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LUMINARY MEMO #221

FROM: Craig Work

DATE: 12 July 1971

SUBJECT: DAP performance in the Apollo 15 Level 6 Tests

REFERENCES: LUMINARY MEMOS, #227, #214 (Revision 1)

DAP performance was found to be normal and satisfactory in all eight Powered Flight tests received for Level 6 review. DAP edit summary sheets are appended for all tests in this report.

DAP edits from the following list of Level 6 tests were evaluated for this report: (see Luminary Memo #214, Revision 1). DAP edit summary for test 6.5.7, ABORT from Lunar Surface with Erasable DSKY Backup, is included with LUMINARY MEMO #227. DAP edits were not received for level 6 test runs excluded from this list.

All tests were run with simulated non-linear slosh, and all but 6.3.2-A used a detailed simulation of the IMU. All the Lunar Landing tests use an initial thrust vector mistrim (including compliance at 1200 lb. thrust) of -0.56° in pitch and -0.86° in roll.

ABORTS: ABORT back-up bit set in these tests.

6.2.1 ABORT at 33K ft.
The yaw in this maneuver was via X-axis override, which leaves the control in AUTO rather than ATT HOLD. Control was normal.

6.2.2 ABORT at 7K ft.
The ABORT-STAGE roll transient rate reached 6.8°/sec, but returned immediately to normal levels.

6.2.3-A ABORT-STAGE from TOUCHDOWN, A

The landing was nominal and DAP control after the staging looked likc a normal ascent.

ASCENT

6.3.2-A P12 Ascent with target 26 n. m. out of plane

A faster, less detailed model of the IMU was used in this run. Guidance requested sizable maneuvers in roll, pitch, and in yaw, immediately after the liftoff. FINDCDUW, the guidance-DAP interface routine, was performing its functions of limiting rate requests to the DAP, but it was not limiting about vehicle body axes. The resulting rate request went to 14°/sec in pitch, and DAP overshort momentarily carried to 20°/sec. The transient was quickly nulled, and control was normal for ascent after that.

DESCENT: ROD switch exercised in these landings

6.4.2.1 Lunar Landing

Effects on DAP control were small, when a Noun 69 Redesignation was performed early in P63.

6.4.2.2 Lunar Landing

A Noun 69 redesignation early in P63 was combined with an ACA redesignation immediately after the P64 pitchover. DAP response was correct and satisfactory.

6.4.2.3 Lunar Landing

The P64 pitchover, immediately followed by an ACA redesignation, generated a 13°/sec pitch rate transient. This was quickly damped, and the rest of the landing was normal.

6.5.4 Lunar Landing (Special tests)

The AUTO THROTTLE backup discrete was set for this run. A Noun 69 redesignation was performed in P63 and ROD control was performed shortly before TOUCHDOWN. DAP control was correct and satisfactory.

Apollo 15, LM 10, Luminary 1E (Rev 210), Level VI test
JOB A139211 07/01/71 4:56 (edit)
MARSROT 17707385 MOORE. D ABORT AT 33K FT

Test 6.2.1 ABORT at 33 K FT.

This edit covers the period 376460 to 376734 seconds.
The ABORT back-up discrete is set in the DAP data load.

376472	ATT HOLD
376477	P70, AUTO, pitch through vertical
376481	ACA yaw (-36° at -10°/sec)
376491	Pitch forward
376727	Thrust termination

P-axis: The combined yaw requests of guidance (P70) and the ACA were satisfied at -10.2°/sec max. Rates were negligible, otherwise. Attitude errors reflected normal control.

Q-axis: The pitch through vertical reached -10.7°/sec, and the pitch forward peaked at -8.5°/sec. Maximum slosh effect reached -2°/sec, then died down. Attitude errors reflected normal control.

R-axis: ACA yaw, pitch through vertical, and pitch forward combined to produce compensating roll transient rate of -6°/sec. Attitude errors reflected normal control.

Apollo 15, LM 10, Luminary 1E (Rev 210) , Level VI Test
JOB A139213 07/01/71 4:36 (edit).
MARSROT 17700302 MOORE. D. ABT-ABTSTG AT 7K

Test 6.2.2 ABORT at 7K feet

This edit covers the period 376700 - 377165 seconds.
The ABORT backup discrete is set in the DAP data load.

376700	P64 pitchover in progress
376705	ATT HOLD, P70, AUTO
376812	ABORT STAGE, ATT HOLD, P71
376821	AUTO
376890	ATT HOLD, Manual yaw (-36° at -10°/sec), AUTO
377160	Thrust Termination

P-axis: Manual yaw rate reached -10.7°/sec, and rate envelope maxima during cross-coupling resonance damped from 3.3°/sec within 80 sec. Attitude errors were nominal.

Q-axis: Pitch-down rates of -11.3°/sec showed at P64 and in P70, while pitch to vertical rise after ABORT was at -6.6°/sec. Rate peak envelope maxima went from 5.5°/sec after ABORT-STAGE down to 1.5°/sec, increasing to ±3.5°/sec at orbital insertion, common for ascent control.

R-axis: The ABORT-STAGE transient reached 6.8°/sec, and the rate peak envelope maxima were within ±3.7°/sec, which is normal for ascent.

Overall DAP control was normal.

Apollo 15, LM 10, Luminary 1E (Rev 210), Level VI test
JOB A139210 07/01/71 5:09 (edit)
MARSROT 17620242 MOORE.D ABTSTG FROM TDWN-A

Test 6.2.3 A - ABORT Stage from Touch-down, A

This edit covers the period 376850 to 377310 seconds.
The ABORT back-up discrete was set in the DAP data load.

376854	TOUCH DOWN
376858	ABORT-STAGE, LIFTOFF, ATT HOLD
376862	P71 entry (V 37 E), AUTO
376939	ATT HOLD, Manual yaw (-36° at -10°/sec), AUTO
377294	Thrust termination

P-axis: Manual yaw rate reached -11.2°/sec, and the period of cross-coupled resonance from Q, R axes showed ±2.5°/sec.

Q-axis: +10°/sec was the ABORT-STAGE transient rate, while the 55° pitch forward generated a max rate of -13.5°/sec. Rate peak envelope maxima went steadily from ±6°/sec to ±2.5°/sec at insertion.

R-axis: Liftoff transient rate was 8.3°/sec. The rate peak envelope maxima rose to ±4°/sec and stayed there until insertion.

DAP control was normal and satisfactory.

Apollo 15, LM 10, Luminary 1E (Rev 210), Level 6 test
JOB A145109 07/07/71 13:00
MARSROT 18101232 WHITE.P ASCENT L6 SPEC

Test 6.3.2-A P12 Ascent with target 26 n.m. out of plane.

617844	LIFTOFF (P12), with SCSMODE AUTO
617903	ACA yaw (40° at 5°/sec), X-axis override
618285	ENGINOFF

This edit covers the period 617840 - 618322 seconds.
The N85 values at engine off were (-0.1, -0.3, +1.3), quite acceptable for a burn with a large out of plane component.

P-axis: The automatic yaw at liftoff traversed 57° with a peak rate of 11°/sec. The manual yaw peaked at 5.5°/sec. Automatic yaw attitude error transients reached +4.3°, -5.0°.
A 50 sec. period of yaw activity centered about 618145.

Q, R axes: The lift-off maneuver required large rotations in all 3 axes. Because of that, FINDCDUW, (the interface routine between the guidance and the DAP), was performing its rate-limiting functions about axes quite different from the vehicle Q,R axes. As a result, a fairly common -6°/sec rate overshoot combined with a requested -14°/sec rate to produce a -20°/sec pitch rate transient, and the roll rate lift-off transient was 11.2°/sec. After the pitch-forward maneuver, the rate peak envelope maxima behaved normally for ascent, the Q-axis decreasing from ±6°/sec to ±3°/sec and the R-axis remaining fairly constant about 4.5°/sec. DAP control was normal for ascent, other than the initial maneuver transient.

Note: fast IMU

Apollo 15, LM 10, Luminary 1E (Rev 210), Level 6 test.
JOB A139899 06/29/71 3:07 (edit)
MARSROT 17710573 ALBERT 6.4.2.1

Test 6.4.2.1 Lunar Landing

This edit covers the period 376134-376920 seconds.
The ABORT backup bit is set in the DAP data load.

