The Sea Swift Experiments October 1974 : Parts 1-4

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1975

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CTOBER 1974.

ART IV

KÄLLSTRÖM

port 7516(C) June 1975
partment of Automatic Control
nd Institute of Technology

THE SEA SWIFT EXPERIMENTS, OCTOBER 1974 - PART IV

Claes Källström

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EXPERIMENT B7

Date	1974-10-11
Time	11.43
Duration	26 min
Position	N 26° 07' E 55° 16'
Water depth	100 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	97°, 71°
RREF	0.07 deg/s
Rudder limit	$\pm 4^{\circ}$ - $\pm 10^{\circ}$
DELlM after the yaw	0.82°
Approximate mean value of AN	75.0 rpm
Approximate mean value of U	15.0 knots

The main engine tripped during the experiment. 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
ISPM = 600	IN0 = 1	AN0 = 45	

Final values

$$\begin{bmatrix} a_1 \\ a_2 \\ a_3 \\ b_1 \\ c_1 \end{bmatrix} = \begin{bmatrix} -12.844 \\ 18.512 \\ -7.225 \\ 0.432 \\ 156.177 \end{bmatrix} \qquad \text{P unknown}$$

$a_1 + a_2 + a_3 = -1.557$

Regulator parameter values for low speed were used after 13 min of the experiment, but initial high speed parameter values were introduced again after 23 min.

Yaw regulator structure

NAY = 3	NBY = 2	KY = 5
IREGY = 10	RLY = 0.95	IRR = 1
AK1V = 30	AK2V = 1.4	AK3V = 120
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

$$\begin{bmatrix} a'_1 \\ a'_2 \\ a'_3 \\ b'_1 \\ b'_2 \end{bmatrix} = \begin{bmatrix} -14.7 \\ 7.2 \\ -6.9 \\ 1.2 \\ 0.6 \end{bmatrix} \qquad PY = \begin{bmatrix} 100 & & & & \\ 0 & 100 & & & \\ 0 & 0 & 100 & & \\ 0 & 0 & 0 & 10 & \\ 0 & 0 & 0 & 0 & 10 \end{bmatrix}$$

$a'_1 + a'_2 + a'_3 = -14.4$

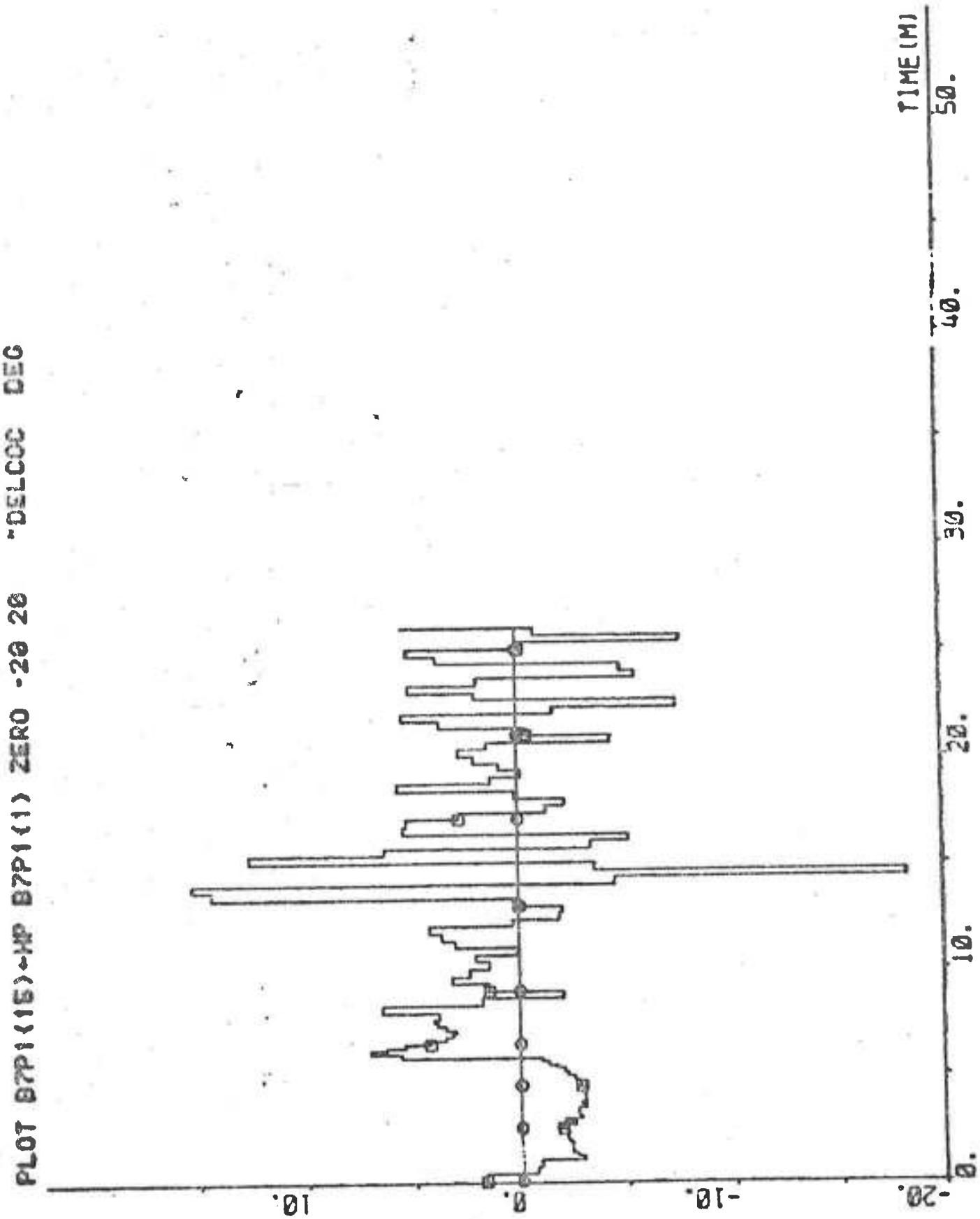
Final yaw regulator values

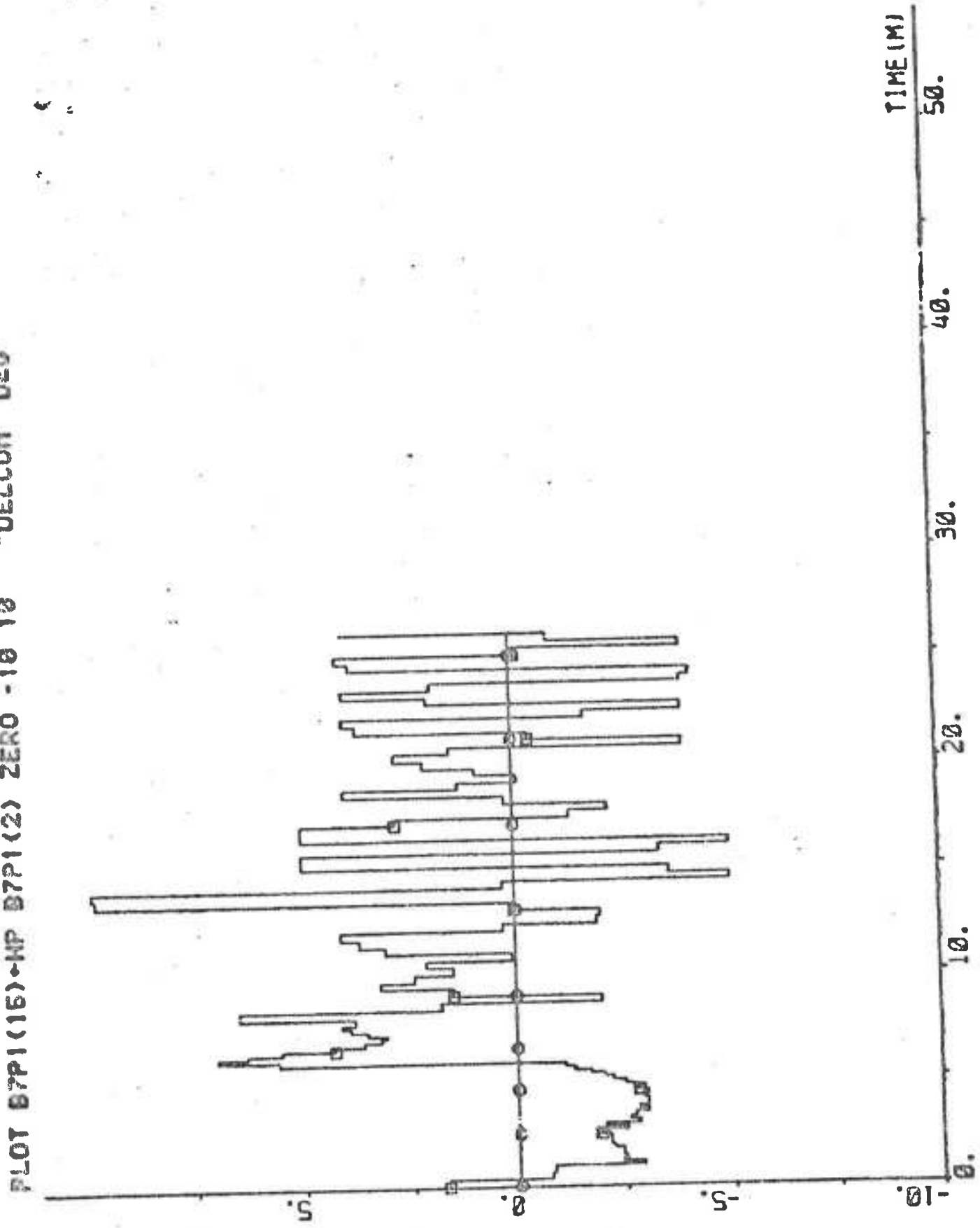
$$\begin{bmatrix} a_1' \\ a_2' \\ a_3' \\ b_1' \\ b_2' \end{bmatrix} = \begin{bmatrix} -14.246 \\ 7.898 \\ -8.806 \\ 1.296 \\ 0.713 \end{bmatrix} \qquad PY = \begin{bmatrix} 223.039 & & & & \\ -666.916 & 1600.364 & & & \\ 555.104 & -208.102 & -514.165 & & \\ -4.729 & -78.567 & 42.855 & 4.925 & \\ -8.304 & -71.308 & 41.513 & 3.720 & 4.074 \end{bmatrix}$$

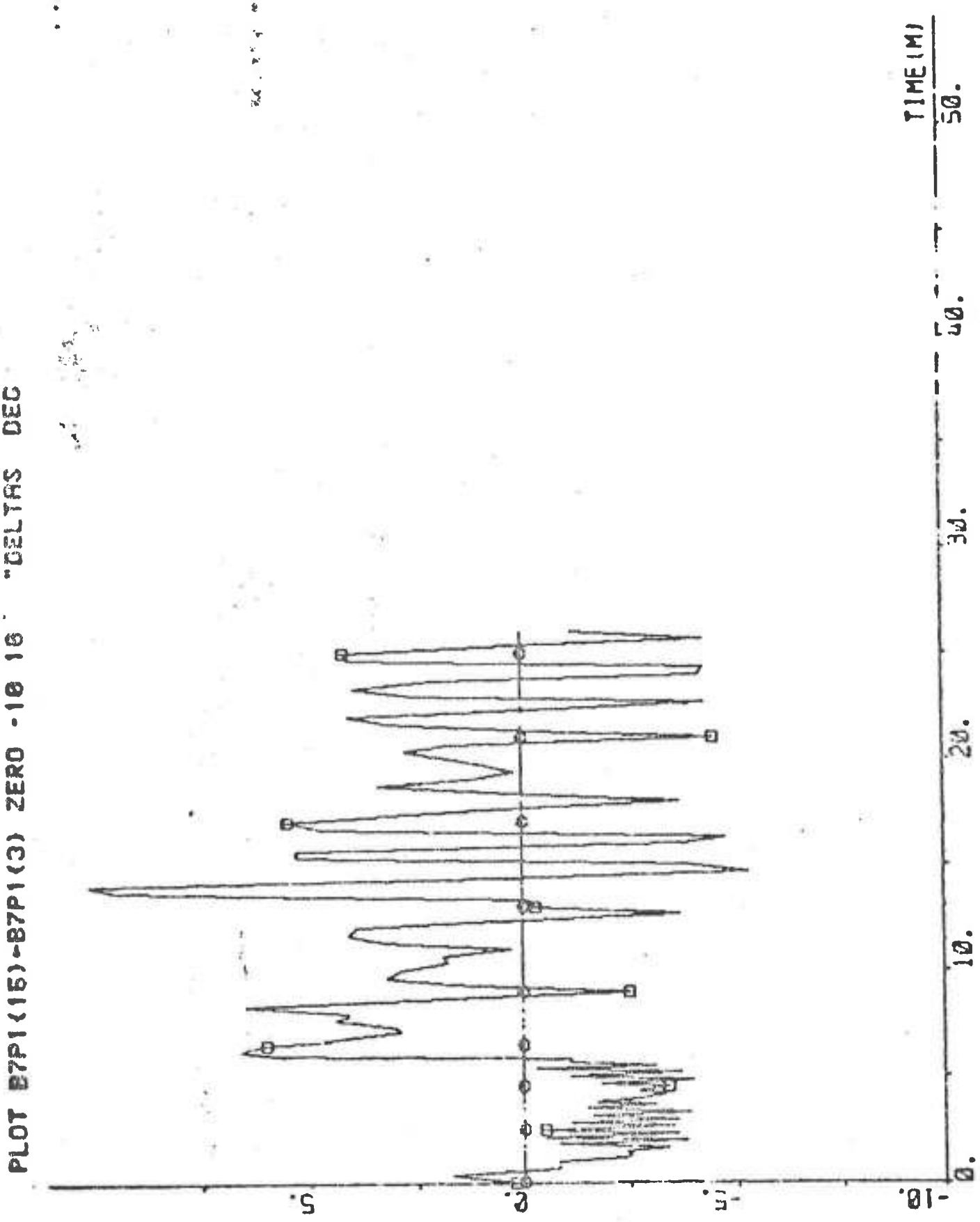
$a_1' + a_2' + a_3' = -15.154$

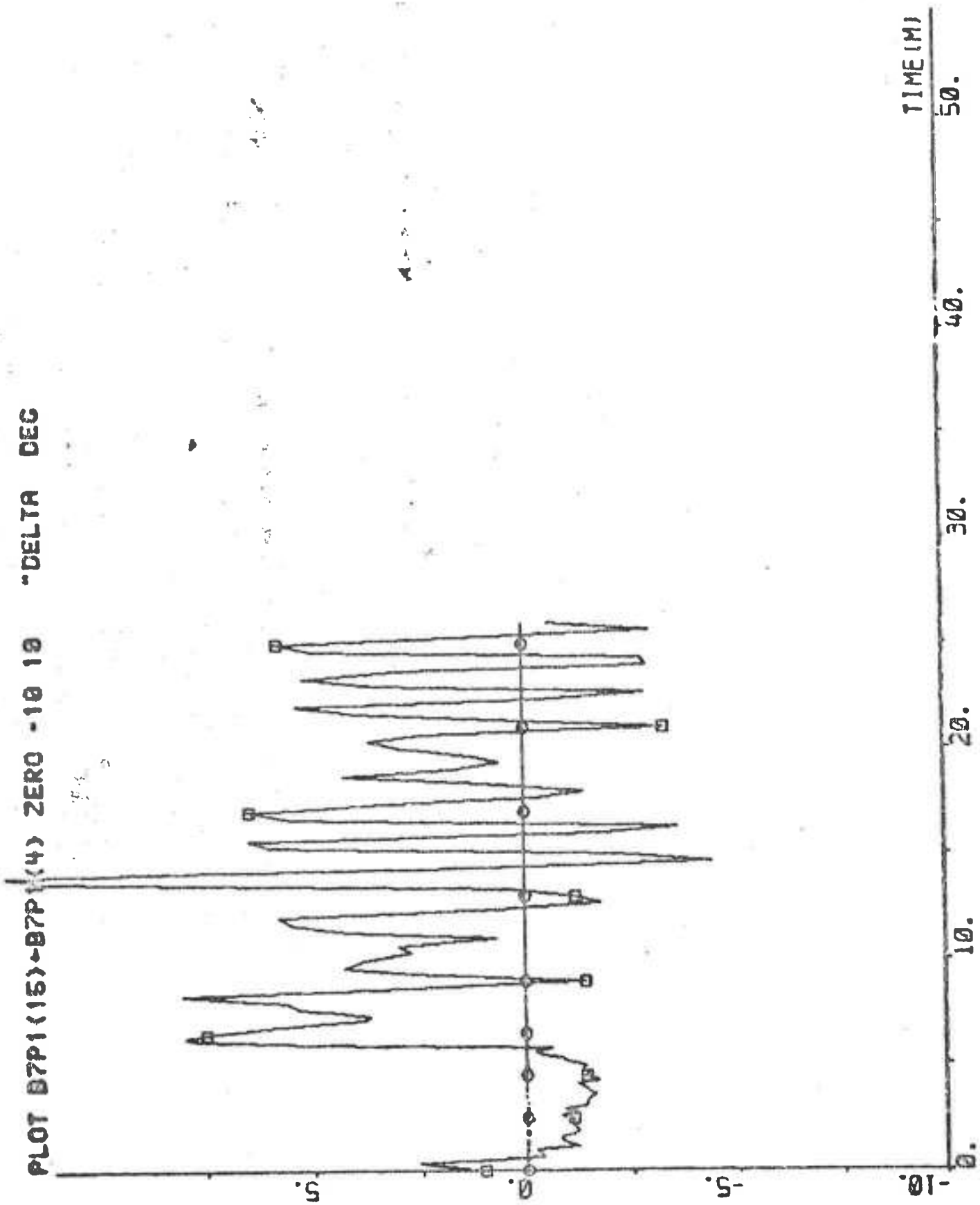
Notice that PY is not positive definite, because of the program error mentioned above.

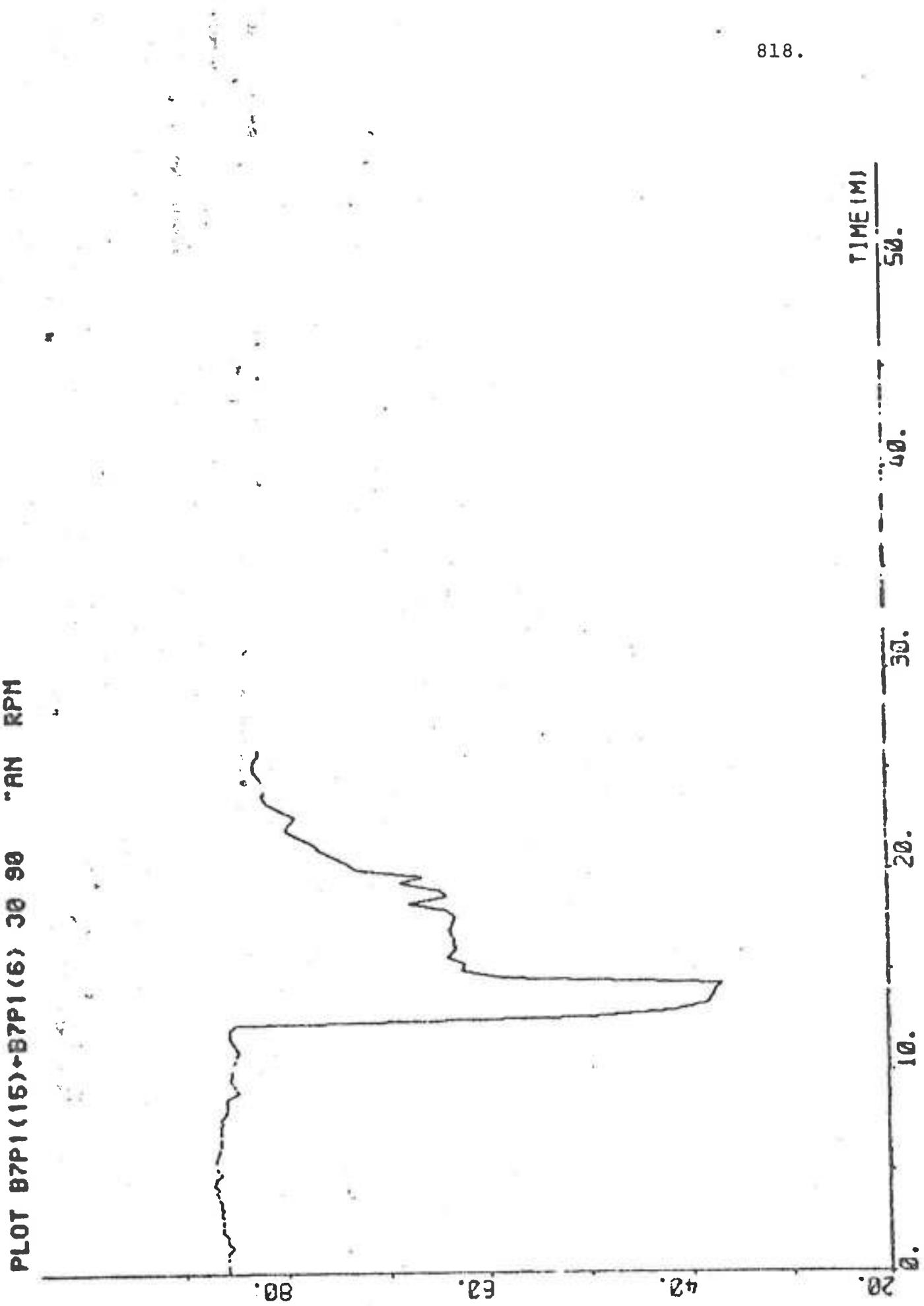
The yaw was not affected by the main engine trip.

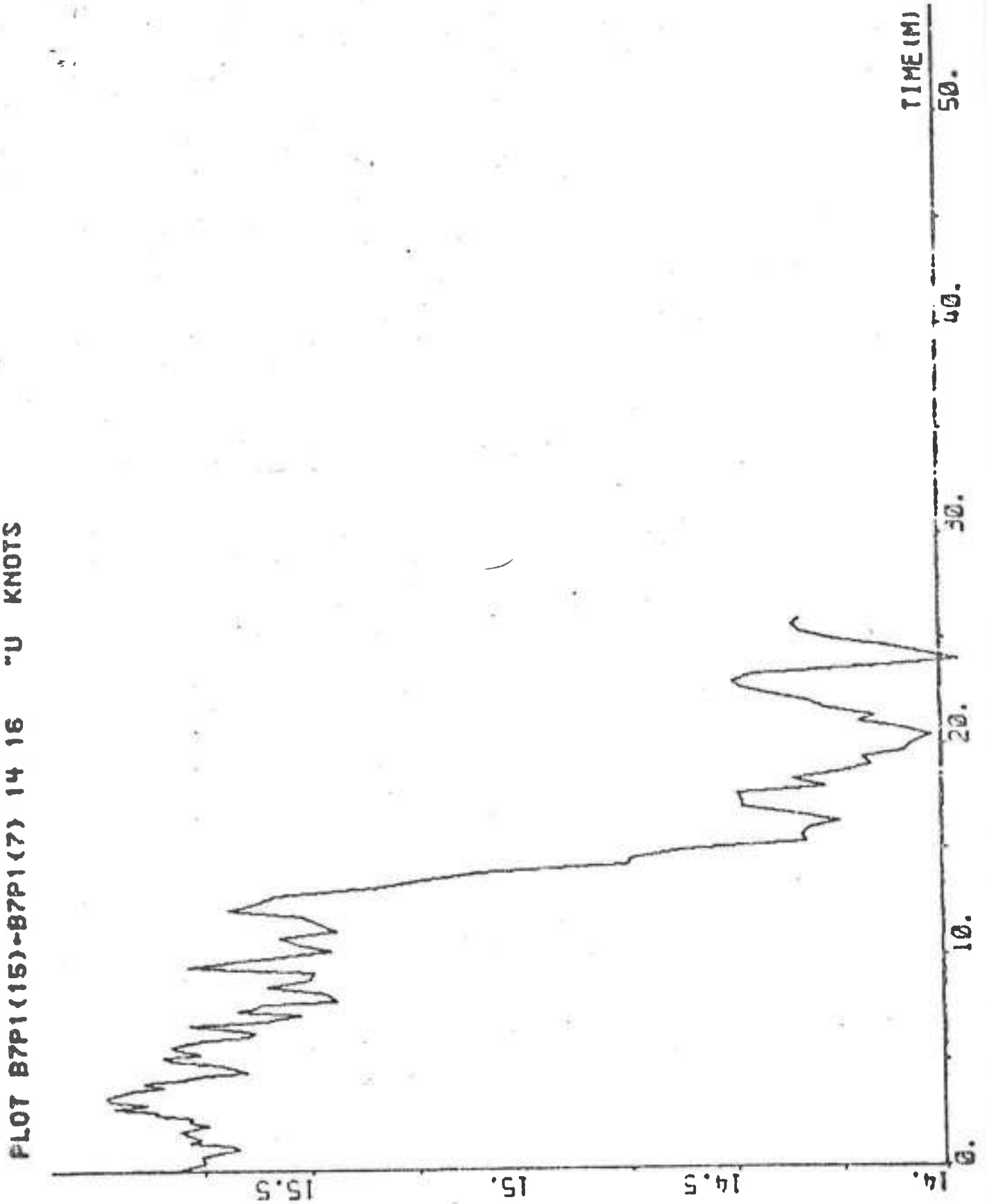

PLOT B7P1(15)-HP B7P1(1) ZERO -20 20 "DELCOC DEG
TIME(M)
0.
10.
20.
30.
40.
50.
-20.
-10.
0.
10.

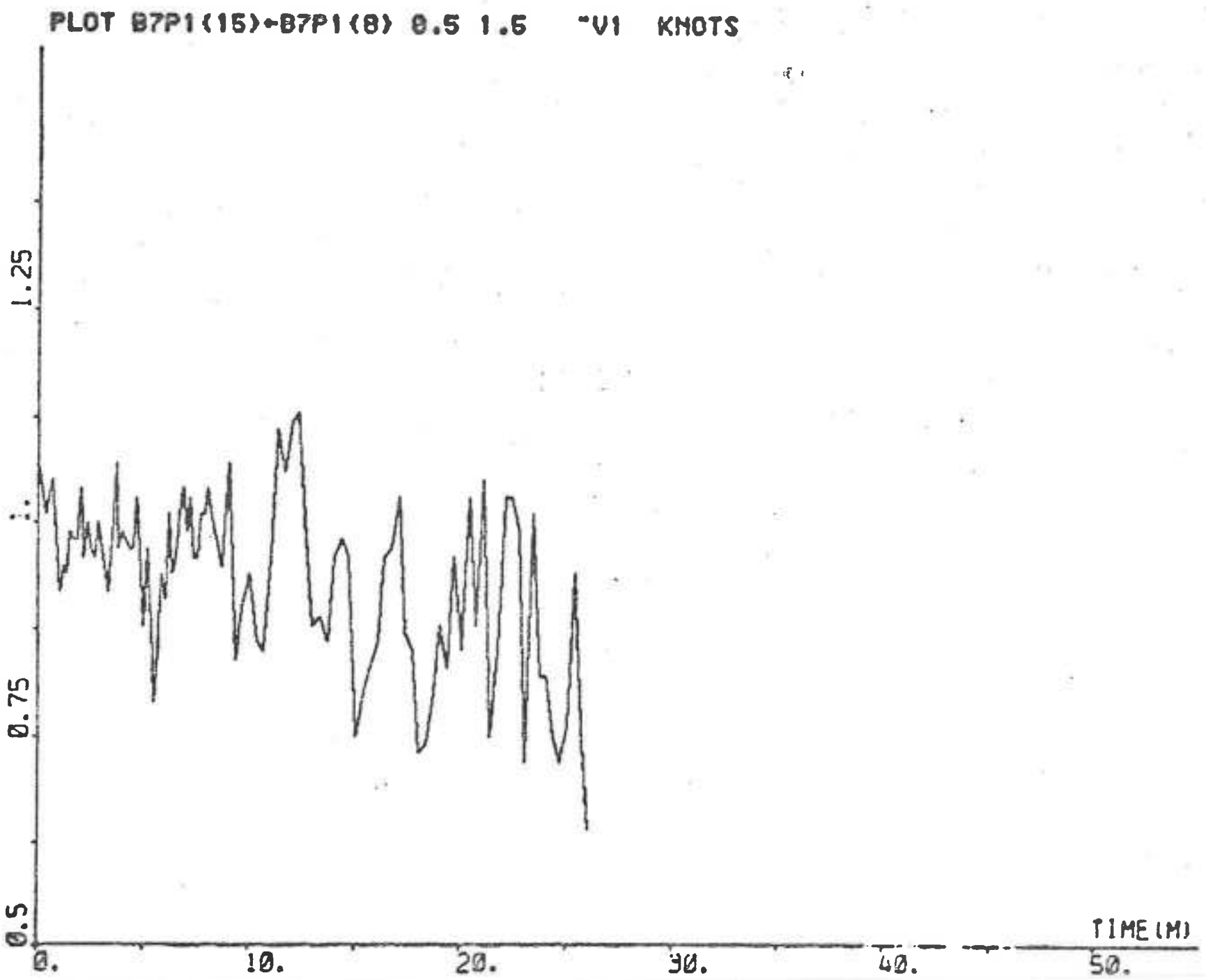

PLOT B7P1(16)-HP B7P1(2) ZERO -10 10 "DELCOH DEG
TIME (M)
0.
10.
20.
30.
40.
50.
-10.
-5.
0.
5.

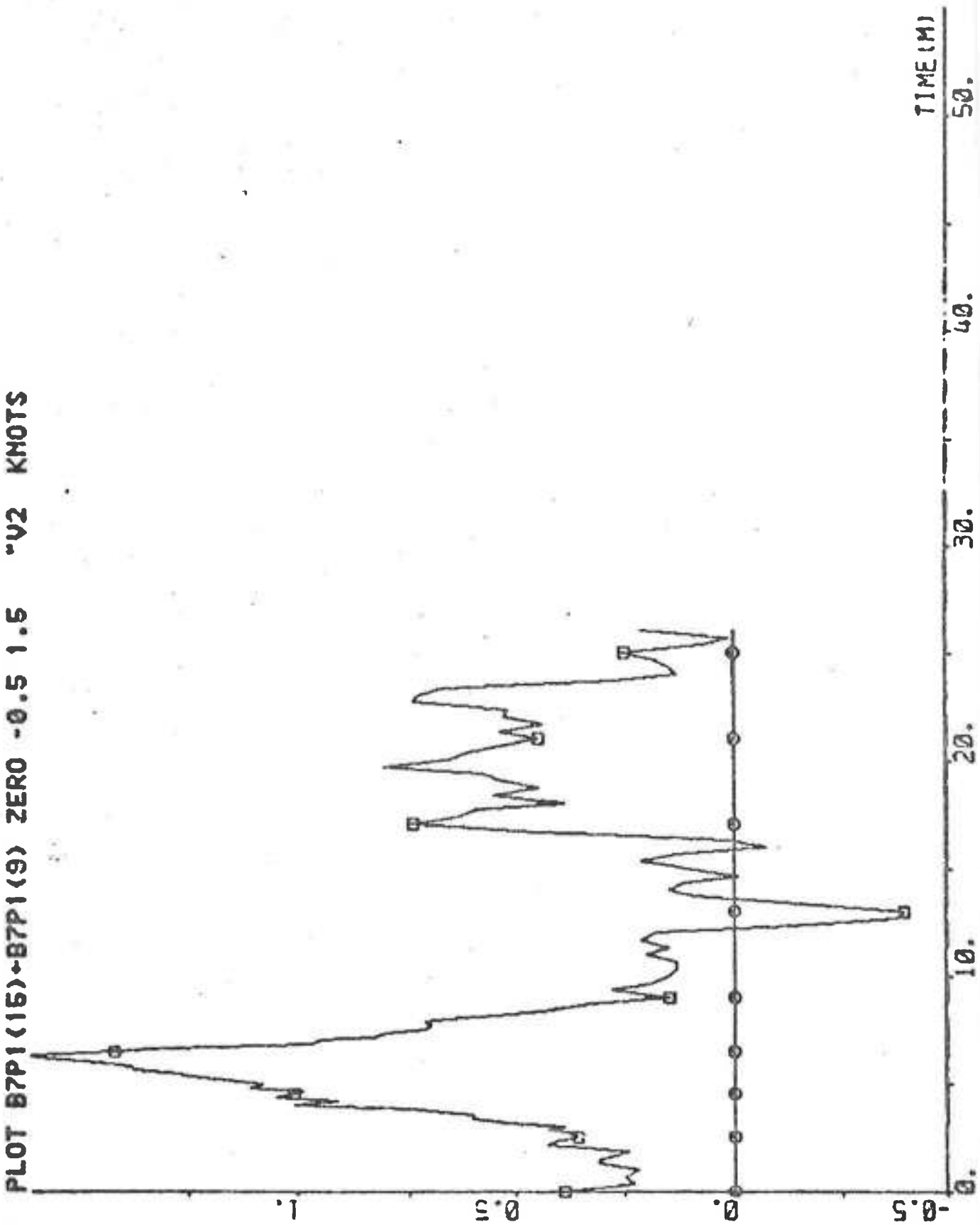

PLOT B7P1(16)-B7P1(3) ZERO -10 10 "DELTAS DEC
TIME(M)
0.
10.
20.
30.
40.
50.
-10.
-5.
0.
5.

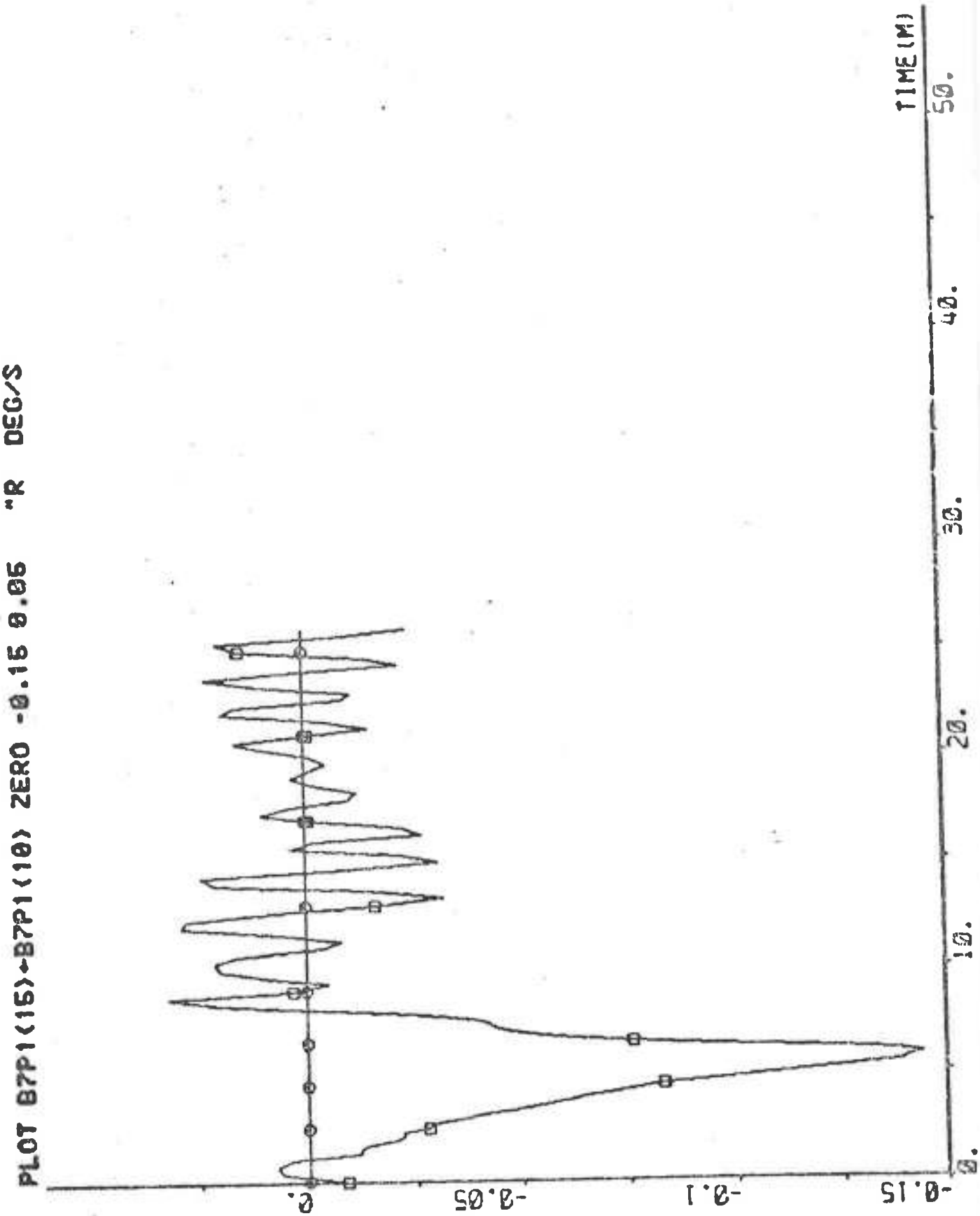

PLOT B7P1(15)-B7P1(4) ZERO -10 10 "DELTA DEC
10.
5.
0.
-5.
-10.
0.
10.
20.
30.
40.
50.
TIME(MI

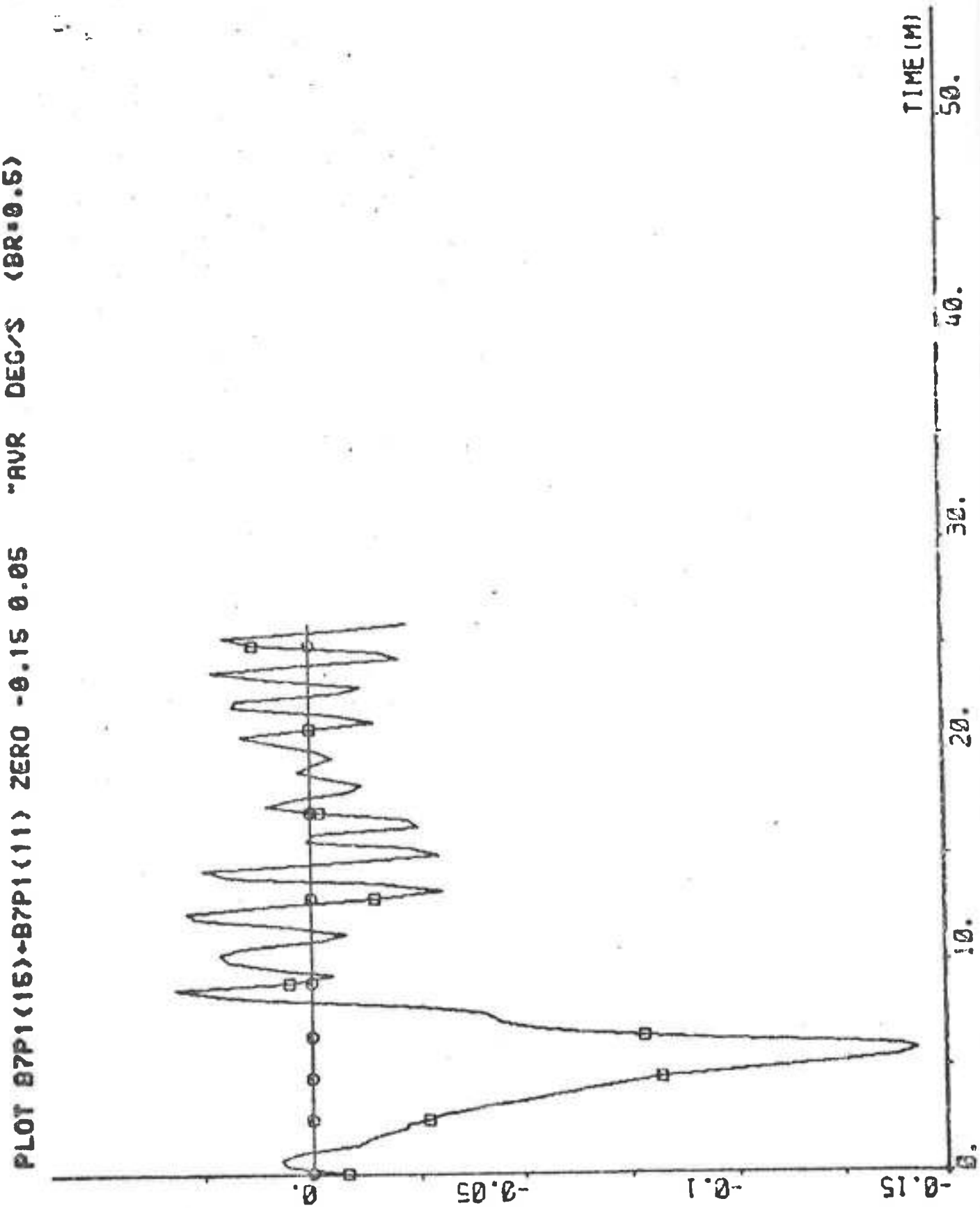

PLOT B7P1(16)-B7P1(6) 30 90 "AN RPM
TIME(MI)
0.
10.
20.
30.
40.
50.
20.
42.
63.
80.

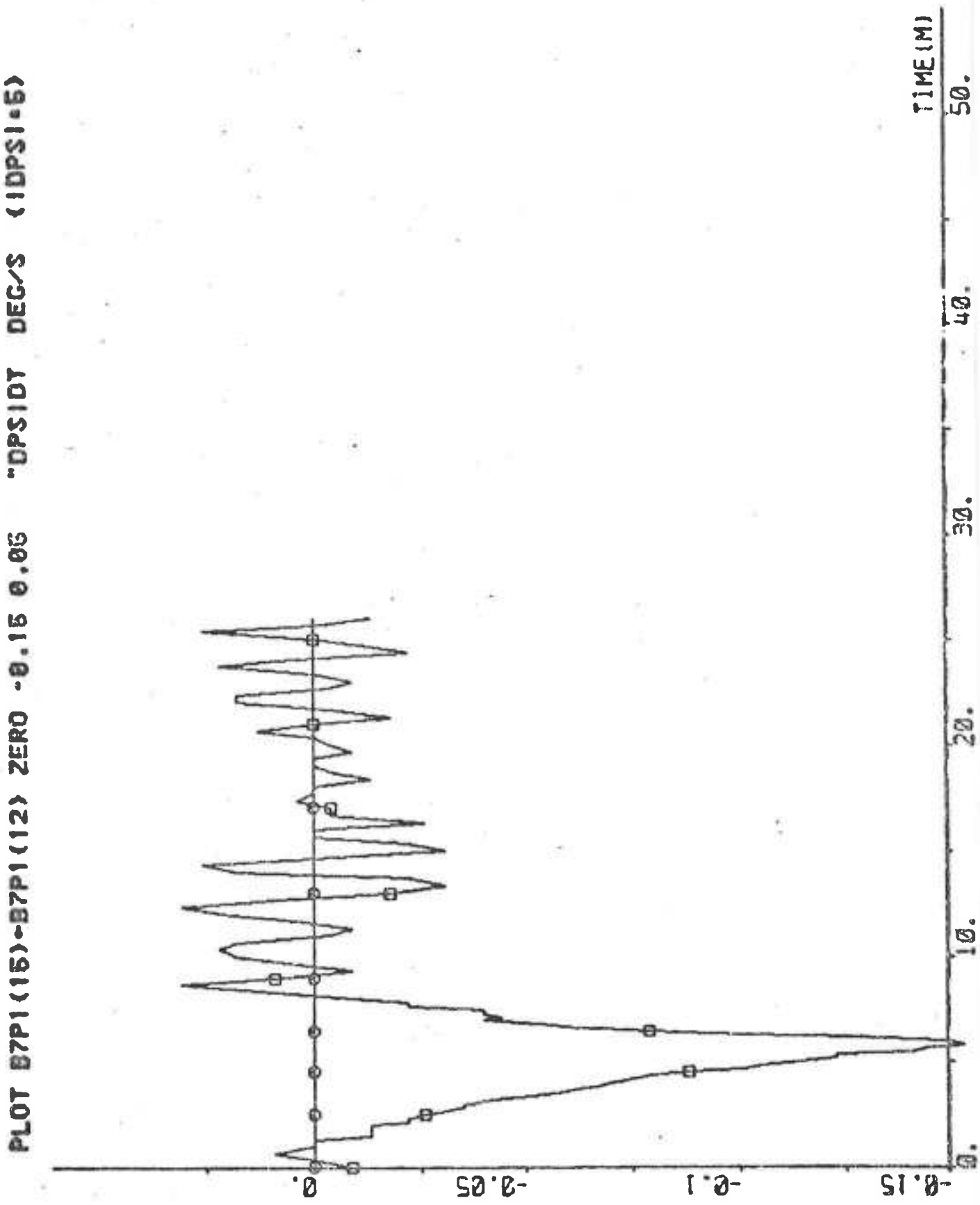

PLOT B7P1(15)-B7P1(7) 14 16 "U KNOTS
14.
14.5
15.
15.5
0.
10.
20.
30.
40.
50.
TIME(M)

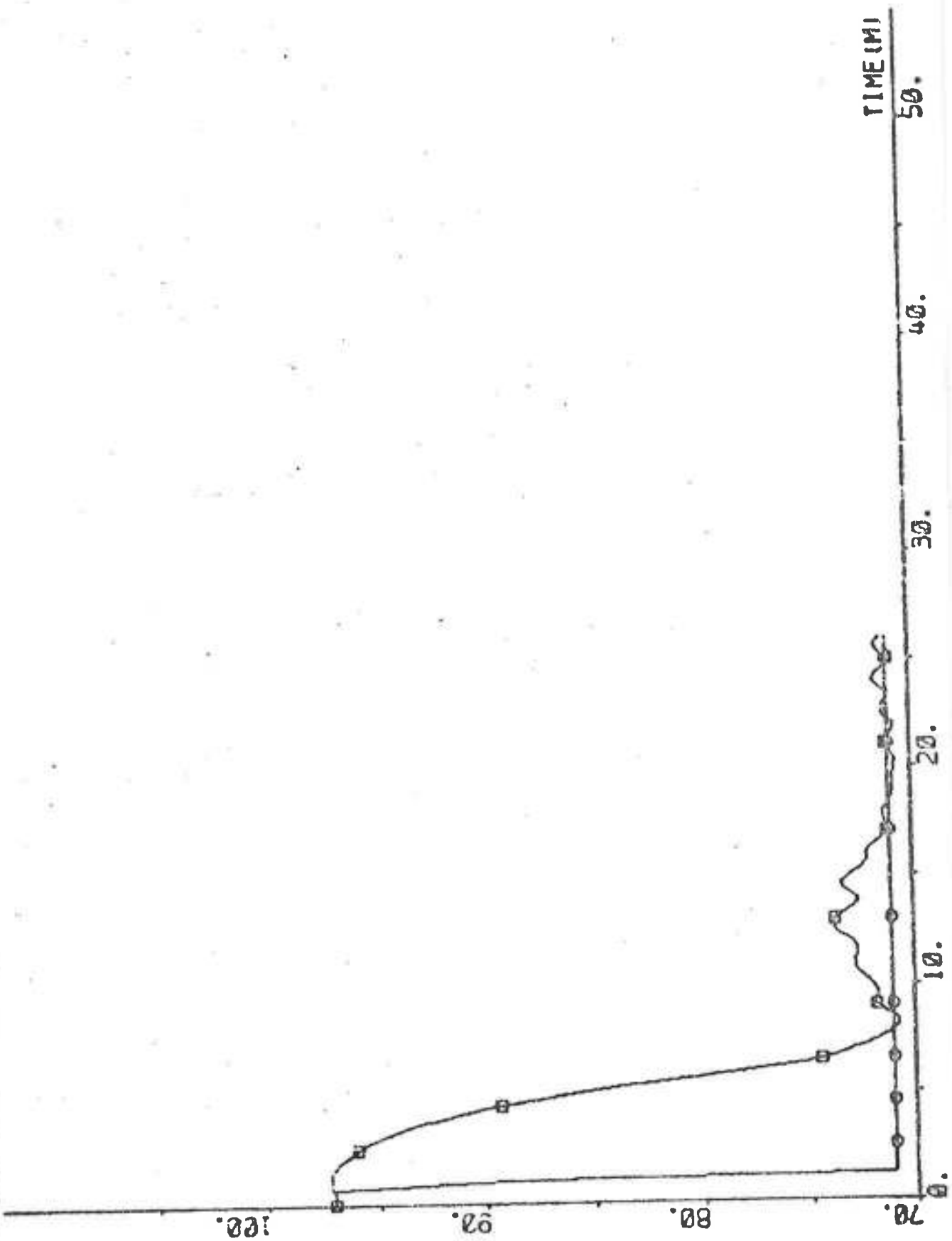

PLOT B7P1(15)-B7P1(8) 0.5 1.5 "V1 KNOTS
1.25
0.75
0.5
0.
10.
20.
30.
40.
50.
TIME(M)

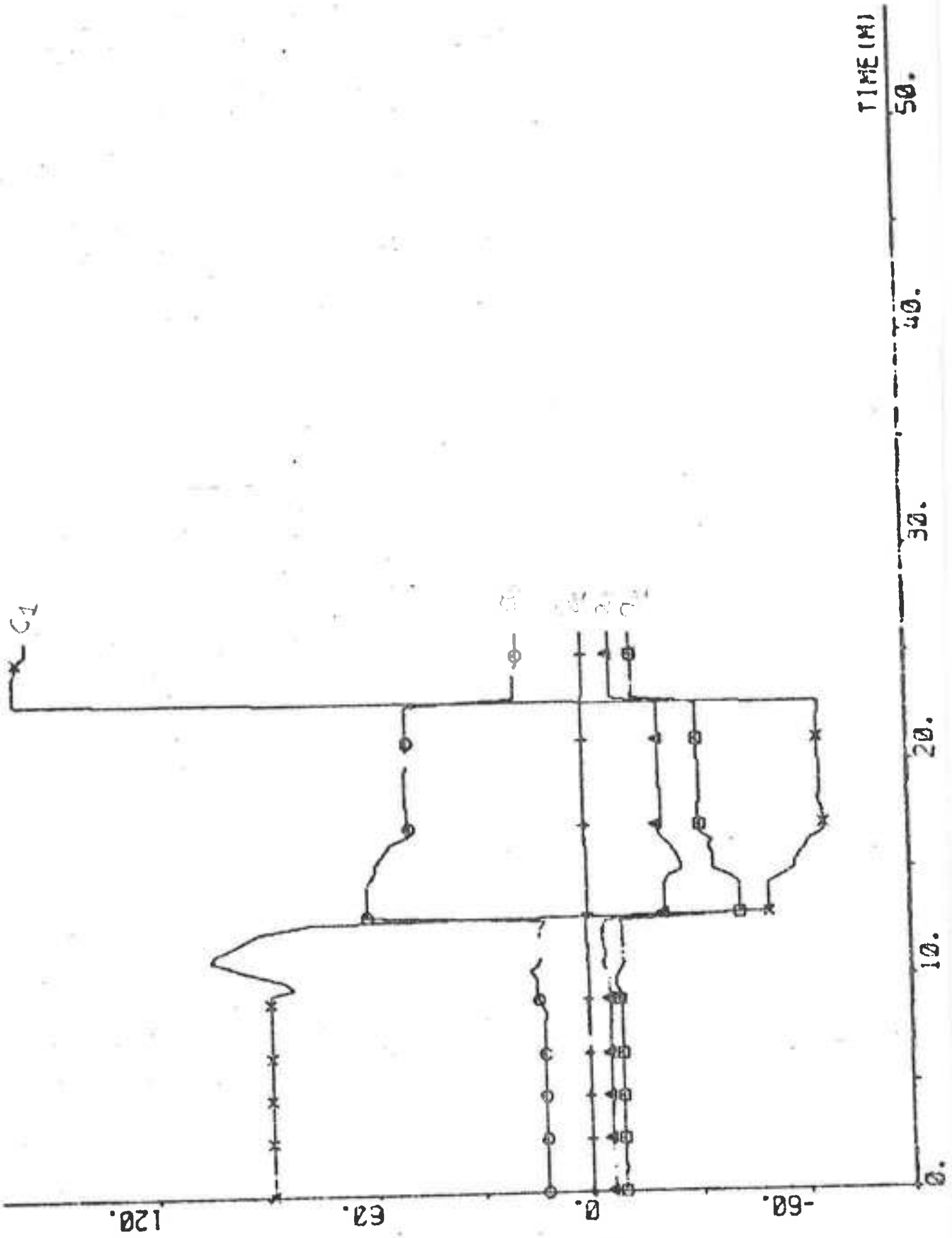

PLOT B7P1(15)-B7P1(9) ZERO -0.5 1.5 "V2 KNOTS
1.
0.5
0.
-0.5
0.
10.
20.
30.
40.
50.
TIME(M)

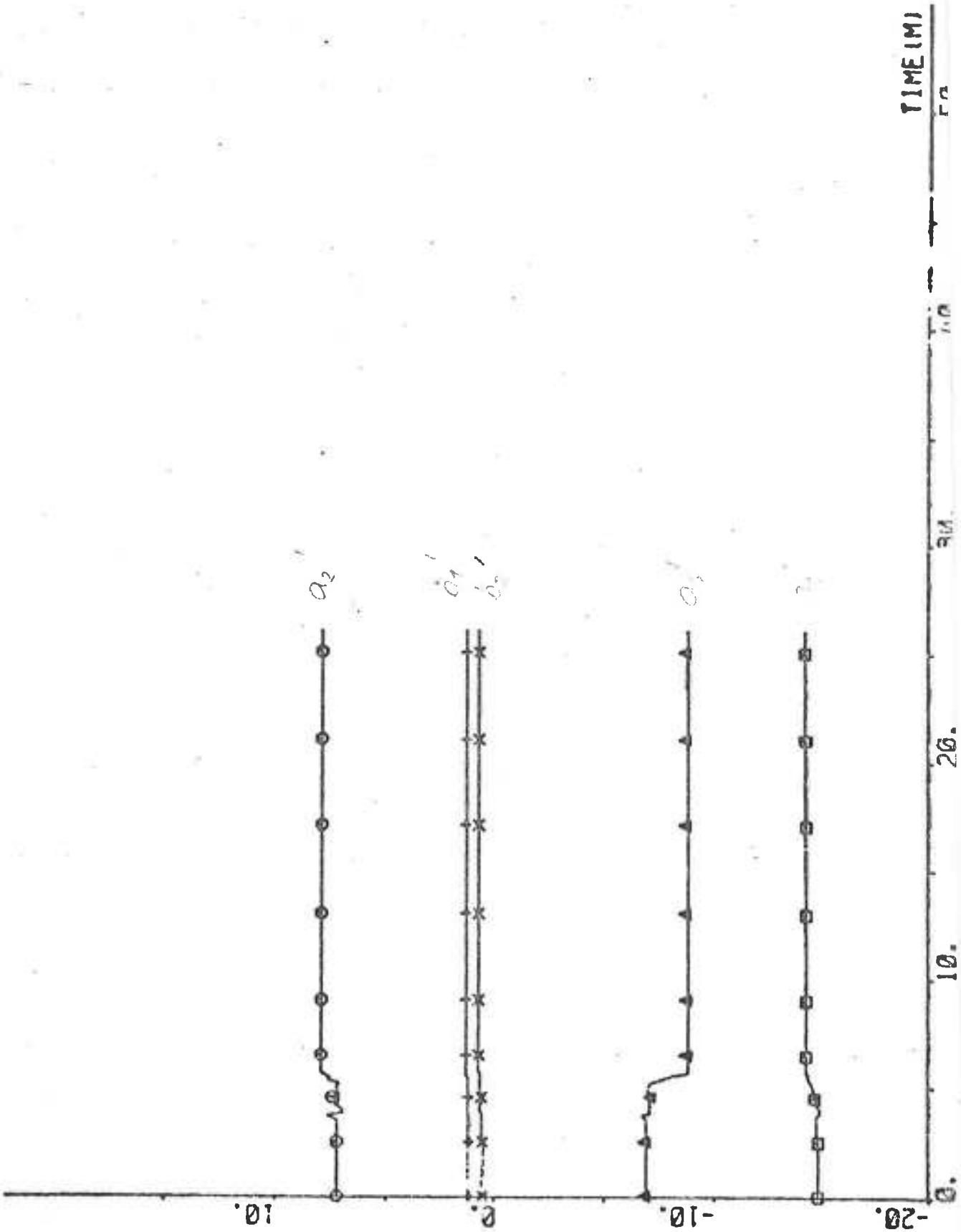

PLOT B7P1(15)-B7P1(10) ZERO -0.15 0.05 "R DEG/S
TIME(M)
0.
10.
20.
30.
40.
50.
-0.15
-0.1
-0.05
0.


