

1. Report No. HWA-AR-80-001		2. Government Accession No.		3. Recipient's Catalog No.	
4. Title and Subtitle Skid Research Program				5. Report Date May 1981	
				6. Performing Organization Code	
7. Author(s) J. R. Westerman				8. Performing Organization Report No.	
9. Performing Organization Name and Address Arkansas State Highway & Transportation Dept. Post Office Box 2261 Little Rock, Arkansas 72203				10. Work Unit No.	
				11. Contract or Grant No. HRC-29	
12. Sponsoring Agency Name and Address ARKANSAS STATE HIGHWAY AND TRANSPORTATION DEPT. P.O. BOX 2261 LITTLE ROCK, ARKANSAS 72203				13. Type of Report and Period Covered Final	
				14. Sponsoring Agency Code	
15. Supplementary Notes This Project was conducted in cooperation with the U.S. Department of Transportation, Federal Highway Administration					
16. Abstract This report presents the actions taken in the development and acquisition of a skid testing unit that would be economical, efficient, and safe as well as repeatable and reliable while the statewide inventory was conducted. This report also contains specifications and operating procedures.					
17. Key Words Skid Resistance Skid Tester			18. Distribution Statement  NO RESTRICTIONS		
19. Security Classif. (of this report) UNCLASSIFIED		20. Security Classif. (of this page) UNCLASSIFIED		21. No. of Pages 61	22. Price

## TABLE OF CONTENTS

	Page
Table of Contents	2
List of Figures	3
Chapters	
I. Introduction	4
A. General	4
B. Objectives and Scope of HRC-29	5
II. Selection, Acquisition, and Operation of the Arkansas Skid Testing Unit	
A. Evaluation of Skid Testing Devices	8
B. Comparison of Two-Wheel Testing Devices	9
C. Selection and Acquisition of a Skid Testing Device	11
D. Performance of Skid Testing Device	14
E. Modification of Skid Testing Device	16
III. Development of Inventory System	
A. General	23
B. Data Collection	23
C. Data Storage and Retrieval	25
IV. Coordination with HRC-38 and HRC-40	29
V. Conclusions	32
VI. Implementation	33
VII. References	
VIII. Appendices	
A. Cost	
B. Design Criteria and Specifications - Towing Truck	
C. Specification for Skid Testing Trailer	
D. Specification for SN Computer	
E. Operating Procedures for Skid Testing Trailer	

## LIST OF FIGURES

Figure		Page
1	ST1 (Skid Tester 1)	12
2	Console in ST1	13
3	Component Positioning in Modified Skid Testing Unit	17
4	Microcomputer in Inventory Unit	18
5	Inventory Unit	18
6	Modified Skid Testing Unit	21
7	Water Pump Compartment	22
8	Diagram of Test Pattern	25
9	Typical Skid Inventory Printout	26
10	Data Storage and Retrieval System	28

## CHAPTER 1

### INTRODUCTION

#### GENERAL

The problem of skidding on slippery roads, as well as research into methods to prevent it, has been present for over forty years. Agencies have now fully recognized and accepted skidding as a major hazard in highway transportation.

It was a known fact when this project started that the average travel speed of vehicles had steadily increased over several years and that this increase in speed, coupled with higher traffic density per mile of highway, merely intensified the skidding problem. This problem had reached such proportions that the Federal Highway Safety Standard Number 12 required all state governments to have a program for resurfacing or other surface treatment for correction of locations with low skid resistance and high or potentially high accident rates that could be reduced by providing improved surfaces. The Federal Highway Administration was charged with the administration of this Standard. They ask that the state highway departments compile statewide inventories of skid values covering all sections of pavement on the state highway system.

Prior to the Department's purchase of skid trailers, the Arkansas State Highway and Transportation Department

did preliminary skid investigations by using the stopping distance vehicle method. This procedure was slow, expensive, and hazardous; therefore, it was prohibitive to conduct a continuing inventory of all state highways using this method. Since skid resistance had become a very prominent factor in the field of highway safety, the Arkansas State Highway and Transportation Department initiated this project in cooperation with the Federal Highway Administration. The first requirement of this project was to study various skid testing units, determine specifications, and either acquire or construct a skid trailer.

In addition to a literature review, an informational review was initiated by requesting from various state highway and transportation departments, Federal, and private agencies, a copy of their plans and costs for construction or purchase of a skid trailer. The Department received information from twenty-eight states and three private organizations. The conclusions of this investigation are discussed in appropriate sections of this report.

#### OBJECTIVE AND SCOPE OF HRC-29

During the 1960's, skid testing research became a high priority of various research agencies; Arkansas was no exception. The Arkansas Highway Department (now named the Arkansas State Highway and Transportation Department)

did some preliminary skid testing using the "stopping distance vehicle method". Although this method proved to be adequate for the limited amount of testing performed, the method was too costly, time consuming, and hazardous. Therefore, this research project, "Acquisition, Calibration and Application of a Skid Trailer", was begun on July 1, 1970 in an attempt to develop an economical, efficient, and safe system that could be used to determine the skid characteristics of highway pavements in Arkansas.

This goal was to be accomplished by meeting the following six objectives: 1) acquire or construct a skid trailer; 2) calibrate the equipment; 3) test existing surfaces; 4) test and recommend corrective measures for high or potentially high accident locations; 5) establish minimum frictional values; and 6) develop methods for application of skid technology on a statewide basis. As a result of several modifications to the research proposal and work plan, the modified project was conducted in four separate phases: 1) literature review and acquisition or construction of a skid trailer; 2) establishment of calibration and operation procedures; 3) establishment of a statewide inventory system; and 4) coordination with HRC-38, "Asphalt Surface Durability and Skid Resistance", and HRC-40, "Rapid Wear Track".

At the time this project began, the staff anticipated

that the following benefits would be realized: 1) reduced crew size; 2) reduced time required at each site to conduct each test; 3) reduced cost per test; 4) increased efficiency; 5) improved water delivery; 6) improved uniformity of each test; 7) improved accuracy; 8) increased mobility; and 9) improved safety.

Implementation of the results of HRC-29 is the continuation of the inventory system that was developed as part of this project. The skid resistance of all State highways are coded onto magnetic tape and are updated periodically by the Division of Planning and Research. This system provides a forewarning of highway sections approaching dangerous limits. Each District is notified promptly if any section of highway has a serious decline in skid resistance since previous testing.

## CHAPTER II

### SELECTION, ACQUISITION, AND OPERATION OF THE ARKANSAS SKID TESTING UNIT

#### 1971 EVALUATION OF SKID TESTING DEVICES

Since the method of testing has a profound influence on the value of skid resistance measurements, it was necessary that the Department select the most suitable unit for Departmental use.

The following table compares the various types of testers as to their suitability for research purposes and routine surveys.

SUITABILITY OF PAVEMENT FRICTION TESTERS FOR ROUTINE USE

CRITERION	PORTABLE TESTERS	STOPPING DISTANCE CARS	SKID TRAILERS
Meaningful measurement	Poor to good	Good	Good to excellent
Accuracy of test data	Good	Poor to good	Good to excellent
Data display	Indication	Indirectly derived	Recording
Test frequency	Poor	Poor	Good to excellent
Operating range	Poor	Poor to good	Good to excellent
Mobility and maneuverability	Good to excellent	Excellent	Poor to excellent
Traffic interference	Very high	High	Low
Ruggedness	Good	Poor	Good to excellent
Hazard to test crew	High	Very high	Low
Required test crew, minimum	1-2	3-4	1-2
<i>Procurement and operating cost:</i>			
Initial cost, average (\$)	900	3,500	10,000 to 25,000
Sites tested per day (no.)	8-12	15-25	100-400
Life expectancy (yr)	6	2	5
Maint. and direct cost per season (\$)	50	1,250	1,250
Total wages per season (\$)	4,200	8,400	4,200
Cost per site tested (\$)	3.45	4.70	0.32

\* Table from NCHRP Report No. 37



The conclusion drawn from the above information was that "skid trailers" are the most efficient, economical, and suitable means for determining friction coefficients of pavement surfaces.

#### COMPARISON OF TWO-WHEEL TRAILER UNITS

Results from the 1962 Tappahannock Correlation Study and the Florida Skid Correlation Study were examined to evaluate the degree of standardization which would be achieved by skid test trailers that were constructed in accordance with ASTM Standard, "Test For Skid Resistance of Pavement Using a Two-Wheel Trailer" (ASTM Designation: E174-65T). The Department concluded that: 1) many types of trailers are capable of accurately determining the coefficient of friction resulting from a steady state skid; 2) good agreement existed among trailers which included three different types of force measuring systems; and 3) good repeatability was achieved by the individual trailers. Even though a trailer might have the following characteristics: 1) good repeatability; 2) test results which correlate with skidding accident frequency or risk of skidding on all types of pavement surfaces and over the entire speed range of vehicular traffic; it is understood that frictional measurements under seemingly ideal conditions are affected by conditions beyond the control of the operator.

As a result of our analysis, the following ten requirements were incorporated into the design of Arkansas'

original tester (ST1):

- a) meaningful measurements
- b) precision of test data
- c) minimum data processing
- d) balanced coverage and test cycle frequency
- e) adequate range of operation
- f) high degree of mobility and maneuverability
- g) minimum traffic interference
- h) structural integrity
- i) economy of operation
- j) comfort and safety of crew

During 1971 several states that had skid-testing units were surveyed concerning their skid-testing unit. Based on information from our survey of the states and the fact that the Arkansas State Highway and Transportation Department was not properly staffed nor had adequate facilities for the construction of a skid trailer, the most logical, economical, and desirable alternative was to:

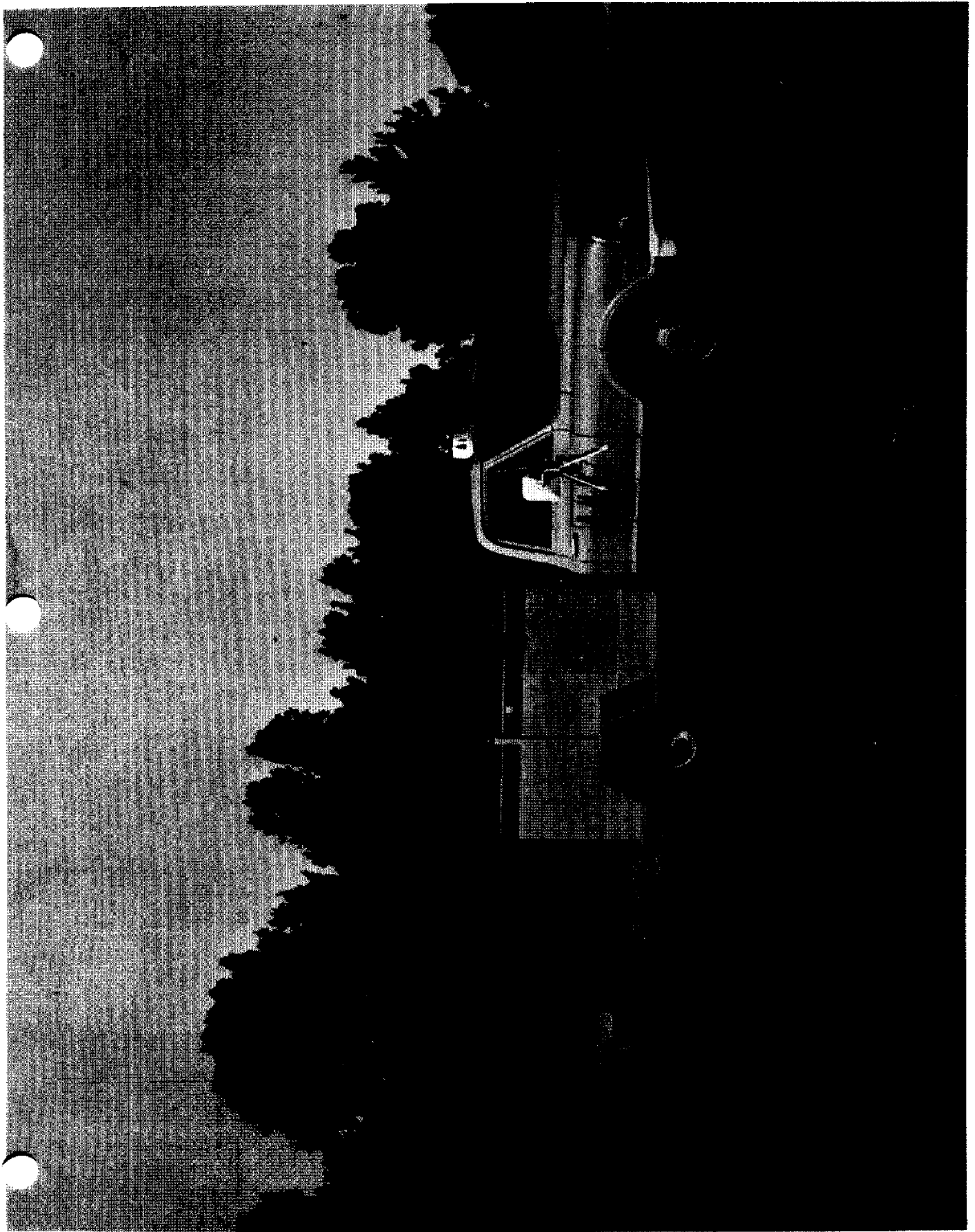
1. Requisition the tow truck from the Department's Equipment Division;
2. Secure from a local source, a water tank and body for the tow truck; and
3. Purchase a commercial model skid-testing trailer and necessary recording and control equipment, with provisions for the installation and hook-up of all components by a successful bidder.

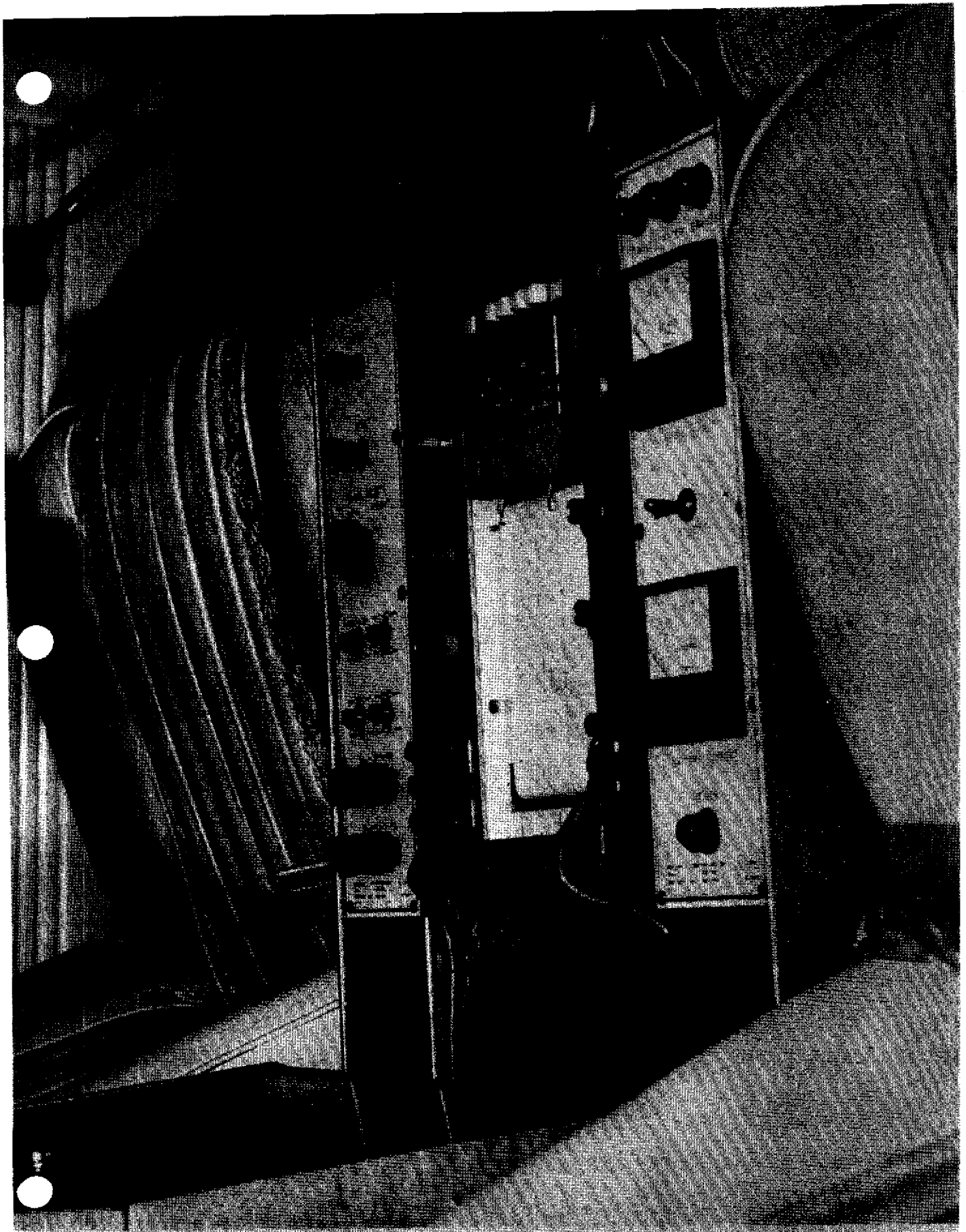
From the survey information, based on the most common use and satisfactory performance, a composite tow vehicle for a skid testing unit was characterized. This vehicle was to have a GVW rating of 10,000 pounds with a V-8 engine of at least 390 cubic inch displacement, standard cab, 4-speed manual transmission, single speed axle, and be capable of maintaining 65 mph test speeds when loaded.

This same approach was used for determining the most desirable characteristics of a skid trailer. Most of the trailers were designed to meet requirements of ASTM E274-65T, and therefore, were of the same basic design. Since the trailer design had to meet the ASTM requirements, the only decisions to be made were which components would be incorporated into the trailer. A detailed list of requirements and specifications are included in the appendices of this report.

#### SELECTION, ACQUISITION, & DESCRIPTION OF A SKID TESTING DEVICE

As a result of the information from the Department's survey of states with skid testing systems, previous studies, and technical reports on commercially built systems, the Department concluded that the only feasible manner of obtaining a skid testing system was to purchase a tow vehicle and then request bids from suppliers of commercially built trailers. Soiltest, Inc. of Evanston, Illinois was awarded the contract to supply the trailer, an ML 350-H, and all the necessary instrumentation. (In future references this skid testing system shall be referred to as ST1.) ST1 was constructed and operated in accordance with ASTM E274.





ST1 consisted of three main components (see Figures No. 1 and 2): 1) a towing vehicle, which carried a water supply, a pumping system and the instrument console; 2) a skid trailer; and 3) an instrument console which is mounted in the cab of the towing vehicle between the driver's and passenger's bucket seats. Included in the appendix of this report are a complete set of specifications, a brief description of ST1, as well as a summary of operational procedures.

ST1 was placed into operation on April 10, 1972.

#### PERFORMANCE OF SKID TESTING DEVICE

After ST1 had been in operation for several weeks, it became evident that ST1 did not have the capabilities or features that were required to conduct an efficient State-wide inventory program over an extended period of time. (A detailed description of the inventory program that was developed for Arkansas highways is included in another chapter of this report.) Some of the problems that were encountered included: 1) slow data reduction; 2) improper water tank location on the tow truck; 3) poorly sealed terminal box on the trailer; and 4) extensive maintenance to ST1.

Of the problems listed above, data reduction was the most frustrating and serious. As each skid test was run, the two-channel, strip chart recorder (as shown in Figure No. 2 and discussed in Appendix C) received an electrical input from the strain gauges in the transducer and then graphically

displayed the traction force as a strip chart trace. Since the data was recorded as a trace, an additional hour was required to interpret the results to arrive at an average skid number for each hour that was spent in the field collecting data. Interpretation of a single trace by two people often resulted in difference in the average skid number for a particular skid test. In addition, storage of the traces for later reference was impossible for obvious reasons.

The second problem that is listed above also had an adverse effect on the reliability of the data that was being recorded. When ST1 was designed, the water tank was located at the rear of the tow vehicle (see Figure 1), and as the quantity of water in the tank changed, the height of the trailer hitch also changed, which meant that the axis of the trailer was rotated so that it was not parallel to the direction of motion. This resulted in an error of up to 5 SN for each test.

Another area of concern in relation to the reliability of the data was that the relays in the terminal box on the trailer were almost impossible to keep dry. Whenever a heavy rain fell or whenever the humidity was high, the relays would become damp or wet. Several different methods and materials were used in trying to seal the box; however, only limited success was achieved. As with any electronic connection that gets wet, the relays transmitted faulty data to the strip chart recorder.

When ST1 went into service on April 10, 1972, its dependability was suspect. It was in the shop for repairs as much as it was working. This caused the operational cost per mile to be approximately \$0.82 per mile driven.

