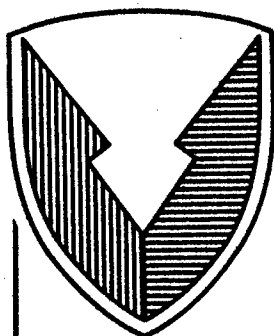# RD&E
CENTER
Technical Report

No. 13228

M9 DRIVER'S HATCH SIMULATION

TEST REPORT

DECEMBER 1986

Harry Zywiol
U.S. Army Tank-Automotive Command
ATTN: AMSTA-RYA
Warren, MI 48397-5000

By

20040105188

**U.S. ARMY TANK-AUTOMOTIVE COMMAND
RESEARCH, DEVELOPMENT & ENGINEERING CENTER
Warren, Michigan 48397-5000**

NOTICES

REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188
Exp. Date: Jun 30, 1986

1a. REPORT SECURITY CLASSIFICATION UNCLASSIFIED			1b. RESTRICTIVE MARKINGS		
2a. SECURITY CLASSIFICATION AUTHORITY			3. DISTRIBUTION/AVAILABILITY OF REPORT Approved for Public Release: Distribution is Unlimited		
2b. DECLASSIFICATION/DOWNGRADING SCHEDULE					
4. PERFORMING ORGANIZATION REPORT NUMBER(S)			5. MONITORING ORGANIZATION REPORT NUMBER(S) 13228		
6a. NAME OF PERFORMING ORGANIZATION U.S. Army Tank-Automotive Command, R&D Center		6b. OFFICE SYMBOL (If applicable) AMSTA-RY	7a. NAME OF MONITORING ORGANIZATION U.S. Army Tank-Automotive Command PM-LCV		
6c. ADDRESS (City, State, and ZIP Code) Warren, MI 48397-5000			7b. ADDRESS (City, State, and ZIP Code) Warren, MI 48397-5000		
8a. NAME OF FUNDING/SPONSORING ORGANIZATION		8b. OFFICE SYMBOL (If applicable)	9. PROCUREMENT INSTRUMENT IDENTIFICATION NUMBER		
8c. ADDRESS (City, State, and ZIP Code)			10. SOURCE OF FUNDING NUMBERS		

			PROGRAM ELEMENT NO.	PROJECT NO.	TASK NO.	WORK UNIT ACCESSION NO.

11. TITLE (Include Security Classification)
M9 Driver's Hatch Simulation Test Report

12. PERSONAL AUTHOR(S)
Zywiol, Harry John

13a. TYPE OF REPORT Final	13b. TIME COVERED FROM 6/86 TO 8/86	14. DATE OF REPORT (Year, Month, Day) DEC 1986	15. PAGE COUNT 32

16. SUPPLEMENTARY NOTATION

17. COSATI CODES			18. SUBJECT TERMS (Continue on reverse if necessary and identify by block number)
FIELD	GROUP	SUB-GROUP	Simulation DADS Real time
			CAMAC Absorb Power

19. ABSTRACT (Continue on reverse if necessary and identify by block number)

A new prototype driver's hatch was designed and developed for the M9 Armored Combat Earthmover. This report details a unique test that was implemented in TACOM's Physical Simulation Laboratory to reproduce the dynamic forces the hatch normally encounters as the M9 travels across terrain. The M9 was simulated over selected terrains which produced the state variables of the hatch. Real-time simulation testing of prototype vehicle systems is a proven method of reducing costly development and field test time.

20. DISTRIBUTION/AVAILABILITY OF ABSTRACT ☒ UNCLASSIFIED/UNLIMITED ☐ SAME AS RPT. ☐ DTIC USERS	21. ABSTRACT SECURITY CLASSIFICATION Unclassified	
22a. NAME OF RESPONSIBLE INDIVIDUAL Harry J. Zywiol, Jr.	22b. TELEPHONE (Include Area Code) (313) 574-6228	22c. OFFICE SYMBOL AMSTA-RYA

DD FORM 1473, 84 MAR

83 APR edition may be used until exhausted.
All other editions are obsolete.

TABLE OF CONTENTS

LIST OF ILLUSTRATIONS

LIST OF TABLES

1.0. INTRODUCTION

This report, prepared by the System Simulation and Technology Division of the Directorate for Tank-Automotive Technology, U.S. Army Tank-Automotive Command (TACOM), describes the testing of a prototype driver's hatch for the M9 Armored Combat Earthmover (ACE) bulldozer. It was desired to determine the safety and operational characteristics of the new hatch while subjected to the dynamic forces encountered as the vehicle traverses various characteristic terrain profiles.

A Dynamic Analysis and Design of Systems (DADS) computer model of the M9 vehicle was created and "simulated" over selected terrain profiles to produce those exact forces the hatch encounters as the M9 traverses terrain. The resultant duty cycle position/time history of the hatch was then transferred to TACOM's full-scale Physical Simulation Laboratory to provide the control signals to hydraulic actuators which reproduce these motions on a test fixture. See Figures 1-1 and 1-2.

2.0. OBJECTIVES

The intent of this work was to effectively test the durability of the new hatch by simulating the M9 ACE traveling over selected terrain profiles. To accomplish this, a new methodology which used TACOM's analytical and physical simulation capabilities is presented and detailed in this report.

3.0. CONCLUSIONS

A DADS M9 ACE computer model was developed and simulated. Difficulty in obtaining vehicle parameter data (mass, geometry, inertia, etc.) contributed to some delay. A total of 88 hours of simulation testing was planned and executed in the Physical Simulation Laboratory. Three unique terrain profiles and vehicle speeds were selected to provide the input disturbance to the model (and subsequently to the hatch). These were as follows:

- Secondary Road (Fort Knox 56A), 15 mi/h

- Mild Cross-Country (Aberdeen Proving Grounds 9), 9 mi/h

- Rough Cross-Country (Fort Hood FR1), 7 mi/h

These vehicle speeds were selected because they are the maximum speeds which an "average male" could endure for long periods of time (greater than 15 minutes). The course/speed selection criteria is further explained in par. 5.0.

