The Sea Swift Experiments October 1974 : Parts 1-4

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1

THE SEA SWIFT EXPERIMENTS, OCTOBER 1974 - PART III

Claes Källström

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EXPERIMENT A37

Date	1974-10-21
Time	07.49
Duration	92 min
Position	S 28° 44' E 32° 39'
Water depth	deep
Forward draught	20.2 m
Aft draught	20.2 m
Wind direction	SW (1; see Appendix A)
Wind velocity	8-9 Beaufort (17-24 m/s, fresh to strong gale)
Wave height	8 - 10 m (sea from SW)
PSIREF	218°, 215°
RREF	0.07 deg/s
Rudder limit	Not active
DELlM at termination	4.09°

A yaw from 218° to 215° was performed between 1 min and 3 min of the experiment. MODYAW was then equal to 1 during the first 10 s of the yaw and then equal to 3.

Regulator structure

NA = 3 NB = 2 NC = 0 K = 5

IREG = 15 RL = 0.99

Final values

$$\begin{bmatrix} a_1 \\ a_2 \\ a_3 \\ b_1 \\ b_2 \end{bmatrix} = \begin{bmatrix} -22.296 \\ 31.504 \\ -9.285 \\ 0.349 \\ 0.316 \end{bmatrix} \qquad P = \begin{bmatrix} 0.291 & & & & \\ -0.480 & 1.309 & & & \\ 0.218 & -0.896 & 0.738 & & \\ 0.001 & -0.026 & 0.027 & 0.002 & \\ 0.000 & -0.017 & 0.018 & 0.001 & 0.001 \end{bmatrix}$$

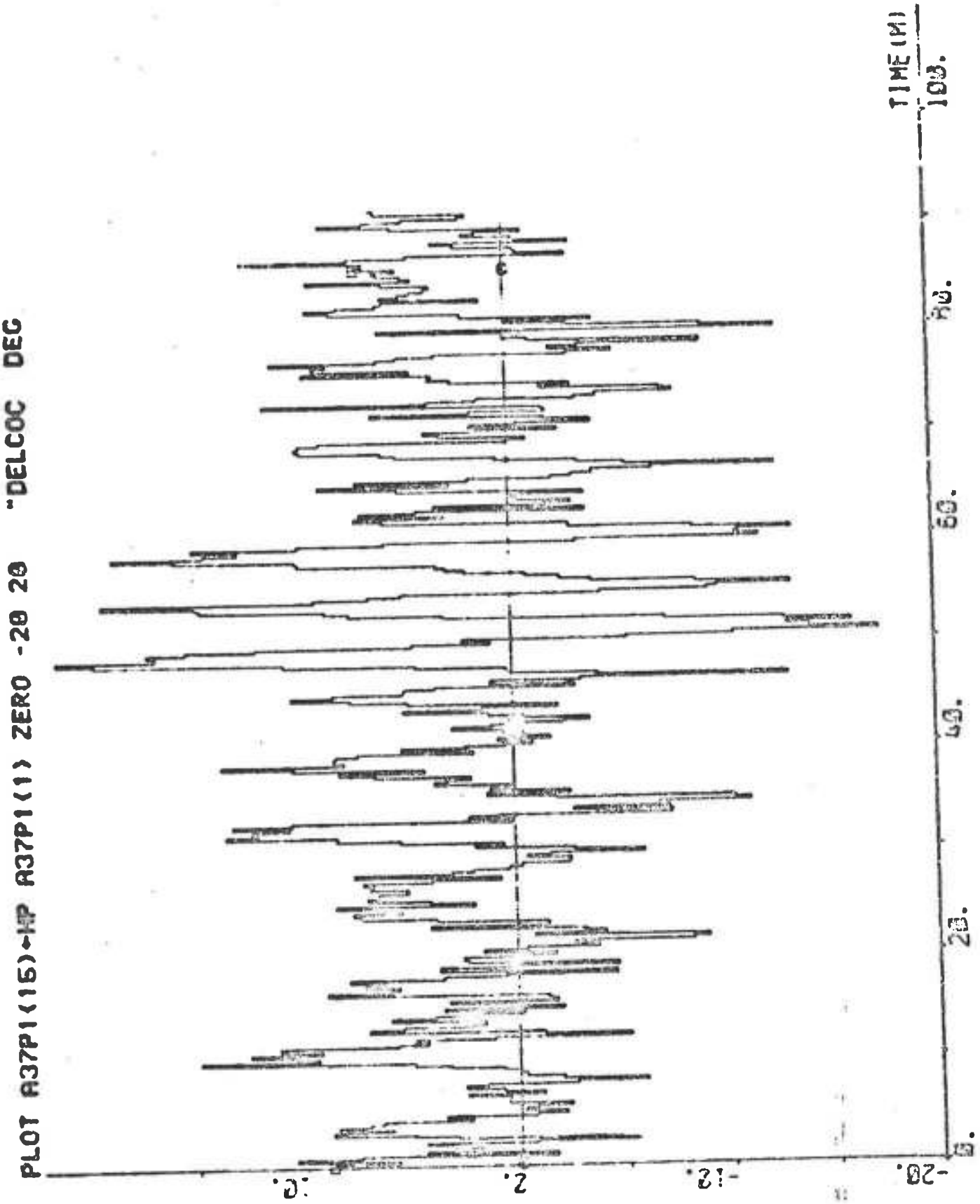
$a_1 + a_2 + a_3 = -0.077$

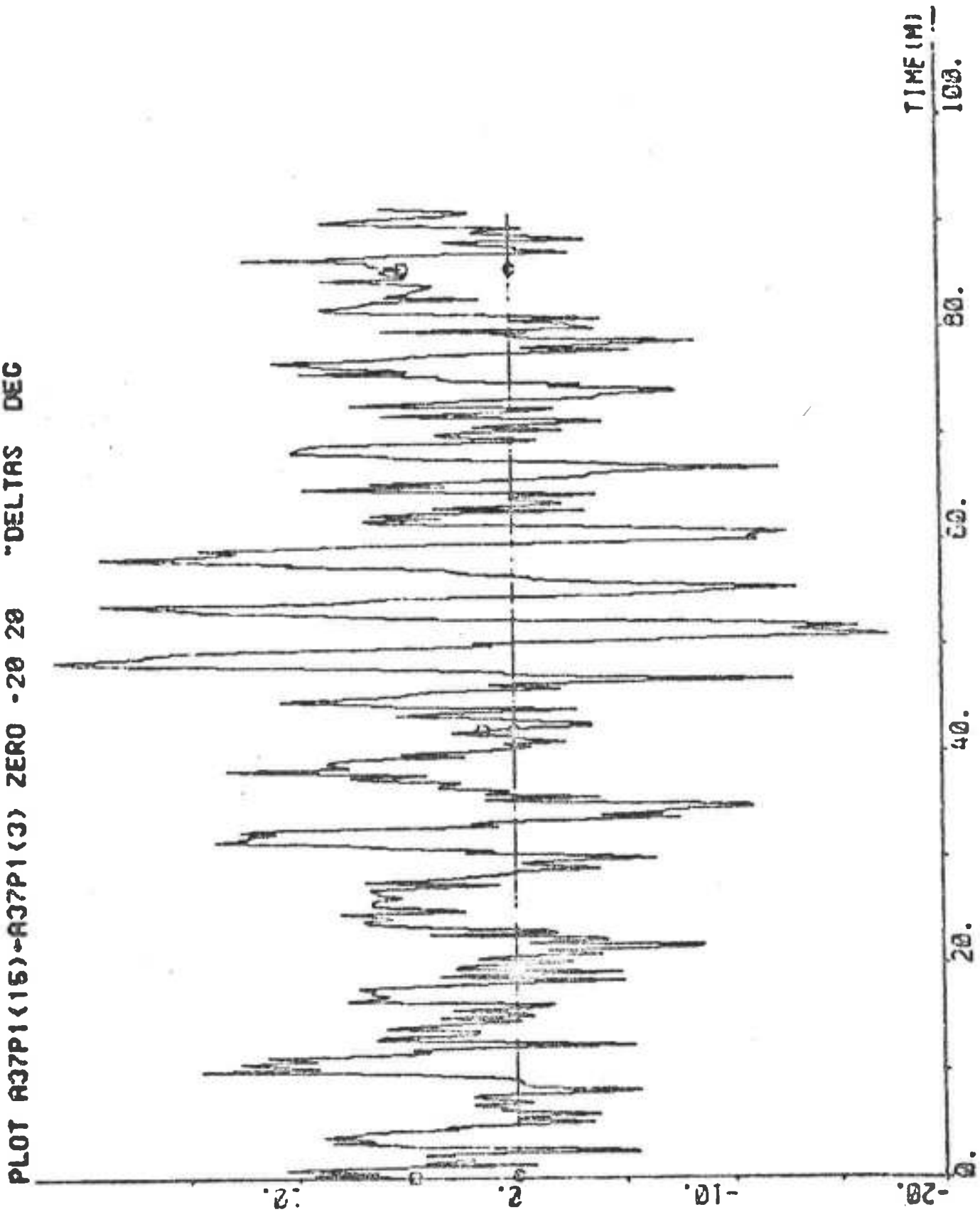
Yaw regulator structure

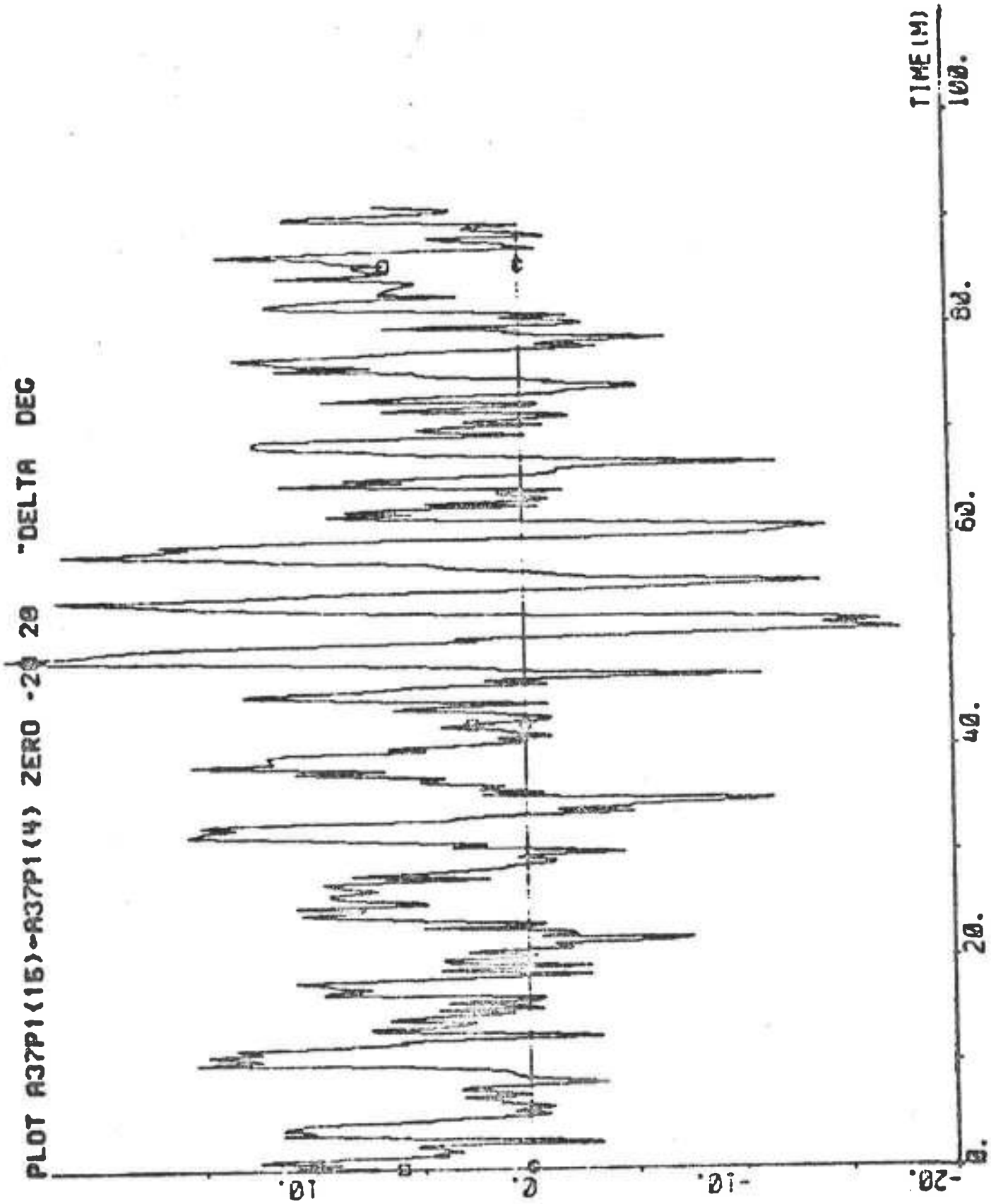
NAY = 3	NBY = 2	KY = 2	
IREGY = 10	RLY = 0.95	IRR = 3	IDPSI = 5
AK1V = 40	AK2V = 1.8	AK3V = 120	
C1V = 10	C2V = 80		
EPS1V = 0.02	EPS2V = 0.03		
PSISV = 0.15	PSISSV = 1.5	PSIMAV = 0.3	
I1MV = 60	I2MV = 300	I3MV = 150	

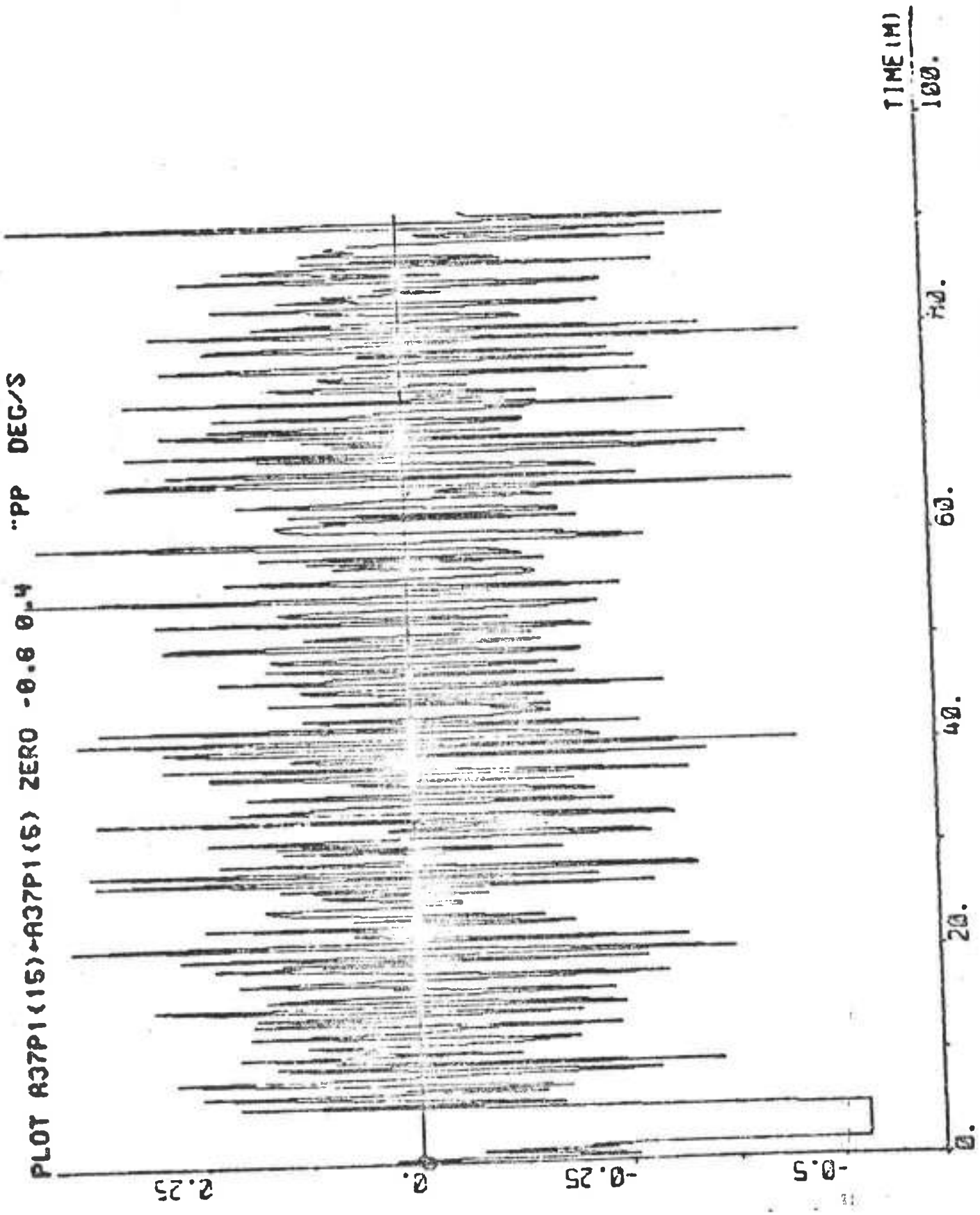
Statistics (mean value and standard deviation)

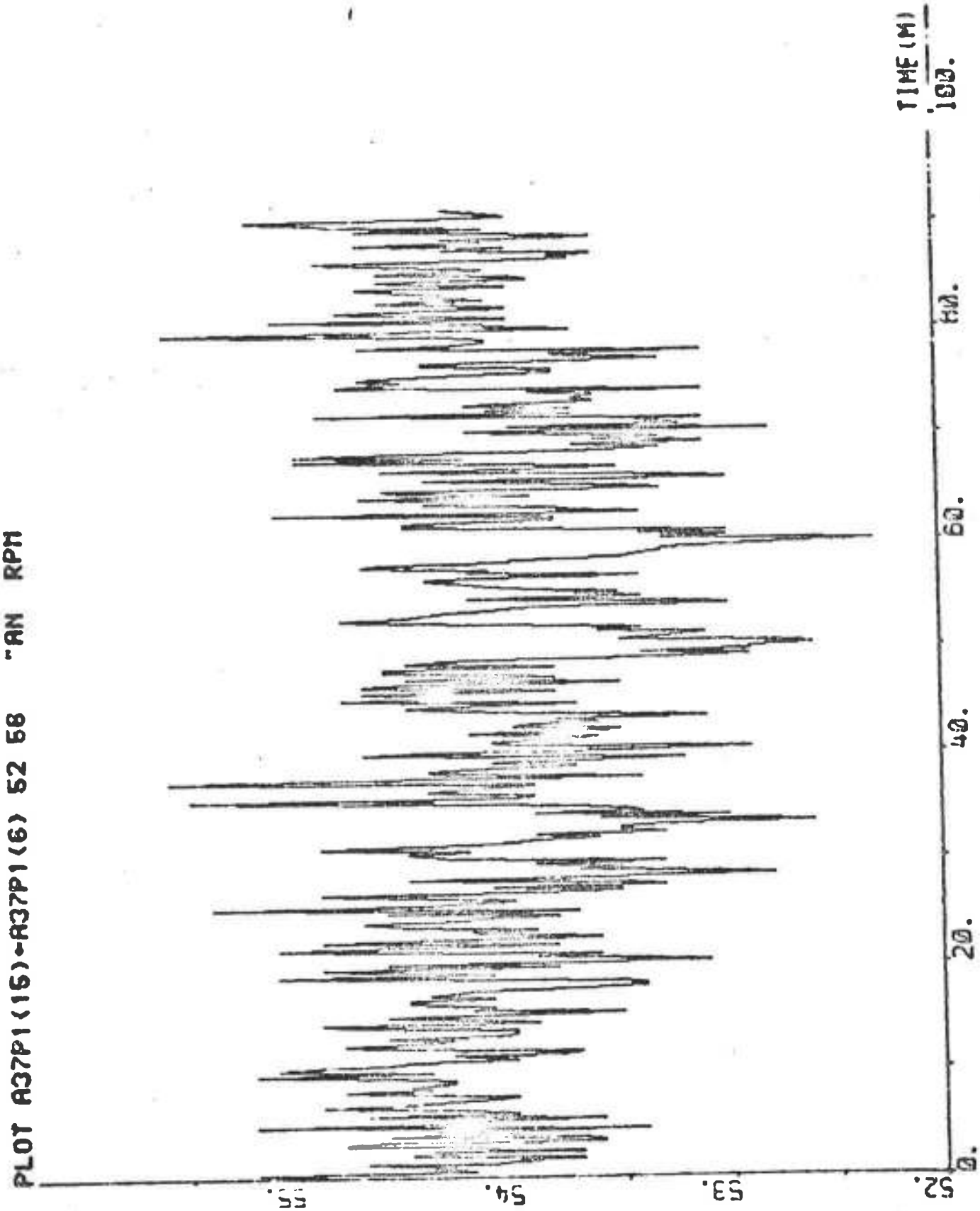
	10 - 92 min
DELTA	3.93 ± 7.09 deg
PSI-PSIREF	0.158 ± 0.847 deg
AN	54.02 ± 0.57 rpm
U	4.82 ± 0.35 knots
V_1	7.314
V_2	5.769

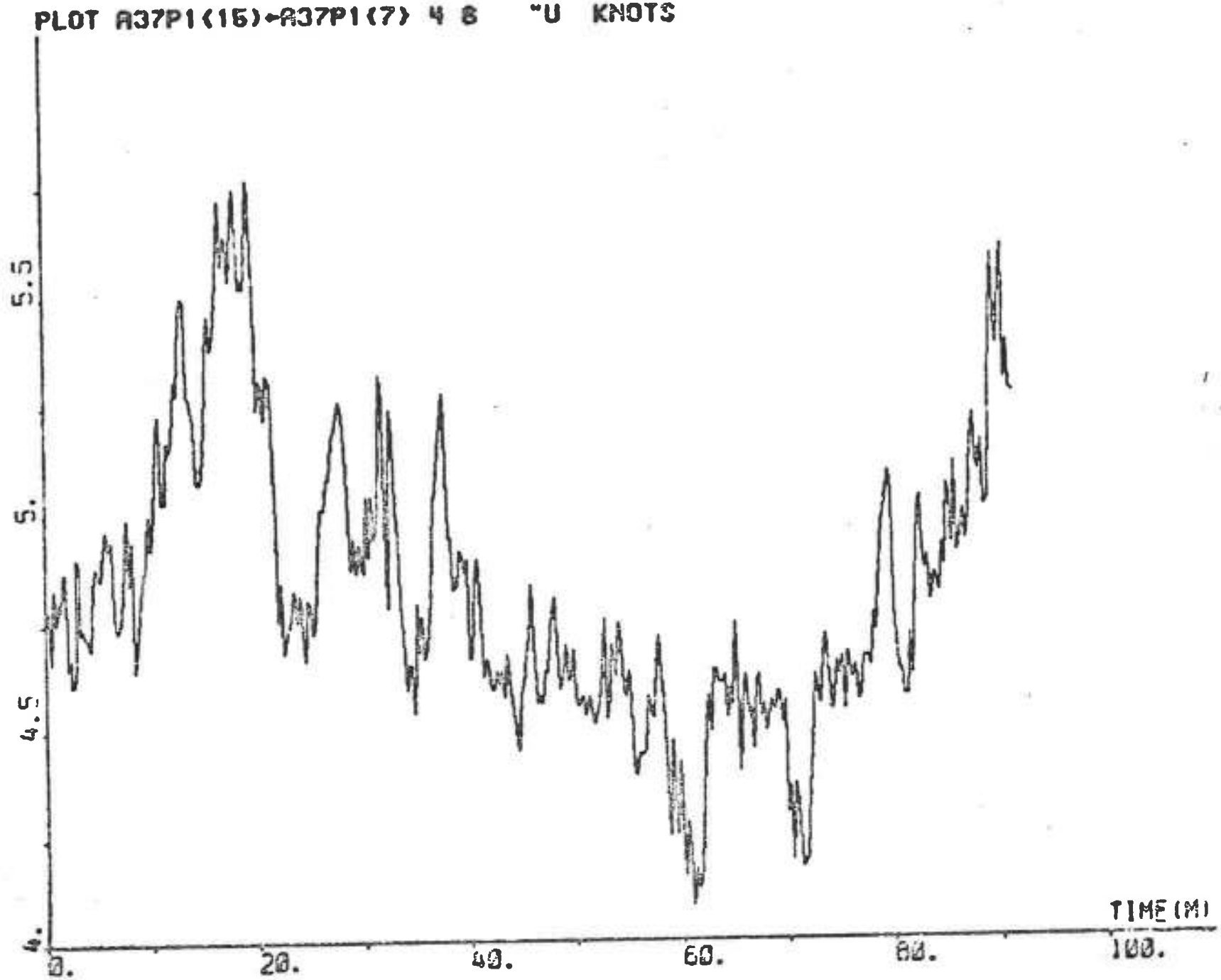

PLOT A37P1(16)-HP A37P1(1) ZERO -20 20 "DELCOC DEG
TIME(M)
103.
80.
60.
40.
20.
0.
10.
2.
-12.
-20.

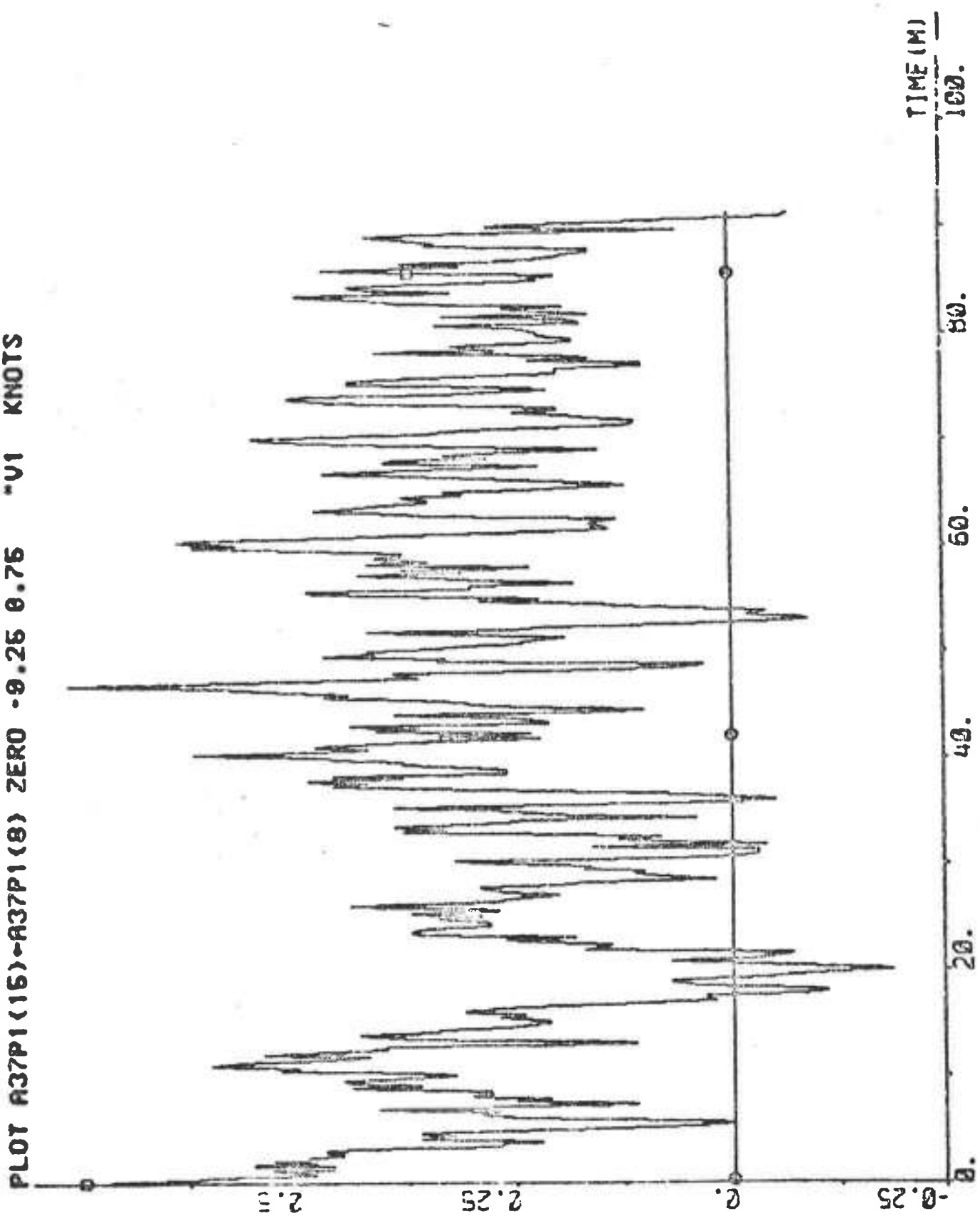

PLOT A37P1(15)-A37P1(3) ZERO -20 20 "DELTAS DEG
TIME(M)
0.
20.
40.
60.
80.
100.
-20.
-10.
2.
12.

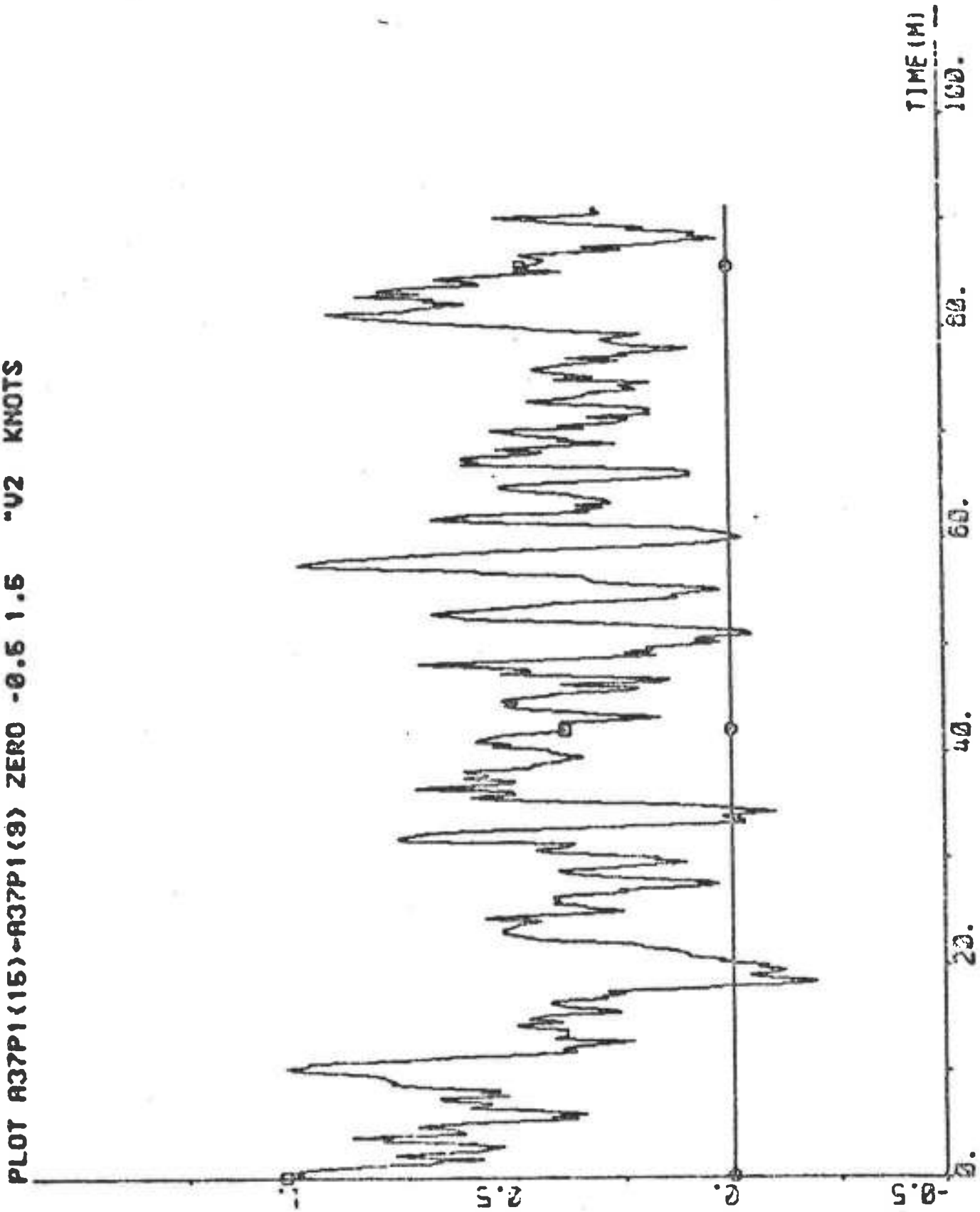

PLOT A37P1(15)-A37P1(4) ZERO -20 20 'DELTA DEC
TIME(M)
0.
20.
40.
60.
100.
-20.
-10.
0.
10.

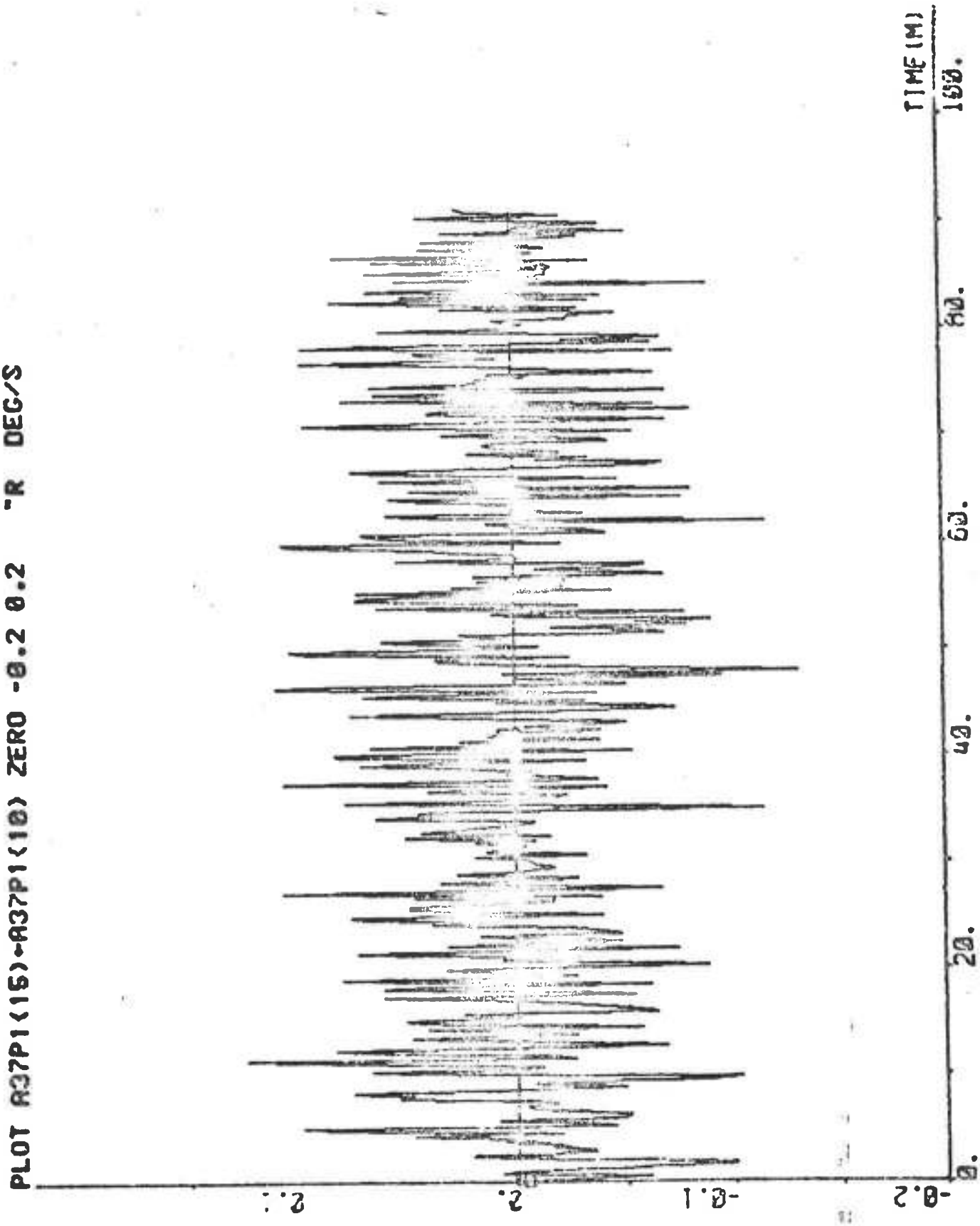

PLOT A37P1(1S)-A37P1(S) ZERO -0.8 0.4 "PP DEG/S
TIME(M)
0.
20.
40.
60.
80.
100.
-0.5
-0.25
0.
0.25

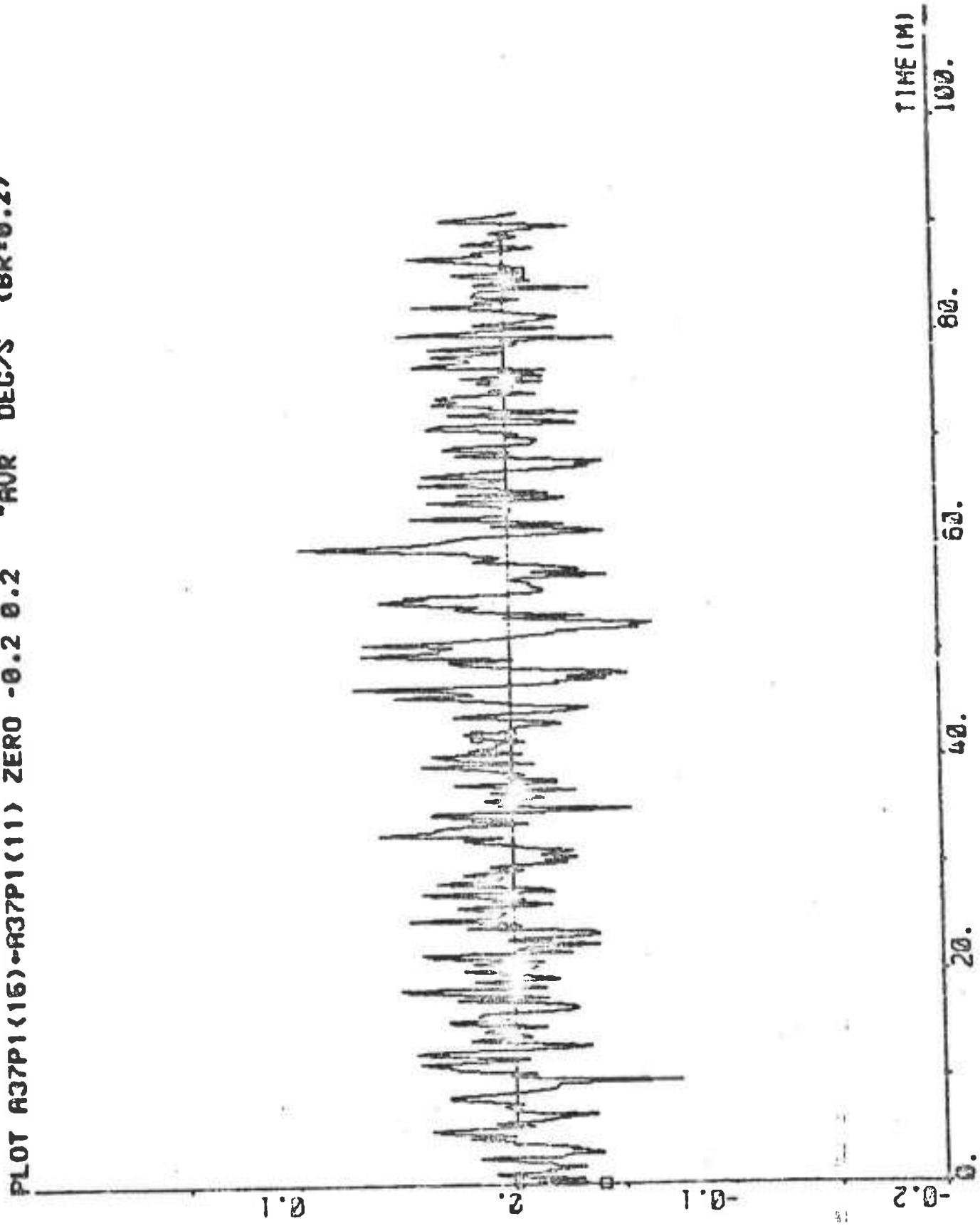

PLOT A37P1(15)-A37P1(6) 52 58 "AN RPM
TIME(M)
0.
20.
40.
60.
80.
100.
52.
53.
54.
55.

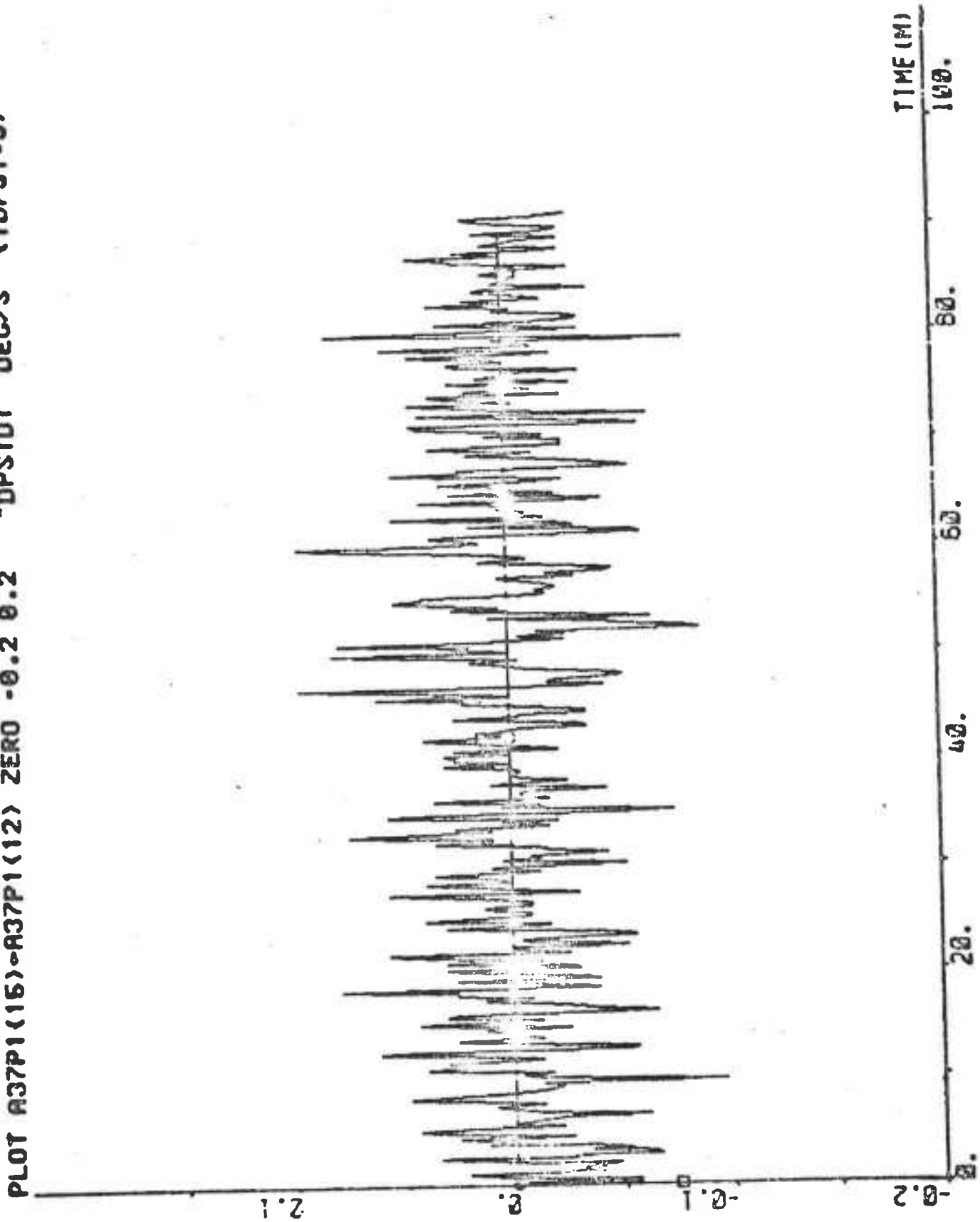

PLOT A37P1(15)-A37P1(7) 4 8 "U KNOTS
5.5
5.
4.5
4.
0.
20.
40.
60.
80.
100.
TIME(M)

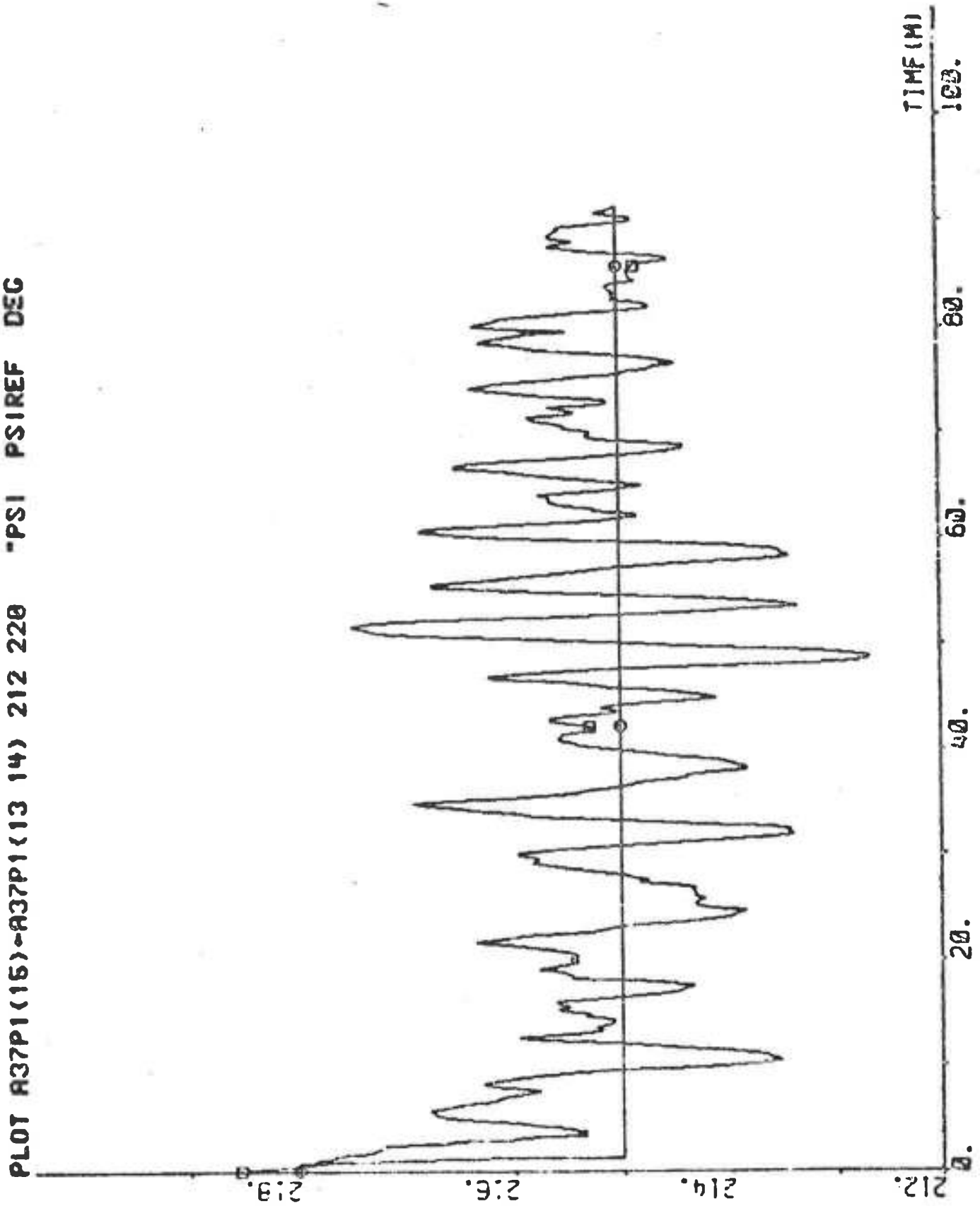

PLOT A37P1(15)-A37P1(8) ZERO -0.25 0.75 "V1 KNOTS
TIME(M)
0.
20.
40.
60.
80.
100.
-0.25
0.
2.25
2.5

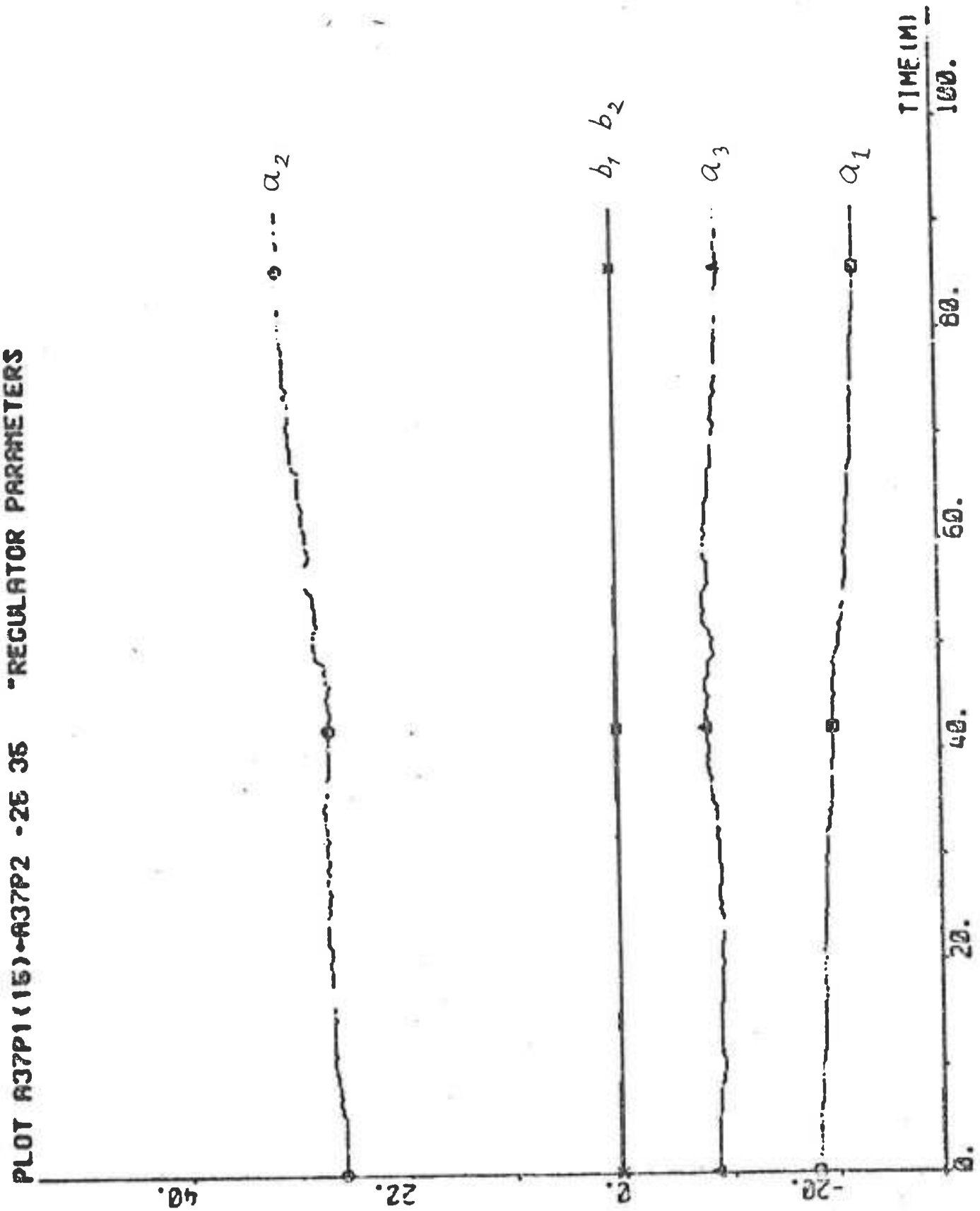

PLOT A37P1(15)-A37P1(9) ZERO -0.5 1.5 "V2 KNOTS
TIME(H)
0.
20.
40.
60.
80.
100.
-0.5
0.
0.5
1.


PLOT R37P1(15)-R37P1(10) ZERO -0.2 0.2 °R DEG/S
TIME(M)
0.
20.
40.
60.
100.
-0.2
-0.1
0.
0.1


PLOT A37P1(16)-A37P1(11) ZERO -0.2 0.2 *AVR DEG/S (BR=0.2)
TIME(M)
0.
20.
40.
60.
80.
100.
-0.2
-0.1
.2
0.1


PLOT A37P1(16)-A37P1(12) ZERO -0.2 0.2 "DPSIDT DEG/S (IDPSI=6)
TIME(M)
0.
20.
40.
60.
80.
100.
-0.2
-0.1
0.
0.1


PLOT A37P1(15)-A37P1(13 14) 212 220 *PSI PSIREF DEG
TIME(M)
0.
20.
40.
60.
80.
100.
212.
214.
216.
218.


PLOT A37P1(15)-A37P2 -25 35 "REGULATOR PARAMETERS
40.
22.
0.
-20.
0.
20.
40.
60.
80.
100.
TIME(M)
a_2
b_1 b_2
a_3
a_1

EXPERIMENT A38

Date	1974-10-21
Time	11.43
Duration	71 min
Position	S 29° 00' E 32° 24'
Water depth	deep
Forward draught	20.2 m
Aft draught	20.2 m
Wind direction	SW (1; see Appendix A)
Wind velocity	8-9 Beaufort (17-24 m/s, fresh to strong gale)
Wave height	8 - 10 m (sea from SW)
PSIREF	215°
Rudder limit	Not active

Regulator structure

NA = 3 NB = 2 NC = 0 K = 5

IREG = 15 RL = 0.99

Final values

$$\begin{bmatrix} a_1 \\ a_2 \\ a_3 \\ b_1 \\ b_2 \end{bmatrix} = \begin{bmatrix} -22.712 \\ 34.185 \\ -11.401 \\ 0.136 \\ 0.187 \end{bmatrix} \qquad P = \begin{bmatrix} 0.358 & & & & \\ -0.603 & 1.941 & & & \\ 0.295 & -1.469 & 1.298 & & \\ 0.004 & -0.050 & 0.050 & 0.003 & \\ 0.001 & -0.027 & 0.028 & 0.001 & 0.001 \end{bmatrix}$$

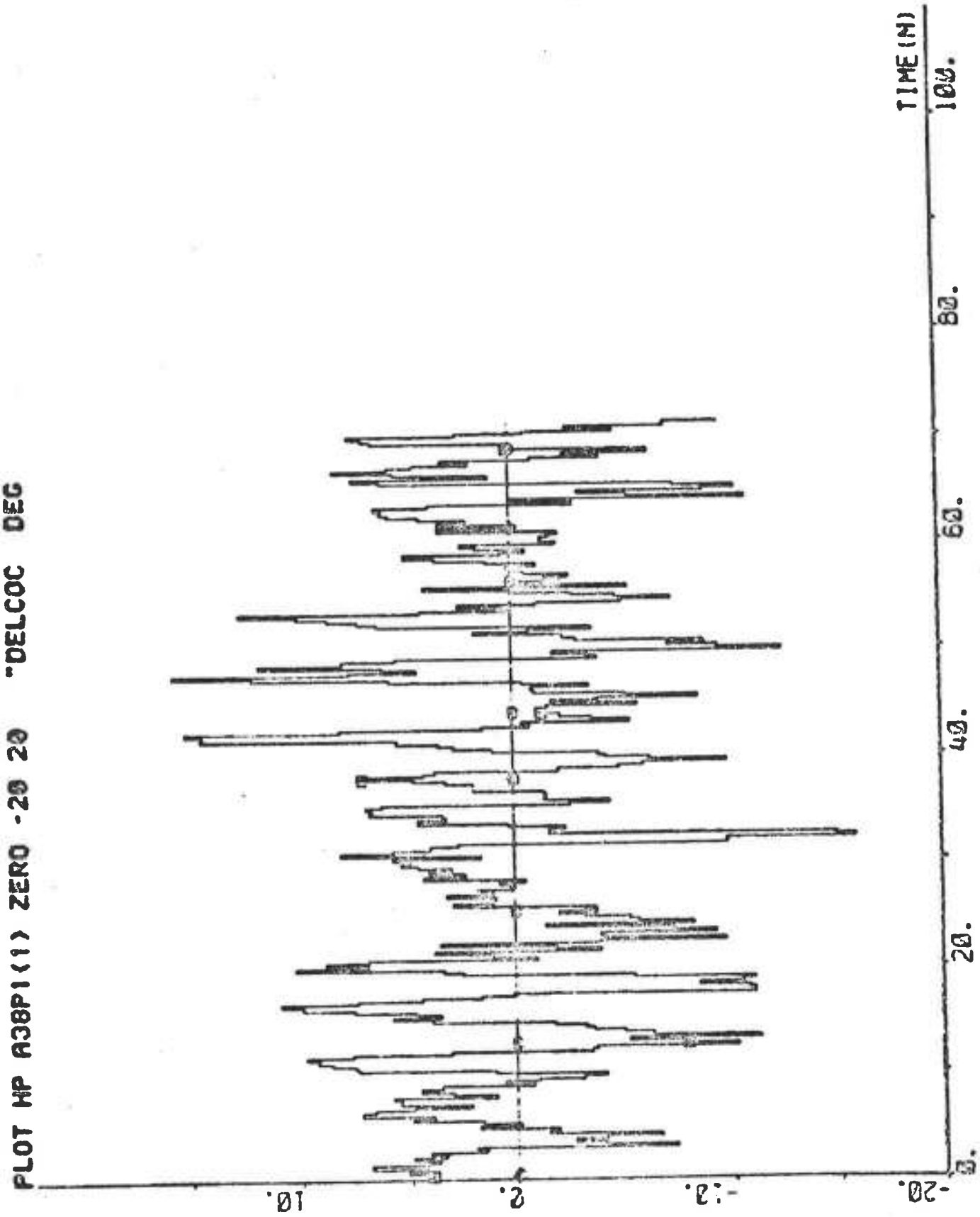
$a_1 + a_2 + a_3 = 0.072$

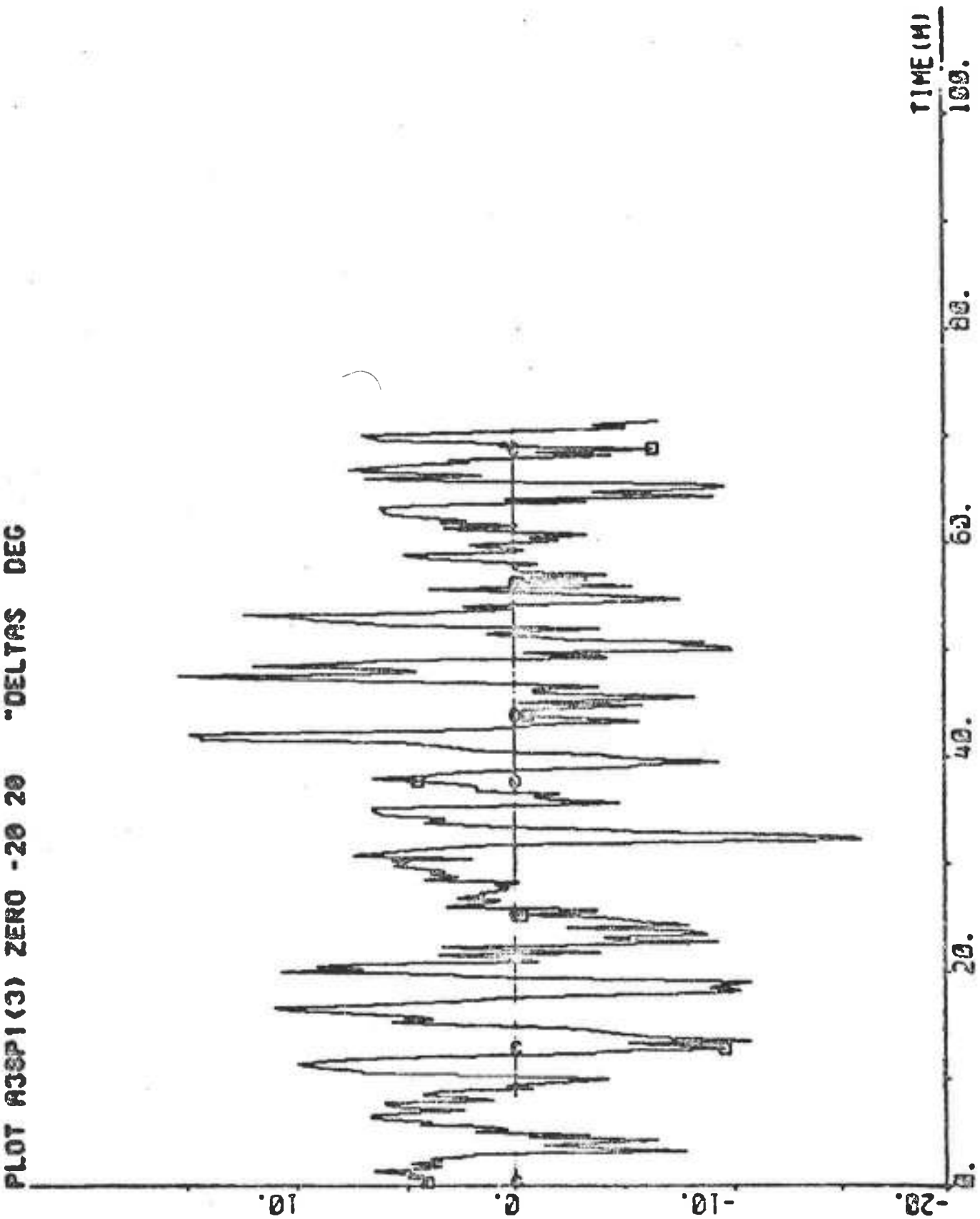
Statistics (mean value and standard deviation)

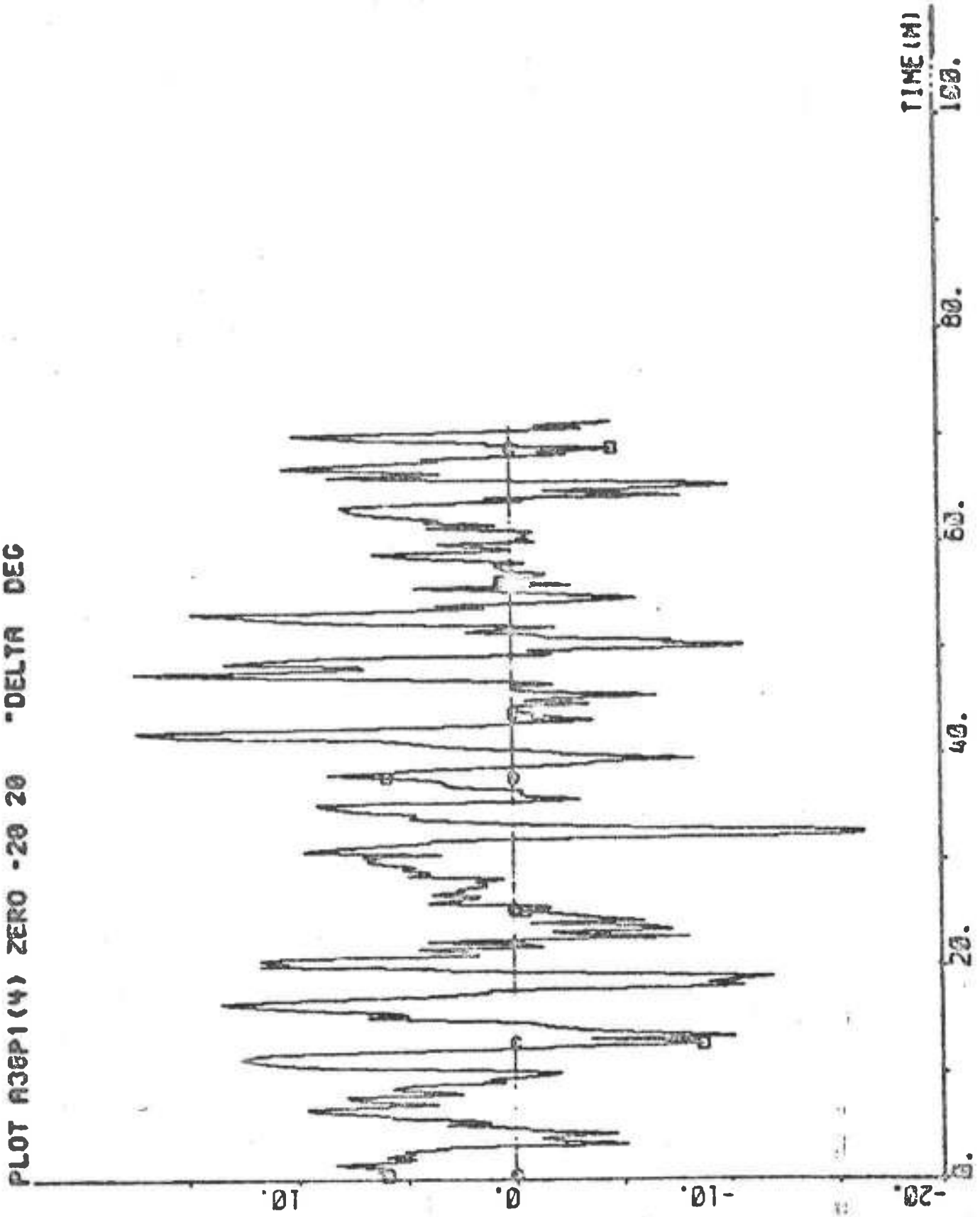
DELTA	1.96 ± 5.91 deg
PSI-PSIREF	0.250 ± 0.622 deg
AN	49.30 ± 0.95 rpm
U	5.24 ± 0.33 knots

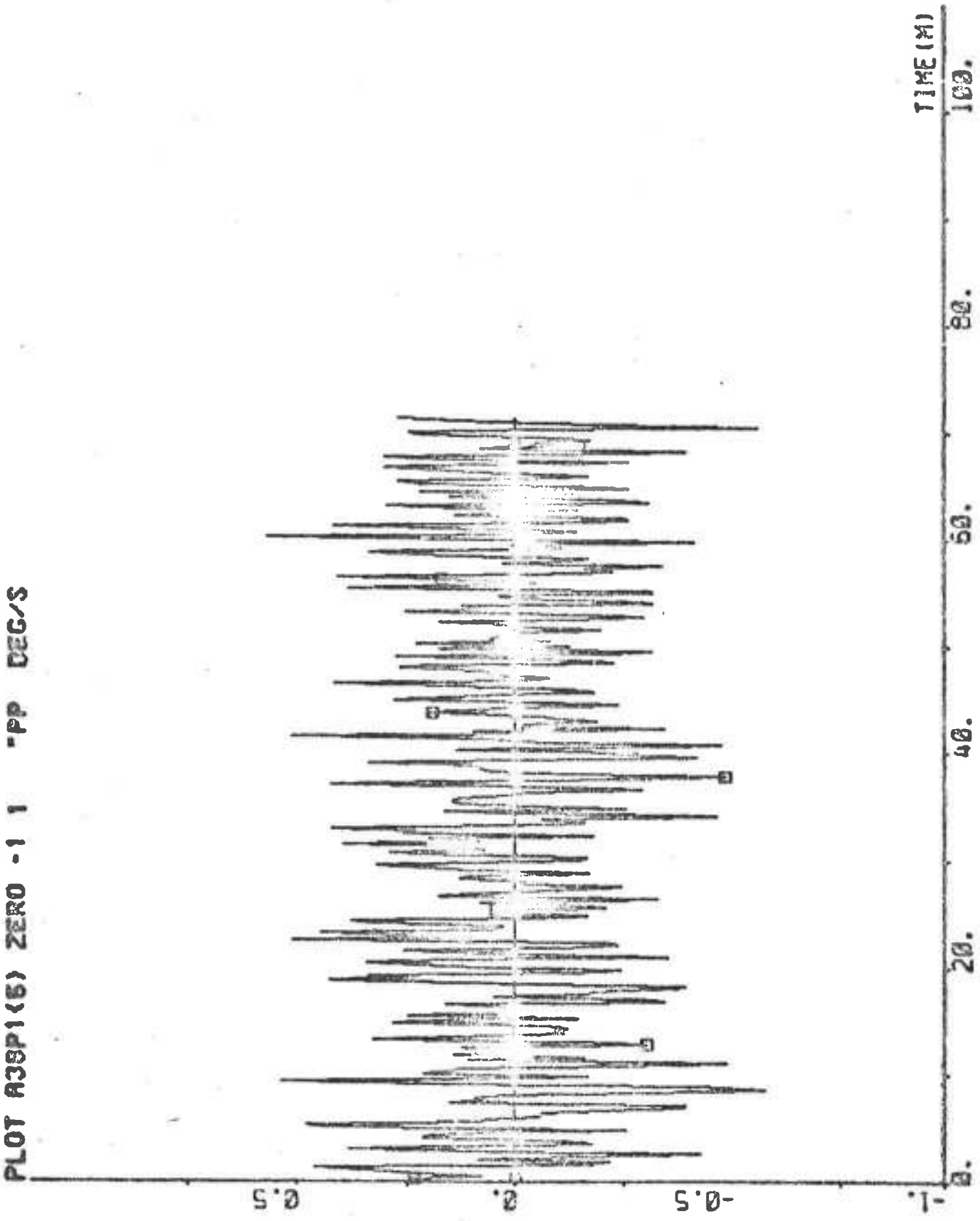
$V_1 = 4.326$

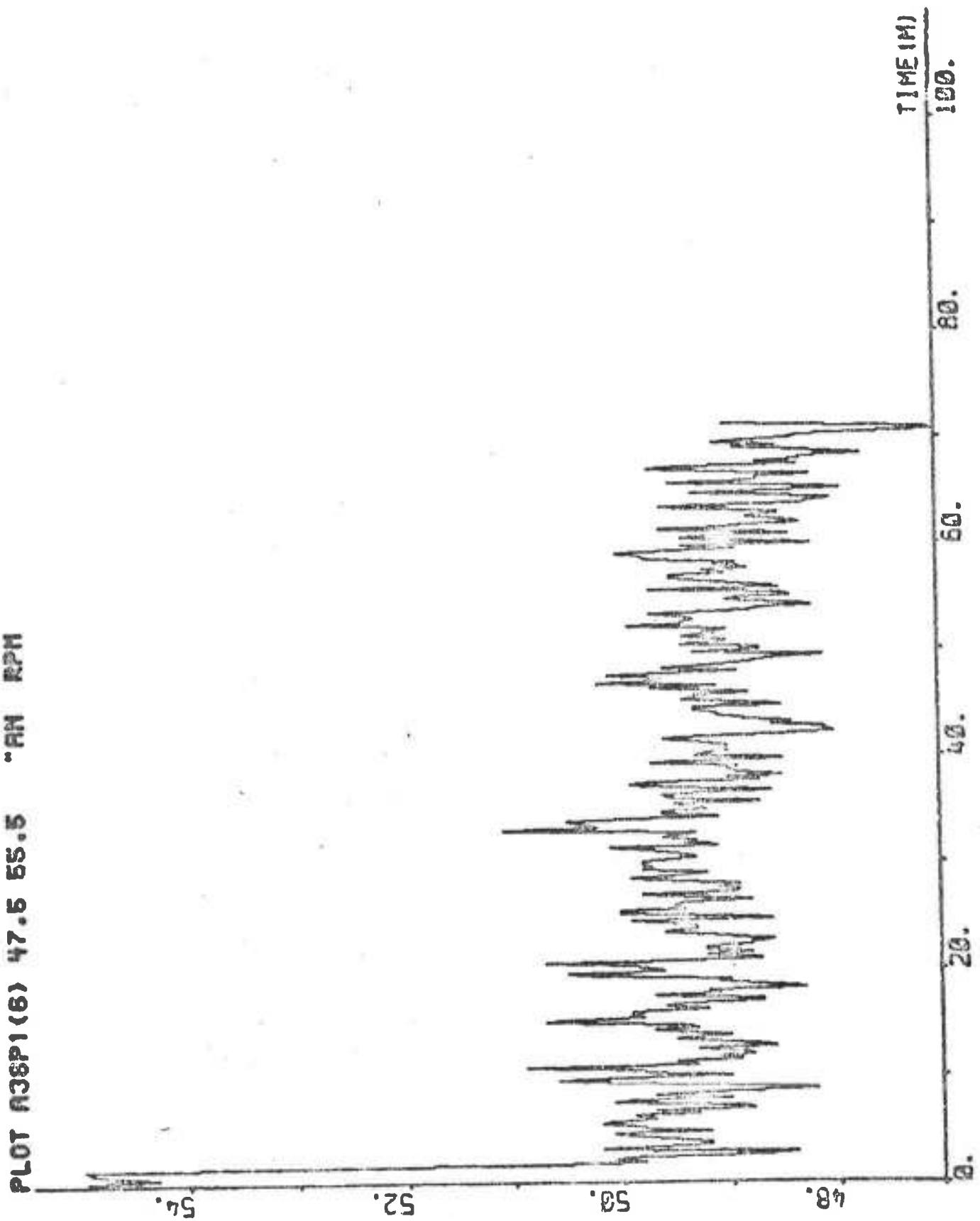
$V_2 = 3.942$

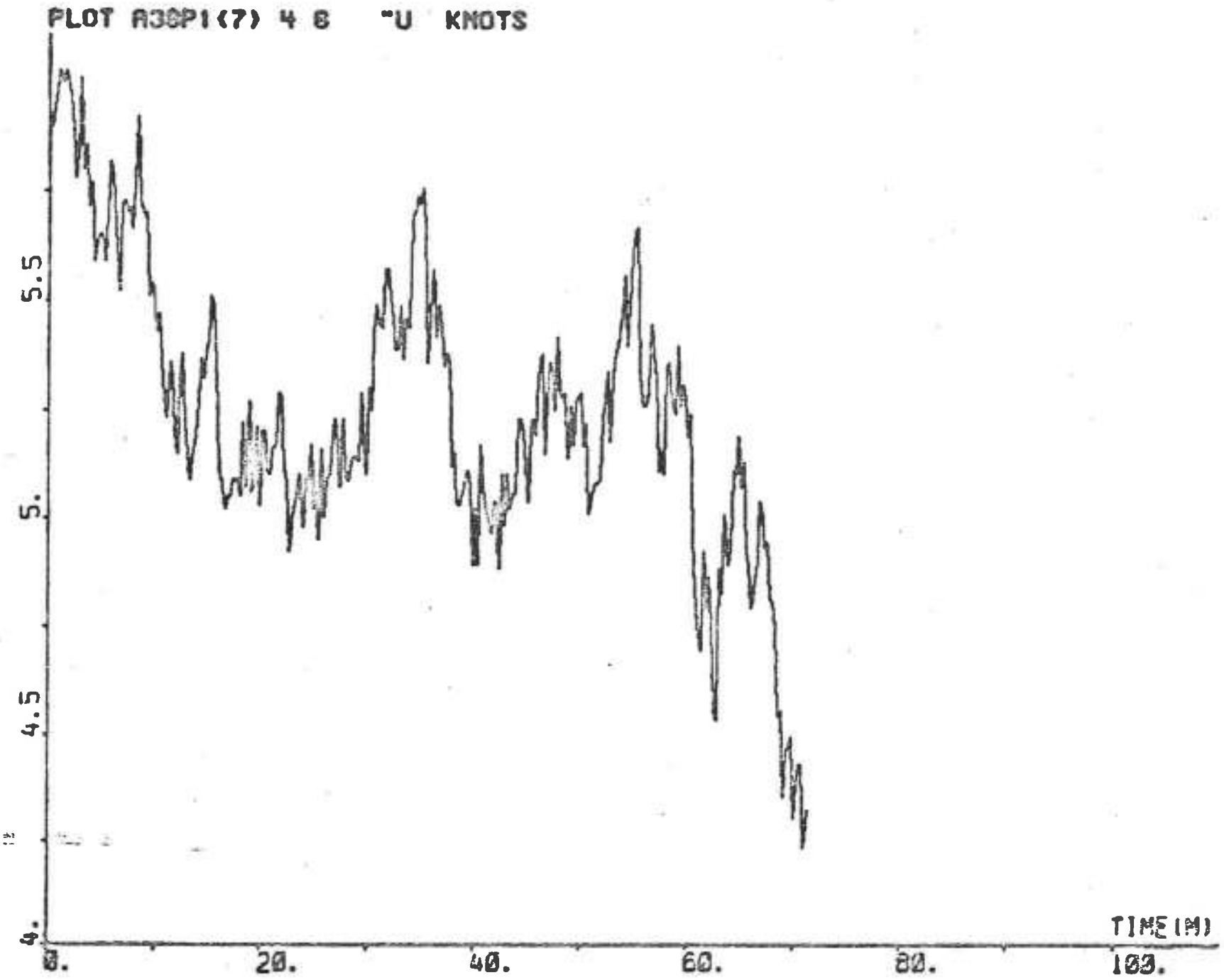

PLOT HP A38P1(1) ZERO -20 20 "DELCOC DEG
TIME(H)
0.
20.
40.
60.
80.
100.
-20.
-10.
0.
10.

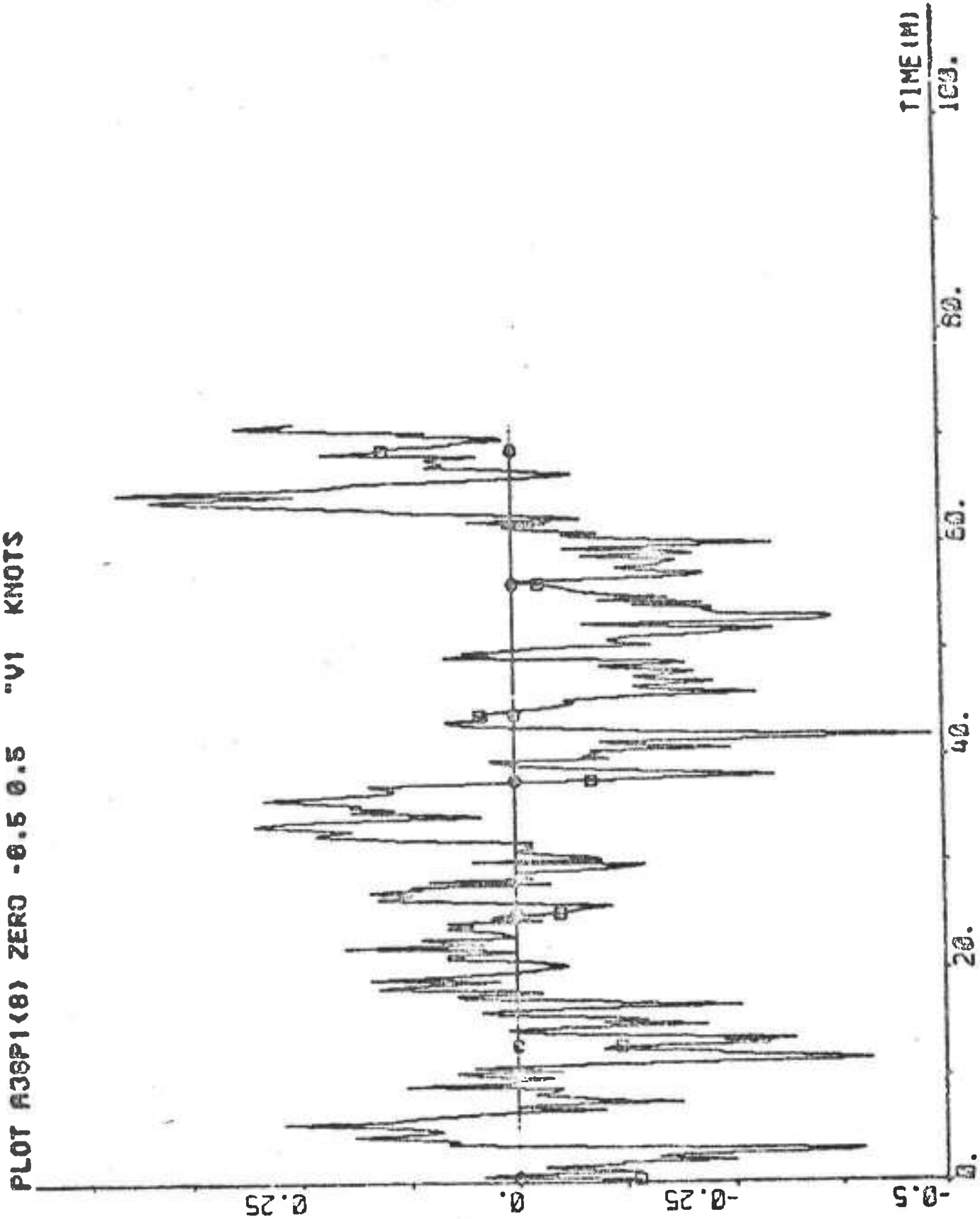

PLOT A3SP1(3) ZERO -20 20 *DELTAS DEG
10.
0.
-10.
-20.
0.
20.
40.
60.
80.
100.
TIME(H)

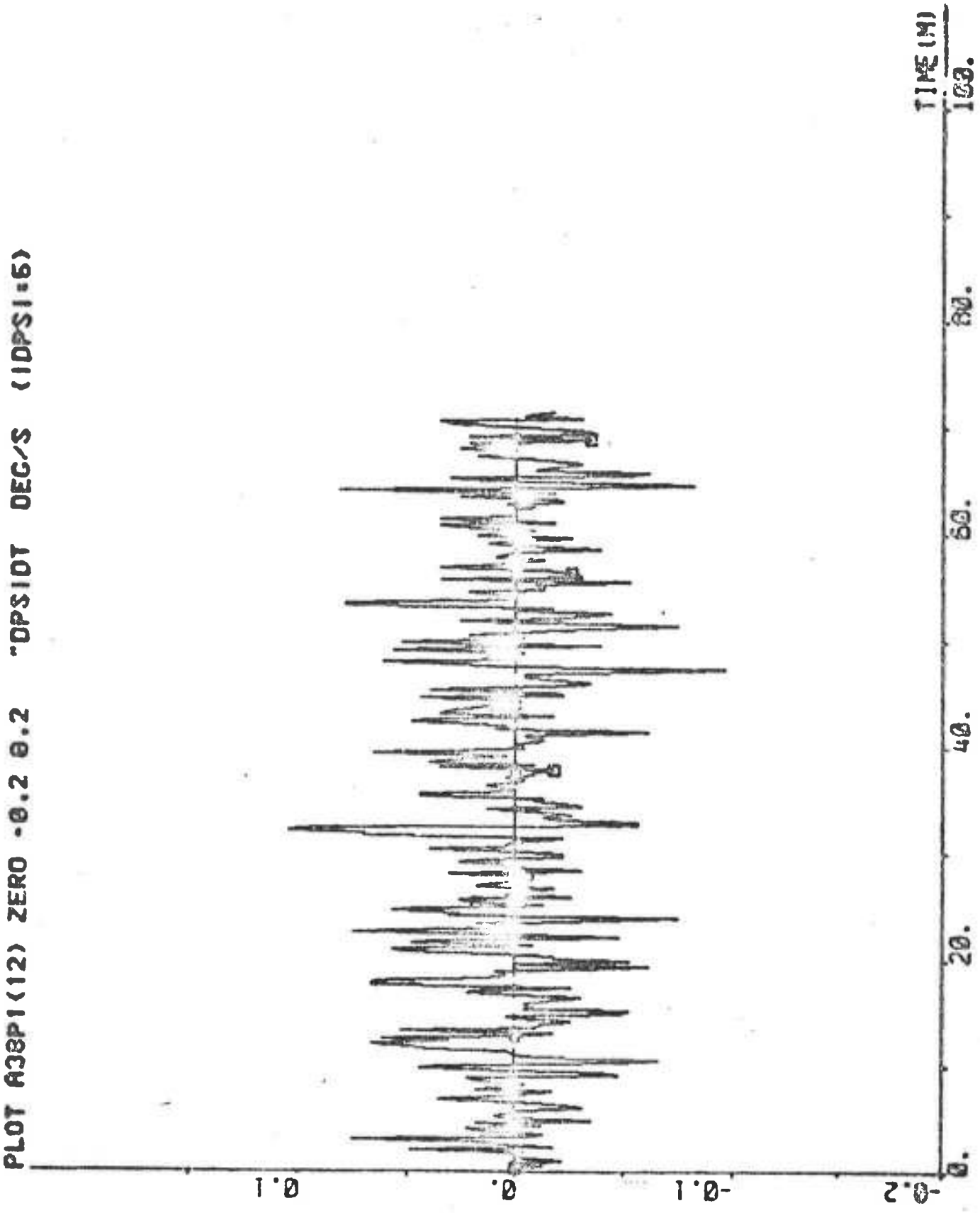

PLOT R3EP1(4) ZERO -20 20 'DELTA DEG
10.
0.
-10.
-20.
0.
20.
40.
60.
80.
100.
TIME(H)

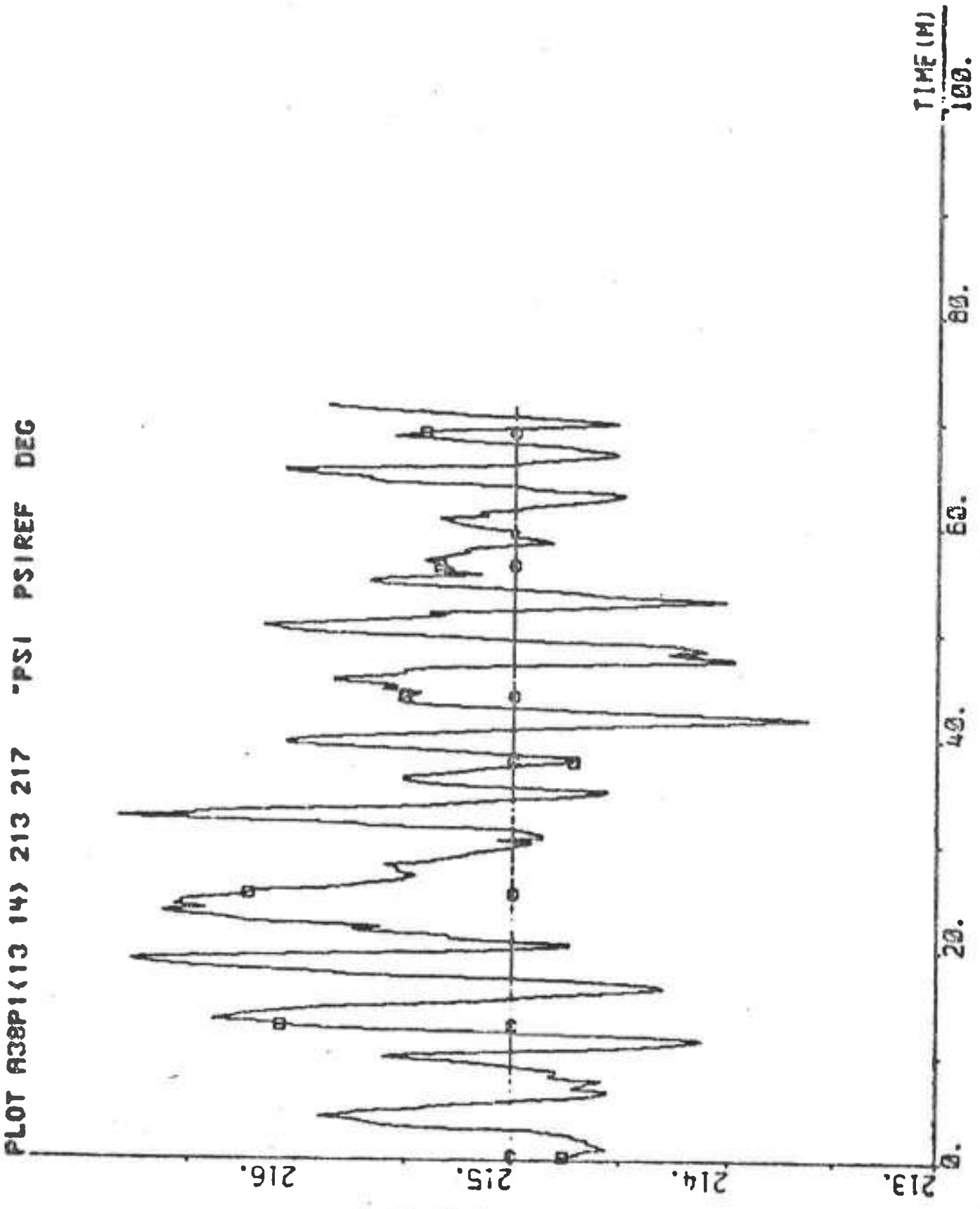

PLOT A38P1(6) ZERO -1 1 *PP DEG/S
-1.
-0.5
0.
0.5
0.
20.
40.
60.
80.
100.
TIME(M)

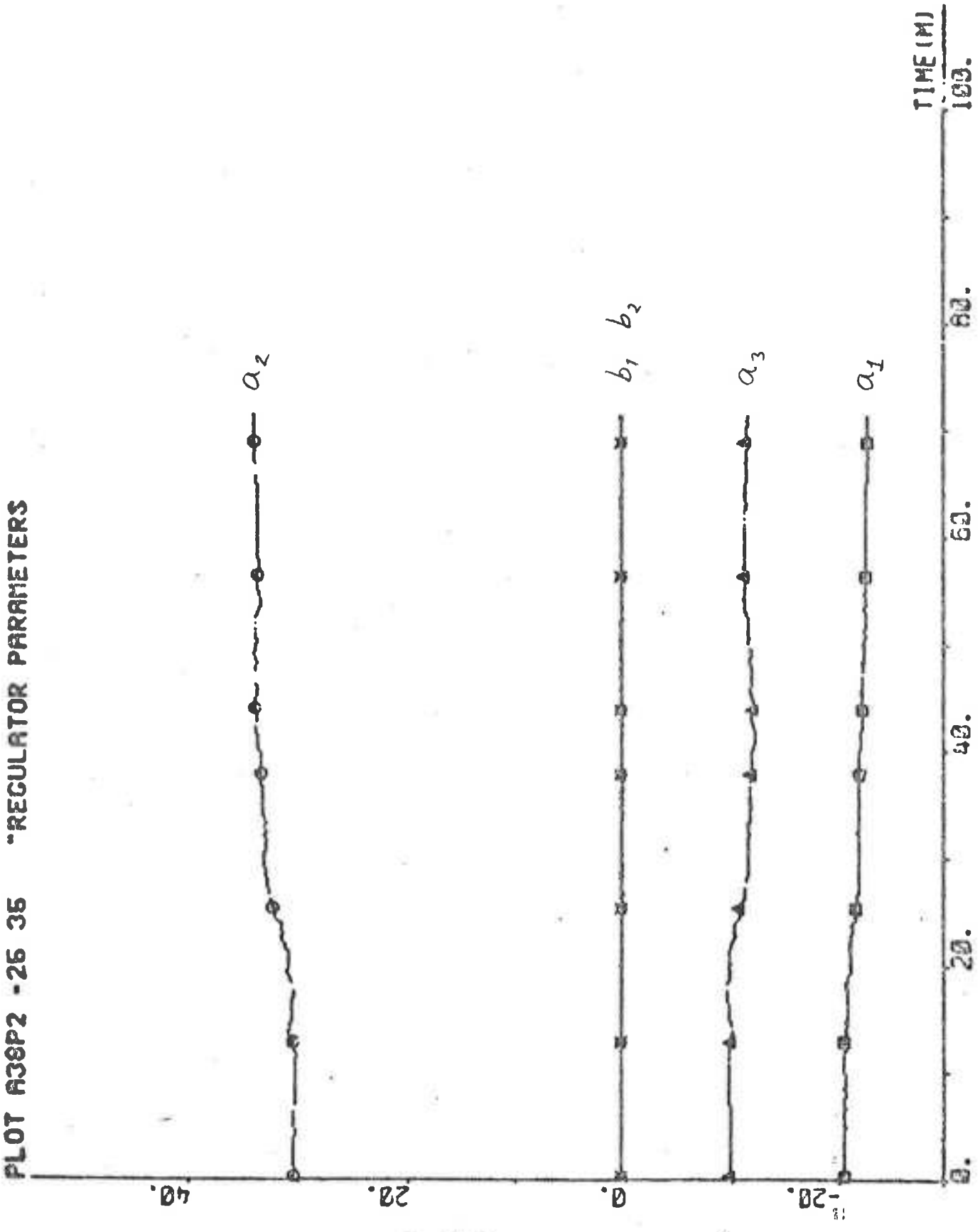

PLOT A36P1(6) 47.6 65.5 *AM RPM
54.
52.
50.
48.
0.
20.
40.
60.
80.
100.
TIME(M)


PLOT A30P1(7) 4 6 "U KNOTS
5.5
5.
4.5
4.
TIME(M)
0.
20.
40.
60.
80.
100.


PLOT A36P1(8) ZERO -0.5 0.5 "V1 KNOTS
-0.5
-0.25
0.
0.25
TIME(M)
0.
20.
40.
60.
80.
100.


PLOT A38P1(12) ZERO -0.2 0.2 "DPSIDT DEG/S (1DPSI=6)
0.1
0.
-0.1
-0.2
0.
20.
40.
60.
80.
100.
TIME(M)


PLOT A38P1(13 14) 213 217 *PSI PSIREF DEG
213.
214.
215.
216.
0.
20.
40.
60.
80.
100.
TIME(M)


PLOT A30P2 -25 35 "REGULATOR PARAMETERS
40.
28.
0.
-20.
0.
20.
40.
60.
80.
100.
TIME(M)
a_2
b_1 b_2
a_3
a_1

EXPERIMENT A39A

Date	1974-10-21
Time	15.51
Duration	22 min
Position	S 29° 30' E 32° 00'
Water depth	deep
Forward draught	20.2 m
Aft draught	20.2 m
Wind direction	SW (1; see Appendix A)
Wind velocity	8-9 Beaufort (17-24 m/s, fresh to strong gale)
Wave height	10 m (sea from SW)
PSIREF	212°
Rudder limit	±25°

Regulator structure

NA = 3 NB = 2 NC = 0 K = 5

IREG = 15 RL = 0.99

Final values

$$\begin{bmatrix} a_1 \\ a_2 \\ a_3 \\ b_1 \\ b_2 \end{bmatrix} = \begin{bmatrix} -24.797 \\ 39.146 \\ -14.606 \\ 0.015 \\ 0.096 \end{bmatrix} \qquad P = \begin{bmatrix} 0.229 & & & & \\ -0.362 & 1.095 & & & \\ 0.150 & -0.792 & 0.694 & & \\ -0.001 & -0.022 & 0.025 & 0.001 & \\ -0.002 & -0.014 & 0.016 & 0.001 & 0.001 \end{bmatrix}$$

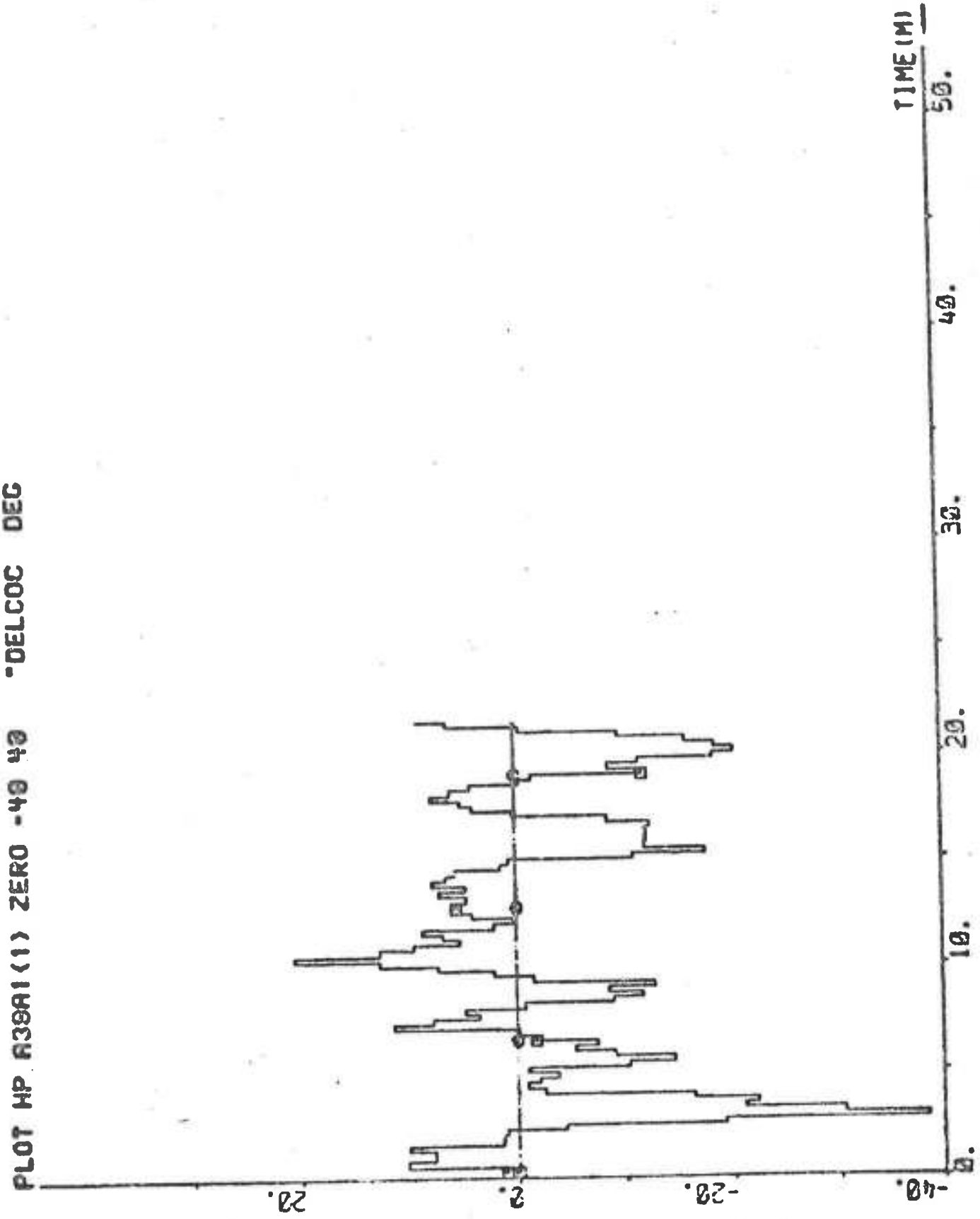
$a_1 + a_2 + a_3 = -0.257$

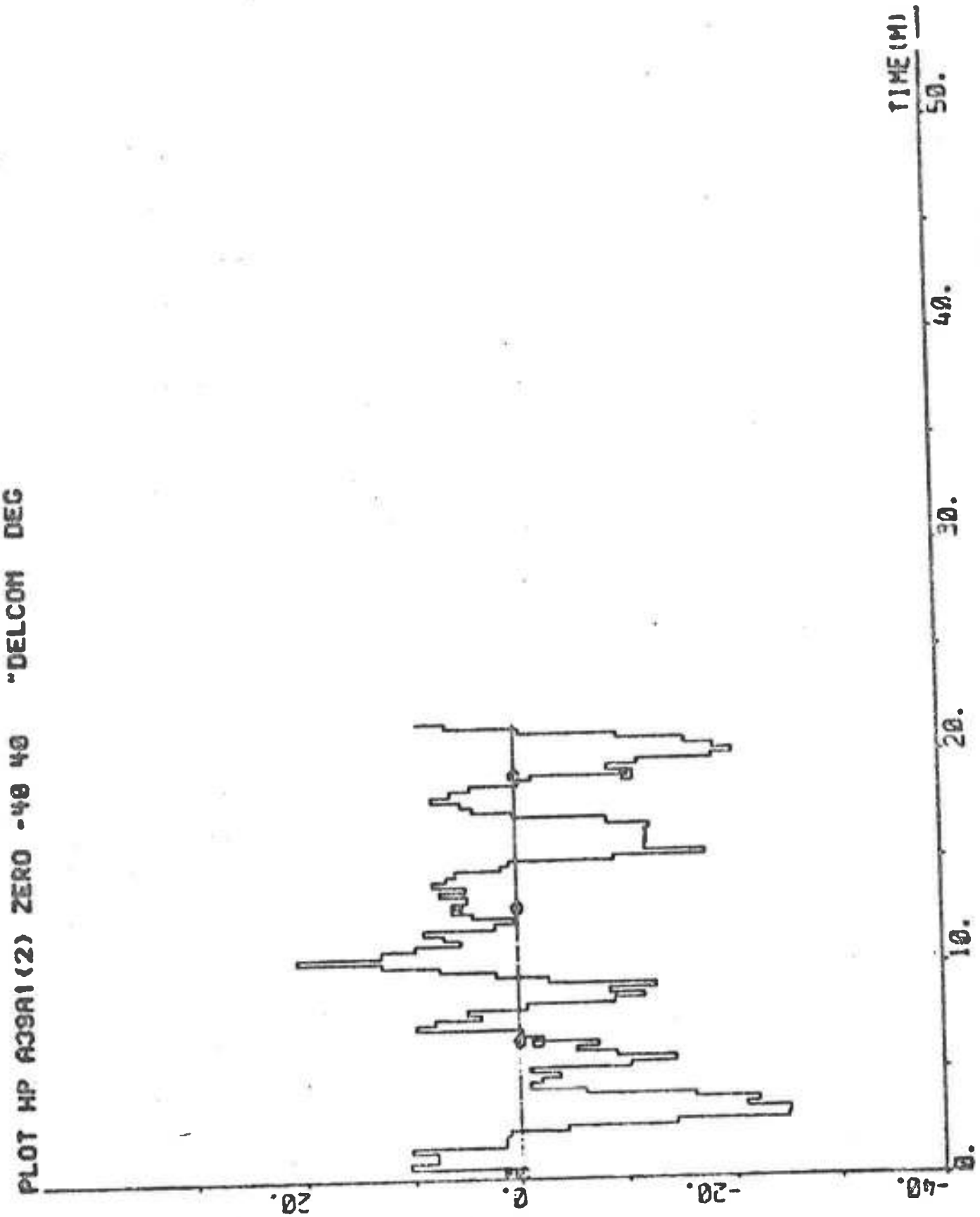
Statistics (mean value and standard deviation)

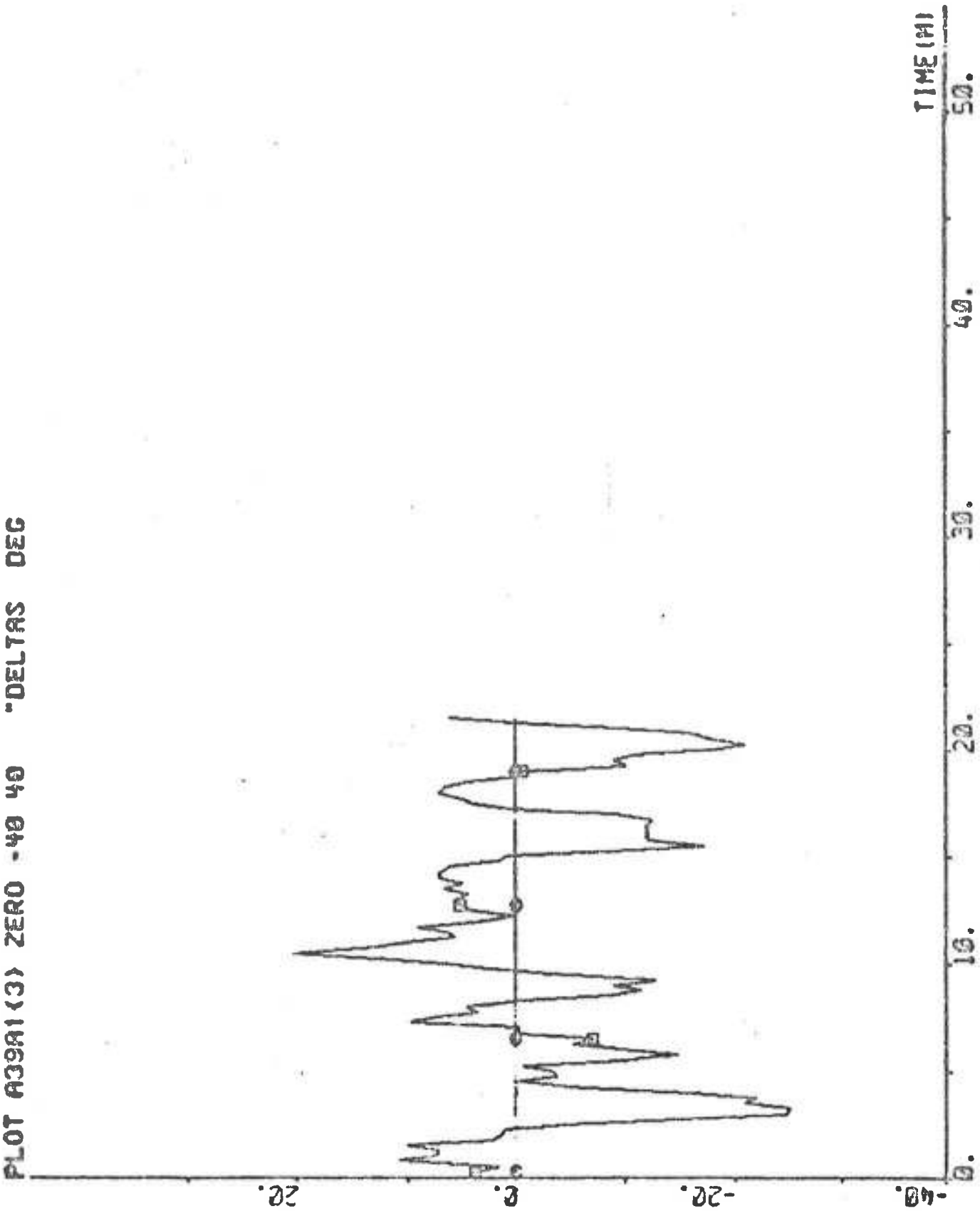
DELTA	-1.51 ± 10.98 deg
PSI-PSIREF	0.522 ± 1.089 deg
AN	48.53 ± 0.71 rpm
U	4.32 ± 0.21 knots

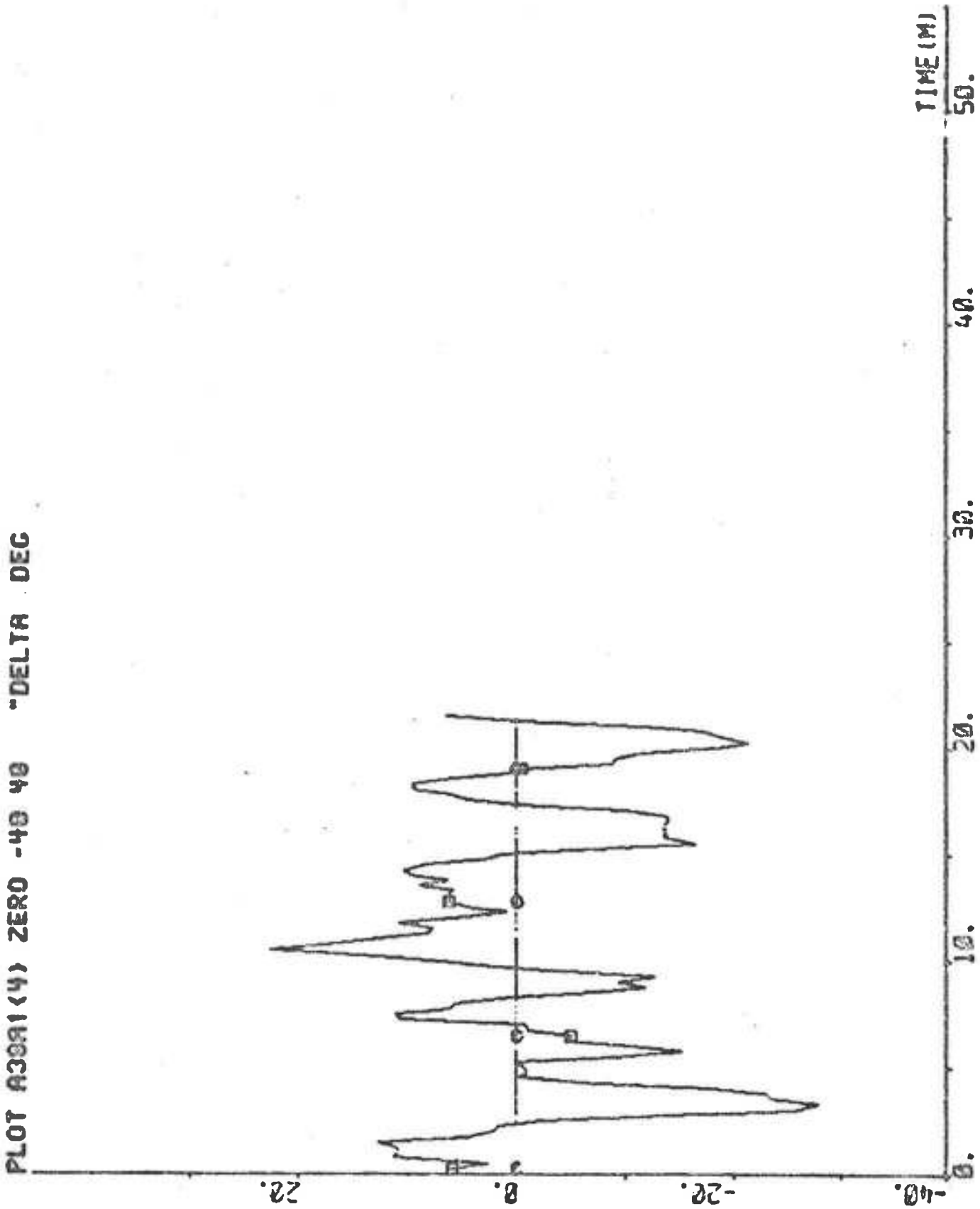
$V_1 = 13.742$

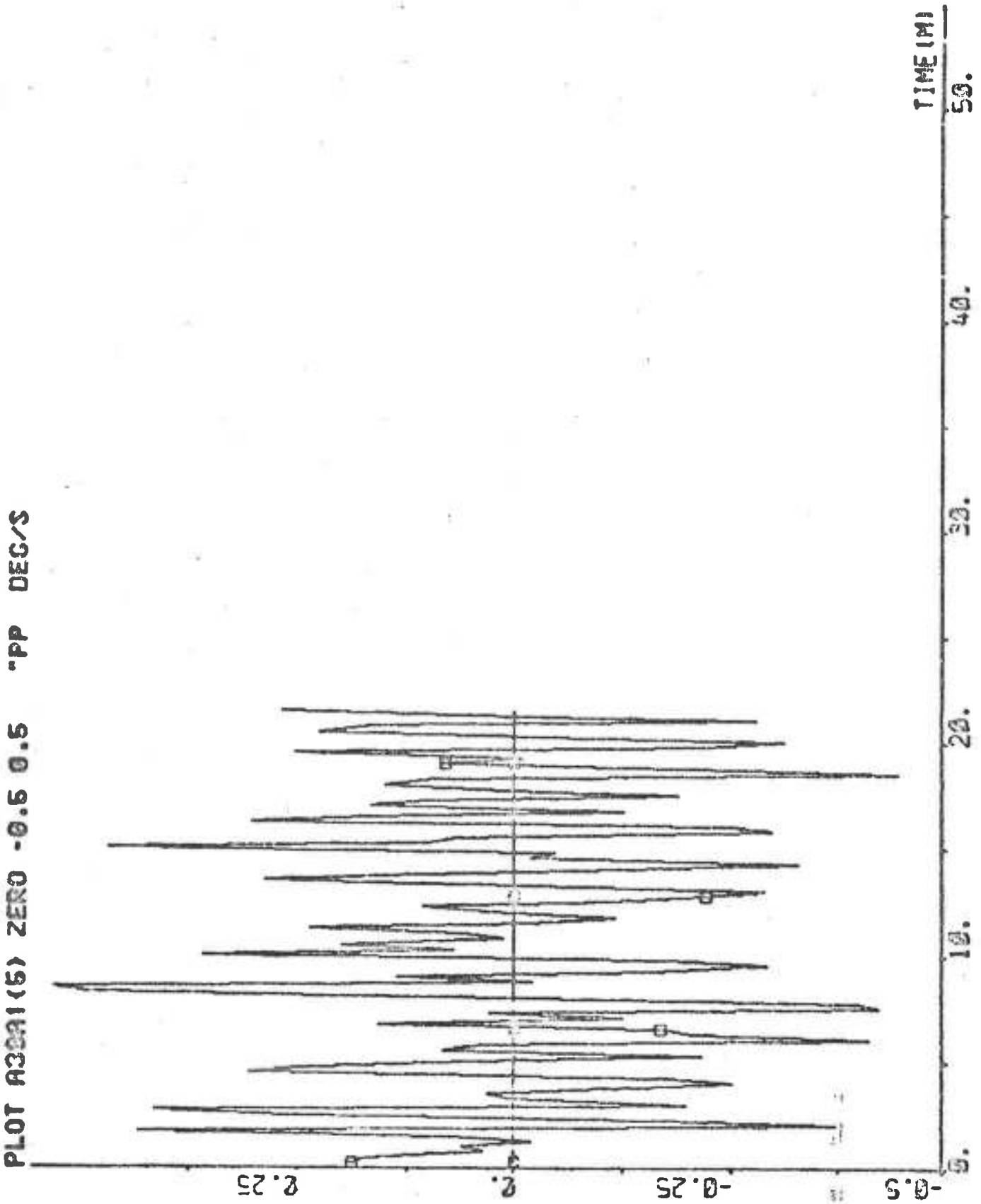
$V_2 = 13.514$

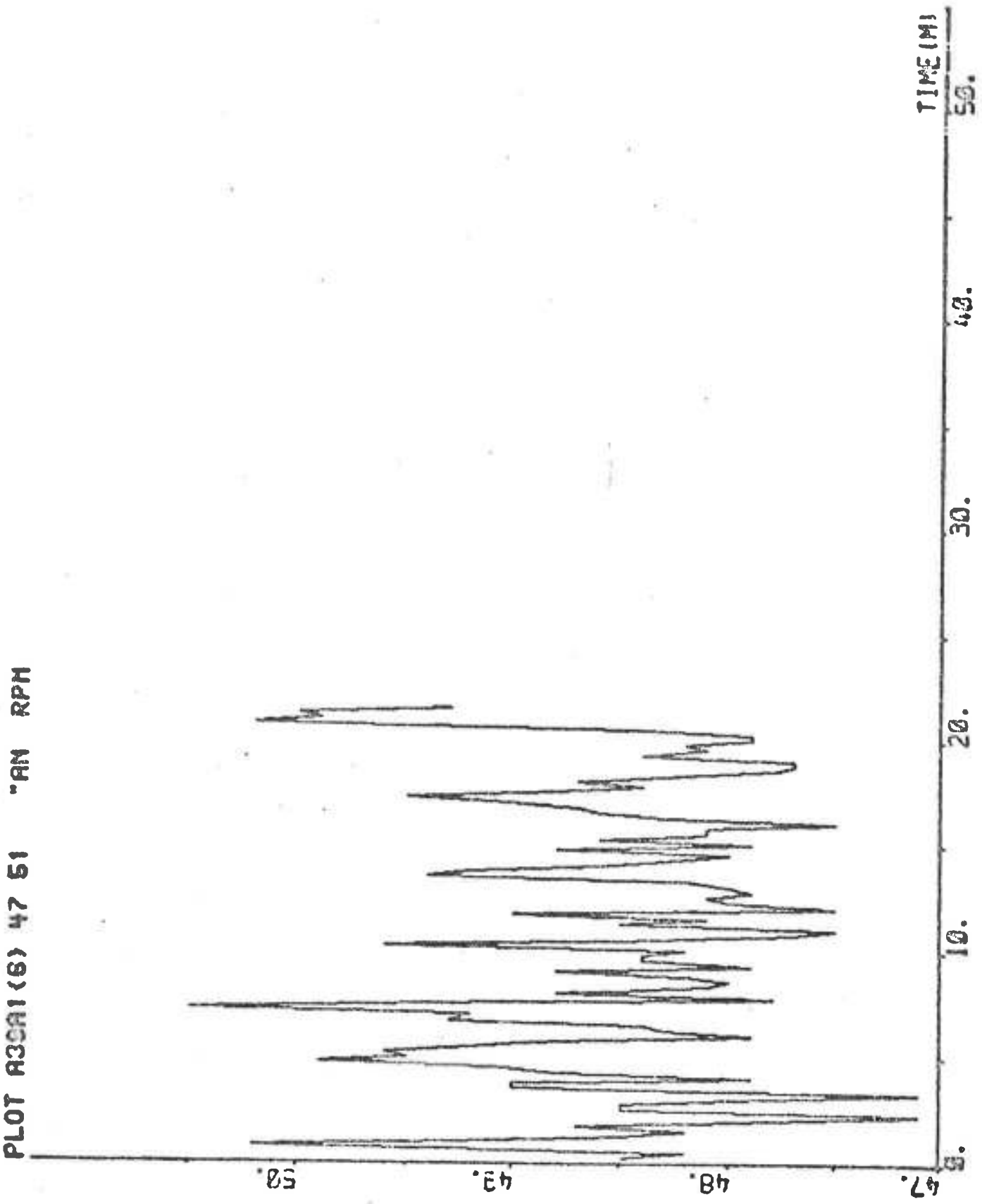

PLOT HP A39A1(1) ZERO -40 40 *DELCOC DEG
TIME(MI)
0.
10.
20.
30.
40.
50.
-40.
-20.
2.
20.

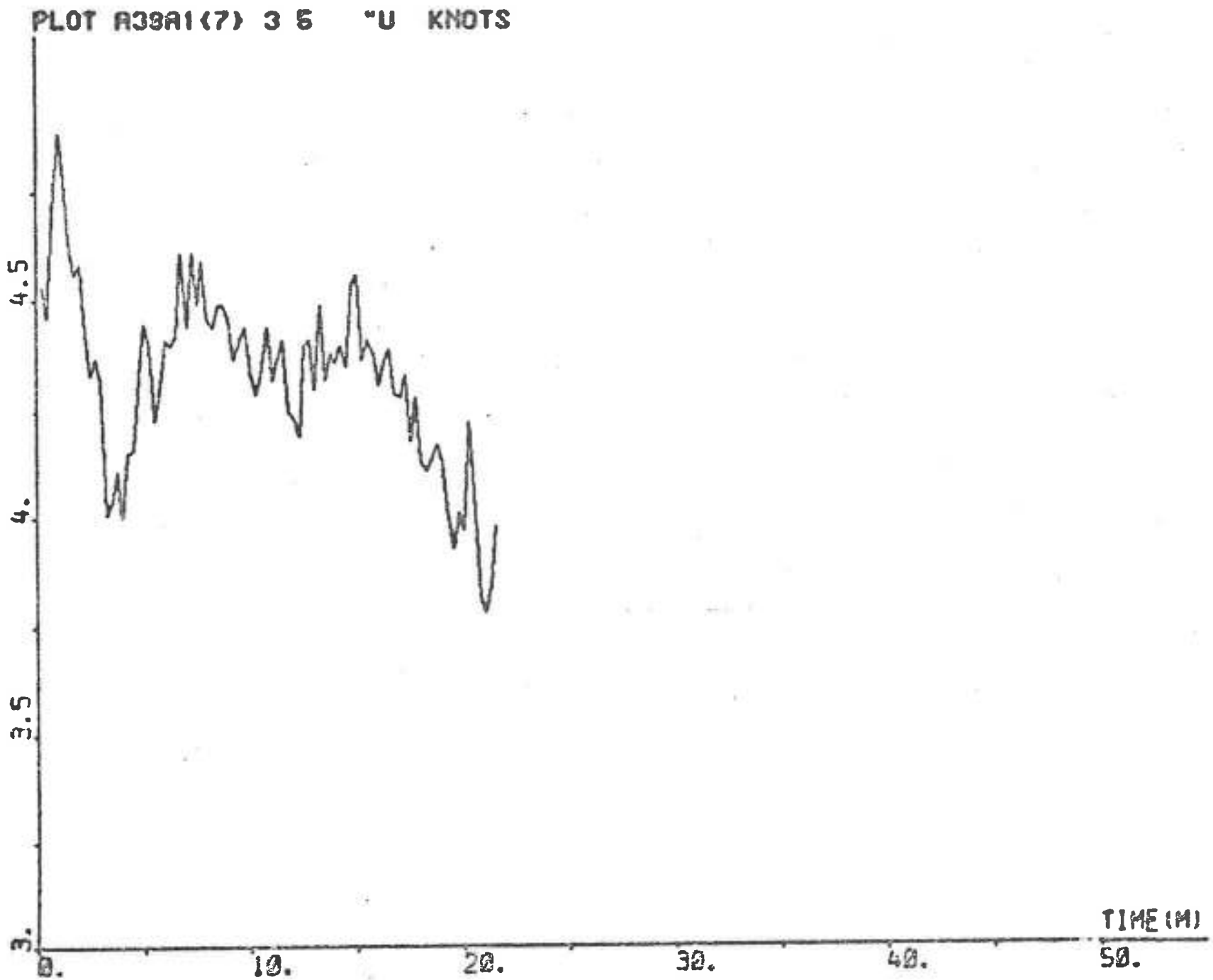

PLOT HP A39A1(2) ZERO -40 40 "DELCOM DEG
TIME(M)
0.
10.
20.
30.
40.
50.
-40.
-20.
0.
20.

