Inter Office

Truck Operations

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LIGHT TRUCK SUSPENSION DESIGN

BRONCO II DYNAMIC HANDLING SIMULATION

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PURPOSE:

The intent of this report is two-fold:

1. Provide Truck Management with an overview of advancements which have been made to the ADAMS total vehicle dynamic handling model relative to the upgrading of the tire model to incorporate the affects of aligning torque, overturning moment, and tire saturation characteristics specifically related to the performance of prototype and production release level Bronco II.

2. Document the improvements made to the Job #1, 1983½ production release level Bronco II relative to early level prototype vehicles in negotiating severe limit handling maneuvers.

OVERVIEW:

The content of this review will consist of the following topics:

1. Advancements in the area of tire modeling for dynamic vehicle handling simulations.

2. Correlation studies of the dynamic handling simulation with the upgraded tire model and addition of steering system compliance.

3. Animated computer graphic displays of the early level Bronco II prototype and Job 1, 1983½ release level production vehicle negotiating ramp steer and obstacle avoidance dynamic maneuvers.

DISCUSSION:

Previous level dynamic handling simulations included a detailed representation of front and rear suspension geometry, bushing compliance, shock absorber valving curves, spring and stabilizer bar characteristics, sprung and unsprung mass definition, and a simplified tire model. The simplified tire model consisted of low speed (2 mph) test data of the Goodyear P205/75R15 All-Terrain Wrangler tire which was generated at relatively small slip angles and zero degrees camber. Curve fit routines which were utilized to extrapolate lateral load characteristics at higher slip angles tended to project an increase in lateral loads for a given vertical tire force and did not accurately represent tire saturation characteristics which develop at the higher slip angle conditions. In addition, data did not exist at higher vehicle speeds and non-zero camber angles to properly incorporate the affects of tire overturning moments (M_x) and aligning torques (M_z). In order to incorporate these affects and enhance the tire model simulation, a detailed test program was initiated at Calspan to develop a dynamic, transient test (as compared to the conventional equilibrium/steady-state procedure currently utilized) to obtain the additional tire data within an environment which more closely represented "real world" situations. A new dynamic testing procedure was developed which consisted of subjecting the tire to a transient sweep through $\pm 30^{\circ}$ slip angle at a given camber angle (maximum 6°), vertical load (maximum 2000 lbs.), and vehicle velocity (45 mph, typical). The data was then smoothed and multiple regression coefficients were developed to define the tire performance characteristics to be used for dynamic handling simulations. The incorporation of this upgraded tire model, which includes saturation characteristics at slip angles between 10-15° (depending upon

DISCUSSION: (Continued)

vertical force) resulted in good overall vehicle performance correlation relative to actual instrumented vehicle data. A detailed description of the tire testing and model development is included in Attachment I.

The upgraded tire model, along with an improved representation of steering system compliance, was then incorporated into the early level prototype model and correlation was then reestablished relative to instrumented vehicle handling performance characteristics (lateral acceleration levels, vehicle roll angles, yaw rates, etc.). Computer simulation vs. actual instrumented data curves are shown in Attachment II.

In addition to establishing correlation relative to specific sub-limit vehicle transient and steady-state characteristics, limit handling maneuvers were simulated and compared to two-wheel lift data on the early level prototype vehicle equipped with P205/75R15 Goodyear Wrangler All-Terrain tires. The following is a summary of the two-wheel lift speeds and ramp steering wheel angles:

APG Early Prototype	ADAMS Model Simulation
35 mph/360° SWA	36 mph/360° SWA
40 mph/360° SWA	40 mph/360° SWA
45 mph/270° SWA	39 mph/270° SWA
45 mph/540° SWA	Stable

The prototype model was then converted to represent the base Job #1, 1983½ production release level (wider track, lower center-of-gravity, forward of axle front stabilizer bar, and rear stabilizer bar) and a stability study at various speeds and ramp steering wheel angles was conducted. The results of this study indicated that, with a single ramp steering wheel input, two-wheel lift could not be generated with the production level configuration at any speeds up through and including 60 mph (maximum speed analyzed). This analysis agrees with an earlier independent study conducted utilizing the newly developed UNIHAND computer program (Reference Program Report entitled "Analytical Comparisons of Utility Vehicle Rollover Performance in a J-Turn Maneuver Using the UNIHAND Computer Program", dated 1-13-83) which indicated similar results up through 60 mph. A matrix summarizing limit performance for the early level prototype vehicle as tested at APG, early level prototype simulation, and final production release level simulation is shown in Attachment III.

Animated computer graphics comparing the performance of the final production release level relative to early prototype level vehicles has been generated for the following dynamic handling maneuvers:

1. Early Prototype Level	J-Turn	36 mph	360° SWA
2. 1983½ Job #1 Release Level	J-Turn	36 mph	360° SWA
3. 1983½ Job #1 Release Level	J-Turn	60 mph	360° SWA
4. Early Prototype Level	Obstacle Avoidance	32 mph	240°L/540°R/700°L/400°R SWA
5. 1983½ Job #1 Release Level	Obstacle Avoidance	32 mph	240°L/540°R/700°L/400°R SWA

DISCUSSION: (Continued)

Copies of the respective handling characteristic time plots for each of these maneuvers have been documented and are included in Attachment IV. The following movie graphically demonstrates the performance of the early level prototype and the 1983½ Job #1 release level vehicle in both J-Turn and obstacle avoidance maneuvers.

SUMMARY:

Based on the results of this study and the previous analysis conducted utilizing the UNIHAND computer code, both mutually exclusive studies concluded that it is virtually impossible to generate a two-wheel lift condition on the 1983½ Job #1 production release level Bronco II with a single steering wheel ramp input J-turn maneuver up through, and including speeds of 60 mph. As a result of our increased understanding and correlation to actual vehicle prototype testing, state-of-the-art computer simulations, and as evidenced by the results of various subjective evaluations by both Truck Management and the independent office of Safety Test Labs, the stability and dynamic performance of the production level Bronco II represents one of the best handling vehicles ever produced by Truck Operations.

This study and film segment basically concludes the dynamic handling analysis being conducted relative to the Bronco II. This model will continue to be exercised in conjunction with the VN- total vehicle dynamic model to develop advancements in subjective vs. objective handling simulations and correlations.

FUTURE PLANS

The majority of future dynamic handling analyses will be directed toward the VN-. Although a limited amount of analysis will be conducted to confirm and document the VN-'s characteristics and stability in J-turn type maneuvers, primary emphasis will be placed on optimizing "down-the-road" stability and handling performance. New analytical methods will be developed to simulate current Light Truck Development procedures such as single and double lane change maneuvers, serpentine (pylon) maneuvers, portions of the handling course, etc. Simulation of subjective handling maneuvers will be developed and correlated relative to the VN- ADAMS model, VN- prototype vehicle (pending availability), Bronco II ADAMS model and production level vehicles.

The VN- model has been completed and is currently being validated relative to front and rear suspension and steering geometry, bushing rates, shock valving, etc. Modifications to reflect recent changes in program direction will be incorporated and meetings will be scheduled with the front suspension, rear suspension, and steering sections to review the detailed models and individual applications. Preliminary handling evaluations will be simulated utilizing the VN- total vehicle model.

The following animated graphics of the VN- front suspension, rear suspension, and total vehicle model has been generated to demonstrate suspension kinematics and response as it negotiated 3 inch deep, offset potholes. (Note that the model does not include a enveloping tire and is meant to demonstrate the front and rear suspension kinematics only).

ATTACHMENTS

I. Light Truck Dynamic Tire Testing and Modeling Development

II. Correlation Runs

A. 30 mph/110° Steering Wheel Angle (SWA)
B. 33 mph/360° SWA
C. 45 mph/210° SWA

III. Plot of Steering Wheel Angle vs. Speed for Two Wheel Lift Thresholds

IV. Film Simulation Plots

D.	Early Level Prototype	36 mph/360° SWA
E.	1983½ Job #1 Production Level	36 mph/360° SWA
F.	1983½ Job #1 Production Level	60 mph/360° SWA
G.	Early Level Prototype	32 mph/IIHS Lane Maneuver #2
H.	1983½ Job #1 Production Level	32 mph/IIHS Lane Maneuver #2

LIGHT TRUCK DYNAMIC TIRE TESTING AND MODELING DEVELOPMENT

PREVIOUS TIRE MODELING

Traditionally, vehicle dynamic simulations have utilized a relatively narrow range of tire/road interaction parameters:

- Lateral Force
- Camber Thrust
- Aligning Torque
- Vertical Load/Deflection

Each of these parameters was assumed to be independent of each other and linearly additive. Steady-state test values were determined in a limited parameter matrix that held the camber and/or slip angle at zero. When roll, slip, and camber are small, this formulation is adequate, and gives reasonable correlation with vehicle tests. However, for performance in severe and limit maneuvers, the use of steady-state test values and the linearly additive assumption cannot be justified. Another problem which resulted from the use of conventional test data and data reduction routines was the reversal of the second derivative of the lateral force vs. slip angle curve which resulted in an unrealistic tire that does not saturate in cornering. (See Page 5)

The incorporation of the ADAMS code for analyzing and predicting total vehicle handling performance opened up a new frontier in the art of dynamic simulation. The correct transient values of slip angle, camber angle and position of each individual tire, under the effect of roll steer, Ackerman, steering compliance and compliance steer, became available at each time step in the dynamic integration. When the conventional carpet plot tire test data was utilized as input to the sophisticated ADAMS model, correlation with test data at limit maneuvers (near 100% lateral weight transfer and slip angles in the range of 20 to 30 degrees) was somewhat disappointing. As a temporary measure, two steps were taken: camber thrust was deleted, and the lateral force curves were artifically adjusted to provide more reasonable values. As an additional expediency, the tire was modeled as being rigid, pentrating the road as required to maintain the proper loaded vertical wheel center to ground distance.

With these modifications, good correlation was obtained and valuable studies were conducted to optimize the dynamic handling characteristics of the Bronco II.

IMPROVED TIRE MODEL

In view of the dynamic simulation capabilities developed through the incorporation of the ADAMS model, state-of-the-art tire test data acquisition and utilization had to be developed to support this level of analysis.

IMPROVED TIRE MODEL (Continued)

First, a creative new tire test procedure had to be established to more acurately simulate dynamic handling maneuvers. The data range had to be extended to at least $\pm 30^{\circ}$ slip angle and camber thrust had to be included in the linear region as well as in the lateral force saturation zone. During the test procedure, heat build-up, pressure rise and tire wear had to be minimized, or inconsistent data would be collected.. Instead of the standard data set of lateral force and aligning torque, it seemed reasonable to desire the full complement of the three force and three moment components as a function of the dynamic slip angle, camber angle and rolling radius. (See Pg. 6 for the SAE convention and definition of terms.)

Second, new algorithms had to be introduced for data analysis. The MTS bi-cubic formulation that is used to generate current conventional carpet plots was not truly representative of dynamic tire performance at relatively high slip angles, or when combined slip and camber angles are present. A Ford ECC program was developed for car engineering tire parameters definition, however this program is limited to low slip angles, and treats lateral force and camber thrust as linearly additive. There was no procedure available for defining general load/deflection relations. These programs neglected the overturning moments (M_x) and rolling resistance was evaluated for straight ahead driving only. New algorithms had to be developed to more efficiently handle these non-linear characteristics and provide for a more sophisticated tire model representative of dynamic tire behavior, without overwhelming the simulation with literally thousands of raw data points for each tire condition.

Finally, since the front spindles would now be supported by a six degree of freedom model instead of a rigid tire, unique routines had to be written to provide the basic ADAMS code with the partial derivatives of the tire forces with respect to the model's generalized coordinates. (This requirement pointed out a deficiency in the current ADAMS code. As a result, Light Truck Suspension Design is cooperating with ECC and Advanced Chassis to enhance the ADAMS code so that external forces acting between defined kinematic links can be simply input through user defined F-sub statements).

NEW TIRE TEST PROCEDURE

In order to obtain representative dynamic tire data, the capabilities of the Calspan tire test machine and its dedicated computer were studied, and the following test procedure was established and executed:

1. Warm up and loosen tire by running for 15 minutes at 45 mph under 100% of the T&RA rated load.

2. Set the machine to the specified camber angle, with the slip angle at -10° and the belt running at the specified speed.

NEW TIRE TEST PROCEDURE (Continued)

3. Load tire to first specified load (usually 500 lbs.) and commence slip angle sweep.

4. Sweep at a rate of 5° per second from -10° to +30° back to -30° and return to +5°. The overlap of the initial -10° to 0° and the final 0° to +5° were specified to assure that full ± 30° data would be obtained with the tire in a transient mode.

5. Take readings every 0.3 seconds (approximately every 1.5°).

6. Maintain the specified load throughout the run.

7. Maintain the warm up tire pressure (specified cold inflation plus 3 psi) throughout the run.

8. To reduce the cost and total number of runs, utilize only 10 of the 31 channels available. (The computer can store a maximum of 7500 data items per run).

9. Repeat steps 2 through 8 for three additional vertical loads up to 150% of rated capacity.

10. Repeat steps 2 through 9 for new camber angle.

The 10 step procedure outlined above is classified as a single test and results in test data for 2 camber angles and 4 vertical load conditions for slip angles from -30° to +30°. Two such tests, at a cost of $600 each, provide one complete set of data for a given tire.

TEST RESULTS

A typical set of raw test data is shown in figures 7 to 14, indicating that:

1. Tire vertical spring rate is nearly linear at zero slip angle, but decreases with load at higher slip angles

2. Lateral force curves (Pg. 9) show clear saturation, with a near linear decrease in loads subsequent to the peak value. Also noteworthy is that the saturation slip angle increases with load. This saturation becomes even more evident when the cornering force is computed (Pg. 10). (Cornering force is the resultant of the tire forces perpendicular to the velocity vector. It is the force that causes the vehicle to turn and have a lateral acceleration).

TEST RESULTS (Continued)

3. The magnitude of the overturning moment M_x (Pg. 12) was surprisingly high, reaching a value of 350 ft. lbs. at 2000 lbs. vertical force, and indicating 2.1 inches of lateral tire distortion. There was considerable scatter in the data, which can be attributed to in-and-out fluctuations of the tire sidewall as different tread blocks and grooves rotate into position to form the tire patch.

4. The aligning torque data (Pg. 14) shows even more scatter than the M_x data. This is attributable to the continually changing distribution of the slip/adhesion zones within the tire patch.

DATA REDUCTION

As previously stated, new data reduction algorithms had to be developed to reduce the magnitude of raw tire data.

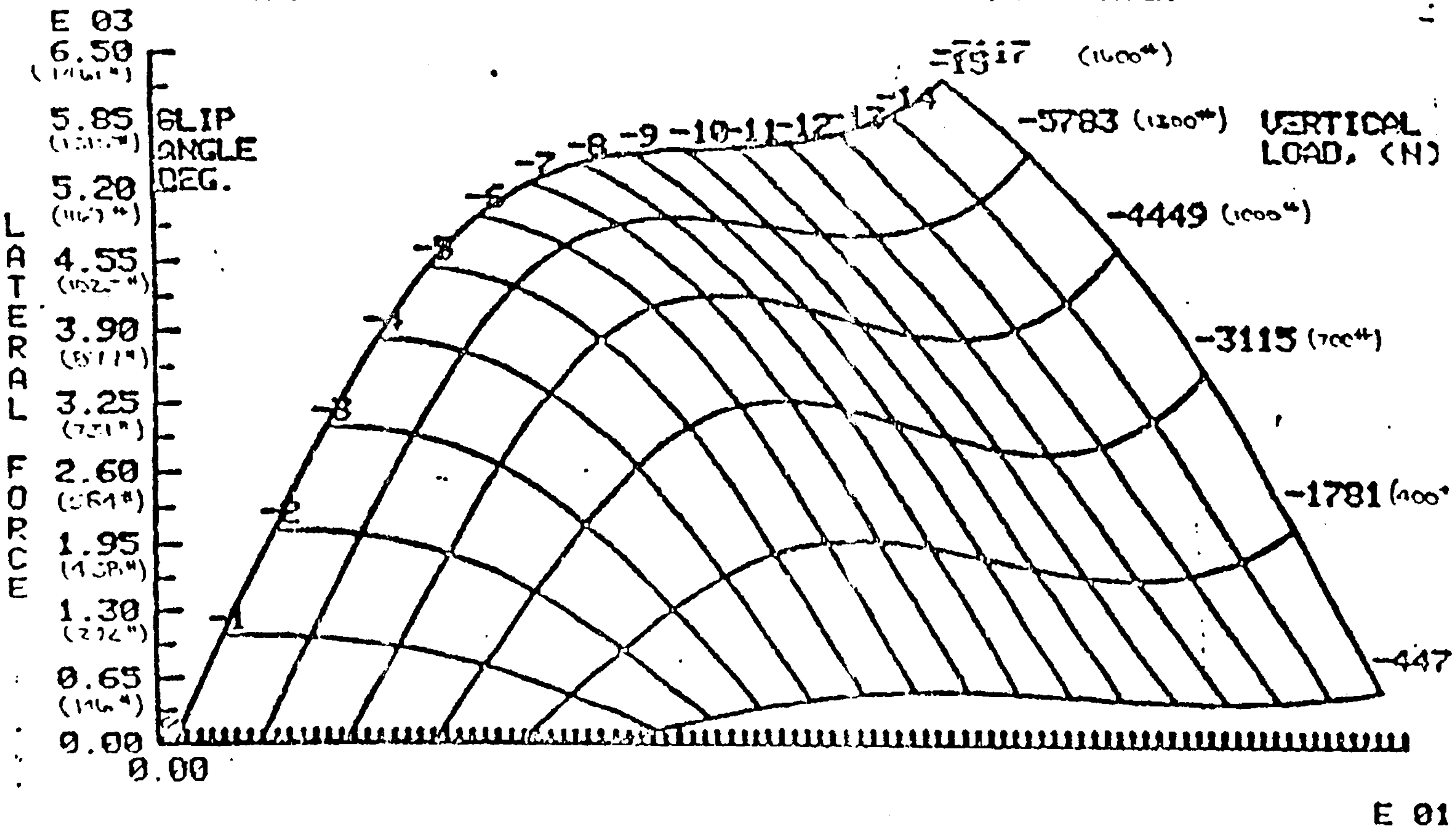
First, the MTS/GM established data region boundries were replaced by new boundries that are more appropriately descriptive of the test data (Pg. 15) Second, the bi-cubic multiple linear regression algorithm was limited to a cubic-quadratic in slip angle (alpha) and vertical force (F_z) in the central four regions, and to a bi-quadratic at the two high slip angle regions. This latter measure eliminated the tendency of slope reversal at high slip angles while maintaining a multiple correlation coefficient of over 0.99. Third, the vertical force/deflection curve was represented by a cubic-quadratic equation in alpha and radial deflection, modified to eliminate pure alpha terms. Again, the cubic terms in alpha were dropped in the high slip angle regions. This formulation gave an excellent fit with a correlation coefficient of 0.9999.

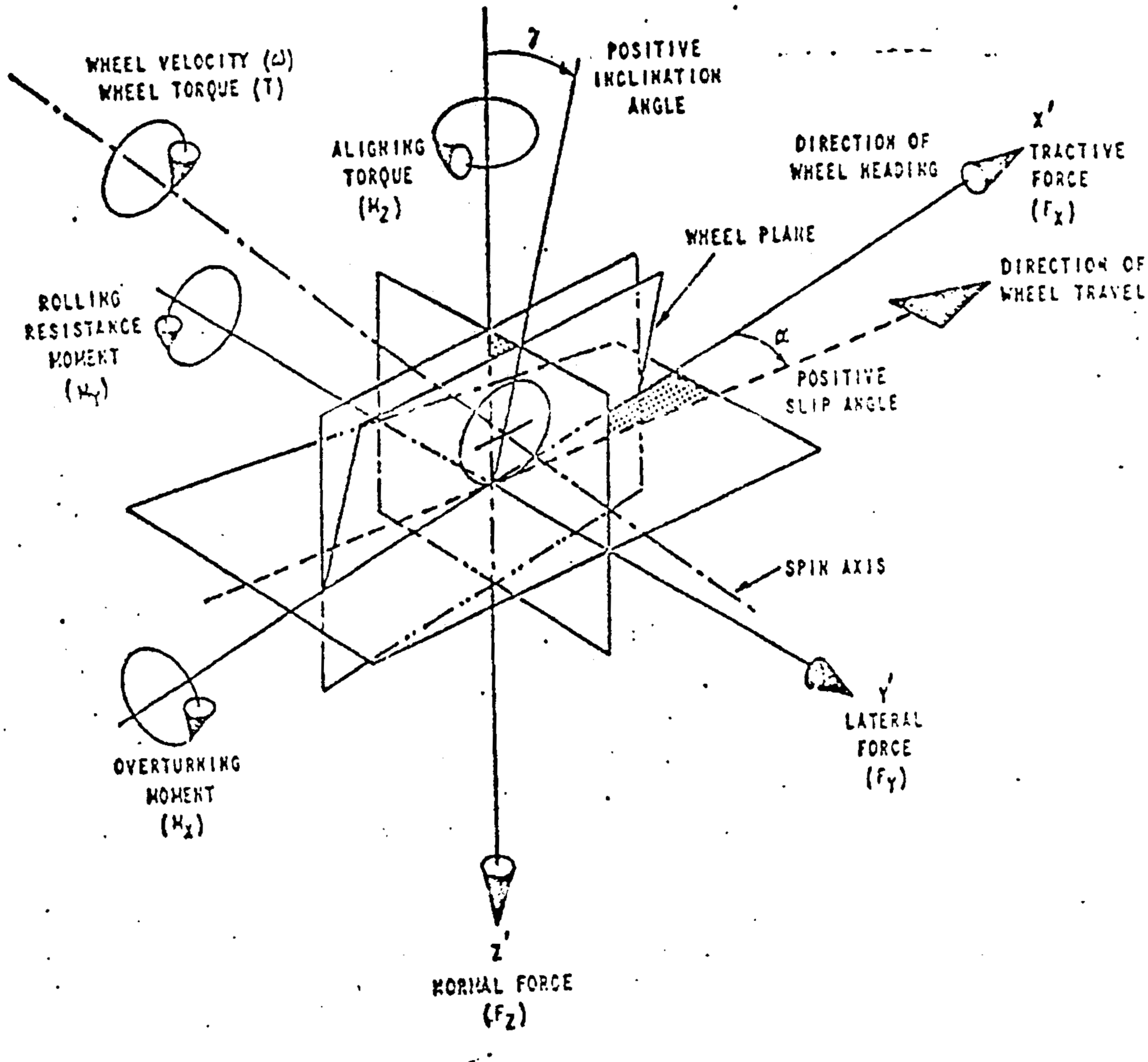
Individual test runs/camber range data was extracted from the test tape, smoothed, divided into overlapping regions, and processed through the multiple linear regression routines. The regression coefficients were written into composite tire data files, and contain all the data required for the ADAMS simulation. For visual inspection of the resulting curves which are defined by these coefficients, routines were written to plot these characteristic curves on local Tektronix graphics tubes. This data is presented in plotted form on pages 24 through 27. Average deviation from test data is 2% for forces and 6% for moments.

In total, twelve computer programs were developed for the full sequence of data reduction and plotting routines.

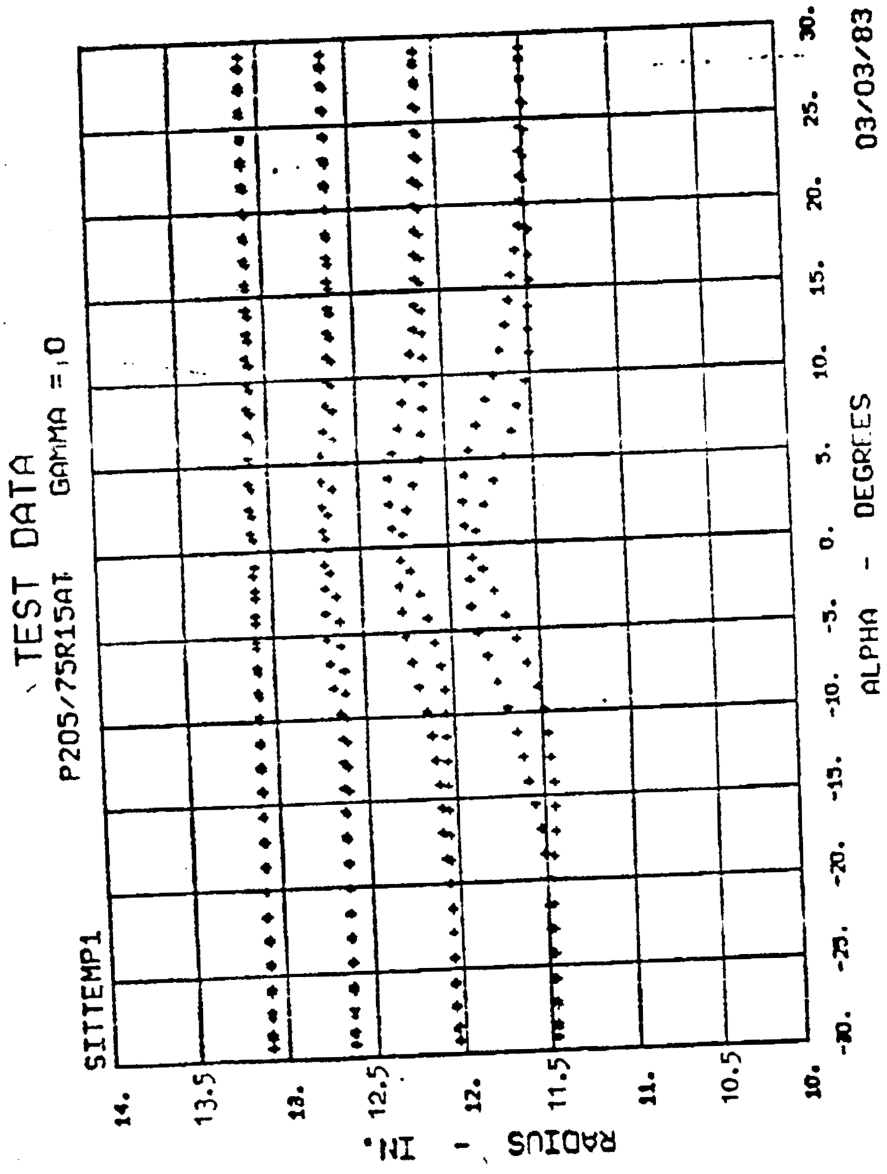
LATERAL FORCE VS SLIP ANGLE AND VERTICAL LOAD

TEST FILE	:T1694	TEST DATE	: 9-APR-82
TIRE SIZE	:P195/75R15	MANUFACTURER	:GOODYEAR
INFLATION (KPA)	:241	RIM WIDTH (IN)	:5.5
CONSTRUCTION	:0X5461A-167	AMB TEMP (C)	:23.6
TEST NO.	:0X546P-L16A	TIRE TYPE	:BUFFED WRANGLER MS
MAX SLIP ANGLE	:14	ORIGINATOR	:RP D4V13 (HDA)
T & RA LOAD (N)	:4448	FIT ERRORS	: 12.2 % AVG.