PLOT B7P1(15)-B7P1(11) ZERO -0.15 0.05 "AVR DEG/S (BR=0.5)
TIME(M)
0.
10.
20.
30.
40.
50.
0.
-0.05
-0.1
-0.15

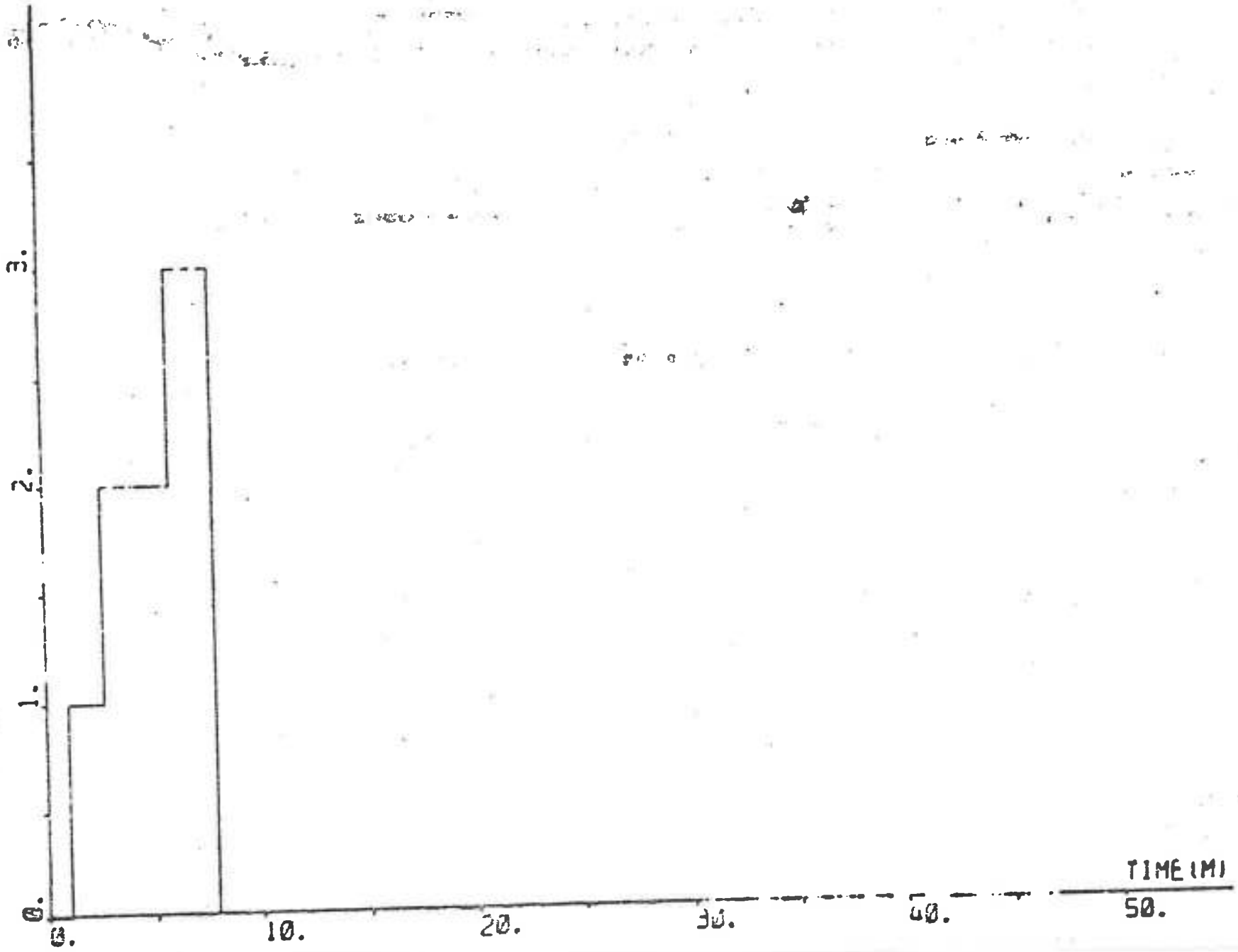

PLOT B7P1(15)-B7P1(12) ZERO -0.15 0.05 "DPSIDT DEG/S (IDPSI=5)
-0.15
-0.1
-0.05
0.
0.
10.
20.
30.
40.
50.
TIME(M)


PLOT B7P1(15)-B7P1(13 14) 70 110 'PSI PSIREF DEG
TIME(M)
0.
10.
20.
30.
40.
50.
70.
80.
90.
100.


PLOT B7P1(15)-B7P2(1 2 3 4 5) -80 180 "REGULATOR PARAMETERS
120.
60.
0.
-60.
0.
10.
20.
30.
40.
50.
TIME(M)


PLOT B7P1(15)-B7P2(8 7 8 9 10) -20 20 "YAW REGULATOR PARAMETERS
TIME(M)
10.
0.
-10.
-20.
0.
10.
20.

PLOT B7P1(15)-HP B7P2(11) 0 4 "MODYAW



828.

EXPERIMENT B8

Date	1974-10-11
Time	15.12
Position	N 25° 25' E 56° 20'

It was not possible to read the paper tape from this experiment.

EXPERIMENT B9

Date	1974-10-12
Time	11.28
Duration	21 min
Position	N 22° 12' E 60° 01'
Water depth	deep
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	171°, 203°
RREF	0.07 deg/s
Rudder limit	Not active
DELlM at termination	0.71°
Approximate mean value of AN	85.5 rpm
Approximate mean value of U	16.3 knots

Regulator structure

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

Final values

$$\begin{bmatrix} a_1 \\ a_2 \\ a_3 \\ b_1 \\ c_1 \end{bmatrix} = \begin{bmatrix} -8.661 \\ 13.078 \\ -5.030 \\ 1.001 \\ 34.971 \end{bmatrix}$$

P unknown

$$a_1 + a_2 + a_3 = -0.613$$

Yaw regulator structure

NAY = 3	NBY = 2	KY = 5
IREGY = 10	RLY = 0.95	IRR = 1
AK1V = 40	AK2V = 1.4	AK3V = 115
C1V = 10	C2V = 70	
EPS1V = 0.02	EPS2V = 0.03	
PSISV = 0.15	PSISSV = 1.5	PSIMAV = 0.6
I1MV = 80	I2MV = 300	I3MV = 180

Initial yaw regulator values

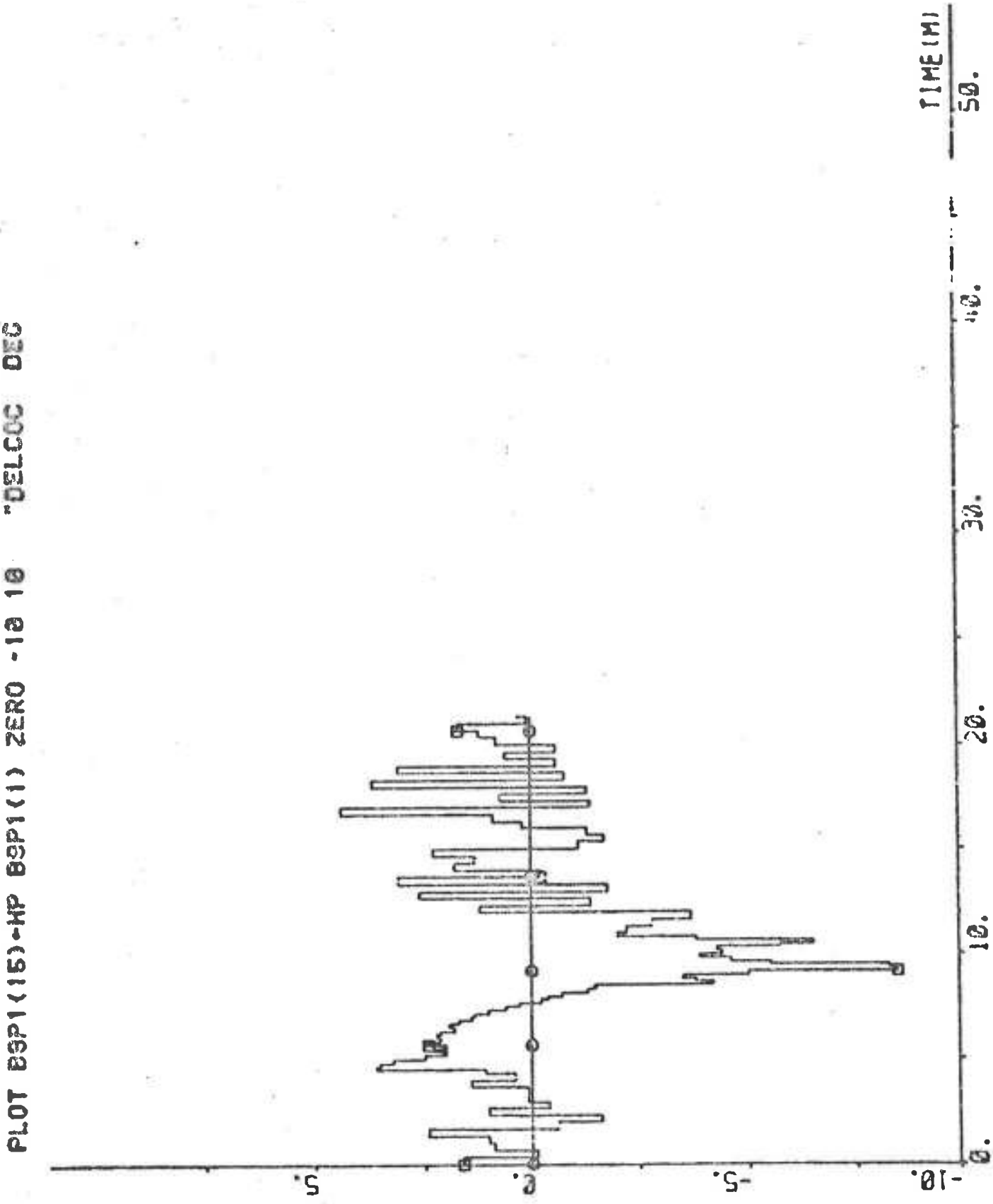
$$\begin{bmatrix} a_1' \\ a_2' \\ a_3' \\ b_1' \\ b_2' \end{bmatrix} = \begin{bmatrix} -14.8 \\ 7.8 \\ -8.8 \\ 1.3 \\ 0.7 \end{bmatrix} \qquad PY = \begin{bmatrix} 1000 & & & & \\ 0 & 1000 & & & \\ 0 & 0 & 1000 & & \\ 0 & 0 & 0 & 10 & \\ 0 & 0 & 0 & 0 & 10 \end{bmatrix}$$

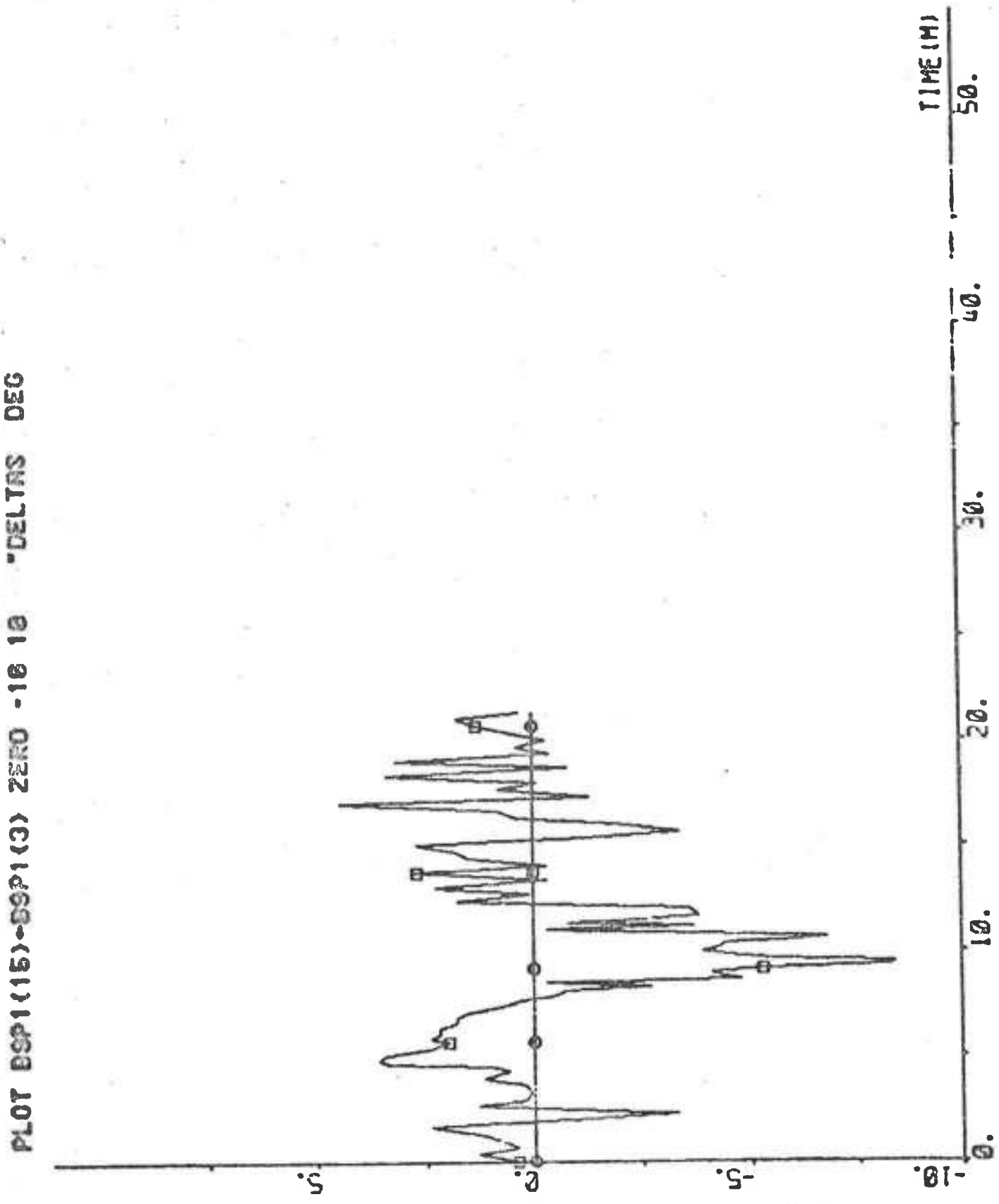
$a_1' + a_2' + a_3' = -15.8$

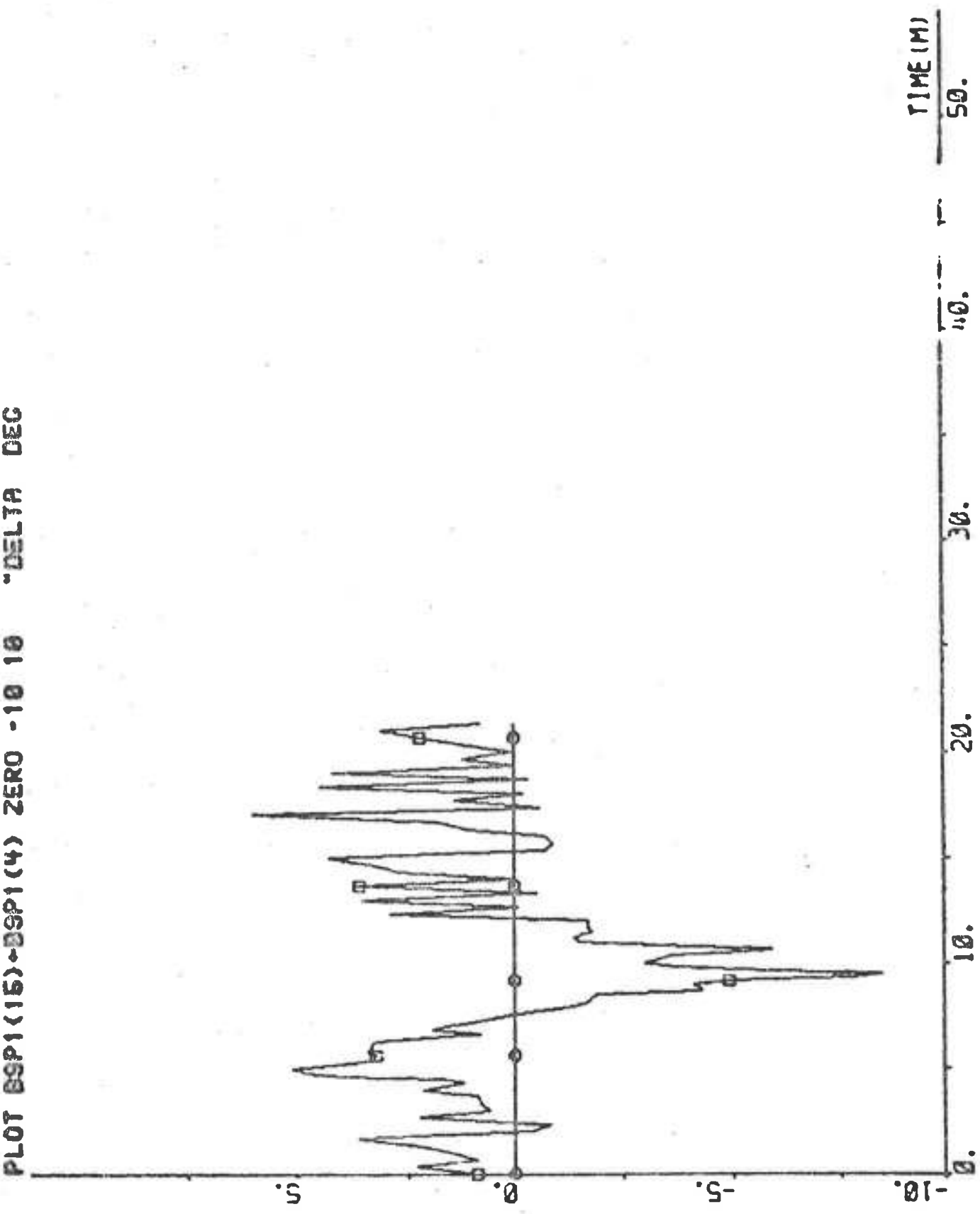
Final yaw regulator values

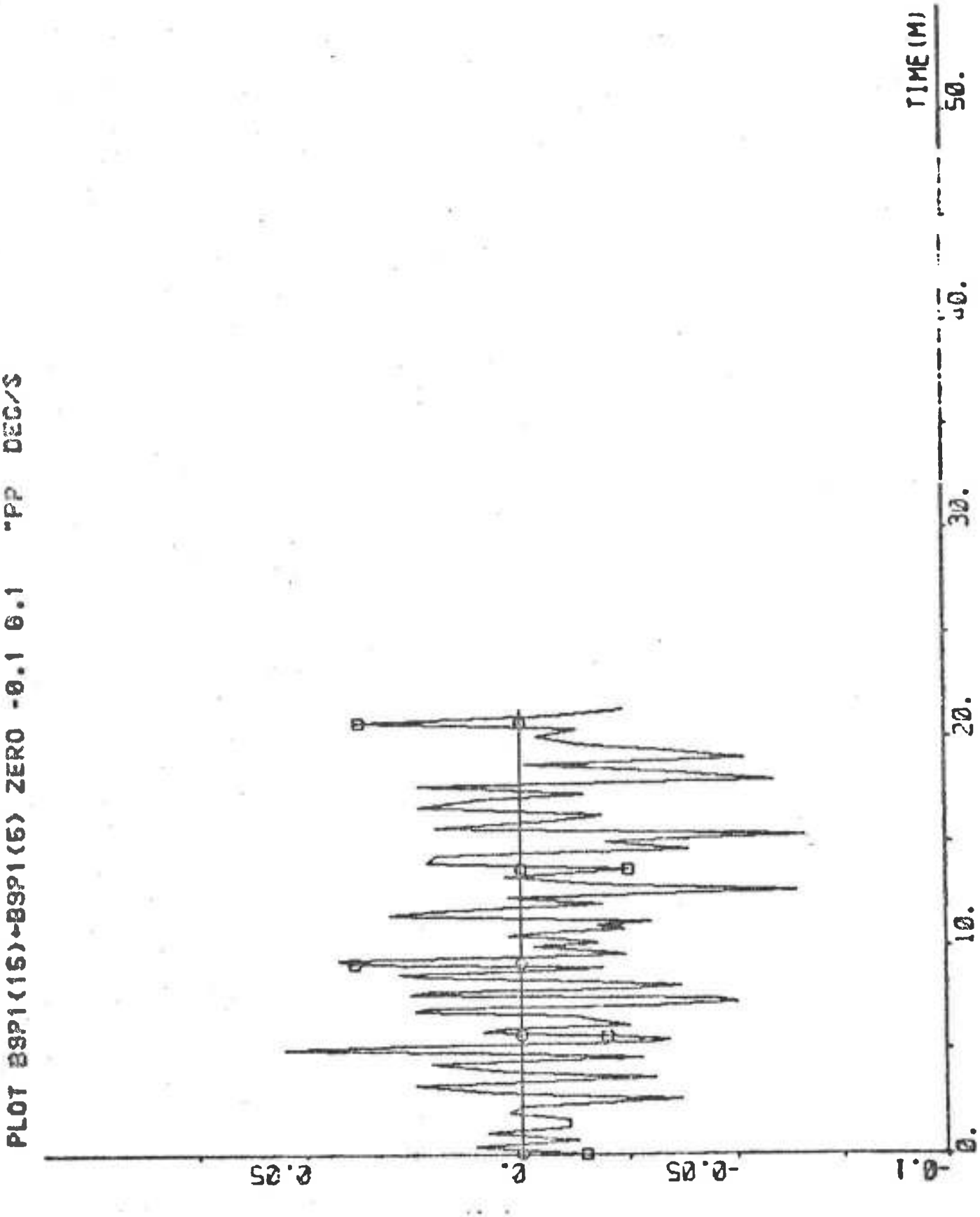
$$\begin{bmatrix} a_1' \\ a_2' \\ a_3' \\ b_1' \\ b_2' \end{bmatrix} = \begin{bmatrix} -15.381 \\ 7.227 \\ -8.735 \\ 1.336 \\ 0.745 \end{bmatrix} \qquad PY = \begin{bmatrix} 842.963 & & & & \\ -582.335 & 1437.434 & & & \\ -238.814 & -619.447 & 1142.139 & & \\ -19.780 & -26.774 & 4.774 & 5.961 & \\ -16.483 & -24.278 & 0.354 & 4.262 & 5.825 \end{bmatrix}$$

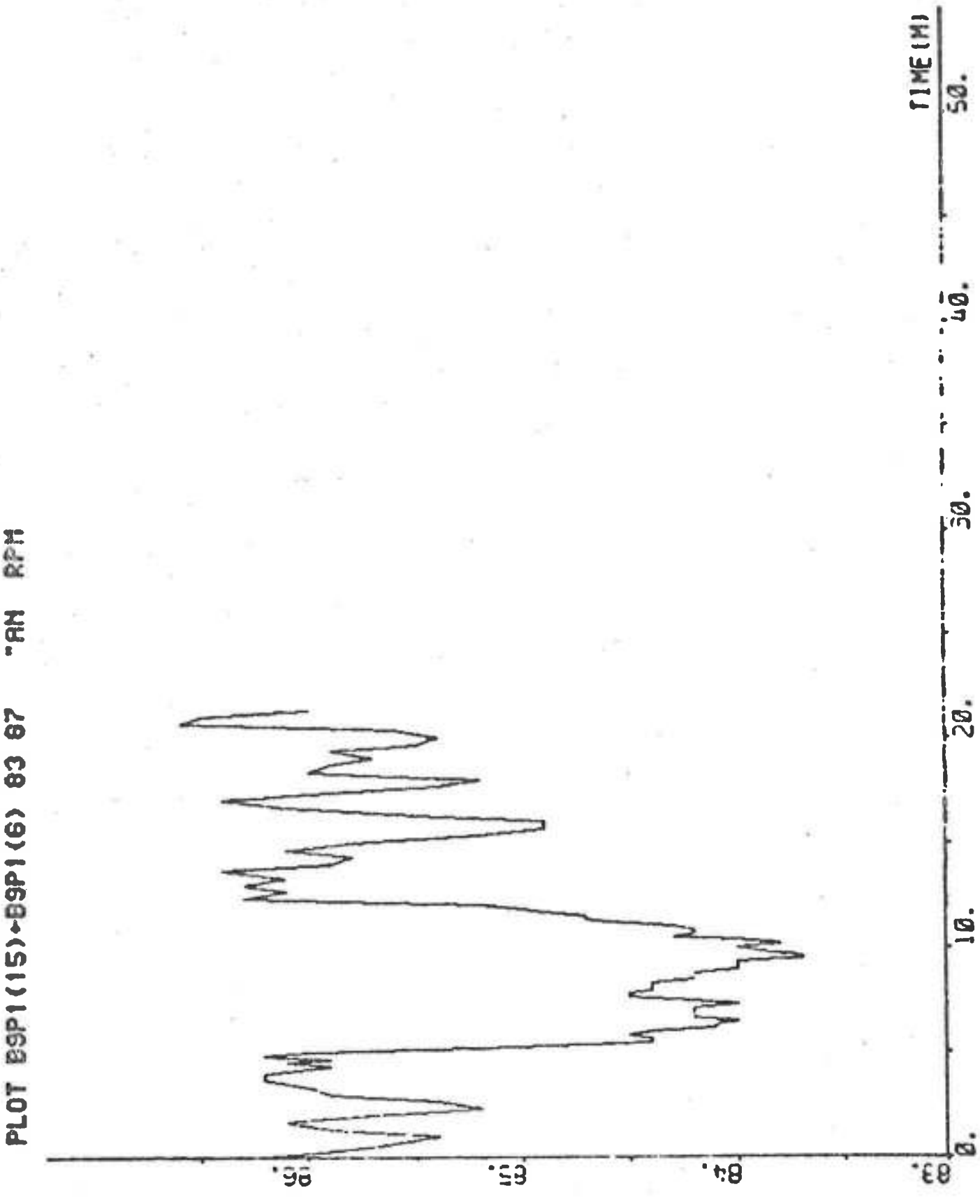
$a_1' + a_2' + a_3' = -16.889$

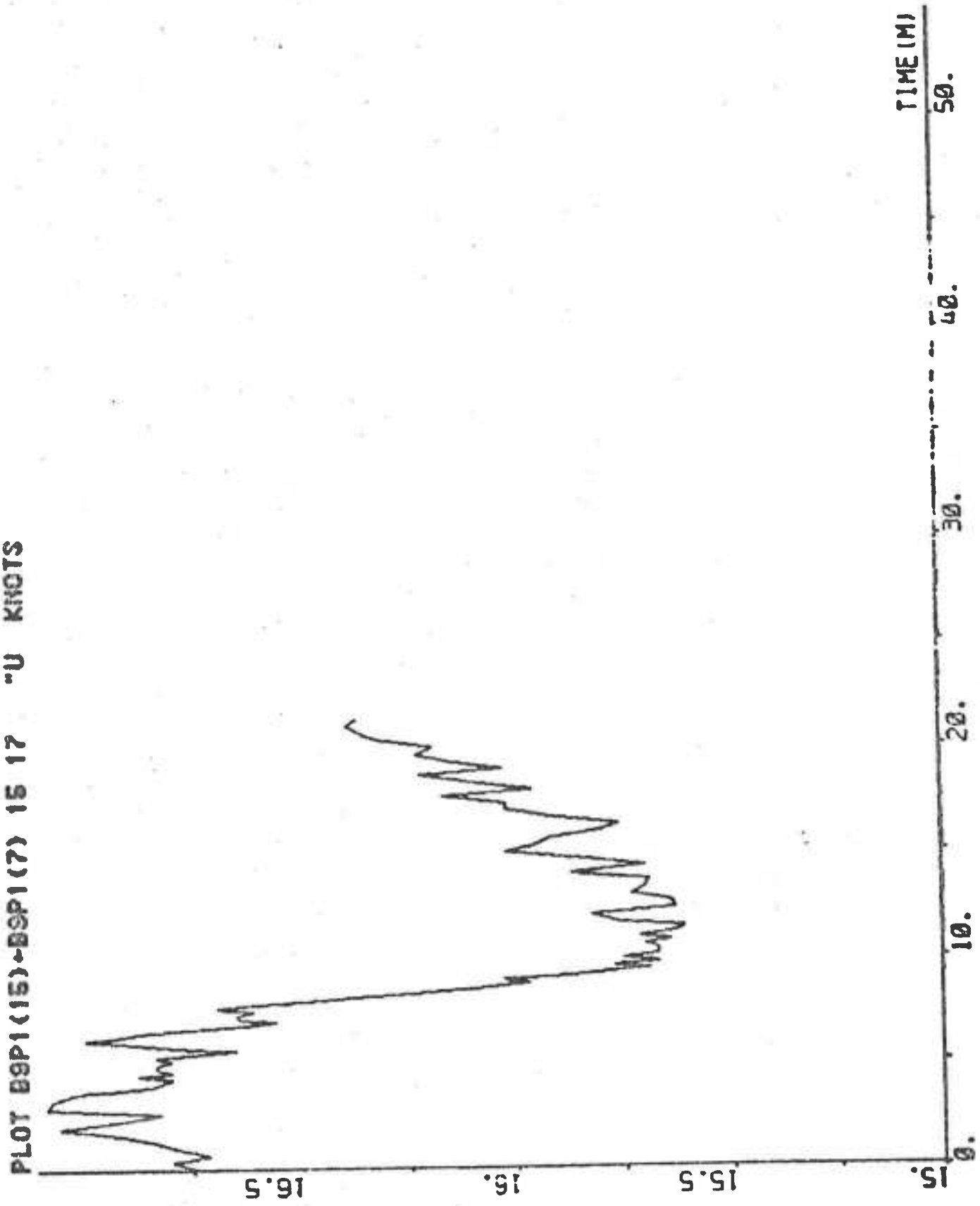

PLOT BSP1(15)-HP BSP1(1) ZERO -10 10 "DELCOC DSC
TIME(M)
0.
10.
20.
30.
40.
50.
-10.
-5.
0.
5.

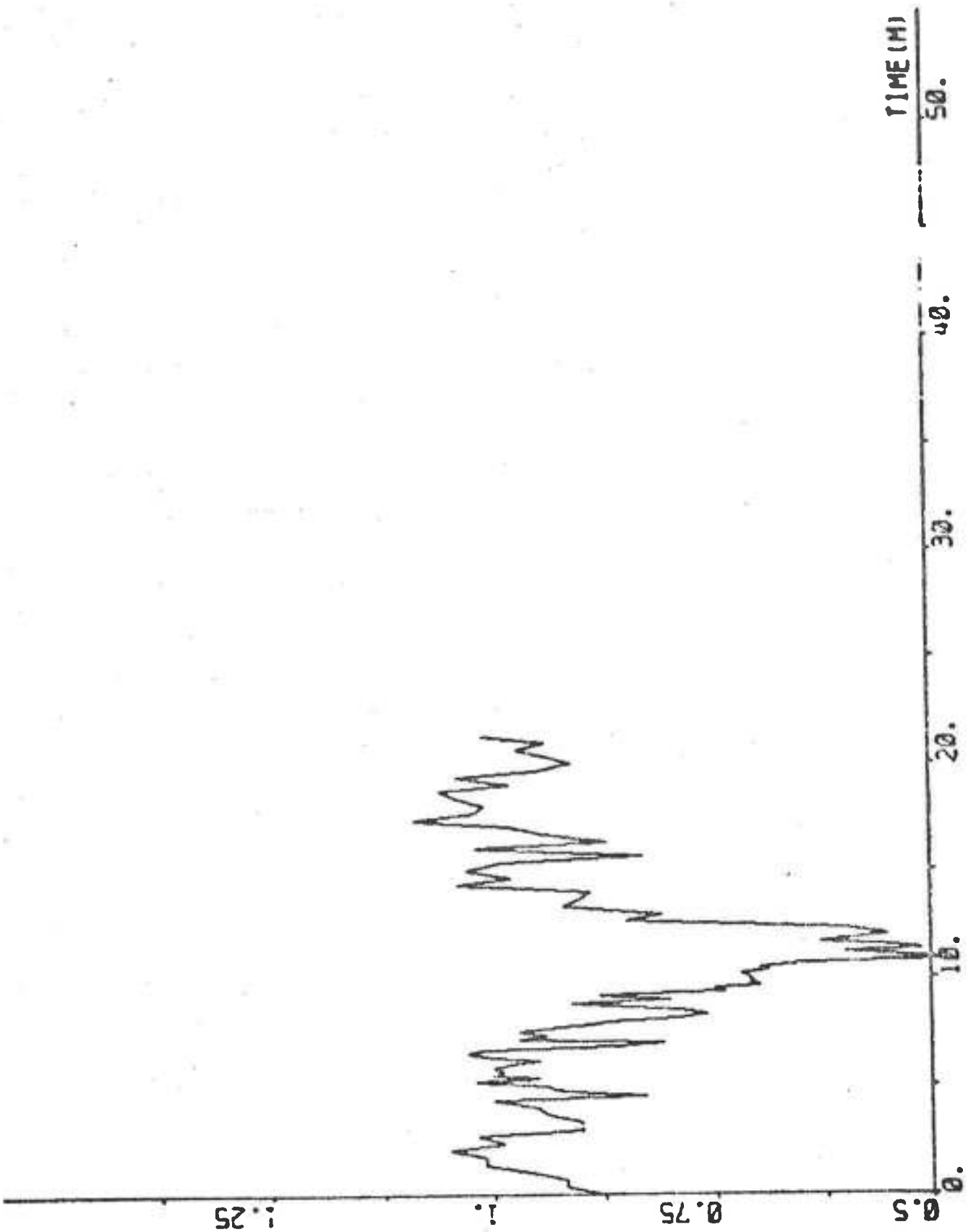

PLOT DSP1(15)-DSP1(3) ZERO -10 10 "DELTAS DEG
5.
0.
-5.
-10.
0.
10.
20.
30.
40.
50.
TIME(H)

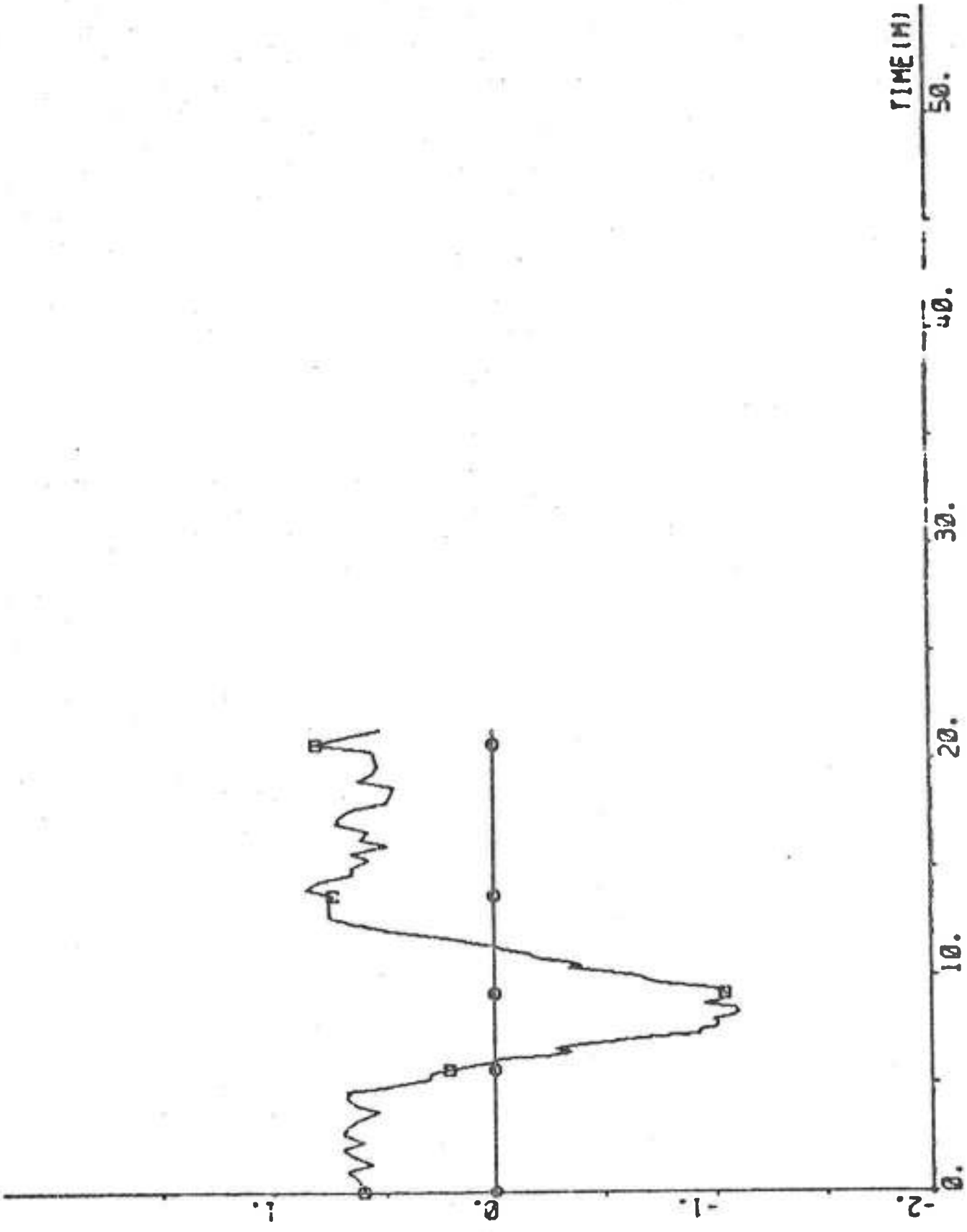

PLOT BSP1(15)-BSP1(4) ZERO -10 10 "DELTA DEC
5.
0.
-5.
-10.
0.
10.
20.
30.
40.
50.
TIME(M)

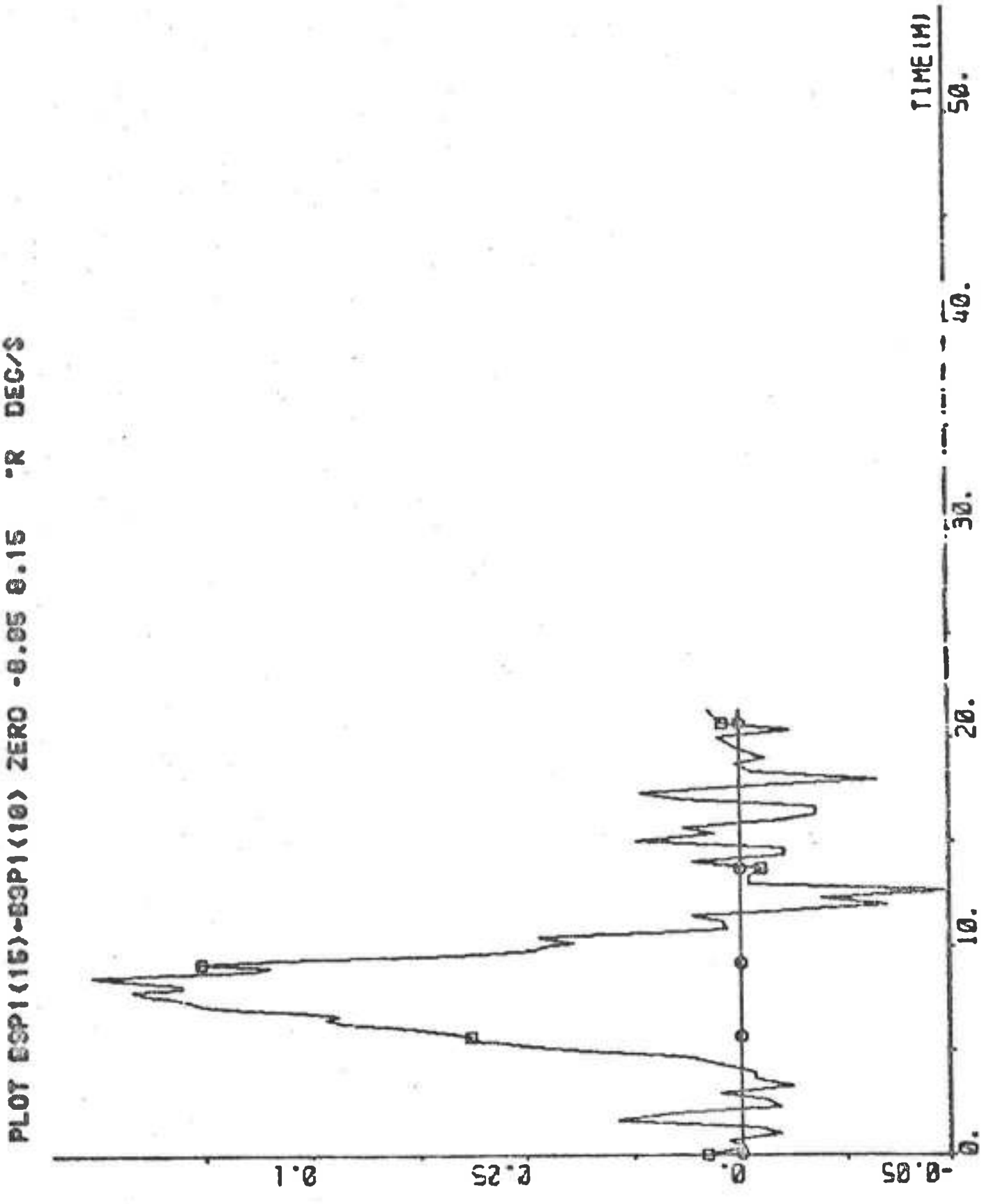

PLOT BSP1(15)-BSP1(6) ZERO -0.1 0.1 "PP DEG/S
TIME(M)
0.
10.
20.
30.
40.
50.
-0.1
-0.05
0.
0.05

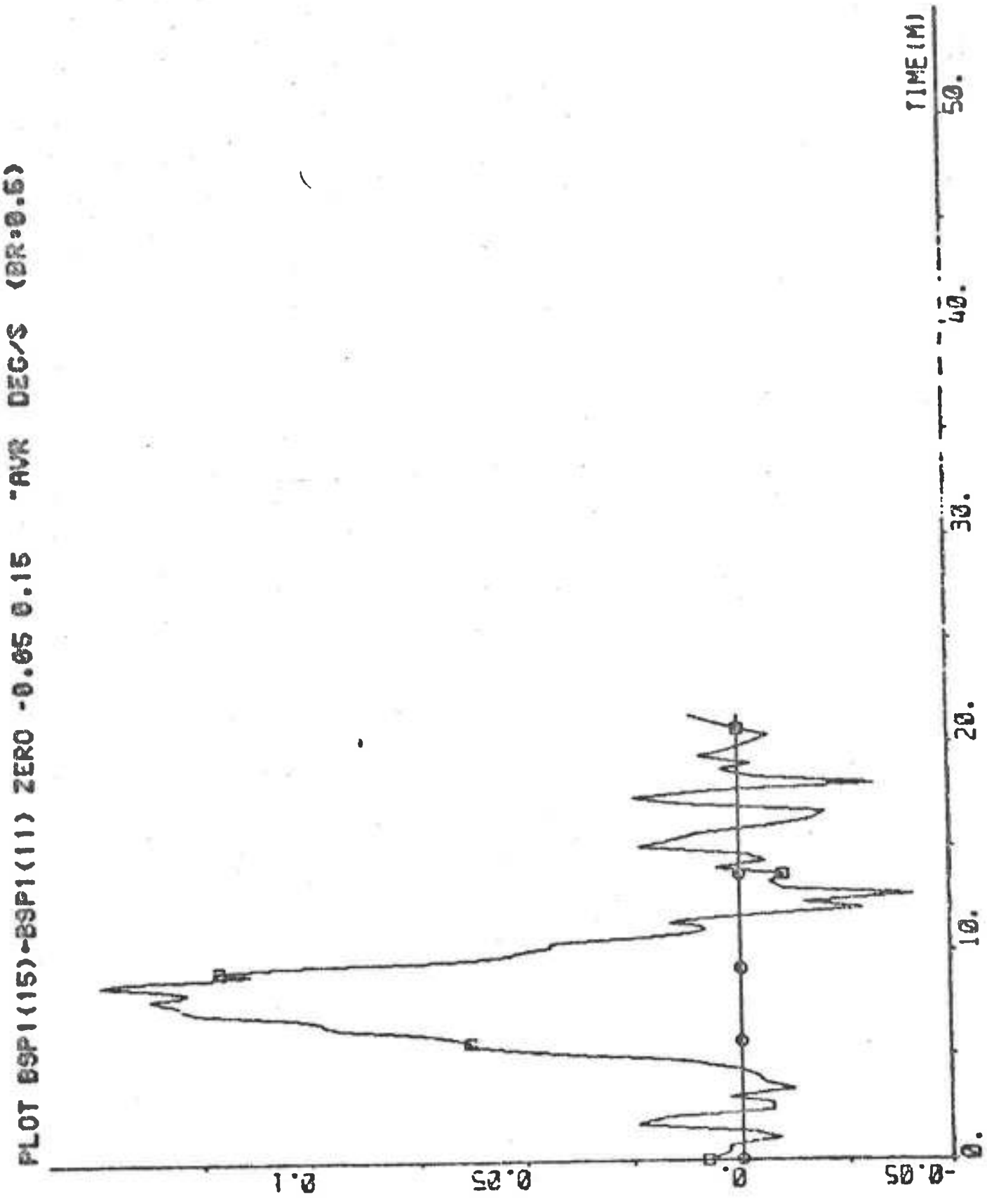

PLOT B9P1(15)-B9P1(6) 83 87 'AN RPM
83.
84.
85.
86.
0.
10.
20.
30.
40.
50.
TIME(M)

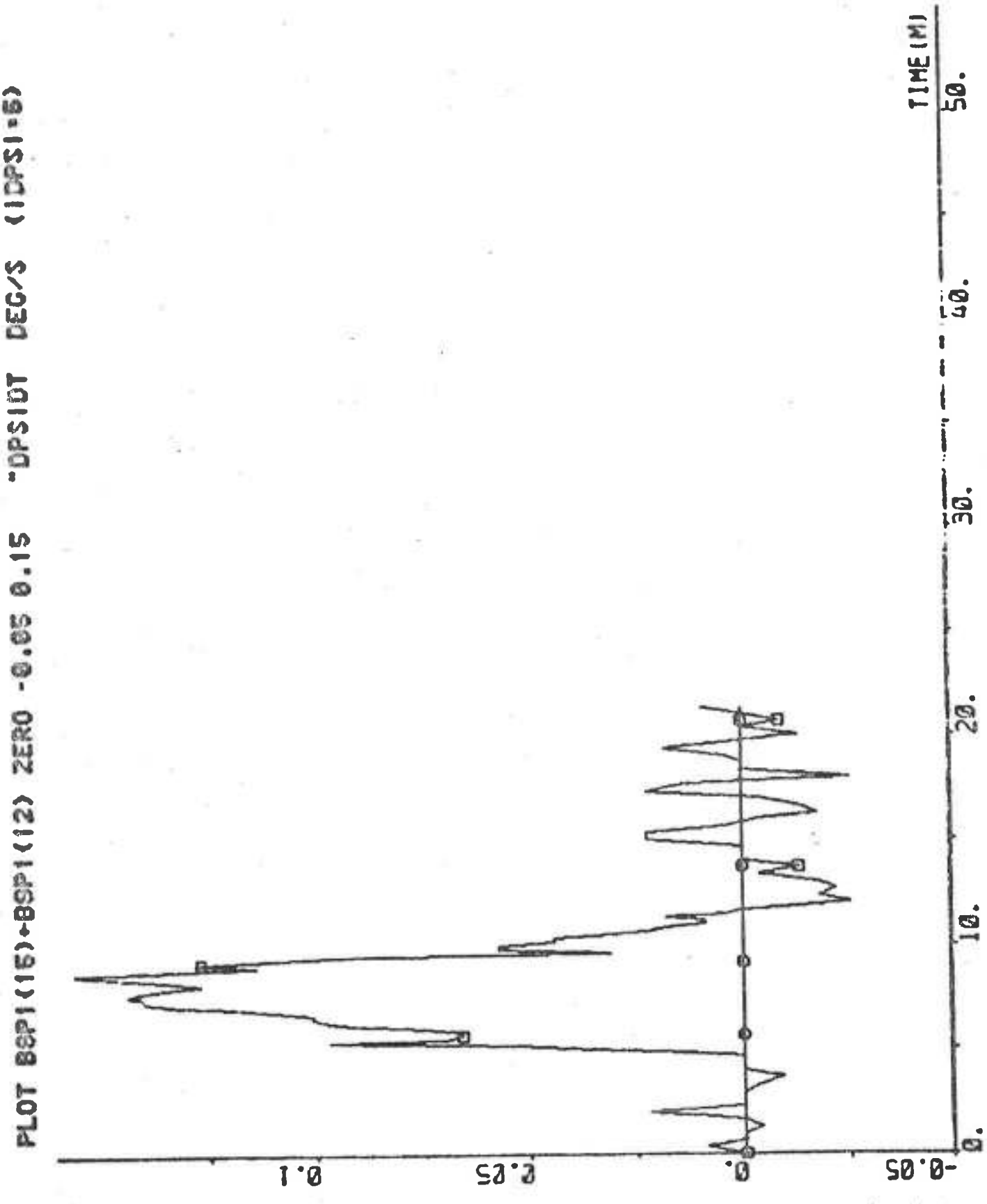

PLOT BSP1(15)-BSP1(7) 15 17 "U KNOTS
16.5
16.
15.5
15.
0.
10.
20.
30.
40.
50.
TIME(M)


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

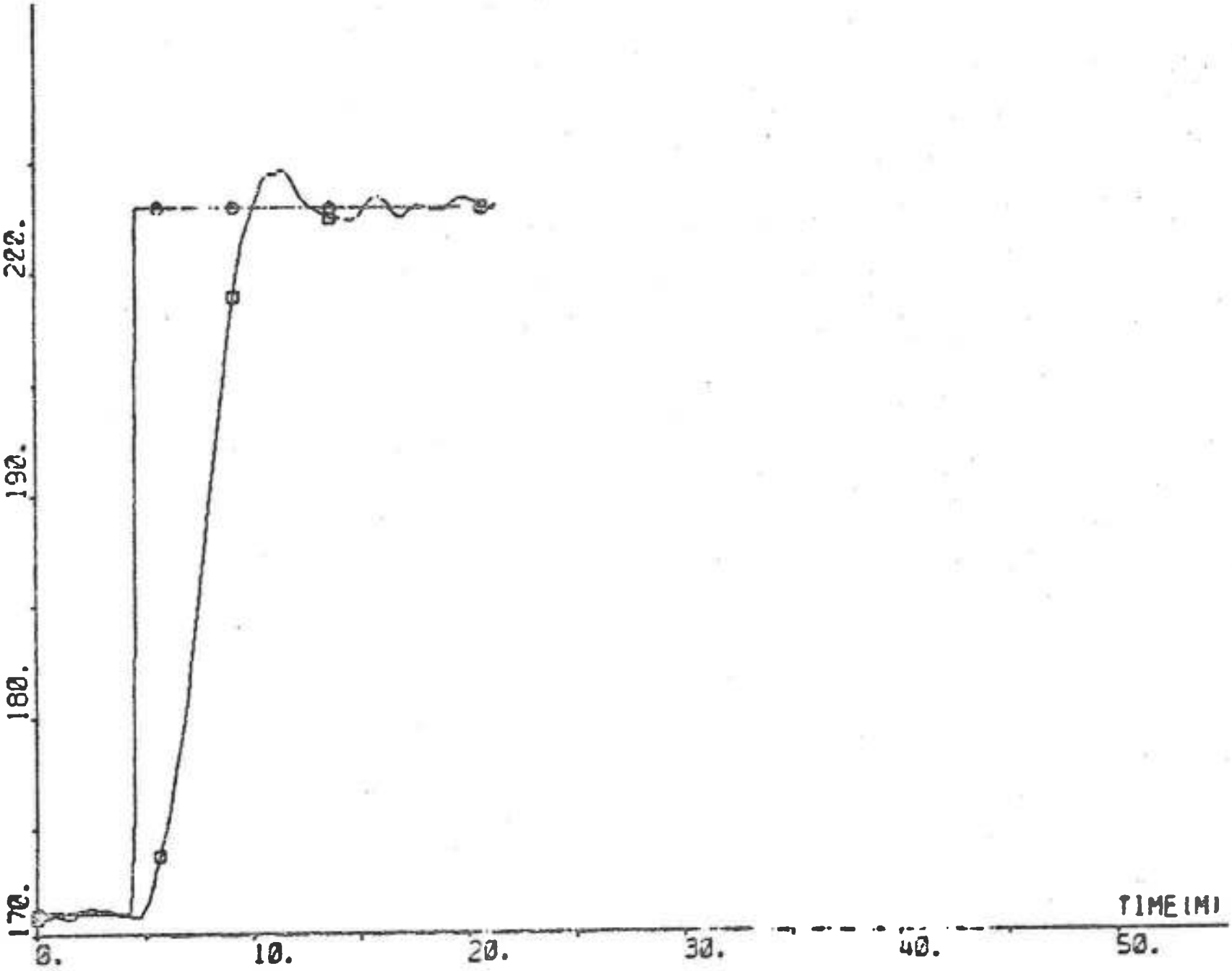

PLOT B9P1(15)-B9P1(9) ZERO -2 2 "V2 KNOTS
1.
0.
-1.
-2.
0.
10.
20.
30.
40.
50.
TIME(M)

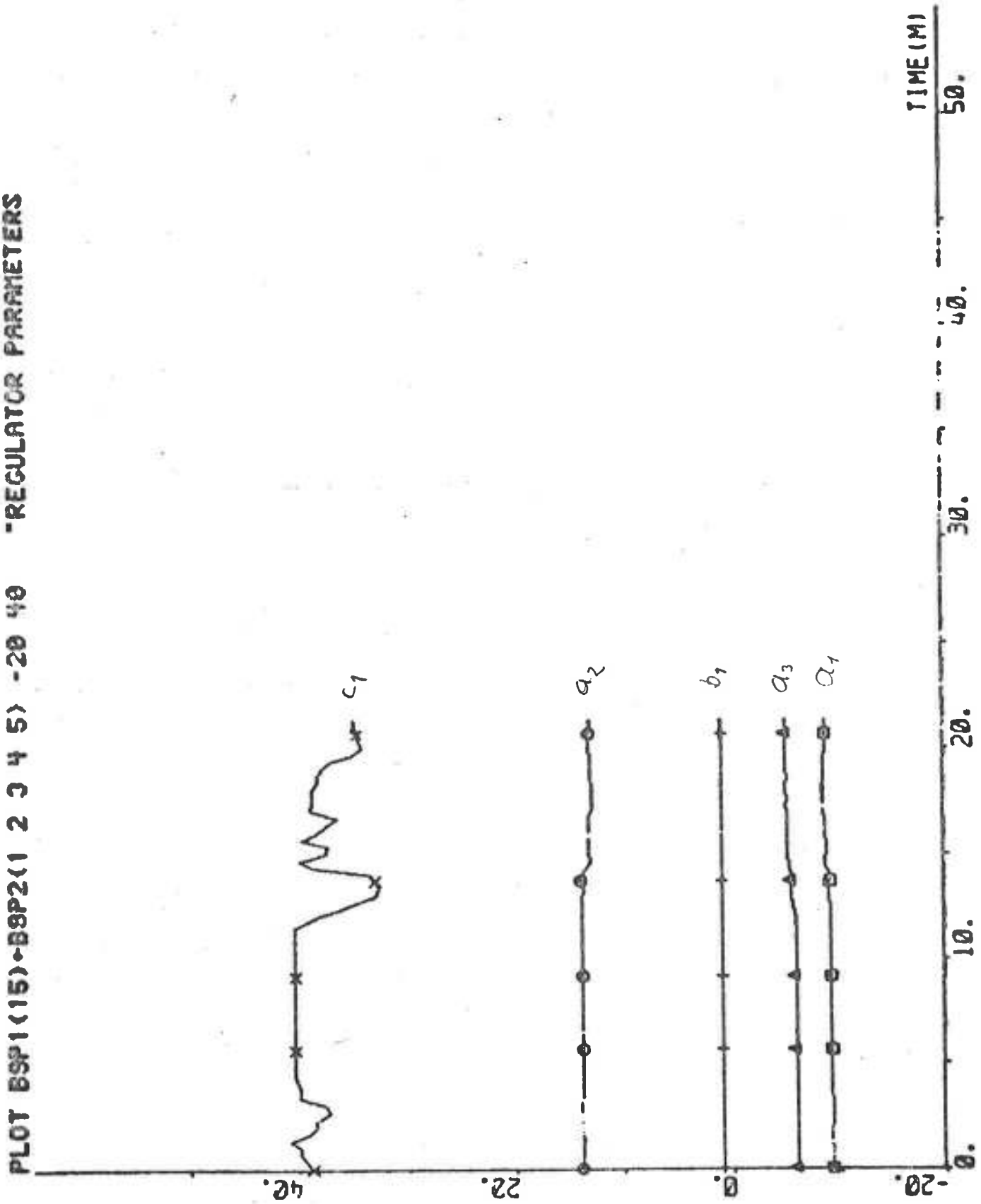

PLOT ESP1(15)-ESP1(10) ZERO -0.05 0.15 °R DEG/S
-0.05
0.
0.25
0.1
0.
10.
20.
30.
40.
50.
TIME(M)


PLOT BSP1(15)-BSP1(11) ZERO -0.05 0.15 "AVR DEG/S (DR=0.5)
TIME(M)
0.
10.
20.
30.
40.
50.
-0.05
0.
0.25
0.1

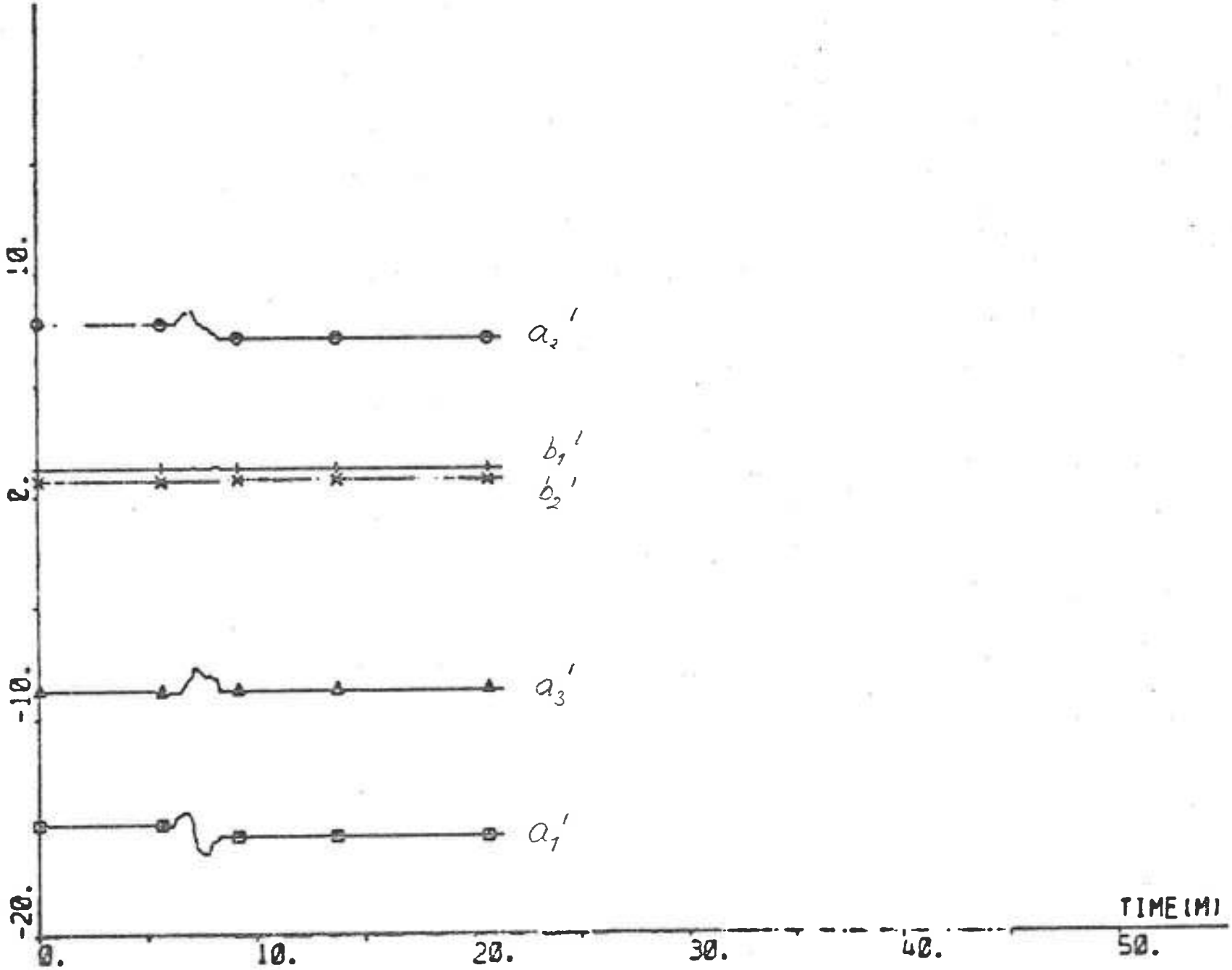

PLOT BSP1(15)+BSP1(12) ZERO -0.05 0.15 *DPSIDT DEG/S (IDPSI=6)
0.1
0.25
0.
-0.05
0.
10.
20.
30.
40.
50.
TIME(M)