A Computer-Automated Measurement and Control (CAMAC) system was programmed and integrated into a lab electrohydraulic motion simulator to accurately produce the real-time position/time control signals to the test fixture.
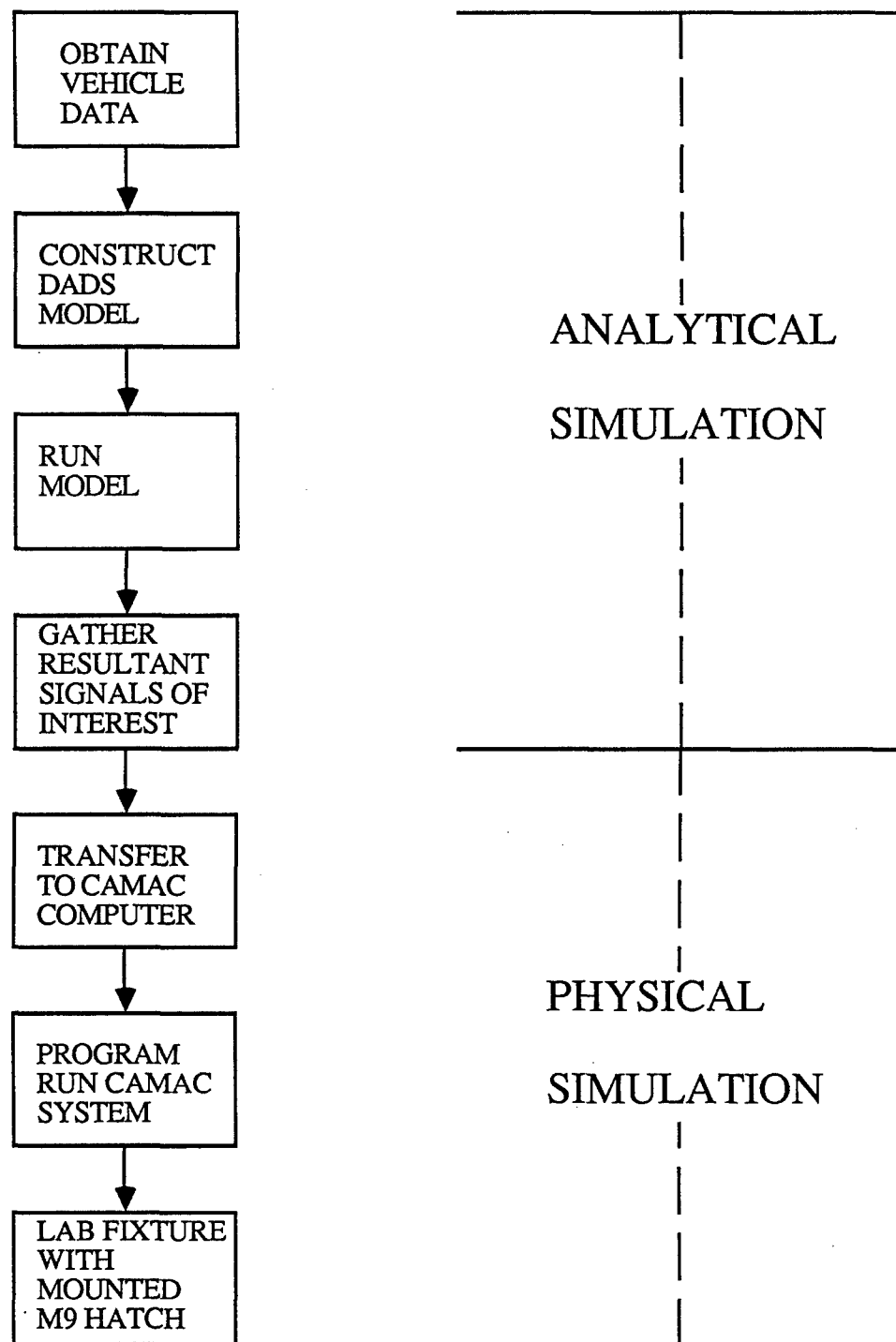
```
┌──────────────┐
│  OBTAIN      │
│  VEHICLE     │
│  DATA        │
└──────────────┘
        │
        ▼
┌──────────────┐
│  CONSTRUCT   │                   ANALYTICAL
│  DADS        │
│  MODEL       │                   SIMULATION
└──────────────┘
        │
        ▼
┌──────────────┐
│  RUN         │
│  MODEL       │
│              │
└──────────────┘
        │
        ▼
┌──────────────┐
│  GATHER      │
│  RESULTANT   │
│  SIGNALS OF  │
│  INTEREST    │
└──────────────┘
        │
        ▼
┌──────────────┐
│  TRANSFER    │
│  TO CAMAC    │
│  COMPUTER    │                   PHYSICAL
└──────────────┘
        │                          SIMULATION
        ▼
┌──────────────┐
│  PROGRAM     │
│  RUN CAMAC   │
│  SYSTEM      │
└──────────────┘
        │
        ▼
┌──────────────┐
│  LAB FIXTURE │
│  WITH        │
│  MOUNTED     │
│  M9 HATCH    │
└──────────────┘
```

Figure 1-1.   Systems Simulation Methodology
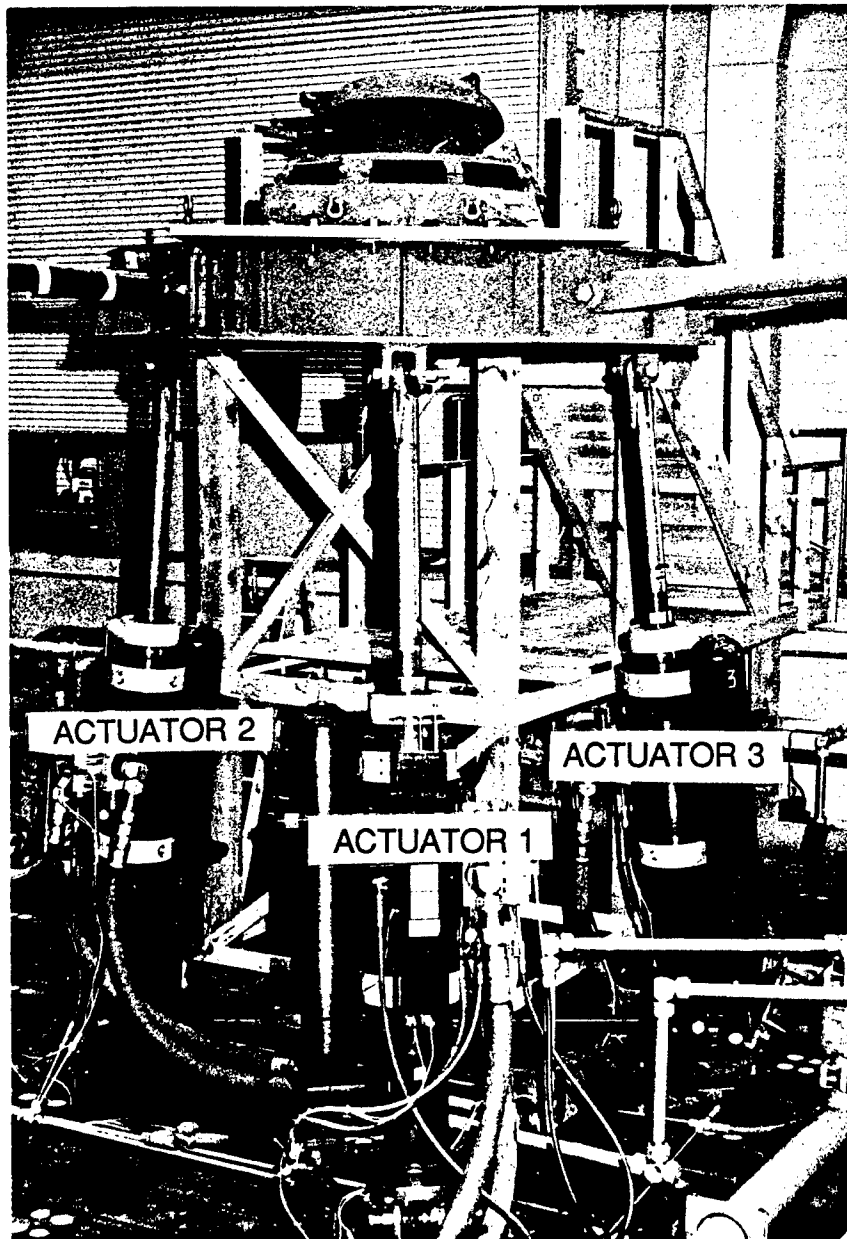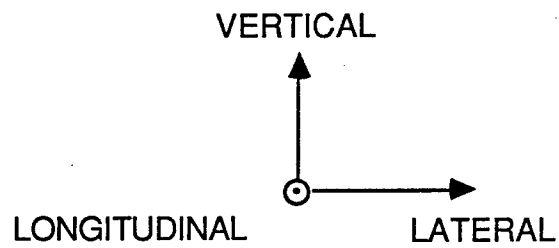
VERTICAL

LONGITUDINAL   LATERAL

Figure 1-2. M9 Hatch Mounted to Motion Base Simulator

9

Several hatch hinge failures occurred throughout the 88 hours of testing. These failures and resultant corrective action issues are presented in the M9 Hatch Test Compendium, submitted to Chassis Branch (AMCPM-LCV-TC) by the Testing Support Division (AMSTA-TB) on 20 August 1986. Testing was resumed after short delays between failures and was completed by 13 August 1986.