SAE TIRE AXIS SYSTEM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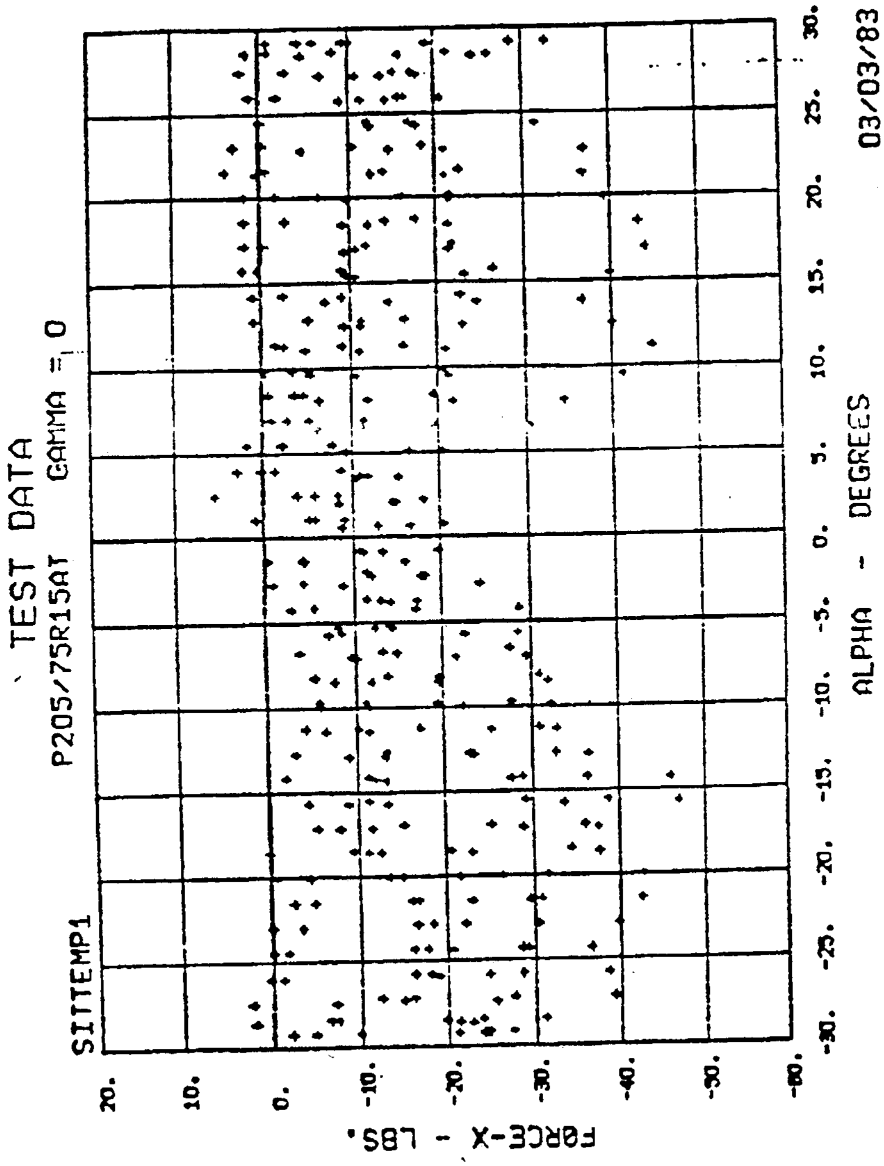
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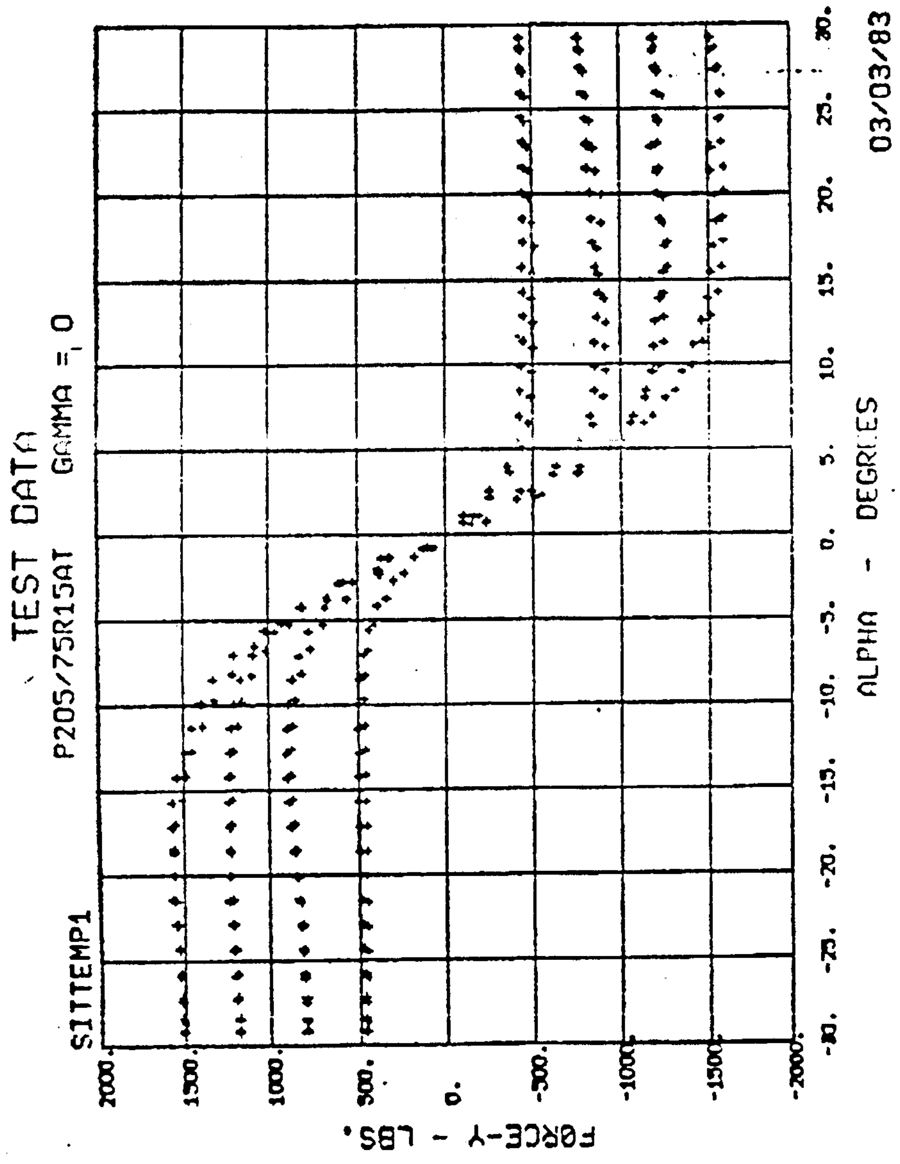
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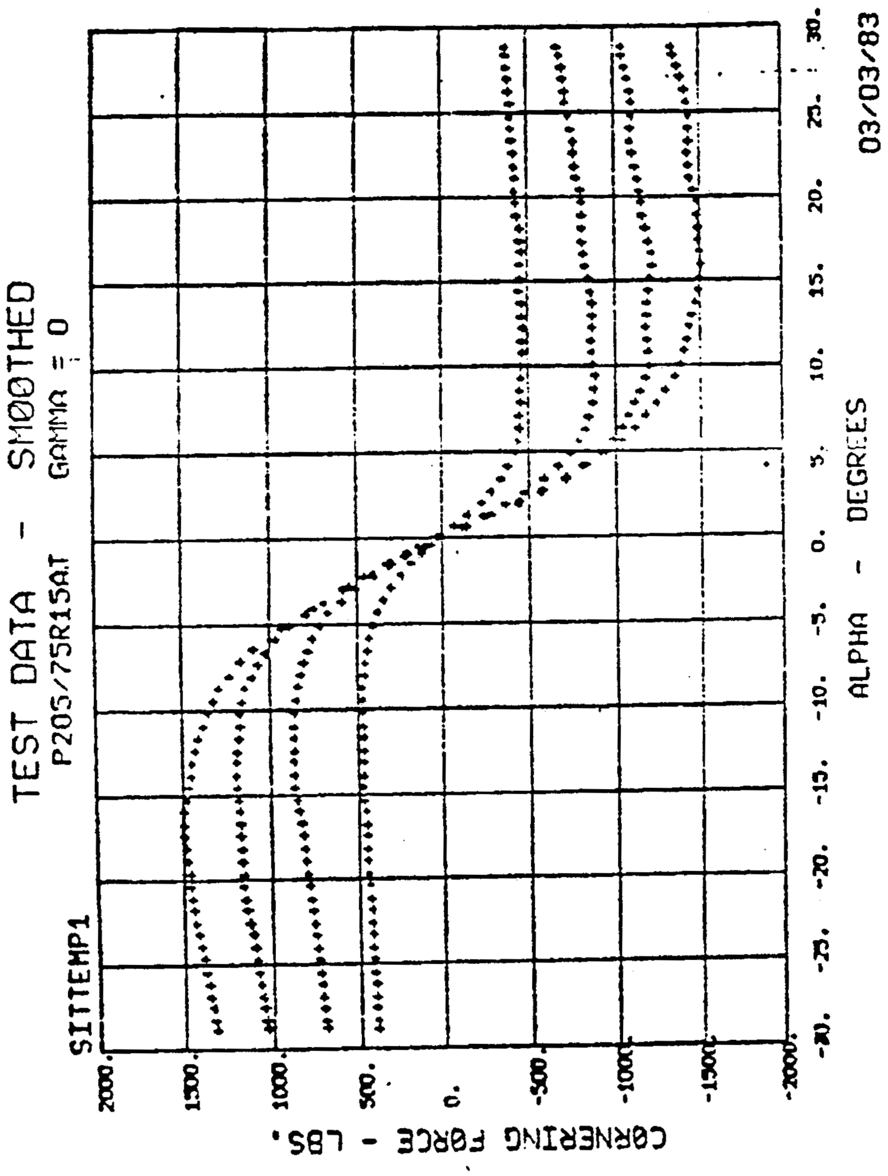
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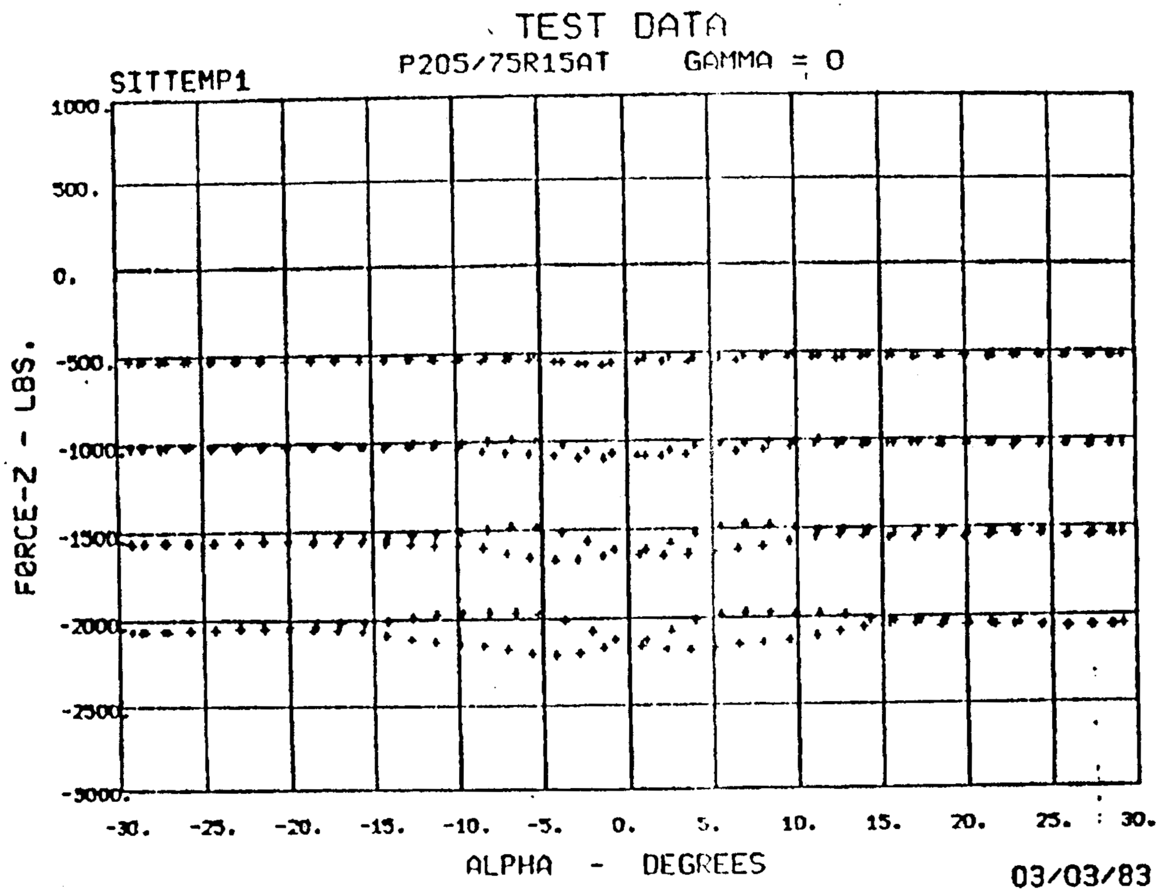

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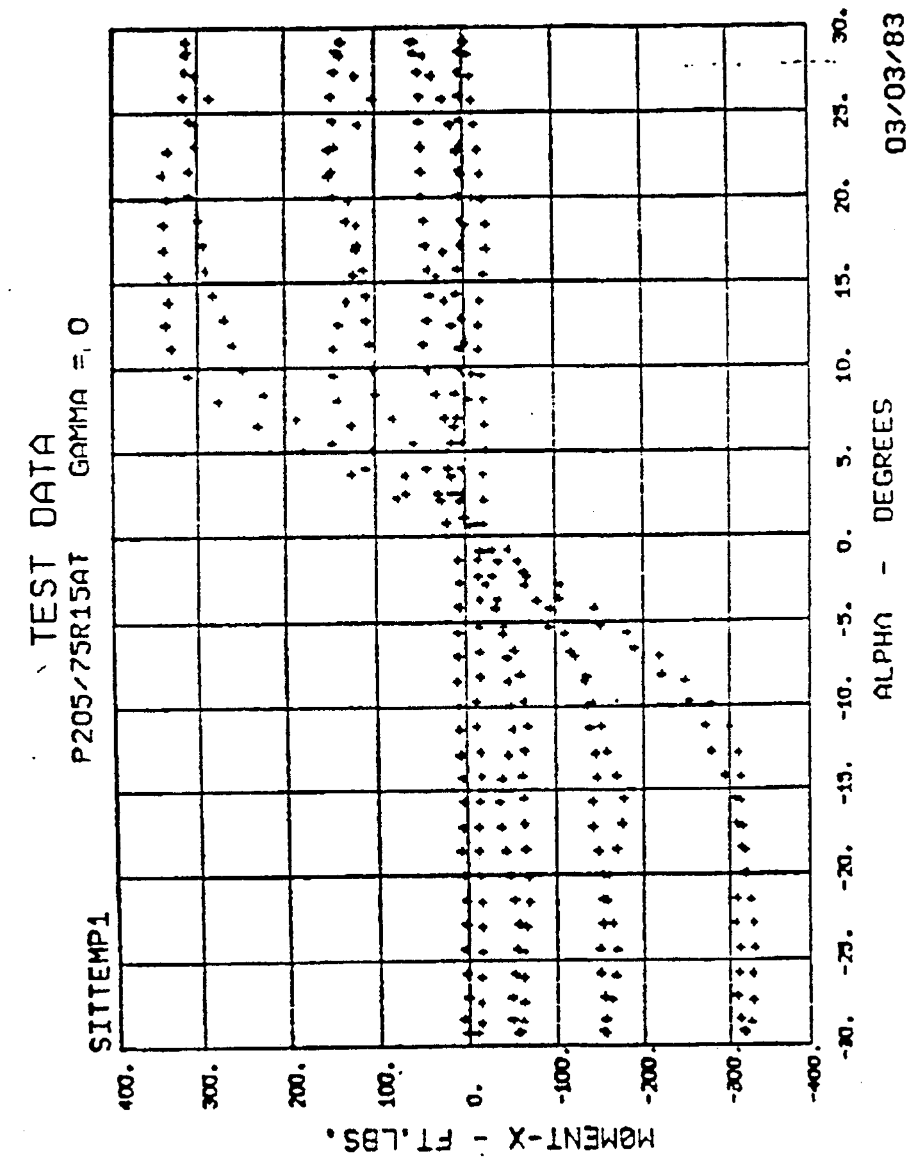
Attachment I
Page 11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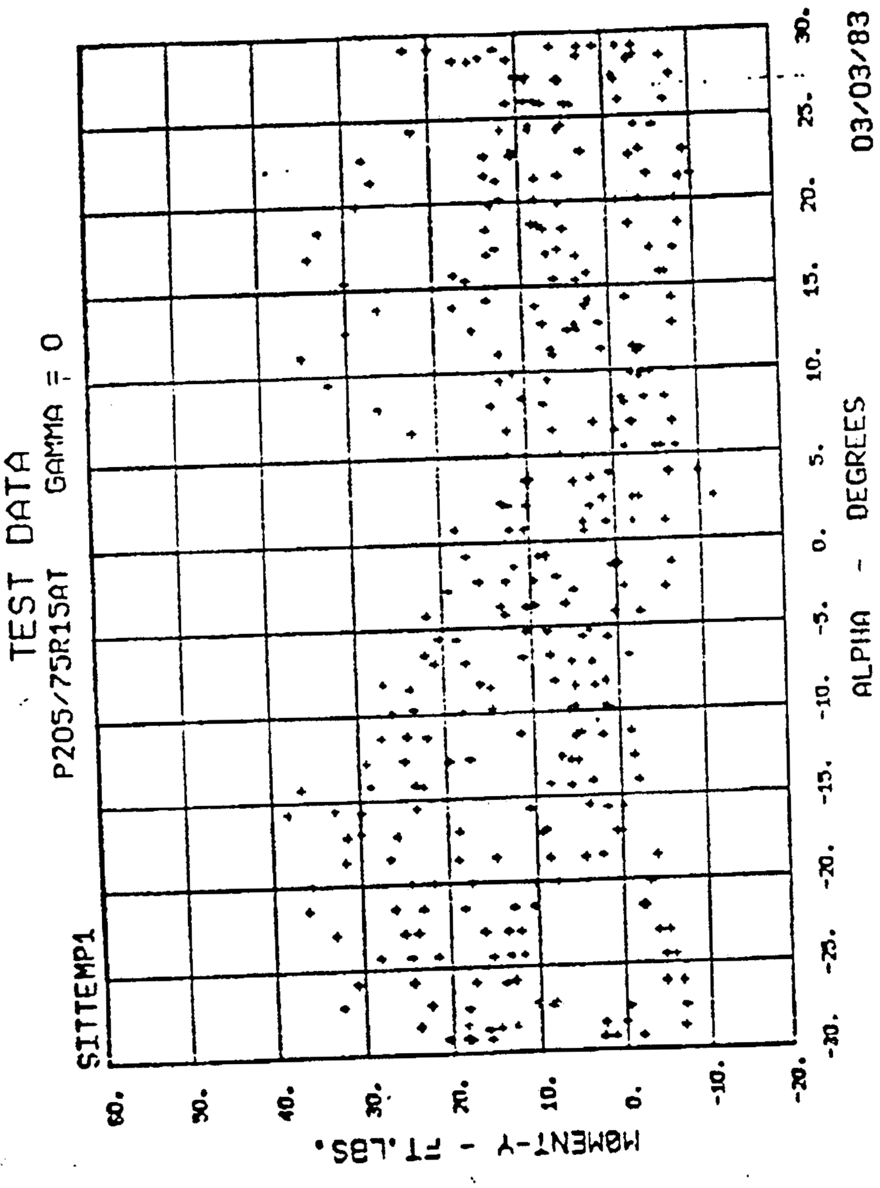
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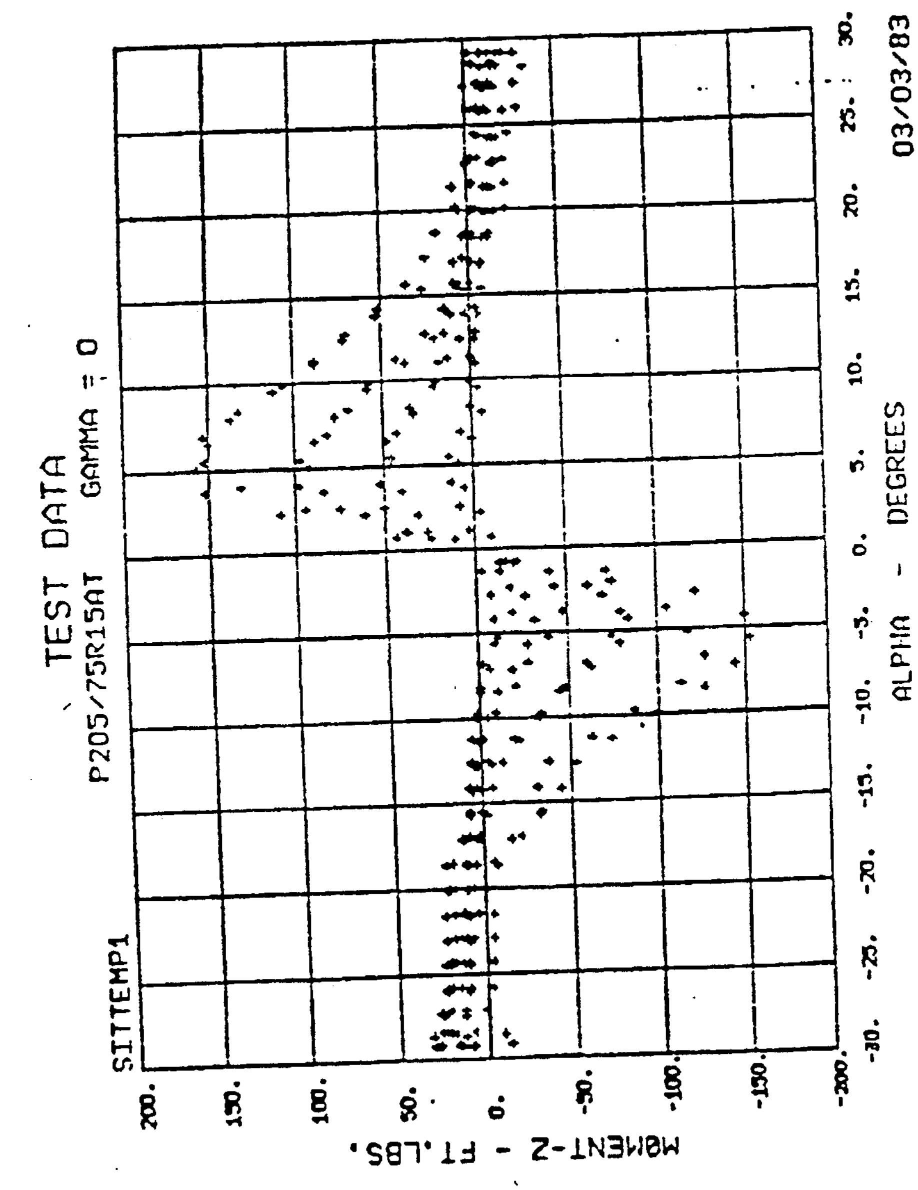
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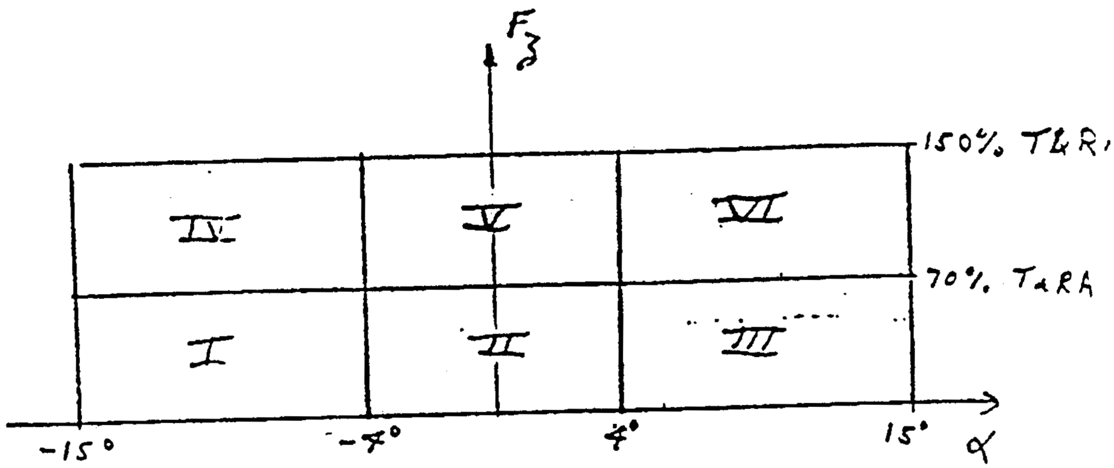

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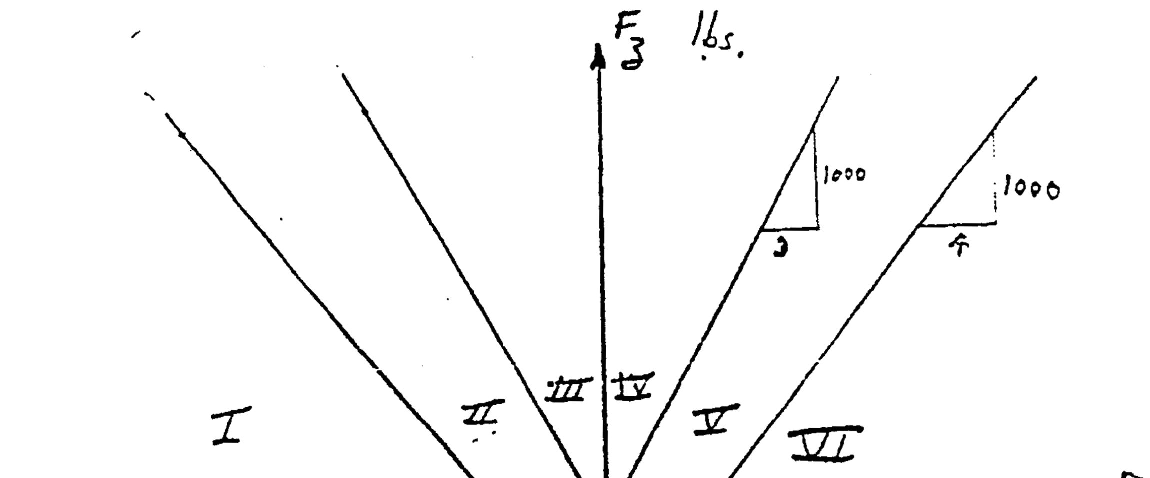

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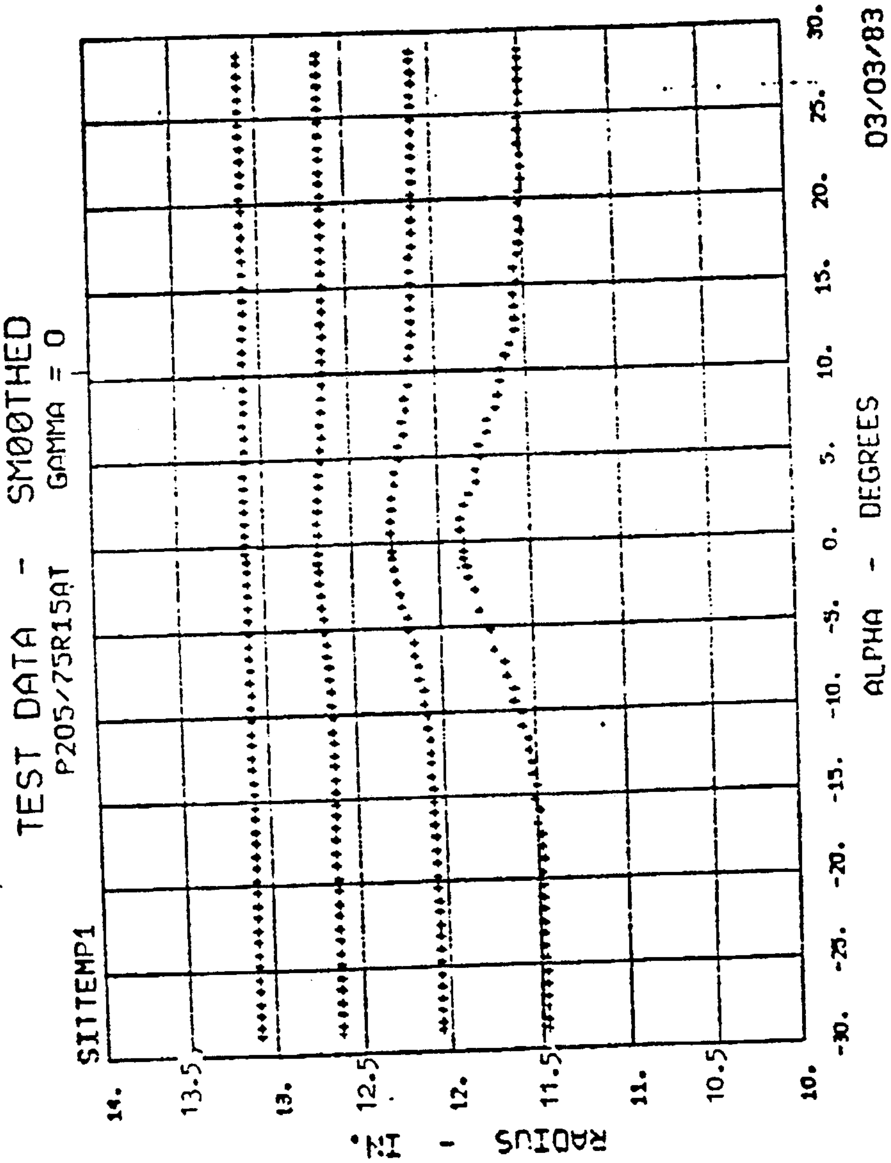
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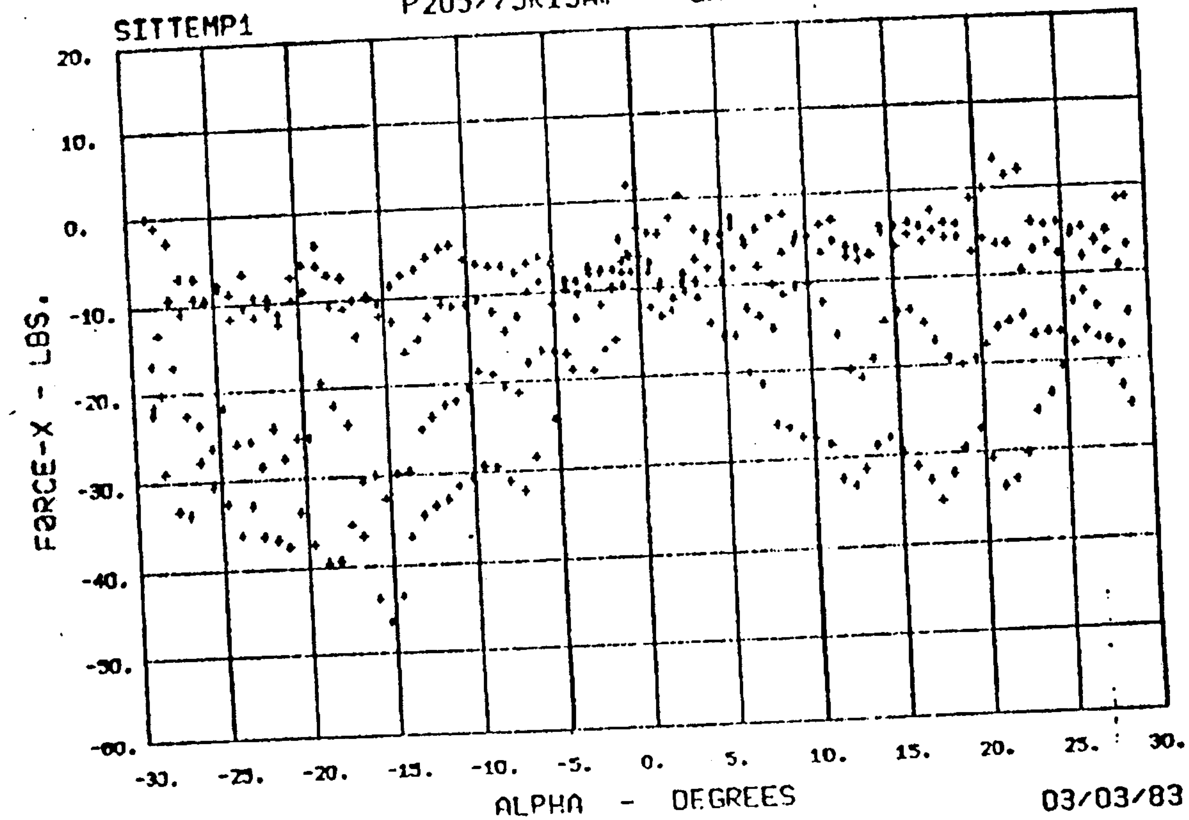