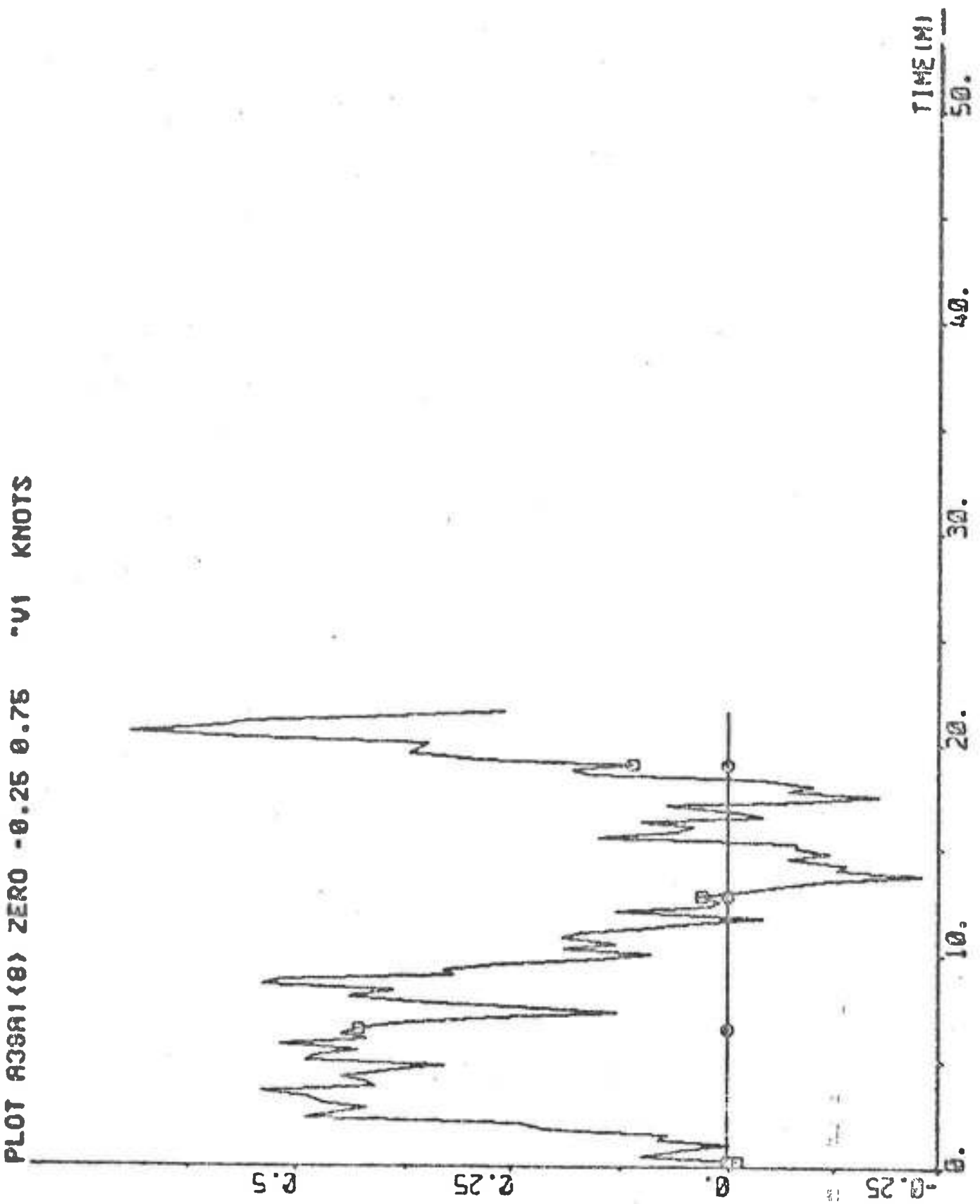

PLOT A39A1(3) ZERO -40 40 *DELTAS DEG
TIME(M)
0.
10.
20.
30.
40.
50.
-40.
-20.
0.
20.

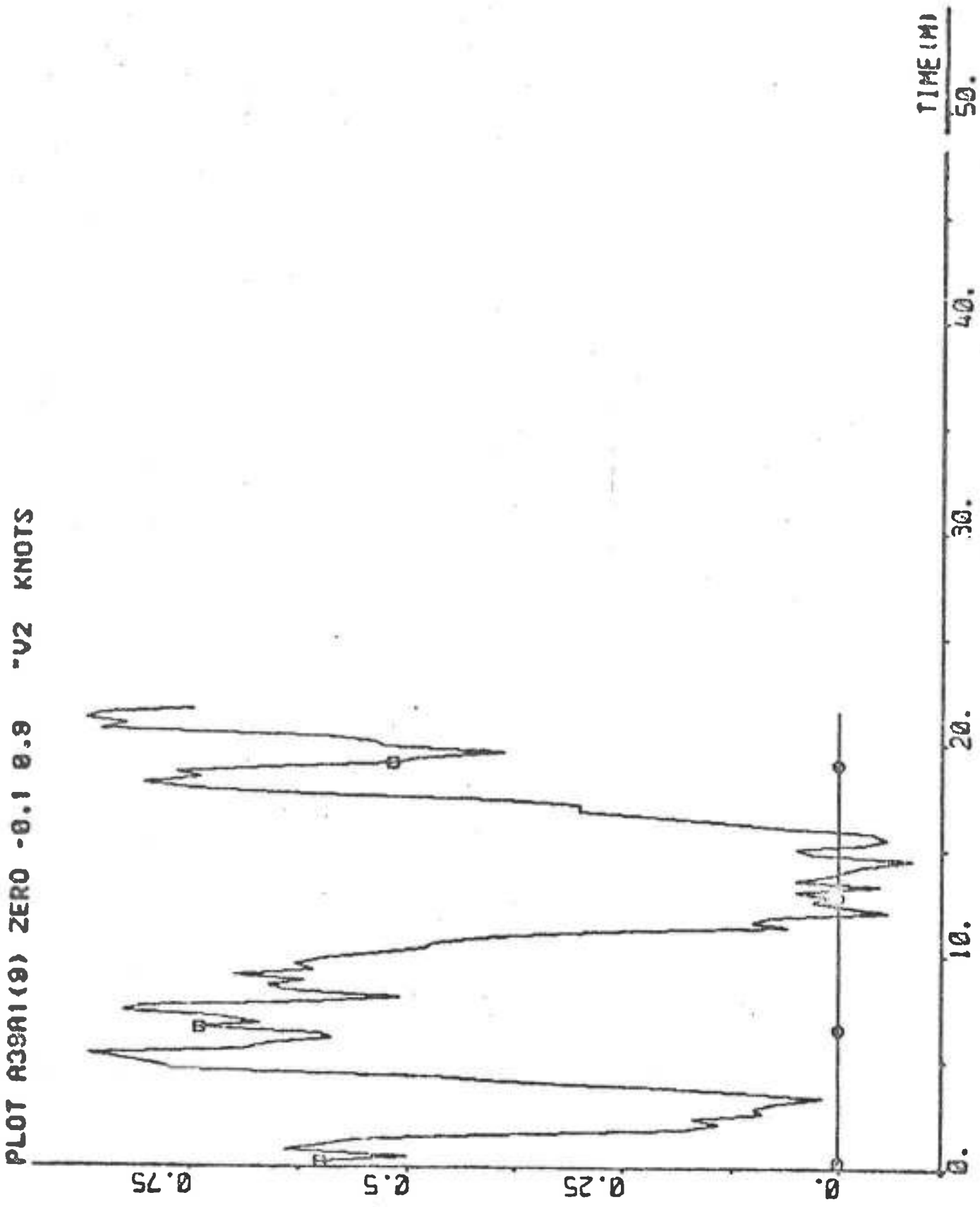

PLOT A3391(4) ZERO -40 40 "DELTA DEC
22.
0.
-22.
-40.
0.
10.
20.
30.
40.
50.
TIME(M)

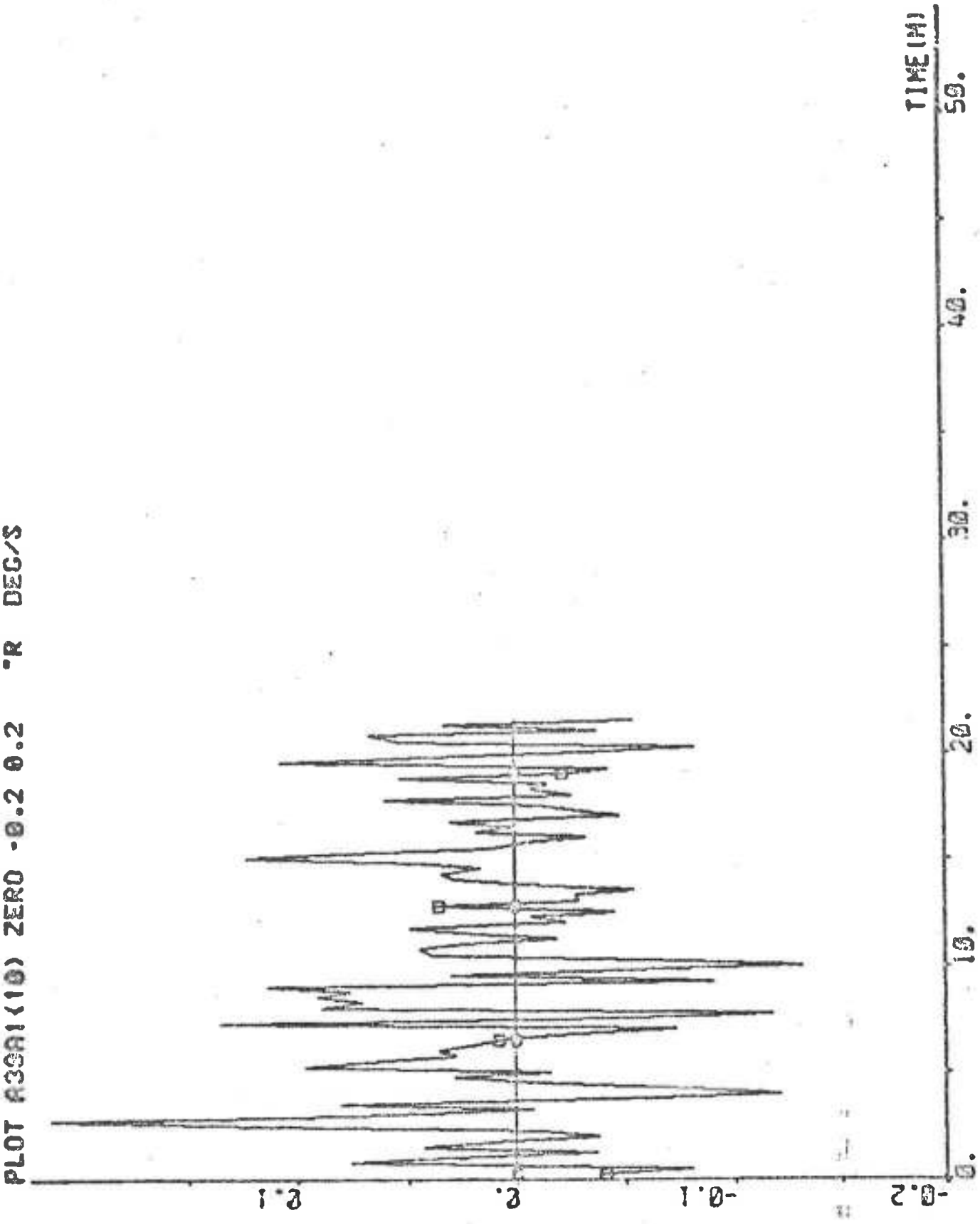

PLOT A3231(5) ZERO -0.5 0.5 PP DEG/S
-0.5
-0.25
0.
0.25
TIME(M)
0.
10.
20.
30.
40.
50.

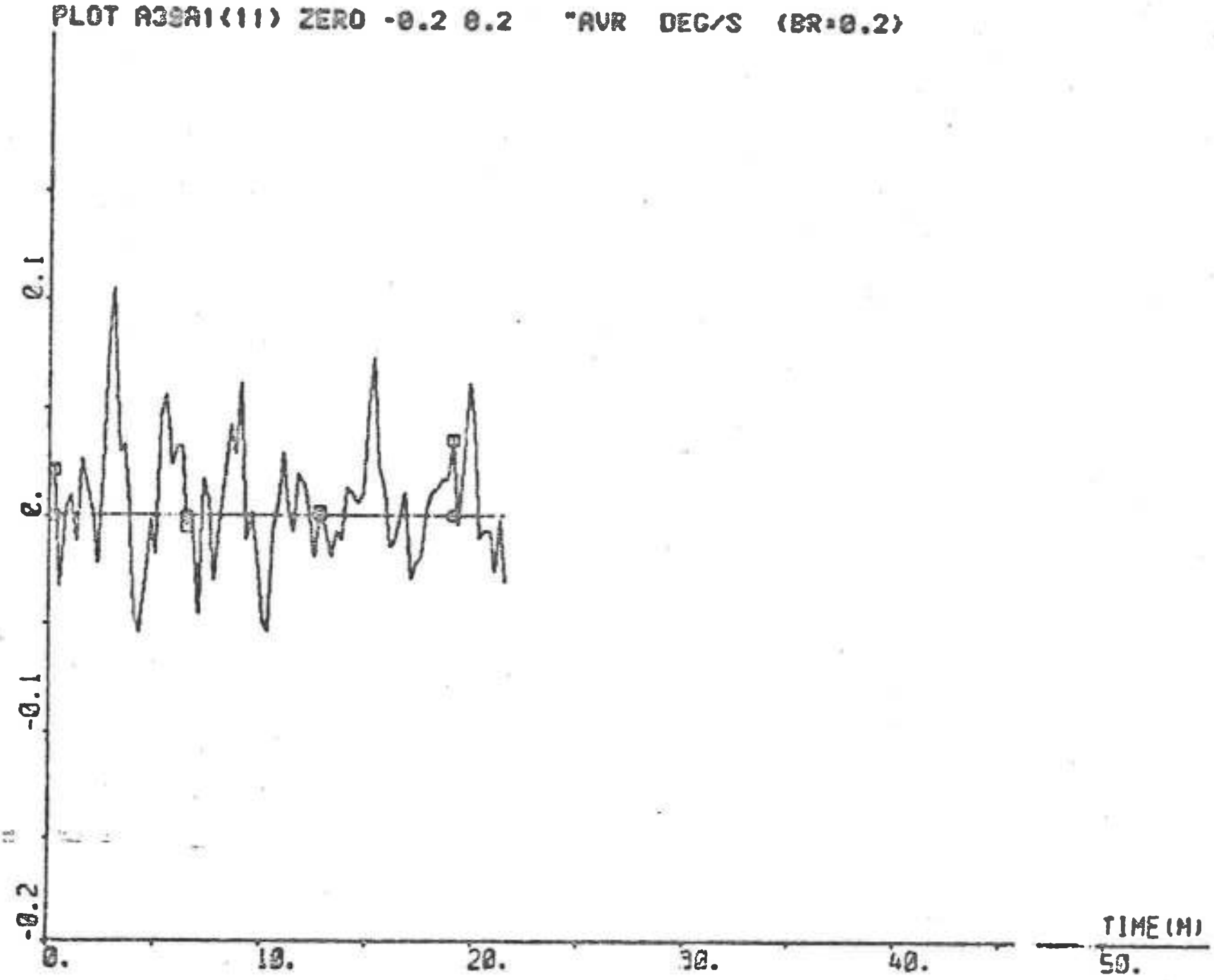

PLOT A3CA1(6) 47 51 "AN RPH
47.
48.
49.
50.
0.
10.
20.
30.
40.
50.
TIME(MI

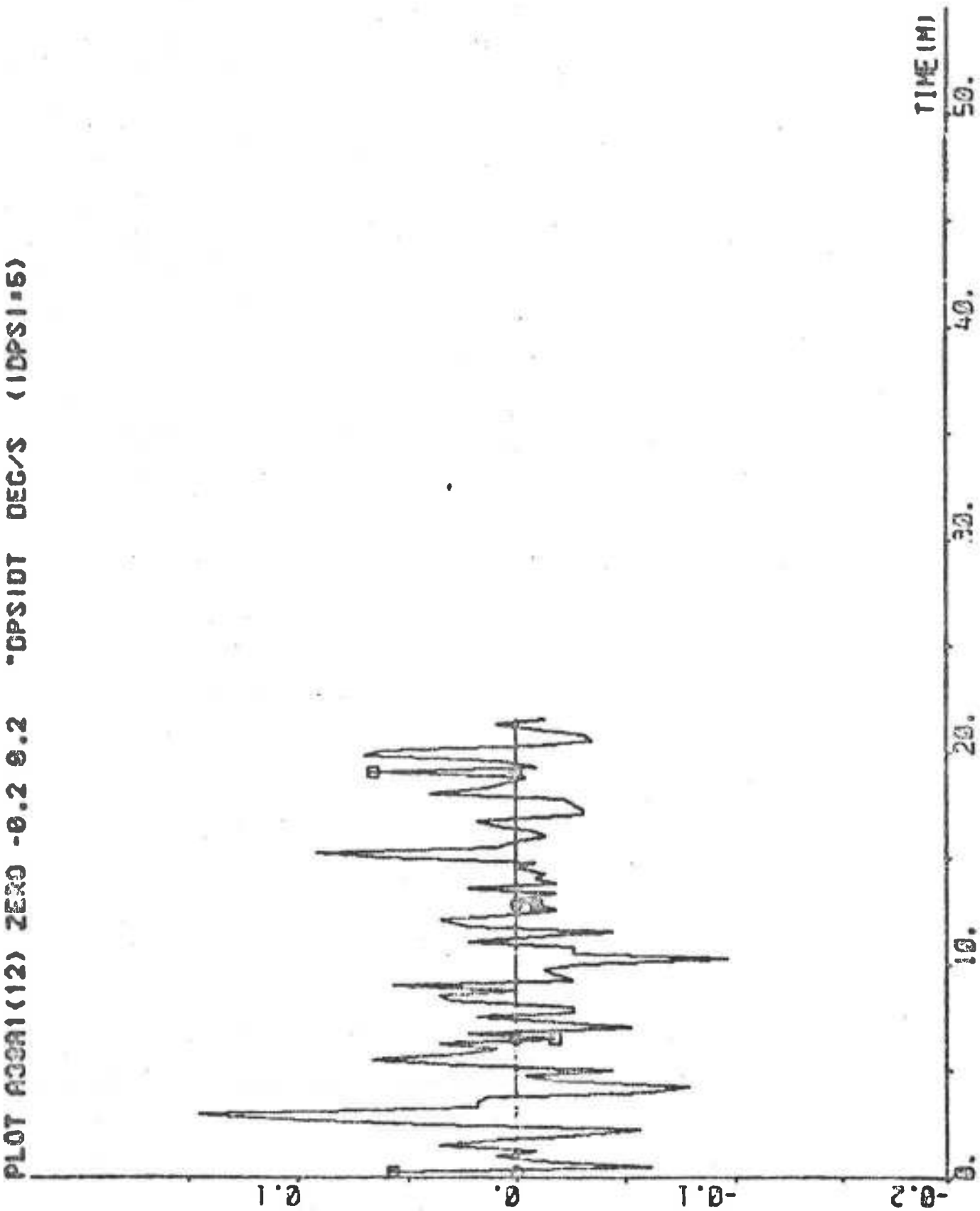

PLOT R30A1(7) 3 5 "U KNOTS
4.5
4.
3.5
3.
0.
10.
20.
30.
40.
50.
TIME(M)

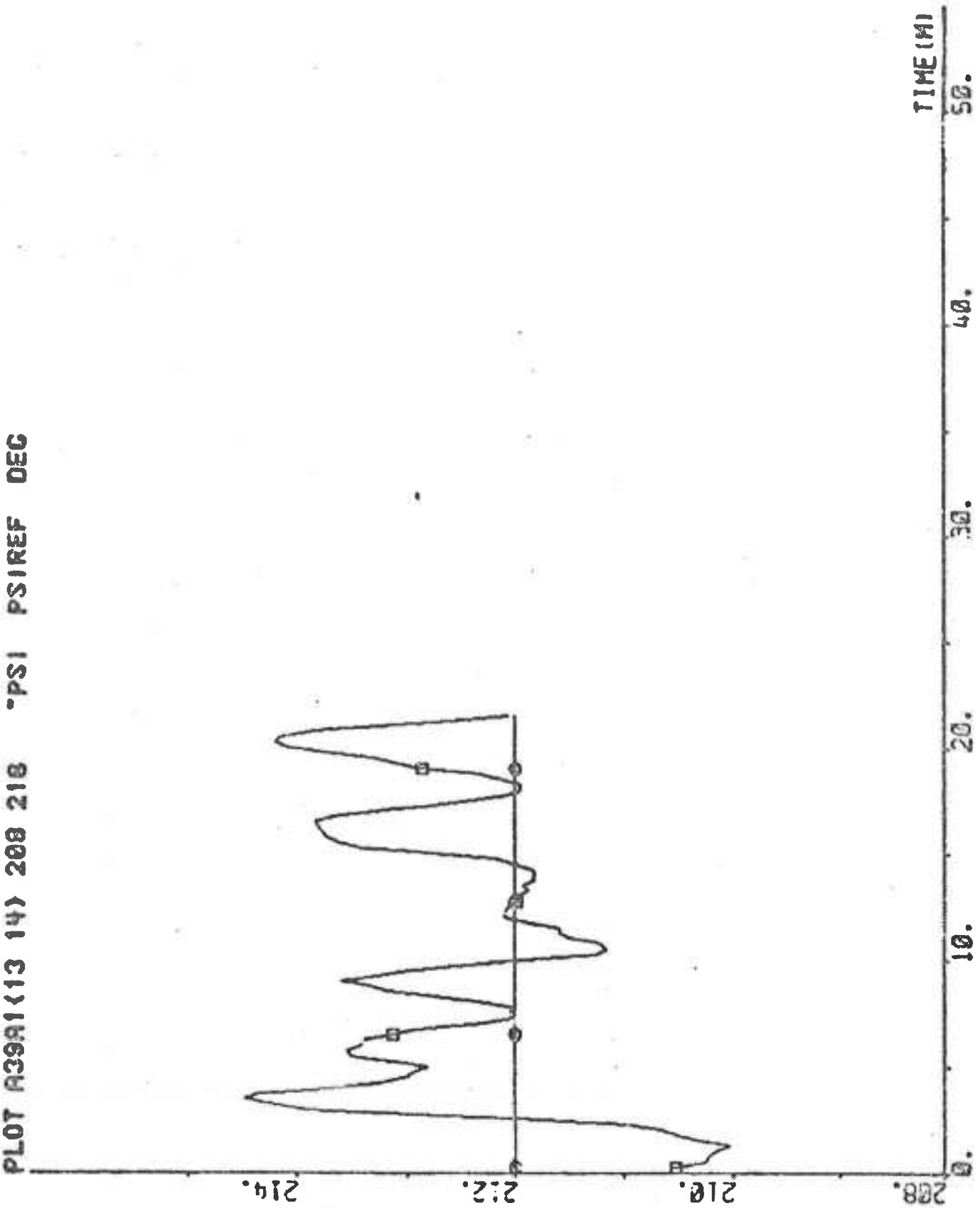

PLOT A3BA1(8) ZERO -0.25 0.75 *V1 KNOTS
-0.25
0.
0.25
0.5
0.
10.
20.
30.
40.
50.
TIME(M)

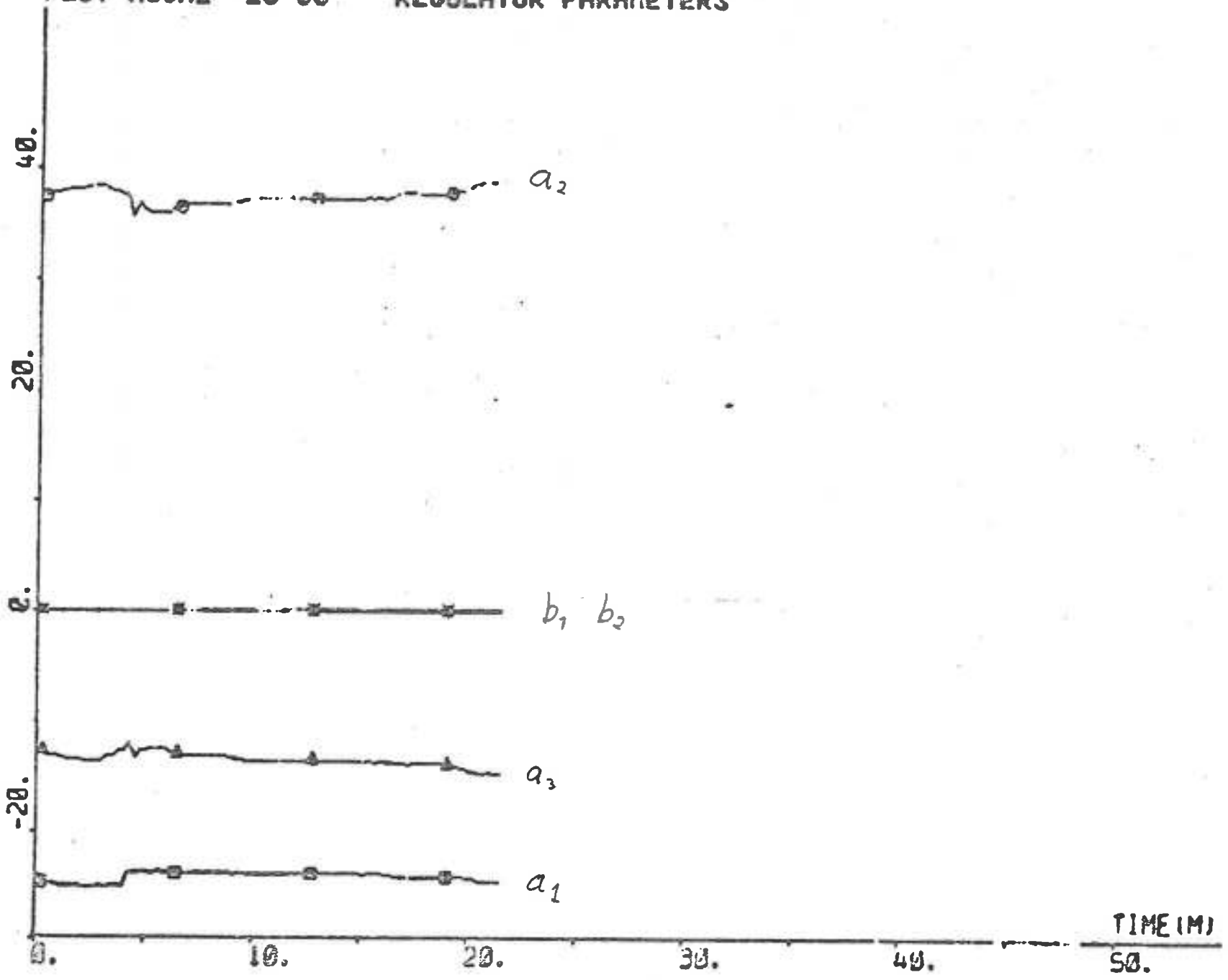

PLOT A39A1(9) ZERO -0.1 0.9 "V2 KNOTS
0.75
0.5
0.25
0.
0.
10.
20.
30.
40.
50.
TIME(M)


PLOT A39A1(10) ZERO -0.2 0.2 'R DEG/S
TIME(M)
0.
10.
20.
30.
40.
50.
.2
.1
0.
-.1
-.2


PLOT A38A1(11) ZERO -0.2 0.2 "AVR DEG/S (BR=0.2)
0.1
0.
-0.1
-0.2
0.
10.
20.
30.
40.
50.
TIME(H)


PLOT A33A1(12) ZERO -0.2 0.2 'DPSIDT DEG/S (1DPSI=5)
0.1
0.
-0.1
-0.2
0.
10.
20.
30.
40.
50.
TIME(M)


PLOT A39A1(13 14) 208 210 *PSI PSIREF DEG
208.
210.
212.
214.
0.
10.
20.
30.
40.
50.
TIME(M)


PLOT A38A2 -25 35 "REGULATOR PARAMETERS
40.
20.
0.
-20.
a_2
b_1 b_2
a_3
a_1
0.
10.
20.
30.
40.
50.
TIME (M)

EXPERIMENT A39B

Date	1974-10-22
Time	07.31
Duration	48 min
Position	S 30° 56' E 30° 40'
Water depth	deep
Forward draught	20.2 m
Aft draught	20.2 m
Wind direction	SSW (1; see Appendix A)
Wind velocity	4-5 Beaufort (6-10.5 m/s, moderate to fresh breeze)
Wave height	Rough sea from SSW
PSIREF	216°
Rudder limit	Not active

Regulator structure

NA = 3 NB = 2 NC = 0 K = 5

IREG = 15 RL = 0.99

Final values

$$\begin{bmatrix} a_1 \\ a_2 \\ a_3 \\ b_1 \\ b_2 \end{bmatrix} = \begin{bmatrix} -22.693 \\ 34.380 \\ -11.816 \\ 0.757 \\ 0.210 \end{bmatrix} \qquad P = \begin{bmatrix} 0.677 & & & & \\ -0.909 & 2.591 & & & \\ 0.410 & -1.982 & 1.919 & & \\ 0.005 & -0.056 & 0.061 & 0.003 & \\ 0.004 & -0.047 & 0.050 & 0.002 & 0.002 \end{bmatrix}$$

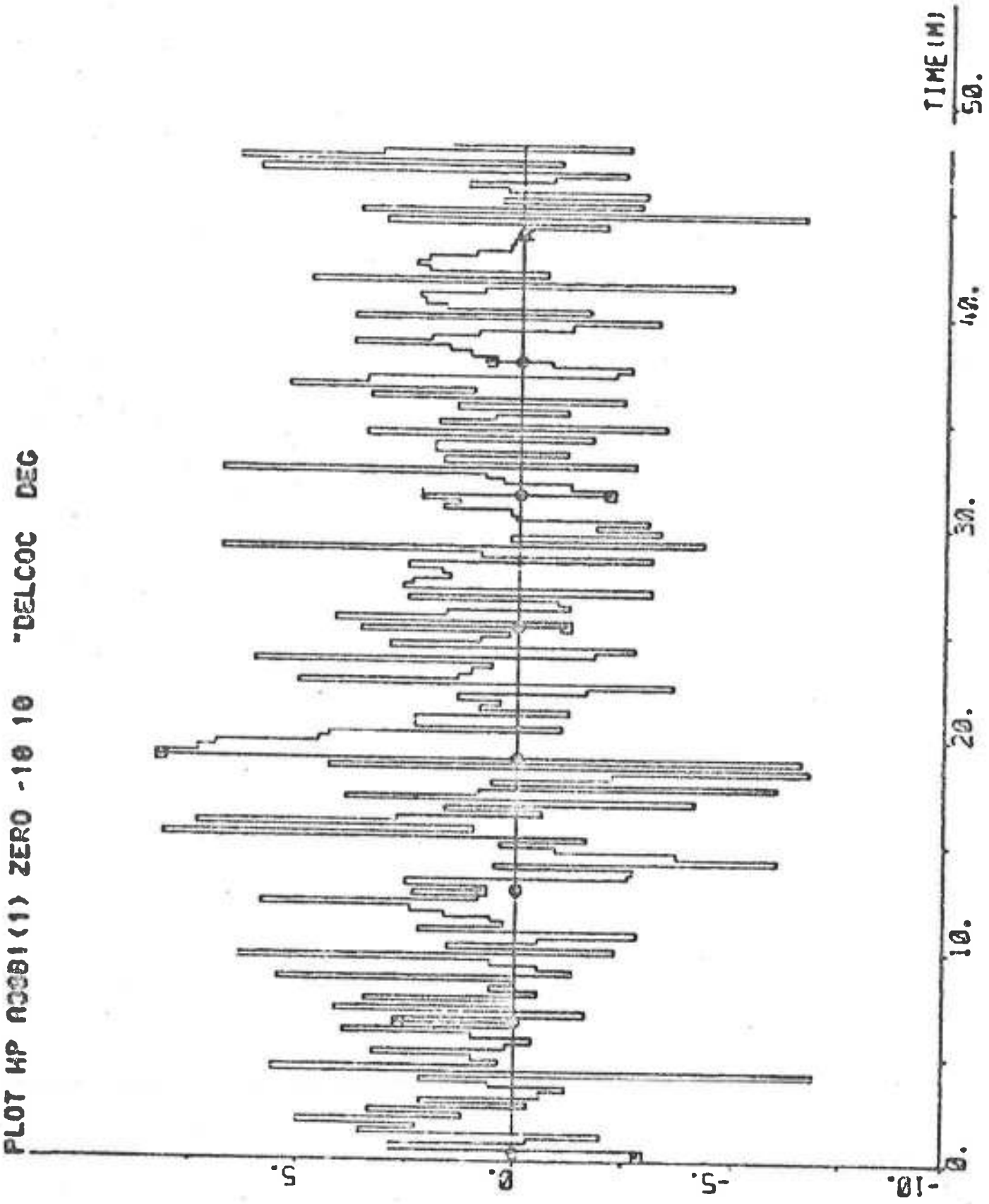
$a_1 + a_2 + a_3 = -0.129$

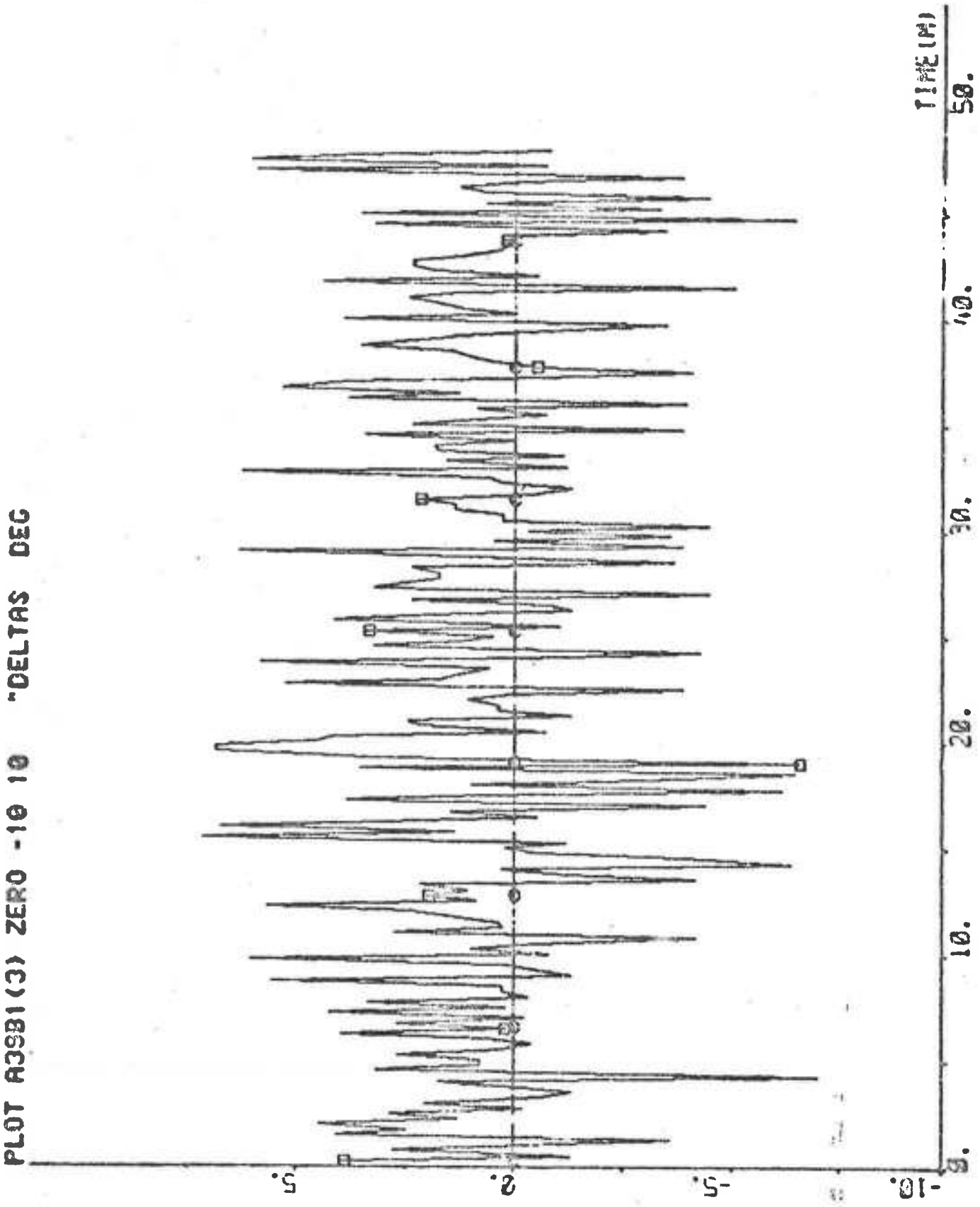
Statistics (mean value and standard deviation)

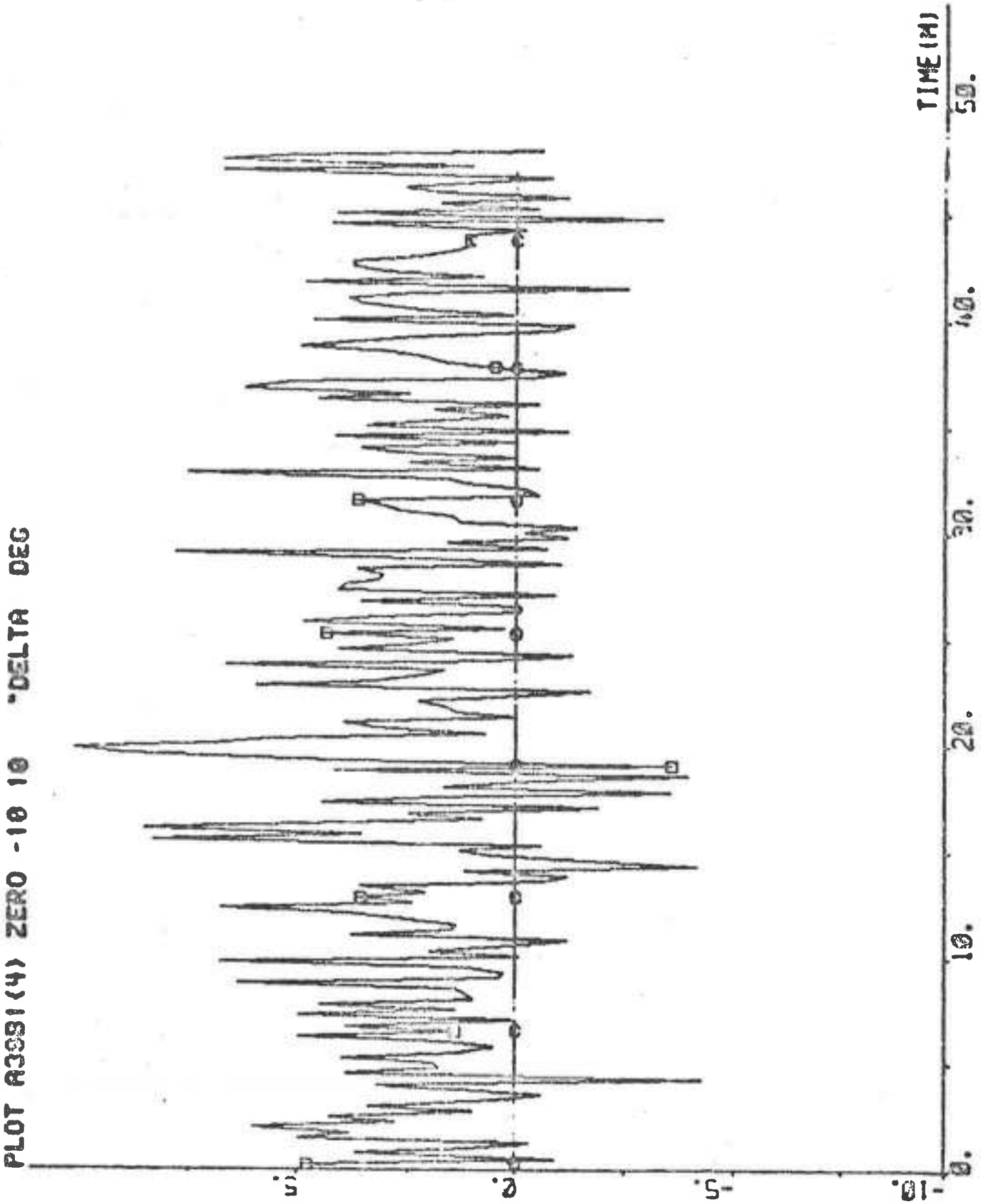
DELTA	2.09 ± 2.62 deg
PSI-PSIREF	0.015 ± 0.240 deg
AN	64.07 ± 1.27 rpm
U	12.64 ± 0.15 knots

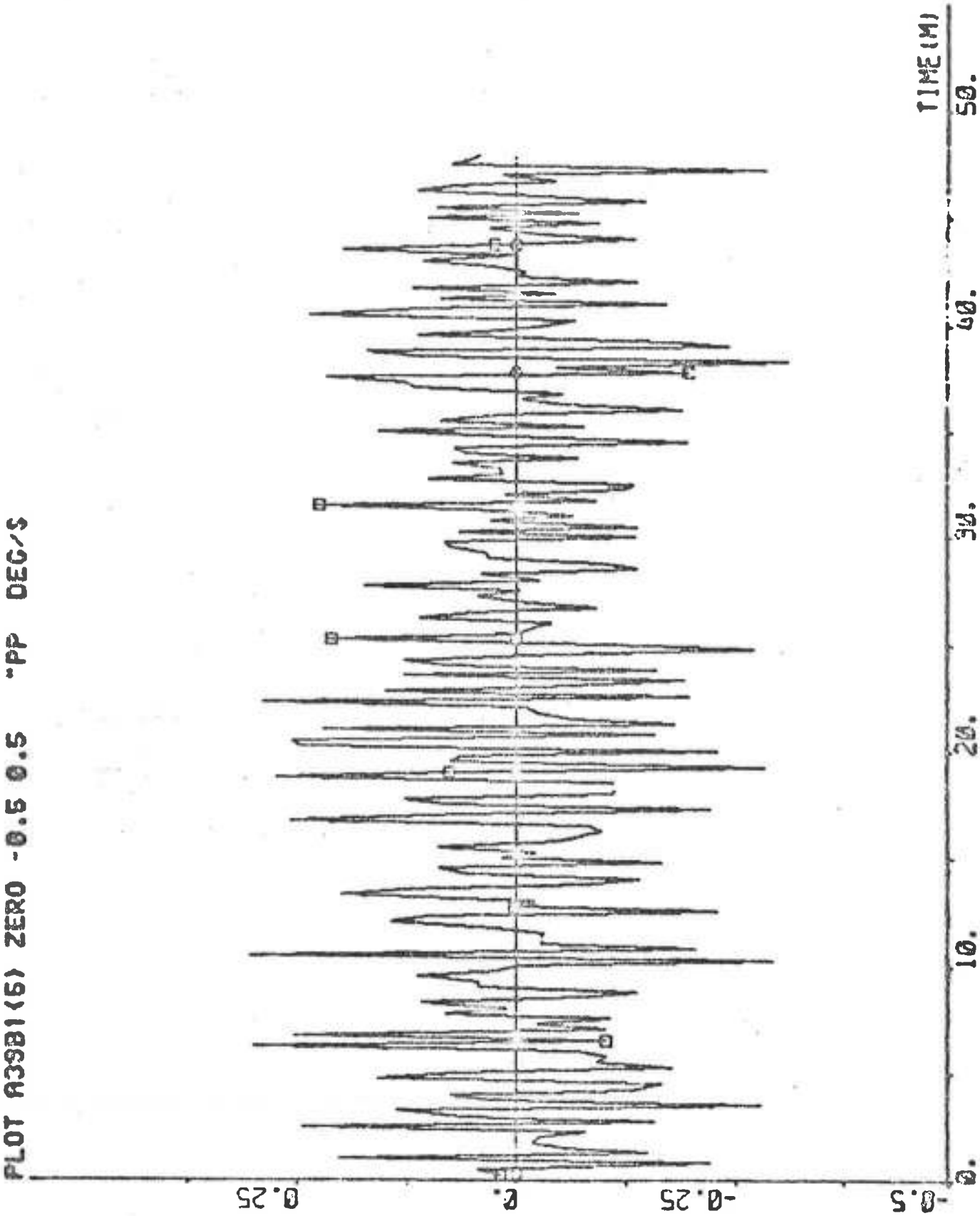
$V_1 = 1.181$

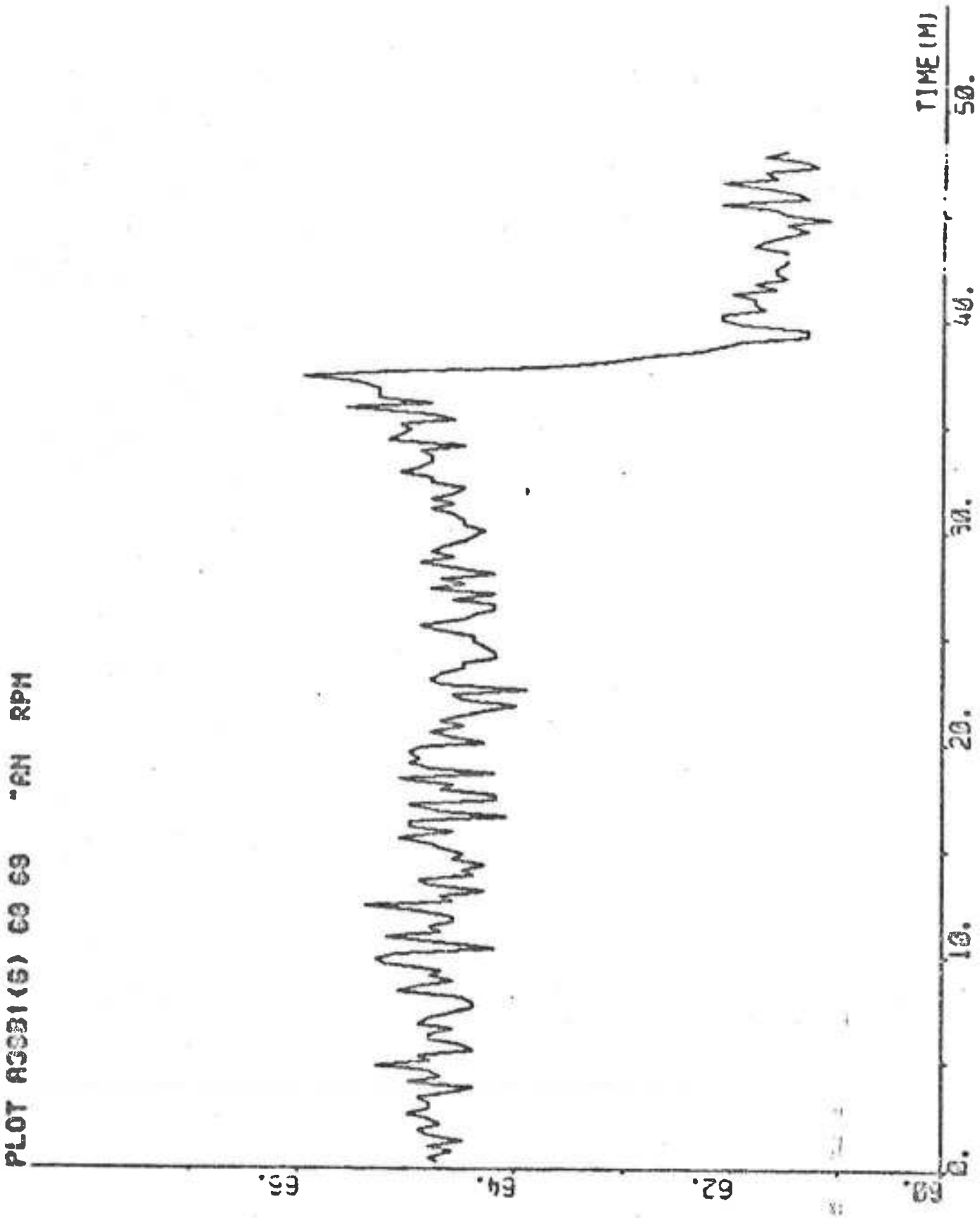
$V_2 = 0.744$

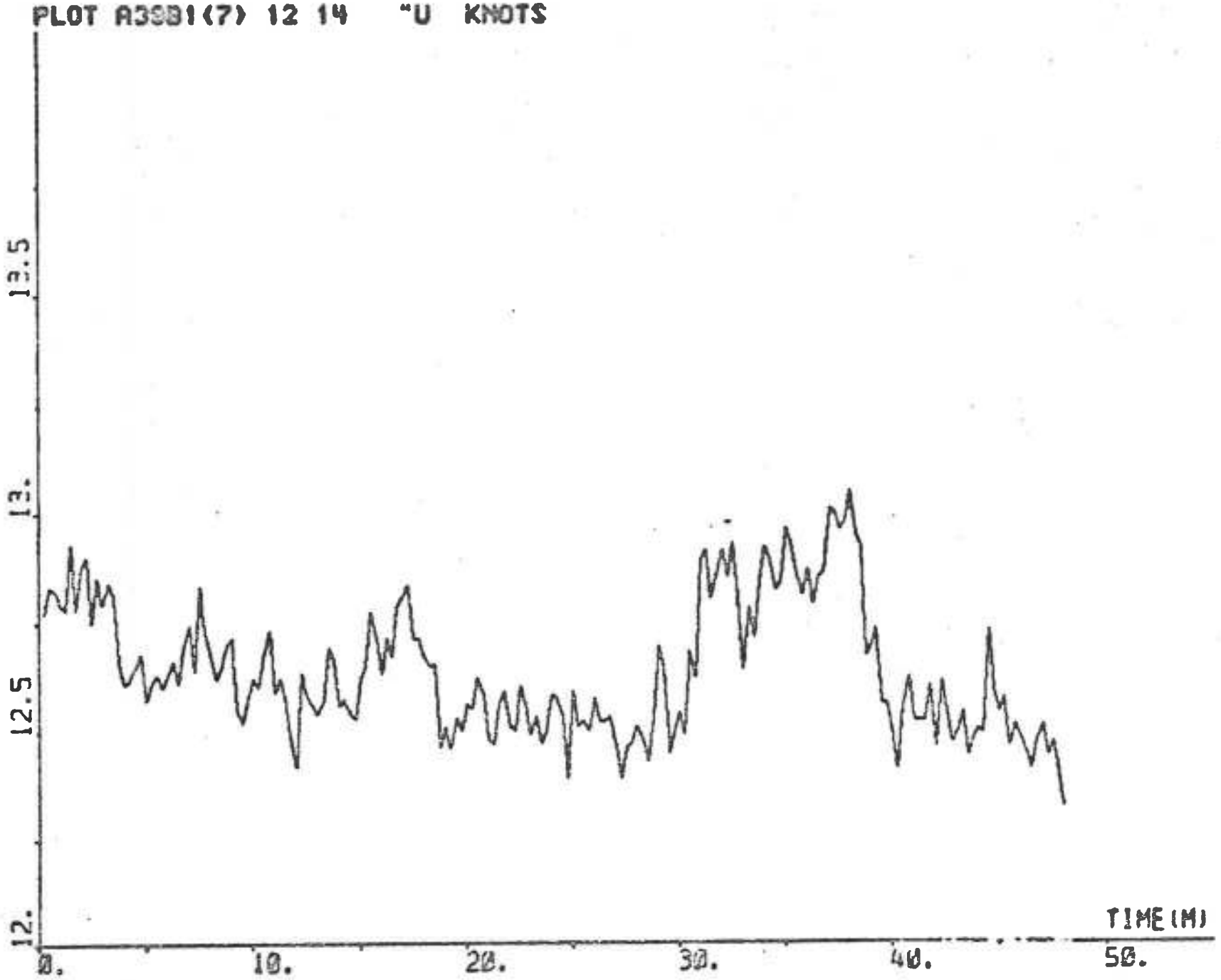

PLOT HP A3301(1) ZERO -10 10 "DELCOC DEG
TIME(M)
50.
40.
30.
20.
10.
0.
5.
0.
-5.
-10.

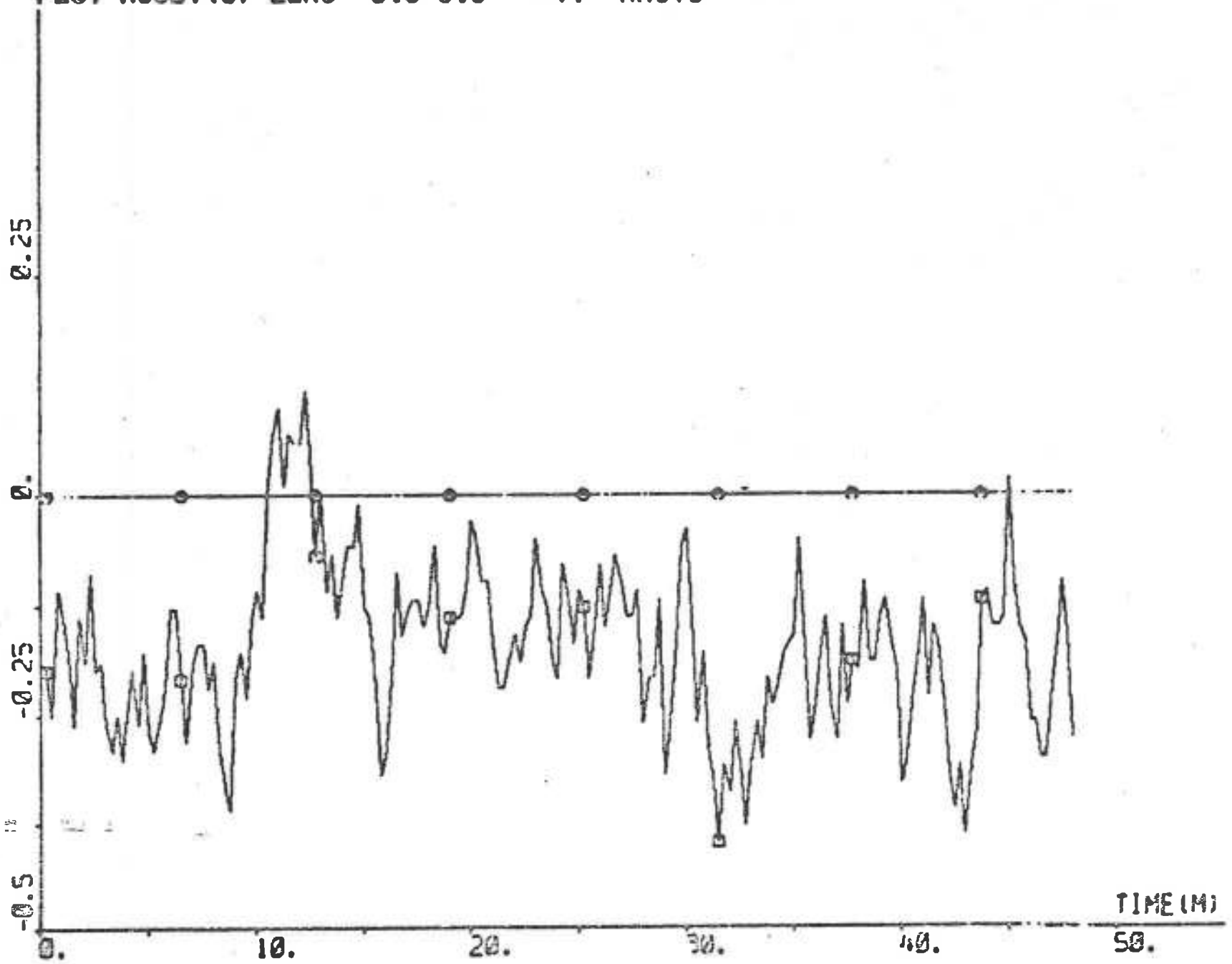

PLOT A3B1(3) ZERO -10 10 'DELTAS DEG
TIME(M)
0.
10.
20.
30.
50.
-10.
-5.
2.
5.

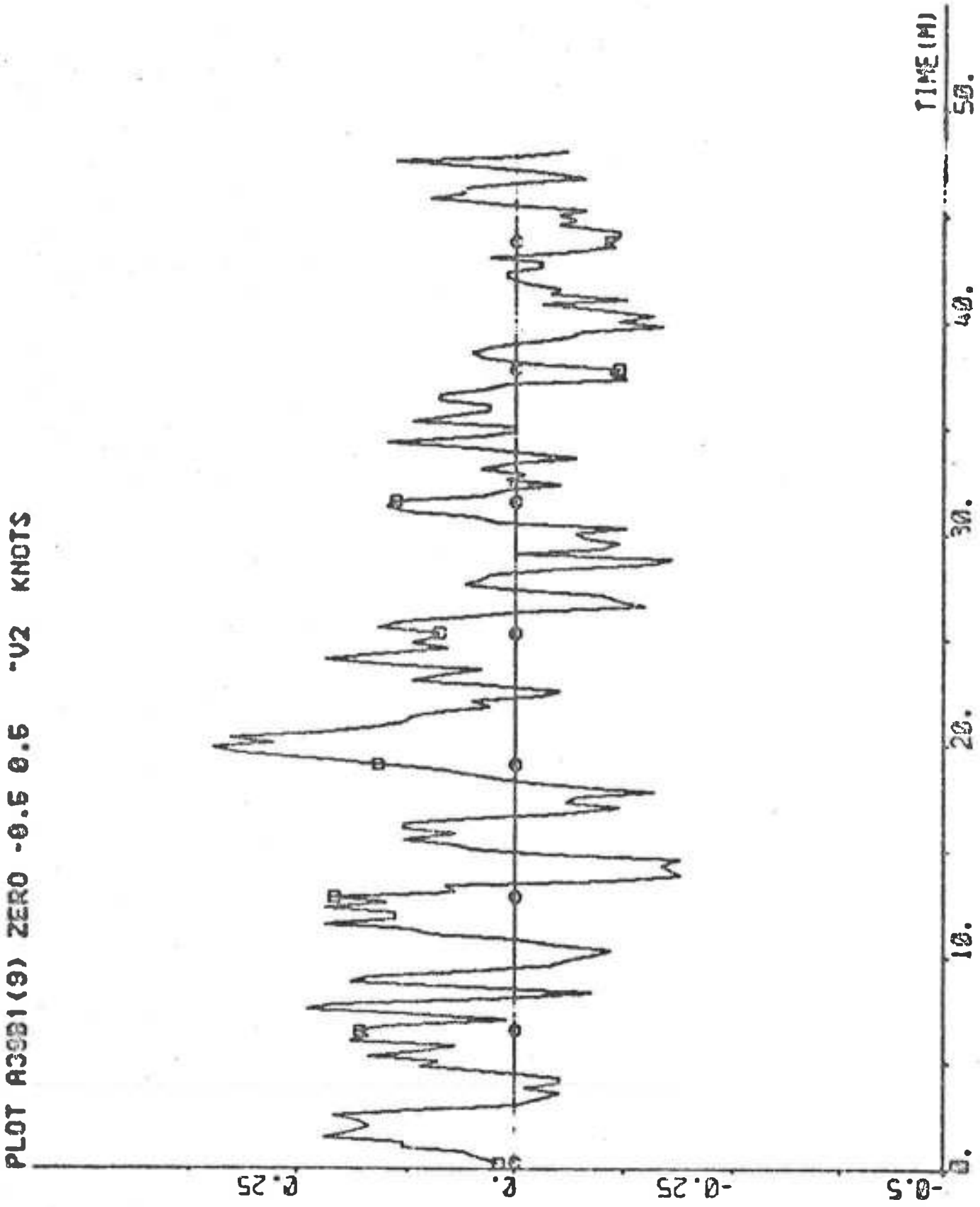

PLOT A3331(4) ZERO -10 10 °DELTA DEG
5.
0.
-5.
-10.
0.
10.
20.
30.
40.
50.
TIME(M)

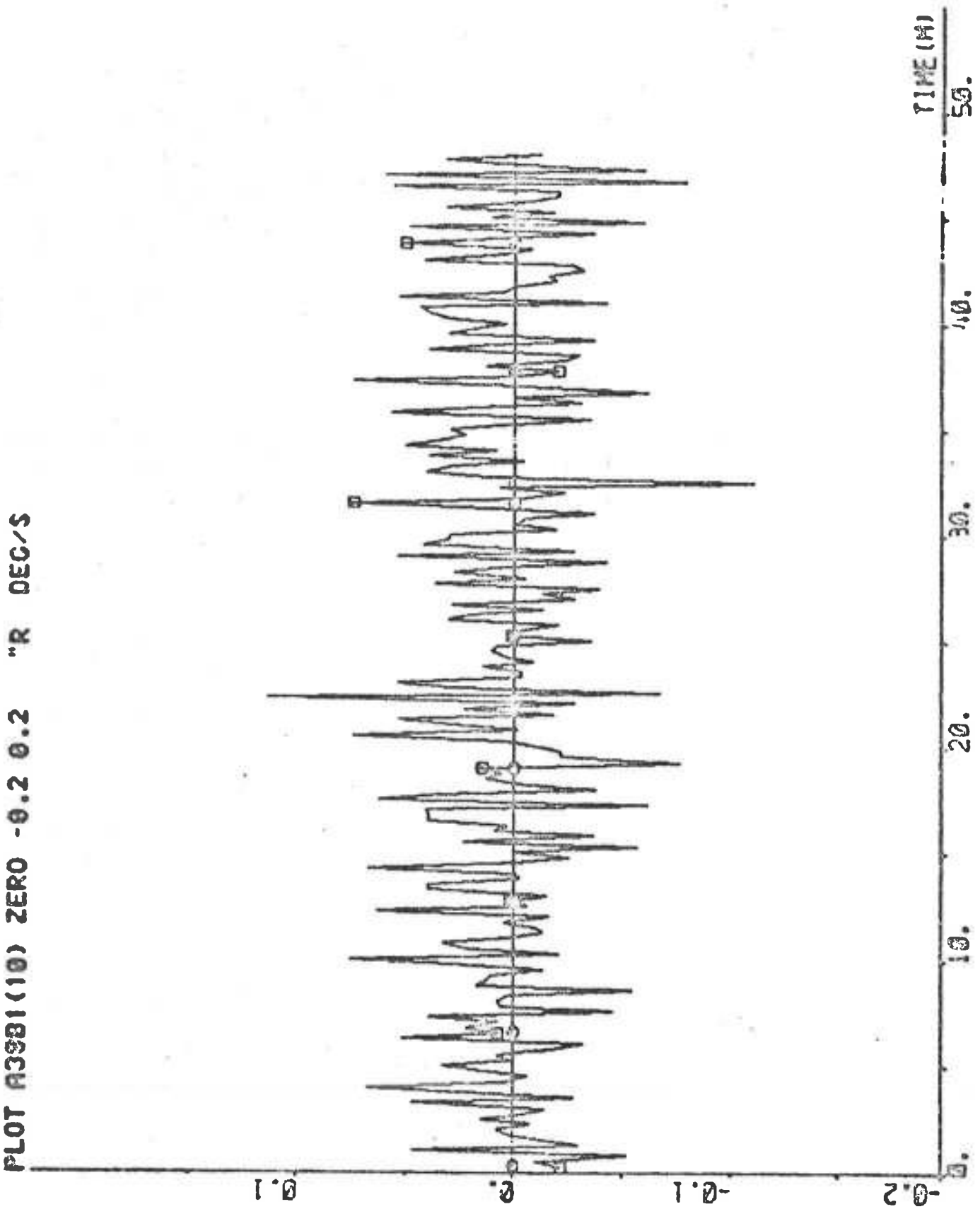

PLOT A39B1(5) ZERO -0.5 0.5 *PP DEG/S
0.25
0.
-0.25
-0.5
0.
10.
20.
30.
40.
50.
TIME(M)

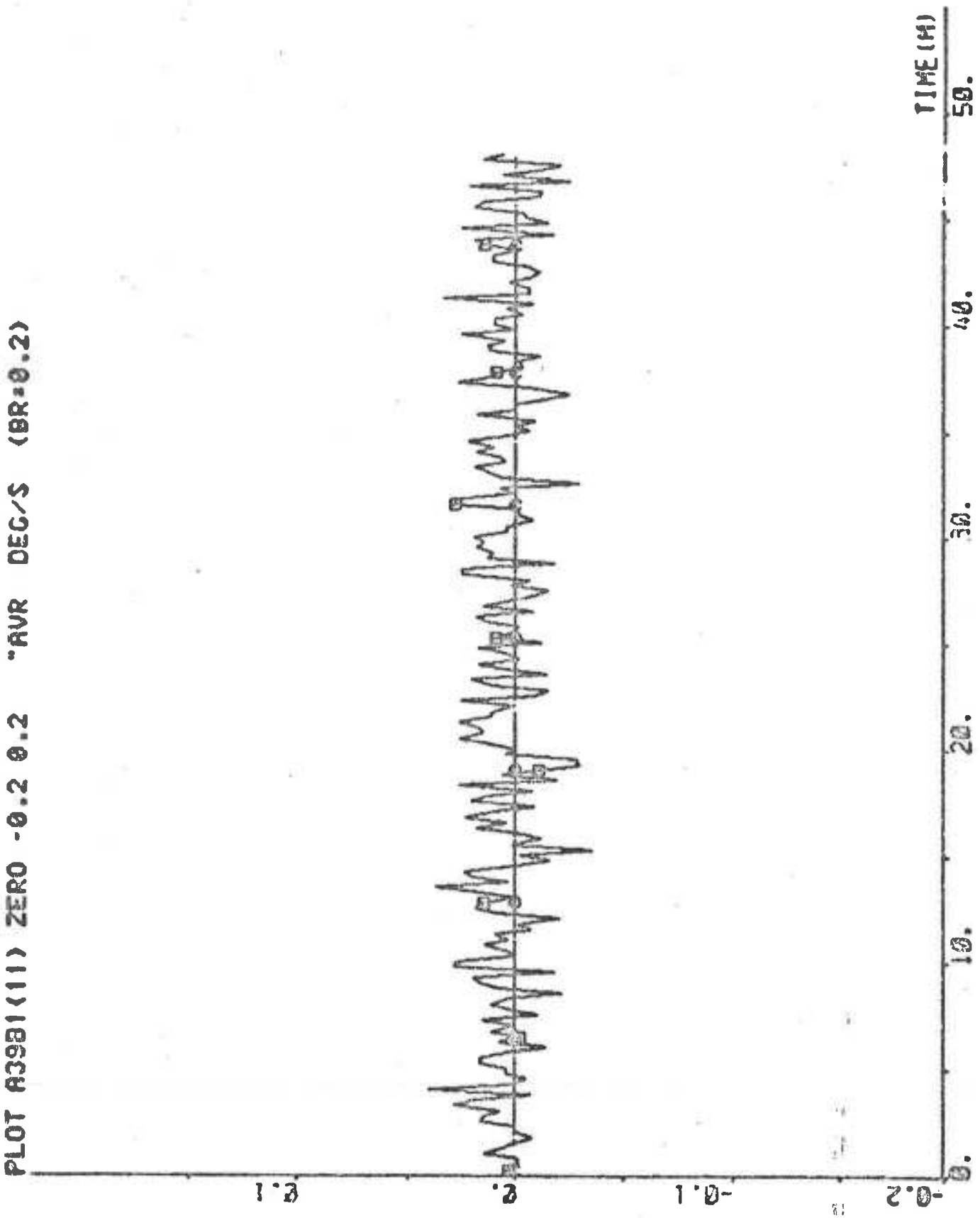

PLOT A3331(5) 60 69 *AN RPM
63.
64.
65.
0.
10.
20.
30.
40.
50.
TIME(M)

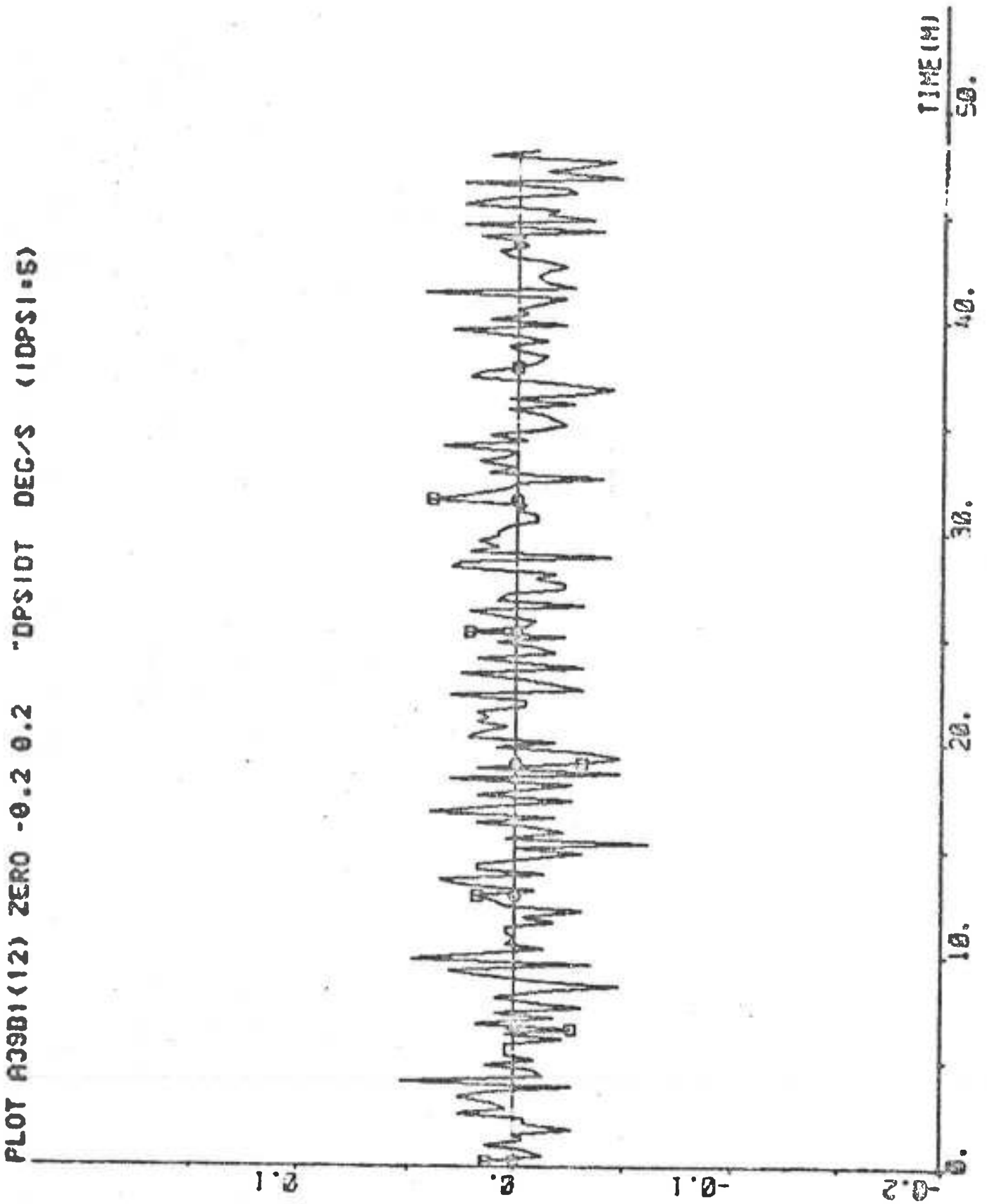

PLOT A39B1(7) 12 14 "U KNOTS
13.5
13.
12.5
12.
TIME(M)
0.
10.
20.
30.
40.
50.

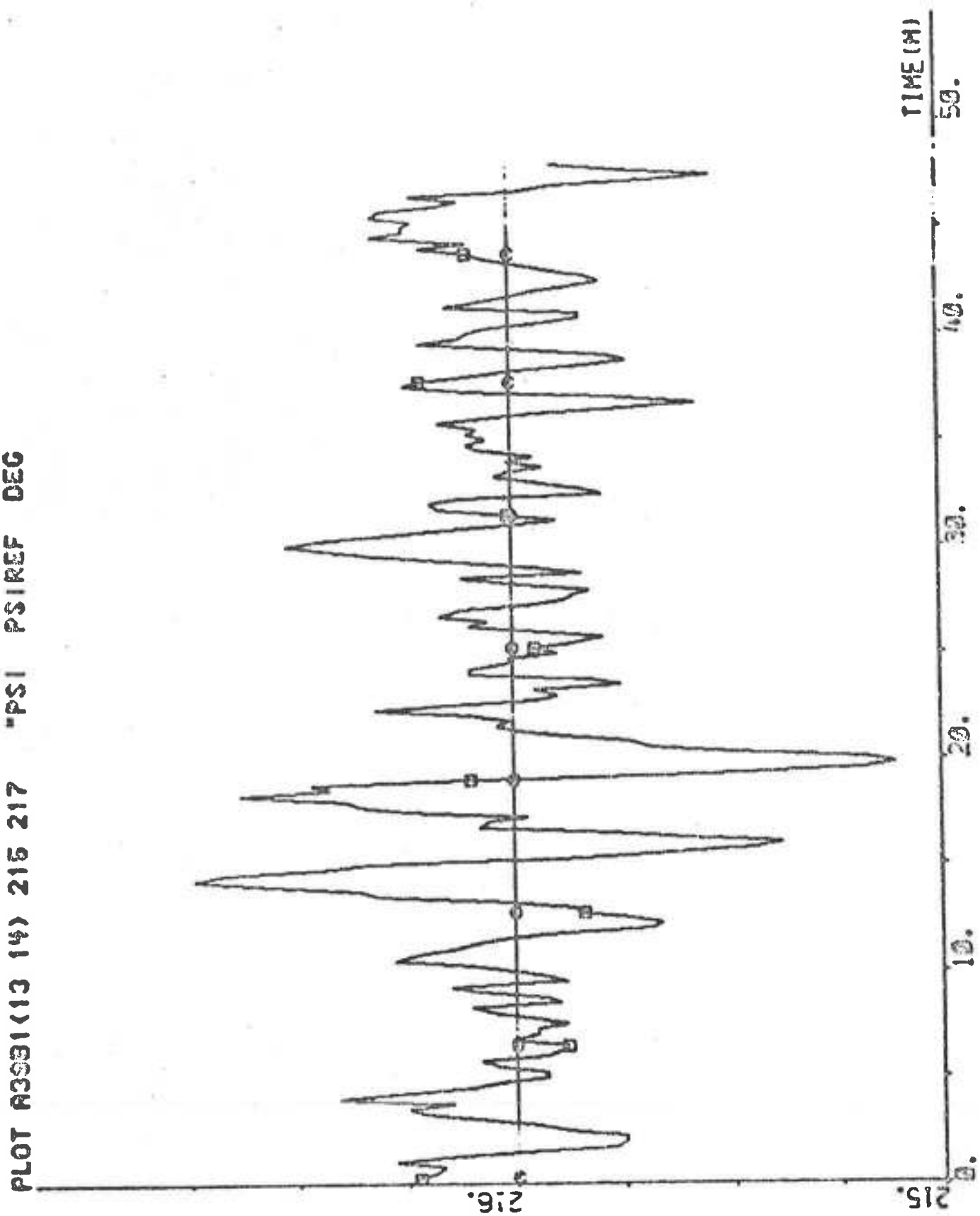

PLOT A3SB1(8) ZERO -0.5 0.5 "V1 KNOTS
0.25
0.
-0.25
-0.5
0.
10.
20.
30.
40.
50.
TIME(M)

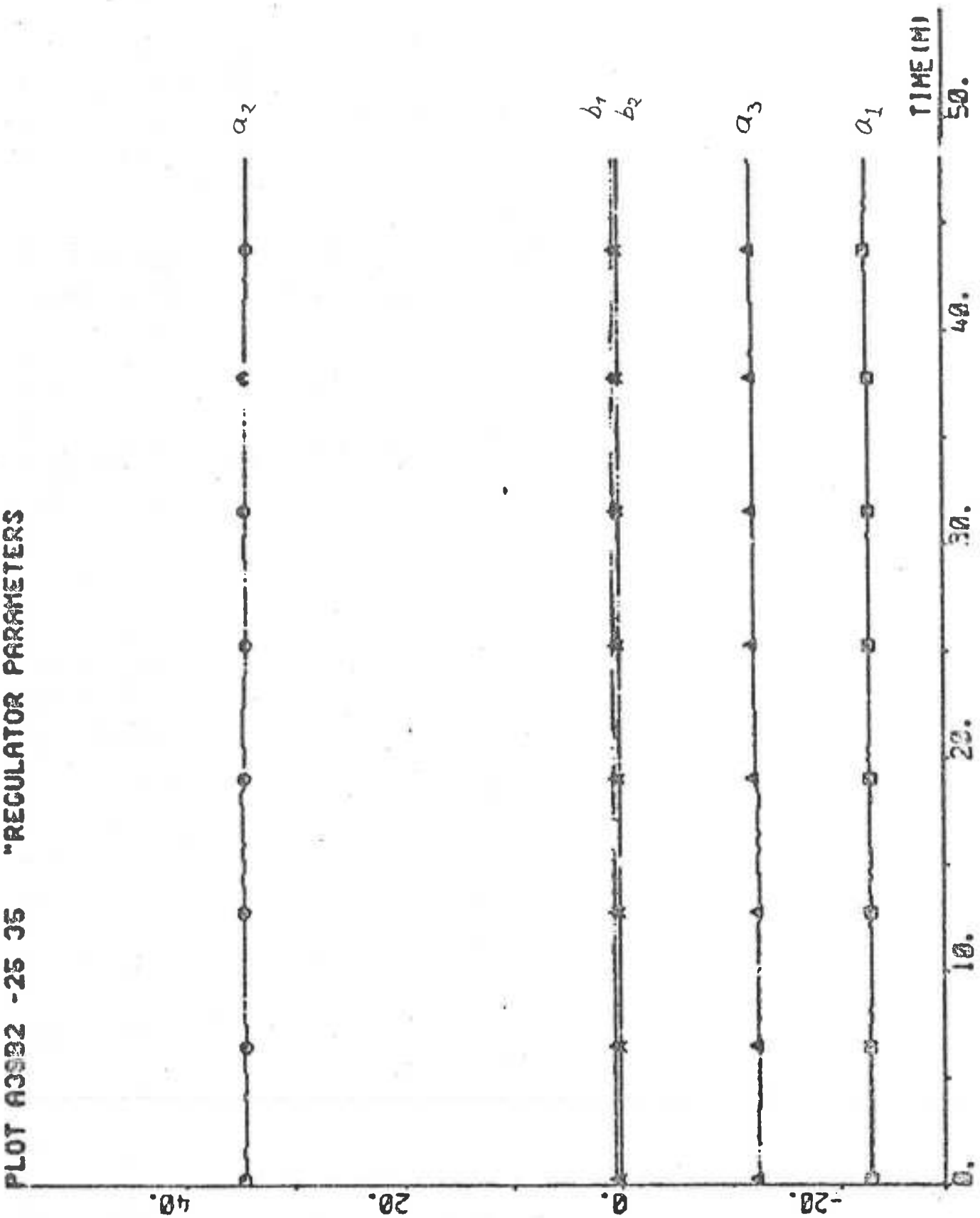

PLOT A3981(9) ZERO -0.5 0.5 'V2 KNOTS
0.25
0.
-0.25
-0.5
0.
10.
20.
30.
40.
50.
TIME(M)


PLOT A3981(10) ZERO -0.2 0.2 "R DEG/S
0.1
0.
-0.1
-0.2
0.
10.
20.
30.
40.
50.
TIME(M)


PLOT A3981(11) ZERO -0.2 0.2 "AVR DEG/S (BR=0.2)
0.2
0.1
0.0
-0.1
-0.2
0.
10.
20.
30.
40.
50.
TIME(M)


PLOT A39B1(12) ZERO -0.2 0.2 "DPSIDT DEG/S (IOPSI=5)
0.2
0.1
0.
-0.1
-0.2
0.
10.
20.
30.
40.
50.
TIME(M)


PLOT A393(13 14) 215 217 *PSI PSIREF DEG
216.
215.
0.
10.
20.
30.
40.
50.
TIME(M)


PLOT A3932 -25 35 "REGULATOR PARAMETERS
40.
20.
0.
-20.
0.
10.
20.
30.
40.
50.
TIME(M)
a_2
b_1
b_2
a_3
a_1

EXPERIMENT A40

Date	1974-10-22
Time	08.44
Duration	140 min
Position	S 31° 11' E 30° 26'
Water depth	deep
Forward draught	20.2 m
Aft draught	20.2 m
Wind direction	SSW (1; see Appendix A)
Wind velocity	4-5 Beaufort (6-10.5 m/s, moderate to fresh breeze)
Wave height	Rough sea from SSW
PSIREF	212.1° - 224.4° (Sailmaster, Course correction)
RREF	0.07 deg/s
Rudder limit	Probably active, but unknown
DELlM at termination	0.38°

The speed was increased during the experiment. The Sailmaster and the Course correction were switched on and off a couple of times, which resulted in course changes. MODYAW was equal to 1, 3 or 4 during all the yaws except during 40 s of the yaw after 121 min, when MODYAW was equal to 2.

Regulator structure

NA = 3 NB = 2 NC = 0 K = 5
IREG = 15 RL = 0.99

Final values

$$\begin{bmatrix} a_1 \\ a_2 \\ a_3 \\ b_1 \\ b_2 \end{bmatrix} = \begin{bmatrix} -20.825 \\ 32.393 \\ -12.147 \\ 0.719 \\ 0.198 \end{bmatrix} \qquad P = \begin{bmatrix} 0.374 & & & & \\ -0.454 & 1.027 & & & \\ 0.190 & -0.754 & 0.759 & & \\ -0.006 & -0.011 & 0.023 & 0.002 & \\ -0.003 & -0.018 & 0.025 & 0.001 & 0.002 \end{bmatrix}$$

$a_1 + a_2 + a_3 = -0.579$

Yaw regulator structure

NAY = 3 NBY = 2 KY = 2
IREGY = 10 RLY = 0.95 IRR = 3 IDPSI = 5
AK1V = 40 AK2V = 1.8 AK3V = 120
C1V = 10 C2V = 80
EPS1V = 0.02 EPS2V = 0.03
PSISV = 0.15 PSISSV = 1.5 PSIMAV = 0.3
I1MV = 60 I2MV = 300 I3MV = 150

Initial yaw regulator values

$$\begin{bmatrix} a'_1 \\ a'_2 \\ a'_3 \\ b'_1 \\ b'_2 \end{bmatrix} = \begin{bmatrix} -43.56 \\ 4.94 \\ 0.90 \\ 1.30 \\ 0.81 \end{bmatrix} \qquad PY = \begin{bmatrix} 500 & & & & \\ 0 & 500 & & & \\ 0 & 0 & 500 & & \\ 0 & 0 & 0 & 1 & \\ 0 & 0 & 0 & 0 & 1 \end{bmatrix}$$

$a'_1 + a'_2 + a'_3 = -37.72$

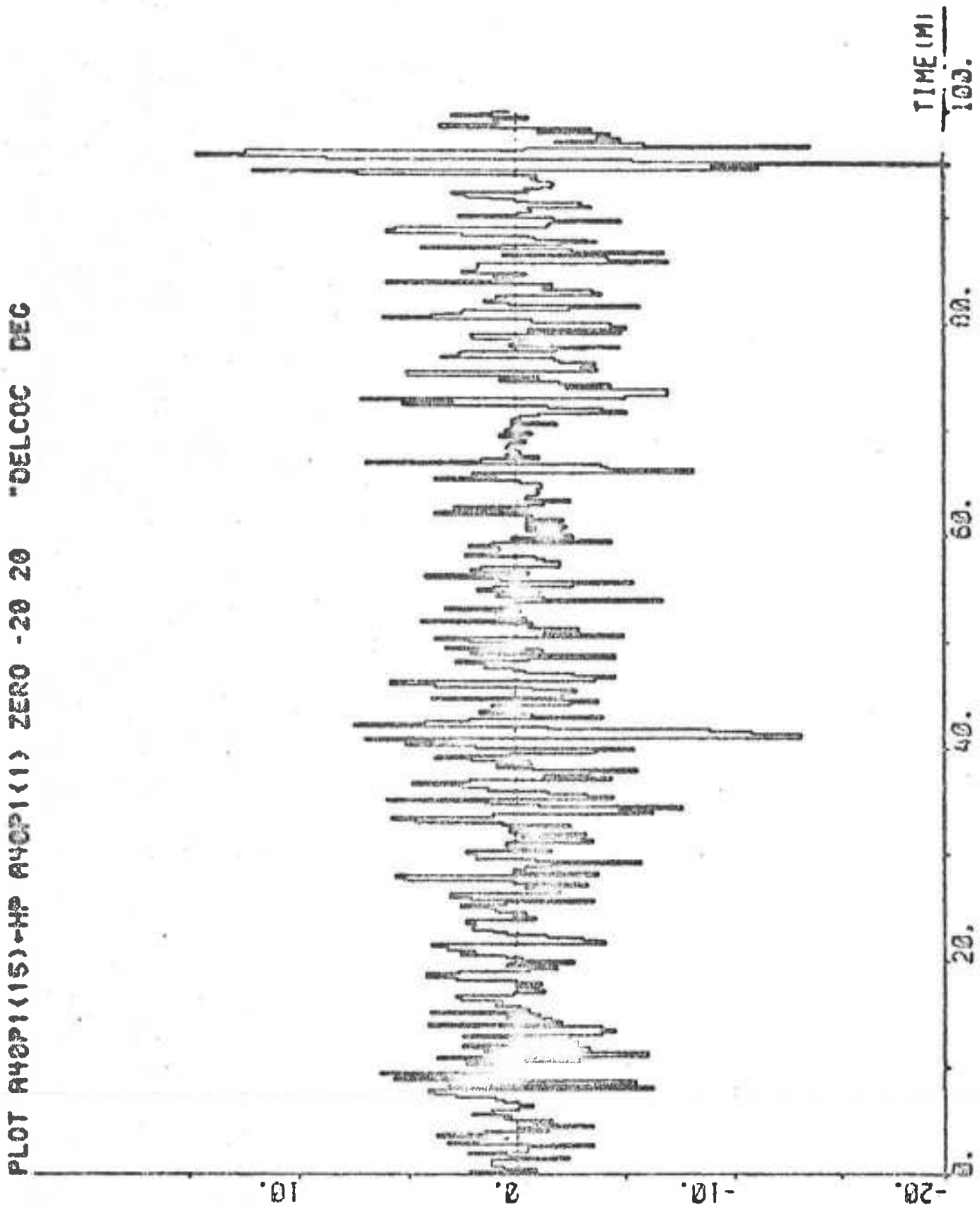
Yaw regulator values after the yaw at 121 min.

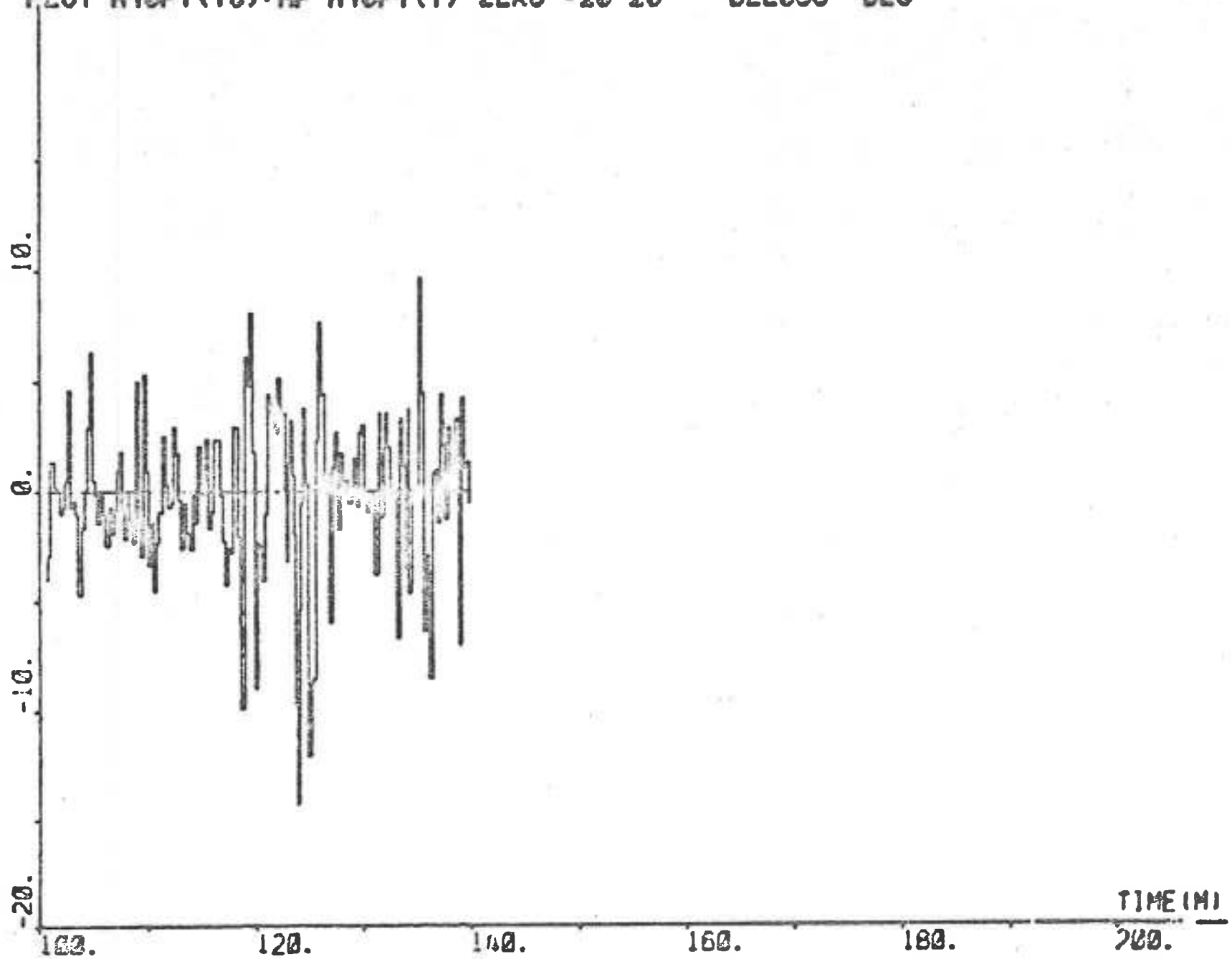
$$\begin{bmatrix} a_1' \\ a_2' \\ a_3' \\ b_1' \\ b_2' \end{bmatrix} = \begin{bmatrix} -43.203 \\ 4.940 \\ 0.900 \\ 1.300 \\ 0.810 \end{bmatrix} \qquad PY = \begin{bmatrix} 212.960 & & & & \\ 0 & 613.869 & & & \\ 0 & 0 & 613.869 & & \\ 0 & 0 & 0 & 1.228 & \\ 0 & 0 & 0 & 0 & 1.228 \end{bmatrix}$$

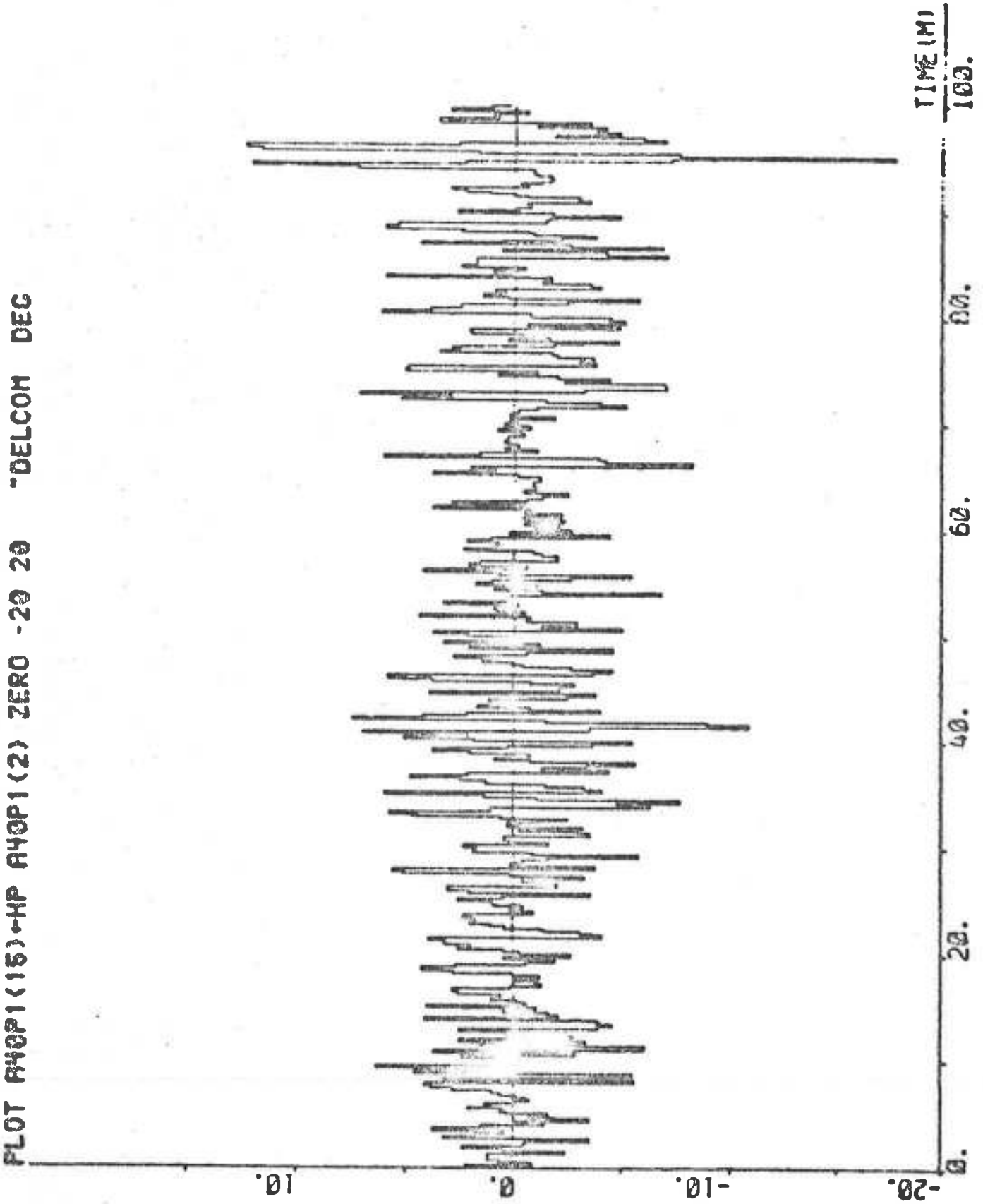
$a_1' + a_2' + a_3' = -37.363$

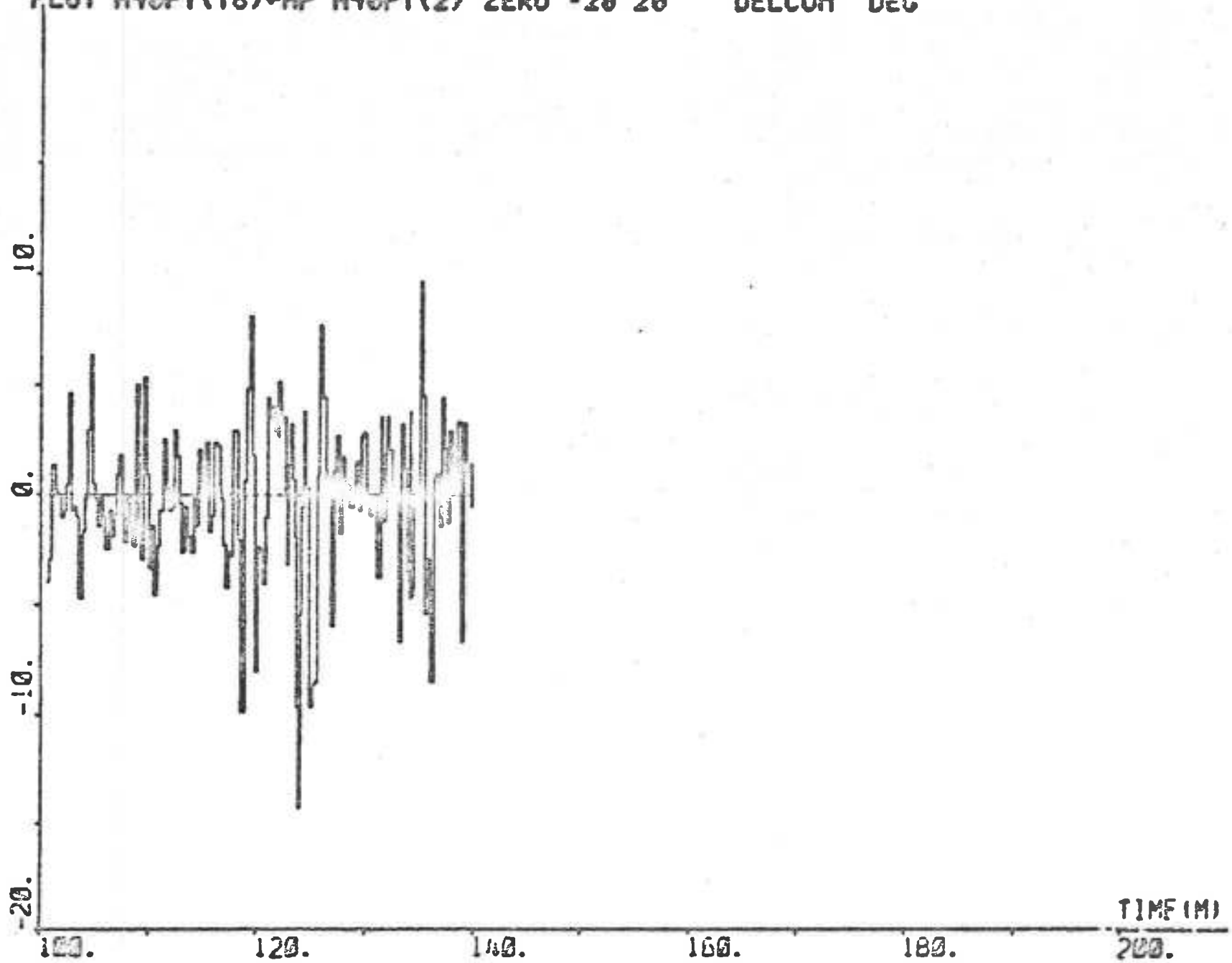
Statistics (mean value and standard deviation)

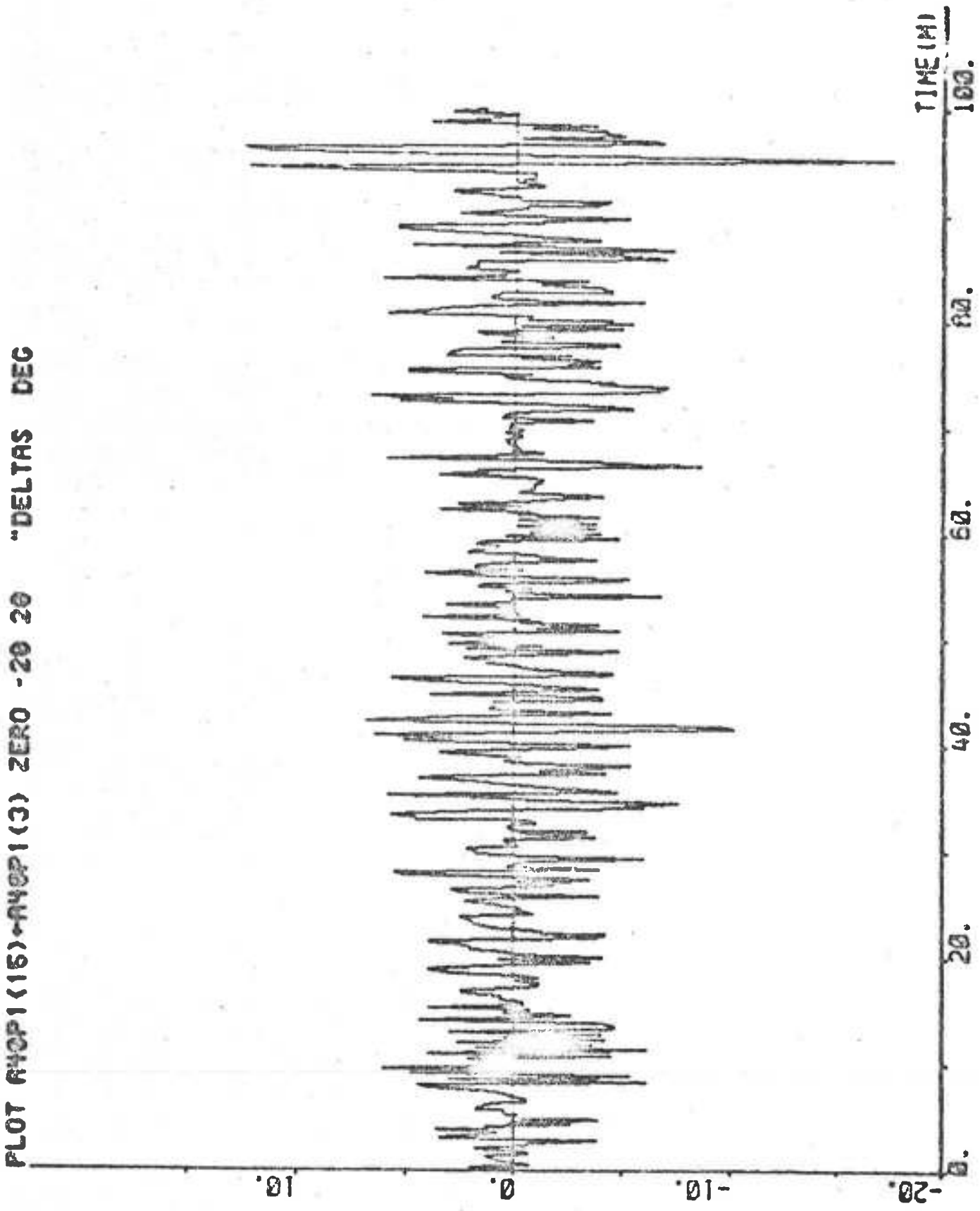
	0-120 min
DELTA	1.10 ± 3.04 deg
PSI-PSIREF	0.183 ± 0.555 deg
AN	78.98 ± 3.37 rpm
U	15.51 ± 1.11 knots
V_1	1.387
V_2	1.266

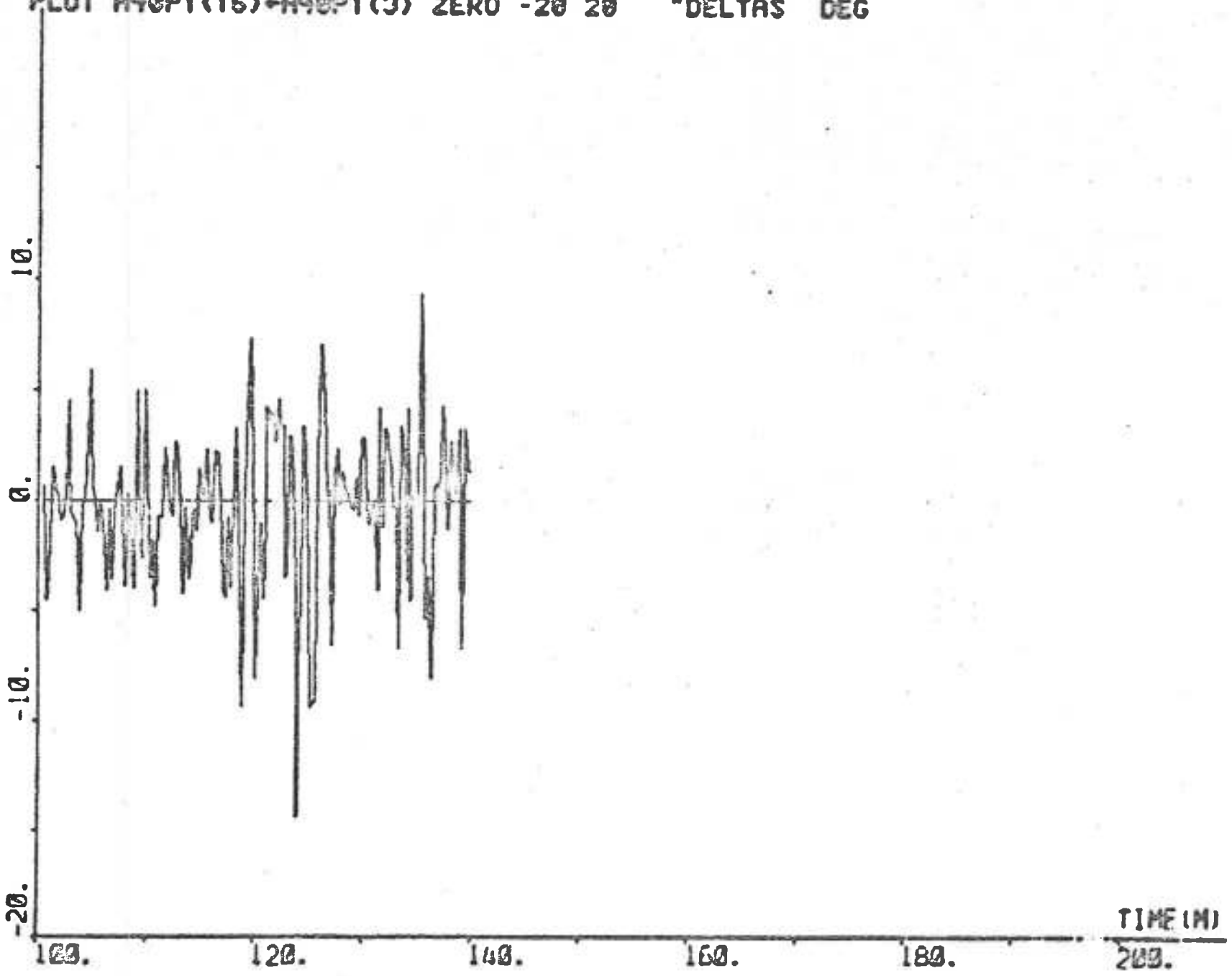

PLOT A40P1(15)-HP A40P1(1) ZERO -20 20 "DELCOC DEC
TIME(MI
100.
80.
60.
40.
20.
0.
10.
0.
-10.
-20.

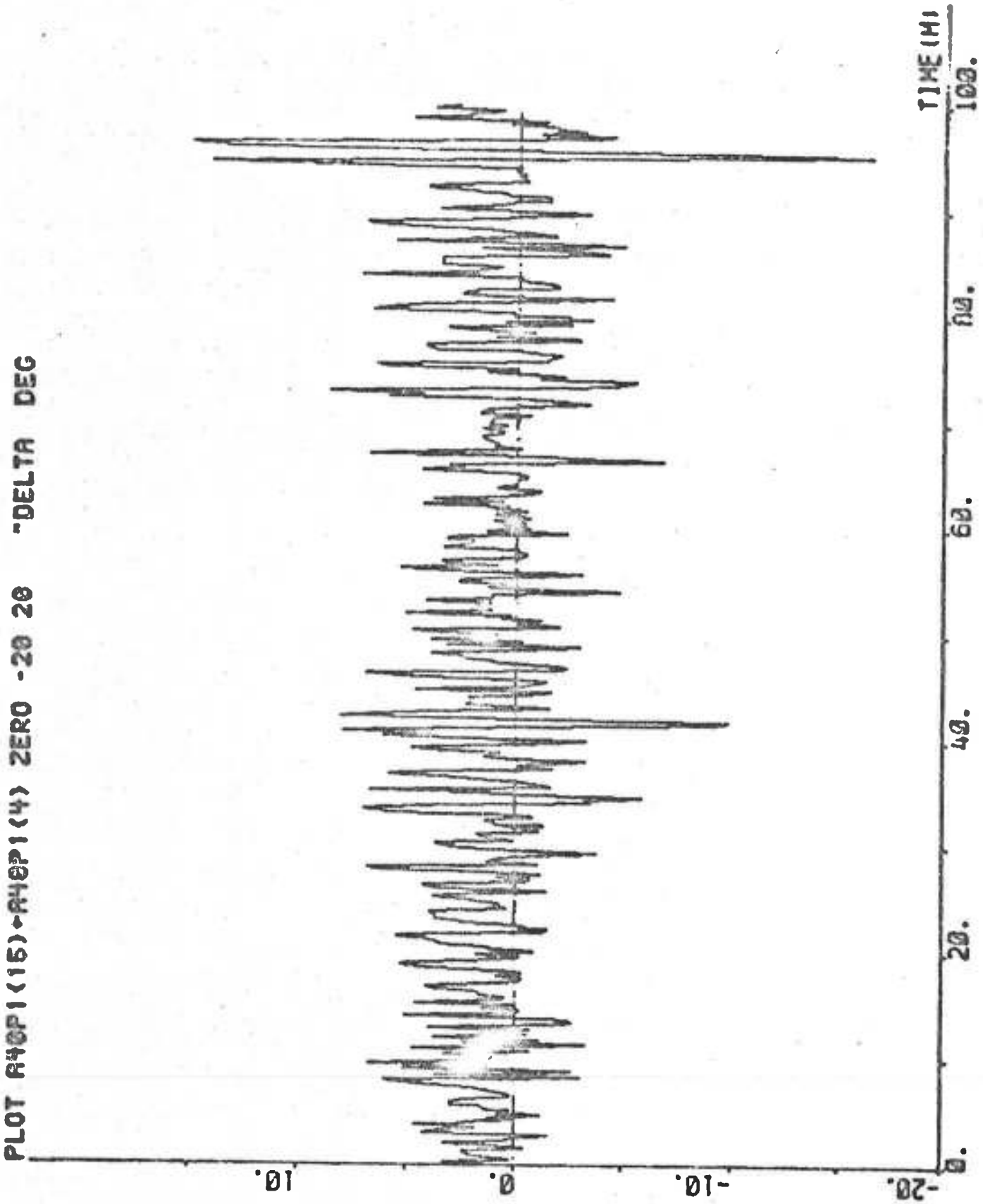

PLOT A40P1(15)-HP A40P1(1) ZERO -20 20 "DELCOC DEG
10.
0.
-10.
-20.
100.
120.
140.
160.
180.
200.
TIME(MI

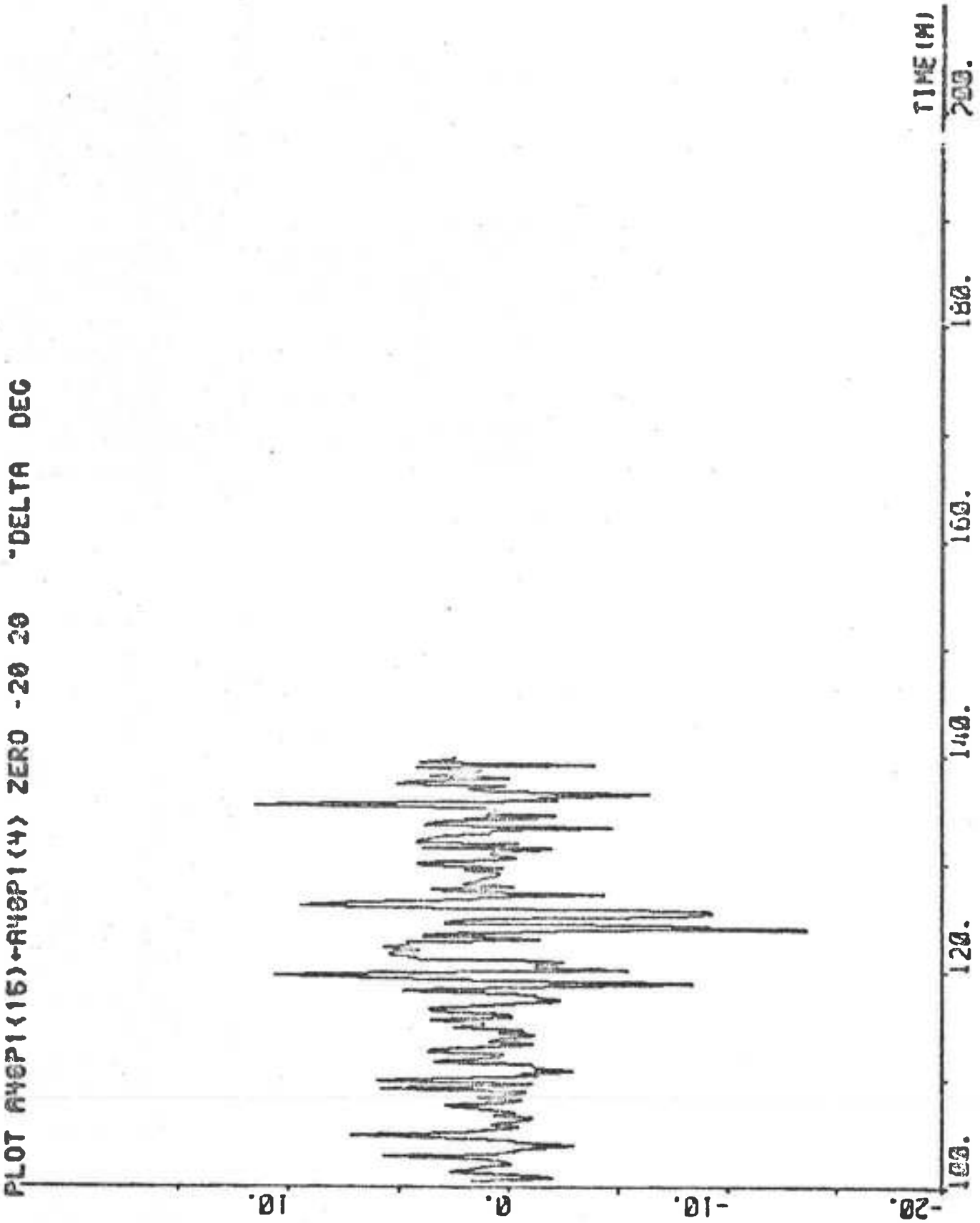

PLOT A40P1(15)+HP A40P1(2) ZERO -20 20 'DELCOM DEG
TIME(M)
100.
80.
60.
40.
20.
0.
10.
0.
-10.
-20.

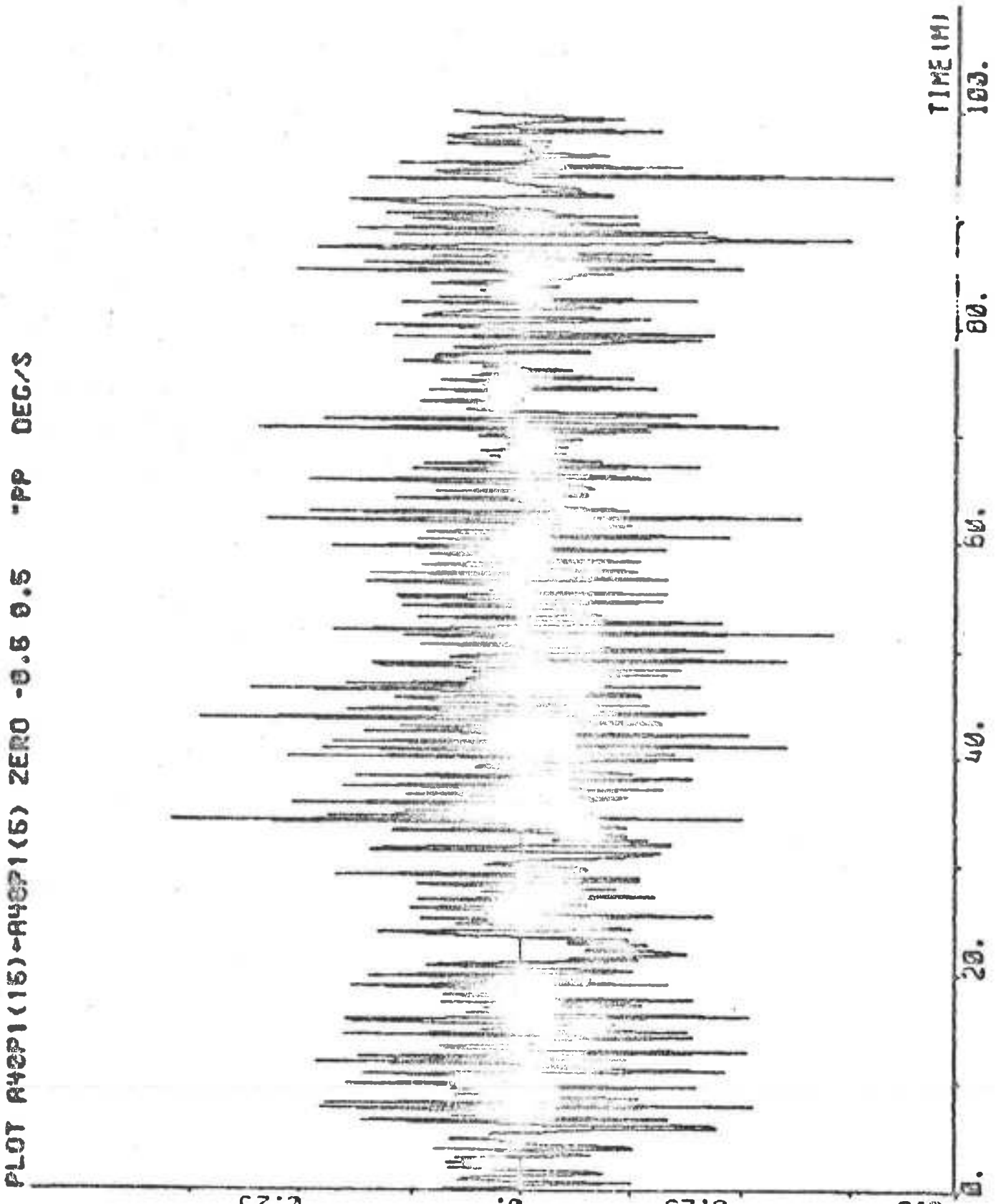

PLOT A40P1(15)+HP A40P1(2) ZERO -20 20 "DELCOM DEG
10.
0.
-10.
-20.
TIME(M)
100.
120.
140.
160.
180.
200.

