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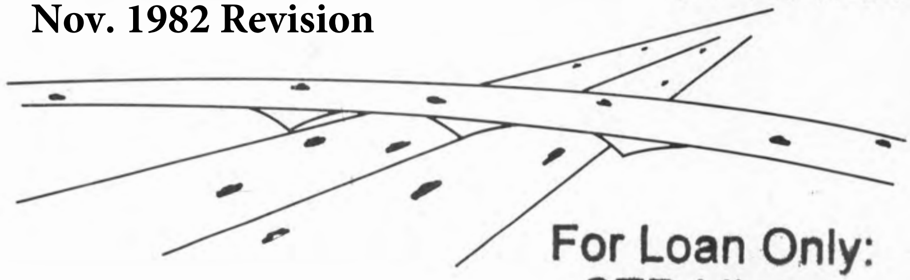

DEPARTMENTAL RESEARCH

Report Number 2-1

EQUIPMENT FOR COLLECTING PAVEMENT ROUGHNESS INFORMATION

in cooperation with
U.S. DEPARTMENT OF TRANSPORTATION
FEDERAL HIGHWAY ADMINISTRATION

STATE DEPARTMENT OF HIGHWAYS
AND PUBLIC TRANSPORTATION

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16. Abstract

This report describes the equipment and methods for obtaining pavement roughness information. Mays Ride Meters are used for collecting inventory information, and the surface dynamics Profilometer is the standard by which the Mays Ride Meters are correlated. The report describes a trailer used to house the Mays Ride Meter equipment and a digital counter system designed to decrease data collection and processing time.

17. Key Words Pavement Roughness, Mays Ride Meter, Surface Dynamics Profilometer, Roughness Correlation, Roughness Equipment Calibration	18. Distribution Statement No Restrictions This document is available to the public through the National Technical Information Service, Springfield, Virginia 22161		
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Form DOT F 1700.7 (8-69)

Equipment For Collecting Pavement
Roughness Information

by

Curtis L. Goss
Kenneth D. Hankins
Allan B. Hubbard

Research Report 2-1

Research Study 1-10-74-2

"Equipment for the Measurement of Pavement
Performance in Texas"

Conducted by

Transportation Planning Division
Research Section
State Department of Highways
and Public Transportation

In Cooperation With the

U.S. Department of Transportation
Federal Highway Administration

December, 1976

The contents of this report reflect the views of the authors who are responsible for the facts and accuracy of the data presented herein. The contents do not necessarily reflect the views or policies of the Federal Highway Administration. This report does not constitute a standard, specification or regulation.

The United States Government does not endorse products or manufacturers. Trade or manurfacturer's names appear herein solely because they are considered essential to the object of this report.

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Acknowledgement is given to Mr. Joseph Smith, Mr. David Edwards and Mr. George Reid for the technical support received in this study. A special thanks is given to Mr. B. D. Cannaday for assistance during the design and construction of the trailer for the Mays Road Meter and to Mr. J. M. Wyatt for the development of the computer software for calibration and data processing.

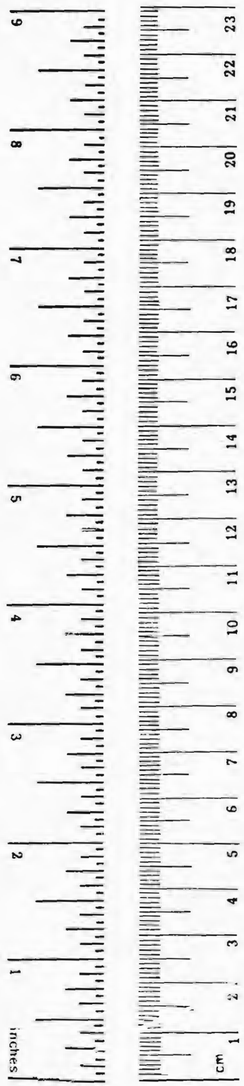
Acknowledgement is given to various personnel with the Equipment and Procurement Division who fabricated the Mays Road Meter trailer used experimentally and finally the six additional inventory test units.

METRIC CONVERSION FACTORS

Approximate Conversions to Metric Measures

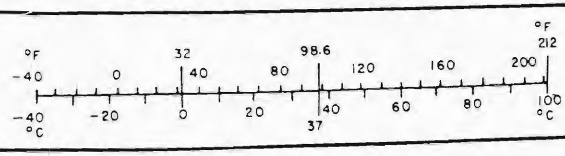
Symbol	When You Know	Multiply by	To Find	Symbol
		LENGTH		
in	inches	*2.5	centimeters	cm
ft	feet	30	centimeters	cm
yd	yards	0.9	meters	m
mi	miles	1.6	kilometers	km
		AREA		
in^2	square inches	6.5	square centimeters	cm^2
ft^2	square feet	0.09	square meters	m^2
yd^2	square yards	0.8	square meters	m^2
mi^2	square miles	2.6	square kilometers	km^2
	acres	0.4	hectares	ha
		MASS (weight)		
oz	ounces	28	grams	g
lb	pounds	0.45	kilograms	kg
	short tons (2000 lb)	0.9	tonnes	t
		VOLUME		
tsp	teaspoons	5	milliliters	ml
Tbsp	tablespoons	15	milliliters	ml
fl oz	fluid ounces	30	milliliters	ml
c	cups	0.24	liters	l
pt	pints	0.47	liters	l
qt	quarts	0.95	liters	l
gal	gallons	3.8	liters	l
ft^3	cubic feet	0.03	cubic meters	m^3
yd^3	cubic yards	0.76	cubic meters	m^3
		TEMPERATURE (exact)		
°F	Fahrenheit temperature	5/9 (after subtracting 32)	Celsius temperature	°C

*1 in = 2.54 (exactly). For other exact conversions and more detailed tables, see NBS Misc. Publ. 286, Units of Weights and Measures, Price $2.25, SD Catalog No. C13.10:286.



Approximate Conversions from Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
		LENGTH		
mm	millimeters	0.04	inches	in
cm	centimeters	0.4	inches	in
m	meters	3.3	feet	ft
m	meters	1.1	yards	yd
km	kilometers	0.6	miles	mi
		AREA		
cm^2	square centimeters	0.16	square inches	in^2
m^2	square meters	1.2	square yards	yd^2
km^2	square kilometers	0.4	square miles	mi^2
ha	hectares (10,000 m^2)	2.5	acres	
		MASS (weight)		
g	grams	0.035	ounces	oz
kg	kilograms	2.2	pounds	lb
t	tonnes (1000 kg)	1.1	short tons	
		VOLUME		
ml	milliliters	0.03	fluid ounces	fl oz
l	liters	2.1	pints	pt
l	liters	1.06	quarts	qt
l	liters	0.26	gallons	gal
m^3	cubic meters	35	cubic feet	ft^3
m^3	cubic meters	1.3	cubic yards	yd^3
		TEMPERATURE (exact)		
°C	Celsius temperature	9/5 (then add 32)	Fahrenheit temperature	°F



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II. MRM Variable Study - District 14 Unit 6

Implementation

This research project was designed to improve and/or develop equipment necessary to obtain an inventory of pavement performance. There were four items selected as a measure of pavement performance:

1. Pavement Roughness
2. Skid Resistance
3. Pavement Deflection
4. Pavement Distress

This report is concerned with the equipment for obtaining pavement roughness measurements. Based on the research and devleopment efforts explained in this report, six trailers were fabricated for use in the performance inventory. The trailer units contain the counter instrumentation. In addition, one trailer with counter will be maintained with the Research Section and two counter packages were fabricated for use in automobile-housed Mays Ride Meter units (one of these is the Texas Transportation Institute Unit). There are four Mays Ride Meter units housed in automobiles without counters. The location and service to other Districts, which was developed by the Maintenance Operations Division, is as follows:

MRM TRAILER

WILL BE PLACED IN DISTRICTS	WILL PROVIDE MEASUREMENT SERVICE TO DISTRICTS
2 - Fort Worth	9 & 23
5 - Lubbock	4 & 25
7 - San Angelo	6,8 & 22
12 - Houston	17 & 20
15 - San Antonio	13 & 16
18 - Dallas	1 & 10
D-10 Research	14

MRM VEHICLES ARE IN THE FOLLOWING DISTRICTS

3
11
19
21 - (Counter Package)
24
TTI - (Counter Package)

SUMMARY

This report gives a comprehensive account of the use of the Mays Ride Meter (MRM)/Counter/Interface System. The components of the system are:

1. Mays Ride Meter
2. Distance Measuring Instrument (DMI)
3. Car Wheel With 8 Attached Magnets and a Transducer
4. The Accumulative Counter
5. Two Alternating Counters
6. Interface Board

The system is designed to collect road roughness data in two different forms:

1. The average serviceability Index (SI) over a given length of highway surface.
2. The SI for each 0.2 mile segment of surface over a given length.

The manual gives a description of each of the equipment components as well as directions for their proper use.

Calibration of the MRM readings with SI values is described, and instructions for making control runs are presented. Examples of all necessary work sheets and charts are given showing their proper use. Finally, a discussion of the MRM data processing and reporting procedures is presented, again, amply illustrated for proper use of the code sheets.

I. BACKGROUND

Research studies concerned with pavement roughness have been conducted in this state for several years. Recently, it was decided to select equipment and develop operation procedures to obtain periodic pavement roughness measurements. Two types of roughness measuring equipment were selected. One was the Surface Dynamic Profilometer (SDP) which is similar to the General Motors Profilometer. The SDP was fabricated and purchased from the K. J. Law Company and contains rather sophisticated electronic equipment.

The second type of roughness equipment was the Mays Ride Meter (MRM). The MRM was designed by Ivan K. Mays in 1967 and is fabricated and sold by the Rainhart Company. This report will describe an electronic counter system that was added versatiltiy. The counter system was shop fabricated by the Research Section of the Transportation Planning Division.

The Serviceability Index (SI) value has been selected as the basis of reporting roughness numbers. The SI concept was originally developed at the AASHO Road Test and consists of a number varying from 0 to 5 with 0 being very rough and 5 very smooth. The SI values used in Texas were developed from the results of several road rating teams. That is, in a research project, a group of teams consisting of people of various professions rated several highway sections from 0 to 5. The SDP was tested on the same sections and a correlation between the ratings and SDP established. In this manner the SDP was correlated to the rating teams and the MRM is correlated to the SDP. Each MRM reports an SI value similar to that which would have been reported by a rating team.

II. MRM VARIABILITY STUDIES

It is possible that vehicular components could cause variation in roughness values. For this reason an experiment was performed in which the following variables were studied:

1. Weight (Two Levels)

   The two weights used were 200 pounds and 550 pounds. These weights were added to the vehicle and the 200 pound weight was the driver. The 550 pound weight was composed of a 200 pound driver, a 170 passenger and a dead weight of 180 pounds placed in the vehicle trunk.

2. Speed (Three Levels)

   Three speeds, 20 mph, 40 mph and 60 mph, were used.

3. Tire Pressure (Two Levels)

   The two tire pressures used were 20 psi and 35 psi.

The MRM was housed in a 1968 Ford Sedan. Sections composing three roughness levels were selected and these can only be described as rough, medium rough and smooth. These sections were selected based on previous tests at 50 mph.

The results of the tests may be found in Table I. The results have also been plotted in Figure 1. The values are in terms of scaled values and have not been converted to S.I. The variation or range in repeat tests have been shown in Figure 1 in the form of a vertical bar to the left and right of each plot. The left side shows the range in the 20 mph values and the right the range in the 60 mph values. The significance of the variation of the variable studied may be compared to the vertical bar or repeatability range.

For example, in Table I the repeatability range of the values of the rough section, heavy weight, low tire pressure at 20 mph is 0.3 (or 5.3 less 5.0). The variation or change in MRM values due to a speed change from 20 mph to 60 mph for the rough section, heavy weight, low tire pressure is 1.75 (or 6.9 - 5.15). The variation or change in MRM values due to a speed change (1.75) from 20 mph to 60 mph is significant when compared to the repeatability range (0.3). A visual display of the example may be found in the upper left plot of Figure 1 (observe the plot marked low tire pressure).

Using the example and observing Figure 1 the following may be stated in terms of significance compared to the repeatability range:

1. Difference between sections is significant (the unit can determine difference in roughness)

TABLE I
MRM VARIABLE STUDY
RESEARCH UNIT

UNIT 29-141-C
MAY 14,15, 1974

		ROUGHNESS								
		ROUGH SECT. NO. 104			MEDIUM ROUGH SECT. NO. 15			SMOOTH SECT. NO. 36		
		20 MPH	40 MPH	60 MPH	20 MPH	40 MPH	60 MPH	20 MPH	40 MPH	60 MPH
HEAVY WT. 550	LOW TIRE PRES. (20 PSI)	5.0	6.2	6.8	2.0	2.1	2.0	0.1	0.6	1.0
		5.3	6.6	7.0	2.6	2.2	1.7	0.1	0.6	1.0
		5.15	6.4	6.9	2.3	2.15	1.85	0.1	0.6	1.0
	HIGH TIRE PRES. (35 PSI)	5.3	6.4	7.3	4.4	2.9	2.5	1.3	0.7	1.1
		5.3	6.2	7.3	4.2	3.3	2.8	1.3	0.7	1.1
		5.3	6.3	7.3	4.3	3.1	2.65	1.3	0.7	1.1
LIGHT WT. 200	LOW TIRE PRES. (20 PSI)	5.5	7.1	7.9	2.9	2.3	2.0	0.05	0.8	1.0
		5.8	7.5	7.4	2.8	2.5	2.0	0.10	0.9	0.9
		5.65	7.3	7.65	2.85	2.4	2.0	0.07	0.85	0.95
	HIGH TIRE PRES. (35 PSI)	6.4	7.0	8.3	5.6	4.3	3.0	0.70	0.80	1.4
		6.0	7.3	7.6	5.3	3.8	3.2	0.60	0.80	1.2
		6.2	7.15	7.95	5.45	4.05	3.1	0.65	0.80	1.3

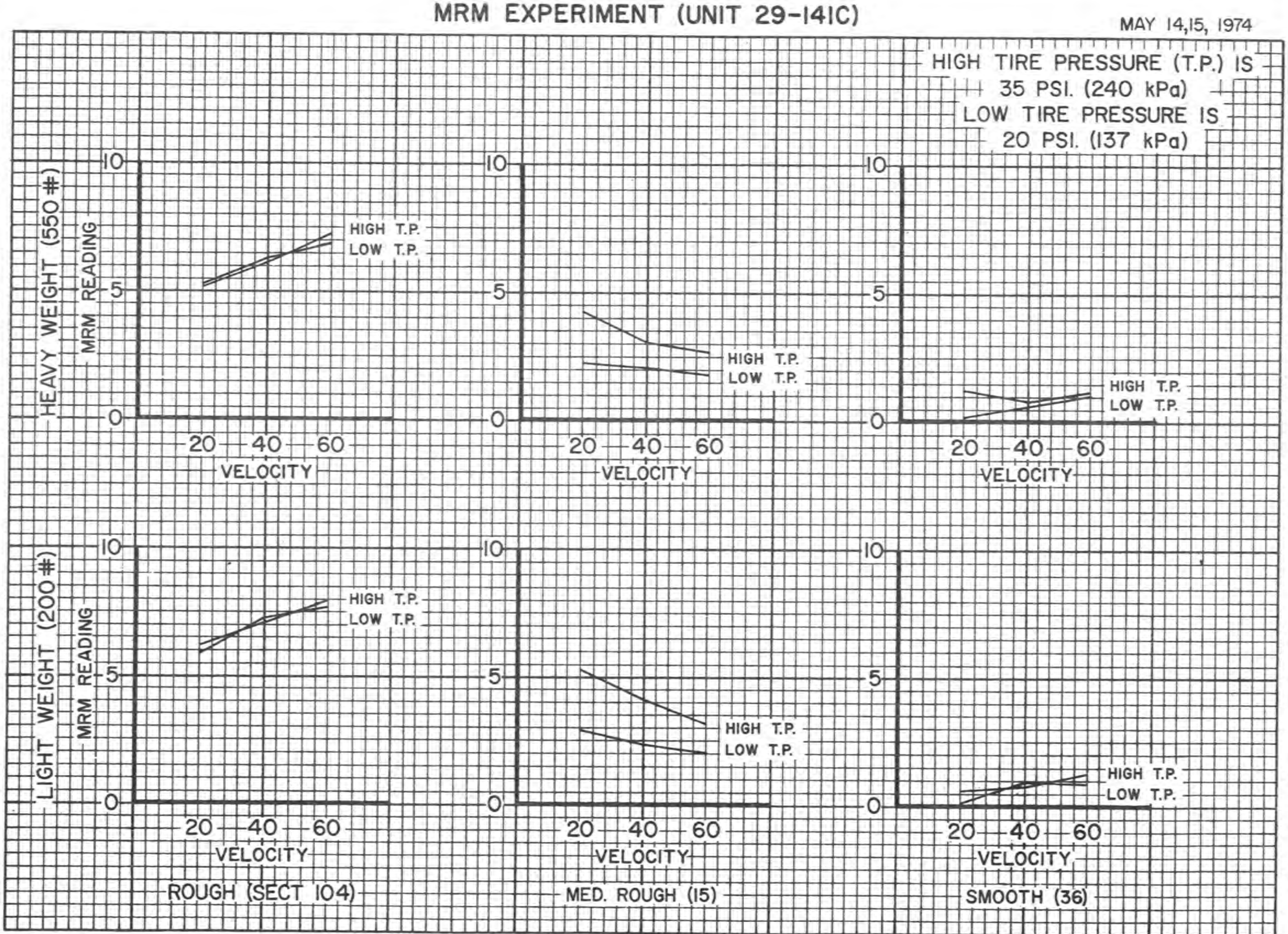


FIGURE 1—MRM VARIABLE STUDY—RESEARCH UNIT

2. Difference in speed (20 mph to 60 mph) is significant in each plot or for each condition.

3. Difference in the pressure (20 psi to 35 psi) is significant in most cases, particularly on the medium rough section and at 20 mph on the smooth section.

4. Difference in weight added to the vehicle (200 lbs. to 500 lbs.) significant in each test condition and on each section. (Weight has less effect on MRM values on smooth sections.)

Figure 1 also indicated:

1. MRM values probably increase (indicate more roughness) with an increase in speed. Usually, the Medium Rough Section showed the reverse or a decrease in value with an increase in speed.

2. Higher tire pressures probably cause higher MRM values even though the effect of tire pressure varied at different test speeds and on different test sections.

3. Lighter weights in the vehicle generally increase MRM values, however, small or opposite effects were observed at various speeds on the smooth section.

The trends of the MRM values due to speed on the Medium Rough Section led to a complete rerun of the experiment using a different vehicle and MRM unit (14-132-F). The second MRM test vehicle was borrowed from District 14 (Austin). The results of the tests are shown in Table II and in Figure 2. If Figures 1 and 2 are compared, the same trends as previously reported may be found even though the values may be slightly different. Based on previous reports concerning the MRM units, it is probable that MRM output is dependant on the roughness profile[1]. Because of the suspension characteristics of the MRM vehicle, the MRM is more active on those surfaces with smaller wave lengths. It is postulated that there is an interaction of the surface profile and speed which produced decreases in MRM values with increased speed.

TABLE II
MRM VARIABLE STUDY
DISTRICT 14 UNIT

UNIT 14-132-F
MAY 30,31 1974

		ROUGHNESS								
		ROUGH SECT. NO. 104			MEDIUM ROUGH SECT. NO. 15			SMOOTH SECT. NO. 36		
		20 MPH	40 MPH	60 MPH	20 MPH	40 MPH	60 MPH	20 MPH	40 MPH	60 MPH
HEAVY WT. 550	LOW TIRE PRES. (20 PSI)	3.9 4.0 3.95	6.9 6.4 6.65	7.2 7.0 7.1	3.2 4.2 3.7	2.1 2.9 2.5	2.4 2.3 2.35	0.1 0.15 0.13	0.8 0.6 0.70	1.0 0.9 0.95
HEAVY WT. 550	HIGH TIRE PRES. (35 PSI)	4.2 4.3 4.25	6.8 7.4 7.1	7.6 7.3 7.45	5.0 4.2 4.6	3.8 4.2 4.0	2.8 3.6 3.2	1.7 2.6 2.15	0.6 0.9 0.75	2.5 1.8 2.15
LIGHT WT. 200	LOW TIRE PRES. (20 PSI)	5.9 3.5 4.7	6.6 6.1 6.35	4.8 7.4 6.1	1.9 2.6 2.25	2.3 2.6 2.45	2.3 2.3 2.3	0.2 0.0 0.1	0.5 0.7 0.6	1.0 1.45 1.23
LIGHT WT. 200	HIGH TIRE PRES. (35 PSI)	4.1 3.9 4.0	6.1 5.7 5.9	7.0 6.6 6.8	5.2 3.7 4.45	3.7 3.8 3.75	3.5 3.3 3.4	0.7 0.4 0.55	1.1 1.3 1.2	2.1 2.0 2.05

MRM EXPERIMENT (UNIT 14-132-F)

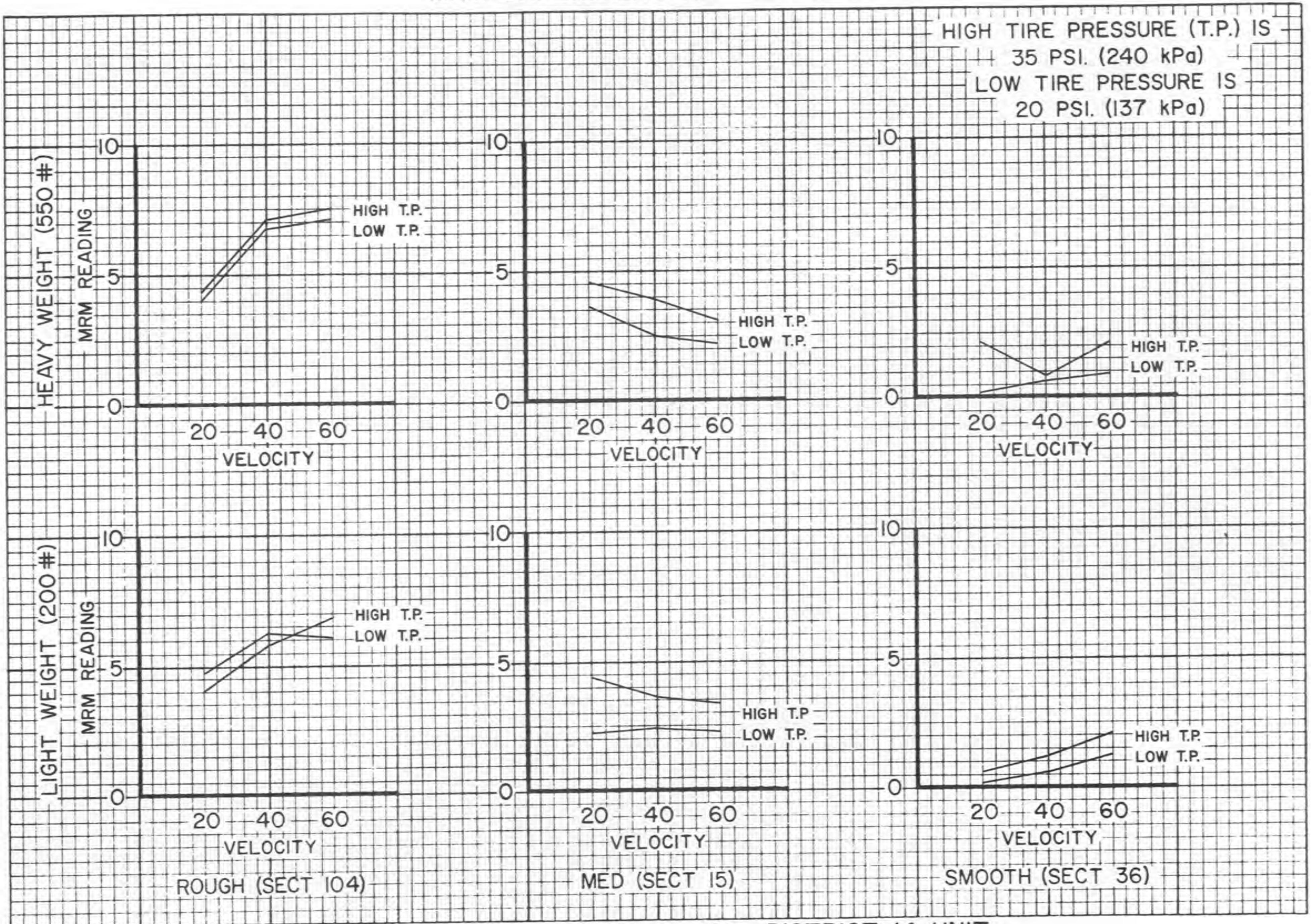


FIGURE 2—MRM VARIABLE STUDY—DISTRICT 14 UNIT

III. THE MRM TRAILER

The variability studies indicated significant variation (or error) due to tire pressure changes, vehicle weight changes and vehicle speed changes when these changes were of a large magnitude. If test standards were adopted, changes in the tire pressure, weight and speed could probably be maintained at small magnitudes. For these reasons, it was decided to develop a trailer in which to house the MRM transducer. The use of a trailer would stabilize the weight variable since weight could be constant due to fuel use (no decrease). A trailer would permit the use of a standard test tire such as the ASTM E-501. The standard test tire would stabilize variation due to tire type particularly during replacement. Also, subsequent testing has shown tire roundness and balance is critical in maintaining test repeatability and the test tire is produced with stricter quality control. The shock absorbers and springs in the suspension system could be standardized.