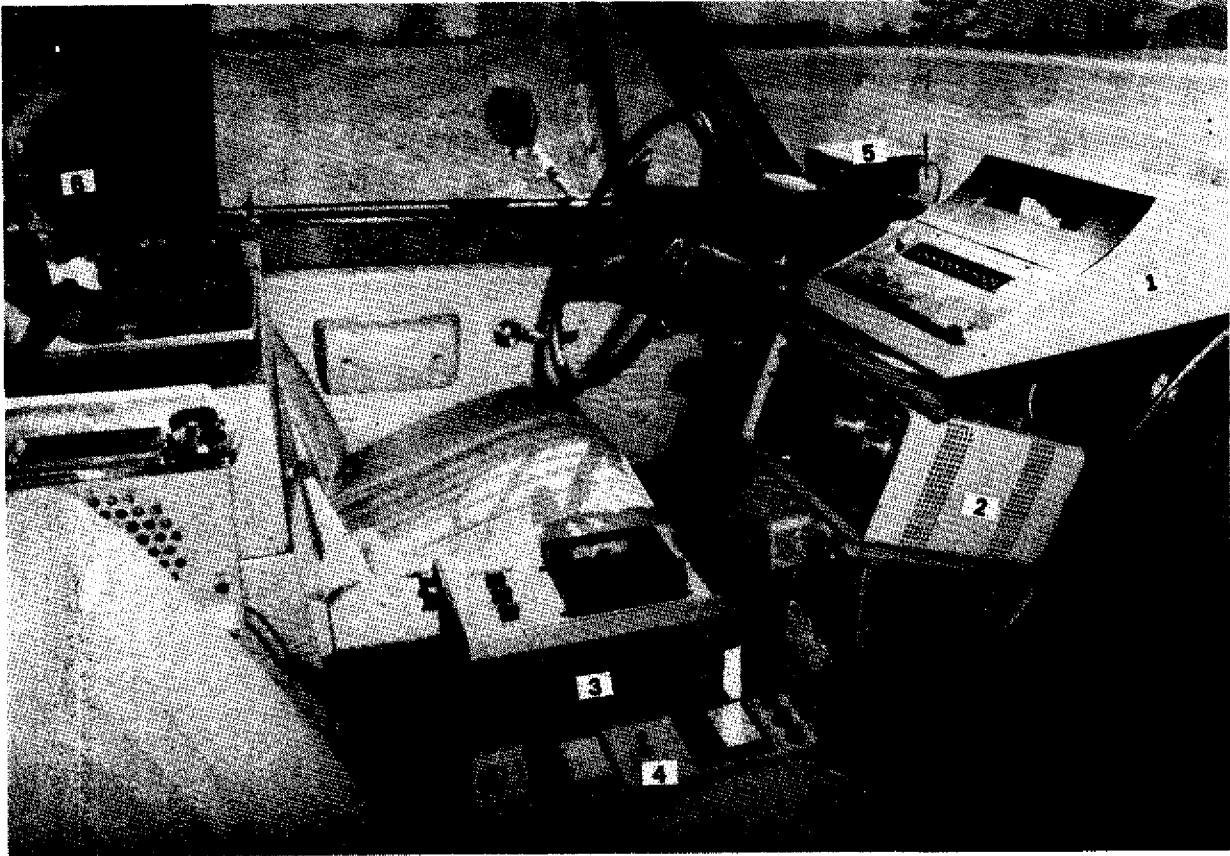
Therefore, it is easy to understand why the Department was disappointed in the performance of ST1, and had the system modified.

#### MODIFICATION OF SKID TESTING DEVICE

As stated in the previous section, ST1 had several characteristics which the Research staff decided would hinder the efficiency and reduce the effectiveness of a Statewide Inventory Program. ST1 was partially modified to eliminate these characteristics, to take advantage of advances in technology, and to reduce the overall cost of performing skid tests.

The first modification was made during the fall and winter of 1974. At that time a DL-12 Data Logging System (as shown in Figure 3) which was designed and built by Data System, Inc., replaced the two-channel, strip chart recorder (as shown in Figure 2). The DL-12 System primarily consists of two components: 1) a SN computer; and 2) a 12-column digital printer. Since the SN computer analyzed the analog signal from the strain gauges, computed and printed an average skid number, a significant manpower

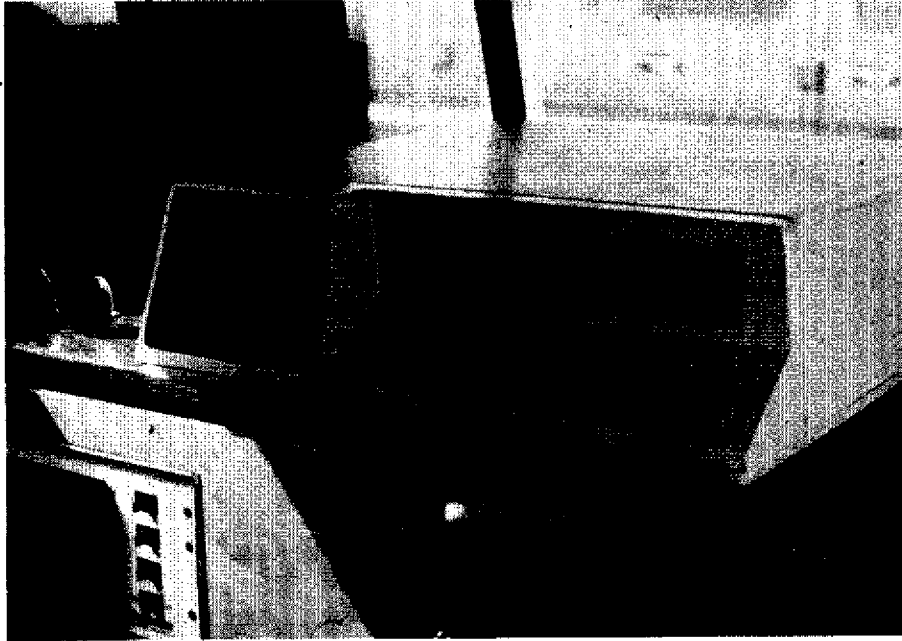




COMPONENT POSITIONING IN MODIFIED SKID TESTING UNIT

1. 12-Column Digital Printer
2. SN Computer
3. Memodyne Data Logger
4. Primary Control Panel
5. Velocity Indicator
6. Flow Meter

FIGURE 3



MICROCOMPUTER IN INVENTORY UNIT

FIGURE 4



INVENTORY UNIT

FIGURE 5

savings has been realized in analyzing the data. This modified skid testing device was used to develop the procedures that are currently being used to conduct the statewide inventory. (These procedures will be discussed in later sections of this report.) Even though this unit is still used to check spot locations, a newer, more advanced skid testing unit was designed and built for the inventory program. Except for this brief statement and Figures 4 and 5, no other reference will be made to this unit since it was developed under a different contract.

Due to excessive down time which was caused by failures of various components, the trailer was only operational approximately 50% of the time. The Department was not satisfied with the trailer's record; so the University of Arkansas' Mechanical Engineering Department was contracted to design and construct a skid testing system which conformed to ASTM Specification E274-70. The system (as shown in Figures 6 and 7) has been in operation since October, 1977, and has been reasonably reliable in its performance. A detailed description of the trailer design and construction can be found in Dr. Jack H. Cole, Mr. James G. Gleason, and Mr. James L. Dale's report, "The Design and Construction of a System Utilizing a Trailer to Measure Skid Resistance of Paved Surfaces", which is available from AHTD or NTIS.

The third modification of ST1 was the installation of a Memodyne Data Logger (a magnetic cassette tape recorder). Additional information will be included in the Data Storage

Section of this report.

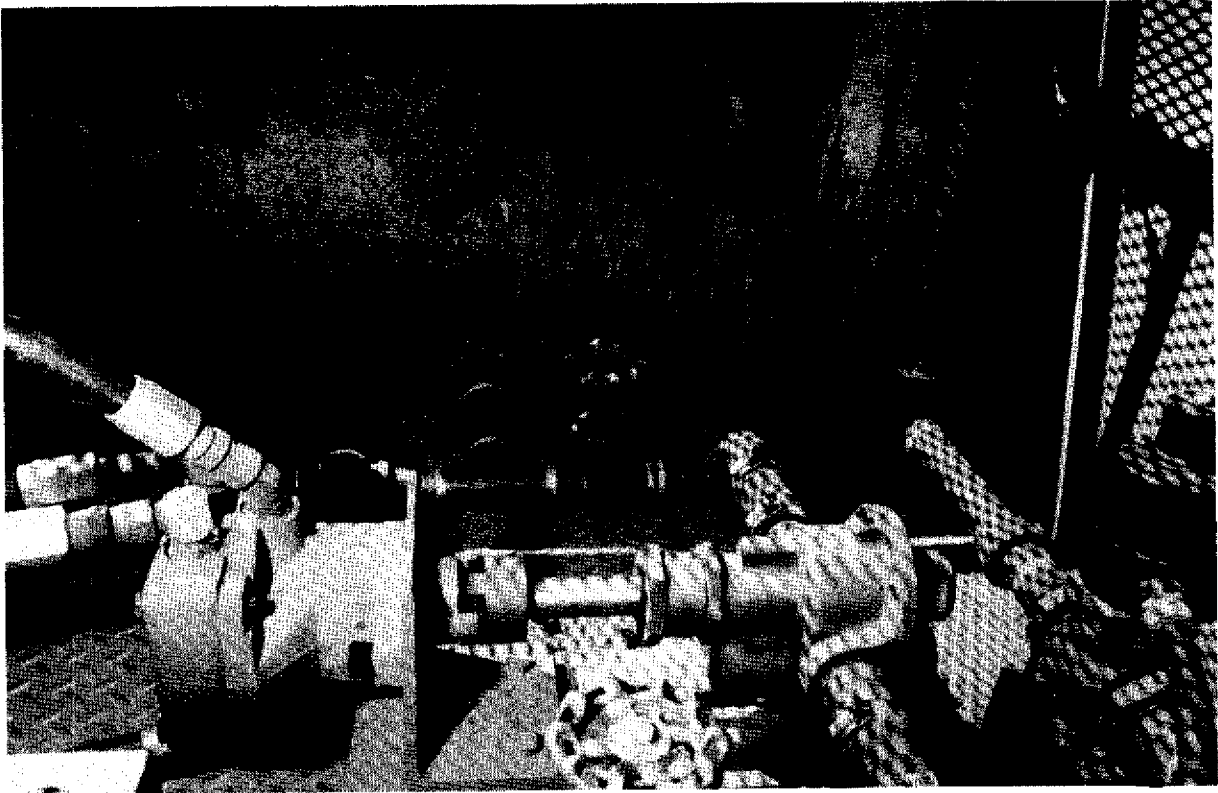
A detailed equipment cost list is provided in Appendix A of this report. The original skid unit, as well as all modification costs, are included in the list.