376136	IGNITION in P63, ABORT button pressed.
376165	N 69 Redesignation (+10K, +5K)
376315	ATT HOLD, Manual yaw (+50° at 5°/sec), AUTO
376706	P64 entry (high gate)
376787	ATT HOLD, ROD, AUTO, ROD
376877	TOUCH DOWN

P-axis: Manual yaw peak rate was 5.3°/sec, while IGNITION and P64 transients were 0.72°/sec. Attitude error was well-controlled.

Q-axis: P64 pitchover peak rate was -10.9°/sec, and sudden guidance requests after ROD completion generated -4.6°/sec. Attitude error went to ±9.5° at P64, showed 1.7° in max slosh period. DAP control was normal.

R-axis: The IGNITION transient roll rate was -1.4 deg/sec; and other rates were smaller. Attitude error was 2.1° during IGNITION transient and 1.8° during redesignation.

Overall DAP control was normal and satisfactory.

Apollo 15, LM 10, Luminary 1E (Rev 210), Level 6 test
JOB A139899 06/29/71 3:21 (edit)
MARSROT 17815443 ALBERT 6.4.2.2

Test 6.4.2.2 Lunar Landing

This edit covers the period 376134 - 376920 seconds.
The ABORT back-up bit was set in the DAP data load.

376136	IGNITION in P63, ABORT button
376171	N 69 redesignation (20K, 20K)
376315	X-axis override yaw (+50° at 5°/sec)
376718	P64 entry
376725	ACA redesignation 2(-EL), 2(+AZ)
376801	ATT HOLD, ROD, AUTO, -ROD
376883	TOUCH DOWN

P-axis: Manual yaw rate peaked at 5.3°/sec, and -2.7°/sec showed during the ACA redesignation. Automatic yaw guidance produced -0.8°/sec at 30K ft. altitude. Attitude error was -1.6° after P63 throttle down, but smaller otherwise.

Q-axis: Max pitchover rate for P64-ACA redesignation was -12.0°/sec, and return to AUTO during ROD sequence produced -2.8°/sec. Pitchover attitude error transient reached -8.7°, +8.2°. During period of maximum slosh, pitch attitude error reached -1.7°.

R-axis: ACA redesignation saw 1.4°/sec roll rate, and the N 69 redesignation showed 1.3°/sec. Maximum attitude error occurred during IGNITION transient, reaching 1.7°.

DAP control was normal and satisfactory.

Apollo 15, LM 10, Luminary 1E (Rev 210), Level 6 test
JOB A139904 06/30/71 3:28 (edit)
MARSROT 17713001 ALBERT 6.4.2.3

Test 6.4.2.3 Lunar Landing

*This edit covers the period 376134 - 376920 seconds.
The ABORT back-up bit was set in the DAP data load.

376136	IGNITION in P63, SCSMODE AUTO
376315	ATT HOLD, Manual yaw (+50° at +5°/sec), AUTO
376700	P64
376704	ACA redesignation 2(+EL), 2(-AZ)
376787	ATT HOLD, ROD, AUTO, ROD
*376928	TOUCH DOWN

P-axis: The manual yaw rates peaked at 5.3°/sec, and ACA redesignation saw a 1.1°/sec yaw rate. The yaw attitude error once reached 1.8° during P63, due to the phase plane flat and very low rates.

Q-axis: P64 pitchover rate reached a -13°/sec maximum, and guidance recovery, (after return to AUTO during ROD period), produced -3.6°/sec pitch rate. The maximum slosh period saw a peak DAP rate of -1.6°/sec. Attitude errors were less than 1.8° in magnitude, except during the P64 pitchover transient, when they peaked at ±8.8°.

R-axis: The IGNITION transient roll rate was -1.4°/sec, and all others were smaller. Roll attitude errors were 2.1° at IGNITION, less than ±1.3° otherwise.

DAP control was normal and satisfactory.

Apollo 15, LM 10, Luminary 1E (Rev 210), Level 6 test
JOB A139904 06/30/71 3:43 (edit)
MARSROT 17821185 ALBERT 6.5.4

Test 6.5.4 Lunar Landing

This edit covered the period 376134 to 376920 seconds.
The AUTO THROTTLE backup discrete is set in the DAP data load.

	IGNITION in P63
376315	ATT HOLD, Manual yaw (+50° at 5°/sec), AUTO
376435	N 69 redesignation (+10K, +5K)
376705	P64
376795	ATT HOLD, ROD, AUTO, ROD
376837	TOUCH DOWN

P-axis: Manual yaw rate peaked at 5.5°/sec, and P63 inhibition of x-axis override saw 1.4°/sec yaw. Attitude error was well controlled, with -1.4° the largest value.

Q-axis: P64 pitchover rate peaked at -11.2°/sec, and the guidance response to the rapid ROD inputs required -3.5°/sec pitch. Attitude errors reached -9.4° at P64 and 1.8° during maximum slosh.

R-axis: P64 pitchover showed a 1.7°/sec roll rate, and 1.6°/sec at the N 69 redesignation. The attitude error reached ±1.7° during the redesignation, but was quiet otherwise.

DAP control was normal and satisfactory.

Initialization Parameters

$\underline{R}$ = (-1723749.4, -50395.9, -648540.4) meters
$\underline{V}$ = (-443.72, +1130.54, +1090.42) meters/sec.
T = 178:56:20 G.E.T.

$$\text{REFSMMAT} = \begin{bmatrix} +.055099073 & +.66312594 & +.7467713 \\ -.22872524 & -.71935067 & +.65591112 \\ +.97193849 & -.20687825 & +.11203809 \end{bmatrix}$$

RCS fuel = 317.7 lb.
APS fuel = 302.4 lb.
Total LM weight = 5345 lb.

$\underline{CG}$ = (258.17, 0.52, 1.2) inches

IMU compensation errors = 0

TABLE I

Burn Parameters and Desired Results

TIG = 179:6:22.7 G. E. T.

ΔV = (-161.1, 57.3, 94.6) fps

$|\Delta V|$ = 195.4 fps

Desired apolune = 62 n. mi.

Desired perilune = -52.8 n. mi.

Desired burn time = 82.3 sec.

Desired Impact time = 179:31:7.9 G. E. T.

Desired Latitude = 26.3° N

Desired Longitude = 1.7° E

TABLE II

Tabulated Displays

DSKY(VN)	R1	R2	R3	Mode
V37E00E				00
V82E				
V04N12	00002	00001		
V16N44	+60.5	+58.2		
V48E				
V21N46	12021			
V21N47	+5345			
V37E30E				30
V6N33	+179	+6	+22.70	
V6N81	-161.1	+57.3	+94.6	
V6N42	+60.9	-53.1	+195.4	
V16N45	0	-8x50	+16.93	
V96E				00
V71				27
V71				
V71				
V71				
V72				
V5N26E	13001	1420	12067	00
V62E				
V30E				99
V50N18	+162.52	+21.58	+13.91	
V6N40	-01x00	+195.4	0	
V6N40	-00x20	+195.4	+.1	
V6N40	-00x01	+195.4	+.3	
V16N40	-00401	+.1	+195.9	
V16N85	-.1	-0	+0	
V82E				
V16N44	+60.9	-53.2	-21x30	
V16N85	-.2	-0	+0	
V37E00E				00

TABLE III

Test Facility Data Comparison

Data	MIT/CSDL Value	NASA Value
TIG	179:6:22.7 G.E.T.	179:6:22.7 G.E.T.
ΔV	195.4 fps	195.4 fps
B.T.	81.79 sec	82.3 sec
RCS fuel used	117.16 lb	115 lb
Impact Velocity	5527.3 fps	5527.9 fps
Impact Latitude	26.25° N	26.3° N
Impact Longitude	1.782° E	1.7° E
Impact Time	1:79:31:7 G.E.T.	179:31:7.9 G.E.T.