In addition, a tow vehicle would not be tied up solely as a roughness measuring unit and the trailer could be easily transferred to the district responsible for data collection thus eliminating the need for a MRM unit in each district.

The trailer was designed and fabricated in the department's Equipment and Procurement Division shops. A shop drawing of the trailer is shown in Figure 3. A photograph of the completed trailer and tow vehicle is shown in Figure 4. Figure 5 shows the MRM transducer or sending unit, as does Figure 6. Note in Figure 6 that weight can be adjusted by removing or adding metal plates. Figure 7 shows the storage area for the spare ASTM E-501 test tire. Figure 8 reveals the "surge" type trailer brake arrangement on the tongue of the trailer. Note in Figure 4, 6 and 7 a metal cover was used to reduce aerodynamic effects.

A study was made to determine the optimum trailer weight. The following weights were used:

Weight on Each Wheel	Tongue Weight
600 lbs	110
820 lbs	120
1080 lbs	140

The roughness values (average of five report tests) obtained with the variably loaded trailer were compared to the roughness values collected with an automobile MRM unit (Research Unit). The findings indicated results similar to that reported in the MRM Variability Studies previously described. The exception was the weight caused MRM values to vary differently on each section tested. It appeared that any of the weights studied could be used if the MRM trailer unit was then correlated with the SDP.

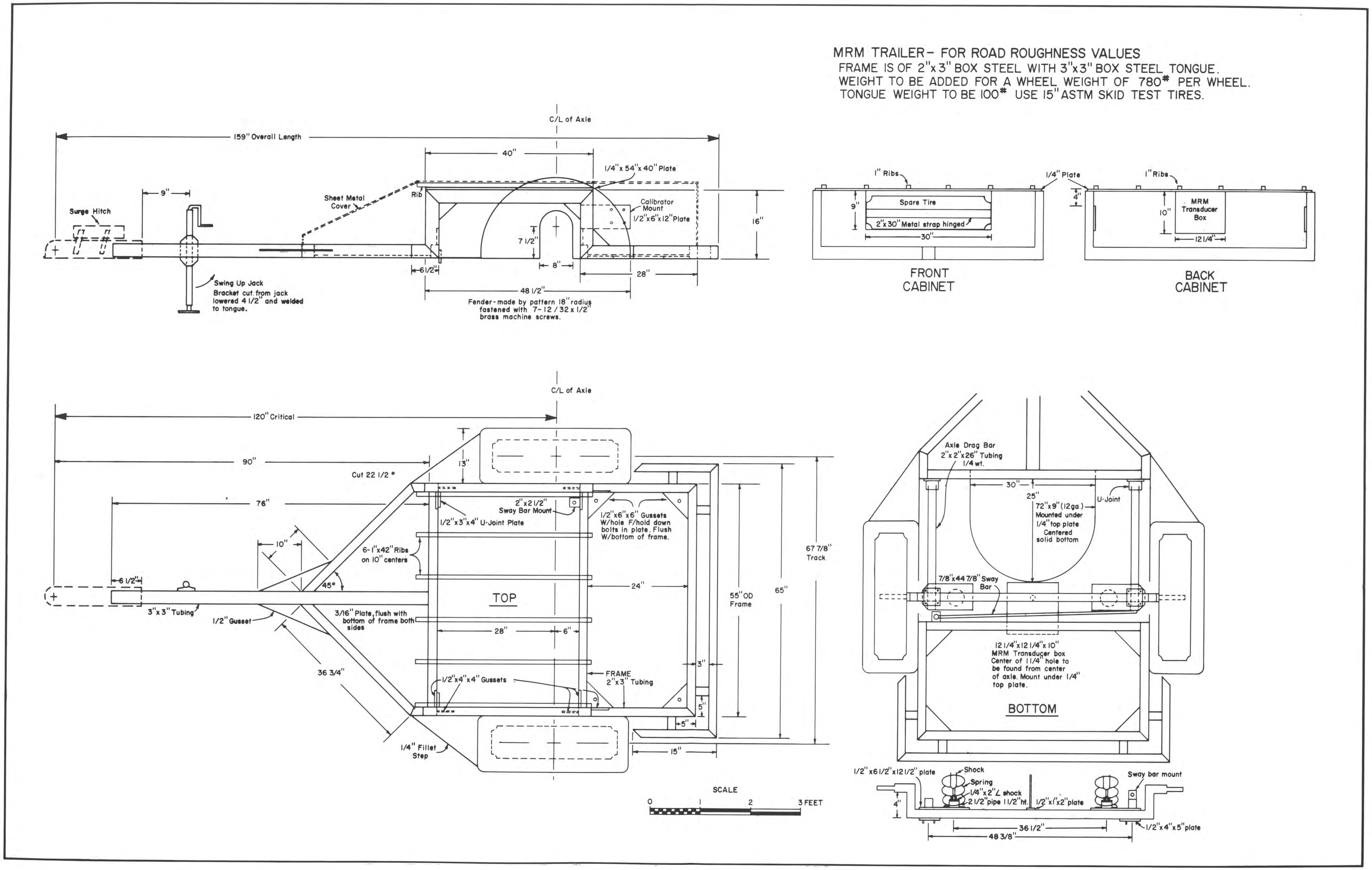


FIGURE 3 SHOP DRAWING OF MRM TRAILER

FIGURE 4 - GENERAL VIEW OF MRM TRAILER UNIT

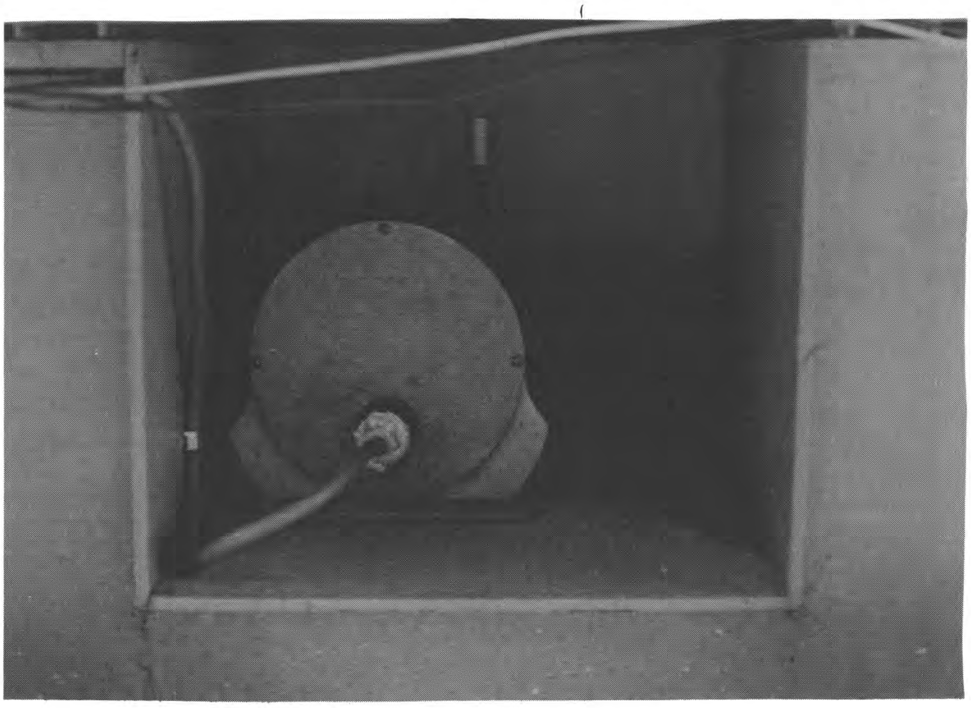


FIGURE 5 - TRAILER MOUNT OF MRM TRANSDUCER

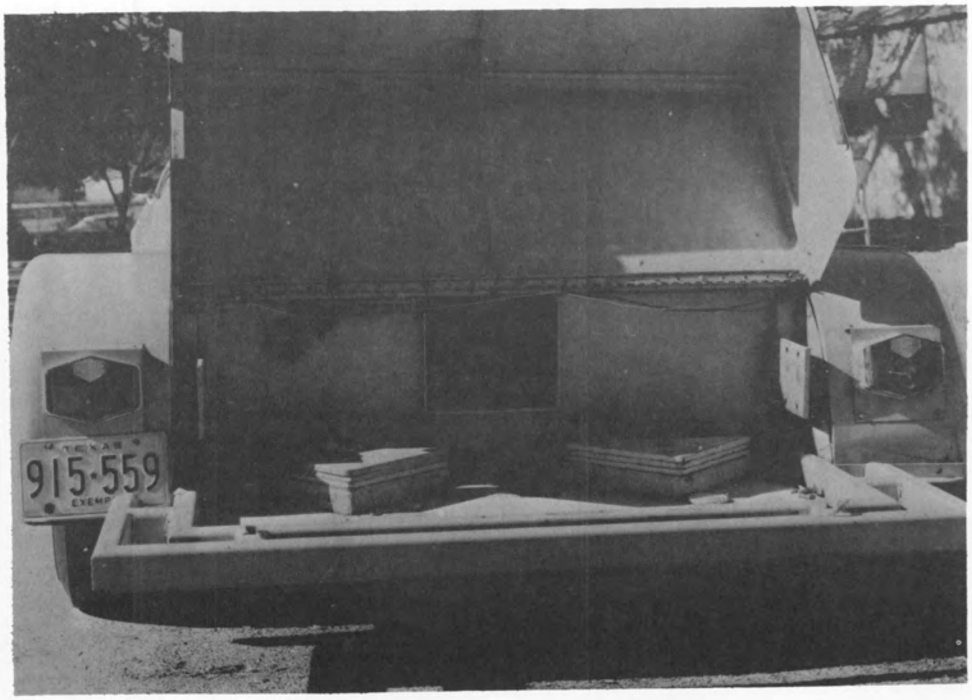


FIGURE 6 - REAR VIEW OF MRM TRAILER

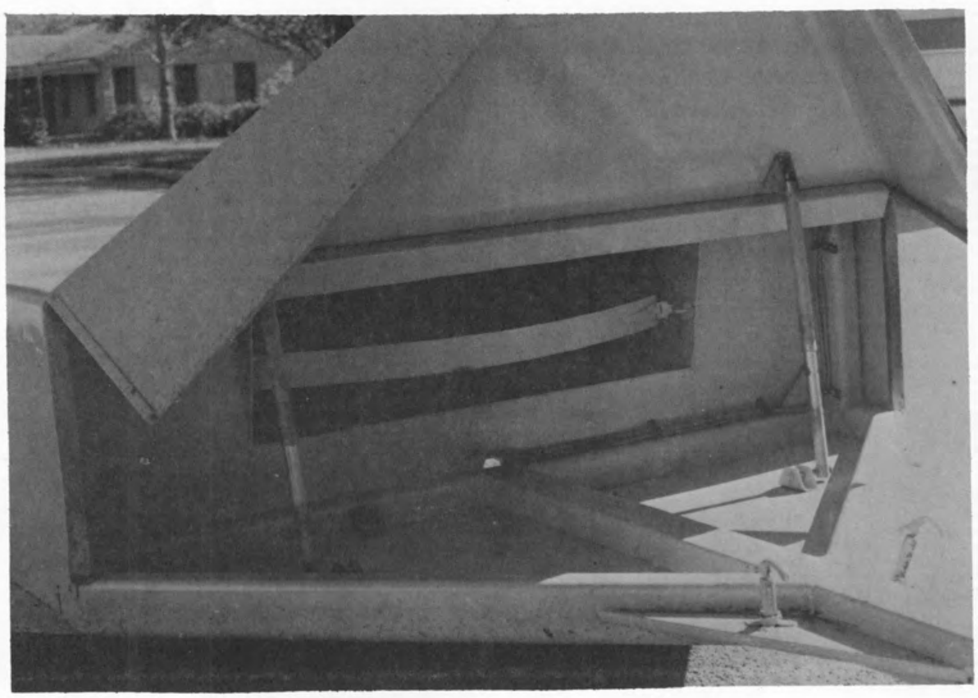


FIGURE 7 - FRONT VIEW OF MRM TRAILER

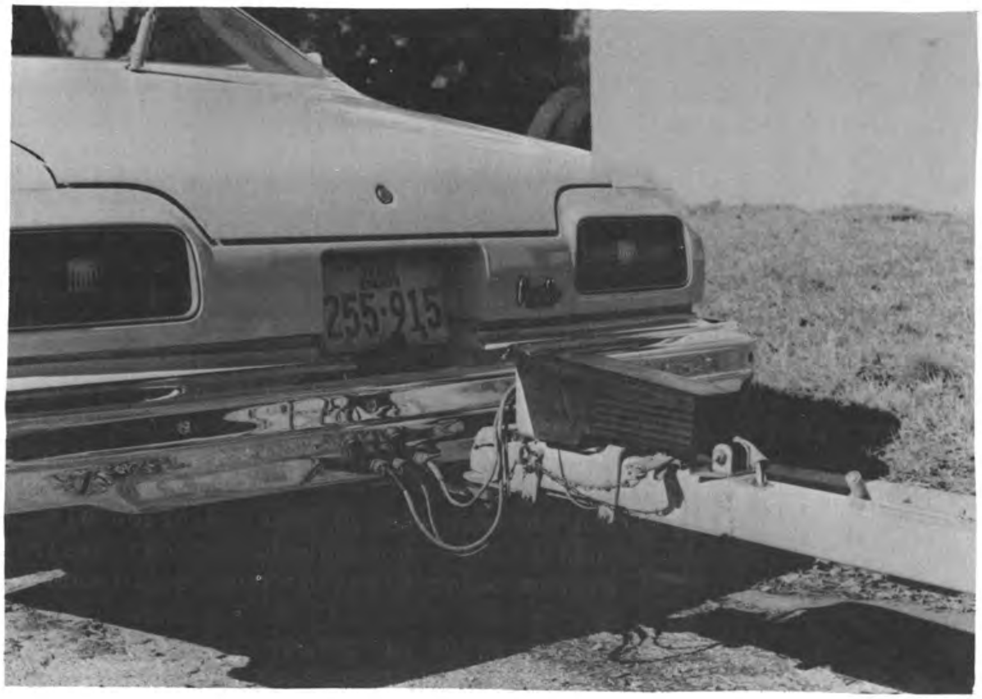


FIGURE 8 -VIEW OF SURGE HITCH BRAKE ARRANGEMENT

The smaller weights did reveal less variation when compared with the automobile mounted MRM unit. As a result, a weight of 780 pounds per wheel was selected with a tongue weight of 100 pounds.

IV. AUTOMOBILE-MOUNTED MRM COMPARED WITH THE TRAILER-MOUNTED MRM

Figure 9 shows the relationship between an automobile-mounted MRM unit and a trailer-mounted unit. Note the trailer-mounted unit produced values which were about 73 percent of the magnitude of the automobile-mounted unit. It is believed the difference in the values is due to the difference in weight and the suspension (shocks and springs) systems of the two vehicles.

Interesting items are:

1. The damping rate of both suspension systems is about the same or between one and two cycles per second (1-2Hz).

2. The experiment with the three which weights on the trailer, mentioned previously produced a variance in values much smaller than the difference in values produced by the suspension system of the two vehicles.

3. When the trailer mounted unit is static or not moving on a horizontal plane, vertical movement at the rear of the tow vehicle (or the tongue of the trailer) will not produce MRM output. (The tow vehicle does not appear to affect the actions of the trailer suspension system.)

Both the automobile- and trailer-mounted MRM units were correlated with the SDP in a manner to be explained in the Calibration chapter. This correlation produces an equation relating a given MRM unit to the SDP in terms of Serviceability Index (S.I.) values. If the values for each unit as shown in Figure 9 were converted to S.I. and then replotted a 1:1 or equivalent relationship would be expected. Figure 10 shows such a plot and the relationship is indeed very close to equivalency. This means the trailer-mounted unit(s) can be associated with the automobile-mounted unit(s) through a correlation excercise. This correlation exercise is of course not new, being first described by Walker and Hudson aroudn 1973 and has been used by the Department since that time.[2] However, it is believed that the same exercise can be used for both trailers and automobiles.

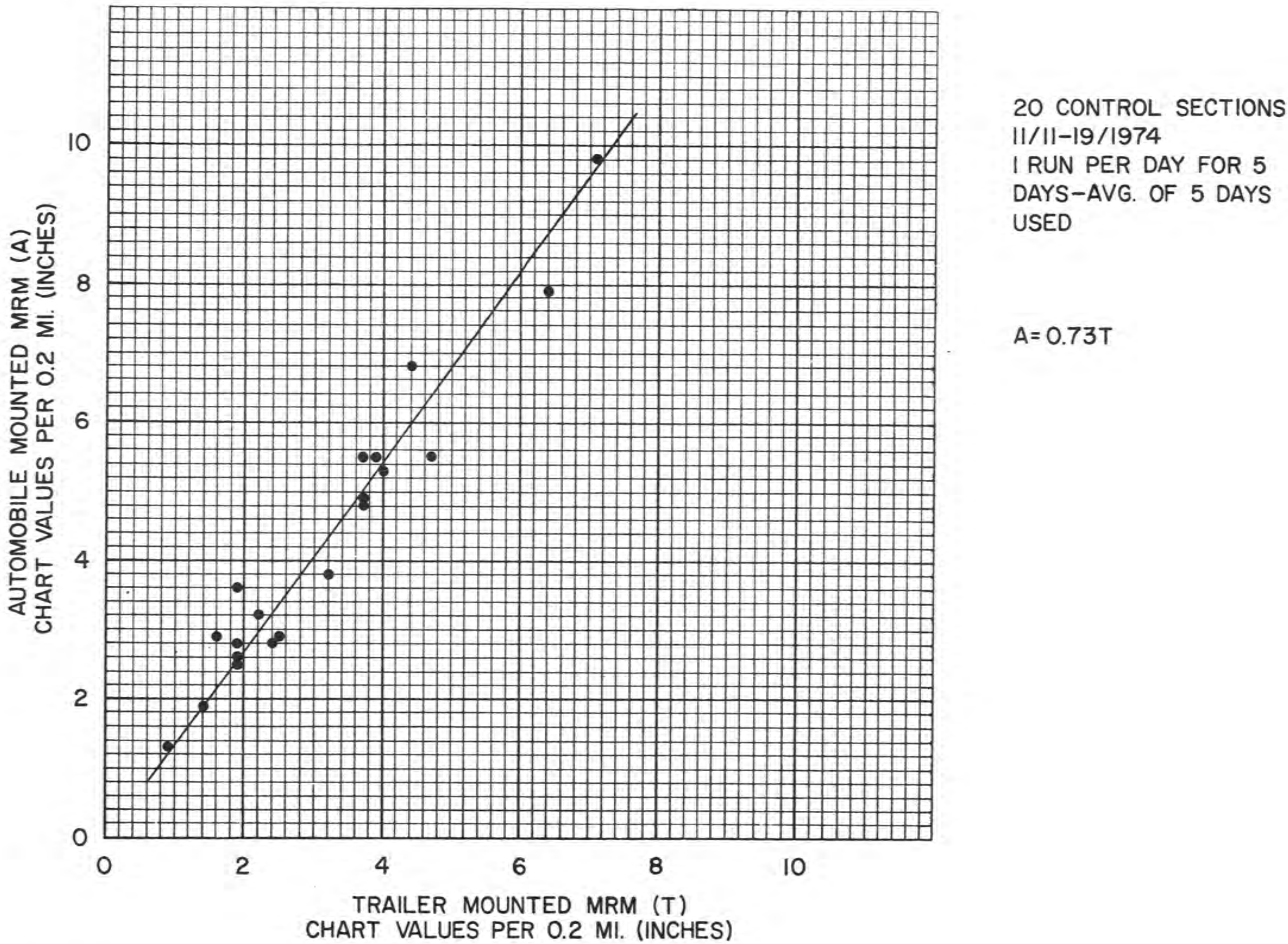


FIGURE 9—A COMPARISON OF CHART VALUES SCALED FROM AUTO AND TRAILER MRM UNITS

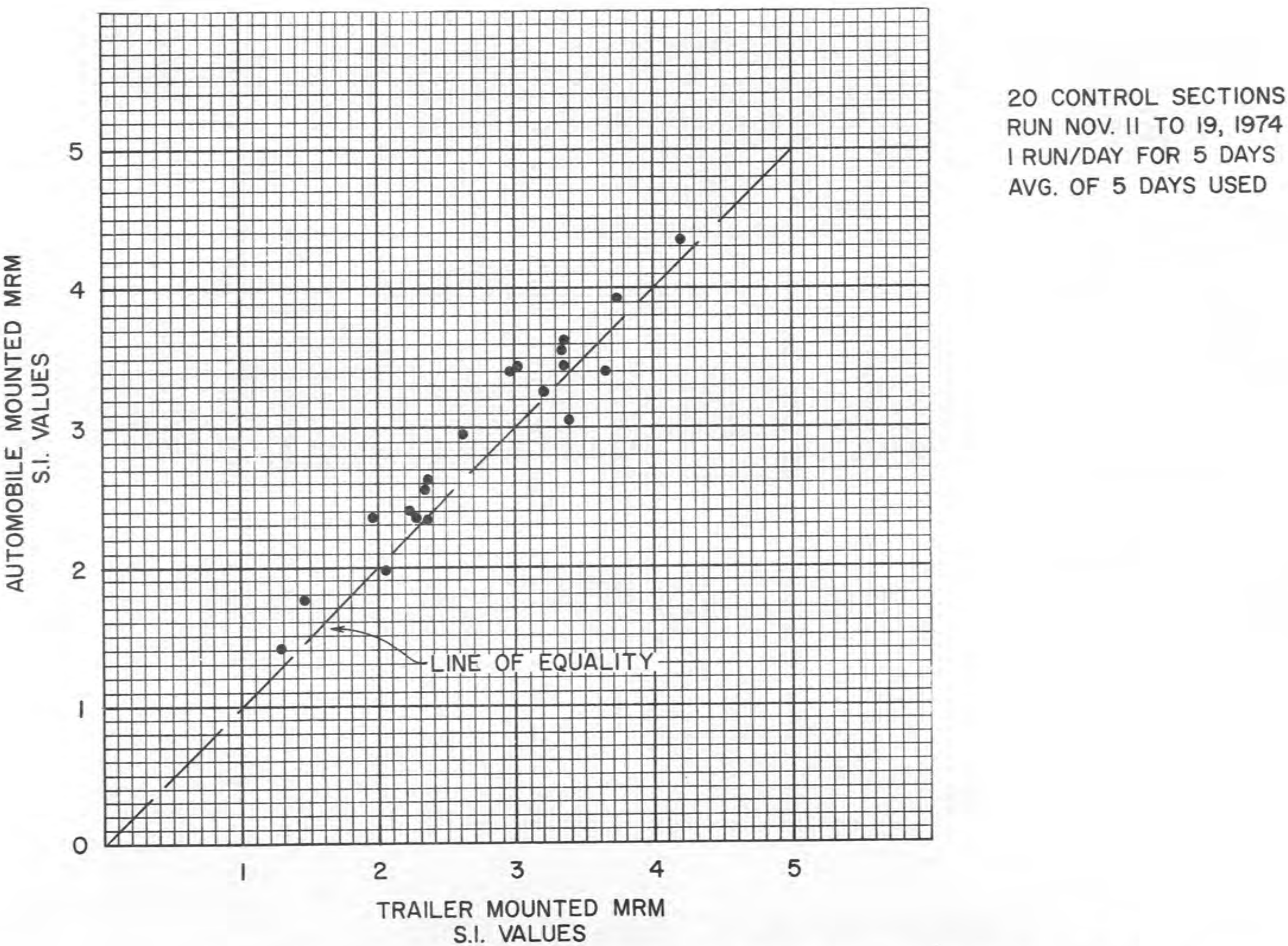


FIGURE 10—A COMPARISON OF AUTO AND TRAILER MRM UNITS BY S.I.

