	0.356	12020	20298

Wheelbase Statistics

Speeds	Mean	STD	Vehicles
<30	-0.000	0.000	1
30.0-34.9	-0.067	0.178	3
35.0-39.9	0.130	0.218	4
40.0-44.9	0.087	0.221	23
45.0-49.9	0.192	0.332	107
50.0-54.9	0.146	0.277	530
55.0-59.9	0.141	0.318	1719
60.0-64.9	0.125	0.319	4747
65.0-69.9	0.077	0.263	3300
70.0-74.9	0.069	0.238	1264
75.0-79.9	0.098	0.191	298
>80	0.113	0.217	24
Overall	0.109	0.293	12020

Figure 33. Measurement Accuracy Versus Speed (MPH)
Peek TrafiCOMP III - 2nd 48-Hour Test

Table VI. Accuracy Summary for Peek TrafiCOMP III 2nd 48-Hour Test

	Sensor Errors	Correct	Correct (no 2,3)	Axle Mean	Axle S.D.	Length Mean	Length S.D.	%L Mean	%L S.D.
Total	3.53	74.8	93.2	0.064	0.356	*	*	*	*
% Trucks									
0-20	2.96	73.5	93.7	0.069	0.340	*	*	*	*
20-40	3.74	75.6	93.1	0.061	0.361				
40-60	6.09	77.9	89.8	0.069	0.407				
Air Temp									
60-69	4.57	72.3	90.8	0.059	0.364	*	*	*	*
70-79	3.29	75.5	93.8	0.045	0.331				
80-89	2.93	75.9	94.7	0.107	0.389				
Pav Temp									
60- 69	6.24	68.3	88.3	0.061	0.385				
70- 79	3.95	74.8	92.0	0.062	0.347				
80- 89	3.23	76.4	94.1	0.036	0.334	*	*	*	*
90- 99	3.44	74.4	93.9	0.049	0.346				
100-109	2.43	76.1	95.0	0.088	0.365				
110-119	2.91	74.8	93.2	0.069	0.363				

* - Does Not Measure Overall Vehicle Length

5.2.2.3 Seven-Day Test

The results of the 7-day test to determine long-term statistics on classification accuracy, vehicle count and axle count are summarized in Table VII. The totals for the entire seven days for the vendor and classifier are listed. Also, the difference (ground truth minus vendor) and the percent difference (ground truth * 100 / classifier) are listed. To assess the change inaccuracy over the seven days, the percent difference is calculated for the first and last of the seven days.

Table VII. Long-Term Count/Classification Accuracy
Peek TrafiCOMP III

	Total Grnd Truth	Total Classifier	Total Difference	Total Percent	1st Day Percent	Last Day Percent
Vehicles	64734	62433	2301	103.69	103.02	102.36
Axles	165917	N/A	N/A	N/A	N/A	N/A
Class 1	103	604	-501	17.05	16.05	15.19
Class 2	31124	41126	-10002	75.68	76.58	75.40
Class 3	19417	6377	13040	304.48	292.89	267.08
Class 4	138	283	-145	48.76	31.82	37.21
Class 5	1921	1157	764	166.03	99.43	176.77
Class 6	746	736	10	101.36	100.00	101.64
Class 7	9	4	5	225.00	--	--
Class 8	862	2204	-1342	39.11	47.44	43.95
Class 9	9981	8427	1554	118.44	117.17	118.31
Class 10	109	86	23	126.74	136.36	141.67
Class 11	254	248	6	102.42	100.00	102.27
Class 12	70	77	-7	90.91	100.00	100.00
Class 13	0	36	-36	0.00	--	0.00
Class 15	0	1068	-1068	0.00	0.00	0.00

5.2.3 Peek Traffic Inc. GK-6000

The Peek Traffic Inc. model GK-6000 classifier was configured to monitor two lanes each using a P-P sensor configuration and Philips Vibracoax axle sensors. Although configured for two lanes, both sets of sensors were placed in the same lane of traffic (the test lane). The results from both sets of sensors are presented below.

5.2.3.1 First 48-Hour Test

The classification matrices for the first 48 hour test and the summary of number of vehicles (real and vendor), mistyped vehicles, sensor errors, extra vendor vehicles, missing vendor vehicles, correctly classified vehicles, suspected splits and suspected combinations are presented in Figures 34 and 35 for lanes 1 and 2, respectively. The classification matrix is presented in both absolute numbers, and percentages. The classifier designated lane 1 correctly classified 73.7% of the vehicles (90.1% if class 2-3 errors not included). The number of vehicle axles was miscounted 6.29% (percent sensor errors) of the time. The classifier designated lane 2 correctly classified 77.1% of the vehicles (92.4% if class 2-3 errors not included). The number of vehicle axles was miscounted 4.02% (percent sensor errors) of the time. Approximately 2.5% of the vehicles classified by either of the lanes were the result of a suspect split or combination of an actual vehicle.

The measurement accuracy of the classifier as a function of vehicle speed is depicted in Figures 36 and 37 for lanes 1 and 2, respectively. The GK-6000 classifier measures axles spacings and wheelbase length. The measurement error statistics (mean and deviation) for all measurements are included in the figure as a function of measured vehicle speed (mph). Note that all measurements are in feet.

Tables VIII and IX contains a summary of the results of the classification accuracy as a function of percent vehicles with greater than two axles, air temperature and pavement temperature for lanes 1 and 2, respectively.

Time interval: 2

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0
2	3	3444	224	5	32	10	0	15	69	3	1	0	0	0	0
3	4	1393	973	5	58	9	0	26	49	0	0	0	0	0	0
4	0	0	3	32	0	6	0	1	0	0	0	0	0	0	0
5	1	60	103	70	214	2	1	20	12	1	0	0	0	0	0
6	3	18	6	10	1	308	0	1	13	1	0	0	0	0	0
7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
8	1	13	10	5	1	3	4	184	7	0	0	0	0	0	0
9	31	100	36	19	11	18	40	12	2067	0	1	0	1	0	0
10	2	3	0	0	0	0	0	0	4	14	0	0	2	0	0
11	0	1	0	1	0	0	0	1	2	0	33	0	0	0	0
12	0	1	0	0	0	0	0	0	0	0	0	7	0	0	0
13	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
14	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
15	0	2	2	3	2	1	3	1	1	0	0	1	0	0	0

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	0.0	100.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2	0.1	90.5	5.9	0.1	0.8	0.3	0.0	0.4	1.8	0.1	0.0	0.0	0.0	0.0	0.0
3	0.2	55.3	38.7	0.2	2.3	0.4	0.0	1.0	1.9	0.0	0.0	0.0	0.0	0.0	0.0
4	0.0	0.0	7.1	76.2	0.0	14.3	0.0	2.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0
5	0.2	12.4	21.3	14.5	44.2	0.4	0.2	4.1	2.5	0.2	0.0	0.0	0.0	0.0	0.0
6	0.8	5.0	1.7	2.8	0.3	85.3	0.0	0.3	3.6	0.3	0.0	0.0	0.0	0.0	0.0
7	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
8	0.4	5.7	4.4	2.2	0.4	1.3	1.8	80.7	3.1	0.0	0.0	0.0	0.0	0.0	0.0
9	1.3	4.3	1.5	0.8	0.5	0.8	1.7	0.5	88.5	0.0	0.0	0.0	0.0	0.0	0.0
10	8.0	12.0	0.0	0.0	0.0	0.0	0.0	0.0	16.0	56.0	0.0	0.0	8.0	0.0	0.0
11	0.0	2.6	0.0	2.6	0.0	0.0	0.0	2.6	5.3	0.0	86.8	0.0	0.0	0.0	0.0
12	0.0	12.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	87.5	0.0	0.0	0.0
13	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
14	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
15	0.0	12.5	12.5	18.8	12.5	6.2	18.8	6.2	6.2	0.0	0.0	6.2	0.0	0.0	0.0

#Real:	18593
#Vendor:	11567
#mistyped:	2594
#sensor err:	621
#extra Vend:	1339
#Missing Vend:	8406
#Correct:	7276
#Splits:	133
#Combinations:	92

Figure 34. Classification Matrix for Peek GK-6000 (Lane 1) 1st 48-Hour Test

Axles Spacing Statistics

Speeds	Mean	STD	Veh	Axle_Spacings
<30	0.040	0.000	1	1
30.0-34.9	0.140	0.000	1	1
35.0-39.9	0.090	0.095	4	5
40.0-44.9	-0.032	0.240	6	15
45.0-49.9	0.218	0.859	25	61
50.0-54.9	0.179	3.415	188	468
55.0-59.9	0.131	1.597	858	2016
60.0-64.9	0.075	1.366	2095	4913
65.0-69.9	0.126	1.386	2632	4985
70.0-74.9	0.116	0.644	1186	1625
75.0-79.9	0.106	0.462	203	217
>80	0.178	0.220	32	32
Overall	0.110	1.449	7231	14339

Wheelbase Statistics

Speeds	Mean	STD	Vehicles
<30	0.040	0.000	1
30.0-34.9	0.140	0.000	1
35.0-39.9	0.113	0.137	4
40.0-44.9	-0.080	0.363	6
45.0-49.9	0.531	1.845	25
50.0-54.9	0.447	2.969	188
55.0-59.9	0.308	1.464	858
60.0-64.9	0.175	1.358	2095
65.0-69.9	0.239	1.841	2632
70.0-74.9	0.159	0.826	1186
75.0-79.9	0.113	0.471	203
>80	0.178	0.220	32
Overall	0.218	1.545	7231

Figure 35. Measurement Accuracy Versus Speed (MPH)
Peek GK-6000 (Lane 1) - 1st 48-Hour Test

Time interval: 2

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2	2	3686	218	9	28	11	0	12	48	3	1	0	0	0	0
3	3	1413	1036	8	59	9	2	25	40	0	0	0	0	0	0
4	0	0	2	41	1	7	0	0	1	0	0	0	0	0	0
5	0	54	111	74	241	1	2	17	12	1	0	0	0	0	0
6	2	15	5	12	1	342	0	1	11	0	0	0	0	0	0
7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
8	1	9	8	4	1	1	4	212	5	0	0	0	0	0	0
9	10	65	23	10	9	5	22	5	2583	0	0	0	1	0	0
10	0	3	0	0	0	0	0	0	4	17	0	0	2	0	0
11	0	0	0	2	0	0	1	2	3	0	70	0	0	0	0
12	0	1	0	0	0	0	0	0	0	0	0	21	0	0	0
13	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0
14	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
15	0	2	3	3	3	3	2	1	1	0	0	1	0	0	0

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
2	0.0	91.7	5.4	0.2	0.7	0.3	0.0	0.3	1.2	0.1	0.0	0.0	0.0	0.0	0.0
3	0.1	54.5	39.9	0.3	2.3	0.3	0.1	1.0	1.5	0.0	0.0	0.0	0.0	0.0	0.0
4	0.0	0.0	3.8	78.8	1.9	13.5	0.0	0.0	1.9	0.0	0.0	0.0	0.0	0.0	0.0
5	0.0	10.5	21.6	14.4	47.0	0.2	0.4	3.3	2.3	0.2	0.0	0.0	0.0	0.0	0.0
6	0.5	3.9	1.3	3.1	0.3	87.9	0.0	0.3	2.8	0.0	0.0	0.0	0.0	0.0	0.0
7	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
8	0.4	3.7	3.3	1.6	0.4	0.4	1.6	86.5	2.0	0.0	0.0	0.0	0.0	0.0	0.0
9	0.4	2.4	0.8	0.4	0.3	0.2	0.8	0.2	94.5	0.0	0.0	0.0	0.0	0.0	0.0
10	0.0	11.5	0.0	0.0	0.0	0.0	0.0	0.0	15.4	65.4	0.0	0.0	7.7	0.0	0.0
11	0.0	0.0	0.0	2.6	0.0	0.0	1.3	2.6	3.8	0.0	89.7	0.0	0.0	0.0	0.0
12	0.0	4.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	95.5	0.0	0.0	0.0
13	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	100.0	0.0	0.0	0.0
14	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
15	0.0	10.5	15.8	15.8	15.8	15.8	10.5	5.3	5.3	0.0	0.0	5.3	0.0	0.0	0.0

#Real:	18592
#Vendor:	12220
#mistyped:	2449
#sensor err:	430
#extra Vend:	1129
#Missing Vend:	7513
#Correct:	8249
#Splits:	135
#Combinations:	123

Figure 36. Classification Matrix for Peek GK-6000 (Lane 2) 1st 48-Hour Test

Axles Spacing Statistics

Speeds	Mean	STD	Veh	Axle_Spacings
<30	0.000	0.000	0	0
30.0-34.9	-0.010	0.050	2	2
35.0-39.9	0.133	0.127	3	4
40.0-44.9	0.017	0.228	6	12
45.0-49.9	0.198	0.830	27	66
50.0-54.9	0.079	2.934	198	506
55.0-59.9	0.283	6.629	976	2356
60.0-64.9	0.043	1.115	2388	5870
65.0-69.9	0.084	1.351	3001	6091
70.0-74.9	0.080	0.567	1335	1947
75.0-79.9	0.113	0.489	244	272
>80	0.169	0.247	33	33
Overall	0.098	2.722	8213	17159

Wheelbase Statistics

Speeds	Mean	STD	Vehicles
<30	0.000	0.000	0
30.0-34.9	-0.010	0.050	2
35.0-39.9	0.177	0.184	3
40.0-44.9	0.033	0.407	6
45.0-49.9	0.483	1.790	27
50.0-54.9	0.202	2.246	198
55.0-59.9	0.683	16.064	976
60.0-64.9	0.105	1.072	2388
65.0-69.9	0.170	1.859	3001
70.0-74.9	0.117	0.710	1335
75.0-79.9	0.126	0.524	244
>80	0.169	0.247	33
Overall	0.204	5.702	8213

Figure 37. Measurement Accuracy Versus Speed (MPH)
Peek GK-6000 (Lane 2) - 1st 48-Hour Test

Table VIII. Accuracy Summary for Peek GK-6000 (Lane 1)
1st 48-Hour Test

	Sensor Errors	Correct	Correct (no 2,3)	Axle Mean	Axle S.D.	Length Mean	Length S.D.	%L Mean	%L S.D.
Total	6.29	73.7	90.1	0.110	1.449	*	*	*	*
% Trucks									
0-20	4.31	73.9	92.2	0.114	0.643	*	*	*	*
20-40	6.09	73.8	90.2	0.113	1.568				
40-60	25.62	71.9	71.9	-0.002	0.704				
60-80	53.57	46.4	46.4	0.100	0.952				
Air Temp									
50-59	52.59	42.2	43.1	-0.001	1.411	*	*	*	*
60-69	3.02	86.5	92.4	0.012	0.664				
70-79	4.12	77.6	92.2	0.087	1.533				
80-89	6.11	71.8	90.4	0.148	1.551				
Pav Temp									
60- 69	51.61	44.5	45.2	-0.010	1.170	*	*	*	*
70- 79	3.59	84.7	91.7	0.031	0.667				
80- 89	4.59	78.6	92.8	0.067	1.561				
90- 99	3.59	77.3	92.3	0.143	2.227				
100-109	4.88	71.0	91.6	0.177	1.664				
110-119	7.00	71.3	89.4	0.116	0.763				

* - Does Not Calculate Overall Vehicle Length

Table IX. Accuracy Summary for Peek GK-6000 (Lane 2)
1st 48-Hour Test

	Sensor Errors	Correct	Correct (no 2,3)	Axle Mean	Axle S.D.	Length Mean	Length S.D.	%L Mean	%L S.D.
Total	4.02	77.1	92.4	0.098	2.722	*	*	*	*
% Trucks									
0-20	2.43	76.1	93.5	0.083	0.486				
20-40	4.12	76.5	92.2	0.075	1.426	*	*	*	*
40-60	5.17	92.8	93.1	-0.019	0.579				
60-80	16.30	84.4	84.4	1.119	15.00				
Air Temp									
50-59	7.72	86.2	86.6	-0.044	0.703				
60-69	3.38	89.6	92.9	-0.029	0.556	*	*	*	*
70-79	3.29	78.6	92.7	0.065	1.547				
80-89	4.08	74.2	92.4	0.113	1.364				
Pav Temp									
60- 69	11.30	85.31	85.6	0.414	9.463				
70- 79	3.08	88.9	93.1	-0.020	0.537				
80- 89	3.85	80.1	93.1	0.043	1.622	*	*	*	*
90- 99	3.28	77.2	92.5	0.113	2.123				
100-109	3.24	73.9	93.4	0.133	1.244				
110-119	4.41	74.0	92.0	0.094	0.821				

5.2.3.2 Second 48-Hour Test

The classification matrix for the second 48 hour test and the summary of number of vehicles (real and vendor), mistyped vehicles, sensor errors, extra vendor vehicles, missing vendor vehicles, correctly classified vehicles, suspected splits and suspected combinations for lanes 1 and 2 are presented in Figures 38 and 40. The classification matrix is presented in both absolute numbers, and percentages. The classifier designated lane 1 correctly classified 79.0% of the vehicles (96.2% if class 2-3 errors not included). The number of vehicle axles was miscounted 1.19% (percent sensor errors) of the time. The classifier designated lane 2 correctly classified 79.1% of the vehicles (96.2% if class 2-3 errors not included). The number of vehicle axles was miscounted 1.07% (percent sensor errors) of the time. Less than 0.5% of the vehicles classified by either of the lanes were the result of a suspect split or combination of an actual vehicle.

The measurement accuracy of the classifier as a function of vehicle speed is depicted in Figures 39 and 41 for lanes 1 and 2, respectively. The GK-6000 classifier measures axles spacings and wheelbase length. The measurement error statistics (mean and deviation) for all measurements are included in the figure as a function of measured vehicle speed (mph). Note that all measurements are in feet.

Tables X and XI contain summaries of the results from lanes 1 and 2, respectively, of the classification accuracy as a function of percent vehicles with greater than two axles, air temperature and pavement temperature.

Time interval: 2

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	0	2	1	0	0	0	0	0	0	0	0	0	0	0	0
2	0	5501	174	0	6	1	2	2	10	1	1	0	0	0	0
3	0	2080	1541	4	219	2	2	19	4	0	0	0	0	0	0
4	0	1	1	26	3	6	0	0	0	0	0	0	0	0	0
5	0	5	45	73	176	0	2	17	3	0	0	0	0	0	0
6	0	2	1	6	0	168	0	1	7	0	0	0	0	0	0
7	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0
8	0	2	6	1	0	1	3	231	0	0	0	0	0	0	0
9	0	6	4	0	1	0	2	3	2575	0	2	0	0	0	0
10	0	0	1	0	0	0	0	0	3	17	0	1	0	0	0
11	0	0	0	0	0	0	1	0	1	0	63	0	0	0	0
12	0	0	0	0	0	0	0	0	0	0	0	26	0	0	0
13	0	0	0	0	0	0	0	0	0	4	0	0	0	0	0
14	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
15	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	0.0	66.7	33.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2	0.0	96.5	3.1	0.0	0.1	0.0	0.0	0.0	0.2	0.0	0.0	0.0	0.0	0.0	0.0
3	0.0	53.7	39.8	0.1	5.7	0.1	0.1	0.5	0.1	0.0	0.0	0.0	0.0	0.0	0.0
4	0.0	2.7	2.7	70.3	8.1	16.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
5	0.0	1.6	14.0	22.7	54.8	0.0	0.6	5.3	0.9	0.0	0.0	0.0	0.0	0.0	0.0
6	0.0	1.1	0.5	3.2	0.0	90.8	0.0	0.5	3.8	0.0	0.0	0.0	0.0	0.0	0.0
7	0.0	0.0	0.0	0.0	0.0	50.0	50.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
8	0.0	0.8	2.5	0.4	0.0	0.4	1.2	94.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0
9	0.0	0.2	0.2	0.0	0.0	0.0	0.1	0.1	99.3	0.0	0.1	0.0	0.0	0.0	0.0
10	0.0	0.0	4.5	0.0	0.0	0.0	0.0	0.0	13.6	77.3	0.0	4.5	0.0	0.0	0.0
11	0.0	0.0	0.0	0.0	0.0	0.0	1.5	0.0	1.5	0.0	96.9	0.0	0.0	0.0	0.0
12	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	100.0	0.0	0.0	0.0
13	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	100.0	0.0	0.0	0.0	0.0	0.0
14	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
15	0.0	0.0	0.0	0.0	0.0	0.0	0.0	50.0	50.0	0.0	0.0	0.0	0.0	0.0	0.0

#Real:	20116
#Vendor:	13671
#mistyped:	2750
#sensor err:	155
#extra Vend:	539
#Missing Vend:	6978
#Correct:	10325
#Splits:	17
#Combinations:	23

Figure 38. Classification Matrix for Peek GK-6000 (Lane 1) 2nd 48-Hour Test

Axles Spacing Statistics

Speeds	Mean	STD	Veh	Axle_Spacings
<30	0.360	0.000	1	1
30.0-34.9	0.000	0.000	0	0
35.0-39.9	0.067	0.454	1	4
40.0-44.9	0.049	0.316	18	24
45.0-49.9	0.056	0.267	52	96
50.0-54.9	0.006	0.333	313	655
55.0-59.9	0.003	0.361	1243	2653
60.0-64.9	-0.009	0.354	3049	6662
65.0-69.9	0.007	0.369	3599	6385
70.0-74.9	0.027	0.294	1697	2228
75.0-79.9	-0.014	0.746	258	304
>80	0.081	0.291	40	40
Overall	0.004	0.363	10271	19052

Wheelbase Statistics

Speeds	Mean	STD	Vehicles
<30	0.360	0.000	1
30.0-34.9	0.000	0.000	0
35.0-39.9	0.270	0.000	1
40.0-44.9	0.066	0.209	18
45.0-49.9	0.103	0.248	52
50.0-54.9	0.012	0.315	313
55.0-59.9	0.007	0.388	1243
60.0-64.9	-0.019	0.389	3049
65.0-69.9	0.013	0.351	3599
70.0-74.9	0.036	0.285	1697
75.0-79.9	-0.016	1.012	258
>80	0.081	0.291	40
Overall	0.007	0.387	10271

Figure 39. Measurement Accuracy Versus Speed (MPH)
Peek GK-6000 (Lane 1) - 2nd 48-Hour Test

Time interval: 2

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	0	2	1	0	0	0	0	0	0	0	0	0	0	0	0
2	0	5810	182	0	5	0	3	3	8	0	1	0	0	0	0
3	0	2146	1590	2	227	0	2	17	6	0	0	0	1	0	0
4	0	0	1	28	4	7	0	0	0	0	0	0	0	0	0
5	0	5	44	73	171	0	3	20	3	0	0	1	0	0	0
6	1	2	0	5	1	170	0	2	5	0	0	0	0	0	0
7	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0
8	0	1	5	1	1	1	3	239	0	0	0	0	0	0	0
9	12	2	6	0	0	0	4	2	2624	0	2	0	0	0	0
10	0	0	4	0	0	0	0	0	3	16	0	1	0	0	0
11	0	0	0	1	0	0	0	0	0	0	60	0	0	0	0
12	0	0	0	0	0	0	0	0	0	0	0	20	0	0	0
13	0	0	0	0	0	0	0	0	0	5	0	0	0	0	0
14	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
15	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	0.0	66.7	33.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2	0.0	96.6	3.0	0.0	0.1	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0
3	0.0	53.8	39.8	0.1	5.7	0.0	0.1	0.4	0.2	0.0	0.0	0.0	0.0	0.0	0.0
4	0.0	0.0	2.5	70.0	10.0	17.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
5	0.0	1.6	13.8	22.8	53.4	0.0	0.9	6.2	0.9	0.0	0.0	0.3	0.0	0.0	0.0
6	0.5	1.1	0.0	2.7	0.5	91.4	0.0	1.1	2.7	0.0	0.0	0.0	0.0	0.0	0.0
7	0.0	0.0	0.0	0.0	0.0	50.0	50.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
8	0.0	0.4	2.0	0.4	0.4	0.4	1.2	95.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0
9	0.5	0.1	0.2	0.0	0.0	0.0	0.2	0.1	98.9	0.0	0.1	0.0	0.0	0.0	0.0
10	0.0	0.0	16.7	0.0	0.0	0.0	0.0	0.0	12.5	66.7	0.0	4.2	0.0	0.0	0.0
11	0.0	0.0	0.0	1.6	0.0	0.0	0.0	0.0	0.0	0.0	98.4	0.0	0.0	0.0	0.0
12	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	100.0	0.0	0.0	0.0
13	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	100.0	0.0	0.0	0.0	0.0	0.0
14	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
15	0.0	0.0	0.0	0.0	0.0	0.0	0.0	50.0	50.0	0.0	0.0	0.0	0.0	0.0	0.0

#Real:	20116
#Vendor:	14180
#mistyped:	2842
#sensor err:	145
#extra Vend:	563
#Missing Vend:	6486
#Correct:	10729
#Splits:	11
#Combinations:	24

Figure 40. Classification Matrix for Peek GK-6000 (Lane 2) 2nd 48-Hour Test

Axles Spacing Statistics

Speeds	Mean	STD	Veh	Axle_Spacings
<30	0.370	0.210	2	2
30.0-34.9	0.000	0.000	0	0
35.0-39.9	0.117	0.460	1	4
40.0-44.9	-0.010	0.315	15	21
45.0-49.9	0.040	0.262	51	101
50.0-54.9	0.010	0.325	314	636
55.0-59.9	0.007	0.349	1257	2665
60.0-64.9	-0.009	0.337	3149	6764
65.0-69.9	0.003	0.353	3757	6653
70.0-74.9	0.022	0.273	1826	2411
75.0-79.9	0.041	0.274	275	316
>80	0.030	0.308	42	42
Overall	0.003	0.335	10689	19615

Wheelbase Statistics

Speeds	Mean	STD	Vehicles
<30	0.370	0.210	2
30.0-34.9	0.000	0.000	0
35.0-39.9	0.470	0.000	1
40.0-44.9	-0.014	0.237	15
45.0-49.9	0.079	0.256	51
50.0-54.9	0.020	0.327	314
55.0-59.9	0.015	0.390	1257
60.0-64.9	-0.018	0.360	3149
65.0-69.9	0.005	0.338	3757
70.0-74.9	0.028	0.265	1826
75.0-79.9	0.047	0.278	275
>80	0.030	0.308	42
Overall	0.005	0.338	10689

Figure 41. Measurement Accuracy Versus Speed (MPH)
Peek GK-6000 (Lane 2) - 2nd 48-Hour Test

Table X. Accuracy Summary for Peek GK-6000 (Lane 1)
2nd 48-Hour Test

	Sensor Errors	Correct	Correct (no 2,3)	Axle Mean	Axle S.D.	Length Mean	Length S.D.	%L Mean	%L S.D.
Total	1.19	79.0	96.2	0.004	0.363	*	*	*	*
% Trucks									
0-20	0.94	77.1	96.7	0.023	0.329	*	*	*	*
20-40	1.50	80.4	95.5	-0.001	0.401				
40-60	1.54	92.3	96.9	-0.084	0.305				
Air Temp									
60-69	1.46	82.5	95.5	-0.047	0.322	*	*	*	*
70-79	1.15	78.5	96.5	-0.012	0.338				
80-89	1.18	78.7	96.5	0.070	0.379				
Pav Temp									
60- 69	2.13	89.4	89.4	-0.075	0.364				
70- 79	1.37	86.0	96.0	-0.063	0.318				
80- 89	1.58	80.8	96.5	-0.014	0.334	*	*	*	*
90- 99	1.10	77.1	96.0	0.008	0.332				
100-109	0.97	77.6	96.1	0.048	0.397				
110-119	1.08	75.2	98.0	0.035	0.286				

* - Does Not Measure Overall Vehicle Length

**Table XI. Accuracy Summary for Peek GK-6000 (Lane 2)
2nd 48-Hour Test**

	Sensor Errors	Correct	Correct (no 2,3)	Axle Mean	Axle S.D.	Length Mean	Length S.D.	%L Mean	%L S.D.
Total	1.07	79.1	96.2	0.003	0.335	*	*	*	*
% Trucks									
0-20	0.83	77.3	96.6	0.014	0.316	*	*	*	*
20-40	1.27	80.5	95.7	-0.003	0.360				
40-60	3.41	89.8	95.1	-0.038	0.286				
Air Temp									
60-69	1.73	82.0	95.5	-0.036	0.307	*	*	*	*
70-79	1.07	78.6	96.2	-0.031	0.305				
80-89	0.77	78.9	97.0	0.056	0.355				
Pav Temp									
60- 69	3.12	95.3	95.3	-0.043	0.334				
70- 79	1.15	84.9	96.8	-0.016	0.305				
80- 89	1.62	80.6	96.5	-0.025	0.313	*	*	*	*
90- 99	0.87	77.4	96.3	-0.003	0.318				
100-109	0.72	77.9	96.0	0.043	0.328				
110-119	0.80	75.0	98.0	0.027	0.299				

* - Does Not Measure Overall Vehicle Length

5.2.3.3 Seven-Day Test

The results of the 7-day test to determine long-term statistics on classification accuracy, vehicle count and axle count are summarized in Tables XII and XIII for lanes 1 and 2, respectively. The totals for the entire seven days for the vendor and classifier are listed. Also, the difference (ground truth minus vendor) and the percent difference (ground truth * 100 / classifier) are listed. To assess the change inaccuracy over the seven days, the percent difference is calculated for the first and last of the seven days.

Table XII. Long-Term Count/Classification Accuracy Peek GK-6000 (Lane 1)

	Total Grnd Truth	Total Classifier	Total Difference	Total Percent	1st Day Percent	Last Day Percent
Vehicles	44841	32872	11969	136.41	144.59	121.37
Axles	118765	N/A	N/A	N/A	134.04	N/A
Class 1	58	10	48	580.00	433.33	400.00
Class 2	20744	16769	3975	123.70	130.28	118.99
Class 3	12746	4110	8636	310.12	307.37	275.70
Class 4	87	278	-191	31.29	25.00	25.00
Class 5	1399	1006	393	139.07	82.00	139.44
Class 6	589	504	85	116.87	103.77	105.98
Class 7	6	42	-36	14.29	40.00	12.50
Class 8	735	742	-7	99.06	98.60	96.53
Class 9	8101	7093	1008	114.21	108.23	102.78
Class 10	96	61	35	157.38	155.56	130.77
Class 11	215	180	35	119.44	104.76	104.65
Class 12	65	67	-2	97.01	92.86	92.86
Class 13	0	29	-29	0.00	0.00	0.00
Class 15	0	1981	-1981	0.00	--	0.00

Table XIII. Long-Term Count/Classification Accuracy Peek GK-6000 (Lane 2)

	Total Grnd Truth	Total Classifier	Total Difference	Total Percent	1st Day Percent	Last Day Percent
Vehicles	44841	36240	8601	123.73	140.28	116.07
Axles	118765	N/A	N/A	N/A	131.13	N/A
Class 1	58	60	-2	96.67	100.00	100.00
Class 2	20744	17242	3502	120.31	124.79	121.20
Class 3	12746	4282	8464	297.66	299.74	282.07
Class 4	87	305	-218	28.52	24.14	24.62
Class 5	1399	1080	319	129.54	80.79	137.25
Class 6	589	538	51	109.48	100.92	107.83
Class 7	6	49	-43	12.24	40.00	20.00
Class 8	735	808	-73	90.97	96.58	93.30
Class 9	8101	7761	340	104.38	106.80	101.92
Class 10	96	68	28	141.18	175.00	130.77
Class 11	215	200	15	107.50	125.71	102.27
Class 12	65	70	-5	92.86	144.44	92.86
Class 13	0	28	-28	0.00	0.00	0.00
Class 15	0	3749	-3749	0.00	--	0.00

5.2.4 PAT Equipment Corporation, Inc. AVC-100 (P-L-P)

PAT Equipment Corporation, Inc. loaned two model AVC-100 classifier for use in the project. The first was setup in a P-L-P sensor configuration using Atochem Roadtrax Series 'P' axle sensors. The equipment appeared to operate normally during all of the testing sessions. However, the reporting software provided by PAT Equipment Corporation failed to convert the binary data files into ASCII (text) data files which could be used to perform data reduction. After this problem was discussed with the technical representative from PAT Equipment Corporation the binned data for part of the seven day test was recovered. No data from either 48 hour test was recovered.

5.2.4.1 Seven-Day Test

The results of the 7-day test to determine long-term statistics on classification accuracy, vehicle count and axle count are summarized in Table XIV. The totals for the portion of the seven days recovered for the vendor and classifier are listed. Also, the difference (ground truth minus vendor) and the percent difference (ground truth * 100 / classifier) are listed. To assess the change inaccuracy over the seven days, the percent difference is calculated for the first and last of the seven days. Since only a portion of the test data was recovered, the first day listed in the table refers to 12:45 pm on 9-13-93 through 10:45 am on 9-14-93, and the last day refers to 4:15 pm on 9-15-93 to 4:15 pm on 9-16-93.

Table XIV. Long-Term Count/Classification Accuracy PAT AVC-100 (P-L-P)

	Total Grnd Truth	Total Classifier	Total Difference	Total Percent	1st Day Percent	Last Day Percent
Vehicles	39400	44537	-5137	88.47	101.87	101.92
Axles	104608	N/A	N/A	N/A	N/A	N/A
Class 1	60	18	42	333.33	200.00	240.00
Class 2	18062	14334	3728	126.01	72.42	74.76
Class 3	11417	2467	8950	462.79	261.15	262.70
Class 4	76	29	47	262.07	109.09	133.33
Class 5	1161	435	726	266.90	225.00	197.74
Class 6	458	286	172	160.14	113.00	113.76
Class 7	5	4	1	125.00	100.00	--
Class 8	620	1791	-1171	34.62	25.70	26.63
Class 9	7196	3824	3372	188.18	131.43	131.09
Class 10	84	24	60	350.00	257.14	212.50
Class 11	201	112	89	179.46	120.00	132.35
Class 12	60	33	27	181.82	120.00	144.44
Class 13	0	16	-16	0.00	0.00	0.00
Class 15	0	21164	-21164	0.00	0.00	0.00

5.2.5 PAT Equipment Corporation, Inc. AVC-100 (L-P-L)

The second PAT Equipment Corporation, Inc. mode AVC-100 classifier used an L-P-L sensor configuration with Philips Vibracoax axle sensors. The AVC-100 used for the second (L-P-L) configuration did not have sufficient memory to store vehicle-by-vehicle records for the testing periods. Therefore, the data was recorded by a portable computer via the serial port on the classifier. No conversion was necessary and thus data reduction was accomplished for the second PAT configuration.

5.2.5.1 First 48-Hour Test

The classification matrix for the first 48 hour test and the summary of number of vehicles (real and vendor), mistyped vehicles, sensor errors, extra vendor vehicles, missing vendor vehicles, correctly classified vehicles, suspected splits and suspected combinations are presented in Figure 42. The classification matrix is presented in both absolute numbers, and percentages. The classifier correctly classified 76.6% of the vehicles (95.0% if class 2-3 errors not included). The number of vehicle axles was miscounted 1.49% (percent sensor errors) of the time. Less than 1.0% of the vehicles classified were the result of a suspected split or combination of an actual vehicle.

The measurement accuracy of the classifier as a function of vehicle speed is depicted in Figure 43. The PAT classifier measures axles spacings and wheelbase length. The measurement error statistics (mean and deviation) for all measurements are included in the figure as a function of measured vehicle speed (mph). Note that all measurements are in feet.

Table XV contains a summary of the results of the classification accuracy as a function of percent vehicles with greater than two axles, air temperature and pavement temperature.

Time interval: 2

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	0	2	0	0	0	0	0	0	0	0	0	0	0	0	2
2	0	7447	167	0	20	4	0	8	11	0	1	0	1	0	23
3	0	3109	1617	3	38	6	0	176	12	0	0	0	0	0	15
4	0	4	3	25	26	5	0	1	0	0	0	0	0	0	1
5	0	62	215	1	348	0	0	43	1	0	0	0	0	0	22
6	2	11	4	3	0	416	0	0	12	1	0	0	0	0	4
7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
8	0	2	0	0	0	0	0	284	1	0	0	0	0	0	11
9	0	35	3	0	2	0	0	8	3348	0	0	0	1	0	27
10	0	0	0	0	0	0	0	0	5	23	0	0	10	0	0
11	0	1	0	0	0	0	0	1	1	0	89	0	0	0	1
12	0	1	0	0	0	0	0	0	0	0	0	26	0	0	1
13	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0
14	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
15	0	0	0	0	0	0	0	17	6	0	0	1	0	0	11

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	0.0	50.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	50.0
2	0.0	96.9	2.2	0.0	0.3	0.1	0.0	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.3
3	0.0	62.5	32.5	0.1	0.8	0.1	0.0	3.5	0.2	0.0	0.0	0.0	0.0	0.0	0.3
4	0.0	6.2	4.6	38.5	40.0	7.7	0.0	1.5	0.0	0.0	0.0	0.0	0.0	0.0	1.5
5	0.0	9.0	31.1	0.1	50.3	0.0	0.0	6.2	0.1	0.0	0.0	0.0	0.0	0.0	3.2
6	0.4	2.4	0.9	0.7	0.0	91.8	0.0	0.0	2.6	0.2	0.0	0.0	0.0	0.0	0.9
7	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
8	0.0	0.7	0.0	0.0	0.0	0.0	0.0	95.3	0.3	0.0	0.0	0.0	0.0	0.0	3.7
9	0.0	1.0	0.1	0.0	0.1	0.0	0.0	0.2	97.8	0.0	0.0	0.0	0.0	0.0	0.8
10	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	13.2	60.5	0.0	0.0	26.3	0.0	0.0
11	0.0	1.1	0.0	0.0	0.0	0.0	0.0	1.1	1.1	0.0	95.7	0.0	0.0	0.0	1.1
12	0.0	3.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	92.9	0.0	0.0	3.6
13	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	100.0	0.0	0.0	0.0
14	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
15	0.0	0.0	0.0	0.0	0.0	0.0	0.0	48.6	17.1	0.0	0.0	2.9	0.0	0.0	31.4

#Real: 18591
#Vendor: 19476
#mistyped: 4163
#sensor err: 265
#extra Vend: 1363
#Missing Vend: 615
#Correct: 13634
#Splits: 151
#Combinations: 14

Figure 42. Classification Matrix for PAT AVC-100 (L-P-L) 1st 48-Hour Test

Axles Spacing Statistics

Speeds	Mean	STD	Veh	Axle_Spacings
<30	0.498	0.507	19	19
30.0-34.9	0.330	0.228	3	3
35.0-39.9	0.179	0.316	11	18
40.0-44.9	0.174	0.347	24	51
45.0-49.9	0.117	0.255	134	262
50.0-54.9	0.108	0.318	825	1794
55.0-59.9	0.175	4.057	2860	6104
60.0-64.9	0.045	0.527	4815	9745
65.0-69.9	0.035	0.605	3863	5859
70.0-74.9	0.014	0.496	863	1028
75.0-79.9	-0.044	0.546	159	172
>80	-0.163	0.664	24	24
Overall	0.078	2.055	13600	25079

Wheelbase Statistics

Speeds	Mean	STD	Vehicles
<30	0.498	0.507	19
30.0-34.9	0.330	0.228	3
35.0-39.9	0.257	0.317	11
40.0-44.9	0.306	0.507	24
45.0-49.9	0.189	0.379	134
50.0-54.9	0.188	0.510	825
55.0-59.9	0.317	9.378	2860
60.0-64.9	0.053	0.786	4815
65.0-69.9	0.021	0.762	3863
70.0-74.9	0.010	0.665	863
75.0-79.9	-0.051	0.671	159
>80	-0.163	0.664	24
Overall	0.106	4.353	13600

Figure 43. Measurement Accuracy Versus Speed (MPH) PAT AVC-100 (L-P-L) - 1st 48-Hour Test

Table XV. Accuracy Summary for PAT AVC-100 (L-P-L)
1st 48-Hour Test

	Sensor Errors	Correct	Correct (no 2,3)	Axle Mean	Axle S.D.	Length Mean	Length S.D.	%L Mean	%L S.D.
Total	1.49	76.6	95.0	0.078	2.055	*	*	*	*
% Trucks									
0-20	1.08	73.8	95.5	0.061	0.452	*	*	*	*
20-40	1.63	76.5	94.8	0.072	0.527				
40-60	1.05	85.0	96.9	-0.014	0.363				
60-80	0.51	86.5	97.0	0.433	9.701				
Air Temp									
50-59	0.90	73.3	96.5	-0.036	0.516	*	*	*	*
60-69	1.14	79.6	95.6	0.106	4.530				
70-79	1.42	76.5	94.6	0.093	0.348				
80-89	1.82	76.4	94.5	0.107	0.564				
Pav Temp									
60- 69	1.13	75.4	95.8	0.077	5.346	*	*	*	*
70- 79	1.18	79.3	95.6	0.030	0.488				
80- 89	1.49	76.9	95.2	0.079	0.386				
90- 99	1.46	76.2	94.1	0.102	0.381				
100-109	1.48	76.7	95.4	0.119	0.393				
110-119	2.06	76.2	93.9	0.100	0.666				

* - Overall Vehicle Length Not Calculated

5.2.5.2 Second 48-Hour Test

The classification matrix for the second 48 hour test and the summary of number of vehicles (real and vendor), mistyped vehicles, sensor errors, extra vendor vehicles, missing vendor vehicles, correctly classified vehicles, suspected splits and suspected combinations are presented in Figure 44. The classification matrix is presented in both absolute numbers, and percentages. The classifier correctly classified 76.6% of the vehicles (95.1% if class 2-3 errors not included). The number of vehicle axles was miscounted 0.51% (percent sensor errors) of the time. Less than 0.2% of the vehicle classified were the result of a suspected split or combination of an actual vehicle.

