FIELD EVALUATION OF FHWA VEHICLE CLASSIFICATION CATEGORIES

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Mr. John H. Wyman is Director of the Maine Facility and was Principal Investigator of this project. Mr. Edward Kashuba was the FHWA Contract Manager.

16. Abstract

Four systems are available, programmable to classify vehicles to the FHWA scheme. In a study conducted by the Maine Facility (Lyles, Wyman; July 31, 1982; Evaluation of Vehicle Classification Equipment) a scheme "E" was selected from five candidate schemes and recommended to the FHWA for adoption as a standard. In order to correct logic errors in that scheme and to add categories for motorcycles and buses the classification scheme "E" logic has been changed and a new scheme called "F" has been evolved. This scheme "F" has been evaluated and appears workable as a classification scheme at about 95% classification accuracy. The I.R.D. unit is a permanent all weather system. The Golden-River unit is a semi-permanent, clear road system only. The Streeter-Amet unit and the G.K. Inst. units are clear road systems using pneumatic tubes only. The fifth system tested, a Sarasota unit classifies by road loops to 7 length categories only. Sarasota expects to have the same electronic package operating from road tubes with scheme E or F programs available after January, 1985. All systems operated satisfactorily during the three month test period within the limitations listed under the Detailed Evaluation.

17. Key Words

VEHICLE CLASSIFICATION, INDUCTIVE LOOPS, W.I.M. AXLE COUNTERS, PNEUMATIC TUBES

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1.0 INTRODUCTION

Vehicle classification data are extremely important as planning information for use by the various states' transportation departments in their efforts to allocate costs associated with highway damage and repair.

The FHWA Office of Highway Planning requires that the various states furnish vehicle classification data as part of the HPMS reports. The collection of sufficient data for highway design planning purposes requires the use of automatic data collection equipment. Manual collection of the amount of such data required is far too lengthy and costly a process. Thus, it is essential that the development and improvement of such automatic classification systems be continued.

On December 2, 1983, the FHWA Office of Highway Planning issued guidance on the vehicle classifications of interest over the long term. These classifications had been developed in consultation with the States and evolved out of a number of earlier classification efforts including the Maine Facility Vehicle Classification Report of 1982 by Lyles and Wyman.

During this study, five possible classification schemes were reviewed. These schemes varied from a simple (7 category) to a complex (32 category) scheme. A scheme, called scheme "E", with 14 categories was selected and recommended for adoption by FHWA as a standard.

As a result of a study of the comments received on the above referenced Highway Planning guidance document a report entitled, "Revision of The FHWA Vehicle Classification Categories" was issued by the FHWA. The classification categories recommended in this report are to be used as a part of the FHWA long term vehicle monitoring program.

In order to assess the capability of existing equiment to classify according to this scheme, manufacturers of such equipment were approached to determine their interest in and ability to, furnish such equipment. Seven companies responded affirmatively.

The FHWA Office of Highway Planning issued a request for a project proposal which would review the various systems on the market as to their suitability to provide such classification information as well as the quality and durability of the equipment when used in the field.

The Materials and Research Division of the Maine Department of Transportation responded to this request for a proposal and was awarded a contract to undertake the study. The seven companies mentioned above were invited by the FHWA, to submit sample equipment to the Maine DOT for use in such a study and evaluation. All initially agreed to provide such equipment.

2.0 STATEMENT OF WORK

2.1 OBJECTIVE

To evaluate the ability of presently available automatic vehicle classifiers to accurately identify the vehicle types defined in the FHWA vehicle classification scheme. For those classifiers capable of being adjusted by the users, decision rules will be developed to identify FHWA vehicle categories. All equipment will have accuracy checks made based on field data observations. Appendix I lists the FHWA Vehicle Classification Categories with definitions of the vehicle types covered by each category.

2.2 SCOPE

This study encompasses collection of vehicle classification data under controlled field conditions with the subsequent comparison of the data automatically collected to the data collected under the controlled field conditions. The comparison should lead to a comprehensive evaluation of available equipments' ability to identify the FHWA vehicle types and the equipments' sensitivity to vehicle headways, mix of heavy and light vehicles, and vehicle speeds. The equipment's ability to monitor traffic at mainline speeds will be emphasized. For that equipment allowing user specification of vehicle characteristics, it will be necessary to develop alternative decision rules that are compatible with the equipments range of sensitivity and that are responsive to the FHWA vehicle classifications. This work will build on previous efforts documented in the FHWA report "Evaluation of Vehicle Classification Equipment" completed under contract DOT-FH-61-C-00156.

2.3 TASK A

After review of the vehicle classification scheme documented in the attached report, "Revision of FHWA Vehicle Classification Categories" (See Appendix I), the testing agency will develop a set of decision rules that will adequately sort vehicles in the traffic stream into the appropriate FHWA vehicle classes. These decision rules shall build on the decision rules developed in the contract mentioned in the "Scope" section of this statement of work. It is recognized that available devices may have difficulty in classifying buses, motorcycles, and in differentiating passenger cars from other two-axle, four-tire vehicles. Nevertheless, there is a need to know how various decision rules will affect the assignment of these various vehicle types to FHWA categories. It is not necessary that a single scheme be selected. More appropriately, the advantages and disadvantages of the decision criteria should be evaluated along with the expected error due to misclassified vehicles. To the degree deemed practicable by the testing agency, alternative sets of decision criteria shall be developed for equipment using point sensors and for equipment using loops. Prior to field testing of any equipment, FHWA Headquarters will select a decision rule for use with point sensors and a decision rule for use with loops which will be used in further testing.

2.4 TASK B

The following equipment manufacturers have been contacted by FHWA and have indicated a willingness to loan equipment for this project:

*1. Golden River Corporation
7672 Standish Pl.
Rockville, Md. 20855

Contact: Ray Redpath - Marvin Segel
(301) 340-6800

*2. IRD Equipment
CMI-Dearborn Inc.
820 Lafayette Rd.
Bldg. No. 1, Suite 203
Hampton, New Hampshire 03844

Contact: Jeffrey B. Davis, Marketing Manager
(603) 926-1200

3. Leupold & Stevens, Inc.
P.O. Box 688
Beaverton, Oregon 97075

Withdrew Equipment - out of vehicle classifier business

Contact: Rainer Poersch
(503) 646-9171

*4. Sarasota Automation
1500 North Washington Boulevard
Sarasota, Florida 33577

Contact: Mike Weeks - Jim Stemitz
(183) 366-8770

5. Streeter-Amet
Division of Mangood Corporation
1227 Walnut Street
Allentown, Pennsylvania 18102

Contact: C. J. Duke, Regional Manager
(215) 434-4581

*6. G. K. Instrument Co. Ltd.
Jamar Sales Co., Inc.
1170 Orchid Rd.
Warmister, Pa. 18974

Contact: James E. Martin
(215) 322-6344

7. Winko-Matic Signal Company
659 Miller Road
Avon Lake, Ohio 44012

Did not submit- identifies buses only.

Contact: Erwin Hart
(216) 933-2122

Note: Information on companies starred has been up-dated either as to addresses, phone numbers, or contacts.

It is the participating manufacturer's option to supply that equipment believed to be most appropriate to monitor the FHWA vehicle classification. It is a manufacturer's further option to make equipment modifications that will enhance the equipment's ability to identify the FHWA vehicle classes. Such modifications include the use of the decision rule selected in Task A or the use of an alternative.

2.5 TASK C

Equipment made available by the manufacturers and vendors identified in Task B will be tested under field conditions. Test sites shall be of three types:

1. A two-lane highway

2. A rural Interstate highway

3. An urban Interstate highway

Available equipment will be operated for one week at each site.

During field testing, hourly and daily summaries by FHWA vehicle category as recorded by the equipment shall be provided as part of the work's documentation. Accuracy checks will compare a minimum of 25 documented observations of each FHWA vehicle type to the category identified by the automated equipment. Documented observations shall include manual observations and collection of pertinent vehicle characteristics used in the decision rule or the use of photographic or video techniques to collect the same information. The FHWA Headquarters will approve the method of obtaining observations prior to its use.

2.6 TASK D

Comparisons of data gathered during accuracy checks in Task C will be of automatically collected data to observe data by categories. The documented results of this comparison will include a discussion of variations by vehicle type and reasons for the variations. This discussion shall include identification of the lowest vehicle speed at which reliable automatic data collection is possible. Although sensing and/or identification of motorcycles, differentiation of passenger cars from other two-axle, four-tire vehicles, and differentiation of buses from single unit trucks is limited for many automatic vehicle classification devices, specific analysis of the equipment's treatment and categorization of these vehicles shall be included as part of the study's findings.

2.7 TASK E

Progress reports will be submitted at two week intervals.

The results of Tasks A through D shall be thoroughly documented in a final report which will include:

A. The decision rules developed under Task A and the rules chosen by FHWA for testing.

B. The types of equipment used along with their modifications and sensor devices. The automatic classification equipment used in this study shall be thoroughly described in a format similar to that used in Appendix 1 of the aforementioned FHWA report, "Evaluation of Vehicle Classification Equipment". Each description shall include typical equipment costs.

C. A description of the sites used.

D. The data collection procedures.

E. Tabular comparisons of automatic to observed classifications.

F. Discussions of any systematic errors found with the automated devices.

G. Recommendations for equipment improvements.

3.0 SYSTEMS AVAILABLE FOR TEST

As a result of the withdrawal of the Leupold and Stevens Company from the vehicle classification market and the fact that the Winko Matic Company did not submit a system, as their equipment identifies buses only, there are five systems to be evaluated. These are shown on Table 1.

3.1 SYSTEM OPERATION

Each system submitted for testing and evaluation uses a different data acquisition system thus the exact logic used by each microprocessor system is slightly different.

In order to provide data inputs from the road, (vehicle generated data) necessary for any system to provide a classification output, an axle count and the speed of the vehicle must be recorded.

Inductance loops are used to obtain the speed of the vehicle in three of the systems (technical details of operation of inductance loops and other sensors are given in considerable detail in a report by Lyles-Wyman FHWA/PL/80/006 dated August 31, 1980 entitled "Evaluation of Speed Monitoring Systems", conducted by the Maine Facility, Materials and Research Division, Maine Department of Transportation and sponsored by the FHWA Office of Highway Planning under contract DOT-FH-11-9401).

Speed is calculated, for a two loop system, by dividing the distance from the leading edge of the first loop to the leading edge of the second loop by the time it takes the vehicle to travel this distance. In two of the systems pneumatic tubes are used to make the speed measurement. Since the tubes are only about an inch in diameter, on such systems the axle count is also accomplished by counting the number of pulse outputs generated by one of the tubes during the passage of the vehicle.

On two of the systems using loops, axle count is obtained by using a third element in the array (see Figure I in Chapter 5.3). One system, I.R.D., uses a permanent, cast in place rectangular steel frame, enclosing a series of 12 magnetic sensors. The system can also identify dual tires.

The Golden River System uses a capacitance pad to count axles. The capacitance of the pad is a part of a resonant electrical circuit. The passage of the wheel of the vehicle causes a change in the value of the capacitance of the pad,

TABLE 1
SYSTEMS AVAILABLE FOR TEST

SYSTEM NUMBER	MANUFACTURER	MODEL NUMBER	SENSING DEVICES
1	C.M.I. Dearborn	I.R.D. Classifier	Inductance Loops (2) Axle Counter (12 magnetic coils)
2	Golden River	Weighman Vehicle Classification & Weight System MK-3	Inductance Loops (2) Axle Counter (Weigh Pad)
3	Streeter-Amet	Traficomp 141A Recorder Reader 140A	Two Pneumatic Tubes
4	G.K. Instruments	Model 6000	Two Pneumatic Tubes
5	Sarasota	Model VC1900	Two Inductance Loops

by compressing it slightly, which changes the frequency of the resonant circuit. This change is identified by the microprocessor logic to provide an axle count. This pad and resonant circuit can also be used to provide an output proportional to the force imposed by the passage of the vehicles wheel. (The Golden-River system also provides vehicle and axle weights). An evaluation of the weighing function is not a part of this project but is being undertaken by the Maine DOT, Materials and Research Division under a different study. The system tested is the only Golden-River unit available in the U.S. that provides classification by axle spacing and thus to the vehicle type classification. The Golden-River marksman classifier operates on two inductance loops and provides classification by vehicle length only. Thus, two loops and an axle counter will permit recording speed, number of axles, axle spacing, and thus classification by vehicle type. Total length is also available. Total length is determined by the time of occupancy of the field of one loop by the vehicle.

Two pneumatic tube systems (Streeter-Amet and G.K. Instrument) can detect speed and axle spacing and thus can classify by vehicle type whereas the fifth system (Sarasota) uses two loops and can provide classification by vehicle overall length only. A classification scheme which differs from Scheme F and is shown in Chapter 7 - Table 14 was developed for this system. Further details on each system are shown on Table 2.

TABLE 2
CHARACTERISTICS OF SYSTEMS

SYS. #	COMPANY & MODEL	# CLASS.	LANES CAP.	APPROX. COST**	SENSORS	RECORDING MEDIUM	POWER SOURCE	PRINT OUT Ind. Veh.	PRINT OUT Sum. Tables	READOUT	
1	C.M.I. Dearborn IRD Class.	14	2 4 6	21,000 24,500 30,500	Ind. Loops Axle Counter	Solid State Bat. Pro-tected	120v 60 Hertz A.C.	yes	yes	Class	Speed Lengt Axle Spaci
2	Golden River Weighman MK-3	14	1*	25,000	Ind. Loops Axle Counter	Solid State Bat. Pro-tected	6v D.C. Bat.	yes	yes	Class	Speed Weigh Lengt
3	Streeter-Amet 141A 140A	13	1	3,875	Pneu. tubes	Cassette Tape	12v D.C. Bat.	no	yes	Class	--
4	G.K. Instrument Model 6000	14	1	3,090	Pneu. tubes	Solid State	12v D.C. Bat.	no	yes	Class	--
5	Sarasota VC 1900	7	1	4,600	Ind. Loops	Solid State	12v D.C. Bat.	no	yes	Lengths	Speed

* One lane per pad.
** See appendix II for details of costs. Cost of installation of permanent axle counter not included in estimate.

4.0 TASK A - REVIEW OF CLASSIFICATION SCHEMES

4.1 CLASSIFICATION SCHEME "E"

Table 3 shows the Scheme "E" vehicle classification logic program chosen as the proposed FHWA scheme during the vehicle classification equipment evaluation project by the Maine Facility in 1982; Lyles-Wyman. As a result of the review of this classification scheme by the FHWA and the various states, new classification categories were proposed and are discussed under paragraph 4.2. The new scheme is called classification scheme "F".

In addition to changes to the scheme an error was found in scheme "E" in classifications E-6 and E-5. Step 6 which calls for identifying four-axle single unit trucks should have been placed ahead of step E-5, because the logic in this step looks at axle 3 to 4 spacing. If axle 2-3 spacing had been interrogated first, spacing less or equal to 5 feet, the later check of axle 3-4 spacing would have properly categorized the 2S2 semi-trailer.

Where the systems under evaluation in this program used the old category "E", errors in class 6 and 5 were listed as 'Program' logic. Errors are not counted in the system accuracy calculation.

4.2 SYSTEM FLOW CHART FOR SCHEME "F"

A system flow chart was developed correcting the error mentioned above and also making the changes dictated by the review of scheme "E", among which were the addition of class 1, motorcycles and class 4, buses. The classification flow chart "F" follows as Table 4 through 4F and a review follows in paragraph 4.3. Table 5 gives a short summary of the classes of scheme "F" for ease in following the discussion in paragraph 4.3.

4.3 COMMENTS ON THE FLOW CHARTS FOR SCHEME "F"

Photographs of representative types of vehicles are shown in Appendix III.

Referring to two-axle categories:

F-1 - Motorcycles - optional to the user but if used defined by 2-axle - wheel base under 70".

F-2 - Passenger cars, light pickups or vans defined by 2-axle - wheel base under 120". The Streeter-Amet system uses 138" and the question of making a change to some slightly longer figure than 120" has been considered.

TABLE 3
CLASSIFICATION SCHEME "E"

Vehicle Categories	Description	Proposed Rule
E-1	Passenger cars, light trucks, vans	Axles = 2 and wheelbase ≤ 10'
E-2	Heavy-duty pick-ups, delivery trucks, 2A6T's	Axles = 2 and wheelbase > 10'
E-3	Cars and light trucks with one-or-two-axle trailers	Axles = 3 or 4 and 1,2 spacing ≤ 10' and 5.5' < 2,3 spacing < 22'
E-4	Three-axle SU trucks	Axles = 3 and not E-3
E-5	Trucks and semi-trailers - 2S2	Axles = 4 and not E-3 and 3' ≤ 3,4 spacing ≤ 10'
E-6	Four-axle SU trucks	Axles = 4 and not E-3 and 3' ≤ 2,3 spacing ≤ 5'
E-7	Other four-axle combinations	Axles = 4 and not E-3, E-5, and E-6
E-8	Trucks and semi-trailers - 3S2	Axles = 5 and 2' ≤ 4,5 spacing ≤ 10'
E-9	Other five-axle combinations	Axles = 5 and not E-8 and 3' ≤ 2,3 spacing ≤ 5'
E-10	Trucks and semi-trailers plus full trailers - 2S1-2	Axles = 5 and not E-8 or E-9
E-11	Trucks and semi-trailers plus full trailers - 3S1-2	Axles = 6 and 5,6 spacing > 7'
E-12	Trucks and semi-trailers - 3S3	Axles = 6 and not E-11 and 4,5 spacing ≤ 6'
E-13	Other six-axle combinations	Axles = 6 and not E-11 or E-12
E-14	Other seven-or-more-axle combinations	Axles = 7 or more