COUNTER SYSTEM FUNCTION DIAGRAM

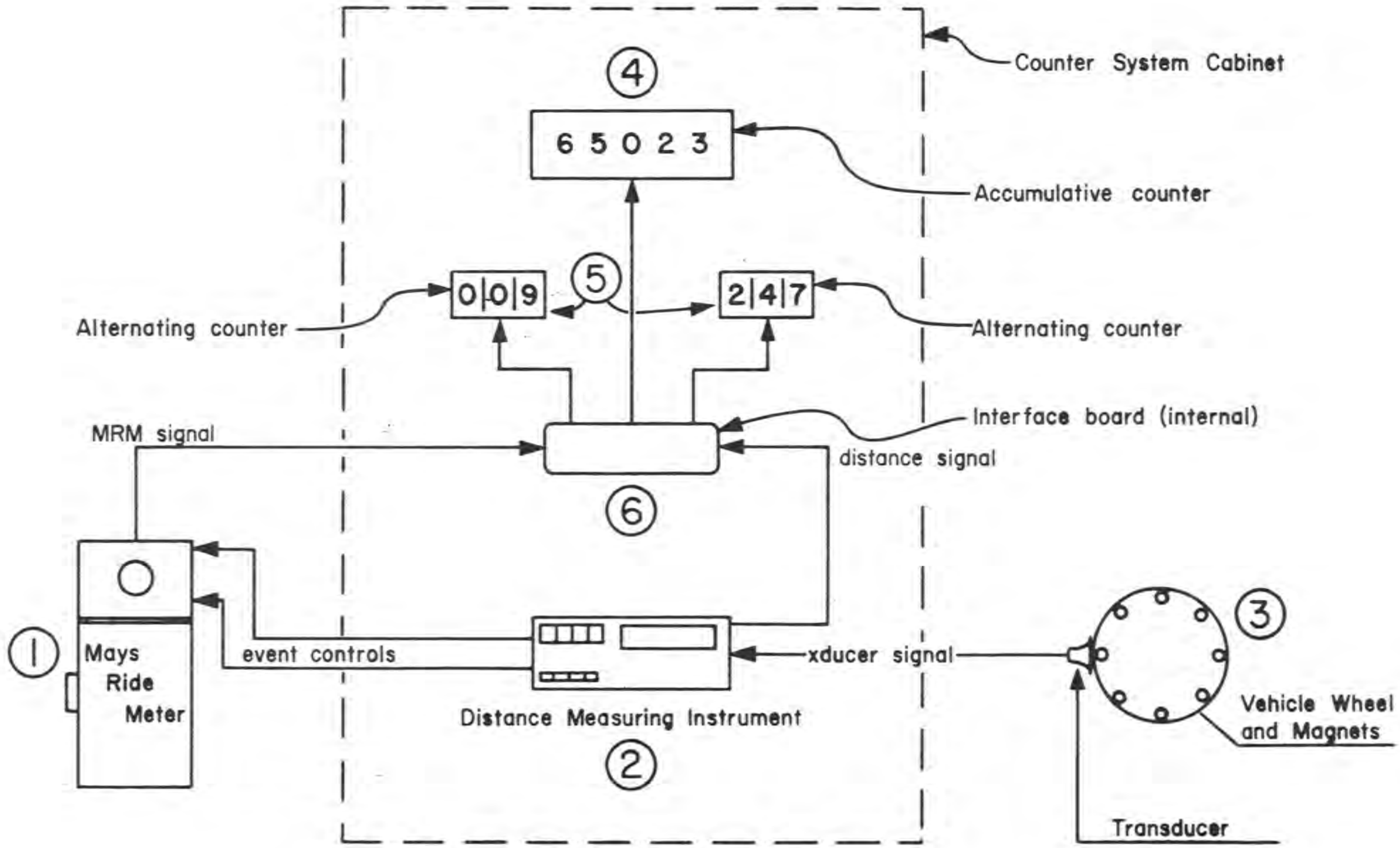
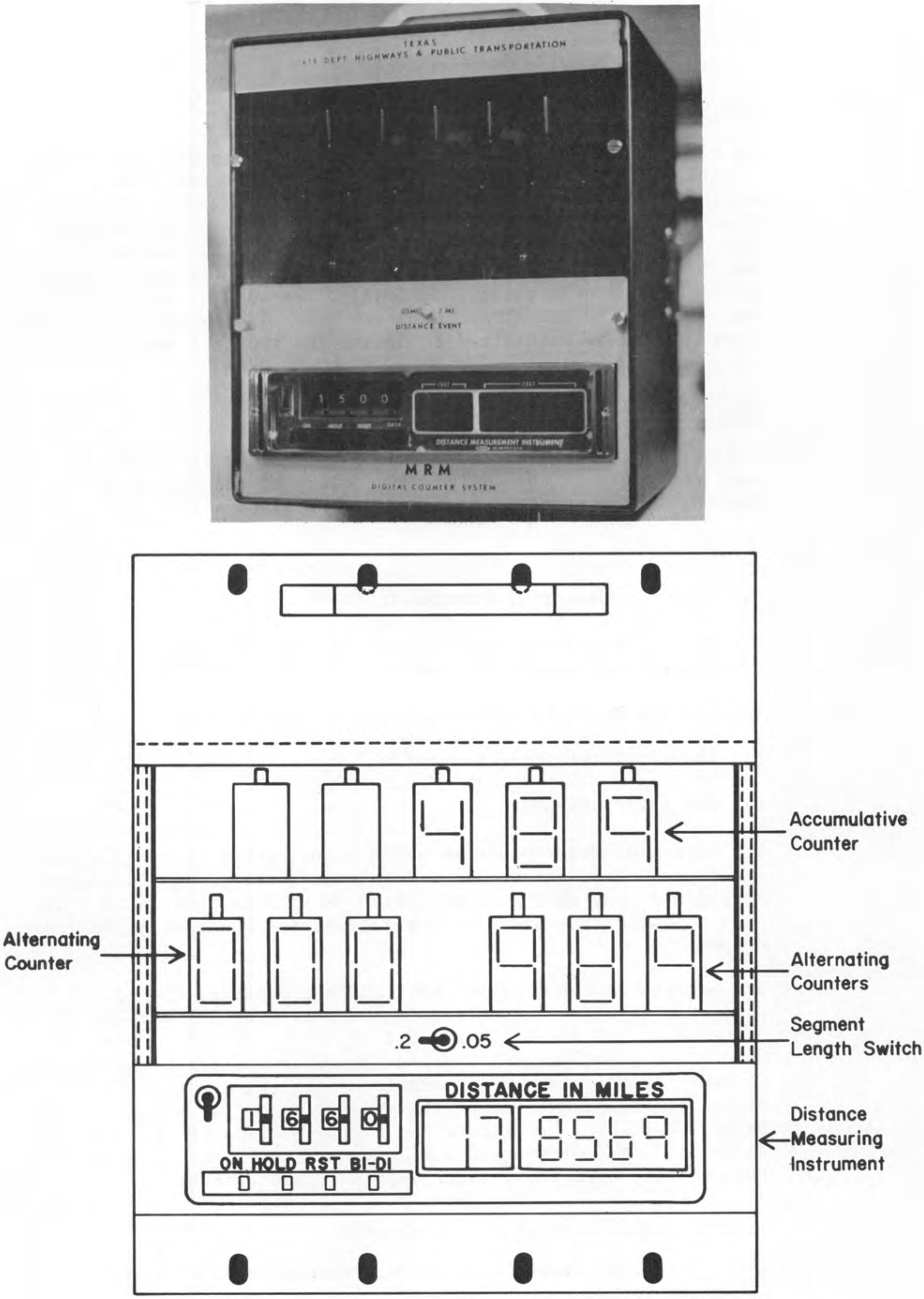


Figure 11



THE ELECTRONIC COUNTER SYSTEM

Figure 12

V. THE COUNTER SYSTEM DESIGN

An electronic counter system was developed to reduce the time needed for data collection and processing. Rather than collect roughness data on a strip chart, scale the roughness values from the strip chart, and record the values on a code sheet, the counter system was designed so that the roughness values may be read from a digital display on the counter and recorded directly on a code sheet. Basically, the work of scaling the values from the MRM strip chart has been eliminated. The strip chart should be maintained to denote the type and exact occurrence of roughness.

MRM/DMI/Counter/Interface Operation Theory

Figure 11 shows the various components and the functions of each component in the design methodology of the measuring system. The components found on Figure 1 are as follows:

1. Mays Ride Meter
2. Distance Measuring Instrument (DMI)
3. The automobile or trailer wheel with 8 attached magnets and the transducer.
4. The Accumulative Counter
5. The two Alternating Counters
6. The Interface Board

The Mays Ride Meter produces a MRM signal which proceeds to the Interface Board. At the Interface Board, the signal is conditioned and sent to the Accumulative Counter to be displayed and also to one or the other of the Alternating Counters to be displayed.

The magnets on the vehicle wheel and the distance transducer produce a signal which is fed to the DMI. The DMI develops a distance signal which is transmitted to the Interface Board. When the distance signal reaches the Interface Board and is processed, it activates an alternating electronic switch which allows the MRM singal to be transmitted to one of the two Alternating Centers. The alternating electronic switch is activated every 0.05 mile or every 0.2 mile depending on the setting of the manually operated Segment Length Toggle Switch.

Accumulative and Alternating Counters

There have been requests to collect roughness data in two different forms:

1. The average SI over a given length of highway surface.

2. The SI for each 0.2 mile segment of surface over a given length.

Personnel from several divisions along with the researcher performing the original statistical studies at the University of Texas' Center for Highway Research were involved in suggesting the above lengths. Therefore, these lengths should be adopted as standard, which means the smallest length for which roughness is to be reported will be 0.2 mile.

For this reason the counter system was designed with two sets of counters - an Accumulative Counter and an Alternating Counter (See Figure 12). The Accumulative Counter was designed to collect roughness information over a given length as denoted in (1) above. The Alternating Counter was designed for (2) above. The Alternating Counter is actually two counters designed such that one counter is recording information while the other is in a hold mode so that the roughness of the previous 0.2 mile may be recorded. In this manner, a roadway may be traversed at 50 mph, recording roughness values every 0.2 mile, first from one counter, then the other. About 15 seconds are available to record the data each 0.2 mile before the counter resets in preparation for the next series of information.

<u>Segment Lengths - 0.05 Mile and 0.2 Mile</u>

As previously stated, 0.2 mile has been selected as the segment length in which to collect data while obtaining a roughness inventory in (2) above. However, a method of correlating the MRM to the SDP has been developed which requires a 0.05 mile segment length. For this reason the alternating counter system was designed to alternate at either 0.05 mile increments or 0.2 mile increments. This is accomplished by activating the segment length toggle switch (shown in Figure 12) to the correct value as denoted on the face of the counter package. <u>It should be noted that this switch will usually be in the 0.2 mile position.</u> The 0.05 mile position will only be used while correlating.

<u>Distance Measuring Instrument</u>

The Distance Measuring Instrument (DMI) is a commercially produced product sold by Nu Metric Instrumentation. The DMI is used to provide an accurate distance as a base for both counter and MRM values. The DMI is believed to be more accurate than the mechanical odometer system originally provided with the RMR. Basically, the DMI provides distance information to the interface board which triggers the distance event pen on the MRM every 0.05 mile and activates the Alternating Counters in the counter system either at 0.05 mile or 0.2 mile. Also the total distance traveled in a test section may be used in conjunction with the Accumulative Counter to calculate the average SI for that section.

For additional information concerning the DMI, consult the Instruction Manual and Operating Procedure for Model DE-140 Distance Measuring Instrument - Manual P-107 produced by Nu Metric Instrumentation. (1)*

Interface Board

The Interface Board contains the circuitry which ties the MRM, DMI and the counters together and makes them function in the desired way and at the correct time. The board circuitry receives two basic signals plus manual signals from two switches.

1. The first basic signal considered is the roughness count generated by the Mays Ride Meter. This is a 12 volt, square wave digital signal of 32 pulses or cycles for each inch of chart paper. This signal is modified to a 5 volt signal by instrumentation described later. This signal is hereafter referred to as the MRM count.

2. The second basic signal is the distance signal from the DMI. This signal is a series of pulses generated by the Distance Measuring Instrument. There is one pluse for each least significant digit shown or read on the DMI. (Furthermost digit to the right). It should be noted that this signal is generated at all times when the DMI is in use, regardless of the "HOLD" control on the DMI. When the DMI is calibrated according to the instructions presented in another part of this manual, each pulse will represent one (1 only) ten thousandth of a mile. Therefore, 500 of these 1/10,000 signals constitute .05 miles, which is the basic sub-unit of count for distance and counter sequencing as will be explained in the more detailed circuit theory.

3. The reset signal is obtained from the DMI reset control. This signal is first conditioned by a cross coupled NAND gate for switch quieting, and then connected directly to all the circuits marked "reset" on the circuit.

4. The hold signal is obtained in the same way from the "hold" control on the DMI. This signal is also conditioned and tied directly to all the circuits marked HOLD.

Detailed Circuit Theory

The digital counter system described uses the 7400 series, or family, of intergrated circuits. The 7400 family uses Transistor Transistor Logic (TTL). These circuits are digital "two state" devices, and

*Numbers in parenthesis refer to items in Reference.

act as electronic switches, that is, they are either on or off.

The power supply or basic supply voltage for this family is a 5 volt, regulated D.C. voltage. For this reason, the output lines will either be 0 or 5 volts, (either off or on), with no in-between state.

The Mays Ride Meter uses a similar TTL family (Motorola High Level Transistor Logic, MHTL) which operates in identical fashion with the exception of the power supply, which is 0 to 12 volts D.C. The signal from the MRM which is applied to the counter system is obtained from Pin 8 of I.C. 2 of the Mays Ride Meter circuitry.

Additional information on the TTL integrated circuits may be obtained from any industrial electronic parts supplier, or from the many books published on the subject. One such publication is listed in the references.

The MRM count is applied through IC-7 to the two each quad 2 input NAND gates IC-8 and IC-4 (See figure 13, 14, 15 & 16). These gates allow the control or "shut-off" of the signal to the counters when desired. This happens when the hold button is depressed on the DMI, or in the case of IC-8 only, when the two alternating hold lines applied to IC-8 from IC-9 are automatically activated. When the signal is allowed to pass through each gate, it proceeds to the appropriately marked counter.

IC-7 is a MC665 Triple Level Translator Interface chip which reduces the 0 to 12 volts used in the MRM to the 0 to 5 volts used in the 7400 series intergrated circuits (IC) of the digital counters. IC-8 and IC-4 are both 7400 quad 2 input NAND gates. These are 14 Pin packages which actually have 4 NAND gates in each IC. These circuits respond like a switch. They allow a signal to pass in one condition or not pass in another.

IC-9 is a 7472 JK Flip-Flop IC. When the 7472 receives a signal from a clock or trigger source the device changes states.

The distance count is applied to IC-4 and on to the first decade counter IC-1. It should be noted that this signal is also held when the hold button is depressed. IC-1, 2 & 3 comprise a three decade counter system which counts up to 500 and then applies a count of one (1) to the fourth counter, IC-5, through the control gate IC-6. A reset signal is simultaneously applied from IC-6

INTERFACE BOARD BLOCK DIAGRAM (Bottom View)

