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Källström, Claes

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1

THE SEA SWIFT EXPERIMENTS,
OCTOBER 1974 - PART III

Claes Källström

TABLE OF CONTENTS

Page

PART I

1. Introduction	1
2. Measurement Equipment	3
3. The Adaptive Autopilot	5
3.1. The straight course keeping regulator	6
3.2. The yaw regulator	7
4. Computer Programs	11
5. Discussion of the Experiments	13
5.1. The straight course keeping experiments	13
5.2. The yawing experiments	22
5.3. The experiments for identification	23
6. Conclusions	25
7. Acknowledgements	28
8. References	29
APPENDIX A - Notations	30
APPENDIX B - Program Listings	36
APPENDIX C - Experiments	45
A1	55
A2	69
A3	84
A4	96
A5	108
A6	120
A7	133
A8	146
A9	159
A10	172
A11	185
A12	201
A13	214
A14	227
A15	242
A16	255

PART II

Page

A17	268
A18	281
A19	294
A20	309
A21	323
A22	336
A23	349
A24	362
A25	375
A26	388
A27	401
A28	414
A29	427
A30	440
A31	453
A32	466
A33	479
A34	494
A35	507
A36	520

PART III

A37	533
A38	548
A39 A	563
A39 B	579
A40	594
A41	625
A42	642
A43	658
A44	673
A45	688
B1	703
B2	721

	<u>Page</u>
B3	740
B4	758
B5	775
B6	794

PART IV

B7	811
B8	829
B9	830
B10	847
B11	868
B12	887
B13	906
B14	926
B15	943
C1	962
C2	973
C3	984
D1	996
D2	1007
E1	1018
E2	1032
E3	1047
E4	1061

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

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

$$a_1 + a_2 + a_3 = -0.077$$

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

DELCO DEC

A37P1(1) ZERO -20 20

A37P1(15) HP

TIME (M)
100.

80.

60.

40.

20.

-20.

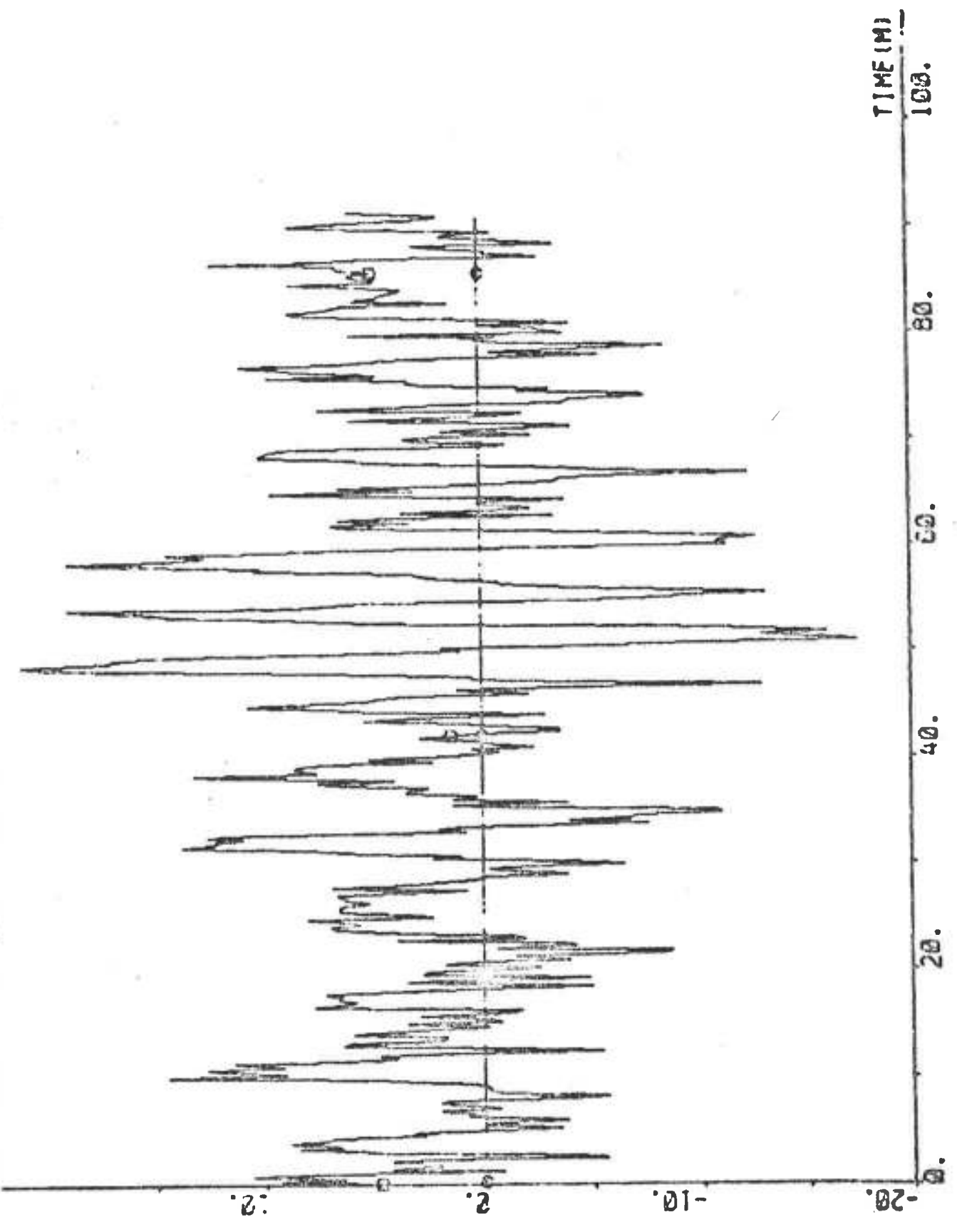
0.

2.

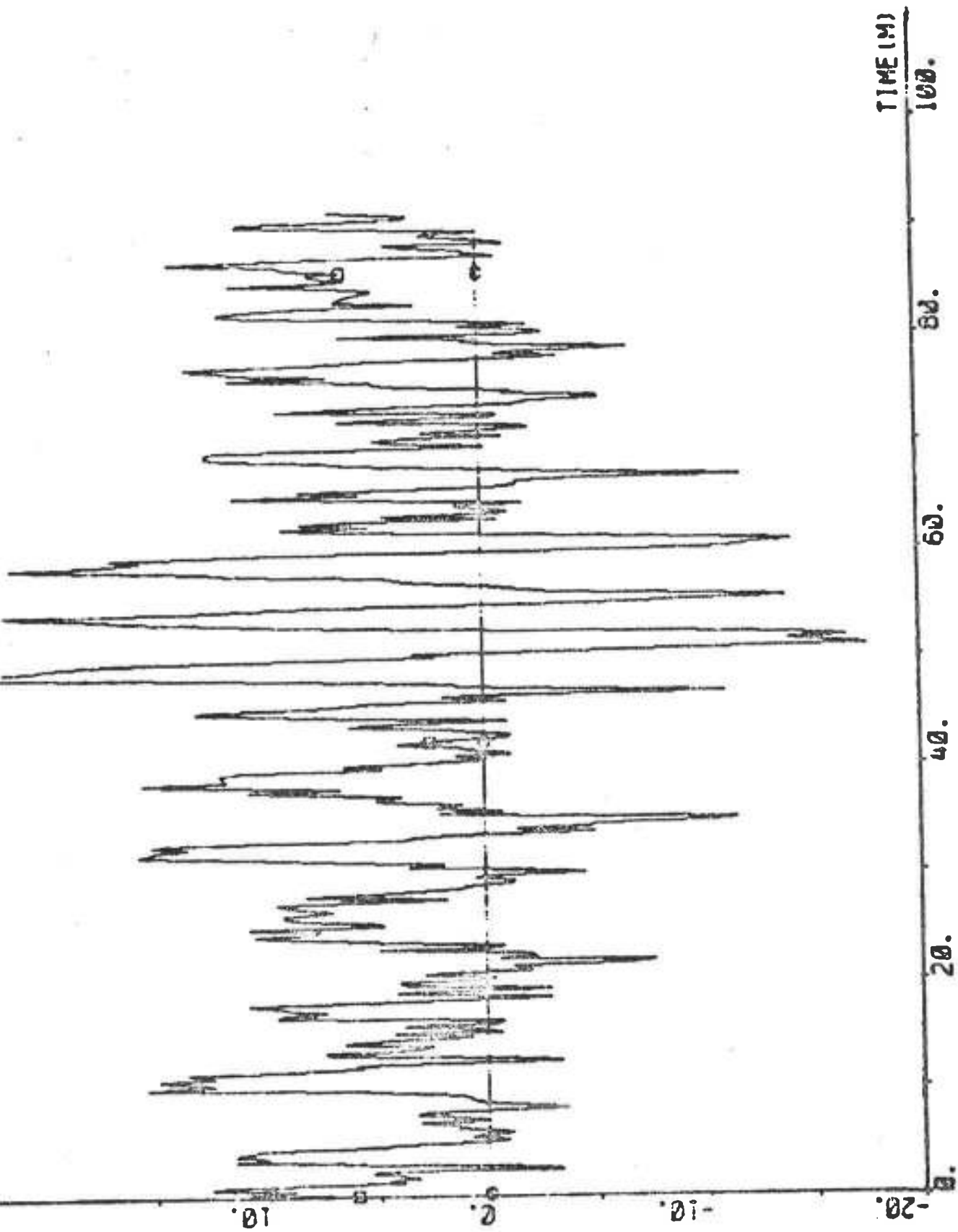
-12.



PLOT A37P1(16)-A37P1(3) ZERO -20 20 "DELTA" DEG

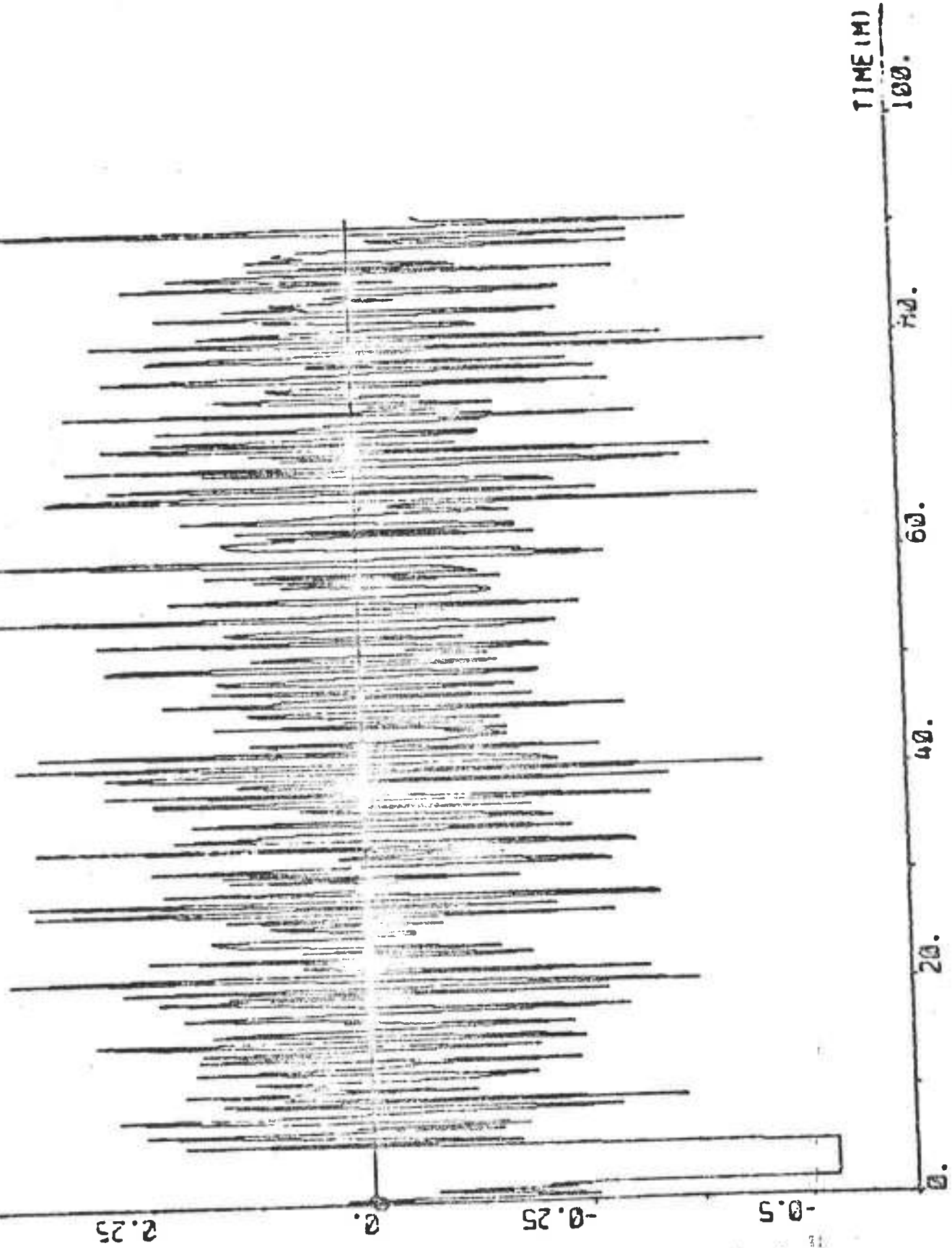


PLOT R37P1(15)-R37P1(4) ZERO -20 20 "DELTA DEG

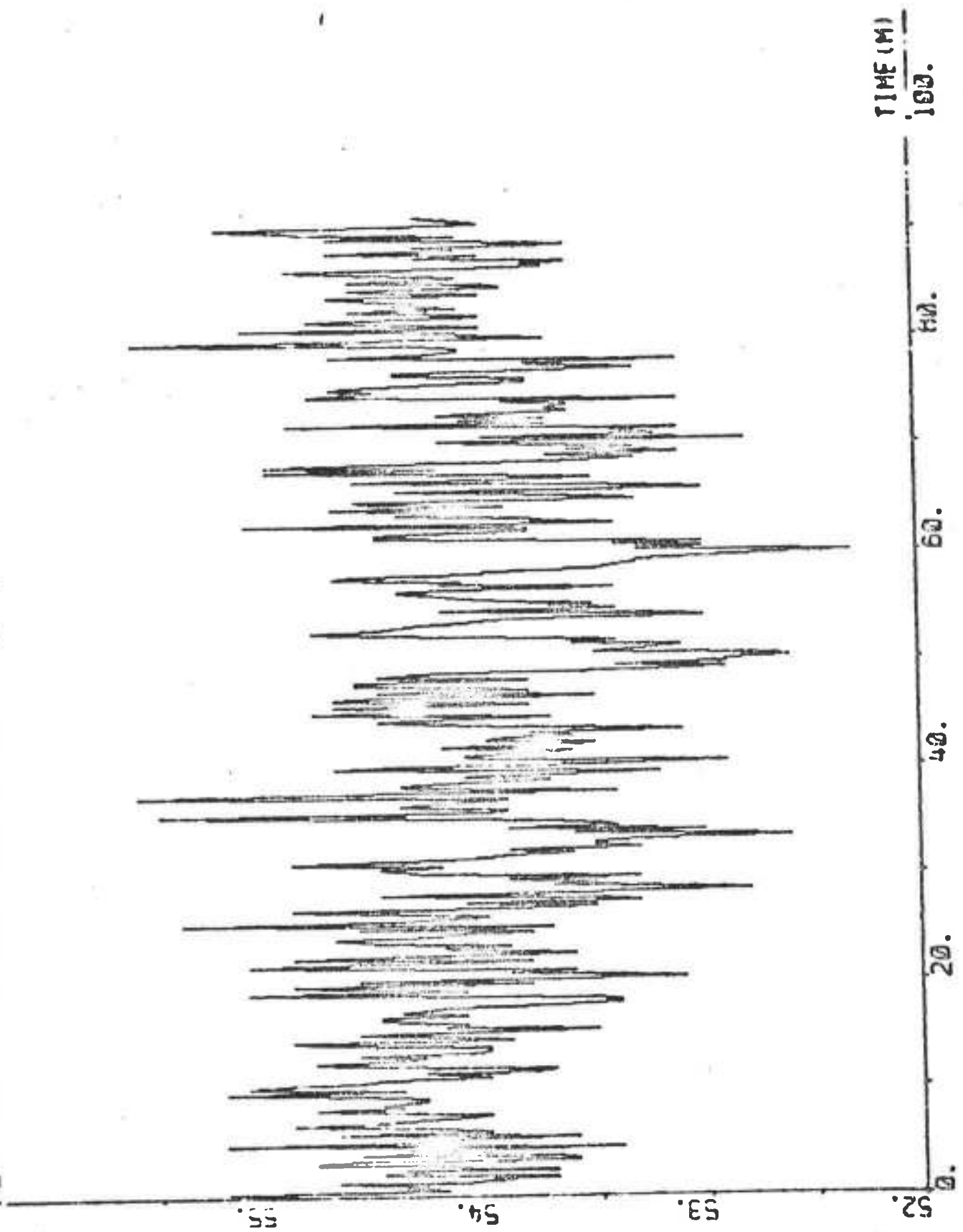


PP DEG/S

PLOT A37P1(15)→A37P1(5) ZERO -0.6 0.4

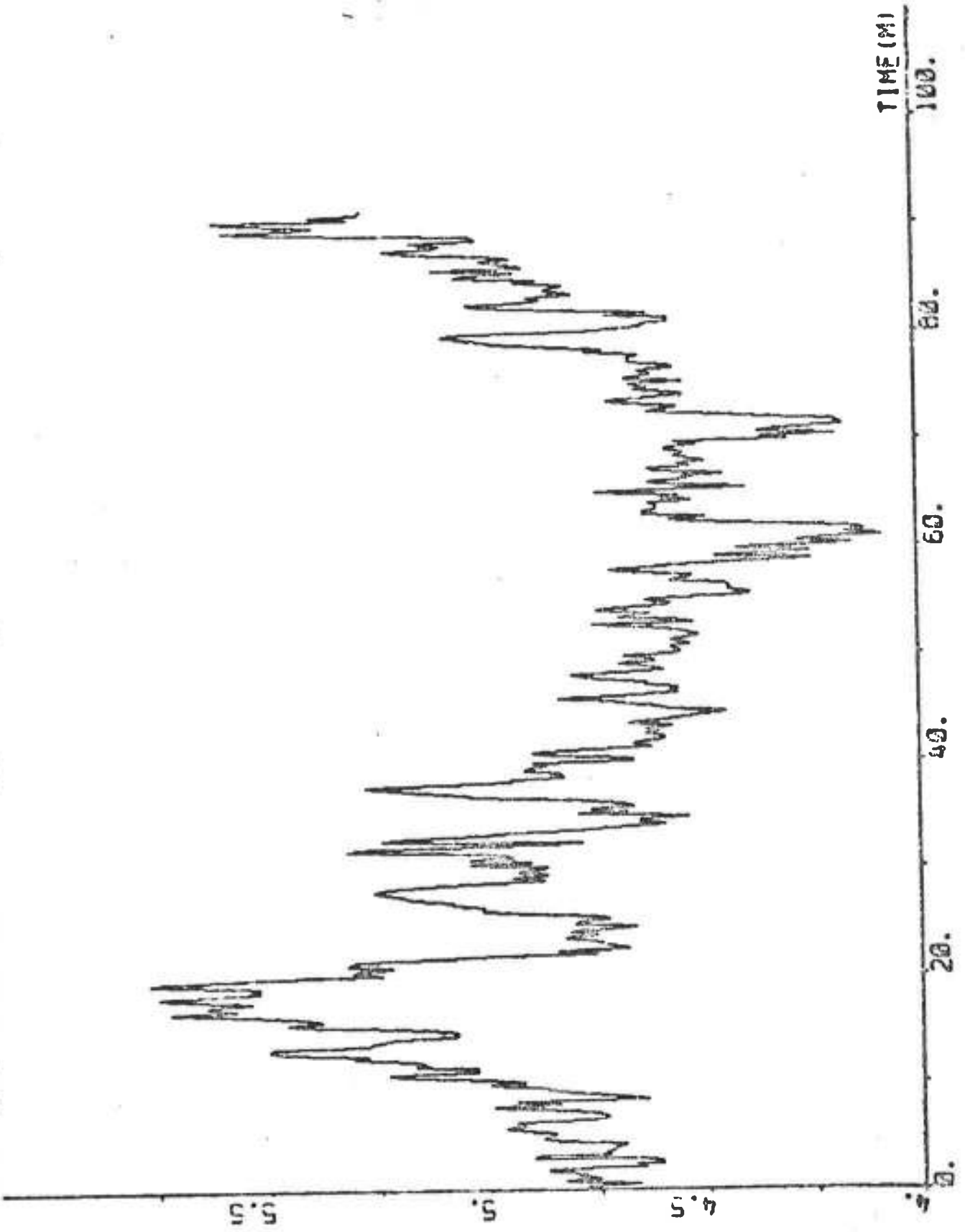


PLOT A37P1(15)-A37P1(6) 52 58 "AN RPM

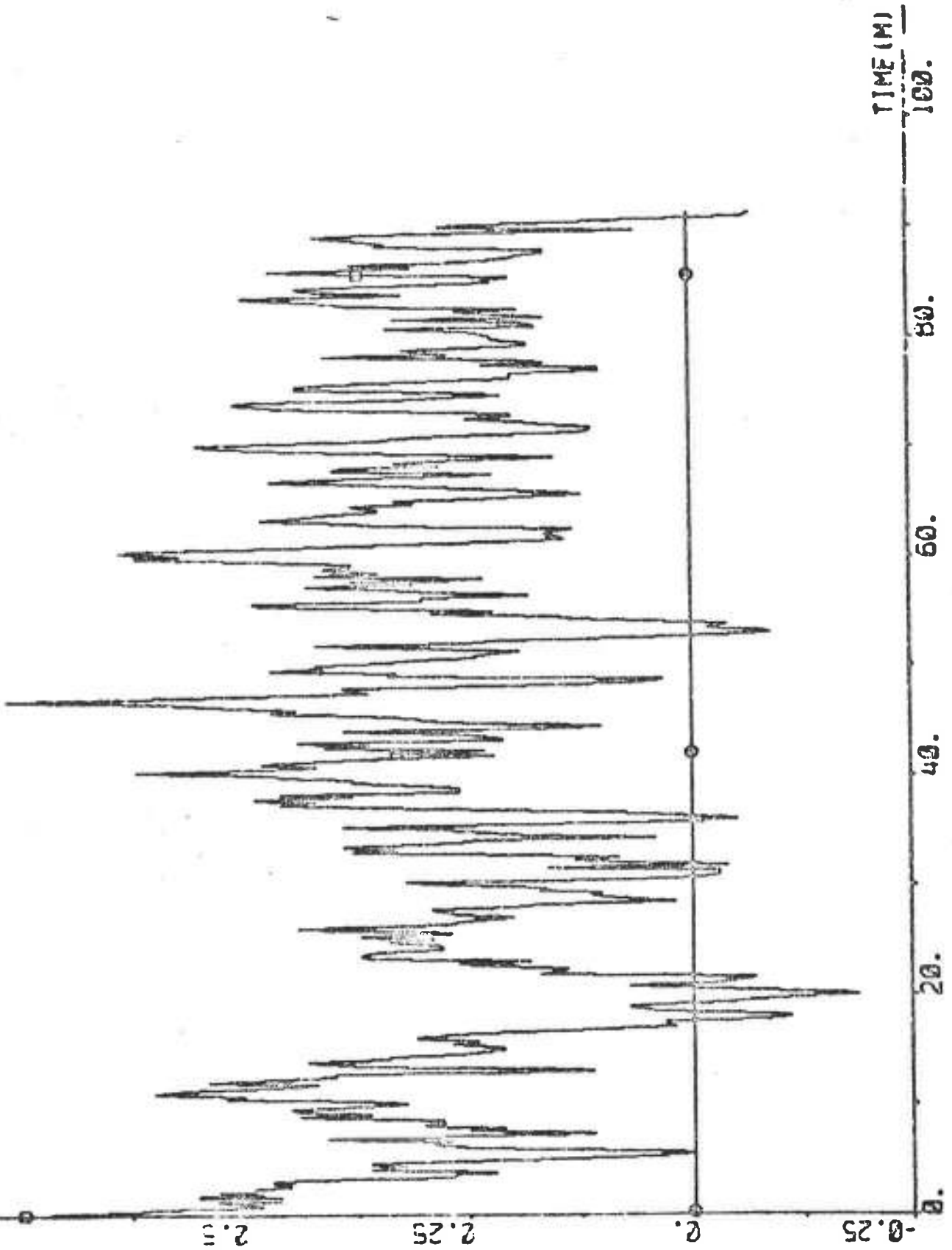


TIME (M)
100.

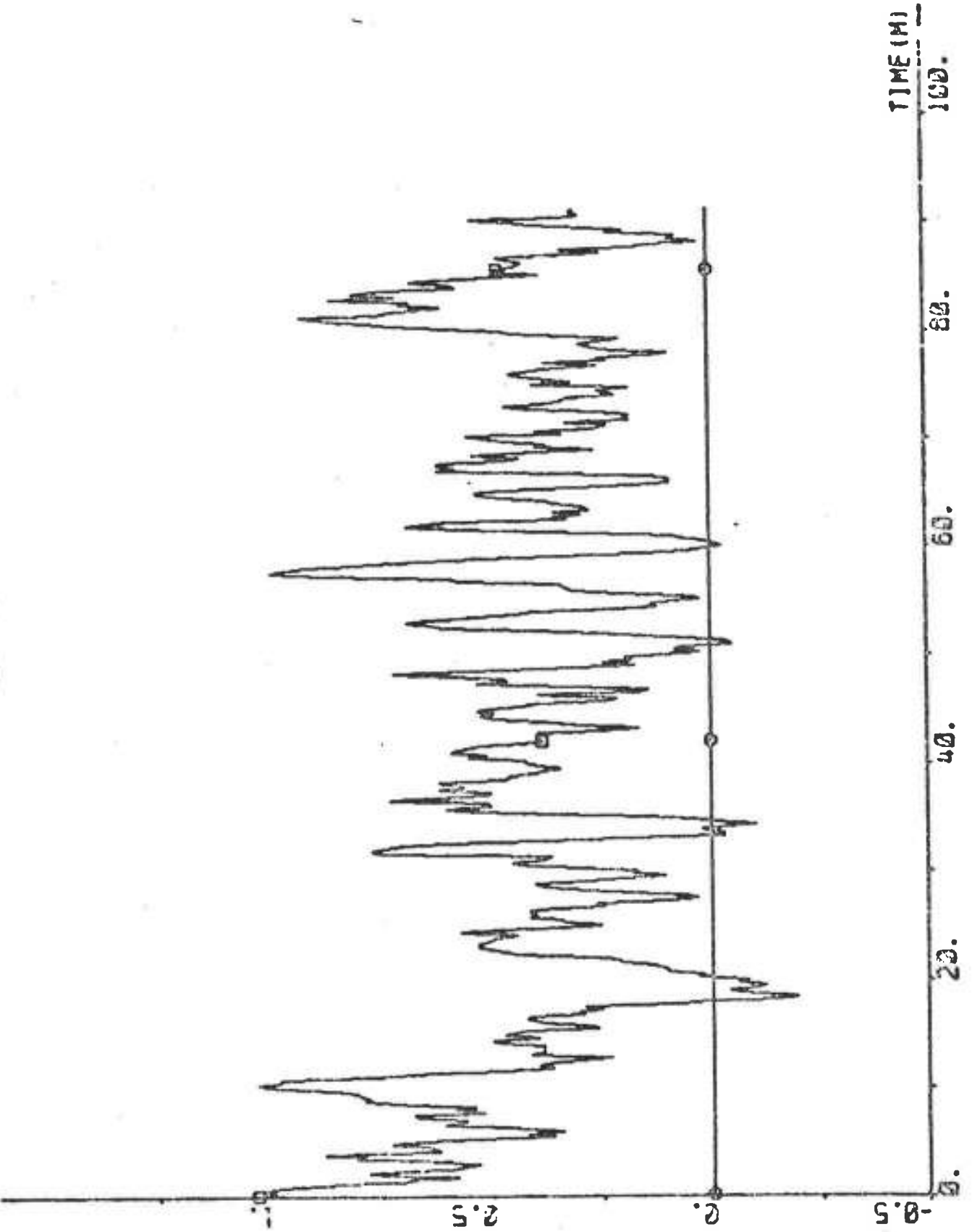
PLOT A37P1(15)←A37P1(7) 4 8 "U KNOTS



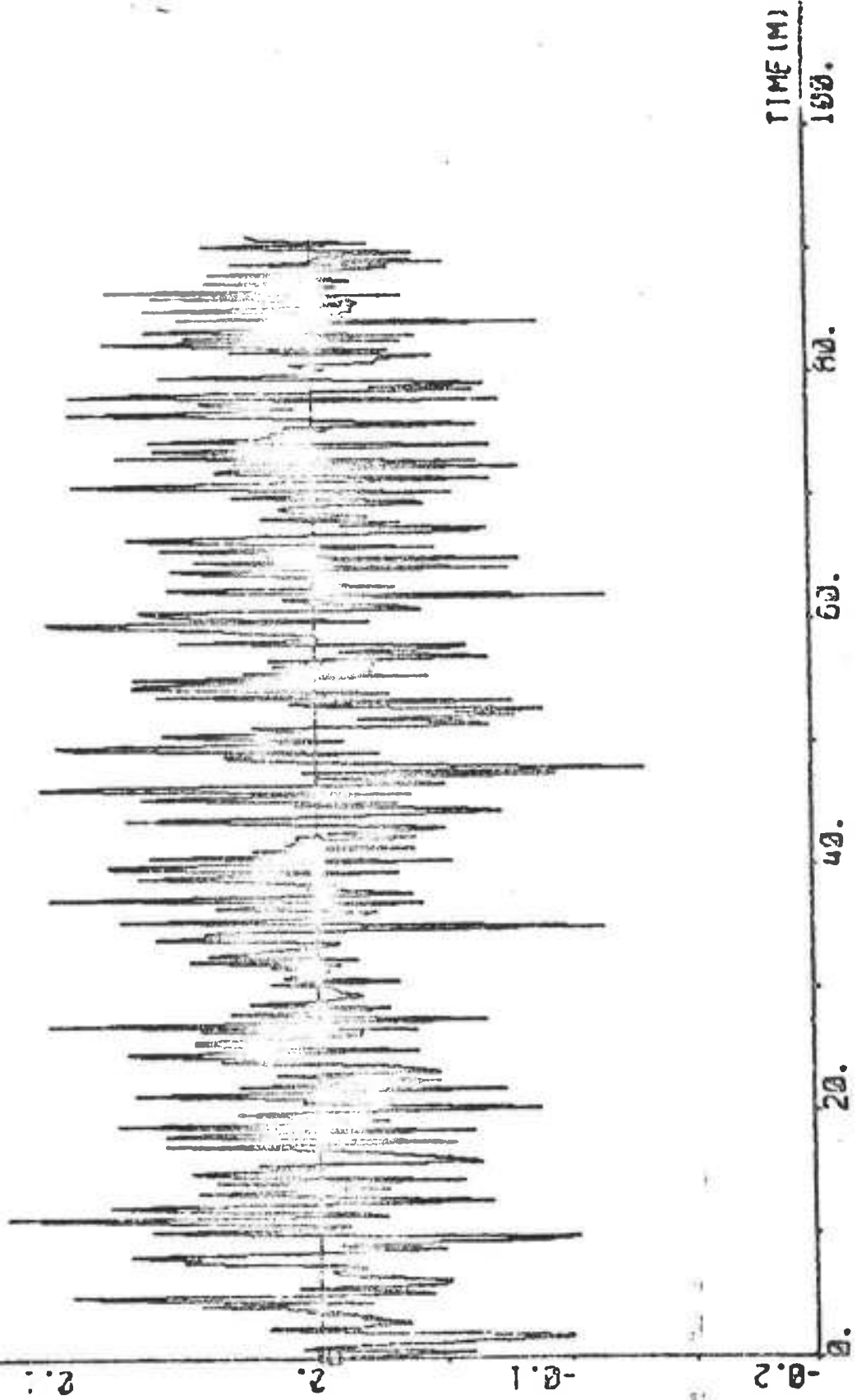
PLOT A37P1(16)←A37P1(8) ZERO -0.25 0.75 *V1 KNOTS



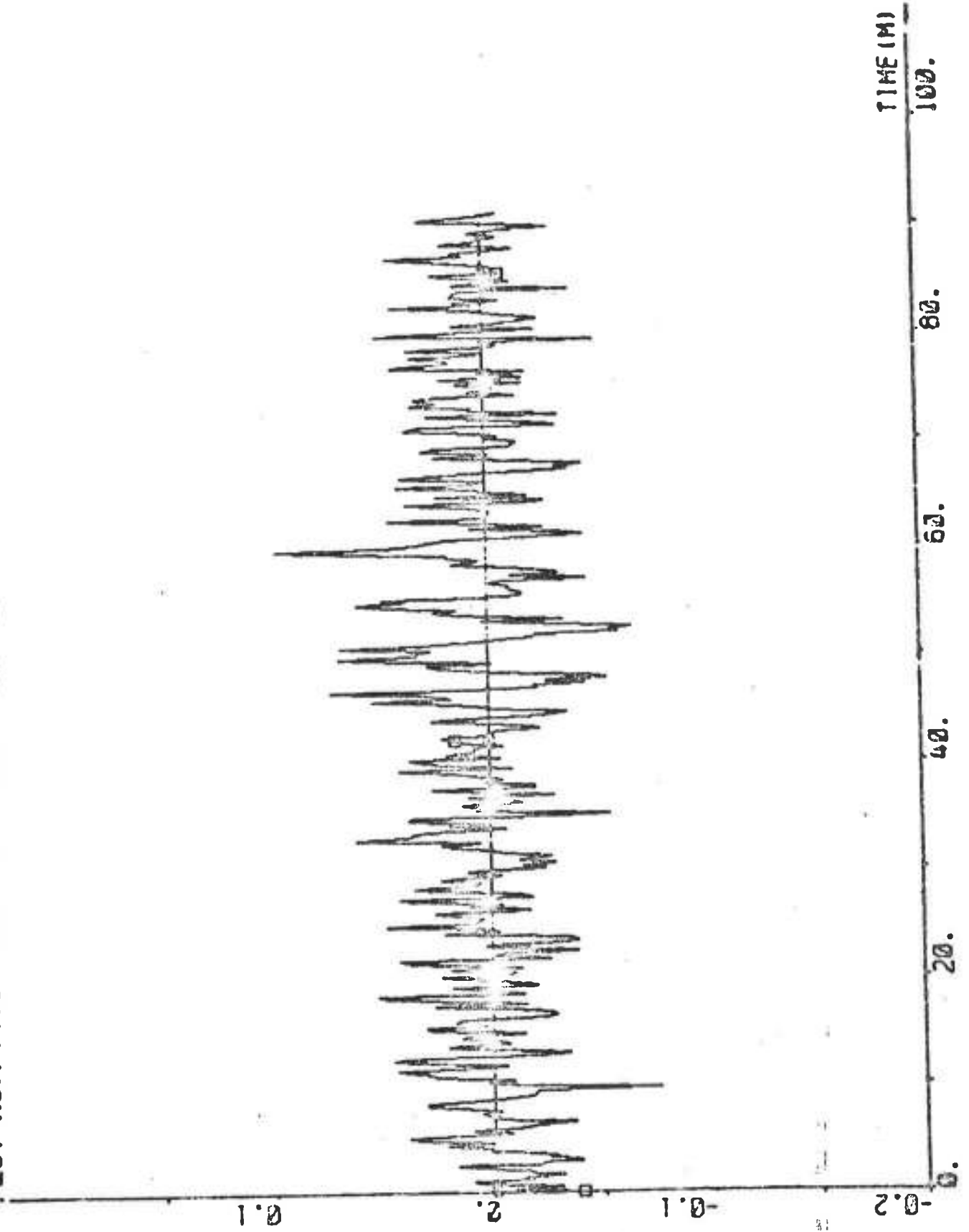
PLOT A37P1(15)-A37P1(9) ZERO -0.5 1.5 "V2 KNOTS



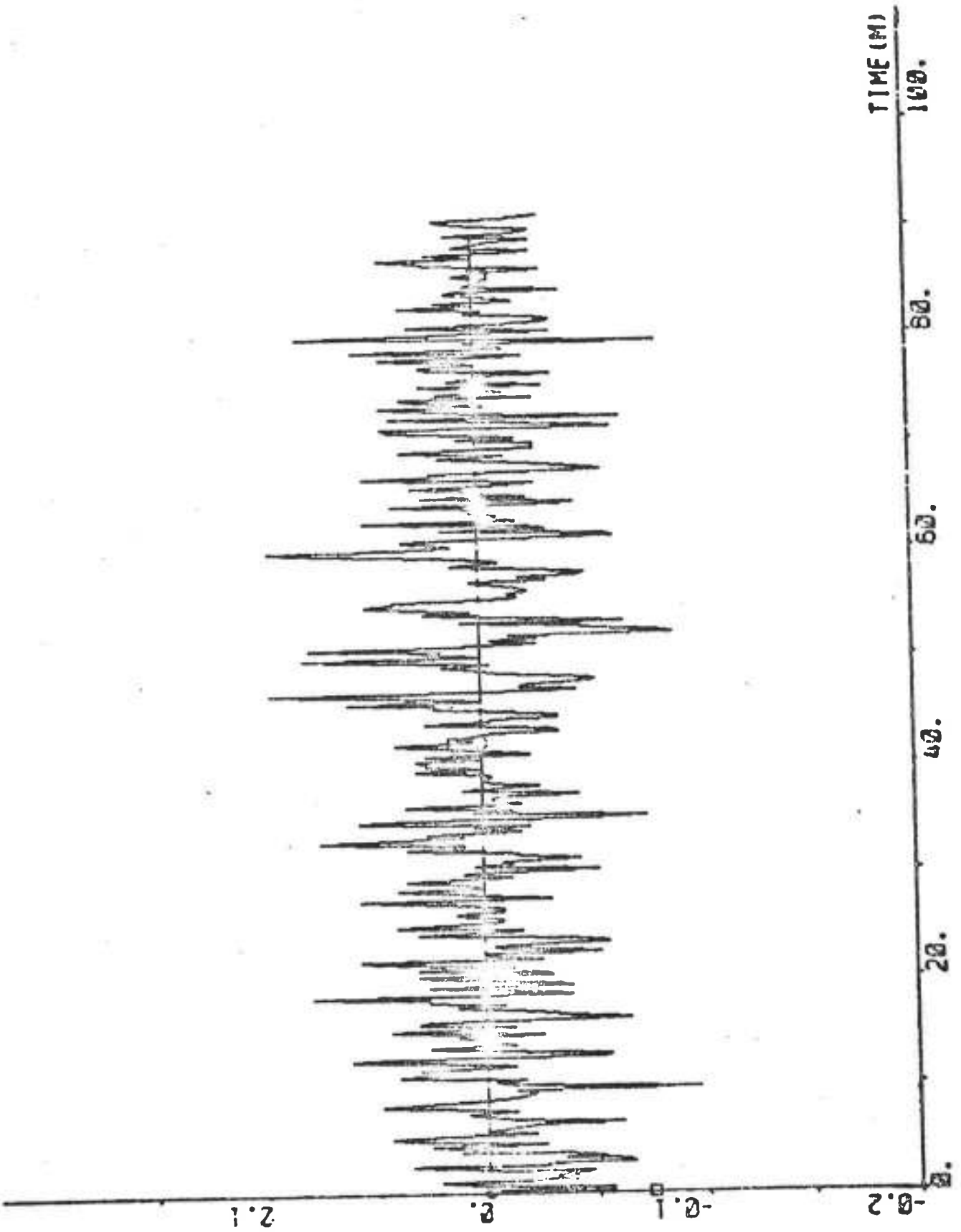
PLOT A37P1(15)-A37P1(10) ZERO -0.2 0.2 °R DEG/S



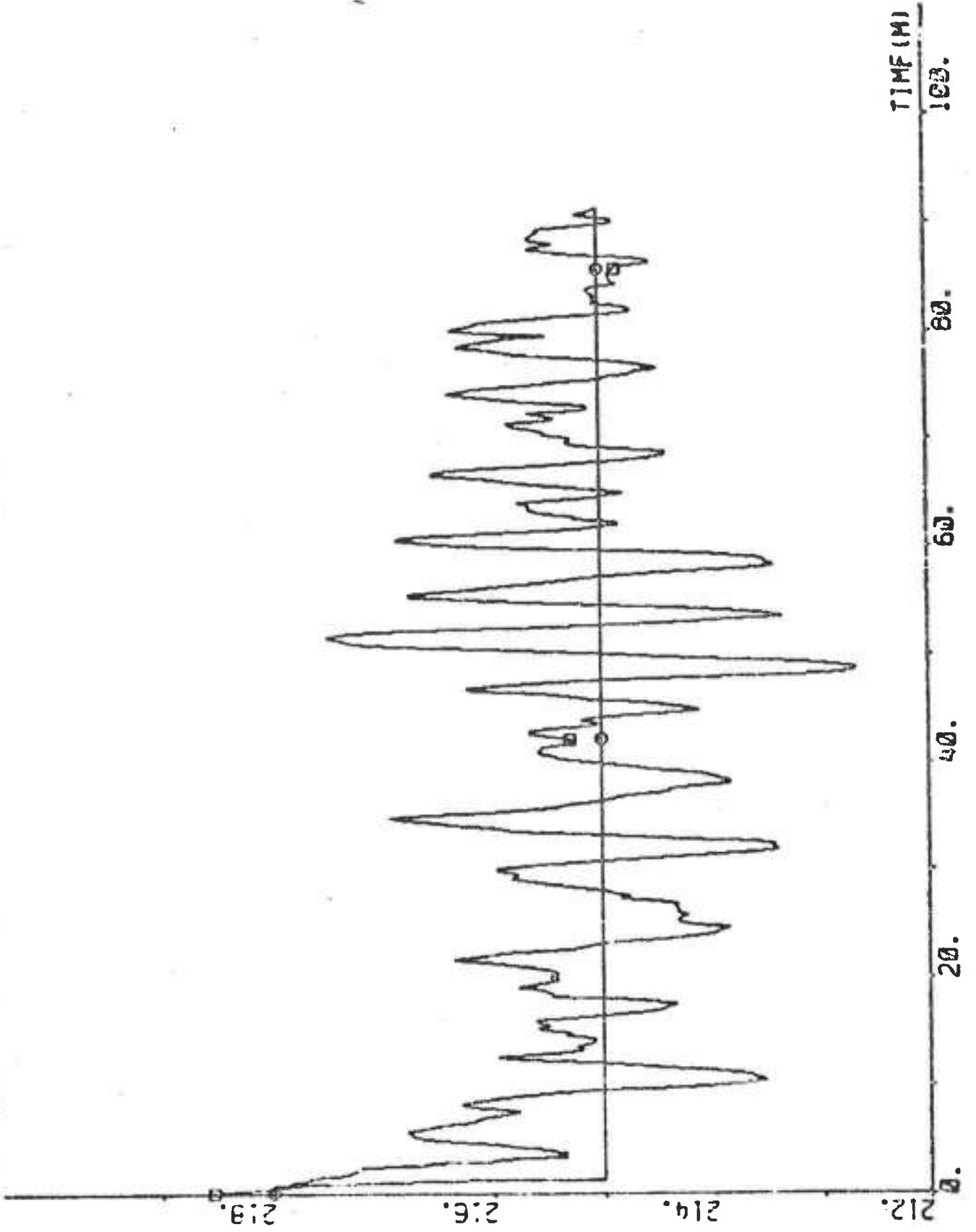
PLOT A37P1(16)-A37P1(11) ZERO -0.2 0.2 "AVR DEG/S (BR=0.2)



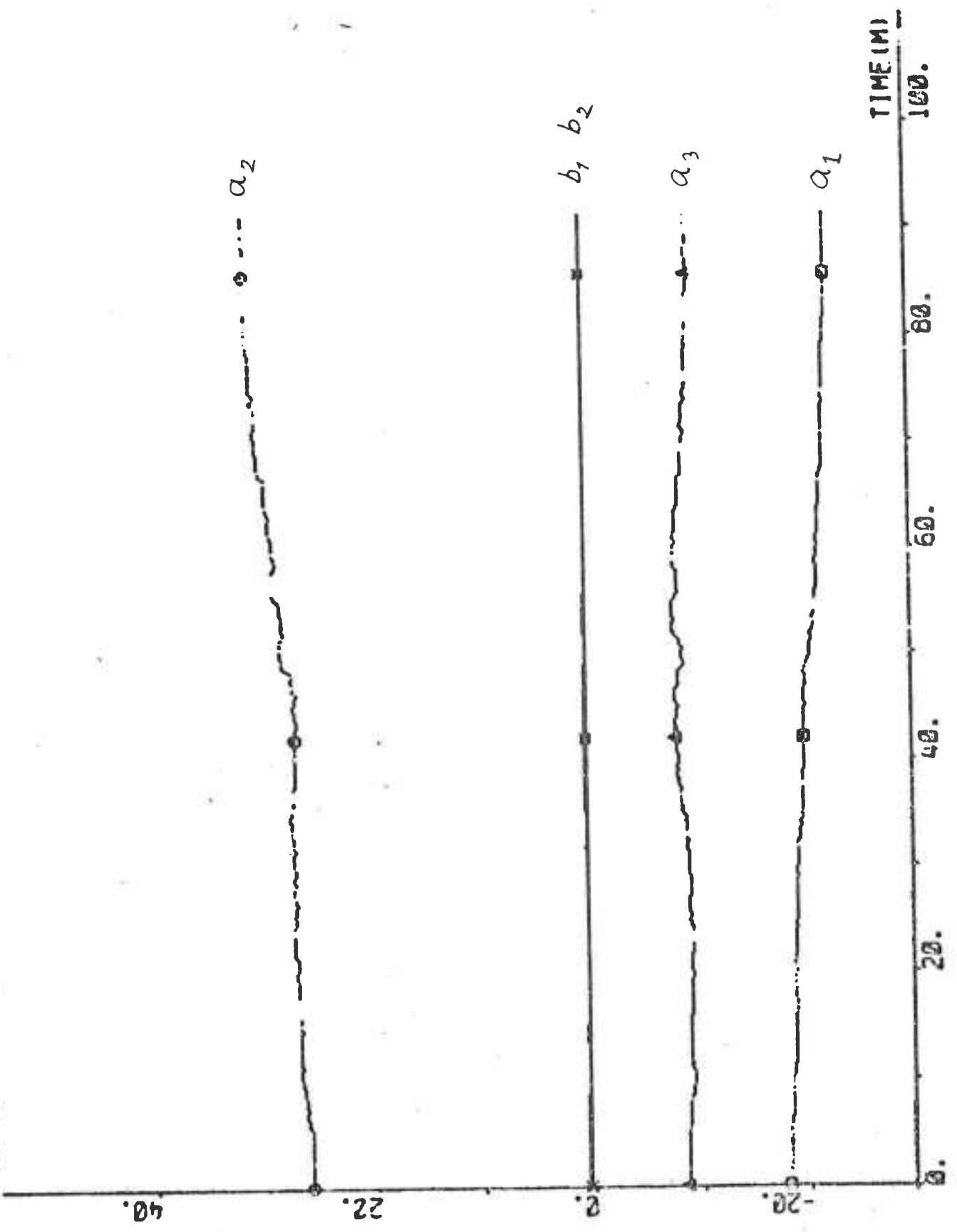
PLOT A37P1(16)-A37P1(12) ZERO -0.2 0.2 "DPSIDT DEG/S (IDPSI=5)



PLOT A37P1(15)-A37P1(13 14) 212 220 -PSI PSIREF DEG



PLOT A37P1(15)•A37P2 -2E 35 -REGULATOR PARAMETERS



EXPERIMENT A38

Date 1974-10-21
 Time 11.43
 Duration 71 min
 Position S 29^o 00' E 32^o 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^o
 Rudder limit Not active

Regulator structure

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

Final values

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

$$a_1 + a_2 + a_3 = 0.072$$

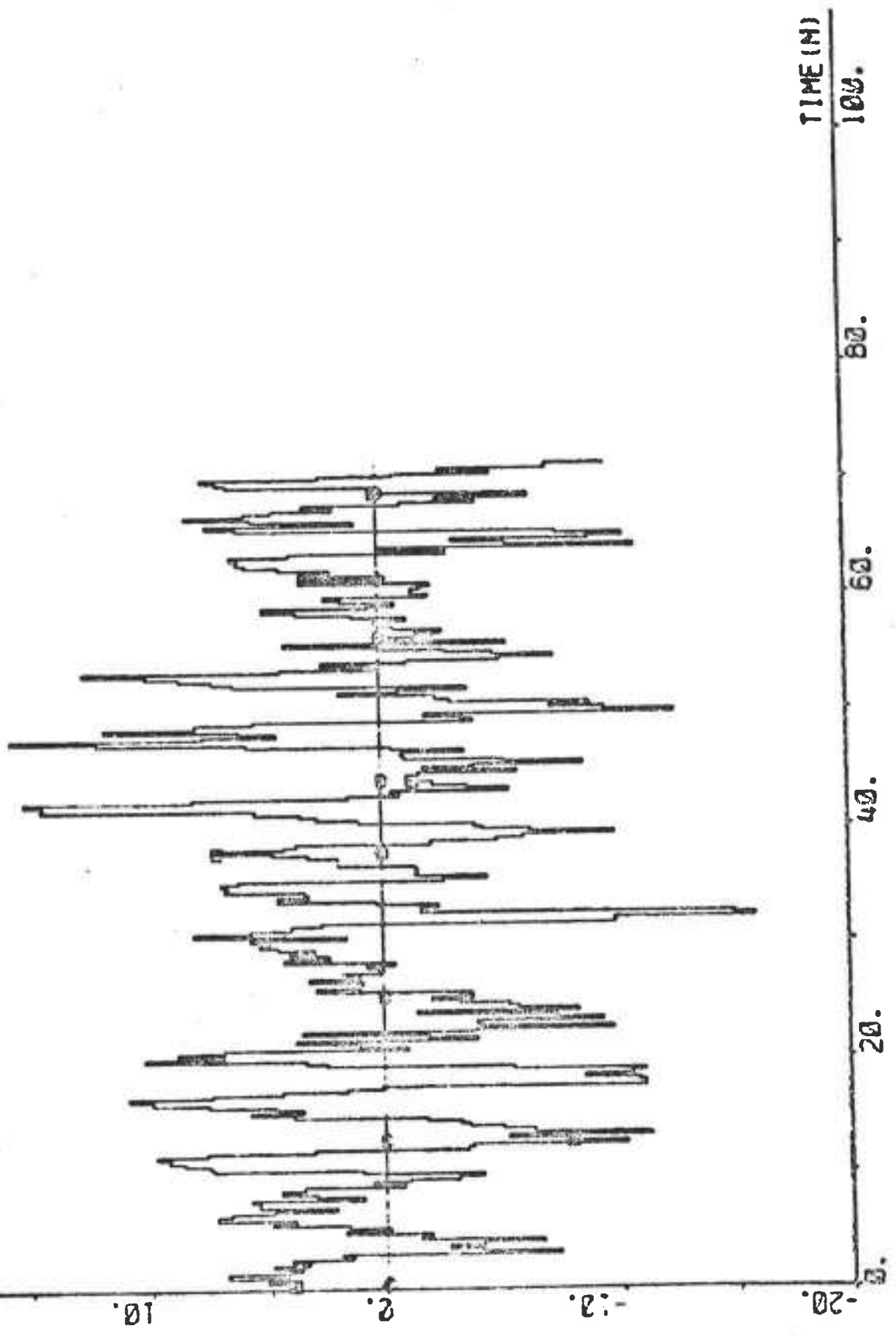
Statistics (mean value and standard deviation)

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

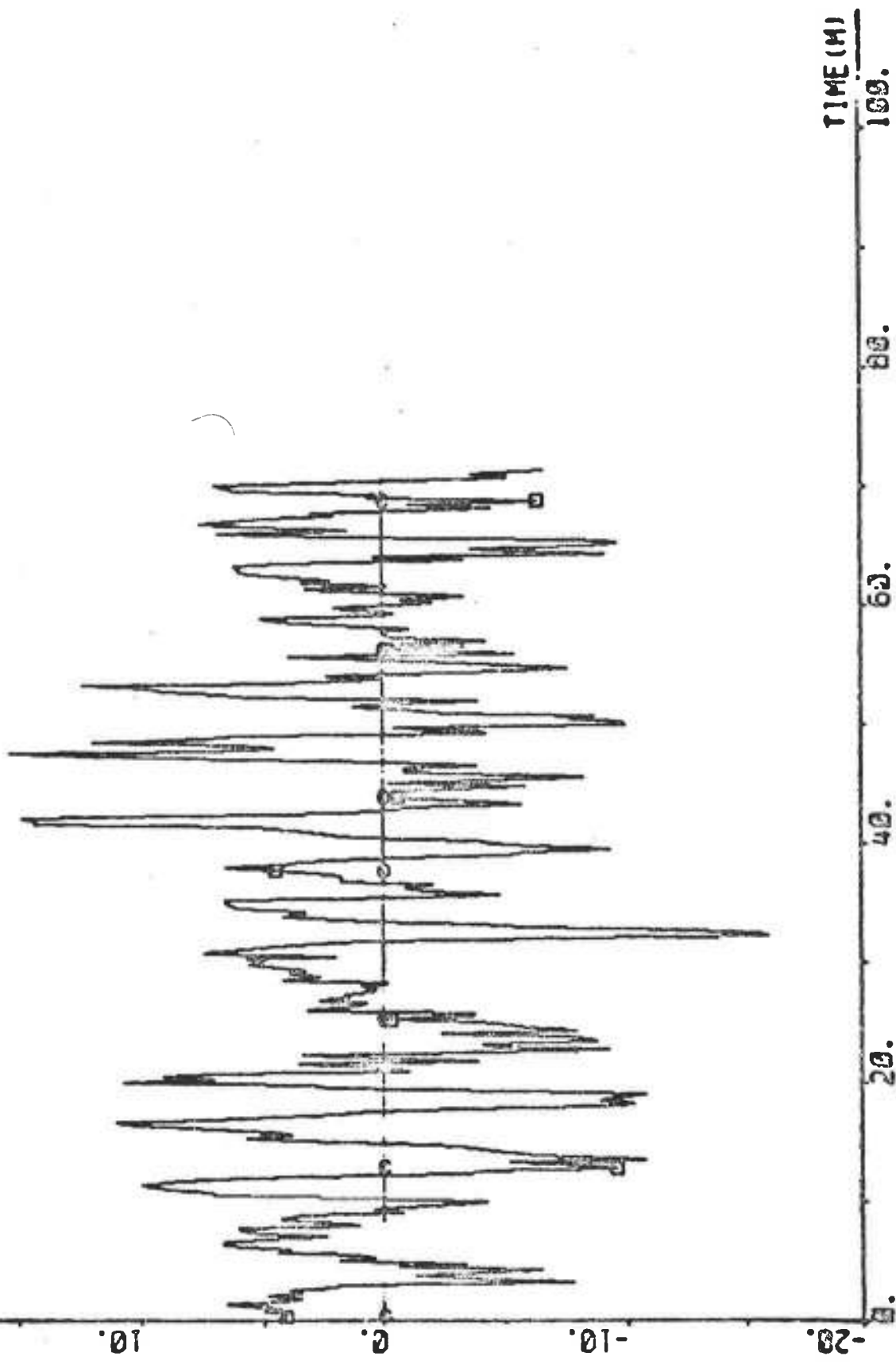
$$V_1 = 4.326$$

$$V_2 = 3.942$$

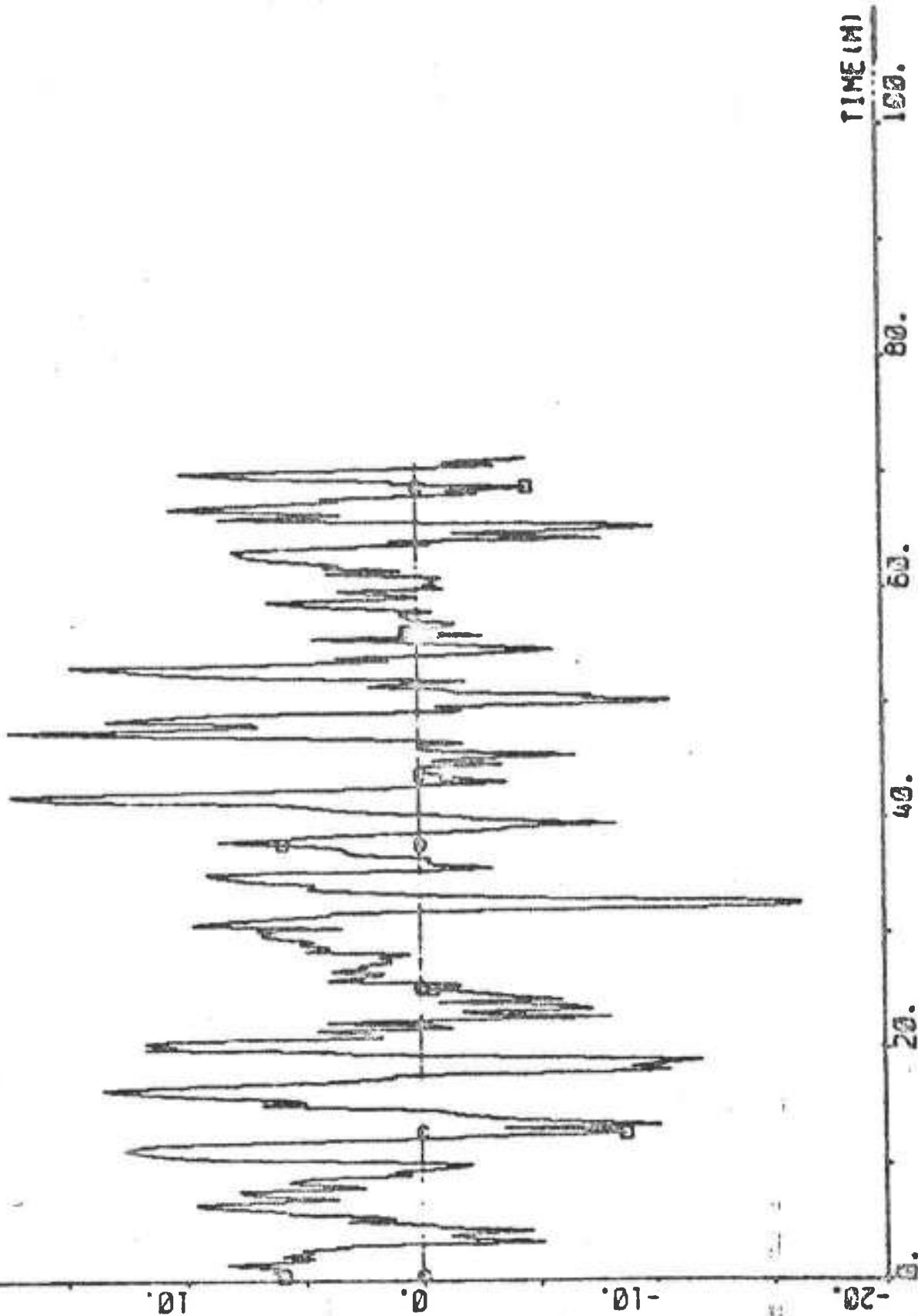
PLOT HP A38P1(1) ZERO -20 20 "DELCOG DEG



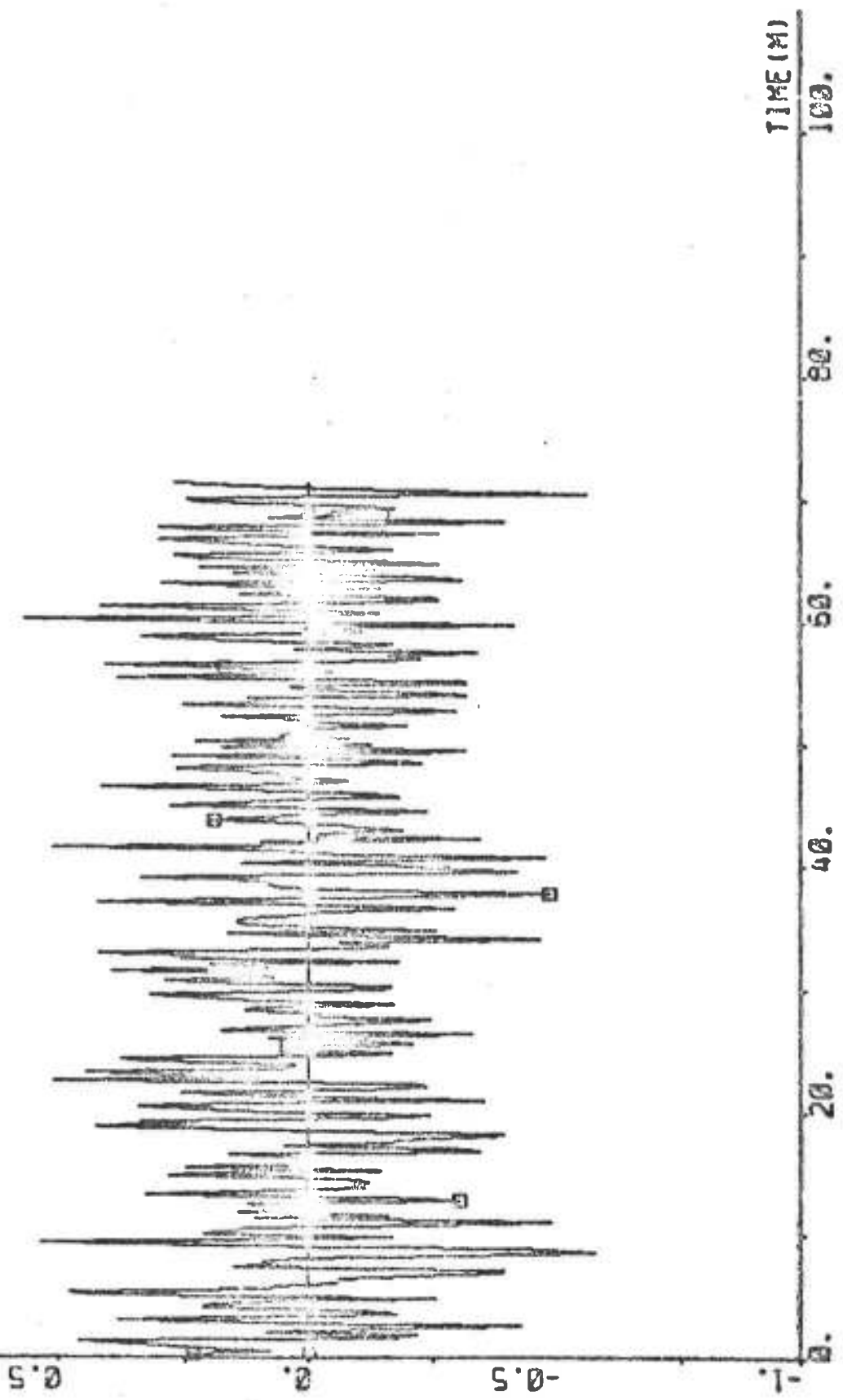
PLOT R33P1(3) ZERO -20 20 "DELTA" DEG



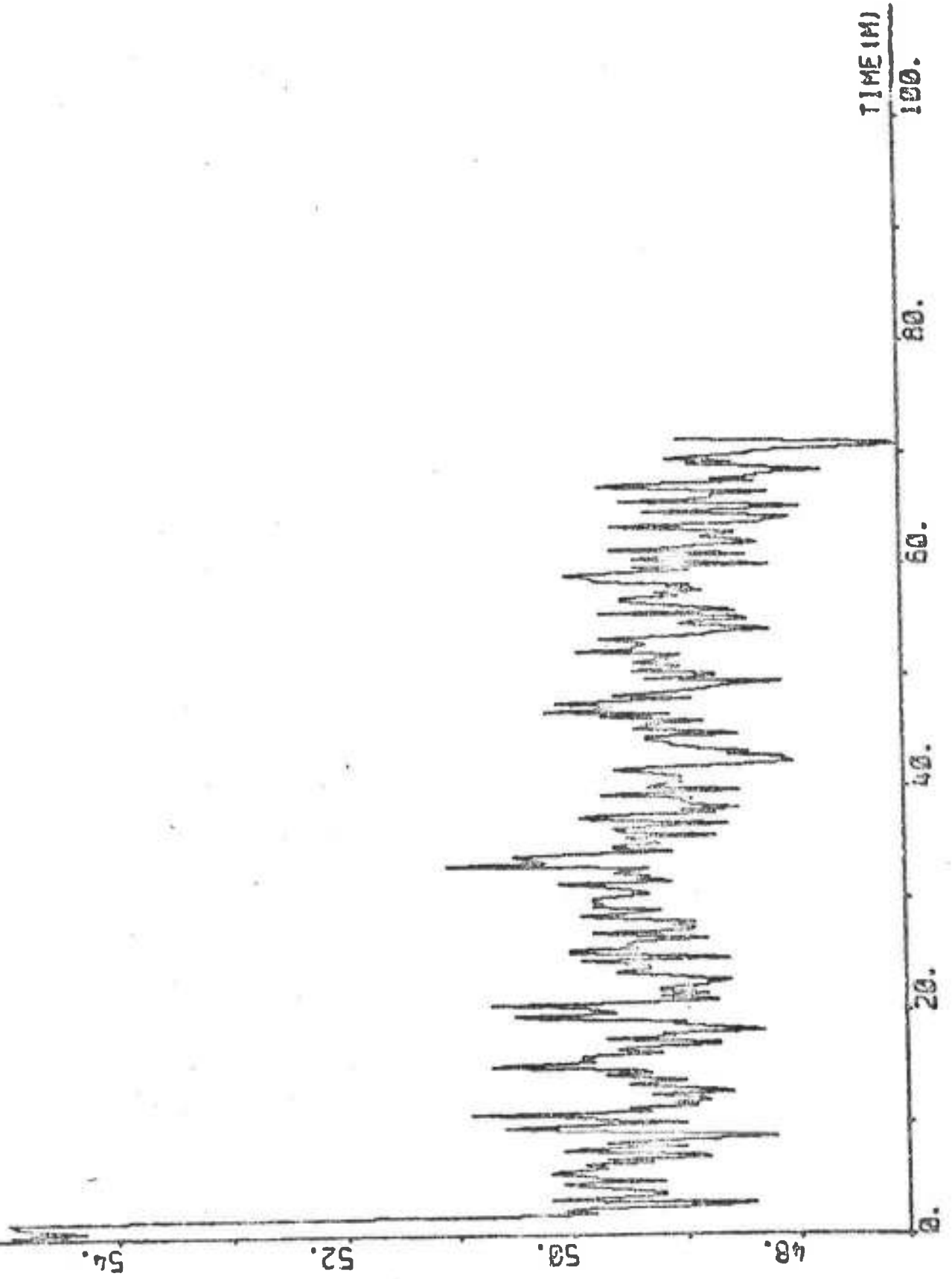
PLOT R36P1(4) ZERO -20 20 -DELTA DEG



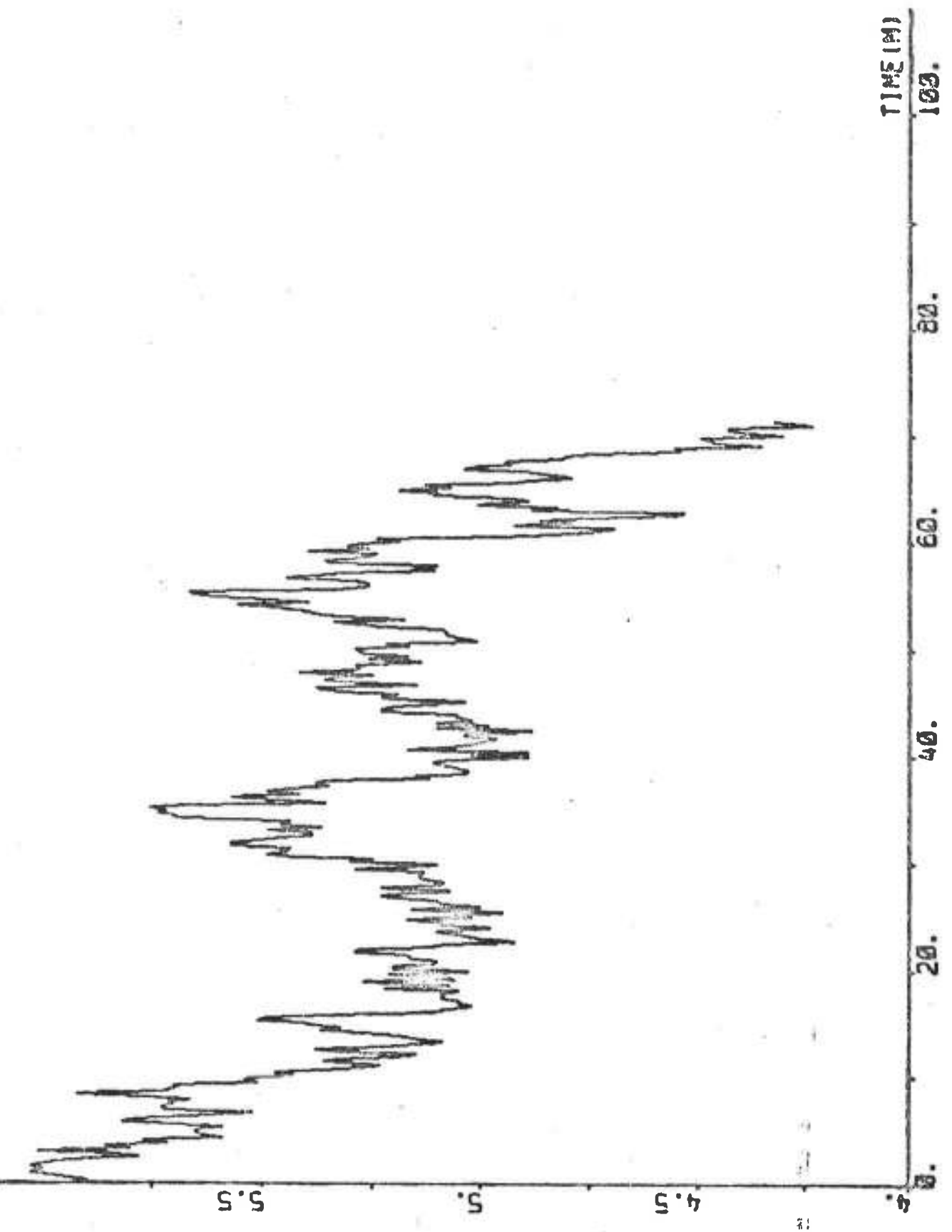
PLOT A3BP1(6) ZERO -1 1 -PP DEG/S



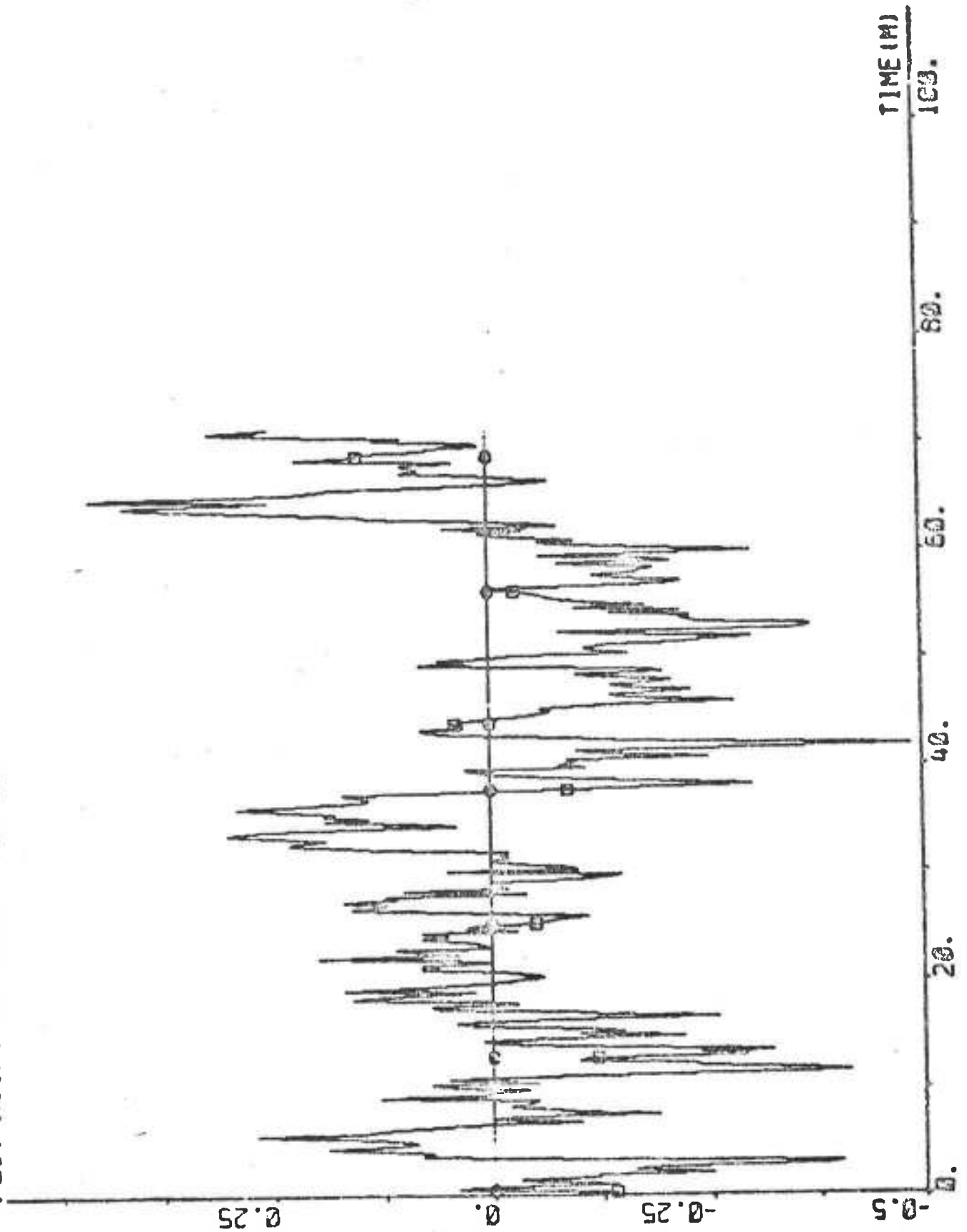
PLOT R36P1(6) 47.5 55.5 "RH RPM



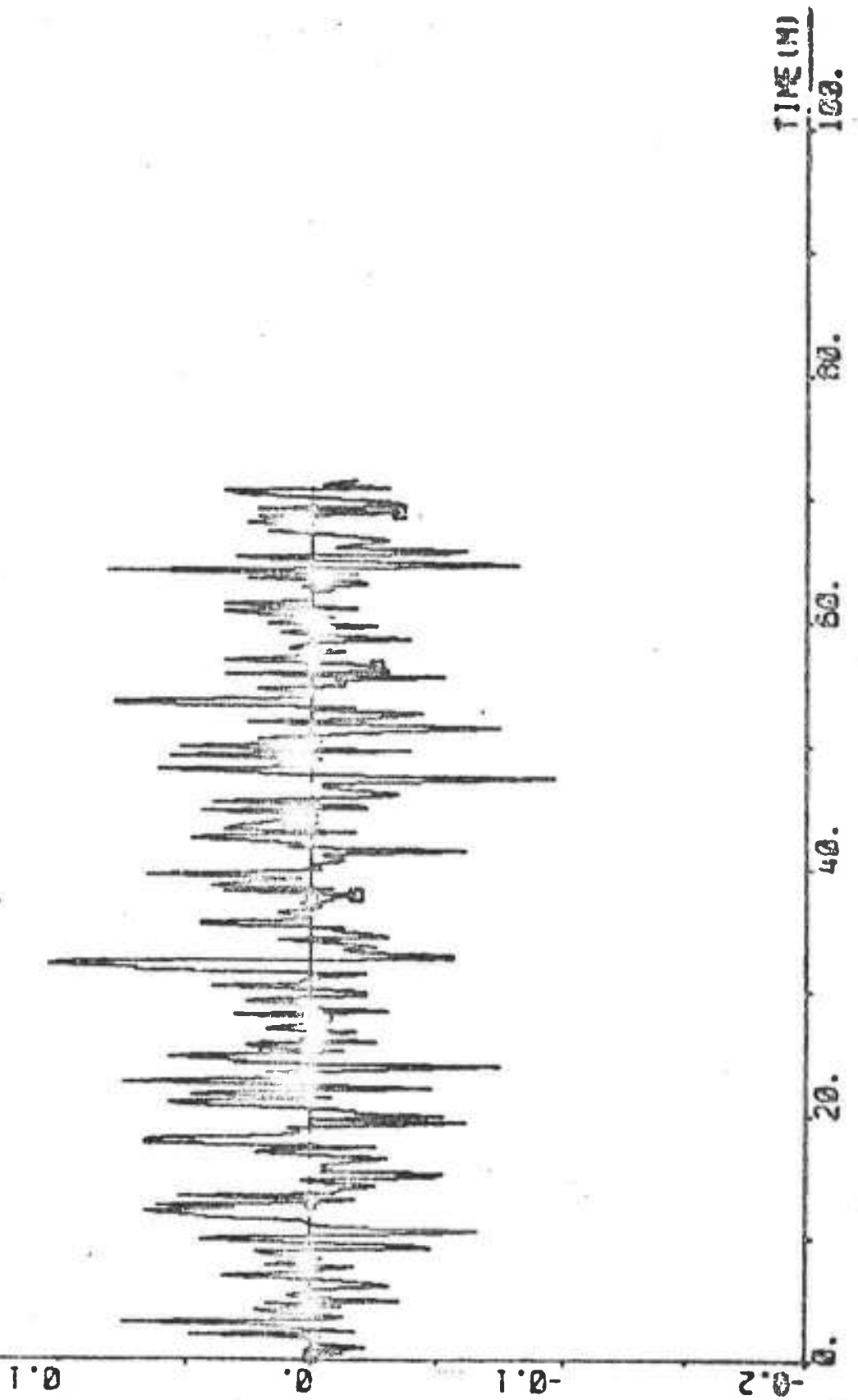
PLOT A30P1(7) 4 E -U KNOTS



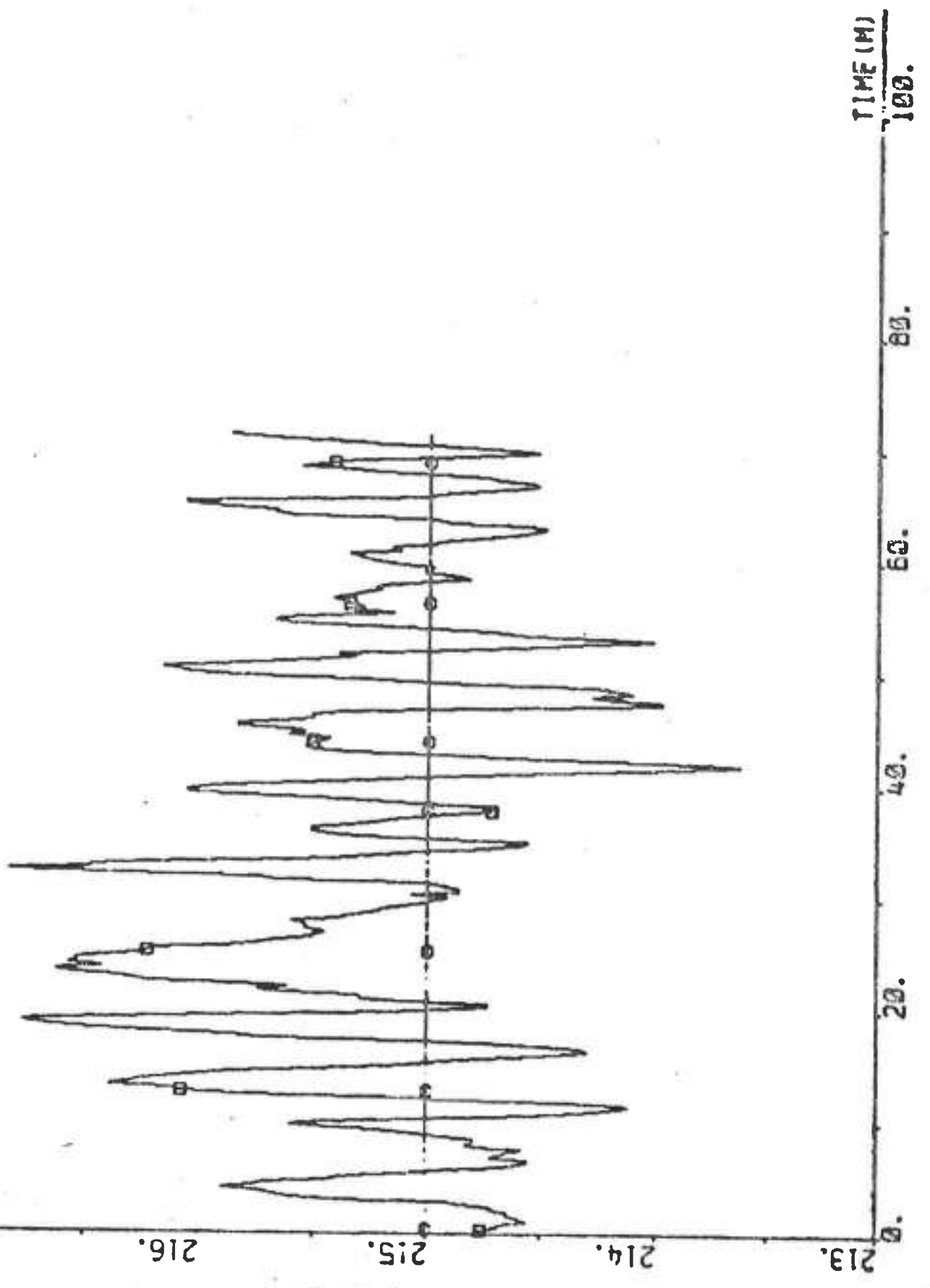
PLOT A36P1(8) ZERO -0.5 0.5 "V1 KNOTS



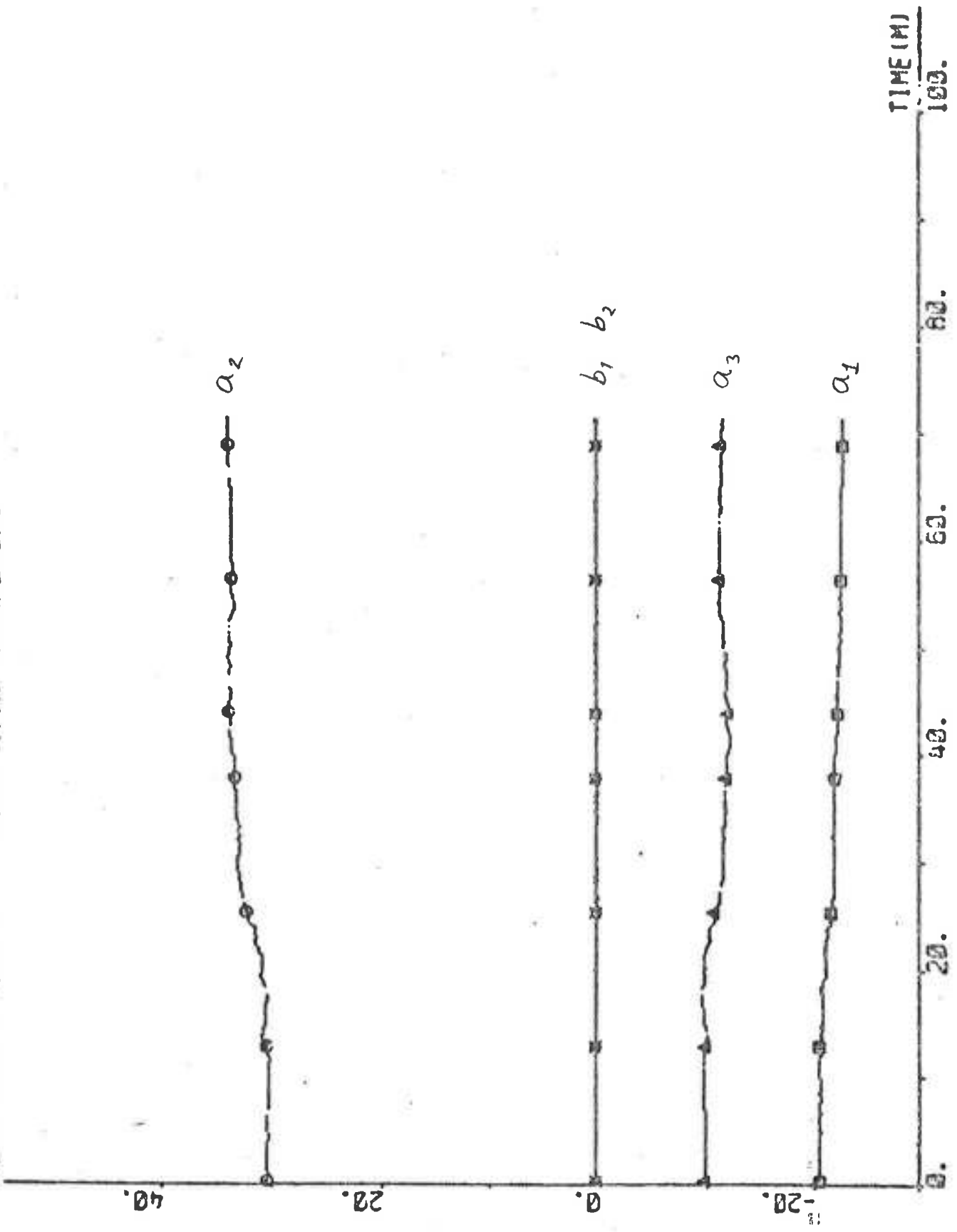
PLOT A38P1(12) ZERO -0.2 0.2 "DPSIDT DEG/S (IDPSI.6)



PLOT A38P1(13 14) 213 217 °PSI PSIREF DEG



PLOT A38P2 - 25 35 "REGULATOR PARAMETERS



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

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

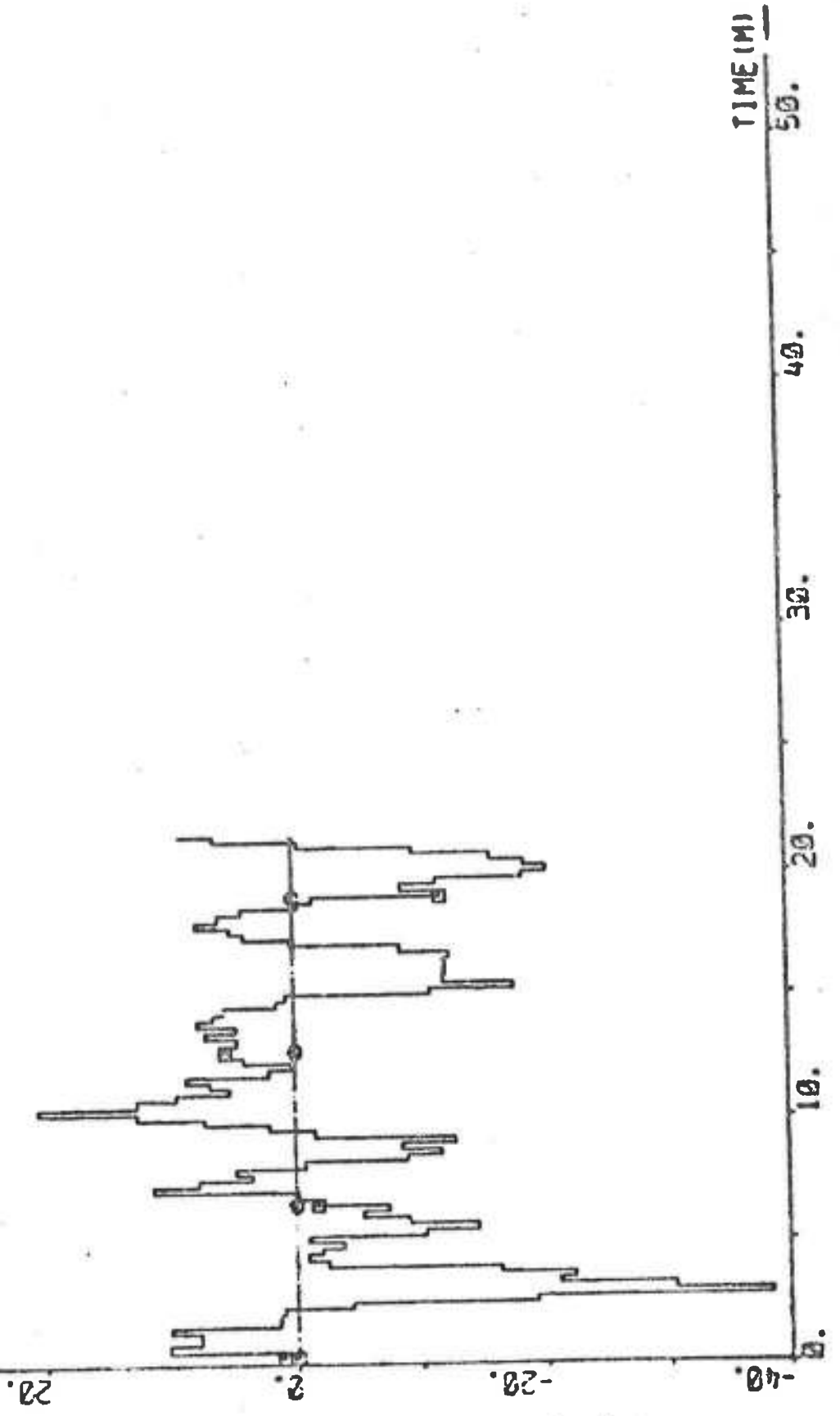
$$a_1 + a_2 + a_3 = -0.257$$

Statistics (mean value and standard deviation)

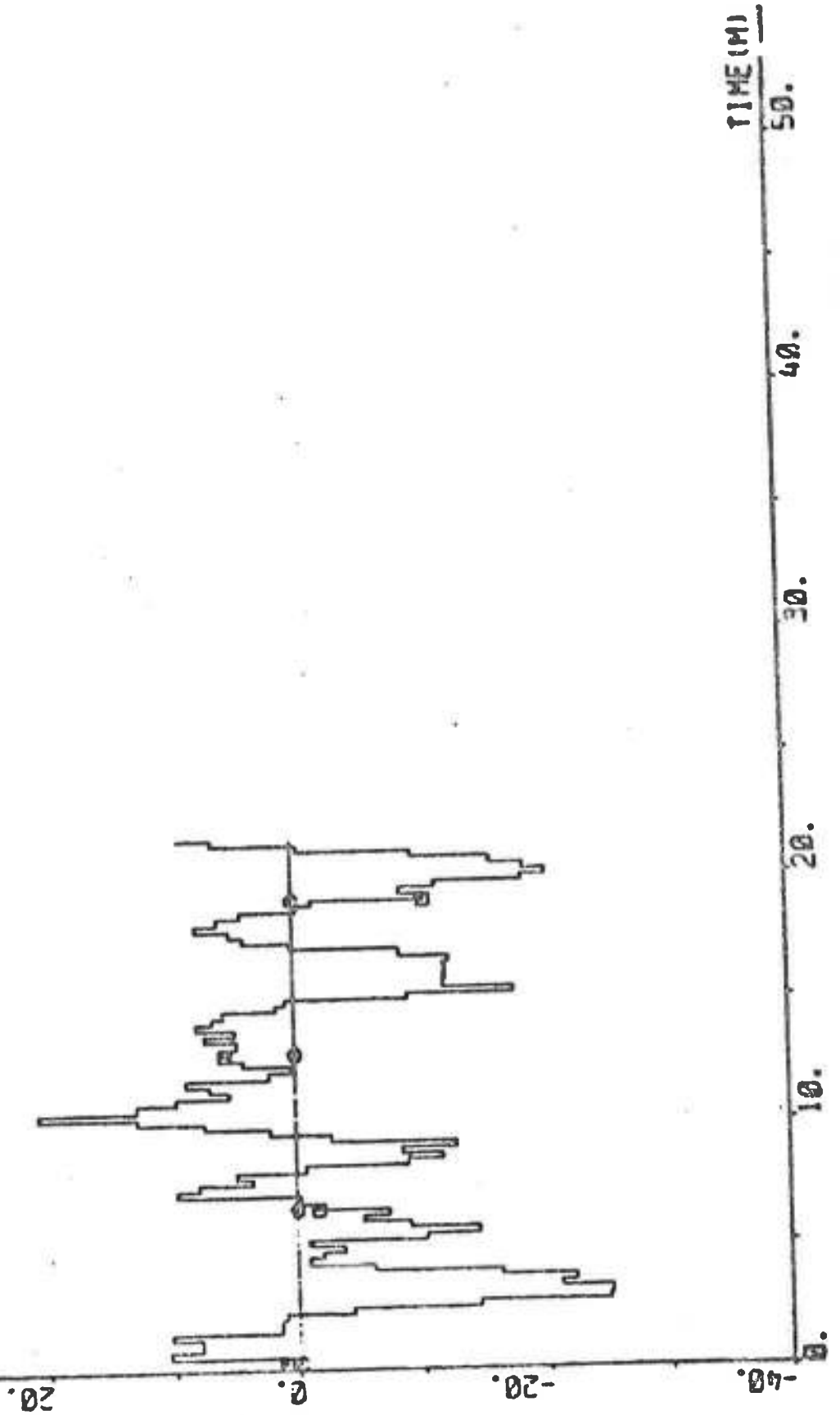
DELTA	-1.51 ± 10.98 deg
PSI-PSIREF	0.522 ± 1.089 deg
AN	48.53 ± 0.71 rpm
U	4.32 ± 0.21 knots

 $V_1 = 13.742$ $V_2 = 13.514$

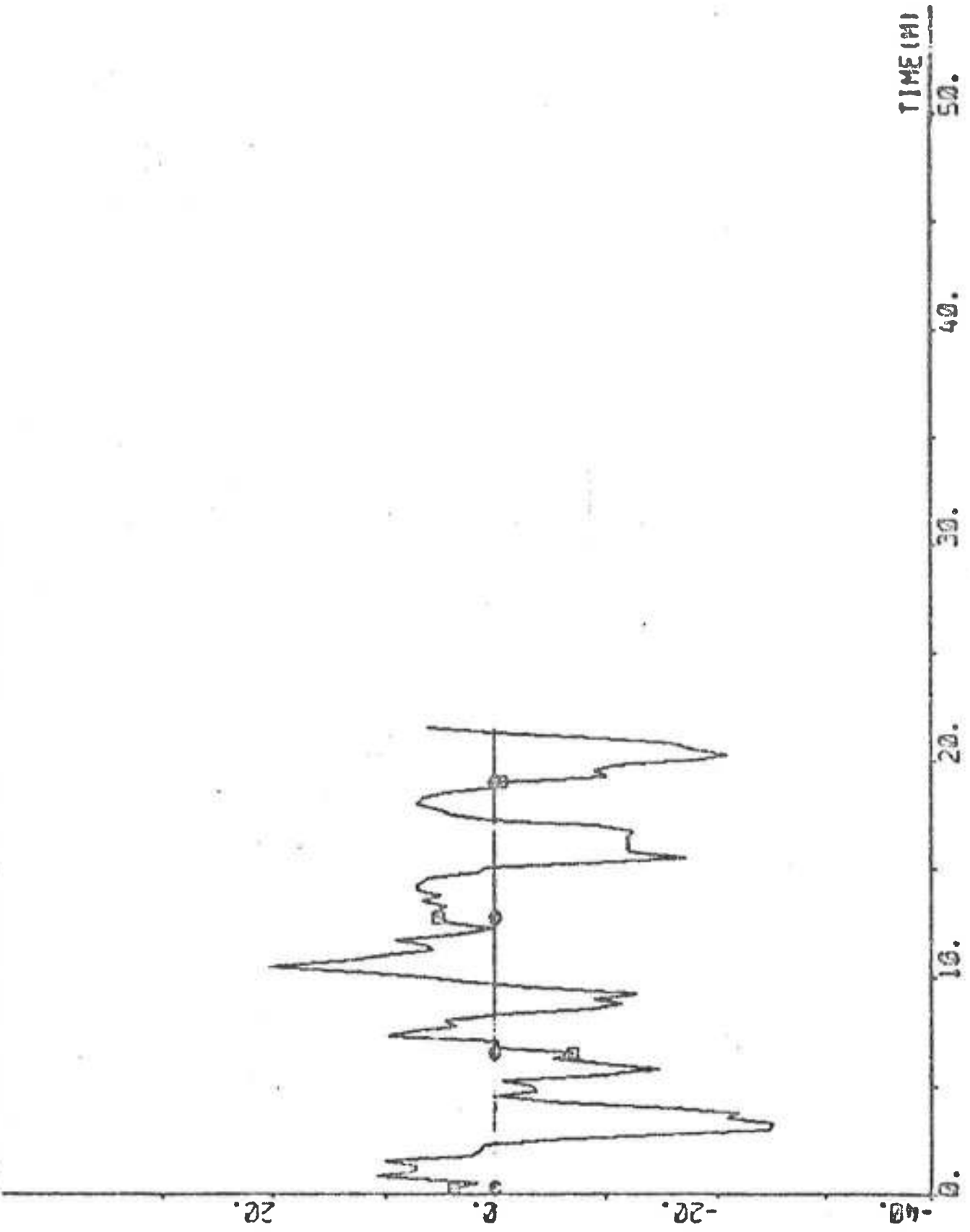
PLOT HP R39A1(1) ZERO -49 49 °DELCOG DEG



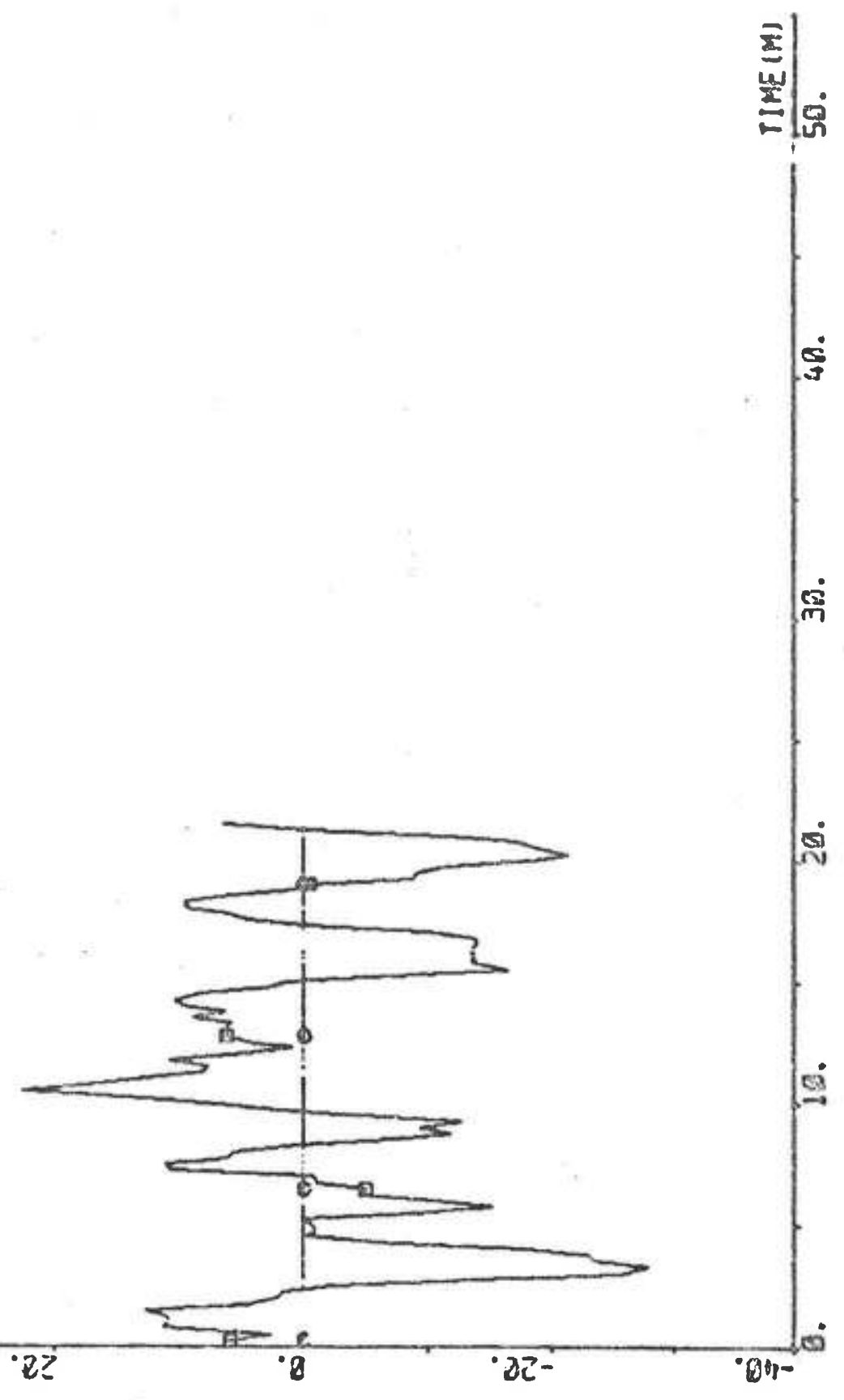
PLOT HP A39A1(2) ZERO -48 40 "DELCON DEG