The measurement accuracy of the classifier as a function of vehicle speed is depicted in Figure 45. The PAT classifier measures axles spacings and wheelbase length. The measurement error statistics (mean and deviation) for all measurements are included in the figure as a function of measured vehicle speed (mph). Note that all measurements are in feet.

Table XVI contains a summary of the results of the classification accuracy as a function of percent vehicles with greater than two axles, air temperature and pavement temperature.

Time interval: 2

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	1	4	0	0	0	0	0	0	0	0	0	0	0	0	0
2	1	9263	224	1	0	1	0	11	4	0	0	0	0	0	88
3	0	3405	2087	0	1	0	0	185	3	0	0	0	0	0	222
4	0	0	5	18	19	8	0	1	0	0	0	0	0	0	0
5	0	9	257	1	62	0	0	40	0	0	0	0	0	0	17
6	0	2	2	1	0	186	0	3	7	0	0	0	0	0	0
7	0	0	0	0	0	1	0	0	0	0	0	0	0	0	1
8	0	0	2	0	0	1	0	254	1	0	0	0	0	0	10
9	0	5	2	2	0	0	0	2	2965	0	2	0	0	0	14
10	0	0	4	0	0	0	0	0	3	16	0	0	2	0	1
11	0	0	0	0	0	0	0	0	0	0	87	0	0	0	0
12	0	0	0	0	0	0	0	0	0	0	0	28	0	0	0
13	0	0	0	0	0	0	0	0	0	4	0	0	0	0	1
14	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
15	0	1	0	0	0	0	0	1	0	0	0	0	0	0	0

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	20.0	80.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2	0.0	96.6	2.3	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.9
3	0.0	57.7	35.4	0.0	0.0	0.0	0.0	3.1	0.1	0.0	0.0	0.0	0.0	0.0	3.8
4	0.0	0.0	9.8	35.3	37.3	15.7	0.0	2.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
5	0.0	2.3	66.6	0.3	16.1	0.0	0.0	10.4	0.0	0.0	0.0	0.0	0.0	0.0	4.4
6	0.0	1.0	1.0	0.5	0.0	92.5	0.0	1.5	3.5	0.0	0.0	0.0	0.0	0.0	0.0
7	0.0	0.0	0.0	0.0	0.0	50.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	50.0
8	0.0	0.0	0.7	0.0	0.0	0.4	0.0	94.8	0.4	0.0	0.0	0.0	0.0	0.0	3.7
9	0.0	0.2	0.1	0.1	0.0	0.0	0.0	0.1	99.1	0.0	0.1	0.0	0.0	0.0	0.5
10	0.0	0.0	15.4	0.0	0.0	0.0	0.0	0.0	11.5	61.5	0.0	0.0	7.7	0.0	3.8
11	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	100.0	0.0	0.0	0.0	0.0
12	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	100.0	0.0	0.0	0.0
13	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	80.0	0.0	0.0	0.0	0.0	20.0
14	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
15	0.0	50.0	0.0	0.0	0.0	0.0	0.0	50.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

#Real:	20116
#Vendor:	20710
#mistyped:	4584
#sensor err:	99
#extra Vend:	1103
#Missing Vend:	519
#Correct:	14967
#Splits:	22
#Combinations:	12

Figure 44. Classification Matrix for PAT AVC-100 (L-P-L) 2nd 48-Hour Test

Axles Spacing Statistics

Speeds	Mean	STD	Veh	Axle_Spacings
<30	-2.773	3.958	7	7
30.0-34.9	0.070	0.000	1	1
35.0-39.9	-0.193	0.180	3	3
40.0-44.9	-0.142	0.299	34	53
45.0-49.9	-0.013	0.795	115	172
50.0-54.9	-0.173	0.343	606	1145
55.0-59.9	-0.207	0.380	2839	5465
60.0-64.9	-0.260	0.399	4912	9192
65.0-69.9	-0.280	0.439	4733	6988
70.0-74.9	-0.278	0.349	1383	1585
75.0-79.9	-0.379	0.684	286	312
>80	-0.376	0.699	34	34
Overall	-0.252	0.420	14953	24957

Wheelbase Statistics

Speeds	Mean	STD	Vehicles
<30	-2.773	3.958	7
30.0-34.9	0.070	0.000	1
35.0-39.9	-0.193	0.180	3
40.0-44.9	-0.251	0.440	34
45.0-49.9	-0.046	1.316	115
50.0-54.9	-0.366	0.584	606
55.0-59.9	-0.439	0.689	2839
60.0-64.9	-0.526	0.748	4912
65.0-69.9	-0.437	0.768	4733
70.0-74.9	-0.325	0.525	1383
75.0-79.9	-0.416	1.087	286
>80	-0.376	0.699	34
Overall	-0.450	0.743	14953

Figure 45. Measurement Accuracy Versus Speed (MPH)
PAT AVC-100 (L-P-L) - 2nd 48-Hour Test

Table XVI. Accuracy Summary for PAT AVC-100 (L-P-L)
2nd 48-Hour Test

	Sensor Errors	Correct	Correct (no 2,3)	Axle Mean	Axle S.D.	Length Mean	Length S.D.	%L Mean	%L S.D.
Total	0.51	76.6	95.1	-0.252	0.420	*	*	*	*
% Trucks						*	*	*	*
0-20	0.48	74.7	95.0	-0.244	0.401				
20-40	0.61	78.4	95.2	-0.251	0.429				
40-60	0.15	84.0	96.2	-0.278	0.505				
Air Temp						*	*	*	*
60-69	0.24	76.6	95.5	-0.291	0.436				
70-79	0.60	76.1	94.9	-0.253	0.412				
80-89	0.60	77.9	95.6	-0.193	0.403				
Pav Temp						*	*	*	*
60- 69	0.27	76.3	94.8	-0.327	0.382				
70- 79	0.15	77.9	96.0	-0.269	0.428				
80- 89	0.57	77.6	95.1	-0.245	0.422				
90- 99	0.73	75.9	95.1	-0.250	0.425				
100-109	0.72	75.9	94.3	-0.223	0.426				
110-119	0.64	72.4	95.2	-0.221	0.316				

* - Does Not Measure Overall Vehicle Length

5.2.5.3 Seven-Day Test

The results of the 7-day test to determine long-term statistics on classification accuracy, vehicle count and axle count are summarized in Table XVII. The totals for the entire seven days for the vendor and classifier are listed. Also, the difference (ground truth minus vendor) and the percent difference (ground truth * 100 / classifier) are listed. To assess the change inaccuracy over the seven days, the percent difference is calculated for the first and last of the seven days.

Table XVII. Long-Term Count/Classification Accuracy PAT AVC-100 (L-P-L)

	Total Grnd Truth	Total Classifier	Total Difference	Total Percent	1st Day Percent	Last Day Percent
Vehicles	60846	60634	212	100.35	99.78	100.18
Axles	156689	N/A	N/A	N/A	100.12	N/A
Class 1	93	11	82	845.45	1300.00	600.00
Class 2	29130	39145	-10015	74.42	75.73	74.60
Class 3	18047	7929	10118	227.61	208.65	207.11
Class 4	133	79	54	168.35	127.27	133.33
Class 5	1822	239	1583	762.34	407.32	972.22
Class 6	726	723	3	100.41	103.70	103.33
Class 7	8	1	7	800.00	--	--
Class 8	837	1652	-815	50.67	65.14	59.01
Class 9	9627	9524	103	101.08	100.82	100.84
Class 10	104	62	42	167.74	166.67	141.67
Class 11	249	244	5	102.05	100.00	102.27
Class 12	70	77	-7	90.91	108.33	92.86
Class 13	0	24	-24	0.00	0.00	0.00
Class 15	0	924	-924	0.00	0.00	0.00

5.2.6 Mitron Systems Corp. MSC-3000 DCP

The Mitron Systems Corp. model MSC-3000 DCP classifier used a P-P sensor configuration with Autologger MINI axle sensors. The MITRON classifier did not generate vehicle-by-vehicle records for detailed comparison. It produced only binned records at 15 minute intervals.

The Mitron classifier was included in the first 48-hour test. Piezoelectric axle sensor failures resulted in Mitron withdrawing its classifier from the project prior to the second 48-hour test and the 7-day test.

The data recorded by the classifier was sent to Mitron Systems for reduction into the binned data format. The resulting binned data is summarized in Table XVIII. The counts included in the summary are all time periods where both the classifier and the pole camera are operating without gaps (i.e. gaps caused by tape changes).

Table XVIII. Binned Count/Classification Accuracy
Mitron MSC-3000 DCP - 1st 48-Hour Test

	Total Grnd Truth	Total Classifier	Total Difference	Total Percent
# Vehicles	15886	16461	-575	96.51
# Axles	42799	N/A	N/A	N/A
Class 1	14	26	-12	53.85
Class 2	6851	9702	-2851	70.61
Class 3	4493	1993	2500	225.44
Class 4	62	117	-55	52.99
Class 5	628	581	47	108.09
Class 6	410	420	-10	97.62
Class 7	0	0	0	--
Class 8	264	361	-97	73.13
Class 9	2987	3100	-113	96.35
Class 10	31	23	8	134.78
Class 11	89	101	-12	88.12
Class 12	25	28	-3	89.29
Class 13	0	9	-9	0.00
Class 15	32	0	32	--

5.2.7 Electronic Control Measure HESTIA

The Electronic Control Measure model HESTIA classifier used a P-L-P sensor configuration with ECM PB2N33/25 piezoelectric axle sensors. The results of this classifier are presented below.

5.2.7.1 First 48-Hour Test

The classification matrix for the first 48 hour test and the summary of number of vehicles (real and vendor), mistyped vehicles, sensor errors, extra vendor vehicles, missing vendor vehicles, correctly classified vehicles, suspected splits and suspected combinations are presented in Figure 46. The classification matrix is presented in both absolute numbers, and percentages. The classifier correctly classified 67.5% of the vehicles (86.4% if class 2-3 errors not included). The number of vehicle axles was miscounted 10.05% (percent sensor errors) of the time. About 2.2% of the vehicles classified by the HESTIA were the result of a suspected split or combination.

The measurement accuracy of the classifier as a function of vehicle speed is depicted in Figure 47. The HESTIA classifier measures axles spacings, wheelbase length, and overall vehicle length. The measurement error statistics (mean and deviation) for all measurements, and the overall length percentile statistics are included in the figure as a function of measured vehicle speed (mph). Note that all measurements are in feet.

Table XIX contains a summary of the results of the classification accuracy as a function of percent vehicles with greater than two axles, air temperature and pavement temperature.

Time interval: 2

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	0	3	0	0	0	0	0	0	0	0	0	0	0	0	0
2	0	2041	62	8	7	17	0	12	51	0	0	0	0	0	65
3	0	878	336	5	10	3	0	22	22	0	0	0	0	0	70
4	0	7	0	4	1	0	0	0	0	0	0	0	0	0	0
5	0	35	41	13	68	2	0	10	9	0	0	0	0	0	22
6	0	10	3	1	0	50	0	2	9	0	0	0	0	0	5
7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
8	0	12	0	1	0	1	0	76	1	0	0	0	0	0	4
9	0	68	14	1	2	4	0	4	735	1	2	1	0	0	79
10	0	1	0	0	0	0	0	0	1	8	0	0	0	0	2
11	0	2	0	0	0	0	0	0	2	0	23	0	0	0	3
12	0	0	0	0	0	0	0	0	0	0	1	5	0	0	0
13	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
14	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
15	0	0	0	0	1	0	0	0	0	0	0	0	0	0	5

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	0.0	100.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2	0.0	90.2	2.7	0.4	0.3	0.8	0.0	0.5	2.3	0.0	0.0	0.0	0.0	0.0	2.9
3	0.0	65.2	25.0	0.4	0.7	0.2	0.0	1.6	1.6	0.0	0.0	0.0	0.0	0.0	5.2
4	0.0	58.3	0.0	33.3	8.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
5	0.0	17.5	20.5	6.5	34.0	1.0	0.0	5.0	4.5	0.0	0.0	0.0	0.0	0.0	11.0
6	0.0	12.5	3.8	1.2	0.0	62.5	0.0	2.5	11.2	0.0	0.0	0.0	0.0	0.0	6.2
7	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
8	0.0	12.6	0.0	1.1	0.0	1.1	0.0	80.0	1.1	0.0	0.0	0.0	0.0	0.0	4.2
9	0.0	7.5	1.5	0.1	0.2	0.4	0.0	0.4	80.7	0.1	0.2	0.1	0.0	0.0	8.7
10	0.0	8.3	0.0	0.0	0.0	0.0	0.0	0.0	8.3	66.7	0.0	0.0	0.0	0.0	16.7
11	0.0	6.7	0.0	0.0	0.0	0.0	0.0	0.0	6.7	0.0	76.7	0.0	0.0	0.0	10.0
12	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	16.7	83.3	0.0	0.0	0.0
13	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
14	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
15	0.0	0.0	0.0	0.0	16.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	83.3

#Real:	18369
#Vendor:	6543
#mistyped:	1616
#sensor err:	499
#extra Vend:	1401
#Missing Vend:	13253
#Correct:	3351
#Splits:	67
#Combinations:	41

Figure 46. Classification Matrix for ECM HESTIA 1st 48-Hour Test

Axles Spacing Statistics

Speeds	Mean	STD	Veh	Axle_Spacings
<30	0.660	1.146	48	54
30.0-34.9	0.000	0.000	0	0
35.0-39.9	0.540	0.000	1	1
40.0-44.9	0.113	0.082	3	6
45.0-49.9	0.096	0.574	27	47
50.0-54.9	0.127	0.385	154	338
55.0-59.9	0.112	0.494	579	1174
60.0-64.9	0.094	0.899	1177	2328
65.0-69.9	0.126	0.655	946	1437
70.0-74.9	0.204	0.654	258	301
75.0-79.9	0.155	0.304	45	48
>80	0.602	0.770	6	6
Overall	0.120	0.732	3244	5740

Wheelbase Statistics

Speeds	Mean	STD	Vehicles
<30	0.742	1.295	48
30.0-34.9	0.000	0.000	0
35.0-39.9	0.540	0.000	1
40.0-44.9	0.227	0.231	3
45.0-49.9	0.163	0.973	27
50.0-54.9	0.273	0.572	154
55.0-59.9	0.221	0.667	579
60.0-64.9	0.182	1.308	1177
65.0-69.9	0.189	0.796	946
70.0-74.9	0.238	0.699	258
75.0-79.9	0.165	0.325	45
>80	0.602	0.770	6
Overall	0.209	0.990	3244

Length Statistics

Speeds	Mean	STD	Vehicles
<30	2.703	3.139	48
30.0-34.9	0.000	0.000	0
35.0-39.9	-0.100	0.000	1
40.0-44.9	0.203	1.020	3
45.0-49.9	0.265	2.049	27
50.0-54.9	0.534	1.485	154
55.0-59.9	0.565	1.504	579
60.0-64.9	0.590	1.808	1177
65.0-69.9	0.484	2.954	946
70.0-74.9	0.785	1.256	258
75.0-79.9	0.602	1.260	45
>80	1.795	2.048	6
Overall	0.598	2.157	3244

Length Percentile Statistics

Speeds	Mean	STD	Vehicles
<30	125.35	32.30	48
30.0-34.9	0.000	0.000	0
35.0-39.9	99.446	0.030	1
40.0-44.9	98.941	2.927	3
45.0-49.9	100.870	6.272	27
50.0-54.9	101.773	5.114	154
55.0-59.9	101.840	6.205	579
60.0-64.9	102.250	6.168	1177
65.0-69.9	102.925	7.646	946
70.0-74.9	104.971	6.973	258
75.0-79.9	104.885	6.305	45
>80	113.24	15.49	6
Overall	102.95	8.25	3244

Figure 47. Measurement Accuracy Versus Speed (MPH)
ECM HESTIA - 1st 48-Hour Test

Table XIX. Accuracy Summary for ECM HESTIA
1st 48-Hour Test

	Sensor Errors	Correct	Correct (no 2,3)	Axle Mean	Axle S.D.	Length Mean	Length S.D.	%L Mean	%L S.D.
Total	10.05	67.5	86.4	0.120	0.732	0.598	2.157	102.95	8.25
% Trucks									
0-20	5.78	73.1	92.2	0.150	0.492	0.538	1.296	102.84	6.94
20-40	10.41	66.0	85.6	0.112	0.708	0.585	2.270	103.01	8.36
40-60	11.72	75.5	85.5	0.128	1.064	0.666	2.351	101.51	5.81
60-80	28.21	69.2	79.5	0.155	1.075	2.031	2.730	103.87	4.92
Air Temp									
50-59	57.14	14.3	28.6	2.495	3.253	12.450	0.0 *	122.13	0.0 *
60-69	11.83	76.3	86.1	0.114	0.934	0.672	2.092	101.62	5.33
70-79	4.74	74.3	93.0	0.128	0.335	0.620	1.200	102.76	6.12
80-89	11.83	63.6	83.8	0.114	0.832	0.568	2.507	103.22	9.39
Pav Temp									
60- 69	48.48	42.4	51.5	0.509	2.222	1.225	4.078	100.59	9.70
70- 79	9.15	78.3	88.7	0.108	0.837	0.693	1.980	101.84	5.20
80- 89	4.97	73.6	92.7	0.120	0.334	0.579	1.233	102.54	5.87
90- 99	3.95	73.5	92.9	0.137	0.230	0.719	1.076	103.29	5.81
100-109	9.37	62.3	87.1	0.136	0.614	0.703	1.440	103.77	7.96
110-119	15.72	58.7	79.1	0.090	1.107	0.400	3.387	102.74	11.40

* - Only 1 Vehicle Measured

5.2.7.2 Second 48-Hour Test

The classification matrix for the second 48 hour test and the summary of number of vehicles (real and vendor), mistyped vehicles, sensor errors, extra vendor vehicles, missing vendor vehicles, correctly classified vehicles, suspected splits and suspected combinations are presented in Figure 48. The classification matrix is presented in both absolute numbers, and percentages. The classifier correctly classified 72.0% of the vehicles (94.3% if class 2-3 errors not included). The number of vehicle axles was miscounted 6.70% (percent sensor errors) of the time. There were less than 0.7% of the vehicles classified by the HESTIA that were the result of a suspected split or combination.

The measurement accuracy of the classifier as a function of vehicle speed is depicted in Figure 49. The HESTIA classifier measures axles spacings, wheelbase length, and overall vehicle length. The measurement error statistics (mean and deviation) for all measurements, and the overall length percentile statistics are included in the figure as a function of measured vehicle speed (mph). Note that all measurements are in feet.

Table XIX contains a summary of the results of the classification accuracy as a function of percent vehicles with greater than two axles, air temperature and pavement temperature.

Time interval: 2

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	11	2	0	0	0	0	0	0	0	0	0	0	0	0	0
2	180	8734	300	17	170	0	0	2	5	0	1	0	0	0	0
3	57	3919	1441	7	318	0	0	12	5	0	0	0	0	0	0
4	0	2	3	30	8	0	0	0	0	0	0	0	0	0	0
5	0	13	72	42	223	0	0	18	0	0	0	0	0	0	0
6	3	16	3	11	3	0	0	4	7	0	1	0	0	0	0
7	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0
8	0	2	1	3	8	0	0	255	0	0	0	0	0	0	0
9	4	13	1	3	9	0	0	35	2829	0	2	0	0	0	0
10	0	0	0	0	0	0	0	0	2	14	0	0	0	0	0
11	0	0	0	0	0	0	0	0	1	0	81	0	0	0	0
12	0	0	0	0	0	0	0	0	0	0	0	24	0	0	0
13	0	0	0	0	0	0	0	0	1	3	0	0	0	0	0
14	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
15	0	1	0	0	0	0	0	1	1	0	0	0	0	0	0

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	84.6	15.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2	1.9	92.8	3.2	0.2	1.8	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0
3	1.0	68.1	25.0	0.1	5.5	0.0	0.0	0.2	0.1	0.0	0.0	0.0	0.0	0.0	0.0
4	0.0	4.7	7.0	69.8	18.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
5	0.0	3.5	19.6	11.4	60.6	0.0	0.0	4.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0
6	6.2	33.3	6.2	22.9	6.2	0.0	0.0	8.3	14.6	0.0	2.1	0.0	0.0	0.0	0.0
7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	100.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
8	0.0	0.7	0.4	1.1	3.0	0.0	0.0	94.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0
9	0.1	0.4	0.0	0.1	0.3	0.0	0.0	1.2	97.7	0.0	0.1	0.0	0.0	0.0	0.0
10	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	12.5	87.5	0.0	0.0	0.0	0.0	0.0
11	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.2	0.0	98.8	0.0	0.0	0.0	0.0
12	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	100.0	0.0	0.0	0.0
13	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	25.0	75.0	0.0	0.0	0.0	0.0	0.0
14	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
15	0.0	33.3	0.0	0.0	0.0	0.0	0.0	33.3	33.3	0.0	0.0	0.0	0.0	0.0	0.0

#Real:	20109
#Vendor:	20714
#mistyped:	5294
#sensor err:	1268
#extra Vend:	1552
#Missing Vend:	1042
#Correct:	13642
#Splits:	107
#Combinations:	12

Figure 48. Classification Matrix for ECM HESTIA 2nd 48-Hour Test

Axles Spacing Statistics

Speeds	Mean	STD	Veh	Axle_Spacings
<30	0.443	1.516	12827	22174
30.0-34.9	0.000	0.000	0	0
35.0-39.9	0.000	0.000	0	0
40.0-44.9	0.000	0.000	0	0
45.0-49.9	0.000	0.000	0	0
50.0-54.9	1.800	0.000	1	1
55.0-59.9	0.000	0.000	0	0
60.0-64.9	2.130	0.000	1	1
65.0-69.9	0.000	0.000	0	0
70.0-74.9	-2.825	0.995	2	2
75.0-79.9	-1.843	0.288	3	3
>80	-3.329	1.186	14	14
Overall	0.441	1.519	12848	22195

Length Statistics

Speeds	Mean	STD	Vehicles
<30	2.242	3.061	12827
30.0-34.9	0.000	0.000	0
35.0-39.9	0.000	0.000	0
40.0-44.9	0.000	0.000	0
45.0-49.9	0.000	0.000	0
50.0-54.9	5.520	0.001	1
55.0-59.9	0.000	0.000	0
60.0-64.9	4.360	0.001	1
65.0-69.9	0.000	0.000	0
70.0-74.9	-6.705	1.475	2
75.0-79.9	-2.567	1.589	3
>80	-5.186	3.121	14
Overall	2.232	3.073	12848

Wheelbase Statistics

Speeds	Mean	STD	Vehicles
<30	20.158	19.208	12827
30.0-34.9	0.000	0.000	0
35.0-39.9	0.000	0.000	0
40.0-44.9	0.000	0.000	0
45.0-49.9	0.000	0.000	0
50.0-54.9	6.280	0.001	1
55.0-59.9	0.000	0.000	0
60.0-64.9	6.020	0.000	1
65.0-69.9	0.000	0.000	0
70.0-74.9	0.375	0.545	2
75.0-79.9	1.893	0.647	3
>80	0.711	1.609	14
Overall	20.127	19.208	12848

Length Percentile Statistics

Speeds	Mean	STD	Vehicles
<30	114.35	16.01	12827
30.0-34.9	0.000	0.000	0
35.0-39.9	0.000	0.000	0
40.0-44.9	0.000	0.000	0
45.0-49.9	0.000	0.000	0
50.0-54.9	131.169	0.000	1
55.0-59.9	0.000	0.000	0
60.0-64.9	128.202	0.000	1
65.0-69.9	0.000	0.000	0
70.0-74.9	71.491	5.560	2
75.0-79.9	87.673	7.255	3
>80	77.83	14.29	14
Overall	114.30	16.07	12848

Figure 49. Measurement Accuracy Versus Speed (MPH)
ECM HESTIA - 2nd 48-Hour Test

Table XX. Accuracy Summary for ECM HESTIA
2nd 48-Hour Test

	Sensor Errors	Correct	Correct (no 2,3)	Axle Mean	Axle S.D.	Length Mean	Length S.D.	%L Mean	%L S.D.
Total	6.70	72.0	94.3	0.441	1.519	2.232	3.073	114.30	16.07
% Trucks									
0-20	06.55	69.9	94.3	0.508	1.349	2.232	2.910	115.62	16.39
20-40	07.00	74.2	94.4	0.403	1.548	2.229	3.130	113.14	15.48
40-60	05.08	79.2	94.8	0.252	1.874	2.174	4.127	109.35	14.43
Air Temp									
60-69	05.03	70.5	93.7	0.449	1.496	2.310	3.059	114.86	16.47
70-79	06.11	72.0	94.1	0.429	1.392	2.193	3.116	114.21	16.13
80-89	10.17	74.4	96.3	0.457	1.904	2.186	2.942	113.78	15.42
Pav Temp									
60- 69	3.43	69.6	93.6	0.383	1.198	2.335	3.296	115.65	17.32
70- 79	5.26	73.1	94.3	0.423	1.748	2.246	3.141	113.39	15.76
80- 89	5.98	73.4	94.3	0.420	1.292	2.223	3.010	114.01	16.06
90- 99	6.91	71.5	94.0	0.452	1.282	2.259	2.883	114.59	15.61
100-109	8.76	72.3	94.5	0.460	1.646	2.122	3.280	114.06	15.75
110-119	7.41	67.7	95.7	0.515	1.617	2.160	2.506	116.58	17.54

5.2.7.3 Seven-Day Test

The results of the 7-day test to determine long-term statistics on classification accuracy, vehicle count and axle count are summarized in Table XXI. The totals for the entire seven days for the vendor and classifier are listed. Also, the difference (ground truth minus vendor) and the percent difference (ground truth * 100 / classifier) are listed. To assess the change inaccuracy over the seven days, the percent difference is calculated for the first and last of the seven days.

Table XXI. Long-Term Count/Classification Accuracy Electronic Control Measure HESTIA

	Total Grnd Truth	Total Classifier	Total Difference	Total Percent	1st Day Percent	Last Day Percent
Vehicles	63474	60446	3028	105.01	104.33	104.57
Axles	162780	148081	14699	109.93	110.01	108.78
Class 1	101	0	101	--	--	--
Class 2	30500	47439	-16939	64.29	64.47	64.01
Class 3	19015	2660	16355	714.85	622.16	655.24
Class 4	135	9986	-9851	1.35	0.90	0.87
Class 5	1897	55	1842	3449.09	3420.00	2875.00
Class 6	738	231	507	319.48	254.76	305.00
Class 7	8	63	-55	12.70	18.18	7.69
Class 8	848	0	848	--	--	--
Class 9	9804	0	9804	--	--	--
Class 10	106	0	106	--	--	--
Class 11	253	0	253	--	--	--
Class 12	69	0	69	--	--	--
Class 13	0	0	0	--	--	--
Class 15	0	12	-12	0.00	--	0.00

5.2.8 TimeMark, Inc. Delta II

The TimeMark, Inc. model Delta II classifier used a P-P sensor configuration with Philips Vibracoax piezoelectric axle sensors. The results of this classifier are presented below.

5.2.8.1 First 48-Hour Test

The classification matrix for the first 48 hour test and the summary of number of vehicles (real and vendor), mistyped vehicles, sensor errors, extra vendor vehicles, missing vendor vehicles, correctly classified vehicles, suspected splits and suspected combinations are presented in Figure 50. The classification matrix is presented in both absolute numbers, and percentages. The classifier correctly classified 78.9% of the vehicles (94.4% if class 2-3 errors not included). The number of vehicle axles was miscounted 2.83% (percent sensor errors) of the time. Approximately 1.3% of the vehicles classified by the Delta II were the result of a suspected split or combination.

There were more than 3600 vehicles missed (see "#Missing Vend:" in Figure 50) by this classifier that were recorded on video tape. Most of the other vendors (with no gaps in recording time) missed less than 2000, most of which can be accounted for by lane changes. By reviewing binned data for this classifier and the ground truth data, it was found that roughly half of the class 2 and 3 vehicles were missed by this classifier. Apparently, the sensitivity of the sensors and classifier electronics was not sufficient to detect a large number of the passenger cars and small trucks. While the classification accuracy of those detected was fairly good, a large number of vehicles were missed by this unit.

The measurement accuracy of the classifier as a function of vehicle speed is depicted in Figure 51. The TimeMark classifier measures axles spacings and wheelbase length. The measurement error statistics (mean and deviation) for all measurements are included in the figure as a function of measured vehicle speed (mph). Note that all measurements are in feet.

Table XXII contains a summary of the results of the classification accuracy as a function of percent vehicles with greater than two axles, air temperature and pavement temperature.

Time interval: 2

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2	5	2856	141	4	15	6	0	5	24	1	0	0	0	0	0
3	5	1150	975	2	62	2	0	13	9	0	0	0	1	0	0
4	0	0	0	17	6	1	0	0	0	0	0	0	0	0	0
5	0	23	66	62	195	0	0	7	5	0	0	0	0	0	0
6	1	2	1	6	1	229	0	0	7	0	0	0	0	0	0
7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
8	0	4	5	0	2	1	0	177	1	0	0	0	0	0	0
9	2	12	4	26	0	21	0	6	2030	0	0	0	0	0	0
10	0	0	0	0	0	0	0	0	4	16	0	0	5	0	0
11	0	0	0	0	0	0	0	2	1	0	45	0	0	0	0
12	0	0	0	0	0	0	0	0	0	0	0	17	0	0	0
13	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0
14	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
15	0	3	4	3	4	0	0	4	0	0	0	1	0	0	0

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
2	0.2	93.4	4.6	0.1	0.5	0.2	0.0	0.2	0.8	0.0	0.0	0.0	0.0	0.0	0.0
3	0.2	51.8	43.9	0.1	2.8	0.1	0.0	0.6	0.4	0.0	0.0	0.0	0.0	0.0	0.0
4	0.0	0.0	0.0	70.8	25.0	4.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
5	0.0	6.4	18.4	17.3	54.5	0.0	0.0	2.0	1.4	0.0	0.0	0.0	0.0	0.0	0.0
6	0.4	0.8	0.4	2.4	0.4	92.7	0.0	0.0	2.8	0.0	0.0	0.0	0.0	0.0	0.0
7	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
8	0.0	2.1	2.6	0.0	1.1	0.5	0.0	93.2	0.5	0.0	0.0	0.0	0.0	0.0	0.0
9	0.1	0.6	0.2	1.2	0.0	1.0	0.0	0.3	96.6	0.0	0.0	0.0	0.0	0.0	0.0
10	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	16.0	64.0	0.0	0.0	20.0	0.0	0.0
11	0.0	0.0	0.0	0.0	0.0	0.0	0.0	4.2	2.1	0.0	93.8	0.0	0.0	0.0	0.0
12	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	100.0	0.0	0.0	0.0
13	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	100.0	0.0	0.0	0.0
14	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
15	0.0	15.8	21.1	15.8	21.1	0.0	0.0	21.1	0.0	0.0	0.0	5.3	0.0	0.0	0.0

#Real:	12068
#Vendor:	8915
#mistyped:	1753
#sensor err:	235
#extra Vend:	446
#Missing Vend:	3602
#Correct:	6557
#Splits:	54
#Combinations:	51

Figure 50. Classification Matrix for TimeMark Delta II 1st 48-Hour Test

Axles Spacing Statistics

Speeds	Mean	STD	Veh	Axle_Spacings
<30	0.000	0.000	0	0
30.0-34.9	0.000	0.000	0	0
35.0-39.9	0.000	0.000	0	0
40.0-44.9	0.100	0.444	1	4
45.0-49.9	0.137	0.320	10	22
50.0-54.9	0.139	0.356	91	253
55.0-59.9	0.435	7.819	638	1638
60.0-64.9	0.089	0.662	2641	6366
65.0-69.9	0.072	0.592	2093	3834
70.0-74.9	0.059	0.351	877	1150
75.0-79.9	0.070	0.316	113	122
>80	0.002	0.339	42	42
Overall	0.124	2.791	6506	13431

Wheelbase Statistics

Speeds	Mean	STD	Vehicles
<30	0.000	0.000	0
30.0-34.9	0.000	0.000	0
35.0-39.9	0.000	0.000	0
40.0-44.9	0.400	0.000	1
45.0-49.9	0.302	0.380	10
50.0-54.9	0.386	0.540	91
55.0-59.9	1.115	19.817	638
60.0-64.9	0.214	0.932	2641
65.0-69.9	0.132	0.756	2093
70.0-74.9	0.078	0.374	877
75.0-79.9	0.075	0.313	113
>80	0.002	0.339	42
Overall	0.256	6.258	6506

Figure 51. Measurement Accuracy Versus Speed (MPH)
TimeMark Delta II - 1st 48-Hour Test

Table XXII. Accuracy Summary for TimeMark Delta II 1st 48-Hour Test

	Sensor Errors	Correct	Correct (no 2,3)	Axle Mean	Axle S.D.	Length Mean	Length S.D.	%L Mean	%L S.D.
Total	2.83	78.9	94.4	0.124	2.791	*	*	*	*
% Trucks									
0-20	2.77	76.3	94.3	0.121	0.496	*	*	*	*
20-40	2.91	78.8	94.5	0.078	0.646				
40-60	3.41	86.3	92.2	0.060	0.363				
60-80	0.53	93.1	96.3	0.875	12.44				
Air Temp									
50-59	3.66	76.6	90.5	0.062	0.371	*	*	*	*
60-69	3.61	81.9	95.1	0.061	0.649				
70-79	2.95	77.6	93.9	0.096	0.487				
80-89	2.68	78.3	94.8	0.088	0.684				
Pav Temp									
60- 69	1.16	90.7	94.8	0.553	9.668	*	*	*	*
70- 79	3.50	81.6	94.6	0.076	0.634				
80- 89	3.96	78.1	93.8	0.075	0.501				
90- 99	2.50	78.2	94.2	0.077	0.445				
100-109	2.65	77.4	94.7	0.101	0.642				
110-119	2.56	78.9	95.1	0.088	0.761				

* - Does Not Calculate Overall Vehicle Length

5.2.8.2 Second 48-Hour Test

The classification matrix for the second 48 hour test and the summary of number of vehicles (real and vendor), mistyped vehicles, sensor errors, extra vendor vehicles, missing vendor vehicles, correctly classified vehicles, suspected splits and suspected combinations are presented in Figure 52. The classification matrix is presented in both absolute numbers, and percentages. The classifier correctly classified 77.3% of the vehicles (94.6% if class 2-3 errors not included). The number of vehicle axles was miscounted 1.97% (percent sensor errors) of the time. Approximately 1.3% of the vehicles classified by the Delta II were the result of a suspected split or combination.

There were more than 11,600 vehicles missed (see "#Missing Vend:" in Figure 54) by this classifier that were recorded on video tape. Most of the other vendors missed less than 2000, most of which can be accounted for by lane changes. By reviewing binned data for this classifier and the ground truth data, it was found that roughly half of the class 2 and 3 vehicles were missed by this classifier. Apparently, the sensitivity of the sensors and classifier electronics was not sufficient to detect a large number of the passenger cars and small trucks. While the classification accuracy of those detected was fairly good, a large number of vehicles were missed by this unit.

The measurement accuracy of the classifier as a function of vehicle speed is depicted in Figure 53. The TimeMark classifier measures axles spacings and wheelbase length. The measurement error statistics (mean and deviation) for all measurements are included in the figure as a function of measured vehicle speed (mph). Note that all measurements are in feet.

Table XXIII contains a summary of the results of the classification accuracy as a function of percent vehicles with greater than two axles, air temperature and pavement temperature.

Time interval: 2

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
2	10	2690	152	6	13	1	0	5	11	0	1	0	0	0	0
3	5	1285	913	3	154	0	0	8	13	0	0	0	0	0	0
4	0	0	0	20	4	7	0	0	0	0	0	0	0	0	0
5	1	8	26	37	137	0	0	5	0	0	0	0	0	0	0
6	0	1	0	5	1	124	0	0	4	0	0	0	0	0	0
7	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0
8	0	2	5	0	3	0	0	167	0	0	0	0	0	0	0
9	13	8	5	46	1	19	0	4	2249	0	3	0	0	0	0
10	0	0	0	0	0	1	0	0	2	13	0	1	1	0	0
11	0	0	0	0	0	0	0	0	0	0	74	0	0	0	0
12	0	0	0	0	0	0	0	0	0	0	0	21	0	0	0
13	0	0	0	0	0	0	0	0	0	3	0	0	0	0	0
14	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
15	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	0.0	100.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2	0.3	93.1	5.3	0.2	0.4	0.0	0.0	0.2	0.4	0.0	0.0	0.0	0.0	0.0	0.0
3	0.2	54.0	38.3	0.1	6.5	0.0	0.0	0.3	0.5	0.0	0.0	0.0	0.0	0.0	0.0
4	0.0	0.0	0.0	64.5	12.9	22.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
5	0.5	3.7	12.1	17.3	64.0	0.0	0.0	2.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0
6	0.0	0.7	0.0	3.7	0.7	91.9	0.0	0.0	3.0	0.0	0.0	0.0	0.0	0.0	0.0
7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	100.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
8	0.0	1.1	2.8	0.0	1.7	0.0	0.0	94.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0
9	0.6	0.3	0.2	2.0	0.0	0.8	0.0	0.2	95.8	0.0	0.1	0.0	0.0	0.0	0.0
10	0.0	0.0	0.0	0.0	0.0	5.6	0.0	0.0	11.1	72.2	0.0	5.6	5.6	0.0	0.0
11	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	100.0	0.0	0.0	0.0	0.0
12	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	100.0	0.0	0.0	0.0
13	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	100.0	0.0	0.0	0.0	0.0	0.0
14	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
15	0.0	0.0	0.0	0.0	0.0	0.0	0.0	100.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

#Real:	20089
#Vendor:	8842
#mistyped:	1887
#sensor err:	163
#extra Vend:	386
#Missing Vend:	11625
#Correct:	6408
#Splits:	51
#Combinations:	59

Figure 52. Classification Matrix for TimeMark Delta II 2nd 48-Hour Test

Axles Spacing Statistics

Speeds	Mean	STD	Veh	Axle_Spacings
<30	0.000	0.000	0	0
30.0-34.9	0.000	0.000	0	0
35.0-39.9	0.000	0.000	0	0
40.0-44.9	-0.207	0.918	3	3
45.0-49.9	-0.035	0.379	14	28
50.0-54.9	0.023	0.419	134	323
55.0-59.9	0.011	0.476	715	1870
60.0-64.9	-0.016	0.413	2673	6841
65.0-69.9	-0.033	0.413	1946	3719
70.0-74.9	-0.044	0.366	771	1027
75.0-79.9	-0.066	0.376	90	100
>80	-0.051	0.316	34	34
Overall	-0.018	0.419	6380	13945

Wheelbase Statistics

Speeds	Mean	STD	Vehicles
<30	0.000	0.000	0
30.0-34.9	0.000	0.000	0
35.0-39.9	0.000	0.000	0
40.0-44.9	-0.207	0.918	3
45.0-49.9	-0.071	0.450	14
50.0-54.9	0.058	0.497	134
55.0-59.9	0.027	0.616	715
60.0-64.9	-0.040	0.477	2673
65.0-69.9	-0.062	0.454	1946
70.0-74.9	-0.059	0.349	771
75.0-79.9	-0.074	0.343	90
>80	-0.051	0.316	34
Overall	-0.040	0.474	6380

Figure 53. Measurement Accuracy Versus Speed (MPH)
TimeMark Delta II - 2nd 48-Hour Test

Table XXIII. Accuracy Summary for TimeMark Delta II 2nd 48-Hour Test

	Sensor Errors	Correct	Correct (no 2,3)	Axle Mean	Axle S.D.	Length Mean	Length S.D.	%L Mean	%L S.D.
Total	1.97	77.3	94.6	-0.018	0.419	*	*	*	*
% Trucks									
0-20	1.81	74.7	95.2	-0.011	0.408	*	*	*	*
20-40	2.17	78.9	93.5	-0.022	0.439				
40-60	2.53	88.8	96.1	-0.042	0.373				
Air Temp									
60-69	2.18	79.7	93.9	-0.027	0.404	*	*	*	*
70-79	1.79	76.6	94.8	-0.018	0.423				
80-89	2.53	76.4	94.6	-0.008	0.433				
Pav Temp									
60- 69	2.05	82.4	94.4	-0.041	0.409				
70- 79	1.75	81.7	94.1	-0.015	0.407				
80- 89	2.96	78.5	94.0	-0.019	0.464	*	*	*	*
90- 99	1.62	74.7	93.5	-0.019	0.403				
100-109	1.65	75.4	94.9	-0.012	0.343				
110-119	1.66	72.7	97.3	0.011	0.382				

* - Does Not Measure Overall Vehicle Length

5.2.8.3 Seven-Day Test

The results of the 7-day test to determine long-term statistics on classification accuracy, vehicle count and axle count are summarized in Table XXIV. The totals for the entire seven days for the vendor and classifier are listed. Also, the difference (ground truth minus vendor) and the percent difference (ground truth * 100 / classifier) are listed. To assess the change inaccuracy over the seven days, the percent difference is calculated for the first and last full days recorded of the seven days.