Simulation testing essentially surfaced hatch hinge problems, which, if not discovered, would not have surfaced until Initial Production Testing scheduled for mid-1988.

4.0. RECOMMENDATIONS

When final design modifications to the hatch are completed, it is recommended that a similar test profile be implemented in the Physical Simulation Laboratory. The hatch development risk will be reduced if no failures are encountered in this next test phase.

The System Simulation and Technology Division will retain all computer models and CAMAC programs created during this effort. All fixturing and associated hardware will also remain in-house.

5.0. DISCUSSION

5.1. DADS Modeling

The analytical model of the M9 ACE was created and simulated using the DADS computer code. DADS was developed jointly by the University of Iowa and TACOM. Vehicle parameter data required for the assembly of the model include inertia, mass properties, geometry and external forces applied. DADS simulates a system as a collection of rigid bodies connected by user-selected joints, constraints, and springs to predict forces, torques, and motion time histories when subject to prescribed external forces (terrain profiles).

Once a working model has been developed, a terrain disturbance and vehicle speed are selected, and a simulation is conducted. Several variables of interest are monitored. These include vehicle pitch rate, ride comfort, and (in the case of the M9), hatch position. If the course selection/speed acceptance criteria are met, then the simulation is selected for output generation of control signals for the lab motion simulator. If the criteria are not met, a different vehicle speed is selected and another simulation performed. A typical simulation takes about 48 hours.

5.2. Laboratory and Electrohydraulic Control System

The lab control system consists of the following integrated systems: CAMAC, analog buffer, servo amplifiers and servo valve/actuator/fixture. (See Figure 5-1.) The heart of this system is the CAMAC system. CAMAC
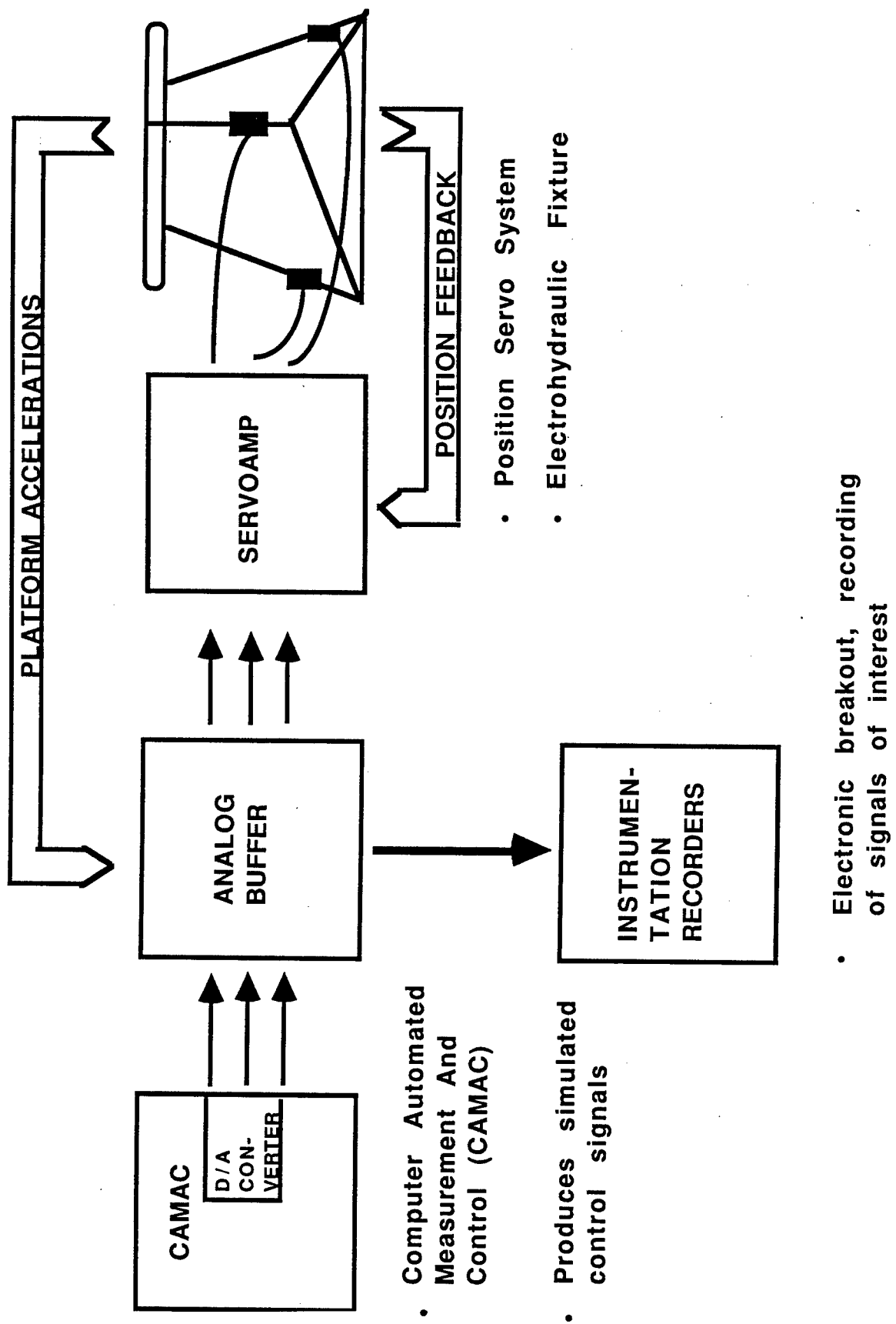
PLATFORM ACCELERATIONS

POSITION FEEDBACK

SERVOAMP

- Position Servo System

- Electrohydraulic Fixture

ANALOG BUFFER

INSTRUMEN-TATION RECORDERS

CAMAC

D/A CON-VERTER

- Computer Automated Measurement And Control (CAMAC)

- Produces simulated control signals

- Electronic breakout, recording of signals of interest

Figure 5-1. Hardware Block Diagram

11

is an internationally accepted laboratory industry standard used for computer-automated measurement and control. The System Simulation and Technology Division used CAMAC to provide all the control and data acquisition functions for the motion simulator. A program was written on the CAMAC to provide real-time analog control signals from the DADS digital output file. Features of this program include:

- Statistical analysis of command signal (maximum, minimum, runtime, etc.)

- Computed maximum velocity of command signal

- Safety features (avoid overloads, extreme velocities, improperly selected scenarios)

- Real-time control (simulate hatch events as they occurred). Functions of other components in the system are given below.

  -Analog Buffer: provides electronic buffering and convenience "breakout" panel for recording and measuring signals of interest
  -Servo Amp: provides position control and current amplifier compatible with servo valves.
  -Fixture: provides electrohydraulic servo-valve-controlled actuation with hatch mounted to planar base. Provides ± 8.0-inch displacements at approximately 10 g's (acceleration of gravity), which is well within the requirements of the test.

5.3. Course/Speed Selection Criteria

It was originally desired to use profiles of the Perryman and Churchville areas at Aberdeen Proving Grounds as the disturbance input to the M9 ACE model. This was not possible for several reasons:

- Both courses are extremely long (several miles) and, as a result, complete profiles have never been made.

- Any attempt to profile a small portion may result in a too-specific (undesirable) characteristic of the course.