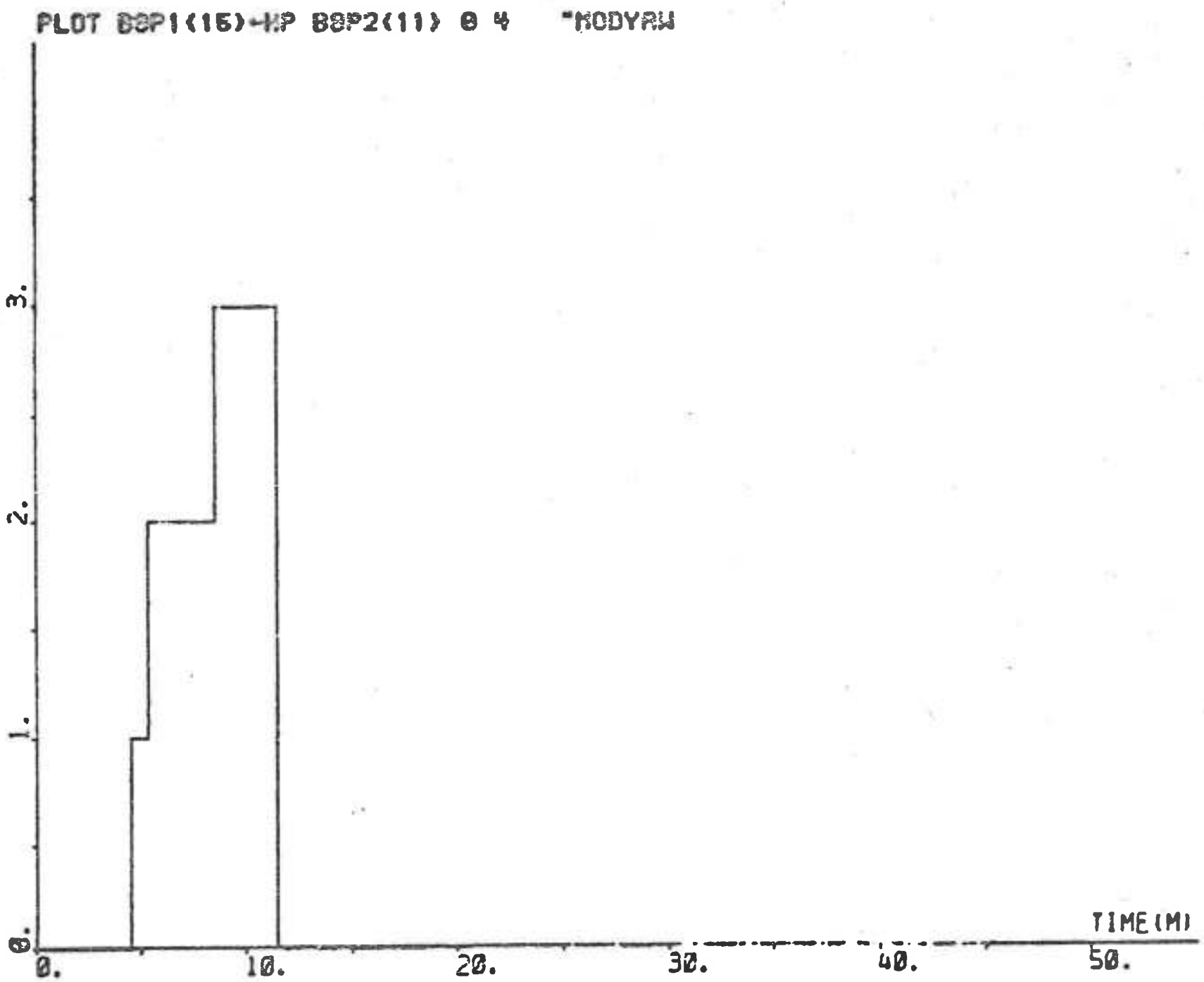
PLOT BSP1(15)-BSP1(13 14) 170 218 "PSI PSIREF DEC




PLOT BSP1(15)-BSP2(1 2 3 4 5) -20 40 "REGULATOR PARAMETERS
40.
22.
0.
-20.
0.
10.
20.
30.
40.
50.
TIME(M)
c_1
a_2
b_1
a_3
a_1

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




PLOT BOP1(15)+HP BOP2(11) 0 4 "MODYRW
3.
2.
1.
0.
0.
10.
20.
30.
40.
50.
TIME(M)

EXPERIMENT B10

Date	1974-10-18
Time	10.11
Duration	99 min
Position	S 12° 02' E 42° 41'
Water depth	deep
Forward draught	20.2 m
Aft draught	20.2 m
Wind direction	ENE (6; see Appendix A)
Wind velocity	3 Beaufort (4-5.5 m/s, gentle breeze)
Wave height	3 m (sea from E)
PSIREF	203°, 185°, 215°, 185°, 225°, 180°, 203°
RREF	0.07 deg/s
Rudder limit	Not active
DELlM at termination	0.04°
Approximate mean value of AN	85.5 rpm
Approximate mean value of U	17.9 knots

Regulator structure

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

IREG = 15 RL = 0.99

Final values

$$\begin{bmatrix} a_1 \\ a_2 \\ a_3 \\ b_1 \\ b_2 \end{bmatrix} = \begin{bmatrix} -13.224 \\ 19.852 \\ -7.459 \\ 0.626 \\ 0.214 \end{bmatrix}$$

P unknown

$$a_1 + a_2 + a_3 = -0.831$$

Initial yaw regulator structure

NAY = 3	NBY = 2	KY = 5
IREGY = 10	RLY = 0.95	IRR = 1
AK1V = 40	AK2V = 1.4	AK3V = 115
C1V = 10	C2V = 70	
EPS1V = 0.02	EPS2V = 0.03	
PSISV = 0.15	PSISSV = 1.5	PSIMAV = 0.6
I1MV = 40	I2MV = 300	I3MV = 120

Initial yaw regulator values for the yaw at 9 min.

$$\begin{bmatrix} a'_1 \\ a'_2 \\ a'_3 \\ b'_1 \\ b'_2 \end{bmatrix} = \begin{bmatrix} -15.4 \\ 7.2 \\ -8.7 \\ 1.3 \\ 0.75 \end{bmatrix} \qquad PY = \begin{bmatrix} 1000 & & & & \\ 0 & 1000 & & & \\ 0 & 0 & 1000 & & \\ 0 & 0 & 0 & 10 & \\ 0 & 0 & 0 & 0 & 10 \end{bmatrix}$$

$a'_1 + a'_2 + a'_3 = -16.9$

Yaw regulator values after the yaw at 9 min.

$$\begin{bmatrix} a'_1 \\ a'_2 \\ a'_3 \\ b'_1 \\ b'_2 \end{bmatrix} = \begin{bmatrix} -15.817 \\ 7.437 \\ -7.966 \\ 1.309 \\ 0.760 \end{bmatrix} \qquad PY = \begin{bmatrix} 412.070 & & & & \\ -324.495 & 856.484 & & & \\ -16.705 & -361.750 & 441.812 & & \\ -1.932 & -18.392 & 2.411 & 1.952 & \\ -2.404 & -13.195 & -2.204 & 1.459 & 1.943 \end{bmatrix}$$

$a'_1 + a'_2 + a'_3 = -16.346$

Initial yaw regulator values for the yaw at 30 min.

$$\begin{bmatrix} a_1' \\ a_2' \\ a_3' \\ b_1' \\ b_2' \end{bmatrix} = \begin{bmatrix} -15.8 \\ 7.4 \\ -8.0 \\ 1.3 \\ 0.76 \end{bmatrix} \qquad PY = \begin{bmatrix} 500 & & & & \\ 0 & 1000 & & & \\ 0 & 0 & 500 & & \\ 0 & 0 & 0 & 5 & \\ 0 & 0 & 0 & 0 & 5 \end{bmatrix}$$

$$a_1' + a_2' + a_3' = -16.4$$

Yaw regulator values after the yaw at 30 min.

$$\begin{bmatrix} a_1' \\ a_2' \\ a_3' \\ b_1' \\ b_2' \end{bmatrix} = \begin{bmatrix} -16.400 \\ 7.498 \\ -7.520 \\ 1.297 \\ 0.757 \end{bmatrix} \qquad PY = \begin{bmatrix} 332.998 & & & & \\ -261.532 & 693.874 & & & \\ -1.202 & -305.942 & 391.886 & & \\ -5.372 & -15.238 & 3.520 & 2.234 & \\ -6.350 & -10.003 & -0.334 & 1.628 & 2.177 \end{bmatrix}$$

$$a_1' + a_2' + a_3' = -16.422$$

Change of yaw regulator structure at 40 min.

KY = 4

IRR = 3 (IDPSI = 5)

Initial yaw regulator values for the yaw at 49 min.

$$\begin{bmatrix} a'_1 \\ a'_2 \\ a'_3 \\ b'_1 \\ b'_2 \end{bmatrix} = \begin{bmatrix} -16.4 \\ 7.5 \\ -7.5 \\ 1.3 \\ 0.76 \end{bmatrix} \qquad PY = \begin{bmatrix} 500 & & & & \\ 0 & 1000 & & & \\ 0 & 0 & 500 & & \\ 0 & 0 & 0 & 5 & \\ 0 & 0 & 0 & 0 & 5 \end{bmatrix}$$

$$a'_1 + a'_2 + a'_3 = -16.4$$

Yaw regulator values after the yaw at 49 min.

$$\begin{bmatrix} a'_1 \\ a'_2 \\ a'_3 \\ b'_1 \\ b'_2 \end{bmatrix} = \begin{bmatrix} -17.438 \\ 7.435 \\ -6.691 \\ 1.309 \\ 0.788 \end{bmatrix} \qquad PY = \begin{bmatrix} 256.899 & & & & \\ -227.056 & 621.280 & & & \\ 43.434 & -277.129 & 297.661 & & \\ -3.347 & -14.966 & 3.282 & 1.781 & \\ -4.846 & -9.076 & -0.946 & 1.353 & 1.717 \end{bmatrix}$$

$$a'_1 + a'_2 + a'_3 = -16.694$$

Change of yaw regulator structure at 60 min.

AK3V = 120

Initial yaw regulator values for the yaw at 65 min.

$$\begin{bmatrix} a_1' \\ a_2' \\ a_3' \\ b_1' \\ b_2' \end{bmatrix} = \begin{bmatrix} -17.4 \\ 7.4 \\ -6.7 \\ 1.3 \\ 0.79 \end{bmatrix} \qquad PY = \begin{bmatrix} 500 & & & & \\ 0 & 1000 & & & \\ 0 & 0 & 500 & & \\ 0 & 0 & 0 & 5 & \\ 0 & 0 & 0 & 0 & 5 \end{bmatrix}$$

$a_1' + a_2' + a_3' = -16.7$

Yaw regulator values after the yaw at 65 min.

$$\begin{bmatrix} a_1' \\ a_2' \\ a_3' \\ b_1' \\ b_2' \end{bmatrix} = \begin{bmatrix} -18.020 \\ 6.853 \\ -7.231 \\ 1.292 \\ 0.783 \end{bmatrix} \qquad PY = \begin{bmatrix} 306.112 & & & & \\ -220.849 & 763.456 & & & \\ -70.393 & -337.549 & 393.669 & & \\ -3.015 & -20.739 & 7.457 & 1.908 & \\ -2.997 & -15.997 & 2.502 & 1.344 & 1.824 \end{bmatrix}$$

$a_1' + a_2' + a_3' = -18.398$

Initial yaw regulator values for the yaw at 79 min.

$$\begin{bmatrix} a_1' \\ a_2' \\ a_3' \\ b_1' \\ b_2' \end{bmatrix} = \begin{bmatrix} -18.02 \\ 6.85 \\ -7.23 \\ 1.30 \\ 0.78 \end{bmatrix} \qquad PY = \begin{bmatrix} 500 & & & & \\ 0 & 1000 & & & \\ 0 & 0 & 500 & & \\ 0 & 0 & 0 & 5 & \\ 0 & 0 & 0 & 0 & 5 \end{bmatrix}$$

$a_1' + a_2' + a_3' = -18.40$

Yaw regulator values after the yaw at 79 min.

$$\begin{bmatrix} a'_1 \\ a'_2 \\ a'_3 \\ b'_1 \\ b'_2 \end{bmatrix} = \begin{bmatrix} -19.119 \\ 6.218 \\ -7.312 \\ 1.307 \\ 0.786 \end{bmatrix} \qquad PY = \begin{bmatrix} 232.180 & & & & \\ -226.431 & 682.297 & & & \\ -16.996 & -311.824 & 313.462 & & \\ -0.077 & -13.305 & 5.325 & 0.763 & \\ -0.042 & -9.359 & 1.700 & 0.570 & 0.707 \end{bmatrix}$$

$a'_1 + a'_2 + a'_3 = -20.213$

Initial yaw regulator values for the yaw at 93 min.

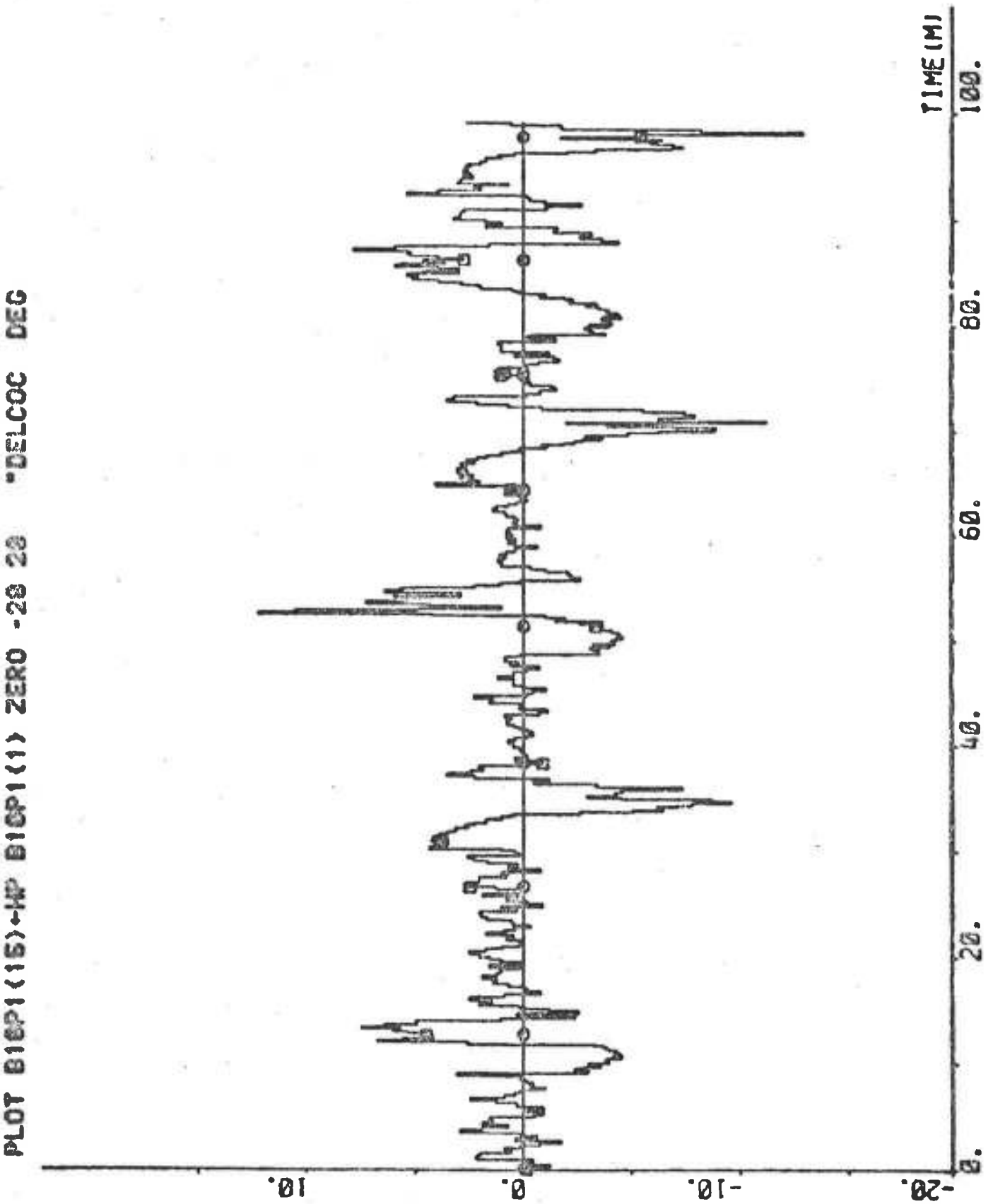
$$\begin{bmatrix} a'_1 \\ a'_2 \\ a'_3 \\ b'_1 \\ b'_2 \end{bmatrix} = \begin{bmatrix} -19.12 \\ 6.22 \\ -7.31 \\ 1.31 \\ 0.79 \end{bmatrix} \qquad PY = \begin{bmatrix} 500 & & & & \\ 0 & 1000 & & & \\ 0 & 0 & 500 & & \\ 0 & 0 & 0 & 5 & \\ 0 & 0 & 0 & 0 & 5 \end{bmatrix}$$

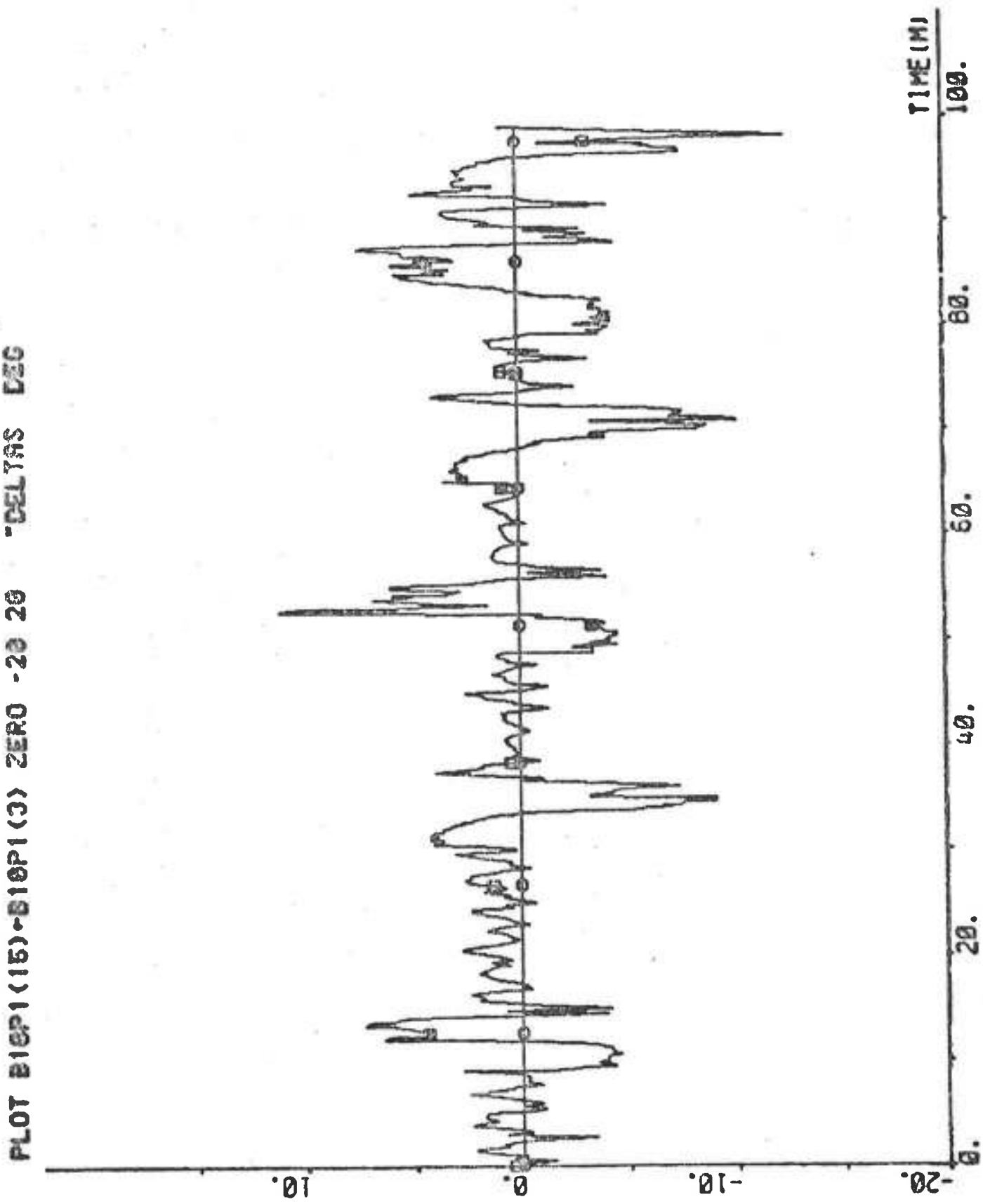
$a'_1 + a'_2 + a'_3 = -20.21$

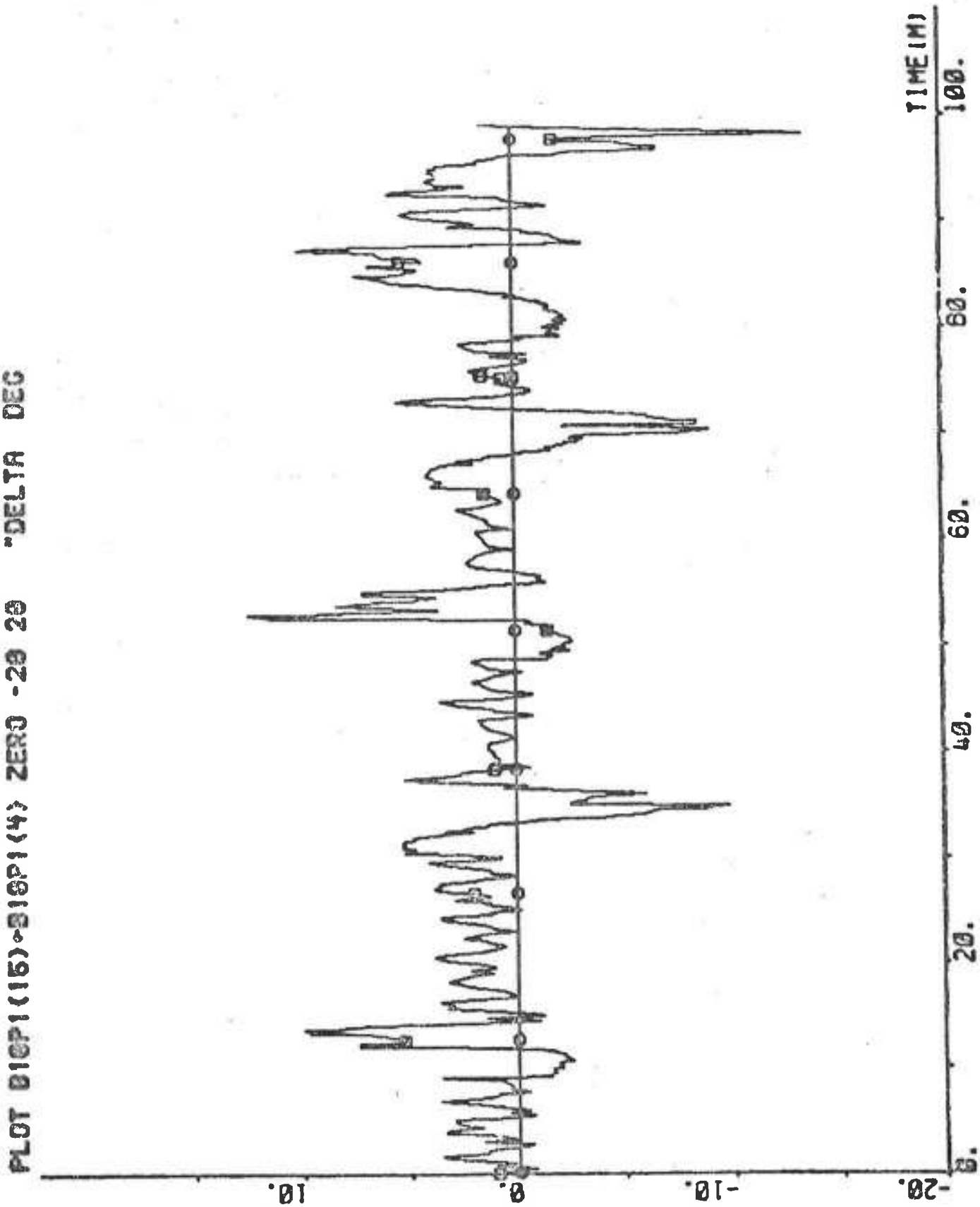
Yaw regulator values after the yaw at 93 min.

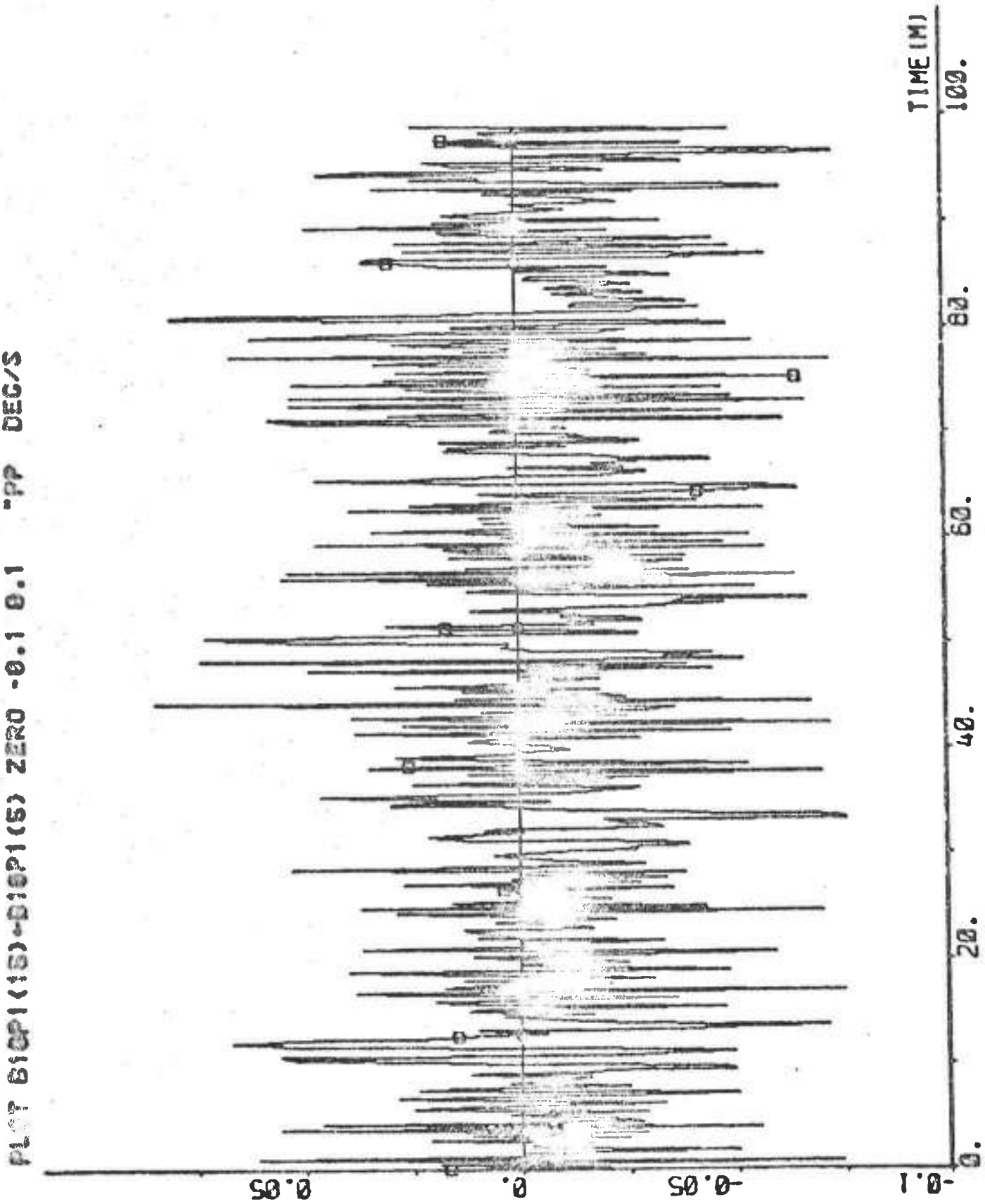
$$\begin{bmatrix} a'_1 \\ a'_2 \\ a'_3 \\ b'_1 \\ b'_2 \end{bmatrix} = \begin{bmatrix} -19.533 \\ 6.541 \\ -6.603 \\ 1.305 \\ 0.823 \end{bmatrix} \qquad PY = \begin{bmatrix} 641.466 & & & & \\ -232.891 & 1107.308 & & & \\ 36.314 & -252.368 & 683.220 & & \\ -6.176 & -26.769 & 1.807 & 4.624 & \\ -12.535 & -11.023 & -8.550 & 2.905 & 4.850 \end{bmatrix}$$

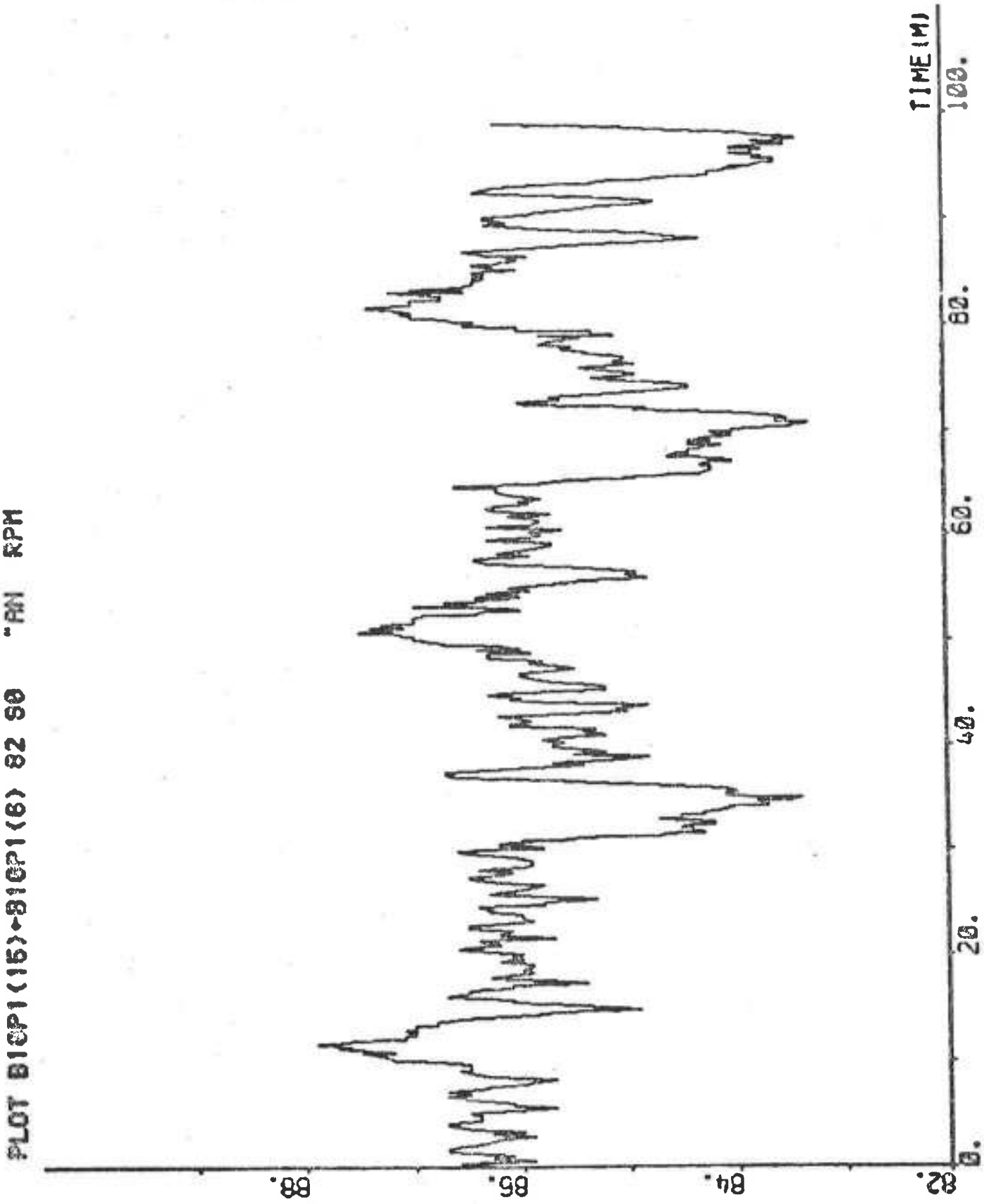
$a'_1 + a'_2 + a'_3 = -19.595$

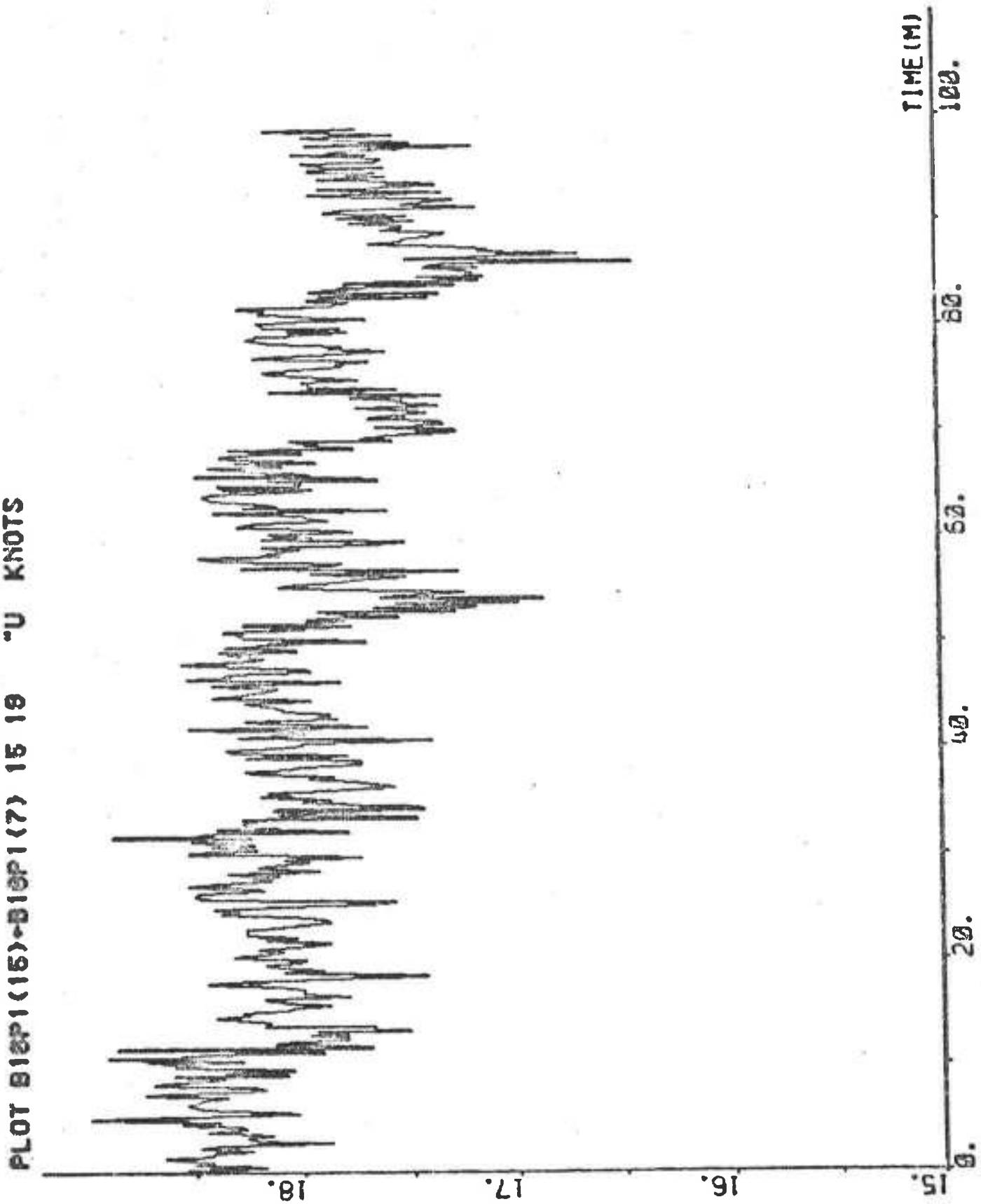

PLOT B16P1(15)-HP B16P1(1) ZERO -28 28 *DELCOC DEG
10.
0.
-10.
-20.
0.
20.
40.
60.
80.
100.
TIME(M)

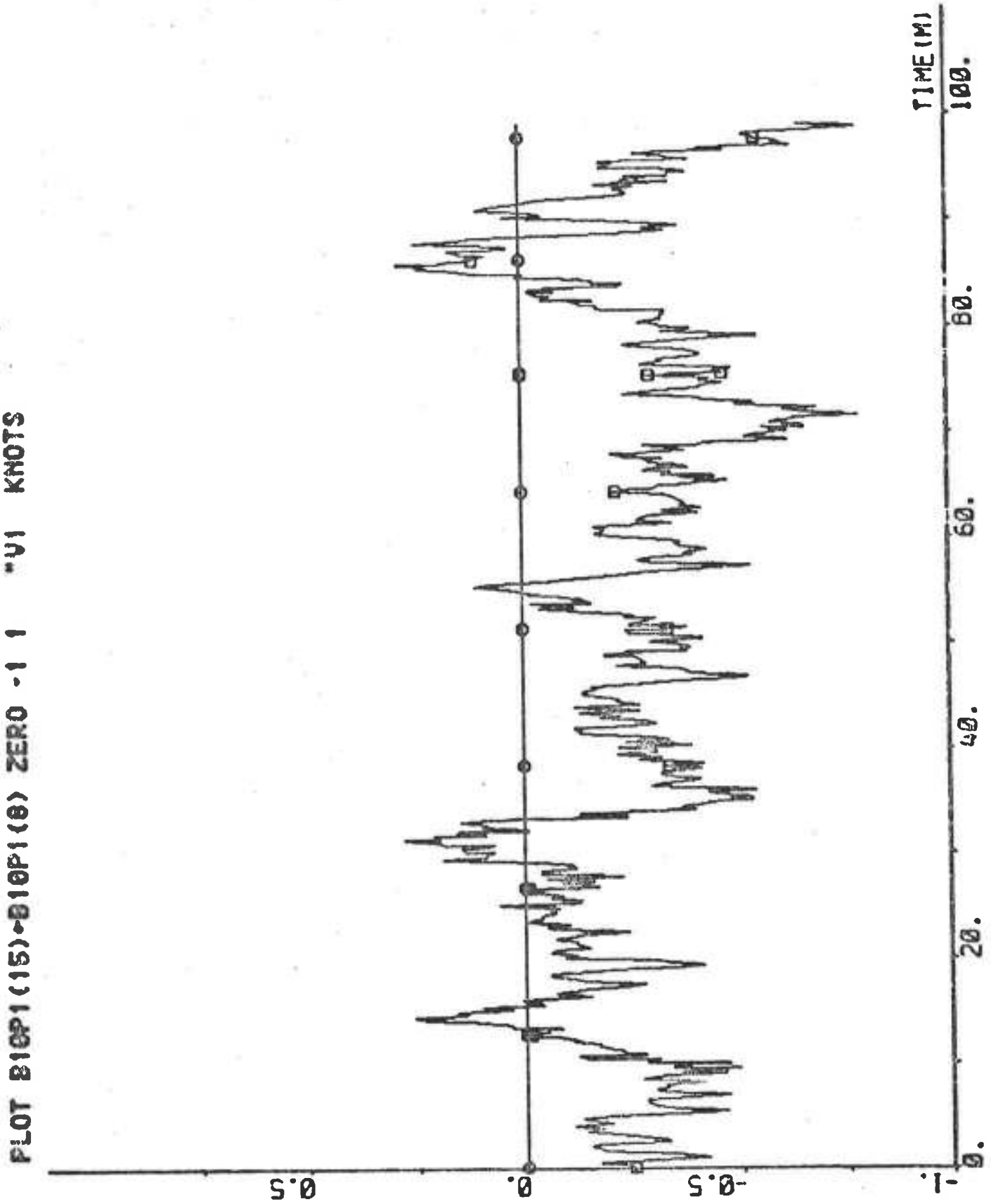

PLOT B10P1(15)-B10P1(3) ZERO -20 20 "DELTAS DEG
10.
0.
-10.
-20.
0.
20.
40.
60.
80.
100.
TIME(M)

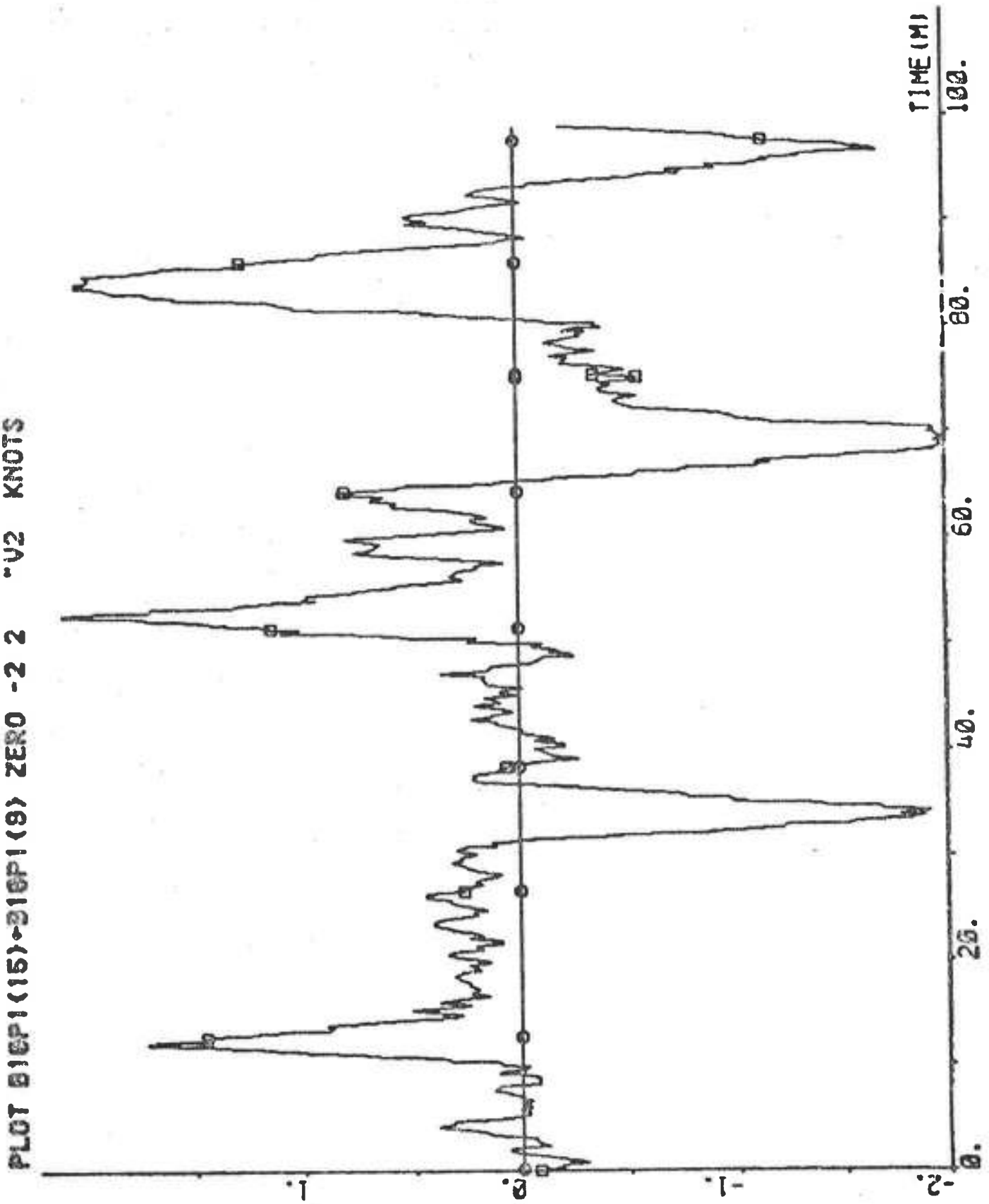

PLOT B10P1(15)-B10P1(4) ZERO -20 20 "DELTA DEG
10.
0.
-10.
-20.
0.
20.
40.
60.
80.
100.
TIME(M)

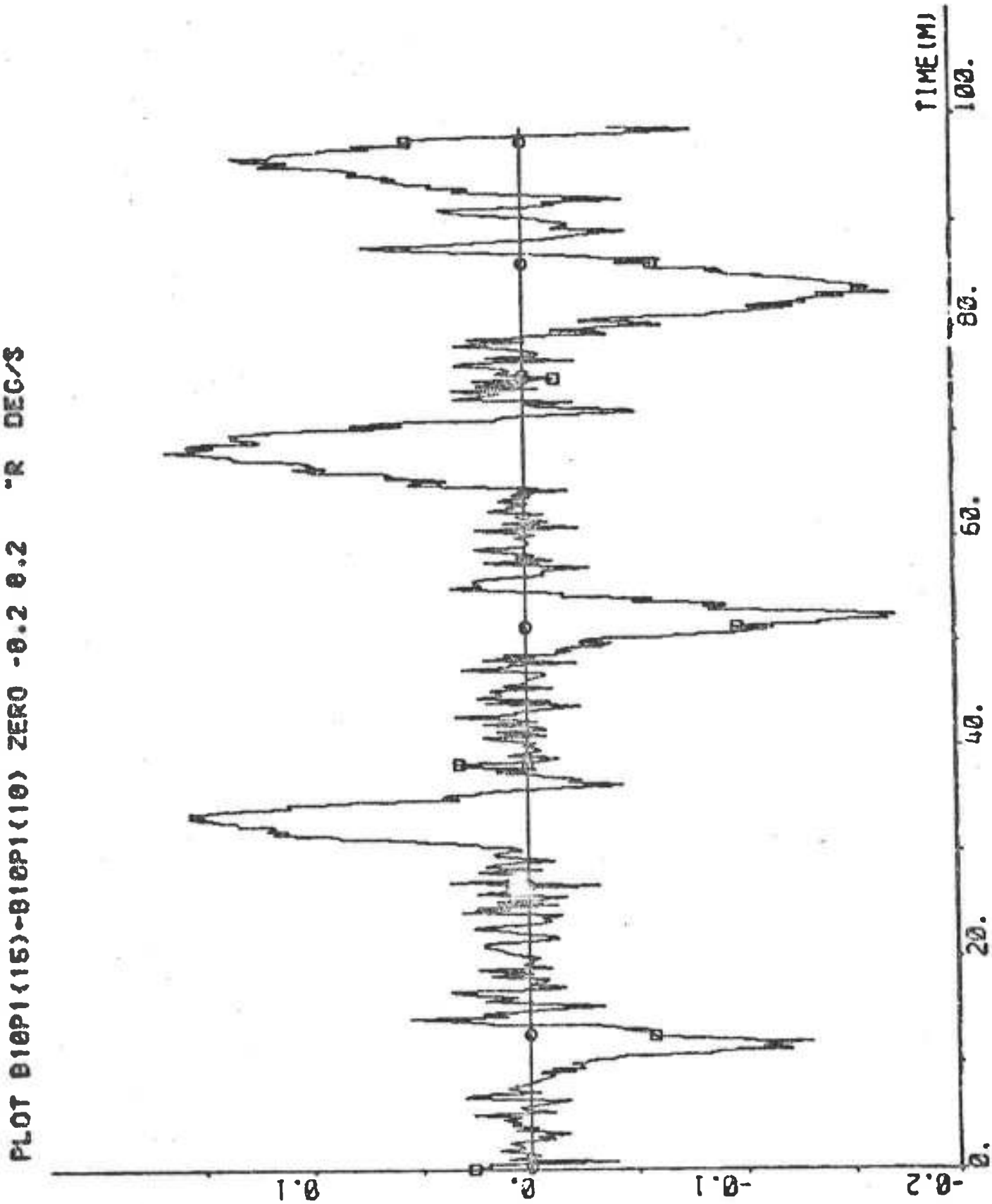

PLOT BIOP1(1S)-BIOP1(5) ZERO -0.1 0.1 *PP DEG/S
TIME(M)
0.
20.
40.
60.
80.
100.
0.1
0.05
0.
-0.05
-0.1

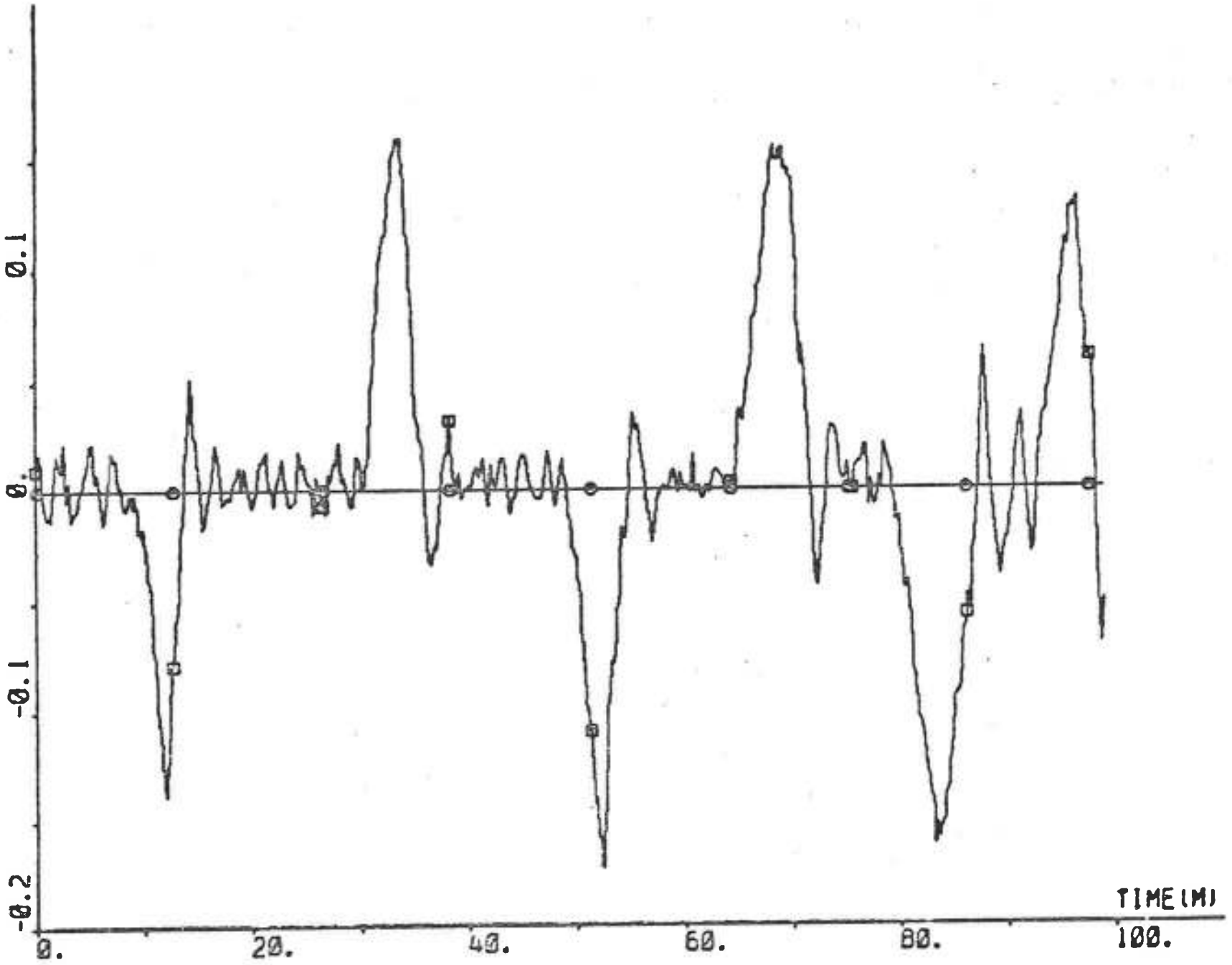

PLOT BICP1(15)-BICP1(6) 82 SO "RM RPM
88.
86.
84.
82.
0.
20.
40.
60.
80.
100.
TIME(M)

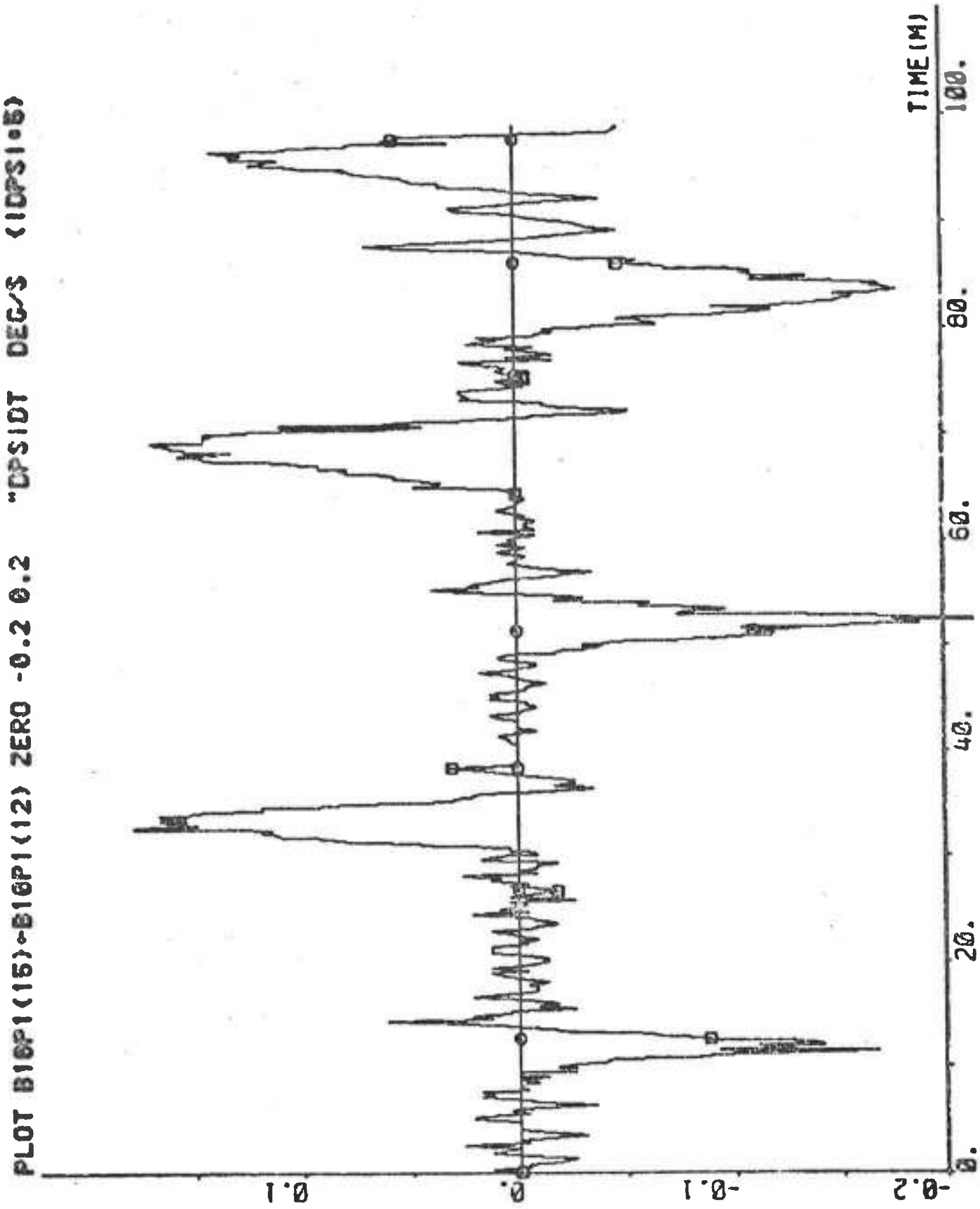

PLOT B12P1(15)-B10P1(7) 15 18 °U KNOTS
18.
17.
16.
15.
TIME(M)
0.
20.
40.
60.
80.
100.