Table XXIV. Long-Term Count/Classification Accuracy
TimeMark Delta II

	Total Grnd Truth	Total Classifier	Total Difference	Total Percent	1st Day Percent	Last Day Percent
Vehicles	55173	26389	28784	209.08	198.42	248.71
Axles	140170	75831	64339	184.85	172.32	208.87
Class 1	88	292	-204	30.14	30.00	11.49
Class 2	26840	12876	13964	208.45	213.69	298.58
Class 3	16803	3754	13049	447.60	444.17	567.24
Class 4	119	358	-239	33.24	35.19	24.24
Class 5	1555	977	578	159.16	86.02	202.25
Class 6	597	659	-62	90.59	96.55	88.89
Class 7	6	2	4	300.00	--	100.00
Class 8	689	609	80	113.14	118.32	147.62
Class 9	8119	6591	1528	123.18	118.72	137.25
Class 10	91	42	49	216.67	200.00	300.00
Class 11	209	167	42	125.15	117.50	134.38
Class 12	57	50	7	114.00	130.00	130.77
Class 13	0	12	-12	0.00	0.00	0.00
Class 15	0	0	0	--	--	--

5.2.9 International Road Dynamics, Inc. TC/C 530-4D/4P/4L (PR-L-PR)

The International Road Dynamics, Inc. Model TC/C 530-4D/4P/4L classifier was tested with two separate sensor configurations. The first configuration used a PR-L-PR sensor configuration using Dynax AS-400 resistive piezoelectric (PR) axle sensors. The results of this classifier and sensor configuration are presented below.

5.2.9.1 First 48-Hour Test

The classification matrix for the first 48 hour test and the summary of number of vehicles (real and vendor), mistyped vehicles, sensor errors, extra vendor vehicles, missing vendor vehicles, correctly classified vehicles, suspected splits and suspected combinations are presented in Figure 54. The classification matrix is presented in both absolute numbers, and percentages. The classifier correctly classified 69.3% of the vehicles (88.4% if class 2-3 errors not included). The number of vehicle axles was miscounted 8.89% (percent sensor errors) of the time. Less than 1.3% of the vehicles classified were the result of a suspected split or combination of an actual vehicle. This IRD unit missed a larger number of vehicles than expected.

The measurement accuracy of the classifier as a function of vehicle speed is depicted in Figure 55. The TC/C 530-4D/4P/4L classifier measures axles spacings, wheelbase length, and overall vehicle length. The measurement error statistics (mean and deviation) for all measurements, and the overall length percentile statistics are included in the figure as a function of measured vehicle speed (mph). Note that all measurements are in feet.

Table XXV contains a summary of the results of the classification accuracy as a function of percent vehicles with greater than two axles, air temperature and pavement temperature.

Time interval: 2

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	6	0	0	0	0	0	0	0	1	0	0	0	0	0	0
2	2	5925	142	0	6	7	11	8	24	1	2	0	6	0	0
3	0	2511	1362	0	9	5	8	40	14	0	1	1	10	0	0
4	0	3	4	12	24	7	0	1	0	0	4	0	2	0	0
5	0	44	268	0	190	0	8	28	1	0	6	0	11	0	0
6	1	10	4	1	1	305	8	4	12	5	11	0	9	0	0
7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
8	0	13	7	0	0	0	2	169	2	7	12	2	21	0	0
9	0	70	22	0	2	1	0	16	1625	73	29	47	561	0	0
10	0	1	0	0	0	0	0	0	1	15	0	0	7	0	0
11	0	0	1	0	0	0	0	0	1	2	22	5	32	0	0
12	0	1	0	0	0	0	0	0	0	0	0	7	10	0	0
13	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
14	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
15	0	0	3	0	0	0	1	20	3	0	0	1	2	0	0

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	85.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	14.3	0.0	0.0	0.0	0.0	0.0	0.0
2	0.0	96.6	2.3	0.0	0.1	0.1	0.2	0.1	0.4	0.0	0.0	0.0	0.1	0.0	0.0
3	0.0	63.4	34.4	0.0	0.2	0.1	0.2	1.0	0.4	0.0	0.0	0.0	0.3	0.0	0.0
4	0.0	5.3	7.0	21.1	42.1	12.3	0.0	1.8	0.0	0.0	7.0	0.0	3.5	0.0	0.0
5	0.0	7.9	48.2	0.0	34.2	0.0	1.4	5.0	0.2	0.0	1.1	0.0	2.0	0.0	0.0
6	0.3	2.7	1.1	0.3	0.3	82.2	2.2	1.1	3.2	1.3	3.0	0.0	2.4	0.0	0.0
7	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
8	0.0	5.5	3.0	0.0	0.0	0.0	0.9	71.9	0.9	3.0	5.1	0.9	8.9	0.0	0.0
9	0.0	2.9	0.9	0.0	0.1	0.0	0.0	0.7	66.4	3.0	1.2	1.9	22.9	0.0	0.0
10	0.0	4.2	0.0	0.0	0.0	0.0	0.0	0.0	4.2	62.5	0.0	0.0	29.2	0.0	0.0
11	0.0	0.0	1.6	0.0	0.0	0.0	0.0	0.0	1.6	3.2	34.9	7.9	50.8	0.0	0.0
12	0.0	5.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	38.9	55.6	0.0	0.0
13	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
14	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
15	0.0	0.0	10.0	0.0	0.0	0.0	3.3	66.7	10.0	0.0	0.0	3.3	6.7	0.0	0.0

#Real:	18511
#Vendor:	15907
#mistyped:	4273
#sensor err:	1236
#extra Vend:	1681
#Missing Vend:	4396
#Correct:	9638
#Splits:	142
#Combinations:	31

Figure 54. Classification Matrix for IRD TC/C 530-4D/4P/4L (PR-L-PR) 1st 48-Hour Test

Axles Spacing Statistics

Speeds	Mean	STD	Veh	Axle_Spacings
<30	2.115	5.082	8	11
30.0-34.9	0.000	0.000	0	0
35.0-39.9	0.300	0.200	1	2
40.0-44.9	0.204	0.312	13	27
45.0-49.9	0.202	0.270	69	122
50.0-54.9	0.150	0.355	327	641
55.0-59.9	0.168	0.423	1404	2595
60.0-64.9	0.158	0.610	3227	5842
65.0-69.9	0.151	0.636	3082	4532
70.0-74.9	0.150	0.416	1203	1396
75.0-79.9	0.179	0.327	206	216
>80	0.161	0.306	33	33
Overall	0.159	0.578	9573	15417

Length Statistics

Speeds	Mean	STD	Vehicles
<30	3.019	24.029	8
30.0-34.9	0.000	0.000	0
35.0-39.9	8.770	0.002	1
40.0-44.9	2.952	18.915	13
45.0-49.9	-1.006	13.535	69
50.0-54.9	-0.370	14.020	327
55.0-59.9	-0.483	14.158	1404
60.0-64.9	-0.712	12.626	3227
65.0-69.9	-1.878	9.549	3082
70.0-74.9	-2.728	6.450	1203
75.0-79.9	-2.037	3.878	206
>80	-1.830	1.619	33
Overall	-1.321	11.302	9573

Wheelbase Statistics

Speeds	Mean	STD	Vehicles
<30	2.907	11.496	8
30.0-34.9	0.000	0.000	0
35.0-39.9	0.600	0.000	1
40.0-44.9	0.423	0.224	13
45.0-49.9	0.356	0.335	69
50.0-54.9	0.294	0.325	327
55.0-59.9	0.311	0.393	1404
60.0-64.9	0.287	0.800	3227
65.0-69.9	0.222	0.807	3082
70.0-74.9	0.175	0.434	1203
75.0-79.9	0.188	0.330	206
>80	0.161	0.306	33
Overall	0.256	0.773	9573

Length Percentile Statistics

Speeds	Mean	STD	Vehicles
<30	60.71	67.81	8
30.0-34.9	0.000	0.000	0
35.0-39.9	147.663	0.040	1
40.0-44.9	129.169	102.212	13
45.0-49.9	104.251	56.669	69
50.0-54.9	105.518	63.187	327
55.0-59.9	105.300	64.520	1404
60.0-64.9	102.362	59.012	3227
65.0-69.9	94.574	42.851	3082
70.0-74.9	88.466	19.976	1203
75.0-79.9	89.575	21.583	206
>80	91.12	14.65	33
Overall	98.35	51.48	9573

Figure 55. Measurement Accuracy Versus Speed (MPH)
IRD TC/C 530-4D/4P/4L (PR-L-PR) - 1st 48-Hour Test

Table XXV. Accuracy Summary for IRD TC/C 530-4D/4P/4L (PR-L-PR) 1st 48-Hour Test

	Sensor Errors	Correct	Correct (no 2,3)	Axle Mean	Axle S.D.	Length Mean	Length S.D.	%L Mean	%L S.D.
Total	8.89	69.3	88.4	0.159	0.578	-1.321	11.302	98.35	51.48
% Trucks									
0-20	5.52	69.8	91.6	0.186	0.458	-1.760	9.097	94.04	41.78
20-40	7.54	70.8	89.7	0.153	0.607	-1.140	11.748	99.79	53.77
40-60	33.99	52.2	64.0	0.160	0.240	-2.501	9.544	91.47	38.04
60-80	45.88	38.2	52.9	0.106	0.537	-3.205	11.505	92.35	42.93
Air Temp									
50-59	13.54	58.2	84.2	0.154	0.310	-2.836	6.852	88.36	22.75
60-69	13.16	65.6	83.6	0.142	0.716	-1.760	11.485	96.98	50.14
70-79	6.46	71.4	90.2	0.156	0.405	-1.127	11.967	100.30	55.80
80-89	5.56	73.8	91.9	0.165	0.637	-0.909	11.523	100.21	53.81
Pav Temp									
60- 69	18.54	53.5	78.4	0.196	0.761	-2.414	7.947	91.05	29.20
70- 79	14.23	65.5	82.5	0.129	0.584	-1.817	11.533	96.86	50.57
80- 89	8.73	69.1	88.2	0.135	0.322	-1.248	11.326	99.04	52.57
90- 99	3.94	73.7	92.3	0.169	0.764	-0.997	12.690	101.91	59.72
100-109	3.70	74.6	93.8	0.167	0.511	-0.808	12.650	101.45	57.36
110-119	6.88	73.5	90.9	0.165	0.590	-0.925	10.770	99.40	51.23

5.2.9.2 Second 48-Hour Test

The classification matrix for the second 48 hour test and the summary of number of vehicles (real and vendor), mistyped vehicles, sensor errors, extra vendor vehicles, missing vendor vehicles, correctly classified vehicles, suspected splits and suspected combinations are presented in Figure 56. The classification matrix is presented in both absolute numbers, and percentages. The classifier correctly classified 72.6% of the vehicles (92.9% if class 2-3 errors not included). The number of vehicle axles was miscounted 5.35% (percent sensor errors) of the time. There were less than 0.5% of the vehicles classified that were the result of a suspected split or combination of an actual vehicle.

The measurement accuracy of the classifier as a function of vehicle speed is depicted in Figure 57. The TC/C 530-4D/4P/4L classifier measures axles spacings, wheelbase length, and overall vehicle length. The measurement error statistics (mean and deviation) for all measurements, and the overall length percentile statistics are included in the figure as a function of measured vehicle speed (mph). Note that all measurements are in feet.

Table XXVI contains a summary of the results of the classification accuracy as a function of percent vehicles with greater than two axles, air temperature and pavement temperature.

Time interval: 2

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	15	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2	1	8762	141	0	2	1	10	13	5	1	0	0	5	0	0
3	4	3577	1823	0	35	3	5	48	6	0	0	0	5	0	0
4	0	0	3	7	23	7	3	0	0	1	2	0	1	0	0
5	0	12	146	1	164	0	6	29	0	1	0	0	8	0	0
6	1	0	3	1	1	170	1	6	8	1	0	0	4	0	0
7	0	0	0	0	0	1	0	1	0	0	0	0	0	0	0
8	0	21	12	0	0	0	2	202	0	5	6	1	11	0	0
9	4	21	16	0	0	0	0	23	2079	87	33	74	508	0	0
10	0	1	2	0	0	0	0	0	1	15	1	0	5	0	0
11	0	0	0	0	0	0	0	0	0	8	44	3	28	0	0
12	0	0	0	0	0	0	0	0	3	0	0	16	8	0	0
13	0	0	0	0	0	0	0	0	0	3	1	0	1	0	0
14	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
15	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	100.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2	0.0	98.0	1.6	0.0	0.0	0.0	0.1	0.1	0.1	0.0	0.0	0.0	0.1	0.0	0.0
3	0.1	65.0	33.1	0.0	0.6	0.1	0.1	0.9	0.1	0.0	0.0	0.0	0.1	0.0	0.0
4	0.0	0.0	6.4	14.9	48.9	14.9	6.4	0.0	0.0	2.1	4.3	0.0	2.1	0.0	0.0
5	0.0	3.3	39.8	0.3	44.7	0.0	1.6	7.9	0.0	0.3	0.0	0.0	2.2	0.0	0.0
6	0.5	0.0	1.5	0.5	0.5	86.7	0.5	3.1	4.1	0.5	0.0	0.0	2.0	0.0	0.0
7	0.0	0.0	0.0	0.0	0.0	50.0	0.0	50.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
8	0.0	8.1	4.6	0.0	0.0	0.0	0.8	77.7	0.0	1.9	2.3	0.4	4.2	0.0	0.0
9	0.1	0.7	0.6	0.0	0.0	0.0	0.0	0.8	73.1	3.1	1.2	2.6	17.9	0.0	0.0
10	0.0	4.0	8.0	0.0	0.0	0.0	0.0	0.0	4.0	60.0	4.0	0.0	20.0	0.0	0.0
11	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	9.6	53.0	3.6	33.7	0.0	0.0
12	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	11.1	0.0	0.0	59.3	29.6	0.0	0.0
13	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	60.0	20.0	0.0	20.0	0.0	0.0
14	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
15	0.0	0.0	0.0	0.0	0.0	0.0	0.0	100.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

#Real:	19091
#Vendor:	19443
#mistyped:	5023
#sensor err:	981
#extra Vend:	998
#Missing Vend:	693
#Correct:	13298
#Splits:	57
#Combinations:	10

Figure 56. Classification Matrix for IRD TC/C 530-4D/4P/4L (PR-L-PR) 2nd 48-Hour Test

Axles Spacing Statistics

Speeds	Mean	STD	Veh	Axle_Spacings
<30	4.584	7.571	13	22
30.0-34.9	8.169	5.037	3	11
35.0-39.9	0.000	0.000	0	0
40.0-44.9	0.061	0.544	11	17
45.0-49.9	0.099	0.324	79	120
50.0-54.9	0.107	0.377	532	955
55.0-59.9	0.100	0.386	1950	3426
60.0-64.9	0.087	0.366	4399	7611
65.0-69.9	0.086	0.357	4320	6078
70.0-74.9	0.086	0.351	1655	1909
75.0-79.9	0.090	0.260	260	280
>80	0.095	0.489	42	42
Overall	0.099	0.515	13264	20471

Length Statistics

Speeds	Mean	STD	Vehicles
<30	12.499	32.407	7
30.0-34.9	34.960	3.250	3
35.0-39.9	0.000	0.000	0
40.0-44.9	0.883	10.818	11
45.0-49.9	-2.419	6.992	79
50.0-54.9	-0.657	13.238	532
55.0-59.9	-1.186	14.202	1950
60.0-64.9	-1.565	11.737	4396
65.0-69.9	-1.870	9.625	4319
70.0-74.9	-2.781	6.377	1655
75.0-79.9	-2.915	5.684	260
>80	-2.078	1.550	41
Overall	-1.739	10.952	13253

Wheelbase Statistics

Speeds	Mean	STD	Vehicles
<30	7.757	15.932	13
30.0-34.9	29.953	3.479	3
35.0-39.9	0.000	0.000	0
40.0-44.9	0.094	0.562	11
45.0-49.9	0.151	0.288	79
50.0-54.9	0.192	0.348	532
55.0-59.9	0.177	0.356	1950
60.0-64.9	0.150	0.305	4399
65.0-69.9	0.121	0.317	4320
70.0-74.9	0.099	0.335	1655
75.0-79.9	0.096	0.241	260
>80	0.095	0.489	42
Overall	0.153	0.783	13264

Length Percentile Statistics

Speeds	Mean	STD	Vehicles
<30	270.92	365.99	7
30.0-34.9	208.355	1.714	3
35.0-39.9	0.000	0.000	0
40.0-44.9	101.734	42.429	11
45.0-49.9	91.341	35.324	79
50.0-54.9	103.801	64.212	532
55.0-59.9	102.173	64.335	1950
60.0-64.9	98.521	56.811	4396
65.0-69.9	93.963	45.941	4319
70.0-74.9	87.473	23.823	1655
75.0-79.9	86.127	19.372	260
>80	89.74	14.09	41
Overall	96.21	52.28	13253

Figure 57. Measurement Accuracy Versus Speed (MPH)
IRD TC/C 530-4D/4P/4L (PR-L-PR) - 2nd 48-Hour Test

Table XXVI. Accuracy Summary for IRD TC/C 530-4D/4P/4L (PR-L-PR) 2nd 48-Hour Test

	Sensor Errors	Correct	Correct (no 2,3)	Axle Mean	Axle S.D.	Length Mean	Length S.D.	%L Mean	%L S.D.
Total	5.35	72.6	92.9	0.099	0.515	-1.739	10.952	96.21	52.28
% Trucks									
0-20	3.58	72.4	94.7	0.100	0.445	-1.856	9.758	94.19	47.46
20-40	5.17	74.6	92.9	0.083	0.378	-1.581	12.028	98.34	55.54
40-60	27.07	57.4	72.0	0.299	1.677	-1.874	13.981	101.29	77.35
Air Temp									
60-69	9.69	67.3	88.9	0.120	0.752	-1.999	9.775	94.09	49.29
70-79	3.99	74.1	94.0	0.076	0.395	-1.701	11.412	96.86	53.27
80-89	2.30	77.2	96.0	0.131	0.421	-1.458	11.132	97.30	53.46
Pav Temp									
60- 69	10.19	66.4	88.6	0.129	0.734	-1.942	9.435	93.93	45.03
70- 79	11.25	67.6	87.4	0.115	0.718	-1.932	10.792	95.54	53.79
80- 89	3.27	75.9	95.1	0.075	0.357	-1.634	12.190	98.28	56.03
90- 99	1.93	74.9	95.7	0.072	0.382	-1.244	10.601	97.62	53.78
100-109	2.13	75.6	95.7	0.110	0.401	-2.032	10.650	94.51	47.30
110-119	1.54	74.5	97.1	0.087	0.362	-1.531	11.255	96.21	55.98

5.2.9.3 Seven-Day Test

The results of the 7-day test to determine long-term statistics on classification accuracy, vehicle count and axle count are summarized in Table XXVII. The totals for the entire seven days for the vendor and classifier are listed. Also, the difference (ground truth minus vendor) and the percent difference (ground truth * 100 / classifier) are listed. To assess the change inaccuracy over the seven days, the percent difference is calculated for the first and last of the seven days.

Table XXVII. Long-Term Count/Classification Accuracy
IRD TC/C 530-4D/4P/4L (PR-L-PR)

	Total Grnd Truth	Total Classifier	Total Difference	Total Percent	1st Day Percent	Last Day Percent
Vehicles	61214	59545	1669	102.80	101.50	102.25
Axles	157450	N/A	N/A	N/A	95.39	N/A
Class 1	101	97	4	104.12	81.25	85.71
Class 2	29377	39427	-10050	74.51	74.39	75.20
Class 3	18134	7558	10576	239.93	228.11	207.44
Class 4	134	39	95	343.59	233.33	228.57
Class 5	1855	719	1136	258.00	141.28	261.19
Class 6	729	686	43	106.27	110.64	108.77
Class 7	9	127	-118	7.09	27.27	9.09
Class 8	832	1061	-229	78.42	97.87	90.27
Class 9	9627	7326	2301	131.41	144.44	127.30
Class 10	107	386	-279	27.72	26.67	26.56
Class 11	242	386	-76	76.10	100.00	90.00
Class 12	67	300	-233	22.33	28.57	21.31
Class 13	0	1501	-1501	0.00	0.00	0.00
Class 15	0	0	0	--	--	--

5.2.10 International Road Dynamics, Inc. TC/C 530-4D/4P/4L (P-L-P)

The second sensor configuration used with the International Road Dynamics mode TC/C 530-4D/4P/4L classifier was P-L-P using Philips vibracoax axle sensors. The results of this classifier and sensor configuration are presented below.

5.2.10.1 First 48-Hour Test

The classification matrix for the first 48 hour test and the summary of number of vehicles (real and vendor), mistyped vehicles, sensor errors, extra vendor vehicles, missing vendor vehicles, correctly classified vehicles, suspected splits and suspected combinations are presented in Figure 58. The classification matrix is presented in both absolute numbers, and percentages. The classifier correctly classified 70.8% of the vehicles (89.7% if class 2-3 errors not included). The number of vehicle axles was miscounted 7.25% (percent sensor errors) of the time. There were less than 1.0% of the vehicles classified that were the result of a suspected split or combination of an actual vehicle.

The measurement accuracy of the classifier as a function of vehicle speed is depicted in Figure 59. The TC/C 530-4D/4P/4L classifier measures axles spacings, wheelbase length, and overall vehicle length. The measurement error statistics (mean and deviation) for all measurements, and the overall length percentile statistics are included in the figure as a function of measured vehicle speed (mph). Note that all measurements are in feet.

Table XXVIII contains a summary of the results of the classification accuracy as a function of percent vehicles with greater than two axles, air temperature and pavement temperature.

Time interval: 2

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	6	0	1	0	0	0	0	0	0	0	0	0	0	0	0
2	0	6958	145	0	8	3	1	3	23	4	1	0	4	0	0
3	3	3041	1677	0	7	2	0	56	10	2	1	0	2	0	0
4	0	2	5	12	28	17	1	0	0	1	0	0	0	0	0
5	2	50	324	0	255	3	2	25	1	1	3	0	1	0	0
6	3	5	8	2	1	403	7	0	10	1	0	0	2	0	0
7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
8	2	27	5	0	0	0	1	241	5	1	4	0	1	0	0
9	3	71	19	0	9	2	1	14	2217	732	37	7	76	0	0
10	0	1	1	0	0	0	0	0	4	23	0	0	1	0	0
11	0	1	1	0	0	0	0	2	2	1	71	9	2	0	0
12	0	0	2	0	0	0	0	0	0	0	1	20	2	0	0
13	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
14	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
15	0	0	1	0	0	0	0	25	4	2	0	0	0	0	0

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	85.7	0.0	14.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2	0.0	97.3	2.0	0.0	0.1	0.0	0.0	0.0	0.3	0.1	0.0	0.0	0.1	0.0	0.0
3	0.1	63.3	34.9	0.0	0.1	0.0	0.0	1.2	0.2	0.0	0.0	0.0	0.0	0.0	0.0
4	0.0	3.0	7.6	18.2	42.4	25.8	1.5	0.0	0.0	1.5	0.0	0.0	0.0	0.0	0.0
5	0.3	7.5	48.6	0.0	38.2	0.4	0.3	3.7	0.1	0.1	0.4	0.0	0.1	0.0	0.0
6	0.7	1.1	1.8	0.5	0.2	91.2	1.6	0.0	2.3	0.2	0.0	0.0	0.5	0.0	0.0
7	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
8	0.7	9.4	1.7	0.0	0.0	0.0	0.3	84.0	1.7	0.3	1.4	0.0	0.3	0.0	0.0
9	0.1	2.2	0.6	0.0	0.3	0.1	0.0	0.4	69.5	23.0	1.2	0.2	2.4	0.0	0.0
10	0.0	3.3	3.3	0.0	0.0	0.0	0.0	0.0	13.3	76.7	0.0	0.0	3.3	0.0	0.0
11	0.0	1.1	1.1	0.0	0.0	0.0	0.0	2.2	2.2	1.1	79.8	10.1	2.2	0.0	0.0
12	0.0	0.0	8.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	4.0	80.0	8.0	0.0	0.0
13	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
14	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
15	0.0	0.0	3.1	0.0	0.0	0.0	0.0	78.1	12.5	6.2	0.0	0.0	0.0	0.0	0.0

#Real:	18512
#Vendor:	18238
#mistyped:	4910
#sensor err:	1217
#extra Vend:	1181
#Missing Vend:	1551
#Correct:	11883
#Splits:	120
#Combinations:	24

Figure 58. Classification Matrix for IRD TC/C 530-4D/4P/4L (P-L-P) 1st 48-Hour Test

Axles Spacing Statistics

Speeds	Mean	STD	Veh	Axle_Spacings
<30	8.598	10.973	4	13
30.0-34.9	8.026	2.622	5	20
35.0-39.9	0.284	0.161	2	5
40.0-44.9	0.414	0.556	13	25
45.0-49.9	0.165	0.314	73	135
50.0-54.9	0.186	0.591	417	853
55.0-59.9	0.171	0.440	1677	3172
60.0-64.9	0.132	0.601	3929	7449
65.0-69.9	0.106	0.588	3803	5814
70.0-74.9	0.084	0.557	1567	1926
75.0-79.9	-0.091	0.903	286	339
>80	0.197	0.189	38	38
Overall	0.139	0.726	11814	19789

Wheelbase Statistics

Speeds	Mean	STD	Vehicles
<30	27.945	18.014	4
30.0-34.9	32.102	0.822	5
35.0-39.9	0.710	0.110	2
40.0-44.9	0.795	1.109	13
45.0-49.9	0.305	0.211	73
50.0-54.9	0.381	0.827	417
55.0-59.9	0.324	0.600	1677
60.0-64.9	0.250	0.797	3929
65.0-69.9	0.162	0.731	3803
70.0-74.9	0.103	0.754	1567
75.0-79.9	-0.108	1.445	286
>80	0.197	0.189	38
Overall	0.232	1.181	11814

Length Statistics

Speeds	Mean	STD	Vehicles
<30	36.280	11.961	4
30.0-34.9	40.598	7.754	5
35.0-39.9	4.155	5.315	2
40.0-44.9	4.882	15.566	13
45.0-49.9	-0.987	17.623	73
50.0-54.9	0.298	14.791	417
55.0-59.9	-0.299	13.708	1677
60.0-64.9	-0.642	12.733	3929
65.0-69.9	-1.804	9.533	3803
70.0-74.9	-2.294	7.251	1567
75.0-79.9	-1.559	7.482	286
>80	-4.580	11.714	38
Overall	-1.154	11.423	11814

Length Percentile Statistics

Speeds	Mean	STD	Vehicles
<30	218.95	136.20	4
30.0-34.9	250.692	84.361	5
35.0-39.9	125.312	28.191	2
40.0-44.9	127.585	84.545	13
45.0-49.9	107.863	69.720	73
50.0-54.9	108.952	66.943	417
55.0-59.9	105.853	63.239	1677
60.0-64.9	103.210	60.397	3929
65.0-69.9	95.026	42.959	3803
70.0-74.9	90.793	30.736	1567
75.0-79.9	93.685	37.820	286
>80	86.97	18.35	38
Overall	99.38	52.81	11814

Figure 59. Measurement Accuracy Versus Speed (MPH)
IRD TC/C 530-4D/4P/4L (P-L-P) - 1st 48-Hour Test

Table XXVIII. Accuracy Summary for IRD TC/C 530-4D/4P/4L (P-L-P) 1st 48-Hour Test

	Sensor Errors	Correct	Correct (no 2,3)	Axle Mean	Axle S.D.	Length Mean	Length S.D.	%L Mean	%L S.D.
Total	7.25	70.8	89.7	0.139	0.726	-1.145	11.423	99.38	52.81
% Trucks									
0-20	3.70	71.3	93.2	0.155	0.482	-1.546	9.088	95.15	43.27
20-40	6.33	71.7	90.7	0.132	0.690	-1.045	11.884	100.39	54.96
40-60	22.02	64.1	75.6	0.162	1.199	-0.986	12.568	101.65	56.69
60-80	31.20	55.4	65.7	0.146	1.144	-1.593	12.152	100.57	51.01
Air Temp									
50-59	8.41	65.3	89.4	0.125	0.634	-2.083	8.809	93.47	39.51
60-69	13.16	67.2	83.8	0.115	1.000	-1.340	12.084	99.56	54.97
70-79	8.86	69.3	87.9	0.134	0.492	-1.065	12.023	100.19	55.55
80-89	3.00	75.2	93.8	0.151	0.680	-0.845	11.571	100.76	54.41
Pav Temp									
60- 69	13.79	62.3	83.5	0.117	0.791	-2.017	9.423	95.02	40.61
70- 79	11.39	68.6	85.3	0.115	1.020	-1.177	12.302	100.01	56.55
80- 89	10.06	68.2	86.9	0.108	0.502	-0.946	12.244	101.06	57.92
90- 99	6.57	71.3	90.0	0.140	0.431	-1.207	12.256	100.38	55.82
100-109	2.74	74.8	94.4	0.157	0.482	-0.795	12.171	101.13	55.84
110-119	2.82	75.7	93.7	0.156	0.818	-0.785	10.907	100.36	52.62

5.2.10.2 Second 48-Hour Test

The classification matrix for the second 48 hour test and the summary of number of vehicles (real and vendor), mistyped vehicles, sensor errors, extra vendor vehicles, missing vendor vehicles, correctly classified vehicles, suspected splits and suspected combinations are presented in Figure 60. The classification matrix is presented in both absolute numbers, and percentages. The classifier correctly classified 73.8% of the vehicles (93.9% if class 2-3 errors not included). The number of vehicle axles was miscounted 4.37% (percent sensor errors) of the time. There were less than 0.5% of the vehicles classified that were the result of a suspected split or combination of an actual vehicle.

The measurement accuracy of the classifier as a function of vehicle speed is depicted in Figure 61. The TC/C 530-4D/4P/4L classifier measures axles spacings, wheelbase length, and overall vehicle length. The measurement error statistics (mean and deviation) for all measurements, and the overall length percentile statistics are included in the figure as a function of measured vehicle speed (mph). Note that all measurements are in feet.

Table XXIX contains a summary of the results of the classification accuracy as a function of percent vehicles with greater than two axles, air temperature and pavement temperature.

Time interval: 2

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	15	1	0	0	0	0	0	0	0	0	0	0	0	0	0
2	3	8565	135	0	4	1	0	12	5	3	1	0	1	0	0
3	1	3503	1881	0	40	1	0	66	6	1	0	0	2	0	0
4	0	0	3	5	21	13	2	0	0	0	0	0	1	0	0
5	0	11	135	4	182	0	1	32	0	0	0	0	2	0	0
6	0	1	7	2	0	164	3	5	7	0	0	0	3	0	0
7	0	0	0	0	0	1	0	1	0	0	0	0	0	0	0
8	2	19	5	0	0	0	2	228	3	0	1	0	1	0	0
9	2	20	12	0	5	2	0	22	2229	507	49	2	34	0	0
10	0	2	1	0	0	0	0	2	2	17	1	0	1	0	0
11	0	1	0	0	0	0	0	0	1	0	80	2	1	0	0
12	0	0	0	0	0	0	0	0	0	0	0	27	1	0	0
13	0	0	0	0	0	0	0	1	0	4	0	0	0	0	0
14	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
15	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	93.8	6.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2	0.0	98.1	1.5	0.0	0.0	0.0	0.0	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0
3	0.0	63.7	34.2	0.0	0.7	0.0	0.0	1.2	0.1	0.0	0.0	0.0	0.0	0.0	0.0
4	0.0	0.0	6.7	11.1	46.7	28.9	4.4	0.0	0.0	0.0	0.0	0.0	2.2	0.0	0.0
5	0.0	3.0	36.8	1.1	49.6	0.0	0.3	8.7	0.0	0.0	0.0	0.0	0.5	0.0	0.0
6	0.0	0.5	3.6	1.0	0.0	85.4	1.6	2.6	3.6	0.0	0.0	0.0	1.6	0.0	0.0
7	0.0	0.0	0.0	0.0	0.0	50.0	0.0	50.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
8	0.8	7.3	1.9	0.0	0.0	0.0	0.8	87.4	1.1	0.0	0.4	0.0	0.4	0.0	0.0
9	0.1	0.7	0.4	0.0	0.2	0.1	0.0	0.8	77.3	17.6	1.7	0.1	1.2	0.0	0.0
10	0.0	7.7	3.8	0.0	0.0	0.0	0.0	7.7	7.7	65.4	3.8	0.0	3.8	0.0	0.0
11	0.0	1.2	0.0	0.0	0.0	0.0	0.0	0.0	1.2	0.0	94.1	2.4	1.2	0.0	0.0
12	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	96.4	3.6	0.0	0.0
13	0.0	0.0	0.0	0.0	0.0	0.0	0.0	20.0	0.0	80.0	0.0	0.0	0.0	0.0	0.0
14	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
15	0.0	0.0	0.0	0.0	0.0	0.0	0.0	100.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

#Real:	19091
#Vendor:	19186
#mistyped:	4751
#sensor err:	793
#extra Vend:	927
#Missing Vend:	864
#Correct:	13393
#Splits:	49
#Combinations:	17

Figure 60. Classification Matrix for IRD TC/C 530-4D/4P/4L (P-L-P) 2nd 48-Hour Test

Axles Spacing Statistics

Speeds	Mean	STD	Veh	Axle_Spacings
<30	-1.550	0.734	4	4
30.0-34.9	6.329	9.248	5	20
35.0-39.9	6.697	4.218	2	8
40.0-44.9	-0.173	0.609	5	8
45.0-49.9	0.028	0.429	63	104
50.0-54.9	0.036	0.457	441	766
55.0-59.9	0.010	0.456	1693	3062
60.0-64.9	-0.006	0.437	4163	7558
65.0-69.9	-0.013	0.394	4481	6509
70.0-74.9	-0.071	0.538	2037	2506
75.0-79.9	-0.372	1.052	384	474
>80	-0.673	1.437	70	91
Overall	-0.014	0.610	13348	21110

Length Statistics

Speeds	Mean	STD	Vehicles
<30	-1.835	1.075	2
30.0-34.9	34.358	5.226	5
35.0-39.9	39.695	4.985	2
40.0-44.9	-3.530	0.984	5
45.0-49.9	-0.600	10.245	63
50.0-54.9	-1.153	13.088	441
55.0-59.9	-1.460	12.965	1693
60.0-64.9	-1.992	11.524	4163
65.0-69.9	-2.329	9.538	4481
70.0-74.9	-2.894	7.127	2037
75.0-79.9	-2.796	7.840	384
>80	-3.264	4.849	70
Overall	-2.152	10.493	13346

Wheelbase Statistics

Speeds	Mean	STD	Vehicles
<30	-1.550	0.734	4
30.0-34.9	25.318	7.203	5
35.0-39.9	26.790	3.580	2
40.0-44.9	-0.276	0.651	5
45.0-49.9	0.047	0.418	63
50.0-54.9	0.063	0.423	441
55.0-59.9	0.018	0.440	1693
60.0-64.9	-0.010	0.441	4163
65.0-69.9	-0.018	0.393	4481
70.0-74.9	-0.087	0.764	2037
75.0-79.9	-0.459	1.833	384
>80	-0.874	2.620	70
Overall	-0.023	0.864	13348

Length Percentile Statistics

Speeds	Mean	STD	Vehicles
<30	89.04	5.96	2
30.0-34.9	226.454	34.741	5
35.0-39.9	274.061	81.253	2
40.0-44.9	85.133	6.336	5
45.0-49.9	99.561	53.997	63
50.0-54.9	100.988	63.026	441
55.0-59.9	100.075	60.539	1693
60.0-64.9	96.799	52.504	4163
65.0-69.9	92.142	42.962	4481
70.0-74.9	87.761	30.352	2037
75.0-79.9	88.837	36.151	384
>80	87.44	14.08	70
Overall	94.21	47.94	13346

Figure 61. Measurement Accuracy Versus Speed (MPH)
IRD TC/C 530-4D/4P/4L (P-L-P) - 2nd 48-Hour Test

Table XXIX. Accuracy Summary for IRD TC/C 530-4D/4P/4L (P-L-P) 2nd 48-Hour Test

	Sensor Errors	Correct	Correct (no 2,3)	Axle Mean	Axle S.D.	Length Mean	Length S.D.	%L Mean	%L S.D.
Total	4.37	73.8	93.9	-0.014	.610	-2.152	10.493	94.21	47.94
% Trucks									
0-20	2.99	73.2	95.2	-0.001	.633	-2.252	9.326	92.19	43.53
20-40	5.26	74.9	93.1	-0.021	.581	-1.971	11.564	96.35	52.15
40-60	12.83	70.3	84.2	-0.074	.626	-2.321	12.864	99.09	56.08
Air Temp									
60-69	5.45	71.4	92.5	-0.024	.744	-2.306	9.634	93.06	44.24
70-79	4.37	74.2	94.0	-0.030	.534	-2.143	11.026	94.68	49.76
80-89	2.80	76.8	95.7	0.040	.603	-2.030	9.847	93.95	46.41
Pav Temp									
60- 69	4.23	71.9	93.6	-0.016	.793	-1.955	10.302	95.30	48.96
70- 79	7.19	71.7	91.1	-0.046	.620	-2.260	10.393	94.21	47.72
80- 89	5.53	74.1	93.0	-0.025	.528	-2.116	11.871	95.67	52.17
90- 99	2.66	74.8	95.5	-0.018	.739	-1.948	10.259	94.43	49.19
100-109	2.18	75.7	95.9	0.024	.480	-2.404	9.670	92.26	42.46
110-119	0.58	75.4	97.9	0.002	.336	-1.786	8.847	92.97	45.20

5.2.10.3 Seven-Day Test

The results of the 7-day test to determine long-term statistics on classification accuracy, vehicle count and axle count are summarized in Table XXX. The totals for the entire seven days for the vendor and classifier are listed. Also, the difference (ground truth minus vendor) and the percent difference (ground truth * 100 / classifier) are listed. To assess the change inaccuracy over the seven days, the percent difference is calculated for the first and last of the seven days.

Table XXX. Long-Term Count/Classification Accuracy
IRD TC/C 530-4D/4P/4L (P-L-P)

	Total Grnd Truth	Total Classifier	Total Difference	Total Percent	1st Day Percent	Last Day Percent
Vehicles	61214	58925	2289	103.88	102.54	103.44
Axles	157450	N/A	N/A	N/A	100.91	N/A
Class 1	101	84	17	120.24	92.86	120.00
Class 2	29377	38695	-9318	75.92	76.42	77.13
Class 3	18134	7660	10474	236.74	225.98	208.79
Class 4	134	41	93	326.83	200.00	177.78
Class 5	1855	794	1061	233.63	127.27	246.48
Class 6	729	680	49	107.21	106.12	103.33
Class 7	9	24	-15	37.50	60.00	50.00
Class 8	832	1191	-359	69.86	82.63	75.23
Class 9	9627	7411	2216	129.90	129.52	130.14
Class 10	107	1690	-1583	6.33	6.37	5.23
Class 11	242	370	-128	65.41	60.00	65.22
Class 12	67	94	-27	71.28	80.00	72.22
Class 13	0	191	-191	0.00	0.00	0.00
Class 15	0	0	0	--	--	--

5.2.11 Golden River Traffic Ltd. Marksman 660

The Golden River Traffic Ltd. mode Marksman 660 classifier used a P-L-P sensor configuration with Traffic 2000 axle sensors. The results of this configuration are presented below.

5.2.11.1 First 48-Hour Test

The classification equipment was not functioning at the time of the running of the first 48-hour test. Therefore, no data was collected or reduced for this test.

5.2.11.2 Second 48-Hour Test

The classification matrix for the second 48 hour test and the summary of number of vehicles (real and vendor), mistyped vehicles, sensor errors, extra vendor vehicles, missing vendor vehicles, correctly classified vehicles, suspected splits and suspected combinations are presented in Figure 62. The classification matrix is presented in both absolute numbers, and percentages.

The classifier correctly classified 63.9% of the vehicles (82.3% if class 2-3 errors are not included). The number of vehicle axles was miscounted 7.91% (percent sensor errors) of the time. There were less than 1.0% of the vehicles classified that were the result of a suspected split or combination of an actual vehicle.

The measurement accuracy of the classifier as a function of vehicle speed is depicted in Figure 63.

The Marksman 660 classifier measures axle spacings and wheelbase length. The measurement error statistics (mean and deviation) for all measurements are included in the figure as a function of measured vehicle speed (mph). Note that all measurements are in feet.

Table XXXI contains a summary of the results of the classification accuracy as a function of percent vehicles with greater than two axles, air temperature and pavement temperature.