An alternative approach was adopted. Terrain surfaces from many areas of the world have been profiled and characterized. The System Simulation and Technology Division holds a large library of these terrain profiles, encompassing the entire spectrum of surface characteristics. This activity has produced the following results and is illustrated in Figure 5-2.

- Secondary roads (hard, graded, nonpaved) have an average surface roughness of 0.2 inches root mean square (rms).
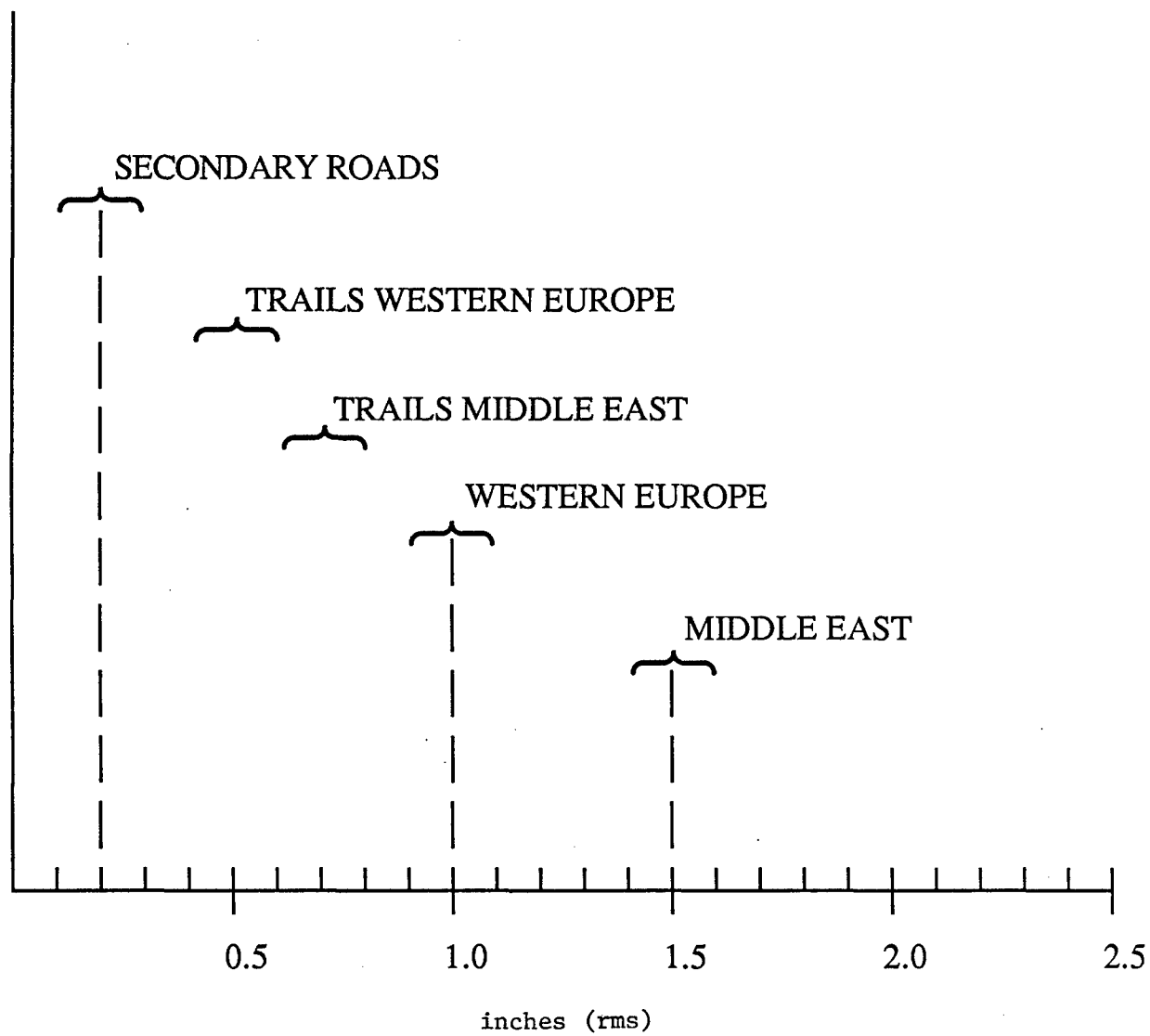
12

Figure 5-2. Surface Roughness

- Cross-country surfaces in Western Europe have an average surface roughness of 1.0 inch rms.

- Cross-country in the Middle East is most severe with average roughness of 1.5 inches rms.

The three course selections were made on the basis of this analysis. They are summarized in Table 5-1. Each course contains a wide spectrum of frequencies and amplitudes and all three courses together cover the variety of terrains likely to be encountered in the field.

The simulated M9 vehicle speed selection was based on satisfying several criteria:

- "Worst-case" ride.

- Driver comfort severity not to exceed that which could be sustained over long periods of time (greater than 15 minutes).

- Resultant hatch position and orientations not to exceed fixture capability (±8 inches).

A degree of ride comfort can be assessed by determining two useful criteria: average vertical absorbed power and pitch rate. The absorbed power is a time-average rate of flow of energy into a vibrating body (human). It characterizes vibration severity by correlating it to the response of a human body. It is a quantitative measurement in units of watts. Extensive past study indicates that crew personnel can comfortably withstand ride qualities that exhibit an absorbed power level of no more than 6 watts over extended periods of time. Past mobility experience also indicates that vehicle pitch rates of greater than 25 degree/second will also approach the maximum ride severity limit. Both driver's absorbed power and vehicle pitch rates were monitored while running the M9 DADS computer model over the selected courses. Therefore, the task was to choose the maximum vehicle speed which approaches and satisfies both criteria.

It can be noted from Table 5-1 that the rough and mild courses produced vehicle pitch rates near the maximum level (25 degree/second), but the absorbed power did not quite reach the 6-watt level.

It would have been desirable to obtain a 6-watt ride with a 25 degree/second pitch rate. This did not occur with the M9 because the vehicle inherently pitches severely when driven cross-country. The dynamic index, a calculated index based on a vehicle's moment of inertia, mass, and radius of gyration, supports this observation. The dynamic index for this vehicle is 6. A typical vehicle exhibits a dynamic index of 1.

Vehicle speeds higher than what was chosen would also have produced positional excursions that would have exceeded the test fixture's

Table 5-1. Course Scenario

Course Name	Severity	Length	Description
Fort Hood FR1	0.4 in. rms	380 ft.	Severe secondary road. Provides high-frequency input.
Aberdeen Proving Ground 9	1.04 in. rms	245 ft.	Average cross-country
Fort Knox 56A	1.76 in. rms	368 ft.	Severe cross-country

±8-inch maximum. In fact, the rough course DADS run at 7 mi/h produced some excursions exceeding this constraint. The CAMAC lab controller, however, was programmed to slightly attenuate the hatch duty cycle profile as necessary to "fit" the motion simulator in order to avoid slamming and damage to the fixture and test specimen. The position/time duty cycles of all runs made are included in the Addendum to this report.

5.4. Test Results

Several problem areas surfaced in this test. Generally, the hatch assembly required realignment, and excessive play and wear were noted. These problems are detailed in the M9 Hatch Compendium, submitted to Chassis Branch (AMCPM-LCV-TC) by the Testing Support Division (AMSTA-TB) on 20 August 1986.