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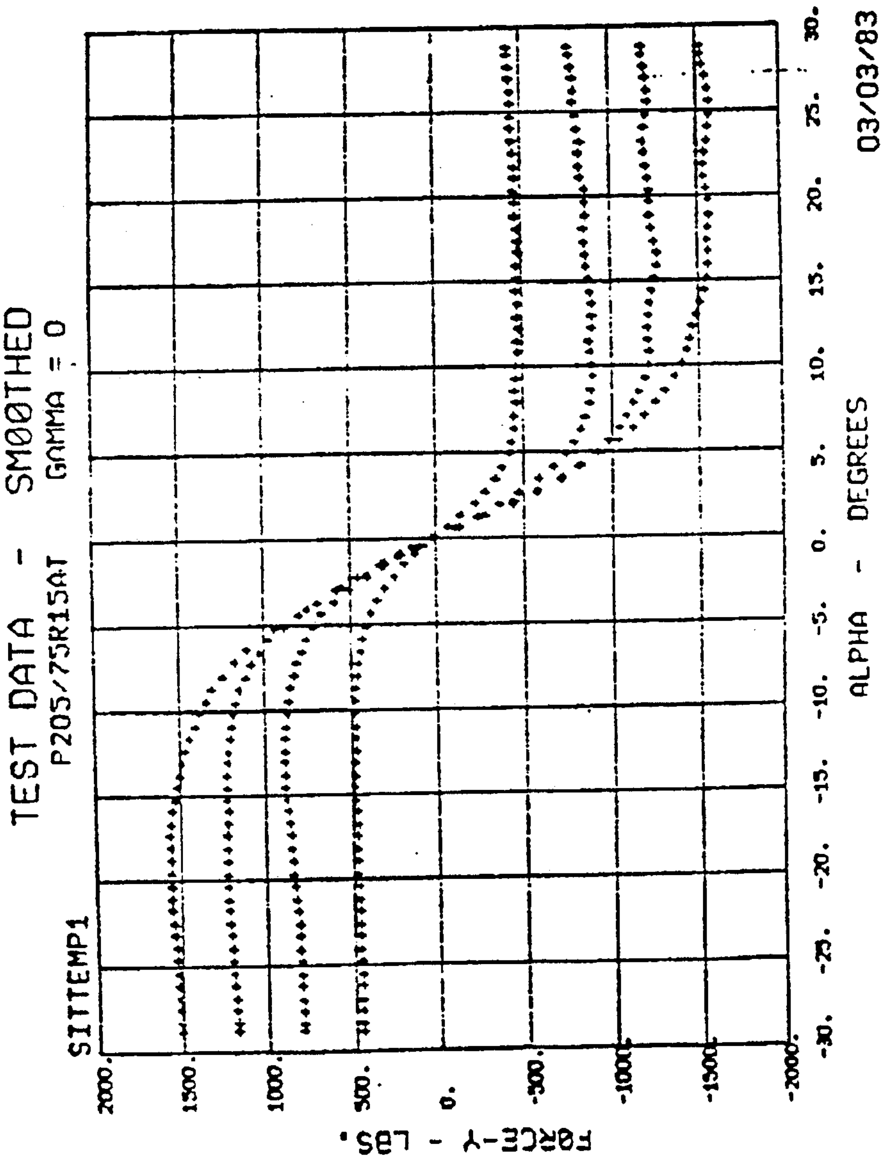
Attachment I
Page 17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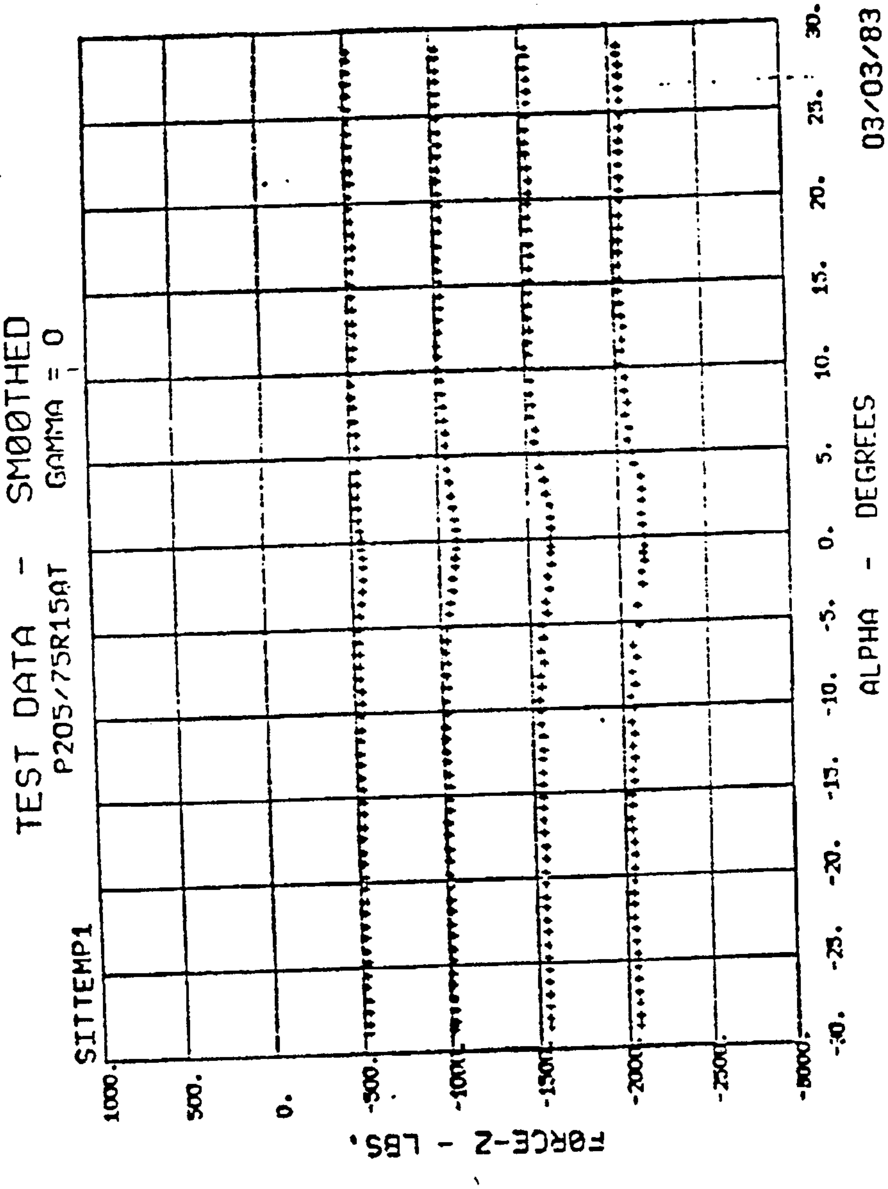
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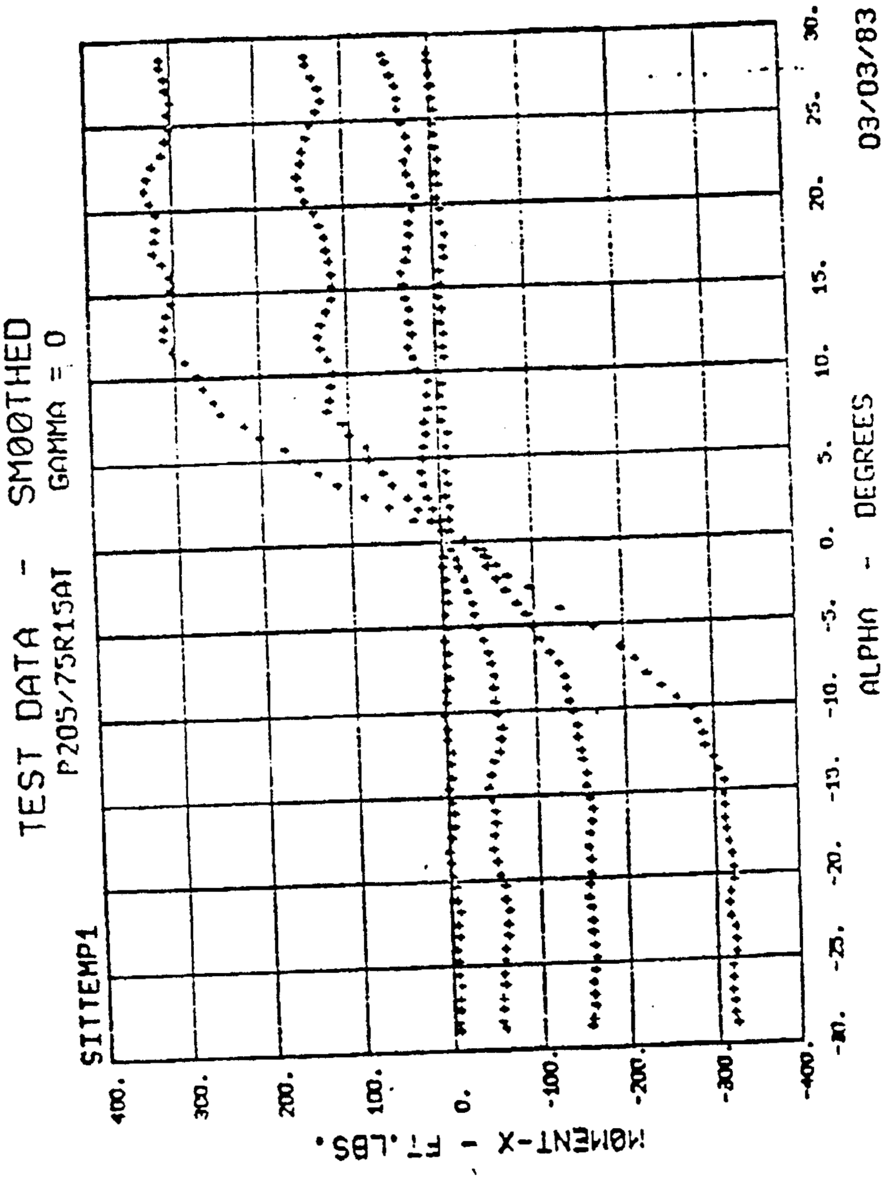
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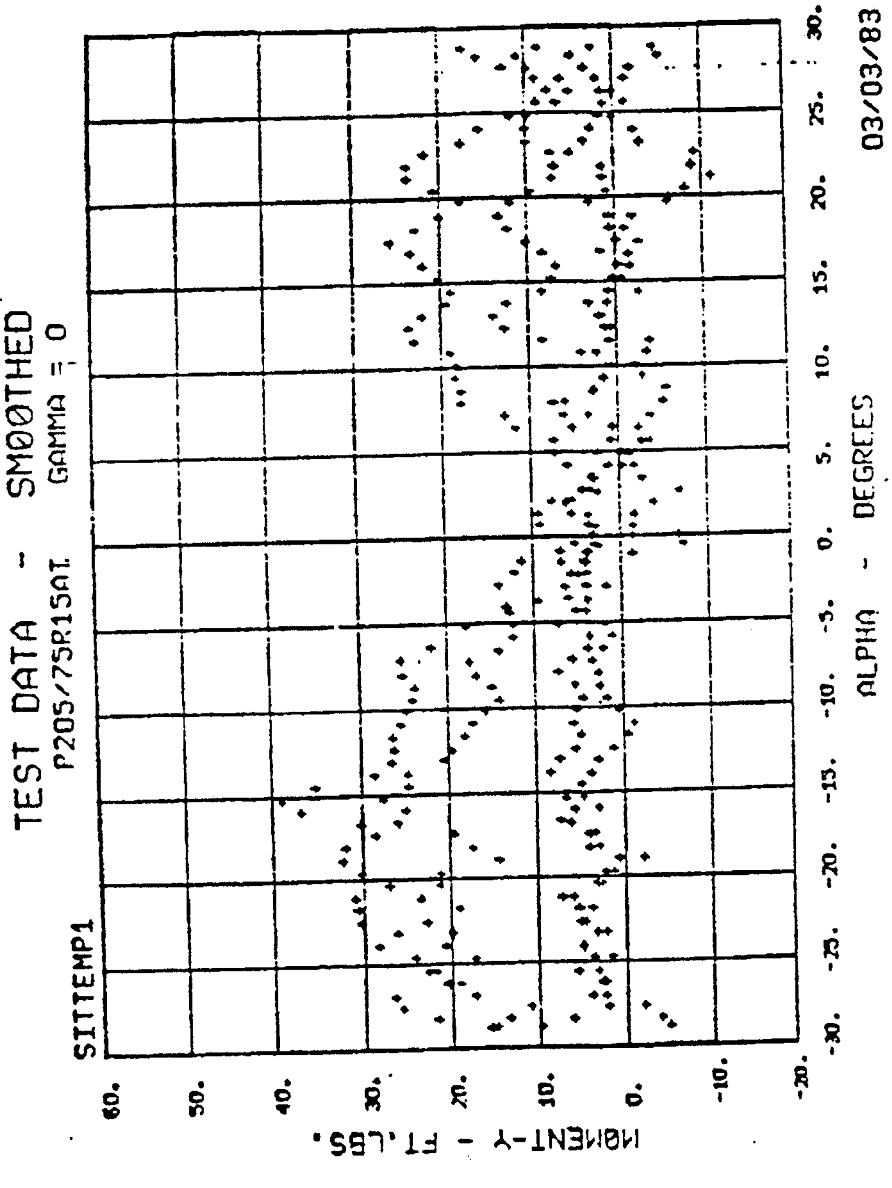
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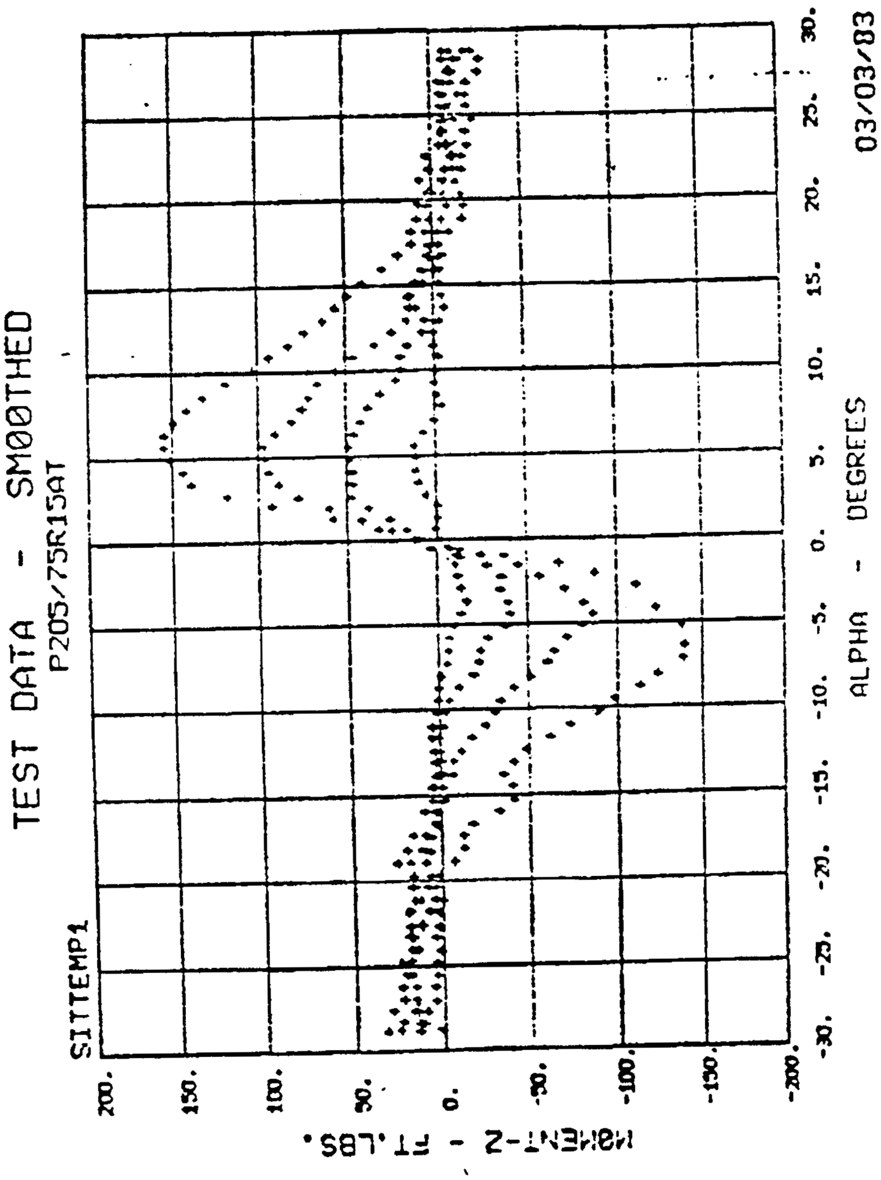
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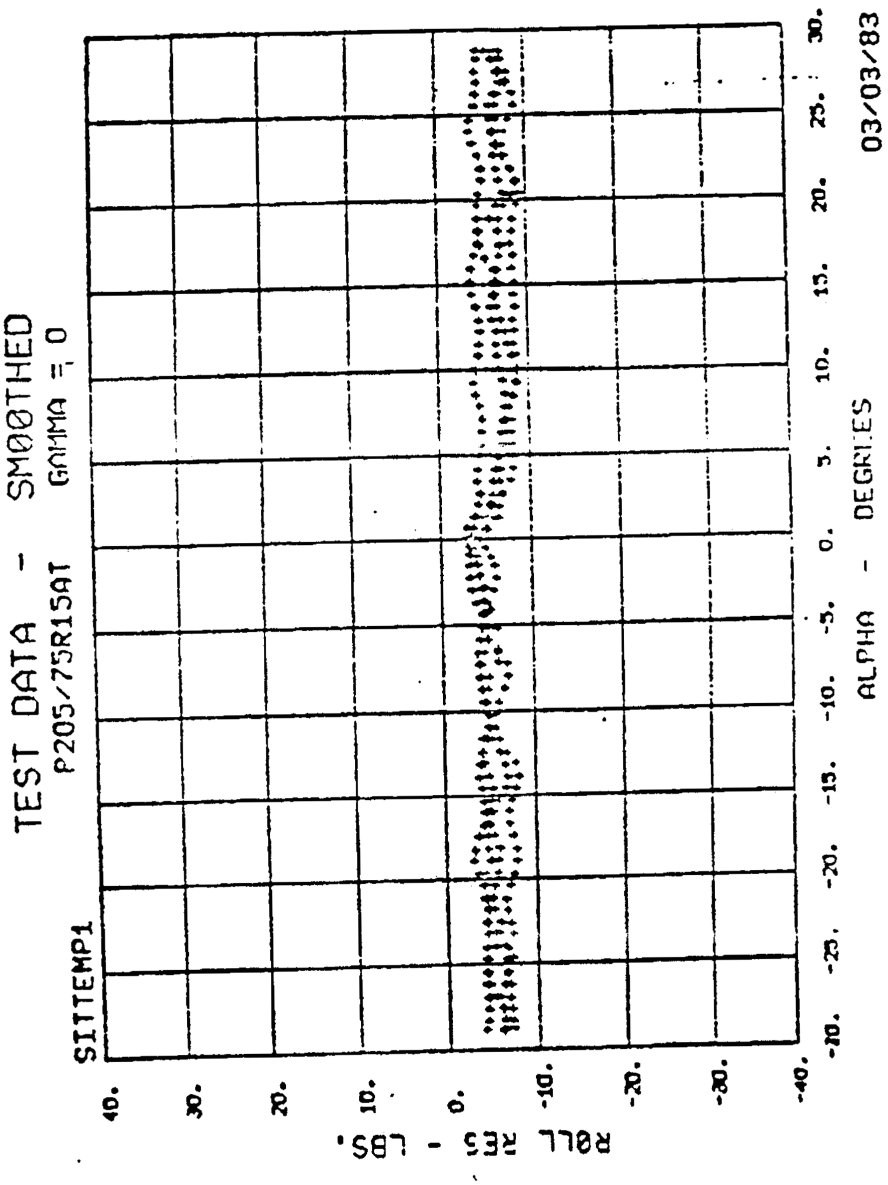
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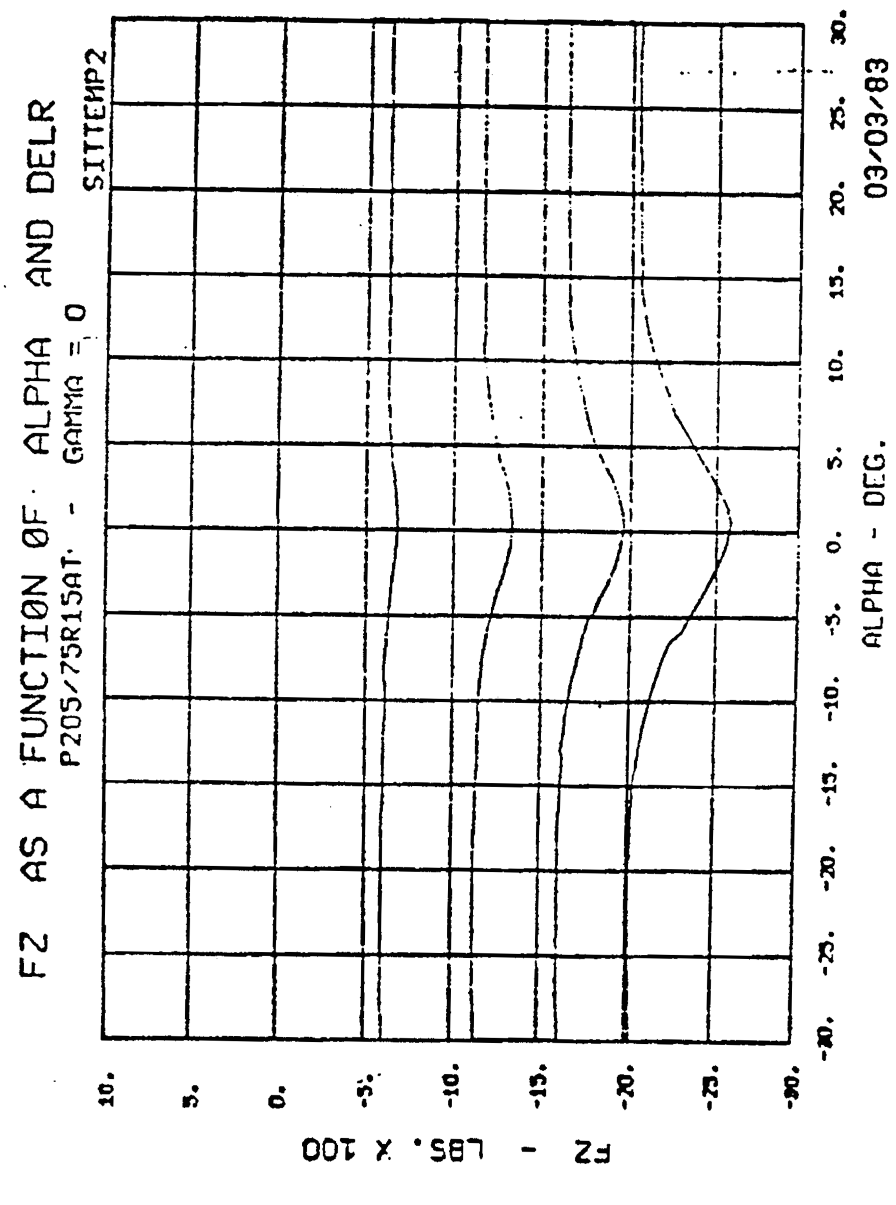
FZ AS A FUNCTION ØF ALPHA AND DELR
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03/03/83
FZ - LBS. X 100
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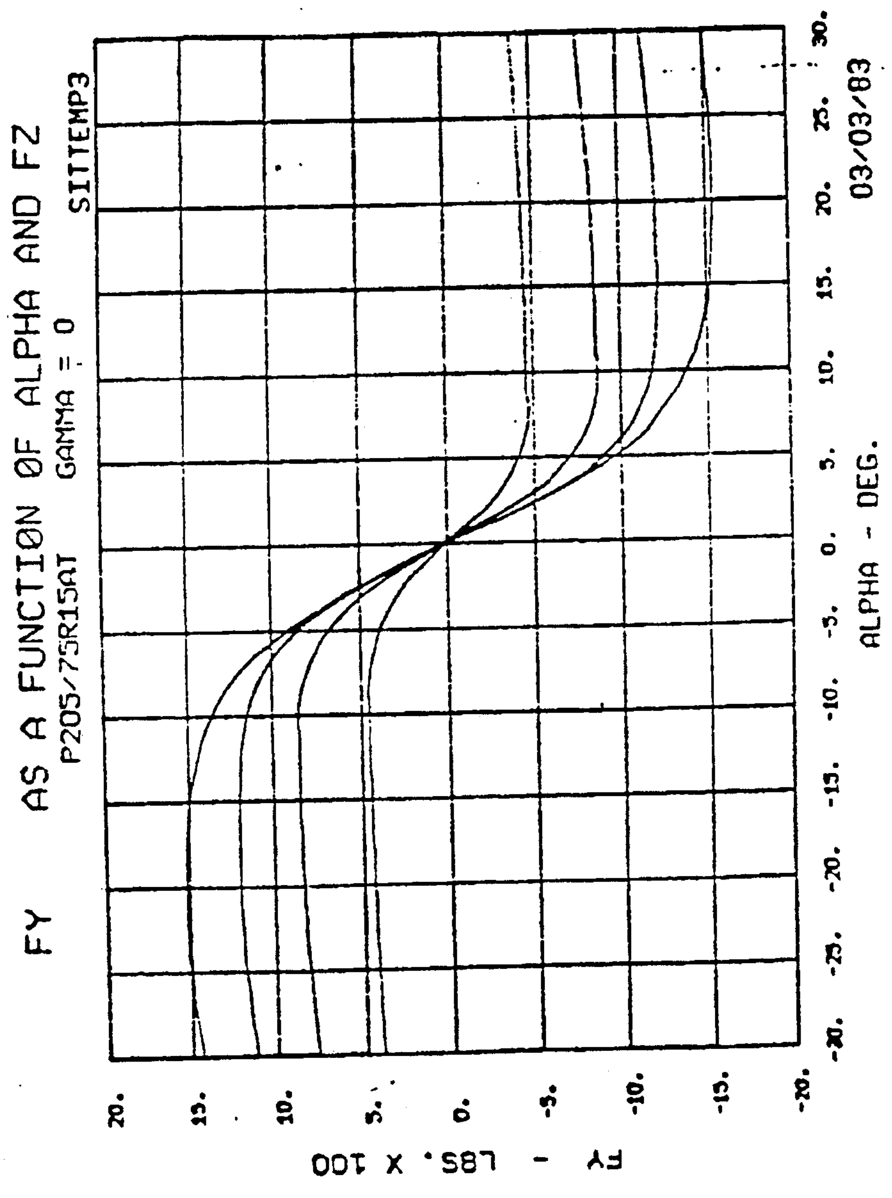
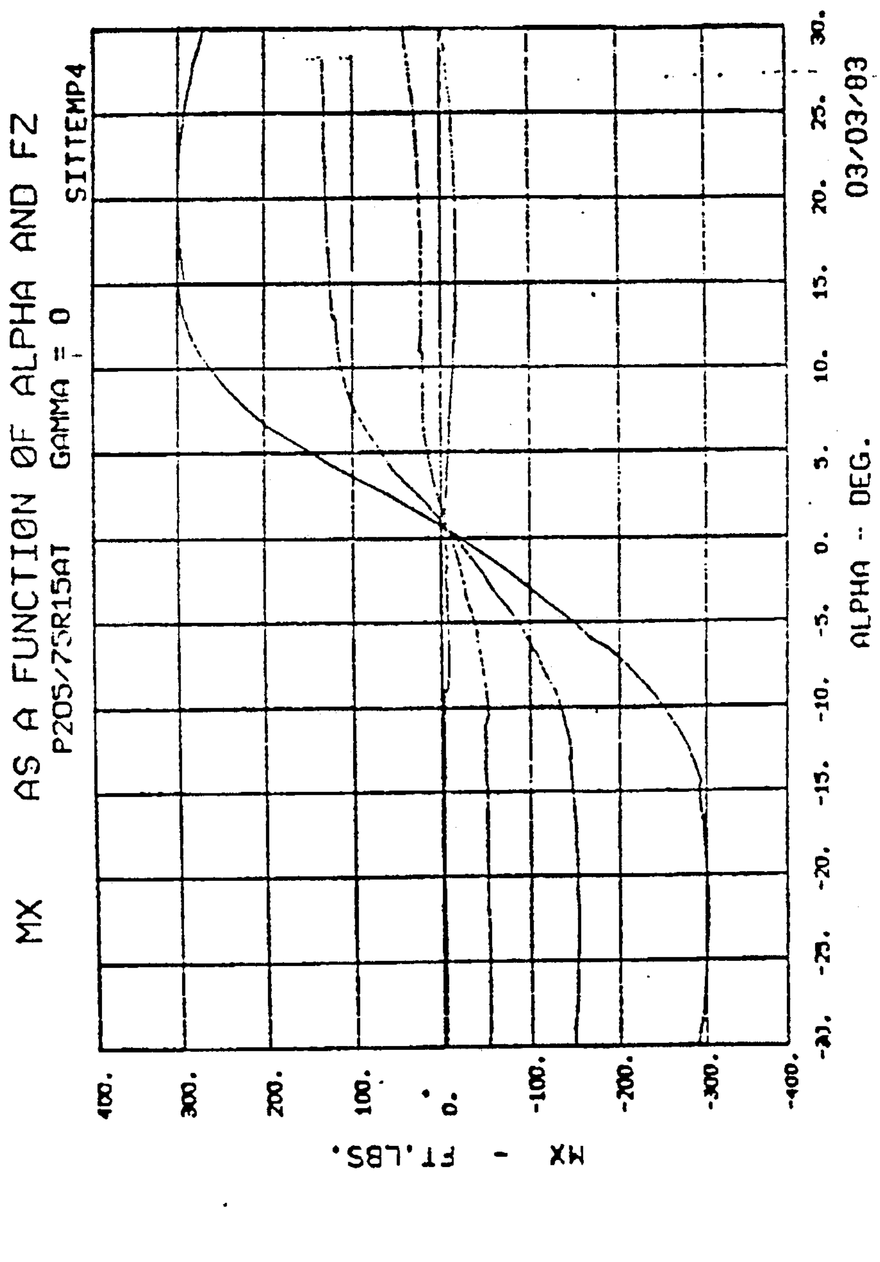
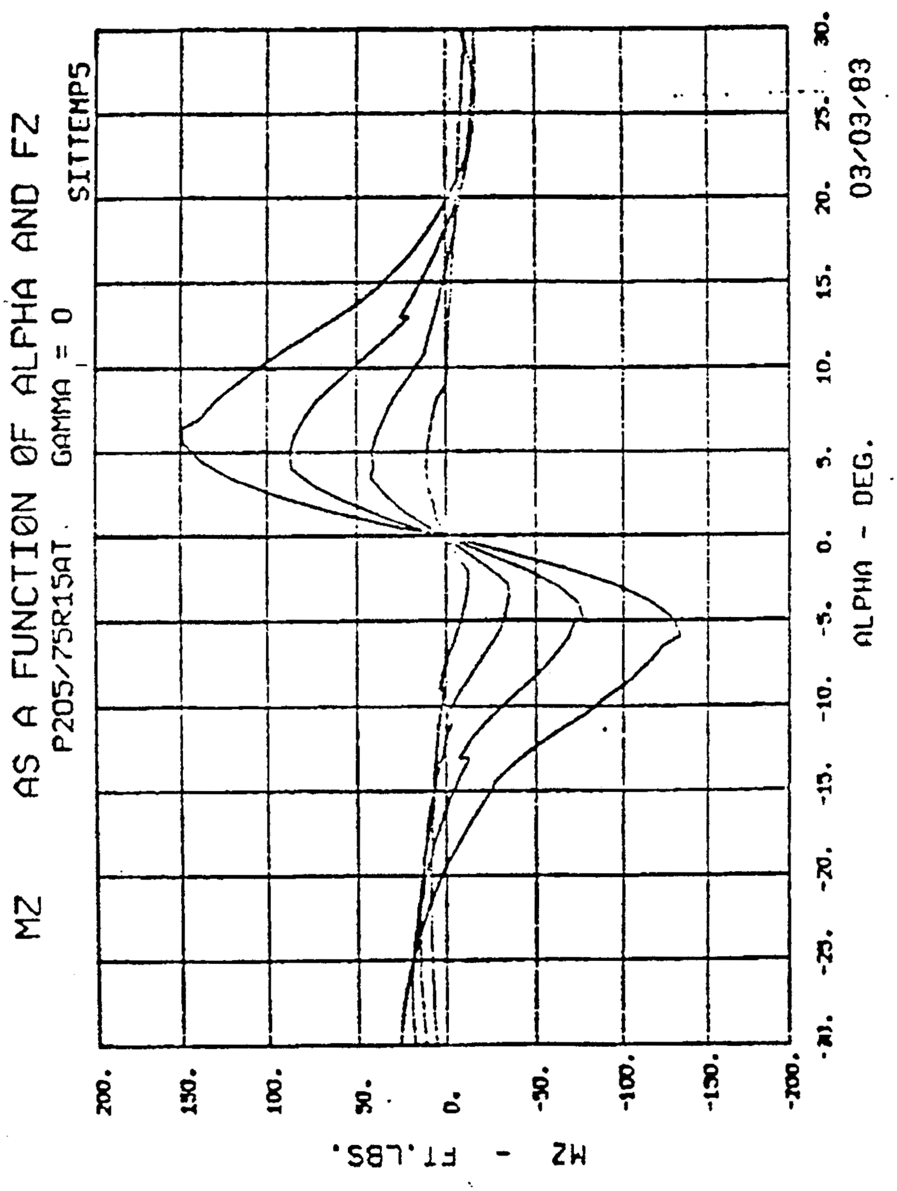
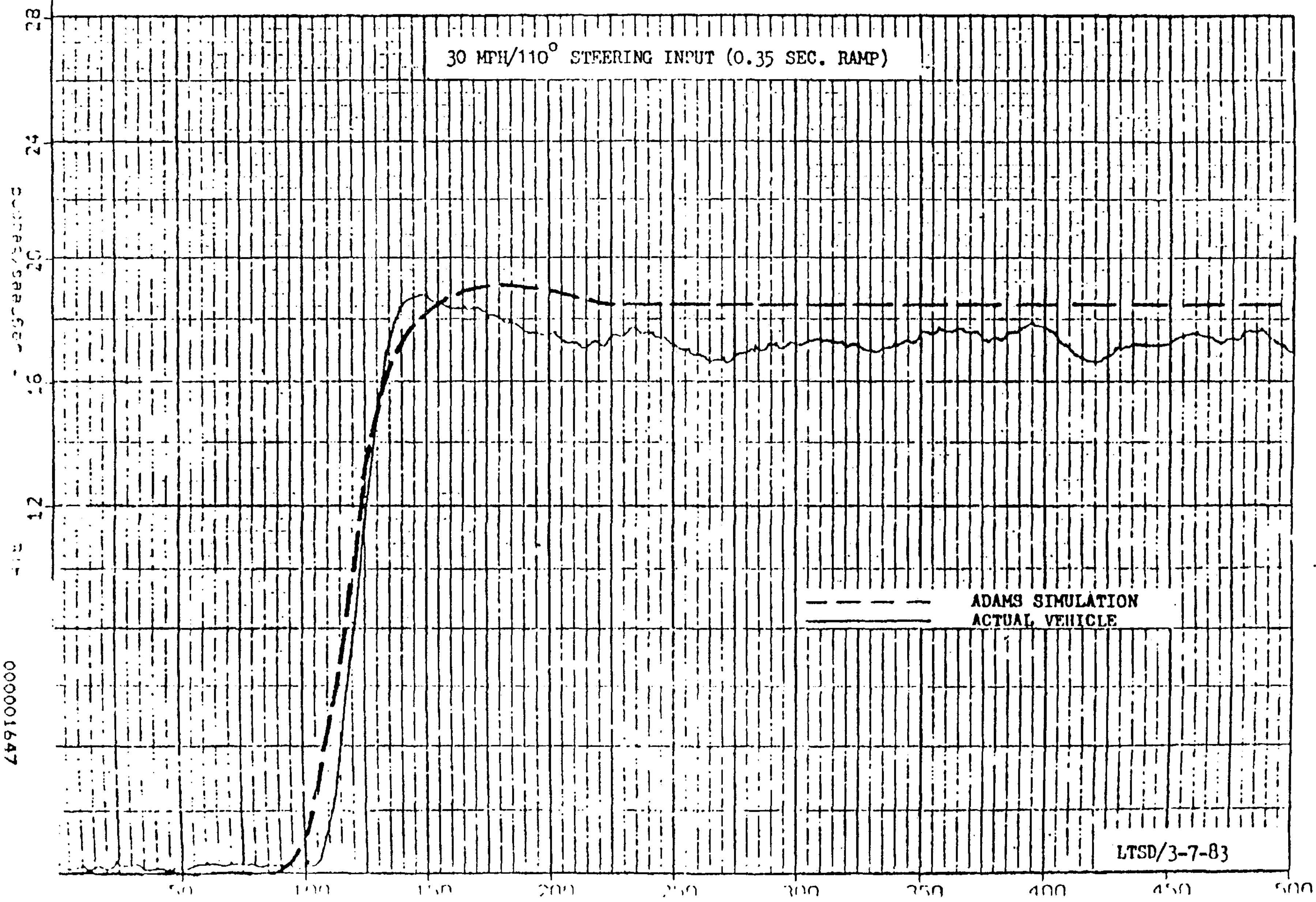

