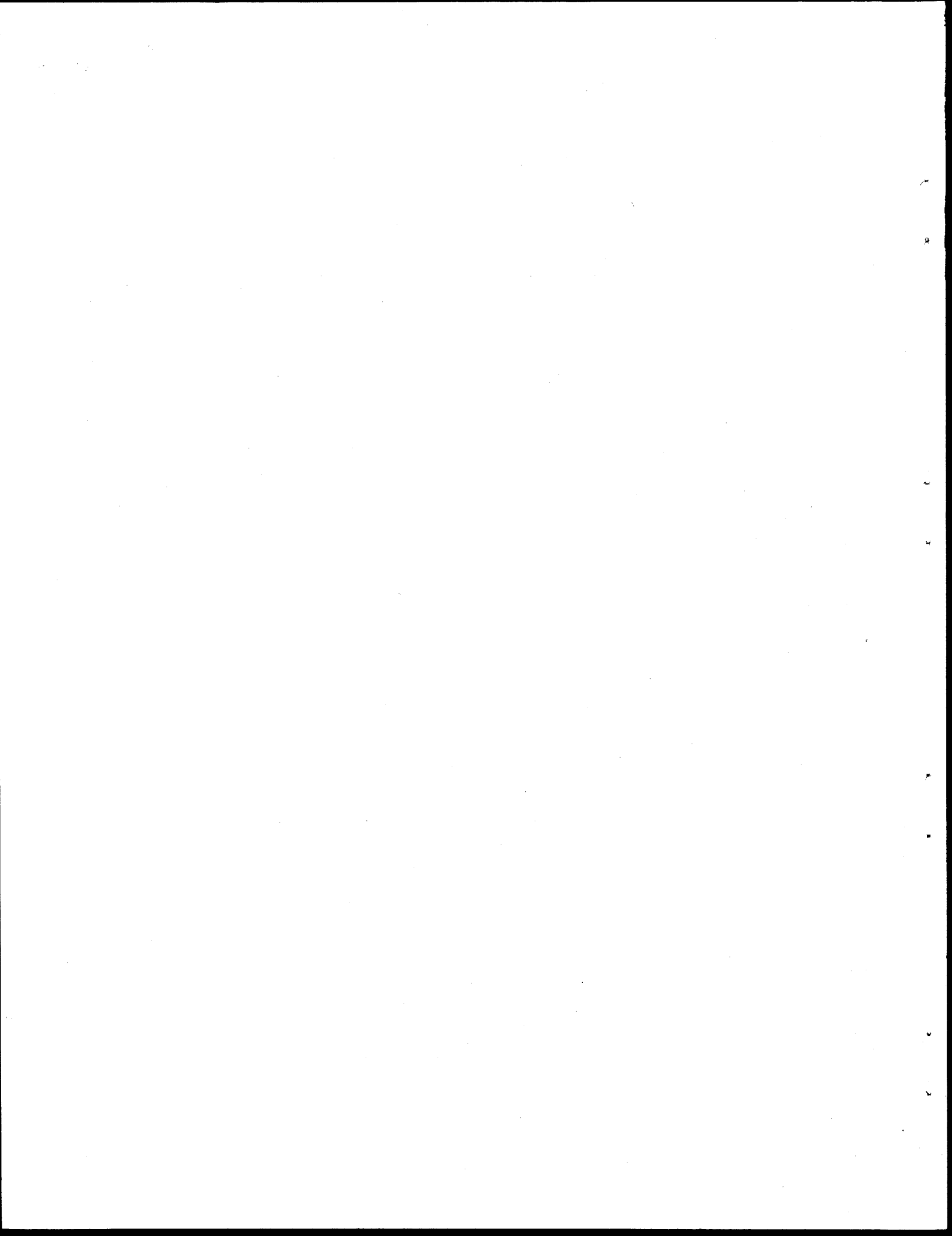


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STUDY OF LOCAL RAMP CONTROL AT CULEBRA  
ENTRANCE RAMP ON THE SOUTHBOUND IH 10 FREEWAY  
IN SAN ANTONIO

by

William R. McCasland  
Research Engineer

Research Report 165-15

Development of Urban Traffic Management  
and Control Systems  
Research Study Number 2-18-72-165

Sponsored by  
The Texas Highway Department  
In Cooperation with the  
U. S. Department of Transportation  
Federal Highway Administration

Texas Transportation Institute  
Texas A&M University  
College Station, Texas

May 1974

## ABSTRACT

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## SUMMARY

The Texas Highway Department developed plans and specifications for a signal controller to meter a freeway entrance ramp based on the concentration of freeway traffic flow and traffic characteristics on the ramp. A detailed discussion of operational capabilities of the controller are presented in the specifications in Appendix A. The controller, the signal hardware and vehicle detectors were installed by the San Antonio District Office personnel at the Culebra entrance ramp on southbound IH 10 in San Antonio on May 1, 1973.

The controller has operated in general accordance with the functional specifications established for ramp control, although there were numerous problems with the hardware during the check out period. The deficiencies have been summarized by the San Antonio District Office and presented in Appendix B. The results of the study have provided information for improving future specifications.

The effects of ramp control on freeway operations were minimal since adjacent ramps were uncontrolled. Accident experience was improved on the entrance ramp and the freeway lanes. The freeway volumes, average speeds, and travel times were not changed significantly. The degree of acceptance of ramp control was 90 to 94 percent, which is consistent with the results of other control systems in the country. The study has shown that as a rule more than one ramp along a section of freeway should be controlled to achieve significant improvements in freeway operation.

The study satisfied the objectives of the project by the examination

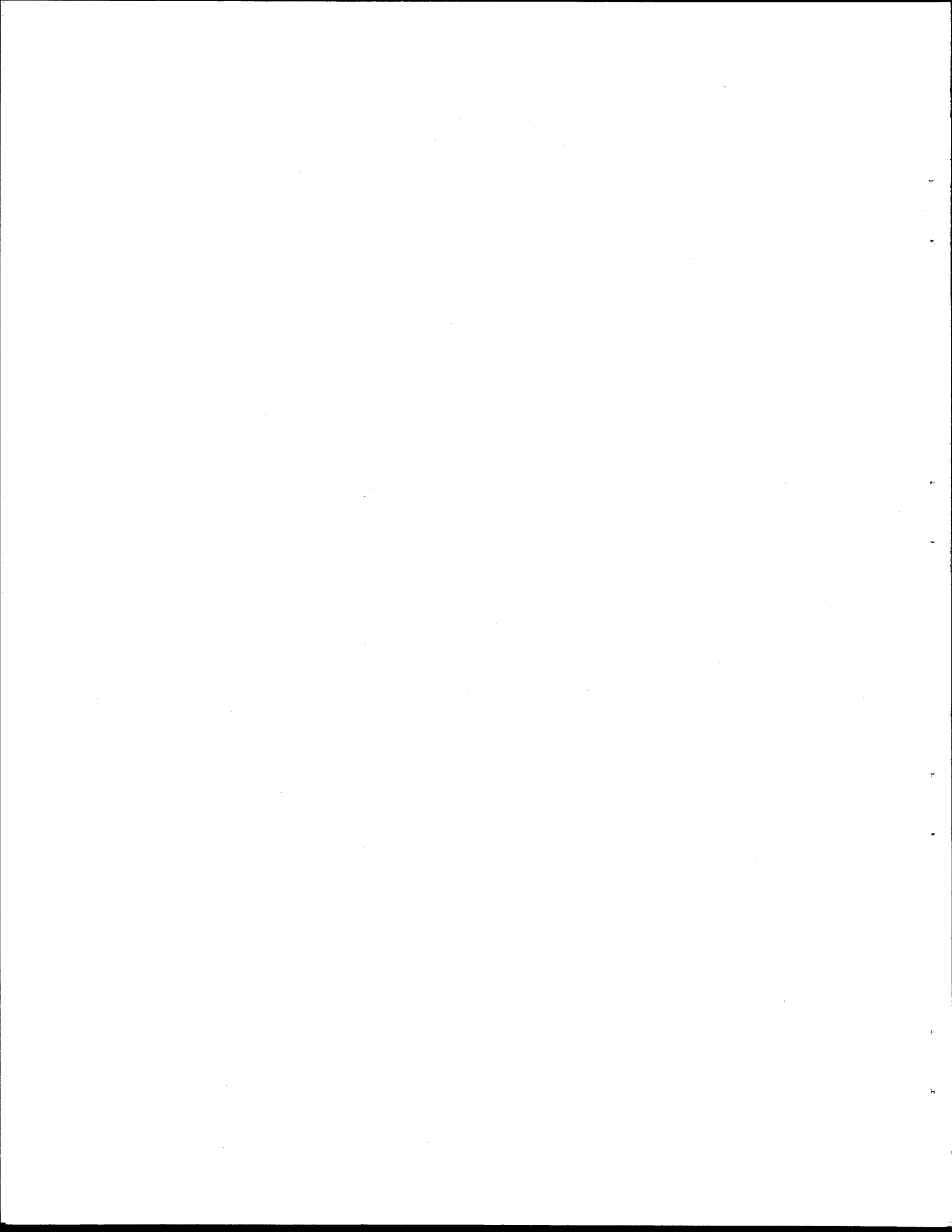
of a remote ramp controller for metering freeway traffic and by the establishment of a demonstration installation for gaining experience and information for applications to future control systems.