Time interval: 2

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	1	14	2	6	3	0	0	0	1	0	0	0	0	0	0
2	23	7633	450	637	27	17	0	40	120	2	13	3	10	0	0
3	12	2902	1725	685	54	10	2	73	53	0	9	4	7	0	0
4	0	6	3	34	3	0	0	0	0	0	0	0	0	0	0
5	3	39	110	65	104	4	5	19	0	1	6	0	0	0	0
6	0	1	4	17	11	139	0	3	7	0	3	2	0	0	0
7	0	0	0	1	0	1	0	0	0	0	0	0	0	0	0
8	0	1	10	23	5	1	2	174	3	2	20	7	1	0	0
9	0	19	15	6	0	1	0	201	1804	93	188	197	203	0	0
10	0	0	3	0	0	0	0	1	3	10	2	0	5	0	0
11	0	1	0	0	0	0	0	9	2	3	27	18	23	0	0
12	0	0	0	0	0	0	0	0	0	0	0	13	12	0	0
13	0	0	0	0	0	0	0	0	0	3	1	0	2	0	0
14	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
15	0	0	1	0	0	0	0	1	2	0	0	0	0	0	0

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	3.7	51.9	7.4	22.2	11.1	0.0	0.0	0.0	3.7	0.0	0.0	0.0	0.0	0.0	0.0
2	0.3	85.0	5.0	7.1	0.3	0.2	0.0	0.4	1.3	0.0	0.1	0.0	0.1	0.0	0.0
3	0.2	52.4	31.2	12.4	1.0	0.2	0.0	1.3	1.0	0.0	0.2	0.1	0.1	0.0	0.0
4	0.0	13.0	6.5	73.9	6.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
5	0.8	11.0	30.9	18.3	29.2	1.1	1.4	5.3	0.0	0.3	1.7	0.0	0.0	0.0	0.0
6	0.0	0.5	2.1	9.1	5.9	74.3	0.0	1.6	3.7	0.0	1.6	1.1	0.0	0.0	0.0
7	0.0	0.0	0.0	50.0	0.0	50.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
8	0.0	0.4	4.0	9.2	2.0	0.4	0.8	69.9	1.2	0.8	8.0	2.8	0.4	0.0	0.0
9	0.0	0.7	0.6	0.2	0.0	0.0	0.0	7.4	66.2	3.4	6.9	7.2	7.4	0.0	0.0
10	0.0	0.0	12.5	0.0	0.0	0.0	0.0	4.2	12.5	41.7	8.3	0.0	20.8	0.0	0.0
11	0.0	1.2	0.0	0.0	0.0	0.0	0.0	10.8	2.4	3.6	32.5	21.7	27.7	0.0	0.0
12	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	52.0	48.0	0.0	0.0
13	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	50.0	16.7	0.0	33.3	0.0	0.0
14	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
15	0.0	0.0	25.0	0.0	0.0	0.0	0.0	25.0	50.0	0.0	0.0	0.0	0.0	0.0	0.0

#Real:	20116
#Vendor:	20654
#mistyped:	6583
#sensor err:	1444
#extra Vend:	2156
#Missing Vend:	1681
#Correct:	11666
#Splits:	104
#Combinations:	41

Figure 62. Classification Matrix for Golden River Marksman 660 2nd 48-Hour Test

Axles Spacing Statistics

Speeds	Mean	STD	Veh	Axle_Spacings
<30	-558.115	591.180	6	18
30.0-34.9	2.098	13.125	6	18
35.0-39.9	-26.070	98.663	19	73
40.0-44.9	-15.847	70.250	28	100
45.0-49.9	-7.329	10.963	102	324
50.0-54.9	-6.438	38.716	313	625
55.0-59.9	-2.803	16.394	1146	1875
60.0-64.9	-2.876	16.509	3241	5182
65.0-69.9	-2.501	16.172	4075	6149
70.0-74.9	-2.071	21.635	2099	2636
75.0-79.9	-1.278	11.552	445	523
>80	-85.445	261.123	127	241
Overall	-4.625	45.606	11607	17764

Wheelbase Statistics

Speeds	Mean	STD	Vehicles
<30	-1674.345	1739.790	6
30.0-34.9	6.295	11.000	6
35.0-39.9	-100.165	260.605	19
40.0-44.9	-56.598	180.700	28
45.0-49.9	-23.280	16.209	102
50.0-54.9	-12.856	75.988	313
55.0-59.9	-4.587	13.629	1146
60.0-64.9	-4.599	13.778	3241
65.0-69.9	-3.775	11.416	4075
70.0-74.9	-2.601	34.359	2099
75.0-79.9	-1.502	9.046	445
>80	-162.144	592.644	127
Overall	-7.078	88.453	11607

Figure 63. Measurement Accuracy Versus Speed (MPH)
Golden River Marksman 660 - 2nd 48-Hour Test

Table XXXI. Accuracy Summary for Golden River Marksman 660
2nd 48-Hour Test

	Sensor Errors	Correct	Correct (no 2,3)	Axle Mean	Axle S.D.	Length Mean	Length S.D.	%L Mean	%L S.D.
Total	7.91	63.9	82.3	-4.625	45.61	*	*	*	*
% Trucks									
0-20	5.79	63.8	84.0	-3.235	37.58	*	*	*	*
20-40	8.30	66.0	82.8	-4.269	34.23				
40-60	26.87	51.0	62.7	-18.76	122.4				
Air Temp									
60-69	11.61	59.9	78.2	-7.968	75.11	*	*	*	*
70-79	6.27	65.8	84.2	-3.396	27.16				
80-89	6.02	65.0	84.6	-2.469	16.05				
Pav Temp									
60- 69	20.24	48.8	66.9	-2.908	26.61				
70- 79	8.81	64.0	80.9	-5.601	60.09				
80- 89	5.24	68.4	86.6	-2.975	16.36	*	*	*	*
90- 99	5.52	67.0	86.2	-3.445	35.64				
100-109	4.66	67.5	85.7	-2.586	15.85				
110-119	5.88	56.9	80.9	-0.794	12.97				

5.2.11.3 Seven-Day Test

The results of the 7-day test to determine long-term statistics on classification accuracy, vehicle count and axle count are summarized in Table XXXII. The totals for the entire seven days for the vendor and classifier are listed. Also, the difference (ground truth minus vendor) and the percent difference (ground truth * 100 / classifier) are listed. To assess the change inaccuracy over the seven days, the percent difference is calculated for the first and last of the seven days.

Table XXXII. Long-Term Count/Classification Accuracy
Golden River Marksman 660

	Total Grnd Truth	Total Classifier	Total Difference	Total Percent	1st Day Percent	Last Day Percent
Vehicles	61389	57803	3586	106.20	97.74	110.57
Axles	157475	N/A	N/A	N/A	95.32	N/A
Class 1	99	220	-121	45.00	33.33	66.67
Class 2	29467	32698	-3231	90.12	85.11	98.45
Class 3	18347	7884	10463	232.71	207.58	211.03
Class 4	134	4467	-4333	3.00	2.38	2.58
Class 5	1862	880	982	211.59	110.16	214.72
Class 6	734	712	22	103.09	99.02	99.20
Class 7	9	37	-28	24.32	100.00	12.50
Class 8	817	1851	-1034	44.14	47.70	45.75
Class 9	9508	7233	2275	131.45	141.93	124.07
Class 10	102	283	-181	36.04	24.07	60.71
Class 11	244	642	-398	38.01	28.91	46.39
Class 12	66	485	-419	13.61	9.09	30.95
Class 13	0	411	-411	0.00	0.00	0.00
Class 15	0	0	0	--	--	--

5.2.12 Diamond Traffic Products TT-2001 (Autologger Maxi)

The Diamond Traffic Products model TT-2001 classifier was tested using two different sets of sensors. Each set of the sensors was used in a P-L-P configuration. The first set of sensors used Autologger Maxi piezoelectric axle sensors. The results of this classifier using the Autologger Maxi axle sensors are presented below.

5.2.12.1 First 48-Hour Test

The classification matrix for the first 48 hour test and the summary of number of vehicles (real and vendor), mistyped vehicles, sensor errors, extra vendor vehicles, missing vendor vehicles, correctly classified vehicles, suspected splits and suspected combinations are presented in Figure 64. The classification matrix is presented in both absolute numbers, and percentages. The classifier correctly classified 73.1% of the vehicles (92.0% if class 2-3 errors not included). The number of vehicle axles was miscounted 3.17% (percent sensor errors) of the time. There were less than 0.5% of the vehicles classified by the TT-2001 that were the result of a suspected split or combination of an actual vehicle.

The measurement accuracy of the classifier as a function of vehicle speed is depicted in Figure 65. The TT-2001 classifier measures axles spacings, wheelbase length, and overall vehicle length. The measurement error statistics (mean and deviation) for all measurements, and the overall length percentile statistics are included in the figure as a function of measured vehicle speed (mph). Note that all measurements are in feet.

Table XXXIII contains a summary of the results of the classification accuracy as a function of percent vehicles with greater than two axles, air temperature and pavement temperature.

Time interval: 2

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	4	1	1	0	0	0	0	0	0	0	0	0	0	0	0
2	83	6526	395	3	43	10	0	3	6	0	1	0	3	0	0
3	51	2761	1761	4	38	3	0	62	1	0	1	0	5	0	0
4	0	1	4	26	27	8	0	0	0	0	0	0	0	0	0
5	5	54	314	12	238	4	2	26	4	0	0	0	2	0	0
6	33	17	8	1	1	333	4	4	7	0	0	0	10	0	0
7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
8	1	6	3	7	1	0	4	249	2	1	5	0	2	0	0
9	8	38	2	0	3	0	0	92	2901	63	108	37	17	0	0
10	0	1	0	0	0	0	0	1	5	26	1	0	3	0	0
11	0	0	0	0	0	0	0	3	1	0	91	0	0	0	0
12	0	0	0	0	0	0	0	0	0	0	0	28	0	0	0
13	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0
14	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
15	0	1	2	0	0	0	0	24	4	0	1	2	1	0	0

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	66.7	16.7	16.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2	1.2	92.3	5.6	0.0	0.6	0.1	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0
3	1.1	58.9	37.6	0.1	0.8	0.1	0.0	1.3	0.0	0.0	0.0	0.0	0.1	0.0	0.0
4	0.0	1.5	6.1	39.4	40.9	12.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
5	0.8	8.2	47.5	1.8	36.0	0.6	0.3	3.9	0.6	0.0	0.0	0.0	0.3	0.0	0.0
6	7.9	4.1	1.9	0.2	0.2	79.7	1.0	1.0	1.7	0.0	0.0	0.0	2.4	0.0	0.0
7	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
8	0.4	2.1	1.1	2.5	0.4	0.0	1.4	88.6	0.7	0.4	1.8	0.0	0.7	0.0	0.0
9	0.2	1.2	0.1	0.0	0.1	0.0	0.0	2.8	88.7	1.9	3.3	1.1	0.5	0.0	0.0
10	0.0	2.7	0.0	0.0	0.0	0.0	0.0	2.7	13.5	70.3	2.7	0.0	8.1	0.0	0.0
11	0.0	0.0	0.0	0.0	0.0	0.0	0.0	3.2	1.1	0.0	95.8	0.0	0.0	0.0	0.0
12	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	100.0	0.0	0.0	0.0
13	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	100.0	0.0	0.0	0.0
14	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
15	0.0	2.9	5.7	0.0	0.0	0.0	0.0	68.6	11.4	0.0	2.9	5.7	2.9	0.0	0.0

#Real:	18477
#Vendor:	17471
#mistyped:	4481
#sensor err:	528
#extra Vend:	751
#Missing Vend:	1731
#Correct:	12183
#Splits:	10
#Combinations:	36

Figure 64. Classification Matrix for Diamond TT-2001 (Autologger) 1st 48-Hour Test

Axles Spacing Statistics

Speeds	Mean	STD	Veh	Axle_Spacings
<30	1.861	4.659	16	22
30.0-34.9	4.188	5.095	6	15
35.0-39.9	3.929	7.993	16	38
40.0-44.9	1.886	3.650	23	53
45.0-49.9	0.879	2.071	60	139
50.0-54.9	0.152	0.938	383	852
55.0-59.9	0.211	5.640	1515	3164
60.0-64.9	0.014	0.460	3749	7922
65.0-69.9	-0.019	0.577	3895	6716
70.0-74.9	-0.127	1.431	1798	2425
75.0-79.9	-0.640	1.669	469	589
>80	-1.519	3.481	173	212
Overall	0.011	2.340	12103	22147

Length Statistics

Speeds	Mean	STD	Vehicles
<30	4.239	25.328	9
30.0-34.9	22.640	16.251	6
35.0-39.9	13.127	22.179	14
40.0-44.9	5.371	26.835	23
45.0-49.9	6.621	18.561	60
50.0-54.9	1.471	12.734	383
55.0-59.9	0.178	17.204	1515
60.0-64.9	-1.312	6.931	3746
65.0-69.9	-1.799	4.483	3894
70.0-74.9	-1.855	5.280	1797
75.0-79.9	-3.097	6.185	469
>80	-2.164	9.579	173
Overall	-1.271	8.747	12089

Wheelbase Statistics

Speeds	Mean	STD	Vehicles
<30	2.559	8.595	16
30.0-34.9	10.470	11.944	6
35.0-39.9	9.331	12.288	16
40.0-44.9	4.347	7.494	23
45.0-49.9	2.037	4.268	60
50.0-54.9	0.337	1.517	383
55.0-59.9	0.441	12.888	1515
60.0-64.9	0.029	0.660	3749
65.0-69.9	-0.033	0.836	3895
70.0-74.9	-0.172	1.405	1798
75.0-79.9	-0.804	2.479	469
>80	-1.861	2.928	173
Overall	0.020	4.773	12103

Length Percentile Statistics

Speeds	Mean	STD	Vehicles
<30	247.63	212.66	9
30.0-34.9	318.294	264.479	6
35.0-39.9	177.501	114.071	14
40.0-44.9	173.979	175.556	23
45.0-49.9	163.931	177.111	60
50.0-54.9	114.360	74.276	383
55.0-59.9	104.430	59.097	1515
60.0-64.9	97.656	39.052	3746
65.0-69.9	93.527	21.824	3894
70.0-74.9	93.072	31.101	1797
75.0-79.9	89.697	17.570	469
>80	106.16	133.96	173
Overall	97.62	45.35	12089

Figure 65. Measurement Accuracy Versus Speed (MPH)
Diamond TT-2001 (Autologger) - 1st 48-Hour Test

Table XXXIII. Accuracy Summary for Diamond TT-2001 (Autologger) 1st 48-Hour Test

	Sensor Errors	Correct	Correct (no 2,3)	Axle Mean	Axle S.D.	Length Mean	Length S.D.	%L Mean	%L S.D.
Total	3.17	73.1	92.0	0.011	2.340	-1.271	8.747	97.62	45.35
% Trucks									
0-20	1.15	74.3	95.7	0.054	0.431	-1.419	5.523	94.46	29.70
20-40	3.96	71.3	90.5	-0.031	1.169	-1.248	7.697	98.48	49.49
40-60	1.51	84.4	95.8	0.003	0.304	-1.489	6.272	96.95	33.20
60-80	1.44	86.8	96.6	0.544	10.28	-0.379	32.202	98.98	57.29
Air Temp									
50-59	0.64	74.8	98.1	0.010	0.258	-1.662	3.656	93.73	26.01
60-69	1.41	79.9	95.7	0.132	4.538	-1.219	13.297	97.20	42.98
70-79	1.52	78.1	95.8	0.052	0.297	-1.278	6.564	96.41	36.63
80-89	5.16	68.9	88.7	-0.036	1.583	-1.288	7.707	98.64	56.55
Pav Temp									
60- 69	1.70	83.0	97.4	0.431	8.964	-0.706	27.135	98.42	53.78
70- 79	1.18	79.6	95.6	0.035	0.450	-1.349	7.117	97.05	40.53
80- 89	1.59	77.4	95.8	0.033	0.322	-1.230	6.553	96.76	37.18
90- 99	1.65	78.4	96.0	0.052	0.292	-1.424	5.655	95.53	31.28
100-109	2.72	74.3	93.9	-0.061	1.126	-1.506	6.385	96.77	55.86
110-119	7.63	62.9	83.1	-0.023	2.123	-0.985	9.298	101.36	62.40

5.2.12.2 Second 48-Hour Test

The classification matrix for the second 48 hour test and the summary of number of vehicles (real and vendor), mistyped vehicles, sensor errors, extra vendor vehicles, missing vendor vehicles, correctly classified vehicles, suspected splits and suspected combinations are presented in Figure 66. The classification matrix is presented in both absolute numbers, and percentages. The classifier correctly classified 11.0% of the vehicles (11.8% if class 2-3 errors not included). The number of vehicle axles was miscounted 11.65% (percent sensor errors) of the time. There were problems involving the recording software for the classifier during this test. These problems occurred after an upgrade to the software was received between the first and second 48-hour tests. The problems are associated with the data recording and not the actual classifying of vehicles.

The measurement accuracy of the classifier as a function of vehicle speed is depicted in Figure 67. The TT-2001 classifier measures axles spacings, wheelbase length, and overall vehicle length. The measurement error statistics (mean and deviation) for all measurements, and the overall length percentile statistics are included in the figure as a function of measured vehicle speed (mph). Note that all measurements are in feet.

Table XXXIV contains a summary of the results of the classification accuracy as a function of percent vehicles with greater than two axles, air temperature and pavement temperature.

Time interval: 2

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2	1	36	2	0	1	0	0	0	1	0	0	11	0	0	0
3	1	27	31	1	3	0	0	4	1	0	1	32	0	0	0
4	0	1	2	0	1	1	0	0	0	0	0	4	0	0	0
5	0	3	5	0	14	0	0	0	0	0	0	12	0	0	0
6	0	0	0	0	0	21	0	0	1	0	0	123	0	0	0
7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
8	0	2	1	0	0	0	0	15	0	0	1	150	0	0	0
9	15	23	0	1	0	1	0	28	268	2	7	1587	3	0	0
10	0	0	0	0	0	0	0	0	0	0	0	20	0	0	0
11	0	0	0	0	0	0	0	1	0	0	8	44	0	0	0
12	0	0	0	0	0	0	0	0	0	4	0	19	0	0	0
13	0	0	0	0	0	0	0	0	0	1	0	3	0	0	0
14	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
15	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
2	1.9	69.2	3.8	0.0	1.9	0.0	0.0	0.0	1.9	0.0	0.0	21.2	0.0	0.0	0.0
3	1.0	26.7	30.7	1.0	3.0	0.0	0.0	4.0	1.0	0.0	1.0	31.7	0.0	0.0	0.0
4	0.0	11.1	22.2	0.0	11.1	11.1	0.0	0.0	0.0	0.0	0.0	44.4	0.0	0.0	0.0
5	0.0	8.8	14.7	0.0	41.2	0.0	0.0	0.0	0.0	0.0	0.0	35.3	0.0	0.0	0.0
6	0.0	0.0	0.0	0.0	0.0	14.5	0.0	0.0	0.7	0.0	0.0	84.8	0.0	0.0	0.0
7	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
8	0.0	1.2	0.6	0.0	0.0	0.0	0.0	8.9	0.0	0.0	0.6	88.8	0.0	0.0	0.0
9	0.8	1.2	0.0	0.1	0.0	0.1	0.0	1.4	13.9	0.1	0.4	82.0	0.2	0.0	0.0
10	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	100.0	0.0	0.0	0.0
11	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.9	0.0	0.0	15.1	83.0	0.0	0.0	0.0
12	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	17.4	0.0	82.6	0.0	0.0	0.0
13	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	25.0	0.0	75.0	0.0	0.0	0.0
14	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
15	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A

#Real:	14519
#Vendor:	3951
#mistyped:	3332
#sensor err:	436
#extra Vend:	126
#Missing Vend:	10616
#Correct:	412
#Splits:	1
#Combinations:	79

Figure 66. Classification Matrix for Diamond TT-2001 (Autologger) 2nd 48-Hour Test

Axles Spacing Statistics

Speeds	Mean	STD	Veh	Axle_Spacings
<30	6.525	6.377	1	4
30.0-34.9	8.061	2.857	2	8
35.0-39.9	0.000	0.000	0	0
40.0-44.9	0.000	0.000	0	0
45.0-49.9	-0.300	0.320	1	4
50.0-54.9	-0.341	0.623	16	51
55.0-59.9	-0.155	0.481	54	186
60.0-64.9	-0.231	0.390	157	555
65.0-69.9	-0.264	0.465	138	442
70.0-74.9	-0.223	0.961	32	85
75.0-79.9	-0.120	0.273	2	5
>80	-1.660	0.000	1	1
Overall	-0.166	0.978	404	1341

Length Statistics

Speeds	Mean	STD	Vehicles
<30	31.890	0.000	1
30.0-34.9	37.030	0.130	2
35.0-39.9	0.000	0.000	0
40.0-44.9	0.000	0.000	0
45.0-49.9	-3.540	0.000	1
50.0-54.9	-4.438	2.040	16
55.0-59.9	-3.690	3.204	54
60.0-64.9	-3.993	1.967	157
65.0-69.9	-4.176	4.013	138
70.0-74.9	-3.863	3.861	32
75.0-79.9	-0.400	0.530	2
>80	-6.280	0.000	1
Overall	-3.717	4.613	404

Wheelbase Statistics

Speeds	Mean	STD	Vehicles
<30	26.100	0.000	1
30.0-34.9	32.245	1.015	2
35.0-39.9	0.000	0.000	0
40.0-44.9	0.000	0.000	0
45.0-49.9	-1.200	0.000	1
50.0-54.9	-1.088	0.916	16
55.0-59.9	-0.535	0.946	54
60.0-64.9	-0.816	0.688	157
65.0-69.9	-0.845	0.833	138
70.0-74.9	-0.592	0.760	32
75.0-79.9	-0.300	0.010	2
>80	-1.660	0.000	1
Overall	-0.552	2.789	404

Length Percentile Statistics

Speeds	Mean	STD	Vehicles
<30	196.93	0.00	1
30.0-34.9	212.398	1.140	2
35.0-39.9	0.000	0.000	0
40.0-44.9	0.000	0.000	0
45.0-49.9	95.056	0.000	1
50.0-54.9	91.433	7.020	16
55.0-59.9	94.871	18.648	54
60.0-64.9	93.194	6.028	157
65.0-69.9	93.096	11.563	138
70.0-74.9	92.092	11.743	32
75.0-79.9	97.301	2.904	2
>80	69.95	0.00	1
Overall	94.04	14.75	404

Figure 67. Measurement Accuracy Versus Speed (MPH) Diamond TT-2001 (Autologger) - 2nd 48-Hour Test

Table XXXIV. Accuracy Summary for Diamond TT-2001 (Autologger) 2nd 48-Hour Test

	Sensor Errors	Correct	Correct (no 2,3)	Axle Mean	Axle S.D.	Length Mean	Length S.D.	%L Mean	%L S.D.
Total	11.65	11.0	11.8	-0.166	0.978	-3.717	4.613	94.04	14.75
% Trucks									
0-20	7.40	13.6	15.0	-0.063	1.389	-3.108	6.291	95.36	20.54
20-40	12.24	9.7	10.1	-0.250	0.444	-4.279	2.088	92.75	5.76
40-60	27.72	1.6	1.6	-0.051	0.244	-3.180	0.480	95.79	0.65
Air Temp									
60-69	21.42	23.6	24.3	-0.057	1.499	-3.473	6.363	95.34	17.84
70-79	10.73	11.2	12.1	-0.225	0.552	-3.802	3.632	93.43	13.50
80-89	6.86	0.3	0.3	0.096	0.243	-3.415	0.775	95.83	1.00
Pav Temp									
60- 69	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
70- 79	24.54	45.9	48.0	-0.097	1.351	-3.512	6.458	95.13	18.80
80- 89	11.68	24.1	26.2	-0.214	0.528	-3.813	2.552	93.16	11.35
90- 99	7.89	0.6	0.6	-0.494	0.982	-4.618	1.157	93.50	1.59
100-109	5.04	0.2	0.2	-0.049	0.370	-3.945	1.305	95.01	1.82
110-119	2.78	0.0	0.0	0.000	0.000	0.000	0.000	0.00	0.00

N/A - Data Not Available

5.2.12.3 Seven-Day Test

The results of the 7-day test to determine long-term statistics on classification accuracy, vehicle count and axle count are summarized in Table XXXV. The totals for the entire seven days for the vendor and classifier are listed. Also, the difference (ground truth minus vendor) and the percent difference (ground truth * 100 / classifier) are listed. To assess the change inaccuracy over the seven days, the percent difference is calculated for the first and last of the seven days.

Table XXXV. Long-Term Count/Classification Accuracy Diamond Traffic TT-2001 (Autologger)

	Total Grnd Truth	Total Classifier	Total Difference	Total Percent	1st Day Percent	Last Day Percent
Vehicles	37250	11318	25932	329.12	354.63	346.06
Axles	99403	N/A	N/A	N/A	252.10	N/A
Class 1	50	261	-211	19.16	--	11.54
Class 2	16987	1989	14998	854.05	--	851.83
Class 3	10457	1158	9299	903.02	--	726.35
Class 4	71	24	47	295.83	--	266.67
Class 5	1226	313	913	391.69	--	384.62
Class 6	533	338	195	157.69	--	122.77
Class 7	7	7	0	100.00	--	--
Class 8	644	719	-75	89.57	--	66.80
Class 9	6956	3563	3393	195.23	--	153.83
Class 10	81	70	11	115.71	--	73.91
Class 11	183	190	-7	96.32	--	72.58
Class 12	55	1681	-1626	3.27	0.93	100.00
Class 13	0	42	-42	0.00	--	0.00
Class 15	0	963	-963	0.00	0.00	--

5.2.13 Diamond Traffic Products (Philips Vibracoax)

The second set of sensors (also in the P-L-P configuration) used with the Diamond Traffic Products model TT-2001 classifier used Philips Vibracoax axle sensors. The results of this classifier using the Philips axle sensors are presented below.

5.2.13.1 First 48-Hour Test

The classification matrix for the first 48 hour test and the summary of number of vehicles (real and vendor), mistyped vehicles, sensor errors, extra vendor vehicles, missing vendor vehicles, correctly classified vehicles, suspected splits and suspected combinations are presented in Figure 68. The classification matrix is presented in both absolute numbers, and percentages. The classifier correctly classified 75.5% of the vehicles (93.9% if class 2-3 errors not included). The number of vehicle axles was miscounted 3.47% (percent sensor errors) of the time. There were less than 0.5% of the vehicles classified that were the result of a suspected split or combination of an actual vehicle.

The measurement accuracy of the classifier as a function of vehicle speed is depicted in Figure 69. The TT-2001 classifier measures axles spacings, wheelbase length, and overall vehicle length. The measurement error statistics (mean and deviation) for all measurements, and the overall length percentile statistics are included in the figure as a function of measured vehicle speed (mph). Note that all measurements are in feet.

Table XXXVI contains a summary of the results of the classification accuracy as a function of percent vehicles with greater than two axles, air temperature and pavement temperature.

Time interval: 2

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	6	0	1	0	0	0	0	0	0	0	0	0	0	0	0
2	0	7541	62	0	2	3	0	6	7	0	0	0	1	0	0
3	1	3170	1741	0	4	3	0	59	3	1	2	0	4	0	0
4	0	0	2	22	29	9	0	0	0	0	0	0	0	0	0
5	1	41	326	0	270	3	2	27	3	0	1	0	5	0	0
6	3	5	0	2	1	404	3	2	11	0	0	0	1	0	0
7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
8	0	3	3	2	0	0	2	280	5	0	3	0	0	0	0
9	2	5	0	0	0	0	0	33	2889	223	56	3	98	0	0
10	0	0	0	0	0	0	0	0	4	28	2	0	2	0	0
11	0	0	0	0	0	0	0	3	1	0	89	0	1	0	0
12	0	0	0	0	0	0	0	0	0	0	0	20	8	0	0
13	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0
14	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
15	0	0	2	0	0	0	0	25	6	0	0	1	0	0	0

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	85.7	0.0	14.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2	0.0	98.9	0.8	0.0	0.0	0.0	0.0	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0
3	0.0	63.6	34.9	0.0	0.1	0.1	0.0	1.2	0.1	0.0	0.0	0.0	0.1	0.0	0.0
4	0.0	0.0	3.2	35.5	46.8	14.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
5	0.1	6.0	48.0	0.0	39.8	0.4	0.3	4.0	0.4	0.0	0.1	0.0	0.7	0.0	0.0
6	0.7	1.2	0.0	0.5	0.2	93.5	0.7	0.5	2.5	0.0	0.0	0.0	0.2	0.0	0.0
7	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
8	0.0	1.0	1.0	0.7	0.0	0.0	0.7	94.0	1.7	0.0	1.0	0.0	0.0	0.0	0.0
9	0.1	0.2	0.0	0.0	0.0	0.0	0.0	1.0	87.3	6.7	1.7	0.1	3.0	0.0	0.0
10	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	11.1	77.8	5.6	0.0	5.6	0.0	0.0
11	0.0	0.0	0.0	0.0	0.0	0.0	0.0	3.2	1.1	0.0	94.7	0.0	1.1	0.0	0.0
12	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	71.4	28.6	0.0	0.0
13	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	100.0	0.0	0.0	0.0
14	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
15	0.0	0.0	5.9	0.0	0.0	0.0	0.0	73.5	17.6	0.0	0.0	2.9	0.0	0.0	0.0

#Real:	18480
#Vendor:	18568
#mistyped:	4309
#sensor err:	610
#extra Vend:	909
#Missing Vend:	833
#Correct:	13290
#Splits:	24
#Combinations:	12

Figure 68. Classification Matrix for Diamond TT-2001 (Philips) 1st 48-Hour Test

Axles Spacing Statistics

Speeds	Mean	STD	Veh	Axle_Spacings
<30	7.023	2.404	1	4
30.0-34.9	7.057	2.498	6	24
35.0-39.9	0.000	0.000	0	0
40.0-44.9	-0.072	2.786	3	9
45.0-49.9	0.113	0.230	38	89
50.0-54.9	0.094	0.332	397	836
55.0-59.9	0.257	5.287	1790	3578
60.0-64.9	0.091	0.454	4387	8934
65.0-69.9	0.103	0.410	4424	7209
70.0-74.9	0.130	0.263	1755	2173
75.0-79.9	0.121	0.265	330	366
>80	0.080	0.326	67	67
Overall	0.133	2.124	13198	23289

Wheelbase Statistics

Speeds	Mean	STD	Vehicles
<30	28.090	0.000	1
30.0-34.9	28.227	0.356	6
35.0-39.9	0.000	0.000	0
40.0-44.9	-0.217	1.560	3
45.0-49.9	0.265	0.241	38
50.0-54.9	0.198	0.447	397
55.0-59.9	0.513	11.847	1790
60.0-64.9	0.185	0.609	4387
65.0-69.9	0.167	0.470	4424
70.0-74.9	0.161	0.285	1755
75.0-79.9	0.134	0.266	330
>80	0.080	0.326	67
Overall	0.234	4.436	13198

Length Statistics

Speeds	Mean	STD	Vehicles
<30	39.010	0.000	1
30.0-34.9	38.602	0.499	6
35.0-39.9	0.000	0.000	0
40.0-44.9	-0.337	0.537	3
45.0-49.9	-1.290	1.502	38
50.0-54.9	-1.223	2.732	397
55.0-59.9	-0.876	13.647	1790
60.0-64.9	-1.385	4.181	4387
65.0-69.9	-1.260	2.248	4424
70.0-74.9	-1.069	1.379	1755
75.0-79.9	-1.052	1.156	330
>80	-1.101	1.300	67
Overall	-1.196	5.845	13198

Length Percentile Statistics

Speeds	Mean	STD	Vehicles
<30	215.07	0.00	1
30.0-34.9	213.950	2.313	6
35.0-39.9	0.000	0.000	0
40.0-44.9	100.109	1.880	3
45.0-49.9	95.707	5.170	38
50.0-54.9	95.927	14.330	397
55.0-59.9	96.801	28.774	1790
60.0-64.9	95.033	11.194	4387
65.0-69.9	94.440	9.202	4424
70.0-74.9	94.324	8.587	1755
75.0-79.9	94.476	8.355	330
>80	94.52	11.25	67
Overall	95.06	14.46	13198

**Figure 69. Measurement Accuracy Versus Speed (MPH)
Diamond TT-2001 (Philips) - 1st 48-Hour Test**

Table XXXVI. Accuracy Summary for Diamond TT-2001 (Philips) 1st 48-Hour Test

	Sensor Errors	Correct	Correct (no 2,3)	Axle Mean	Axle S.D.	Length Mean	Length S.D.	%L Mean	%L S.D.
Total	3.47	75.5	93.9	0.133	2.124	-1.196	5.845	95.06	14.46
% Trucks									
0-20	1.91	74.0	95.5	0.136	0.375	-1.250	2.349	94.09	11.40
20-40	3.40	75.7	93.9	0.107	0.516	-1.213	3.638	95.16	12.17
40-60	6.77	79.1	90.5	0.104	0.282	-1.466	1.312	94.75	6.01
60-80	10.43	75.9	86.1	0.764	11.31	0.689	34.369	100.01	59.84
Air Temp									
50-59	2.34	72.6	96.5	0.123	0.456	-1.311	2.393	94.01	10.96
60-69	5.11	75.6	91.9	0.240	4.815	-1.062	12.154	95.46	23.82
70-79	4.93	75.1	92.8	0.142	0.549	-1.266	2.823	94.64	13.44
80-89	2.62	76.8	95.1	0.114	0.525	-1.197	2.328	94.78	9.85
Pav Temp									
60- 69	9.00	74.7	89.1	0.604	9.789	-0.148	28.254	97.53	48.96
70- 79	4.62	75.5	92.0	0.138	0.643	-1.286	2.688	94.75	10.81
80- 89	4.94	74.5	93.1	0.139	0.566	-1.218	3.123	95.14	16.33
90- 99	4.44	75.7	93.4	0.115	0.287	-1.306	1.565	94.49	6.24
100-109	3.17	75.8	95.0	0.124	0.254	-1.216	1.611	94.41	8.09
110-119	2.18	77.8	95.1	0.109	0.683	-1.212	2.830	94.83	11.46

5.2.13.2 Second 48-Hour Test

The classification matrix for the second 48 hour test and the summary of number of vehicles (real and vendor), mistyped vehicles, sensor errors, extra vendor vehicles, missing vendor vehicles, correctly classified vehicles, suspected splits and suspected combinations are presented in Figure 70. The classification matrix is presented in both absolute numbers, and percentages. The classifier correctly classified 13.0% of the vehicles (16.2% if class 2-3 errors not included). The number of vehicle axles was miscounted 3.40% (percent sensor errors) of the time. There were problems involving the recording software for the classifier during this test. These problems occurred after an upgrade to the software was received between the first and second 48-hour tests. The problems are associated with the data recording and not the actual classifying of vehicles.

The measurement accuracy of the classifier as a function of vehicle speed is depicted in Figure 71. The TT-2001 classifier measures axles spacings, wheelbase length, and overall vehicle length. The measurement error statistics (mean and deviation) for all measurements, and the overall length percentile statistics are included in the figure as a function of measured vehicle speed (mph). Note that all measurements are in feet.

Table XXXVII contains a summary of the results of the classification accuracy as a function of percent vehicles with greater than two axles, air temperature and pavement temperature.

Time interval: 2

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0
2	2	903	46	0	1	0	0	1	4	2	0	13	0	0	0
3	0	337	172	0	4	1	0	14	1	0	1	106	1	0	0
4	0	1	0	2	2	3	0	0	0	0	0	8	0	0	0
5	0	0	5	0	21	0	0	4	0	0	0	25	0	0	0
6	1	0	0	0	0	22	0	0	1	0	0	145	0	1	0
7	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0
8	0	0	0	0	0	0	0	21	0	0	0	168	0	0	0
9	1	2	0	0	0	0	0	1	367	31	3	1898	11	0	0
10	0	0	0	0	0	0	0	0	0	0	0	21	0	0	0
11	0	0	0	0	0	0	0	0	1	0	11	50	0	0	0
12	0	0	0	0	0	0	0	0	0	0	0	22	1	0	0
13	0	0	0	0	0	0	0	0	0	0	0	5	0	0	0
14	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
15	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	33.3	33.3	33.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2	0.2	92.9	4.7	0.0	0.1	0.0	0.0	0.1	0.4	0.2	0.0	1.3	0.0	0.0	0.0
3	0.0	52.9	27.0	0.0	0.6	0.2	0.0	2.2	0.2	0.0	0.2	16.6	0.2	0.0	0.0
4	0.0	6.2	0.0	12.5	12.5	18.8	0.0	0.0	0.0	0.0	0.0	50.0	0.0	0.0	0.0
5	0.0	0.0	9.1	0.0	38.2	0.0	0.0	7.3	0.0	0.0	0.0	45.5	0.0	0.0	0.0
6	0.6	0.0	0.0	0.0	0.0	12.9	0.0	0.0	0.6	0.0	0.0	85.3	0.0	0.6	0.0
7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	100.0	0.0	0.0	0.0
8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	11.1	0.0	0.0	0.0	88.9	0.0	0.0	0.0
9	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	15.9	1.3	0.1	82.0	0.5	0.0	0.0
10	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	100.0	0.0	0.0	0.0
11	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.6	0.0	17.7	80.6	0.0	0.0	0.0
12	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	95.7	4.3	0.0	0.0
13	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	100.0	0.0	0.0	0.0
14	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
15	0.0	0.0	0.0	0.0	0.0	0.0	0.0	100.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

#Real:	14539
#Vendor:	12658
#mistyped:	10305
#sensor err:	403
#extra Vend:	765
#Missing Vend:	2633
#Correct:	1542
#Splits:	11
#Combinations:	24

Figure 70. Classification Matrix for Diamond TT-2001 (Philips) 2nd 48-Hour Test

Axles Spacing Statistics

Speeds	Mean	STD	Veh	Axle_Spacings
<30	0.000	0.000	0	0
30.0-34.9	0.000	0.000	0	0
35.0-39.9	-2.850	0.000	1	1
40.0-44.9	0.000	0.000	0	0
45.0-49.9	-0.310	0.000	1	1
50.0-54.9	-0.184	0.421	25	58
55.0-59.9	-0.205	0.737	150	325
60.0-64.9	-0.185	0.378	415	898
65.0-69.9	-0.203	0.430	587	1054
70.0-74.9	-0.207	0.605	268	378
75.0-79.9	-0.203	0.447	67	79
>80	-0.758	0.904	23	23
Overall	-0.203	0.498	1537	2817

Length Statistics

Speeds	Mean	STD	Vehicles
<30	0.000	0.000	0
30.0-34.9	0.000	0.000	0
35.0-39.9	2.720	0.000	1
40.0-44.9	0.000	0.000	0
45.0-49.9	-3.350	0.000	1
50.0-54.9	-2.820	1.676	25
55.0-59.9	-2.443	1.469	150
60.0-64.9	-2.626	1.944	415
65.0-69.9	-2.376	1.336	587
70.0-74.9	-2.030	1.416	268
75.0-79.9	-1.972	1.301	67
>80	-2.752	2.724	23
Overall	-2.382	1.600	1537

Wheelbase Statistics

Speeds	Mean	STD	Vehicles
<30	0.000	0.000	0
30.0-34.9	0.000	0.000	0
35.0-39.9	-2.850	0.000	1
40.0-44.9	0.000	0.000	0
45.0-49.9	-0.310	0.000	1
50.0-54.9	-0.427	0.711	25
55.0-59.9	-0.444	1.104	150
60.0-64.9	-0.401	0.550	415
65.0-69.9	-0.365	0.586	587
70.0-74.9	-0.291	0.618	268
75.0-79.9	-0.240	0.465	67
>80	-0.758	0.904	23
Overall	-0.373	0.661	1537

Length Percentile Statistics

Speeds	Mean	STD	Vehicles
<30	0.00	0.00	0
30.0-34.9	0.000	0.000	0
35.0-39.9	122.295	0.000	1
40.0-44.9	0.000	0.000	0
45.0-49.9	82.275	0.000	1
50.0-54.9	91.556	5.835	25
55.0-59.9	91.553	5.994	150
60.0-64.9	91.165	5.755	415
65.0-69.9	90.733	5.467	587
70.0-74.9	90.447	6.734	268
75.0-79.9	89.413	7.387	67
>80	88.45	22.17	23
Overall	90.82	6.56	1537

Figure 71. Measurement Accuracy Versus Speed (MPH) Diamond TT-2001 (Philips) - 2nd 48-Hour Test

Table XXXVII. Accuracy Summary for Diamond TT-2001 (Philips) 2nd 48-Hour Test

	Sensor Errors	Correct	Correct (no 2,3)	Axle Mean	Axle S.D.	Length Mean	Length S.D.	%L Mean	%L S.D.
Total	3.40	13.0	16.2	-0.203	0.498	-2.382	1.600	90.82	6.56
% Trucks									
0-20	2.42	14.3	18.2	-0.186	0.429	-2.291	1.312	90.12	5.86
20-40	3.90	12.1	14.8	-0.229	0.566	-2.492	1.873	91.26	7.31
40-60	6.74	1.1	1.1	0.078	0.255	-2.328	0.395	96.90	0.53
Air Temp									
60-69	4.10	28.1	34.0	-0.209	0.452	-2.435	1.998	91.45	7.15
70-79	3.41	13.1	16.6	-0.204	0.537	-2.359	1.346	90.30	6.26
80-89	2.89	0.1	0.1	0.136	0.281	-2.565	0.725	96.84	0.94
Pav Temp									
60- 69	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
70- 79	4.75	55.5	69.0	-0.218	0.512	-2.375	1.830	91.12	6.93
80- 89	4.33	26.6	33.4	-0.201	0.489	-2.389	1.328	90.19	6.29
90- 99	3.05	0.3	0.5	-0.324	0.971	-3.350	2.481	90.24	5.45
100-109	2.17	0.1	0.1	0.051	0.383	-2.845	1.005	96.34	1.43
110-119	2.20	0.0	0.0	0.000	0.000	0.000	0.000	0.00	0.00

N/A - Data Not Available

5.2.13.3 Seven-Day Test

The results of the 7-day test to determine long-term statistics on classification accuracy, vehicle count and axle count are summarized in Table XXXVIII. The totals for the entire seven days for the vendor and classifier are listed. Also, the difference (ground truth minus vendor) and the percent difference (ground truth * 100 / classifier) are listed. To assess the change inaccuracy over the seven days, the percent difference is calculated for the first and last of the seven days.

Table XXXVIII. Long-Term Count/Classification Accuracy Diamond Traffic TT-2001 (Philips)

	Total Grnd Truth	Total Classifier	Total Difference	Total Percent	1st Day Percent	Last Day Percent
Vehicles	37250	30162	7088	123.50	115.75	123.31
Axles	99403	N/A	N/A	N/A	111.49	N/A
Class 1	50	54	-4	92.59	--	70.59
Class 2	16987	12112	4875	140.25	--	101.31
Class 3	10457	3108	7349	336.45	--	238.96
Class 4	71	21	50	338.10	--	177.78
Class 5	1226	432	794	283.80	--	236.49
Class 6	533	361	172	147.65	--	105.98
Class 7	7	10	-3	70.00	--	25.00
Class 8	644	617	27	104.38	--	72.93
Class 9	6956	4573	2383	152.11	--	116.71
Class 10	81	363	-282	22.31	--	12.50
Class 11	183	191	-8	95.81	--	68.18
Class 12	55	2083	-2028	2.64	0.74	86.67
Class 13	0	124	-124	0.00	--	0.00
Class 15	0	6113	-6113	0.00	0.00	--

5.3 CLASSIFICATION ACCURACY VERSUS SENSOR ERRORS

The classification accuracy of all the equipment tested appears to be dependent on the sensor accuracy. A sensor error, as listed in Section 5.2, is defined for this analysis as a miscount of the number of axles of a vehicle. The number of sensor error were calculated for each of the classifier equipments and each of the 48-hour tests. A plot of the classification accuracy (percent correctly classified) versus the percent of the vehicles which had sensor errors for both test 1 and test 2 is depicted in Figure 72. The lower points on the plot are the total percent correctly classified, and upper points are the classification accuracy ignoring errors between class 2 and class 3 (the most common classification error). The classification errors appear to be linearly dependent on the sensor error (axle miscounts). By extrapolating the data, it appears that the classification accuracy would average about 78% if there were no sensor errors and 96% if errors between class 2 and 3 were ignored.