FY AS A FUNCTION ØF ALPHA AND FZ
P205/75R15AT GAMMA = 0 SITTEMP3
03/03/83
ALPHA - DEG.
FY - LBS. X 100


MX AS A FUNCTION ØF ALPHA AND FZ
P205/75R15AT
GAMMA = 0
SITTEMP4
03/03/83
ALPHA - DEG.
-30. -25. -20. -15. -10. -5. 0. 5. 10. 15. 20. 25. 30.
MX - FT.LBS.
400. 300. 200. 100. 0. -100. -200. -300. -400.


MZ AS A FUNCTION OF ALPHA AND FZ
P205/75R15AT GAMMA = 0 SITTEMPS
-30. -25. -20. -15. -10. -5. 0. 5. 10. 15. 20. 25. 30.
ALPHA - DEG.
03/03/83
200. 150. 100. 50. 0. -50. -100. -150. -200.
MZ - FT.LBS.

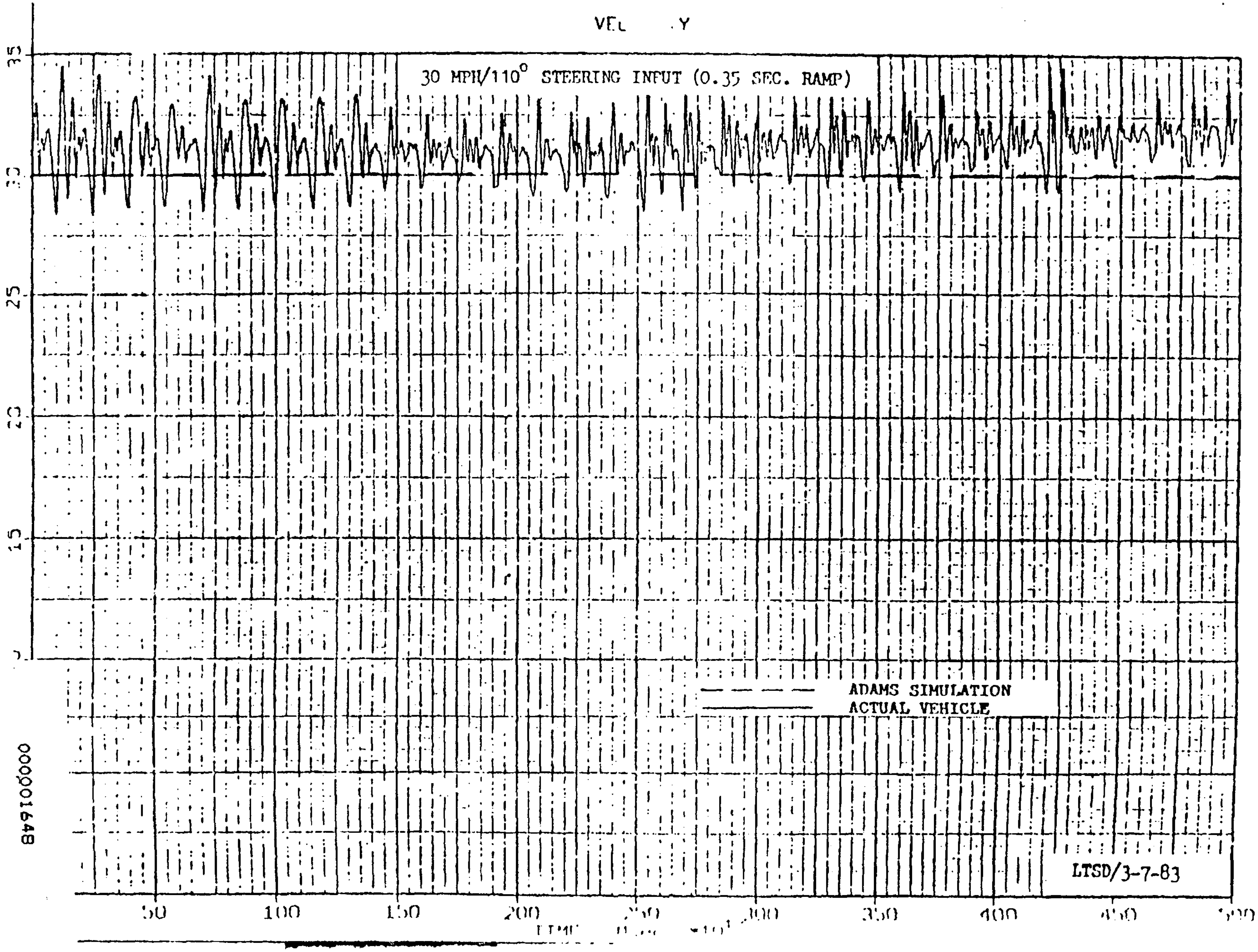
TAPE 08:   RUN 39

YAW RATE

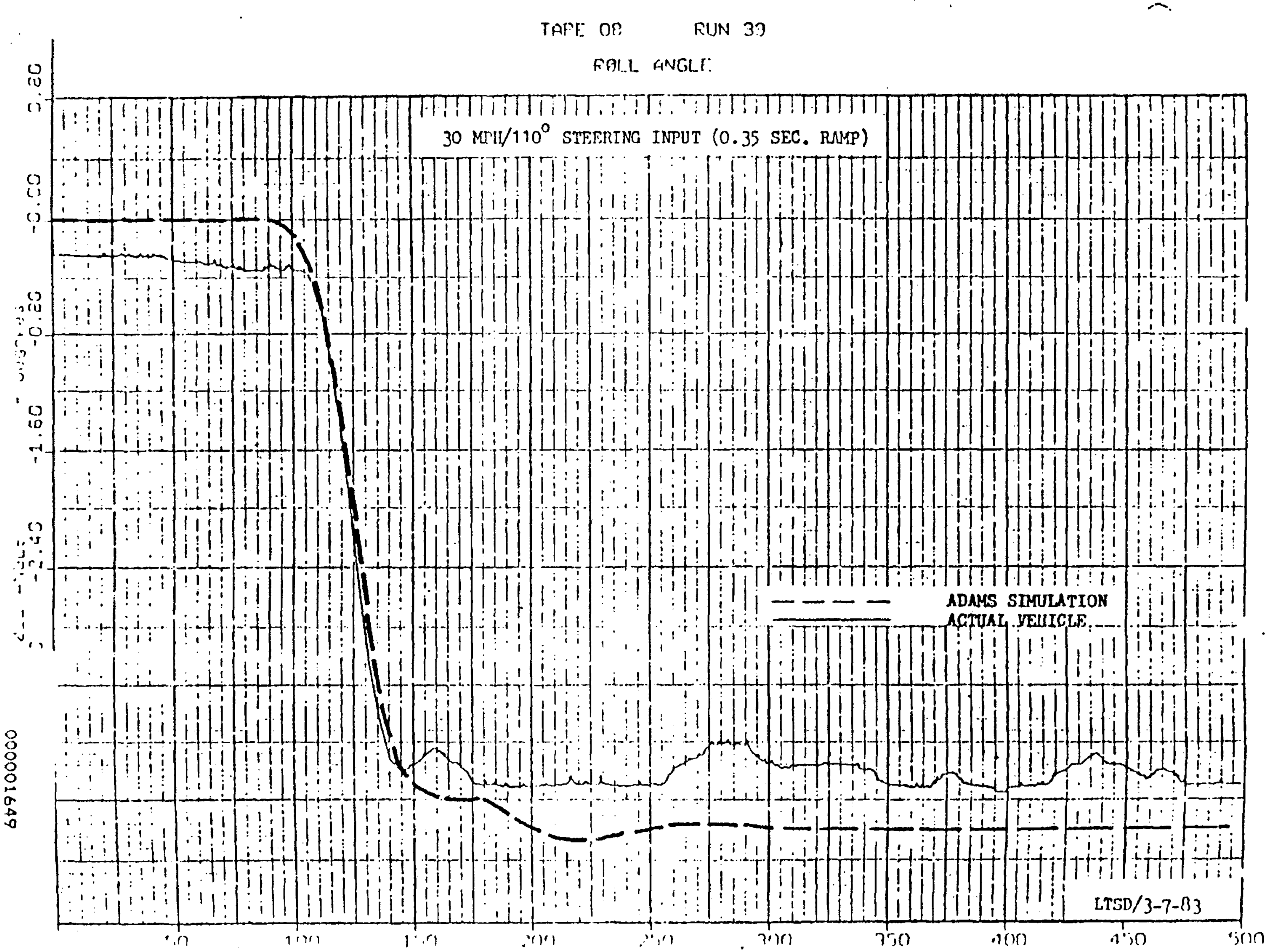


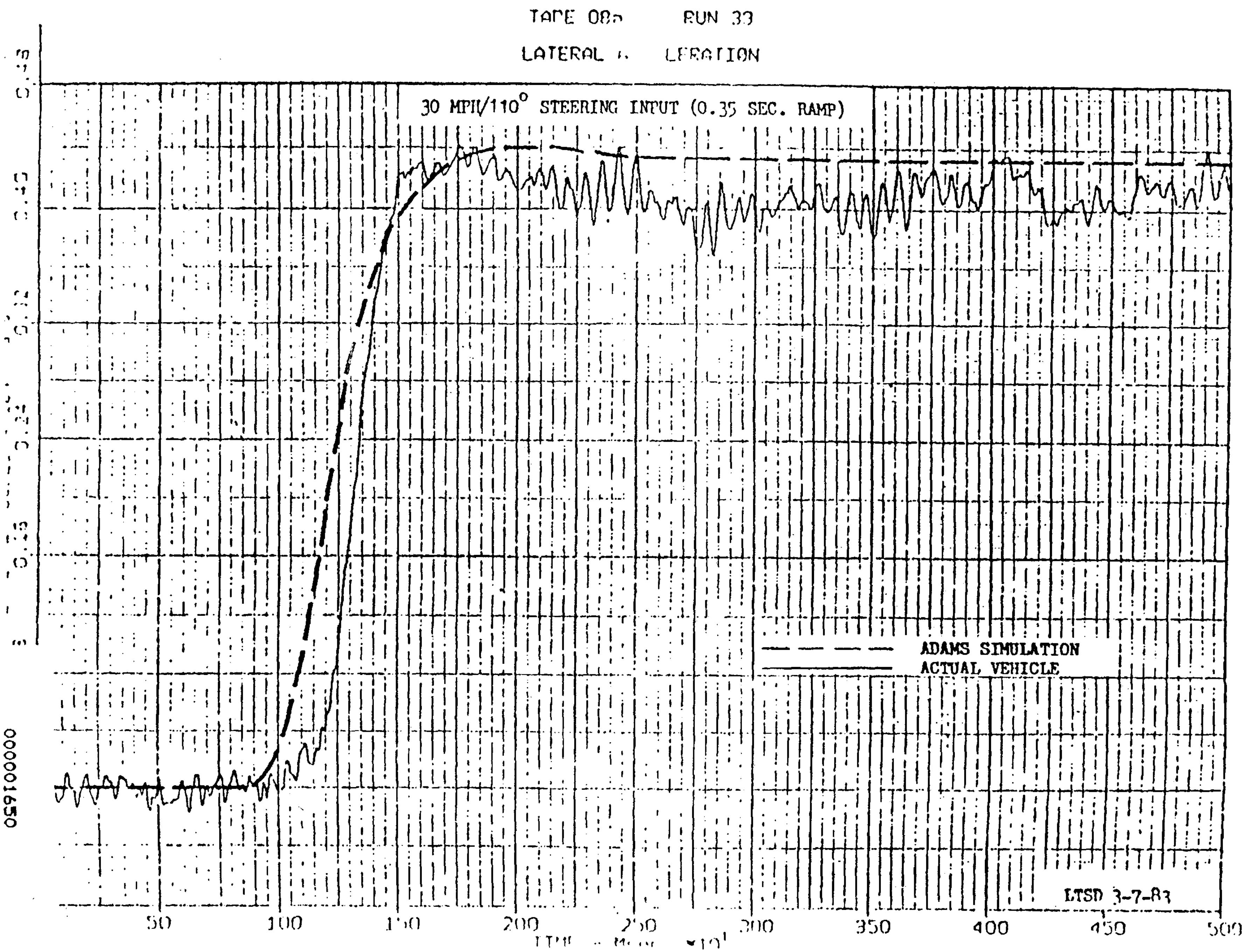
000001647

RUN 33



000001648


TAPE 08 RUN 39
ROLL ANGLE
30 MPH/110° STEERING INPUT (0.35 SEC. RAMP)
ADAMS SIMULATION
ACTUAL VEHICLE
LTSD/3-7-83
0.80
-0.00
-0.80
-1.60
-2.40
50
100
200
300
350
400
450
500

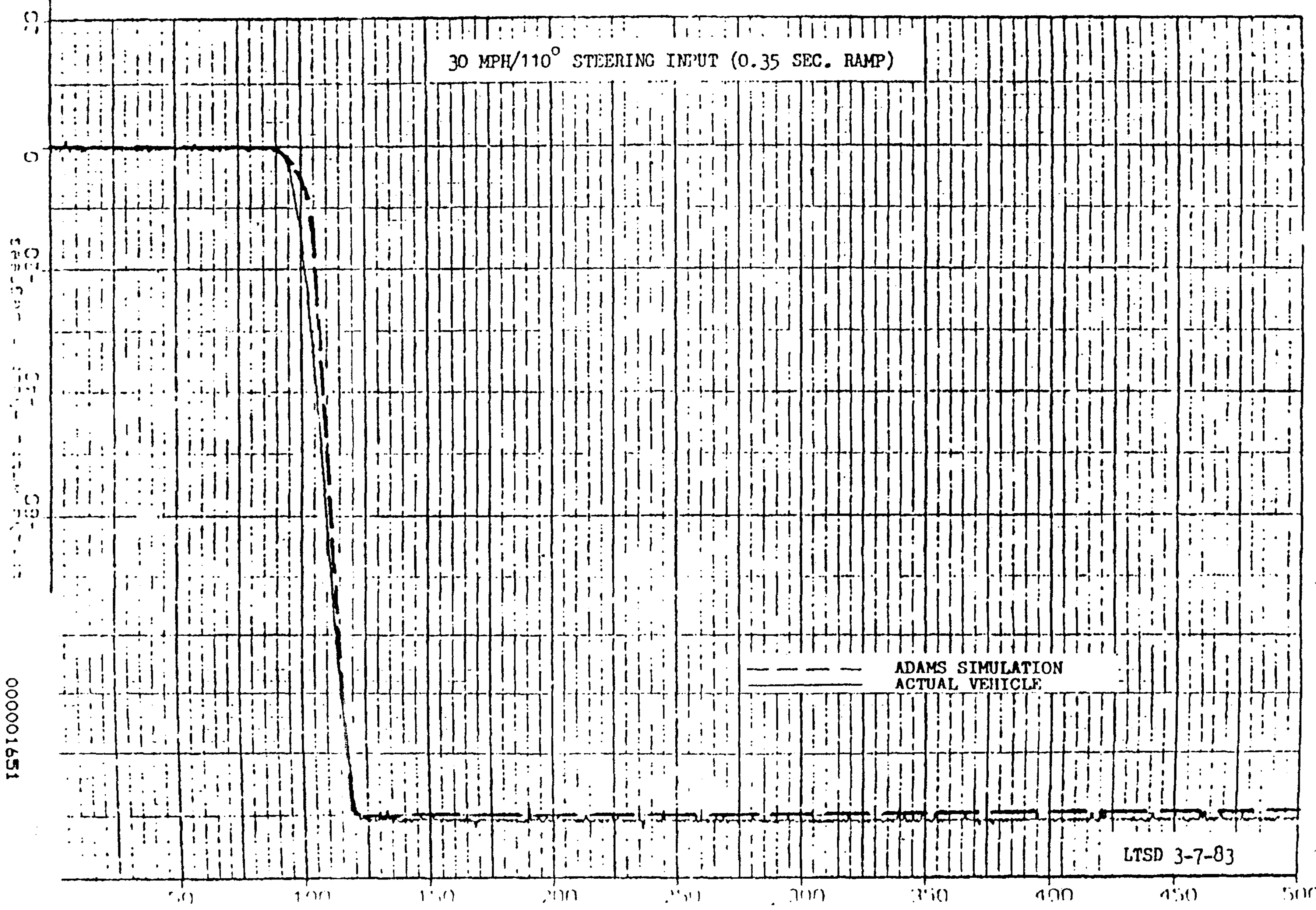


TAPE 08
RUN 33
LATERAL
30 MPH/110° STEERING INPUT (0.35 SEC. RAMP)
ADAMS SIMULATION
ACTUAL VEHICLE
LTSD 3-7-83
50
100
150
200
250
300
350
400
450
500

000001650

TAPE 08 RUN 3?