#### ACKNOWLEDGEMENT

In September 1970, the Texas Highway Department established Research Study 1-8-71-501, entitled Freeway Control Demonstration, with the objectives to develop a minimum ramp control system at one location in each of three districts and to develop a knowledge and understanding of the process of ramp control within the Highway Department. During the next two years, D-8 Research and the Texas Transportation Institute worked with District Offices in Fort Worth, San Antonio, Houston, and Austin to develop plans and specifications for a ramp controller and to select a site for a demonstration of ramp control. In September 1972, Research Study 501 was terminated and the demonstration objectives were incorporated in a new Research Study 2-8-72-165, Development of Urban Traffic Management and Control Systems. This report is submitted as partial fulfillment of the requirements of those objectives.

TABLE OF CONTENTS

	<u>Page</u>
INTRODUCTION . . . . .	1
OBJECTIVE OF THE STUDY . . . . .	1
DESCRIPTION OF STUDY AREA AND TRAFFIC PROBLEM . . . . .	4
APPROACH TO THE PROBLEM . . . . .	4
OPERATION OF THE RAMP CONTROLLER . . . . .	6
COST OF THE RAMP CONTROLLER . . . . .	8
RESULTS OF CONTROL . . . . .	9
Travel Time and Speed Data . . . . .	10
Volume Counts . . . . .	10
Accident Experience . . . . .	14
Acceptance of Ramp Control . . . . .	17
CONCLUSIONS . . . . .	17
APPENDIX A . . . . .	20
APPENDIX B . . . . .	28





## INTRODUCTION

Ramp metering is a means of controlling the flow of traffic entering a freeway to improve freeway and merging operations. On May 1, 1973, the Texas Highway Department in San Antonio began the control of traffic entering the southbound lanes of IH 10 at the Culebra Avenue entrance ramp. The control was accomplished by advanced warning signs and flashers (Figure 1A) and by regular traffic signals mounted on each side of the entrance ramp, and operated by a traffic actuated controller housed in a cabinet on the right side of the ramp (Figure B). The actuated controller uses an analogue measure of freeway density to select one of several metering rates (Figure 2). Copies of the controller specifications as prepared by the Department are presented in Appendix A.

The installation was made in accordance with standard construction procedures by San Antonio District personnel. Since this installation was the first of its type (single ramp control by a remote local controller) in Texas, the evaluation of the operation was included as an objective of the Highway Program of Research for the Department. This installation also served as a demonstration project for the San Antonio District on which to obtain the experience and data to develop the design, operation and maintenance requirements for an urban wide freeway surveillance and control system in San Antonio.

## OBJECTIVE OF THE STUDY

The objective of this study is to determine if a controller of the type and design specified can operate effectively and reliably as a remote ramp control system.

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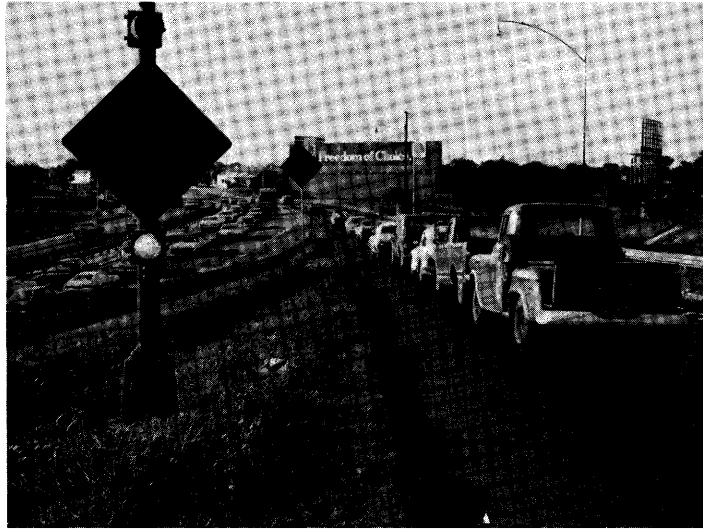


FIGURE 1a

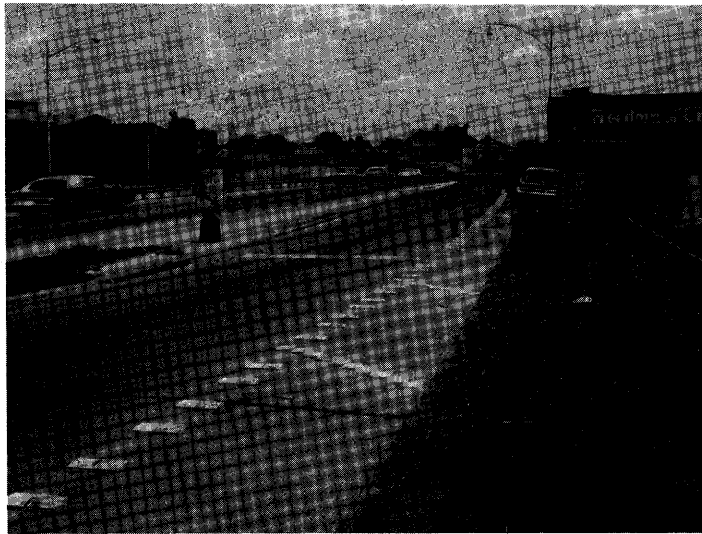


FIGURE 1b

Advanced Signs and Flashers  
and Ramp Metering Signals

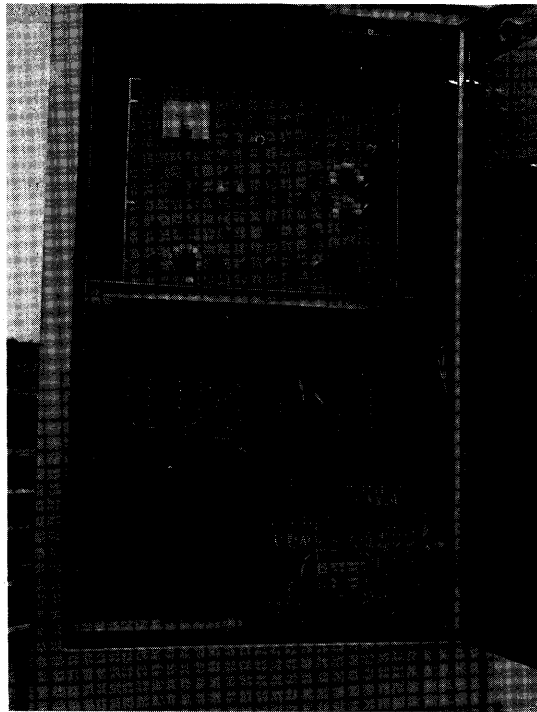


FIGURE 2a



FIGURE 2b

Ramp Signal Controller  
and Cabinet Installation

## DESCRIPTION OF STUDY AREA AND TRAFFIC PROBLEM

The section of Interstate Highway 10 in the study area is four lanes depressed, with sharp horizontal curves and frequent entrance and exit ramps (Figure 3). These characteristics are of an old freeway design constructed in a limited right-of-way. The Culebra entrance ramp is on a downgrade with the merge area in a horizontal curve to the left on the approach to a restrictive railroad overpass. This merge area is a bottleneck section because of the high demand on the Culebra ramp. Ramp volumes of over 900 vehicles per hour were measured before control.

Downstream of the merge area, there is another bottleneck section caused by the merging operations of traffic from the Colorado entrance ramp. Ramp demand is low (100 vehicles per hour) but sight distance restrictions are very severe and cause slow speed merging.

Upstream of the Culebra entrance ramp, there are high traffic demands created by an imbalance of exit and entrance volumes and the loss of one freeway lane at Fredericksburg Road. Therefore, queuing develops daily from the Culebra - Colorado merge areas north to the six-lane section of the freeway, a distance of approximately 1.6 miles.