ADDENDUM

DATA SECTION
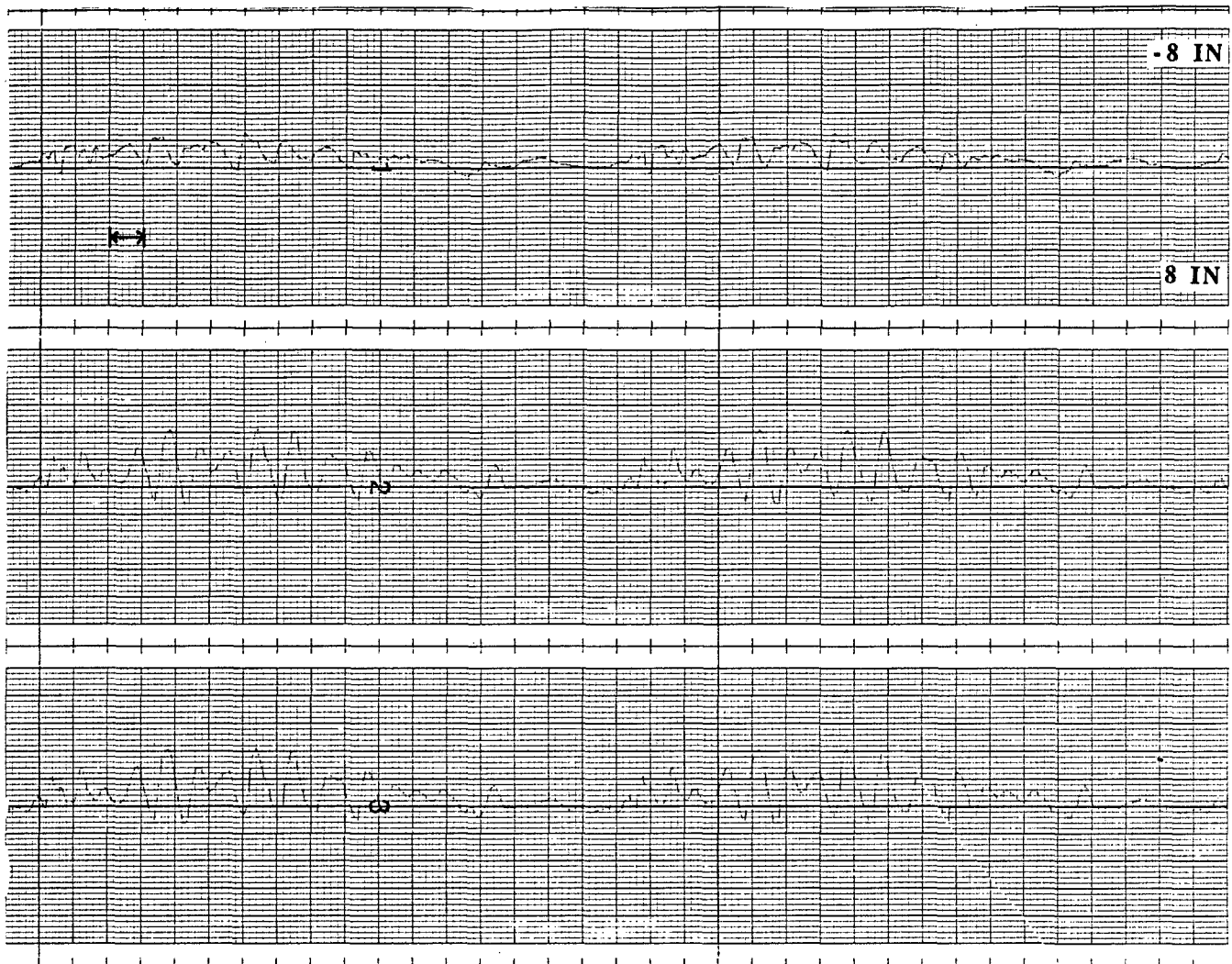
SECONDARY ROAD 15 MPH

Number of data samples in file = 865
Time for one iteration = 17.299 seconds

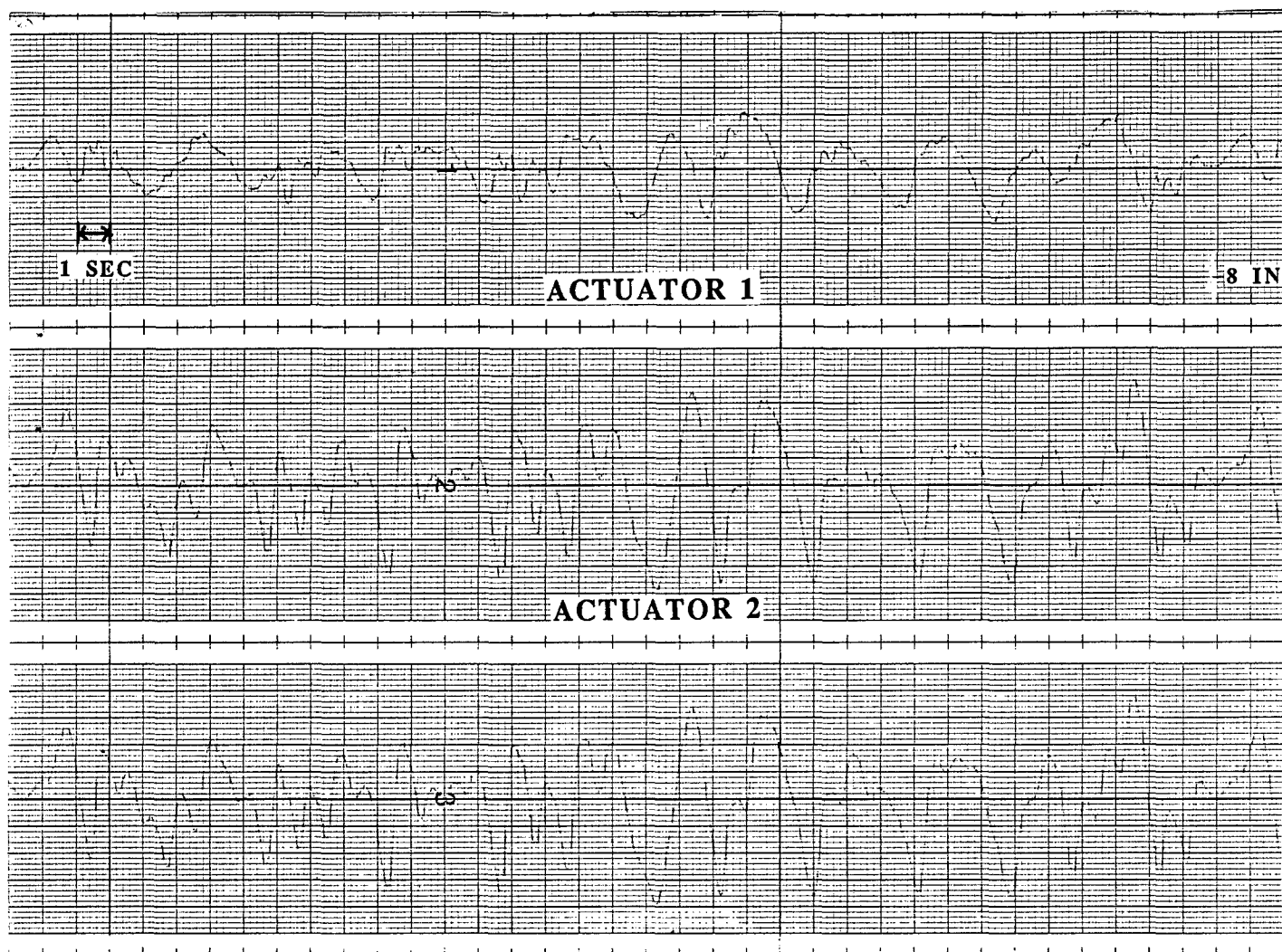|	ACTUATOR 1	ACTUATOR 2	ACTUATOR 3
Minimum Position (In)	-2.42200	-4.28800	-4.29100
Maximum Position (In)	0.80500	1.34600	1.33300
Maximum Velocity (In/Sec)	19.00928	21.71060	21.71060