STEERING WHEEL ANGLE



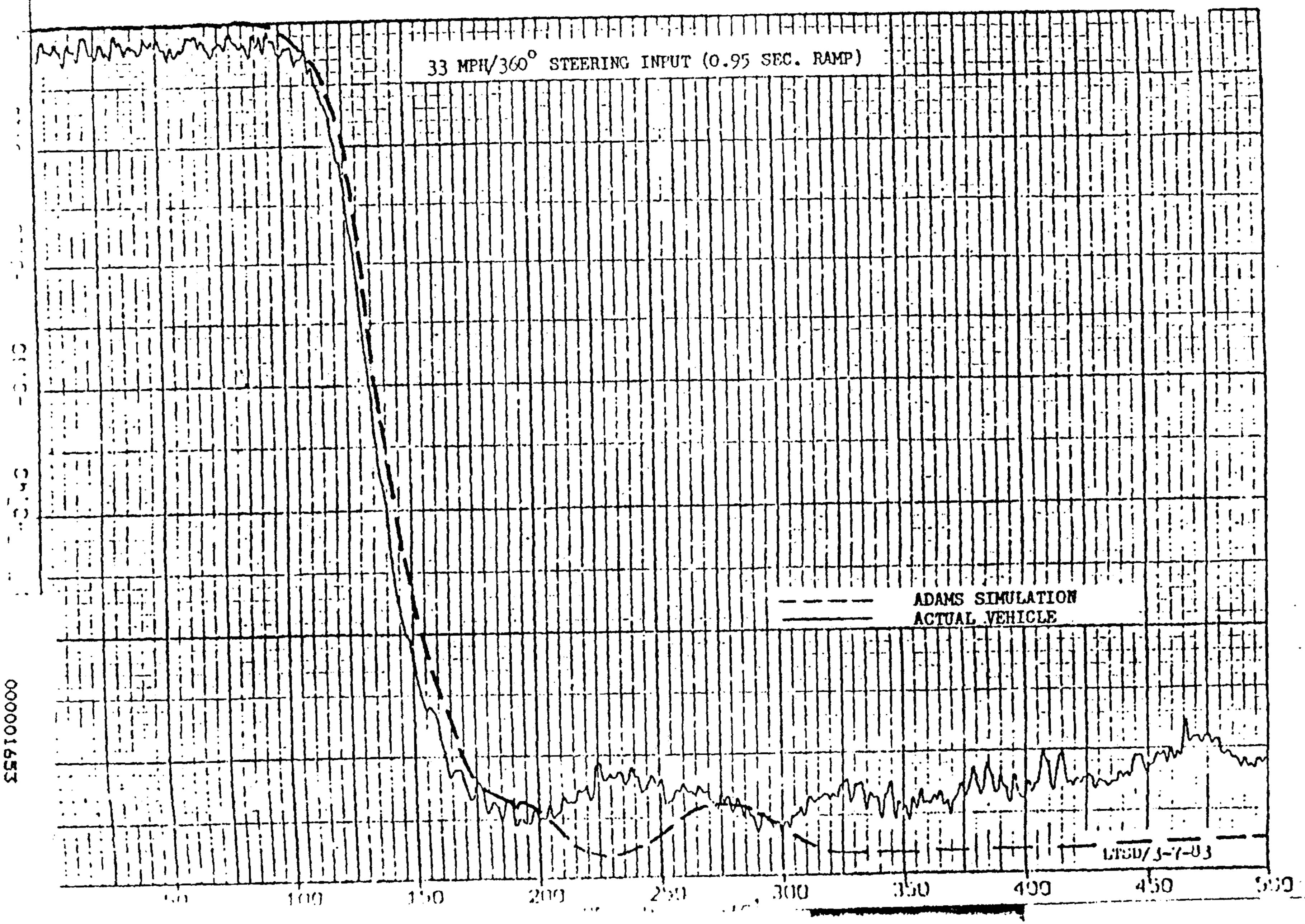
000001651

STEERING L ANGLE

000001652

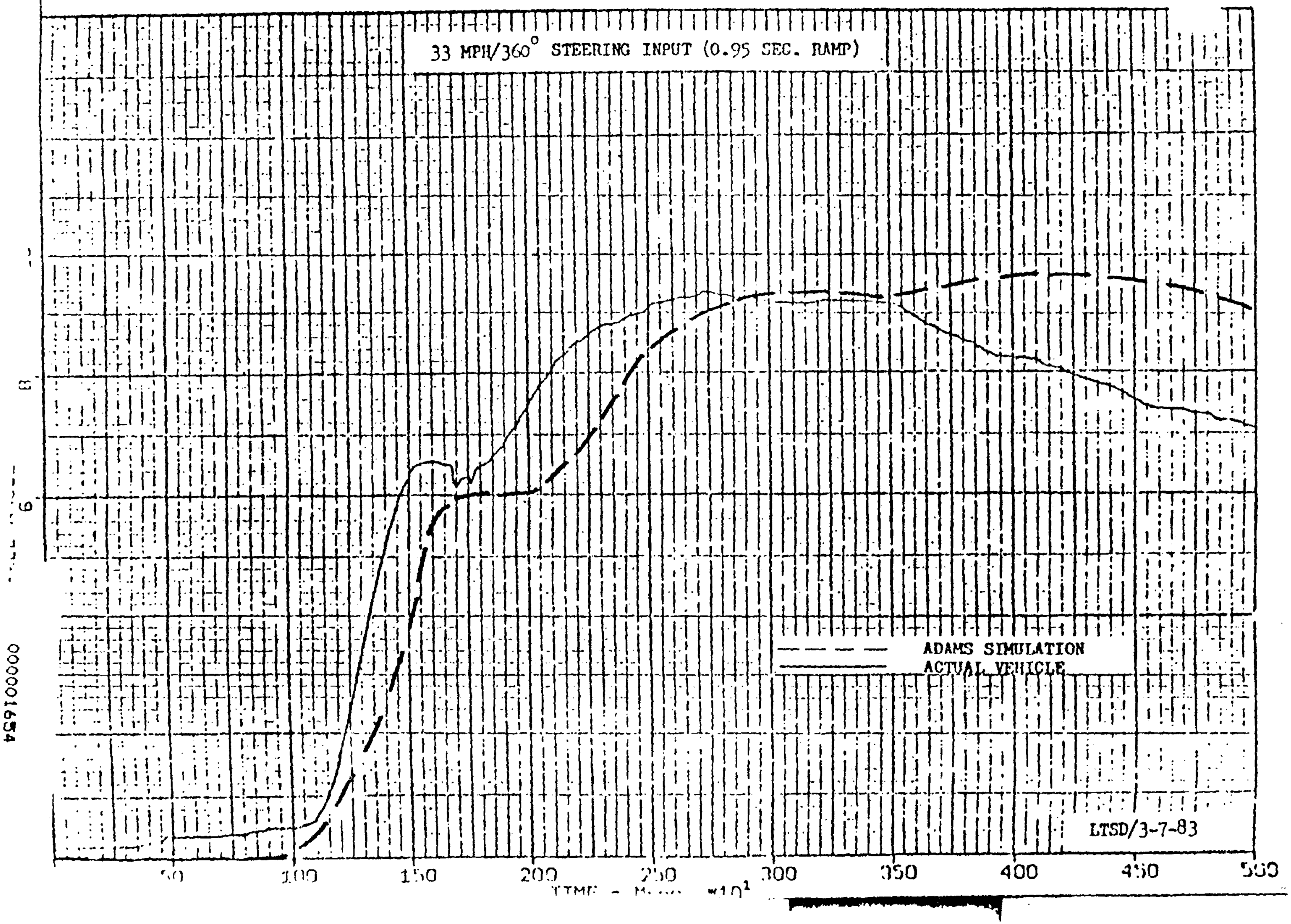
TAPE U5J6 RUN 1?

LATERAL ACL RATION

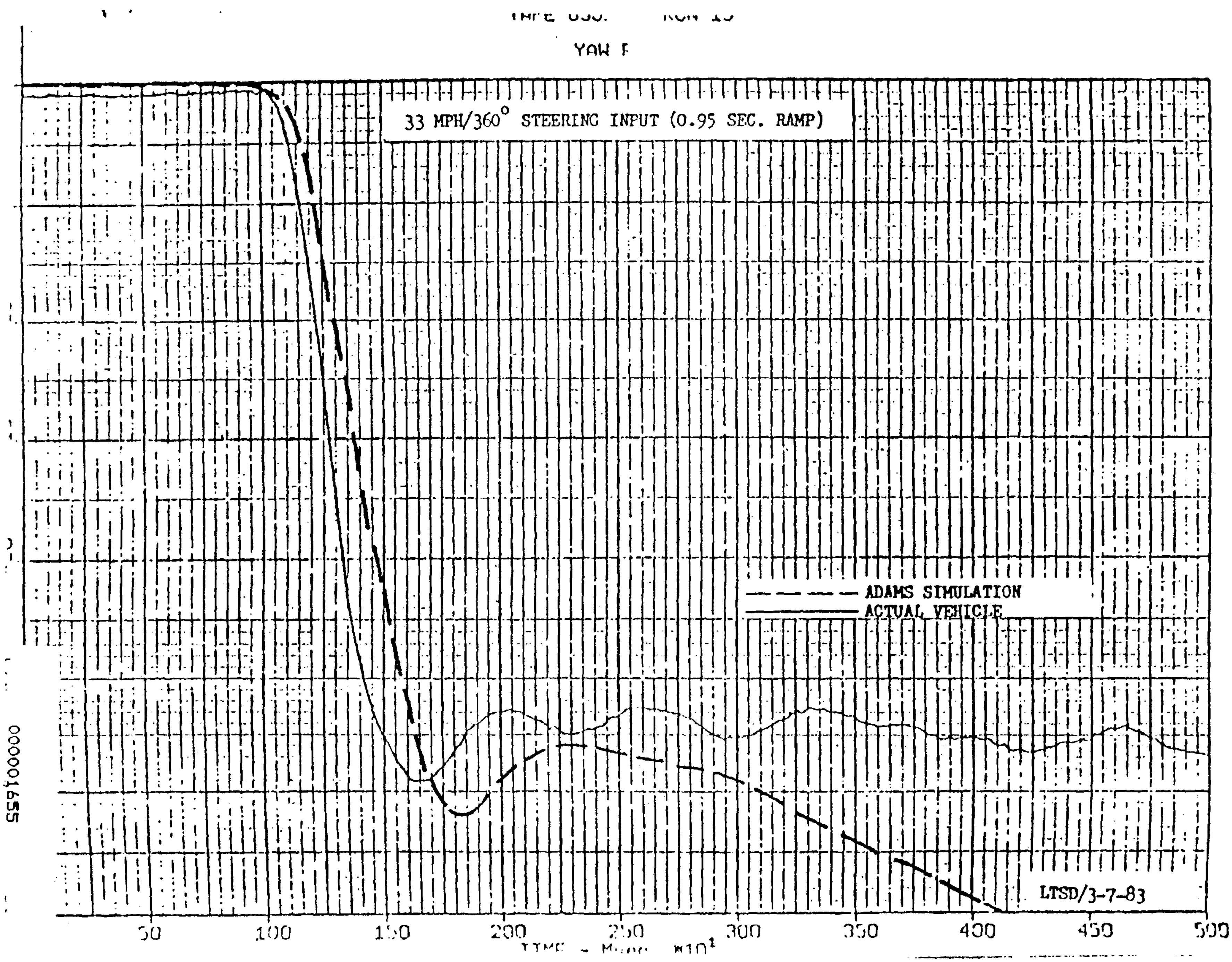


000001653

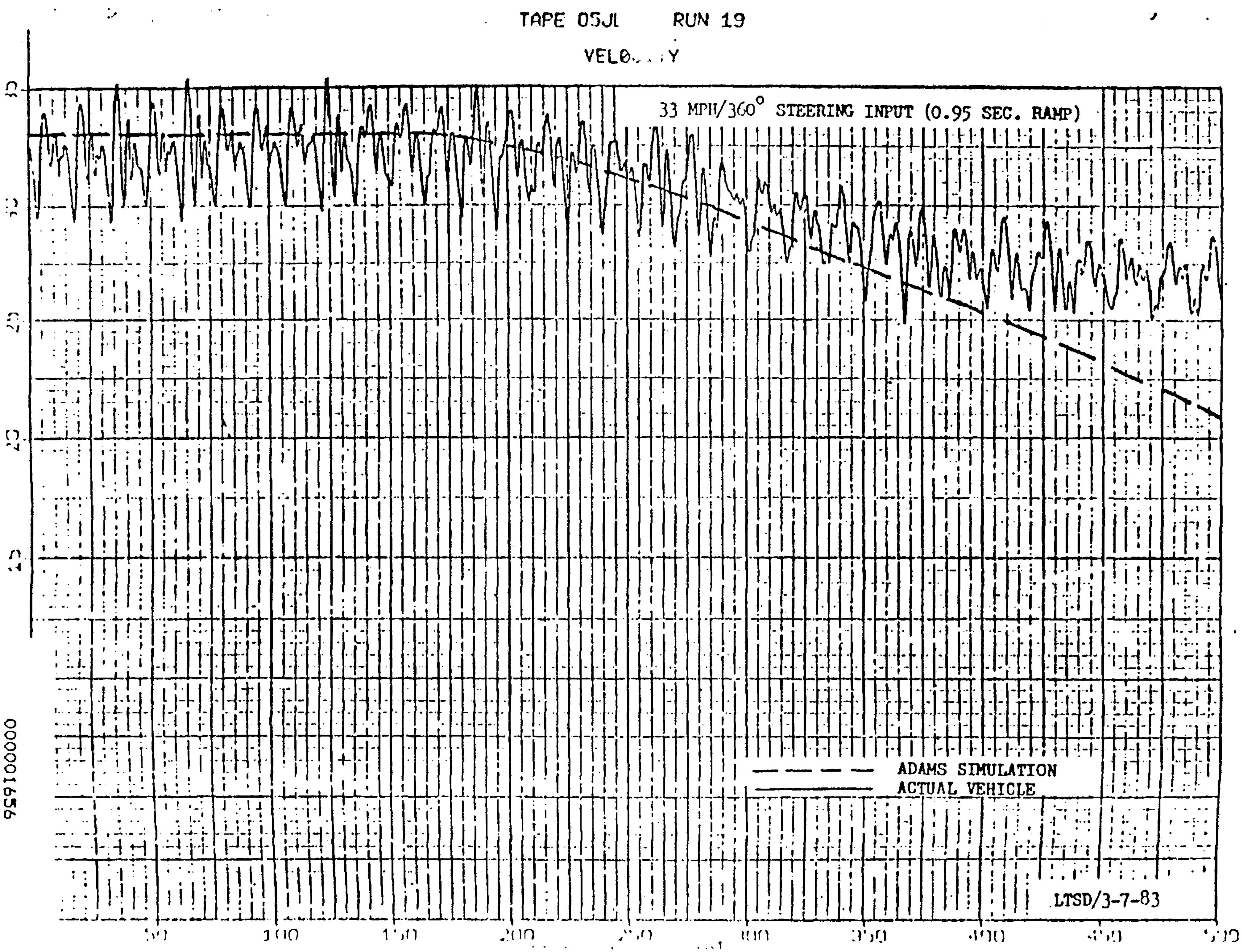
ROLL AN



33 MPH/360° STEERING INPUT (0.95 SEC. RAMP)
ADAMS SIMULATION
ACTUAL VEHICLE
LTSD/3-7-83
50
100
150
200
250
300
350
400
450
500
8
9


YAW F
33 MPH/360° STEERING INPUT (0.95 SEC. RAMP)
ADAMS SIMULATION
ACTUAL VEHICLE
LTSD/3-7-83
50
100
150
200
250
300
350
400
450
500

000001655

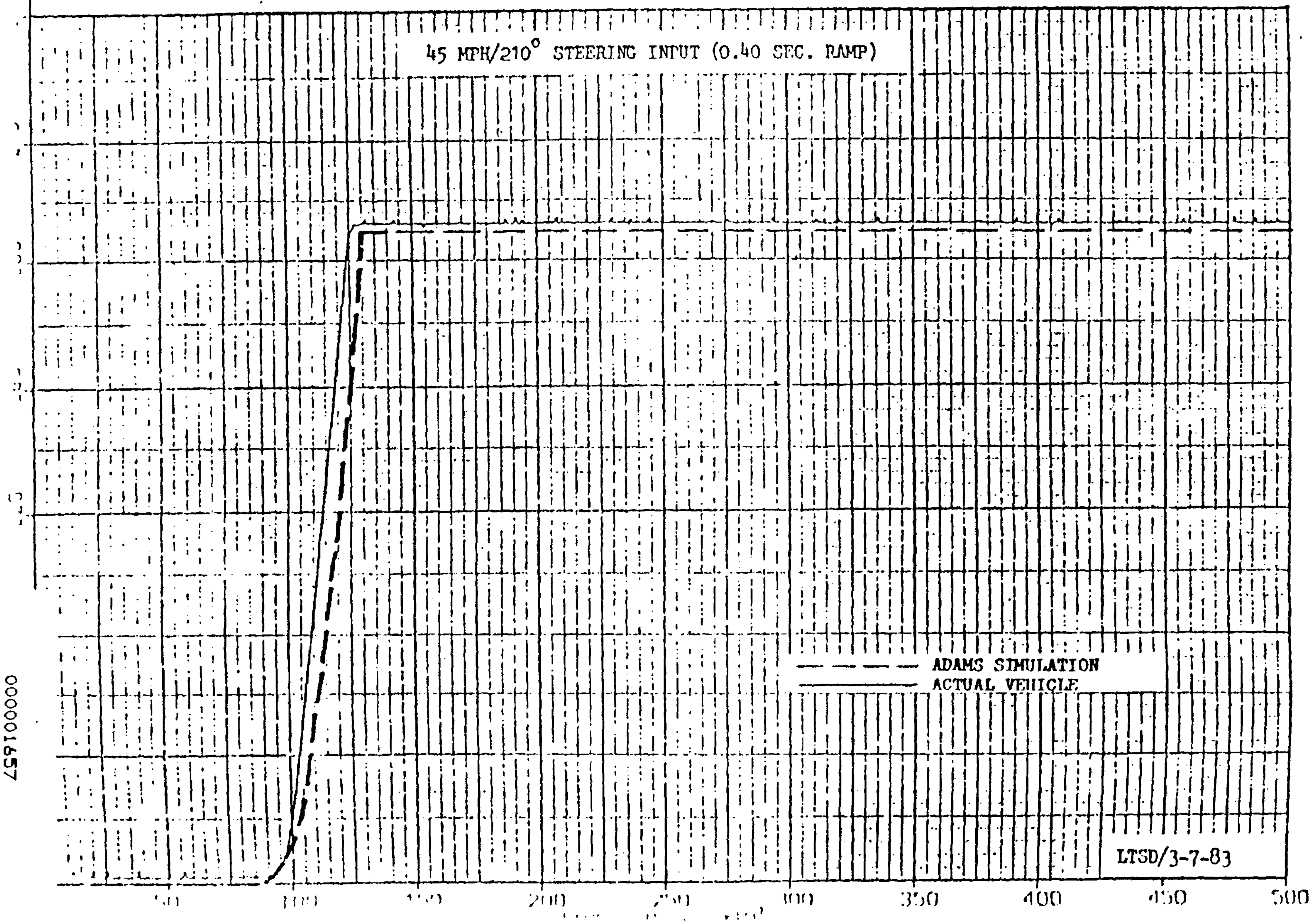


TAPE 05JL RUN 19
VEL0...Y
33 MPH/360° STEERING INPUT (0.95 SEC. RAMP)
ADAMS SIMULATION
ACTUAL VEHICLE
LTSD/3-7-83
50
100
150
200
300
350
400