## APPROACH TO THE PROBLEM

By regulating the entrance ramp volume at Culebra, the Texas Highway Department expected the following results; reduced demand at the critical bottleneck sections, less congestion and smoother operations in the bottleneck sections, fewer accidents on the ramp and main lanes in the study area, and more use of alternate routes on arterial streets.

SCHEMATIC DIAGRAM  
OF STUDY AREA ON RAMP  
METERING PROJECT  
I.H. 10 EXPRESSWAY  
IN SAN ANTONIO

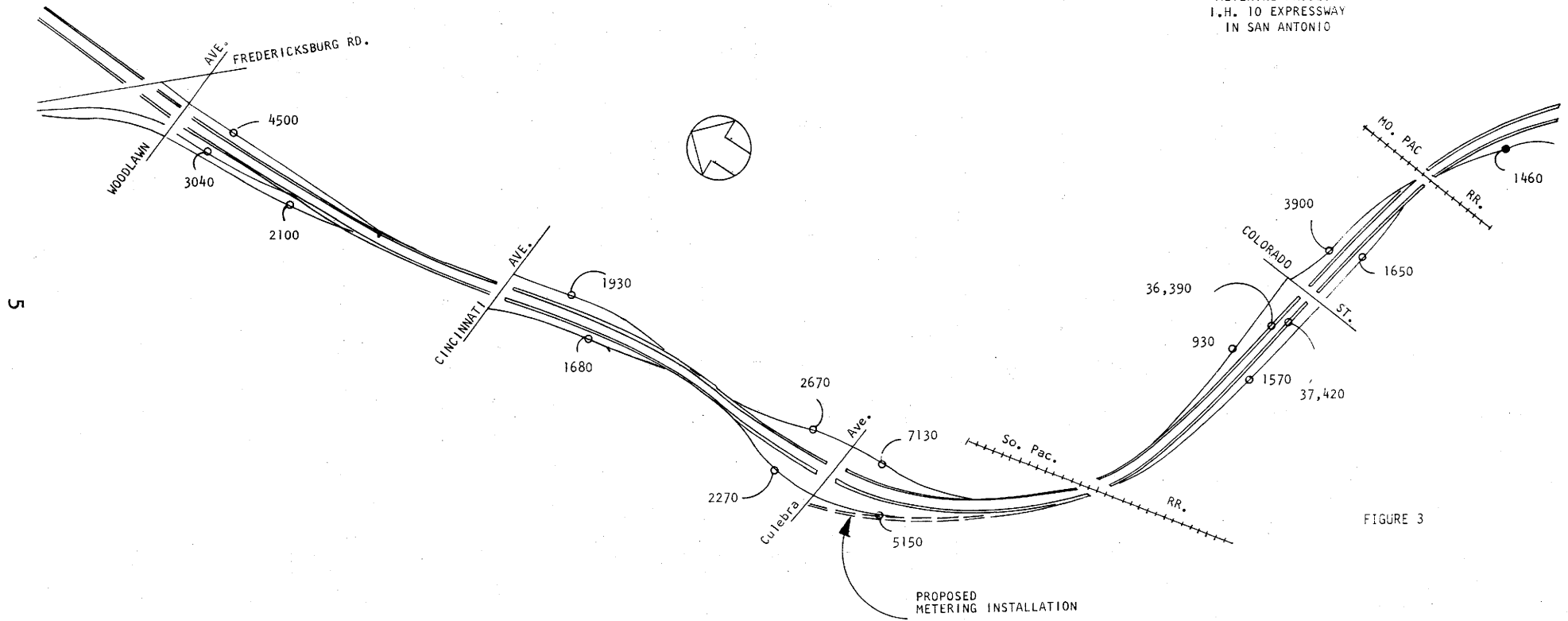


FIGURE 3

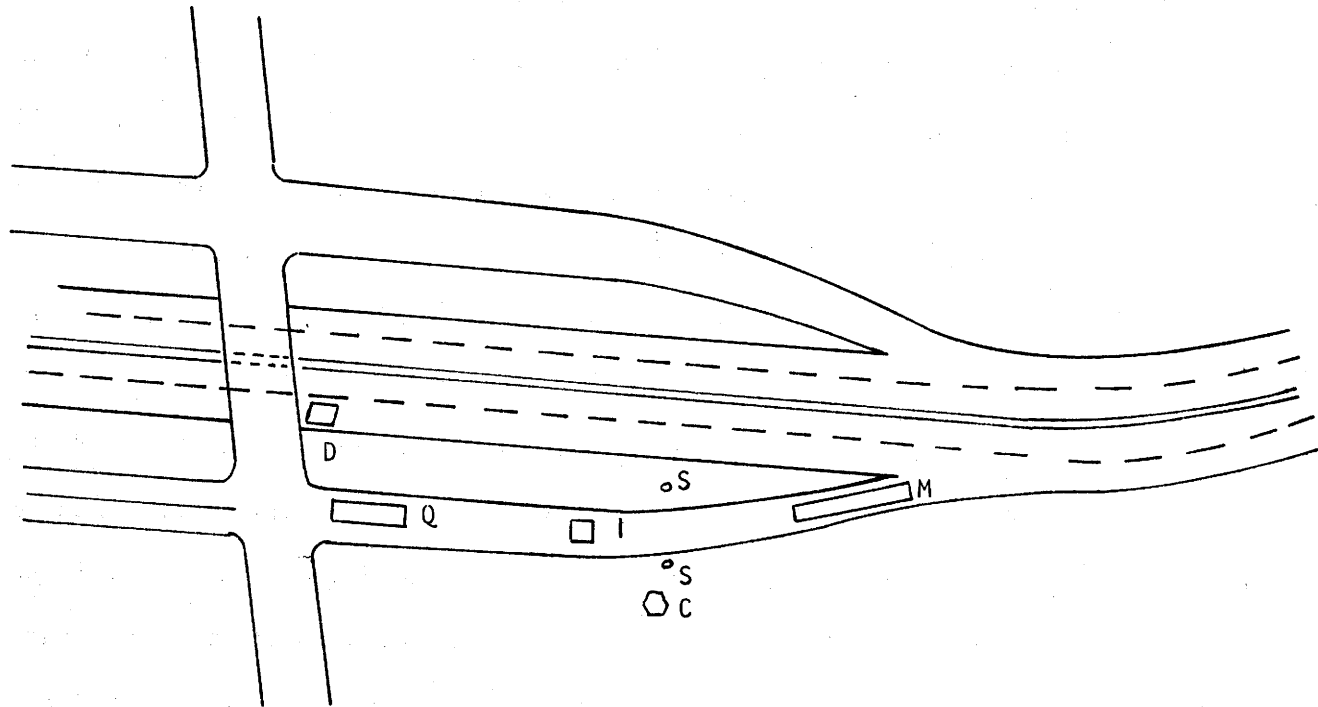
## OPERATION OF THE RAMP CONTROLLER

The ramp controller is traffic actuated and traffic responsive. The detection system is shown in Figure 4 and consists of the following detectors:

- D - A freeway detector to measure the density of traffic approaching the entrance ramp. (Density)
- I - A ramp detector to indicate the presence of a vehicle waiting to enter the freeway. (Input Demand)
- M - A ramp detector to indicate the presence of vehicles stopped in the merge area of the entrance ramp at the point of entry to the freeway. (Merge)
- Q - A ramp (or frontage road) detector to indicate the presence of a vehicle in the queue waiting for the ramp signal. (Queue)

The signal control is activated and deactivated by the freeway detector D. When the traffic density measure exceeds a preset density level on the meter of the analogue computer, the signal is made operative. A density level of 50 vehicles per mile was used by the District. When the density measure drops below a preset density level, the signal is made inoperative and rests in a dark state. A density level of 35 vehicles per mile was used by the District.

The signal controller has four metering rates that are selectable according to changes in main lane density levels, but the settings, are now set to produce only one metering rate of 10 vehicles per minute for all main lane density conditions. When traffic backs over the queue detector, the highest metering rate level is automatically used by the controller until the queue detector is cleared.



- D - Freeway Density Detector
- M - Merge Detector
- I - Input Demand Detector
- Q - Queue Detector
- S - Ramp Signal
- C - Controller Cabinet

Culebra Entrance Ramp Detector System

FIGURE 4



The merge detectors are operative and will inhibit the control by holding a red signal if the time of occupancy exceeds a preset value on the controller. However, the merge area is quite adequate to encourage ramp traffic to enter smoothly and quickly into the freeway and thus this override function of the controller is used infrequently. It appears from the study that merge detectors are not needed for entrance ramps that are properly designed. A detailed discussion of the operational capabilities of the controller are presented in the specifications in Appendix A.