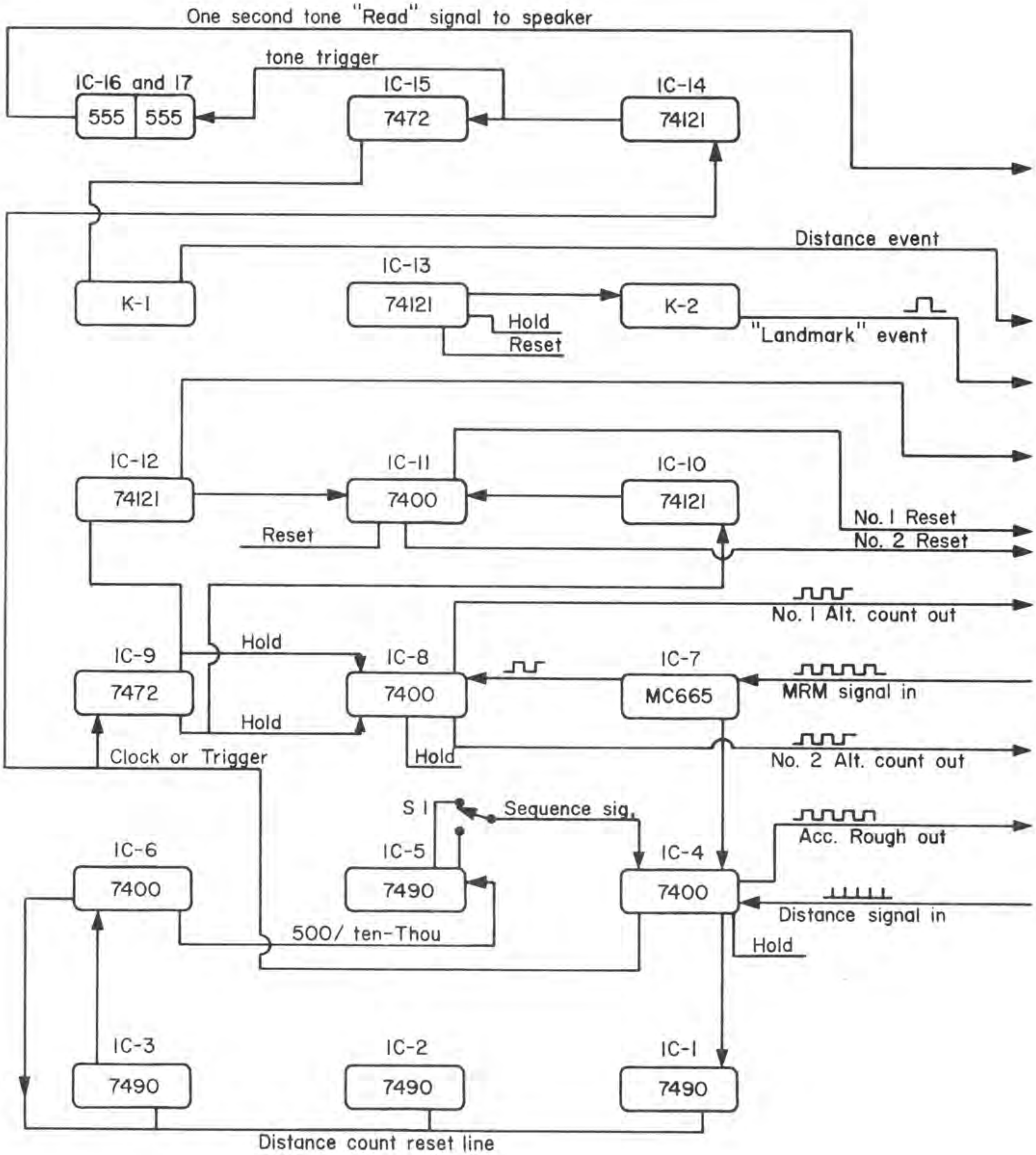


Figure 13

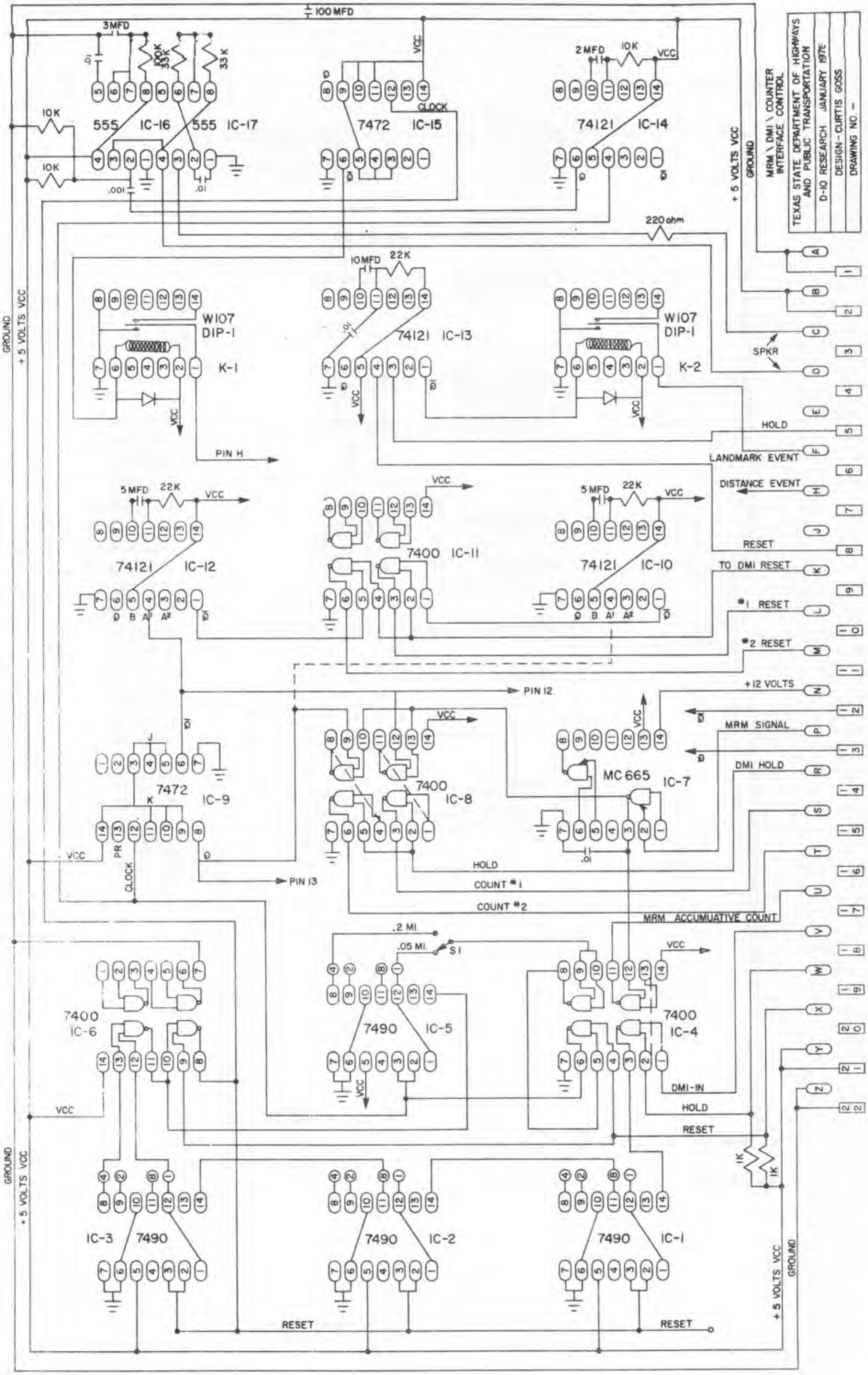


FIGURE 14 — POSITIONAL SCHEMATIC OF THE INTERFACE CONTROL

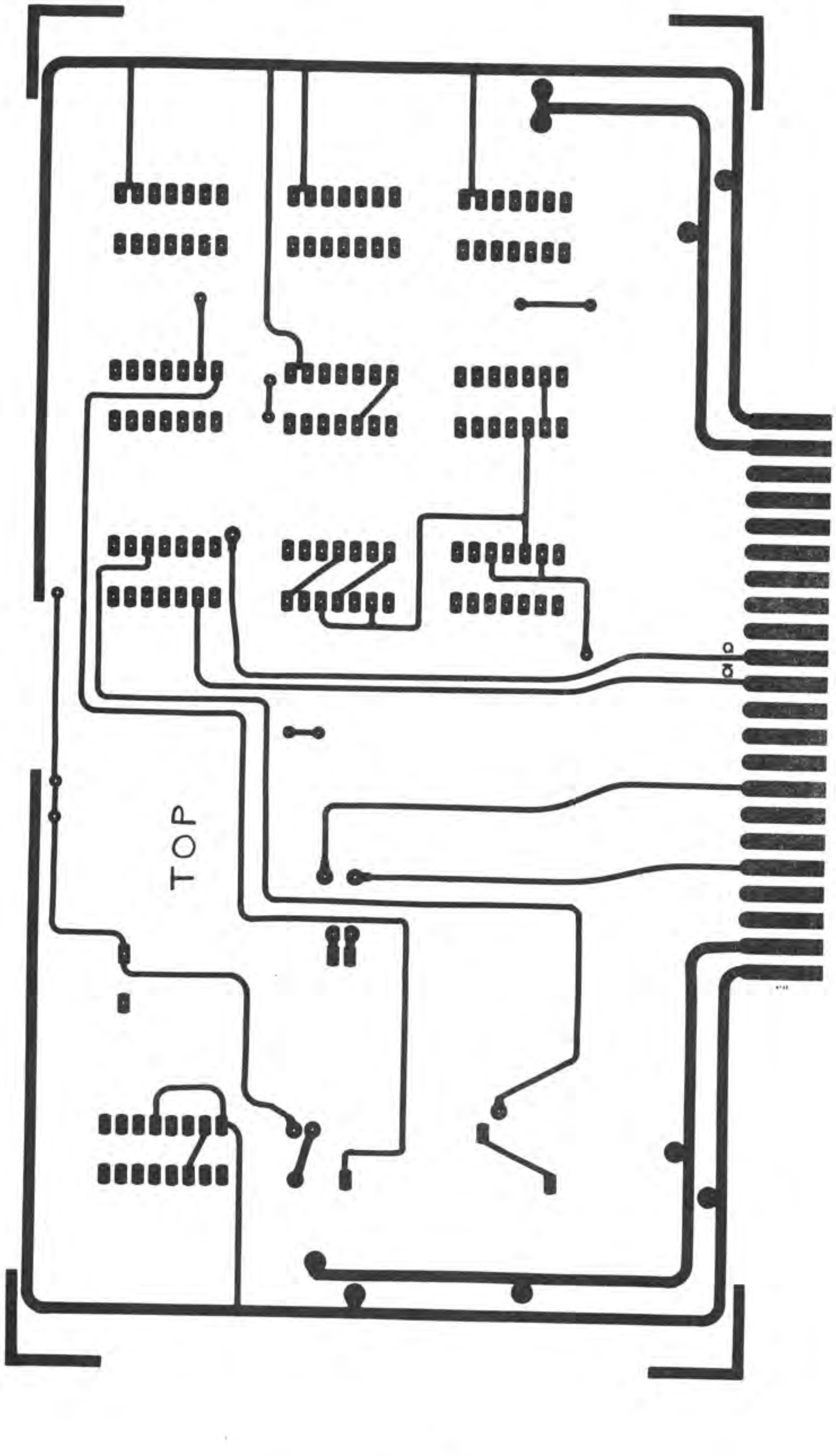


FIGURE 15
TOP OF THE INTERFACE CONTROL BOARD

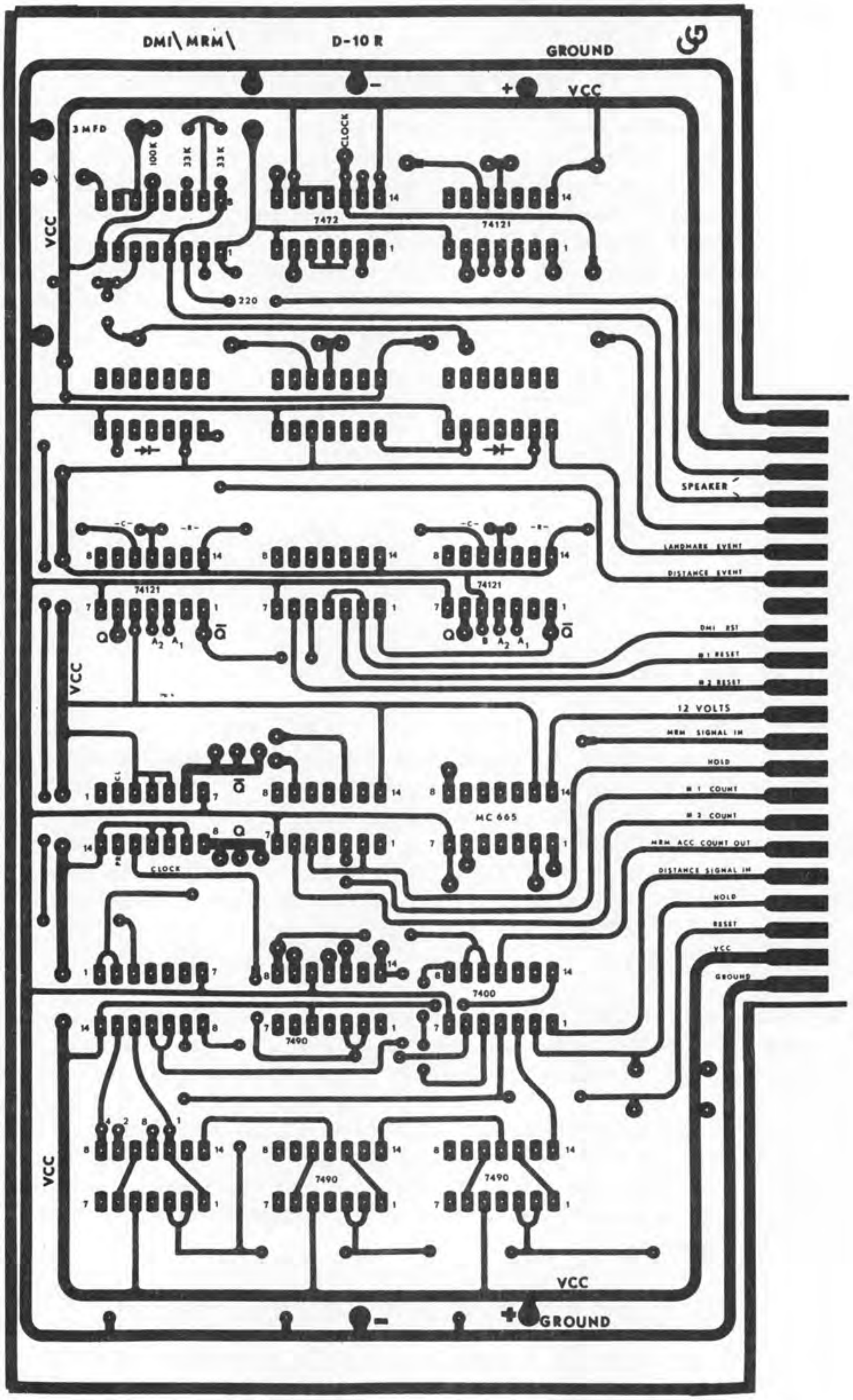


FIGURE 16

BOTTOM OF THE INTERFACE CONTROL BOARD

To the first three counters so that they immediatley reset and begin another 500 count.

IC-1, IC-2 and IC-3 are 7490 decade counters which count up to 10, pass a carry signal, reset, then start the sequence over. The carry signal is forwarded to the next 7490 decade counters which does the same as the previously described counter. Each 7490 has a BCD or Binary Coded Digit output which has four lines or codes which are a 1, 2, 4 or 8. Out of the 1, 2, 4 or 8 any combination of 10 can be developed (for example 1 and 2 is equal to 3, 1 and 4 equal 5, etc.) The following chart shows the exact arrangement:

	8	4	2	1
0	0	0	0	0
1	0	0	0	1
2	0	0	1	0
3	0	0	1	1
4	0	1	0	0
5	0	1	0	1
6	0	1	1	0
7	0	1	1	0
8	1	0	0	0
9	1	0	0	1

Lines 1 and 4 on the IC-3 (7490) which are Pins 8 and 12 are used to develop a 5 count. When the count of 5 comes up on IC-3 or lines 1 and 4 go high, the NAND gates in IC-6 are activated. The reset line is tied to Pin 8 of IC-6. When Pin 8 is high, all three decade counters IC-1, 2 & 3 are reset. Note that when a count of 5 first shows on IC-3, there are zeros on IC-2 and IC-1 so the total count is 500 or 0.05 Mile.

IC-5 and switch S-1 make up the sequence selector section. IC-5 counts the .05 mile pulses and either a .05 or a .2 mile sequence signal may be selected by switch S-1. This signal is then fed via IC-4 to IC-9. IC-9 is a JK flip flop. This is a bi-stable element which changes state each time it is triggered by one of the pulses from the sequence selector. It has two outputs, a Q and a $\overline{Q}$, which are complimentary, that is, one is positive while the other is negative, until another trigger pulse is received and then the opposite is true.

IC-5 (7490 decade counter) counts 1 for each 500 or 0.05-mile. If the 51 switch is set on 0.2 mi., IC-5 will count to 4 then a pulse is forwarded through the switch to Pins 9 and 10 of a NAND gate of IC-4, then to Pin 8, back into the other NAND gate, out Pin 6, over to Pins 2 and 3 which resets IC-5. This same signal to IC-5 also sends a trigger pulse to IC-9

(7472 JK Flip-Flop) which causes IC-9 to change states.

These two outputs from IC-9 are used to control IC-8 which in turn controls the MRM count going to the alternating counters. These two outputs are also used to trigger the two one-shot multivibrators IC-10 and IC-12. These two one-shot vibrators are tied directly to the reset circuit of each respective alternating counter, through another control gate, IC-11. These five circuits IC-9, 10, 11, 12 & 8 allow the operation of the reset and hold circuits automatically, in the right order, so that the following sequence of the counters may be obtained:

1. With counter #1 in the count mode, counter #2 is in the hold mode.

2. When a trigger pulse is applied to IC-9, #2 is immediately reset and placed in the count mode, while #1 is simultaneously placed in the hold mode.

3. On the next trigger pulse the counters will reverse states. This allows one counter to be held and record while the second is counting.

   NOTE: The accumulative counter is not affected by these events, but continues to count until it receives a command from one of the manual controls.

4. As noted in the operating portion of the manual, when a reset command is initiated via the manual reset control, all counters immediately reset including the DMI. Likewise, when a command from the hold control is initiated all counters go into a hold condition.

IC-8 is a 7400 Quad 2-Input NAND Gate. IC-10 and IC-12 are 74121 One-Shot Multi-Vibrators. These circuits work through a resistance - capacitance timing network (RC) comprised of the 5 micro-farad capacitor and the 22K resistor as shown on the schematic diagram (see Figure 14). This RC network produces a short duration pulse which resets the alternating counter(s) via the IC-11 NAND gates. There are separate controls for each of the alternating counters. IC-10 is used for one alternating counter and IC-12 is used for the other alternating counter. IC-11 permits automatic or manual reseting of the alternating counters.

Following the MRM signal in Figure 14, the signal is applied to Pin 2 or IC-7. IC-7 translates the signal from 12 Volt logic to 5 Volt logic appearing on Pin 3. From Pin 3 on IC-7 applied to Pin 13 and 10 on IC-8 (NAND gate). This signal is also applied to Pin 12 of IC-4 which is the control gate for the accumulative count.

When one input line is held high on IC-8, the signal applied to the other input line is allowed to pass through the gate circuits to Pin 3 or 6 (depending on the State of IC-9). If the "hold" button on the DMI is depressed, pins 2 & 5 on IC-8 will be grounded (taken low). This prevents the flow of signal through IC-8.

The next item for discussion is the event circuits for the event pens of the MRM. Two event pens are mounted on the MRM. One records a distance event (left hand side) and the second, a landmark event (right side). The "landmark" pen is used to mark the beginning and the end of a section. However, other landmarks such as intersections or structures may be shown by manual operation of the landmark button on the MRM.

A re-occurring distance event is obtained on the left pen by controlling the pen with IC-15 and relay K-1. IC-15 is fed a .05 mile event pulse via IC-14 and as a result, the pen changes "state" every .05 mile. This change in "state" alternately energizes relay K-1 which in turn energizes the distance pen solenoid mounted on the MRM.

The landmark pen is controlled by the one shot multi-vibrator IC-13 and relay K-2. IC-13 has a short duration output which keeps K-2 energized for only a very short time, about a tenth of a second. As a result, the landmark pen will give a momentary mark of "Blip". IC-13 is triggered <u>only</u> by the manual "hold" and "reset" controls on the DMI. The manual operation of other landmark events should be obtained by using the square white event switch on the MRM. Refer to the MRM operating manual for instructions on use of the landmark pen.

The signal entering Pin 4 on IC-14 is the clock or trigger pulse originating from the sequence selector (IC-5, IC-4 & SI). When a clock or trigger pulse occurs, IC-14, in turn, triggers IC-15 (JK Flip-Flop - 7472). IC-15 controls relay K-1. The only purpose of IC-14 is to improve the triggering of IC-15.

IC-16 & 17 comprise a tone generator which gives a one-second audio signal each time a distance sequence initiates a counter alternation. This feature helps the observer to determine when the counters have changed.

IC-16 and 17 (555's) are Integrated Circuit Timers. When used in the application described, one is used as an oscillator which generates a tone (about 1000 hertz). The other 555 is a timer which permits a tone duration of about one second. The tone is used as an alerting signal, generally every 0.2 mile, indicating the alternating counters are changing and a "new" roughness readout should be recorded. If the unit is operating in the calibration mode with switch 51 set at 0.05 mile, the tone would be heard every 0.05 mile.

Digital Counters

The MRM digital counters used with the interface board previously described are TTL digital decade counters. They use seven segment displays, which have high visibility and long life. As shown in Figures 17 through 21, the MRM count signal is fed through the interface board to the first 7490 decade counter, which counts up to 10 and delivers a count of one to the next counter which counts up to 10 and delivers a count of one to the next counter, etc.

The decade counters have a BCD (Binary Coded Digit) output which is applied to the 7447 integrated circuits which in turn decode this BCD count, and drive the seven segment displays. A reset line is connected to each individual counter, so that it may be reset at the correct time.

The 7400 integrated circuits on the accumulative counter are control gates which allow additional features to be added at a later date.

> The 7447 integrated circuits shown in Figures 17 through 21 are called "BCD to Seven Segment Decader Drivers." These circuits take the binary coded digit which is an output of each 7490 and decodes or changes the output to a 7 segment code which is applied to the proper segment of each readout. This causes the segments to "light up" showing a digital number.
>
> The reset line is tied directly to the reset line on the interface board. The number 1 counter uses Pin L and the number 2 counter uses Pin M. Note the lines are controlled automatically or manually (through the reset button on the DMI.)

Appendix C offers a cost and parts list for the counter system. The costs were developed October, 1976.

Figure 22 shows the interconnection wiring proposed for use. Figure 23 indicates the MRM modifications for DMI use. Figure 24 shows the rear view of the assembled counter and the wiring from the MRM. Figure 25 shows the MRM and counter unit mounted in the front seat of the two vehicle.

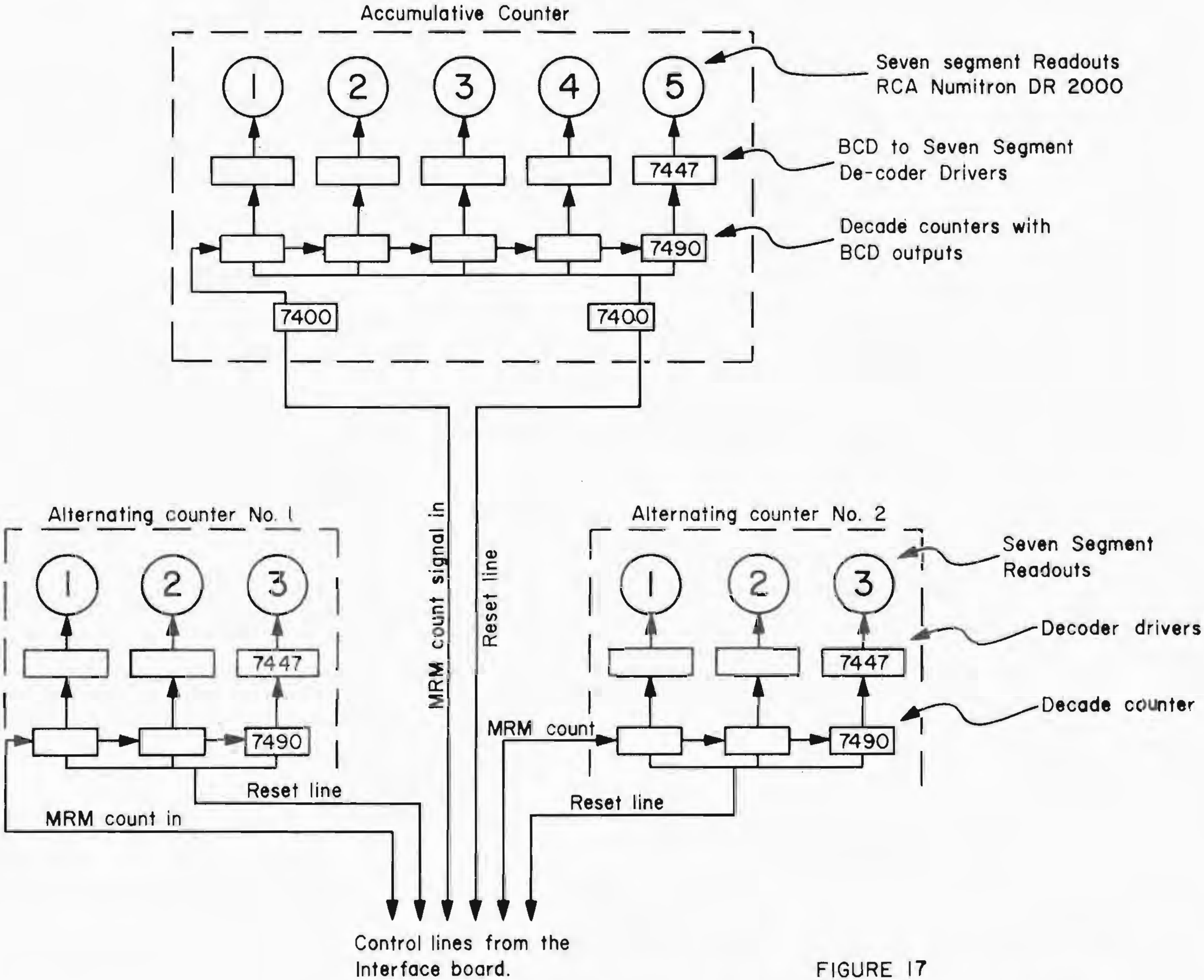
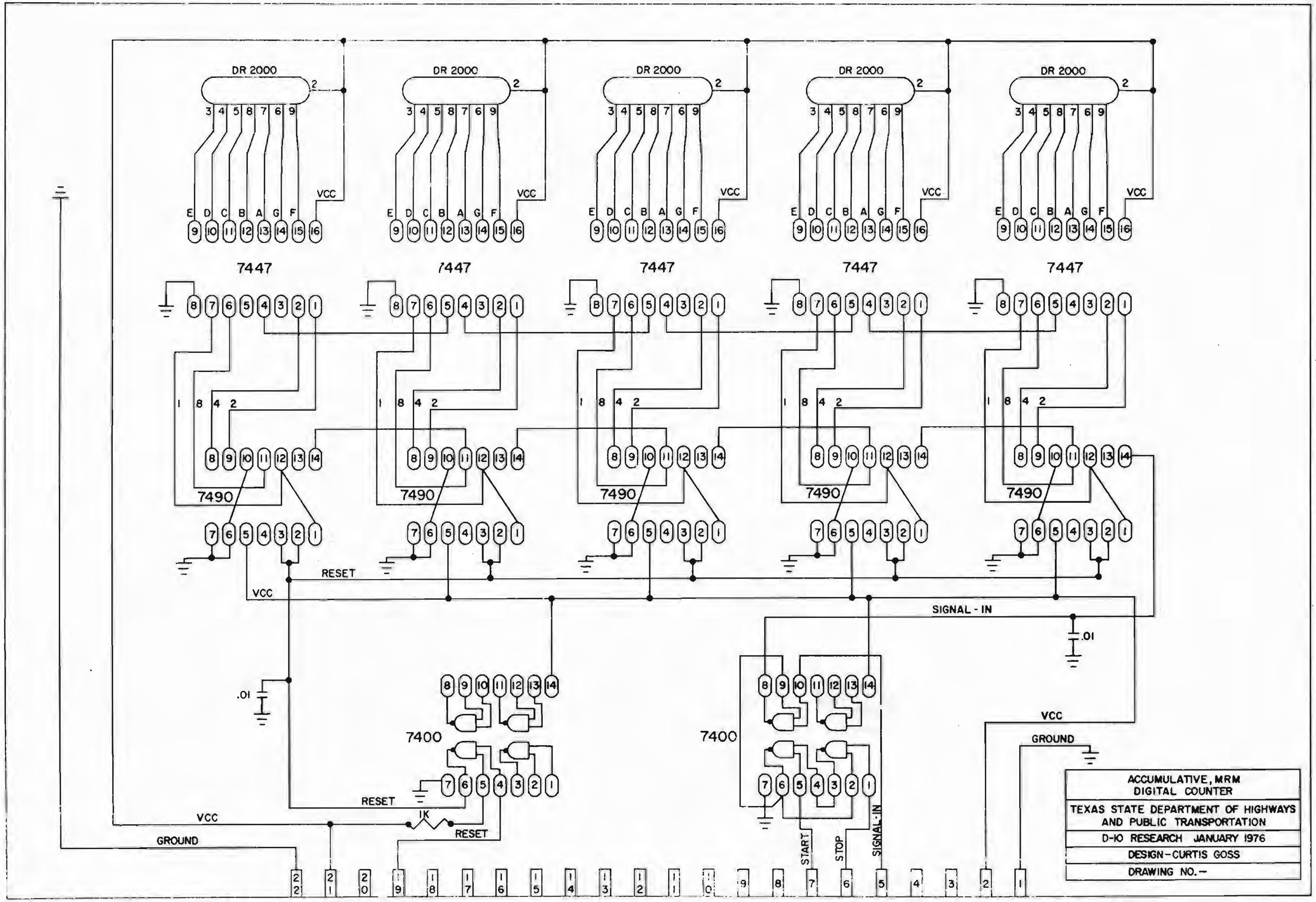


FIGURE 17

MRM DIGITAL COUNTER SYSTEM

FIGURE 18—POSITIONAL SCHEMATIC OF THE ACCUMULATIVE COUNTER



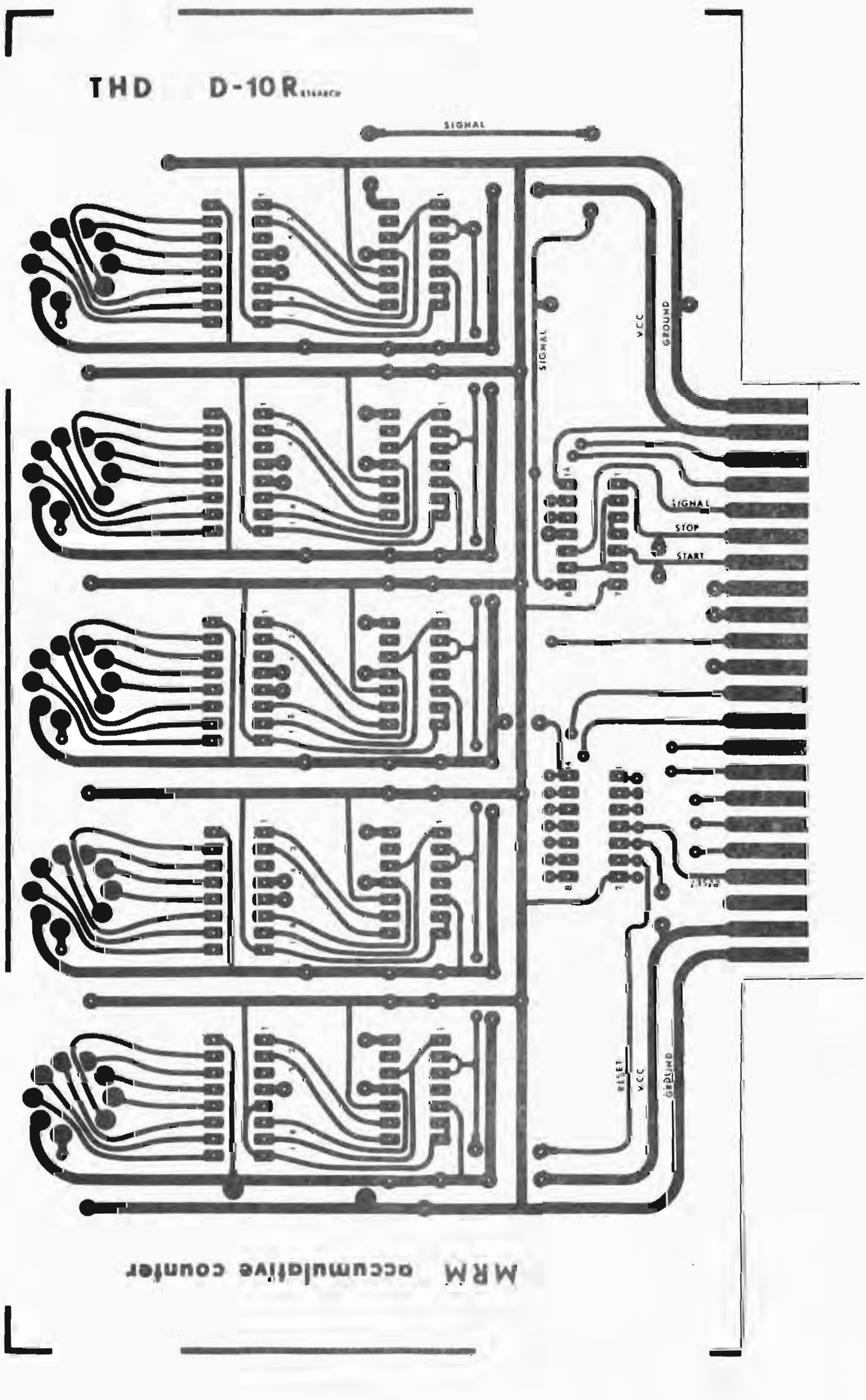
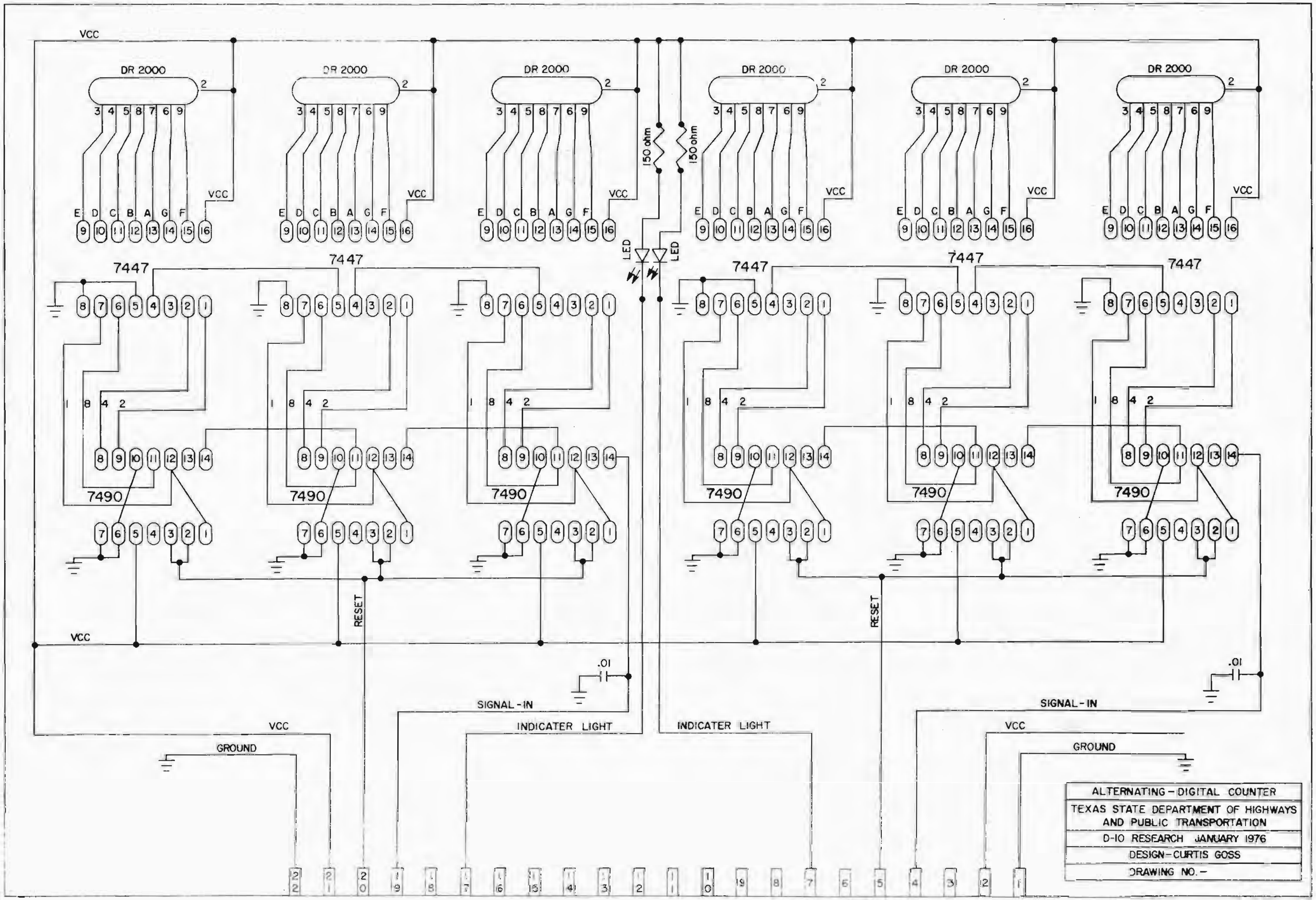