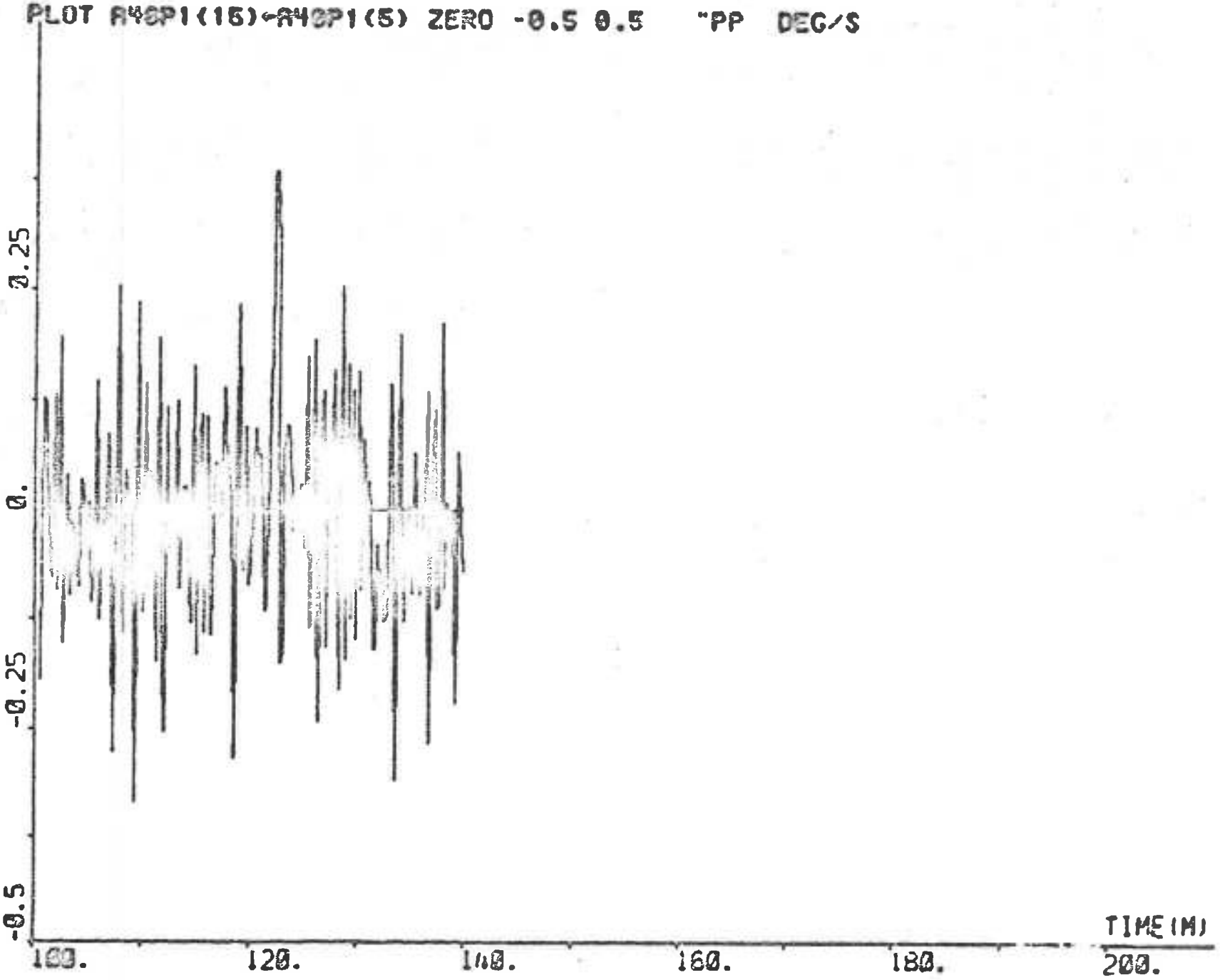

PLOT AHOP1(15)-AHOP1(3) ZERO -20 20 "DELTAS DEC
10.
0.
-10.
-20.
0.
20.
40.
60.
80.
100.
TIME(M)

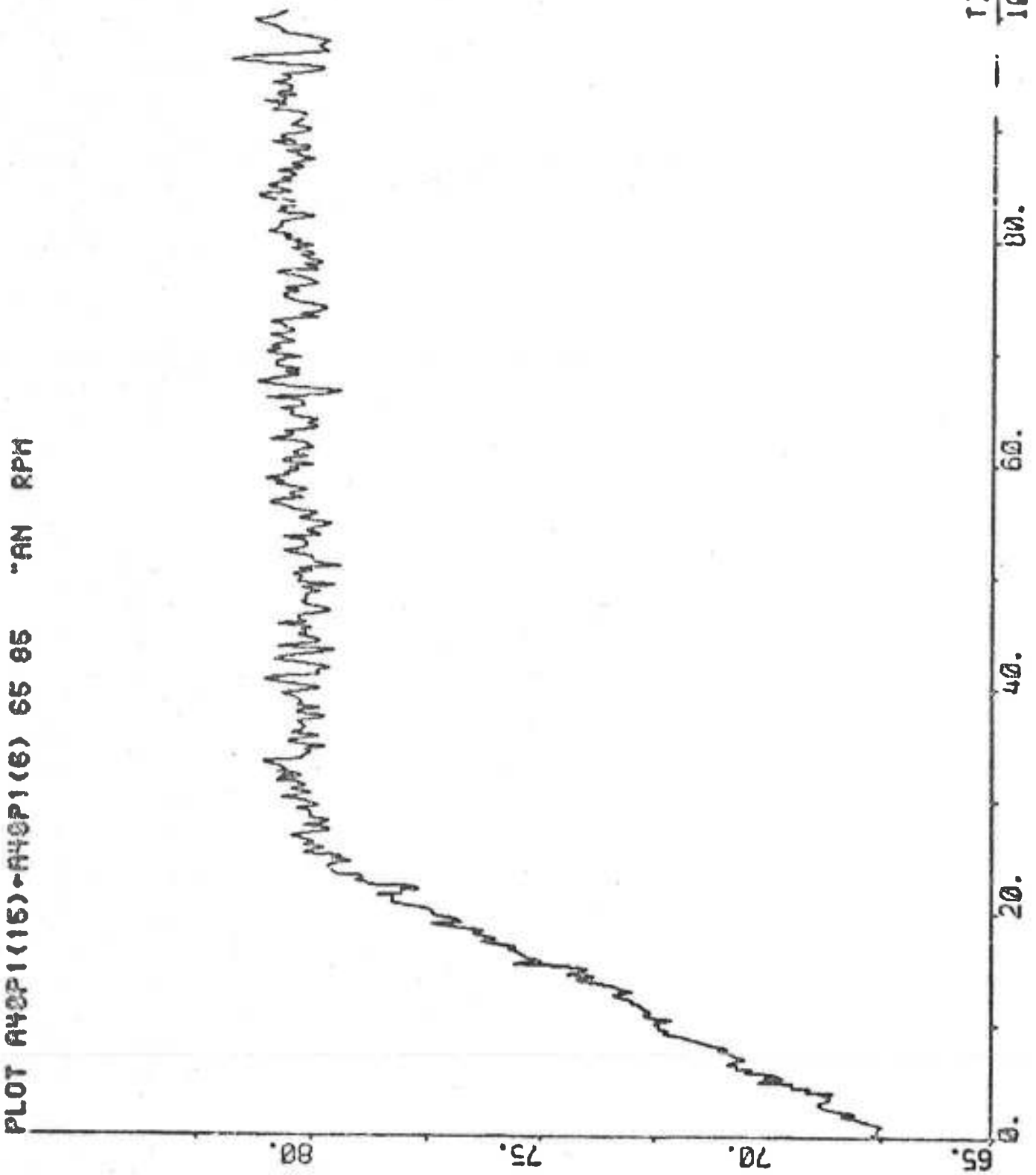

PLOT A40P1(15)-A40P1(3) ZERO -20 20 "DELTAS DEG
10.
0.
-10.
-20.
100.
120.
140.
160.
180.
200.
TIME(M)

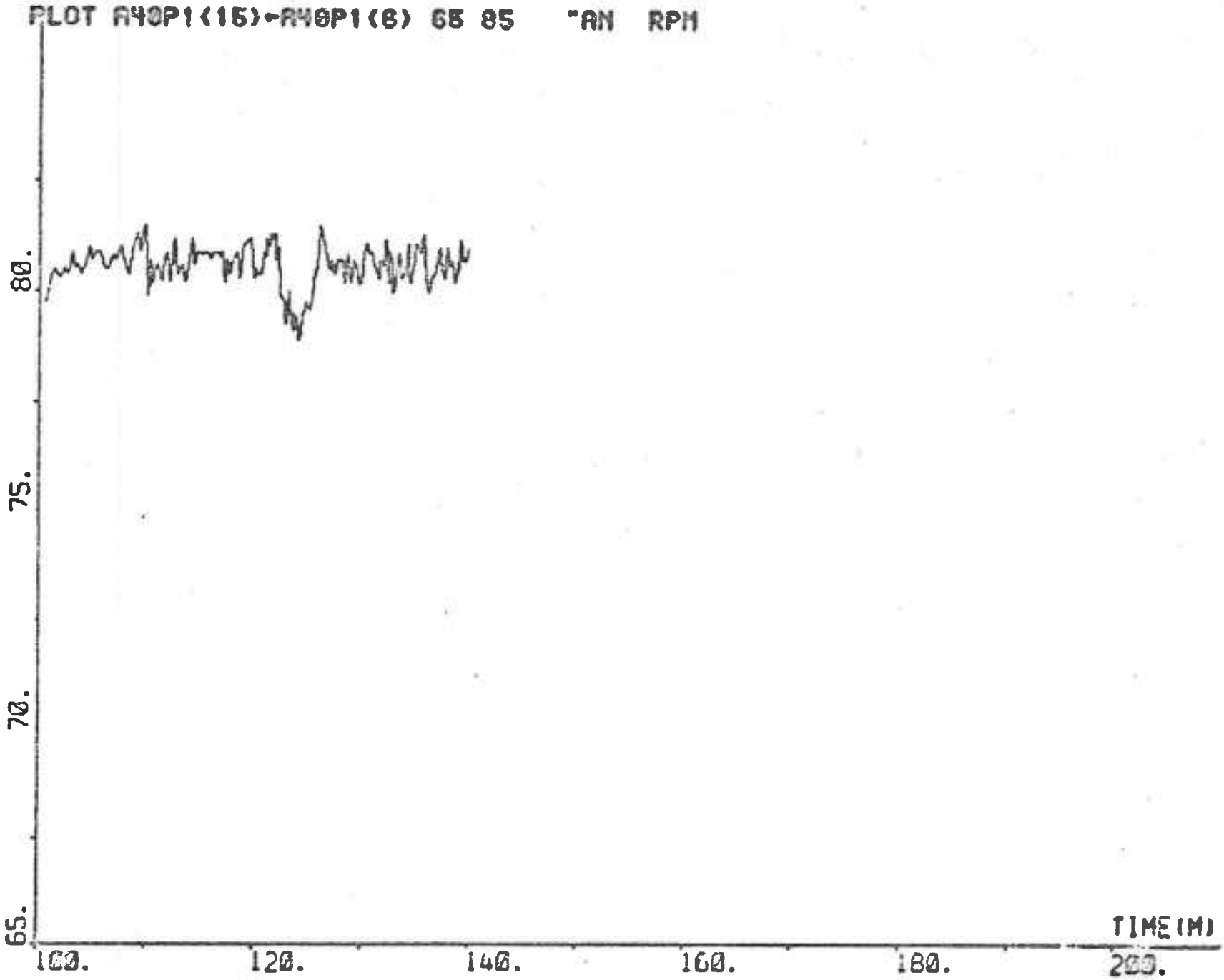

PLOT AHDP1(15)-AHDP1(4) ZERO -20 20 "DELTA DEG
TIME(M)
0.
20.
40.
60.
80.
100.
-20.
-10.
0.
10.


PLOT AYGP1(16)-AYGP1(4) ZERO -20 20 'DELTA DEG
10.
0.
-10.
-20.
100.
120.
140.
160.
180.
200.
TIME(M)

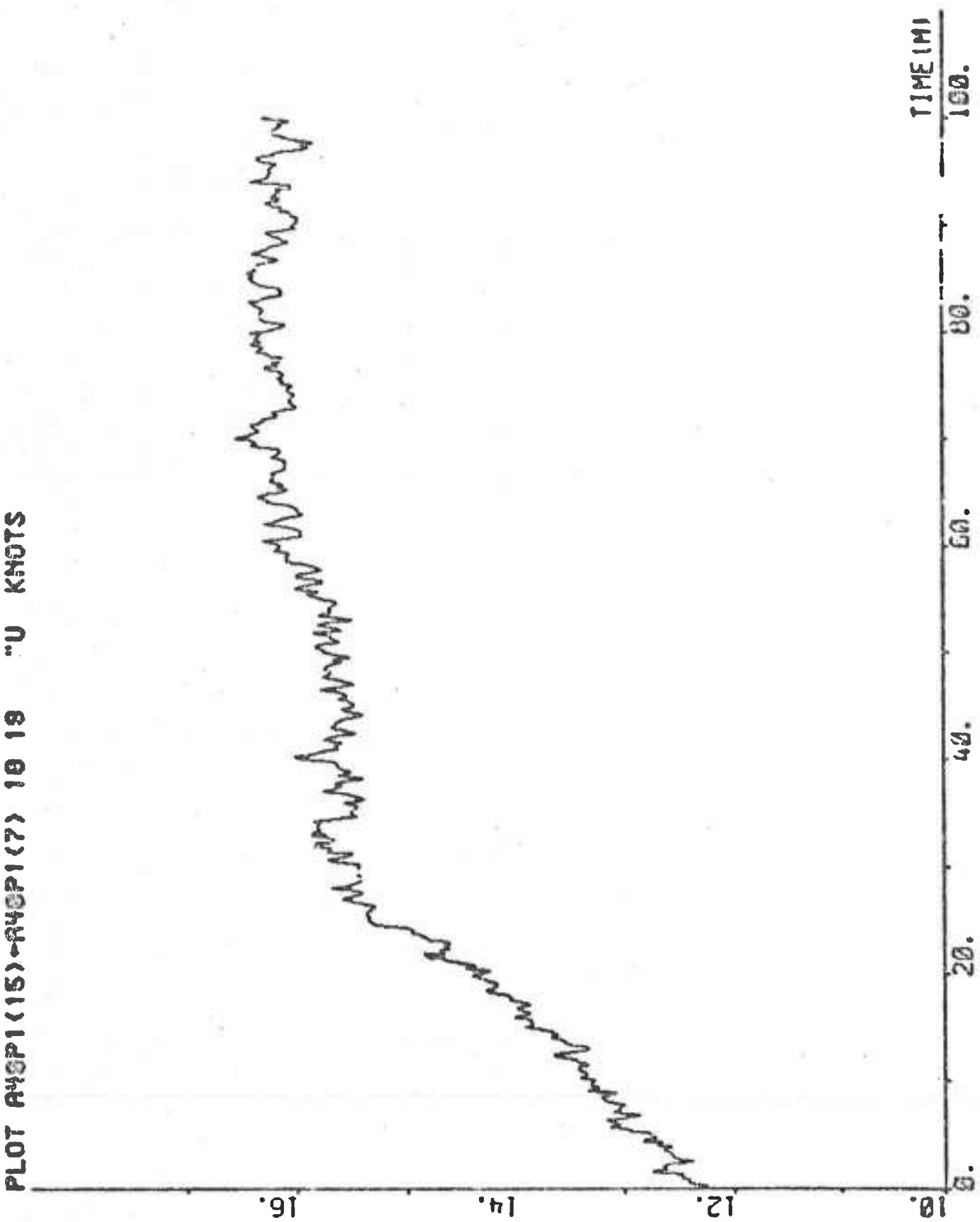

PLOT A42P1(15)-A42P1(5) ZERO -0.8 0.5 "PP DEG/S
0.25
0.
-0.25
-0.5
TIME(M)
0.
20.
40.
60.
80.
100.

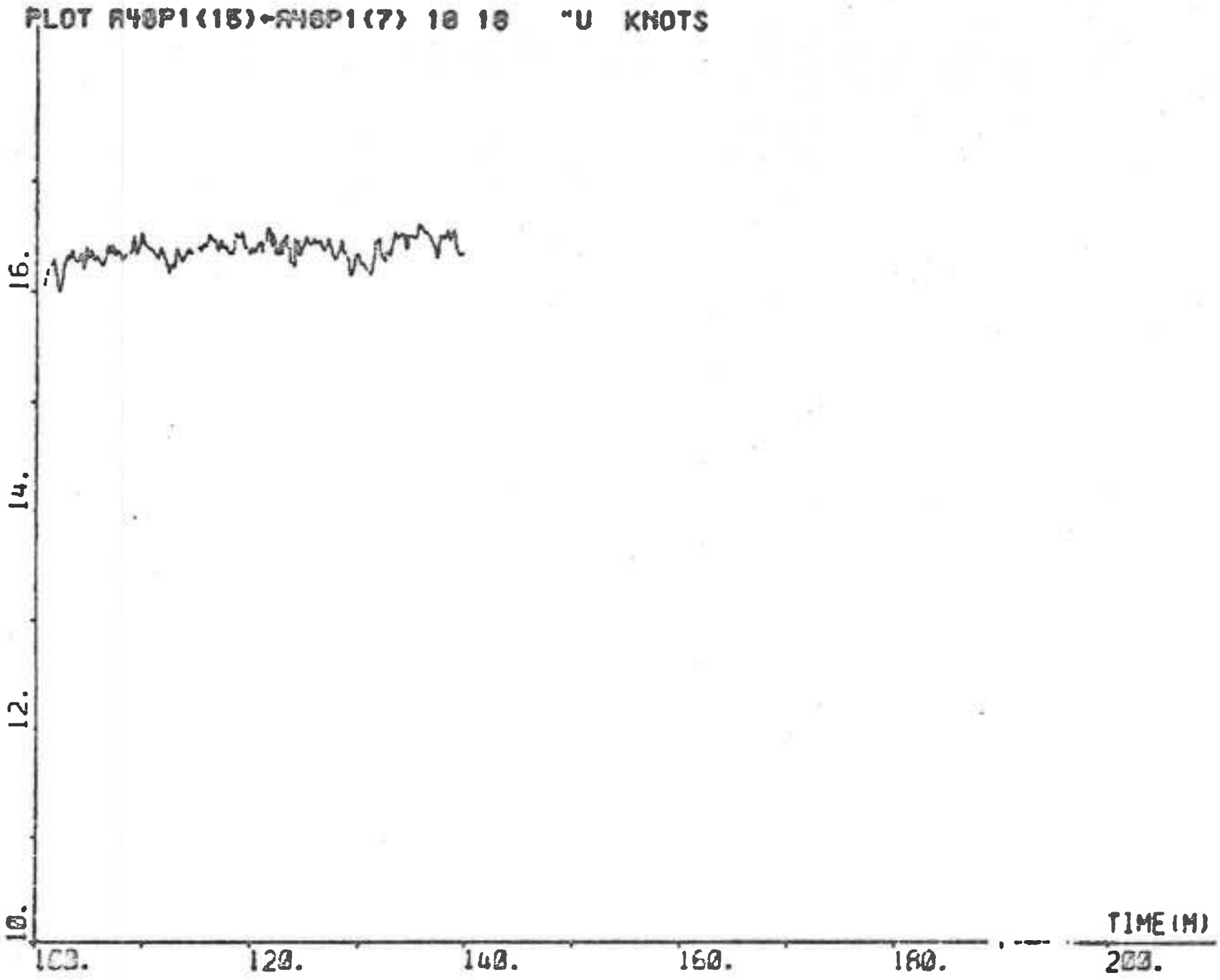

PLOT A40P1(15)-A40P1(5) ZERO -0.5 0.5 "PP DEG/S
0.25
0.
-0.25
-0.5
100.
120.
140.
160.
180.
200.
TIME(M)

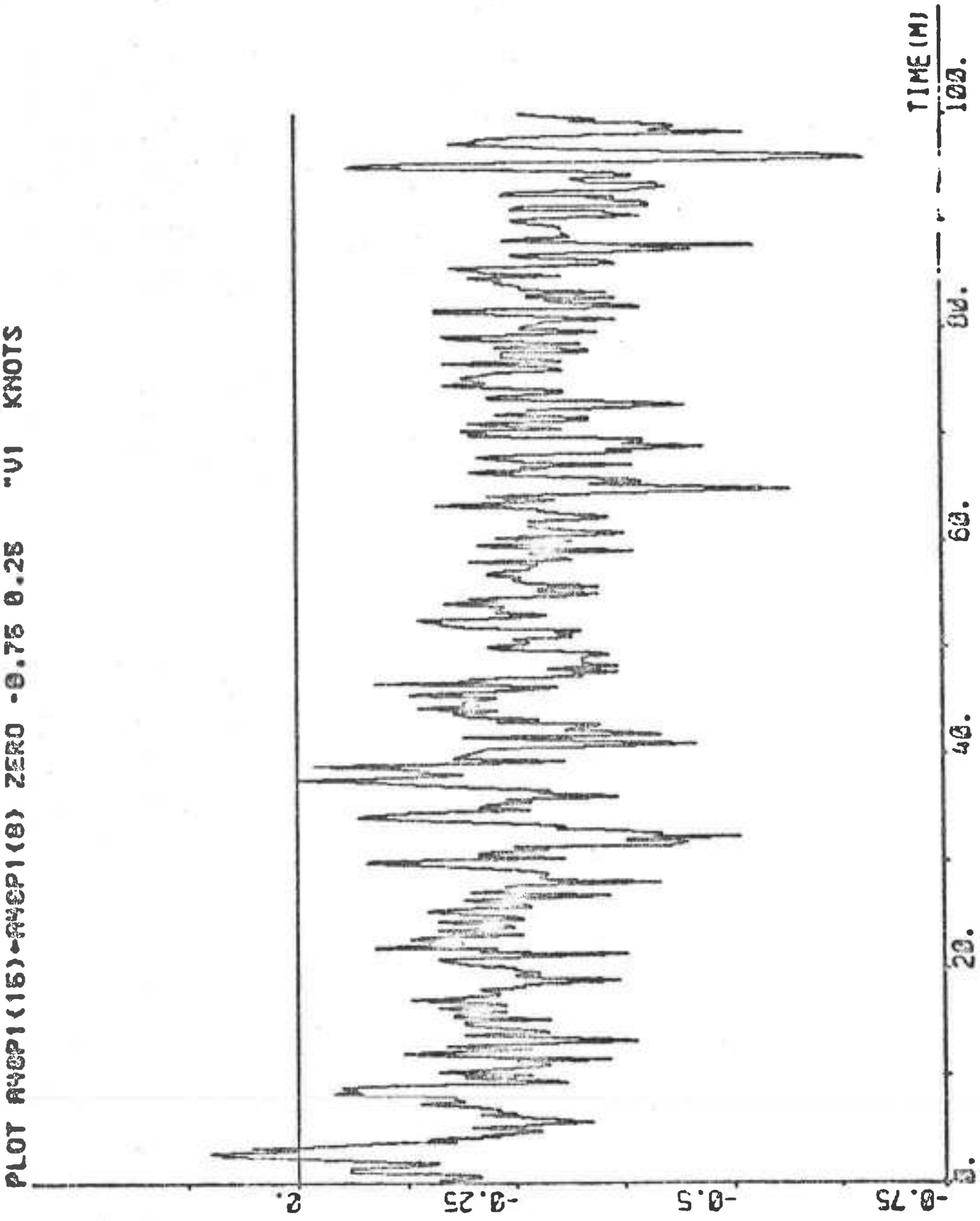

PLOT A42P1(15)-A40P1(8) 65 85 "AN RPM
65.
70.
75.
80.
0.
20.
40.
60.
80.
100.
TIME(M)

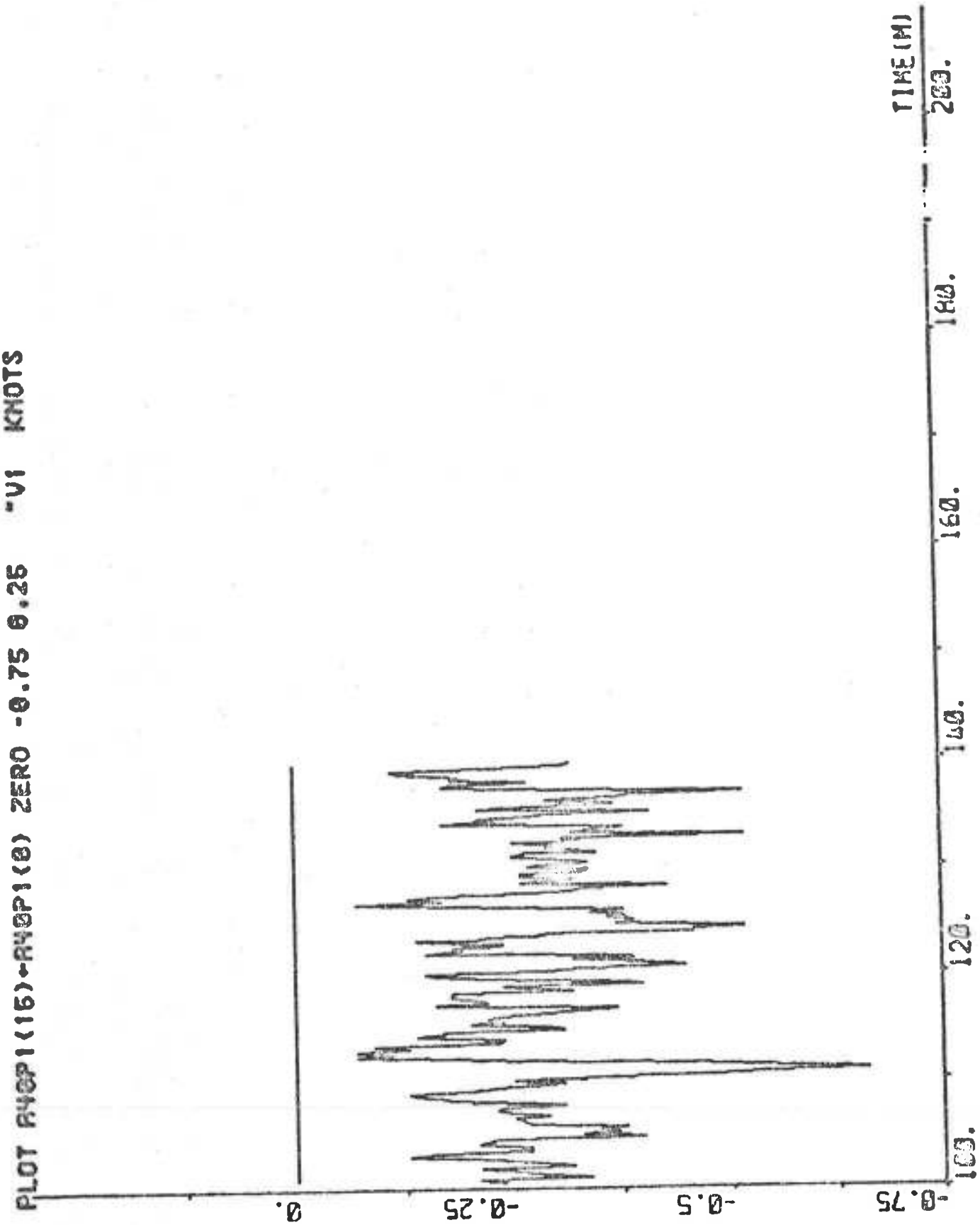

PLOT R40P1(15)-R40P1(8) 65 85 "RN RPM
80.
75.
70.
65.
TIME(M)
100.
120.
140.
160.
180.
200.

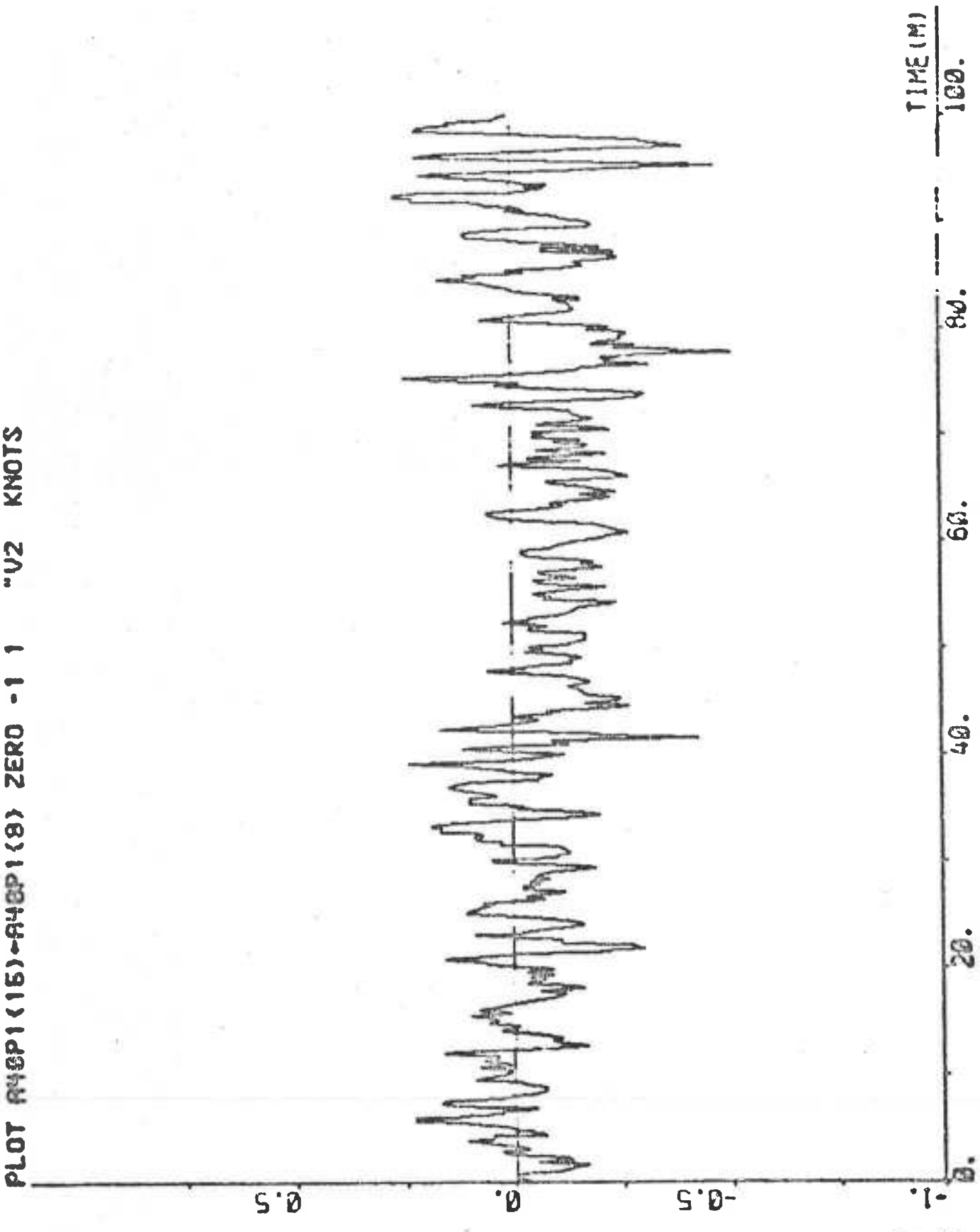
.809

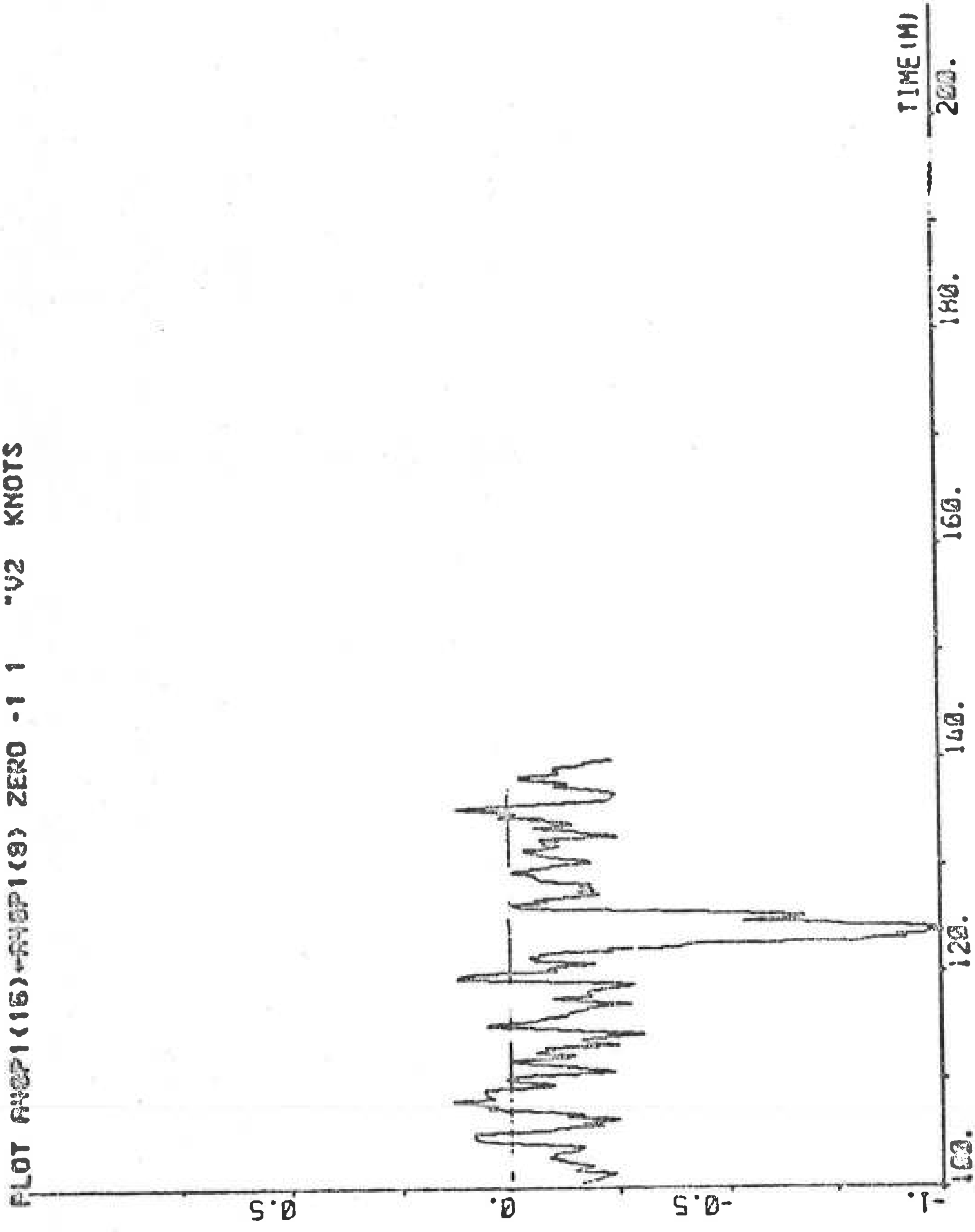

PLOT A43P1(15)-A43P1(7) 10 10 "U KNOTS
TIME(MI
0.
20.
40.
60.
80.
100.
10.
12.
14.
16.

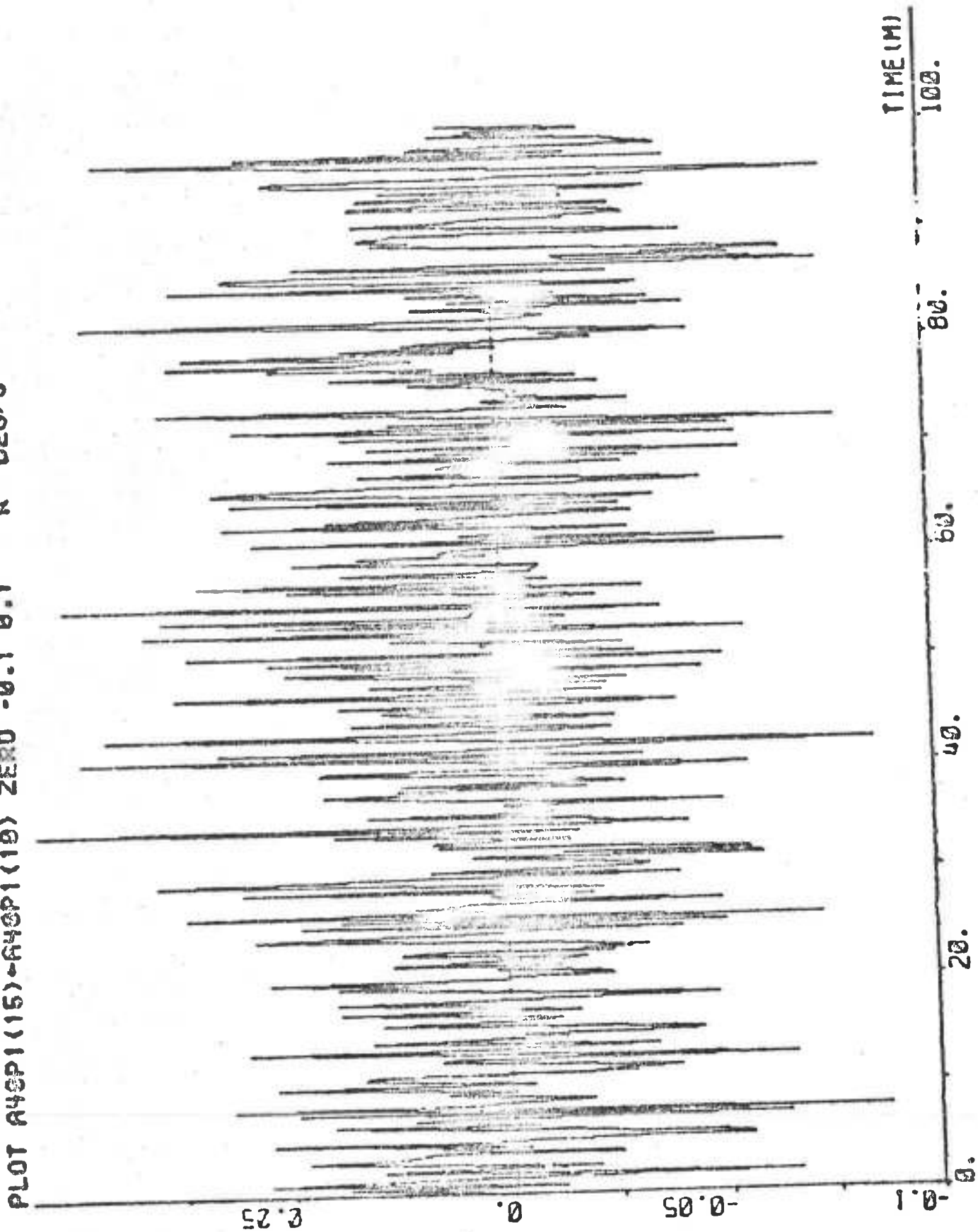

PLOT R48P1(15)-R48P1(7) 10 10 "U KNOTS
16.
14.
12.
10.
TIME(M)
100.
120.
140.
160.
180.
200.

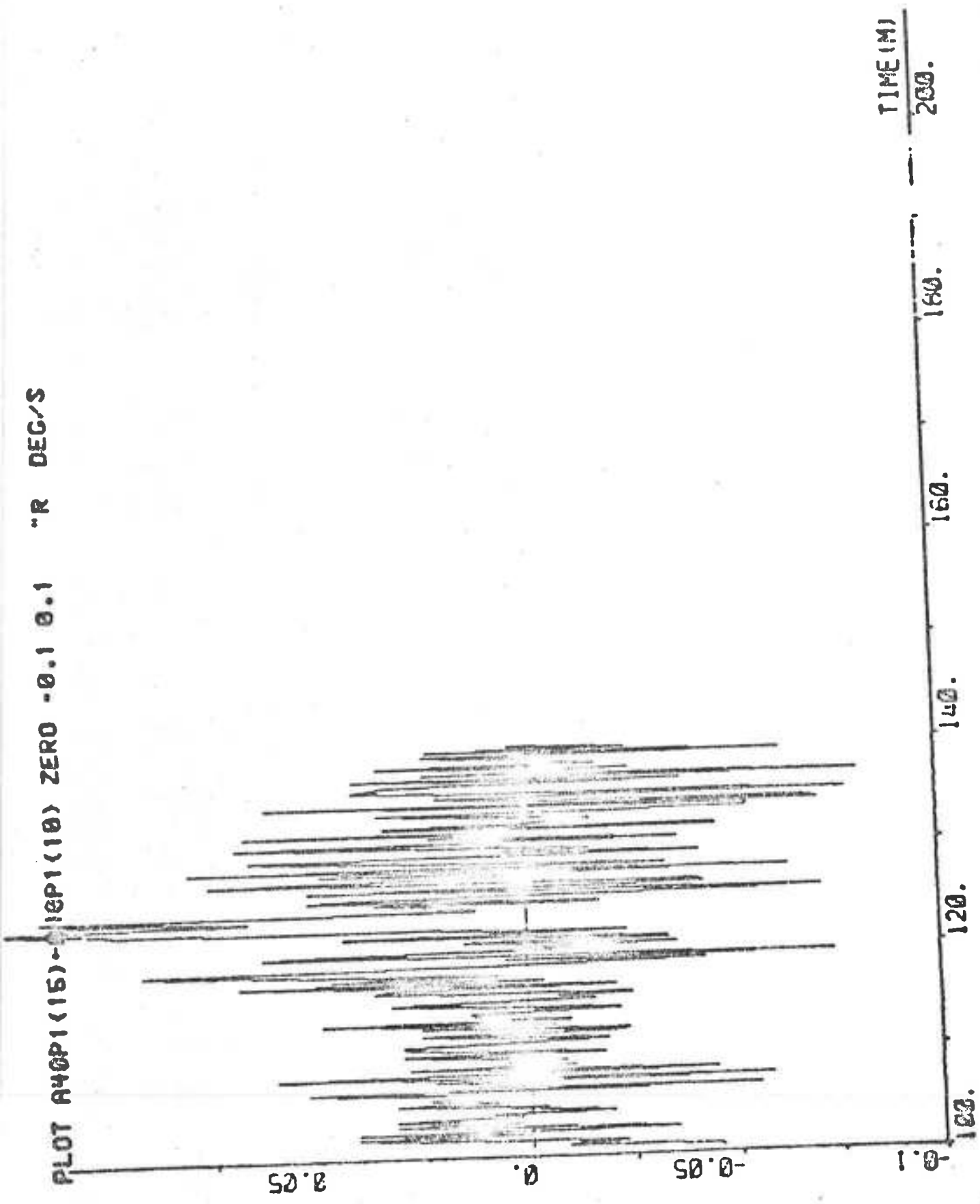

PLOT A40P1(15)-A40P1(8) ZERO -0.75 0.25 "V1 KNOTS
TIME(M)
0.
20.
40.
60.
80.
100.
-0.75
-0.5
-0.25
0.

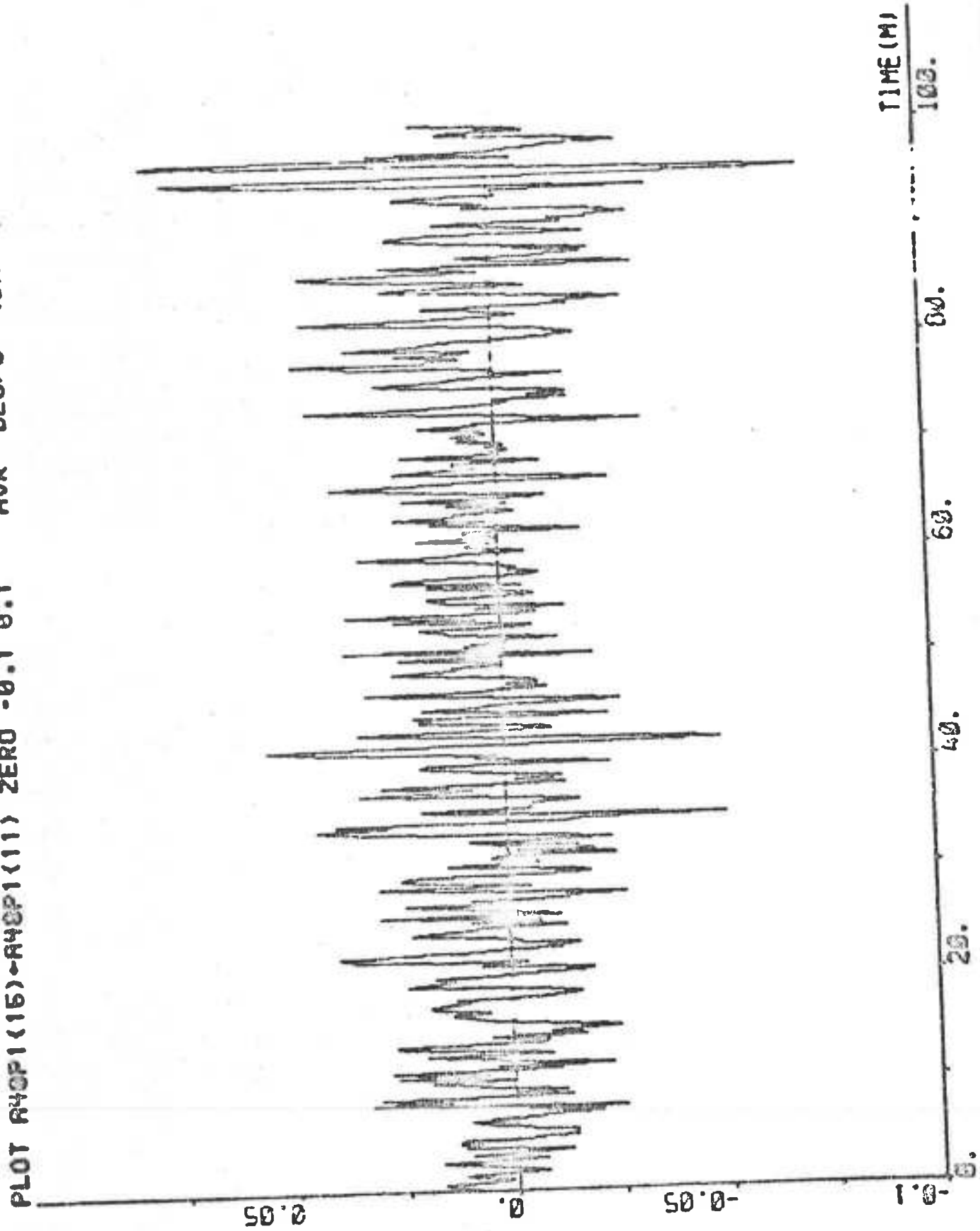

PLOT R40P1(16)-R40P1(8) ZERO -0.75 0.25 "V1 KNOTS
0.
-0.25
-0.5
-0.75
100.
120.
140.
160.
180.
200.
TIME(M)

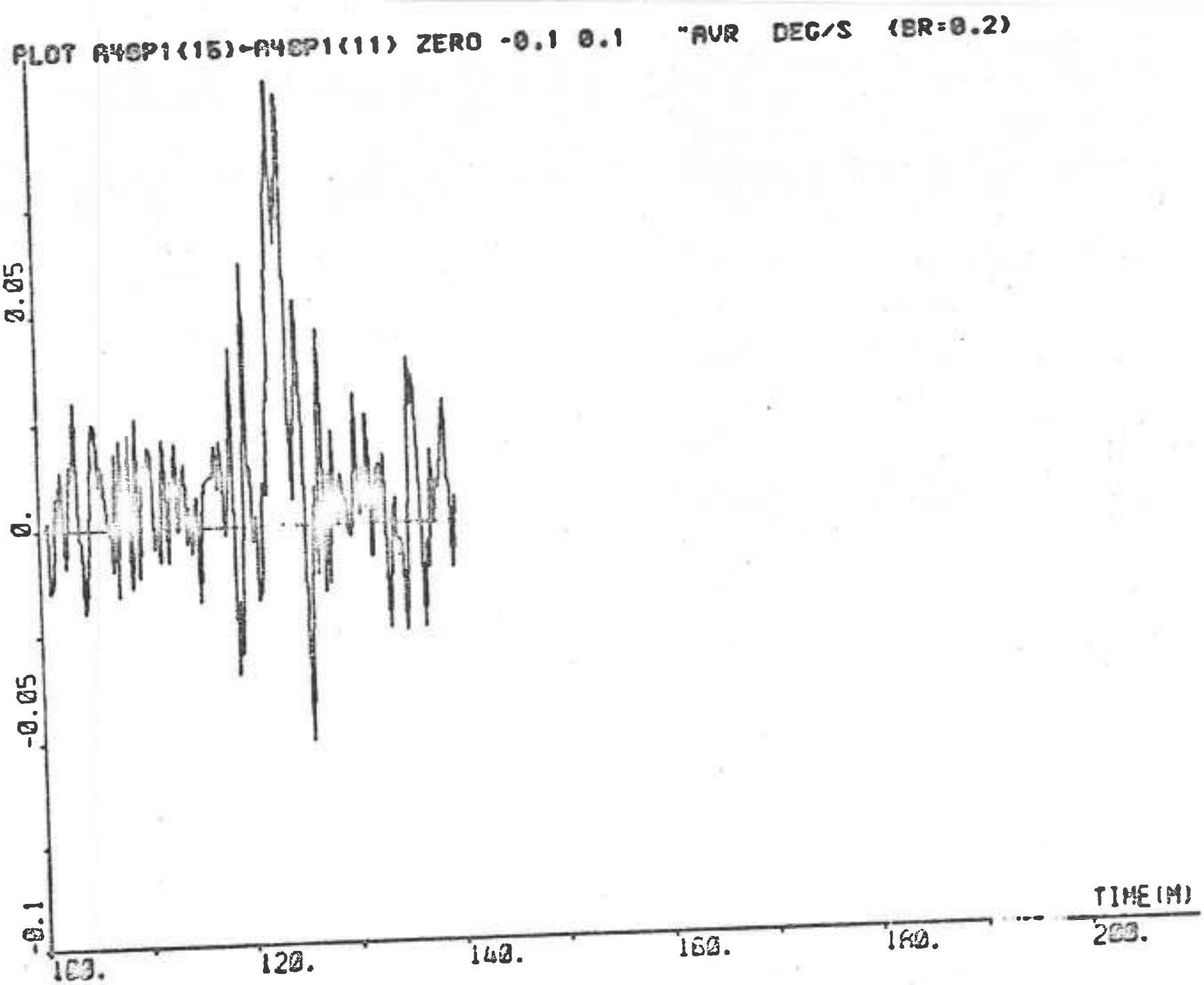

PLOT A4&P1(15)-A4&P1(8) ZERO -1 1 "V2 KNOTS
0.5
0.
-0.5
-1.
0.
20.
40.
60.
80.
100.
TIME(M)

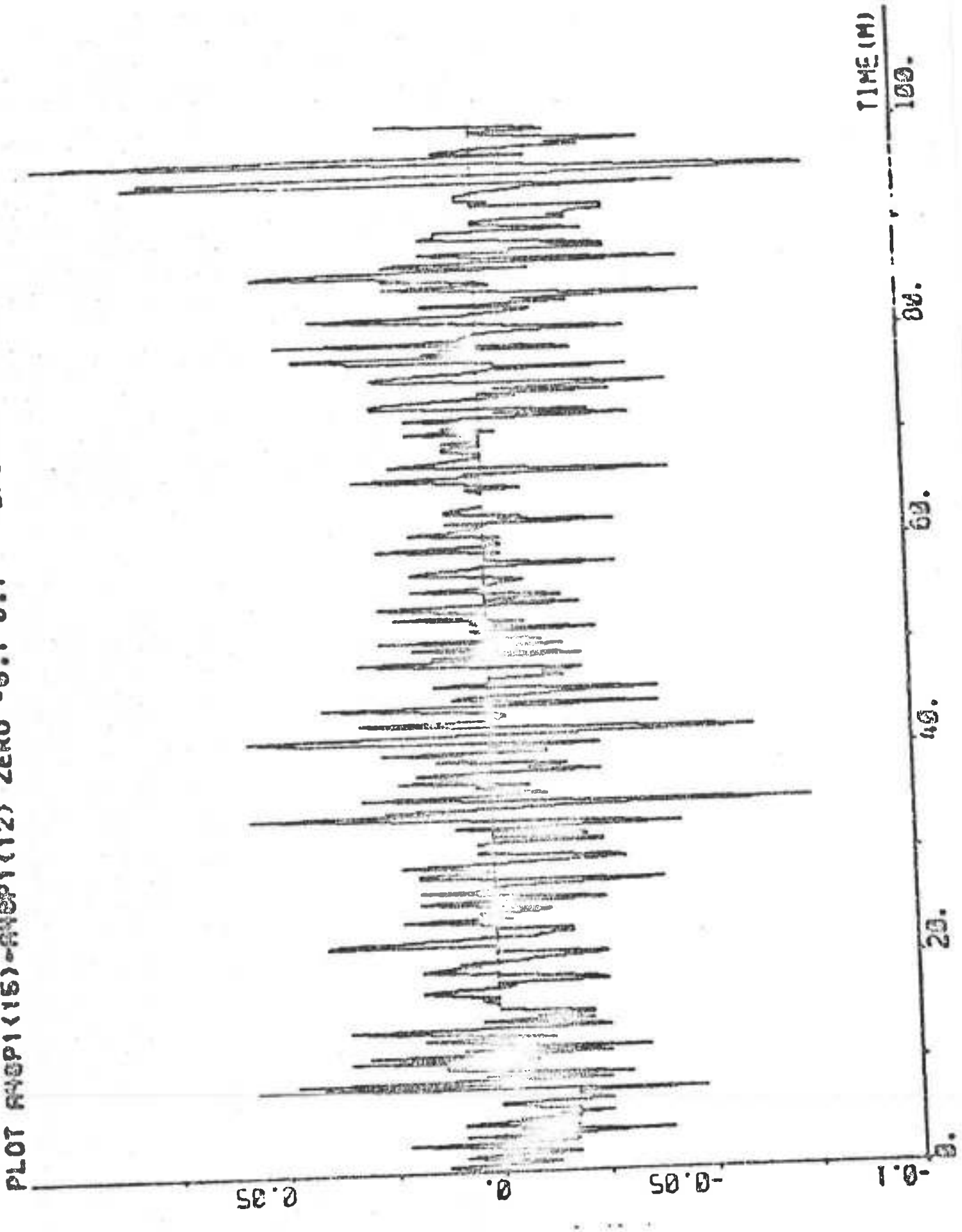

PLOT
ZERO -1 1
V2 KNOTS
TIME(H)
100.
120.
140.
160.
180.
200.
0.5
0.
-0.5
-1.

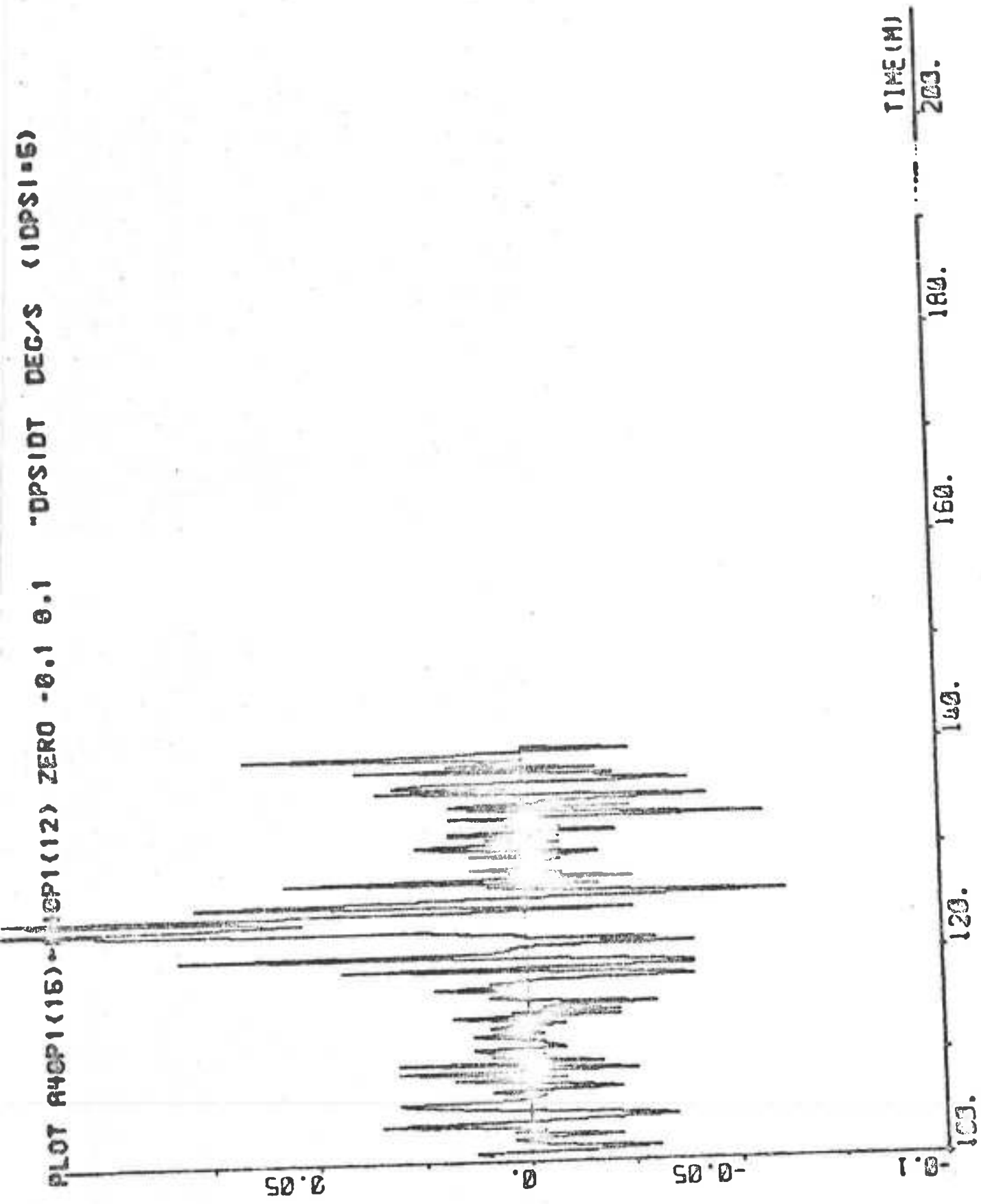

PLOT A40P1(15)-A40P1(10) ZERO -0.1 0.1 "R DEG/S
0.25
0.
-0.05
-0.1
0.
20.
40.
60.
80.
100.
TIME(M)

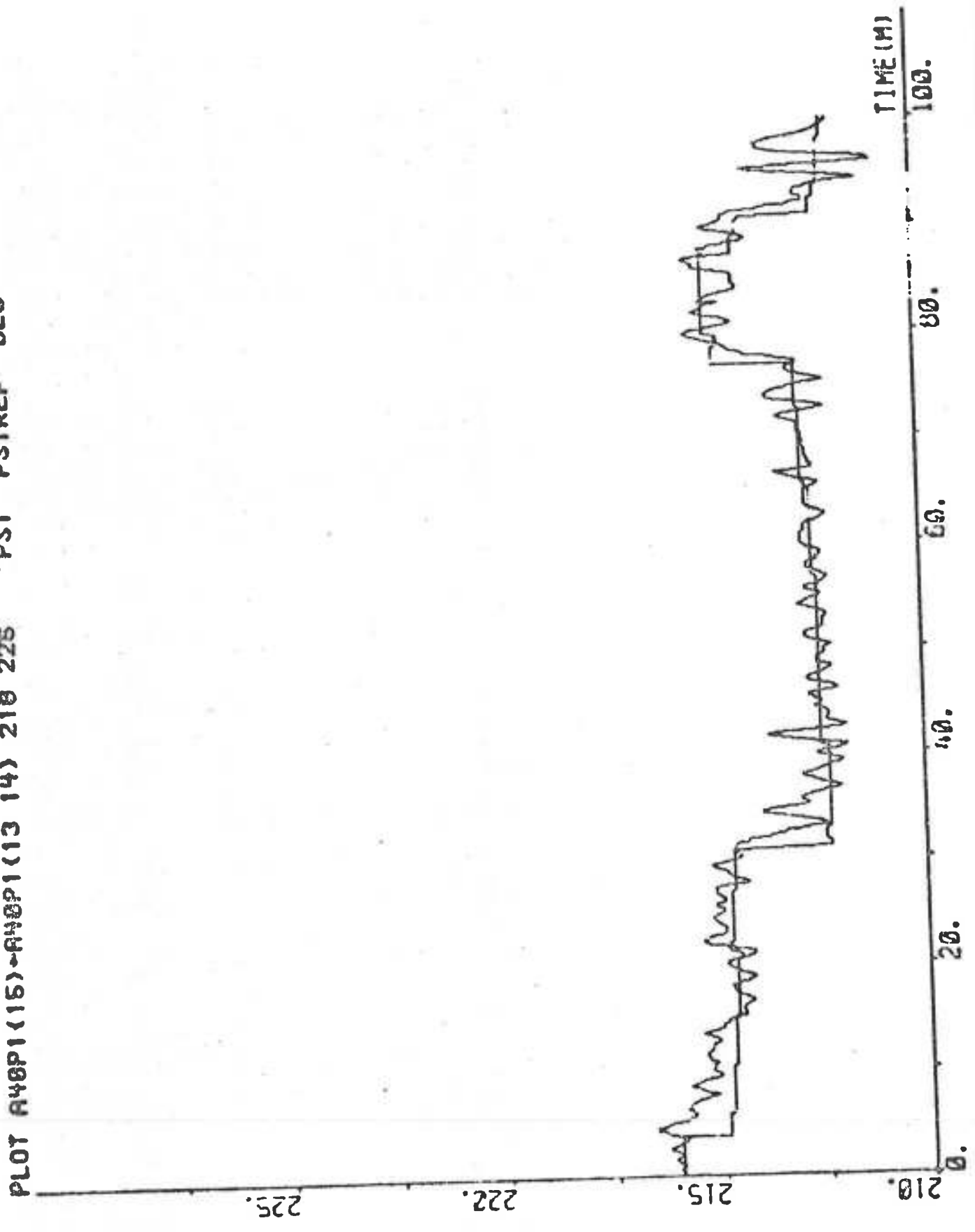

PLOT A40P1(15)-10P1(10) ZERO -0.1 0.1 "R DEG/S
0.1
-0.05
0.
0.05
100.
120.
140.
160.
180.
200.
TIME(M)

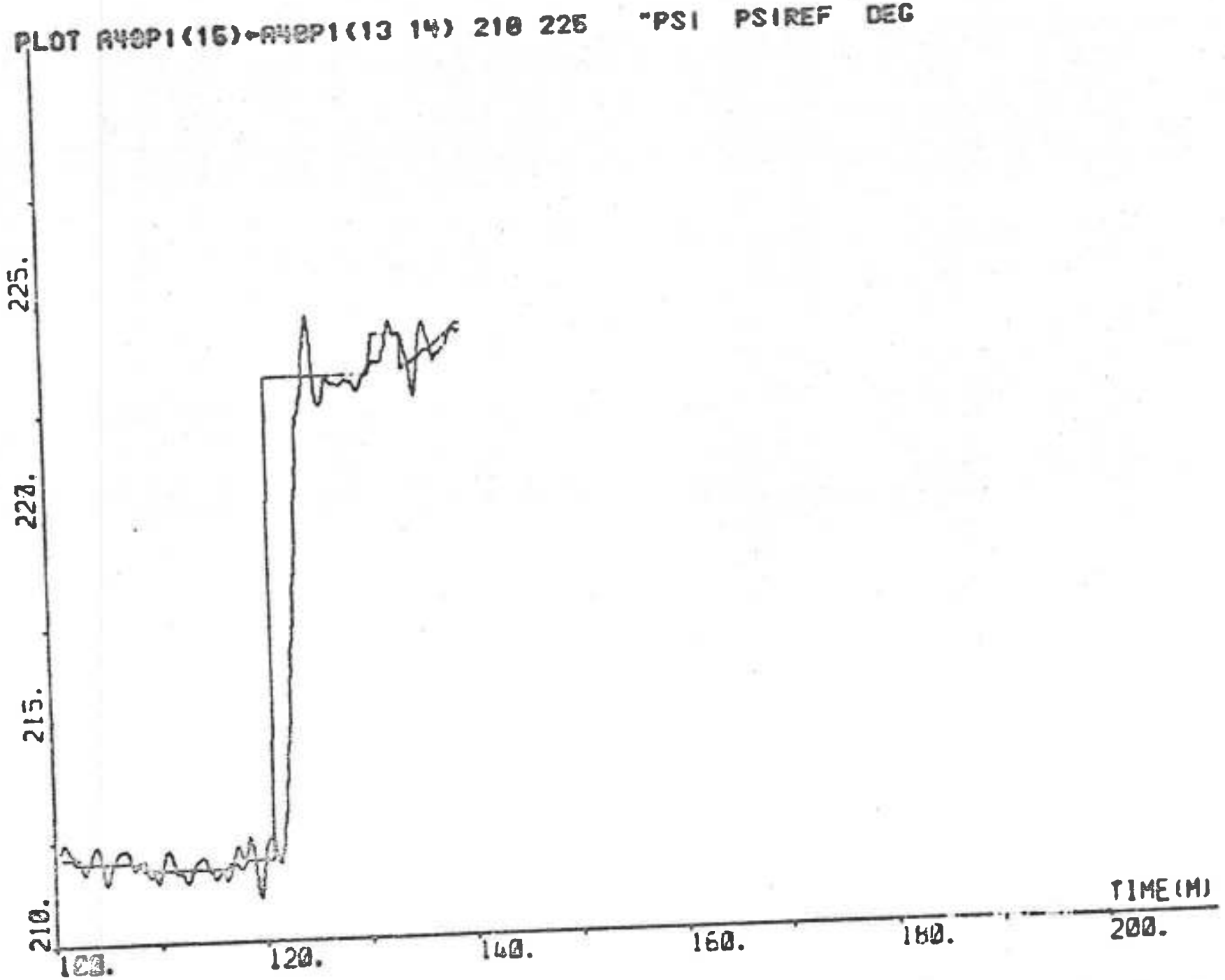

PLOT A4OP1(16)-A4OP1(11) ZERO -0.1 0.1 "AVR DEG/S (DR=0.2)
TIME(M)
0.
20.
40.
60.
80.
100.
1.0
-0.05
0.
0.05

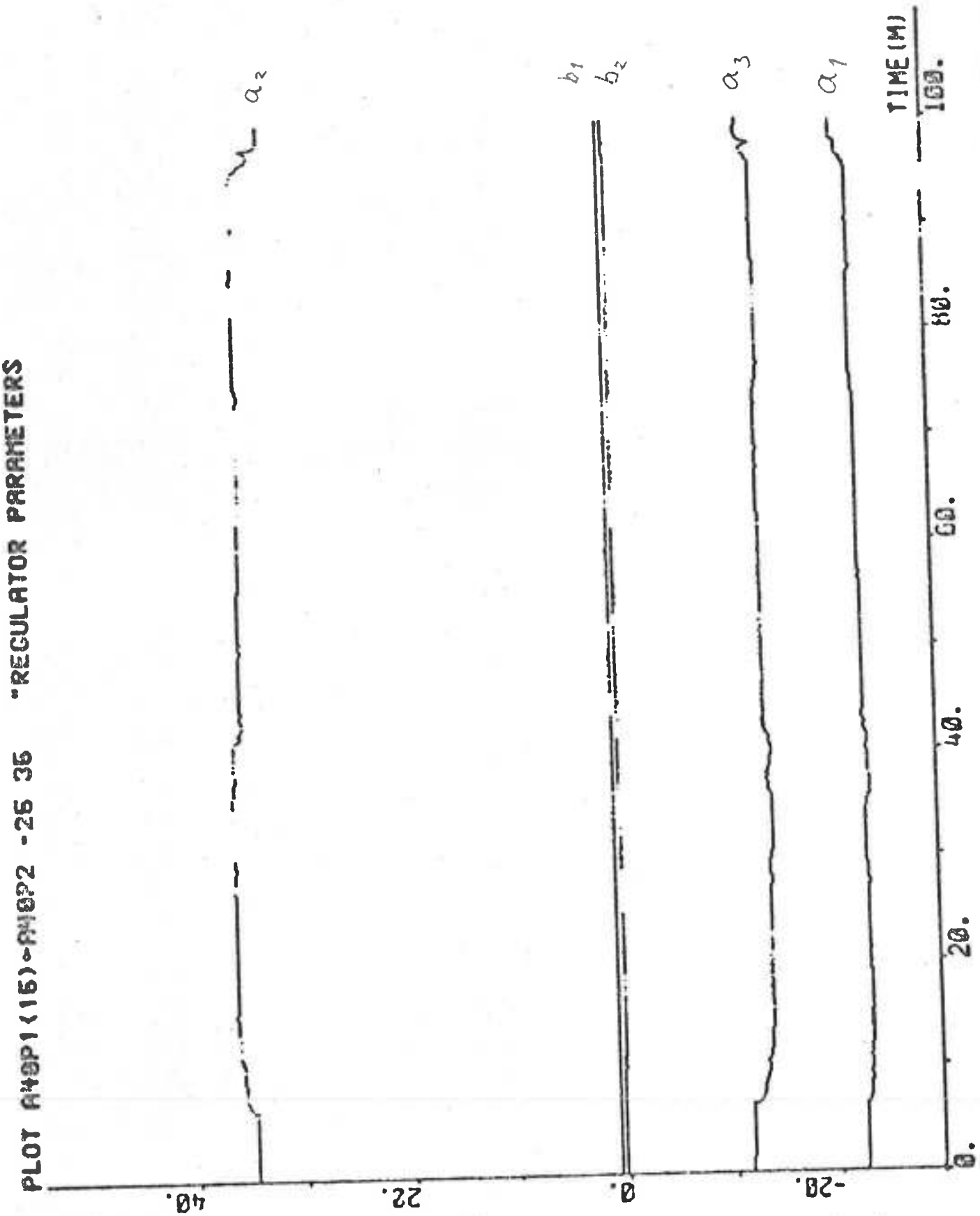

PLOT R4SP1(15)-R4SP1(11) ZERO -0.1 0.1 "AVR DEG/S (BR=0.2)
0.05
0.
-0.05
-0.1
100.
120.
140.
160.
180.
200.
TIME(M)

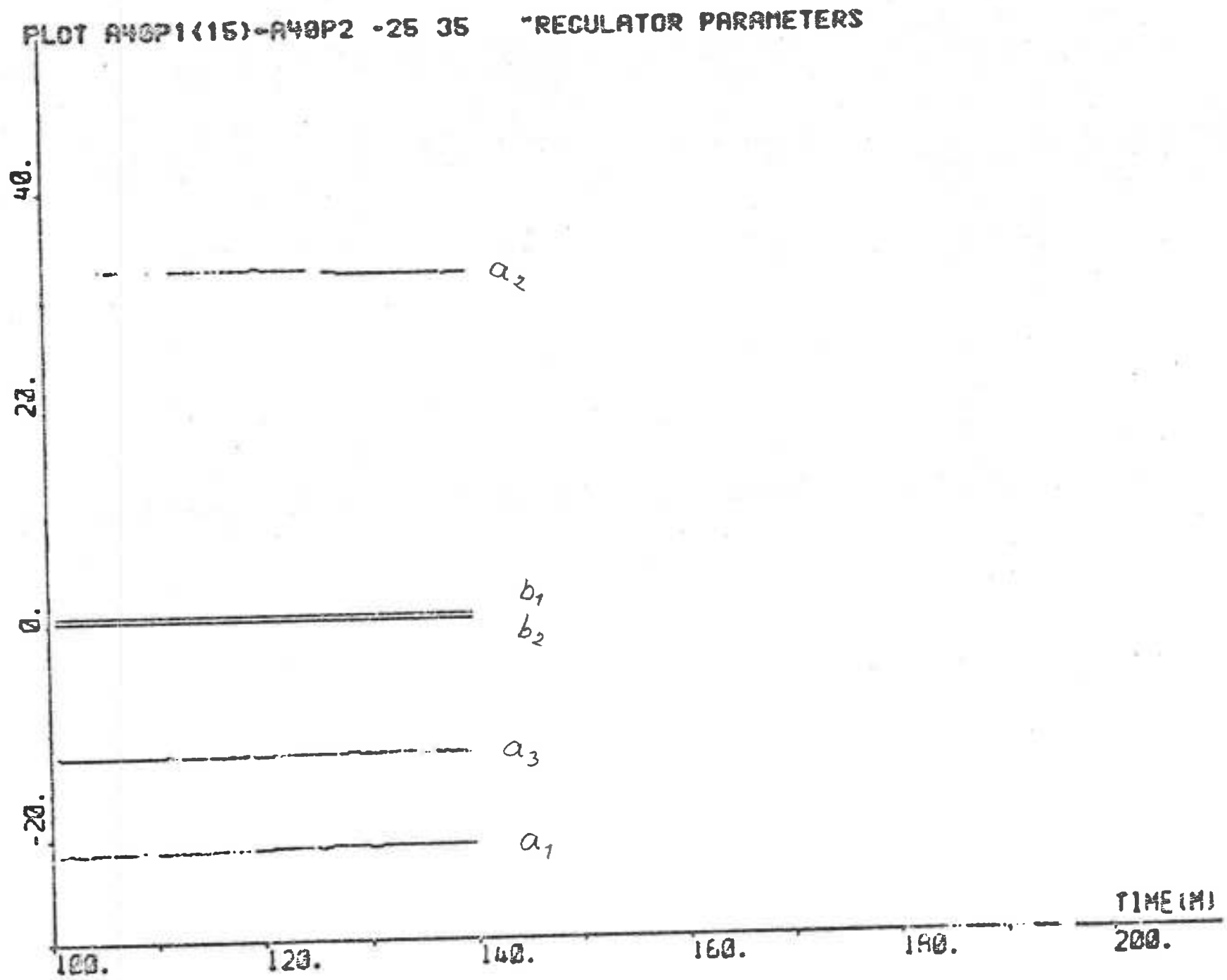

PLOT RHOP1(15)-RHOP1(12) ZERO -0.1 0.1 "DPSIDT DEG/S (10PSI*S)
0.35
0
-0.05
TIME(M)
0.
20.
40.
60.
80.
100.


PLOT A4CP1(15)-A0P1(12) ZERO -0.1 0.1 "DPSIDT DEG/S (10PSI=5)
TIME(M)
103.
120.
140.
160.
184.
203.
0.1
-0.05
0.
0.05


PLOT A40P1(15)-A40P1(13 14) 210 225 "PSI PSIREF DEG
210.
215.
220.
225.
0.
20.
40.
60.
80.
100.
TIME(M)


PLOT R40P1(16)-R40P1(13 14) 210 225 "PSI PSIREF DEG
225.
220.
215.
210.
100.
120.
140.
160.
180.
200.
TIME(M)


PLOT AVOP1(15)-AVOP2 -25 35 "REGULATOR PARAMETERS
40.
22.
0.
-28.
0.
20.
40.
60.
80.
100.
TIME(M)
a_2
b_1
b_2
a_3
a_1


PLOT A40P1(15)-A40P2 -25 35 *REGULATOR PARAMETERS
40.
20.
0.
-20.
a_2
b_1
b_2
a_3
a_1
TIME(M)
100.
120.
140.
160.
180.
200.

EXPERIMENT A41

Date	1974-10-22
Time	13.06
Duration	104 min
Position	S 31° 59' E 29° 39'
Water depth	deep
Forward draught	20.2 m
Aft draught	20.2 m
Wind direction	SW (1; see Appendix A)
Wind velocity	4 Beaufort (6-8 m/s, moderate breeze)
Wave height	Rough sea from SW
PSIREF	210.0° - 230.7° (Sailmaster, Course correction)
RREF	0.07 deg/s
Rudder limit	Possibly active, but unknown
DELlM at termination	-0.12°

The Sailmaster and the Course correction were switched on and off a couple of times during the experiment, which resulted in course changes. However, the two yaws after 52 min and 63 min were manually requested. MODYAW was equal to 1, 3 or 4 during all the yaws except during 120 s of the yaw after 52 min, 90 s of the yaw after 63 min and 10 s of the yaw after 81 min, when MODYAW was equal to 2.

Note that the resolution of the course measurement only was 1/6 deg.

Regulator structure

NA = 3 NB = 2 NC = 0 K = 5

IREG = 15 RL = 0.99

Final values

$$\begin{bmatrix} a_1 \\ a_2 \\ a_3 \\ b_1 \\ b_2 \end{bmatrix} = \begin{bmatrix} -20.736 \\ 32.124 \\ -12.391 \\ 0.695 \\ 0.176 \end{bmatrix} \qquad P = \begin{bmatrix} 0.204 & & & & \\ -0.243 & 0.838 & & & \\ 0.066 & -0.632 & 0.625 & & \\ -0.001 & -0.018 & 0.021 & 0.001 & \\ 0.001 & -0.018 & 0.018 & 0.001 & 0.001 \end{bmatrix}$$

$$a_1 + a_2 + a_3 = -1.003$$

Yaw regulator structure

NAY = 3 NBY = 2 KY = 2
IREGY = 10 RLY = 0.95 IRR = 3 IDPSI = 10
AK1V = 40 AK2V = 1.8 AK3V = 120
C1V = 10 C2V = 80
EPS1V = 0.02 EPS2V = 0.04
PSISV = 0.15 PSISSV = 1.5 PSIMAV = 0.35
I1MV = 60 I2MV = 300 I3MV = 150

Initial yaw regulator values

$$\begin{bmatrix} a'_1 \\ a'_2 \\ a'_3 \\ b'_1 \\ b'_2 \end{bmatrix} = \begin{bmatrix} -43.56 \\ 4.94 \\ 0.90 \\ 1.30 \\ 0.81 \end{bmatrix} \qquad PY = \begin{bmatrix} 500 & & & & \\ 0 & 500 & & & \\ 0 & 0 & 500 & & \\ 0 & 0 & 0 & 1 & \\ 0 & 0 & 0 & 0 & 1 \end{bmatrix}$$

$$a'_1 + a'_2 + a'_3 = -37.72$$

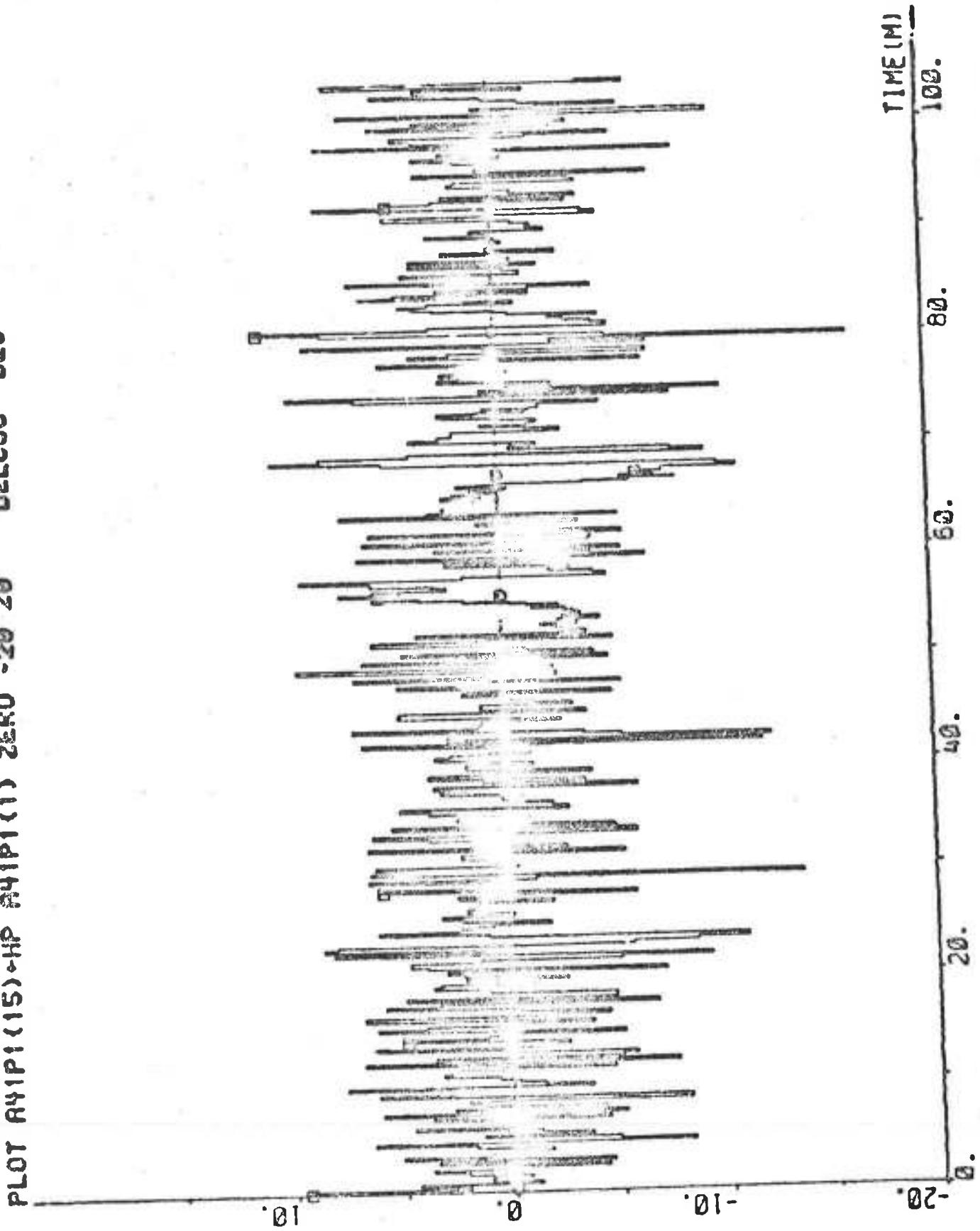
Yaw regulator values after the yaw at 81 min

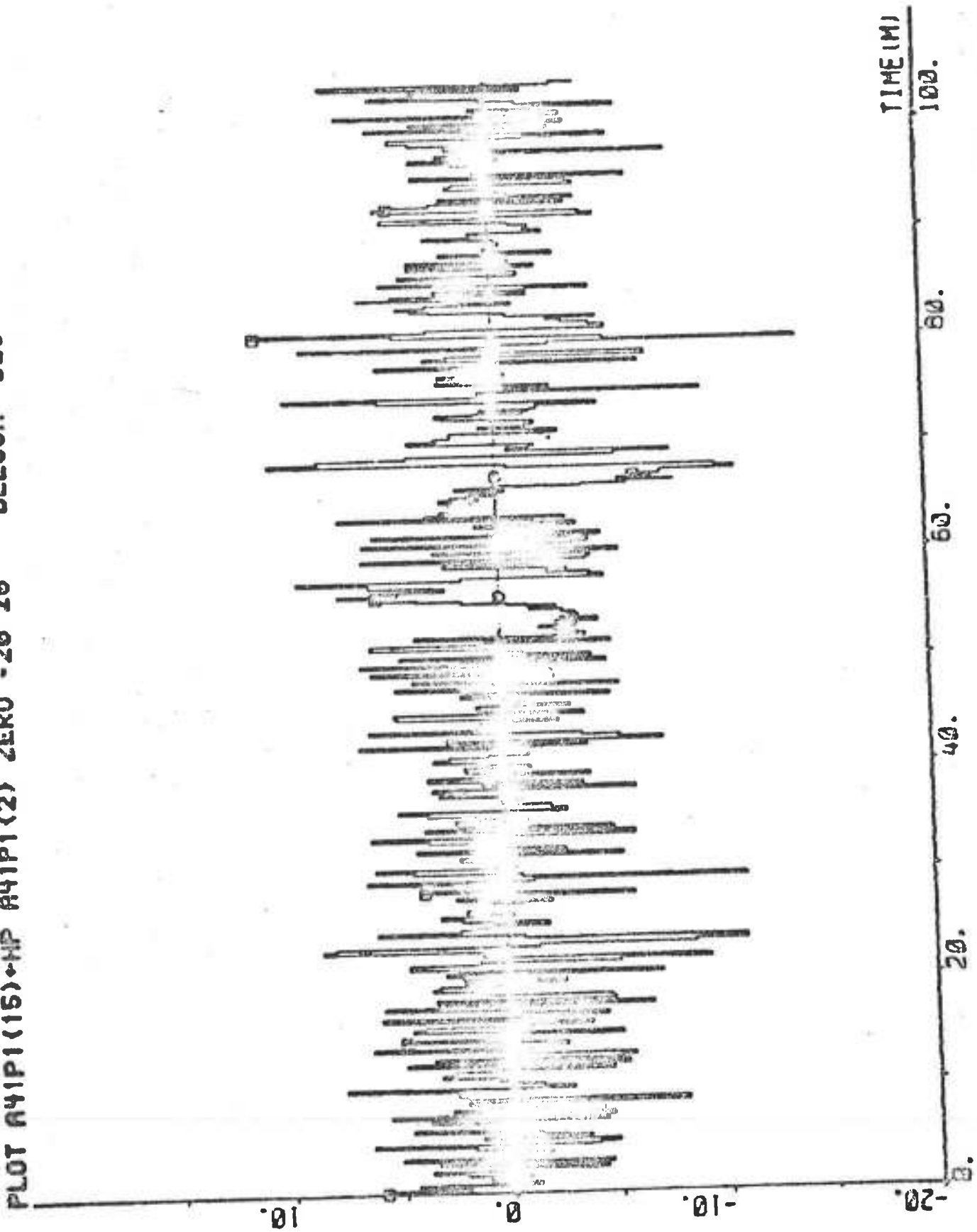
$$\begin{bmatrix} a_1' \\ a_2' \\ a_3' \\ b_1' \\ b_2' \end{bmatrix} = \begin{bmatrix} -43.56 \\ 4.94 \\ 0.90 \\ 1.30 \\ 0.81 \end{bmatrix} \qquad PY = \begin{bmatrix} 526.316 & & & & \\ 0 & 526.316 & & & \\ 0 & 0 & 526.316 & & \\ 0 & 0 & 0 & 1.053 & \\ 0 & 0 & 0 & 0 & 1.053 \end{bmatrix}$$

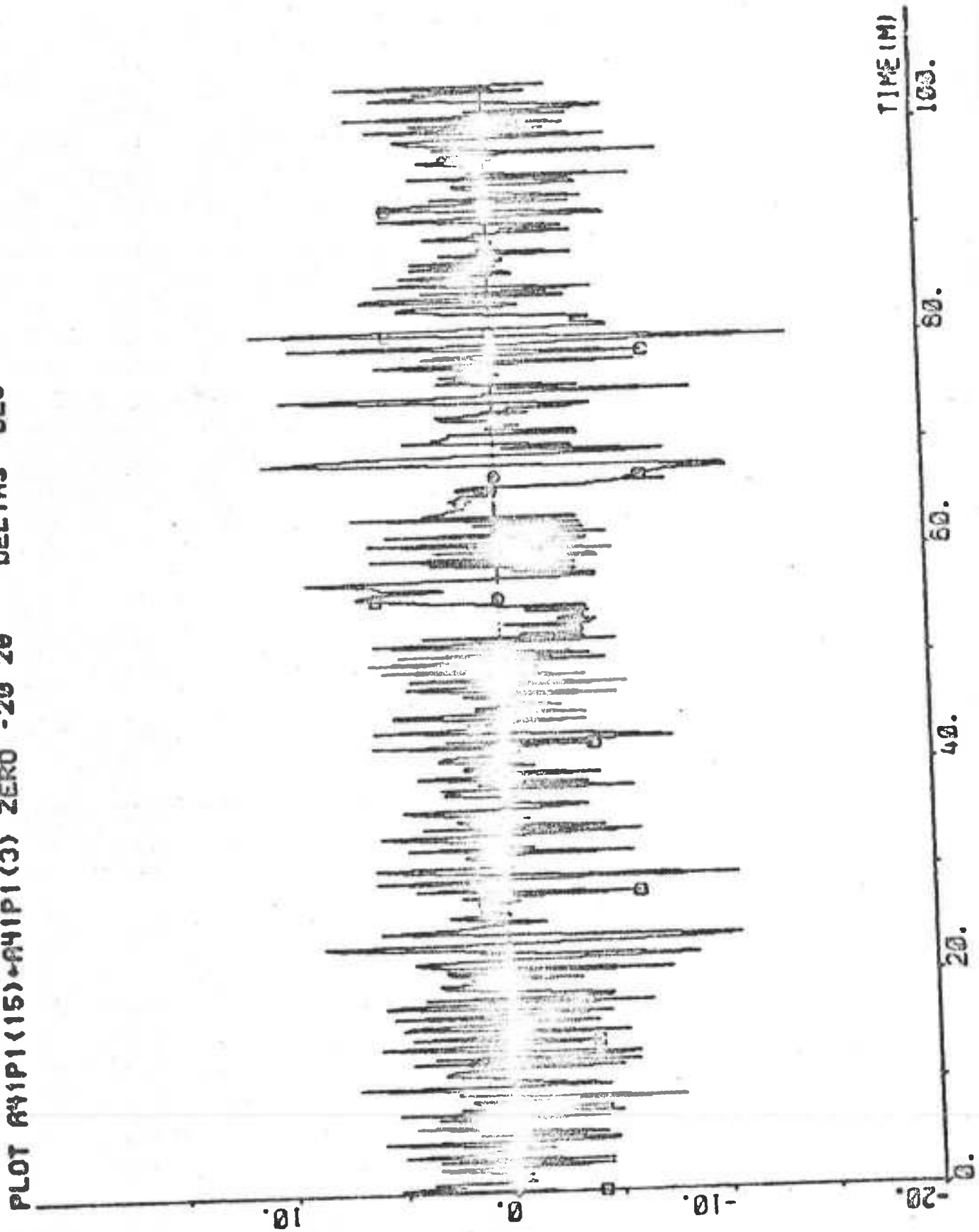
$$a_1' + a_2' + a_3' = -37.72$$

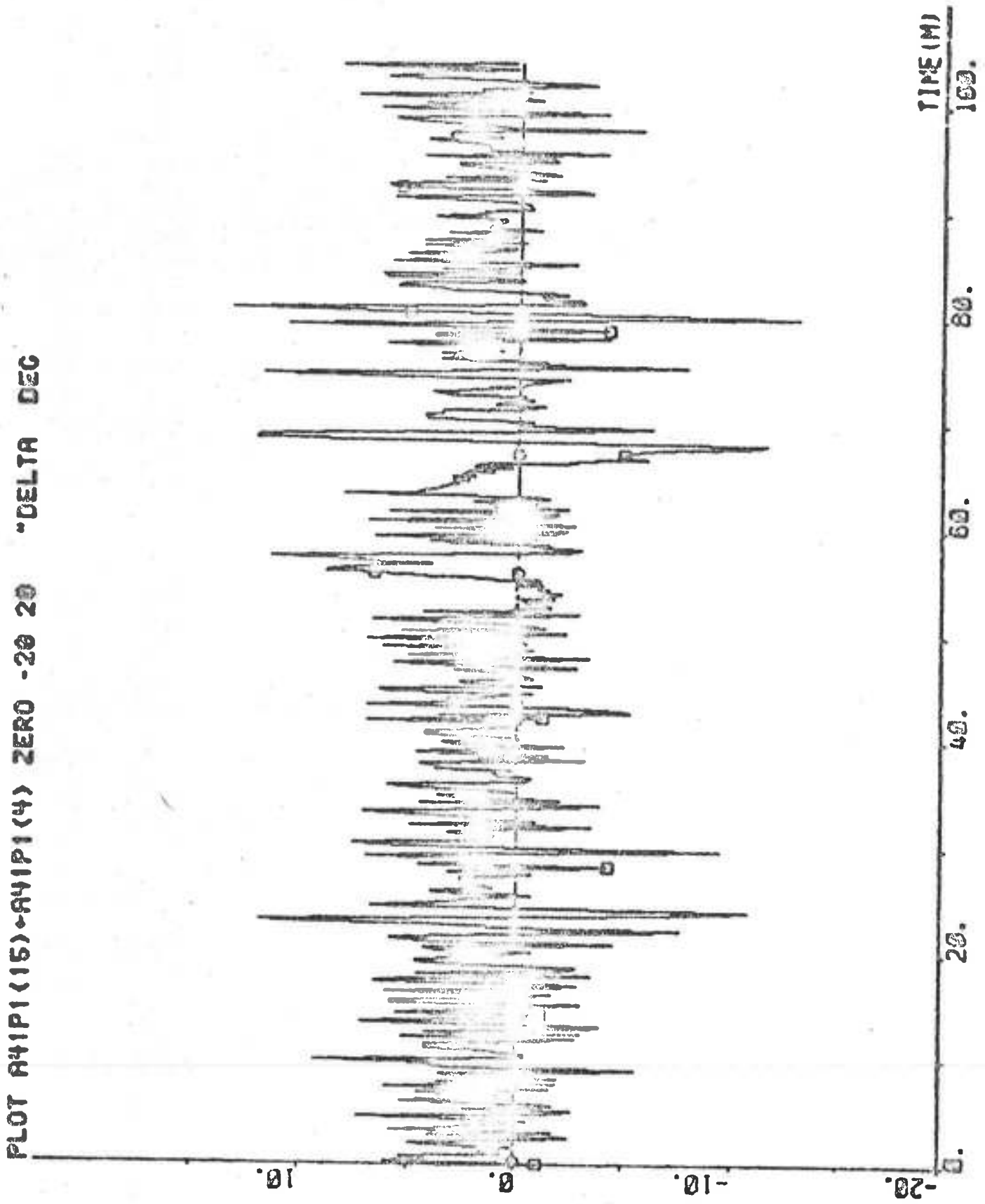
Statistics (mean value and standard deviation)

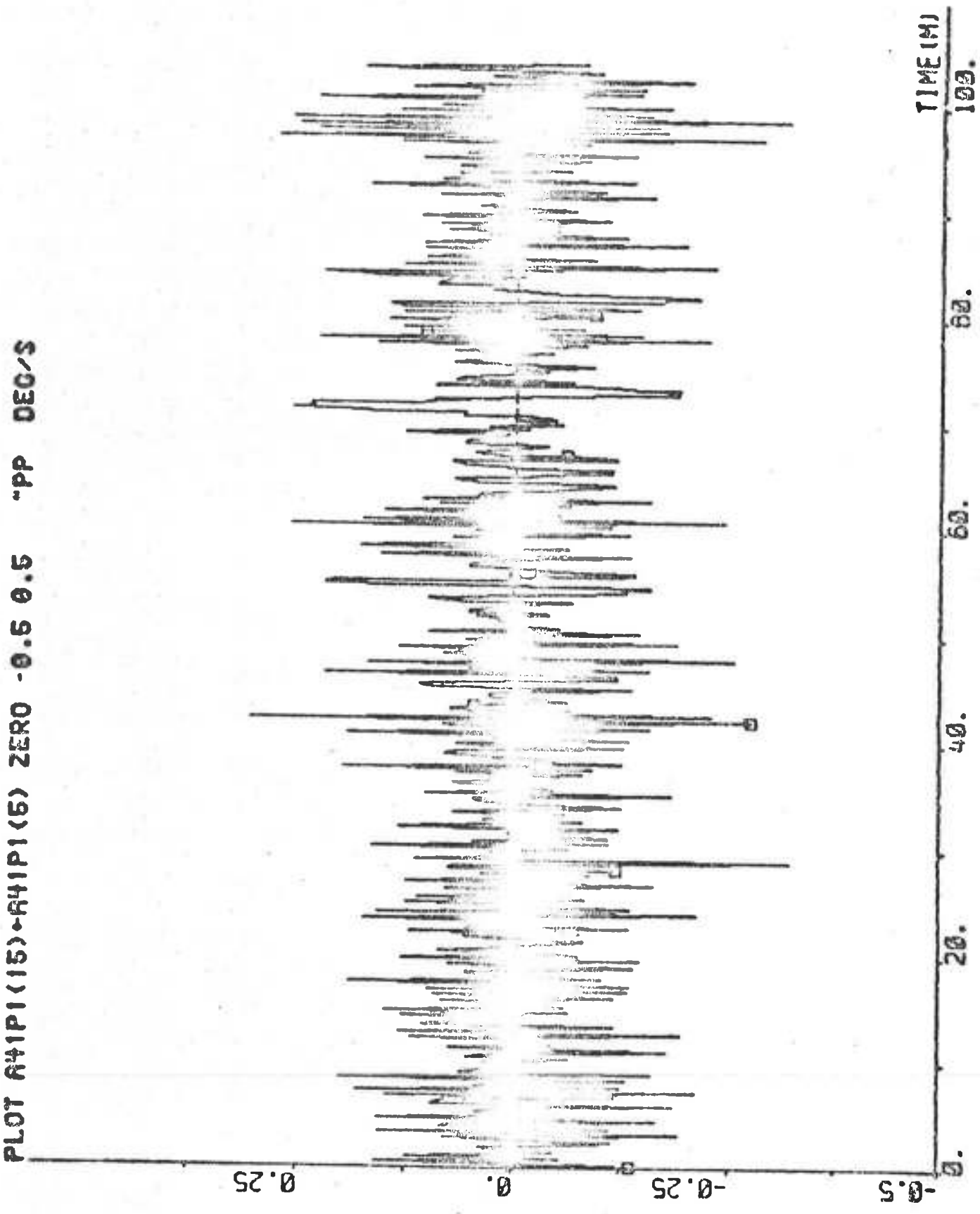
	0-50 min
DELTA	1.64 ± 3.47 deg
PSI-PSIREF	0.002 ± 0.322 deg
AN	81.61 ± 0.33 rpm
U	17.40 ± 0.20 knots
V_1	1.577
V_2	1.308

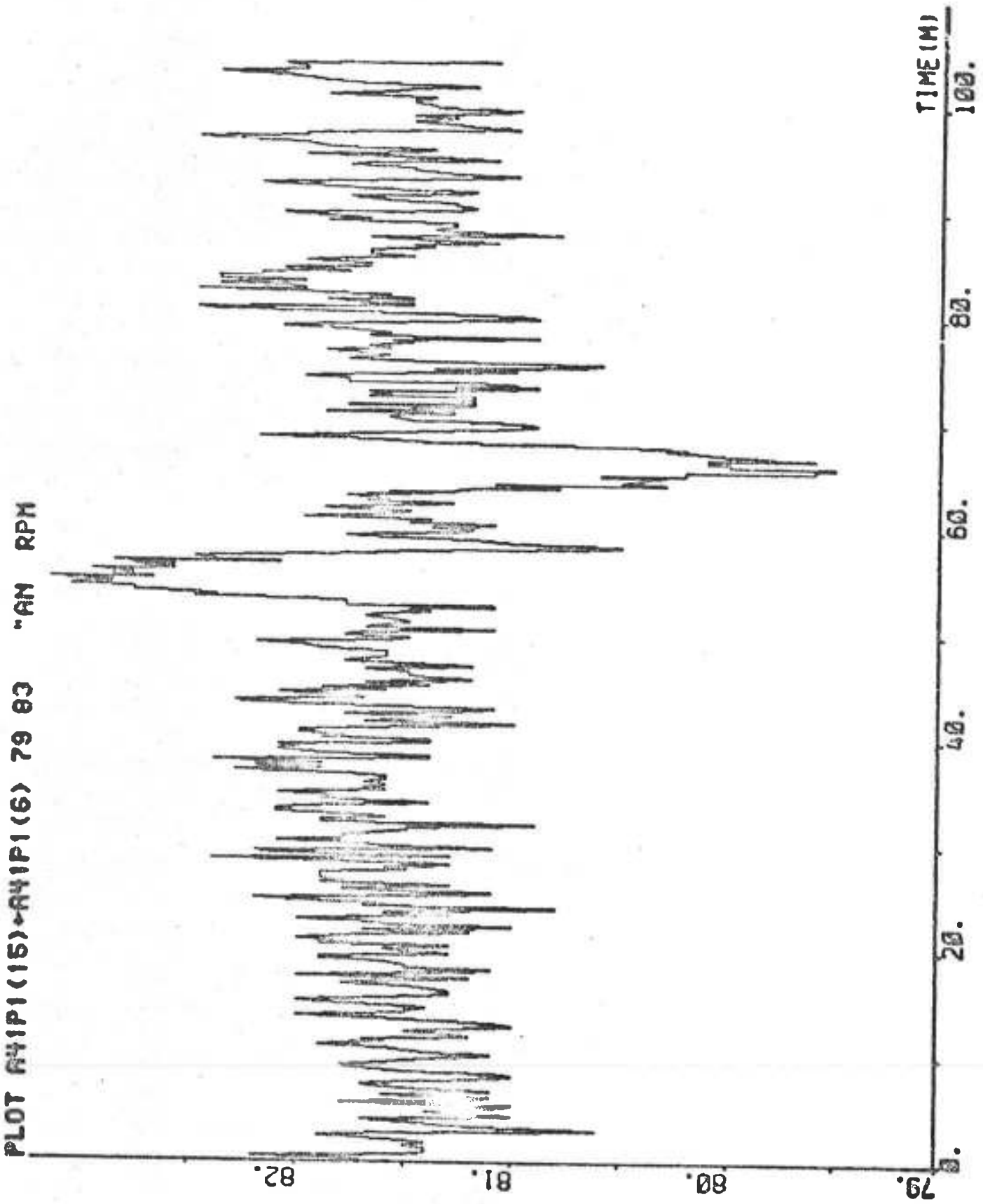

PLOT AY1P1(15)-HP AY1P1(1) ZERO -20 20 "DELCOC DEG
TIME(MI)
100.
80.
60.
40.
20.
0.
10.
0.
-10.
-20.

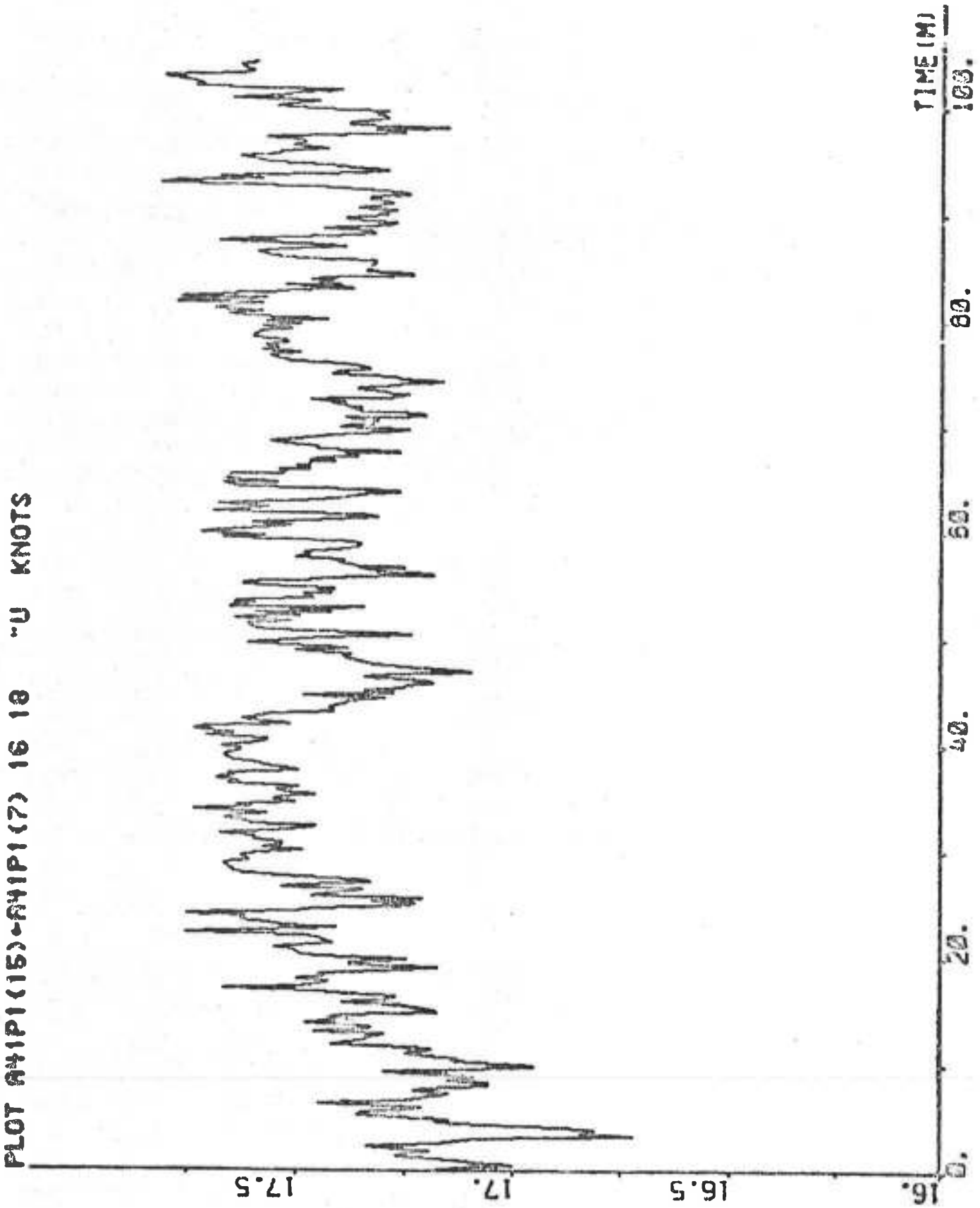

PLOT A41P1(15)+HP A41P1(2) ZERO -20 20 "DELCOM DEG
TIME(MI
100.
80.
60.
40.
20.
0.
-20.
-10.
0.
10.

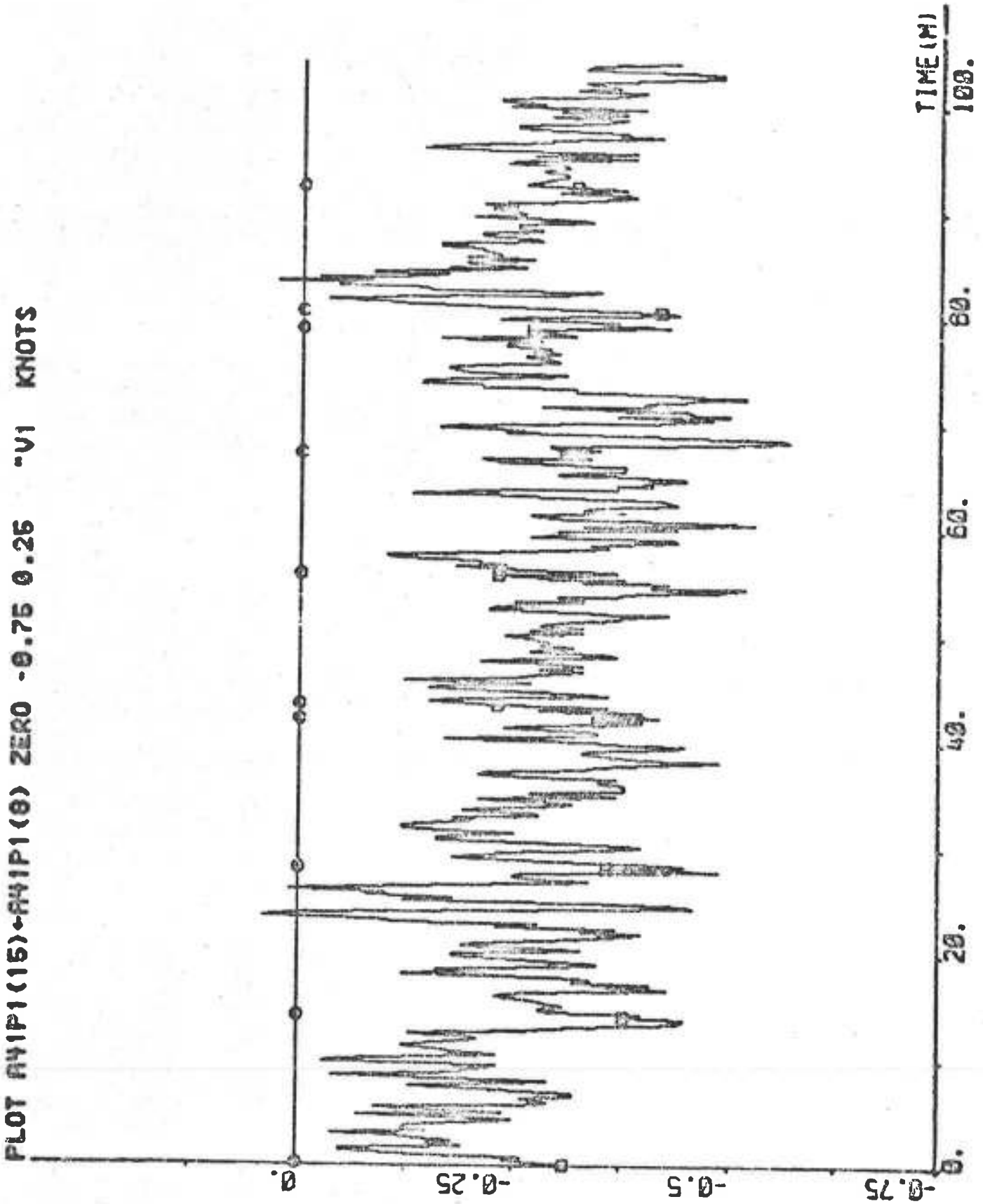

PLOT A41P1(15)=A41P1(3) ZERO -20 20 "DELTAS DEG
TIME(M)
0.
20.
40.
60.
80.
100.
-20.
-10.
0.
10.

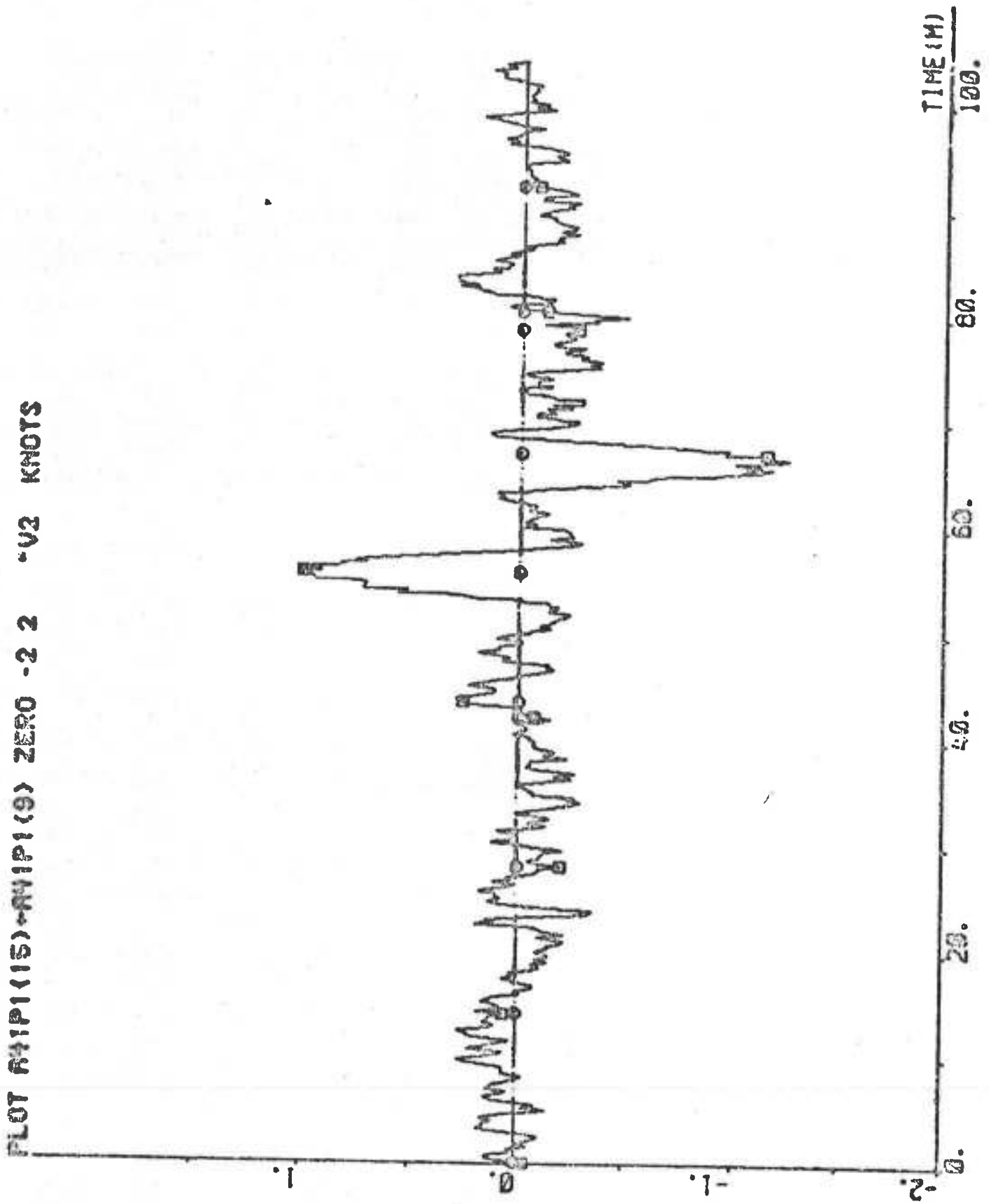

PLOT A41P1(15)-A41P1(4) ZERO -20 20 "DELTA DEC
TIME(M)
0.
20.
40.
60.
80.
100.
-20.
-10.
0.
10.

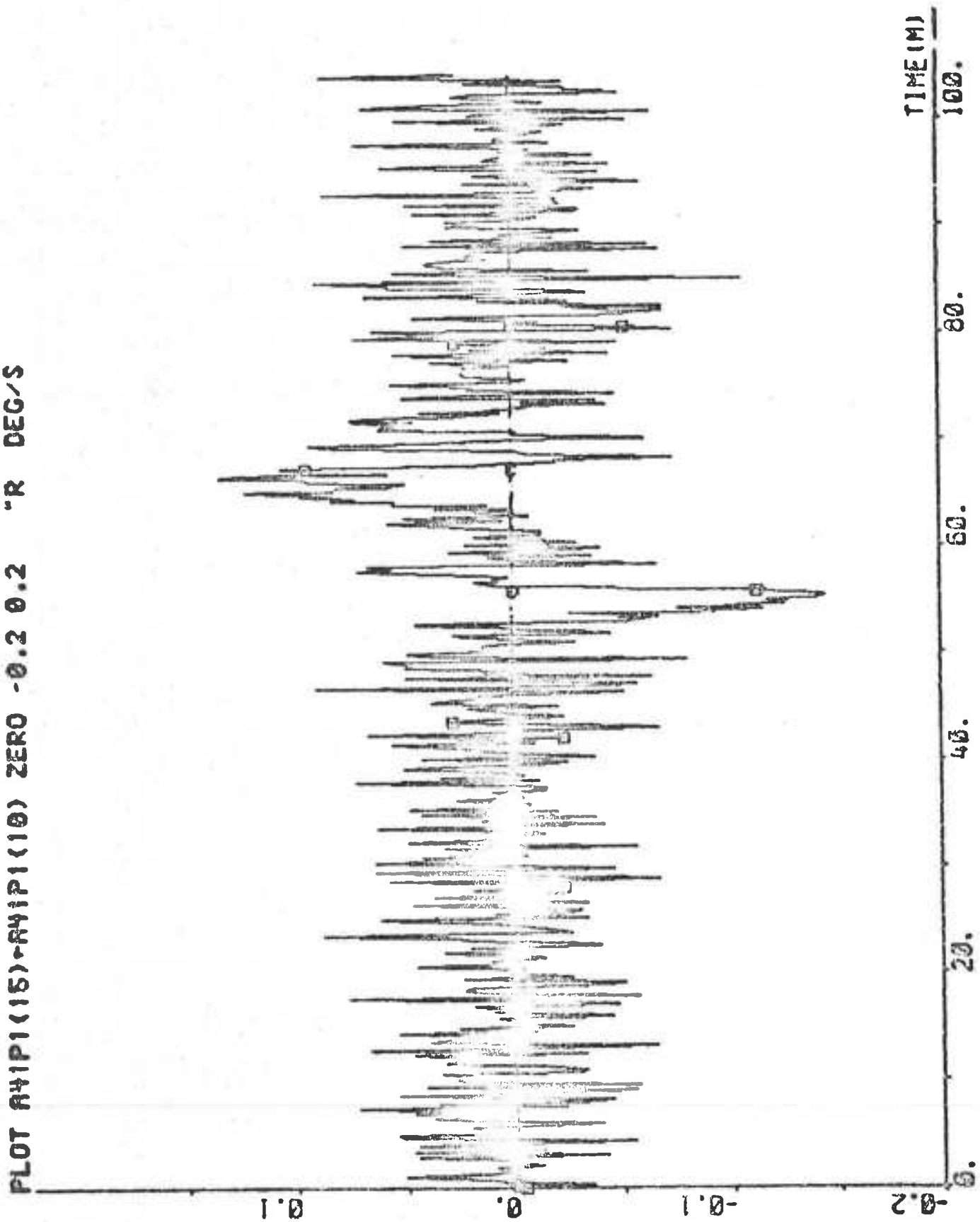

PLOT A41P1(15)-A41P1(6) ZERO -0.5 0.5 *PP DEG/S
-0.5
-0.25
0.
0.25
0.
20.
40.
60.
80.
100.
TIME(M)

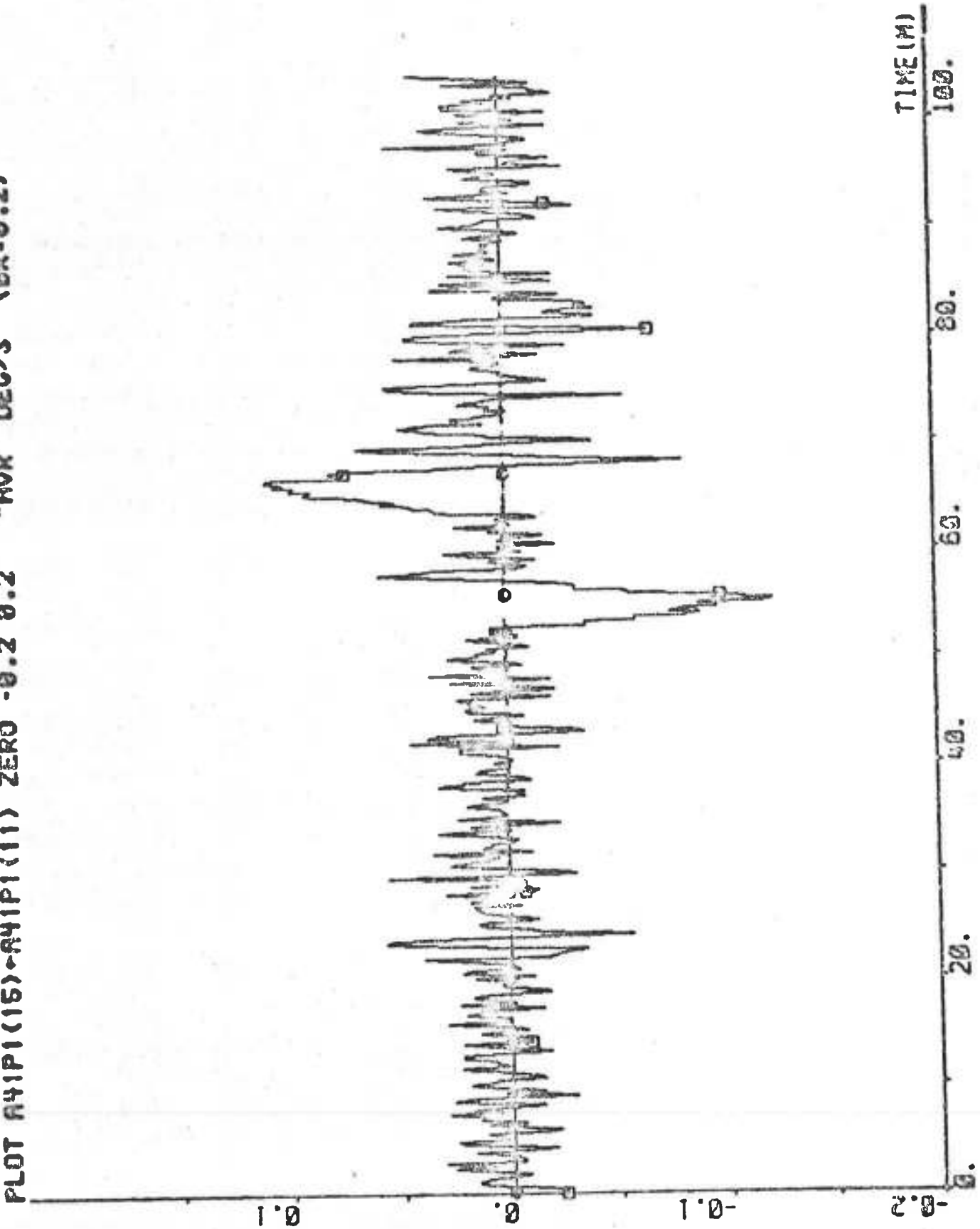

PLOT A41P1(15)-A41P1(6) 79 83 'AN RPM
TIME(M)
0.
20.
40.
60.
80.
100.
79.
80.
81.
82.