SCHEME "F" FLOW CHART

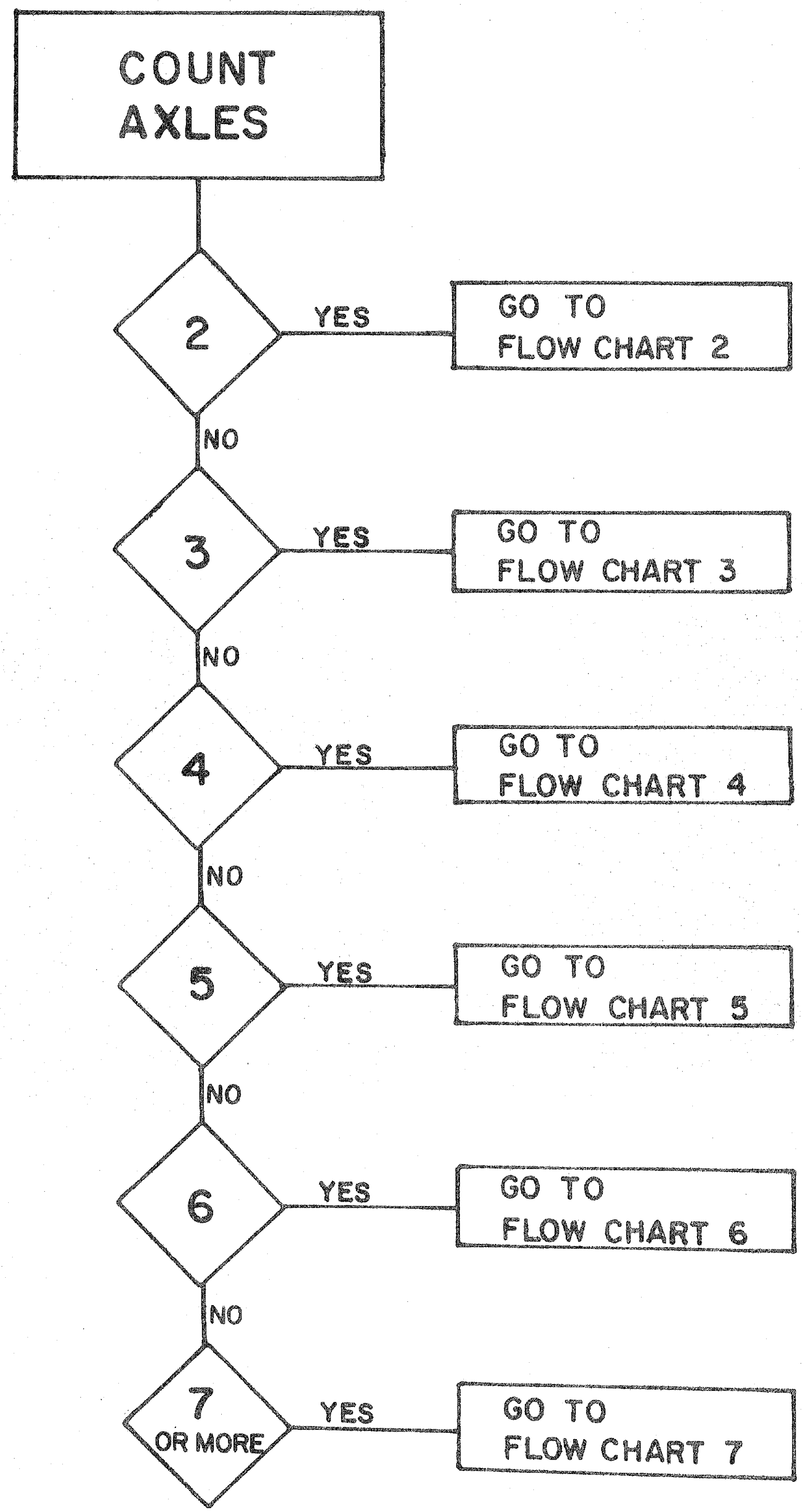


TABLE 4

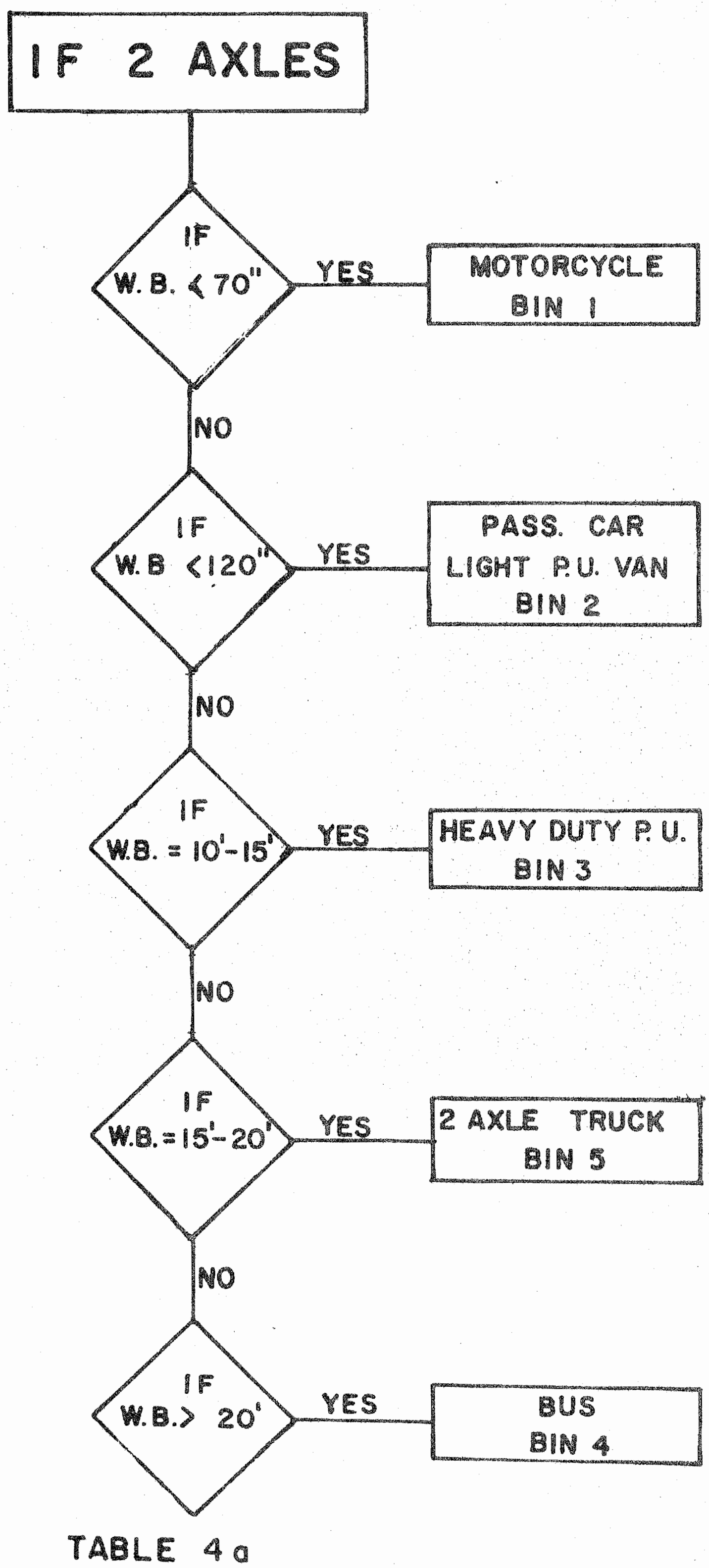

IF 2 AXLES
IF
W. B. < 70"
YES
MOTORCYCLE
BIN 1
NO
IF
W.B <120"
YES
PASS. CAR
LIGHT P.U. VAN
BIN 2
NO
IF
W.B. = 10'-15'
YES
HEAVY DUTY P. U.
BIN 3
NO
IF
W.B.=15'-20'
YES
2 AXLE TRUCK
BIN 5
NO
IF
W.B.> 20'
YES
BUS
BIN 4

TABLE 4a

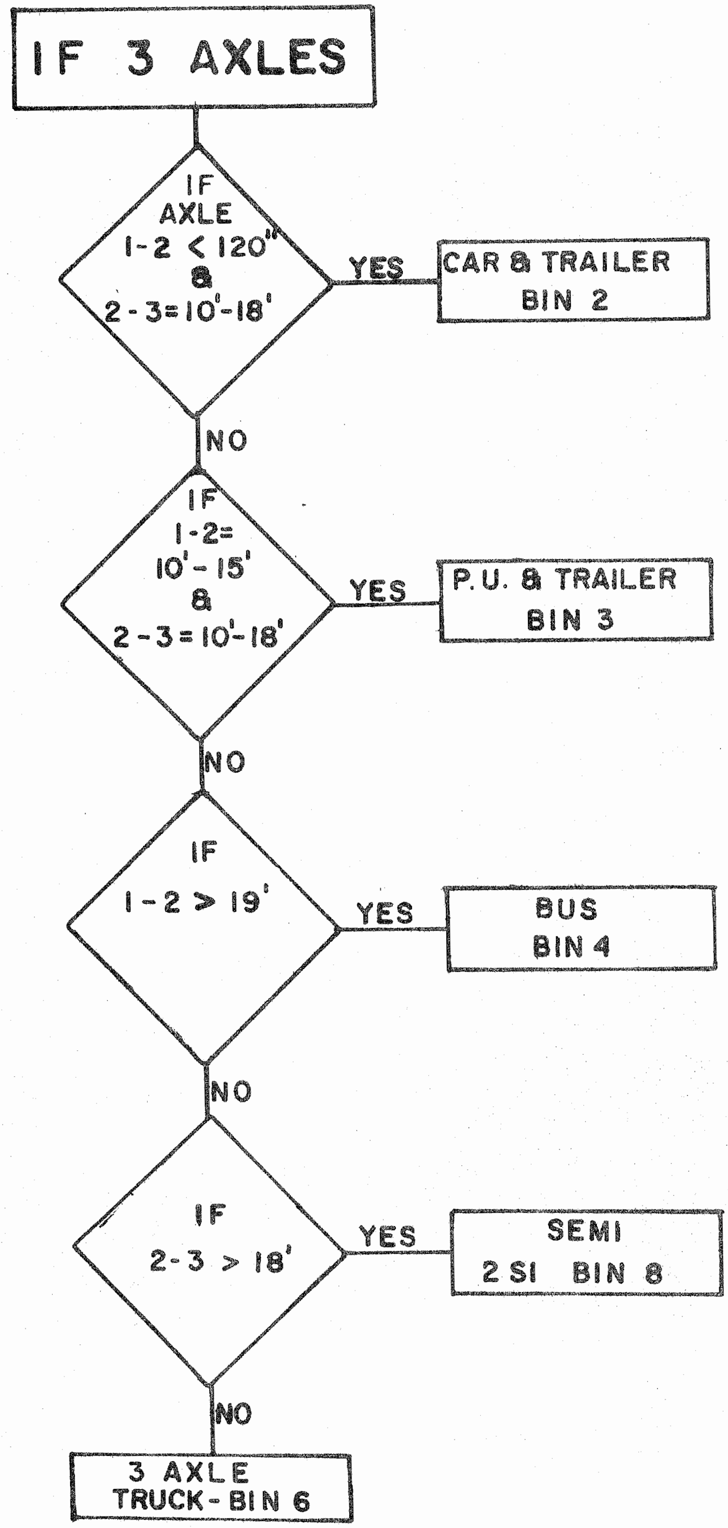

IF 3 AXLES
IF AXLE 1-2 < 120" & 2-3=10'-18'
YES
CAR & TRAILER BIN 2
NO
IF 1-2= 10'-15' & 2-3=10'-18'
YES
P.U. & TRAILER BIN 3
NO
IF 1-2 > 19'
YES
BUS BIN 4
NO
IF 2-3 > 18'
YES
SEMI 2 S1 BIN 8
NO
3 AXLE TRUCK-BIN 6

TABLE 4b

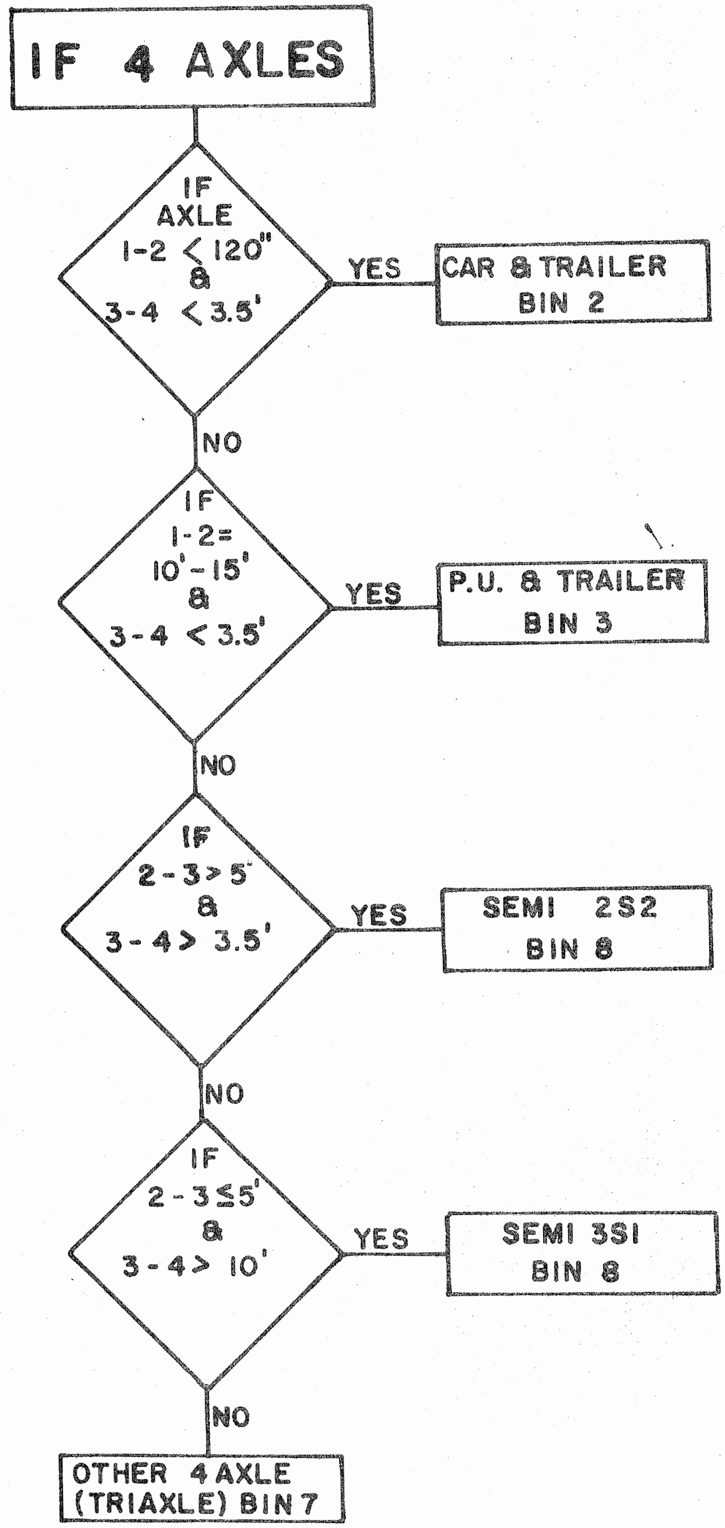

IF 4 AXLES
IF AXLE 1-2 < 120" & 3-4 < 3.5'
YES
CAR & TRAILER BIN 2
NO
IF 1-2= 10'-15' & 3-4 < 3.5'
YES
P.U. & TRAILER BIN 3
NO
IF 2-3 > 5' & 3-4 > 3.5'
YES
SEMI 2S2 BIN 8
NO
IF 2-3 ≤ 5' & 3-4 > 10'
YES
SEMI 3S1 BIN 8
NO
OTHER 4 AXLE (TRIAXLE) BIN 7

TABLE 4c

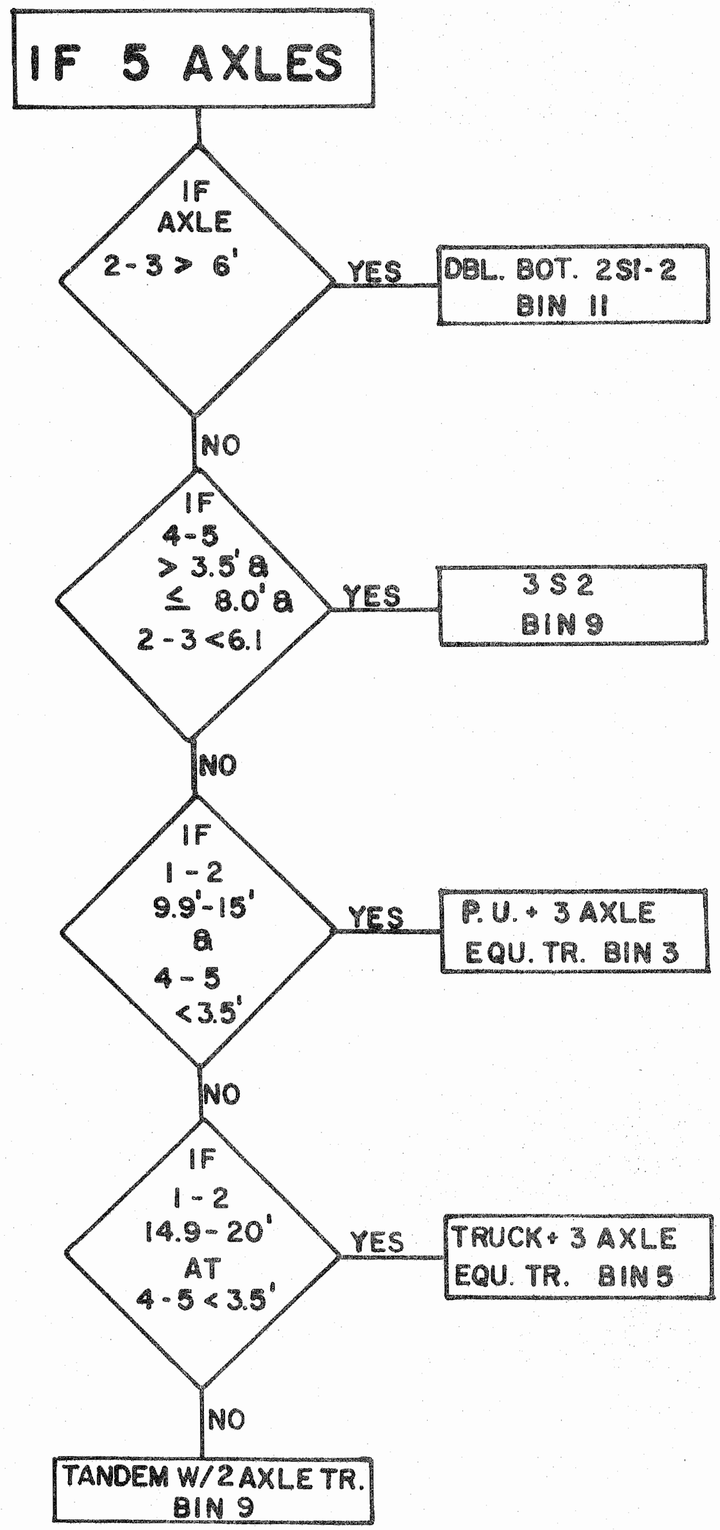

IF 5 AXLES
IF AXLE 2-3 > 6'
YES
DBL. BOT. 2S1-2 BIN 11
NO
IF 4-5 > 3.5' & ≤ 8.0' & 2-3 <6.1
YES
3 S 2 BIN 9
NO
IF 1-2 9.9'-15' & 4-5 <3.5'
YES
P. U. + 3 AXLE EQU. TR. BIN 3
NO
IF 1-2 14.9-20' AT 4-5 < 3.5'
YES
TRUCK + 3 AXLE EQU. TR. BIN 5
NO
TANDEM W/2 AXLE TR. BIN 9

TABLE 4d

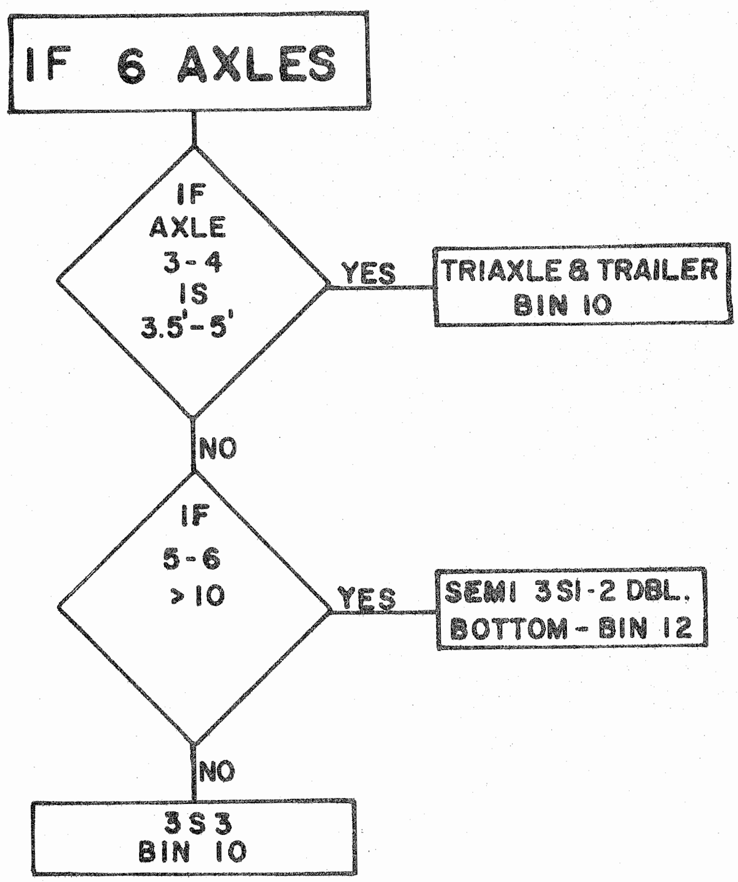

IF 6 AXLES
IF AXLE 3-4 IS 3.5'-5'
YES
TRIAXLE & TRAILER BIN 10
NO
IF 5-6 >10
YES
SEMI 3S1-2 DBL. BOTTOM - BIN 12
NO
3S3 BIN 10

TABLE 4e

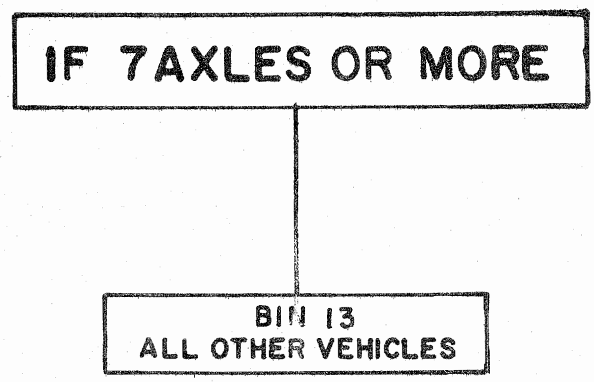


TABLE 4f

TABLE 5
SHORT SUMMARY OF SCHEME "F"

Vehicle Classification	Vehicle Type
F1	Motorcycles (optional)
F2	Passenger Cars
F3	Other Two-Axle, Four-Tire Single Unit Vehicles
F4	Buses
F5	Two-axle, Six-tire, Single Unit Trucks
F6	Three-Axle, Single Unit Trucks
F7	Four or More Axle, Single Unit Trucks
F8	Four or Less Axle, Single Trailer Trucks
F9	Five-Axle, Single Trailer Trucks
F10	Six or More Axle, Single Trailer Trucks
F11	Five or Less Axle, Multi-Trailer Trucks
F12	Six-Axle, Multi-Trailer Trucks
F13	Seven or More Axle, Multi-Trailer Trucks

Note: Detailed definitions of vehicles in each type may be found in Appendix I on pages 68 and 69.

Systems are designed with logic which will differentiate between Class 2 and Class 3 on a determination of this wheel base distance. The only system which provides an immediate printout of axle spacing on each vehicle is the I.R.D. On this system tests have been run using several vehicles with a known wheel base. Repeated runs were made to determine the magnitude of error involved in the axle spacing measurement.

Tests run on a long station wagon with a measured wheel base of 123" gave an $\bar{x}$ of 121.3 and d_n of 3.13. The range was 117"-127".

Tests on a pickup Class 3 with a measured wheel base of 133" gave an $\bar{x}$ of 133" with a d_n of 4.2. The range was 127"-140".

$\bar{x}$ = arithmetic mean value of n runs

d_n = 1 standard deviation

The range give the high and low value of the distribution.

On the basis of these tests showing the top of the Class 2 range equal to the bottom of the Class 3 range it was decided to leave the 120" wheel base decision length as is. A few longer older vehicles or long station wagons will fall in Class 3 as this test station wagon did part of the time. The new midsize pickups will drop into Class 2 on occasion.