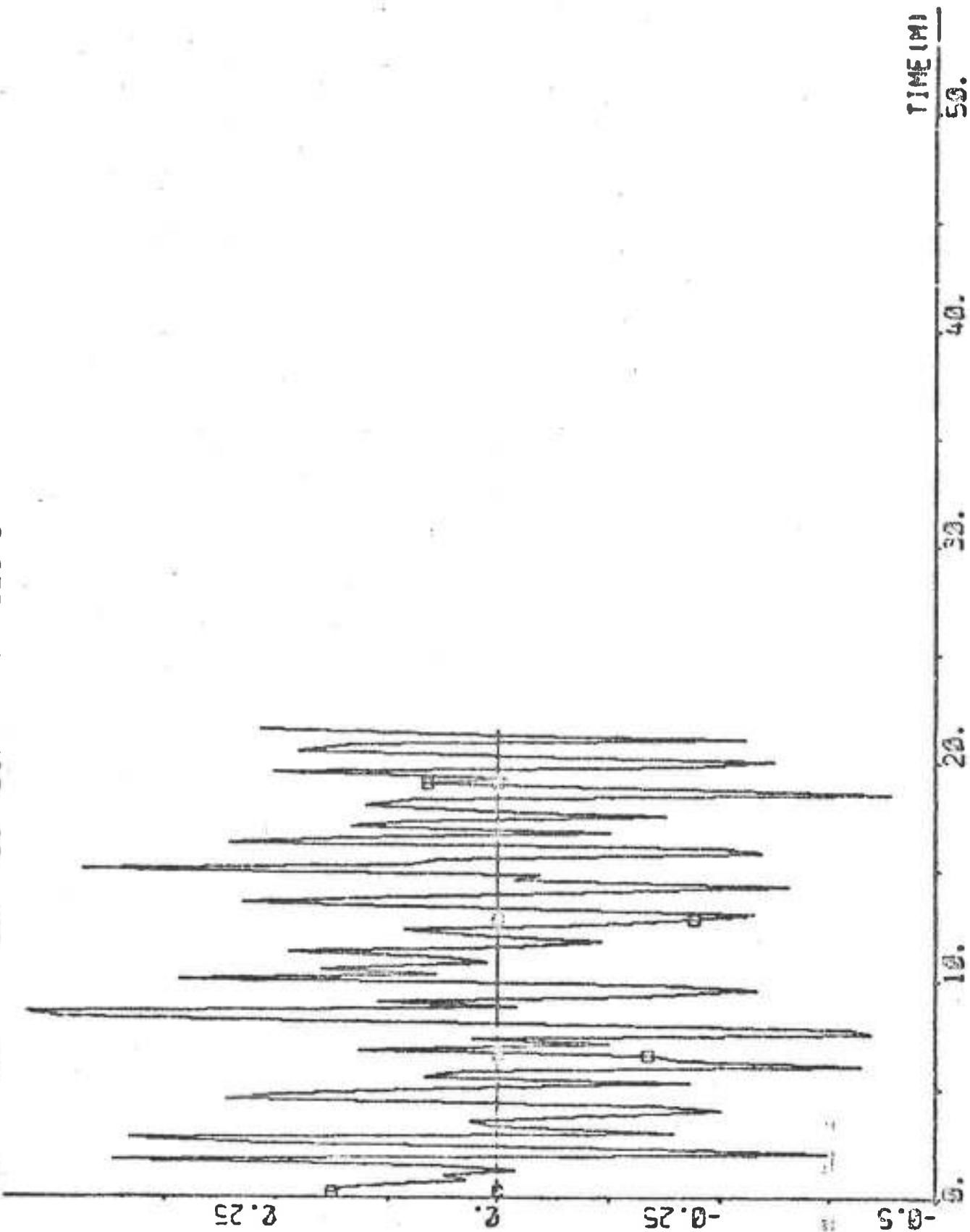
PLOT A39A1(3) ZERO -40 40 "DELTA" DEG



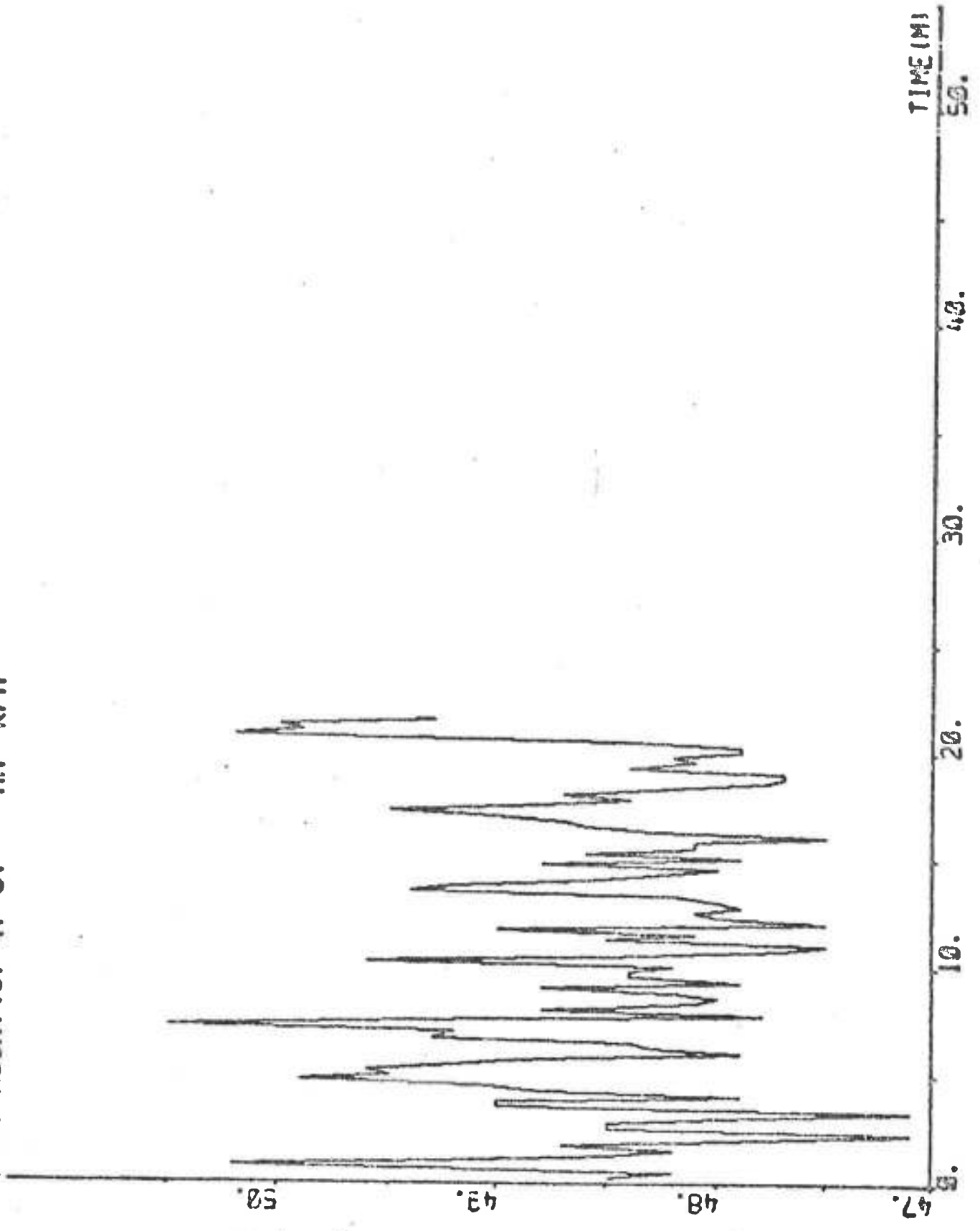
PLOT A39A1(4) ZERO -40 40 "DELTA DEC



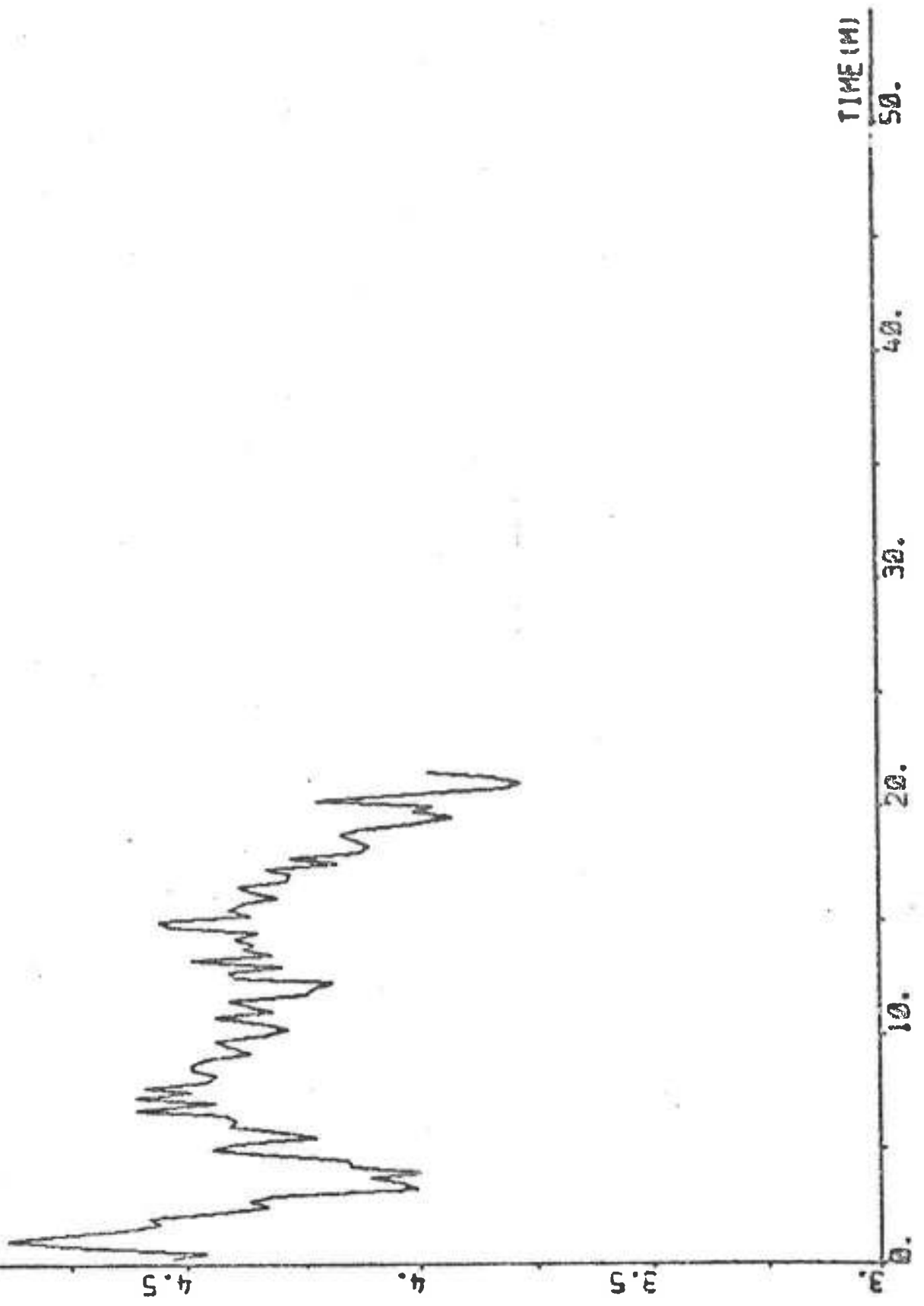
PLOT A3221(5) ZERO -0.5 0.5 "PP DEG/S



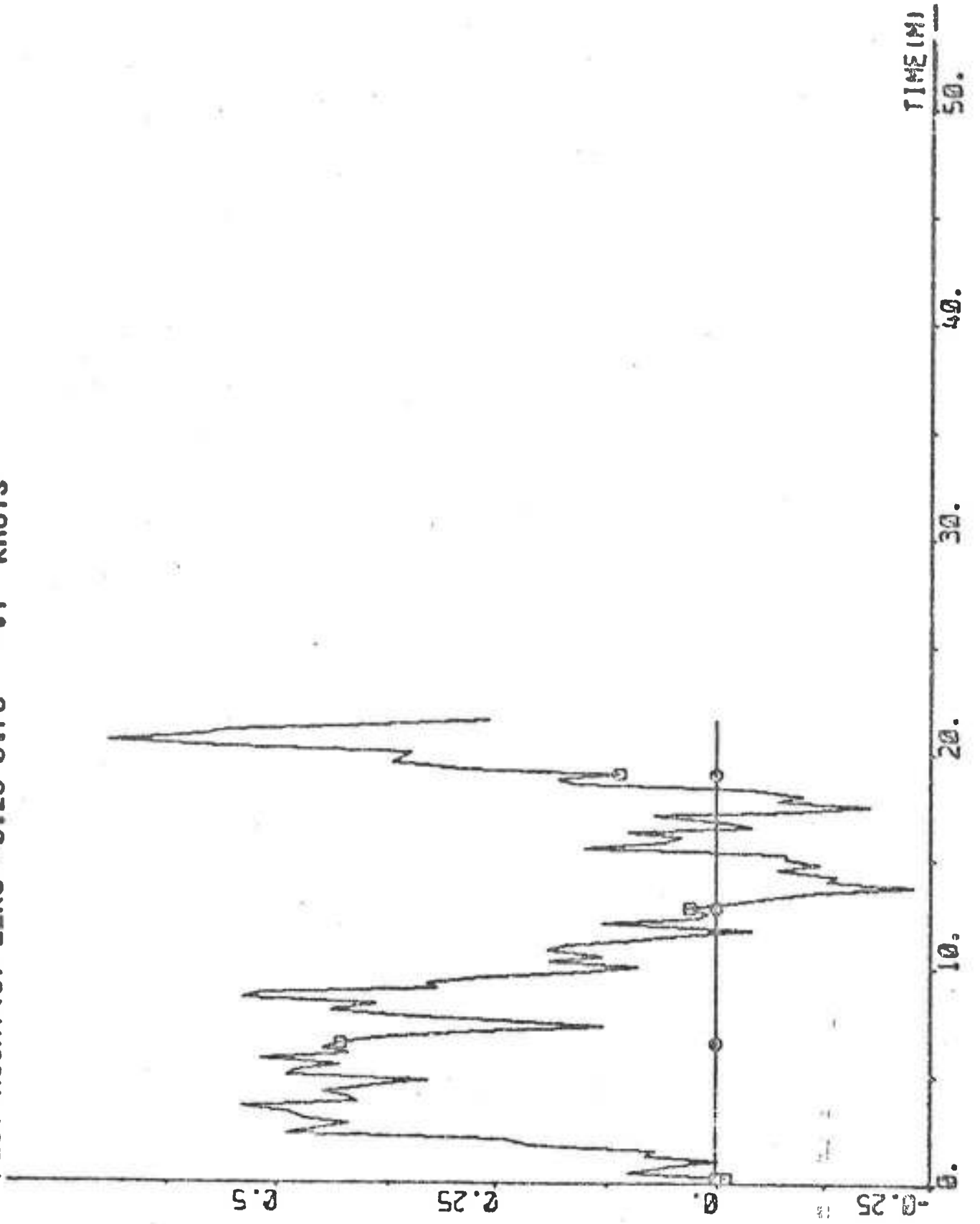
PLOT A3CA1(6) 47 51 "AN RPM



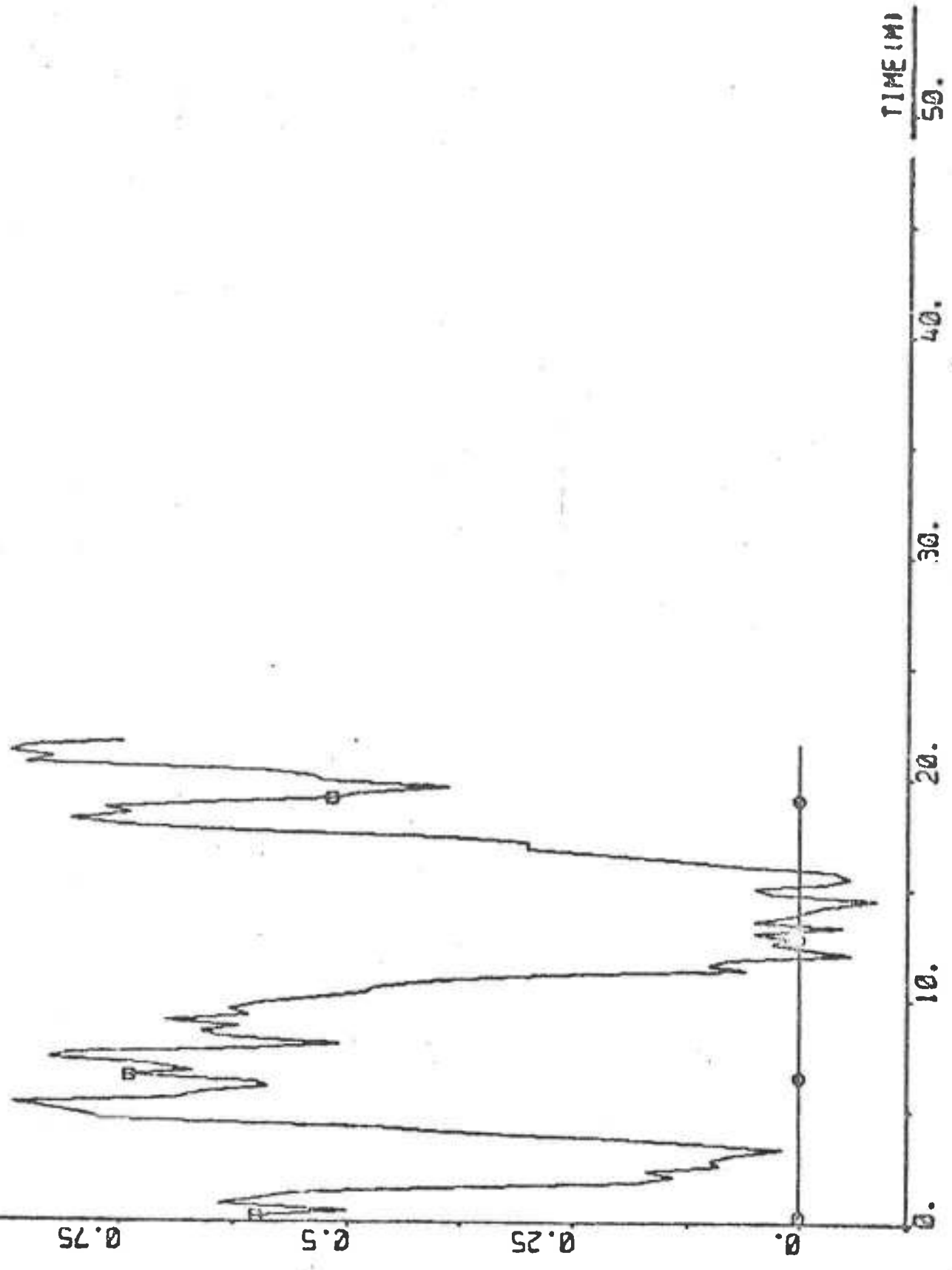
PLOT R39A1(7) 3 5 "U KNOTS



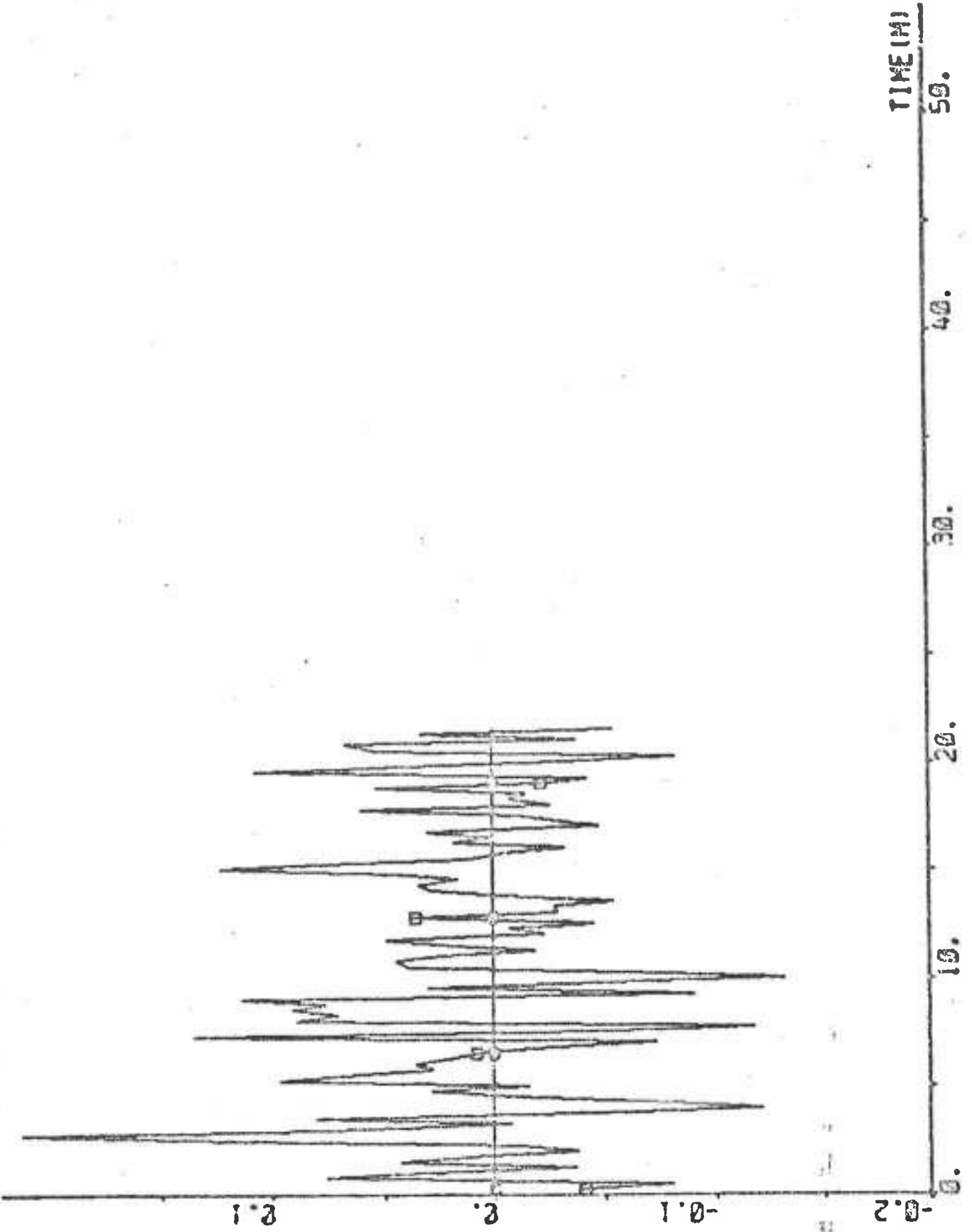
PLOT A38A1(8) ZERO -0.25 0.75 ~V1 KNOTS



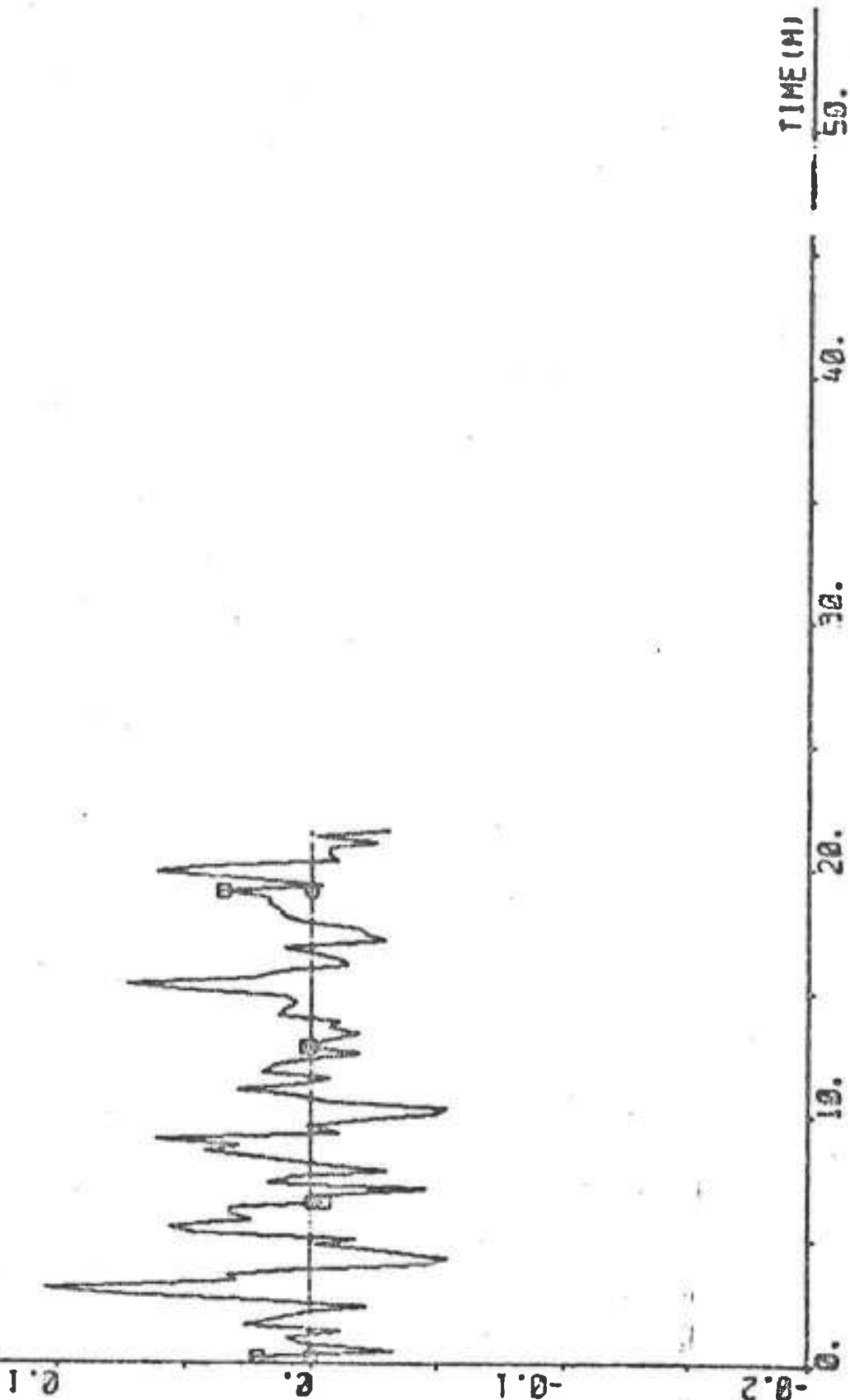
PLOT A38A1(8) ZERO -0.1 0.9 ~V2 KNOTS



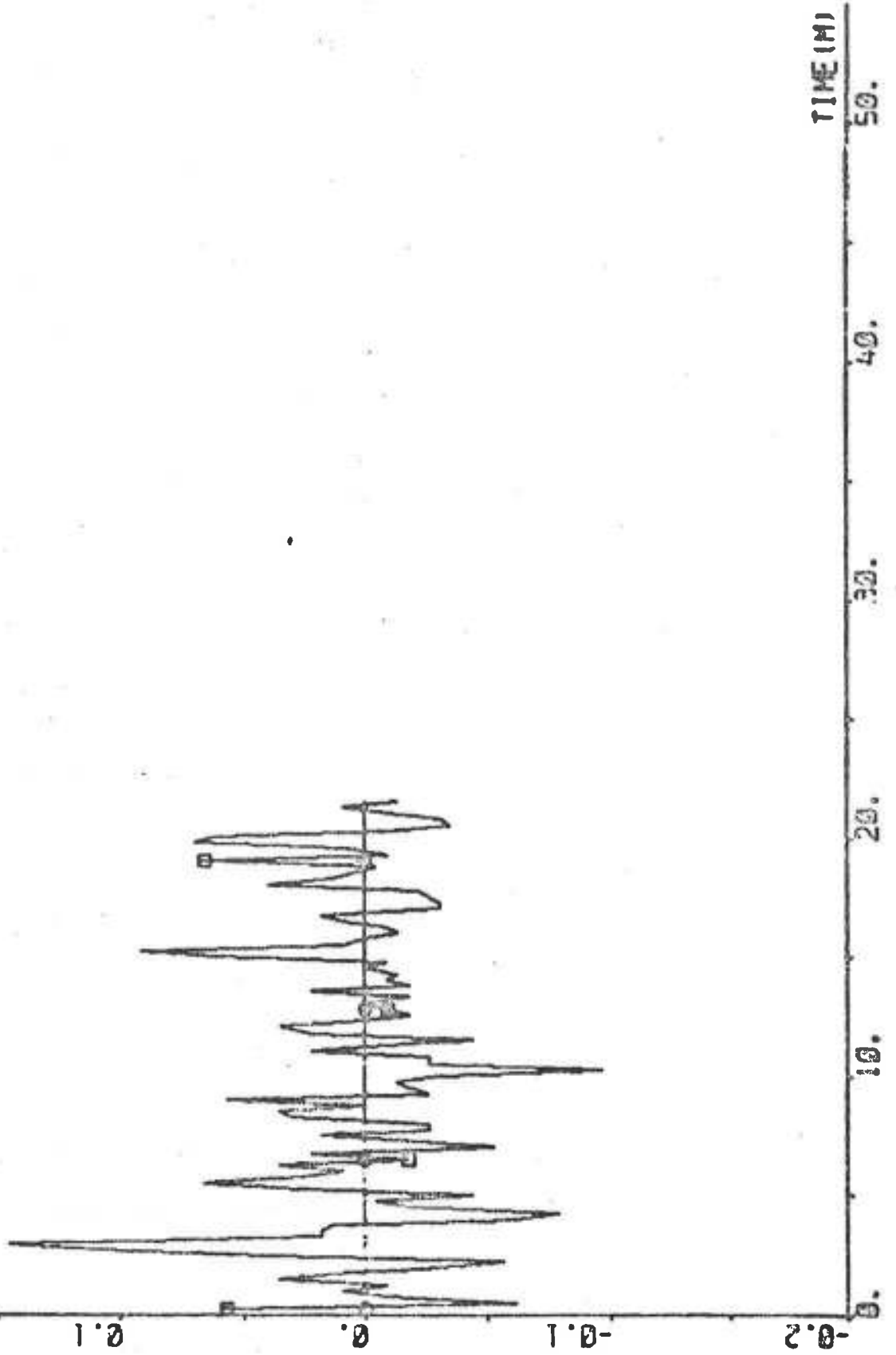
PLOT A30A1(10) ZERO -0.2 0.2 °R DEG/S



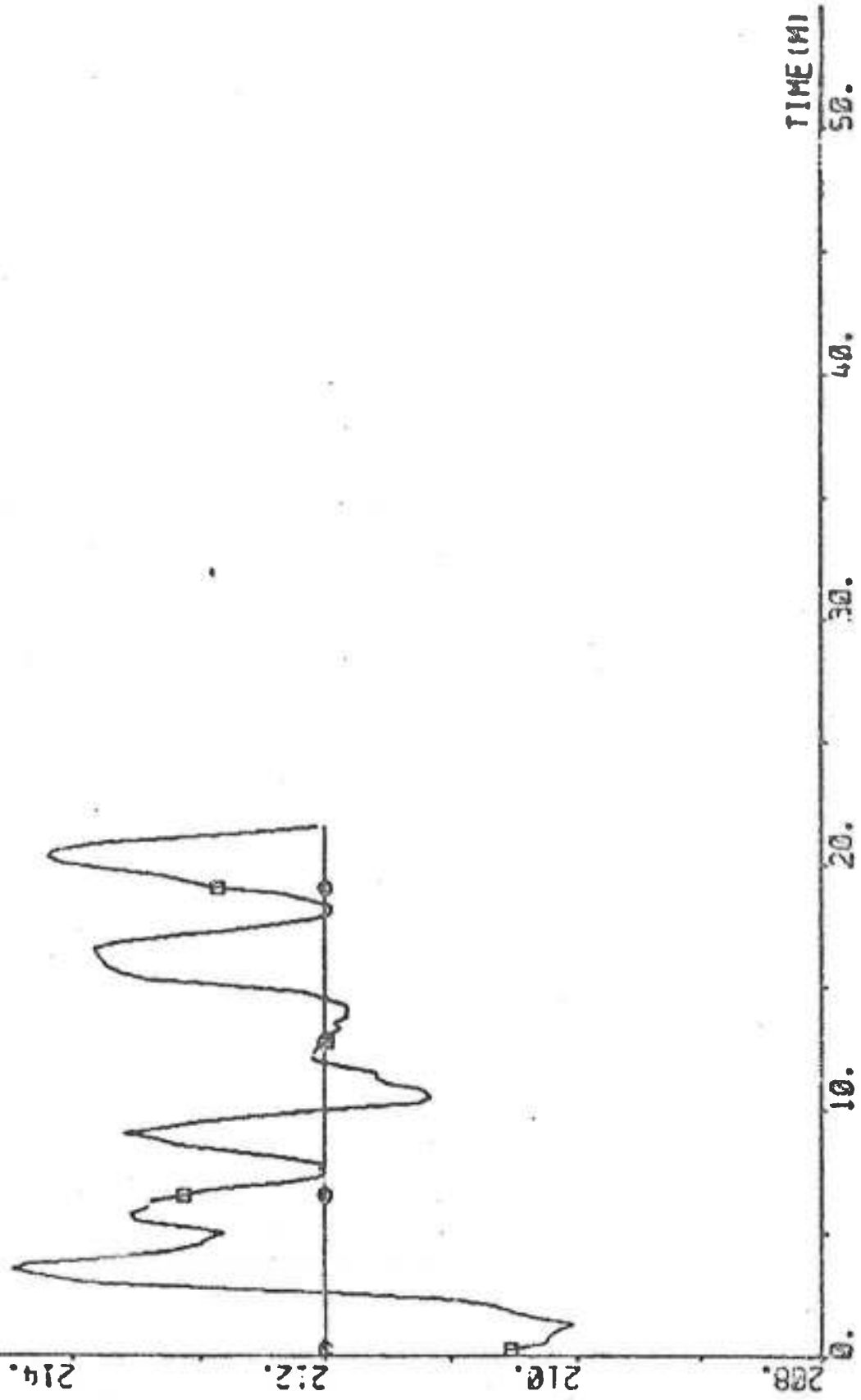
PLOT R39A1(11) ZERO -0.2 0.2 "AVR DEG/S (BR-0.2)



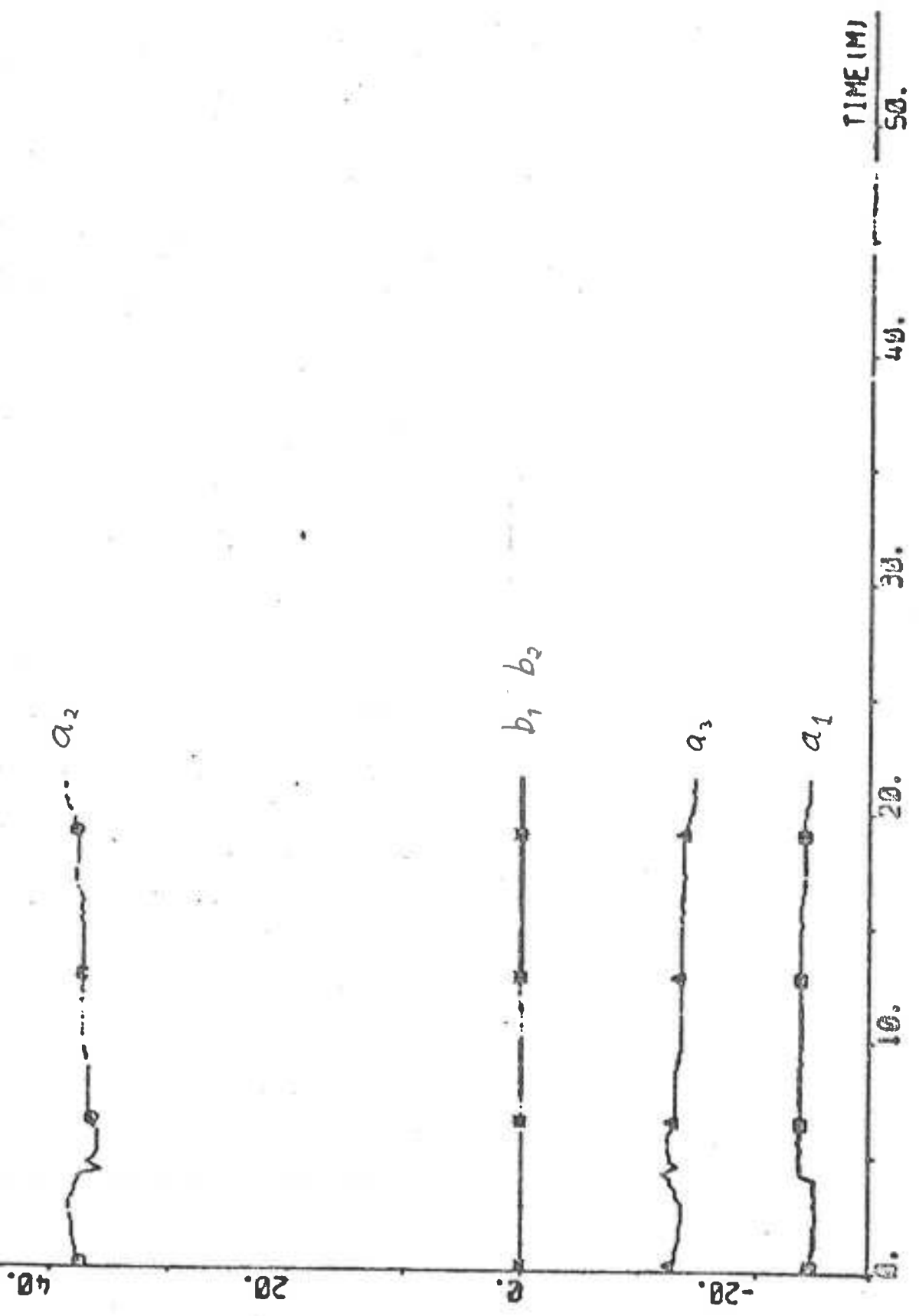
PLOT ACCR1(12) ZERO -0.2 0.2 *DPSIOT DEG/S (IDPSI*6)



PLOT A39A1(13 14) 208 210 212 214 °PSI PSIREF DEC



PLOT A38A2 -25 35 REGULATOR PARAMETERS



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

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

$$a_1 + a_2 + a_3 = -0.129$$

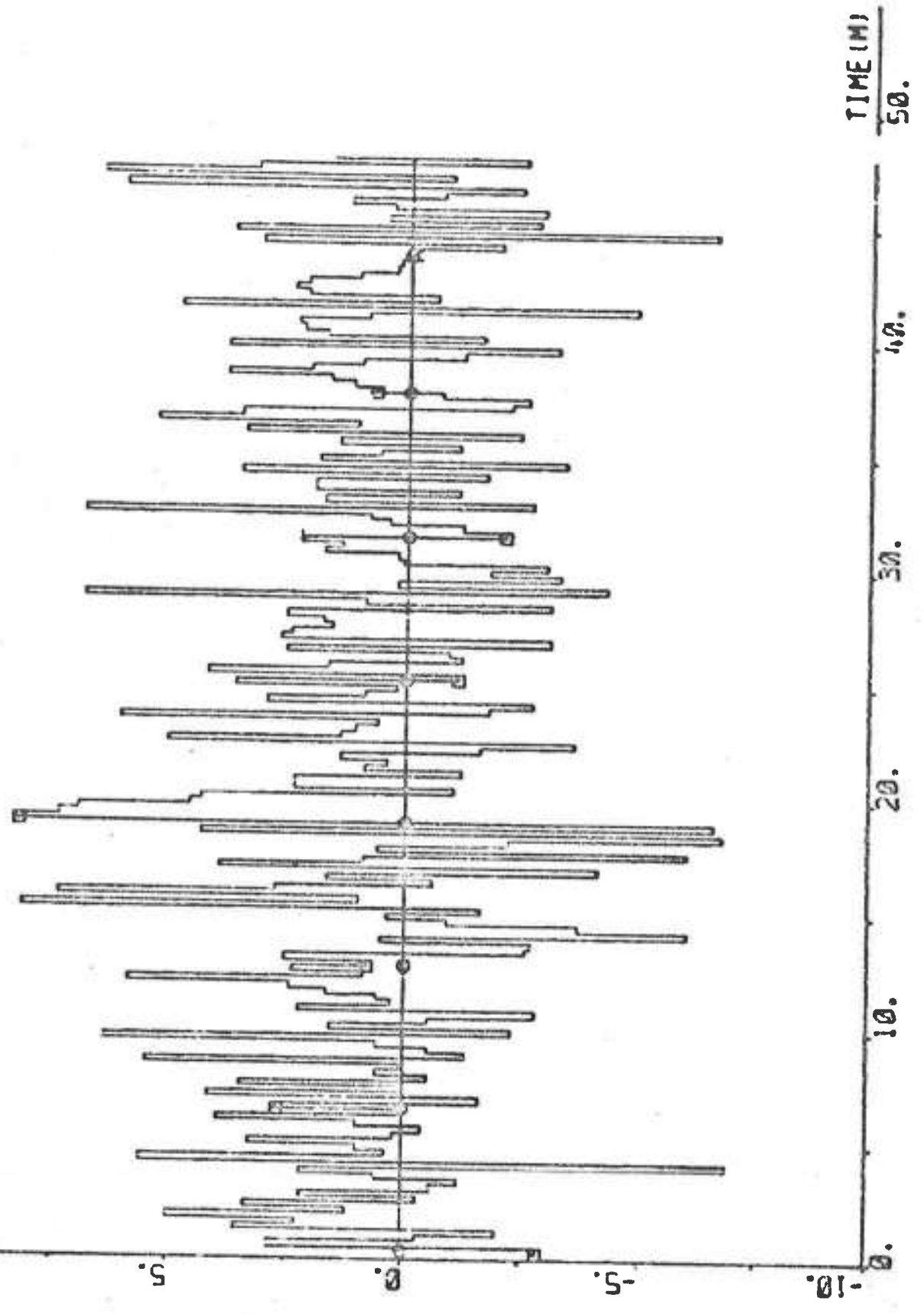
Statistics (mean value and standard deviation)

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

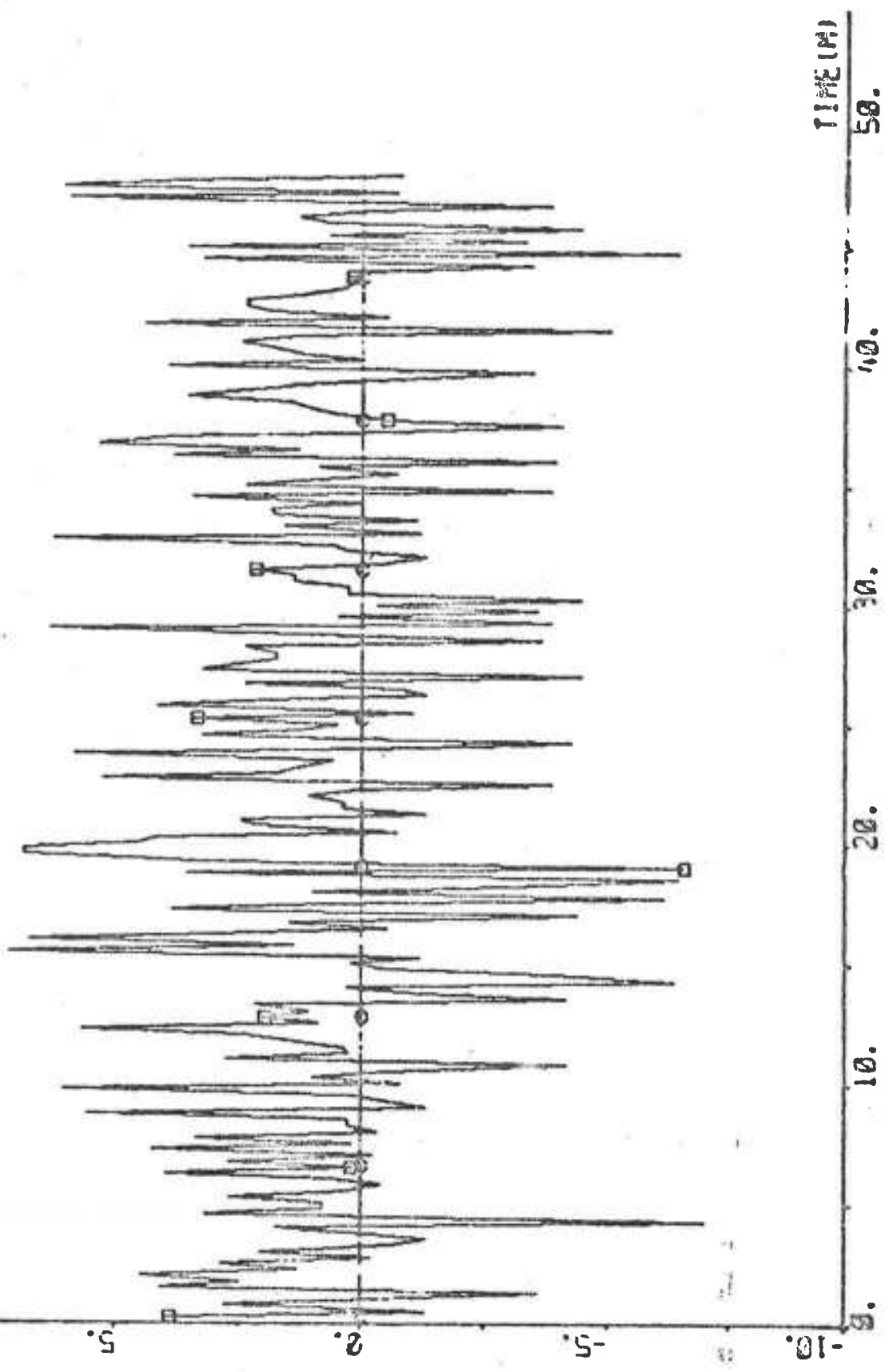
$$V_1 = 1.181$$

$$V_2 = 0.744$$

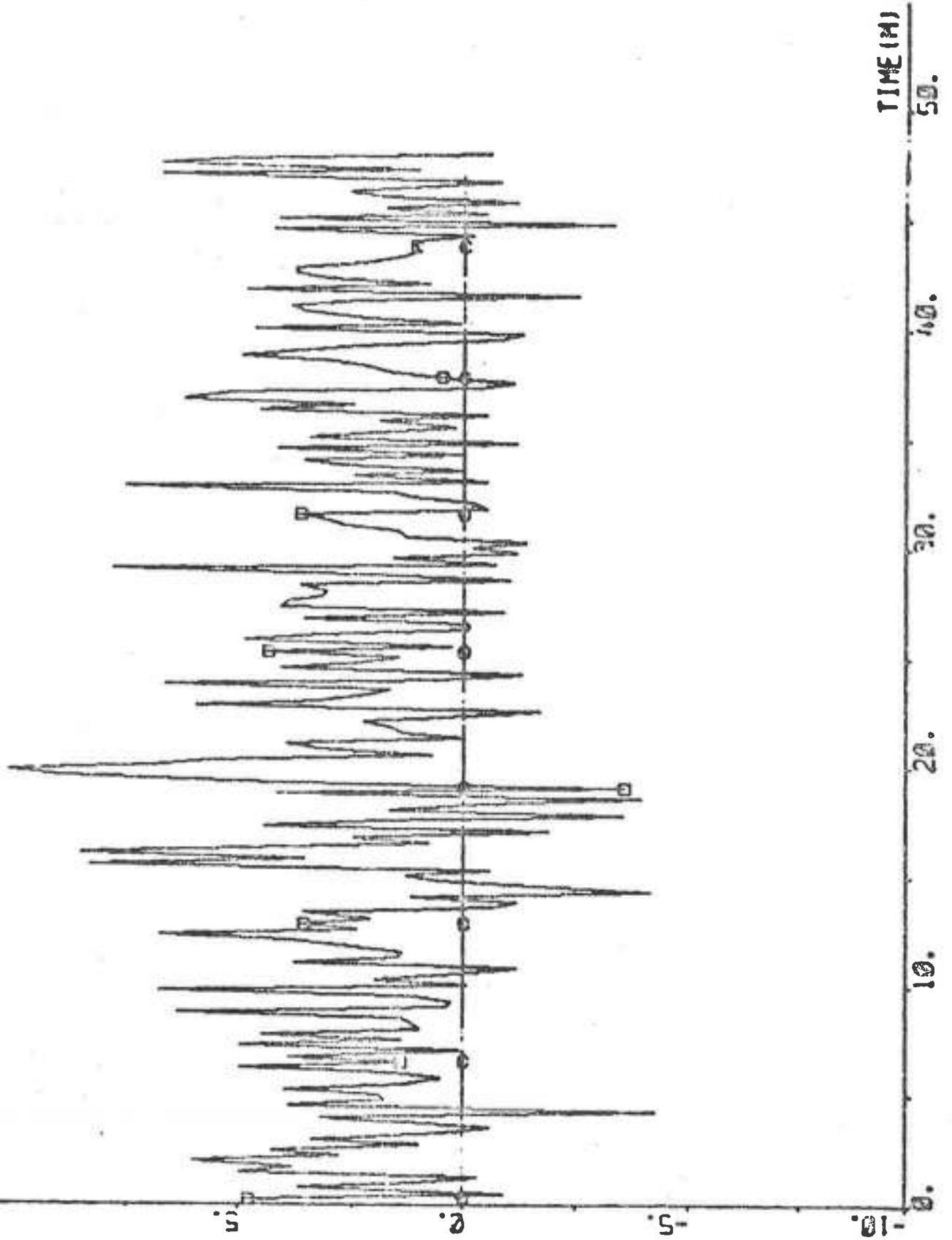
PLOT HP N3301(1) ZERO -10 10 DELCOC DEG



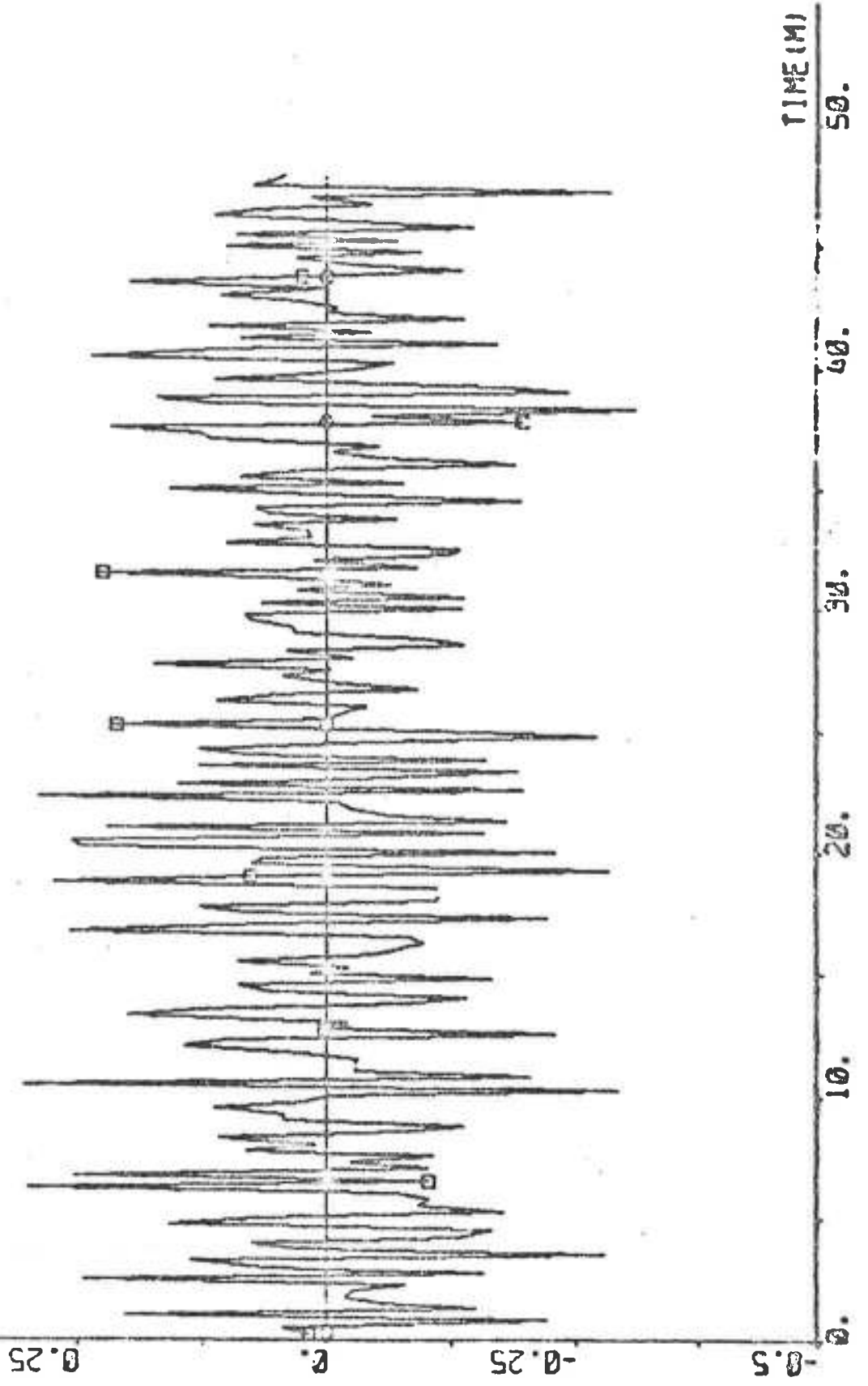
PLOT A39B1(3) ZERO -10 10 "DELTA" DEG



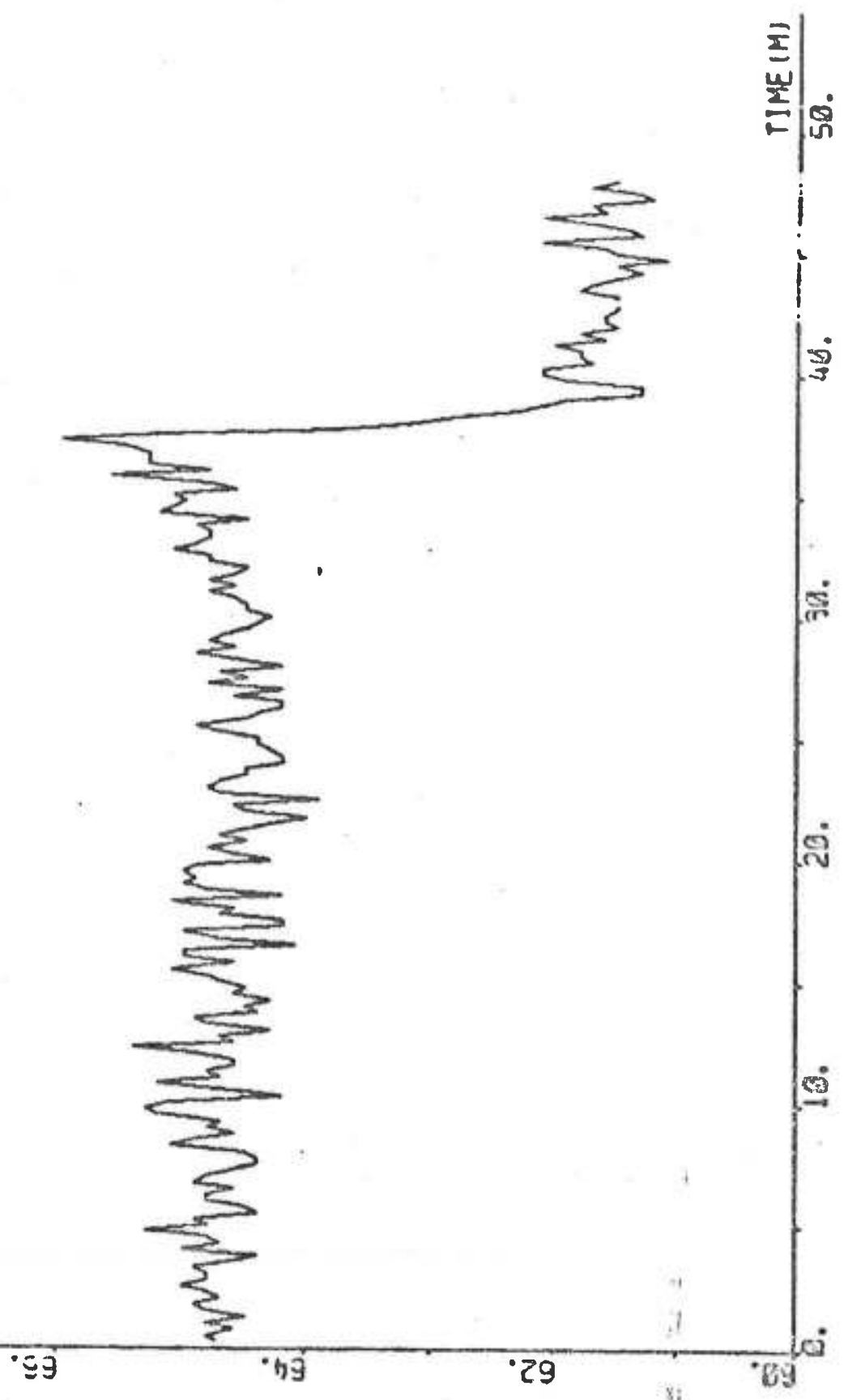
PLOT A3381(4) ZERO -10 10 °DELTA DEG



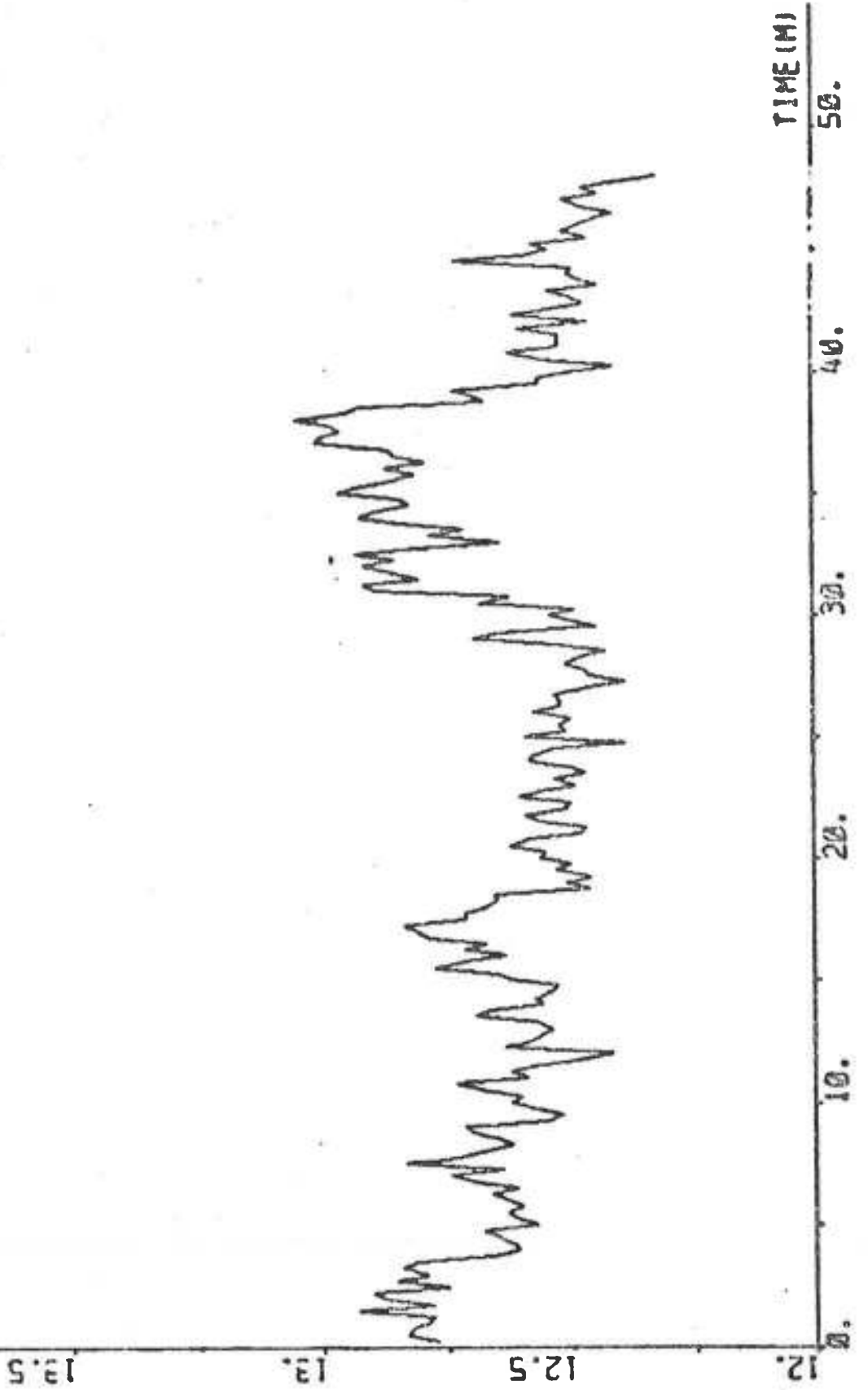
FLOT A39B1(5) ZERO -0.5 0.5 *PP DEC/S



PLOT ACCBI(5) 60 69 -AN RPH



PLOT A33B1(7) 12 14 "U KNOTS



PLOT A3581(8) ZERO -0.5 0.5 "VI KNOTS

0.25

0

-0.25

-0.5

TIME (M)

50.

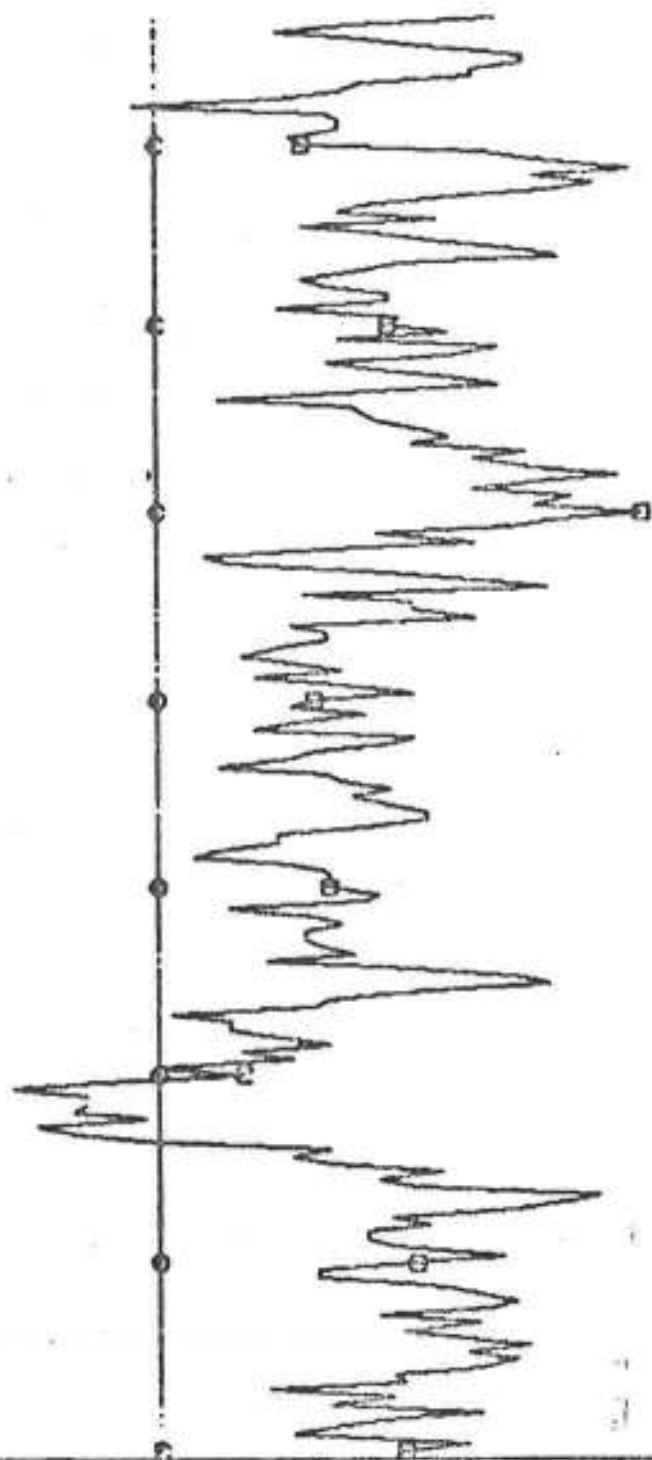
40.

30.

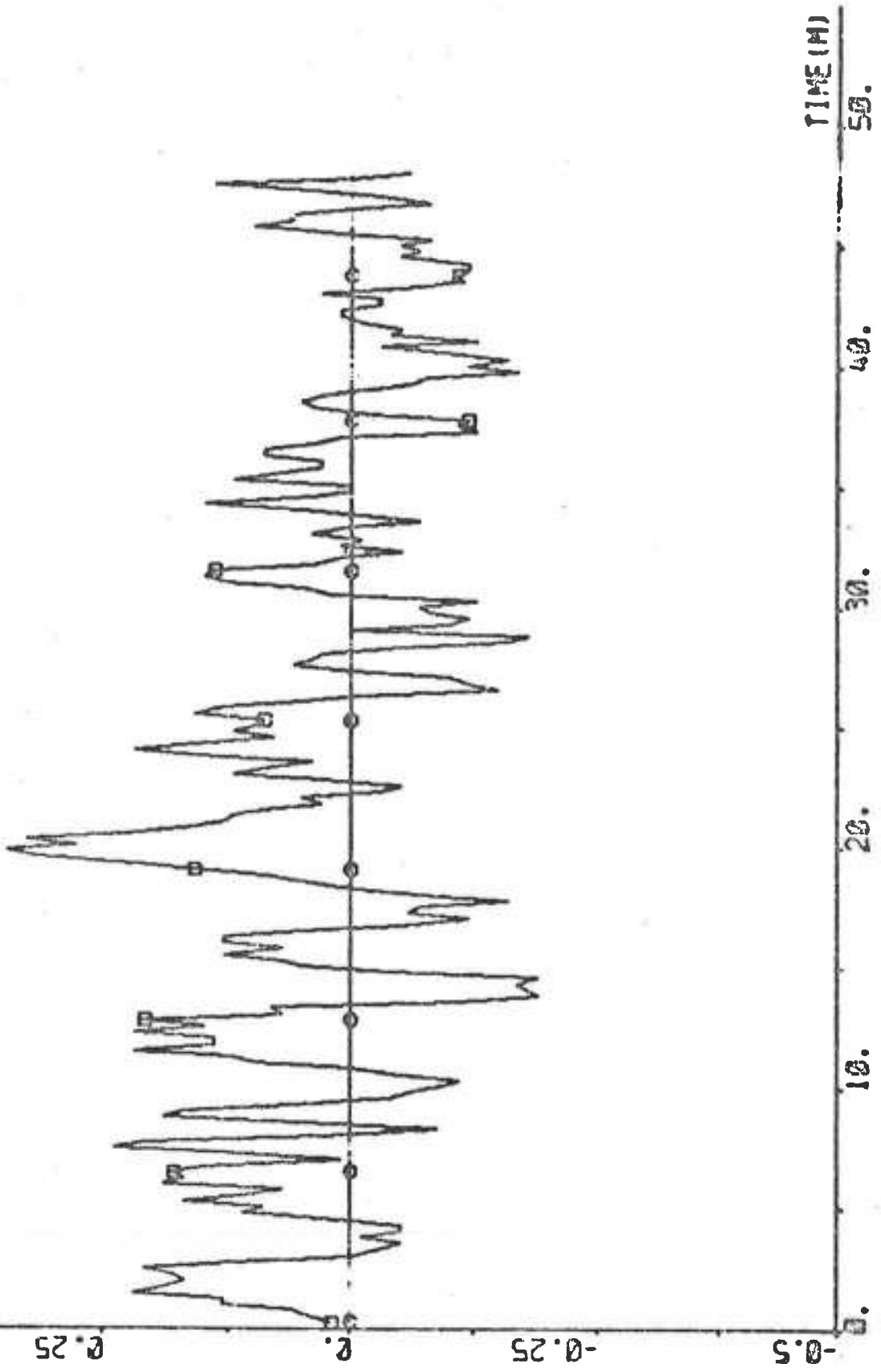
20.

10.

0.

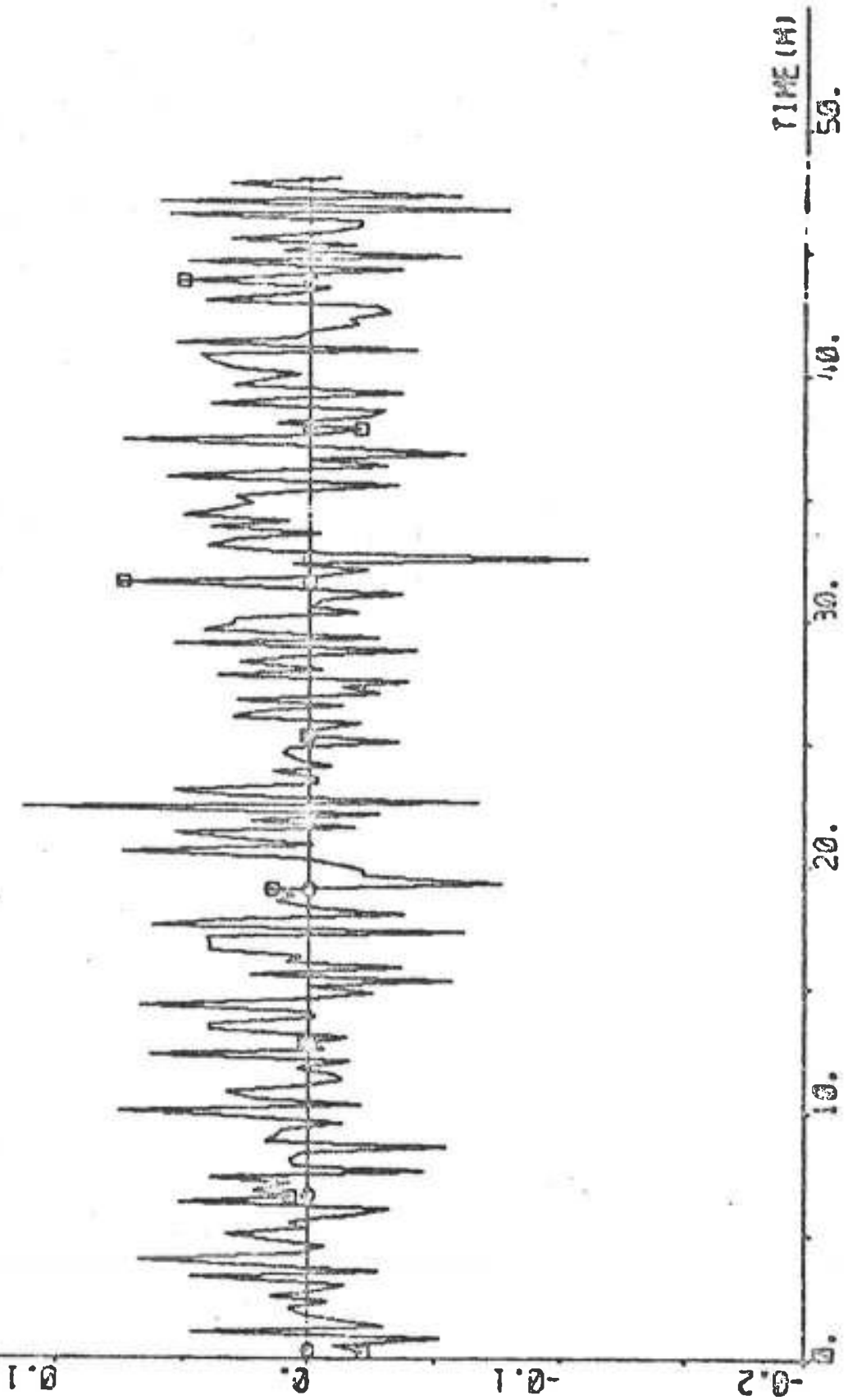


PLOT A39B1(8) ZERO -0.5 0.5 -V2 KNOTS



TIME (M) 50.

PLOT A3981(10) ZERO -0.2 0.2 "R DEG/S



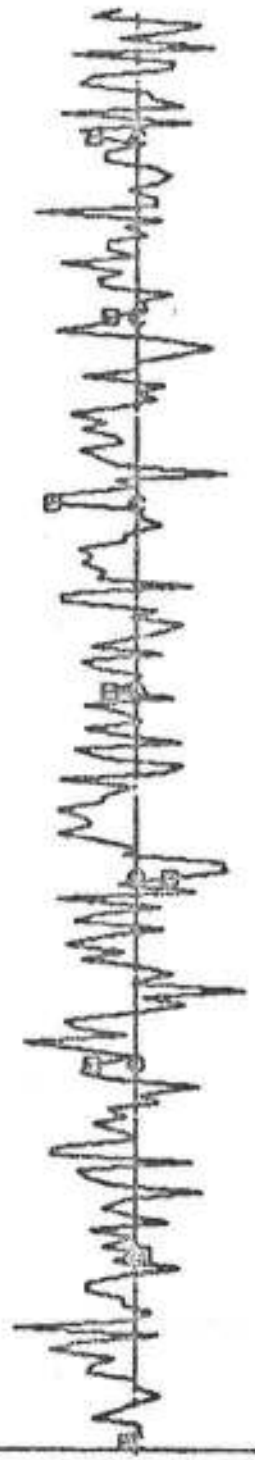
PLOT A39B1(11) ZERO -0.2 0.2 "AVR DEG/S (BR:0.2)

0.1

0.

-0.1

-0.2



TIME (H)

50.

40.

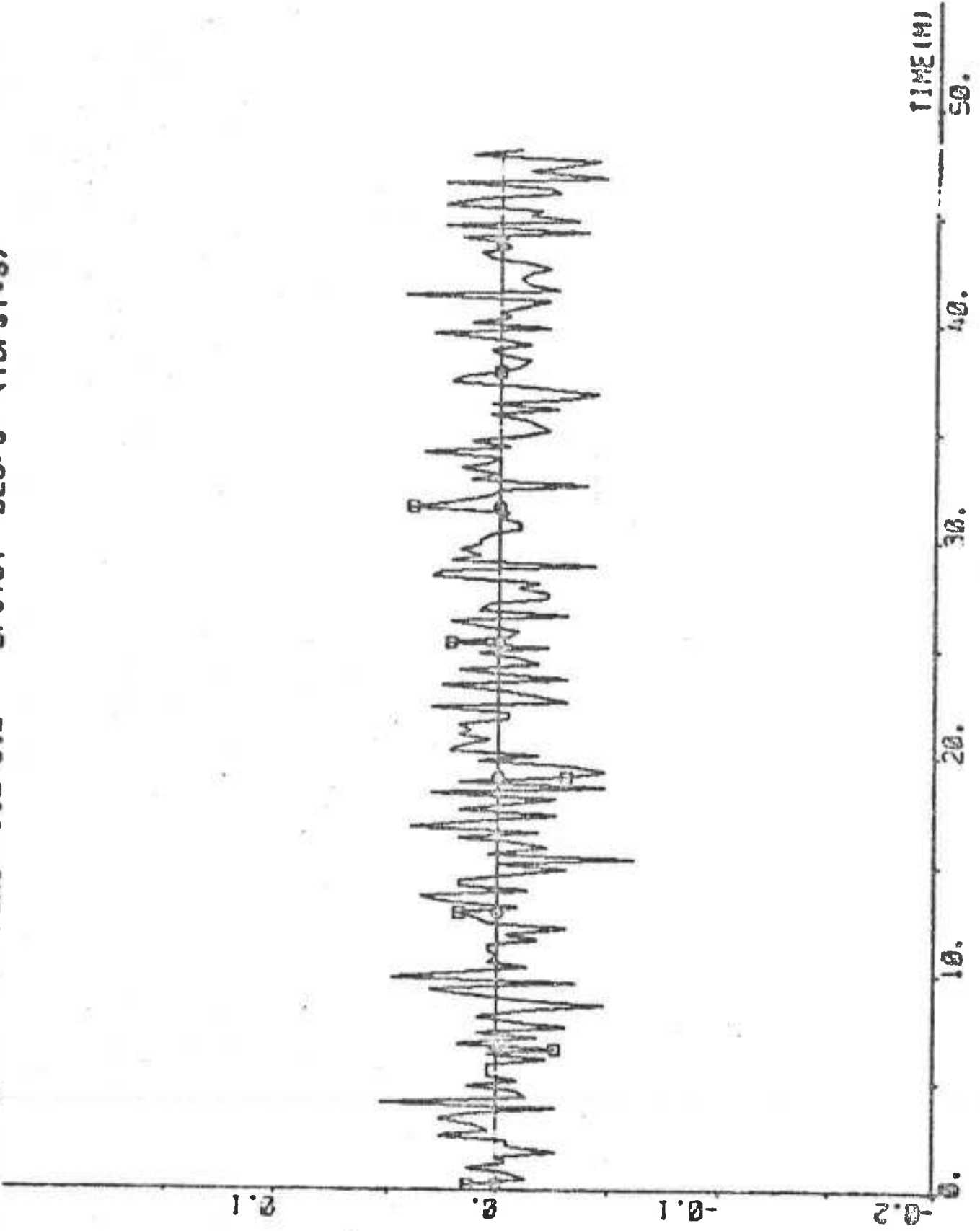
30.

20.

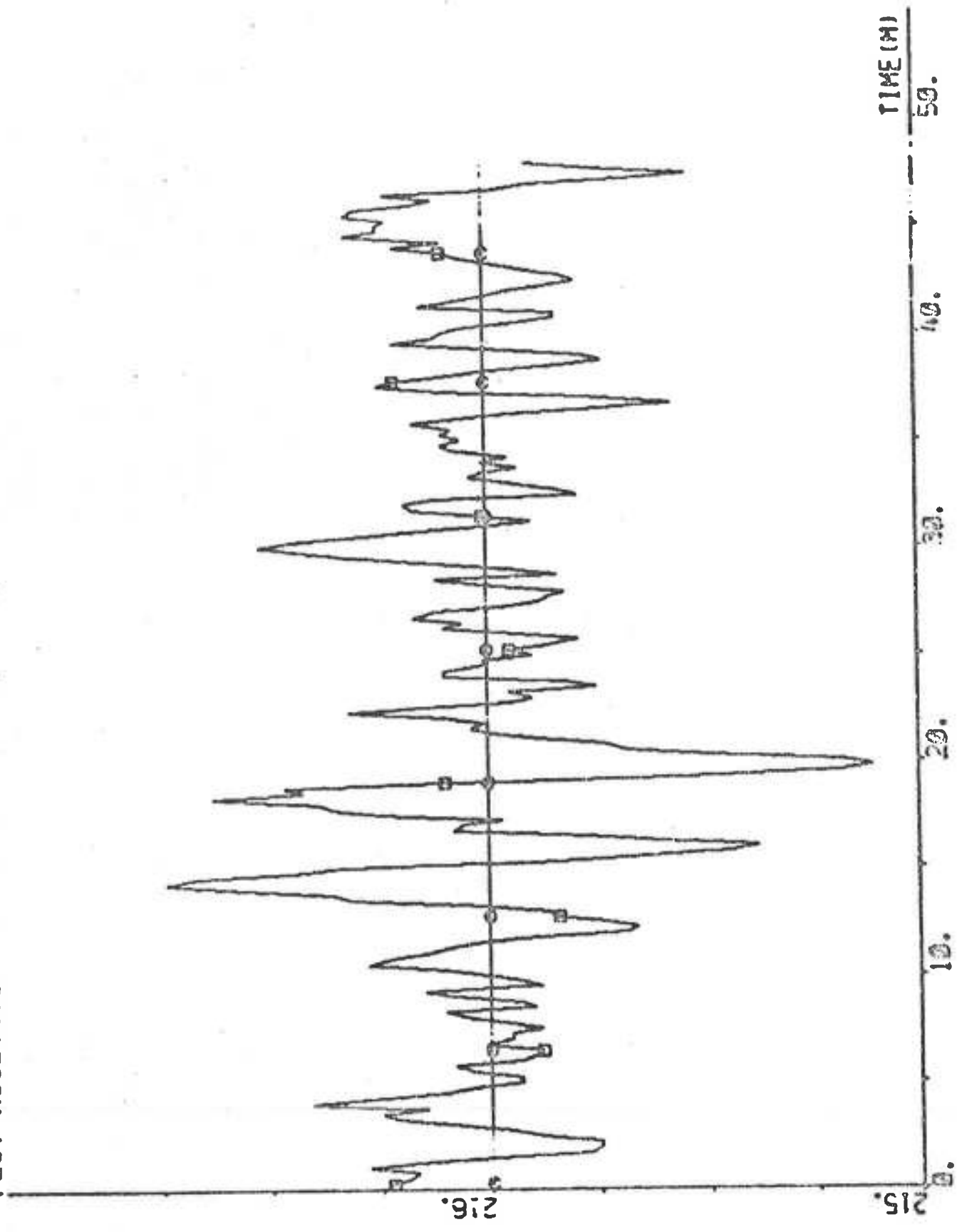
10.

0.

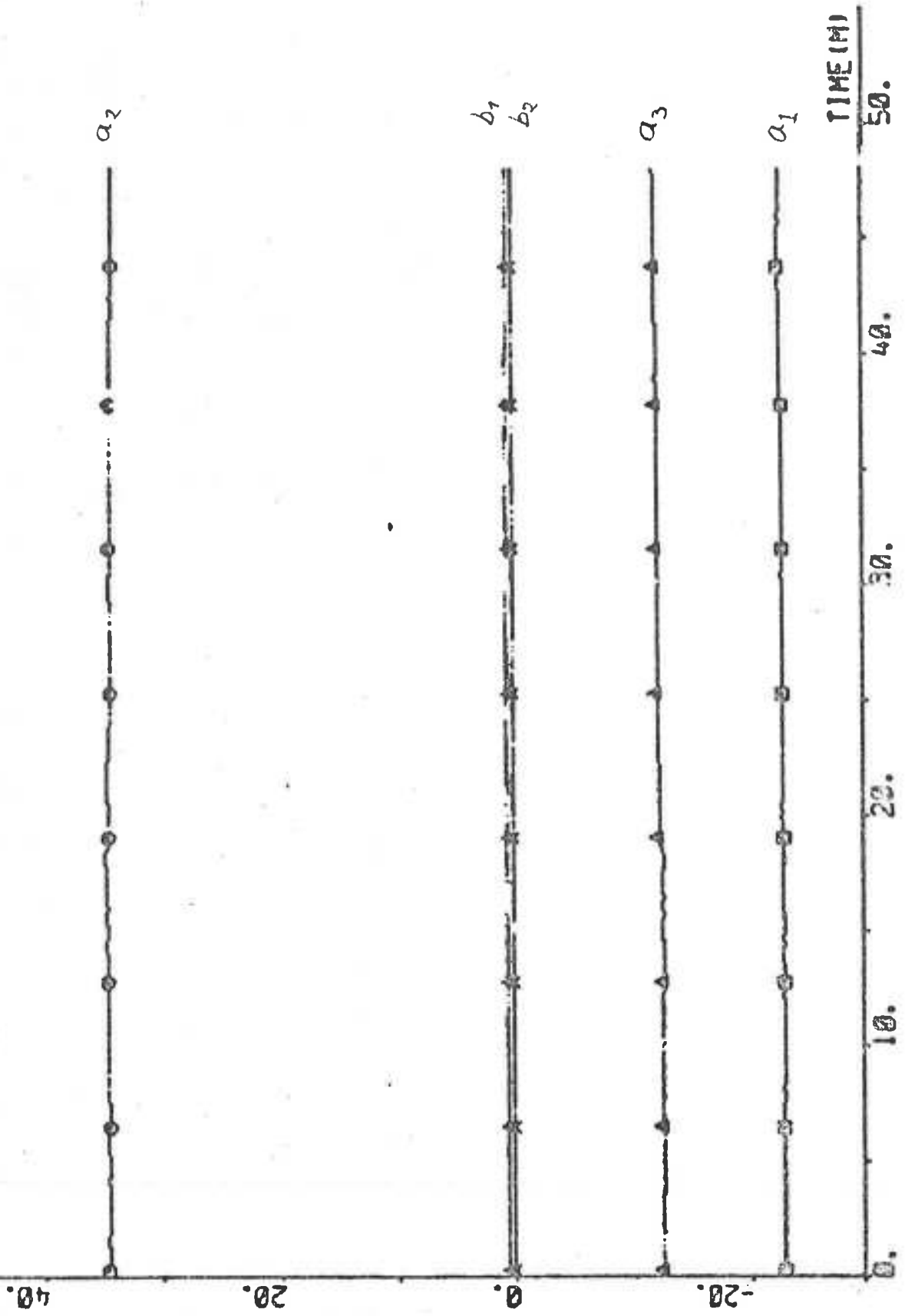
PLOT A39B1(12) ZERO -0.2 0.2 "DPSIOT DEG/S (IDPSI=5)



PLOT R3981(13 14) 215 217 -PSI PSIREF DEG



PLOT A39B2 -25 35 "REGULATOR PARAMETERS



EXPERIMENT A40

Date	1974-10-22
Time	08.44
Duration	.140 min
Position	S 31 ^o 11' E 30 ^o 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 ^o - 224.4 ^o (Sailmaster, Course correction)
RREF	0.07 deg/s
Rudder limit	Probably active, but unknown
DEL1M at termination	0.38 ^o

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

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

$$a_1 + a_2 + a_3 = -0.579$$

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

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

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

Yaw regulator values after the yaw at 121 min.

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

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

Statistics (mean value and standard deviation)

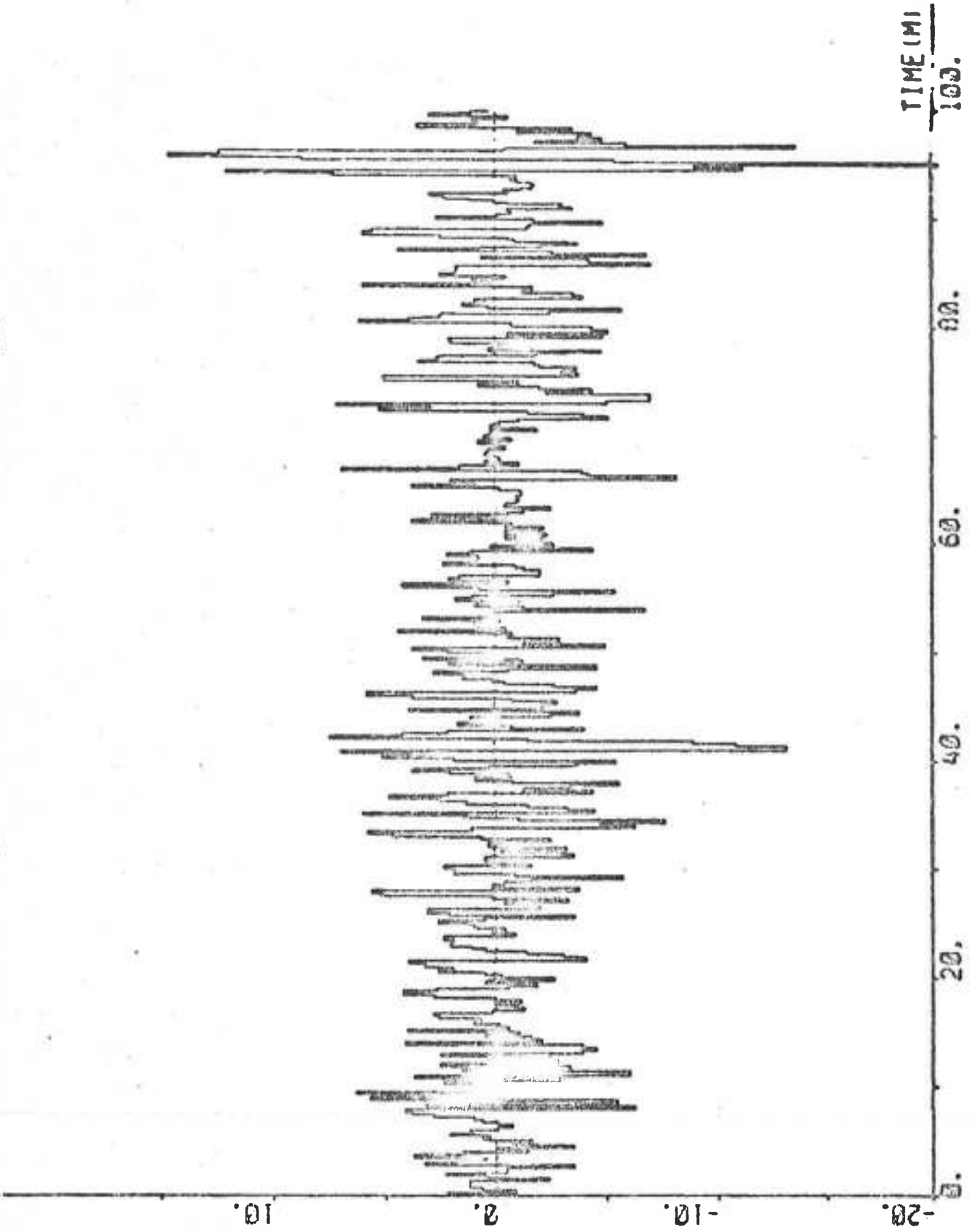
0-120 min

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

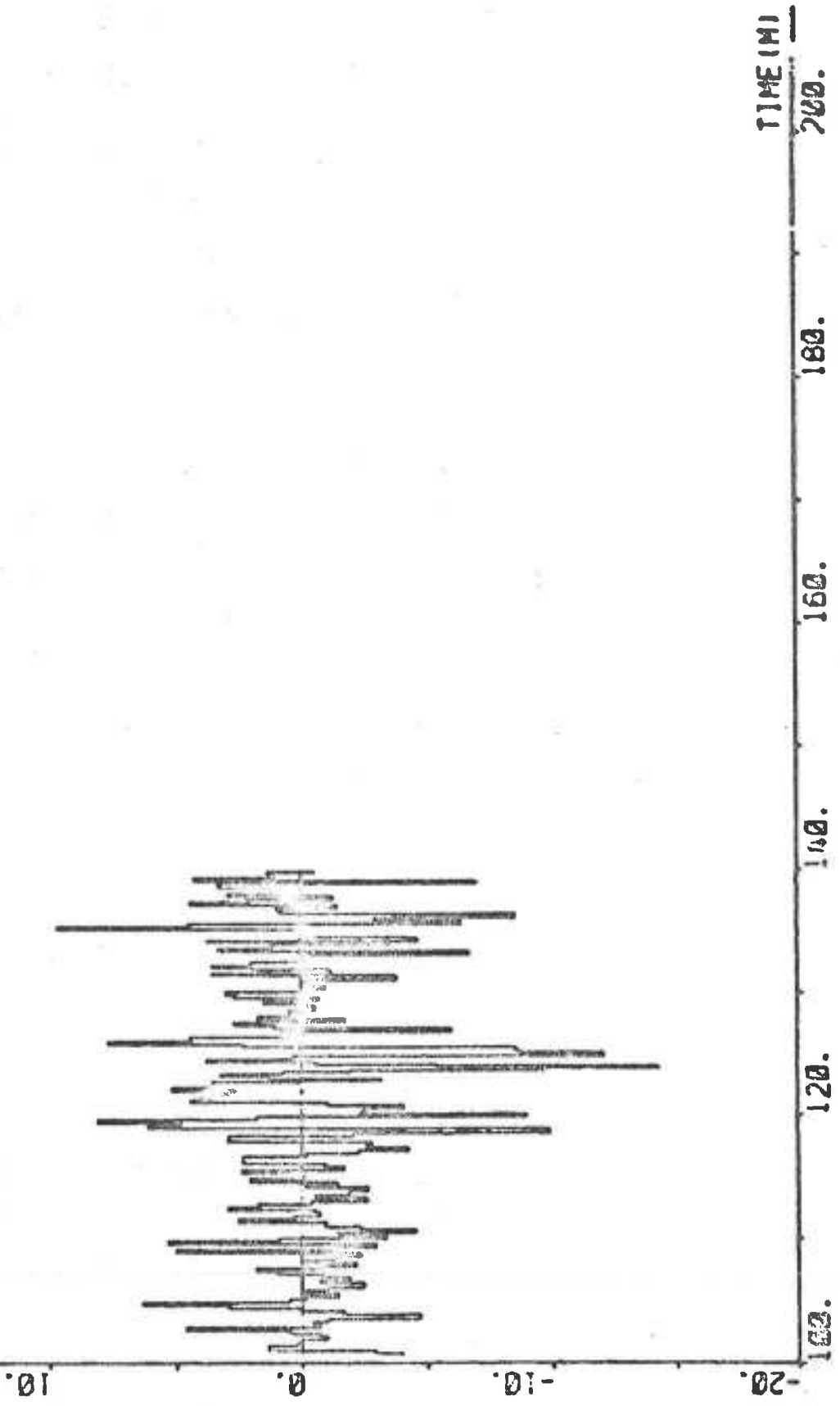
V₁ 1.387

V₂ 1.266

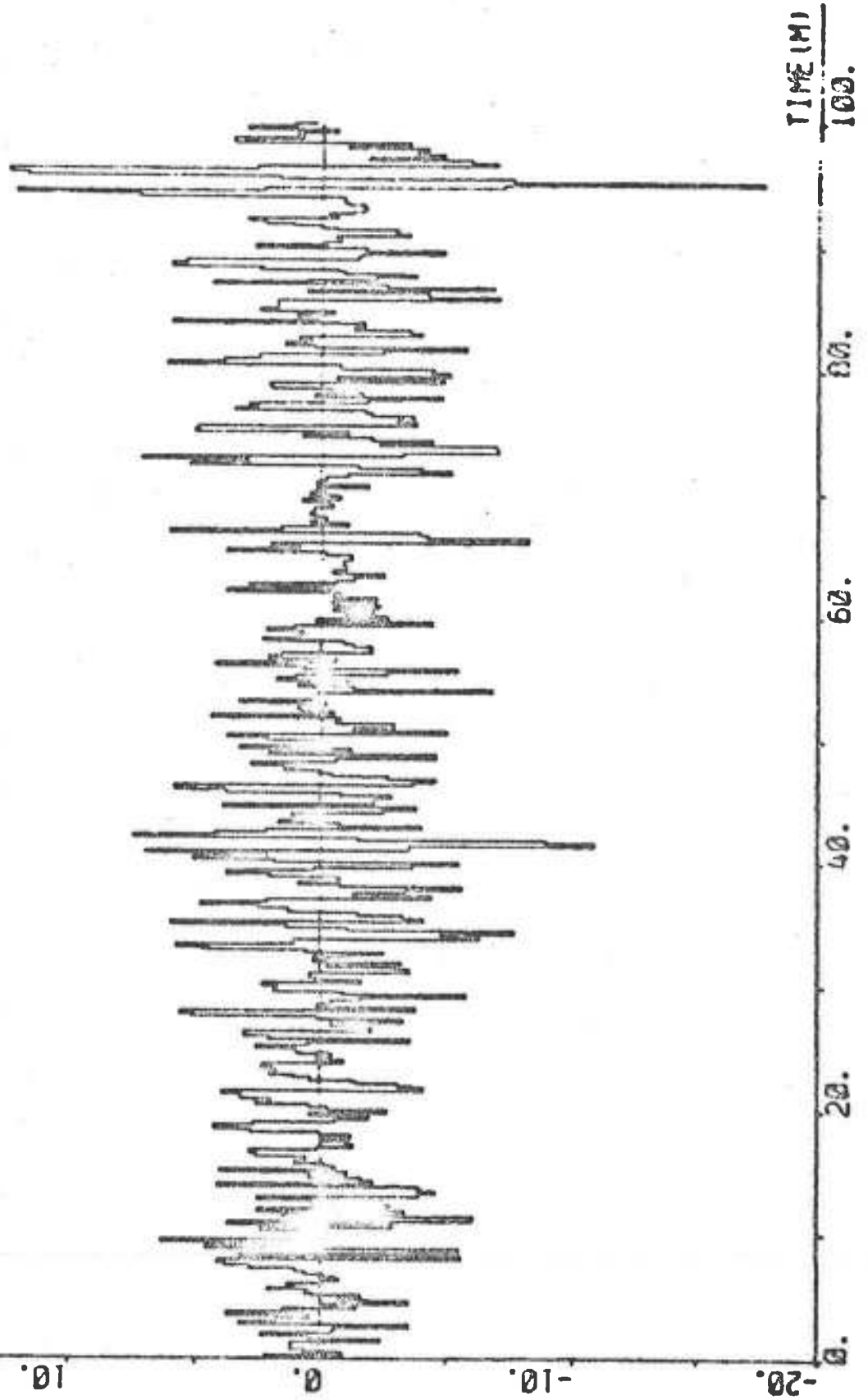
PLOT A40P1(15)-HP A40P1(1) ZERO -20 20 "DELCO" DEC



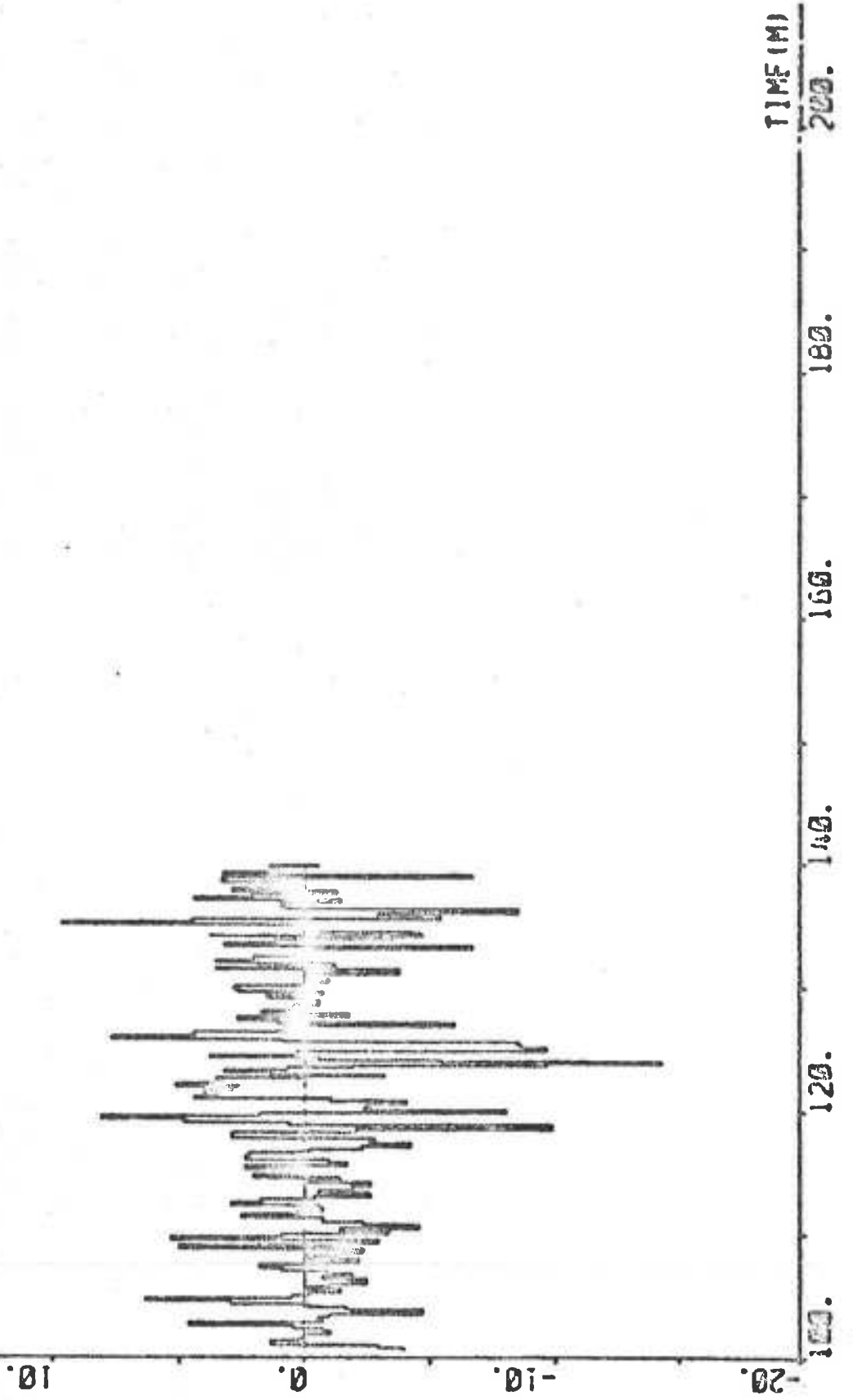
PLOT R4CP1(16)•HP R4CP1(1) ZERO -20 20 °DELCOX DEG



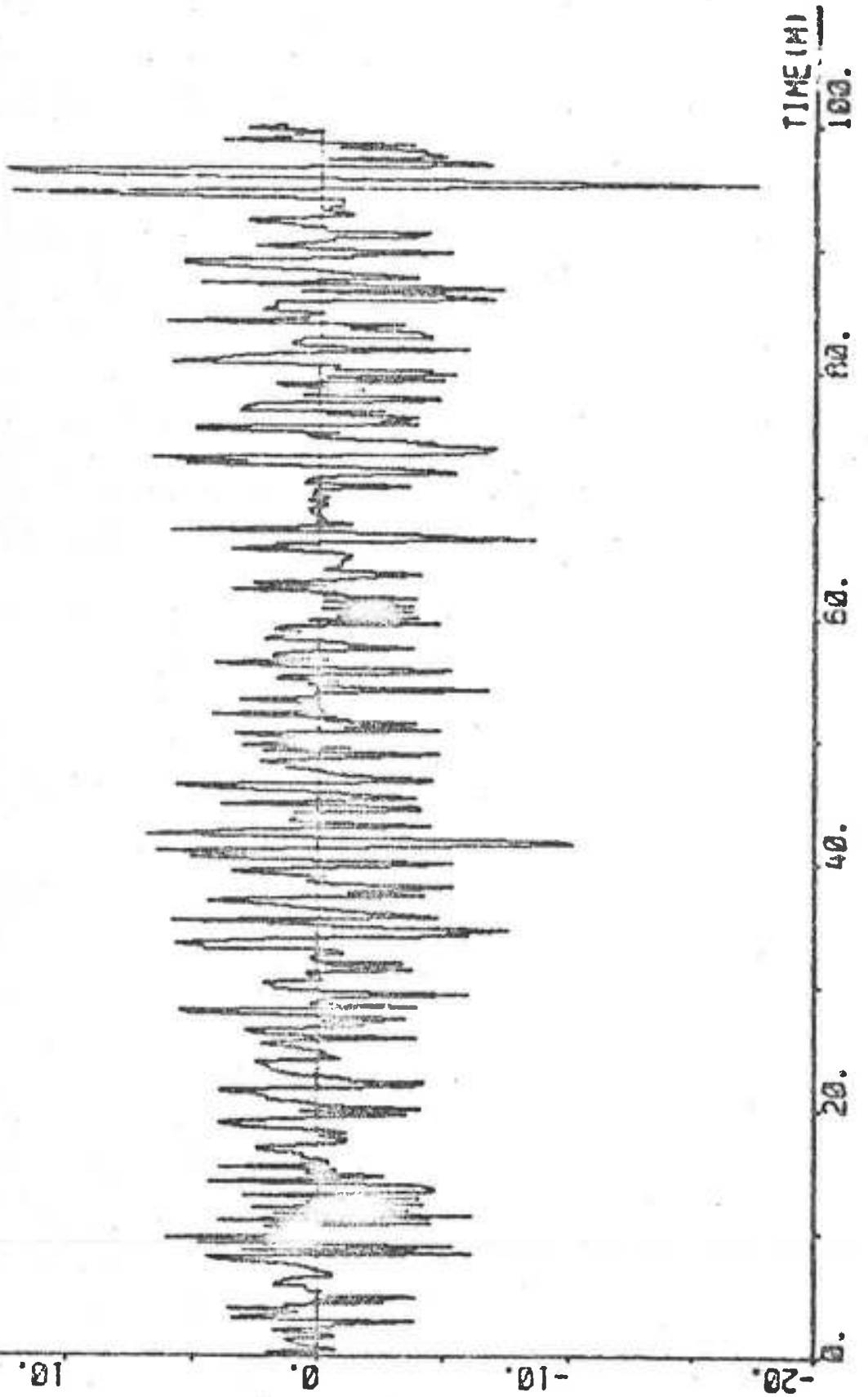
FLOT R40P1(15)+HP R40P1(2) ZERO -20 20 -DELCOM DEG



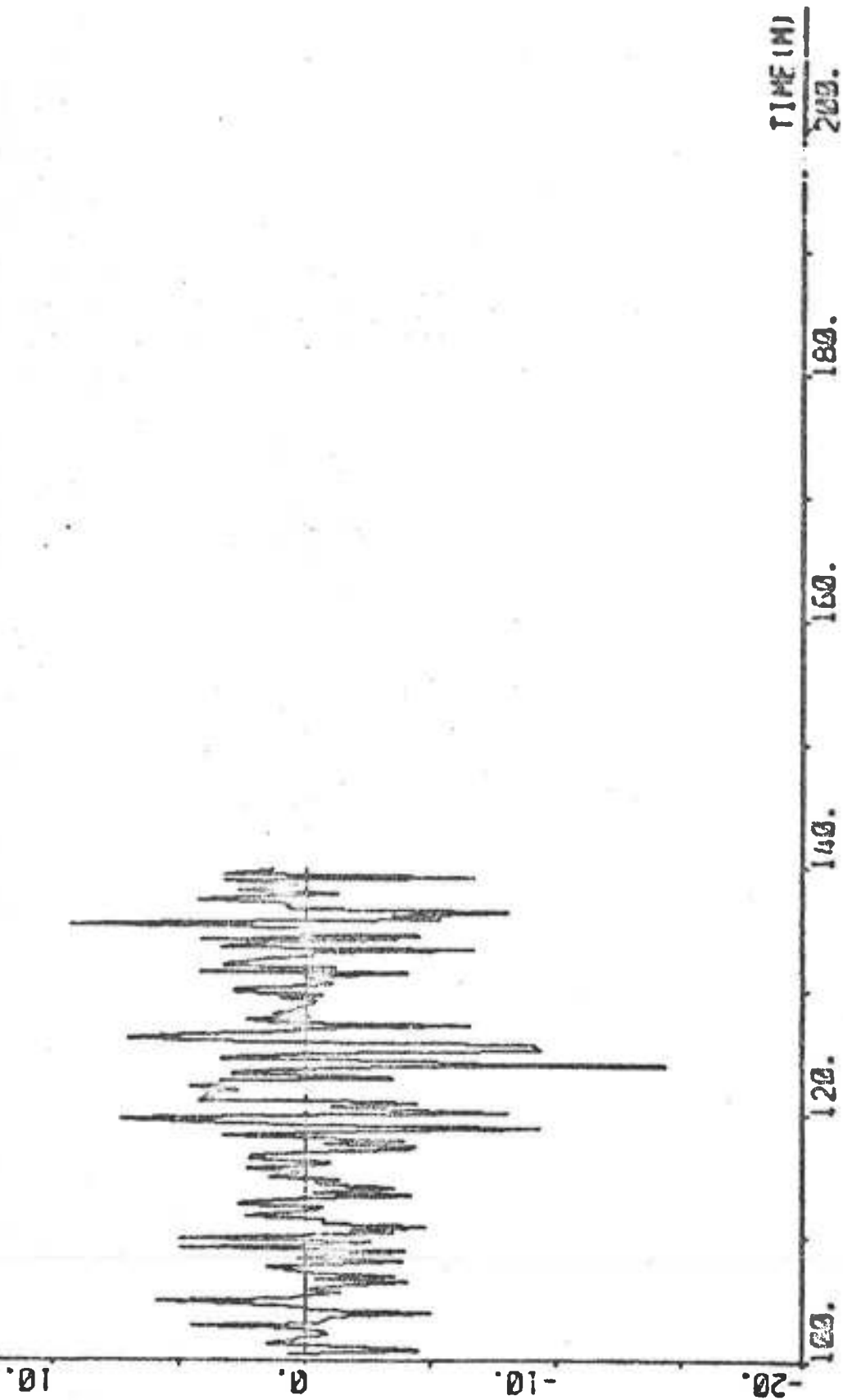
PLOT A4CP1(15)•HP A4CP1(2) ZERO -20 20 "DELCON DEG



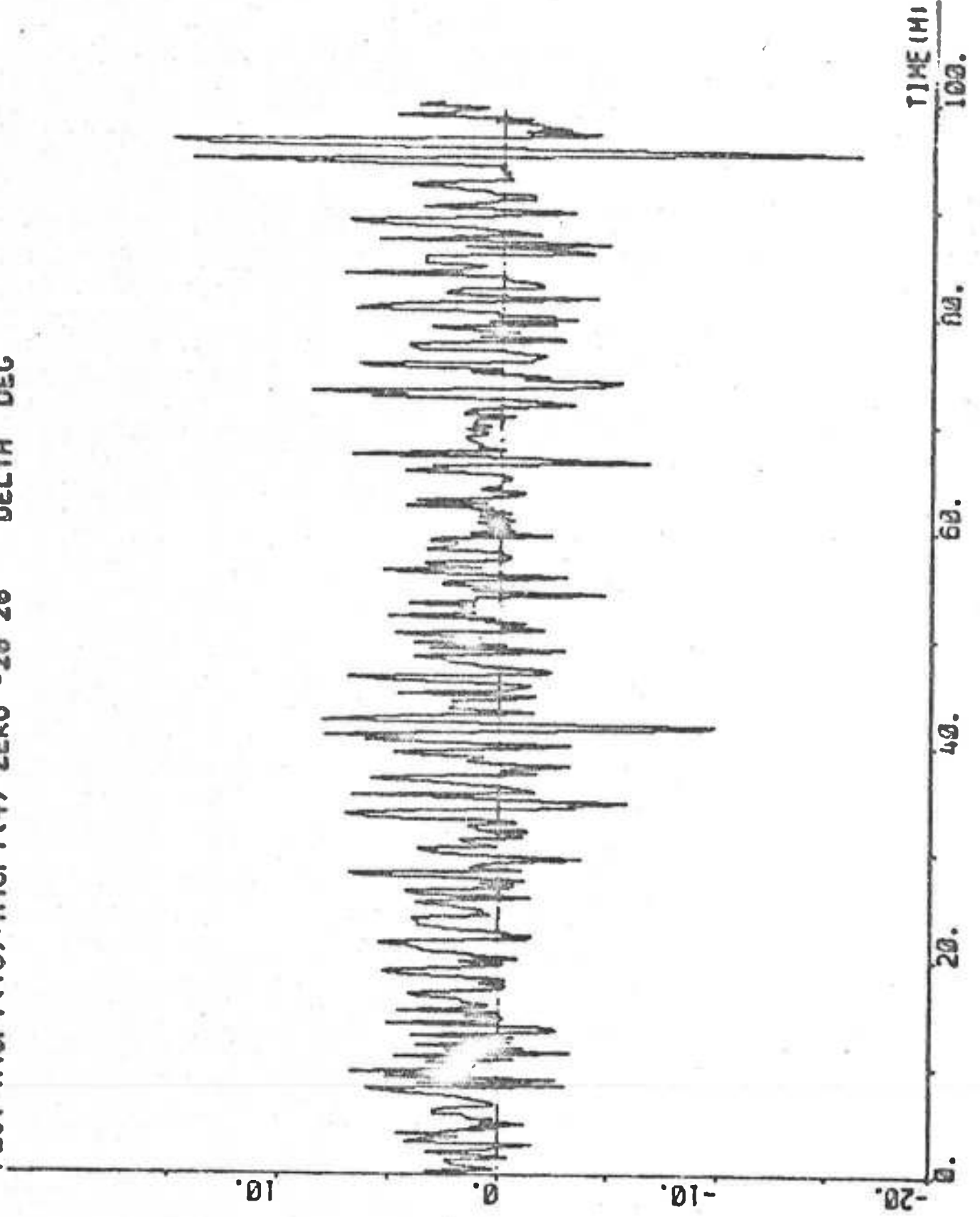
PLOT AYOP1(15)-AYOP1(3) ZERO -20 20 "DELTA" DEG



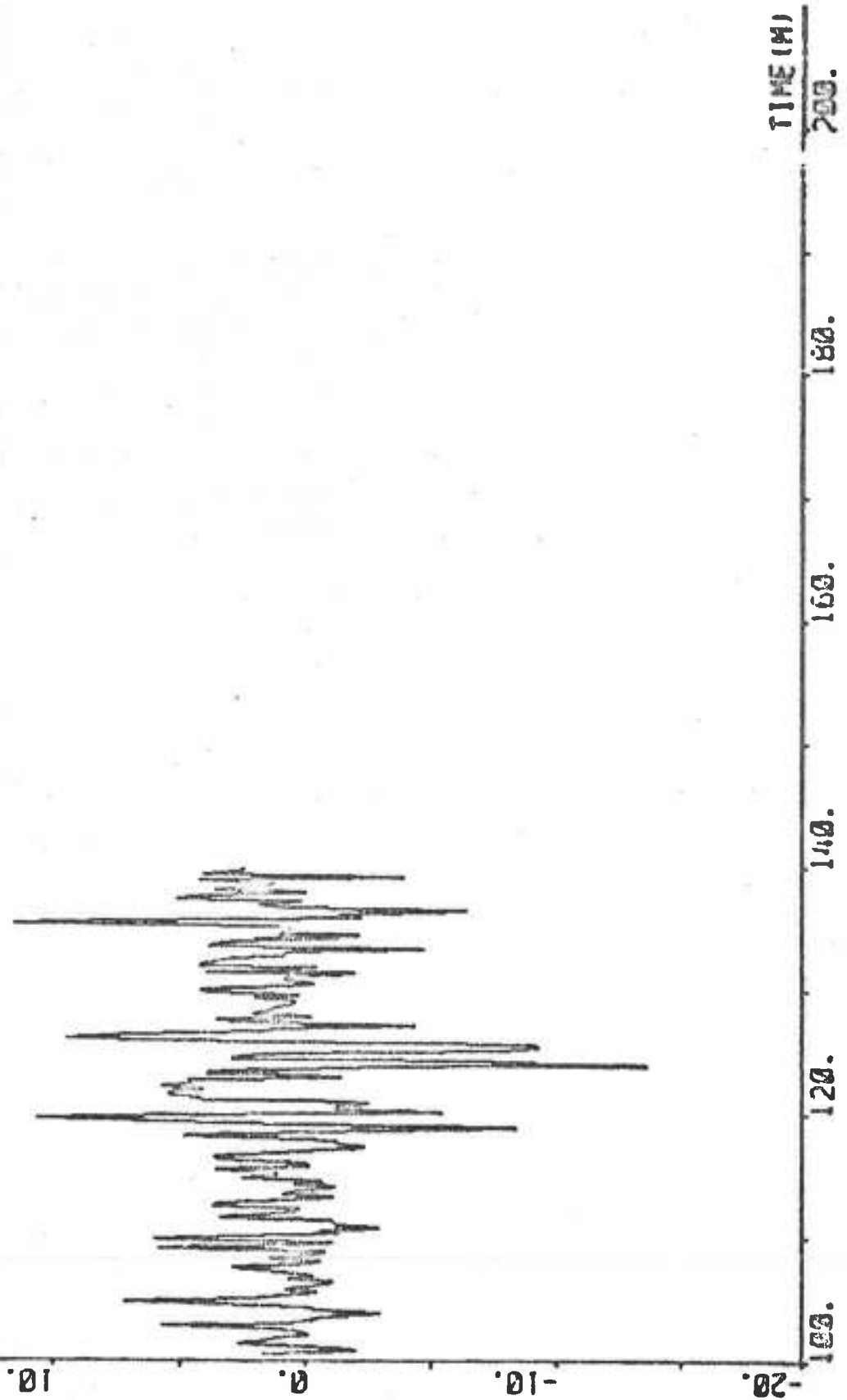
PLOT AWCPI(15)-AWCPI(3) ZERO -20 20 "DELTA" DEG