MODIFIED SKID TESTING UNIT: TRAILER AND WATER DELIVERY SYSTEM  
DESIGNED AND BUILT BY UNIVERSITY OF ARKANSAS  
DEPARTMENT OF MECHANICAL ENGINEERING

1. Water Tank
2. Hose to Nozzles from Water Tank
3. Fifth Wheel for Speed and Distance Measurements
4. Water Delivery Nozzle
5. Compartment Containing Water Pumps (Figure 7)

FIGURE 6



WATER PUMP COMPARTMEN

FIGURE 7

## CHAPTER III

### DEVELOPMENT OF A STATEWIDE SKID INVENTORY PROGRAM

The Statewide Skid Inventory Program that is currently being used by the AHTD's Division of Planning and Research was developed for the three following reasons: 1) a recognized need to maintain a reliable record of potentially high accident locations; 2) the need to provide the Department's maintenance personnel with an additional method of identifying hazardous locations that require maintenance; and 3) the Federal Highway Administration's Instructional Memorandum on Skid Accident Reduction which required that a comprehensive, as well as continuing, Skid Inventory Program be established by January 1, 1975.

For the inventory to be of value, blanket type coverage of all highways in the State was required. Several factors were considered by the Research staff during the evaluation and development of the Inventory Program: 1) 15,000 miles of State highways were to be inventoried; 2) 10,000 miles of paved county roads and city streets eventually needed to be inventoried; 3) a limited amount of fiscal resources would be available to purchase, operate and maintain the operation; 4) type, amount, and method of data to be collected during the testing phase; 5) data storage and retrieval; 6) complexity of equipment operation during data collection; 7) frequency of tests; 8) direction of testing;

9) routing of tests; 10) number of individuals needed to operate each phase of the program; 11) rate that data could be collected; and 12) establishment of specific reference points so skid numbers could be evaluated for any given section of highway.

The approach that was selected consisted of a two-man crew completing the inventory in one county at a time. As a result of this approach, a realistic time table for completing the skid inventory could be established, maintained and modified if needed. A Research crew tested the approach and concluded that, in most cases, one week per county provided more than enough time to complete the skid inventory in each county. By applying the schedule, approximately 75 to 80 weeks would be required to complete the inventory, if no major difficulties arise. (Weather and equipment malfunctions have caused long delays in completing the inventory.) A central location in each county was selected, and the inventory crew tested to the county line in a "spider web" type configuration. The inventory began in Miller County and moved east until the southern counties had been inventoried. The next row of counties would then be inventoried by moving toward the west.

Skid tests are made every  $1/2$  lane mile in each direction, and the tests are staggered every  $1/4$  mile (as shown by Figure 8). Thereby, four tests per mile are obtained. In the event of a bad test, another will be run immediately after the bad test cycle is completed. Special tests may



also be made on changes of surface type. All skid testing is conducted in accordance with ASTM Specifications.

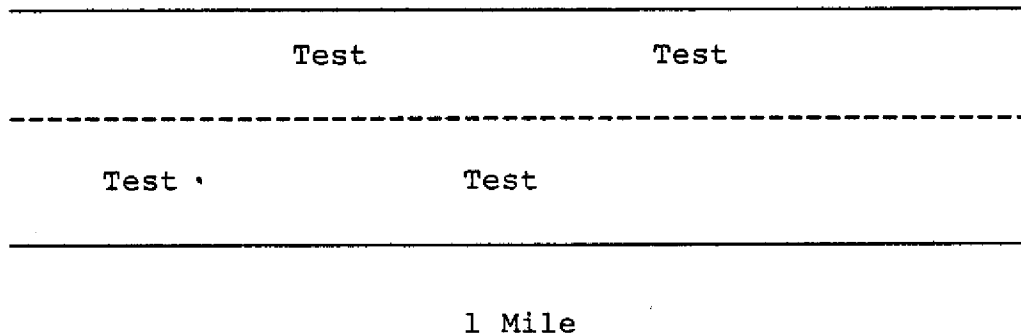


FIGURE 8

#### DATA STORAGE AND RETRIEVAL SYSTEM

Any discussion of the data storage and retrieval system must begin with a brief discussion of the data that is collected by the skid inventory unit. An example of the data is illustrated in Figure 9. As shown in Figure 9, the data is divided into two categories, a twenty-four digit identity code and a twelve digit skid code.

The identity code is the name which makes a particular set of data unique. A complete description of the highway section is contained within the code. For example, the code is comprised of nine definitive parameters: 1) district number; 2) county number; 3) route number; 4) section designation; 5) alternate section designation; 6) direction of data collection; 7) date of data collection; 8) time of data collection; and 9) pavement temperature. Prior to the start of

# TYPICAL SKID INVENTORY PRINTOUT

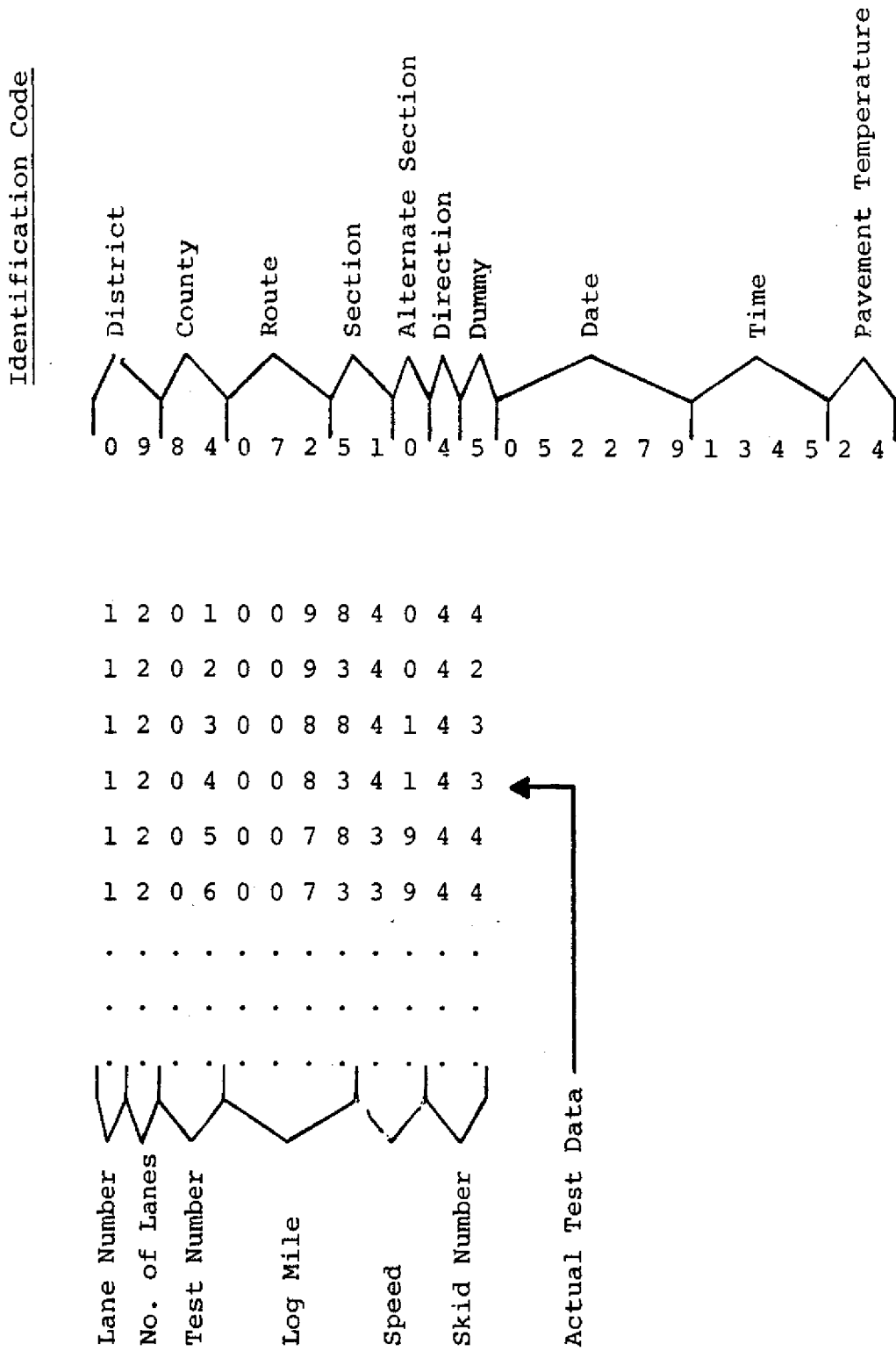
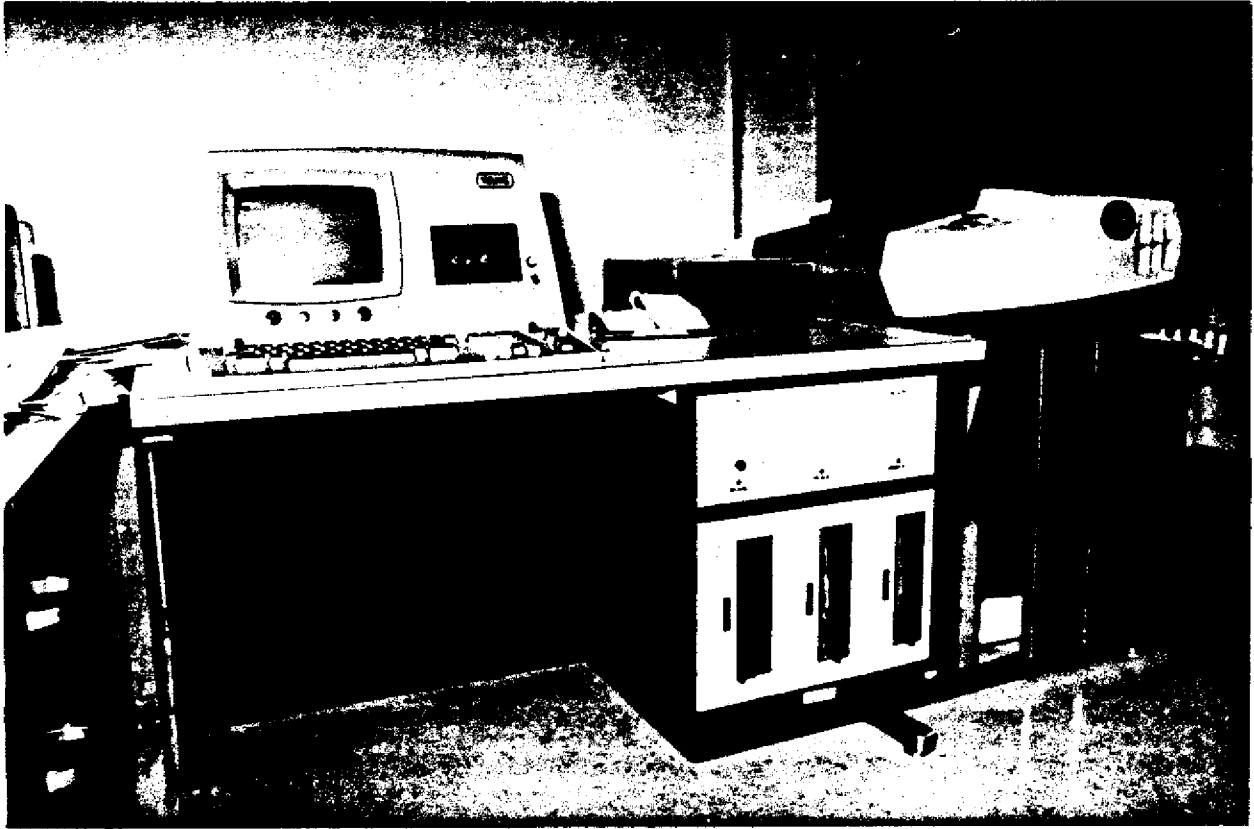


FIGURE 9

data collection for a highway section, the inventory crew inputs the identity code into the inventory data collection unit in digital form which is then printed on paper tape printout and stored on the magnetic cassette tape.