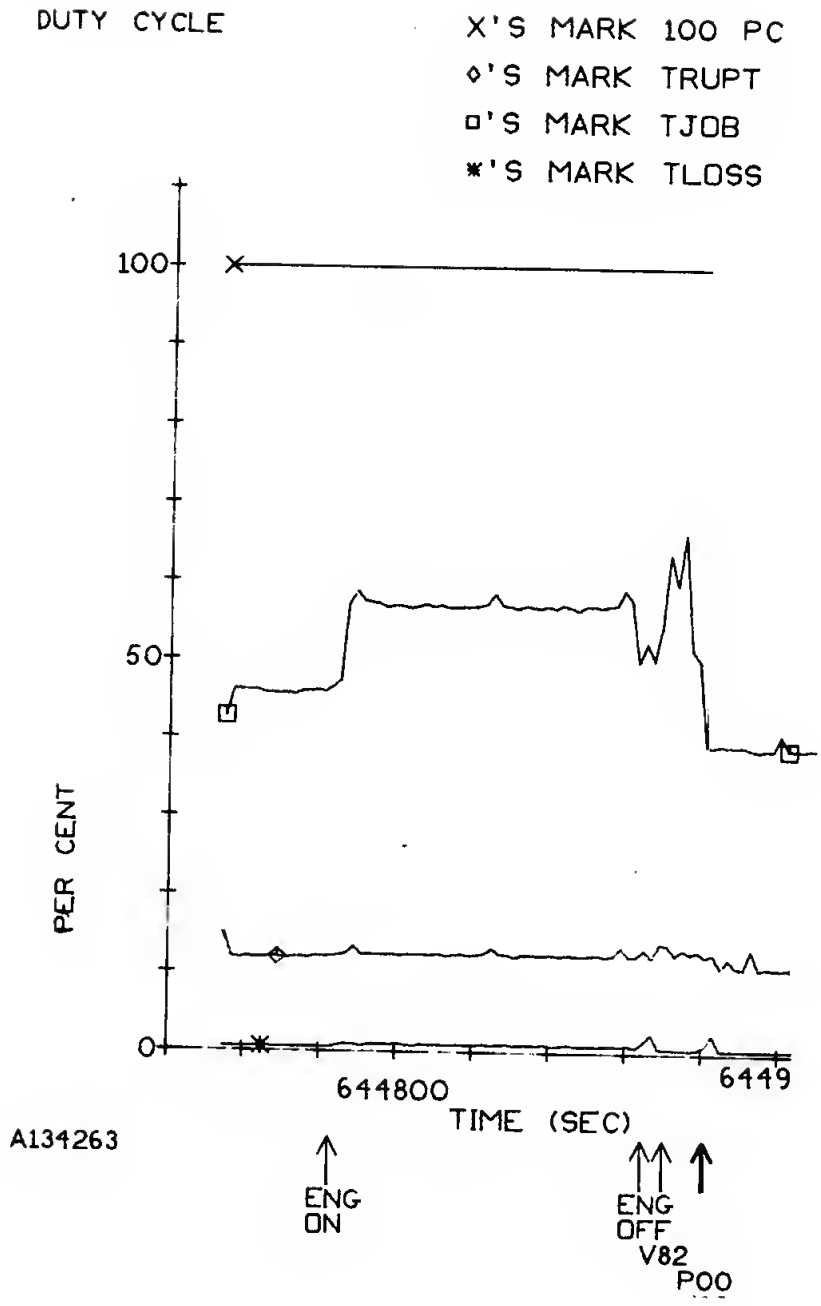
TABLE IV

RCS DATA SUMMARY

Jet #	Time on (sec)	# Firings	Fuel Used (lb)
1	0.10	9	0.05
2	81.88	8	29.65
3	0.11	8	0.05
4	0.08	7	0.04
5	0.10	9	0.05
6	80.27	26	29.09
7	0.10	8	0.05
8	0.08	7	0.04
9	0.08	7	0.03
10	77.66	55	28.19
11	0.11	8	0.05
12	0.08	7	0.04
13	0.07	7	0.03
14	81.90	10	29.66
15	0.10	8	0.05
16	0.08	7	0.04

Total RCS fuel used = 117.16 lb

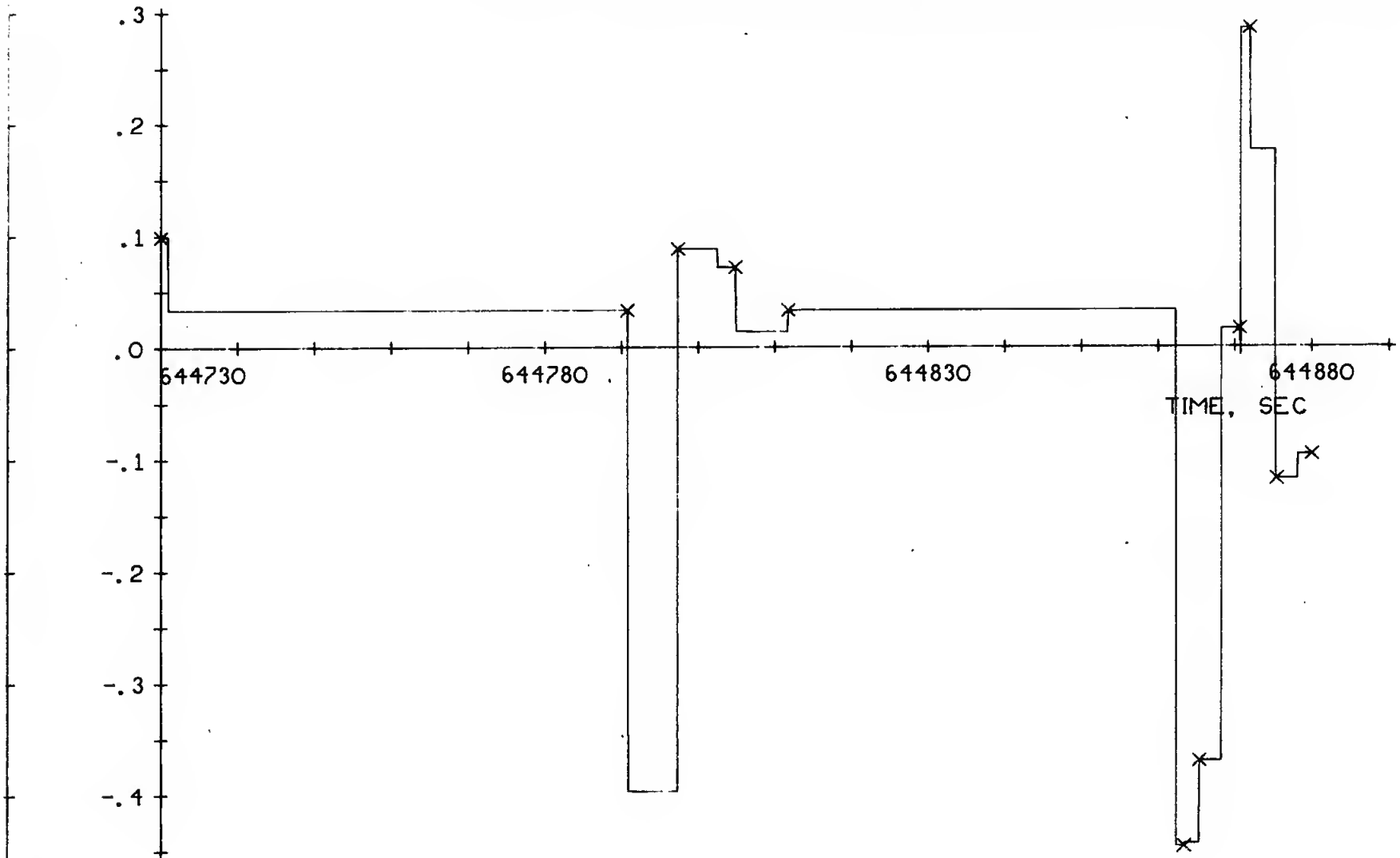
TABLE V


DUTY CYCLE
X'S MARK 100 PC
◇'S MARK TRUPT
□'S MARK TJOB
*'S MARK TLOSS
100
50
0
PER CENT
644800
6449
TIME (SEC)
A134263
ENG ON
ENG OFF
V82 P00