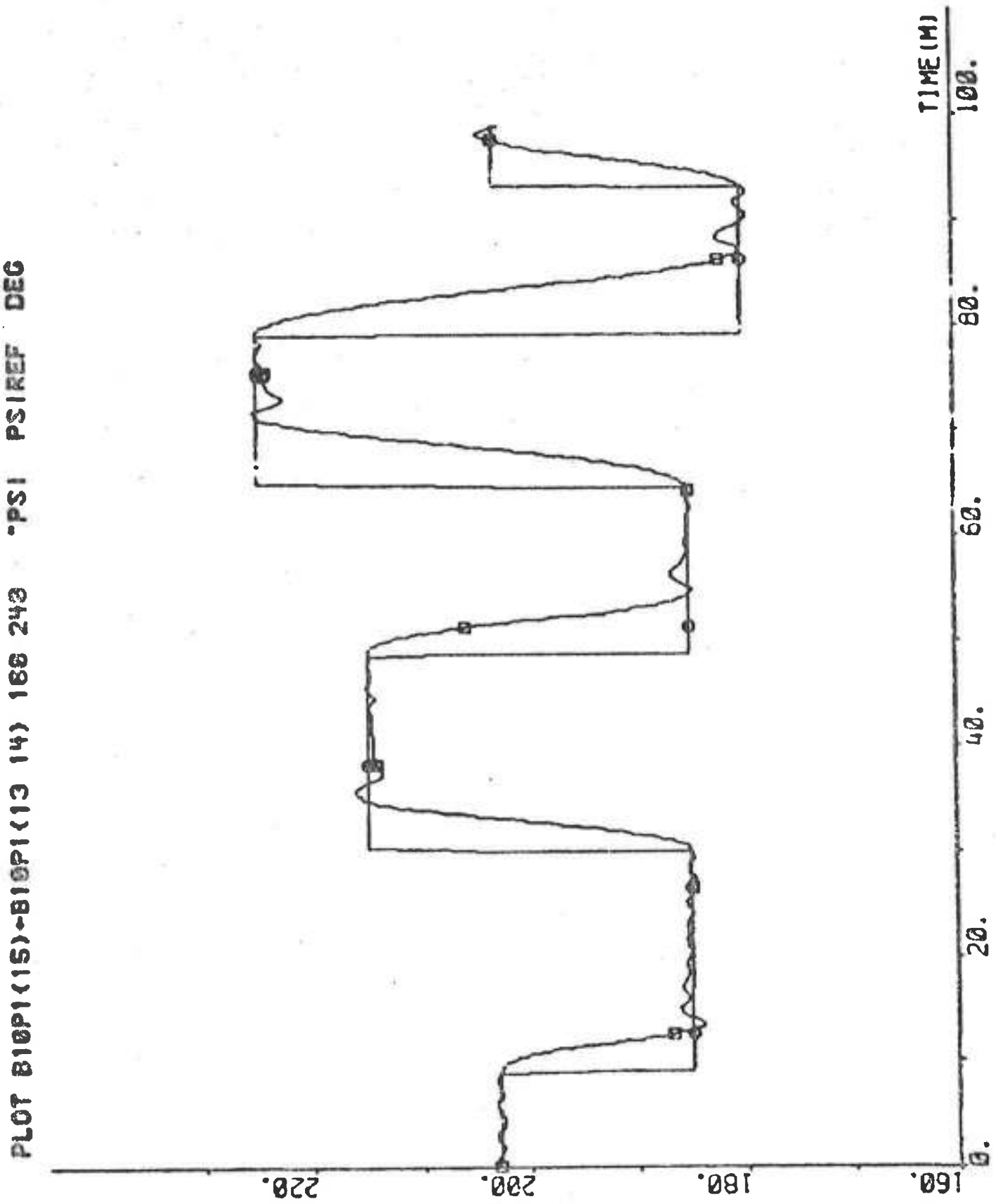

PLOT B10P1(15)-B10P1(8) ZERO -1 1 "V1 KNOTS
TIME(M)
0.
20.
40.
60.
80.
100.
-1.
-0.5
0.
0.5

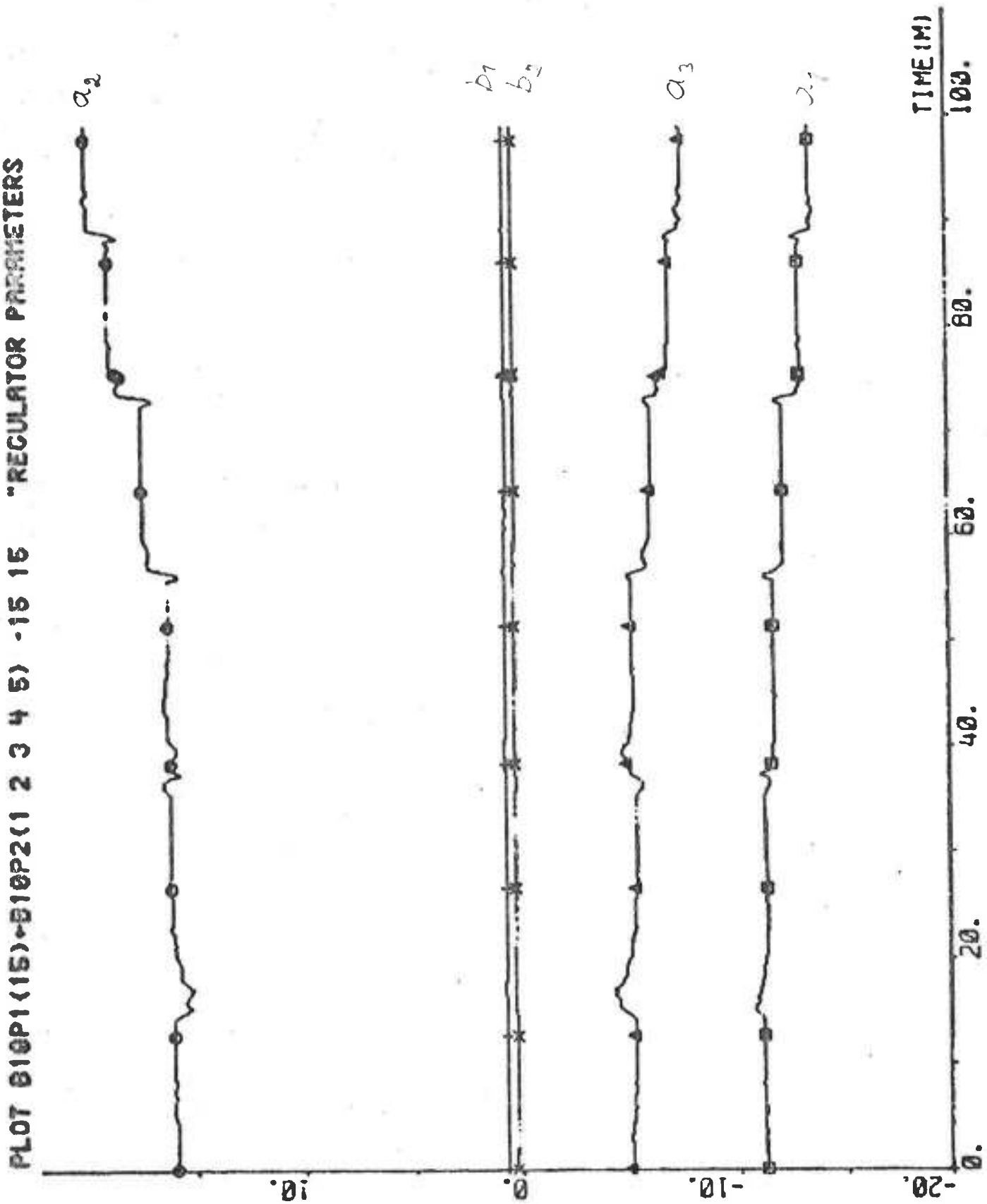

PLOT B1EP1(15)-21EP1(9) ZERO -2 2 "V2 KNOTS
TIME(MI
1.
0.
-1.
-2.
0.
20.
40.
60.
80.
100.

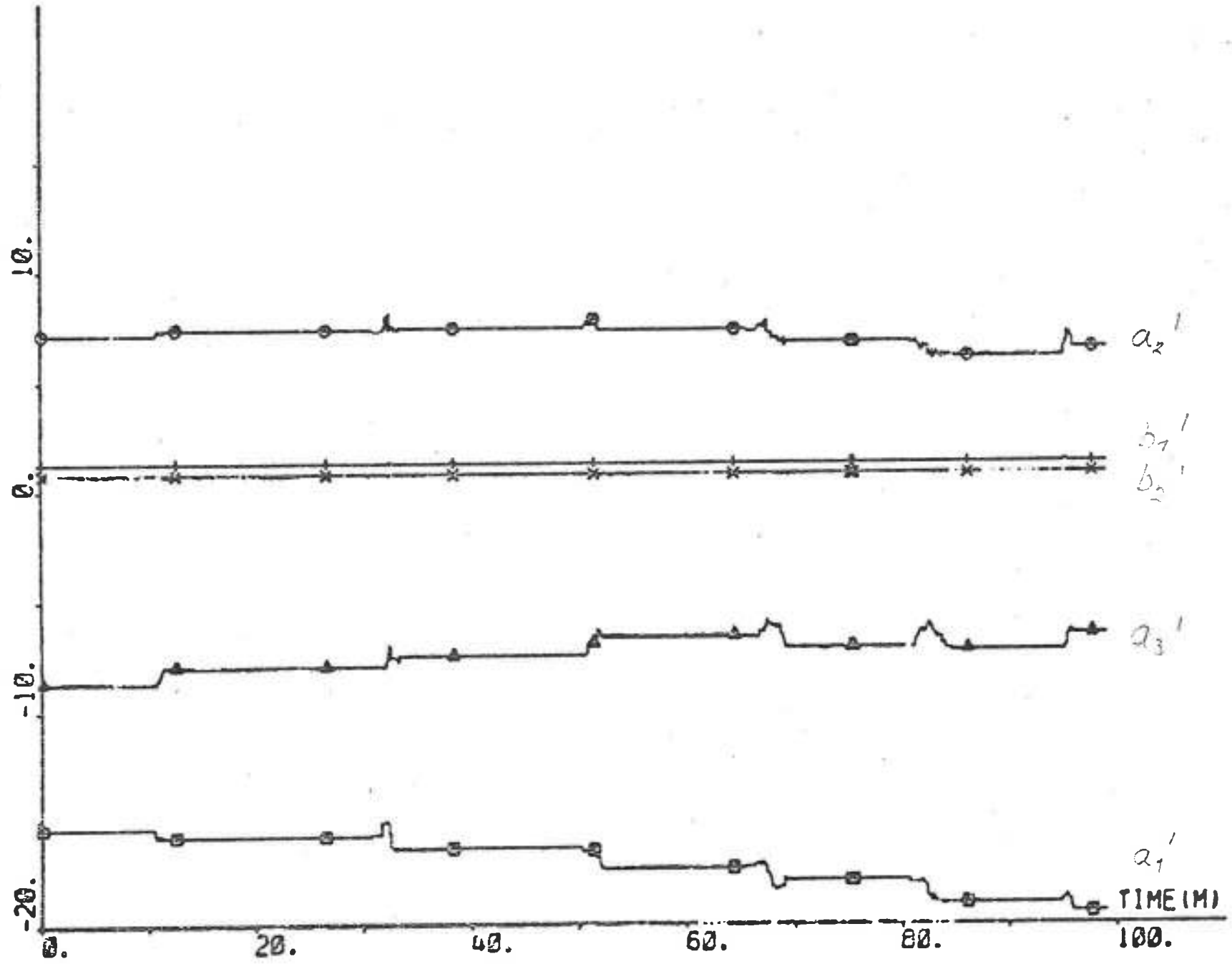

PLOT B10P1(15)-B10P1(10) ZERO -0.2 0.2 °R DEG/S
0.1
0.
-0.1
-0.2
TIME(M)
0.
20.
40.
60.
80.
100.

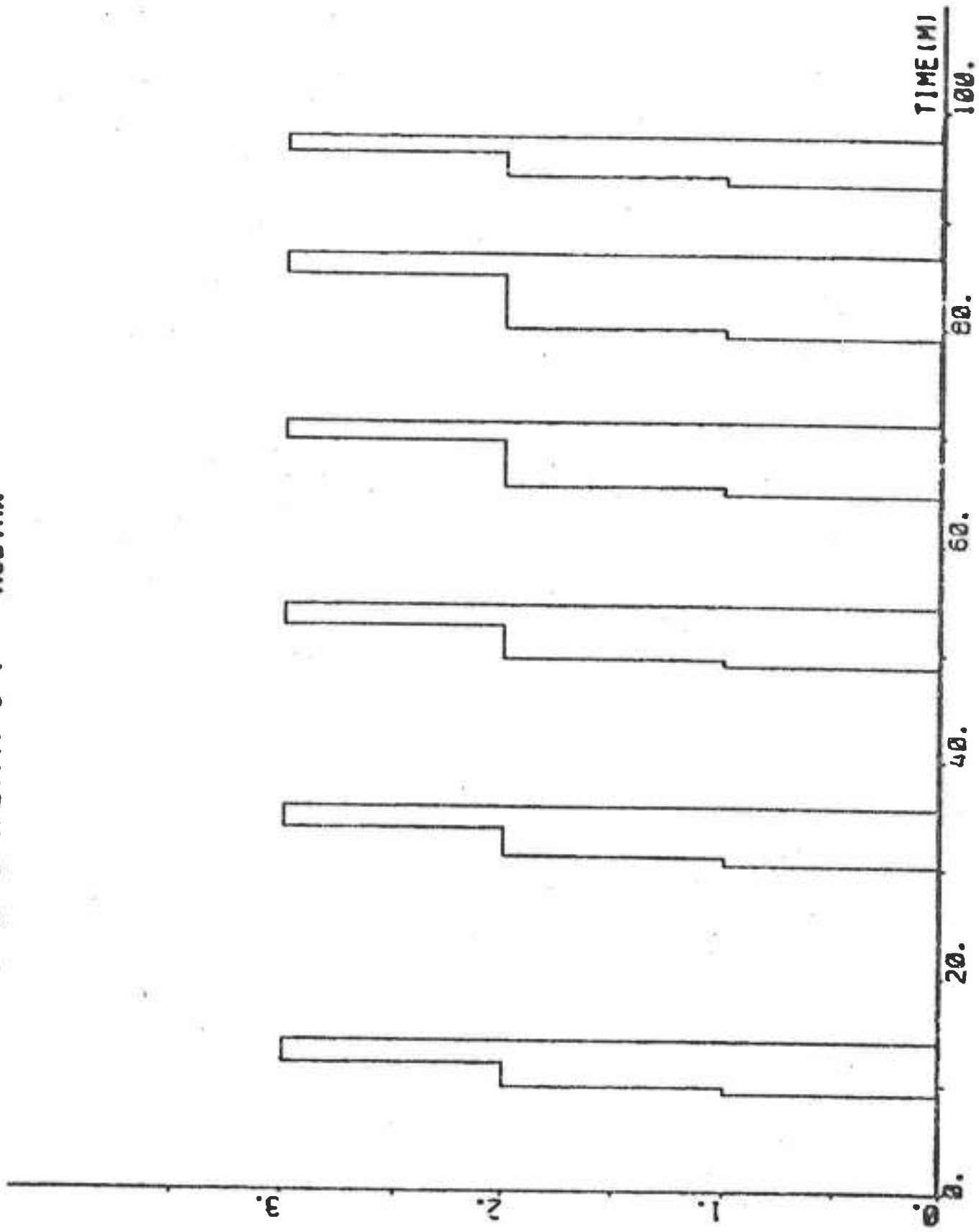

PLOT B18P1(15)-B18P1(11) ZERO -0.2 0.2 "AVR DEG/S (BR=0.2)
0.1
0.
-0.1
-0.2
0.
20.
40.
60.
80.
100.
TIME(M)


PLOT B16P1(15)-B16P1(12) ZERO -0.2 0.2 "DPSIDT DEG/S (IDPSI-B)
TIME(M)
0.
20.
40.
60.
80.
100.
0.1
0.
-0.1
-0.2


PLOT B10P1(15)-B10P1(13 14) 160 240 *PSI PSIREF DEG
160.
200.
240.
0.
20.
40.
60.
80.
100.
TIME(M)


PLOT B10P1(15)=B10P2(1 2 3 4 5) -15 15 "REGULATOR PARAMETERS
a_2
b_1
b_2
a_3
a_1
10.
0.
-10.
-20.
0.
20.
40.
60.
80.
100.
TIME(M)


PLOT B16P1(15)-B16P2(6 7 8 9 16) -20 20 "YAW RECULATOR PARAMETERS
10.
0.
-10.
-20.
0.
20.
40.
60.
80.
100.
TIME(M)
a_2'
b_1'
b_2'
a_3'
a_1'


PLOT B10P1(15)-HP B10P2(11) @ 4 "KODYAW
TIME(MI
0.
20.
40.
60.
80.
100.
0.
1.
2.
3.

EXPERIMENT B11

Date	1974-10-18
Time	13.04
Duration	46 min
Position	S 12° 30' E 42° 30'
Water depth	deep
Forward draught	20.2 m
Aft draught	20.2 m
Wind direction	NE (5, 6; see Appendix A)
Wind velocity	3 Beaufort (4-5.5 m/s, gentle breeze)
Wave height	2 m (sea from NE)
PSIREF	204°, 180°, 225°, 180°
RREF	0.07 deg/s
Rudder limit	Not active
DELlM at termination	Unknown
Approximate mean value of AN	85.5 rpm
Approximate mean value of U	17.7 knots

Regulator structure

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

IREG = 15 RL = 0.99

Final values

$$\begin{bmatrix} a_1 \\ a_2 \\ a_3 \\ b_1 \\ b_2 \end{bmatrix} = \begin{bmatrix} -13.917 \\ 20.837 \\ -7.849 \\ 0.645 \\ 0.192 \end{bmatrix}$$

P unknown

$a_1 + a_2 + a_3 = -0.929$

Yaw regulator structure

NAY = 3	NBY = 2	KY = 3	
IREGY = 10	RLY = 0.95	IRR = 3	IDPSI = 5
AK1V = 40	AK2V = 1.4	AK3V = 120	
C1V = 10	C2V = 80		
EPS1V = 0.02	EPS2V = 0.03		
PSISV = 0.15	PSISSV = 1.5	PSIMAV = 0.6	
I1MV = 40	I2MV = 300	I3MV = 150	

Initial yaw regulator values for the yaw at 2 min.

$$\begin{bmatrix} a'_1 \\ a'_2 \\ a'_3 \\ b'_1 \\ b'_2 \end{bmatrix} = \begin{bmatrix} -19.53 \\ 6.54 \\ -6.60 \\ 1.31 \\ 0.82 \end{bmatrix} \qquad PY = \begin{bmatrix} 500 & & & & \\ 0 & 500 & & & \\ 0 & 0 & 500 & & \\ 0 & 0 & 0 & 5 & \\ 0 & 0 & 0 & 0 & 5 \end{bmatrix}$$

$a'_1 + a'_2 + a'_3 = -19.59$

Yaw regulator values after the yaw at 2 min.

$$\begin{bmatrix} a'_1 \\ a'_2 \\ a'_3 \\ b'_1 \\ b'_2 \end{bmatrix} = \begin{bmatrix} -20.339 \\ 6.621 \\ -5.699 \\ 1.323 \\ 0.821 \end{bmatrix} \qquad PY = \begin{bmatrix} 268.805 & & & & \\ -153.743 & 546.196 & & & \\ -41.883 & -230.400 & 315.061 & & \\ -1.181 & -11.307 & 4.956 & 0.745 & \\ -0.844 & -10.305 & 2.367 & 0.616 & 0.783 \end{bmatrix}$$

$a'_1 + a'_2 + a'_3 = -19.417$

Initial yaw regulator values for the yaw at 16 min.

$$\begin{bmatrix} a_1' \\ a_2' \\ a_3' \\ b_1' \\ b_2' \end{bmatrix} = \begin{bmatrix} -20.34 \\ 6.62 \\ -5.70 \\ 1.31 \\ 0.82 \end{bmatrix} \qquad PY = \begin{bmatrix} 500 & & & & \\ 0 & 500 & & & \\ 0 & 0 & 500 & & \\ 0 & 0 & 0 & 1 & \\ 0 & 0 & 0 & 0 & 1 \end{bmatrix}$$

$a_1' + a_2' + a_3' = -19.42$

Yaw regulator values at 24 min.

$$\begin{bmatrix} a_1' \\ a_2' \\ a_3' \\ b_1' \\ b_2' \end{bmatrix} = \begin{bmatrix} -22.679 \\ 6.616 \\ -5.095 \\ 1.321 \\ 0.822 \end{bmatrix} \qquad PY \text{ unknown}$$

$a_1' + a_2' + a_3' = -21.158$

Initial yaw regulator values for the yaw at 31 min.

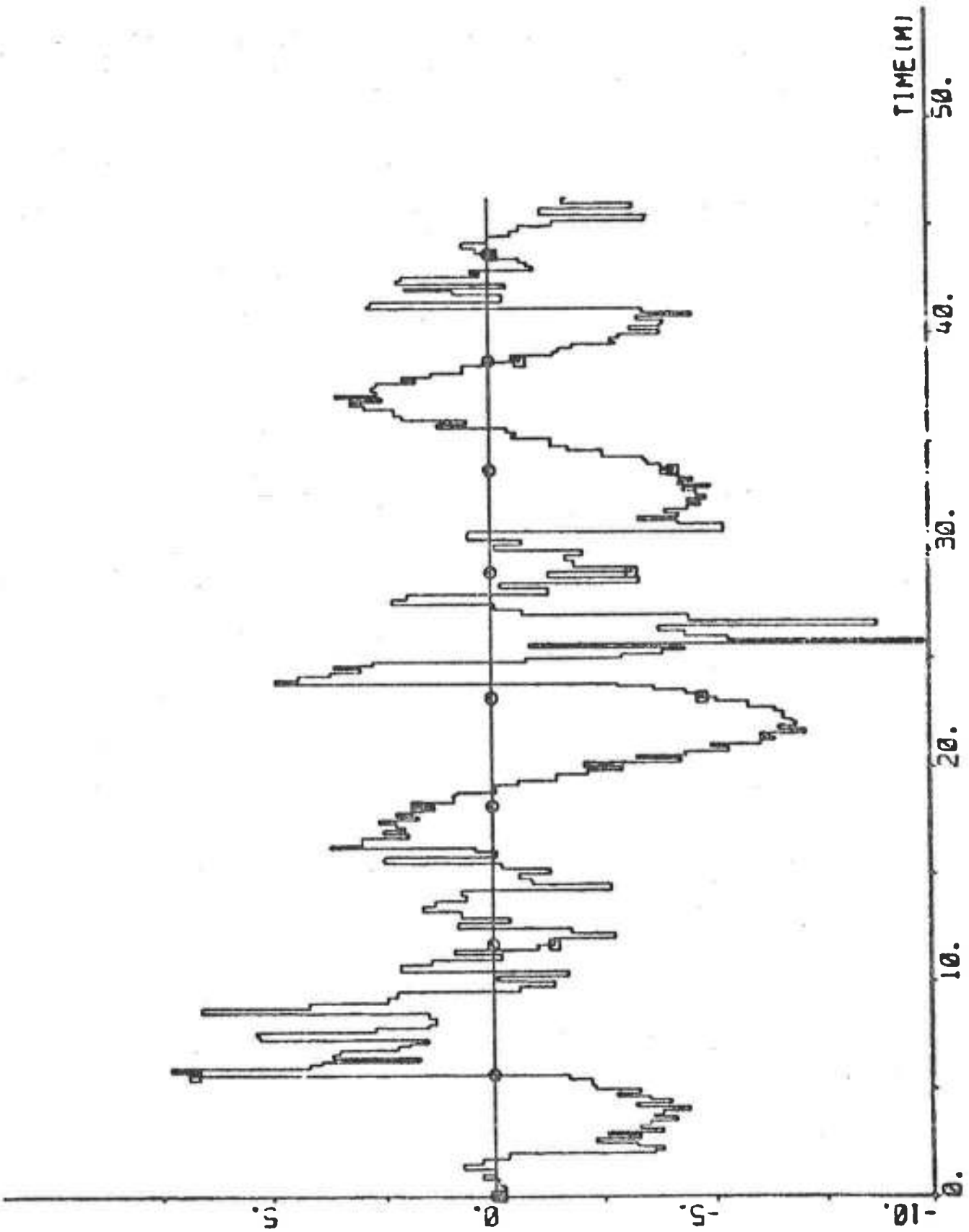
$$\begin{bmatrix} a_1' \\ a_2' \\ a_3' \\ b_1' \\ b_2' \end{bmatrix} = \begin{bmatrix} -22.68 \\ 6.62 \\ -5.10 \\ 1.31 \\ 0.82 \end{bmatrix} \qquad PY = \begin{bmatrix} 500 & & & & \\ 0 & 500 & & & \\ 0 & 0 & 500 & & \\ 0 & 0 & 0 & 1 & \\ 0 & 0 & 0 & 0 & 1 \end{bmatrix}$$

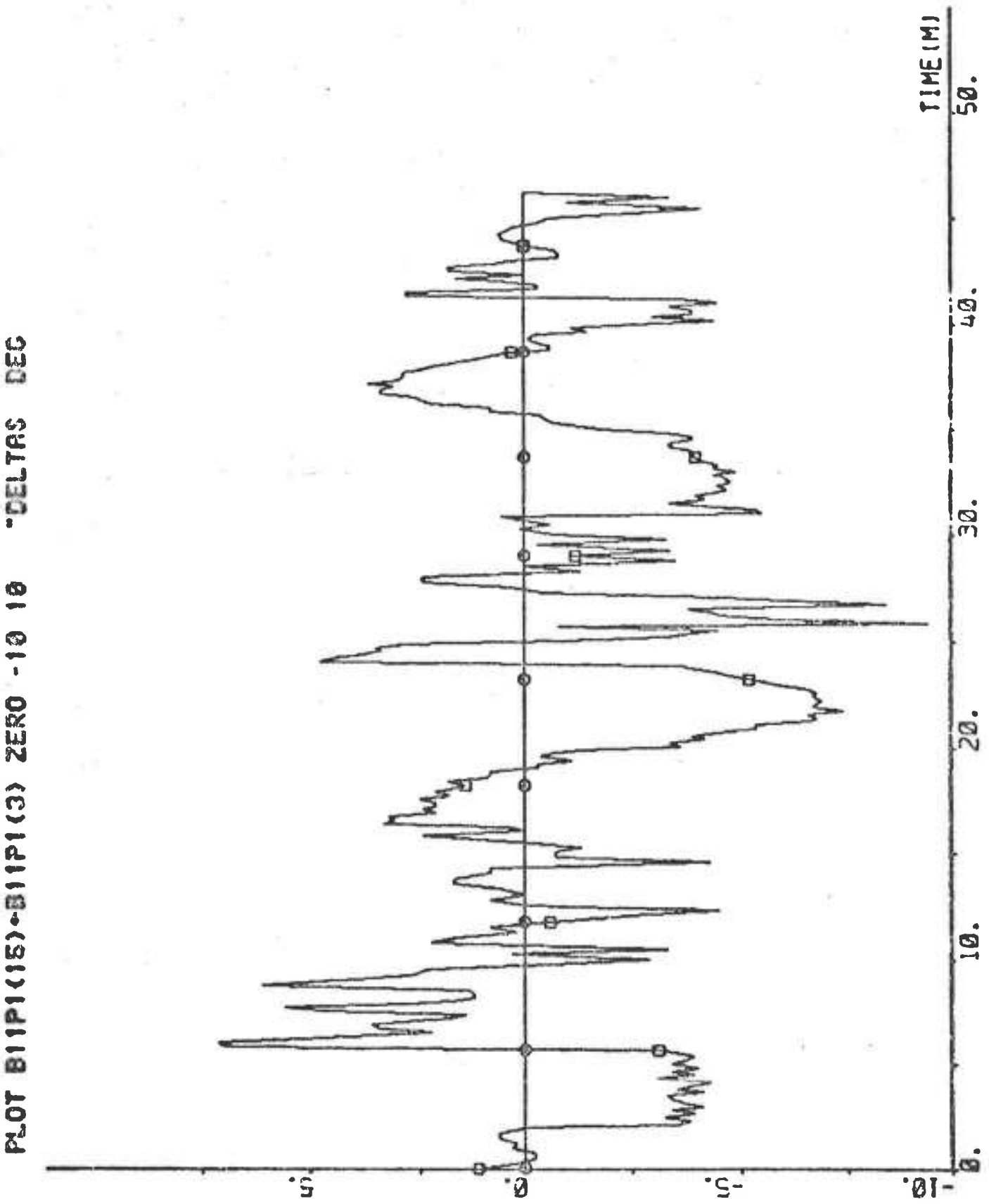
$a_1' + a_2' + a_3' = -21.16$

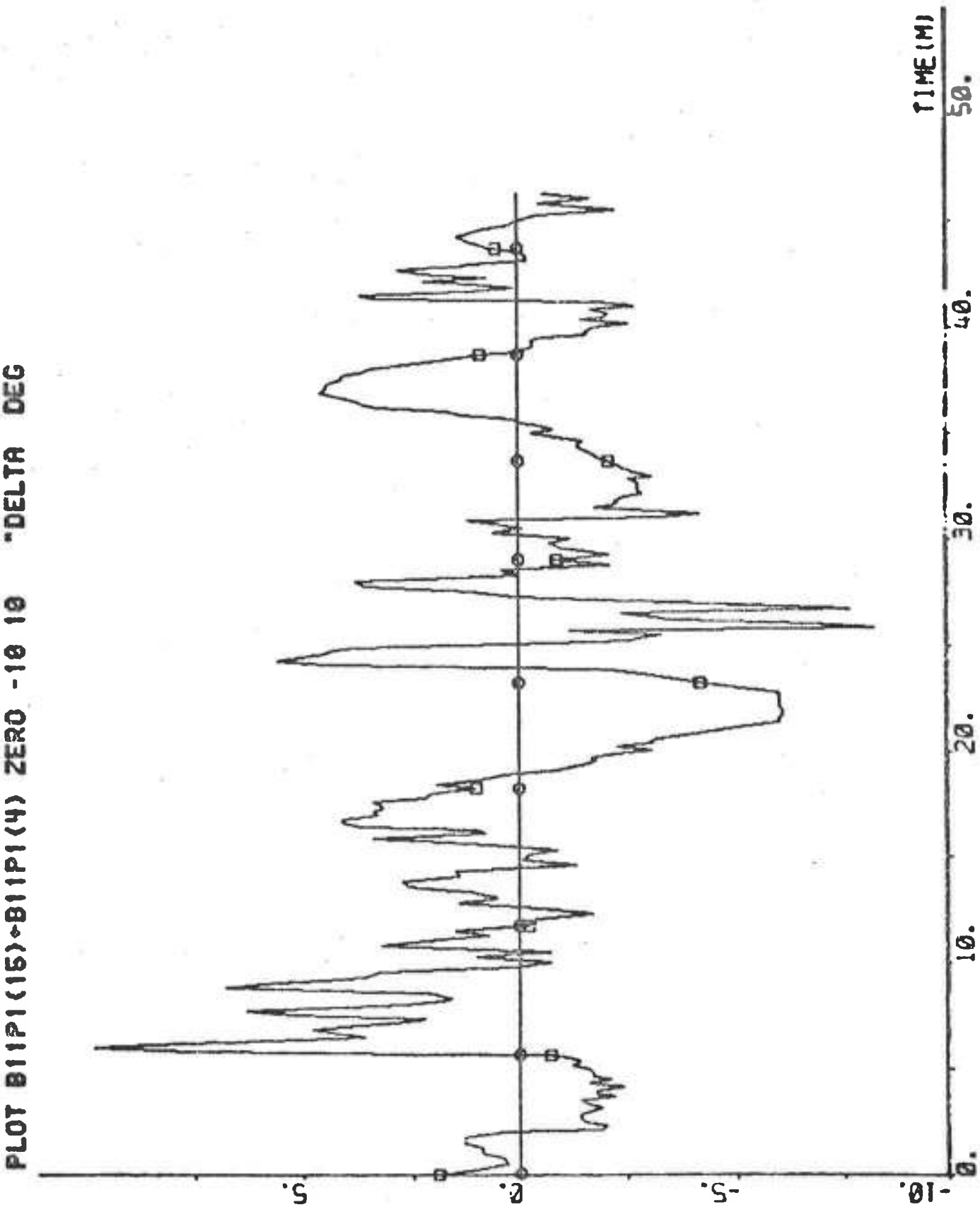
Yaw regulator values after the yaw at 31 min.

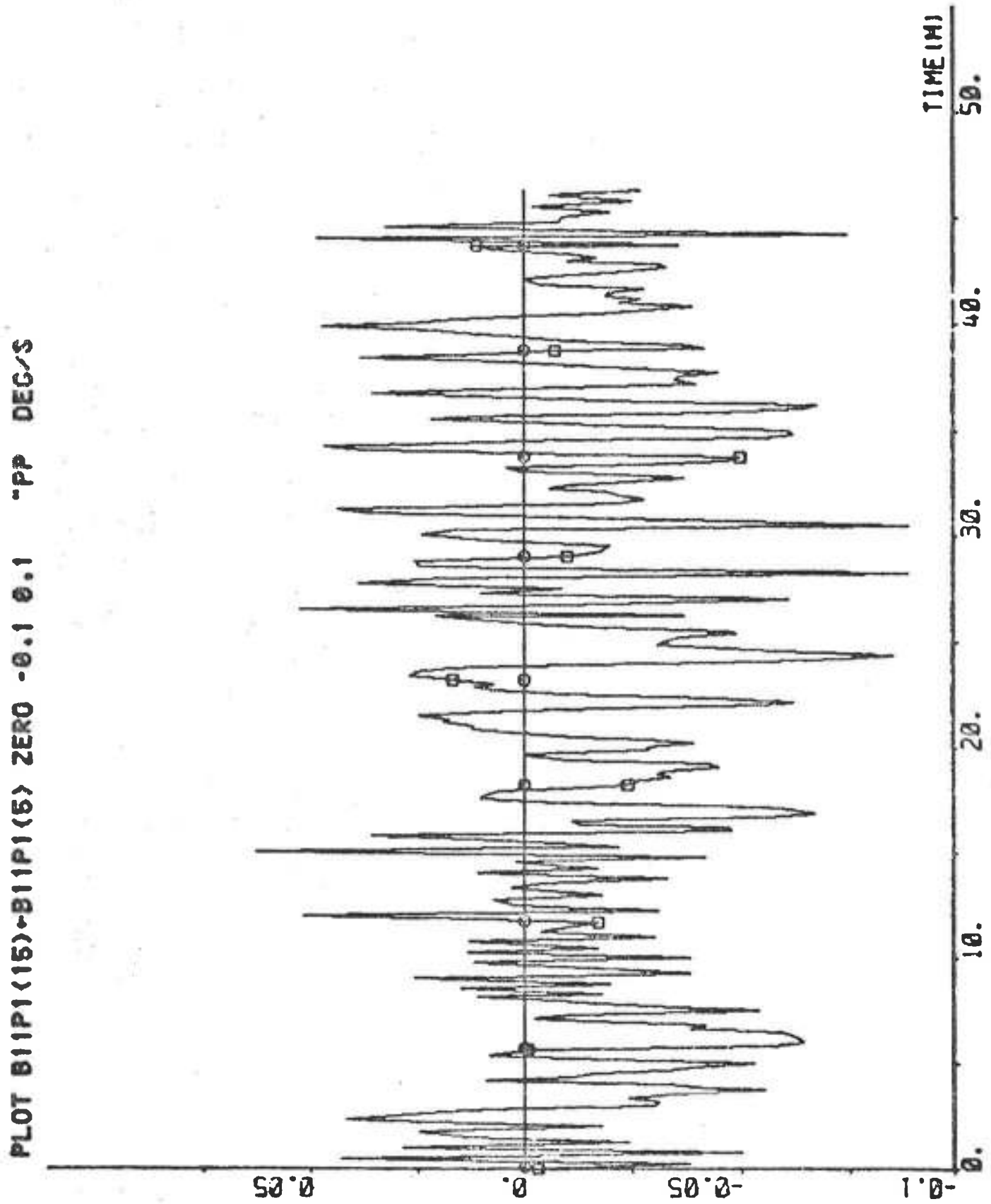
$$\begin{bmatrix} a_1' \\ a_2' \\ a_3' \\ b_1' \\ b_2' \end{bmatrix} = \begin{bmatrix} -24.916 \\ 6.629 \\ -5.083 \\ 1.325 \\ 0.824 \end{bmatrix} \qquad PY = \begin{bmatrix} 369.611 & & & & \\ -361.661 & 1034.462 & & & \\ 3.954 & -488.299 & 411.048 & & \\ -0.866 & -13.245 & 6.715 & 0.612 & \\ 1.041 & -12.880 & 4.852 & 0.441 & 0.552 \end{bmatrix}$$

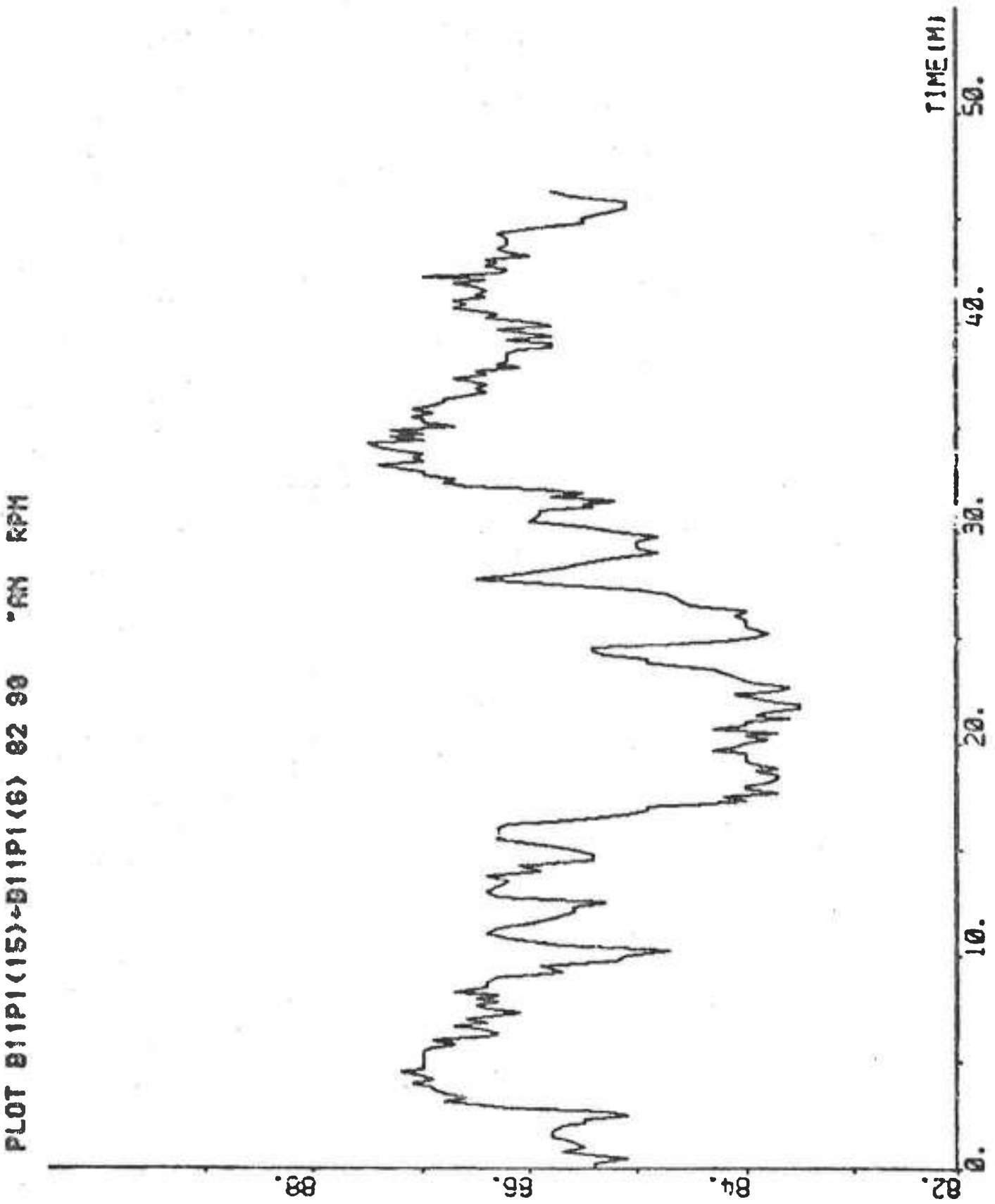
$a_1' + a_2' + a_3' = -23.370$

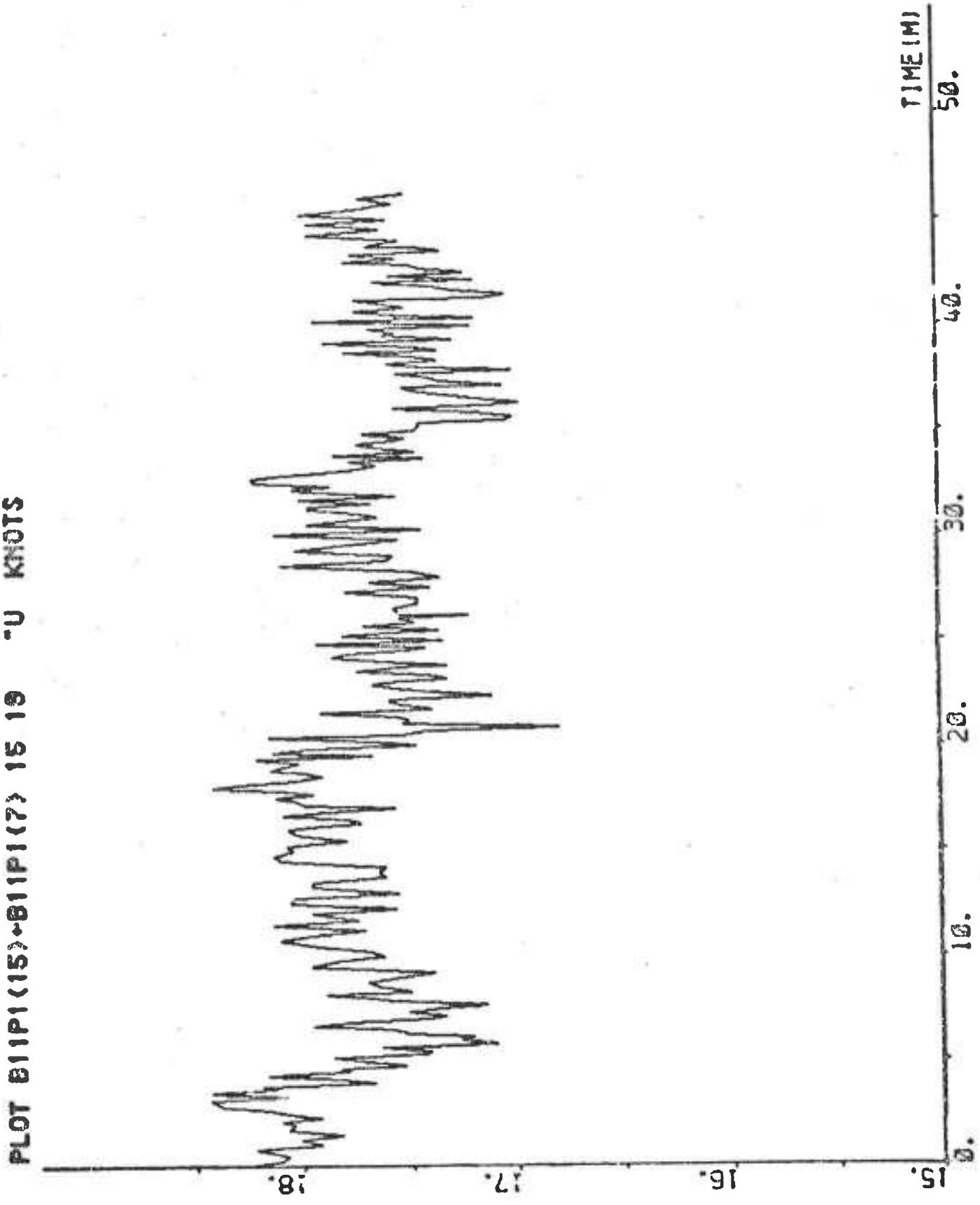

PLOT B11P1(15)-HP B11P1(1) ZERO -10 10 "DELCOC DEC
TIME(M)
0.
10.
20.
30.
40.
50.
-10.
-5.
0.
5.

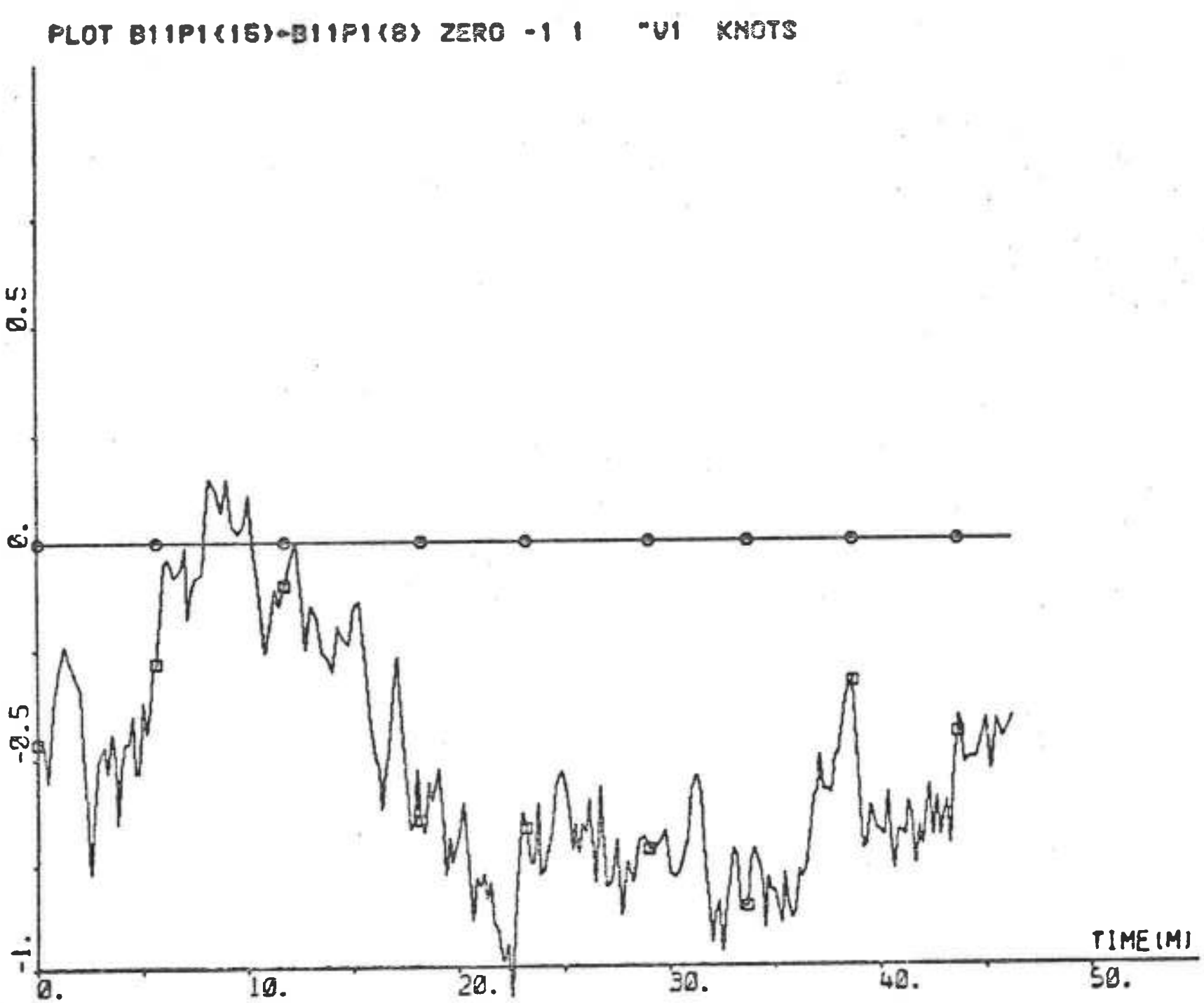

PLOT B11P1(1S)-B11P1(3) ZERO -10 10 *DELTAS DEC
TIME(M)
0.
10.
20.
30.
40.
50.
5.
0.
-5.
-10.

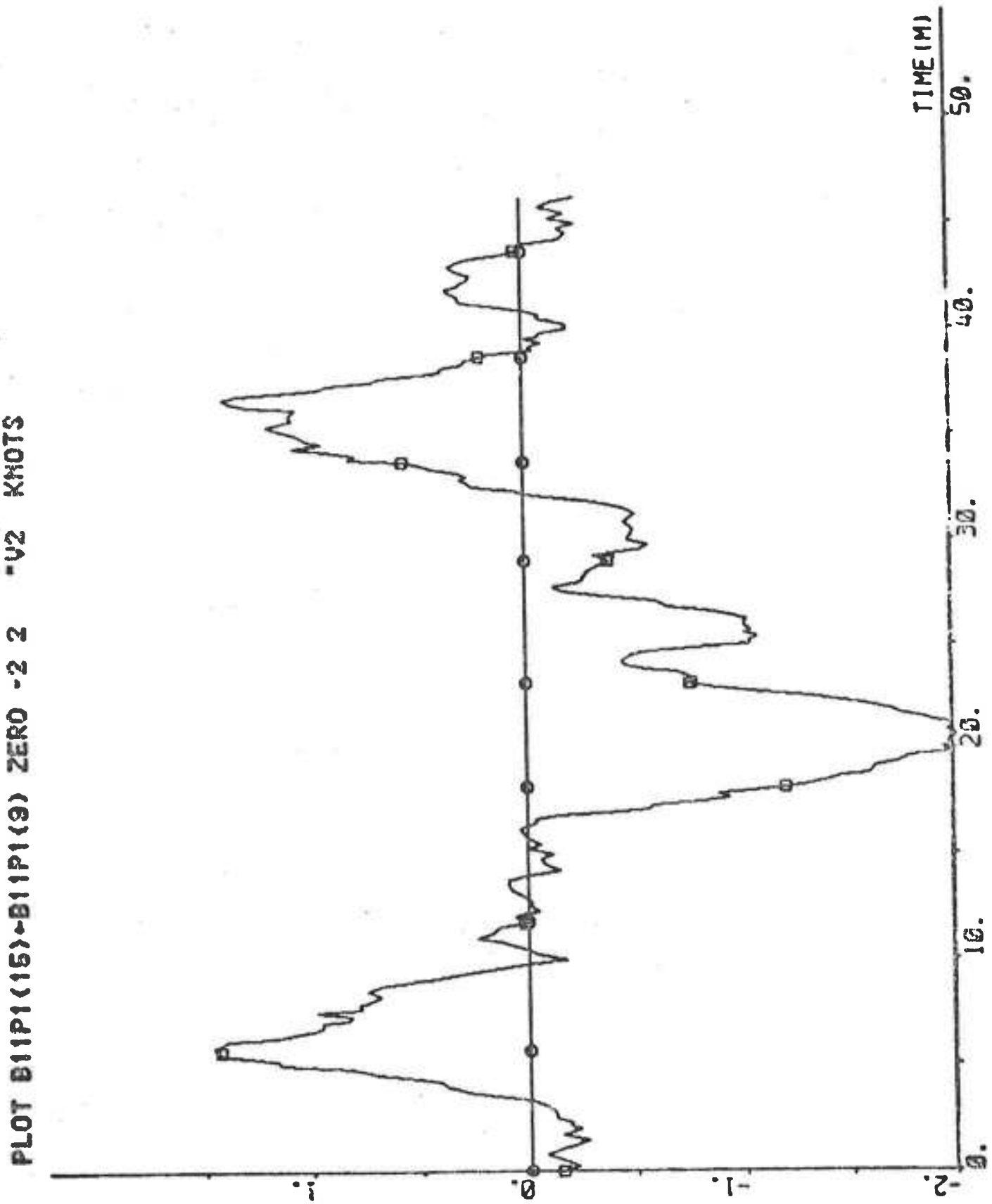

PLOT B11P1(15)*B11P1(4) ZERO -10 10 "DELTA DEG
5.
0.
-5.
-10.
0.
10.
20.
30.
40.
50.
TIME(M)

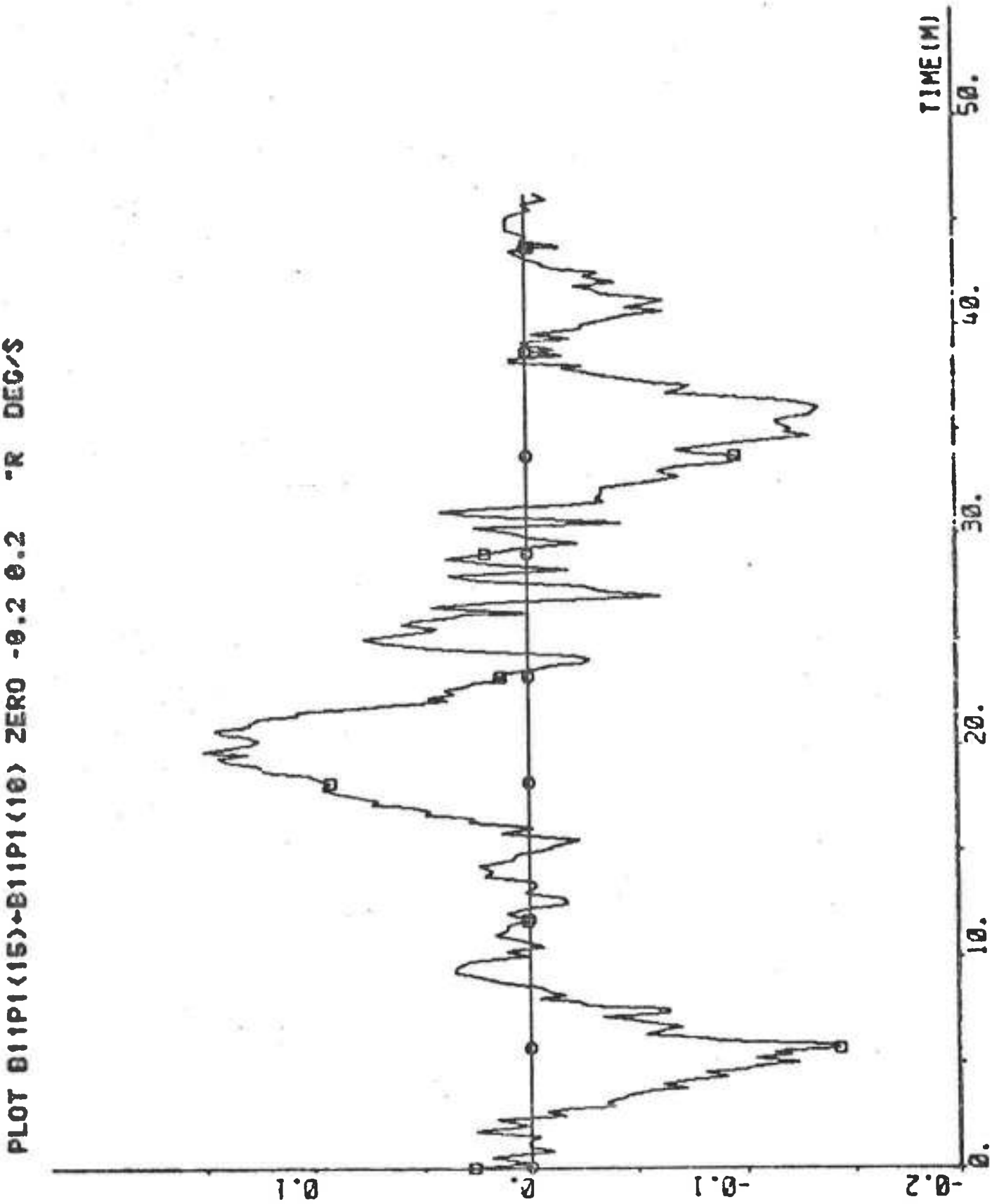

PLOT B11P1(15)-B11P1(6) ZERO -0.1 0.1 "PP DEG/S
TIME(H)
0.
10.
20.
30.
40.
50.
0.1
0.05
0.
-0.05
-0.1

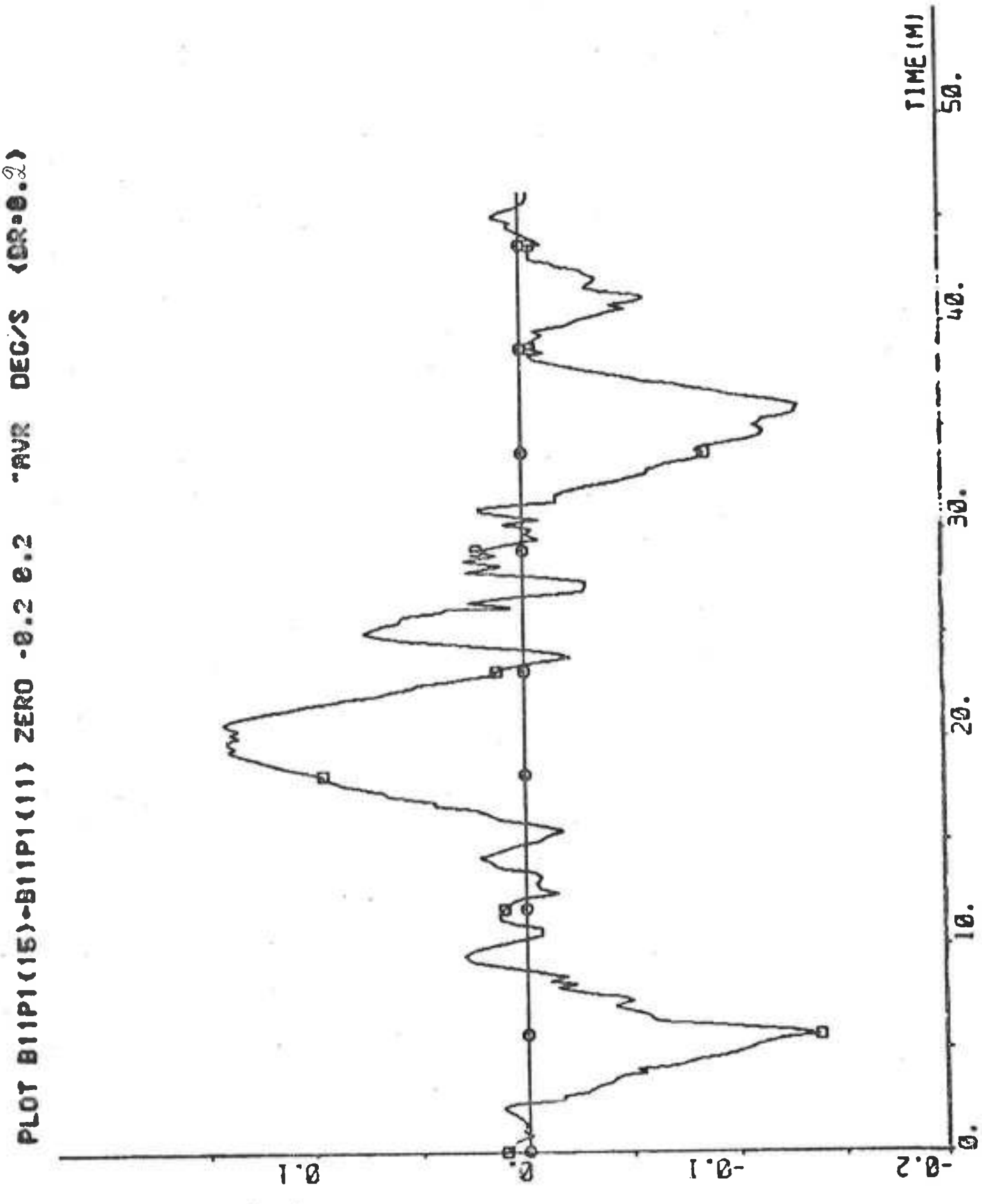

PLOT B11P1(15)-B11P1(6) 82 90 *RN RPH
82.
84.
86.
88.
0.
10.
20.
30.
40.
50.
TIME(H)