According to San Antonio District personnel, the controller has operated in general accordance with the functional specifications established for ramp control, and provides the type of control selected by the traffic engineer. However, there were numerous technical and design deficiencies that resulted in increased costs to the manufacturer and the Department, unreliable operation of the controller, and a lower quality of operation, appearance and maintenance capabilities. These deficiencies have been summarized by District 15 and presented in Appendix B. Even with the problems of the system, the controller has operated for one year and appears to be functioning well at the time of this report, June 1974.

#### COST OF THE RAMP CONTROLLER

The bid price for the ramp controller was \$5,250 (four bids were received with the highest bid being \$9,500). However, considerable time and effort were expended before the controller was made operational and the problems outlined in Appendix B were resolved. Additional costs to the Department for checkout and modification of the controller were required. The modifications made are described in Appendix B of the report. The

installation of the signal hardware, detectors and controller was done by State forces at an estimated cost of \$5,000. Annual maintenance costs of the system are estimated at \$400.

#### RESULTS OF CONTROL

The objective of the study is satisfied if the controller operates effectively as a remote ramp control system. The section above indicates that the controller operates effectively. What, then have been the effects of this control on the operational characteristics of the ramp and the freeway.

In general, the traffic conditions on the freeway have not been significantly changed by the control for the following reasons:

1. The demand on the Culebra merge area continues to exceed the capacity.
2. The downstream bottleneck at the Colorado entrance ramp causes queuing through the Culebra merge area.
3. Apparently, most of the 500 vehicles per hour that were diverted from the Culebra entrance ramp did not use arterial streets, but appear to have back-tracked to upstream entrance ramps at Cincinnati, Woodlawn and Fredericksburg to enter the freeway. These three ramps are located within a 3/4-mile section of the freeway.

The results point out that this section of IH 10 must be controlled as a system consisting of five ramps (Colorado, Culebra, Cincinnati, Woodlawn and Fredericksburg), not one. The results, as reported in the following sections, indicate no change in freeway operational characteristics, but there is a reduction in the accident experience on the ramp and the main

lanes of the freeway. This is significant in the savings of traffic delay, as well as property damage.

A large amount of data was not collected before the start of control. The available data are presented together with the judgment and evaluation of the traffic engineers familiar with the traffic conditions on this freeway.

#### Travel Time and Speed Data

Although the data available on travel time from Fresno to the M.P.R.R. are small, the trends for before and after periods are very similar. It appears that there has been no significant improvement in the total travel time through the section (Table 1). This is verified by the subjective evaluation of the Texas Highway Department personnel in District 15.

The data imply that with control, the breakdown occurs later in the peak period, but the severity and length of the breakdown is slightly greater than that without control (Figure 5). The breakdown started at the M.P.R.R. bridge at 7:02-7:05, but the most severe section is from Culebra to Colorado. This section remains very slow throughout the peak period while speeds downstream of Colorado increase above 30 mph. It is evident from this speed profile that the Colorado entrance ramp is a bottleneck, primarily due to the merging maneuver, and the Culebra entrance ramp is a bottleneck, primarily due to the demand exceeding the capacity.

#### Volume Counts

The volume of traffic entering at the Culebra entrance ramp has dropped from an average peak hour volume of 954 vehicles per hour to 476 vehicles per hour with the addition of ramp control. From Figure 6, the effects of

TABLE 1

TRAVEL TIME COMPARISONS  
 IN SECONDS  
OVER 2.7-MILE SECTION OF I.H. 10

<u>TIME OF DAY</u>	<u>WITHOUT CONTROL</u>	<u>WITH CONTROL</u>	<u>DIFFERENCE</u>
6:40	179	179	0
7:00	261	203	-58
7:20	582	635	+53
7:40	710	619	-91
8:00	377	399	+22
Average Travel Time	422	407	-15
Average Speed	23.0 MPH	23.9 MPH	