21

MILD XCOUNTRY 9 MPH

Absorbed Power = 4 Watts
Number of data samples in file = 928
Time for one iteration = 18.559 seconds

|	ACTUATOR 1	ACTUATOR 2	ACTUATOR 3
Minimum Position (In)	-2.04000	-5.65300	-5.66100
Maximum Position (In)	3.01500	4.77000	4.75900
Maximum Velocity (In/Sec)	24.71207	43.07103	42.92096

22

1 SEC ACTUATOR 1 8 IN

ACTUATOR 2

ROUGH XCOUNTRY 7 MPH

Absorbed Power = 4.1 Watts
Number of data samples in file = 1197
Time for one iteration = 35.909 seconds
Data attenuated 0.75 between pt.704 and pt.1020

	ACTUATOR 1	ACTUATOR 2	ACTUATOR 3
Minimum Position (In)	-4.10000	-7.69300	-7.71100
Maximum Position (In)	4.04600	7.68800	7.75400
Maximum Velocity (In/Sec)	26.94649	51.29171	51.02491

23

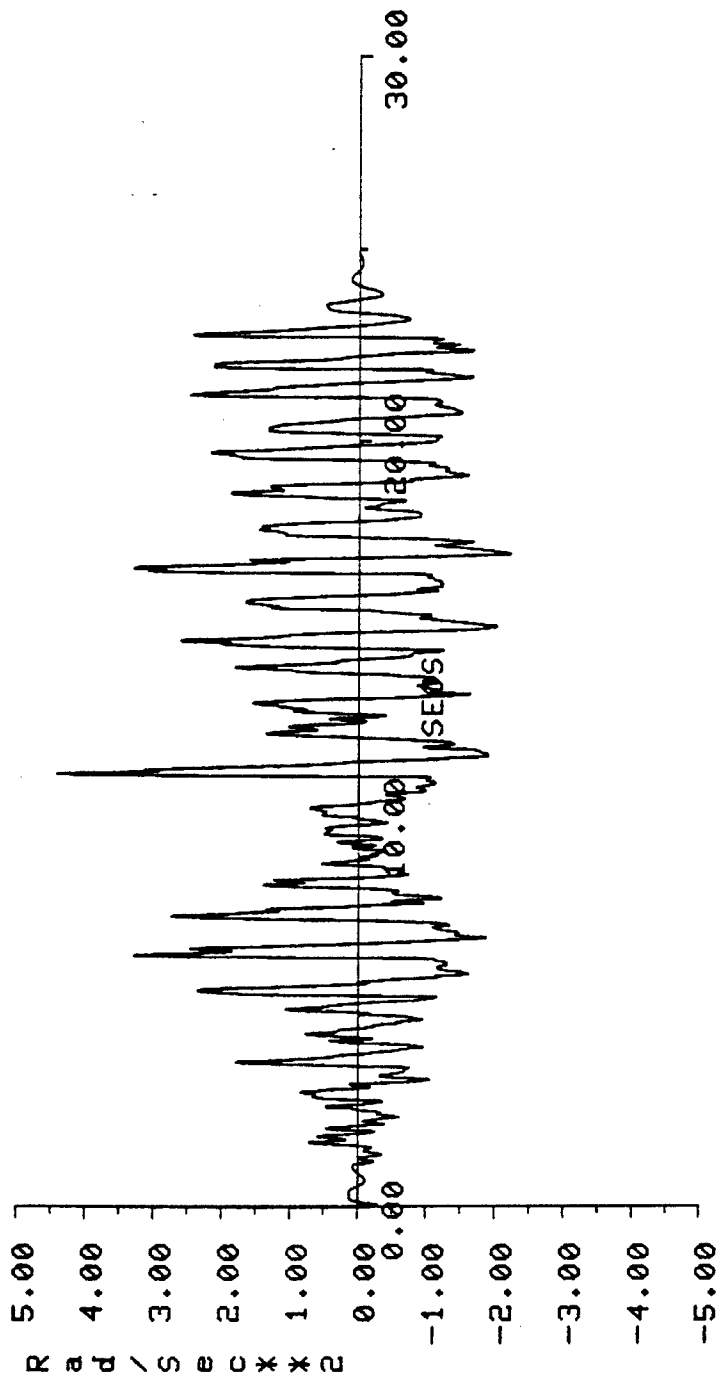LOCAL PITCH ACCEL. — M9ACE — 15MPH (SECROAD)