It is considered that an error in wheel base of approximately 2-3% here is unimportant as road use (passengers carried) or weight (road damage imposed) will not vary greatly between these two categories. Discussion with the equipment manufacturer about this error and its cause indicates that it is implicit in the rate at which the microprocessor queries the axle counter outputs and will be essentially the same number on longer vehicles, being a constant and not a percentage error.

Tests run on a tandem truck with a measured spacing between axle 1 and 2 of 159" gave a $\bar{x}$ = 159.4 on 15 runs thru the classifier with d_n = 3.8. The range was 154 to 170. The manufacturer indicates that this amount of error is normal and occurs because of the time error introduced by the clock rate at which each input to the recorder is interrogated.

On the I.R.D. system a check of overall length, which is measured by the time of occupancy of a loop, was made. The overall length of the truck as measured was 306". For 15 test runs an $\bar{x}$ of 311.6" with a d_n of 6.4 was obtained. The range was 304"-327". Errors here consist of variations in time of closure of the loop detectors output which varies with position of the vehicle with respect to the loop. A correction is programmable into the logic to bring the $\bar{x}$ more nearly to the actual. Since this loop closure time, on which speed and thus length calculations depend, varies with type of vehicle - chassis height - mass of metal, etc. no change was made in the logic for this one type of classification since the length error will probably vary from different classes of vehicles. The measurement of axle spacings was the more important characteristic to record accurately, as this dimension is used in the classification logic. Axle spacing error was not a fixed percentage but stayed more nearly within the same range numerically for the longer spacings. Thus, the errors in this measurement should not effect classification seriously above Class 3. Accuracy of speed measurements made by the system were checked by radar to be within $\pm 2\%$.

In order to determine proper wheel base lengths for the classification break points for vehicles with more than two axles, a study was made of actual spacings of axles on existing vehicles.

This study was accomplished by reviewing calibrated photographs and by obtaining actual vehicle axle measurements by visiting automobile sales outlets, truck stops, and rest areas to find and inspect the various types of vehicles of interest.

Actual axle spacings were measured for the range of vehicles involved. Sufficient varieties of each of the general types of vehicles of interest were selected to obtain a range of values so that proper high and low break points for the vehicle category differentiation could be selected as required.

Category "F"-4 was added to cover buses. Visual observation showed that the selected wheel base will properly categorize 95% or more of the buses. Short urban buses may fall into the truck category.

The classification for a pickup towing a trailer was corrected to place such vehicles in F3 along with heavy duty pickups.

All standard commercially manufactured two axle campers or R.V. type trailers have the two axles approximately at the trailer center of gravity and have axle center to centers of less than 3.5'. An occasional home built unit or road construction vehicle may vary from this but classification using the 3.5' criteria should be correct for over 99% of the vehicles.

Five and six axle double bottom vehicle arrangements were checked by leasing a unit with a tractor unit on which the first set of driving wheels could be hydraulically raised so that this unit could be used to verify F11 and F12 categories. Multiple passes were made through the test section with both wheel arrangements. Photograph (#1) of this test vehicle is shown on page 25.

Because of the different techniques used in collecting vehicle generated data each companies' system uses a slightly different logic to determine the proper class for each vehicle.

However, the system flow chart "F" developed and listed in detail under paragraph 4.3 can be translated by the programmers to provide the necessary microprocessor logic programs so that all systems except the Sarasota should be able to classify to this system.

Because of the time required to rewrite the program no attempt was made to have the system F actually checked on all systems.

4.4 COMPUTER CHECK OF SCHEME "F"

The FHWA Office of Highway Planning ran a computer check of Scheme F using data supplied by the State of Washington of some 12,927 vehicles classified by types. One error in logic in scheme F was identified and corrected.

The data was again compared by computer which indicated that scheme F would provide an acceptable classification system having an accuracy averaging well over 95% and better in the truck types.

An error in logic on the 4 axle classification, third and fourth steps was detected and corrected. This correction was not computer tested against the truck weight data file.

Double Bottom Truck
Used in classification test runs.

PHOTO #1

5.0 TEST SITE

5.1 PROBLEMS

Several problems arose to delay the start of the test evaluation program. One was the fact that the pavement in front of the Maine Facility building, where the initial check out of each equipment was to be performed, had deteriorated so that bouncing of vehicle's axles occurred causing errors in axle count. The second problem was the delay in receiving completely operative equipment and working out the problems with the various manufacturers.

Problem One: The bituminous concrete two-lane road, U.S. 2, passing the Facility had deteriorated as mentioned and it was decided to repave an appropriate section of the road before testing the various equipments.

A four-hundred foot section of the road was shimmed and then repaved with 1 1/4" of bituminous concrete. Three of the systems were then installed with a 200' section as level as could be obtained prior to the vehicle crossing the various system's sensors.

The required loops and sensors were then installed in sequence so that several systems could be tested at the same time and results compared. As each system was installed preliminary testing was undertaken with the result that defects and errors were found. These problems were then discussed with each equipment manufacturer and corrections made as rapidly as possible.

Problem Two: Because of the more or less permanent nature of the I.R.D. system installation and the Golden River pad it was decided to run both the proof testing and the longer term volume testing on these two systems at the facility only, rather than move the systems to one of the sites on I-95. The traffic mix at the facility, because of its location on U.S. Route 2, the only primary east-west highway, was adequate for an acceptable test of the various systems ability to properly classify all categories of vehicles. Heavily loaded logging trucks, other types of heavy semi-trailers, and most all varieties of recreation vehicles use this highway. Also because of the position of the site at the top of the hill, slow-moving heavily loaded trucks cause following vehicles to slow down to about 20 mph. Thus, queues of slow-moving vehicles formed. Queues and slow-moving vehicles cause program logic problems in the various types of equipment. Where two loops are used the interception of the first loop by a vehicle starts the recording logic, and the time to interception of the second loop provides information by which the system calculates the vehicle speed. Departure from the second loop provides a total time in the system from which overall vehicle length is calculated by the system. The departure from this loop also stops data collection for that vehicle.

When queues form, vehicles stopping within the loop to loop system will cause time errors so the program logic instructs the system to disregard the data and the vehicle is not counted.

Slow-moving vehicles transiting the loop system are usually changing speed either up or down.

Thus, since speed and loop spacing are used in the calculation of axle spacing and thus in vehicle type classification a speed change may cause false classification.

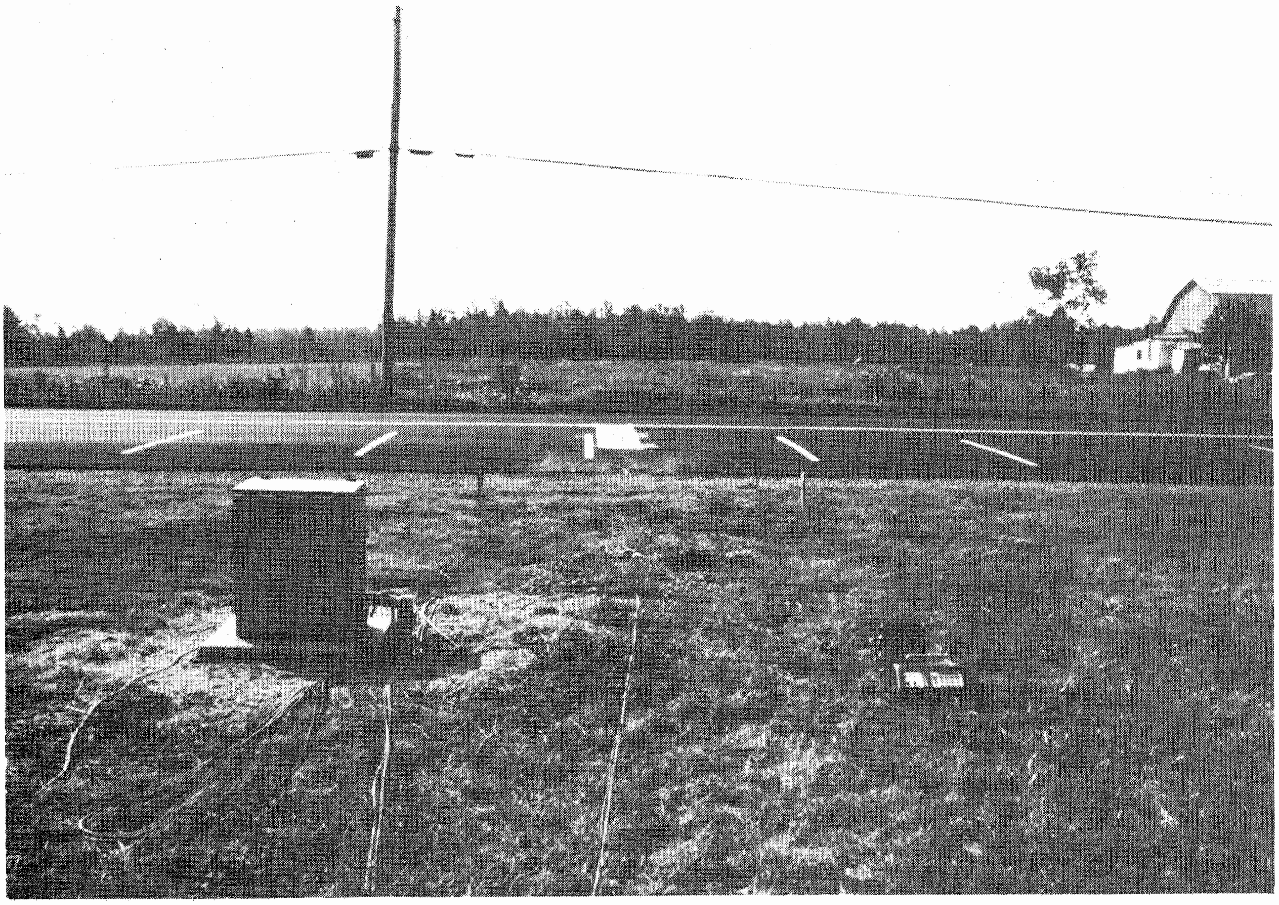
If simultaneous occupancy of both loops occurs, by two vehicles they will be added togehter and recorded as one; and with a resulting incorrect classification.

In system using pneumatic tubes similar problems occur, particularly the misclassifications due to speed error, so this type of system usually has instructions in the program logic to not count or classify vehicles whose speed is less than 20 mph.

The loop and axle counter type systems do not have such program logic instructions.

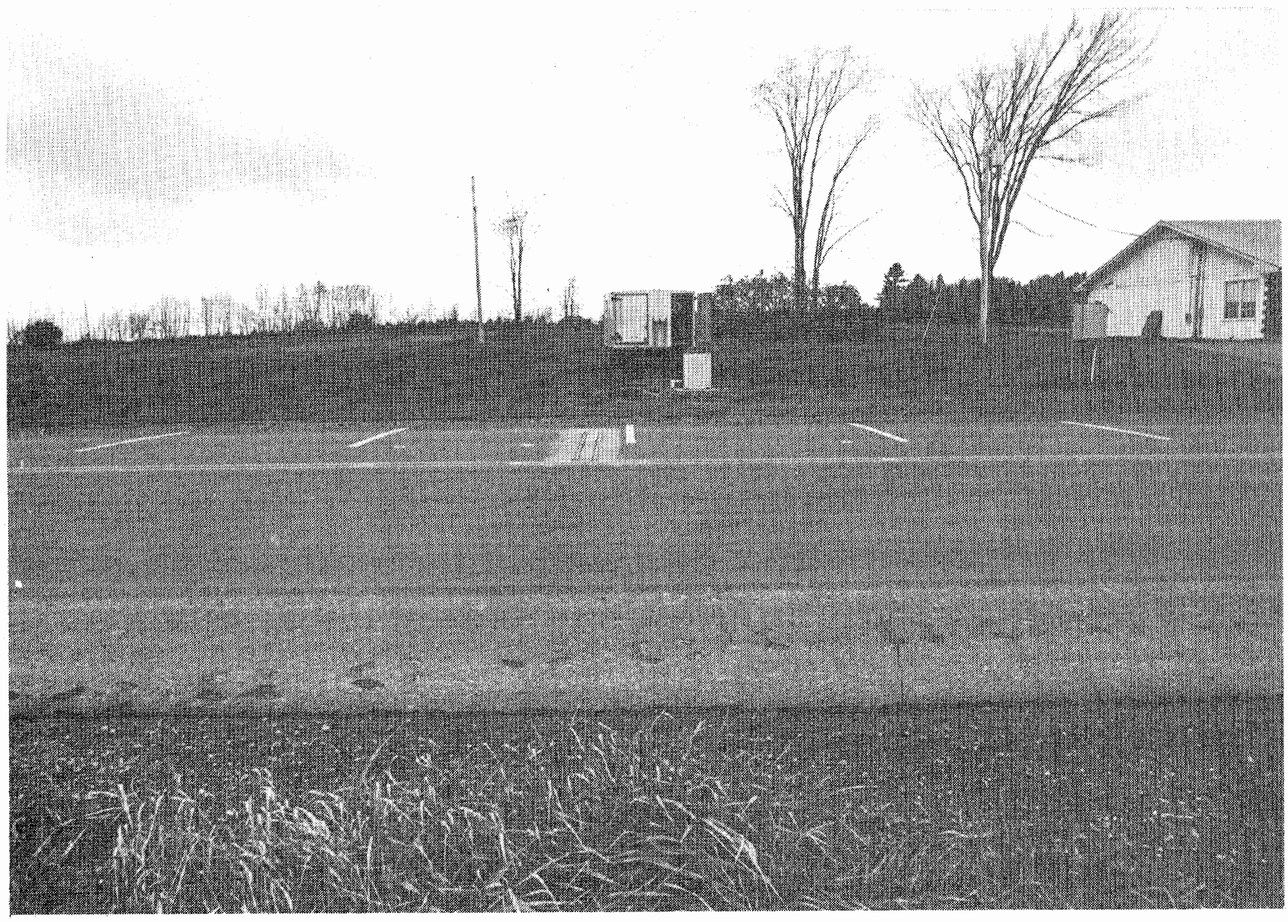
All systems should be used only in free flow traffic conditions.

Short headway at high speeds (under 30' separation) will also cause errors in the classification in the two loops system. (Combining two vehicles as one). The pneumatic tube systems with tube spacings of 16' or under would have to be intercepted by vehicles separated by approximately the tube spacing before errors of the above type would occur. Evaluation of the various systems' ability to handle queues and slow-moving vehicles was readily accomplished visually. The placement of the test station was such that visual observation as well as photographs as required could be made at the same time as the equipment tests were performed. See photos #2 and #3, respectively.



View at photographic
site at Maine Facility
on U.S. Rte. 2.

PHOTO #2



View of equipment van
at U.S. Rte. 2 site.

PHOTO #3

5.2 I-95 VOLUME SITE

Volume checks on the Streeter-Amet and the G.K. Systems were run at the site on I-95 north at Pittsfield as previously described. At this site traffic is almost always in a free flow condition and the volume checks on these two systems, which had difficulty handling queues and slow-moving vehicles, was more accurately analyzed for the larger volume the system can handle (see Figure II, paragraph 6.3). Also see photo #4.

5.3 MAINE FACILITY, U.S. ROUTE 2 TEST SITE

During the repavement of the two lane road passing the facility an opportunity was taken to place the loops for three systems between the shim layer and the final bituminous top course. This provided a clean roadway with no obvious exposed loops. Of course the axle counters and pneumatic tubes are visible, but in general the lack of visible loop slots and fill reduces the visibility of the system to passing traffic. All systems were installed in the westbound lane.

Loops were provided as on Figure I. Two 6'x6' loops with a 9.84' spacing leading edge to leading edge were installed for the Sarasota system.

Two loops 8'x10' with 20' leading edge to leading edge were provided for the I.R.D. system. Two 6'x6' loops with 16' leading edge to leading edge were provided for the Golden River system. Photographs #5 and #6 show the site installation before and after placement of the bituminous wearing course.

Figure I also shows the placement of the axle counter for the I.R.D. system and the W.I.M. pad, which provides axle count, for the Golden River system. See photograph #7 and #8.

Pneumatic tubes for the Streeter-Amet and G.K. Systems were placed from the centerline to the edge of pavement over the open areas between axle counters when required for data recording on these systems.

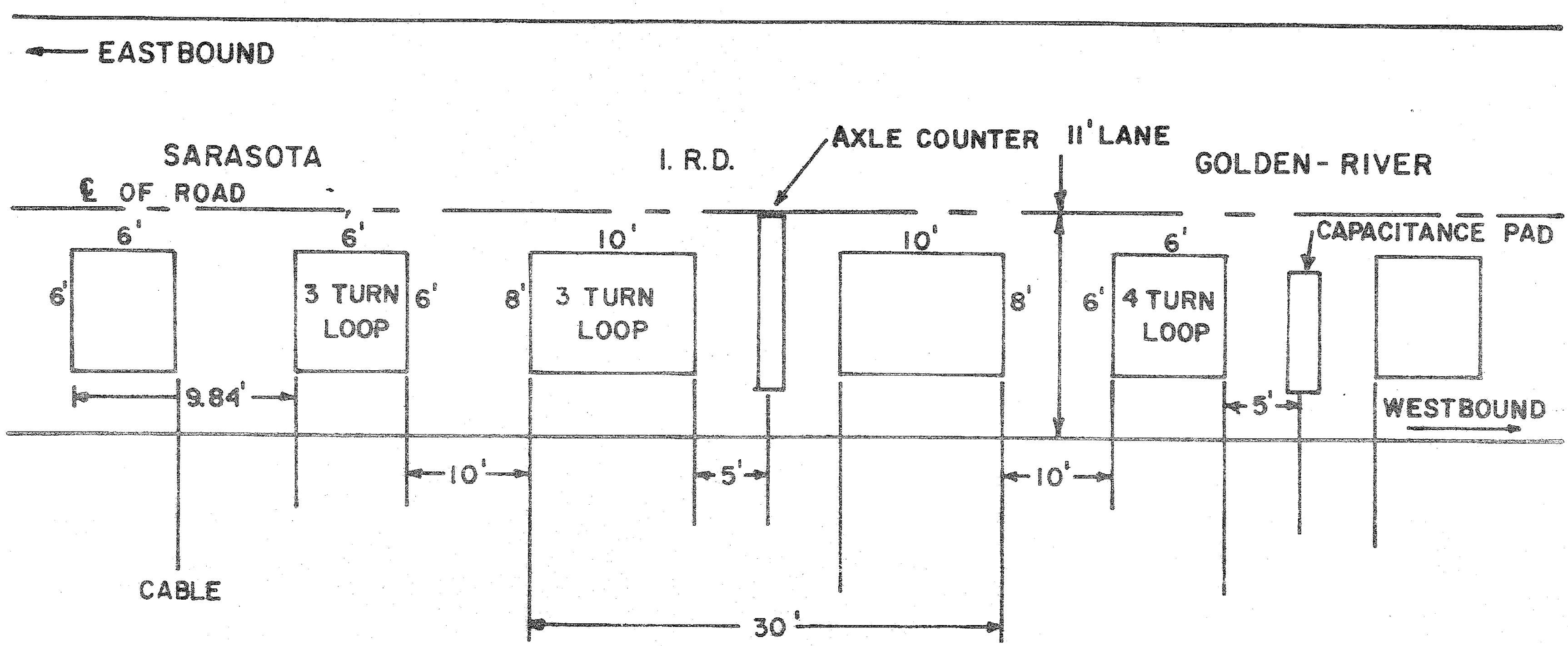
The 8' wide loops of the I.R.D. system placed in a 11' wide lane were often activated by traffic in the opposite direction. This was indicated by the recorder noting "Wrong Direction" on the printout. It was recommended to the manufacturer that 6' wide loops be used. They agreed and 6' wide loops were installed at the W.I.M. site in Sidney on I-95,

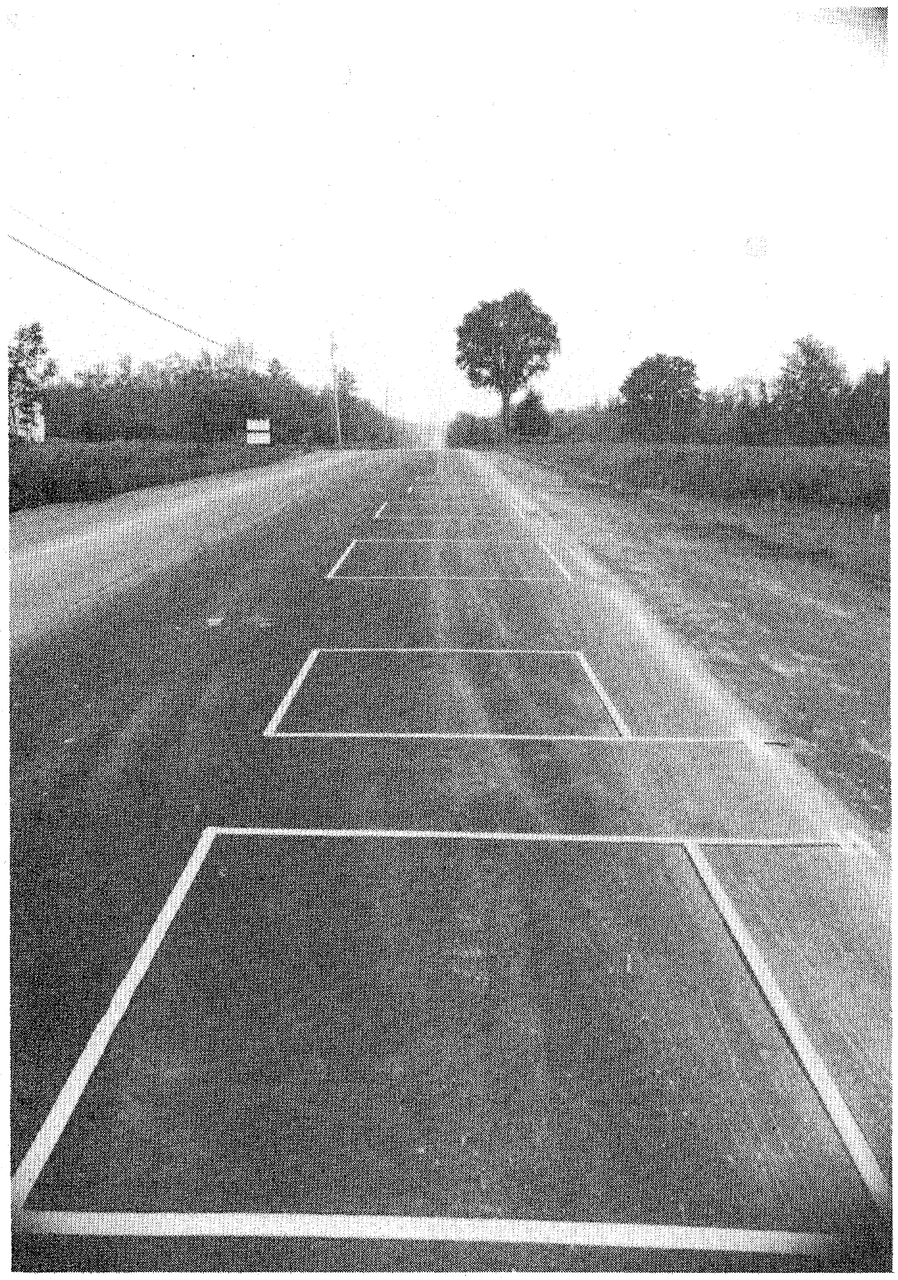
I-95 northbound site
at Pittsfield, showing
Streeter-Amet and G.K. Instrument pneumatic
tube installation.