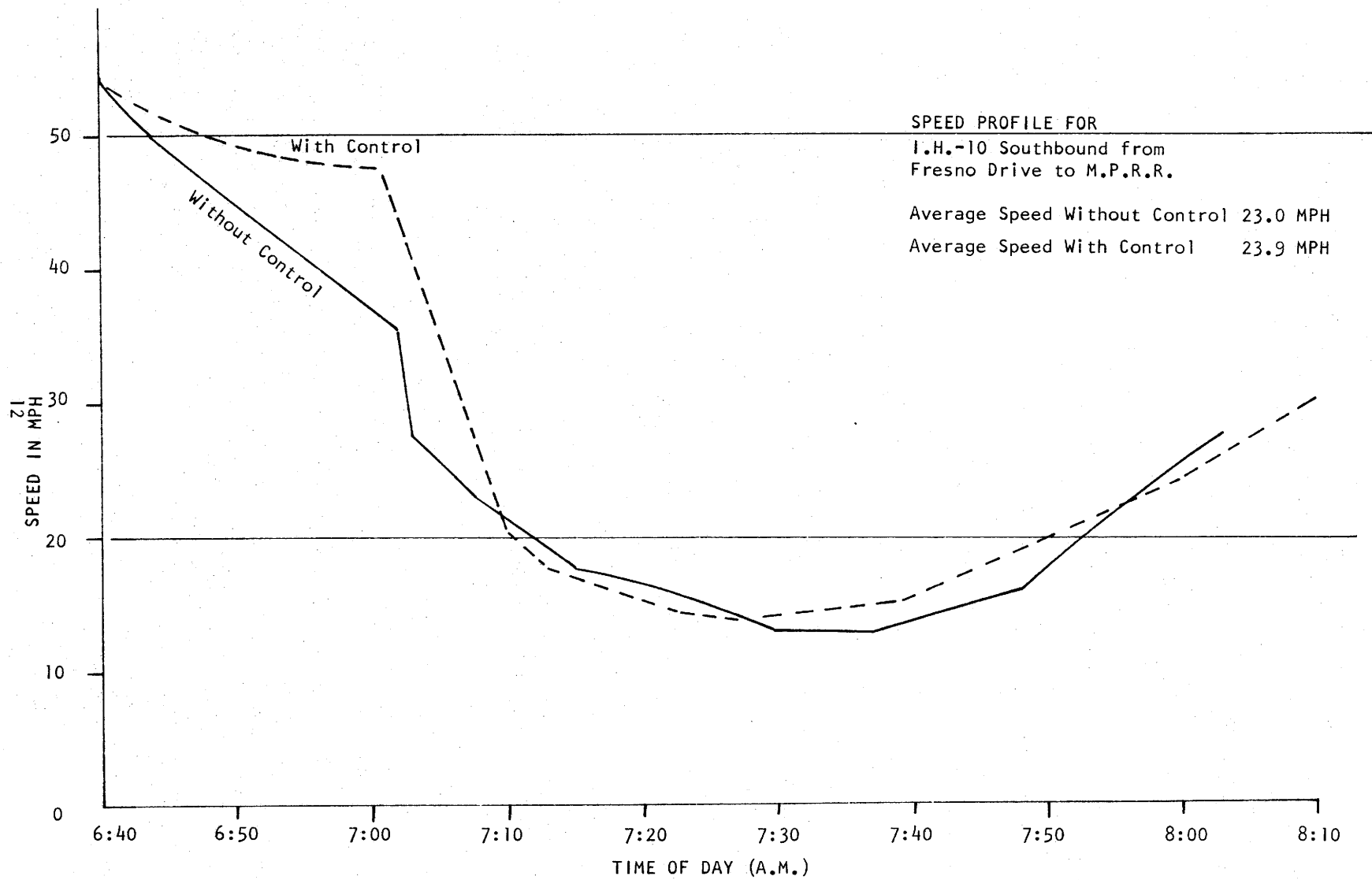


FIGURE 5

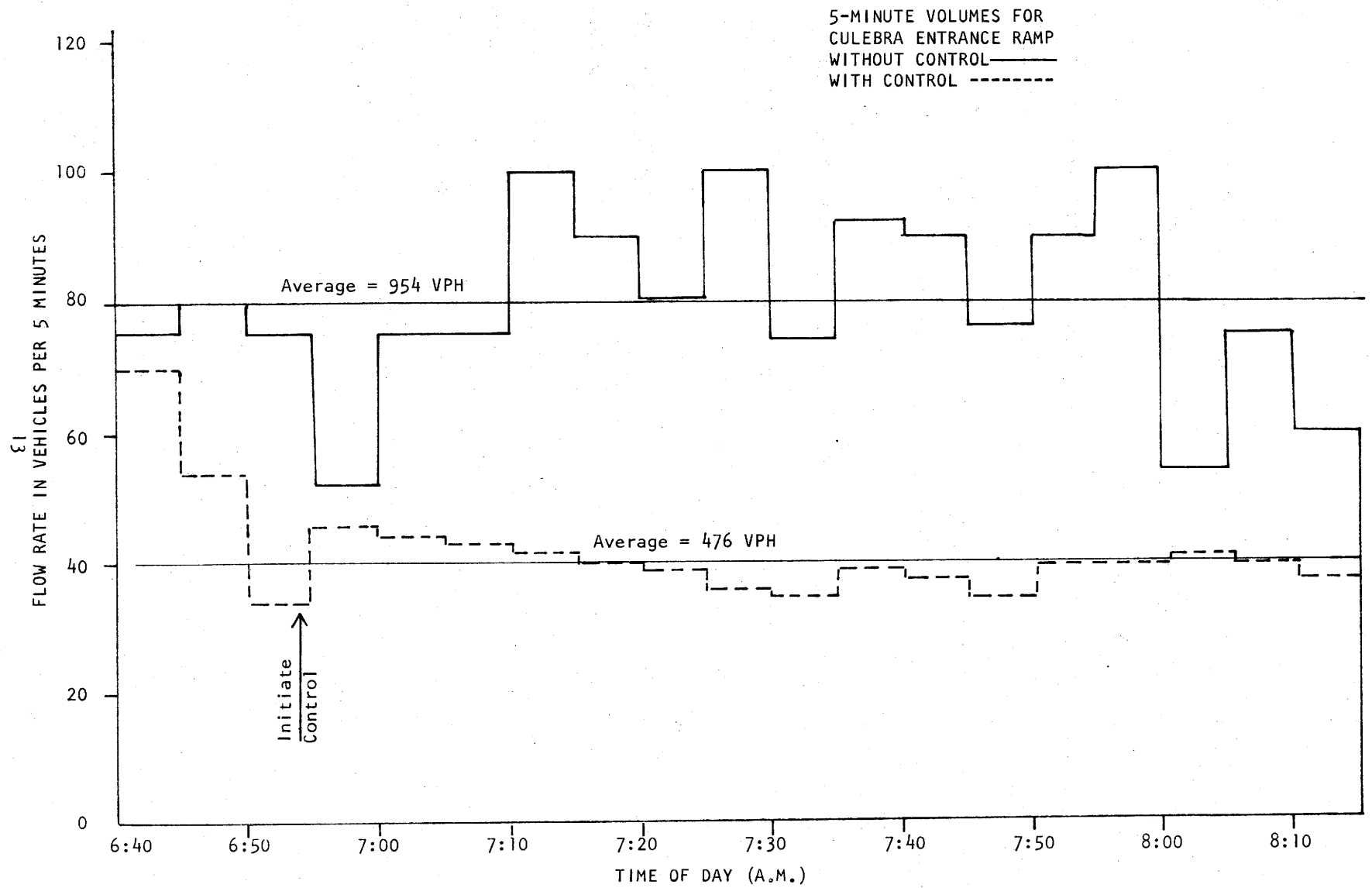


FIGURE 6

the 10 vehicles per minute metering rate can be seen. The actual flow rate, 8 vehicles per minute, is due to the merge override operation, slow approach to the demand detector, and lack of demand.

The volume of traffic on the main lanes of IH 10 approaching the merge area of the Culebra entrance ramp are shown in Figure 7. The flow rates after control was initiated were approximately the same as before control. There was an increase in upstream demand, as determined by the traffic counts for the three-hour peak period at this location.

Comparison of data from Traffic Recorder Station S094 indicates that this increase is not a significant change, since it amounts to only 1.63 percent over a three-hour period as indicated in Table 2.

Before	March 19	March 20	March 21	March 22	Average
6-9 AM	9,990	10,920	10,840	10,760	10,627
After	July 2	July 3	July 4	July 9	
6-9 AM	10,720	11,020	11,030	10,810	10,800
				Difference	+ 173

Three-Hour Volumes on Southbound IH 10

TABLE 2

Accident Experience

The accident experience for Southbound IH 10 and Culebra entrance ramp for 1970, 71 and 72, shown in Table 3, is compared with accident experience for one year after the initiation of control on May 1, 1973. The reduction of accidents from 22 in 1972 to 10 in 1973 is significant in time saved as well as property damage. It indicates 12 more incident free days out of 260 total working days. Of the 10 accidents reported after the initiation of

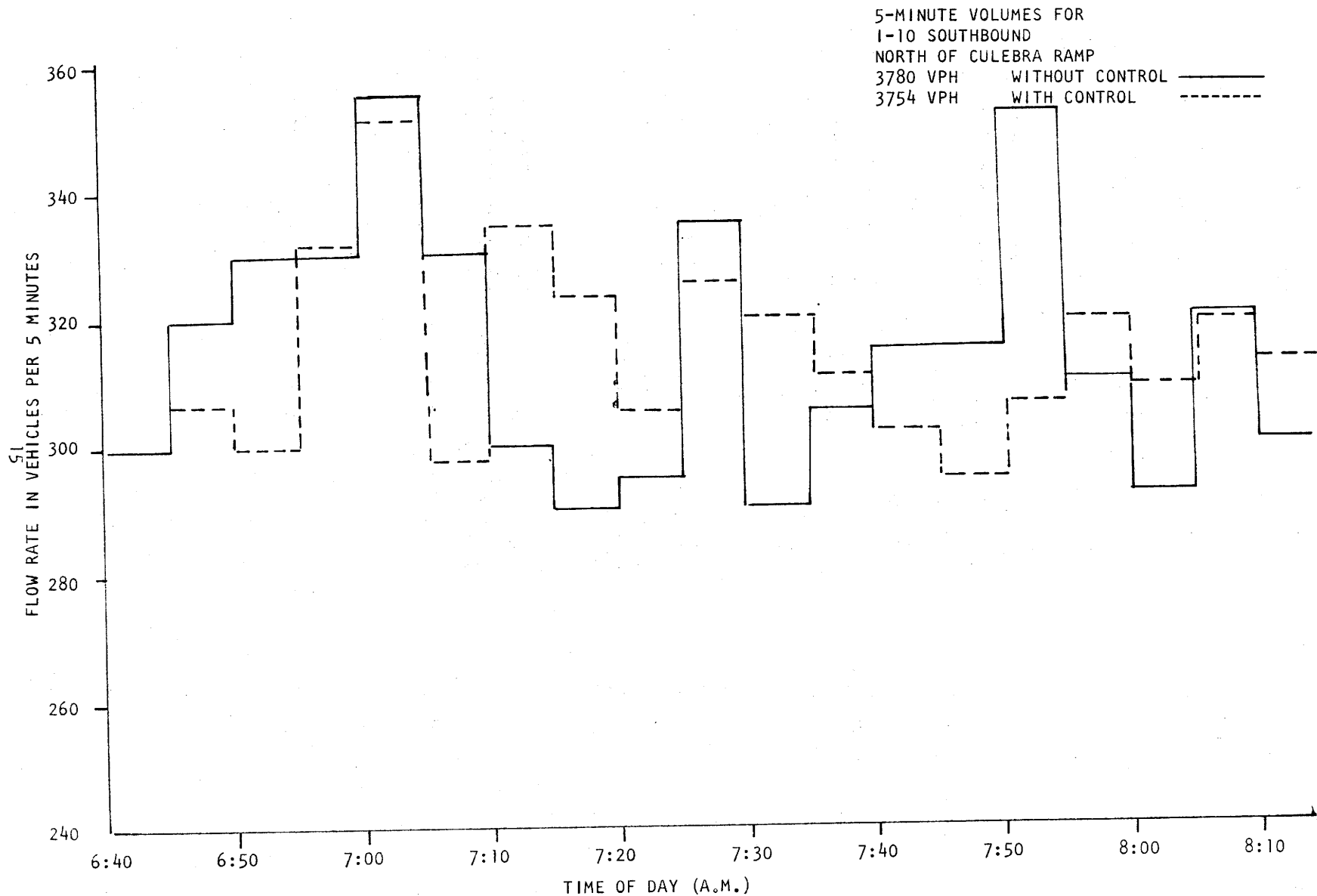


FIGURE 7



TABLE 3

ACCIDENT EXPERIENCE  
Culebra Entrance Ramp

Type of Accident	Before Control			After Control
	1970	1971	1972	1973
Rear End	13	6	8	1
Loss of Control			1	
<b>Total</b>	<b>13</b>	<b>6</b>	<b>9</b>	<b>1</b>

ACCIDENT EXPERIENCE  
Southbound IH-10  
From Fresno Dr. to M.P.R.R.