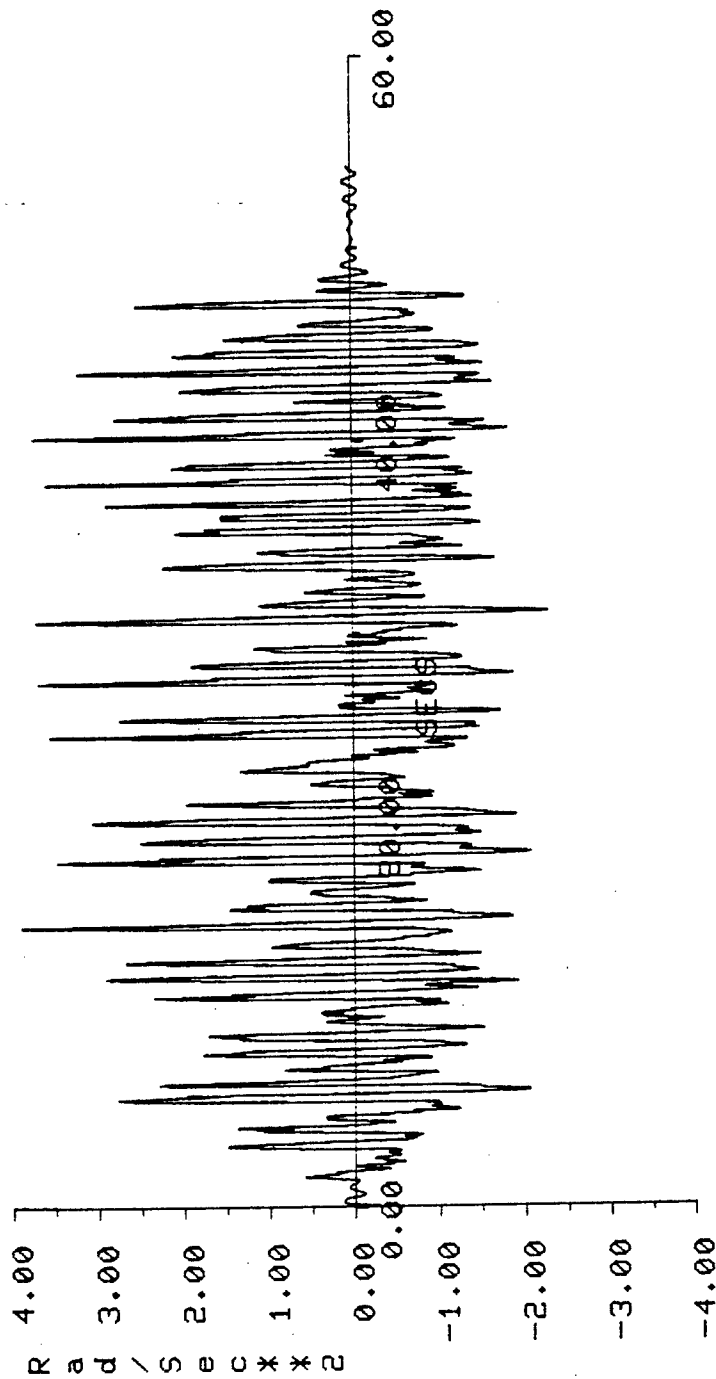Ymax = 2.86619
Ymin = -1.79817

Y1: RYAL9
X: TIME

24
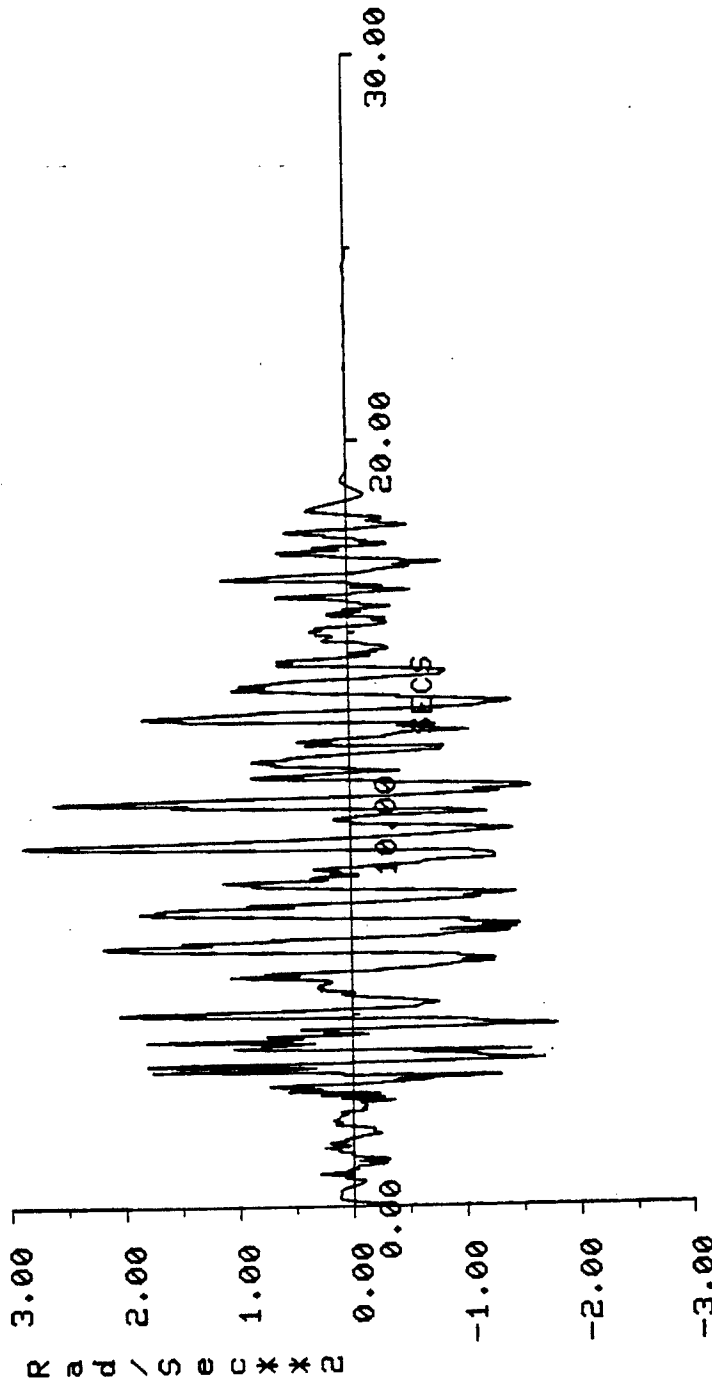
LOCAL PITCH ACCELERATION - M9ACE - 9MPH(MILDXC)

Ymax = 4.40052

Ymin = -2.21104

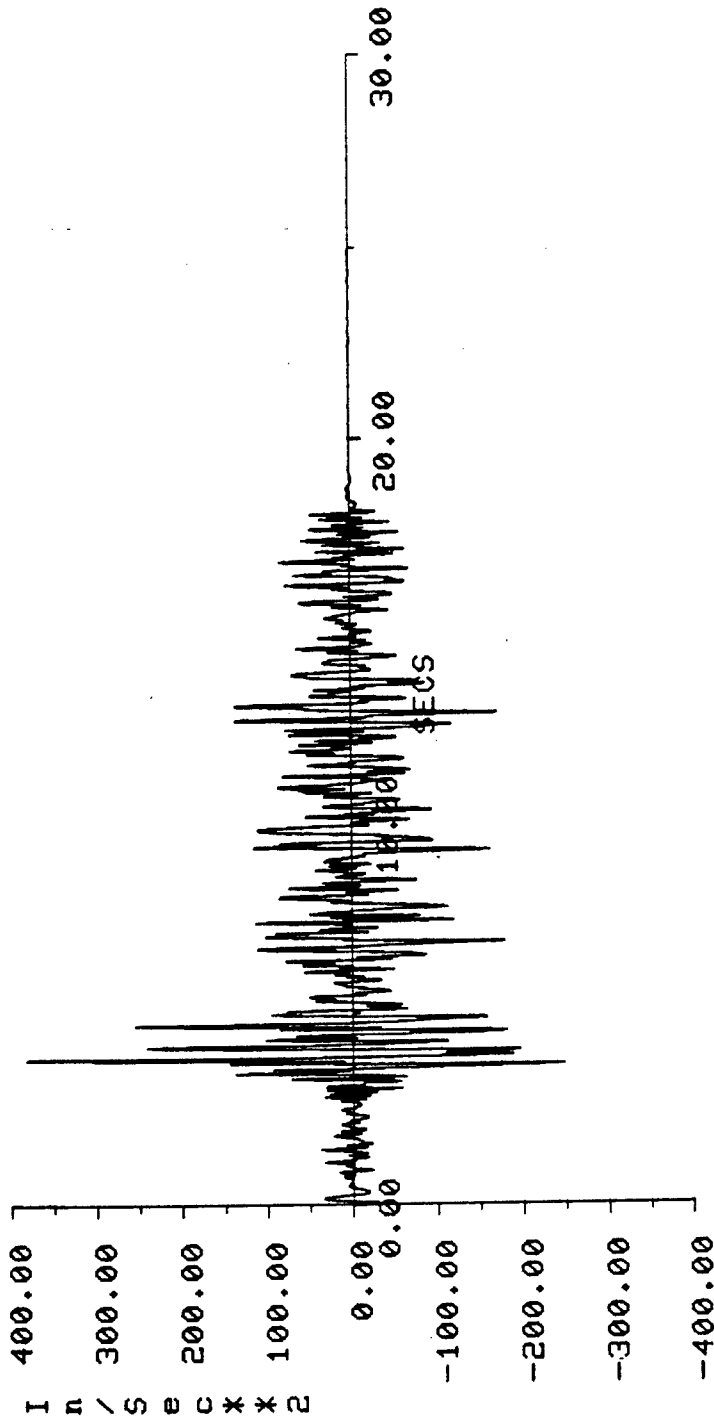LOCAL PITCH ACCELERATION — M9ACE — ROUGHXC(7MPH)