000001656

TAPE 10ab   IH 12

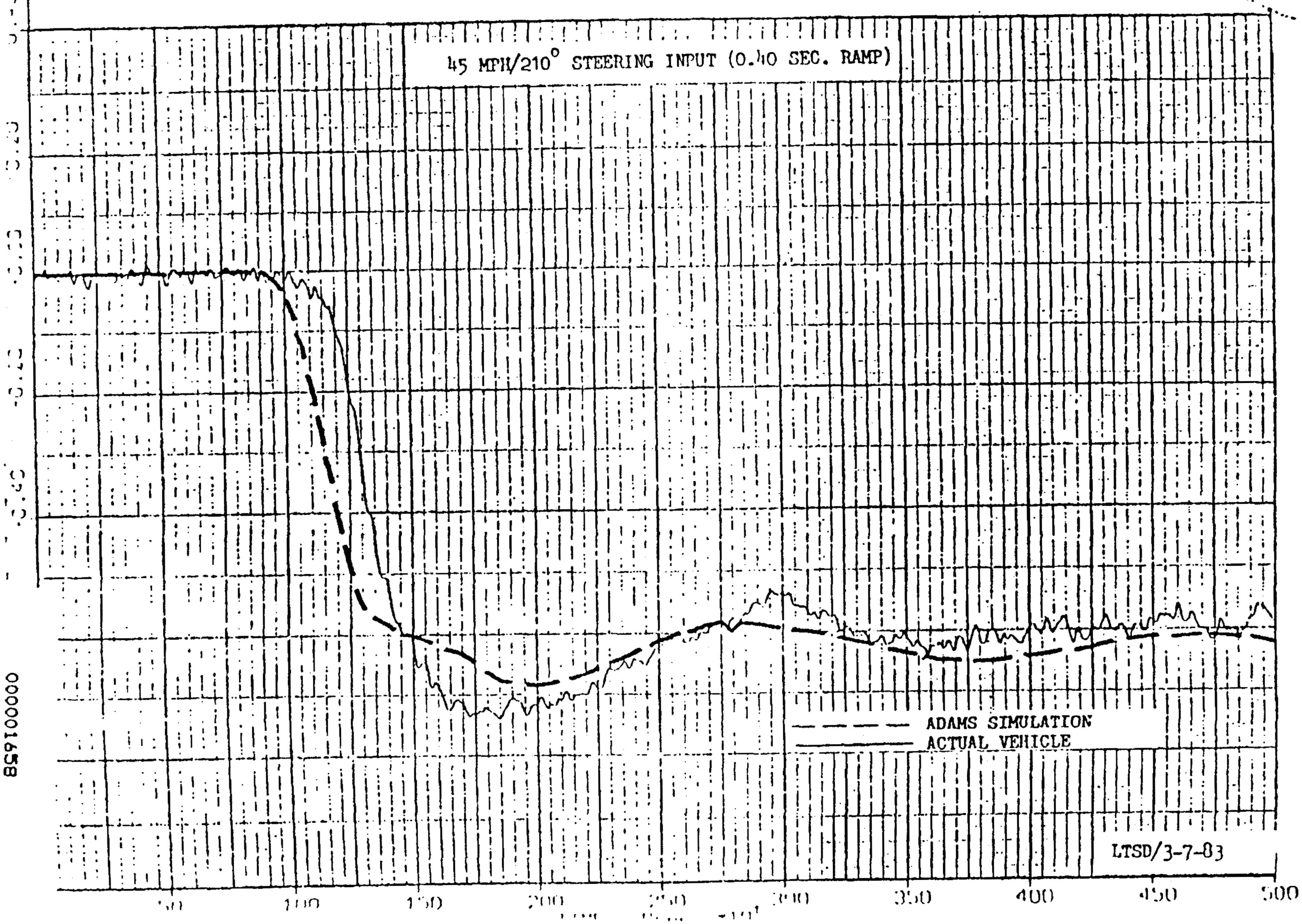
STEERING WHEEL ANGLE



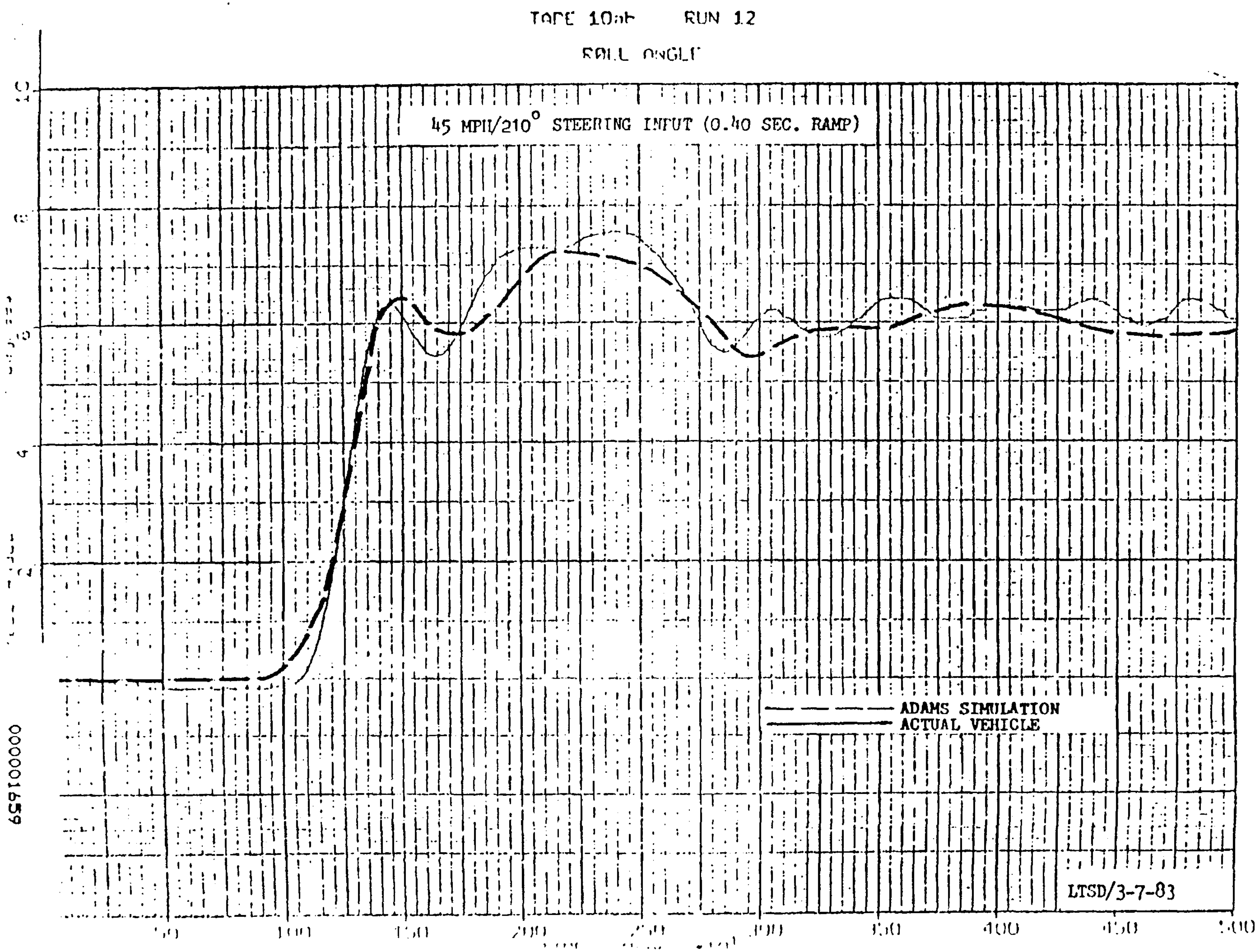
000001657

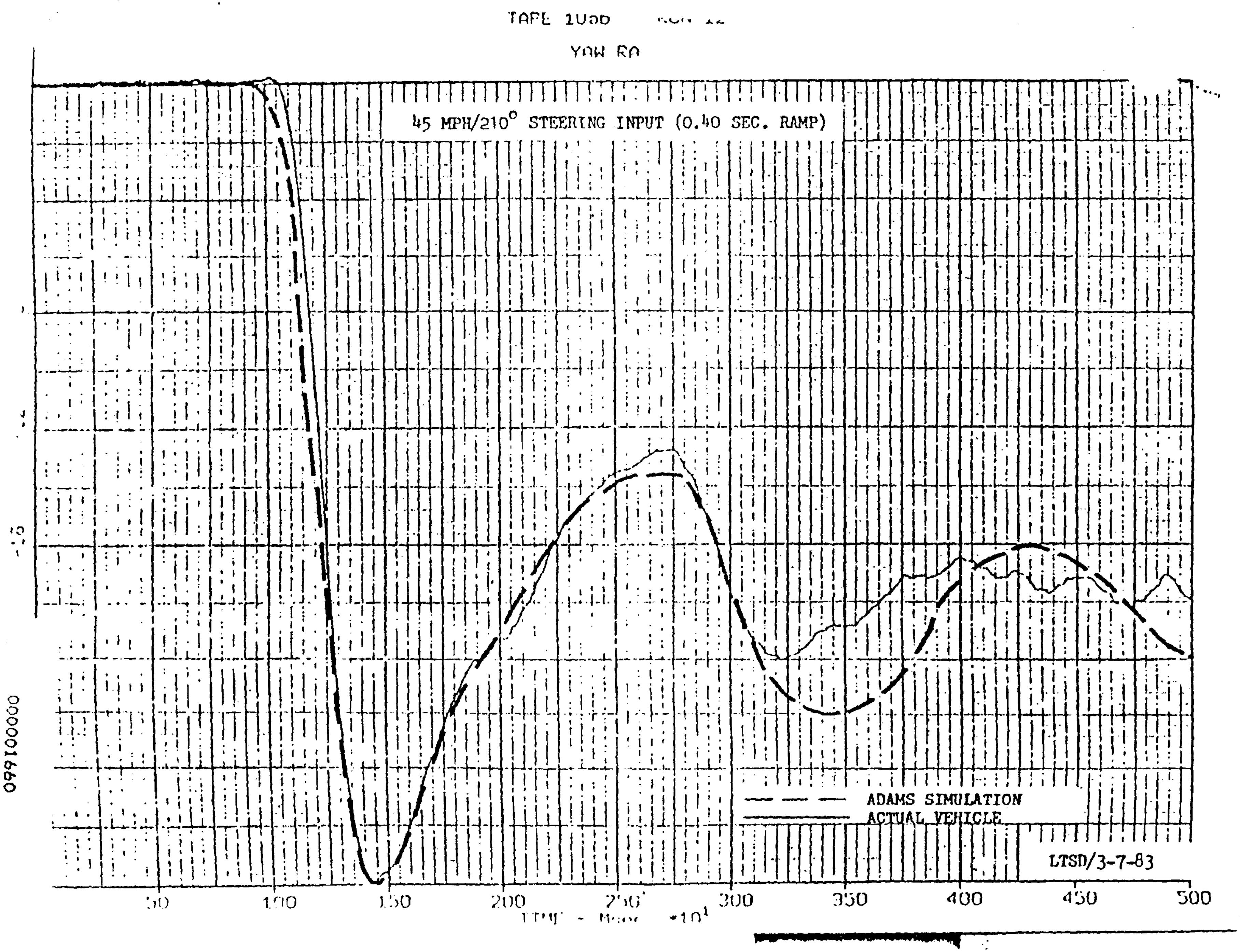
TAPE 10ab RUN 12

LATERAL ACCELERATION



000001658


RUN 12
45 MPH/210° STEERING INPUT (0.40 SEC. RAMP)
ADAMS SIMULATION
ACTUAL VEHICLE
LTSD/3-7-83
100
400
000001659

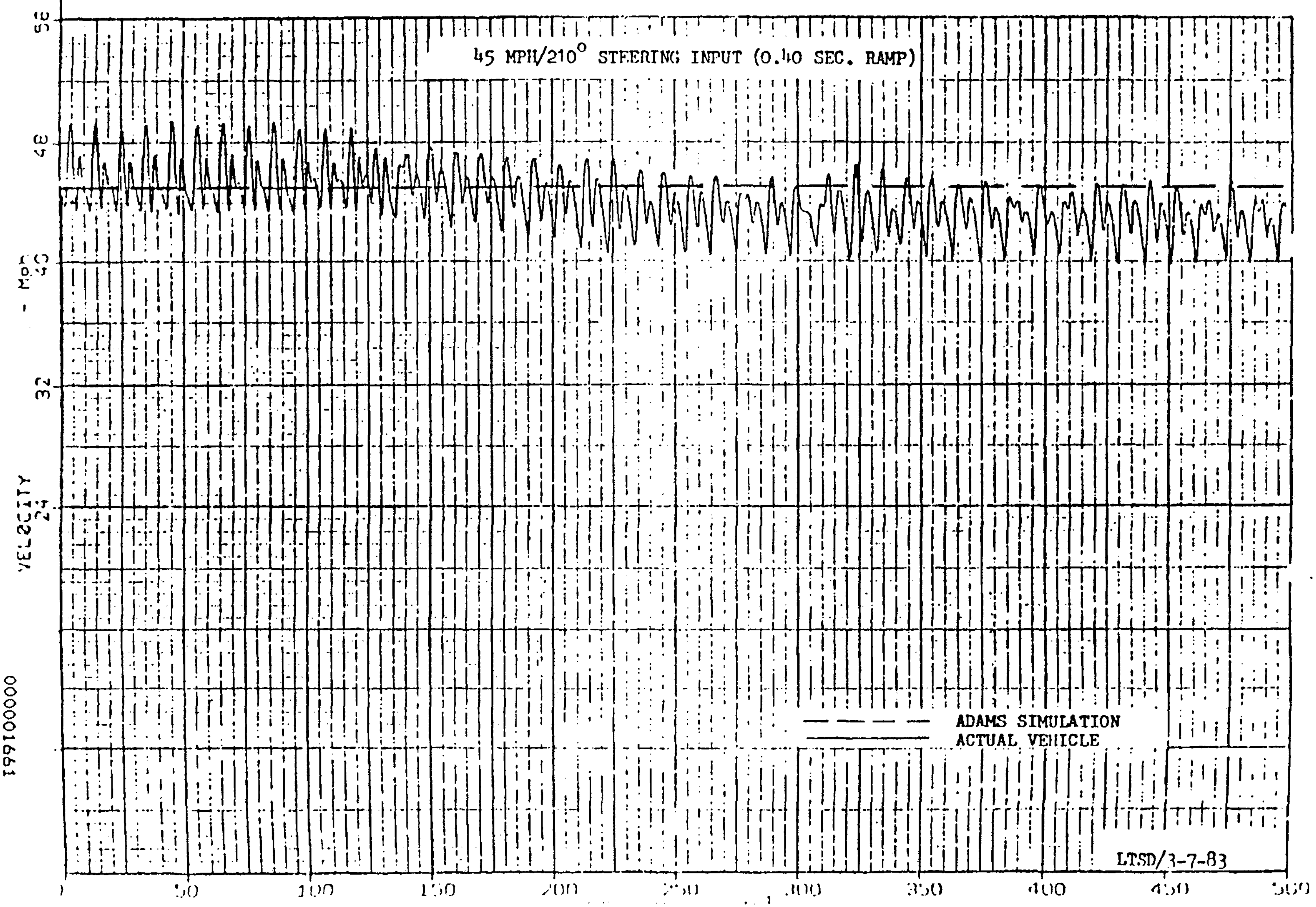


TAPE 1050
YAW RA
45 MPH/210° STEERING INPUT (0.40 SEC. RAMP)
ADAMS SIMULATION
ACTUAL VEHICLE
LTSD/3-7-83
50
100
150
200
250
300
350
400
450
500

00001660

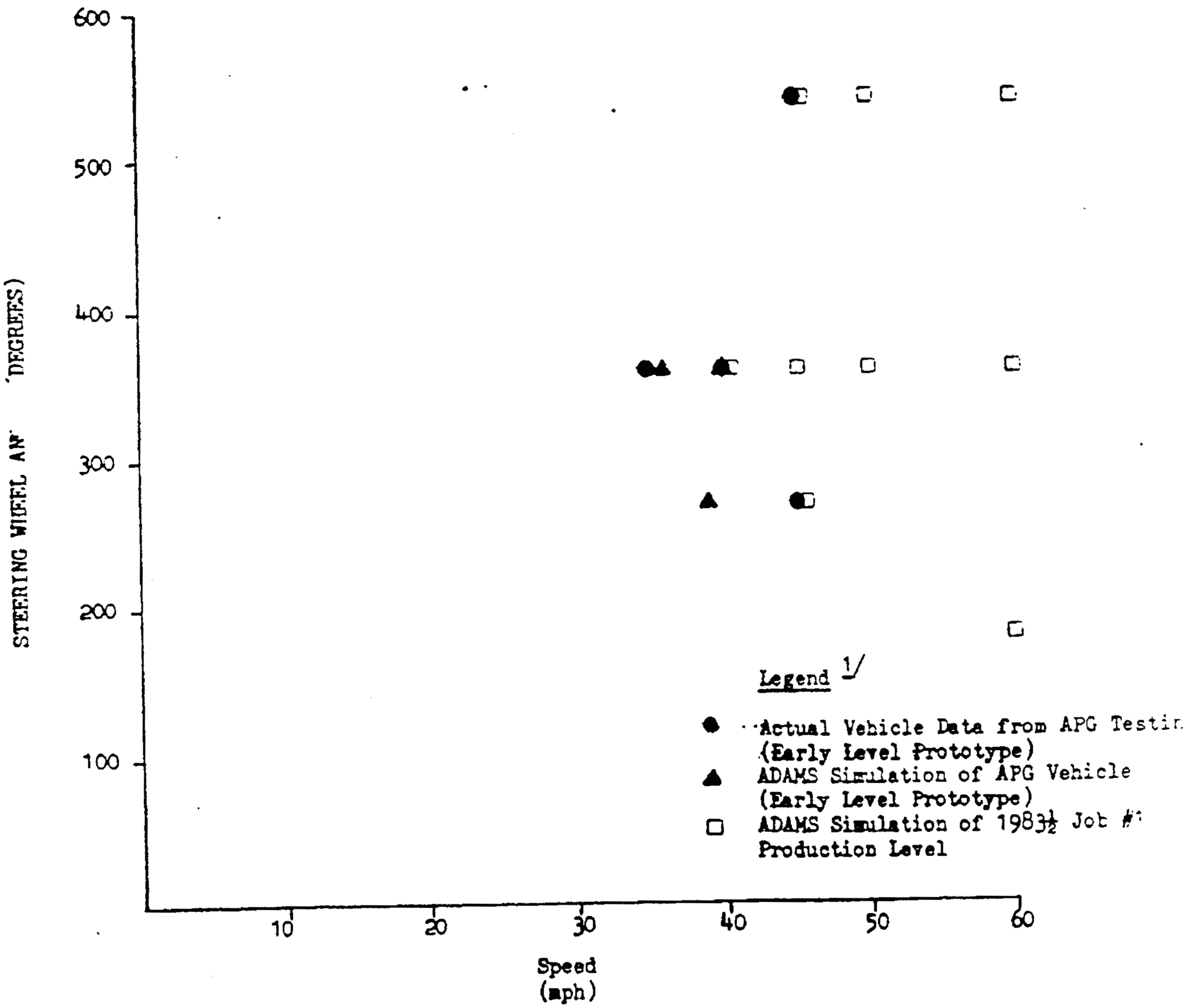
TAPE 10 RUN 12

VELOCITY



000001661

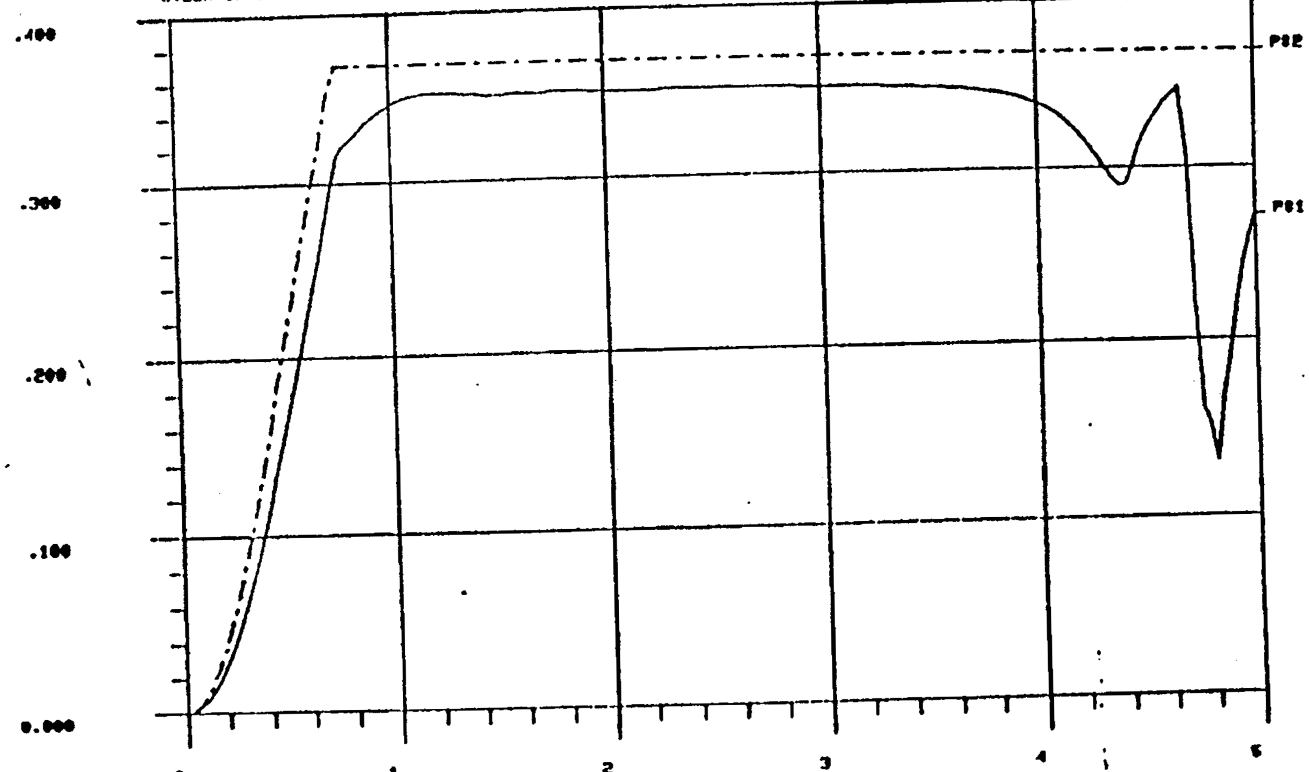
STEERING WHEEL ANGLE VS. SPEED
FOR
TWO WHEEL LIFT TRESHOLDS



1/ Darkened points denote 2 wheel lift
Non-darkened points denote stable performance throughout maneuver

ENTER COMMAND

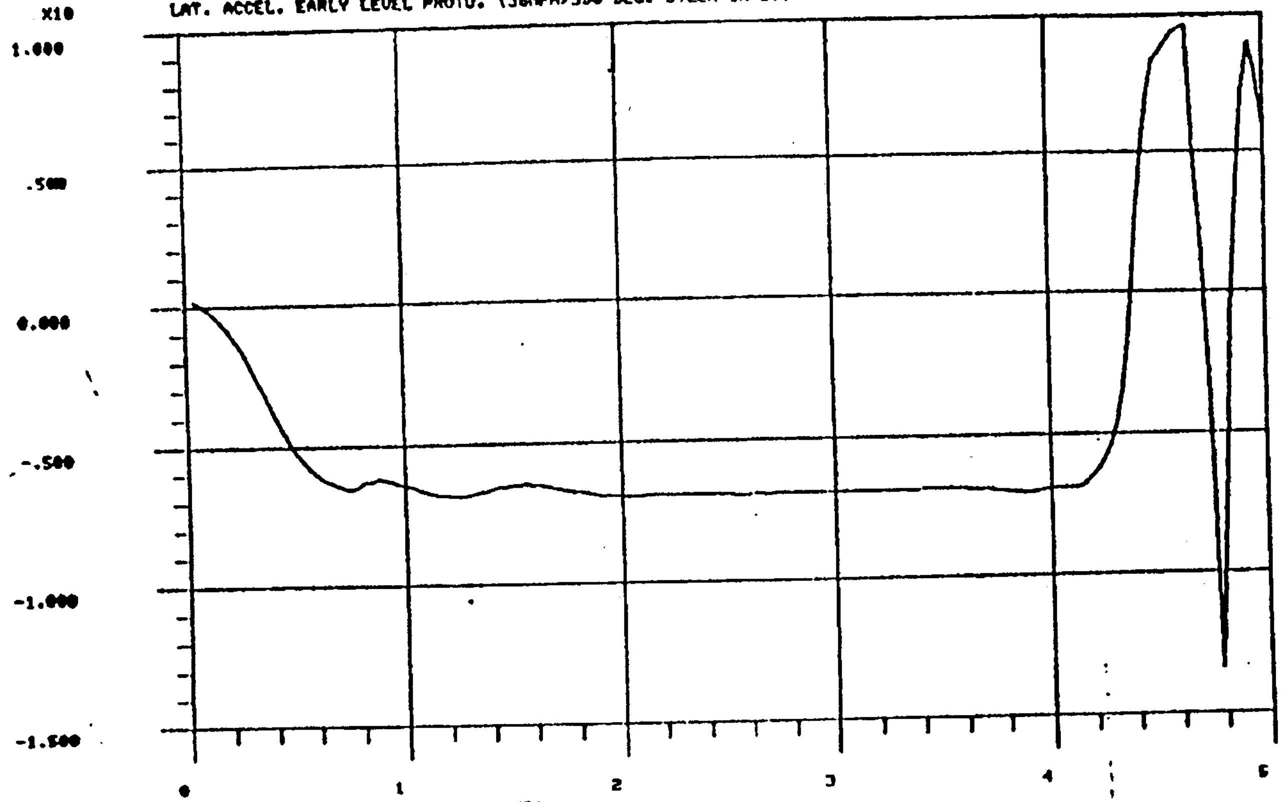
STEER INPUT (0 SEC. SHAFT W/ & W/OUT COMPLIANCE) FOR 380 SVA



PLOT NO	REQ0 COMP	X AXIS TYPE	I	J	REQ0 COMP	Y AXIS TYPE	I	J	RUN	FILE
1		TIME			15 ANGI	DISP	815	5115	1	12
2		TIME			18 ANGI	DISP	3515	5115	1	12

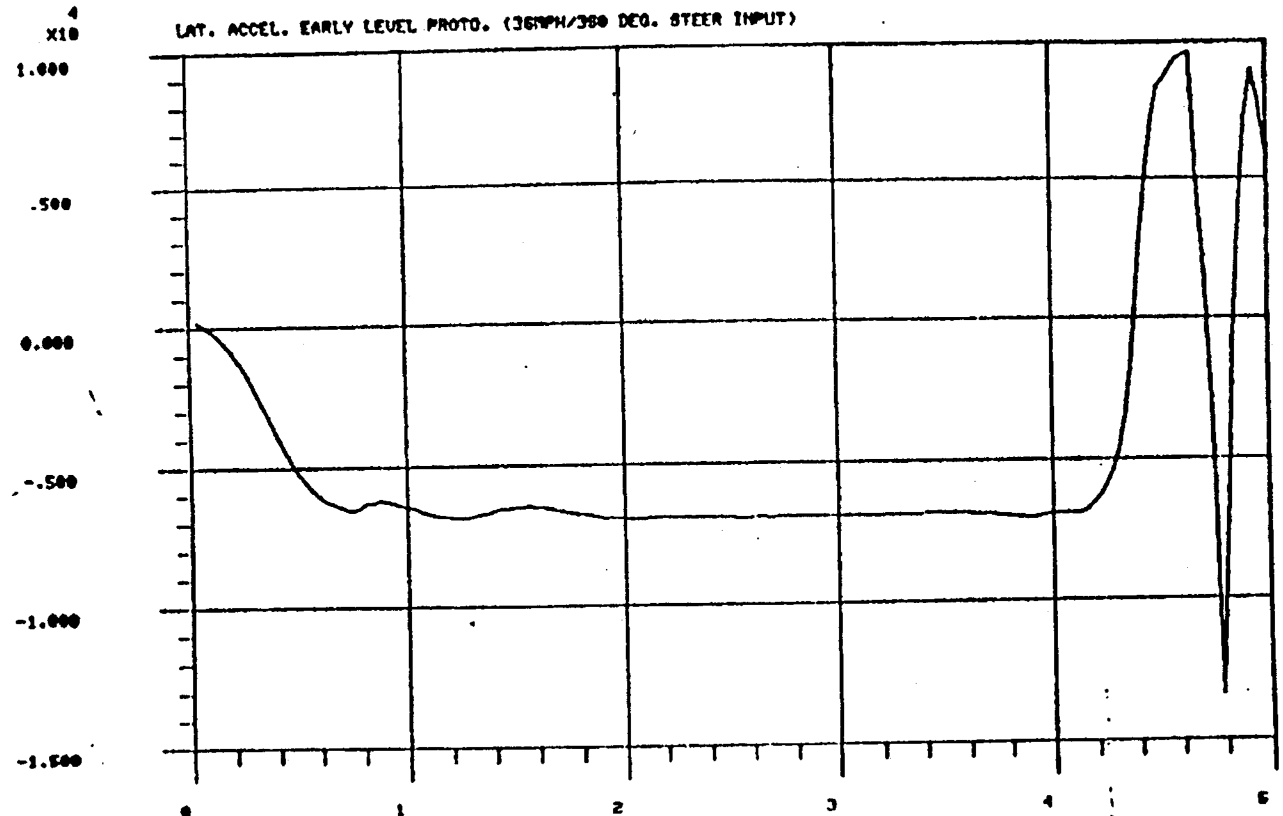
ENTER COMMAND

LAT. ACCEL. EARLY LEVEL PROTO. (36MPH/360 DEG. STEER INPUT)



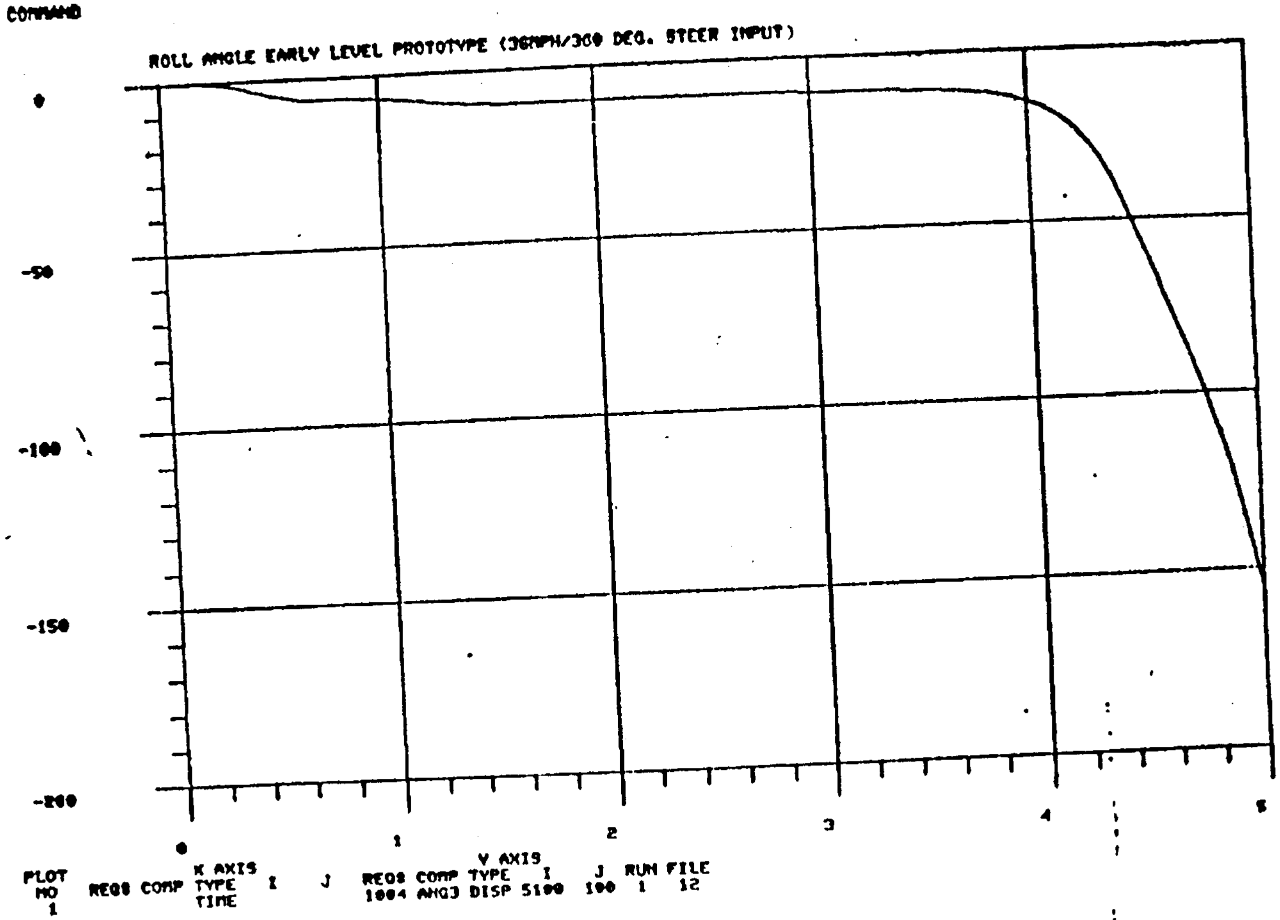
PLOT NO	REQ# COMP	X AXIS TYPE	I	J	REQ# COMP	Y AXIS TYPE	I	J	RUN	FILE
1		TIME			999 Y	ACC	5100	100	1	12