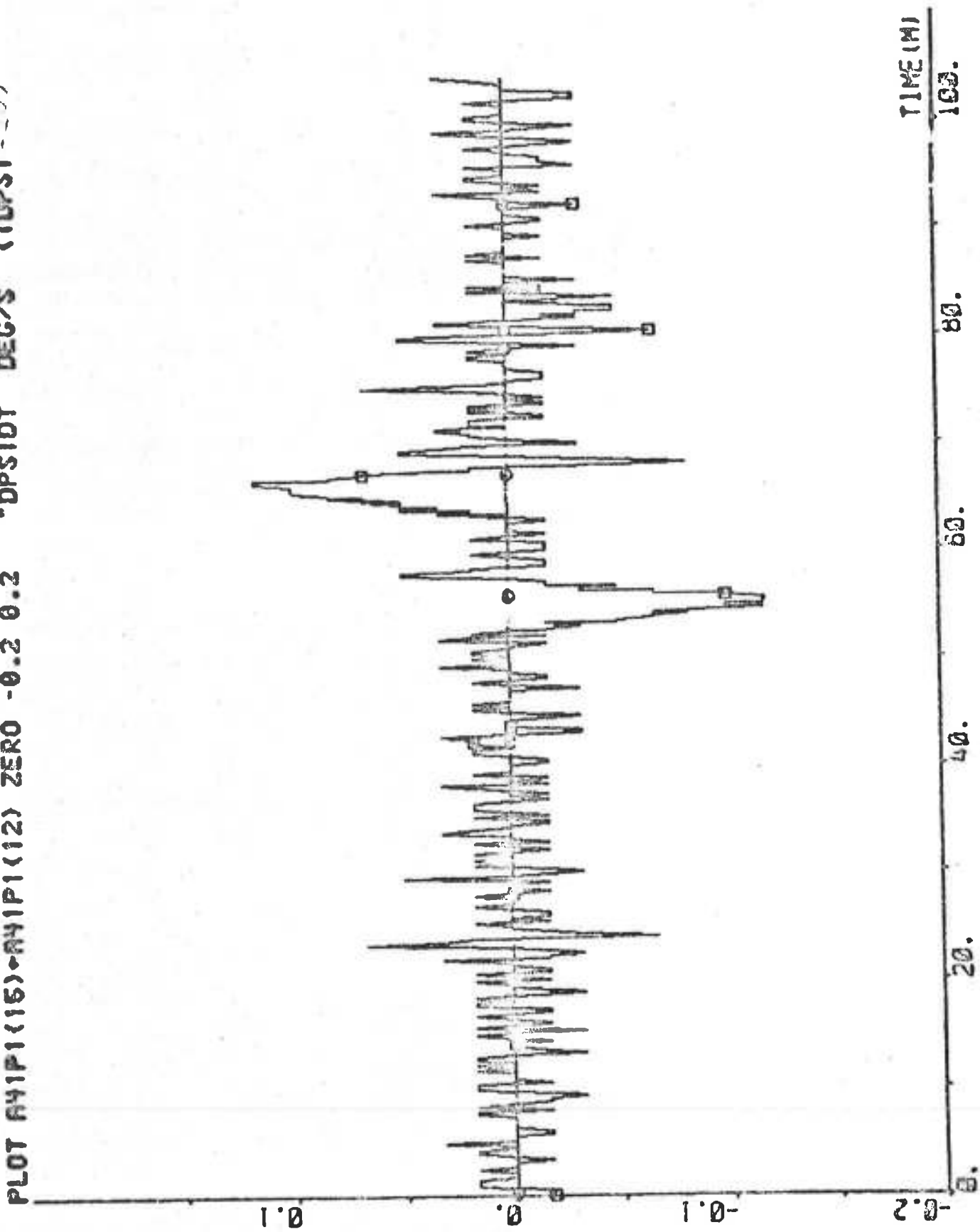

PLOT A41P1(15)-A41P1(7) 16 18 "U KNOTS
16.
16.5
17.
17.5
0.
20.
40.
60.
80.
100.
TIME(M)

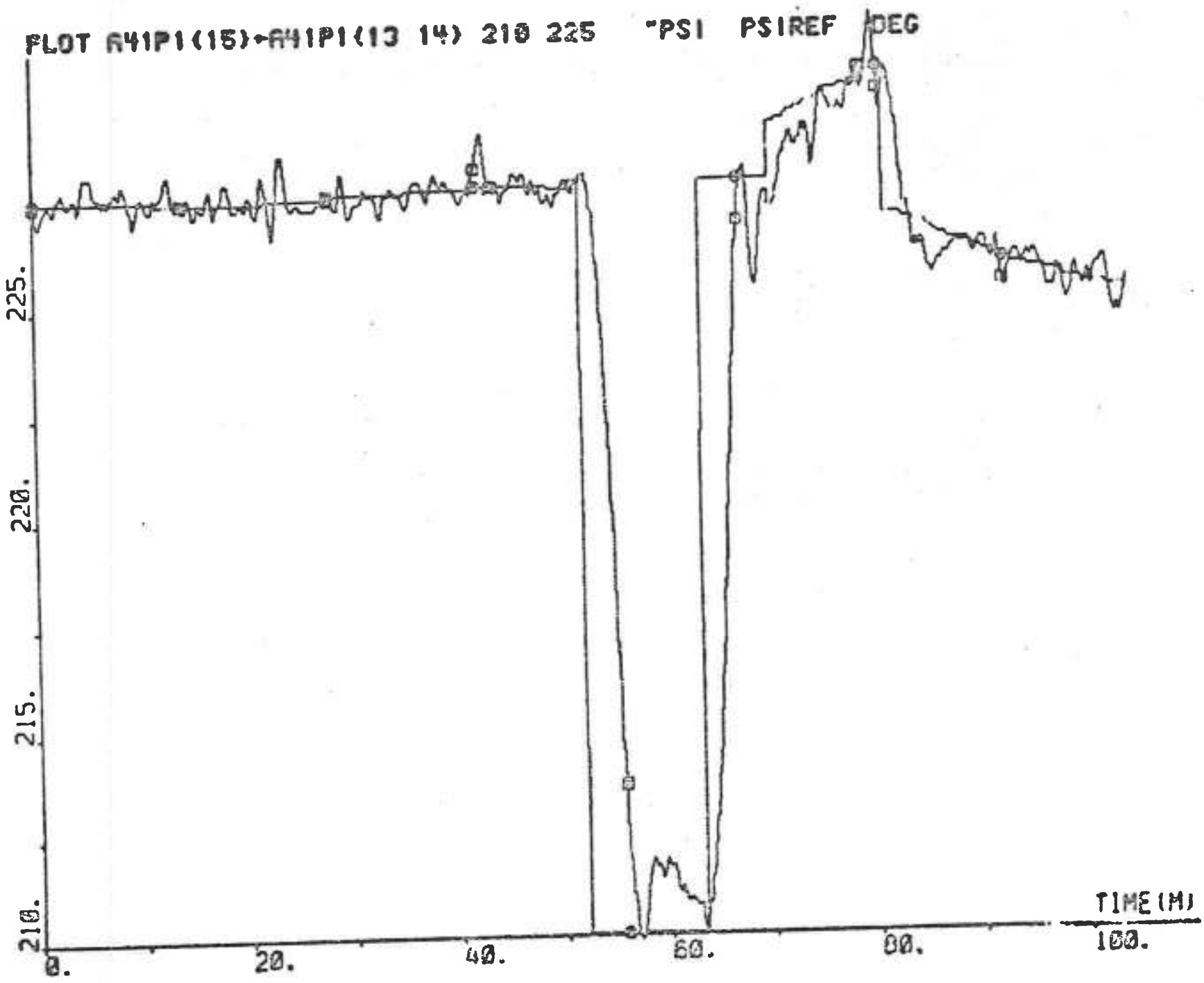

PLOT AY1P1(15)-AY1P1(0) ZERO -0.75 0.25 "V1 KNOTS
-0.75
-0.5
-0.25
0.
0.
20.
40.
60.
80.
100.
TIME(M)

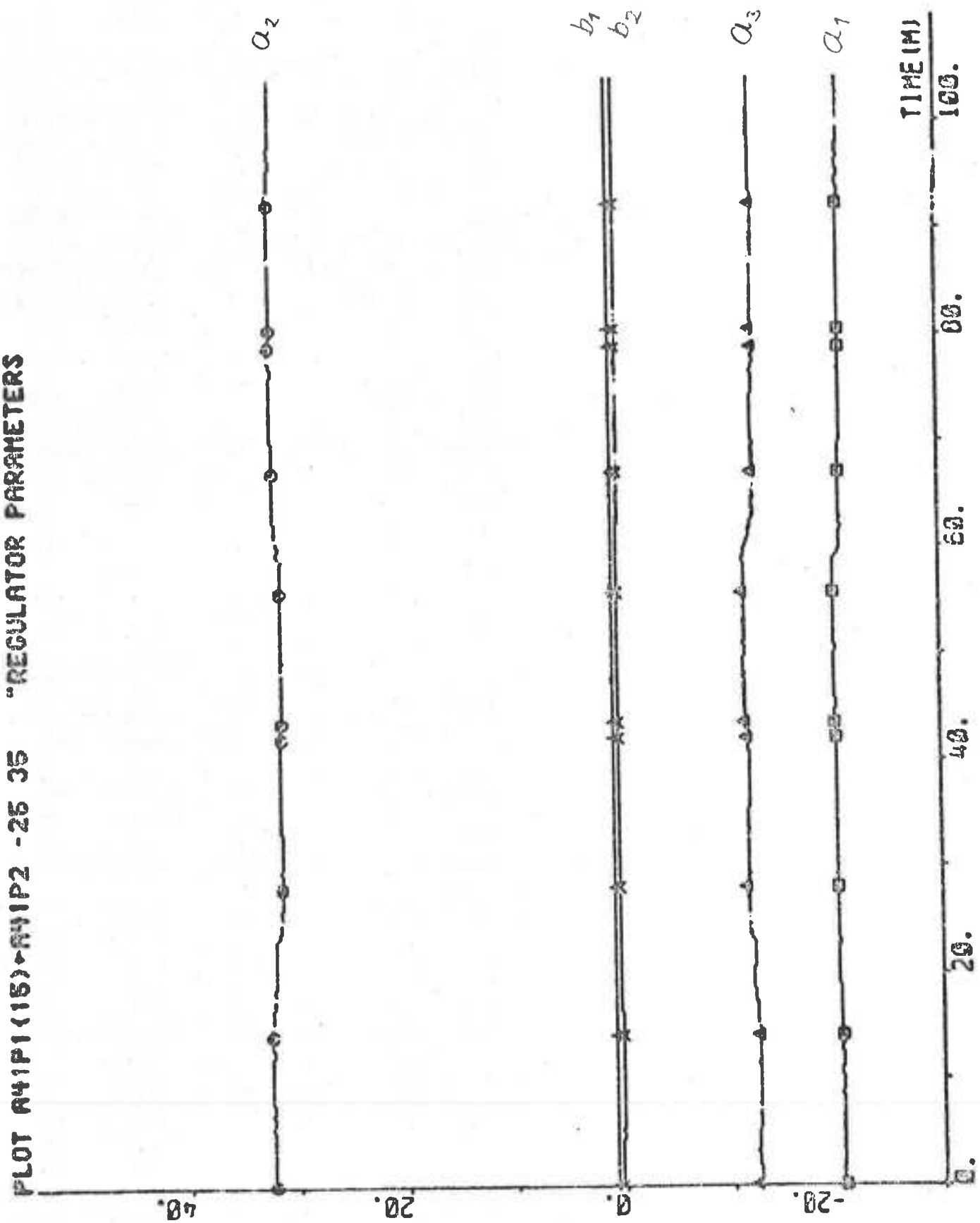

PLOT R4IP1(15)-R4IP1(9) ZERO -2 2 *V2 KNOTS
1.
0.
-1.
-2.
0.
20.
40.
60.
80.
100.
TIME(H)


PLOT R41P1(15)-R41P1(10) ZERO -0.2 0.2 °R DEG/S
TIME(M)
0.
20.
40.
60.
80.
100.
0.1
0.
-0.1
-0.2


PLOT AVIP1(15)-AVIP1(11) ZERO -0.2 0.2 "AVR DEC/S (BR=0.2)
0.1
0.
-0.1
-0.2
0.
20.
40.
60.
80.
100.
TIME(M)


PLOT AY1P1(15)-AY1P1(12) ZERO -0.2 0.2 "DPSIDT DEG/S (IDPSI=20)
TIME(M)
0.
20.
40.
60.
80.
100.
1.0
.0
-1.0
-2.0


PLOT A41P1(15)-A41P1(13 14) 210 225 "PSI PSIREF DEG
225.
220.
215.
210.
0.
20.
40.
60.
80.
100.
TIME(M)


PLOT A41P1(15)=A41P2 -25 35 "REGULATOR PARAMETERS
40.
20.
0.
-20.
0.
20.
40.
60.
80.
100.
TIME(M)
a_2
b_1
b_2
a_3
a_1

EXPERIMENT A42

Date	1974-10-23
Time	00.56
Duration	380 min
Position	S 33° 30' E 26° 30'
Water depth	deep
Forward draught	20.0 m
Aft draught	20.0 m
Wind direction	NE (4-5; see Appendix A)
Wind velocity	3-4 Beaufort (4-8 m/s, gentle to moderate breeze)
Wave height	Sea from ENE
PSIREF	230.0° - 285.0° (Sailmaster, Course correction)
RREF	0.07 deg/s
Rudder limit	Not active
DELlM at termination	-0.65°

Data were recorded every second min. The Sailmaster and the Course correction were switched on and off a couple of times during the experiment, which resulted in course changes.

Regulator structure

NA = 3 NB = 2 NC = 0 K = 5

IREG = 15 RL = 0.99

Final values

$$\begin{bmatrix} a_1 \\ a_2 \\ a_3 \\ b_1 \\ b_2 \end{bmatrix} = \begin{bmatrix} -17.942 \\ 28.377 \\ -10.738 \\ 0.830 \\ 0.159 \end{bmatrix} \qquad P = \begin{bmatrix} 0.645 & & & & \\ -0.830 & 2.088 & & & \\ 0.361 & -1.542 & 1.529 & & \\ -0.001 & -0.046 & 0.059 & 0.004 & \\ -0.001 & -0.042 & 0.052 & 0.003 & 0.004 \end{bmatrix}$$

$a_1 + a_2 + a_3 = -0.303$

Yaw regulator structure

NAY = 3 NBY = 2 KY = 2
IREGY = 10 RLY = 0.95 IRR = 3 IDPSI = 5
AK1V = 40 AK2V = 1.8 AK3V = 120
C1V = 10 C2V = 80
EPS1V = 0.02 EPS2V = 0,04
PSISV = 0.15 PSISSV = 1.5 PSIMAV = 0.35
I1MV = 60 I2MV = 300 I3MV = 150

Initial yaw regulator values

$$\begin{bmatrix} a_1' \\ a_2' \\ a_3' \\ b_1' \\ b_2' \end{bmatrix} = \begin{bmatrix} -43.56 \\ 4.94 \\ 0.90 \\ 1.30 \\ 0.81 \end{bmatrix} \qquad PY = \begin{bmatrix} 500 & & & & \\ 0 & 500 & & & \\ 0 & 0 & 500 & & \\ 0 & 0 & 0 & 1 & \\ 0 & 0 & 0 & 0 & 1 \end{bmatrix}$$

$a_1' + a_2' + a_3' = -37.72$

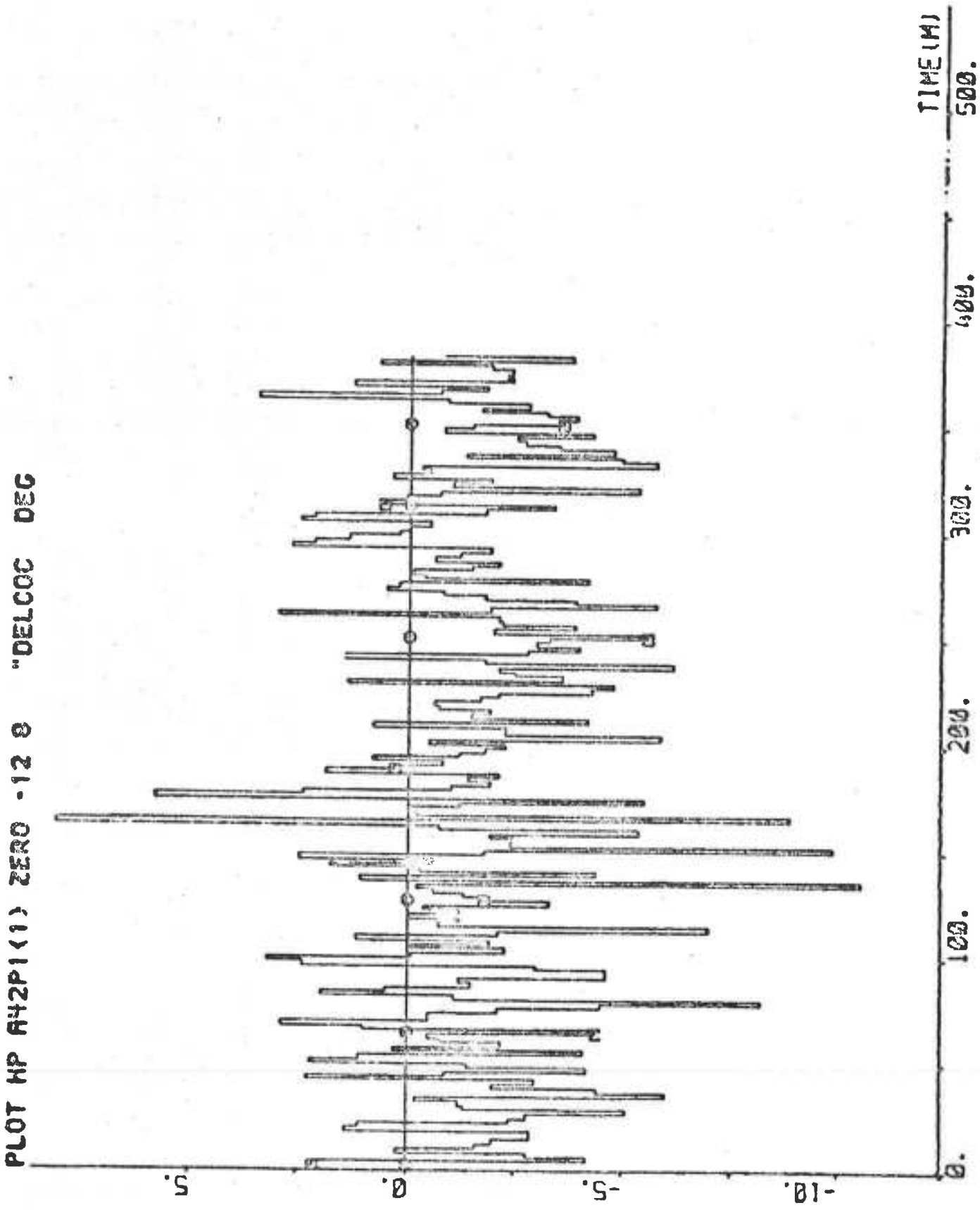
Yaw regulator values after the last yaw

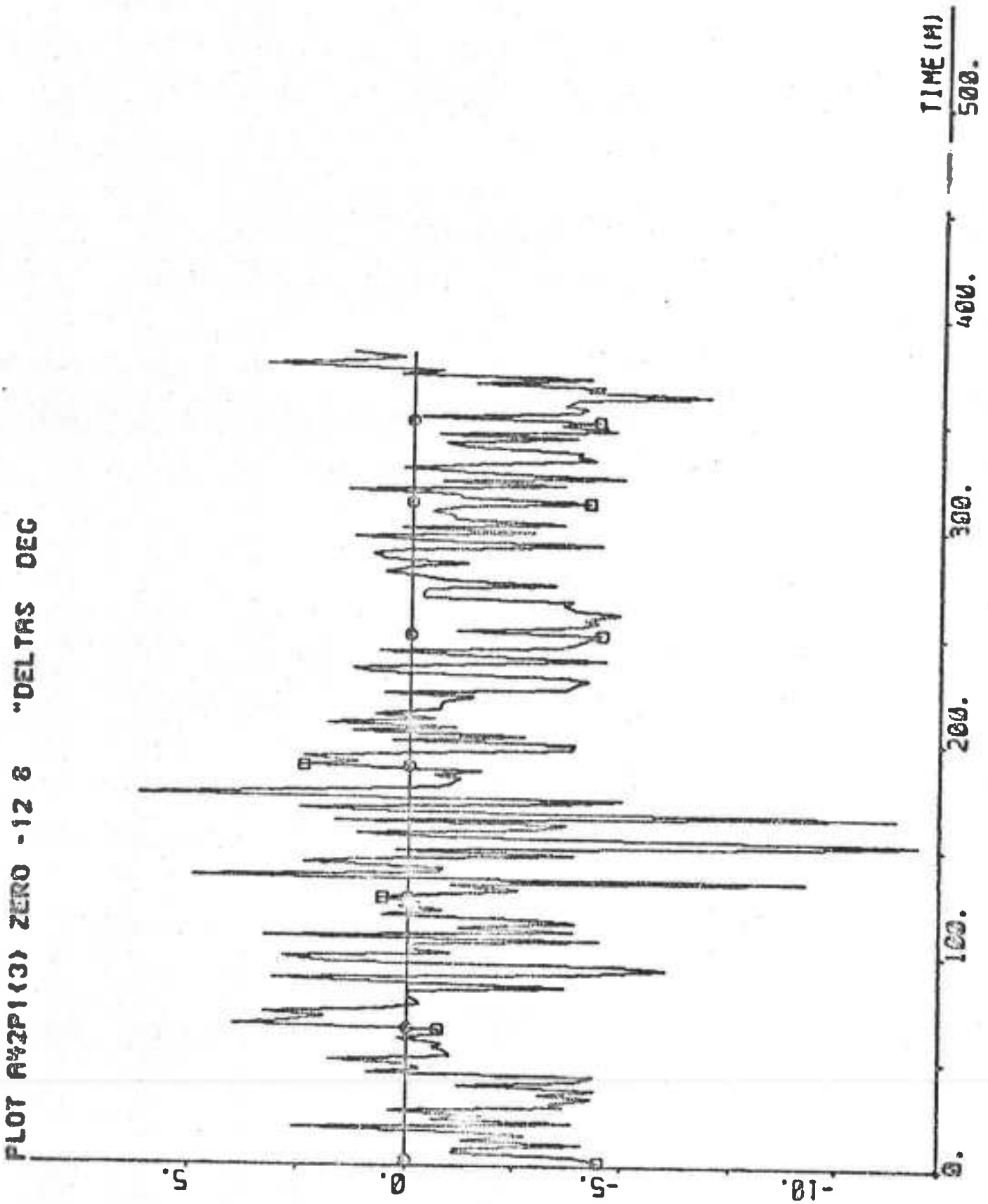
$$\begin{bmatrix} a_1' \\ a_2' \\ a_3' \\ b_1' \\ b_2' \end{bmatrix} = \begin{bmatrix} -43.855 \\ 5.006 \\ 0.900 \\ 1.306 \\ 0.810 \end{bmatrix} \qquad PY = \begin{bmatrix} 32.466 & & & & \\ -6.043 & 513.950 & & & \\ 0 & 0 & 646.178 & & \\ -0.526 & -11.520 & 0 & 0.289 & \\ 0 & 0 & 0 & 0 & 1.292 \end{bmatrix}$$

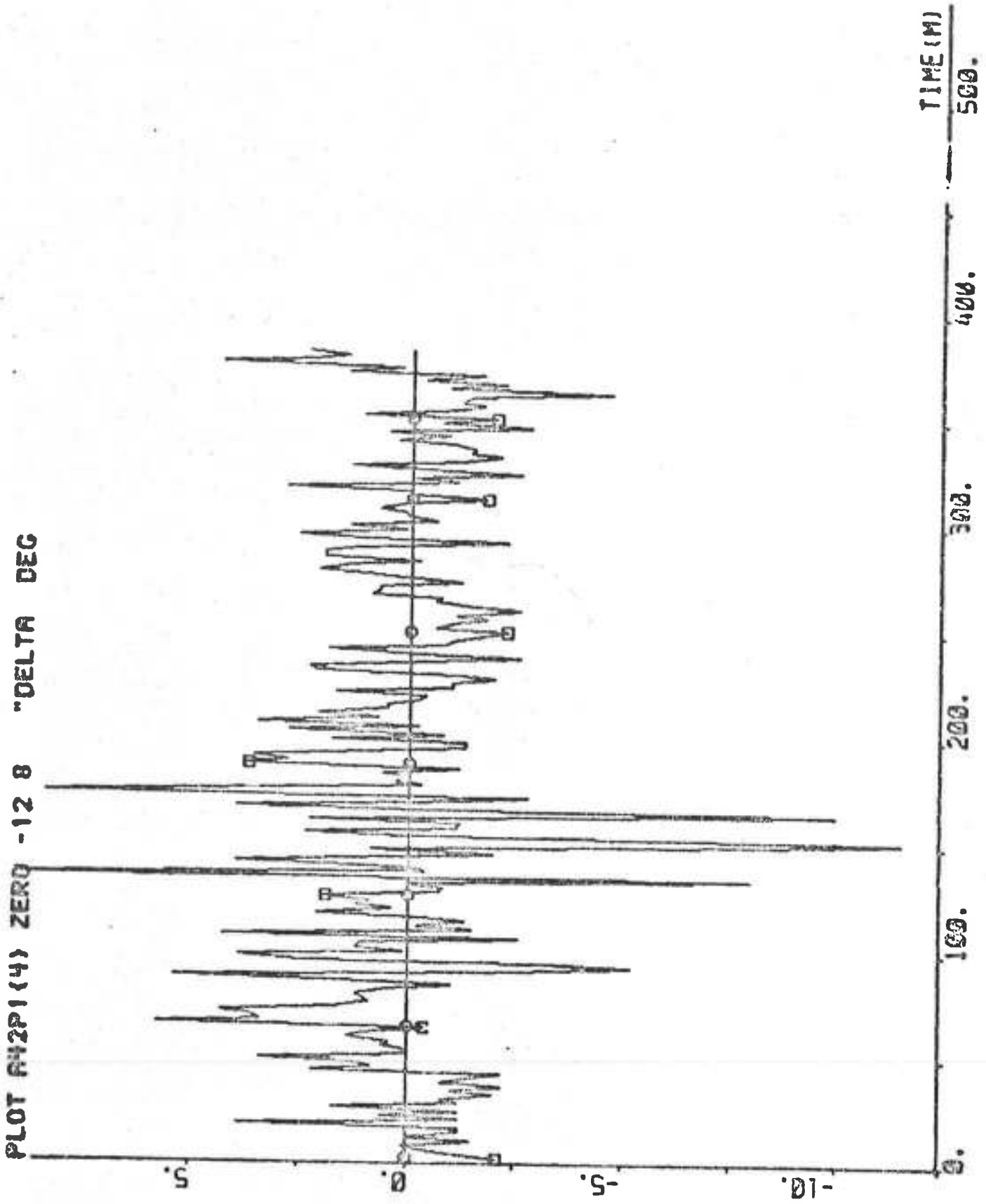
$a_1' + a_2' + a_3' = -37.949$

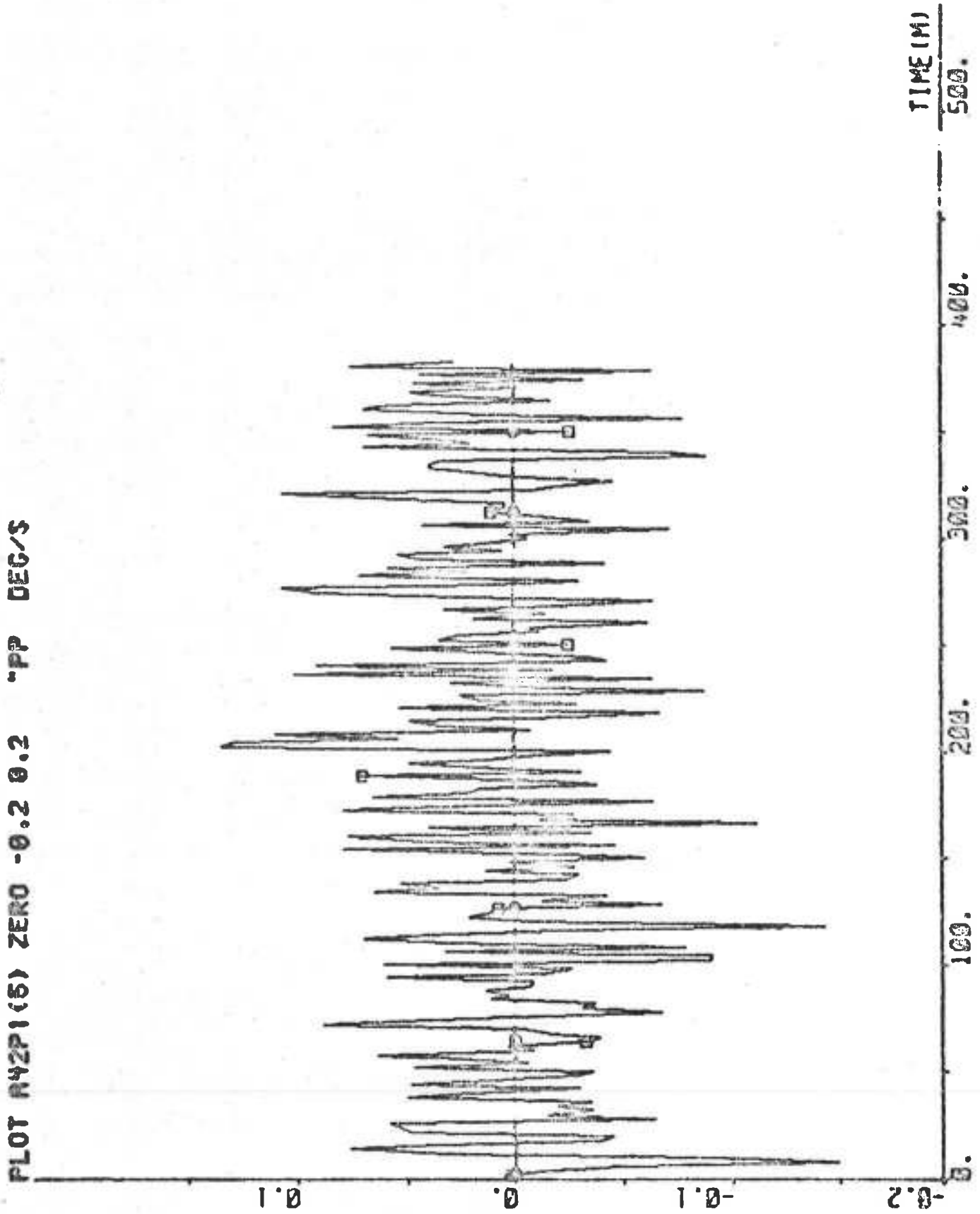
Statistics (mean value and standard deviation)

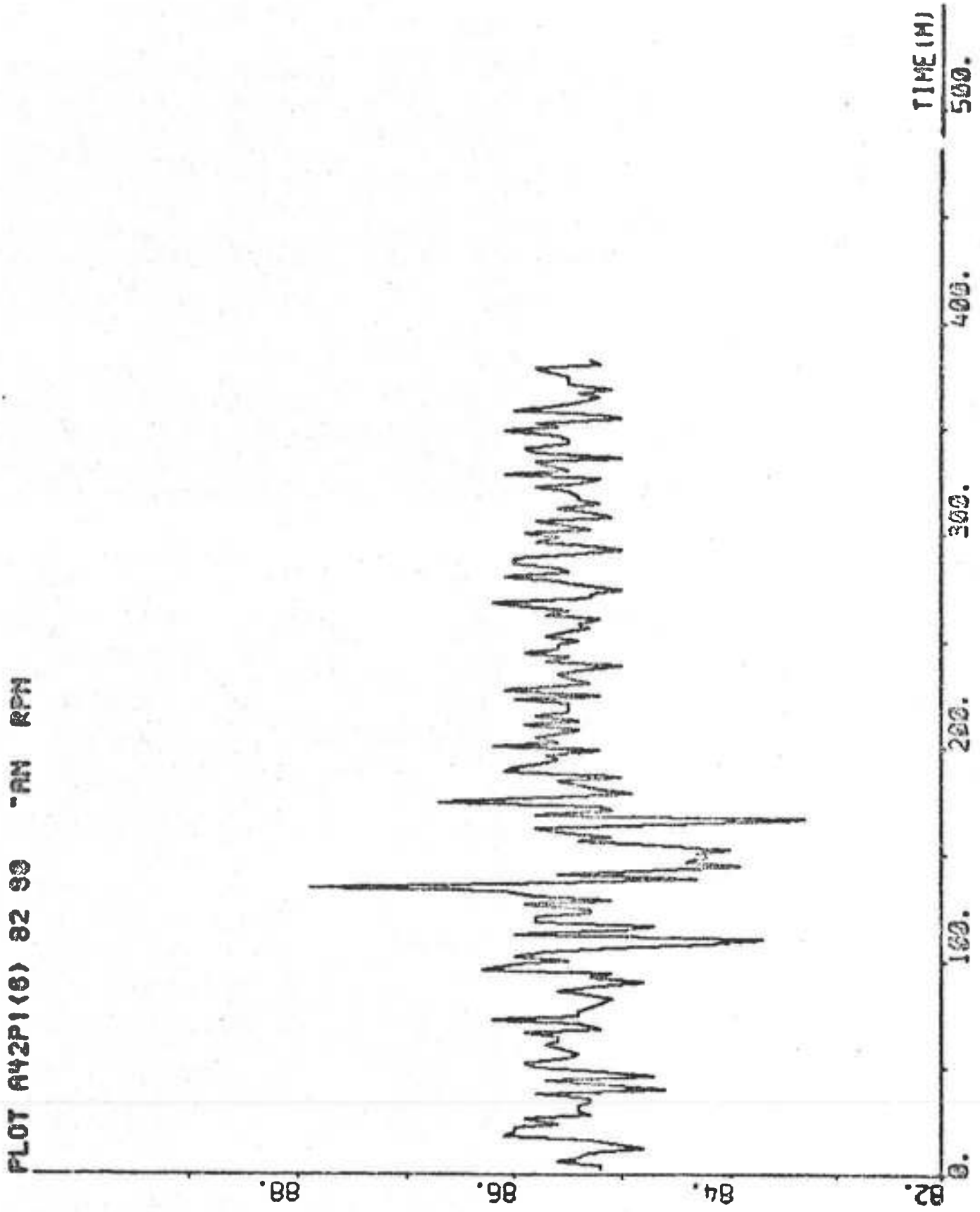
	200-380 min
DELTA	-0.10 ± 1.62 deg
PSI-PSIREF	-0.019 ± 0.186 deg
AN	85.55 ± 0.28 rpm
U	16.29 ± 0.27 knots
V_1	0.298
V_2	0.297

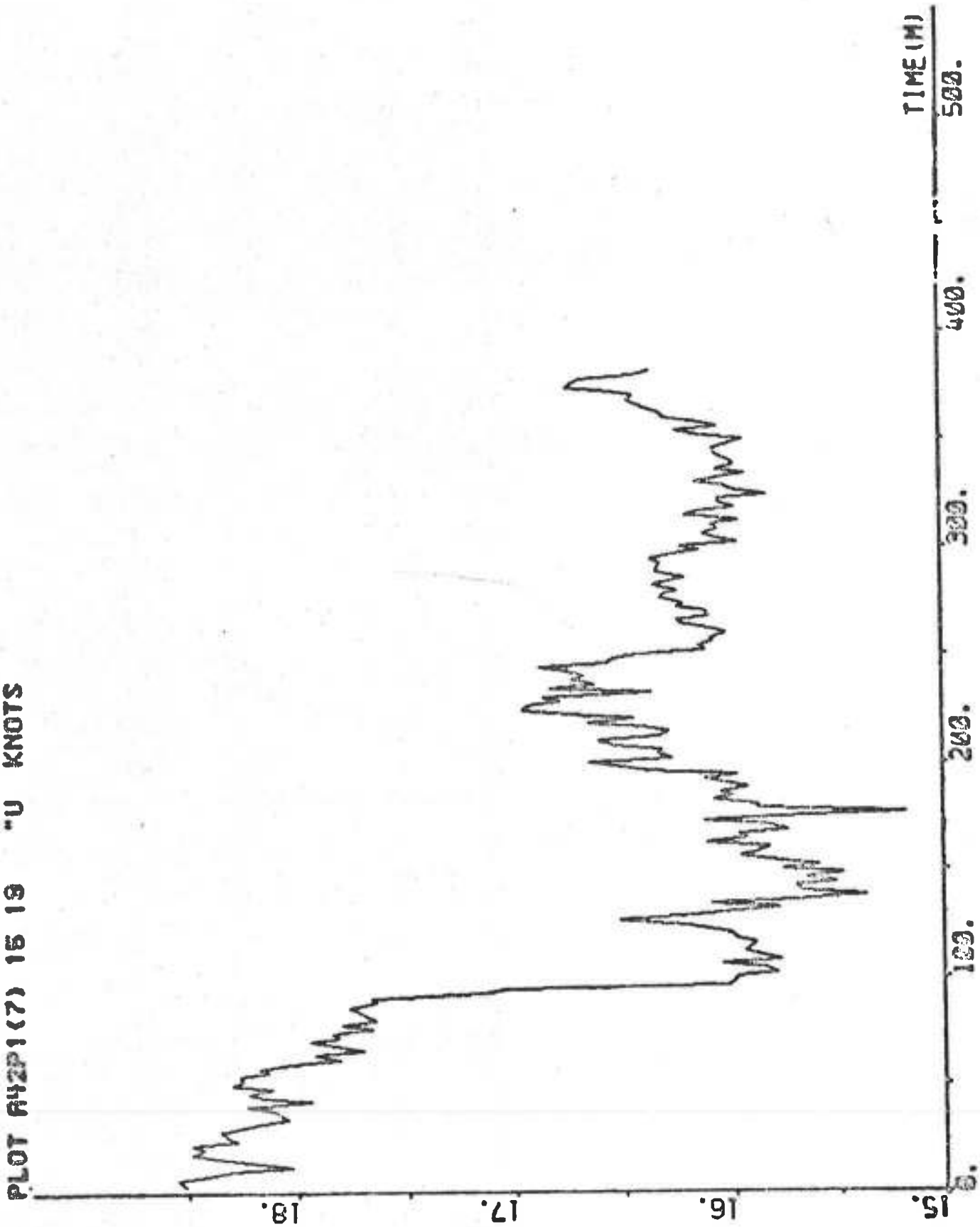

PLOT HP AH2P1(1) ZERO -12 0 "DELCOC DEG
TIME(M)
0.
100.
200.
300.
400.
500.
5.
0.
-5.
-10.

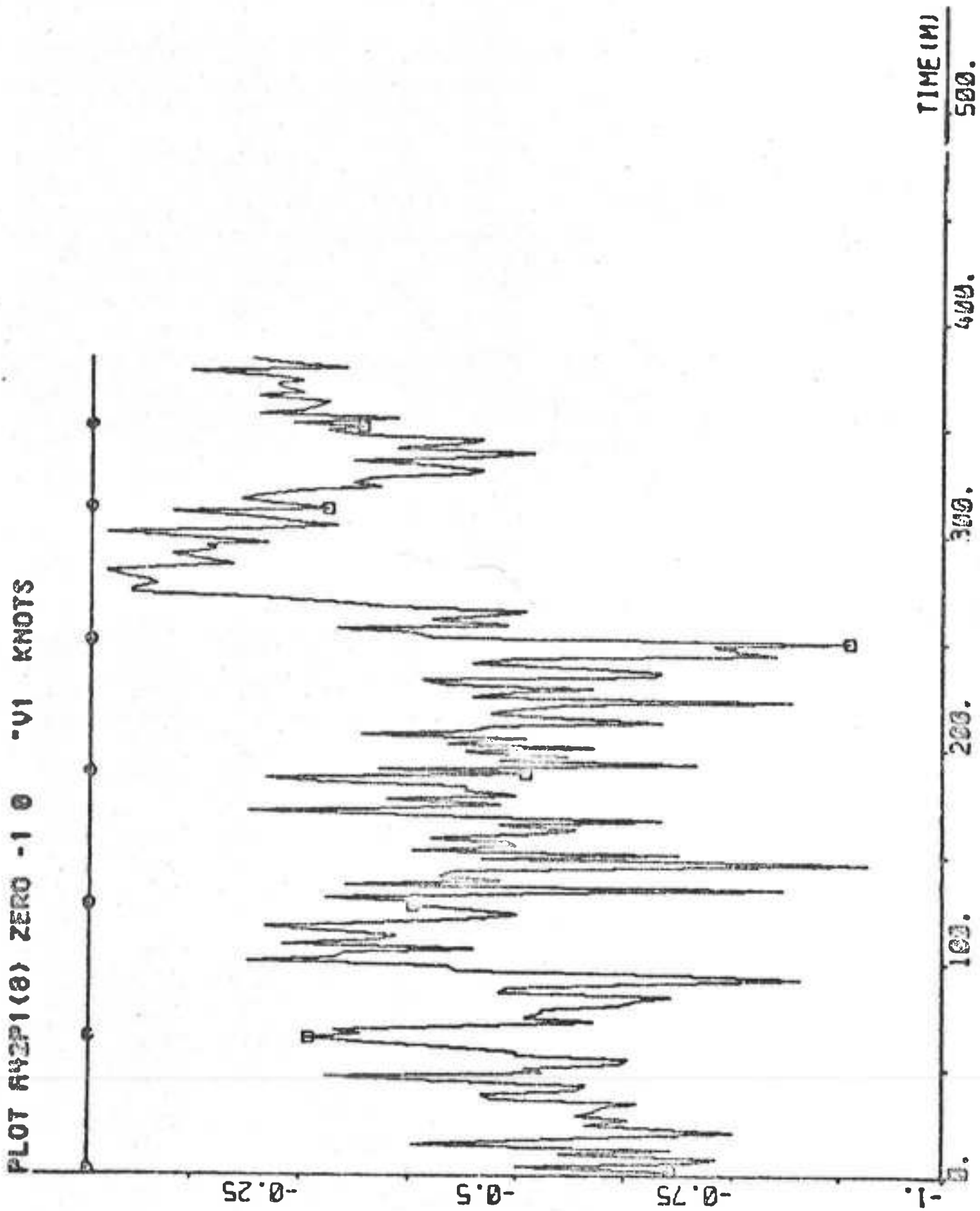

PLOT A%2P1(3) ZERO -12 8 "DELTAS DEG
5.
0.
-5.
-10.
0.
100.
200.
300.
400.
500.
TIME(M)

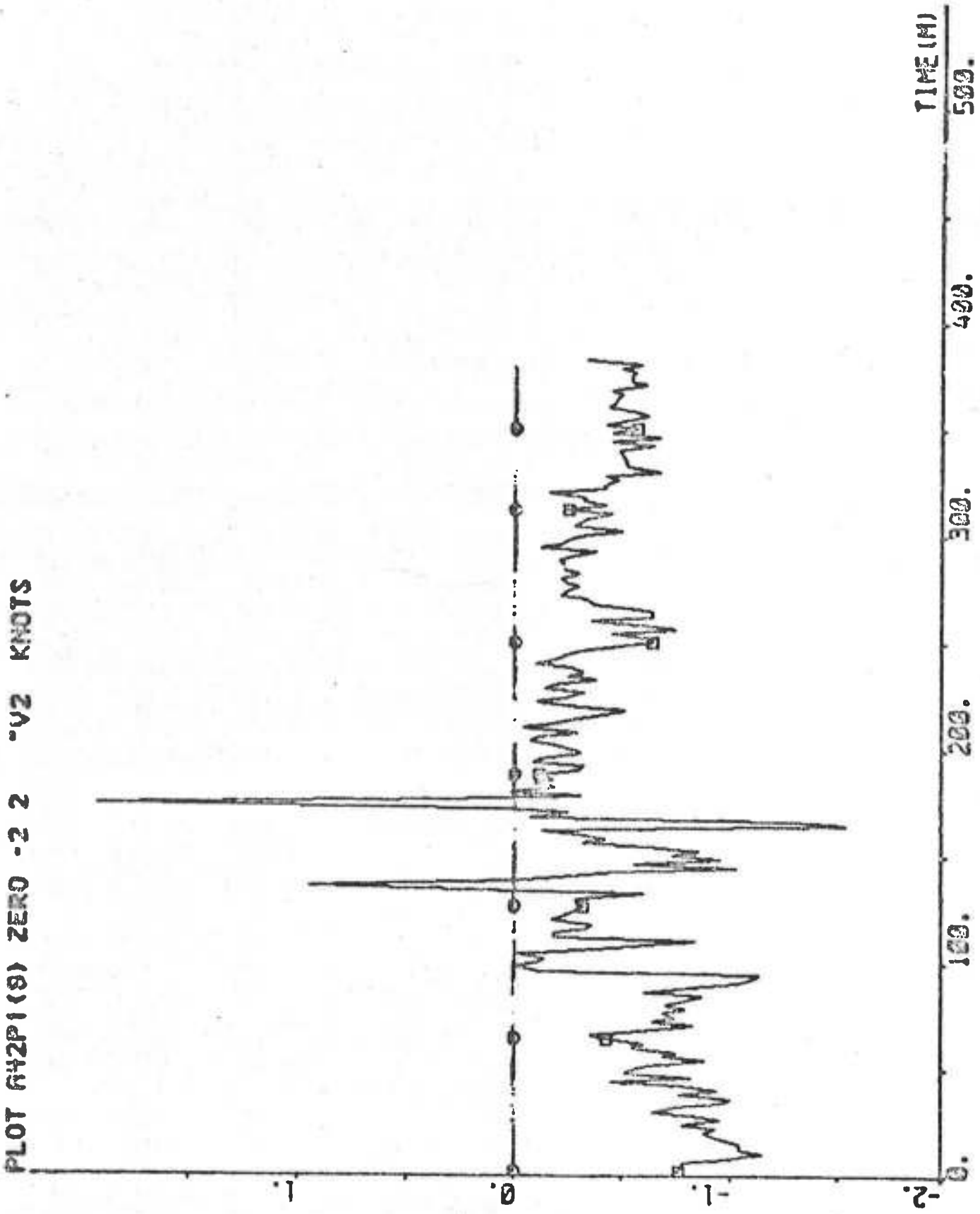

PLOT AH2P1(4) ZERO -12 8 "DELTA DEG
5.
0.
-5.
-10.
0.
100.
200.
300.
400.
500.
TIME(M)

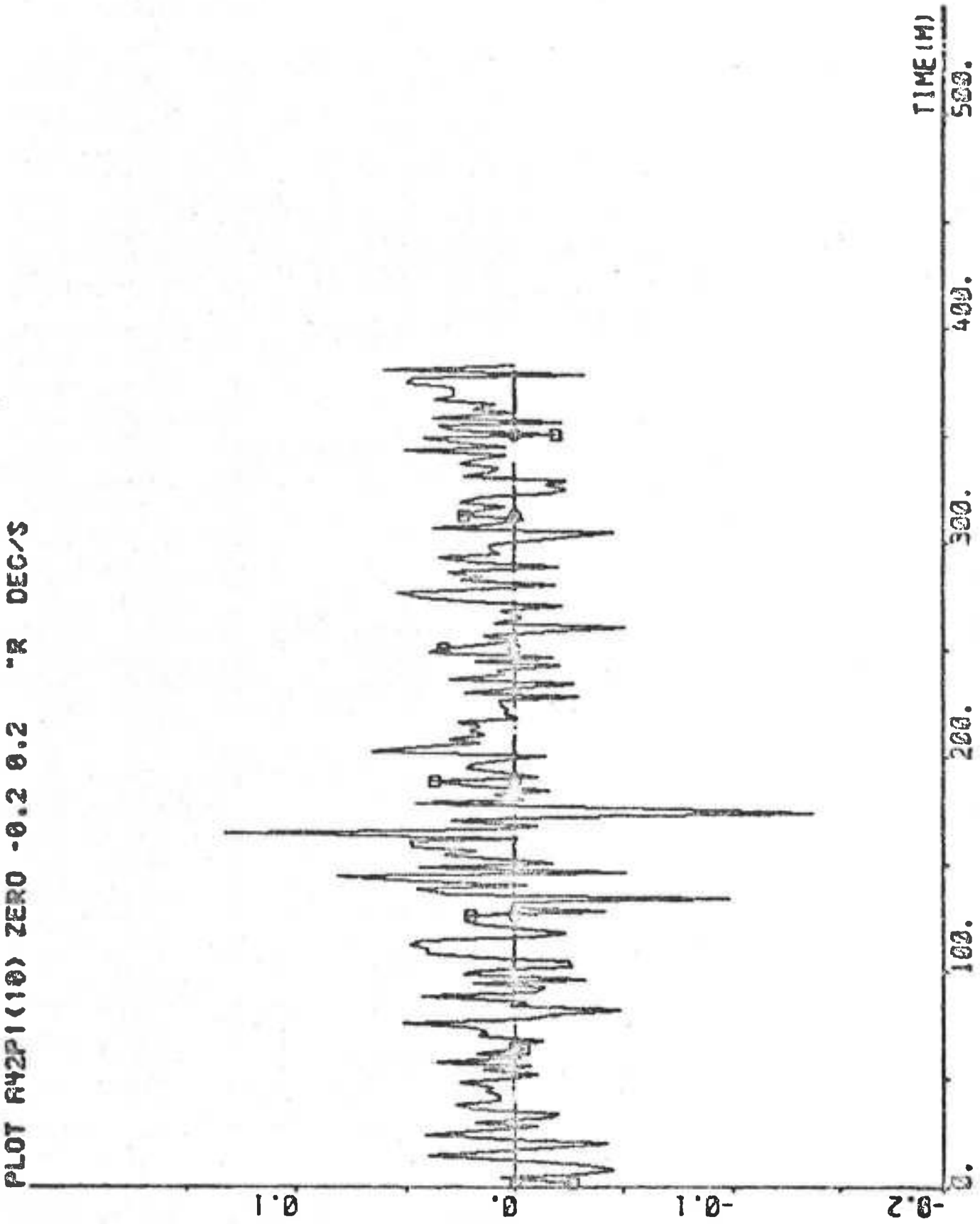

PLOT R42P1(S) ZERO -0.2 0.2 'PP DEG/S
TIME(M)
0.
100.
200.
300.
400.
500.
0.2
0.1
0.
-0.1
-0.2

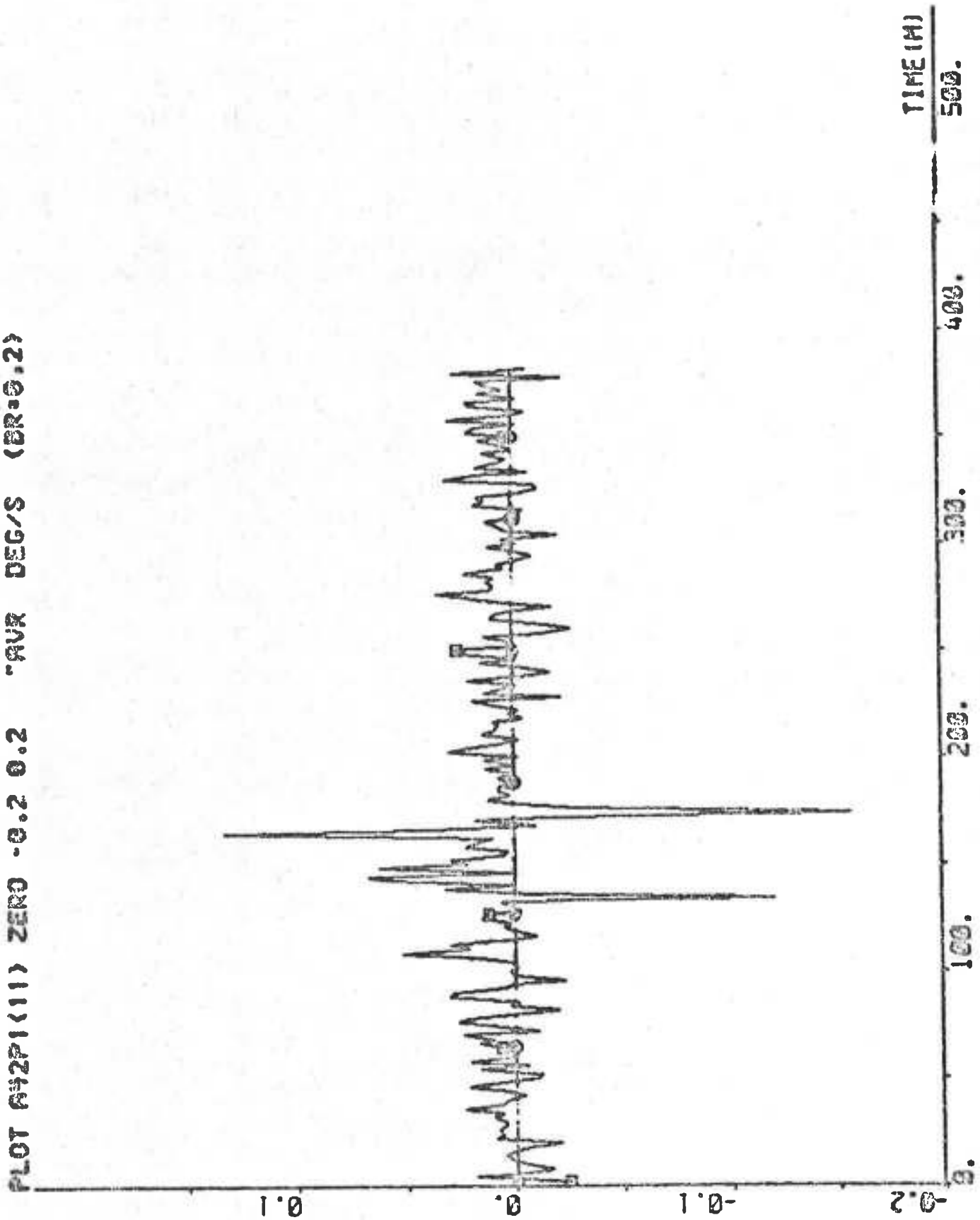

PLOT A42P1(8) 82 90 'AN RPN
82.
84.
86.
88.
0.
100.
200.
300.
400.
500.
TIME(H)

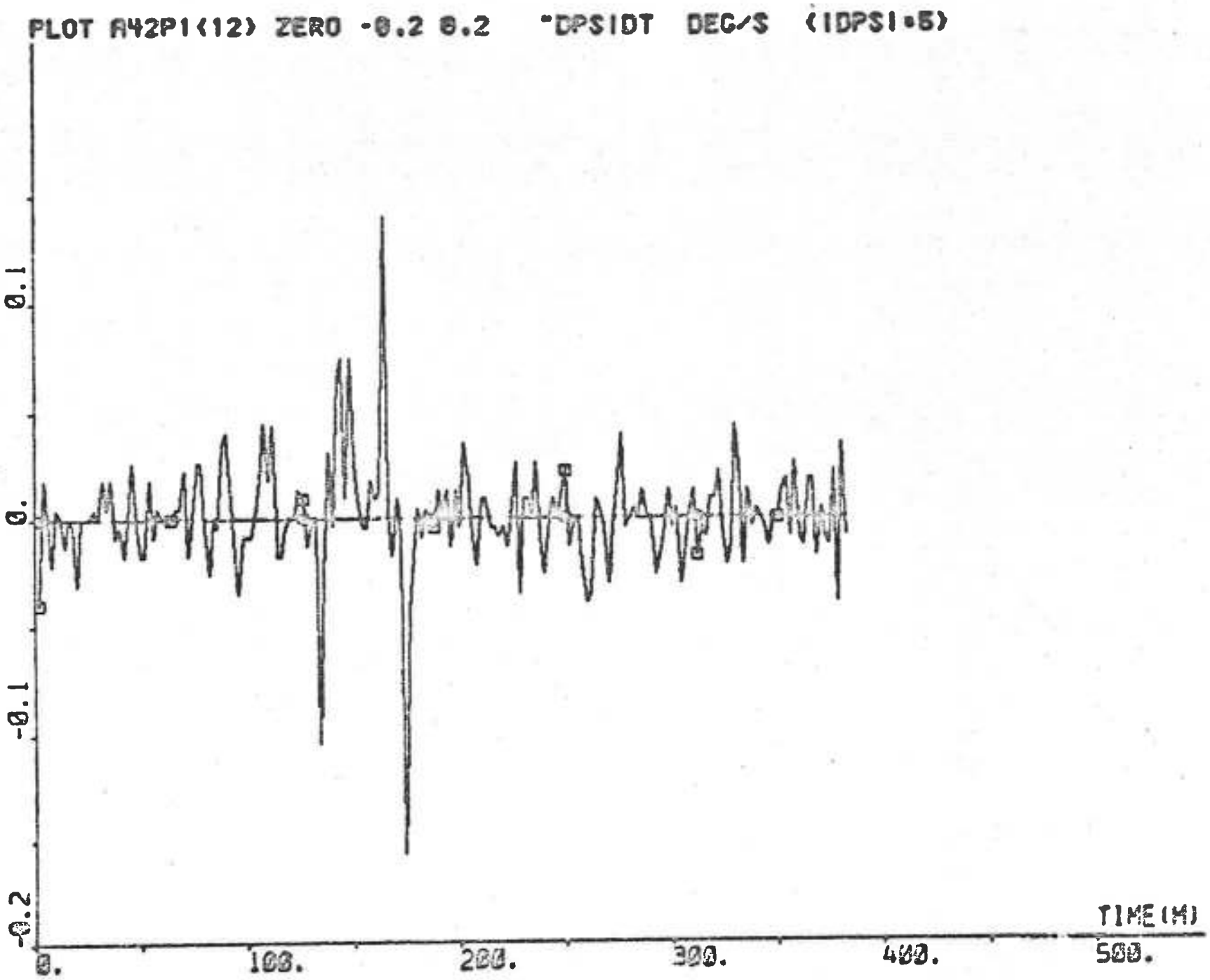

PLOT AH2P1(7) 15 18 "U KNOTS
18.
17.
16.
15.
0.
100.
200.
300.
400.
500.
TIME(M)

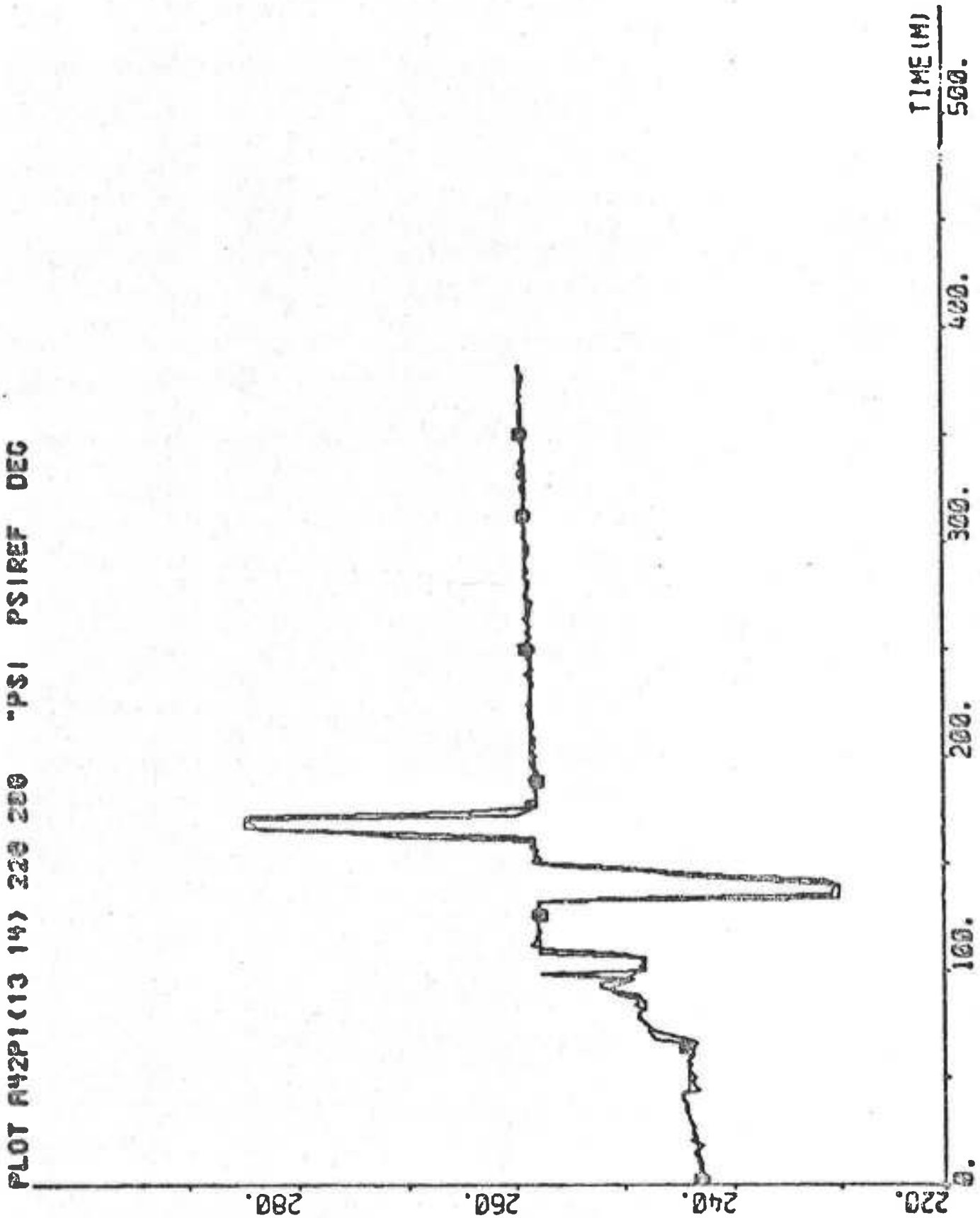

PLOT AV2P1(8) ZERO -1 0 'V1 KNOTS
-0.25
-0.5
-0.75
-1.
0.
100.
200.
300.
400.
500.
TIME(M)

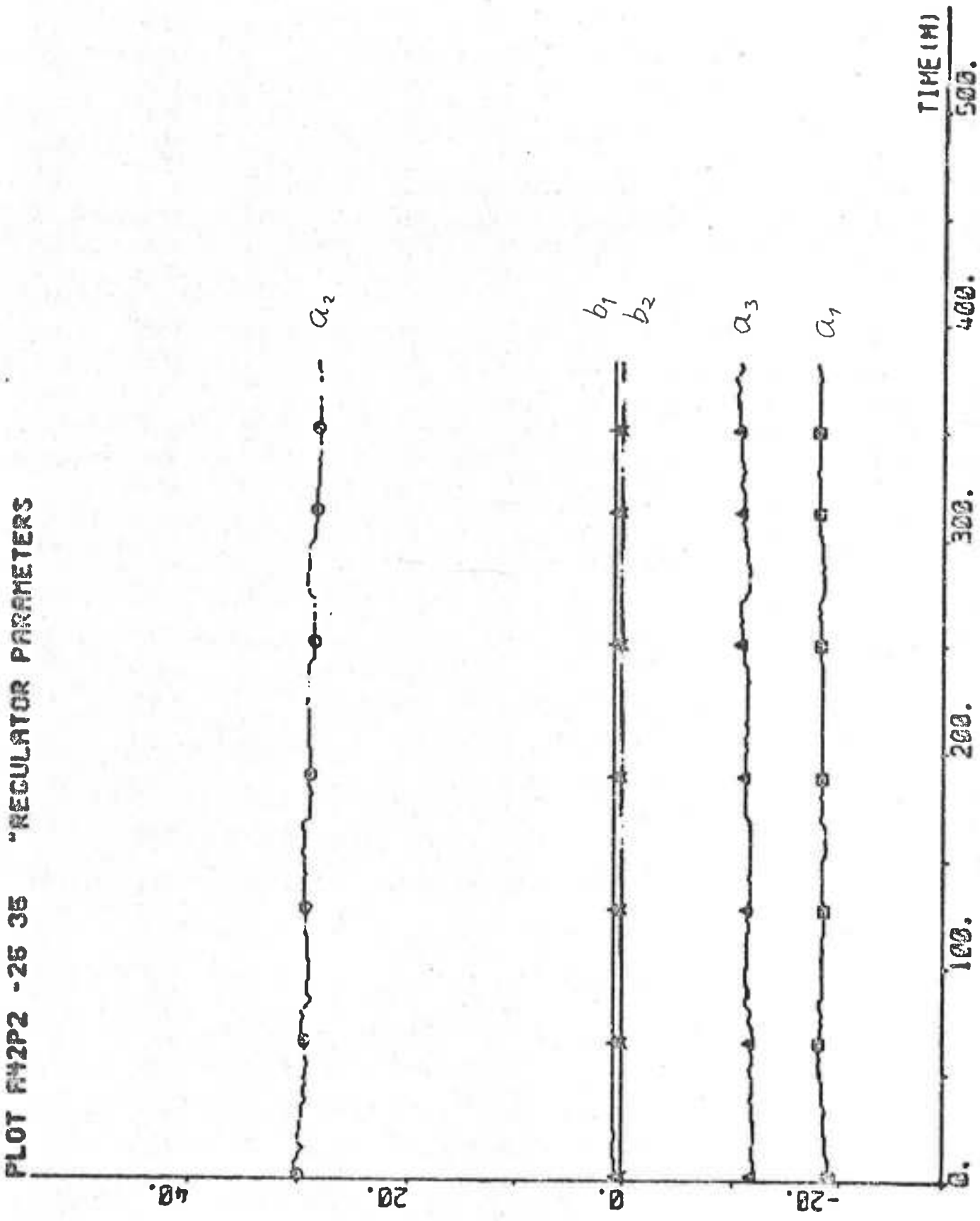

PLOT AH2P1(8) ZERO -2 2 'V2 KNOTS
1.
0.
-1.
-2.
0.
100.
200.
300.
400.
500.
TIME(M)


PLOT R42P1(10) ZERO -0.2 0.2 "R DEG/S
0.1
0.
-0.1
-0.2
0.
100.
200.
300.
400.
500.
TIME(M)


PLOT A42P1(11) ZERO -0.2 0.2 "AVR DEG/S (BR=0.2)
0.1
0.
-0.1
-0.2
0.
100.
200.
300.
400.
500.
TIME(H)


PLOT A42P1(12) ZERO -0.2 0.2 "DPSIDT DEG/S (IDPSI*5)
0.1
0.
-0.1
-0.2
0.
100.
200.
300.
400.
500.
TIME(M)


PLOT A42P1(13 14) 220 280 *PSI PSIREF DEG
220.
240.
260.
280.
0.
100.
200.
300.
400.
500.
TIME(M)


PLOT RM2P2 -25 35 "REGULATOR PARAMETERS
40.
20.
0.
-20.
0.
100.
200.
300.
400.
500.
TIME(M)
a_2
b_1
b_2
a_3
a_1

EXPERIMENT A43

Date	1974-10-23
Time	08.29
Duration	62 min
Position	S 34° 47' E 24° 01'
Water depth	deep
Forward draught	20.0 m
Aft draught	20.0 m
Wind direction	E (5; see Appendix A)
Wind velocity	3-4 Beaufort (4-8 m/s, gentle to moderate breeze)
Wave height	Sea from E
PSIREF	259.6° - 259.9° (Sailmaster)
Rudder limit	Not active

The yaw regulator was never used, because PSIMAV was equal to 0.35° and the course changes requested by the Sailmaster were only 0.1°.

Regulator structure

NA = 3 NB = 2 NC = 0 K = 5
IREG = 15 RL = 0.99

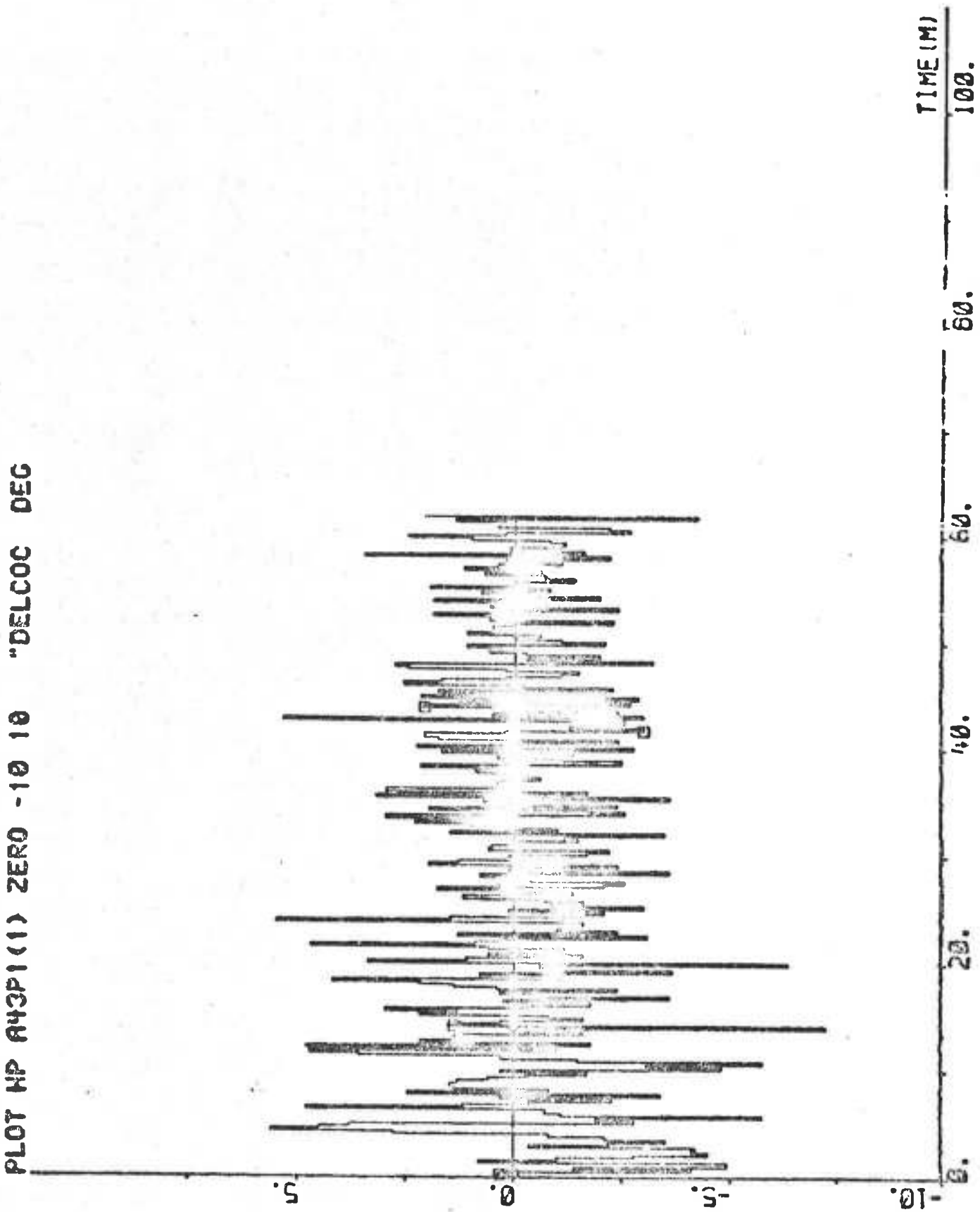
Final values

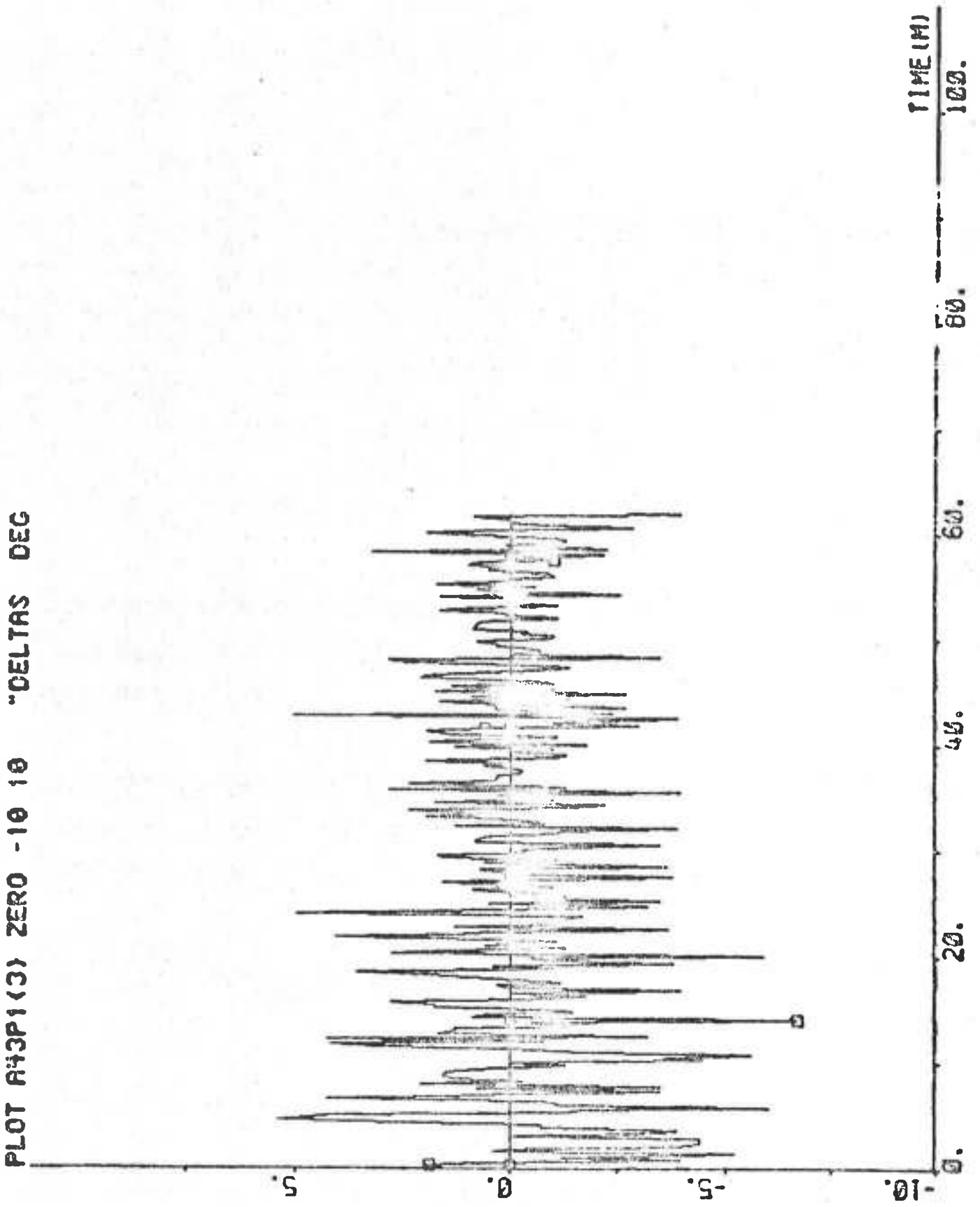
$$\begin{bmatrix} a_1 \\ a_2 \\ a_3 \\ b_1 \\ b_2 \end{bmatrix} = \begin{bmatrix} -18.071 \\ 29.138 \\ -11.124 \\ 0.802 \\ 0.129 \end{bmatrix} \qquad P = \begin{bmatrix} 0.929 & & & & \\ -1.068 & 2.663 & & & \\ 0.400 & -1.921 & 2.099 & & \\ -0.010 & -0.052 & 0.080 & 0.006 & \\ -0.006 & -0.057 & 0.078 & 0.005 & 0.005 \end{bmatrix}$$

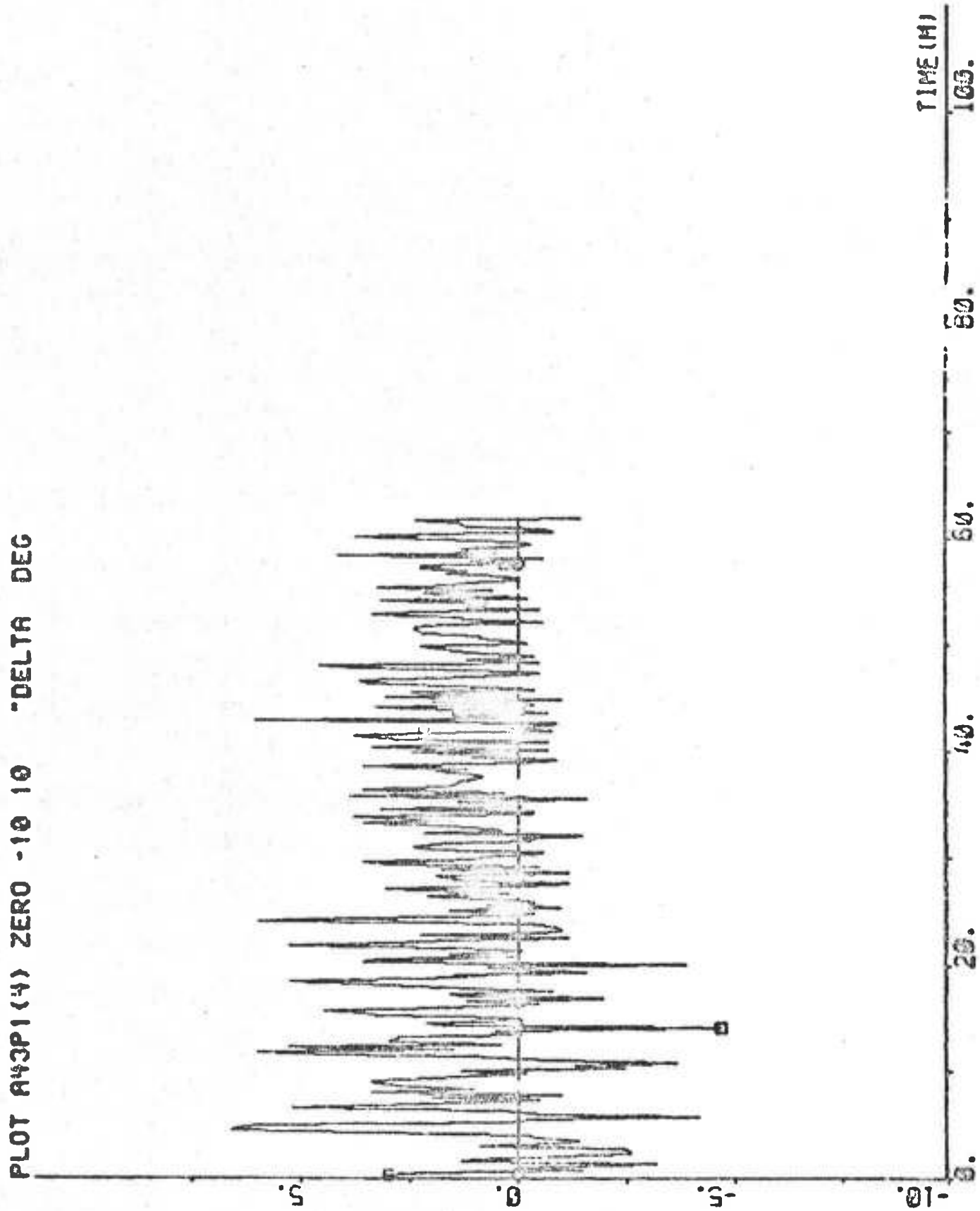
$$a_1 + a_2 + a_3 = -0.057$$

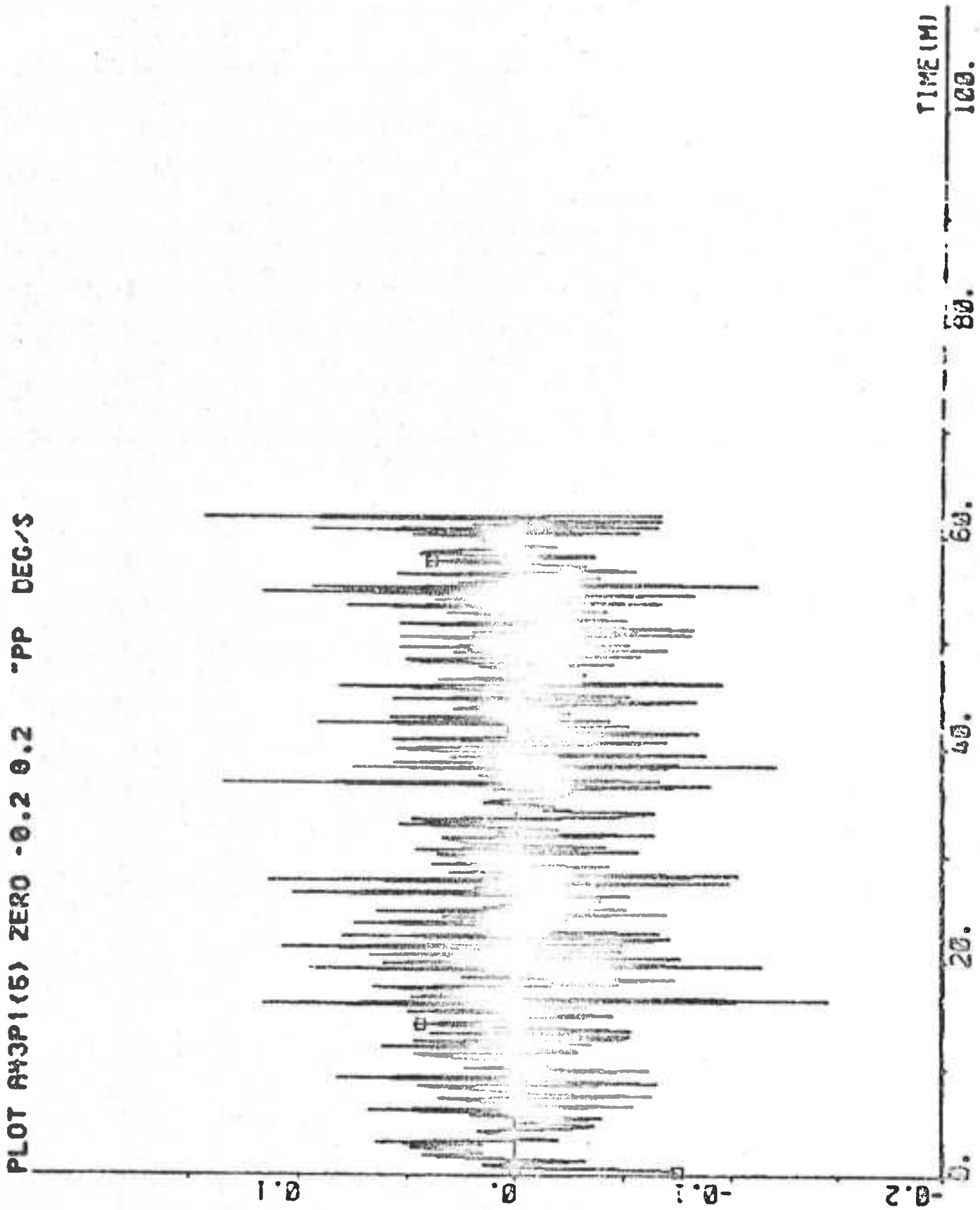
Statistics (mean value and standard deviation)

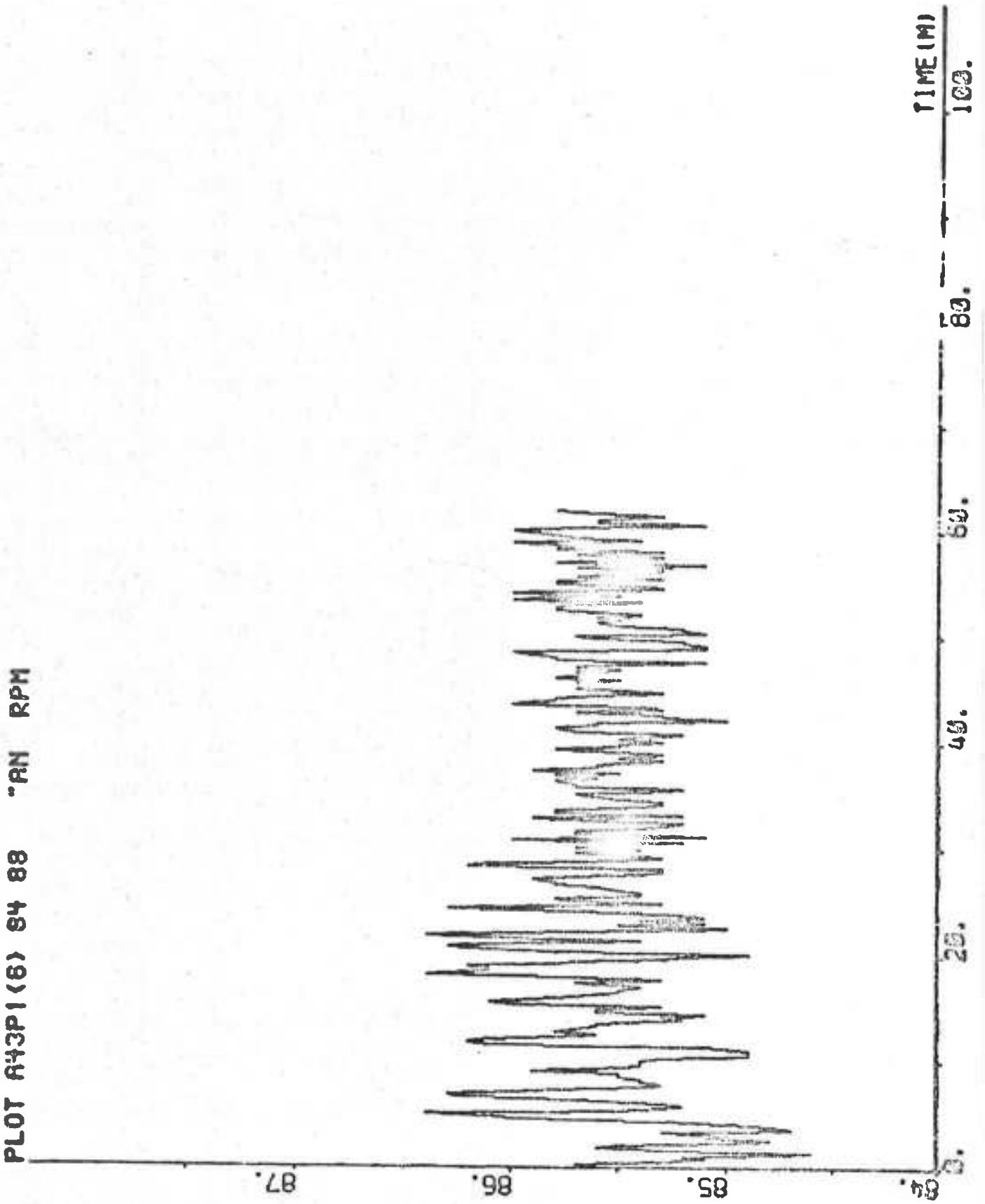
	0-62 min	20-62 min
DELTA	1.14 ± 1.94 deg	1.21 ± 1.58 deg
PSI-PSIREF	0.050 ± 0.291 deg	0.003 ± 0.152 deg
AN	85.55 ± 0.33 rpm	85.57 ± 0.28 rpm
U	15.19 ± 0.16 knots	15.12 ± 0.09 knots
V_1	0.594	0.419
V_2	0.464	0.273

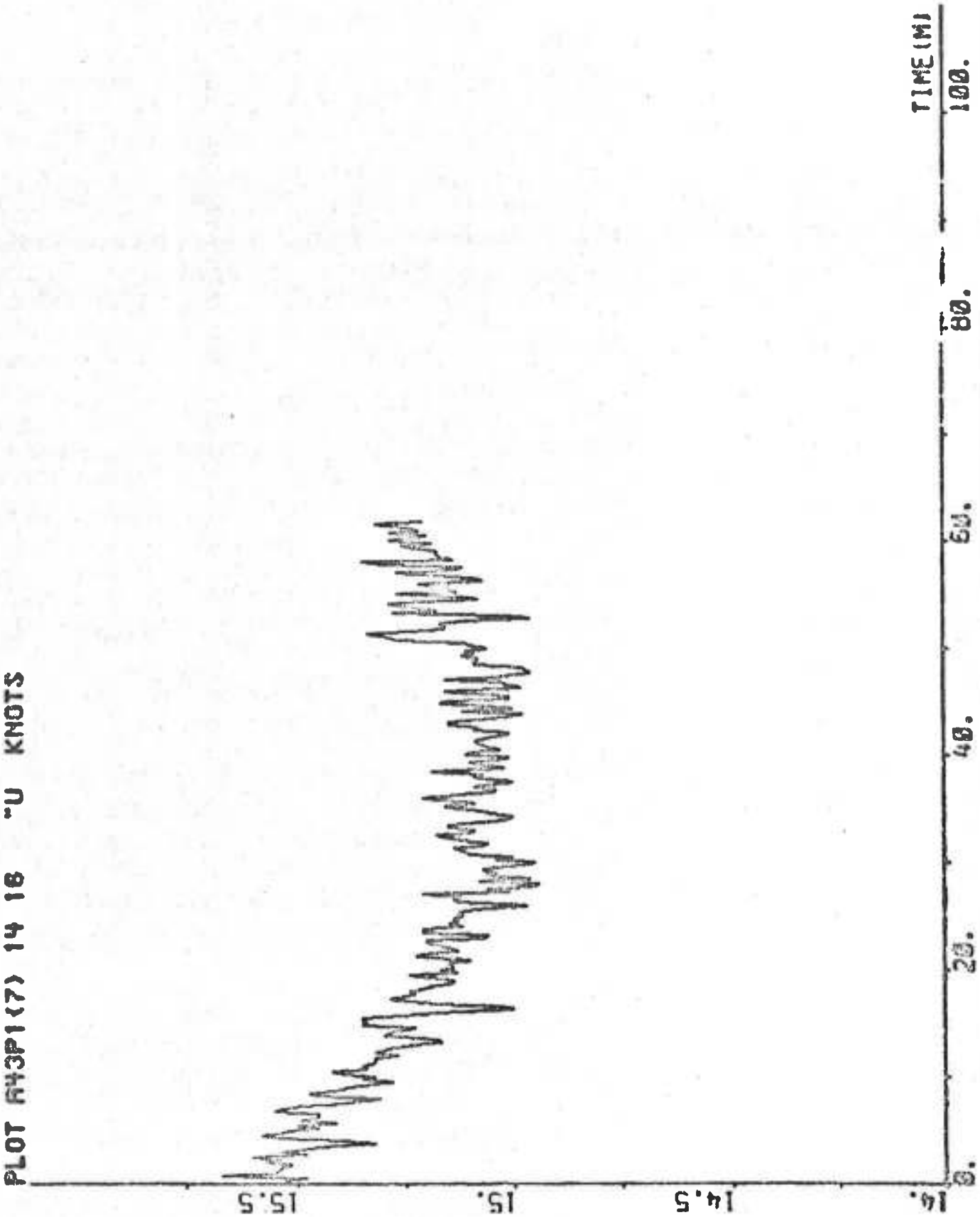

PLOT HP A43P1(1) ZERO -10 10 "DELCOC DEC
TIME(M)
0.
20.
40.
60.
100.
5.
0.
-5.
-10.

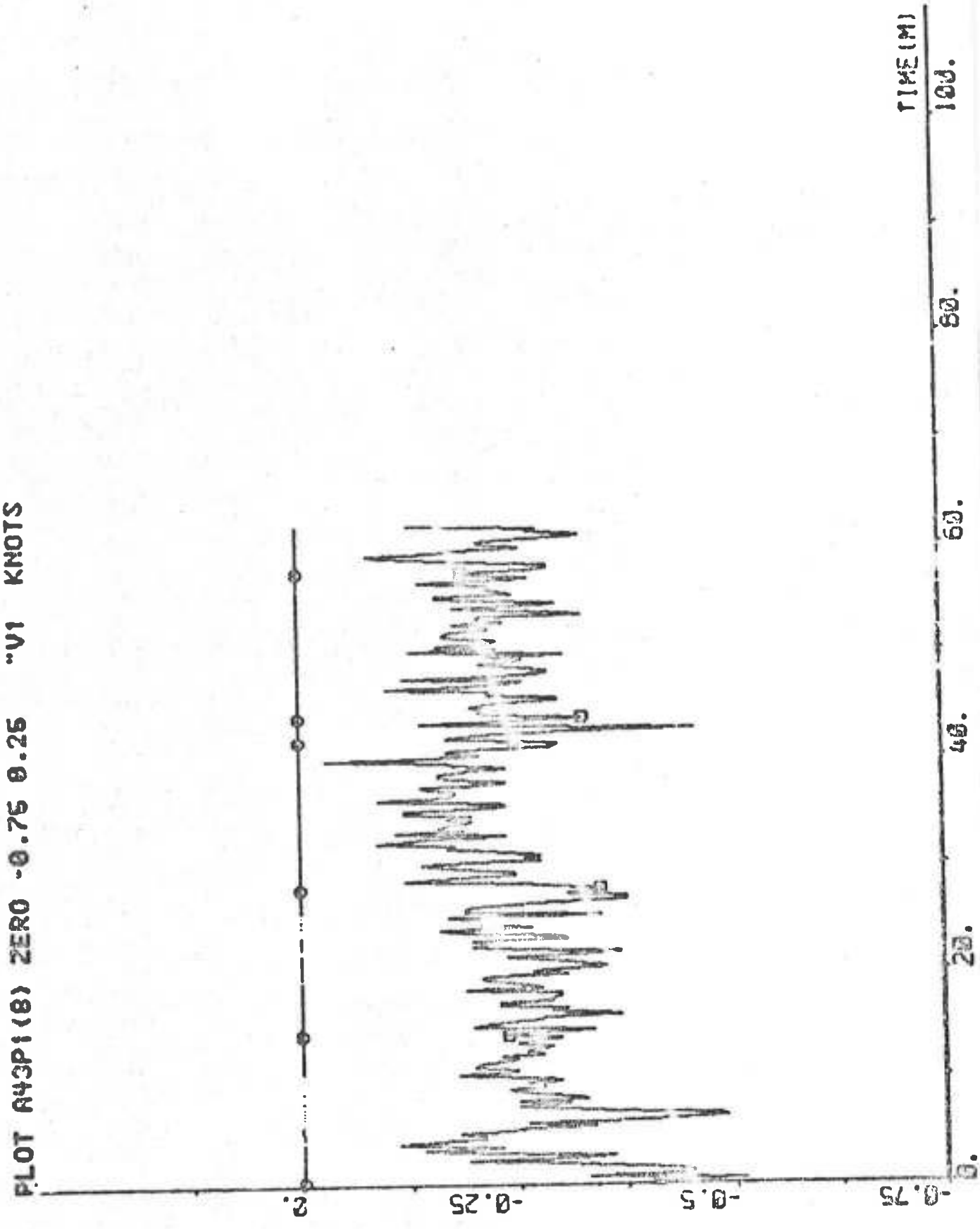

PLOT A43P1(3) ZERO -10 10 "DELTAS DEG
5.
0.
-5.
-10.
0.
20.
40.
60.
80.
100.
TIME(M)

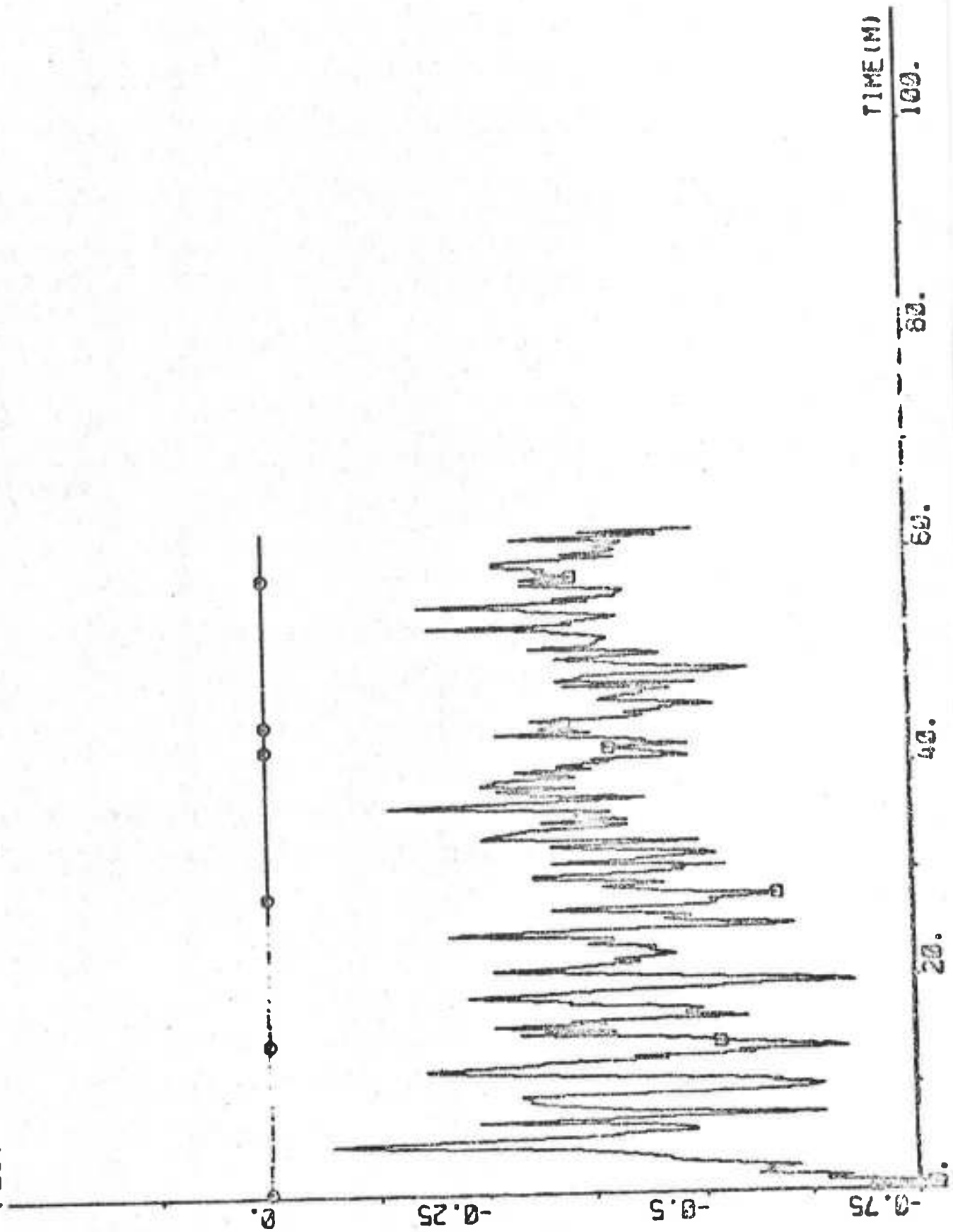

PLOT A43P1(4) ZERO -10 10 'DELTA DEG
5.
0.
-5.
-10.
TIME(H)
0.
20.
40.
60.
80.
100.

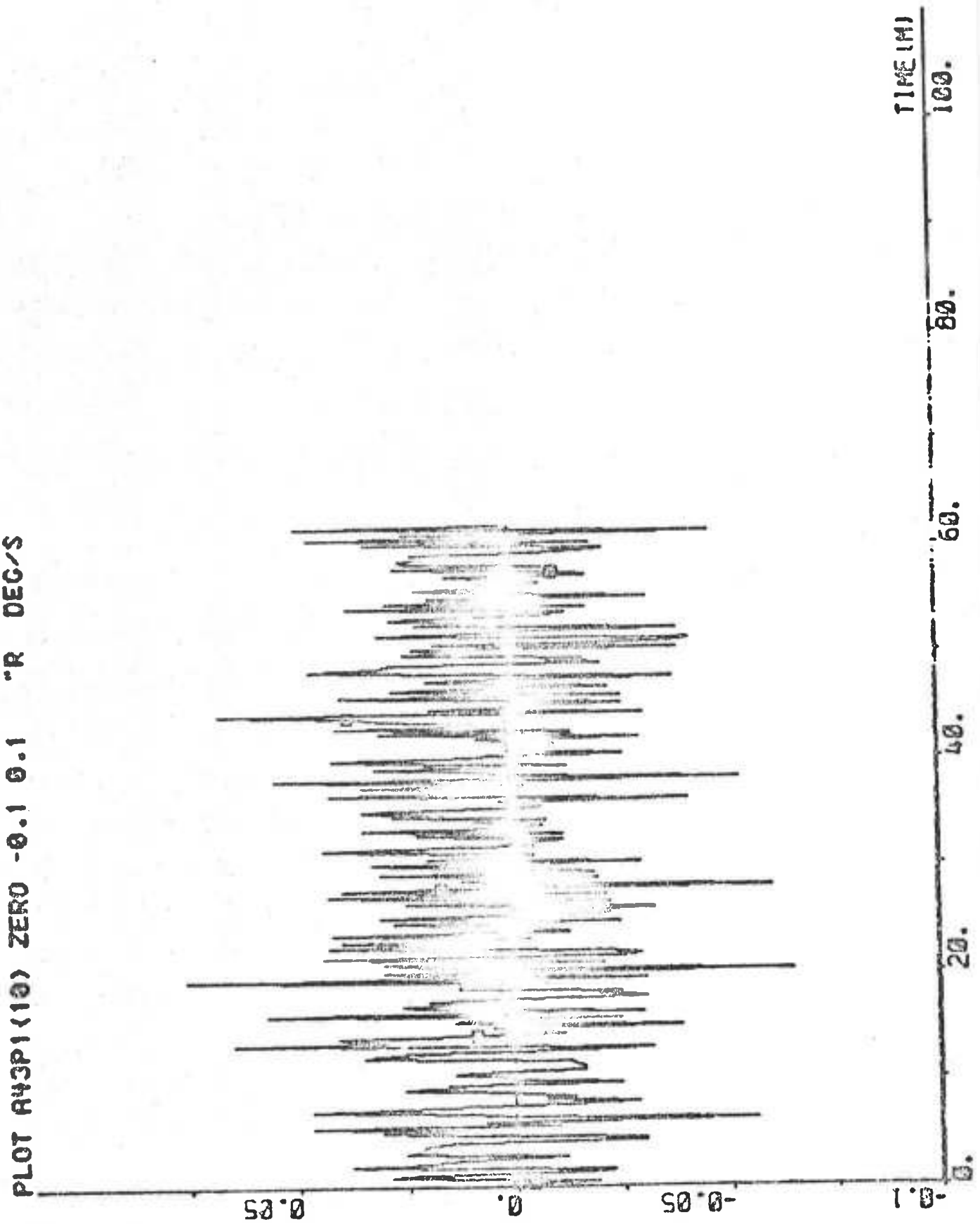

PLOT AM3P1(5) ZERO -0.2 0.2 "PP DEG/S
0.1
0.
-0.1
-0.2
0.
20.
40.
60.
80.
100.
TIME(M)

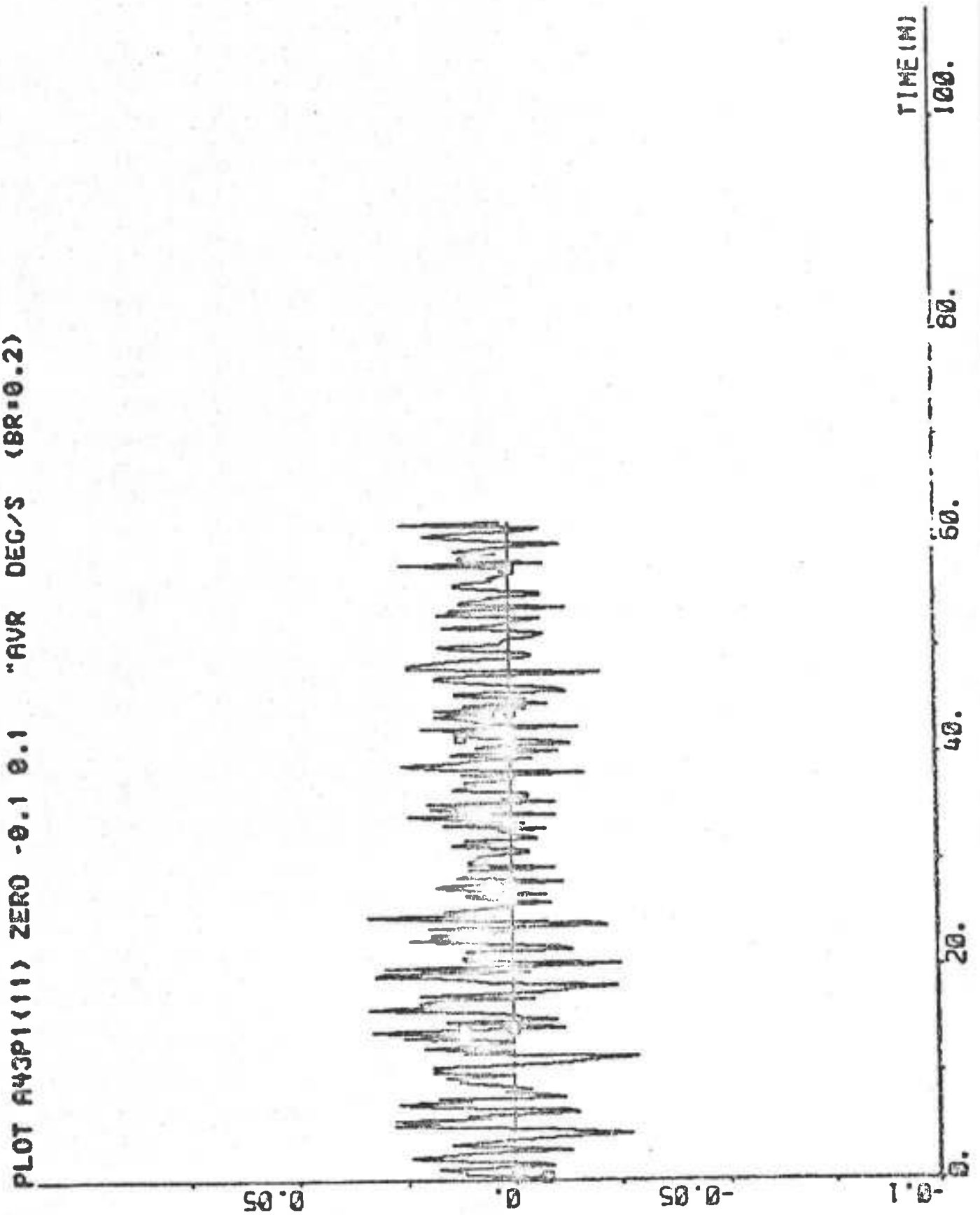

PLOT A43P1(6) 84 88 *AN RPM
84.
85.
86.
87.
0.
29.
49.
69.
83.
103.
TIME(M)

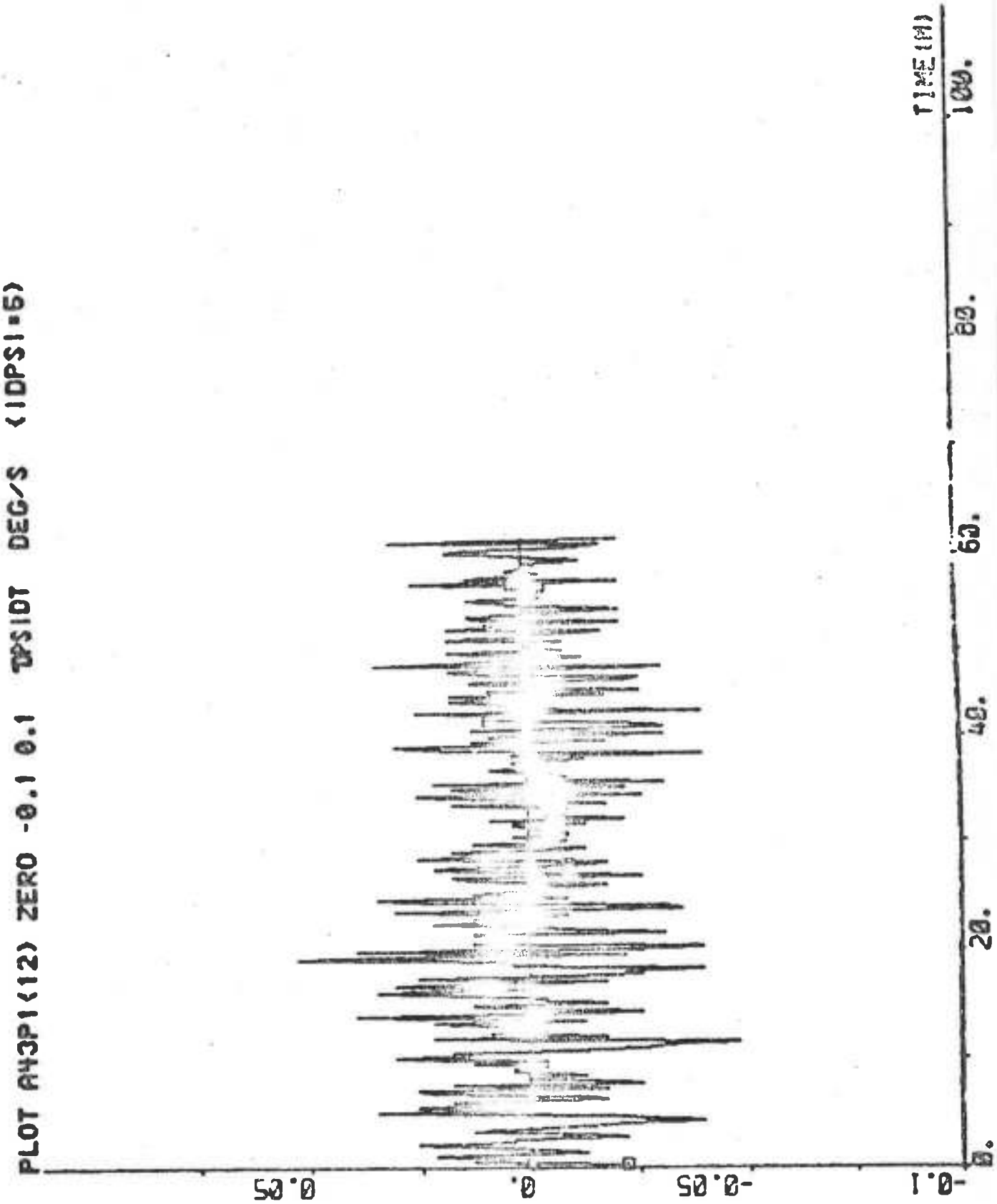

PLOT A43P1(7) 14 18 "U KNOTS
15.5
15.
14.5
14.
0.
20.
40.
60.
80.
100.
TIME(MI

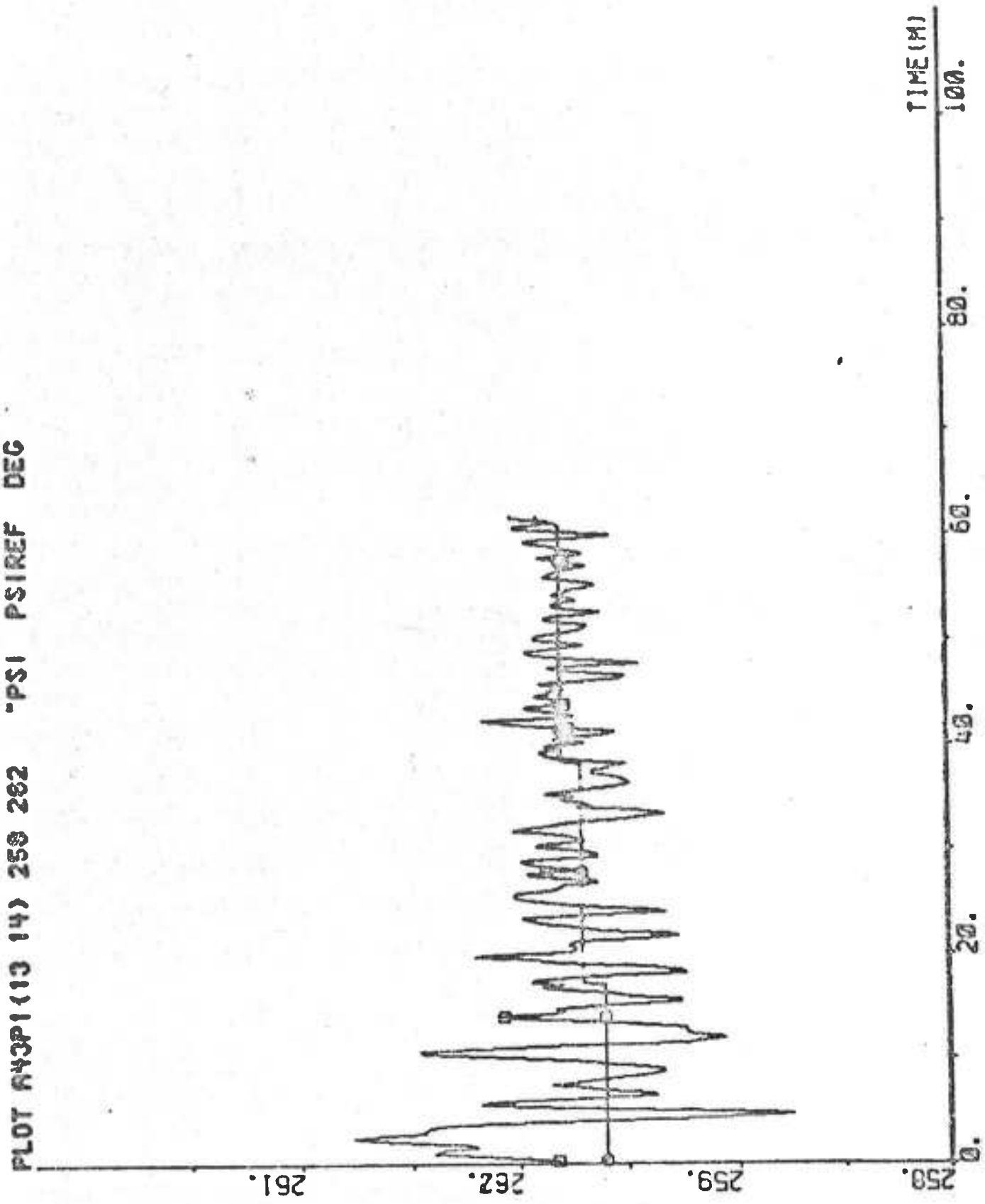

PLOT A43P1(8) ZERO -0.75 0.25 "V1 KNOTS
TIME(M)
0.
20.
40.
60.
80.
100.
-0.75
-0.5
-0.25
0.

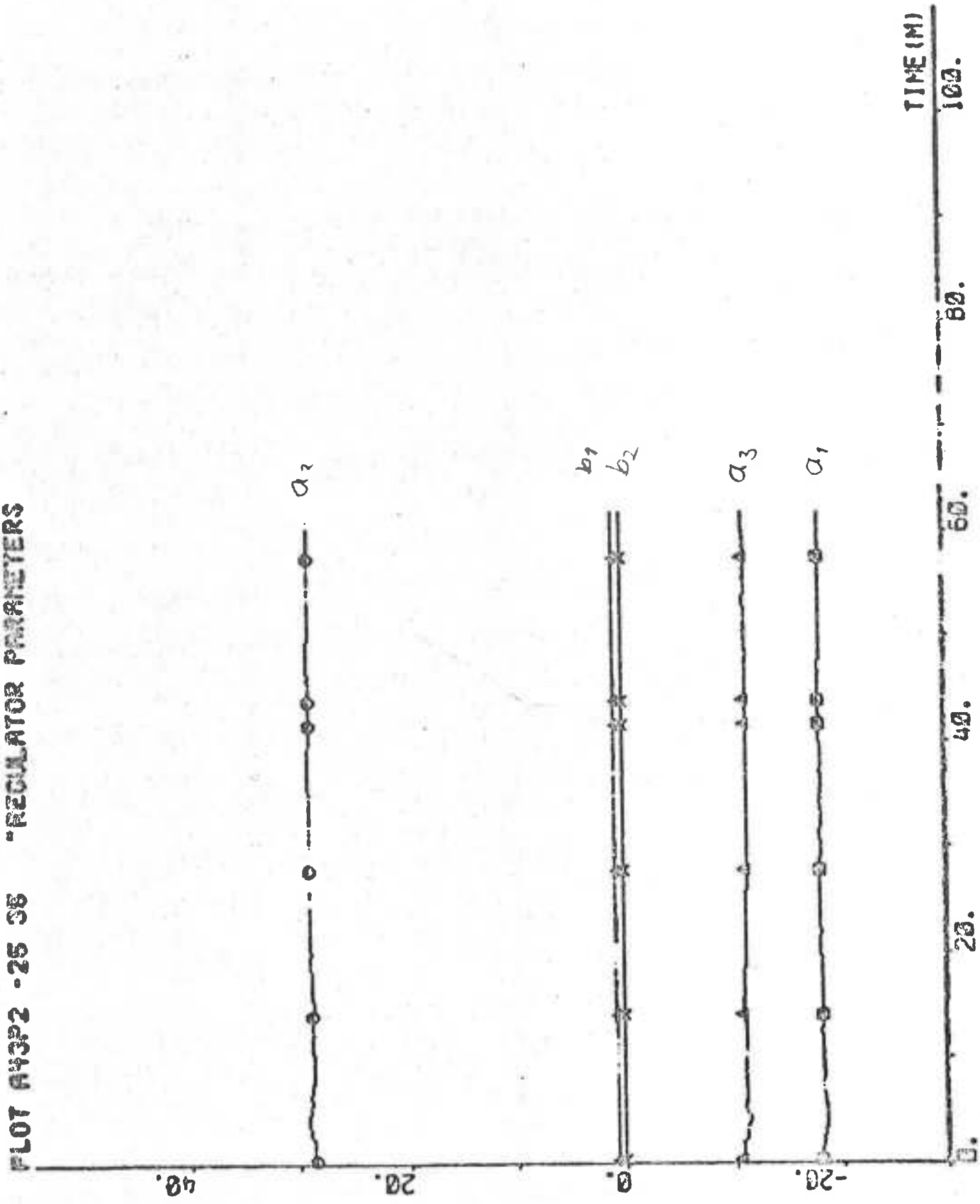

PLOT A43P1(9) ZERO -0.75 0.25 "V2 KNOTS
0.
-0.25
-0.5
-0.75
TIME(M)
0.
20.
40.
60.
80.
100.