Note that data recorded by the Diamond Traffic TT-2001 classifier during the second 48-hour test was not included in the plot. The Diamond classifier had a software bug which resulted in the recording of excessive errors which would bias the results in the plot. Data from the Mitron MSC-3000 DCP classifier is not included since the Mitron classifier did not generate vehicle-by-vehicle data.

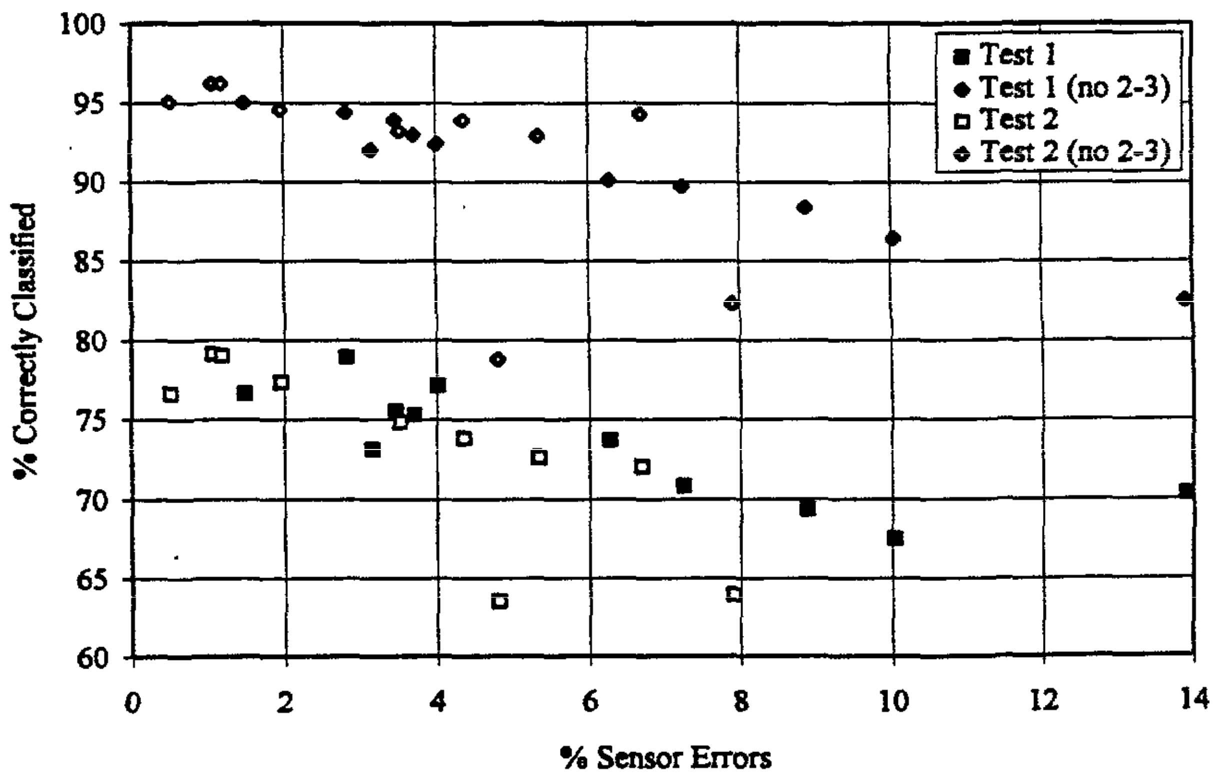


Figure 72. Classification Accuracy Versus Sensor Errors

6. ANSWERS TO SPECIFIC QUESTIONS

The data analysis portion of this project was intended, in part, to answer eleven specific questions. These questions will be addressed specifically in this section of the report with references to related section of the report for additional information.

Question 1. How Accurately do the various types of vehicle classifiers sort the traffic stream into each of the 13 FHWA vehicle types?

Table XXXIX depicts the accuracy of each of the classifiers to sort the vehicle stream into the 13 FHWA vehicle types. This table lists the percent of the vehicle stream correctly classified and the percent sensor errors (axle miscounts) for each vendor and each 48-hour test. Note that the number in parenthesis in the "% Correctly Classified" column is the percentage of correctly classified vehicles with classes 2 and 3 combined. Errors between classes 2 and 3 are by far the most common errors since often time small pickup trucks have shorter lengths and wheelbases than large cars. Therefore, it is often impossible to correctly sort vehicles between class 2 and 3 based on axle spacing and length.

The accuracy of the classification appears to be inversely proportional to the ability of the classifiers to count axles. Missed axles (referred to as sensor errors) seem to directly relate to sensor errors and can be used as an indicator of overall classifier accuracy. Figure 72 in Section 5.3 plots the percentage of correctly classified vehicles as a function of the percent sensor errors (miscounted axles). As the number of sensor errors increased the accuracy of the classifiers declined almost linearly.

Question 2. For those vehicles that may be incorrectly classified by a device, into what class did the devices place the vehicle?

The classification matrices for each of the vendors are shown is Section 5.2. The matrices show the count and percentage of vehicles that were correctly and incorrectly classified into each of the categories. The classes into which an incorrectly classified vehicle was placed varied somewhat between the individual classifiers devices. Some general trends can however be noted.

The primary misclassification noted in the test results was the classification of class 3 vehicles as class 2 vehicles. Since these two classes of vehicles often have similar overall and wheelbase lengths (the primary measures for sorting the vehicles), this error is easily understood. Classifications of class 2 vehicles as class 3 occurred much less often than class 3 to class 2, but did occur in significant numbers.

Classification errors between all of the 2-axle classes (classes 2, 3, 4, and 5) were also common. Again, there are a number of small buses and 5-tire trucks, and large cars and pickup trucks with very near the same lengths and wheelbases. Therefore, differentiation of the classes based entirely on axle spacing and length is nearly impossible.

Table XXXIX. Classification Accuracy

Equipment Vendor	Model Number	Sensor Config.	48-Hour Test #	% Sensor Errors	% Correctly Classified
Mikros Systems	TEL-2CM	L-P-L (Philips)	1 2	13.91 4.81	70.3 (82.5) 63.5 (78.8)
Peek Traffic, Inc.	TrafiCOMP III	P-L-P (Philips)	1 2	3.71 3.53	75.3 (93.0) 74.8 (93.2)
	GK-6000	P-P (Philips)	1 2	6.29 1.19	73.7 (90.1) 79.0 (96.2)
		P-P (Philips)	1 2	4.02 1.07	77.1 (92.4) 79.1 (96.2)
PAT Equipment Corporation, Inc.	AVC-100	P-L-P (Atochem)	1 2	N/A N/A	N/A N/A
	AVC-100	L-P-L (Philips)	1 2	1.49 0.51	76.6 (95.0) 76.6 (95.1)
MITRON Systems Corporation	MSC-3000 DCP	P-P (Autologger)	1 2	N/A N/A	N/A N/A
Electronic Control Measure	HESTIA	P-L-P (ECM)	1 2	10.05 6.70	67.5 (86.4) 72.0 (94.3)
TimeMark, Inc.	Delta II	P-P (Philips)	1 2	2.83 1.97	78.9 (94.4) 77.3 (94.6)
International Road Dynamics, Inc.	TC/C 530-4D/4P/4L	PR-L-PR (Dynax)	1 2	8.89 5.35	69.3 (88.4) 72.6 (92.9)
		P-L-P (Philips)	1 2	7.25 4.37	70.8 (89.7) 73.8 (93.9)
Golden River Traffic Ltd.	Marksman 660	P-L-P (Traffic)	1 2	N/A 7.91	N/A 63.9 (82.3)
Diamond Traffic Products	TT-2001	P-L-P (Autologger)	1 2	3.17 11.65 *	73.1 (92.0) 11.0 (11.8)*
		P-L-P (Philips)	1 2	3.47 3.40 *	75.5 (93.9) 13.0 (16.2)*

* - Software During Test 2 Had Bug N/A - Not Available for This Test

Classification of large trucks, especially classes 8 and 9, was very good. Classification errors were relatively uncommon. Common classification error that did occur included splitting a class 9 into a class 6 and a class 2, and classification of a class 9 as a class 8 (miscounted axles).

Question 3. For those vehicle classification devices that capture individual vehicle records of number of axles and distances between axles, how accurately monitored was this axle and distance information?

The accuracies of individual classifiers to measure axle spacings for both 48-hour tests are summarized in Table XL. The magnitude of the mean of the error in measuring the axle spacings ranged from 0.003 to 0.441 feet (0.4 to 5.3 inches), and the standard deviation ranged from 0.335 to 2.791 feet. Note that these ranges do not include those values for the Marksman 660 model, which had considerable errors throughout its data.

Question 4. For those vehicle classification devices that allow the operator to set the dimensional threshold between various vehicle classes, how accurate were these devices as defined by preceding points 1 through 3?

Virtually all of the equipment tested had the ability in some way or another to allow the operator to adjust the dimensional thresholds between vehicle classes. All of the equipment tested used the default dimensional thresholds of the classifier except the Mikros classifier. The Mikros classifier was programmed with the dimensional thresholds known as Schedule F or the Streeter-Amet Classification Categories ("Field Evaluation of FHWA Vehicle Classification Categories", Final Report, Technical Paper 84-5, Maine Department of Transportation, January 1985).

Question 5. How is the equipment accuracy as defined in the preceding points 1 through 3 affected by vehicle speed?

The accuracy of the classification equipment as a function of speed is discussed in the individual classifier results in Section 5.2. Most of the devices reported vehicle speed in their output files. The speed calculated by the vendor was used to separate the axle spacing, wheelbase and overall length measurements into separate speed bins. The mean and standard deviation of the measurements were calculated for each 5 MPH wide speed bin over the range of speeds from 30 to 80 MPH. Very few vehicles were recorded with speeds greater than 80 MPH or less than 30 MPH during any of the tests.

The effect of speed on the accuracy of the measurements varied from classifier to classifier. Typically, the mean error and standard deviation of the error slowly changed as a function of speed. The direction (towards positive or negative errors) and the magnitude of the change varied depending on the classifier. The absolute magnitude of the change was, however, fairly small for all of the classifiers.

Table XL. Accuracy of Axle Spacing Measurements
(All measurements in feet)

Equipment Vendor	Model Number	Sensor Config.	48-Hour Test #	Mean Error	Standard Deviation
Mikros Systems	TEL-2CM	L-P-L (Philips)	1	0.099	1.113
			2	-0.022	0.988
Peek Traffic, Inc.	TrafiCOMP III	P-L-P (Philips)	1	0.172	0.399
			2	0.064	0.356
	GK-6000	P-P (Philips)	1	0.110	1.449
			2	0.004	0.363
		P-P (Philips)	1	0.098	2.722
			2	0.003	0.335
PAT Equipment Corporation, Inc.	AVC-100	P-L-P (Atochem)	1	N/A	N/A
			2	N/A	N/A
	AVC-100	L-P-L (Philips)	1	0.078	2.055
			2	-0.252	0.420
MITRON Systems Corporation	MSC-3000 DCP	P-P (Autologger)	1	N/A	N/A
			2	N/A	N/A
Electronic Control Measure	HESTIA	P-L-P (ECM)	1	0.120	0.732
			2	0.441	1.519
TimeMark, Inc.	Delta II	P-P (Philips)	1	0.124	2.791
			2	-0.018	0.419
International Road Dynamics, Inc.	TC/C 530-4D/4P/4L	PR-L-PR (Dynax)	1	0.159	0.578
			2	0.099	0.515
		P-L-P (Philips)	1	0.139	0.726
			2	-0.014	0.610
Golden River Traffic Ltd.	Marksman 660	P-L-P (Traffic)	1	N/A	N/A
			2	-4.625	45.606
Diamond Traffic Products	TT-2001	P-L-P (Autologger)	1	0.011	2.340
			2	-0.166	0.978
		P-L-P (Philips)	1	0.133	2.124
			2	-0.203	0.498

N/A - Data Not Available

Question 6. How is equipment accuracy as defined in the preceding points 1 through 3 affected by the percentage of vehicles with more than 2 axles in the traffic stream being measured?

The equipment accuracy as a function of the number of trucks (vehicles with greater than two axles) for each classifier is presented in tables in Section 5.2. In that section, it shows that the classification accuracy as a function of the percentage of trucks does tend to show an improvement as the percentage of trucks increases. However, the percentage of trucks generally rose dramatically in the late evening and early morning hours when the traffic volume was very low. The effects of the lower traffic volume is likely to have had at least as great an impact on the classification accuracy as the percentage of trucks in the vehicle stream.

The general patterns of incorrect classifications showed no appreciable change as a function of the number of trucks in the traffic stream. The total number of class 3 vehicles classified as class 2 (the most common classification error) decreased as the traffic volume and number of class 3 vehicles decreased, but the tendencies and percentage of class 3 vehicles incorrectly classified stayed nearly the same.

Axle spacing measurements tended to show little or no appreciable variation with the percentage of vehicles with more than two axles. The response of individual classifiers are shown in tables in Section 5.2.

Question 7. What is the impact of pavement and/or air temperature on equipment accuracy?

The impact of pavement and air temperature on the classification and axle spacing measurement accuracy for each classifier and test is presented in tables in Section 5.2. Very few conclusions can be drawn from the data collected from the tests conducted in this project. The range of temperatures experienced during the test was relatively limited with no near or below freezing air temperatures experienced. Over the range of air and pavement temperatures experienced during the two 48-hour tests, the classification accuracy appeared to vary very little. At very low pavement temperatures (60-69 degrees), the mean error did appear to rise slightly, but at these times (early mornings) the traffic was also very light and consisted mainly of large trucks. Therefore, the measurement of axle spacings appeared to be affected very little by the temperature ranges experienced in these tests.

Question 8. What is the impact of precipitation on equipment accuracy?

During the tests performed for this project, no appreciable precipitation was recorded. Therefore, no information of sensor or classifier accuracy can be derived from the test results. All of the classifiers tested used combinations of piezoelectric sensors and magnetic loop detectors. While there is the possibility of some sensor degradation due to hydroplaning of vehicle tires or interference with the magnetic loops, the degradation is expected to be relatively minor. However, there is no test information which can be used to validate this assumption.

Question 9. How accurately can devices monitor overall vehicle length as a function of vehicle speed, traffic volume, temperature, or vehicle mix?

The accuracy of the classification devices which measured overall vehicle lengths is listed in Tables XLI and XLII. In Table XLI, the mean and standard deviation of the measurement errors (ground truth (true) length minus measured length) are listed for each vendor, classifier model and test. In Table XLII, the mean and standard deviation of the percentage length measurements are listed. The length percentage is calculated by multiplying the true length by 100 and dividing by the length measured by the classification equipment. These tables are summaries of the results of the individual classifiers listed in Section 5.2.

The effects of traffic speed on the overall length measurements of the individual classifiers can be examined by reviewing the figures in Section 5.2. The effects of traffic speed on the accuracy of the overall length measurements varied considerable from classifier to classifier. The Electronic Control Measure HESTIA had increasing mean errors at higher speeds (approaching 70 mph). The Mikros TEL-2CM showed a trend towards higher errors at lower speeds. The International Road Dynamics TC/C 530-4D/4P/4L and the Diamond TT-2001 units tended to have the greatest accuracies at speeds near 50-55 mph, and tended towards higher errors at higher and lower speeds (though there were very few vehicles with much lower speeds).

The accuracy of overall length measurements as a function of the air and pavement temperature tended to be nearly constant. The accuracy varied very little as the temperature changed for the classifiers tested. This is reasonable since the overall length measurements are made primarily using the loop sensor inputs (and possibly speed measured by the axle sensors). Magnetic loop sensors do not exhibit large variations as a function of temperature.

The overall length measurement accuracy as a function of the percentage of trucks (vehicles with greater than two axles) tended to degrade as the percentage of trucks increased. The magnitude of the mean error in overall length measurement increased by as much as 40% when the percentage of trucks increased from 0-20% to 40-60% (HESTIA during Test 2).

The accuracy of overall length measurements as a function of the traffic density is nearly impossible to separate from the accuracy versus temperature and percent of vehicles with greater than two axles. The high volume traffic occurred during the daytime hours where temperature was highest and the percentage of trucks was lowest. The traffic at the

Table XLI. Overall Length Measurement Errors
(All measurements in feet)

Equipment Vendor	Model Number	Sensor Config.	48-Hour Test #	Mean Error	Standard Deviation
Mikros Systems	TEL-2CM	L-P-L (Philips)	1	2.093	2.549
			2	-2.167	4.031
Peek Traffic, Inc.	TrafiCOMP III	P-L-P (Philips)	1	N/A	N/A
			2	N/A	N/A
		P-P	1	N/A	N/A
	GK-6000	(Philips)	2	N/A	N/A
		P-P	1	N/A	N/A
		(Philips)	2	N/A	N/A
PAT Equipment Corporation, Inc.	AVC-100	P-L-P (Atochem)	1	N/A	N/A
			2	N/A	N/A
	AVC-100	L-P-L (Philips)	1	N/A	N/A
			2	N/A	N/A
MITRON Systems Corporation	MSC-3000 DCP	P-P (Autologger)	1	N/A	N/A
			2	N/A	N/A
Electronic Control Measure	HESTIA	P-L-P (ECM)	1	0.598	2.157
			2	2.232	3.073
TimeMark, Inc.	Delta II	P-P (Philips)	1	N/A	N/A
			2	N/A	N/A
International Road Dynamics, Inc.	TC/C 530-4D/4P/4L	PR-L-PR (Dynax)	1	-1.321	11.302
			2	-1.739	10.952
		P-L-P (Philips)	1	-1.154	11.423
			2	-2.152	10.493
Golden River Traffic Ltd.	Marksman 660	P-L-P (Traffic)	1	N/A	N/A
			2	N/A	N/A
Diamond Traffic Products	TT-2001	P-L-P (Autologger)	1	-1.271	8.747
			2	-3.717	4.613
		P-L-P (Philips)	1	-1.196	5.845
			2	-2.382	1.600

N/A - Data Not Available

Table XLII. Overall Length Measurement Percentiles
(All measurements in percent of ground truth)

Equipment Vendor	Model Number	Sensor Config.	48-Hour Test #	Mean Percent	Standard Deviation
Mikros Systems	TEL-2CM	L-P-L (Philips)	1 2	108.43 91.29	26.62 28.32
Peek Traffic, Inc.	TrafiCOMP III	P-L-P (Philips)	1 2	N/A N/A	N/A N/A
	GK-6000	P-P (Philips)	1 2	N/A N/A	N/A N/A
		P-P (Philips)	1 2	N/A N/A	N/A N/A
PAT Equipment Corporation, Inc.	AVC-100	P-L-P (Atochem)	1 2	N/A N/A	N/A N/A
	AVC-100	L-P-L (Philips)	1 2	N/A N/A	N/A N/A
MITRON Systems Corporation	MSC-3000 DCP	P-P (Autologger)	1 2	N/A N/A	N/A N/A
Electronic Control Measure	HESTIA	P-L-P (ECM)	1 2	102.95 114.30	8.25 16.07
TimeMark, Inc.	Delta II	P-P (Philips)	1 2	N/A N/A	N/A N/A
International Road Dynamics, Inc.	TC/C 530-4D/4P/4L	PR-L-PR (Dynax)	1 2	98.35 96.21	51.48 52.28
		P-L-P (Philips)	1 2	99.38 94.21	52.81 47.94
Golden River Traffic Ltd.	Marksman 660	P-L-P (Traffic)	1 2	N/A N/A	N/A N/A
Diamond Traffic Products	TT-2001	P-L-P (Autologger)	1 2	97.62 94.04	45.35 14.75
		P-L-P (Philips)	1 2	95.06 90.82	14.46 6.56

N/A - Data Not Available

test site did tend to increase in the mornings and evenings, but there was no heavy rush hour traffic that could be used to assess performance under extreme traffic conditions. Therefore, the dependence on traffic volume is not expressly calculated for this study.

Question 10. How is the device accuracy affected by the sensing device used?

All of the classification systems tested for this project used some combination of piezoelectric axle sensors and inductive loops as sensing devices. The combination and configuration of the sensing devices can possibly have a significant impact on the accuracy of the classifiers. Two of the vendors (PAT Equipment Corp. and International Road Dynamics) used two identical classification models with two different sensor configurations. These provided good points for comparisons of the accuracy as a function of the sensing device configuration.

The primary difference between the sensing devices used by the individual classifiers was the number of piezoelectric axle sensors and inductive loops used. Most used 2 axle sensors and a single loop as the sensing devices. The Peek GK-6000, the TimeMark Delta II and the Mitron MSC 3000 DCP classifiers used no inductive loops. The Mikros TEL-2CM and one configuration of the PAT AVC-100 used a single axle sensor and two inductive loops. The remaining classifiers used two axle sensors and one inductive loop for their sensor configuration.

There was no appreciable difference in the classification accuracy between the equipment using different sensor configurations. Within the set of classifiers using each particular sensor configuration there was considerable variation in classification accuracy, but there was no trend or pattern between sensor configurations.

The magnitude of the mean error of the axle spacing measurements for classifiers using a single piezoelectric axle sensor averaged 0.113 feet, and the standard deviation averaged 1.144 feet. The magnitude of the mean error for classifiers using two piezoelectric axle sensors averaged 0.115 feet, and the standard deviation averaged 1.081 feet. The difference between one and two axle sensor configurations showed no appreciable difference in these tests. Again, due to considerable errors, the data for the Marksman 660 model was not included in these calculations.

All but one of the classifiers which measured overall vehicle length used the P-L-P sensor configuration. Only the Mikros TEL-2CM used the L-P-L configuration. The Mikros classifier's overall length measurement errors were near the average for the units using the P-L-P configuration. Therefore, there was not appreciable difference in overall length measurement accuracy noted in this project.

Question 11. Does the accuracy change over time? Is the accuracy the same when the equipment is first installed and when it is picked up, or does the length of time in operation affect the equipment?

The two detailed 48-hour tests were conducted approximately 4 months apart. Between the tests, the sensing devices remained in the roadway and were subjected to normal traffic volume. Comparing the classification accuracy of the each vendor classifier in the first and second 48-hour test can be accomplished by reviewing Table XXXIX (of Question 1. above). No Piezoelectric sensors were replaced between the two tests, but some piezoelectric sensors did fail. Those classifiers which used the failed sensors were not included in the second test and their results are not included in the table.

Nearly all of the classifiers had nearly equal to or better vehicle classification accuracy during the second 48-hour test than during the first test. The only notable exception to this pattern was the Diamond TT-2001 which had a software upgrade between tests that included a data recording bug. Using lessons learned during the first test, greater care was taken during the second test to prepare the piezoelectric sensors. Where axle sensors were installed low in the pavement, or where piezoelectric output was low, bituthane tape was placed over the sensor to increase its output voltage levels. This resulted in a lower sensor error (miscounted axle) rate during the second test and a corresponding higher percentage of correctly classified vehicles. The axle sensor accuracy appeared to have a greater effect on classification accuracy than time, and the sensor accuracy was dependent primarily on installation and preparation prior to each test.

Axle spacing and overall length measurement accuracy revealed no noticeable trend between the first and second 48-hour test. Almost all had mean errors which remained nearly constant between the tests.

An assessment of the accuracy over time during a continuous test can be made by reviewing the results in Section 5.2 of the 7-day test results for each vendor. No specific trends were noted in the accuracy of the classifiers over the 7-day test. Some classifiers displayed some accuracy improvement from the first to the last day of the test, but others showed some degradation. Therefore, the classification accuracy as a function of time over a seven day period depended on the particular classifier and no overall trends were noted.

7. AUGMENTED PNEUMATIC TUBE TEST

An augmented pneumatic tube test was conducted during the second 48-hour test. A Peek 241 (TrafiCOMP III) was configured to monitor both westbound lanes of traffic using pneumatic tubes. One pair of tubes covered the near lane (same lane as used for all other tests), and one pair of tubes were placed across both lanes of traffic.

The goal of the test was to determine how accurately the classifier could count vehicles and axles in two lanes at the same time. Obviously, the second set of tubes would detect axles in both lanes of traffic simultaneously. The goal of the test was to determine if the lanes of traffic could be separated and counted accurately.

The Peek 241 was intended to be configured to record and bin the separate lanes of traffic. Unfortunately, the classifier was configured to sum both lanes of traffic into one bin. The resulting data file had all vehicles in the near lane counted twice and the far lane counted once. This format adds to the ambiguity of the counting if one lane or the other has an error and thus would not be a fair test of the pneumatic tubes to count vehicles and axles.

It is recommended that this test be repeated in the future. The test should be conducted either with two separate classifiers, or with one classifier configured to store the results of each pneumatic tube pair in separate bins.

8. SUMMARY AND CONCLUSIONS

The classification accuracies resulting from this test ranged from 63.5% to 79.1%. The most common errors occurred between Class 2 (passenger vehicles) and Class 3 (other 2-axle, 4-tire vehicles). A small pickup truck (class 3) is very difficult to distinguish from a large car (class 2) based on length and axle spacing. If class 2 and 3 are combined, then the classification accuracies ranged from 78.8% to 96.2%.

Temperature of the air and pavement was found to have little effect on the performance of the classifiers. However, the range of temperatures was somewhat limited for this test. The percentage of trucks (vehicles with more than 2 axles) tended to have some effect on the classifier accuracies. The classification of class 9 vehicles (a majority of the trucks) was very good on most classifiers, and hence the classification accuracy tended to improve as the percentage of trucks increased. The longer vehicle lengths and axles spacings did result in greater measurement errors as the percentage of trucks increased.

Precipitation, although expected during the second 48-hour test and the 7-day test, did not occur during any of the tests. Therefore, no results concerning the performance of these devices in rain was obtained.

The sensor configuration used by the classifiers did not appear to have a significant effect on the accuracy. Classification accuracy, axle spacing measurement errors, and overall length measurement errors appeared to be independent on the sensor configurations. The primary factor observed in this test to affect the classification accuracy was the performance of the axle sensors. The ability of the equipment to accurately classify vehicles was linearly dependent on the ability of the sensor and classifier to accurately count the number of axles. Therefore, performance of the piezoelectric axle sensor and the interface electronics in the classification equipment are the primary factors effecting the accuracy of the equipment.

A further opportunity has arisen to collect more data concerning the performance of these classification equipments. Road construction is under way at the test site and will result in the sensors in the roadway being overlaid as part of a widening of the road. This presents an opportunity to test the performance of the devices after a pavement overlay. This issue is important to the maintainability of a traffic monitoring site. The results of the overlay tests will be reported in and addendum to this report.

The augmented tube test performed in parallel with the second 48-hour test was essentially unsuccessful. The Peek TrafiCOMP III was incorrectly programmed resulting in the data from the two lanes monitored being summed into one record and no individual lanes being recorded. While there is some possibility that limited results can be obtained from the single data file, there will be much greater potential for analysis if the test is repeated. Therefore, a repeat of the augmented tube test is planned in conjunction with the overlay tests. These tests should be conducted in time for the results to be included in the final report.

APPENDIX A

PARTICIPATING VENDORS AND CONTACT PERSONS

LIST OF PARTICIPATING VENDORS AND CONTACT PERSONS

DIAMOND TRAFFIC PRODUCTS P.O. Box 975 Port Richey, FL 34673-0975	Jerry Schiff (813) 843-0270 FAX (813) 843-0270 TT-2001 Classifier
DOCAL ASSOCIATES, INC. Suite 211, 264 Amity Road Woodbridge, CT 06525	Tony Docal (203) 387-3218 FAX (203) 387-4957 Autologger Sensors
ELECTRONIC CONTROL MEASURE P.O. Box 888 Manor, TX 78653	Ron White (512) 272-4346 FAX (512) 272-5161 HESTIA Classifier
GOLDEN RIVER TRAFFIC LIMITED c/o B B K ELECTRONICS, INC. 9470 Sacramento Drive New Port Richey, FL 34655-1619	Bob Klaush (813) 376-5661 FAX (813) 372-6918 Marksman 660 Classifier
INTERNATIONAL ROAD DYNAMICS, INC. 702 43rd Street Saskatoon, Saskatchewan Canada S7K 3T9	Rod Klashinsky (306) 934-6777 FAX (306) 242-5599 TC/C 530 Classifier
MIKROS SYSTEMS P.O. Box/POSBUS 20309 ALKATRANT 0005 SOUTH AFRICA	Johan Steyn +27 12 73 1010 FAX +27 12 73 4646 TEL-2CM Classifier
MITRON SYSTEMS CORPORATION 2000 Century Plaza Columbia, MD 21044	Donald Dixon (410) 992-7700 FAX (301) 596-5119 MSC-3000 DCP Classifier
PAT EQUIPMENT CORPORATION, INC. 1665 Orchard Drive Chambersburg, PA 17201-9206	Siegfried Gassner (717) 263-7655 FAX (717) 263-7845 AVC-100 Classifier

PEEK TRAFFIC, INC.
1500 North Washington Blvd.
Sarasota, FL 34236

Jim Stemitz (813) 366-8770
FAX (813) 365-0837
TrafiCOMP III and GK-6000 Classifiers

TIMEMARK, INC.
P.O. Box 12947
Salem, OR 97309

Dan Gossack (503) 363-2012
FAX (503) 363-1716
Delta II Classifier

APPENDIX B

EQUIPMENT BRIEFING FORMS

DIAMOND TRAFFIC PRODUCTS

P.O. Box 975
Port Richey, FL 34673-0975

SALES REPRESENTATIVE
Jerry Schiff (813) 843-0270
FAX (813) 843-0270

MODEL NAME
Traffic Tally 2001

GENERAL DESCRIPTION OF EQUIPMENT
Multi-lane vehicle classifier. Operates in raw data or binning mode, up to four lanes classification or eight lanes of count. Available with inductive loops, piezoelectric sensors, or road tubes. Equipment also operates with remote center line air switch.

METHOD OF OPERATION
Unattended, capability to access data via telemetry is standard.

METHOD OF DATA STORAGE
Battery-backed static RAM.

DATA STORAGE CAPACITY
68K Standard. Memory can be expanded up to 960K in 128K increments to allow collection of more raw vehicle data.

VEHICLE CLASSIFICATION SCHEME
Raw data and up to 20 bins, but FHWA Scheme F is default setting.

POWER SOURCE
12 Volt 6-1/2 amp-hr Lead Gel/Solar/110 Volt rechargeable internal battery (new equipment uses 6V 12 amp-hr batteries)

OPERATING TEMPERATURE RANGE
-40°F to 158°F (Electronics)

OPERATING VEHICLE SPEED RANGE
5 to 105 mph

DIMENSIONS AND WEIGHT OF EACH MAJOR COMPONENT
12" x 12" x 7.5", 1/8" T-5052 welded alum. construction - 18 lbs

MAXIMUM LENGTH OF LEAD CABLE
Loops - 800 feet; Piezo - 800 feet

PURCHASE COST OF EQUIPMENT
$1450 to $3100

INSTALLATION COST

Varies with users desire for enclosures and type of sensors

NOMINAL INSTALLATION TIME

10 - 20 minutes

INSTALLATION PROCEDURE

Attach loops or piezoelectric sensors/solar power (if used).

SOME STATES CURRENTLY USING THIS EQUIPMENT

Idaho, Washington, Florida, North Carolina, Michigan, Wyoming, Alabama, California, Nevada, New York, Tennessee, Oklahoma

OTHER COMMENTS

Other equipment available from Diamond Traffic Products:

TT-501 - Whereas the TT-2001 will classify up to 4 lanes and count as many as 8, the TT-501 is a less expensive, basic version that will classify only one lane and count vehicles in two.

GTRI COMMENTS

Piezo-Loop-Piezo

ELECTRONIC CONTROL MEASURE

P.O. Box 888
Manor, TX 78653

SALES REPRESENTATIVE

Ron White (512) 272-4346
FAX (512) 272-5161

MODEL NAME

HESTIA Classifier

GENERAL DESCRIPTION OF EQUIPMENT

Card/rack mounted portable or permanent classification and counting system. CMOS component-based electronics for low power consumption at 12 Volts DC. Collects classification and count data in up to 8 lanes of traffic. Collects both individual vehicle data and/or binned data. Available with piezoelectric sensors and/or inductive loops.

METHOD OF OPERATION

Unattended operation with data access via telemetry. Piezo detector is fully automated to allow reliable operation with variable sensor sensitivity.

METHOD OF DATA STORAGE

Binned and/or individual vehicle storage

DATA STORAGE CAPACITY

8M

VEHICLE CLASSIFICATION SCHEME

User programmable (default FHWA scheme F) with up to 56 vehicle configurations.

POWER SOURCE

12V DC

OPERATING TEMPERATURE RANGE

-40°F to 176°F

OPERATING VEHICLE SPEED RANGE

10 to 120 mph

DIMENSIONS AND WEIGHT OF EACH MAJOR COMPONENT

6" x 8" x 12"; 15 lbs

MAXIMUM LENGTH OF LEAD CABLE

Loop: 900 feet
Piezo: 600 feet

PURCHASE COST OF EQUIPMENT
$3000 to $6000

INSTALLATION COST
Variable depending on permanent or portable installation

NOMINAL INSTALLATION TIME
Permanent: 3 hours/lane; portable: 5 - 20 minutes

INSTALLATION PROCEDURE
Attach sensors, use computer to set up study

SOME STATES CURRENTLY USING THIS EQUIPMENT
Information not available

GOLDEN RIVER TRAFFIC LIMITED

c/o B B K ELECTRONICS INC.
9470 Sacramento Drive
New Port Richey, FL 34655-1619

SALES REPRESENTATIVE
Bob Klaush (813) 376-5661
FAX (813) 372-6918

MODEL NAME
Marksman 660 Classifier

GENERAL DESCRIPTION OF EQUIPMENT
Self-contained multi-lane traffic counter classifier and weighing in motion. Available for use with loops, tubes, piezo, wim strip and switch inputs.

METHOD OF OPERATION
Stand-alone unit that can be addressed with a computer or via telemetry.

METHOD OF DATA STORAGE
Information not supplied

DATA STORAGE CAPACITY
64K standard, 128K or 1024K can be added.

VEHICLE CLASSIFICATION SCHEME
FHWA 13, 12 speed bins, 6 axle bins, 5 length bins, 4 time bins.

POWER SOURCE
6V 10 APR battery, can be continuously connected to a 12 to 18 Volt AC or DC power source.

OPERATING TEMPERATURE RANGE
-40°C to 80°C (-40°F to 176°F)

OPERATING VEHICLE SPEED RANGE
5 to 80 mph

DIMENSIONS AND WEIGHT OF EACH MAJOR COMPONENT
Outer case: 340 mm x 300 mm x 160 mm deep
Inner case: 250 mm x 145 mm x 190 mm deep
Weight: 8.9 kg and 4.9 kg

MAXIMUM LENGTH OF LEAD CABLE
Not specified

PURCHASE COST OF EQUIPMENT
$2200 to $3500, depending upon options.

INSTALLATION COST

Varies with users, type of road, and amount of sensors being installed.

NOMINAL INSTALLATION TIME

Depends upon experience of operator and type of sensors being installed.

INSTALLATION PROCEDURE

Attach sensors, use computer to set up study.

SOME STATES CURRENTLY USING THIS EQUIPMENT

Idaho, Maryland, Texas

OTHER COMMENTS

This unit can be purchased as a dual tube counter through 4 lanes of weighing in motion.

INTERNATIONAL ROAD DYNAMICS, INC.

702 43rd Street
Saskatoon, Saskatchewan
Canada S7K 3T9

SALES REPRESENTATIVE
Rod Klashinsky (306) 934-6777
FAX (306) 242-5599

MODEL NAME
Traffic Counting/Classifying System - 500 Series

GENERAL DESCRIPTION OF EQUIPMENT
Multi-lane vehicle counter/classifier. Operates in raw data or binning mode, up to four lanes classification or eight lanes of count. Available with inductive loops, Dynox axle sensors, piezoelectric sensors, or road tubes.

METHOD OF OPERATION
Unattended, remote access is available with user-supplied modem.

METHOD OF DATA STORAGE
Battery-backed CMOS RAM.

DATA STORAGE CAPACITY
68K standard. Memory can be expanded up to 960K in 128K increments to allow collection of more raw vehicle data.

VEHICLE CLASSIFICATION SCHEME
Raw data and up to 20 bins.

POWER SOURCE
12 Volt 9-1/2 amp-hr rechargeable battery or optional solar power cell

OPERATING TEMPERATURE RANGE
-40°F to 158°F (Electronics)

OPERATING VEHICLE SPEED RANGE
Dependent upon the sensor being used

DIMENSIONS AND WEIGHT OF EACH MAJOR COMPONENT
12.5" x 9" x 8.25" alum. construction - 25 lbs

MAXIMUM LENGTH OF LEAD CABLE
200 feet

PURCHASE COST OF EQUIPMENT
$1200 to $2500, depending on the model

INSTALLATION COST

Varies with type of sensors

NOMINAL INSTALLATION TIME

10 minutes with portable sensors; 1/2 day per lane with permanent sensors

INSTALLATION PROCEDURE

Tape or clamp for portable sensors; saw-cut and epoxy for permanent sensors

SOME STATES CURRENTLY USING THIS EQUIPMENT

Louisiana, New Mexico, Tennessee

OTHER COMMENTS

Other equipment from IRD includes Weigh-in-Motion axle and vehicle sensors, Automatic Vehicle Identification (AVI) toll plaza equipment

GTRI COMMENTS

Testing three configurations:

530-4B/BR/4L	Bi'Piezo-Loop-Bi'Piezo
530-4D/4P/4L	Dynax-Loop-Dynax
	Piezo-Loop-Piezo

MIKROS SYSTEMS
P.O. Box/POSBUS 20309
ALKATRANT 0005
SOUTH AFRICA

SALES REPRESENTATIVE
Johan Steyn +27 12 73 1010
FAX +27 12 73 4646

MODEL NAME
TEL-2CM Traffic Event Logger

GENERAL DESCRIPTION OF EQUIPMENT
Multi-lane vehicle classifier. Operates in raw data or binning mode. Available with inductive loops, piezoelectric sensors, or road tubes. Also available with capacitance weigh mats.

METHOD OF OPERATION
Unattended, capability to access data via telemetry is standard.

METHOD OF DATA STORAGE
Non-volatile memory.

DATA STORAGE CAPACITY
32K, expandable to 8M.

VEHICLE CLASSIFICATION SCHEME
Raw data and up to 15 bins. FHWA scheme F selectable.

POWER SOURCE
12 V sealed lead-acid battery (will operate 12 days from a fully charged, 24 A-h battery). Optional solar panel.

OPERATING TEMPERATURE RANGE
Sensors: -20°F to 140°F
Electronics: 0°F to 140°F

OPERATING VEHICLE SPEED RANGE
3 to 100 mph

DIMENSIONS AND WEIGHT OF EACH MAJOR COMPONENT
13.8" x 10.0" x 10.2" alum. casing - 26.5 lbs

MAXIMUM LENGTH OF LEAD CABLE
400 feet

PURCHASE COST OF EQUIPMENT
$2500 to $3500

INSTALLATION COST

Varies with users desire for enclosures and type of sensors

NOMINAL INSTALLATION TIME

5 to 15 minutes

INSTALLATION PROCEDURE

Attach sensors to termination box and select a typical small vehicle. The system will perform automatic calibration.

SOME STATES CURRENTLY USING THIS EQUIPMENT

West Virginia

OTHER COMMENTS

The TEL-2CM can be fitted with a weigh interface to collect axle and total weight data with either piezo or capacitance weight sensors. The PC-based software TELCOM allows the user to either directly or remotely via a modem, view live traffic information, extract data, detect violations and monitor the diagnostic features of the system.

Local USA agent: I.D.C.
P.O. Box 5397
Long Beach, CA 90805
Fax: (813) 789-0568

GTRI COMMENTS

Loop-Piezo-Loop

MITRON SYSTEMS CORPORATION

2000 Century Plaza
Columbia, MD 21044

SALES REPRESENTATIVE

Donald A. Dixon (410) 992-7700
FAX (301) 596-5119

MODEL NAME

MSC 3000 Traffic Counter

GENERAL DESCRIPTION OF EQUIPMENT

Multi-lane vehicle classifier. Operates in binning mode. Operates with inductive loops, piezoelectric sensors, and road tubes.

METHOD OF OPERATION

Unattended, data is retrieved with a separate unit, or via modem/PC (celluar available).