ENTER COMMAND

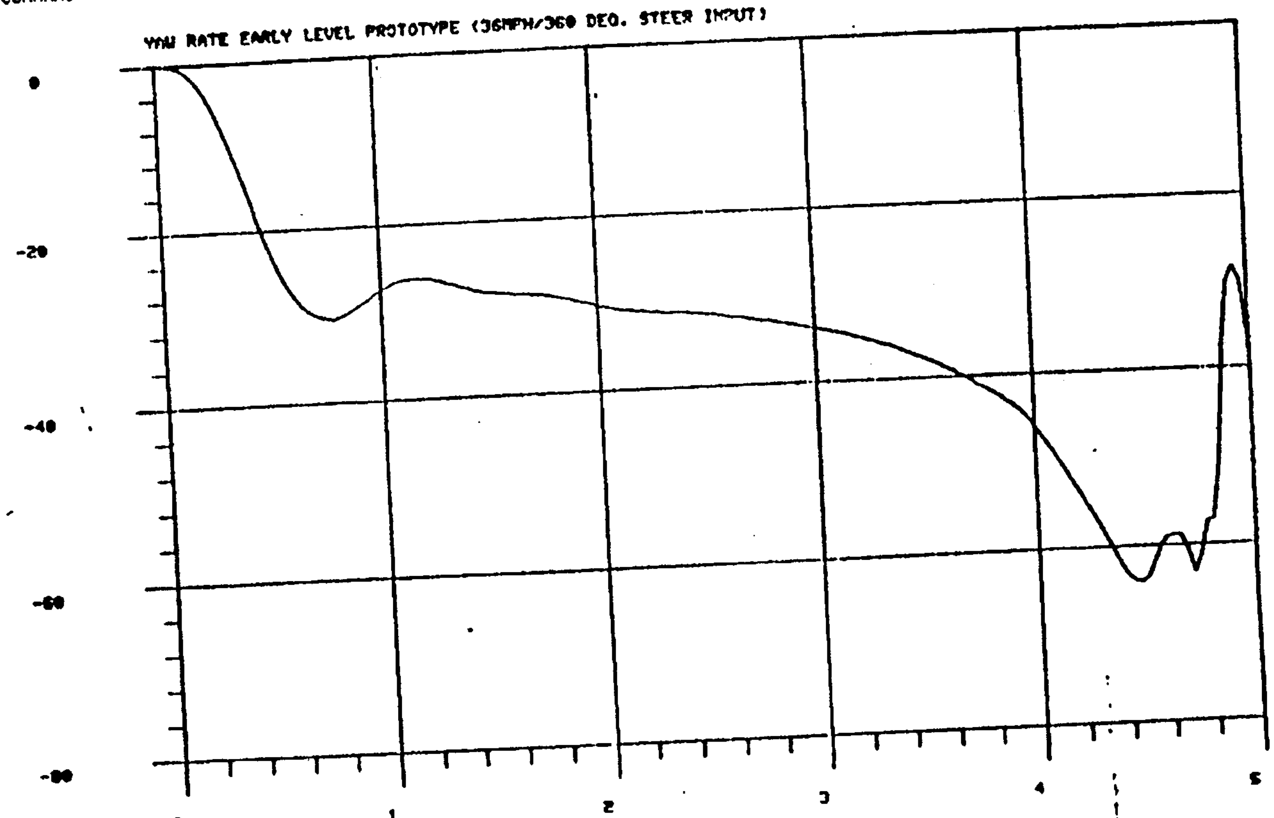


PLOT NO	REQ# COMP	X AXIS TYPE	I	J	REQ# COMP	Y AXIS TYPE	I	J	RUN	FILE
1		TIME			999 Y	ACC	5100	100	1	12

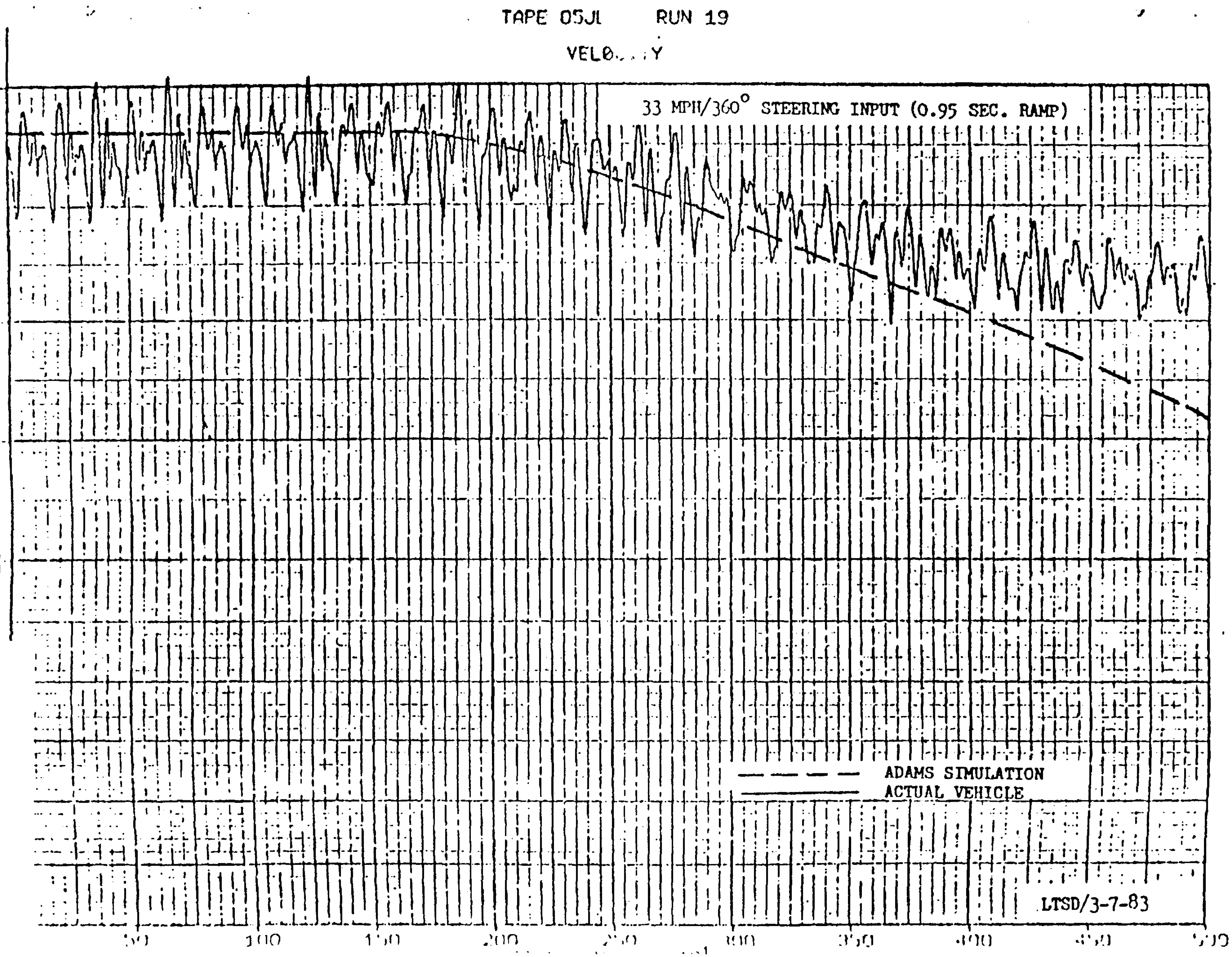
ENTER COMMAND



ENTER COMMAND



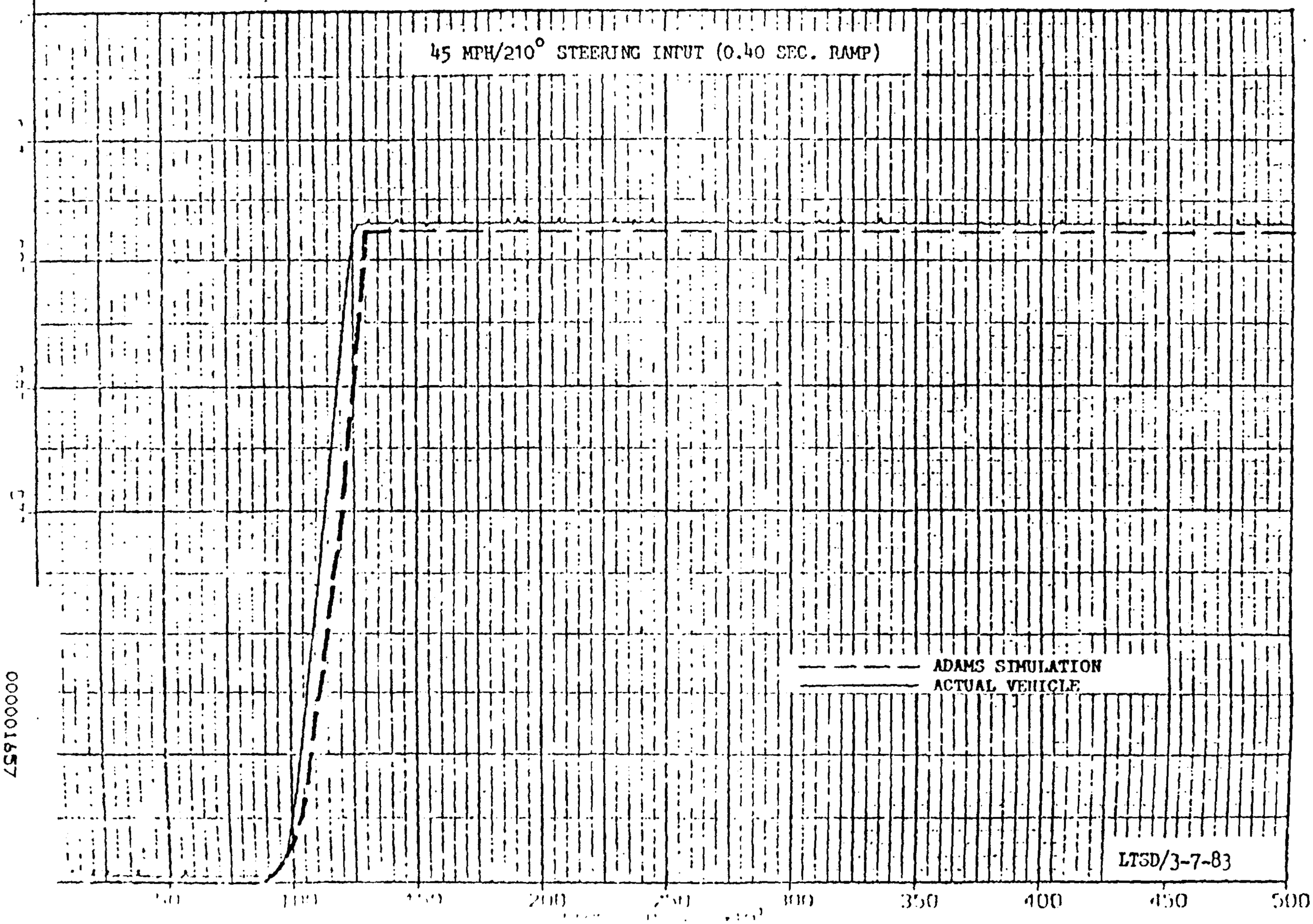
PLOT NO 1 REO8 COMP X AXIS TYPE TIME I J REO8 COMP 1005 Y AXIS TYPE ANG3 VEL I 100 J 5100 RUN 1 FILE 12


TAPE 05JL RUN 19
VELO...Y
33 MPH/360° STEERING INPUT (0.95 SEC. RAMP)
ADAMS SIMULATION
ACTUAL VEHICLE
LTSD/3-7-83
100
200
300
350
400
500

000001656

TAPE 10nb   N 12

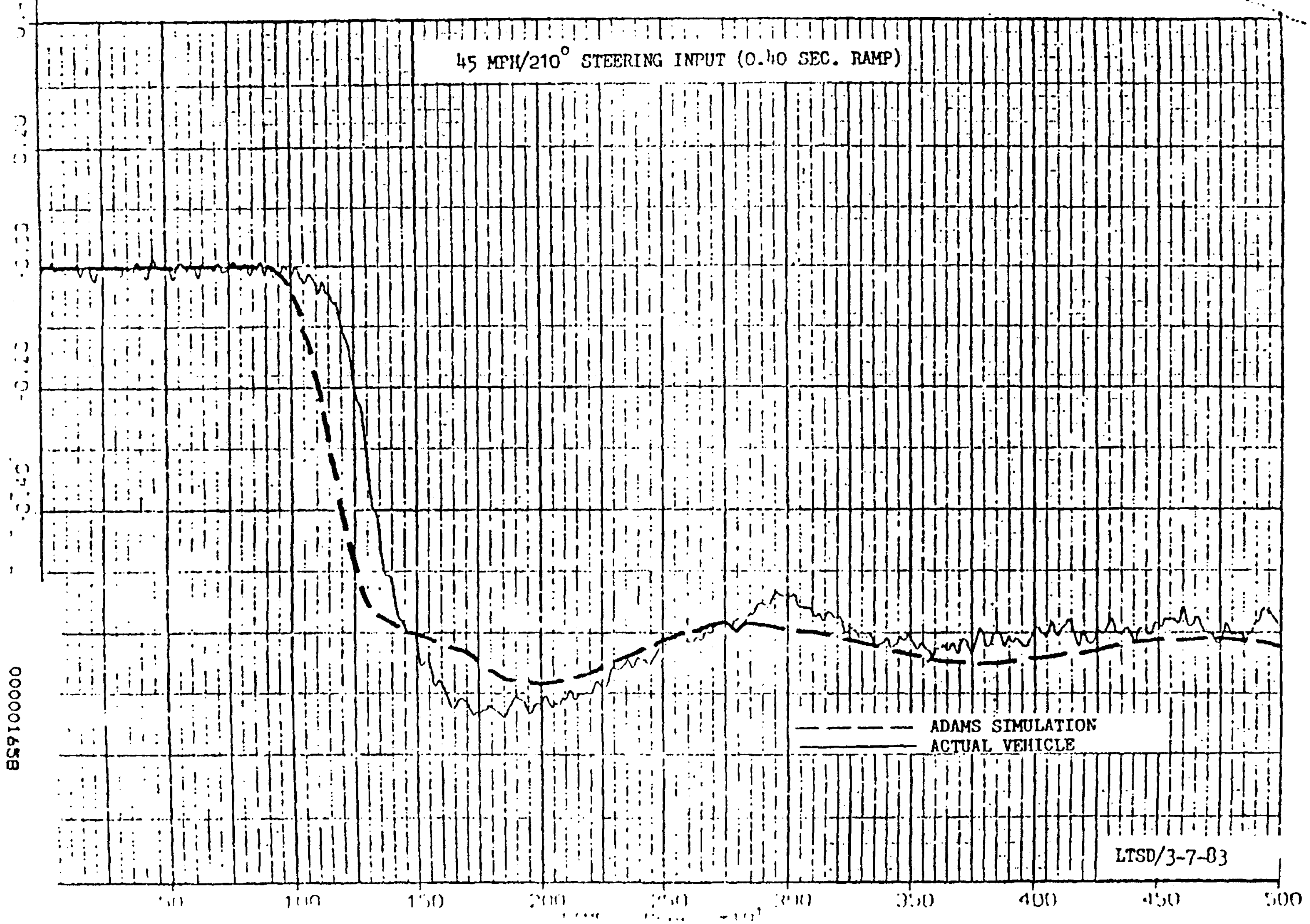
STEERING WHEEL ANGLE



000001657

TAPE 10ab RUN 12

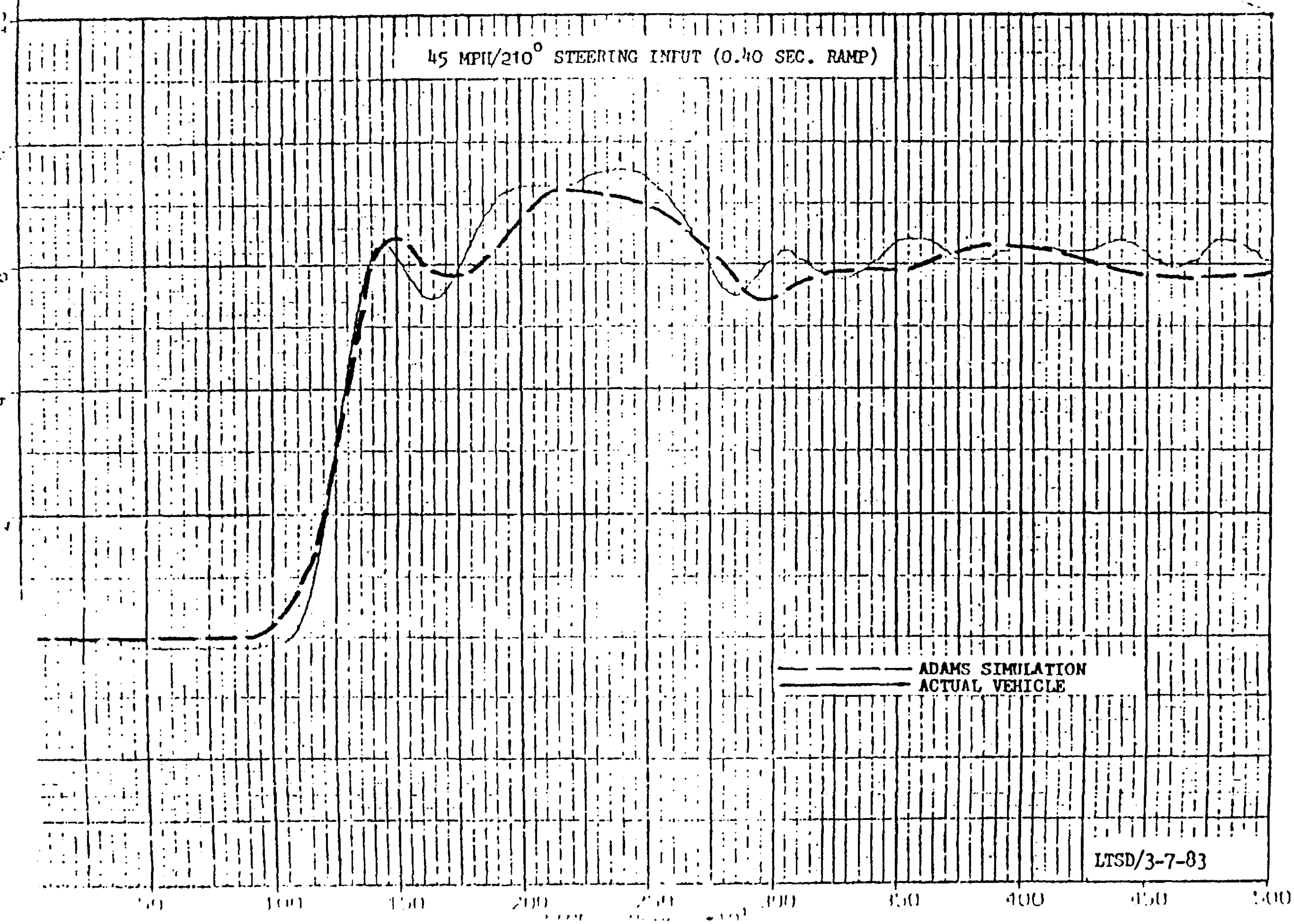
LATERAL ACCELERATION

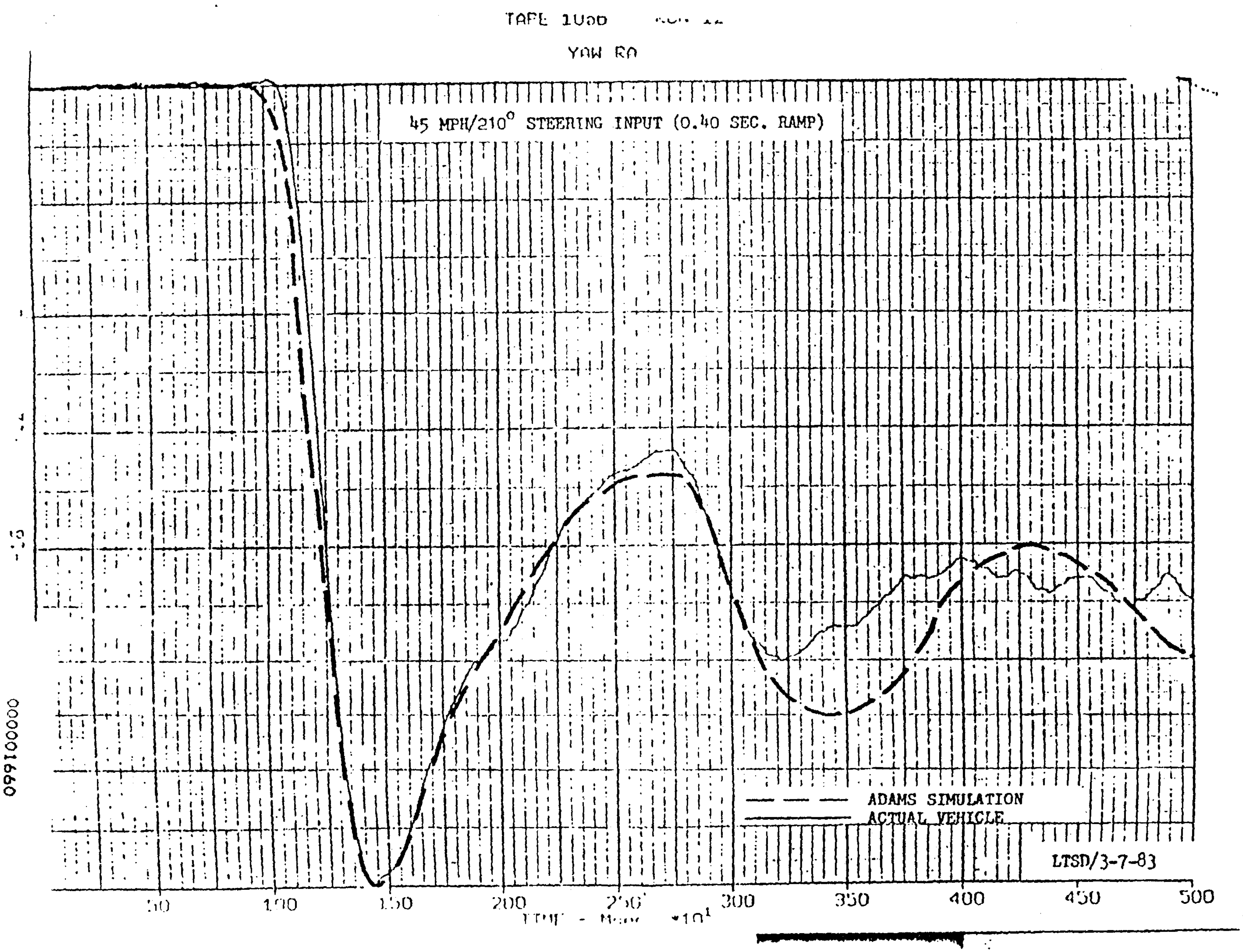


000001658

TAPE 10[illegible] RUN 12

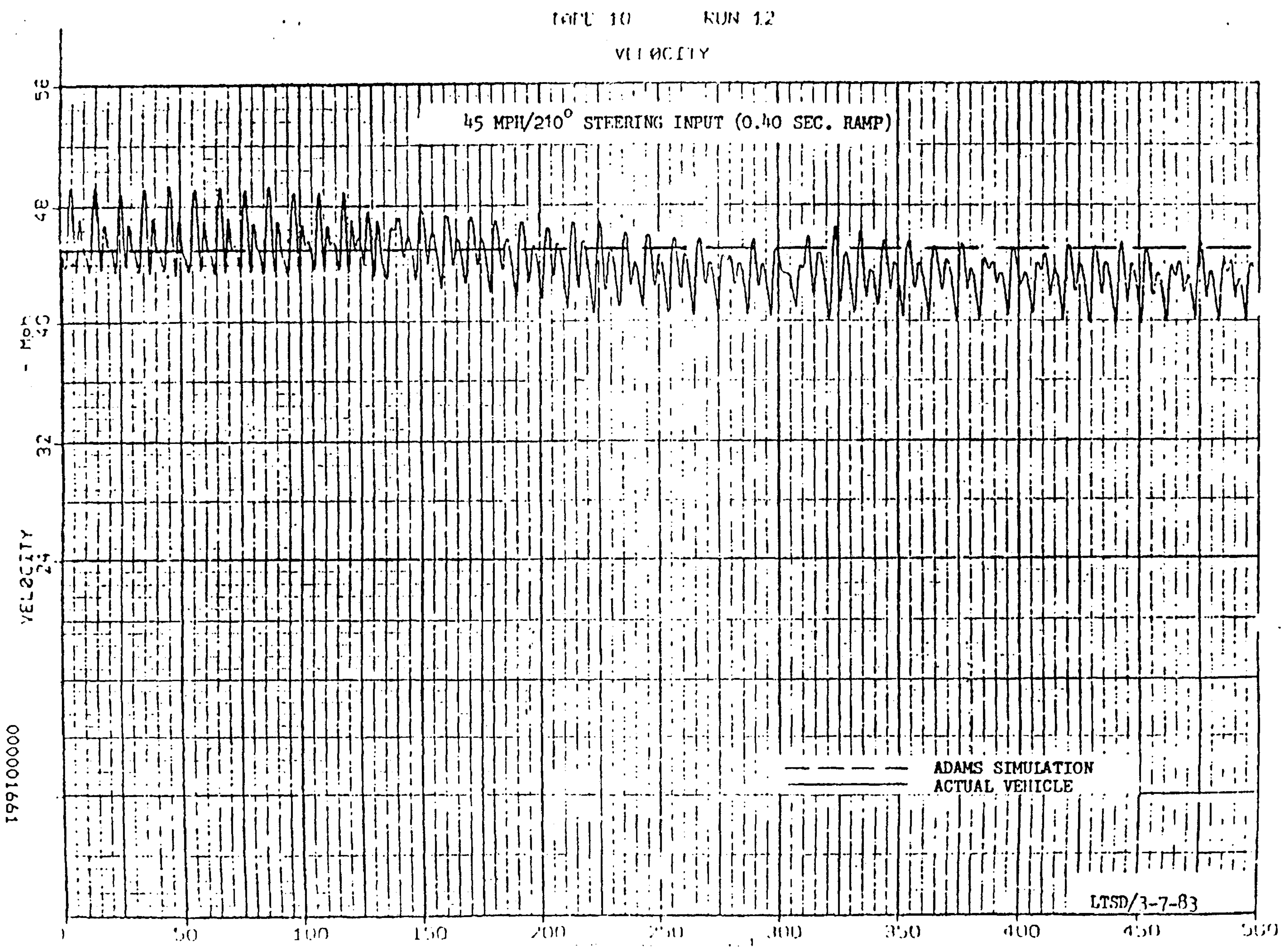
ROLL ANGLE





YAW RA
45 MPH/210° STEERING INPUT (0.40 SEC. RAMP)
ADAMS SIMULATION
ACTUAL VEHICLE
LTSD/3-7-83
150
200
300
350
400
450
500

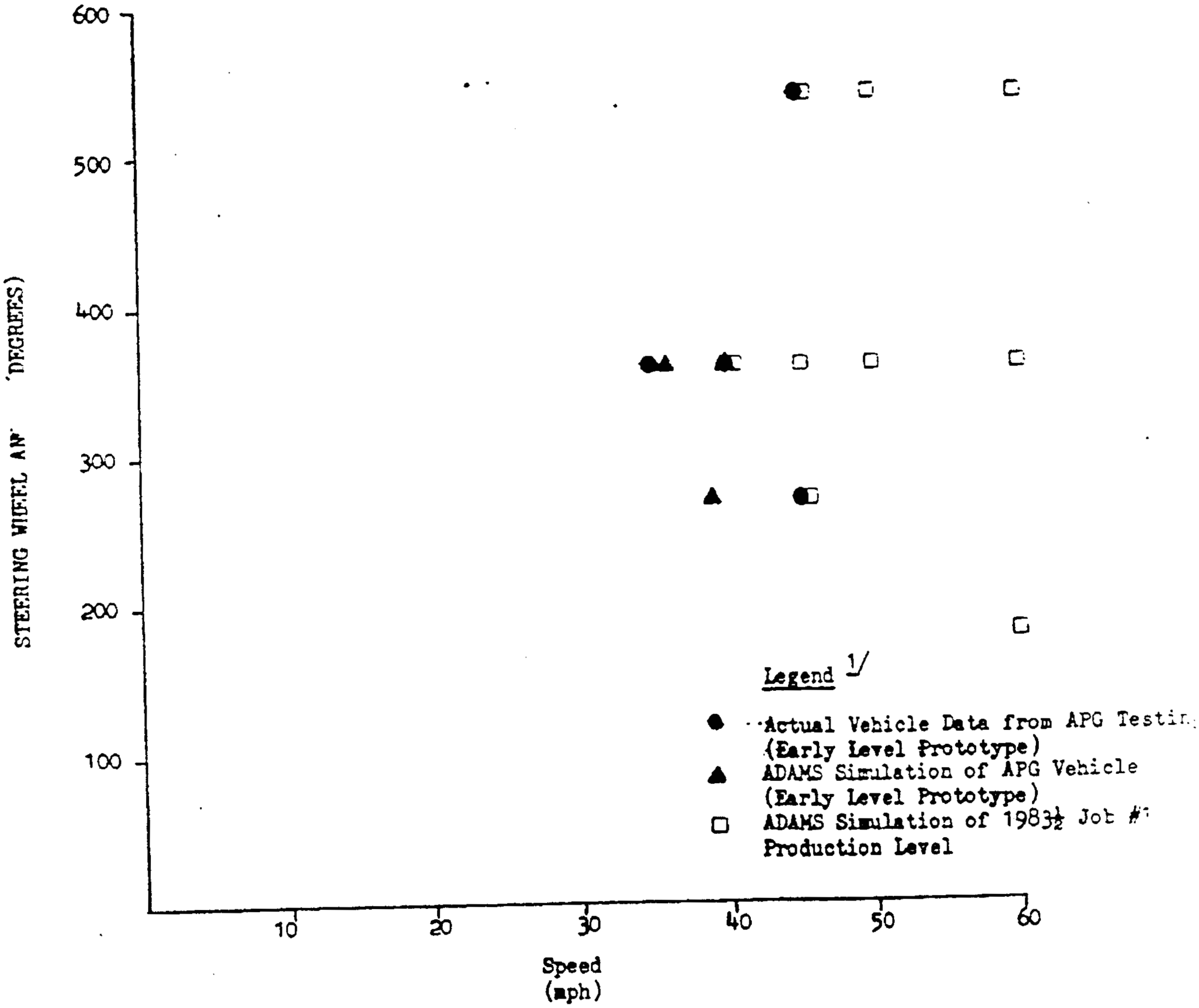
000001660



TAPE 10 RUN 12
VELOCITY
45 MPH/210° STEERING INPUT (0.40 SEC. RAMP)
56
48
40
32
24
VELOCITY - MPH
ADAMS SIMULATION
ACTUAL VEHICLE
LTSD/3-7-83
0
50
100
150
200
250
300
350
400
450
500