PLOT AY3P1(10) ZERO -0.1 0.1 "R DEG/S
0.05
0.
-0.05
-0.1
0.
20.
40.
60.
80.
100.
TIME(M)


PLOT A43P1(11) ZERO -0.1 0.1 "AVR DEG/S (BR=0.2)
0.05
0.
-0.05
-0.1
0.
20.
40.
60.
80.
100.
TIME(M)


PLOT A43P1(12) ZERO -0.1 0.1 PSIDT DEG/S (IDPSI=6)
TIME(M)
0.
20.
40.
60.
80.
100.
-0.1
-0.05
0.
0.05


PLOT A43P1(13 14) 250 282 *PSI PSIREF DEG
261.
262.
259.
258.
0.
20.
40.
60.
80.
100.
TIME(M)


PLOT A432 -25 38 "REGULATOR PARAMETERS
40.
20.
0.
-20.
0.
20.
40.
60.
80.
100.
TIME(M)
a_2
b_1
b_2
a_3
a_1

EXPERIMENT A44

Date	1974-10-23
Time	10.15
Duration	92 min
Position	S 34° 52' E 23° 27'
Water depth	deep
Forward draught	20.0 m
Aft draught	20.0 m
Wind direction	E (5; see Appendix A)
Wind velocity	4 Beaufort (6-8 m/s, moderate breeze)
Wave height	Sea from E
PSIREF	260.1° - 260.5° (Sailmaster)
Rudder limit	Not active

The yaw regulator was never used, because PSIMAV was equal to 0.35° and the course changes requested by the Sailmaster were only 0.1°.

Regulator structure

NA = 3 NB = 2 NC = 0 K = 5

IREG = 15 RL = 0.99

Final values

$$\begin{bmatrix} a_1 \\ a_2 \\ a_3 \\ b_1 \\ b_2 \end{bmatrix} = \begin{bmatrix} -17.867 \\ 29.214 \\ -11.686 \\ 0.776 \\ 0.109 \end{bmatrix} \qquad P = \begin{bmatrix} 0.736 & & & & \\ -0.738 & 2.529 & & & \\ 0.298 & -2.184 & 2.594 & & \\ 0.005 & -0.073 & 0.089 & 0.004 & \\ 0.009 & -0.071 & 0.081 & 0.004 & 0.004 \end{bmatrix}$$

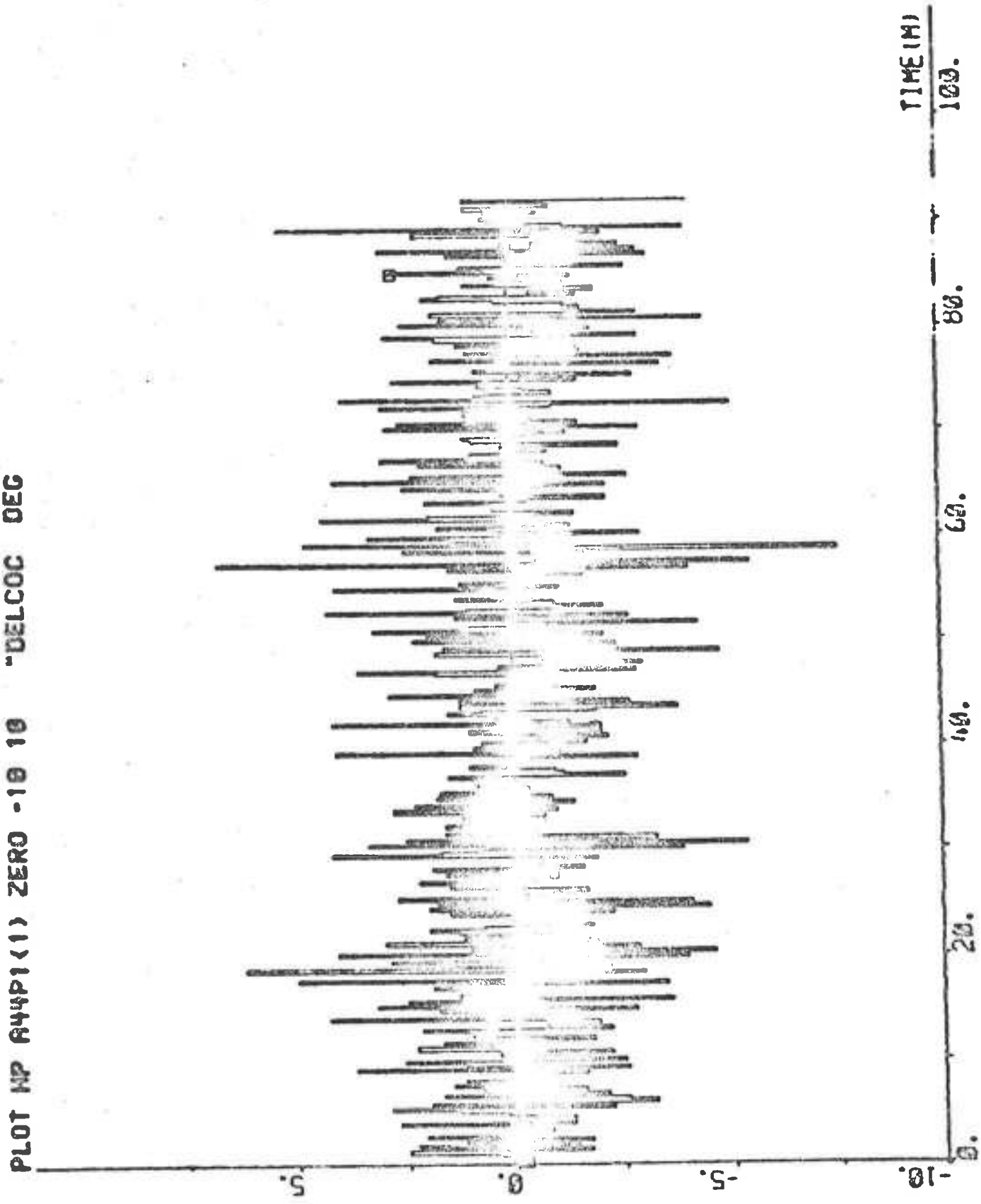
$$a_1 + a_2 + a_3 = -0.339$$

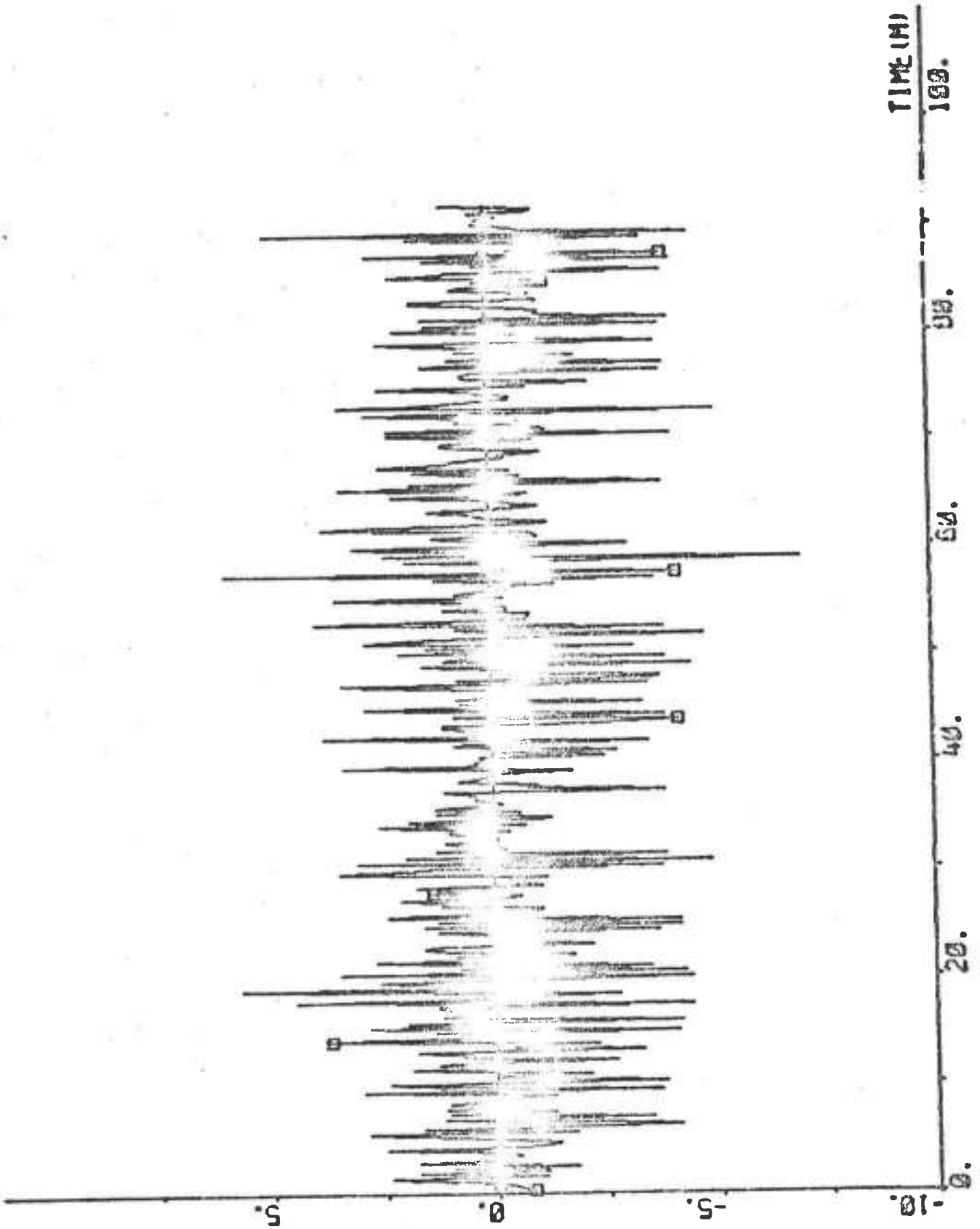
Statistics (mean value and standard deviation)

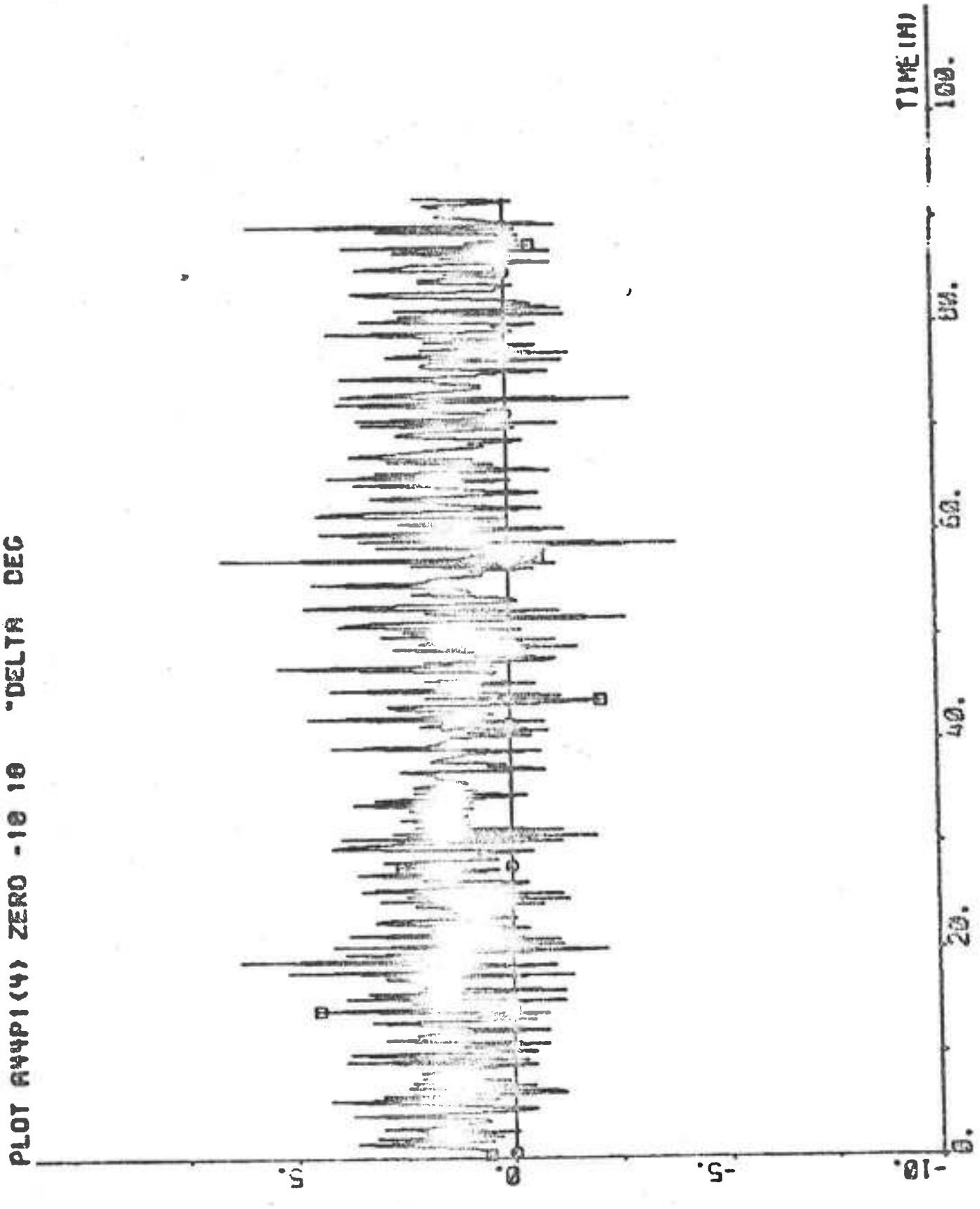
DELTA	1.28 ± 1.67 deg
PSI-PSIREF	0.002 ± 0.159 deg
AN	85.25 ± 0.28 rpm
U	15.43 ± 0.14 knots

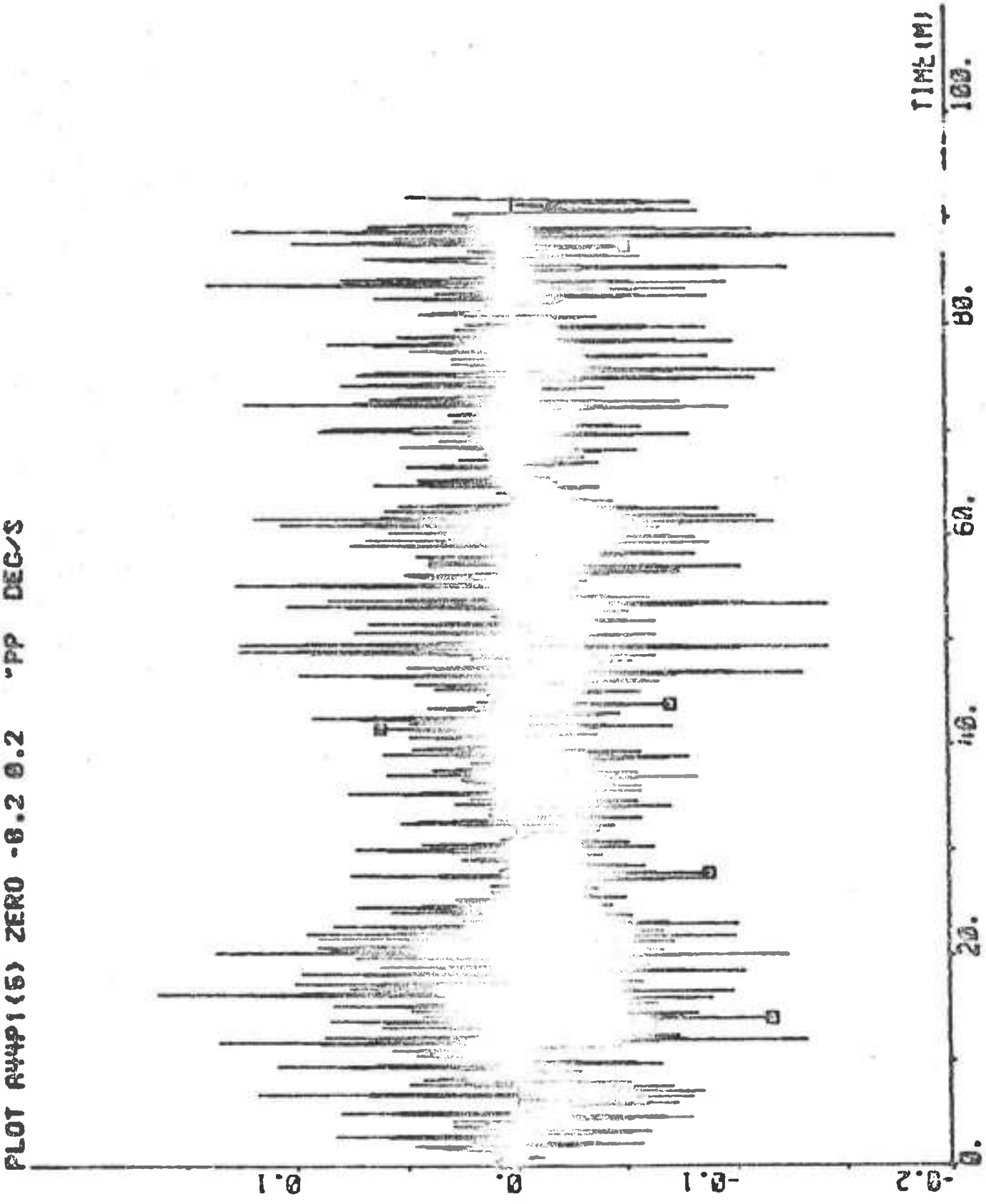
$V_1 = 0.468$

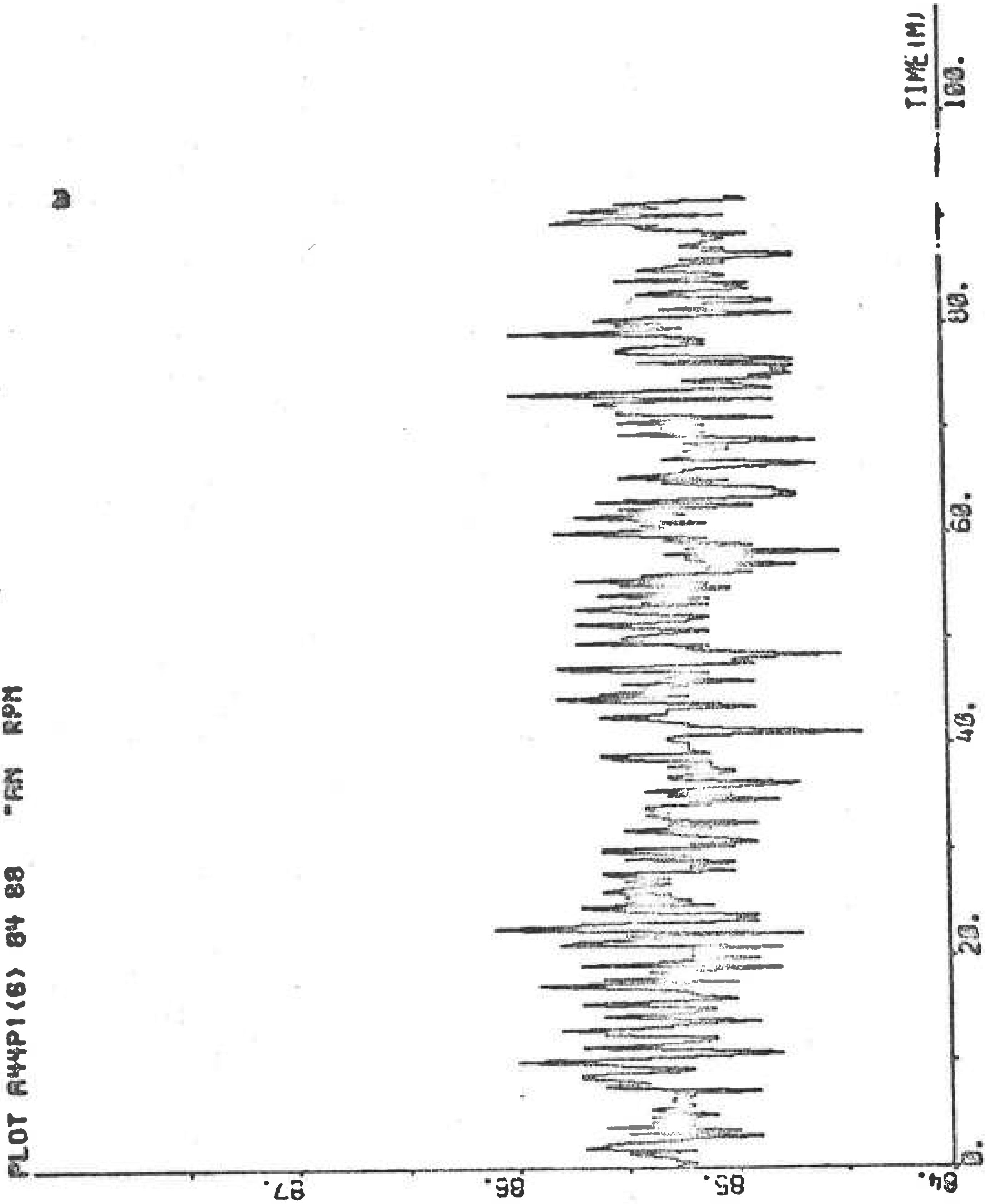
$V_2 = 0.304$

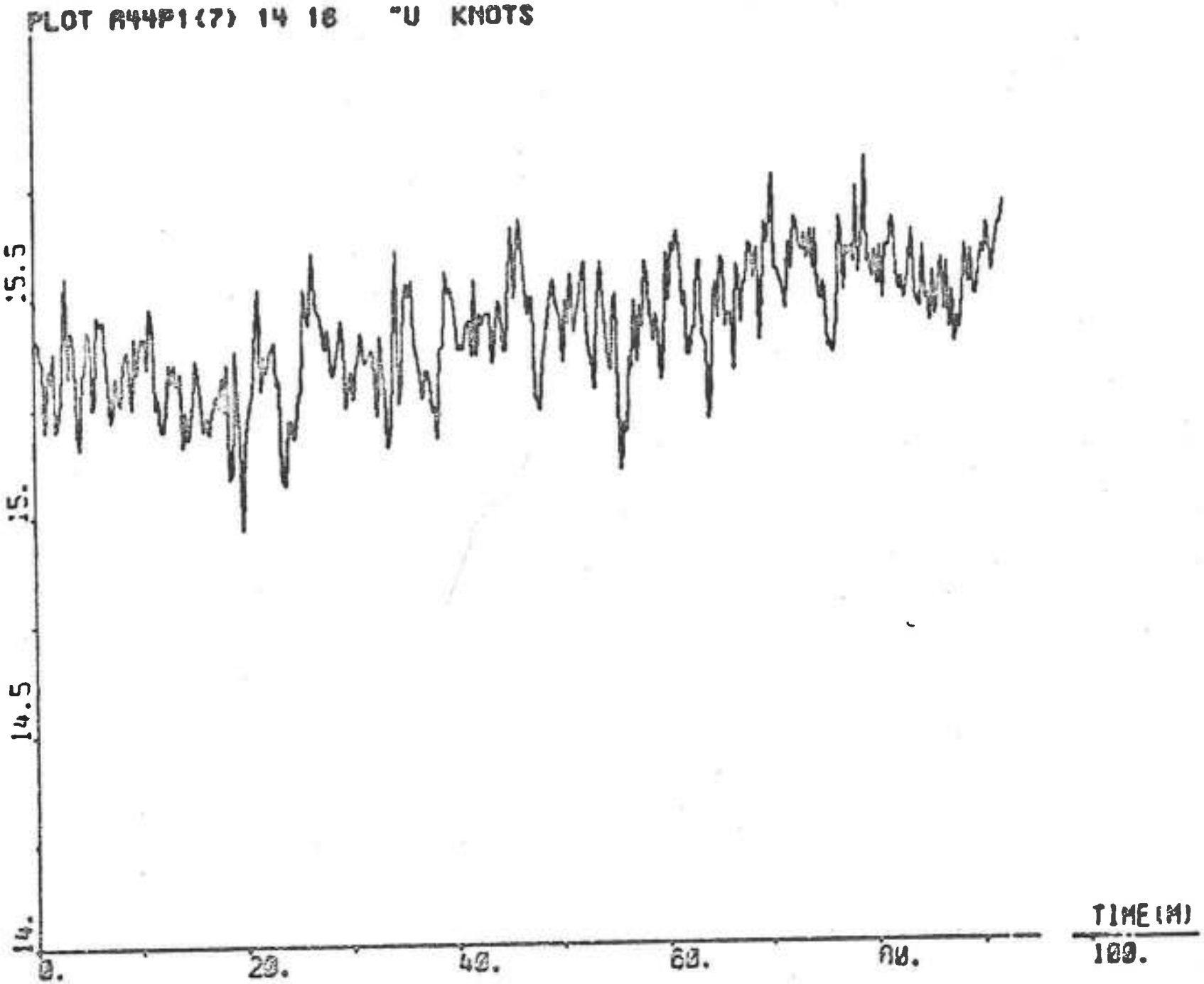

PLOT MP A44P1(1) ZERO -10 10 "DELCOC DEC
TIME(H)
0.
20.
40.
60.
80.
100.
-10.
-5.
0.
5.

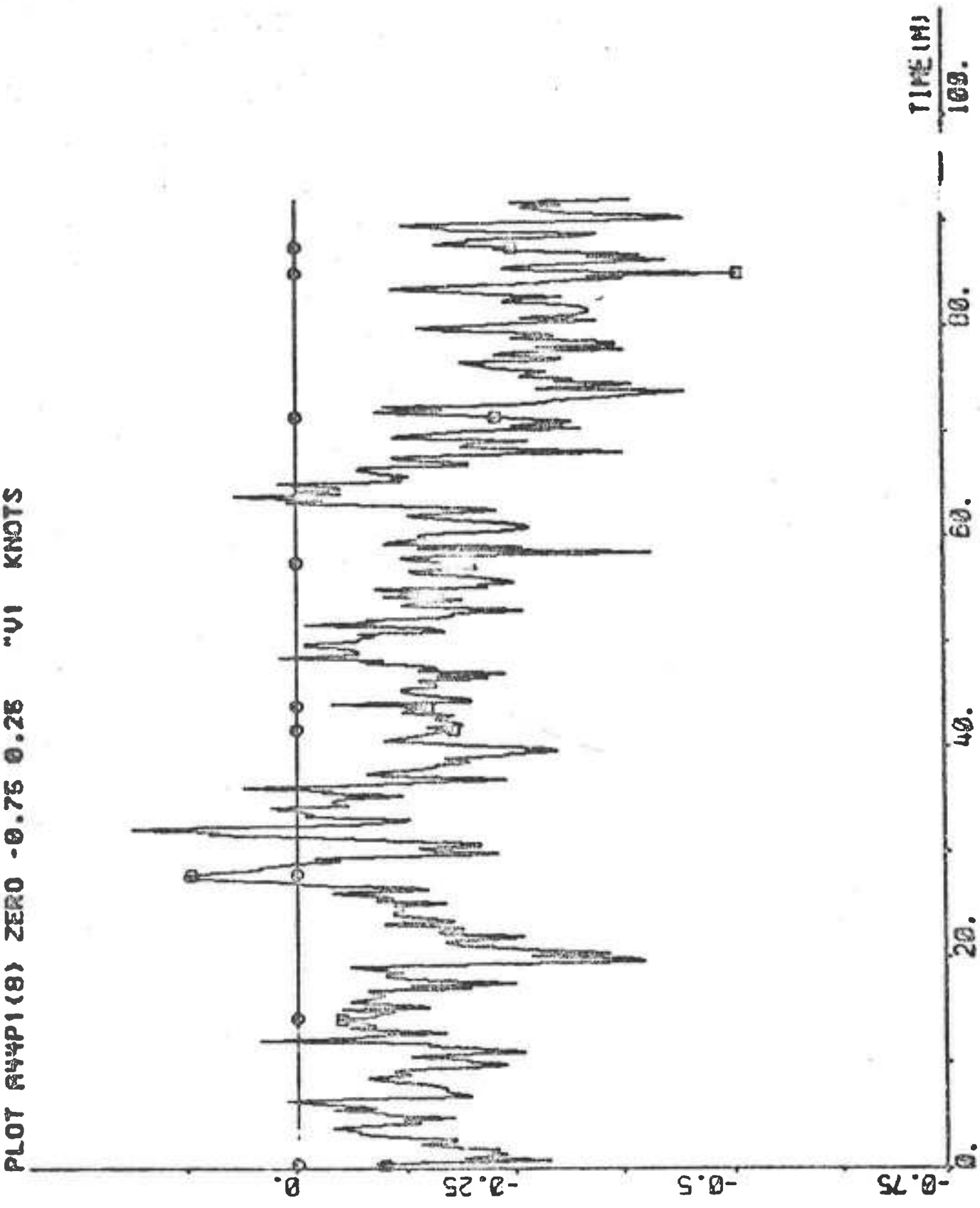

PLOT A44P1(3) ZERO -10 10 'DELTAS DEC
TIME(M)
0.
20.
40.
60.
80.
100.
-10.
-5.
0.
5.

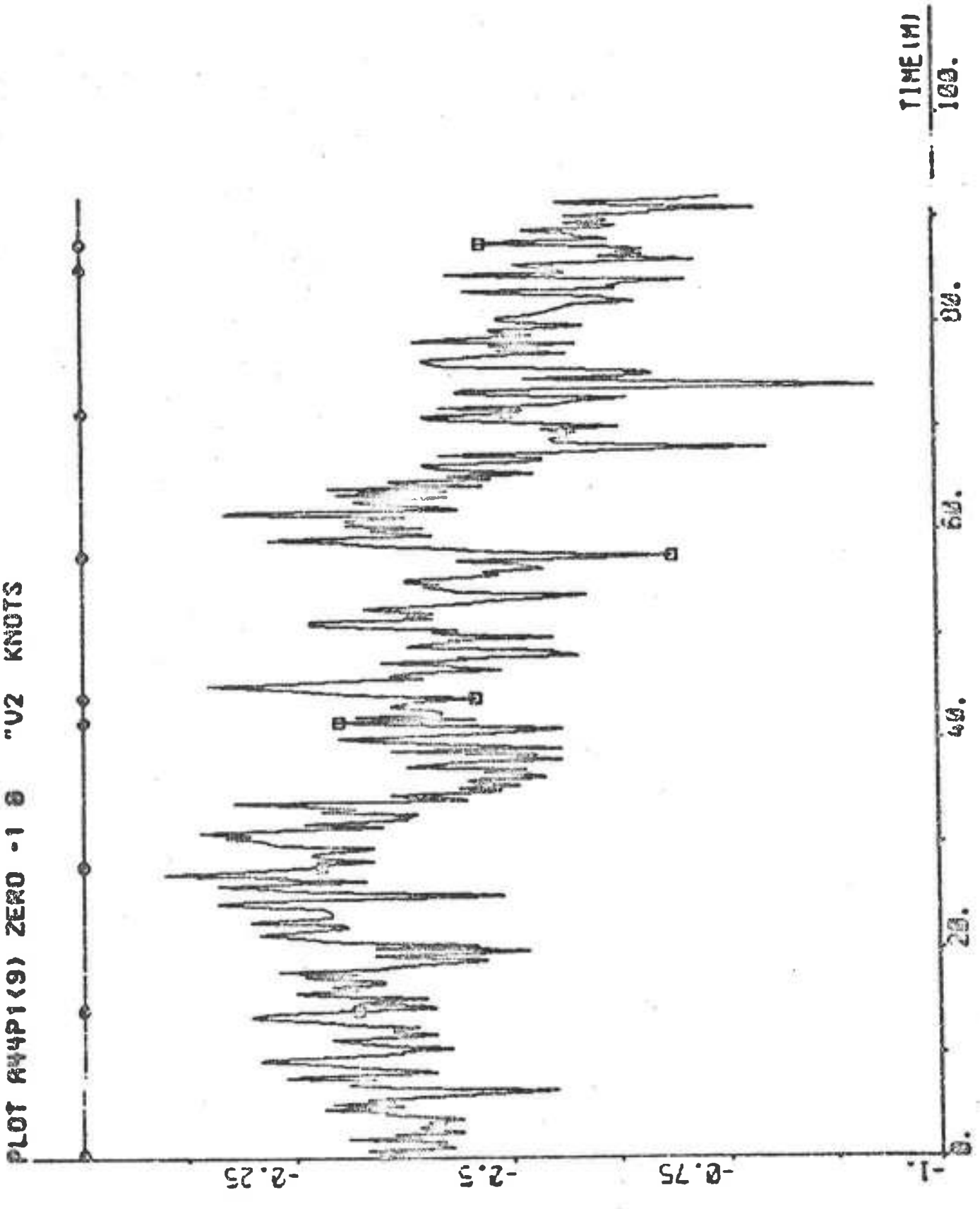

PLOT A44P1(4) ZERO -10 10 'DELTA DEG
5.
0.
-5.
-10.
0.
20.
40.
60.
80.
100.
TIME(H)

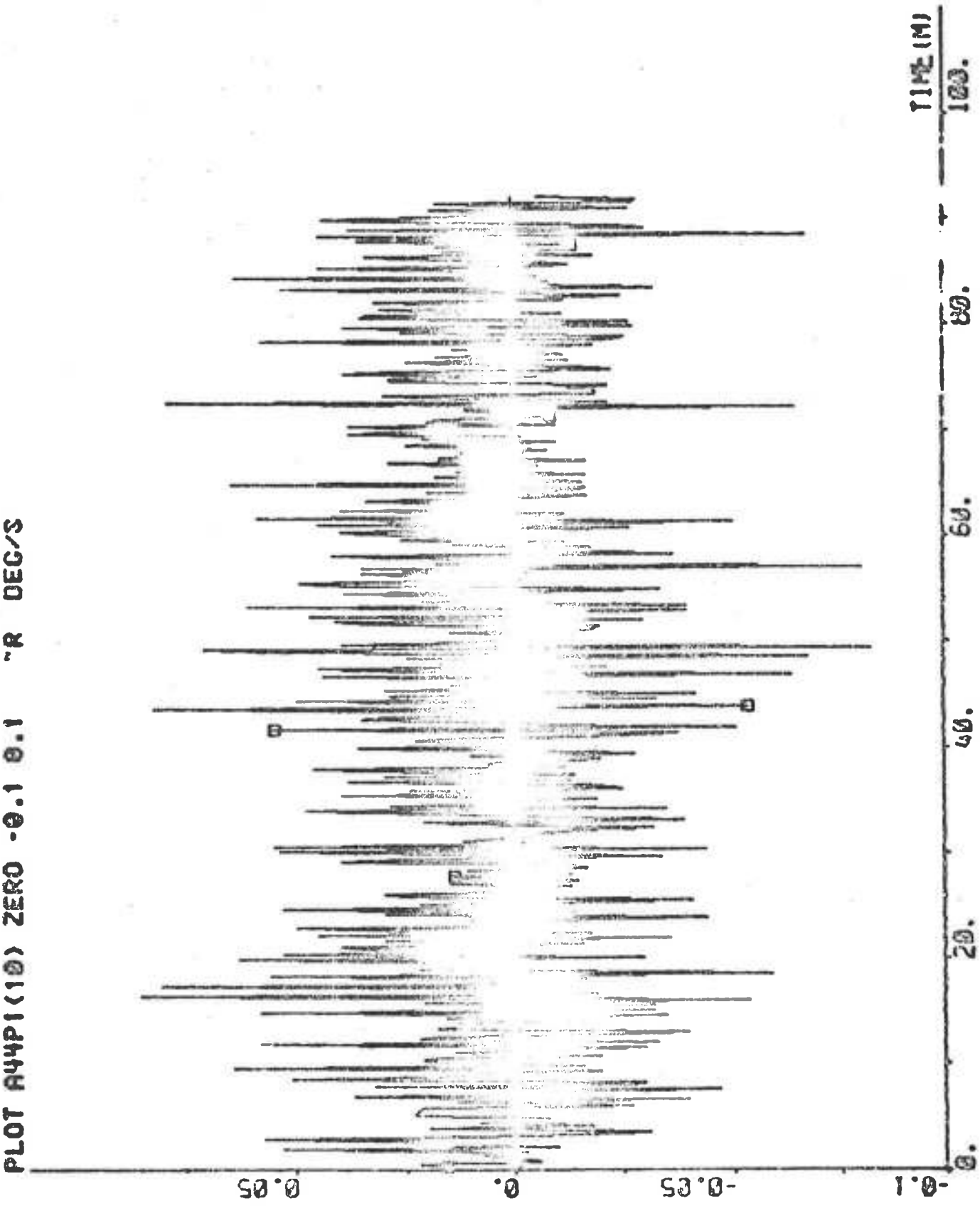

PLOT A4491(5) ZERO -0.2 0.2 'PP DEG/S
0.1
0.
-0.1
-0.2
0.
20.
40.
60.
80.
100.
TIME(M)

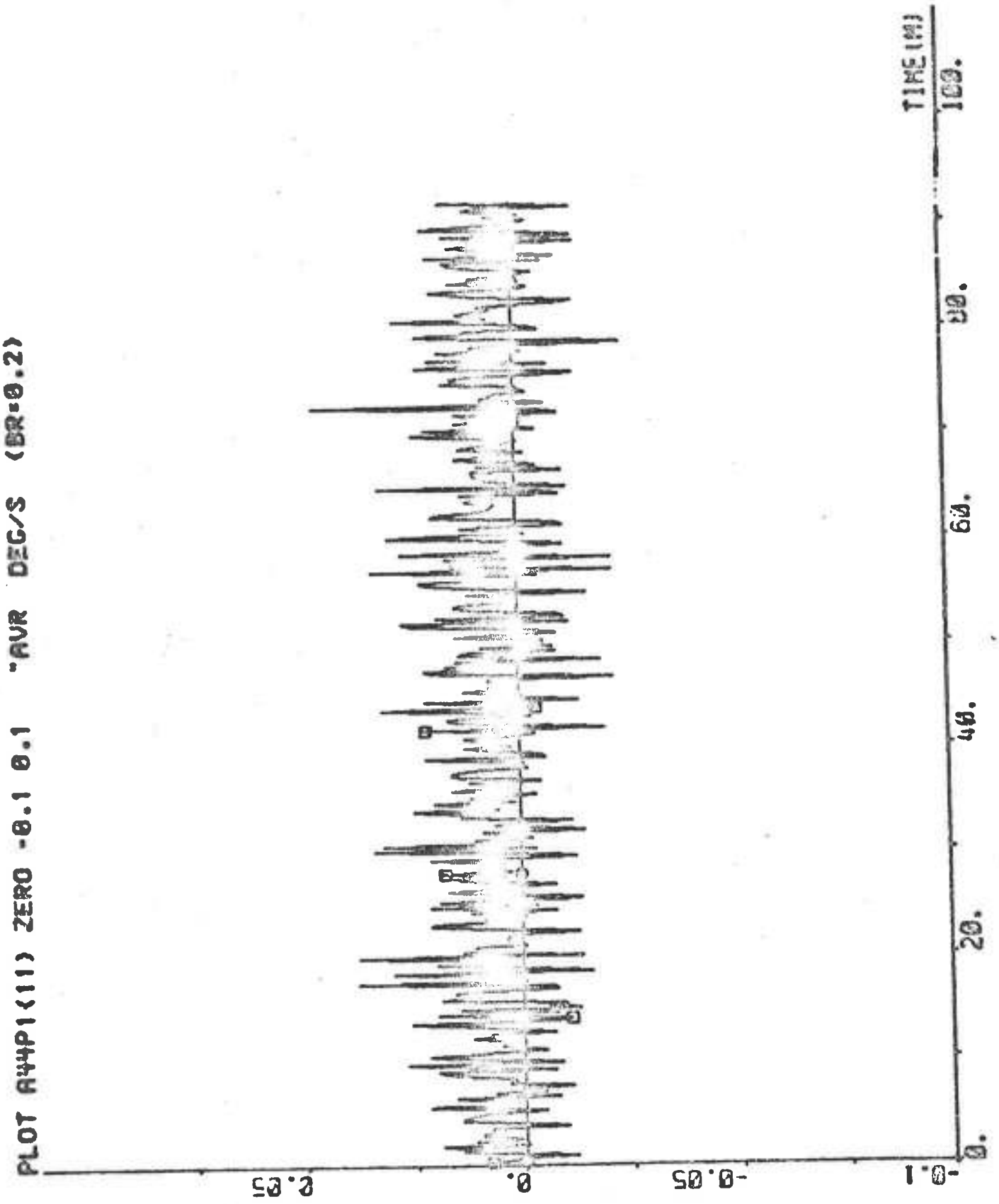

PLOT A44P1(6) 84 88 *AN RPM
TIME(M)
0.
20.
40.
60.
80.
100.
84.
85.
86.
87.

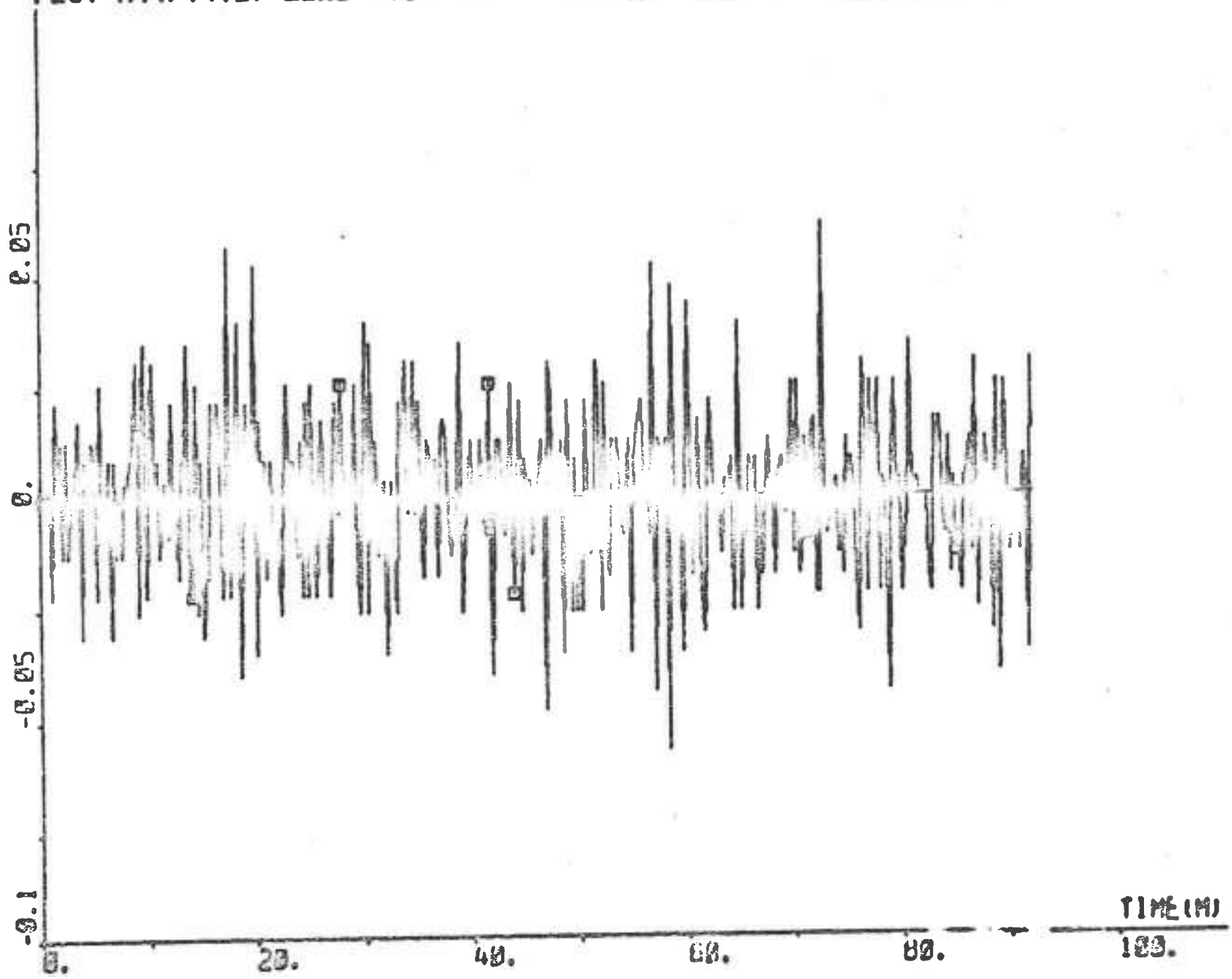

PLOT R44F1(7) 14 16 "U KNOTS
15.5
15.
14.5
14.
0.
20.
40.
60.
80.
TIME(M)
100.

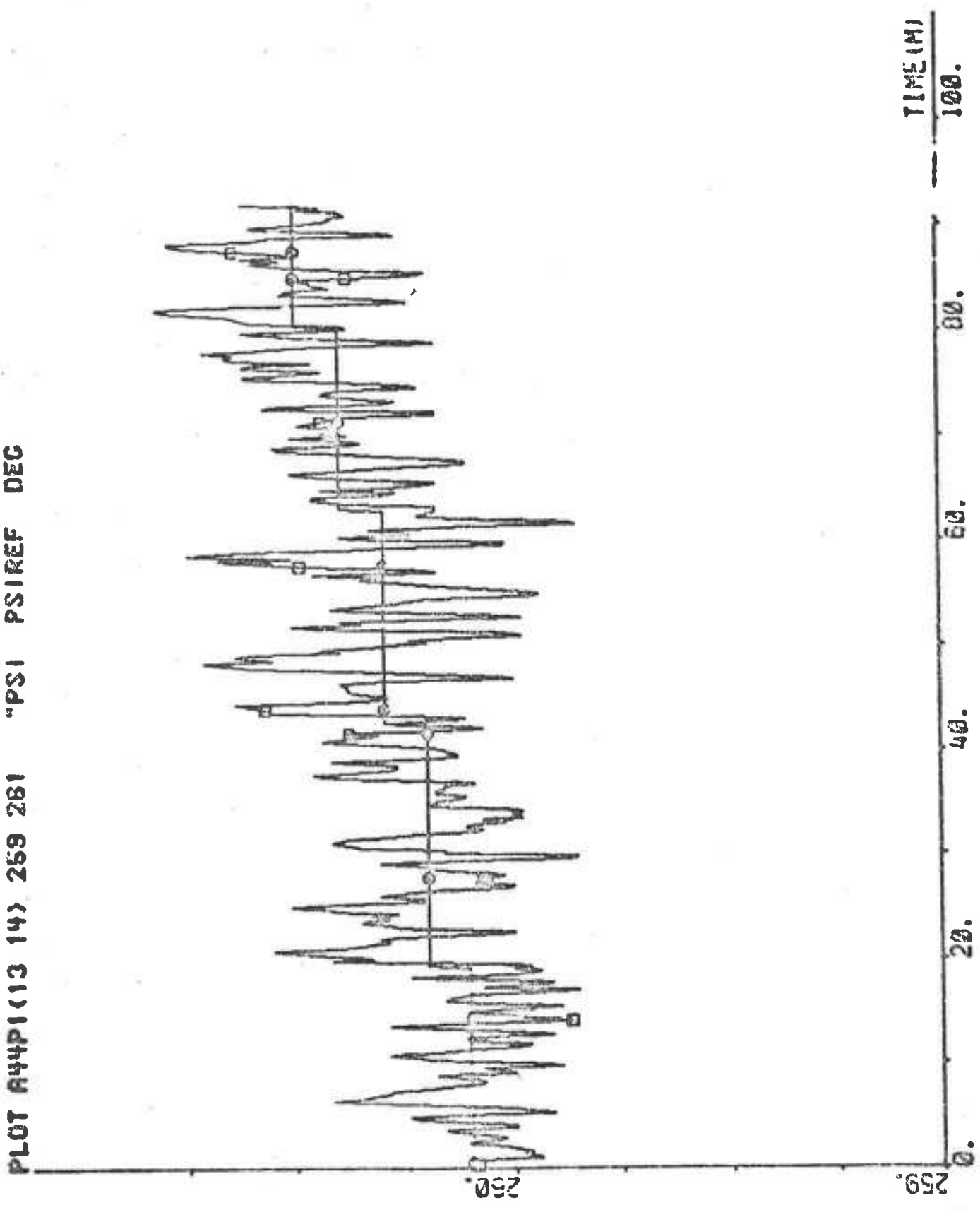

PLOT R44P1(8) ZERO -0.75 0.25 "V1 KNOTS
-0.75
-0.5
-0.25
0.
0.
20.
40.
60.
80.
100.
TIME (M)

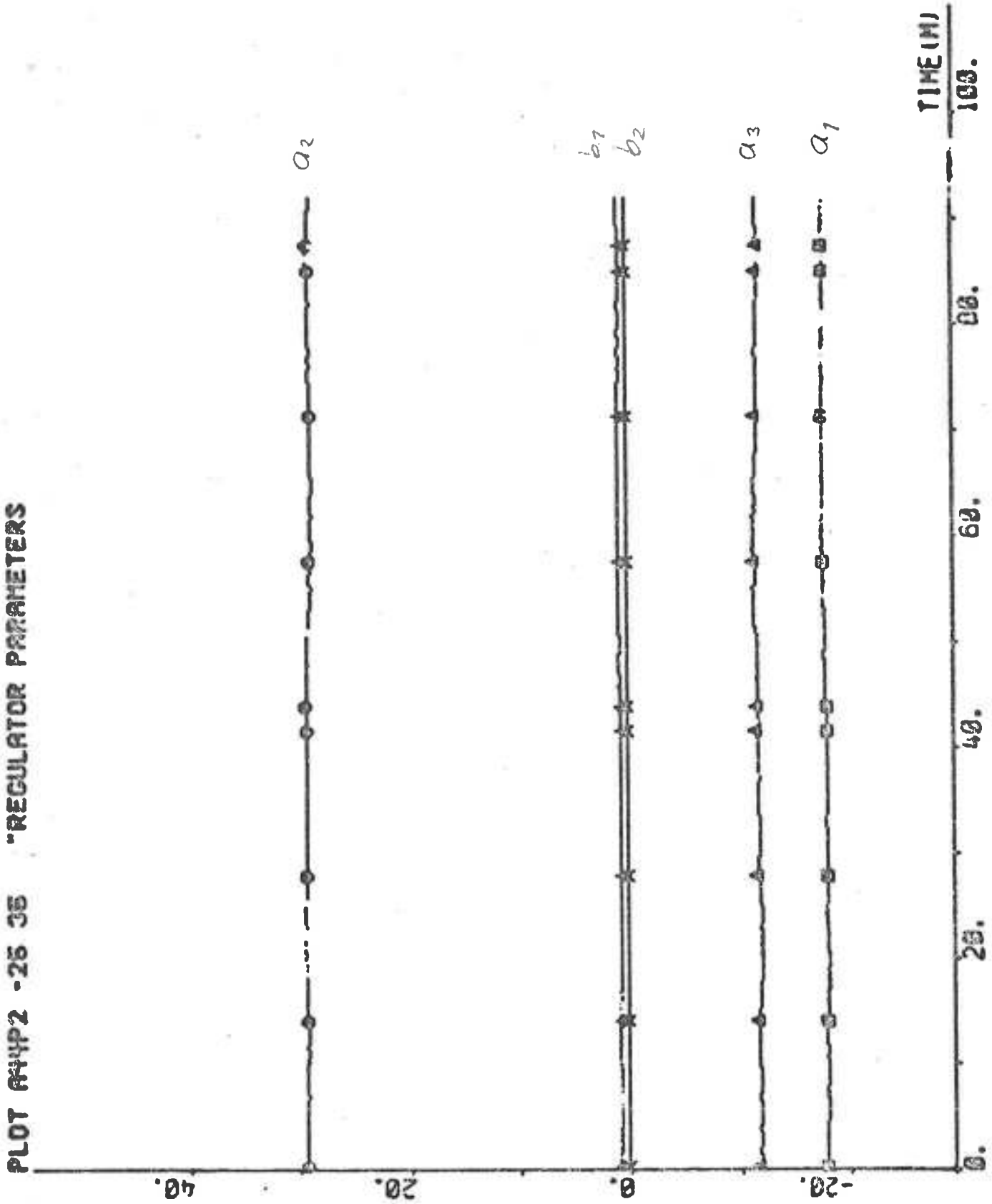

PLOT A44P1(9) ZERO -1 0 "V2 KNOTS
-2.25
-2.5
-0.75
-1.
0.
20.
40.
60.
80.
100.
TIME(M)


PLOT A44P1(10) ZERO -0.1 0.1 °R DEC/S
0.05
0.
-0.05
-0.1
0.
20.
40.
60.
80.
100.
TIME (M)


PLOT A44P1(11) ZERO -0.1 0.1 'AVR DEG/S (BR=0.2)
0.05
0.
-0.05
-0.1
0.
20.
40.
60.
80.
100.
TIME(M)


PLOT A44P1(12) ZERO -0.1 0.1 *DPSIDT DEG/S (1DPSI=5)
0.05
0.
-0.05
-0.1
0.
20.
40.
60.
80.
100.
TIME(M)


PLOT A4P1(13 14) 259 261 "PSI PSIREF DEG
259.
260.
0.
20.
40.
60.
80.
100.
TIME(M)


PLOT A4YP2 -26 35 "REGULATOR PARAMETERS
40.
20.
0.
-20.
0.
20.
40.
60.
80.
100.
TIME(M)
a2
b1
b2
a3
a1

EXPERIMENT A45

Date	1974-10-23
Time	12.49
Duration	78 min
Position	S 34° 59' E 22° 40'
Water depth	deep
Forward draught	20.0 m
Aft draught	20.0 m
Wind direction	SW (8; see Appendix A)
Wind velocity	4-5 Beaufort (6-10.5 m/s, moderate to fresh breeze)
Wave height	-
PSIREF	260.9° - 261.4° (Sailmaster)
Rudder limit	Not active

The yaw regulator was never used, because PSIMAV was equal to 0.35° and the course changes requested by the Sailmaster were only 0.1°.

Regulator structure

NA = 3 NB = 2 NC = 0 K = 5

IREG = 15 RL = 0.99

Final values

$$\begin{bmatrix} a_1 \\ a_2 \\ a_3 \\ b_1 \\ b_2 \end{bmatrix} = \begin{bmatrix} -17.858 \\ 29.931 \\ -12.077 \\ 0.757 \\ 0.097 \end{bmatrix} \qquad P = \begin{bmatrix} 0.820 & & & & \\ -1.070 & 2.984 & & & \\ 0.449 & -2.240 & 2.214 & & \\ 0.009 & -0.078 & 0.085 & 0.005 & \\ 0.007 & -0.067 & 0.073 & 0.004 & 0.004 \end{bmatrix}$$

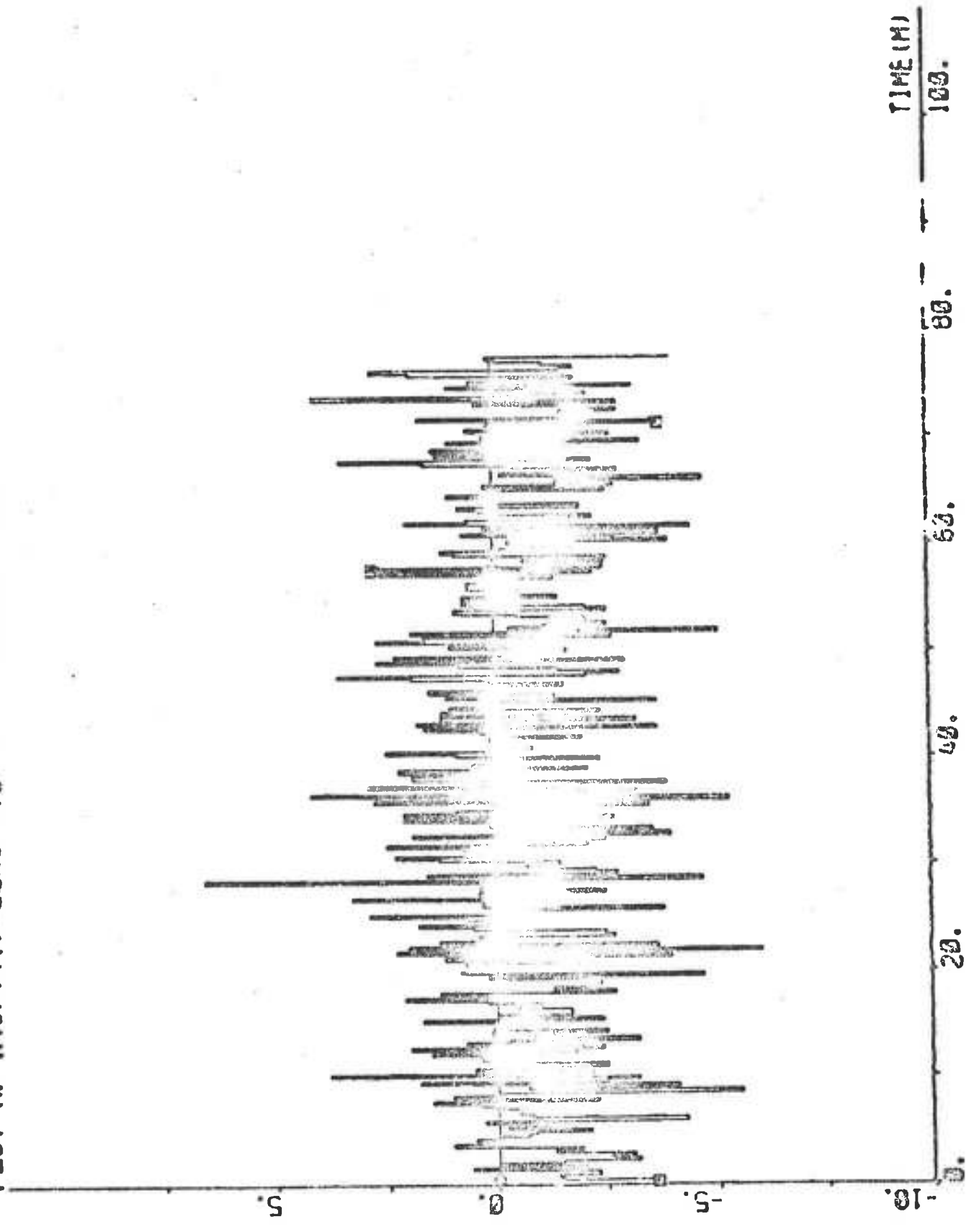
$a_1 + a_2 + a_3 = -0.004$

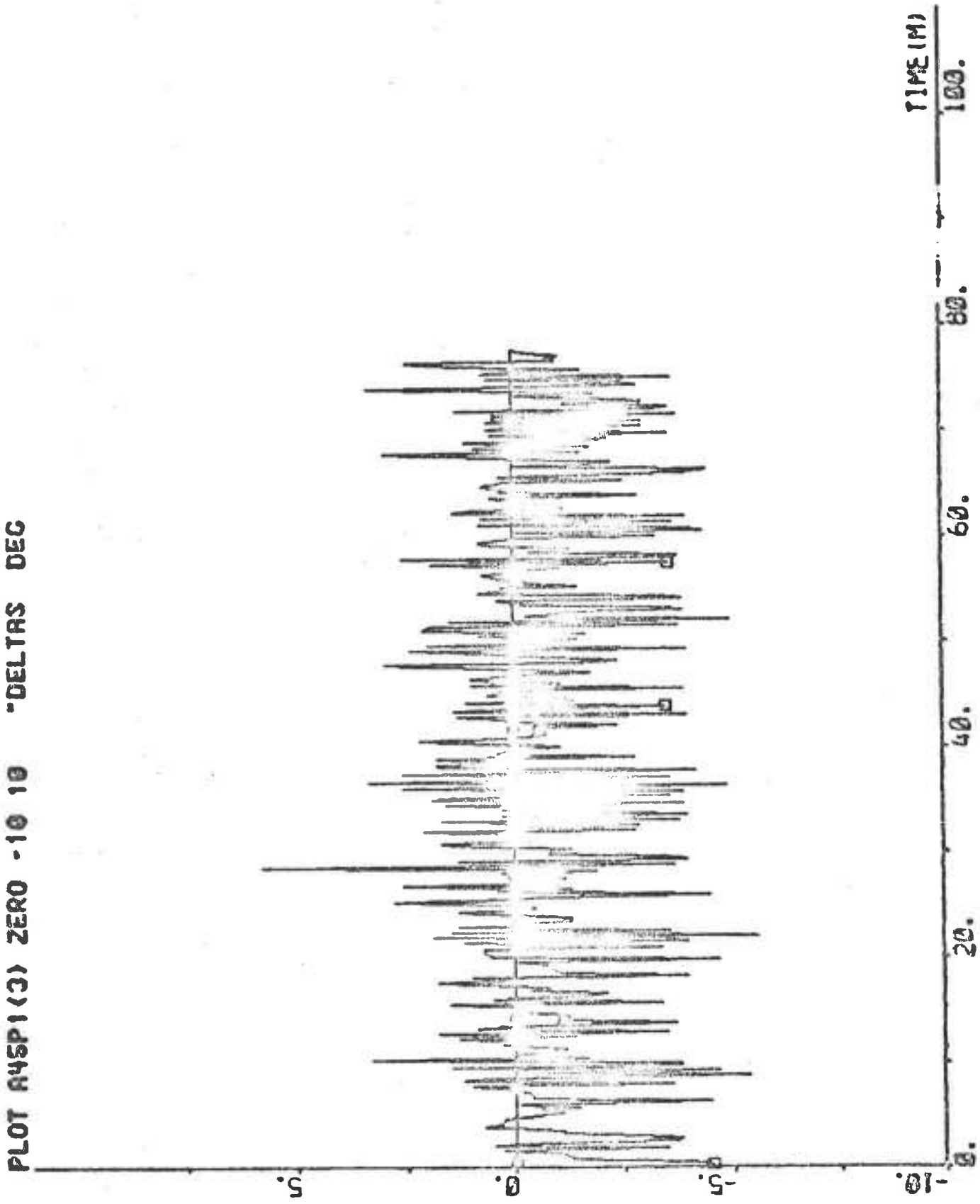
Statistics (mean value and standard deviation)

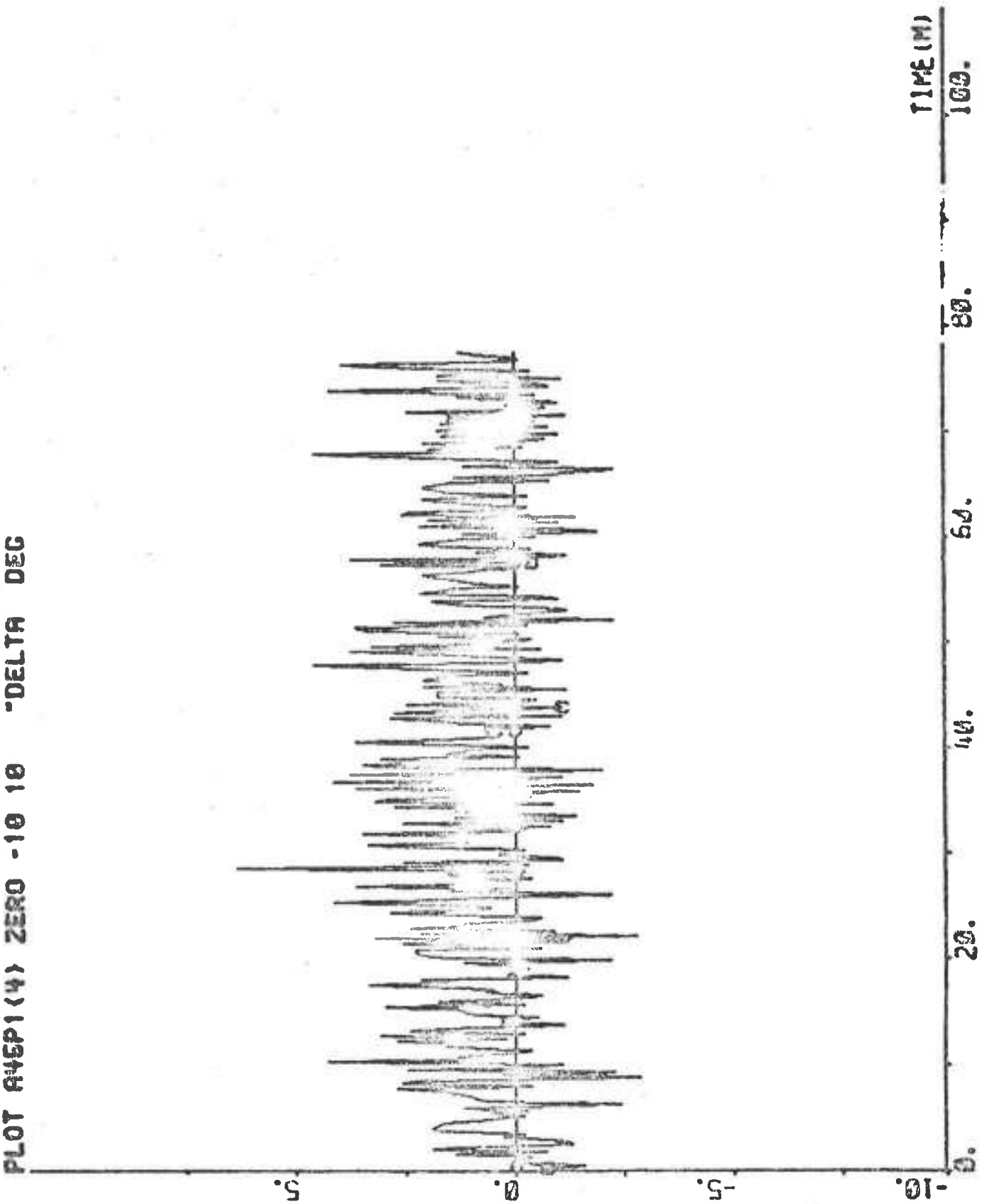
DELTA	0.86 ± 1.54 deg
PSI-PSIREF	0.023 ± 0.208 deg
AN	85.13 ± 0.27 rpm
U	15.43 ± 0.12 knots

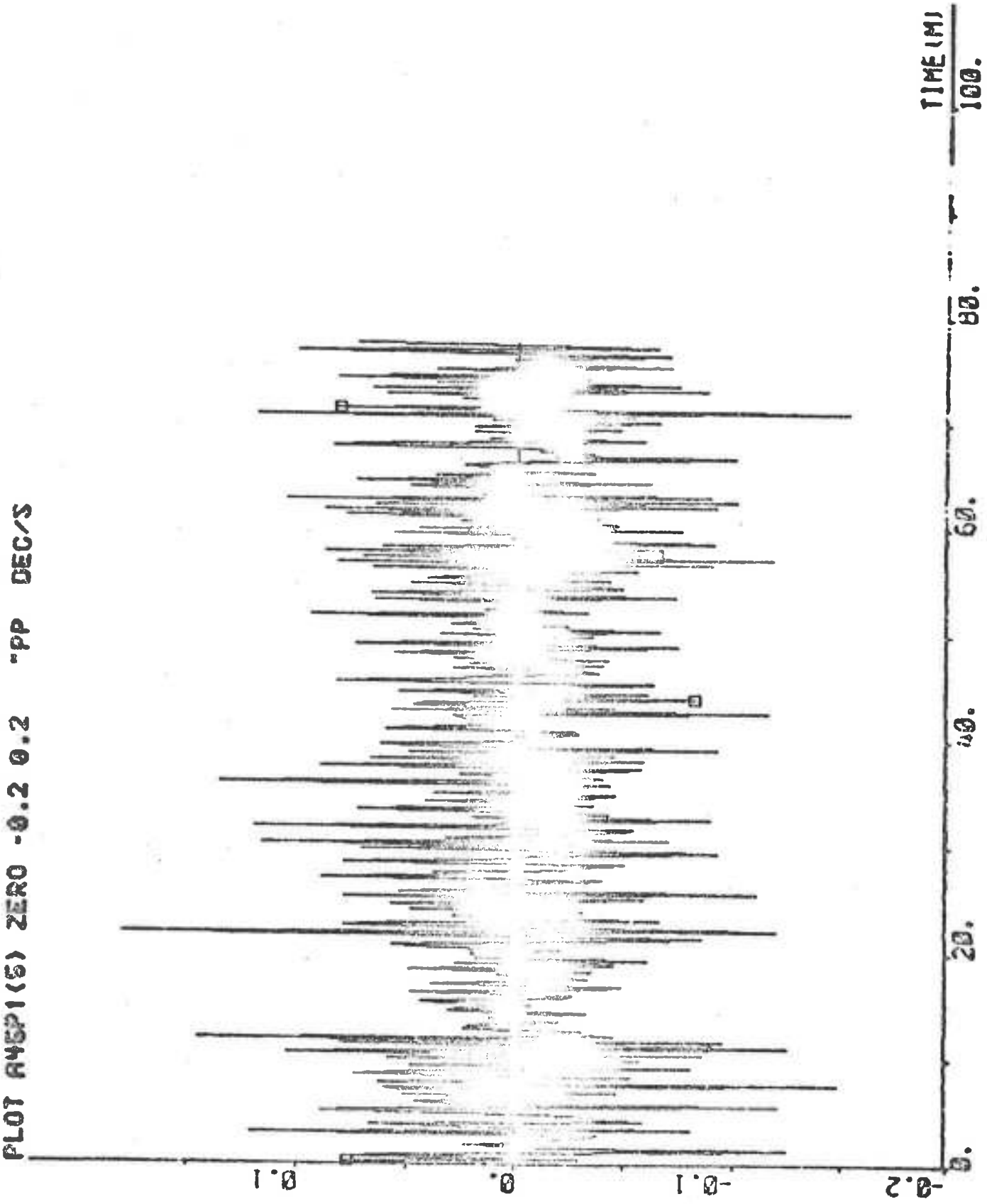
$V_1 = 0.355$

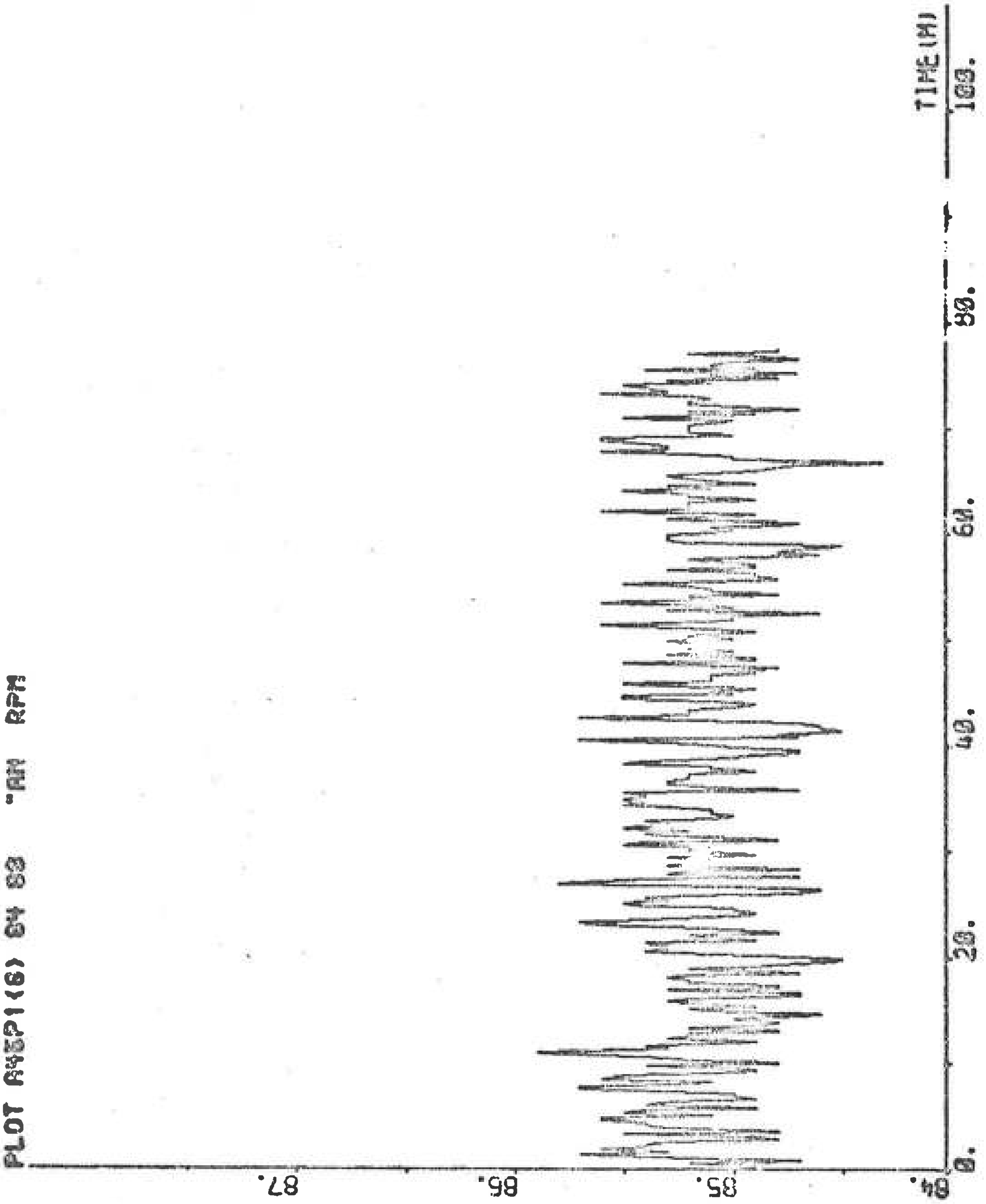
$V_2 = 0.281$

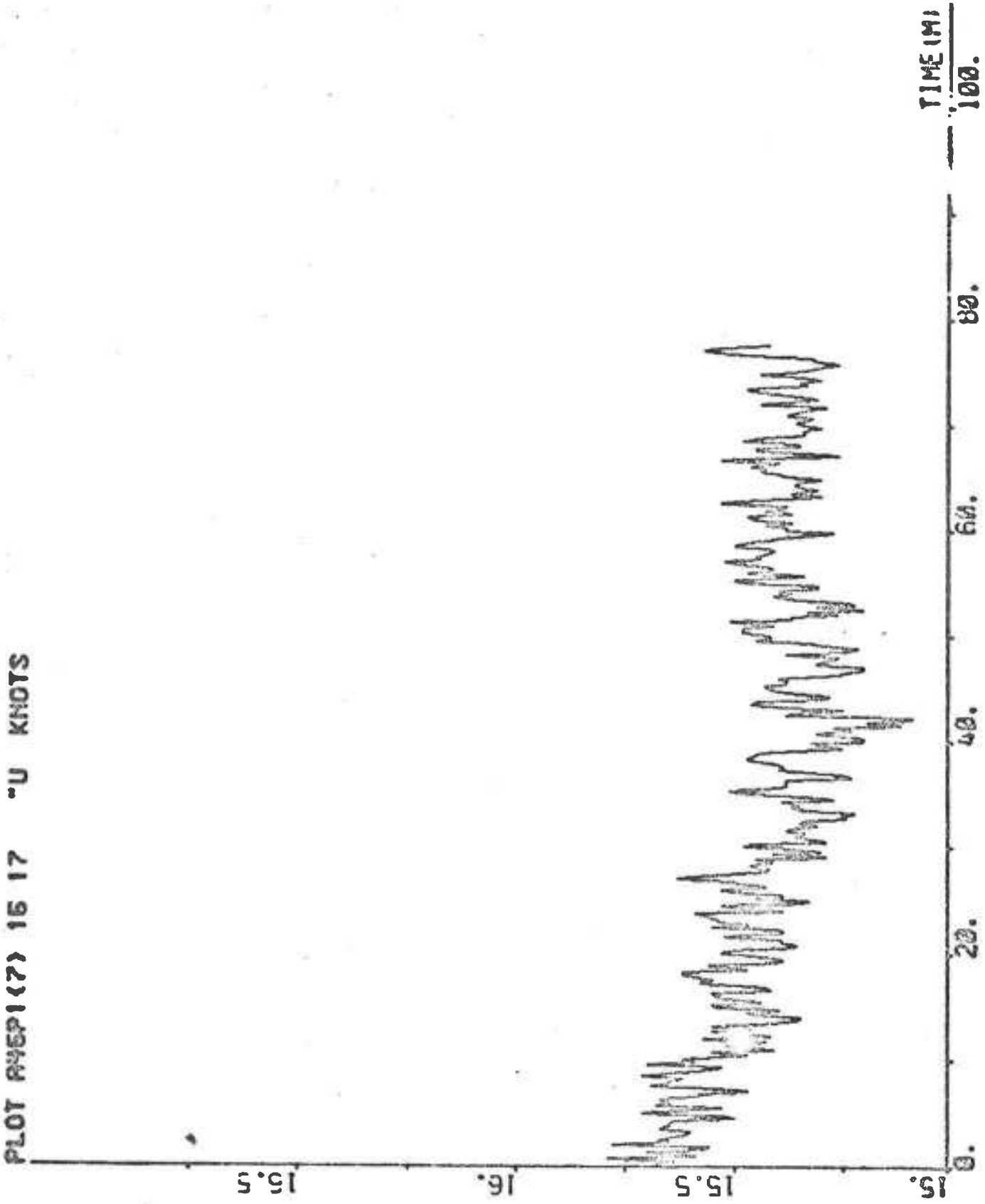

PLOT HP A4SPI(I) ZERO -10 10 *DELCOC DEG
5.
0.
-5.
-10.
0.
20.
40.
60.
80.
100.
TIME(H)

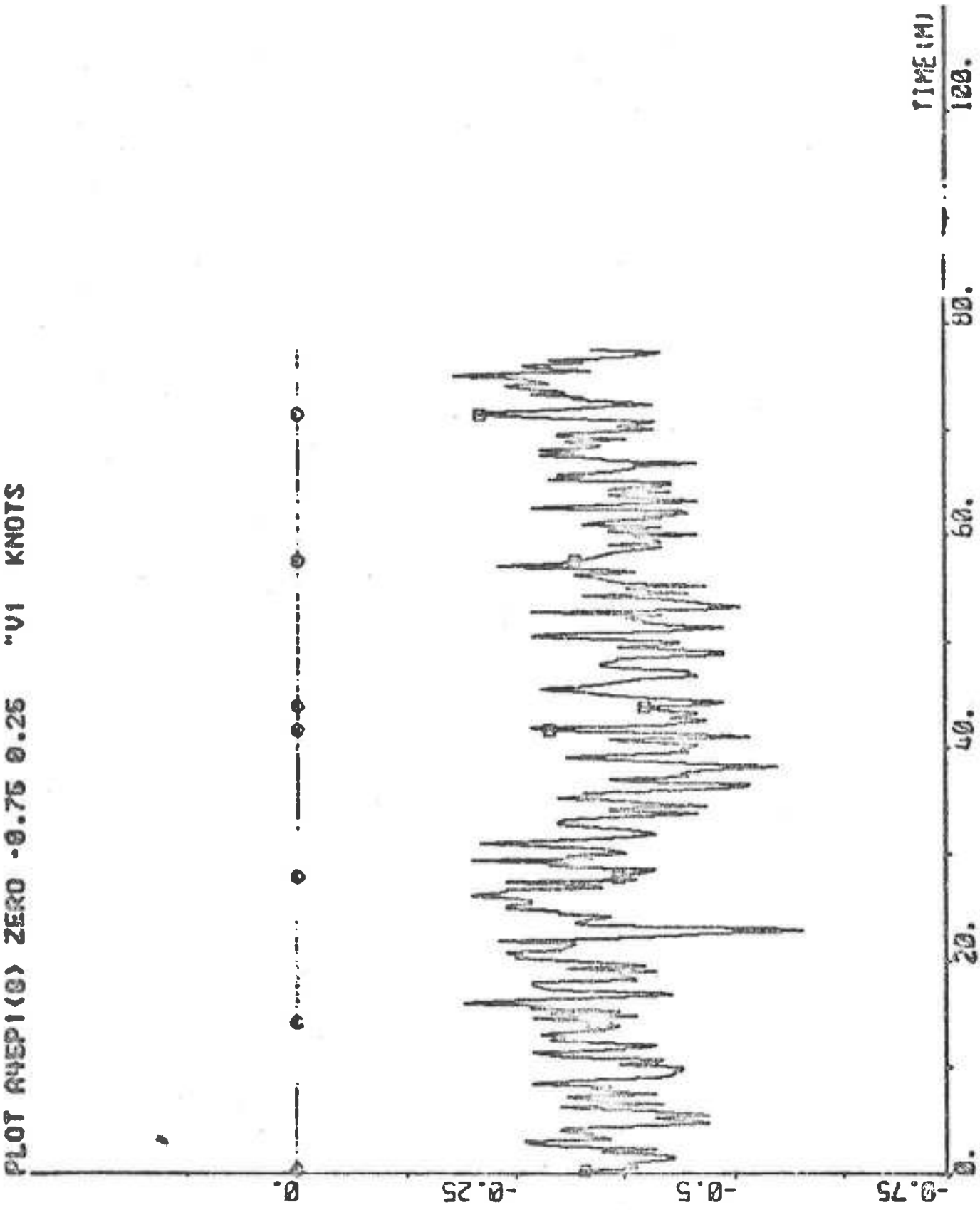

PLOT A4SP1(3) ZERO -10 10 "DELTAS DEC
5.
0.
-5.
-10.
0.
20.
40.
60.
80.
100.
TIME(M)

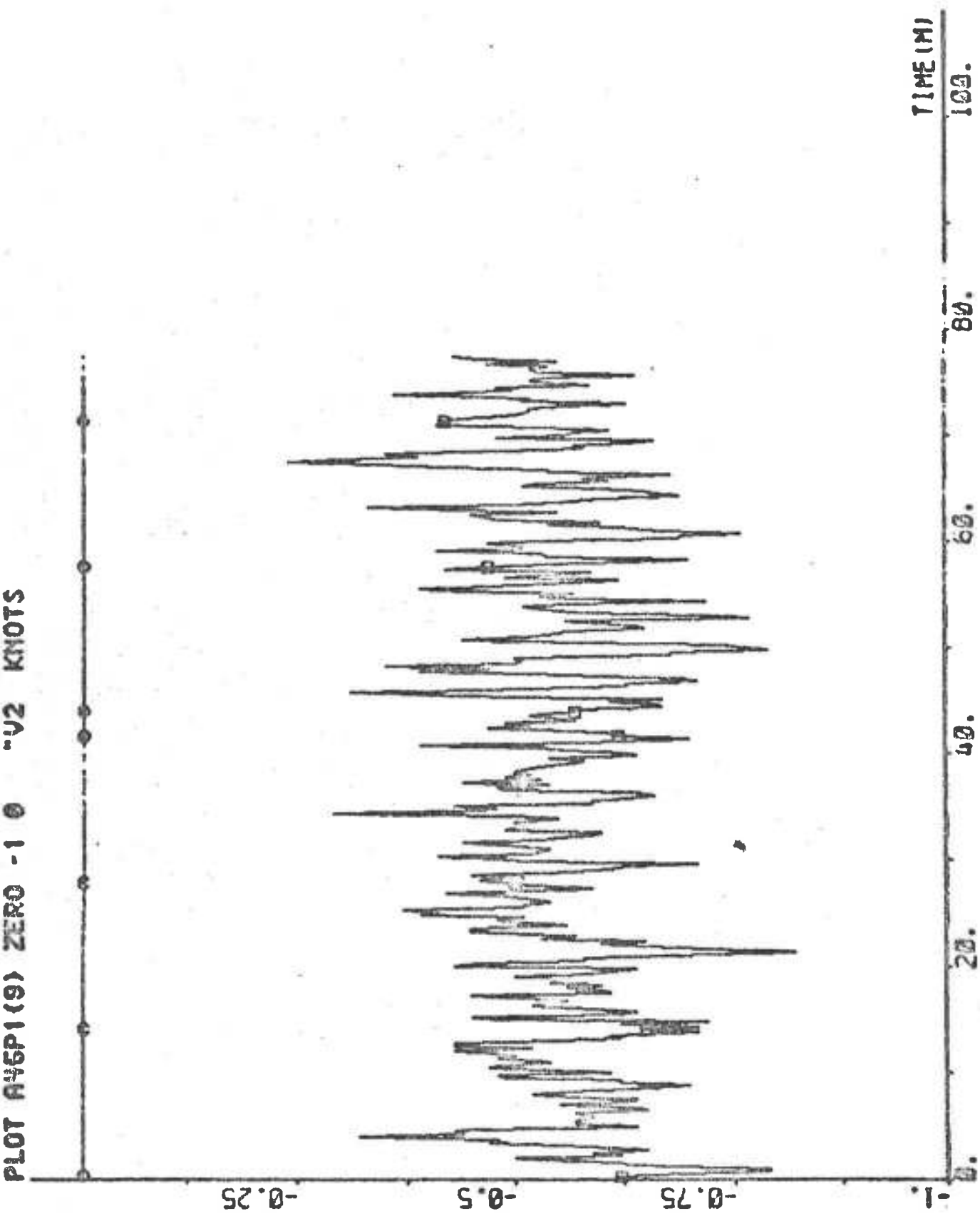

PLOT A4SP1(4) ZERO -10 10 'DELTA DEG
5.
0.
-5.
-10.
0.
20.
40.
60.
80.
100.
TIME(M)

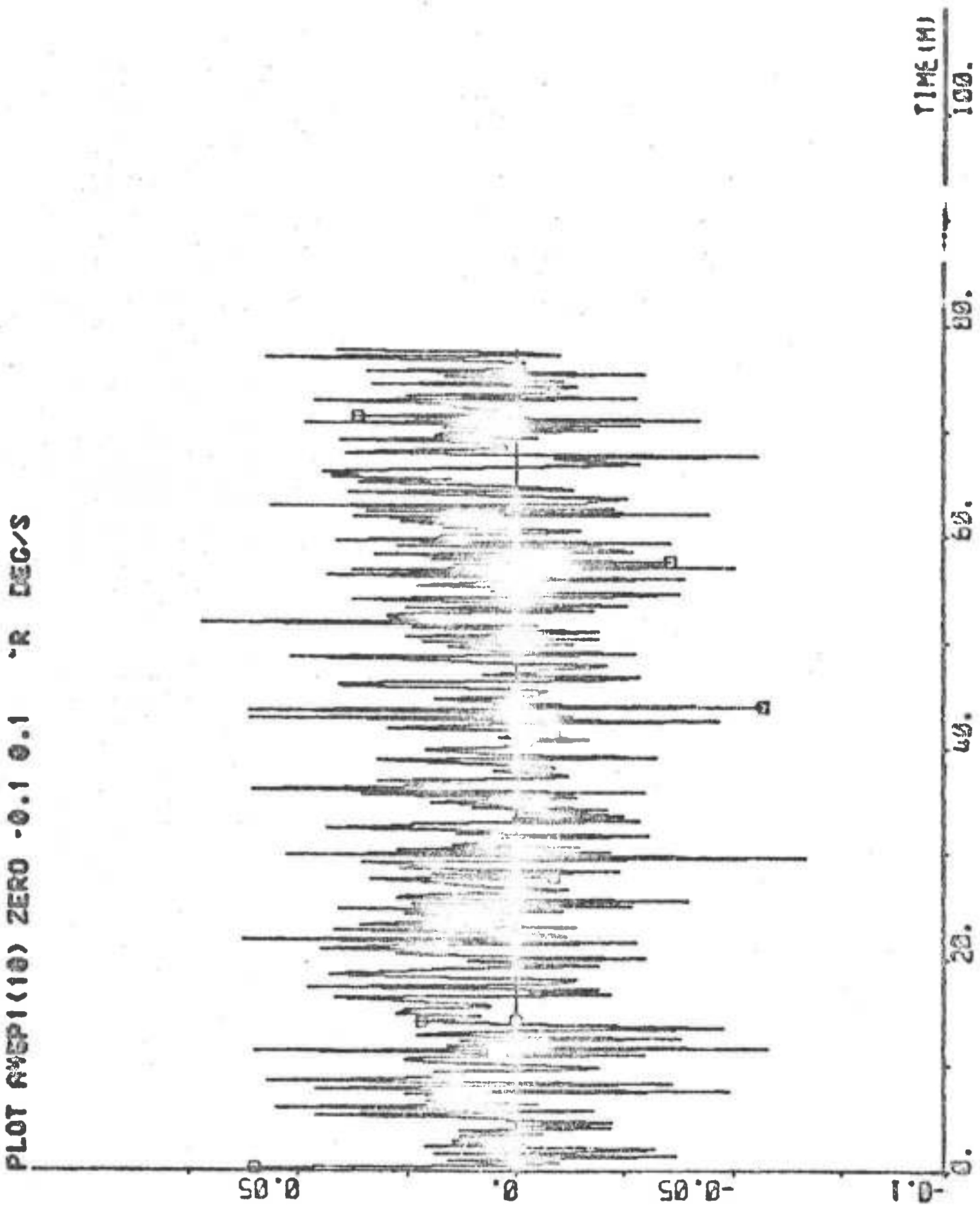

PLOT AVSP1(S) ZERO -0.2 0.2 "PP DEG/S
TIME(MI
0.
20.
40.
60.
80.
100.
-0.2
-0.1
0.
0.1

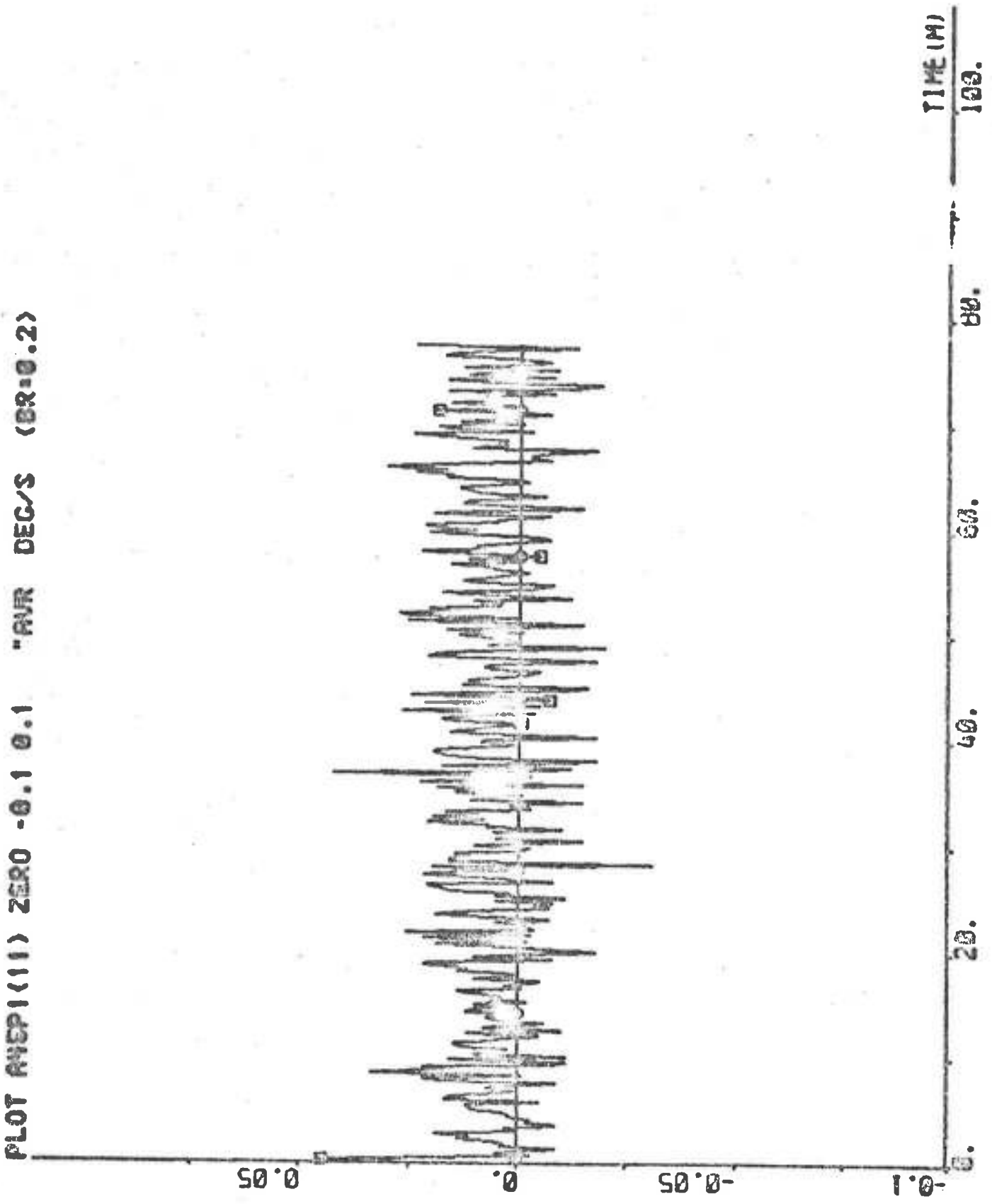

PLOT A45P1(6) 04 80 'AN RPM
TIME (M)
0.
20.
40.
60.
80.
100.
84.
85.
86.
87.

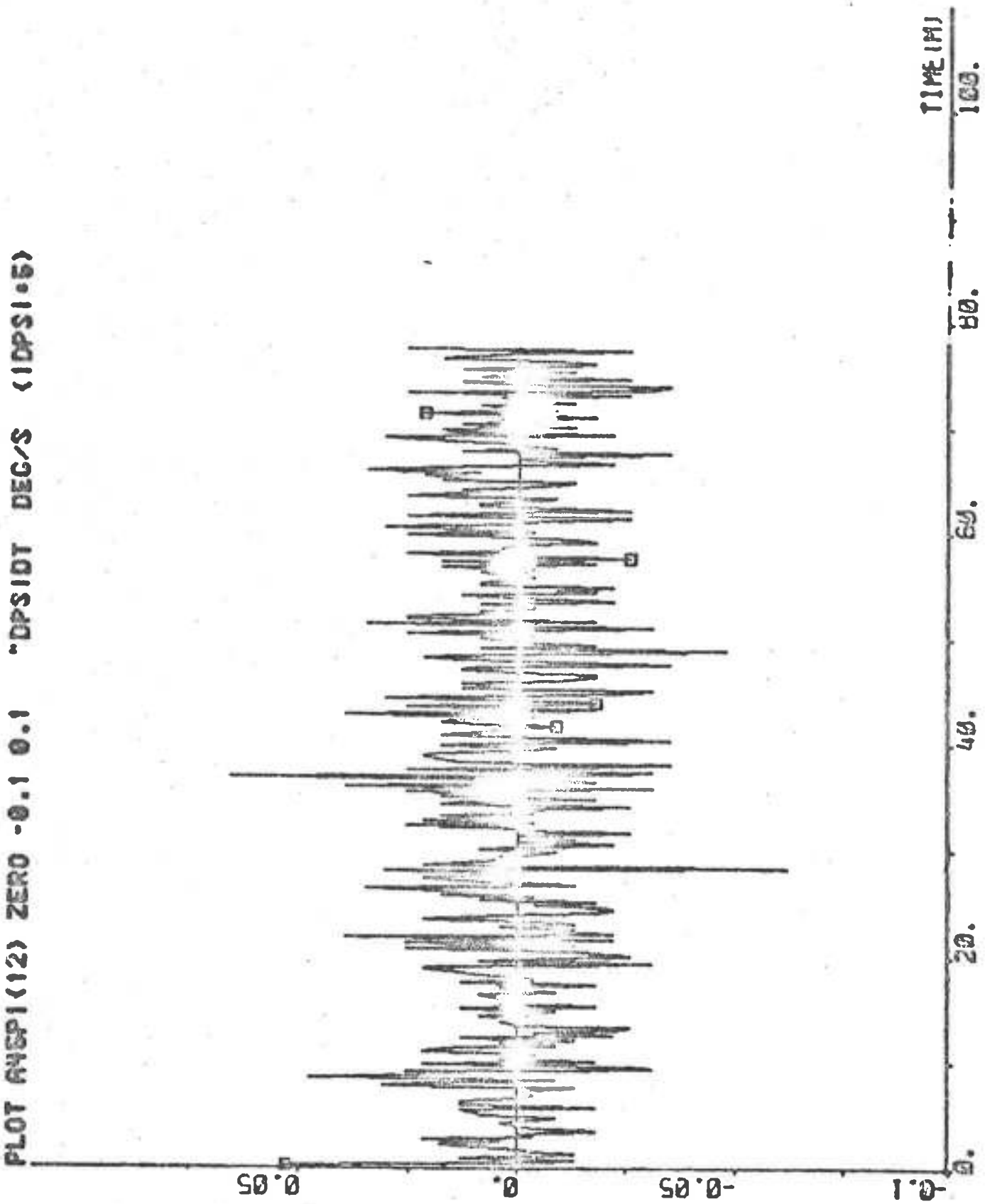

PLOT AVEP1(7) 16 17 U KNOTS
15.
15.5
16.
15.5
0.
20.
40.
60.
80.
TIME(M)
100.

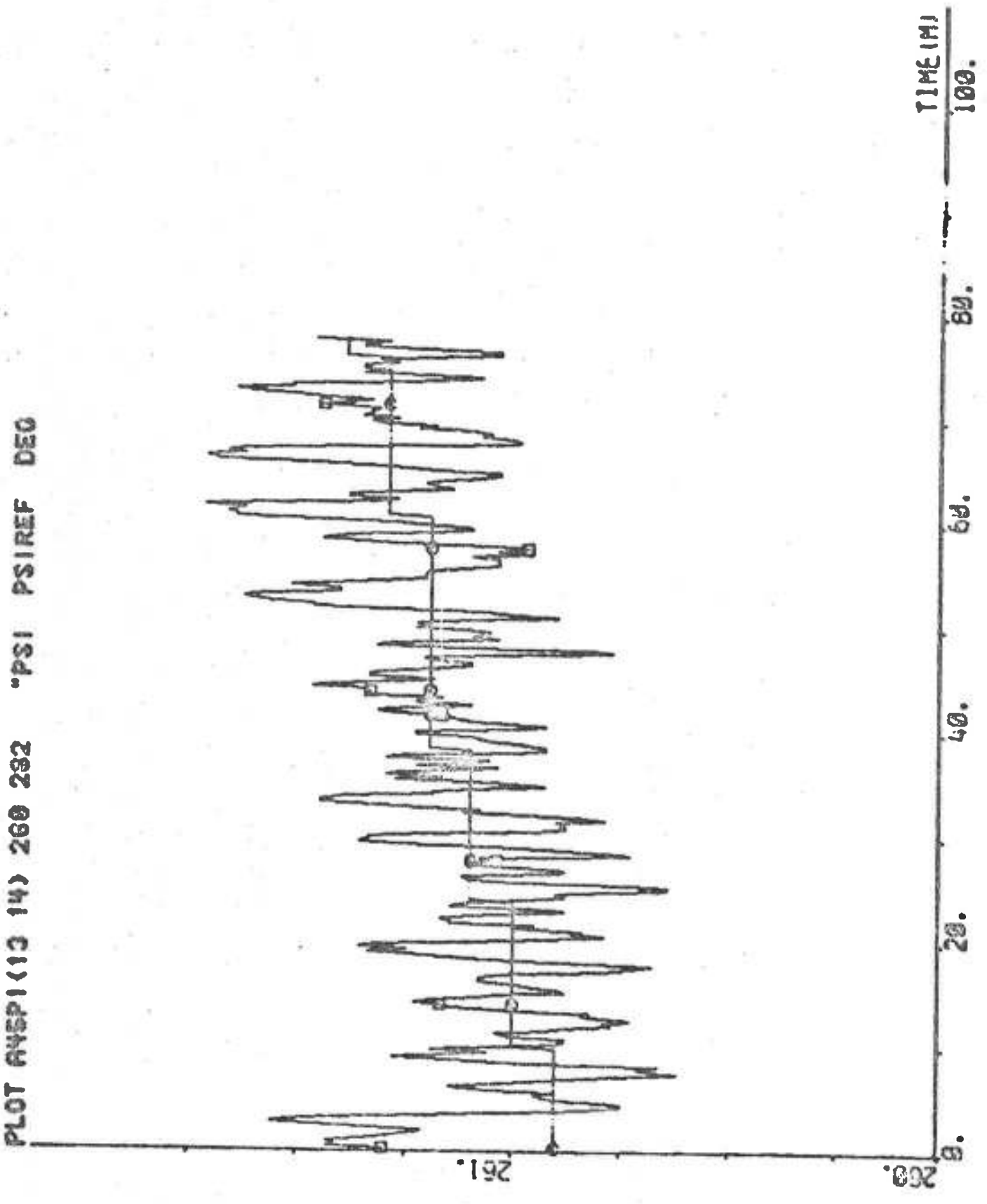

PLOT A4EP1(0) ZERO -0.75 0.25 "V1 KNOTS
0.
-0.25
-0.5
-0.75
0.
20.
40.
60.
80.
100.
TIME(M)

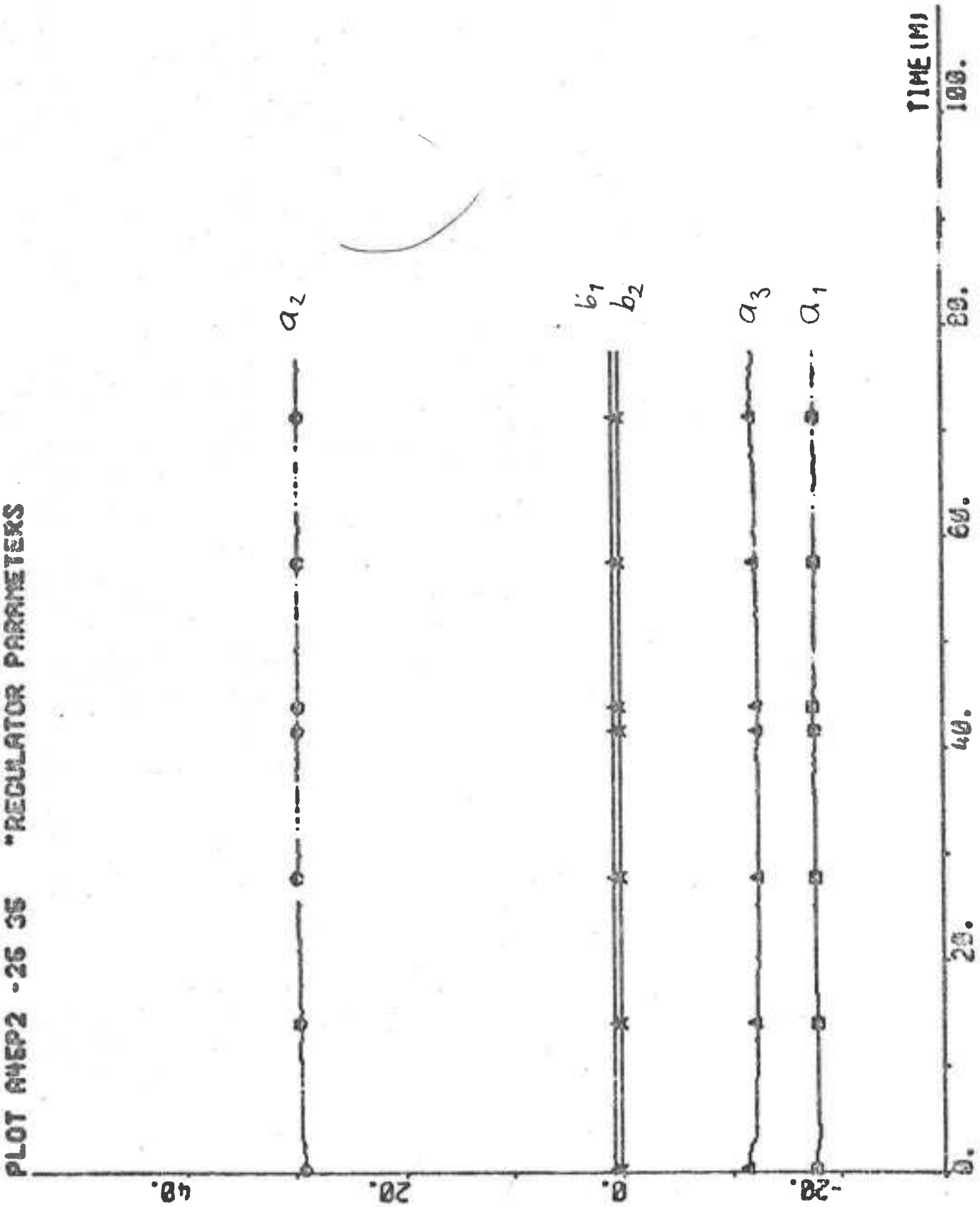

PLOT A46P1(9) ZERO -1 0 "V2 KNOTS
-0.25
-0.5
-0.75
-1.
0.
20.
40.
60.
80.
100.
TIME(M)


PLOT A*EP1(10) ZERO -0.1 0.1 'R DEG/S
TIME(M)
0.
20.
40.
60.
80.
100.
0.05
0
-0.05
-0.1


PLOT AVEP1(11) ZERO -0.1 0.1 "AVR DEG/S (BR=0.2)
0.05
0.
-0.05
-0.1
0.
20.
40.
60.
80.
100.
TIME(M)


PLOT A4SP1(12) ZERO -0.1 0.1 "DPSIDT DEG/S (IDPSI.6)
0.05
0.
-0.05
-0.1
0.
20.
40.
60.
80.
100.
TIME(M)


PLOT AVSP1(13 14) 260 282 "PSI PSIREF DEG
TIME(M)
0.
20.
40.
60.
80.
100.
260.
261.


PLOT A4EP2 -25 35 *REGULATOR PARAMETERS
40.
20.
0.
-20.
0.
20.
40.
60.
80.
100.
TIME(M)
a_2
b_1
b_2
a_3
a_1

EXPERIMENT B1

Date	1974-10-08
Time	11.43
Duration	36 min
Position	N 25° 04' E 53° 23'
Water depth	20 - 22 m
Forward draught	10.9 m
Aft draught	10.9 m
Wind direction	NNW (7; see Appendix A)
Wind velocity	1-2 Beaufort (1-3.5 m/s, light air to light breeze)
Wave height	0.5 - 1.0 m
PSIREF	60°, 52°, 64°, 71°, 67°
RREF	0.07 deg/s (0-7.5 min), 0.14 deg/s (7.5-36 min)
Rudder limit	±6° - ±12°
DEL1M at termination	-1.91°
Approximate mean value of AN	78.5 rpm
Approximate mean value of U	16.3 knots

Data were recorded every 20th second.
A program error caused IDELC not to be assigned the value -1 when the rudder limit became active, which meant that the autopilot never obtained that information. Another program error caused the off-diagonal elements of the covariance matrix P for the straight course regulator parameters to be put zero instead of the off-diagonal elements of PY for the yaw regulator parameters, when phase 2 of the yaw regulator was initiated, which affected both the straight course keeping and the yawing.