X FOR VAR 01 = OMEGAP

NO PLOT FOR VAR 02 = OMEGAP DESIRED; CONST = 0

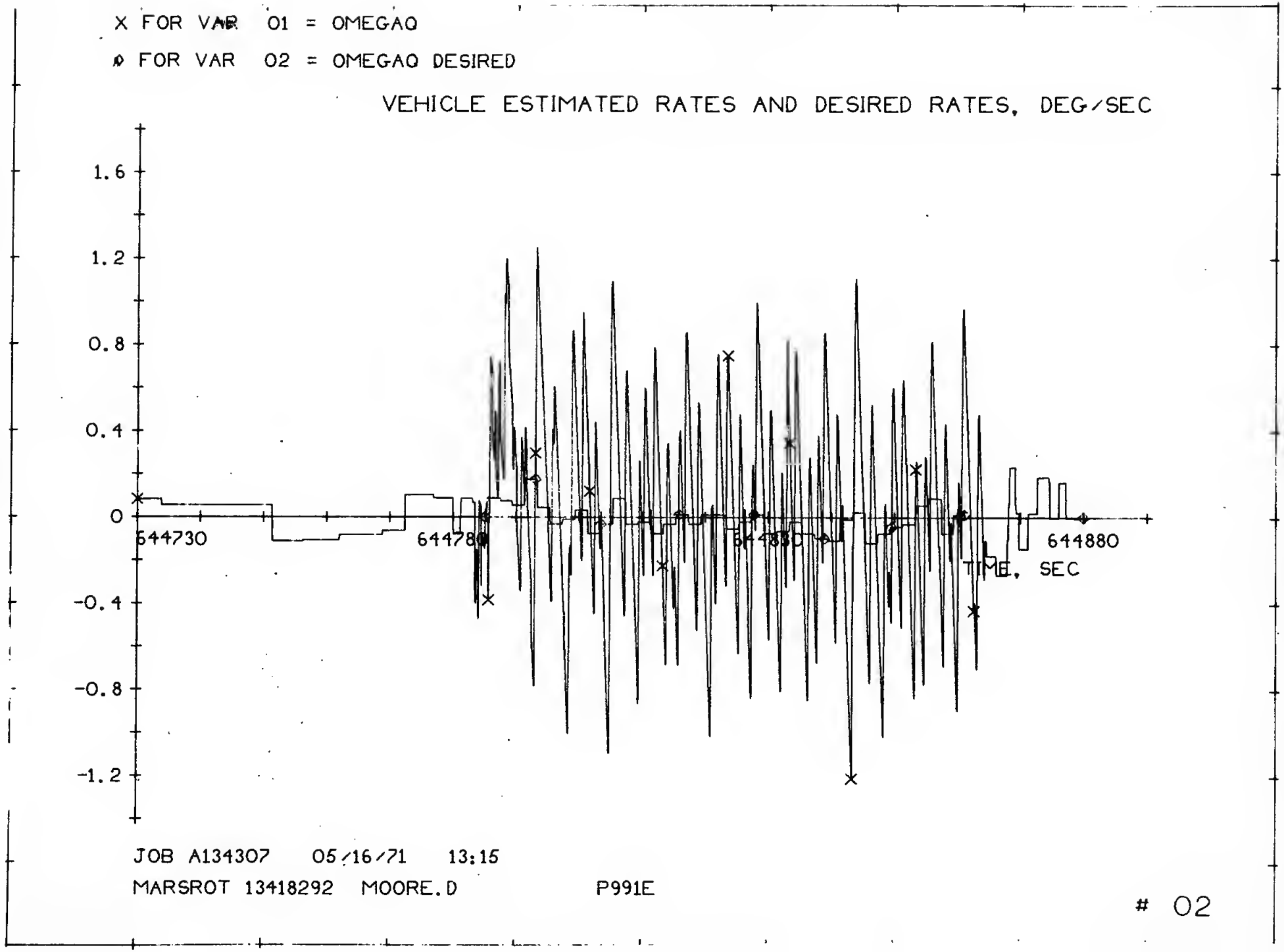
VEHICLE ESTIMATED RATES AND DESIRED RATES, DEG/SEC



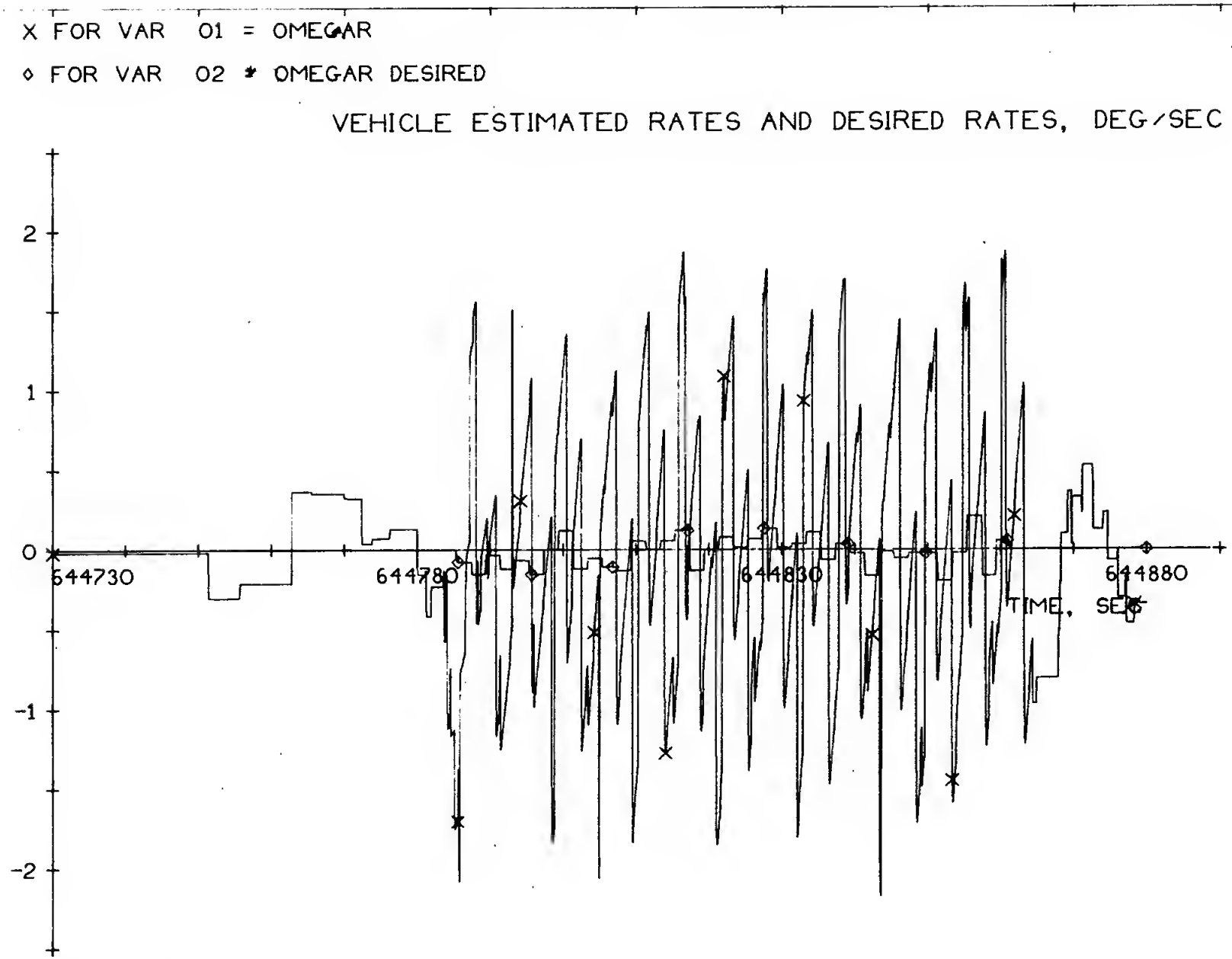
JOB A134307 05/16/71 13:15

MARSROT 13418292 MOORE.D P991E

01


X FOR VAR 01 = OMEGAQ
0 FOR VAR 02 = OMEGAQ DESIRED
VEHICLE ESTIMATED RATES AND DESIRED RATES, DEG/SEC
1.6
1.2
0.8
0.4
0
-0.4
-0.8
-1.2
644730
644780
644880
TIME, SEC
JOB A134307 05/16/71 13:15
MARSROT 13418292 MOORE.D P991E
02