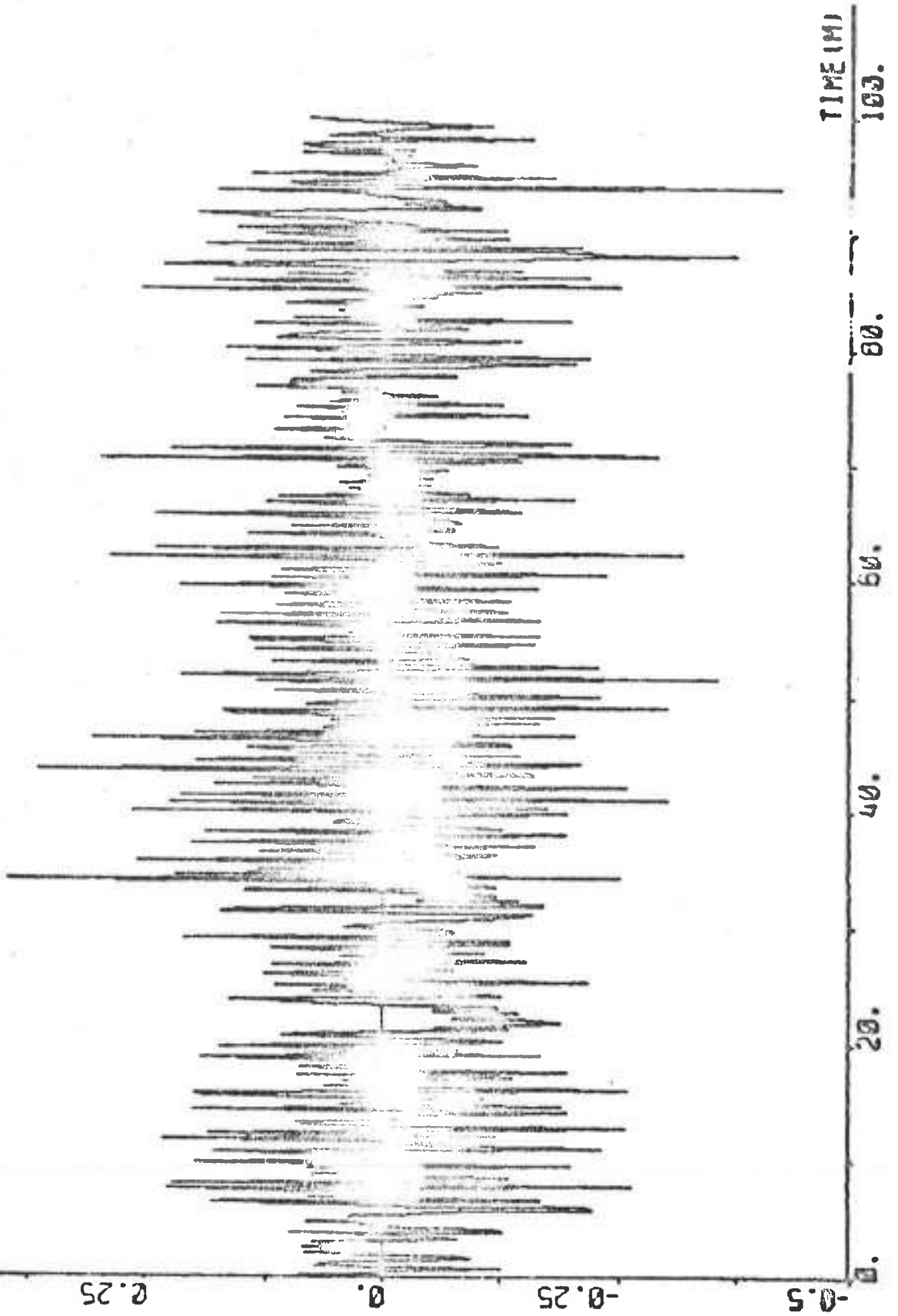
PLOT R4CP1(15) - R4CP1(4) ZERO -20 20 -DELTA DEG



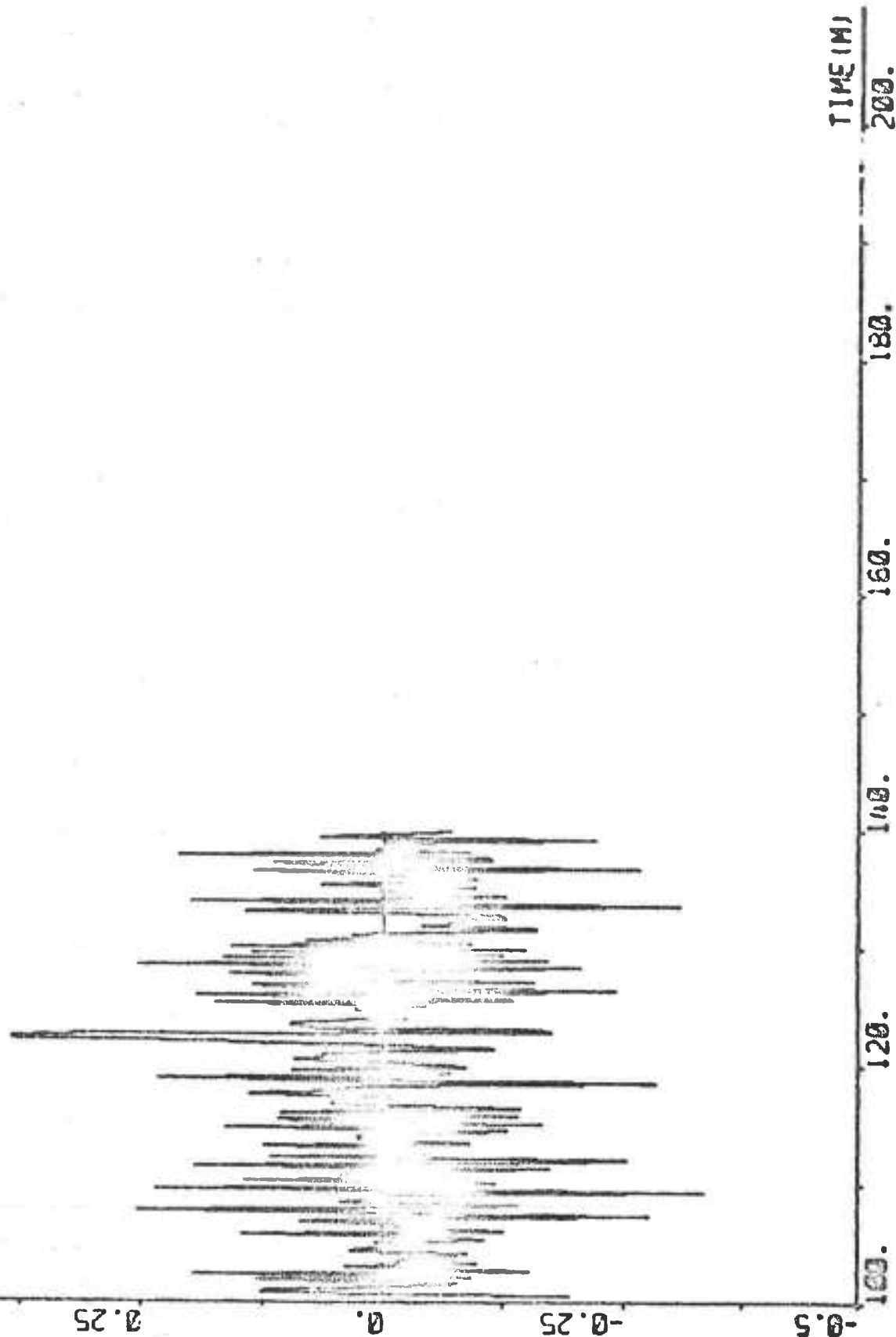
PLOT AYSP1(15)-AYSP1(4) ZERO -20 20 °DELTA DEG



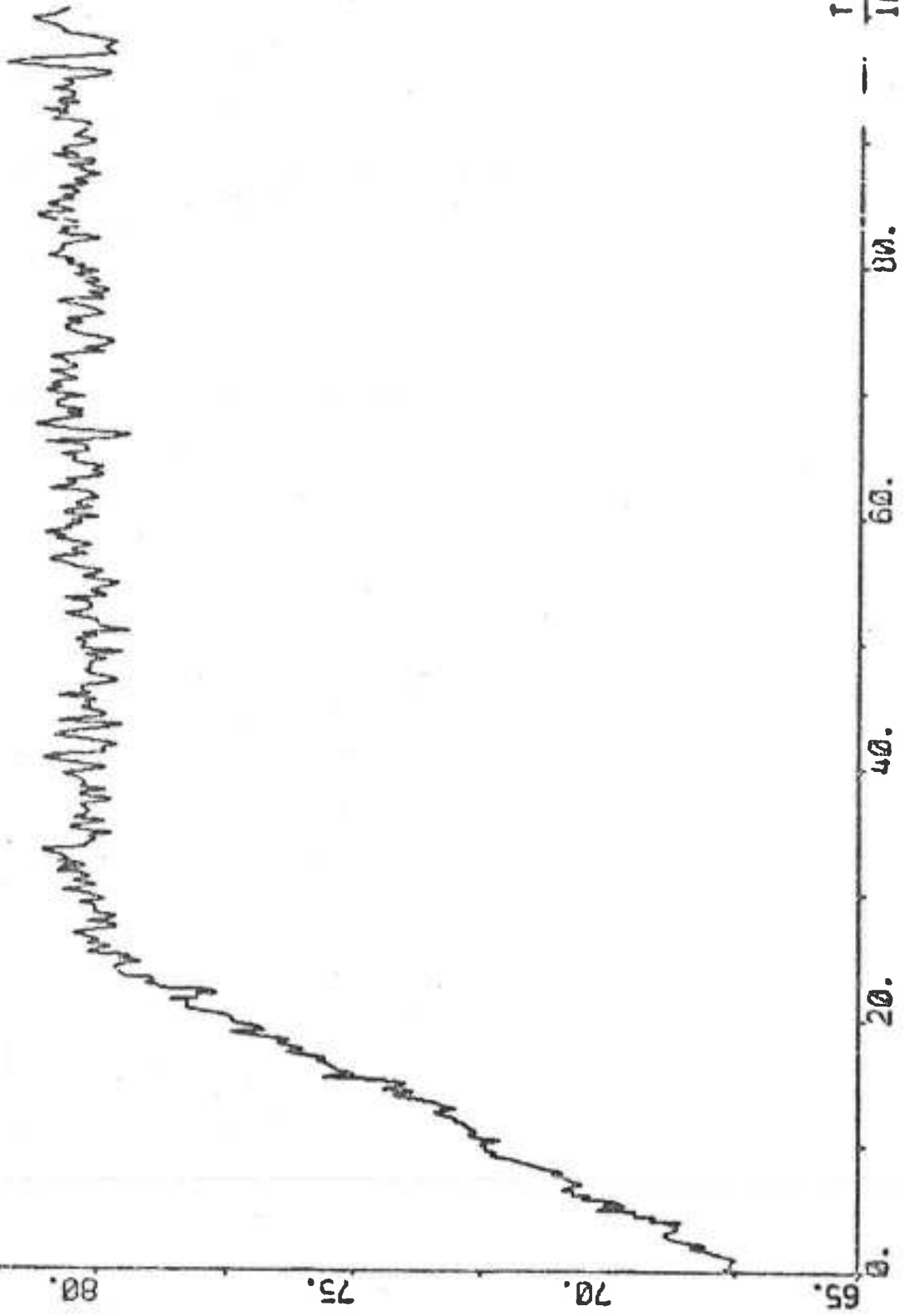
PLOT A4CP1(15)-A4CP1(5) ZERO -0.5 0.5 -PP DEG/S



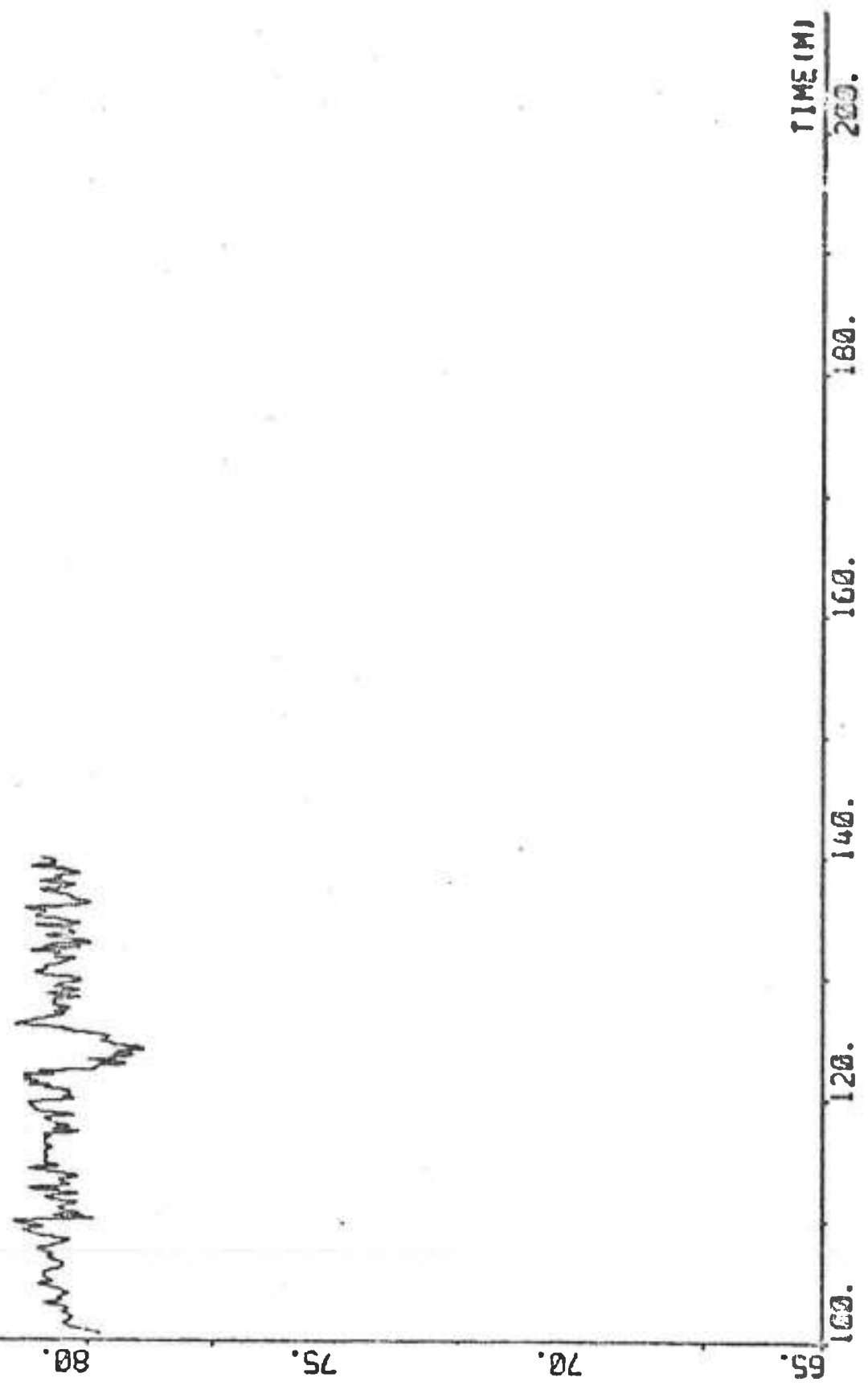
PLOT R48P1(15)←R4CP1(5) ZERO -0.5 0.5 "PP DEG/S



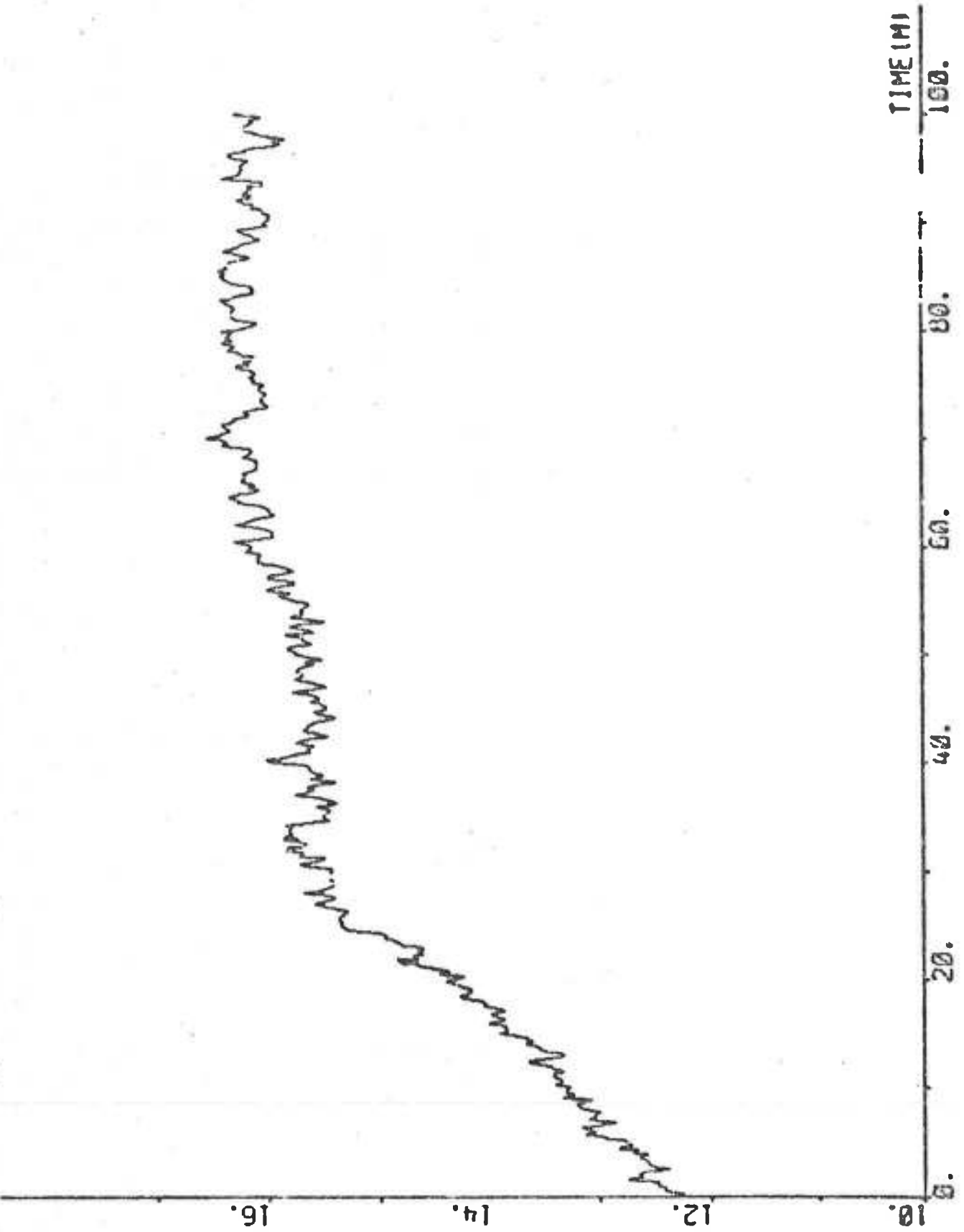
PLOT AYOP1(15)-AYOP1(6) 65 85 "AN RPH



PLOT R40P1(15)-R40P1(6) 65 85 "AN RPH



PLOT R4CP1(15)-R4CP1(7) 10 19 "U KNOTS

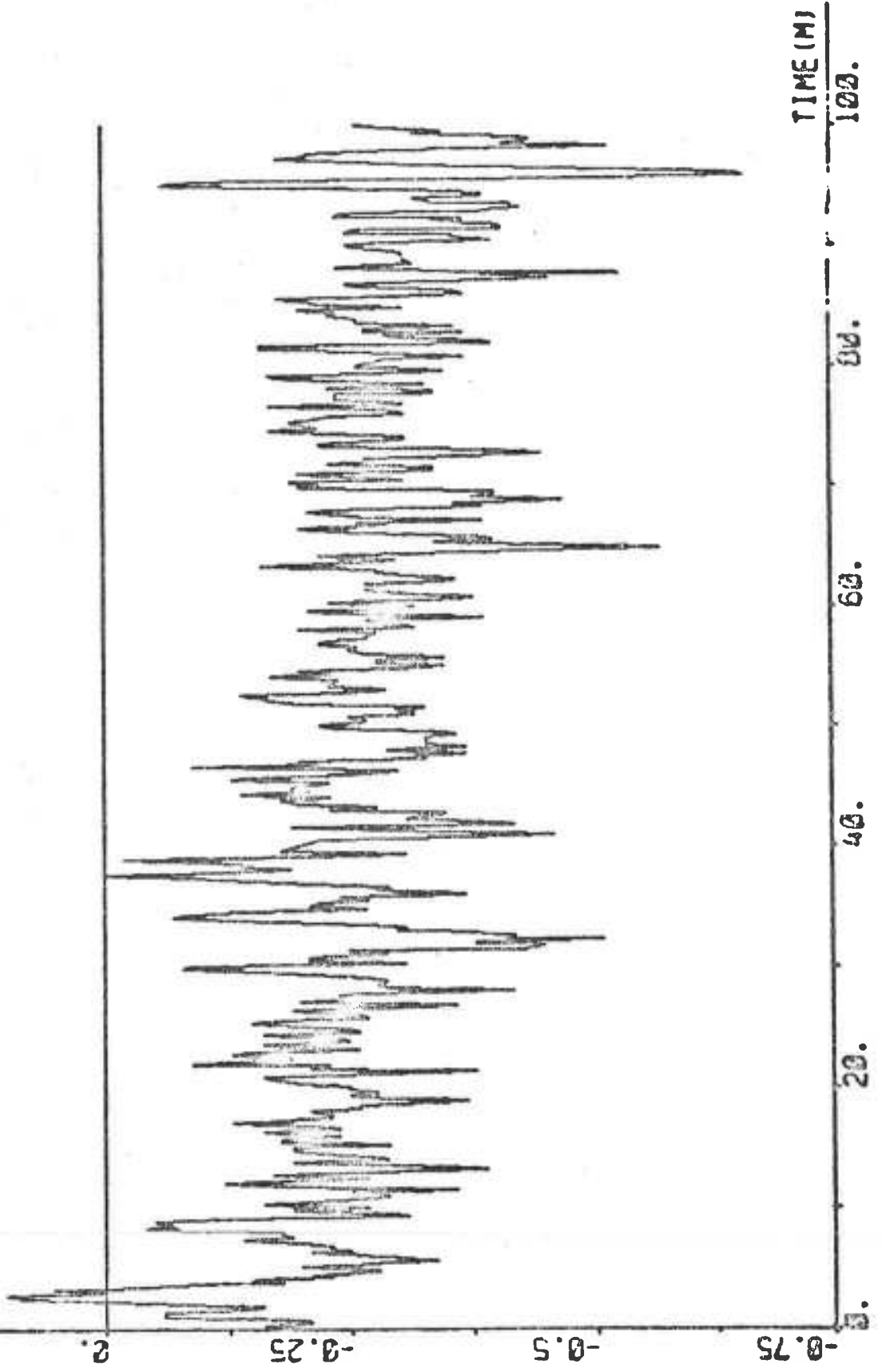


PLOT R4SP1(15)-R4SP1(7) 10 18 "U KNOTS

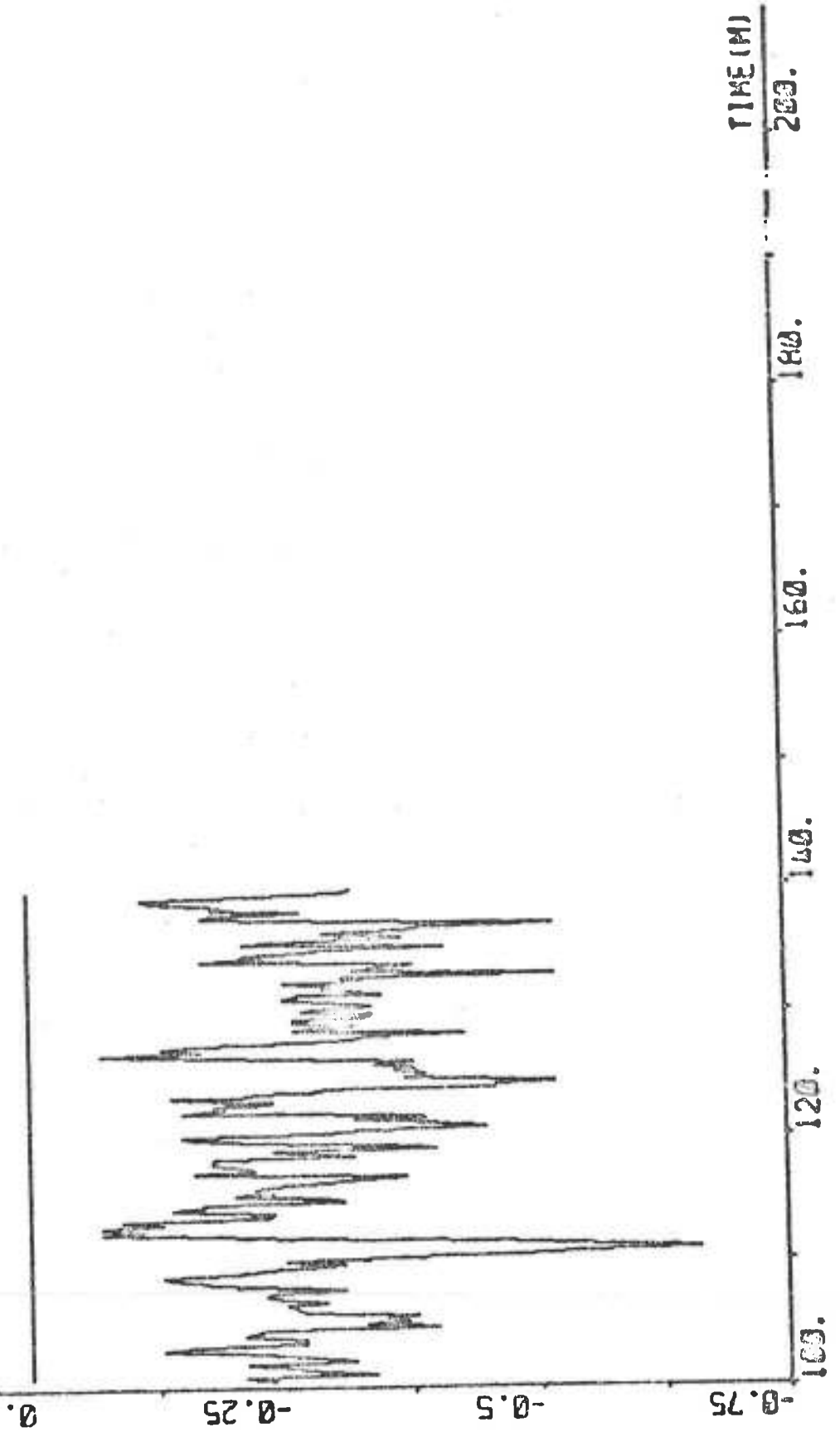


10.
12.
14.
16.
100.
120.
140.
160.
180.
200.
TIME (M)

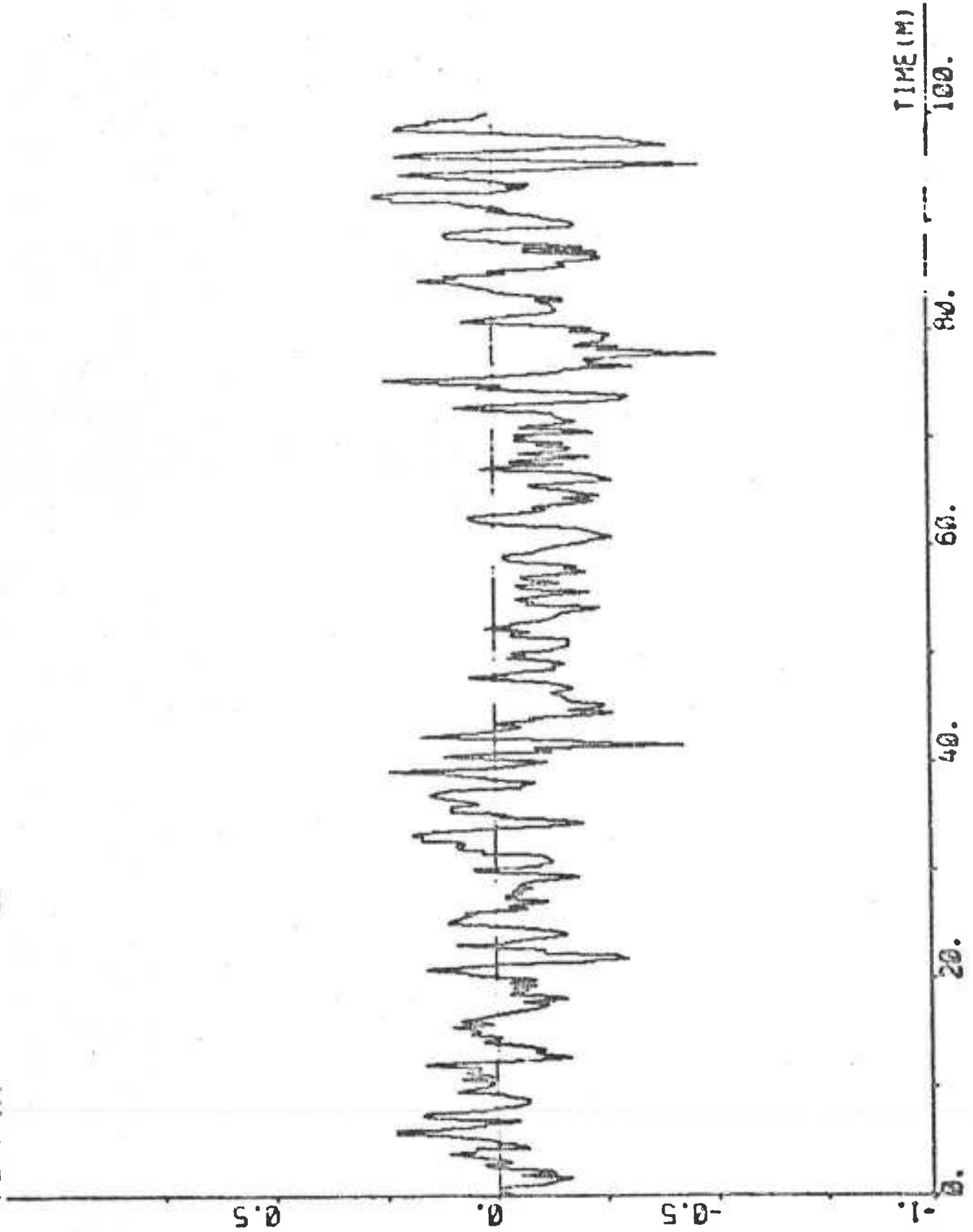
PLOT AVOP1(15) - AVOP1(8) ZERO - 0.75 0.25 "VI KNOTS



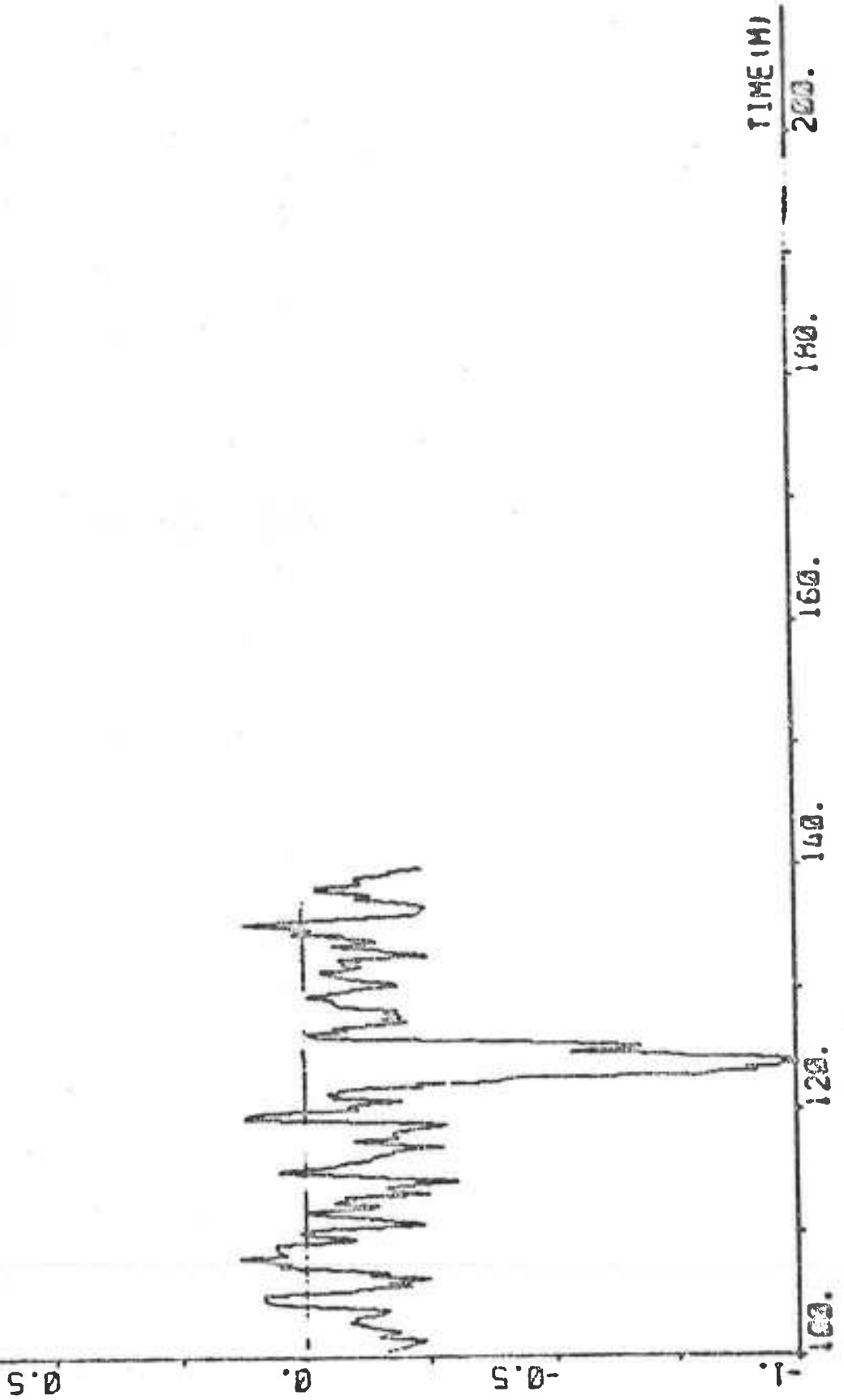
PLOT R4CP1(16)-R4CP1(8) ZERO -0.75 0.25 -V1 KNOTS



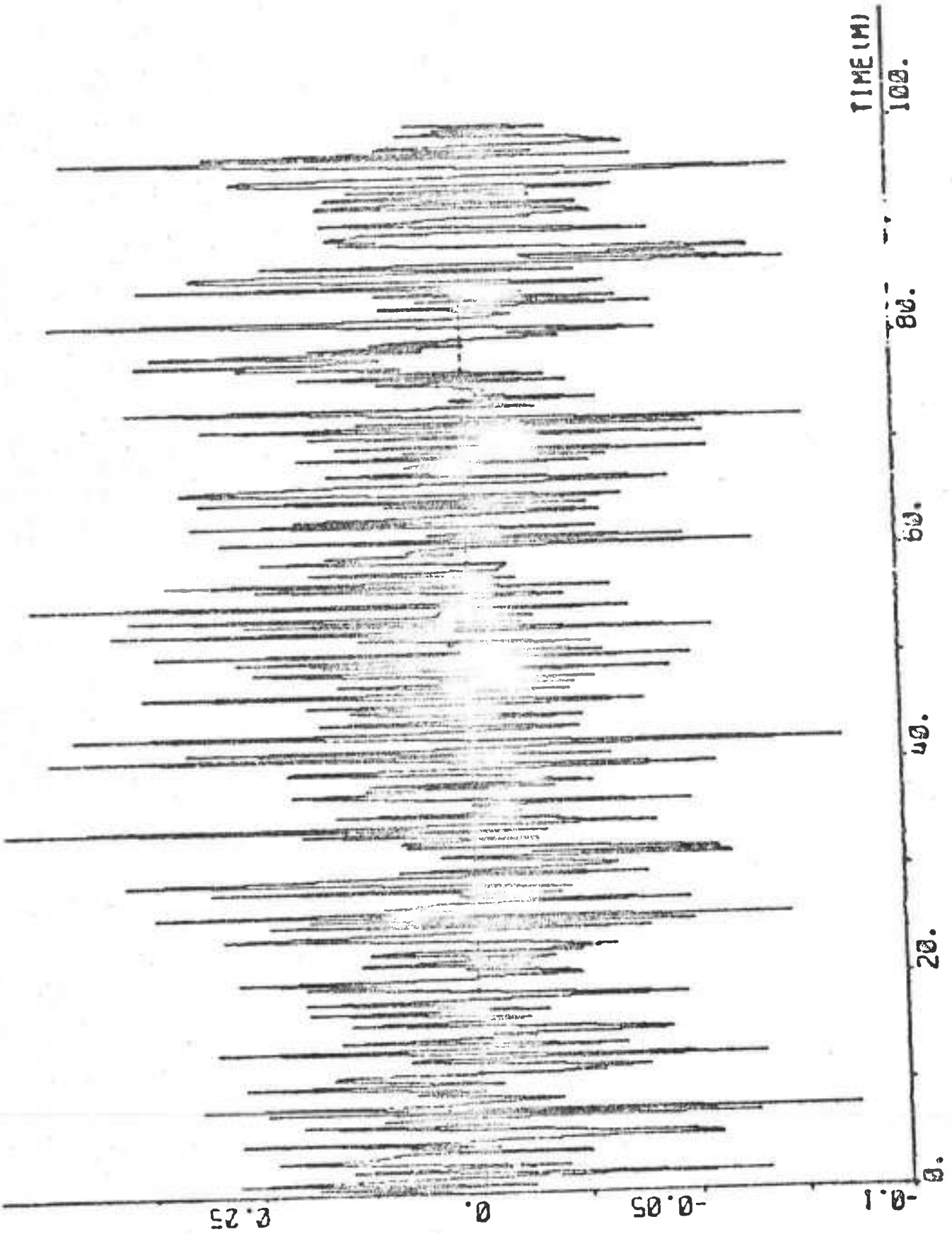
PLOT R4GP1(16)-R4GP1(8) ZERO -1 1 "V2 KNOTS



FLOT RHP1(15) RHP1(9) ZERO -1 1 ~V2 KNOTS



PLOT A4SP1(15)-A4SP1(10) ZERO -0.1 0.1 "R DEG/S



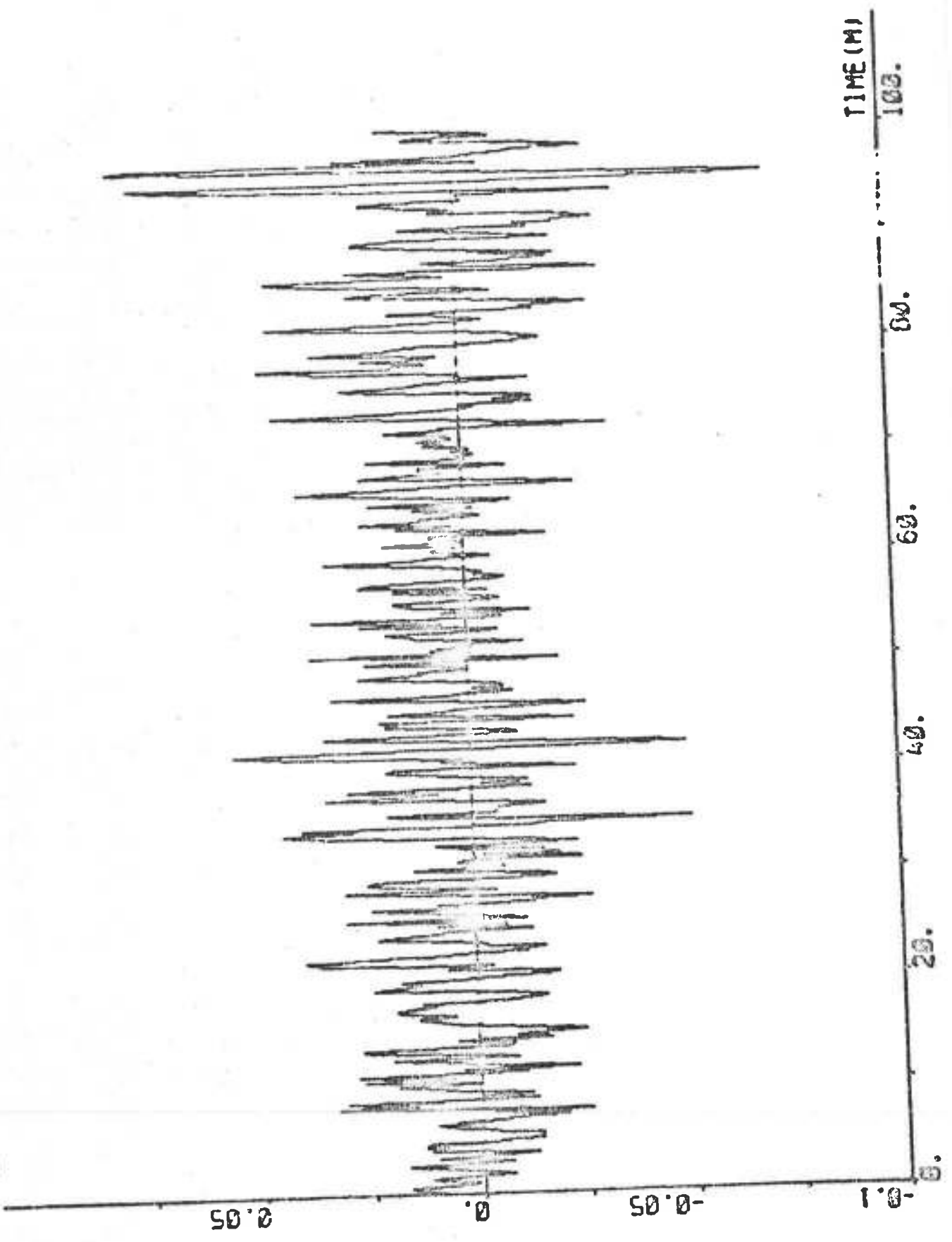
"R DEG/S

PLOT AHOP1(15) - IEP1(10) ZERO -0.1 0.1

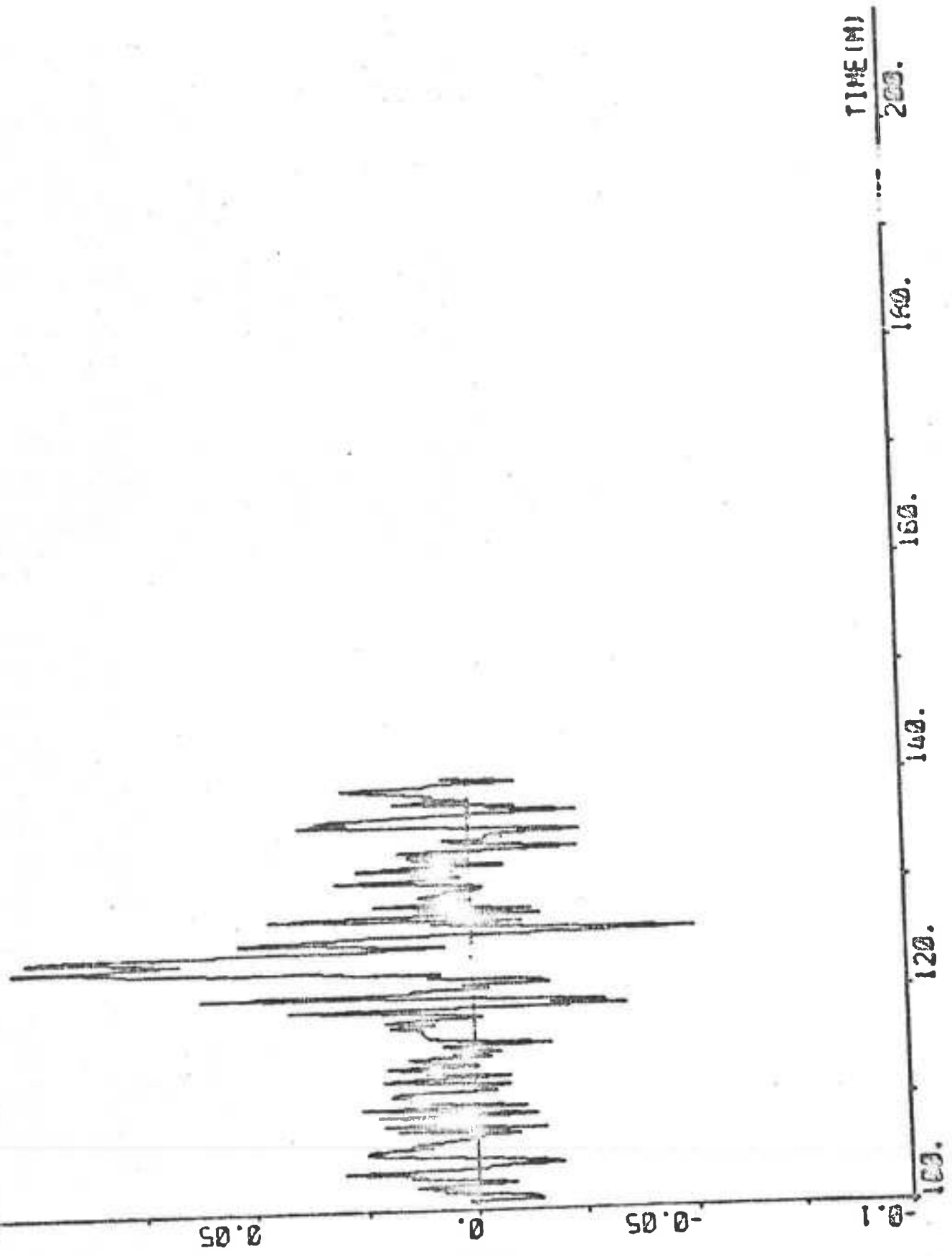


TIME (M)
200.
160.
140.
120.
100.

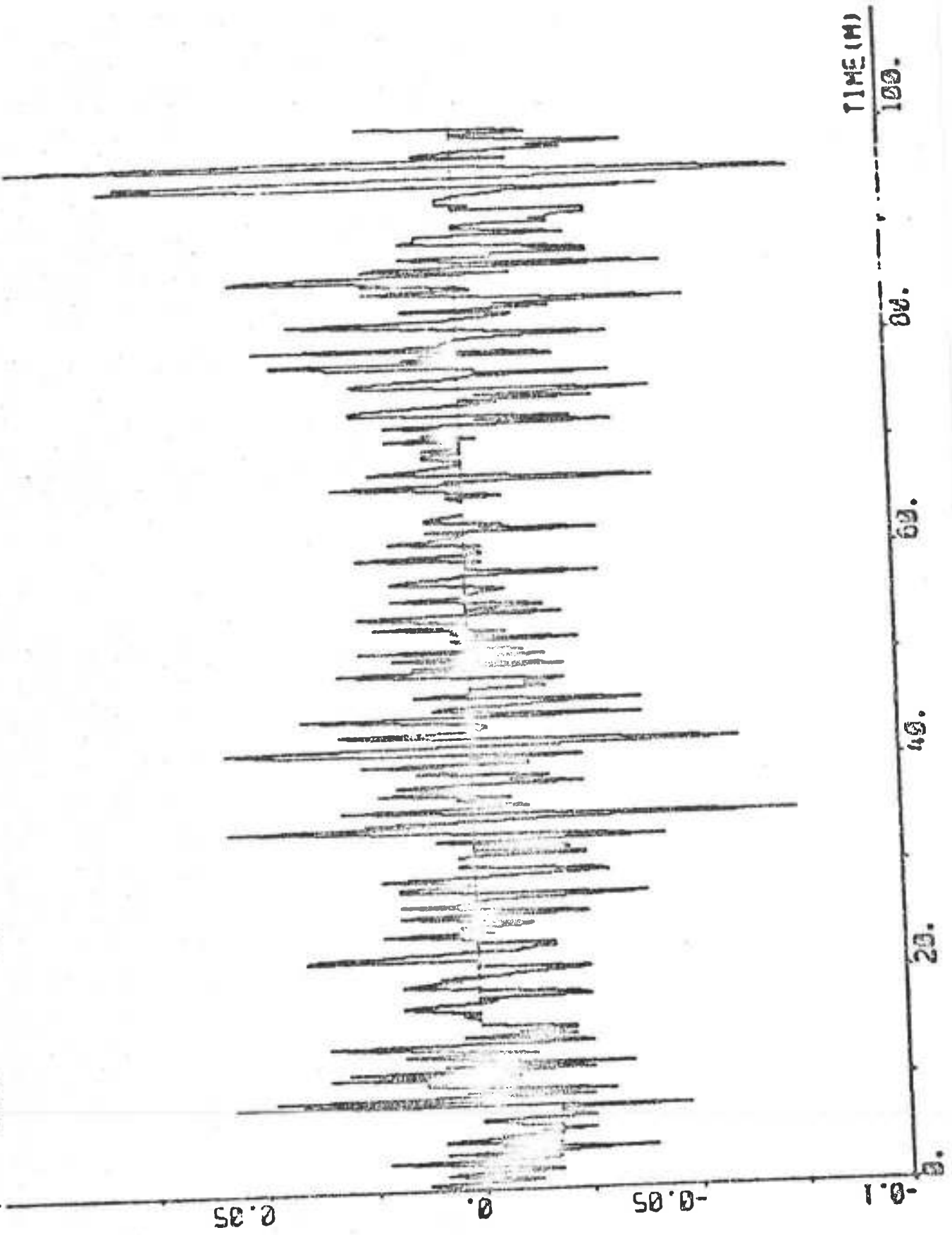
PLOT R4CP1(16)-R4CP1(11) ZERO -0.1 0.1 -AVR DEG/S (BR=0.2)



PLOT R4SP1(15)-R4SP1(11) ZERO -0.1 0.1 "AVR DEG/S (ER=0.2)



PLOT R4SP1(15)-R4SP1(12) ZERO -0.1 0.1 "DPS1DT DEG/S (1DPS1.5)



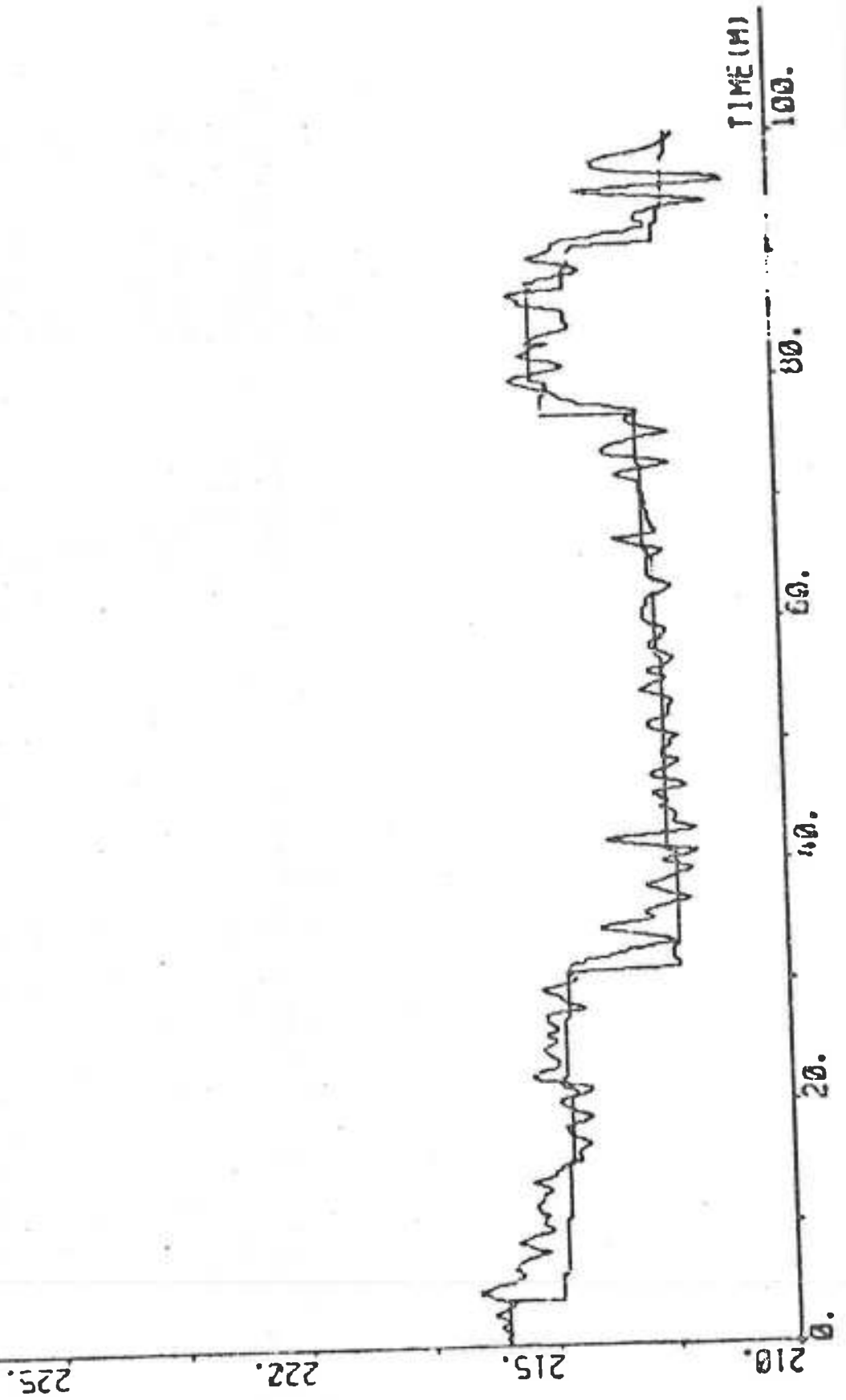
PLOT R4CP1(15) CP1(12) ZERO -0.1 0.1 "DPSIDT DEG/S (IDPSI=5)

0.1
-0.05
0.
0.05

TIME (M)
100.
120.
140.
160.
180.
200.

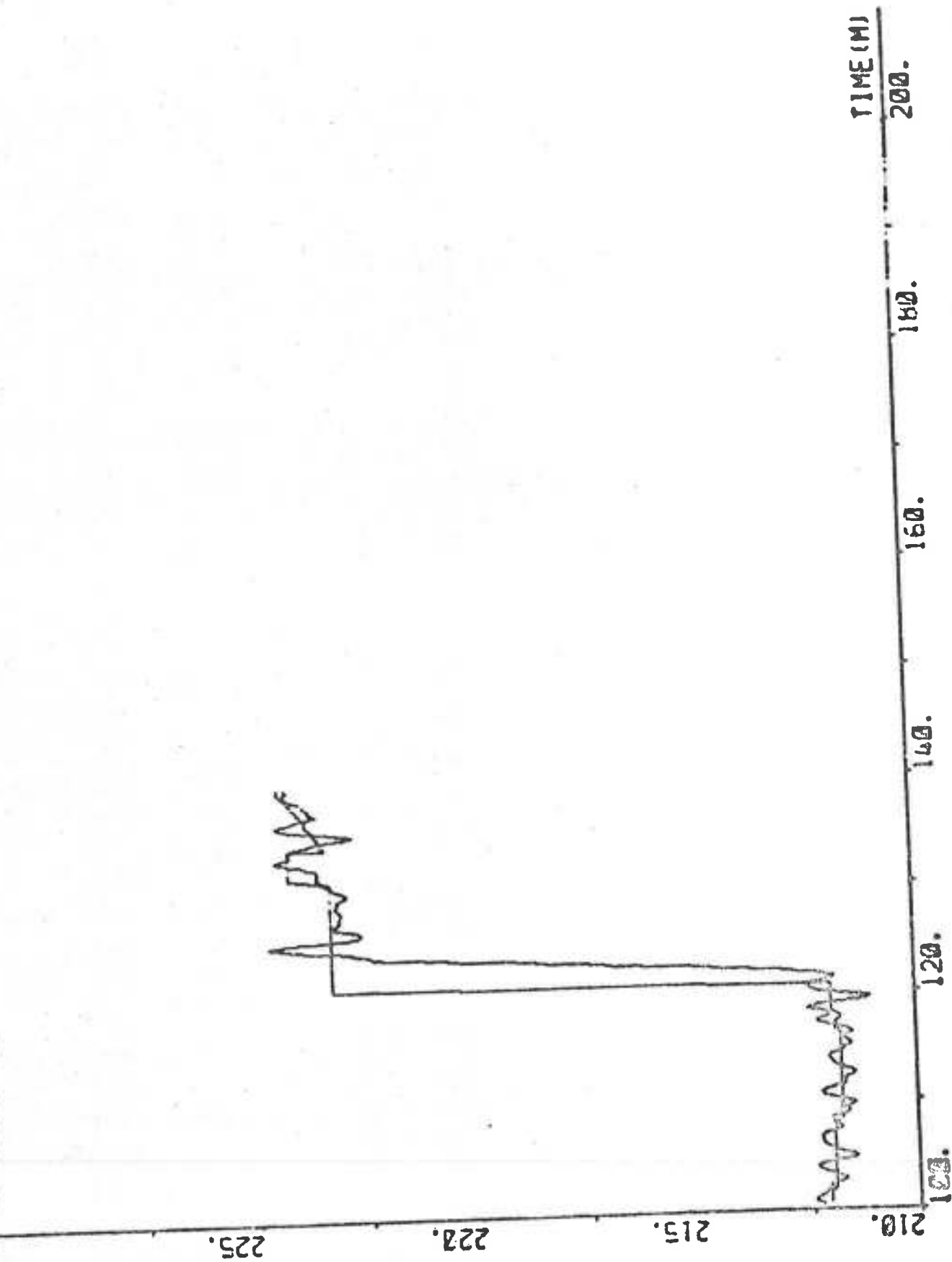


PLOT AY8P1(15)-AH8P1(13 14) 210 225 -PSI PSIREF DEG

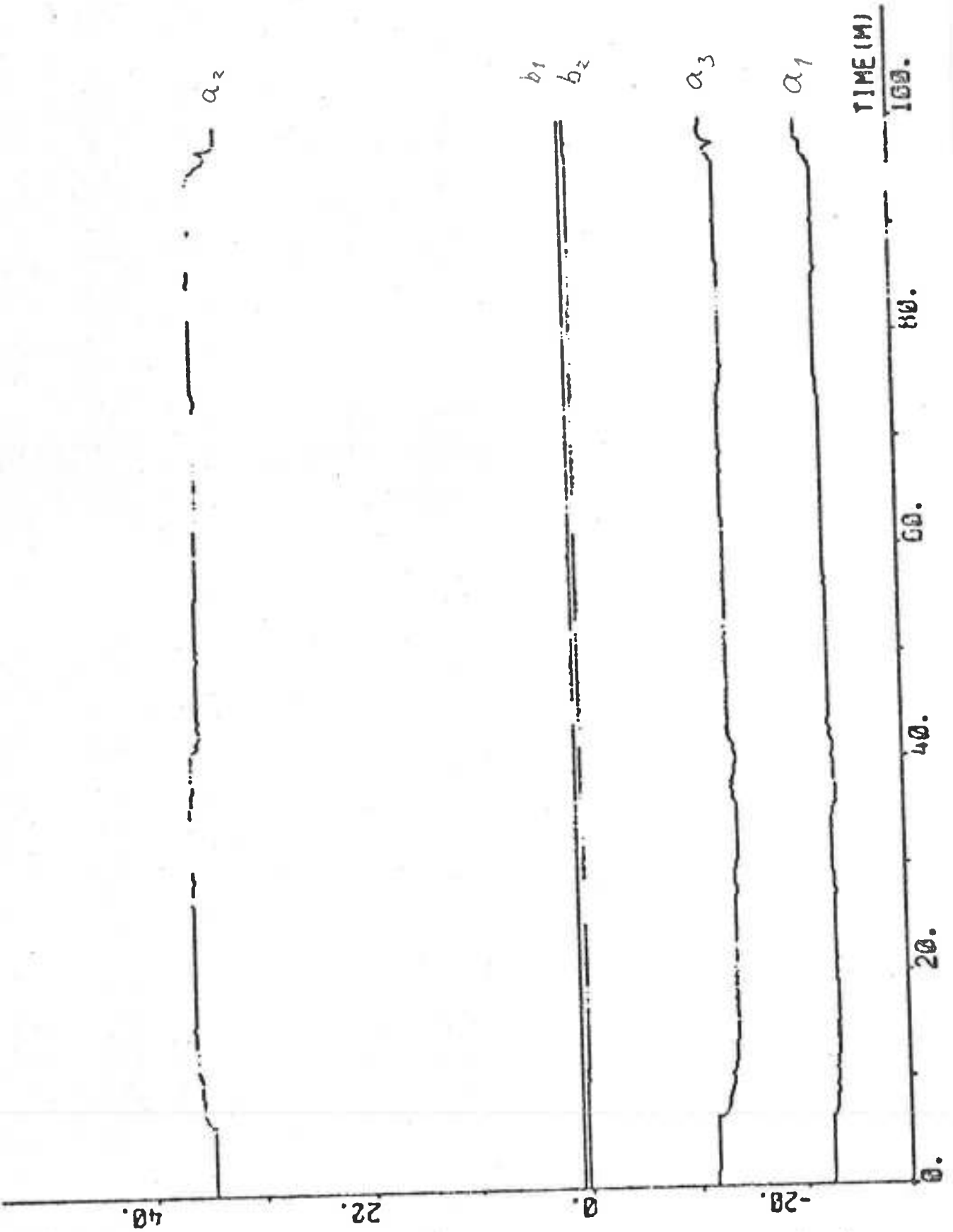


PSI PSIREF DEG

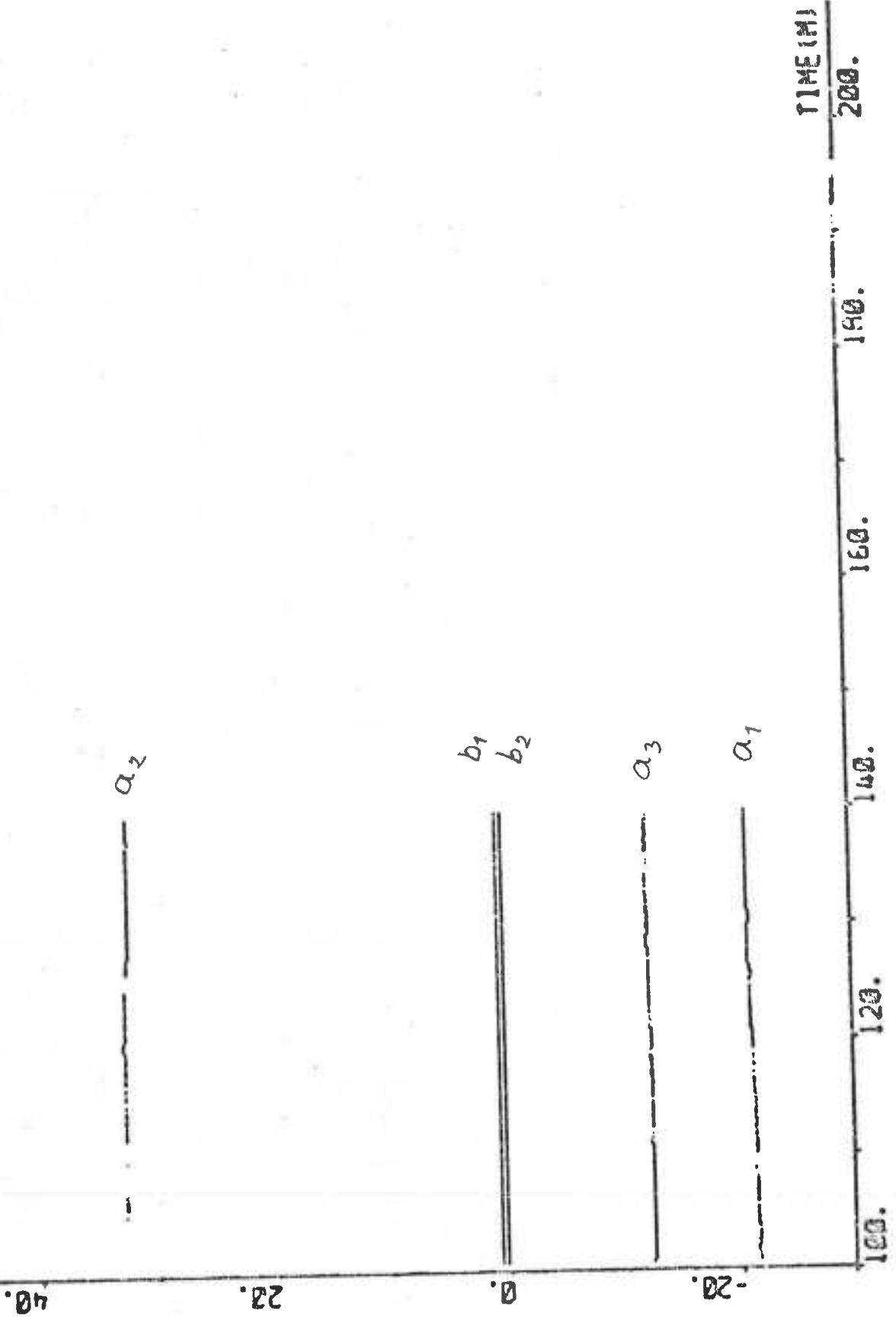
PLOT RHP1(15)-RHP1(13 14) 210 225



PLOT A40P1(15)-A410P2 -25 35 "REGULATOR PARAMETERS



PLOT ANSP1(15)-A48P2 -25 35 "REGULATOR PARAMETERS



EXPERIMENT A41

Date	1974-10-22
Time	13.06
Duration	104 min
Position	S 31 ^o 59' E 29 ^o 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 ^o - 230.7 ^o (Sailmaster, Course correction)
RREF	0.07 deg/s
Rudder limit	Possibly active, but unknown
DELLM at termination	-0.12 ^o

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		

Yaw regulator values after the yaw at 81 min

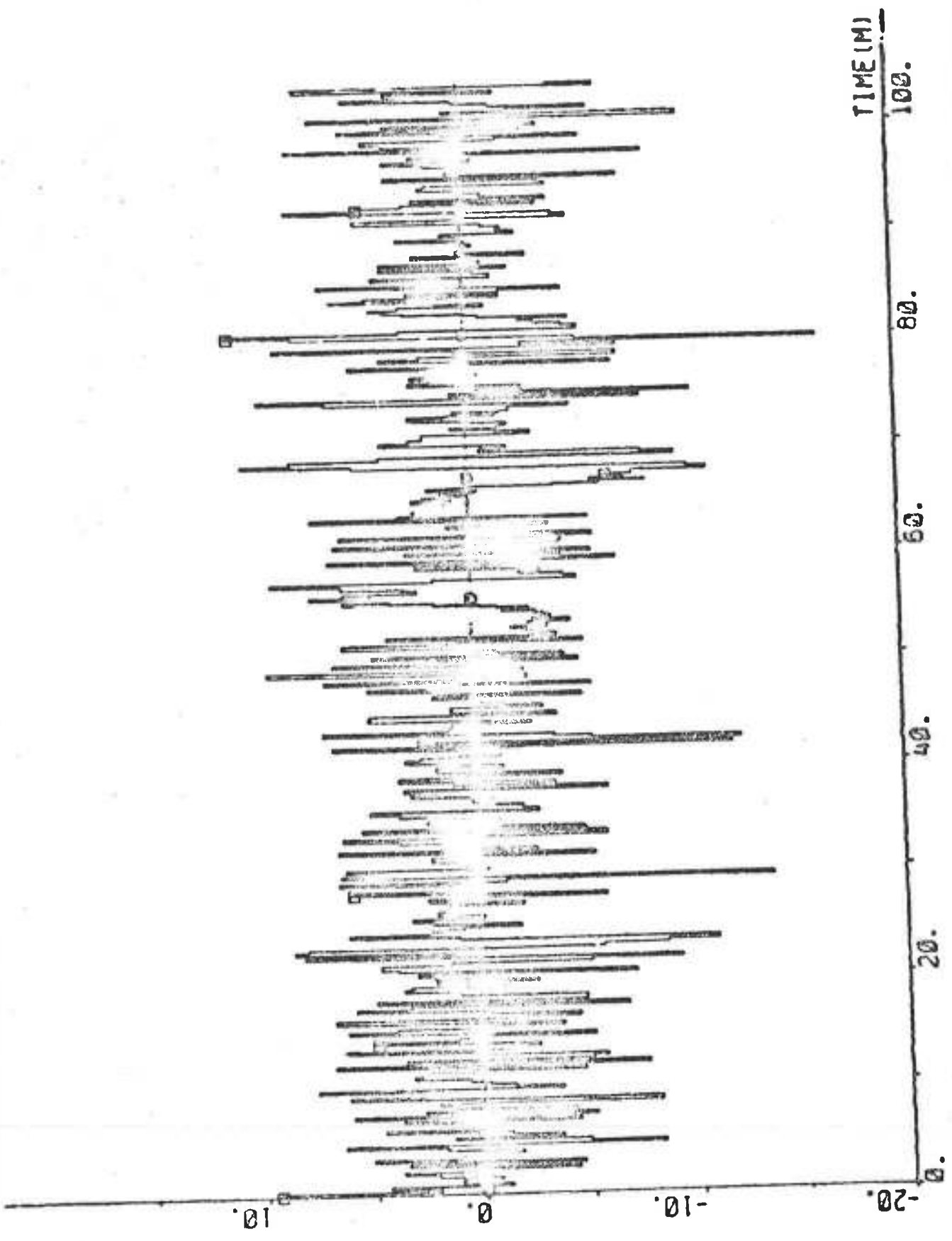
$$\begin{bmatrix} a_1' \\ a_2' \\ a_3' \\ b_1' \\ b_2' \end{bmatrix} = \begin{bmatrix} -43.56 \\ 4.94 \\ 0.90 \\ 1.30 \\ 0.81 \end{bmatrix} \quad PY = \begin{bmatrix} 526.316 & & & & \\ & 0 & 526.316 & & \\ & 0 & & 0 & 526.316 \\ & 0 & & 0 & & 1.053 \\ & 0 & & 0 & & & 0 & 1.053 \end{bmatrix}$$

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

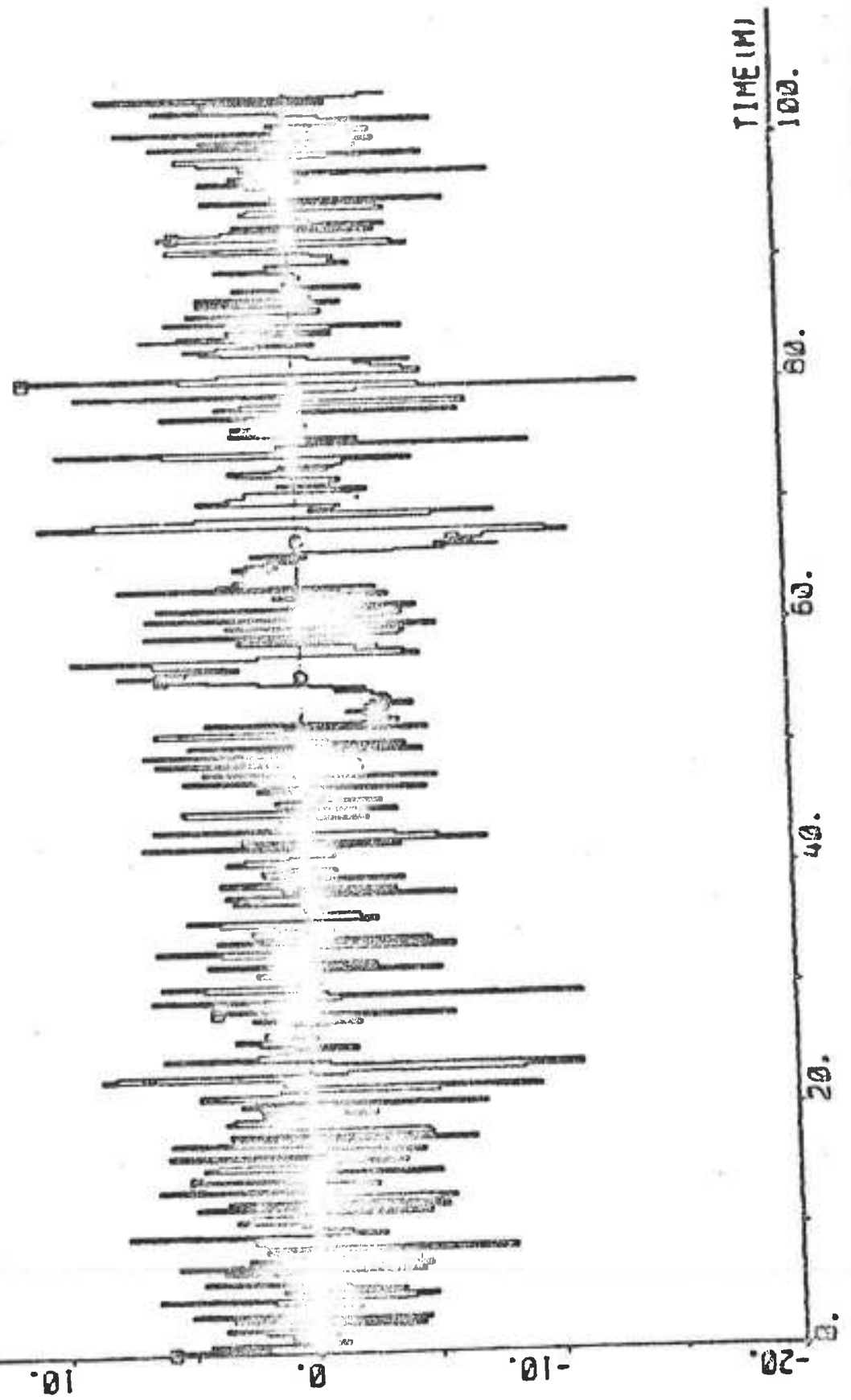
Statistics (mean value and standard deviation)

	<u>0-50 min</u>
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

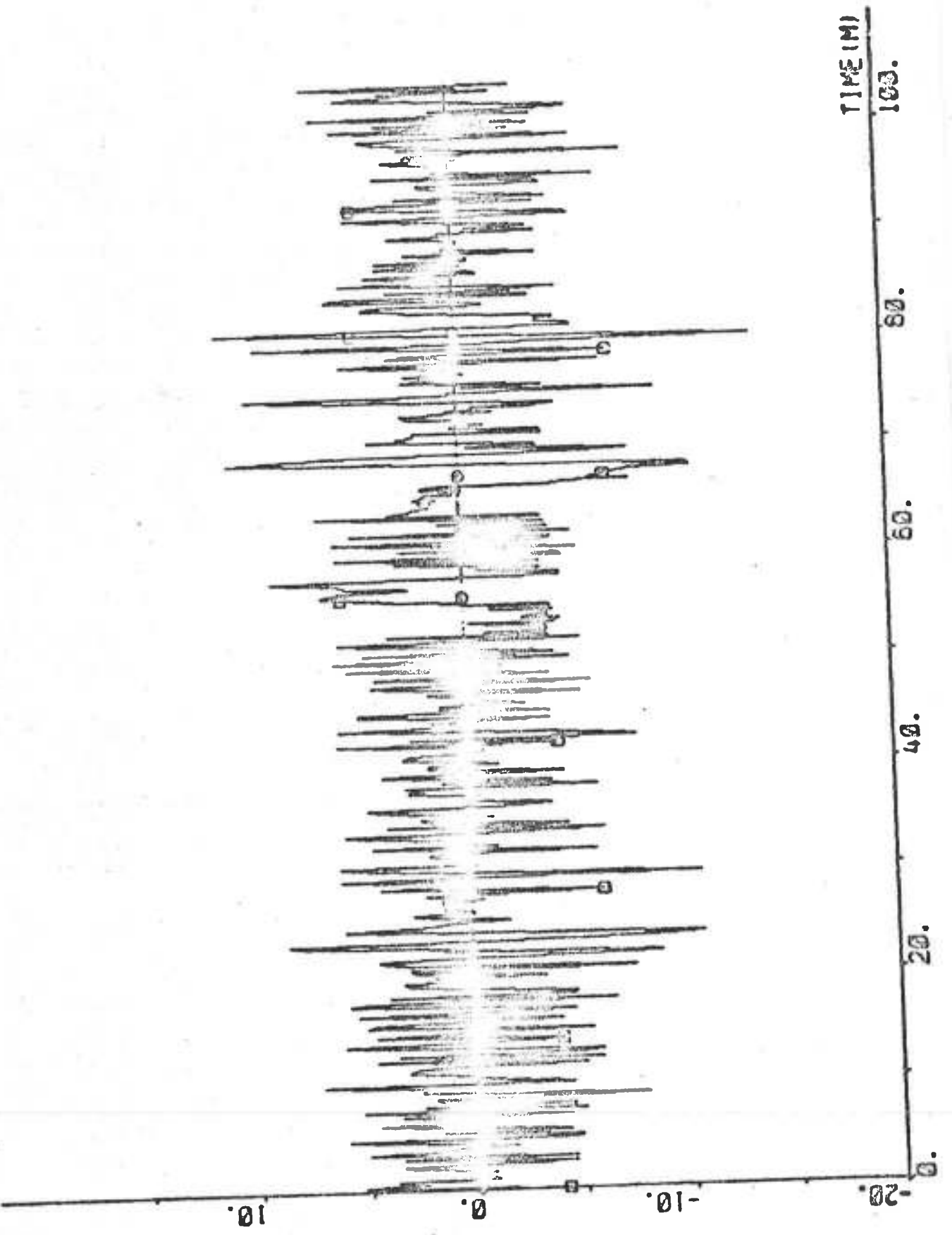
PLOT A41P1(15)←HP A41P1(1) ZERO -20 20 DELCOC DEG



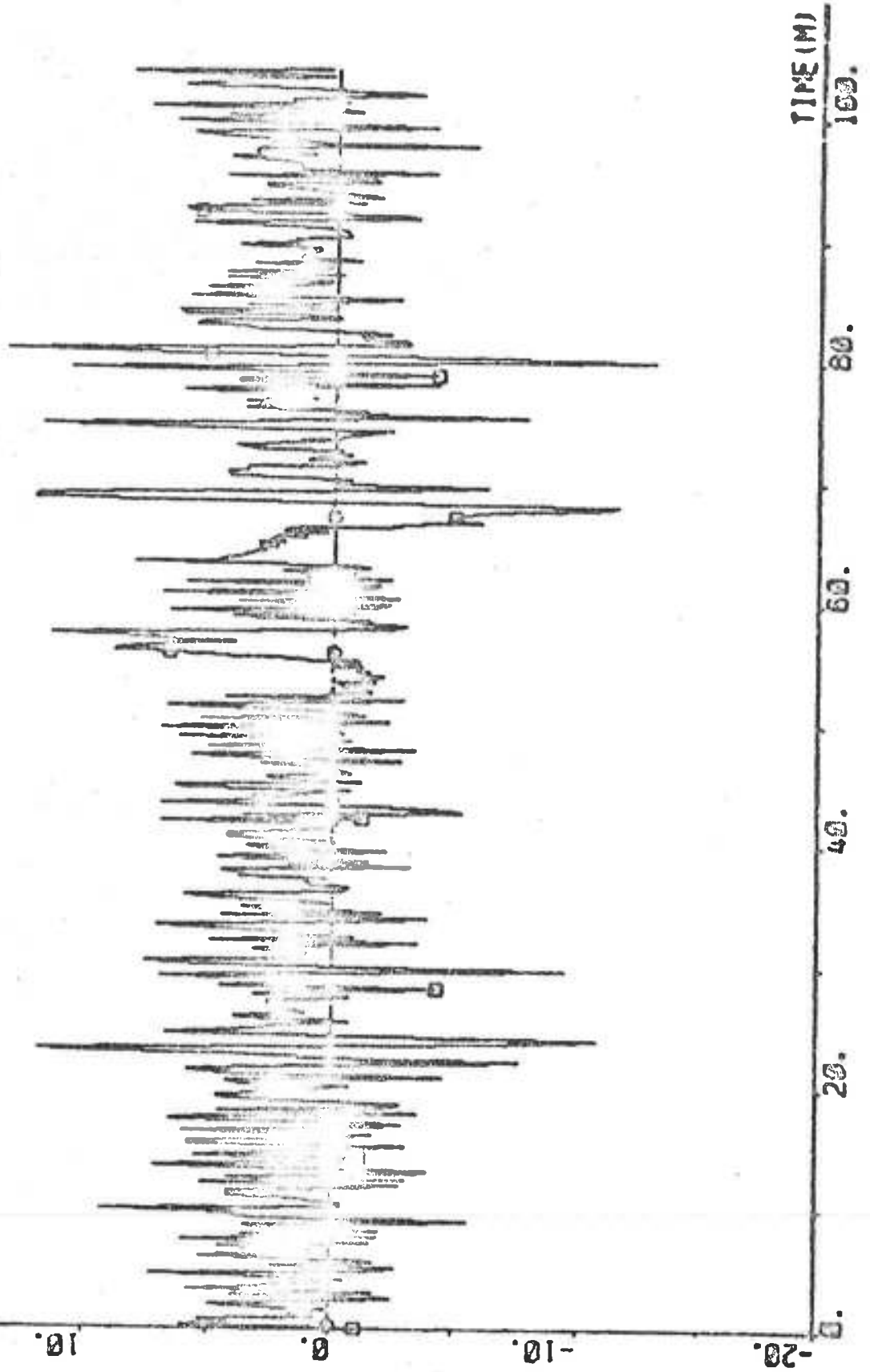
PLOT R41P1(15) HP R41P1(2) ZERO -20 20 "DELCON DEG



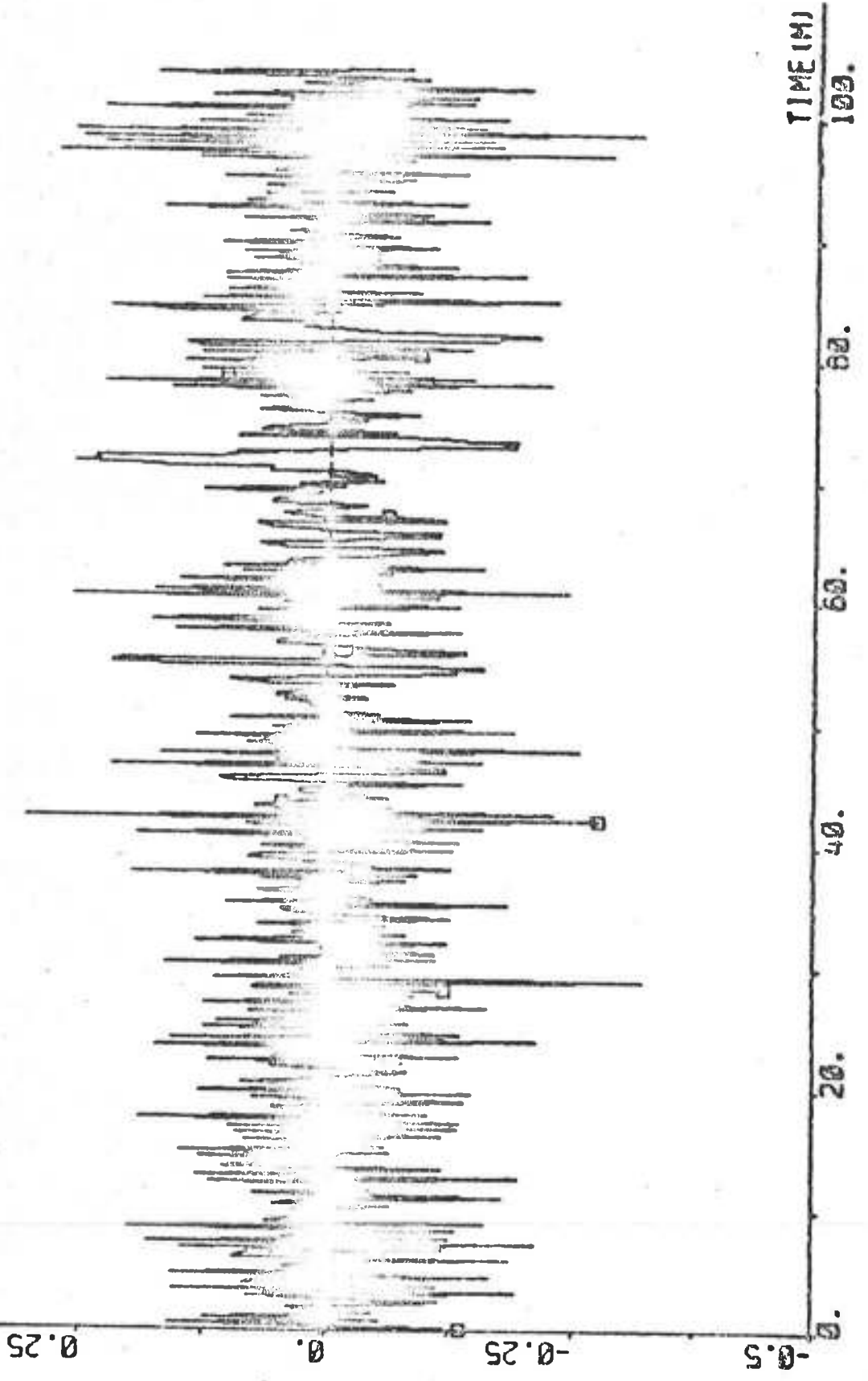
PLOT A41P1(15)+A41P1(3) ZERO -20 20 "DELTA S DEG



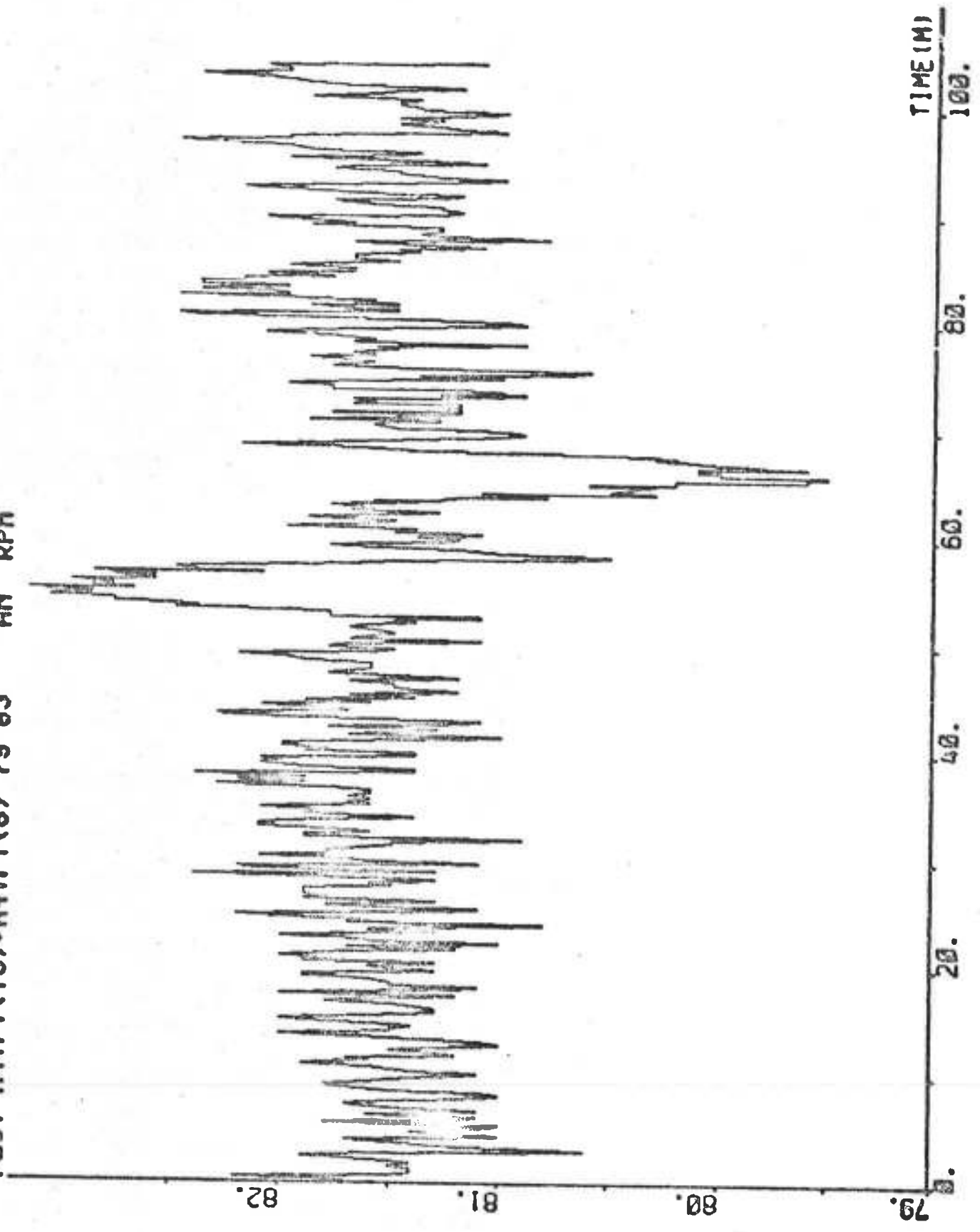
PLOT A41P1(15)-A41P1(4) ZERO -20 20 "DELTA DEC



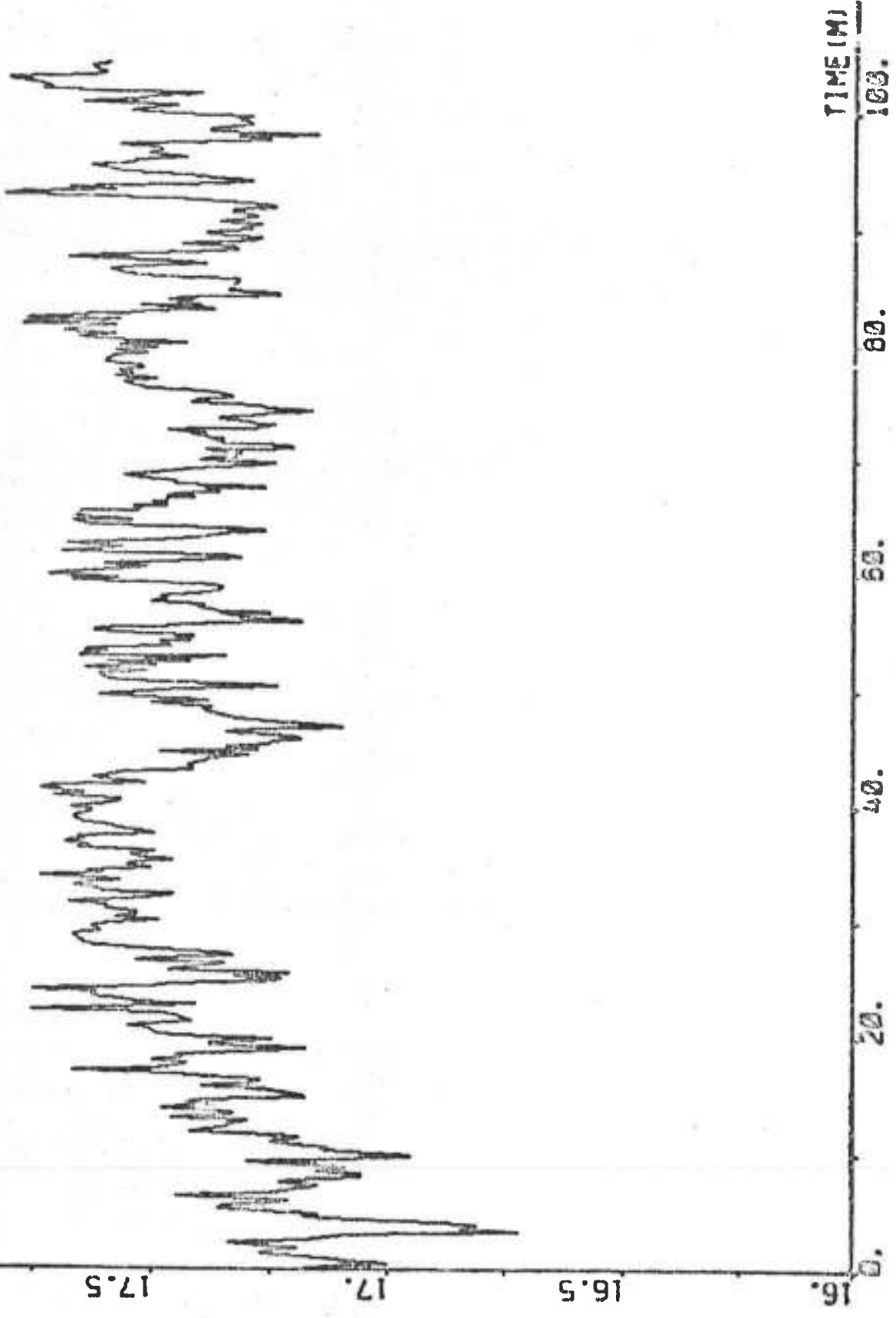
PLOT R41P1(15) R41P1(5) ZERO -0.5 0.5 "PP DEC/S



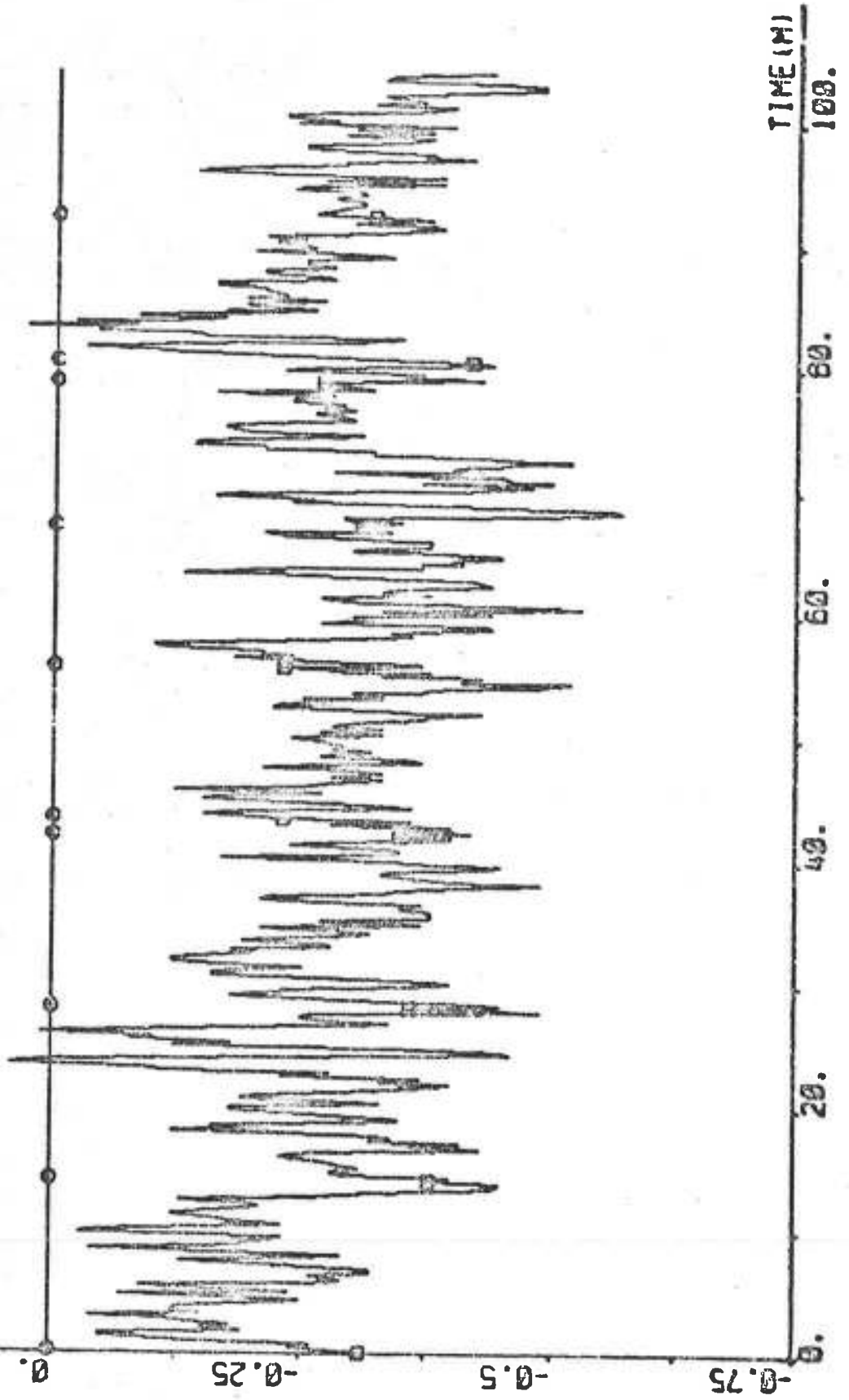
PLOT R41P1(15) R41P1(6) 79 83 "AN RPM



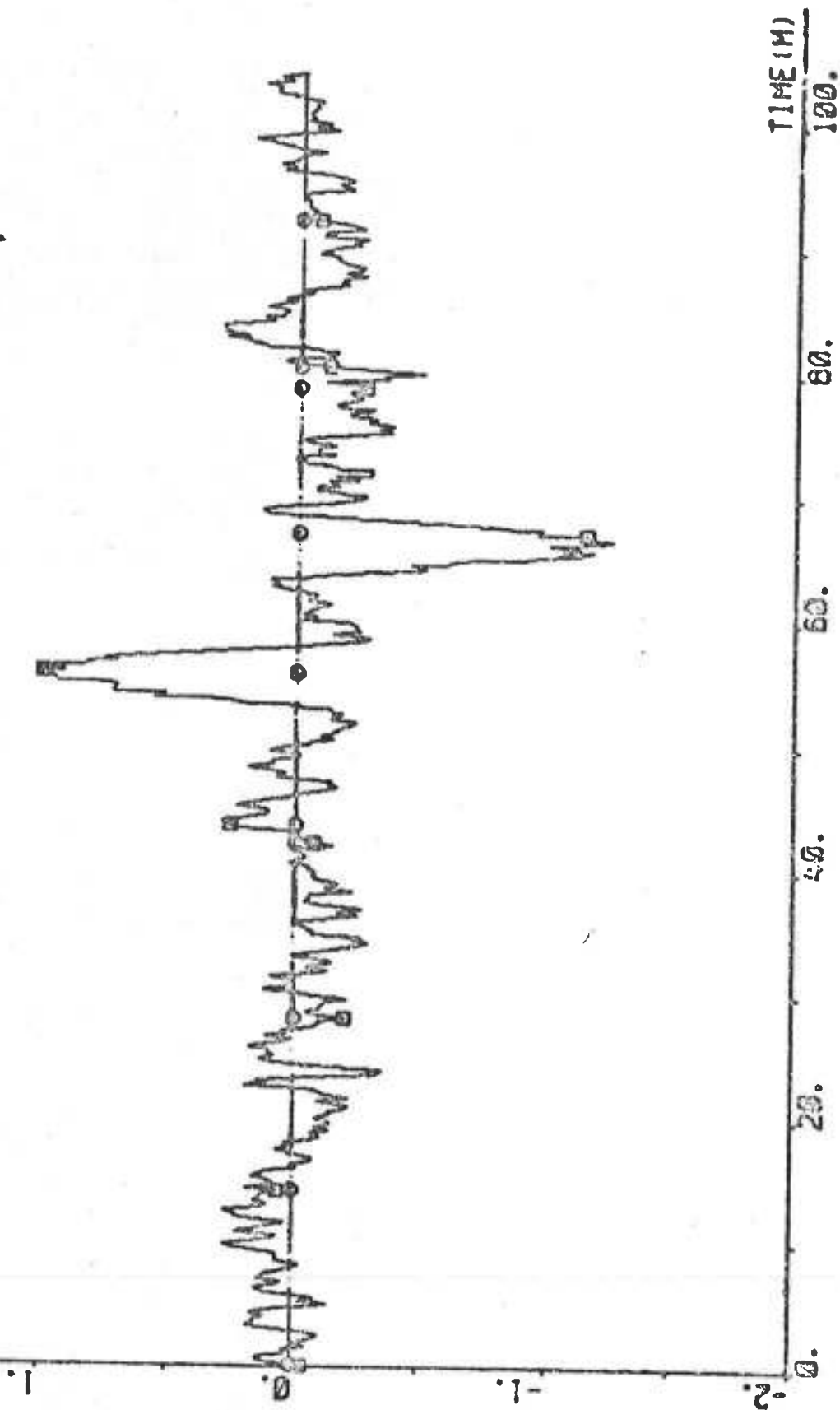
PLOT A41P1(15)-A41P1(7) 16 18 "U KNOTS



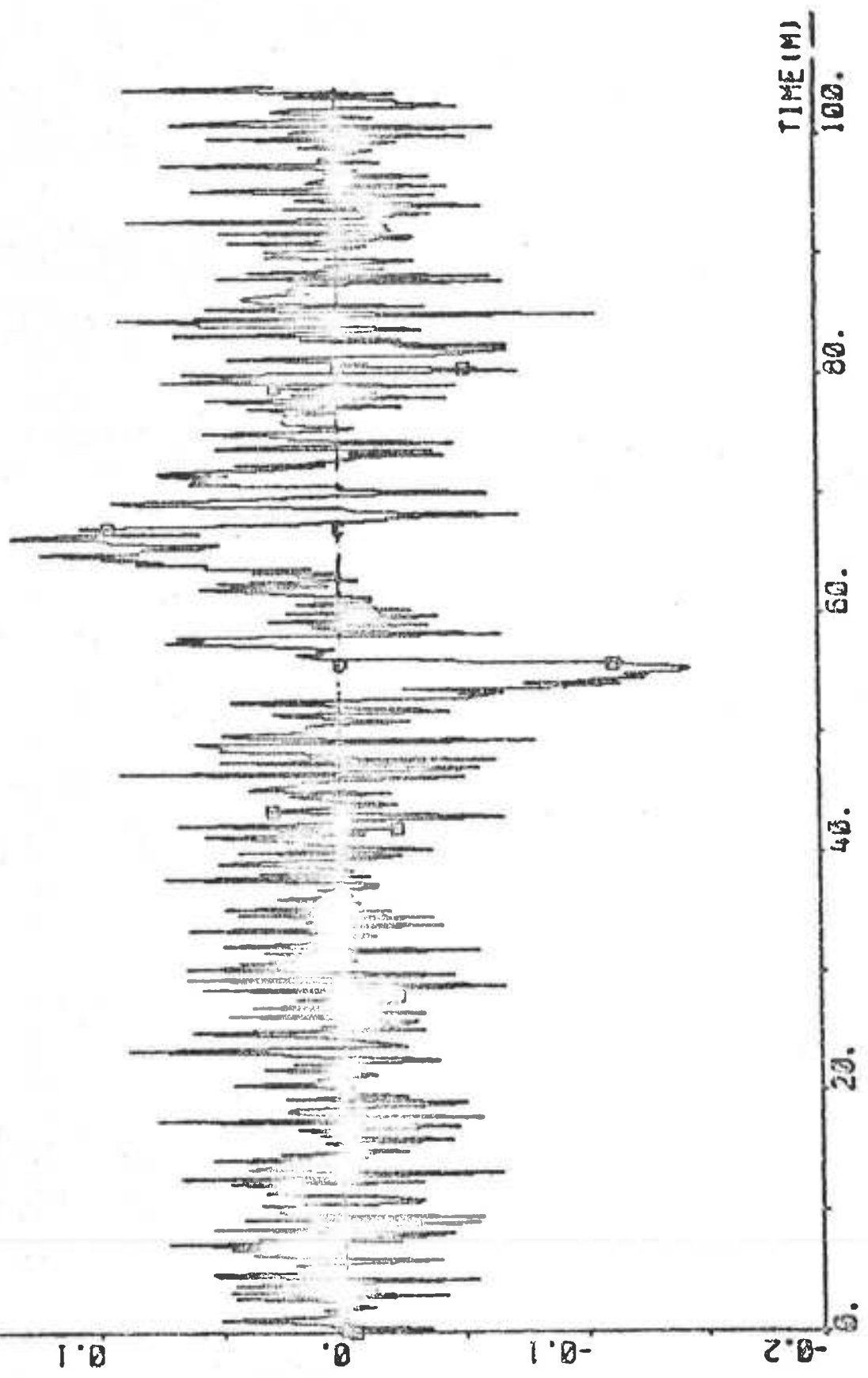
PLOT R41P1(15) ← R41P1(8) ZERO -0.75 0.25 "V1 KNOTS



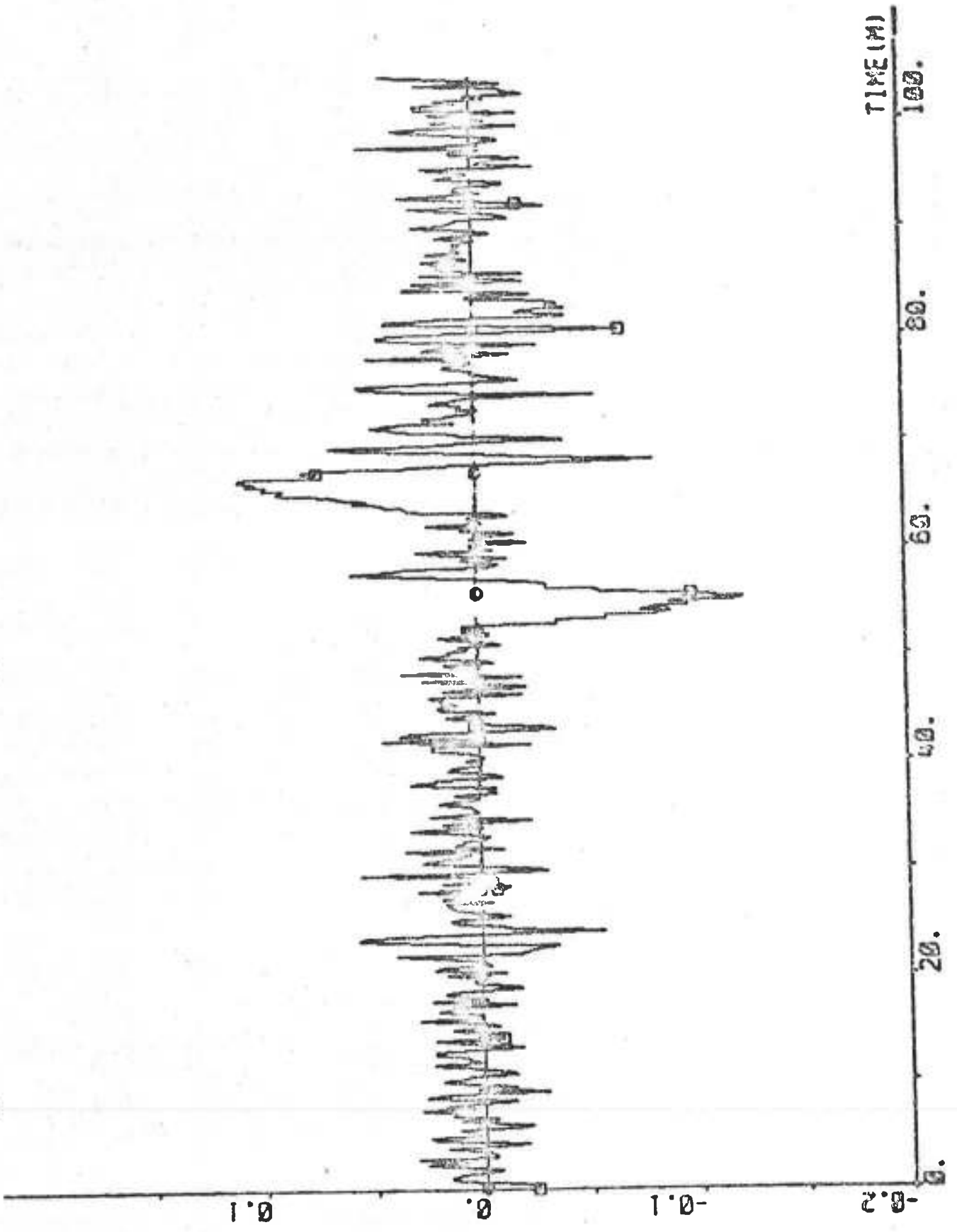
PL0T R41P1(15)+R41P1(9) ZERO -2 2 -V2 KNOTS