FIGURE 19
ACCUMULATIVE COUNTER

FIGURE 20—POSITIONAL SCHEMATIC OF THE ALTERNATING COUNTERS



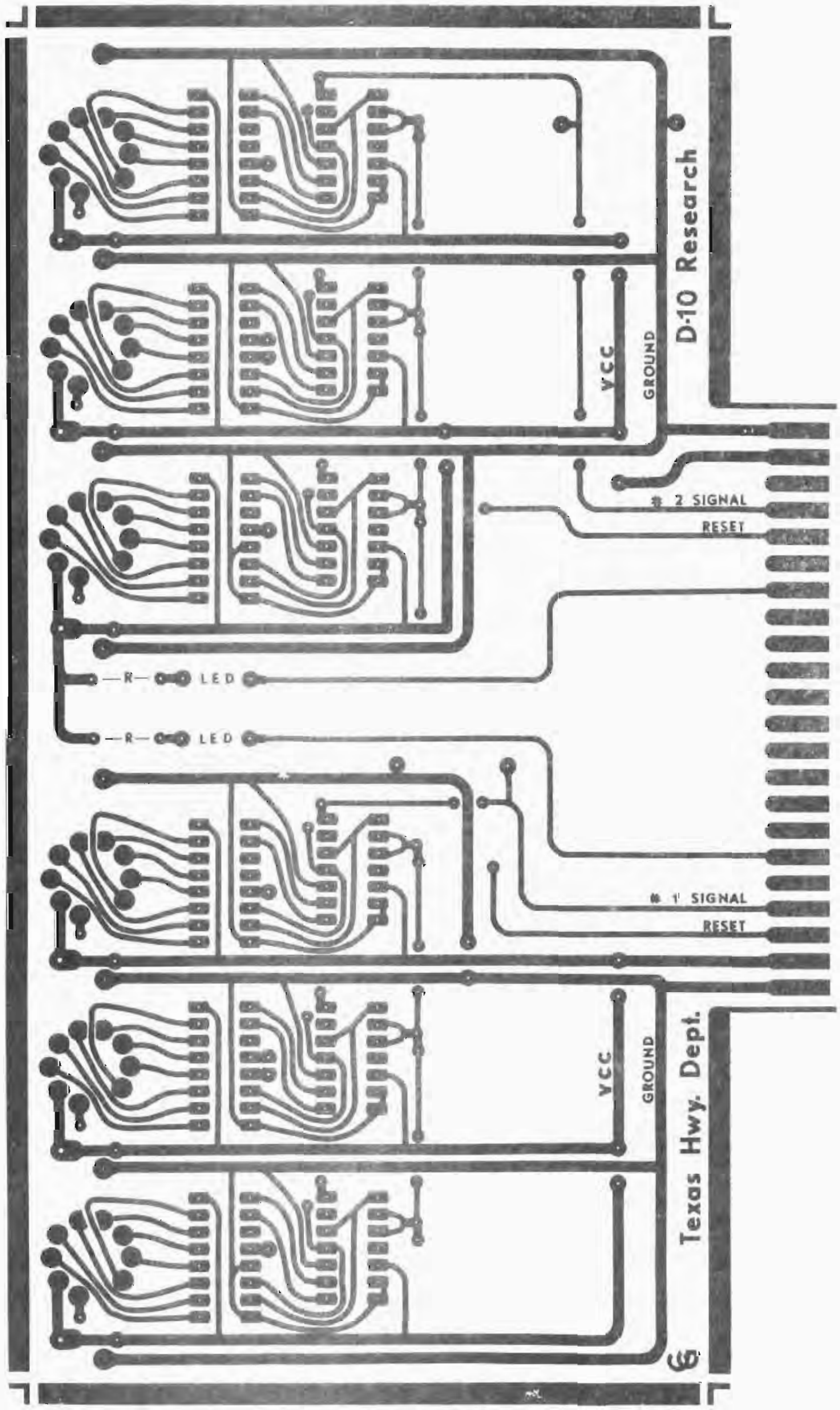


FIGURE 21
ALTERNATING COUNTER

FIGURE 22—INTERCONNECTING WIRING

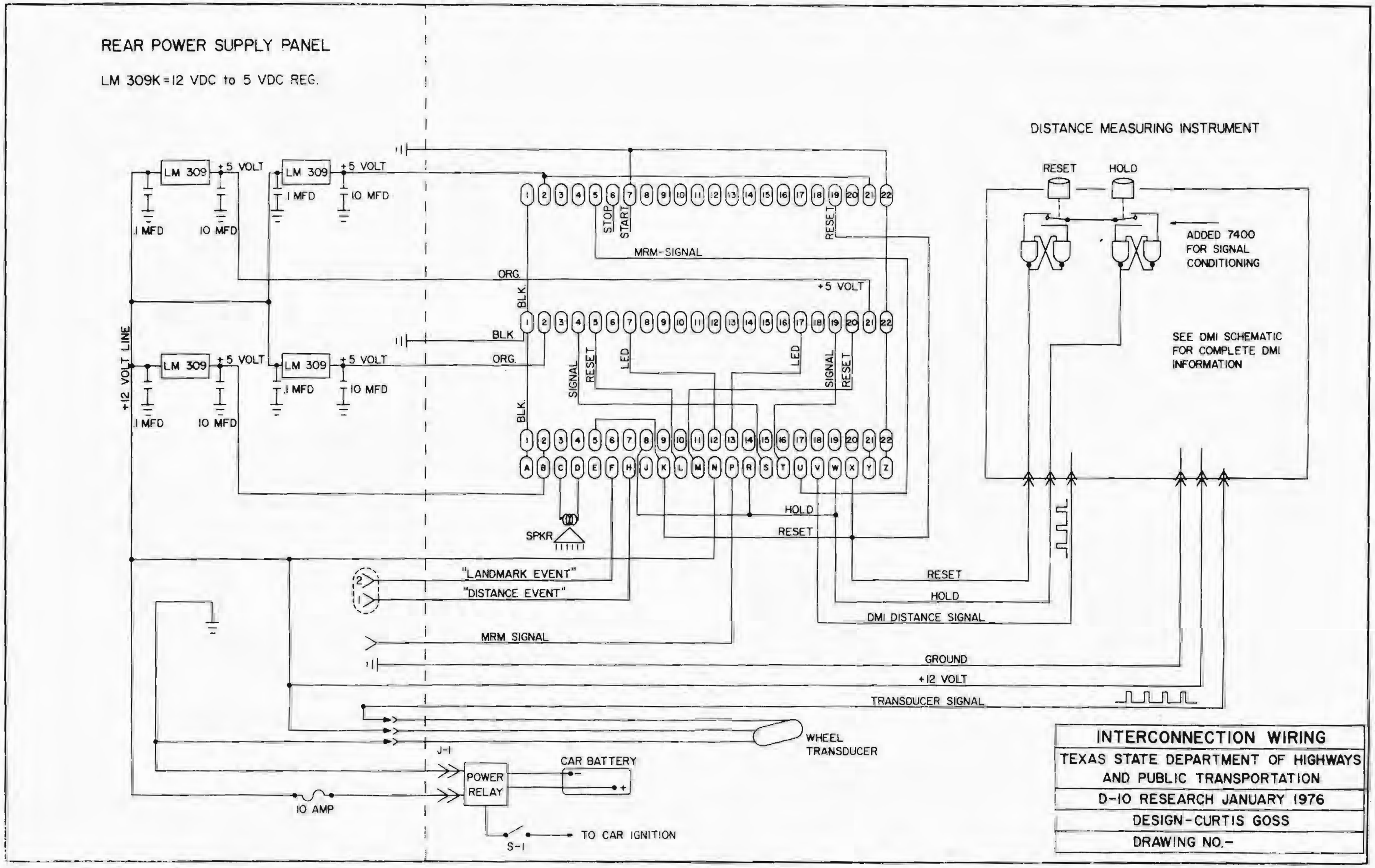
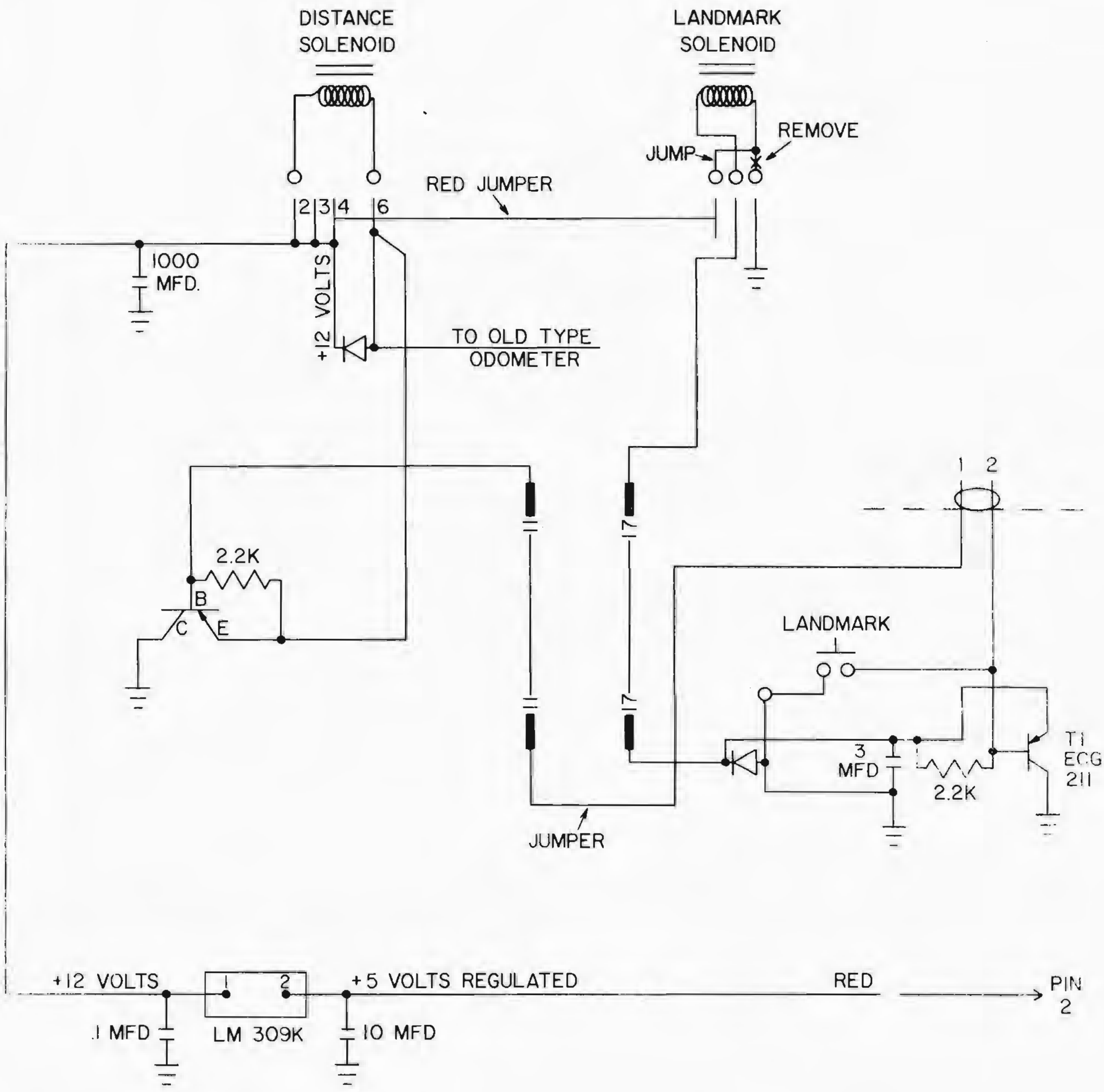


FIGURE 23
MRM MODIFICATIONS FOR DMI USE



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AND PUBLIC TRANSPORTATION
D-10 RESEARCH JANUARY 1976

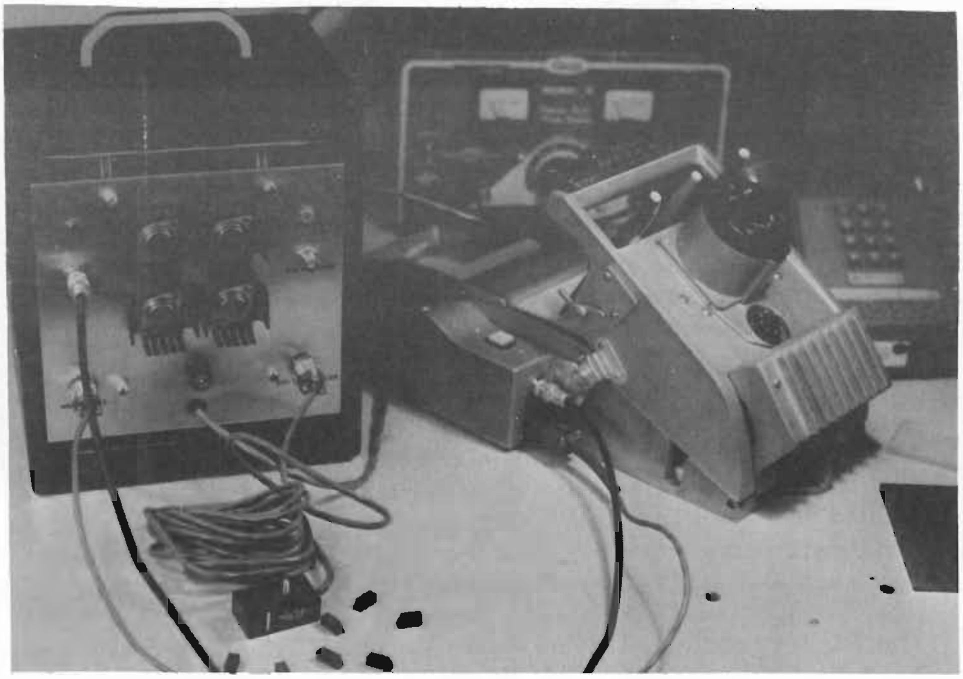


FIGURE 24 - REAR VIEW OF MRM COUNTER

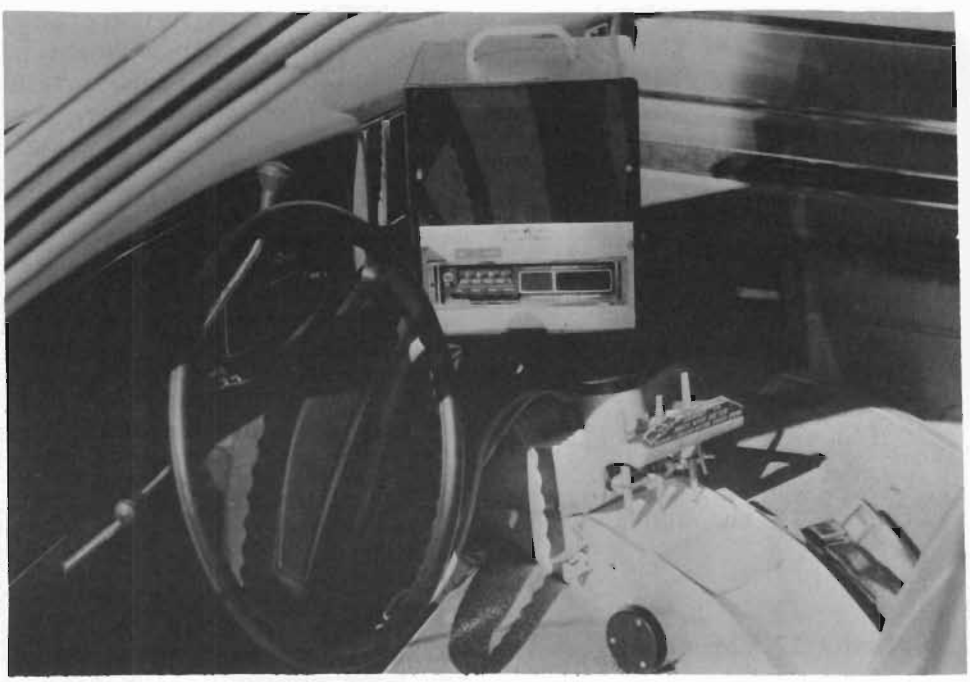


FIGURE 25 - MRM AND COUNTER MOUNTED IN TOW VEHICLE

VI DATA PROCESSING AND REPORTING

The Maintenance Operations Division and Highway Design Division of the State Department of Highways and Public Transportation have been interested in the equipment to obtain a roughness inventory. The data collected, processing and reporting has been patterned for the needs of these divisions. At the present time, the roughness inventory work will basically be performed by maintenance personnel in conjunction with the maintenance rating data collection procedures.[3] In the present version of the maintenance rating work, condition ratings are performed on small segments and are hereafter referred to as Pavement Performance Section (PPS). The average SI for the PPS is needed as a part of the condition rating. The Accumulative Counter and the total section should be used for this purpose. As an additional part of the maintenance rating work, it has been suggested that SI values be reported for each 0.2 mile length within the PPS.

The SI for each 0.2 mile would be used by maintenance personnel to determine areas within the PPS which should be maintained. The alternating counters should be used for this information.

The Highway Design Division is interested in obtaining SI values for use in the Flexible and Rigid Pavement Design Systems and as a history of the roughness values for future pavement design improvements. For this reason a program has been developed by which the information may be stored as it is received from the maintenance rating work. The stored information may also be of interest to maintenance personnel as a means of predicting future maintenance needs in order that budgets may be developed in advance.

As a result of the above information, code sheets were developed as shown in Figures 26 through 29. A description of the card formats follows:

Card No. 1

Columns 1 through 5	- Are Self Explanatory (District No. - Right Justified)
Columns 6 through 12	- Pavement Performance Section Number, Same as CSN used in Skid Inventory (Right Justified)
Columns 13 through 16	- District Security Identifier, Same as used in Skid Inventory for District in which data is being collected.
Columns 17 through 23	- Calibration value shown as "ALPHA" on the most recent calibration chart for the MRM unit used.

MRM DATA CODE SHEET

CARD NO 0 0 1 (1 2 3) | DISTRICT (4 5) | PPSN (6 7 8 9 10 11 12) | SECURITY IDENTIFIER (13 14 15 16) | ALPHA (17 18 19 20 21 22 23) | BETA (24 25 26 27 28 29 30)

0 = Zero 1 = One 2 = Two	Ø = Alpha O I = Alpha I Ƶ = Alpha Z

TOTAL LENGTH OF TEST SECTION (31 32 33 34 35) | TOTAL COUNTER READING (36 37 38 39 40) | LANE (41) | MONTH (42 43) | DAY (44 45) | YEAR (46 47) | MRM EQUIPT. NO. (48 49 50 51 52 53 54 55 56) X

PPSN - Same as CSN used in Skid Inventory (Right Justified).

SECURITY IDENTIFIER - Same as used in Skid Inventory for District.

ALPHA & BETA - Calibration Values shown on most recent calibration chart for the MRM unit used.

CARD NO 0 0 2 (1 2 3) | COUNTY NO (4 5 6) | HIGHWAY (7 8 9 10 11 12 13) | CONTROL (14 15 16 17) | SECTION (18 19)

FROM (20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43) | BEGINNING MILE POINT (44 45 46 47 48)

TO (49 50 51 52 53 54 55 56 57 58 59 60 61 62 63 64 65 66 67 68 69 70 71 72) | ENDING MILE POINT (73 74 75 76 77) X

LANE - Has same designation as on the Maintenance Rating Form

F.R. F.R.

Ⓧ Ⓨ Ⓛ Ⓜ Ⓝ Ⓣ Ⓢ Ⓡ Ⓑ Ⓐ

Face in direction of increasing mile post.

CARD NO	MRM READING	VELOCITY	REMARKS
0 0 3			X
0 0 4			
0 0 5			
0 0 6			
0 0 7			
0 0 8			
0 0 9			
0 1 0			
0 1 1			
0 1 2			
0 1 3			
0 1 4			X
1 2 3	4 5 6 7	8 9	10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37

It is not necessary to use Card No. 002, if Card No. 001 is completely filled in.

MRM READING - Can be either Counter or Inches of chart paper. But it can"not" be a combination of the two because the ALPHA & BETA are different for each.

FORM 1392-1 9/75

CONTINUE

SHEET 1 OF ___

FIGURE 26

MRM DATA CODE SHEET

MRM DATA CODE SHEET

CARD NO	MRM READING	VELOCITY	REMARKS
015	.		
016	.		
017	.		
018	.		
019	.		
020	.		
021	.		
022	.		
023	.		
024	.		
025	.		
026	.		
027	.		
028	.		
029	.		
030	.		
031	.		
032	.		
033	.		
034	.		
035	.		
036	.		
037	.		
038	.		
039	.		
040	.		
041	.		
042	.		
043	.		
1 2 3	4 5 6 7	8 9	10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37

FORM 1392-2 9/75

SHEET 2 OF ____

FIGURE 27

MRM DATA CODE SHEET

MRM DATA CODE SHEET

CARD NO.	MRM READING	VELOCITY	REMARKS
0 4 4			
0 4 5			
0 4 6			
0 4 7			
0 4 8			
0 4 9			
0 5 0			
0 5 1			
0 5 2			
0 5 3			
0 5 4			
0 5 5			
0 5 6			
0 5 7			
0 5 8			
0 5 9			
0 6 0			
0 6 1			
0 6 2			
0 6 3			
0 6 4			
0 6 5			
0 6 6			
0 6 7			
0 6 8			
0 6 9			
0 7 0			
0 7 1			
0 7 2			
1 2 3	4 5 6 7	8 9	10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37

Form 1392-3 (9/75)

SHEET 3 OF ___

FIGURE 28

MRM DATA CODE SHEET

MRM DATA CODE SHEET

CARD NO.	MRM READING	VELOCITY	REMARKS
073			
074			
075			
076			
077			
078			
079			
080			
081			
082			
083			
084			
085			
086			
087			
088			
089			
090			
091			
092			
093			
094			
095			
096			
097			
098			
099			
100			
101			
1 2 3	4 5 6 7	8 9	10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37

Form 1392-4 (9/75)

SHEET 4 OF ___

FIGURE 29

MRM DATA CODE SHEET

Columns 24 through 30 - Calibration value shown as "BETA" on the most recent calibration chart for the MRM unit used.