After each skid test is completed, the skid code is printed on a paper tape printout and stored on magnetic tape for future use. The twelve digit skid code provides six distinct and necessary pieces of information: 1) lane number; 2) number of lanes; 3) test number; 4) log mile; 5) speed; and 6) average SN.

Upon completion of tests in each county, the cassettes and paper printouts are forwarded to the Planning and Research office for editing and processing. A Wang Mini-Computer, Model 2200T (as shown in Figure 10) is used for this purpose. In addition, it is used for transferring the data to diskettes for storage. Programs were developed to retrieve data by route, by county and route, and any other special data configurations which may be required.



DATA STORAGE AND RETRIEVAL SYSTEM

FIGURE 10

## CHAPTER IV

### COORDINATION OF HRC-29, "SKID PROGRAM" WITH HRC-38, "ASPHALT SURFACE DURABILITY AND SKID RESISTANCE" AND HRC-40, "DESIGN, CONSTRUCTION, AND EVALUATION OF A RANDOM PATH RAPID WEAR TRACK"

Two projects, HRC-38 and HRC-40, were already underway when this project was revised in 1975. Both of these projects dealt with topics which were either directly or indirectly connected with skid resistance. Therefore, it was logical for the work activities of all three projects to be coordinated throughout the life of each project.

"HRC-38 was a four-year investigation of the durability and skid resistance of existing asphalt concrete hot mix pavements. The study included field and laboratory evaluation of the polish characteristics and stripping resistance of 18 most commonly used mineral aggregates in Arkansas. Aggregate polishing was accomplished by a small circular wear track that was designed to polish 12 Marshall size specimens at one time, with in-place specimen frictional measurements obtained by a British Portable Tester. The laboratory work included tests of aggregate cast in polyester, Marshall specimens, and pavement cores. The asphalt mixtures were evaluated for their Marshall stability and immersion-compression retained strength. The principal findings are as follows: 1) the field tests results indicated a good correlation between SN40 and BPN values; 2) the laboratory tests yielded a good correlation between the Texas

polish value from the British wheel and the Arkansas polish value from the accelerated circular track; 3) a good correlation was obtained between the BPN (field) value and the Arkansas polish value (laboratory); 4) polish tests on cores indicated that most cores had a higher polish value than was shown from the parent coarse aggregate in the Marshall polish test (the difference in these values was attributed to the fine aggregate that was used in the actual paving mixture); 5) the data indicated that the Arkansas accelerated polish test results on asphalt mixtures can be used to estimate minimum SN40 values of the mix in the pavement".<sup>1</sup>

Dr. Miller Ford of the University of Arkansas, Department of Civil Engineering, conducted the research for the Department, and any additional information is available from Dr. Ford, the Department, or the HRC-38 Final Report, "Asphalt Surface Durability and Skid Resistance", which was published in 1978.

HRC-40 was to be a fifty-four month study to determine the aggregate's influence on the wear characteristics of asphalt concrete hot mix and Portland cement concrete pavements which is one variable that does influence skid resistance. To accomplish this task, Dr. Jack Cole, Mr. James Gleason, and Mr. Jack Helms of the University of Arkansas' Department of Mechanical Engineering designed and constructed a random path rapid wear track which would accelerate the

<sup>1</sup> Ford, Miller C., Jr., Asphalt Surface Durability and Skid Resistance - Investigation, Civil Engineering Department, University of Arkansas, Final Report, March 1978.

aggregate wear. A final report on the design and construction of the wear track was published in August, 1975. Due to several serious problems in the hydraulic system, the system was modified by Dr. Cole and Mr. Gleason. The modified rapid wear track will be discussed in the pending final HRC-40 report. Operational problems with the wear track prevented coordination of work activities with this project.

CHAPTER V  
CONCLUSIONS

1) The initial skid testing unit was adequate for developing and testing procedures to be used in the Inventory Program, but was not sufficient to implement the Inventory Program.

2) A newer and improved skid testing unit is recommended to implement the Inventory Program.

3) The procedures developed for collecting, storing, and analyzing skid data have proven to be excellent in meeting the Department's needs.

4) The skid Inventory Program has improved the Department's method of determining priorities for overlaying State highways.



CHAPTER VI  
IMPLEMENTATION

The Statewide Skid Inventory Program that was developed as part of this research project has been incorporated into the Department's overall Inventory Program of streets and highways. The initial Skid Inventory Program has been completed, and the results have been used to identify highways or portions of highways where work is needed to correct deficiencies. As changes to data collection and storage procedures are needed, a modification of skid inventory procedures is made.

## BIBLIOGRAPHY

1. McCullough, F. F. and Hankins, K. D., "Development of a Skid Test Trailer", Texas Highway Department, April, 1965.
2. Stone, J. and Gulden, W., "Skid Resistance of Highway Pavement Surfaces", Georgia Department of Transportation, June, 1974.
3. Ford, M. C., "Asphalt Surface Durability and Skid Resistance", University of Arkansas, March, 1978.
4. Cole, J. H., Gleason, J. G., and Dale, J. L., "The Design and Construction of a System Utilizing a Trailer to Measure Skid Resistance of Paved Surfaces", University of Arkansas, January, 1976.
5. Csathy, T. I., Burnett, W.C., Armstong, M.D., "State of the Art of Skid Resistance Research", Highway Research Board Special Report 95, 1968.
6. Beaton, J.S., "Providing Skid Resistant Pavements", Transportation Research Board Record 622, 1977.
7. "Skid Resistance", National Cooperative Highway Research Program Synthesis of Highway Practice No. 14, Highway Research Board, 1972.
8. Giles, C. G., Sabey, B. E., Cardew, K. H. F., "Development and Performance of the Portable Skid-Resistance Tester", STP 326, American Society for Testing and Materials, 1962.
9. Hankins, K. D., "A Program for Reducing Skidding Accidents During Wet Weather", Transportation Research Board Record 622, 1977.
10. Gramling, W. L. and Hopkins, J. G., "Skid Resistance Studies: Aggregate-Skid Resistance Relationship as Applied to Pennsylvania Aggregates", Pennsylvania Department of Transportation, May, 1974.
11. Stocker, A. J. and Albert, J. W., "Comparison of the Ohio State University and Penn State University Skid System Water Nozzle", Texas Transportation Institute, August, 1977.
12. Stapler, W. T., Stone, J. S., and Chase, H.D., "A Skid Resistance Study of Georgia Pavements", Georgia Highway Department, December, 1970.
13. Rushing, H. B., "Skid Resistance Study", Louisiana Department of Highways, October, 1968.

14. Mullen, W. G., Whitfield, J. K., Gibson, D., Cahoon, T., Dixon, W., Robinson, J., "Surface Wear and Skid Resistance Properties for Portland Cement Concrete Pavements", North Carolina State University, May, 1974.
15. "Highway Skid Resistance", ASTM Special Technical Publication 456, American Society for Testing Materials, October, 1968.
16. "An Analysis of the Literature on Tire-Road Skid Resistance", ASTM Special Technical Publication 541, American Society for Testing Materials, July, 1973.
17. Walter, W. C., "Skid Resistance Study", Louisiana Department of Transportation and Development, June, 1977.
18. Bigelow, N., "Skid Trailer Construction", Maine State Highway Commission, November, 1969.
19. Sandvig, L. D., Macgregor, L. M., and Shaffer, R. K., "Development and Results of a Skid Research and Road Inventory Program in Pennsylvania", Pennsylvania Highway Department, August, 1968.
20. Ganung, G. A., "Development and Implementation of a Skid Test Program in Connecticut", Connecticut Department of Transportation, April, 1971.
21. "Revised Skid Code Manual", Texas Highway Department.

APPENDIX

APPENDIX A

COST

The cost of each piece of equipment contained in the skid inventory unit and the data retrieval system is as follows:

<u>Item</u>	<u>Description</u>	<u>Cost</u>
1	1972 Chevrolet Truck Chassis	\$ 3,852.00*
2	Skid Trailer ML 350-HX (Soiltest, Inc.)	23,230.00
3	Water Tank & Body	1,700.00
4	DL-12 Data Logging System (Data System Inc.)	3,440.00
	12 Column Data Printer	
	SN Computer	
	Digital Readout	
	Automatic SN Computation	
	Push-Button Print Command	
5	Skid Trailer (University of Arkansas)	22,400.00
6	Body and Water Tank	1,759.00
7	Memodyne Data Logger	2,493.00
8	Memodyne (Installation)	1,030.00
9	Wang 2200T	11,663.00
10	Printer 2221W	5,085.00
11	Floppy Diskette	6,295.00

The original skid testing unit cost \$28,782; the first modification cost \$3,440; and the second modification cost \$27,682. Cost of the data storage and retrieval system (Items

\*Note: All prices are actual dollar values and are not based on a base year dollar comparison.

8, 9 and 10) was \$23,043. Funding for the second modification and data storage and retrieval system was through the Arkansas Governor's Office of the Coordinator of Public Safety.

Due to equipment failure, the operational cost of the skid testing unit has averaged \$0.82 per mile. All cost of operating and maintaining the unit was included in determining the operational cost.

## APPENDIX B

### DESIGN CRITERIA AND SPECIFICATIONS

#### A. Towing Truck:

Information from 28 states was investigated to determine the type, size, make and other pertinent data on tow trucks currently in use. It was found that a wide variety of vehicles from light station wagons to heavy trucks are currently being used. Some states preferred to have a light weight vehicle with maximum horsepower engine in order to achieve test speeds rapidly and with a minimum of effort. Others, preferred the heavy trucks which were more cumbersome to handle, accelerated more slowly, but maintain a constant speed during the test because of greater mass.