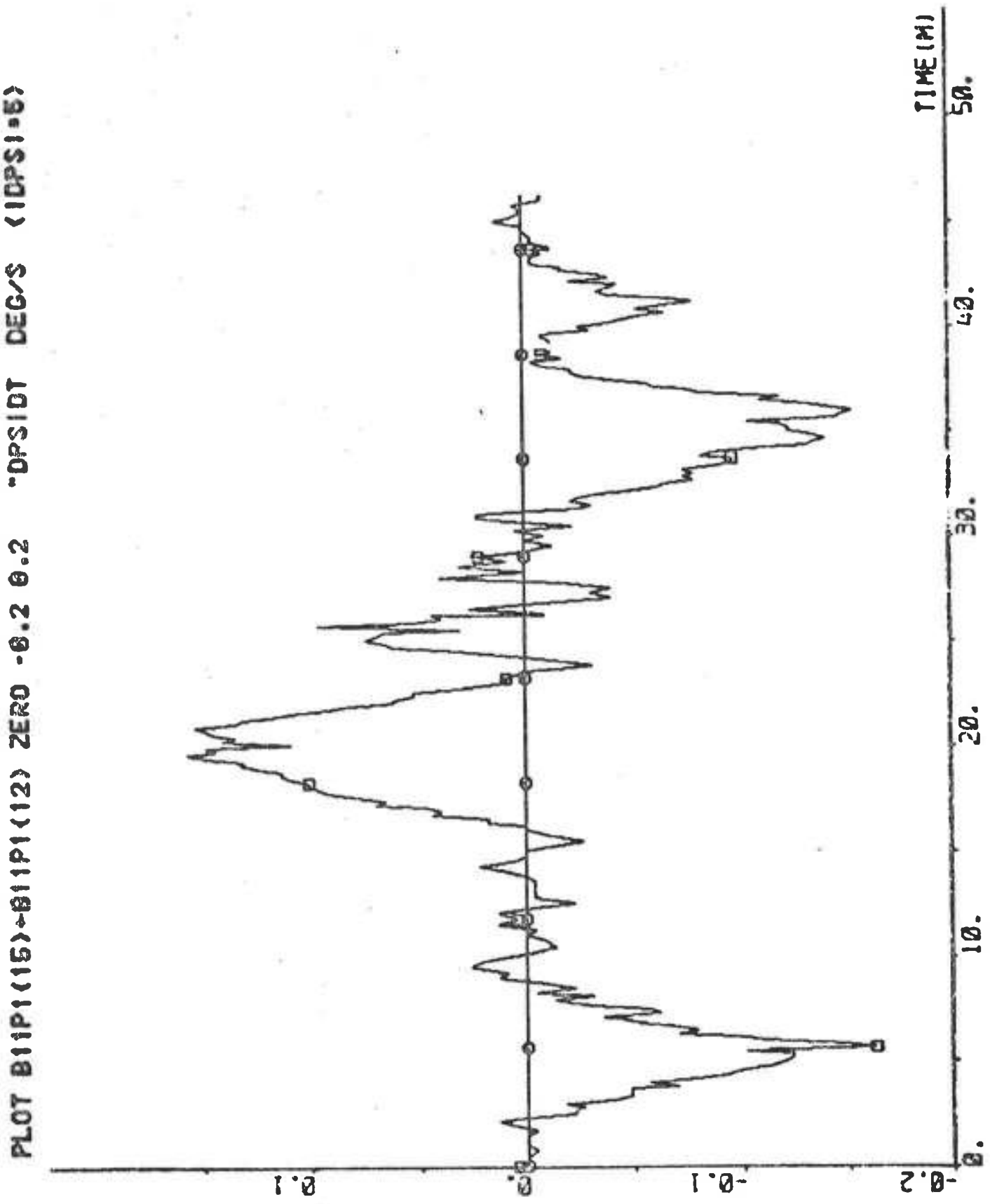

PLOT B11P1(15)-B11P1(7) 15 10 *U KNOTS
18.
17.
16.
15.
0.
10.
20.
30.
40.
50.
TIME(M)

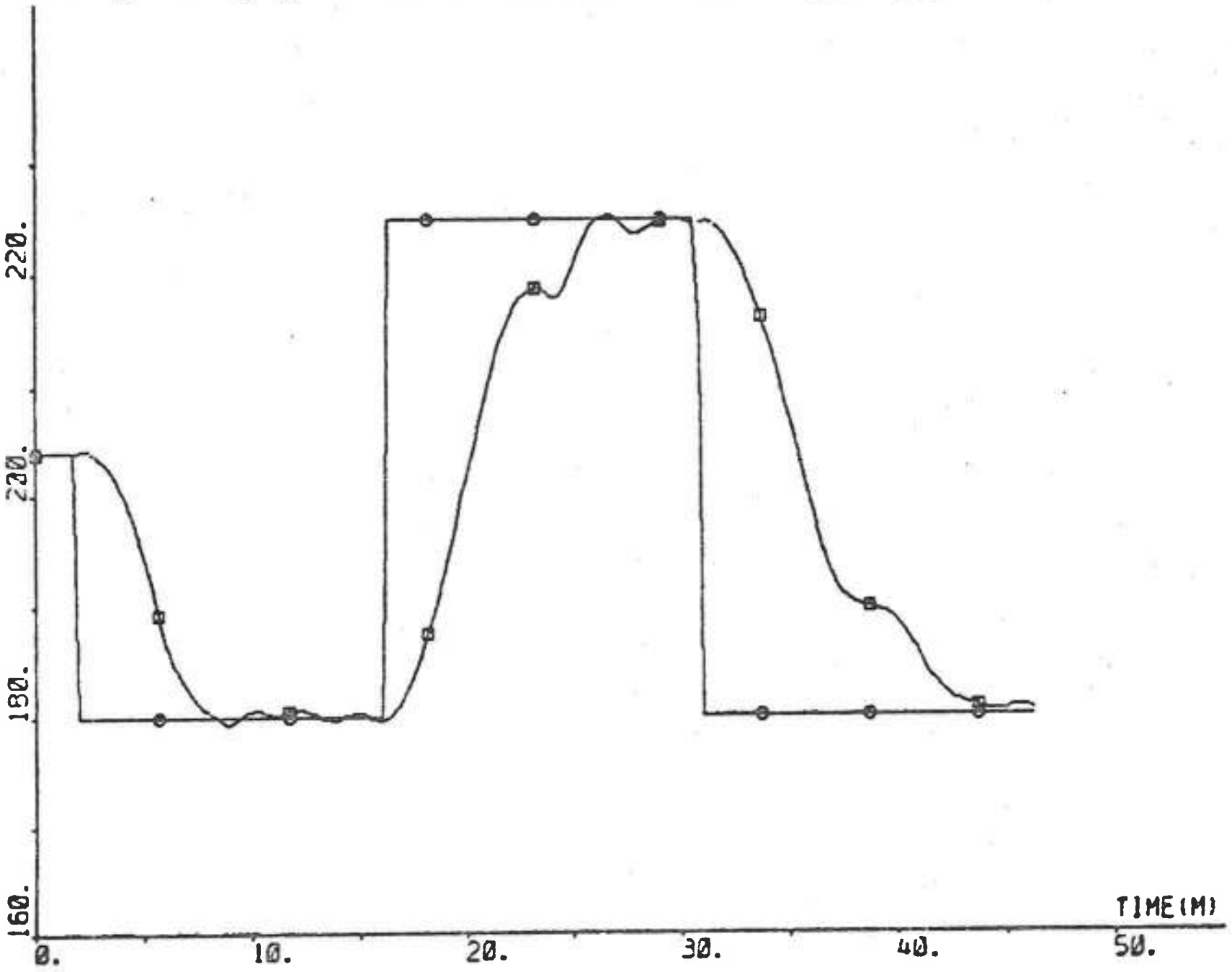

PLOT B11P1(16)-B11P1(8) ZERO -1 1 "V1 KNOTS
0.5
0.
-0.5
-1.
0.
10.
20.
30.
40.
50.
TIME(M)

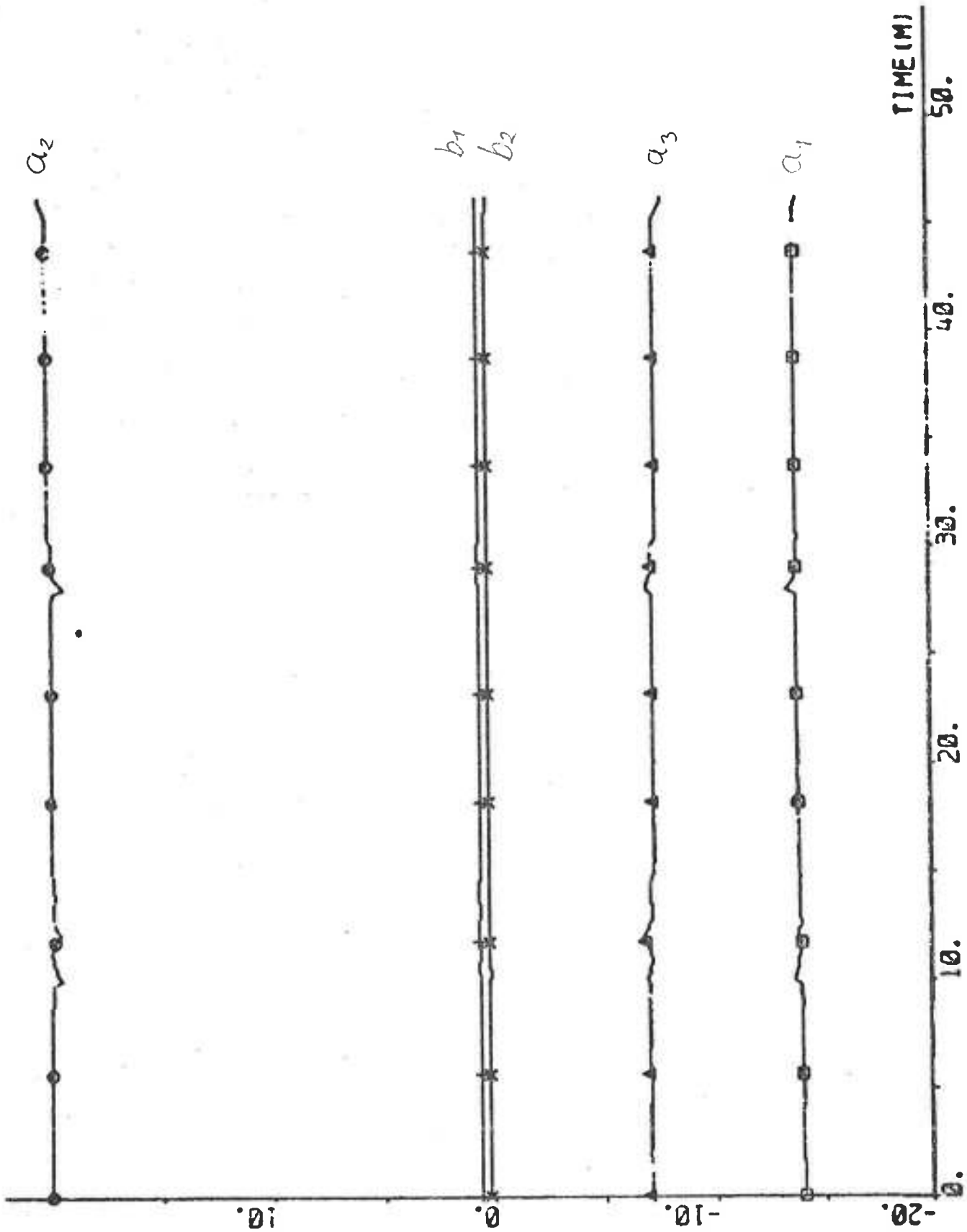

PLOT B11P1(15)-B11P1(9) ZERO -2 2 "V2 KNOTS
1.
0
-1.
-2.
0.
10.
20.
30.
40.
50.
TIME(M)

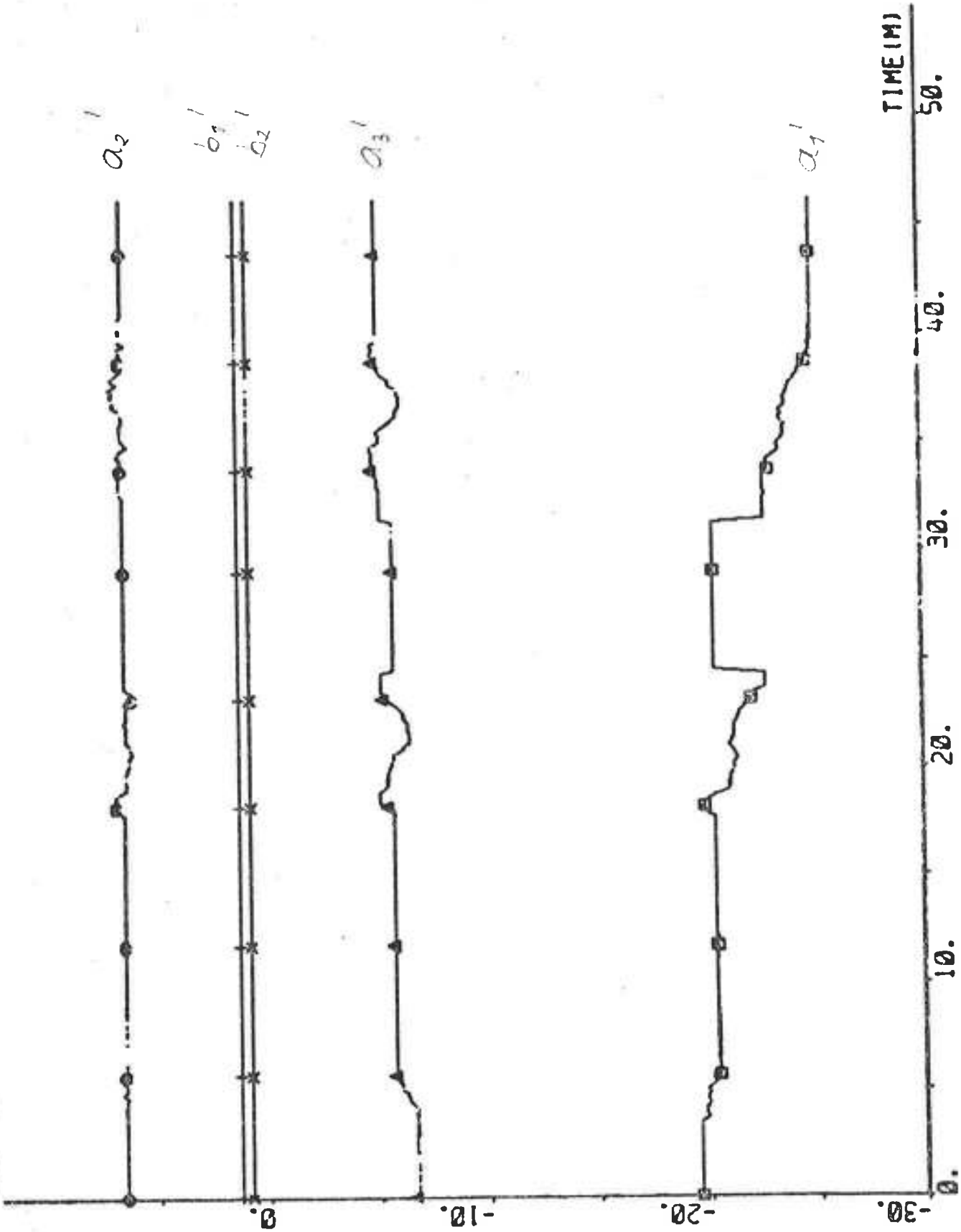

PLOT B11P1(15)-B11P1(10) ZERO -0.2 0.2 °R DEG/S
0.1
0.
-0.1
-0.2
0.
10.
20.
30.
40.
50.
TIME(M)

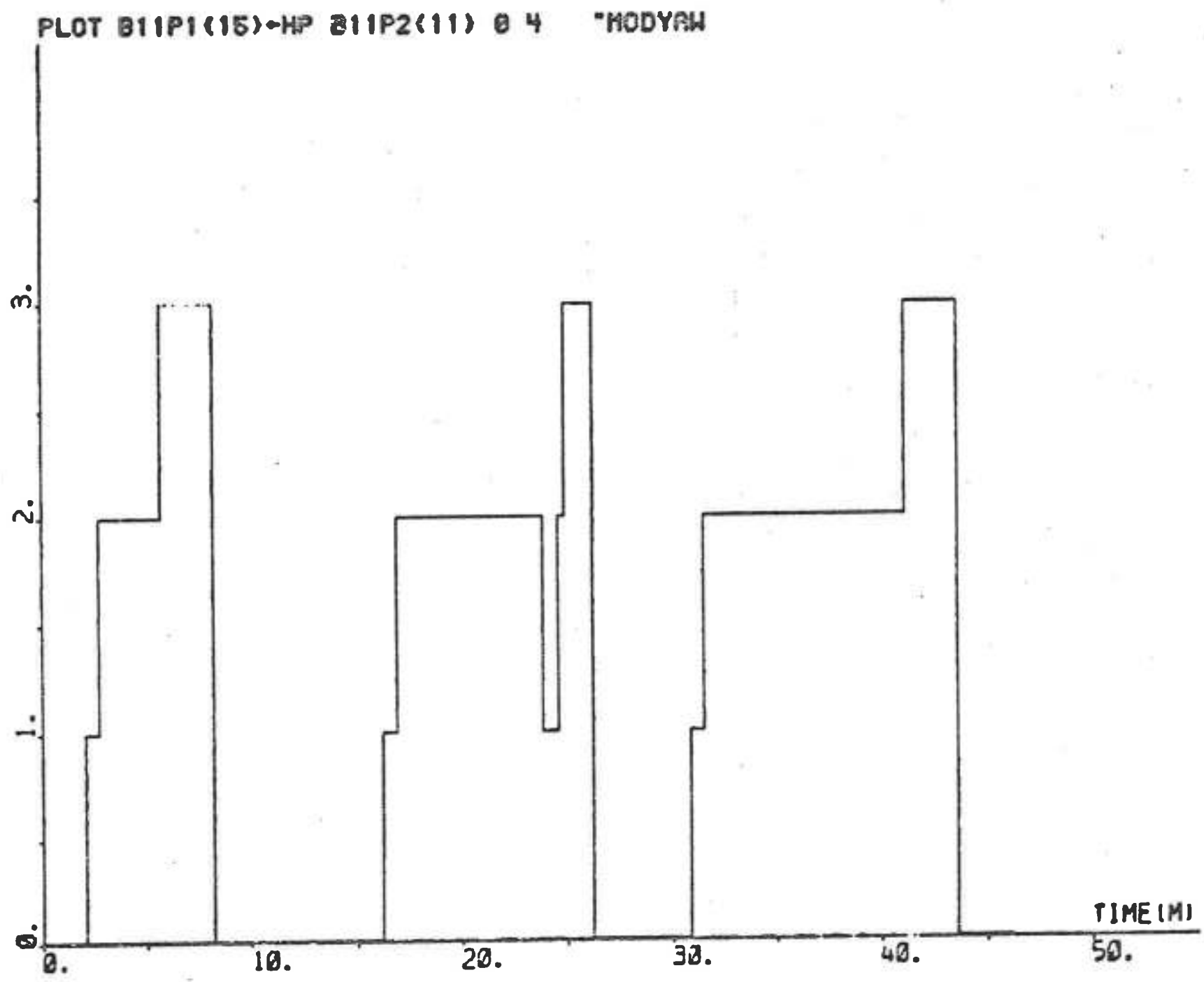

PLOT B11P1(15)-B11P1(11) ZERO -0.2 0.2 "AVR DEG/S (DR=0.2)
0.1
0.
-0.1
-0.2
0.
10.
20.
30.
40.
50.
TIME(M)
AVR


PLOT B11P1(15)-B11P1(12) ZERO -0.2 0.2 "DPSIDT DEG/S (IDPSI=5)
0.1
0
-0.1
-0.2
0.
10.
20.
30.
40.
50.
TIME(M)


PLOT B11P1(15)-B11P1(13 14) 160 240 "PSI PSIREF DEG
220.
200.
180.
160.
TIME(M)
0.
10.
20.
30.
40.
50.


PLOT B11P1(16)-B11P2(1 2 3 4 5) -15 15 "REGULATOR PARAMETERS
a_2
b_1
b_2
a_3
a_1
10.
0.
-10.
-20.
0.
10.
20.
30.
40.
50.
TIME(M)


PLOT B11P1(15)-B11P2(8 7 8 9 10) -30 10 "YAW REGULATOR PARAMETERS
a_2'
b_0'
b_2'
a_3'
a_1'
TIME(M)
0.
10.
20.
30.
40.
50.
0.
-10.
-20.
-30.


PLOT B11P1(15)-HP B11P2(11) 0 4 "MODYAW
3.
2.
1.
0.
0.
10.
20.
30.
40.
50.
TIME(M)

EXPERIMENT B12

Date	1974-10-18
Time	13.52
Duration	41 min
Position	S 13° 00' E 42° 20'
Water depth	deep
Forward draught	20.2 m
Aft draught	20.2 m
Wind direction	NE (5, 6; see Appendix A)
Wind velocity	3 Beaufort (4-5.5 m/s, gentle breeze)
Wave height	2 m (sea from NE)
PSIREF	180°, 225°, 180°, 225°
RREF	0.07 deg/s (0-35 min),
	0.14 deg/s (35-41 min)
Rudder limit	Not active
DELlM at termination	Unknown
Approximate mean value of AN	85.5 rpm
Approximate mean value of U	17.8 knots

Regulator structure

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

IREG = 15 RL = 0.99

Final values

$$\begin{bmatrix} a_1 \\ a_2 \\ a_3 \\ b_1 \\ b_2 \end{bmatrix} = \begin{bmatrix} -14.001 \\ 20.837 \\ -7.742 \\ 0.650 \\ 0.197 \end{bmatrix}$$

P unknown

$a_1 + a_2 + a_3 = -0.906$

Yaw regulator structure

NAY = 3	NBY = 2	KY = 2	
IREGY = 10	RLY = 0.95	IRR = 3	IDPSI = 5
AK1V = 40	AK2V = 1.4	AK3V = 120	
C1V = 10	C2V = 80		
EPS1V = 0.02	EPS2V = 0.1		
PSISV = 0.15	PSISSV = 1.5	PSIMAV = 0.6	
I1MV = 40	I2MV = 300	I3MV = 150	

Initial yaw regulator values for the yaw at 2 min.

$$\begin{bmatrix} a_1' \\ a_2' \\ a_3' \\ b_1' \\ b_2' \end{bmatrix} = \begin{bmatrix} -25.00 \\ 6.62 \\ -5.10 \\ 1.31 \\ 0.82 \end{bmatrix} \qquad PY = \begin{bmatrix} 500 & & & & \\ 0 & 500 & & & \\ 0 & 0 & 500 & & \\ 0 & 0 & 0 & 1 & \\ 0 & 0 & 0 & 0 & 1 \end{bmatrix}$$

$a_1' + a_2' + a_3' = -23.48$

Yaw regulator values after the yaw at 2 min.

$$\begin{bmatrix} a_1' \\ a_2' \\ a_3' \\ b_1' \\ b_2' \end{bmatrix} = \begin{bmatrix} -26.073 \\ 6.164 \\ -5.168 \\ 1.303 \\ 0.812 \end{bmatrix} \qquad PY = \begin{bmatrix} 312.138 & & & & \\ -214.178 & 666.216 & & & \\ -61.612 & -350.575 & 383.342 & & \\ -1.170 & -6.940 & 4.497 & 0.284 & \\ -0.043 & -6.445 & 3.10 & 0.203 & 0.251 \end{bmatrix}$$

$a_1' + a_2' + a_3' = -25.077$

Initial yaw regulator values for the yaw at 20 min.

$$\begin{bmatrix} a_1' \\ a_2' \\ a_3' \\ b_1' \\ b_2' \end{bmatrix} = \begin{bmatrix} -26.07 \\ 6.16 \\ -5.17 \\ 1.30 \\ 0.81 \end{bmatrix} \qquad PY = \begin{bmatrix} 500 & & & & \\ 0 & 500 & & & \\ 0 & 0 & 500 & & \\ 0 & 0 & 0 & 1 & \\ 0 & 0 & 0 & 0 & 1 \end{bmatrix}$$

$a_1' + a_2' + a_3' = -25.08$

Yaw regulator values after the yaw at 20 min.

$$\begin{bmatrix} a_1' \\ a_2' \\ a_3' \\ b_1' \\ b_2' \end{bmatrix} = \begin{bmatrix} -28.376 \\ 5.911 \\ -3.669 \\ 1.299 \\ 0.805 \end{bmatrix} \qquad PY = \begin{bmatrix} 421.512 & & & & \\ -303.251 & 1154.956 & & & \\ -48.991 & -579.292 & 517.920 & & \\ -3.336 & -20.109 & 10.312 & 0.968 & \\ -2.790 & -14.114 & 5.321 & 0.672 & 0.763 \end{bmatrix}$$

$a_1' + a_2' + a_3' = -26.134$

Initial yaw regulator values for the yaw at 37 min.

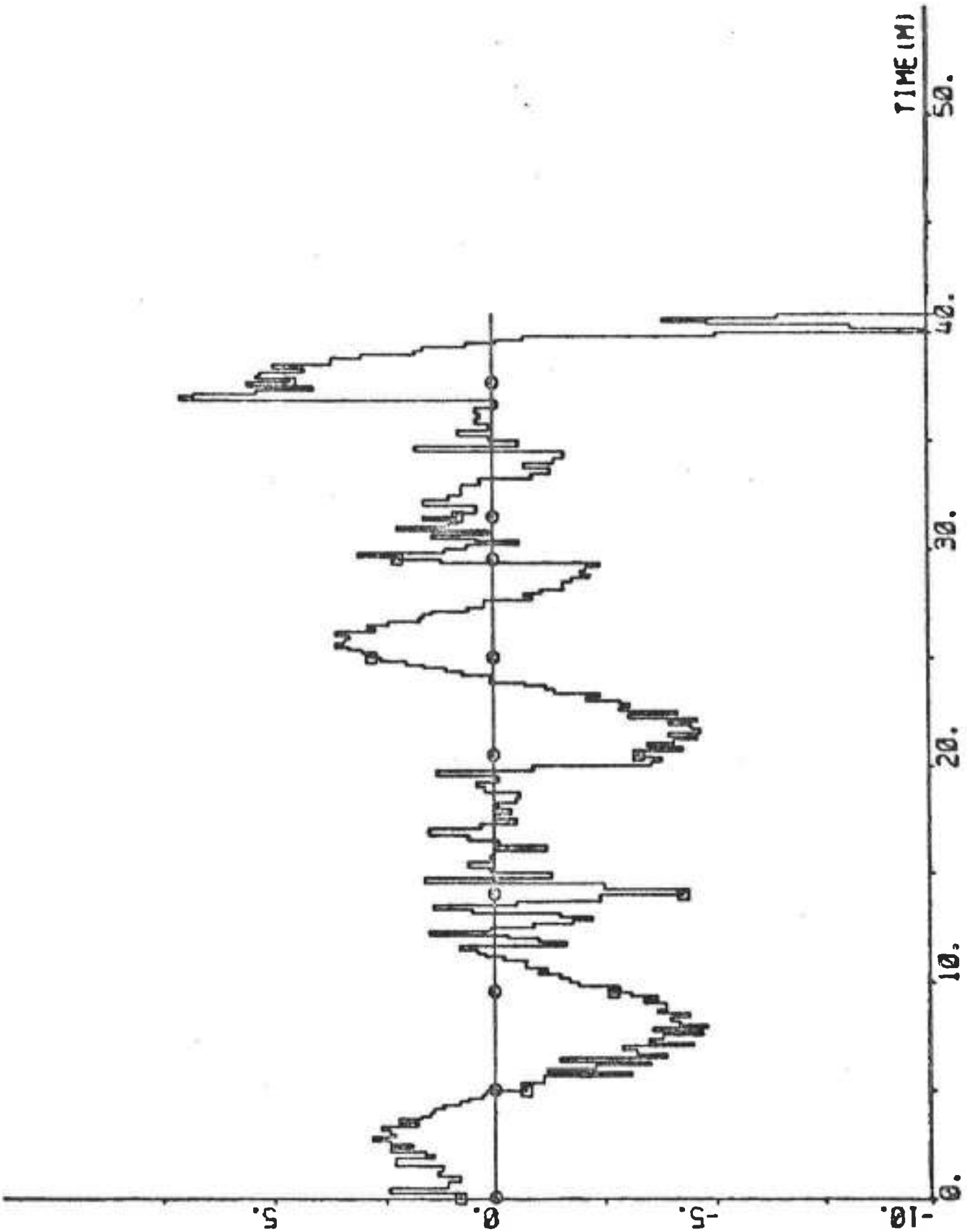
$$\begin{bmatrix} a_1' \\ a_2' \\ a_3' \\ b_1' \\ b_2' \end{bmatrix} = \begin{bmatrix} -28.38 \\ 5.91 \\ -3.67 \\ 1.30 \\ 0.81 \end{bmatrix} \qquad PY = \begin{bmatrix} 500 & & & & \\ 0 & 500 & & & \\ 0 & 0 & 500 & & \\ 0 & 0 & 0 & 1 & \\ 0 & 0 & 0 & 0 & 1 \end{bmatrix}$$

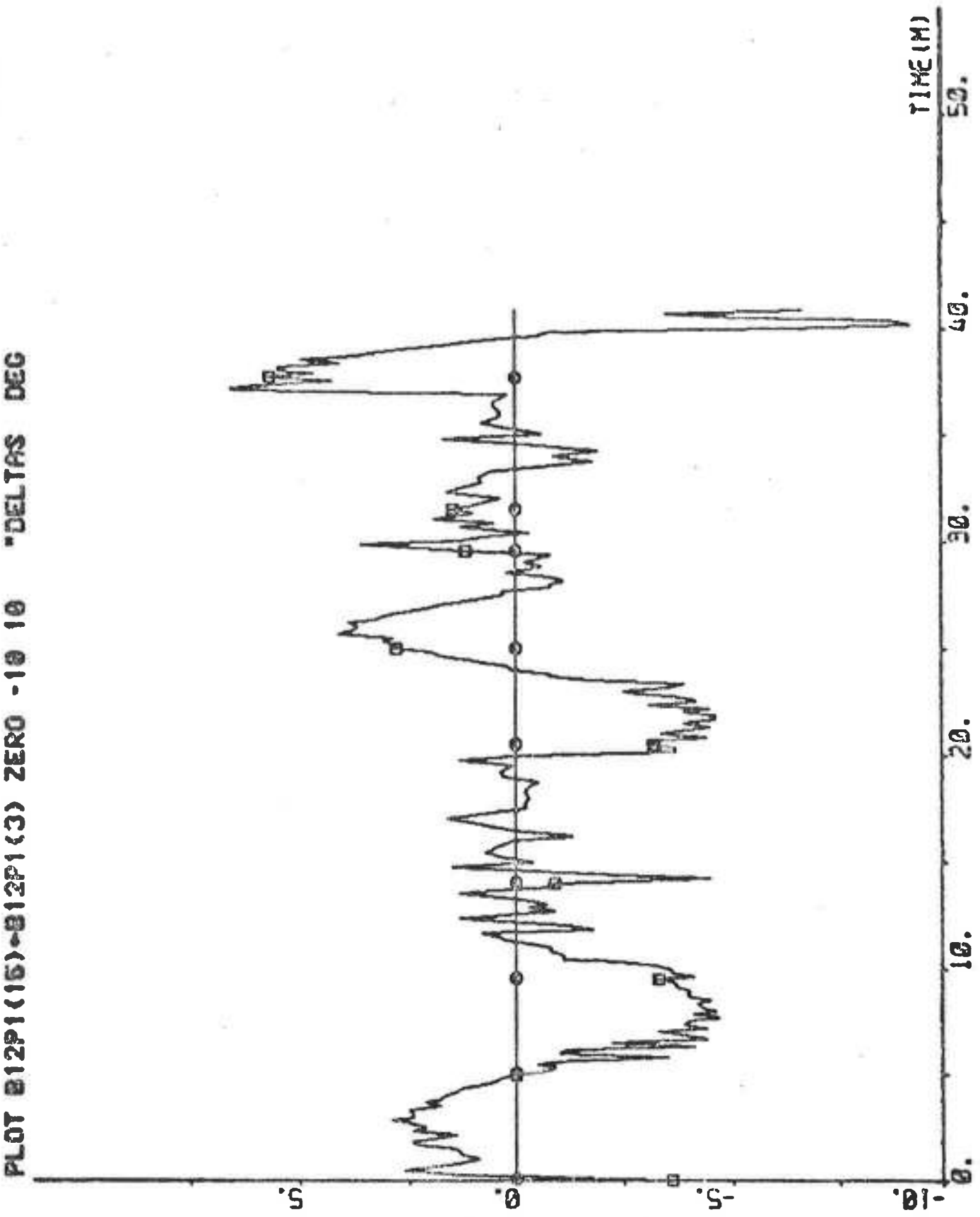
$a_1' + a_2' + a_3' = -26.14$

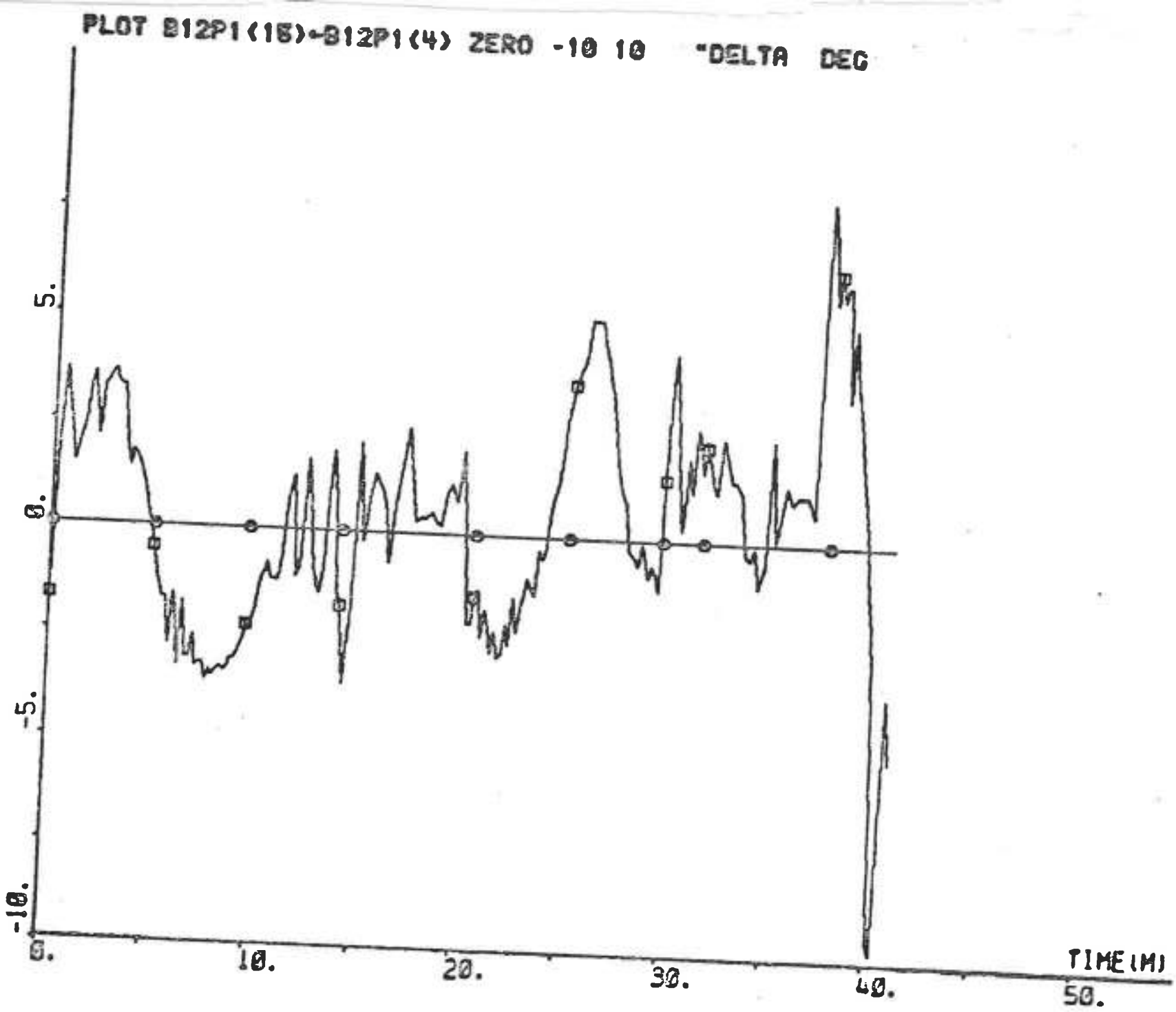
Yaw regulator values after the yaw at 37 min.

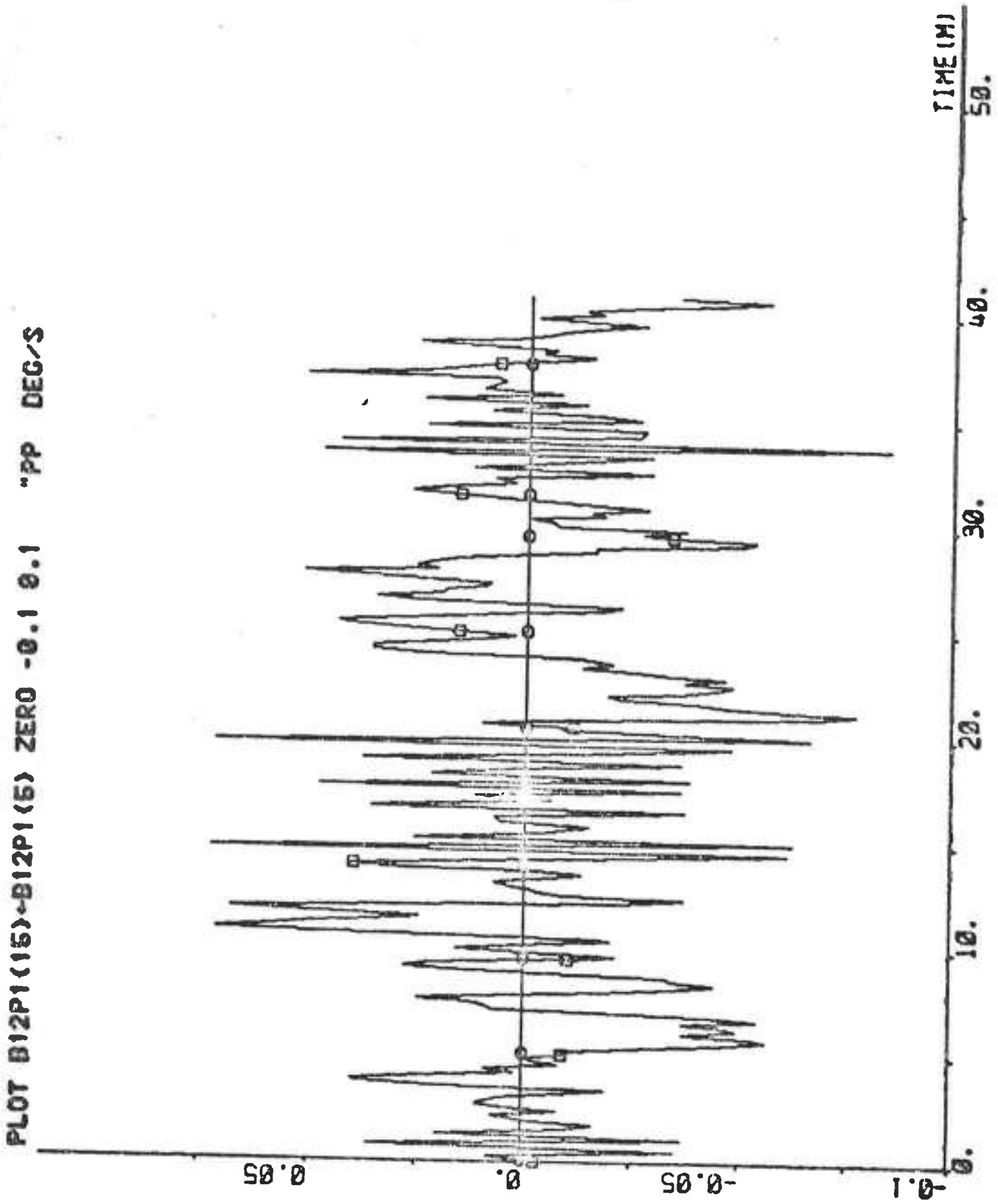
$$\begin{bmatrix} a_1' \\ a_2' \\ a_3' \\ b_1' \\ b_2' \end{bmatrix} = \begin{bmatrix} -29.101 \\ 5.883 \\ -2.418 \\ 1.303 \\ 0.815 \end{bmatrix} \qquad PY = \begin{bmatrix} 209.880 & & & & \\ -170.925 & 493.423 & & & \\ 34.681 & -235.097 & 311.261 & & \\ -0.782 & -7.691 & 3.288 & 0.455 & \\ -1.179 & -4.736 & 0.660 & 0.323 & 0.459 \end{bmatrix}$$

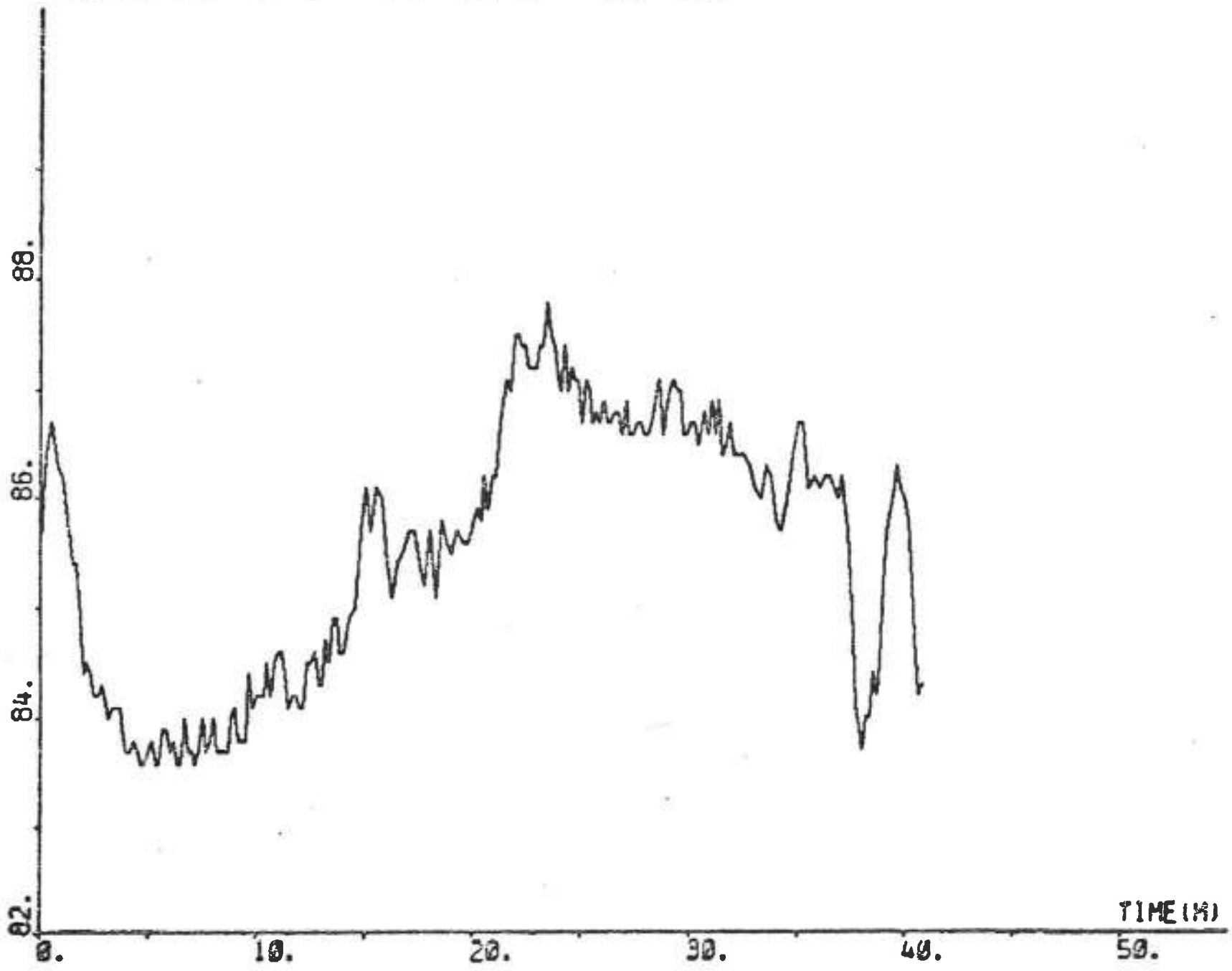
$a_1' + a_2' + a_3' = -25.636$

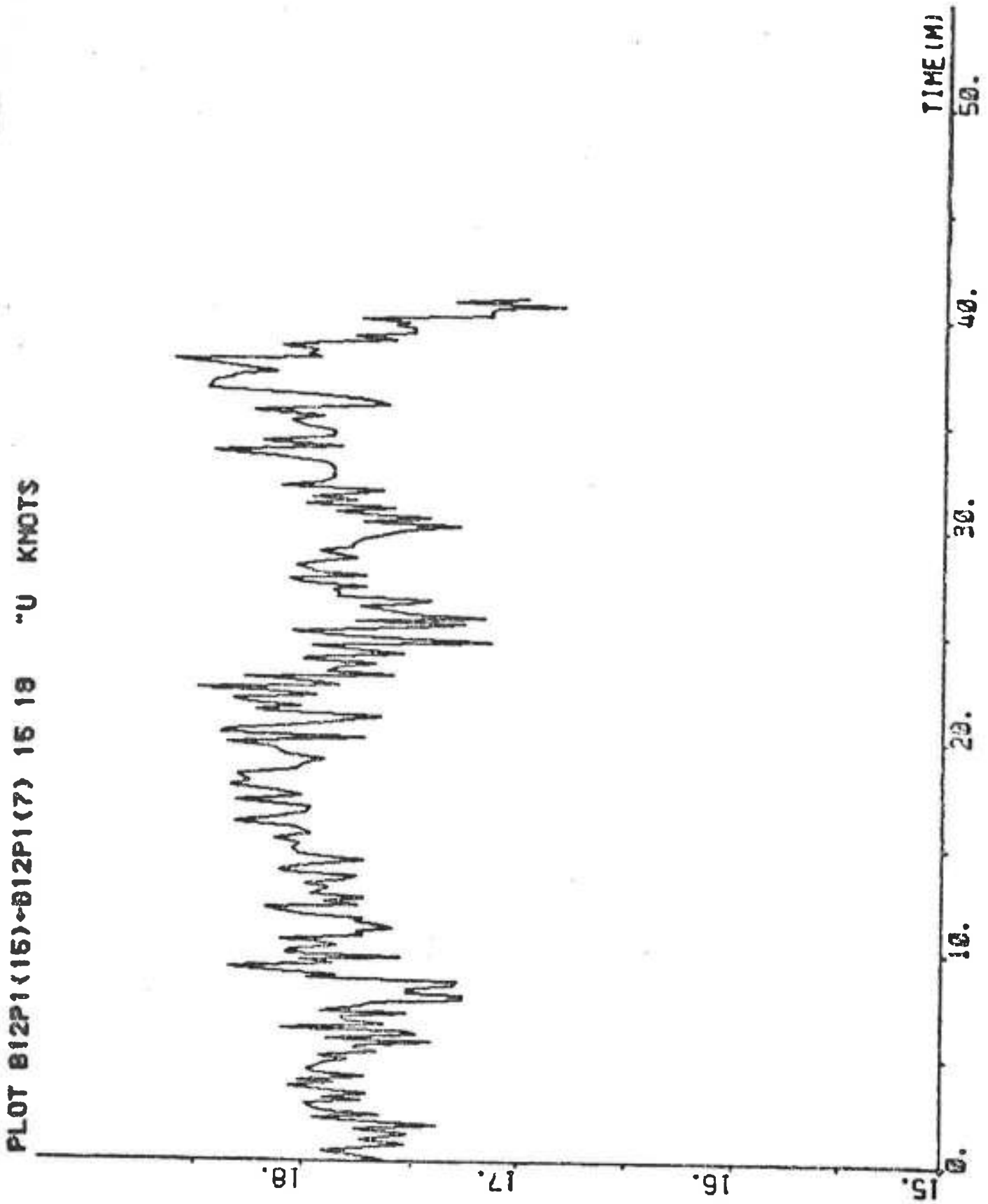

PLOT B12P1(15)-HP B12P1(1) ZERO -10 10 'DELCOC DEG
5.
0.
-5.
-10.
0.
10.
20.
30.
40.
50.
TIME(M)

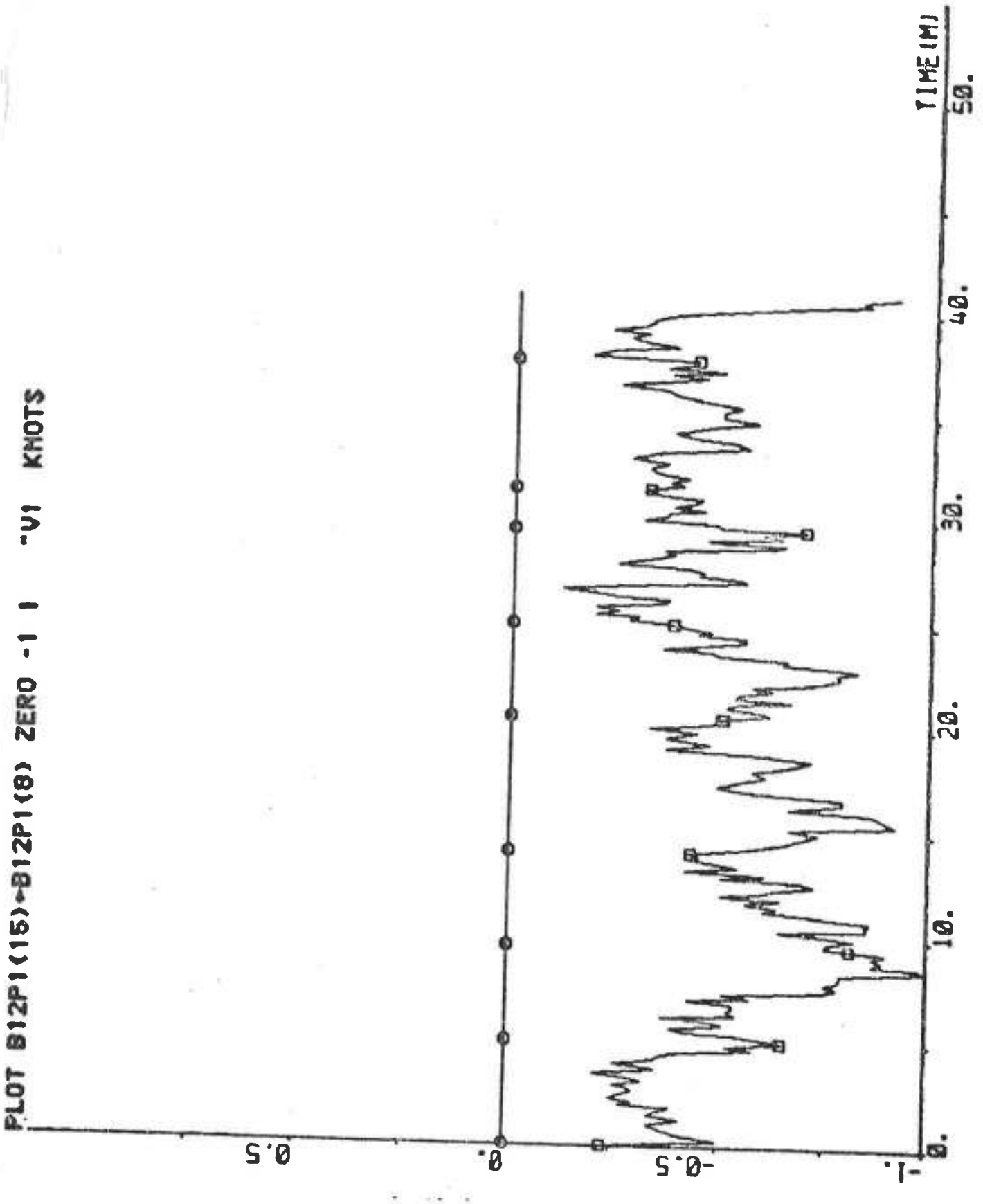

PLOT B12P1(15)-B12P1(3) ZERO -10 10 "DELTAS DEG
TIME(M)
0.
10.
20.
30.
40.
50.
-10.
-5.
0.
5.