Columns 31 through 35 - Length of test section to be taken from the DMI readout at the end of the section.

Columns 36 through 40 - Total counter reading to be taken from the 5 digit accumulative counter "at the end of the section". (Right Justified)

Column 41 - Lane using the designation as used on the Maintenance Rating Forms.

Columns 42 through 56 - Are self explanatory

Card No. 2 (See NOTE at bottom of Page)

Columns 1 through 19 - Are self explanatory
(County No. - Right Justified)
(Control No. - Right Justified)
(Section No. - Right Justified)

Columns 20 through 43 - General description of beginning point of the section.

NOTE:

It is not necessary to use Card No. 2 if Card No. 1 is completely filled in. The information on Card No. 2 will be retrieved from the Skid Inventory File.

Columns 44 through 48	- Milepoint at the beginning of the section, obtained from the RI logs.
Columns 49 through 72	- General description of ending point of the section
Columns 73 through 77	- Milepoint at the end of the section, obtained from the RI logs.

Card Numbers Greater Than 2

Columns 1 through 3	- Self Explanatroy
Columns 4 through 7	- Counter readings to be taken from 3-digit counters (numbered 1 & 2) that alternate at the end of each 0.2 mile, or inches of chart paper measured from the chart paper in the MRM unit. (See NOTE at Bottom of Page)
Columns 8 and 9	- Velocity to be taken from vehicle speedometer.
Columns 10 through 37	- Remarks or observations for any 0.2 mile segment should be recorded here.

NOTE:

MRM readings can be either counter values or inches of chart paper but not a combination of the two within any one test section, because the ALPHA and BETA's are different for each.

It is postulated that only one code sheet will be needed for any PPS; however, the additional code sheets shown in Figures 15 and 17 may be used for longer sections.

Data may be key-punched in the district, processed through the computer terminal and the results returned over the terminal. The Division of Automation (D-19) will have available and will forward information concerning card input and data processing at the terminals.

An example of a complete code sheet and the output of the processed data are shown in Figures 30 through 38. While studying Figure 32, note that the low, average and high SI is reported at the bottom of the page or below the 0.2 mile information. The low, average and high SI values result from calculations of each individual 0.2 mile segment.

The computer program which processes the data basically reads the data and then prints it; however, the SI values are calculated from the MRM counter values or from the inches of chart paper. The MRM values may be either counter or inches of chart paper, but not a combination of the two. The calibration values (ALPHA and BETA) used with the counter are different from the values used with the chart paper. The calculations within the program are based on the correlation equation mentioned in the MRM Calibration chapter and depend largely on "ALPHA" and "BETA" which are constants in the equation. The computer program contains a feature which extracts the following items for each test section and maintains the items on storage for automated recall in later use:

1. District No.
2. County No.
3. Control-Section
4. Beginning Mile Point
5. Ending Mile Point
6. Highway Type and No.
7. PPSN
8. Lane
9. Date of Test
10. Lowest SI in Test Section
11. Average SI in Test Section
12. Highest SI in Test Section
13. Date Stored on Tape
14. Length of Test Section

MRM DATA CODE SHEET

CARD NO.	DISTRICT	PPSN	SECURITY IDENTIFIER	ALPHA	BETA
001	23			5.65653	5.48432
1 2 3	4 5	6 7 8 9 10 11 12	13 14 15 16	17 18 19 20 21 22 23	24 25 26 27 28 29 30

0 = Zero
I = One
2 = Two

Ø = Alpha O
I = Alpha I
Ƶ = Alpha Z

TOTAL LENGTH OF TEST SECTION	TOTAL COUNTER READING	LANE	MONTH	DAY	YEAR	MRM EQUIPT. NO.
4.466		R	08	27	75	29-9867-A
31 32 33 34 35	36 37 38 39 40	41	42 43	44 45	46 47	48 49 50 51 52 53 54 55 56 X

PPSN - Same as CSN used in Skid Inventory (Right Justified).

SECURITY IDENTIFIER - Same as used in Skid Inventory for District.

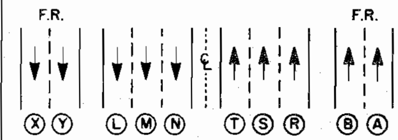
ALPHA & BETA - Calibration Values shown on most recent calibration chart for the MRM unit used.

CARD NO	COUNTY NO	HIGHWAY	CONTROL	SECTION
002	42	US-60	9999	77
1 2 3	4 5 6	7 8 9 10 11 12 13	14 15 16 17	18 19

FROM	BEGINNING MILE POINT
SPRINGFIELD RØAD	9.571
20–43	44 45 46 47 48

TO	ENDING MILE POINT
CØPPERS CREEK	14.037
49–72	73 74 75 76 77 X

LANE - Has same designation as on the Maintenance Rating Form



Face in direction of increasing mile post.

CARD NO.	MRM READING	VELOCITY	REMARKS
003	5.3	50	
004	3.7		
005	3.9		
006	4.3		
007	2.8		
008	3.0		
009	1.8		
010	2.2		
011	1.2	40	HEAVY TRAFFIC
012	1.6	40	
013	3.8	40	
014	3.2	50	
1 2 3	4 5 6 7	8 9	10–37 X

It is not necessary to use Card No. 002, if Card No. 001 is completely filled in.

MRM READING - Can be either Counter or Inches of chart paper. But it can"not" be a combination of the two because the ALPHA & BETA are different for each.

CONTINUE

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SHEET 1 OF 2

FIGURE 30

EXAMPLE OF A COMPLETED MRM DATA CODE SHEET - SCALED

MRM DATA CODE SHEET

CARD NO.	MRM READING	VELOCITY	REMARKS
015	1.9	50	
016	1.1		
017	2.8		
018	5.1		
019	4.3		
020	4.1		
021	3.0		
022	3.4		
023	2.8		
024	3.8		
025	0.5		
026			
027			
028			
029			
030			
031			
032			
033			
034			
035			
036			
037			
038			
039			
040			
041			
042			
043			
1 2 3	4 5 6 7	8 9	10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37

FORM 1392-2 9/75

SHEET 2 OF 2

FIGURE 31

EXAMPLE OF COMPLETED MRM DATA CODE SHEET - SCALED

STATE DEPARTMENT OF HIGHWAYS AND PUBLIC TRANSPORTATION PAGE 1

SERVICEABILITY INDEX (SI) COMPUTED FROM THE MAYS RIDE METER

THIS PROGRAM WAS RUN - 10-01-75

****

PROJECT IDENTIFICATION

DIST	COUNTY	HIGHWAY	CONT-SEC	BMP	EMP	PPSN	LANE	DATE
23	COLEMAN	US-60	9999-77	9.571	14.037	0	R	08-27-75

CALIBRATION CONSTANTS ALPHA	CALIBRATION CONSTANTS BETA	TOTAL LENGTH FOR SECTION	TOTAL COUNTER FOR SECTION	MRM NUMBER
5.65653	5.48432	4.466	0.	29-9867-A

****

LOCATION INFORMATION

FROM - SPRINGFIELD ROAD
TO - COPPERS CREEK

****

MAYS RIDE METER DATA

LOCATION	MAYS METER (READING/0.2 MI)	SI	SPEED	REMARKS
BMP TO 0.2	5.3	2.5	50	
0.4	3.7	3.2	50	
0.6	3.9	3.1	50	
0.8	4.3	2.9	50	
1.0	2.8	3.6	50	
1.2	3.0	3.5	50	
1.4	1.8	4.2	50	
1.6	2.2	3.9	50	
1.8	1.2	4.5	40	HEAVY TRAFFIC
2.0	1.6	4.3	40	
2.2	3.8	3.1	40	
2.4	3.2	3.4	50	
2.6	1.9	4.1	50	
2.8	1.1	4.6	50	
3.0	2.8	3.6	50	
3.2	5.1	2.6	50	
3.4	4.3	2.9	50	
3.6	4.1	3.0	50	
3.8	3.0	3.5	50	
4.0	3.4	3.3	50	
4.2	2.8	3.6	50	
4.4	3.8	3.1	50	
4.466	0.5	4.3	50	

LOW SI = 2.5 AVERAGE SI = 3.5 HIGH SI = 4.6

Figure 32 - Example of Processed Data

DIST	COUNTY	HIGHWAY	CONT-SEC	BMP	EMP	PPSN	LANE	DATE
23	COLEMAN	US-60	9999-77	9.571	14.037	0	R	08-27-75

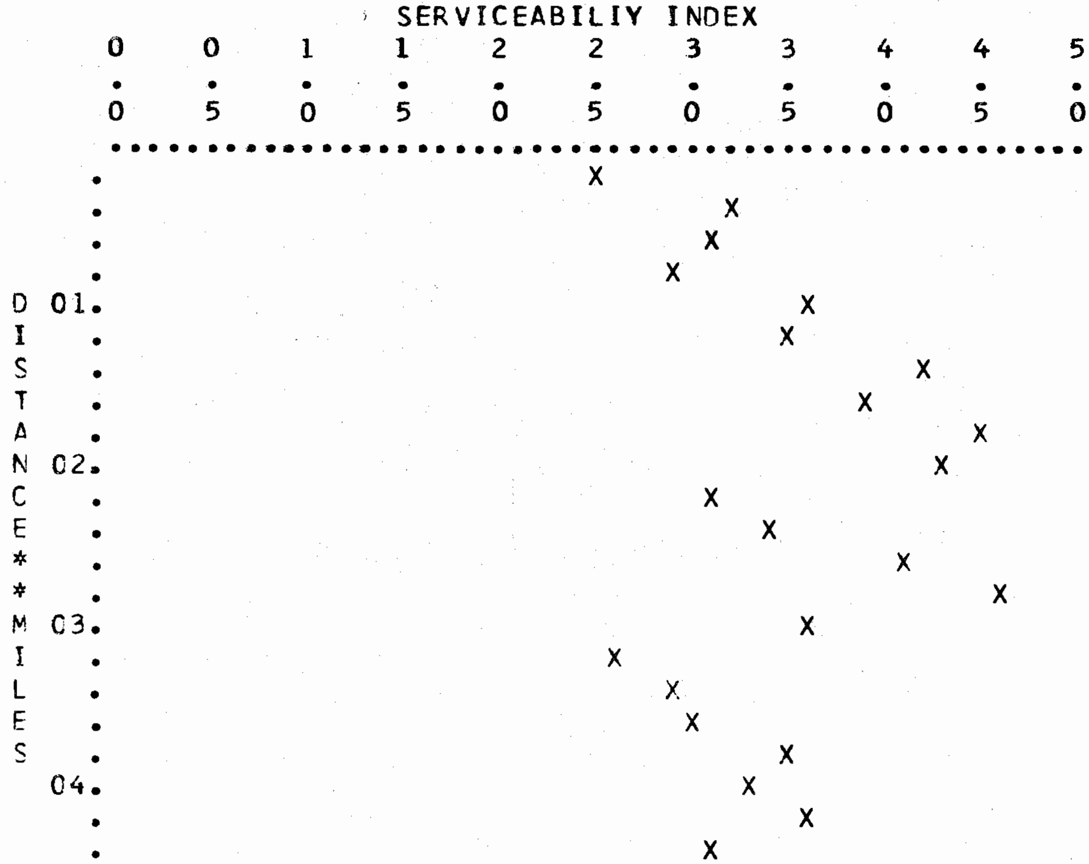


Figure 33 - Plot of Processed Data - Scaled

MRM DATA CODE SHEET

CARD NO	DISTRICT	PPSN	SECURITY IDENTIFIER	ALPHA	BETA
001	19	1	X19Y	1022652	890040
1 2 3	4 5	6 7 8 9 10 11 12	13 14 15 16	17 18 19 20 21 22 23	24 25 26 27 28 29 30

TOTAL LENGTH OF TEST SECTION	TOTAL COUNTER READING	LANE	MONTH	DAY	YEAR	MRM EQUIPT NO.
7.434	2591	L	09	25	75	29-8765-A
31 32 33 34 35	36 37 38 39 40	41	42 43	44 45	46 47	48 49 50 51 52 53 54 55 56 X

CARD NO	COUNTY NO	HIGHWAY	CONTROL	SECTION
002		—		
1 2 3	4 5 6	7 8 9 10 11 12 13	14 15 16 17	18 19

FROM	BEGINNING MILE POINT
	.
20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43	44 45 46 47 48

TO	ENDING MILE POINT
	.
49 50 51 52 53 54 55 56 57 58 59 60 61 62 63 64 65 66 67 68 69 70 71 72	73 74 75 76 77 X

CARD NO.	MRM READING	VELOCITY	REMARKS
003	63.	50	
004	59.		
005	61.		
006	48.		
007	37.		
008	34.		
009	49.		
010	52.	40	
011	51.	40	PEACH CREEK
012	64.	40	
013	69.	50	
014	75.	50	X
1 2 3	4 5 6 7	8 9	10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37

O = Zero
I = One
2 = Two

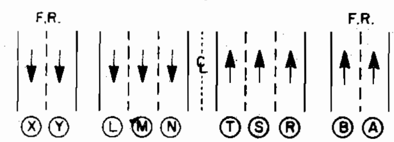
Ø = Alpha O
I = Alpha I
Ƶ = Alpha Z

PPSN - Same as CSN used in Skid Inventory (Right Justified).

SECURITY IDENTIFIER - Same as used in Skid Inventory for District.

ALPHA & BETA - Calibration Values shown on most recent calibration chart for the MRM unit used.

LANE - Has same designation as on the Maintenance Rating Form



Face in direction of increasing mile post.

It is not necessary to use Card No. 002, if Card No. 001 is completely filled in.

MRM READING - Can be either Counter or Inches of chart paper. But it can "not" be a combination of the two because the ALPHA & BETA are different for each.

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CONTINUE

SHEET 1 OF 2

FIGURE 34

EXAMPLE OF COMPLETED MRM DATA CODE SHEET - COUNTER

MRM DATA CODE SHEET

CARD NO	MRM READING	VELOCITY	REMARKS
015	82.	50	
016	97.		
017	81.		
018	105.		INTERSECTIØN
019	118.		
020	59.		
021	67.		
022	55.		
023	49.		
024	65.		
025	69.		
026	53.		
027	62.		
028	80.		
029	69.		
030	58.		
031	91.		
032	103.		
033	87.		
034	68.		
035	37.		
036	49.		
037	75.		
038	147.		
039	94.		
040	9.	30	END ØF SECTIØN
041			
042			
043			

FORM 1392-2 9/75

SHEET 2 OF 2

FIGURE 35

EXAMPLE OF COMPLETED MRM DATA CODE SHEET - COUNTER

STATE DEPARTMENT OF HIGHWAYS AND PUBLIC TRANSPORTATION PAGE 1

SERVICEABILITY INDEX (SI) COMPUTED FROM THE MAYS RIDE METER

THIS PROGRAM WAS RUN - 10-01-75

****

PROJECT IDENTIFICATION

DIST	COUNTY	HIGHWAY	CONT-SEC	BMP	EMP	PPSN	LANE	DATE
19	CAMP	FM -2455	1579- 2	0.0	1.701	1	L	09-25-75
	UPSHUR		1579- 3	0.0	1.170			
	CAMP		1579- 4	0.0	3.835			
	UPSHUR		1579- 5	0.0	0.056			

CALIBRATION CONSTANTS ALPHA	BETA	TOTAL LENGTH FOR SECTION	TOTAL COUNTER FOR SECTION	MRM NUMBER
10.22652	8.90040	7.434	2591.	29-8765-A

****

LOCATION INFORMATION

FROM - WOOD C/L
TO - FM 556

****

MAYS RIDE METER DATA

LOCATION	MAYS METER (READING/0.2 MI)	SI	SPEED	REMARKS
BMP TO 0.2	63.0	4.1	50	
0.4	59.0	4.2	50	
0.6	61.0	4.1	50	
0.8	48.0	4.4	50	
1.0	37.0	4.5	50	
1.2	34.0	4.6	50	
1.4	49.0	4.3	50	
1.6	52.0	4.3	40	
1.8	51.0	4.3	40	PEACH CREEK
2.0	64.0	4.1	40	
2.2	69.0	4.0	50	
2.4	75.0	3.9	50	
2.6	82.0	3.8	50	
2.8	97.0	3.5	50	
3.0	81.0	3.8	50	
3.2	105.0	3.4	50	INTERSECTION
3.4	118.0	3.2	50	
3.6	59.0	4.2	50	
3.8	67.0	4.0	50	
4.0	55.0	4.2	50	
4.2	49.0	4.3	50	
4.4	65.0	4.1	40	
4.6	69.0	4.0	40	
4.8	53.0	4.3	50	
5.0	62.0	4.1	50	

Figure 36 - Example of Processed Data - Counter

SERVICEABILITY INDEX (SI) COMPUTED FROM THE MAYS RIDE METER

MAYS RIDE METER DATA

LOCATION	MAYS METER (READING/0.2 MI)	SI	SPEED	REMARKS
5.2	80.0	3.8	50	
5.4	69.0	4.0	50	
5.6	58.0	4.2	50	
5.8	91.0	3.6	50	
6.0	103.0	3.4	50	
6.2	87.0	3.7	50	
6.4	68.0	4.0	50	
6.6	37.0	4.5	50	
6.8	49.0	4.3	50	
7.0	75.0	3.9	50	
7.2	147.0	2.8	50	
7.4	94.0	3.6	50	
7.434	9.0	4.3	30	END OF SECTION

LOW SI = 2.8 AVERAGE SI = 4.0 HIGH SI = 4.6*

Figure 37 - Example of Processed Data - Counter (Con't)

DIST	COUNTY	HIGHWAY	CONT-SEC	BMP	EMP	PPSN	LANE	DATE
19	CAMP	FM -2455	1579- 2	0.0	1.701	1	L	09-25-75
	UPSHUR		1579- 3	0.0	1.170			
	CAMP		1579- 4	0.0	3.835			
	UPSHUR		1579- 5	0.0	0.056			

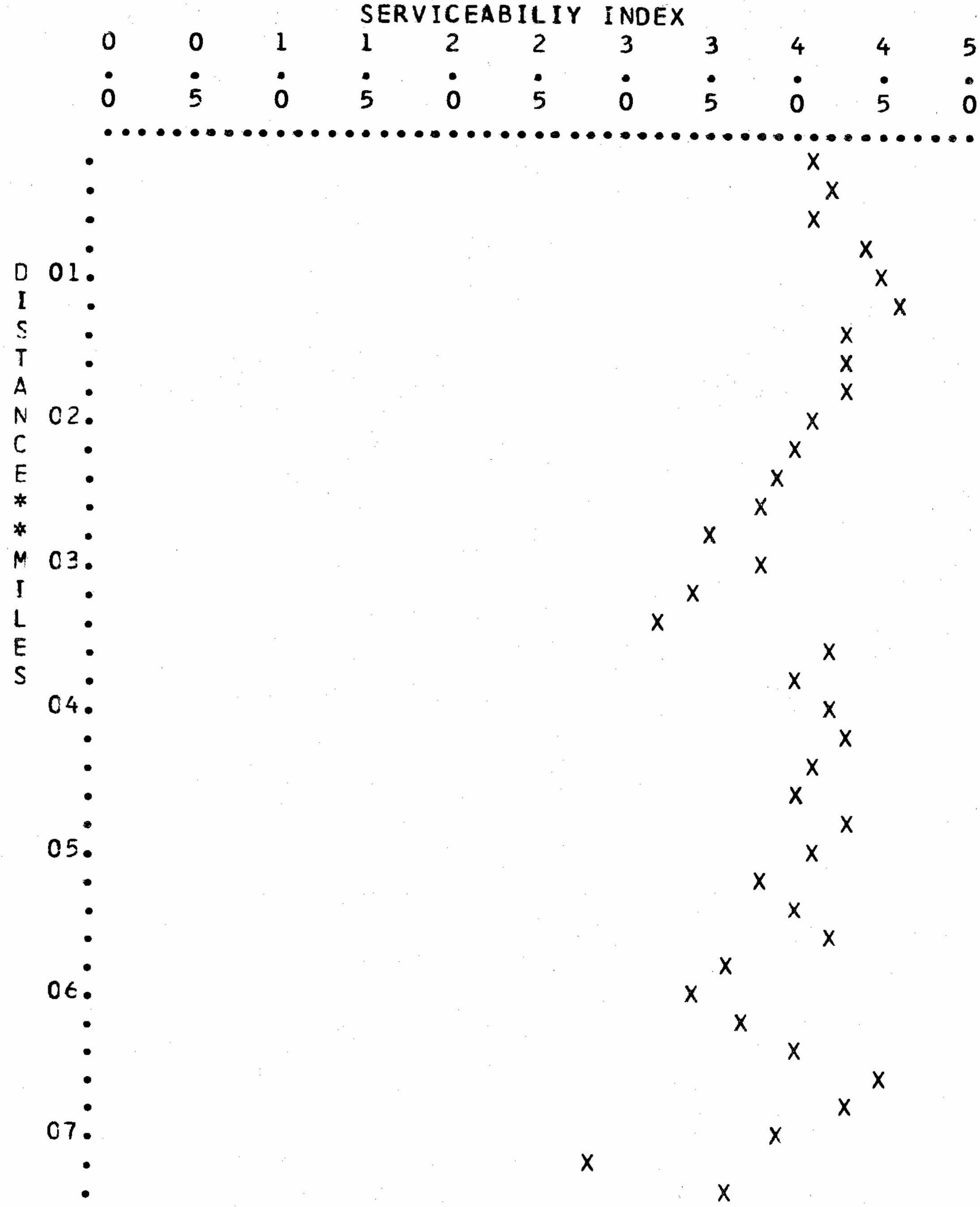

FIGURE 38 - Plot of Processed Data

VII CALIBRATION

Two types of calibration are treated as: (1) Calibration of the MRM unit and (2) the Distance Measurement Calibration. The information for the calibration of the MRM unit was basically obtained from Research Report 156-1.[2] The reader is referred to this report for the calibration development and detailed infromation. The calibration of the MRM may be separated into two basic actions:

1. the "correlation calibration".
2. the "calibration condition".

The "correlation calibration" is actually a correlation performed on test sections in the Austin area where a relationship is established with the Surface Dynamics Profilometer resulting in SI values. The "calibration condition" is performed on test sections near the area where the MRM is housed or based. The "calibration condition" is used to determine if the MRM is in need of re-correlating by using the Austin test sections.

The distance measuring calibration is used to obtain accurate distance measurements. The procedure described was obtained from the Instruction Manual and Operating Procedure for Model DE-140 Distance Measuring Instrument - Manual P-107 and the reader is referred to this manual for more specific information.[1]

Calibration of the MRM Unit

Correlation - Calibration

The MRM unit should be correlated initially and maintained in a calibrated condition to produce a standard roughness value. Roughness values may then be compared regardless of which MRM produced the data. SI values may be converted from the roughness measurements (both inches from chart paper and count from the digital counter system) by use of a table developed from a correlation equation. The table referred to as an MRM calibration table and examples are shown in Figures 39 and 40.

Calibration is accomplished by measuring the roughness on 28 calibration sections (0.25 mile in length) in the Austin area with the MRM unit and correlating this data with the Surface Dynamics Profilometer. The correlation is accomplished by use of a computer program which develops a correlation equation. The computer program also produces tables to convert roughness readings to SI values. Each section should be run five consecutive times. Each run should be at a constant speed and this speed attained approximately 0.2 mile before entering the section. The test speed should be 50 mph. Contact should be made with the Transportation Planning Division (D-10) for information involving the calibration in Austin. D-10 will process the data and forward the calibration information.