15



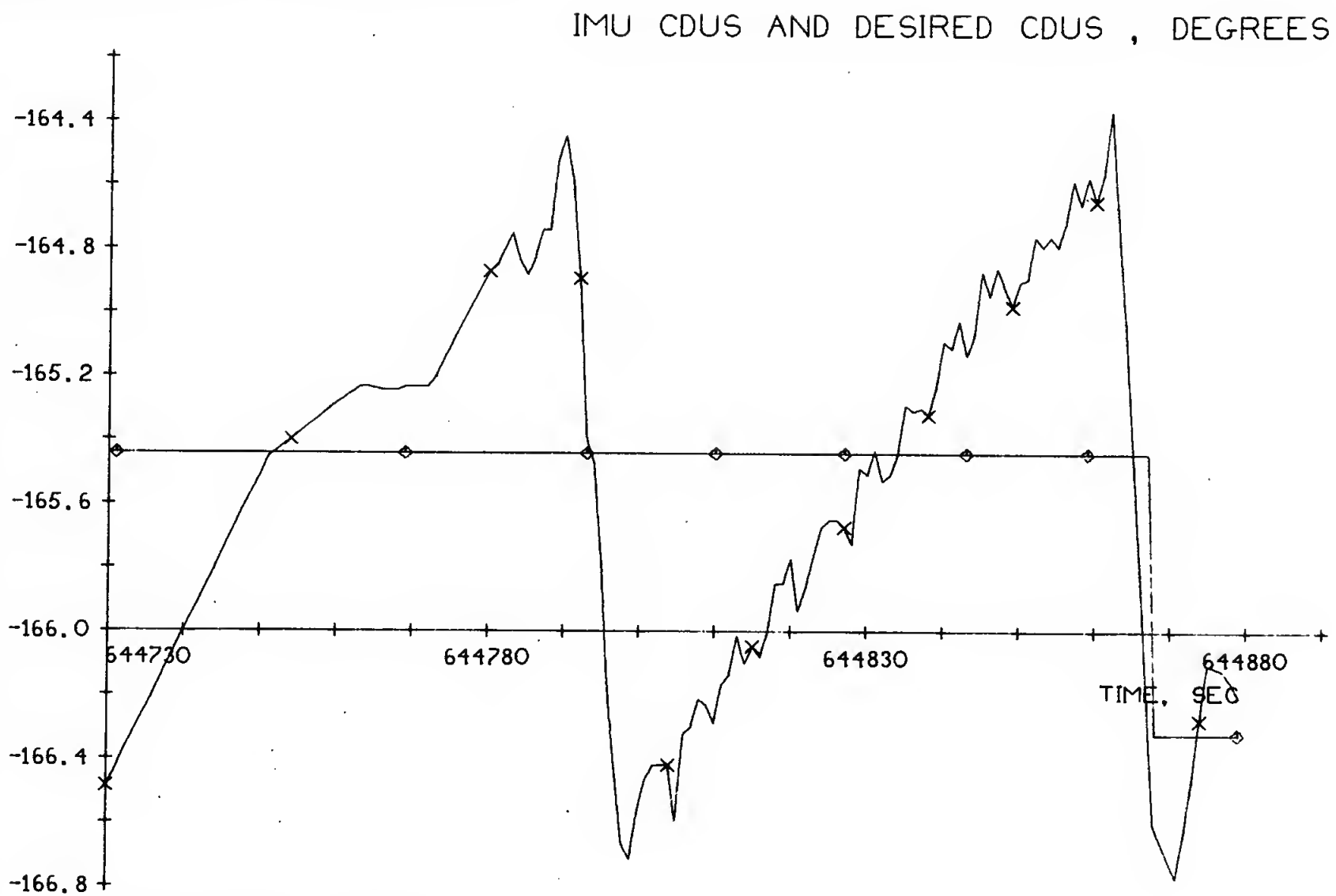
JOB A134307 05/16/71 13:15

MARSROT 13418292 MOORE, D P991E

03

OFFSET X FOR VAR 01 = CDUX

OFFSET ◇ FOR VAR 02 = CDUX DESIRED



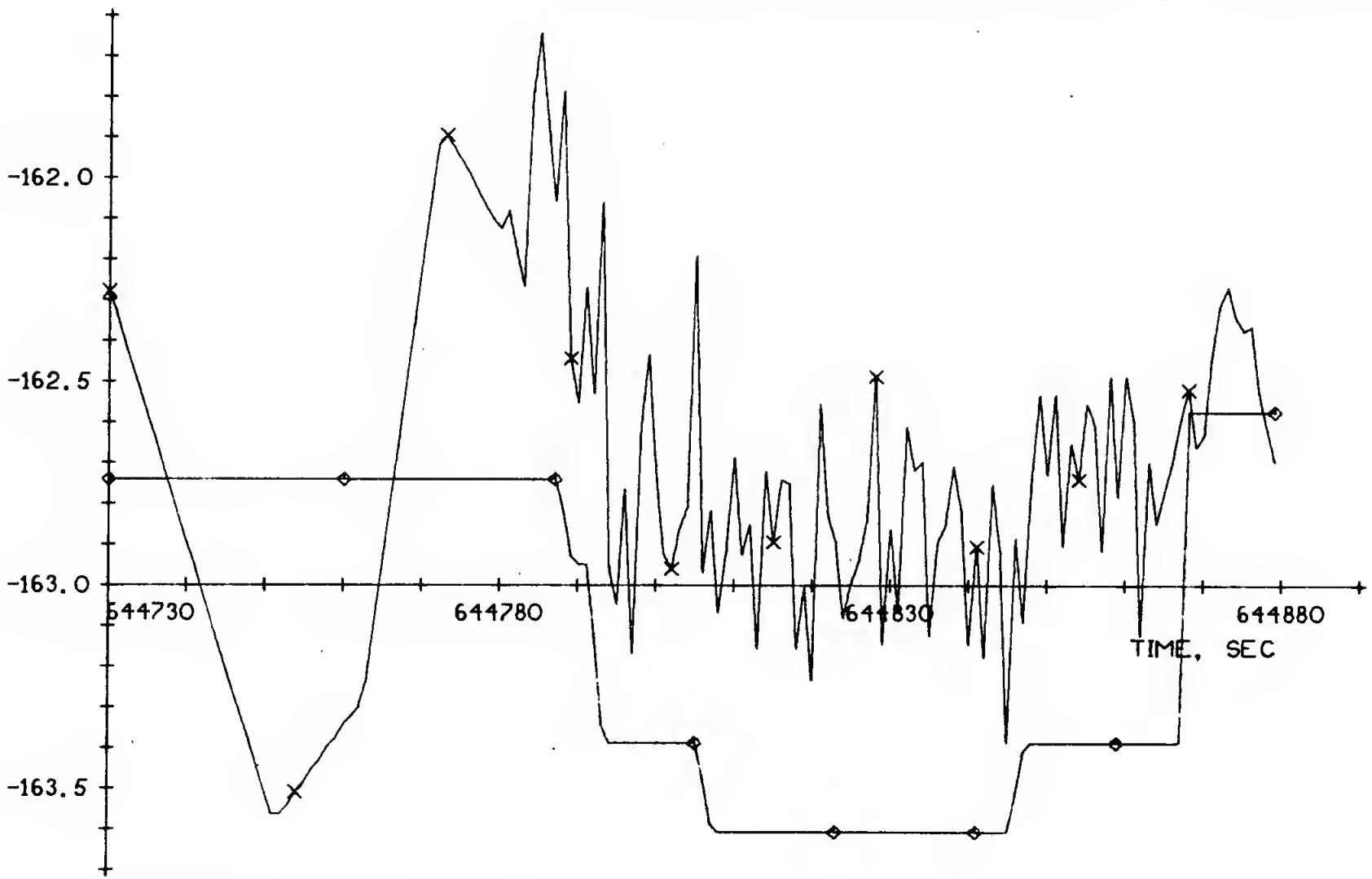
JOB A134307 05/16/71 13:15

MARSROT 13418292 MOORE.D P991E

04

OFFSET X FOR VAR 01 = CDUY

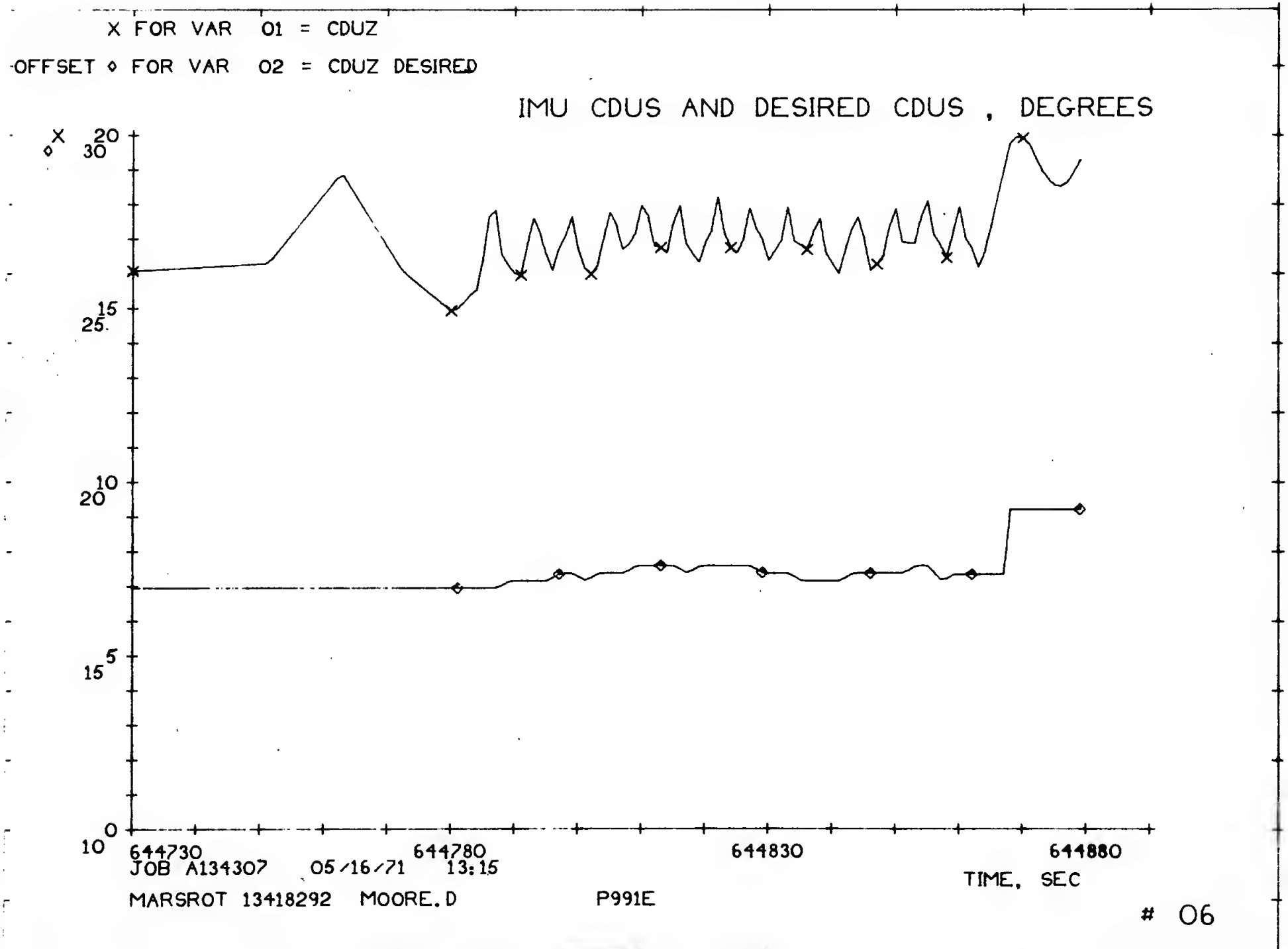
OFFSET ◇ FOR VAR 02 = CDUY DESIRED