METHOD OF DATA STORAGE

Battery-backed CMOS RAM portable Memory Pack

DATA STORAGE CAPACITY

8K standard, 10K optional; 32K for telemetry unit

VEHICLE CLASSIFICATION SCHEME

FHWA Scheme F capability; custom schemes available

POWER SOURCE

1 each 6 Volt, 12 amp-hr rechargeable and 4 ea. 1.5 V, C-size alkaline batteries (solar or AC available)

OPERATING TEMPERATURE RANGE

-40°F to 176°F (Electronics)

OPERATING VEHICLE SPEED RANGE

0 to 99 mph

DIMENSIONS AND WEIGHT OF EACH MAJOR COMPONENT

12" x 10" x 6.5" painted stainless steel housing - 26 lbs

MAXIMUM LENGTH OF LEAD CABLE

Loop - 800'; Piezo - depends upon the type; Road Tube - 15' to 200', depending on the traffic

PURCHASE COST OF EQUIPMENT

$739 to $1600

INSTALLATION COST

Varies with users desire for enclosures and type of sensors

NOMINAL INSTALLATION TIME

5 to 10 minutes

INSTALLATION PROCEDURE

Attach sensors, program study to be conducted

SOME STATES CURRENTLY USING THIS EQUIPMENT

Arizona, Illinois, Florida, North Carolina, South Carolina

OTHER COMMENTS

Piezo unit has multiple threshold adjustments for use with any sensor. New model performs 16 lanes of volume, 8 lanes speed/classification.

GTRI COMMENTS

Piezo-Piezo.

PAT EQUIPMENT CORPORATION, INC.

1665 Orchard Drive
Chambersburg, PA 17201-9206

SALES REPRESENTATIVE

Siegfried Gassner (717) 263-7655
FAX (717) 263-7845

MODEL NAME

AVC 100 Vehicle Classifier

GENERAL DESCRIPTION OF EQUIPMENT

Multi-lane vehicle classifier. Operates in binning mode, up to four lanes classification or raw vehicle data collection. Available with inductive loops, piezoelectric sensors, or road tubes. Uses a loop-axle detector-loop or axle detector-loop-axle detector configuration.

METHOD OF OPERATION

Unattended, capability to access data via telemetry is standard.

METHOD OF DATA STORAGE

Battery-backed CMOS RAM.

DATA STORAGE CAPACITY

256K Standard. Memory can be expanded up to 4M.

VEHICLE CLASSIFICATION SCHEME

FHWA Scheme F is default setting and other types can be added up to a total of 48 bins

POWER SOURCE

12V, 30 VA solar power panel
12V, 6 VA line - DC supply
(internal battery for backup of parameter, clock, and data memory)

OPERATING TEMPERATURE RANGE

-50°F to 175°F (Electronics)

OPERATING VEHICLE SPEED RANGE

> 2 mph

DIMENSIONS AND WEIGHT OF EACH MAJOR COMPONENT

16" x 15" x 8.5" steel housing - 15 lbs

MAXIMUM LENGTH OF LEAD CABLE

The axle sensors are supplied with a 65' standard length cable. This cable can be extended up to an additional 300' by using a splice kit and coax cable. Should several sensors be installed at a road section, the cables can be concentrated in a bundled multi-conductor coax cable with a maximum length of 300'. This cable should have an outer shield for additional lightning protection. The loop wires are extended with 2 #16 shielded cables and a splice kit.

PURCHASE COST OF EQUIPMENT

Depending on quantity and memory capacity, $2200 to $4300

INSTALLATION COST

Depending on location, lane closure requirements, weather, number of lanes and systems, installation costs can vary from $1500 to $8000 per lane

NOMINAL INSTALLATION TIME

Installation of 2 sensors in one lane takes approximately 4 hours for the permanent sensors.

INSTALLATION PROCEDURE

Install permanent induction loops and permanent piezo axle detectors, lay conduits, cabinet base concrete and pullboxes as required, power and phone line connection.

SOME STATES CURRENTLY USING THIS EQUIPMENT

Alaska, Florida, North Carolina

OTHER COMMENTS

System upgradable to WIM; other electronics for WIM available:

- DAW 100 Bending Plate, permanent
- DAW 190P Portable for Piezo, capacitance mat and bending plate.

GTRI COMMENTS

Pat will be testing two sensor configurations, one with a Piezo-Loop-Piezo and the other with a Loop-Piezo-Loop.

PEEK TRAFFIC, INC.
1500 North Washington Blvd.
Sarasota, FL 34236

SALES REPRESENTATIVE
Jim Stemitz (813) 366-8770
FAX (813) 365-0837

MODEL NAME
TrafiCOMP III Model 241

GENERAL DESCRIPTION OF EQUIPMENT
Multi-lane vehicle classifier. Operates in binning mode, up to four lanes classification or eight lanes of volume. Available with inductive loops, piezoelectric sensors, or road tubes. Equipment also operates with other sensors which provide a contact closure.

METHOD OF OPERATION
Unattended, capability to access data via telemetry is standard.

METHOD OF DATA STORAGE
Battery-backed RAM.

DATA STORAGE CAPACITY
64K Standard.

VEHICLE CLASSIFICATION SCHEME
Up to 15 bins.

POWER SOURCE
6 Volt 10 amp-hr battery, can be powered by AC source or solar power depending on the options selected.

OPERATING TEMPERATURE RANGE
-40°F to 158°F (Electronics)

OPERATING VEHICLE SPEED RANGE
5 to 80 mph

DIMENSIONS AND WEIGHT OF EACH MAJOR COMPONENT
6.5" x 9.5" x 10" cast aluminum housing - 15 lbs

MAXIMUM LENGTH OF LEAD CABLE
Approximately 800 feet

PURCHASE COST OF EQUIPMENT
$1,475 to $3,000

INSTALLATION COST

Varies with users desire for type of sensors.

NOMINAL INSTALLATION TIME

10 to 20 minutes

INSTALLATION PROCEDURE

Attach loops, tubes, or piezoelectric sensors and AC or solar power (if used).

SOME STATES CURRENTLY USING THIS EQUIPMENT

Florida, Georgia, Illinois, Maryland, New York

OTHER COMMENTS

Configuration varies with number and type of sensors connectors desired.

GTRI COMMENTS

Piezo-Loop-Piezo

PEEK TRAFFIC, INC.
1500 North Washington Blvd.
Sarasota, FL 34236

SALES REPRESENTATIVE

Jim Stemitz (813) 366-8770
FAX (813) 365-0837

MODEL NAME

GK 6000 Series Counter/Classifier

GENERAL DESCRIPTION OF EQUIPMENT

Two or four-lane vehicle classifier. Operates in binning mode. Can operate with loops, piezoelectric cable, or road tubes.

METHOD OF OPERATION

Unattended.

METHOD OF DATA STORAGE

Battery-backed RAM. Can be expanded with the optional Data Module.

DATA STORAGE CAPACITY

40k (104k with 64k optional Data Module)

VEHICLE CLASSIFICATION SCHEME

Up to 14 bins

POWER SOURCE

Rechargeable 6 Volt 16 amp-hr sealed lead acid gel battery

OPERATING TEMPERATURE RANGE

-40°F to 158°F (Electronics)

OPERATING VEHICLE SPEED RANGE

5 to 128 mph

DIMENSIONS AND WEIGHT OF EACH MAJOR COMPONENT

8.25" x 8.5" x 5.75" - 6.31 lbs

MAXIMUM LENGTH OF LEAD CABLE

Up to 1000 feet. (varies with set up)

PURCHASE COST OF EQUIPMENT

$1,500 to $4,000

INSTALLATION COST

Varies with users desire for type of sensors.

NOMINAL INSTALLATION TIME

Approximately 4 hours for permanent sensors and 15 minutes to set up configuration.

INSTALLATION PROCEDURE

Attach loops, tubes, or piezoelectric sensors.

SOME STATES CURRENTLY USING THIS EQUIPMENT

Arkansas, Georgia, Illinois, New York

GTRI COMMENTS

Piezo-Loop-Piezo

TIMEMARK, INC.
P.O. Box 12947
Salem, OR 97309

SALES REPRESENTATIVE
Dan Gossack (503) 363-2012
FAX (503) 363-1716

MODEL NAME

Delta II Classifier (Lambda)

GENERAL DESCRIPTION OF EQUIPMENT

The Lambda is a multi-sensor vehicle classifier for portable or permanent installation. It will operate up to twelve sensors simultaneously including road tube, inductive loop, and piezo. The unit will count, provide binned speeds, axle or length classifications, gaps, or provide per vehicle or time-tagged event data.

METHOD OF OPERATION

The Lambda can be set up in the field with a built-in display and keyboard or via local or remote link with a computer.

METHOD OF DATA STORAGE

The Lambda has battery-backed static RAM or can use PCMCIA Series 1 Flash memory cards.

DATA STORAGE CAPACITY

The Lambda comes standard with 256K of onboard memory. The memory card allows expansion of the memory up to the size of card available, currently 20M with a 64M maximum.

VEHICLE CLASSIFICATION SCHEME

The Lambda has a 34 bin axle classification scheme based on Scheme F which can be combined to the thirteen bin standard. Also will allow user defined schemes to be loaded or processed from time-tagged events.

POWER SOURCE

The Lambda comes with a 6V - 10 amp-hour rechargeable battery which can be connected to solar or other charging unit. The unit will run for 10 days from full charge with eight loop capability.

OPERATING TEMPERATURE RANGE

The electronics except for the display will operate down to -20°C and up to 70°C (-4°F to 158°F)

OPERATING VEHICLE SPEED RANGE

The sensors will activate down to 5 mph and up to 120 mph but speeds greater than 80 mph are recorded only as such.

DIMENSIONS AND WEIGHT OF EACH MAJOR COMPONENT

The Lambda unit is 14.5" long, 8" wide, 5" high, and weighs about 18 pounds fully configured.

MAXIMUM LENGTH OF LEAD CABLE

The loop detector can handle inductance of up to 500 micro Henries and the piezo detector can handle down to a 5 milliamp signal.

PURCHASE COST OF EQUIPMENT

The Lambda ranges from $1500 for a two road tube model to $2850 for four road tube, eight loop, and eight piezo capability.

INSTALLATION COST

Installation cost will depend on the on-site enclosure, power capabilities, communication options, and sensors.

NOMINAL INSTALLATION TIME

Once all the permanent items are in place it takes less than 10 minutes to attach sensors and configure recorder for data collection.

INSTALLATION PROCEDURE

Connect sensors, power, and communications cables then go through menu to set up for data collection.

SOME STATES CURRENTLY USING THIS EQUIPMENT

Information not available

OTHER COMMENTS

The Lambda is in final testing phase and will be available by January 1994. The loop detector has low current draw without sacrificing speed accuracy. The piezo detector can be adjusted to amplify the signal as well as adjust the sensitivity.

APPENDIX C

FLOW CHART FOR THE VEHICLE MATCHING ALGORITHM OF THE ANALYZE PROGRAM

The matching algorithm used in the ANALYZE program looks at a set of three vehicles from the ground truth and three vehicles from the vendor classifier at a time. I performs a search based on time and the number of axles. The result of the algorithm is one of the following five options:

1. Match - Clear vehicle match found in time and number of axles. Comparison data entered into the classification matrix, and the length and axle spacing statistics. Ground truth (tape data) and vendor (classifier) files are both advanced one vehicle.

2. Sensor Error - Clear vehicle match in time, but not in number of axles. Classification data stored, but not vehicle length and axle spacings. Ground truth (tape data) and vendor (classifier) files are both advanced one vehicle.

3. Missing Vehicle - No vehicle match was found for a vehicle in the ground truth data. The vehicle is stored in a separate file and the ground truth (tape data) file is advanced one vehicle.

4. Extra Vendor Vehicle - No vehicle match was found for a vehicle in the vendor data file. The vehicle is stored in a separate file and the vendor data file is advanced one vehicle.

5. Split - A vehicle in the ground truth (tape data) file is found to match two smaller vehicles in the vendor data file. These are stored in a separate file, the ground truth file is advanced one vehicle, and the vendor data file is advanced two vehicles.

6. Combination - Two vehicle in the ground truth file are found to match to one larger vehicle in the vendor data file. These are stored in a separate file, the ground truth file is advance two vehicles, and the vendor data file is advanced one vehicle.

The algorithm looks only at the time and number of axles of three vehicles from both the ground truth and vendor data files. In the flow charts on the following pages, the following acronyms are used:

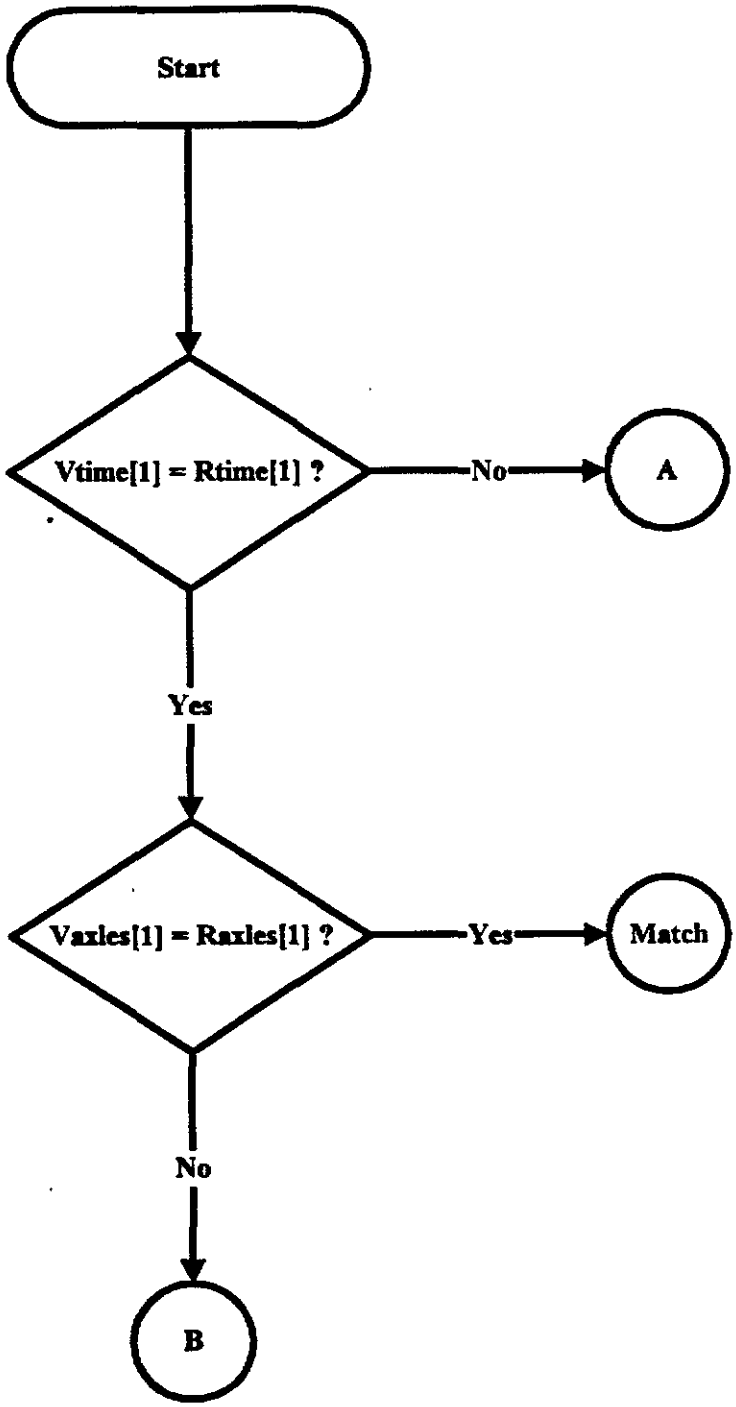
Vtime[#] - Time of vehicle # from the vendor (classifier) data file.

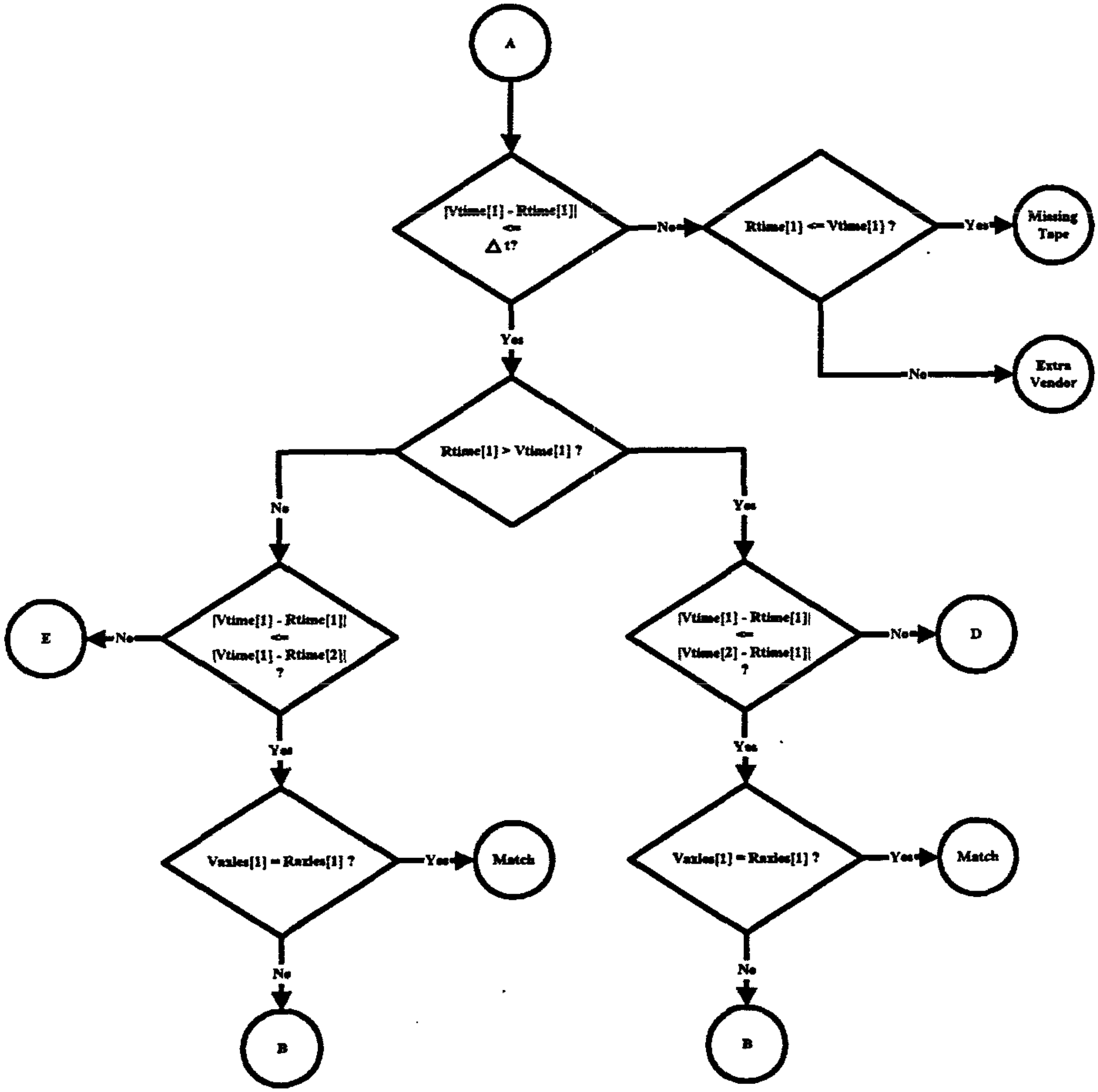
Rtime[#] - Time of vehicle # from the ground truth (tape) data file.

Vaxles[#] - Number of axles on vehicle # from the vendor data file.

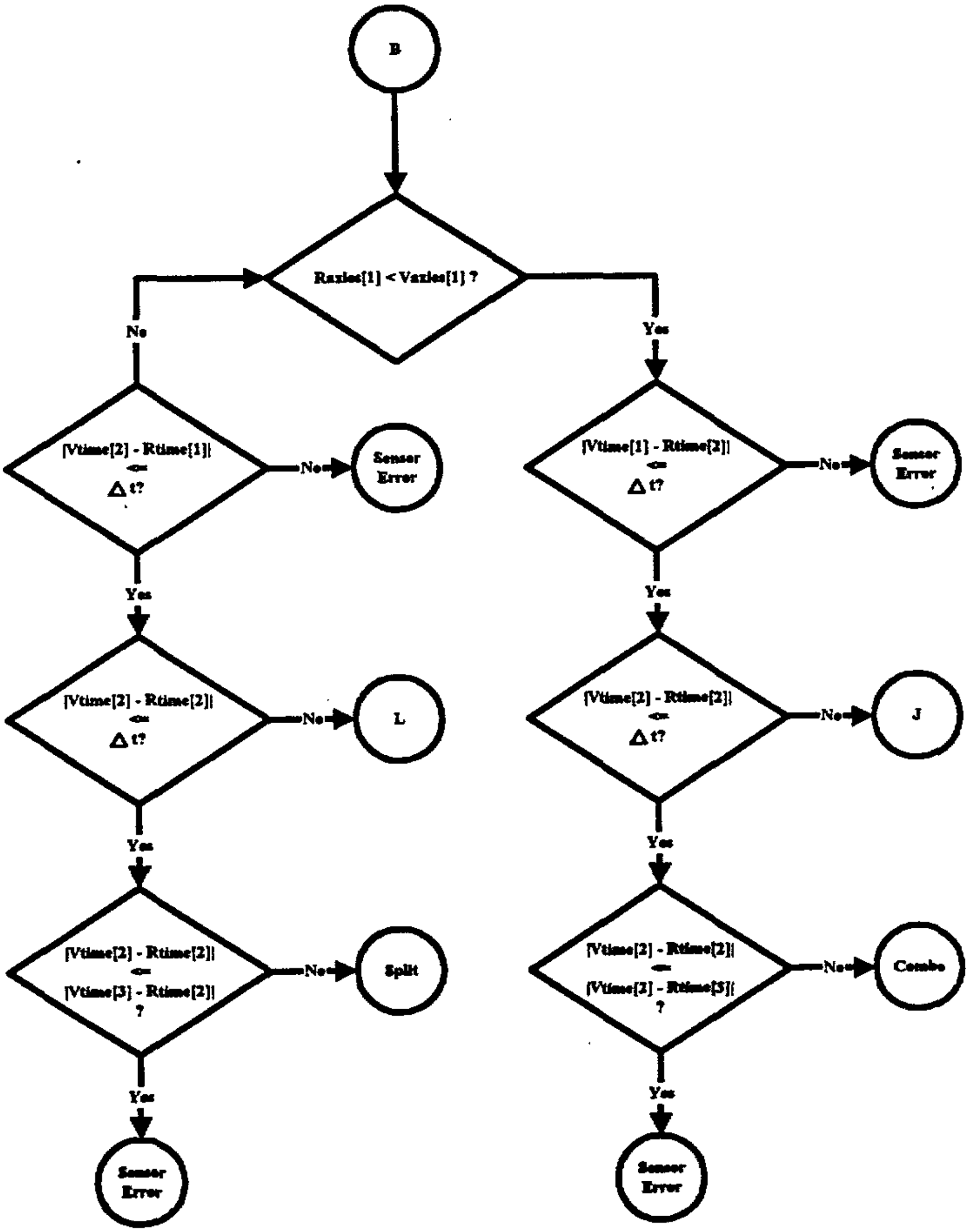
Raxles[#] - Number of axles on vehicle # from the ground truth data file.

<delta>t - Maximum time difference allowed to form match.

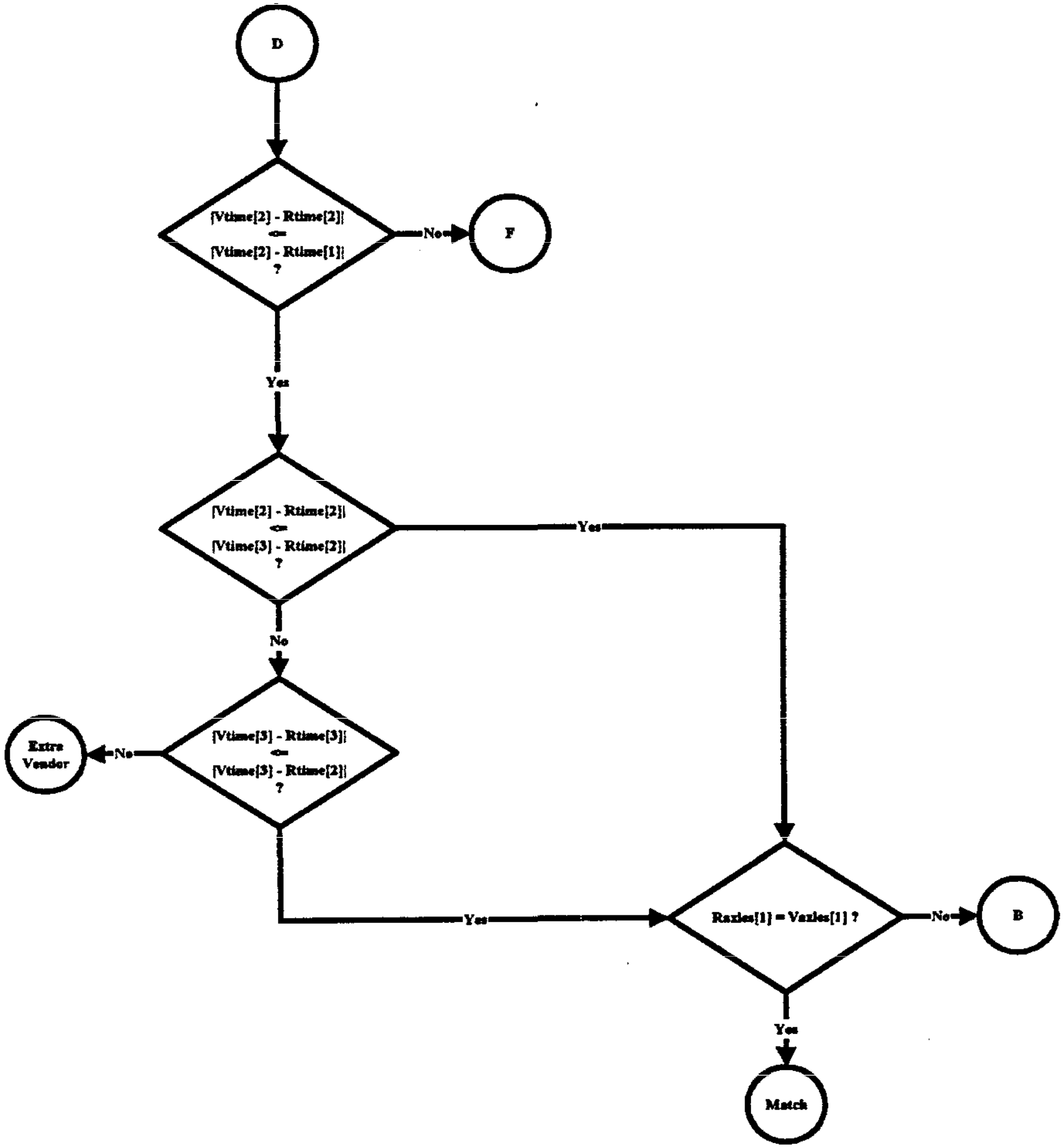

Start
Vtime[1] = Rtime[1] ?
No
A
Yes
Vaxles[1] = Raxles[1] ?
Yes
Match
No
B



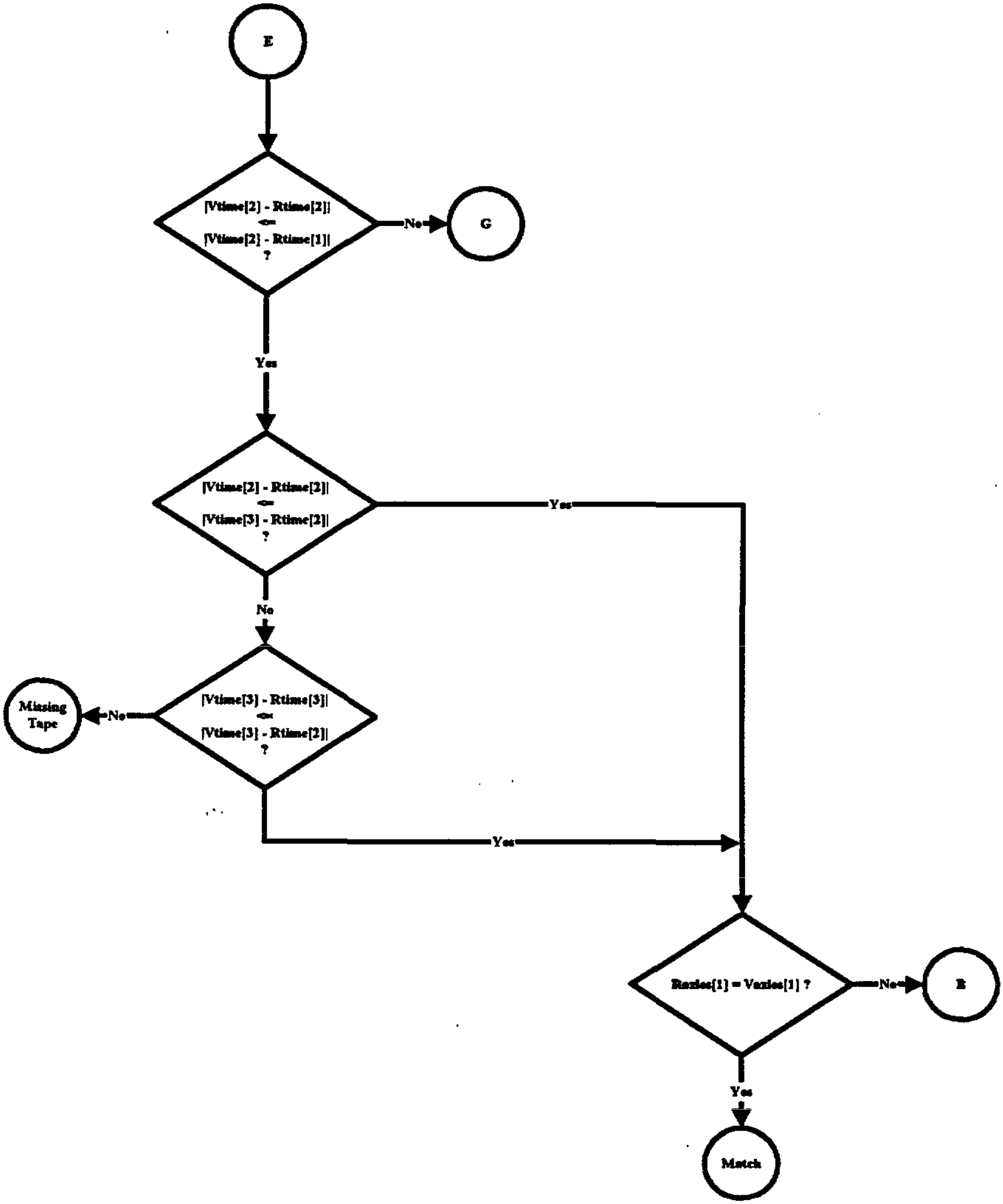
A
|Vtime[1] - Rtime[1]|
<=
Δ t?
No
Rtime[1] <= Vtime[1] ?
Yes
Missing Tape
No
Extra Vendor
Yes
Rtime[1] > Vtime[1] ?
No
Yes
|Vtime[1] - Rtime[1]|
<=
|Vtime[1] - Rtime[2]|
?
No
E
|Vtime[1] - Rtime[1]|
<=
|Vtime[2] - Rtime[1]|
?
No
D
Yes
Vaxles[1] = Raxles[1] ?
Yes
Match
No
B
Yes
Vaxles[1] = Raxles[1] ?
Yes
Match
No
B

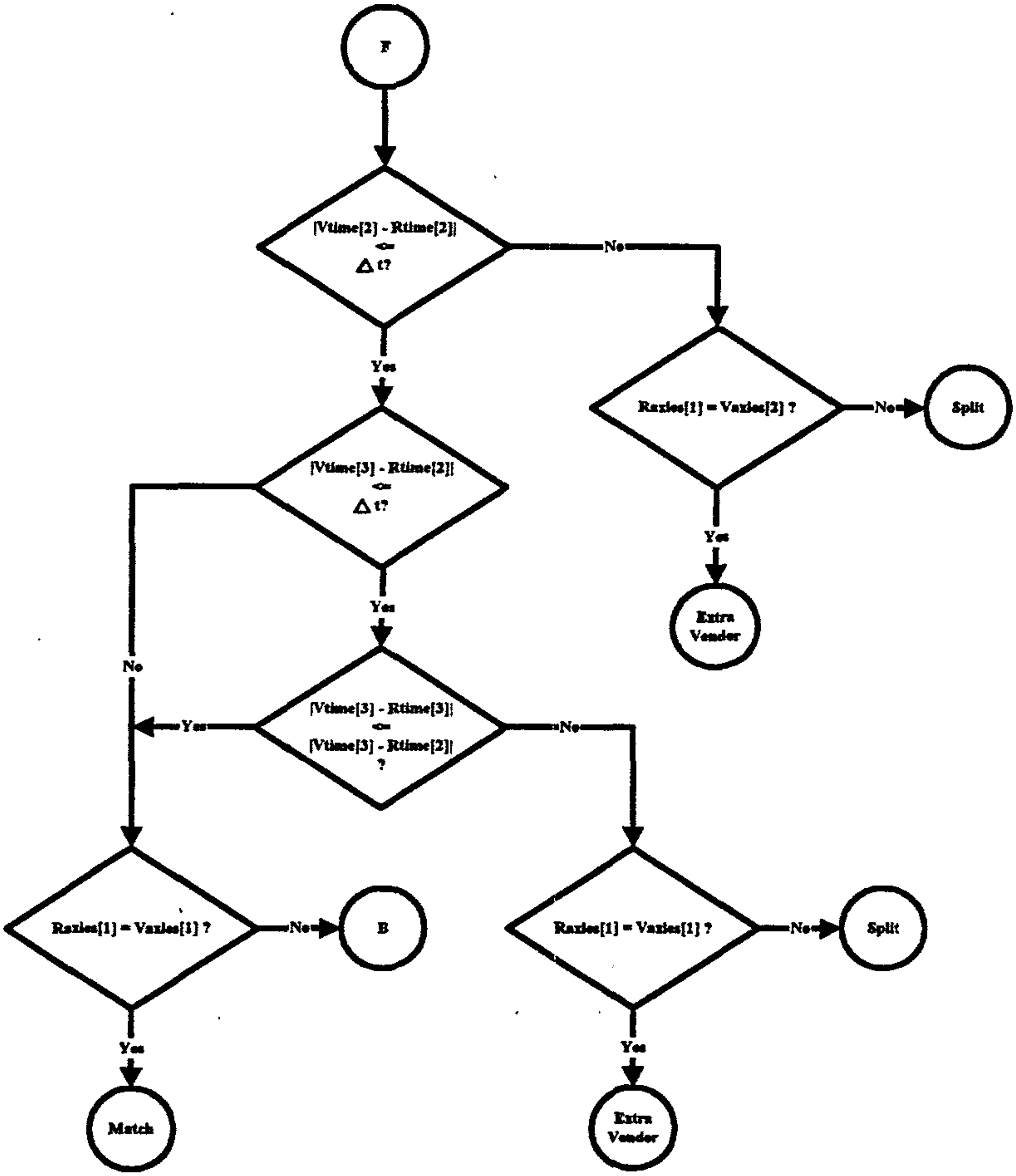


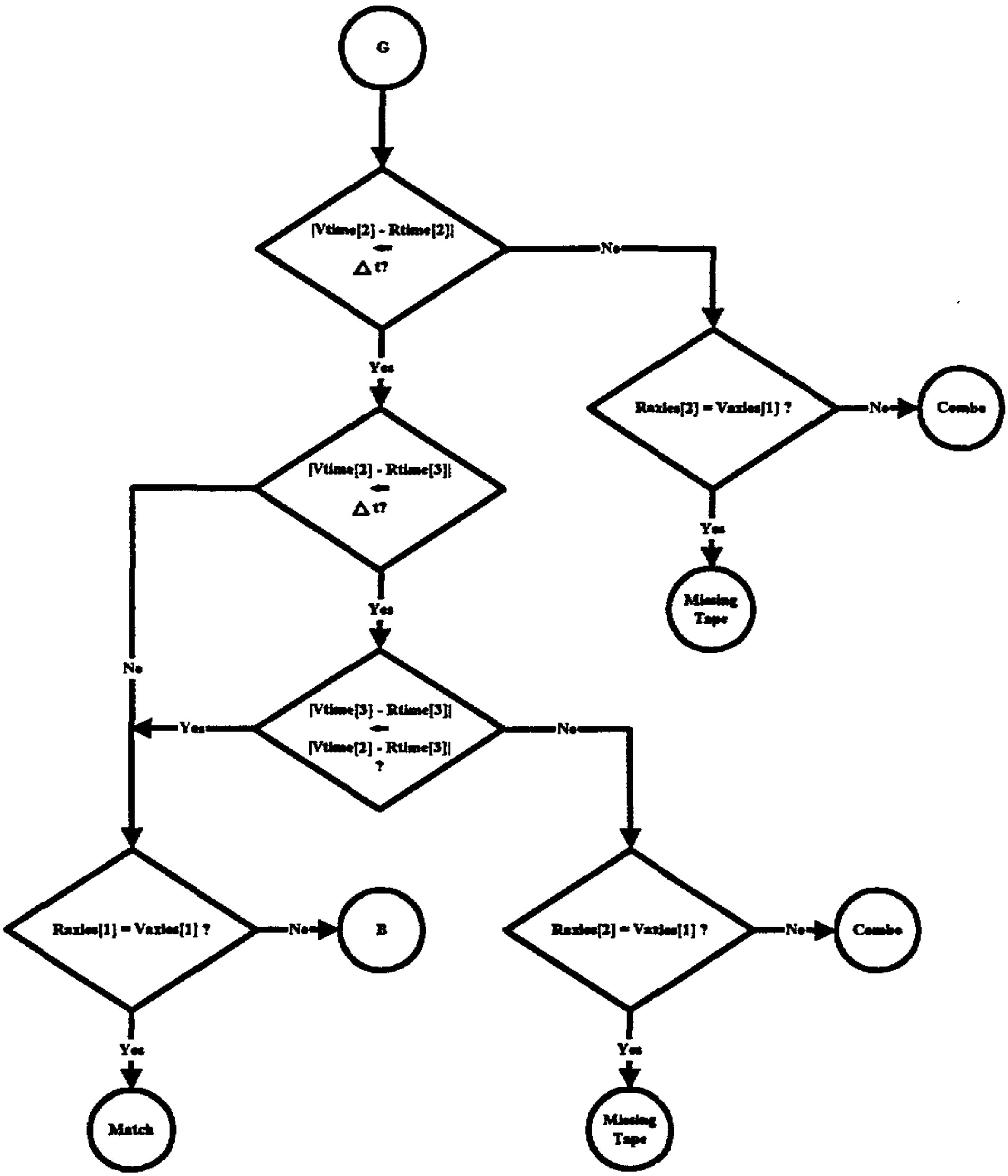
B
Raxles[1] < Vaxles[1] ?
No
Yes
|Vtime[2] - Rtime[1]|
<=
Δt?
No
Sensor Error
Yes
|Vtime[2] - Rtime[2]|
<=
Δt?
No
L
Yes
|Vtime[2] - Rtime[2]|
<=
|Vtime[3] - Rtime[2]|
?
No
Split
Yes
Sensor Error
|Vtime[1] - Rtime[2]|
<=
Δt?
No
Sensor Error
Yes
|Vtime[2] - Rtime[2]|
<=
Δt?
No
J
Yes
|Vtime[2] - Rtime[2]|
<=
|Vtime[2] - Rtime[3]|
?
No
Combo
Yes
Sensor Error

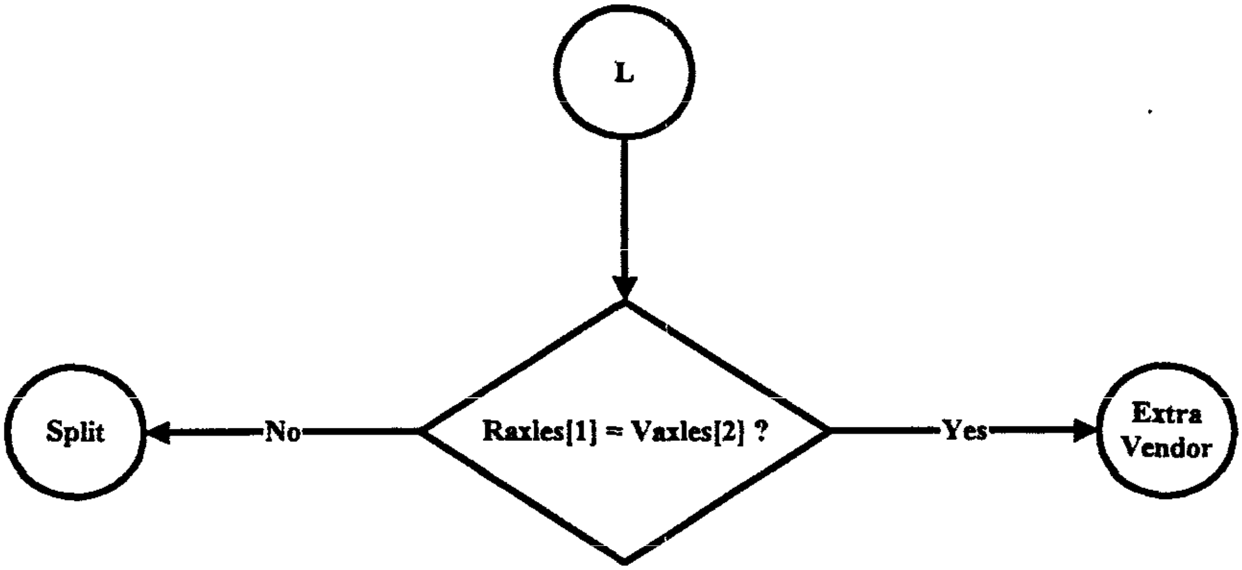


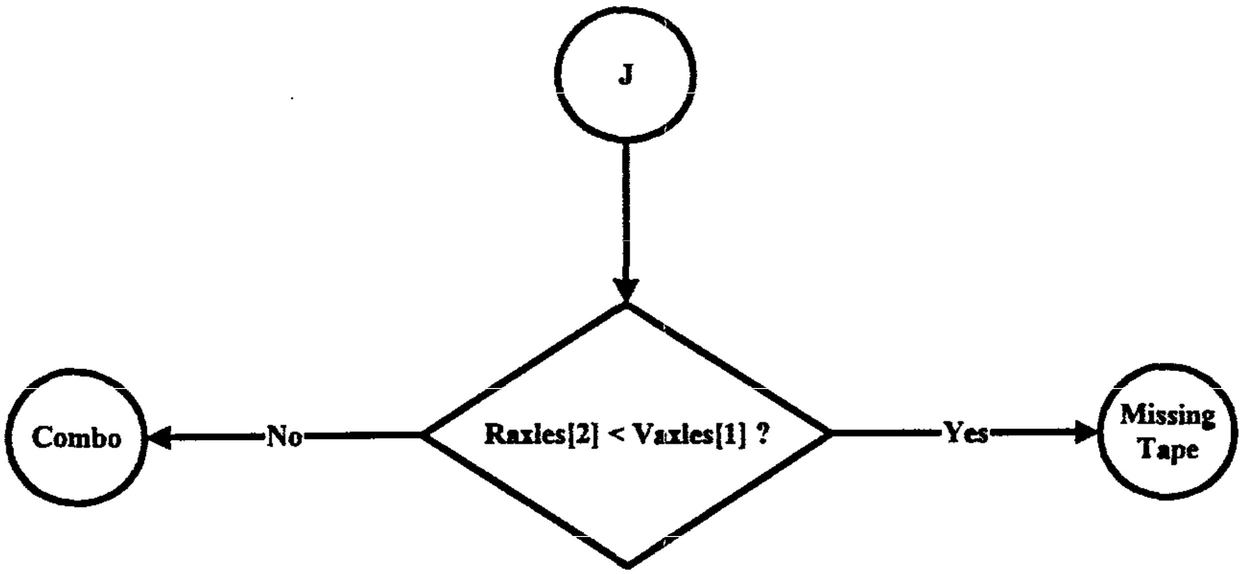
D
|Vtime[2] - Rtime[2]|
<=
|Vtime[2] - Rtime[1]|
?
No
F
Yes
|Vtime[2] - Rtime[2]|
<=
|Vtime[3] - Rtime[2]|
?
Yes
No
|Vtime[3] - Rtime[3]|
<=
|Vtime[3] - Rtime[2]|
?
No
Extra Vendor
Yes
Raxles[1] = Vaxles[1] ?
No
B
Yes
Match


E
|Vtime[2] - Rtime[2]|
<=
|Vtime[2] - Rtime[1]|
?
No
G
Yes
|Vtime[2] - Rtime[2]|
<=
|Vtime[3] - Rtime[2]|
?
Yes
No
|Vtime[3] - Rtime[3]|
<=
|Vtime[3] - Rtime[2]|
?
No
Missing Tape
Yes
Raxles[1] = Vaxles[1] ?
No
E
Yes
Match


F
|Vtime[2] - Rtime[2]| <= Δt?
No
Yes
Raxles[1] = Vaxles[2] ?
No
Split
Yes
Extra Vendor
|Vtime[3] - Rtime[2]| <= Δt?
No
Yes
|Vtime[3] - Rtime[3]| <= |Vtime[3] - Rtime[2]| ?
Yes
No
Raxles[1] = Vaxles[1] ?
No
B
Yes
Match
Raxles[1] = Vaxles[1] ?
No
Split
Yes
Extra Vendor


G
|Vtime[2] - Rtime[2]| <= Δt?
No
Yes
Raxles[2] = Vaxles[1] ?
No
Combo
Yes
Missing Tape
|Vtime[2] - Rtime[3]| <= Δt?
No
Yes
|Vtime[3] - Rtime[3]| <= |Vtime[2] - Rtime[3]| ?
Yes
No
Raxles[1] = Vaxles[1] ?
No
B
Yes
Match
Raxles[2] = Vaxles[1] ?
No
Combo
Yes
Missing Tape


L
Raxles[1] = Vaxles[2] ?
No
Split
Yes
Extra Vendor


J
Raxles[2] < Vaxles[1] ?
No
Combo
Yes
Missing Tape

APPENDIX D

MATERIAL SPECIFICATION/INSTRUCTION SHEETS

THERMOCOAX NORCROSS	NO: VB 901 D 003
PHILIPS ELECTRONIC INSTRUMENTS COMPANY INDUSTRIAL AUTOMATION DIVISION 2975 COURTYARDS DRIVE NORCROSS, GEORGIA 30071, USA	PAGE: 1/5 DATE: 06/18/92
VIBRACOAX PIEZOELECTRIC SENSORS INSTALLATION GUIDE	DISTRIBUTION: C APPENDIX: -E-BOND DATA SHEET -CONCRESIVE PASTE
	THERMOCOAX REF:
	CUSTOMER REF:

REV	DATE	AUTHOR	DESIGN	MANUFACTURING	QUALITY
0	06/18/92	GB	T. LLOYD	A. WHARTON	GB

F1001

I. Tools - Equipment

This is a non exhaustive list of tools and equipment needed for the Vibracoax sensors installation in road pavements (either asphalt or concrete):

- Traffic Control Signs
- Paint to mark pavement, rulers, strings
- Diamond blade saw
- Chisel and hammer
- Compressed air, hose
- Hot air generator or gas burner
- Temperature probe
- Duck tape
- Generator
- Electric drill with mixer paddles
- Latex rubber or leather gloves, safety glasses

II. Vibracoax Sensors

The appended figures describe the standard Vibracoax Piezoelectric Sensors:

- Class 1, for Weigh In Motion, 11.5 ft long
- Class 2, for classification, 6 ft long

The sensitive piezoelectric sensors are encapsulated inside a protective aluminum channel 1" high 1 1/2" wide, 4" longer than the sensor. The aluminum channel has lips on the bottom to ensure a perfect anchoring inside the pavement.