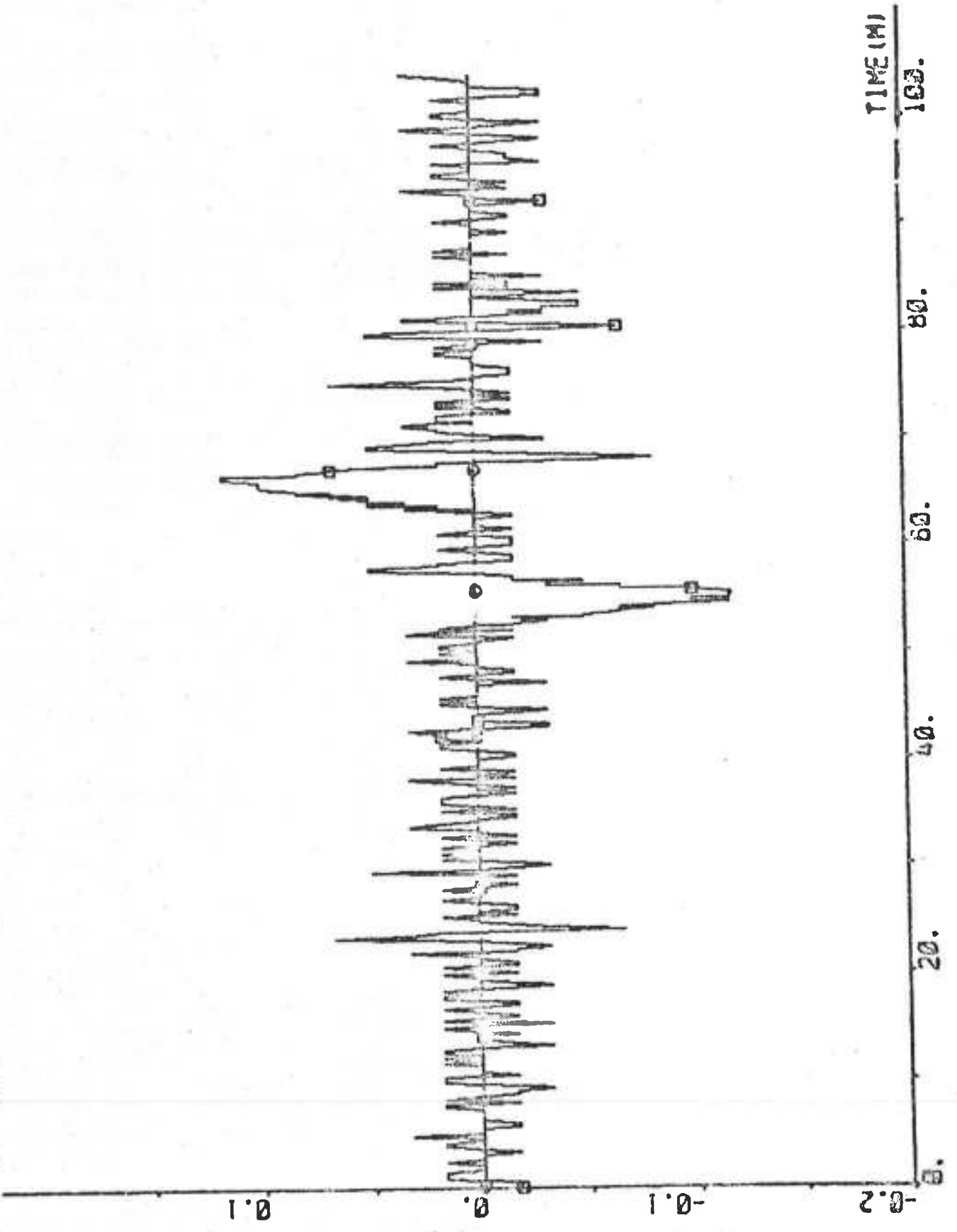
PLOT RHIP1(15)-RHIP1(10) ZERO -0.2 0.2 "R DEG/S



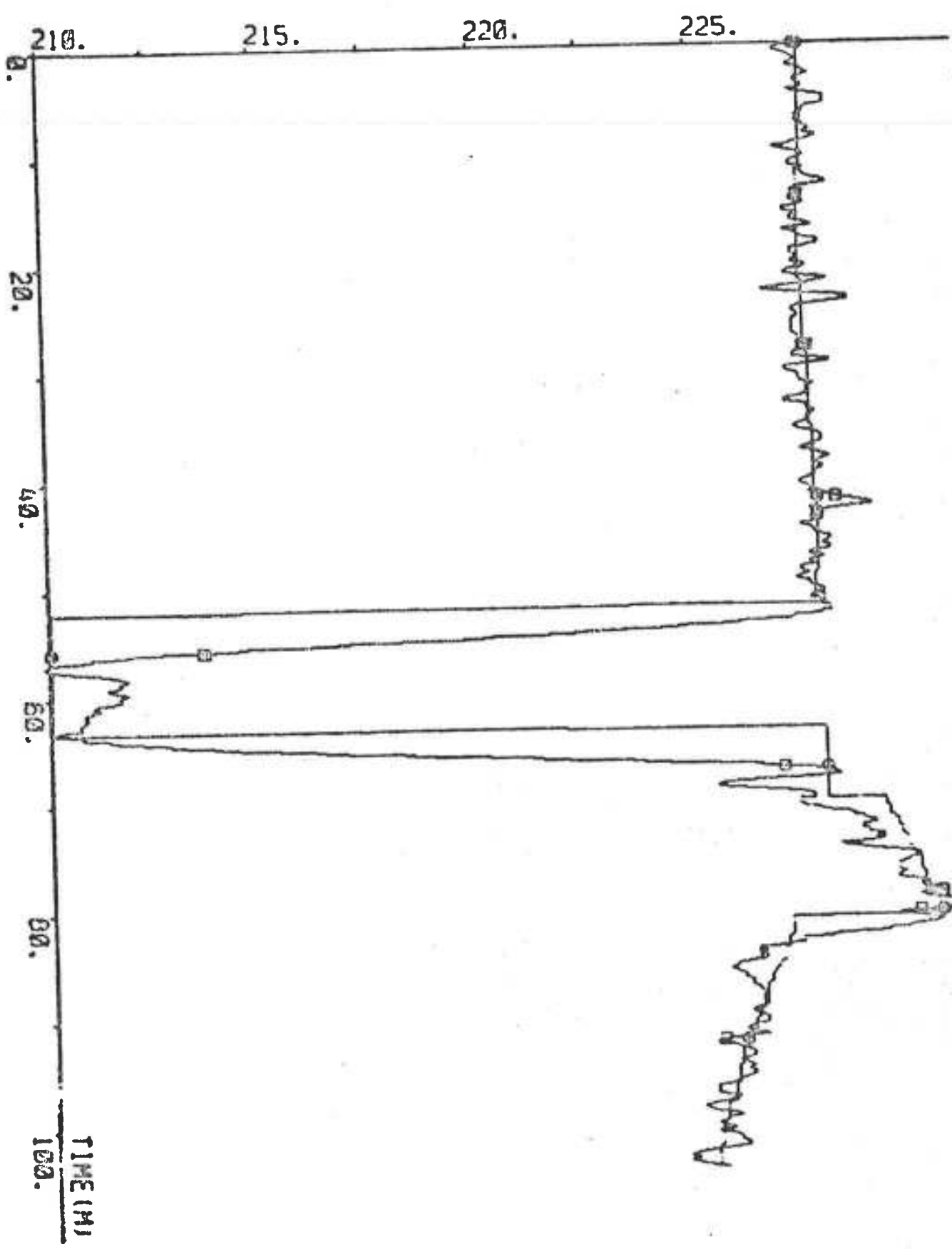
PLOT R41P1(16) R41P1(11) ZERO -0.2 0.2 "AVR DEC/S (GR-0.2)



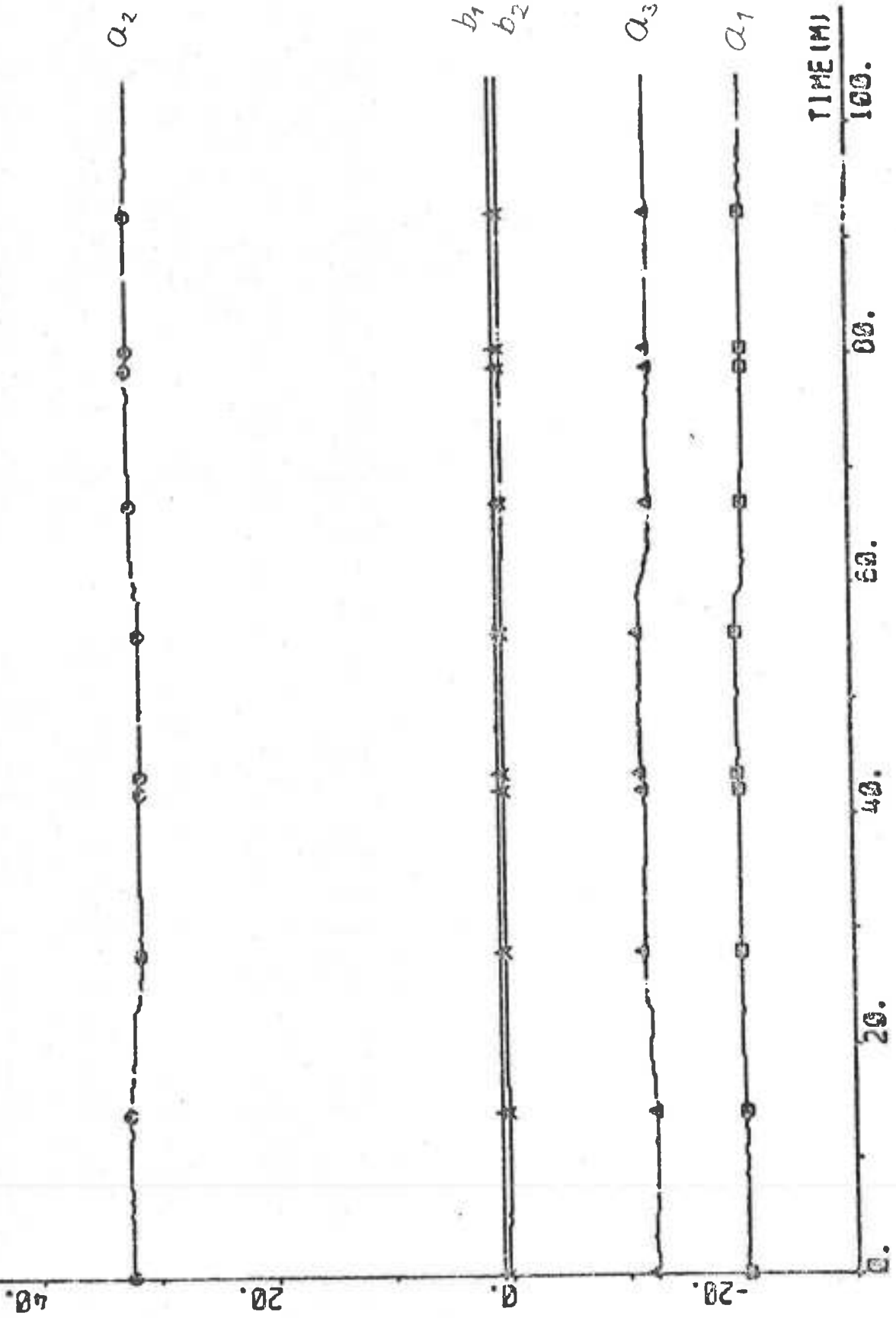
PLOT A41P1(15)→A41P1(12) ZERO -0.2 0.2 "DPSIDT DEG/S (IDPSI = 10)



PLOT RYPI(15) - RYPI(13 14) 210 225 - PSI PSIREF DEG



PLOT A41P1(15) A41P2 -25 35 "REGULATOR PARAMETERS



EXPERIMENT A42

Date	1974-10-23
Time	00.56
Duration	380 min
Position	S 33 ^o 30' E 26 ^o 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 ^o - 285.0 ^o (Sailmaster, Course correction)
RREF	0.07 deg/s
Rudder limit	Not active
DELLM at termination	-0.65 ^o

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

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

$$a_1 + a_2 + a_3 = -0.303$$

Yaw regulator structure

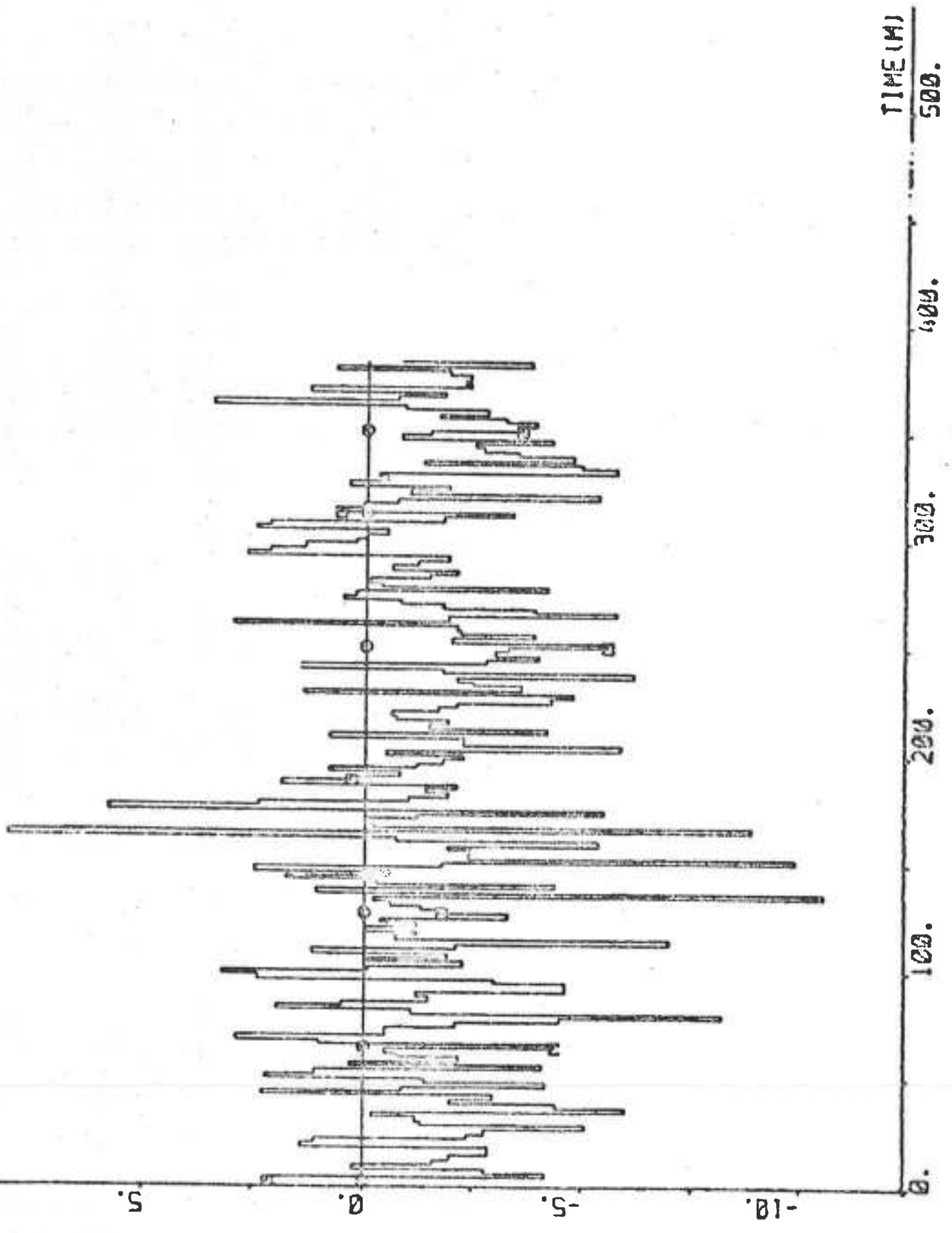
$$\begin{aligned} \text{NAY} &= 3 & \text{NBY} &= 2 & \text{KY} &= 2 \\ \text{IREGY} &= 10 & \text{RLY} &= 0.95 & \text{IRR} &= 3 & \text{IDPSI} &= 5 \\ \text{AK1V} &= 40 & \text{AK2V} &= 1.8 & \text{AK3V} &= 120 \\ \text{C1V} &= 10 & \text{C2V} &= 80 \\ \text{EPS1V} &= 0.02 & \text{EPS2V} &= 0.04 \\ \text{PSISV} &= 0.15 & \text{PSISSV} &= 1.5 & \text{PSIMAV} &= 0.35 \\ \text{I1MV} &= 60 & \text{I2MV} &= 300 & \text{I3MV} &= 150 \end{aligned}$$

Initial yaw regulator values

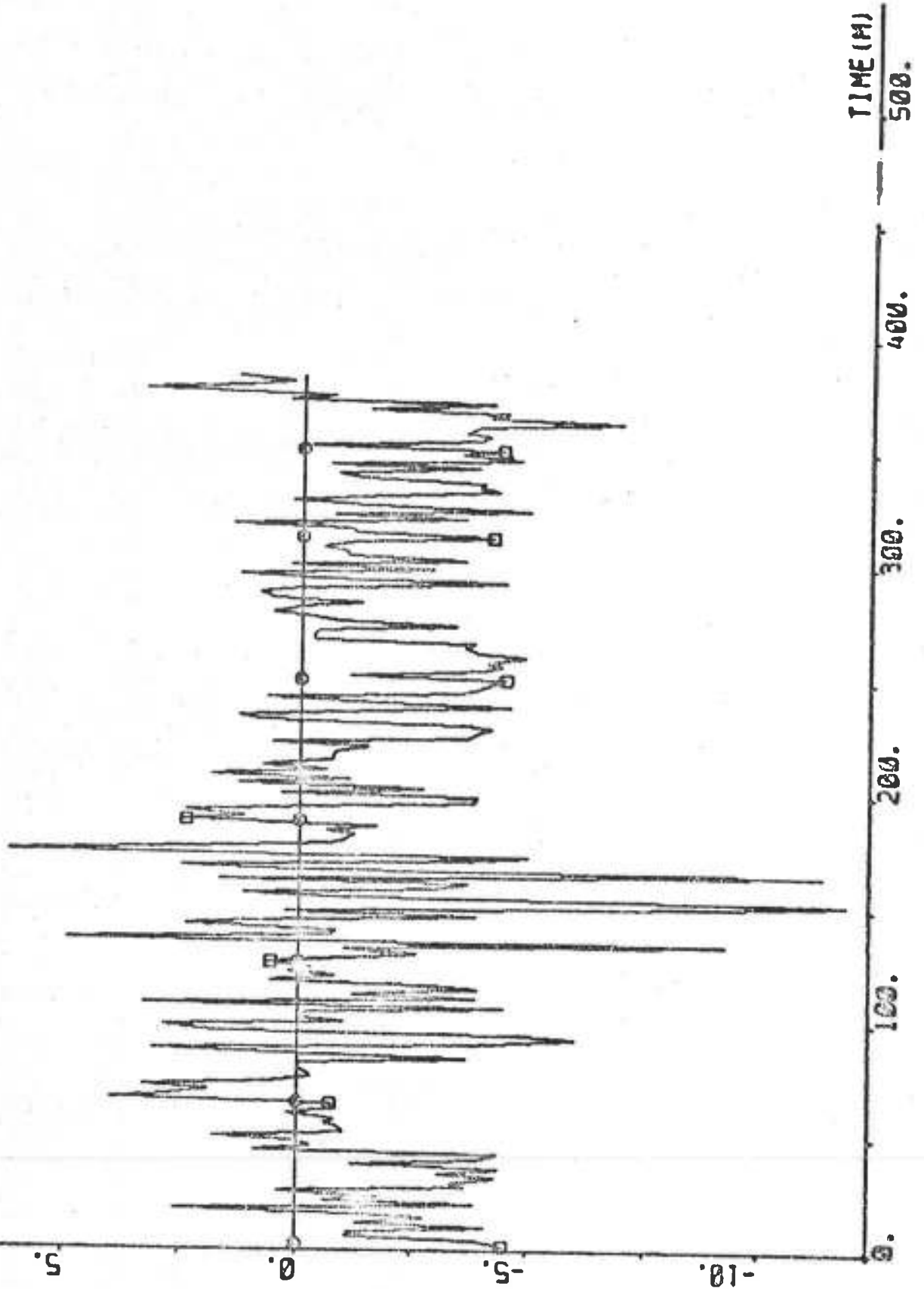
$$\begin{bmatrix} a'_1 \\ a'_2 \\ a'_3 \\ b'_1 \\ b'_2 \end{bmatrix} = \begin{bmatrix} -43.56 \\ 4.94 \\ 0.90 \\ 1.30 \\ 0.81 \end{bmatrix} \quad \text{PY} = \begin{bmatrix} 500 & & & & \\ 0 & 500 & & & \\ 0 & 0 & 500 & & \\ 0 & 0 & 0 & 1 & \\ 0 & 0 & 0 & 0 & 1 \end{bmatrix}$$

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

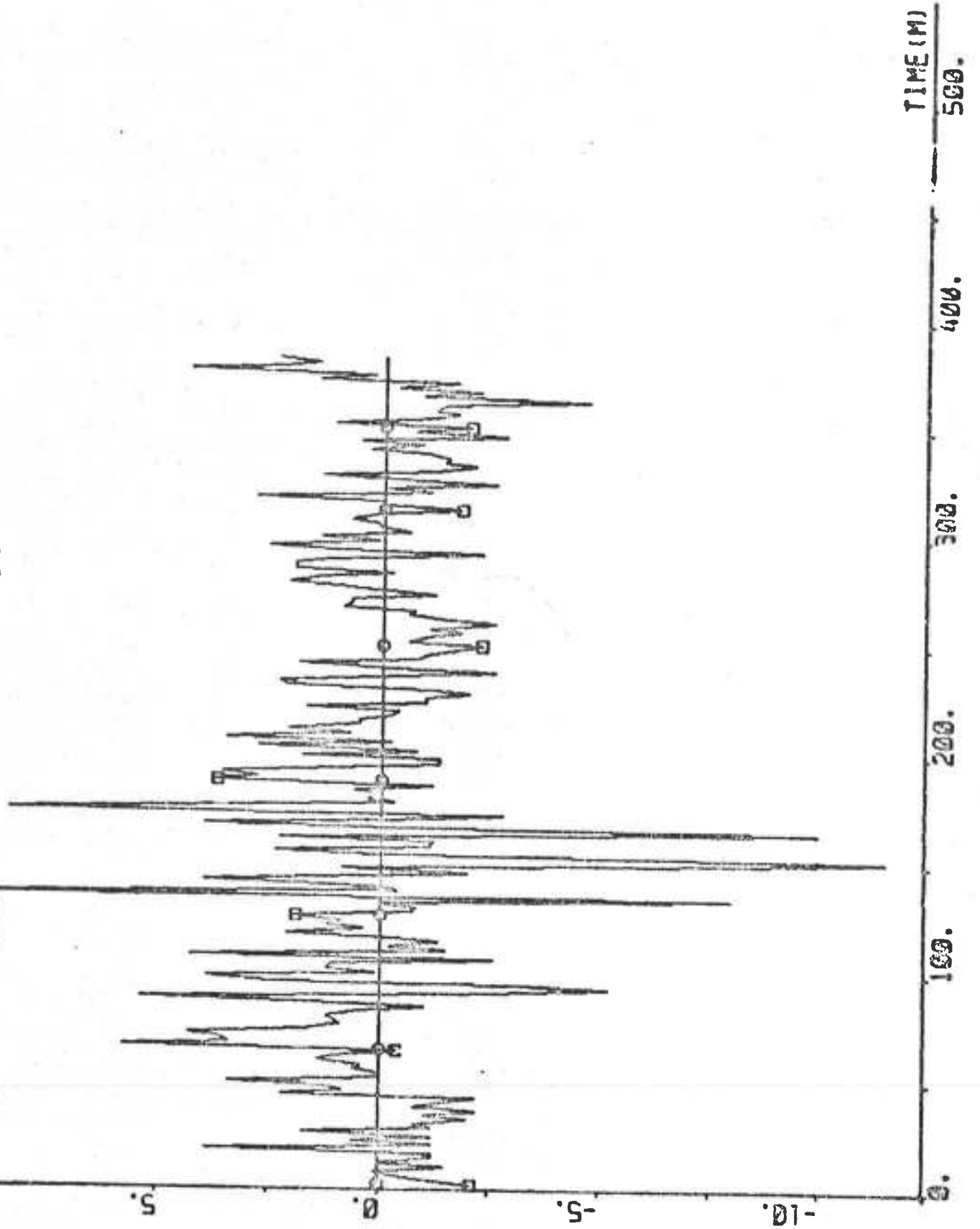
PLOT HP R42P1(1) ZERO -12 8 "DELCOC DEG



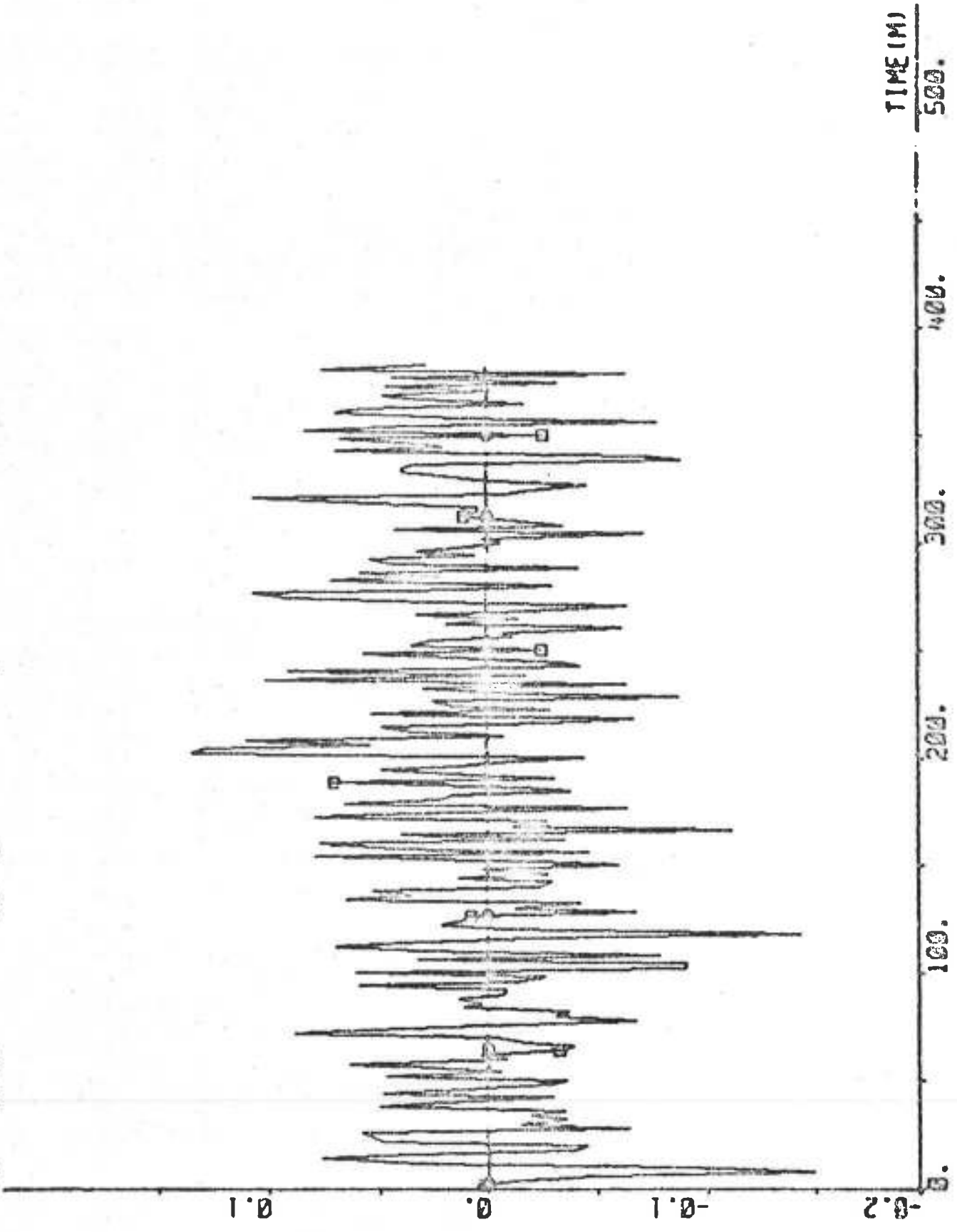
PL0T A42P1(3) ZERO -12 8 "DELTA S DEG



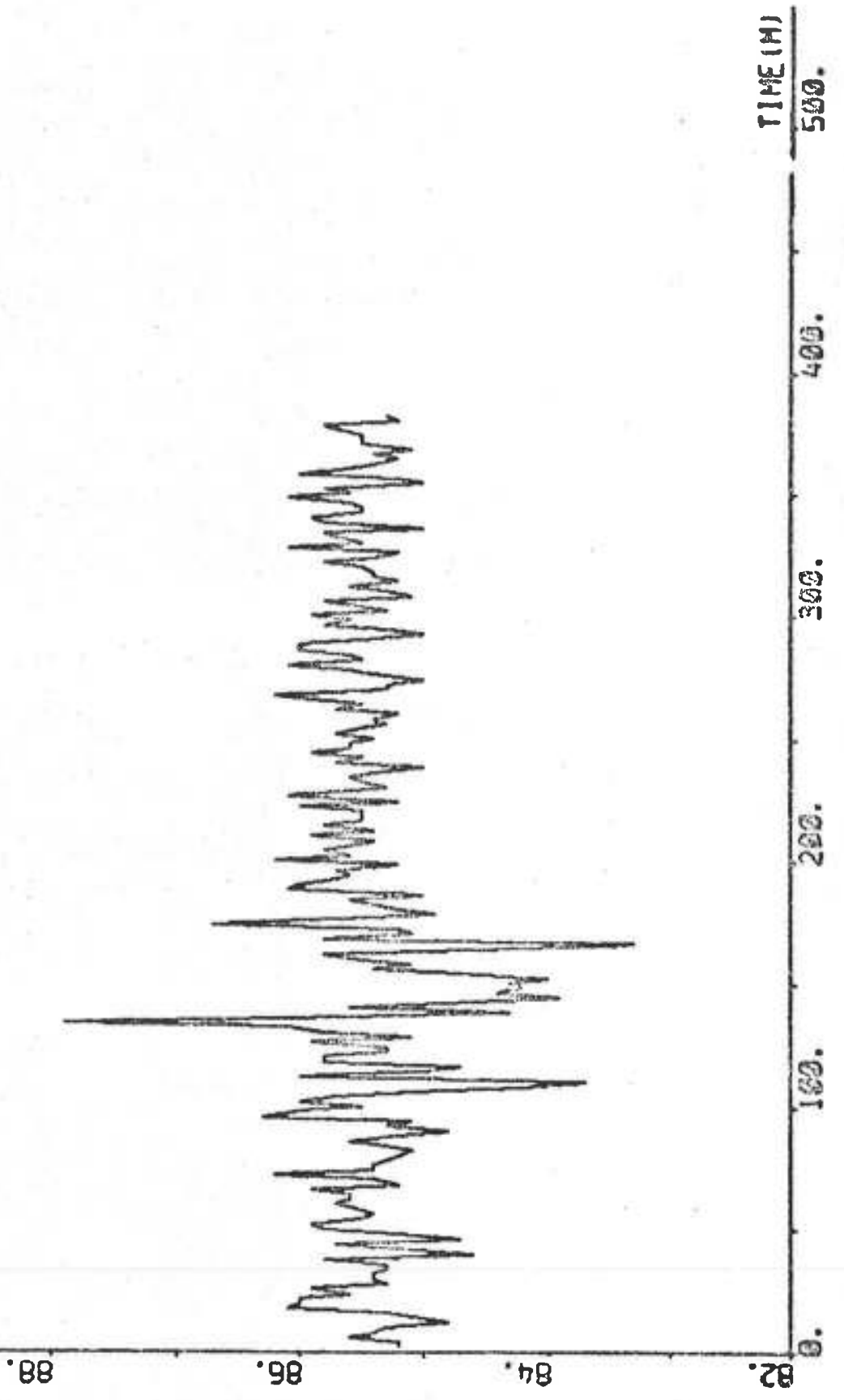
PLOT AN2P1(4) ZERO -12 8 "DELTA DEG



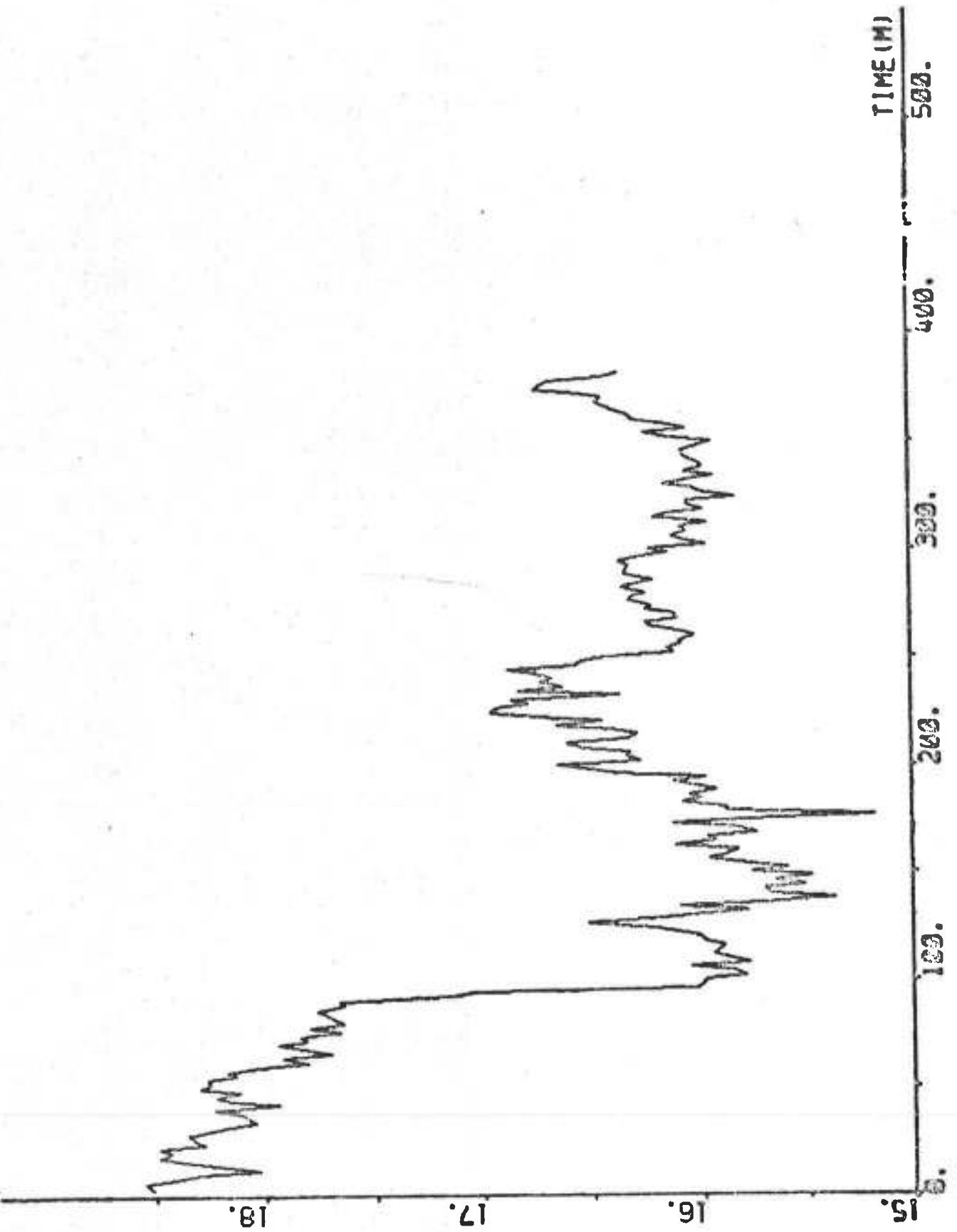
PLOT AY2P1(5) ZERO -0.2 0.2 *PP DEG/S



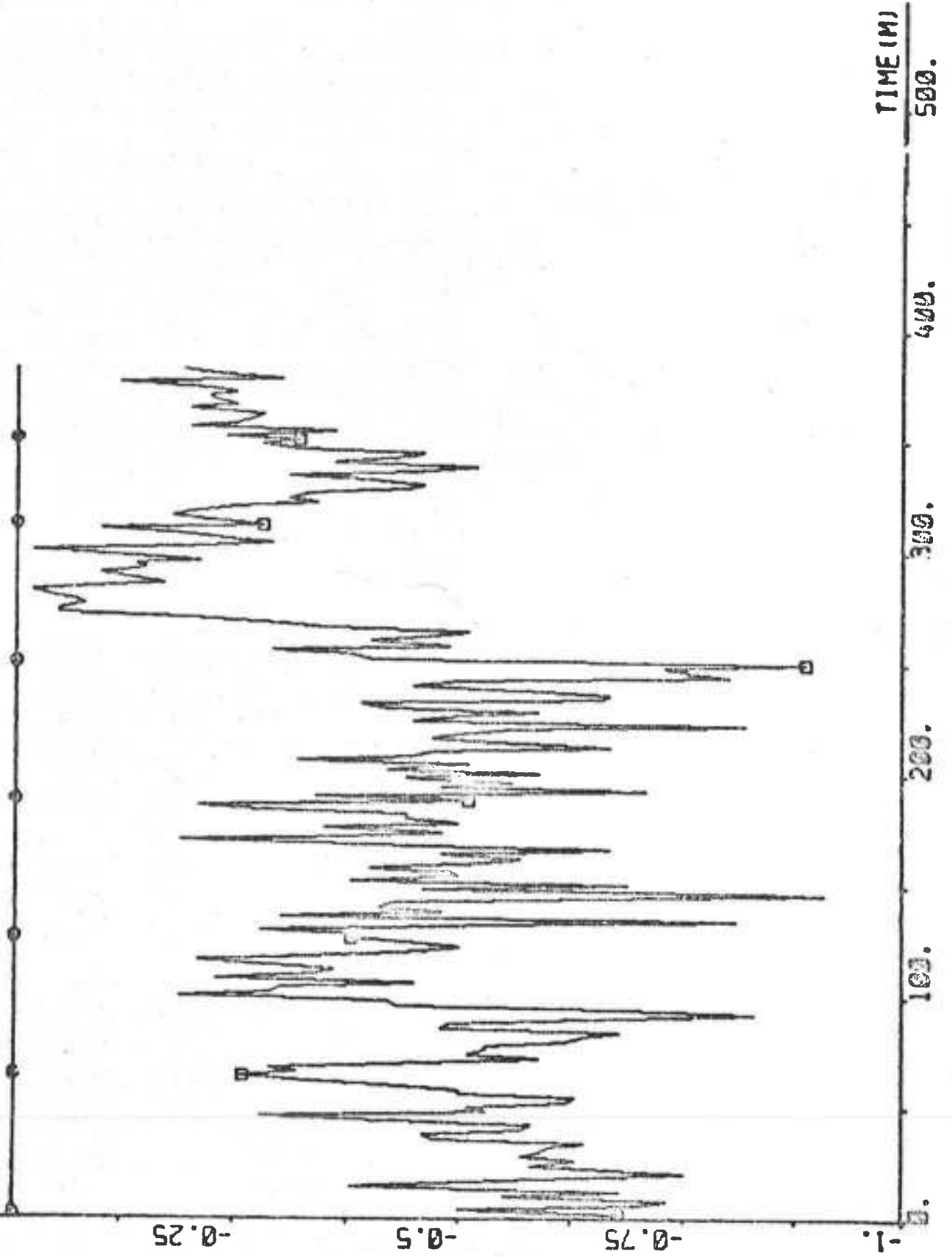
PLOT A42P1(6) 82 90 -AN RPN



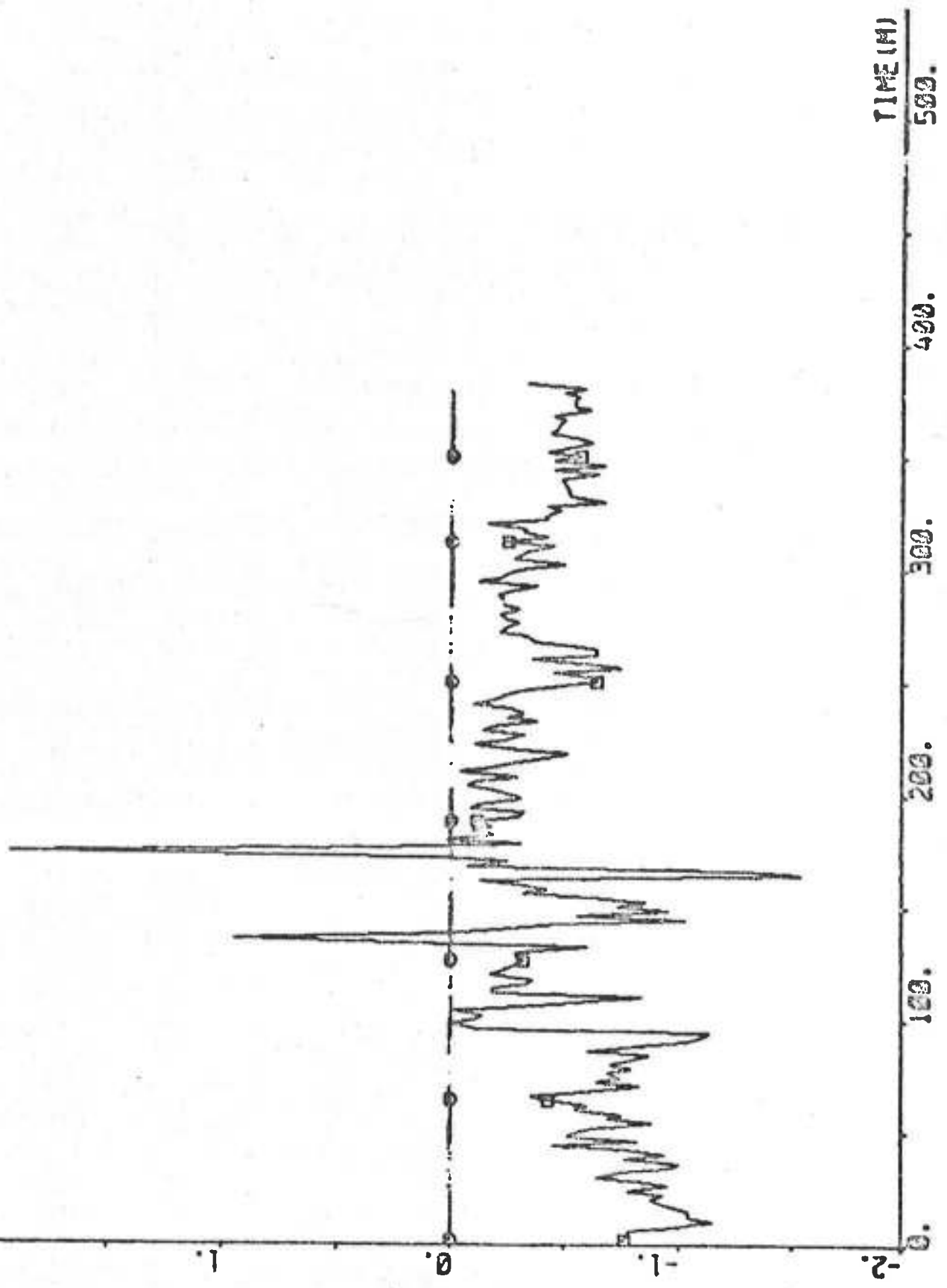
PLOT AH2P1(7) 15 19 "U KNOTS



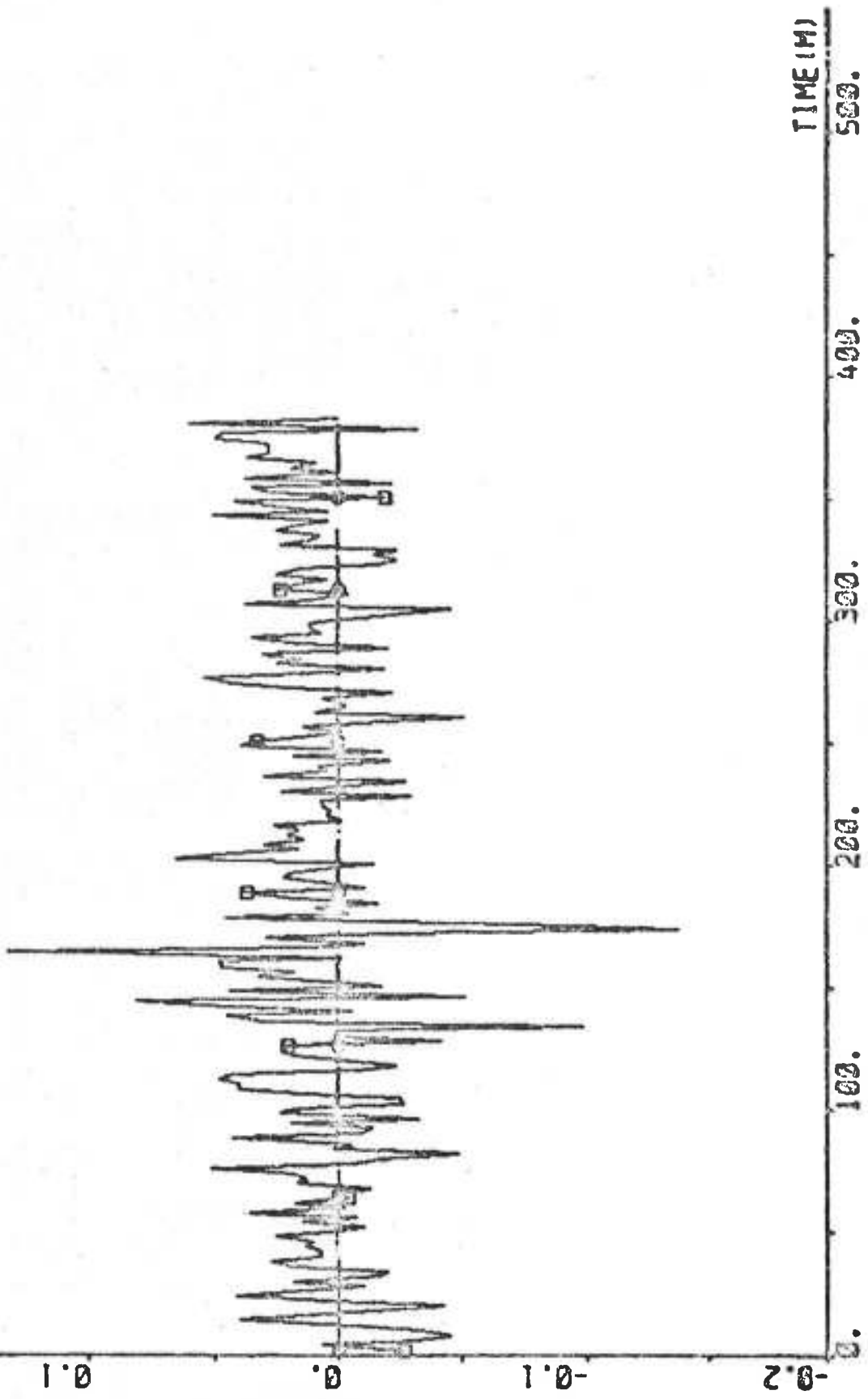
PLOT R42P1(8) ZERO -1 0 -V1 KNOTS



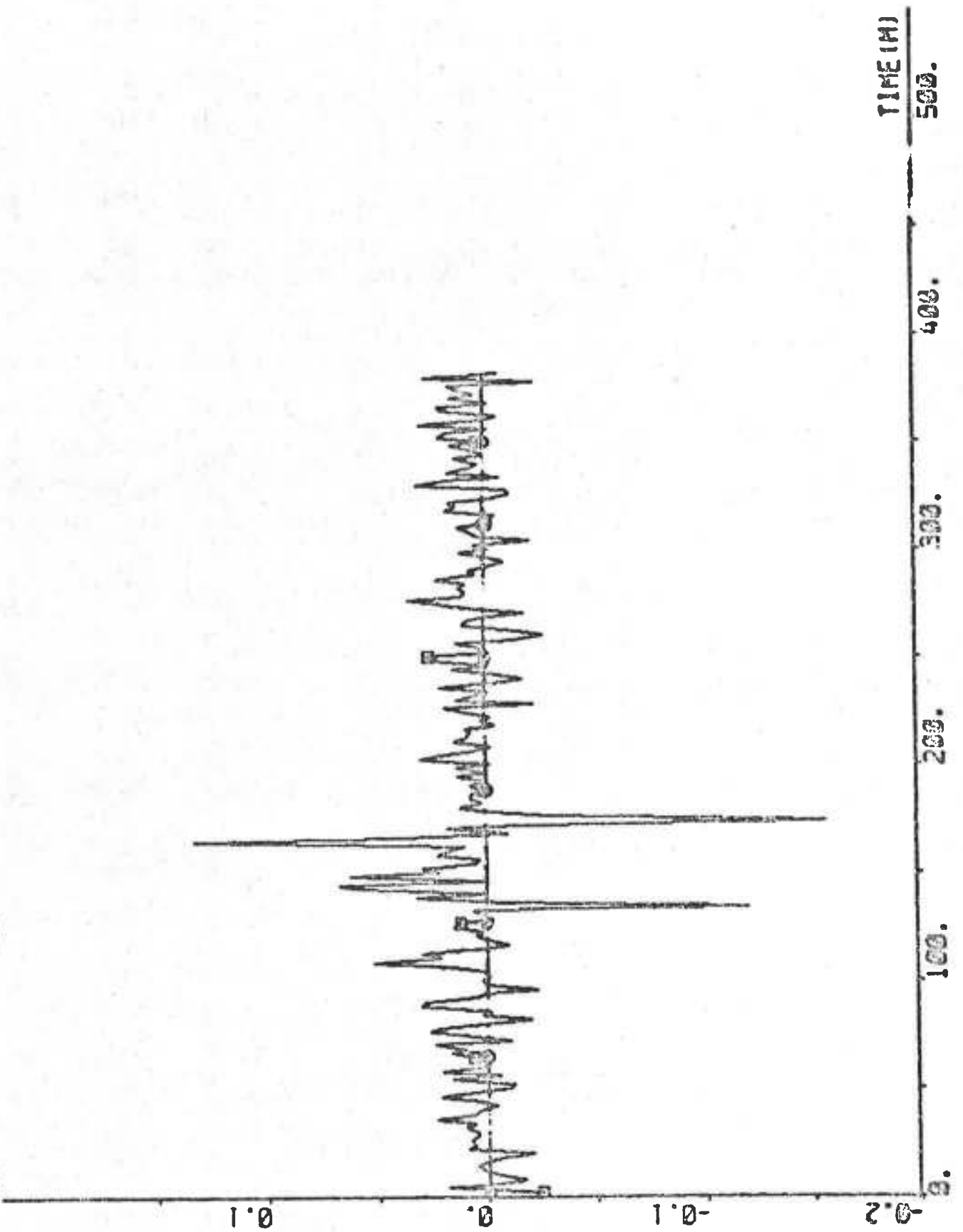
PLOT A42P1(8) ZERO -2 2 -V2 KNOTS



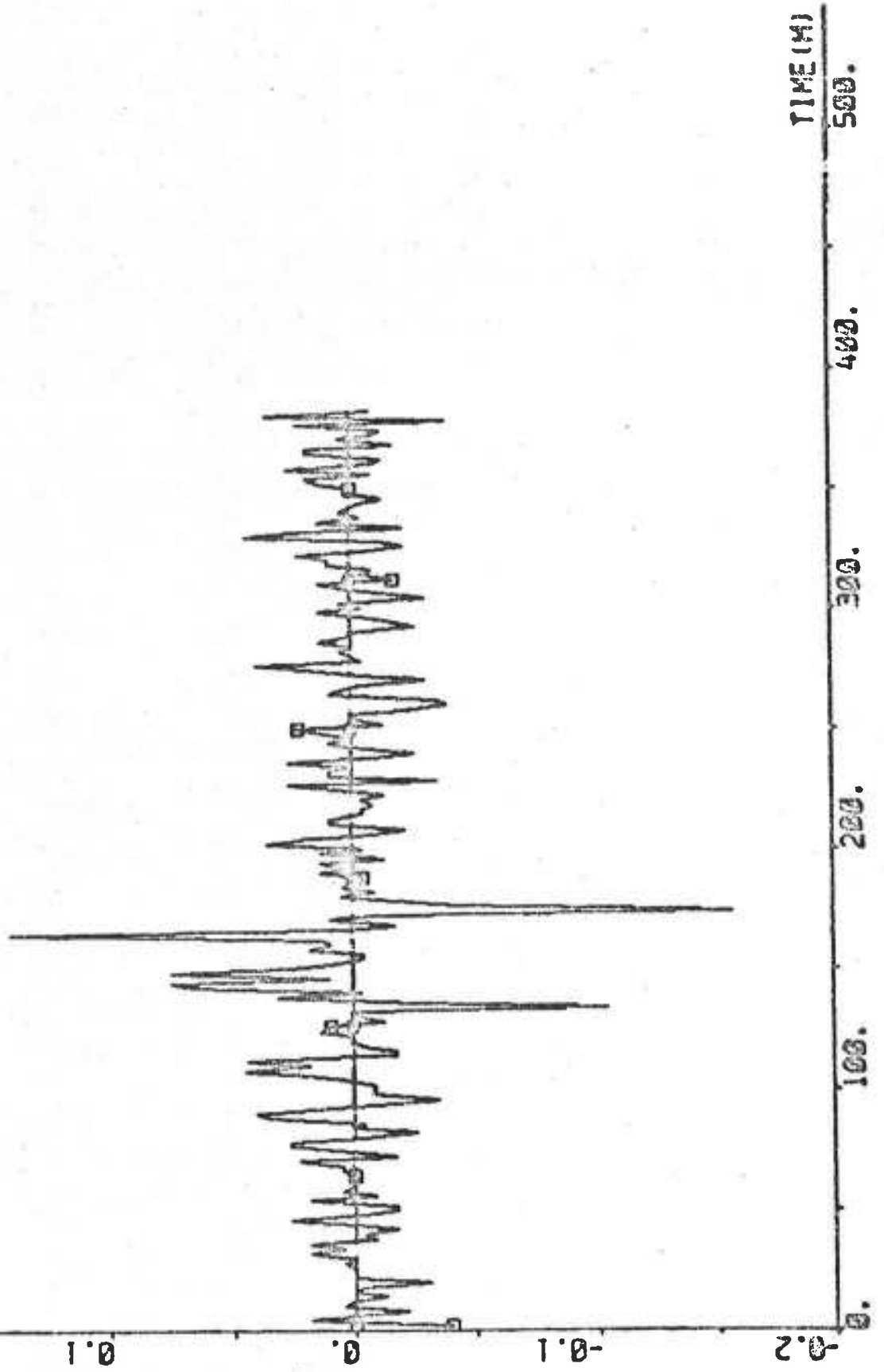
PLOT R42P1(10) ZERO -0.2 0.2 "R DEG/S



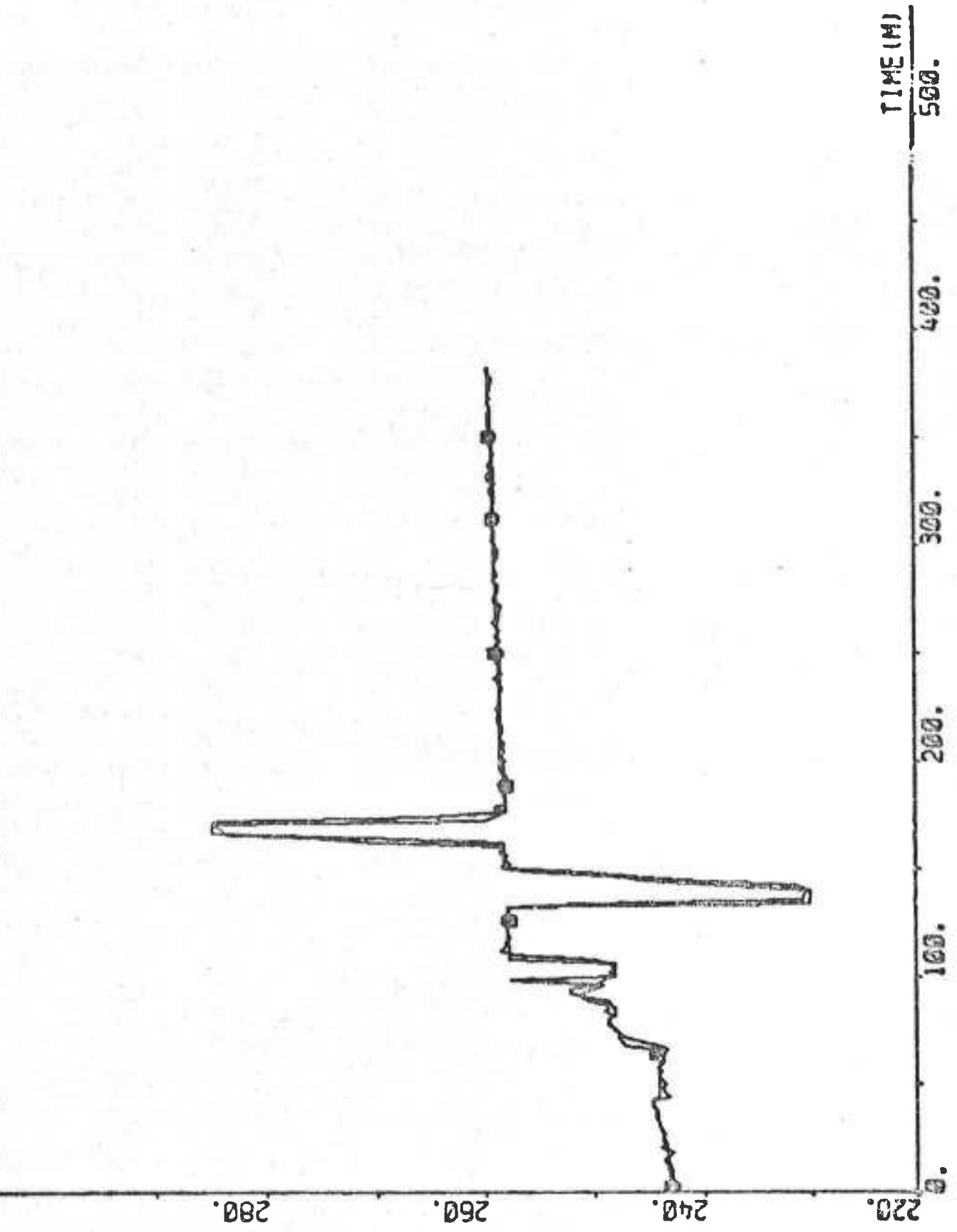
PLOT A#2P1(11) ZERO -0.2 0.2 "AVR DEG/S (BR.0.2)"



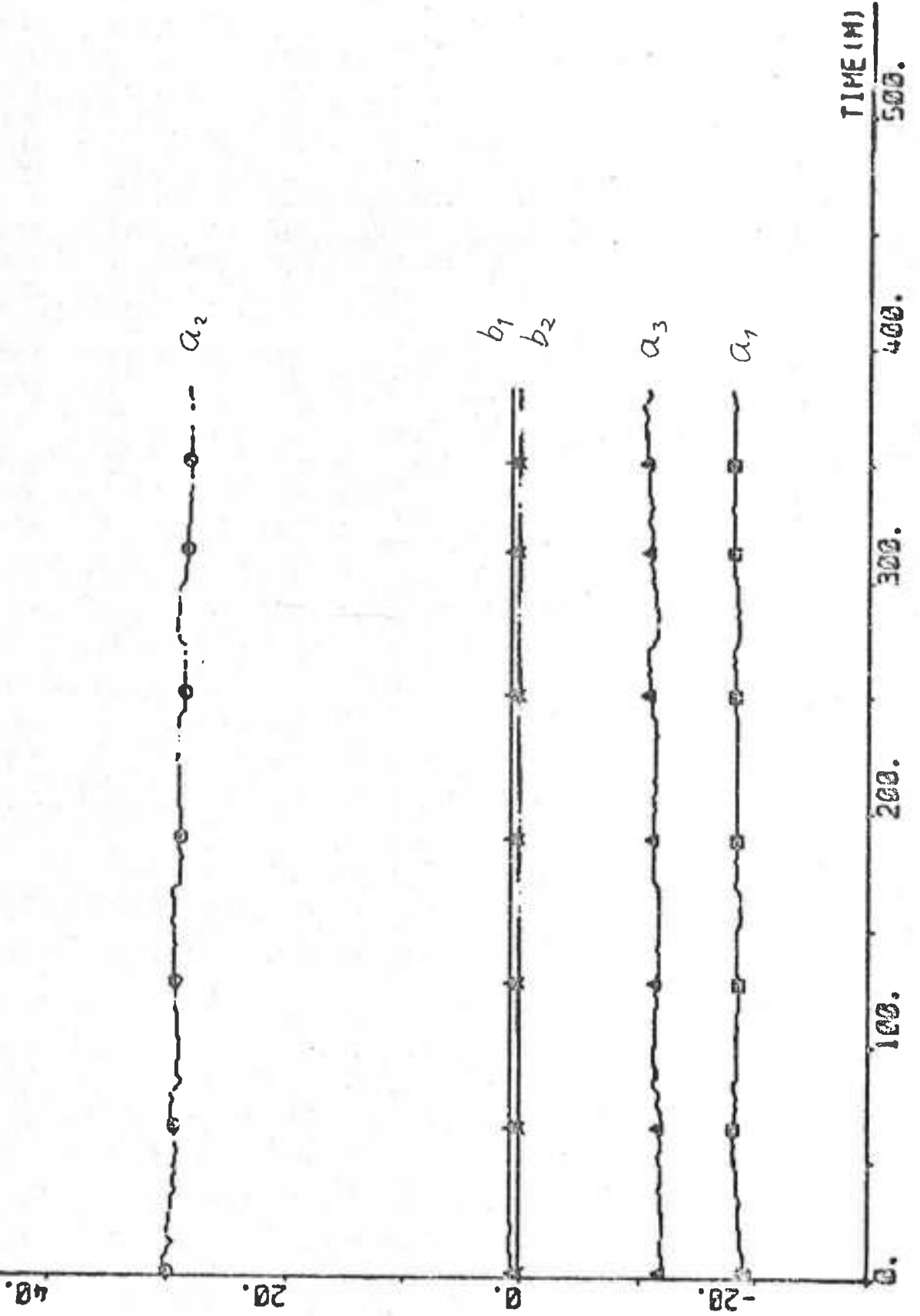
PLOT R42P1(12) ZERO -0.2 0.2 "DPSIDT DEG/S (IDPSI*5)



PLOT A42P1(13 14) 220 250 -PSI PSIREF DEG



PLOT F42P2 -25 35 REGULATOR PARAMETERS



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

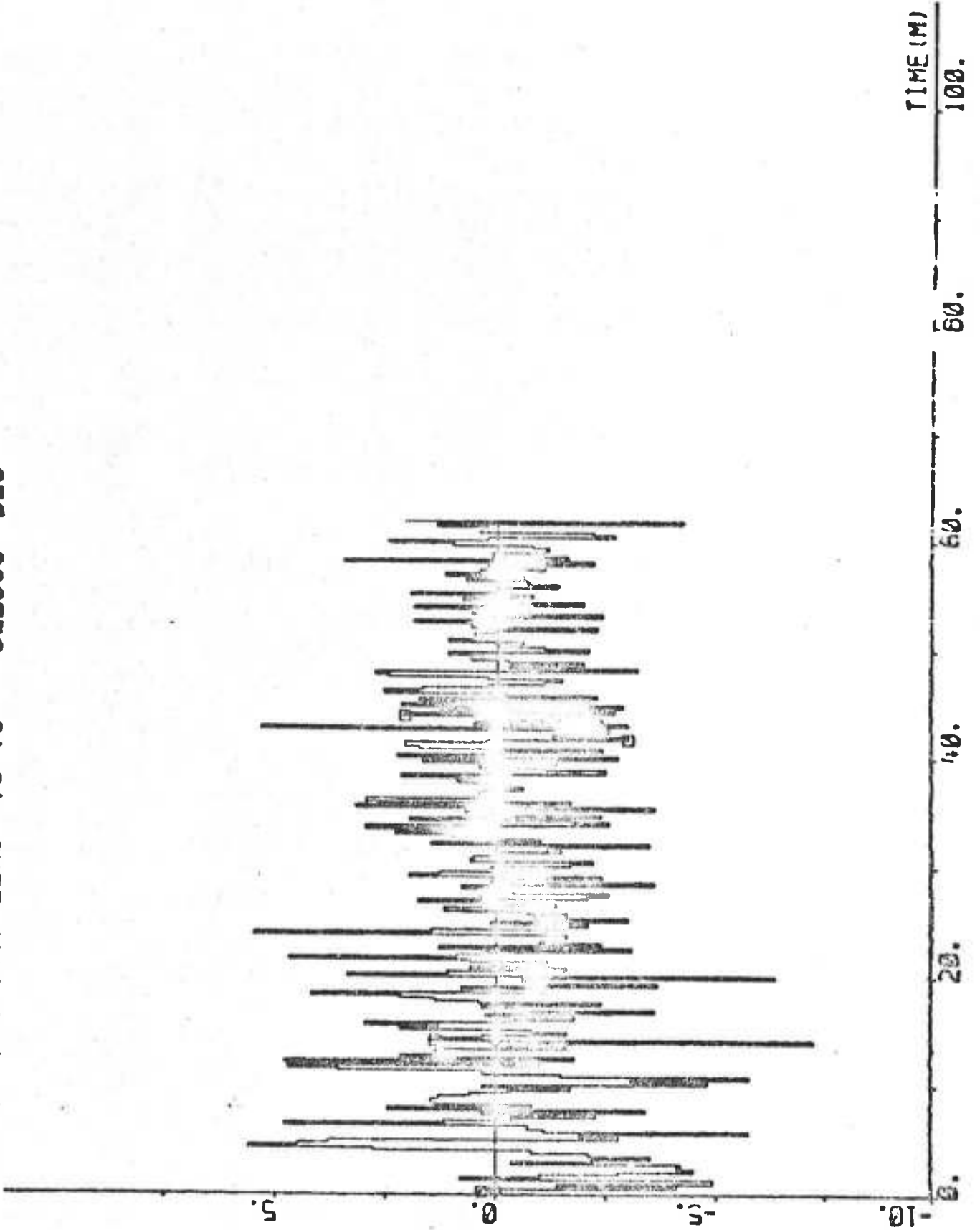
$$\begin{bmatrix} a_1 \\ a_2 \\ a_3 \\ b_1 \\ b_2 \end{bmatrix} = \begin{bmatrix} -18.071 \\ 29.138 \\ -11.124 \\ 0.802 \\ 0.129 \end{bmatrix} \quad P = \begin{bmatrix} 0.929 & & & & \\ -1.068 & 2.663 & & & \\ 0.400 & -1.921 & 2.099 & & \\ -0.010 & -0.052 & 0.080 & 0.006 & \\ -0.006 & -0.057 & 0.078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

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

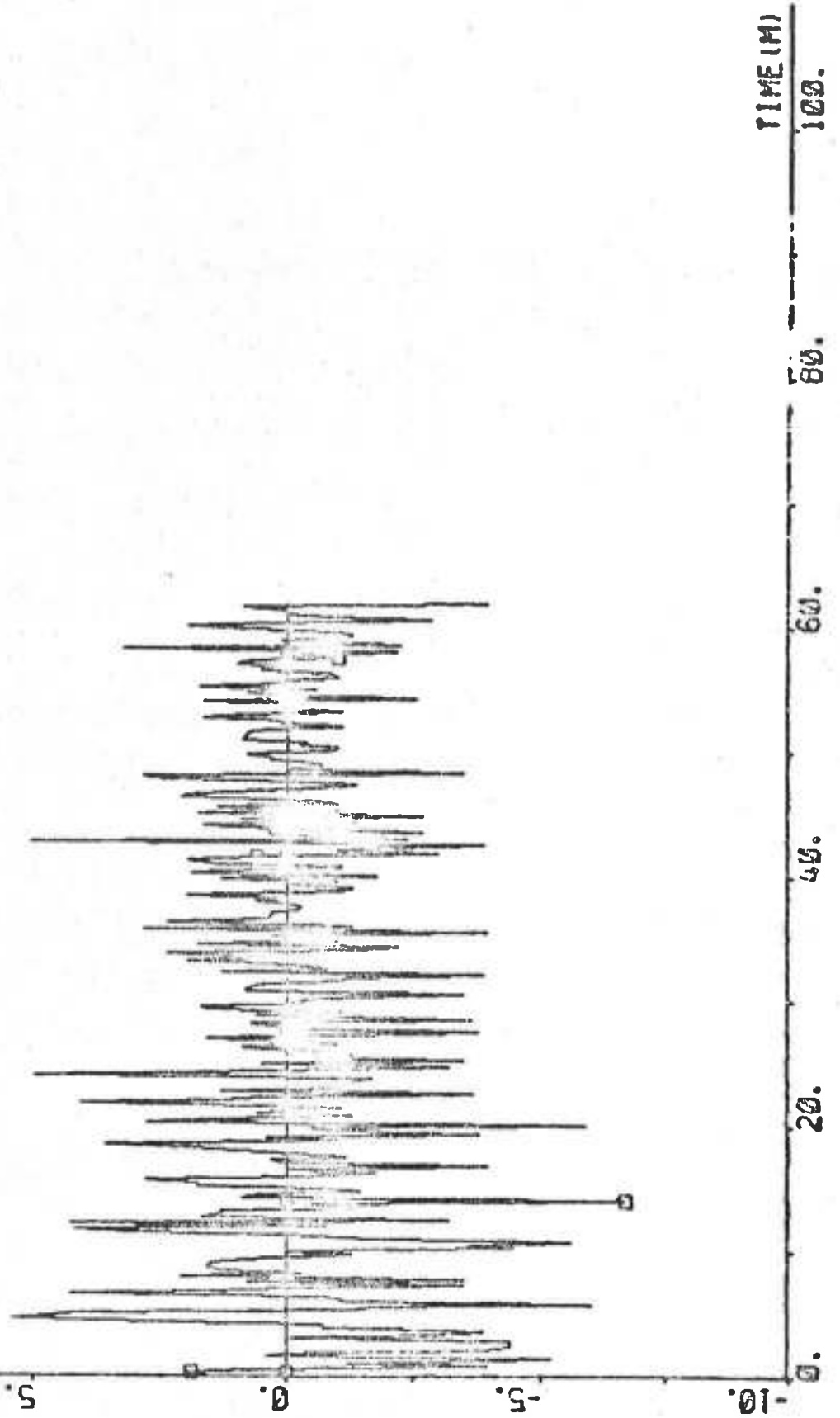
Statistics (mean value and standard deviation)

	<u>0-62 min</u>	<u>20-62 min</u>
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

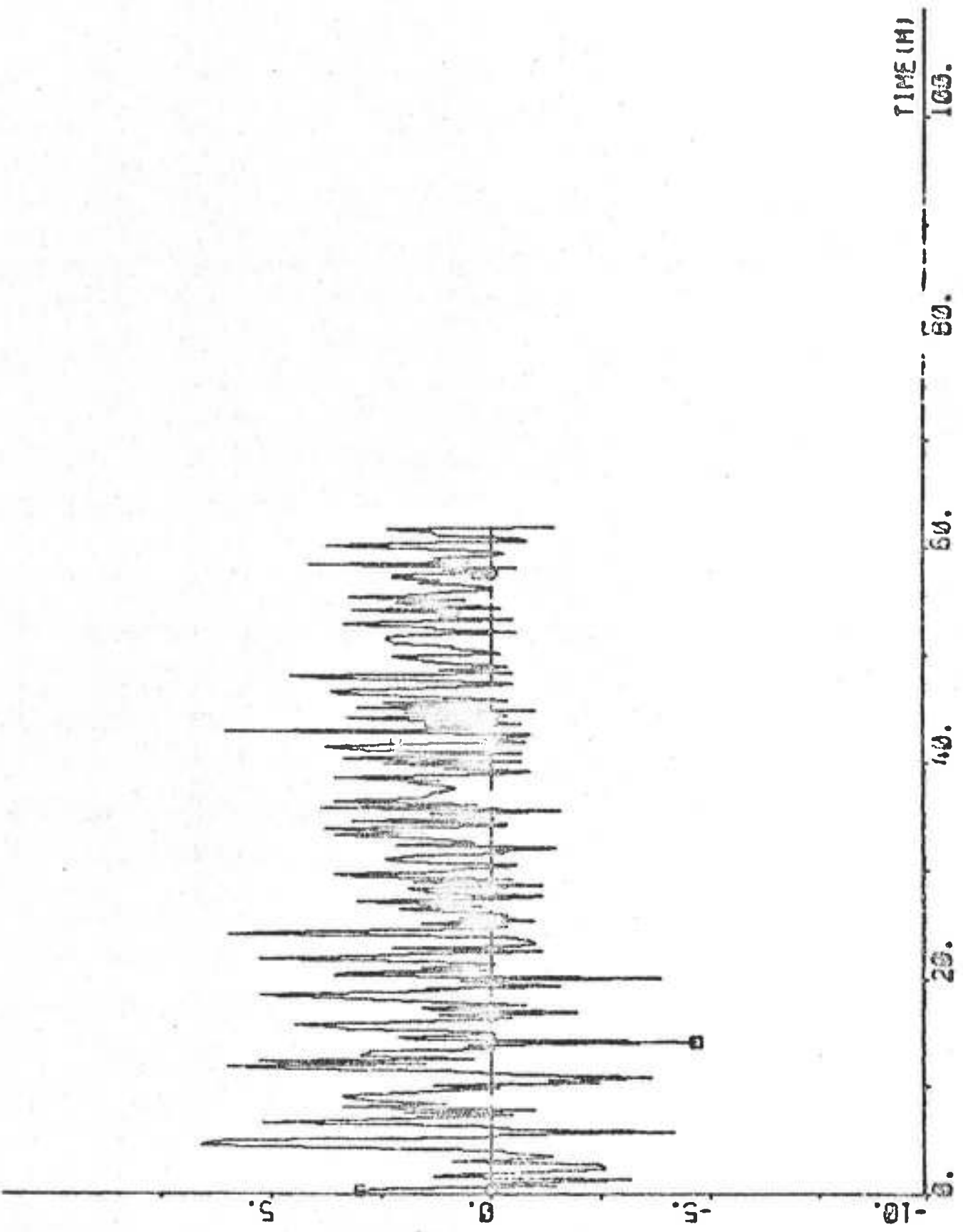
PLOT HP A43P1(1) ZERO -10 10 "DELCOC DEG



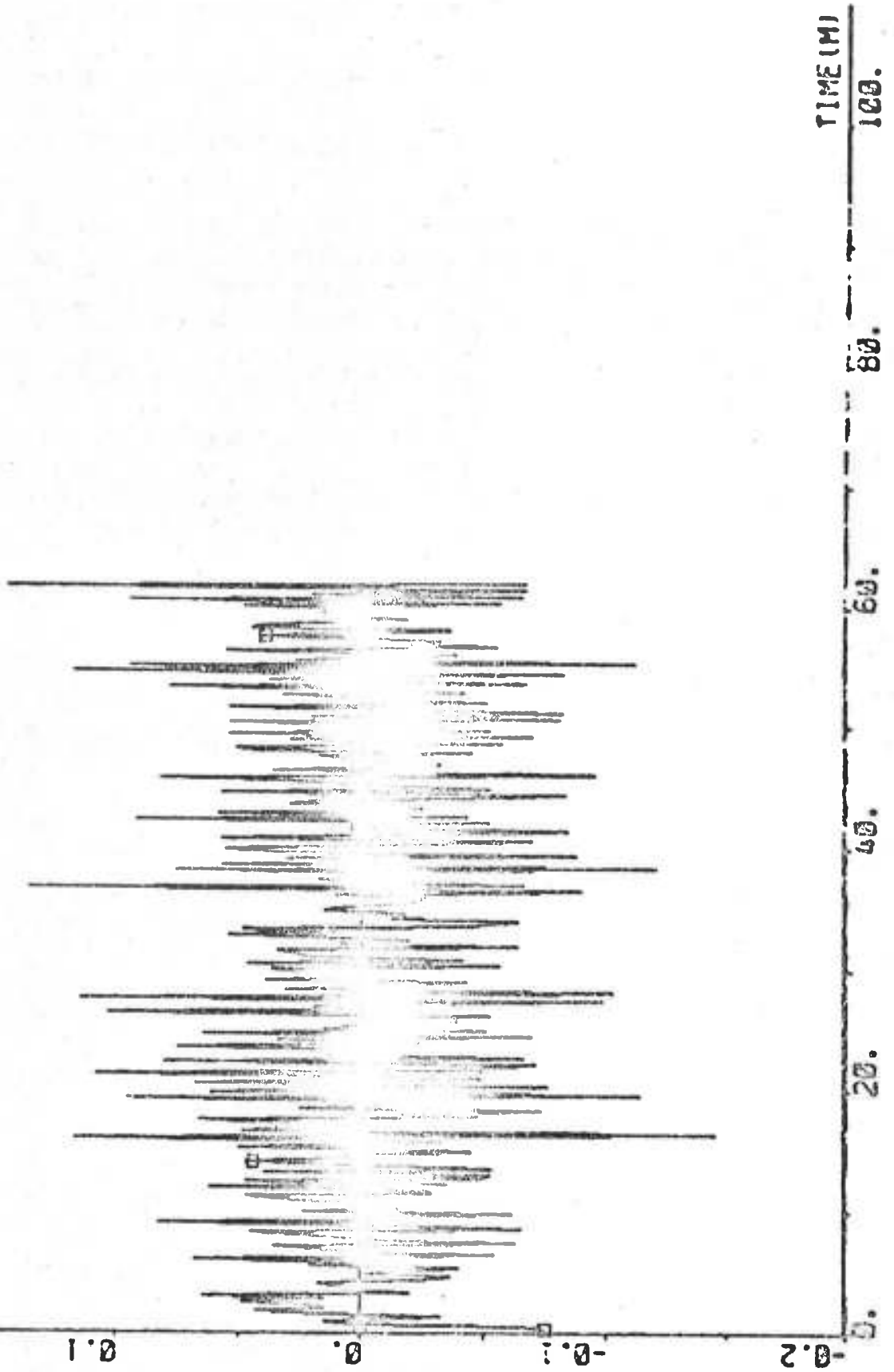
PLOT A43P1(3) ZERO -10 10 "DELTA" DEG



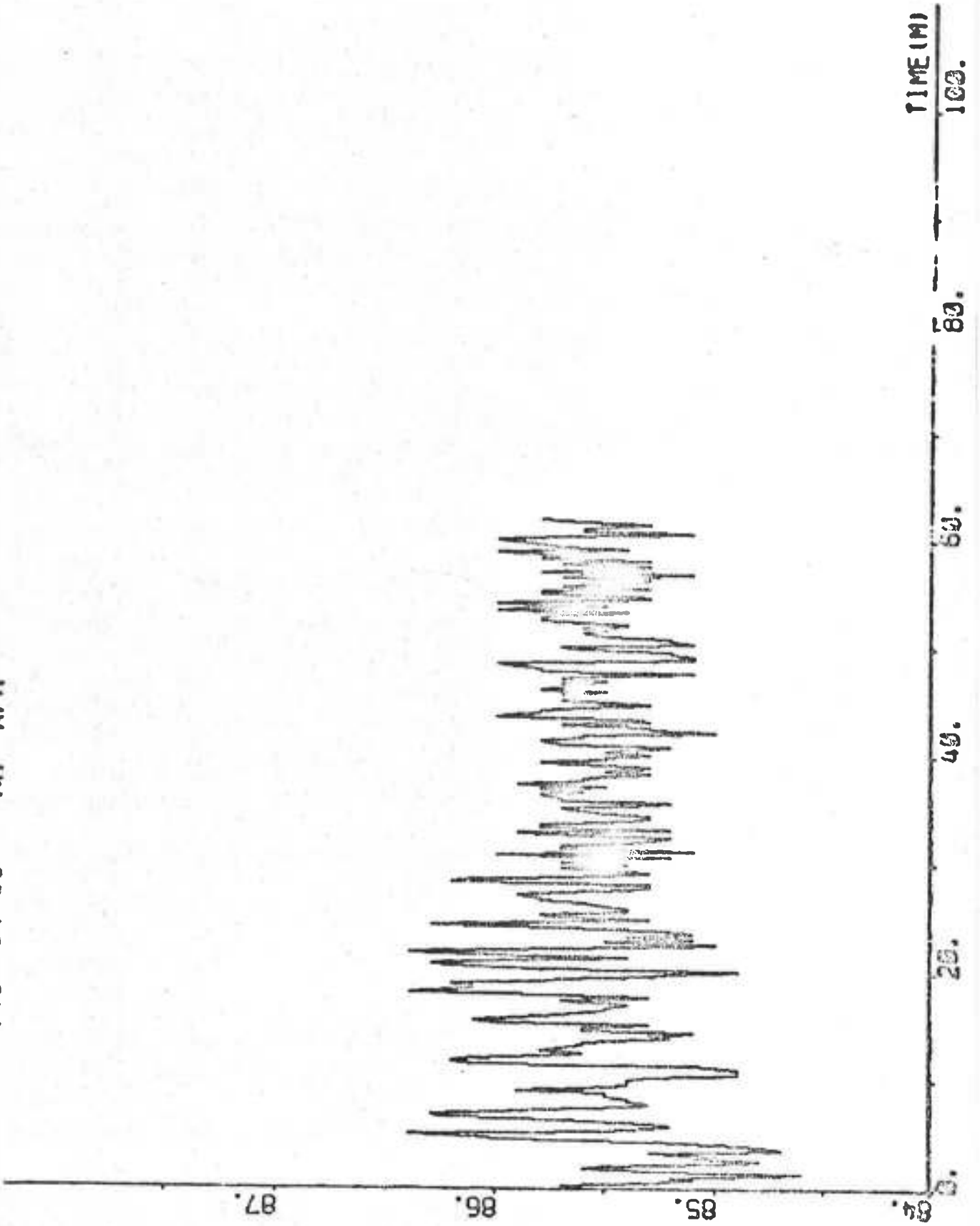
PLOT A43P1(4) ZERO -10 10 DELTA DEG



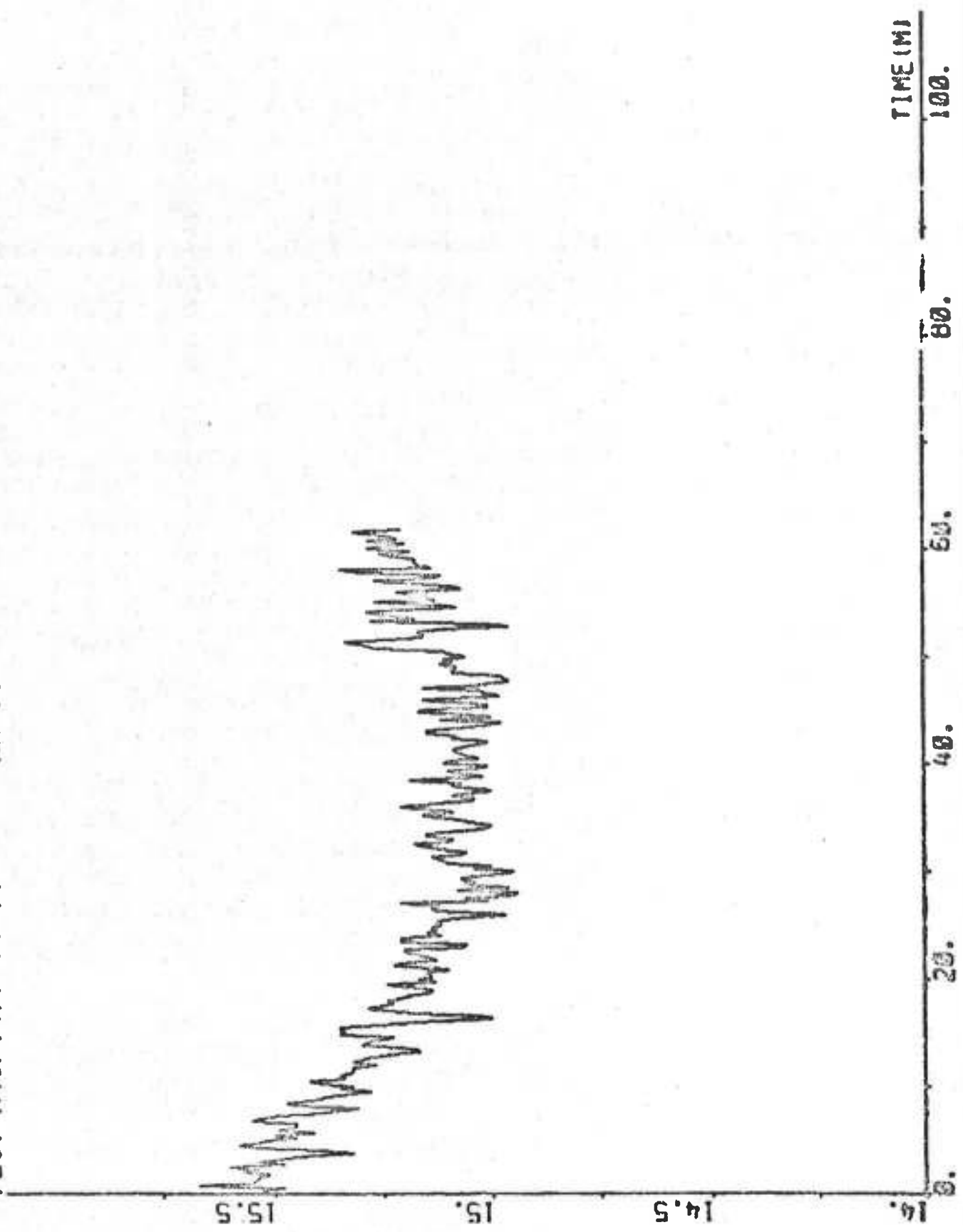
PLOT A43P1(5) ZERO -0.2 0.2 PP DEG/S



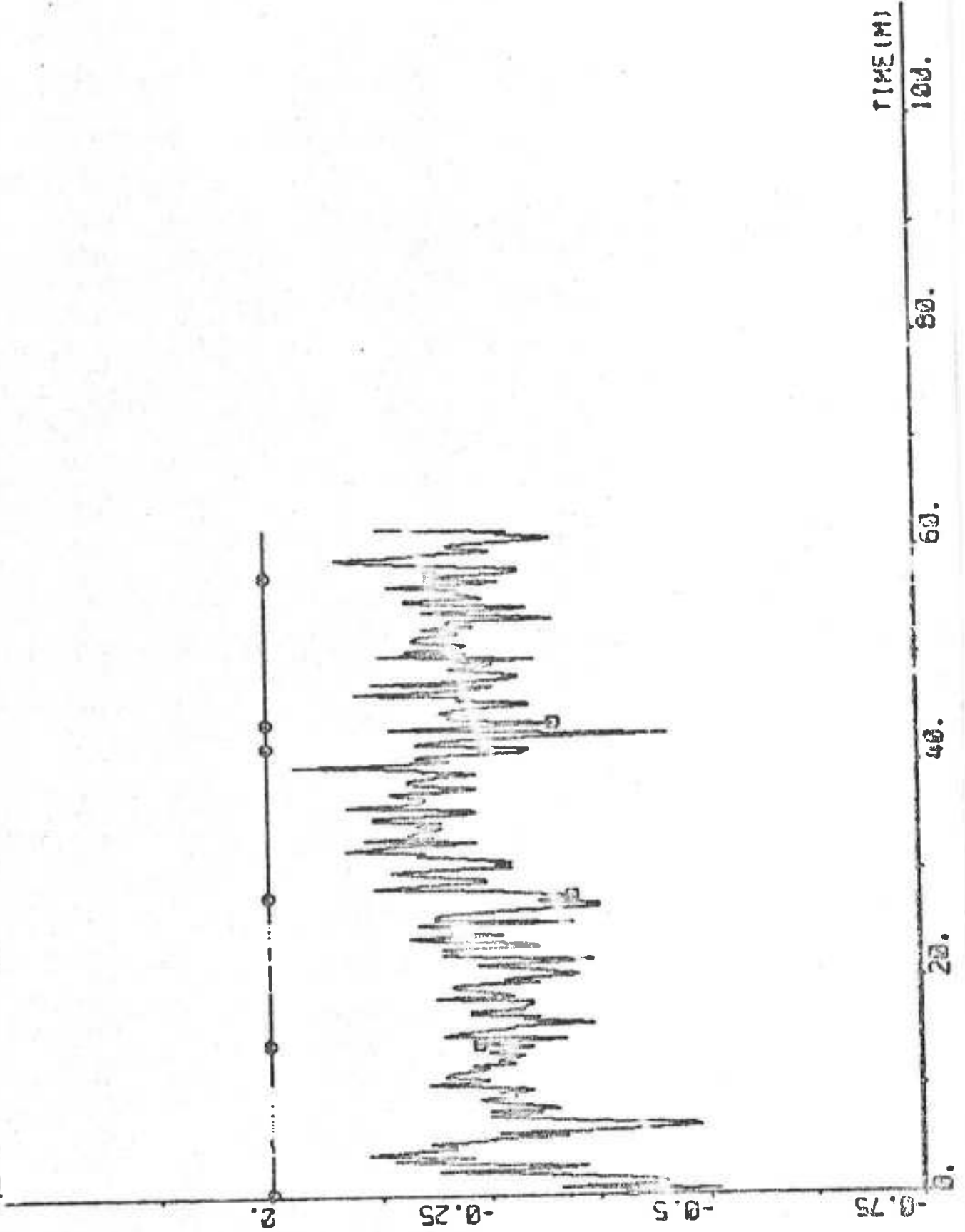
PLOT R43P1(6) S4 88 "AN RPM



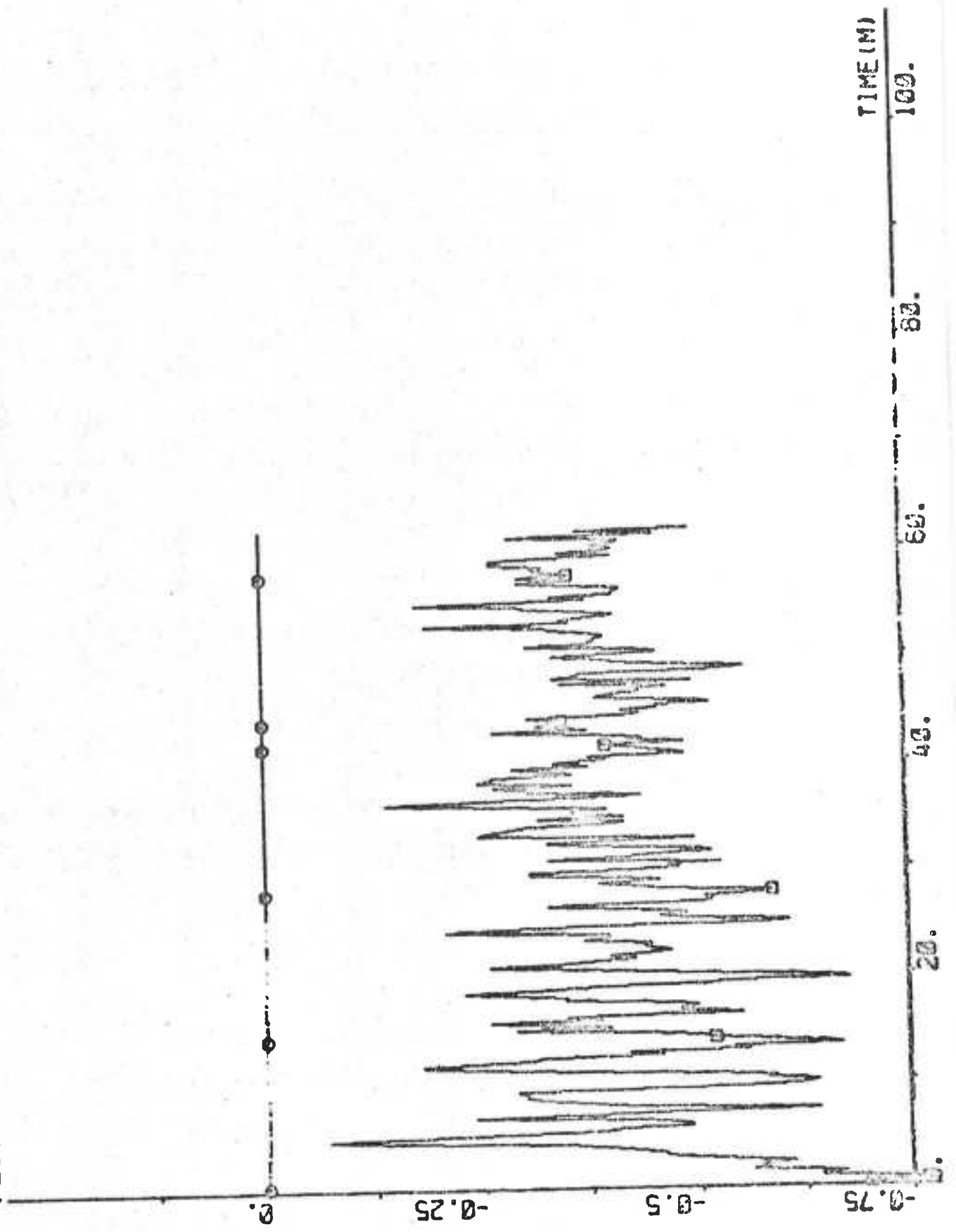
PLOT R43P1(7) 14 16 "U KNOTS



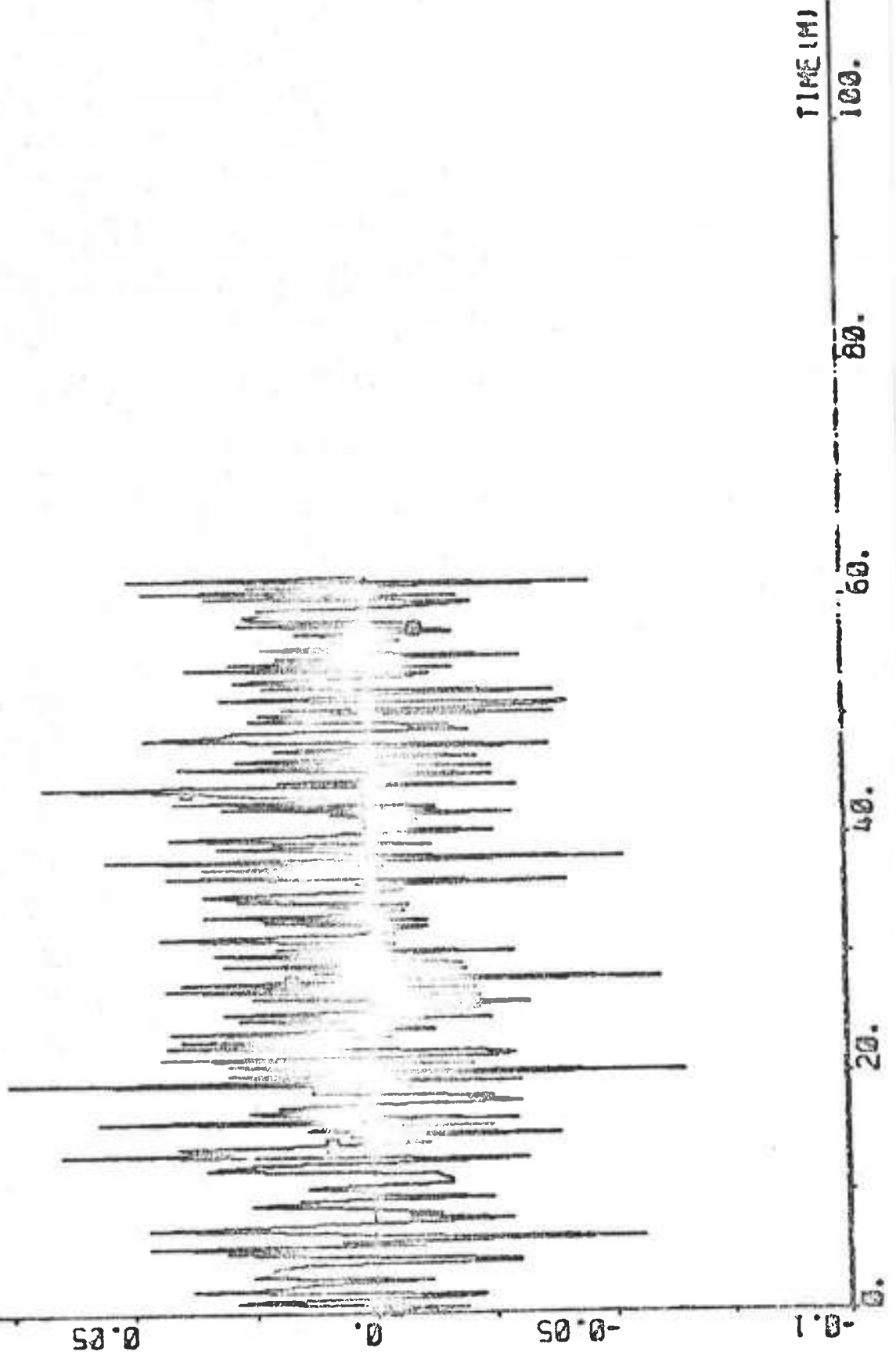
PLOT A43P1(8) ZERO -0.75 0.25 "V1 KNOTS



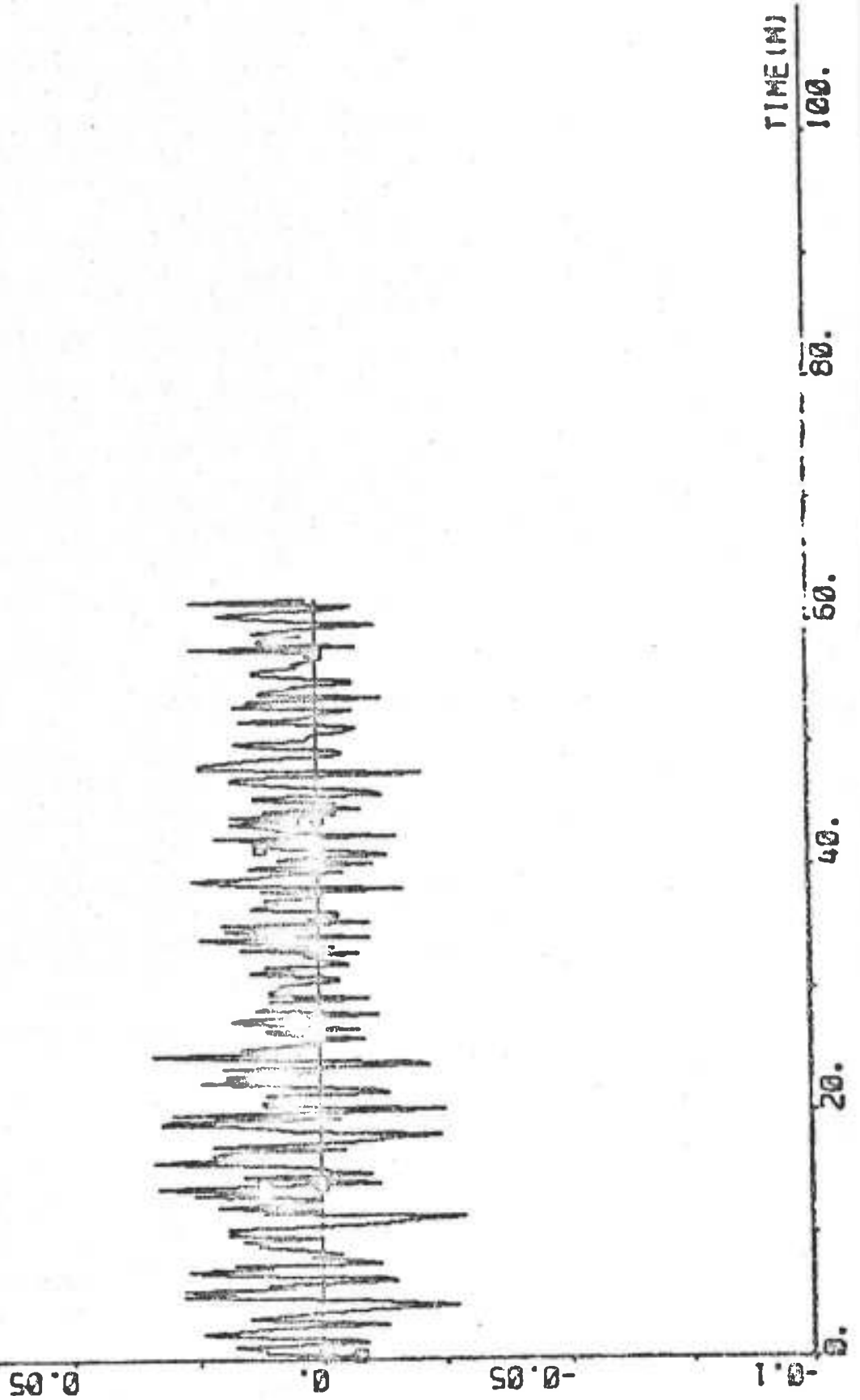
PLOT R43P1(9) ZERO -0.75 0.25 "V2 KNOTS



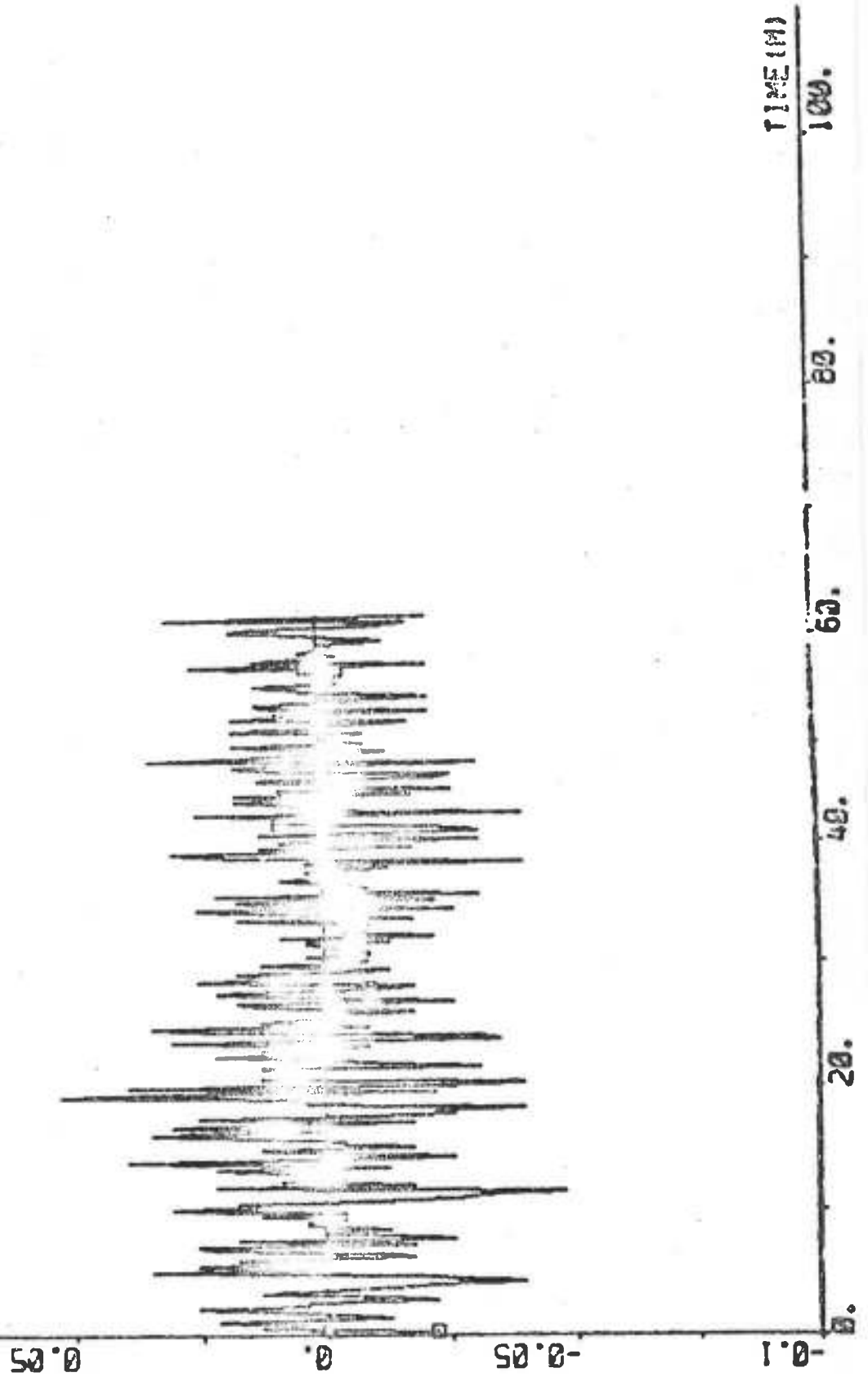
PLOT R43P1(10) ZERO -0.1 0.1 "R DEG/S



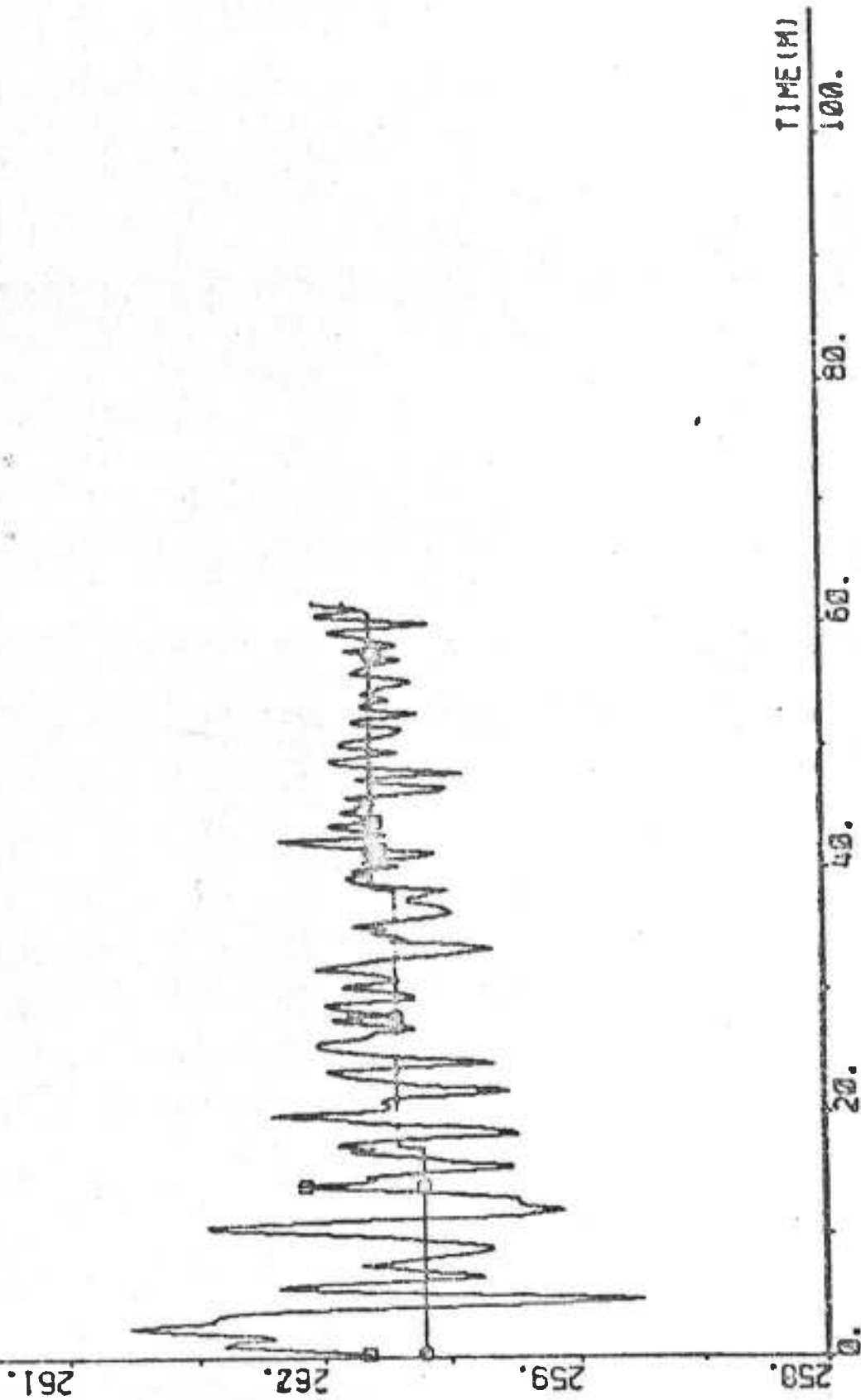
PLOT A43P1(11) ZERO -0.1 0.1 "AVR DEG/S (BR=0.2)



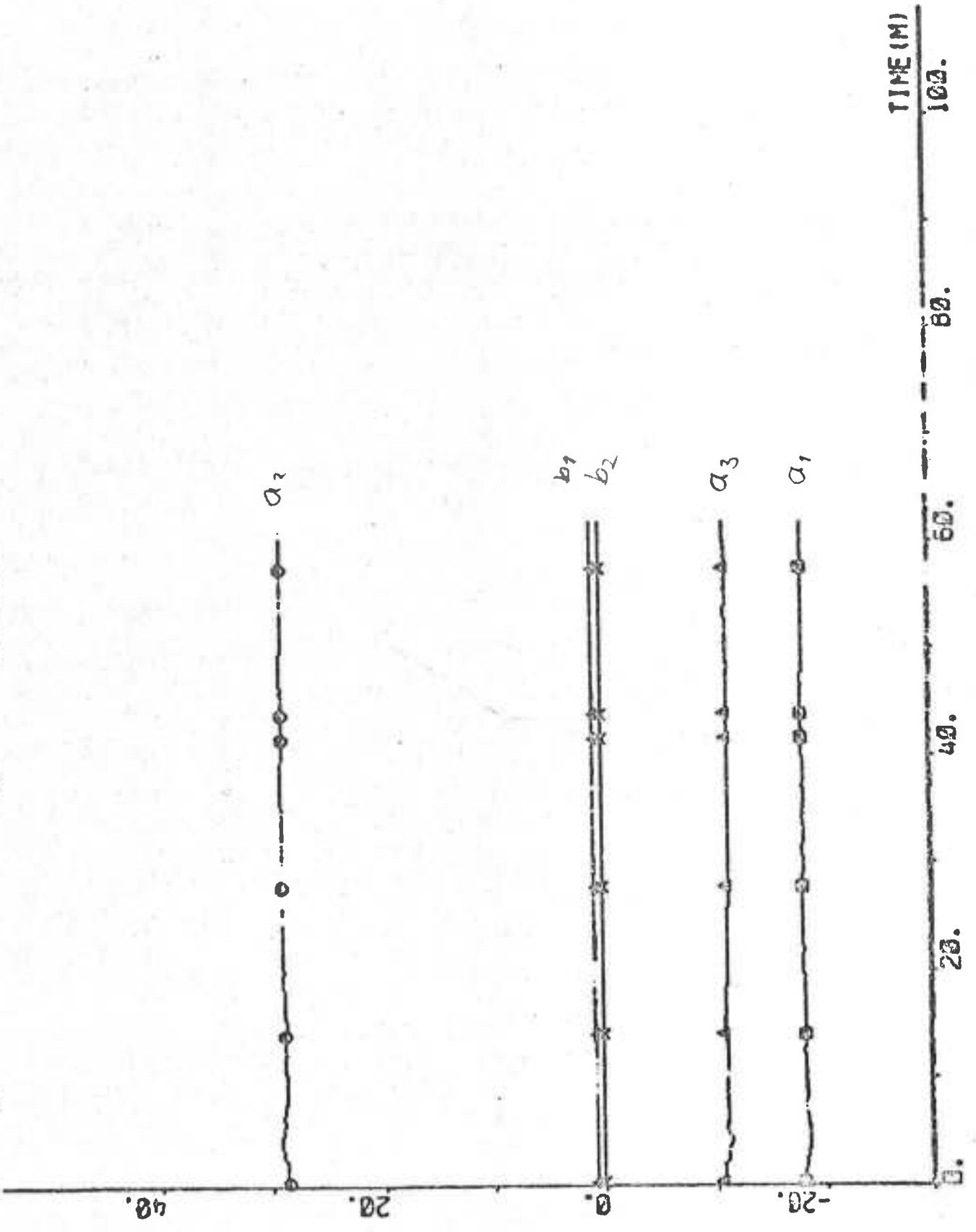
PLOT A43P1(12) ZERO -0.1 0.1 DPSIDT DEG/S (IDPSI=5)



PLOT A43P1(13 14) 250 262 °PSI PSIREF DEG



FL07 A4322 -25 36 REGULATOR PARAMETERS



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

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

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

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 HP A44P1(1) ZERO -19 19 "DELCOG DEG

TIME (H)
100.