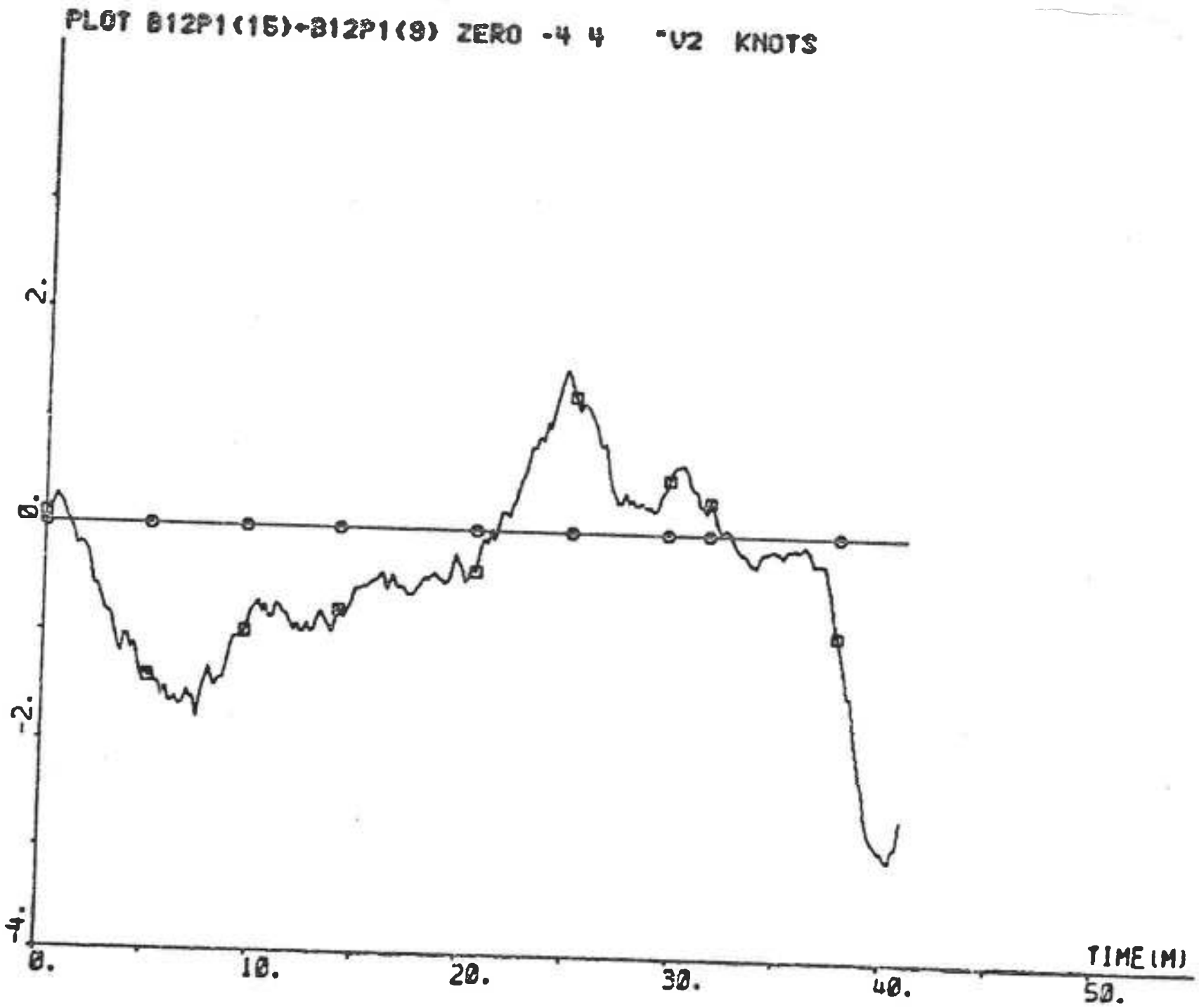

PLOT B12P1(15)-B12P1(4) ZERO -10 10 "DELTA DEC
5.
0.
-5.
-10.
0.
10.
20.
30.
40.
50.
TIME(M)

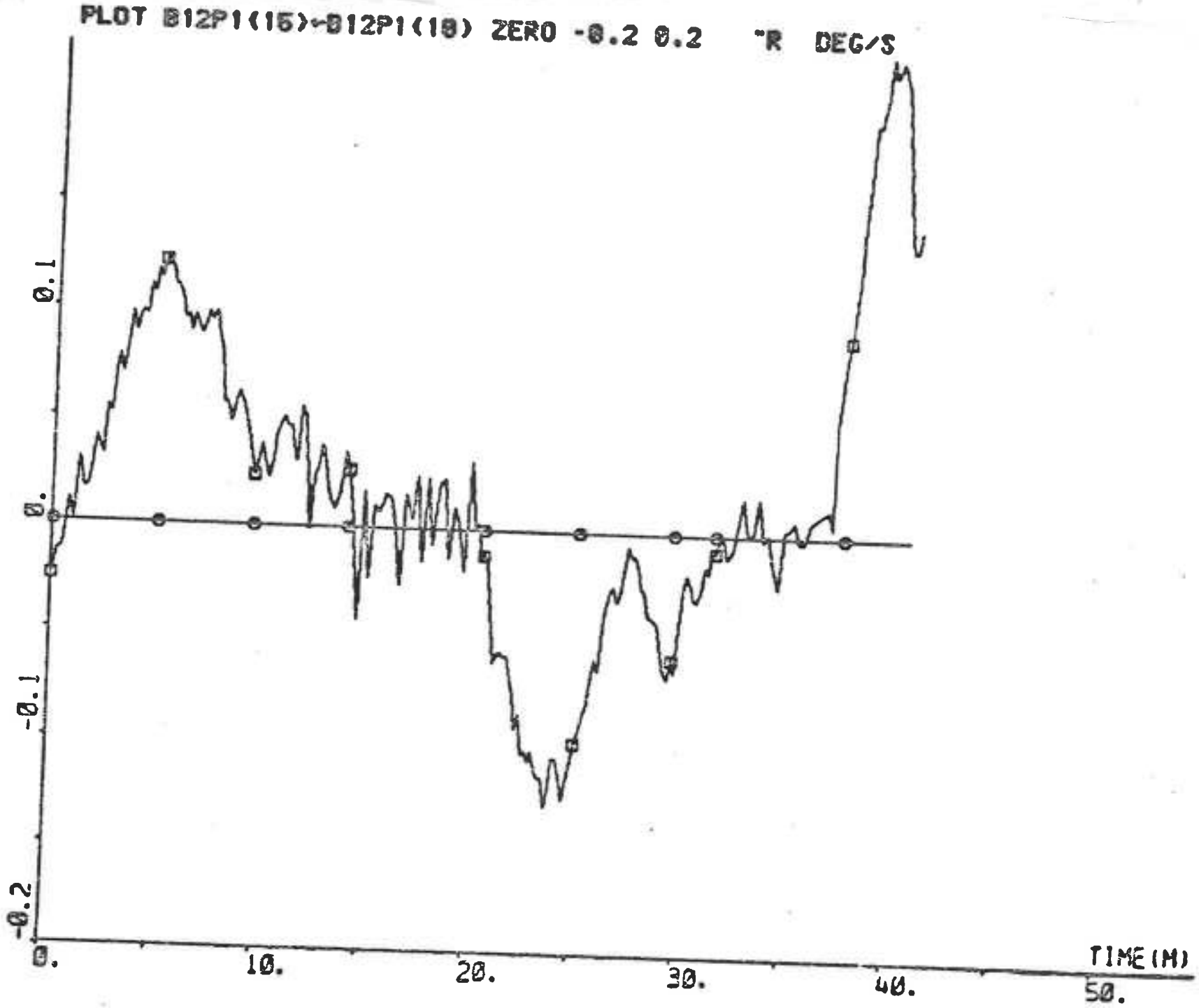

PLOT B12P1(15)-B12P1(5) ZERO -0.1 0.1 "PP DEG/S
TIME(M)
0.
10.
20.
30.
40.
50.
0.1
0.05
0.
-0.05

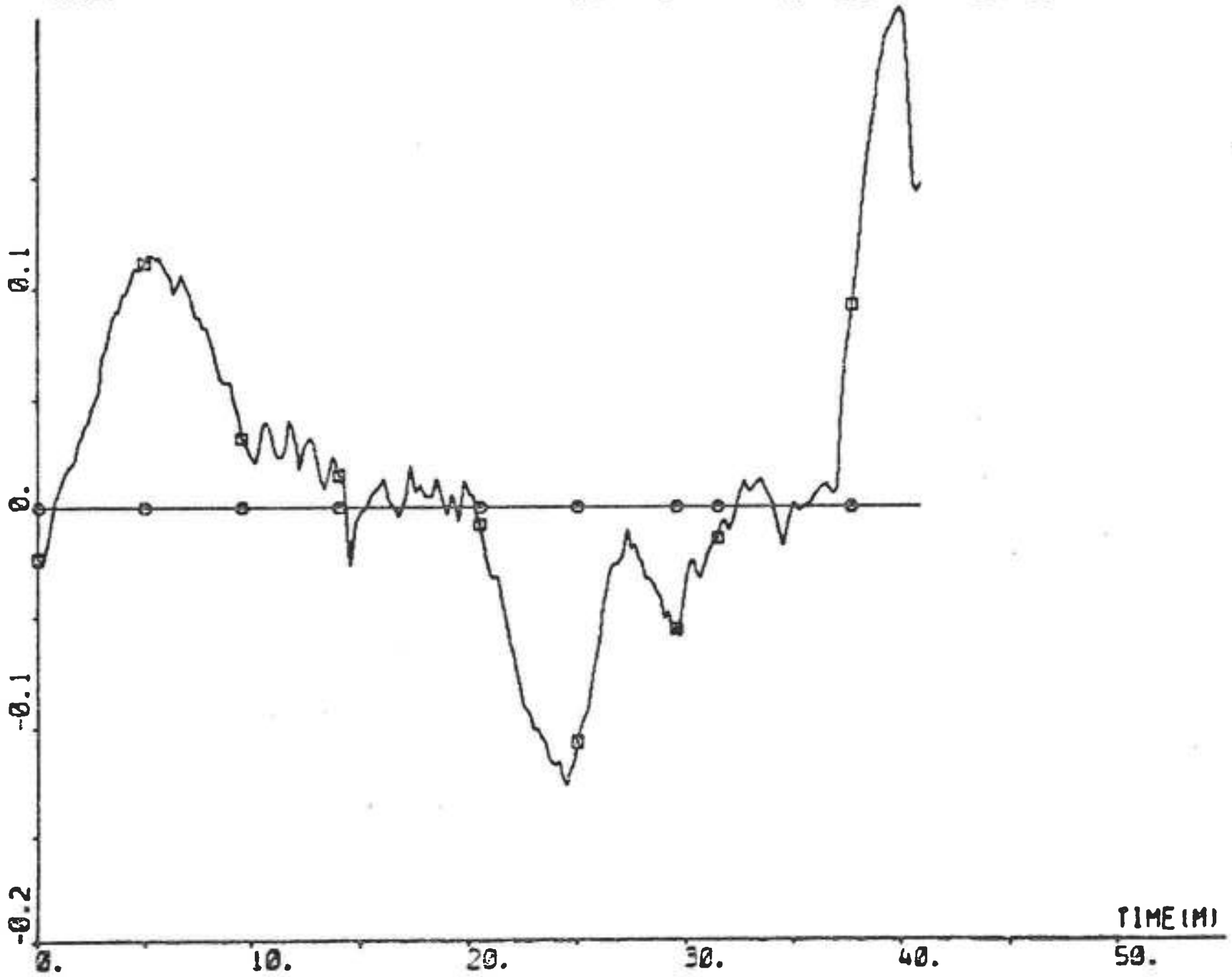

PLOT B12P1(15)-B12P1(8) 82 88 "RN RPM
88.
86.
84.
82.
0.
10.
20.
30.
40.
50.
TIME(M)

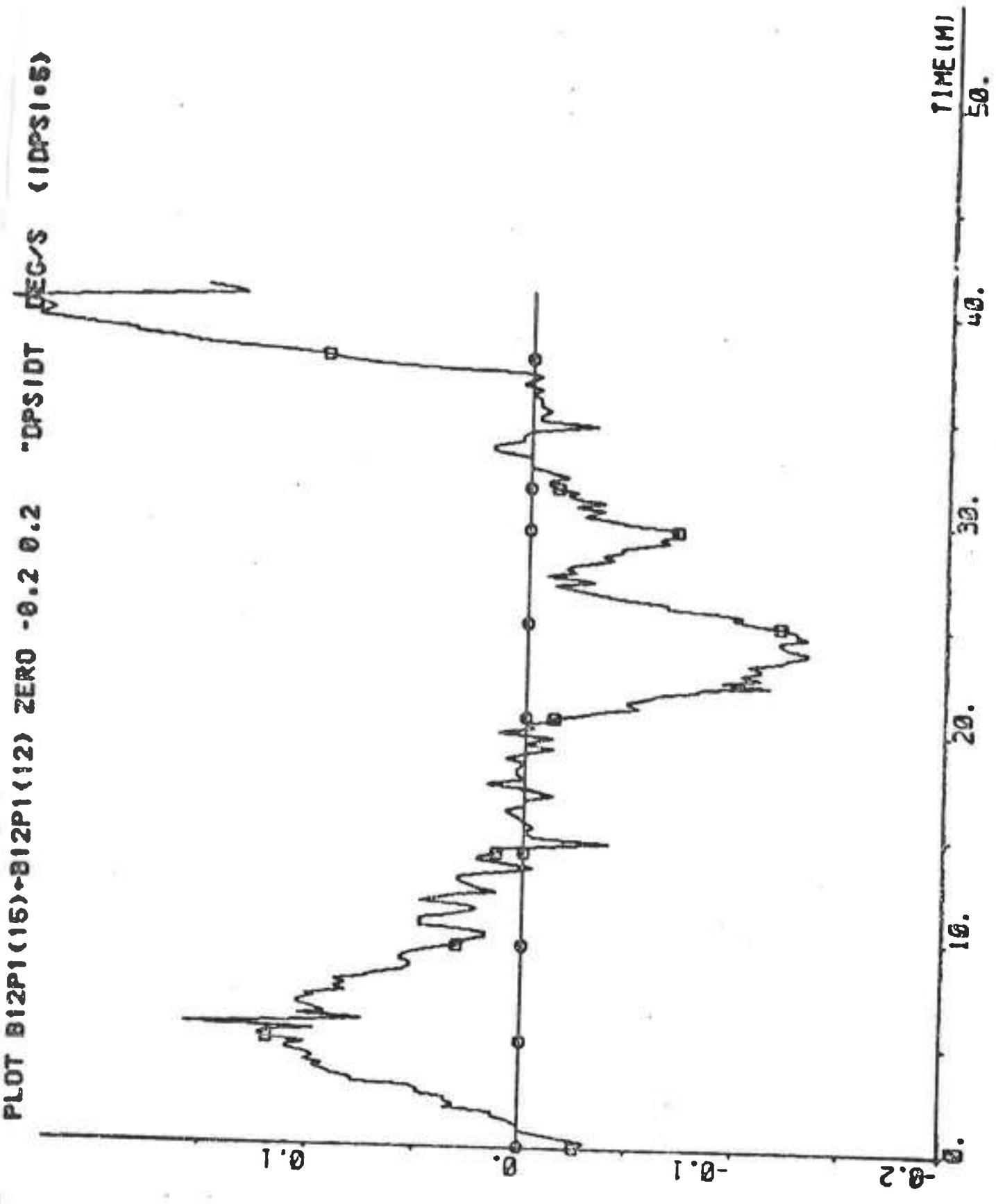

PLOT B12P1(15)-B12P1(7) 15 18 "U KNOTS
18.
17.
16.
15.
0.
10.
20.
30.
40.
50.
TIME(M)

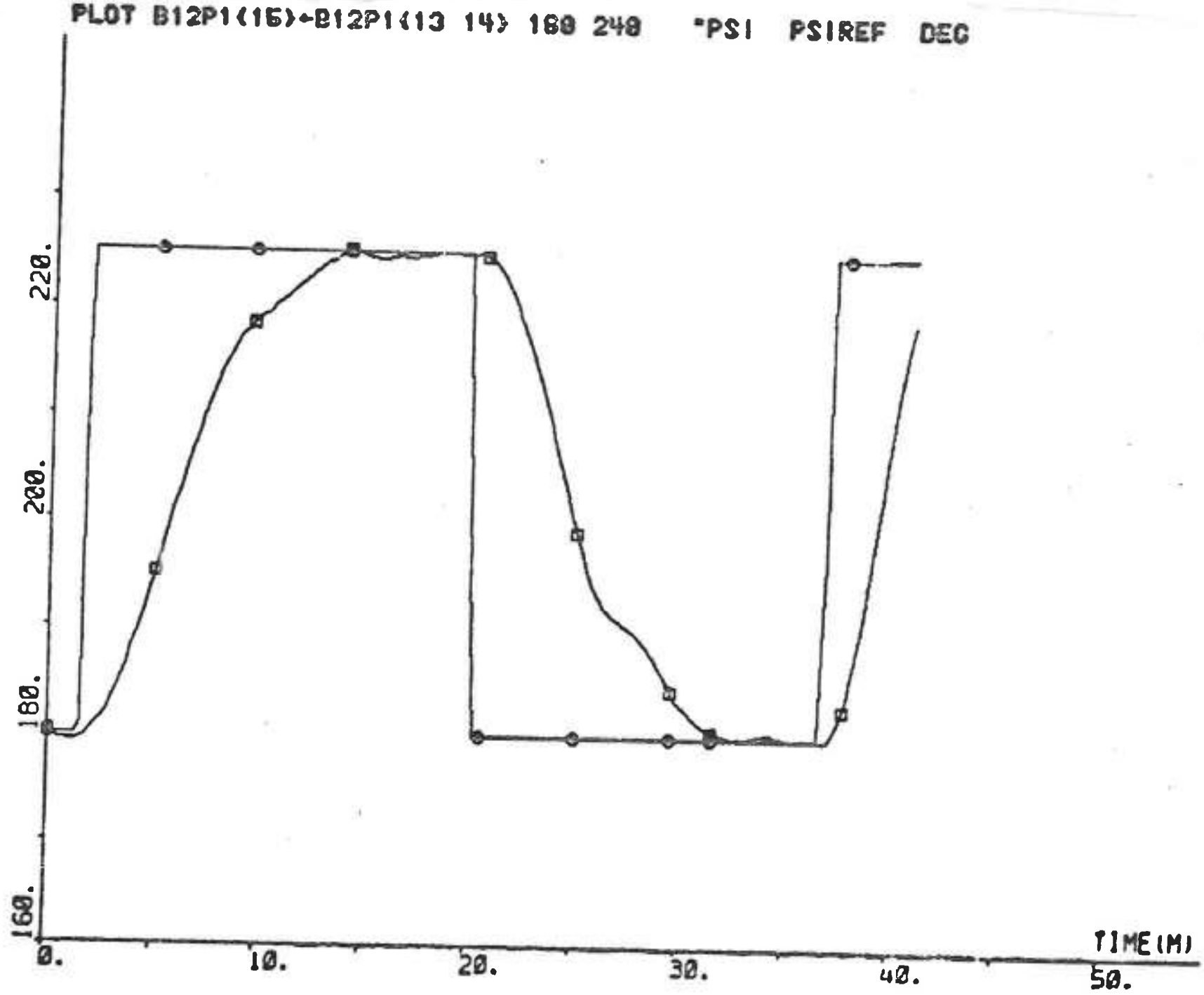

PLOT B12P1(16)-B12P1(8) ZERO -1 1 "V1 KNOTS
0.5
0.
-0.5
-1.
0.
10.
20.
30.
40.
50.
TIME(M)

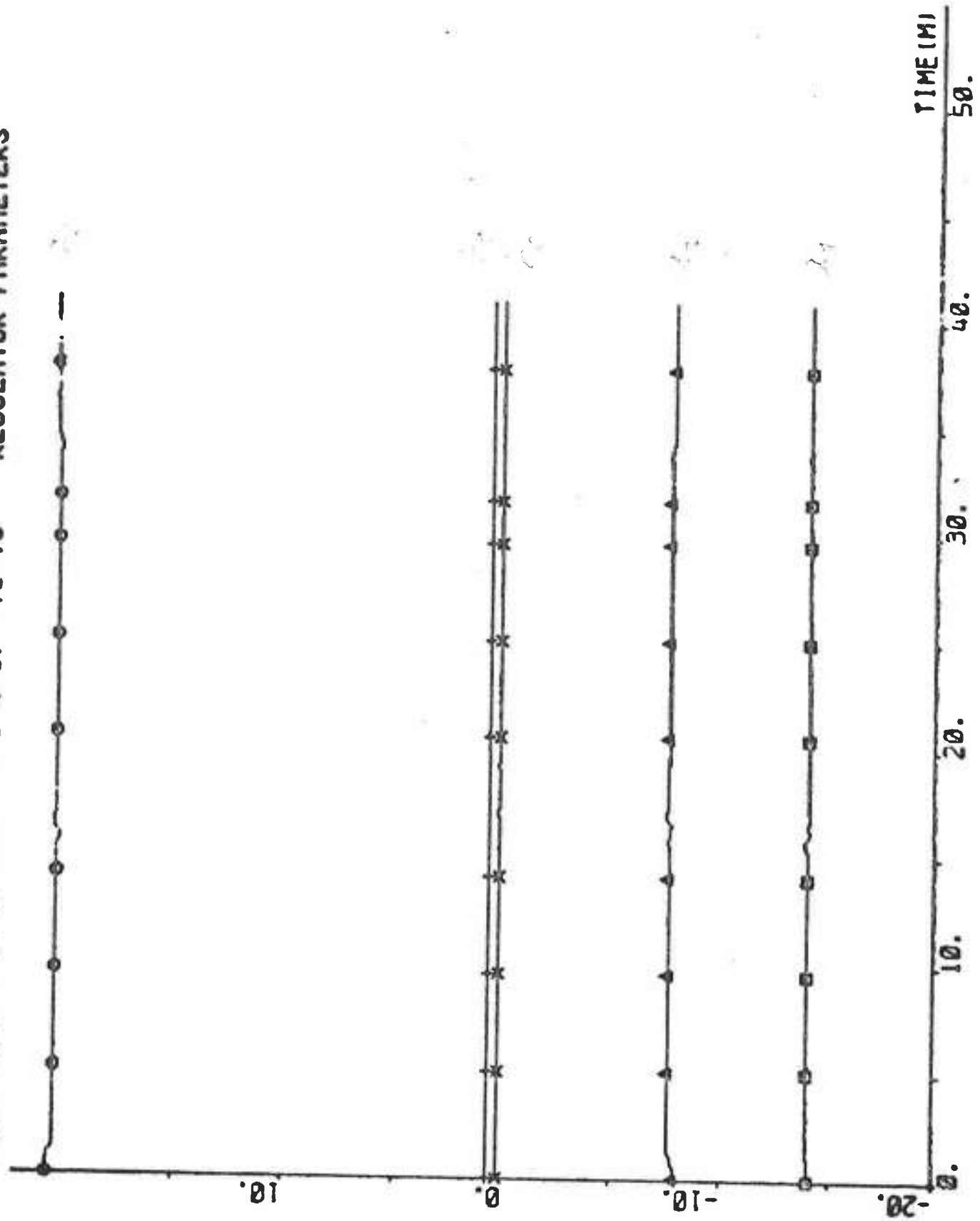

PLOT B12P1(15)-B12P1(9) ZERO -4 4 -V2 KNOTS
2.
0.
-2.
-4.
0.
10.
20.
30.
40.
50.
TIME(M)

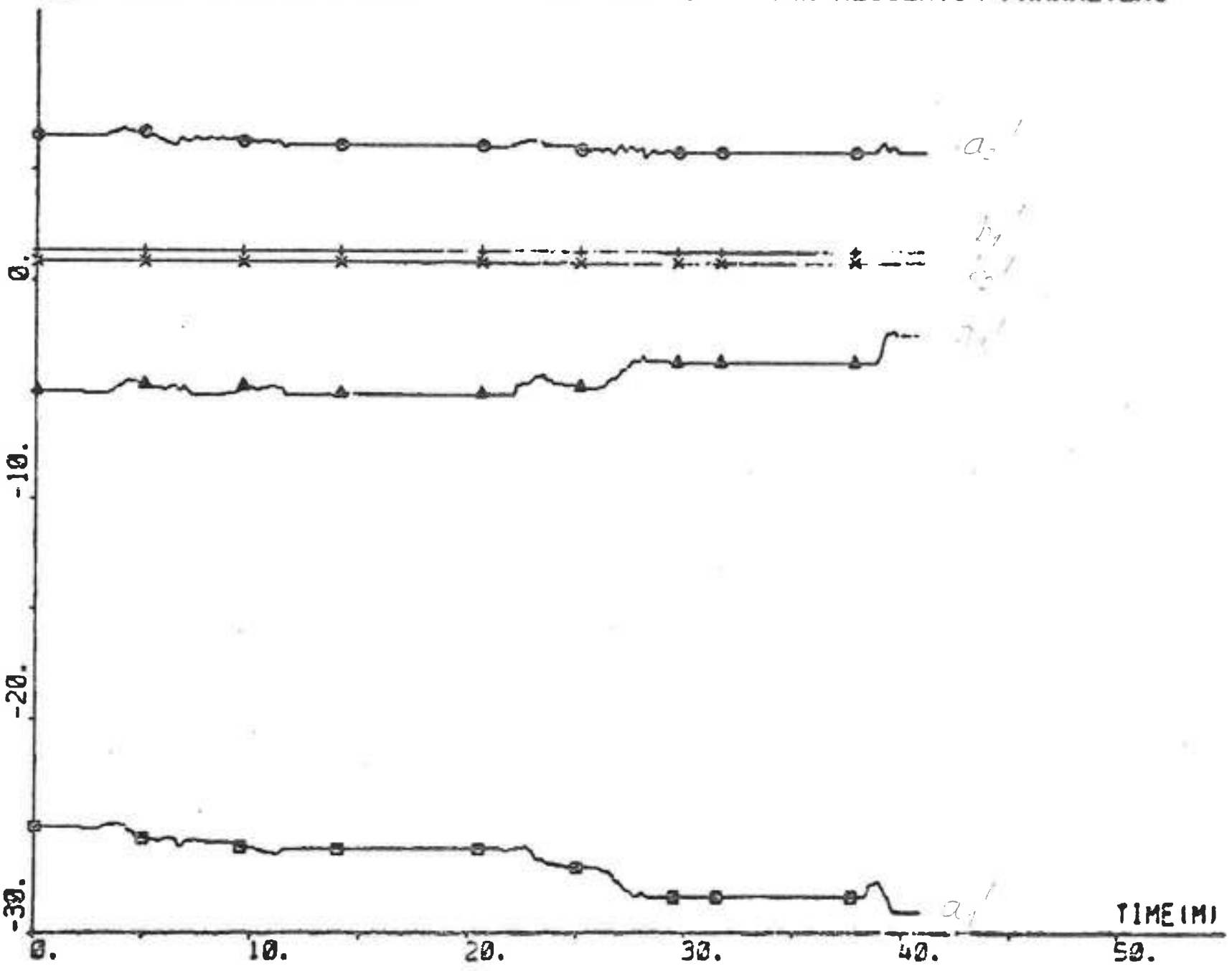

PLOT B12P1(15)-B12P1(18) ZERO -0.2 0.2 °R DEG/S
0.1
0.
-0.1
-0.2
0.
10.
20.
30.
40.
50.
TIME(M)

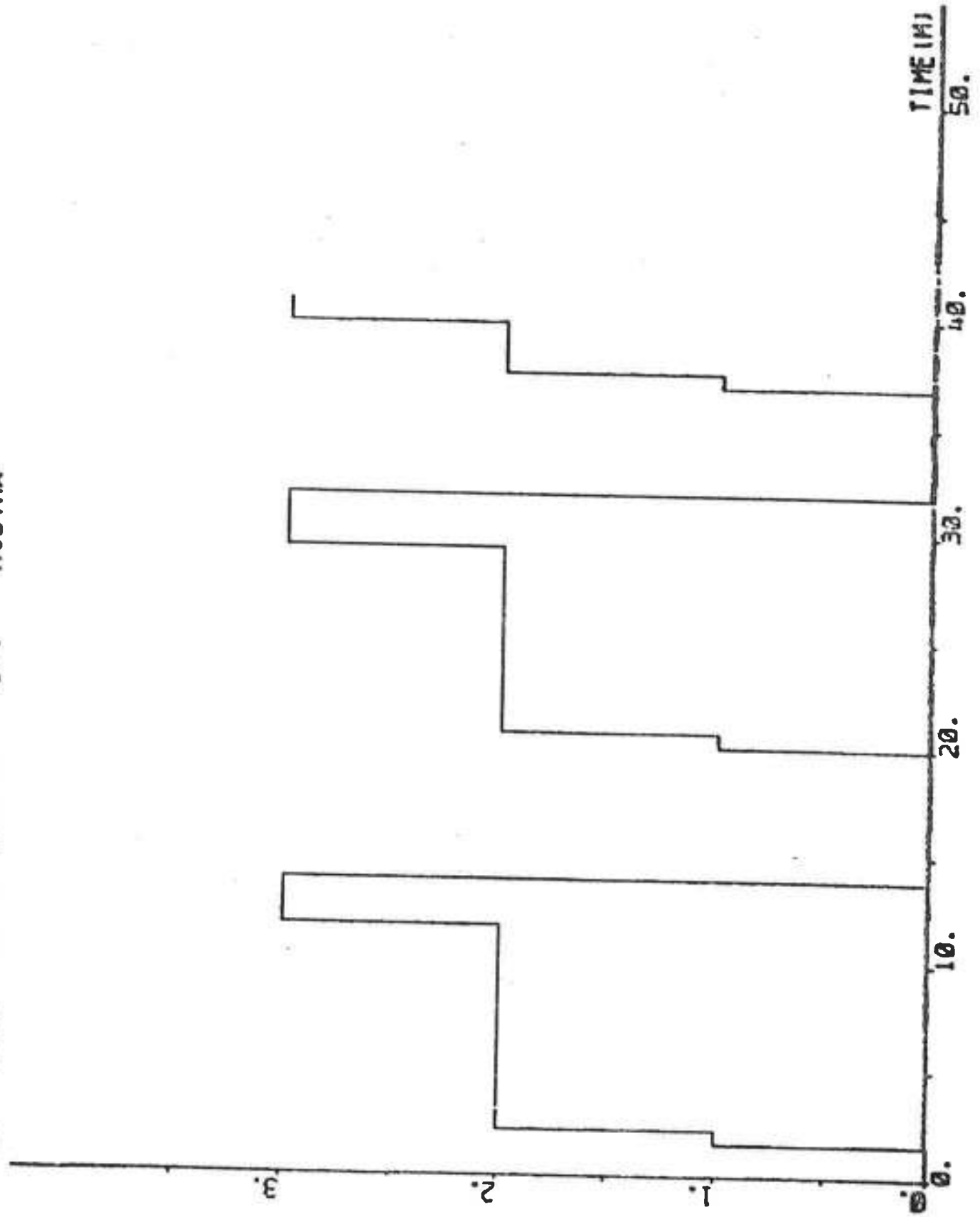

PLOT B12P1(15)-B12P1(11) ZERO -0.2 0.2 "AVR DEG/S (BR=0.2)
0.1
0.
-0.1
-0.2
0.
10.
20.
30.
40.
50.
TIME(M)


PLOT B12P1(15)-B12P1(12) ZERO -0.2 0.2 "DPSIDT DEG/S (IDPSI*5)
0.1
0.
-0.1
-0.2
0.
10.
20.
30.
40.
50.
TIME(M)


PLOT B12P1(15)-B12P1(13 14) 160 240 *PSI PSIREF DEC
220.
200.
180.
160.
0.
10.
20.
30.
40.
50.
TIME(M)


PLOT B12P1(15)-B12P2(1 2 3 4 6) -15 15 "REGULATOR PARAMETERS
TIME(M)
0.
10.
20.
30.
40.
50.
-20.
-10.
0.
10.


PLOT B12P1(15)-B12P2(6 7 8 9 10) -30 10 "YAW REGULATOR PARAMETERS
0.
-10.
-20.
-30.
0.
10.
20.
30.
40.
50.
TIME(M)


PLOT B12P1(15)-HP B12P2(11) 0 4 "HODYAW
TIME(H)
0.
10.
20.
30.
40.
50.
0.
1.
2.
3.

EXPERIMENT B13

Date	1974-10-18
Time	14.49
Duration	69 min
Position	S 13° 40' E 42° 02'
Water depth	deep
Forward draught	20.2 m
Aft draught	20.2 m
Wind direction	NE (5,6; see Appendix A)
Wind velocity	3 Beaufort (4-5.5 m/s, gentle breeze)
Wave height	1.5 m (sea from NE)
PSIREF	225°, 180°, 225°, 180°, 225°, 204°
RREF	0.07 deg/s (0-56 min), 0.21 deg/s (56-69 min)
Rudder limit	Not active
DELlM at termination	Unknown
Approximate mean value of AN	85.5 rpm
Approximate mean value of U	17.7 knots

Regulator structure

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

IREG = 15 RL = 0.99

Final values

$$\begin{bmatrix} a_1 \\ a_2 \\ a_3 \\ b_1 \\ b_2 \end{bmatrix} = \begin{bmatrix} -14.436 \\ 21.611 \\ -8.203 \\ 0.661 \\ 0.215 \end{bmatrix}$$

P unknown

$$a_1 + a_2 + a_3 = -1.028$$

Yaw regulator structure

NAY = 3	NBY = 2	KY = 2	
IREGY = 10	RLY = 0.95	IRR = 3	IDPSI = 5
AK1V = 40	AK2V = 1.4	AK3V = 120	
C1V = 10	C2V = 80		
EPS1V = 0.02	EPS2V = 0.1		
PSISV = 0.15	PSISSV = 1.5	PSIMAV = 0.6	
I1MV = 40	I2MV = 300	I3MV = 150	

Initial yaw regulator values for the yaw at 1 min.

$$\begin{bmatrix} a'_1 \\ a'_2 \\ a'_3 \\ b'_1 \\ b'_2 \end{bmatrix} = \begin{bmatrix} -35.00 \\ 5.91 \\ -3.67 \\ 1.30 \\ 0.81 \end{bmatrix} \qquad PY = \begin{bmatrix} 500 & & & & \\ 0 & 500 & & & \\ 0 & 0 & 500 & & \\ 0 & 0 & 0 & 1 & \\ 0 & 0 & 0 & 0 & 1 \end{bmatrix}$$

$a'_1 + a'_2 + a'_3 = -32.76$

Yaw regulator values after the yaw at 1 min.

$$\begin{bmatrix} a'_1 \\ a'_2 \\ a'_3 \\ b'_1 \\ b'_2 \end{bmatrix} = \begin{bmatrix} -36.191 \\ 5.915 \\ -2.606 \\ 1.306 \\ 0.803 \end{bmatrix} \qquad PY = \begin{bmatrix} 478.510 & & & & \\ -490.041 & 1360.512 & & & \\ 38.858 & -661.526 & 565.202 & & \\ 0.993 & -13.705 & 5.772 & 0.410 & \\ -0.395 & -7.214 & 1.504 & 0.273 & 0.318 \end{bmatrix}$$

$a'_1 + a'_2 + a'_3 = -32.882$

Initial yaw regulator values for the yaw at 16 min.

$$\begin{bmatrix} a_1' \\ a_2' \\ a_3' \\ b_1' \\ b_2' \end{bmatrix} = \begin{bmatrix} -38.00 \\ 5.91 \\ -2.61 \\ 1.30 \\ 0.81 \end{bmatrix} \qquad PY = \begin{bmatrix} 500 & & & & \\ 0 & 500 & & & \\ 0 & 0 & 500 & & \\ 0 & 0 & 0 & 1 & \\ 0 & 0 & 0 & 0 & 1 \end{bmatrix}$$

$a_1' + a_2' + a_3' = -34.70$

Yaw regulator values after the yaw at 16 min.

$$\begin{bmatrix} a_1' \\ a_2' \\ a_3' \\ b_1' \\ b_2' \end{bmatrix} = \begin{bmatrix} -38.965 \\ 5.536 \\ -1.518 \\ 1.310 \\ 0.811 \end{bmatrix} \qquad PY \text{ unknown}$$

$a_1' + a_2' + a_3' = -34.947$

Initial yaw regulator values for the yaw at 29 min.

$$\begin{bmatrix} a_1' \\ a_2' \\ a_3' \\ b_1' \\ b_2' \end{bmatrix} = \begin{bmatrix} -40.00 \\ 5.54 \\ -1.52 \\ 1.30 \\ 0.81 \end{bmatrix} \qquad PY = \begin{bmatrix} 500 & & & & \\ 0 & 500 & & & \\ 0 & 0 & 500 & & \\ 0 & 0 & 0 & 1 & \\ 0 & 0 & 0 & 0 & 1 \end{bmatrix}$$

$a_1' + a_2' + a_3' = -35.98$

Yaw regulator values after the yaw at 29 min.

$$\begin{bmatrix} a_1' \\ a_2' \\ a_3' \\ b_1' \\ b_2' \end{bmatrix} = \begin{bmatrix} -40.869 \\ 5.545 \\ -1.100 \\ 1.306 \\ 0.806 \end{bmatrix} \qquad PY = \begin{bmatrix} 362.657 & & & & \\ -334.834 & 1081.050 & & & \\ -1.341 & -539.284 & 473.293 & & \\ 0.446 & -11.820 & 5.755 & 0.307 & \\ -0.199 & -6.807 & 2.226 & 0.203 & 0.222 \end{bmatrix}$$

$a_1' + a_2' + a_3' = -36.424$

Initial yaw regulator values for the yaw at 43 min.

$$\begin{bmatrix} a_1' \\ a_2' \\ a_3' \\ b_1' \\ b_2' \end{bmatrix} = \begin{bmatrix} -40.87 \\ 5.54 \\ -1.10 \\ 1.30 \\ 0.81 \end{bmatrix} \qquad PY = \begin{bmatrix} 500 & & & & \\ 0 & 500 & & & \\ 0 & 0 & 500 & & \\ 0 & 0 & 0 & 1 & \\ 0 & 0 & 0 & 0 & 1 \end{bmatrix}$$

$a_1' + a_2' + a_3' = -36.43$

Yaw regulator values after the yaw at 43 min.

$$\begin{bmatrix} a_1' \\ a_2' \\ a_3' \\ b_1' \\ b_2' \end{bmatrix} = \begin{bmatrix} -41.589 \\ 5.488 \\ -0.531 \\ 1.308 \\ 0.814 \end{bmatrix}$$

PY unknown

$a_1' + a_2' + a_3' = -36.632$

Initial yaw regulator values for the yaw at 57 min.

$$\begin{bmatrix} a_1' \\ a_2' \\ a_3' \\ b_1' \\ b_2' \end{bmatrix} = \begin{bmatrix} -41.60 \\ 5.49 \\ -0.53 \\ 1.30 \\ 0.81 \end{bmatrix} \qquad PY = \begin{bmatrix} 500 & & & & \\ 0 & 500 & & & \\ 0 & 0 & 500 & & \\ 0 & 0 & 0 & 1 & \\ 0 & 0 & 0 & 0 & 1 \end{bmatrix}$$

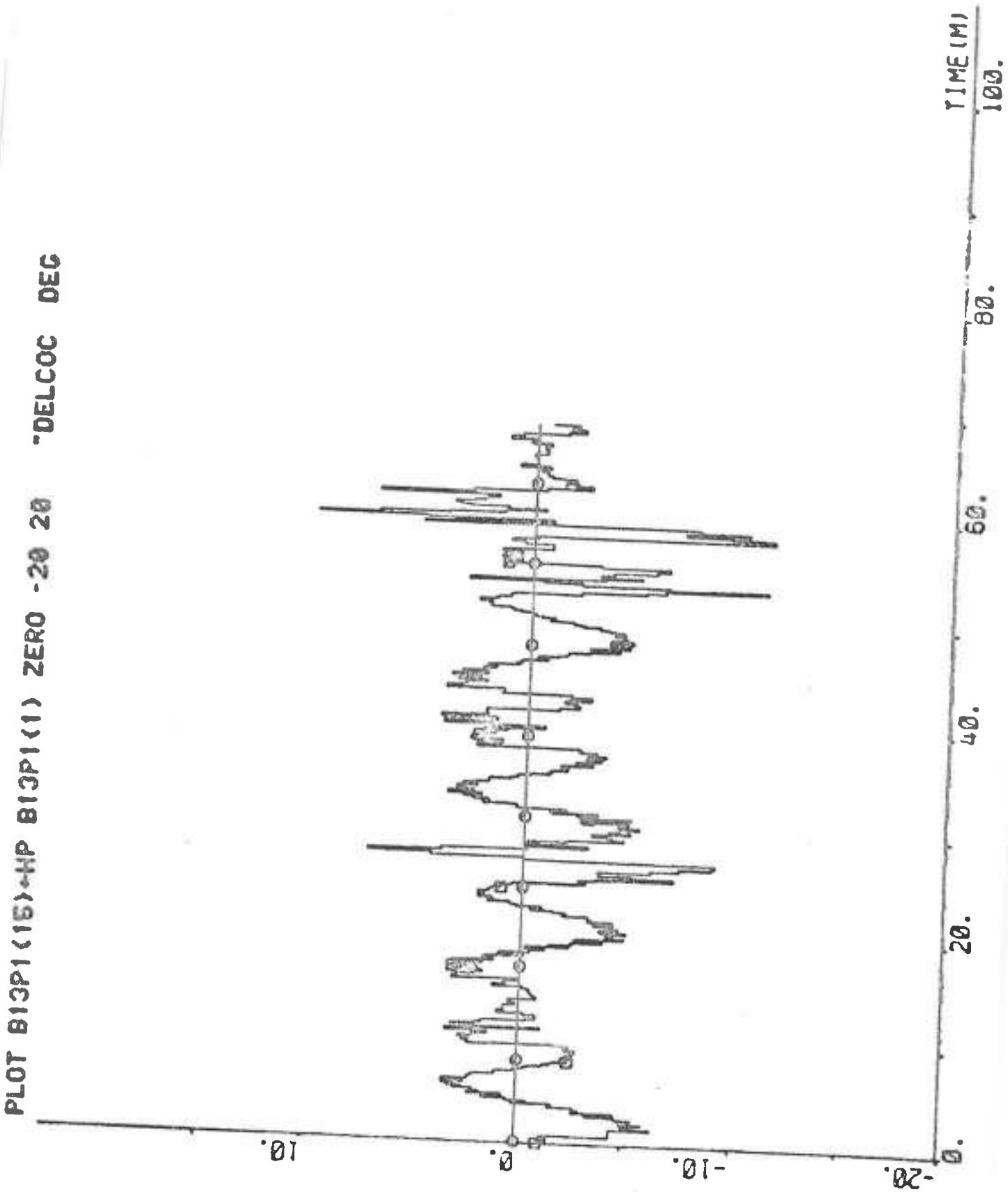
$a_1' + a_2' + a_3' = -36.64$

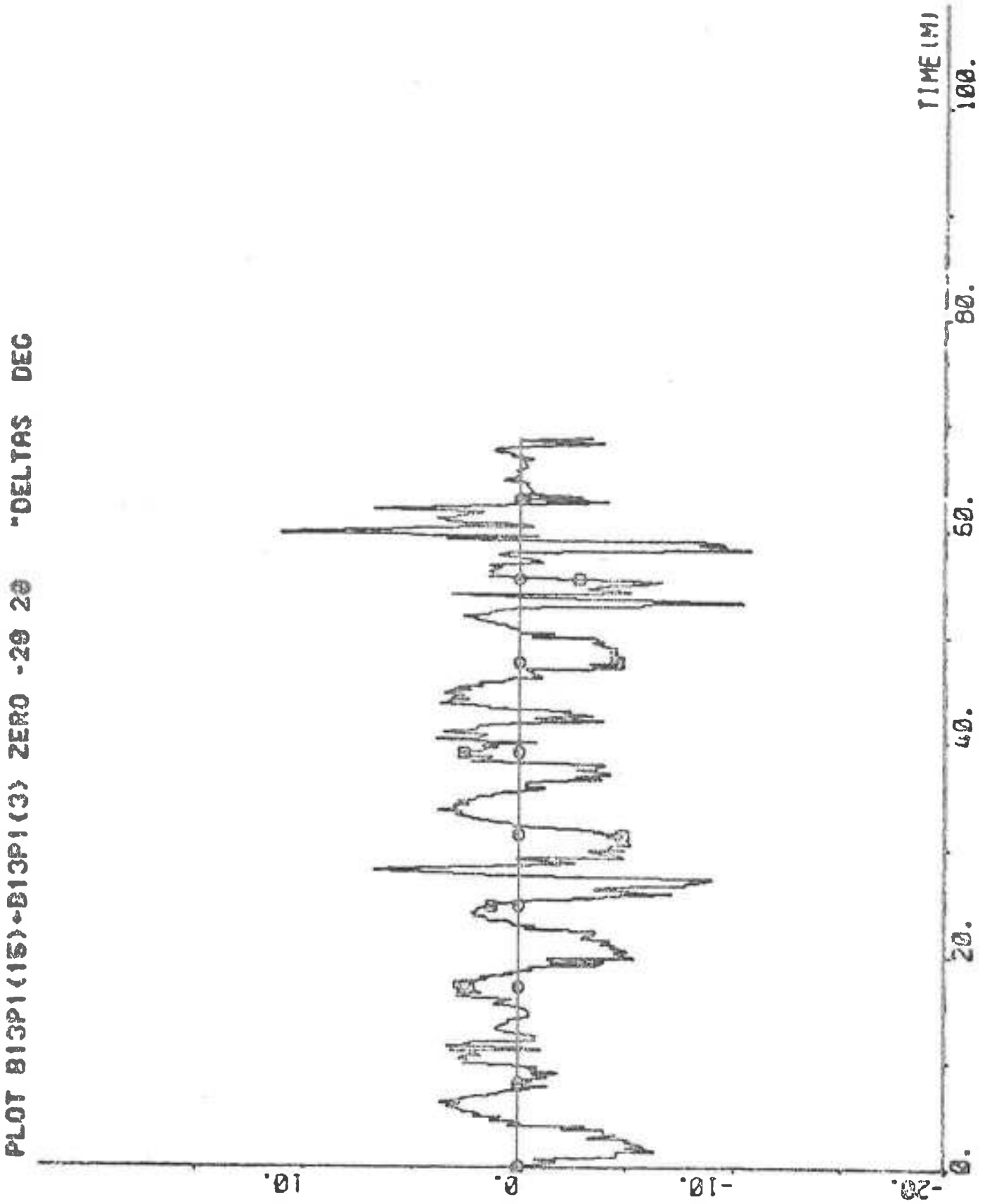
Yaw regulator values after the yaw at 57 min.

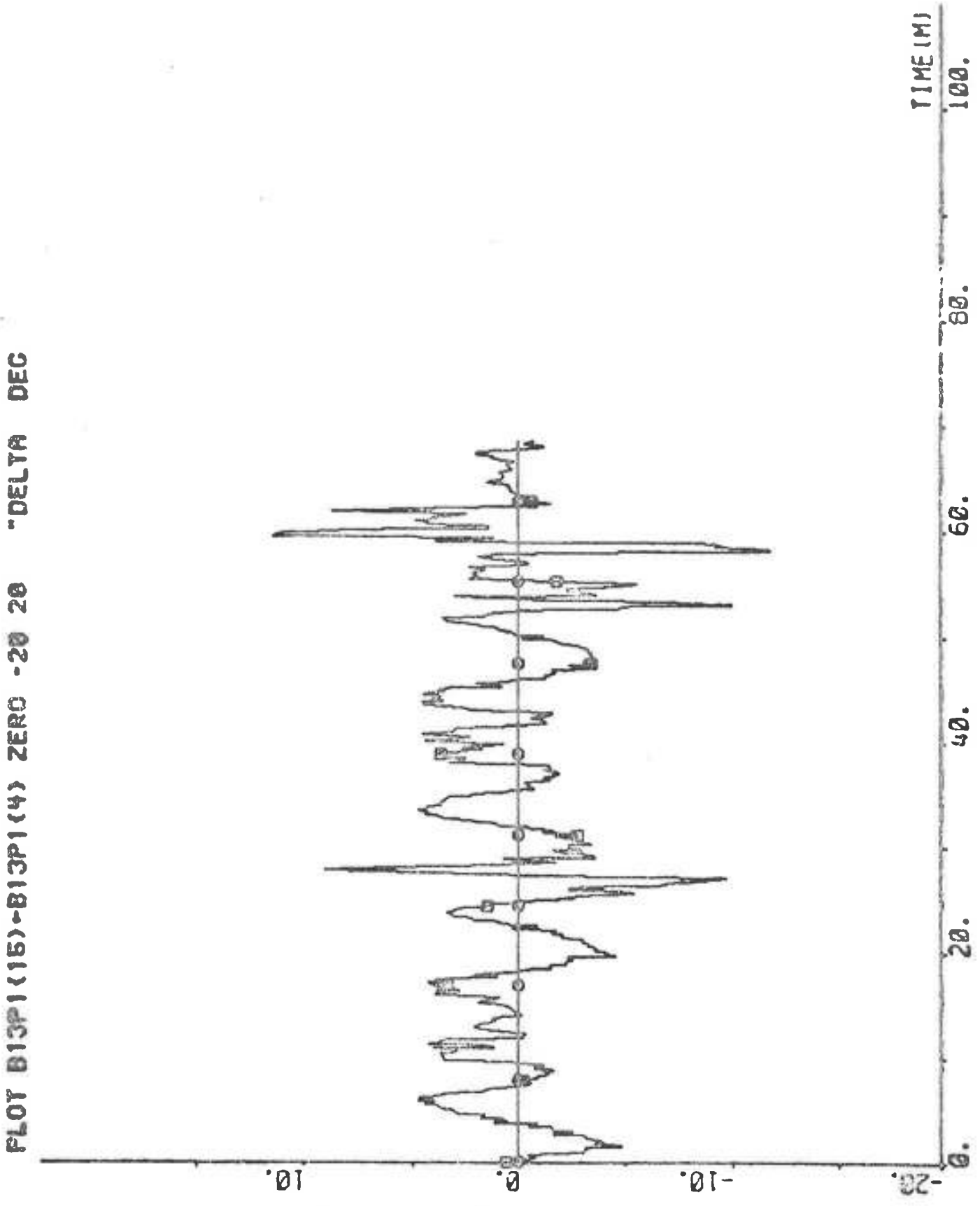
$$\begin{bmatrix} a_1' \\ a_2' \\ a_3' \\ b_1' \\ b_2' \end{bmatrix} = \begin{bmatrix} -41.60 \\ 5.49 \\ -0.53 \\ 1.30 \\ 0.81 \end{bmatrix}$$

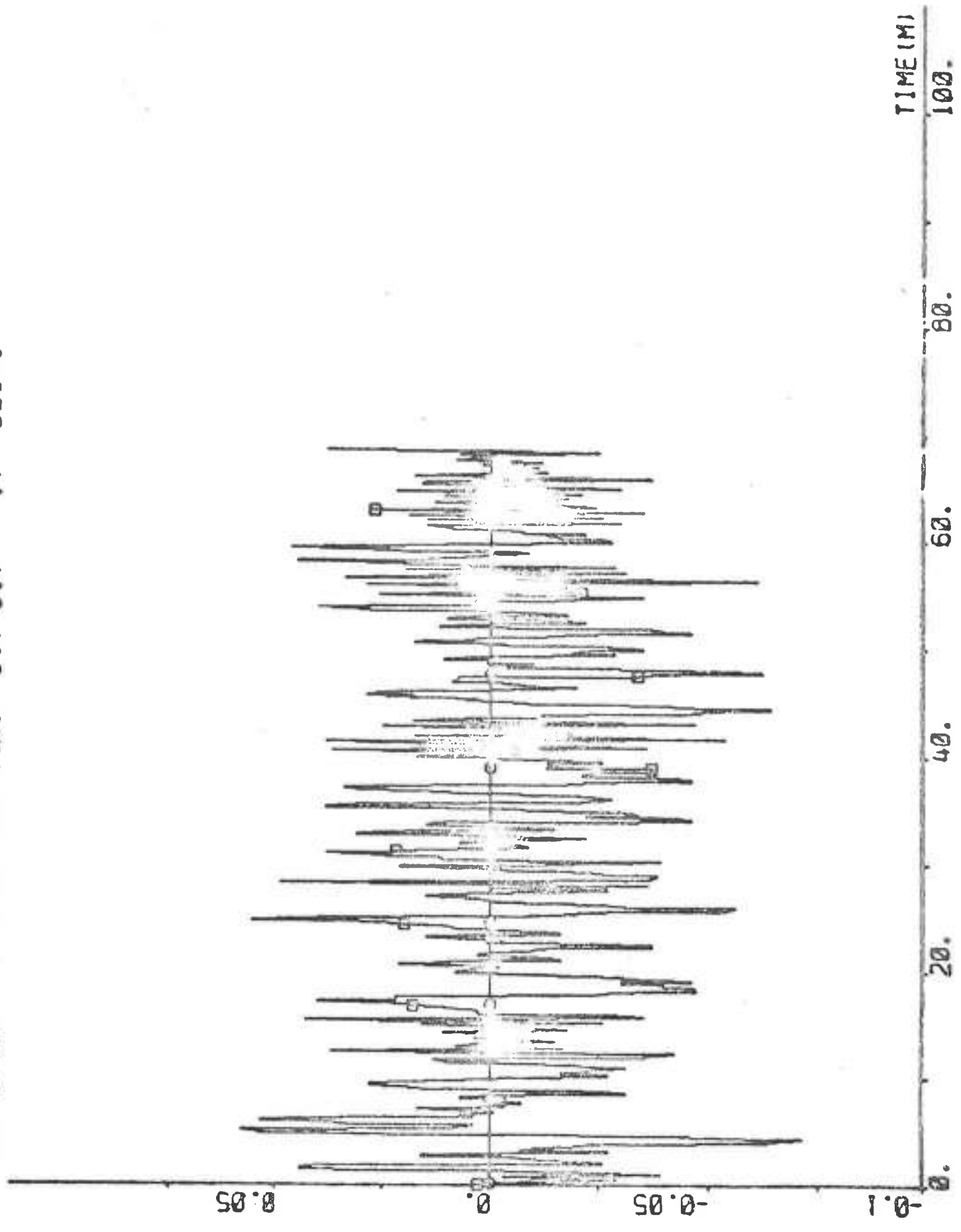
PY unknown

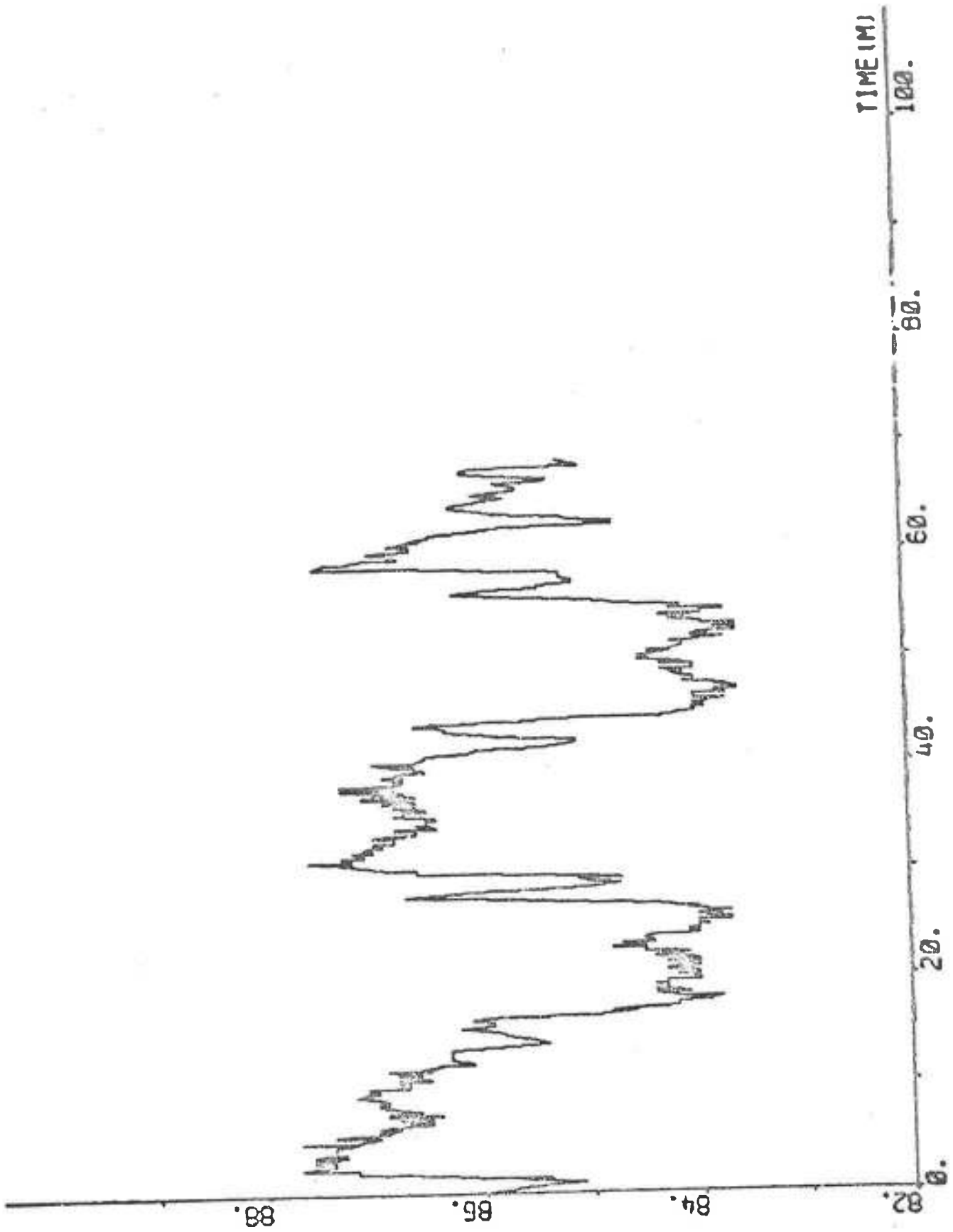
$a_1' + a_2' + a_3' = -36.64$

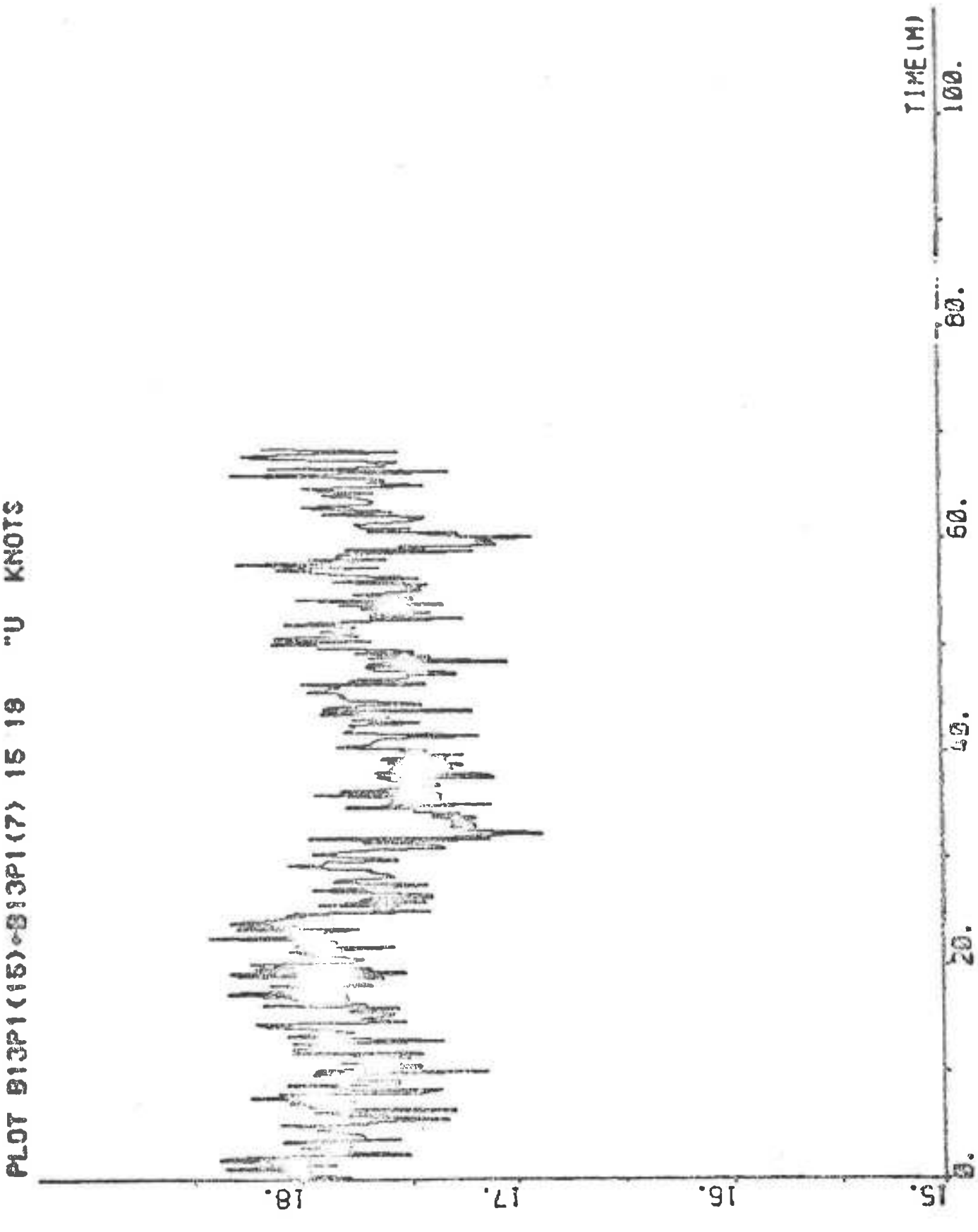

PLOT B13P1(15)-HP B13P1(1) ZERO -20 20 "DELCOC DEG
TIME(M)
0.
20.
40.
60.
80.
100.
-20.
-10.
0.
10.