PHOTO #4

FIGURE I

U.S. ROUTE 2 - TEST LAYOUT - VEHICLE CLASSIFICATION PROJECT



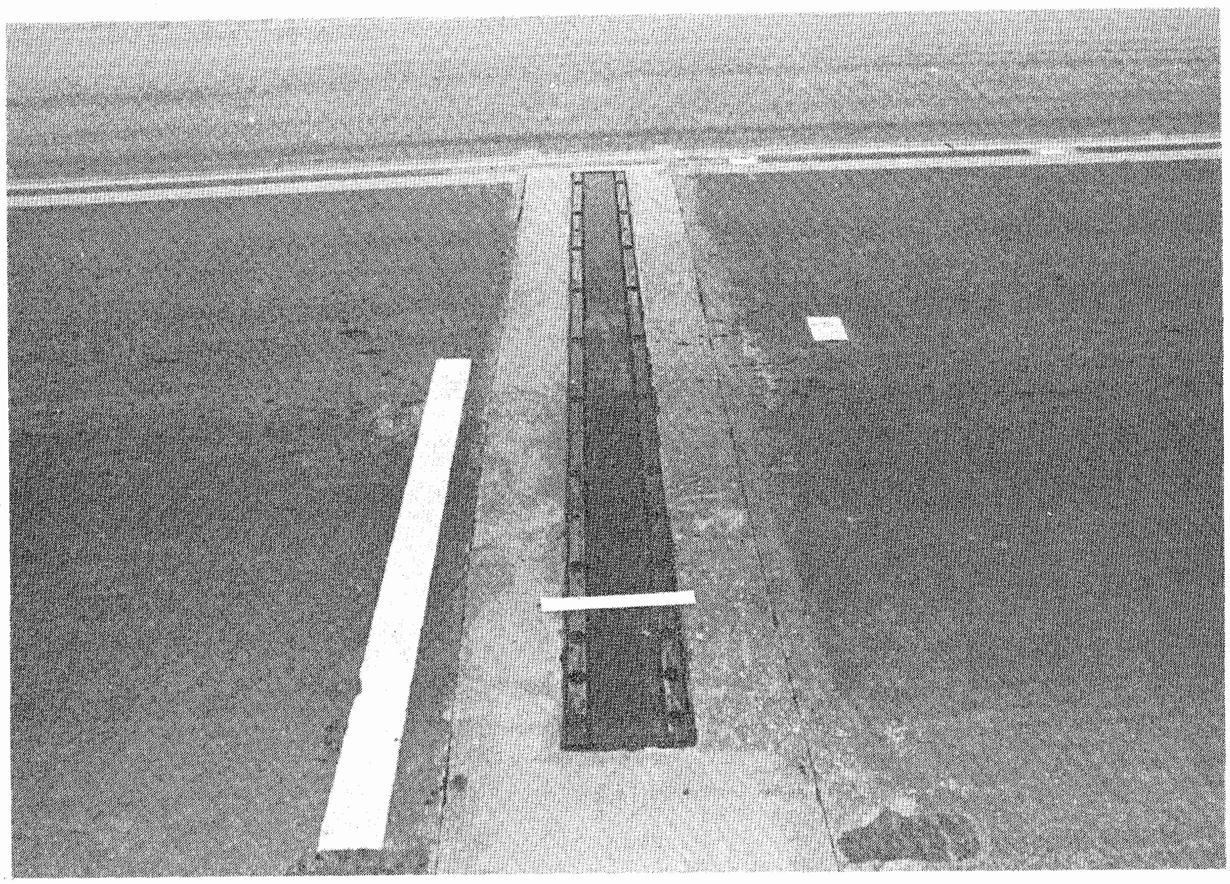


View of loop installation on U.S. 2
at Facility - loops visible
on base course of bituminous
concrete before application
of top wearing surface.

PHOTO #5

View thru test site on U.S. 2
at Maine Facility.
I.R.D. axle counter in foreground.
White lines 10 feet apart are
The photo identification lines
for length verification.

PHOTO #6



I.R.D. axle counter
One foot ruler indicated.

PHOTO #7

View east on U.S. 2
showing westbound lane with
Golden River weigh pad
in foreground.

PHOTO #8

then being installed. They proved to work satisfactorily, eliminating cross talk from the adjacent lane. Also setting the loop detectors on the low gain position, instead of medium, reduced the problem of "missed axle detectors" that had previously occurred frequently.

G.K. Instruments recommended that we install the pneumatic tubes for their system to cover only 2/3 of the lane, to shorten the length of exposed tube and thus reduce motion when the tube was hit. This was done on operation of this system at the Facility; but full lane coverage was still employed on the volume tests on I-95, where the system was always checked at the same time as the Streeter-Amet system, so that both systems saw the same tube conditions.

6.0 EVALUATION METHODOLOGY

The testing and evaluation program was undertaken to examine the logic, reliability, and accuracy of the existing systems. The testing program had three major phases, 1. Set up and preliminary testing of each system to find and eliminate initial electrical and installation problems; 2. Proof testing, conducted at a test section on U.S. Route 2 in front of the Facility for photographic and visual confirmation of the ability of each system to properly follow its logic in placing the vehicles observed in the proper category; 3. Collection and analysis of larger volume of data under high volume of vehicular traffic and study of the reliability of the systems.

6.1 INITIAL EXAMINATION

Each classifier system was examined and set up in the facility laboratory and run under simulated conditions. All systems had some initial problems varying from missing connection cables to the more serious situation of incorrect cables for connection to the printers. In one case defective chips in a collection device and in another incorrectly inserted chips were a problem. Improper transmission code setting for the printers supplied also caused difficulty.

Problems with interpreting the instruction books that came with each system arose. Although in most instances well written technically, they were hard to follow because the writers assumed in too many instances that the reader had information about the systems that in fact were not known. Video tapes of set up and operation of the systems might be a helpful instruction aid. Acceptance of these new systems by potential purchasers and their speedy installation and use in the field will in many cases depend upon a more thorough communication of the equipment's operating parameters and potential problem areas, to the users, by the manufacturers.

6.2 PROOF TESTING

Proof testing, as defined for this project, is the determination of the accuracy with which each system places a specific type of vehicle in the proper category as defined by the systems' logic scheme.

This evaluation was accomplished by having an observer record the type of each of 100 consecutive vehicles passing the test site. This evaluation was repeated on five separate days for an observation of a minimum of 500 vehicles thru each system.

When necessary photographs were also taken. The test site had five sets of white lines, 4" wide, painted on the road 10' apart. Comparison of the spacing of a vehicles axles and its overall length with the lines, by measurement on the photograph as required, permitted a check as to whether the particular system had correctly classified the vehicle. Photographs of representative vehicles are shown in Appendix III.

In addition, in order to obtain a better measure of the systems' ability to accurately use these two variables where necessary in arriving at a classification, another source of data was also used.

The axle spacing and overall length of several different types of vehicles was obtained by tape measurements and then the vehicles were run thru the system and the classification checked.

The following vehicles were checked in this way.

1. A double bottom semi-trailer,
2. A 3S2,
3. A 2S2,
4. A pickup,
5. A standard passenger car.

Although all systems except Sarasota used axle spacing in the logical determination of vehicle type, the only system that provides a concurrent readout of each vehicle's axle spacings as measured by the system was the I.R.D. which provides a continuous printout of axle spacings, speed, overall length and class for all vehicles. Also this system missed fewer vehicles then other systems so it provided a standard count for comparison with the other systems. Tests conducted on U.S. 2 at the Facility, were run in comparison with the I.R.D. system. If an axle count was missed by the I.R.D. unit the logic of this system caused a statement to be printed out that read, "Missed Axle Counter", so that even though a classification might be missed the count was intact. U.S. Route 2 at this point is a two lane rural highway with 11' lanes. Traffic in a westbound direction is heavy and consists of a broad mix of trucks and vehicles of most varieties.

6.3 VOLUME AND QUALITY TESTING

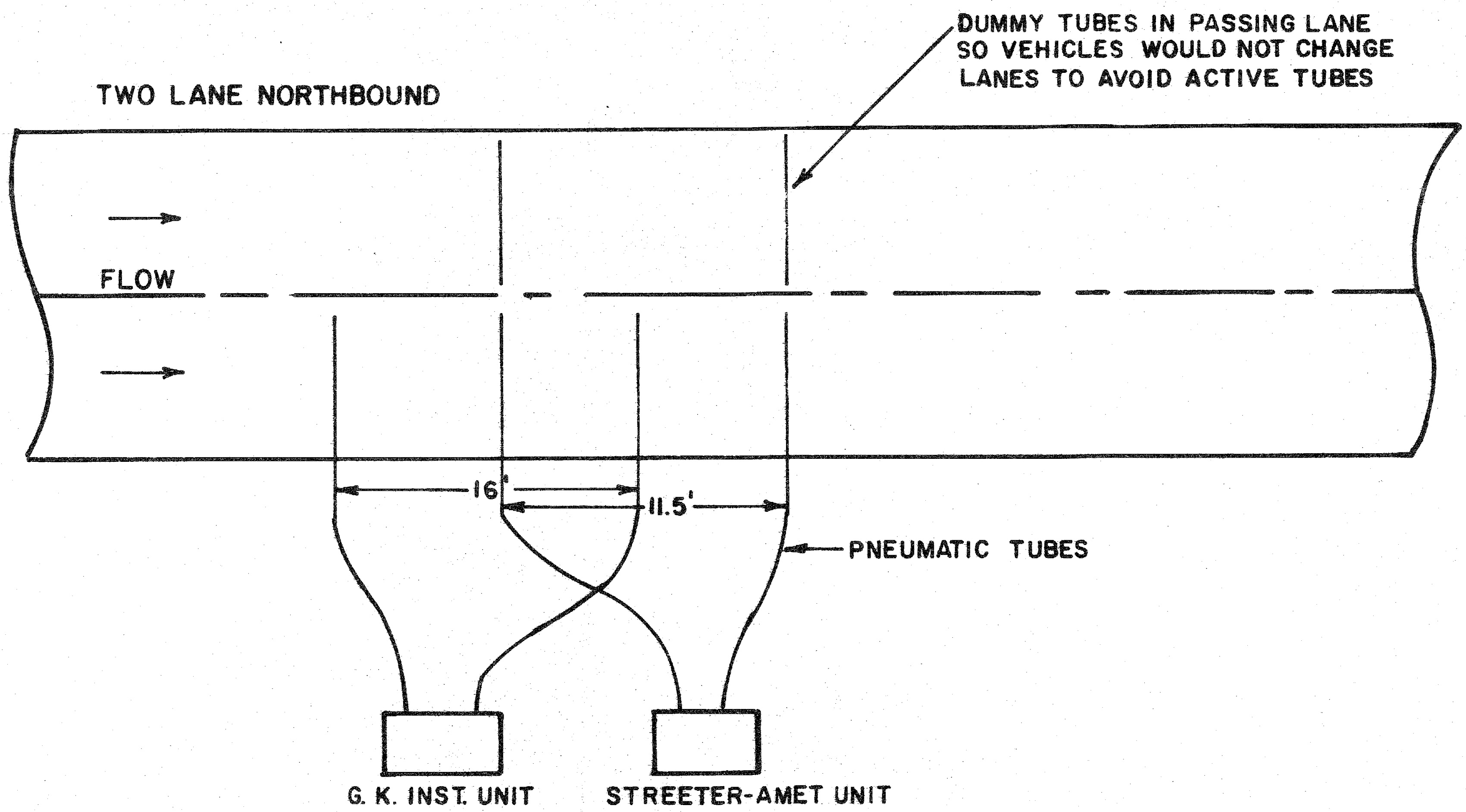
Volume testing was done by conducting 24 hour or longer data runs either on U.S. 2 at the Facility for I.R.D, Golden River and Sarasota, or on I-95 northbound at Pittsfield for the Streeter-Amet and G.K. Instrument systems.

Two systems were run simultaneously so that a check could be made as to missed counts. This test is basically one to prove continuity of operation of the system and quality of the electronics to operate without failure. Streeter-Amet and G.K. Instrument classify by bin count only, and since discrete identity of vehicle is lost, one on one comparison of classification is impossible. Therefore, this test is essentially a qualitive one for these systems. See Figure II for the I-95 layout for the two pneumatic tube systems. Photo #4 on page 31 also shows the pneumatic tube layout.

Each system was run on volume testing for at least 200 hours. These times were not necessarily continuous but the sum of several separate runs.

FIGURE II

I-95 NORTHBOUND - TEST LAYOUT - VEHICLE CLASSIFICATION PROJECT



7.0 EVALUATION OF DATA

Because of the considerable difference in operation of the various systems as to data collection and printout techniques each system will be reviewed separately.

However, all systems had some common problems and these will be discussed together.

A general summary of the accuracy and system reliability should be valuable to potential users of these systems and will be provided at the end of the section. Also these data will be listed along with other users' parameters to help in selecting the type of system needed in any particular situation.

7.1 COMMON PROBLEMS

Four of the five systems provide vehicle classification data based on number of axles and spacing, while the fifth, the Sarasota System categorizes by vehicle lengths only.

All systems on occasion missed counting and classifying vehicles. Systems using pneumatic hoses missed more often than systems using other types of axle counters. In general the hose type systems missed vehicles in queues and when the vehicles were travelling under twenty miles per hour. The instruction manual for Streeter-Amet makes note that their system will operate satisfactorily only in free flow traffic above 20 mph and this was found to be true for both hose type units although an occasional vehicle at 18 mph if not in a queue would be successfully classified. Discussions with one manufacturer, Streeter-Amet, indicated that this slow speed or queue cut off is a deliberate logic program device to avoid errors due to varying vehicle speeds in slow-moving queues or to prevent two vehicles simultaneously occupying both loops and thus appearing as one vehicle.

Both the I.R.D. and the Golden River System occasionally missed an axle count and thus could not classify that particular vehicle. The I.R.D. systems logic, however as previously mentioned, is provided with the capability to printout "Missed Axle Counter" so that although not classified, that vehicle was counted. These two systems also would combine two vehicles and class the result in the over 7 axles or 'all other' category if simultaneous occupancy of both loops occurred. A 5 axle semi-trailer followed closely by a 2 axle car towing a camper for instance would show up as a class 14 on the I.R.D. or Golden River system with an obviously erroneous overall length. This type of problem will occur infrequently however and only in tailgating and queue situations.

The original "E" classification developed in the 1982 Maine Facility study has some problem logic errors and where a program followed this scheme closely those classification errors were not included in calculating the percent accuracy.

For instance class 6 and 5 should be processed thru the logic in the reverse order, as mentioned in paragraph 4.1.

7.2 PROOF TESTING DATA AND DISCUSSION

7.2.1 I.R.D. System

The I.R.D. system program logic followed the Scheme "F" closely as to categorization but employed additional logic inputs. Table 6 shows the classification scheme. The ability of the axle counter to identify dual tires, by virtue of its multiple magnetic sensors permitted the use of such detection to provide an additional logic input. However, because of the way the logic system interrogated the various axles for duals, (interrogating only certain axles in various axle classes) occasional classification errors were generated by this technique. It would seem that this is an ideal additional data input to aid in classification, but the technique should be refined to avoid the generation of additional logic errors.

Since this was the only system to provide a readout of axle spacings, photographic comparison was used extensively here. It was determined that the photographic technique could be depended upon to provide a spacing measurement of plus or minus 6" on a vehicle with an axle spacing of 10 to 15 feet. Table 7 shows the proof test results for five, 100 or more vehicle runs, in this case a total of 590 vehicles. Photo verification permitted the identification of the probable misclassification of 4 vehicles identified as class 2 which should have been class 3 and 2 in class 3 which should have been in class 2. However they are not classed as errors in determining the percentage correct since no other system can be photo checked to this accuracy and class 2 and 3 overlaps are common.

This system correctly classified all the 5 and 6 axle double bottoms' processed thru during the proof test period.

Other types of errors such as missed axle sensor, missed duals, vehicle going in the wrong direction (this is cross talk from the opposing lane traffic) are identified by their column heading. A vehicle with an unusual spacing such as a four axle

TABLE 6
INTERNATIONAL ROAD DYNAMICS
VEHICLE CLASSIFICATION CATEGORIES

TYPE	AXLE CONFIGURATION	NOTES
1	o o	Motorcycle (- 70")
2	o o	Cars (70" - 120")
	o o o	Car (- 120") w/ trailer
	o o o o	Car (- 120") w/ tandem trailer
	o o öö	Car w/ short tandem (- 42")
3	o o	Truck (120" - 240")
	o 8	
4	o o	Bus (240" -)
	o 8	
	o o o	
	o 8 o	
5	o 8	Truck (120"-240")
6	o 8 8	Single unit
	o o o	
7	o 8 8 8	
	o 8 8 8	
8	o 8 8	3 Axle, 4 Axle Double Units
	o 8 8 8	
	o 8 8 8	
9	o 8 8 8 8	5 Axle Double Units
	o 8 8 8 8	
	o 8 8 8 8	
10	o 8 8 8 8 8	6 Axle Double Units
	o 8 8 8 8 8	
11	o 8 8 8 8	Multi Units
	o 8 8 8	
12	o 8 8 8 8 8	
	o 8 8 8 8 8	
13	o 8 8 8 8 8 8	
	o 8 8 8 8 8 8 8	
	o 8 8 8 8 8 8 8	
	o 8 8 8 8 8 8 8 8	
14		all other combinations

o - single tire
8 - dual tire
|| - short tandem space (- 42")
| - tandem space (- 96")
| - tridem space (- 144")
| - bike space (- 70")
| - normal space (- 120")
| - truck space (- 240")
| - bus space (240" -)

TABLE 7

I.R.D. PROOF TEST SUMMARY

Class	Correct	Incorrect Class 1	2	3	4	5	6	7	8	9	10	11	12	13	14	Miss Sensor	Mis-Class Que	Class OK Miss Tlr.	Class OK Miss Duals	Total Error	Total	% Correct
1	2															1				1	3	66.0
2	284			4	Note 1											9	1	3		13	297	95.6
3	116		2	Note 1		7												1		8	124	93.5
4	6						1												3	4	10	60.0
5	29			4	2				1							2	1			10	39	74.4
6	36														1				4	5	41	87.8
7	6																			0	6	100
8	7			1																1	8	87.5
9	31														1*		1			1	32	96.8
10	5																			0	5	100
11	9																			0	9	100
12	7																			0	7	100
13	0																			0	0	
14	1		1*	10	note 3				1*	1*		note 2								10		
Totals	539																			53	591	91.2

Note 1 - See text (par. 7.2.1) not called mis-class.
Note 2 - *starred items program error - not called mis-class.
Note 3 - Dual tired van pulling single wheel trailer - mis-class because of dual - logic error.

crane, or a camper trailer classed improperly as having duals were put into class 14. Of the vehicles monitored 91.2 percent were correctly classified.

Program errors are not classed as errors in the percentage calculation but failure to follow program differentiation is classed as an error. Thus the use of duals in the classification and then missing the dual is an error. It is believed that this use of duals as a logic input is 'State of the Art' and should be encouraged, but that correction of the logic problem in the use of this data input should be undertaken. Such a correction would bring the percent correct up 3 or 4 percentage points.