Regulator structure

NA = 3 NB = 1 NC = 1 K = 4
IREG = 20 IRDIF = 1 RL = 0.98 IRR = 1

Final values

$$\begin{bmatrix} a_1 \\ a_2 \\ a_3 \\ b_1 \\ c_1 \end{bmatrix} = \begin{bmatrix} -13.881 \\ 20.427 \\ -6.941 \\ 0.437 \\ 0.596 \end{bmatrix} \qquad P = \begin{bmatrix} 0.171 & & & & \\ -0.142 & 0.289 & & & \\ 0.024 & -0.132 & 0.161 & & \\ -0.013 & 0.006 & 0.007 & 0.002 & \\ 0.539 & -2.236 & 0.456 & -0.053 & 48.246 \end{bmatrix}$$

$a_1 + a_2 + a_3 = -0.395$

Yaw regulator structure

NAY = 3 NBY = 2 KY = 5
IREGY = 10 RLY = 0.95 IRR = 1
AK1V = 40 AK2V = 1.4 AK3V = 115
C1V = 30 C2V = 60
EPS1V = 0.02 EPS2V = 0.03
PSISV = 0.4 PSISSV = 1.5 PSIMAV = 0.6
I1MV = 100 I2MV = 300 I3MV = 120

Initial yaw regulator values

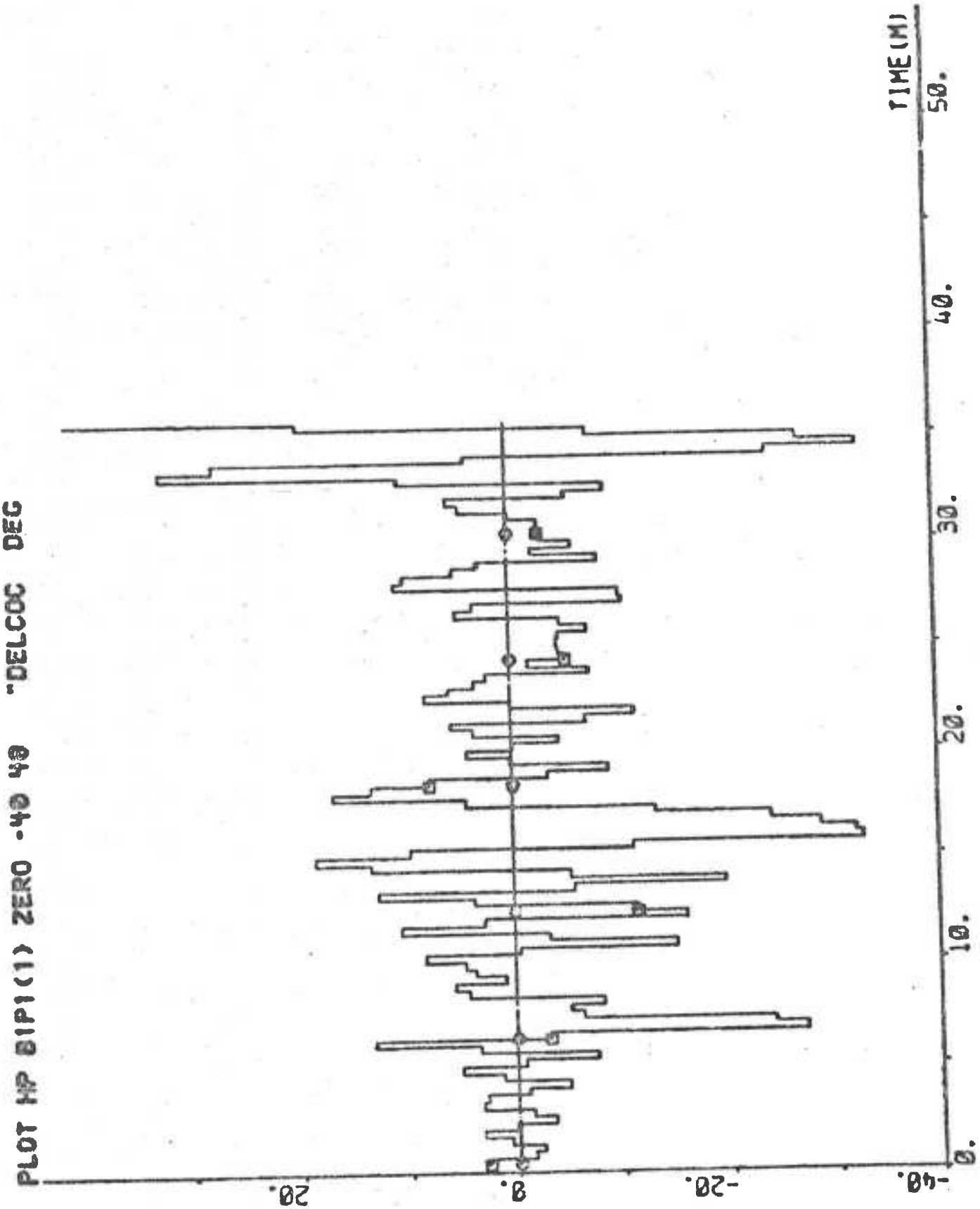
$$\begin{bmatrix} a'_1 \\ a'_2 \\ a'_3 \\ b'_1 \\ b'_2 \end{bmatrix} = \begin{bmatrix} -12.90 \\ 6.02 \\ -6.87 \\ 1.30 \\ 0.649 \end{bmatrix} \qquad PY = \begin{bmatrix} 1000 & & & & \\ 0 & 1000 & & & \\ 0 & 0 & 1000 & & \\ 0 & 0 & 0 & 10 & \\ 0 & 0 & 0 & 0 & 10 \end{bmatrix}$$

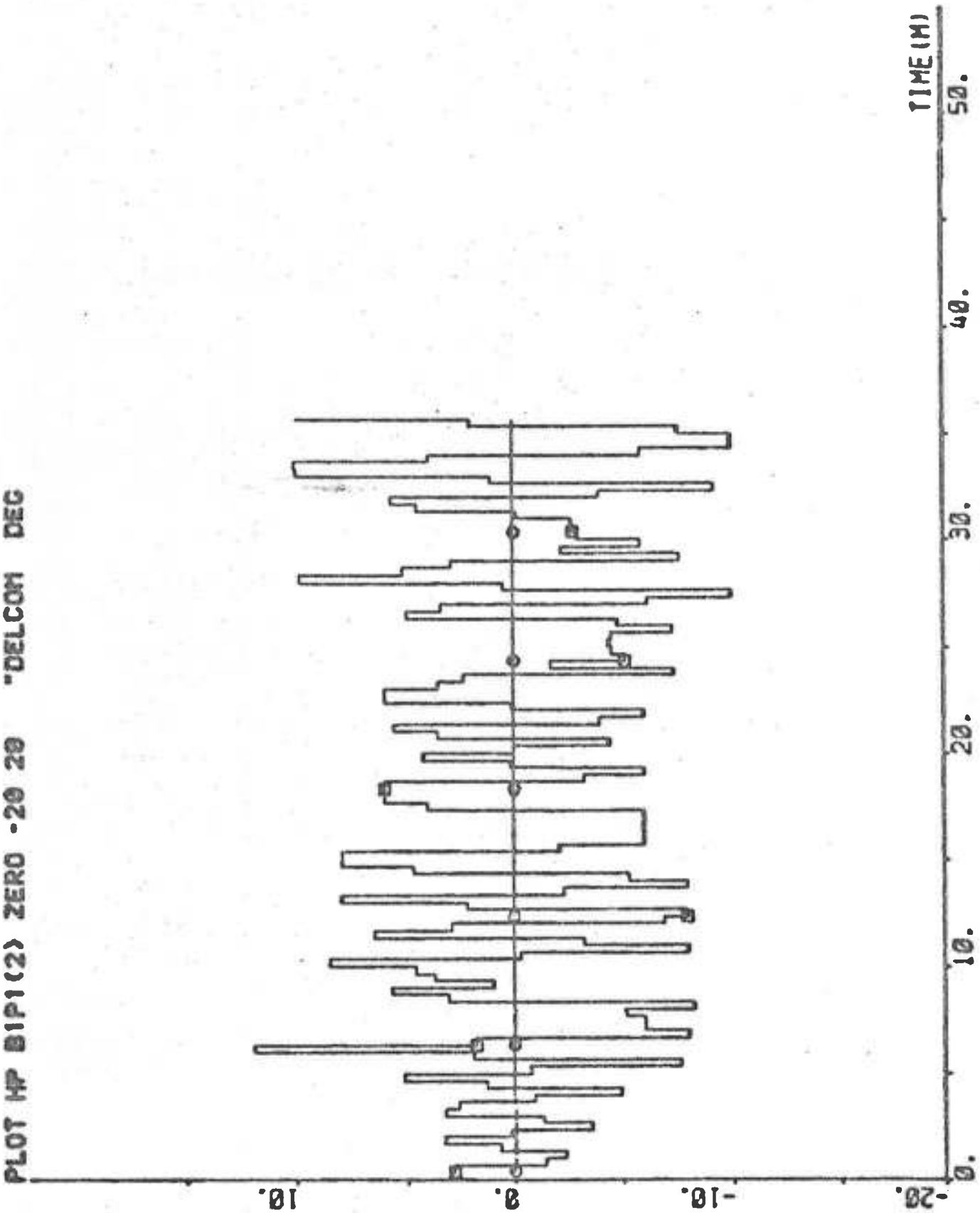
$a'_1 + a'_2 + a'_3 = -13.75$

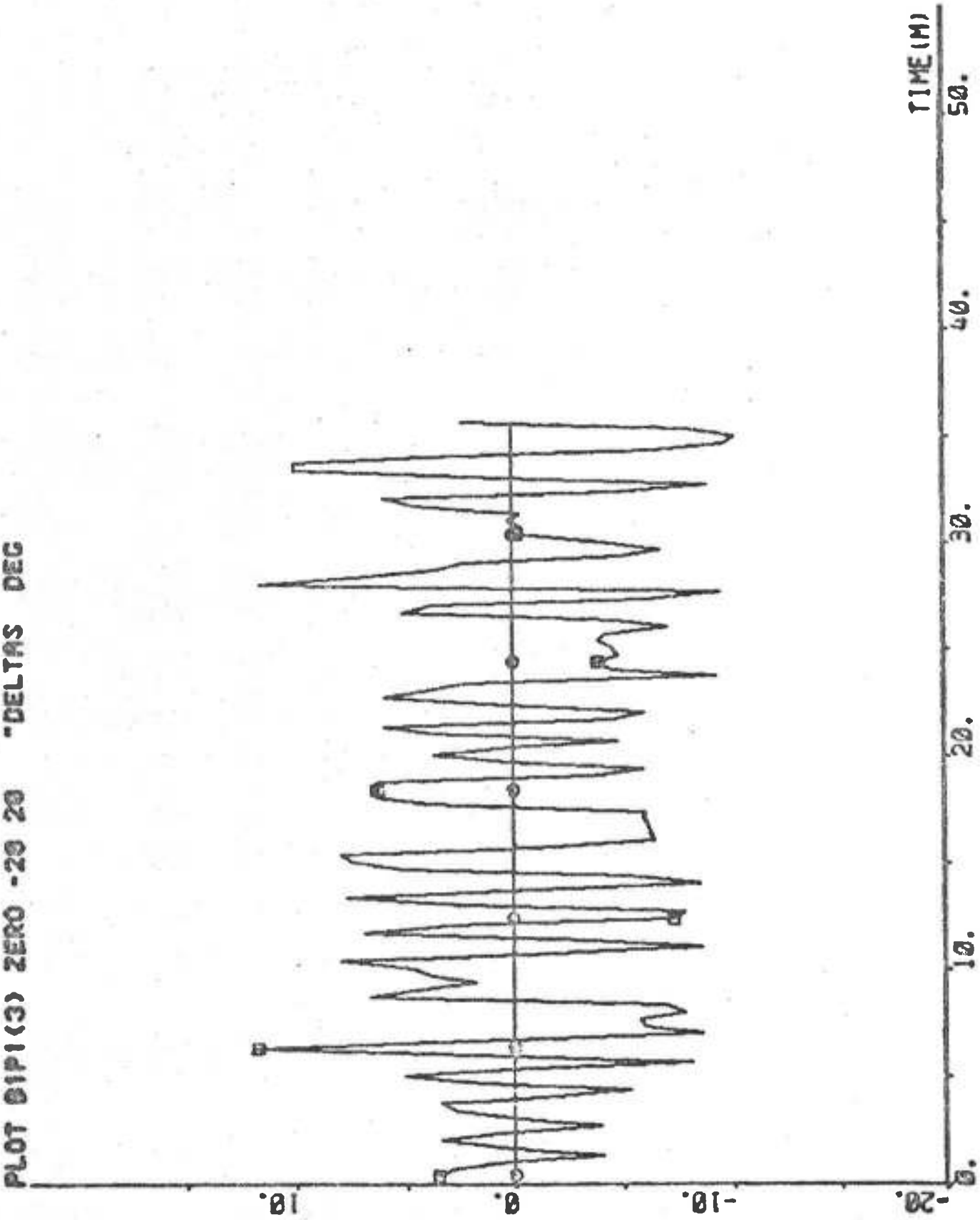
Yaw regulator values after the yaw at 22 min

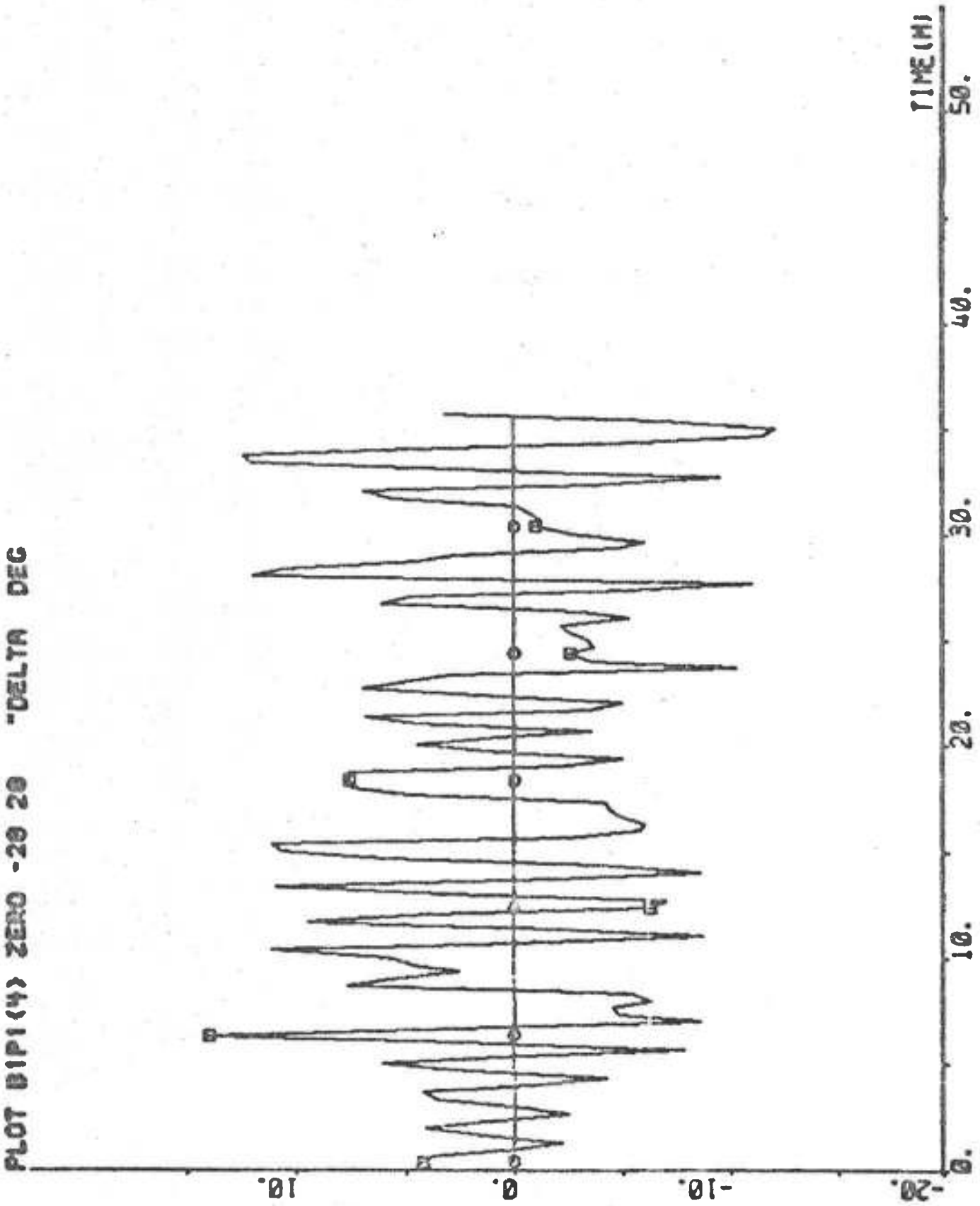
$$\begin{bmatrix} a_1' \\ a_2' \\ a_3' \\ b_1' \\ b_2' \end{bmatrix} = \begin{bmatrix} -12.90 \\ 6.02 \\ -6.87 \\ 1.30 \\ 0.649 \end{bmatrix} \qquad PY = \begin{bmatrix} 1052.632 & & & & \\ -2131.196 & 1052.632 & & & \\ 280.764 & -2636.618 & 1052.632 & & \\ 4.632 & -167.430 & 21.118 & 10.526 & \\ -12.469 & -97.469 & -14.887 & 6.704 & 10.526 \end{bmatrix}$$

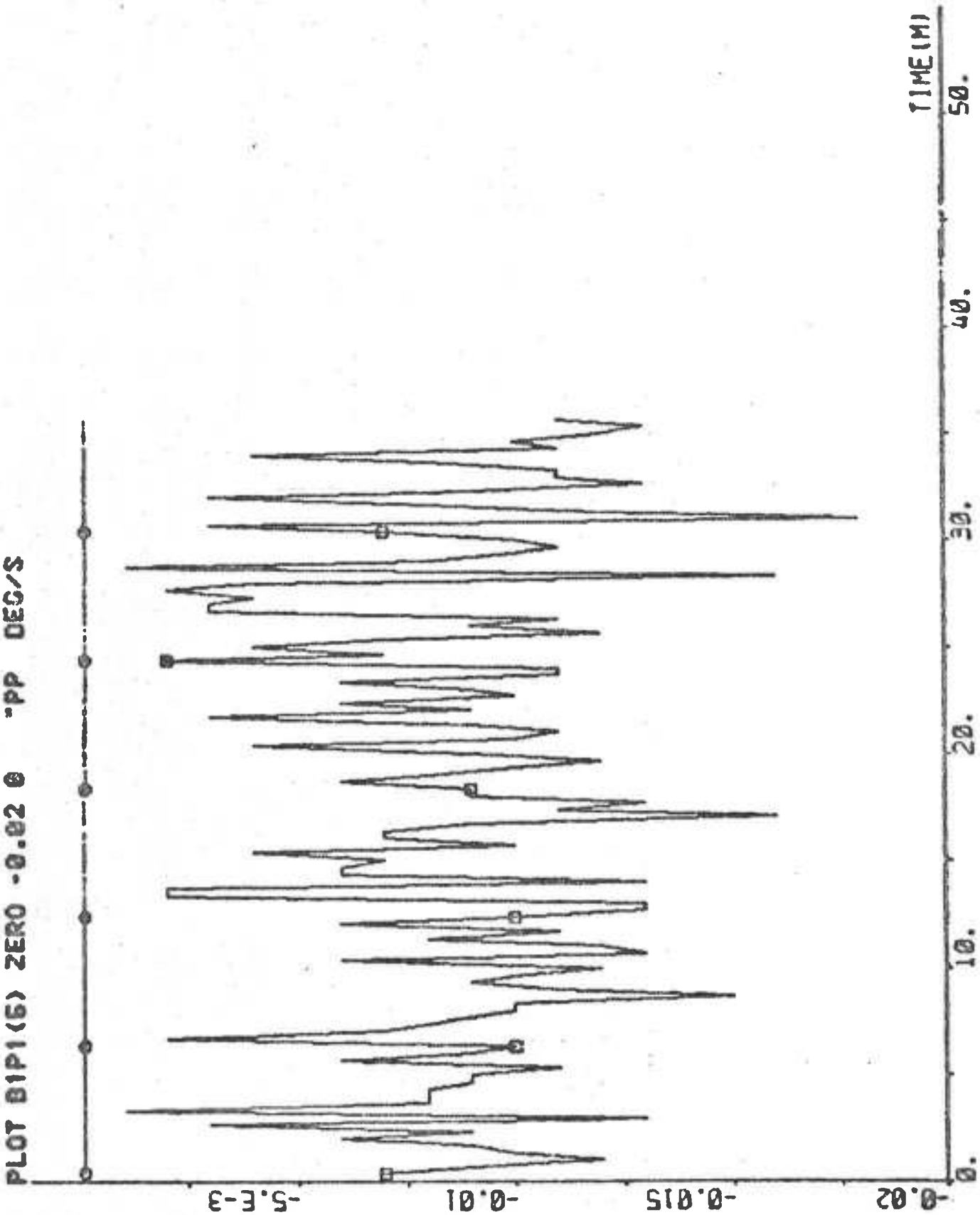
$a_1' + a_2' + a_3' = -13.75$

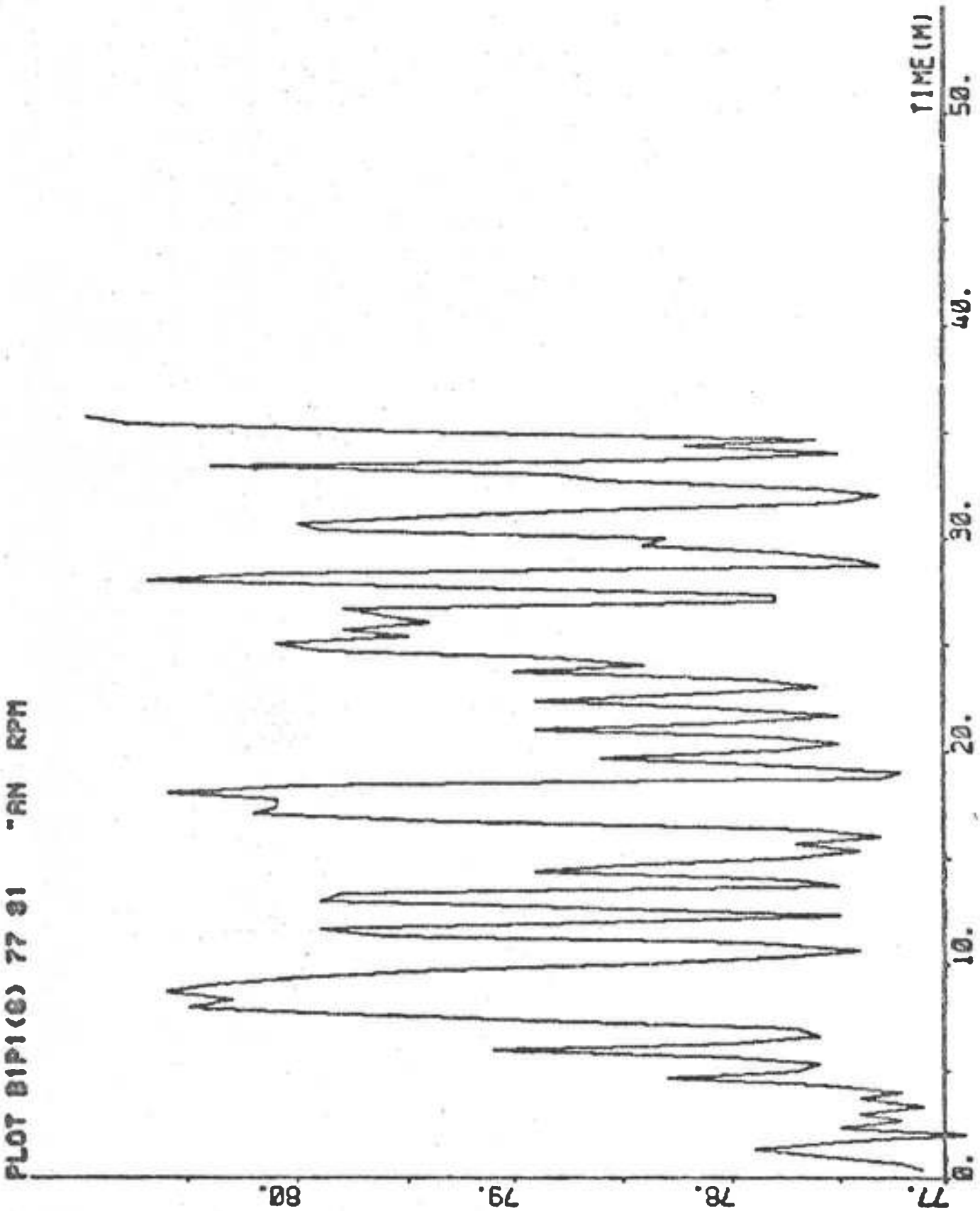

PLOT HP BIP1(1) ZERO -40 40 "DELCOC DEG
TIME(M)
0.
10.
20.
30.
40.
50.
-40.
-20.
0.
20.

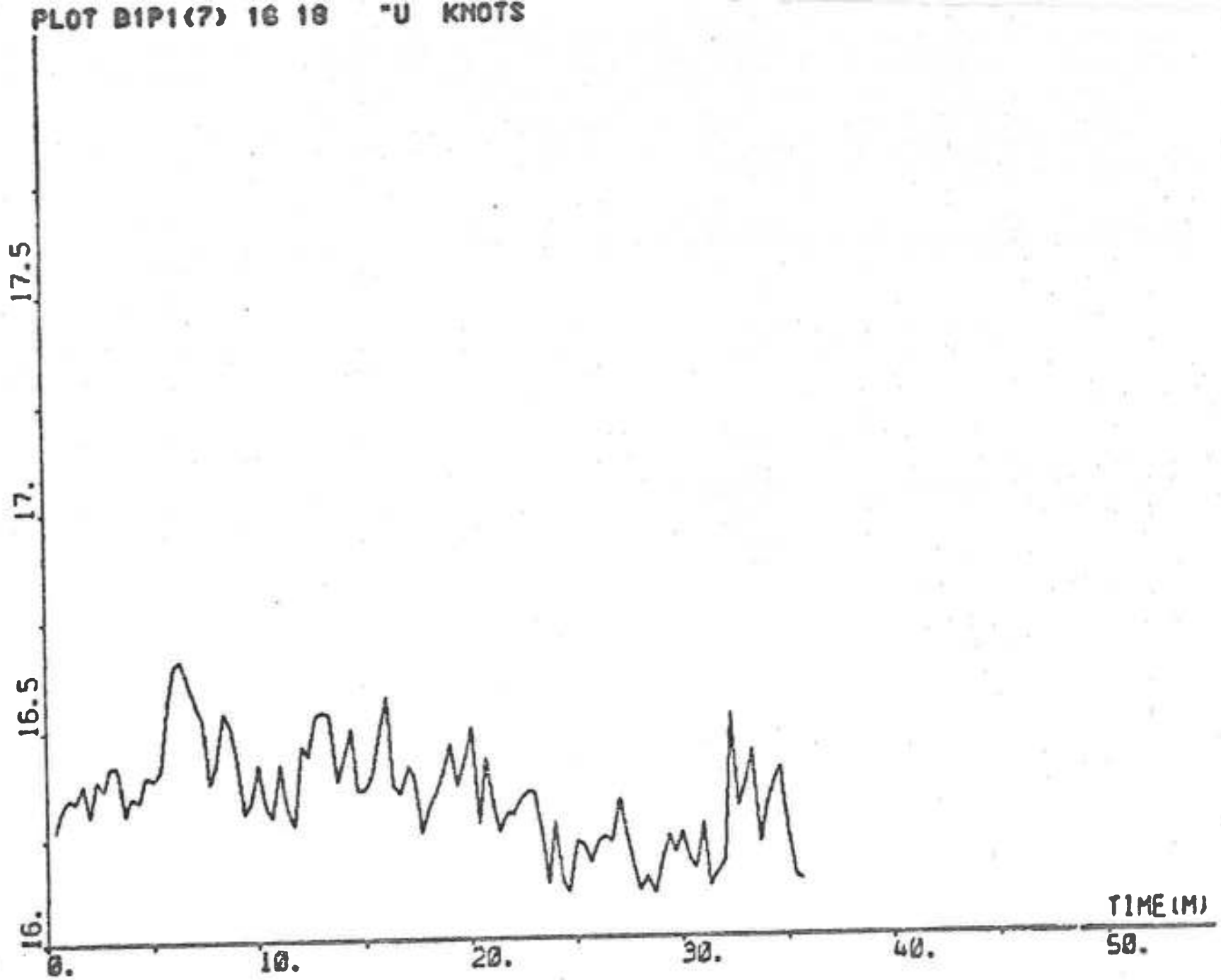

PLOT HP BIP1(2) ZERO -20 20 "DELCOM DEC
TIME(M)
0.
10.
20.
30.
40.
50.
-20.
-10.
0.
10.

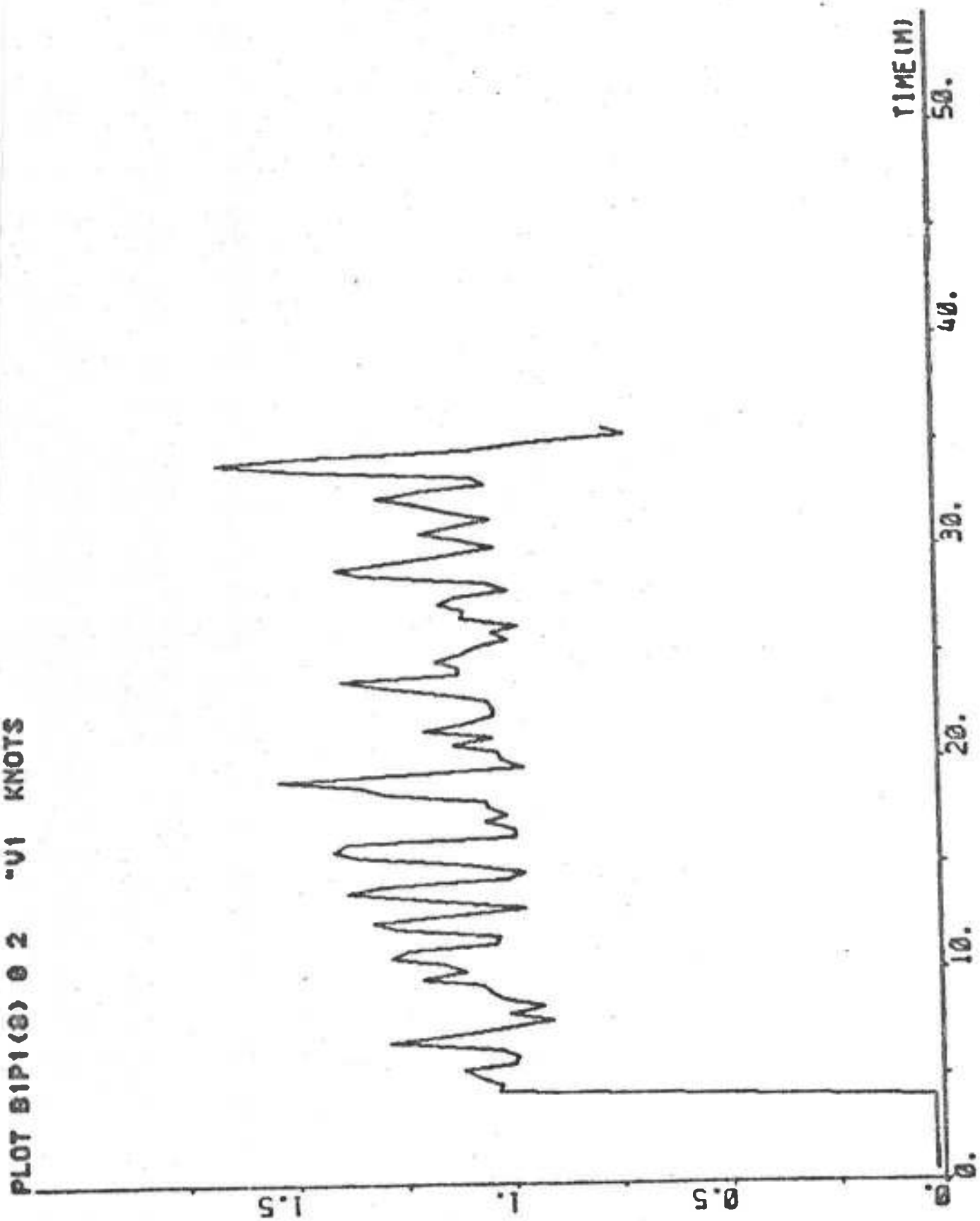

PLOT BIP1(3) ZERO -20 20 "DELTAS DEG
TIME(M)
0.
10.
20.
30.
40.
50.
20.
10.
0.
-10.
-20.

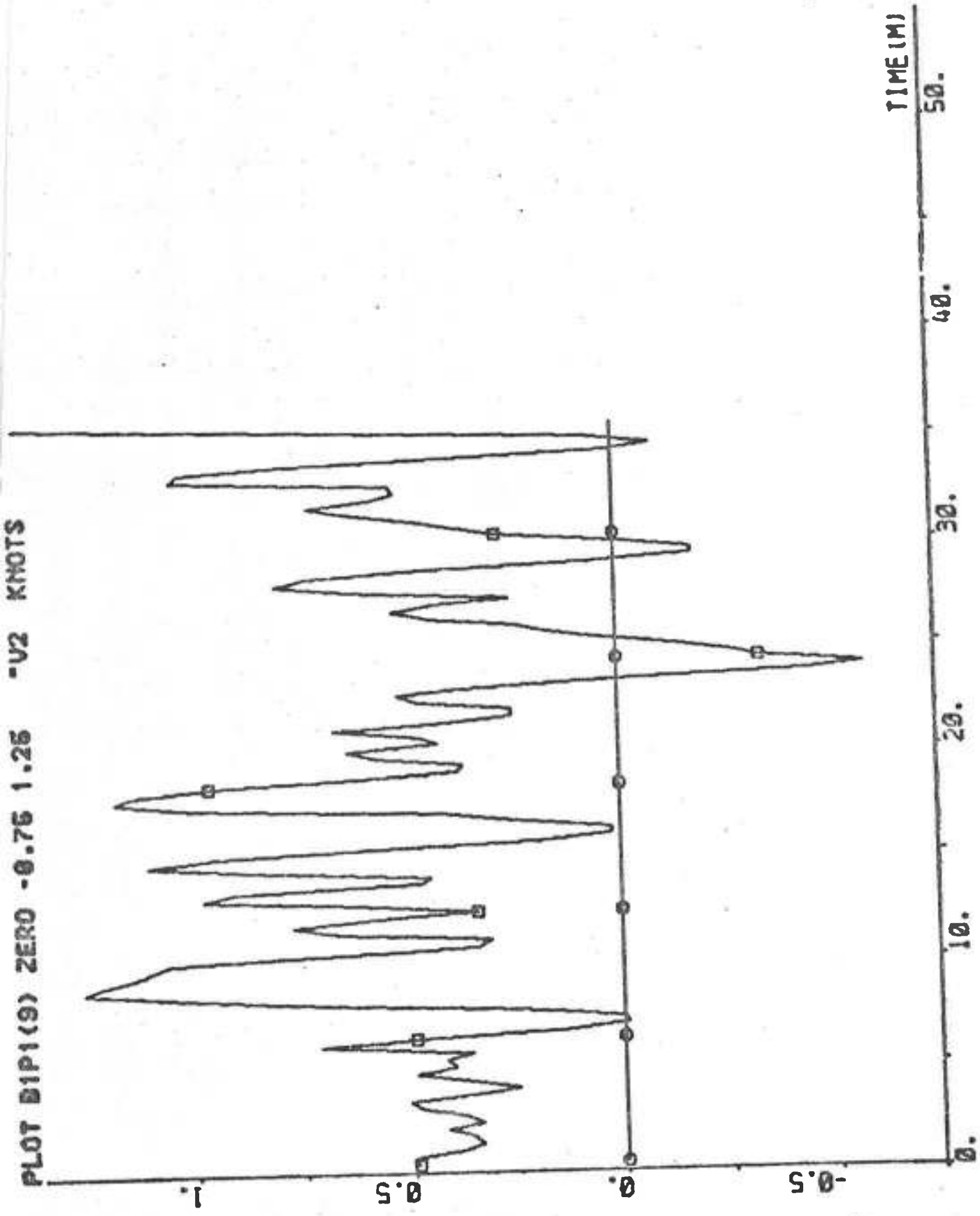

PLOT BIPI(4) ZERO -20 20 "DELTA DEC
TIME(H)
0.
10.
20.
30.
40.
50.
-20.
-10.
0.
10.

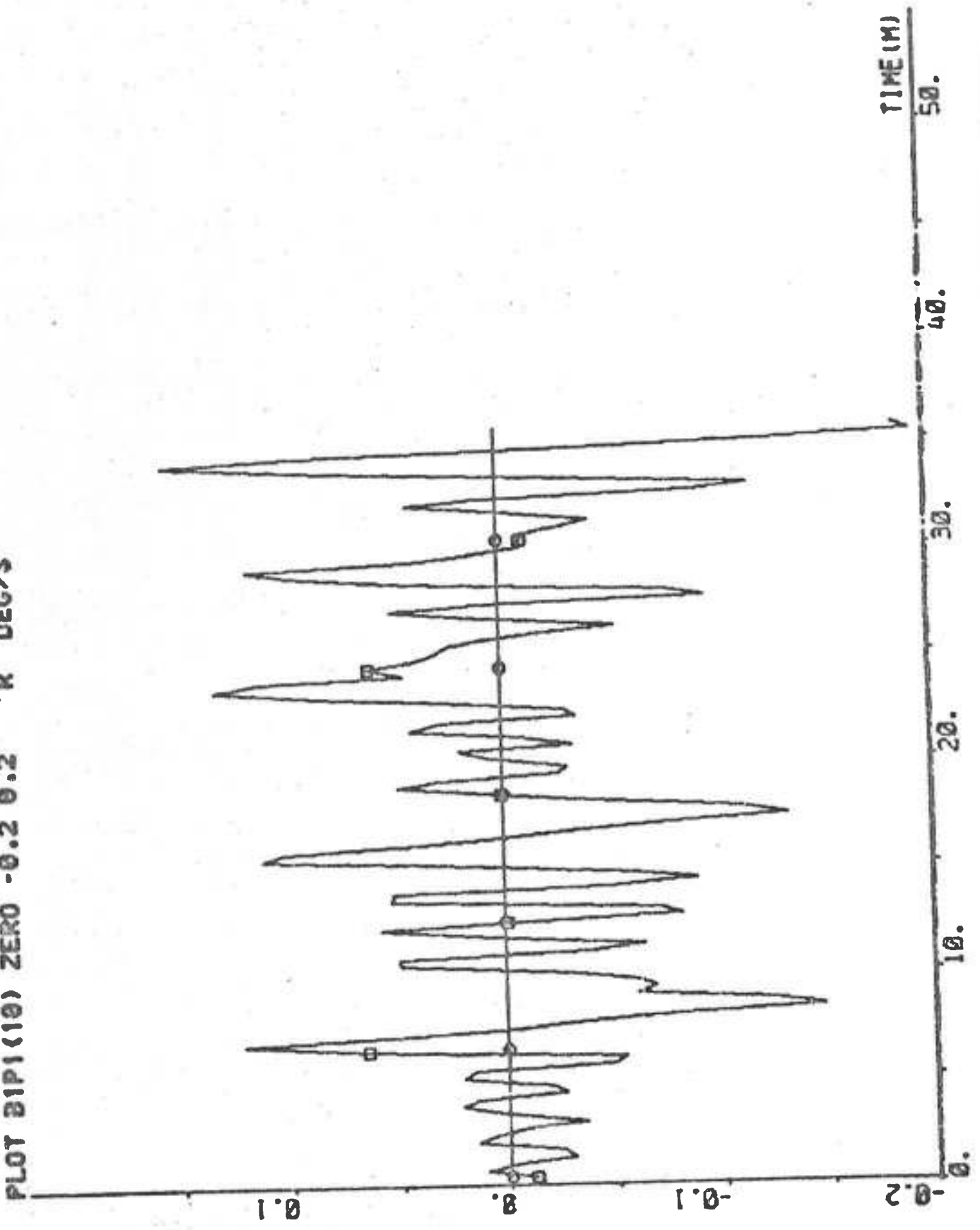

PLOT B1P1(6) ZERO -0.02 @ *PP DEG/S
-0.02
-0.015
-0.01
-5.E-3
0.
10.
20.
30.
40.
50.
TIME(M)

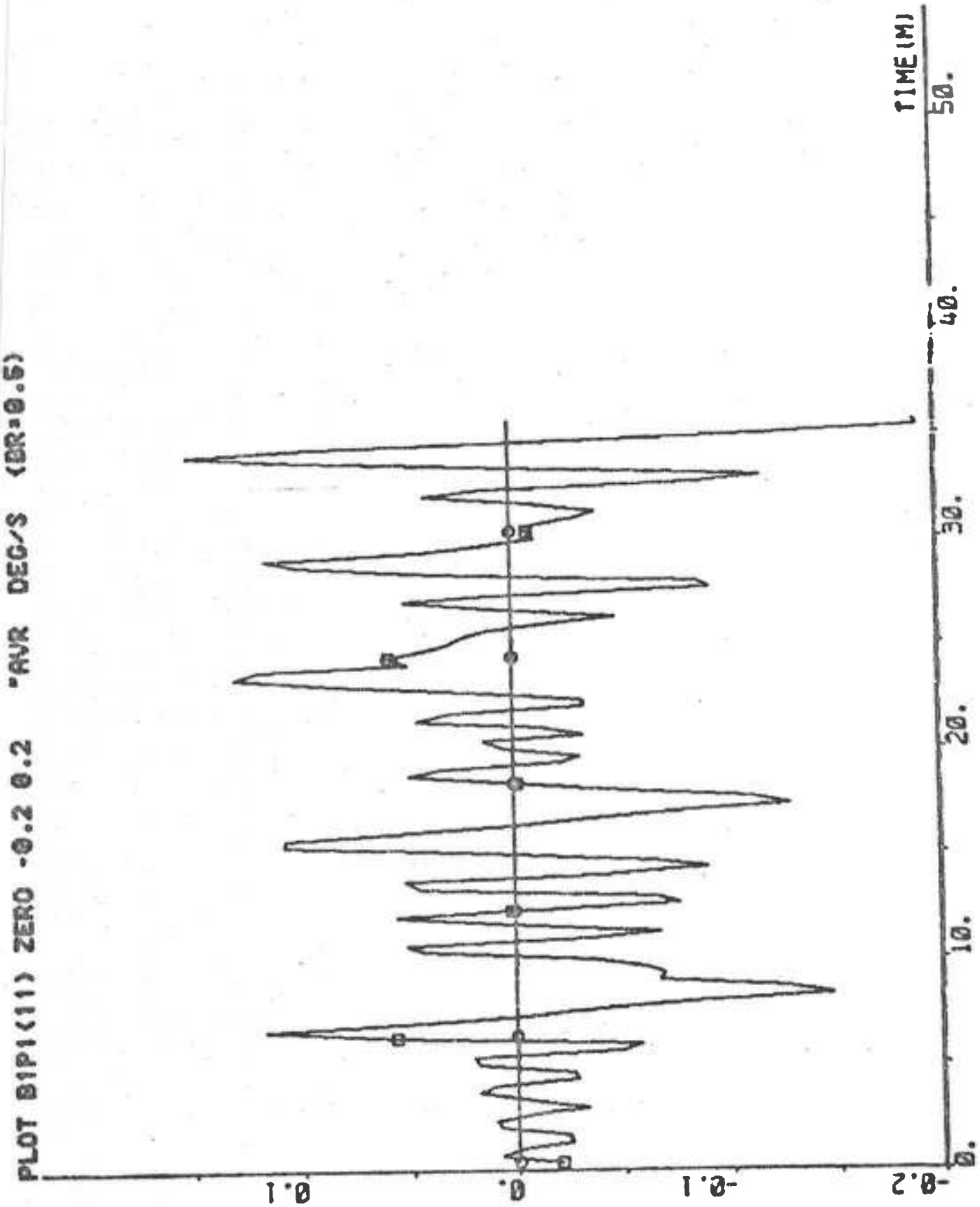

PLOT B1P1(0) 77 81 "AN RPM
77.
78.
79.
80.
0.
10.
20.
30.
40.
50.
TIME(M)

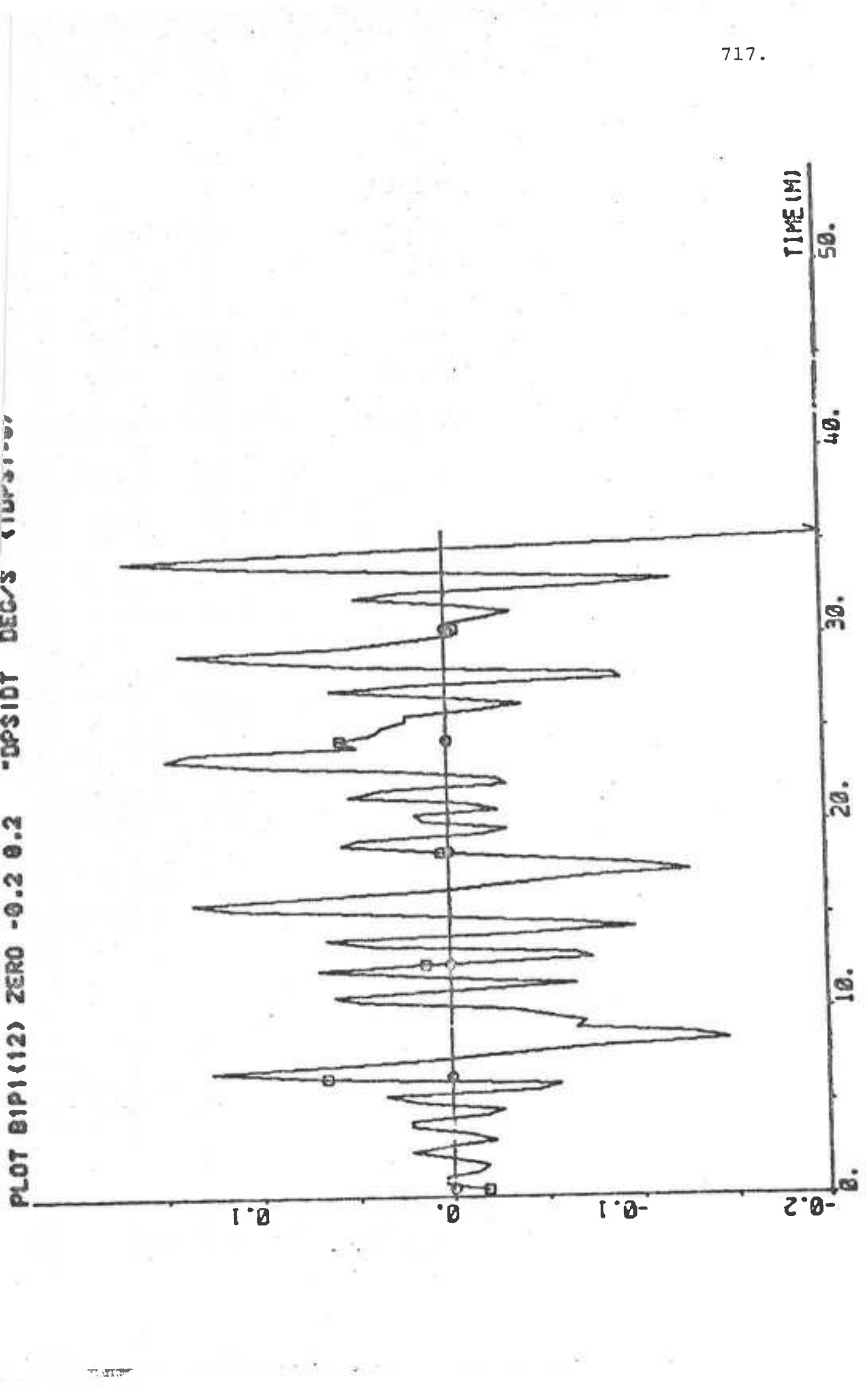

PLOT B1P1(7) 16 18 "U KNOTS
17.5
17.
16.5
16.
0.
10.
20.
30.
40.
50.
TIME(M)

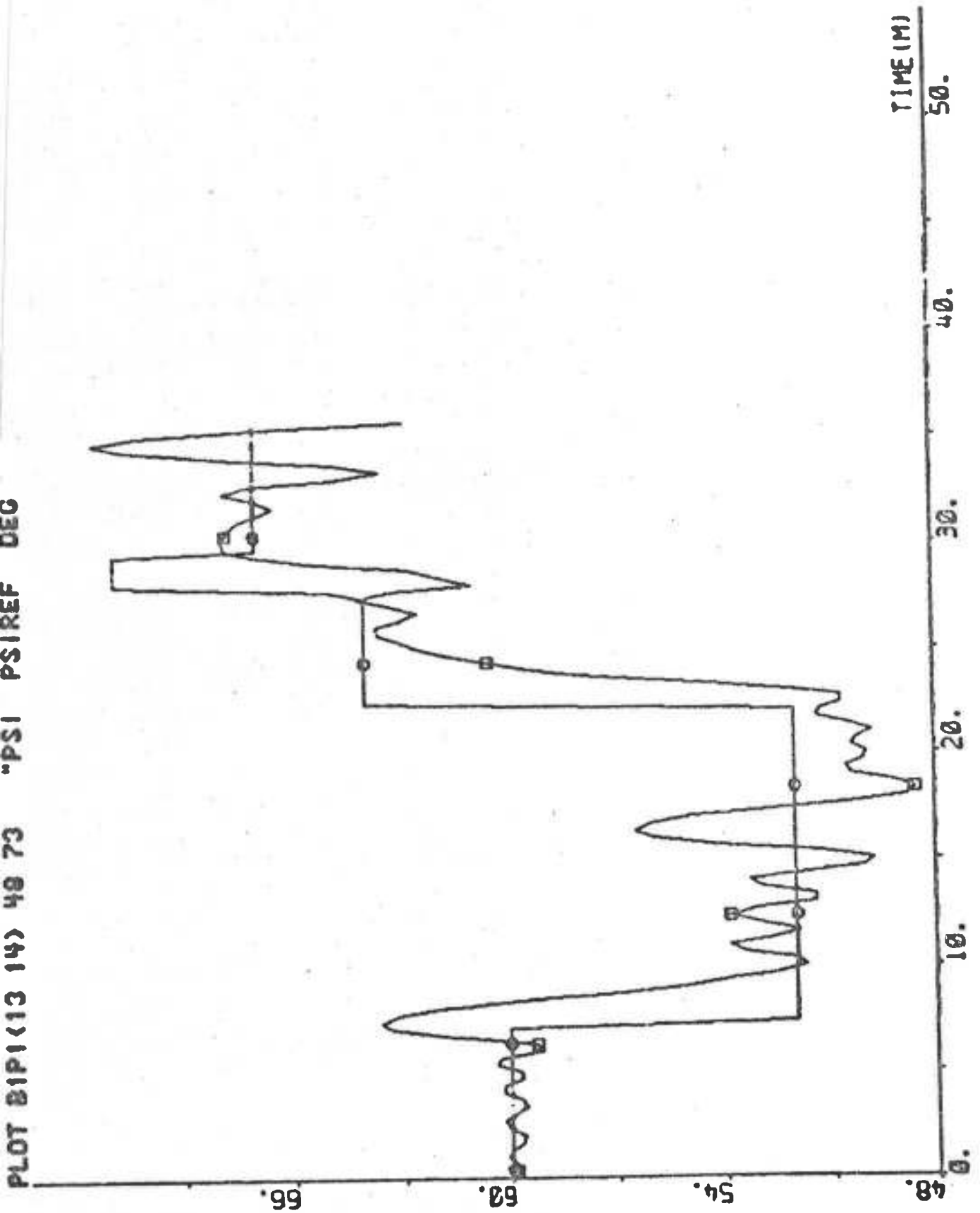

PLOT B1P1(8) 0 2 *V1 KNOTS
1.5
1.
0.5
0.
0.
10.
20.
30.
40.
50.
TIME(M)

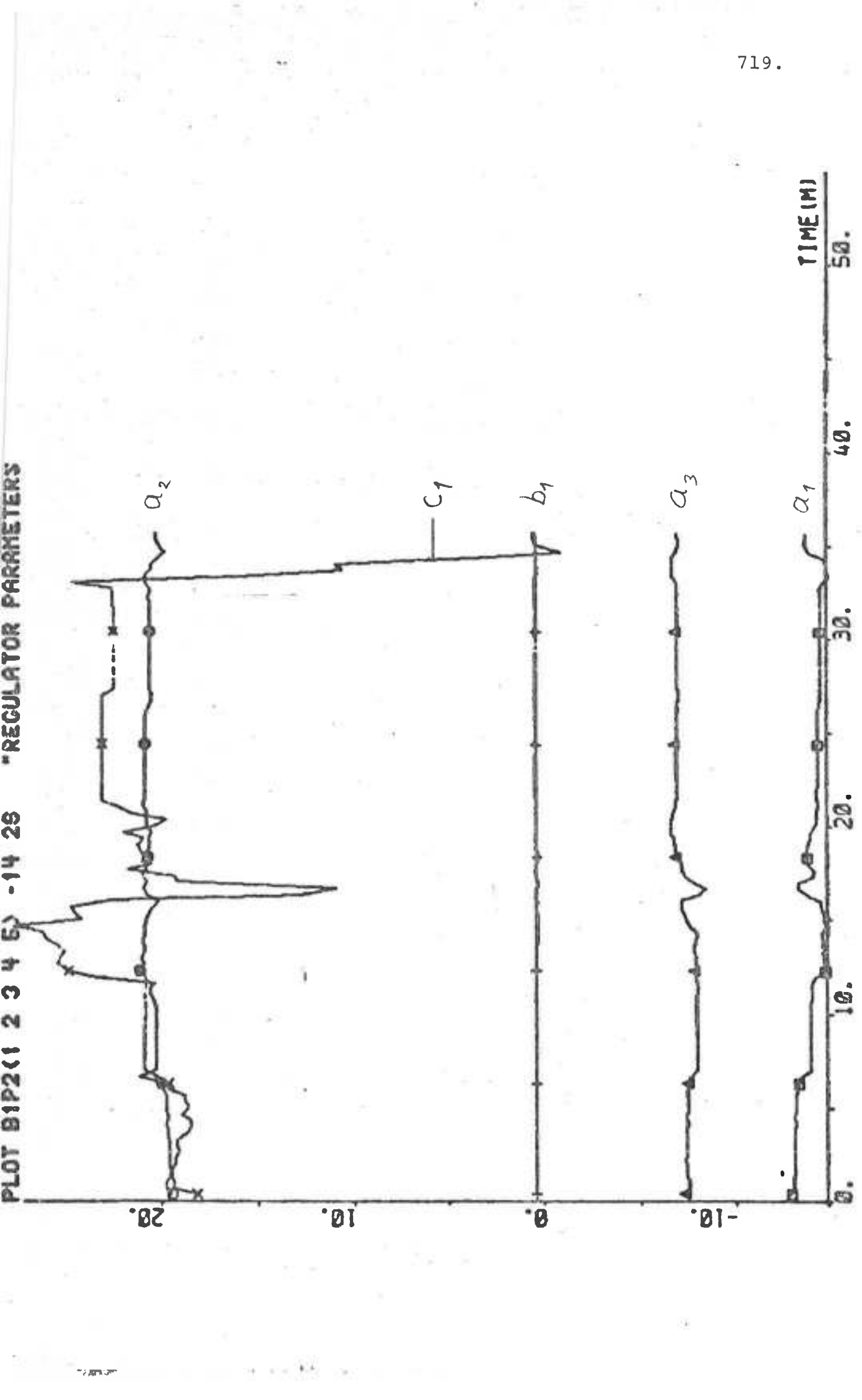

PLOT B1P1(9) ZERO -0.75 1.25 -V2 KNOTS
1.
0.5
0.
-0.5
0.
10.
20.
30.
40.
50.
TIME(M)

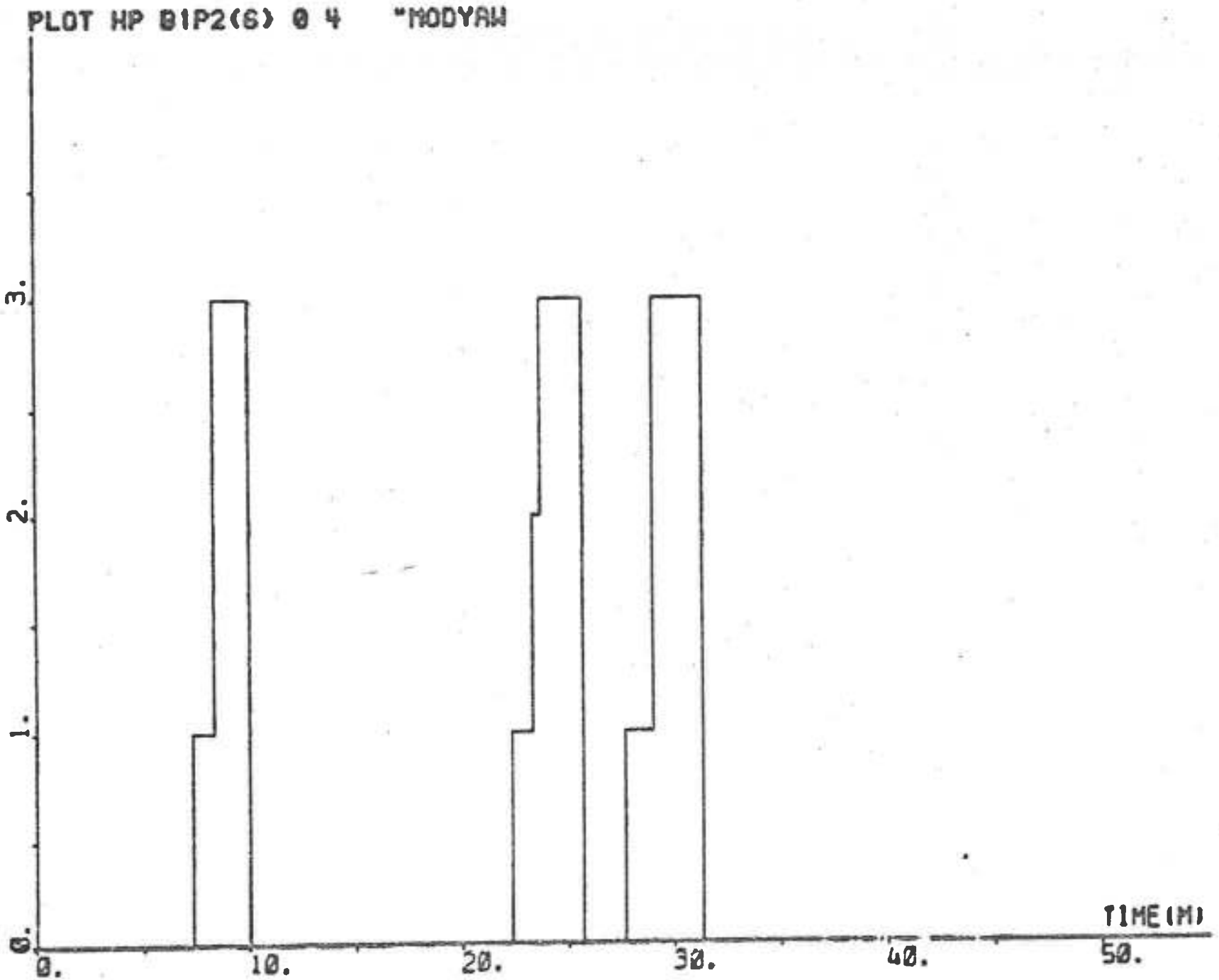

PLOT BIP1(10) ZERO -0.2 0.2 °R DEG/S
0.1
0.
-0.1
-0.2
0.
10.
20.
30.
40.
50.
TIME(M)


PLOT B1P1(11) ZERO -0.2 0.2 "AVR DEG/S (BR=0.5)
0.1
0.
-0.1
-0.2
0.
10.
20.
30.
40.
50.
TIME(M)


PLOT B1P1(12) ZERO -0.2 0.2 "DPSIDT DEG/S
-0.2
-0.1
0.
0.1
0.
10.
20.
30.
40.
50.
TIME(M)


PLOT BIP1(13 14) 48 73 "PSI PSIREF DEG
66.
60.
54.
48.
0.
10.
20.
30.
40.
50.
TIME(M)


PLOT B1P2(1 2 3 4 5) -14 28 "REGULATOR PARAMETERS
20.
10.
0.
-10.
0.
10.
20.
30.
40.
50.
TIME(M)
a_2
c_1
b_1
a_3
a_1


PLOT HP B1P2(6) 0 4 "MODYAW
3.
2.
1.
0.
0.
10.
20.
30.
40.
50.
TIME(M)

EXPERIMENT B2

Date	1974-10-08
Time	13.02
Duration	83 min
Position	N 25° 17' E 53° 27'
Water depth	22 - 25 m
Forward draught	10.9 m
Aft draught	10.9 m
Wind direction	NNW (7, 8, 1; see Appendix A)
Wind velocity	1-2 Beaufort (1-3.5 m/s, light air to light breeze)
Wave height	0.5 - 1.0 m
PSIREF	76°, 7°, 4°, 1°, 358°, 359°, 1°, 350°
RREF	0.07 deg/s
Rudder limit	±5° - ±10°
DELlM at termination	- 1.15°
Approximate mean value of AN	78.0 rpm
Approximate mean value of U	16.5 knots

The plot of the course PSI is misleading, because the course 0° was passed a couple of times. A program error caused IDELC not to be assigned the value -1 when the rudder limit became active, which meant that the autopilot never obtained that information. Another program error caused the off-diagonal elements of the covariance matrix P for the straight course regulator parameters to be put zero instead of the off-diagonal elements of PY for the yaw regulator parameters, when phase 2 of the yaw regulator was initiated, which affected both the straight course keeping and the yawing.

Regulator structure

NA = 3 NB = 1 NC = 1 K = 4
IREG = 20 IRDIF = 1 RL = 0.98 IRR = 1

Final values

$$\begin{bmatrix} a_1 \\ a_2 \\ a_3 \\ b_1 \\ c_1 \end{bmatrix} = \begin{bmatrix} -11.420 \\ 17.996 \\ -8.036 \\ 0.229 \\ -22.936 \end{bmatrix} \qquad P = \begin{bmatrix} 0.215 & & & & \\ -0.245 & 0.502 & & & \\ 0.075 & -0.287 & 0.279 & & \\ -0.019 & 0.008 & 0.012 & 0.004 & \\ 1.556 & -4.379 & 2.155 & -0.116 & 73.880 \end{bmatrix}$$

$a_1 + a_2 + a_3 = -1.460$

Yaw regulator structure

NAY = 3 NBY = 2 KY = 5
IREGY = 10 RLY = 0.95 IRR = 1
AK1V = 40 AK2V = 1.4 AK3V = 115
C1V = 30 C2V = 60
EPS1V = 0.02 EPS2V = 0.03
PSISV = 0.4 PSISSV = 1.5 PSIMAV = 0.6
I1MV = 100 I2MV = 300 I3MV = 120

Initial yaw regulator values

$$\begin{bmatrix} a'_1 \\ a'_2 \\ a'_3 \\ b'_1 \\ b'_2 \end{bmatrix} = \begin{bmatrix} -12.90 \\ 6.02 \\ -6.87 \\ 1.30 \\ 0.649 \end{bmatrix} \qquad PY = \begin{bmatrix} 1000 & & & & \\ 0 & 1000 & & & \\ 0 & 0 & 1000 & & \\ 0 & 0 & 0 & 10 & \\ 0 & 0 & 0 & 0 & 10 \end{bmatrix}$$

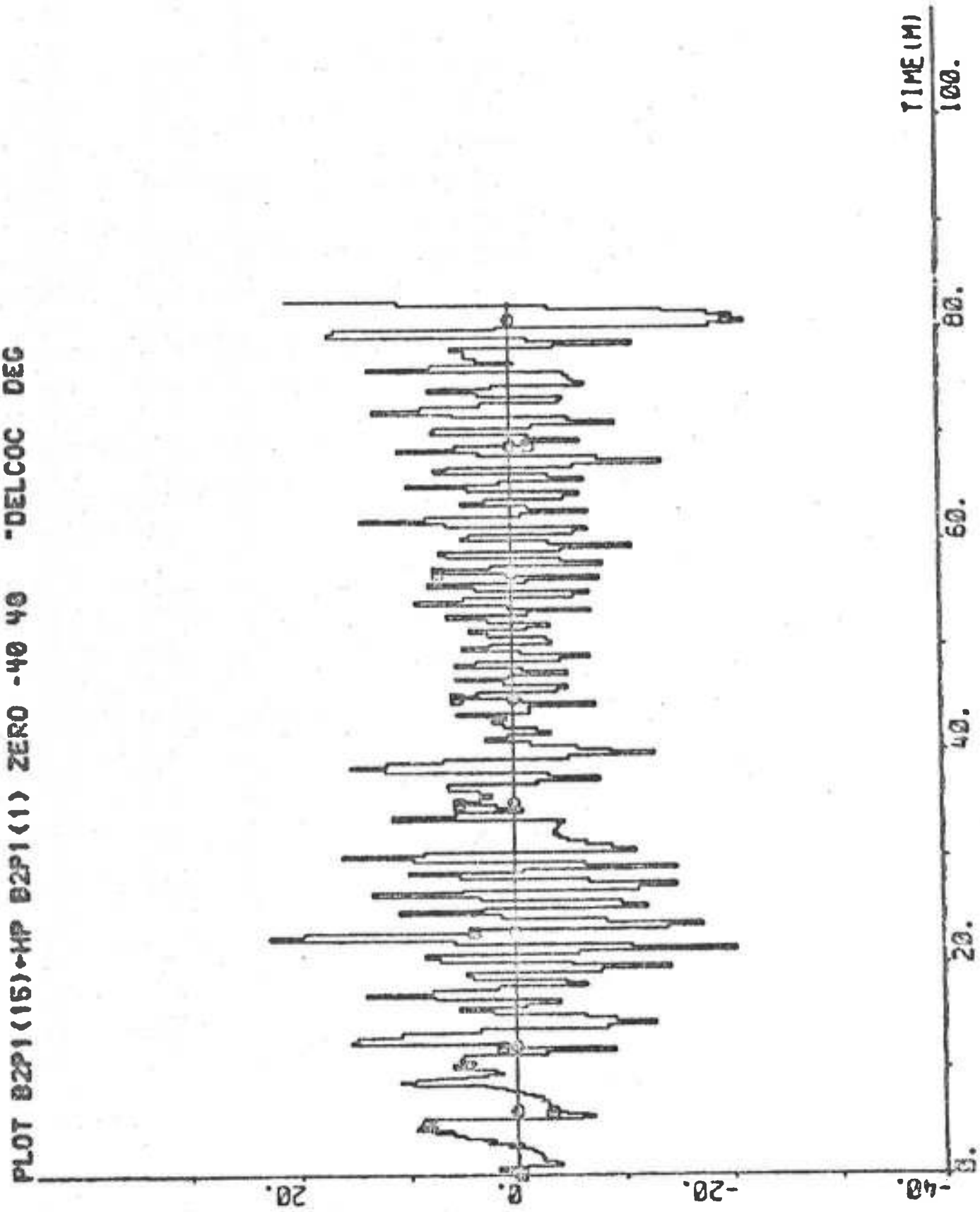
$a'_1 + a'_2 + a'_3 = -13.75$

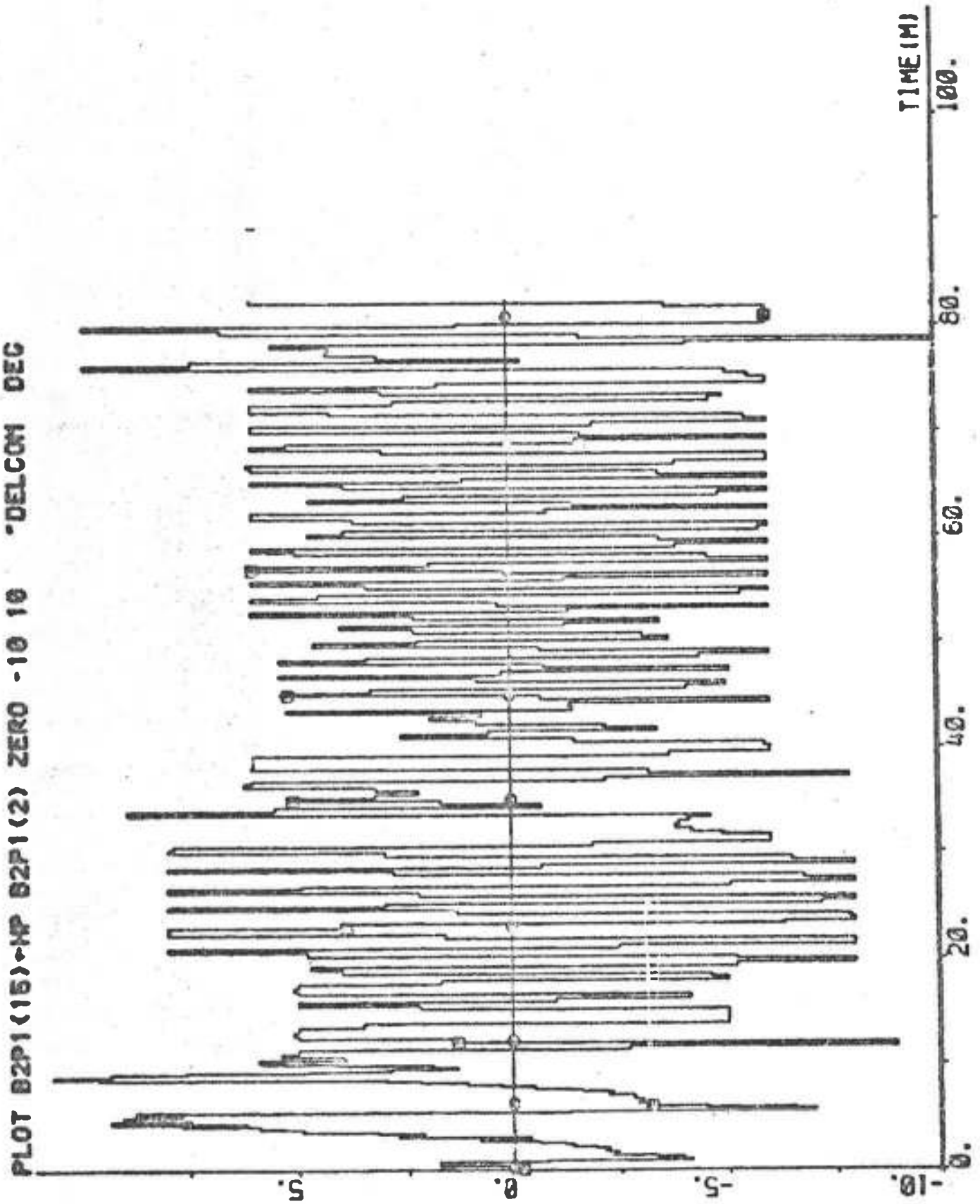
Yaw regulator values after the yaw at 1 min.

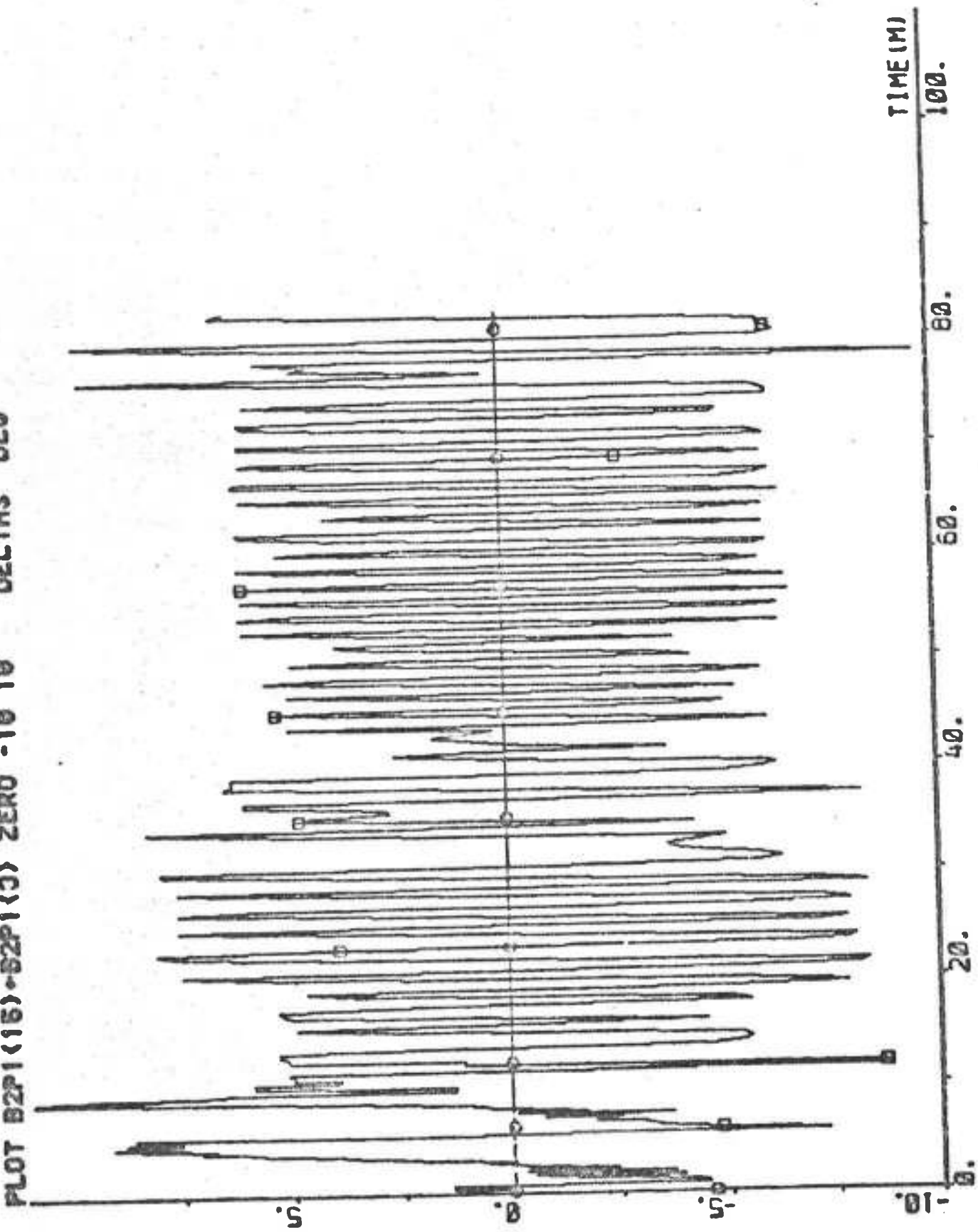
$$\begin{bmatrix} a_1' \\ a_2' \\ a_3' \\ b_1' \\ b_2' \end{bmatrix} = \begin{bmatrix} -16.347 \\ 7.948 \\ -6.272 \\ 1.213 \\ 0.609 \end{bmatrix}$$

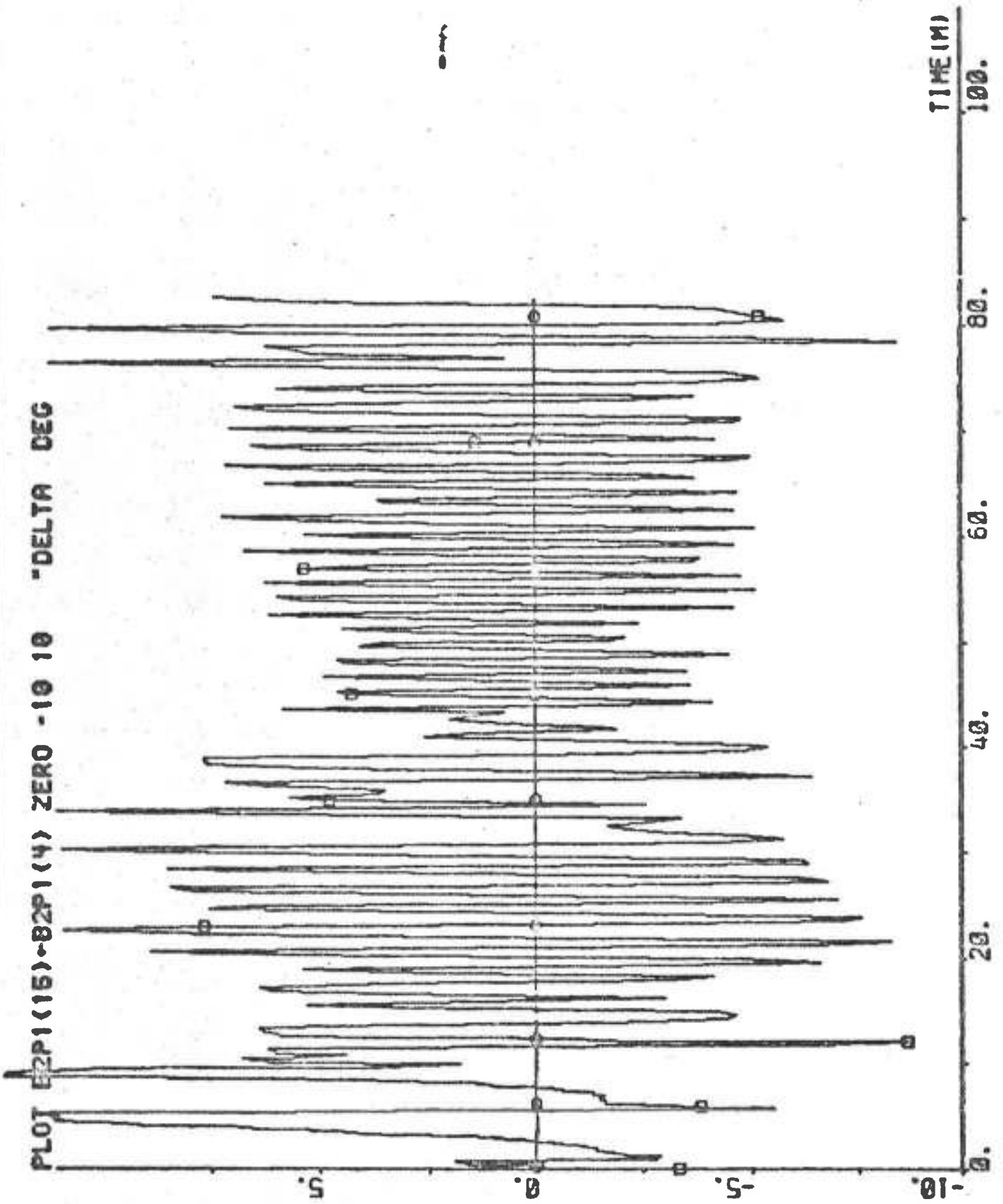
PY unknown

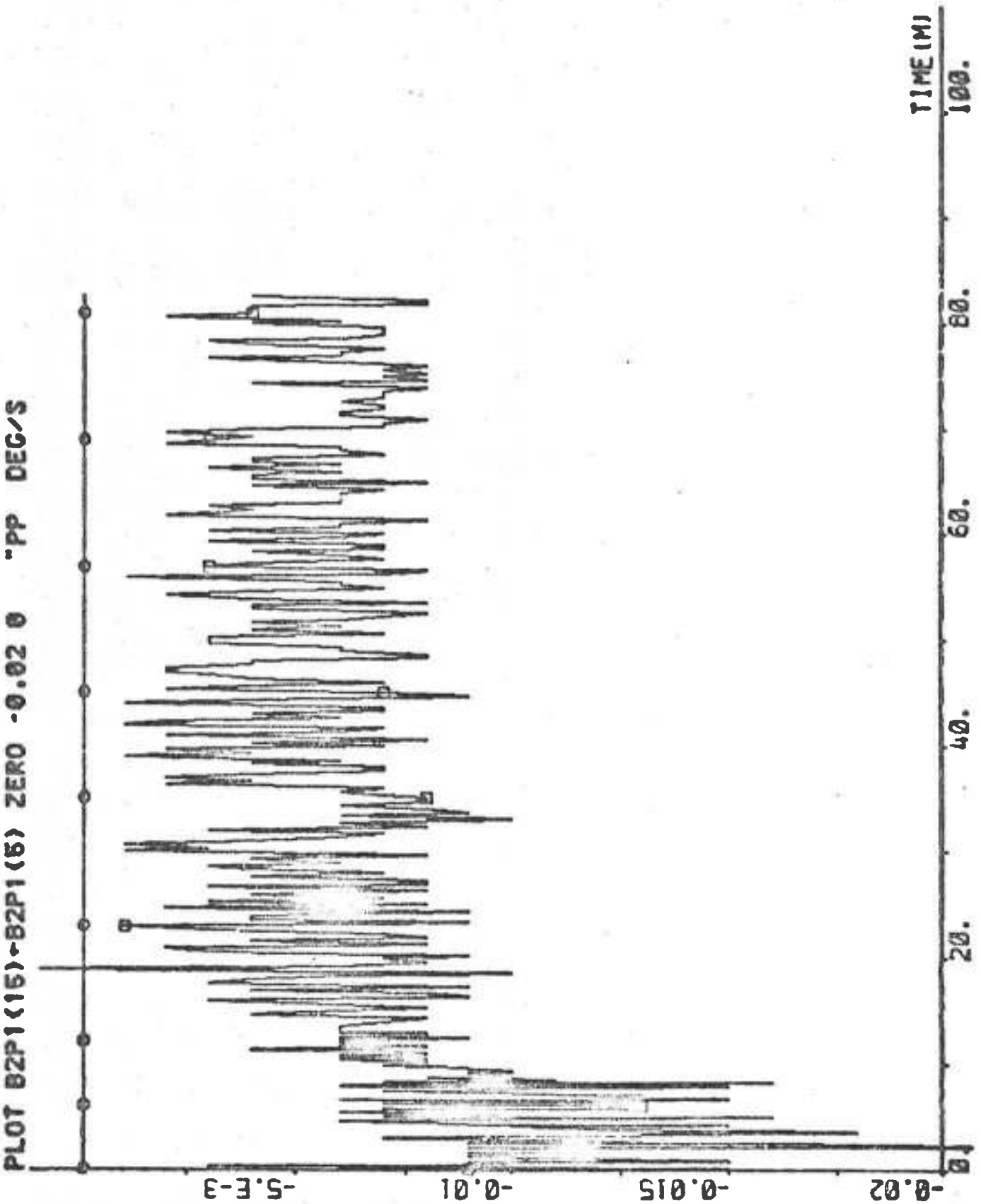
$a_1' + a_2' + a_3' = -14.671$

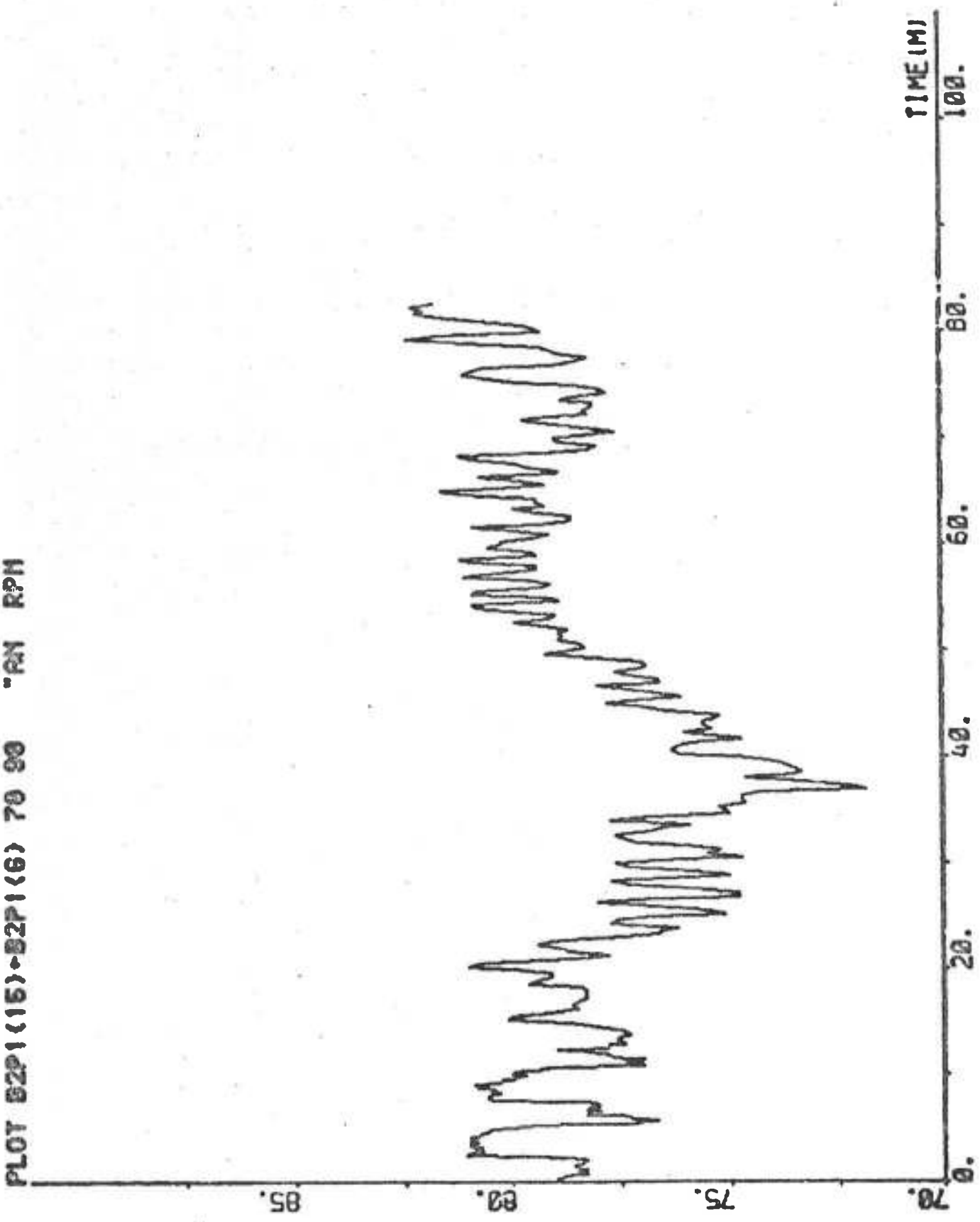

PLOT B2P1(16)-HP B2P1(1) ZERO -40 40 "DELCOC DEG
TIME(M)
20.
0.
-20.
-40.
0.
20.
40.
60.
80.
100.

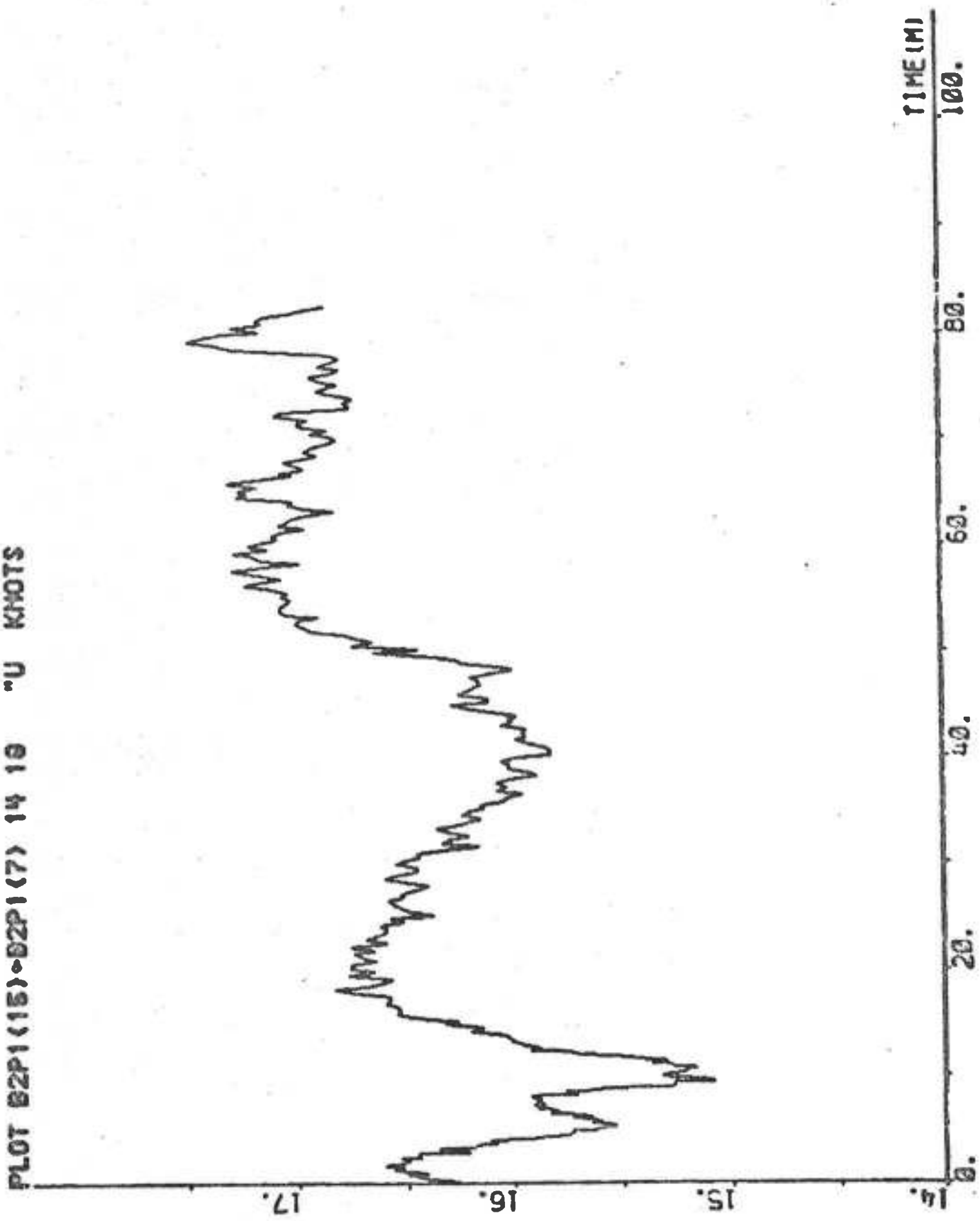

PLOT B2P1(15)-HP B2P1(2) ZERO -10 10 *DELCHN DEC
TIME(M)
0.
20.
40.
60.
80.
100.
-10.
-5.
0.
5.

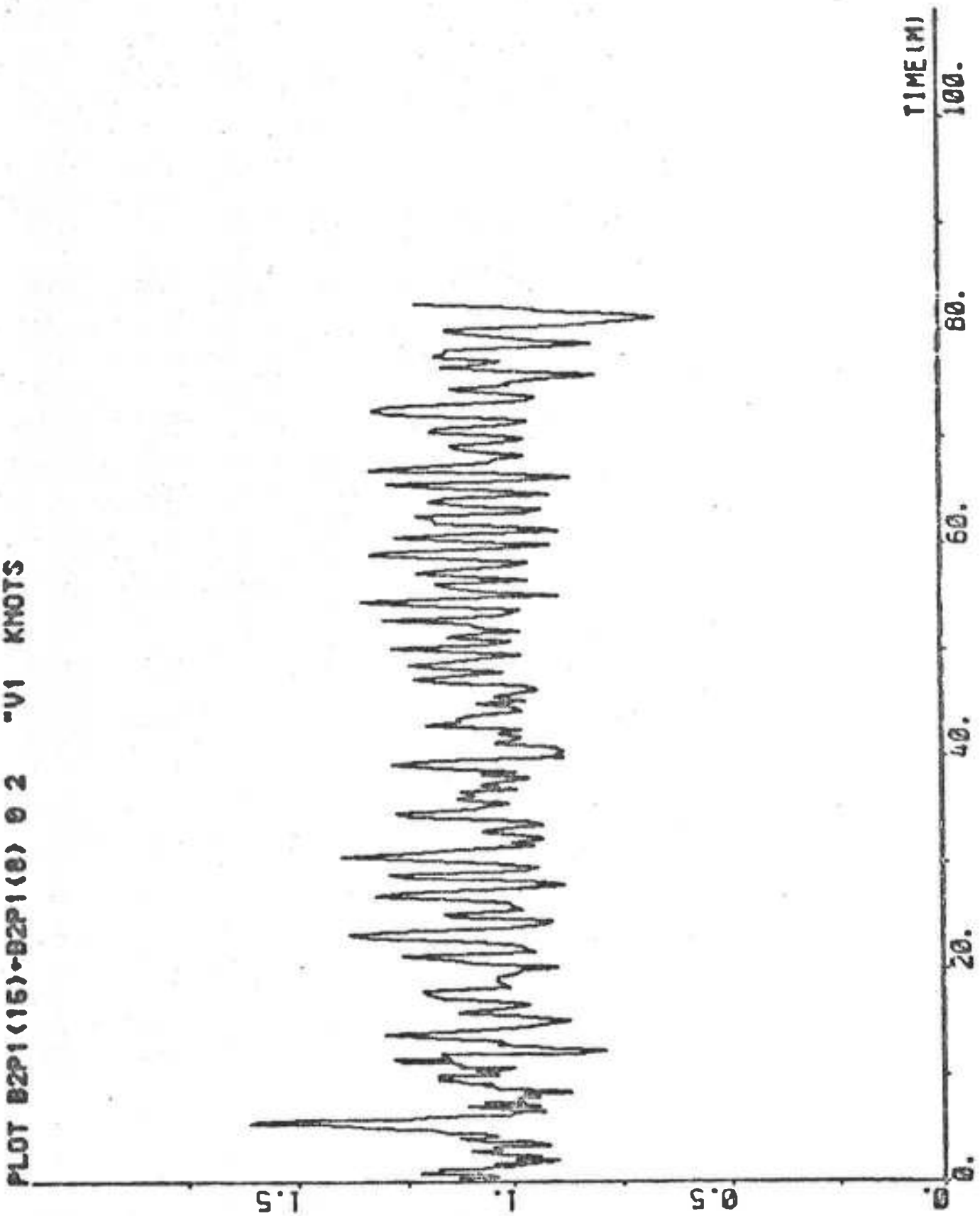

PLOT B2P1(16)-B2P1(3) ZERO -10 10 "DELTAS DEC
TIME(M)
100.
80.
60.
40.
20.
0.
5.
0.
-5.
-10.

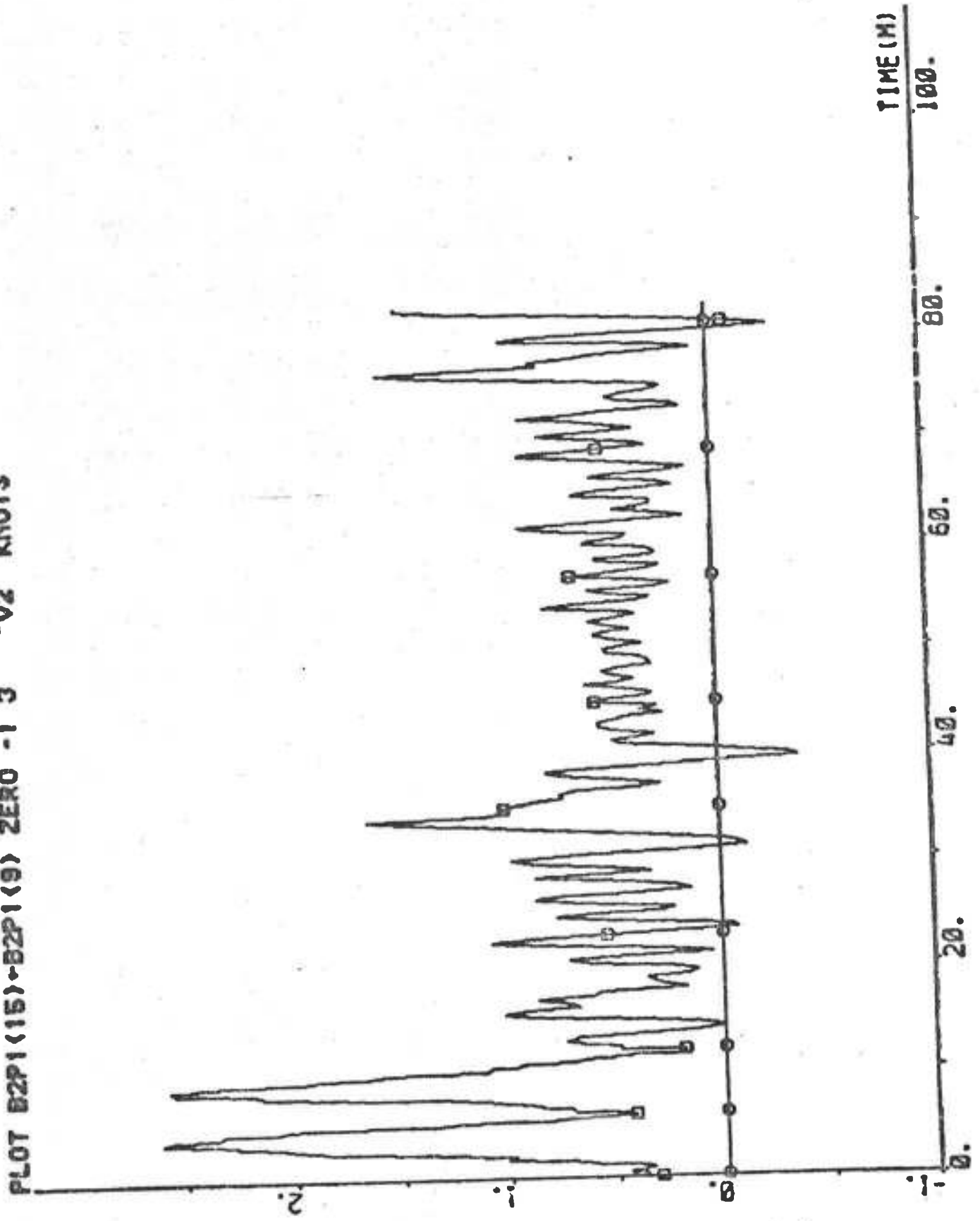

PLOT E2P1(15)-B2P1(4) ZERO -10 10 "DELTA DEG
TIME(M)
0.
20.
40.
60.
80.
100.
-10.
-5.
0.
5.

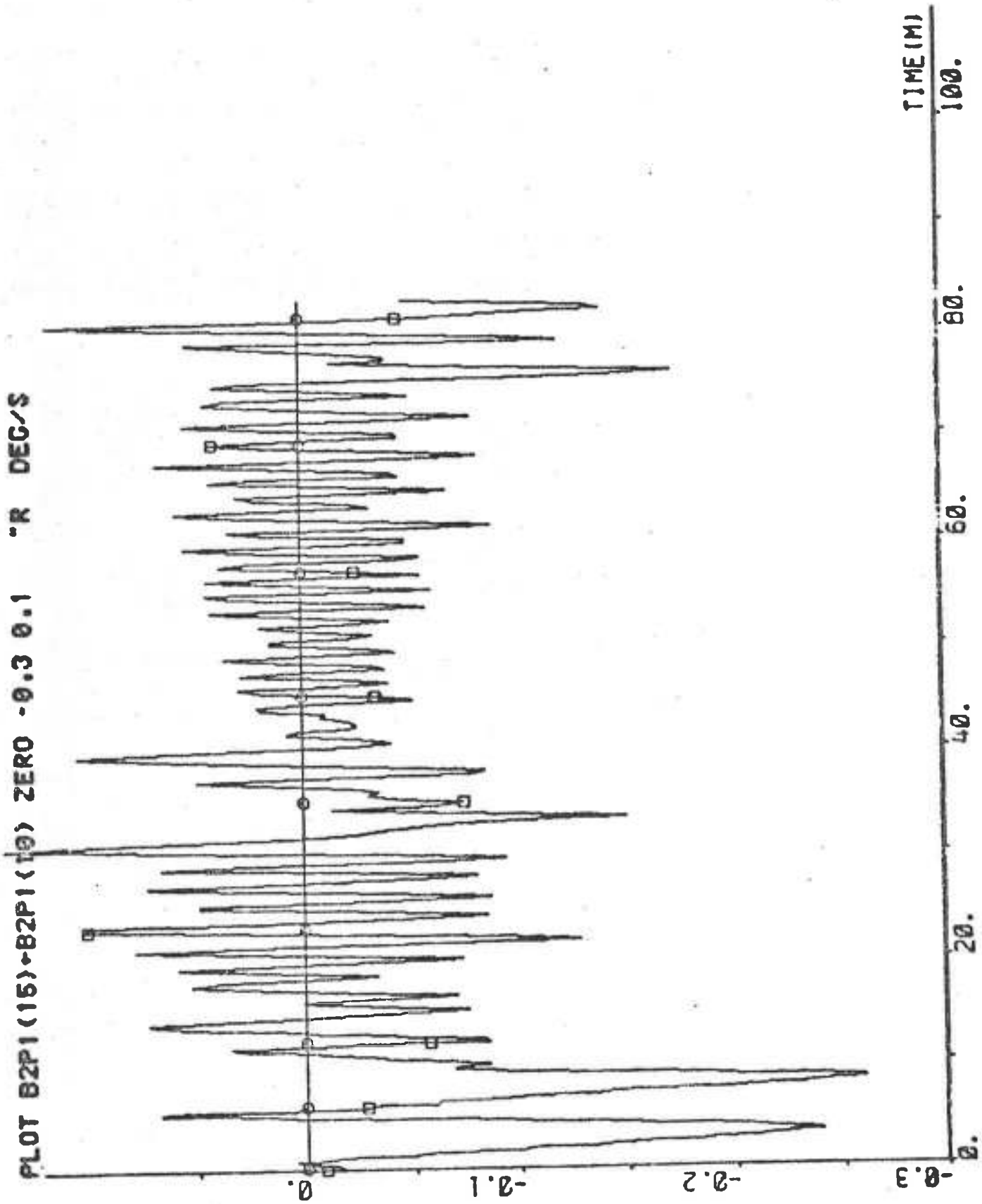

PLOT B2P1(15)-B2P1(6) ZERO -0.02 0 "PP DEG/S
-5.E-3
-0.01
-0.015
-0.02
0
20.
40.
60.
80.
100.
TIME(M)

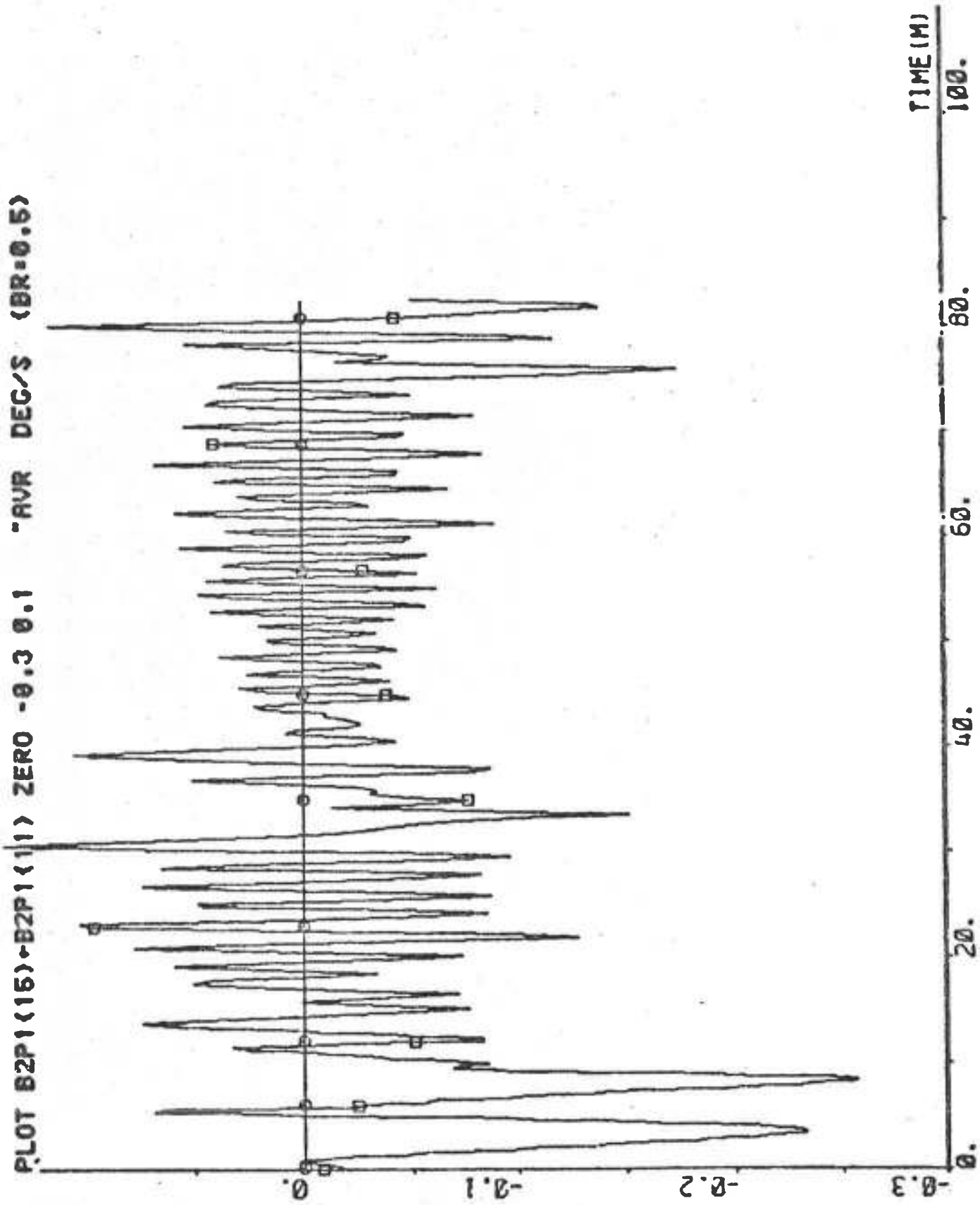

PLOT B2P1(15)-B2P1(6) 70 90 "AN RPM
70.
75.
80.
85.
0.
20.
40.
60.
80.
100.
TIME(MI

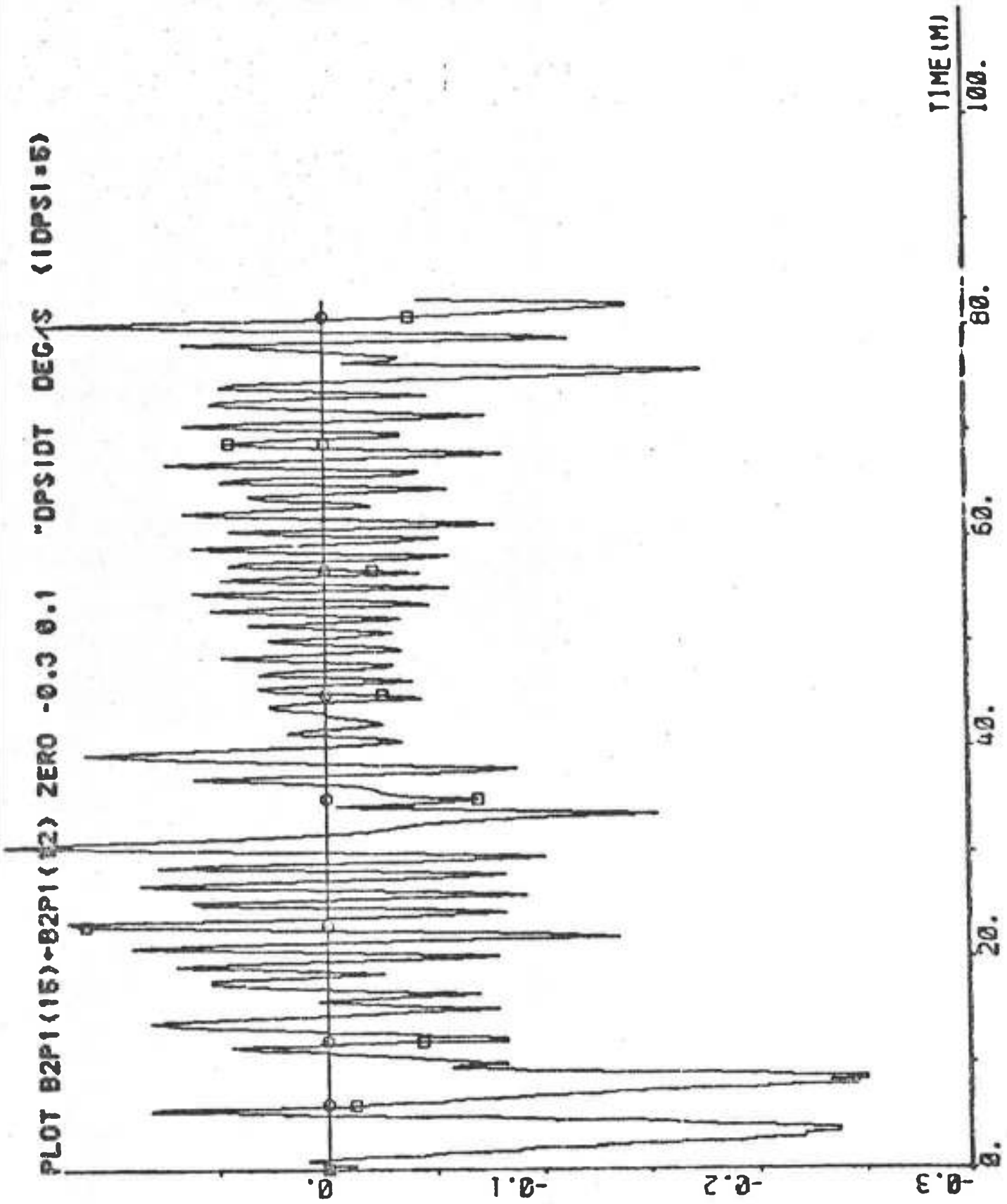

PLOT B2P1(15)-B2P1(7) 14 10 "U KNOTS
14.
15.
16.
17.
0.
20.
40.
60.
80.
100.
TIME(M)

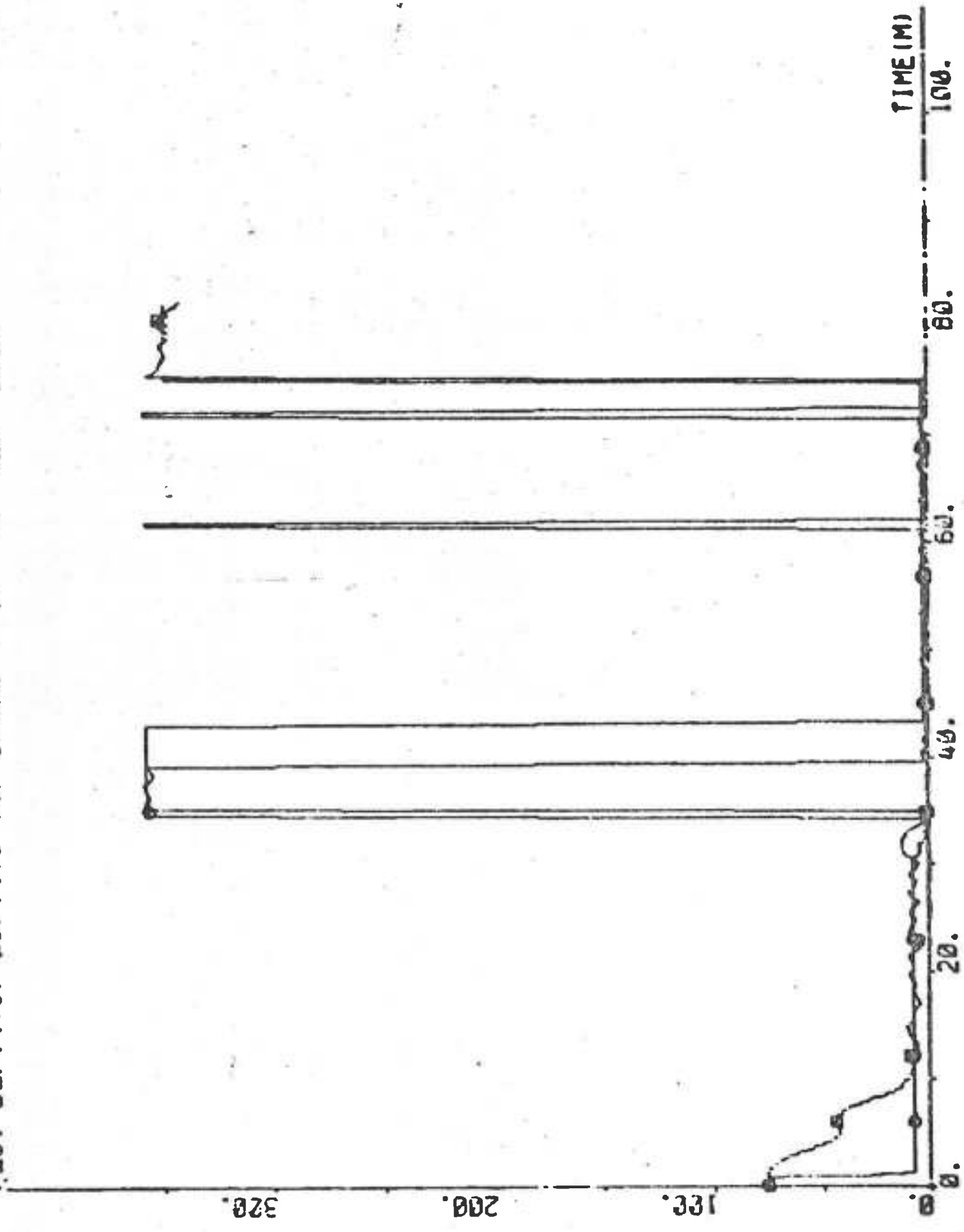

PLOT B2P1(15)-B2P1(0) 0 2 "V1 KNOTS
1.5
1.
0.5
0.
0.
20.
40.
60.
80.
100.
TIME(M)

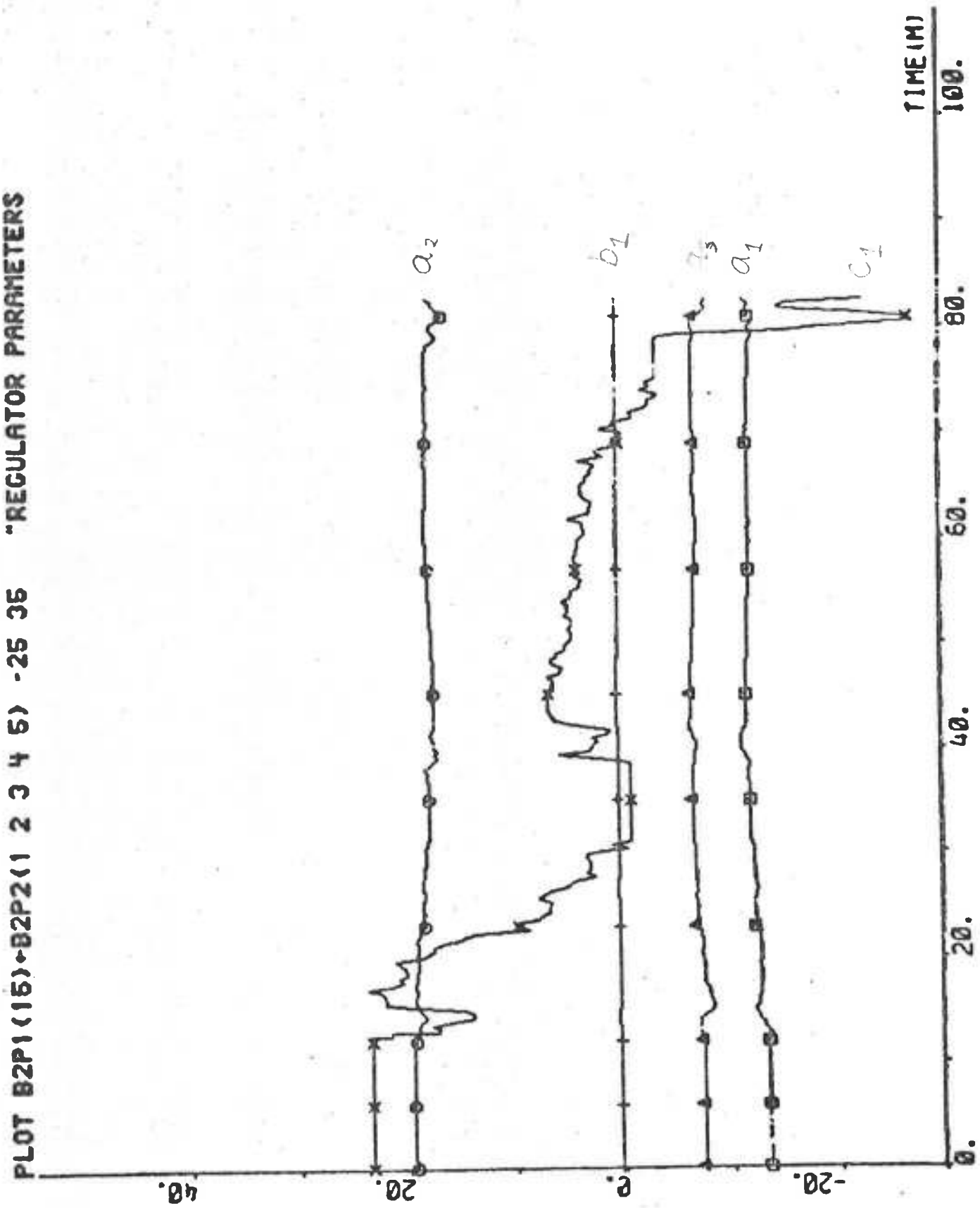

PLOT B2P1(15)-B2P1(9) ZERO -1 3 "V2 KNOTS
2.
1.
0
-1.
0.
20.
40.
60.
80.
100.
TIME(H)

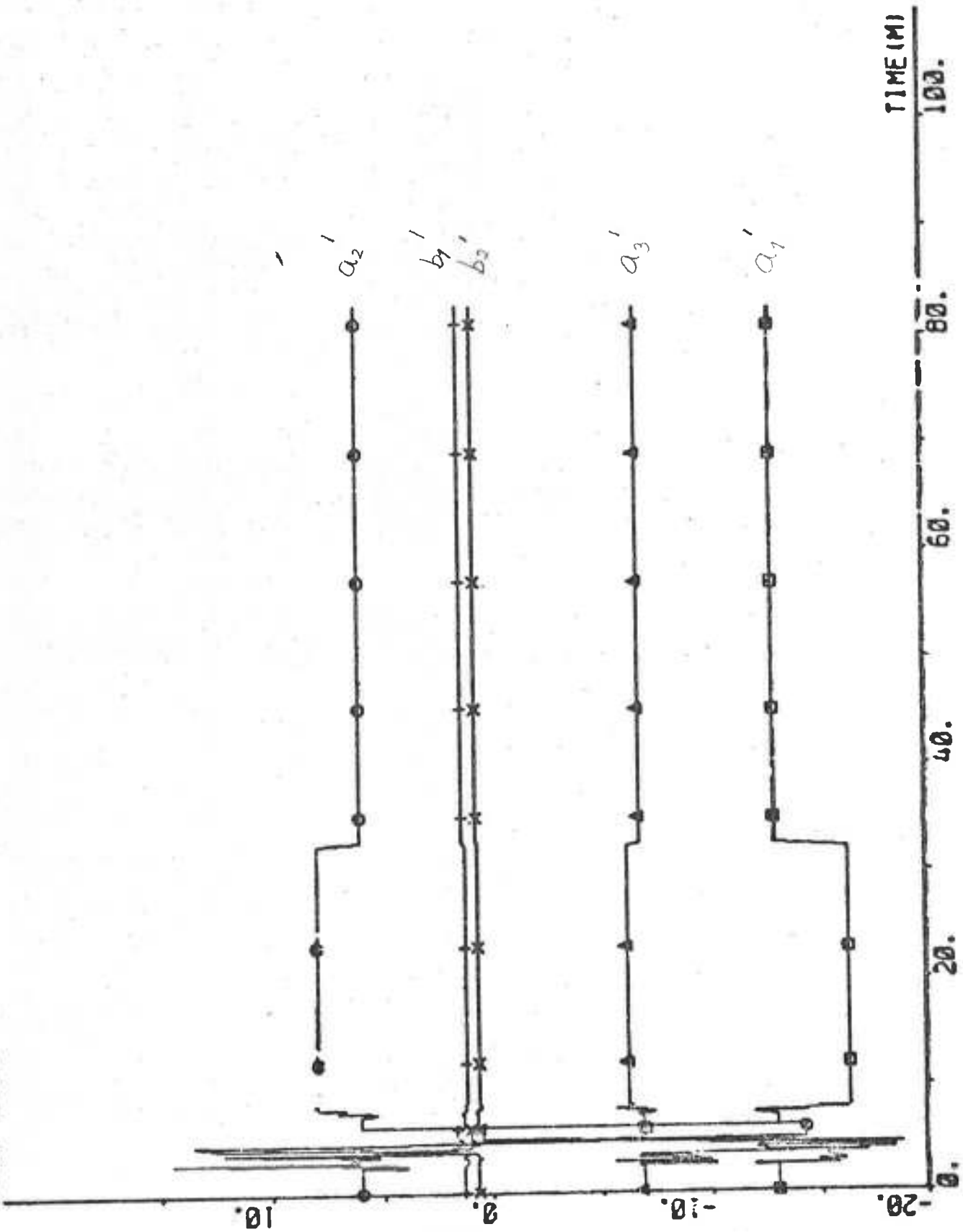

PLOT B2P1(15)-B2P1(10) ZERO -0.3 0.1 °R DEG/S
TIME(M)
0.
20.
40.
60.
80.
100.
0.
-0.1
-0.2
-0.3

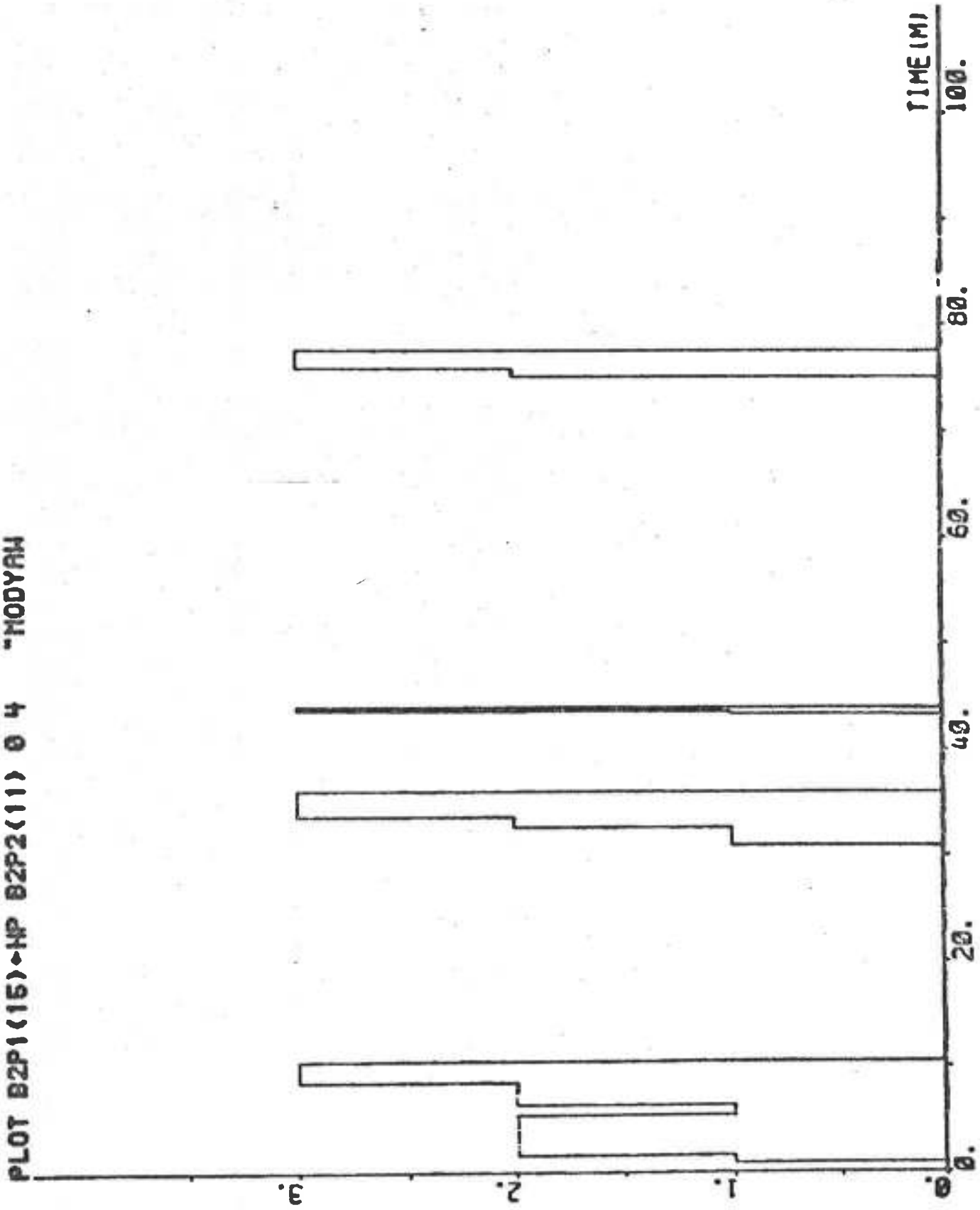

PLOT B2P1(15)-B2P1(11) ZERO -0.3 0.1 "AVR DEG/S (BR=0.5)
TIME(M)
0.
20.
40.
60.
80.
100.
0.
-0.1
-0.2
-0.3


PLOT B2P1(15)-B2P1(12) ZERO -0.3 0.1 "DPSIDT DEG/S (IDPSI=5)
TIME(M)
0.
20.
40.
60.
80.
100.
0.
-0.1
-0.2
-0.3


PLOT B2P1(15)+B2P1(13 14) 0 400 "PSI PSIREF DEG
TIME(M)
0.
20.
40.
60.
80.
100.
0.
132.
200.
320.


PLOT B2P1(15)*B2P2(1 2 3 4 5) -25 35 "REGULATOR PARAMETERS
40.
20.
0.
-20.
0.
20.
40.
60.
80.
100.
TIME(M)
a2
b1
a3
a1
c1


PLOT B2P1(15)-B2P2(6 7 8 9 10) -20 20 "YAW REGULATOR PARAMETERS
TIME(M)
0.
20.
40.
60.
80.
100.
10.
0.
-10.
-20.
a2'
b1'
b2'
a3'
a1'


PLOT B2P1(15)-HP B2P2(11) 0 4 "HODYAW
TIME(MI)
0.
20.
40.
60.
80.
100.
0.
1.
2.
3.

EXPERIMENT B3

Date	1974-10-10
Time	08.28
Duration	14 min
Position	N 29° 01' E 50° 29'
Water depth	40 m
Forward draught	20.1 m
Aft draught	20.4 m
Wind direction	SE (1; see Appendix A)
Wind velocity	1 Beaufort (1-1.5 m/s, light air)
Wave height	0.5 m
PSIREF	115°, 157°
RREF	0.14 deg/s
Rudder limit	±15°
DELlM at termination	Unknown
Approximate mean value of AN	64.5 rpm
Approximate mean value of U	9.2 knots

A program error caused the off-diagonal elements of the covariance matrix P for the straight course regulator parameters to be put zero instead of the off-diagonal elements of PY for the yaw regulator parameters, when phase 2 of the yaw regulator was initiated, which affected both the straight course keeping and the yawing.