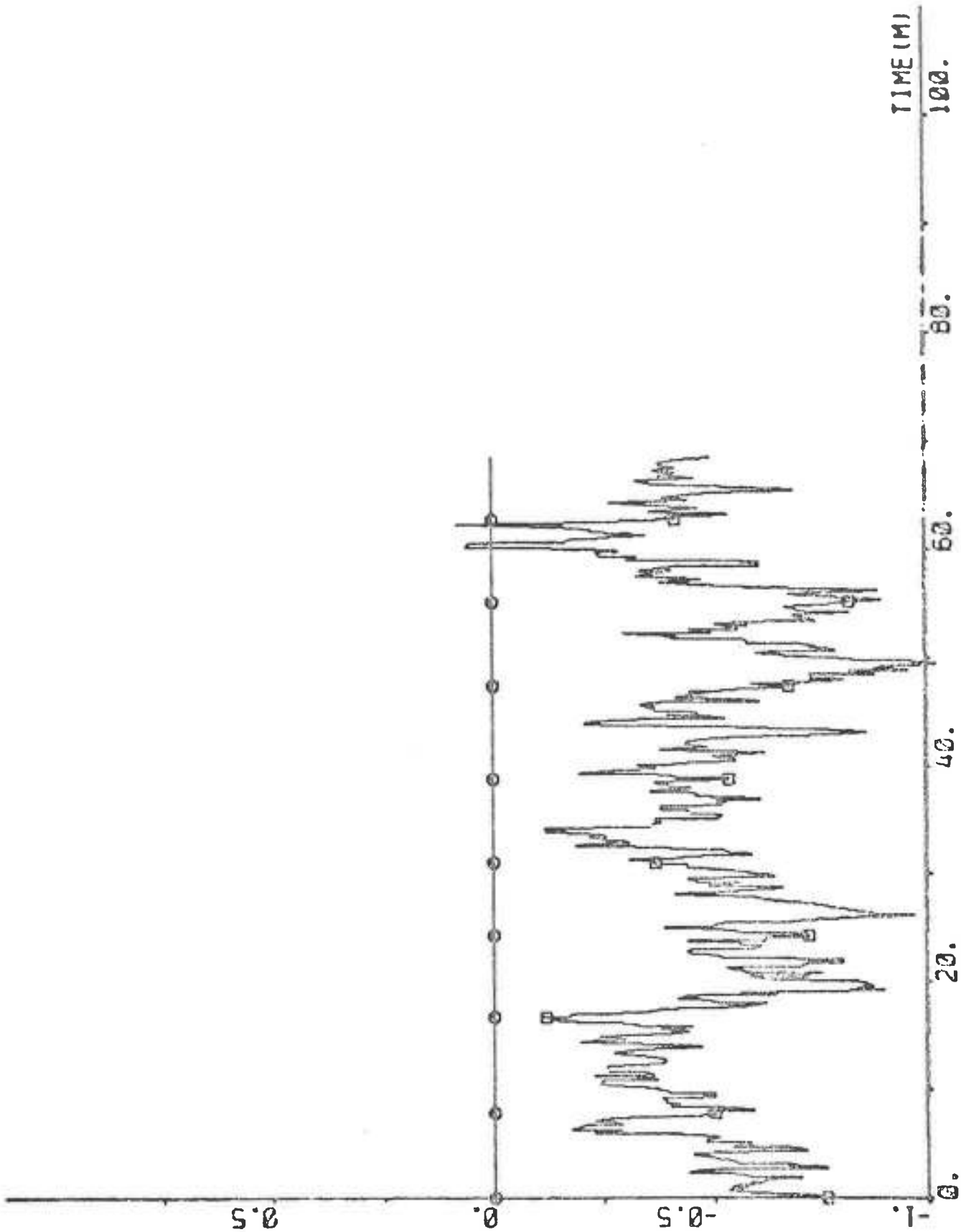

PLOT B13P1(15)-B13P1(3) ZERO -20 20 *DELTAS DEG
TIME(M)
0.
20.
40.
60.
80.
100.
-20.
-10.
0.
10.

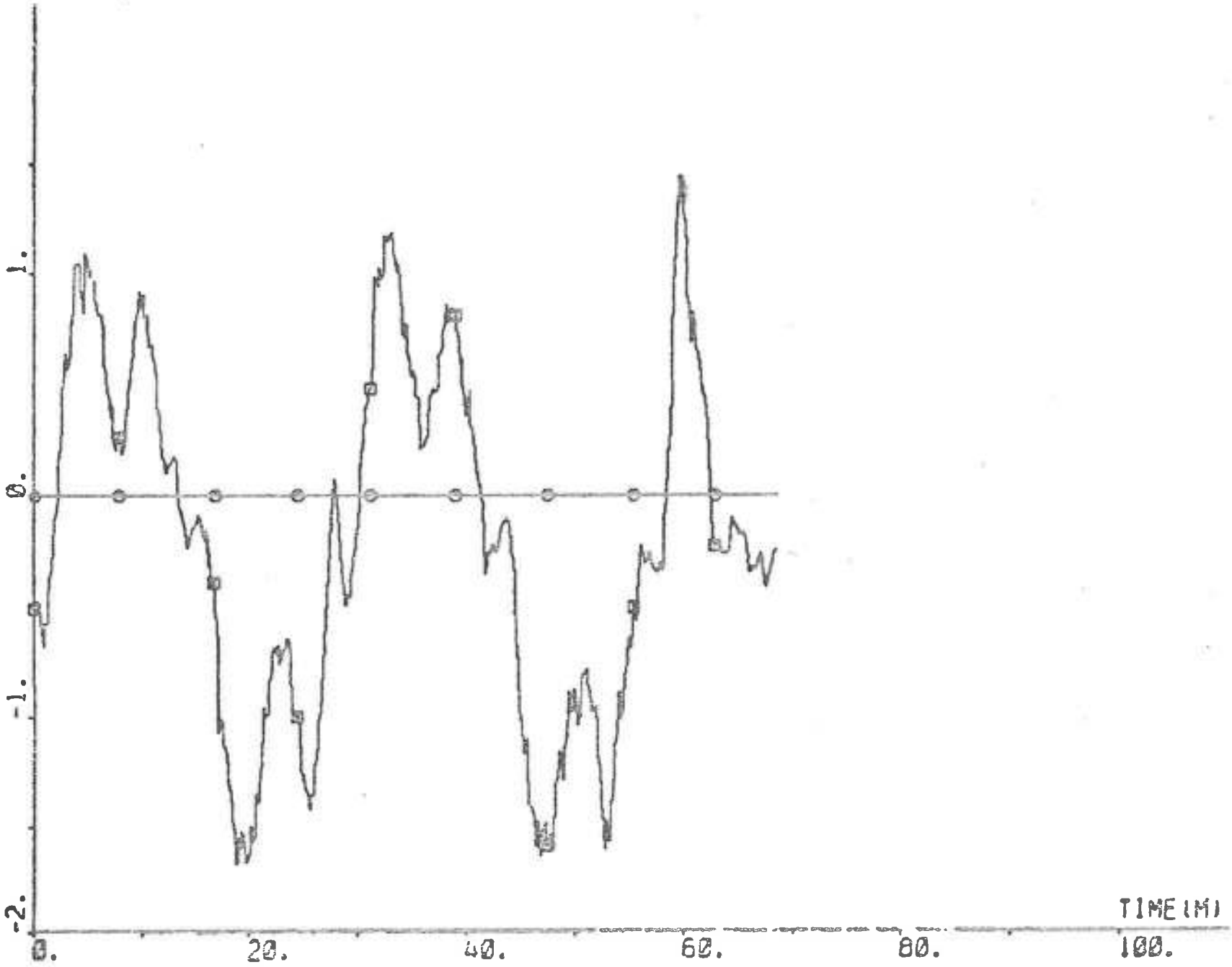

PLOT B13P1(15)-B13P1(4) ZERO -20 20 "DELTA DEC
TIME(MI)
0.
20.
40.
60.
80.
100.
-20.
-10.
0.
10.

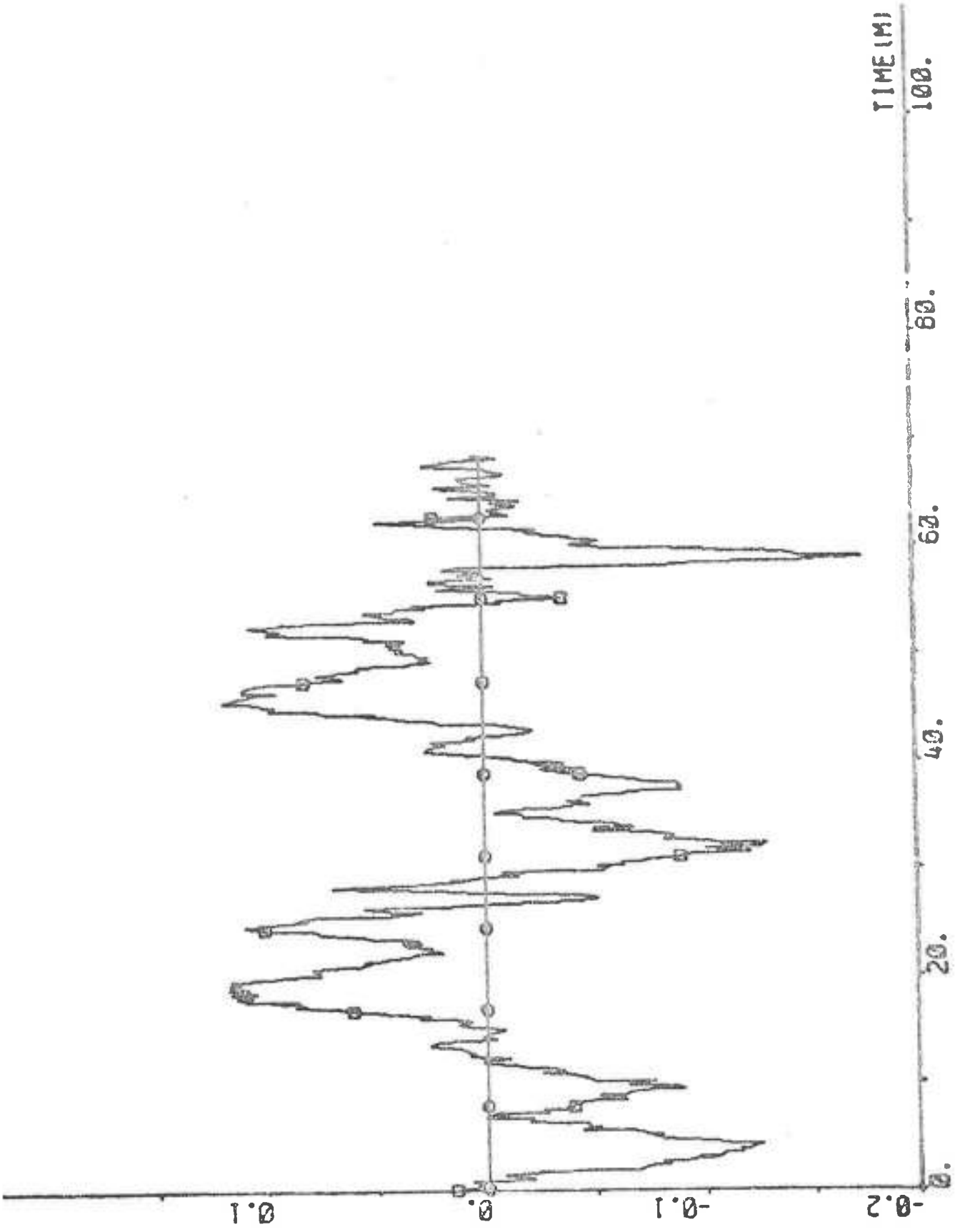

PLOT B13P1(15)-B13P1(6) ZERO -0.1 0.1 "PP DEG/S
TIME(M)
0.
20.
40.
60.
80.
100.
-0.1
-0.05
0.
0.05

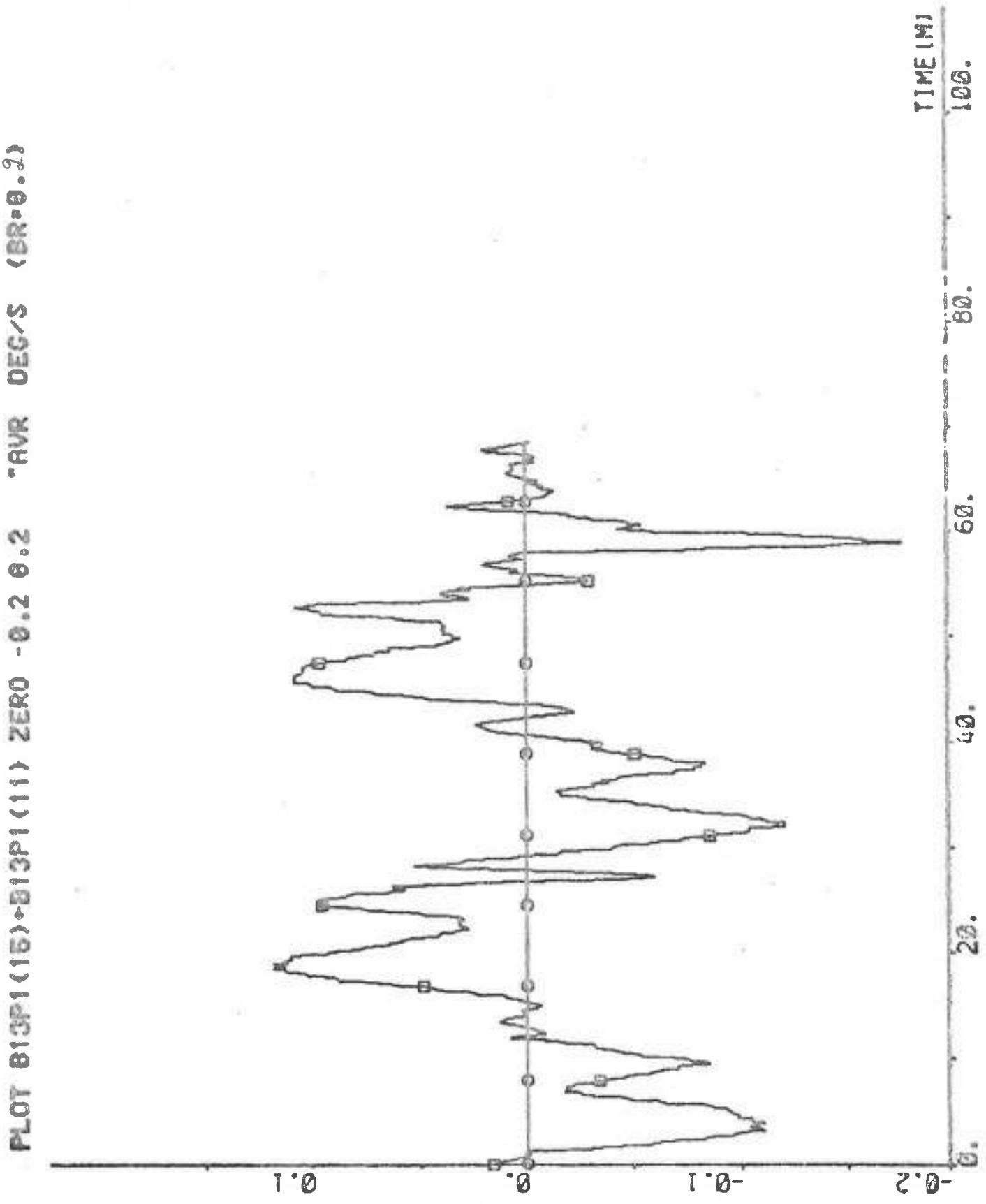

PLOT B13P1(15)-B13P1(8) 82 88 'AN RPM
88.
86.
84.
82.
0.
20.
40.
60.
80.
100.
TIME(M)

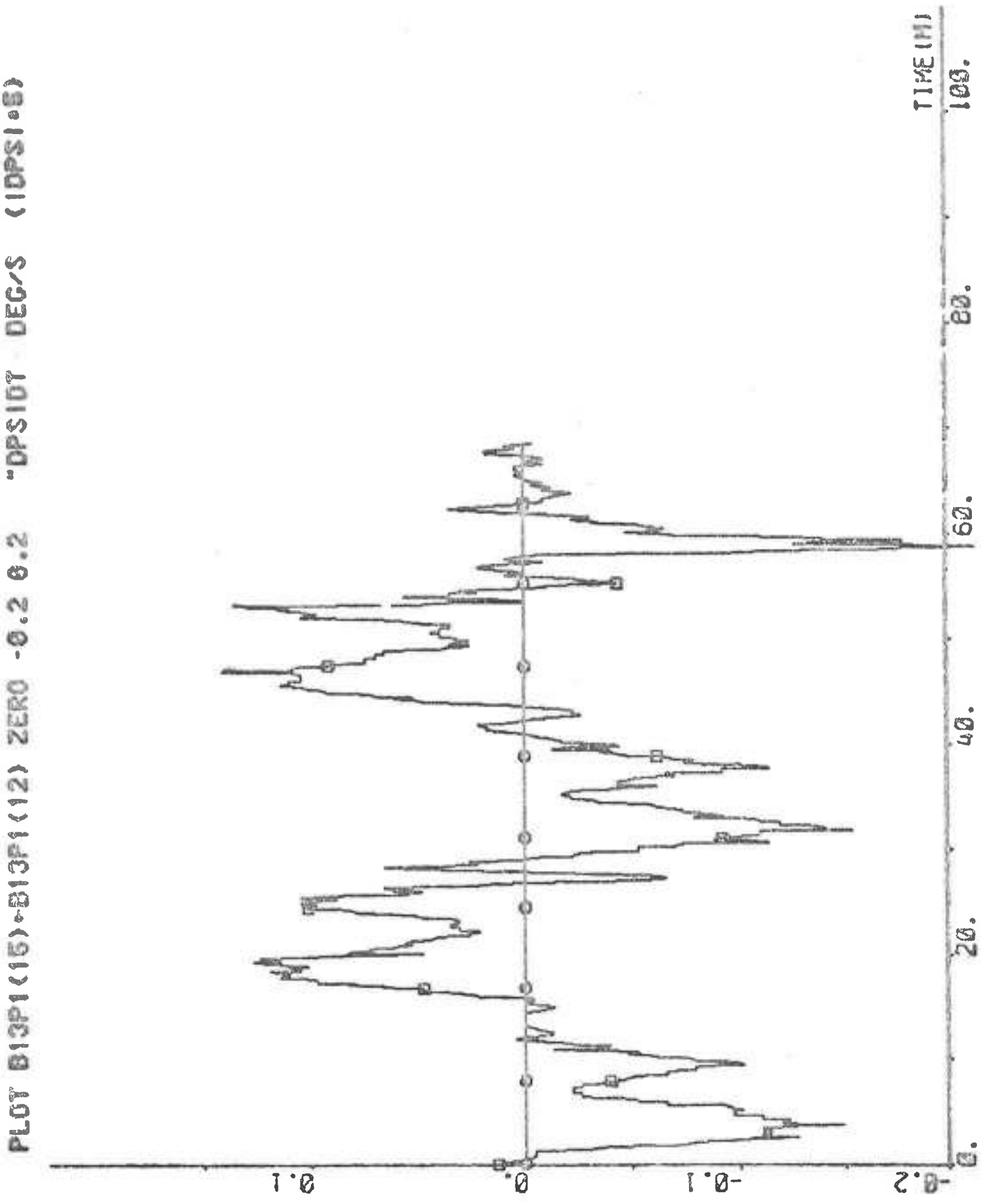

PLOT B13P1(15)-B13P1(7) 15 19 "U KNOTS
TIME(M)
0.
20.
40.
60.
80.
100.
15.
16.
17.
18.


PLOT B13P1(15)-B13P1(8) ZERO -1 1 "V1 KNOTS
TIME(M)
0.
20.
40.
60.
80.
100.
-1.
-0.5
0.
0.5

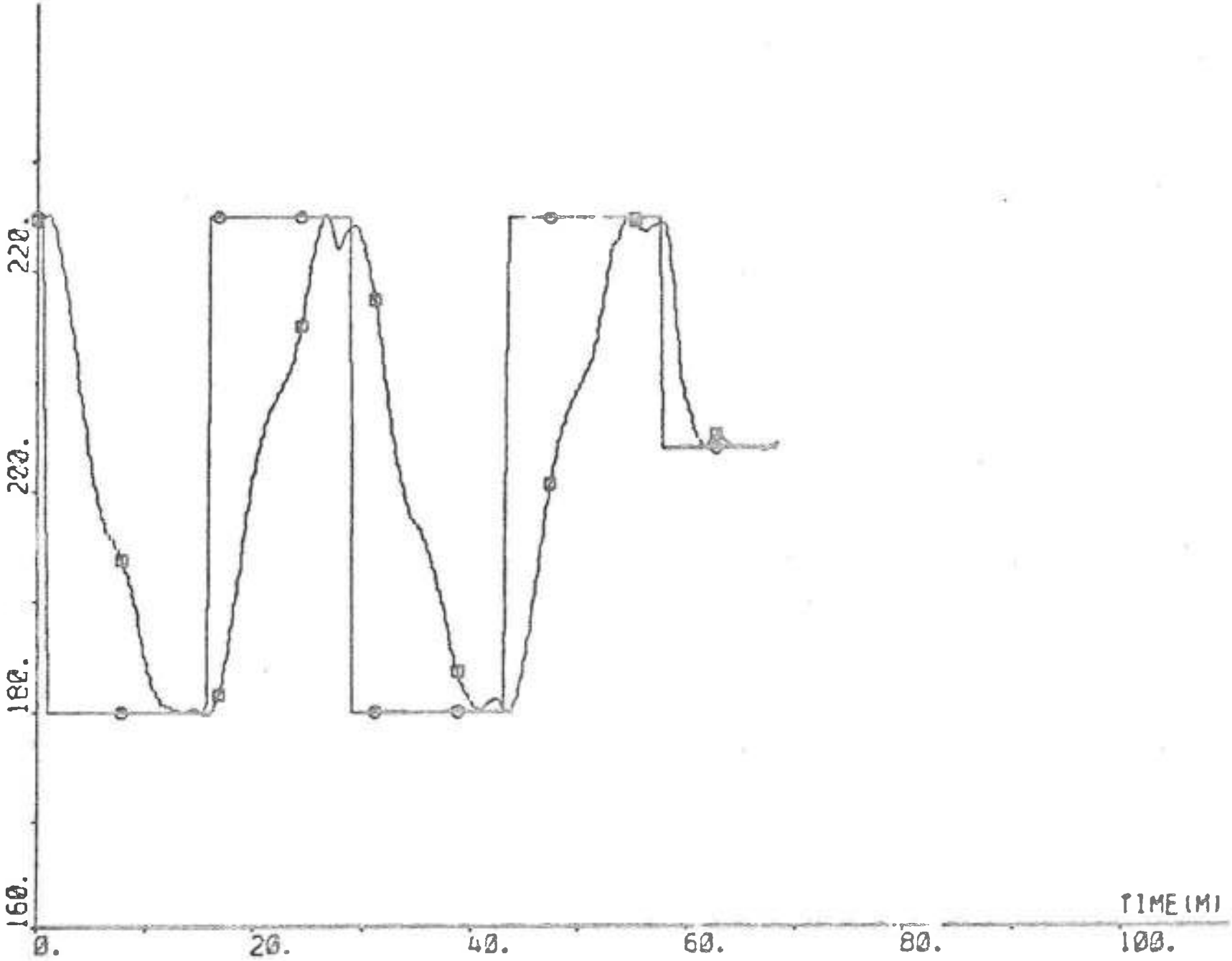

PLOT B13P1(16)-B13P1(9) ZERO -2 2 *V2 KNOTS
1.
0.
-1.
-2.
0.
20.
40.
60.
80.
100.
TIME(M)

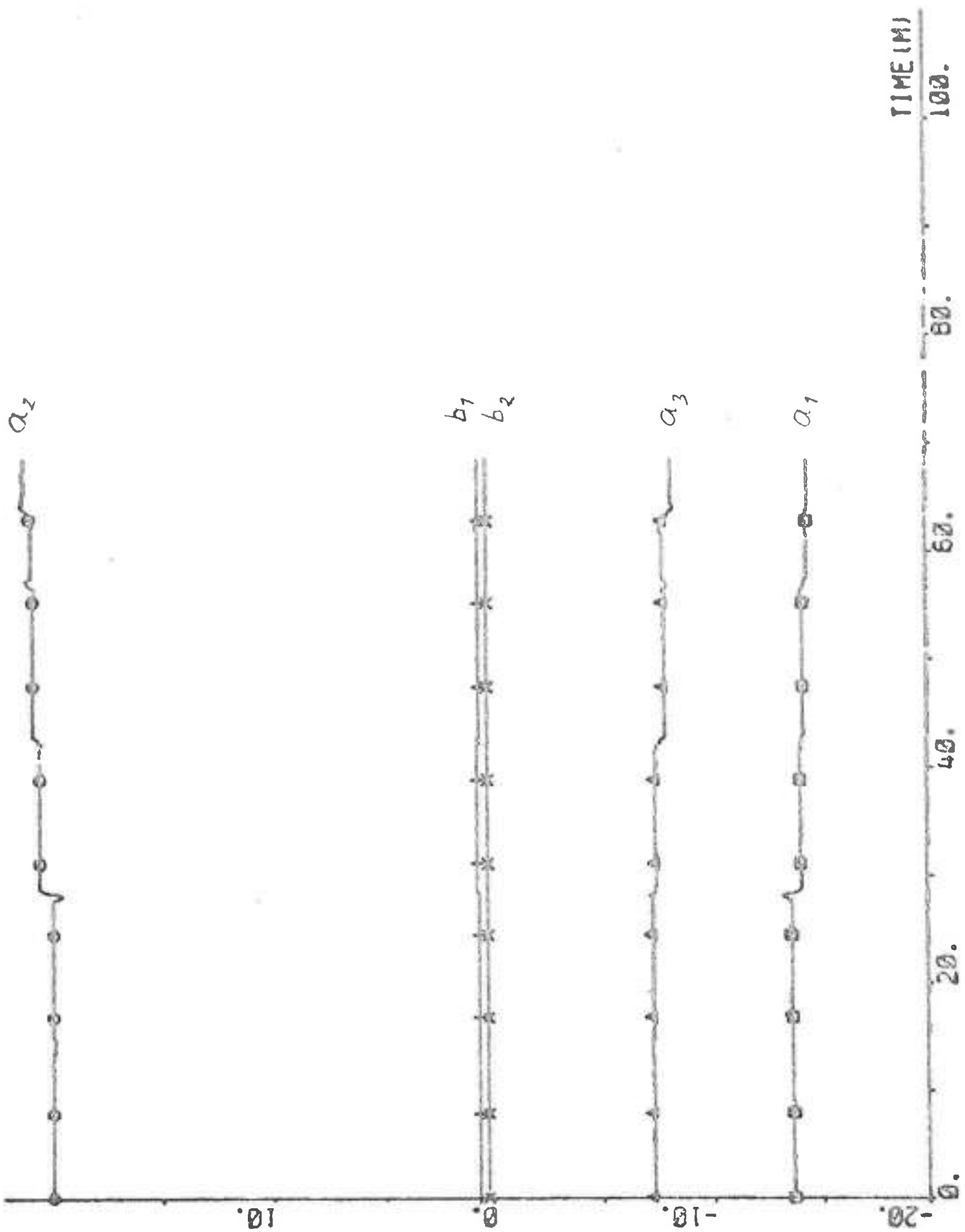

PLOT B13P1(15)-B13P1(10) ZERO -0.2 0.2 °R DEG/S
TIME(M)
0.
20.
40.
60.
80.
100.
-0.2
-0.1
0.
0.1


PLOT B13P1(15)*B13P1(11) ZERO -0.2 0.2 "AVR DEG/S (BR*0.2)
TIME(M)
0.
20.
40.
60.
80.
100.
0.1
0.
-0.1
-0.2

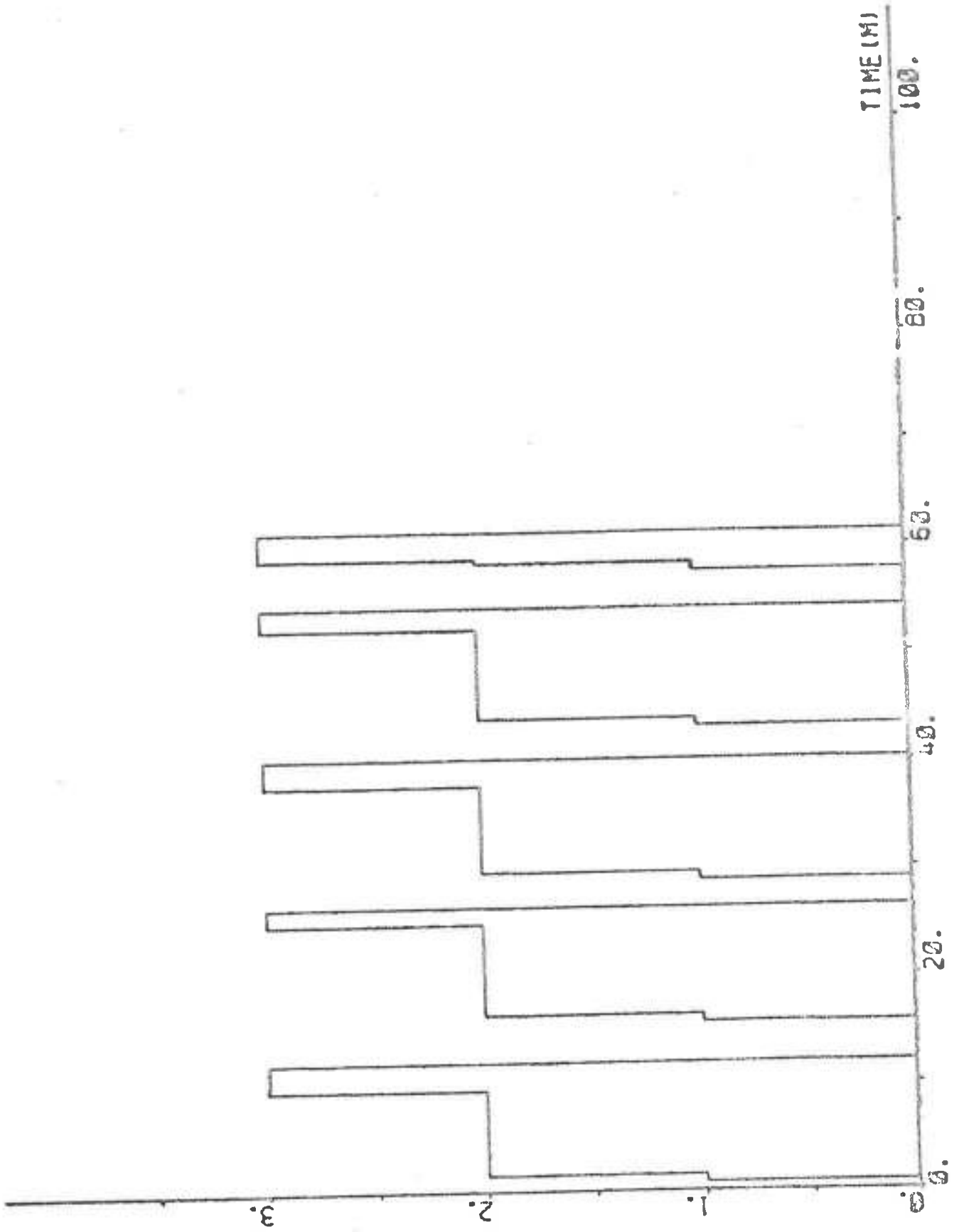

PLOT B13P1(15)-B13P1(12) ZERO -0.2 0.2 "DPSIDT DEG/S (IDPSI*B)
TIME(H)
0.
20.
40.
60.
80.
100.
0.1
0.
-0.1
-0.2

PLOT B13P1(15)-B13P1(13 14) 160 240 "PSI PSIREF DEG




PLOT B13P1(15)-B13P2(1 2 3 4 5) -15 15 "REGULATOR PARAMETERS
a_2
b_1
b_2
a_3
a_1
10.
0.
-10.
-20.
0.
20.
40.
60.
80.
100.
TIME(M)


PLOT 813P1(15)-813P2(8 7 8 9 10) -80 20 "YAW REGULATOR PARAMETERS
TIME(M)
0.
20.
40.
60.
80.
100.
0.
-20.
-40.
-60.
a_2'
b_1', b_2'
a_3'
a_1'


PLOT B13P1(15)-HP B13P2(11) 0 4 "MODYAW
TIME(M)
0.
20.
40.
60.
80.
100.
0.
1.
2.
3.

EXPERIMENT B14

Date	1974-10-19
Time	08.29
Duration	68 min
Position	S 17° 52' E 39° 54'
Water depth	deep
Forward draught	20.2 m
Aft draught	20.2 m
Wind direction	N (4; see Appendix A)
Wind velocity	3-4 Beaufort (4-8 m/s, gentle to moderate breeze)
Wave height	4 m
PSIREF	209°, 210°, 208°, 209°, 208°, 209°, 208°, 210°, 206°, 212°, 202°
RREF	0.07 deg/s
Rudder limit	Not active
DELlM at termination	- 0.99°
Approximate mean value of AN	85.5 rpm
Approximate mean value of U	17.0 knots

Regulator structure

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

Final values

$$\begin{bmatrix} a_1 \\ a_2 \\ a_3 \\ b_1 \\ b_2 \end{bmatrix} = \begin{bmatrix} -18.996 \\ 29.767 \\ -11.306 \\ 0.700 \\ 0.273 \end{bmatrix} \qquad P = \begin{bmatrix} 0.951 & & & & \\ -1.420 & 3.275 & & & \\ 0.551 & -1.942 & 1.454 & & \\ -0.018 & -0.011 & 0.028 & 0.004 & \\ 0.013 & -0.072 & 0.060 & 0.002 & 0.005 \end{bmatrix}$$

$a_1 + a_2 + a_3 = - 0.535$

Initial yaw regulator structure

NAY = 3	NBY = 2	KY = 2	
IREGY = 10	RLY = 0.95	IRR = 3	IDPSI = 5
AK1V = 40	AK2V = 1.4	AK3V = 120	
C1V = 10	C2V = 80		
EPS1V = 0.02	EPS2V = 0.03		
PSISV = 0.15	PSISSV = 1.5	PSIMAV = 0.4	
I1MV = 60	I2MV = 300	I3MV = 150	

Initial yaw regulator values

$$\begin{bmatrix} a_1' \\ a_2' \\ a_3' \\ b_1' \\ b_2' \end{bmatrix} = \begin{bmatrix} -41.61 \\ 5.49 \\ -0.53 \\ 1.30 \\ 0.81 \end{bmatrix} \qquad PY = \begin{bmatrix} 500 & & & & \\ 0 & 500 & & & \\ 0 & 0 & 500 & & \\ 0 & 0 & 0 & 1 & \\ 0 & 0 & 0 & 0 & 1 \end{bmatrix}$$

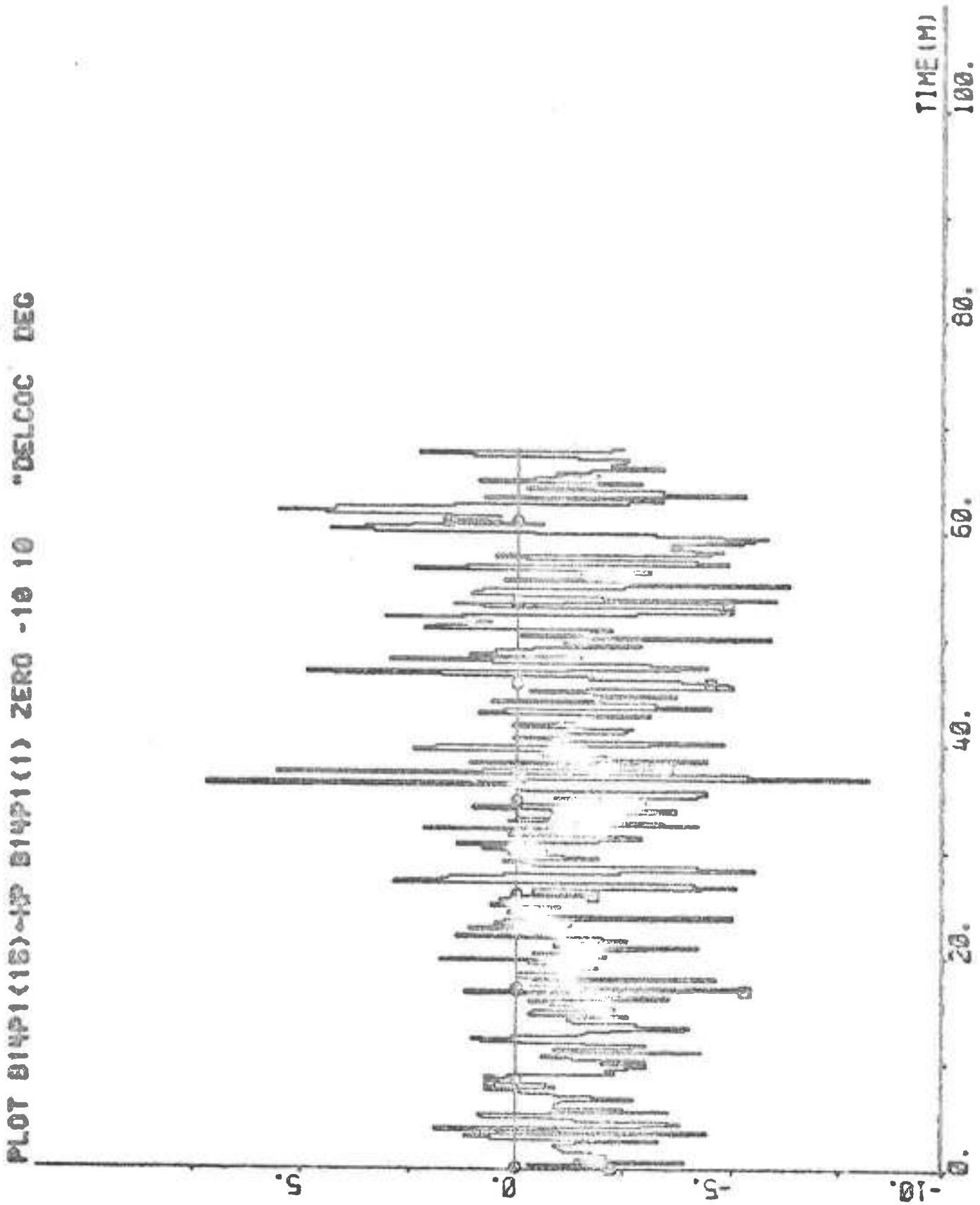
$a_1' + a_2' + a_3' = -36.65$

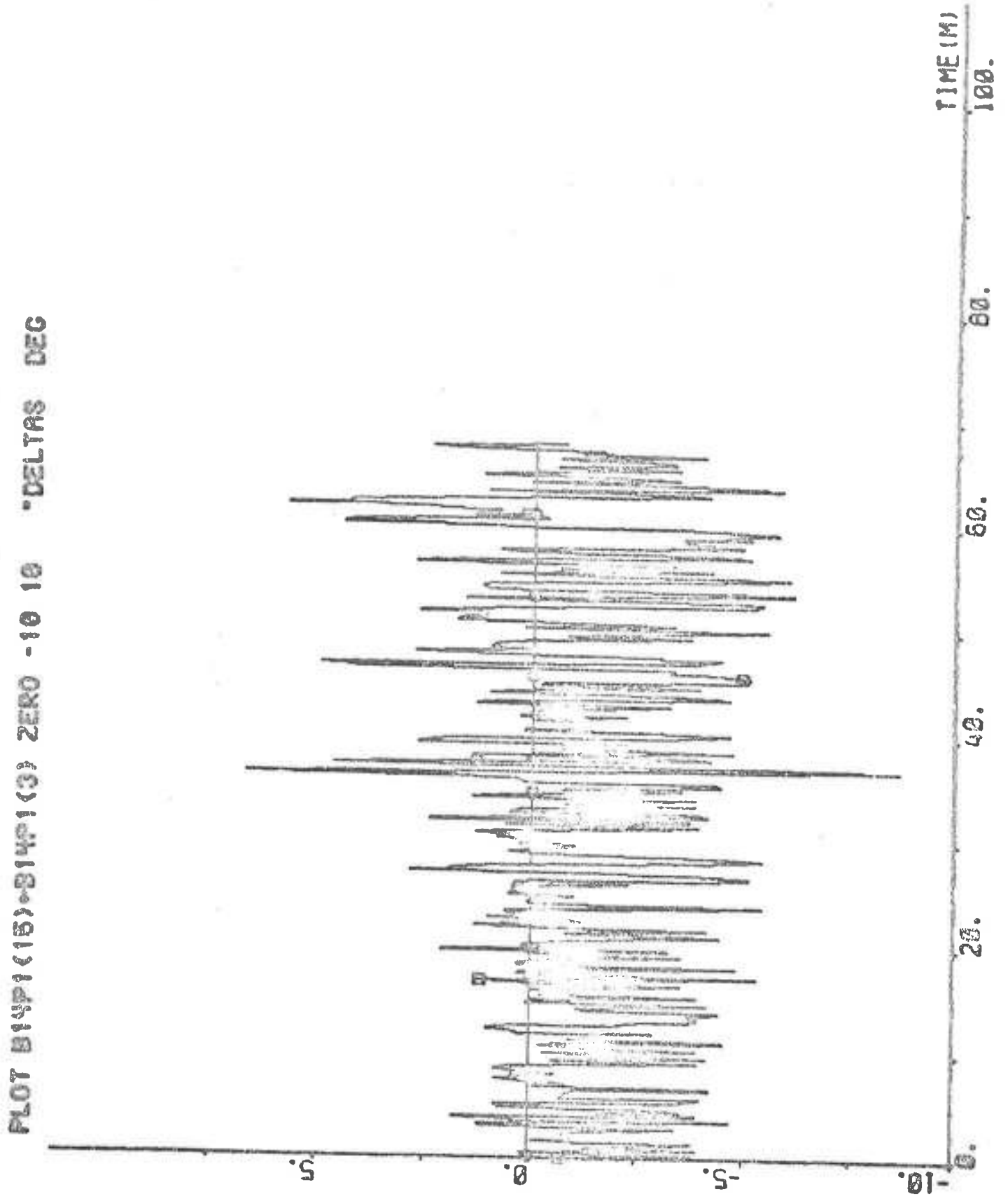
Change of yaw regulator structure at 18 min.

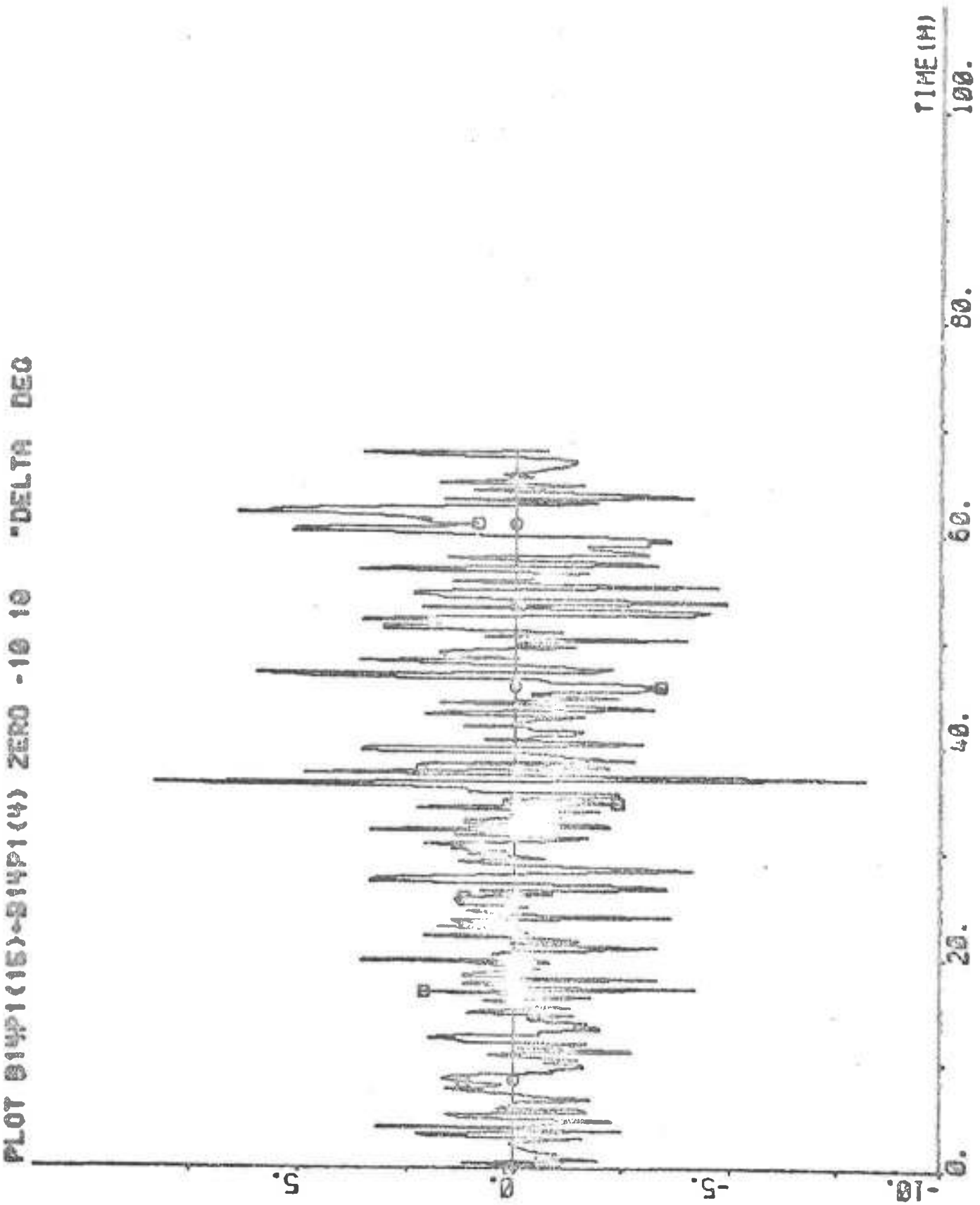
AK2V = 1.6

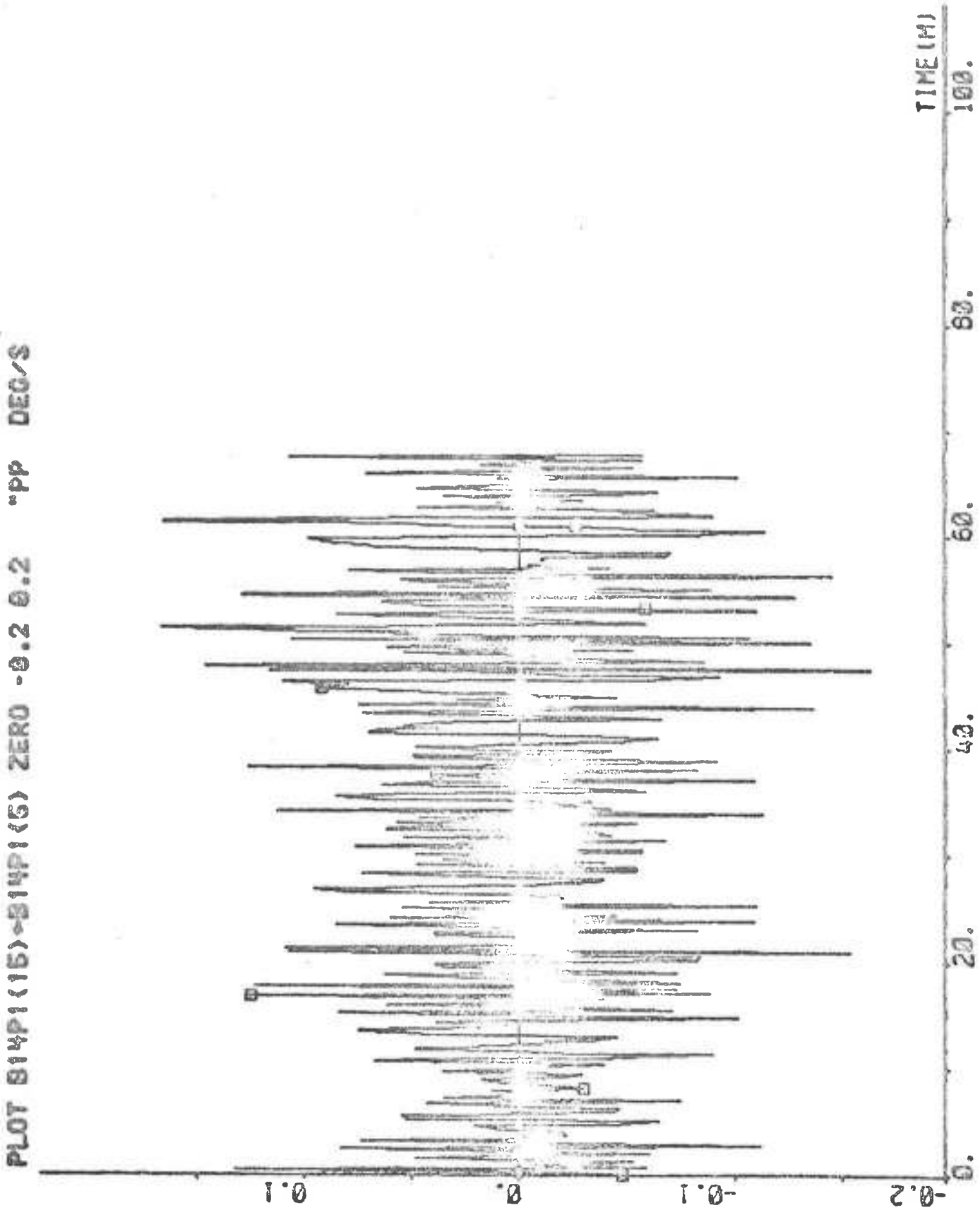
Change of yaw regulator structure at 31 min.

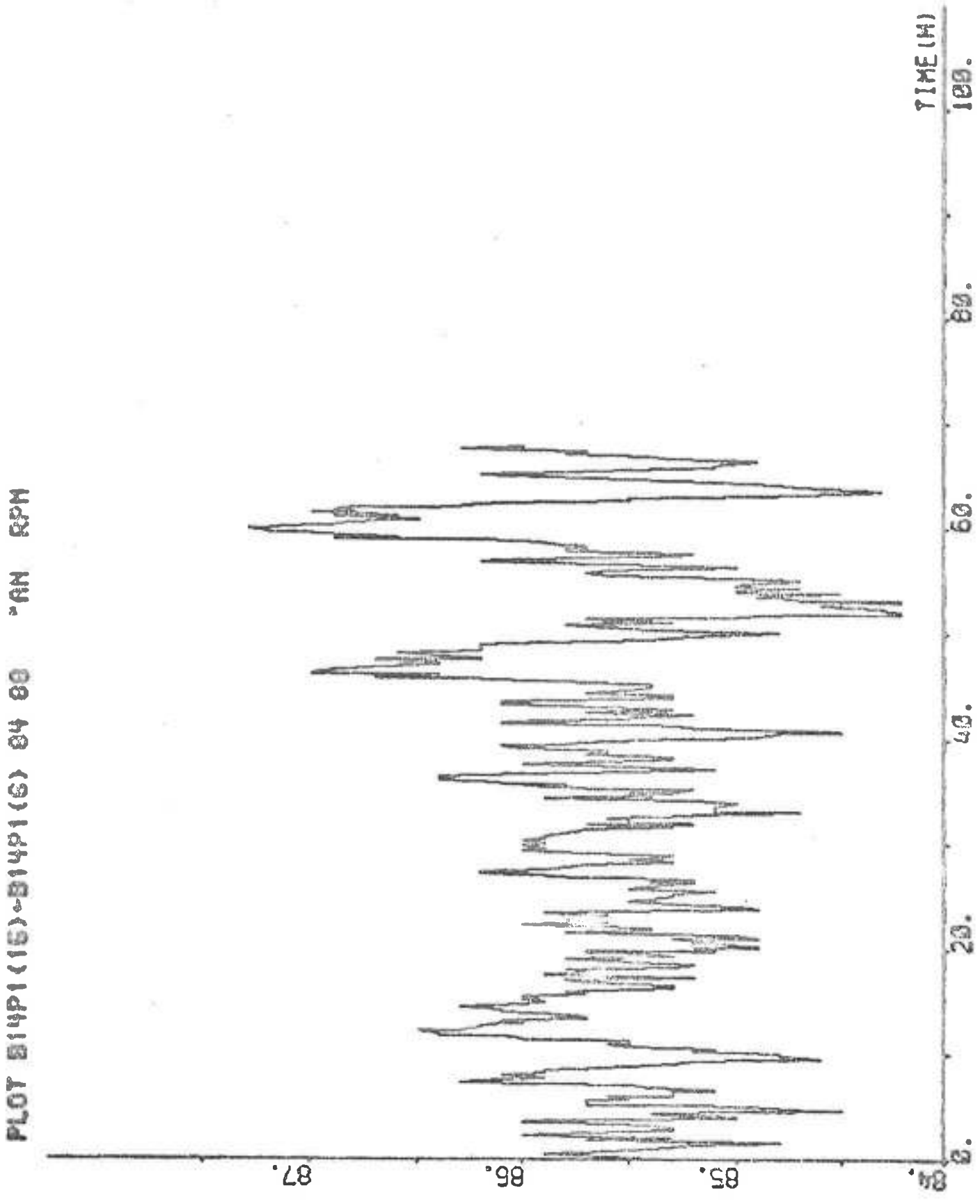
AK2V = 1.8

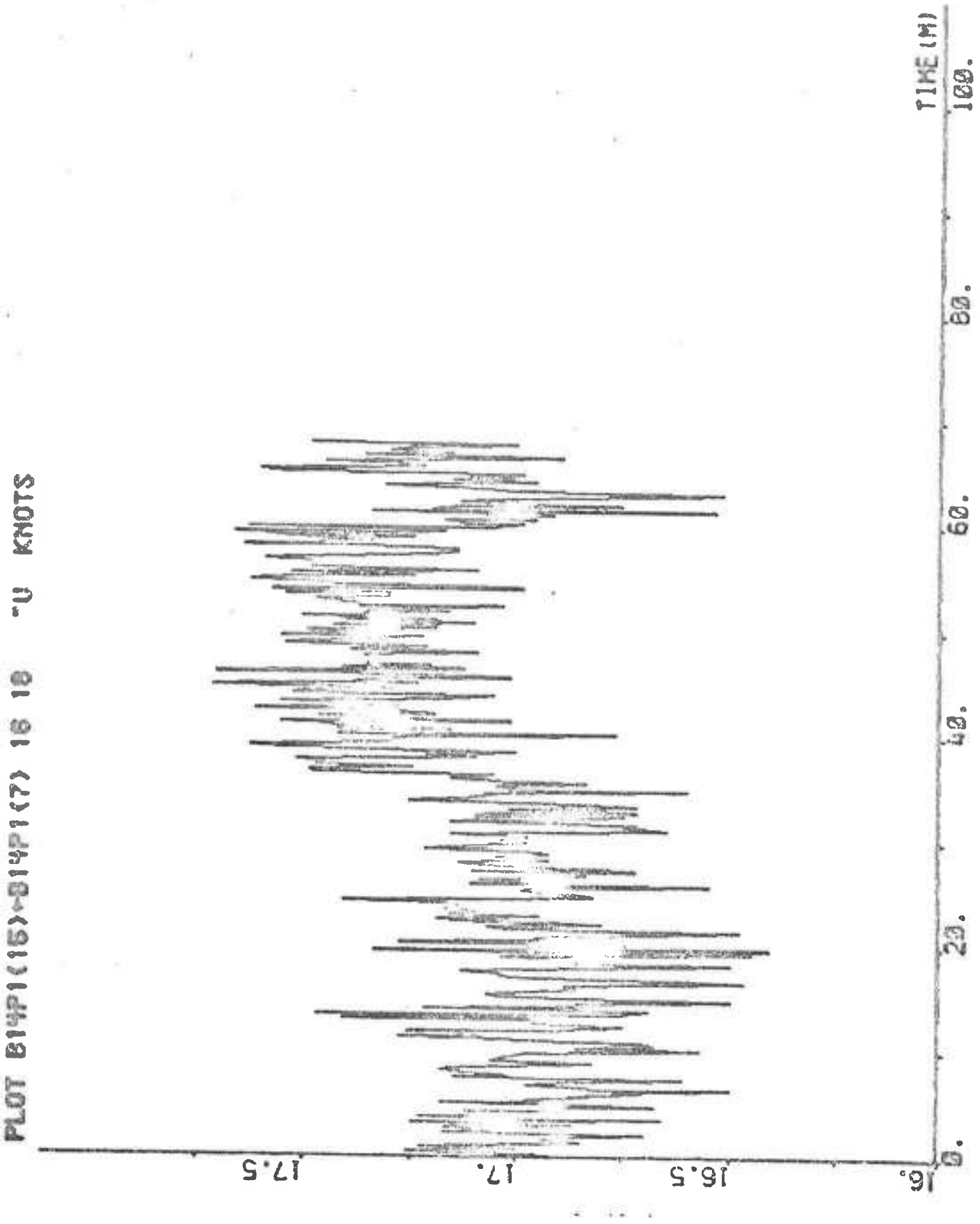

PLOT B14P1(16)-HP B14P1(1) ZERO -10 10 "DSLCOC DEC
TIME(M)
0.
20.
40.
60.
80.
100.
-10.
-5.
0.
5.