The states using the lighter weight trucks did not indicate any safety problems due to undesirable swaying, even though some reports had mentioned this as a reason for selection of heavier units. After considering the various possibilities, it is proposed that we use a one-ton truck powered by a V-8 gasoline engine, standard cab, manual transmission, single speed rear axle and other special equipment necessary to control and operate the skid-trailer. Detailed specifications include:

1. Capacity: Manufacturer's gross vehicle weight rating of 10,000 lbs.
2. Net Design Payload: Minimum of 5,000 lbs.
3. Wheelbase: Shall be at least 125 inches and no more than 133 inches.
4. Engine: Shall be an eight cylinder model of not less than 390 cubic inches displacement and develop not less than 225 net horsepower at manufacturer's rated speed. Shall be equipped with a mechanically operated tachometer. The engine shall have sufficient output, in conjunction with the selected transmission and rear axle ratio, to maintain 70 mph when testing on a pave-

ment surface having a skid resistance of 75 SN and when fully loaded (i.e., full crew, water tank filled and required load on trailer).

5. Cooling System: Shall be equipped with heavy-duty radiator to provide adequate cooling.
6. Transmission: Shall be 4-speed heavy duty synchromesh.
7. Front Axle: Shall be solid "I" beam-type with a rated capacity of not less than 3,500 lbs.
8. Rear Axle: Manufacturer's rated capacity not less than 7,200 lbs. Single speed with dual wheels and shall be capable of a top test speed of at least 70 mph.
9. Types of Wheels: Seven only steel, disc, with proper rims for tire equipment furnished. Not less than the standard SAE specified tire chain clearance of 1.65 inches shall be maintained between dual rear tires and between inside dual tires and springs or other chassis parts.
10. Tire Equipment: 7.50-16 8-ply rating, tube-type, same size all around, dual in rear. One spare shall be supplied mounted on spare wheel.
11. Brakes: Air over hydraulic.
12. Steering Gear: Equipped with hydraulic power assist.
13. Cab: Manufacturer's standard type cab, steel enclosed, with two doors. Two bucket seats having no less than 19 inches between them.

The following items, supplementing if necessary those items already cataloged as standard cab equipment, shall be furnished and in place:

- a. Air conditioning: Deluxe factory air conditioner (necessary to control instrument temperature and dust).



- b. Deluxe fresh-air heater with windshield defrosters.
  - c. Two (2) outside rear view mirrors (West Coast Jr's.).
  - d. Dual, windshield washers
  - e. Two (2) arm rests
  - f. Dome light
  - g. Floor mat and headlining
  - h. Directional lights
  - i. Warning lights
14. Electrical System: Shall be a 12 volt system with a two belt driven 65 amp heavy-duty alternator with built-in silicon rectifier and matching regulator. Wiring shall be adequate to handle full output of selected alternator.
- Two (2) heavy-duty batteries of not less than 66 plates, 70 amp hr. shall be furnished. Extra 12 volt battery shall be installed for furnishing power to the recorder and other systems through a frequency controlled solid-state inverter.
15. Gasoline Capacity: Not less than 30 gallons. (Location of rupture proof tank shall be outside of cab.)
16. Body: Bare chassis on rear.
17. Accessories and Special Equipment:
- a. Substantial front bumper (heavy duty steel attached to frame).
  - b. Heavy duty suspension
  - c. Jack - 8 ton capacity
18. Water Tank and Body: Capacity of water tank shall be at least 60 cu. ft. Baffle plates of the same size shall be inserted to divide the tank into four equal compartments to prevent turbulence and load shift when truck is in motion. All interior surfaces shall be coated for corrosion resistance. A two (2) inch shut-

off valve will be installed to control water flow from tank. Manholes at the top of the tank will provide access for cleaning the tank interior. Hinged cap will be used for filling purposes. (See sketch of tank for more details). The final design will be completed after determining which tow truck is obtained. Basically, the outside dimensions will be approximately 60 x 102 x 24 inches with steps 8" wide on each side.

19. Power take-off for water pumps - The power take-off on truck shall deliver approximately .20 horsepower, 1300 RPM at 40 miles per hour. The power take-off shall be set up for speed proportional to the rear wheel speeds and not proportional to engine speeds. (Note - a chelsea type PY-41R-C3E, is normally used on F-600 Ford with 5-speed forward transmission.)

APPENDIX C

ARKANSAS

STATE HIGHWAY DEPARTMENT

Division

of

Planning and Research

SPECIFICATIONS

for

Skid Testing Trailer

Project No. HRC-29

Skid Testing Trailer:

1. General - Information from 26 State Highway Departments on design and specifications of their skid testing trailers has been reviewed and analyzed. We found that many of these trailers are of the same basic design but have minor differences as necessitated by the needs or desires of each state. After considering the various possibilities available, it is proposed that the unit consist of a two-wheel towed trailer incorporating a water laying system for spreading water under the tires, a braking system for applying the braking action, strain gauge bridges (transducers) used in measuring skid resistance, and pavement skid-test tires. The testing unit must be designed to meet all requirements of ASTM-E274-65T (latest revision).
2. Trailer Specifications - Detailed specifications will include the following:

The trailer shall be a two wheel side by side design of rugged construction, the vertical center of gravity shall be less than 22 inches above the tire-road interface. The distance between the center line of the wheels shall be  $60 \pm 5$  inches. The tow hitch shall be midway between the wheels transversely and 100 inches longitudinally ahead of the axle center line. It shall be as low vertically as practicable and in no case higher than the wheel center line height. A hinged stabilizing strut with a caster shall be provided for supporting the trailer near the hitch point when it is uncoupled from the towing vehicle.

The trailer design shall be such that the service load on each wheel will be 1085 pounds  $\pm$  25 pounds and a down load of from 100 to 200 pounds will result at the hitch point.

The trailer axle shall be such that shoe-brakes can be accommodated. The wheel suspension shall be such that both springing and shock-strut damping will be provided.

The shoe brakes shall be hydraulically actuated with air over the hydraulic system. They shall be capable of locking either or both wheels in  $\frac{1}{2}$  second holding for the duration of the test (normally 2 seconds) and releasing the brakes in  $\frac{1}{2}$  second. Provisions must be made so that either the left wheel or the right wheel can be locked independently or both may be locked simultaneously. Brakes will be automatically applied during test through manually preselection on the selector switch. Torque developed by braking action is sensed by two balanced bridge strain gauge systems, one at each wheel of the trailer, mounted on aluminum torque tubes placed concentrically around the trailer axle inboard of each wheel. Output from these strain gauges feeds to the electronic control and recording system. Measurement of braking action torque curve expressing the skid-resistance force exerted by the tire-pavement contact.

Provision shall be made to provide an interconnection between the towing vehicle brakes and the trailer brakes so that they will be actuated simultaneously during cross country travel when testing is not in progress.

The tires shall be the standard tire for pavement tests, ASTM specification E-249. Two spare wheels complete with rims, tires and valve stems shall be mounted on the trailer.

A safety chain must be provided at the trailer hitch that is capable of holding the trailer in case of hitch failure. Fenders will be provided for the wheels of the trailer. A removable protection cover for the trailer will be provided. Running lights and safety lights should be provided as required by Arkansas and Federal Safety laws. Easily operated disconnects shall be provided between the trailer and the towing vehicle for the water, air and electronic circuits.

Spray nozzles shall be mounted on the trailer and connected to the water supply on the towing truck with flexible hose so that water can be sprayed in front of the test tires, either right or left or both at the same time. They must be so mounted that they can be raised when not being used and will swing upward if they should hit any unexpected object on the pavement to protect them from damage. Flexible connections are to be provided where necessary to prevent stresses from being transmitted to the pump or valves.

The nozzle configuration shall be such that high velocity water jets are directed toward the pavement surface at an angle that will produce a minimum splash and that water is not applied directly to the tread of the test tire. The water layer thickness shall conform to specifications in ASTM-E274 (latest revision).

The suspension system shall consist of coil springs and shocks adjusted so that when the trailer is properly loaded and level the wheel center-line height is never lower than the tow hitch.

C. Recording Instrumentations:

The instrumentation necessary to control and record all phases of skid testing shall include the following major components: control head (including the timer); instrument panel; two channel recorder; water pumps; skid trailer instrumentation (including the strain gauge bridges).

A solid state timer shall be provided so that the driver of the towing vehicle after making the proper settings can throw one switch and all the equipment necessary to be actuated during a test will be actuated in the proper sequence and for the proper duration. The proper sequence shall include all phases of skid test--application of brakes, release of water, control of recording devices--programmed through custom-designed multiflex timer with vernier controls for pre-selection of automatic timing. Automatic timing shall be accurate to  $\pm 1/100$ th second on vernier control. The recorder sensitivity shall be at least 10 mv input for full scale deflection.

The strain in the braking system will be measured by strain gauges (transducer) mounted on the aluminum torque tube concentric to each axle, that is between the brake drum housing and axle housing. Output from the strain gauge bridges with a regulated DC power supply is fed to the two-track recorder. The speed will be obtained from a DC electrical tachometer generator that is driven by a take off from the towing vehicle's speedometer driver.

The recorder shall be a specially modified two-channel pressurized

ink recorder with two event markers. Speed of response shall be such that not more than one second is required for full scale deflection. All controls are preset. A dual chart drive allows use of the recorder during test operation or in static condition. During tests, the chart shall be driven at a speed proportional to the tester speed by a speedometer-cable takeoff which is energized by a solenoid clutch--assuring that paper is consumed only during test cycles. When the skid tester is not in operation a motor drive can be used to move the charts for static calibration and testing. A third pen marks a reference pulse on the chart, as the last event in the sequence of actions comprising one test. The reference pulse shows reference calibration of the output obtained and also the speed at which the test was made.

The instrument console will be mounted between the driver's and passenger's custom bucket seats in truck cab. It will house the main fuse, ammeter, voltmeter, and recorder (timer is in a separate, tamper-proof cabinet). Also, included will be circuit lights for the tester, timer, water system and brakes and manual control switches to start, defeat, and stop the test sequence and select right, left, or both wheel brakes. Console will be designed to allow installation of additional, expanded circuitry and more controls and instrumentation.

#### D. Electrical System:

The electrical power for the recorder and other systems will be supplied by a frequency controlled solid-state inverter mounted in the vehicle cab and powered by a separate 12-volt battery system. When the test system is in operation, provisions will be made to disconnect the power-supply battery from the truck electrical system, to assure that

the test system receives nonfluctuating power. Provision will be made to tie the power supply battery into the trucks electrical system during the time the recorder is not operating.

E. Water Pumps:

The water pumps are to be a positive-displacement type, that delivers water to the water-laying system, proportional to the forward vehicle speed. The pump unit is mounted in the towing truck beneath the water tank.

F. Other Requirements:

The instrumentation system shall conform to the following overall requirements at ambient temperatures between 40 and 100°F.

Overall system accuracy  $\pm$  3% of full scale

Time stability 10 hours minimum

The exposed portions of the system must tolerate 100% relative humidity and all other adverse conditions such as dust, shock, and vibrations which may be encountered in highway operation.