Volume Runs

Volume runs on the I.R.D. system were made on U.S. Route 2 on October 5, 6, 7, 8, 9, 13, 14, 15, 16, 17, 18, 19, 20, 21 and 22 for a total of 331 hours and a total of 13,375 vehicles counted. (See Tables 16 thru 20). Axle sensor misses were checked on October 5th thru 9th with 103 misses or a 96.3 percent classified. After a discussion with the manufacturer a reduction was made on the loop detector gain and from October 12 thru the 23rd, 8100 vehicles were counted with a 99.86% accuracy.

The I.R.D. system ran for the entire evaluation and was continuously on from October 5th thru the 23rd without any electrical problems or failures.

The system electronics appears well constructed and reliable. The 'in the road' axle counter and loop installation is designed for year round permanent all weather use and should stand up to continuous use with minimum maintenance.

7.2.2 Golden River System

The Golden River system followed the Scheme "E" closely. (See Table 8) During the 5 separate 100 vehicle data observation periods, the system correctly classified 567 vehicles out of 591 for a percent classified of 95.9% correct. Since the logic error previously discussed was present 18 vehicles were improperly classified in the 7, 6 and 3 categories. Five vehicles were missed, four for no known reason and one because of a queue. All of the systems including Golden River do occasionally miss a vehicle completely. Observation of this throughout the project has not lead to any well defined reason except for those that are in the slow speed and queue categories. The Golden River system correctly classified the 9- five axle 'Double Bottoms' and the 7- six axle 'Double Bottoms' that were sent thru the system during proof testing to verify the systems'

TABLE 8

GOLDEN RIVER MK3 WEIGHMAN
VEHICLE CLASSIFICATION CATEGORIES

Vehicles are classified according to the FHWA scheme E classification system.

Vehicle Class	Description
1	Passenger cars, light trucks, and vans (2 axles).
2	Heavy-duty pick-ups, delivery trucks, 2A6T,s (2 axles).
3	Cars and light trucks with one or two axle trailers.
4	Three axle single unit trucks.
5	Four axle trucks and semi trailers - 2S2.
6	Four axle single unit trucks.
7	Other four axle combinations.
8	Five axle trucks and semi trailers - 3S2.
9	Other five axle combinations.
10	Trucks and semi trailers plus full trailers (5 axles) 2S1-2.
11	Trucks and semi trailers plus full trailers (6 axles) 3S1-2.
12	Six axle trucks and semi trailers - 3S3.
13	Other six axle combinations.
14	Other seven or more axle combinations.

ability to handle this type of vehicle. Table 9 gives the summary of the classification results of the 591 vehicles.

Volume Runs

Volume runs were made on U.S. Route 2 on October 5, 6, 7, 13, 14, 16, 17, 18, 19, 20, 21 and 22 (see Tables 16, 18,19 and 20). A total of 9143 vehicles were recorded by the system over a period of 253 hours. Using the I.R.D. System's count for comparison[1] during those periods when the data collection times were equal; showed a total of 9345 vehicles for the I.R.D. vs 8064 for the Golden River for a difference in count of 1281 or 13.7%. Observations indicate that the Golden River misses counts more frequently than the I.R.D. since the weight pad used as the axle counter covers only one wheel path and misses were more likely to occur.

The electronics operated satisfactorily during the entire test period with no failures or difficulty after the initial set up problems.

The capacitance pad was in place from July 7th thru October 24th on U.S. Route 2 and had no failures or obvious damage during this period in spite of some heavy construction trucks passing over the system daily.

7.2.3 Streeter-Amet System

The Streeter-Amet classification system essentially followed the revised FHWA scheme with the addition of extra axle spacing logic interrogations as shown on Table 10. Table 11 shows the summary of the proof test runs. During the five proof test runs of approximately 100 vehicles each for a total of 647; 604 or 93.5% were classified correctly. Missed vehicles, reason unknown (16), and missed in queue or slow speed (10) accounted for over half of the errors. The Streeter-Amet system classified the 'Double Bottoms' correctly except for one class 12, a 6 wheel unit which was missed completely. It is believed that this is one of the 'Reason Unknown' misses, and not a function of the vehicle type. Two 'logic errors' were detected with one class 2 vehicle classed as an 8 and one class 4 vehicle classed as a 5. The reason is not known.

(1) Although the I.R.D. system did fail to classify correctly on occasion it was the most accurate in providing a true total vehicle count, thus its use for a count standard on the long term test runs.

TABLE 9

GOLDEN RIVER - PROOF TEST SUMMARY

Class	Correct	Incorrect Class														Miss	Miss Que	Total Error	Total	% Correct
		1	2	3	4	5	6	7	8	9	10	11	12	13	14					
1	291			1												2		3	294	98.97
2	215															2	1	3	218	98.62
3	2	1			8*													1	4	50.00
4	22									1								1	23	95.6
5	2																		2	100
6					1	3*												1	1	
7	5				1	5*			1									1	7	71.4
8	13						1								1			2	15	86.6
9	2										1							1	3	66.6
10	9																		9	100
11	7																		7	100
12	5		1															1	6	83.3
13	1																	1	2	50.0
14																				
Total	567	1	1	1	2	0	1		1	1	1				1	4	1	15	591	95.9

*Logic Problem - Not Fault of Equipment.

TABLE 10
STREETER-AMET CLASSIFICATION CATEGORIES

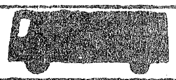
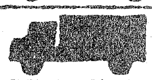
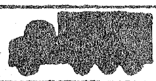
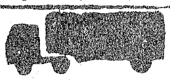
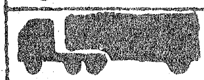
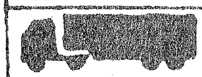
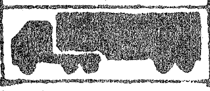
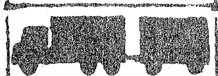
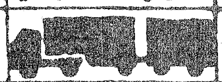
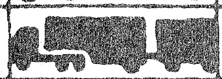
VEH. TYPE	VEHICLE TYPE	No. of Axles	AXLE SPACING IN FEET: Axle 1 to 2	Axle 2 to 3	Axle 3 to 4	Axle 4 to 5	Axle 5 to 6	Total Wheelbase
1		2	0 - 5.8	-	-	-	-	0 - 5.8
2		2	5.8 - 11.5	-	-	-	-	5.8 - 11.5
		3	5.8 - 11.5	5.8 - 17.3	-	-	-	11.5 - 28.8
		4	5.8 - 11.5	8.6 - 17.3	0 - 5.8	-	-	17.3 - 40.3
3			11.5 - 17.3					11.5 - 17.3
4		2	23 - 40.3	-	-	-	-	23 - 40.3
5		2	17.3 - 23					17.3 - 23
6		3	5.8 - 23	0 - 5.8	-	-	-	11.5 - 40.3
7		4	5.8 - 23	0 - 8.6	0 - 5.8	-	-	17.3 - 40.3
8		3	5.8 - 17.3	17.3 - 40.3	-	-	-	23 - 46
		4	5.8 - 17.3	0 - 5.3	5.8 - 40.3	-	-	23 - 57.3
		4	5.8 - 17.3	17.3 - 40.3	0 - 5.8	-	-	23 - 57.3
9		5	5.8 - 17.3	0 - 5.8	11.5 - 40.3	0 - 11.5	-	40.3 - 69
		5	5.8 - 17.3	0 - 5.8	5.8 - 23	11.5 - 23	-	40.3 - 69
10		6	5.8 - 17.3	0 - 5.8	0 - 40.3	0 - 11.5	0 - 11.5	40.3 - 69
11		5	5.8 - 17.3	11.5 - 23	5.8 - 17.2	11.5 - 23	-	40.3 - 69
12		6	5.8 - 17.3	0 - 5.8	11.5 - 23	5.8 -17.3	11.5 - 23	- 69
13	ANY 7-AXLE	7	5.8 - 17.3	0 - 5.8	0 - 23	0 - 23	0 - 23	- 69
14	TOTAL VEHICLES							

TABLE 11

STREETER-AMET - PROOF TEST SUMMARY

Class	Correct	Incorrect Class 1	2	3	4	5	6	7	8	9	10	11	12	13	14	Miss	Miss Que	Mis-Class Que	Error Speed <20	Total Error	Total	% Correct
1	1																			0	1	100
2	512			1	2		1		2*							7	5	2	2	20	532	97.9
3	28																			0	28	100
4	2					1*											1			1	3	66.6
5	1																1			1	2	50
6	21							4								3	1			8	29	72.4
7	4						1									2			2	5	9	44.0
8	1																	1		1	2	50
9	21							1			1			1						3	24	87.5
10	6													1		2				3	9	66.6
11	5															1				1	6	83.3
12	2																			0	2	100
13																						
14																						
Total	604			1	2	0	2	5	0		1			2		15	8	3	4	43	647	93.5

*Logic Error - Not fault of equipment.

Volume Runs

The volume runs were conducted in comparison with the G.K. System, (both pneumatic tube systems) on I-95 northbound at Pittsfield. The results are shown on Table 21. Data was taken on October 12, 13, 14, 15, 16, 17, 18, 19, and 20 for 24 hour periods. On October 17 a pneumatic tube failed on the Streeter-Amet system and on October 20 both set of tubes were found to have been pulled out of the restraining devices. One tube had been ripped in two pieces on the Streeter-Amet system. A different type of tube was used on the G.K. System which will be discussed under that heading.

For those runs in which the data was complete for both systems, 5 runs had a total of 24,910 for the Streeter-Amet system and 24,307 vehicles for the G.K. System for a difference of 603 less for the G.K. This gives a difference of 2.4%. Considering the history of problems, both in the 1982 evaluation and on this project with pneumatic tube failure this is considered a very reasonable agreement between the two systems.

On October 19 the Streeter-Amet count was 5011 and the G.K. Instrument count was 5705 the difference was 694 and opposite to the previous 6 days total the G.K. count being higher. The difference was 12.1%. It is suspected that the pneumatic tubes on the Streeter-Amet system had started to fail, probable either a hole or slit was developing since this tube failed the next day. The electronics operated satisfactorily and with no failures during the entire test project.

7.2.4 G.K. Instruments

Prooftest

The G.K. Instrument system logic followed most closely the Scheme "E" classification scheme. (see Table 12) The proof test summary showed 16 missed vehicles, and 8 missed classification because of queues for a total of 24 missed vehicles. (see Table 13) The % correct classification was 95.5%. There were 18 logic errors caused by the program errors of scheme "E", as mentioned previous. As in the other systems these errors were not counted. The system counted all the 5 axle 'Double Bottom' units that passed thru the system and missed 3 of the 6 axle 'Double Bottom' vehicles. Two were not recorded at all, one unit was classed as a #4. No reason for this could be assigned.

TABLE 12
G.K. INSTRUMENT
AXLE CLASSIFICATION PLAN CATEGORIES

The program for axle classification results in clusters of counts distributed into the following classifications (bins):

BIN 0:	Total volume.
BIN 1:	2 axle, passenger cars, light trucks, etc. WHB1 = 120" (WHB1 is wheelbase from axle 1 to axle 2)
BIN 2:	2 axle, large pickups, delivery vans, light trucks with 2 axles. WHB1 120".
BIN 3:	3 or 4 axle, car and 1 or 2 axle trailer, WHB1 = 120" and 65" WHB2 = 216" for 3 axle or 65" WHB2 = 264" for 4 axle vehicle *(WHB2 is wheelbase, axle 2 to 3).
BIN 4:	3 axle single unit truck and 3 axle buses 3 axles and not bin 3.
BIN 5:	4 axles, 2 axle tractor with two axle trailer not bin 3 and 36" = 120" *(WHB3 is wheelbase, axle 3 and 4).
BIN 6:	4 axle single unit truck not bin 3 and not bin 5 and 36" WHB2 = 60".
BIN 7:	4 axle, 3 axle tractor with single axle trailer and fallout from bin 3 not bin 3 and not bin 5 and not bin 6.
BIN 8:	5 axle, 3 axle tractor with 2 axle trailer (eighteen wheeler) 24" WHB4 = 120".
BIN 9:	5 axle single unit truck and odd combinations 36" WHB2 = 60".
BIN 10:	5 axle, 2 axle tractor with single axle trailer and 2 axle trailer not bin 8 and not bin 9.
BIN 11:	6 axle, 3 axle tractor with single axle trailer and 2 axle trailer WHB5 = 84".
BIN 12:	6 axle, 3 axle tractor with 3 axle trailer WHB4 = 72" and not bin 11.
BIN 13:	6 axle, all other 6 axle vehicles not bin 11 and not bin 12.
BIN 14:	7 to 11 axles.

TABLE 13
G.K. INSTRUMENTS - PROOF TEST SUMMARY

Class	Correct	Incorrect Class 1	2	3	4	5	6	7	8	9	10	11	12	13	14	Miss	Miss Que	Mis-Class Que	Error Speed ≤20	Total Error	Total	% Correct
1	338															3	4	7		14	352	96.0
2	121															2				2	123	98.3
3	6		1		9*															1	7	85.7
4	55		3													2				5	60	91.7
5	3																				3	100
6						3*										1				1	1	
7	12					6*															12	100
8	11															2		1		3	14	78.6
9																						
10	3																				3	100
11	2				1											2					5	40.0
12	2																		1	1	3	66.6
13																						
14																						
Total	557		4		1	0										12	4	8	1	27	583	95.5

*Logic Error - Not fault of equipment.

Volume Test

The volume testing was run on I-95 in comparison with the Streeter-Amet and the details of the count were discussed with that system.

The G.K. Instrument used a different type of pneumatic tube, which was supplied by Jamar the U.S. distributors of the system. This tube had a cross section approximating a "D" in shape. The purpose of this shape was to reduce the tendency of the tube to roll when hit. This tube did fail on the last run at the same time that the round Streeter-Amet tube failed. One tube had been ripped into two pieces. This tube failed by a split in the bottom of the "D" section and in shear thru the side of the "D" at the level of the hole. The general idea of the construction appears to be a sound one and perhaps some improvement in the strength of the material used or some change in the cross section might improve its performance

The electronics operated satisfactorily throughout the test run.

7.2.5 Sarasota - Loop System Only

Given that the Sarasota system provides categorization by lengths only, direct comparisons with the other four systems is not possible. However, since Sarasota expects to have a pneumatic tube system available using essentially the same electronics shortly after January 1, 1985, the evaluation of the system should be of value.

Table 14 shows the 7 length classes with the type vehicles which are categorized by each length class. Few errors were observed in the 563 vehicle proof test run on U.S. 2 at the Facility. The system gave 98.4% accuracy on this test. Table 15 provides a summary of the vehicles correctly and incorrectly classified from which the percent accuracy is derived.

Volume Test

The volume test was run at the Facility on U.S. 2 in comparison with the I.R.D. system.

On October 13, 14, 15, 16, 17, 18, 19, 20, 21 and 22, a comparison of vehicles classed by the I.R.D. with those classed by the Sarasota system was made. I.R.D. classed 8882 vehicles as against 9063 for the Sarasota system, for an over count error of 181 for the Sarasota. This is an error of 2.0% which is well

TABLE 14
SARASOTA VC 1900
(Classes By Length Only)

Class		Actual	Vehicles
A	8'	1'-7'	Motorcycles
B	15'	8'-14'	Small cars
C	20'	15'-19'	Midsize cars, large cars, pickups
D	26'	20'-25'	Large pickups, sm. recreational vehicles 2 axle - 6 tire - tandems
E	41'	26'-40'	Single unit del. truck triaxles, recreational vehicles, cars in tow
F	61'	41'-60'	Semi's, recreational vehicles and car, cars w/large trailers, buses
G	+	61'-	Double bottoms, special semi's

Height of vehicle chassis does influence loop detector activation point so the length class cut off point may vary, placing vehicles whose length is close to cut off in next class bin.

The system can be programmed to classify into 14 different categories.

TABLE 15
SARASOTA - PROOF TEST SUMMARY
(Loop Only System)
Classes By Length

Class	Correct	Incorrect Class							Total Incorrect	Total Vehicles	% Correct
		1	2	3	4	5	6	7			
A	3									3	100
B	72	1							1	73	98.6
C	351				10*					351	100
D	77			1*		3*/1			1	78	98.7
E	17				1*					17	100
F	33			1				6	7	40	82.5
G	1									1	100
Total	554								9	563	98.4

*Logic Errors - incorrect choice of class cutoff points.

within the accepted count accuracy of any of the systems.

The electronics performed without problems during the entire test period.

Tables 16 thru 21 show summaries and comparison of the volume runs made with the various units. Comments on each are to be found under the sections discussing each system.

7.3 SYSTEM PERFORMANCE

Summary

Five systems were available for test. Four of these systems provided vehicle type categorization chiefly by interogation of axle spacings (I.R.D., Golden River, Streeter-Amet, G.K. Instrument). The fifth system (Sarasota) had the capacity to measure the approximate vehicle length only.

The first four systems were subjected to similar testing to determine their ability to accurately classify vehicles by types and also volume testing to determine their ability to perform well over lengthy operation in the field.

All systems had problems with slow-moving vehicles and vehicles in queues. Contrary to the test results in the earlier 1982 study, previously mentioned, a considerable improvement in classifying longer and multiple axle vehicles is evident. The four systems did better in these classes than in the vehicle towing light trailer categories, where most experienced some errors.

All systems operated thru the two month test period without electrical or other failure (except road tube damage).

The I.R.D. system is a permanent year round system and no trouble with the loops or axle counter were experienced.

The Golden River is a semi portable system for clear road operation only. The axle counter, a pad nailed to the pavement and removable as desired was left down for a two and a half month period and operated without problem. This system is slightly less expensive than the I.R.D. system.

The Streeter-Amet and the G.K. Instrument systems operate on pneumatic tubes and thus are for clear pavement use only. Road tube problems were experienced with both systems. Drivers on semi-trailers recognize the road tubes and damage them by

TABLE 16
VOLUME RUNS ON U.S. 2

	I.R.D.	Golden River	Sarasota	G.K. Instrument
Fri., Oct. 5	10 hours 746*	12 hours 612	12 hours 991	12 hours 897
Sat., Oct. 6	24 hours 1323	24 hours 883	24 hours 1328	24 hours 1281
Sun., Oct. 7	24 hours 1062	24 # 647	24 hours 1094	24 hours 1047
Mon., Oct. 8	24 hours 1196	memory full	24 hours 1215	24 hours 1159
Tue., Oct. 9	8½ hours 156	--	0-6 29	152

* I.R.D. only 10 hours.

Golden River 13 minutes short of 24 hours.

TABLE 17
I.R.D. VOLUME RUNS VS % MISSED

	#	% Class.	Miss Sensor	%
Oct. 5-9 *	4654	96.3	103	2.2
Oct. 12-16	3138	99.2	6	0.2
Oct. 16-19	2277	98.8	3	0.1
Oct. 20-23	2685	99.1	2	0.1

*Loop detector sensivity changed to low range Oct. 10th.

TABLE 18
VOLUME RUNS ON U.S. 2

	I.R.D.	Golden River	Sarasota
Sat., Oct. 13	1215	24 hours 1126	1239
Sun., Oct. 14	905	798	917
Sub Total	2120	1924	2156
Mon., Oct. 15	990	memory full	1028
TOTAL	3110		3184

TABLE 19
VOLUME RUNS ON U.S. 2

	I.R.D.	Golden River	Sarasota
Tue., Oct. 16	488	19 hours 438	431
Wed., Oct. 17	837	24 hours 755	841
Thu., Oct. 18	925	839	934
Fri., Oct. 19	871	877	906

TABLE 20
VOLUME RUNS ON U.S. 2

	I.R.D.	Golden River	Sarasota
Sat., Oct. 20	931	24 hours 918	1000
Sun., Oct. 21	788	782	826
Mon., Oct. 22	942	468*	941

*Mem. Full - 6 hours - 6 hr. run on I.R.D. and Sarasota data used.

TABLE 21
VOLUME RUNS ON I-95
PITTSFIELD NORTHBOUND

Pneumatic Tubes

24 Hour Period	Streeter-Amet	G.K. Instrument	△	% Var.
Fri., Oct. 12	4255	4099	+156	3.8
Sat., Oct. 13	5135	5030	+105	2.1
Sun., Oct. 14	3526	3452	+ 74	2.1
Mon., Oct. 15	4291	4225	+ 66	1.6
Tue., Oct. 16	3983	3837	+146	3.8
Wed., Oct. 17	*Pneu. Tube Failed	4906		
Thu., Oct. 18	3720	3664	+ 56	1.5
Fri., Oct. 19	5011	5705	-694	12.0
Sat., Oct. 20	*tubes failed	#tubes failed		
			Dif.	% Dif.
Summary Oct.12-19 (omitting Oct. 17)	29,921	30,012	- 91	0.3
Summary Oct. 19	5011	5705	-694	12.0
Summary Oct.12-18 (omitting Oct. 17)	24,910	24,307	+603	2.4

*Tubes torn out from restraining attachments.

#"D" tube torn apart.