Ymax =   3.88347
Ymin =   -2.28248

Y1: RYAL9
X: TIME

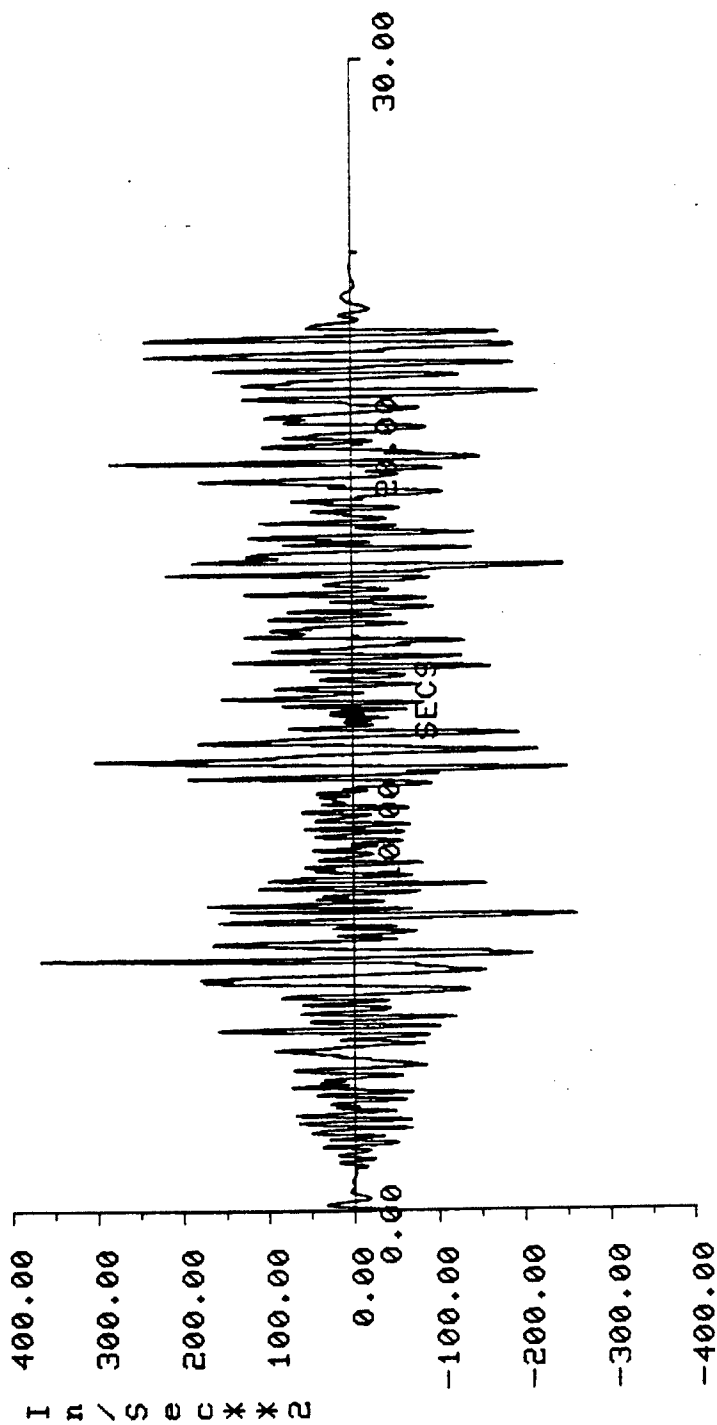26

VERTICAL ACCEL. - DRIVER'S STATION - 15MPH(SCROAD)

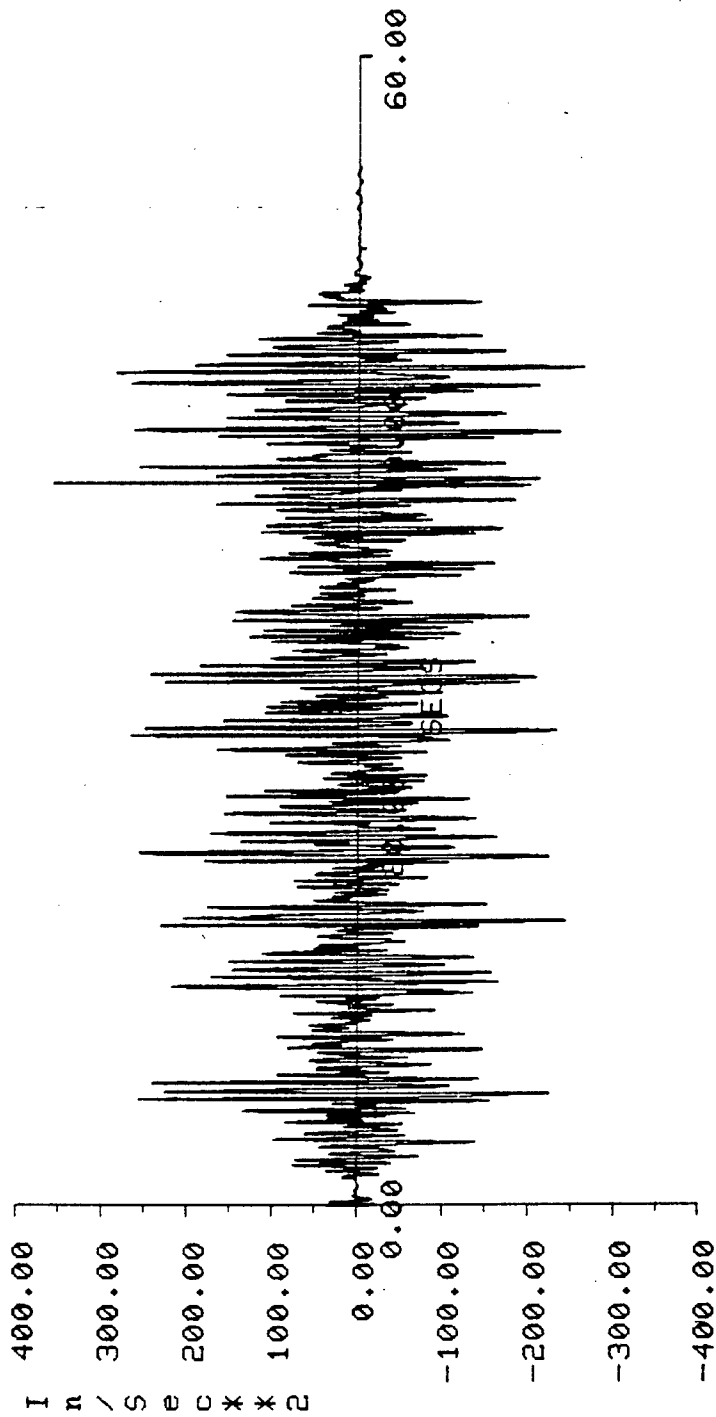Ymax = 381.11871
Ymin = -247.22635

Y1: PZAG1
X: TIME

27

VERTICAL ACCEL. - DRIVER'S STATION - 9MPH(MILDXC)

Ymax = 365.86084
Ymin = -260.92865

VERTICAL ACCEL - DRIVER'S STATION - ROUGHXC(7MPH)

Ymax =   354.93347
Ymin =   -263.13354

Y1: PZAG1
X: TIME

DISTRIBUTION LIST

Copies

Commander   12
Defense Technical Information Center
Bldg. 5, Cameron Station
ATTN: DDAC
Alexandria, VA 22314

Manager   2
Defense Logistics Studies
Information Exchange
ATTN: AMXMC-D
Fort Lee, VA 23801-6044

Commander   1
U.S. Army Tank-Automotive Command
ATTN: AMSTA-CF (Mr. Orlicki)
Warren, MI 48397-5000

Commander   1
U.S. Army Tank-Automotive Command
ATTN: AMSTA-R (Mr. Jackovich)
Warren, MI 48397-5000

Commander   15
U.S. Army Tank-Automotive Command
ATTN: AMSTA-RY
Warren, MI 48397-5000

Commander   3
U.S. Army Tank-Automotive Command
ATTN: AMCPM-LCV-TC
Warren, MI 48397-5000

Commander   3
U.S. Army Tank-Automotive Command
ATTN: AMCPM-M9
Warren, MI 48397-5000

Commander   2
U.S. Army Tank-Automotive Command
ATTN: AMSTA-DDL (Technical Library)
Warren, MI 48397-5000