The encapsulation compound is either a sand epoxy or a hard polyurethane F80. This assembly can survive exposure to temperature up to 200F for half an hour without damage. The sensor is connected to a 50 ohms coaxial cable. The outer sleeve is made of PVC, the inner insulation being polyethylene. The maximum temperature the coaxial cable can survive is 170F. To protect the coaxial cable while transportation and installation, the first 3" of the cable outside the sensor are surrounded by a plastic tubing. Sensors must be electrically checked prior to and after the installation (see procedure VB 901 D 002) procedure.

III. Site Selection

The selection of the site is a critical factor for both the life of the sensor and the accuracy of the measurement. The sensor installed in the pavement is surviving not only the traffic but also of the road deformations and movements.

* It is obvious that sensors must not be installed in pavement that is uneven, deeply rutted, cracked. They must be installed in a homogeneous material (concrete or asphalt) and not in 2 adjacent layers.

The signal delivered by the Vibracoax sensors is proportional to the dynamic weight of the vehicle axles. To get a signal as close as possible to the static weigh, all vehicle vertical acceleration must be prohibited. This means:

- the pavement must be reasonably flat for 100 yards ahead of the sensor,
- avoid curves, inclines or declines,
- avoid crossings, traffic lights, railroads...,
- avoid areas of speeds less than 20mph.

IV. Sensor Installations

The installation process is to remove part of the pavement to install the sensor in it and to secure it via a grout. Best results are achieved when the sensor is flush to the top surface of the pavement. To allow a fast reopening of the highway lane, the pavement and the grout are usually heated between 90° to 100°F. The sensors are designed to easily survive this temperature but care must be taken to avoid overheating of the grout which can damage the extension cable. While curing the grout, temperature will rise by another 20° to 30°F depending on the size of the groove (the larger the groove, the larger the rise). A careful control of the grout temperature is a must.

The 50 ohms extension cable can also be damaged by bad handling. Avoid: twists, kinks, knots....

For a proper installation follow these steps:

- Step 1: Protection of the site with the required signs and cones for safe operation.

- Step 2: Mark the pavement with paint for loops and sensors. The slot size for Vibracoax sensors is 2" wide, 2" deep and 3" longer than the sensor. For Class 2 sensors, as they are only 6 ft long, be sure that they are always hit by one wheel per axle. Class 1 sensors must be hit by both wheels.

For installation with one Vibracoax sensor and two (2) loops, the sensor must be approximately 1 ft ahead of the second loop.

For installation with one loop and two (2) Vibracoax sensors, the sensors can be placed very close outside the loop. For optimum placement of the sensors, consult the electronic instrument manufacturer.

- Step 3: Cutting of the grooves with a diamond blade saw (see drawings). The depth of the groove is 2". It is critical that the grooves are as straight as possible, parallel each other and perpendicular to the axis of the lane. The groove for the extension cable must be in the center of the sensor's grooves and at the same depth.

- Step 4: Remove the pavement material between the grooves with a chisel and hammer. Particularly in asphalt pavement be careful that the slot width is not larger at the top than at the bottom. Clean and dry the slot with compressed air. Check with a sensor that the slot is large enough to accommodate the sensor with at least 1/8" clearance in all directions.

- Step 5: Without a sensor inside the slot, finish to dry the pavement with hot air or a gas burner. In cold weather it is recommended to reheat the pavement, on approximately 6 inches on each side of the slot, up to 90°F (the human body temperature is 99°F, the pavement will feel warm but not burning). With asphalt pavement be careful not to overheat and burn the asphalt to keep a good adherence with the grout.

- Step 6: Apply a layer of duck tape around the slot to keep the pavement surface clean after the installation is finished. Clean the sensor aluminum channel with an organic solvent or alcohol to achieve a good adherence with the grout. Hang the sensor from holding devices (3 to 4 per sensor) via copper wires.

- Step 7: Grout preparation - Whichever brand is selected carefully read the product data sheet and instructions. Most popular brands are: E-bond G-100, Concresive Paste epoxies and IRD methyl metacrylate. All grouts contain sand and must be thoroughly mixed and homogenized. Quantity is approximately 1.5 gallon (26lbs) for 6 ft. sensor and 3 gallon (52 lbs) for 11.5 ft sensors. It depends on the exact slot size. Temperature is an extremely critical factor for epoxy resin. If too cold, it requires a long time to cure. If too hot it starts to cure in the container or can exhibit cracks when cured. For E-bond, resin components must be at least 80°F before mixing.

While mixing with an electric drill, the temperature rises - check that temperature stays below 100°F. The optimum temperature is 90°F. The temperature can be checked with a handhold thermometer (e.g., Model HH-21 from Omega Engineering, Inc.)

While curing, the inner epoxy grout rises due to the exothermic chemical reaction. If the mixed grout is left too long in the container the temperature can rise too much leading to possible damage on the extension cable or the impossibility to pour the grout in the slot.

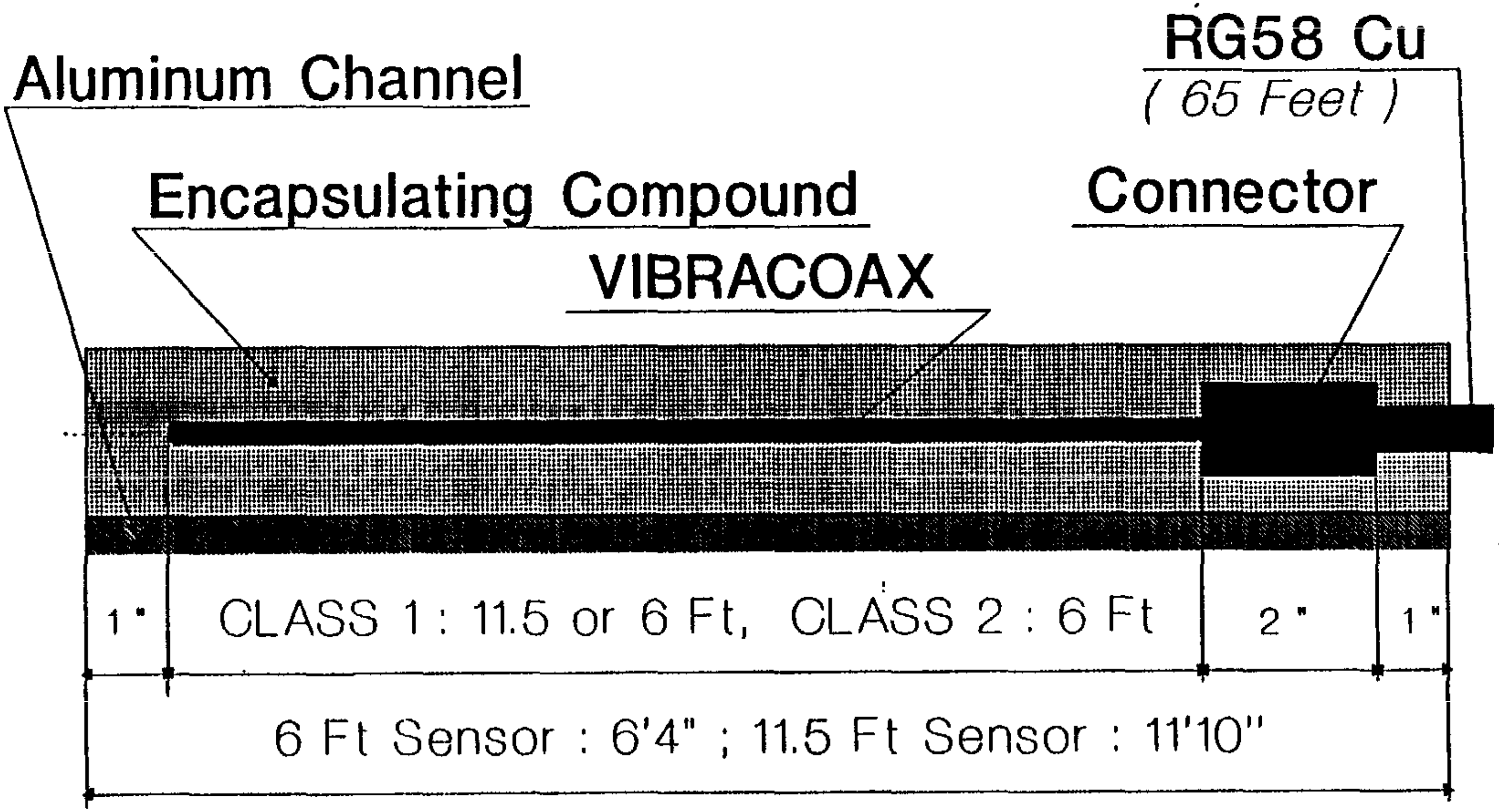
- Step 8: Pour the grout to fill the slot up to half its depth. Install the sensor flush to the top surface of the road, none of the aluminum channel protruding, (e.g., the channel a little bit below the top surface of the duck tape, in the middle of the slot). Be sure that all the sensor's bottom is resting in the epoxy grout and that there is no air pocket underneath the sensor. Lay the extension cable in its slot.

- Step 9: Completely fill the slot with the grout avoiding air bubbles. Level the top surface of the grout with a tongue depressor trial or equivalent. After the grout is mixed (Step 7) the grout must be poured inside the slot (Steps 8 & 9) as fast as possible to avoid the sand to settle down to the bottom of the container and the slot.

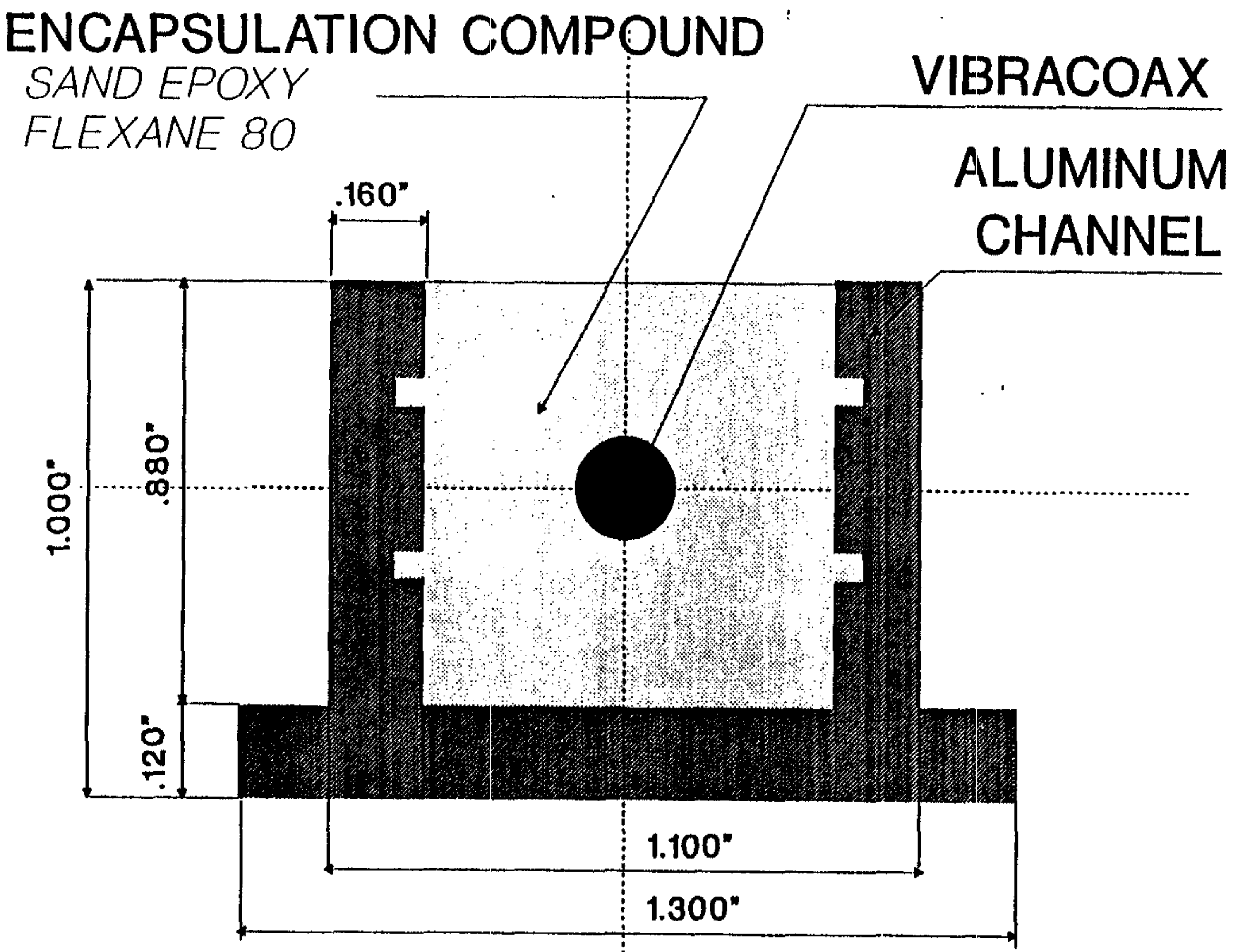
- Step 10: Allow the grout to cure. In cold weather it is possible to shorten the curing time by gently heating the pavement and the grout with hot air. Be careful not to overheat and damage the extension cable. The surface temperature of the grout must remain below 110°F. Route the extension cable in its slot and seal it with a conventional magnetic loop sealant.

- Step 11 When the grout is cured (hard enough not to move when a strong pressure is applied to it) cut the hanging wires and remove the holding fixture and duck tapes. The top surface of the grout can be smoothed with a grinder.

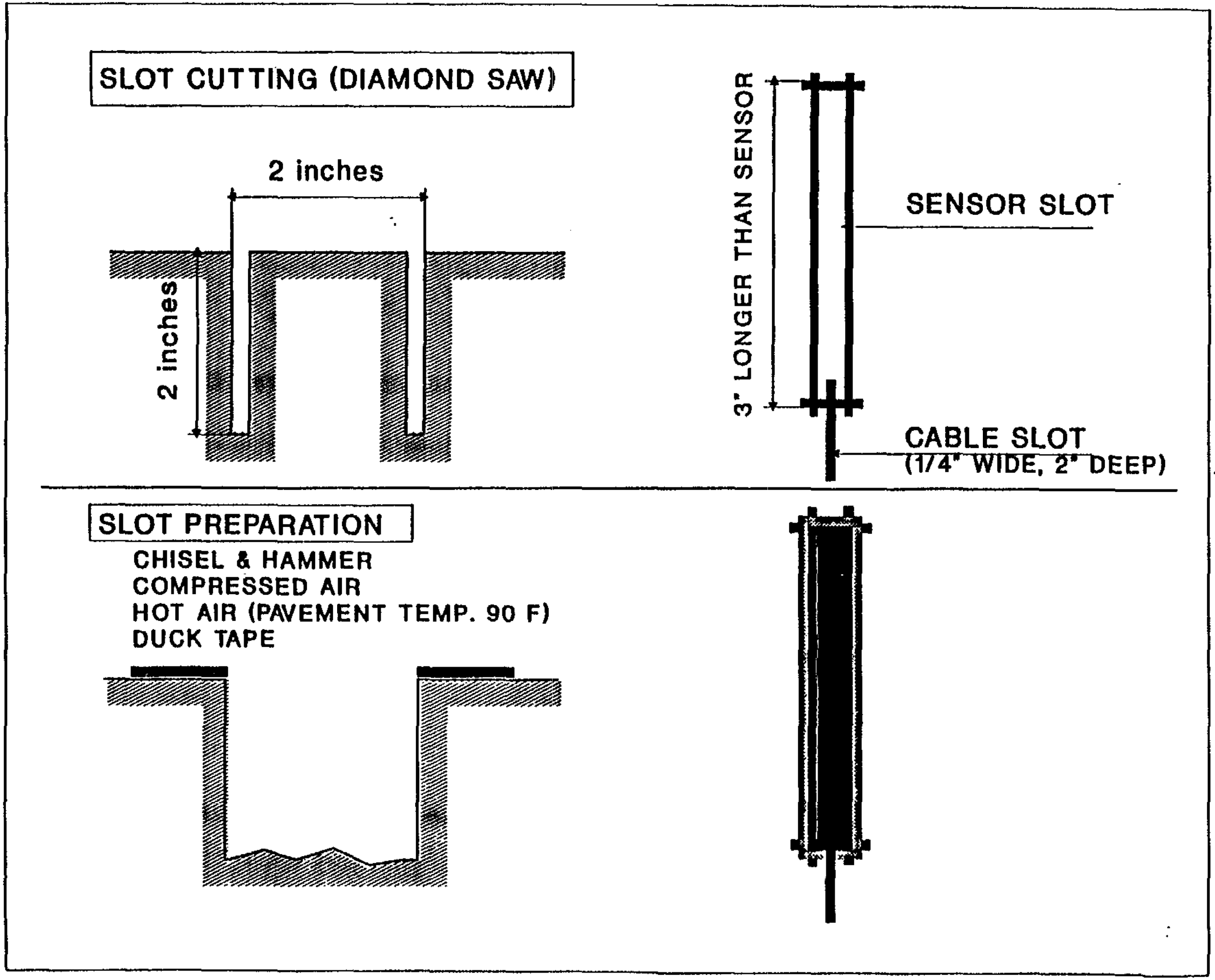
- Step 12 After routing and connection of the extension cable, check the integrity of the sensors. Remove traffic signs and allow traffic on the lane. Check the voltage generated by vehicles over the sensors. The actual reading will depend on the voltmeter model. For a truck, the reading should be around 100 mV.

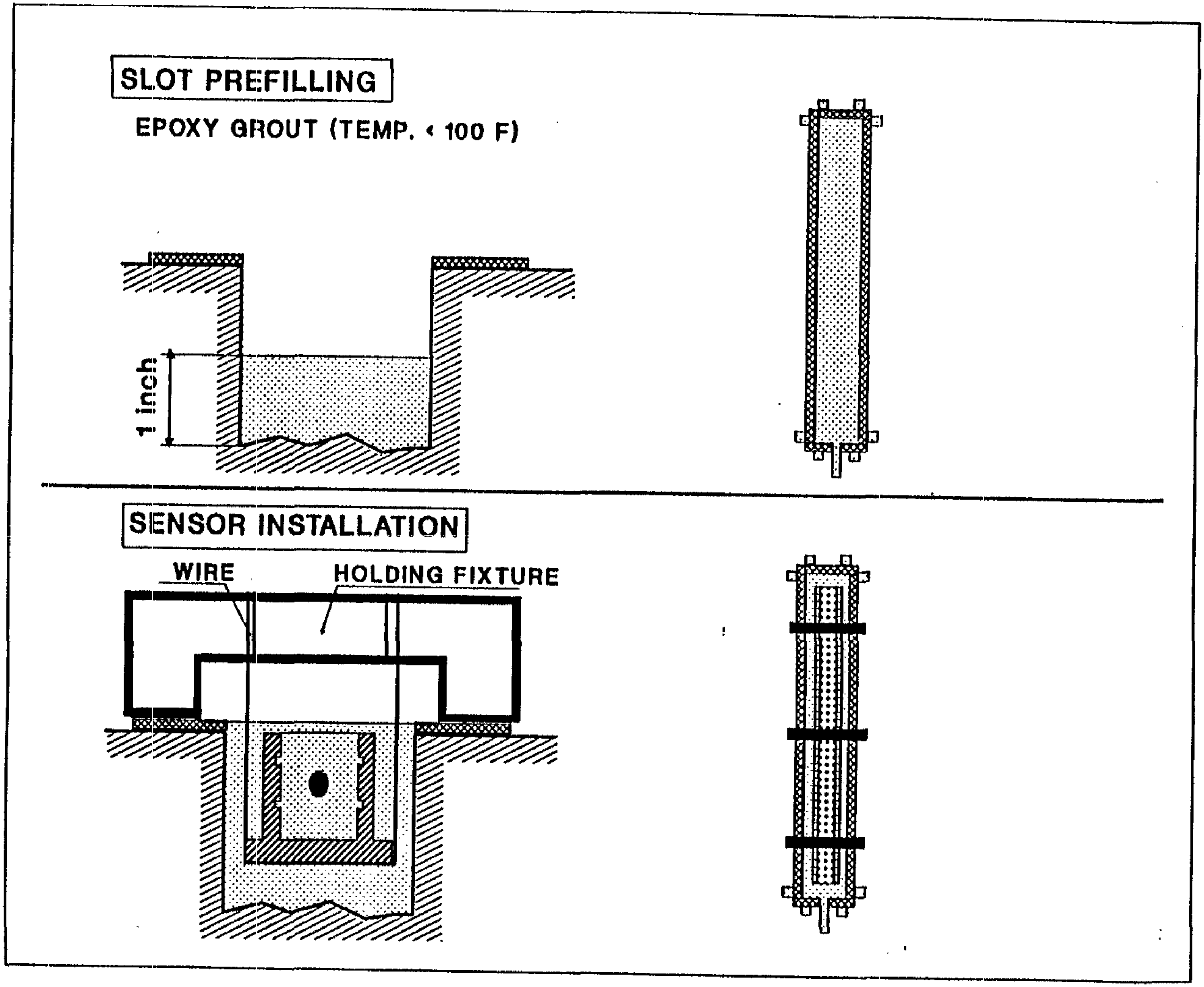


PHILIPS VIBRACOAX SENSORS



PHILIPS PIEZO SENSOR


SLOT CUTTING (DIAMOND SAW)
2 inches
2 inches
3" LONGER THAN SENSOR
SENSOR SLOT
CABLE SLOT
(1/4" WIDE, 2" DEEP)
SLOT PREPARATION
CHISEL & HAMMER
COMPRESSED AIR
HOT AIR (PAVEMENT TEMP. 90 F)
DUCK TAPE


SLOT PREFILLING
EPOXY GROUT (TEMP. < 100 F)
1 inch
SENSOR INSTALLATION
WIRE
HOLDING FIXTURE

THERMOCOAX NORCROSS	NO: VB 901 D 002
PHILIPS ELECTRONIC INSTRUMENTS COMPANY INDUSTRIAL AUTOMATION DIVISION 2975 COURTYARDS DRIVE NORCROSS, GEORGIA 30071, USA	PAGE: 1/3 DATE: 06/09/92
VIBRACOAX SENSORS FIELD TEST PROCEDURE	DISTRIBUTION: APPENDIX:
	THERMOCOAX REF: CUSTOMER REF:

REV	DATE	AUTHOR	DESIGN	MANUFACTURING	QUALITY
0	06/09/92	GB	AW		GB

F1001

- Vibracoax sensors are rugged sensors and if installed properly in a pavement they can last for several years delivering good signals.

Nevertheless construction work on highway is not always easy and particularly the use of excessive heating with powerful gas burner can damage the coaxial extension cable.

Then we recommend that immediately after the installation the electrical characteristics of the Vibracoax sensors are thoroughly checked: insulation resistance, capacitance, generated voltage (in this order).

I. INSTRUMENTS

- o Insulation Resistance: ohmmeter capable of reading at least 20 Megohm.
- o Capacitance: Capacitance meter capable of reading at least 30 nanofarad.
- o Voltage: voltmeter capable of reading millivolts D.C.

II. TESTS

All the electrical tests are done between the core and the screen of the extension cable.

II.I Insulation Resistance (IR)

The insulation resistance must be found higher than 1,000,000,000 ohms (1,000 Megohm) on new sensors.

Practically many multimeter read up to 20 Megohm. If the IR is higher than 20 Megohm the sensor passes the test.

If the IR is lower than 1,000 ohms this means the extension cable was burnt by a severe heating. (the internal insulation material melts and the cable core moves toward the screen resulting in a short-circuit). Locate the defect and repair the cable if possible or the sensor has to be replaced.

II.2 Capacitance (C)

Sensors are made of 2 components:

- o Vibracoax piezoelectric cable: 2,600 pF/ft. (8500 pF/m) typical.
- o RG58 extension cable: 33 pF/ft. (110 pF/m) typical.

Standard sensors with 65 feet of extension cable will exhibit:

CL2 (6 ft): about 18nF
CL1 (11.5 ft): about 32nF

A reading lower than 2nF will tell a rupture in the extension cable continuity (core or screen).

Capacitance measurements are valid only on well insulated sensors

III.3 Voltage Generation Test

The Vibracoax piezoelectric sensors are generating a voltage when submitted to a pressure variation.

When installed in the highway pavement, a pressure variation on a sensor (vehicle passing over, hammer shock, jumping on it) will create a peak voltage of 30 to 100 mv for less than a second but easily visible on a DC Voltmeter connected at the end of the extension cable.

SCHUL INTERNATIONAL

TECHNICAL BULLETIN

READY-SET PAVEMENT GROUT

DESCRIPTION: READY-SET Pavement Grout is an epoxy compound designed for use in sealing sensors into roadway surfaces. It can be traffic ready in 1/2 hour if all of the recommendations in this report are followed. It is supplied in a kit which contains:

A) 5-gallon pail of graded aggregate.

B) 1-gallon pail of epoxy (Part A).

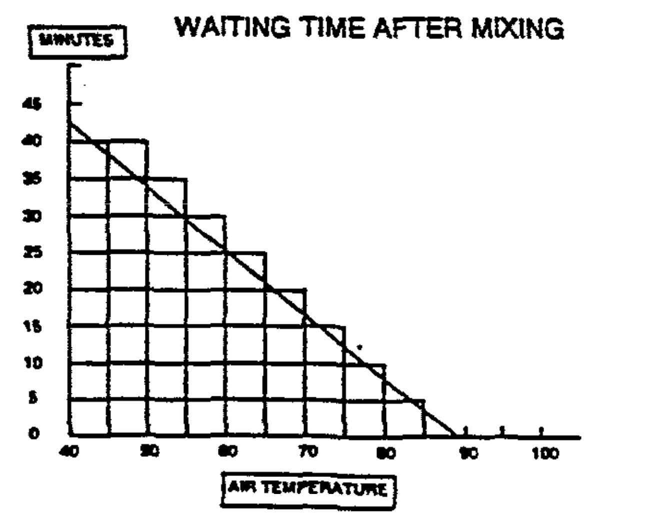
C) 1-quart can of hardener (Part B).

When cured, the epoxy product produces an environment for the sensor which protects it against snow, ice, rain, salts, chemicals, abrasion and temperature extremes.

APPLICATION: READY-SET Pavement Grout is supplied in a kit which measures 1.625 gallons or 375 cubic inches. This amount of material is sufficient to set one 6'4" sensor. Two kits are required to set an 11'10" sensor.

USING THE KIT: As mentioned in the description, the kit contains one 5-gallon pail, one 1-gallon pail and one 1-quart can. Open the 1/2 full gallon of epoxy. Remove the lid from the quart can of hardener and pour the hardener (Part B) into the epoxy (Part A) contained in the gallon pail. Stir them together for 2-3 minutes, either with a stirring stick or with power stirring. Take care to scrape the sides and bottom of the 1-gallon pail during the 2-3 minutes of mixing. Use the stick which is provided for this purpose. After thoroughly blending the epoxy with the hardener, transfer this blend immediately into the 5-gallon pail of graded aggregate and begin power agitation. Continue blending the aggregate with the blended epoxy for 2-3 minutes. Once again, scrape the walls and bottom of the aggregate mix to insure a full wetting of all of the aggregate.

Know the air temperature. A thermometer is a handy tool for this purpose AND it should be used. Consult the following graph to determine the waiting period necessary before potting the sensors in their prepared groove. The graph shows the approximate waiting time and could vary upward in time if the wind velocity is over 5 MPH. For example: If the air temperature is 60°F., the graph states that you should wait 25 minutes before potting the sensors. Adding the time that it takes to do the potting, the epoxy will be ready for traffic in 1/2 hour.



TRICKS OF THE TRADE: The reason for allowing the epoxy, hardener and aggregate mix to wait for some period of time is to allow the exothermic heat of reaction to develop to a temperature of 90°-100°F. The colder the air temperature; the longer it takes to do this. Keeping the full reaction mix in the pail, allows the reaction to proceed as indicated.

A glance at the graph will show that at air temperatures above 90°F., there is no waiting period. Ideally, READY-SET Pavement Grout should be stored at 80°F at all times prior to use. The 80°F. temperature (use the thermometer) is high enough to safely mix, then use the system without further waiting since the actual mixing develops frictional heat and could bring the temperature to 90°F. rapidly.

Finally, heat applied to the cut groove from a propane torch will both dry and heat the groove. Carefully lay your hand upon the pavement next to the groove. If the pavement feels slightly hotter than your hand, the temperature will be slightly above body temperature. At this point, stop heating and begin potting. Simply pour, spread and finish the grout with appropriate tools (trowel, etc.) to a smooth finish that is flush with the surface of the highway.

NOTE: Always follow the sensor manufacturers recommendations for positioning the sensor and any other techniques of importance which may be suggested in their presentation.

PROPERTIES @ 77°F.

	Typical Values	ASTM Method
Shelf Life	2 years	N/A
Mix Ratio	4.6 : 2 : 20 (A : B : Aggregate)	N/A
Viscosity	Pourable	N/A
Pot Life (Full Mix)	28 minutes	N/A
Hardness (Shore)	87-D to 90-D	D-2240
Tack-Free (10 min. wait) 77°F.	1/2 hour	N/A
Tack-Free (30 min. wait) 55°F.	1/2 hour	N/A
Compressive Strength	8,000-10,000 psi	D-695
Bond Strength	500 psi	C-321
Water Absorption	0.30%	D-570

The values reported are believed to be a true representation of this system. Your evaluation, of course, will be necessary in order to determine the suitability of this system for your specific application.

CAUTION: Can cause skin irritation. Wear protective clothing. Wash contaminated skin with soap and water – NEVER SOLVENT. In case of eye contact, flush with water for 15 minutes; contact a physician immediately.

FOR PROFESSIONAL USE ONLY

INTERNATIONAL ROAD DYNAMICS INC.

CORPORATE OFFICE: 702 43rd Street East, Saskatoon, Saskatchewan, CANADA S7K 3T9
Telephone: (306) 653-6600 Facsimile: (306) 242-5599

AS-475 AXLE SENSOR GROUT
- DIRECTIONS FOR USE -

GENERAL

IRD's AS-475 Sensor Grout is a resin based grout. Specifically designed to embed permanent axle sensors in asphalt or portland concrete pavements.

The grout serves two purposes:
a) Adhesive bond between the sensor and road pavement material
b) Isolation medium between the sensor and road pavement.

AS-475 grout comes pre-mixed in convenient sized pails and is packaged in kit form to correspond with the sensor type to be installed: **AS-475-1 *(20kg)*, AS-475-2 *(15kg)*, AS-475-3 *(5kg)*.** The grout consists of a resin material mixed with fine mineral aggregate. The aggregate provides strength, consistency, and acts as a heat sink during the curing reaction *(The curing of the resin liberates heat. The sand absorbs excess heat to prevent the resin from cracking).*

Curing of the grout begins once the catalyst *(the white BPO-Benzoyl Peroxide Organic)* powder has been added. The reaction time for curing is dependent on external temperature conditions. However the curing time can be controlled by adjusting the amount of BPO catalyst added to the grout for various temperature conditions.

DIRECTIONS FOR USE

AS-475 grout comes with pre-packaged vials of BPO as follows:

Grout Kit	BPO Supplied
AS-475-1 20kg *(12 US quarts)*	6 Vials, 33g each
AS-475-2 15kg *(9 US quarts)*	3 Vials, 33g each + 3 Vials, 17g each
AS-475-3 5kg *(3 US quarts)*	3 Vials, 17g each

Depending on the installation temperature, you use either 1, 2, or 3 of the vials per pail of grout. Working time *(pot life)* will be between 10 and 50 minutes.

INTERNATIONAL ROAD DYNAMICS INC.

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Telephone: (306) 653-6600 Facsimile: (306) 242-5599

TEMPERATURE:

°F	°C	Vials/Pail of Grout
<55	<13	3 x 33g - 10 kg *(6 qt)* Pail
		3 x 17g - 5 kg *(3 qt)* Pail
56-75	14-24	2 x 33g - 10 kg *(6 qt)* Pail
		2 x 17g - 5 kg *(3 qt)* Pail
>75	>25	1 x 33g - 10 kg *(6 qt)* Pail
		1 x 17g - 5 kg *(3 qt)* Pail

MIXING DIRECTIONS

Equipment Required:

- Electric drill
- Mixing paddle for drill
- Grout and BPO
- Well ventilated space

Procedure:

a) Open pail and start mixing using the drill and mixing paddle. Mix until all fine aggregate at the bottom of the pail is thoroughly mixed in and the grout takes on a smooth texture (no lumps).

b) Add appropriate BPO as indicated in *"Directions For Use"*.

c) Mix thoroughly for an additional 2 minutes.

d) Apply grout - *(10-50 minutes working time)*. Ensure no voids or air bubbles become trapped in the grout - *(45-60 minutes cure)*.

e) Traffic may be allowed to pass after surface is tack free.

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Telephone: (306) 653-6600 Facsimile: (306) 242-5599

Precautions:

Read Material Safety Data Sheets (MSDS) as provided

a) Avoid breathing grout vapors.

b) Do not use in enclosed areas. Always ensure adequate ventilation.

c) Do not use BPO powder near heat or open flame. BPO is a very powerful oxidizer *(it supplies its own oxygen when burning).*

d) Use dust mask if required to prevent inhalation of BPO. Wash skin if contacted by powder.

e) Always wear appropriate protective clothing, boots, coveralls, gloves and safety glasses.

CLEAN-UP

Wash any uncured grout from tools and equipment with water.
After curing, grout can only be removed by mechanical means.

AUTOLOGGER Vehicle and Axle Sensors

To: Glen Champion

DOCAL ASSOCIATES INC.
Suite 211, 264 Amity Road
Woodbridge, CT 06525
Tel. 203-387-3218
Fax: 203-387-4957

January 15, 1993

Mr. Jerry Schiff
Diamond Traffic
FAX 613-843-0270

Dear Jerry:

Please find attached copies of the installation instructions from the product brochure for the Autologger range of piezo axle sensors. Towards the back of the packet are two sections titled "Maxi Replaceable Sensor" and "Maxi Replaceable Housing" where you would find these installation instructions for the housings and the sensors. These installation instructions are written for someone who is generally familiar with the installation procedures for different types of piezo axle sensors. It is important that the instructions be carefully read and understood prior to the actual installation. Please be sure that if there are any questions or concerns that we are contacted well in advance of the installation date.

There are several points that you should keep in mind regarding the installation of the specific sensors that we have shipped to Glenn Champion, at GA Tech for installation in the Accuracy of Traffic Monitoring Equipment Project.

1. We recommend the use of E-Bond G-100 Epoxy or of Traffic Coil Adhesives Epoxy.

2. The installation instructions discuss the need to drill through the floor of the housing and install rawl plugs into the road surface below. It has been found that the use of rawl plugs is not necessary and in fact that they can reduce sensor life as they loosen up and begin to come up from the sensor floor.

3. It is very important that the epoxy used to install the housing be allowed to set very hard before installing the sensor element into the housing. This will prevent the housing walls from splaying outward resulting in a loose sensor fit. In this manner, when the sensor is installed into the housing it will be a tight fit and may require the use of a rubber hammer or mallet.

4. Please note that the installation instructions indicate that the height of the fitted sensor above the housing surface should be 3 mm. This is not the case with the sensors that were shipped for this project which are designed to be flush fitting, ie there is no protrusion of the sensor over the housing. This is a design improvement to reduce the possibility of something like a snow plow or muffler dragging the sensor element out of the housing.

INSTALLATION NOTES

Maxi Replaceable Housing:

The highway surface should be flat and free from excessive irregularity. Dishing or bowing should be limited to 1cm over the length of the housing.

Mark out two straight parallel lines 60mm apart, with a tolerance of better than ±5mm across the full width of the lane. Offer up the sensor housing to the desired position and mark out its length plus 50mm across the parallel lines, ensuring that they are perpendicular to the traffic flow.

Aerosol paint and the use of a straight edge as a masking device will be found to be a good method.