Type of Accident	Before Control			After Control
	1970	1971	1972	1973
Rear End	2	4	10	9
Side Swipe	6	2	2	
Loss of Control	1	2	1	
<b>Total</b>	<b>9</b>	<b>8</b>	<b>13</b>	<b>9</b>

control, the one ramp accident occurred when the driver was distracted while adjusting a load in his vehicle. Of the 9 freeway accidents, only one occurred during the time ramp control was in operation.

From the data of one year, conclusive statements on the effectiveness of ramp control in reducing accidents cannot be drawn. However, the trend is favorable, as it has been in other ramp control installations in the Country.

#### Acceptance of Ramp Control

The initiation of the control was widely publicized just prior to the May 1, 1973 date. The motorists using the ramp received handouts a week before the start of control (Figure 8). The first few days of operation were used by the Department to calibrate the ramp controller. A few adverse telephone calls were received, but after a few days of operation the public accepted the control system. The level of ramp signal violations range from 6 to 10 percent.

#### SUMMARY OF FINDINGS

The following findings from the study of the Culebra ramp control system are presented.

1. The signal controller and the detection system operated effectively in controlling the entry of the ramp vehicles.
2. The control strategy applied to Culebra did not significantly change the traffic operations characteristics on IH 10 southbound.
3. The 90 to 94 percent acceptance by the public of ramp control in San Antonio was good and compares favorably to other control

TEXAS HIGHWAY DEPARTMENT  
TRAFFIC BULLETIN

Beginning May 1, 1973, the Culebra Avenue Southbound Entrance Ramp will be metered in an effort to improve the efficiency of operation of Interstate Highway 10.

You will note the installation of a stop and go signal on this ramp which is designed to feed entering traffic at a rate which is acceptable to the through traffic on the main lanes. Please observe the signal and when you receive the green indication, move safely to merge with main lane traffic. The green indication does not guarantee a gap in the main lane traffic, but is intended to regulate entry from the ramp to the main lanes.

We regret any inconvenience to you, but you can be assured that every effort is being made to improve the total transportation problem. Alternate routes to the downtown area are shown on the sketch below.

Should you have questions related to the metering of this ramp, please call 696-1110, Ext. 349. Also, any problems involving unusually high traffic delays should be reported.

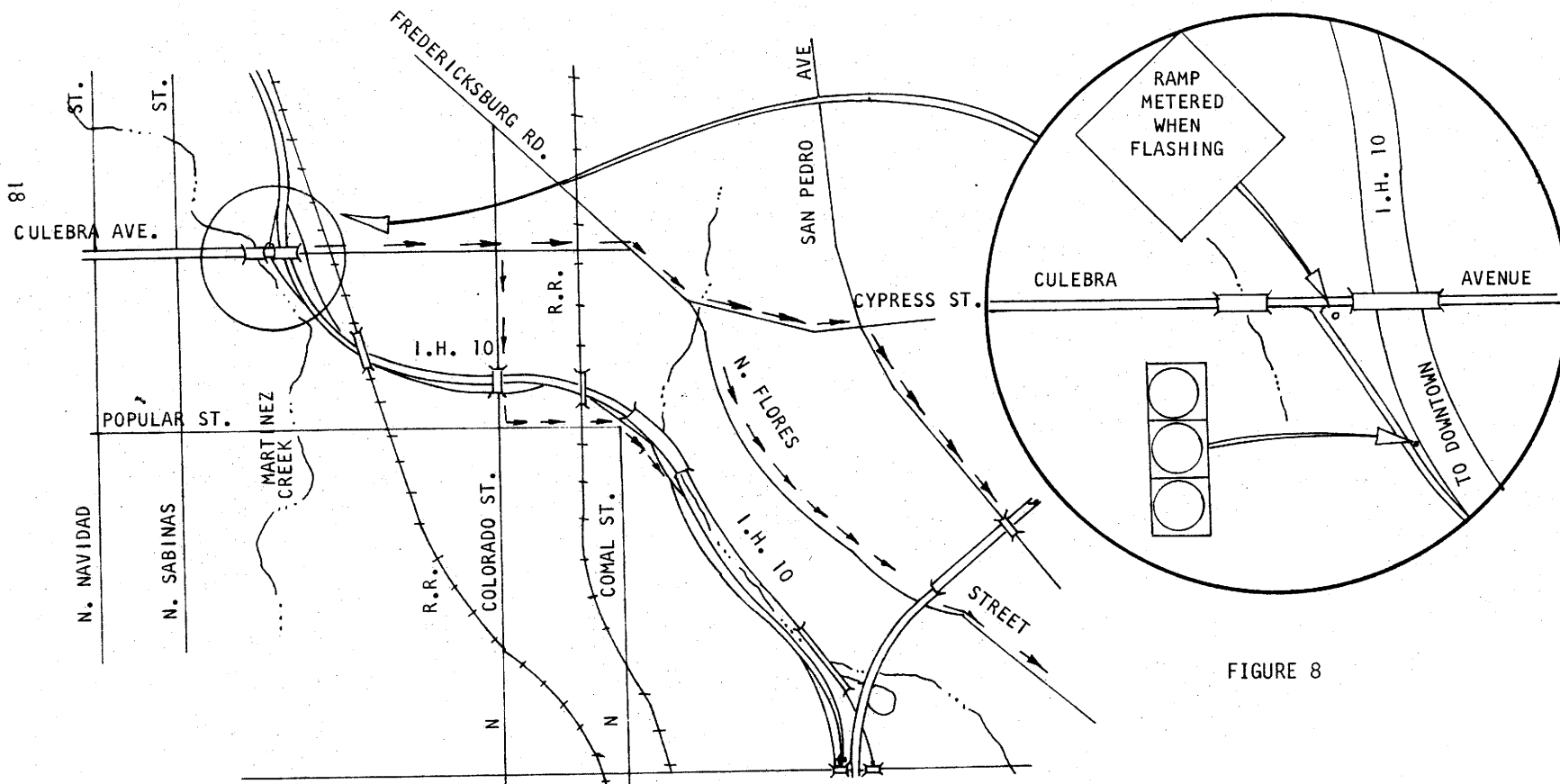
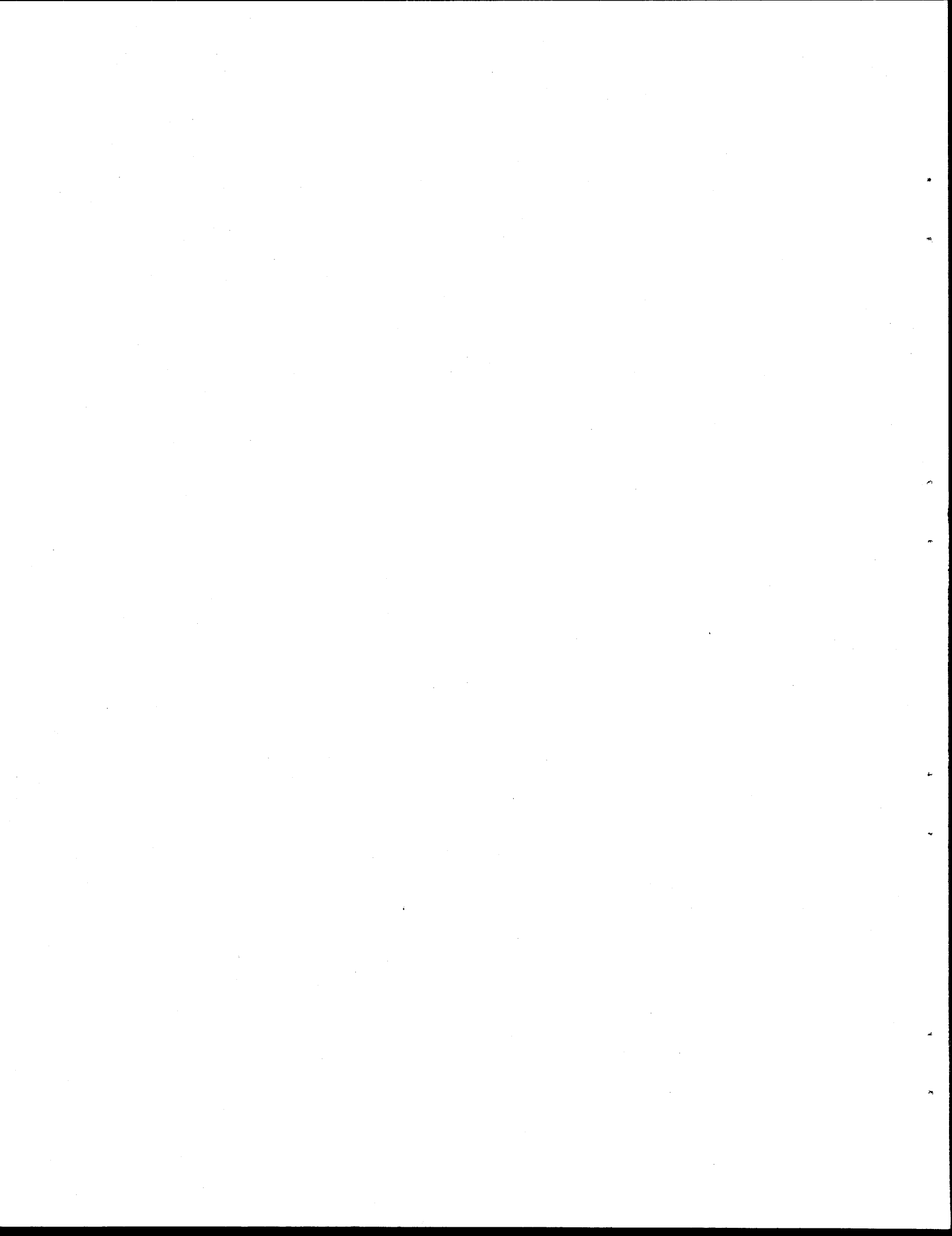