Regulator structure

NA = 3	NB = 1	NC = 1	K = 4
IREG = 15	IRDIF = 0	RL = 0.98	IRR = 1

Final values

$$\begin{bmatrix} a_1 \\ a_2 \\ a_3 \\ b_1 \\ c_1 \end{bmatrix} = \begin{bmatrix} -14.891 \\ 20.054 \\ -4.410 \\ 0.705 \\ 7.180 \end{bmatrix} \qquad P = \begin{bmatrix} 0.579 & & & & \\ -0.744 & 1.352 & & & \\ 0.139 & -0.672 & 0.734 & & \\ -0.019 & 0.005 & 0.022 & 0.010 & \\ 4.765 & -3.157 & -2.480 & 0.014 & 98.402 \end{bmatrix}$$

$a_1 + a_2 + a_3 = 0.753$

Yaw regulator structure

NAY = 3	NBY = 2	KY = 5
IREGY = 10	RLY = 0.95	IRR = 1
AK1V = 40	AK2V = 1.4	AK3V = 115
C1V = 30	C2V = 60	
EPS1V = 0.02	EPS2V = 0.03	
PSISV = 0.4	PSISSV = 1.5	PSIMAV = 0.6
I1MV = 100	I2MV = 300	I3MV = 120

Initial yaw regulator values

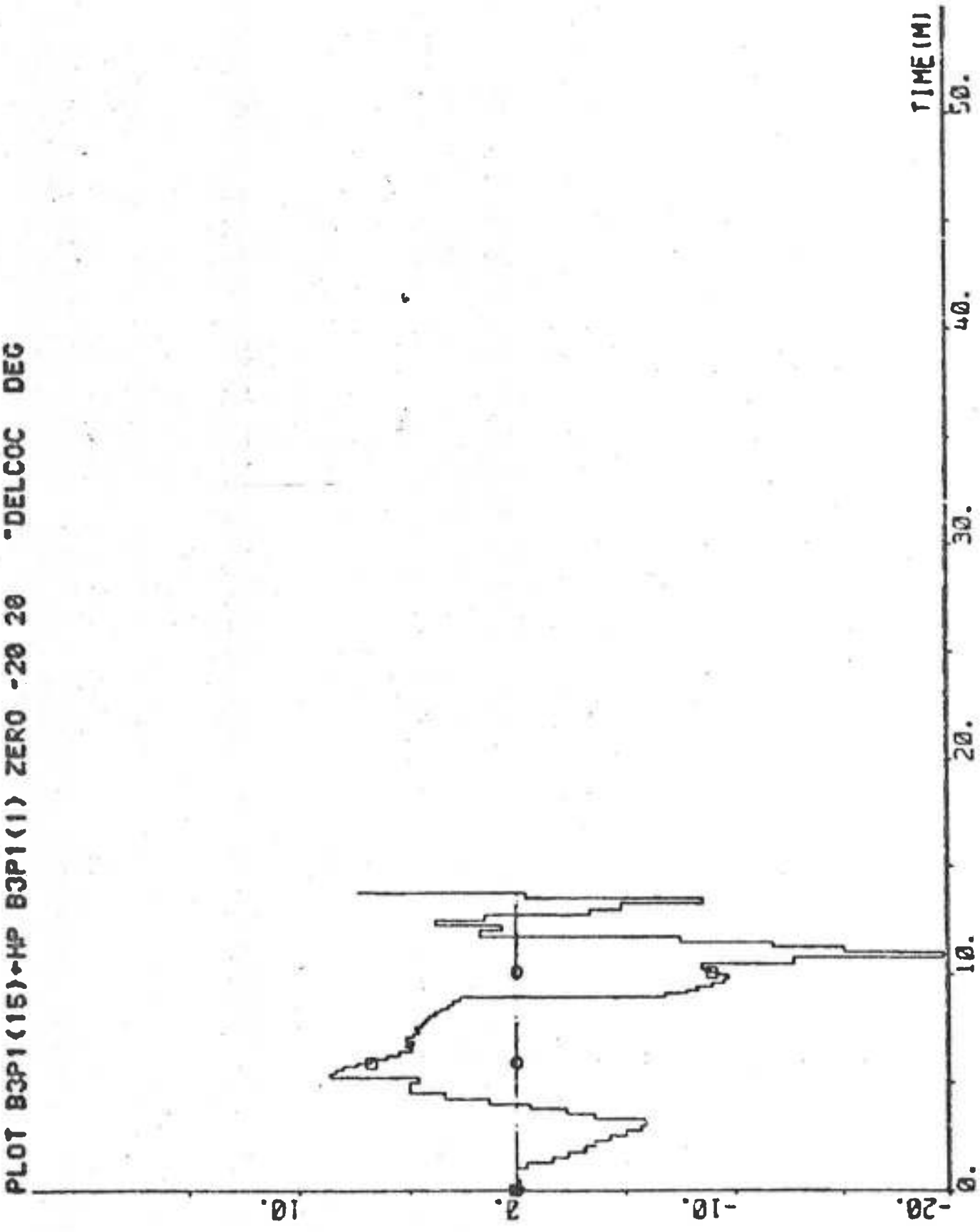
$$\begin{bmatrix} a'_1 \\ a'_2 \\ a'_3 \\ b'_1 \\ b'_2 \end{bmatrix} = \begin{bmatrix} -12.90 \\ 6.02 \\ -6.87 \\ 1.30 \\ 0.649 \end{bmatrix} \qquad PY = \begin{bmatrix} 1000 & & & & \\ 0 & 1000 & & & \\ 0 & 0 & 1000 & & \\ 0 & 0 & 0 & 10 & \\ 0 & 0 & 0 & 0 & 10 \end{bmatrix}$$

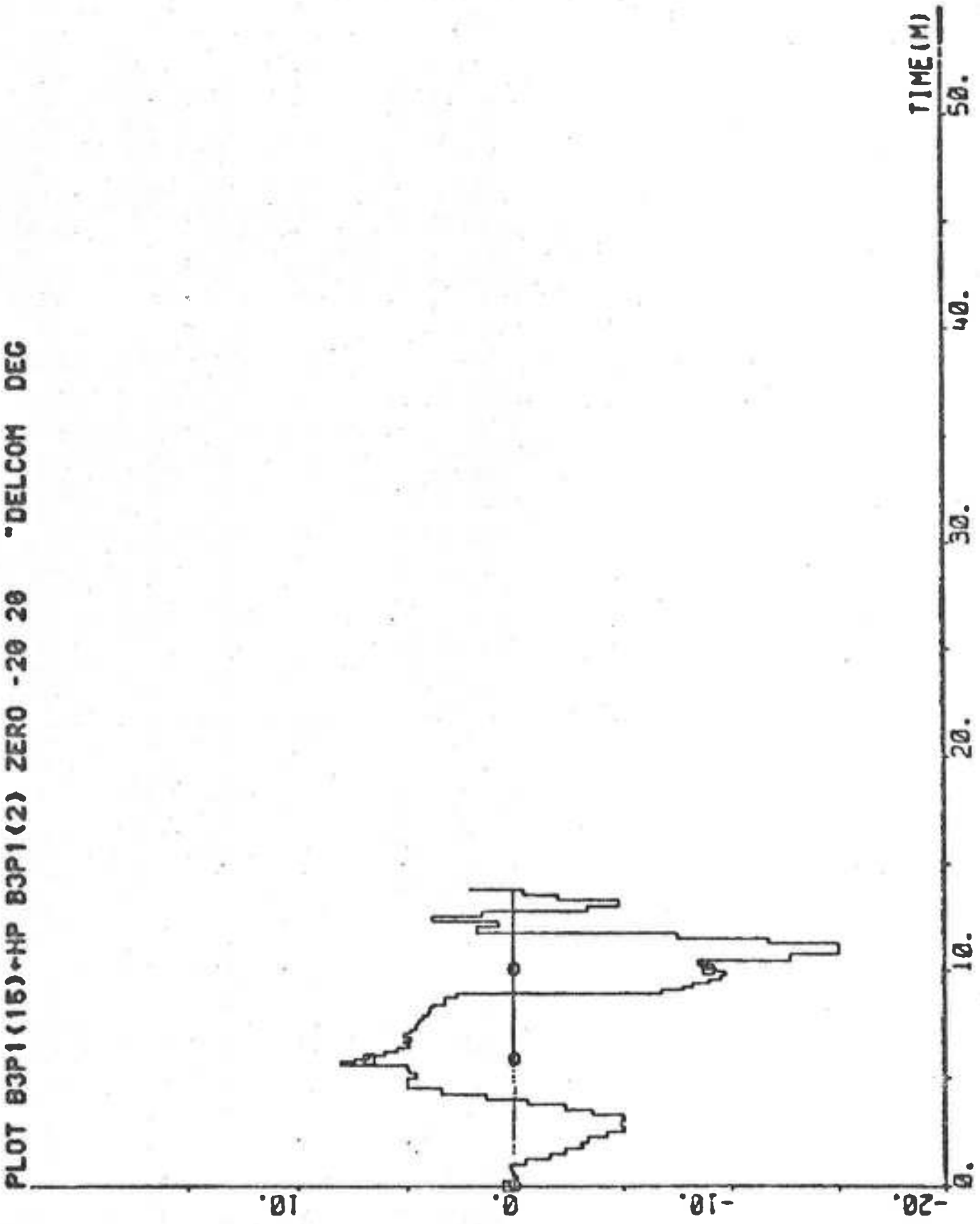
$a'_1 + a'_2 + a'_3 = -13.75$

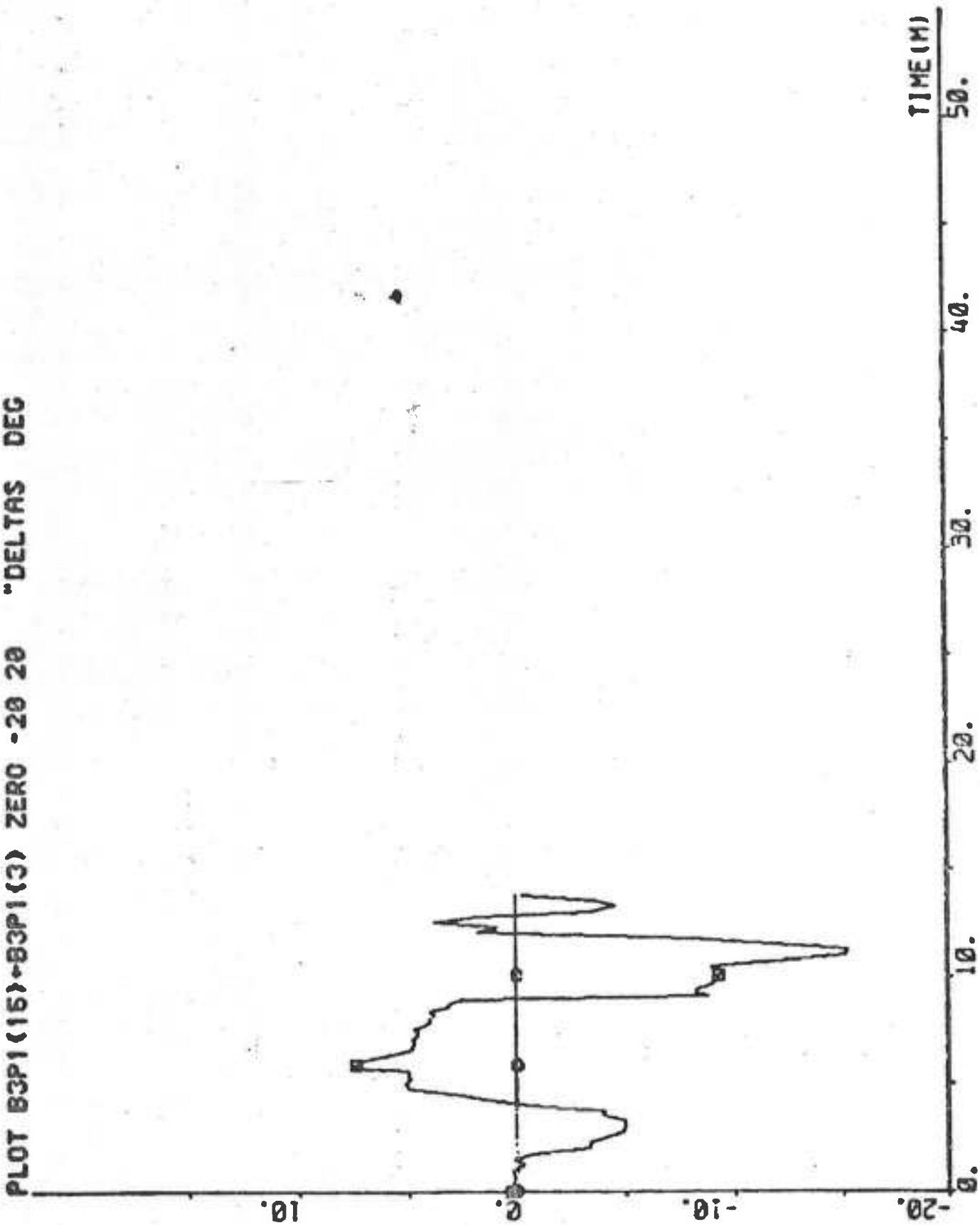
Final yaw regulator values

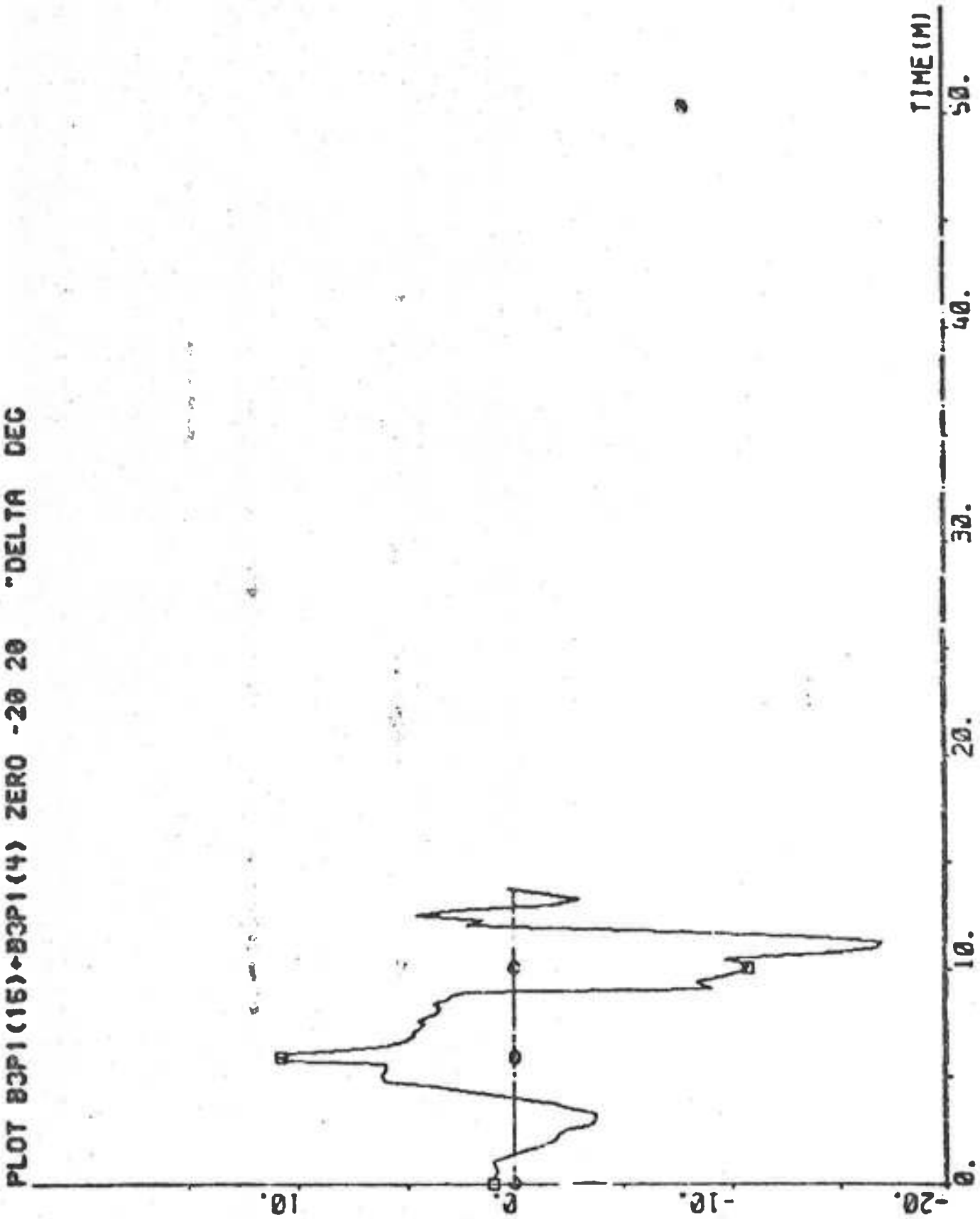
$$\begin{bmatrix} a_1' \\ a_2' \\ a_3' \\ b_1' \\ b_2' \end{bmatrix} = \begin{bmatrix} -14.088 \\ 6.178 \\ -5.834 \\ 1.324 \\ 0.652 \end{bmatrix} \qquad PY = \begin{bmatrix} 671.445 & & & & \\ -498.822 & 1257.655 & & & \\ -139.348 & -456.727 & 1038.426 & & \\ -17.265 & -28.618 & 1.036 & 6.997 & \\ -12.495 & -23.926 & -5.841 & 4.515 & 7.122 \end{bmatrix}$$

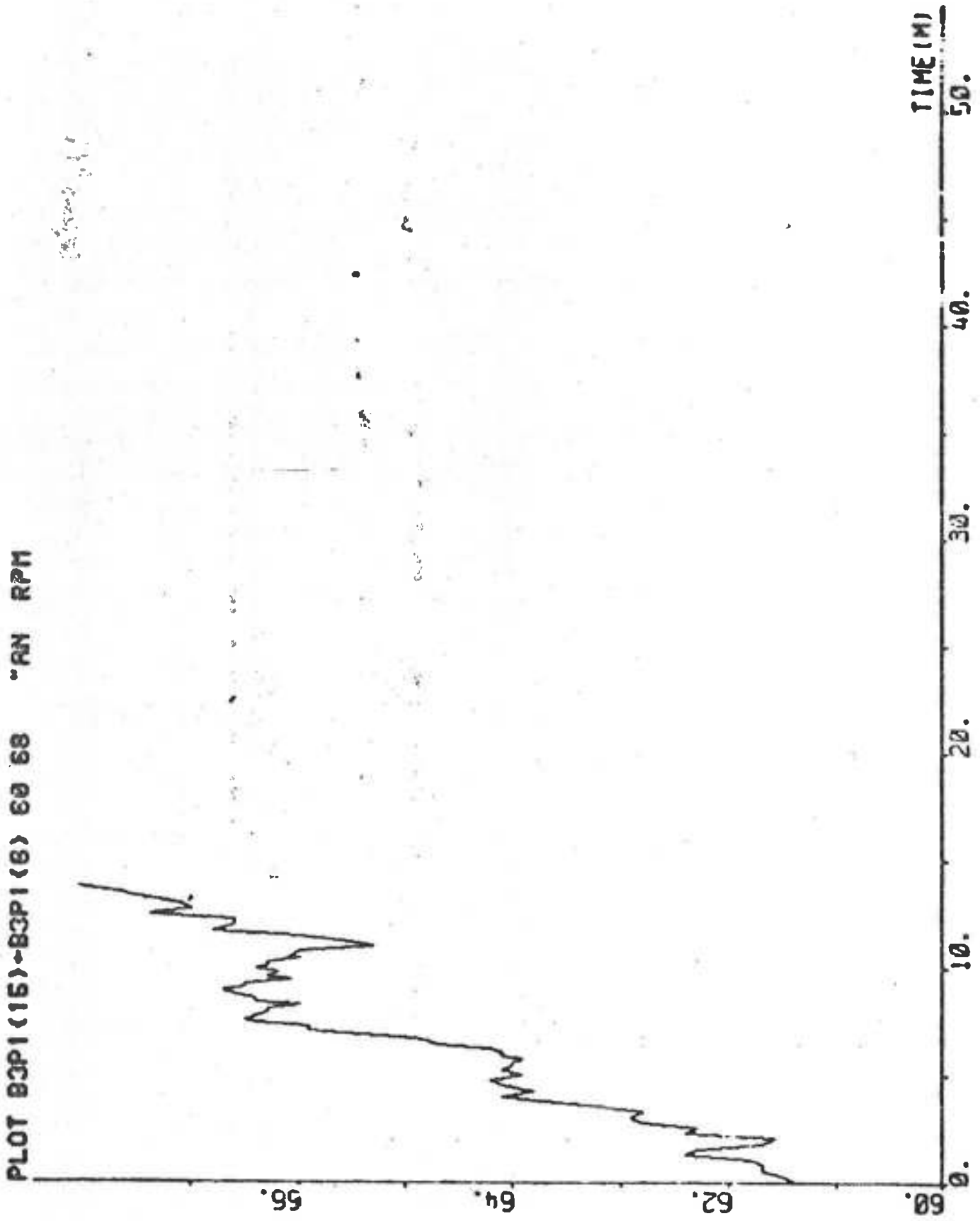
$a_1' + a_2' + a_3' = -13.744$

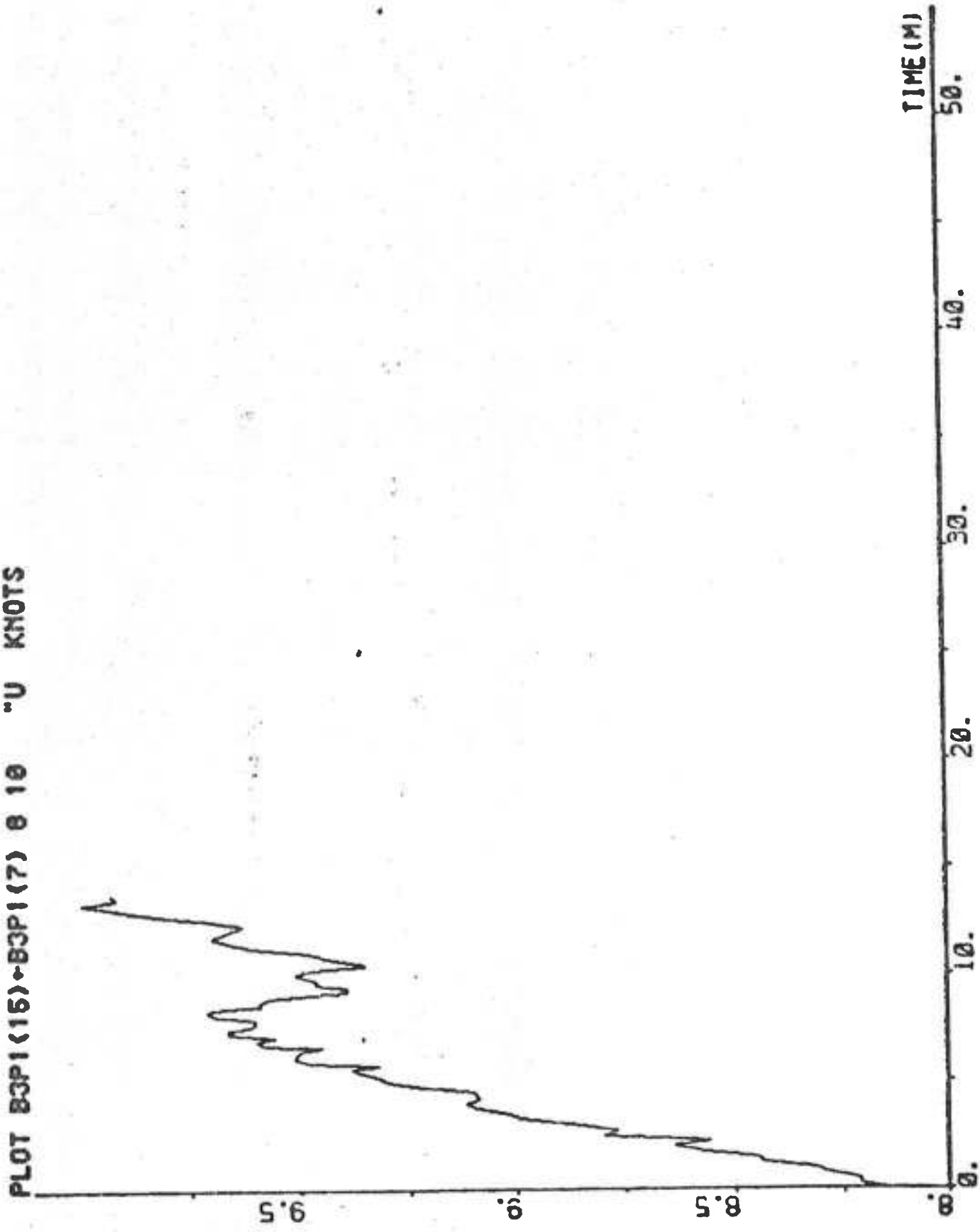

PLOT B3P1(15)-HP B3P1(1) ZERO -20 20 "DELCOC DEG
TIME(MI)
0.
10.
20.
30.
40.
50.
-20.
-10.
0.
10.

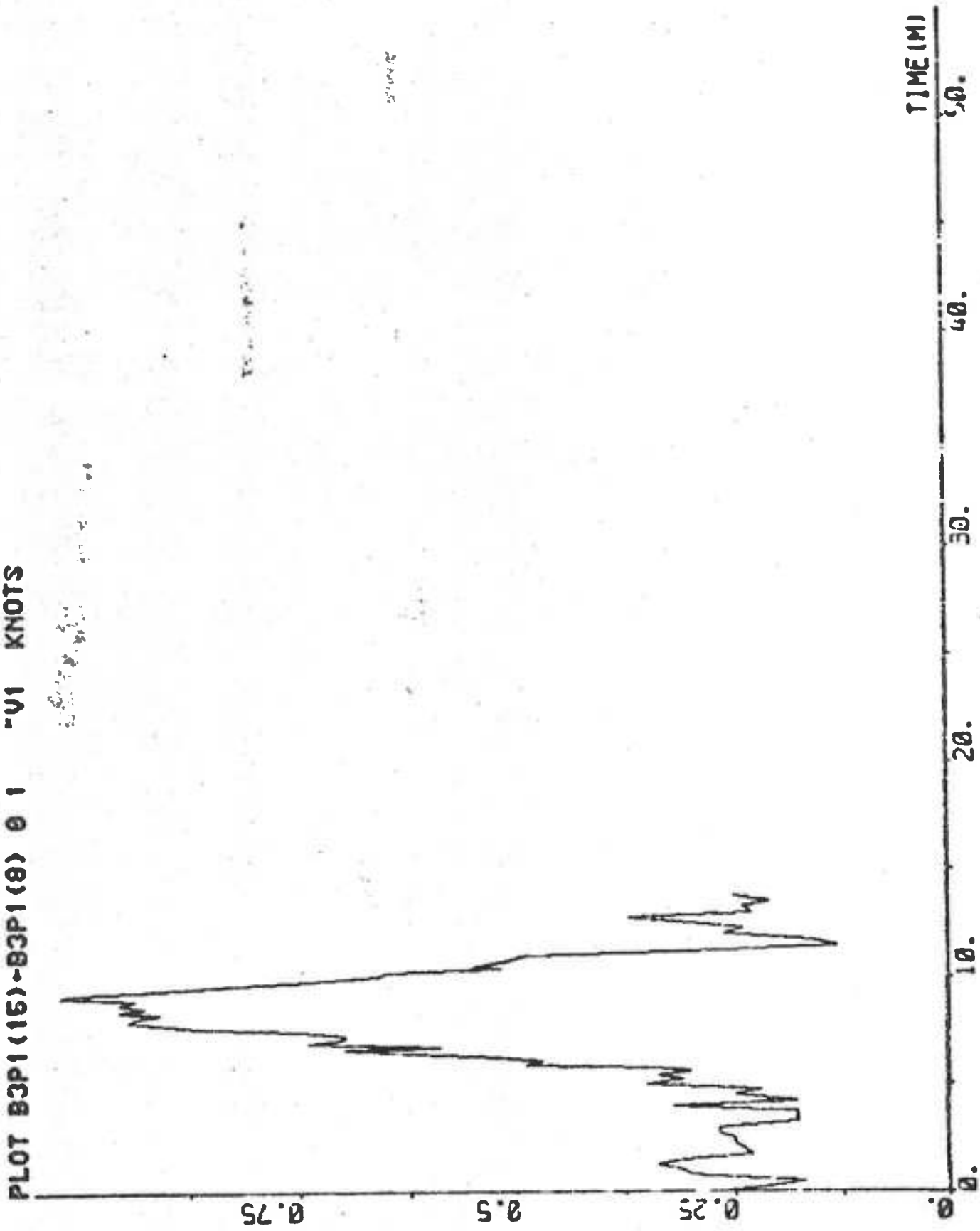

PLOT B3P1(15)-HP B3P1(2) ZERO -20 20 "DELCOM DEG
10.
0.
-10.
-20.
0.
10.
20.
30.
40.
50.
TIME(M)

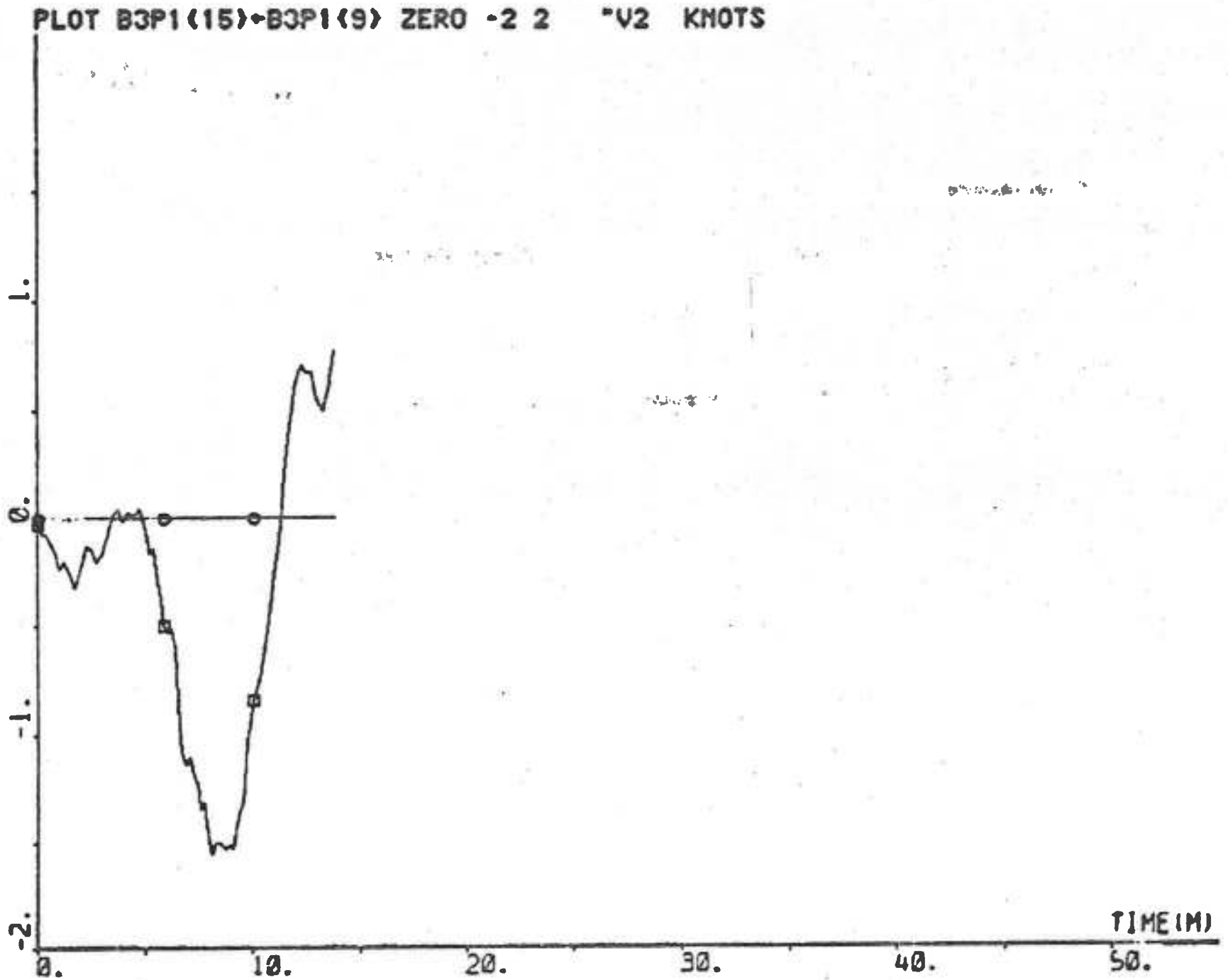

PLOT B3P1(15)-B3P1(3) ZERO -20 20 "DELTAS DEG
10.
0.
-10.
-20.
0.
10.
20.
30.
40.
50.
TIME(M)

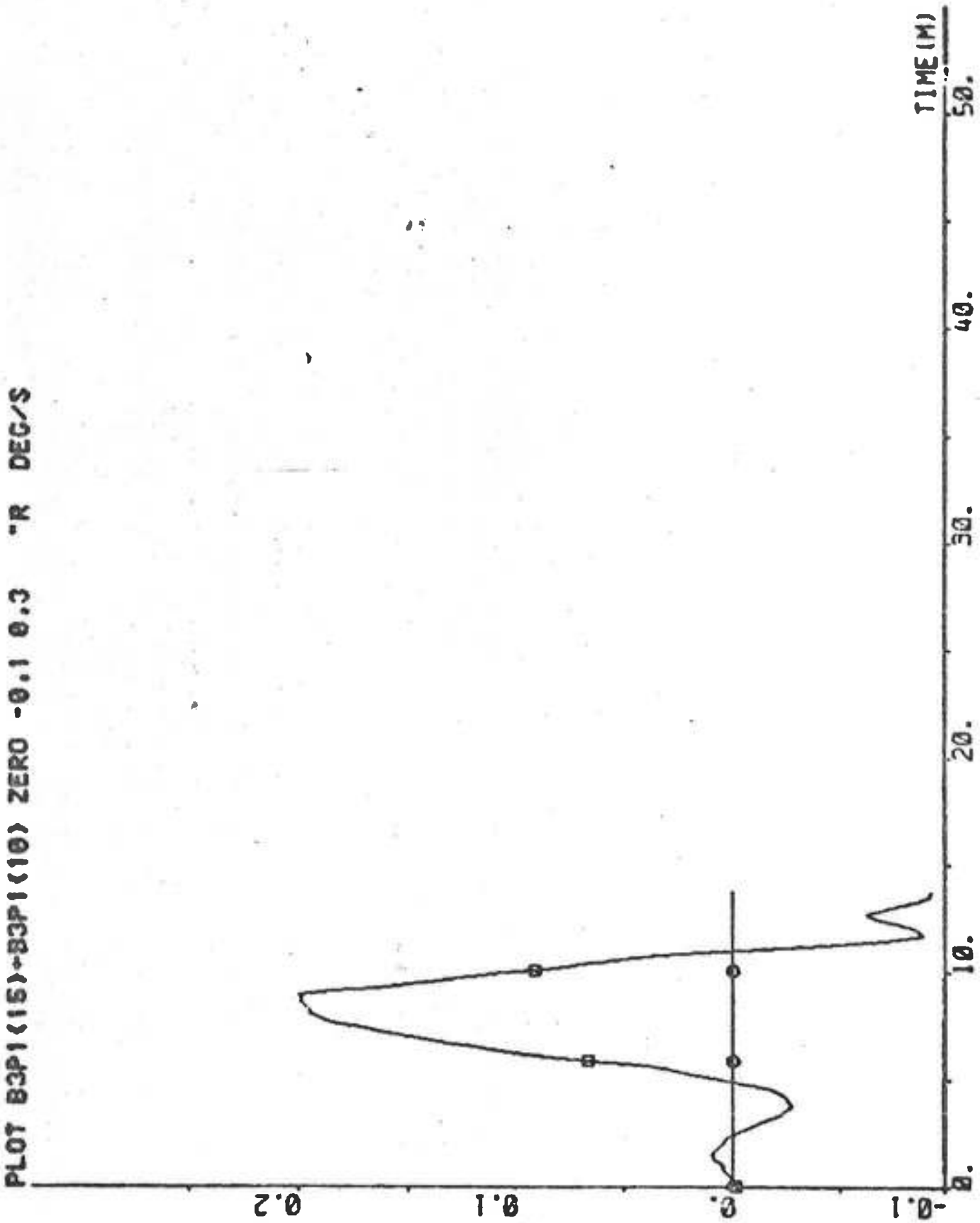

PLOT B3P1(16)-B3P1(4) ZERO -20 20 "DELTA DEG
10.
0.
-10.
-20.
0.
10.
20.
30.
40.
50.
TIME(M)

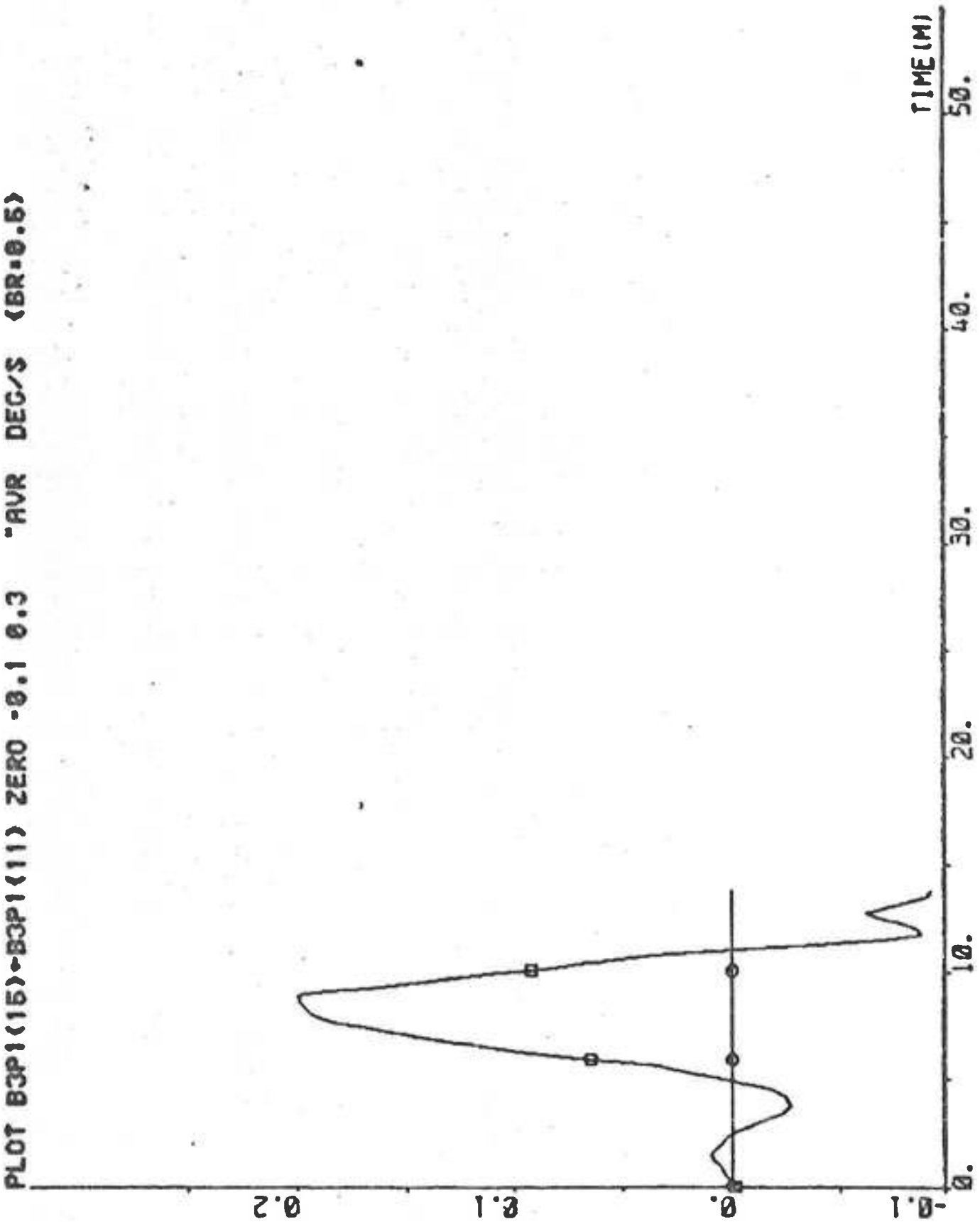

PLOT B3P1(15)-B3P1(8) 60 68 "AN RPM
60.
62.
64.
66.
0.
10.
20.
30.
40.
50.
TIME(M)

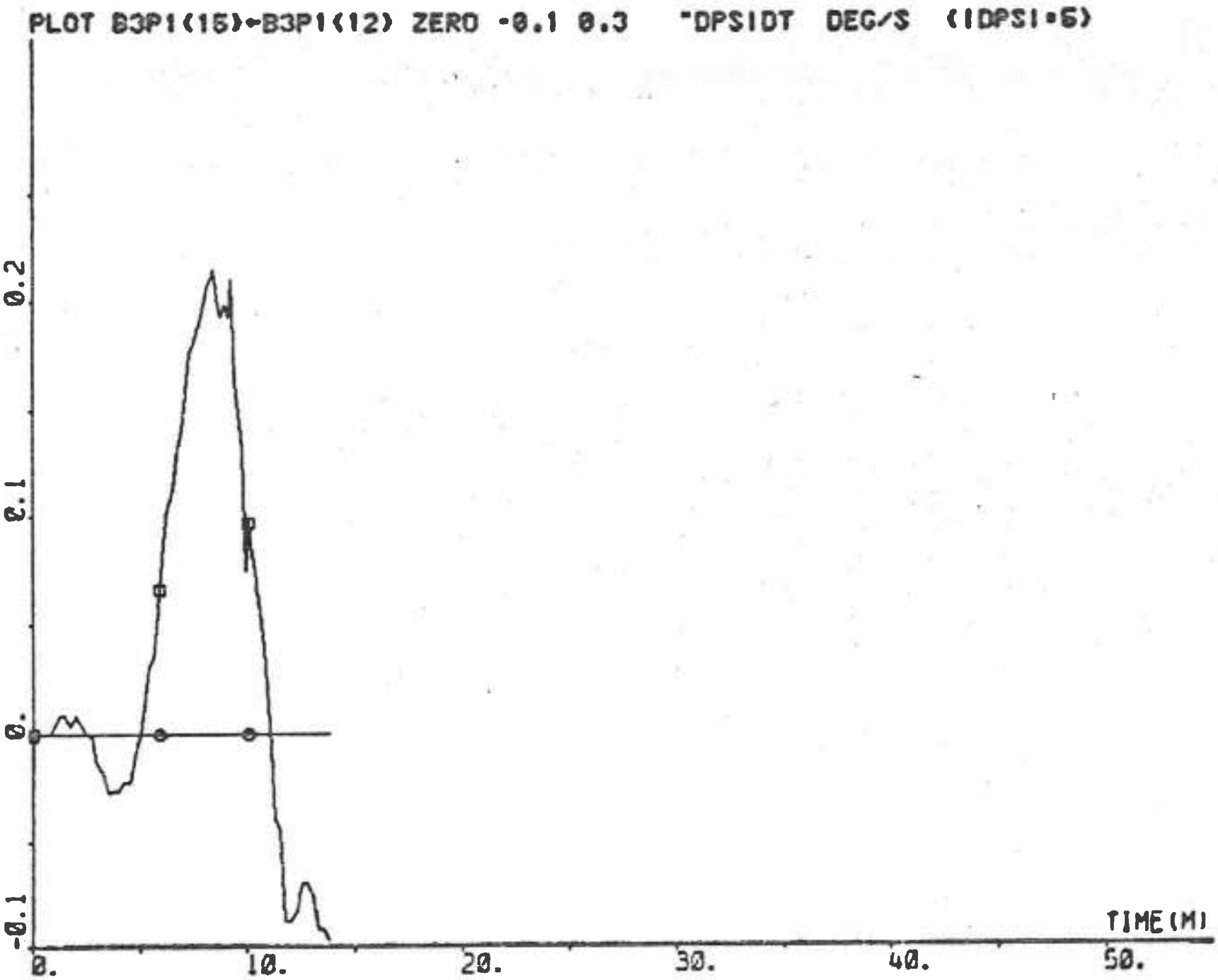

PLOT B3P1(15)-B3P1(7) 0 10 "U KNOTS
9.5
9.
8.5
0.
0.
10.
20.
30.
40.
50.
TIME(M)

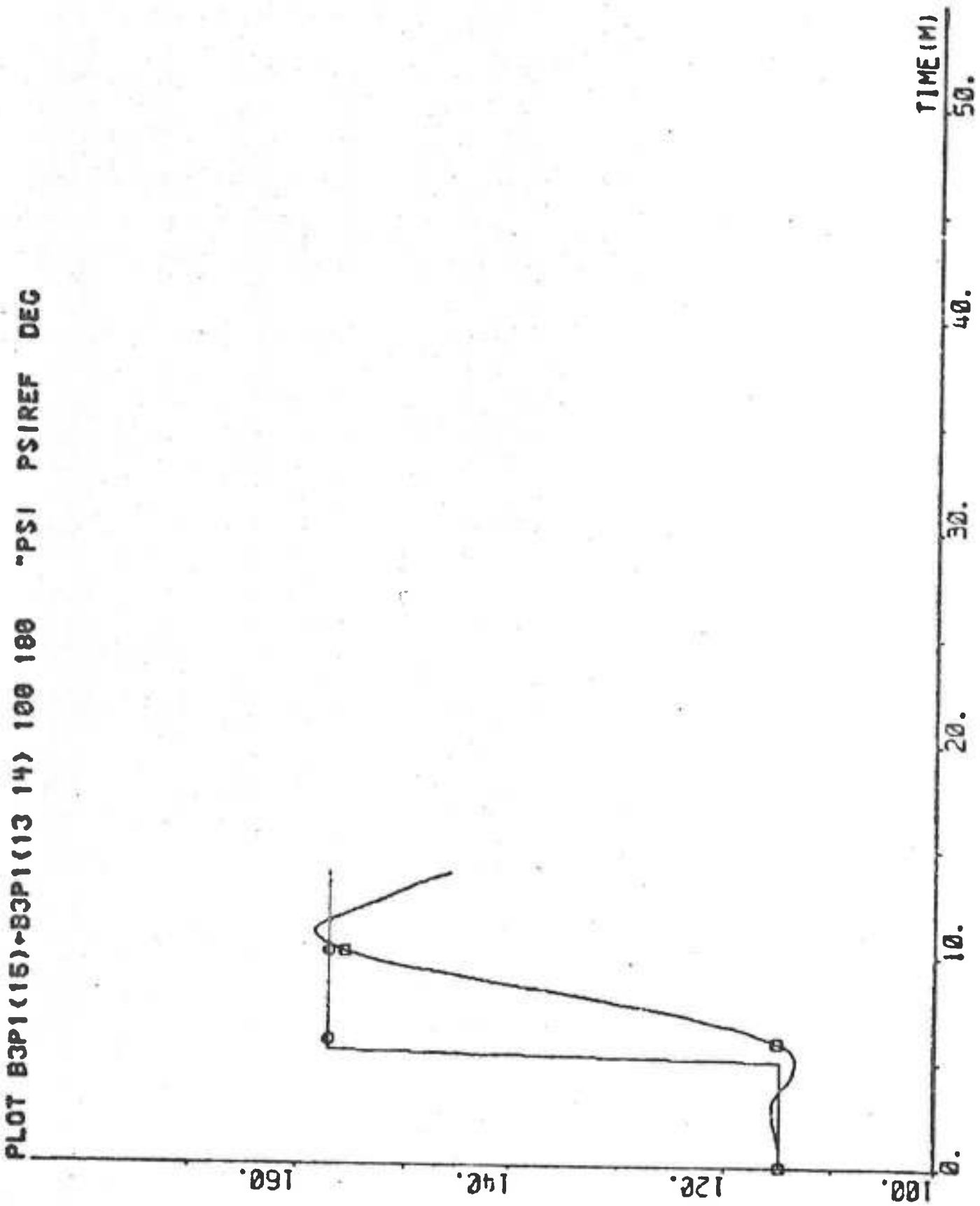

PLOT B3P1(16)-B3P1(8) 0 1 "V1 KNOTS
0.75
0.5
0.25
0.
0.
10.
20.
30.
40.
50.
TIME(M)

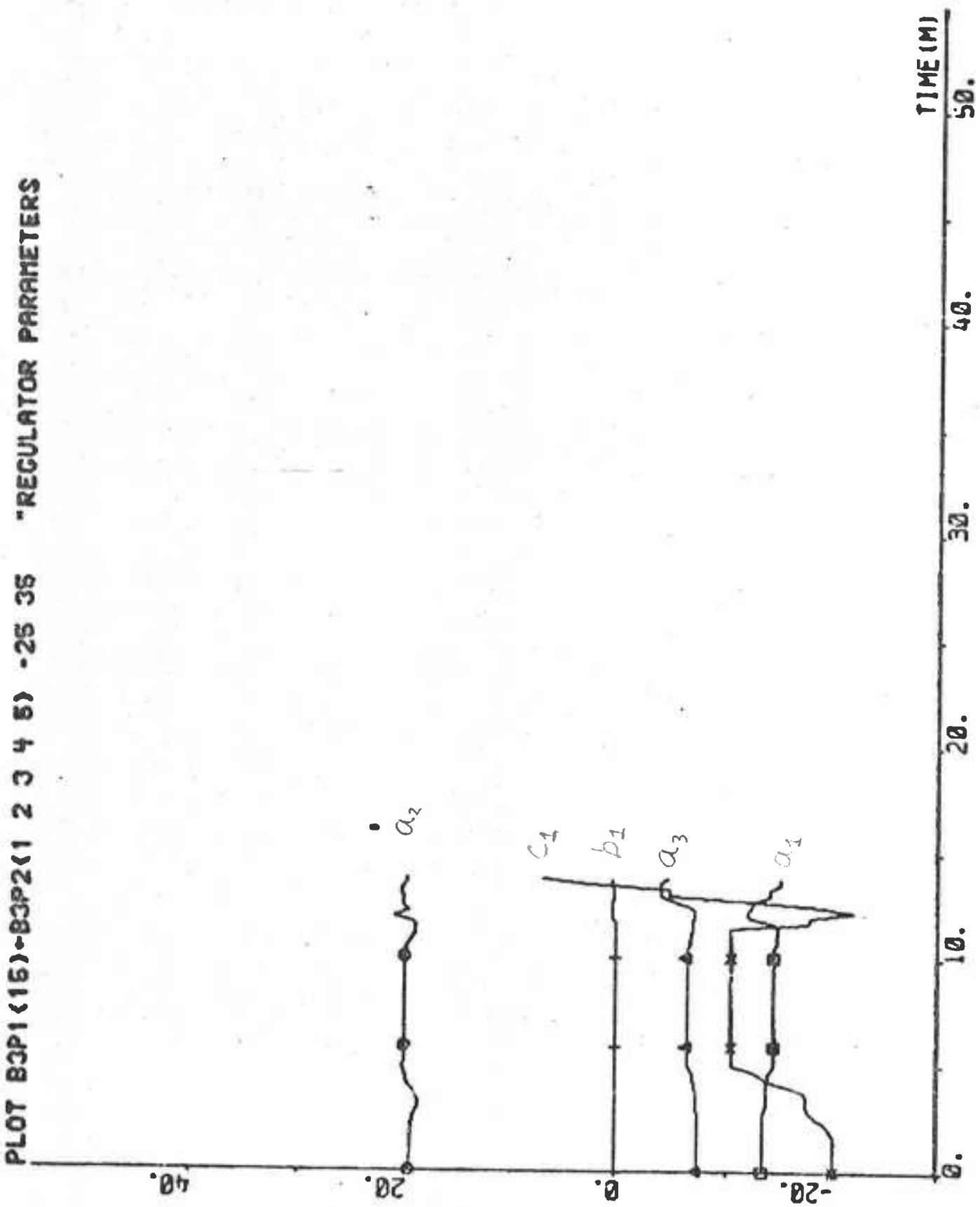

PLOT B3P1(15)-B3P1(9) ZERO -2 2 "V2 KNOTS
1.
0.
-1.
-2.
0.
10.
20.
30.
40.
50.
TIME(M)

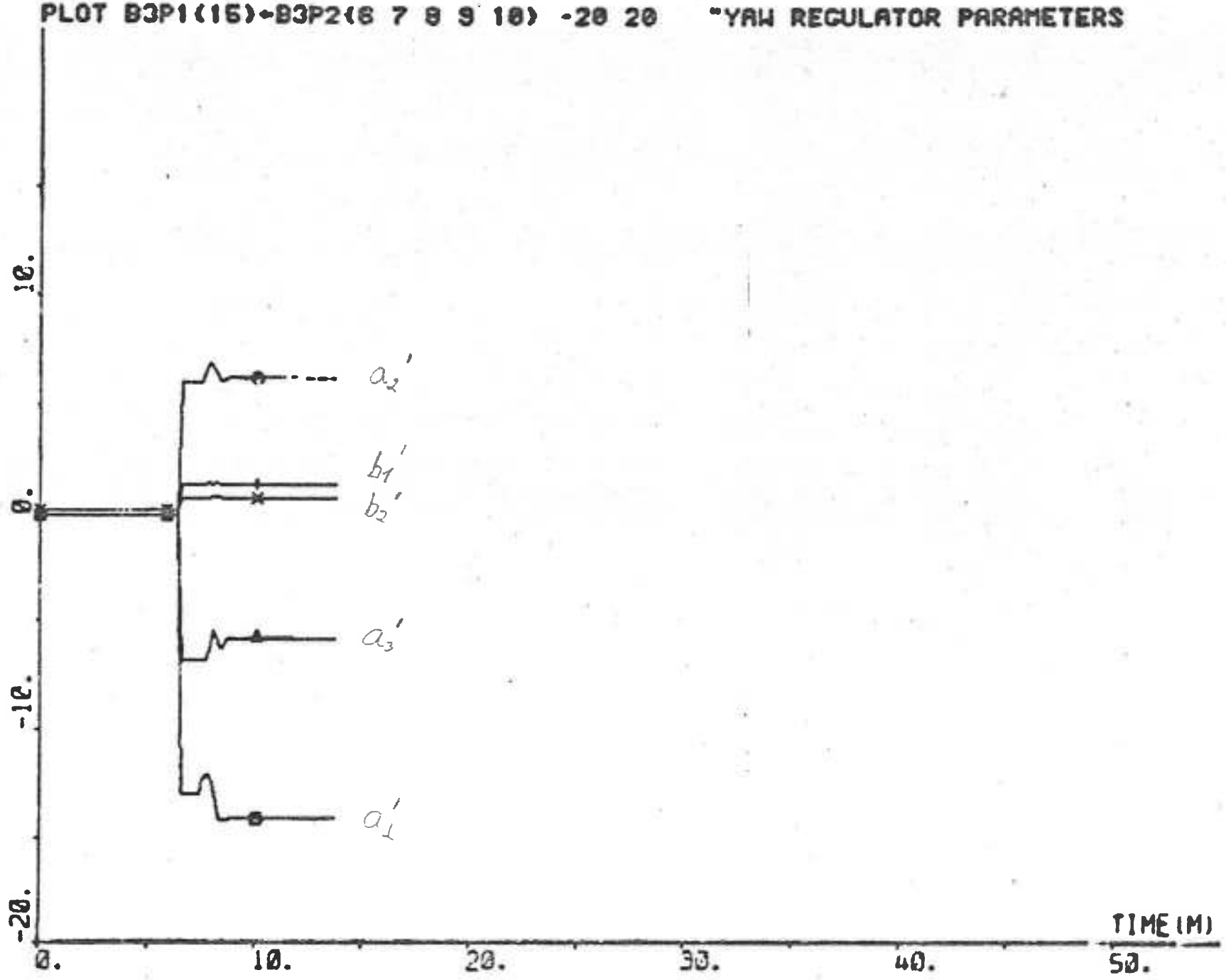

PLOT B3P1(15)-B3P1(10) ZERO -0.1 0.3 °R DEG/S
TIME(M)
0.
10.
20.
30.
40.
50.
-0.1
0.
0.1
0.2

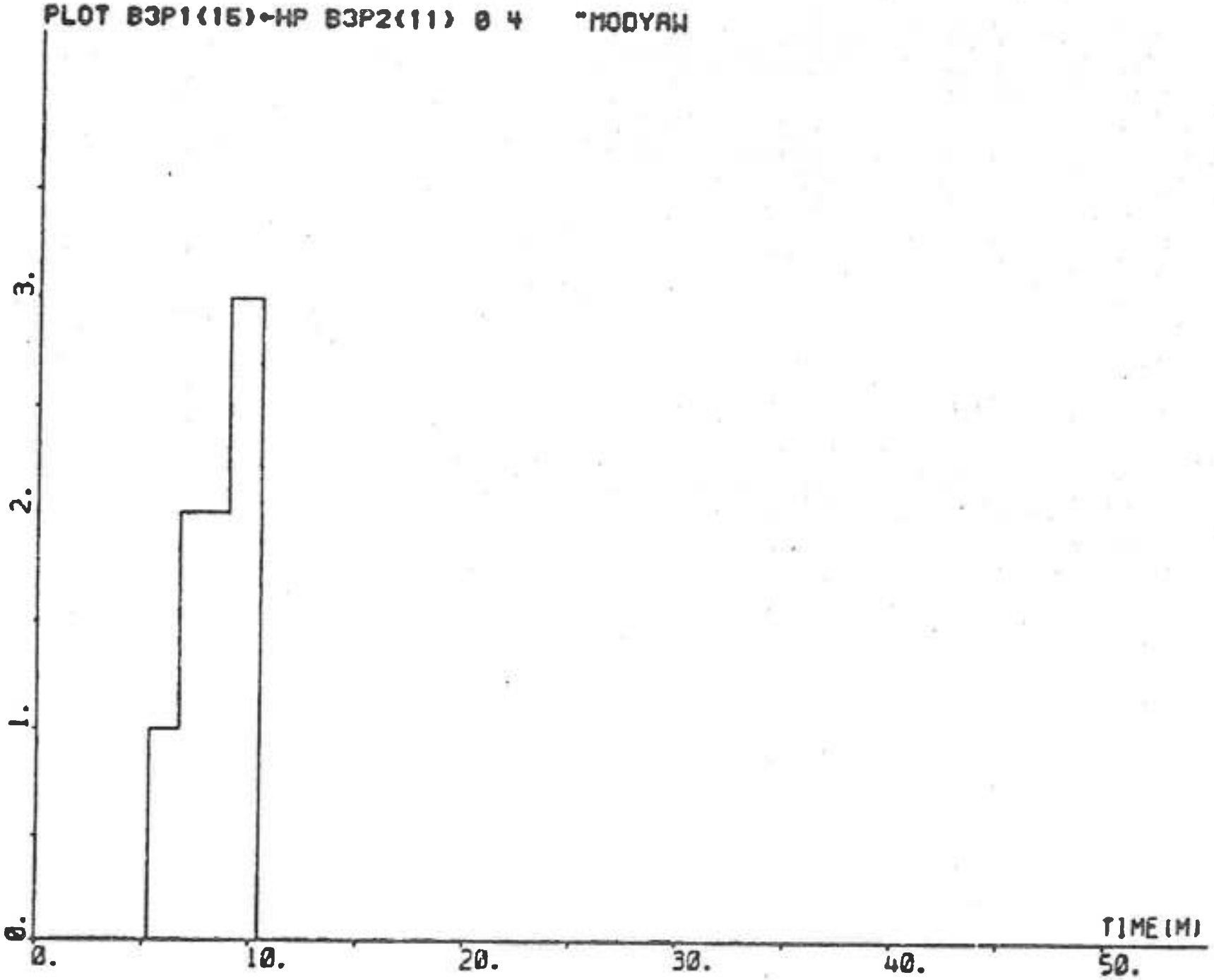

PLOT B3P1(15)-B3P1(11) ZERO -0.1 0.3 'AVR DEG/S (BR=0.5)
-0.1
0.
0.1
0.2
0.
10.
20.
30.
40.
50.
TIME(M)


PLOT B3P1(15)-B3P1(12) ZERO -0.1 0.3 "DPSIDT DEG/S (IDPSI*6)
0.2
0.1
0.
-0.1
0.
10.
20.
30.
40.
50.
TIME(M)


PLOT B3P1(15)-B3P1(13 14) 100 180 "PSI PSIREF DEG
100.
120.
140.
160.
0.
10.
20.
30.
40.
50.
TIME(M)


PLOT B3P1(16)-B3P2(1 2 3 4 5) -25 35 "REGULATOR PARAMETERS
40.
20.
0.
-20.
0.
10.
20.
30.
40.
50.
TIME(M)
a_2
c_1
b_1
a_3
a_1


PLOT B3P1(15)-B3P2(6 7 8 9 10) -20 20 "YAW REGULATOR PARAMETERS
10.
0.
-10.
-20.
a_2'
b_1'
b_2'
a_3'
a_1'
TIME (M)
0.
10.
20.
30.
40.
50.


PLOT B3P1(15)-HP B3P2(11) 0 4 "MODYAW
3.
2.
1.
0.
TIME(M)
0.
10.
20.
30.
40.
50.

EXPERIMENT B4

Date	1974-10-10
Time	19.23
Duration	31 min
Position	N 27° 38' E 51° 09'
Water depth	70 m
Forward draught	20.1 m
Aft draught	20.4 m
Wind direction	S (2; see Appendix A)
Wind velocity	1 Beaufort (1-1.5 m/s, light air)
Wave height	0.5 m
PSIREF	157°, 119°
RREF	0.07 deg/s
Rudder limit	Not active
DELlM at termination	0.10°
Approximate mean value of AN	82.0 rpm
Approximate mean value of U	14.9 knots

A program error caused the off-diagonal elements of the covariance matrix P for the straight course regulator parameters to be put zero instead of the off-diagonal elements of PY for the yaw regulator parameters, when phase 2 of the yaw regulator was initiated, which affected both the straight course keeping and the yawing.

Regulator structure

NA = 3	NB = 1	NC = 1	K = 4
IREG = 15	IRDIF = 0	RL = 0.98	IRR = 1

Final values

$$\begin{bmatrix} a_1 \\ a_2 \\ a_3 \\ b_1 \\ c_1 \end{bmatrix} = \begin{bmatrix} -10.020 \\ 19.975 \\ -12.195 \\ 0.772 \\ 167.570 \end{bmatrix} \qquad P = \begin{bmatrix} 15.692 & & & & \\ -21.352 & 31.241 & & & \\ 6.094 & -10.355 & 4.756 & & \\ -0.303 & 0.395 & -0.108 & 0.025 & \\ 120.492 & -159.480 & 33.504 & -0.213 & 1720.745 \end{bmatrix}$$

$a_1 + a_2 + a_3 = -2.240$

Yaw regulator structure

NAY = 3	NBY = 2	KY = 5
IREGY = 10	RLY = 0.95	IRR = 1
AK1V = 40	AK2V = 1.4	AK3V = 115
C1V = 30	C2V = 60	
EPS1V = 0.02	EPS2V = 0.03	
PSISV = 0.4	PSISSV = 1.5	PSIMAV = 0.6
I1MV = 100	I2MV = 300	I3MV = 120

Initial yaw regulator values

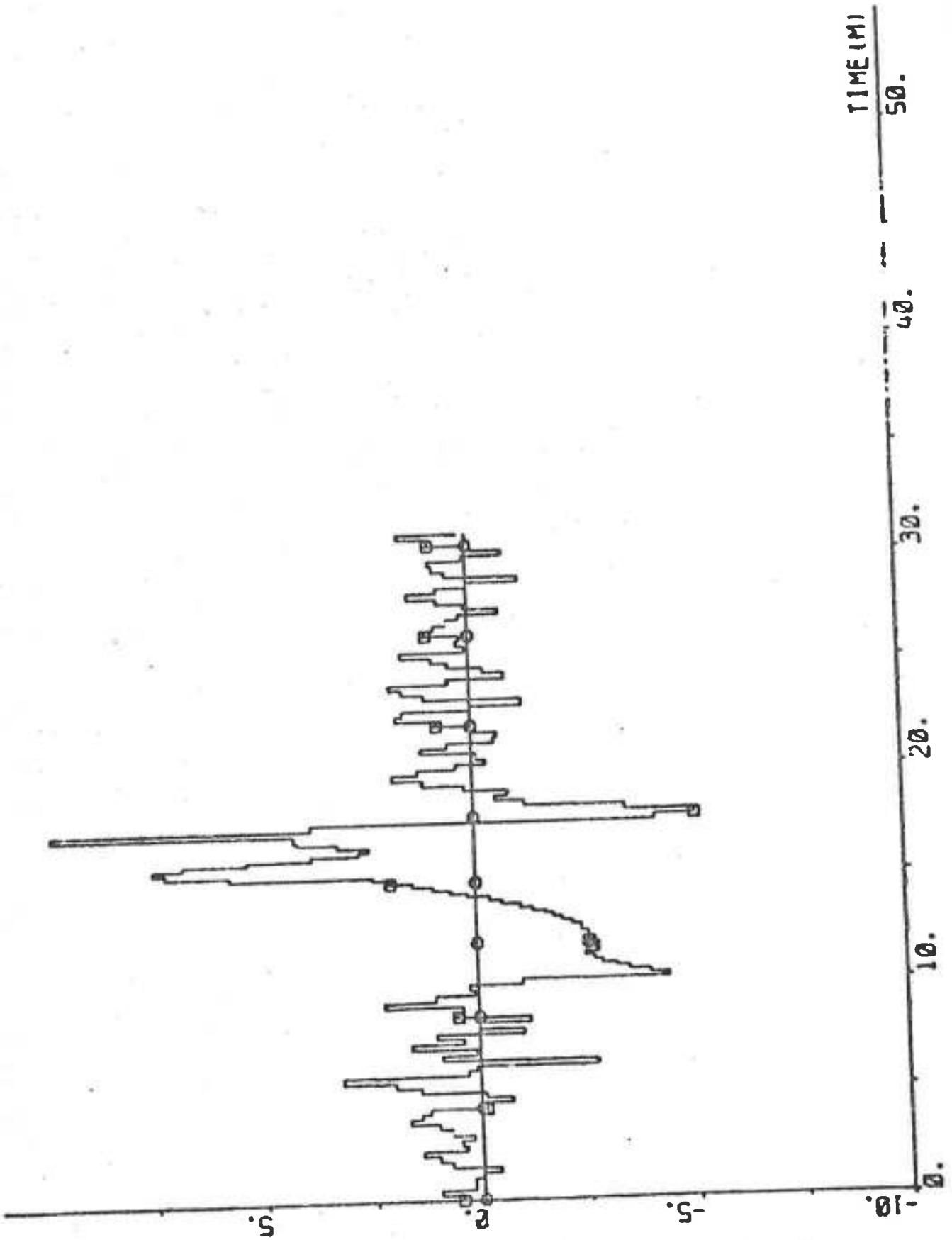
$$\begin{bmatrix} a_1' \\ a_2' \\ a_3' \\ b_1' \\ b_2' \end{bmatrix} = \begin{bmatrix} -12.90 \\ 6.02 \\ -6.87 \\ 1.30 \\ 0.649 \end{bmatrix} \qquad PY = \begin{bmatrix} 1000 & & & & \\ 0 & 1000 & & & \\ 0 & 0 & 1000 & & \\ 0 & 0 & 0 & 10 & \\ 0 & 0 & 0 & 0 & 10 \end{bmatrix}$$

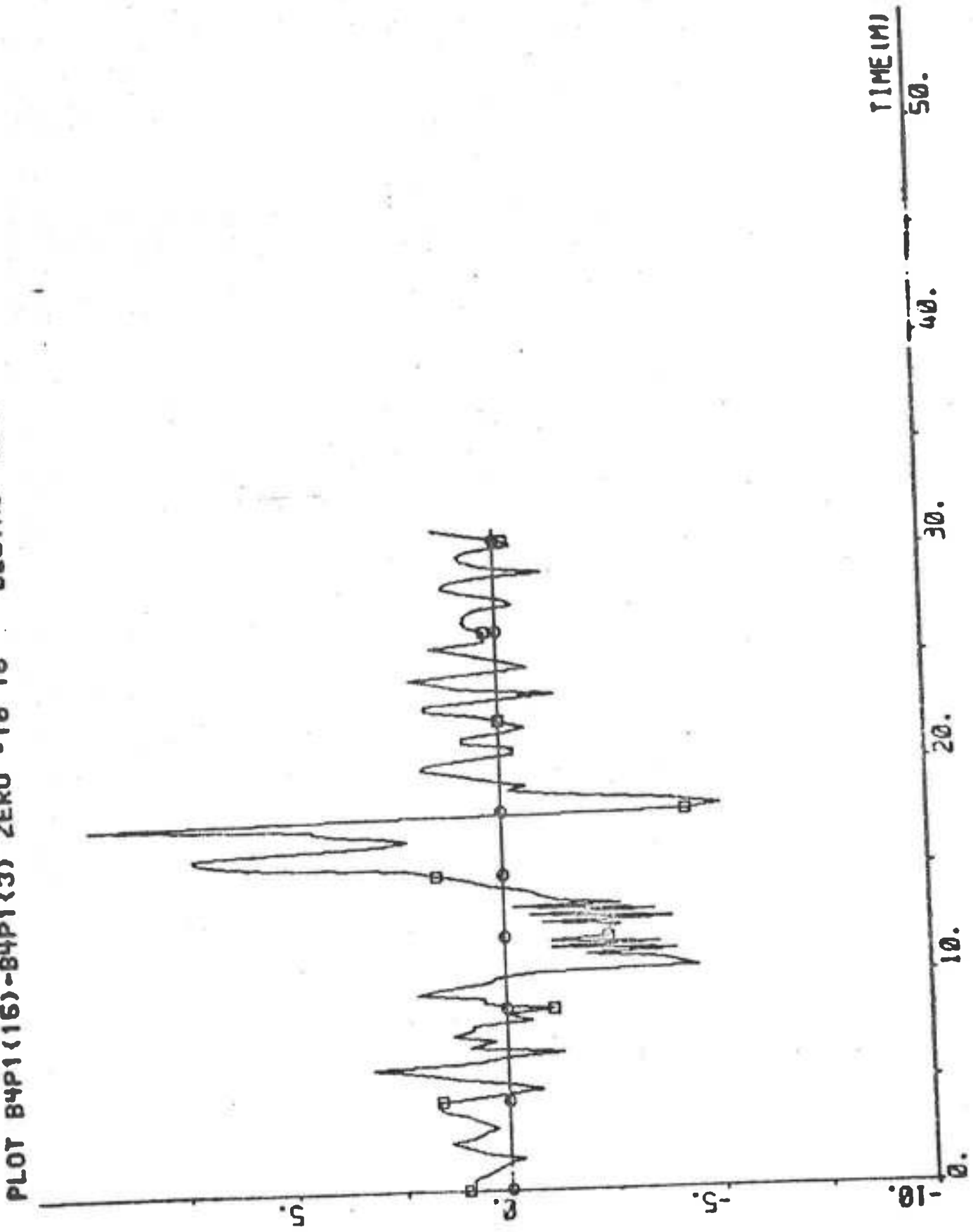
$a_1' + a_2' + a_3' = -13.75$

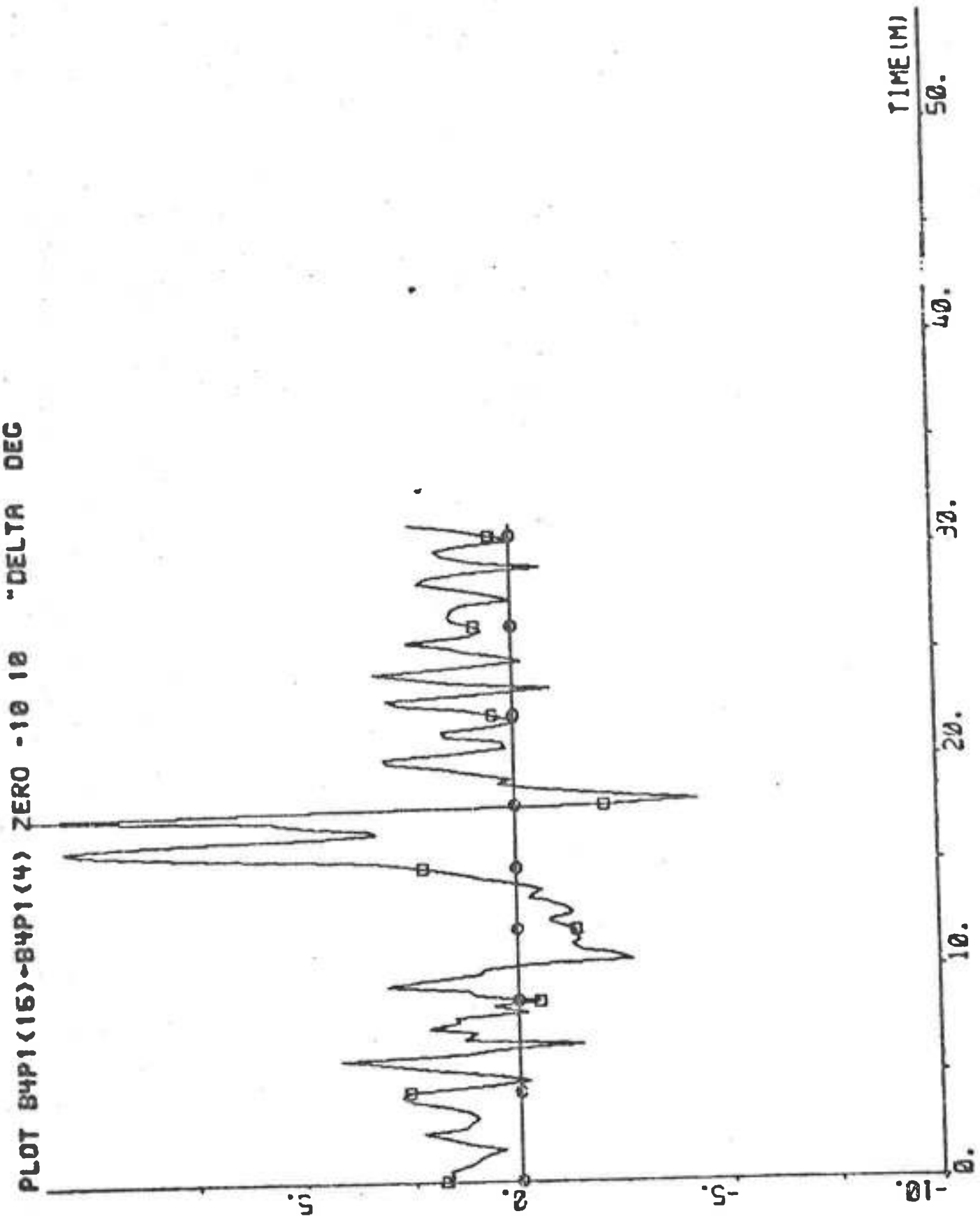
Final yaw regulator values

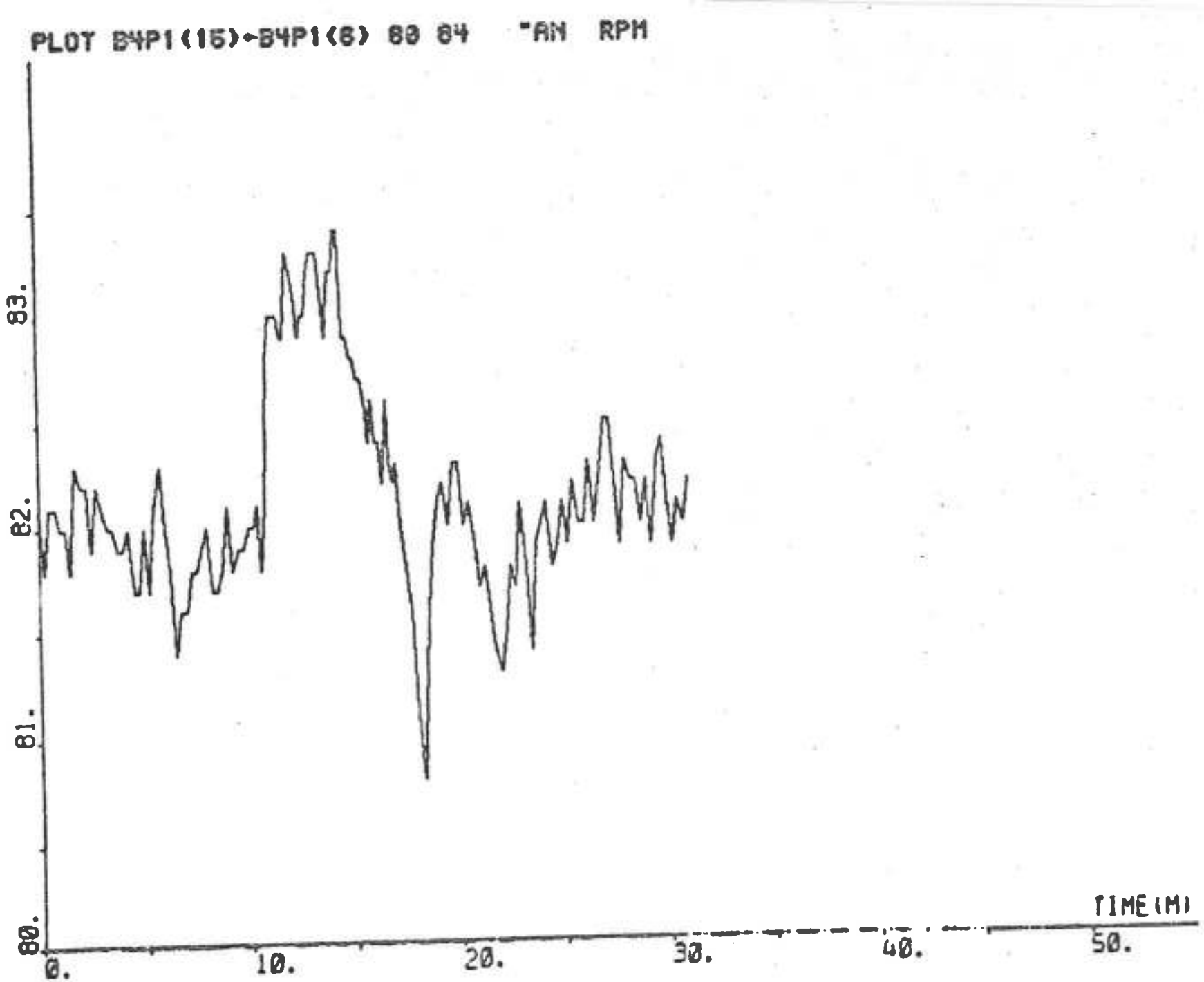
$$\begin{bmatrix} a_1' \\ a_2' \\ a_3' \\ b_1' \\ b_2' \end{bmatrix} = \begin{bmatrix} -14.616 \\ 6.853 \\ -7.220 \\ 1.237 \\ 0.595 \end{bmatrix} \qquad PY = \begin{bmatrix} 1229.793 & & & & \\ -943.045 & 2397.505 & & & \\ -185.826 & -1000.036 & 1518.064 & & \\ -26.980 & -57.732 & -4.159 & 11.491 & \\ -23.215 & -44.126 & -19.200 & 8.270 & 10.884 \end{bmatrix}$$

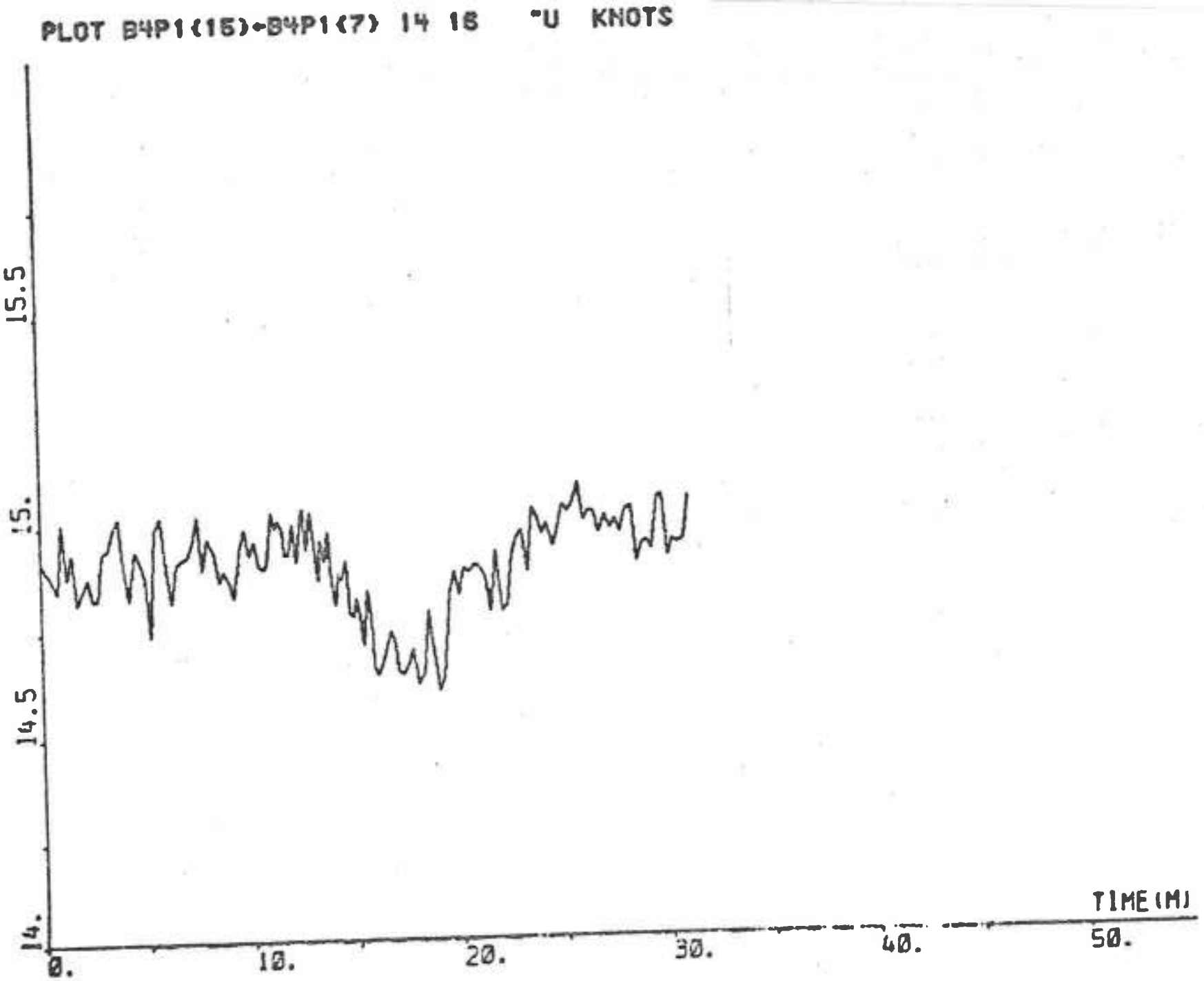
$$a_1' + a_2' + a_3' = -14.983$$

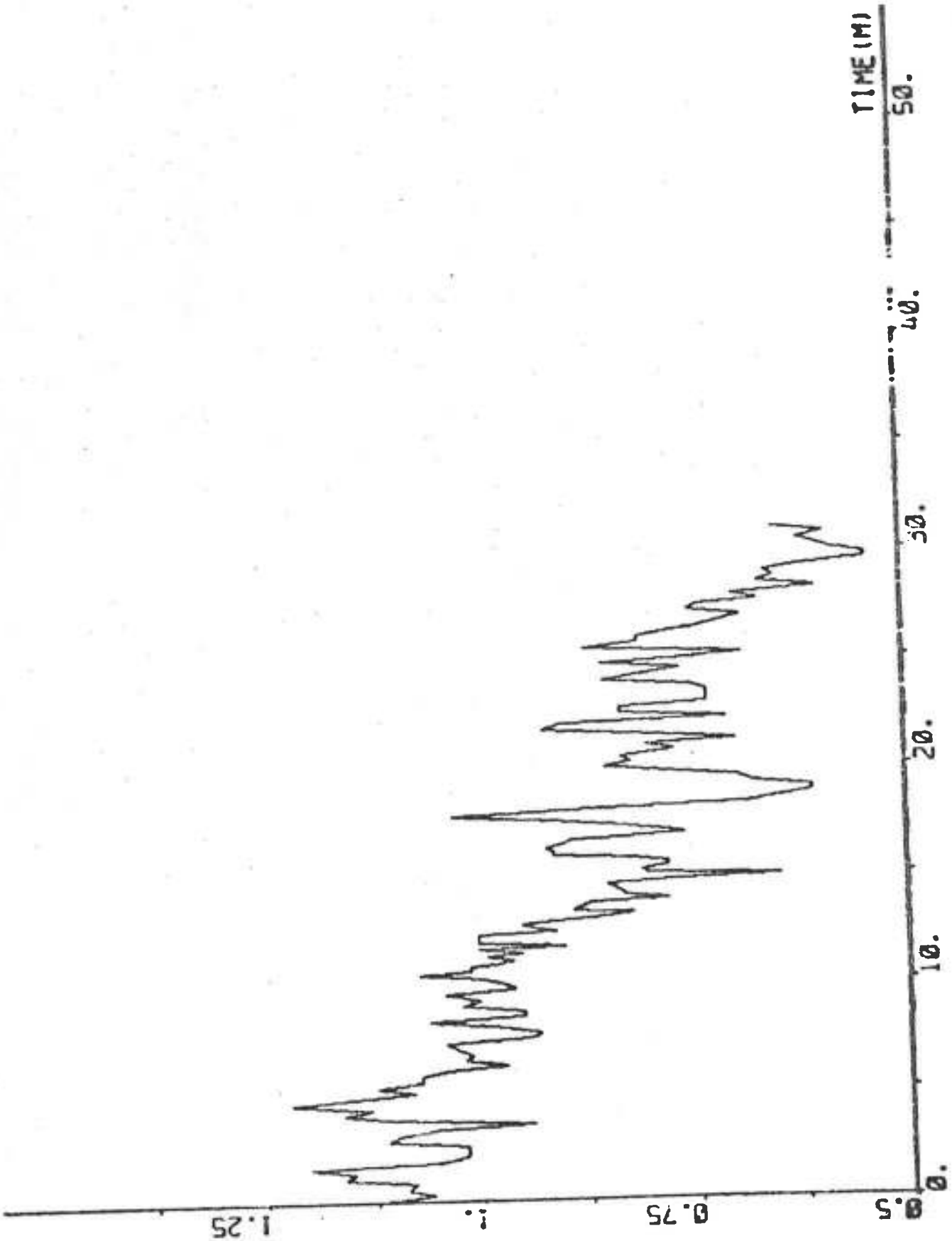

PLOT B4P1(15)-HP B4P1(1) ZERO -18 18 "DELCOC DEG
TIME(M)
0.
10.
20.
30.
40.
50.
-10.
-5.
0.
5.

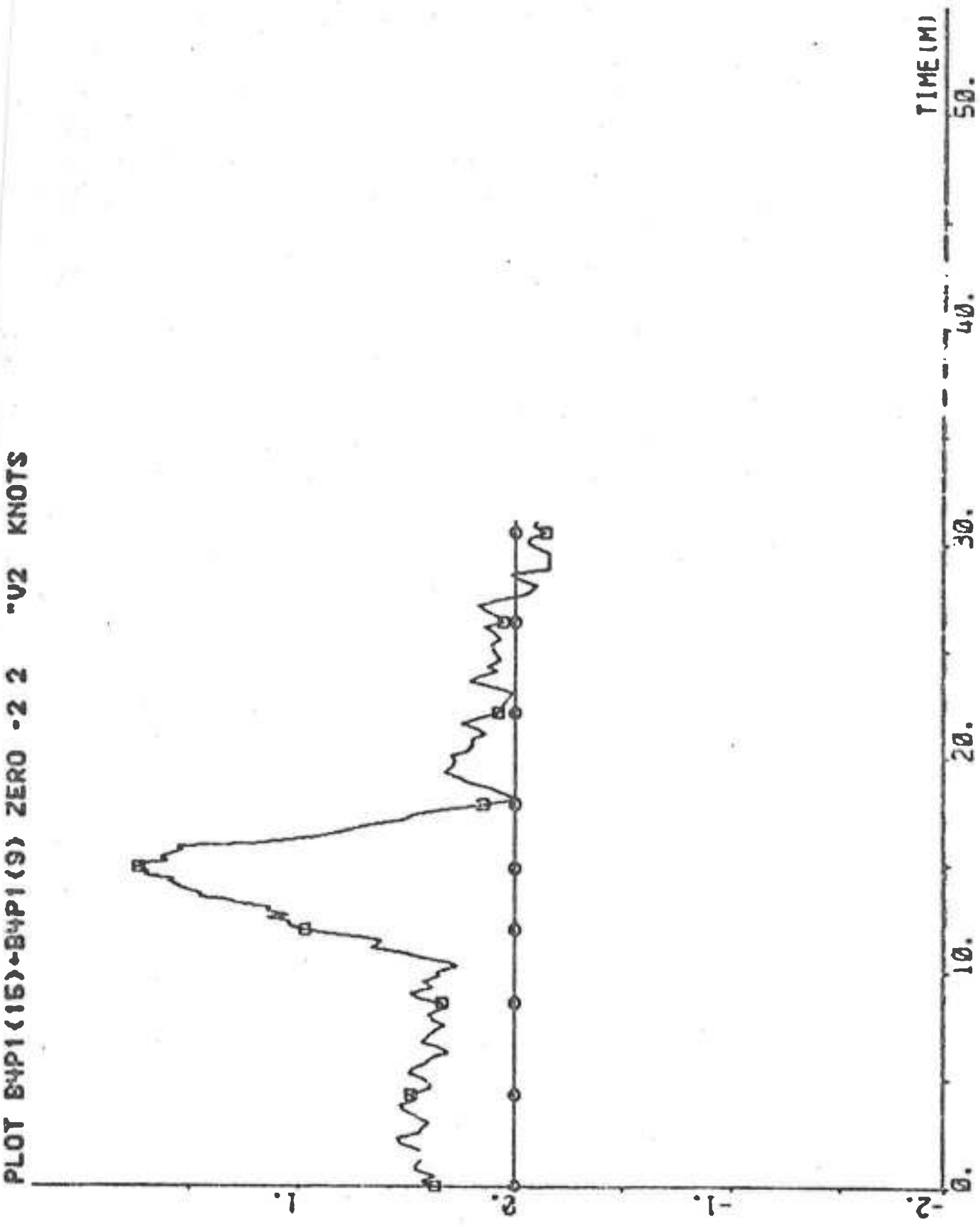

PLOT B4P1(16)-B4P1(3) ZERO -10 10 "DELTAS DEG
TIME(M)
0.
10.
20.
30.
40.
50.
-10.
-5.
0.
5.

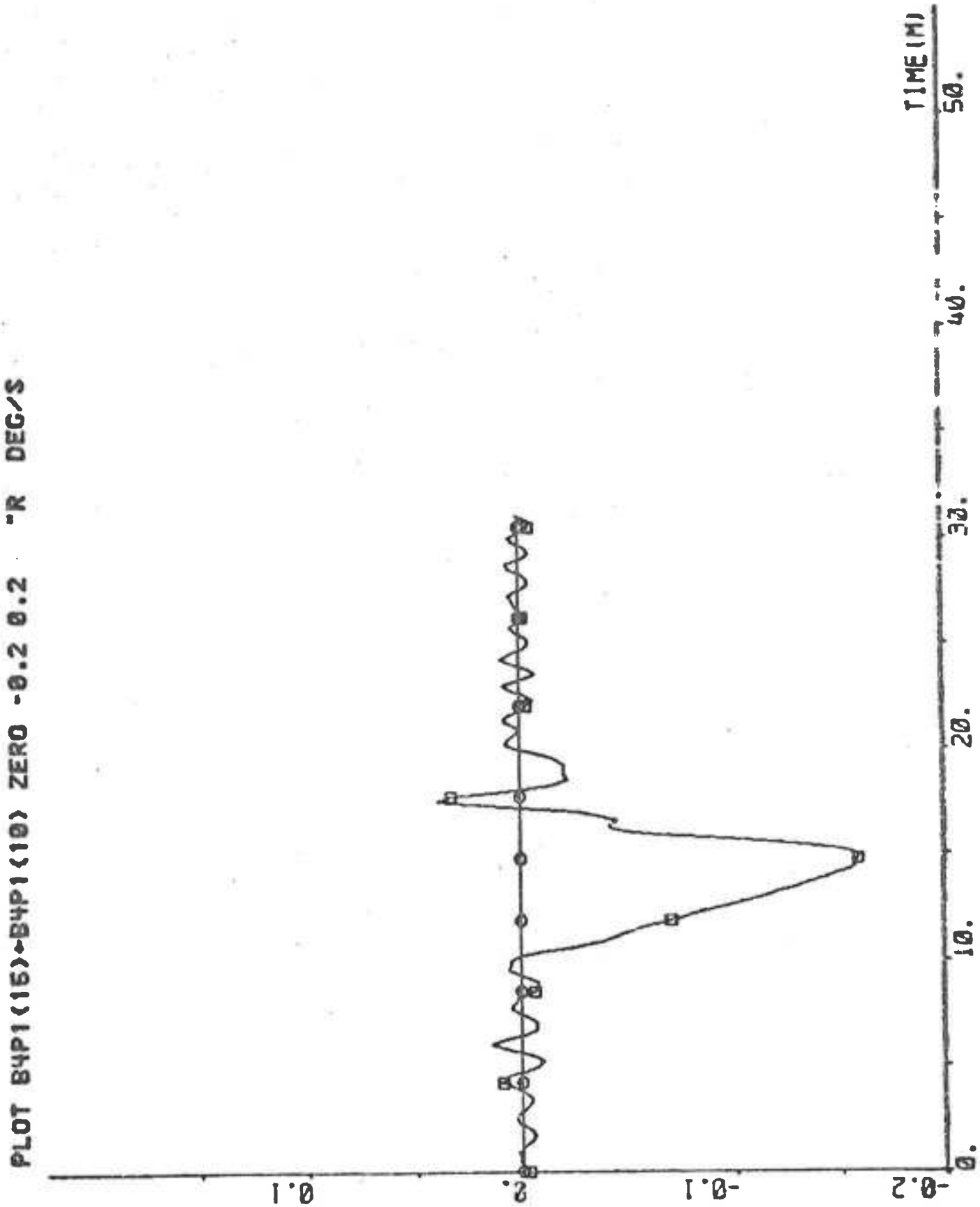

PLOT B4P1(15)-B4P1(4) ZERO -10 10 "DELTA DEG
TIME(M)
0.
10.
20.
30.
40.
50.
-10
-5.
0.
5.

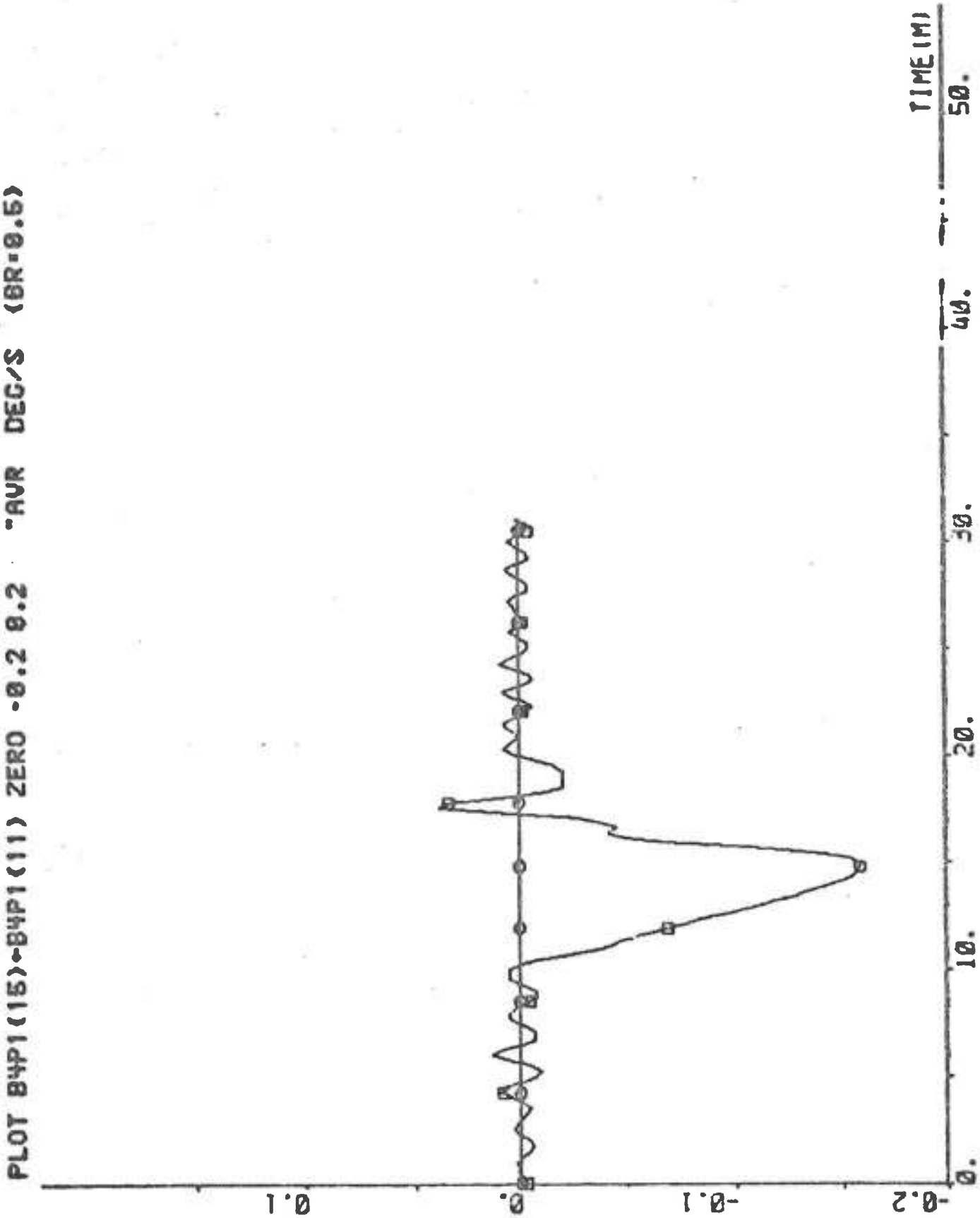

PLOT B4P1(15)-B4P1(6) 80 84 "AN RPM
83.
82.
81.
80.
0.
10.
20.
30.
40.
50.
TIME(M)

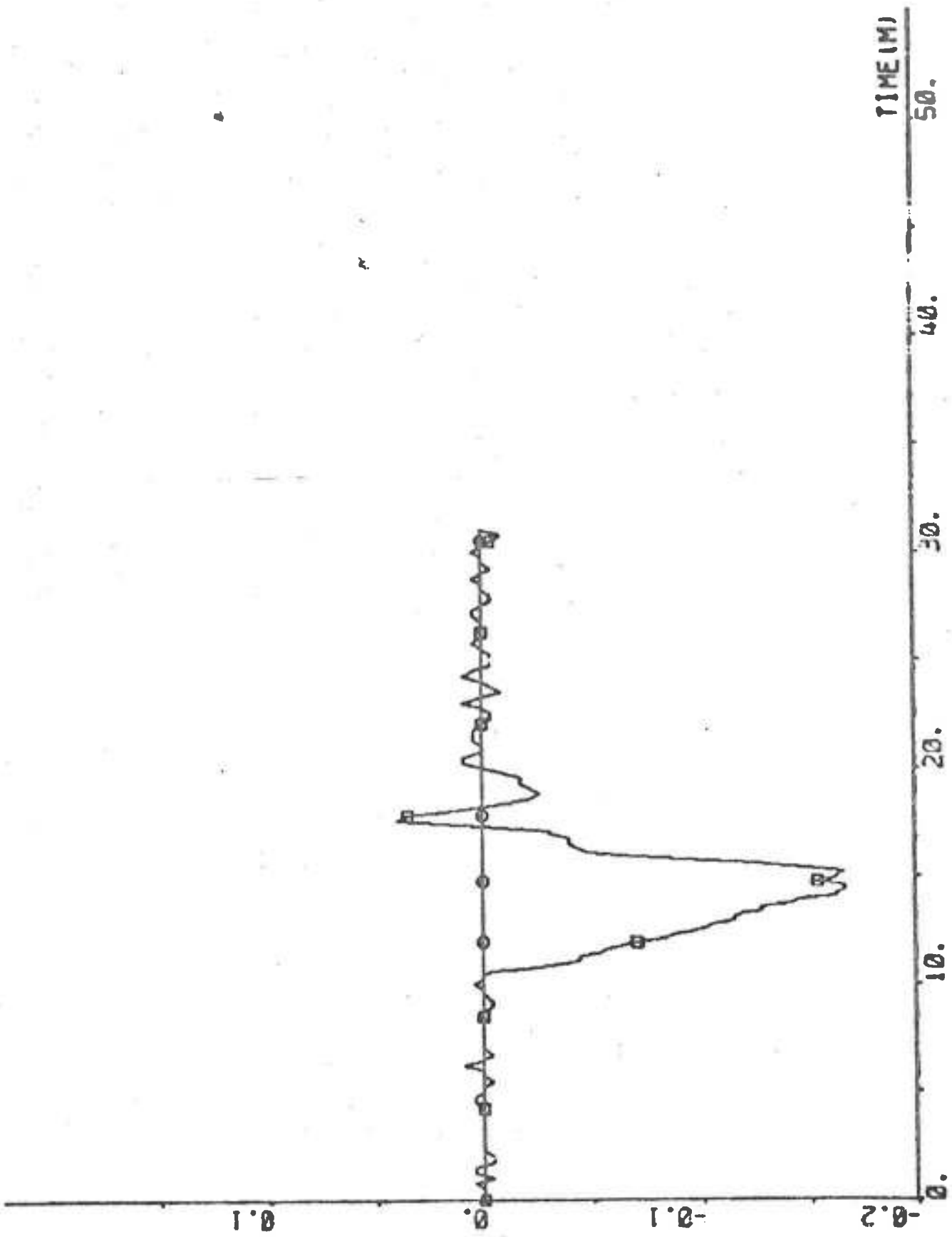

PLOT B4P1(15)-B4P1(7) 14 16 "U KNOTS
15.5
15.
14.5
14.
0.
10.
20.
30.
40.
50.
TIME(M)

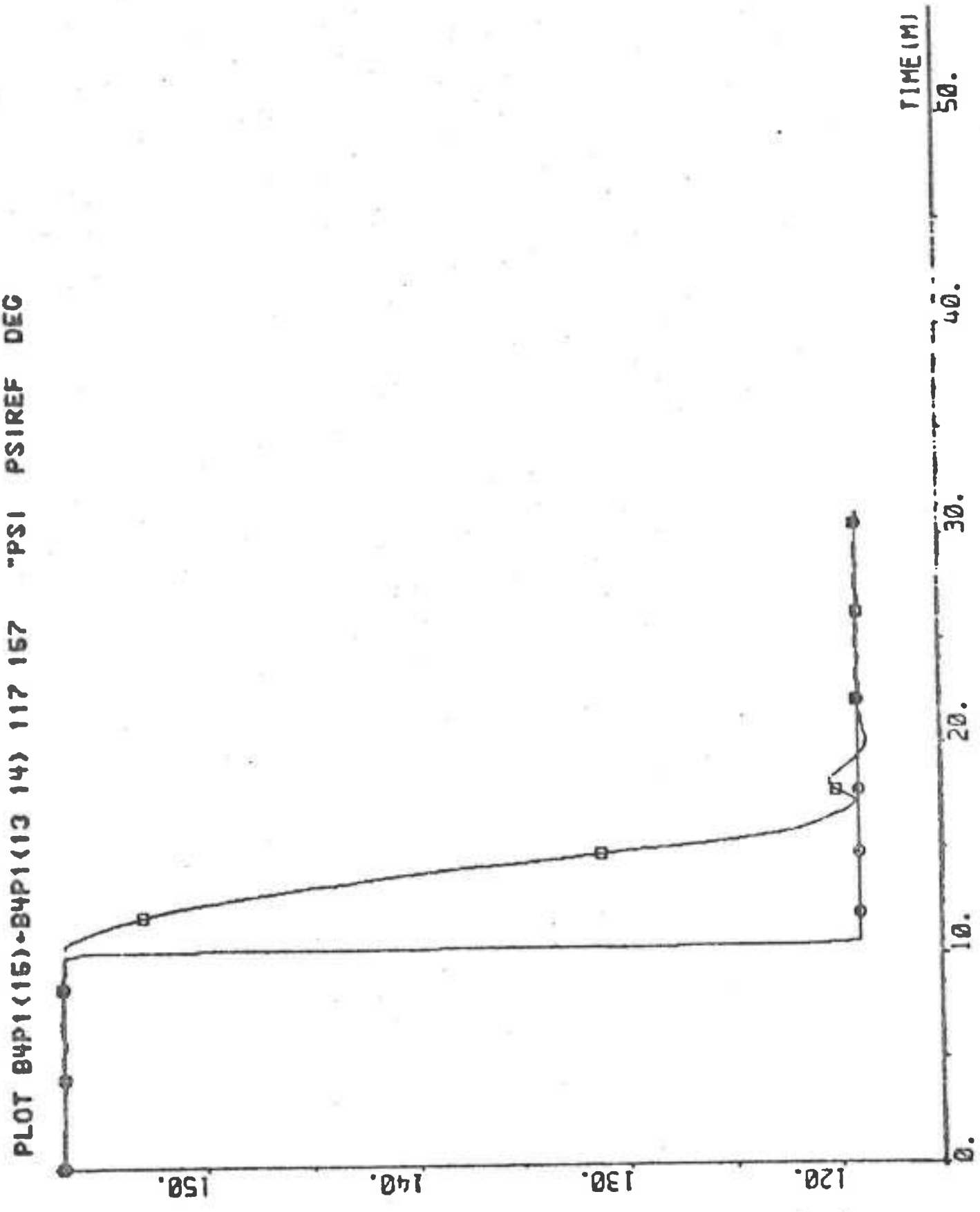

PLOT B4P1(15)-B4P1(8) 0.5 1.5 "V1 KNOTS
0.5
0.75
1.25
0.
10.
20.
30.
40.
50.
TIME(M)

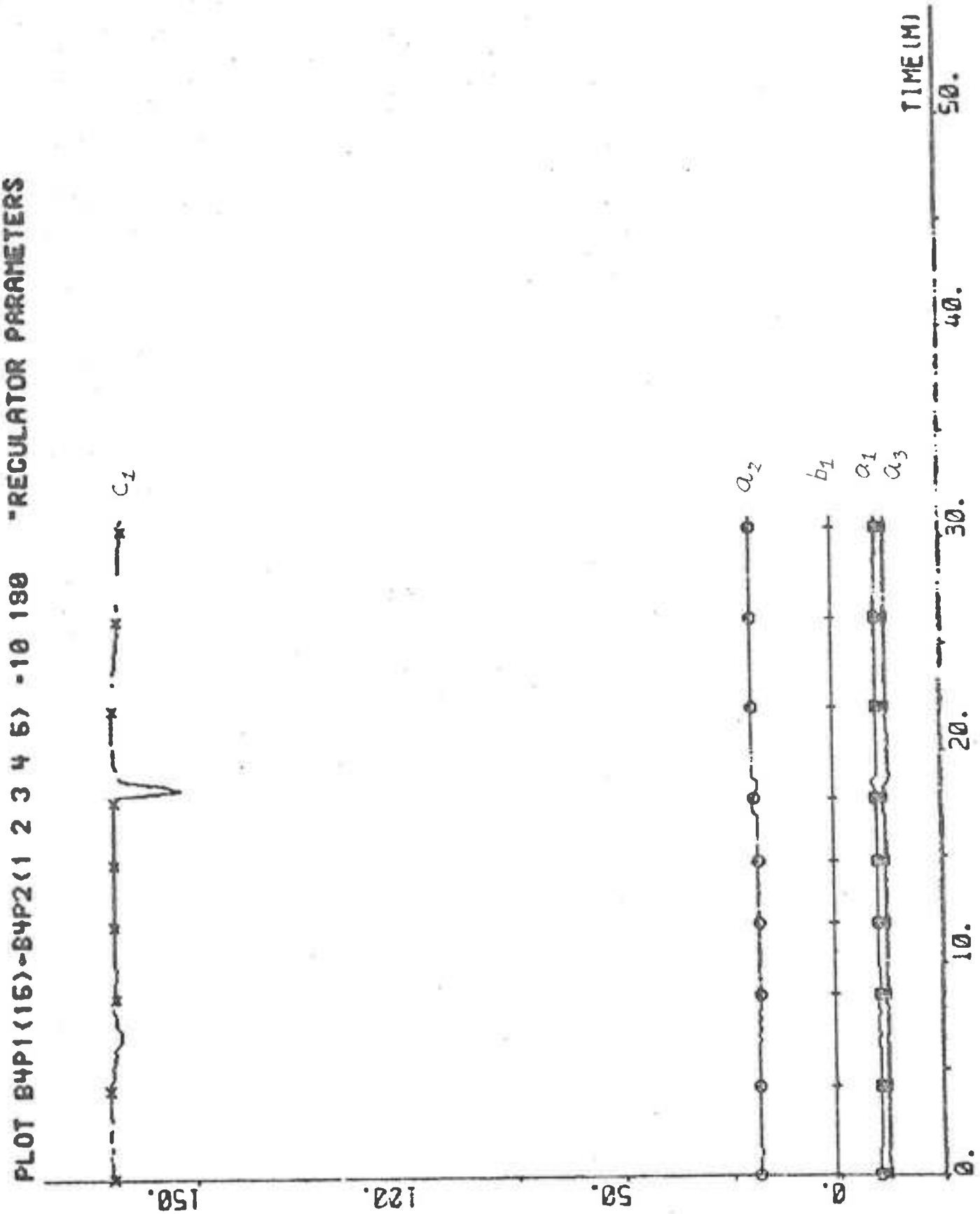

PLOT B4P1(15)-B4P1(9) ZERO -2 2 "U2 KNOTS
1.
.5
-1.
-2.
0.
10.
20.
30.
40.
50.
TIME(M)

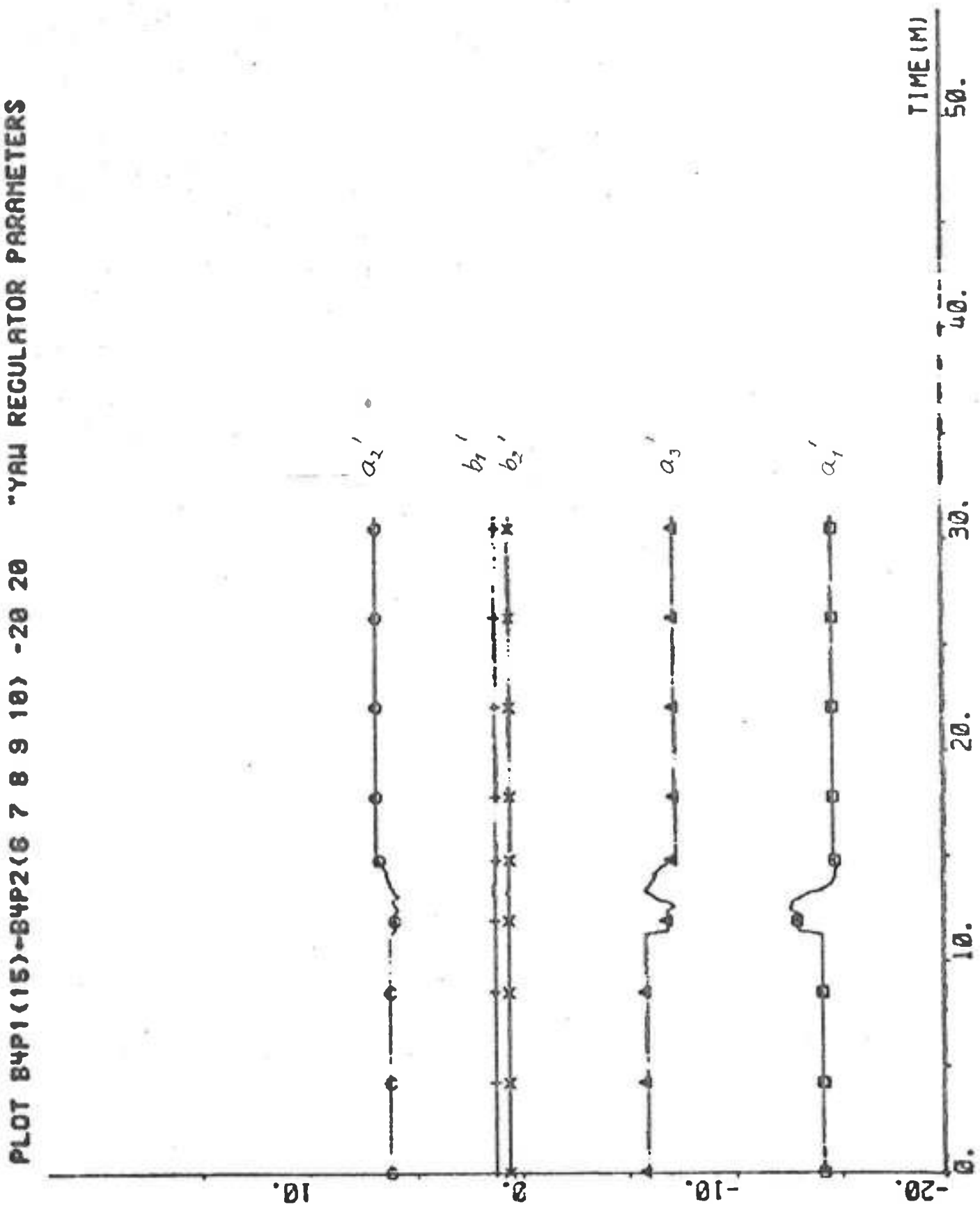

PLOT B4P1(15)-B4P1(10) ZERO -0.2 0.2 °R DEG/S
0.1
.2
-0.1
-0.2
0.
10.
20.
30.
40.
50.
TIME(M)

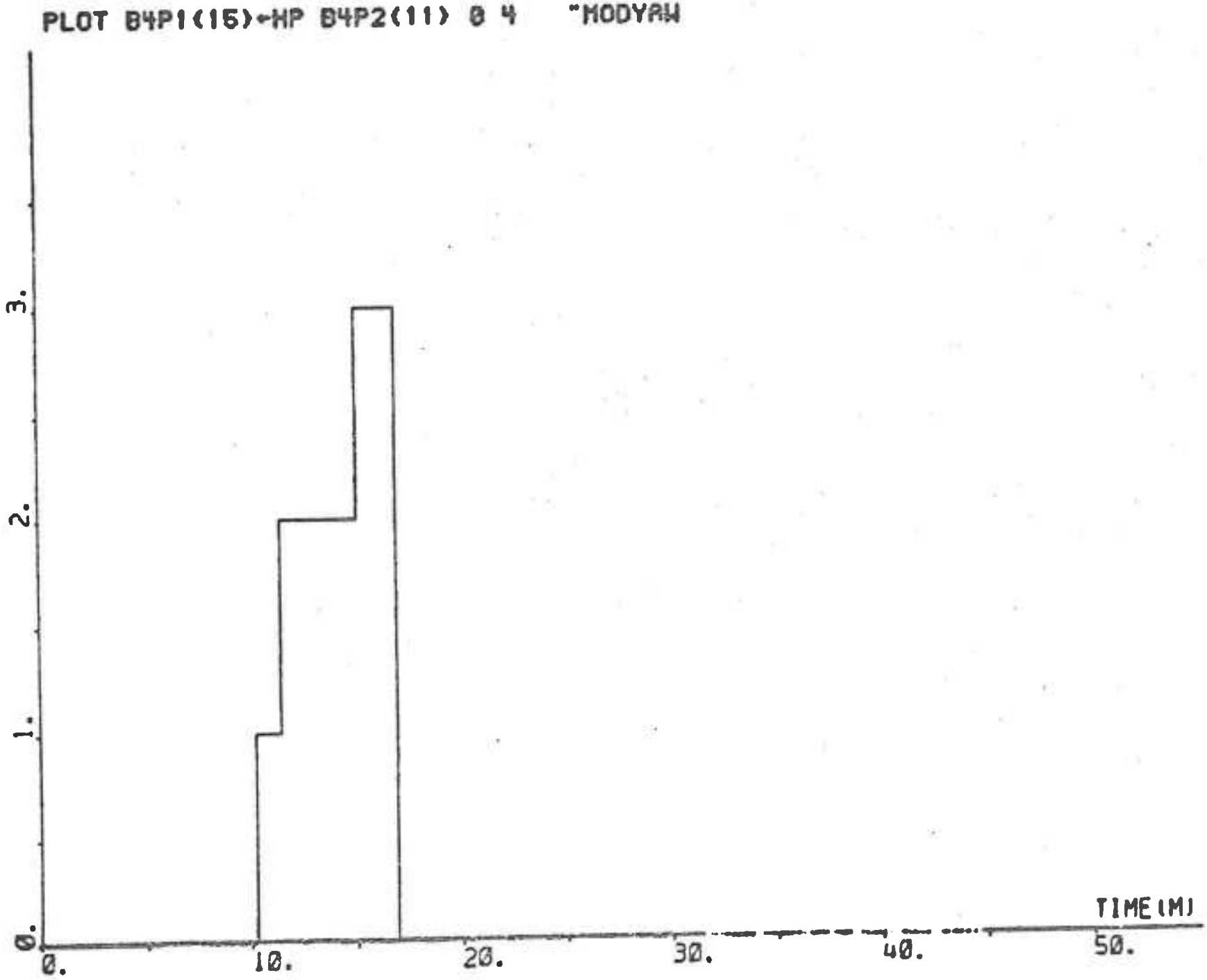

PLOT B4P1(15)-B4P1(11) ZERO -0.2 0.2 "AVR DEG/S (BR=0.5)
0.1
0.
-0.1
-0.2
0.
10.
20.
30.
40.
50.
TIME(M)


PLOT B4P1(15)-B4P1(12) ZERO -0.2 0.2 "DPSIDT DEG/S (10PSI=5)
0.1
0.
-0.1
-0.2
0.
10.
20.
30.
40.
50.
TIME(M)


PLOT B4P1(15)-B4P1(13 14) 117 157 "PSI PSIREF DEC
TIME(M)
0.
10.
20.
30.
40.
50.
120.
130.
140.
150.


PLOT B4P1(16)-B4P2(1 2 3 4 5) -10 190 "REGULATOR PARAMETERS
150.
120.
50.
0.
0.
10.
20.
30.
40.
50.
TIME(M)
c_1
a_2
b_1
a_1
a_3


PLOT B4P1(15)-B4P2(6 7 8 9 10) -20 20 "YAW REGULATOR PARAMETERS
10.
0.
-10.
-20.
0.
10.
20.
30.
40.
50.
TIME(M)
a_2'
b_1'
b_2'
a_3'
a_1'


PLOT B4P1(15)-HP B4P2(11) 0 4 "MODYAW
3.
2.
1.
0.
0.
10.
20.
30.
40.
50.
TIME(M)

EXPERIMENT B5

Date	1974-10-10
Time	20.25
Duration	7 min
Position	N 27° 25' E 50° 47'
Water depth	40 m
Forward draught	20.1 m
Aft draught	20.4 m
Wind direction	S (2; see Appendix A)
Wind velocity	1 Beaufort (1-1.5 m/s, light air)
Wave height	0.5 m
PSIREF	119°, 135°
RREF	0.07 deg/s
Rudder limit	±15° - ±20°
DELlM at termination	2.90°
Approximate mean value of AN	80.5 rpm
Approximate mean value of U	14.6 knots

A program error caused the off-diagonal elements of the covariance matrix P for the straight course regulator parameters to be put zero instead of the off-diagonal elements of PY for the yaw regulator parameters, when phase 2 of the yaw regulator was initiated, which affected both the straight course keeping and the yawing.