000001661

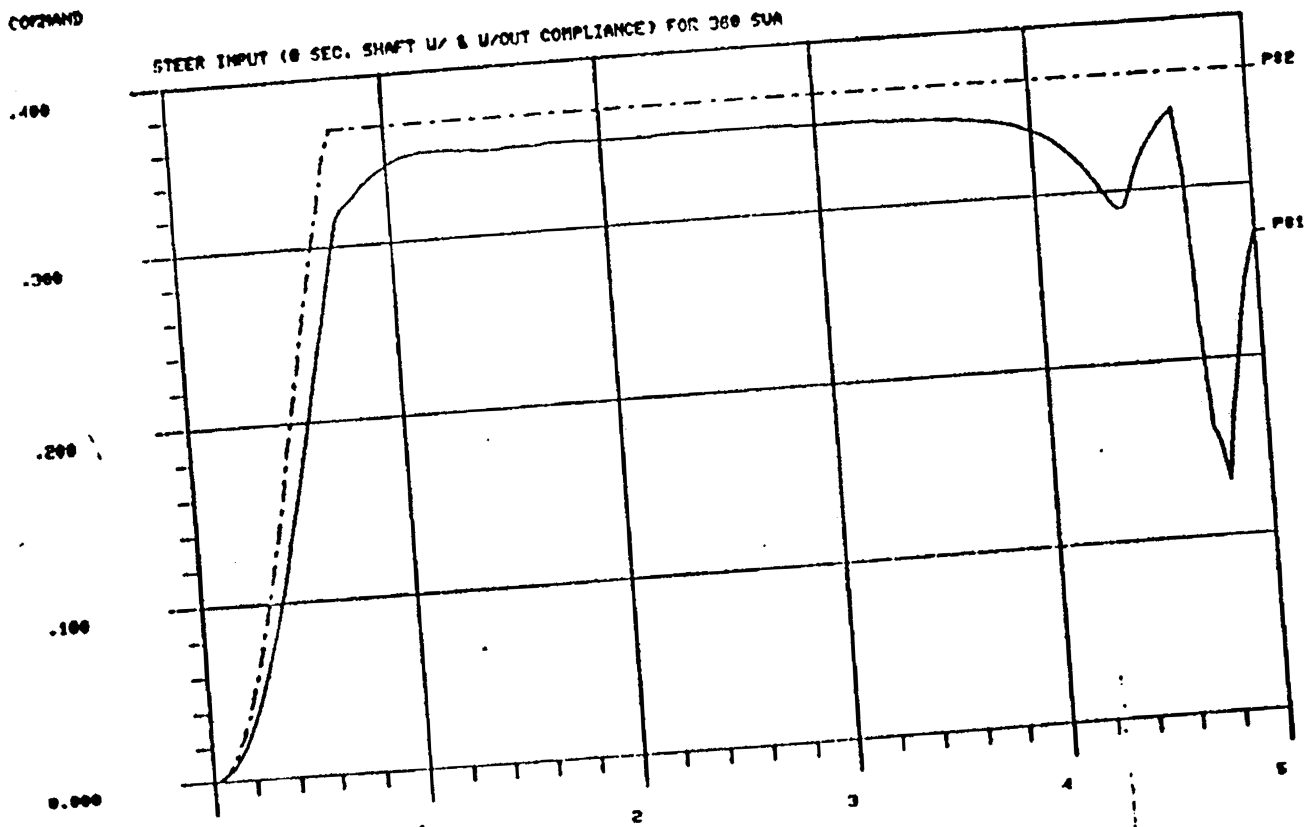
STEERING WHEEL ANGLE VS. SPEED
FOR
TWO WHEEL LIFT TRESHOLDS



1/ Darkened points denote 2 wheel lift
Non-darkened points denote stable performance throughout maneuver

ENTER COMMAND

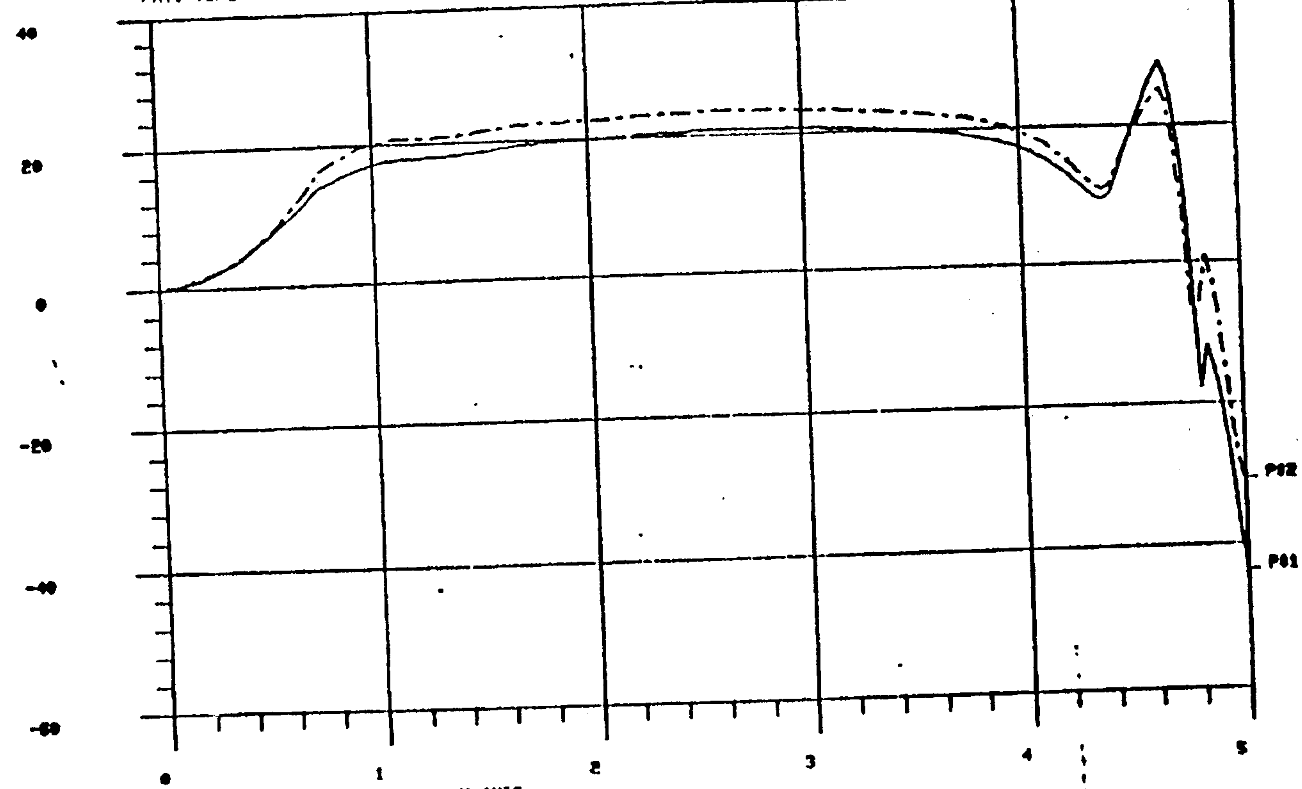
STEER INPUT (8 SEC. SHAFT W/ & W/OUT COMPLIANCE) FOR 380 SVA



PLOT NO	REQ8 COMP	X AXIS TYPE	I	J	REQ8 COMP	Y AXIS TYPE	I	J	RUN	FILE
1		TIME			15	ANG1 DISP	815	5115	1	12
2		TIME			18	ANG1 DISP	3515	5115	1	12

ENTER COMMAND

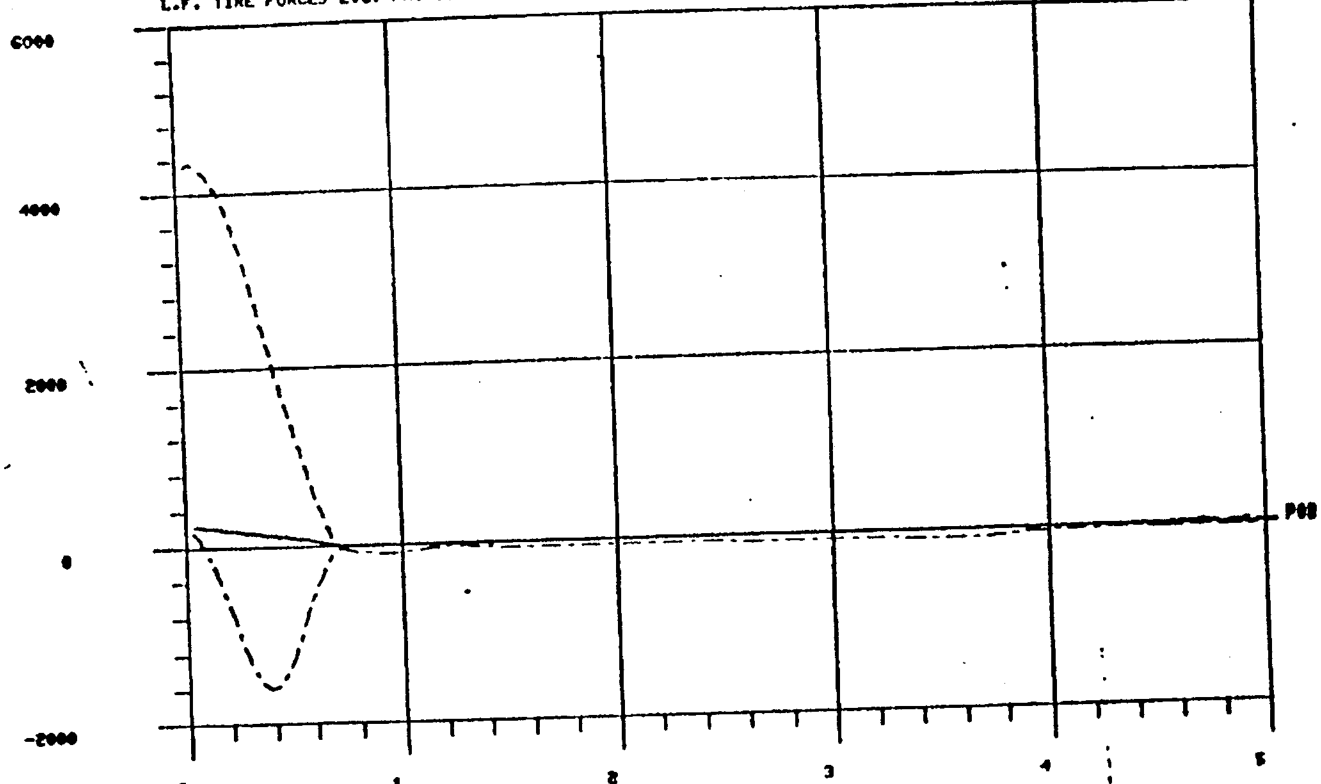
FRT. TIRE SLIP ANGLES E.L.P. (36MPH/360 DEG. STEER INPUT) $



PLOT NO	REG# COMP	X AXIS TYPE	I	J	REG# COMP	Y AXIS TYPE	I	J	RUN	FILE
1		TIME			Z	FRT.			1	12
2		TIME			ANGI	FRT.			1	12

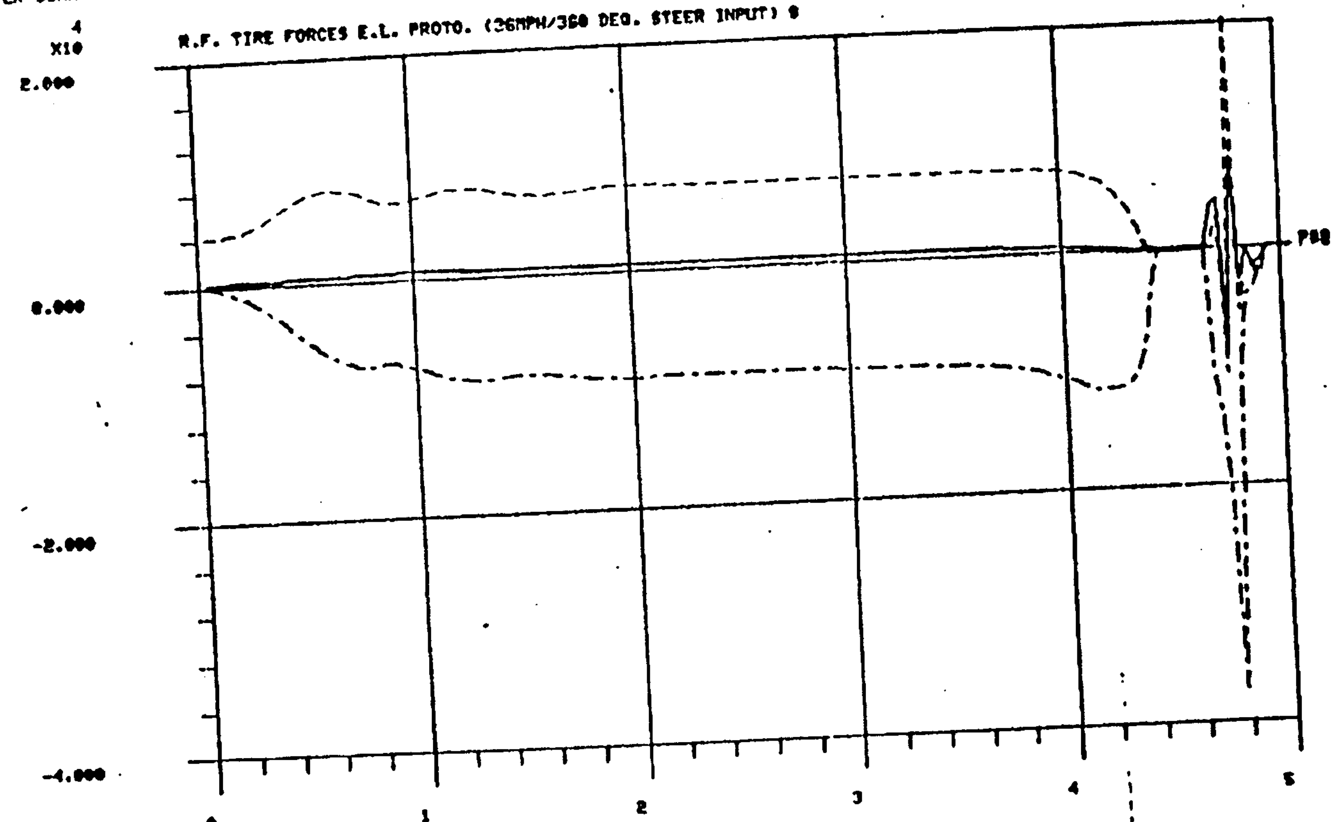
ENTER COMMAND

L.F. TIRE FORCES E.L. PROTO. (36MPH/360 DEG. STEER INPUT) 8



PLOT NO	REQ#	COMP	X AXIS TYPE	I	J	REQ#	COMP	Y AXIS TYPE	I	J	RUN	FILE
1			TIME			1032	X	FORC	404	0	1	12
2			TIME			1032	Y	FORC	404	0	1	12
3			TIME			1032	Z	FORC	404	0	1	12

ENTER COMMAND

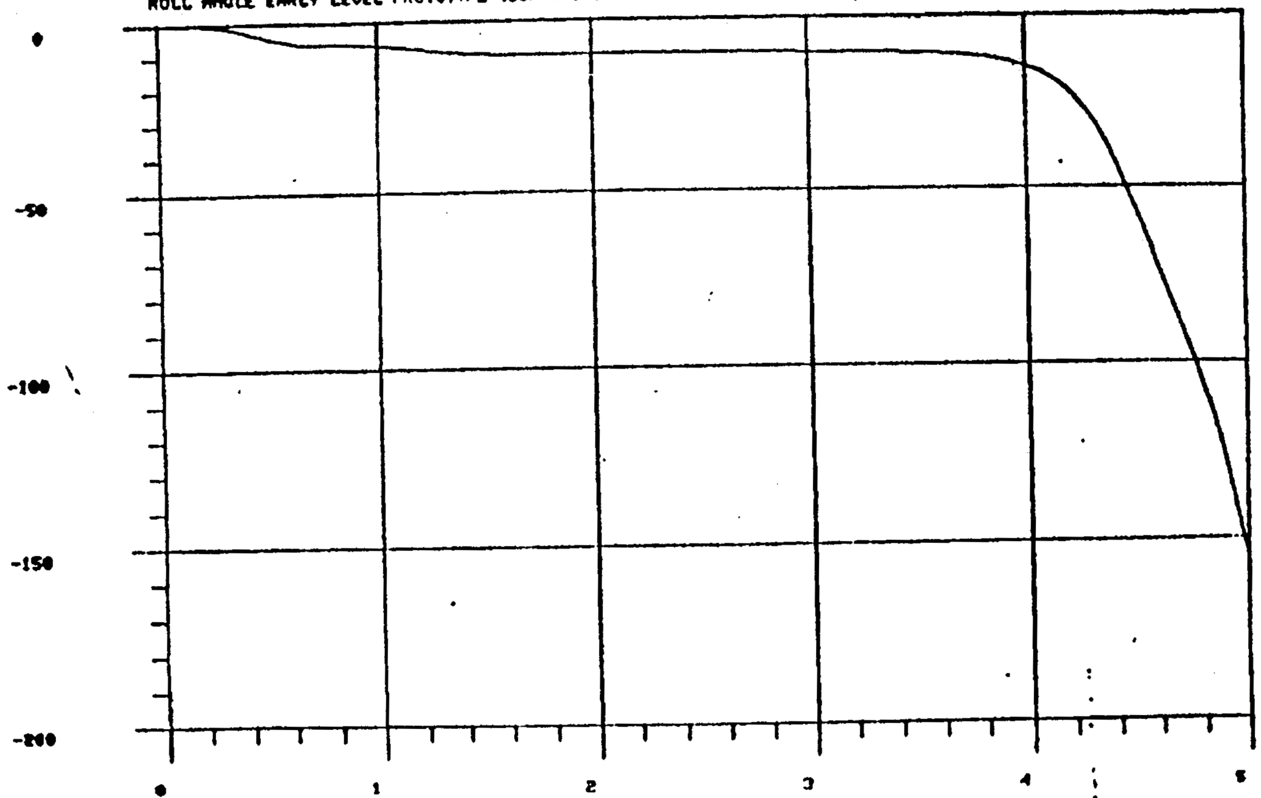


PLOT NO	X AXIS REQ#	X AXIS COMP	X AXIS TYPE	X AXIS I	X AXIS J	Y AXIS REQ#	Y AXIS COMP	Y AXIS TYPE	Y AXIS I	Y AXIS J	RUN	FILE
1			TIME			1033	X	FORC	504	0	1	12
2			TIME			1033	Y	FORC	504	0	1	12
3			TIME			1033	Z	FORC	504	0	1	12

0000001669

ENTER COMMAND

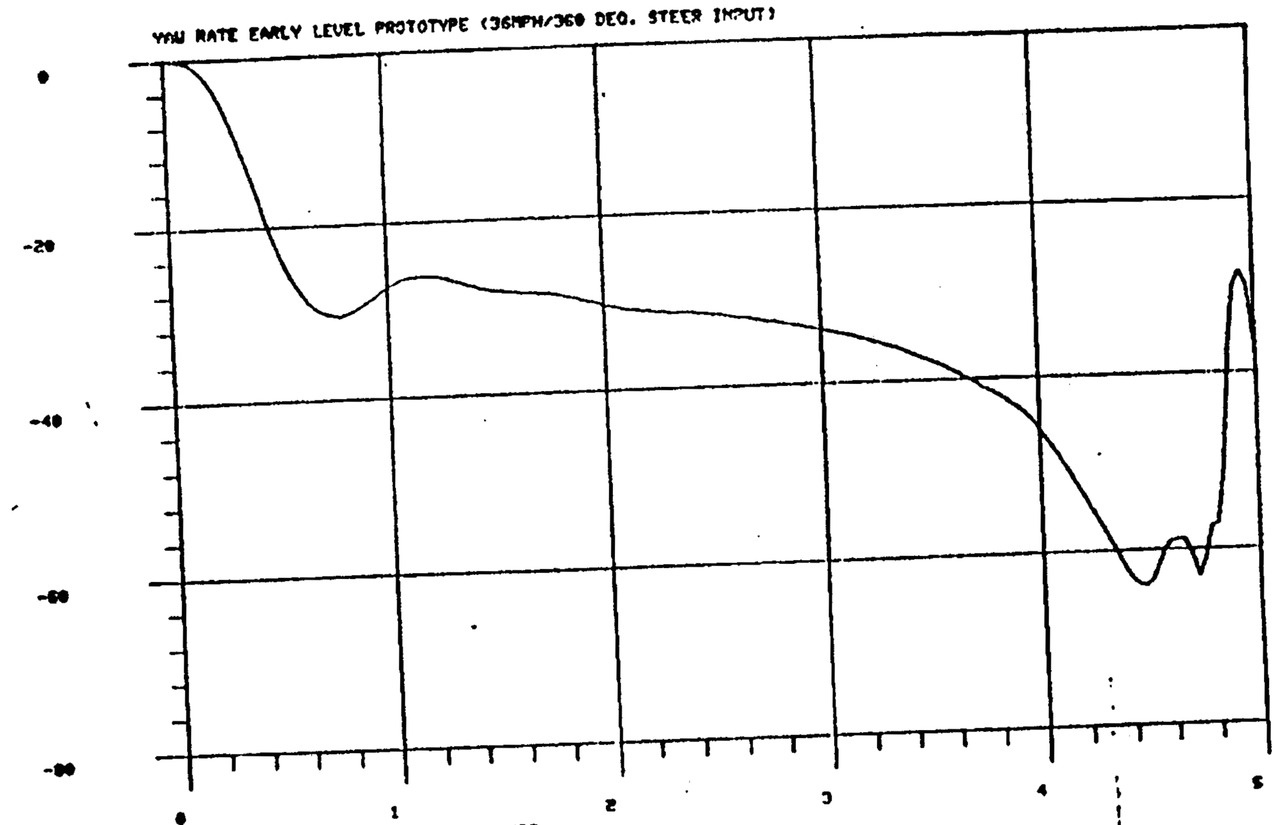
ROLL ANGLE EARLY LEVEL PROTOTYPE (30MPH/300 DEG. STEER INPUT)



PLOT NO		X AXIS TYPE	I	J		Y AXIS TYPE	I	J	RUN	FILE
1	REG0 COMP	TIME			REG0 COMP 1004 ANG3	DISP	5100	100	1	12

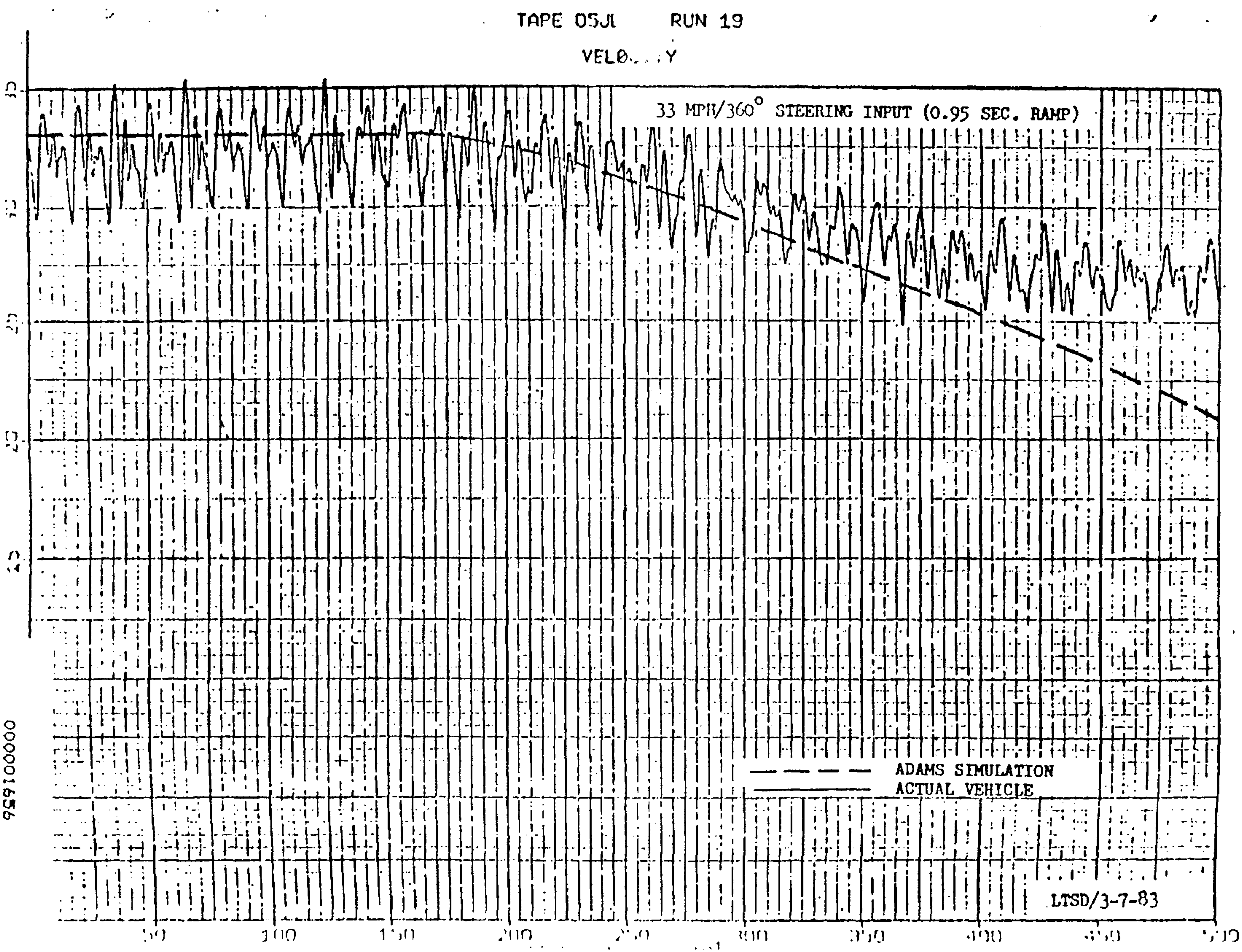
000001665

ENTER COMMAND



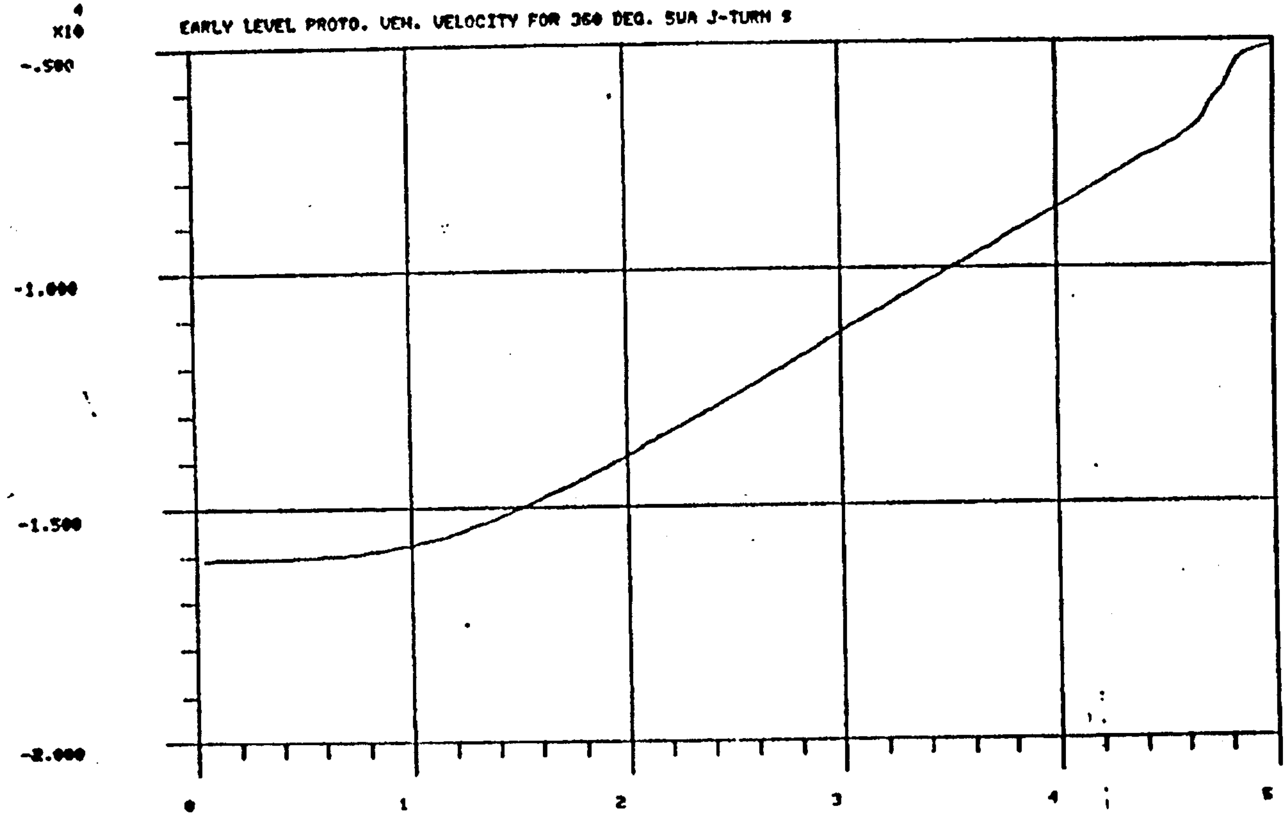
PLOT NO		X AXIS TYPE	I	J		Y AXIS TYPE	I	J	RUN	FILE
1	REQ# COMP	TIME			REQ# COMP 1005	ANG3 VEL	100	5100	1	12

0000001666



TAPE 05JI RUN 19
33 MPH/360° STEERING INPUT (0.95 SEC. RAMP)
ADAMS SIMULATION
ACTUAL VEHICLE
LTSD/3-7-83
100

ENTER COMMAND



PLOT NO	REQ# CCMP	X AXIS TYPE	I	J	REQ# COMP	Y AXIS TYPE	I	J	RUN	FILE
1		TIME			998 X	VEL	5100	100	1	12