MAY 13-16, 1975 DISTRICT/FILE TTI MRM NO. UNIT 27

SD-PROFILOMETER SI VALUES WERE RUN MAY,1975

MAYS METER CALIBRATION TABLE FOR 50 MPH

ALPHA = 5.65653 **** BETA = 5.48432

MAYS METER (READING/0.2 MI)	SI	MAYS METER (READING/0.2 MI)	SI
18.0	0.5	4.5	2.8
16.4	0.6	4.3	2.9
15.1	0.7	4.1	3.0
14.0	0.8	3.8	3.1
13.0	0.9	3.6	3.2
12.2	1.0	3.4	3.3
11.4	1.1	3.2	3.4
10.7	1.2	3.0	3.5
10.1	1.3	2.8	3.6
9.6	1.4	2.6	3.7
9.0	1.5	2.5	3.8
8.6	1.6	2.3	3.9
8.1	1.7	2.1	4.0
7.7	1.8	1.9	4.1
7.3	1.9	1.8	4.2
6.9	2.0	1.6	4.3
6.6	2.1	1.4	4.4
6.2	2.2	1.2	4.5
5.9	2.3	1.1	4.6
5.6	2.4	0.9	4.7
5.3	2.5	0.7	4.8
5.1	2.6	0.5	4.9
4.8	2.7	0.0	5.0

Figure 39
Calibration Table - Scaled Values

MAY 13-16, 1975 DISTRICT/FILE TTI MRM NO. UNIT 27

SD-PROFILOMETER SI VALUES WERE RUN MAY,1975

MAYS METER CALIBRATION TABLE FOR 50 MPH

ALPHA =10.22652 **** BETA = 8.90040

MAYS METER (READING/0.2 MI)	SI	MAYS METER (READING/0.2 MI)	SI
488.3	0.5	144.4	2.8
451.9	0.6	137.2	2.9
421.1	0.7	130.2	3.0
394.6	0.8	123.3	3.1
371.2	0.9	116.7	3.2
350.2	1.0	110.2	3.3
331.3	1.1	103.8	3.4
314.1	1.2	97.6	3.5
298.2	1.3	91.5	3.6
283.5	1.4	85.5	3.7
269.8	1.5	79.6	3.8
257.0	1.6	73.8	3.9
244.9	1.7	68.1	4.0
233.5	1.8	62.4	4.1
222.7	1.9	56.7	4.2
212.5	2.0	51.0	4.3
202.7	2.1	45.3	4.4
193.4	2.2	39.5	4.5
184.4	2.3	33.6	4.6
175.8	2.4	27.5	4.7
167.6	2.5	21.0	4.8
159.6	2.6	13.6	4.9
151.9	2.7	0.3	5.0

Figure 40
Calibration Table - Counter Values

Calibration Condition

Accurate values are maintained by keeping the unit in a calibrated condition and certain control procedures have been set up to monitor this condition. These procedures provide a means of detecting out-of-calibration conditions and should be strictly followed.

Twenty control sections are to be established immediately following the initial calibration. These sections should be convenient to the assigned location for the MRM unit. Roughness variations within each section should be homogeneous; that is, the roughness within any 0.05 mile segment of the section should be approximately the same as in any other 0.05 mile segment of the section. It is evident that a smooth section with a rough bump within the section would not be a desirable section. Sections where changes in pavement conditions are expected to be minimum are preferred so that the sections will be useful as long as possible. The selection of these control sections is a very important part of the control procedures since they will be used to determine the calibration condition of the MRM unit.

Two control charts are used for monitoring the MRM calibration condition. One is for checking the mean (or average) compared to the initial values and the second for checking the variations from the mean of the replicate values. The control charts are developed with measurements obtained from the twenty control sections established as described above. A work sheet similar to Figure 41 is used to develop the control charts. Each section is run five times.

> NOTE: The control limits will be computed from these initial measurements. Therefore, it is important to include any run-to-run or day-to-day variations to prevent these limits from being too close. Therefore, it is recommended that all sections be run one time per day with at least a day separating replication runs.

The SI value is computed and entered on the work sheet (Figure 41). Then the following values are computed for each section:

1. The mean ($\bar{x}$) of the five test runs is computed and entered on the work sheet and the mean control chart (Figure 42).

2. The range (R) of the five test runs for each section is computed and entered on the work sheet.

3. The mean range ($\bar{R}$) is computed and entered on the work sheet.

4. The upper and lower control limits for the mean control chart are computed by multiplying the mean range ($\bar{R}$) by $\pm$ 0.82. This value is entered on the work sheet and plotted as two straight lines on the mean control chart (Figure 42).

MRM CONTROL CHART
WORK SHEET

DISTRICT D-10R MRM NO. 29-9840-F DATE 11/11 to 11/19/74

Note: SI values calculated from counter readings

SECTION	TEMP. °F	SI REPLICATION 1	2	3	4	5	$\overline{X}$	R
101		3.5	3.4	2.9	2.9	3.0	3.14	0.6
102		4.0	4.0	3.8	3.9	4.1	3.96	0.3
103		3.6	3.5	3.5	3.5	3.6	3.54	0.1
104		2.4	2.2	2.2	2.2	2.2	2.24	0.2
106		2.0	2.1	1.8	2.1	2.1	2.02	0.3
107		2.5	2.5	2.3	2.6	2.3	2.44	0.3
108		3.4	3.4	3.2	3.7	3.3	3.40	0.5
109		2.3	2.7	2.3	2.5	2.5	2.46	0.4
110		3.4	3.4	3.3	3.5	3.2	3.36	0.3
111		3.6	3.4	3.5	3.8	3.7	3.60	0.4
112		1.2	1.4	1.5	1.1	1.3	1.30	0.4
113		3.8	3.8	3.6	3.9	3.8	3.78	0.3
114		2.7	2.7	2.5	2.7	2.7	2.66	0.2
115		2.0	1.9	1.7	2.5	2.2	2.06	0.8
116		2.2	2.3	2.5	2.3	2.3	2.33	0.3
117		3.7	3.7	3.4	3.5	3.6	3.58	0.3
118		4.4	4.6	4.4	4.3	4.5	4.44	0.3
119		3.1	2.4	2.3	2.4	2.5	2.54	0.8
120		1.0	1.0	1.1	1.1	1.0	1.04	0.1
121		3.5	3.6	3.5	3.6	3.8	3.60	0.3
DATE—YEAR 19 74		11/11	11/12	11/13	11/18	11/19		
DRIVER/RECORDER								

Upper Control Limit
For $R = 2.11 \times \overline{R}$
$= 0.7596$

$R_{Total} = 7.2$

$R = \frac{R_{Total}}{20}$

$\overline{R} = 0.360$

Control Limits for
Mean $= \pm 0.82\ \overline{R} = \pm 0.2952$

Figure 41
A Typical MRM Work Sheet - Counter Values

MRM MEAN CONTROL CHART

District D-10R MRM No. 29-9840-F Date 11/11-19/74

Note: SI values calculated from counter readings

INITIAL MEAN

Section	$\overline{X}$
101	3.14
102	3.96
103	3.54
104	2.24
106	2.02
107	2.44
108	3.40
109	2.46
110	3.36
111	3.60
112	1.30
113	3.78
114	2.66
115	2.06
116	2.33
117	3.58
118	4.44
119	2.54
120	1.04
121	3.60

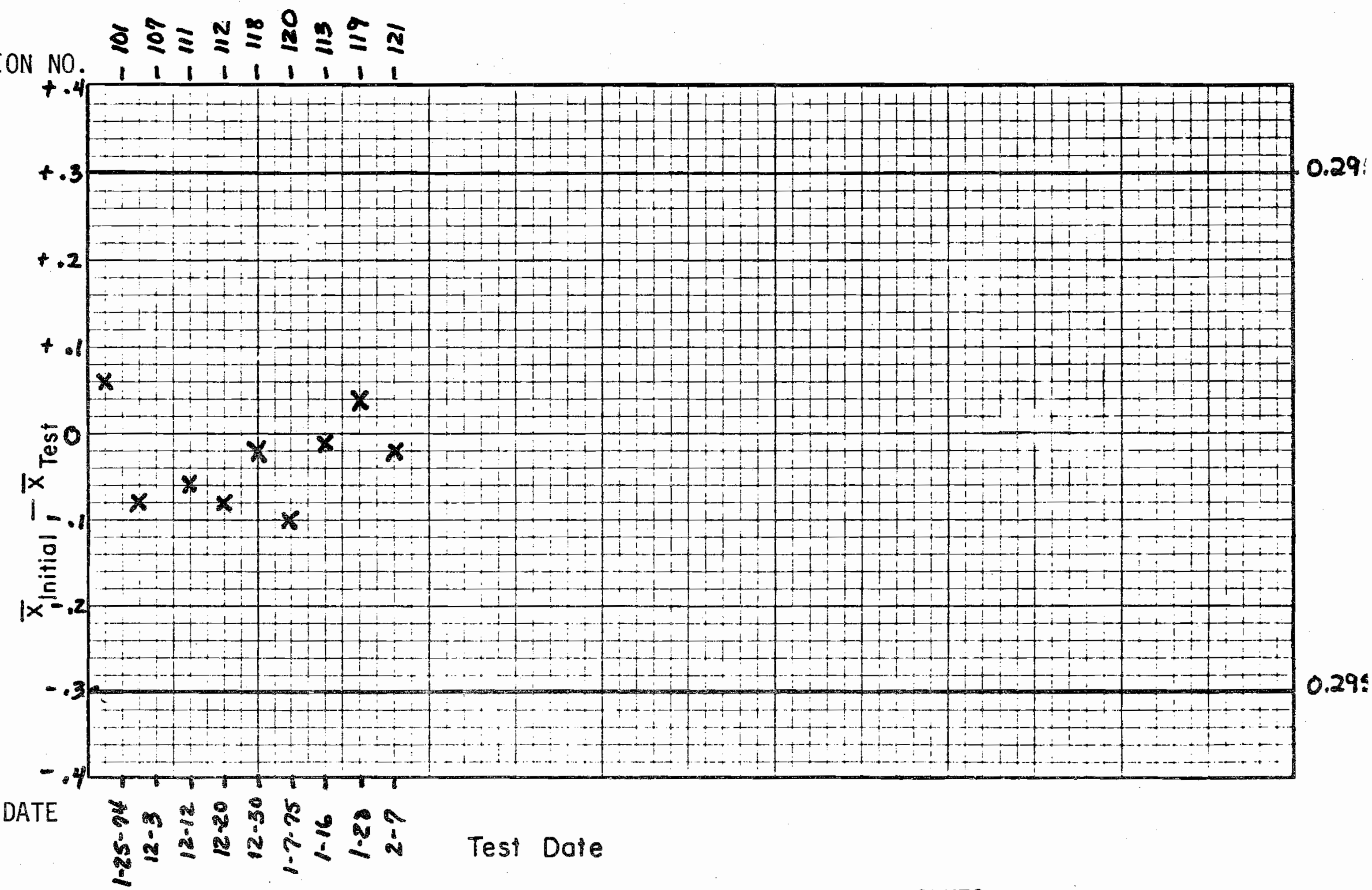

FIGURE 42 - A TYPICAL MRM CONTROL CHART FOR MEAN - COUNTER VALUES

5. The upper range control limit is computed by multiplying the mean range ($\bar{R}$) by 2.11 and entering this value on the work sheet. This value is also plotted on the range control chart (Figure 43).

When the control sections have been established and the Mean and Range charts established, control checks may be made at periodic intervals. Control checks are made by taking a set of <u>five repeat</u> runs over <u>any one</u> of the twenty control sections and finding the mean SI ($\bar{x}$) and range (R) (see Figure 47). The difference between the current mean and the initial mean established for the control section as listed on the left-hand side of Figure 42, is then compared with the upper and lower mean control range. If this difference is greater than the control range, an out-of-control condition can be suspected. The range provides an additional control check and is compared to the upper range control limit on Figure 43. A range value falling outside this limit will also indicate an out-of-control condition. By plotting the mean differences and range values, a past history or record can be maintained to assist in identifying out-of-control conditions.

Periodic control runs should be made at least once per month when the MRM unit is not in use and at least once each week when the MRM unit is being used. The section to be run should be randomly selected and the same section should not be repeated before at least four separate sections have been run for control purposes. The basic idea in the control procedure is to determine if the MRM is giving the same measurements within its measurement errors. Since these errors can and do occur, the control limits are established to identify extreme cases of these measurement errors. As indicated, an out-of-control condition can be suspected when either the range or mean control limits are exceeded. If one or both of these control limits are exceeded, the first action, which would not be delayed, is to closely examine the MRM unit for the possible problem source. If no problem is found, then run 4 or 5 additional control sections. If these exceed the control limits, a thorough check of the entire unit should be made and a new calibration performed in Austin. If none of these additional control checks exceed the control limits then the first control section should be closely examined for changes in roughness.

Figures 41 through 43 are examples using roughness counters whereas Figures 44 through 46 are examples of values scaled from the MRM chart paper.

<u>Distance Measurement Calibration</u>

As stated previously, the thumbwheel setting on the DMI is used to provide distance corrections to the digital display or as a factor to change the units of the distance measured as shown on the display. The distance developed by the DMI results from a sensor placed near a wheel on a vehicle and from eight magnets placed in a circumferential manner around the wheel. As a magnet passes near the sensor, an electrical signal or pulse is generated. These pulses control

MRM RANGE CONTROL CHART

District D-10R MRM No. 29-9840-F Date 11/11-19/74

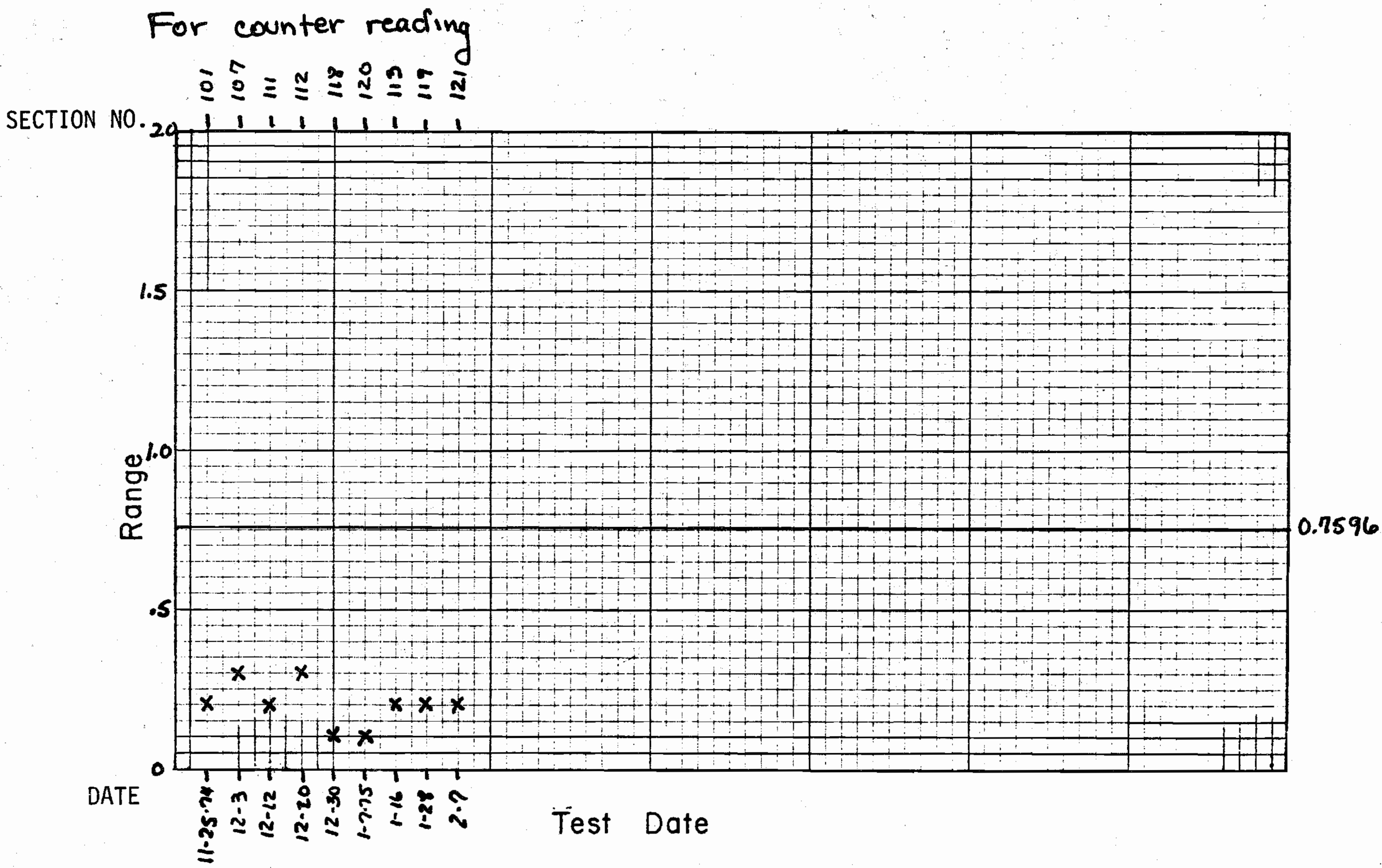

FIGURE 43 - A TYPICAL MRM CONTROL CHART FOR RANGE - COUNTER VALUES

MRM CONTROL CHART
WORK SHEET

DISTRICT D-10R MRM NO. 29-9840-F DATE 11/11 to 11/19/74

Note: SI values calculated from chart paper measurements

SECTION	TEMP. °F	SI REPLICATION 1	2	3	4	5	$\bar{X}$	R
101		3.2	3.2	2.9	2.8	2.8	2.98	0.4
102		4.0	3.8	3.5	3.6	3.8	3.74	0.5
103		3.5	3.3	3.3	3.3	3.4	3.36	0.2
104		2.4	2.2	2.1	2.2	2.2	2.22	0.3
106		2.2	2.1	1.9	2.1	2.0	2.06	0.3
107		2.4	2.4	2.2	2.5	2.3	2.36	0.3
108		3.0	2.6	3.0	3.5	2.9	3.00	0.9
109		2.3	2.3	2.2	2.5	2.3	2.33	0.3
110		3.2	3.2	3.3	3.2	3.1	3.20	0.2
111		3.4	3.2	3.2	3.6	3.5	3.38	0.4
112		1.4	1.6	1.4	1.3	1.5	1.44	0.3
113		3.6	3.6	3.4	3.6	4.0	3.65	0.6
114		2.5	2.6	2.5	2.7	2.8	2.62	0.3
115		2.0	1.9	1.8	1.9	2.2	1.96	0.4
116		2.3	2.2	2.2	2.5	2.2	2.28	0.3
117		3.5	3.4	3.2	3.2	3.5	3.36	0.3
118		4.0	4.3	4.0	4.2	4.5	4.20	0.5
119		2.4	2.3	2.3	2.4	2.3	2.34	0.1
120		1.3	1.3	1.3	1.3	1.2	1.28	0.1
121		3.2	3.4	3.2	3.4	3.5	3.34	0.3
DATE--YEAR 19__		11/11	11/12	11/13	11/18	11/19		
DRIVER/RECORDER								

Upper Control Limit For $R = 2.11 \times \bar{R}$ = 0.7385

R_{Total} = 7.0

$\bar{R} = \frac{R_{Total}}{20}$

$\bar{R}$ = 0.35

Control Limits for Mean = $\pm 0.82\,\bar{R}$ = ± 0.287

Figure 44

A Typical MRM Work Sheet - Scaled Values

MRM MEAN CONTROL CHART

District D-10R MRM No. 29-9840-F Date 11/11-19/74

Note: SI values calculated from inches of chart paper

INITIAL MEAN

Section	$\bar{x}$
101	2.98
102	3.74
103	3.36
104	2.22
106	2.06
107	2.36
108	3.00
109	2.33
110	3.20
111	3.38
112	1.44
113	3.65
114	2.62
115	1.96
116	2.28
117	3.36
118	4.20
119	2.34
120	1.28
121	3.34

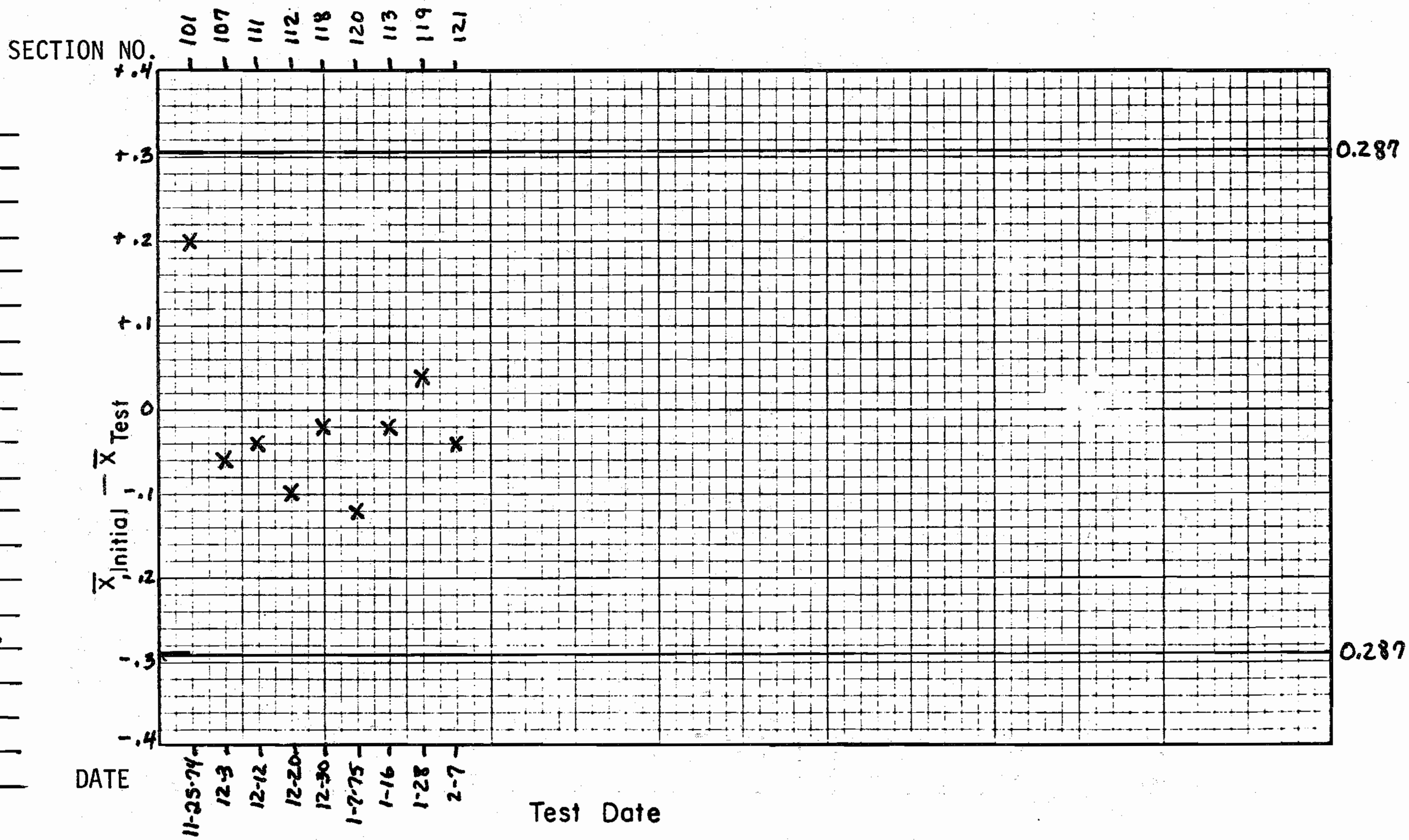

FIGURE 45 - A TYPICAL MRM CONTROL CHART FOR MEAN - SCALED VALUES

MRM RANGE CONTROL CHART

District D-10R MRM No. 29-9840-F Date 11/11-19/74

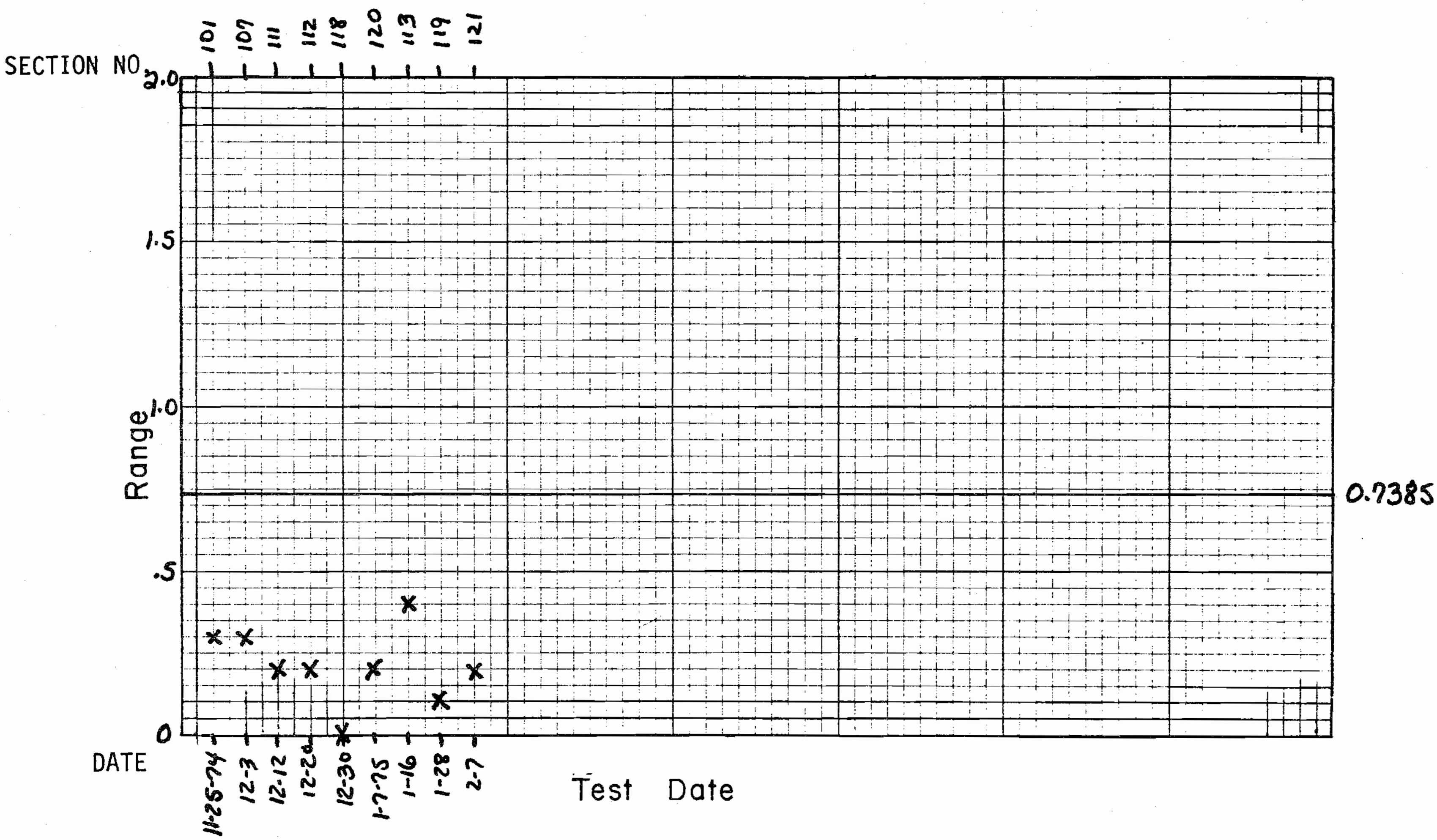

FIGURE 46 - A TYPICAL MRM CONTROL CHART FOR RANGE - SCALED VALUES

WORK SHEET FOR
MRM CONTROL RUN

DISTRICT ___–___ MRM NO. ___1___

DATE ___FEB 1972___ SECTION ___–___

$\bar{X}_{INITIAL}$ (INITIAL SI AVERAGE) = ___3.20___

Run	SI
1	3.2
2	3.4
3	3.5
4	3.1
5	3.1

Sum SI = 16.3

$$\bar{X}_{CURRENT} = \frac{\text{Sum SI}}{5} = 3.26$$

$$\text{RANGE} = SI_{MAX} - SI_{MIN} = 0.4$$ Enter on Range Control Chart

$$\bar{X}_{INITIAL} - \bar{X}_{CURRENT} = -0.06$$ Enter on Mean Control Chart

Figure 47

Typical Work Sheets for MRM Control Run

the distance numbers being displayed. It may be noted that there are eight pulses for each revolution of the wheel. The distance traveled by the vehicle in one revolution of the wheel is of course directly related to the circumference of the inflated tire.