Regulator structure

NA = 3	NB = 1	NC = 1	K = 4
IREG = 20	IRDIF = 0	RL = 0.98	IRR = 1

Final values

$$\begin{bmatrix} a_1 \\ a_2 \\ a_3 \\ b_1 \\ c_1 \end{bmatrix} = \begin{bmatrix} -3.780 \\ 15.188 \\ -18.997 \\ 1.079 \\ 116.786 \end{bmatrix} \qquad P = \begin{bmatrix} 9.722 & & & & \\ -15.834 & 26.733 & & & \\ 1.471 & -0.314 & 11.546 & & \\ -0.216 & 0.387 & 0.074 & 0.008 & \\ 143.728 & -240.096 & -21.858 & -3.415 & 2351.332 \end{bmatrix}$$

$a_1 + a_2 + a_3 = -7.589$

Yaw regulator structure

NAY = 3	NBY = 2	KY = 5
IREGY = 10	RLY = 0.95	IRR = 1
AK1V = 40	AK2V = 1.4	AK3V = 115
C1V = 30	C2V = 60	
EPS1V = 0.02	EPS2V = 0.03	
PSISV = 0.4	PSISSV = 1.5	PSIMAV = 0.6
I1MV = 100	I2MV = 300	I3MV = 120

Initial yaw regulator values

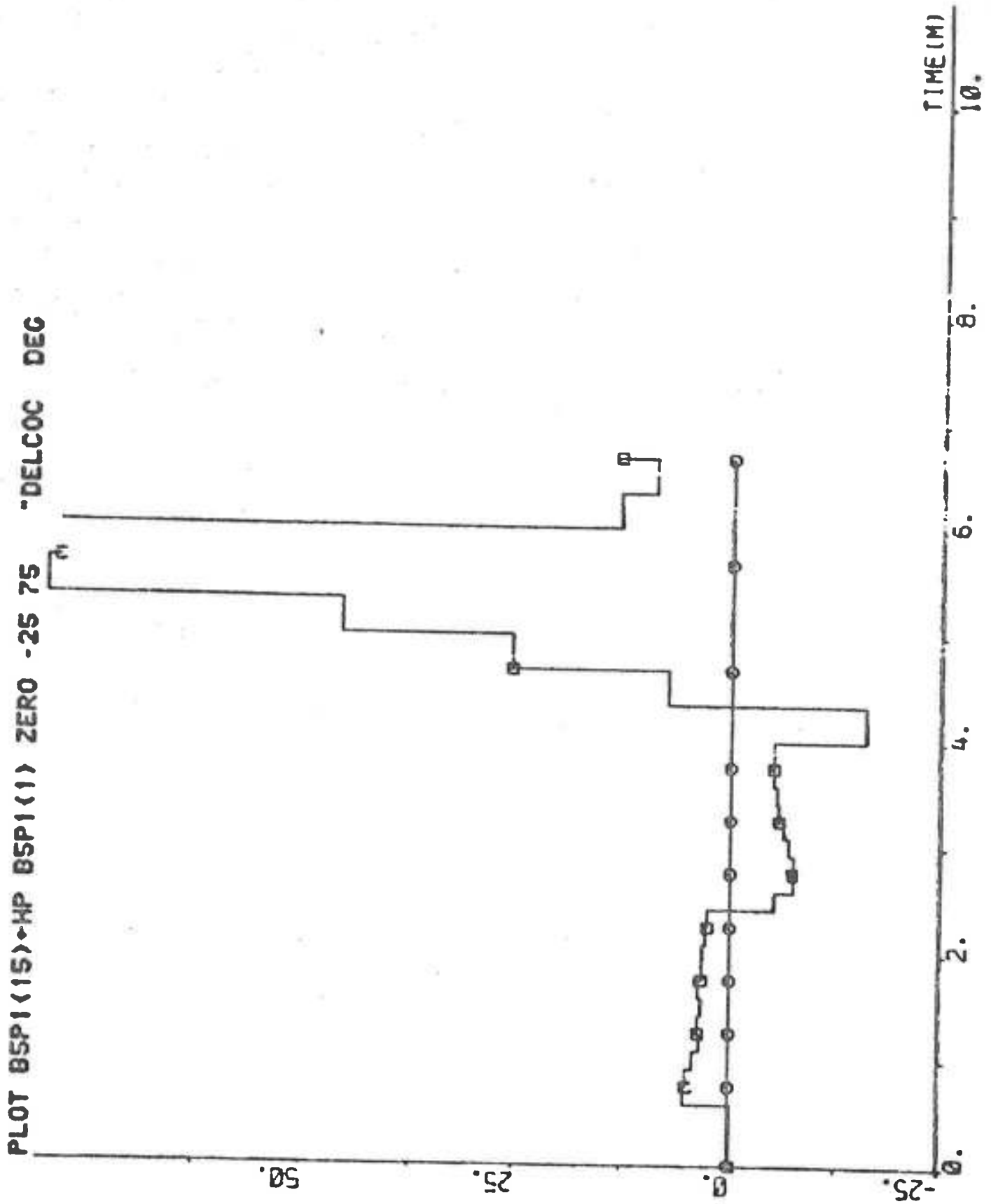
$$\begin{bmatrix} a'_1 \\ a'_2 \\ a'_3 \\ b'_1 \\ b'_2 \end{bmatrix} = \begin{bmatrix} -12.90 \\ 6.02 \\ -6.87 \\ 1.30 \\ 0.649 \end{bmatrix} \qquad PY = \begin{bmatrix} 1000 & & & & \\ 0 & 1000 & & & \\ 0 & 0 & 1000 & & \\ 0 & 0 & 0 & 10 & \\ 0 & 0 & 0 & 0 & 10 \end{bmatrix}$$

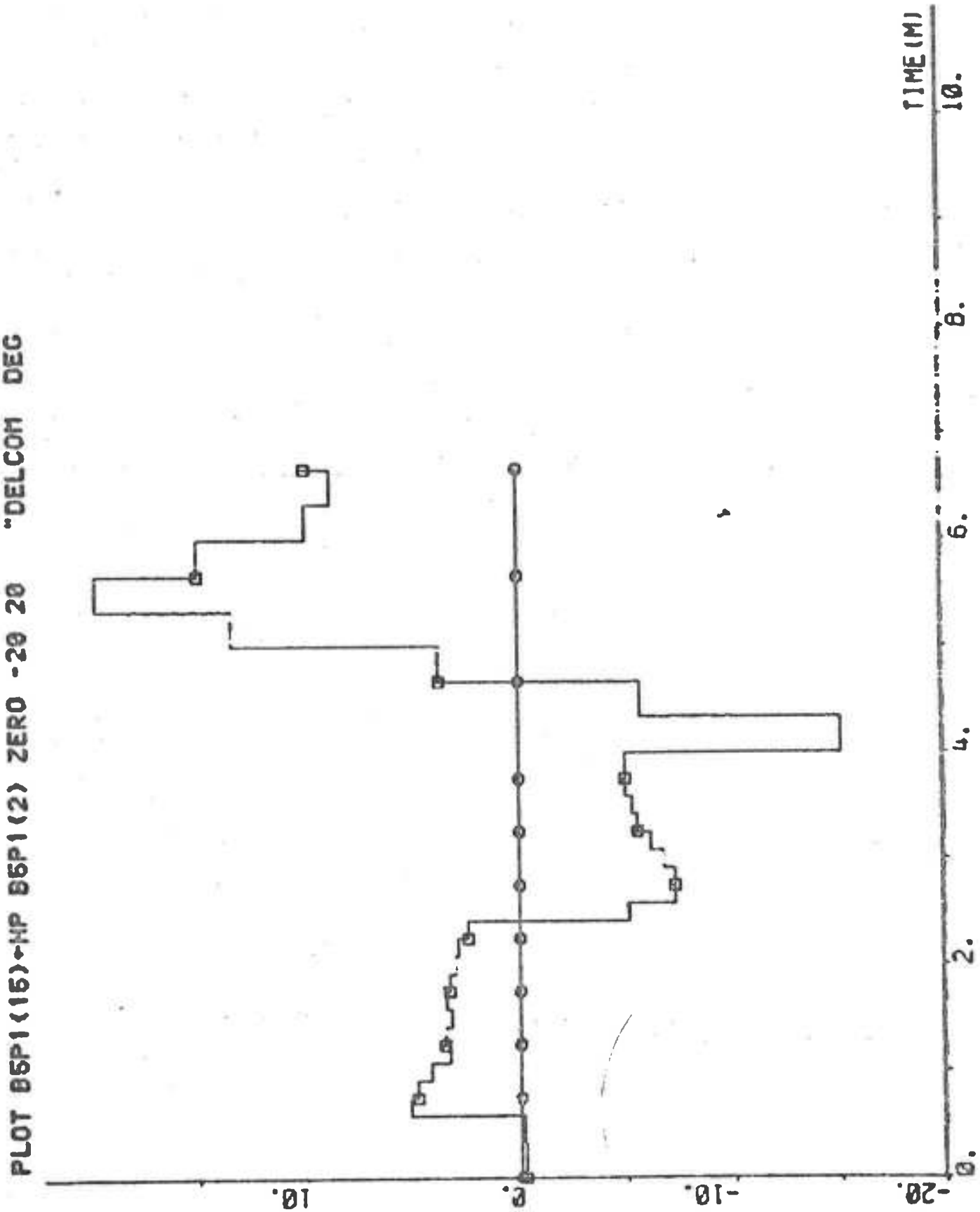
$a'_1 + a'_2 + a'_3 = -13.75$

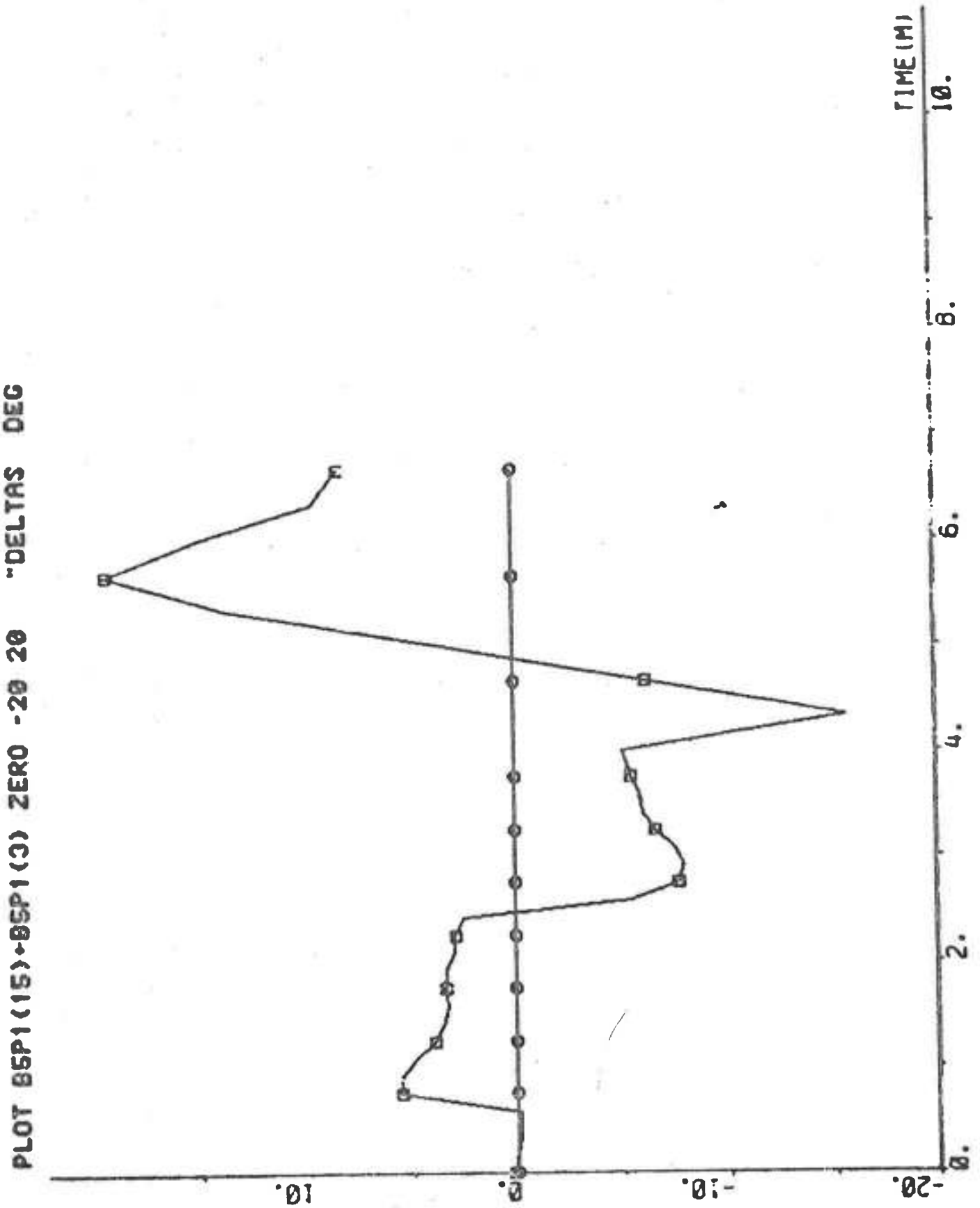
Final yaw regulator values

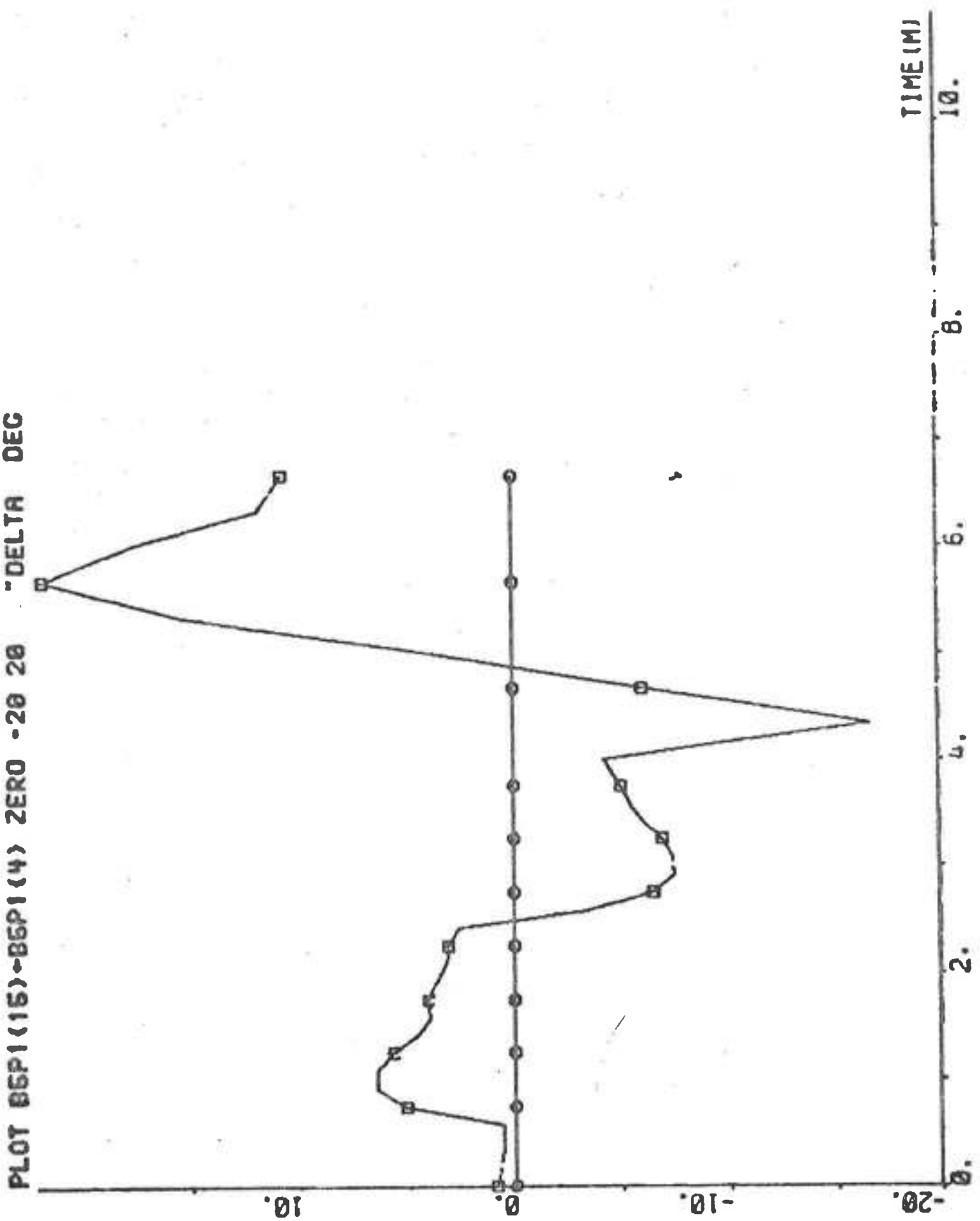
$$\begin{bmatrix} a_1' \\ a_2' \\ a_3' \\ b_1' \\ b_2' \end{bmatrix} = \begin{bmatrix} -12.271 \\ 5.427 \\ -6.987 \\ 1.283 \\ 0.634 \end{bmatrix} \qquad PY = \begin{bmatrix} 1289.822 & & & & \\ -1216.361 & 1305.553 & & & \\ -239.682 & -1456.936 & 1427.064 & & \\ -34.800 & -86.287 & -6.668 & 14.216 & \\ -29.943 & -66.299 & -28.107 & 11.753 & 14.243 \end{bmatrix}$$

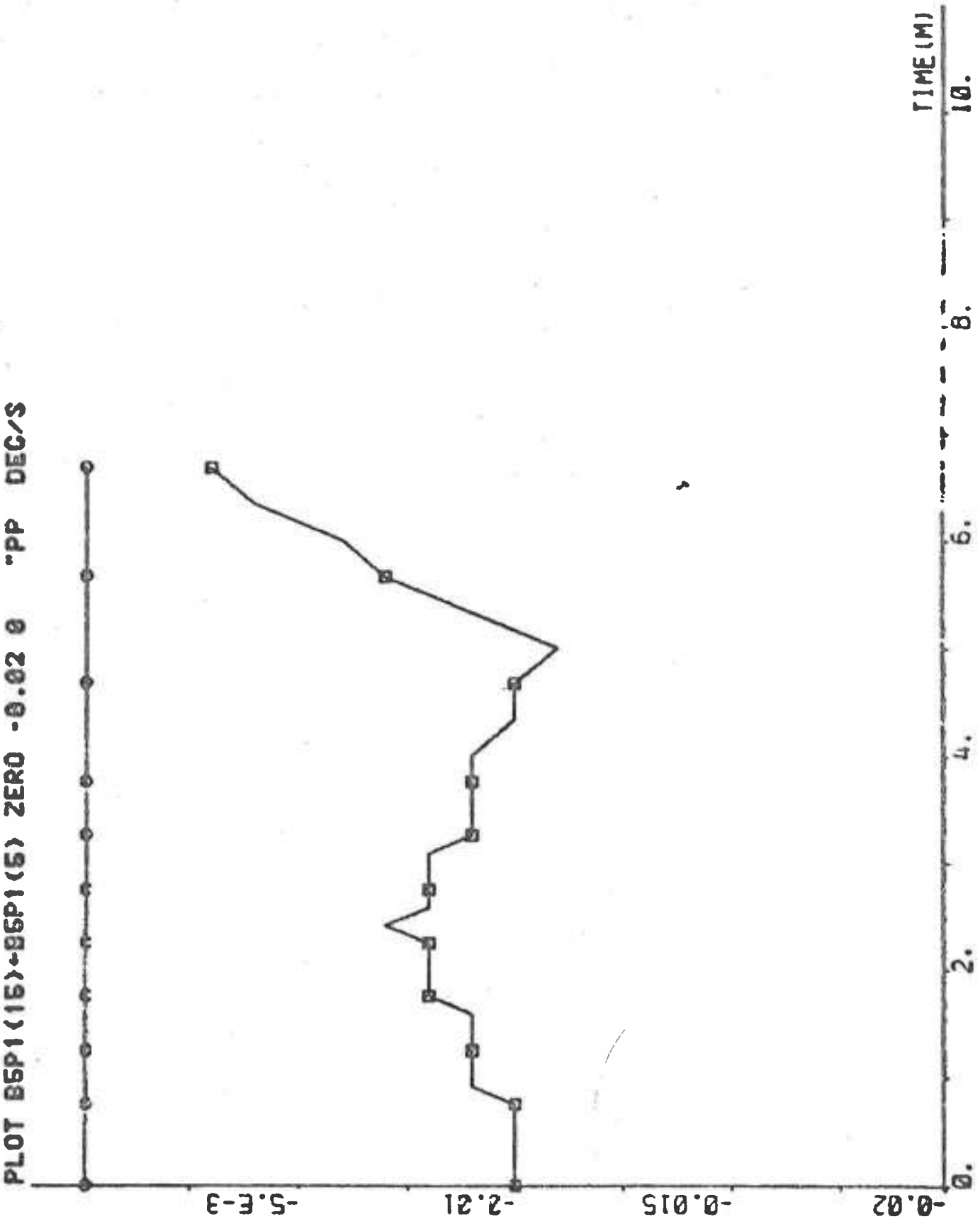
$a_1' + a_2' + a_3' = -13.831$

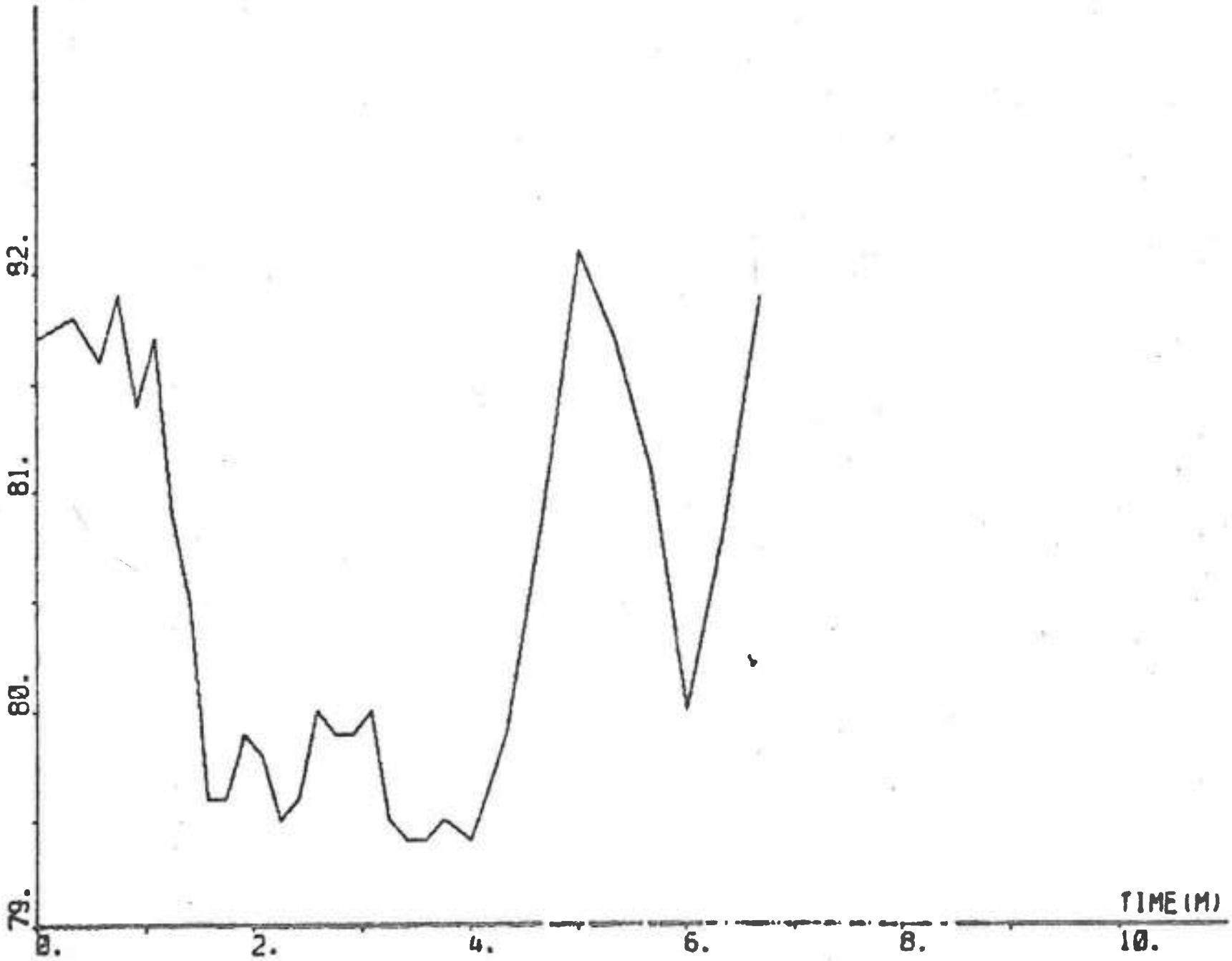

PLOT BSP1(15)*HP BSP1(1) ZERO -25 75 *DELCOC DEG
50.
25.
0.
-25.
0.
2.
4.
6.
8.
10.
TIME(M)

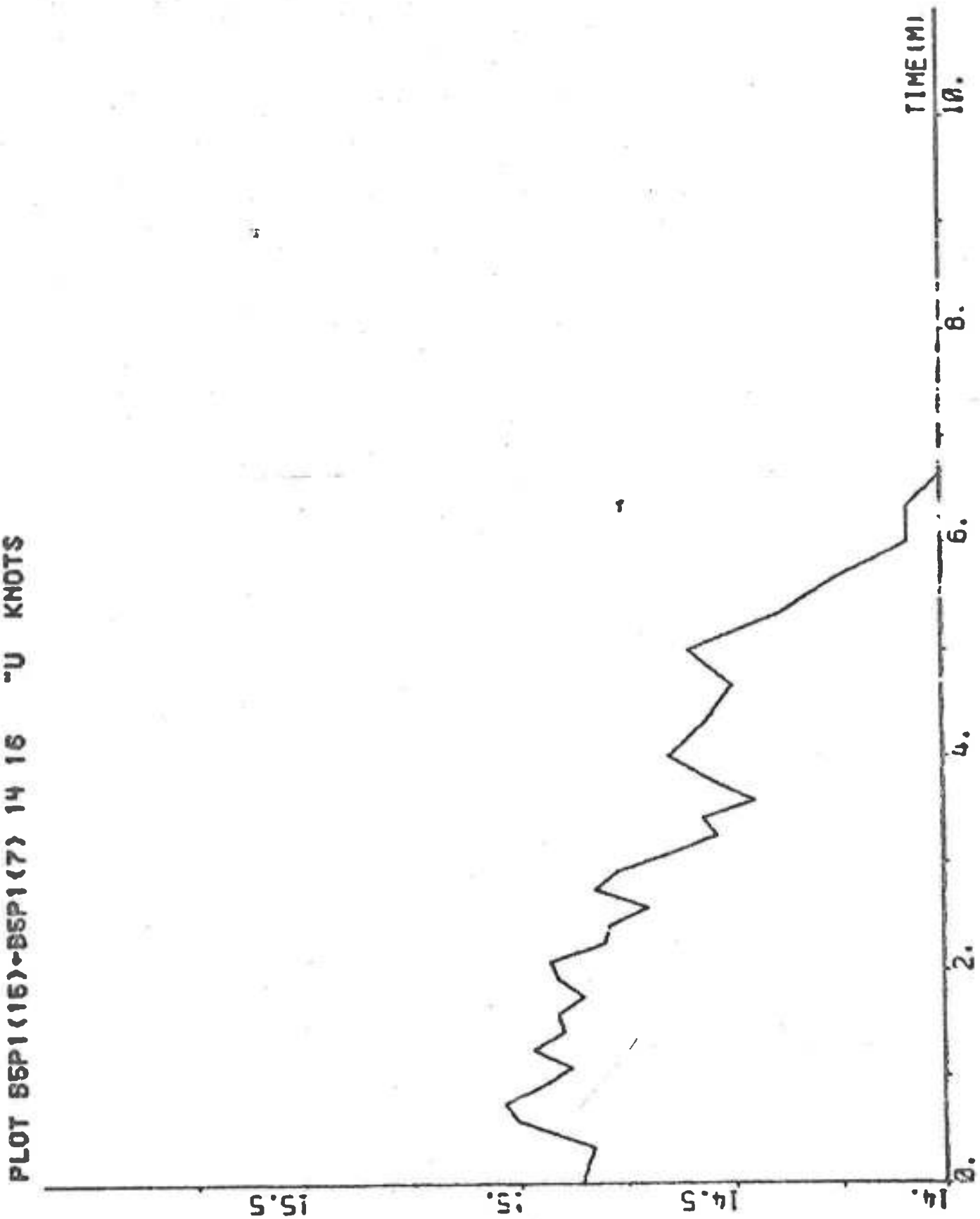

PLOT BSP1(16)-HP BSP1(2) ZERO -20 20 "DELCOM DEG
10.
0.
-10.
-20.
0.
2.
4.
6.
8.
10.
TIME(M)

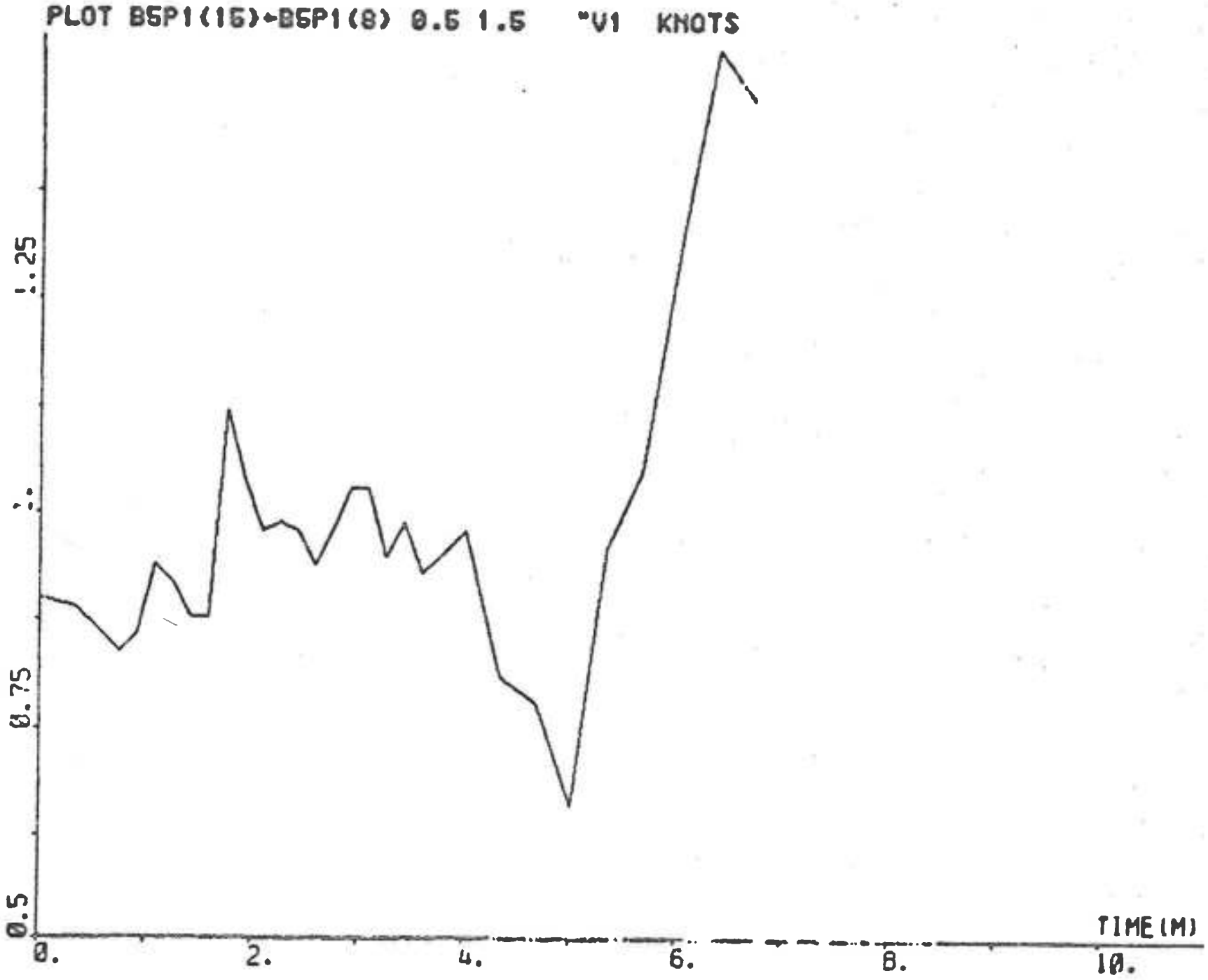

PLOT BSP1(15)-BSP1(3) ZERO -20 20 "DELTAS DEG
10.
0.
-10.
-20.
0.
2.
4.
6.
8.
10.
TIME(M)

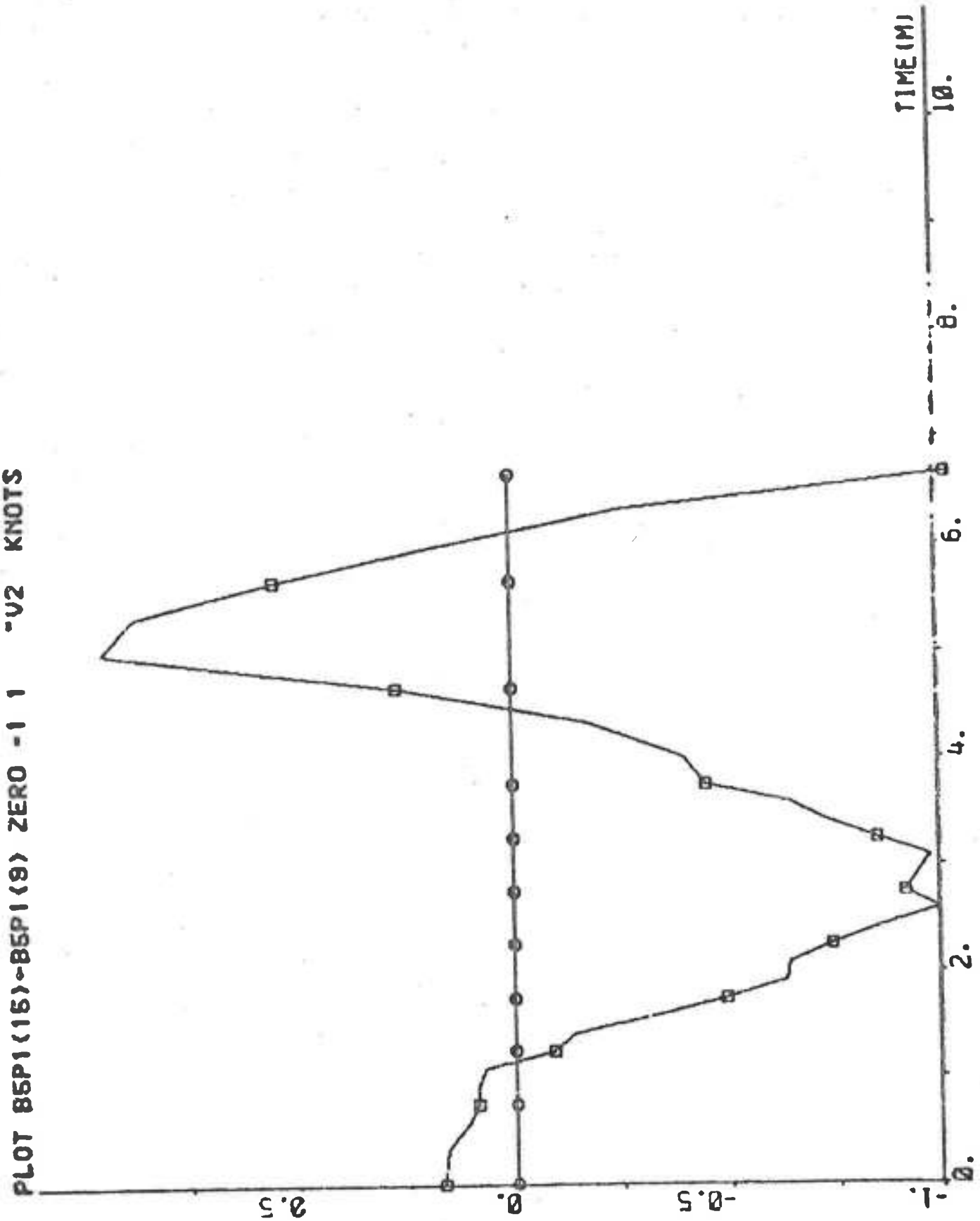

PLOT BSP1(15)-BSP1(4) ZERO -20 20 "DELTA DEG
20.
0.
-10.
-20.
0.
2.
4.
6.
8.
10.
TIME(M)

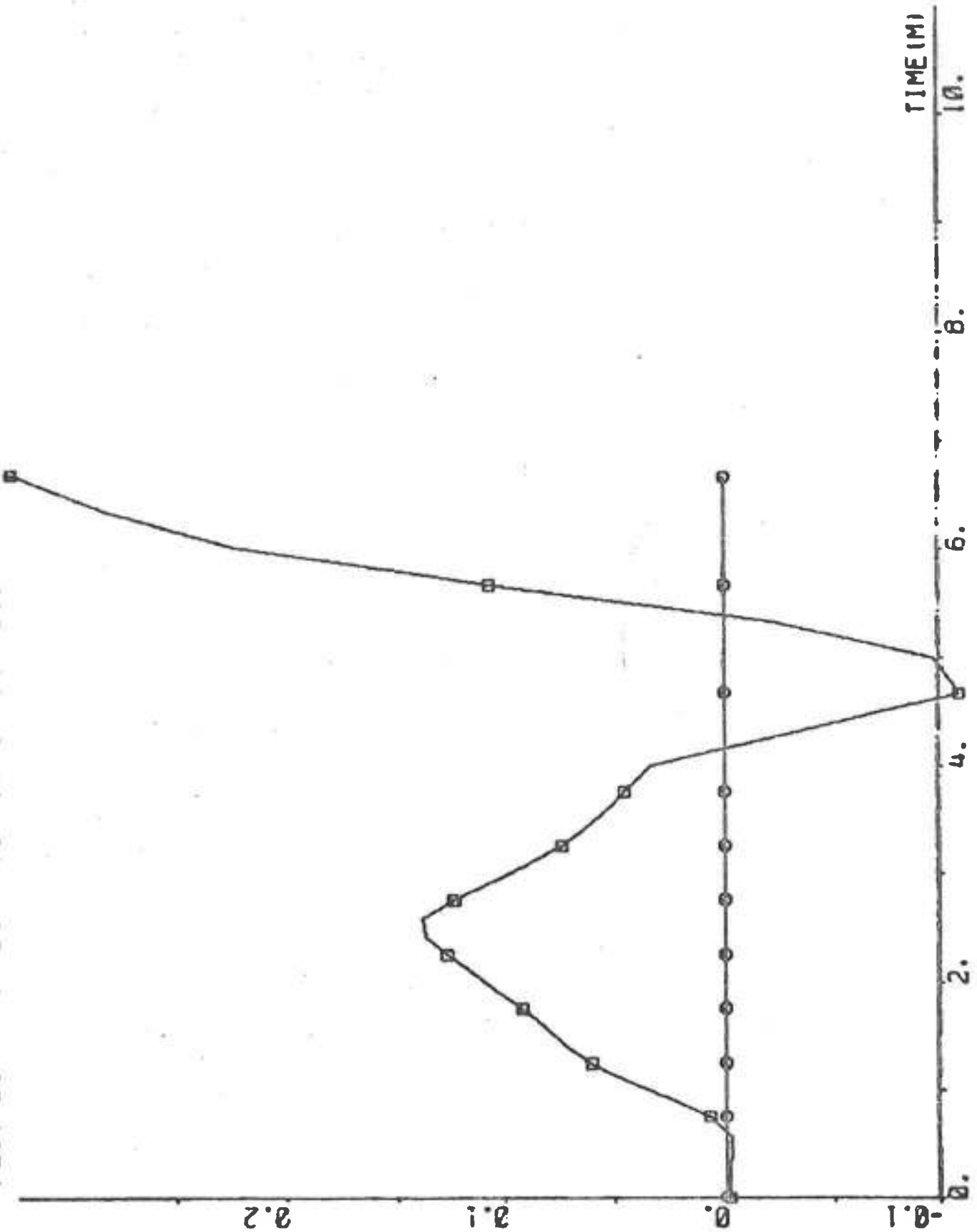

PLOT BSP1(16)-BSP1(5) ZERO -0.02 0 "PP DEG/S
-0.02
-0.015
-2.21
-5.E-3
0.
2.
4.
6.
8.
10.
TIME(M)

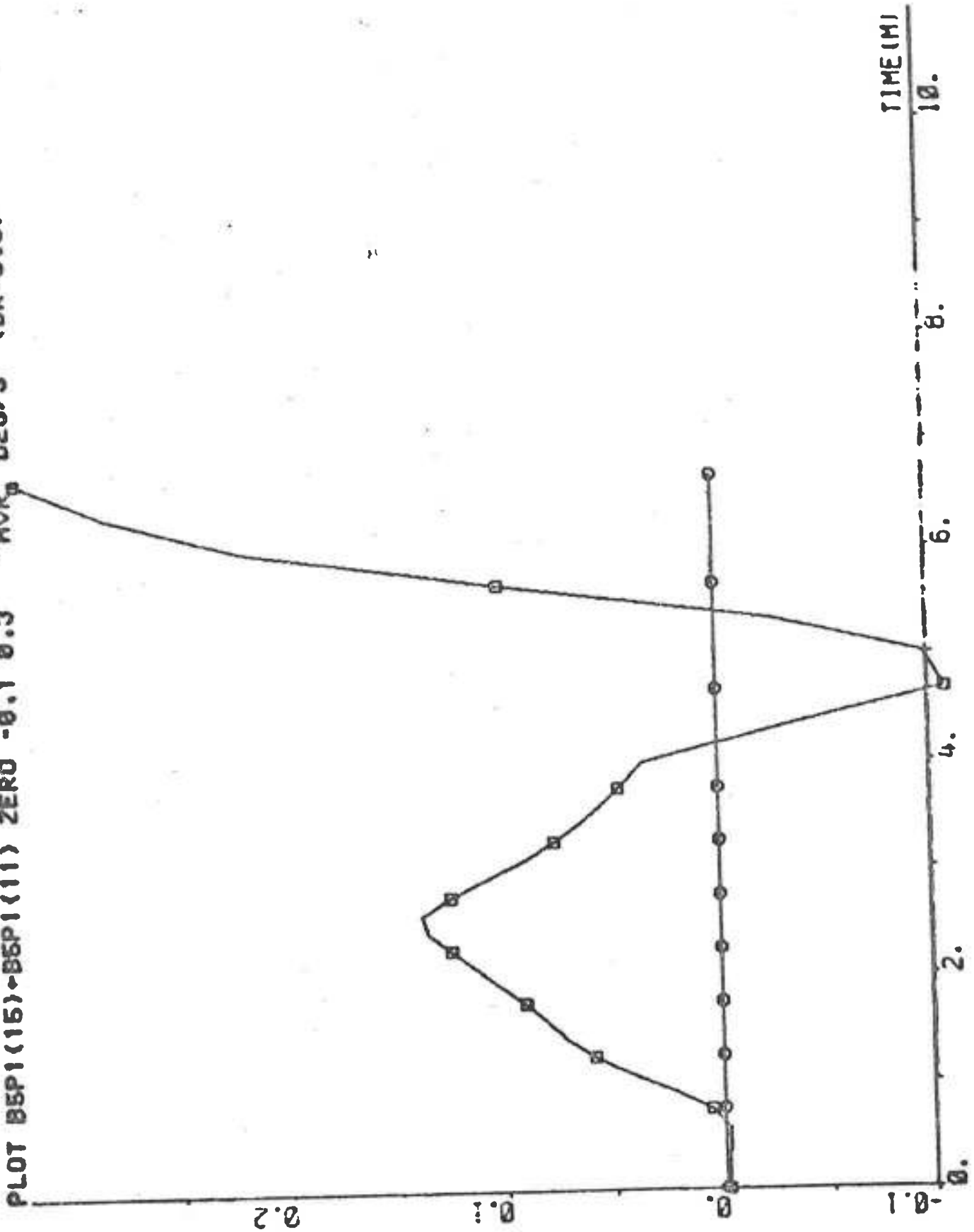

PLOT B5P1(15)-B5P1(6) 79 83 "AN RPM
92.
81.
80.
79.
TIME(M)
0.
2.
4.
6.
8.
10.

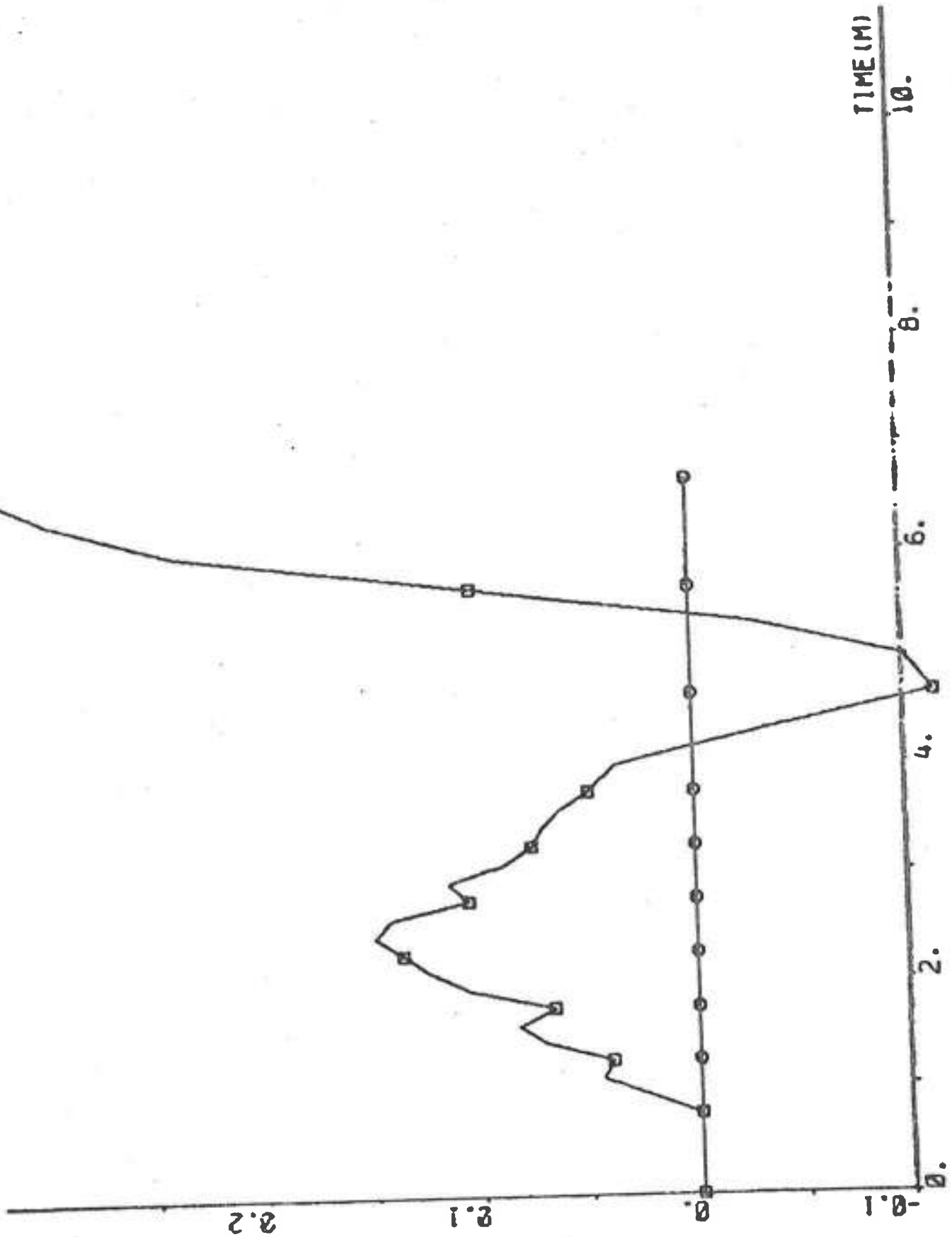

PLOT BSP1(16)-BSP1(7) 14 16 "U KNOTS
15.5
15.
14.5
14.
0.
2.
4.
6.
8.
10.
TIME(M)

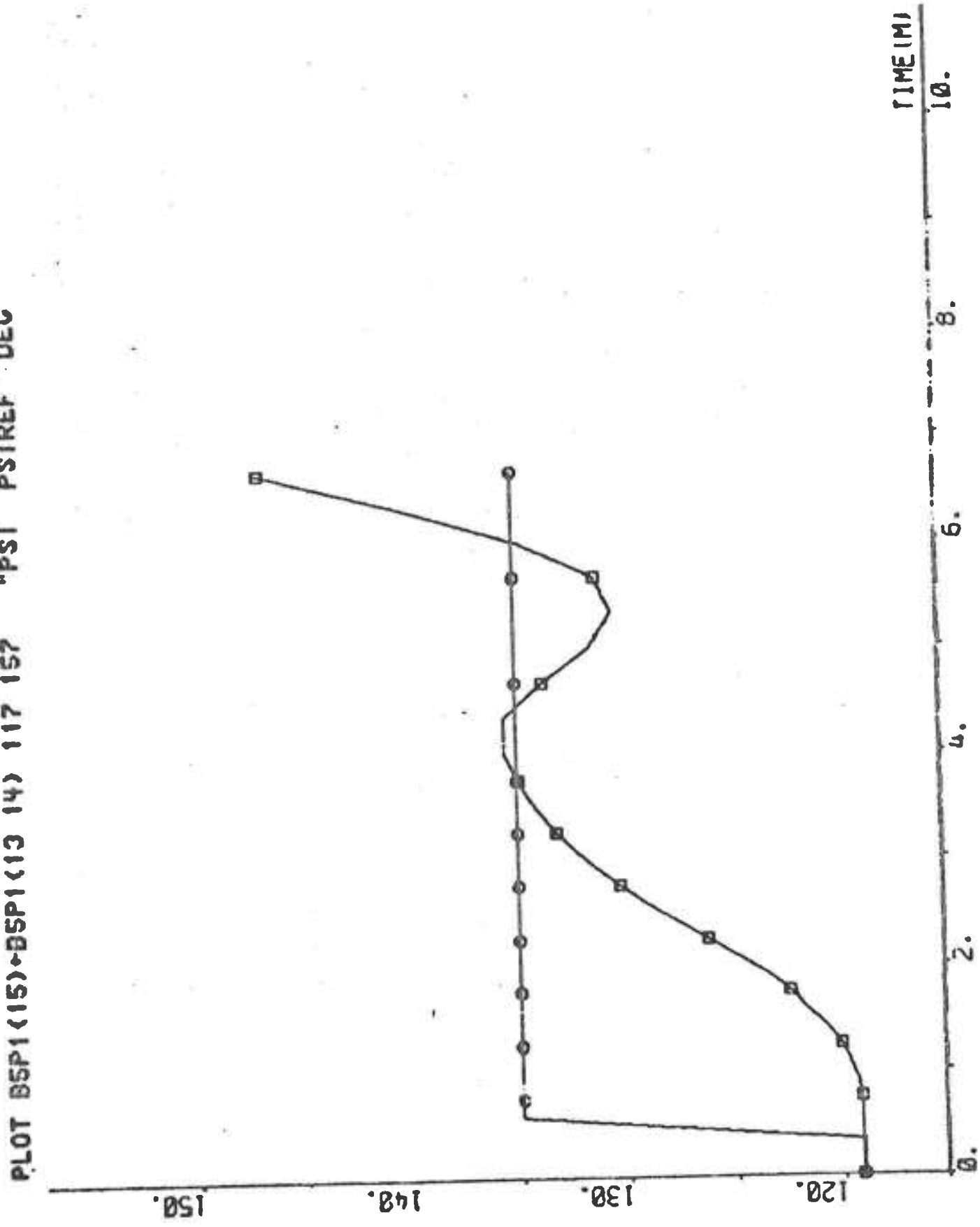

PLOT BSP1(15)-BSP1(8) 0.5 1.5 "V1 KNOTS
1.25
0.75
0.5
0.
2.
4.
6.
8.
10.
TIME(M)

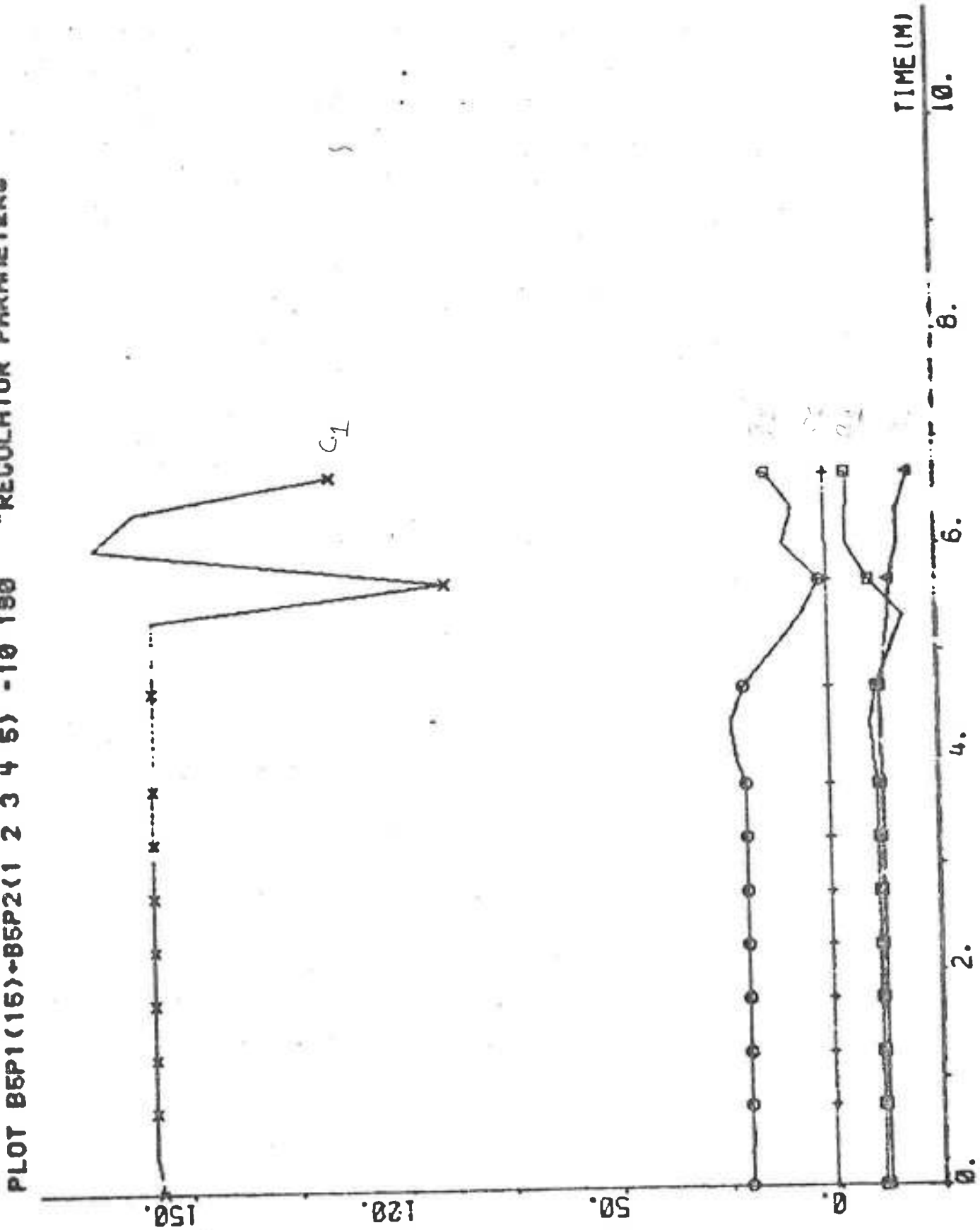

PLOT BSP1(15)-BSP1(9) ZERO -1 1 "V2 KNOTS
TIME(M)
0.
2.
4.
6.
8.
10.
-1.
-0.5
0.
0.5

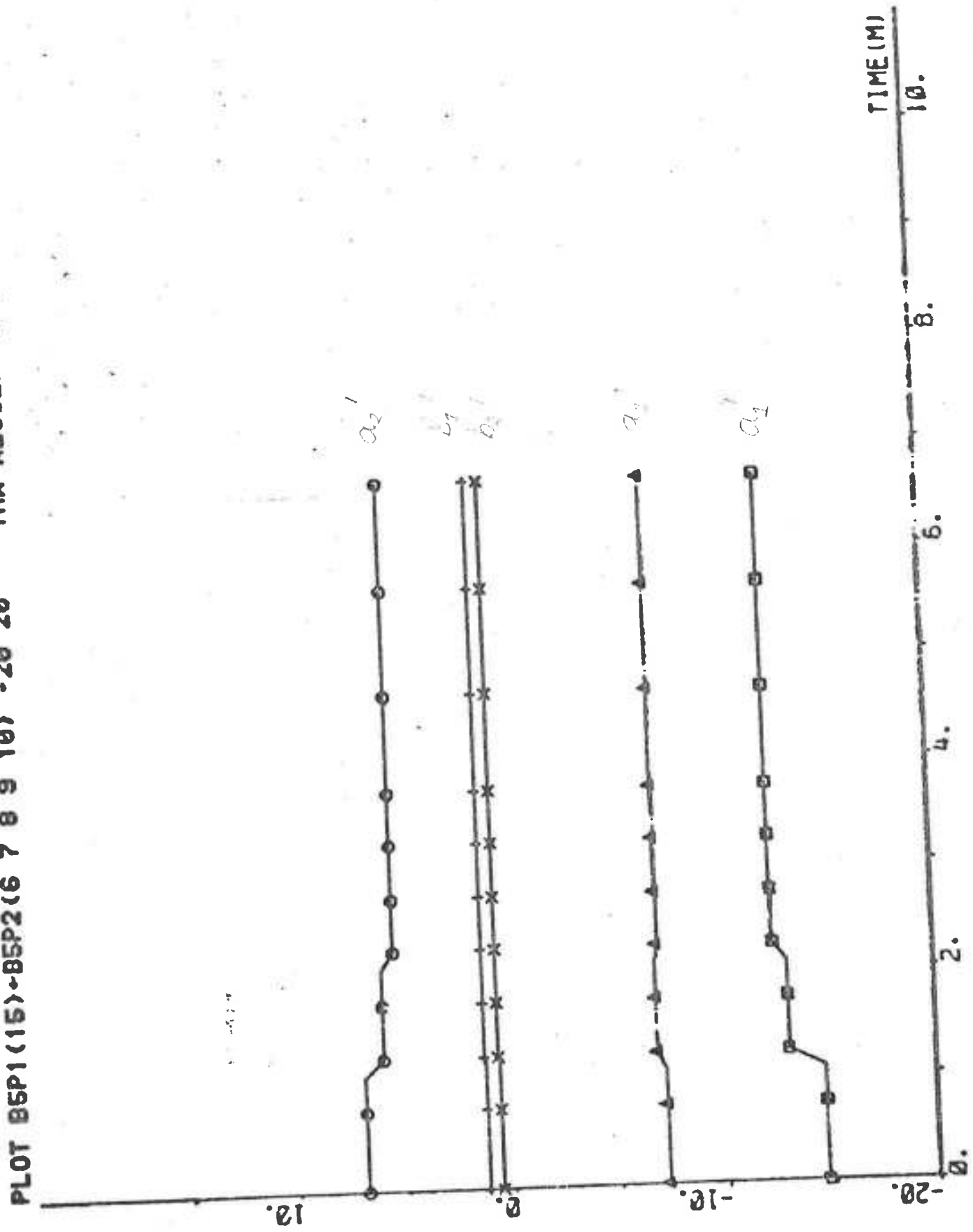

PLOT BSP1(15)-BSP1(10) ZERO -0.1 0.3 °R DEG/S
TIME(M)
0.
2.
4.
6.
8.
10.
-0.1
0.
0.1
0.2

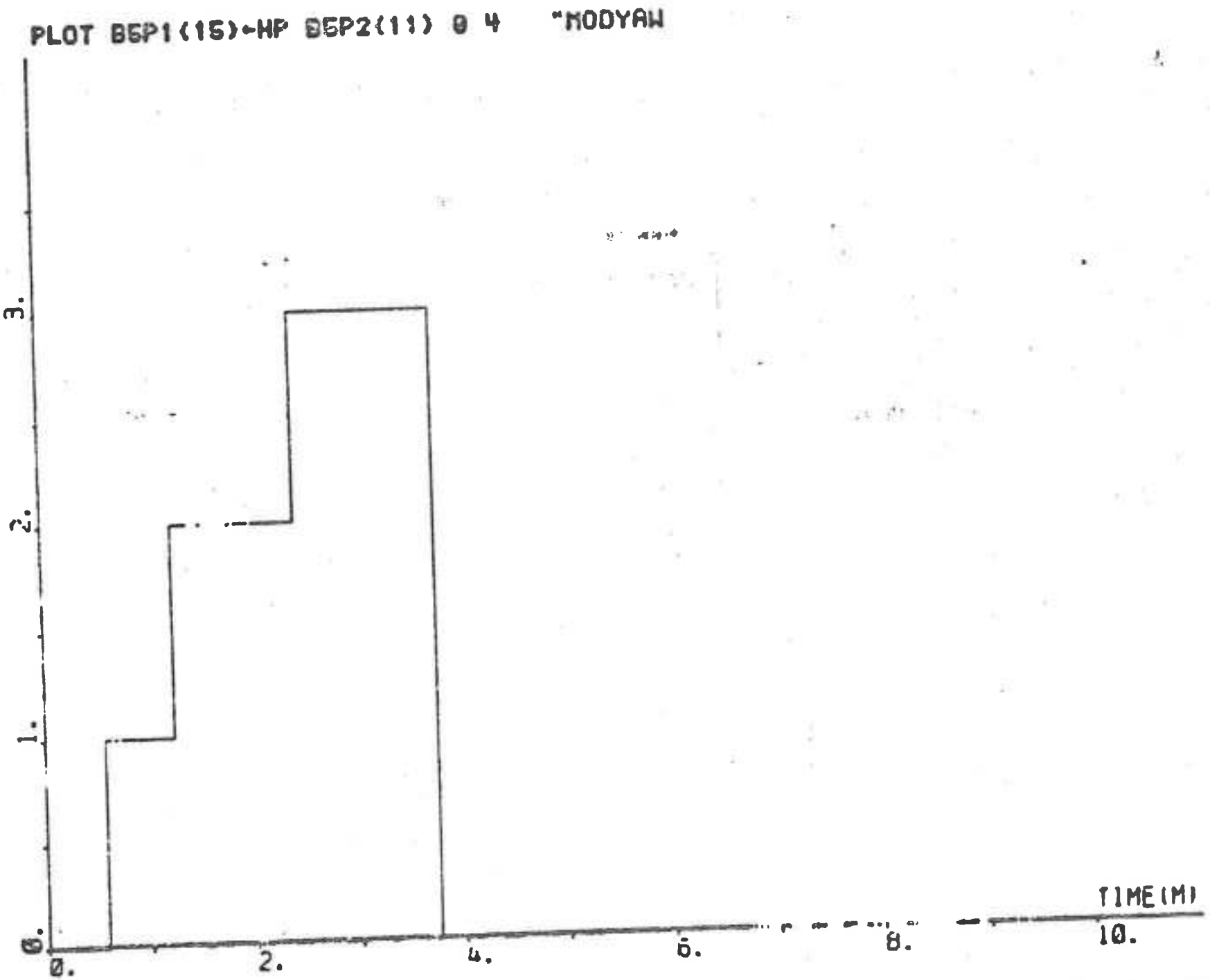

PLOT BSP1(15)-BSP1(11) ZERO -0.1 0.3
*AVR DEG/S (BR=0.5)
TIME(M)
0.
2.
4.
6.
8.
10.
-0.1
0.
0.1
0.2


PLOT BSP1(15)-BSP1(12) ZERO -0.1 0.3 "DPBIDT DEG/S (IDPS1=5)
-0.1
0.
0.1
0.2
0.
2.
4.
6.
8.
10.
TIME(M)


PLOT BSP1(15)-BSP1(13 14) 117 157 "PSI PSIREF DEC
150.
140.
130.
120.
0.
2.
4.
6.
8.
10.
TIME(M)


PLOT B5P1(15)-B5P2(1 2 3 4 5) -10 100 "REGULATOR PARAMETERS
TIME(M)
0.
2.
4.
6.
8.
10.
0.
50.
120.
150.
C_1


PLOT BSP1(15)-BSP2(6 7 8 9 10) -20 20
"YAW REGULATOR PARAMETERS
TIME(M)
0.
2.
4.
6.
8.
10.
-20.
-10.
0.
10.


PLOT B6P1(15)-HP B6P2(11) 0 4 "MODYAW
3.
2.
1.
0.
0.
2.
4.
6.
8.
10.
TIME(M)

EXPERIMENT B6

Date	1974-10-11
Time	08.51
Duration	25 min
Position	N 26° 10' E 54° 33'
Water depth	90 m
Forward draught	20.1 m
Aft draught	20.4 m
Wind direction	-
Wind velocity	0 Beaufort (0-0.5 m/s, calm)
Wave height	0 m
PSIREF	110°, 97°
RREF	0.07 deg/s
Rudder limit	Not active
DELlM at termination	0.24°
Approximate mean value of AN	82.5 rpm
Approximate mean value of U	14.8 knots

A program error caused the off-diagonal elements of the covariance matrix P for the straight course regulator parameters to be put zero instead of the off-diagonal elements of PY for the yaw regulator parameters, when phase 2 of the yaw regulator was initiated, which affected both the straight course keeping and the yawing.

Regulator structure

NA = 3	NB = 1	NC = 1	K = 4
IREG = 20	IRDIF = 0	RL = 0.98	IRR = 1

Final values.

$$\begin{bmatrix} a_1 \\ a_2 \\ a_3 \\ b_1 \\ c_1 \end{bmatrix} = \begin{bmatrix} -8.727 \\ 13.744 \\ -5.940 \\ 0.827 \\ 37.450 \end{bmatrix} \qquad P = \begin{bmatrix} 11.061 & & & & \\ -15.415 & 22.683 & & & \\ 4.340 & -7.343 & 3.120 & & \\ -0.208 & 0.247 & -0.043 & 0.053 & \\ 130.941 & -172.030 & 35.542 & -1.192 & 2176.874 \end{bmatrix}$$

$a_1 + a_2 + a_3 = -0.923$

Yaw regulator structure

NAY = 3	NBY = 2	KY = 5
IREGY = 10	RLY = 0.95	IRR = 1
AK1V = 30	AK2V = 1.4	AK3V = 130
C1V = 10	C2V = 70	
EPS1V = 0.02	EPS2V = 0.03	
PSISV = 0.2	PSISSV = 1.5	PSIMAV = 0.6
I1MV = 100	I2MV = 300	I3MV = 180

Initial yaw regulator values

$$\begin{bmatrix} a_1' \\ a_2' \\ a_3' \\ b_1' \\ b_2' \end{bmatrix} = \begin{bmatrix} -14.6 \\ 6.9 \\ -7.2 \\ 1.2 \\ 0.6 \end{bmatrix} \qquad PY = \begin{bmatrix} 1000 & & & & \\ 0 & 1000 & & & \\ 0 & 0 & 1000 & & \\ 0 & 0 & 0 & 10 & \\ 0 & 0 & 0 & 0 & 10 \end{bmatrix}$$

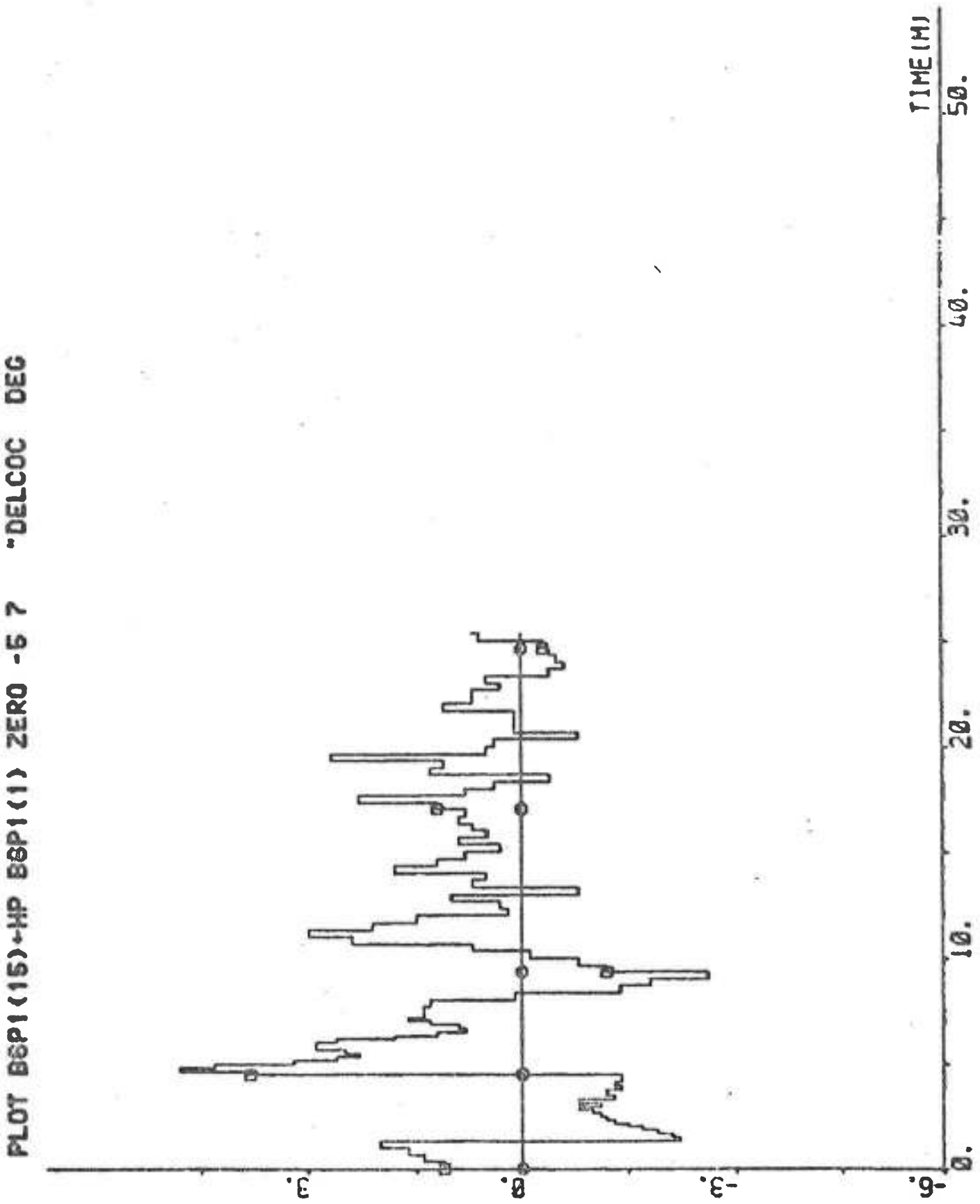
$a_1' + a_2' + a_3' = -14.9$

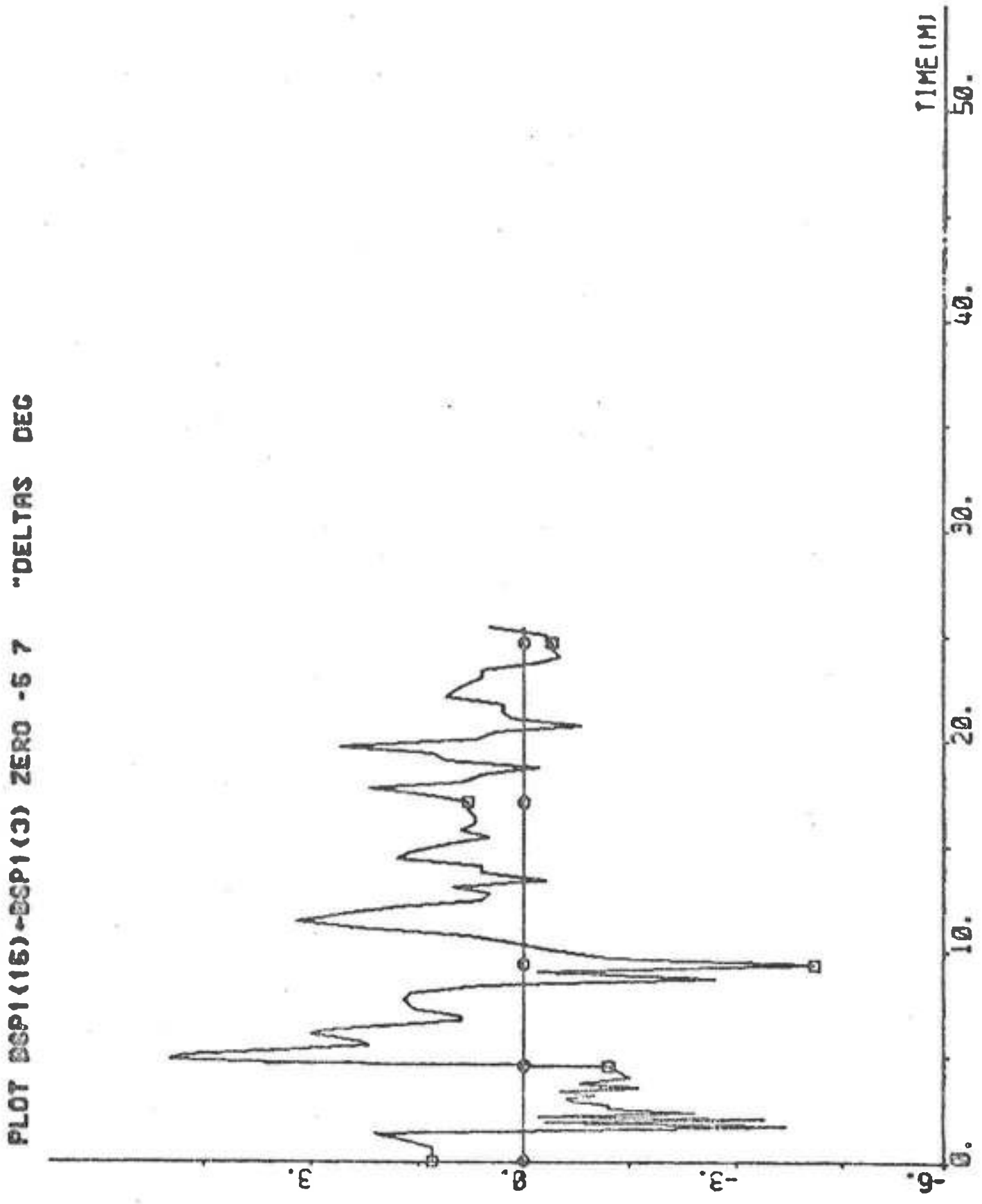
Final yaw regulator values

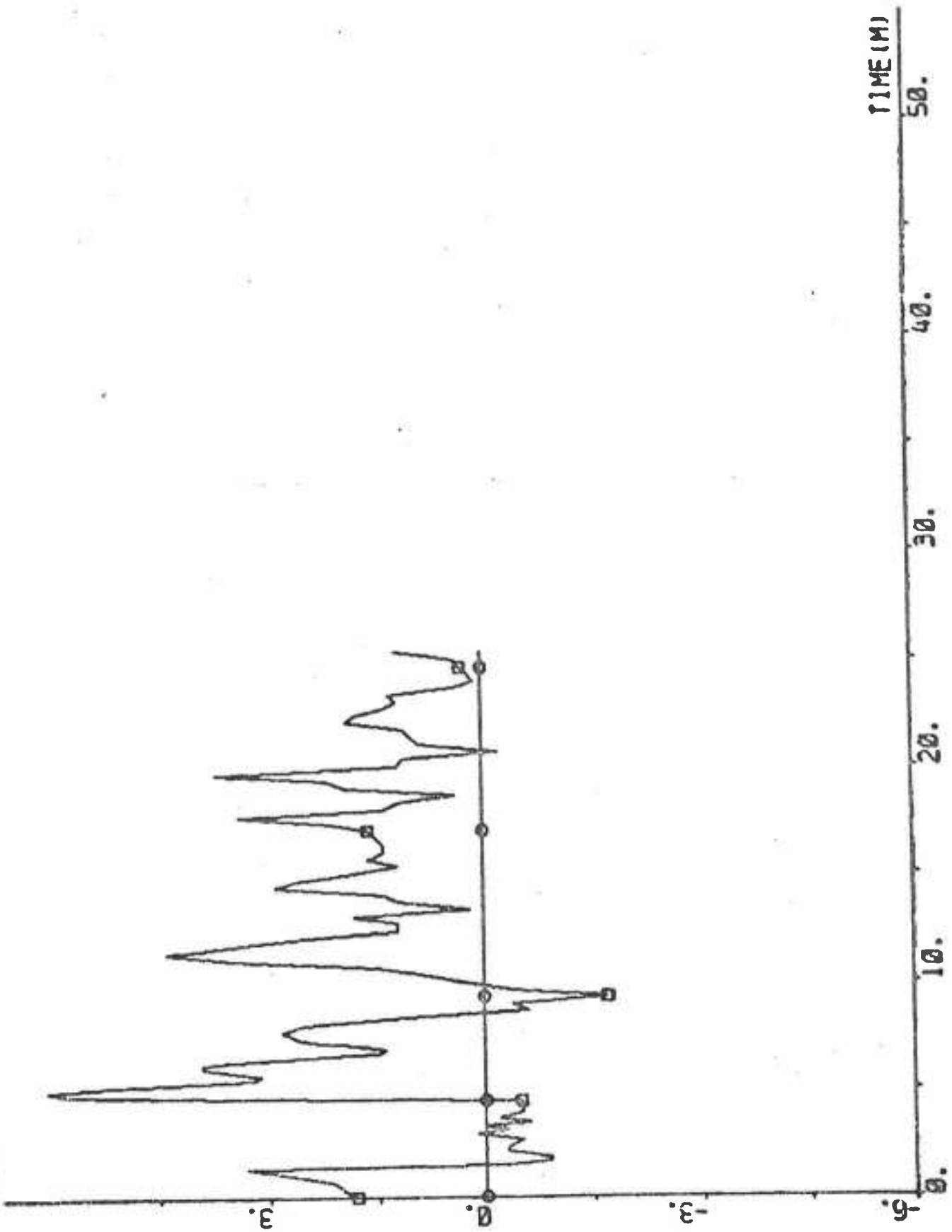
$$\begin{bmatrix} a_1' \\ a_2' \\ a_3' \\ b_1' \\ b_2' \end{bmatrix} = \begin{bmatrix} -14.735 \\ 7.179 \\ -6.892 \\ 1.193 \\ 0.556 \end{bmatrix} \qquad PY = \begin{bmatrix} 729.805 & & & & \\ -726.671 & 1835.190 & & & \\ -293.449 & -2531.493 & -26.471 & & \\ -7.714 & -113.121 & 93.922 & 12.354 & \\ 39.709 & 81.460 & 348.347 & 8.278 & -35.225 \end{bmatrix}$$

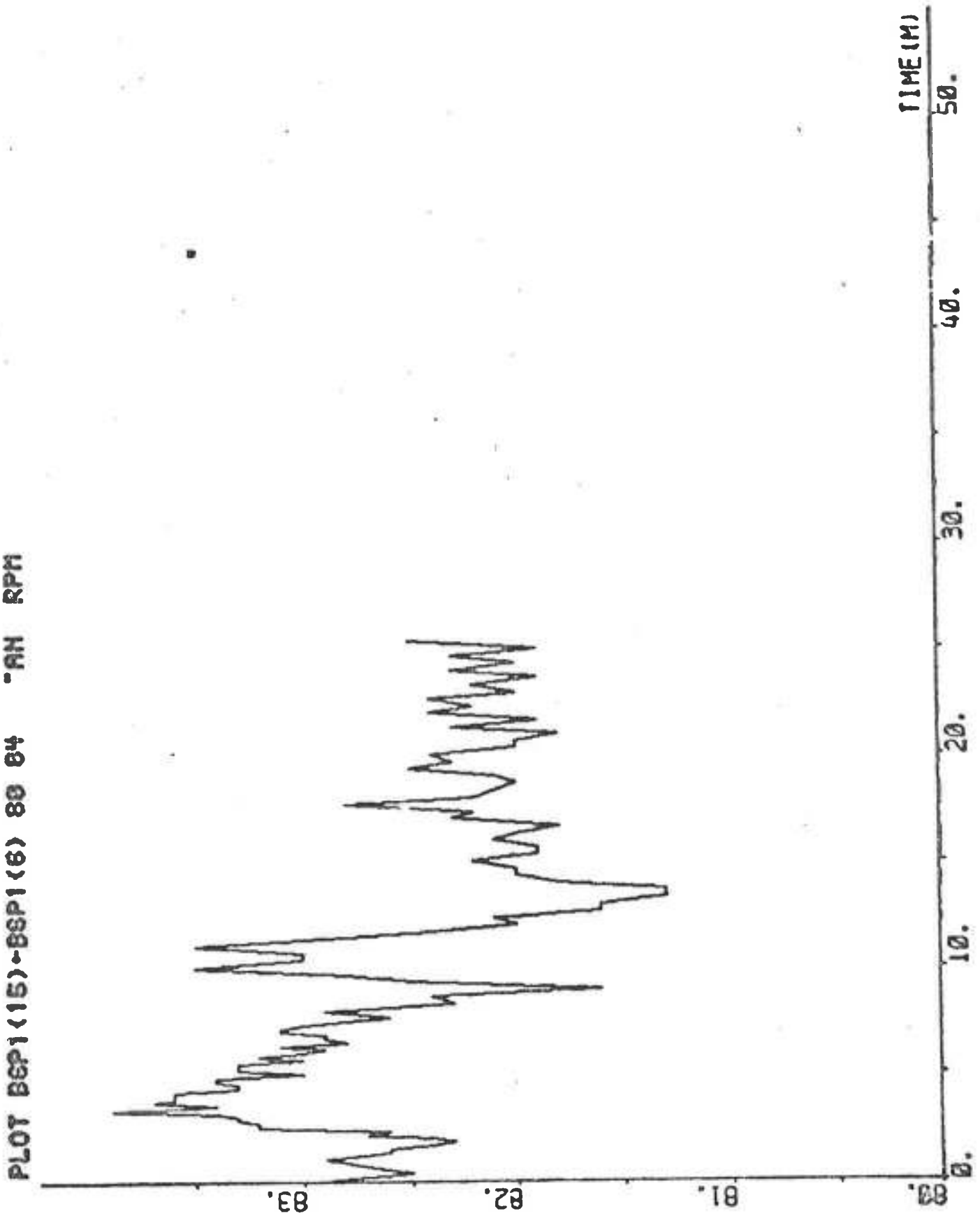
$a_1' + a_2' + a_3' = -14.448$

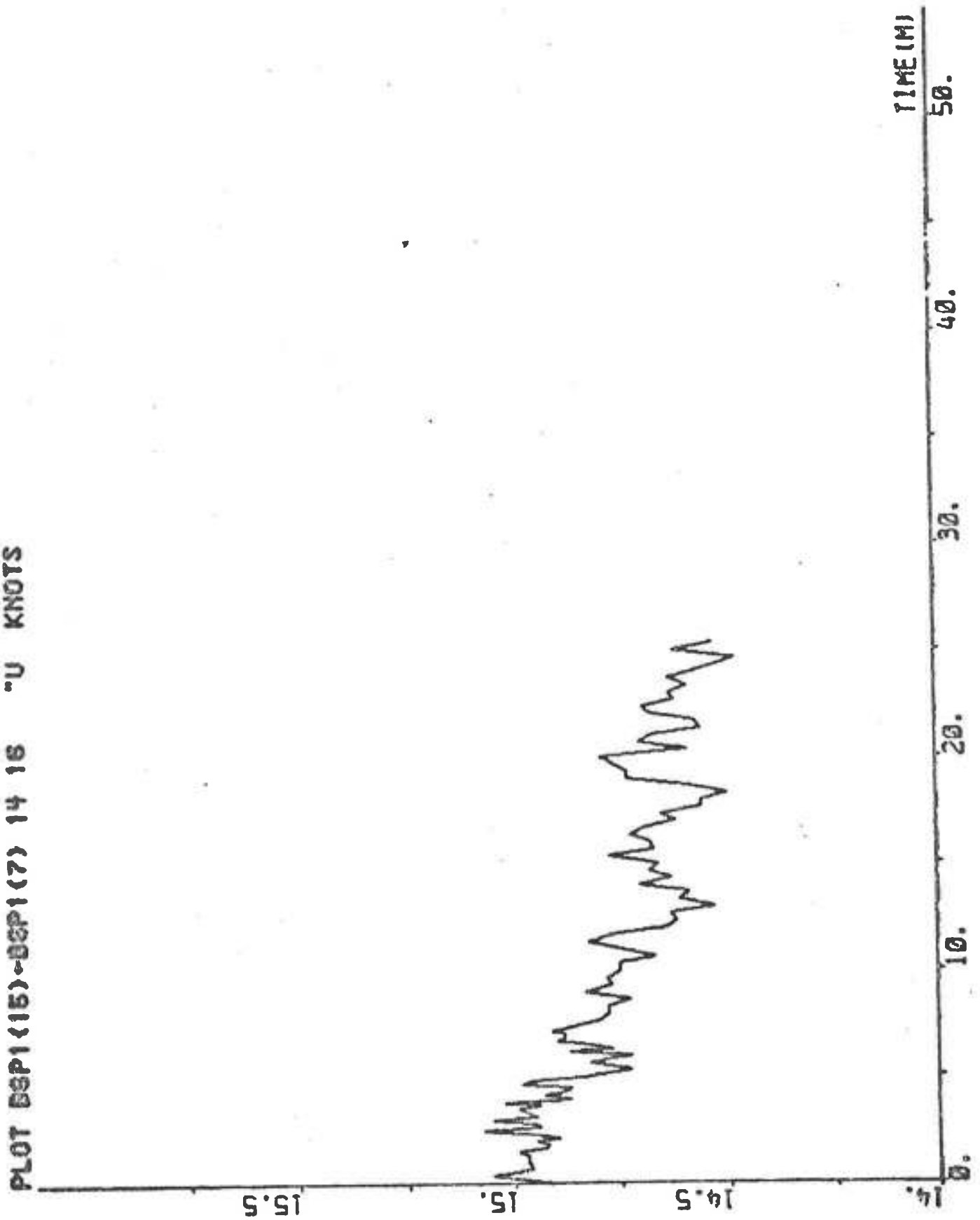
Notice that PY is not positive definite, because of the program error mentioned above.

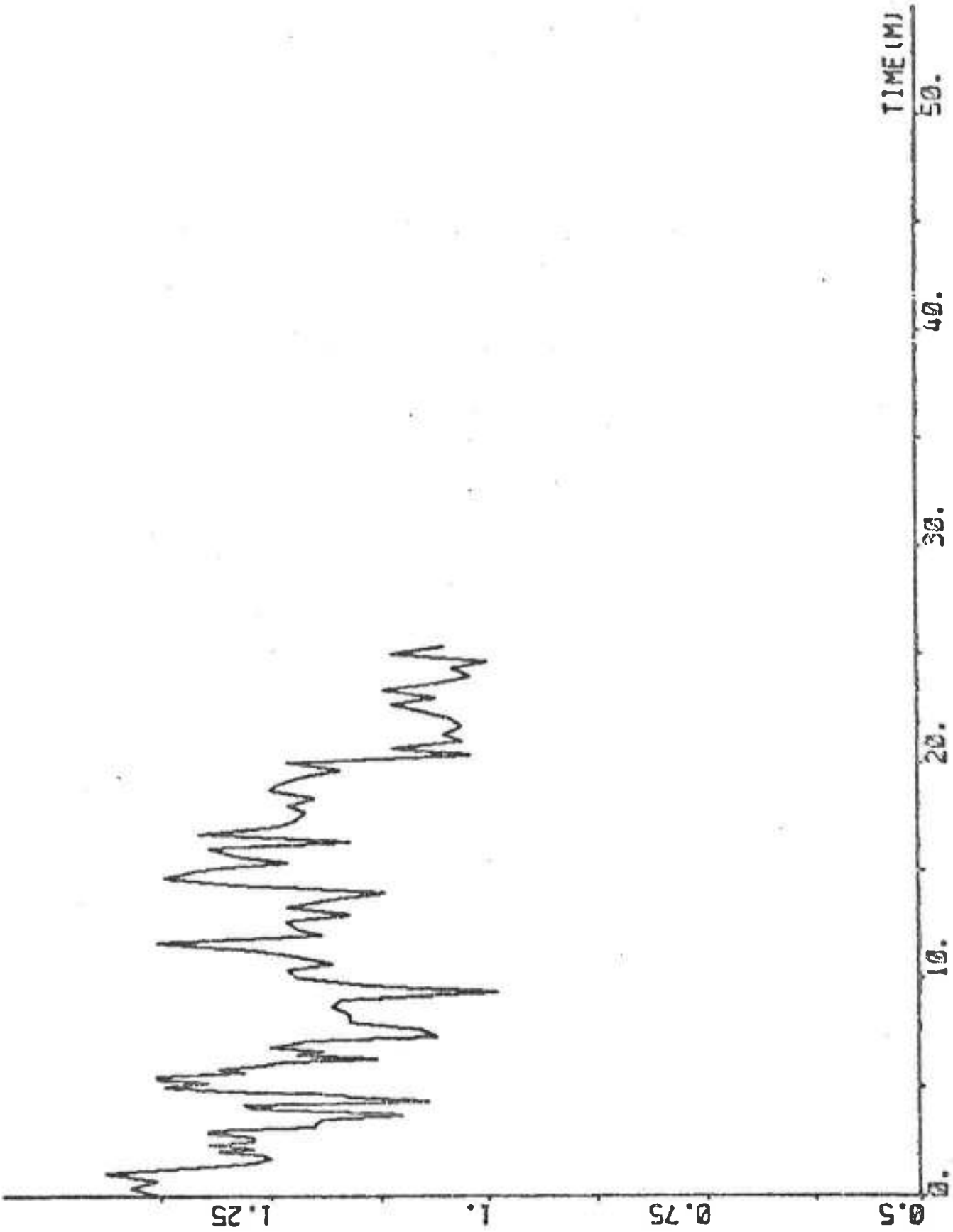

PLOT BSP1(15)-HP BSP1(1) ZERO -5 7 "DELCOC DEG
3.
0.
-3.
-6.
0.
10.
20.
30.
40.
50.
TIME(M)

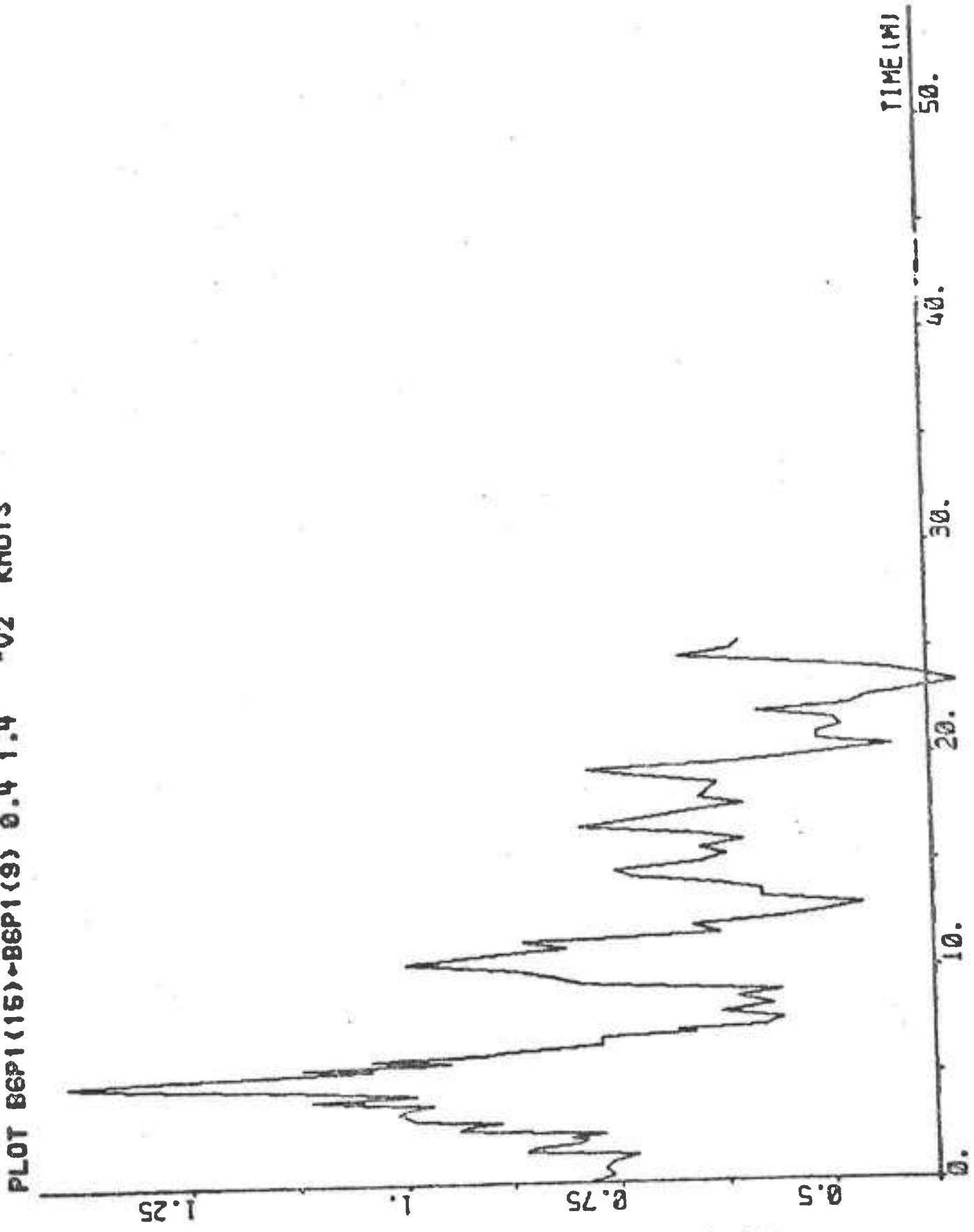

PLOT BSP1(16)-BSP1(3) ZERO -5 7 "DELTAS DEG
6.
3.
0.
-3.
-6.
0.
10.
20.
30.
40.
50.
TIME(MI)

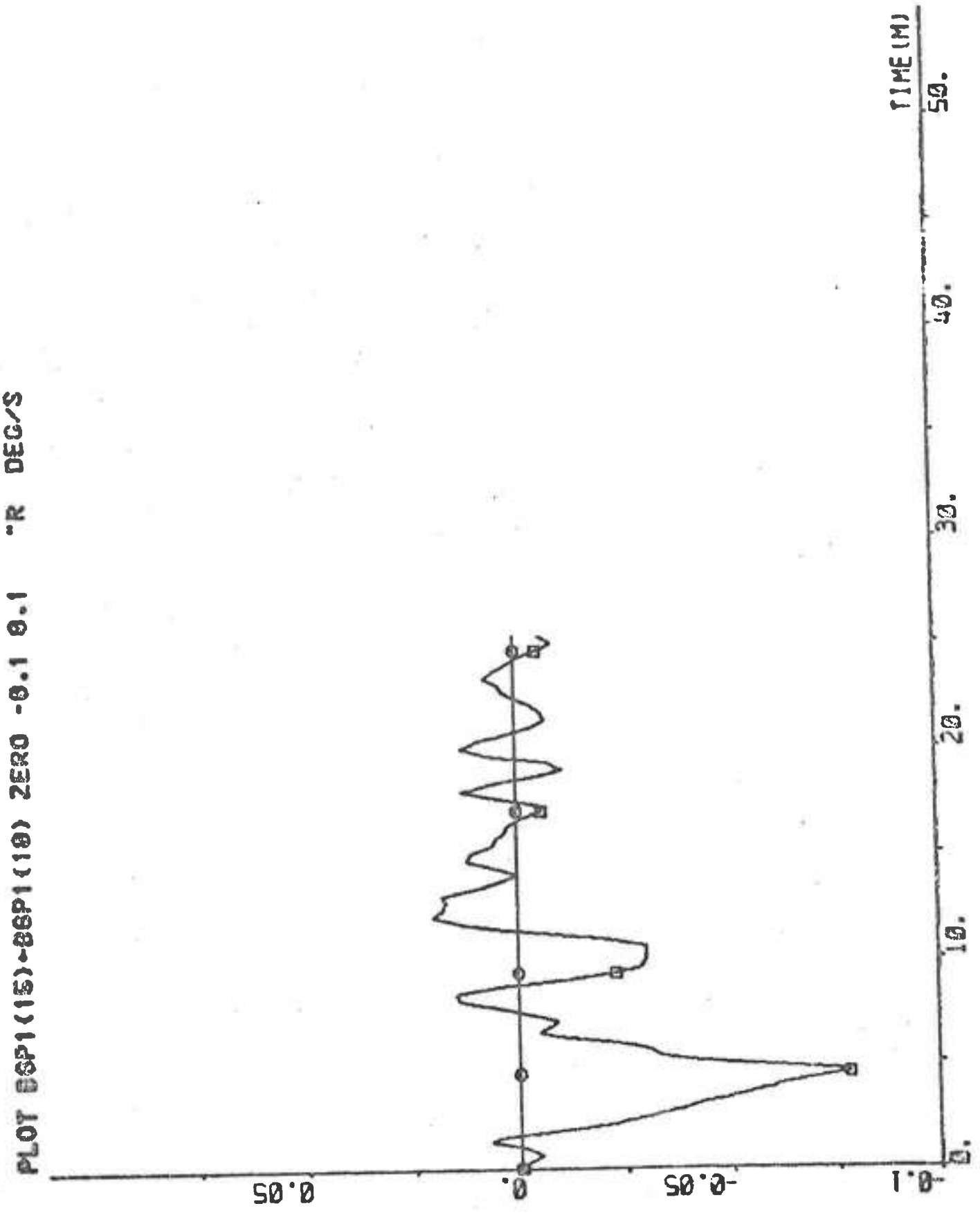

PLOT BSP1(15)-BSP1(4) ZERO -5 7 "DELTA DEC
3.
0.
-3.
-6.
0.
10.
20.
30.
40.
50.
TIME(M)

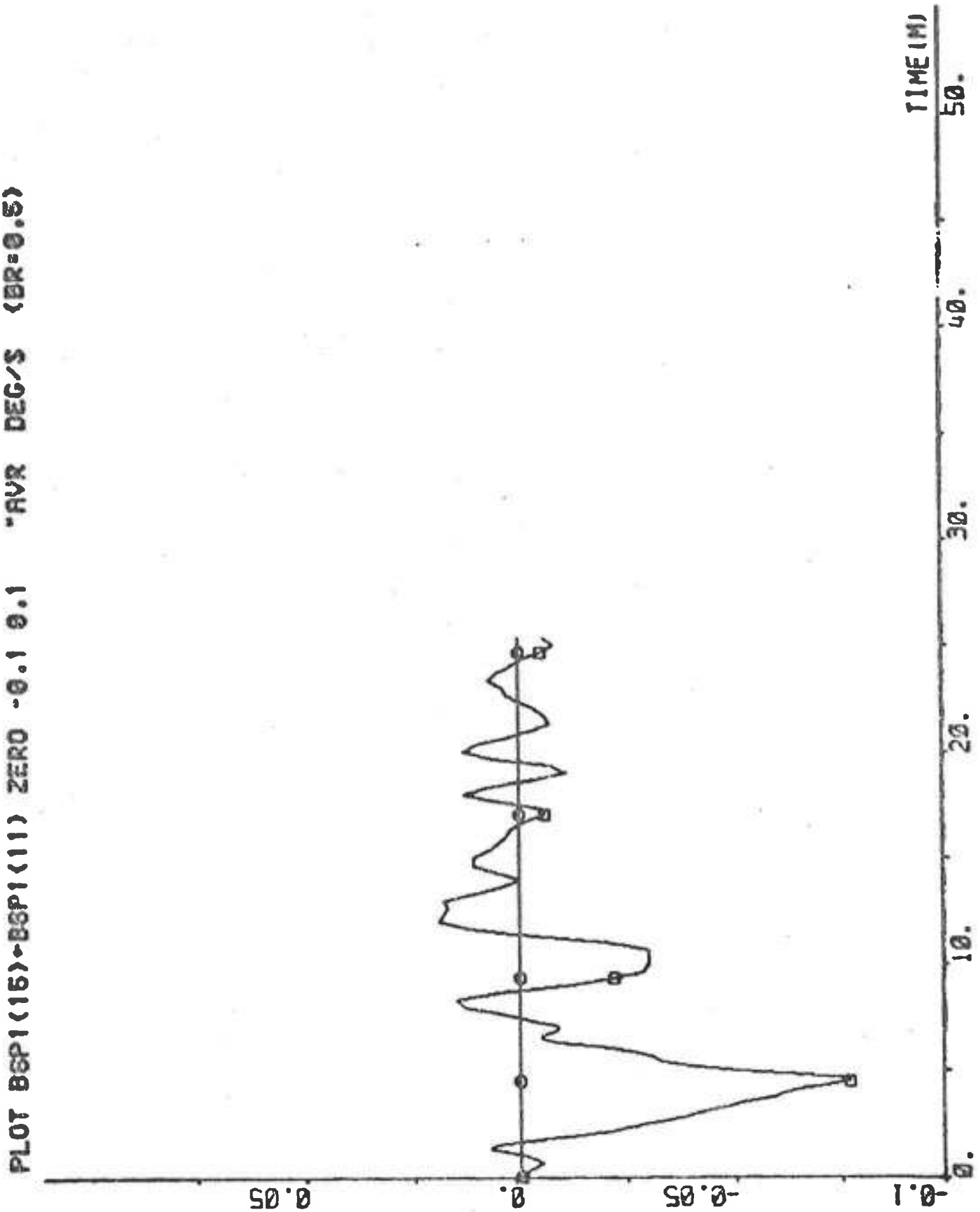

PLOT BSP1(15)-BSP1(6) 80 84 *AN RPM
83.
82.
81.
80.
0.
10.
20.
30.
40.
50.
TIME(M)

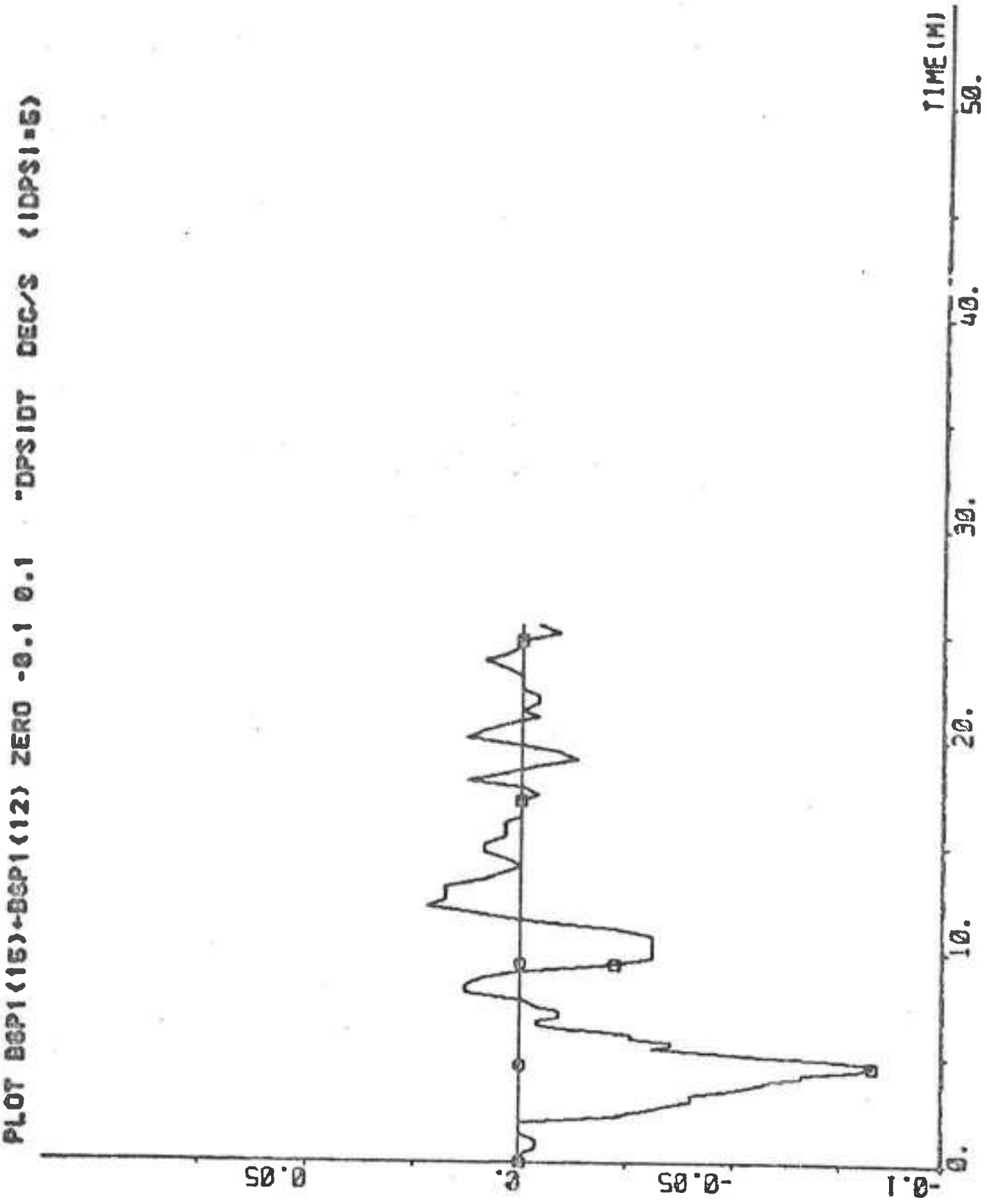

PLOT BSP1(15)-BSP1(7) 14 18 "U KNOTS
15.5
15.
14.5
14.
0.
10.
20.
30.
40.
50.
TIME(M)

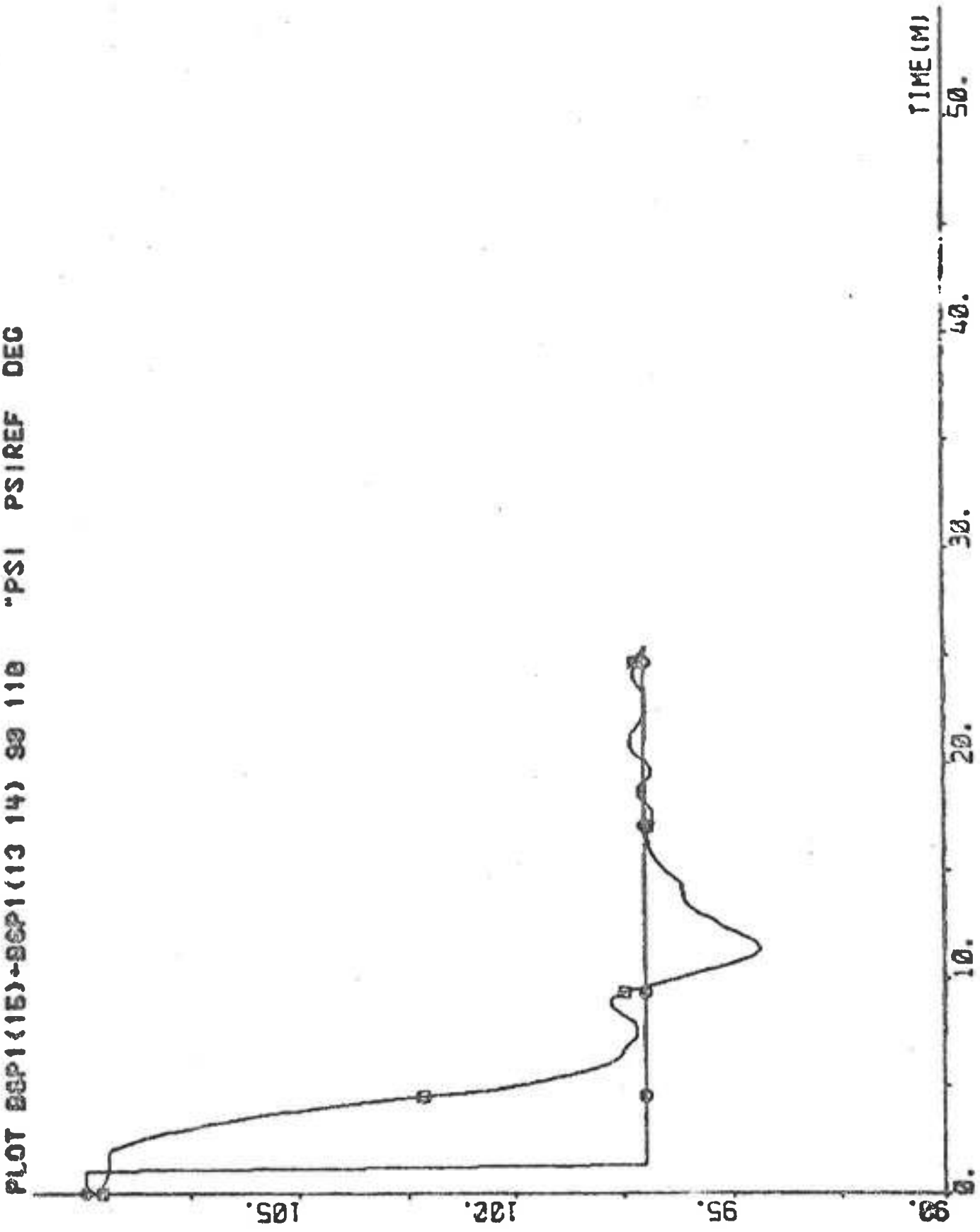

PLOT BSP1(15)+BBP1(8) 0.5 1.5 *V1 KNOTS
0.5
0.75
1.
1.25
0.
10.
20.
30.
40.
50.
TIME(M)

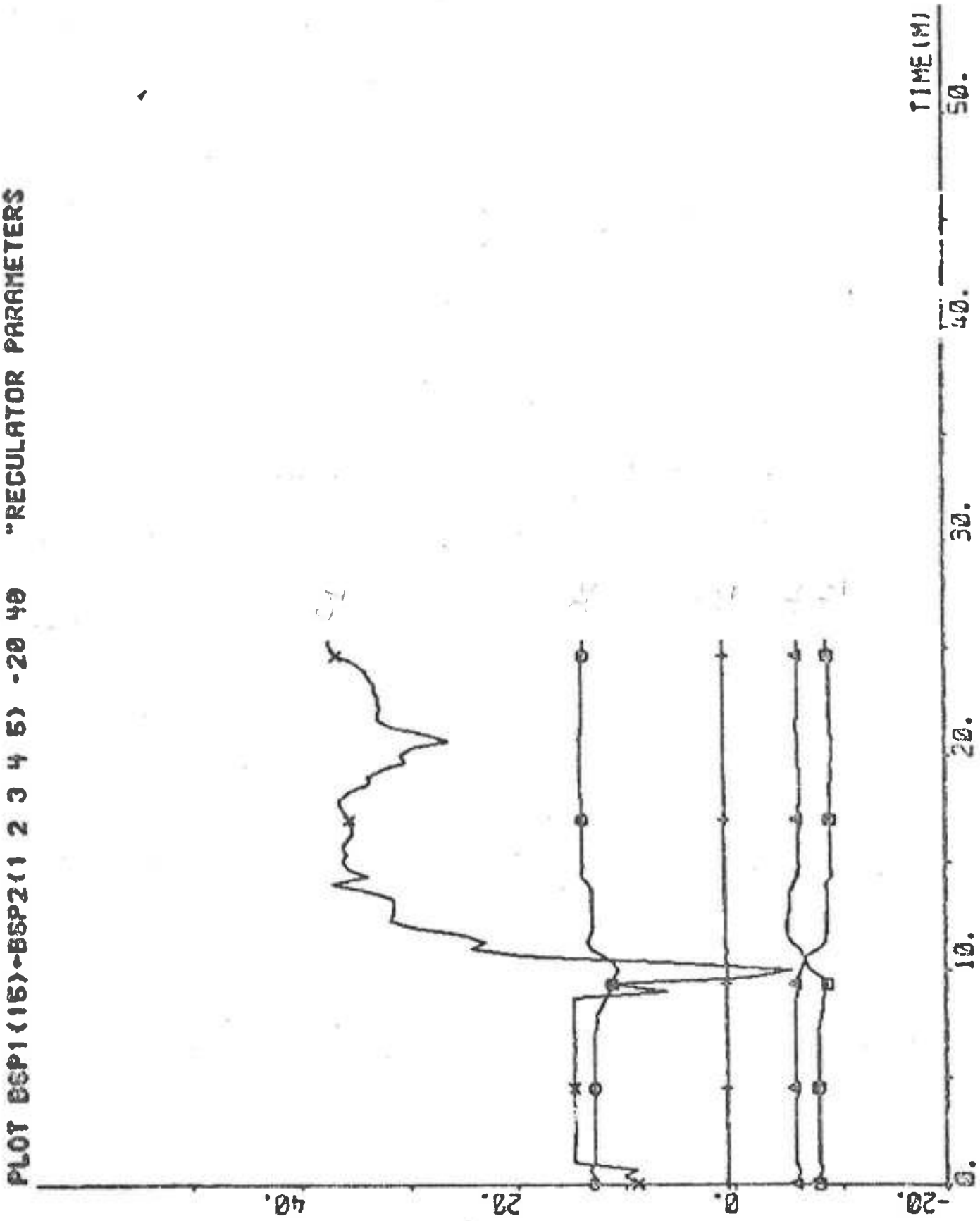

PLOT BBP1(15)-BBP1(9) 0.4 1.4 *V2 KNOTS
TIME(M)
0.
10.
20.
30.
40.
50.
0.5
0.75
1.
1.25


PLOT BSP1(15)-BSP1(10) ZERO -0.1 0.1 "R DEG/S
0.05
0.
-0.05
-0.1
0.
10.
20.
30.
40.
50.
TIME(M)

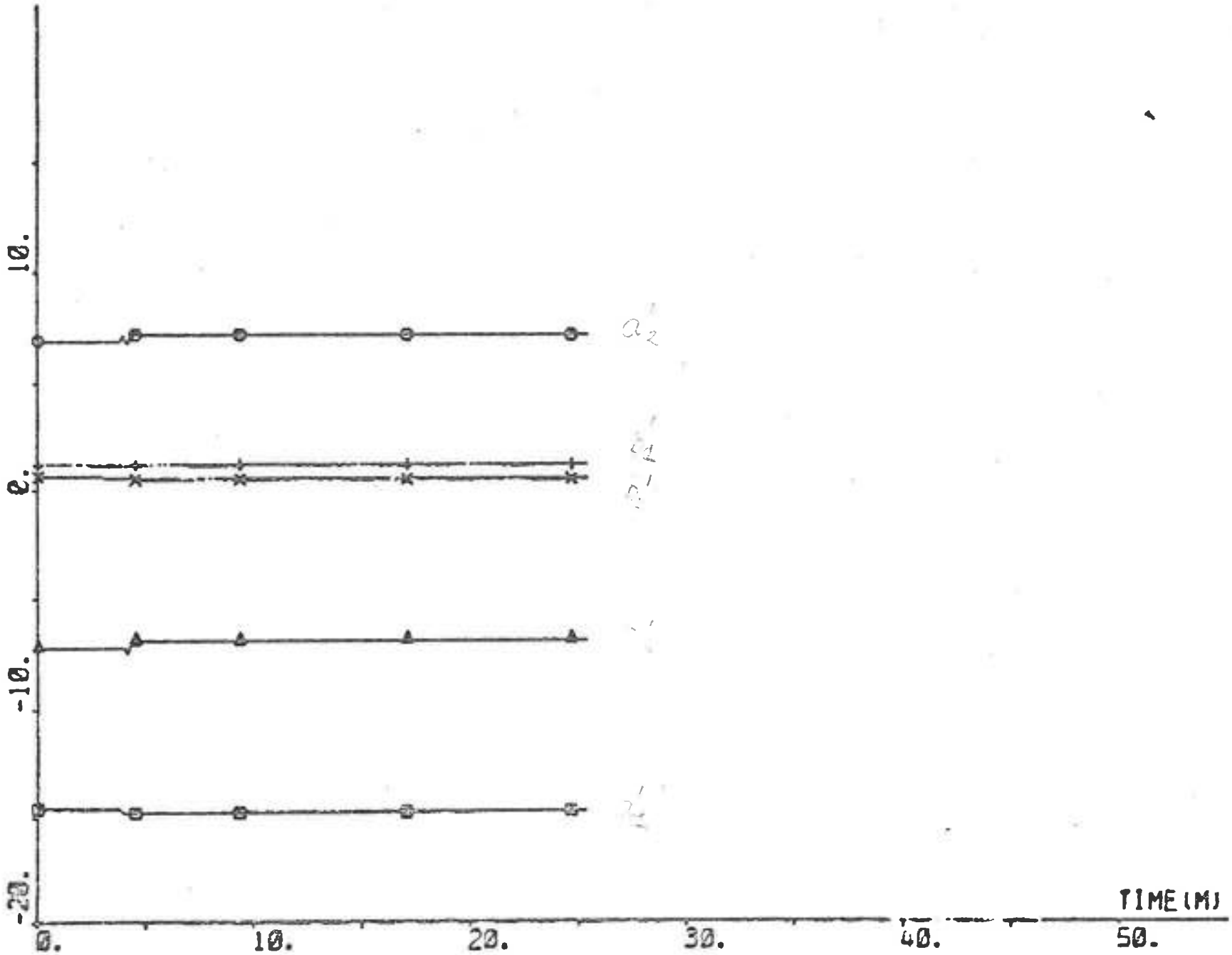

PLOT BSP1(16)-BSP1(11) ZERO -0.1 0.1 "AVR DEG/S (BR=0.5)
0.05
0.
-0.05
-0.1
0.
10.
20.
30.
40.
50.
TIME(M)

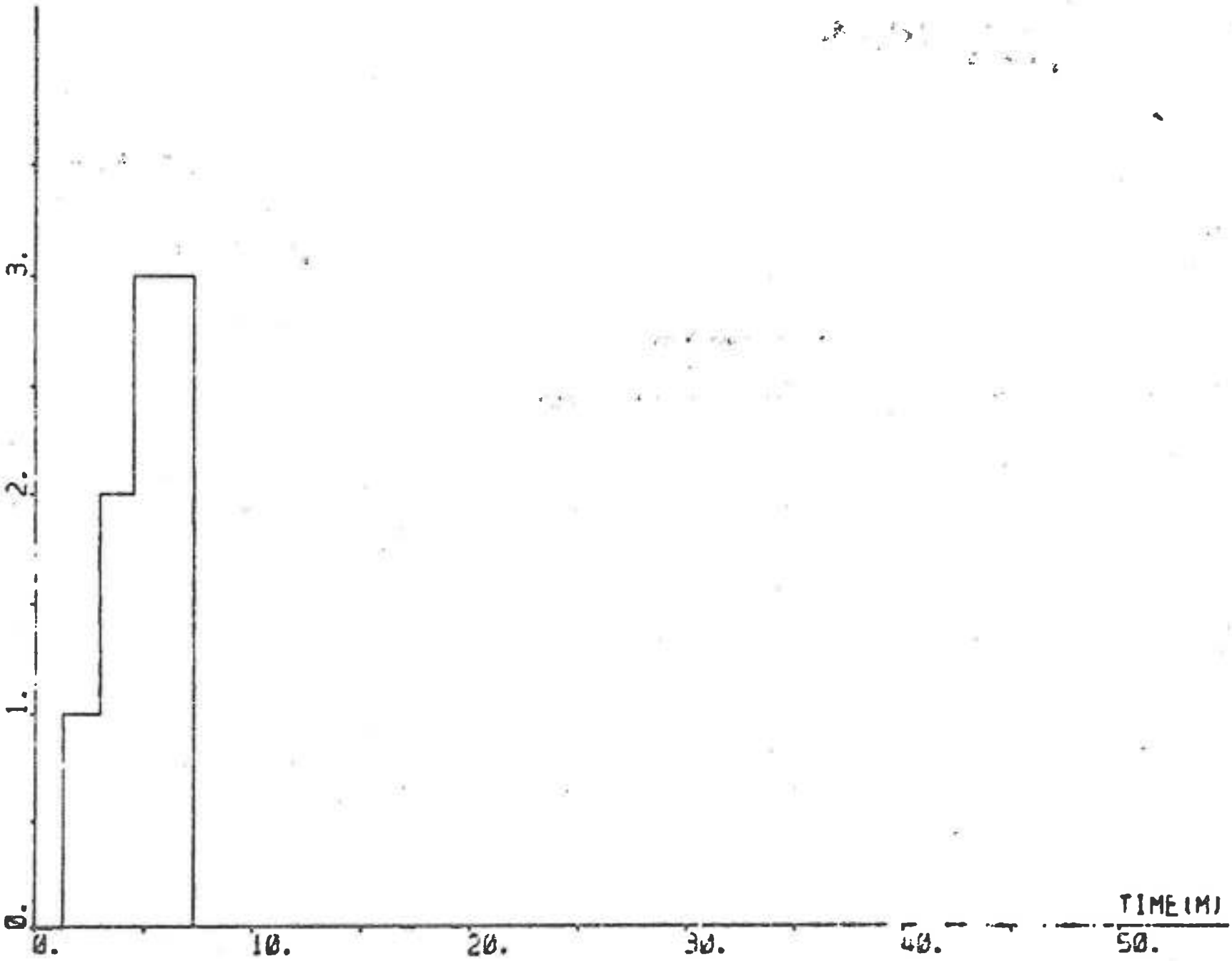

PLOT BSP1(15)-BSP1(12) ZERO -0.1 0.1 "DPSIDT DEG/S (IDPSI=6)
0.05
0.
-0.05
-0.1
0.
10.
20.
30.
40.
50.
TIME(M)


PLOT BSP1(15)-BSP1(13 14) 90 110 "PSI PSIREF DEG
88.
95.
102.
105.
0.
10.
20.
30.
40.
50.
TIME(M)


PLOT BSP1(16)-BSP2(1 2 3 4 5) -20 40 "REGULATOR PARAMETERS
40.
20.
0.
-20.
0.
10.
20.
30.
40.
50.
TIME(M)

PLOT BSP1(15)~BSP2(6 7 8 9 10) -20 20 "YAW REGULATOR PARAMETERS




PLOT B8P1(16)-HP B6P2(11) 0 4 "MODYAW
3.
2.
1.
0.
0.
10.
20.
30.
40.
50.
TIME(M)