80.

60.

40.

20.

-10.

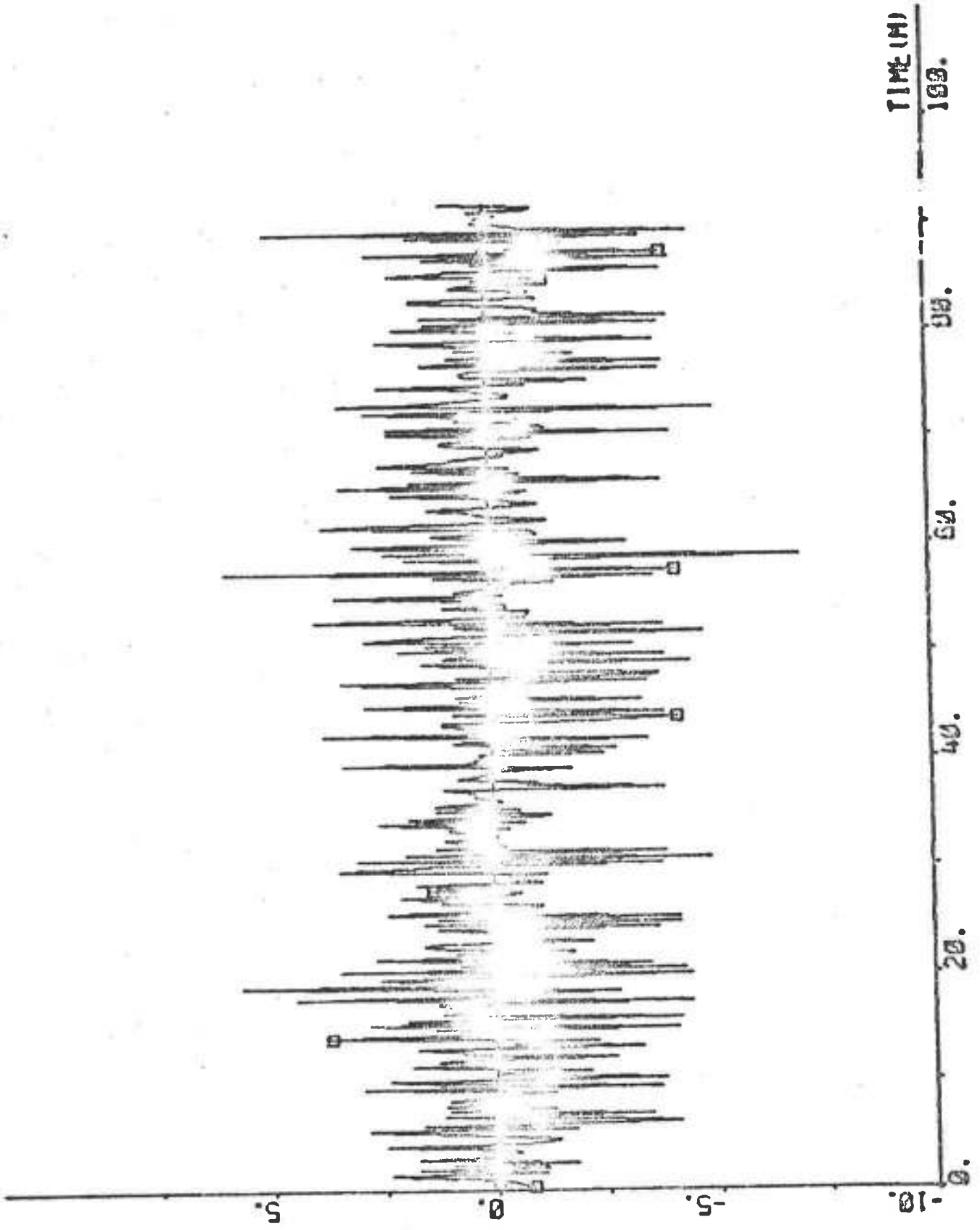
-5.

0.

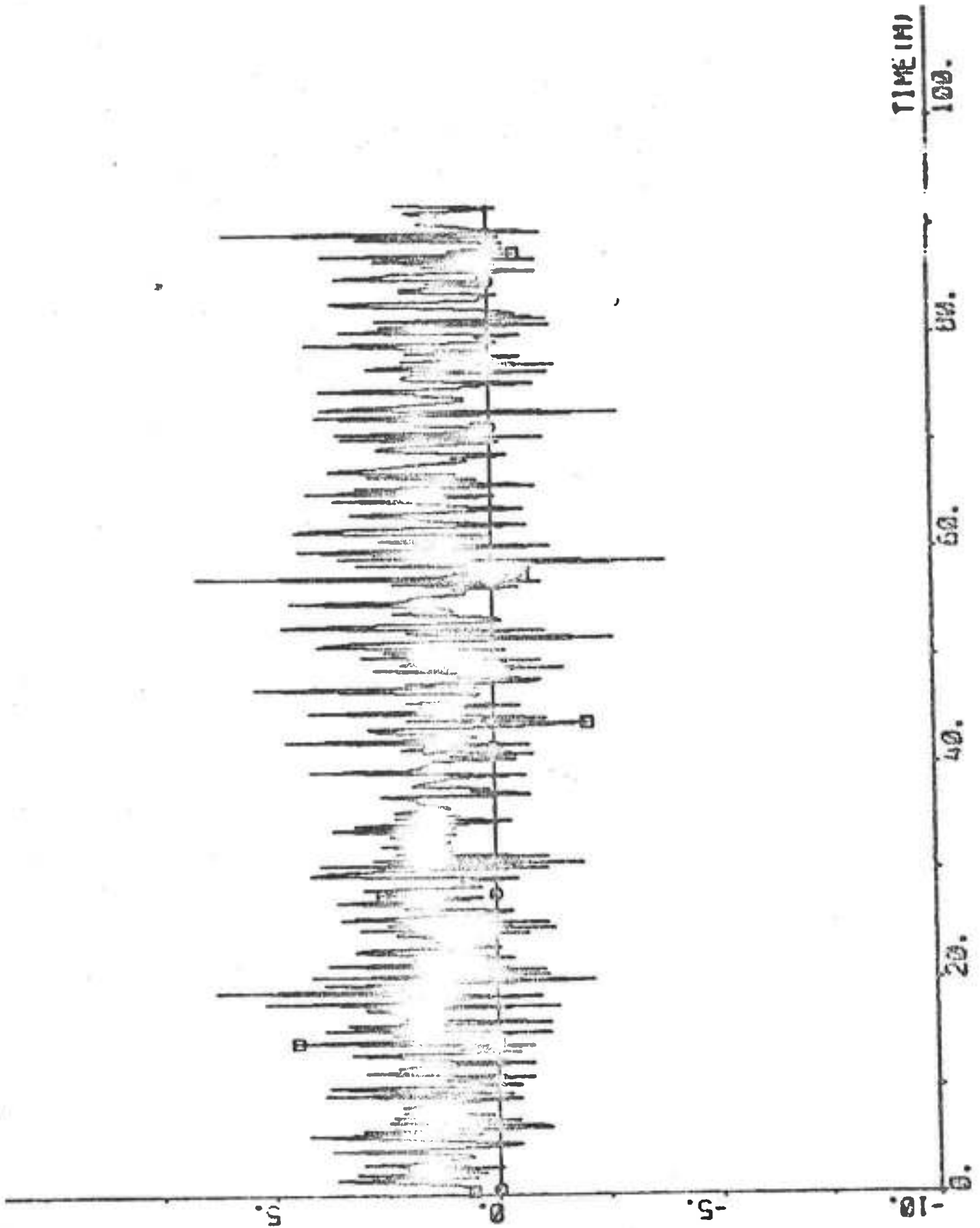
5.



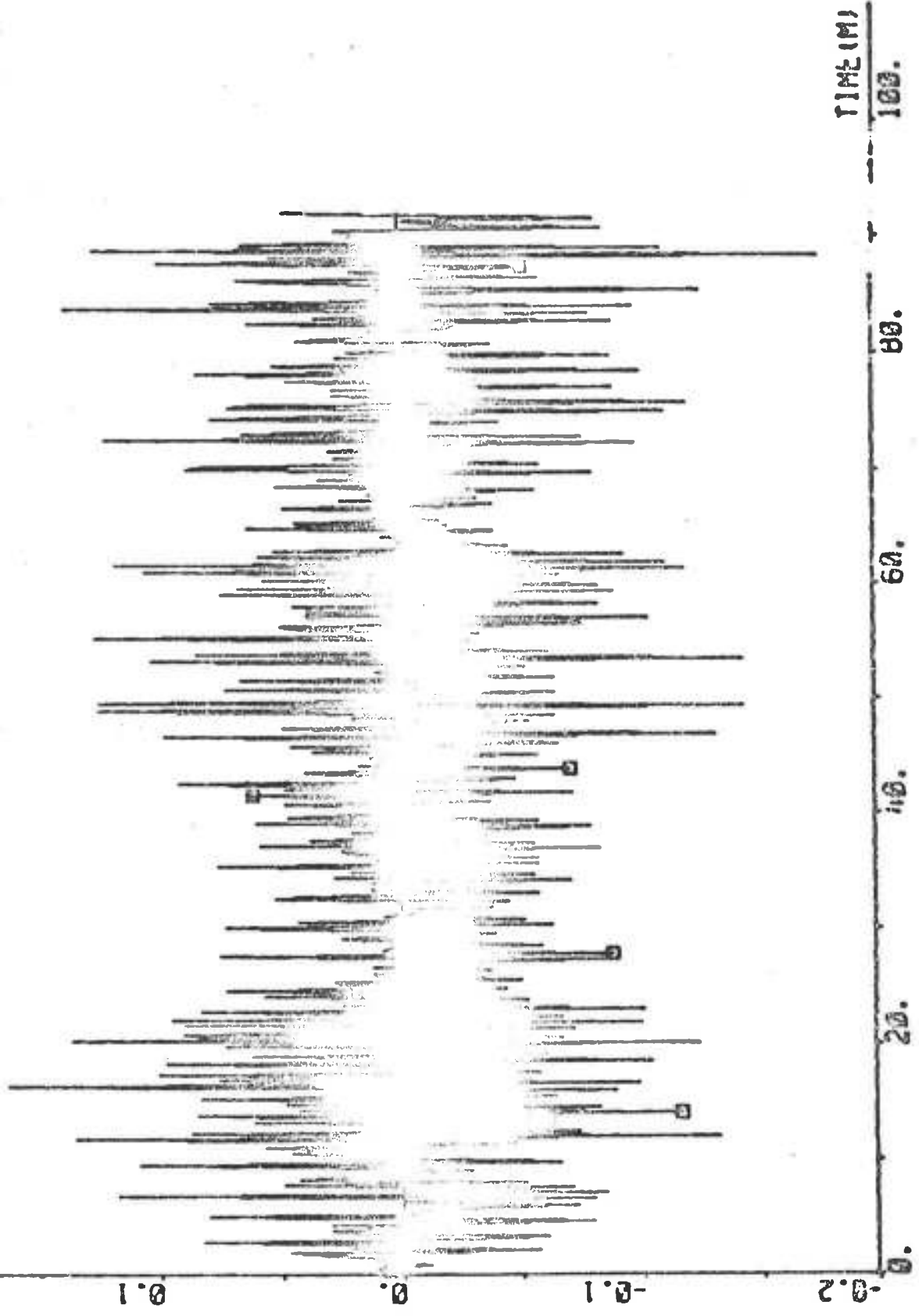
PLOT R44P1(3) ZERO -10 10 DELTAS DEC



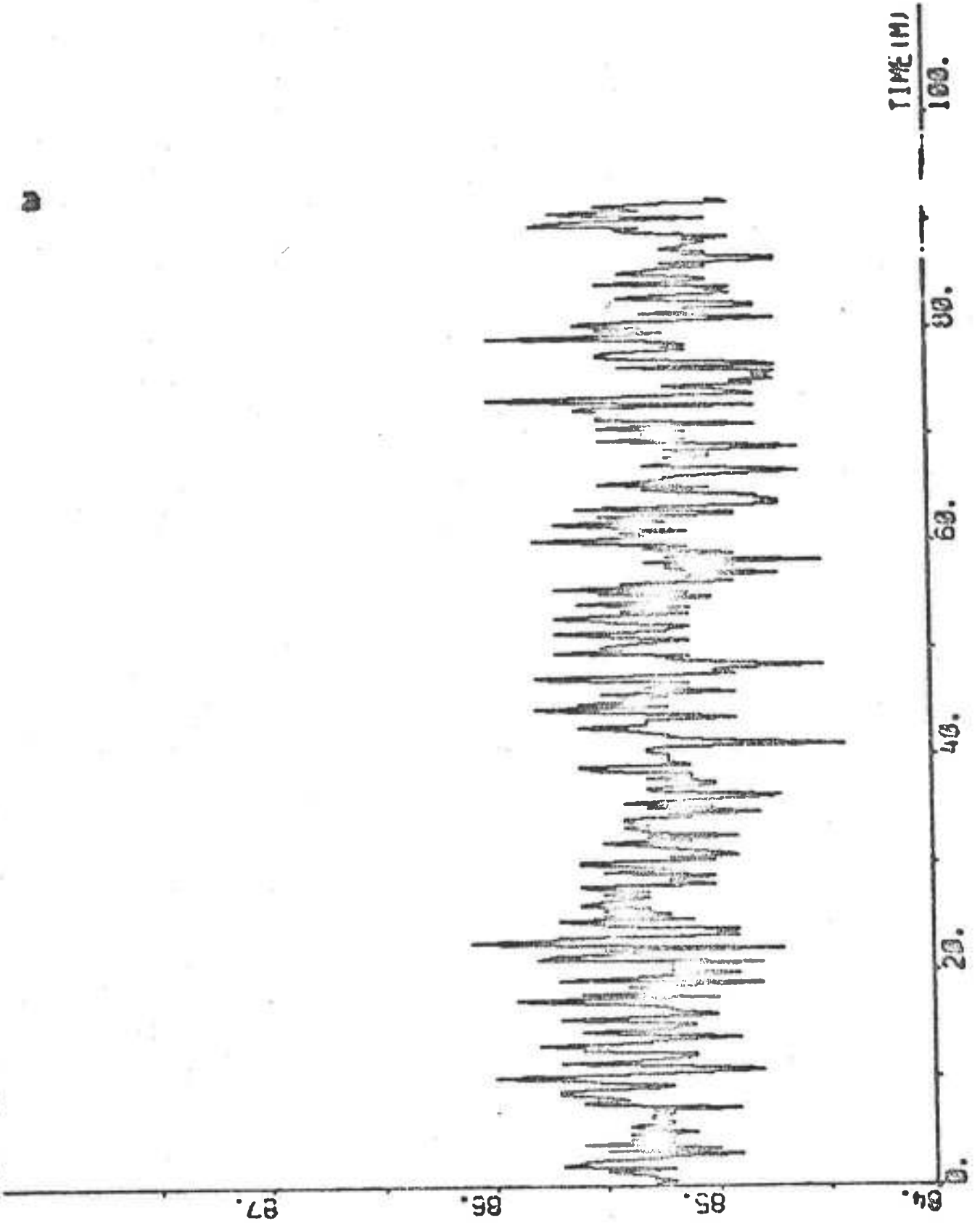
PLOT A44P1(4) ZERO -10 10 "DELTA DEC



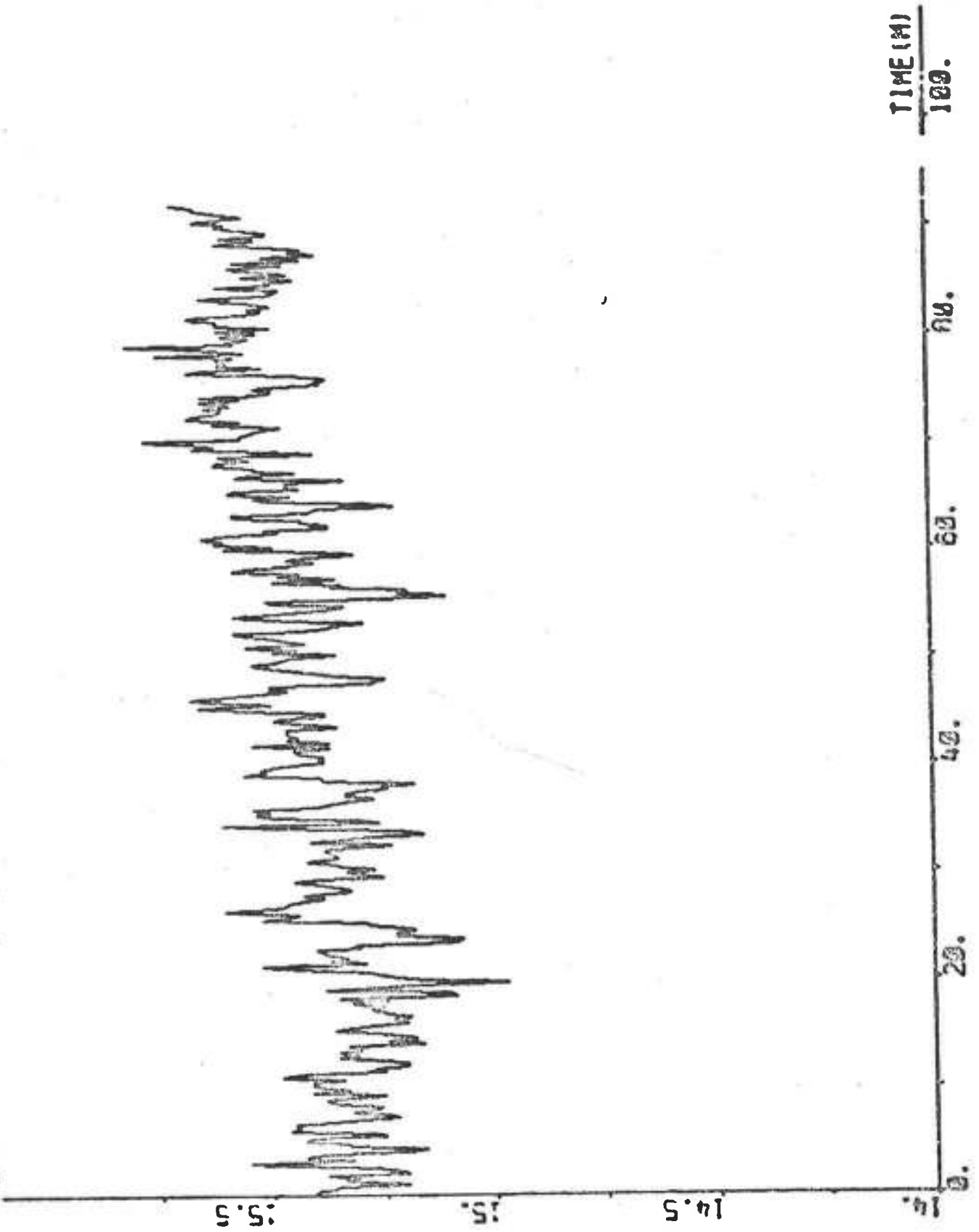
PLOT R44P1(5) ZERO -0.2 0.2 "PP DEG/S



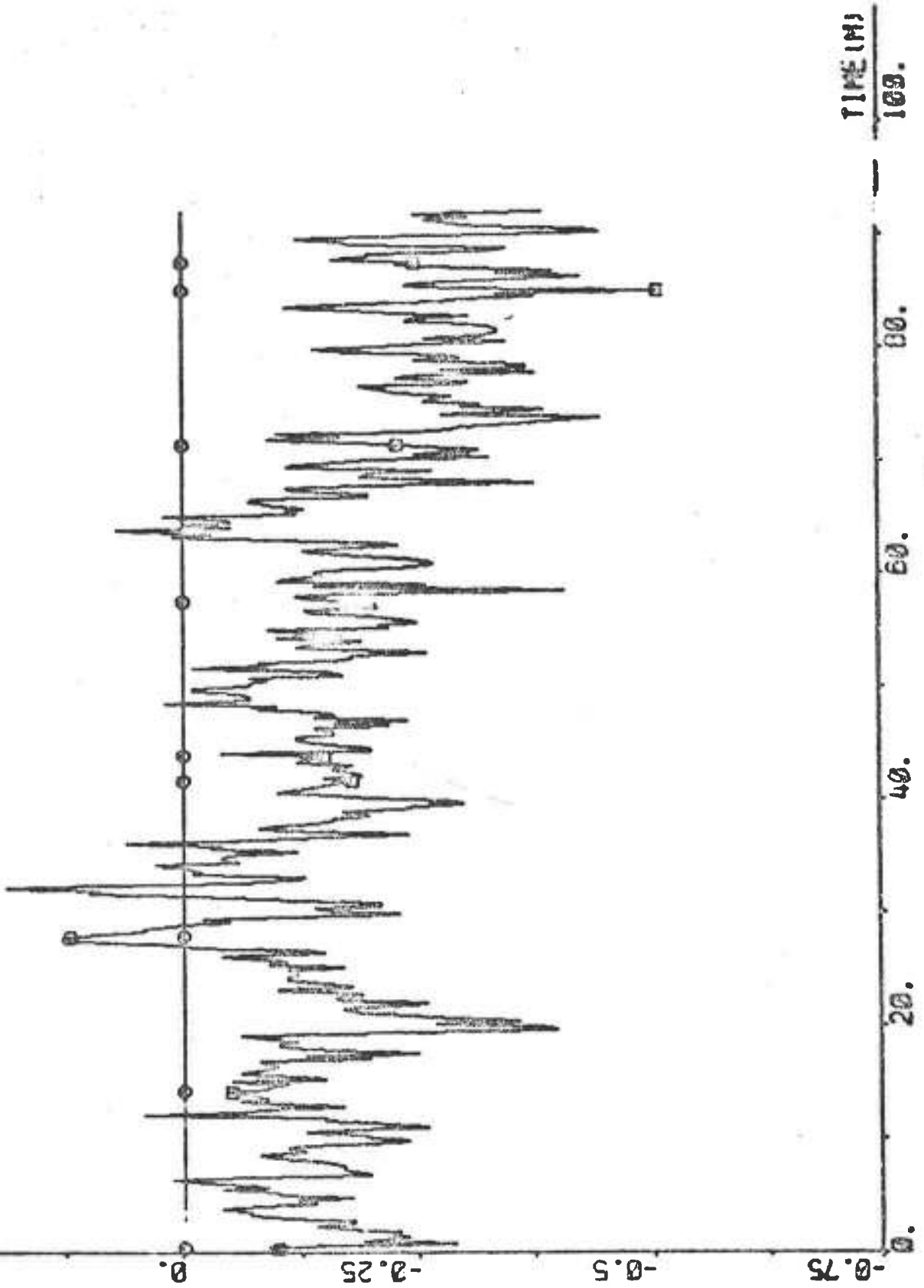
PLOT R44P1(8) 84 88 -FN RPH



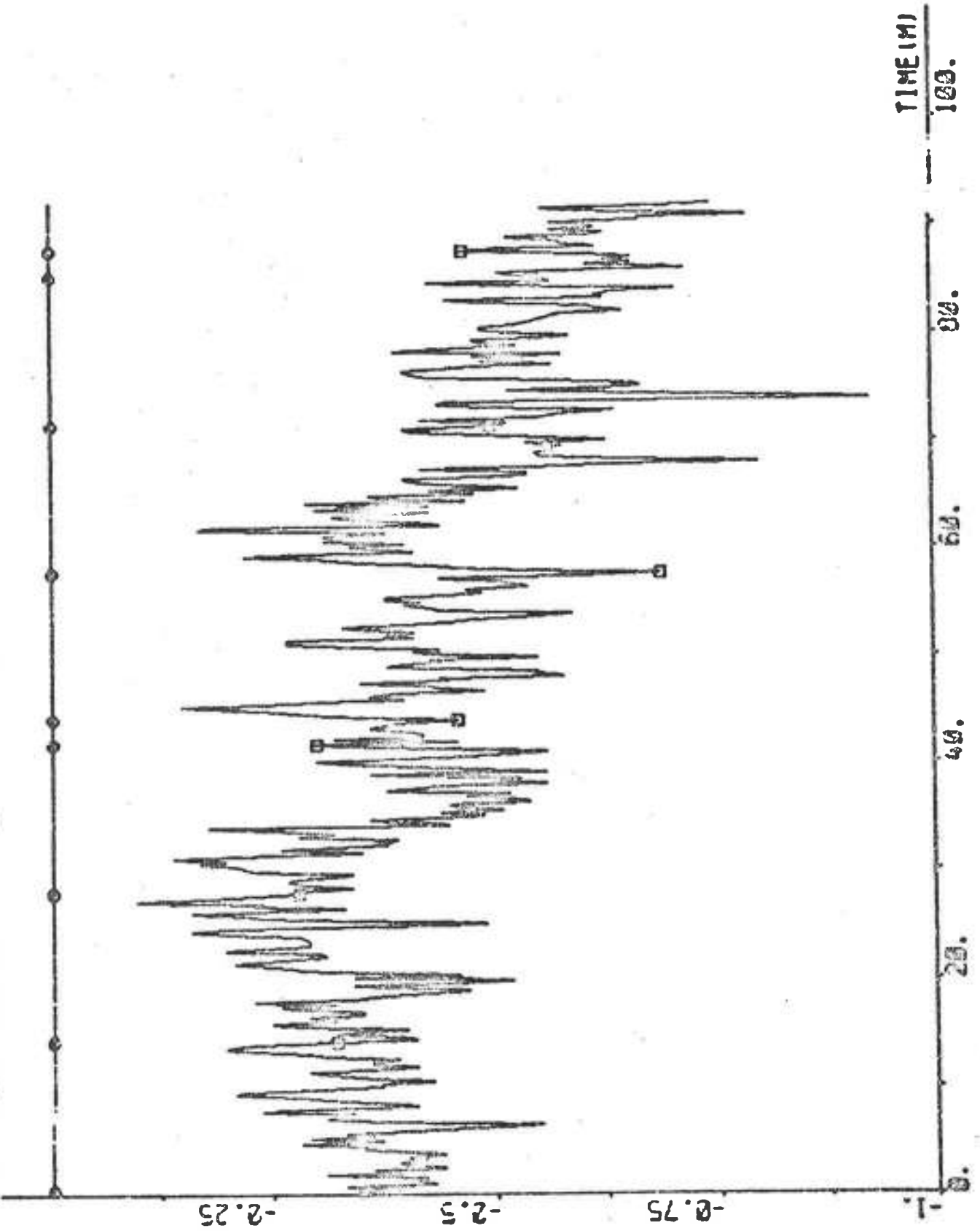
PLOT R44P1(7) 14 18 "U KNOTS



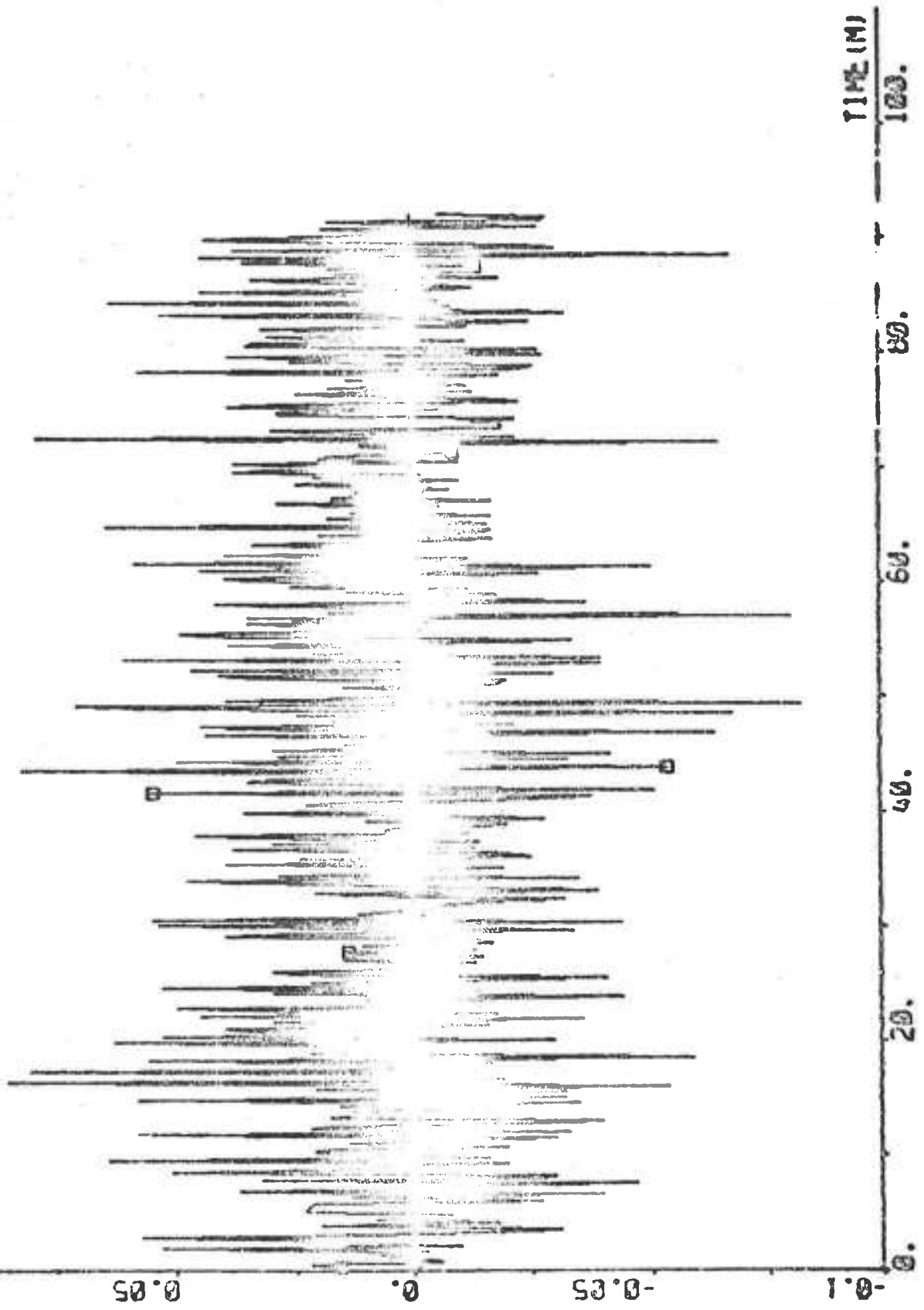
PLOT R44P1(8) ZERO -0.75 0.26 "VI KNOTS



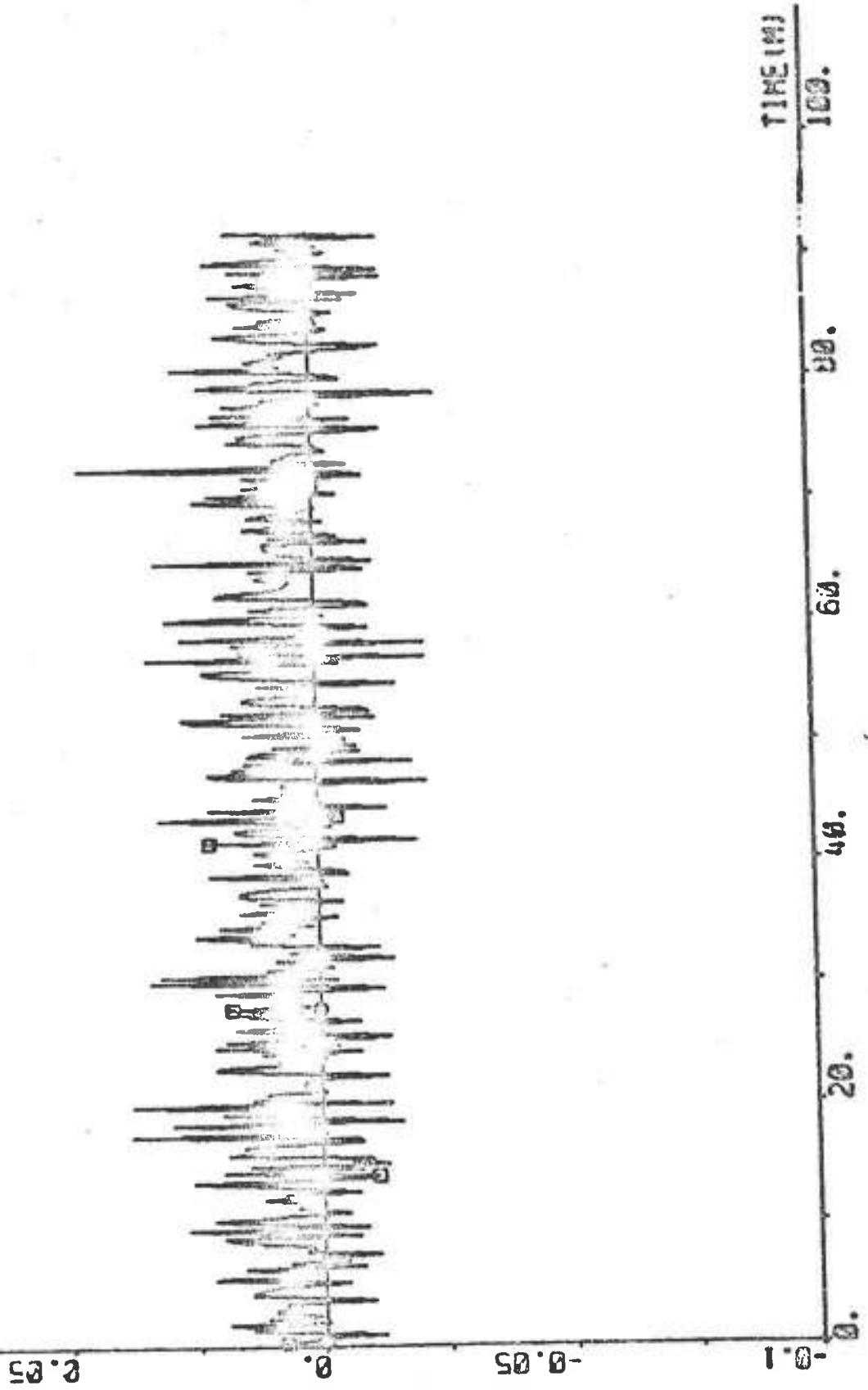
PLOT R44P1(9) ZERO -1 @ "V2 KNOTS



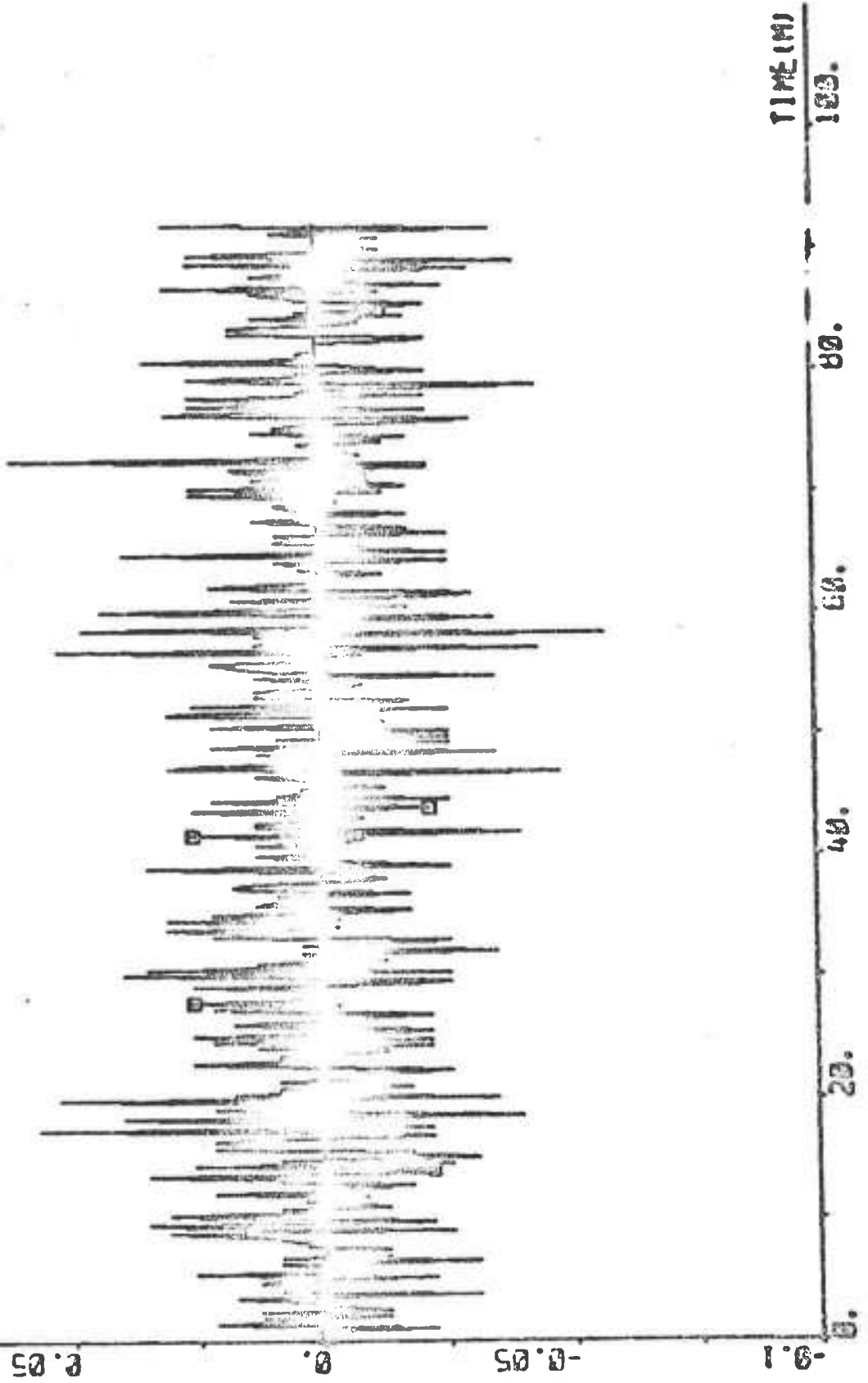
PLOT A44PI(10) ZERO -0.1 0.1 "R DEG/S



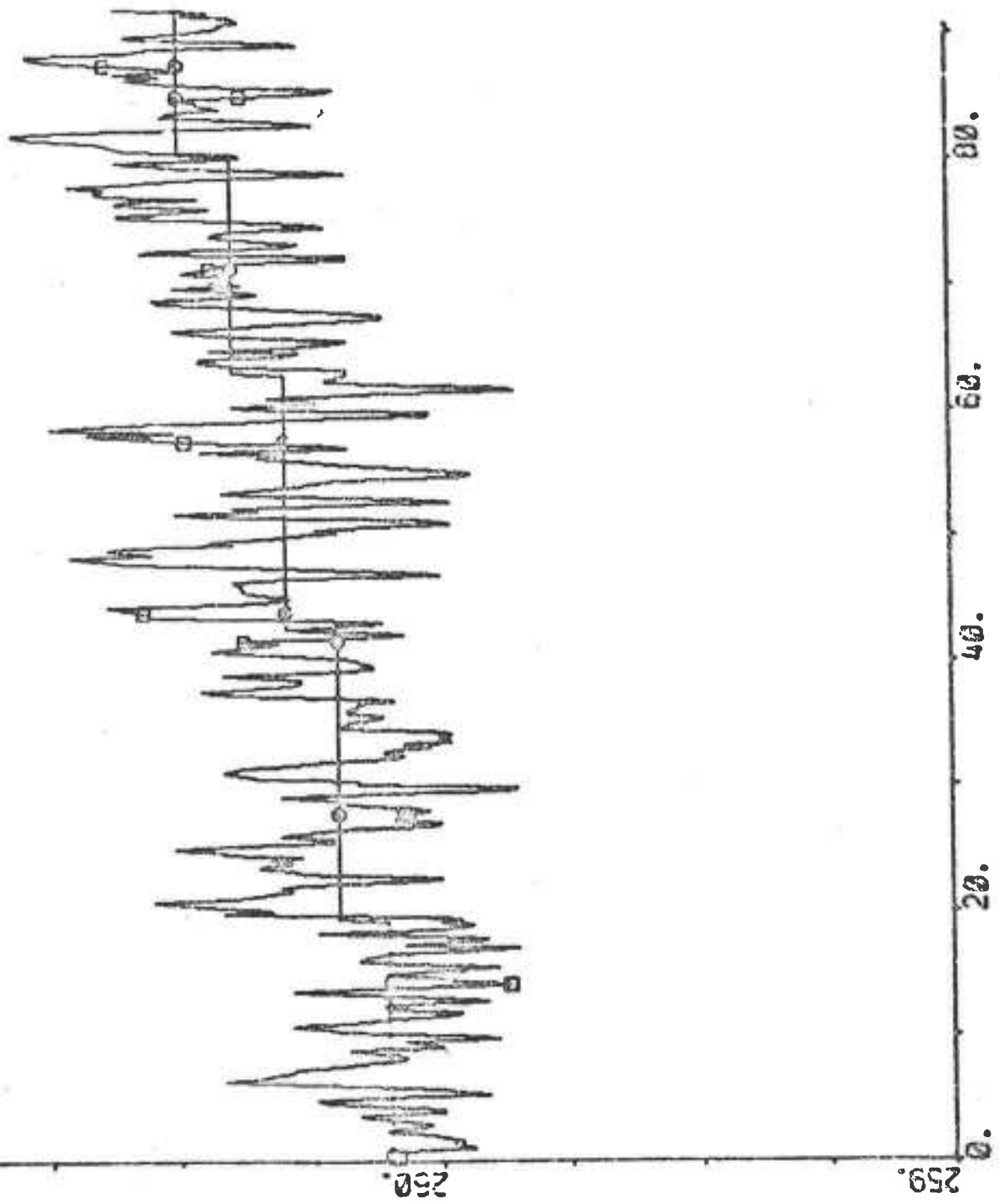
PLOT A44P1(11) ZERO -0.1 0.1 "AVR DEG/S (BR=0.2)



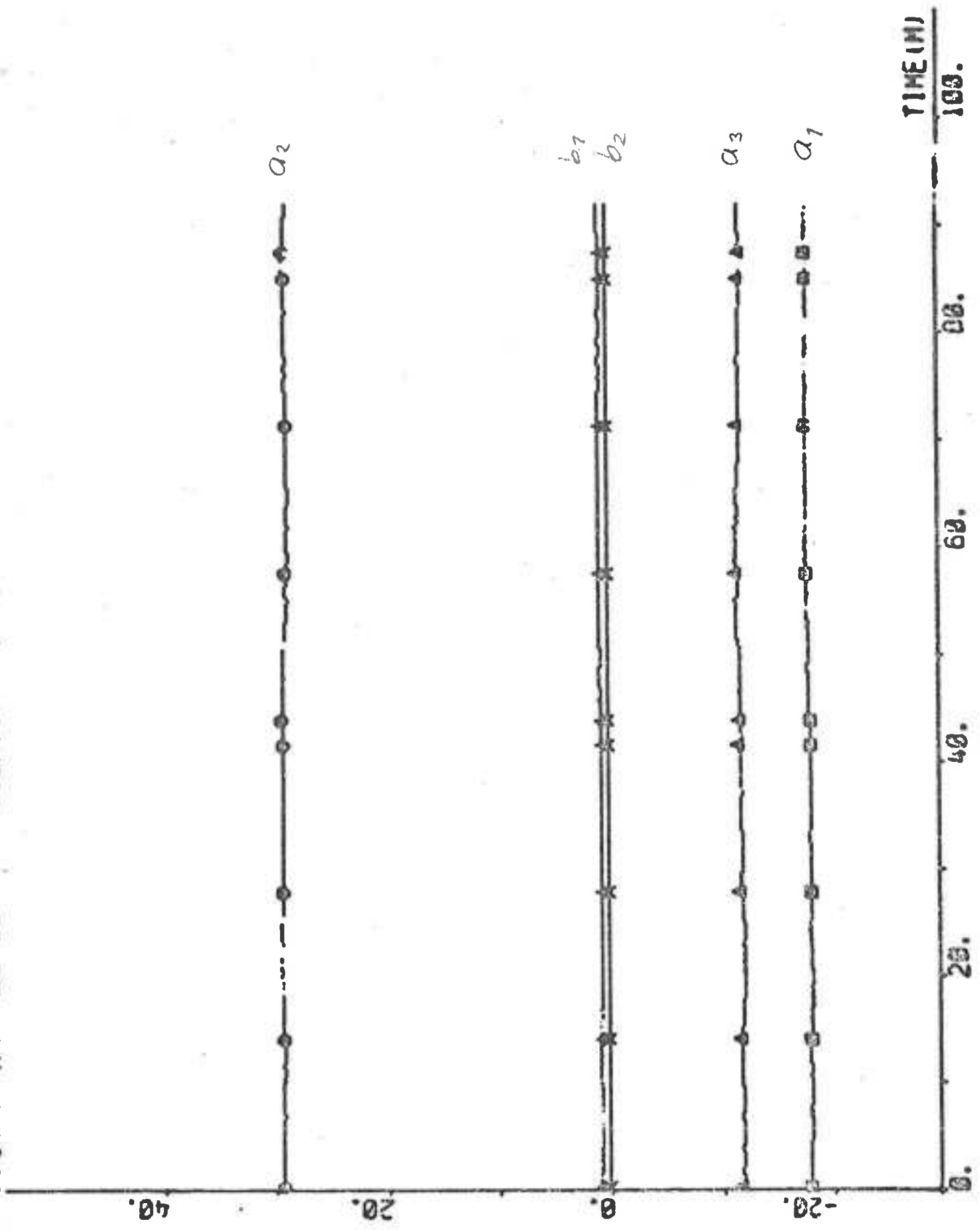
PLOT AWP1(12) ZERO -0.1 0.1 'DPSIDT DEG/S (IDPSI-5)



PLOT A44P1(13 14) 259 261 "PSI PSIREF DEC



PLOT R44P2 -25 35 "REGULATOR PARAMETERS



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

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

$$a_1 + a_2 + a_3 = -0.004$$

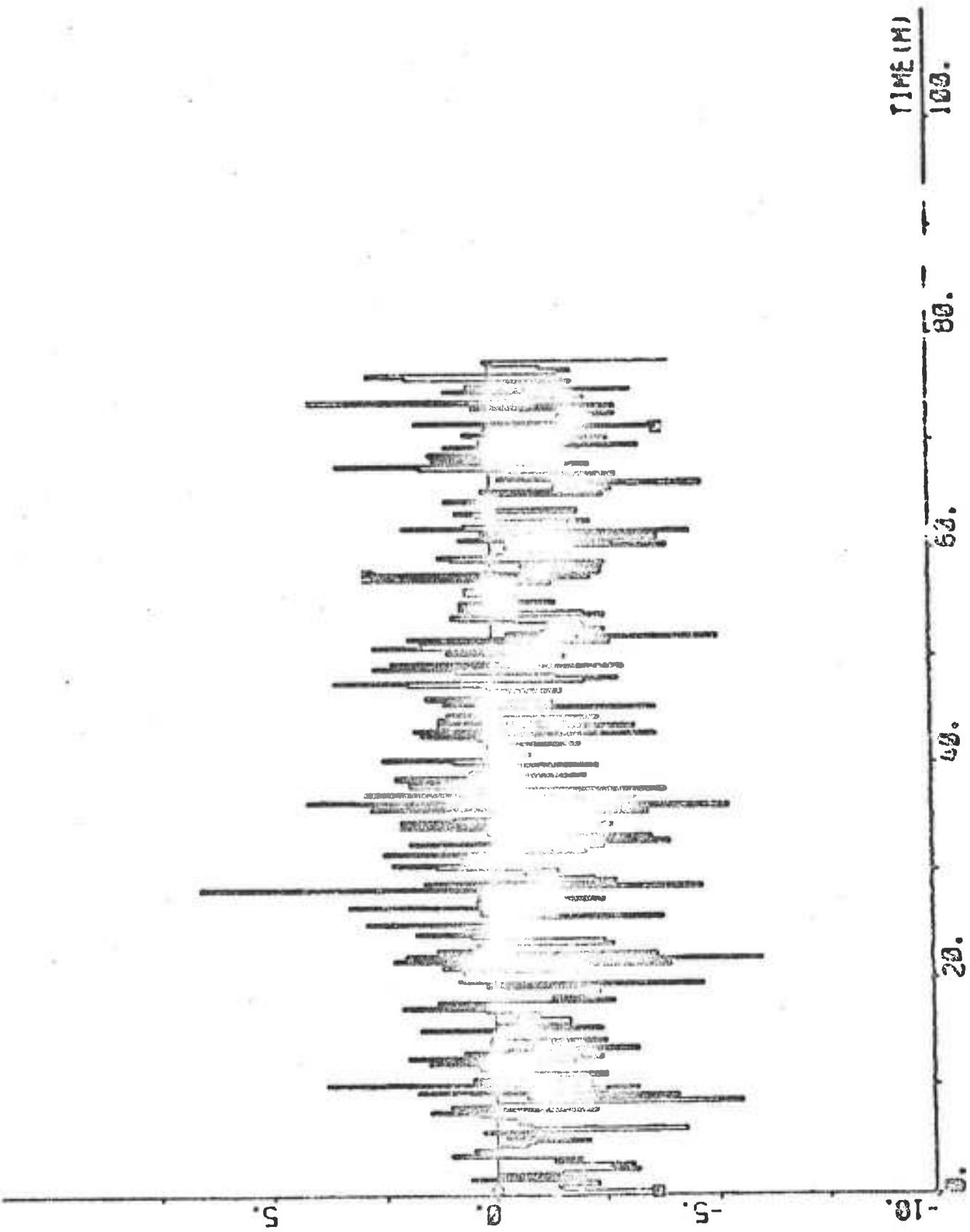
Statistics (mean value and standard deviation)

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

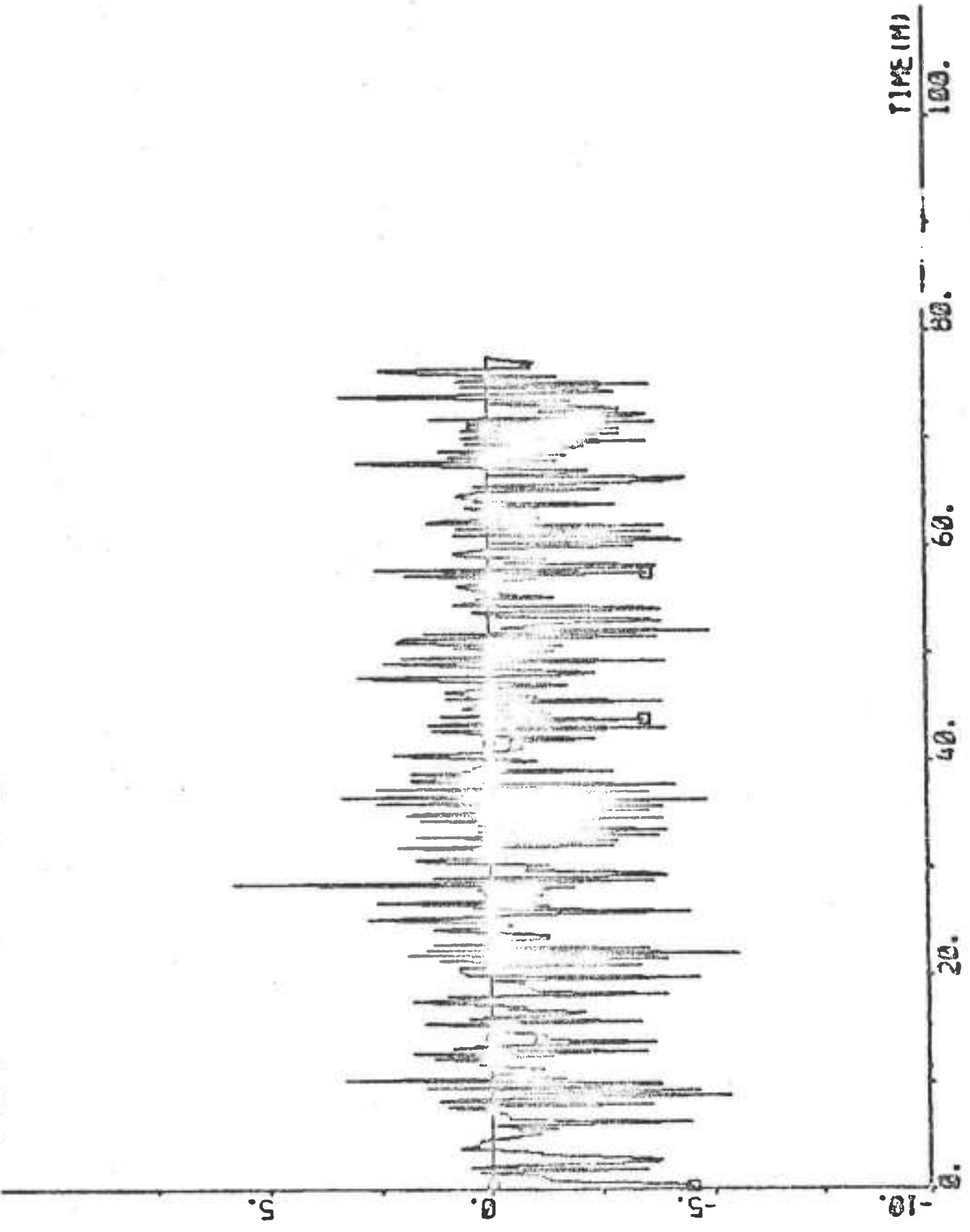
$$V_1 = 0.355$$

$$V_2 = 0.281$$

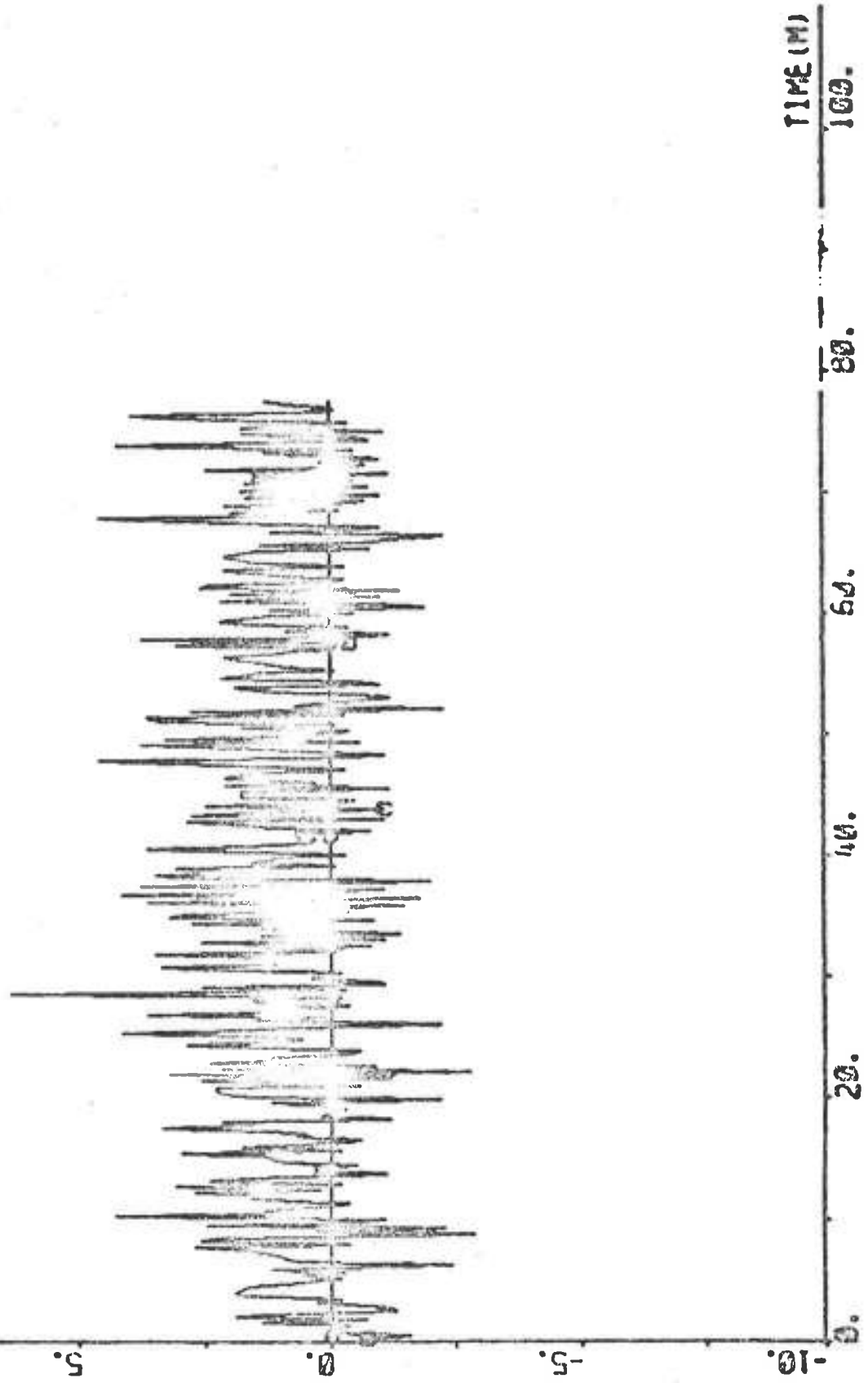
PLOT HP A45PI(1) ZERO -10 10 DELCOG DEG



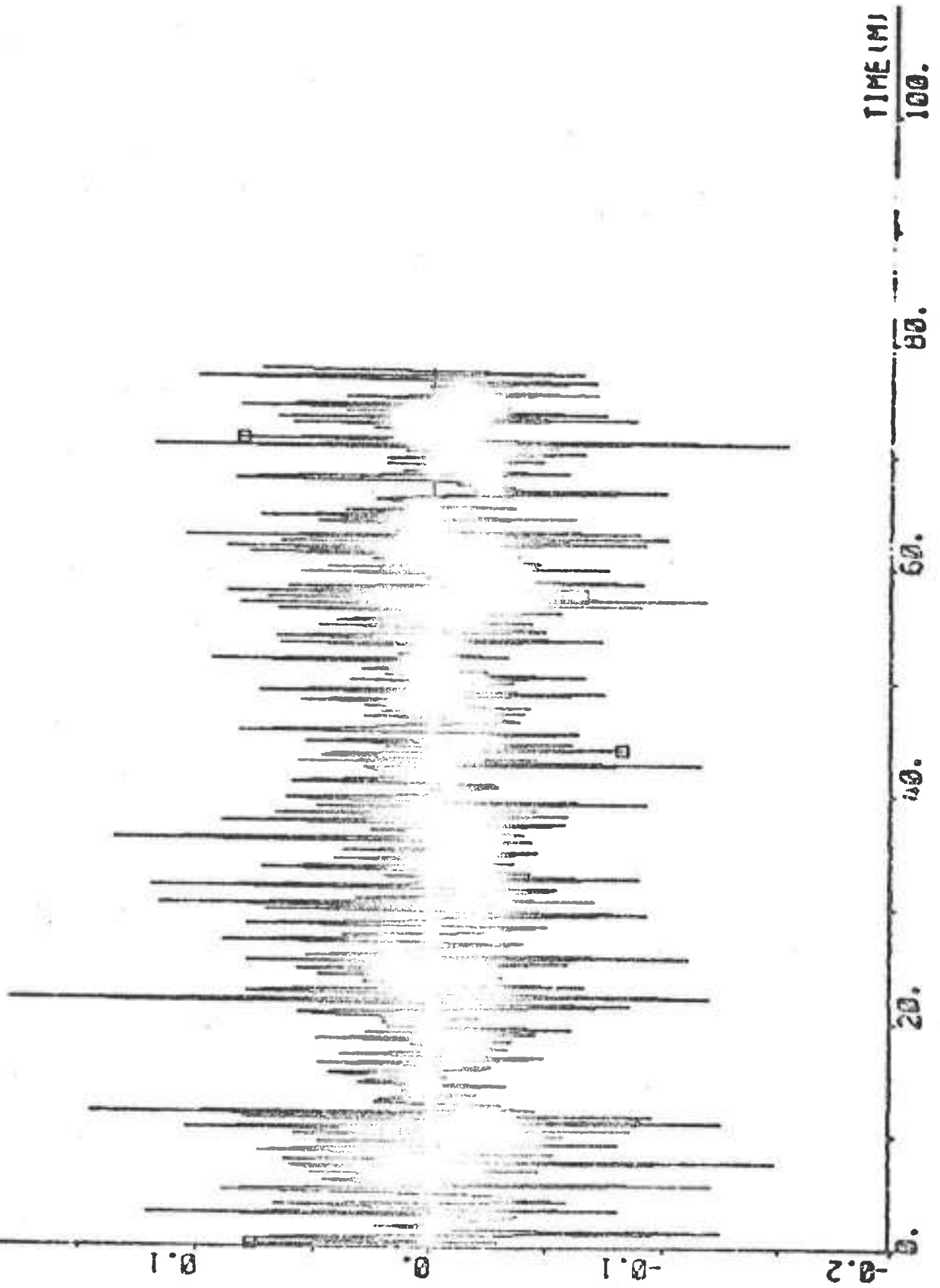
PLOT A4SP1(3) ZERO -10 10 "DELTA" DEG



PLOT AVSP1(4) ZERO -10 10 DELTA DEG



PLOT ANEP1(S) ZERO -0.2 0.2 "PP DEC/S



PLOT A45P1(6) 64 63 "AN RPM

87.

86.

85.

84.



TIME (M)

100.

80.

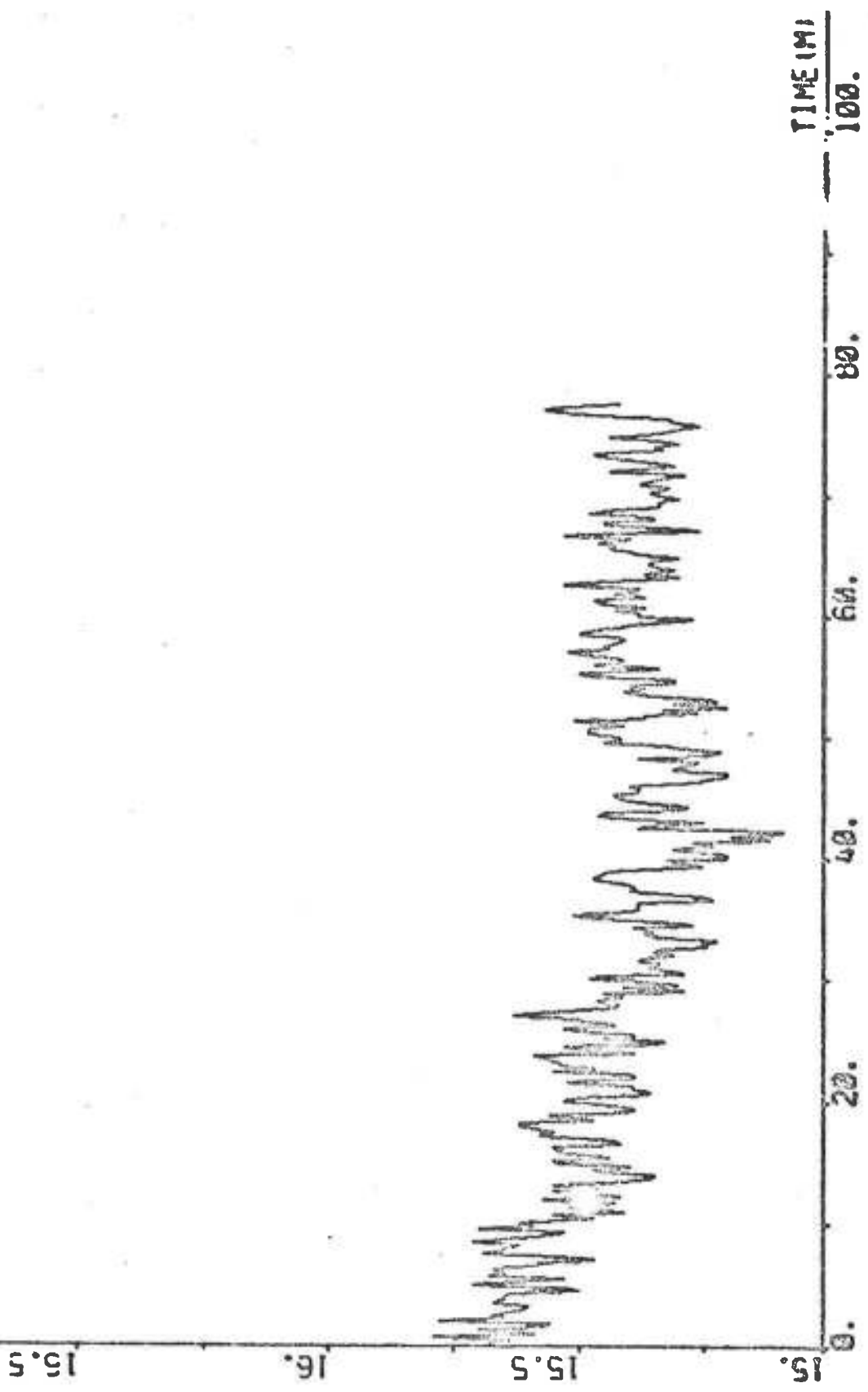
60.

40.

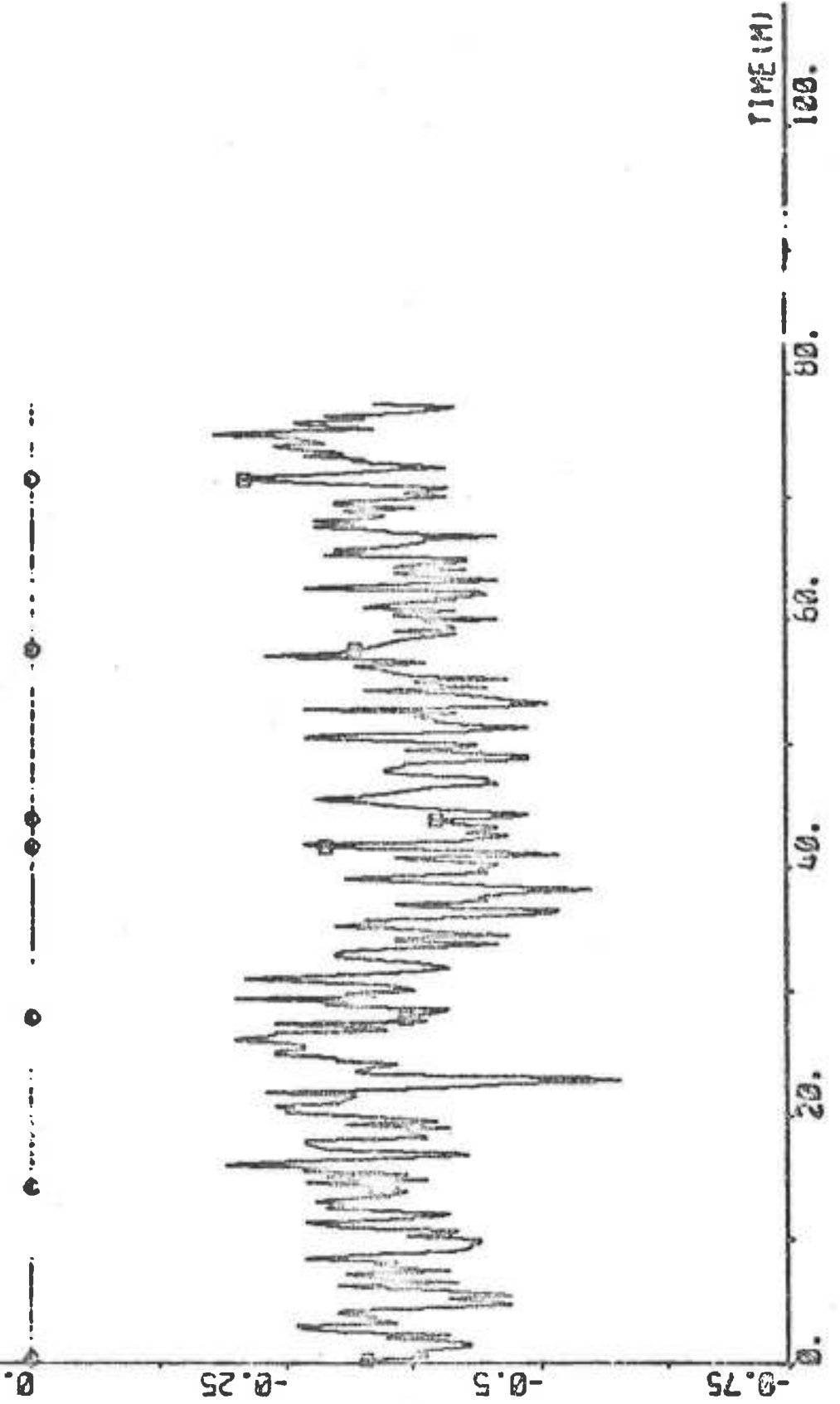
20.

0.

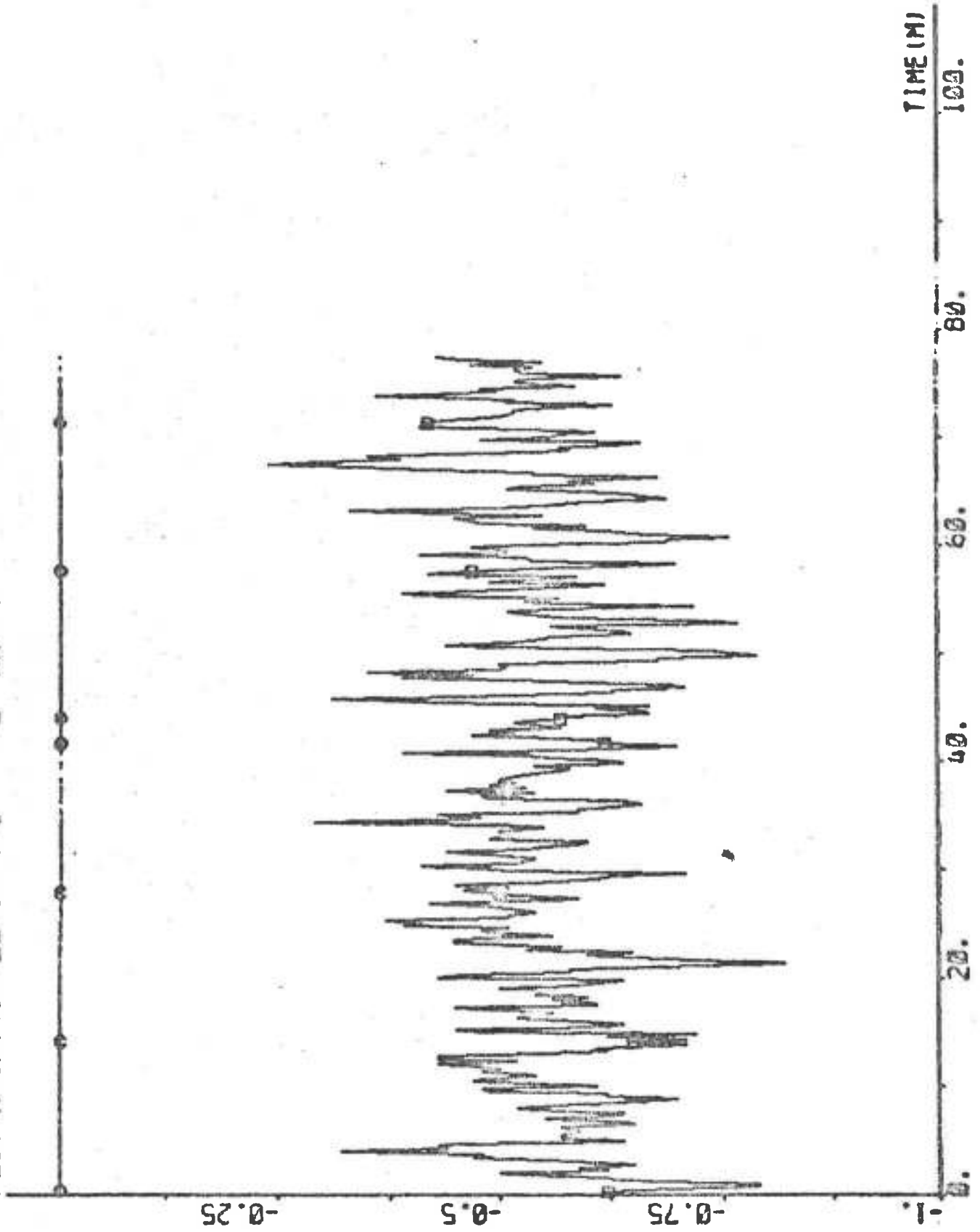
PLOT R45P1(7) 15 17 "U KNOTS



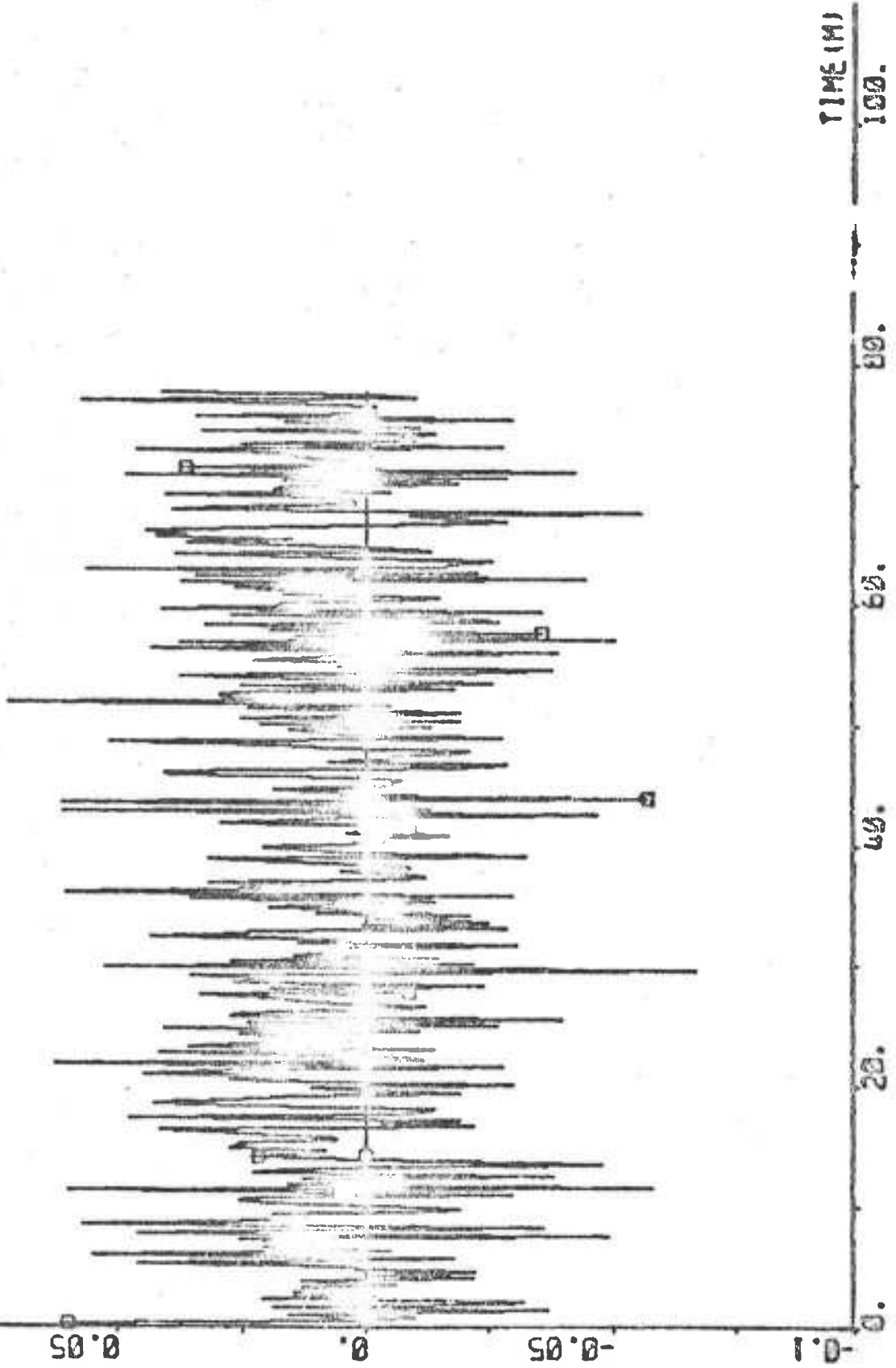
PLOT A4EP1(0) ZERO -0.75 0.25 "V1 KNOTS



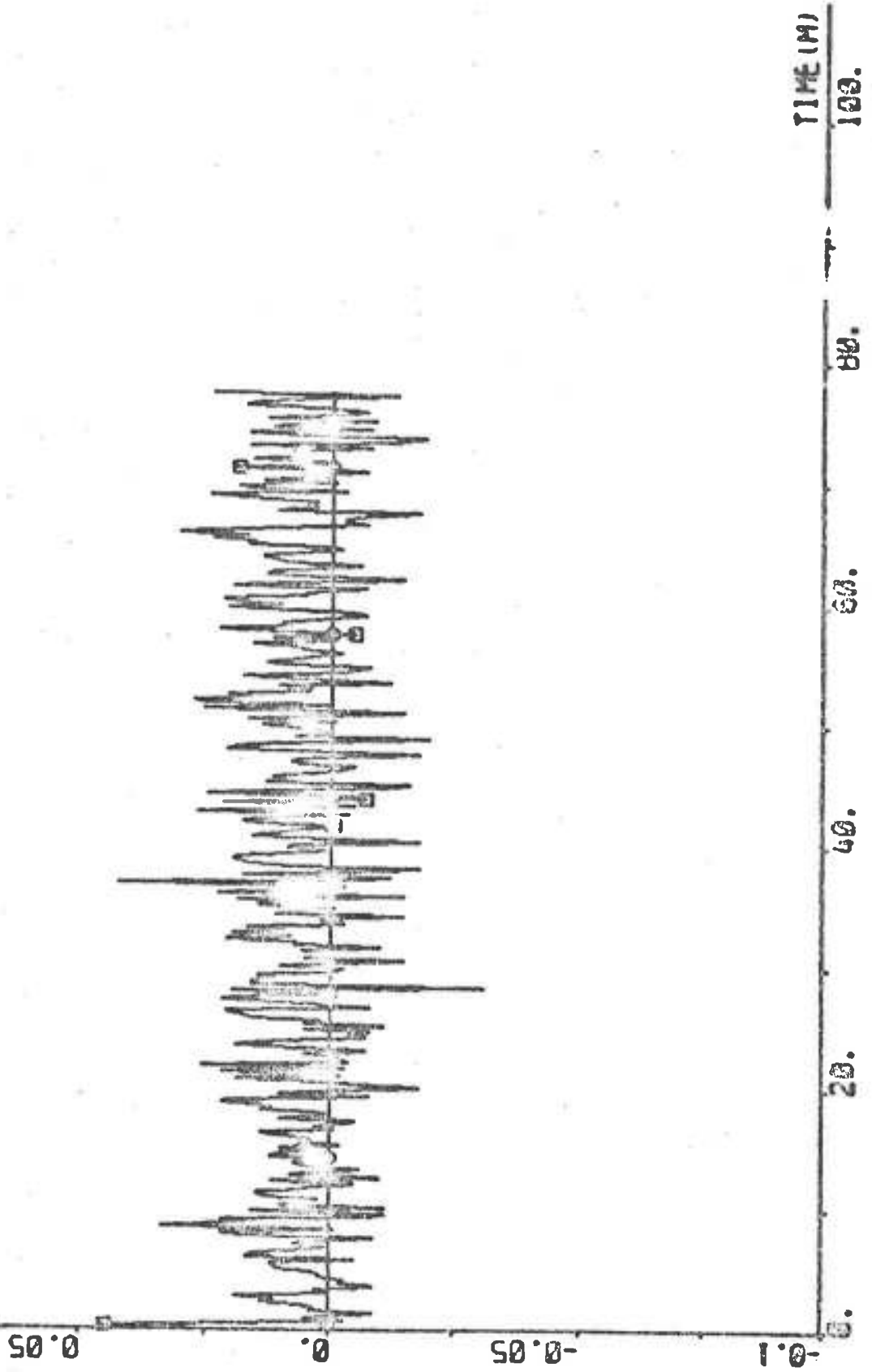
PLOT A46P1(9) ZERO -1 0 "V2 KNOTS



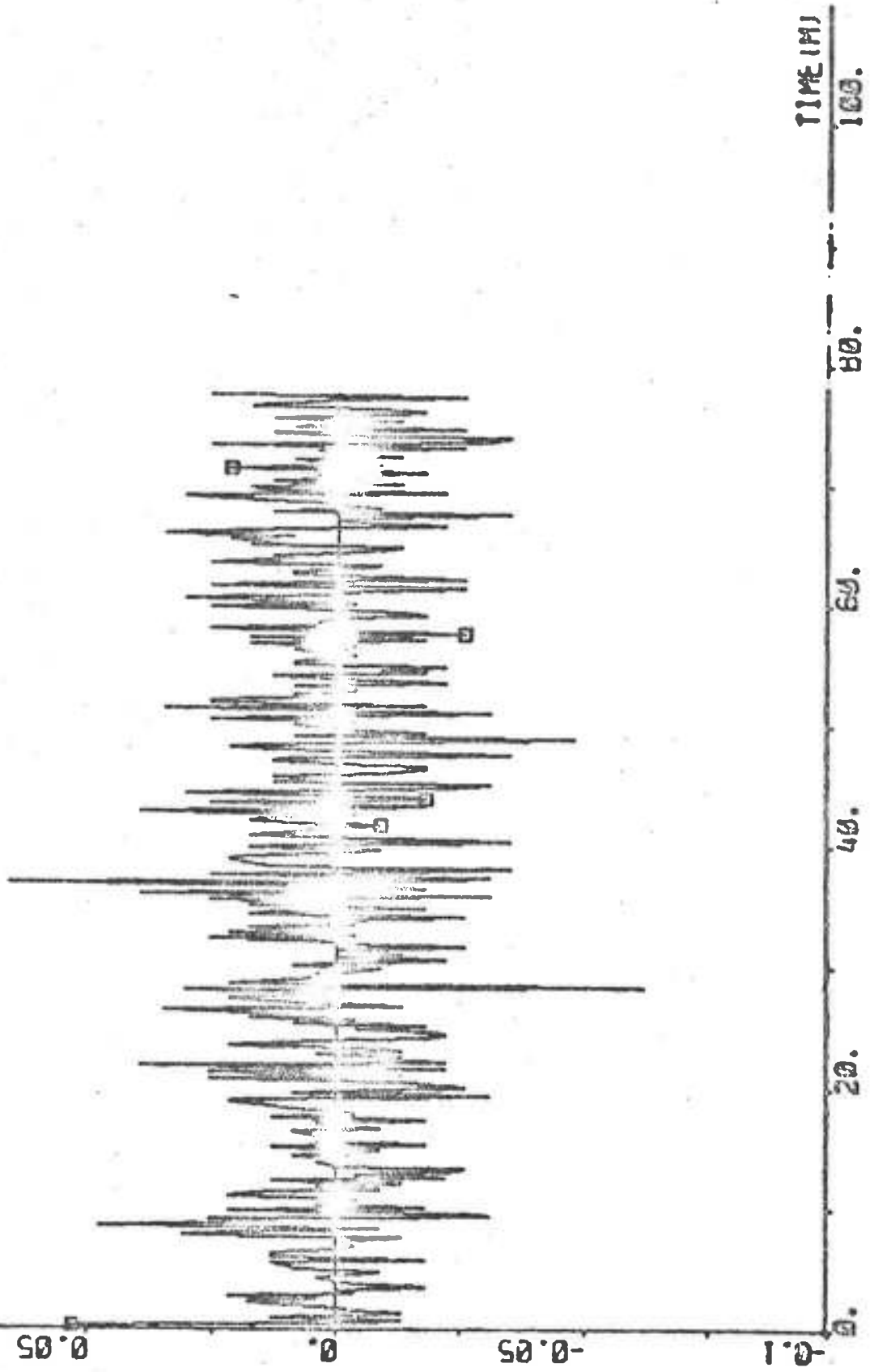
PLOT RATEP1(10) ZERO -0.1 0.1 °R DEG/S



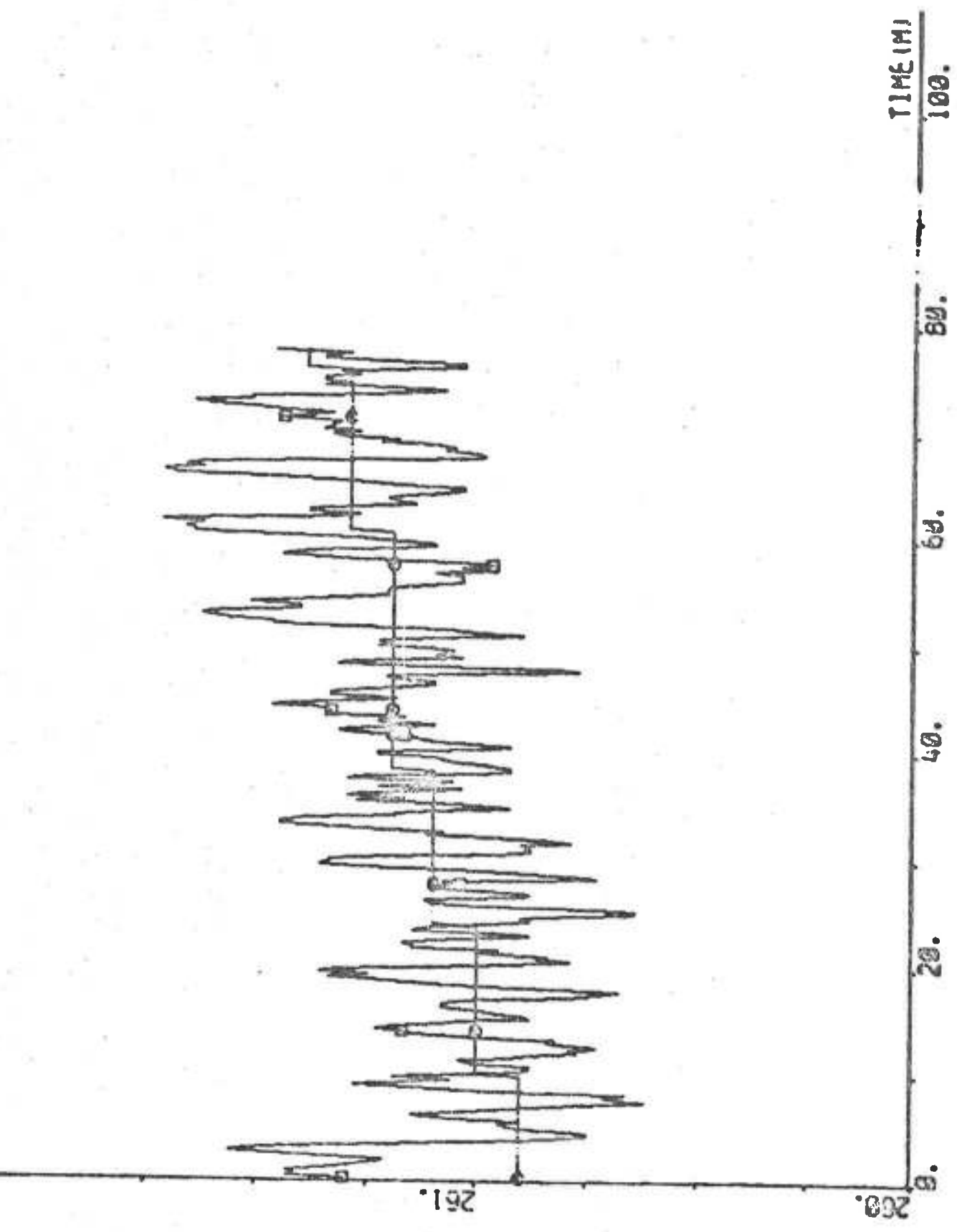
PLOT RATEPI(11) ZERO -0.1 0.1 "AVR DEG/S (SR=0.2)



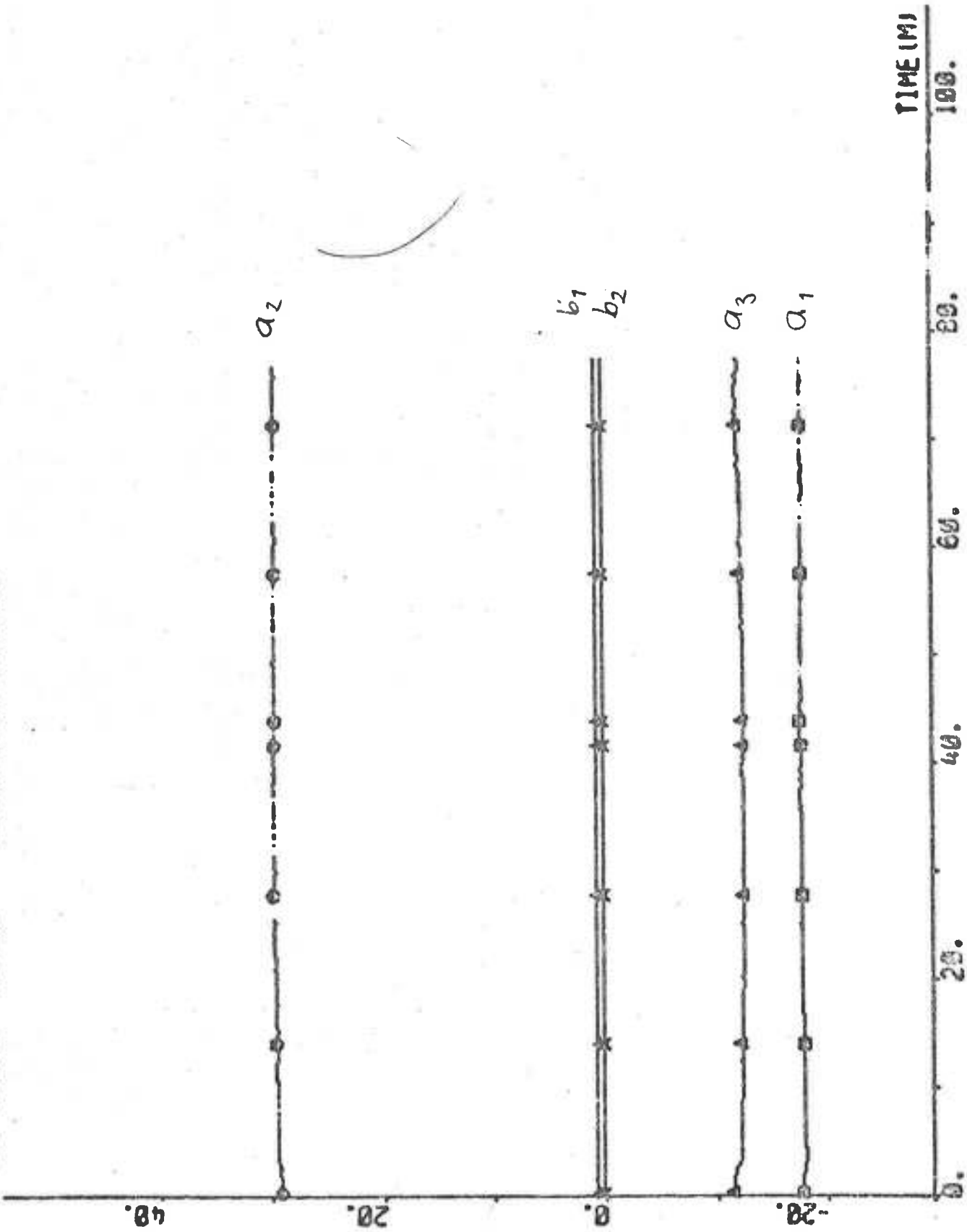
PLOT ANEP1(12) ZERO -0.1 0.1 "DPSIDT DEG/S (1DPSI.5)



PLOT AYEP1(13 14) 260 292 °PSI PSIREF DEG



PLOT A4EP2 -26 35 "REGULATOR PARAMETERS



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°
DELLM 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

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

$$a_1 + a_2 + a_3 = -0.395$$

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

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

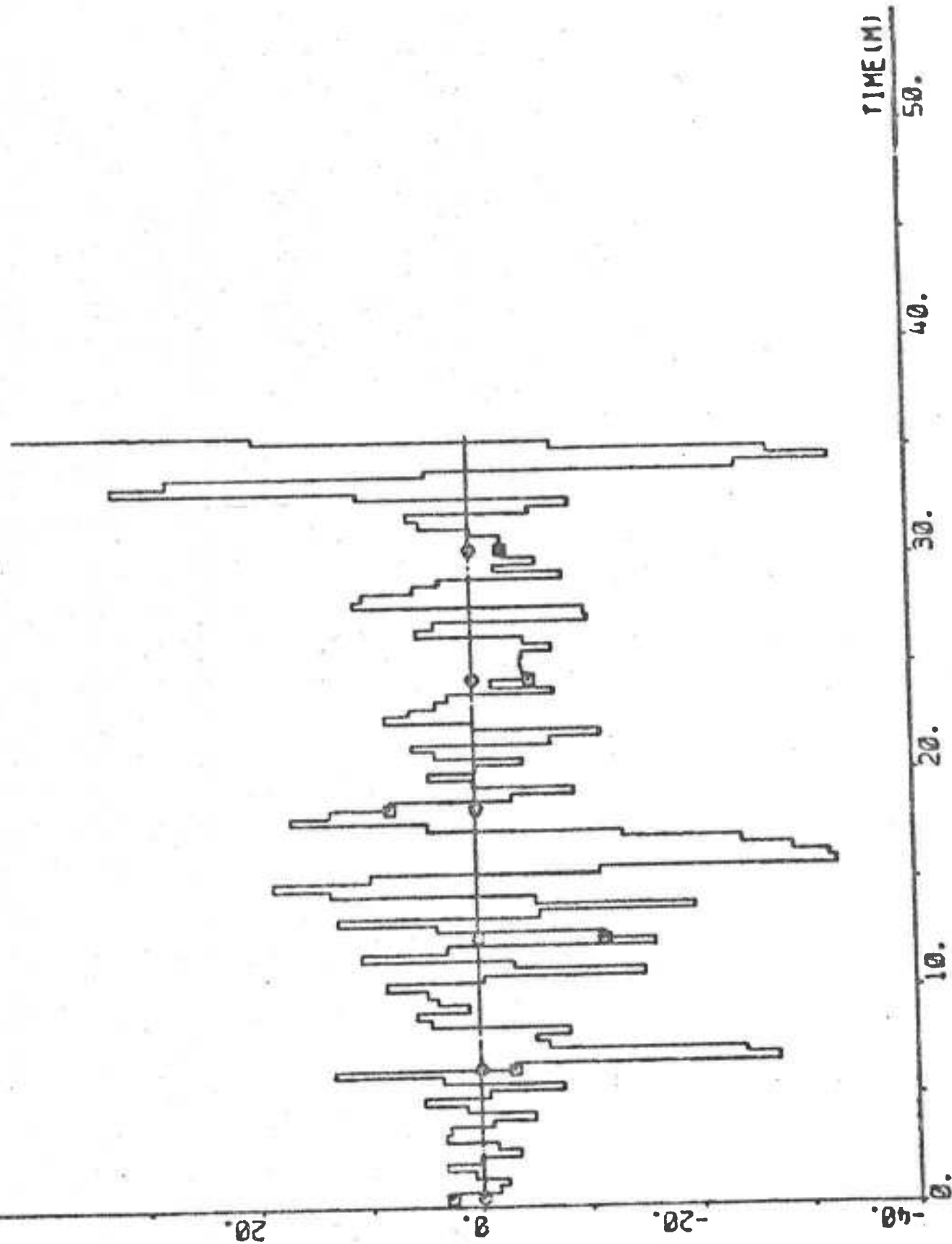
$$a'_1 + a'_2 + a'_3 = -13.75$$

Yaw regulator values after the yaw at 22 min

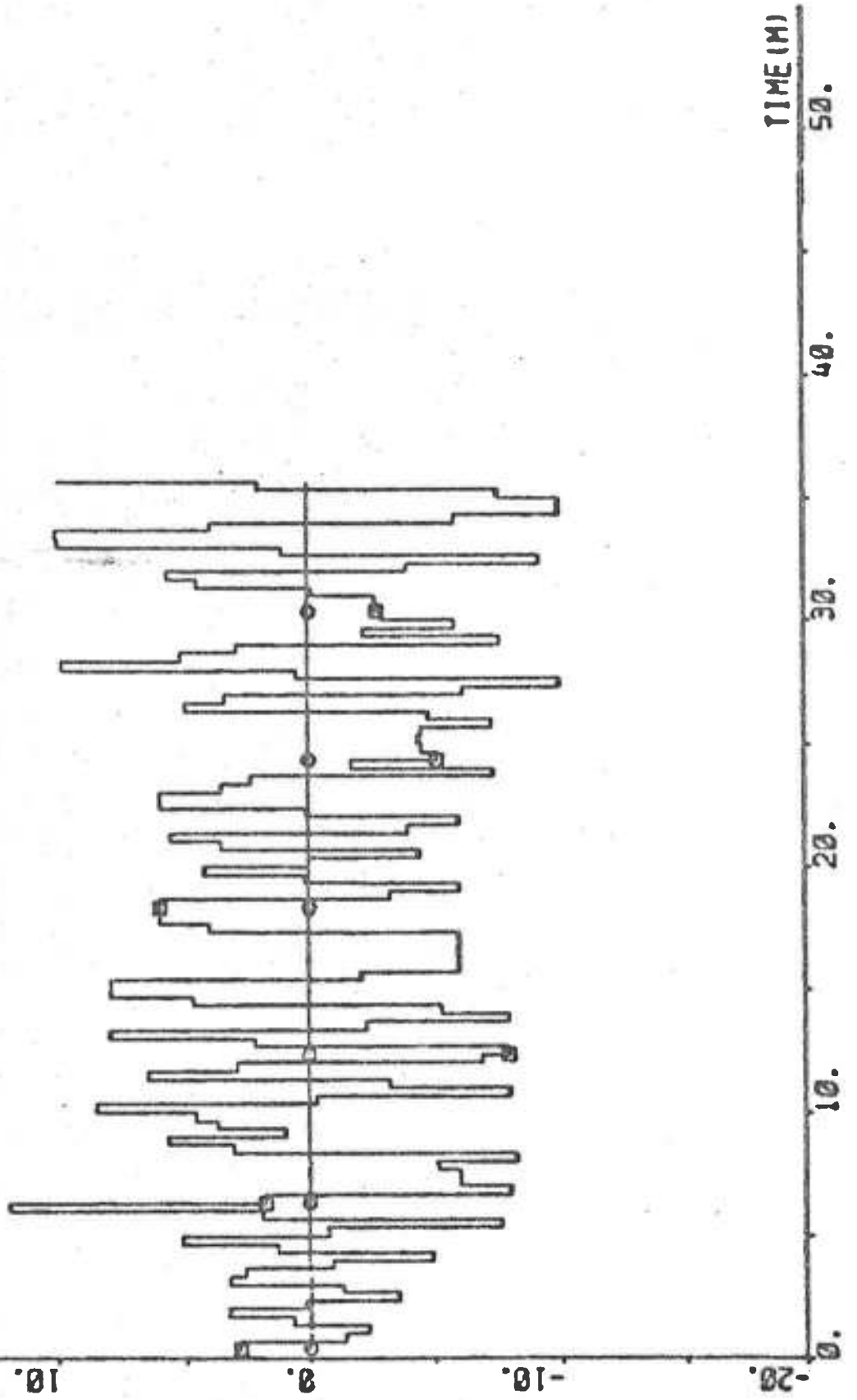
$$\begin{array}{l}
 \left[\begin{array}{l} a_1' \\ a_2' \\ a_3' \\ b_1' \\ b_2' \end{array} \right] = \left[\begin{array}{l} -12.90 \\ 6.02 \\ -6.87 \\ 1.30 \\ 0.649 \end{array} \right] \quad \text{PY} = \left[\begin{array}{cccccc}
 1052.632 & & & & & \\
 -2131.196 & 1052.632 & & & & \\
 280.764 & -2636.618 & 1052.632 & & & \\
 4.632 & -167.430 & 21.118 & 10.526 & & \\
 -12.469 & -97.469 & -14.887 & 6.704 & 10.526 &
 \end{array} \right]
 \end{array}$$

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

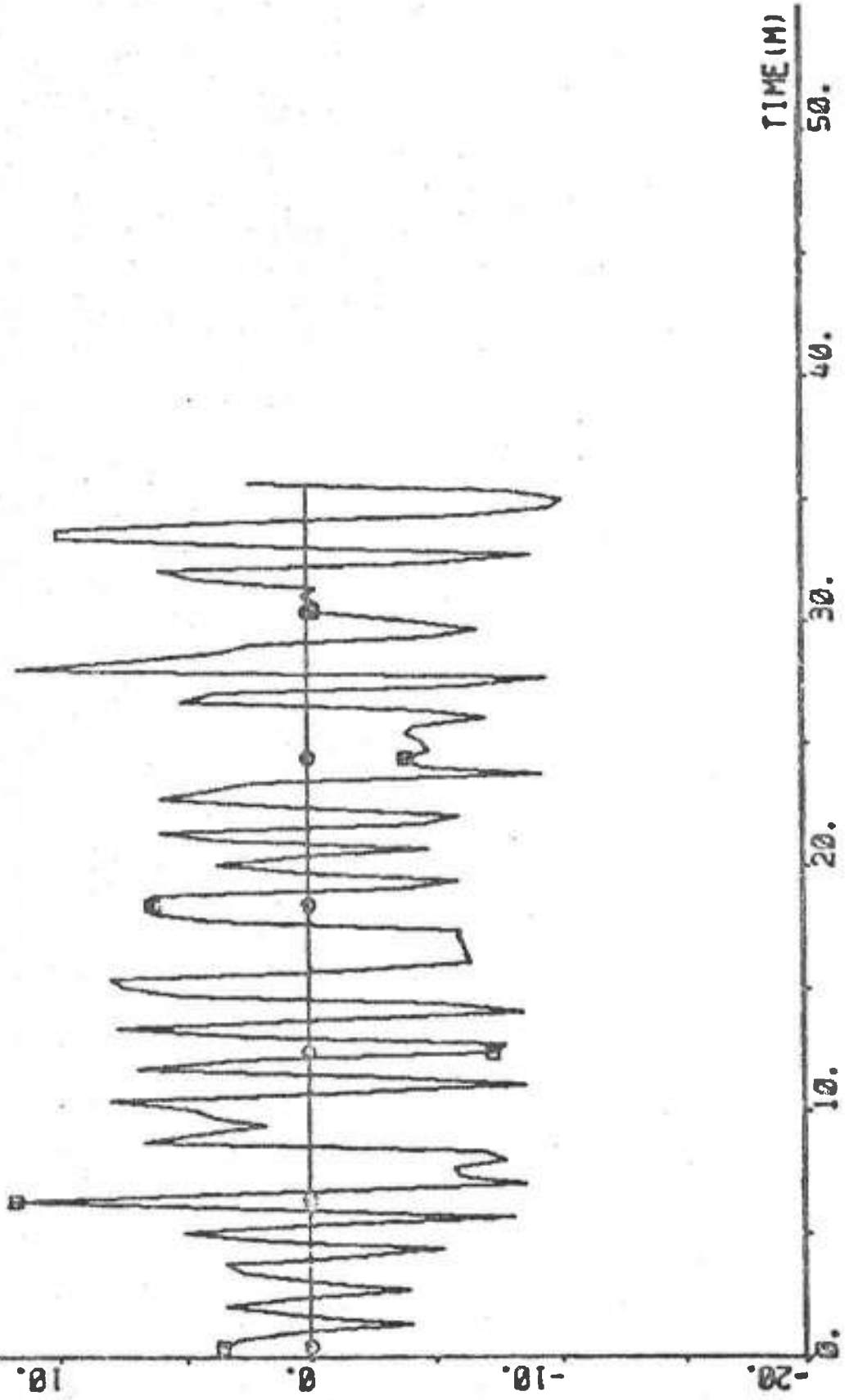
PLOT HP BIP1(1) ZERO -40 40 "DELCOC DEG



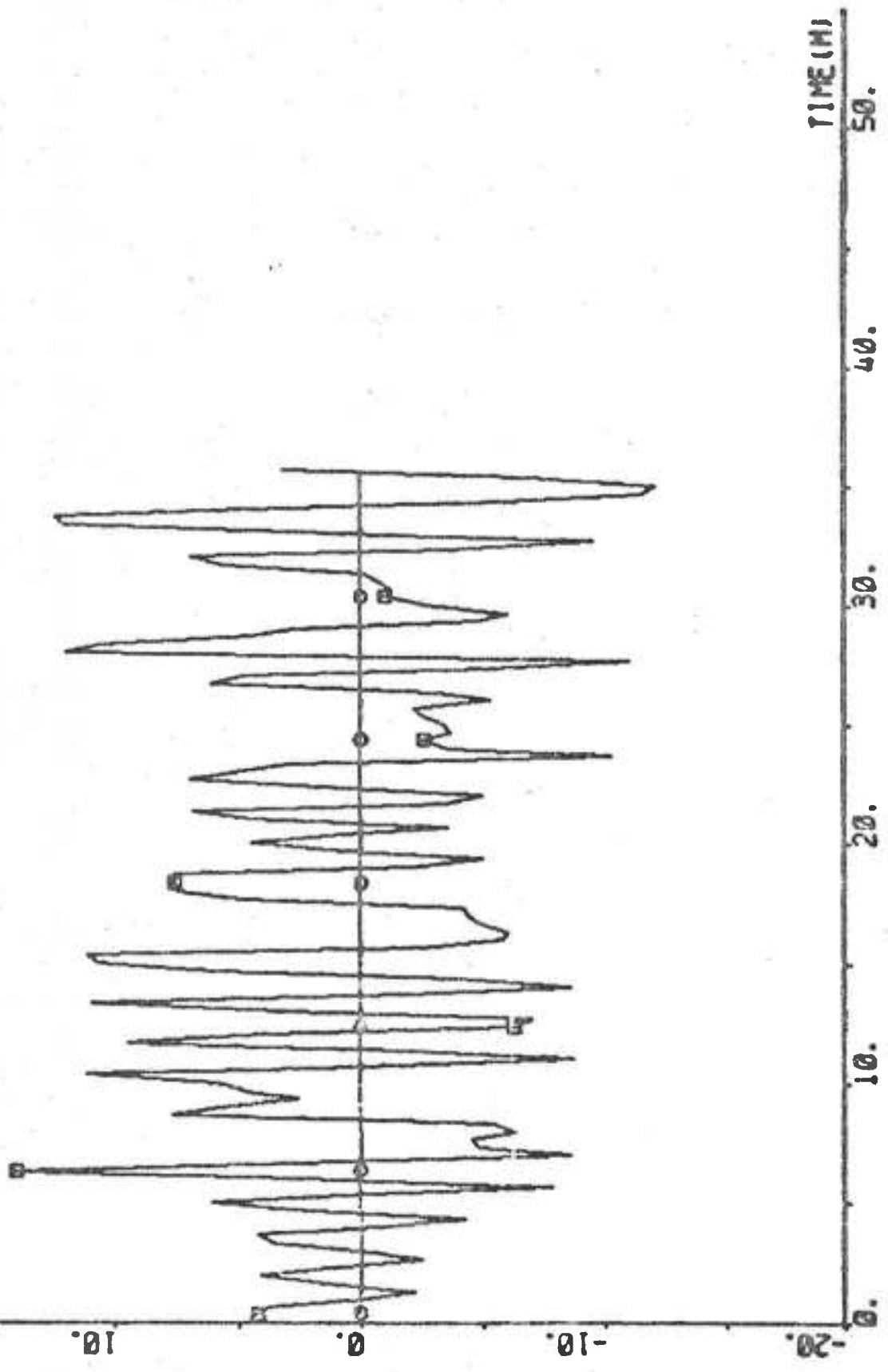
PLOT HP B1P1(2) ZERO -20 20 "DELCON DEG



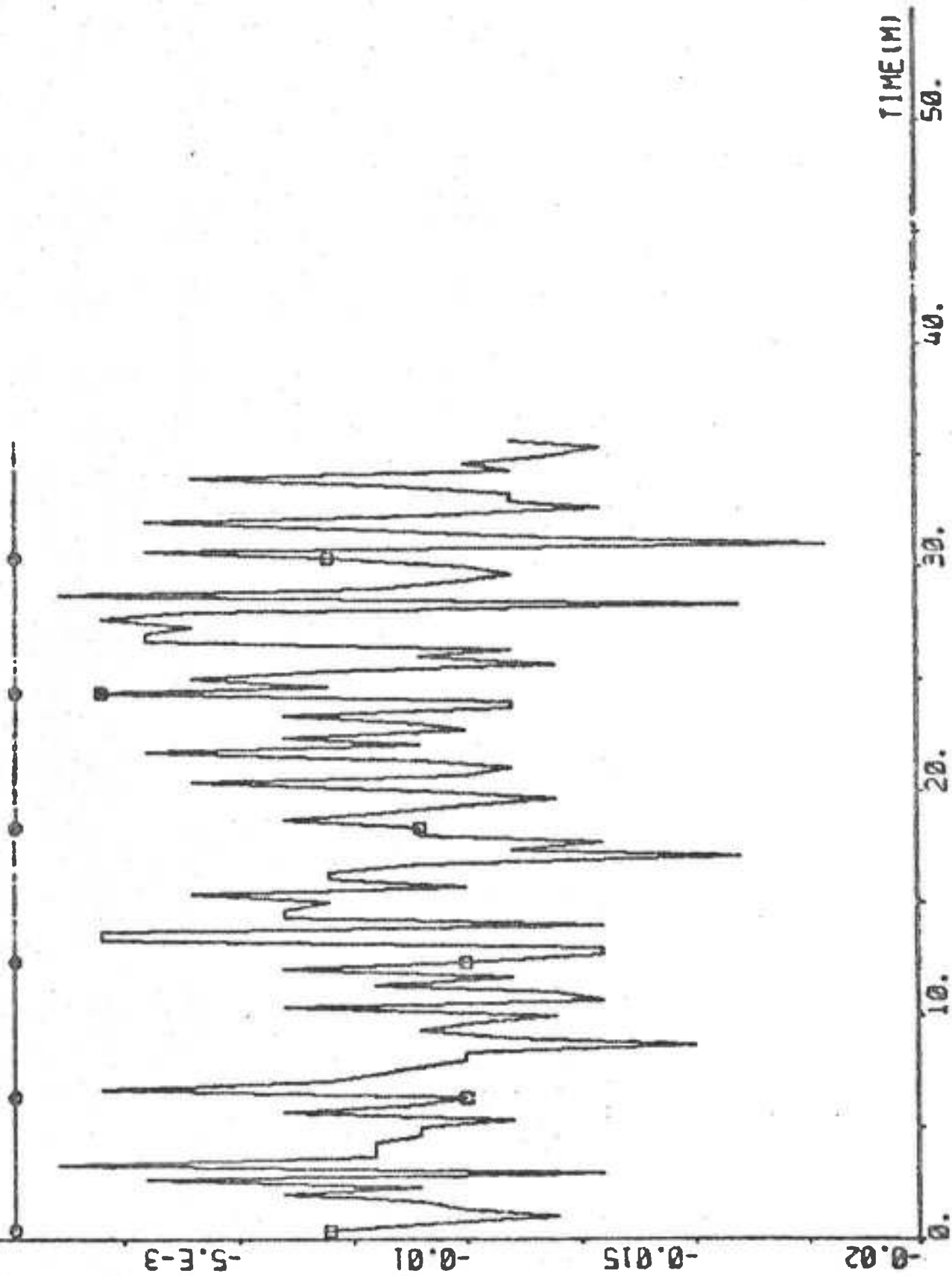
PLOT 01P1(3) ZERO -20 20 "DELTA" DEG



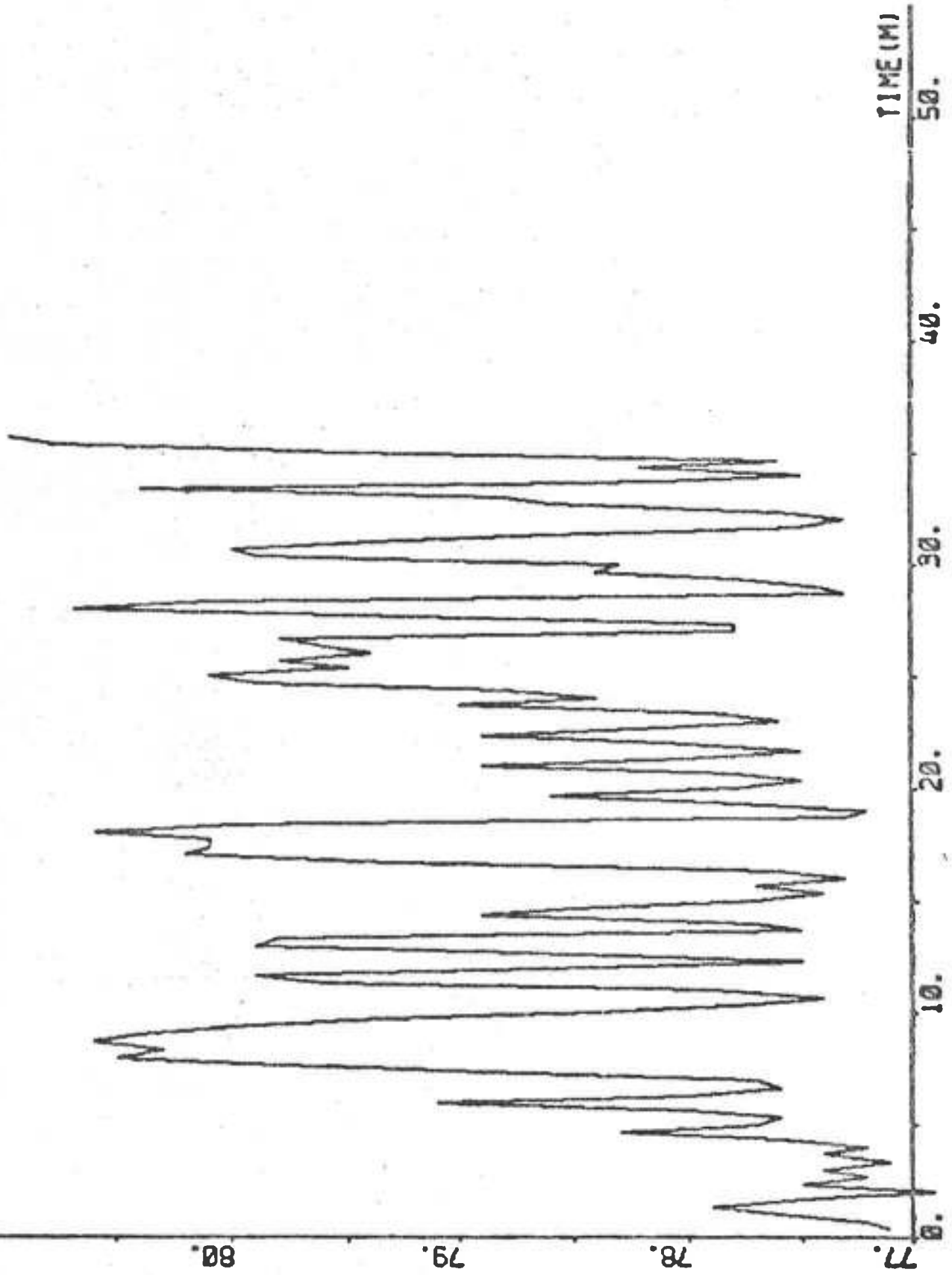
PLOT BIP1(4) ZERO -20 20 "DELTA DEG



PLOT B1P1(5) ZERO -0.02 0 °PP DEG/S



PLOT BIP1(6) 77 81 -AN RPM



PLOT B1P1(7) 16 18 -U KNOTS

16.5
17.
17.5



TIME (M)

50.