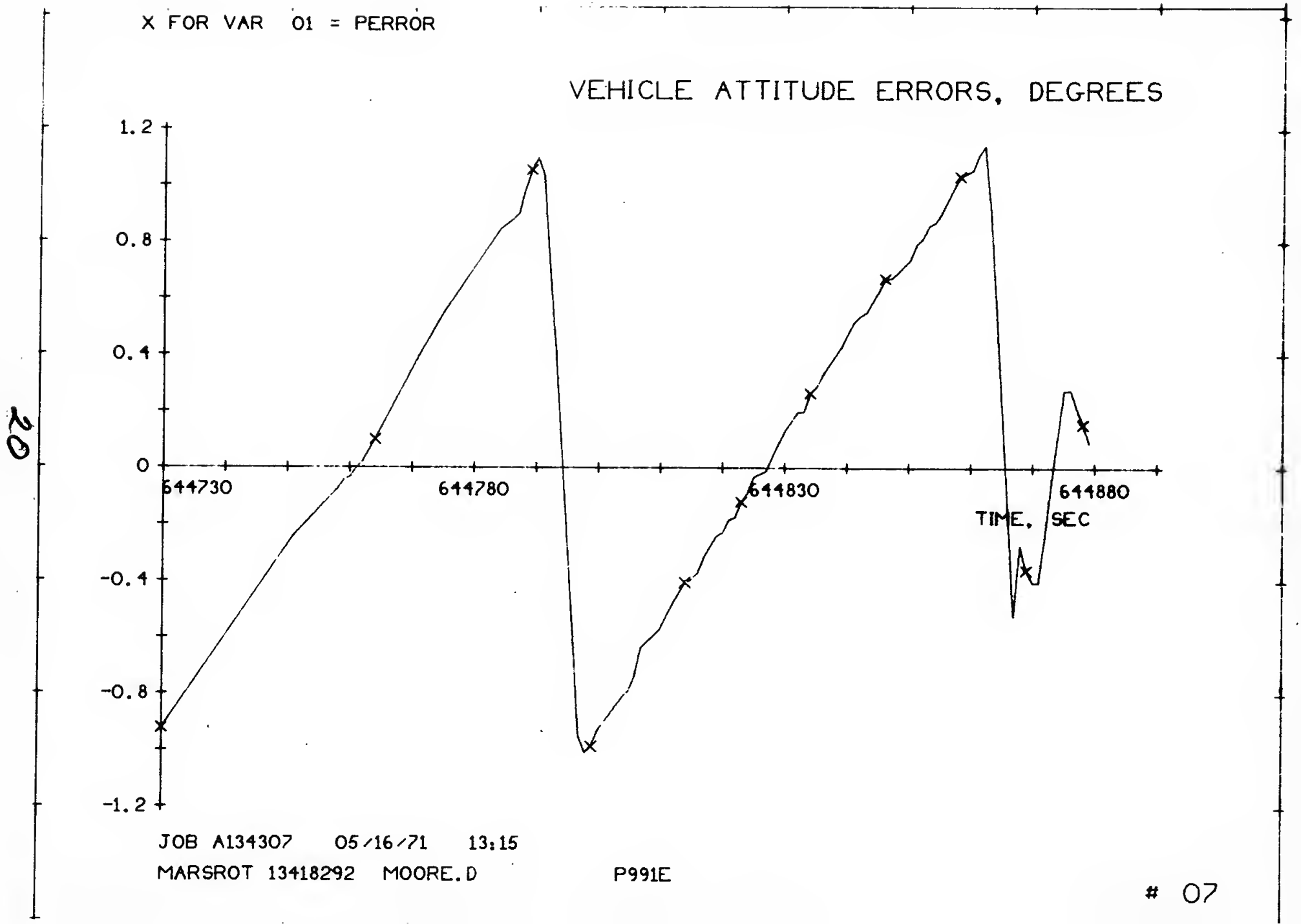


JOB A134307 05/16/71 13:15

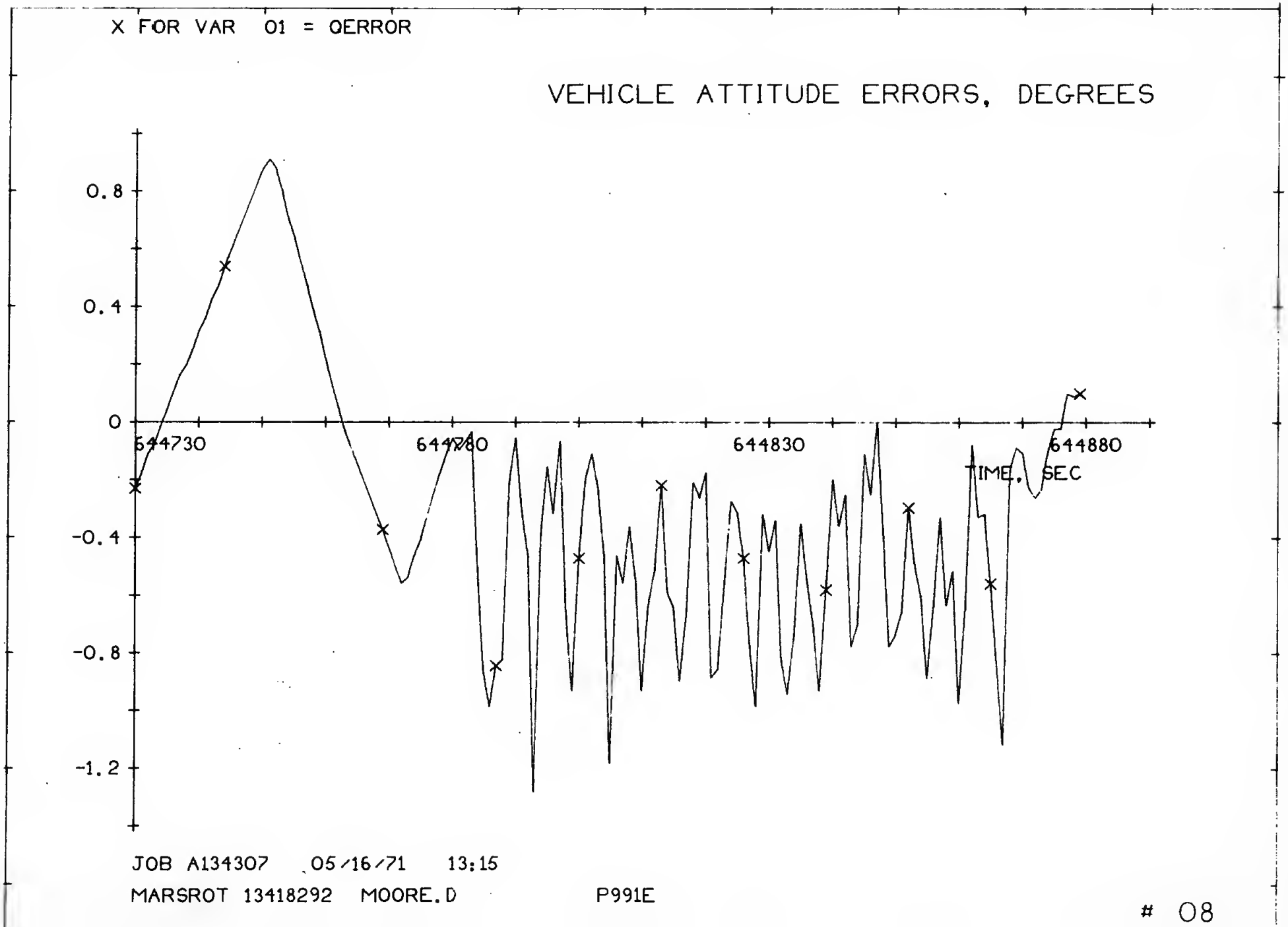
MARSROT 13418292 MOORE.D P991E

05


X FOR VAR 01 = CDUZ
OFFSET ◇ FOR VAR 02 = CDUZ DESIRED
IMU CDUS AND DESIRED CDUS , DEGREES
20
30
15
25
10
20
5
15
0
10
644730
644780
644830
644880
JOB A134307 05/16/71 13:15
TIME, SEC
MARSROT 13418292 MOORE.D P991E
06

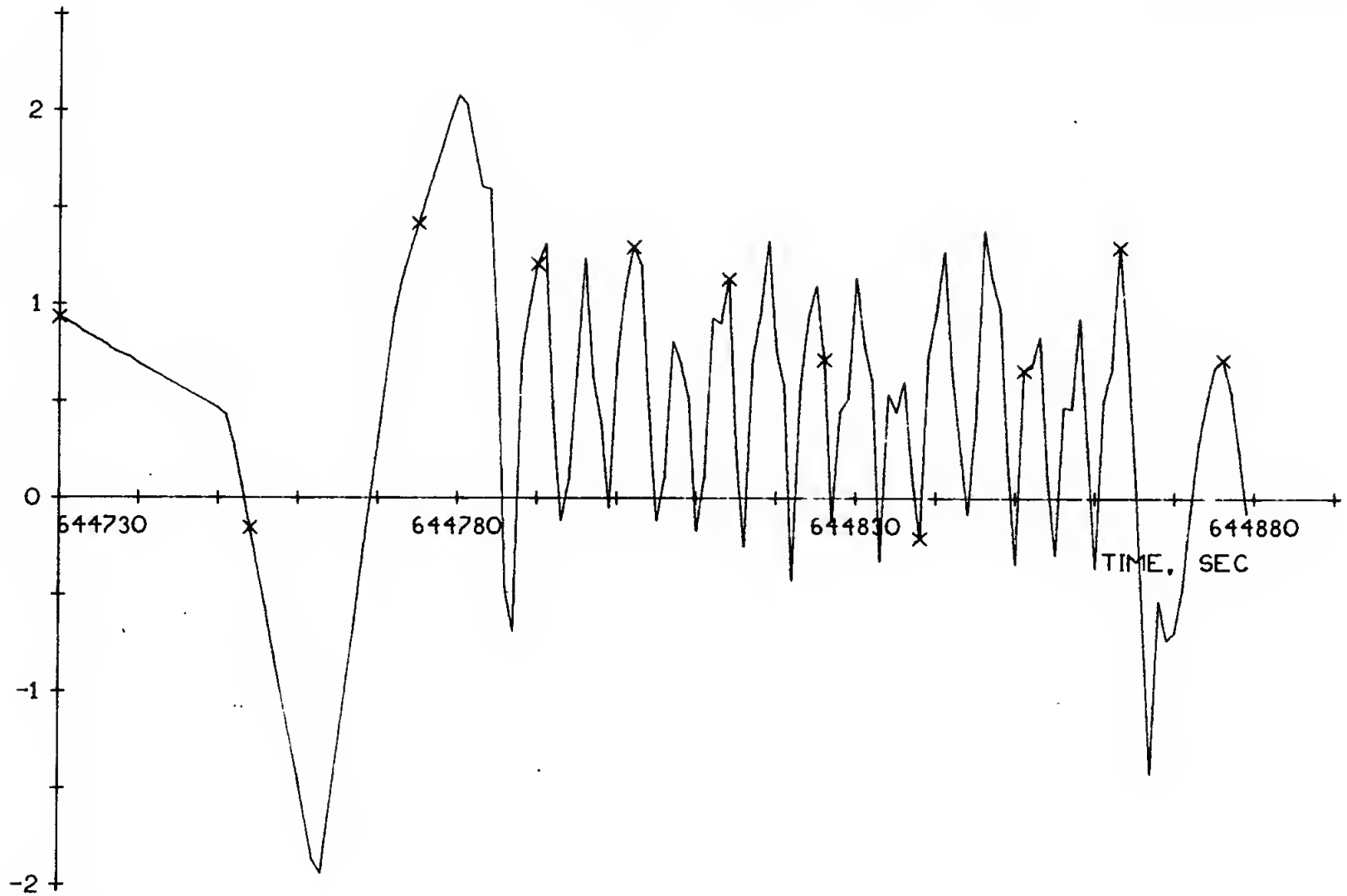

X FOR VAR 01 = PERROR
VEHICLE ATTITUDE ERRORS, DEGREES
1.2
0.8
0.4
0
-0.4
-0.8
-1.2
644730
644780
644830
644880
TIME, SEC
JOB A134307 05/16/71 13:15
MARSROT 13418292 MOORE.D
P991E
07

20


X FOR VAR 01 = QERROR
VEHICLE ATTITUDE ERRORS, DEGREES
0.8
0.4
0
-0.4
-0.8
-1.2
644730
644780
644830
644880
TIME, SEC
JOB A134307 05/16/71 13:15
MARSROT 13418292 MOORE.D P991E
08