Mark out a further two parallel lines, 25mm apart, using the centre line of the previous lines, running from the nearside of the housing to verge of the road or kerbside. Cut clean vertical slots on these four marks to a depth of 50mm, -0 +5mm, using a roadsaw.

Chisel out the gaps between the slots to this depth, ensuring that the base of the rectangular cavity thus created is reasonably smooth, and never less than 50mm. If a double cutter is available, chiselling of the narrower slot may not be necessary to create the conduit channel.

Dam off the conduit slot/sensor slot interface to prevent adhesive loss into this gap. Plasticine or card is adequate.

Remove the spoil from the channels. Blow out all loose debris with compressed air. If a water lubricated cutter has been used, the slot should be dried with a hot air blower. The slots must be clean and dry to ensure that adequate adhesion is obtained.

Ensure that the conduit edges are free from burrs which could damage cable. Install the conduit with one end level with the commencement of the wider channel. The remaining conduit is buried under verge-side soil or kerbing, with its other end passing into the weatherproof box containing signal processing equipment via a weather-proof gland. Conduit radii of less than 200mm should be avoided otherwise it may be found that cable passage will present difficulties.

Conduit materials may vary, but a smooth internal diameter of not less than 10mm is necessary. 12mm copper piping or 'microbore' can provide signal screening, durability and easy cable passage.

Screw metal plates of approx 100mm length and 50mm width at right angles across the housings at intervals of approx 750mm. Small self tapping screws are adequate. The plates suspend the top surface of the housing flush with the highway surface when the housing is set into adhesive.

Observing all Health & Safety and Manufacturers instructions, wipe the outside of the housing with a cloth wetted with hydrocarbon solvent to remove dirt and grease.

Thoroughly mix the two components of the mounting adhesive, observing the maker's safety and handling instructions. An air driven stirrer will be found useful. A two component 4KG pack is adequate for installation on one housing of up to 3.5 metres.

Starting at one end, and gradually working across the lane, pour adhesive into the slot to a depth of 15mm. Place the housing into the channel with the nearside end up to the dam into the conduit slot. Place weights on the mounting plates to hold the housing down against the floating action of the adhesive, and pour adhesive further into the gap between housing and slot. This should be done slowly and with care to avoid cavitation. There should be sufficient spew or excess to ensure the gap is totally full, but this should not be allowed to flow into the housing channel. It should be noted that the retaining screws must be downstream of the traffic flow, i.e. sloping away from the direction of traffic and not sloping into it.

INSTALLATION NOTES

Maxi Replaceable Axle Sensor: Piezo Electric

These sensors should only be installed in Gates Maxi Housings.

Insert the sensor and tap into its seated position. If this is done from the centre out, in each direction, any possibility of kinking the sensor can be avoided. The sensor should be a tight fit, but excessive force should be unnecessary.

Check the height of the fitted sensor above the housing surface. This is specified at 3mm. A vernier calliper gauge will be found useful. Higher protrusion indicates imperfect seating and should be rectified before proceeding further: check for foreign matter between the sensor and housing. Ensure that flexing at cable exit is zero as this will flex break the feeder cable.

Tighten down the retaining screws. A battery powered electric screwdriver makes this quicker. Fill in the screw holes with plasticine.

Fill the space at each end of the sensor, after dam removal, with further plasticine. If particular care is taken at the cable exit end, and the plasticine pushed into the conduit opening, further sealing of the cable can be achieved to help prevent ultimate moisture ingress.

Replacement is straight forward. Remembering to attach a leader cord to the old signal cable can save a lot of frustration! Plasticine sealer should again be used to re-seal both screw heads and the ends of the channel. With experience, replacement can be readily achieved in 5-10 minutes.

The securing bolts in the base of the housing should be checked for protrusion and security whenever sensors are replaced. These bolts must be installed flush or slightly below the base, failure to do this will result in reduced sensor life.

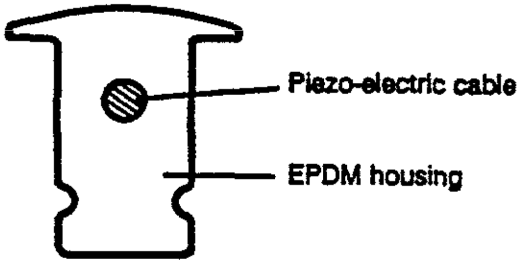
It will be necessary to allow the installed sensor to "bed-in". This is achieved by allowing traffic to flow freely over the installation for a period of time depending on flow rates.

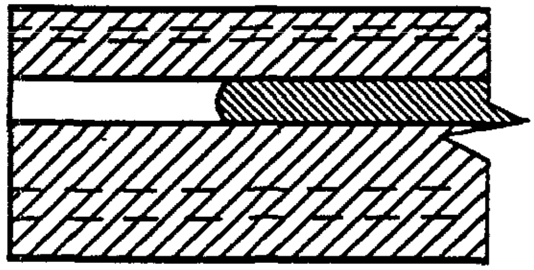
This will achieve a much cleaner signal for tuning purposes.

TRAFFIC 2000

Golden River Instruments, Inc.
7352 Dartford Drive, #7,
McLean, Virginia 22102
Tel 703 847 6645 ;ax 703 847 5648

Single Piezo-electric Cable Sensor





Construction

The sensor comprises a rubber extrusion developed by TRAFFIC 2000 for direct bonding into a road surface. Made from high-performance EPDM, it is impervious to attack from acids, alkalis, salts and ultraviolet. This extrusion houses a pressure-sensitive co-axial cable which produces a voltage when compressed or deformed by impact. The output is used to operate a wide variety of measurement and analysis equipment.

Applications

- A single sensor is used directly for axle counting, enabling simple traffic flow data to be obtained. It also acts as a vehicle detector for car park barrier actuation or security control. It is sensitive to all classes of vehicles, and the output can be used to give an indication of axle weight.
- In conjunction with an inductive-loop presence detector, a single piezo-electric sensor will allow further information to be deduced, such as the number of axles per vehicle.
- Two sensors placed in the road at a known distance apart give a very accurate means of speed measurement. This information is of value in traffic flow surveys, and is also used for speed limit enforcement purposes. Red light violation is detectable, the sensors being used to trigger a camera and to add a speed reading to the photograph.
- If an inductive-loop detector is used with a pair of sensors, complete vehicle classification is possible. This arrangement enables the wheelbase or axle spacing of each vehicle to be calculated, in addition to its speed and approximate weight.
- For some speed law enforcement purposes, two or even three speed measurements are required. In these cases three sensors in parallel are sufficient, allowing a simple and cost-effective installation.
- Other groupings of two or three sensors in various arrays are used to obtain data on, for example, the position of vehicles across the carriageway, width of vehicle, and transverse weight distribution.

Specification

Sensor dimensions

Section widths:	12*, 14*, 16, 18*, 20 mm (* available ex stock)
Depth:	to suit 25 mm minimum slot depth (Other sections can be supplied to customer specifications.)
Lengths:	2, 2.5, 3, 3.5, 4, 5, 6, 7, 8, 9 m. (Other lengths to order.)

Piezo-electric cable

Piezo-electric polymer:	polyvinylidene fluoride (PVDF or PVF2)
Piezo-electric coefficient:	3pC/N at 23°C
Capacitance:	850 pF/m
Temperature range:	- 40 to + 70°C

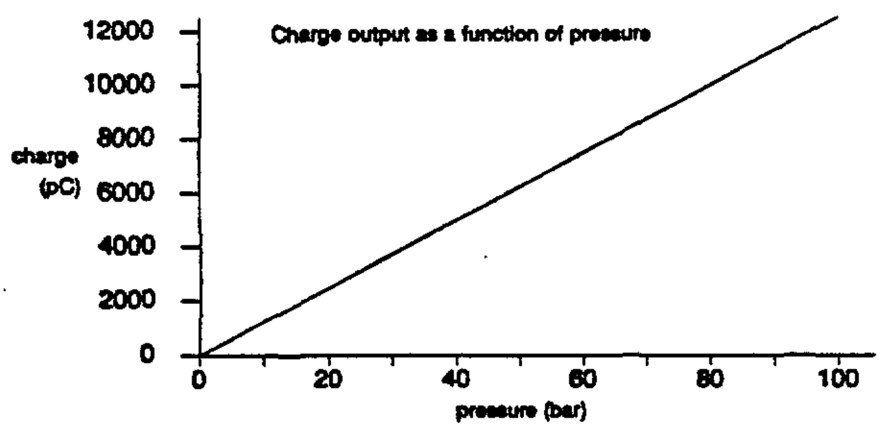
Features: A robust and close-tolerance transducer which provides reliable and repeatable signals over a wide temperature range. It is self-screening, and has a proven performance in many environments.

Signal cable

4mm diameter co-axial cable - see Data Sheet No. 15 for full specifications.

Its joint to the piezo-electric cable is carried within the rubber casing for maximum protection from mechanical damage, and specially matched splicing components are used to ensure the most reliable connections. Ten metres of signal cable are provided with the sensor assembly: other lengths on request.

Typical sensor output characteristic:

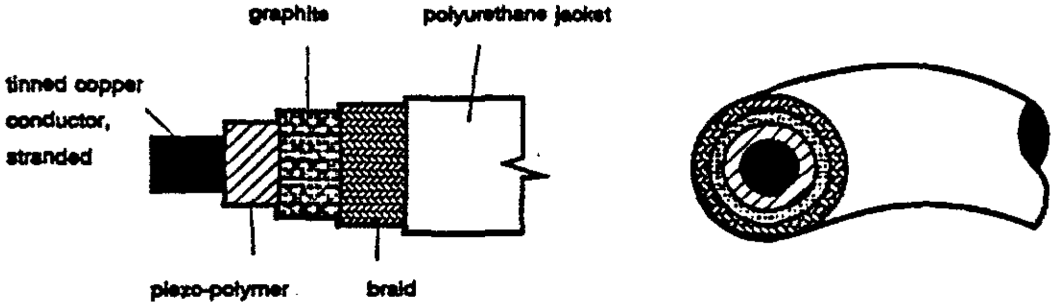


The information in this Data Sheet is believed to be correct. Intending users should carry out their own tests to establish suitability for their application. TRAFFIC 2000 LIMITED will not be liable for consequential damage arising from the use of these products. In line with our policy of continuous product development TRAFFIC 2000 LIMITED reserves the right to amend specifications and prices without prior notice.

Piezo-Electric
Data Sheet No. 2

Golden River Instruments, Inc.
7352 Dartford Drive, #7,
McLean, Virginia 22102
Tel 703 847 6016 Fax 703 847 5648

Piezo-electric Sensors - Performance Data

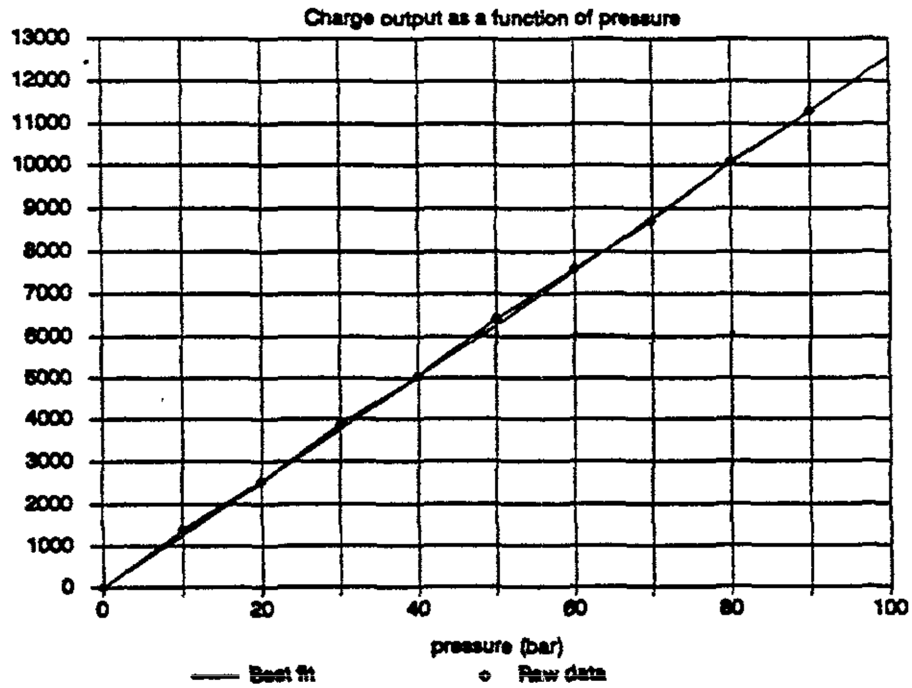


Description

The heart of the sensor cable is a layer of piezo-electric polymer which generates a charge when subjected to changing stress. Thus the cable produces an electrical signal in response to vibration, impact or pressure. Amplitude of the output depends on the intensity of the impact, and frequency is determined by the speed.

TRAFFIC 2000 cable is a very tough and durable transducer with tightly-controlled mechanical and electrical properties. It is supplied embedded in a variety of high-performance rubber profiles, each carefully designed to match the cable characteristics to the particular duty required. Please refer to other Data Sheets in this series for design and application information.

Typical piezo-electric cable characteristic



TRAFFIC 2000 LIMITED
3 Church Terrace, Richmond, Surrey TW10 6SE
Tel: 081 948 6736 Fax: 081 332 0813

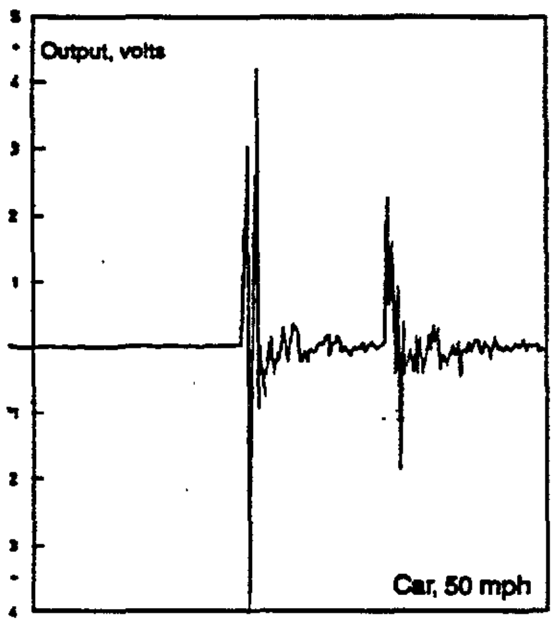
Piezo-Electric
Data Sheet No. 2

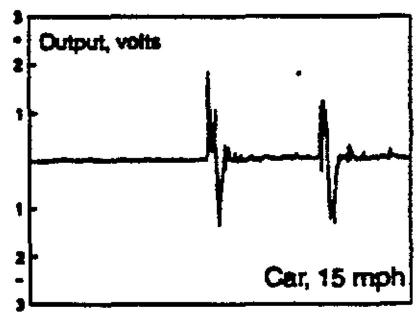
Cable Data

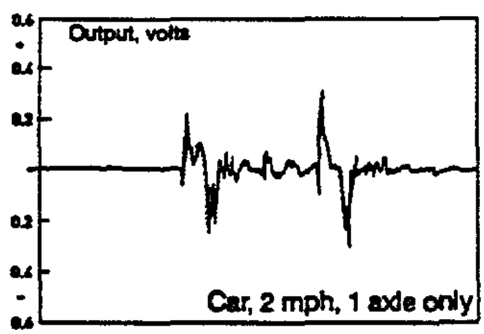
Outer diameter:	2.7mm
Piezo-electric polymer:	polyvinylidene fluoride (PVDF or PVF2)
Piezo-electric coefficient:	3pC/N at 23°C
Capacitance:	850pF/m
Temperature range:	- 40°C to + 60°C

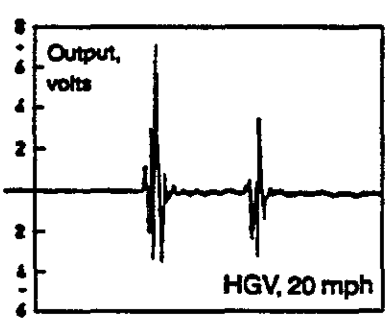
Sensor output signals

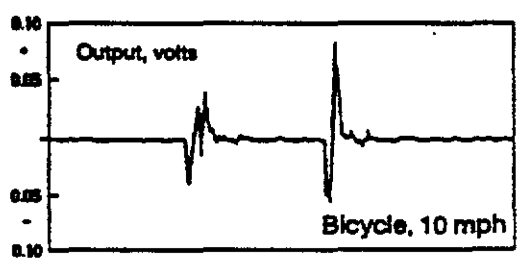
These graphs show actual responses obtained from a **TRAFFIC 2000** piezo-electric sensor bonded into a road surface, during the passage of various vehicles. Note that the signal level is dependent upon the rubber profile selected, and upon the signal conditioning equipment used.











Jan.1992

TRAFFIC/2000

Golden River Instruments, Inc.
7352 Dartford Drive, # 7,
McLean, Virginia 22102
Tel 703 847 6645 Fax 703 847 5648

Installation Instructions

For TRAFFIC 2000 Slot-Mounted Domed-Profile Traffic Sensors

Handling Precautions

The sensors are supplied in a heavy-duty plastic bag which is sealed when the sensor leaves our premises. The contents have been cleaned with solvent and are therefore free from any grease or other agent which might affect its adhesion in the road. You are advised not to open the bag until ready to install the sensor, and then to keep it clean during handling.

The sensor case is extruded in Ethylene Propylene Diene Monomer, which is not affected by weathering and is particularly durable and hardwearing. However, reasonable precautions should be taken during installation not to cut, crush or kink the sensor, as its performance could be affected.

Adhesives and cleaning solvents must be handled with care, and the instructions and precautions given with those products must be followed.

Installation

1. If this is a new installation then all the required ducting for electrical connections should be installed first.

2. The sensor may be supplied in various cross-section widths, from 10mm to 20mm. The width of the slot to be cut in the road must be 2mm wider than the section to be installed, ~~and a minimum of 25mm deep.~~

3. The end of the slot farthest away from the side of the road should be cut 3mm deeper and 25mm wide for a length of 50mm. This is to allow the free end of the sensor to be pushed down below the road surface when it is installed. A similar cut-out should be made towards the other end of the slot, to accommodate the cable end of the sensor. This action is necessary to avoid having the ends standing proud, where they would be vulnerable to damage or vandalism.

4. The slot must be blown clean of all loose material and dust, and the surrounding road surface swept clean.

5. The **T2000 Slotmastic** adhesive or other suitable adhesive should be mixed according to instructions, and poured into the slot such that when the sensor is pushed into the slot the adhesive extrudes along the entire length of the installation, but not excessively.

6. When the sensor is placed into the slot, the extreme end should be pushed down into the enlarged hole and held in place with a piece of timber or similar until the adhesive has gone off.

7. Similarly push the 'rat's tail' end of the sensor down, and hold it down as above.

8. Scrape excess adhesive off the road surface, using it to cover the ends of the sensor and the cable. Leave sufficient adhesive to just cover the feathered edges of the sensor. This is to avoid any edges being visible, and to prevent damage from vehicles braking over the sensor, and from snow ploughs.

   Note: In warm weather the adhesive goes off very rapidly.

9. Whilst steps 6 - 8 are being carried out, the whole length of the sensor should be covered with a piece of timber 50mm wide, this being weighted down sufficiently to hold the sensor in position in the road surface. (Small oil drums filled with water and placed 500mm apart would be suitable). The sensor is correctly positioned when the extremities of the domed section are almost in contact with the road surface, apart from a thin layer of adhesive.

10. When the adhesive has gone off sufficiently to hold the sensor in position, wipe along its length with solvent and a cloth to remove adhesive from the domed surface.

ATOCHEM

Piezo Film Components

Application Note Number 27 (7/92)

INSTALLATION INSTRUCTIONS
ROADTRAX SERIES 'P'
PIEZOELECTRIC TRAFFIC SENSORS

The Elf Atochem Sensors Inc Roadtrax® Series P Traffic Sensor is a Permanent, In-The-Road, Class II traffic sensor for vehicle classification and counting. The sensor consists of an outer aluminum channel to define the area of the sensor, a molded polyurethane elastomer to protect the sensor, and finally a sensor element. The sensor material is a space age polymer - Polyvinylidene Fluoride or PVDF. PVDF, when it is specially processed during manufacturing via a mechanical orientation and electrical polarization process, is piezo electric, and converts mechanical energy into electrical charge when a stress is imparted on it. Although the actual voltage output will vary based on many parameters, it is typically measured in the range of a few 100 millivolts to volts.

INSTALLATION PREPARATION: The installation site should be carefully chosen. Excessive pavement rutting may result in sensor damage or improper sensor operation. Sites where rutting exceeds ¼" under a 3' straight edge should be avoided. The pavement should be checked for adequate depth and structure, as well as having acceptable feeder cable routes and junction box location. It may also be beneficial to observe the traffic flow patterns of a proposed site over a period of time to ensure proper sensor placement. The best results in terms of uniformity of signals will result from sensors which are placed on straight and level roads.

Sensor installation must be carefully coordinated with proper road management, ensuring that all local regulations are complied with for road closure and hazard marking. Although traffic data is very important, it is not worth the life of a installation crew member. So please, ensure that adequate traffic control is in place, and that safety is taken very seriously.

INSTALLATION: First, it is necessary to mark the road for the location of the sensor. The sensor must be laid perpendicular to the flow of traffic. To assist in doing this accurately, use a lumber crayon and mark an 'x' on the road at position 'A' (Figure 1). Next,

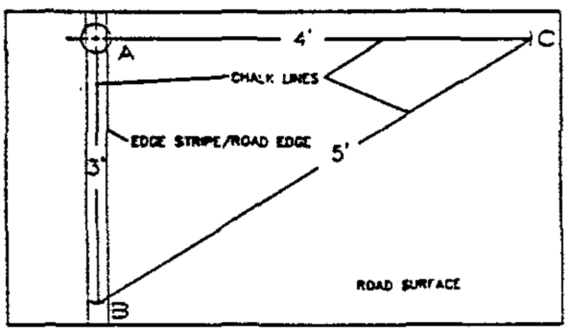


Figure 1: Ensure that the sensor is perpendicular to the flow of traffic.

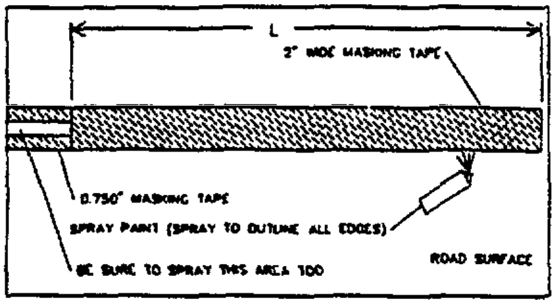


Figure 2: Use tape and a waterproof traffic paint to define the area to be cut.

holding a tape measure at position 'A', measure out 3 feet along the line or road edge and place a mark, called position 'B'. Keeping the same pivot point (position 'A'), rotate the tape straight out onto the roadway, placing the crayon at the 4 foot mark, and marking an arc about 1 foot long. Now move the end or pivot point of the tape measure to position 'B' (on the road edge) and, repeating the above procedure, measure out 5 feet and draw another 1 foot arc so that it intersects with the arc already drawn. Where these two arcs intersect is position 'C'. Using a straight edge or chalk line mark a line on the roadway using positions 'A' and 'C' as guidelines. The line should be a little longer than the sensor shipping box, or about 7 feet. This line will be perpendicular to the traffic flow.

Now mark the cutting location. Measure the sensor (end of sensor to beginning of lead attachment area), then add a couple inches to this. This measurement will be length L on Figure 2. Decide where the sensor should be placed (typically the end of the sensor at the lead attach end will originate from the edge of the edge stripe closest to the shoulder. Place the masking tape as shown in Figure 2, a nd using waterproof, quick drying traffic paint, spray over the tape. When the paint is dry, remove the tape exposing a pattern on the roadway which will be used as a cutting guide, as shown in Figure 3.

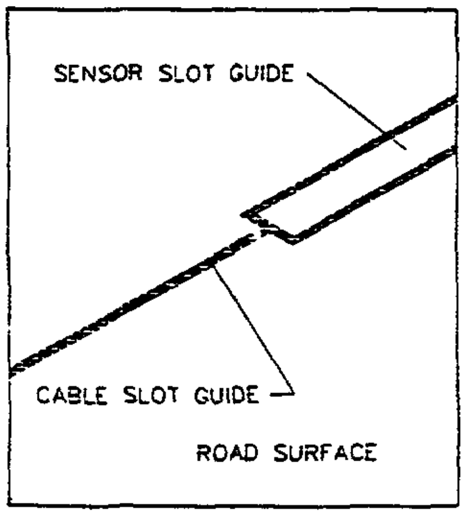


Figure 3: Cut the slot in the sensor slot guide area.

Carefully move the sensor completely out of the work area. Be careful with the sensor so as not to damage it. Although the passive signal cable has a tough outer jacket, it should be handled carefully. **Be especially careful not to step on it or nick it - the jacket can crack if it is nicked and then sharply bent at the nick point.** Also remove any other equipment which could be damaged by dust and grit, since the cutting process generates a significant amount of debris

A diamond tipped blade is recommended for slot cutting, although abrasive blades may be used by experienced personnel. The blade width ideally should be between 1/4" - 1/2" wide, but thinner blades may be used. If using abrasive blades which are 1/8" wide, 'bank' two blades together to give the 1/4" recommended width. Wet cutting blades are generally preferred by most contractors, though dry cutting blades are available and may be preferable during cold weather or when water supplies are not available. Always use dust masks when dry cutting!

Using the guide marks on the road (Figure 3) begin the cutting. Cut the sensor slot first, cutting out the un-painted area (Figure 4) and leaving the painted marks. Two passes should be made,

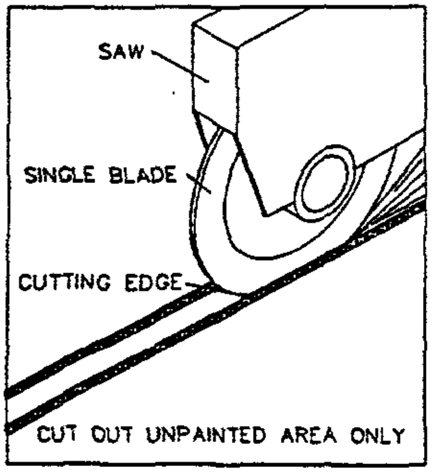


Figure 4 :Carefully cut at an even depth between the lines.

one along each edge - maintaining a depth of 1¾" to 2". Extra care must be taken with regards to cut depth when using abrasive blades, since they wear rather quickly. The *recommended depth must be maintained in the guide* area. It may be necessary to extend the end by a few inches so that this depth is maintained. Next cut the cable slot for the lead wire. In this case, the painted area should be cut out. Ensure that the cable slot is centered on the sensor slot and should be at least 3 inches deep.

Once the cutting is done, chisel out the center (remaining) section of the road, as shown in Figure 5. If wider blades are used (approximately ½" wide) some contractors prefer cutting out the center section with the saw. This is certainly acceptable, though care should be used to ensure the cut depth remains the same. The end result of all of this hard work, dust and toil will a channel cut in the road, as shown in Figure 6. Blow out or sweep out large debris from the channel. Get the sensor and place it in the slot to ensure proper fit - re-work if necessary. Now with a wire brush, rough up the sides and bottom of the sensor slot ensure good adhesion of the epoxy compound.

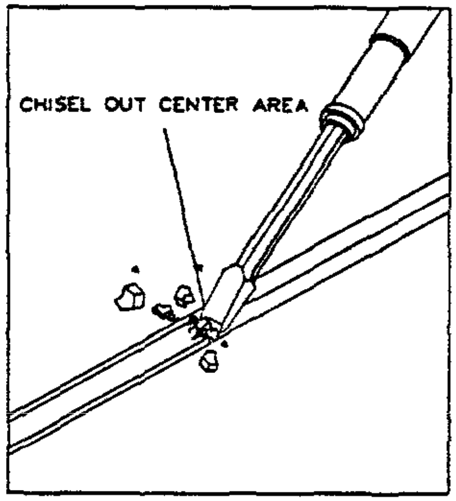


Figure 5: Chisel out the center area to an even depth

There are two recommended ways to mount the sensor. The first is to use cement anchors and large head flat head screws in the bottom of the channel. The sensor will rest on these screws, as shown in Figure 7. Using the cement anchors and screws, drill the holes in the bottom of the channel to accommodate the cement anchors, at about 1½' from each end of the slot. Following the manufacturers instructions for the anchors, insert the anchors in the holes, and screw then down sufficiently to ensure that they are correctly installed. Now clean out the channel using compressed air or a portable blower. If these are unavailable, use a broom, but really sweep hard to ensure the channel is clean.

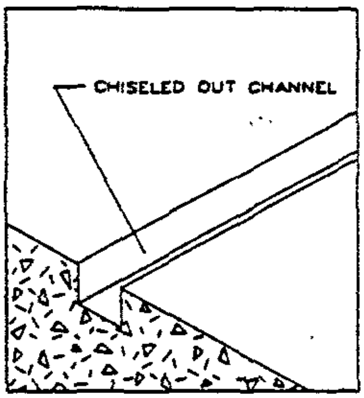


Figure 6: This is the end result of all the hard work

The second option for mounting the sensor is to use the supplied brackets to hold the sensor in place from the top. This is the recommended option, and will be discussed in more detail later.

The slot is now ready for mounting the sensor. If the temperature is below 60° F, it may be

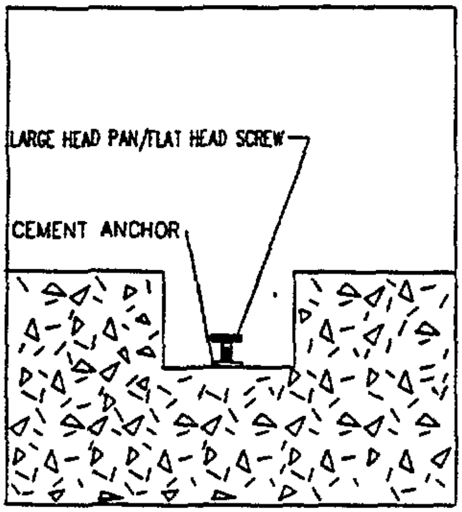


Figure 7: The sensor rests on top of the screw heads

beneficial to place a kerosene ('torpedo') type heater by the slot to gently warm the road surface. If multiple sensors are being installed at the same time, now is a good time to start heating up the channels, to give more time to heat each individual channel. Clean the sensor with a non-petroleum based solvent such as isopropyl alcohol and place the sensor next to the cut channel. The heater may be kept in place, but do not allow it to get too close to the sensor and lead wire; just a gentle warming is suggested. If using screws, insert the sensor into the slot so it rests on the screw heads. Adjust the screws so that the sensor top is resting just above the road surface. The mounting bracket, side 'A' (Figure 8) should be used as a guide. For areas with snowfall and snowplows, side 'B' of the mounting bracket should be used as a guide.

If using the mounting brackets, mount the brackets onto the senso0r (see Figure 9) using the cable ties. In areas without snowfall, use side 'A' of the bracket. This will allow for the sensor to be mounted slightly proud of the road surface, giving the sensor that maximum impact from vehicles. In areas of snowfall, it is recommended that the sensor be mounted flush with the surface of the road. In this case, use the flat side (side 'B') of the mounting bracket in contact with the top of the sensor. Three brackets should be used for each sensor; one about 6" from each end, and one in the middle of the sensor. Note - it is preferable to mount the sensor just above the road surface for higher output, if mounted level, the outputs will be lower.

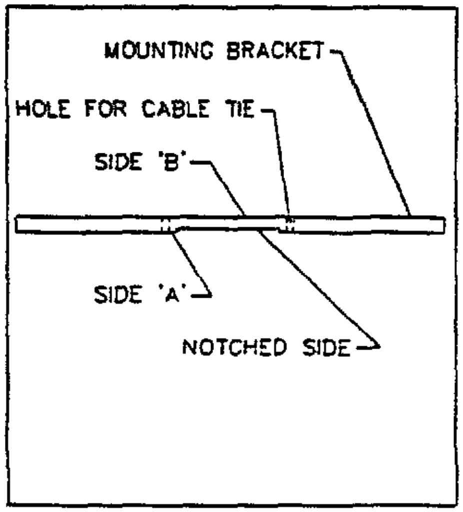


Figure 8: Side 'A' is against the sensor for normal installation; Side 'B' is used in snow areas.

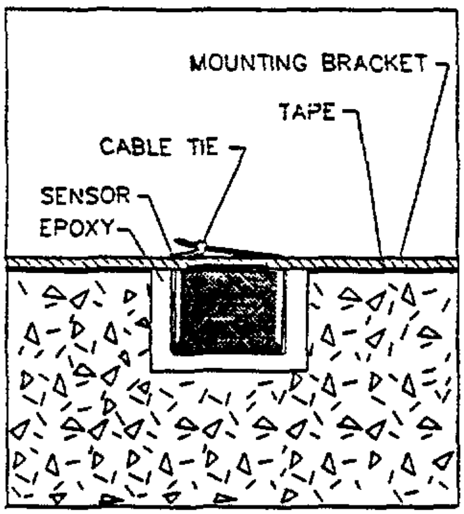


Figure 9: Cable ties are used to hold the sensor to the mounting bracket

If there is some minor curvature of the road, the sensor may be GENTLY bent (see Figure 10) to conform to the curvature. WARNING: This should normally be left to experienced personnel as too much bending may cause some damage.

Once the sensor is set to the proper height, place it alongside the channel. Place some tape around the cut slots - see Figure 11 - to keep excess epoxy off the road surface. The tape should be around the entire perimeter of the cut slot. Insert the lead wire into the cable slot, and build a small dam around it using clay or an equivalent, so that the epoxy does not leak past the sensor slot into the cable slot.

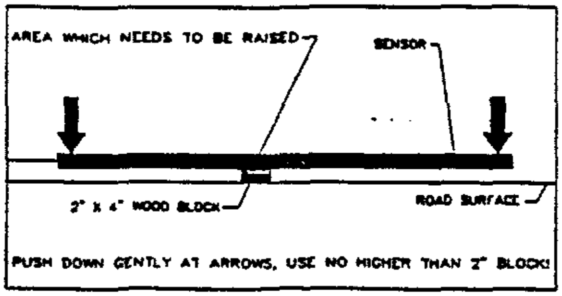


Figure 10: VERY CAREFULLY bend the sensor to conform to the road

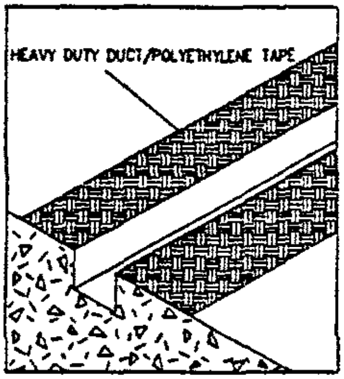


Figure 11: Heavy polyethylene tape is used to keep the epoxy off the road

Mix the epoxy/grout according to manufacturer's instructions (See appendix 1, epoxy notes). Using a plastic bucket or trowel (depending on consistency of epoxy), carefully pour the epoxy/grout into the cut slot until the channel is a little less than 2/3 full. (Figure 12) Be as neat as possible. Once the epoxy is poured into the slot, the sensor should be placed into the slot as before - see Figure 9. Once the sensor is put into the channel, pull any extra lead wire to remove the slack being sure the dam remains in place. Be sure the sensor is properly seated. Any voids should be filled. Carefully removed any excessive amounts of epoxy from the installation. There must be a smooth transition between the sensor and the road surface.

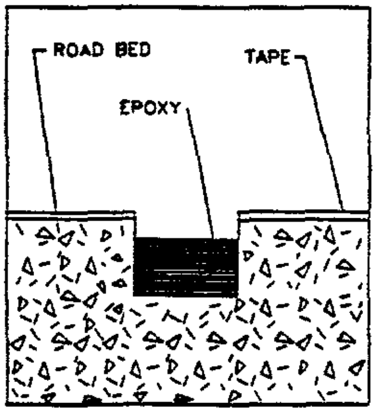


Figure 12: The slot is filled 2/3 full with epoxy

Weights (bricks do well) may be placed on top of the brackets/sensor but it is recommended to put a layer of polyethylene over the sensor to avoid sticking. Allow the epoxy to cure as per manufacturer's instructions. A 'heat tunnel' can be constructed from cardboard boxes or the sensor shipping box if curing time is critical (Figure 13), but, be careful not to get the heat source too close to the cardboard; it may burn!

Route the lead wires to the electronics, keeping the length of the lead wire and the number of turns should be keep to a minimum. If unable to hook up to the electronics immediately, be sure that the exposed end of the lead wire is protected from water penetration and the cable is protected from damage. Conduit is recommended for wire routing but plenum cable may be buried in the ground without conduit. Use caution while burying the cable with conduit being careful not to damage the cable with tools or sharp objects in the ground.

Once the epoxy has gelled to a semi-hard state, cut the cable ties and remove brackets if these have been used. Trim off any exposed part of the cable tie and remove the tape from around

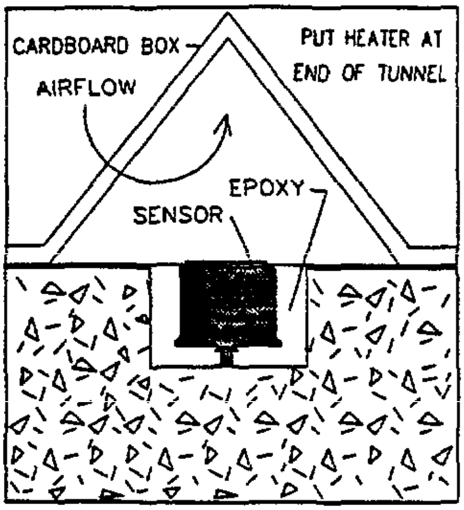


Figure 13: A cardboard 'tent' can be used to speed up the curing times if heaters are used

the slot.

Clean up the area once the epoxy has hardened. The hardening time for the epoxy will vary based on temperature, humidity and type of epoxy used. NO TRAFFIC SHOULD BE ALLOWED TO PASS OVER THE SENSORS UNTIL THE EPOXY IS FULLY HARDENED!

If the sensor was mounted flush with the road and higher signals are desired, a piece of asphaltic adhesive tape know as bituthane or polyguard may be placed over the sensor (Figure 14) to increase the signal level. This tape will give you increased signal levels, additional sensor protection, and, if a snowplow tears off the tape, it can be replaced. The disadvantages of using the tape is that it can only be applied under certain conditions, and that the signal may have to be monitored to ensure uniform levels as the tape wears. Contact Elf Atochem Sensors, Inc. if you have any questions.

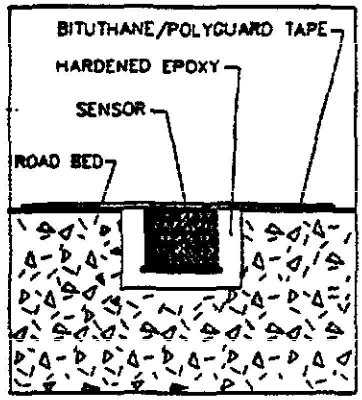


Figure 14: Polyguard tape placed on top of the flush mounted sensor will increase the output level

You are now complete. Once the epoxy has fully hardened, the lane of traffic can be again opened. The electronics needs to be connected, and you are ready to start classifying vehicles. The majority of sensor failures are caused by damage to the lead wire causing water penetration, and improper mounting of the sensor - especially in the use of improper epoxy and allowing traffic to pass over before the epoxy has fully hardened. Please follow all the above procedures and if you have any questions, please call - ELF ATOCHEM SENSORS, Inc. is committed to total customer satisfaction.

Appendix 1
Notes On Epoxy

The following epoxies are recommend for installation of Roadtrax Series P piezoelectric traffic sensors:

1. <u>DURAL 331LV:</u>

   Dural 331LV epoxy is manufactured by Tamms Industries, Route 72 West, Kirkland, Illinois 60146. Tel: 800 582 6670

2. <u>E-Bond G-100:</u>

   E-Bond G-100 epoxy is manufactured by E-Bond Epoxies Inc, Post Office Box 23069, 501 N.E. 33rd Street, Fort Lauderdale, Florida 33307. Tel: 305 566 6555

3. <u>CONCRESIVE PASTE (SPL):</u>

   Concresive Paste (SPL) is manufactured by Master Builders Inc, 23700 Chagrin Blvd, Cleveland, Ohio 44122. Tel: 800 227 3350.

	Epoxy Type		
CURE TIMES @ TEMP†	DURAL 331	E-Bond G-110	CONCRESIVE
Usable Temp. (°F)	25 to 90 °F	50 to 100 °F	25 to 70 °F
Cure Time @ 100 °F	N/A	2 Hours	N/A
Cure Time @ 80 °F	20 Minutes	2.5 hours	N/A
Cure Time @ 70 °F	40 Minutes	3 Hours	1 Hour
Cure Time @ 60 °F	1.25 Hours	6 Hours	2 Hours
Cure Time @ 50 °F	1.75 hours	14 Hours	3.5 Hours

† These times are intended to comparison purposes only. They are only approximate, and dependent on many other factors. They represent an approximate time at which to check the epoxy prior to allowing traffic to pass over the sensor.

In colder temperatures, store and mix the epoxy in a warm area. At warmer temperatures (above 70°F), the Dural and the Concresive should be stored in a cool area such as an ice chest. If these thicken too much from the cold, allow them to sit out for a period of time to gently warm them prior to use. There are many factors which can influence the curing time, especially the use of 'torpedo' heater. Plan to have the required equipment on hand to get the job done in the allotted time. If traffic is allowed to pass over the sensor prior to the epoxy being fully cured, the sensor will be forced too deep into the road, and unacceptably low signal levels could result. Typically, Traffic Management does not allow for extra time for road closure than that authorized. Plan ahead to avoid problems.