40.

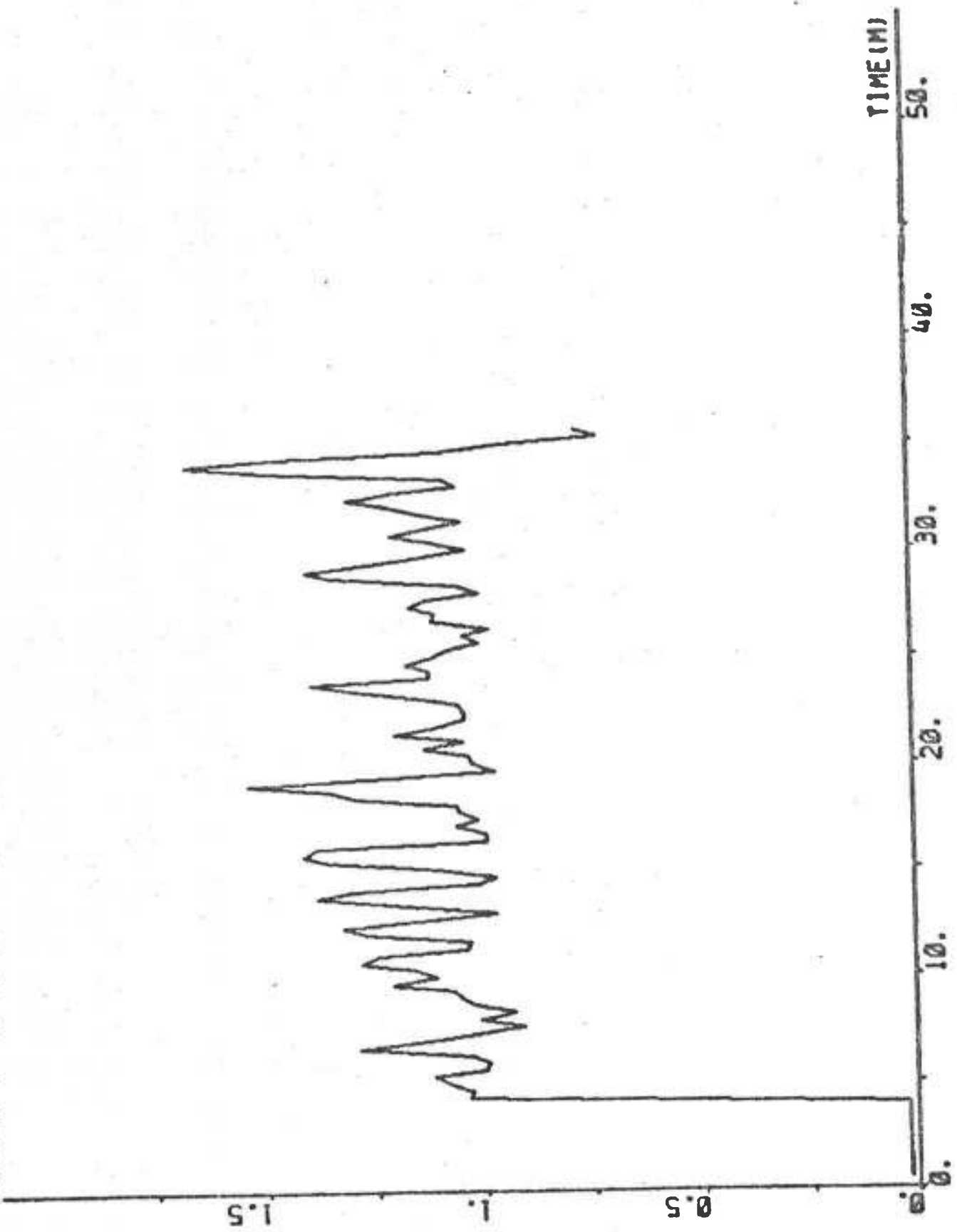
30.

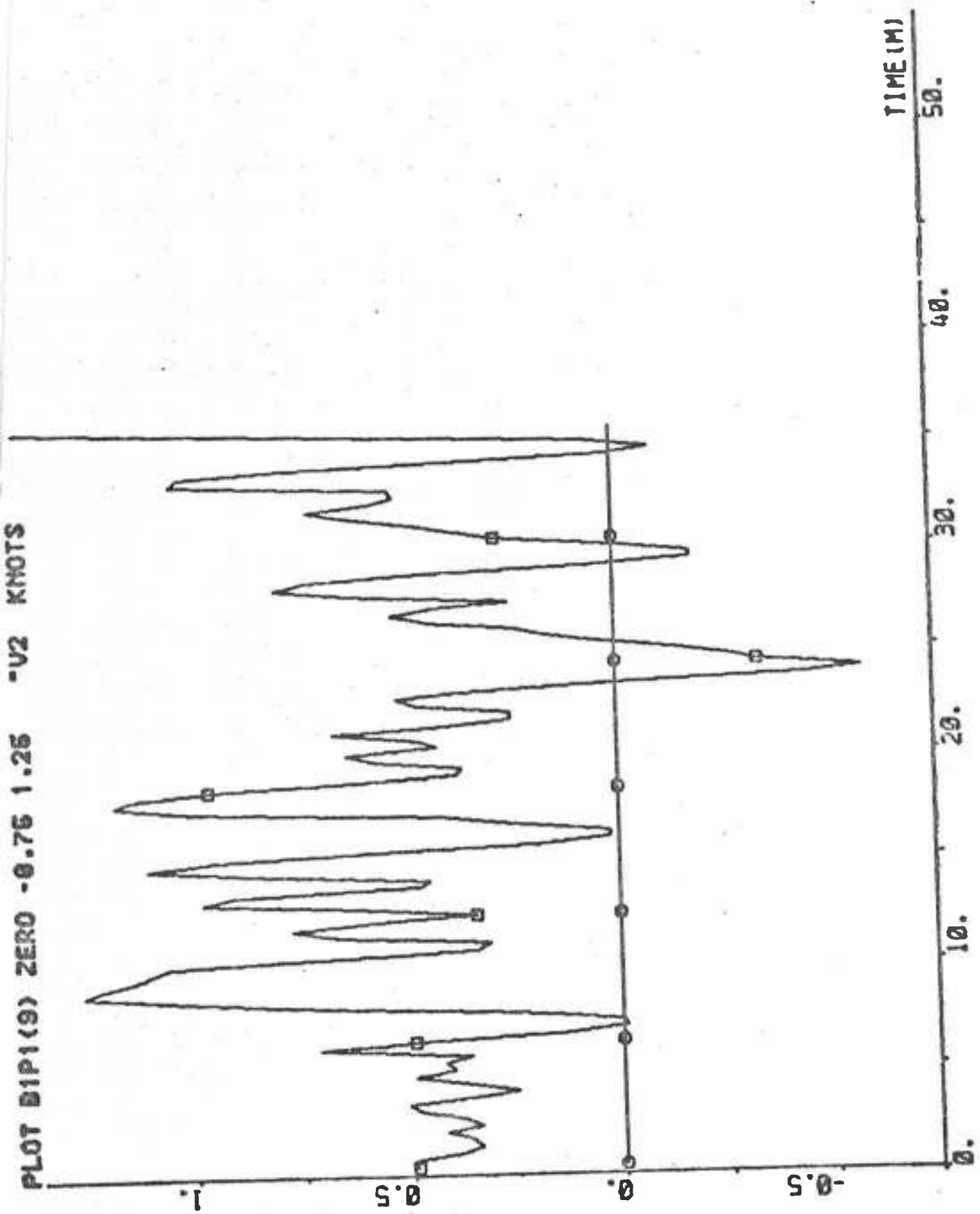
20.

10.

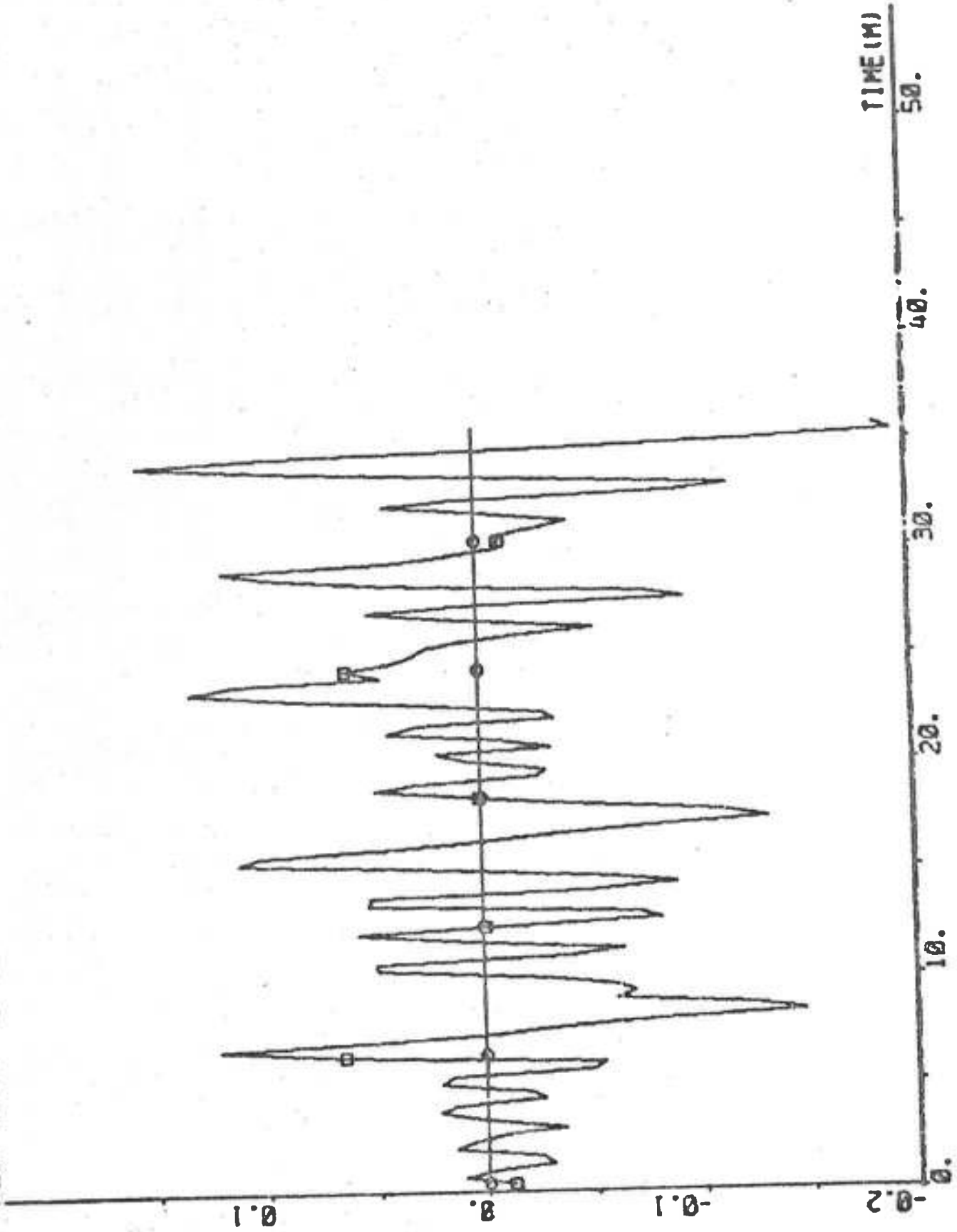
0.

PLOT B1P1(8) 0 2 -V1 KNOTS

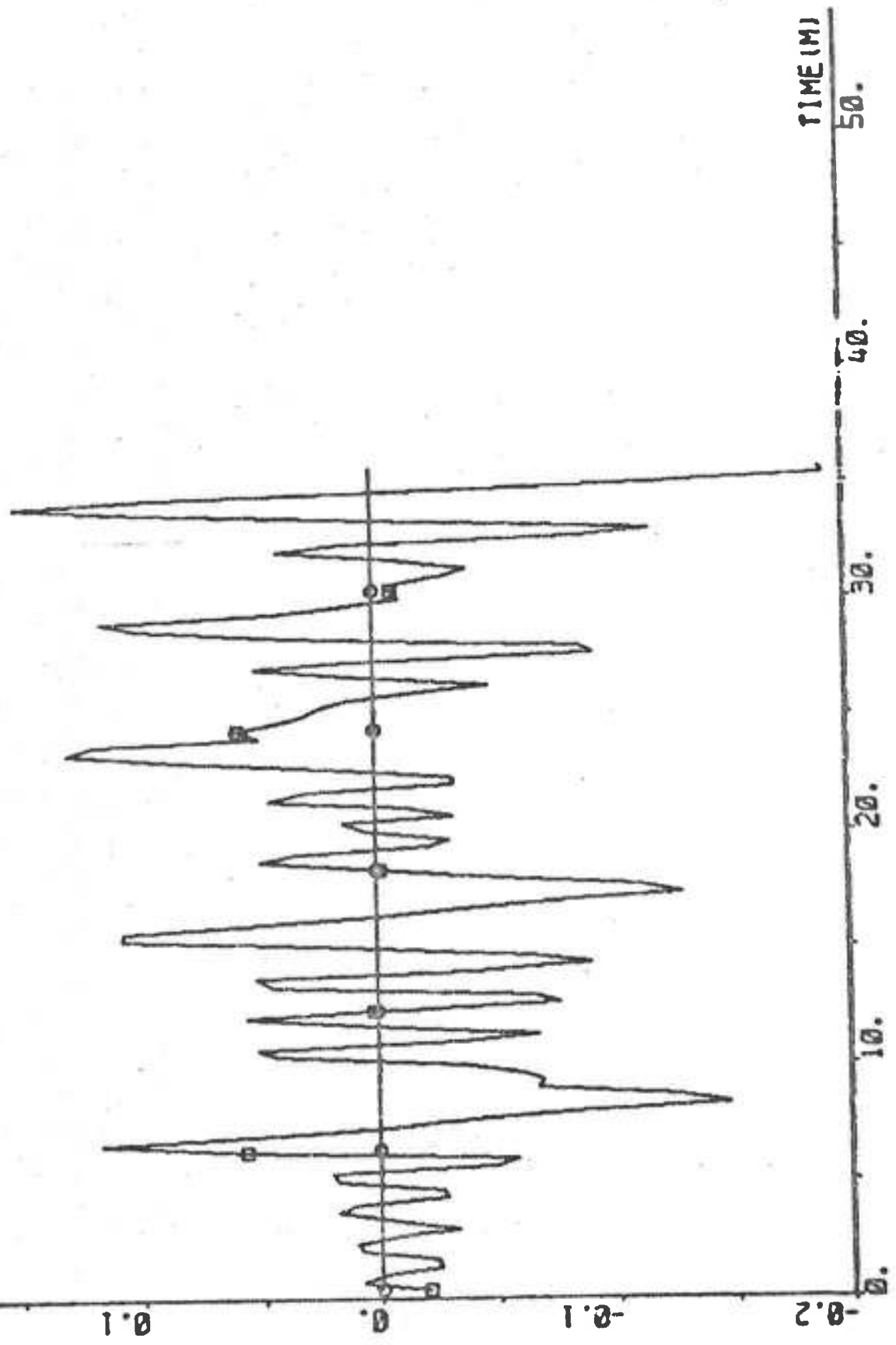




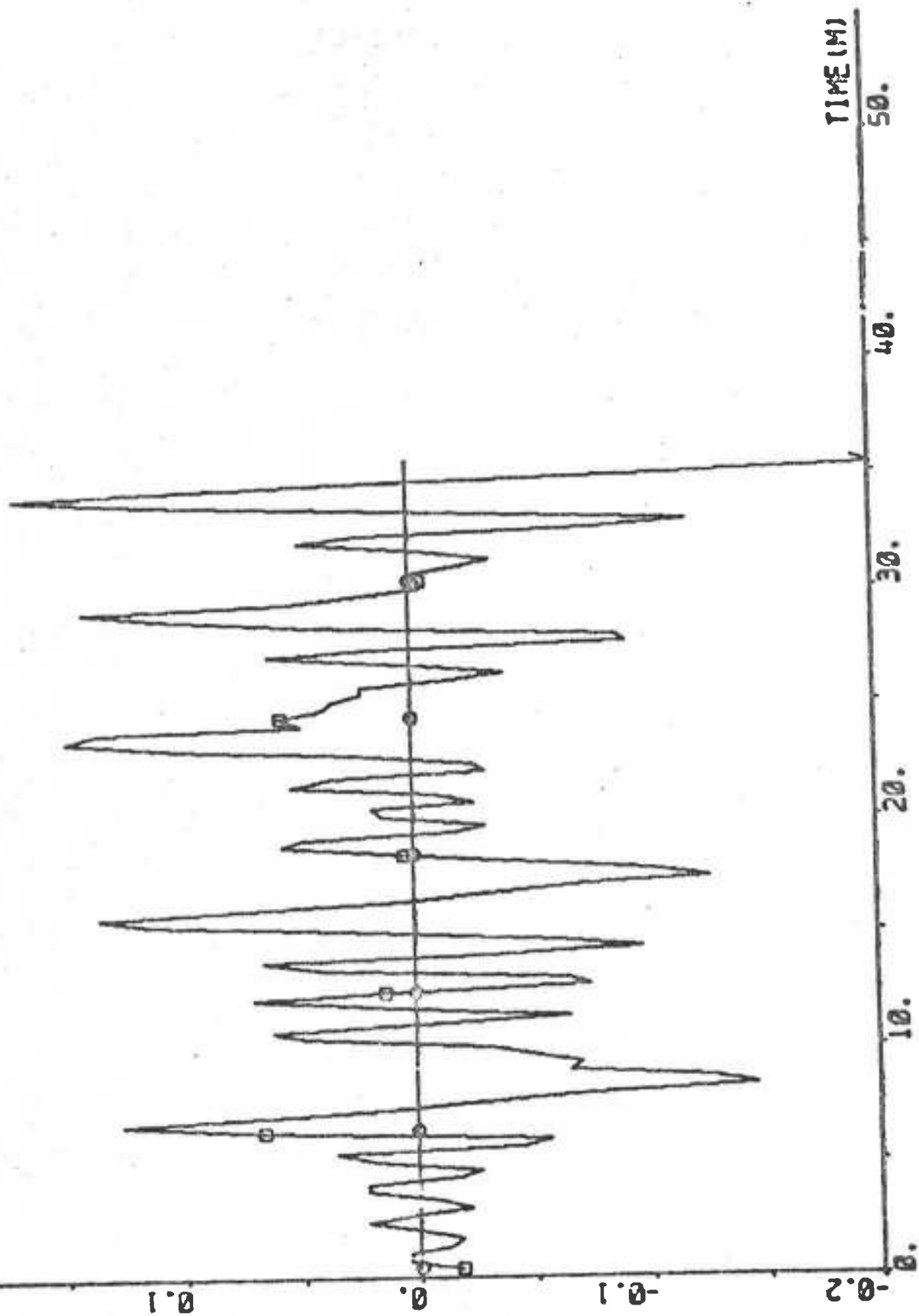
PLOT B1P1(10) ZERO -0.2 0.2 "R DEC/S



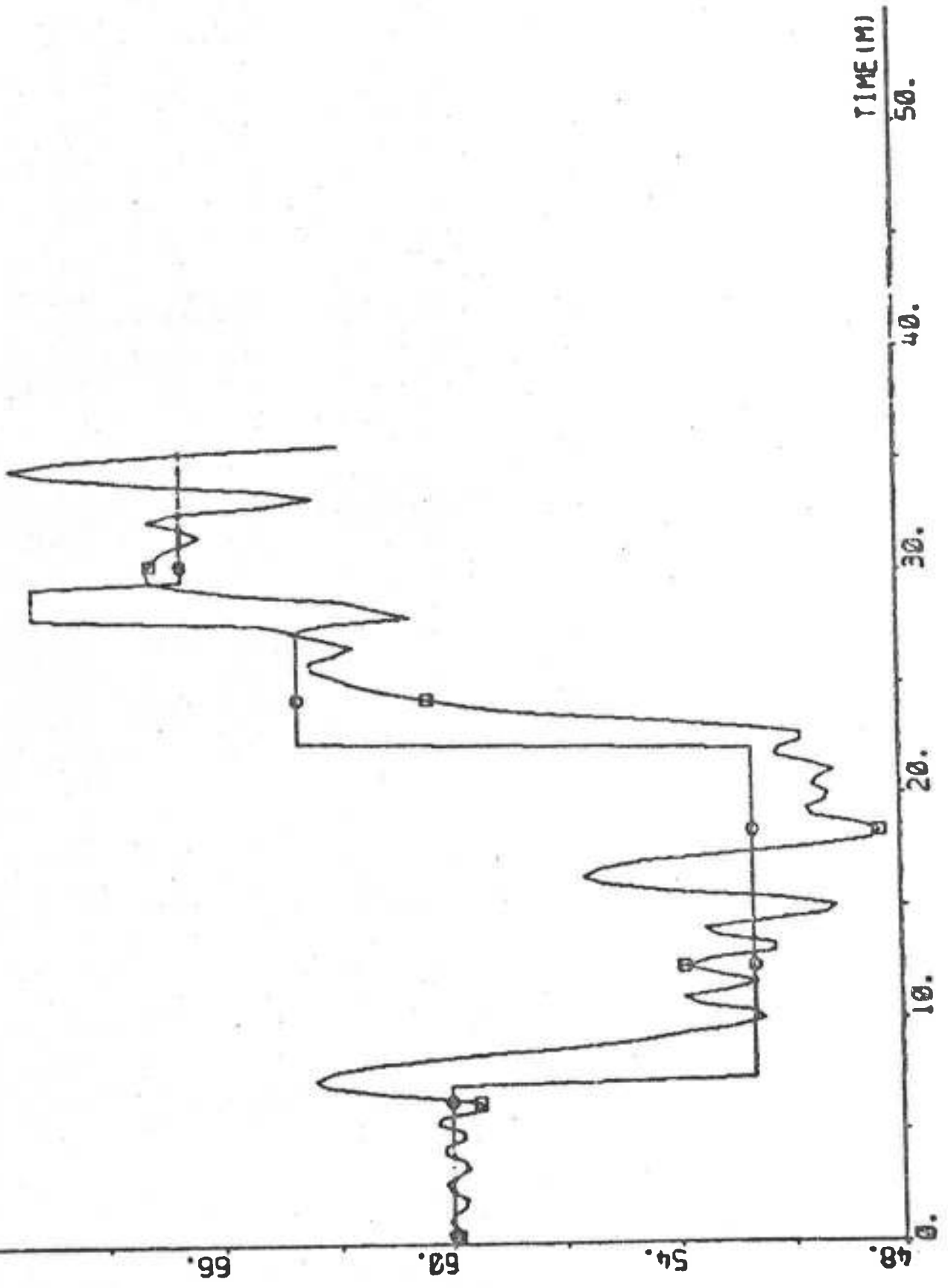
PLOT B1P1(11) ZERO -0.2 0.2 -AVR DEG/S (BR=0.5)



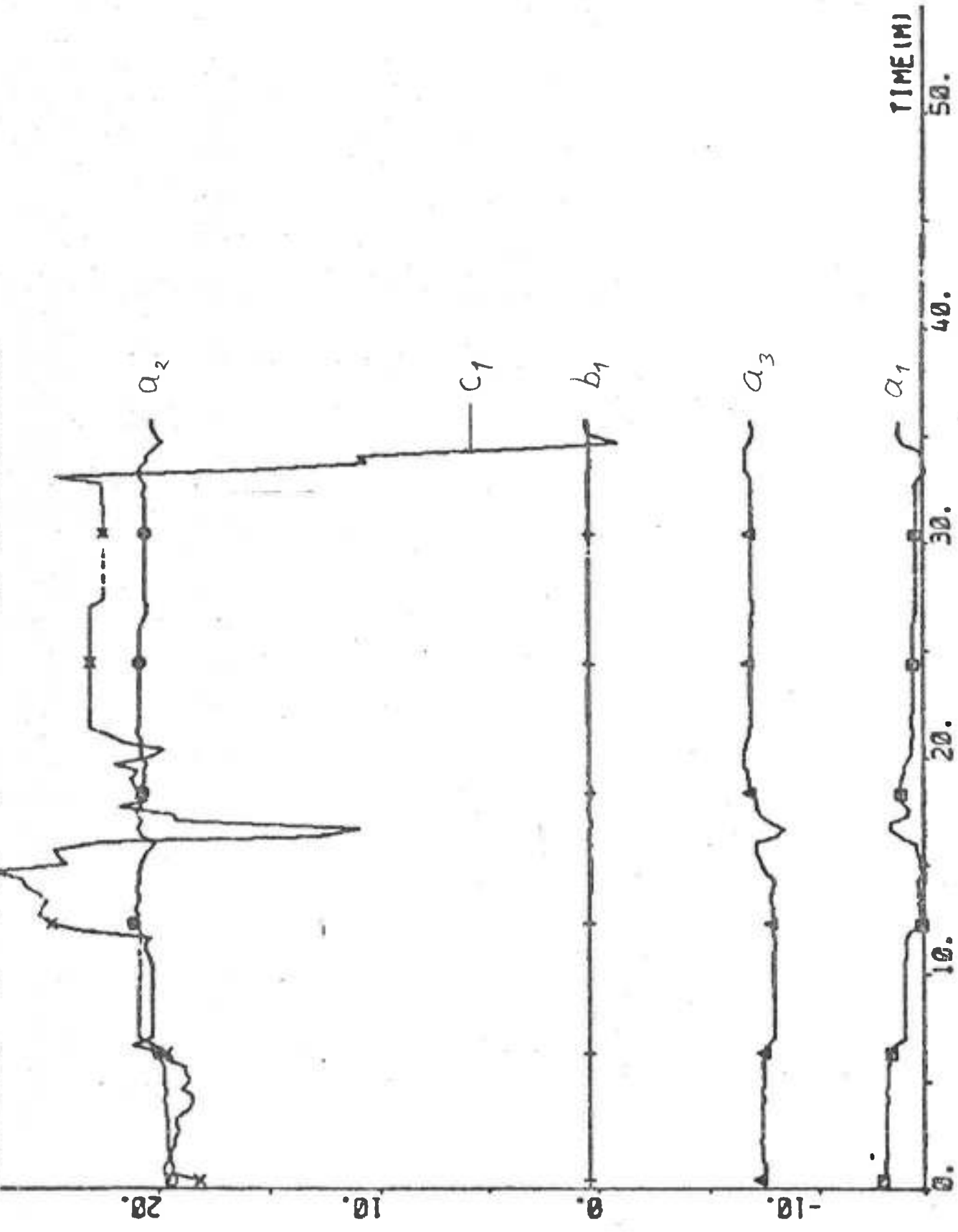
PLOT B1P1(12) ZERO -0.2 0.2 -DPSIDT DEC/S (1UR31-07



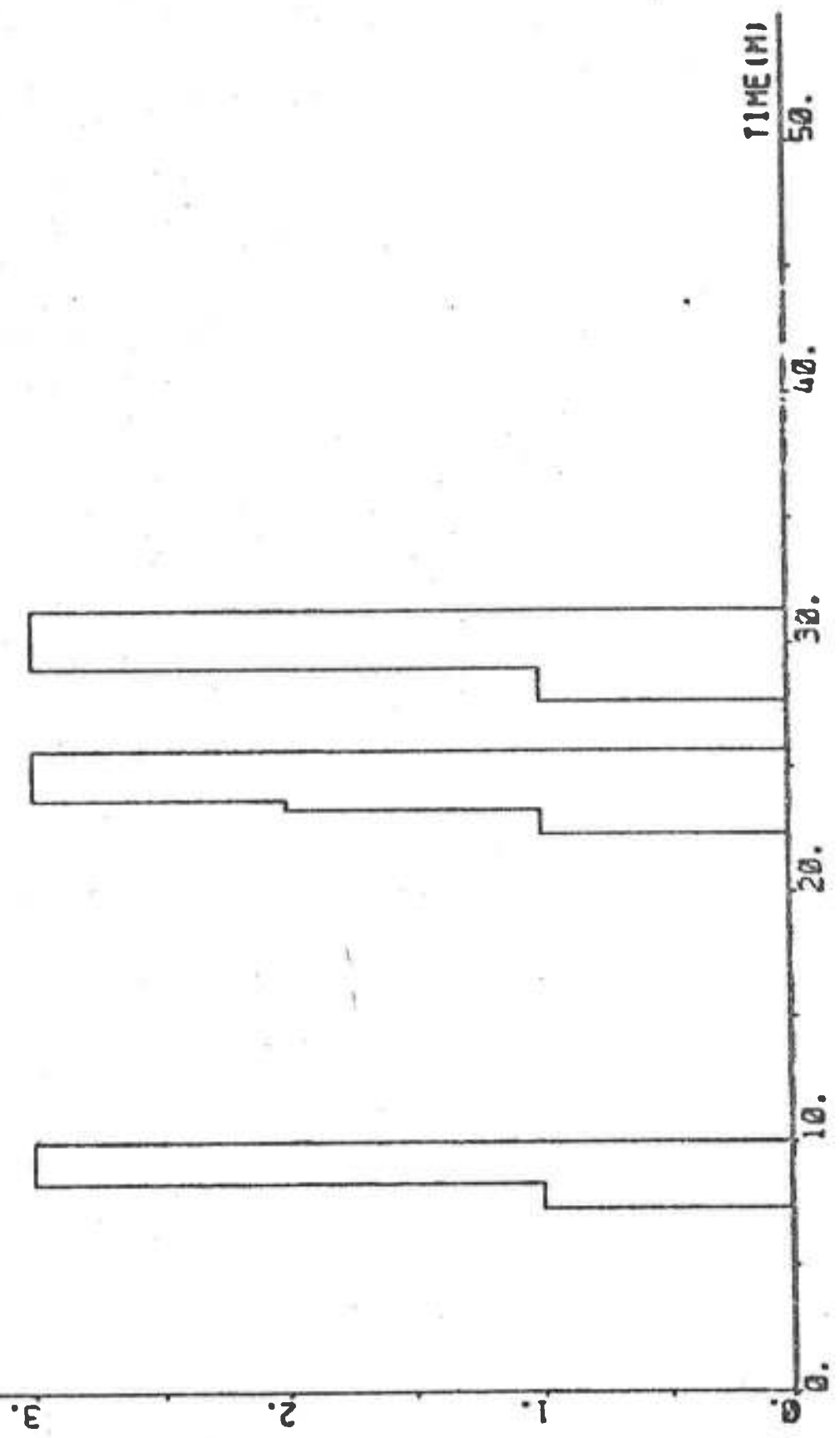
PLOT B1P1(13 14) 49 73 "PSI PSIREF DEG



PLOT B1P2(1 2 3 4 5) -14 28 "REGULATOR PARAMETERS



PLOT HP 01P2(S) 0 4 "MOODYAM



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°
DELIM 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

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

$$a_1 + a_2 + a_3 = -1.460$$

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

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

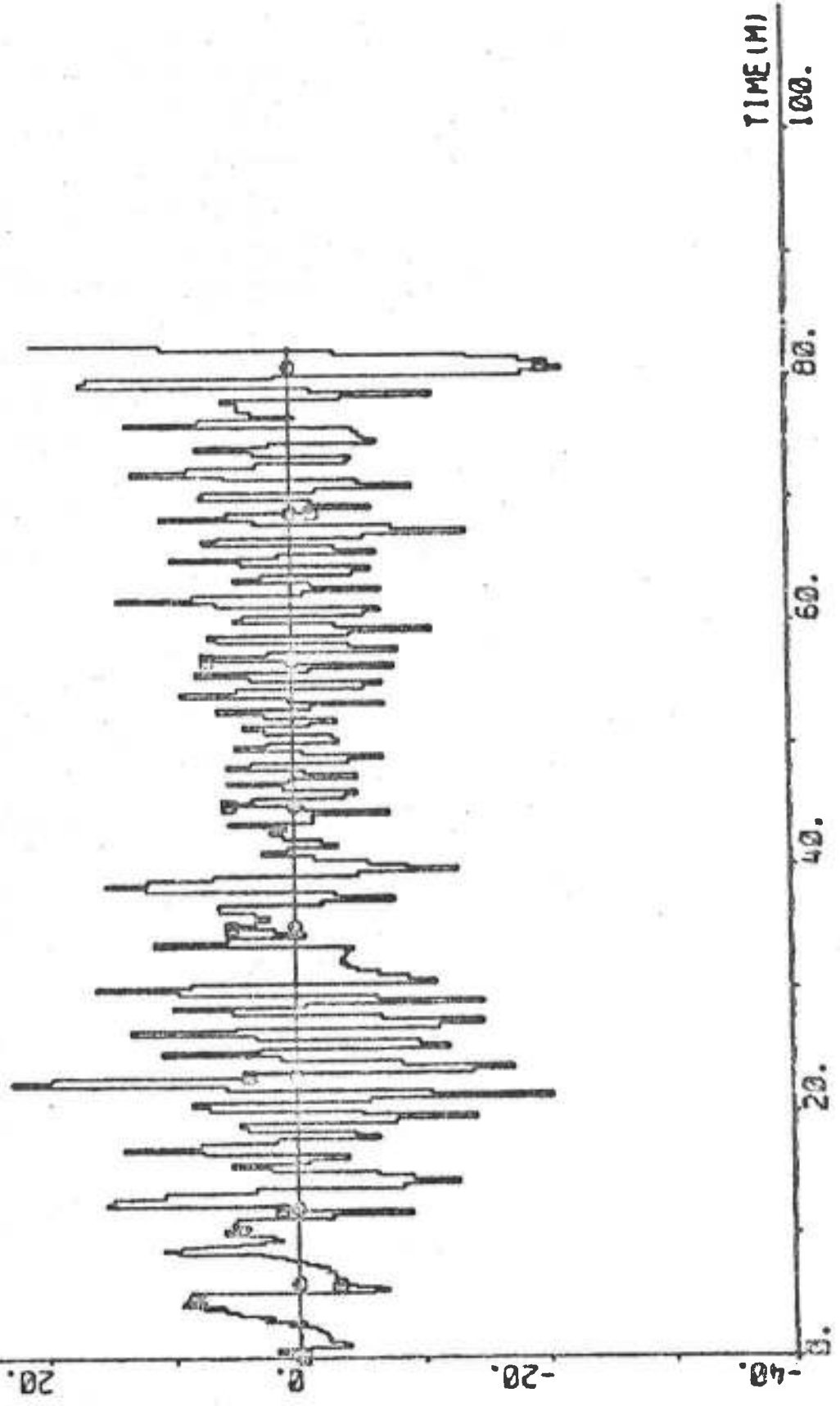
$$a'_1 + a'_2 + a'_3 = -13.75$$

Yaw regulator values after the yaw at 1 min.

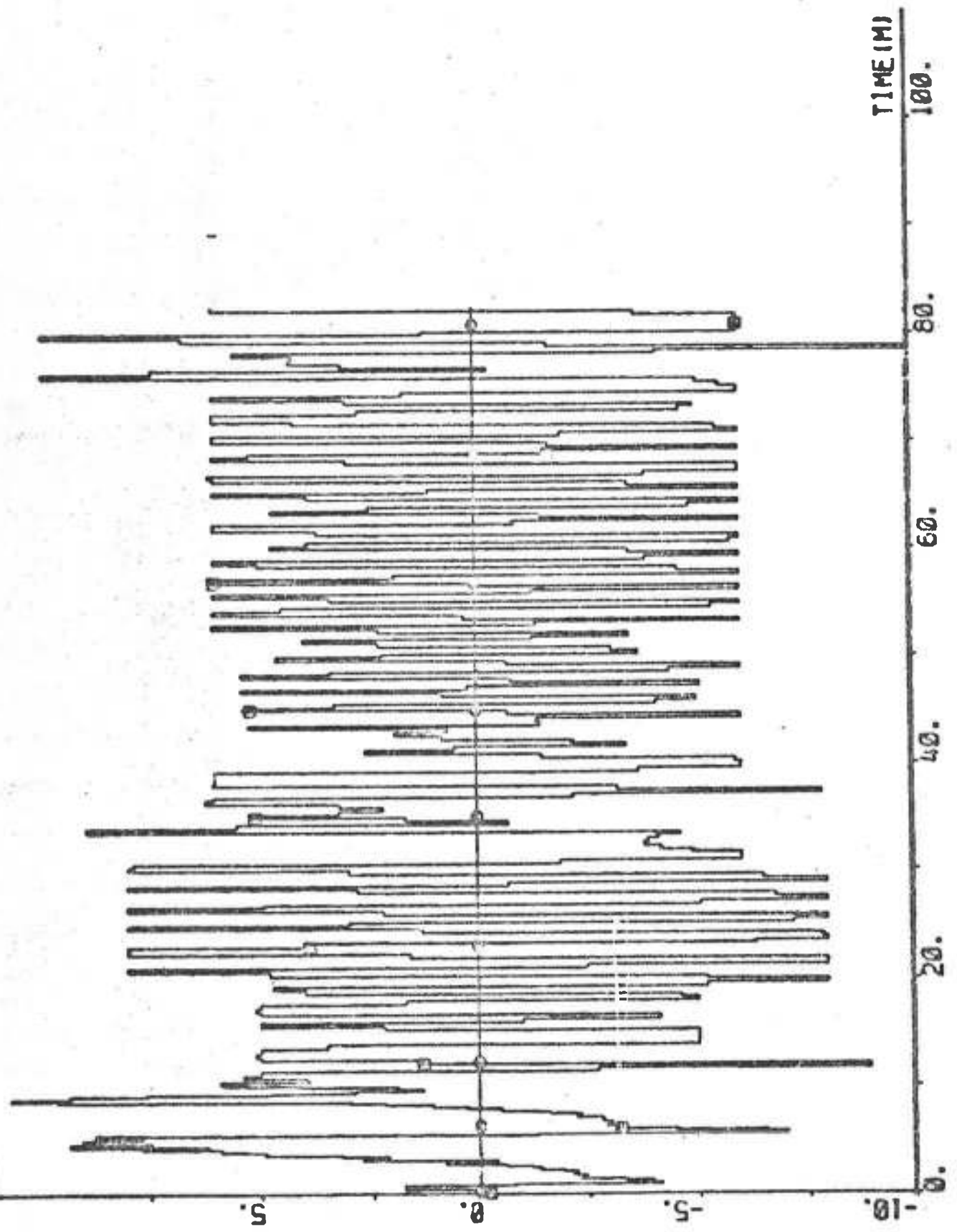
$$\begin{bmatrix} a_1' \\ a_2' \\ a_3' \\ b_1' \\ b_2' \end{bmatrix} = \begin{bmatrix} -16.347 \\ 7.948 \\ -6.272 \\ 1.213 \\ 0.609 \end{bmatrix} \quad \text{PY unknown}$$

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

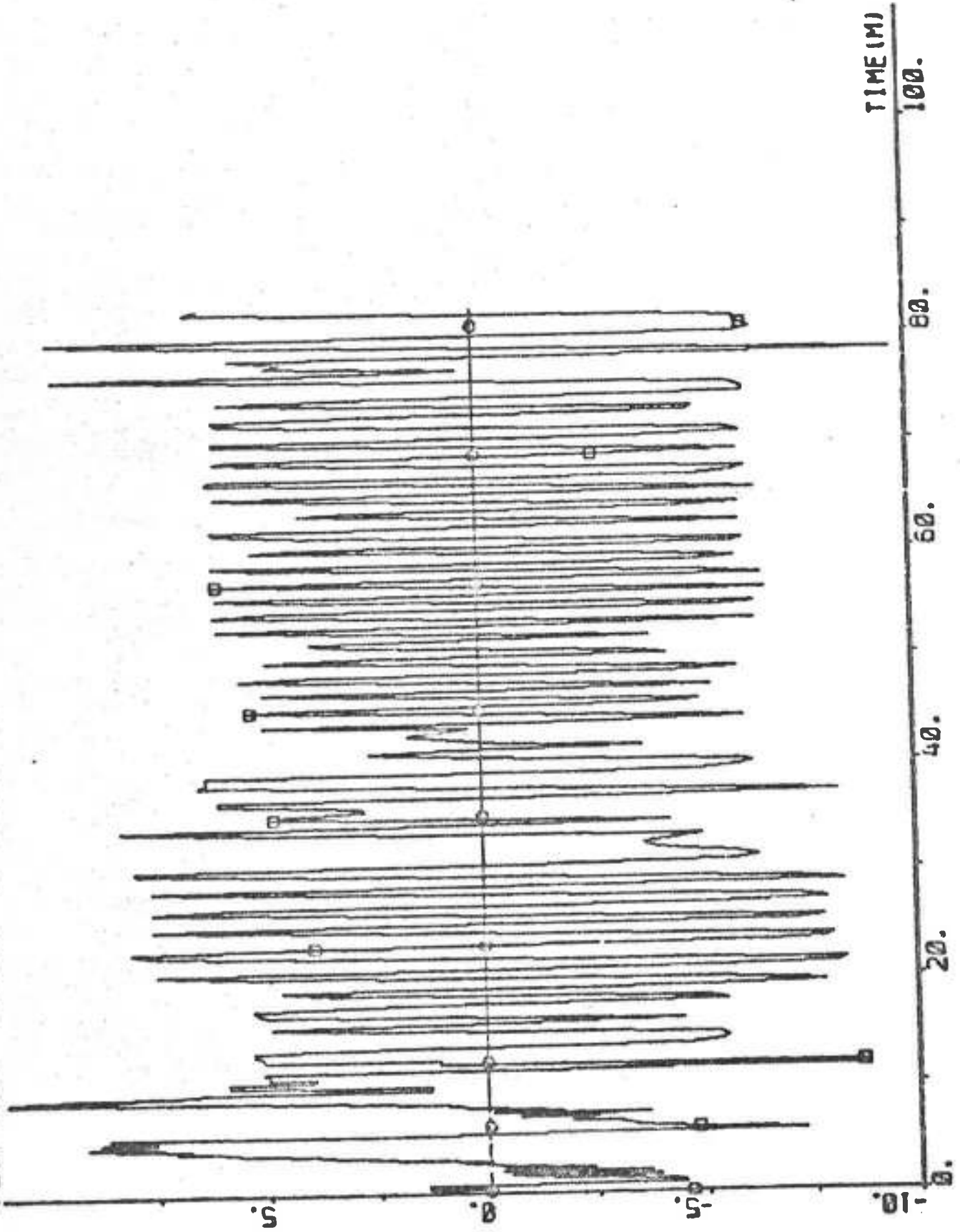
PLOT B2P1(16)←MP B2P1(1) ZERO -40 40 "DELCOC DEG



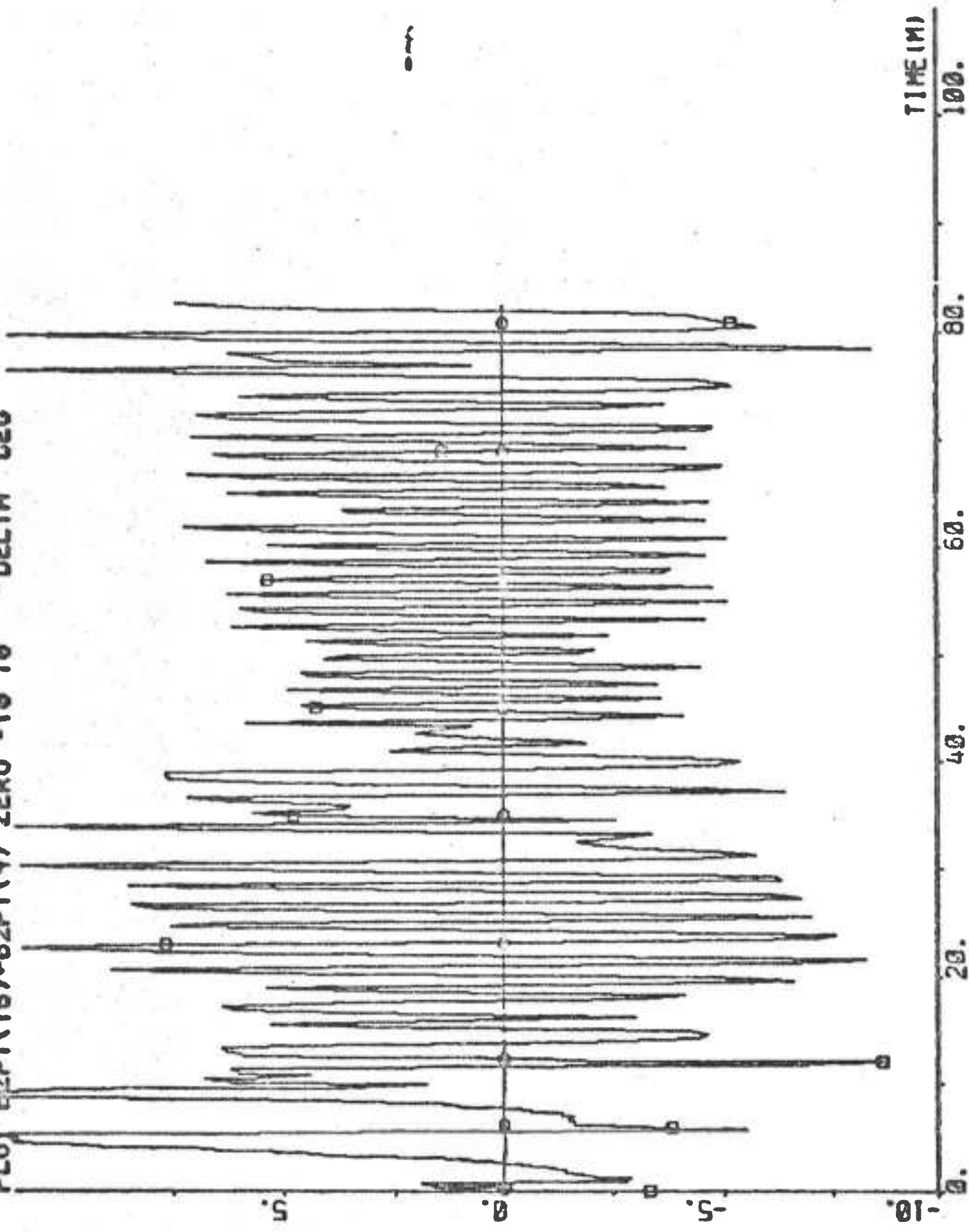
PLOT B2P1(15) HP B2P1(2) ZERO -10 10 DELCON DEC



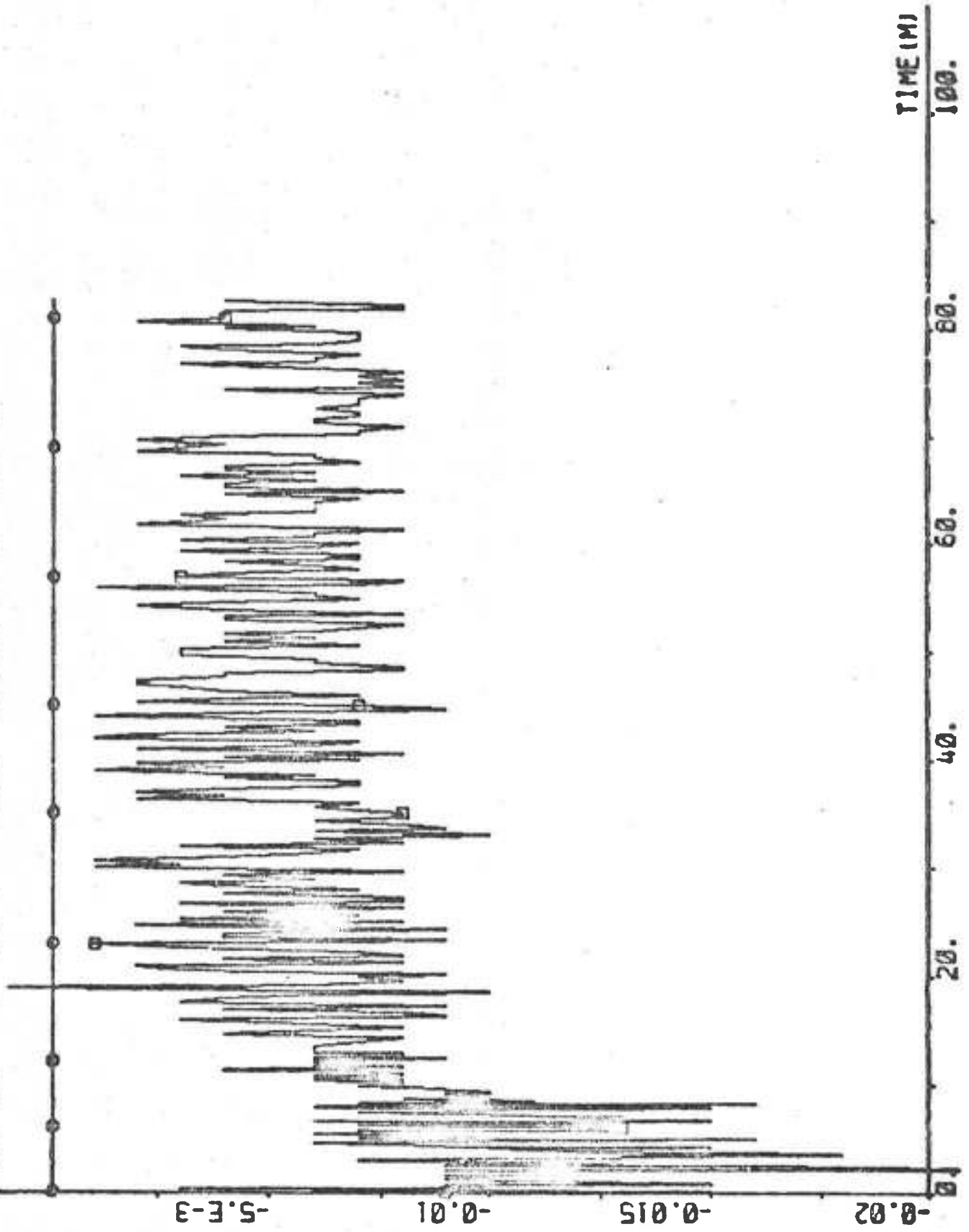
PLOT B2P1(15)-S2P1(3) ZERO -10 10 "DELTA" DEG



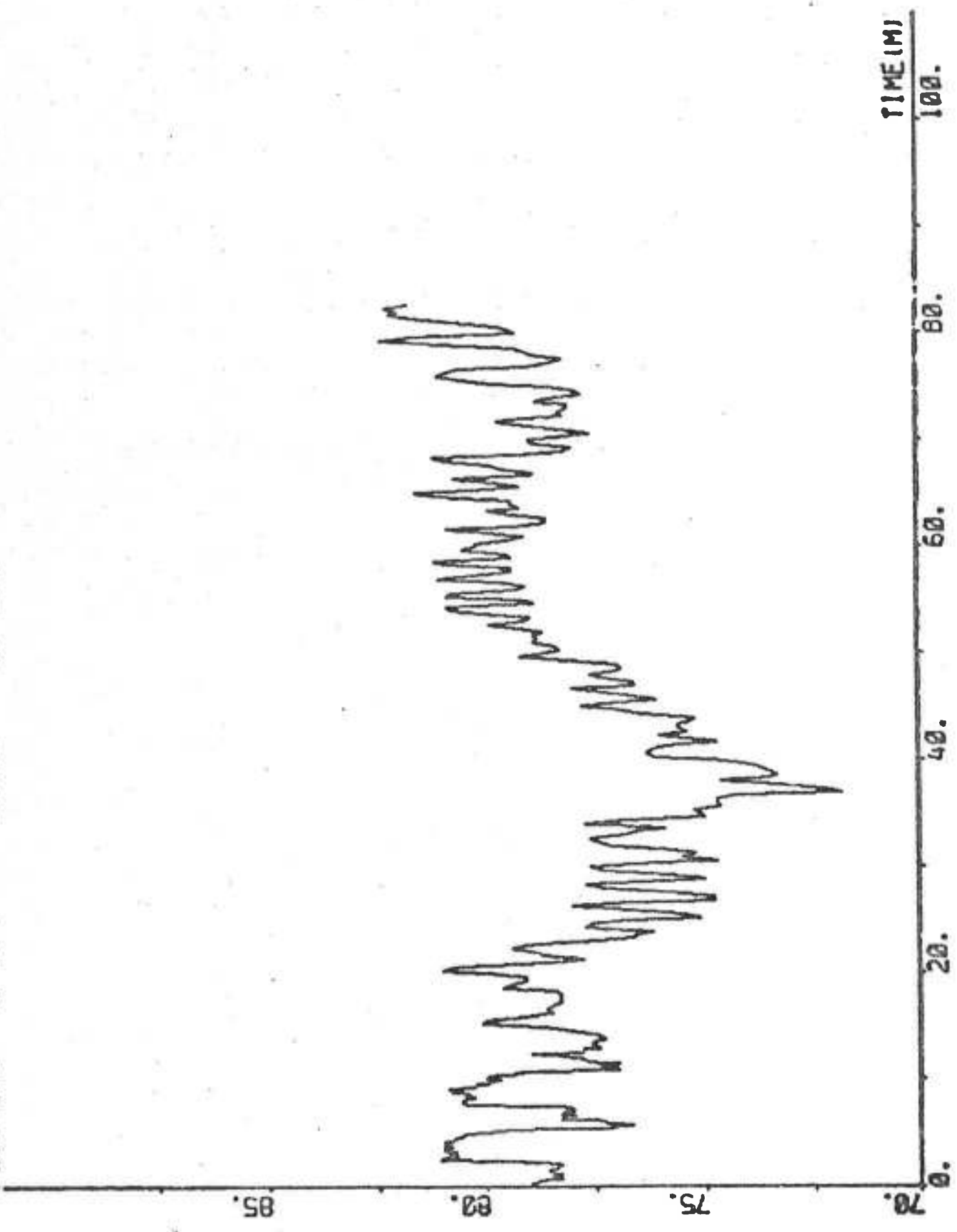
PLOT B2P1(15)-B2P1(4) ZERO -10 10 -DELTA DEG



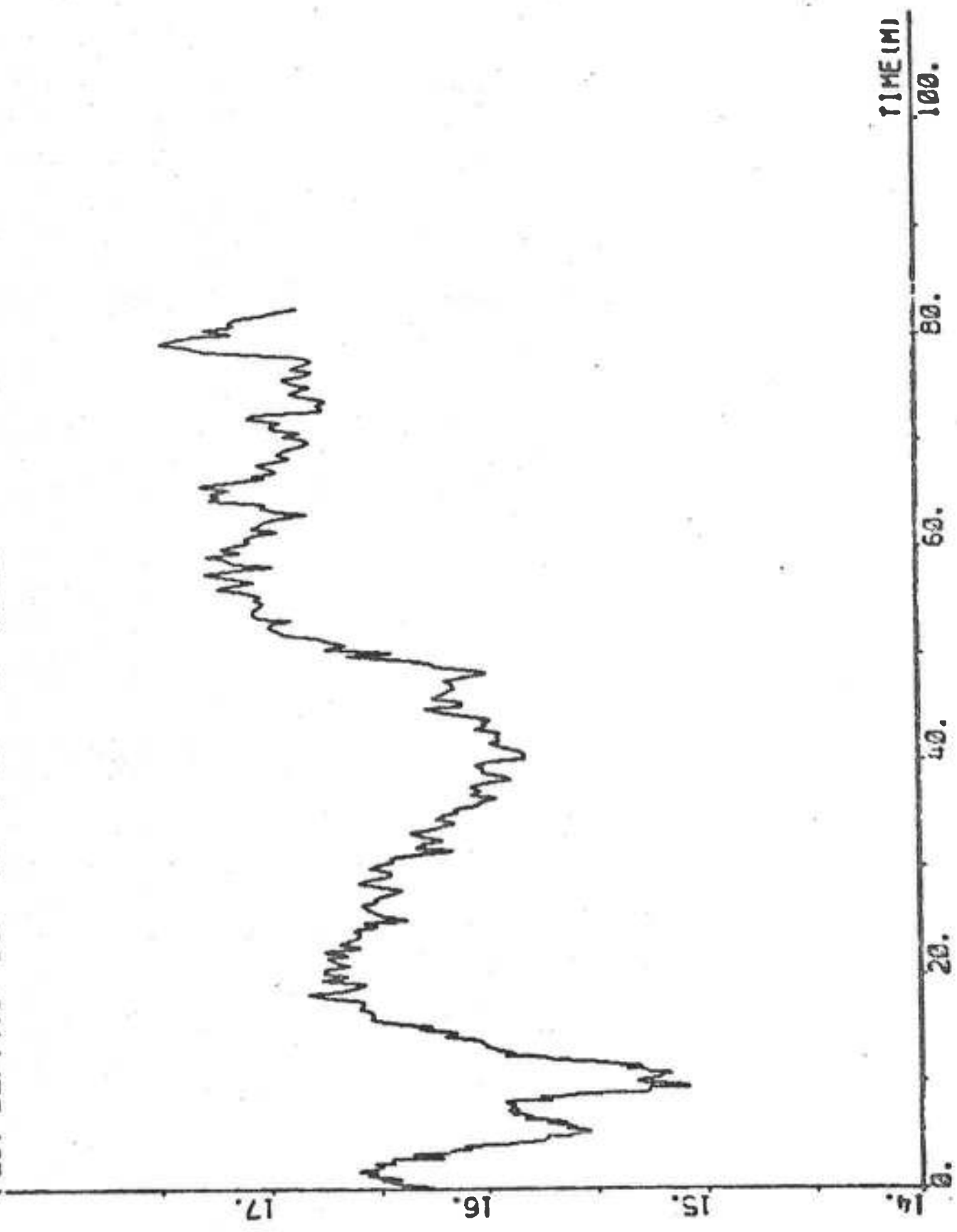
PLOT B2P1(15)-B2P1(5) ZERO -0.02 0 "PP DEG/S



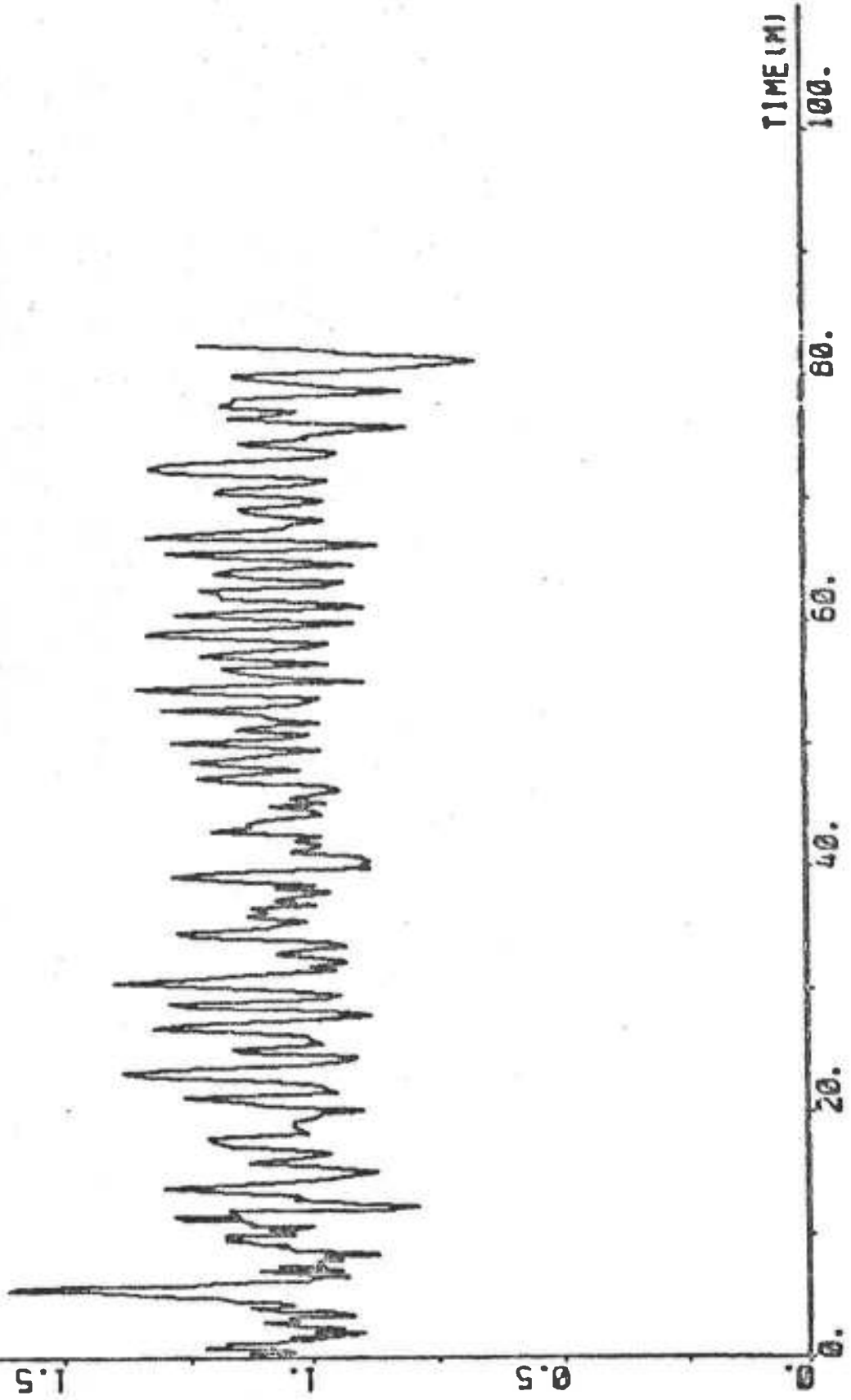
PLOT 62P1(15)-B2P1(6) 70 90 "AN RPH



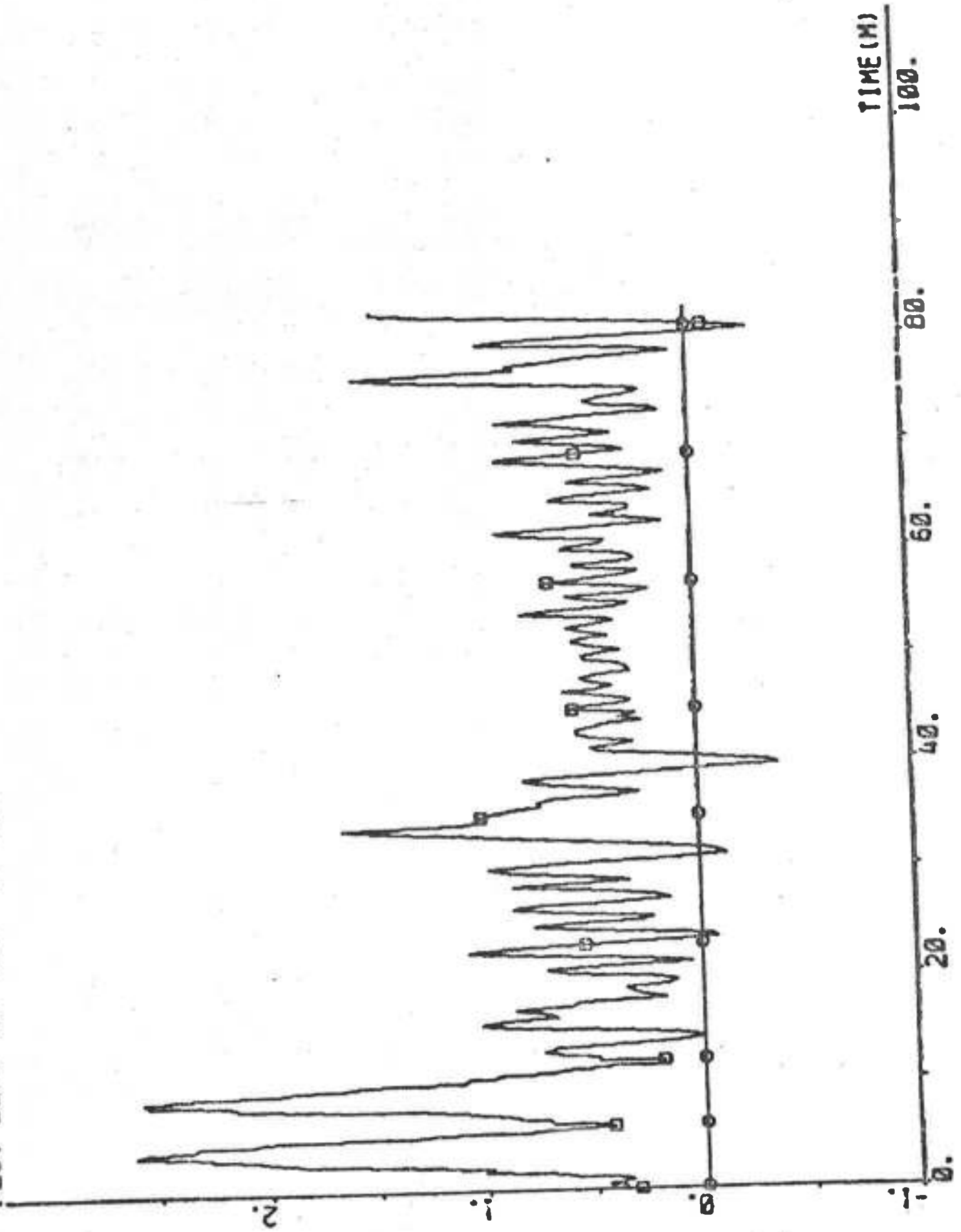
PLOT B2P1(15)-B2P1(7) 14 16 "U KNOTS



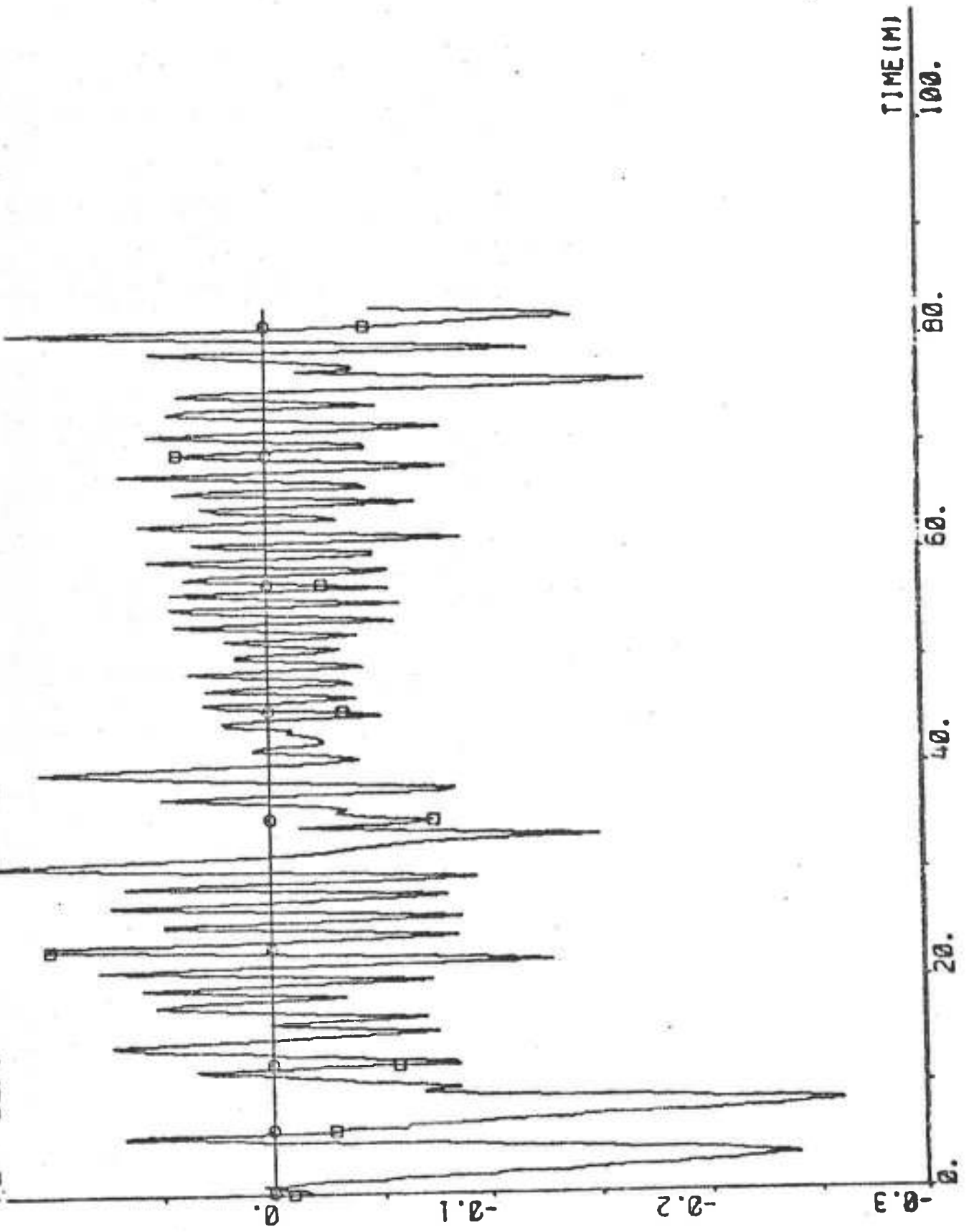
PLOT B2P1(15)-B2P1(0) 0 2 "V1 KNOTS



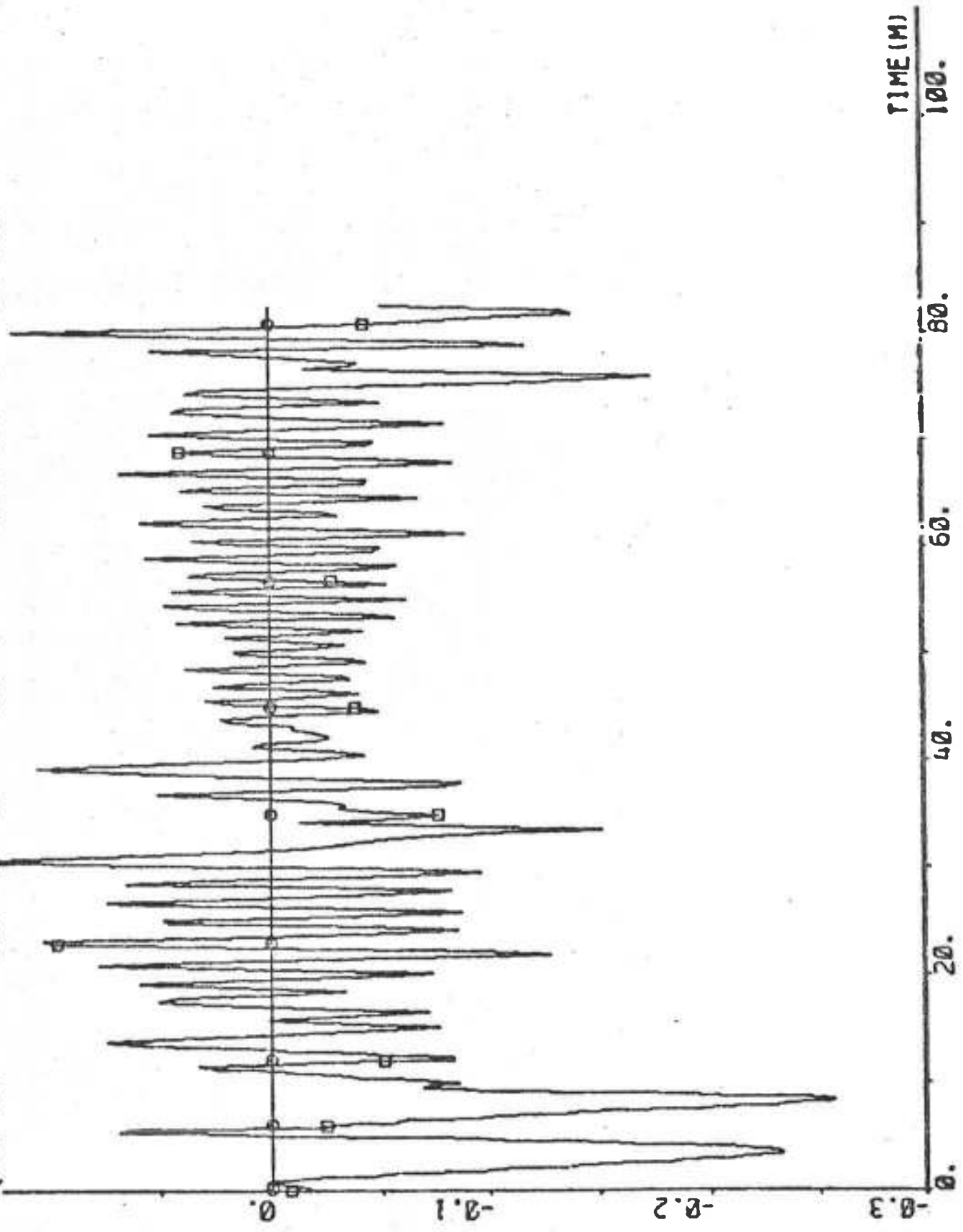
PLOT B2P1(15)-B2P1(9) ZERO -1 3 -V2 KNOTS



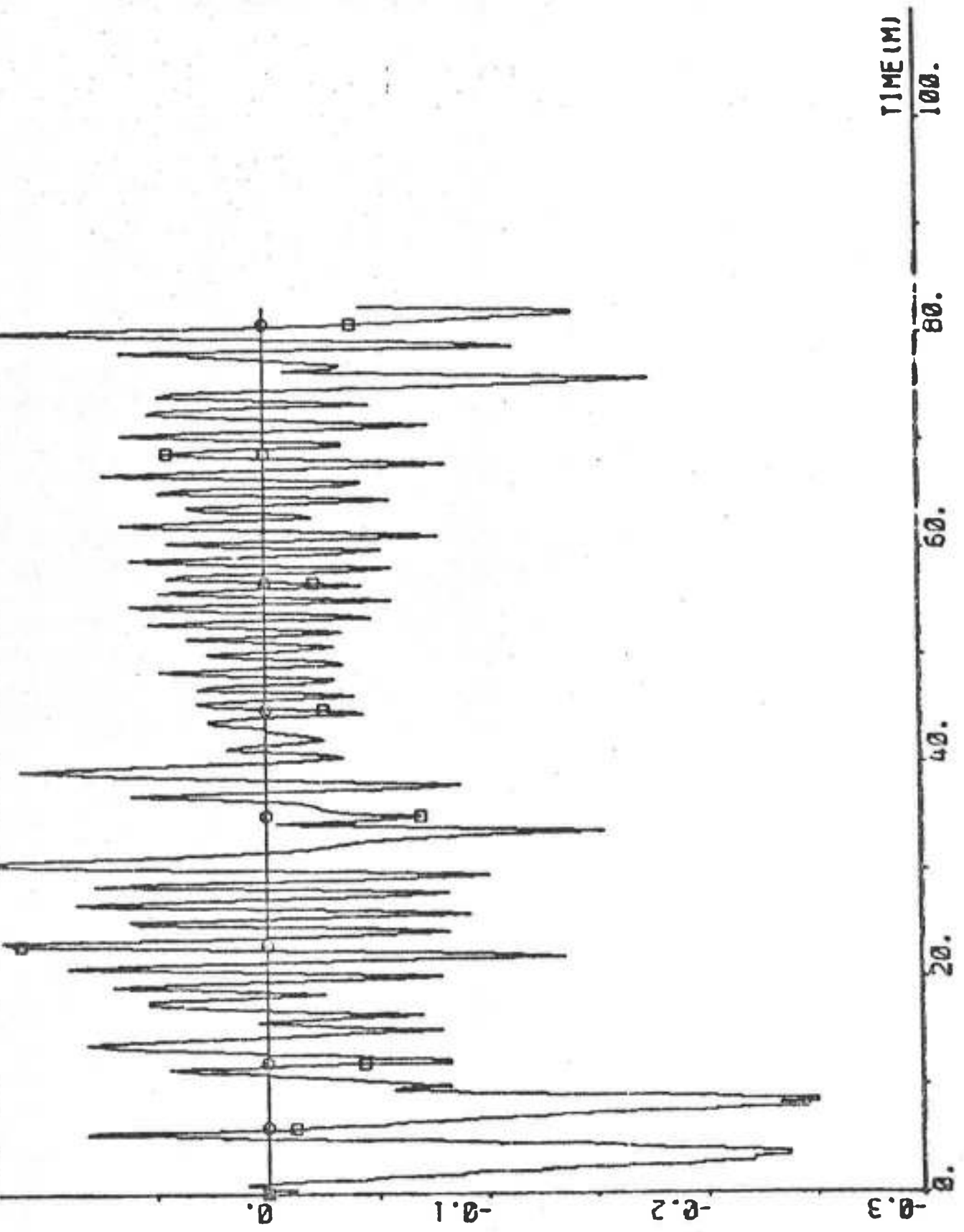
PL0T B2P1(15)+B2P1(10) ZERO -0.3 0.1 "R DEG/S



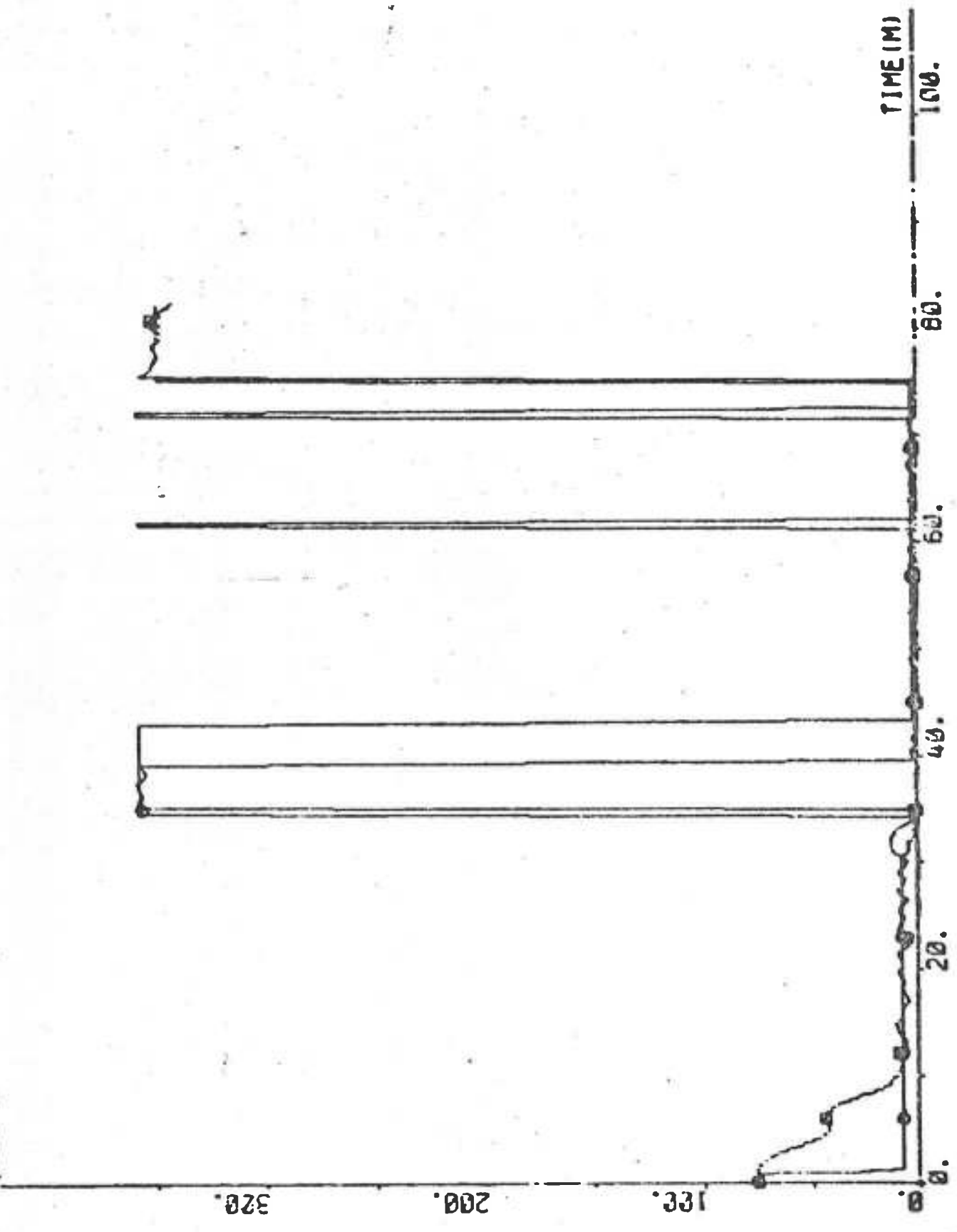
PLOT B2P1(15) B2P1(11) ZERO -0.3 0.1 -AVR DEG/S (BR=0.5)



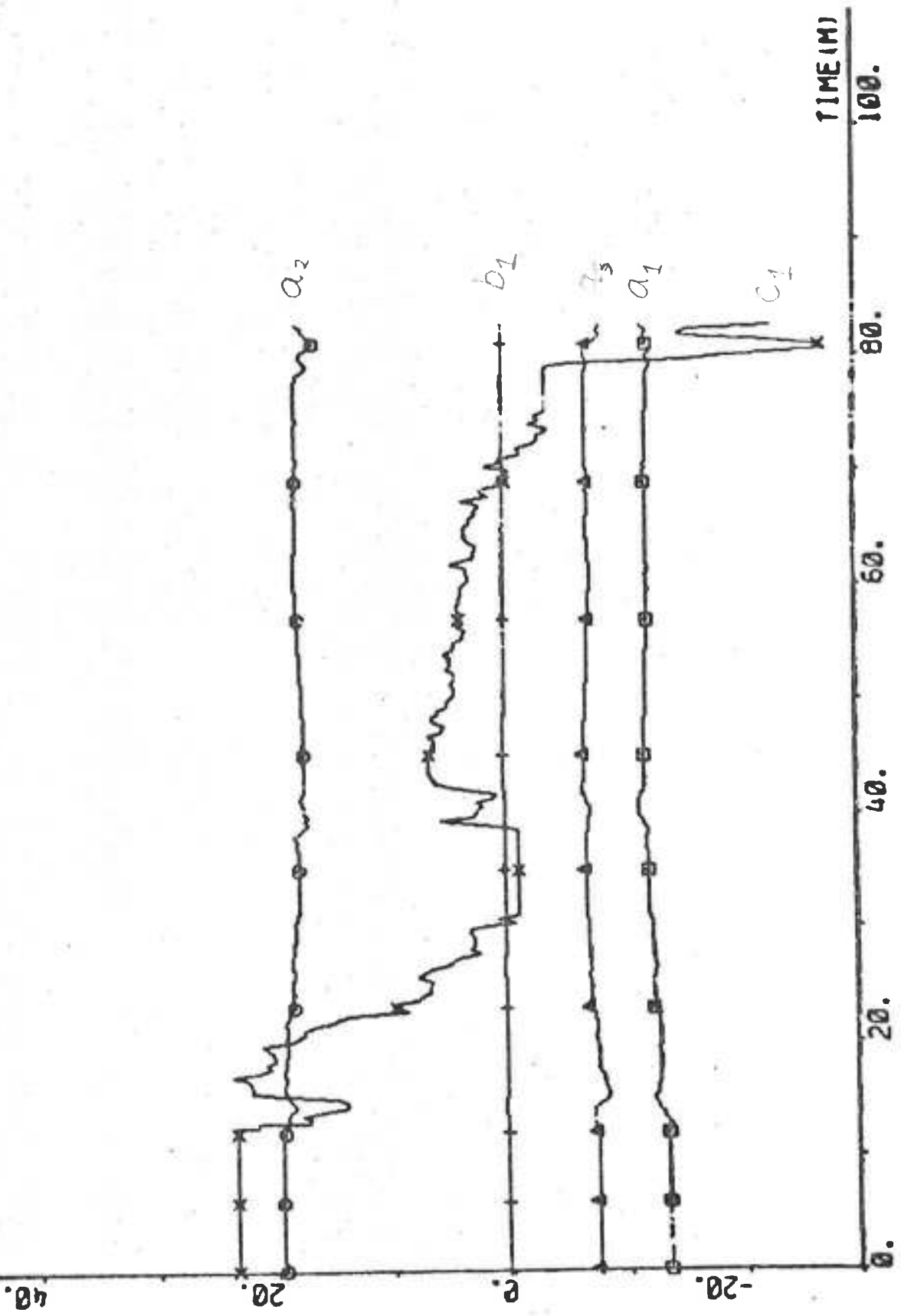
PLOT B2P1(15)~B2P1(12) ZERO -0.3 0.1 "DPSIDT DEG/S (IDPSI=5)



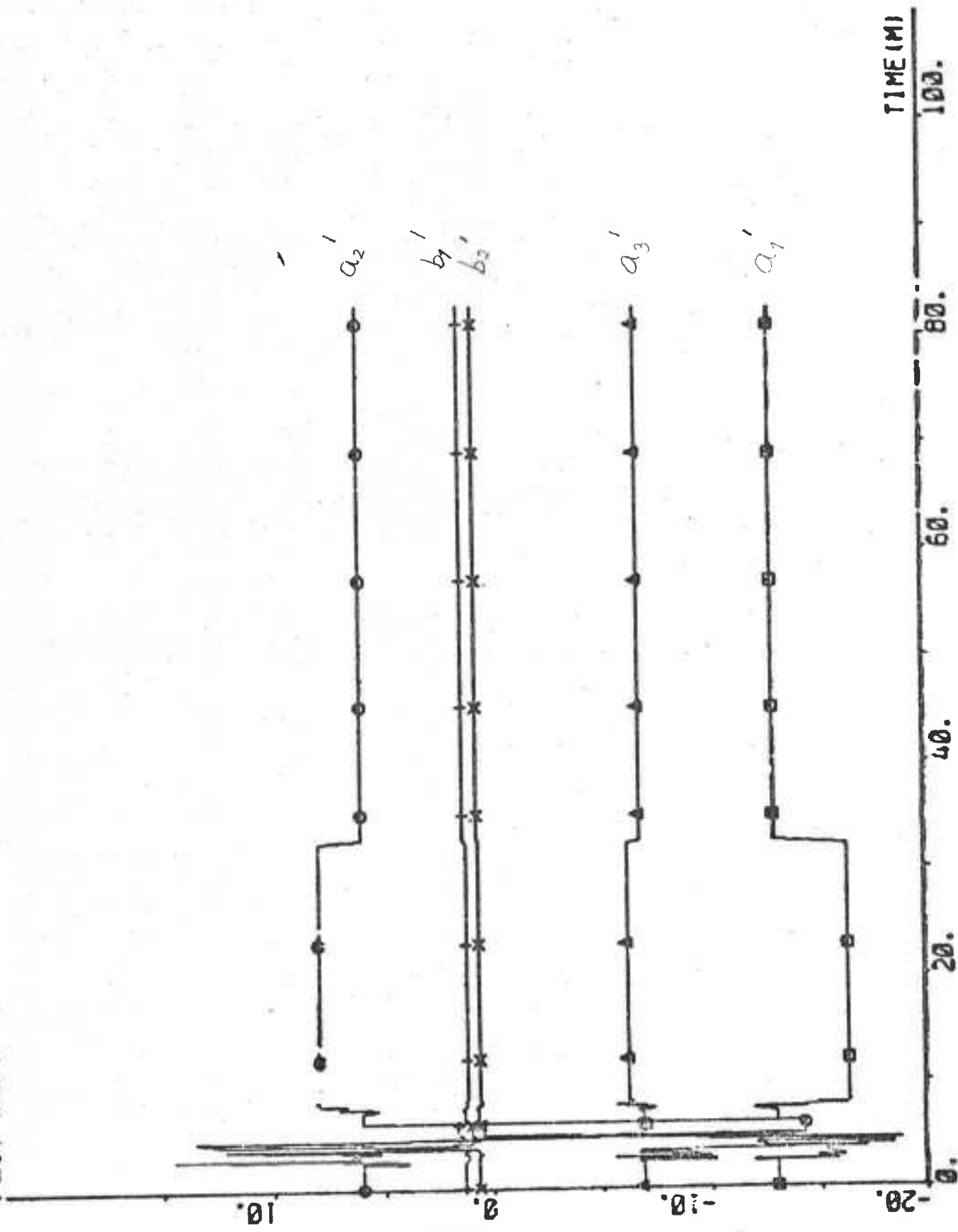
PLOT B2P1(15)→B2P1(13 14) @ 400 °PSI PSIREF DEG



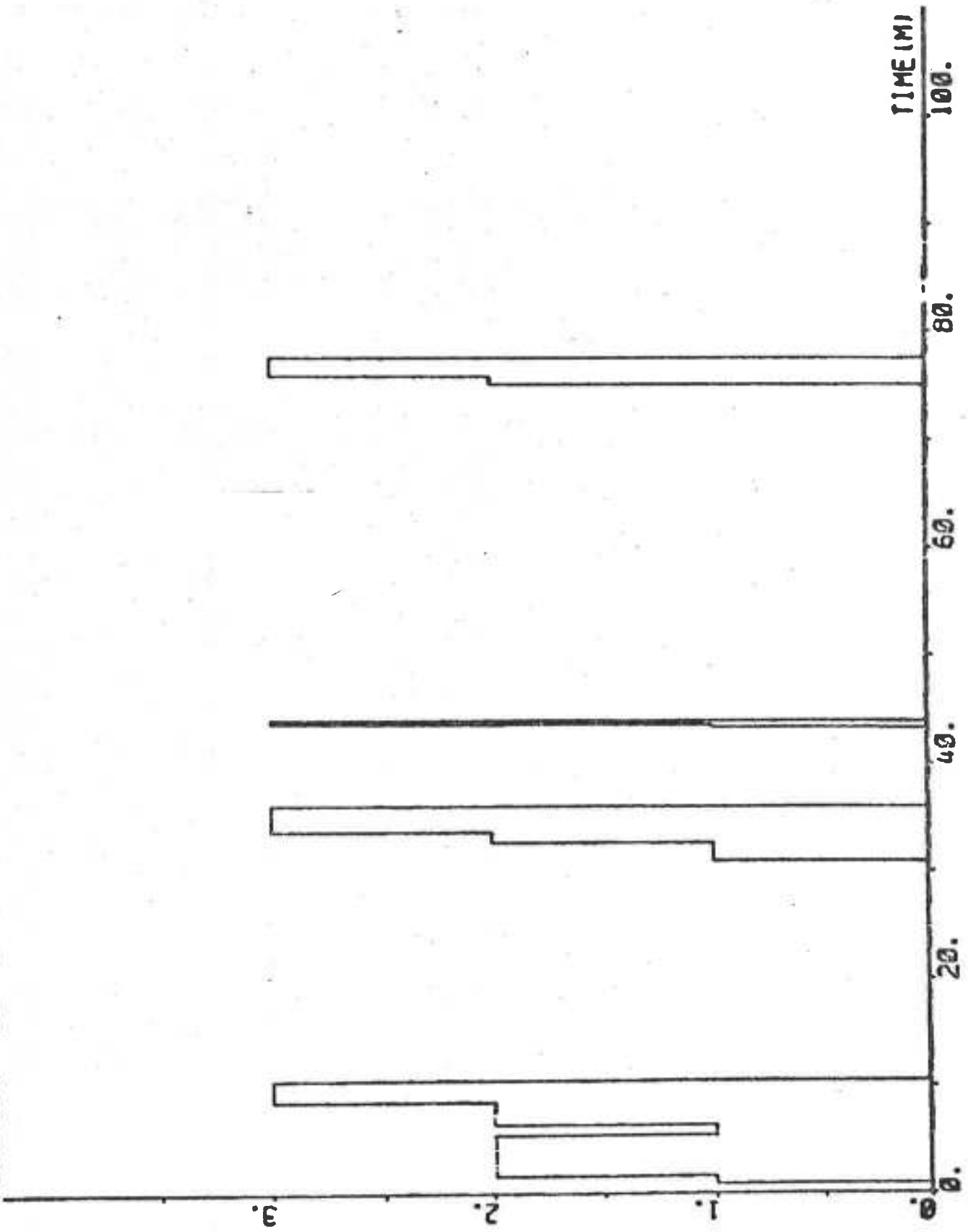
PLOT B2P1(15)•B2P2(1 2 3 4 5) -25 35 "REGULATOR PARAMETERS