X FOR VAR 01 = RERROR

VEHICLE ATTITUDE ERRORS, DEGREES

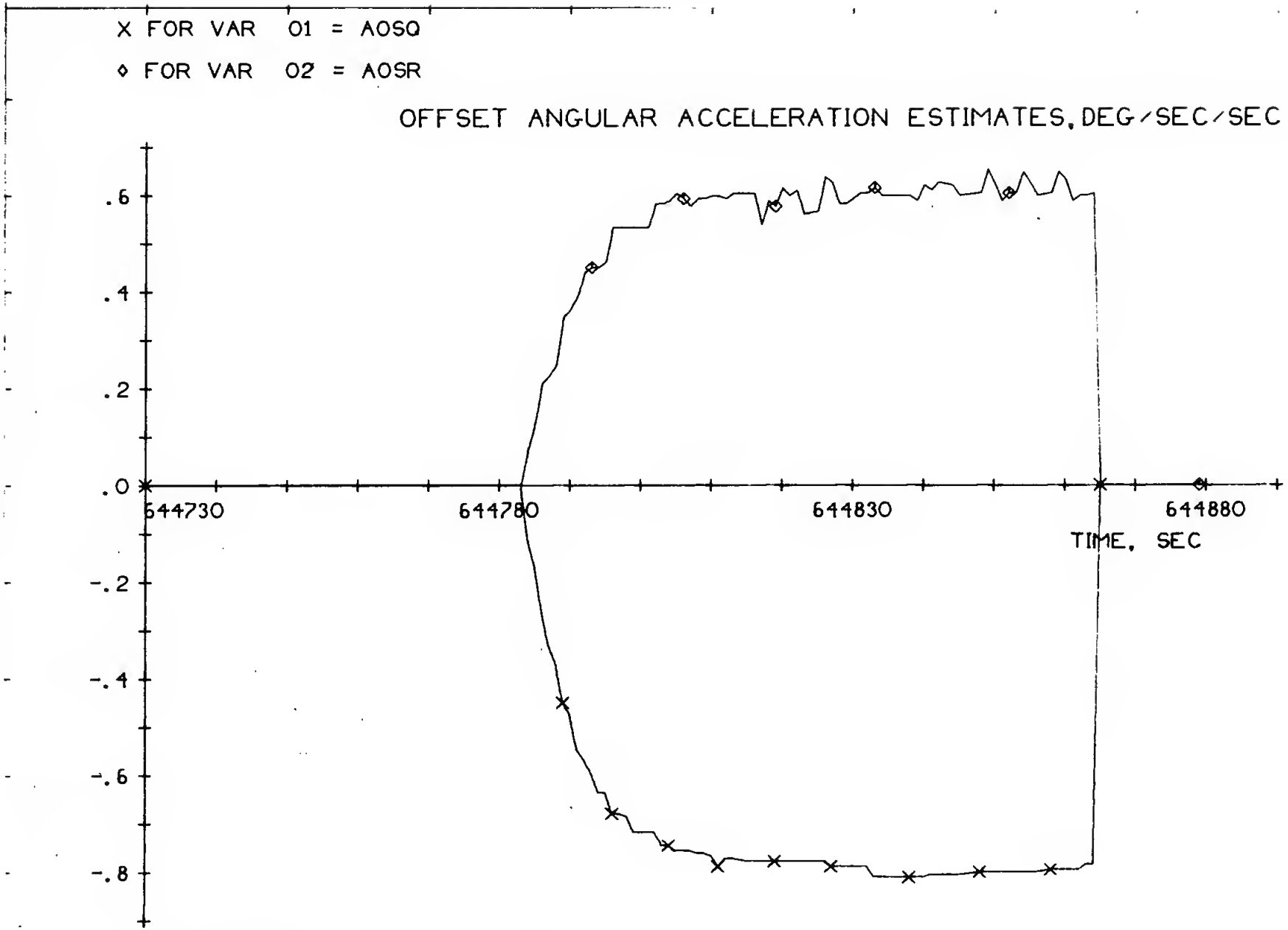


JOB A134307 05/16/71 13:15

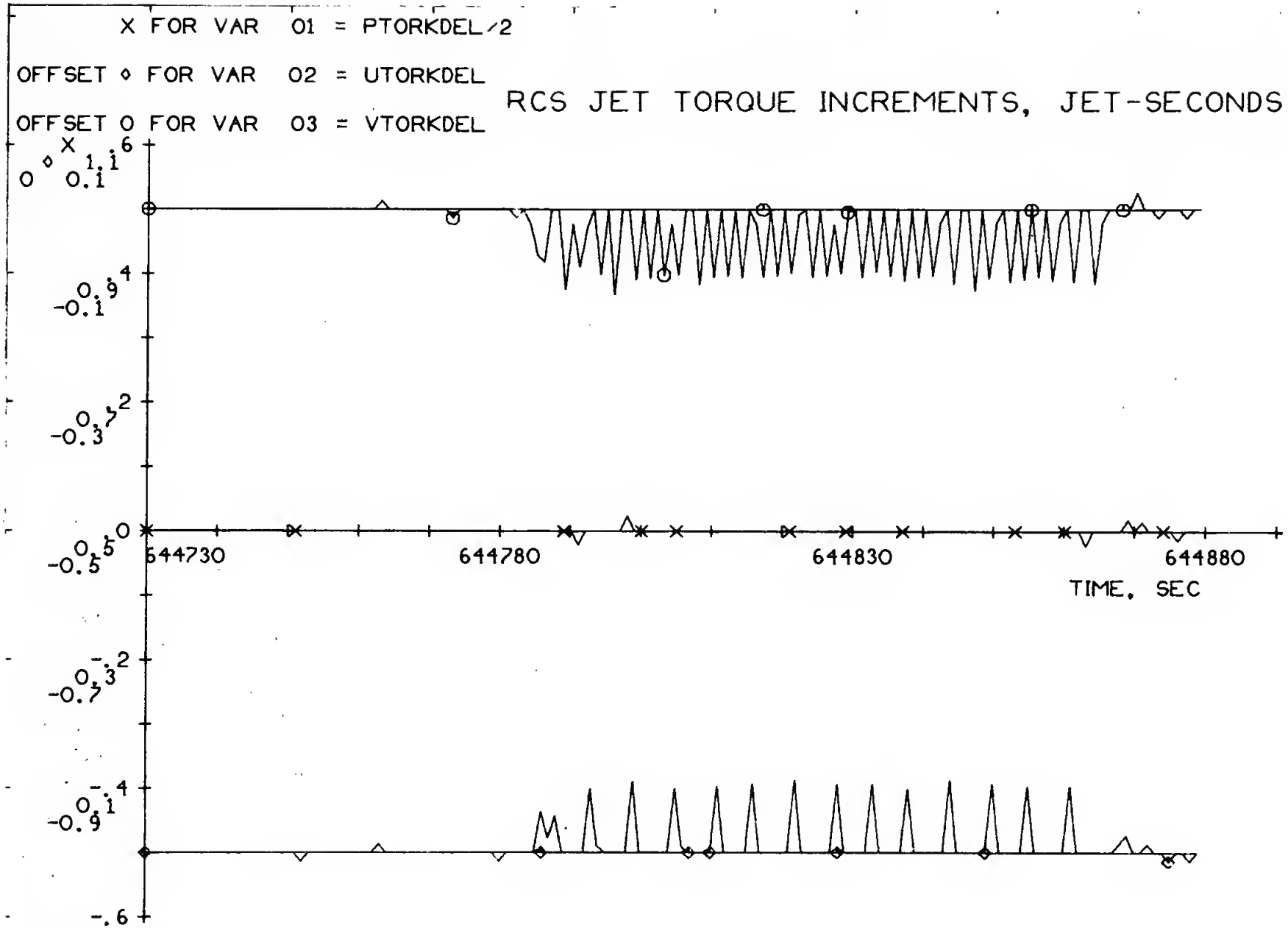
MARSROT 13418292 MOORE.D P991E

09

22



JOB A134307 05/16/71 13:15
MARSROT 13418292 MOORE.D P991E


X FOR VAR 01 = PTORKDEL/2
OFFSET ◇ FOR VAR 02 = UTORKDEL
OFFSET O FOR VAR 03 = VTORKDEL
RCS JET TORQUE INCREMENTS, JET-SECONDS
644730
644780
644830
644880
TIME, SEC
JOB A134307 05/16/71 13:15
MARSROT 13418292 MOORE.D P991E

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