The number shown on the thumbwheels is actually a multiplier. The number of pulses delivered from the sensor will be multiplied by the thumbwheel number and the result will be displayed. If the thumbwheel number is 1000 (actually a 1.000) the multiplier is one (1). If a 1500 (actually a 1.500) is set on the thumbwheel and 1000 pulses are received, the number 001500 will be displayed. An example of using this feature for calibrating follows:

> Assume a wheel with a G78-15 tire is used. Also, assume the radius is 13.78 inches (diameter = 27.56).
> Then:
>
> Circumference = D
> = 27.6 = 86.56 inches =7.21 feet
>
> Calculate the feet per pulse:
>
> $$\frac{7.21 \text{ ft.}}{8 \text{ pulses}} = 0.901 \text{ ft./pulse}$$
>
> Calculate the pulses per foot:
>
> $$\frac{8 \text{ pulses}}{7.21 \text{ ft.}} = 1.110 \text{ pulses/ft.}$$

If there are 1.110 pulses/ft. when the vehicle has traveled 1000 ft., there will be 1110 pulses delivered to the DMI. There is a need then, to set a multiplier on the thumbwheels to cause the 1110 pulses to be factored so that the correct number (1000) is displayed when 1000 ft. have been traversed. The multiplier will be 1000/1110 or 0.901. Note the 0.901 is also the number of feet per pulse. This means that when the number of feet/pulse has been calculated, this number may be set in as the multiplier. However, it should be noted that this multiplier only corrects to produce a display in feet. For roughness measurements a display in mileage is needed. Therefore, it may be noted that:

1. When a one (1) occurs in the least significant digit of the display (the right most of the six display tubes), a distance of 0.0001 mile should have been traversed.

2. The 0.0001 mile is actually 0.5280 feet.

3. The factor to convert feet to miles is 0.0001893 or 1/5280 = 0.0001893 ft/mile.

4. If the least significant digit needed is in terms of 0.001 mile, a multiplier of 1.893 (0.0001893 x 10,000) is also needed with the DMI so that the numbers will be displayed in 1/10,000 mile units.

Therefore, for the G78-15 tire noted in the example, the product of the two multipliers should be used on the thumbwheels to produce a corrected readout in mileage. That is 0.901 to correct pulses to feet and 1.893 to change feet to mileage. The setting on the thumbwheels for the G78-15 tire example should be 0.901 x 1.893 = 1.706 or a 1-7-0-6 on the thumbwheels (reading from left to right).

After the initial setting has been determined, it is suggested that the DMI be calibrated by obtaining the distance of a measured mile. The measured mile should be established in the manner used to develop odometer check stations. The vehicle (and/or trailer) housing the DMI should be tested on the measured mile at 50 mph with at least three repeat passes and the thumbwheels adjusted so that the DMI displays the correct distance ± 0.0005 mile. The adjustment and final setting should be based on the average of the three repeat passes. (Normal range between repeat passes will be within ± 0.0005 mile. If the distance of one pass differs from one of the other two passes by more than 0.0010 mile in the one mile measured distance, it is suggested that that pass be deleted and the remaining two averaged.)

If adjustment of the thumbwheel is needed, it should be noted that larger numbers on the thumbwheel produce larger numbers in the display (after traversing the measured mile). Conversely, smaller number on the thumbwheel produce smaller numbers in display. The usual 14- or 15-inch tires on an automobile or trailer reflect a display change of about 0.0005 mile when the right most thumbwheel is changed one number (in a one mile test).

"Radial run-out" has been mentioned previously. In this condition the radius to the outer edge of the tire changes with speed because centrifugal force causes the tread portion to move away from the axle. In recent tests with a Ford LTD with original equipment tires, distance measurements were made at 30, 40 and 50 mph. With the thumbwheels maintained at one setting, a differential distance of about 0.0005 mile was noted for a speed change of 10 mph when tests were made over a measured mile. Using this information, one may postulate that no change in thumbwheel setting is needed for speed changes up to 5 mph. Speed changes greater than 5 mph from the 50 mph speed should be accompanied with thumbwheel changes of one number (in the rightmost switch) then another number change for every 10 mph velocity change. It is expected that this information will be valid for most vehicles THD will operate in obtaining roughness measurements.

Suggested allowance in distance for speed changes have been offered immediately above; however, it is suggested that all roughness tests be conducted at 50 mph, ± 5 mph.

VIII SYSTEM MAINTENANCE

In order to secure the most reliable roughness values with the Mays Ride Meter (MRM), the following should be observed:

1. The suspension system on the vehicle (trailer or automobile) should be kept in top working order. Coil springs and firm shock absorbers are preferred. This condition should be checked periodically.

2. Tires should be checked daily for proper pressure and periodically for roundness and balance.

3. Moving components on the chart paper recorder and signal transmitter should be checked for mechanical freedom.

4. The rotary drum and cable pulley should be checked to insure proper position. (Top and bottom are marked on the pulley) The check should be accomplished with normal test weights in the car.

5. Voltage to the system must be maintained near 13V (13-3/4V are normal in a 12V automobile system).

6. Magnets on the distance measuring wheel should be checked daily to insure that a magnet has not become dislodged.

7. An air conditioned vehicle is preferred. (Very desirable in the hotter areas of the state as all the solid state circuitry operated more reliably in a cool, dry environment.) The stepper motors and other electronic components dissipate heat much more readily.

IX. OPERATION

It is suggested that the available information on Cards 1 & 2 of the code sheet be completed and sheets prepared for the entire daily route to be tested before testing is initiated. In this manner, continuous data collection may result during the work period. Basically, it will be necessary to have knowledge of the beginning and ending points of each section to be tested and be able to recognize these points while traveling in the test unit at 50 mph. On any one section the 50 mph test speed must be established before entering the section. Data collection must be initiated as the beginning point of the section (PPS) is crossed. Test data is recorded while testing within the section and data collection is ceased at the end of the section. The vehicle driven to the shoulder and stopped so that additional test data can be recorded. If the test sections are in sequence, it will be necessary to re-enter the section just completed and again obtain the 50 mph test speed before data collection can be initiated on the next section to be tested.

Appendices A and B should be duplicated and carried in the test unit to be used as a quick reference by data collection personnel.

REFERENCES

1. Instruction Manual and Operating Procedure, Manual P-107, Nu-Metrics Instrumentation, Vanderbilt, Pennsylvania, 15486

2. Walker, Roger S., and Hudson, W. Ronald, "A Correlation Study of the Mays Road Meter with the Surface Dynamics Profilometer", Research Report No. 156-1, Center for Highway Research, The University of Texas at Austin, February 1973.

3. Epps, J. A., Meyer, A. H., Larrimore, I. E., Jr., and Jones, H. L., "Roadway Maintenance Evaluation User's Manual", Research Report No. 151-2, Texas Transportation Institute, Texas A & M University, College Station, Texas, September 1974.

APPENDIX A

INSTRUCTIONS FOR THE USE OF
MAYS RIDE METER WITH DMI/COUNTER
INTERFACE

INSTRUCTIONS FOR USE OF MAYS RIDE METER WITH DMI/COUNTER INTERFACE

PREPARATORY CHECKS:

1. CHECK TIRE PRESSURE TO BE SURE IT IS 31 PSI AFTER SUFFICIENT TIRE WARM-UP (AT LEAST 5 MILES).

2. MAKE SURE THERE IS ENOUGH CHART PAPER IN MRM RECORDER.

3. CHECK FOR PROPER NUMBER OF MAGNETS ON DMI XDUCER WHEEL. (THIS IS THE LEFT TRAILER WHEEL WHEN USING TRAILER AND LEFT FRONT WHEEL ON AUTOMOBILE) THERE SHOULD BE A TOTAL OF 8 MAGNETS.

4. DRIVE THROUGH A MEASURED DISTANCE SUCH AS A MEASURED MILE TO CHECK THE DMI FOR PROPER CALIBRATION. THIS MAY BE INCLUDED AS THE LAST MILE IN THE TIRE WARM-UP. THE PROGRAMMING THUMBWHEELS ON THE DMI SHOULD BE SET FOR THE PROPER CALIBRATION NUMBER. IT IS SUGGESTED THAT THE CALIBRATION NUMBER BE OCCASIONALLY CHECKED DURING THE DAY.

   NOTE: THE ABOVE INSTRUCTIONS OR DMI CALIBRATION ARE VERY IMPORTANT. IF THE DMI IS NOT IN CALIBRATION THE SI VALUES WILL BE ERRONEOUS.

5. MAKE SURE THE PENS ON THE MRM ARE ALL LINED UP EXACTLY, SO THE EVENTS (RIGHT & LEFT) WILL COINCIDE WITH EACH OTHER.

6. MAKE SURE THAT THE RIGHT PEN IS IN THE NON-ENERGIZED POSITION. THIS CAN BE TESTED BY PRESSING THE RESET BUTTON ON THE DMI. IF THIS DOES NOT GIVE AN EVENT, PRESS THE WHITE "LANDMAKR" (RIGHT) BUTTON ON THE MRM. THIS SHOULD PUT THE PEN IN THE NON-ENERGIZED POSITION.

7. WHILE RUNNING THE MEASURED DISTANCE FOR DMI CALIBRATION, CHECK TO SEE IF THE DISTANCE EVENT PEN (LEFT-ON THE MRM RECORDER) IS EVENTING PROPERLY.

8. THE DMI SWITCHES SHOULD BE IN THE FOLLOWING POSITIONS FOR THE USUAL OPERATION:

   A. THUMBWHEEL SWITCHES -----CORRECT CALIBRATION NO. BE SURE THIS IS CURRENT.

   B. ON/OFF SWITCH -----------ON (DEPRESSED)

   C. DATA SWITCH -------------OFF (DOWN)

   D. HOLD SWITCH -------------OFF (OUT)

9. THE ALTERNATING SEQUENCE SWITCH SHOULD BE IN THE 0.2 MILE POSITION.

APPENDIX B

OPERATING PROCEDURES FOR USE OF MAYS METER WITH DMI/COUNTER SYSTEM

OPERATING PROCEDURES FOR USE OF MAYS METER WITH DMI/COUNTER SYSTEM

1. BE SURE ALL PRE-OPERATION CHECKS HAVE BEEN OBSERVED.

2, COMPLETE THE AVAILABLE INFORMATION ON CARDS 1 & 2 OF THE CODE SHEET.

3. OBTAIN 50 MPH AT LEAST 0.2 MILE BEFORE BEGINNING POINT OF THE SECTION.

4. AS YOU CROSS THE BEGINNING POINT OF THE SECTION, PRESS THE DMI RESET BUTTON. THIS WILL AUTOMATICALLY:

   A. RESET THE DMI READING TO ZERO.
   B. RESET THE ALTERNATING COUNTERS TO ZERO.
   C. PUT AN EVENT MARK ON THE RIGHT SIDE OF THE CHART PAPER.
   D. CHANGE THE POSITION OF THE DISTANCE EVENT PEN ON THE MRM.
   E. RESET THE ACCUMULATIVE COUNTER.

5. AS YOU PROCEED THROUGH THE SECTION, THE ALT. COUNTERS WILL COUNT THE ROUGHNESS WHEN THE END OF THE FIRST 0.2 MILE IS REACHED, THE FIRST COUNTER WILL GO INTO A HOLD MODE AND THE ROUGHNESS COUNT WILL BEGIN TO COUNT ON THE SECOND COUNTER AND THE AUDIO SIGNAL (BEEP) WILL BE HEARD WHICH INDICATES THAT THE COUNT ON NO. 1 SHOULD BE READ AND RECORDED IN COLUMNS 4, 5 AND 6 (RIGHT JUSTIFIED) OF CARD TYPE 3 (OR GREATER). COLUMN 7 IS USED ONLY WHEN THE MRM VALUES ARE CODED IN INCHES OF CHART PAPER. AT THE END OF THE SECOND 0.2 MILE, THE AUDIO SIGNAL WILL BE HEARD AND THE SECOND COUNTER WILL GO INTO THE HOLD MODE AND THE FIRST COUNTER WILL RESET AND BEGIN COUNTING. THE READING FOR EACH 0.2 MILE SHOULD BE RECORDED AS STATED ABOVE. THIS ALTERNATING ACTION WILL CONTINUE THROUGHOUT THE SECTION.

   <u>CLOSE ATTENTION SHOULD BE GIVEN TO THE COUNTERS BOTH VISUALLY AND BY LISTENING FOR THE AUDIO SIGNAL SO THAT NONE OF THE 0.2 MILE READINGS ARE ALLOWED TO RESET BEFORE THEY ARE RECORDED. ABOUT 15 SECONDS ARE AVAILABLE FOR RECORDING BEFORE THE ALTERNATING COUNTERS ARE AUTOMATICALLY RESET.</u>

6. WHEN THE END OF THE SECTION IS REACHED, AND AS YOU CROSS THE END POINT, PRESS THE DMI "HOLD" BUTTON. THIS WILL PLACE THE ACCUMULATIVE COUNTER, ALTERNATING COUNTER AND THE DMI DISTANCE COUNTER IN THE "HOLD" MODE SO THAT A RECORDING OF BOTH MILEAGE AND ROUGHNESS COUNT CAN BE MADE.

7. RECORD THE LENGTH OF THE TEST SECTION IN COLUMNS 31 - 35 OF CARD NO. 1 AND THE NUMBER IN THE ACCUMULATIVE COUNTER IN COLUMNS 36-40 (RIGHT JUSTIFIED) OF CARD NO. 1.

8. RELEASE THE "HOLD" BUTTON.

9. THE ABOVE PROCESS MAY BE REPEATED ON THE NEXT SECTION.

APPENDIX C

OCTOBER 18, 1976 COST AND PARTS LIST
FOR THE
MAYS RIDE METER/DIGITAL COUNTER/INTERFACE SYSTEM

October 18, 1976

TEXAS STATE DEPT. HIGHWAYS & PUBLIC TRANSPORTATION
D-10 RESEARCH

PARTS LIST
for

MAYS RIDE METER/DIGITAL COUNTER/INTERFACE SYSTEM

QTY.	ITEM		DESCRIPTION	COST EA.	TOTAL
11	DR2000		SEVEN SEGMENT READOUTS (RCA Numitrons)	$ 5.00	$55.00
11	7447	*	Seven segment Decoder/Drivers	2.80	30.80
15	7490	*	Decade Counters	1.60	24.00
7	7400	*	Quad 2 input NAND Gates	.86	6.02
4	74121	*	Monostable Multivibrators	.86	6.02
2	7472	*	J K Flip Flop	.75	1.50
1	MG665	*	Triple Level Translator (Motorola MHTL)	1.75	1.75
2	LM555	*	Timer	1.89	3.78
2	W107DIP-1		Reed Relay (Magnecraft)	5.00	10.00
2	ECG211		Transistors (Sylvania)	2.30	4.60
4	LM309K		5 Volt Regulators	3.50	14.00
4	HEP 170		Diodes	.82	3.28
					$160.75

* INTEGRATED CIRCUIT Dual in-line Package

October 18, 1976

TEXAS STATE DEPT. HIGHWAYS & PUBLIC TRANSPORTATION
D-10 RESEARCH

PARTS LIST
for

MAYS RIDE METER/DIGITAL COUNTER/INTERFACE SYSTEM

QTY.	ITEM	DESCRIPTION		COST EA.	TOTAL
2	TVA1207	Electrolytic Capacitor	100MFD@25 VDC	$ 1.25	$ 2.50
5	TVA1204	"	10 MFD@25 VDC	.60	1.20
6	TVA1203	"	5 MFD@25 VDC	.60	3.60
2	TVA1142	"	3 MFD@25 VDC	.50	1.00
1	TVA1211	"	1000 MFD@25 VDC	2.00	2.00
8	M39003	(Military specs) Tantalum	.01 @ 16 VDC	1.00	8.00
		"	.1 @ 16	1.00	4.00
5		Disc Capacitor	.1 @ 50 VDC	.39	1.95
5		"	.01 @ 50 VDC	.20	1.00
5		"	.05 @ 50 VDC	.20	1.00
12	16DIP	Cinch Jones IC socket		1.25	15.00
30	14DIP	Cinch Jones IC socket		1.00	30.00
2	MLED 650	279 Case Light Emitting Diodes (Motorola)		.60	1.20
					$ 72.45

October 18, 1977

TEXAS STATE DEPT. HIGHWAYS & PUBLIC TRANSPORTATION
D-10 RESEARCH

PARTS LIST
for

MAYS RIDE METER/DIGITAL COUNTER/INTERFACE SYSTEM

QTY.	ITEM	DESCRIPTION	COST EA.	TOTAL
		Miniature jacks and plugs (Switchcraft)		
4	#4 (39F744)	Miniature jack	.45	1.80
4	#750 (39F746)	Miniature plug	.55	2.20
10 ft.	RG174/U	Coaxial cable	.	1.00
4	UG88U	BNC Connector	.85	3.40
4	657U	BNC Connector	1.35	5.40
2	50-22A-20	Cinch, Edge connector (PC Board) 22 Pin	1.75	2.50
1	50-44A-30	Cinch, Edge connector (PC Board) 22 Pin Double row	2.25	2.25
1	MST-105	(Alcoswitch) SPDT miniture switch	2.50	2.50
4	#126-010	5 Pin Amphenol plug	1.25	5.00
4	#126-011	5 Pin Amphenol socket	1.75	7.00
4	#126-1063	Hood & clamp for above	.75	3.00
4	#126-1069	Clip retainer	.10	.40
1		2" thin 4 ohm speaker	2.00	2.00
		RESISTORS (carbon)		
3	1 K 1/2 Wat	10%	.20	.60
3	22K "	"	.20	.60
3	33K "	"	.20	.40
3	10K "	"	.20	.60
1	100K "	"	.20	.20
1	180 ohm "	"	.20	.20
				$ 41.05

October 18, 1977

TEXAS STATE DEPT. HIGHWAYS & PUBLIC TRANSPORTATION
D-10 RESEARCH

PARTS LIST
for

MAYS RIDE METER/DIGITAL COUNTER/INTERFACE SYSTEM

QTY.	ITEM	DESCRIPTION	COST EA.	TOTAL
		RESISTORS continued		
2	150 ohm	1/2 Watt 10%	.20	.40
2	2.2K	" "	.20	.40
1		FUSE HOLDER (Chassis mount)	1.50	1.50
1		1/4" Phone Plug	.75	.75
4		1/4" Phone Jacks	.75	3.00
2		Test Jacks	.50	1.00
2	2 ounce copper clad single sided printed circuit boards, fiberglass. 1/16" X 8" X 4&4/4"		2.00	4.00
1	2 ounce copper clad double sided printed circuit fiberglass board. 1/16" X 8" X 4&3/4"		3.00	3.00
4	#6052B Thermalloy	Heat Sinks	1.50	6.00
1	KRP 11 AG	12 volt heavy Duty Relay (Potter/Brm)	10.00	10.00
1	Octal	8 pin socket for above relay	1.00	1.00
1 Gal.	PC Board Developing solution	GC product # 22-235	6.55	6.55
16 oz.	Areosol can etch resist	GC product # 22-231	10.67	10.67
1 Gal.	Ferric Chloride etchant material		5.00	5.00
				$ 53.27

October 18, 1976

TEXAS STATE DEPT. HIGHWAYS & PUBLIC TRANSPORTATION
D-10 RESEARCH

PARTS LIST
for

MAYS RIDE METER/DIGITAL COUNTER/INTERFACE SYSTEM

QTU.	ITEM	DESCRIPTION	COST EA.	TOTAL

MISCELLANEOUS ITEMS NEEDED FOR CONSTRUCTION

SOLDER

PLEXIGLASS FILTER (RED)

FUSES

WIRE (HOOKUP)

UPHOLSTERY MATERIAL FOR CABINET

MISC. NUTS AND BOLTS

SHEET METAL FOR CABINET

PC BOARD DESIGN MATERIALS, LAYOUT PATTERNS, NEGATIVES, ETC.

EST. COST OF ABOVE $50.00

PC BOARD BACK (SEE VECTOR PRODUCTS LIST)

DISTANCE MEASURING INSTRUMENT (DMI) October, 1975 - $583.56

VEHICLE INSTALLATION KIT FOR DMI October, 1975 - 49.92

October 18, 1976

TEXAS STATE DEPT. HIGHWAYS & PUBLIC TRANSPORTATION
D-10 RESEARCH

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THE FOLLOWING IS A LIST OF ITEMS COMPRISING ITEMIZED PARTS FOR THE CONSTRUCTION OF A PREFABRICATED PRINTED CIRCUIT BOARD BACK.

THEY ARE AVAILABLE FROM: VECTOR ELECTRONICS CO. INC.
(costs are estimated) 12460 GLADSTONE AVE.
SYLMAR, CALIFORNIA 91342
213/ 365-9661

QTY.	ITEM	DESCRIPTION			COST EA.	TOTAL
2	#SW-87-P-119	Cage sidewall	Sect.5,Pg.5		$ 4.42	$ 8.84
2	#TSW-300-A	T Slot Struts	Sect.5,Pg.8		4.71	9.42
1Pkg.	#NT6-3	Strut Mounting Hdw.	"	"	1.19	1.19
1(24")	#BR19-240	Case Guide	"	"	1.04	1.04
1Pkg.	#BR33A	Universal Adj. Guides		"	4.31	4.31
1Pkg.	#NT4-7	Square Nut	"	"	1.79	1.79
1Pkg.	#BR20-240	Card Guides,Plastic	"	Pg.9	1.32	1.32
1Pkg.	#SC4-11	Screws, flat head	"	"	1.50	1.50
1Pkg.	#SP09/2	Hex spacer/Hdw.	"	Pg.8a	6.00	6.00
1Pkg.	#SC10-2	Thumbscrews	"	Pg.11	4.20	4.20
1	#HA-12	Handle	"	Pg.7	2.74	2.74
						$42.35