The vehicle speed measuring instruments shall provide an accuracy better than 0.2 mph over the expected range of operation.

The instrumentation must be capable of operating under the vibration conditions normally encountered in the towing vehicle. This will require rugged construction and ability of the marking system to operate properly under vibration.



## RECOMMENDATIONS

The following recommendations are based first, on the needs of the Arkansas Highway Department as compared to the budgetary resources available, and secondly, on the vast experience of several states engaged in skid-testing activities. Therefore, we recommend that:

- A. The Equipment Division procure a tow truck that meets the specifications contained in part III of this report.
- B. The Equipment Division obtain and install a combination water tank and body on the tow truck. (Specifications in part III).
- C. The skid-testing trailer and associated equipment needed for a complete testing unit be obtained from a commercial source.
- D. The successful bidder, furnishing the skid-testing trailer, shall install all equipment required on tow truck and trailer, calibrate and check out the completed unit. Items c and d will be awarded as one contract.

APPENDIX D

ARKANSAS STATE HIGHWAY DEPARTMENT

Division of Planning and Research  
Specifications  
for  
Skid Number Computer and Printer

GENERAL DESCRIPTION: The skid number computer and printer is to be used with an existing skid test trailer conforming to ASTM-E274-65T specifications. The equipment must be capable of receiving and processing raw data obtained from strain gauge torque transducers or from a modified Gould Brush two channel strip chart recorder model Mark 220.

The specified equipment must be capable of rapid acquisition and recording friction data, calculating skid numbers and displaying the skid numbers digitally and in printed form. The printer must accept at least ten (10) columns or digits of information through preset inputs by thumb-wheels or other acceptable means. These inputs will be used for highway number, direction of travel, date, lane number, log mile or any other bits of predetermined information selected by the system operator. The printer must be capable of reproducing this information an infinite number of times until reset by the operator.

GENERAL SPECIFICATIONS: General specifications for the equipment are as follows:

- |                    |   |
|--------------------|---|
| Power Requirements | : 115-120 VAC, 60 Hz sine wave, 40 watts maximum during printing.   |
| Signal Input       | : Single ended analog raw force data or unprocessed strain gauge transducer SN data. Brake signal nominal + 12 VDC @ 1.0 amp.       |
| Dimensions         | : The unit(s) must be small enough to mount in the vehicle for compatible installation with existing equipment and instrumentation. |

Weight : No greater than 30 lbs. gross.

PRINTER SPECIFICATIONS:

Data Columns : 12 per line consisting of; 10 columns thumbwheel data entry by operator. 2 columns - computed skid number.

Printout : Paper tape, pressure sensitive, 3.375 inch width, characters - .110 inch high, .100 inch wide, spacing between columns - .275 inches. (Over 40 lines/foot of tape)

Data Format : 1-2-4-8 BCD, positive true logic. Column suppression - logic "1".

Conversion Time, Analog to Digital : Thumbwheel data - none. Raw traction force data or unprocessed SN data - 400 milliseconds maximum.

Print Rate Versus Temperature : Intermittent duty, 100 consecutive lines at 25% duty cycle @ +20°C for 2.5 lines/second. Continuous duty, 100% duty cycle @ 0°C to +40°C for 1 line/second.

COMPUTER SPECIFICATIONS:

Computation Format : 
$$SN = \frac{F}{W - \begin{bmatrix} h \\ I \\ F \end{bmatrix}} \times 100$$

Input Impedance : Greater than 100 K Ohms.

Input Polarity : Positive. Single ended analog.

Front Panel Digital Display : Skid Number. Display remains in memory until reset.

Digital Readout Accuracy : 0.5% of reading + or - 1 least significant digit over a temperature range of 0°C to +40°C. Temperature coefficient - better than 150 ppm/deg.C.

Timers : Strictly solid state.

Timing Sequencing

: Sampling to begin 0.5 seconds after  
brake initiation. Sampling period -  
1.0 seconds.

Timing Accuracy

: At least 0.5% of longest timer.



## APPENDIX E

**SOILTEST, INC.**2205 LEE STREET  
EVANSTON, ILLINOIS U.S.A.

SUBSIDIARY OF CENCO INSTRUMENTS CORPORATION

TELEPHONE 312/869-5500

CABLE: SOILTEST, EVANSTON

**OPERATING INSTRUCTIONS**

MODEL	DESCRIPTION	DATE
ML-350E & ML-350H	SKID TESTING TRUCK AND TRAILER	4-5-71

SEC. 1-1 - GENERAL DESCRIPTION

The Soiltest Skid Tester is designed for the purpose of measuring the amount of resistance to skidding presented to tires by road surface material.

Two models are available:

ML-350E with electric drum brakes

ML-350H with air over hydraulic disc or drum brakes

In general, this instruction manual is applicable to either model, except where specially noted.

SEC. 1-2 - METHOD OF TESTING

A specially instrumented two-wheel trailer is towed behind a truck. On each wheel is a strain gauge transducer. The transducers measure the amount of torque exerted on the axle of the trailer under locked-brake conditions on wet pavement.

The towing vehicle carries the water supply for wetting the pavement and all necessary instrumentation. The instrumentation records test results on a strip chart recorder, and it also provides complete control of the tests being conducted.

SEC. 1-3 - PHYSICAL DESCRIPTION OF EQUIPMENT

The Soiltest ML-350 is comprised of three basic components: (1) the towing truck, (2) the skid trailer, and (3) the instrument console.

The truck carries the water supply and pumping system and the instrument console.

The trailer carries the torque measuring strain gauge transducers, water laying nozzles for pavement wetting, and water and brake control solenoids.

The instrument console is located between the drivers' and passengers' seats, inside the cab of the towing truck. This console contains all controls for the complete test sequence. Once initiated by the START button, the test sequence is automatic, being governed by a built-in timer. The console also contains the force-measuring recorder.

The truck has a manual control for the trailer brakes for use on the highway when not testing. The truck and trailer lights conform to ICC regulations. The towing truck is equipped with flashing safety lights as standard equipment.

An electronic speed meter is located on the dashboard of the truck to provide precise speed indication.

#### SEC. 1-4 - TYPE OF INDICATION OF SKID RESISTANCE

The instrument console in the truck cab is equipped with a two-channel recorder as standard equipment. The torque required to slide the skid tire on a wetted pavement is read directly on the chart as pounds-torque when the system is correctly calibrated. On most models, the left recorder channel records the torque developed by the left skid tire, and the right channel records the torque developed by the right skid tire. On some models, the left channel is used to record vehicle speed and only the right channel is used to record torque.

#### SEC. 1-5 - THEORY OF OPERATION

The Soiltest Skid Tester basically consists of a special trailer towed by a truck. At a preselected test speed, water is applied to the pavement to be tested ahead of one or both test wheels (as selected) and the brakes on the trailer are locked. The resultant torque is recorded on a strip-chart recorder in the instrument console. The water flow applied to the pavement is designed to leave a film of water .020 inch  $\pm$  .005 inch thick, regardless of vehicle speed. The torque measured is sensed by balanced-bridge strain gauge transducers mounted on special torque tubes. These tubes are mounted concentric to the axles of the trailer. All test functions are automatically controlled by the timer in the instrument console.

The timer is set so that the test sequence occurs in this order: (1) Start recorder. (2) Start water flow. (3) Calibrate pulse is recorded. (4) Brakes lock for 2 seconds. (5) Brakes release. (6) Water is turned off. (7) Recorder stops. (8) Timer resets and the unit is ready for the next test.

#### SEC. 2-1 - PREPARATION FOR OPERATION

Before any instrument preparations are made, a walk-around inspection of the truck and trailer should be made. Check all tires for cuts and

for correct air pressure. Pay particular attention to the pressure in the skid tires; THIS IS IMPORTANT! Correct pressure is 24 pounds and this pressure must be maintained. If skid tire pressure is incorrect, the recorded torque readings will be wrong.

Make certain that the trailer hitch is fastened tightly and that the safety chains are properly fastened. Finally, be sure that all electrical, water and any other connections are properly made.

Fill the water tank on the truck with CLEAN water. Be sure the drain valve on the truck is closed! Turn the instrument console on and allow at least 15 minutes warmup time before attempting any testing.

#### SEC. 2-2 - CONTROLS AND THEIR FUNCTIONS

The instrument console is the "heart" of the skid tester. It controls all functions of the unit. Located behind the passenger seat is a high-quality Topaz brand inverter which is used to convert twelve volts DC to 120 volts 60 Hz AC. This voltage is used to provide power for the timer and the strip chart recorder. The inverter used is capable of providing 250 watts of power continuously, but only a fraction of that amount is used in the skid tester. The inverter is conservatively rated and operated and can be expected to provide many years of service, unless it is abused.

Inside the locked instrument cabinet, toward the rear, is the timer. The timer controls the time of each function of the test and the time of the overall test sequence. The timer may be easily reset to meet any special requirements by simply changing the setting of the on and off time of each function, as labeled. Use caution if you are changing the water and/or brake setting so that you do not inadvertently skid the tires on the pavement before water is applied!

On the passenger side of this same compartment is the primary instrumentation fuse block. The 60-ampere fuse protects all of the instrumentation. The fuse should be removed whenever ANY work is being done on the console, or if any panels are to be removed.

In describing the controls, it will be assumed that the console is being viewed from the drivers' side.

Controls on the left-side panel (at the drivers' side) are as follows:

**START:** Pressing this switch begins the test cycle. Once a test cycle is started, all functions of the skid tester are automatically controlled until the cycle is completed.

**DEFEAT:** Pressing this button will stop a test sequence at any point in its cycle. This function might be used under such conditions as bad roads, traffic hazards, etc.

WHEEL SELECT: This switch is used to determine which brakes are to lock: right, left or both. It also feeds water to the proper wheel(s). Any of the three settings may be used.

ADVANCE CHART: This pushbutton allows the operator to run the chart forward without initiating a test cycle. This function is very useful as an aid in calibration and balancing.

CHECK CALIBRATE: This button provides a calibration pulse and is used as a reference in calibration. Use of this function will be discussed further in the calibration procedure.

ZERO RECORDER: Pressing this button removes all signals from the recorder inputs and allows the operator to balance the recorder to zero. When zeroing the recorder, use the position control on the recorder for each channel, as marked.

LEFT AND RIGHT BALANCE: These knobs allow the operator to balance the two strain gauges to zero.

LEFT AND RIGHT F.S. (FULL SCALE): This knob adjusts the height of the calibrate pulse and is used to ensure proper calibration. This is explained in the section on calibration procedure.

In the center of the console is the strip chart recorder. In normal road testing sequences, the sensitivity switches should both be set at the 1 mv position and the chart speed should be set at 25 mm/sec. Under static test or calibration checks, a chart speed of 1 or 5 mm/sec. can be used to conserve chart paper.