TABLE 22
AVAILABLE EQUIPMENT SUMMARY

System	Portability	Lanes	Environment	App. Cost[7]	Data Line Modem	Can Use Scheme "F"	Ind. Veh. Printout	Proof Test % Class Correct	Road Test Qual.[6]
I.R.D. Classifier	Permanent[1]	2 4 6	Year round	21,000 24,500 30,500	yes	yes	yes	91.2	OK
Golden River Weighman	Semi-[2]	1	Clear Roads	25,000	yes	yes	yes	95.9	OK
Streeter-Amet Traficomp 141A[5]	Portable-Tubes	1	Clear Roads	3,875	yes	yes	no by bins	93.5	OK
G.K. Instrument 6000	Portable-Tubes	1	Clear Roads	3,090	yes	yes	no by bins	95.5	OK
Sarasota VC-1900	Seni-Loops[3]	1	Year round	4,600	yes	no by veh. lengths only[4]	no by bins only	98.4	OK

Note 1: Loops and permanent axle counter. Cost of installation of permanent axle counters not included in cost estimates.

Note 2: Loops and removable axle counter.

Note 3: Loops only - temp. surface loops can be used.

Note 4: Sarasota informs us that they will have A1900 system operating on pneumatic tubes, classifying to Scheme "F" by Jan. 1985.

Note 5: Streeter-Amet will have available a traficomp II model 24 system using solid state programming and memory instead of the cassette type programming and memory device. Unfortunately the system was not available in time for evaluation.

Note 6: Road test qual. (quality) indicates systems performance rating under volume runs.

Note 7: See Appendix II for details of costs.

locking the brakes on the rear set of wheels. Several 2 and 3 day runs were obtained but road tube problems can be expected if much longer periods than this are attempted. These two systems are the least expensive units. Approximate cost of all systems is given in the appendix along with the Technical Characters of each system.

The Sarasota system operates from two loops and measures vehicle lengths only. However, the length categories chosen can be programmed to suit the user. Operation from loops make this a year round system. Sarasota expects to have the same unit available for operation from road tubes after January 1, 1985. This would then provide classification to Scheme "F". This would then be for clear road operation only.

All four vehicle classification systems satisfactorily completed the proof tests with all systems correctly classifying 90% or more of the vehicles. Volume road tests were acceptable on all systems except when road tubes were damaged.

Briefly then, a summary for each system is presented below.

1. I.R.D. - A permanent year round system using two loops and an axle counter. Provides classification to Scheme "F". Printout available for each vehicle in real time as well as retaining data for summaries and telemetry to a central headquarters. In proof test run classified 91.2% correctly. In volume field run counted 99.86% of 8100 vehicles passing the sensor. A quality unit in the $25,000 class.

2. Golden-River - A semi permanent system for clear road seasonal use only. Two loops and a capacitance pad axle counter, provide input data. Data collected to Scheme E. Can be programmed by manufacturer for Scheme F. Real time printout of each vehicle available but not simultaneously with data storage or telemetering. On proof run classified correctly 95.9% of vehicles and in volume run missed 13% of vehicles out of 9345. The missed vehicles were either in a slow queue or a wheel had missed the pad. A quality unit in $25,000 class.

3. Streeter-Amet - A portable system using road tubes, and on proof testing correctly classified 93.5% of vehicles. In the volume run it operated for 9- 24 hour periods with two road tube failures. Comparisons with G.K. Instrument system is the only qualitative measure possible. See Table 21 for a better measure of this factor.

A relatively inexpensive unit for portable data collection which operated satisfactorily.

4. G.K. Instrument System - This is a portable system also using road tubes and successfully classified 95.5% of vehicles on proof testing. On volume testing it was compared with the Streeter-Amet system for volume check. Except for the road tube failure, operation appears reasonable. See Table 21 for comparison with Streeter-Amet.

Also a relatively inexpensive unit and acceptable for short term portable use.

5. Sarasota System - This system operates on two loops and therefore classifies according to vehicle length only. The electronics system operated successfully without failure during the test period.

8.0 RECOMMENDATIONS FOR EQUIPMENT IMPROVEMENT

It is apparent that with the development of systems based on microprocessor technology there does exist at least four and possible five systems that can classify vehicles to various categories based on axle spacings.

While three different types of axle sensors were tested during this evaluation all three had serious limitations. Either high cost (the I.R.D. permanent sensor and the Golden-River axle pad) or seasonal use only for the other two (the capacitance pad and pneumatic tubes). The road tubes also continue to have short life as reported in the previous study, but they tend to fail gradually during a test run making the data collected during that run suspect.

Clearly, it is apparent that the development of a low cost, preferably permanent or at least all weather axle counter, should be high on the agenda for future FHWA or industry support.

It is recommended that work be funded for development in this area. With the FHWA requirement that the various states provide vehicle classification data on a routine basis a system with a more reliable axle counter should have a top priority.

Such a sensor should be able to withstand the higher A.A.D.T.'s and also be impervious to deliberate attempts by vehicle operators to cause damage to it.

Of less importance than the axle counter problem, another shortcoming of the systems should have some attention, however. This is the lack of a direct real time printout of the data for each vehicle. This need not be available for all data but would be of very great help in setting up and evaluating a system as to its correct operation in classifying vehicles. As mentioned two systems tested have this ability, whereas the other three classify the vehicle solely by class number with no opportunity to check the accuracy of such a classification.

The technology is available to provide this now and its reduction to practice will certainly depend on developing the techniques to do this at a lower cost than at present.

In conclusion the importance of further work being done by research or manufacturing facilities should be stressed. The classification accuracy needs improvement. The missed vehicle count needs investigation. Finally instrument programming and data retrival systems need to be further simplified to provide more foolproof systems.

APPENDIX I

FHWA CLASSIFICATION WITH DEFINITIONS

FHWA VEHICLE CLASSIFICATION WITH DEFINITIONS

Type Name and Description

1. Motorcycles (Optional) - All two- or three-wheeled motorized vehicles. Typical vehicles in this category have saddle type seats and are steered by handle bars rather than a wheel. This category includes motorcycles, motor scooters, mopeds, motorpowered bicycles, and three-wheel motorcycles. This vehicle type may be reported at the option of the State.

2. Passenger Cars - All sedans, coupes, and station wagons manufactured primarily for the purpose of carrying passengers and including those passenger cars pulling recreational or other light trailers.

3. Other Two-Axle, Four-Tire Single Unit Vehicles - All two-axle, four-tire vehicles, other than passenger cars. Included in this classification are pickups, panels, vans and other vehicles such as campers, motor homes, El Caminos, Rancheros, ambulances, hearses, carryalls, and four-wheel drive vehicles. Other two-axle, four-tire single unit vehicles pulling recreational or other light trailers are included in this classification.

4. Buses - All vehicles manufactured as traditional passenger-carrying buses with two axles and six tires or three or more axles. This category includes only traditional buses functioning as passenger-carrying vehicles. All two-axle, four-tire minibuses should be classified as other two-axle, four-tire single unit vehicles. Modified buses should be considered to be a truck and be appropriately classified.

   NOTE: In reporting information on trucks the following criteria should be used:

   a. Truck tractor units travelling without a trailer will be considered single unit trucks.

   b. A truck tractor unit pulling other such units in a "piggyback" configuration will be considered as one single unit truck and will be defined only by the axles on the pulling unit.

   c. Vehicles shall be defined by the number of axles in contact with the roadway. Therefore, "floating" axles are counted only when in the down position.

d. The term "trailer" included both semi and full trailers.

5. Two-Axle, Six-Tire, Single Unit Trucks - All vehicles on a single frame including trucks, camping and recreation vehicles, motor homes, etc., having two axles and dual rear wheels.

6. Three-Axle, Single Unit Trucks - All vehicles on a single frame including trucks, camping and recreational vehicles, motor homes, etc., having three axles.

7. Four or More Axle, Single Unit Trucks - All trucks on a single frame with four or more axles.

8. Four or Less Axle, Single Trailer Trucks - All vehicles with four or less axles consisting of two units, one of which is a tractor or straight truck power unit.

9. Five-Axle, Single Trailer Trucks - All five-axle vehicles consisting of two units, one of which is a tractor or straight truck power unit.

10. Six or More Axle, Single Trailer Trucks - All vehicles with six or more axles consisting of two units, one of which is a tractor or straight truck power unit.

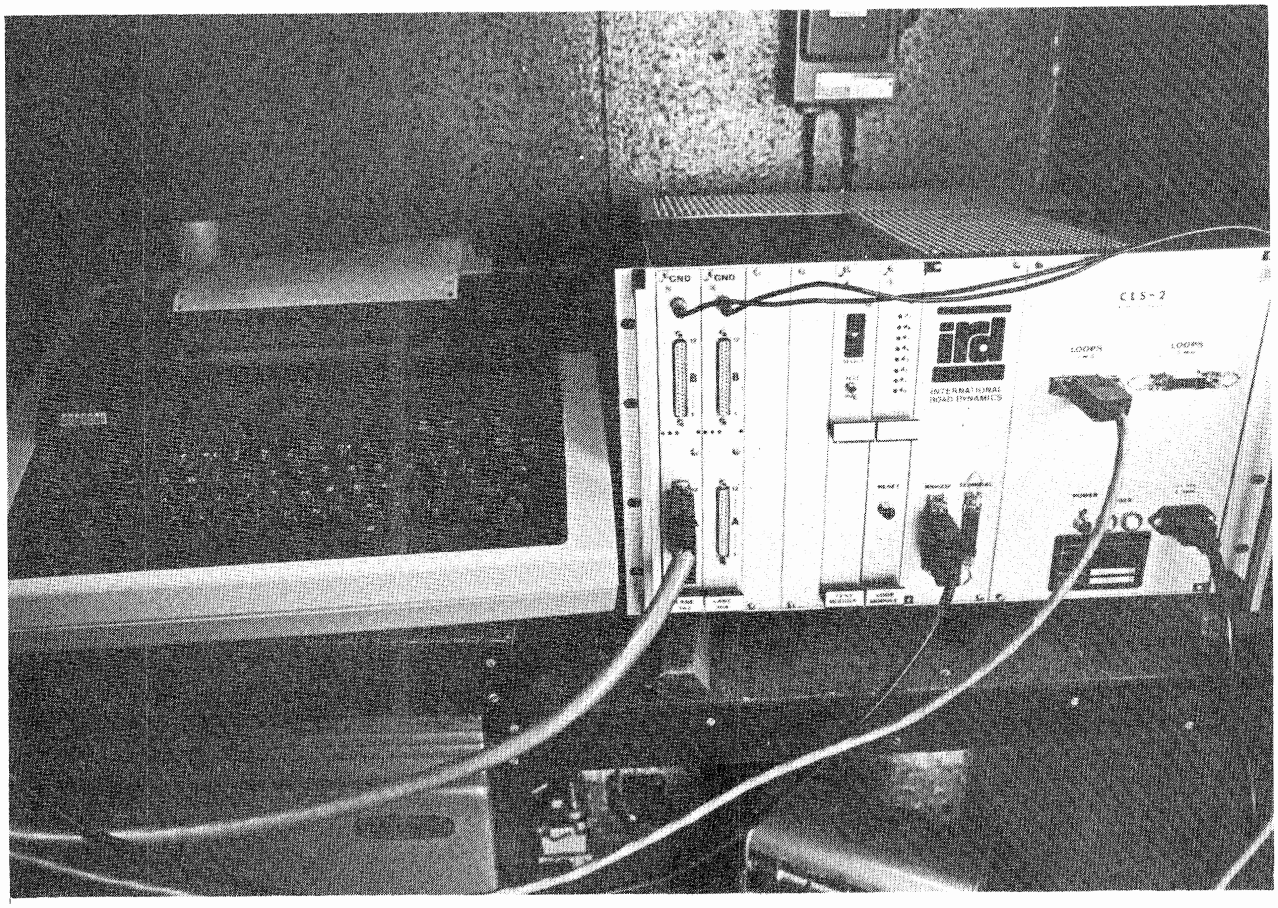
11. Five or Less Axle, Multi-Trailer Trucks - All vehicles with five or less axles consisting of three or more units, one of which is a tractor or straight truck power unit.

12. Six-Axle, Multi-Trailer Trucks - All six-axle vehicles consisting of three or more units, one of which is a tractor or straight truck power unit.

13. Seven or More Axle, Multi-Trailer Trucks - All vehicles with seven or more axles consisting of three or more units, one of which is a tractor or straight truck power unit.

APPENDIX II

TECHNICAL CHARACTERISTICS OF EQUIPMENT EVALUATED



I.R.D. Recorder and Digital Printer.

PHOTO #9

I.R.D. CLASSIFIER SYSTEM

Supplier:

C.M.I. - Dearborn Inc.
5353 Wilcox
Montague, Mi. 49437

Contact: Jeffrey B. Davies
820 Lafayette Rd., Bldg. 1
Suite 203
Hampton, N.H. 03842

(603) 926-1200

General Description:

The I.R.D. International Road Dynamics Vehicle Classifier System consists of a microcomputer and associated electronics housed in a 19"x11"x20" cabinet which must be placed in a weatherproof cabinet near the site.

The system can handle a 4 or 6 lane divided highway or a two lane two way highway. Data from the road is supplied from each lane by two inductive loops and an axle counter.

The system operates from 120-240 volt 50-60 Hz line voltage. Outputs can be to a line printer for on site printout of data on all vehicles. (A 1200 Baud active terminal such as a Decwriter III is required to obtain a printout of every vehicle). Data can be sent by a modem to a central computer.

Technical Characteristics:

Characteristics of Vehicle Classifier:

* Classifies vehicles based on axle spacing and tire configuration.
* Up to twenty classifications.
* Measures speed and vehicle length.
* Records time of occurrence to 1/100 of a second determining accurate gap spacings.
* Roadway sensor environmentally sealed and is not affected by snow and ice removal operations.
* Compact electronics records data from several in-road sensors and transmits daily, weekly or monthly data by telephone to host computer.

* Communications by telemetry to host computer.
* Interface computer can be supplied to provide easy transmission of data to main frame computer.
* Collects data in a format compatable with automatic traffic recorders and weigh-in-motion equipment.
* Provides a unique system of predicting ESAL's and level of service on all links in the system.

Information Collected on Each Vehicle:
(Can be displayed on computer printer if required)

Vehicle Configuration	o oo oo oo oo
Axle Spacing	| - 140" - | -54" - | - 208" - | -61" - |
Speed	65 mph (105 km/hr)
Date	Mon. 5 Mar. 84
Time	10:05 10.2
Lane	3
Classification	9

Sensor identifies single or dual tires. This separates recreational vehicle from three and four axle trucks.

Typical Tables:

* Level of service available (A-E) percentage of time
  - northbound and southbound
* Vehicle distribution by type and lane including ESAL prediction - northbound and southbound
* Traffic speed statistics (average, standard deviation, skewness and 85th precentile)
  - produced daily for cars and trucks by lane
* Vehicle distribution by time of day for various vehicle types - information produced on an hourly basis or smaller time increment.
* Traffic stream characteristics
  - produced hourly lane by lane
  - headway statistics produced for platooning and free flow
* Length class by vehicle type

User determines the vehicle classification and table format.

Technical Specifications:

Electronics:
Microcomputer and electronics (19"x11"x20") housed in traffic control box adjacent to roadway. Temperature requirement in traffic control box 15°F to 140°F. System operates on 110 volt power source. Program provided by manufacturer. Data stored on battery protected solid state memory.

Physical Characteristics:
Sensor 7.5'x5"x2"
Sensor is set directly in pavement flush with surface.
Not affected by ice and snow removal.
Portability:
The sensor is supplied with a dummy and frame to facilitate moving of system from one location to another.

Output:
Produced in metric or British units.

<u>Costs</u>:

Costs are approximate for Planning purposes only.

Model CL-400-2

1.	Two lane classifier (electronics package and two axle counters) Does not include printer, equipment cabinet, loops, cables or installation.	$21,000.00

Model CL-400-4

2.	Four lane classifier (electronics package and 4 axle counters only).	$24,500.00

Model CL-400-6

3.	Six lane classifier (electronics package and 6 axle counters only).	$30,500.00
4.	Digital Printer Decwriter III or equivalent required to obtain on site data.	$ 2,800.00
5.	Modem - auto answer auto dial.	$ 700.00

Golden-River Weighman Recorder and Retriever.

PHOTO #10

GOLDEN RIVER CORP.
WEIGHMAN - ADVANCED VEHICLE CLASSIFICATION SYSTEM

Supplier:

Golden River Corp.
7672 Standish Place
Rockville, Md. 20855

(301) 340-6800

General Description:

Golden Rivers' Weighman Advanced Vehicle Classification and Weight System combines accuracy and portability in a single reasonably priced package. Vehicle data are collected via a set of sensors placed on the road surface. No construction work is required to place the sensors which can be installed in under an hour. The signals from the sensors are analysed and stored by the WEIGHMAN ready for collection using a RETRIEVER or for individual printout on site. The data can then be printed or fed to a computer system for further analysis.

The system can be used to obtain vehicle weight data on a short or long term basis. As such it is suitable for many purposes including aiding in the development of enforcement strategies and bridge and highway design. The WEIGHMAN can also classify vehicles according to the FHWA classification scheme 'F'.

Technical Characteristics:

Outline System Specification

- Single lane advanced vehicle classification and weight system (see note)*
- 14 vehicle classes to FHWA scheme E or F.
- 4 axle categories, front axle, tandem axles, other axles, total weight
- 12 weight bins in each category
- programmable limits for each weight bin
- sensor array of 2 loops and 1 weigh mat
- count of vehicles exceeding FHWA bridge formula
- alarm output for vehicles exceeding FHWA bridge formula
- minimum 30 hour data storage on site
- programmable to collect axle weights or gross weights only
- programmable to collect vehicle classifications only
- programmable to collect certain classes only

*Note: The weight system was not evaluated as a part of the classification project.

- individual vehicle data collection facility
- individual vehicle printer output on site

Retriever

Type	Standard RETRIEVER Montor/Store
Capacity	3 to 25 MARKSMAN Data Files
Memory	32768 Bytes, solid state MOS RAM
Battery Life	Minimum 1 week between 14 hour recharge cycle
Data Security	CRC Checksum on each file
Panel	8 digit LCD Display, 19 touch keys, 18 position LCD Bar Indicator
Connectors	2 parallel 5 pin MARKSMAN and Charger points
Marksman	View and change site number, date, time, configuration, recording interval, number of days of recordings, status, counts, speeds, retrieve data from MARKSMAN, partial of all data.
Standalone	Data examine using B digit display Data clear and restore Examine status and battery voltage Self test facilities
Interface	View and change Baud rate, End of line and end of data control characters, status line control, stop at end of line control, automatic DC1 and DC3 control.
Output Data	Two formats, by file number of all data, CRC checksum error message, and orderly stop. output facility.
Telecommunication	Designed for manual or automatic connection to MARKSMAN via telephone modems for usual operation plus automatic retrieval of data
Operation Temp	-10°C to +55°C (+15°F to +130°F)
Storage Temp	-20°C to +60°C (-5°F to +140°F)

Weighman Specification

Type	Advanced vehicle classification system
Size	250mm x 250mm x 150mm (includes handle)
Weight	8 Kgs
Count Interval	5 minutes to 24 hours (31 programmable intervals)
Maximum count	3999 per bin per recording
Memory size	44K bytes standard
Expansion	memory expandable by 32K
Preset start	starts recording at present time and date
Accuracy	Weight: individual axles typically 10% standard error

	Speed : +/- 1 mph, 60 mph, over 10+ vehicles +/- 2 mph, 60 mph, over 10+ vehicles Length: +/- 10%, 50cm, 60 mph +/- 10%,100cm, 60 mph
Battery	Sealed lead acid 6V / 10 Ah
Battery life	14 days between 14 hour recharge cycles
Battery status	Direct output of battery voltage on Retriever
Status	Self test output
Clock	Full 24 hour clock, +/- 2 mins/month
Calender	Full YYMMDD calender, with leap year correction to 2099
Identification	8 digit number, user assigned
Classification	1) Gross weight, axle weights, FHWA scheme E classification, FHWA Bridge Formula compliance, speed, length, and arrival time. 2) 14 classes: for each class 1- 12 weight bins for each or 3 axle types and gross weight 3) 14 classes: for each class 1- 12 weight binds for gross weight 4) 12 gross weight bins 5) 12 axle weight bins
Telecommunication	Facility for direct telephone connection between Weighman and Retriever
Loop Detectors	2 multiplexed, self tuning detectors
Loop Inductance	40 uH to 200 uH
Drift	Automatic compensation
Sensors	One weight mat, two road loops
Sensor leads	12 metre cable between mat and logger
Standard	
Accessories	Weighman to terminal load
Connections	32 way MIL (loops) 10 way MIL (Weight mat) 5 Pin XLR (Retriever)
Temperature	Weighman - 40 C to + 80 C (-40 F to 175 F) Weight mat 0 C to + 80 C (32 F to 175 F)

The weight mat is not designated for snow/ice conditions.

System Components

The GR0355 WEIGHMAN is a complete roadside system and comes complete with all that is required to start an immediate installation.

A Retriever is required to enable the WEIGHMAN to be set up and data collected. A single Retriever will service a number of WEIGHMAN.

The GR0308 Charger/interface is required to recharge the battery in the Retriever and can also be used to recharge the WEIGHMAN in the office.