PLOT B2P1(15) ← B2P2(6 7 8 9 10) -20 20 "YAW REGULATOR PARAMETERS



PLOT B2P1(15) HP B2P2(11) 0 4 "HODYAH



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

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

$$a_1 + a_2 + a_3 = 0.753$$

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

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

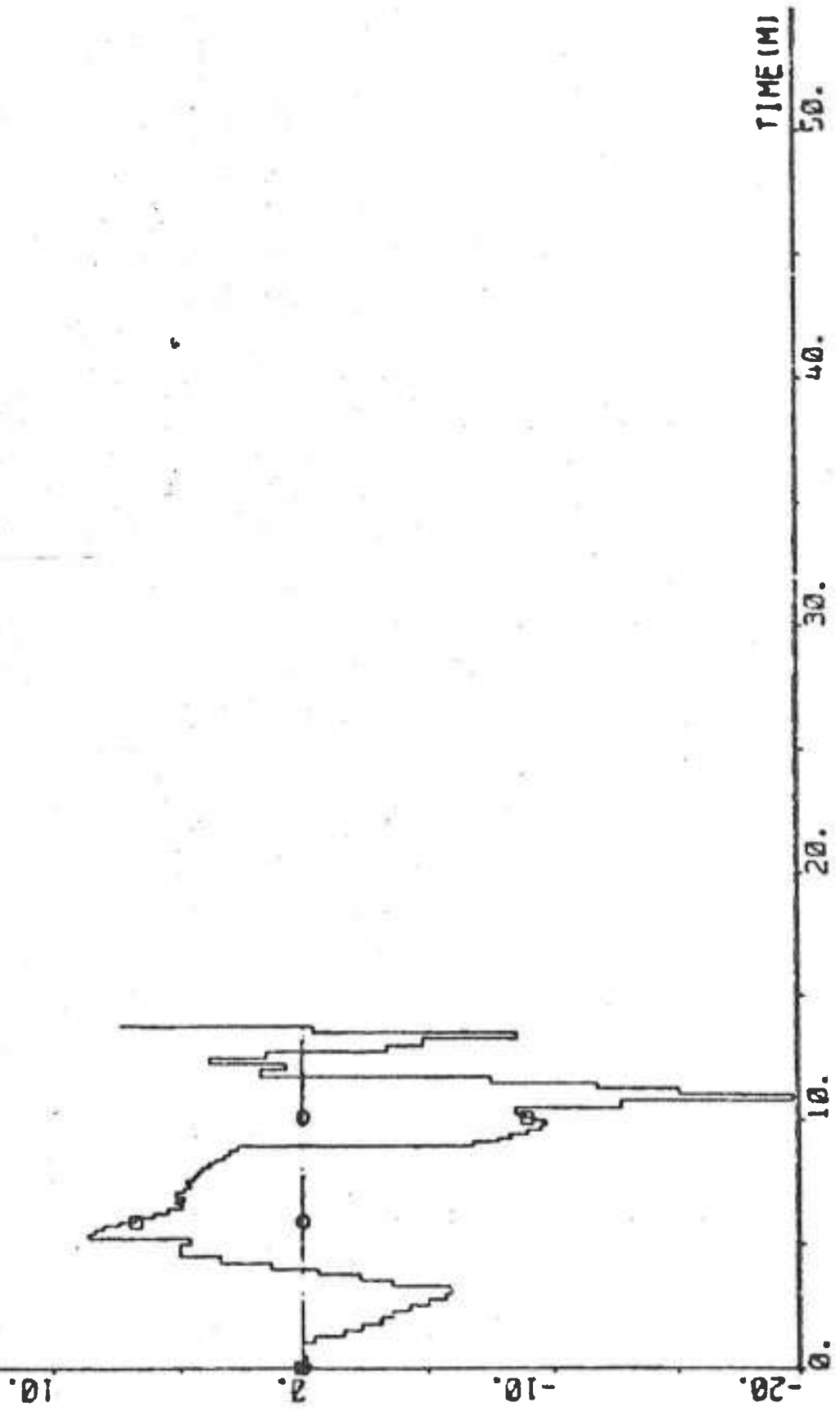
$$a'_1 + a'_2 + a'_3 = -13.75$$

Final yaw regulator values

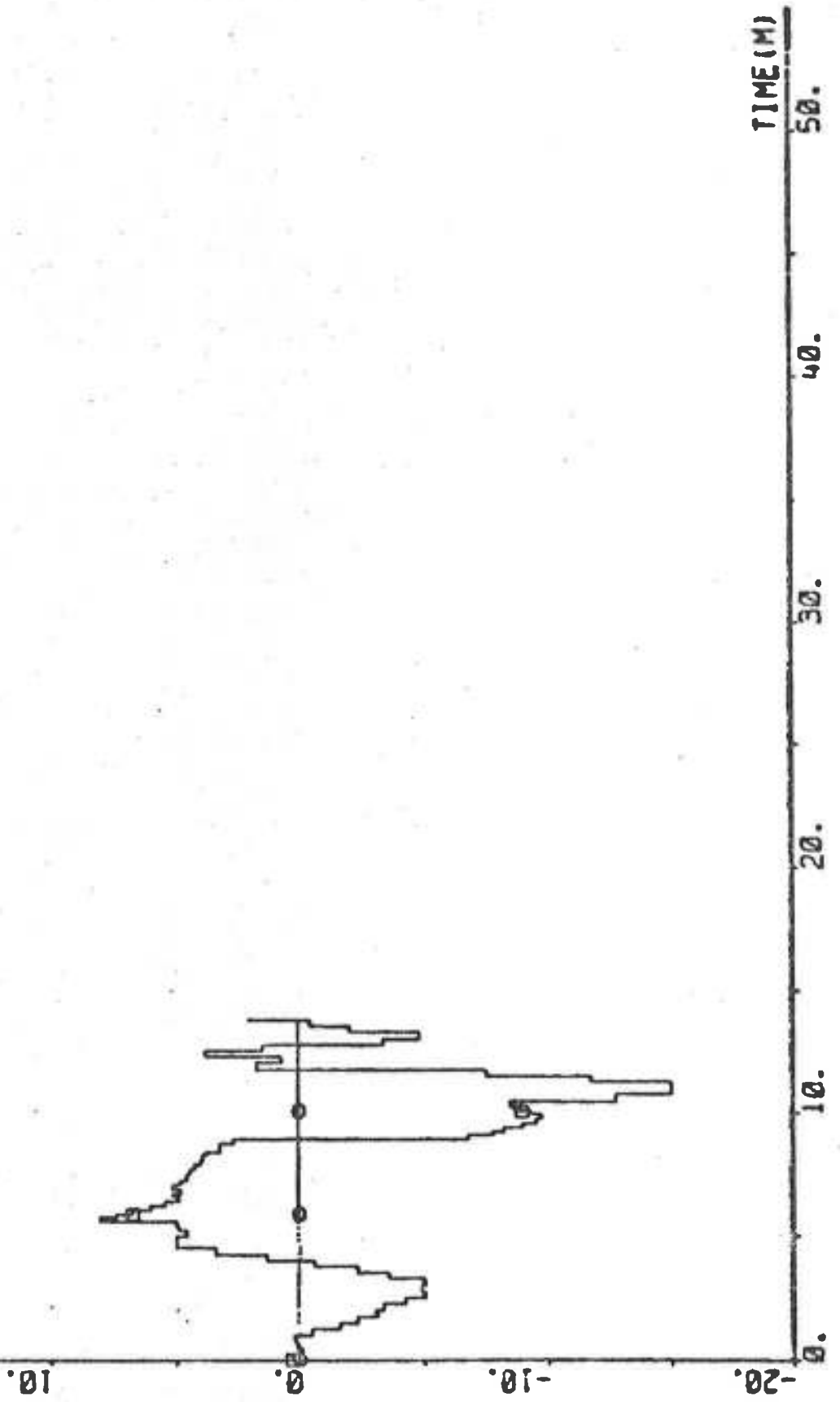
$$\begin{array}{l}
 \left[\begin{array}{c} a_1' \\ a_2' \\ a_3' \\ b_1' \\ b_2' \end{array} \right] = \left[\begin{array}{c} -14.088 \\ 6.178 \\ -5.834 \\ 1.324 \\ 0.652 \end{array} \right] \quad PY = \left[\begin{array}{cccccc}
 671.445 & & & & & \\
 -498.822 & 1257.655 & & & & \\
 -139.348 & -456.727 & 1038.426 & & & \\
 -17.265 & -28.618 & 1.036 & 6.997 & & \\
 -12.495 & -23.926 & -5.841 & 4.515 & 7.122 &
 \end{array} \right]
 \end{array}$$

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

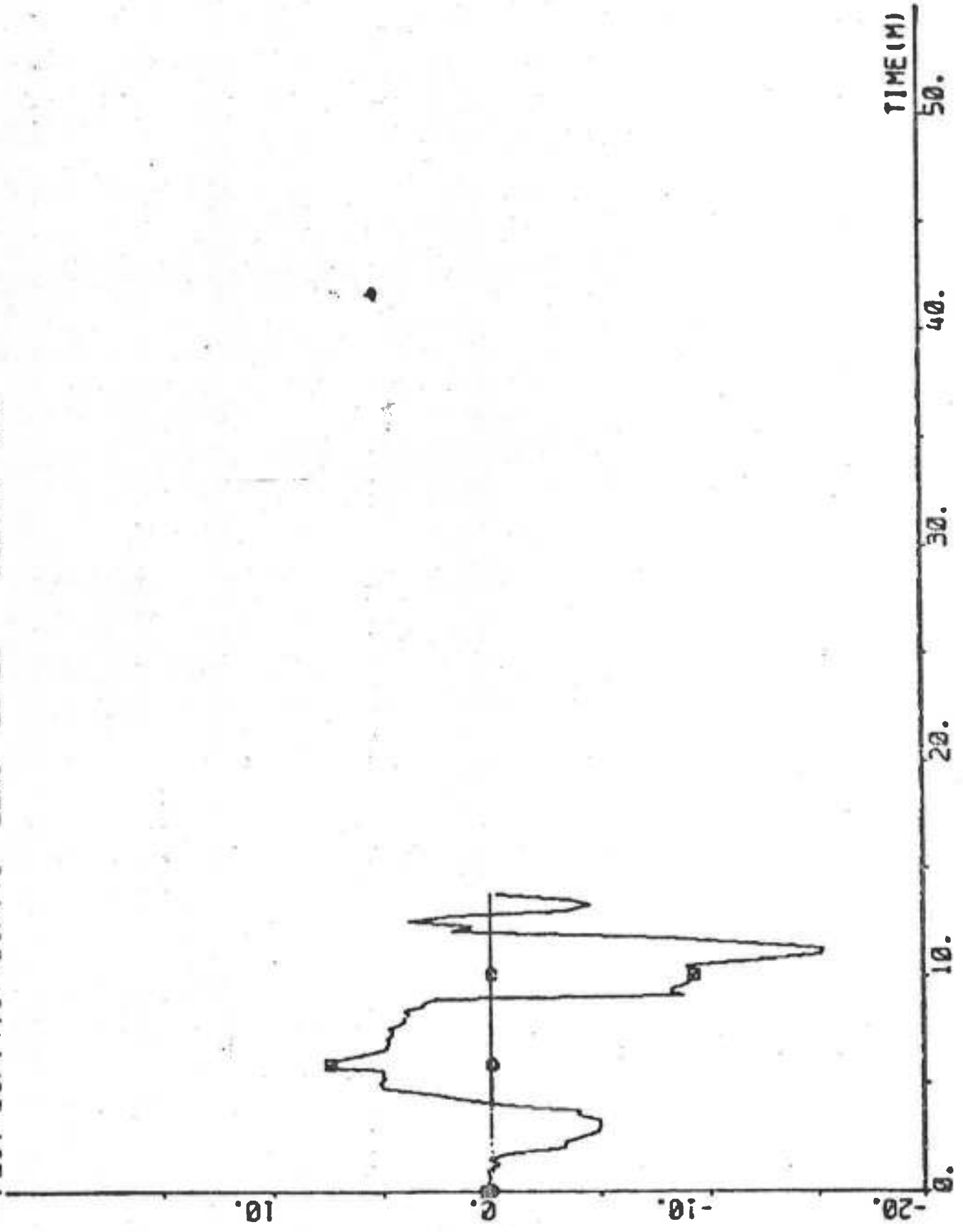
PLOT B3P1(15) HP B3P1(1) ZERO -20 20 DELCOC DEG



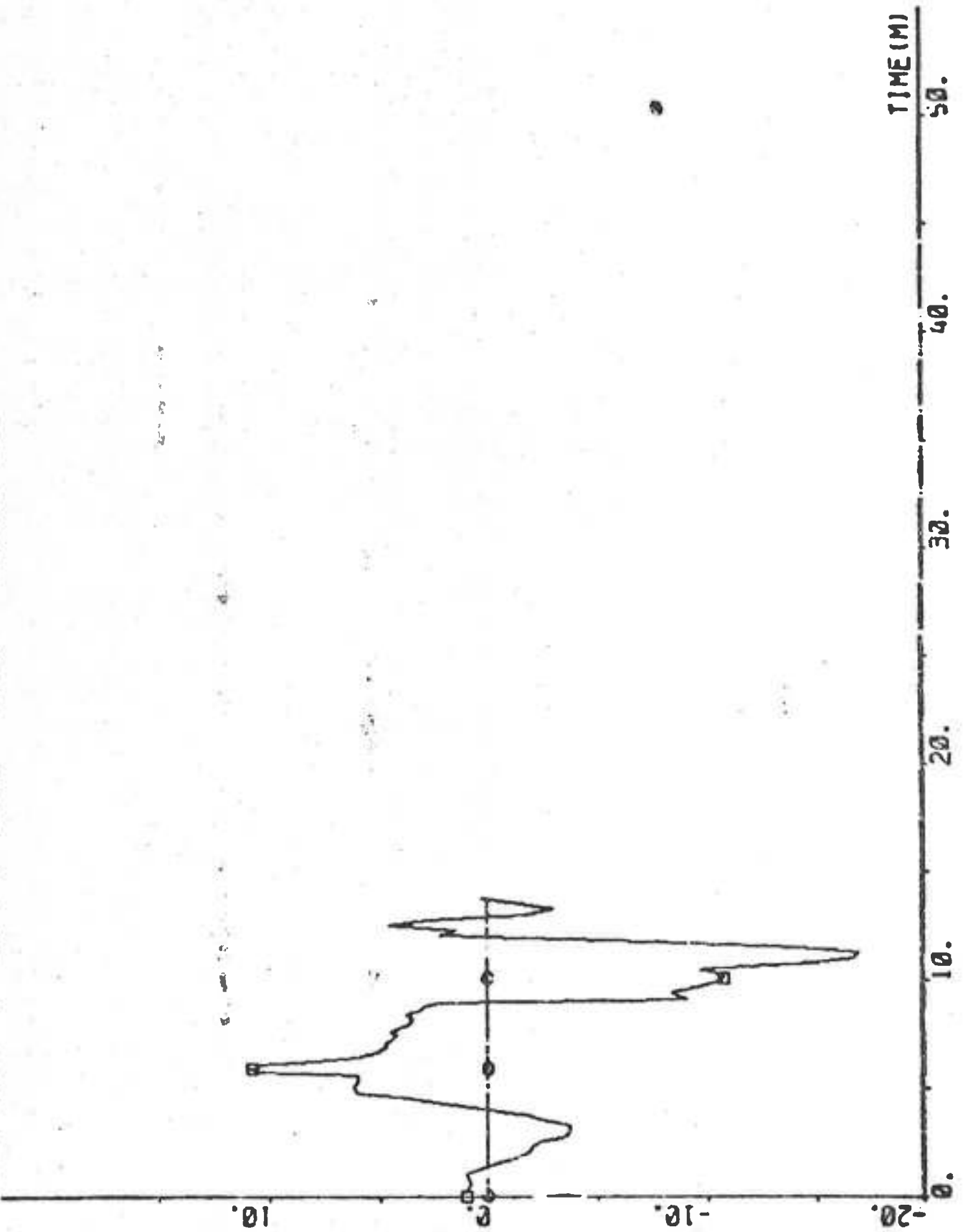
PLOT B3P1(15)+HP B3P1(2) ZERO -20 20 DELCOM DEG



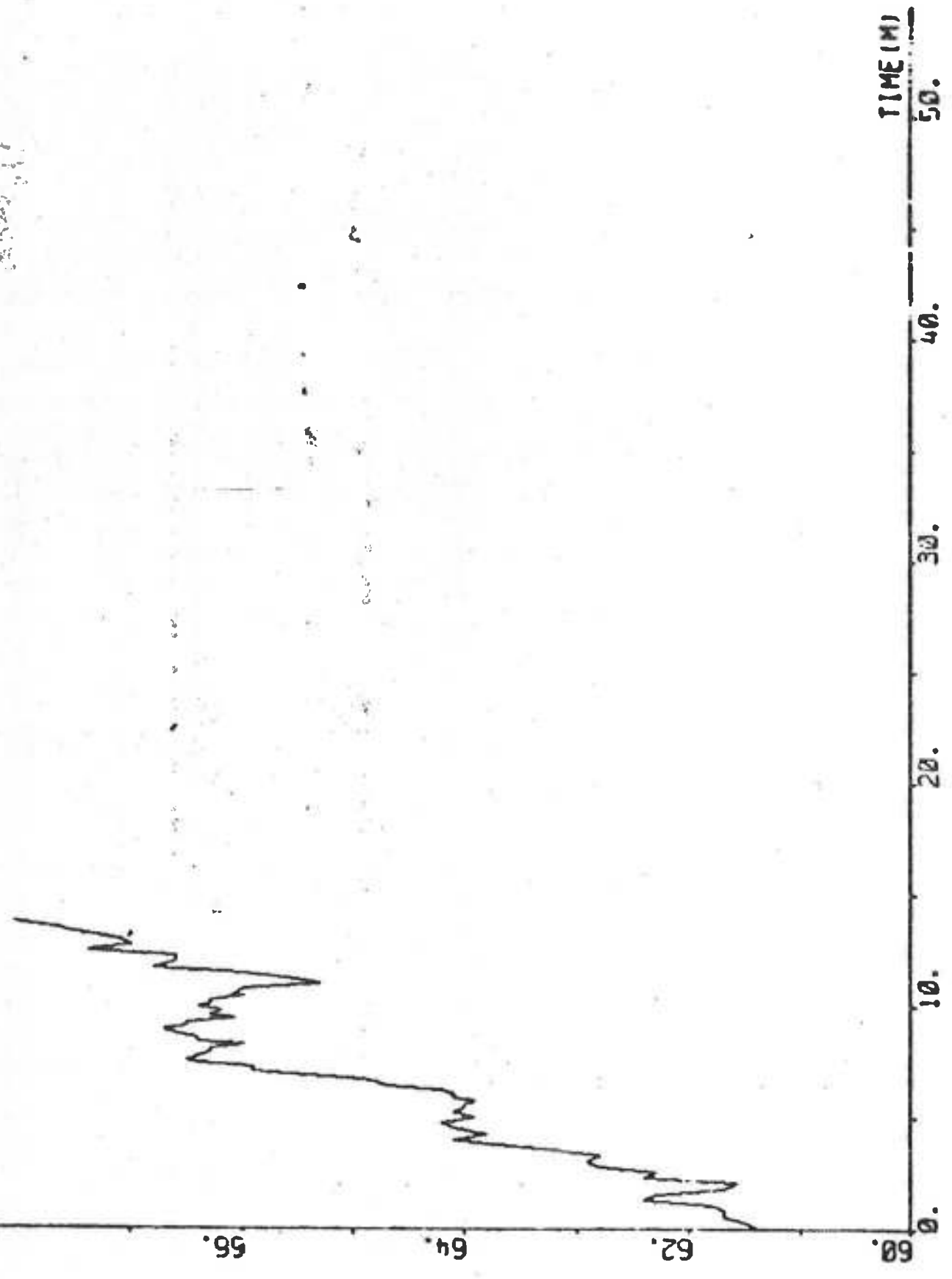
PLOT B3P1(16)+B3P1(3) ZERO -20 20 "DELTAS DEG



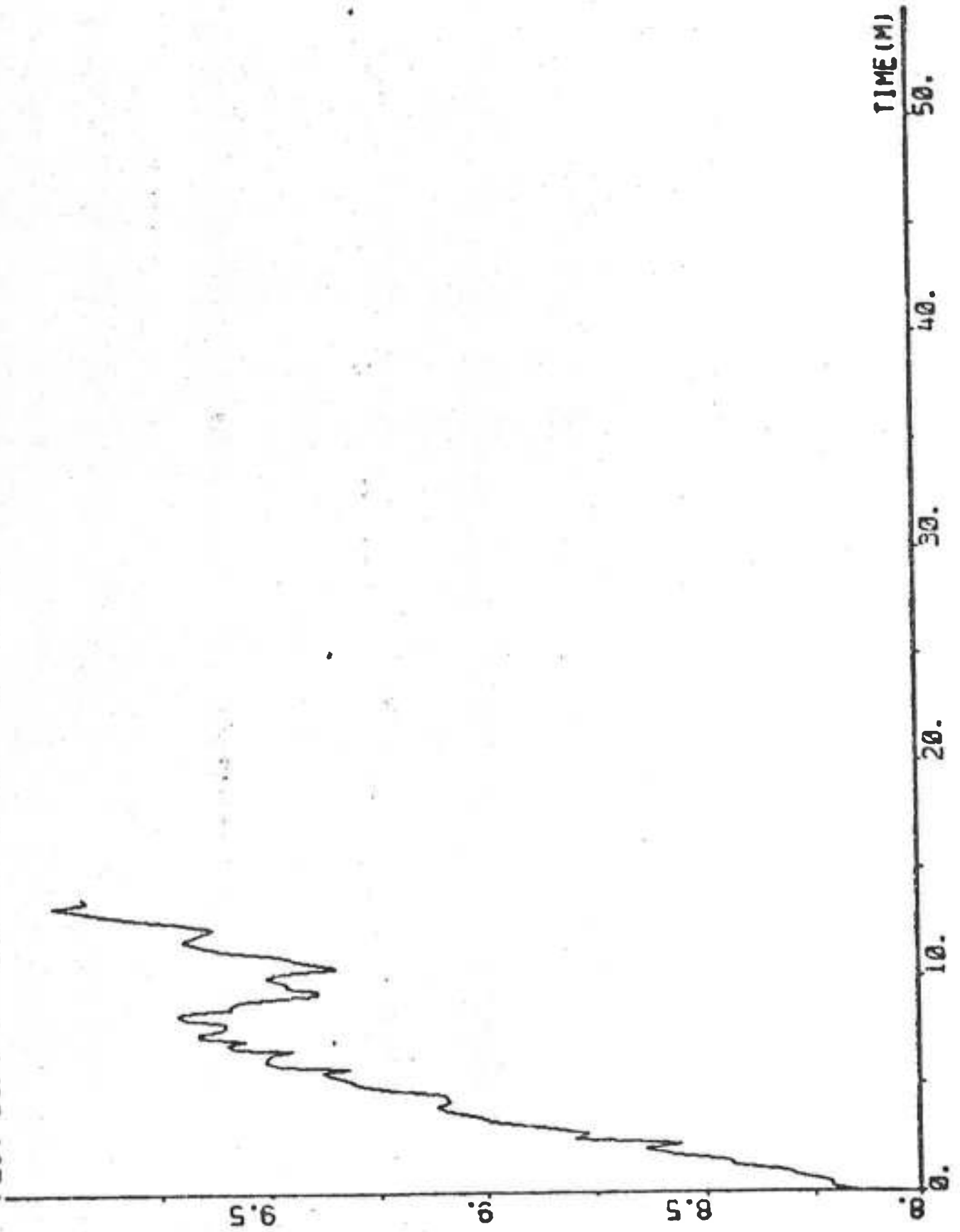
PLOT B3P1(15) ← B3P1(4) ZERO -20 20 ° DELTA DEG



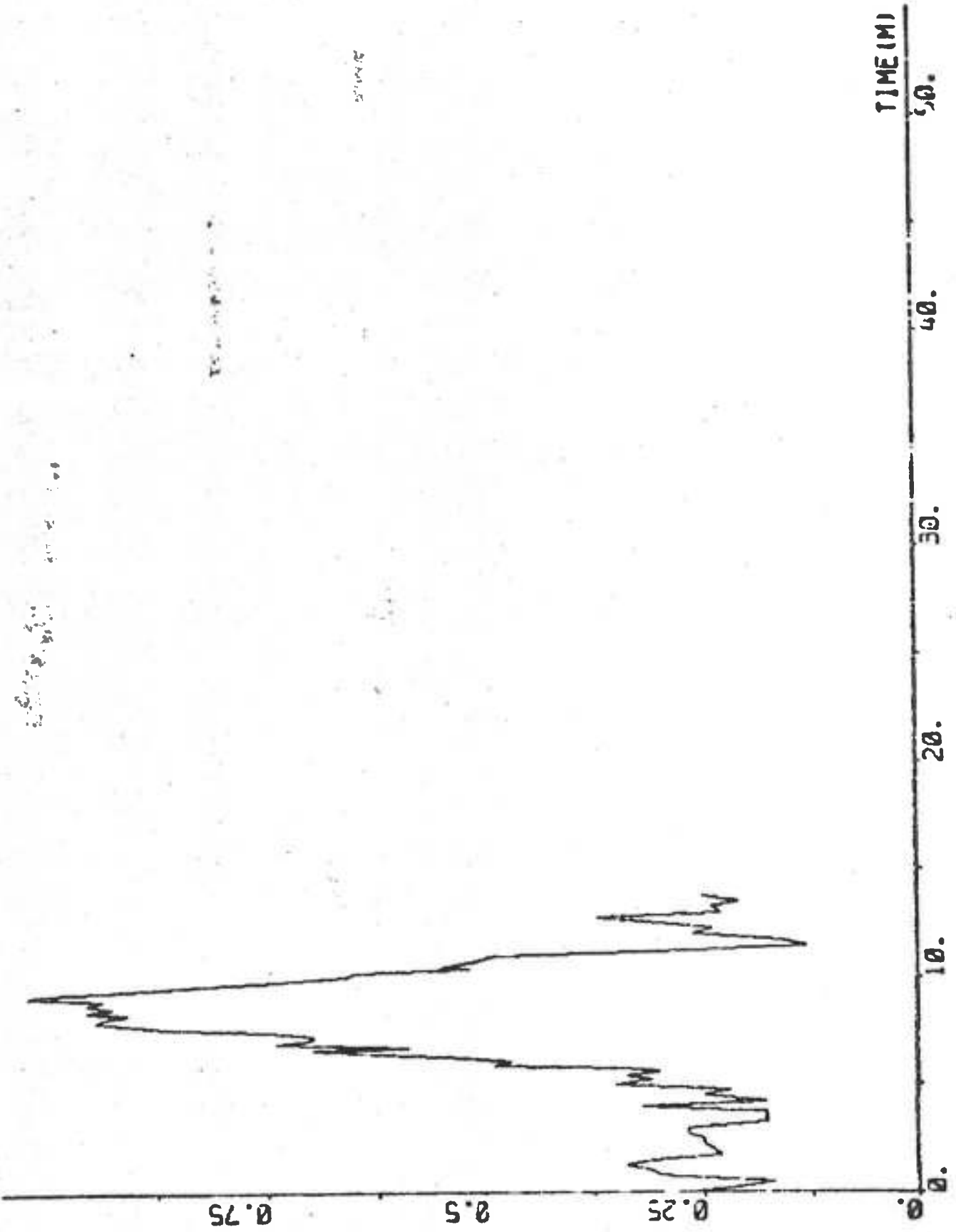
PLOT B3PI (15) - B3PI (6) 60 68 "AN RPM



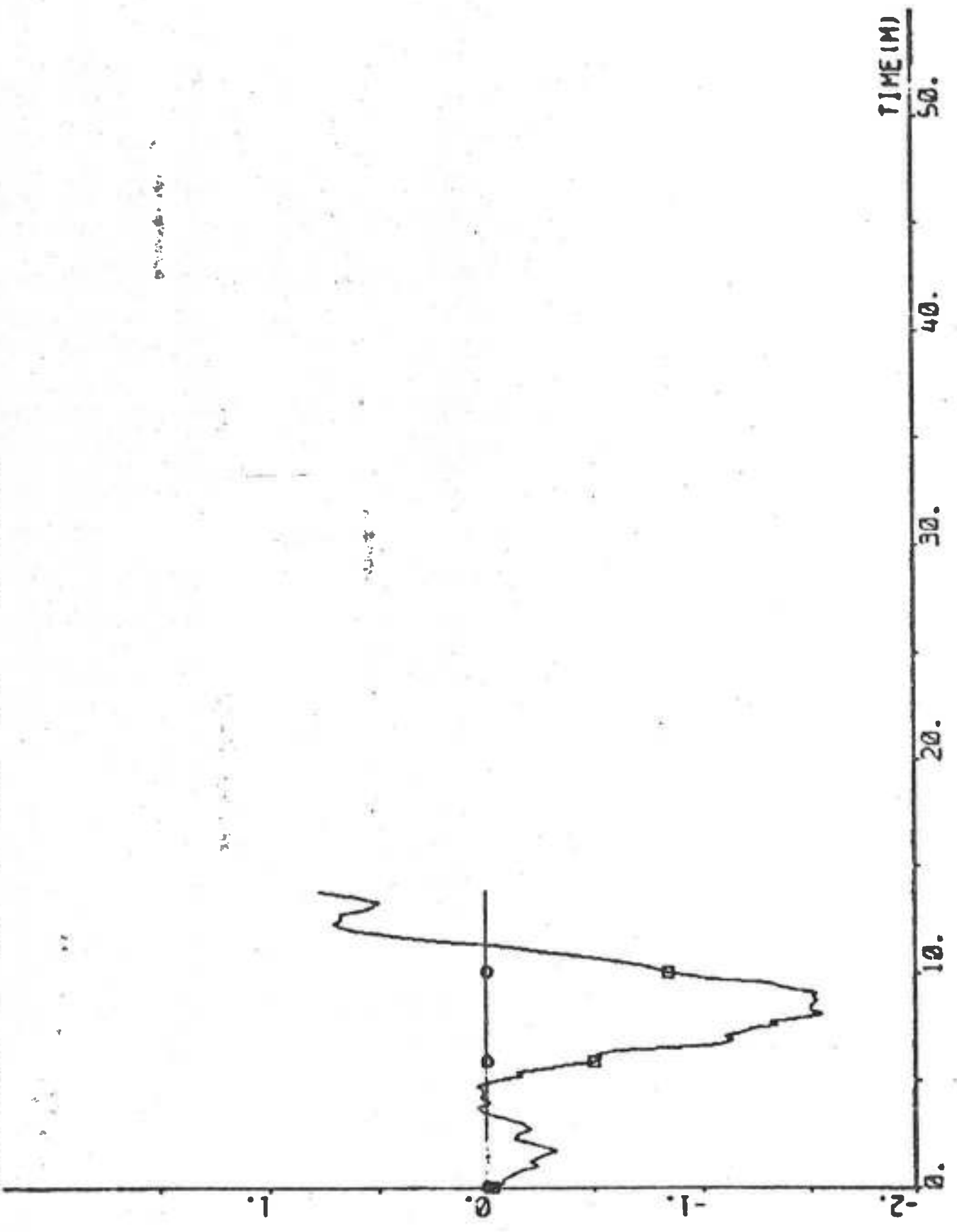
PLOT B3P1(15) - B3P1(7) @ 10 "U KNOTS



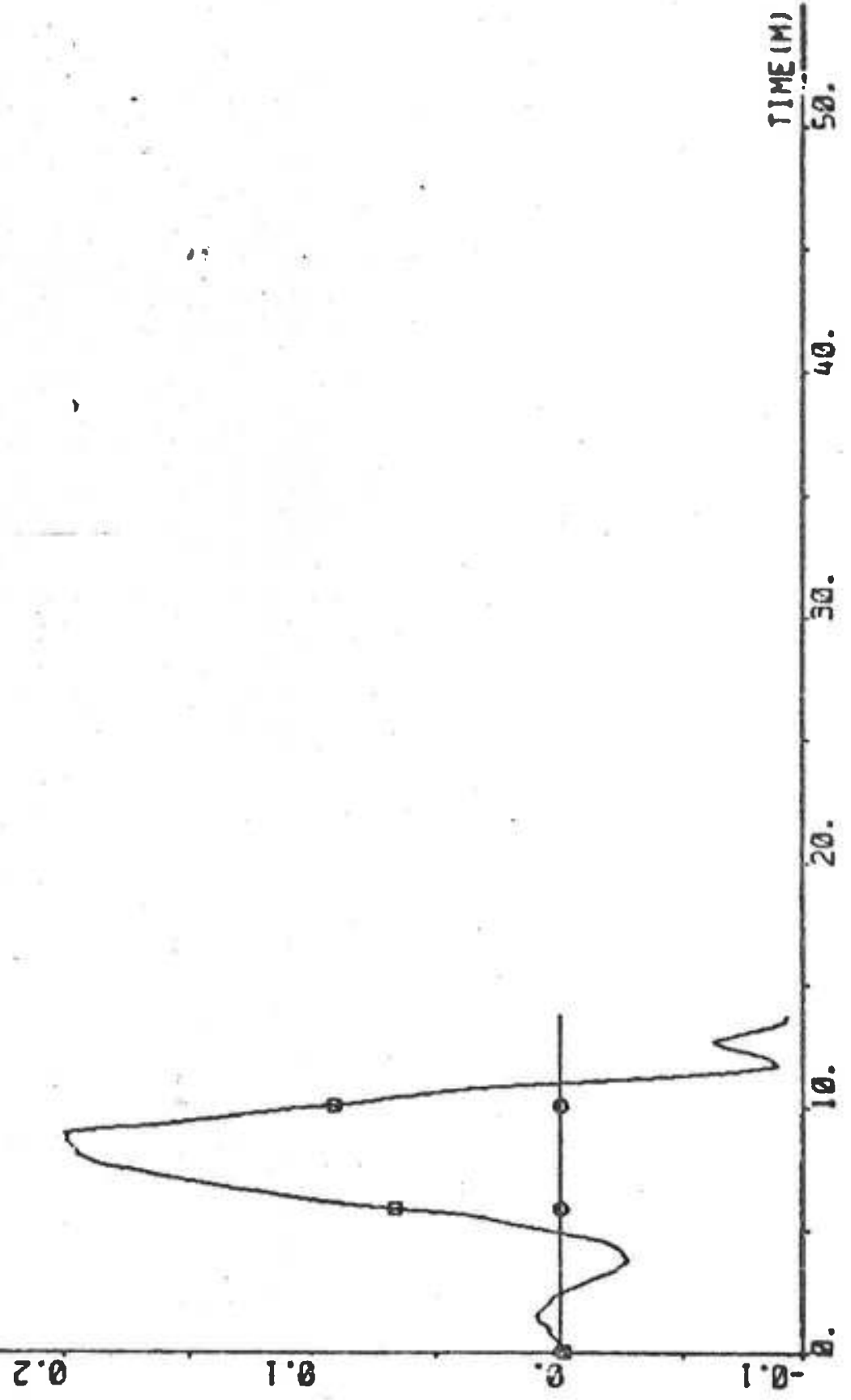
PLOT B3P1(15)-B3P1(8) @ 1 "V1 KNOTS



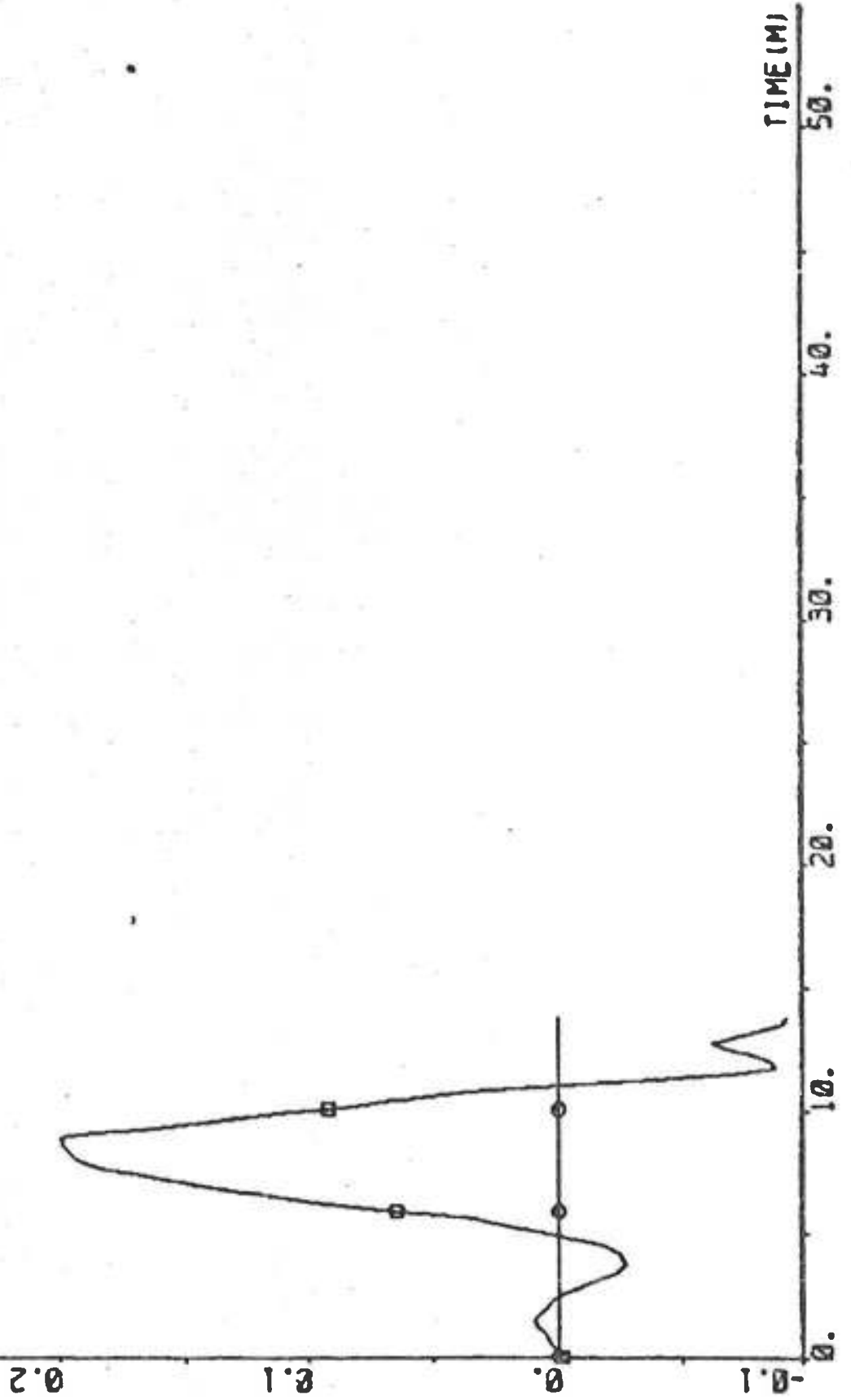
PL0T B3P1(15) B3P1(9) ZERO -2 2 -V2 KNOTS



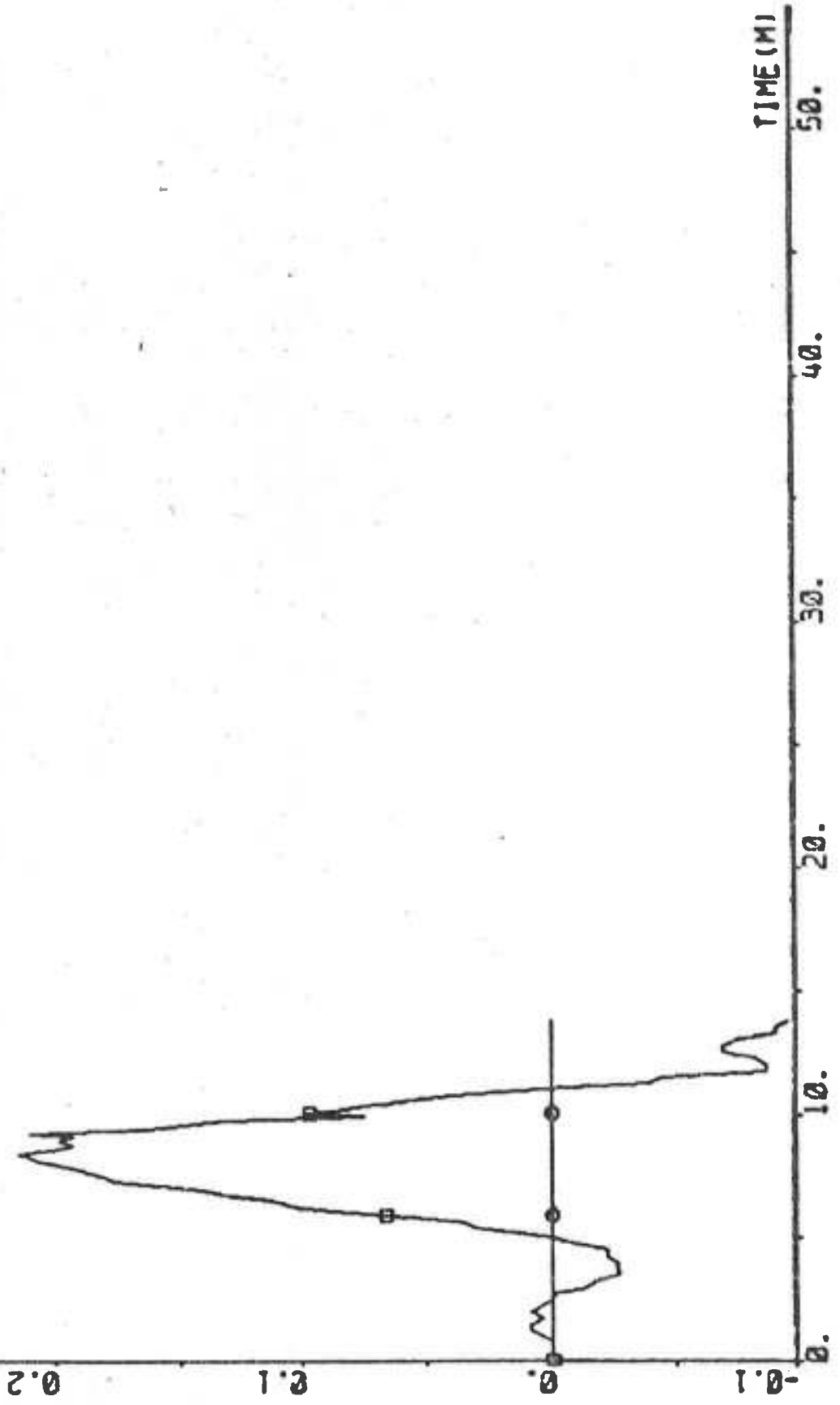
PLOT B3P1(15)-B3P1(10) ZERO -0.1 0.3 "R DEG/S



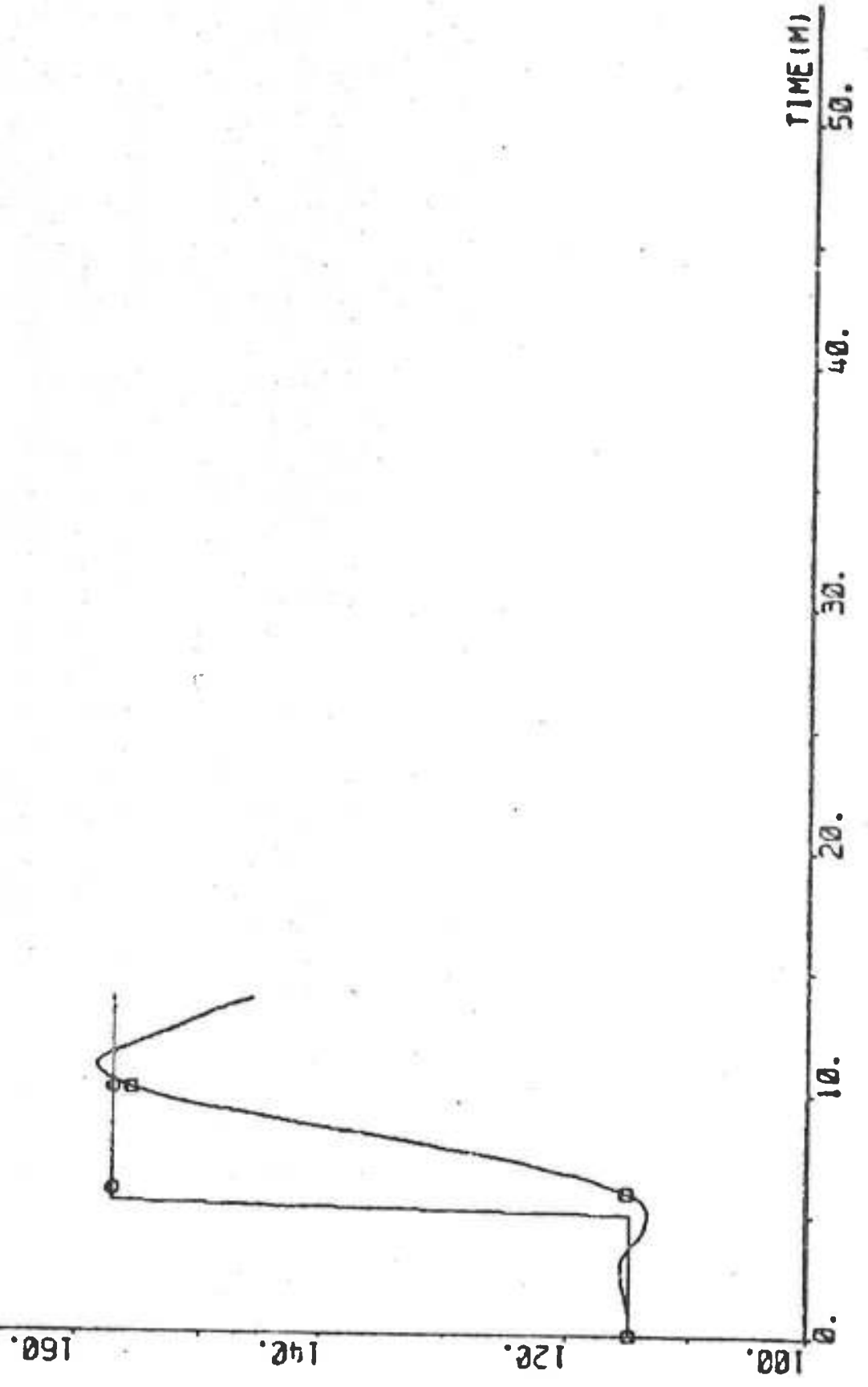
PLOT B3P1(15)-B3P1(11) ZERO -0.1 0.3 "AVR DEC/S (BR=0.5)



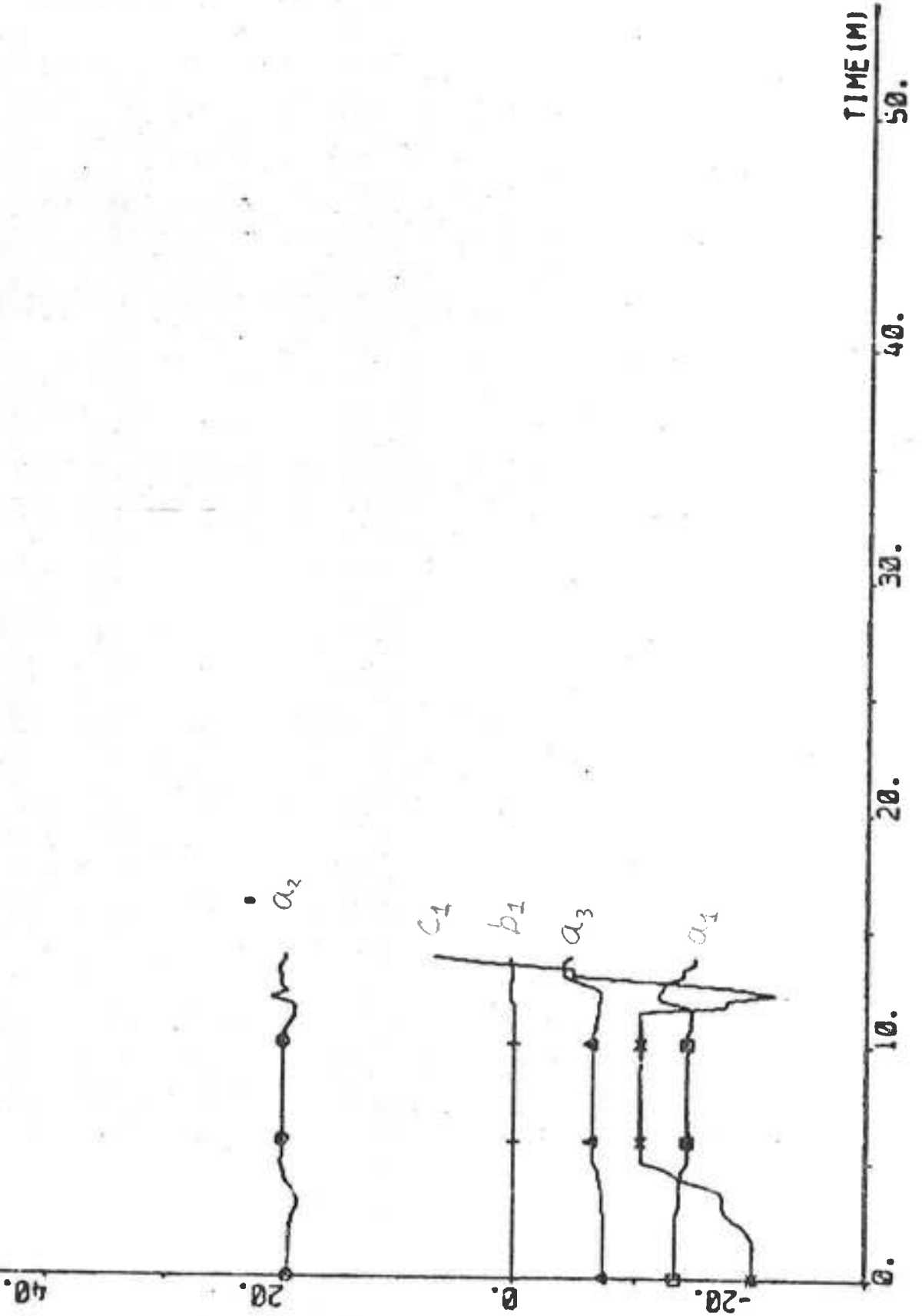
PLOT B3P1(15) - B3P1(12) ZERO -0.1 0.3 -DPS10T DEG/S (IDPS1.05)



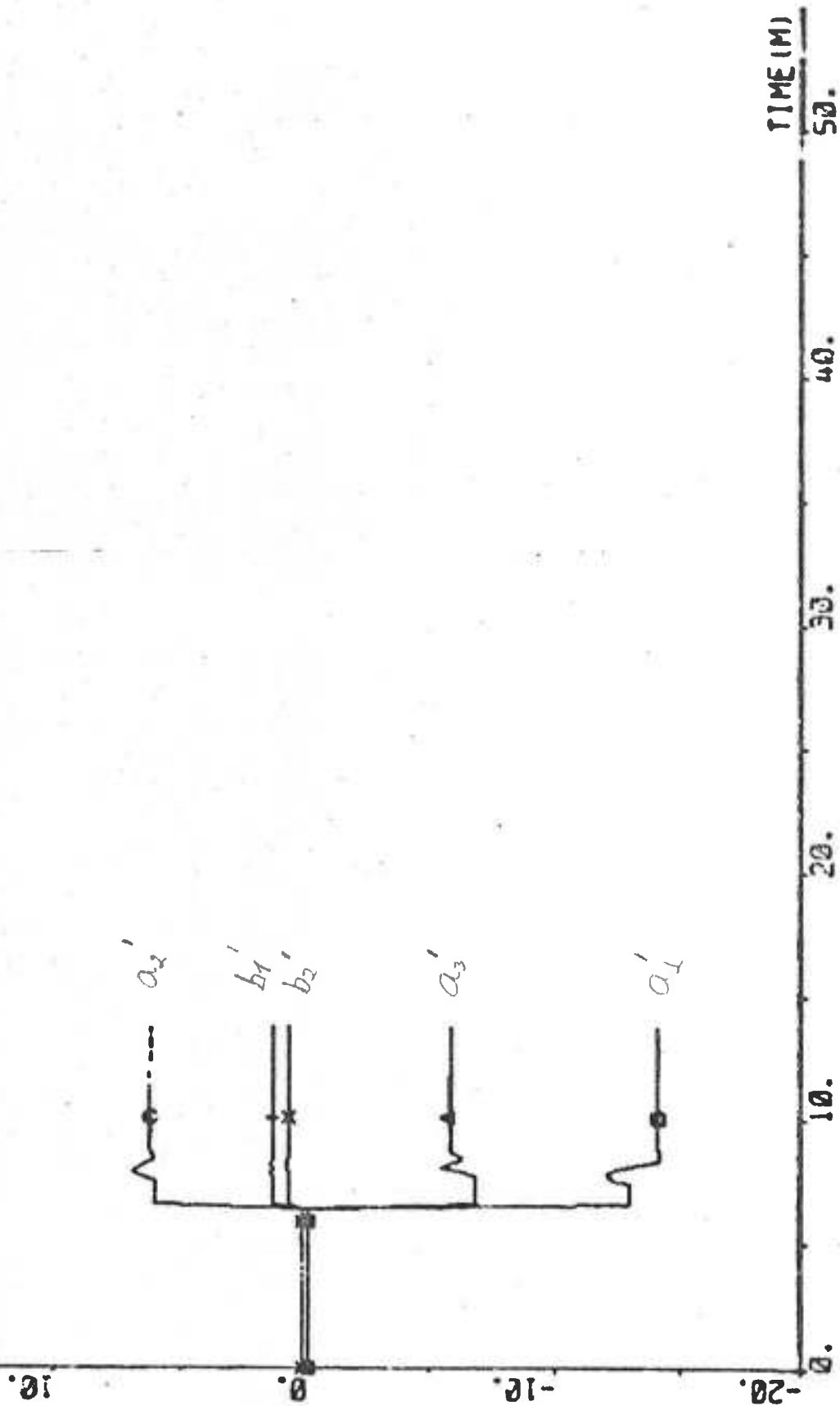
PLOT B3P1(15)~B3P1(13 14) 100 180 °PSI PSIREF DEG



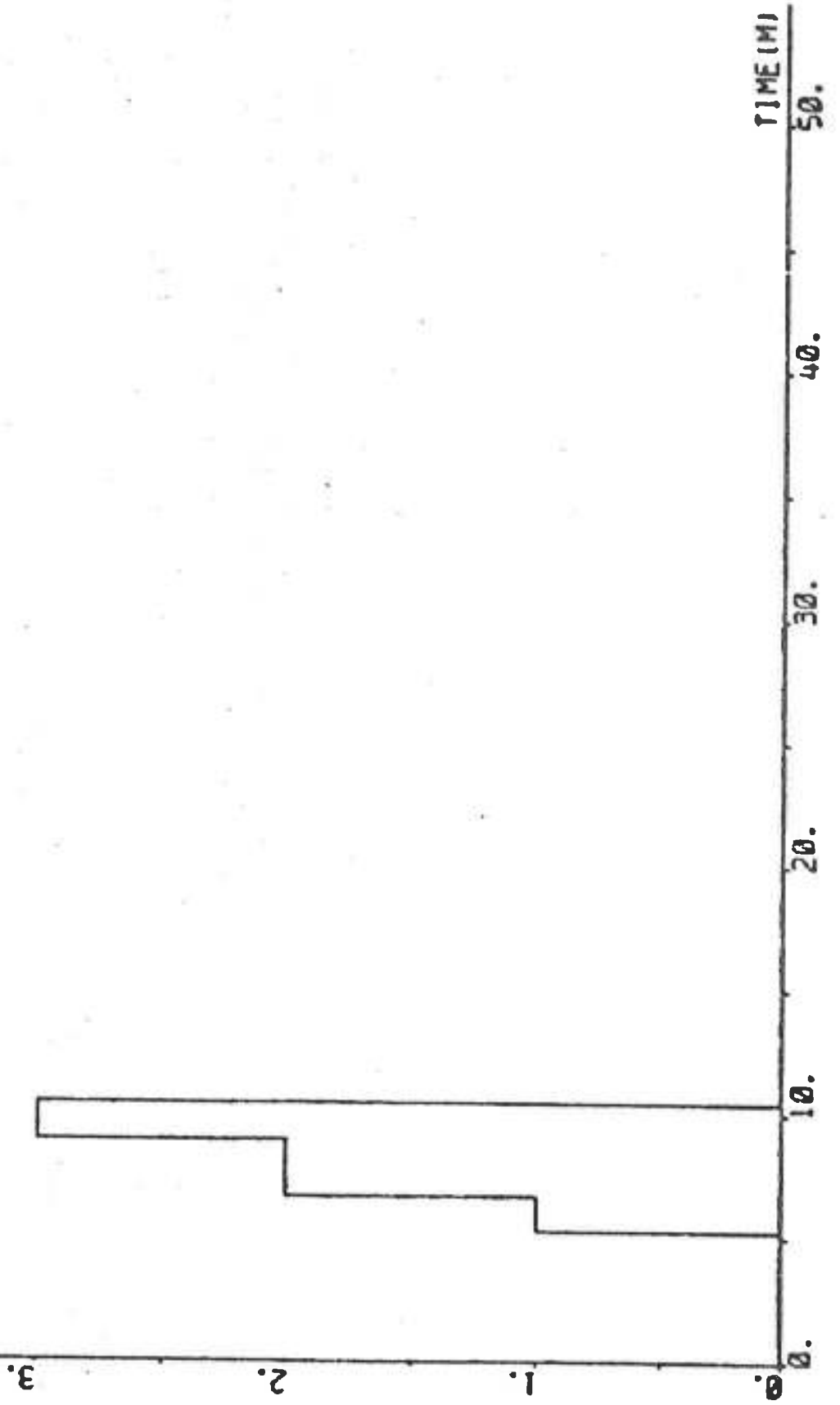
PLOT B3P1(16)-B3P2(1 2 3 4 5) -25 35 "REGULATOR PARAMETERS



PLOT B3P1(15)-B3P2(6 7 8 9 10) -20 20 "YAW REGULATOR PARAMETERS



PLOT B3P1(15)-HP B3P2(11) 0 4 "MOOYAN



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
DEL1M 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

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

$$a_1 + a_2 + a_3 = - 2.240$$

Yaw regulator structure

NAY = 3	NBY = 2	KY = 5
IREGY = 10	RLY = 0.95	IRR = 1
AK1V = 40	AK2V = 1.4	AK3V = 115
ClV = 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

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

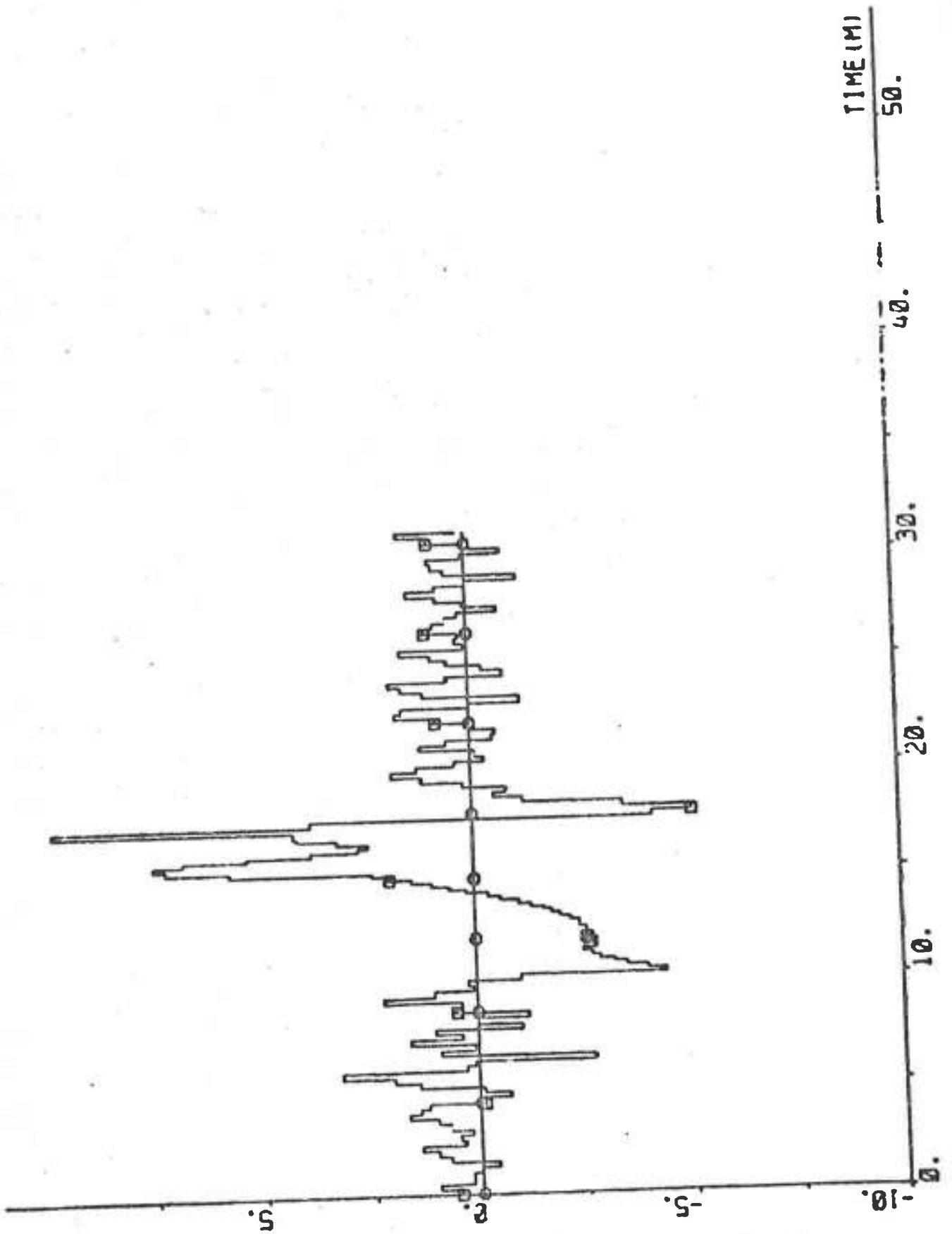
$$a_1^i + a_2^i + a_3^i = - 13.75$$

Final yaw regulator values

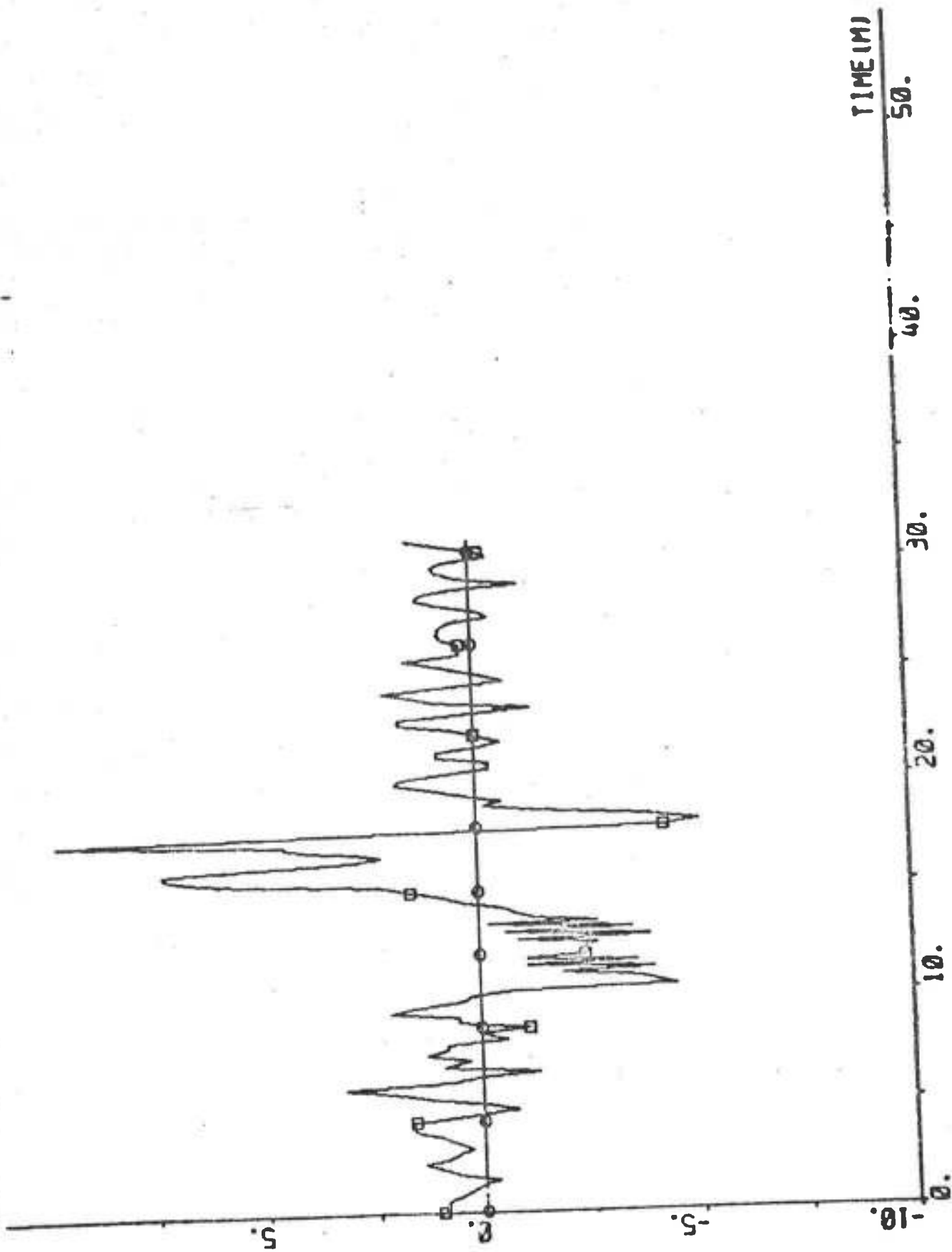
$$\begin{array}{l}
 \left[\begin{array}{l} a_1' \\ a_2' \\ a_3' \\ b_1' \\ b_2' \end{array} \right] = \left[\begin{array}{l} -14.616 \\ 6.853 \\ -7.220 \\ 1.237 \\ 0.595 \end{array} \right] \quad \text{PY} = \left[\begin{array}{l} 1229.793 \\ -943.045 \quad 2397.505 \\ -185.826 \quad -1000.036 \quad 1518.064 \\ -26.980 \quad -57.732 \quad -4.159 \quad 11.491 \\ -23.215 \quad -44.126 \quad -19.200 \quad 8.270 \quad 10.884 \end{array} \right]
 \end{array}$$

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

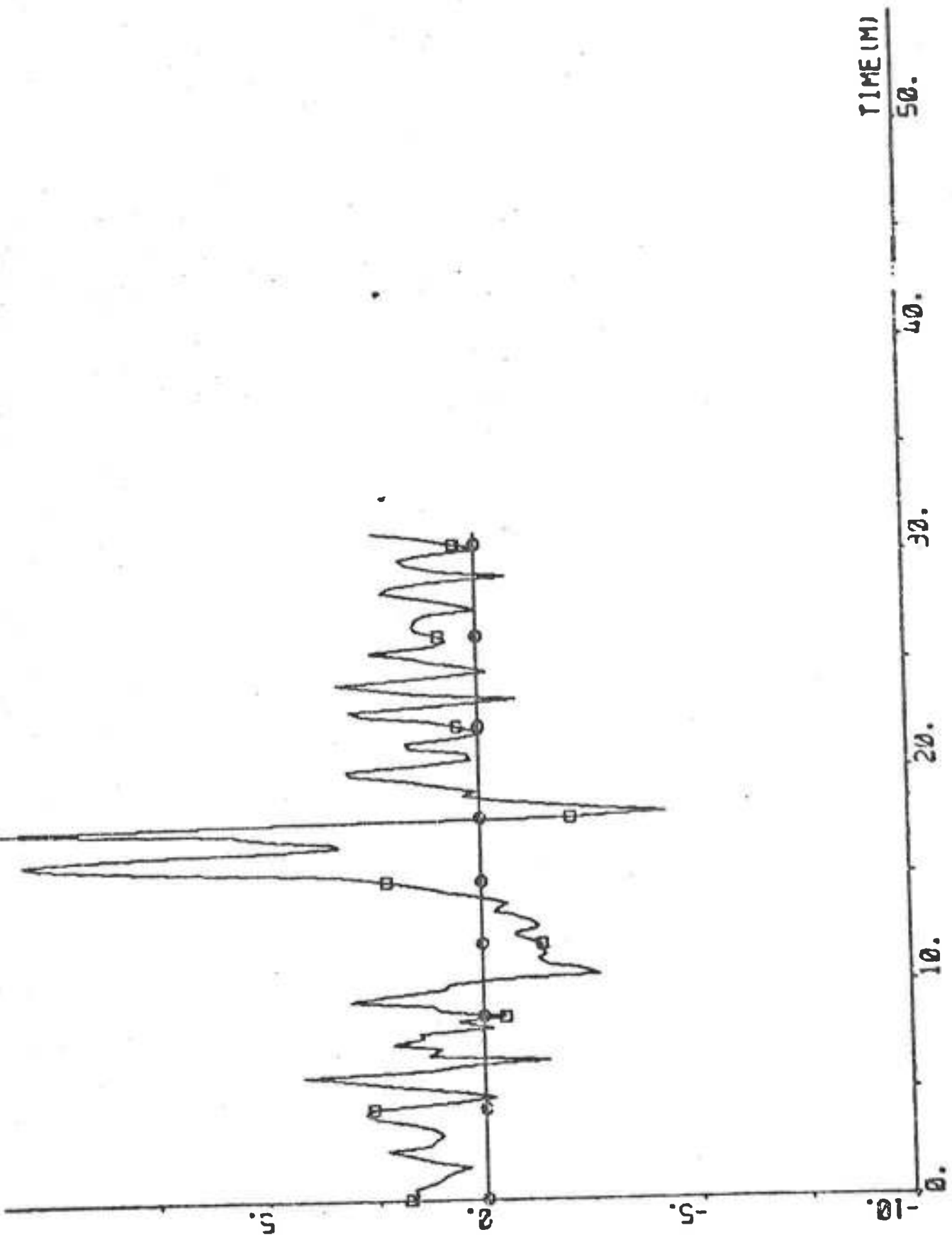
PLOT B4P1(15) HP B4P1(1) ZERO -18 10 "DELCOC DEG



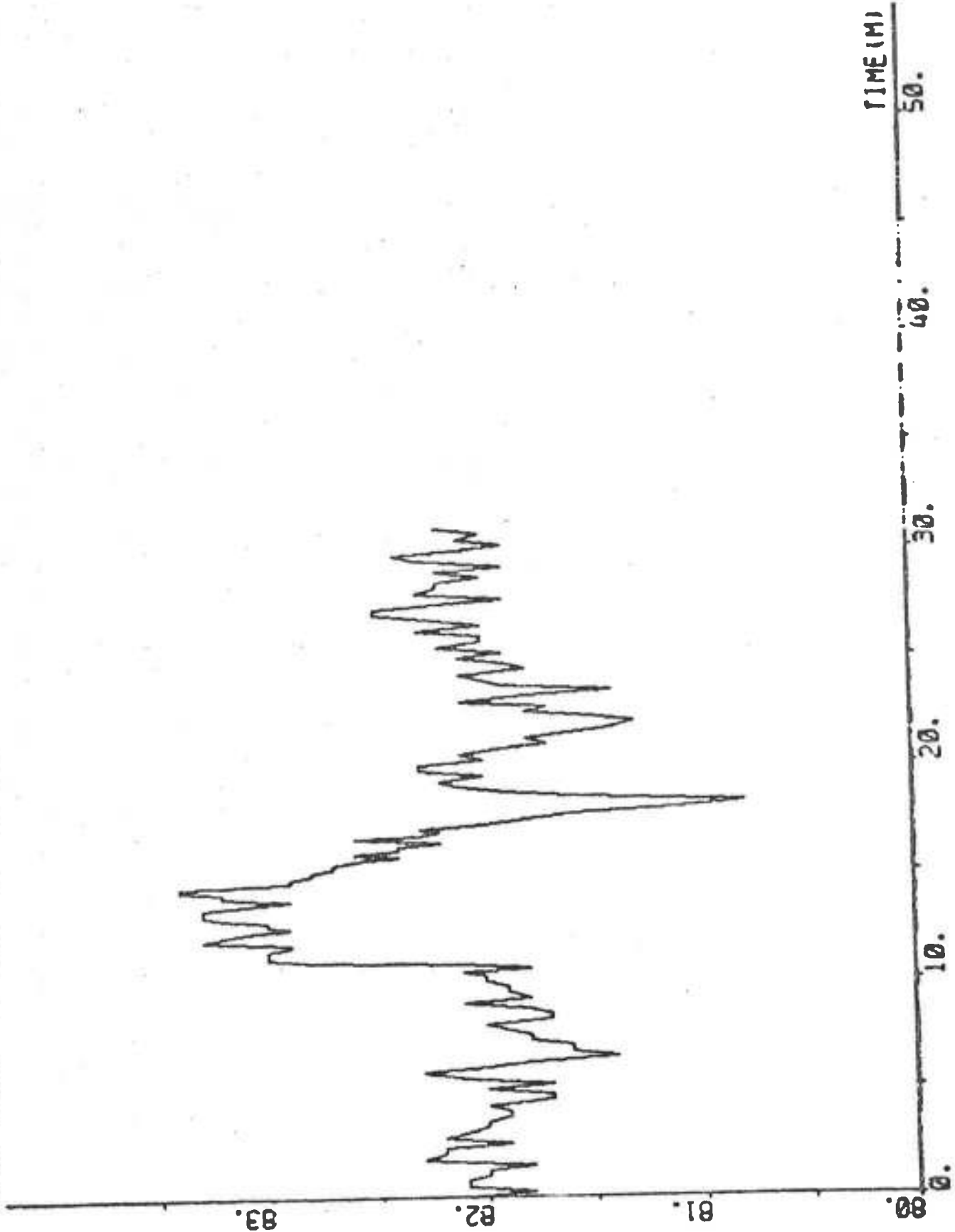
PLOT B4P1(16)-B4P1(3) ZERO -10 10 "DELTA" DEG



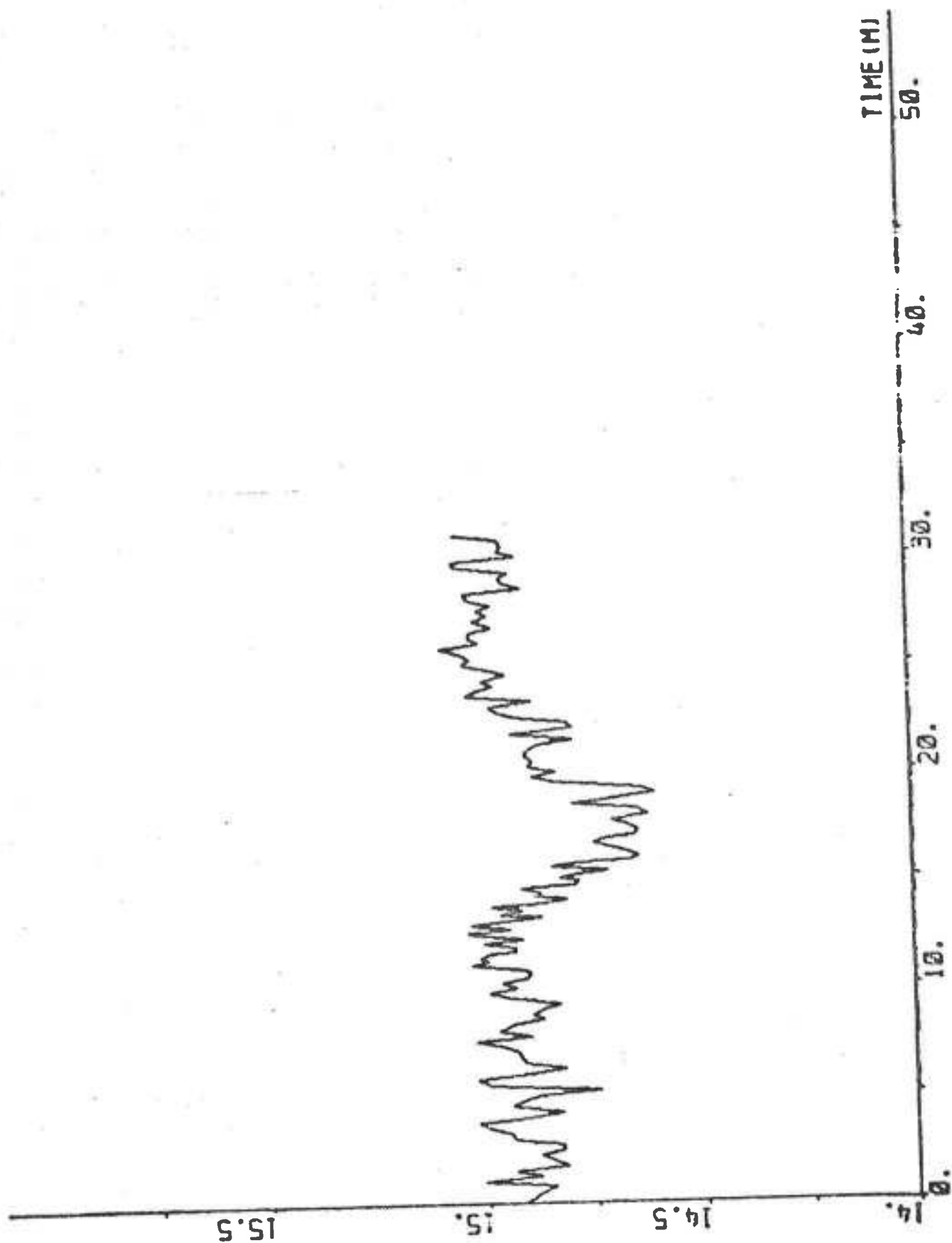
PLOT B4P1(15)-B4P1(4) ZERO -10 10 "DELTA DEG



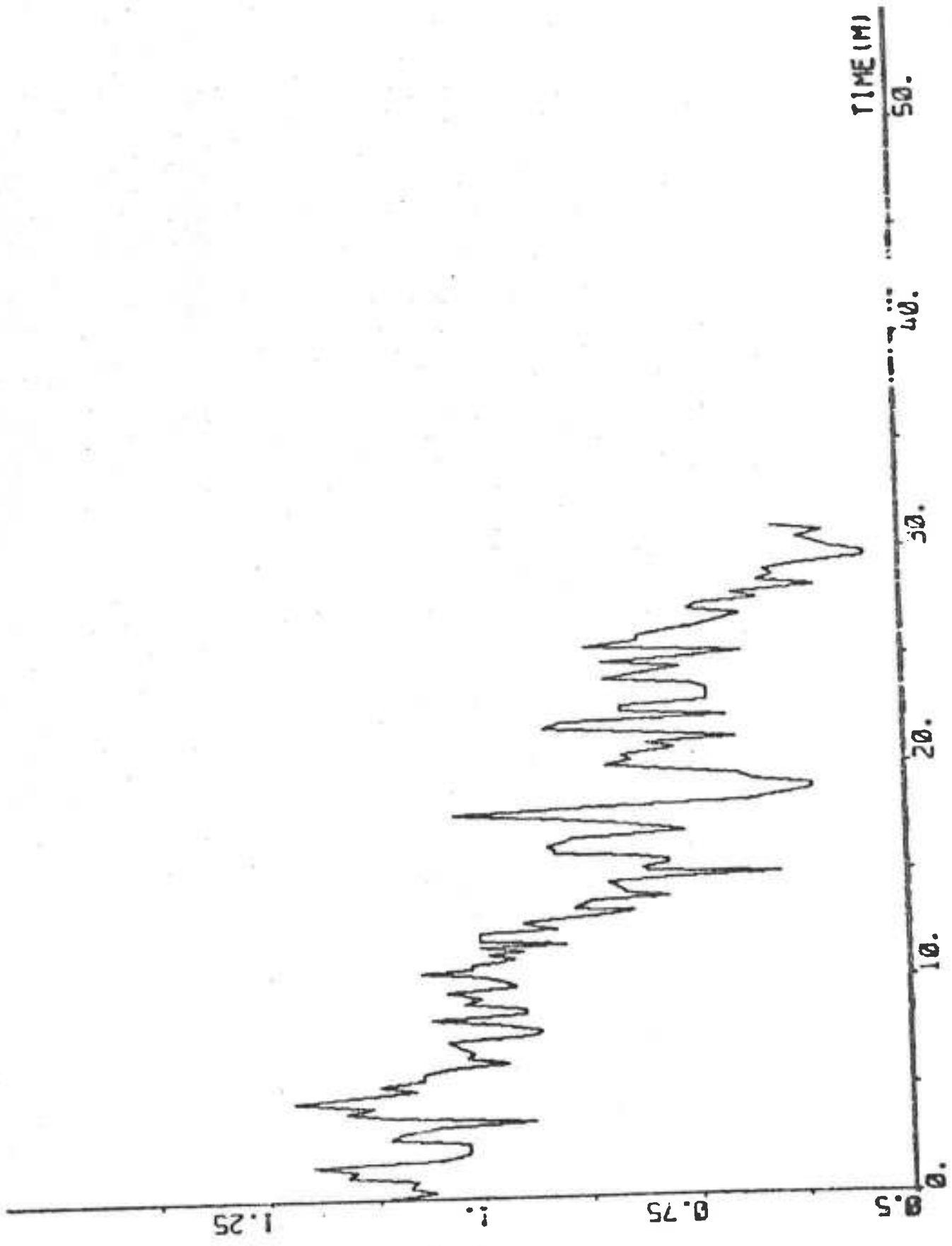
PLOT EXP1(15) ← B4P1(6) 60 64 "AN RPM



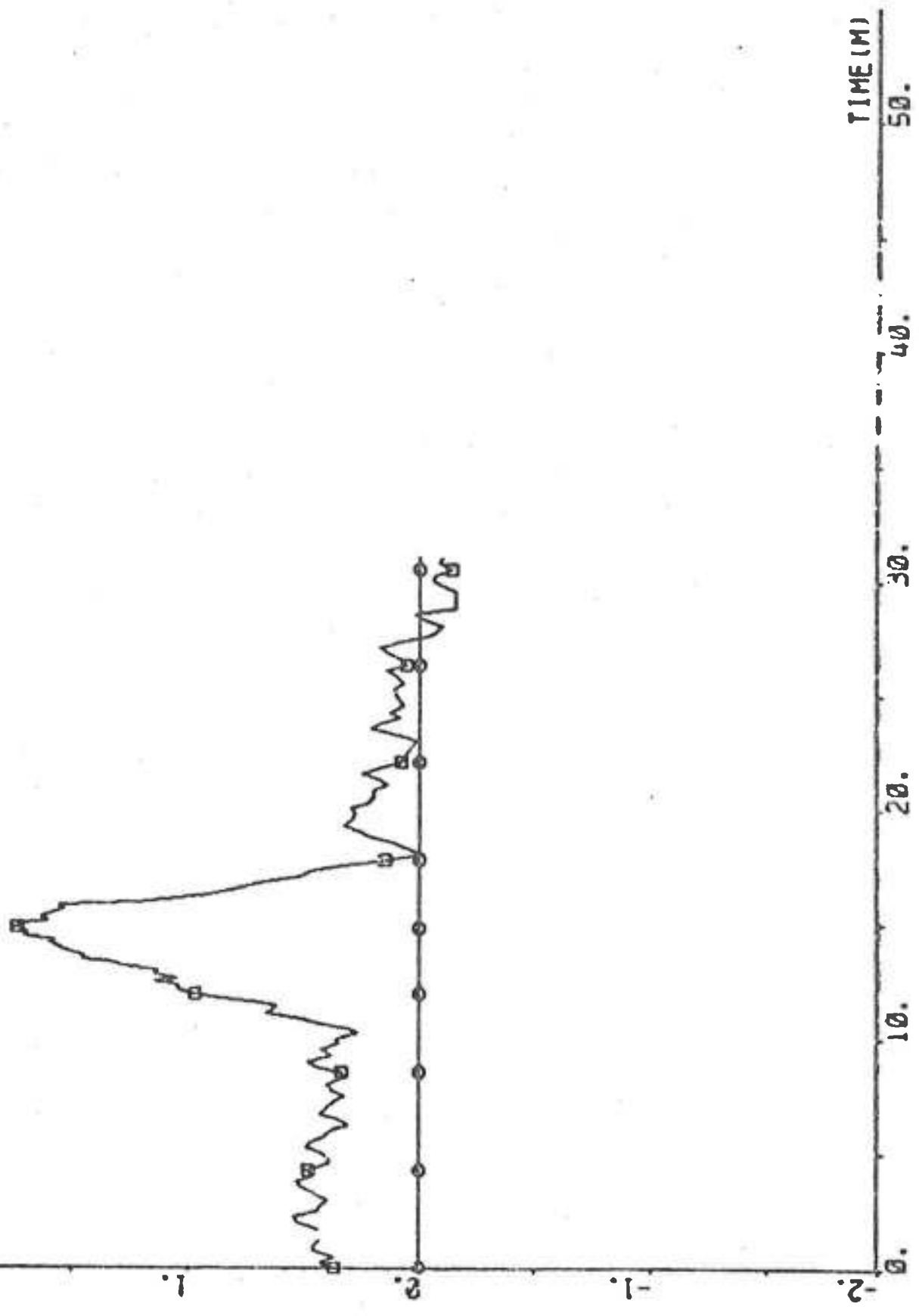
PLOT B4P1(15)-B4P1(7) 14 16 °U KNOTS



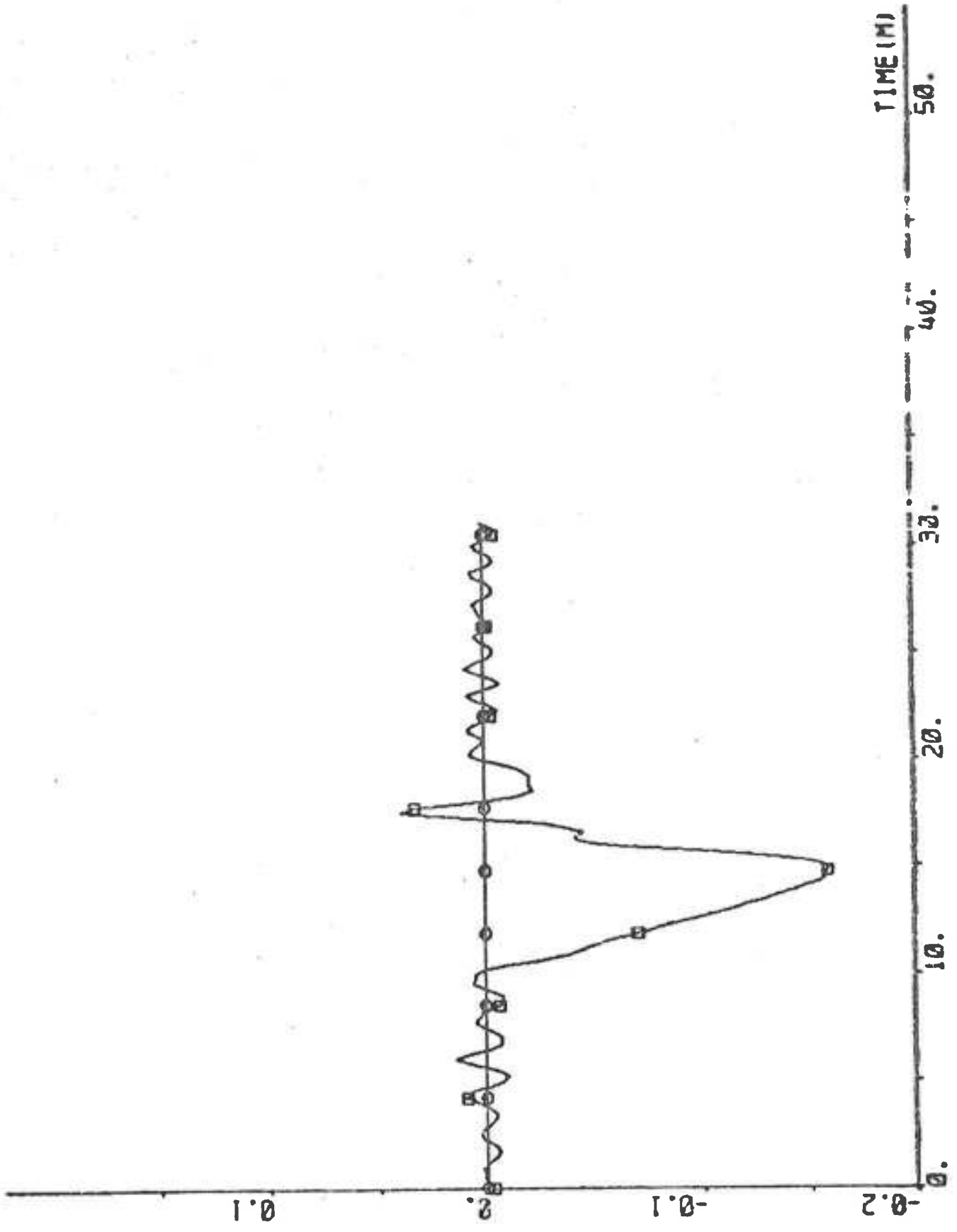
PLOT B4P1(15)~B4P1(8) 0.5 1.5 "V1 KNOTS



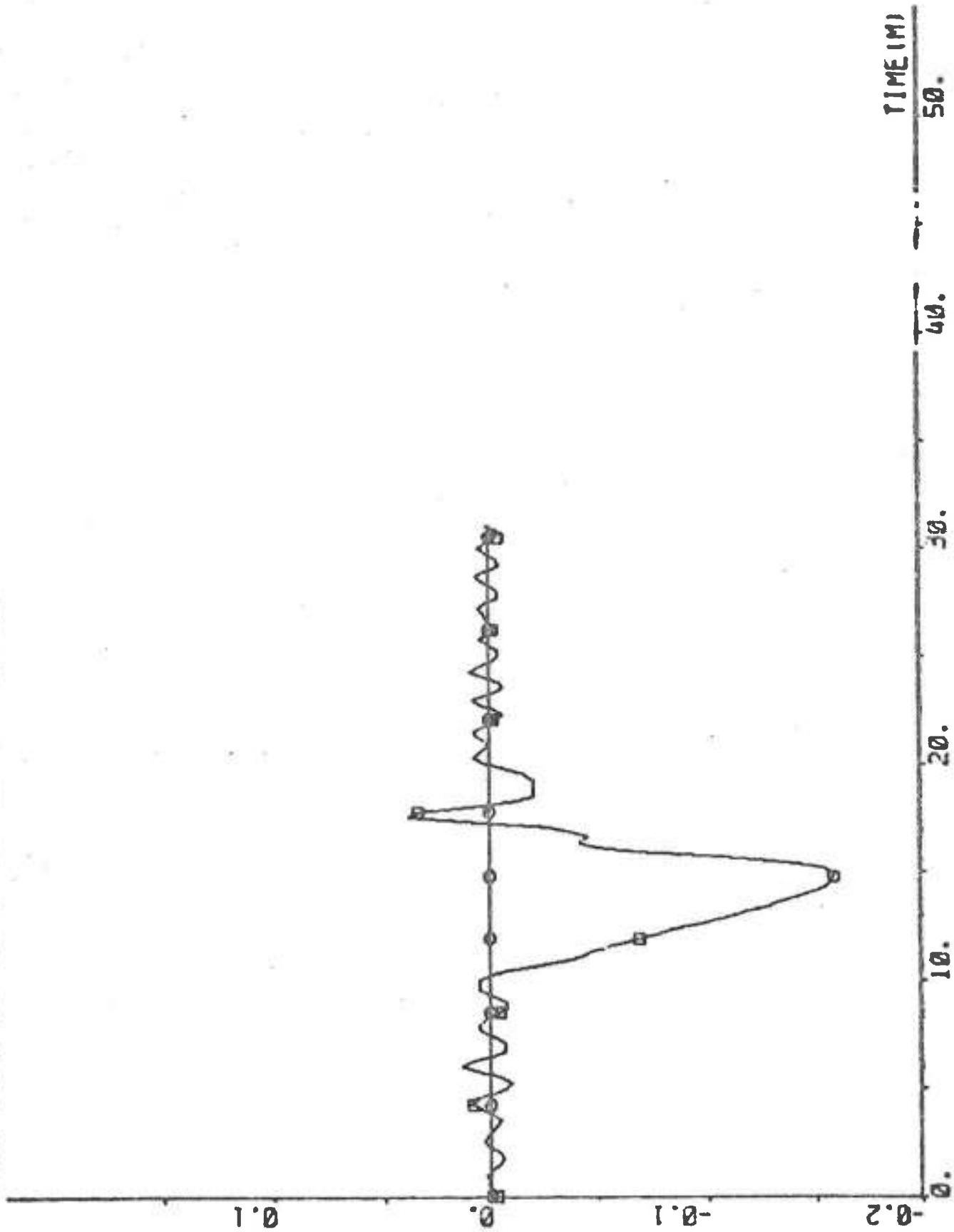
PLOT B4P1(15) ← B4P1(9) ZERO -2 2 "V2 KNOTS



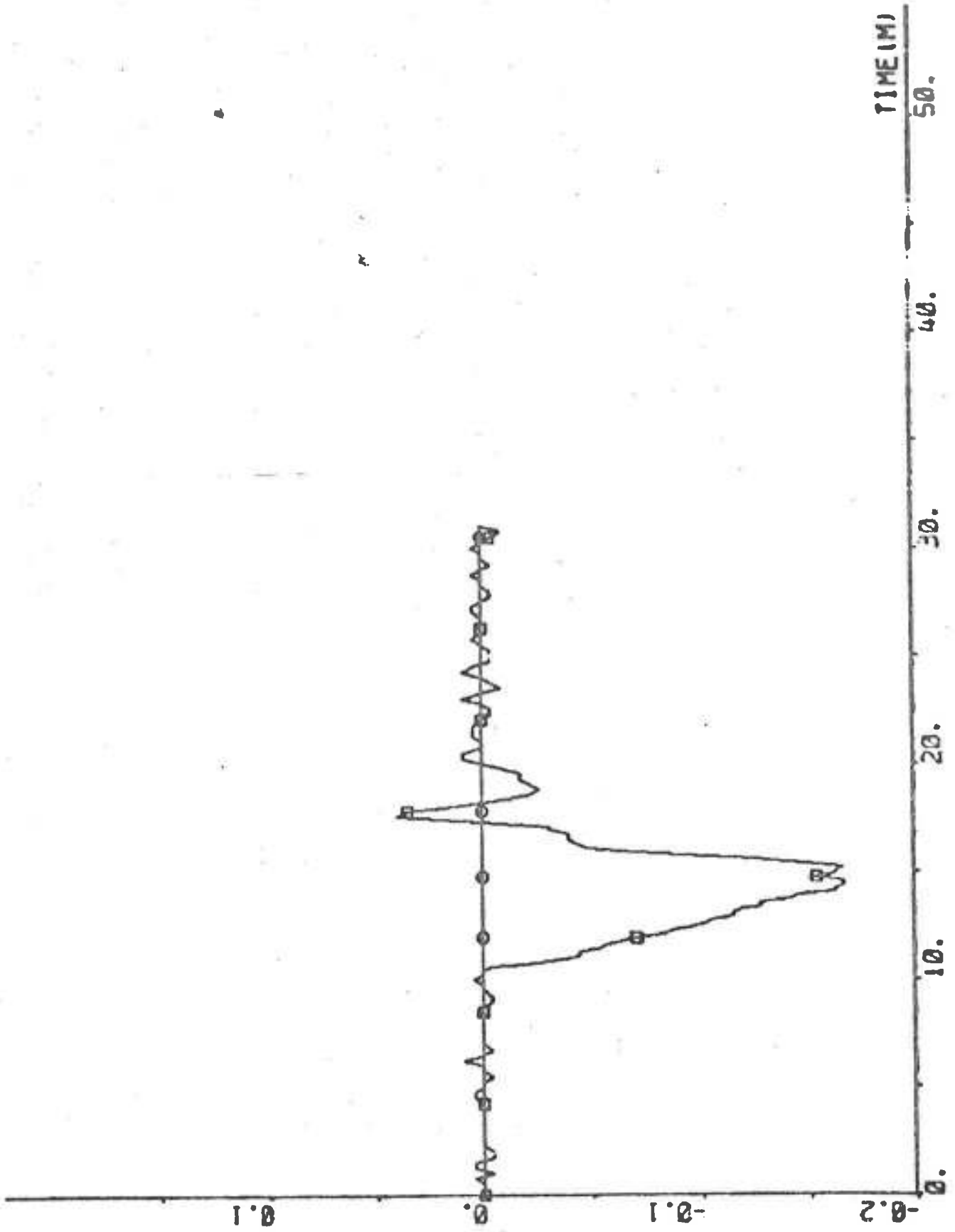
PLOT B4P1(15) - B4P1(10) ZERO - 0.2 0.2 °R DEG/S



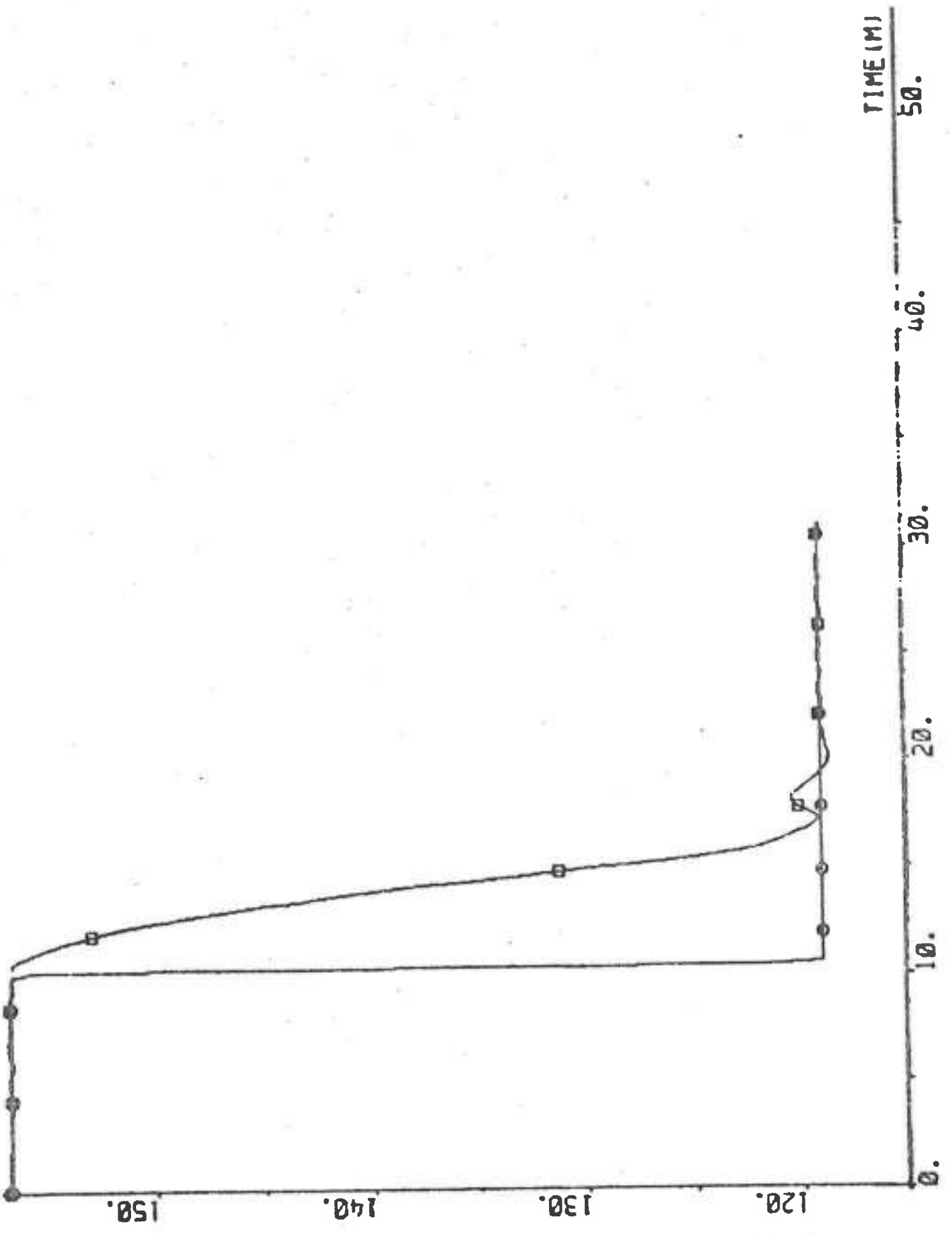
PLOT B4P1(15) - B4P1(11) ZERO - 0.2 0.2 - AVR DEG/S (BR-0.5)



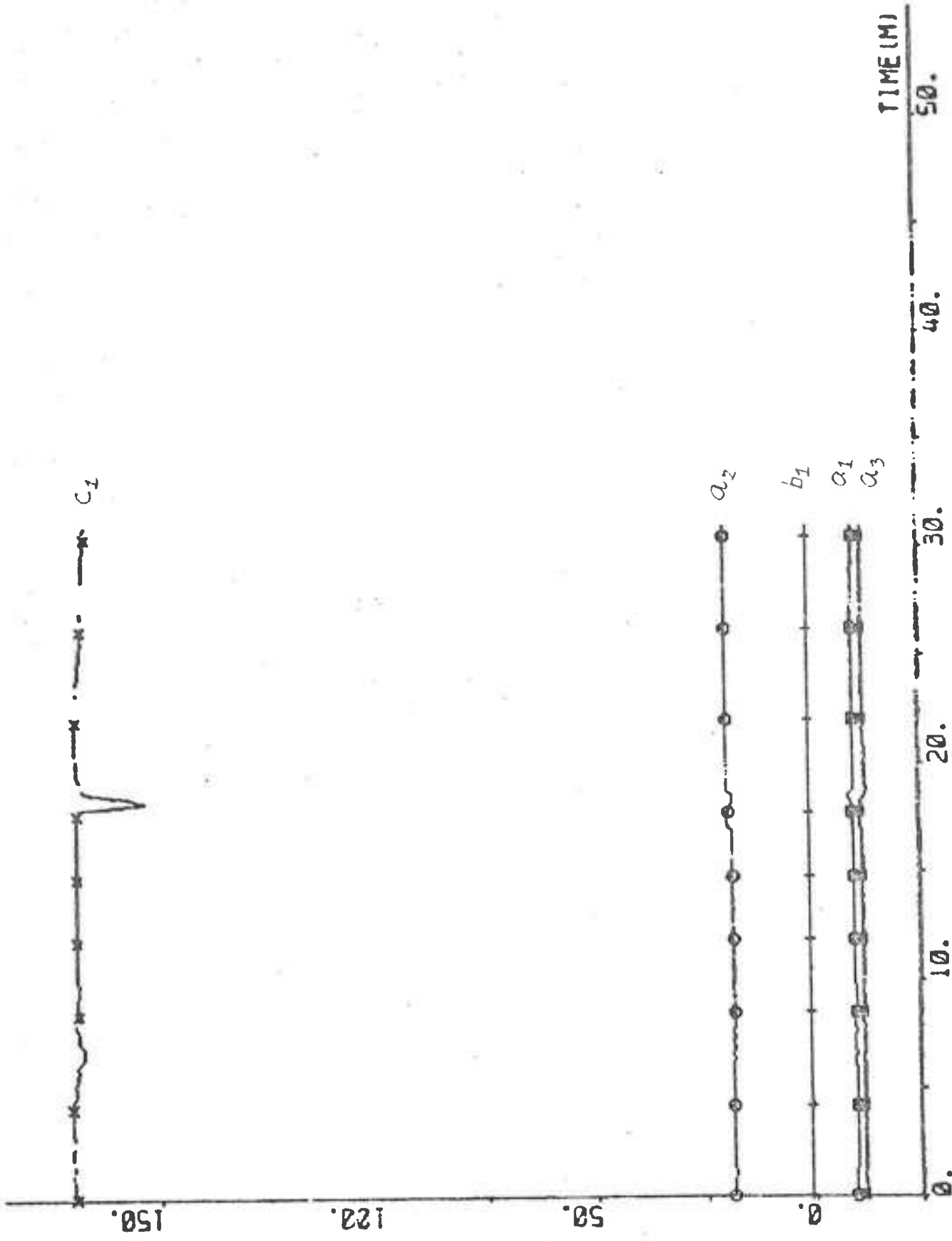
PLOT B4P1(15)-B4P1(12) ZERO -0.2 0.2 "DPSIDT DEG/S (10P51*5)



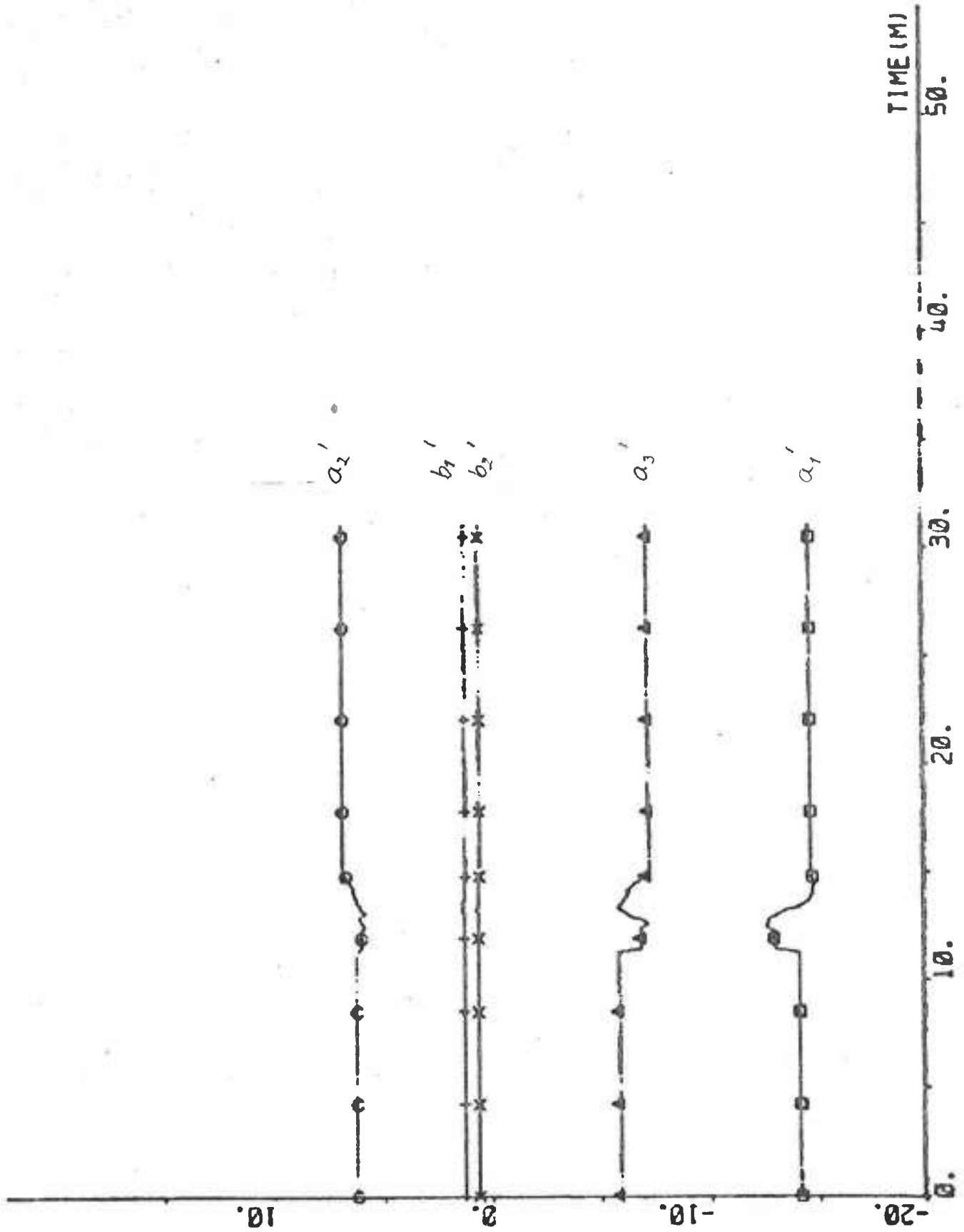
PLOT B4P1(15)-B4P1(13 14) 117 157 °PSI PSIREF DEG



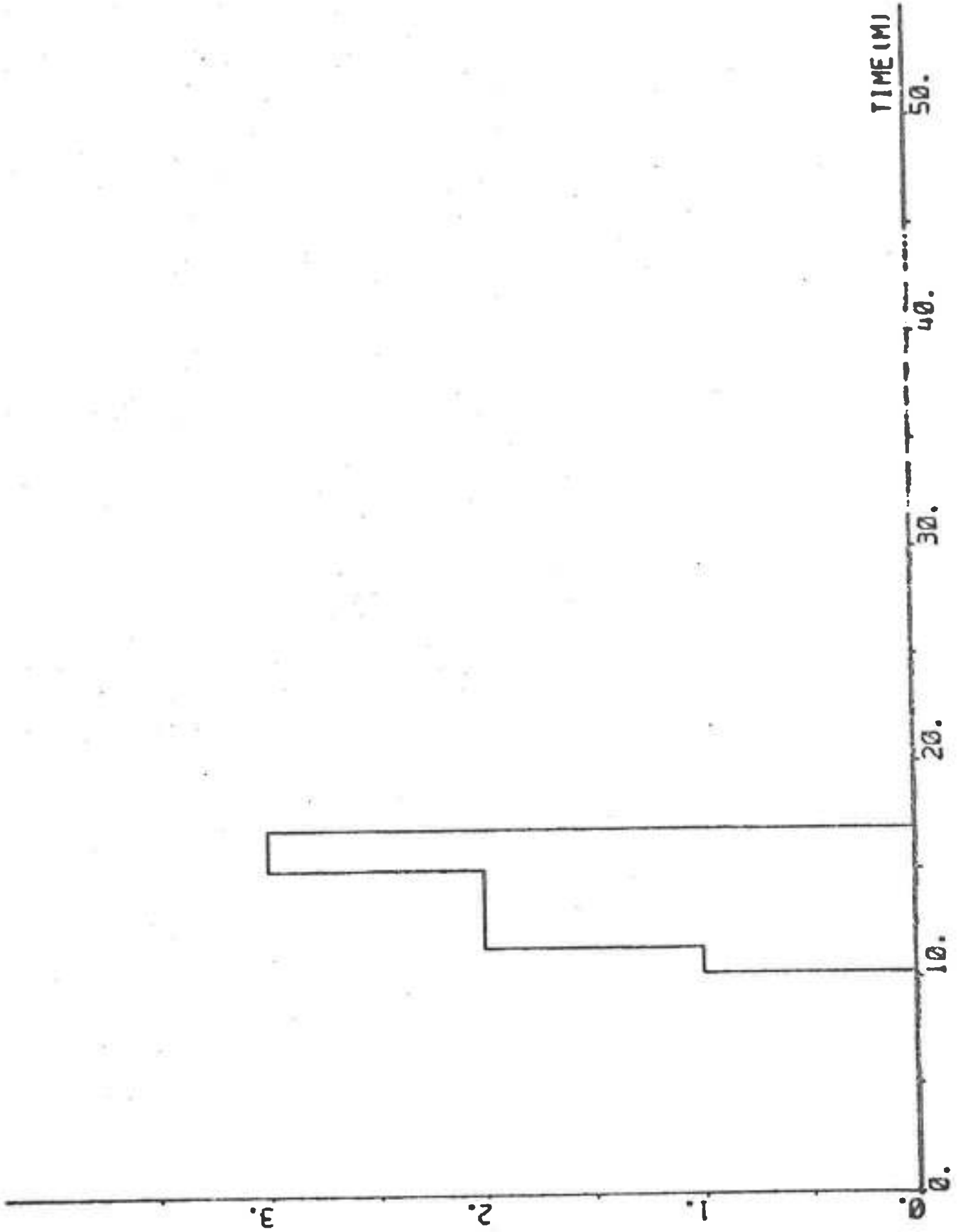
PLOT B4P1(16)-B4P2(1 2 3 4 5) -10 190 REGULATOR PARAMETERS