### SEC. 3-1 - TESTING ON THE ROAD

To operate the Soiltest Skid Tester on the highway, perform the following operations: Be sure that the hitch, safety chains and all supply connections are securely fastened. Close the drain valve on the water supply tank on the truck and fill the tank with CLEAN water through the filling port at the top-rear of the tank. Open the main valve, which is also located on the water tank. Start the engine of the truck and turn on the POWER switch on the console. Be sure to allow at least fifteen minutes warmup time for the equipment to stabilize.

When warmup time has elapsed, press the ADVANCE CHART and ZERO RECORD buttons at the same time and zero both channels of the recorder using the left and right POSITION controls on the recorder itself. Now release the ZERO RECORD button and re-zero the pens, using the left and right BALANCE knobs on the console. Now press the CHECK CALIBRATE button and adjust left and right F.S. knobs to read the number determined in the calibration of the tester.

Next, depress the clutch and, at a dead standstill, pull out the PTO knob on the center of the firewall.



NOTE: In trucks with automatic transmissions, this operation is performed automatically by the timer through a magnetic clutch.

The tester is now ready for operation and you may drive to your test site.

When you have reached the highway to be tested, be sure you have the WHEEL SELECT switch set to the desired position. Attain the chosen test speed (usually 40 miles per hour per ASTM E-274-65T, par. 5.1) and press the START button. All functions of the test will be performed automatically.

At intervals during your test sequences, it is wise to re-check the zero of the recorder, the balance of the bridge(s), and the height of the calibrate pulse. This will eliminate the possibility of drift in the equipment or inadvertently moving the wrong knob, which could give erroneous results.

#### SEC. 3-2 - OPERATING PRECAUTIONS

1. Be sure that the truck is NOT moving when you engage the PTO!
2. Remove the main fuse in the console when any work is being done in the console or if panels are removed.
3. Do NOT operate the truck with the PTO and pumps running unless the main valve is in the OPEN position and the water tank is full.
4. The drain valve should be opened on the tank and the pumps and solenoid valves in the event of freezing weather. This is discussed further in the storage section.
5. When testing, be sure you have an adequate supply of water.

#### SEC. 3-3 - CALIBRATION OF MODELS RECORDING TORQUE ON BOTH RECORDER CHANNELS

It is recommended that the Soiltest Skid Tester be calibrated using the Soiltest model ML-360 Dynamic Skid Calibration Unit, which includes a Soiltest 1000 lb. capacity proving ring with a dial indicator, a proving ring calibration chart, fine thread screw, ratchet wrench, wheel block and complete instructions.

Position the truck and trailer as level as possible. Jack up the trailer and position the calibrator under the left wheel. Place a block of equal height under the right wheel. A wood block is preferable to a concrete or similar block as it is not likely to break. Lower the trailer onto the calibrator and block. Use the jack to level the trailer hitch. Zero the calibrator.

Start the truck and turn on the equipment. Allow the normal 15 minute warmup period so the equipment has time to stabilize. Set both recorder sensitivity switches to the 1 mv position. Press the ZERO RECORD button and adjust both position controls on the recorder so the pens are at zero. Release the ZERO RECORDER button and again zero the recorder, this time using the left and right BALANCE controls on the control console. The F.S. controls should both be at approximately their mid-range positions at this time.

Lock the trailer brakes, using the toggle switch LOCK BRAKES, located inside the locked compartment on the drivers' side. Add the desired wheel load with the calibrator in 100 pound increments, and, with the left SENSITIVITY control on the recorder, adjust the pen to read one (1) major division for each 100 pounds of wheel load. Be sure to tighten the lock nut on this control when finished with calibration.

Now release the trailer brakes and press the CALIBRATE button. Make a note of the reading obtained. This reading is now the calibrate reference number and it is used to indicate that the equipment is working properly and that the unit is in calibration.

To calibrate the right wheel, repeat the above procedure on that wheel. When both wheels are calibrated, the unit is ready for road service.

#### SEC. 3-4 - CALIBRATION OF MODELS RECORDING SPEED/LEFT AND TORQUE/RIGHT

Position the truck and trailer as level as possible. Jack up the trailer and position the calibrator under the left wheel. Use a wood block equal height under the right wheel. Start the truck and turn on the equipment. Allow a fifteen (15) minute warmup period for the equipment to stabilize.

Set the recorder sensitivity switch to the 1 mv position on the right channel. Set the RECORD switch on the console to the left position. Press the ZERO RECORDER button on the console and adjust the right position control on the recorder to indicate zero on the right channel. Release the button and again zero the recorder, this time using the left BALANCE control on the console. The F.S. controls at this time should be in their mid-range position.

Lock the trailer brakes using the toggle switch LOCK BRAKES located inside the locked compartment on the drivers' side of the console. Add the desired wheel load in 100 pound increments and, with the right sensitivity control on the recorder, adjust to read one major division for each 100 pounds. Tighten down the lock nut on this control so the setting cannot change.

The same procedure is used for the right wheel, except that the sensitivity control is not used. Calibrate the right side to match the left, using only the right F.S. pot to give an equal reading.

Press the calibrate button with left record and make a note of the amount of deflection. Do the same on the right record. These readings will enable you to set the F.S. pots to their proper calibration point, if they should happen to be moved by mistake. These readings are for reference only, and are used only to indicate that the system is working properly.

To calibrate the speed, set the left selector switch on the recorder to the 5 mv position and zero the pen using the left position control on the recorder. Remove the top cover of the console by releasing the trunk clasps on each end. Press the CHECK SPEED button on the console. This applies voltage from a 4.05 volt standard cell to the circuit and it should produce a speed reading of 48 mph. If necessary, adjust the sensitivity control on the recorder to give this reading. If 48 mph cannot be reached, adjust the locking-type pot located to the rear of the battery so the reading is 48 mph. Loosen the lock nut to make this adjustment, and, when adjusted, re-tighten the lock nut on the pot. Adjust the dash meter also by adjusting the locking pot located at the end of the battery. Re-install the cover and calibration is complete.

#### SEC. 4-1 - MAINTENANCE

The Soiltest Skid Tester requires a minimum amount of maintenance. Tire air pressure in the trailer tires should be maintained at 24 psi. This should be checked using the special gauge which is provided with the tool kit. The wheel bearings on the trailer should be repacked every 20,000 miles. The brakes should be inspected periodically. The solenoid valves in the water system may be taken apart for cleaning if it should happen that they do not close tightly. This also applies to the relief valves at the top rear of the water tank. Valve closure problems may be caused by the presence of foreign matter, such as dirt or sand.

The service manual provided with the truck should be followed closely with regard to maintenance and lubrication.

The instrument console requires no special care except for that maintenance noted in the manuals for the recorder, timer and inverter.

#### SEC. 5-1 - STORAGE

A. SKID TRAILER: To take the trailer out of service for storage, disconnect the hose connections and lay them out to drain the water. Open the petcocks on the solenoid valves and permit them to drain. Disconnect all electrical connections and install the protective cover attached. Be sure you drain as much water out of the system as possible.

B. TRUCK: When preparing the truck for storage, open the main and drain valves on the water tank. Open the petcock valves on the two water pumps beneath the truck. Install the protective cover attached to the electrical connector on the rear of the truck. Remove the recorder and store it in a warm place. To remove the recorder, proceed as follows:

1. Remove the main fuse (60-ampere cartridge type) which is located in the locked cabinet.
2. Remove the seven (7) silver-head screws in each of the side panels.
3. Lift the panels up and turn them over so they are out of the cabinet.
4. Remove the four (4) hex nuts from the bottom plate of the recorder.
5. Unplug the cable which is plugged into the recorder from the drivers' side. Disconnect the three (3) connections from each of the recorder inputs. These are located on top of the recorder, three on each side at the top-rear.
6. Lift the recorder straight up and out of the console.

#### SEC. 6-1 - REPLACEMENT OF TORQUE TUBES

If a torque tube with its strain gauge transducers should become defective necessitating removal for repair or replacement, proceed as follows:

1. Jack up the trailer and remove the wheels and drums.
2. Remove the four (4) bolts which hold the backing plate to the torque tube. If your trailer has disc-type brakes, the calipers must be removed first. If your trailer has drum-type brakes, the calipers need not be removed.
3. Remove the five (5) bolts which hold the torque tube to the axle.
4. Remove the cover from the small junction box located on the trailer tongue and disconnect the appropriate four (4) wires and shield which is fed through the sealtite waterproofing from the torque tubes. **DO NOT REMOVE THE CONNECTIONS GOING TO THE UMBILICAL CORD!** Mark the cables left and right.
5. Pull the disconnected wire out of the sealtite back to the torque tube.
6. Using a wheel puller, remove the torque tube from the trailer.
7. Install the new torque tube. **BE SURE THAT THE TUBE IS INSTALLED ON THE CORRECT SIDE!** The side is plainly stamped on the torque tube.

8. Pull the tube down tight using the five (5) bolts removed in step three. DO NOT HAMMER THE TUBE INTO PLACE!!!
9. Install the brake backing plate using the four (4) bolts removed in step two. Note: If you have disc brakes, re-install the calipers.
10. Re-install the wheel.
11. Push the new four wire cable and shield through the sealtite and connect it in the junction box. Observe the color code carefully; the wiring must be connected exactly as it was. Re-install the box cover.
12. To check the new torque tube, start the truck and equipment. Allow the usual 15-minute warmup and stabilization period. Lock the trailer brakes using the BRAKE LOCK switch in the locked compartment. Observe the recorder and note in which direction the pens move. If everything is normal, the pens will move to the right. If they do not, it is an indication that the red and white wires to the torque tube on the incorrect side should be reversed.

#### SEC. 7-1 - MODELS WITH CHART RECORDING OF SPEED

In some models of the Soiltest ML-350, the vehicle speed is recorded on the left channel of the strip chart recorder. In these models, an event mark will be printed on the chart at the beginning of the test sequence only when the right wheel is being recorded. If the left wheel is being recorded, no event mark will appear on the chart.

#### SEC. 8-1 - MODELS WITH ELECTRIC SPEED METER

In ML-350 models with an electric dash-mounted speed meter, an event mark will be printed on the chart on one or both channels, depending on the setting of the wheel selector switch. The mark shows the beginning point of a test.

A speed meter is driven by a tachometer-generator from the speedometer cable. A standard cell is located inside the speed meter housing and it is used to determine that the speed meter is in calibration. To check the meter, press the pushbutton on the meter housing. The pointer should deflect to a reading of 48 miles per hour. If it does not, the meter should be recalibrated by loosening the locking nut on the calibration pot, and, while pressing the calibrate button, the potentiometer should be moved until the meter does read 48 mph. Re-tighten the locknut.

The standard cell used for calibration checking is a long-life mercury cell, but to insure freedom from possible deterioration of the cell or possible corrosion, the cell should be replaced once per year.