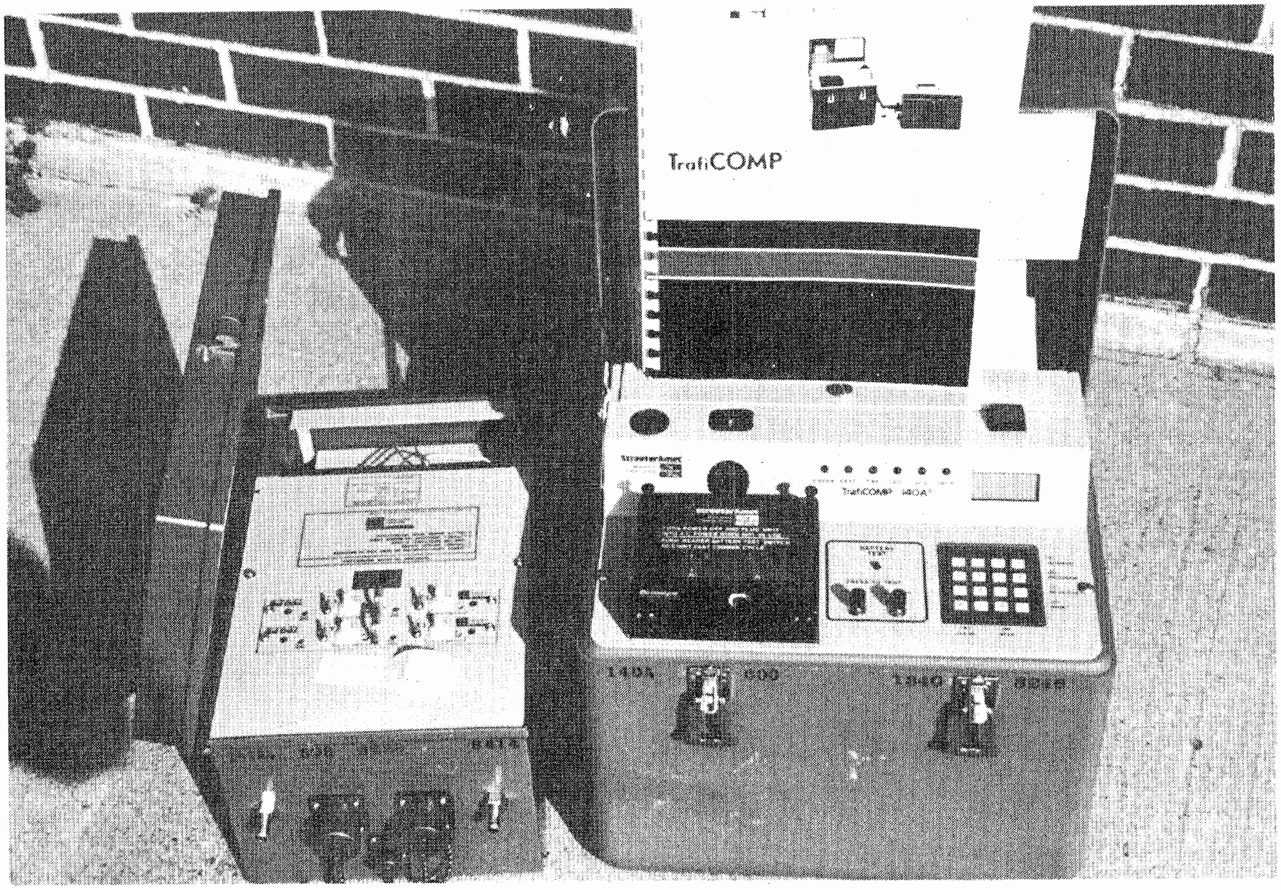
The GR0304 Charger is used to charge a WEIGHMAN when main power is available on site.

Various additional components are available to supplement the equipment supplied as a standard package. These components and consumables are detailed below.

Costs:

Costs are approximate for Planning purposes only.

GR0355	WEIGHMAN:	
	one GR0349 logger	$ 8,875.00
	one GR0352 mat	10,650.00
	one GR0351 oscillator & cable	600.00
	six GR0350 mat fixing kits (12 lays)	875.00
GR0357	Retriever 128K memory	3,325.00
GR0452	Printer and cable	695.00
GR0308	Charger/interface for Retriever or WEIGHMAN	195.00
		$25,215.00



Streeter-Amet Traficomp Model 141-A
Recorder and Reader Model 140-A

PHOTO #11

STREETER-AMET

STREETER-AMET TRAFFIC SURVEILLANCE SYSTEM

Supplier:

Streeter-Amet
Measurement Systems Division
155 Wicks Street
Grayslake, Illinois 60030

(312) 223-4801

General Description:

The TrafiCOMP system consists of two units, a recorder (Model 141-A) and a reader (Model 140A for programming and collecting data from recorder). A printer is also necessary to get a hard copy of the data, but does not necessarily have to be a Streeter-Amet machine. The TrafiCOMP unit is versatile and can collect various kinds of data depending on the program which is in use. Basically the recorder at the roadside collects and stores traffic data in solid state memory monitoring one lane for axle data and two lanes for length data, using inputs from pneumatic tubes for vehicle classification. The reader (not always at roadside) is then used to transfer the information from the solid state memory to a cassette which is then dumped by the printer (at a later time).

Technical Characteristics:

Model 141A TrafiCOMP Recorder General Specification

Size	8-1/4"H x 8-1/2"D x 13"W (21.0 cm x 33.0 cm)
Weight	18 lbs (8.2 Kg) including batteries and detectors
Housing Type	Compact, portable, weatherproof metal cabinet with carrying handle and lock hasp. Full length hinge and gaskets
Functions	Volume counting, velocity classification, length classification, vehicle type classification, multi-directional or multi-lane
Power Source	a) 2-6 volt dry cell batteries; b) 2-6 volt 4 amp hr. rechargeable lead gel batteries (optional)
Temperature Range	$-40^{o}F$ to $158^{o}F$ ($-40^{o}C$ to $70^{o}C$)
Recording Intervals	Available: 1, 2, 3, 4, 5, 6, 10, 15, 20, 30, or 60 minute periods
Maximum Count Rate	20 vehicles per second; 4095 vehicles per recording period

Memory Storage (Data)	Up to 2500 maximum recording periods
Maximum Vehicles Per Counting Period	4095 per lane
Power Consumption	1.6 ma for two roadtube applications; road loop 2 ma per loop-application may vary. Dry cell batteries will yield approximately 200 days of operation for roadtube applications
Recorder Connections	a) 10 pin female MS connector for reader cable; b) 10 pin male MS connector for road loop inputs; (loop detection models) c) 2 air switch tubes for roadtube (roadtube models)
Vehicle Detection	Up to two air switches for roadtubes Up to four internal loop detectors (Model 750P) Up to eight external loop detectors (special order)
Controls & Displays	Loop detector adjustment and LED indicator (if used)
Basic Electronics	CMOS - Microprocessor based. Modular plug-in boards to allow for field service and optional functions
Maximum Count/Lane/Hour	4095
Input Detectors	2 pneumatic tubes for Vehicle Classification
Recording Intervals	1,2,3,4,5,6,10,12,15,20,30 and 60 minutes
Controls & Displays	Reset & 750P LEO-ON switches (also 750P controls)
Setup & Readout Method	By TrafiCOMP 140A reader
Functions	Vehicle type classification
Size & Weight	8-1/4" H x 8-1/2" D x 13" W (21.0 x 21.6 x 33.0 cm); 18 lb (8.2 kg)
Connectors	10 pin female MS connector for reader; cable 10 pin male MS connector for loops
Voltage Source	2 six volt batteries or 115 or 230 50/60 Hz AC (Optional)
Power Consumption	Recorder and two air switches - 1.6 ma
Temperature Range	$-40^{o}F$ - $158^{o}F$ ($-40^{o}C$ - $70^{o}C$)* *loop detectors limited to $-25^{o}F$

<u>Model 140A Reader</u>

Basic Electronics	C/MOS microprocessor
Data Storage	Integral magnetic tape cassette recorder
Data Storage	Two track complementary NRZ1
Storage Capacity	72,000 characters
Controls	Push button power switch; push button recorder battery test switch; 12 digit keyboard

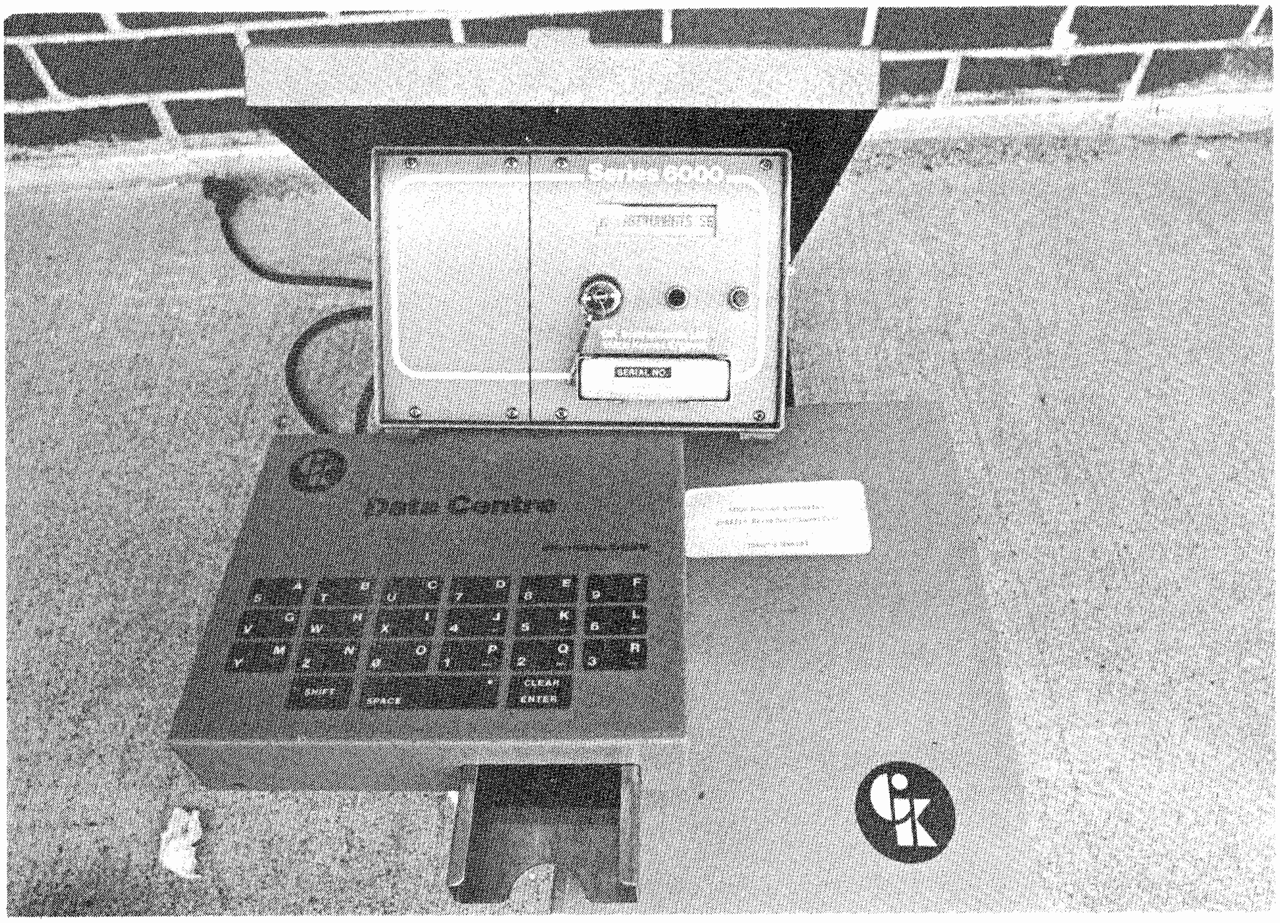
Display	4 digit liquid crystal display; LED's for station, ident, date, time, data, error, recorder battery test.
Cables	6' extendable cable to recorder with 10 pin male MS connector, power cable
Connectors	10 pin female MS output connector 3 pin power connector
Standard Output (during cassette readout)	Format: ASC11 at 110 or 300 baud, RS232C interface standard
Power	2 six volt 4 ampere hour batteries for operation in field; 115 or 230 volt 50/60 AC for use elsewhere
Battery Discharge Time	4 hours; unit has built-in charger for charging batteries when operating from AC
Temperature Range	32° to 140°F (0° to 60°C)*
Size & Weight	13-1/4"W x 9-1/8"D x 11-3/4"H (33.7 x 23.2 x 29.8 cm), 25 lbs (11.3 kg)

*For extended periods. The unit can be operated at much lower temperatures for the shorter periods required for data collection.

Costs:

The following are approximate prices for Planning purposes only.

140A Reader	$2,000.00
141A Recorder	1,250.00
Data Module	500.00
Printer	125.00
	$3,875.00



G.K. Instruments GK6000 Recorder and Data Port.

PHOTO #12

G.K. INSTRUMENTS
G.K.-6000

Supplier:

G.K. Instruments Ltd
Simpson Road
Fenny Stratford
Milton Keynes
Buckinghamshire MK1 1LN

0908-75742

U.S. Agent
Jamar Sales Co., Inc.
1170 Orchid Rd.
Warminster, Pa. 18974

(215) 322-6344

General Description:

The GK 6000 Series Solid State recorder is of a modular design enabling it to suit the needs of the user. The recorder rack can be placed into an existing cabinet or mounted into a pole mounted box. It can also be housed in a weatherproof case for use as a portable instrument enabling it to be installed at the roadside, chained to a lamp column or other suitable street furniture.

Input to the recorder for vehicle classification is by means of rubber road tubes with the use of air switches. A RS232 (V24) communication card can also be inserted into the slot already provided in the recorder, allowing modem operation for use to an auto dial data retrieval system.

The basic 6000 Recorder is the 6000 TC xx, which uses one fixed program chip and one variable one containing the country and configuration options. The 6000-TX-xx is unexpandable, except by replacement of all the program chips.

AXLE CLASSIFICATION This requires two rubber tube inputs and thus is normally used with the weatherproof case version of the 6000. Only one traffic lane can be handled, and the two tubes should protrude two thirds of the way over the lane, be at right angles to the flow of traffic and be spaced according to the option requirements (i.e. 5 metres for 6000-AC-UK or 16 feet for the 6000-AC-US version). The tube that is nearest to the approaching traffic should be connected to the A or first air switch, and the tube that is struck last by the vehicle being classified should be connected to the B or second air switch.

The "Data Module" is a self powered CMOS (RAM) memory pack that has the ability to sustain the recorded data over a life of several months.

The pocket sized pack is housed in a fluorescent yellow high-impact polystyrene sealed wallet, and is available in seven sizes of memory, choice of which is dependent upon the recording time interval and the days duration required between visits to site.

The solid state data module is available with storage capacities of 4K, 8K, 12K, 16K, 32K, 48K, 64K. Each module carries its unique serial number and an indication of its storage capacity on the end opposite the connector.

Technical Characteristics:

Specification Type:	6000 Series Recorder
Options:	Series 6000 Rack only Series 6002 Rack w/2 detectors Series 6004 Rack w/4 detectors Series 6006 Rack w/6 detectors Series 6010 Rack & Weatherproof case (complete 2 airswitches)
Size:	
Weight:	3.0Kgs
Microprocessor:	NSC 800
Inputs:	2 Air Switches 6 Inductive Loop Detectors Contact Closure
Temperature:	-20 to +70 degrees Celcius
Count Rate:	25 counts per second per lane
Count Interval:	1 minute to 24 hours (1, 5, 6, 10, 15, 30, & 60 mins) (1, 2, 3, 6, 12, & 24 hrs)
Capacity:	Up to 96 weeks single channel 60 minute interval, (16384 recordings maximum)
Self Validation:	Each recording re-read for data validation
Accuracy:	+1 count per recording interval
Power:	Rechargable sealing lead acid gel cells, 6v at 19Ah

Autonomy:	2 months plus typically between 14 hour recharge cycle
Loop Detectors:	(When fitted) GK Microdet, fixed frequency detector
Method:	Removable dual channel detectors
Sensitivity:	0.2% normal sensitivity, 2 minutes for 2% change in loop and feeder inductance
Fail Safe:	Loop non connection will cause the output transistor to be held in a non conducting state until manually reset
Inductance Range:	40 to 300 micro-henries micro automatically tuned
Controls:	Reset and lamp test buttons

<u>Data Module</u>

Size:	6.25"(160mm) * 2.875"(73mm) * .75"(20mm)
Weight:	0.4 lbs (180g) typical
Temperature:	-40°C to +80°C
Construction:	Flourescent yellow high impact polystrene wallet

Available Sizes:

Size	Bytes (4 bit)	No. of 4 Digit Readings	Days hr	Duration 1/4 hr
1	4K	1024	42	10
2	8K	2048	85	21
3	12K	3072	128	32
4	16K	4096	170	42
5	32K	8192	341	85
6	48K	12288	512	128
7	64K	16384	682	170

Serial Data Port

The G.K. Instruments Serial Data Port is a convenient sized desk top solid state reader with a standard CCITT V24 (RS232) interface, configured for one start-bit, odd parity, and one stop-bit, making it suitable for interfacing with most computer systems.

The Serial Data Port is accessed by the use of a series of single alpha commands input to the Data Port from the software running in the host computer. These allow for the sizing, header reading, checking, clearing and the test of the data in the module.

Size:	8.75"(220mm) * 7"(175mm) * 2.5" (60mm)
Weight:	5.7 lbs (2.6 Kg)
Power Requirements:	240/115 volts
Serial Interface:	
Interface:	Serial CCITT V24 (RS232)
Baud Rate:	75 - 9600
Start-bits:	One
Parity :	Odd
Stop-bit :	One

Data Centre

Combines the features of the Serial Data Port with the ability to function in a stand alone mode in conjunction with an RS(232) printer.
Entry of header information and control is by an electro-mechanical keyboard with an audible beep.

Size:	8.75"(220mm) * 7"(175mm) * 2.5"(60mm)
Weight:	5.7 lbs (2.6 Kg)
Power Requirements:	240/115 volts
Serial Interface:	
Interface:	Serial CCITT V24 (RS232)
Baud Rate:	75 - 9600
Start-bits:	One
Parity :	Odd
Stop-bit :	One

Description

Data Module

The Data Module is a self powered CMOS (RAM) memory pack that has the ability to sustain the recorded data over a life of several months, when the module has been removed from the recorder.
The pocket sized pack is housed in a fluorescent yellow high-impact polystyrene sealed wallet, and is available in seven sizes of memory, choice of which is dependent upon the recording time interval and the days duration required between visits to site.

Data Processing

Data Centre

The G.K. Instruments Data Centre when connected to a serial printer (RS232) such as an Epson, can produce a stand-alone

printout of the traffic flow on an hourly basis with totals for the 12, 16, 18 & 24 hour, together with the average flows for the week and weekdays. The simple keyboard allows for the entry of suitable titles to complete the printout.
Alternatively the Data Centre or the Serial Data Port can be used to input the data to a microcomputer by the use of a series of single alpha commands input to the Data Port from the software running in the computer.
Such machines as the IBM PC, Sirius, Kaypro, Osborne, Apricot, and Apple can be used to process the data.

Accessories

A full range of accessories is available to compliment the recorder in field operation. These range from the road tube and clamps to chain and padlock for the fixing and security of the roadside installation.

Disclaimer

The company reserves the right to alter any of the Company's products or published technical data relating thereto any time without notice.

Costs:

G.K. 6000	$1,495.00
Data Port	1,295.00
Data Module	175.00
Road Tube	
Printer	125.00
	$3,090.00

Sarasota VC1900 Recorder and Printer.

PHOTO #13

SARASOTA VC1900

Supplier:

Sarasota Automation
1500 N. Washington Blvd.
Sarasota, Fla. 33577

Contact: Mike Weeks
(813) 366-8770

General Description:

The VC1900 is a microprocessor-based traffic analysis instrument designed for traffic data collection either conventionally or remotely, using the Public Switched Telephone network.

Traffic information is collected for processing by hih-fidelity, low-current inductive loop detectors. The detectors have been designed specifically for traffic analysis with an emphasis upon accurate speed information. A maximum of four dual-channel detectors may be fitted into the Roadside Unit (RSU). Also, both vehicle speed and vehicle counting information may be collected using air tubes.

The RSU may be set up using an interactive terminal, such as the Sarasota VC Terminal, or any other equivalent instrument, e.g. Texas Silent 700, or by a central computer over telephone lines, using modems. Alternatively the use of a terminal may be avoided if the RSU is allowed to use its inbuilt default parameters for logging.

The VC1900 may be used in either speed/length mode or count mode. In speed/length mode, the VC1900 allows speed measurement in up to four lanes, using loops, with directional and length discrimination available. It also allows for speed measurement in one lane using two air tubes. Data are stored in either statistical form or histogram form, at the end of each logging period. In count mode, the VC1900 performs vehicle counts in up to eight lanes with inductive loops or air tubes. Using loops, either one, two, four or eight channels are selected to allow for directional discrimination. The count is accumulated and stored at the end of each logging period.

When the equipment is being set up, the operator must select which mode the program is to be run in.

The equipment is modular in construction, consisting of International-size cards. They are mounted in a card-frame and contained in a weatherproof Roadside Unit (RSU) for portable use, or in an instrument case. Alternatively the card frame may be mounted in a streetside cabinet. External wiring is via the M.S. connector at the side of the RSU case and the battery is housed in the Battery Box (10" x 8" x 2-3/4").

The instrument is set up via the RS-232 interface through the 25-way D-type connector. For pin connections and baud rate/parity settings.

TAM Capacity and Use

Take-Away-Memory modules are available in capacities of 4K, 8K, 16K or 32K by 4 bits. The storage capacity of a TAM for "numeric" data (i.e. ASCII codes 0-9, space, full-stop, carriage return, line feed, tab) is equal to the stated capacity. For ASCII data with no numeric content (as specified above) it will provide 50% of stated capacity.