PLOT B4P1(15)-B4P2(6 7 8 9 10) -20 20 "YAW REGULATOR PARAMETERS



PLOT B4P1(15)-HP B4P2(11) 0 4 "MODYAM



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

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

$$a_1 + a_2 + a_3 = -7.589$$

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

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

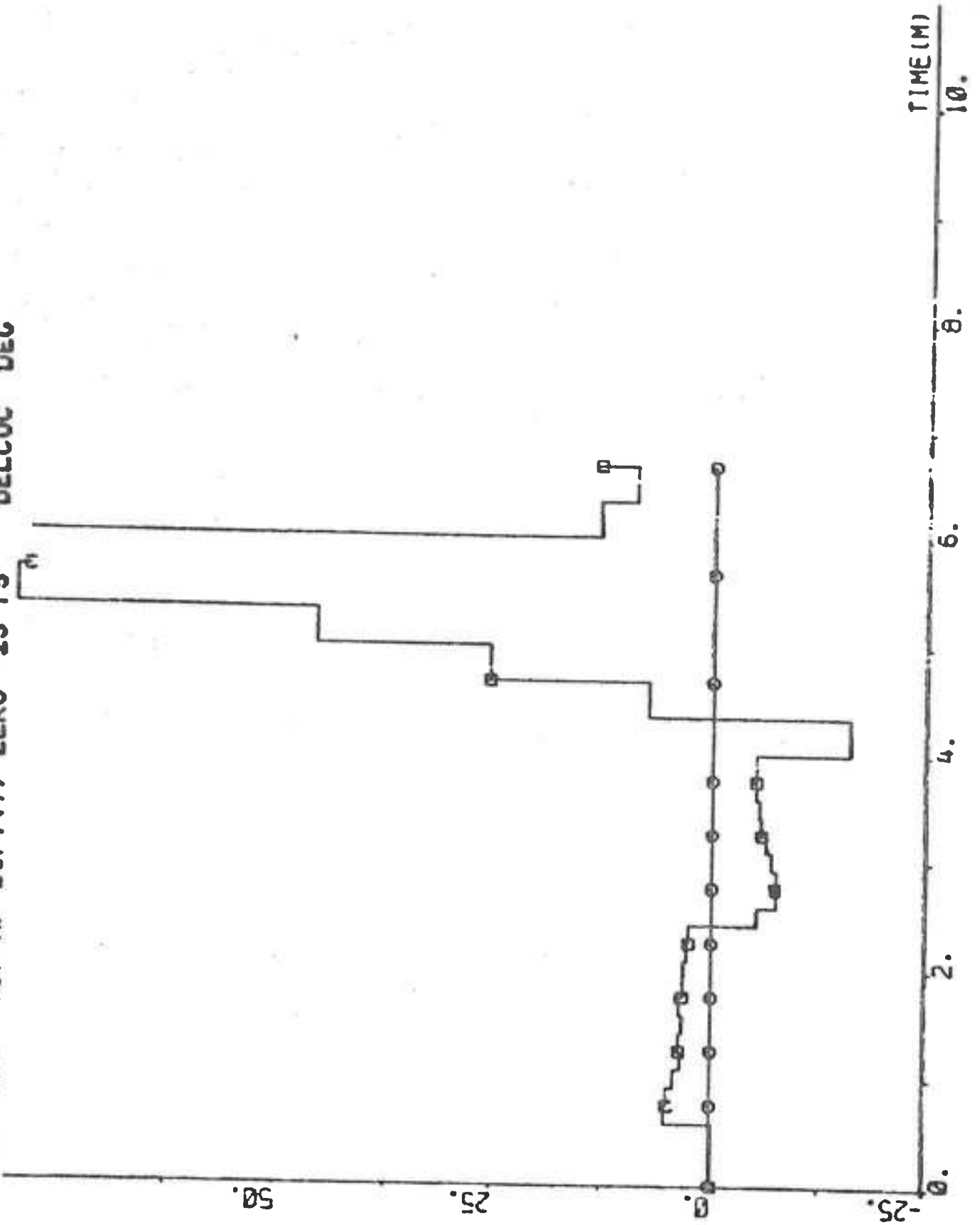
$$a'_1 + a'_2 + a'_3 = -13.75$$

Final yaw regulator values

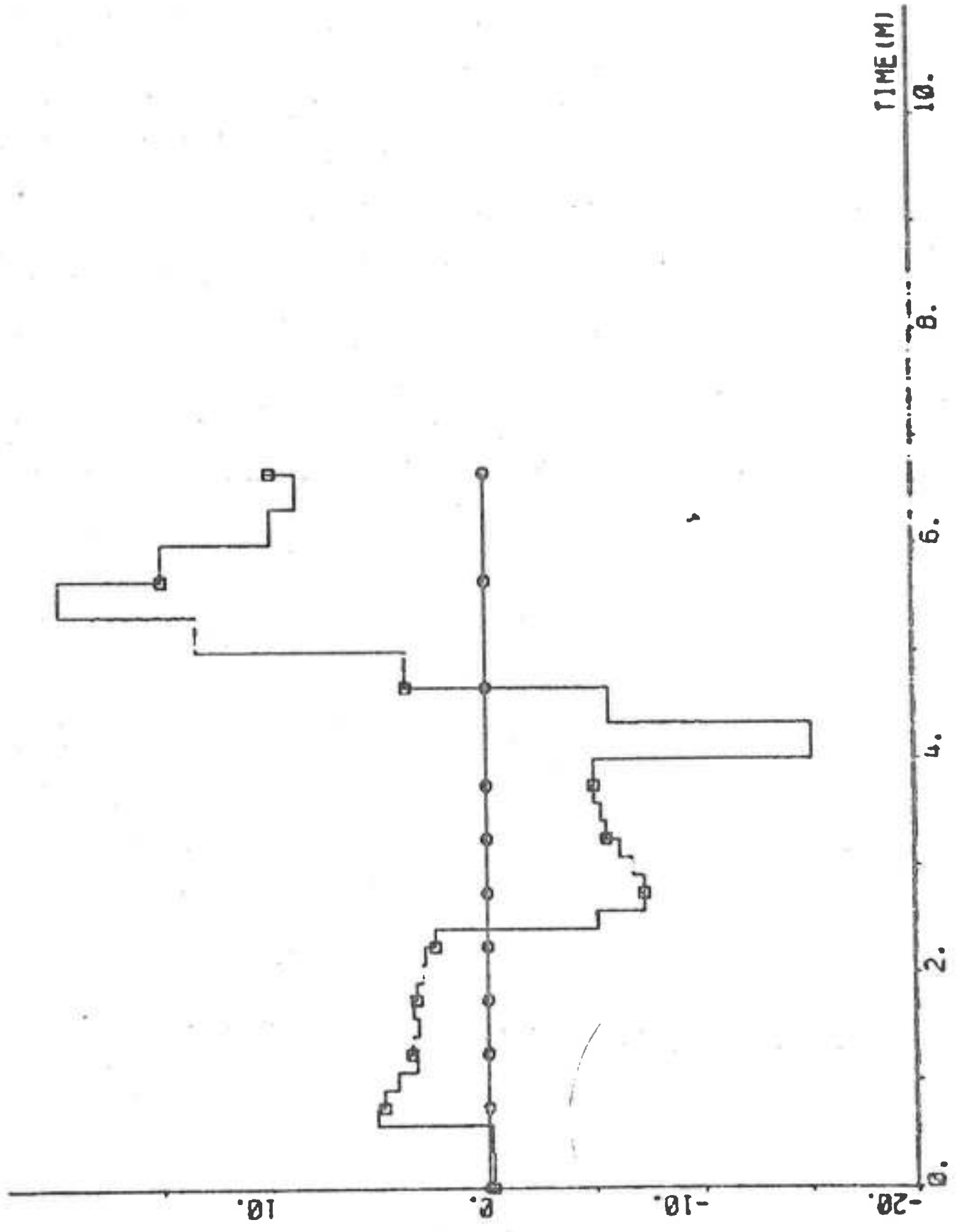
$$\begin{bmatrix} a_1' \\ a_2' \\ a_3' \\ b_1' \\ b_2' \end{bmatrix} = \begin{bmatrix} -12.271 \\ 5.427 \\ -6.987 \\ 1.283 \\ 0.634 \end{bmatrix} \quad PY = \begin{bmatrix} 1289.822 & & & & \\ -1216.361 & 1305.553 & & & \\ -239.682 & -1456.936 & 1427.064 & & \\ -34.800 & -86.287 & -6.668 & 14.216 & \\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

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

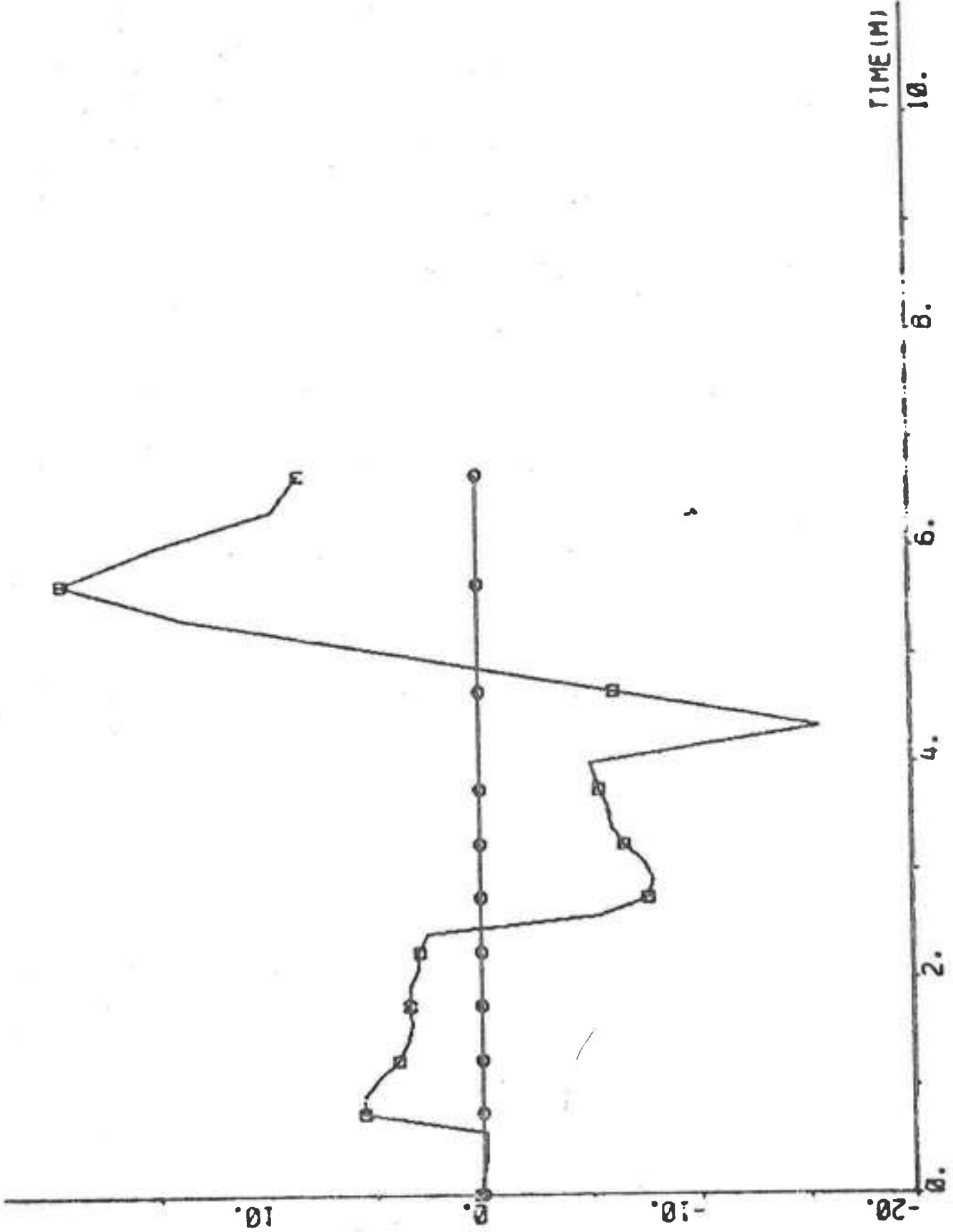
PLOT BSP1(15) HP BSP1(1) ZERO -25 75 DELCOC DEG



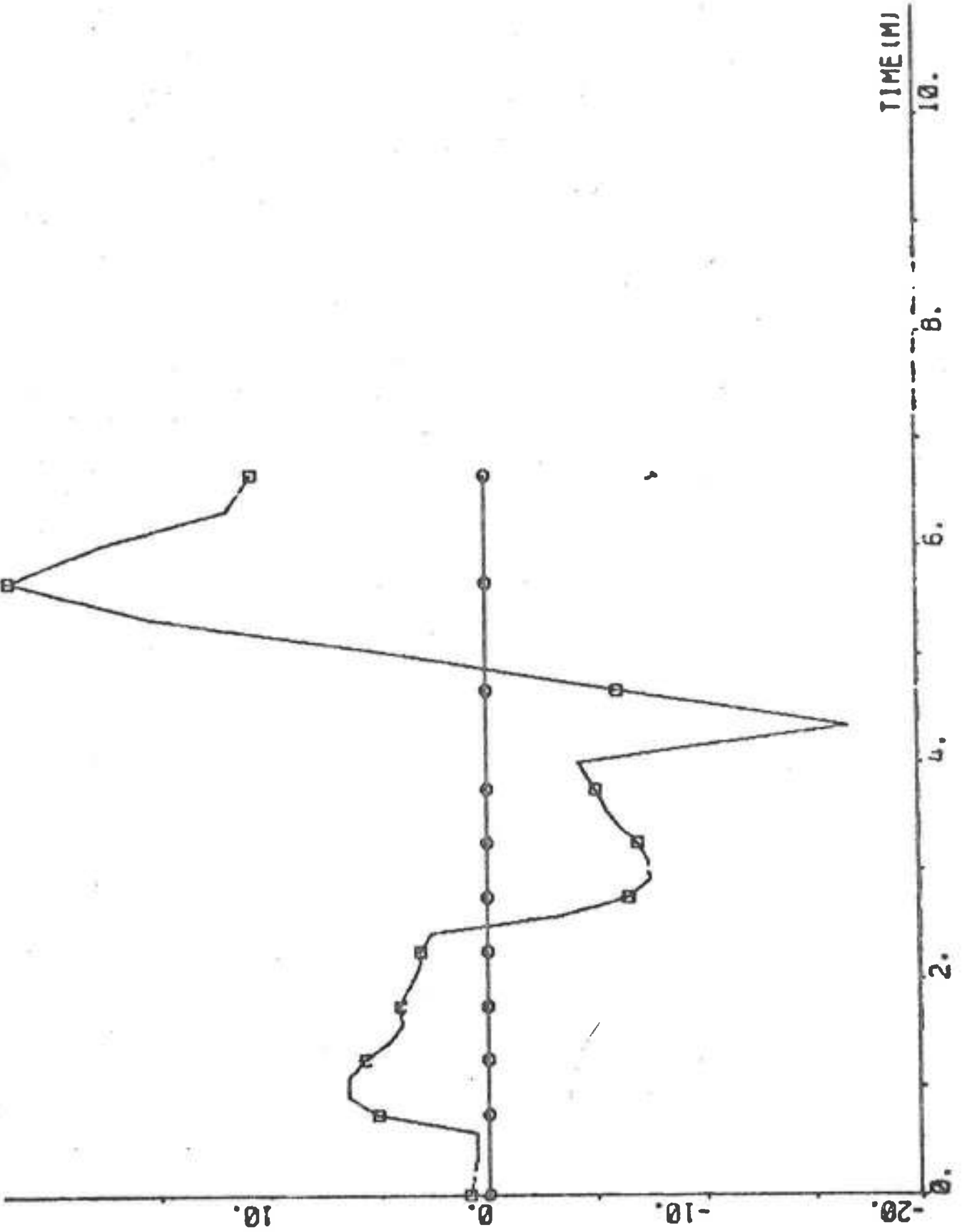
PLOT B6P1(16) ← HP B6P1(2) ZERO -20 20 "DELCON DEG



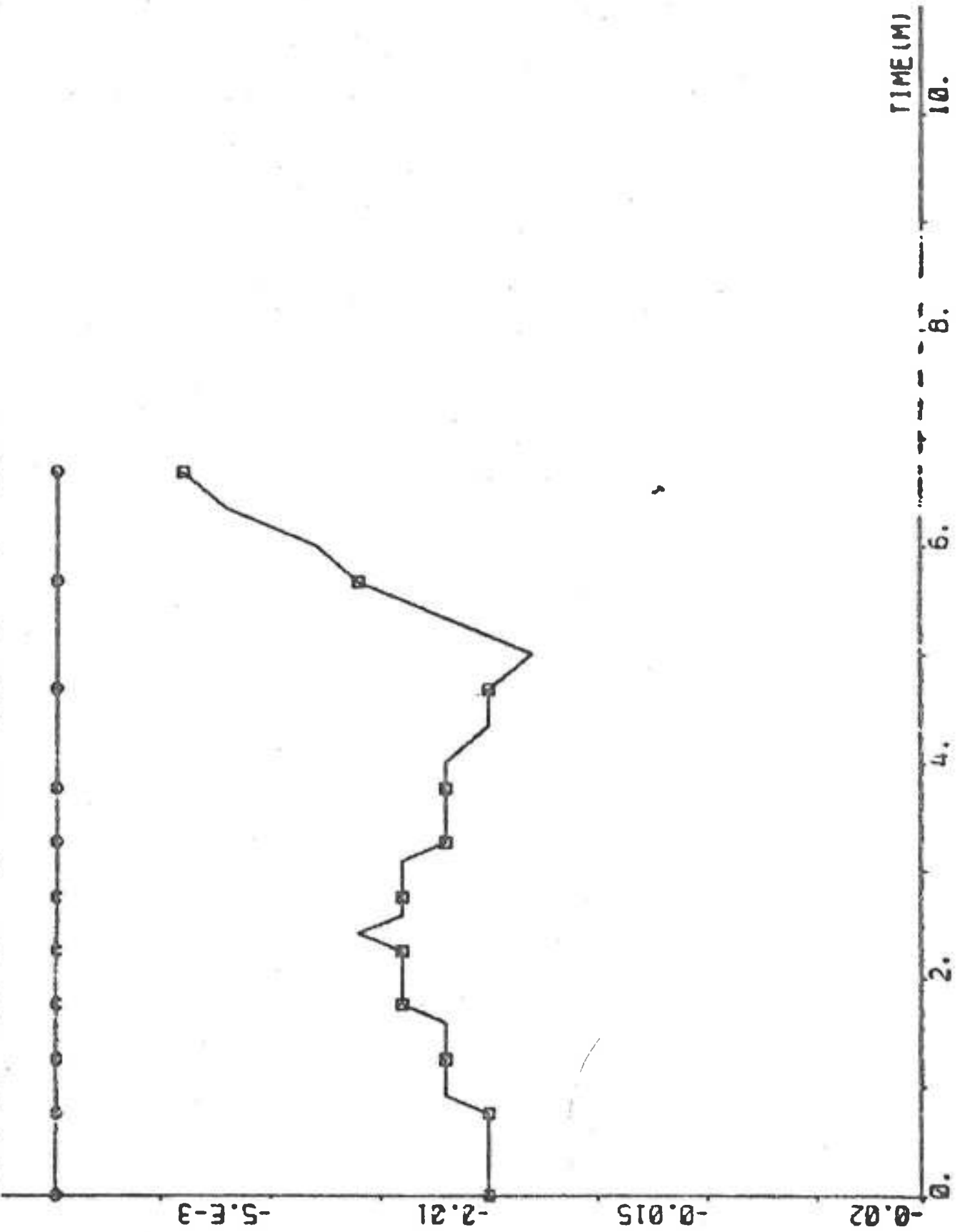
PLOT BSP1(15)+BSP1(3) ZERO -20 20 "DELTA" DEG



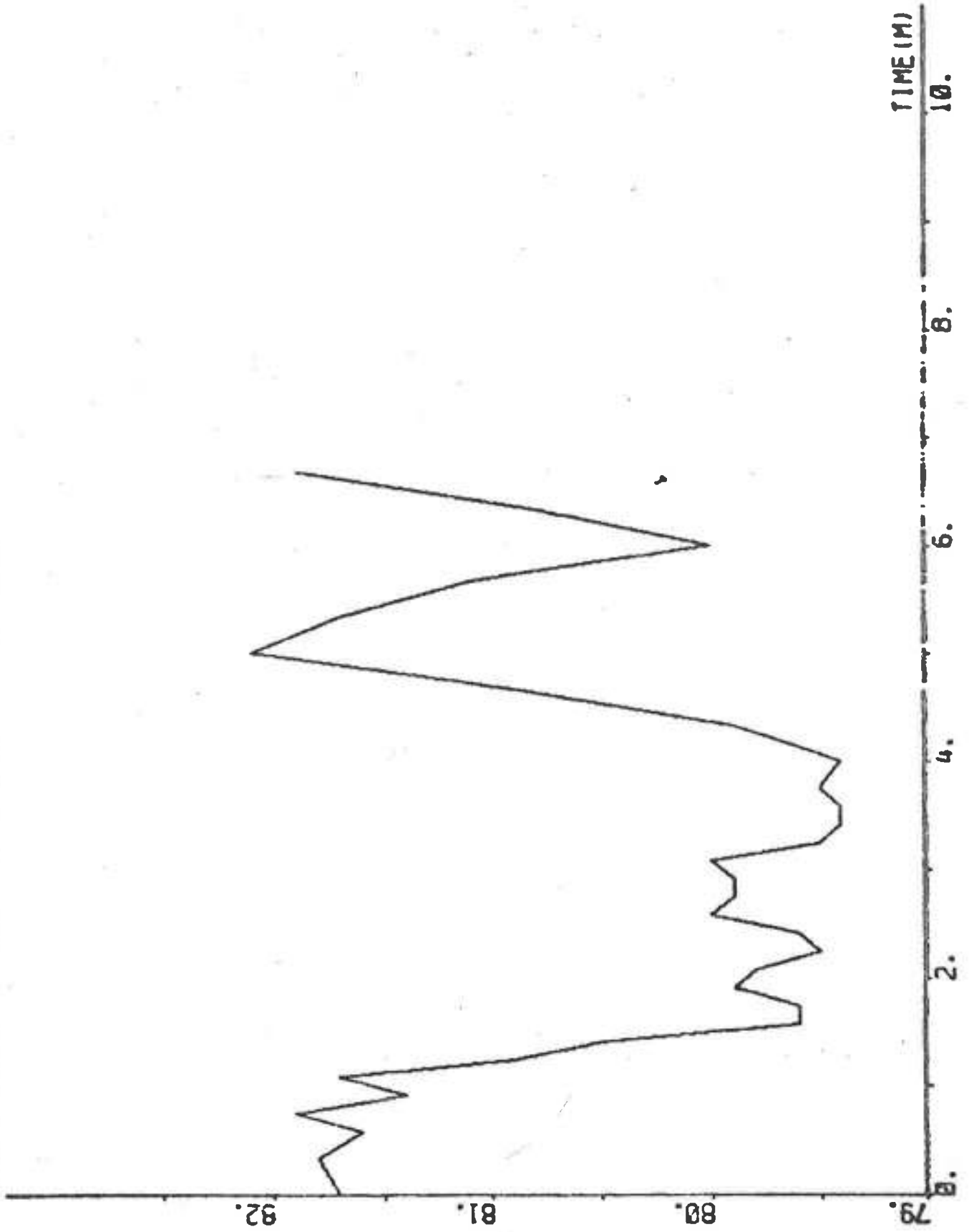
PLOT B5P1(15) - B5P1(4) ZERO -20 20 "DELTA DEG



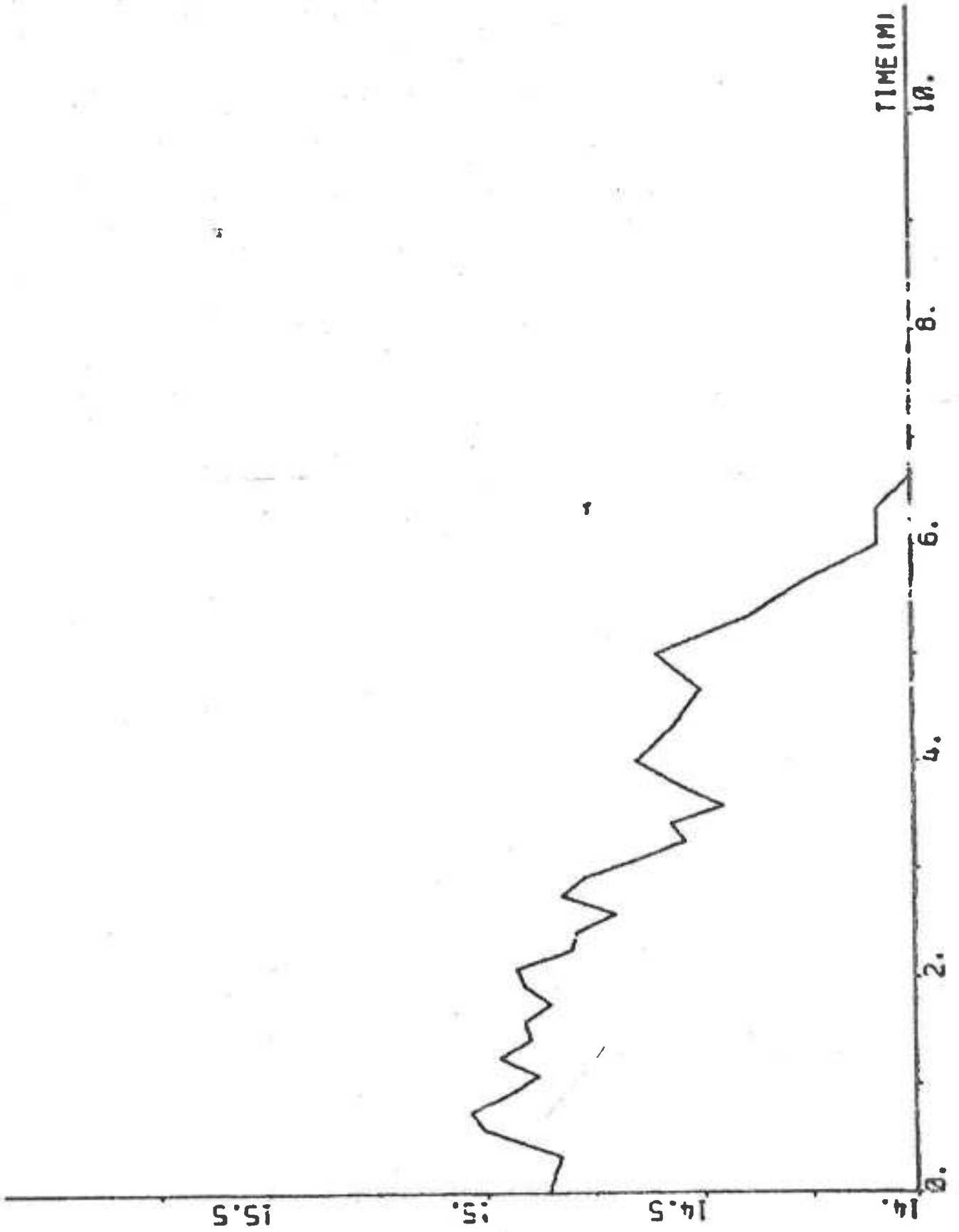
PLOT B5P1(15)~B5P1(5) ZERO -0.02 0 "PP DEC/S



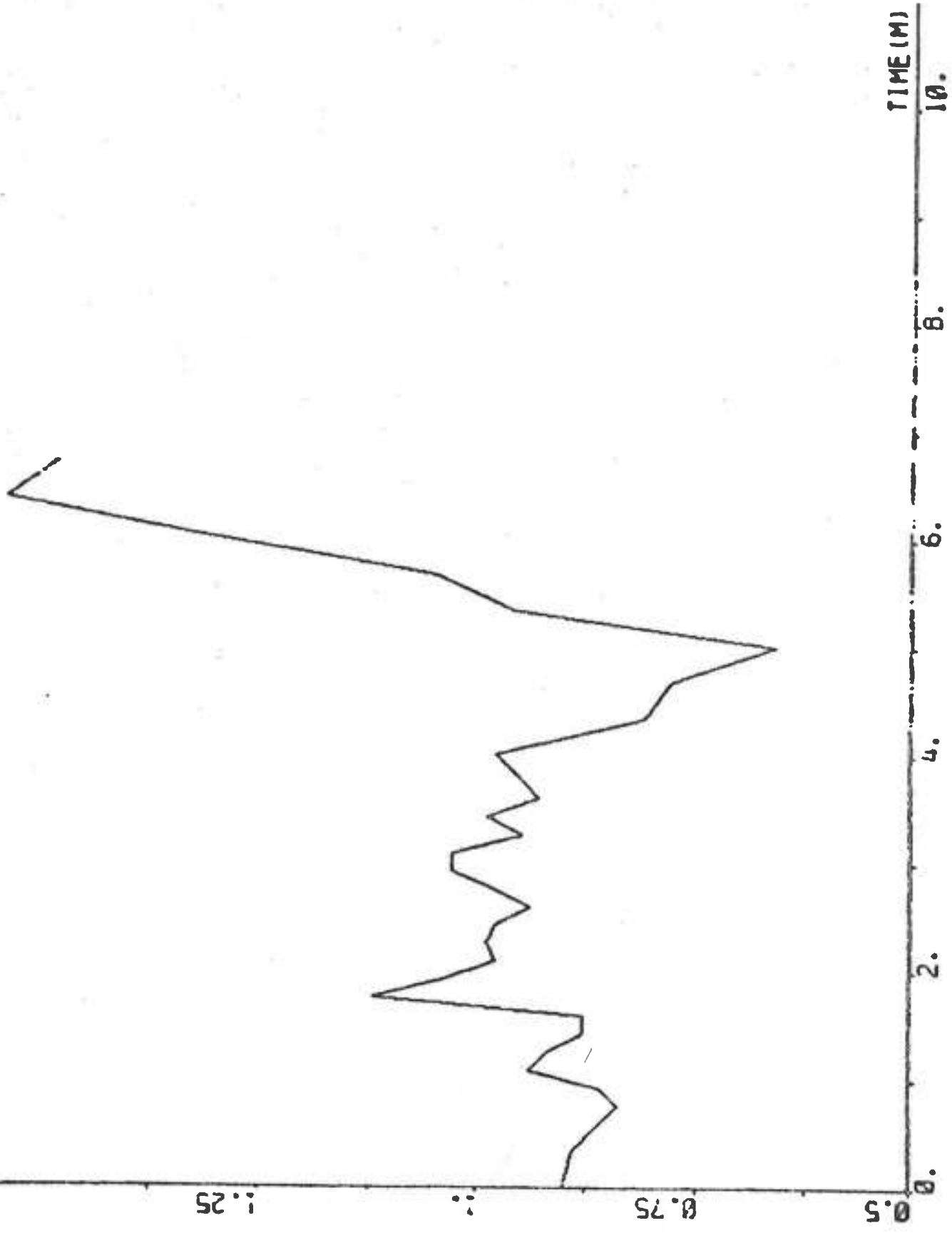
PLOT BSP1(15) * BSP1(6) 79 80 "AN RPM



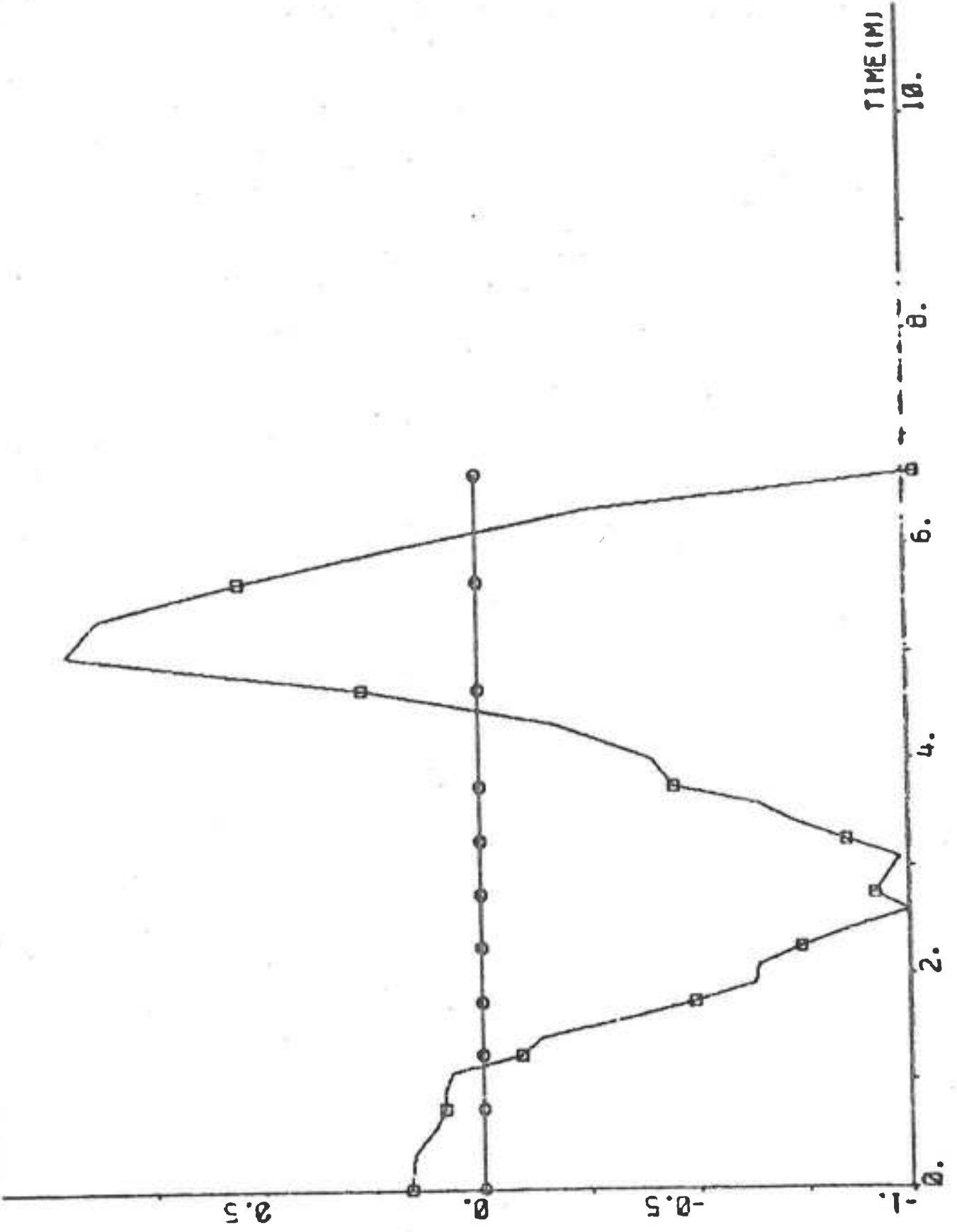
PL0T 66P1(15)-66P1(7) 14 16 "U KNOTS



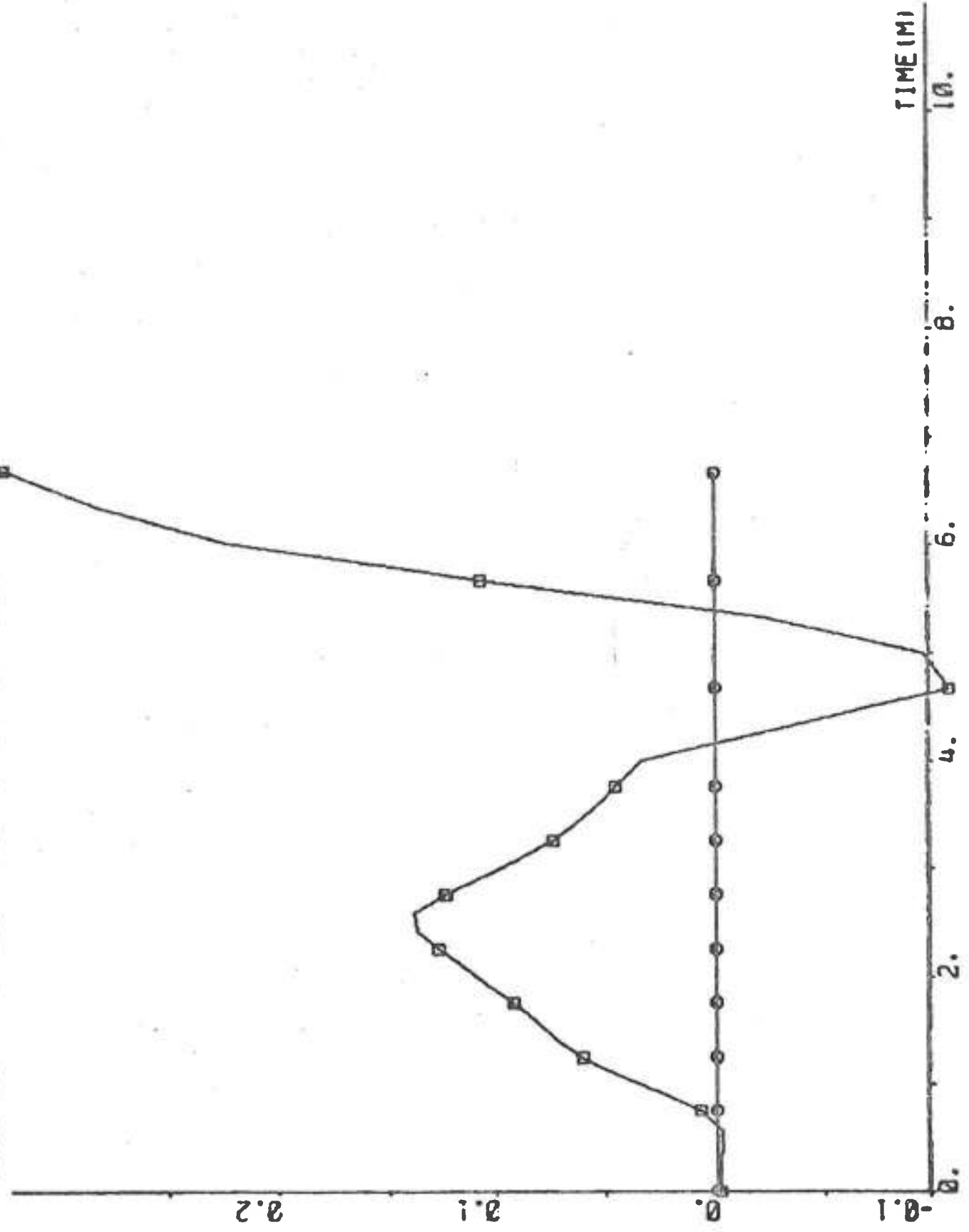
PL0T BSP1(15) BSP1(8) 0.5 1.5 "V1 KNOTS



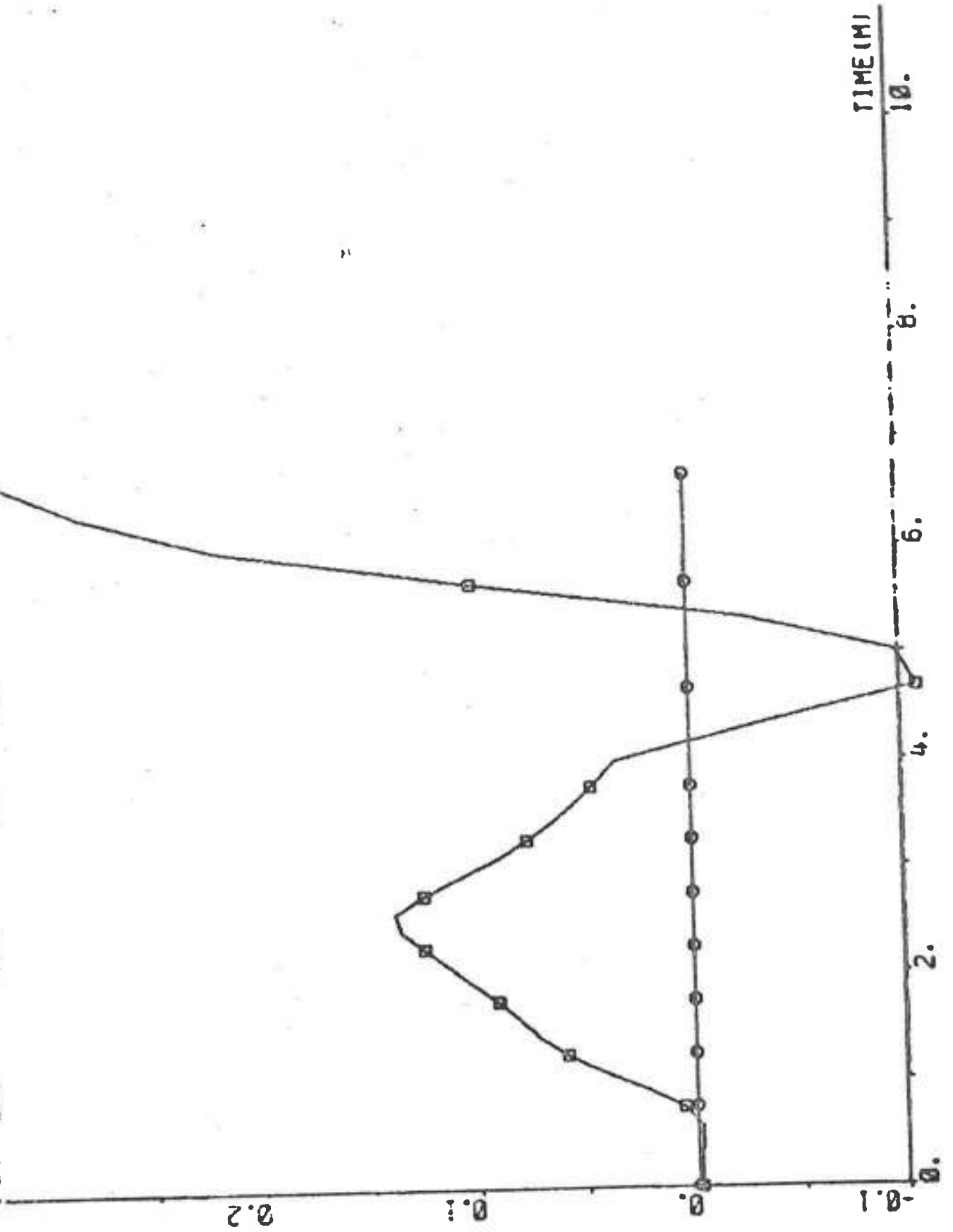
PLOT 85P1(15)~85P1(9) ZERO -1 1 -V2 KNOTS



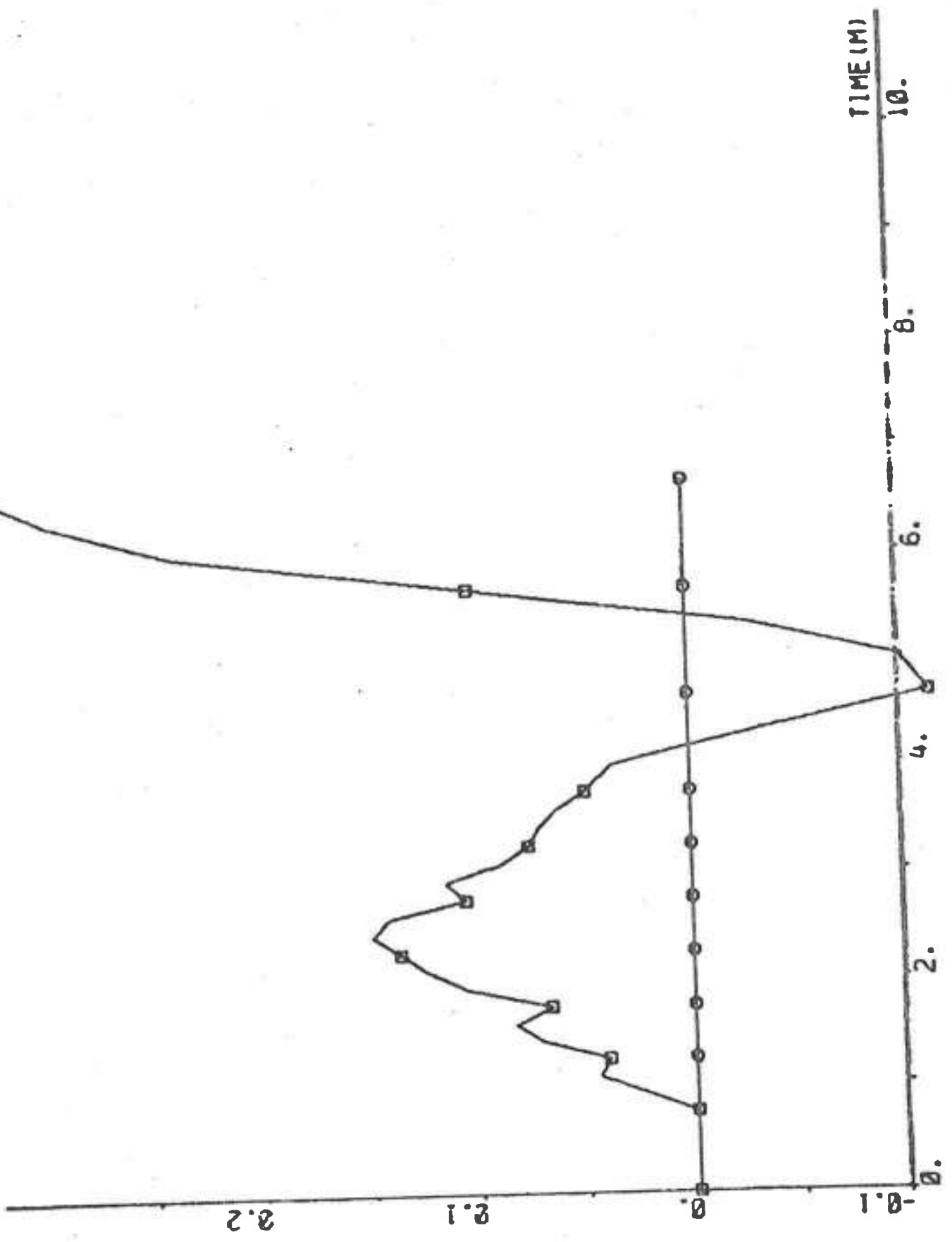
PLOT BSP1(16) ← BSP1(10) ZERO -0.1 0.3 "R DEG/S



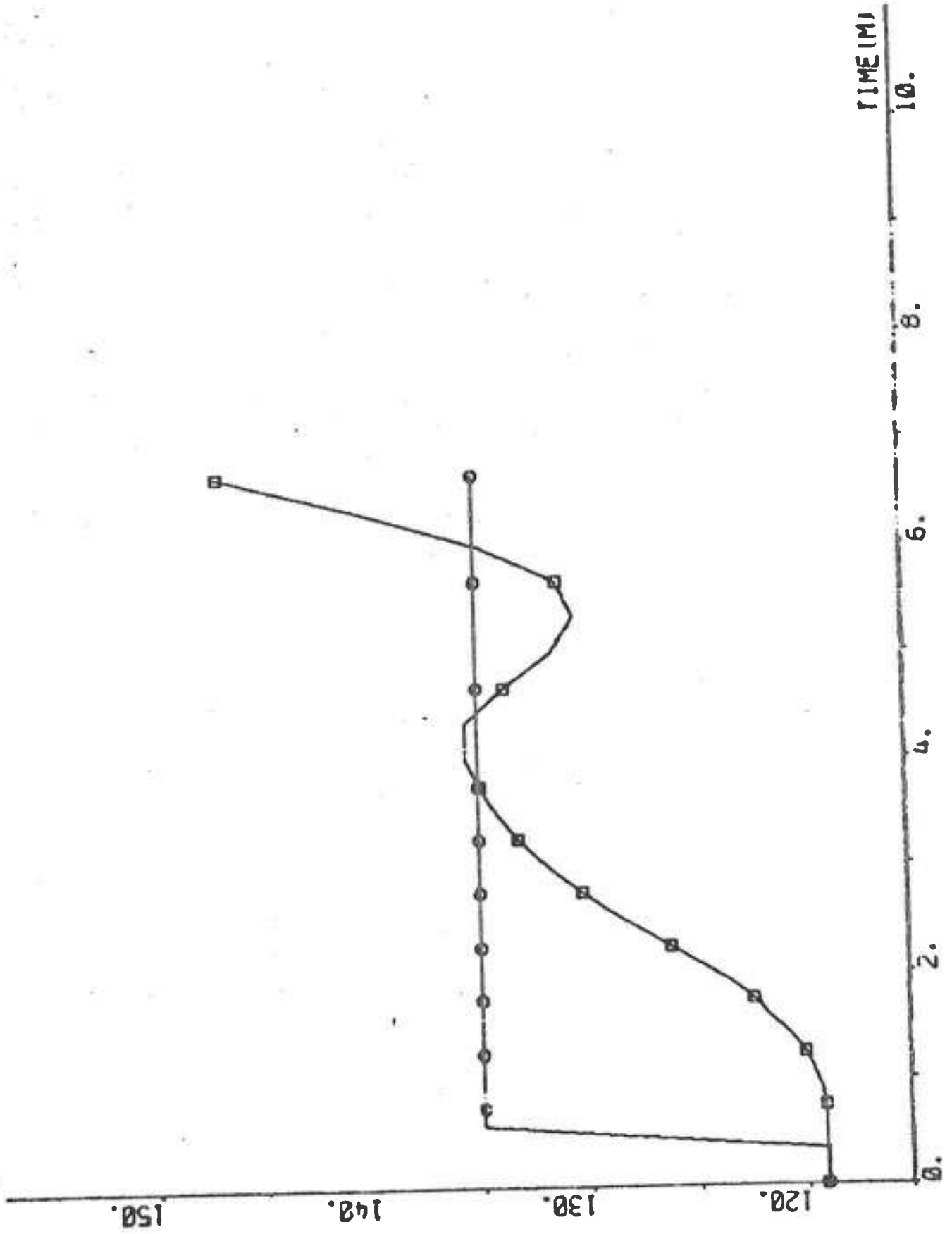
PLOT B5P1(15)←B5P1(11) ZERO -0.1 0.3 -AVR₀ DEG/S (BR=0.5)



PLOT BSP1(15)~BSP1(12) ZERO -0.1 0.3 "DP91DT DEG/S (IDPS1=5)

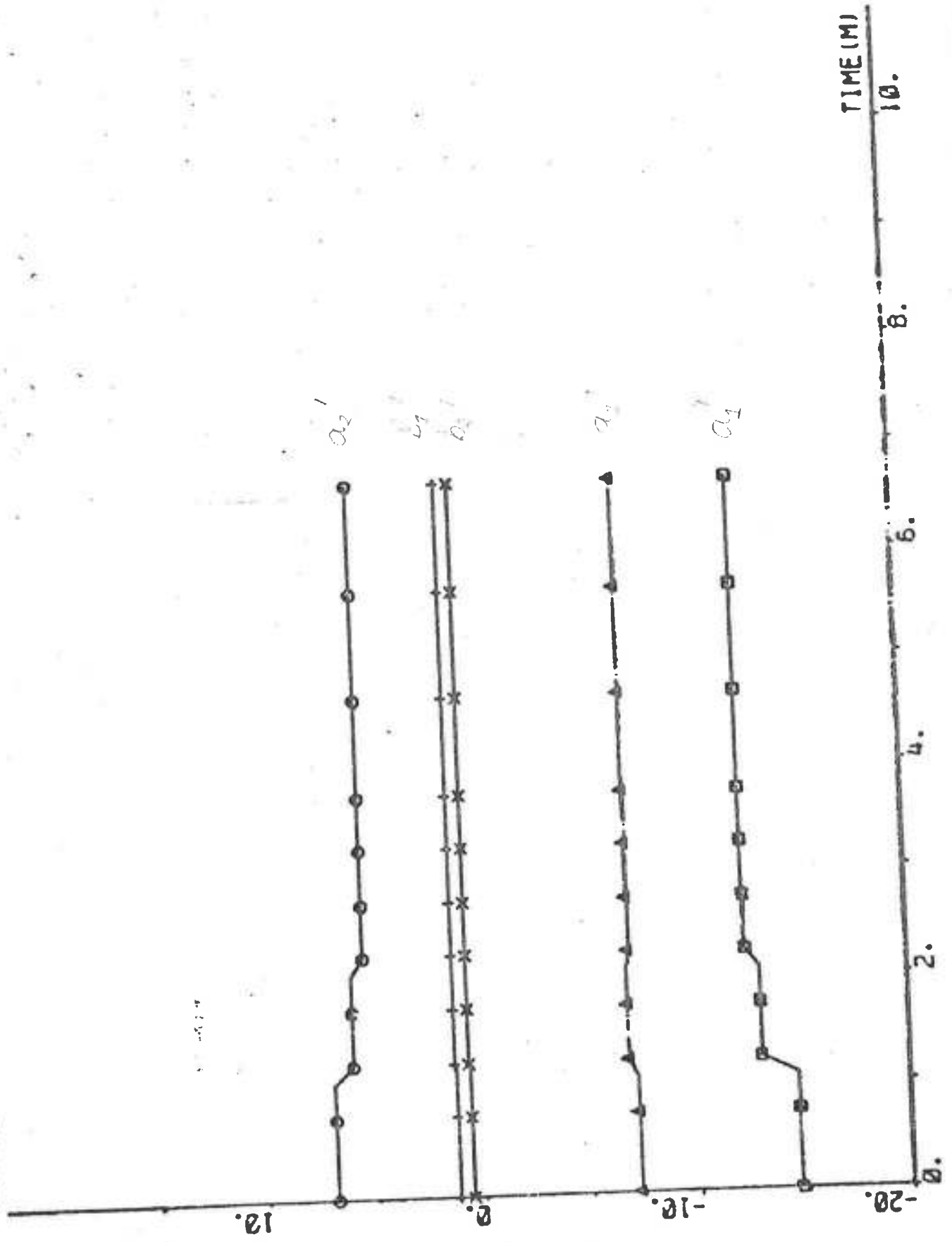


PLOT BSP1(15) BSP1(13 14) 117 157 "PSI PSIREF DEG

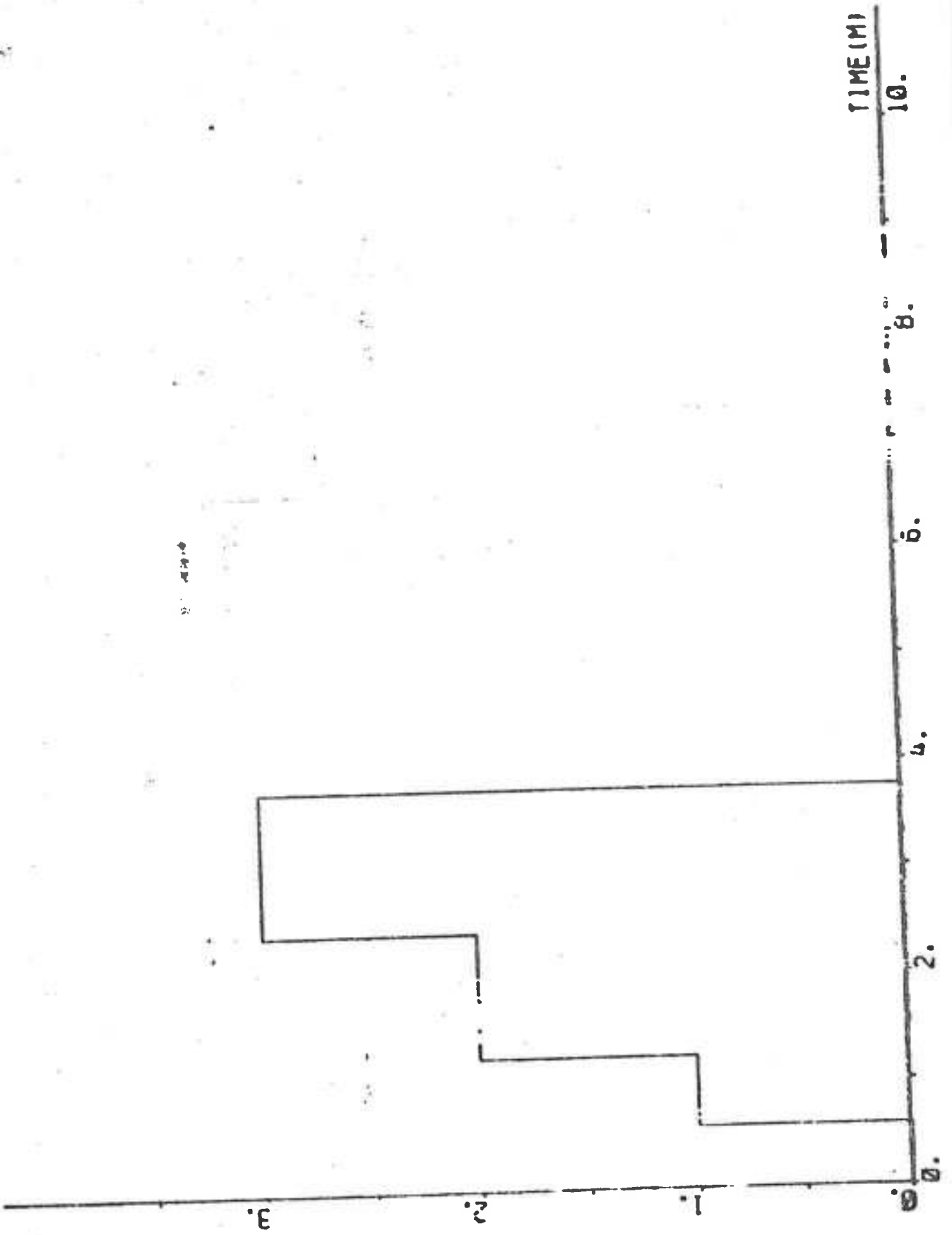


YAW REGULATOR PARAMETERS

PLOT B5P1(15)→B5P2(6 7 8 9 10) -20 20



PLOT BEP1(15)-HF BEP2(11) 0 4 "MOOYAN"



EXPERIMENT B6

Date	1974-10-11
Time	08.51
Duration	25 min
Position	N 26 ^o 10' E 54 ^o 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 ^o , 97 ^o
RREF	0.07 deg/s
Rudder limit	Not active
DELLM at termination	0.24 ^o
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.

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

$$a_1 + a_2 + a_3 = -0.923$$

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

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

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

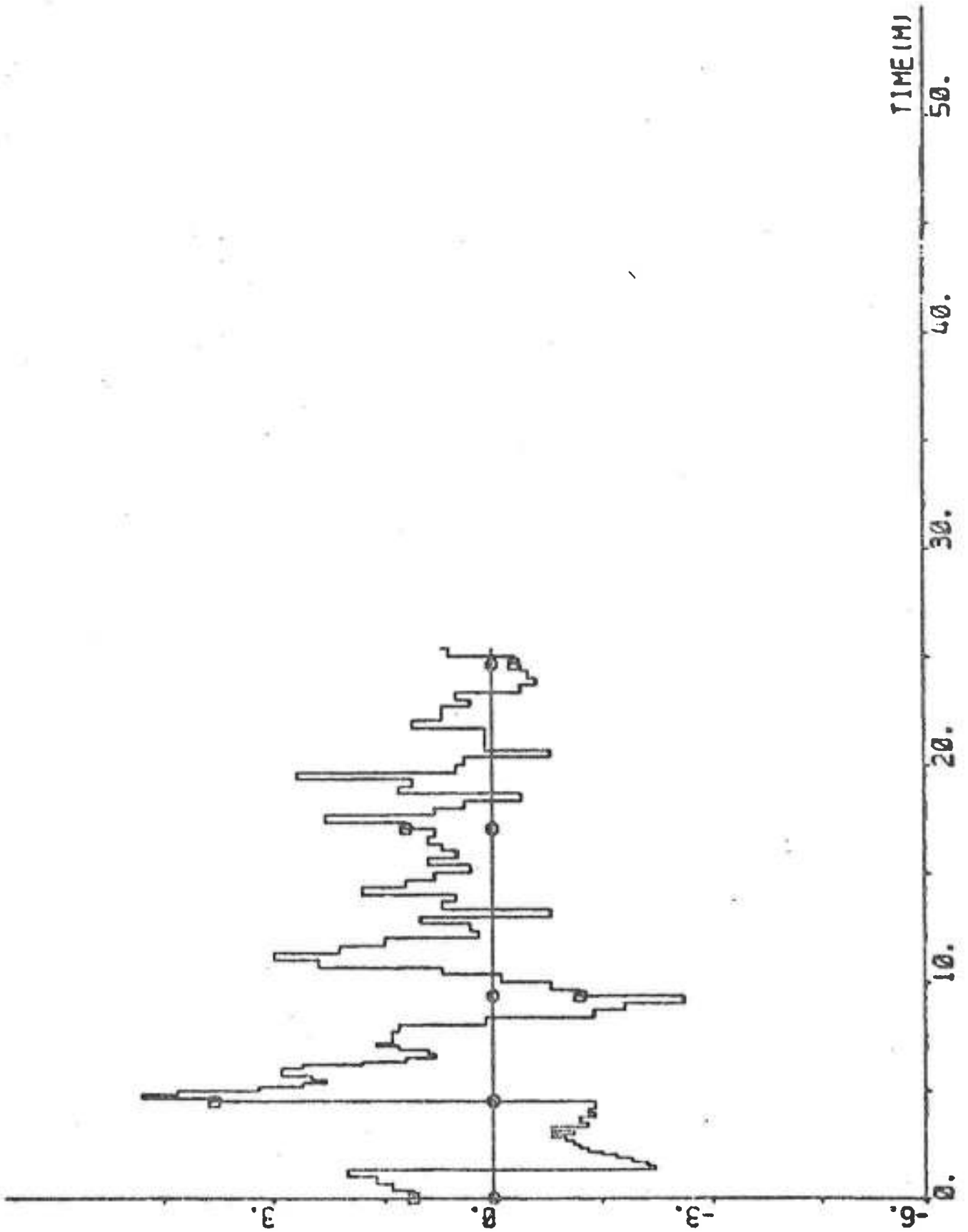
Final yaw regulator values

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

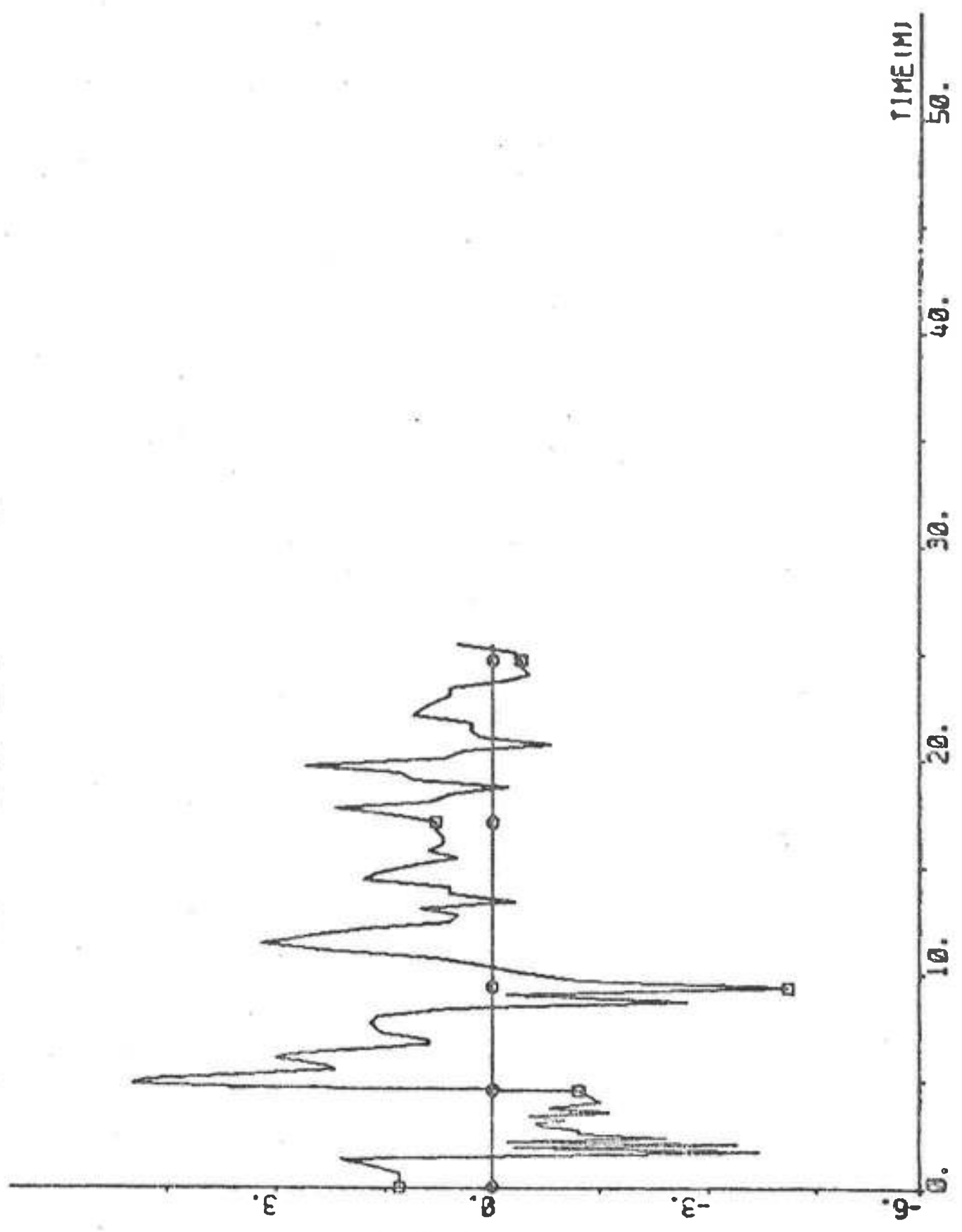
$$a_1' + a_2' + a_3' = -14.448$$

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

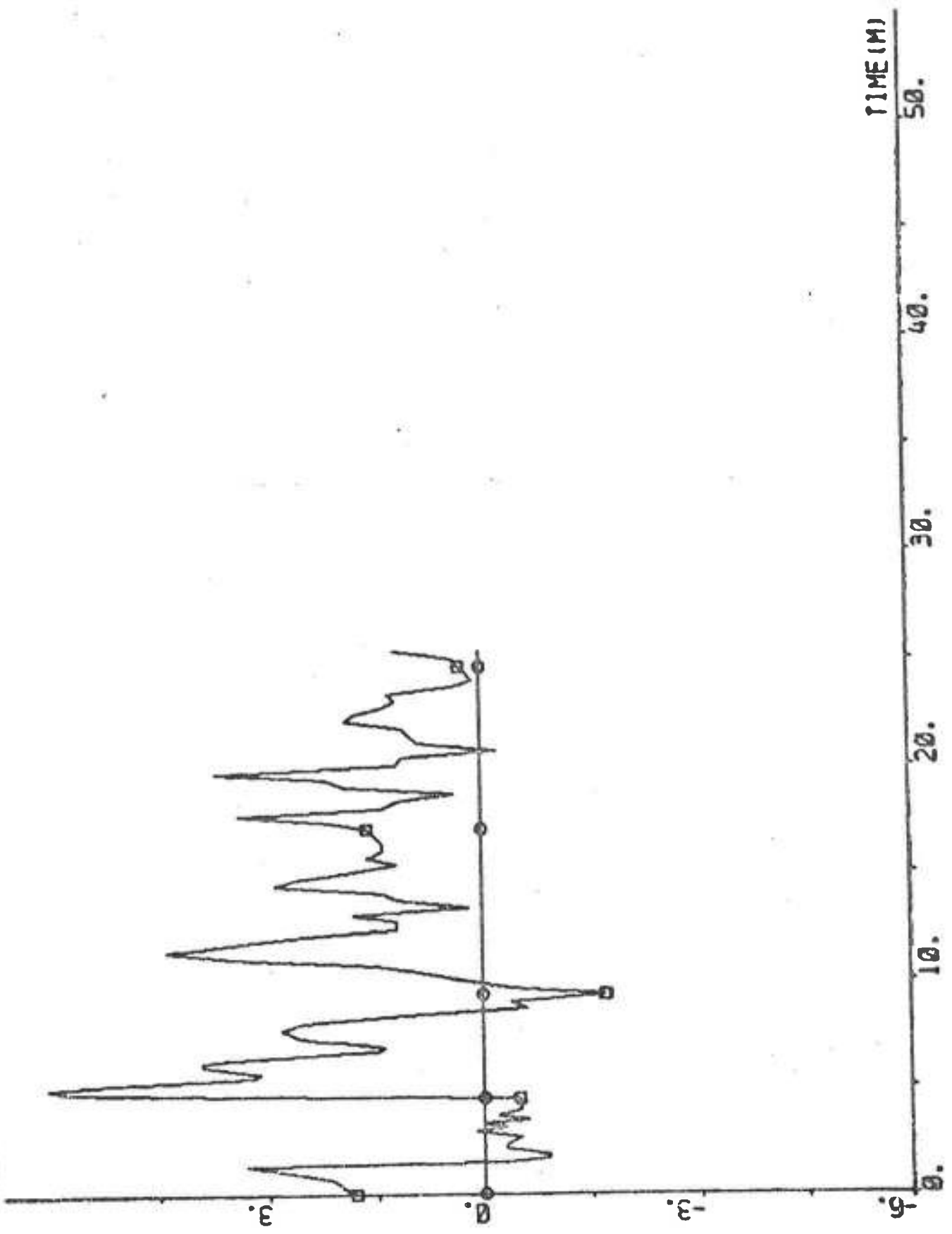
PLOT B6P1(15)←HP B6P1(1) ZERO -5 7 °DELCOG DEG



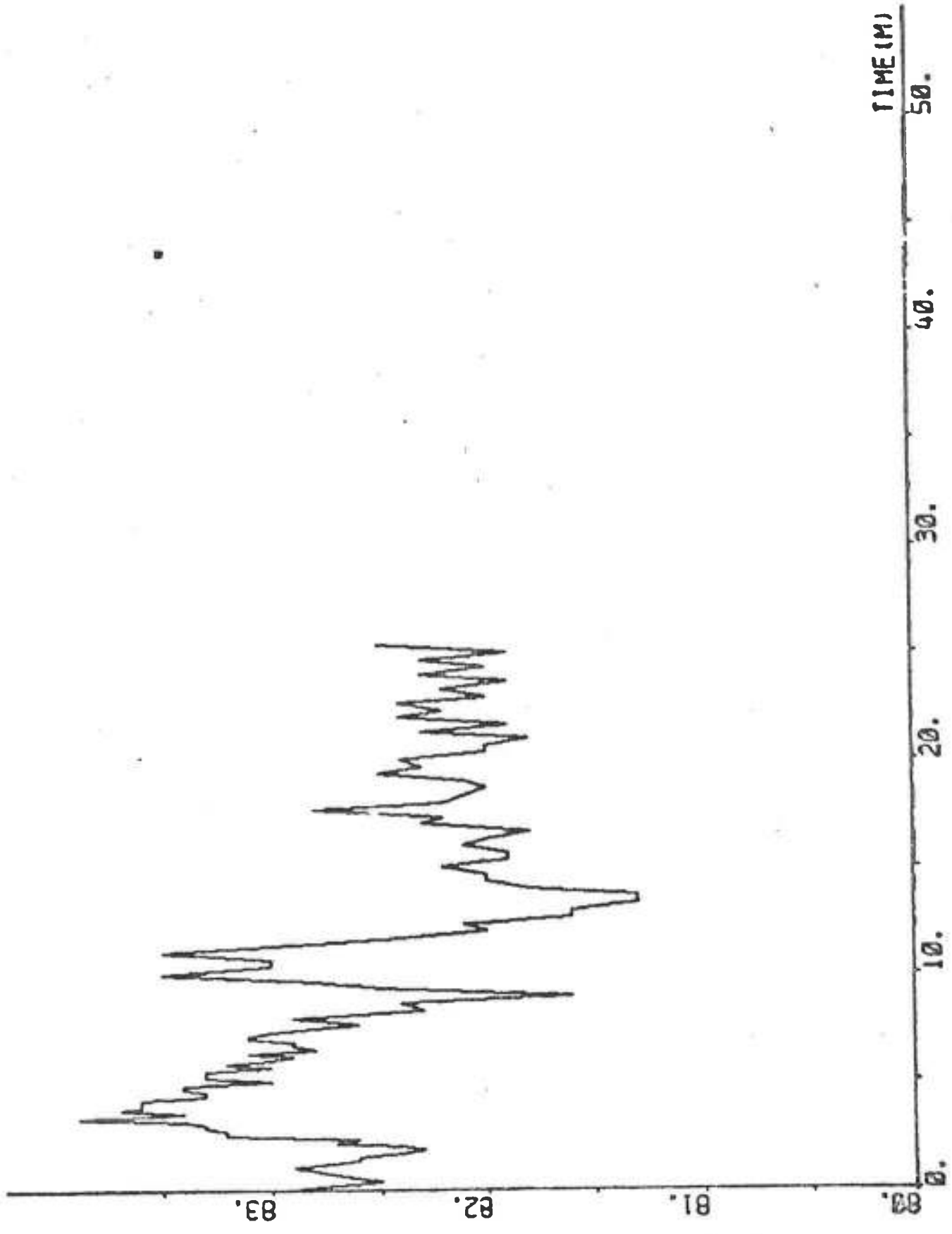
PLOT DSP1(16) - DSP1(3) ZERO - 5 7 "DELTA" DEG



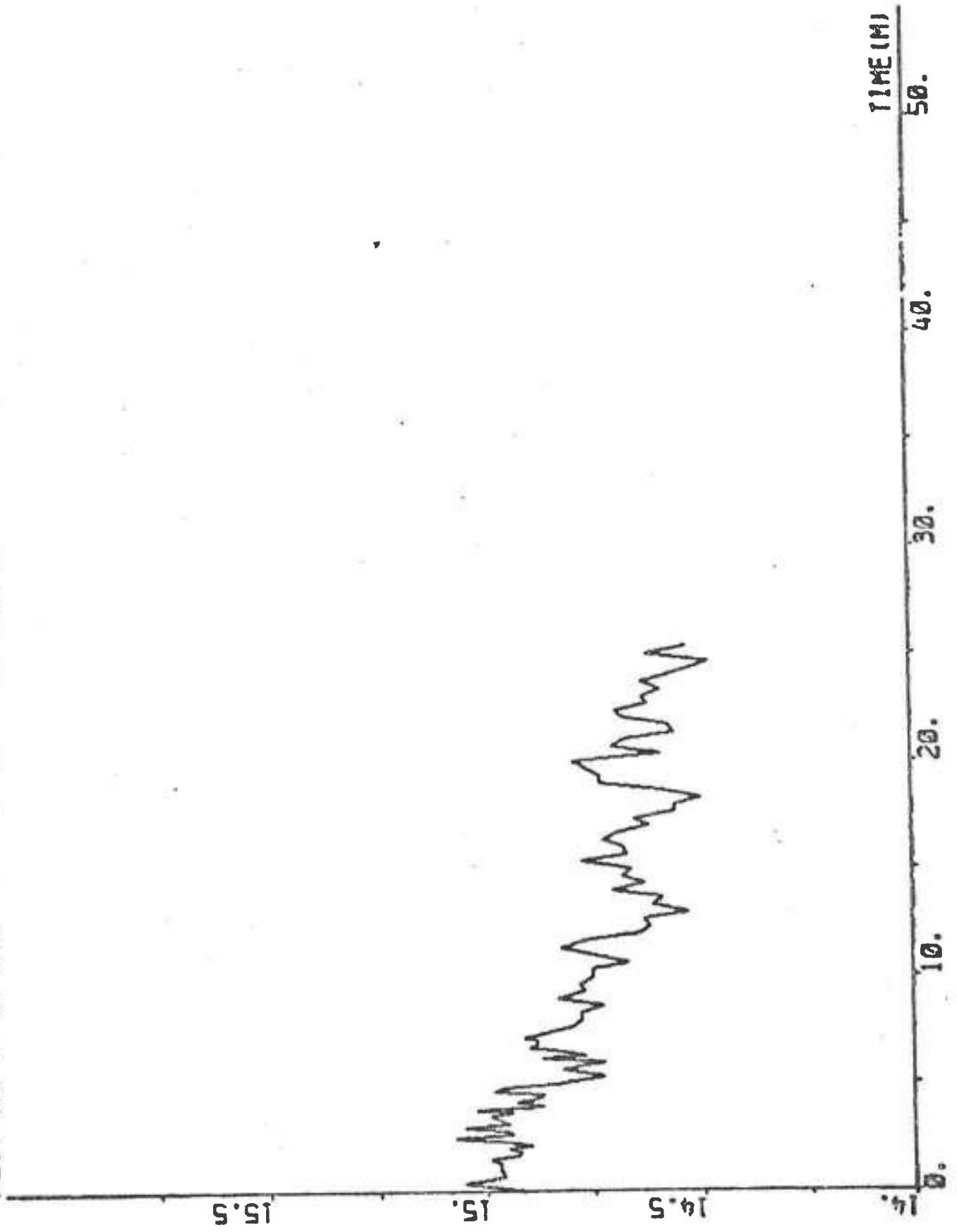
PLOT B6P1(15) ← B6P1(4) ZERO -5 7 ° DELTA DEG



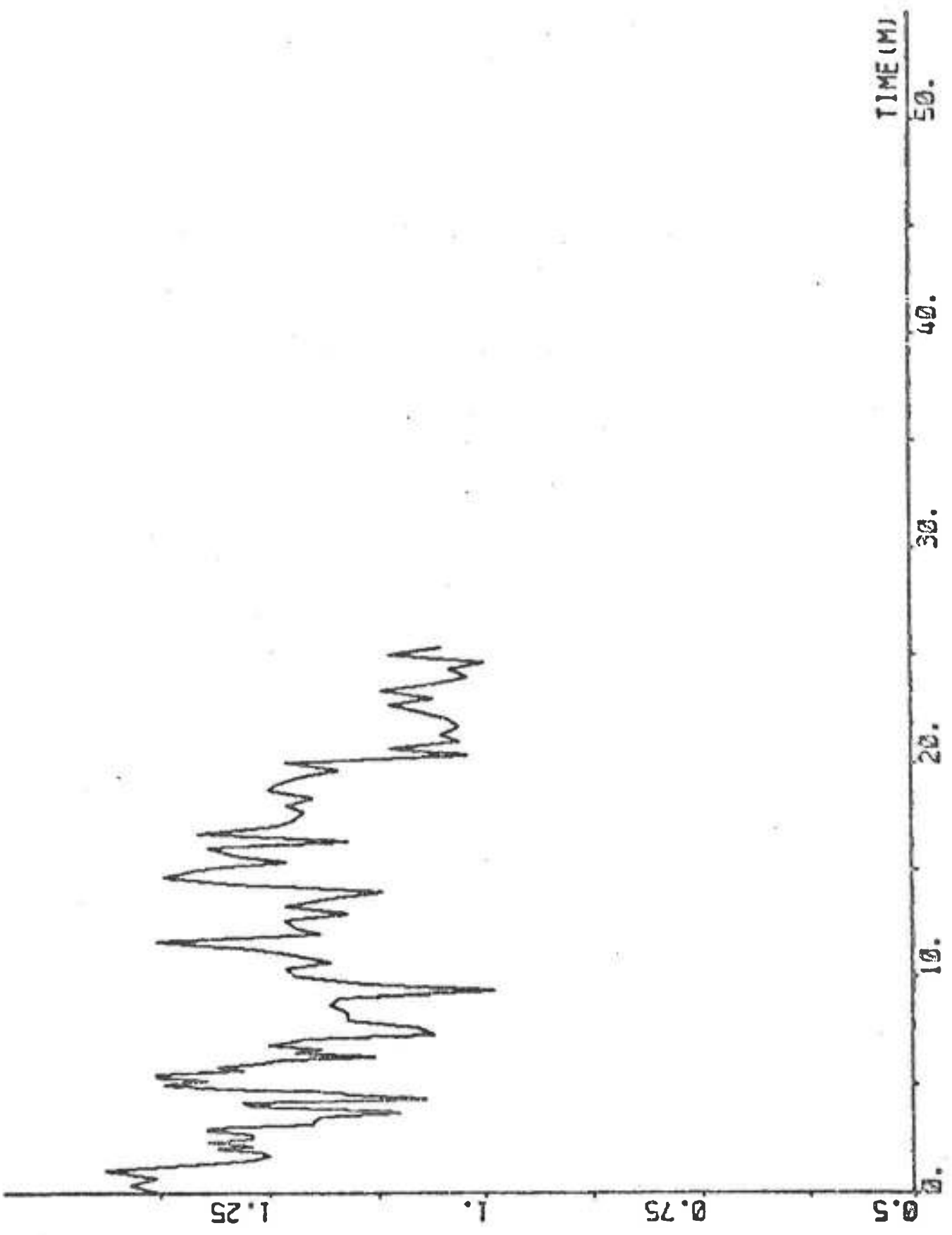
PLOT BCP1(15)-BSP1(6) 80 84 -AN RPH



PLOT BGP1(15)-BGP1(7) 14 16 "U KNOTS

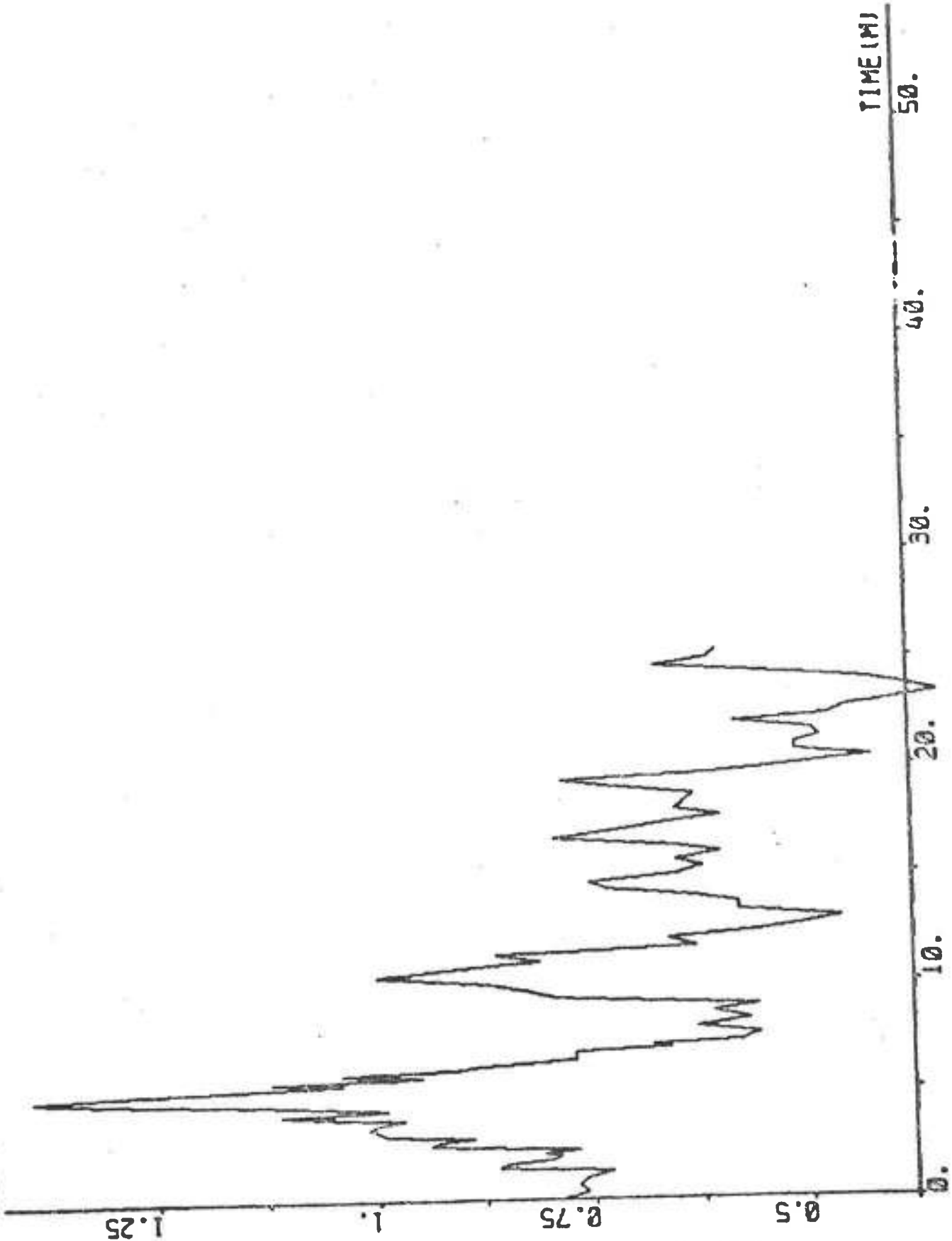


PLOT ESP1(15)-ESP1(8) 0.5 1.5 -V1 KNOTS

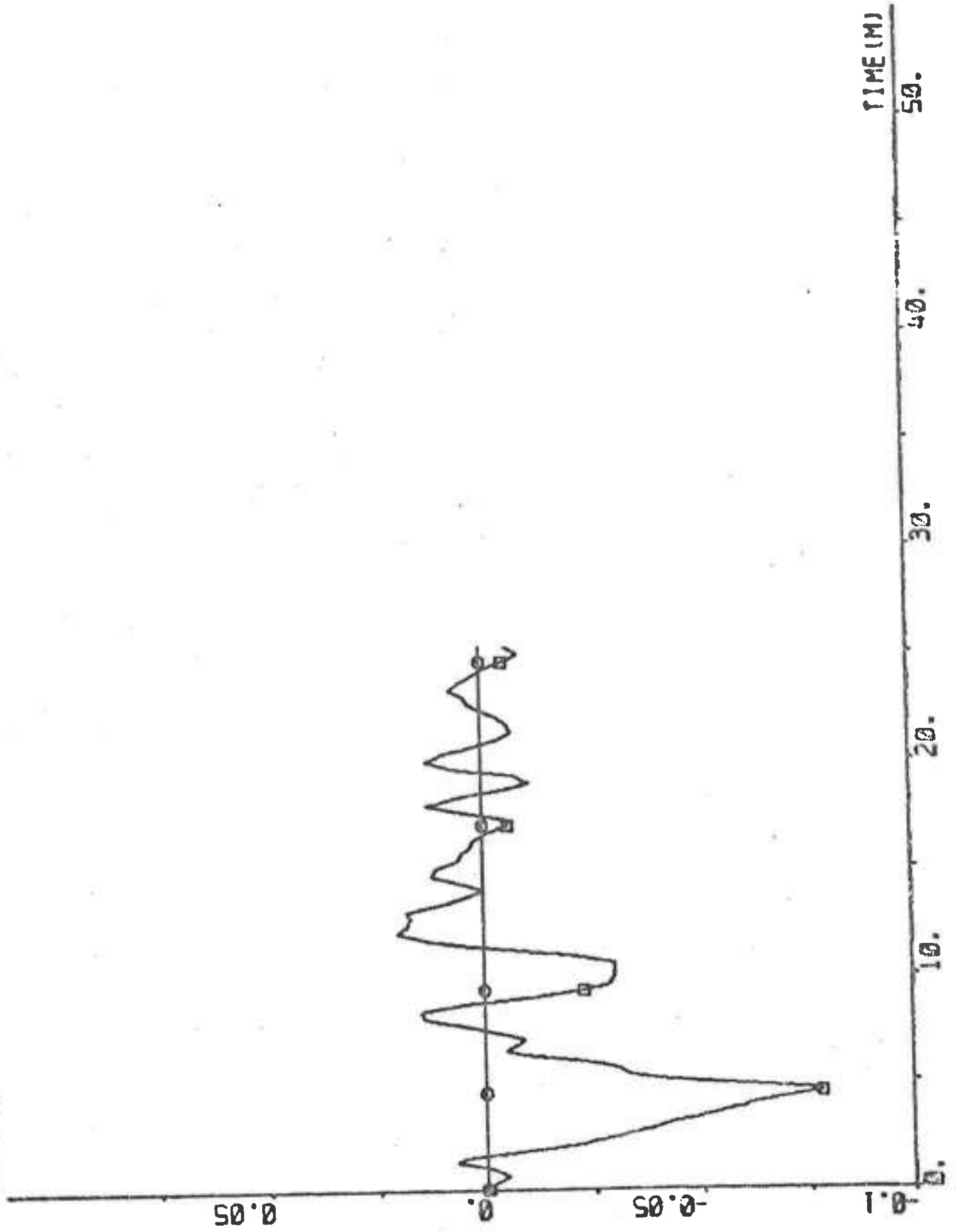


"V2 KNOTS

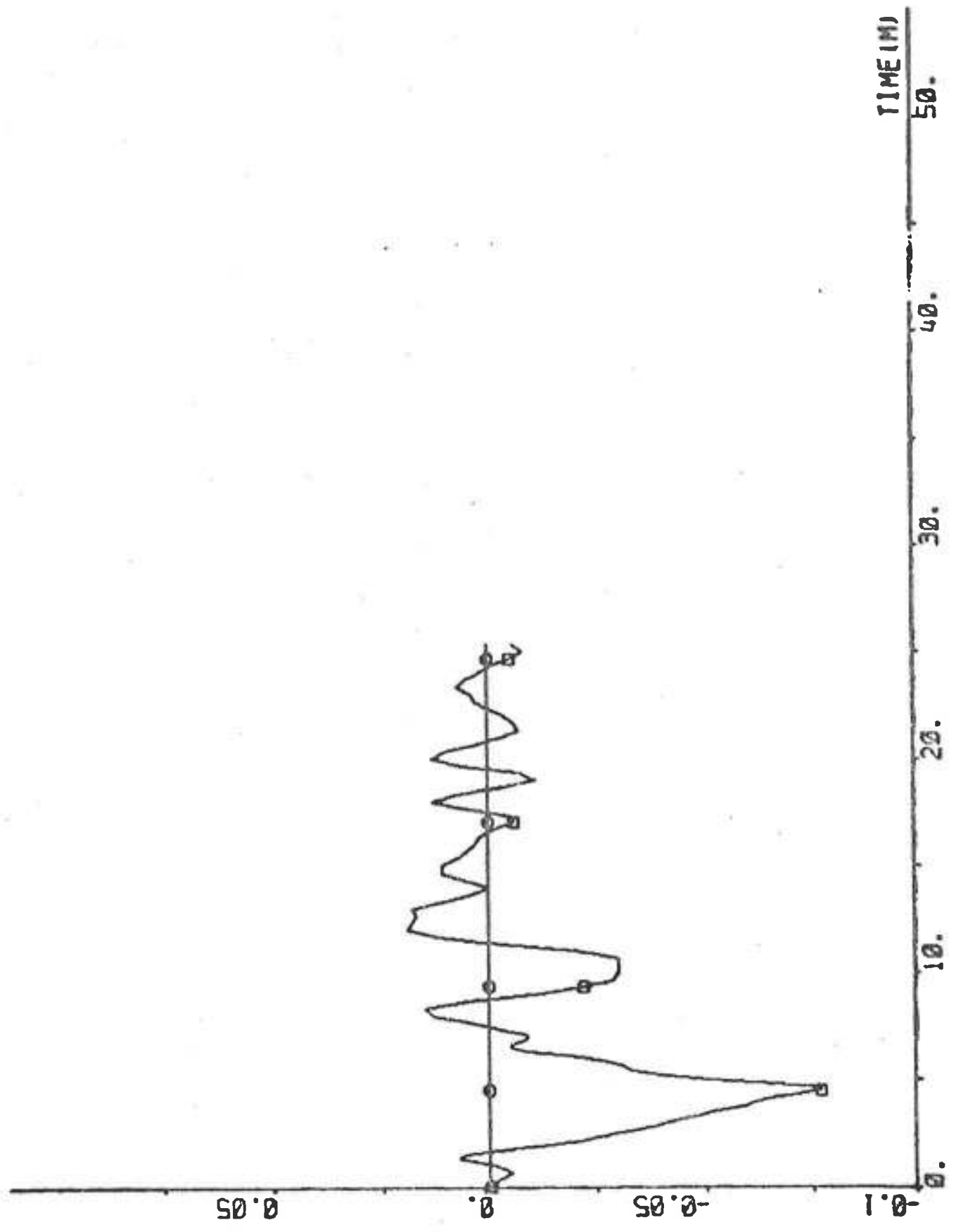
PLOT B6P1(15)~B6P1(9) 0.4 1.4



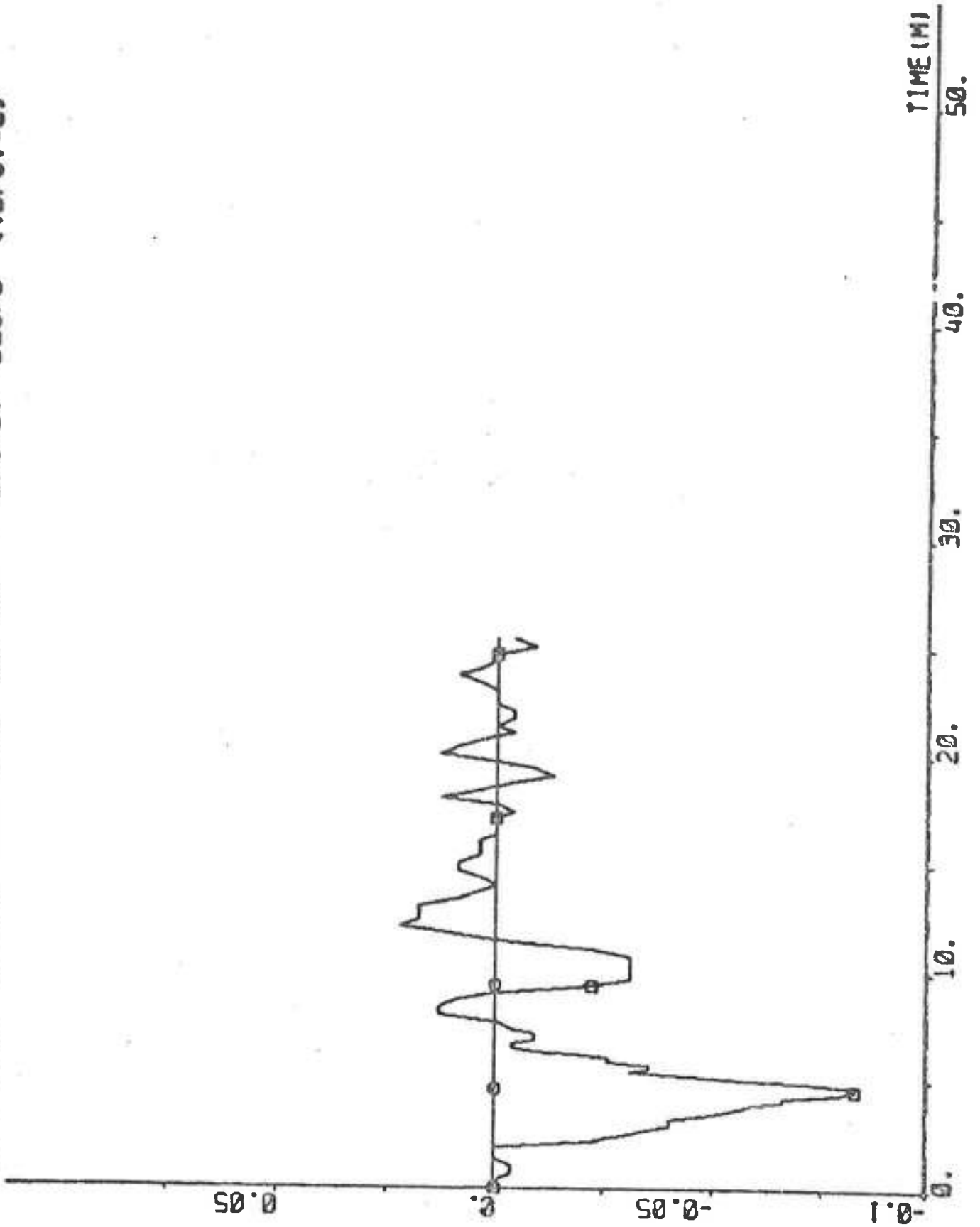
PLOT B6P1(15)-B6P1(10) ZERO -0.1 0.1 "R DEG/S



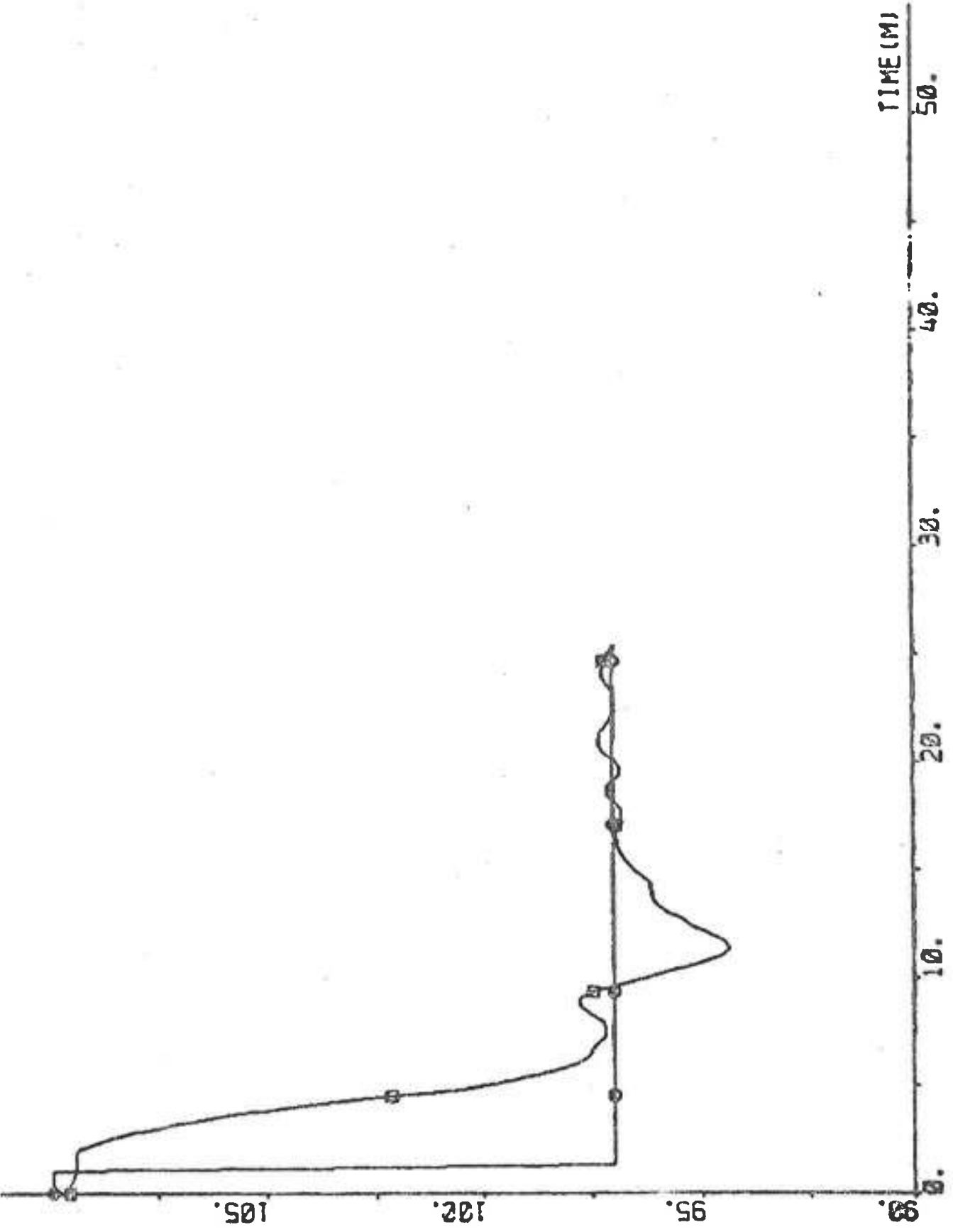
PLOT BGP1(15)-BGP1(11) ZERO -0.1 0.1 "AVR DEG/S (BR=0.5)



PLOT BGP1(15)+BGP1(12) ZERO -0.1 0.1 "DPSIDT DEC/S (IDPSI=5)

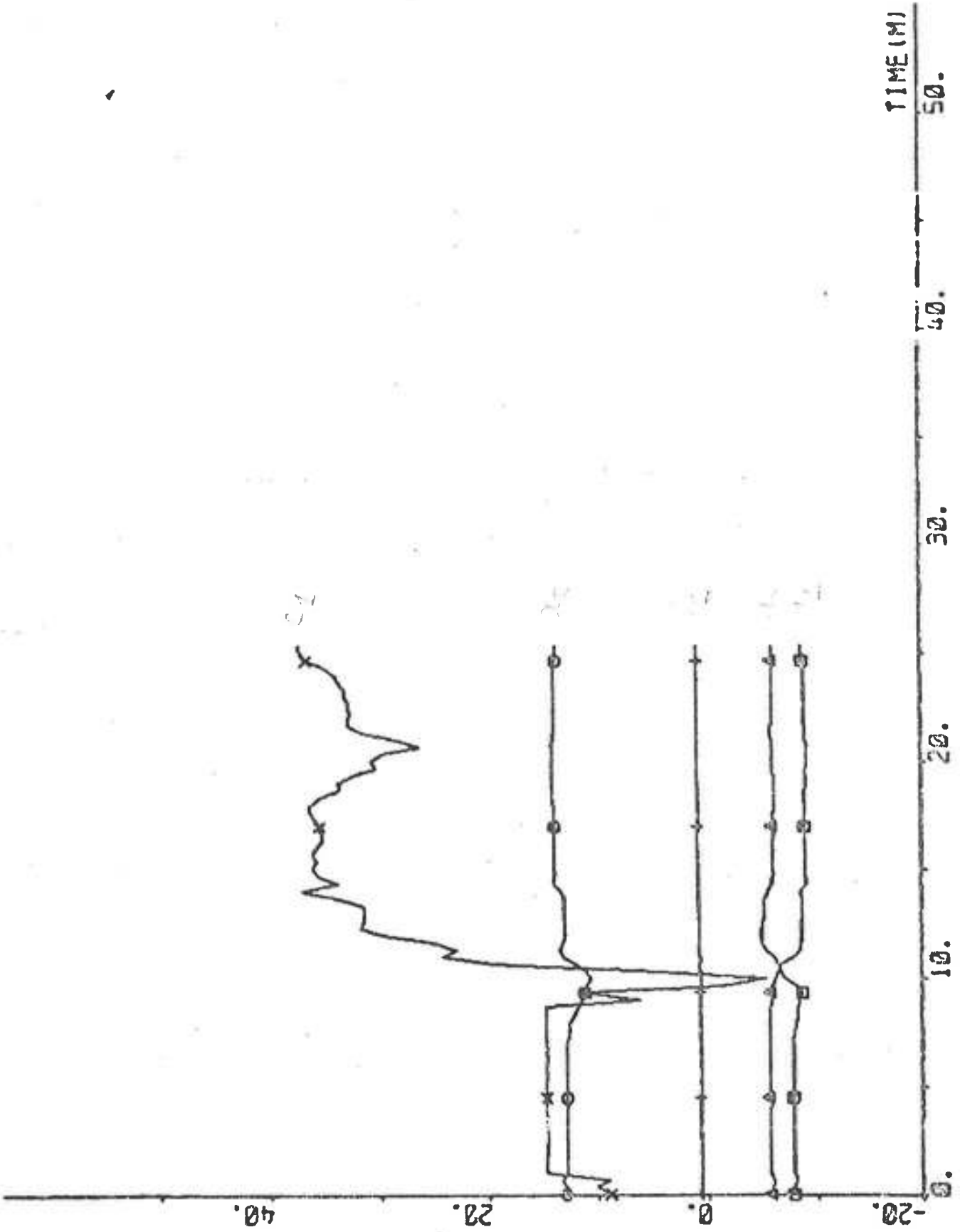


PLOT SEP1(15)-SEP1(13 14) 90 110 "PSI PSIREF DEG

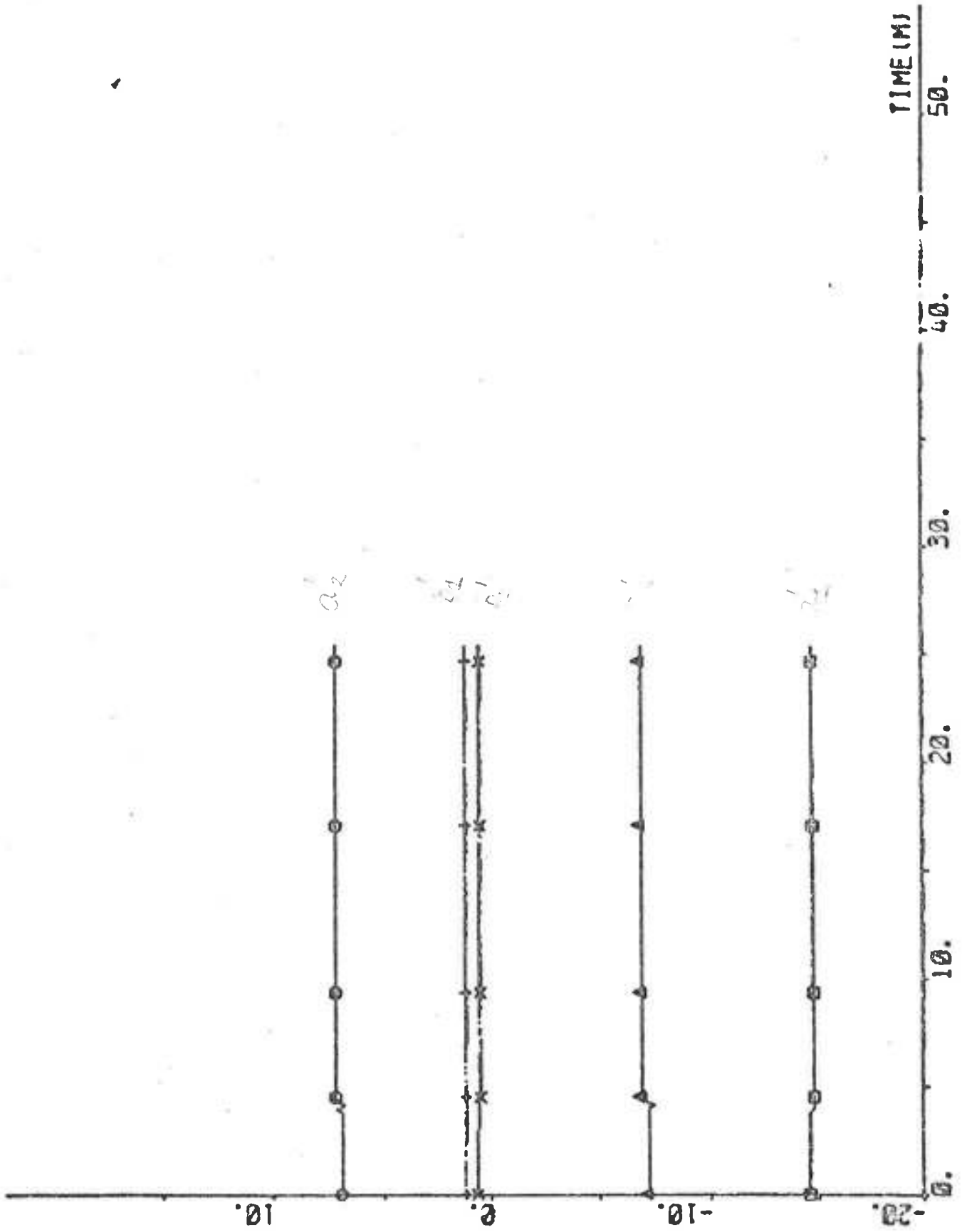


REGULATOR PARAMETERS

PLOT BCP1(16) BCP2(1 2 3 4 5) -20 40



PLOT B6P1(15) B6P2(6 7 8 9 10) -20 20 *YAW REGULATOR PARAMETERS



PLOT B6P1(16)-HP B6P2(11) 9 4 "MODYAH