FIGURE 8

systems in the Country.

4. Accident experience, although not conclusive, was favorable, particularly the reduction of ramp accidents.
5. Changes in the specifications were found to be needed to improve the reliability and accuracy of the ramp signal controller.



1.0 GENERAL

1.1 This specification describes the minimum acceptable design and operation requirements for a solid state, vehicle actuated, Freeway Access Computer and Ramp Metering Signal Controller.

2.0 DESIGN REQUIREMENTS

2.1 Functional

The Ramp Metering Controller shall provide the following operational features:

2.1.1 Measurement of Freeway Traffic shall be responsive to the input from one loop detector and shall be determined either by density measurement or by lane occupancy measurement. The functional details and adjustments shall be as follows:

(A) A Freeway Detector Indicator shall be provided indicating the passage of a vehicle.

(B) A Meter display shall be provided to show either the density in vehicles per mile or lane occupancy in percent of traffic concentration. The meter shall be calibrated in a linear manner either from 0 to 200 vehicles per mile or from 0 to 100 percent traffic concentration.

(C) The Density computation shall be accomplished from the input pulse length from the detector and shall operate to process the individual speed of the vehicles multiplied by the equivalent number of vehicles per hour over the measuring period. The lane occupancy or traffic concentration measurement shall be accomplished from the input pulse length from the detector and shall operate to process the percent of time vehicles are on the loop over the measuring period.

(D) The Averaging Time for the operation density shall be adjustable by means of one or more switches capable of at least eight averaging times. The averaging times shall include 1, 2, 4, 6, 8, and 10 minutes.

2.1.2 The measuring output shall be Segmented into at least five levels for control of the ramp metering rate. The functional details and adjustments shall be as follows:

(A) A minimum of five Segmented Levels shall be provided and adjusted by the setting of two sets of four or more transition points. Five levels shall be designated as A,B,D,C, and E in an ascending density or lane occupancy order.

(B) Four or more transition points shall be set by means of dials for densities or lane occupancies increasing from a lower to a higher level.

(C) Four or more dials shall be provided to set the transition points from higher to lower density or lane occupancy levels.

(J) A switch shall be provided for controlling the time on for each the "Green" and "Amber" traffic indicator. Each control shall be adjustable to "0", ".5", "1", "2", "3", "4", and "5" seconds.

(K) The controller shall be provided with a merge area responsive function. The operation shall be in response to a detector location in the merge area. The function details and adjustments shall be as follows:

(1) A Merge Indicator shall be provided which shall show the presence of a vehicle in the active zone of the merge area detector.

(2) In response to actuation of the merge detector the traffic signal will remain red until the merge loop is cleared.

2.1.6 Initiation of ramp metering after the ramp signals have been turned off, shall be immediate, subject to the constraint that the ramp signal shall not be turned on until there is no vehicle present. The choice of either of these two modes of turning the ramp signal on shall be made by a switch or other suitable means located inside the controller. After any power interrupt to the controller, a 15 second green, then amber, then red shall be displayed. This 15 second green may be provided by a separate timer unit.

2.1.7 The controller shall be designed and provided with the necessary features to allow selection of metering rates by commands from a central digital computer. The functional details are as follows:

(A) Provision shall be made whereby, upon digital command any one of the metering rates may be selected that are programmed within the digital computer.

(B) Provision shall also be made whereby the digital computer may initiate control regardless of the time clock.

(C) Provision shall be included also to monitor the following control functions centrally.

(1) All loop detector inputs

(2) Green confirm

2.1.8 Indicator Lamps shall be provided on the front panel of the controller as follows:

(A)

(A) Indicator Lamps shall be provided for both the Demand detector and the Merge detector.

(B) Indicator Lamps shall be provided for the Green, Amber, and Red signal indications.

(C) An indicator lamp shall be provided for each of the five or more levels of operation.

(D) An indicator lamp shall be provided to show when a vehicle is over the free-way detector.

(E) Indicator lamps shall be provided to show when the controller is under time clock control and when the controller is under digital computer control.

2.1.9 Indicator lights shall also be provided on the front panel of the controller or on a separate queue detector unit as follows:

(A) A Queue detector indicator lamp shall be provided to indicate the presence of a vehicle in the queue detector operating zone.

(B) A "Timed Out" indicator lamp shall be provided to indicate the expiration of the timing provided to clear the queue detector.

## 2.2 Electrical

The ramp metering controller shall be electrically designed to meet the following requirements. These design requirements shall be considered to be minimum acceptable. The electrical design shall be commensurate with that used in the traffic signal control industry. The following specific electrical design shall be provided:

2.2.1 The controller shall operate on 115 V 60 Hz. power and shall not draw more than 100 Watts.

2.2.2 The Demand, Freeway, Queue, and Merge detector input circuits shall operate at not over 24 V or under 10 V. D. C. with respect to ground. The circuit shall draw a minimum of 8 milliamperes when grounded in response to actuation of the detector unit.

2.2.3 The output circuit for energization of the ramp Red, Yellow, and Green signal shall be performed by a solid state signal load switch, jack mounted, rated at 1000 Watts.

2.2.4 All functionally operating equipment except the Metering Programmer, and Remote Metering, shall employ solid state circuitry.

2.2.5 The controller shall be designed so that there will not be over 5% change in timing or measuring intervals when the controller is operated in an ambient temperature between minus 20<sup>o</sup>F. to plus 160<sup>o</sup>F. The controller shall also operate within these limits for power supply inputs between 100 and 130 V. A. C.

2.2.6 An output circuit shall be provided for remote indication or recording the measured Freeway Average Density or Average Percent of Concentration. This circuit shall operate at either a voltage of 0 to 10 V or a Current of 0 to 1 milliampere for the range of the density or percent concentration meter of the controller.

2.2.7 An output circuit shall be provided which shall be 0 Volts when metering "OFF" and 10-20 Volts during metering "ON" operation. The circuit shall be capable of supplying a minimum of 10 milliamperes in the metering "ON" condition.

2.2.8 An output circuit shall be provided similar electrically to that described in the previous paragraph 2.2.6, which indicates each of the five or more levels of segmenting.

2.2.9 An output circuit similar electrically to that in previous paragraph 2.2.6 shall be provided to indicate the Queue "Timed Out" condition.

2.2.10 The Metering Programmer shall be driven by a synchronous motor from the 60 Hz. supply.

2.2.11 All printed circuits shall be of epoxy glass with extra heavy 2 oz. copper per



sq. ft. All printed circuit boards shall be plug in type.

2.2.12 All internal wiring shall be of copper and shall be neat and firm.

2.2.13 Terminals shall be barrier type and suitably identified as to function.

2.2.14 Load side polarity shall be same as line voltage polarity.

2.2.15 Duplex outlet to be provided polarized inside the cabinet.

2.2.16 Thyrector protection shall be provided on Line side.

### 2.3 Mechanical

The ramp metering controller shall be physically constructed in accordance with accepted practice in traffic signal controller industry. It shall be mounted in a weather-proof cabinet of the type used for traffic signal controllers and of sufficient size to house the controller and 4 loop detector amplifiers. The cabinet shall be designed to be on a concrete base, and shall be provided with four anchor bolts. Cabinet shall be suitably ventilated.