The internal batteries of the TAM are charged by the Roadside Unit (RSU) while the TAM is plugged into the RSU and may be stored outside the RSU for up to three months without loss of stored data.

A 16K TAM will be filled in around eight days by a VC1900 program in speed/length mode with directional discrimination, eight speed bands and hourly recording periods. This will be doubled to around sixteen days with no discrimination and hourly recording periods. The maximum count value for one recording period is 9999. The TAM may be utilized to its fullest extent by using the longest recording period possible, while ensuring that the capacity per period is not exceeded.

Methods of Supply

The RSU or instrument case may be powered by one of four methods, the chosen one depending on whether the site is permanent with mains power, or temporary, and upon the length of time required between site visits. The methods are:

a) 12 volt rechargeable lead gel battery;
b) 6 volt rechargeable lead gel battery;
c) 12 volt AC or DC derived from mains supply, 0.2 VA 50/60Hz;
d) 12 volt, 2.0 VA or 12 volt lead and battery charger with 12 volt rechargeable standby battery in case of mains failure.

Costs:

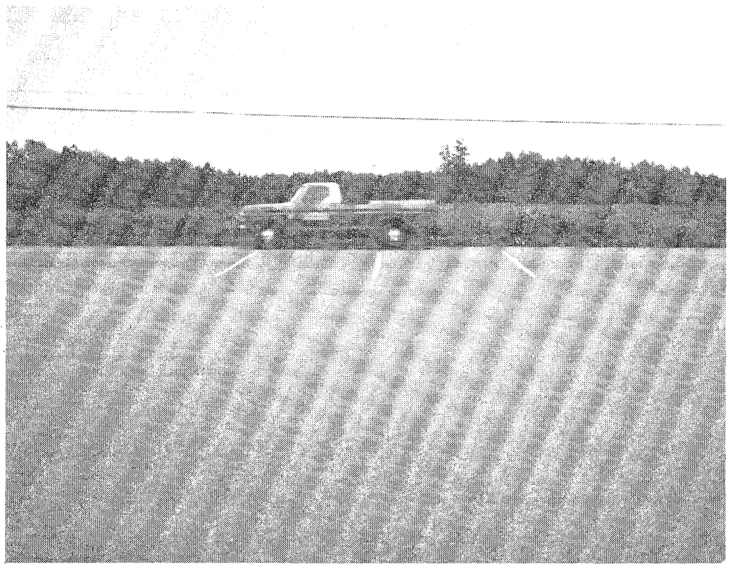
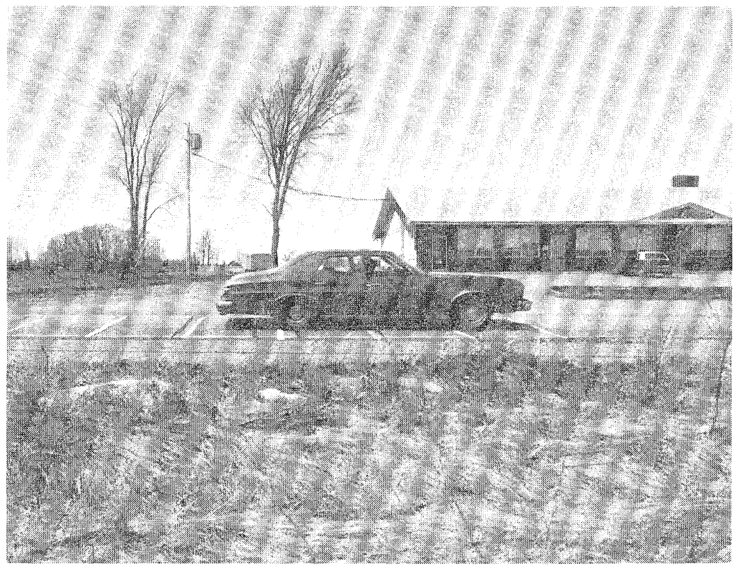
VC1900	$2,000.00
VC Terminal (Data Hunter)	2,600.00
	$4,600.00

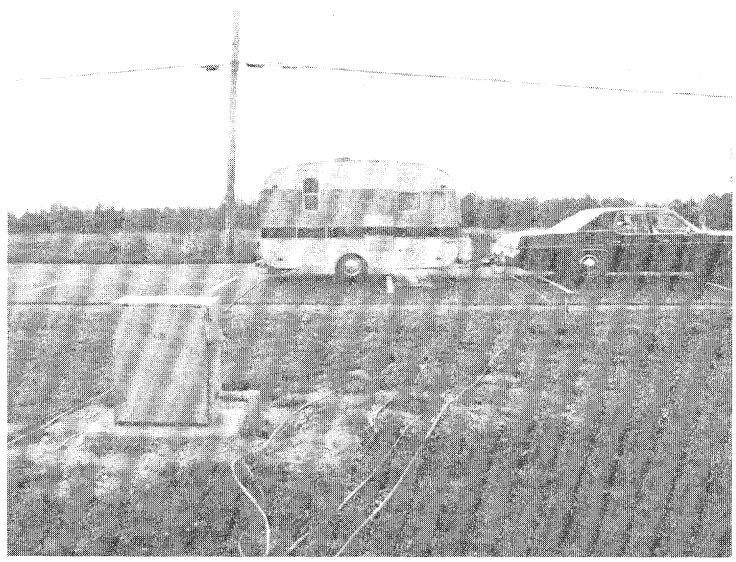
Sarasota has stated that they can now supply the VC1900 to work with road tubes. Therefore, a program should be available for classification to Scheme F.

APPENDIX III

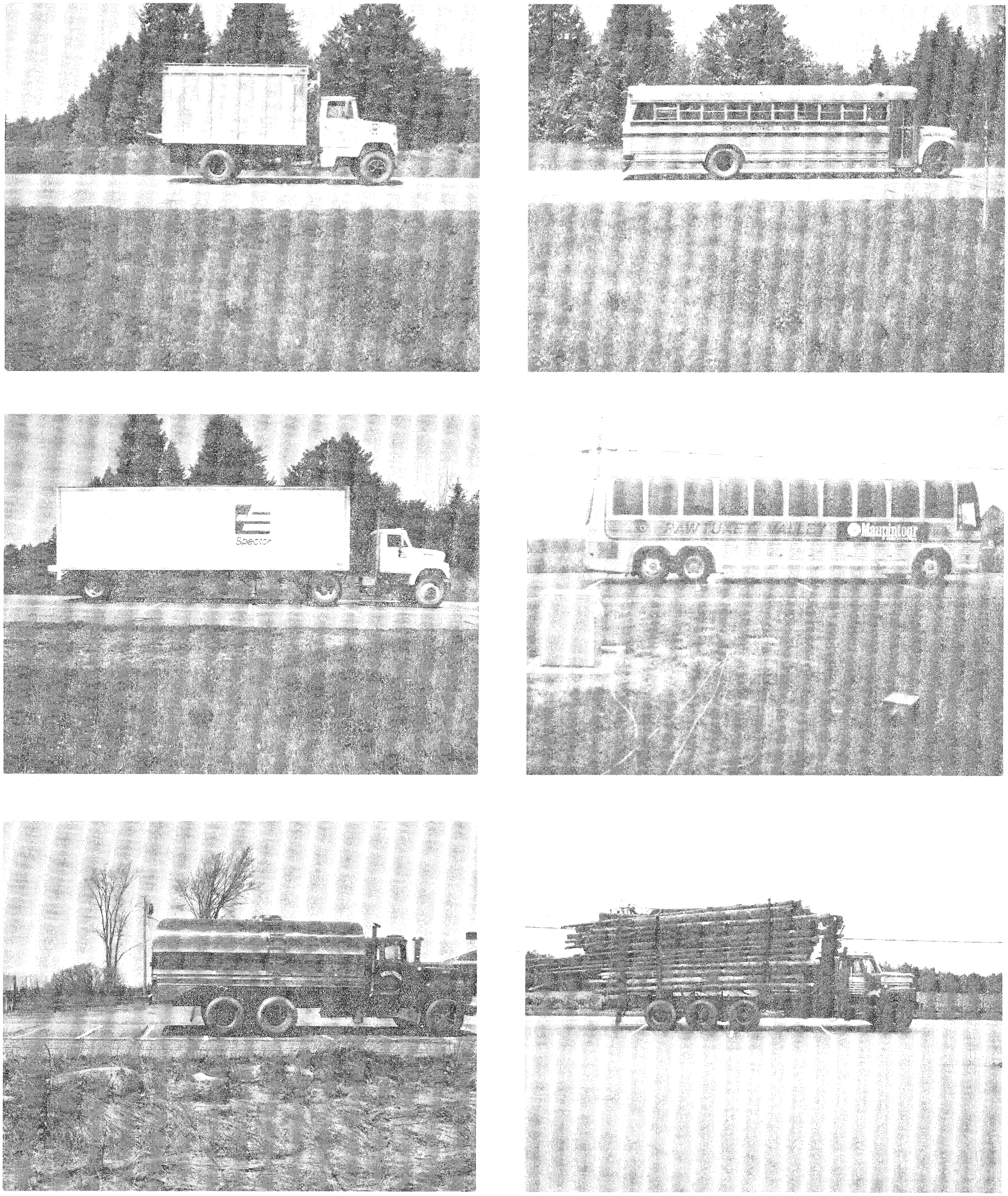
VEHICLE PHOTOS



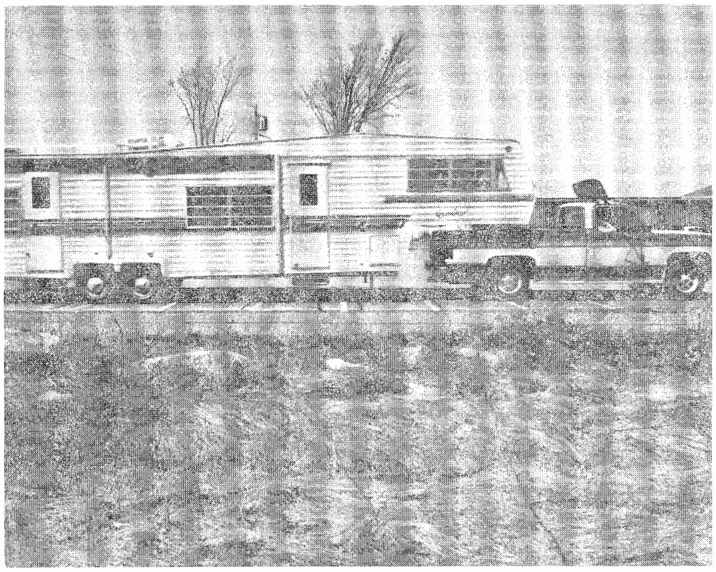
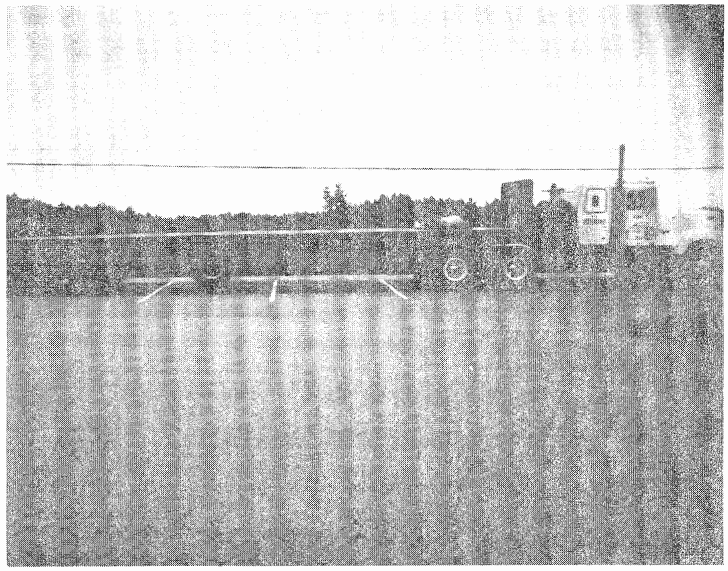
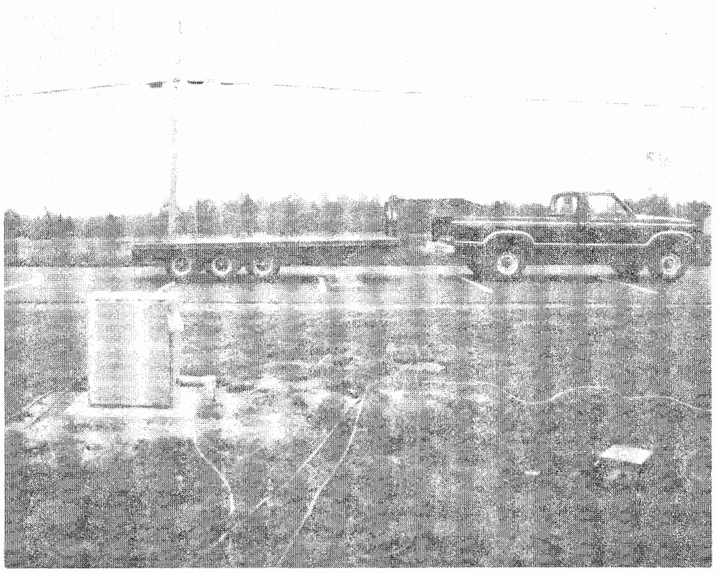
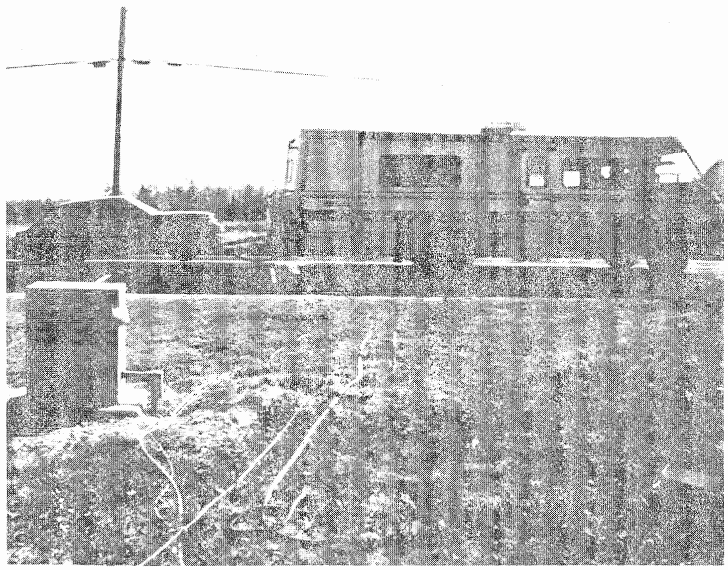
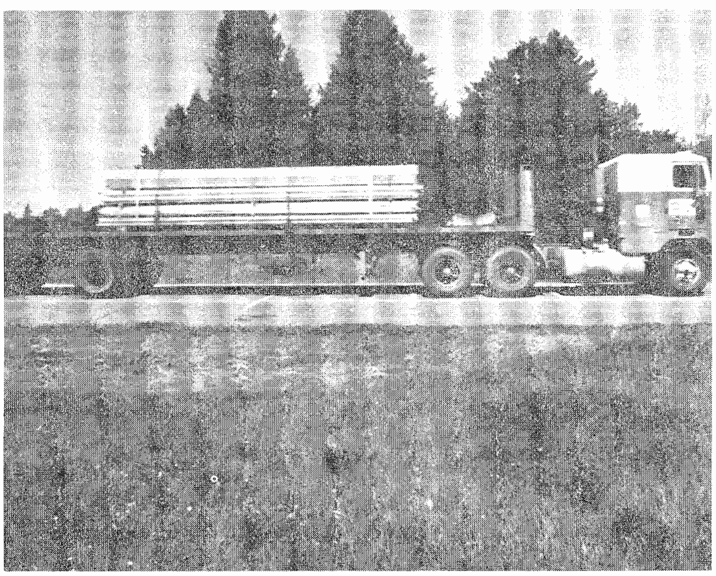
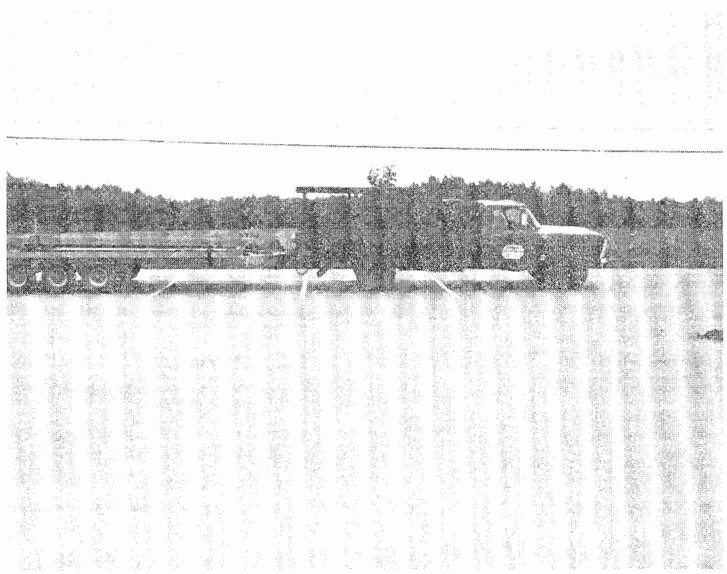


Light Vehicles
PHOTO #14

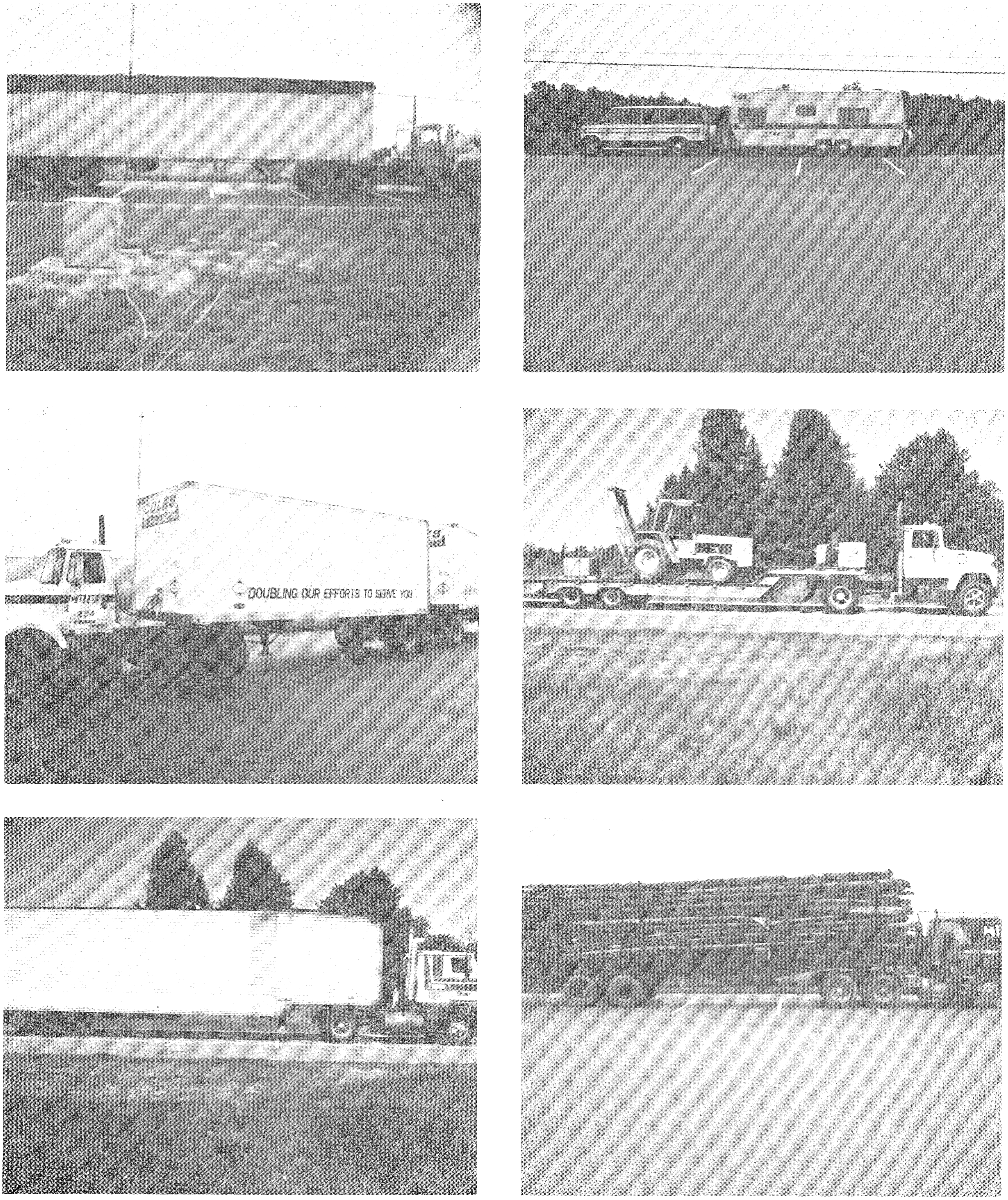


Medium Weight Vehicles

PHOTO #15

Heavier or Odd Vehicles
PHOTO #16



Heavier or Odd Vehicles
PHOTO #17