2.3.1 The controller shall be provided with a standard AN connector for connection between the unit and the terminal strips, etc., located in the cabinet housing. The unit shall be supplied in a weather proof metal housing of the type used for traffic signal controllers. (The housing shall be wired for the necessary detectors, ramp metering controller, power disconnect (20 amp), fuses and other required elements. Ground strip shall be provided with 10 attaching screws.)

2.3.2 The bidder shall furnish the purchaser with one copy per controller of the Instructional Manual, suitably bound, which shall include schematics, parts list, and operating and maintenance instructions.

2.3.3 The equipment shall be warranted for two years from date of acceptance against any imperfections in workmanship or material.

2.3.4 All items furnished shall be brand new.

2.3.5 A two-position Manual Control Switch shall be provided for operation of the metering signal. The positions shall be "Manual" and "Automatic". Automatic is defined as operation according to Freeway Density as described. A jack and a 6-foot extension cord and manual push button control shall be provided.

2.3.6 There shall also be provided a two circuit solid state flasher device to be energized at all times when the metering operation is "on". The output from this flasher will drive Amber caution lights installed in advance of the ramp metering signals indicating that metering operation is in effect.

### 2.4 Delivery

Delivery shall be to Texas Highway Department warehouse as specified on the purchase order.

### 2.5 Measurement and Payment

#### Measurement

Measurement of an acceptable ramp metering signal controller will be made on the basis of its physical appearance and its ability to function as described in this specification and as determined by the Engineer. In any event, the decision of the Engineer will be final and binding.

Payment

Payment will be made at the contract unit price bid for each "Ramp Metering Controller" measured as prescribed above.

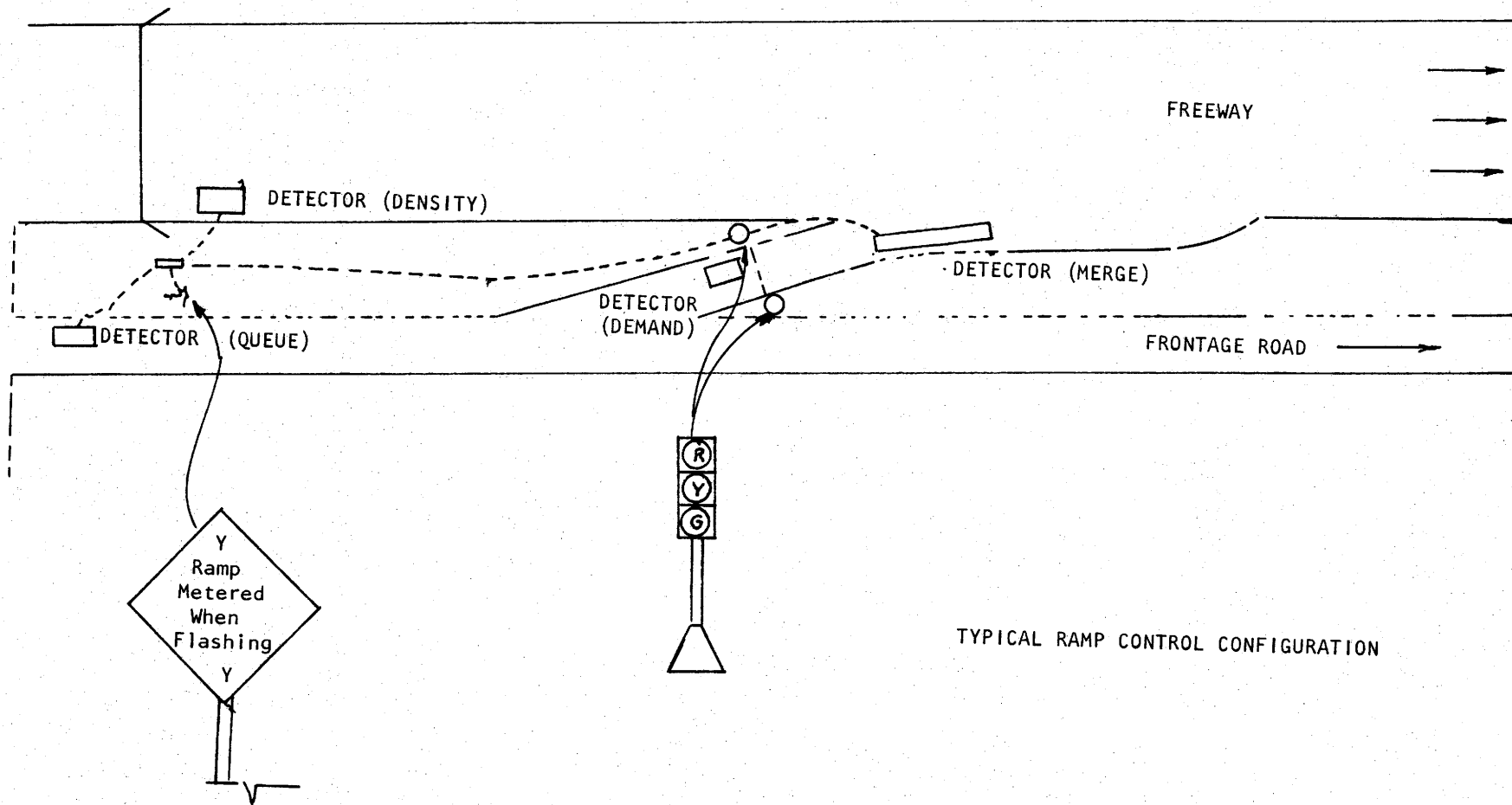


Figure A-1

## APPENDIX B

### PROBLEMS EXPERIENCED WITH E.D.I. RAMP CONTROLLERS

#### PURCHASED BY AUSTIN FOR DISTRICT 15

#### I. BEFORE INSTALLATION

- A. Several merge time-out failures.
- B. Erratic metering rates on all operating levels.
- C. Intermittent, concurrent yellow and green signal outputs.
- D. Inaccurate density operation.
- E. Erratic yellow and green timing intervals.
- F. Green and yellow time adjustments are made with 6-position rotary switches, and timing could be set only at 0, .5, 1, 2, 3, 4 and 5 seconds. For time settings of 1.50 sec., 1.75 sec., etc., all resistors on the rotary switches had to be replaced by District 15 Personnel.
- G. No signal on-off switch was provided. This switch had to be added by T.H.D. personnel.
- H. Load switch outputs to signals were ground instead of A.C. line, and therefore did not meet requirements of the electrical wiring code.
- I. The demand detector had to go to the non-detect position and then back to the detect position to repeat the green. This would leave the signal stuck red, if a vehicle failed to move out on its green signal, or if vehicles were following at close intervals.
- J. The red would not start timing out until a vehicle was present in the demand detector. This was corrected by the manufacturer, but at T.H.D. expense, because it wasn't covered in the specifications.
- K. Controller circuitry lacked buffering required to prevent A.C. line noise problems, especially in the detector circuits.
- L. Detector circuits require all three connections from double-throw output relay in the detector amplifier. All standard control equipment requires only a ground input to detector circuits. This three-wire hook-up is undesirable for many reasons, most of which increase maintenance problems.

#### II. AFTER INSTALLATION

- A. Continuous, erratic timing of metering rates, yellow intervals, and green intervals.

- B. Levels don't always transfer at the density level programmed and need frequent adjustments.
- C. Components are releasing from P.C. boards in the load switches, probably from extreme heat, causing signal output failures.
- D. Load switch pins, which plug into load switch sockets, became loose, causing signal output failures.

### III. GENERAL APPEARANCE AND PACKAGING

- A. Many wire jumpers were added to module P.C. boards for modifications to the original design. These jumpers are a potential maintenance problem.
- B. The controller is mounted in the cabinet on two pieces of angle iron with four bolts and nuts, which are very hard to install and remove. Since there is no shelf provided, it would fall out of the cabinet if it weren't bolted down.
- C. A second controller, which was purchased with the one already installed, cannot be used as a replacement, because the bolt pattern is different. The holes in the controller do not line up with the holes in the cabinet.

### IV. SUMMARY

Most of the problems found before installation were corrected by the manufacturer at his expense. However, many T.H.D. man-hours were necessary in locating the problems. This resulted in numerous phone calls to the manufacturer, with more time lost explaining the problems. Some of the items which were not provided were not covered in detail by the specifications, but they are usually provided anyway by established signal companies.

This only summarizes the problems we have had with this equipment; if more details are needed, please advise.