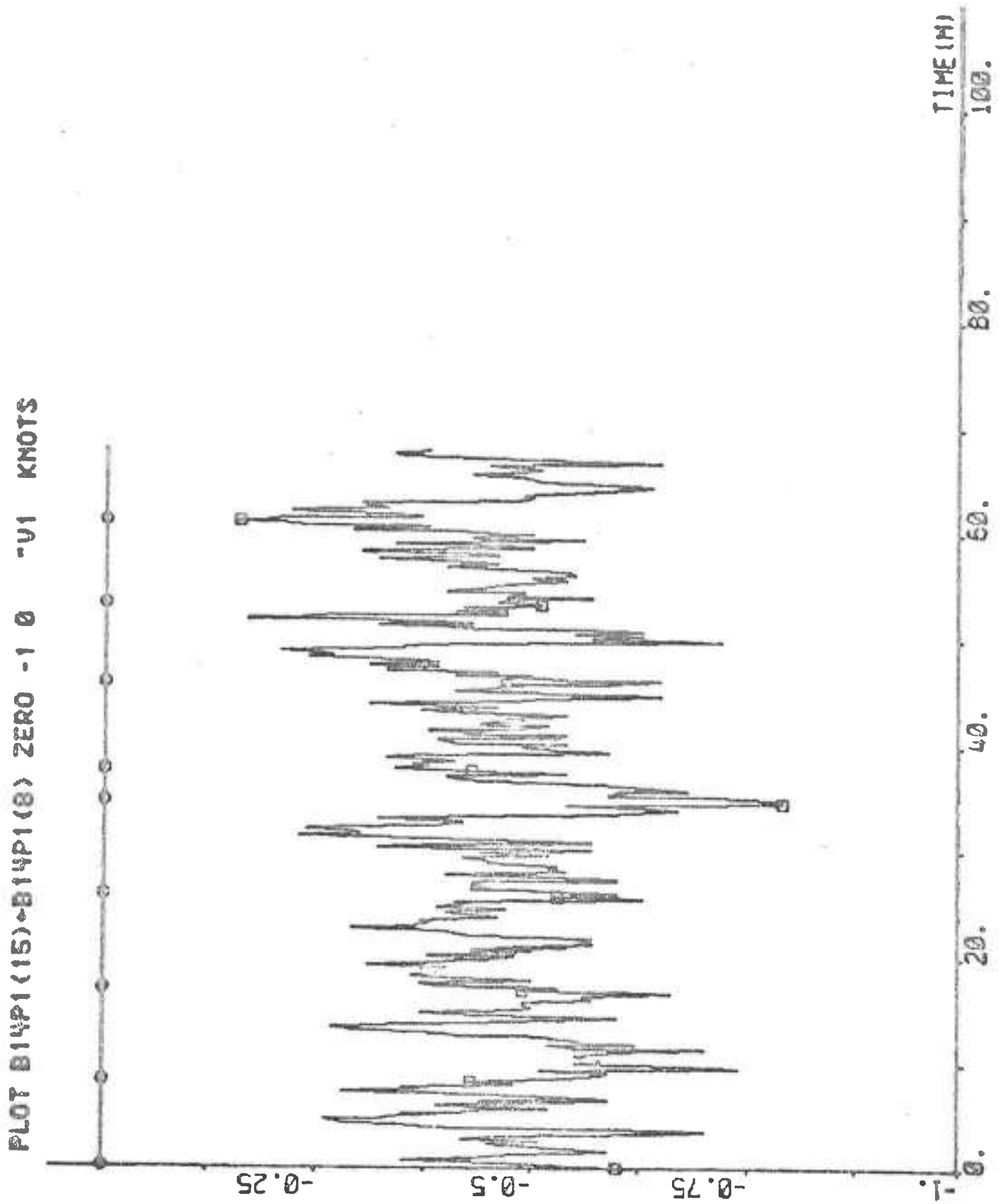

PLOT B1950(1B)-B1950(3) ZERO -10 10 *DELTAS DEC
TIME(M)
0.
20.
40.
60.
80.
100.
-10.
-5.
0.
5.

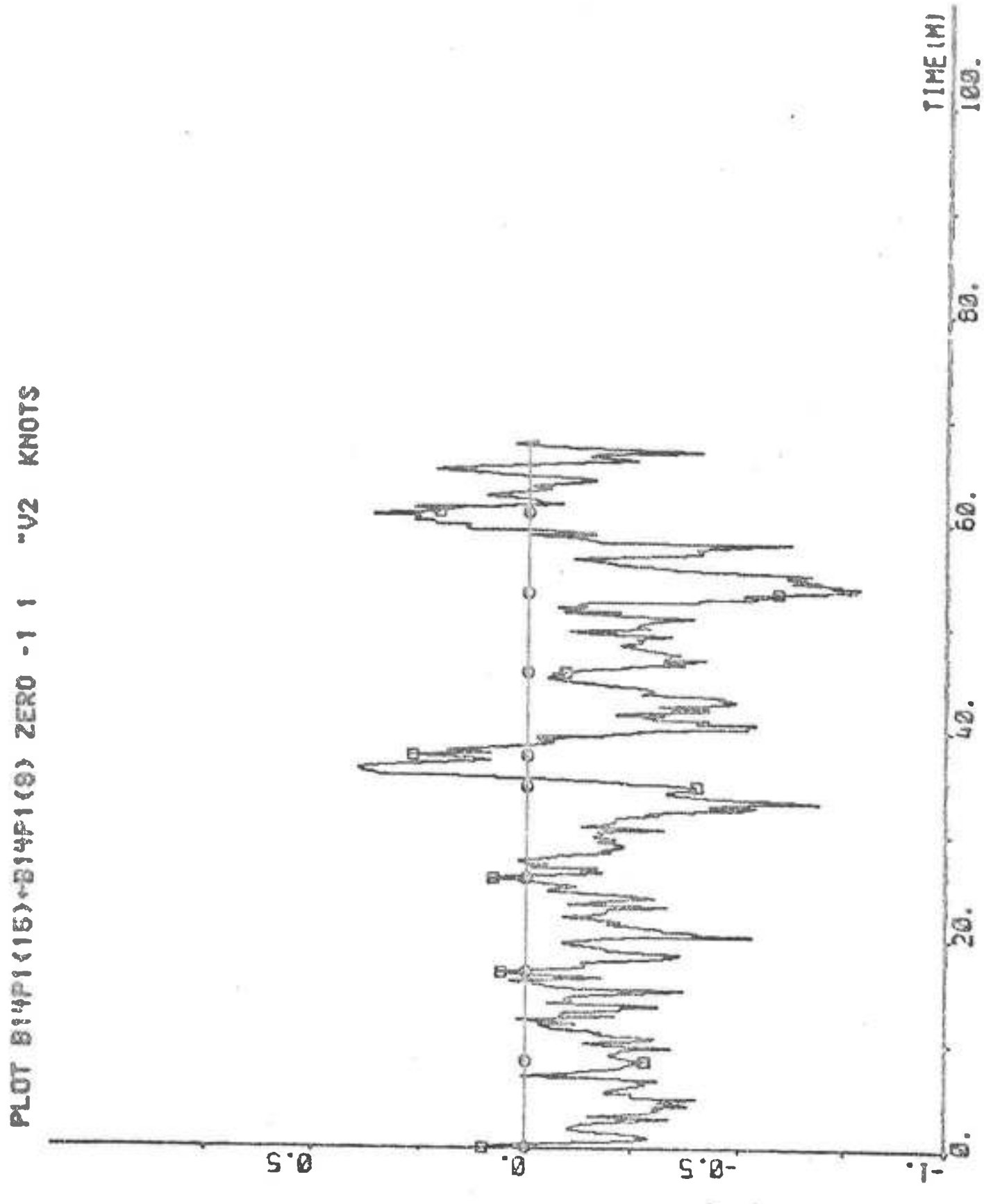

PLOT B14P1(15)-B14P1(4) ZERO -10 10 "DELTA DEG
5.
0.
-5.
-10.
0.
20.
40.
60.
80.
100.
TIME(H)

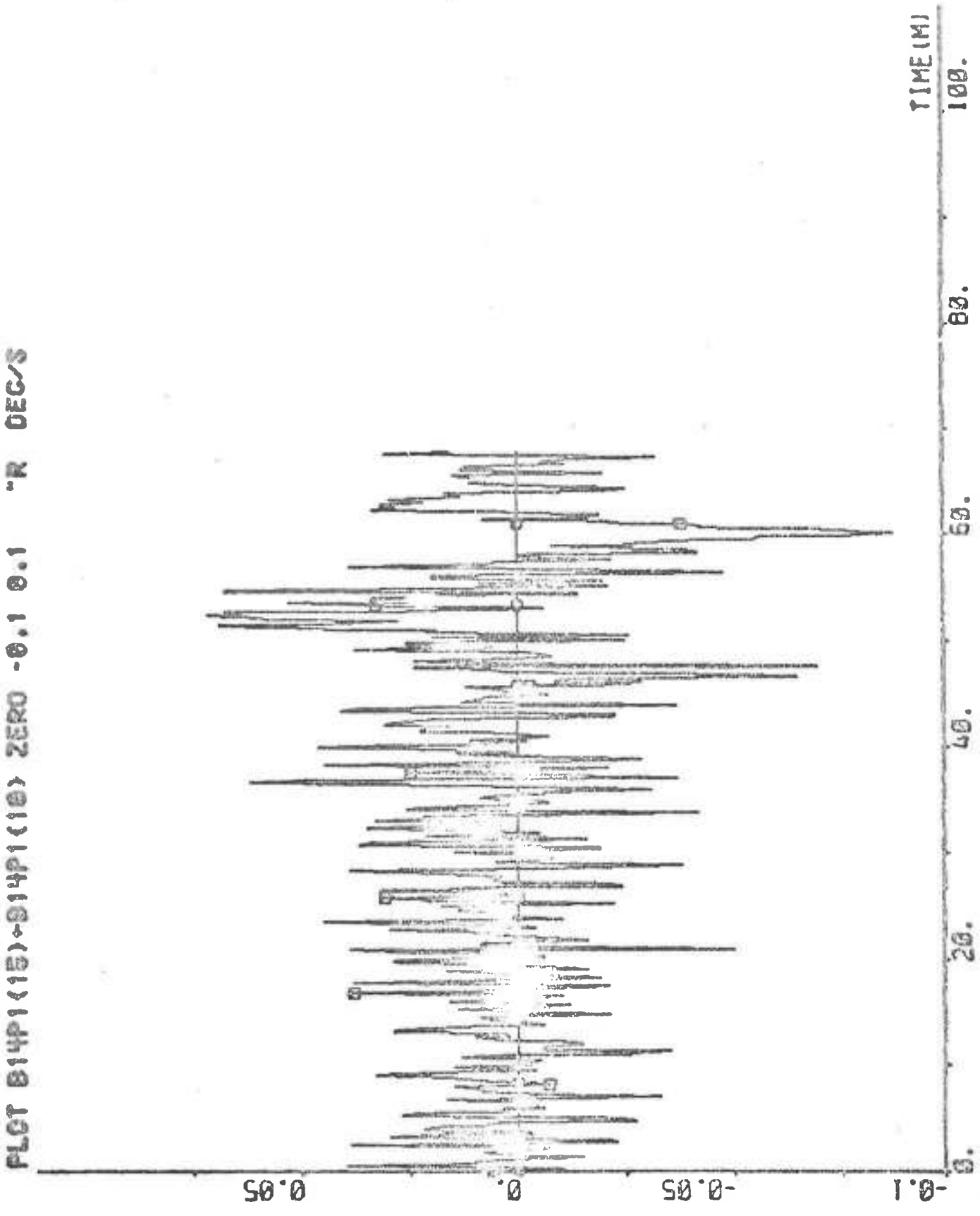

PLOT B14P1(15)=B14P1(5) ZERO -0.2 0.2 "PP DEG/S
TIME(H)
0.
20.
40.
60.
80.
100.
-0.2
-0.1
0.
0.1

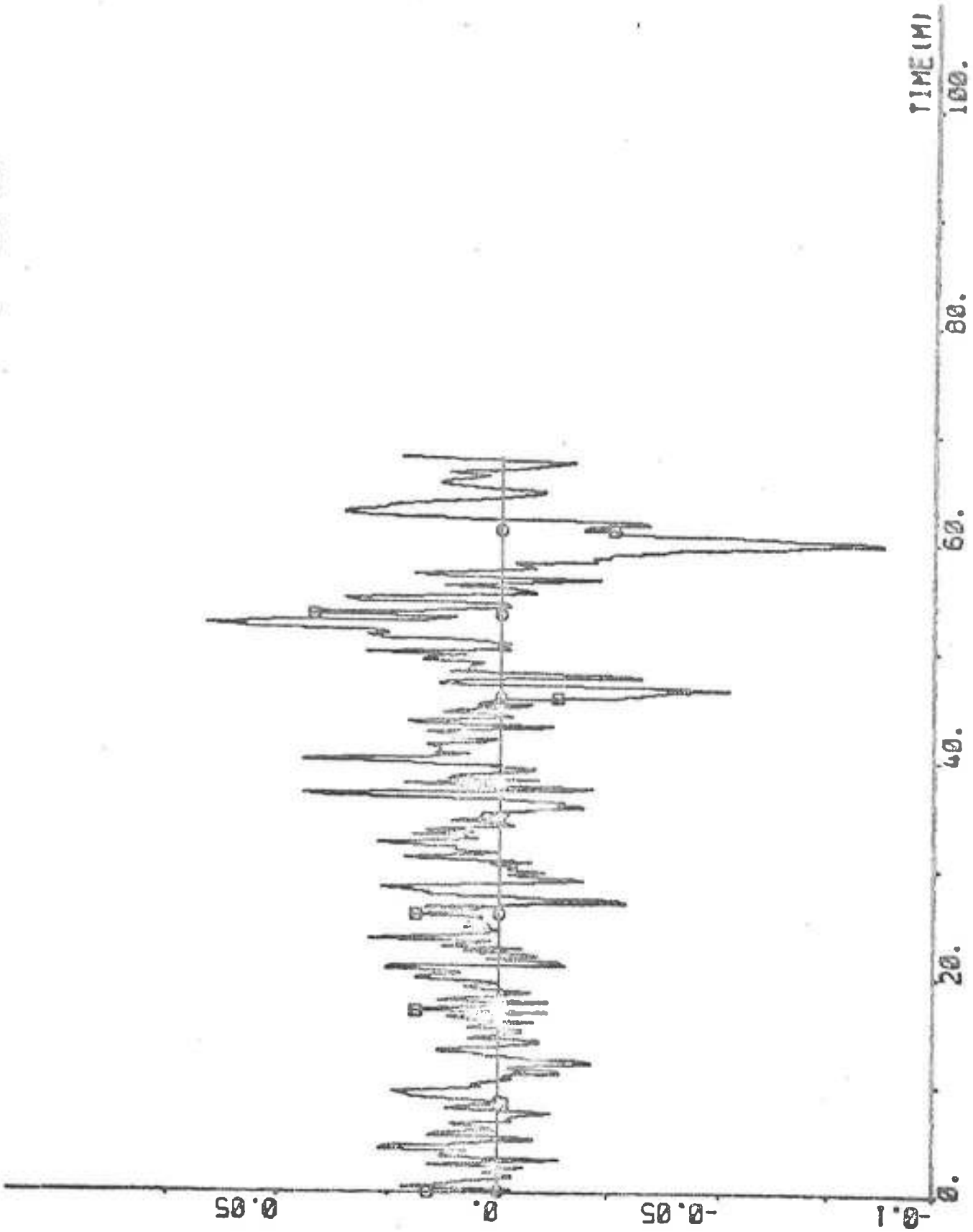

PLOT B14P1(1S)-B14P1(S) 84 88 'AN RPM
TIME(H)
2.
23.
40.
60.
80.
100.
84.
85.
86.
87.

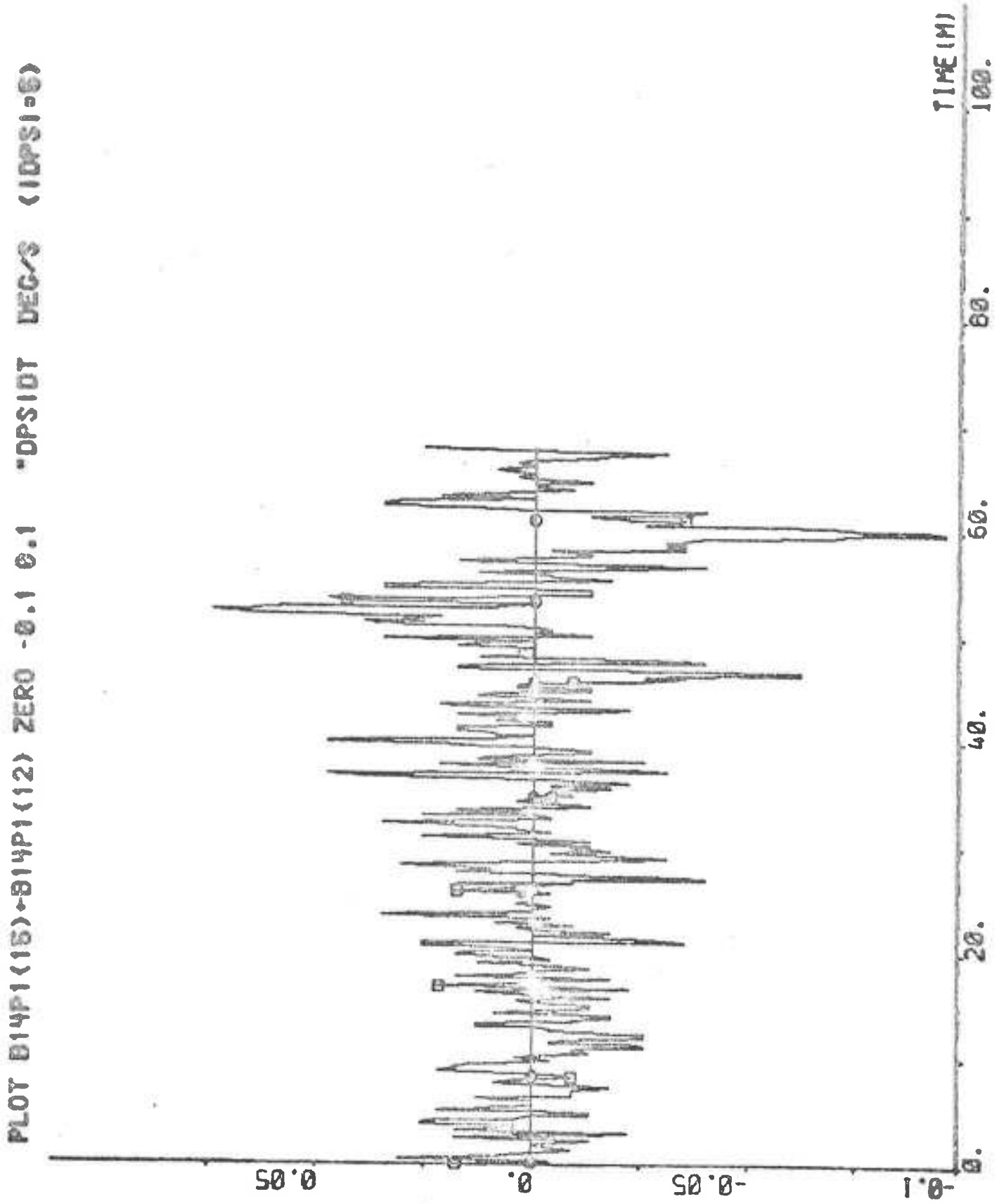

PLOT B14P1(15)-B14P1(7) 16 18 -U KNOTS
TIME(M)
0.
20.
40.
60.
80.
100.
16.
16.5
17.
17.5

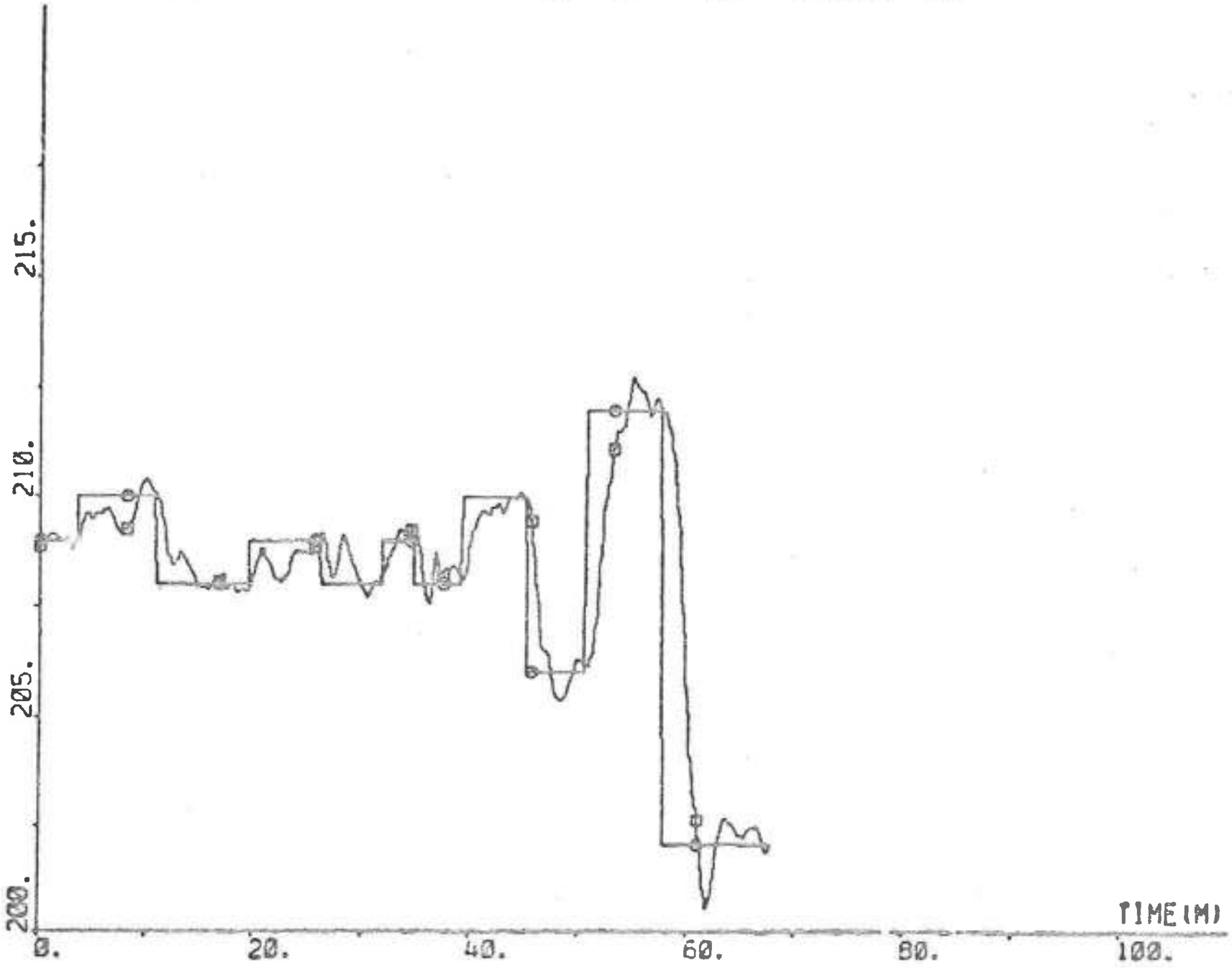

PLOT B14P1(15)-B14P1(8) ZERO -1 0 -V1 KNOTS
-1.
-0.75
-0.5
-0.25
0.
20.
40.
60.
80.
100.
TIME(H)

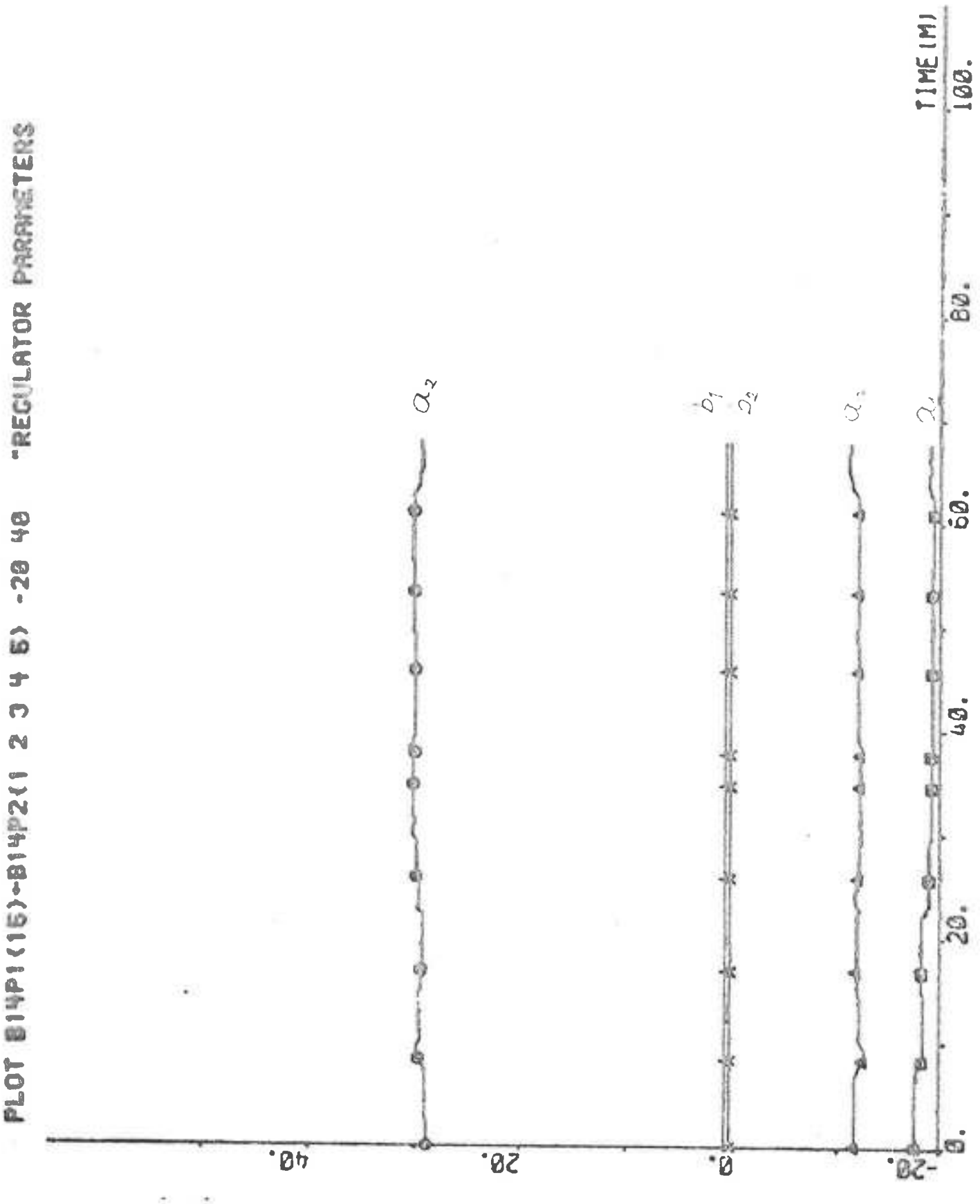

PLOT B14P1(15)-B14P1(8) ZERO -1 1 "V2 KNOTS
0.5
0.
-0.5
-1.
0.
20.
40.
60.
80.
100.
TIME(M)

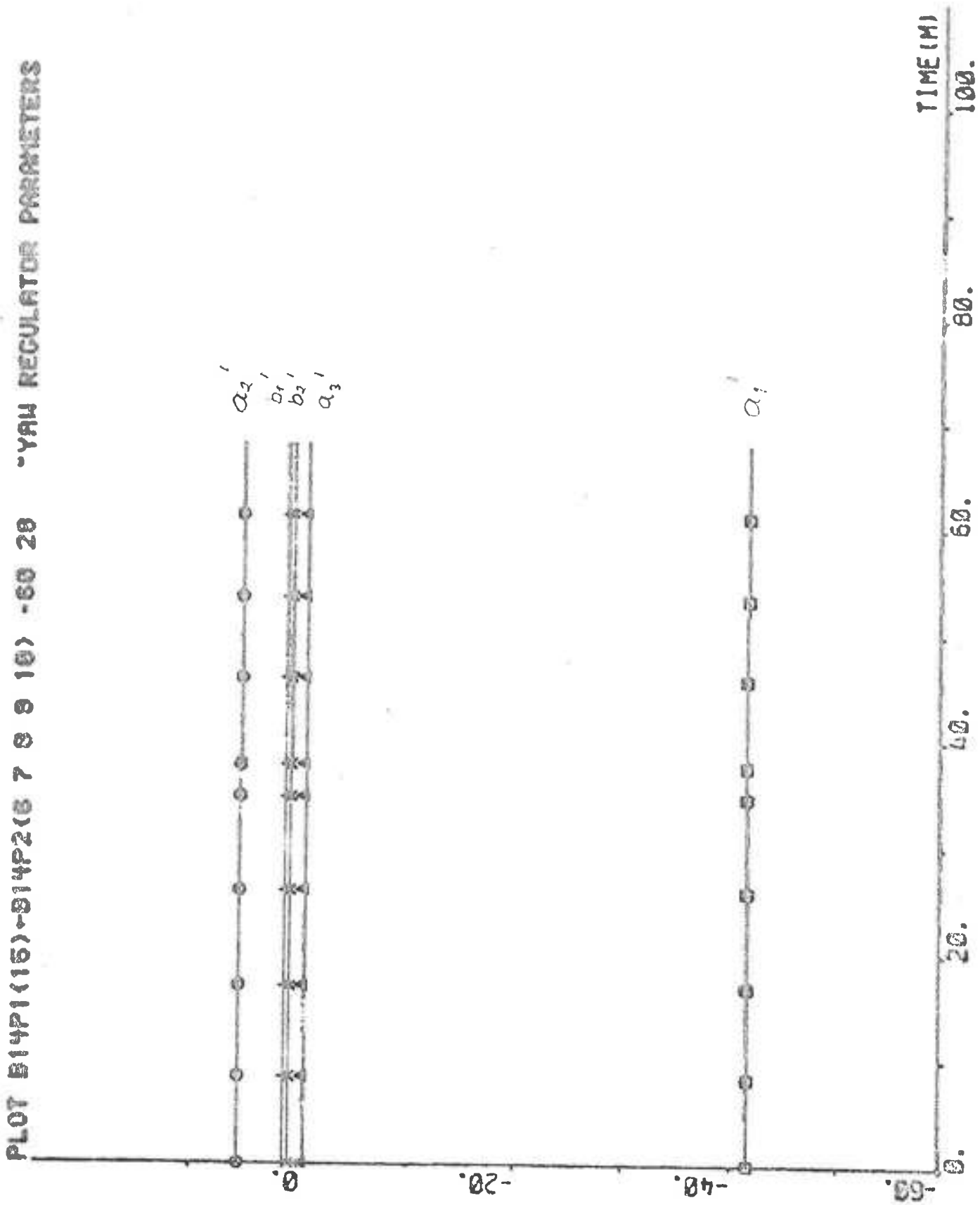

PLOT B14P1(1B)-B14P1(10) ZERO -0.1 0.1 °R DEG/S
-0.1
-0.05
0.
0.05
TIME(M)
0.
20.
40.
60.
80.
100.

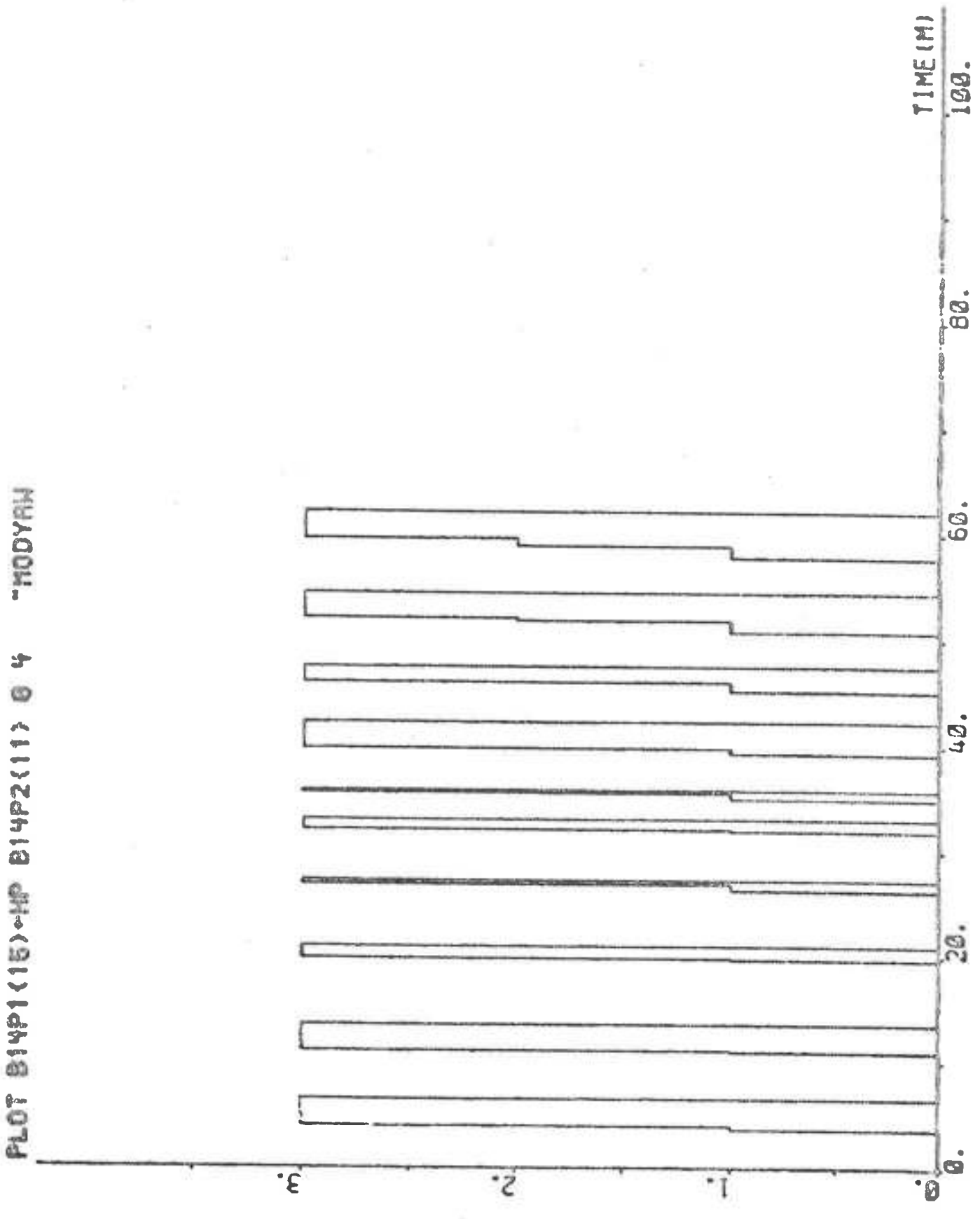

PLOT B14P1(15)-B14P1(11) ZERO -0.1 0.1 *AVR DEG/S (BR=0.2)
TIME(M)
0.
20.
40.
60.
80.
100.
0.1
0.05
0.
-0.05
-0.1


PLOT B14P1(15)-B14P1(12) ZERO -0.1 0.1 *DPSIDT DEG/S (10PSI=S)
TIME(M)
0.
20.
40.
60.
80.
100.
0.1
0.05
0.
-0.05
-0.1


PLOT B14P1(15)-B14P1(13 14) 200 215 "PSI PSIREF DEG
215.
210.
205.
200.
0.
20.
40.
60.
80.
100.
TIME(M)


PLOT B14P1(15)-B14P2(1 2 3 4 5) -20 40 "REGULATOR PARAMETERS
TIME(M)
0.
20.
40.
60.
80.
100.
-20.
0.
20.
40.
a_2
b_1
b_2
a_1


PLOT B14P1(15)-B14P2(8 7 8 8 10) -60 28 "YAW REGULATOR PARAMETERS
TIME(M)
0.
20.
40.
60.
80.
100.
0.
-20.
-40.
-60.
a2'
b1'
b2'
a3'
a1'


PLOT B14P1(15)-HP B14P2(11) 0 4 "MODYAW
TIME(M)
0.
20.
40.
60.
80.
100.
0.
1.
2.
3.

EXPERIMENT B15

Date	1974-10-19
Time	09.51
Duration	59 min.
Position	S 18° 28' E 39° 34'
Water depth	deep
Forward draught	20.2 m
Aft draught	20.2 m
Wind direction	N (4, 5; see Appendix A)
Wind velocity	3-4 Beaufort (4-8 m/s, gentle to moderate breeze)
Wave height	3-4 m
PSIREF	202°, 225°, 180°, 225°, 180°
RREF	0.07 deg/s (0-47 min) 0.14 deg/s (47-59 min)
Rudder limit	Not active
DEL1M at termination	-0.57°
Approximate mean value of AN	85.0 rpm
Approximate mean value of U	17.1 knots

Regulator structure

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

Final values

$$\begin{bmatrix} a_1 \\ a_2 \\ a_3 \\ b_1 \\ b_2 \end{bmatrix} = \begin{bmatrix} -20.296 \\ 31.260 \\ -12.075 \\ 0.702 \\ 0.256 \end{bmatrix} \qquad P = \begin{bmatrix} 0.430 & & & & \\ -0.584 & 1.245 & & & \\ 0.198 & -0.719 & 0.569 & & \\ -0.012 & -0.0002 & 0.013 & 0.002 & \\ -0.003 & -0.020 & 0.023 & 0.001 & 0.002 \end{bmatrix}$$

$a_1 + a_2 + a_3 = -1.111$

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 = 0.4	
I1MV = 60	I2MV = 300	I3MV = 150	

Initial yaw regulator values for the yaw at 2 min.

$$\begin{bmatrix} a'_1 \\ a'_2 \\ a'_3 \\ b'_1 \\ b'_2 \end{bmatrix} = \begin{bmatrix} -41.61 \\ 5.49 \\ -0.53 \\ 1.30 \\ 0.81 \end{bmatrix} \qquad PY = \begin{bmatrix} 500 & & & & \\ 0 & 500 & & & \\ 0 & 0 & 500 & & \\ 0 & 0 & 0 & 1 & \\ 0 & 0 & 0 & 0 & 1 \end{bmatrix}$$

$a'_1 + a'_2 + a'_3 = -36.65$

Yaw regulator values after the yaw at 2 min.

$$\begin{bmatrix} a_1' \\ a_2' \\ a_3' \\ b_1' \\ b_2' \end{bmatrix} = \begin{bmatrix} -41.610 \\ 6.078 \\ 0.289 \\ 1.305 \\ 0.820 \end{bmatrix}$$

PY unknown

$a_1' + a_2' + a_3' = -35.243$

Initial yaw regulator values for the yaw at 13 min.

No change, see above!

Yaw regulator values after the yaw at 13 min.

$$\begin{bmatrix} a_1' \\ a_2' \\ a_3' \\ b_1' \\ b_2' \end{bmatrix} = \begin{bmatrix} -43.557 \\ 4.941 \\ 0.896 \\ 1.288 \\ 0.809 \end{bmatrix} \qquad PY = \begin{bmatrix} 210.072 & & & & \\ -59.415 & 529.770 & & & \\ -87.663 & -292.586 & 296.564 & & \\ -2.073 & -8.585 & 5.261 & 0.266 & \\ -1.650 & -5.516 & 2.541 & 0.181 & 0.200 \end{bmatrix}$$

$a_1' + a_2' + a_3' = -37.720$

Initial yaw regulator values for the yaw at 32 min.

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

Yaw regulator values after the yaw at 32 min.

$$\begin{bmatrix} a_1' \\ a_2' \\ a_3' \\ b_1' \\ b_2' \end{bmatrix} = \begin{bmatrix} -43.827 \\ 4.538 \\ 0.678 \\ 1.285 \\ 0.801 \end{bmatrix}$$

PY unknown

$a_1' + a_2' + a_3' = -38.611$

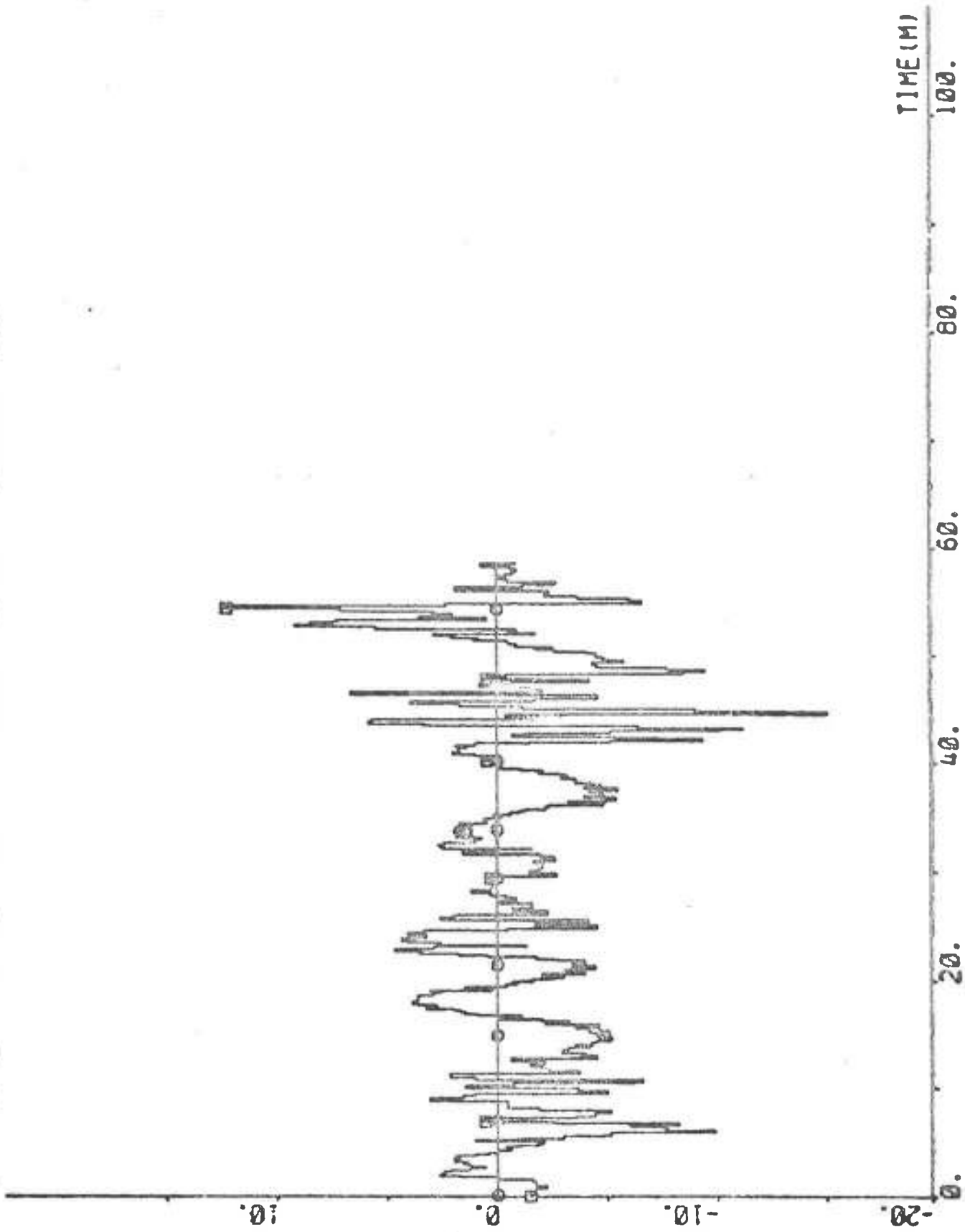
Initial yaw regulator values for the yaw at 49 min.

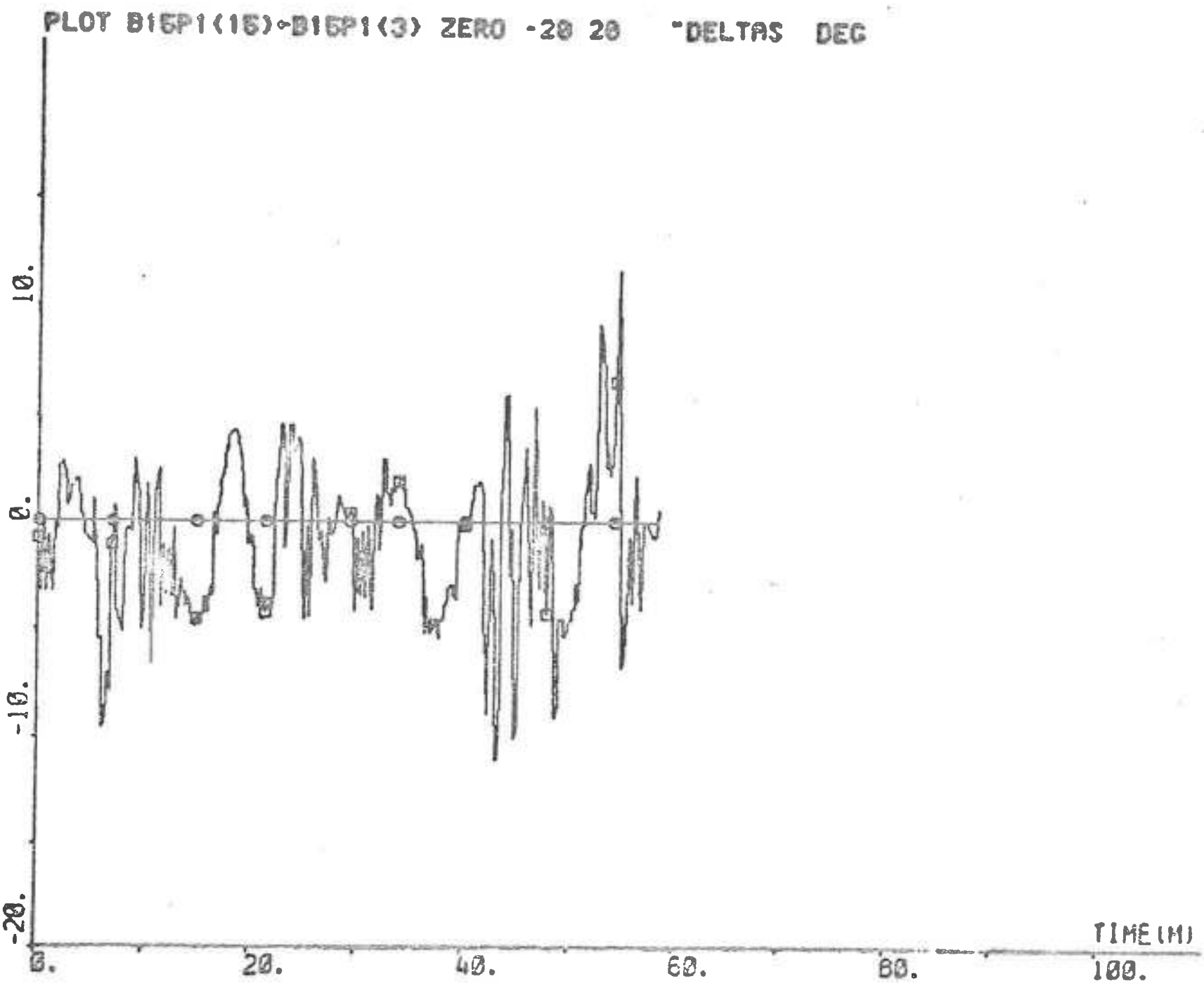
No change, see above!

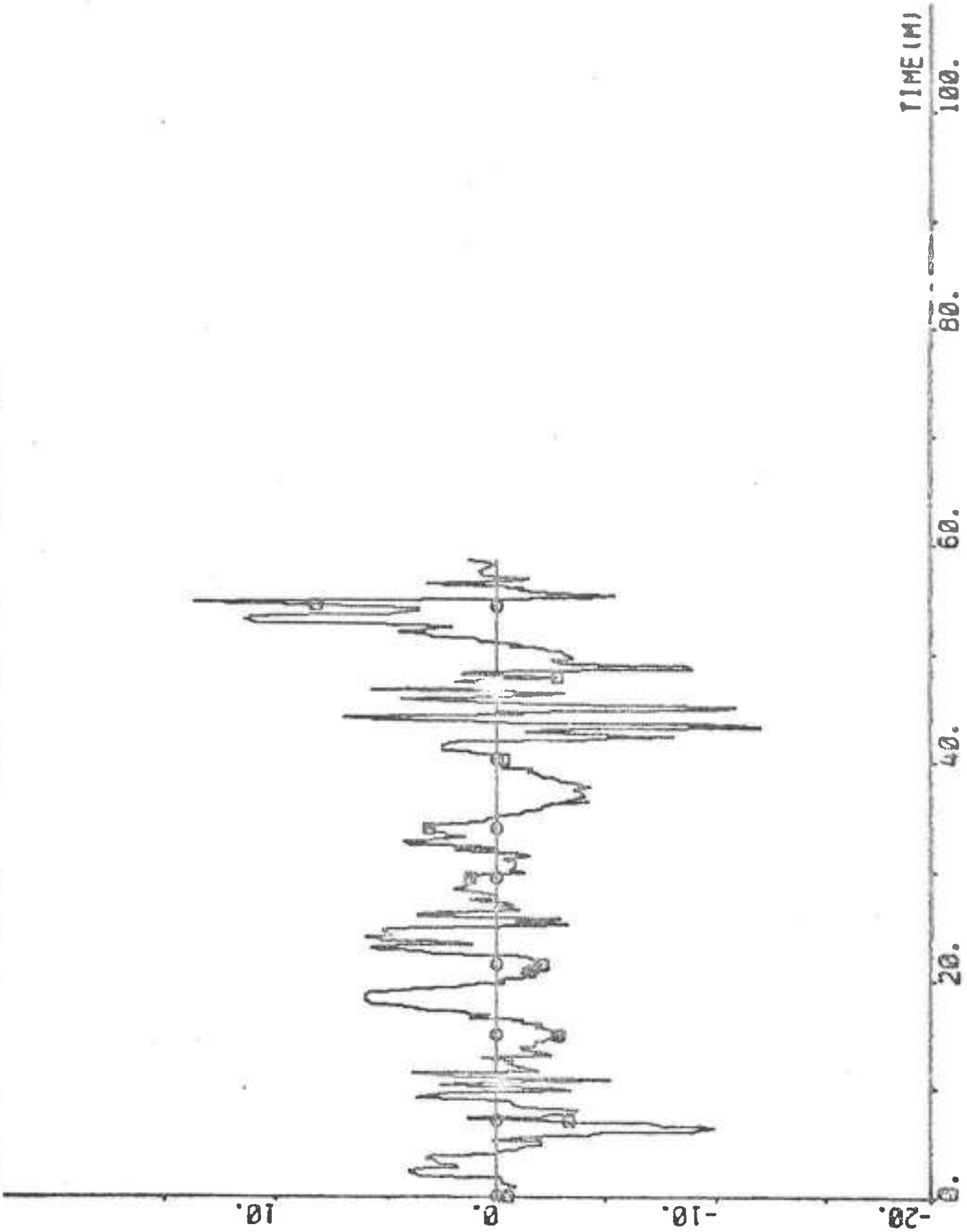
Yaw regulator values after the yaw at 49 min.

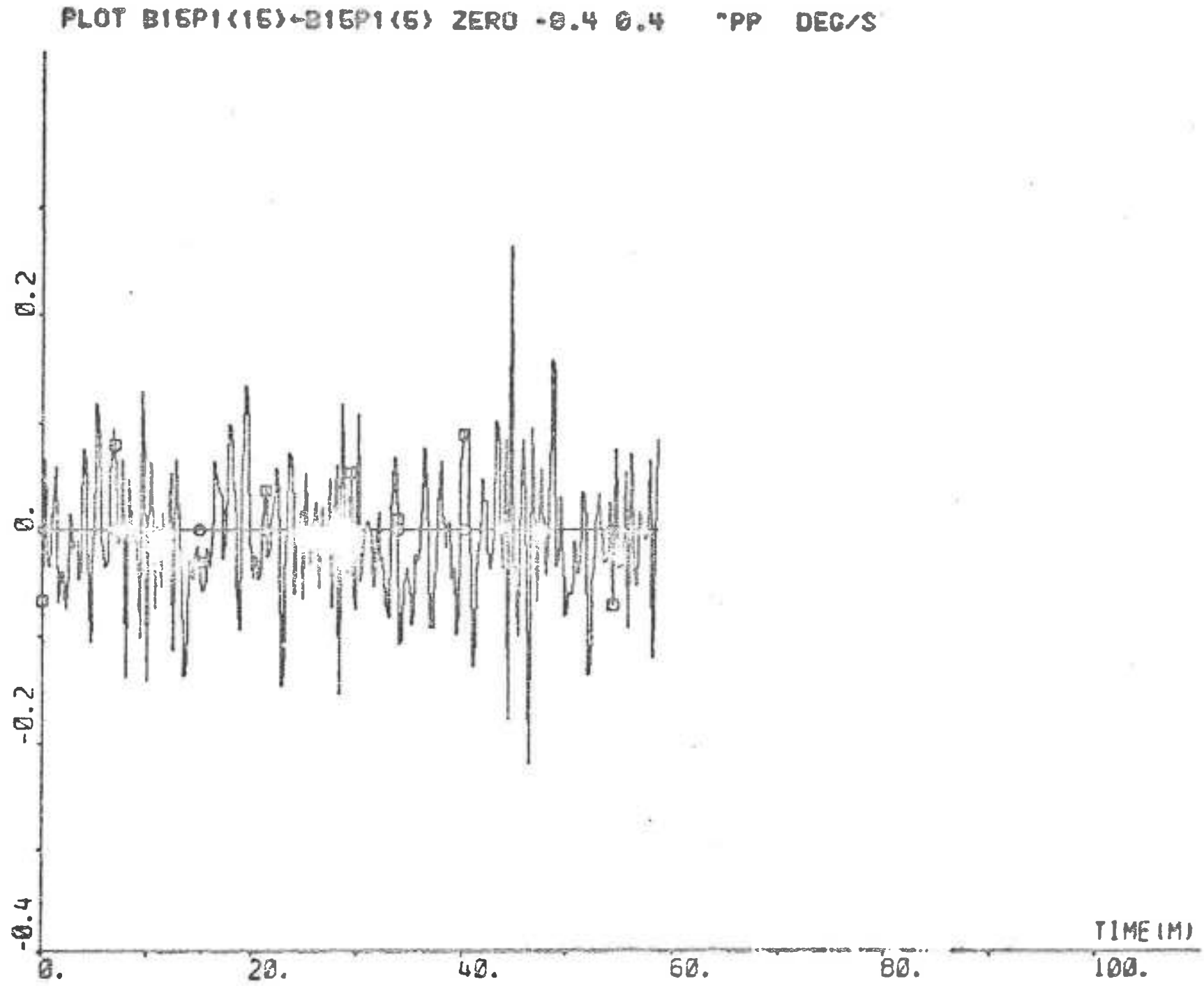
$$\begin{bmatrix} a_1' \\ a_2' \\ a_3' \\ b_1' \\ b_2' \end{bmatrix} = \begin{bmatrix} -43.841 \\ 5.296 \\ 1.558 \\ 1.321 \\ 0.819 \end{bmatrix} \qquad PY = \begin{bmatrix} 252.622 & & & & \\ -66.307 & 612.853 & & & \\ -92.024 & -316.671 & 391.749 & & \\ -5.996 & -10.851 & 10.072 & 0.594 & \\ -1.464 & -10.872 & 1.868 & 0.229 & 0.582 \end{bmatrix}$$

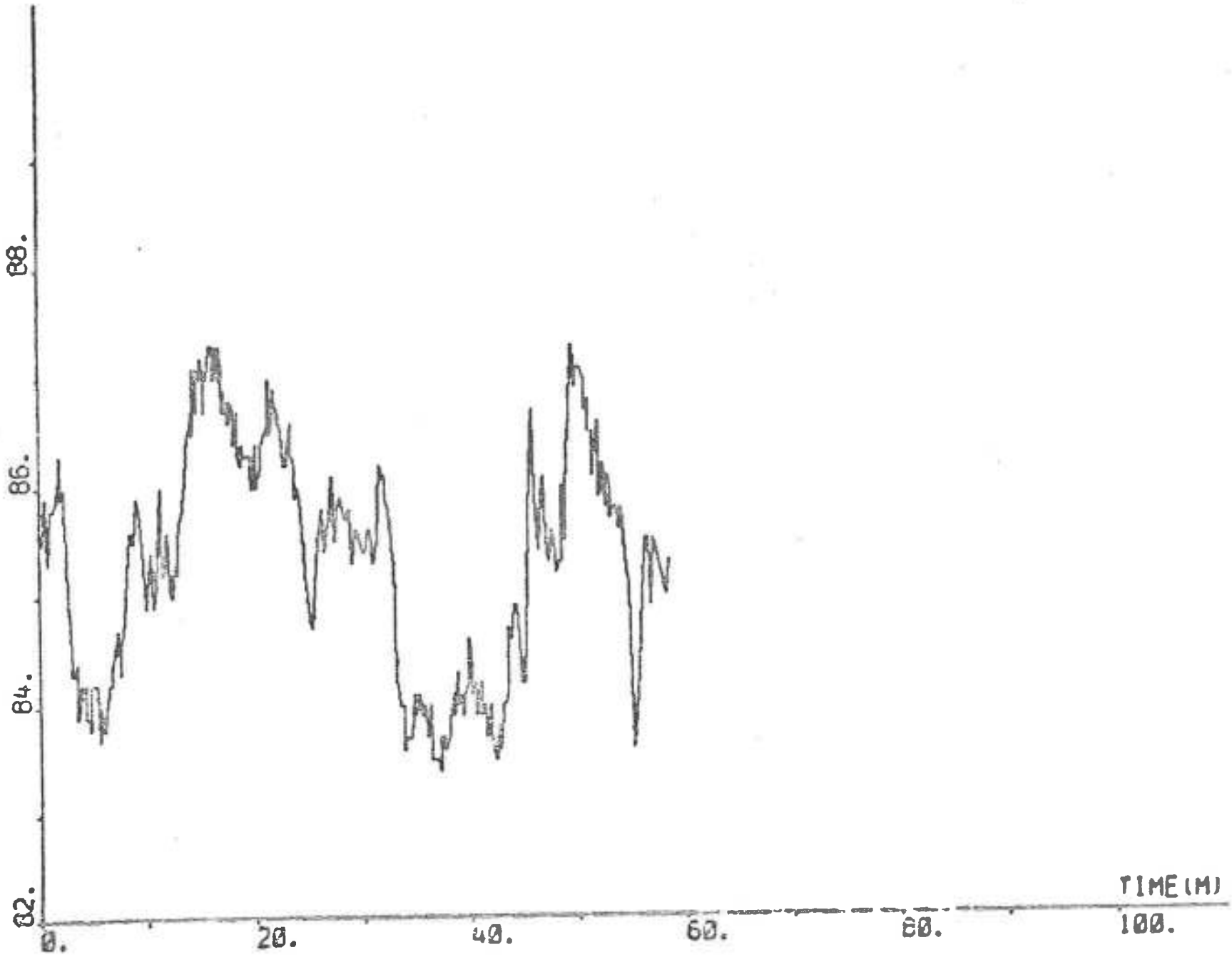
$a_1' + a_2' + a_3' = -36.987$

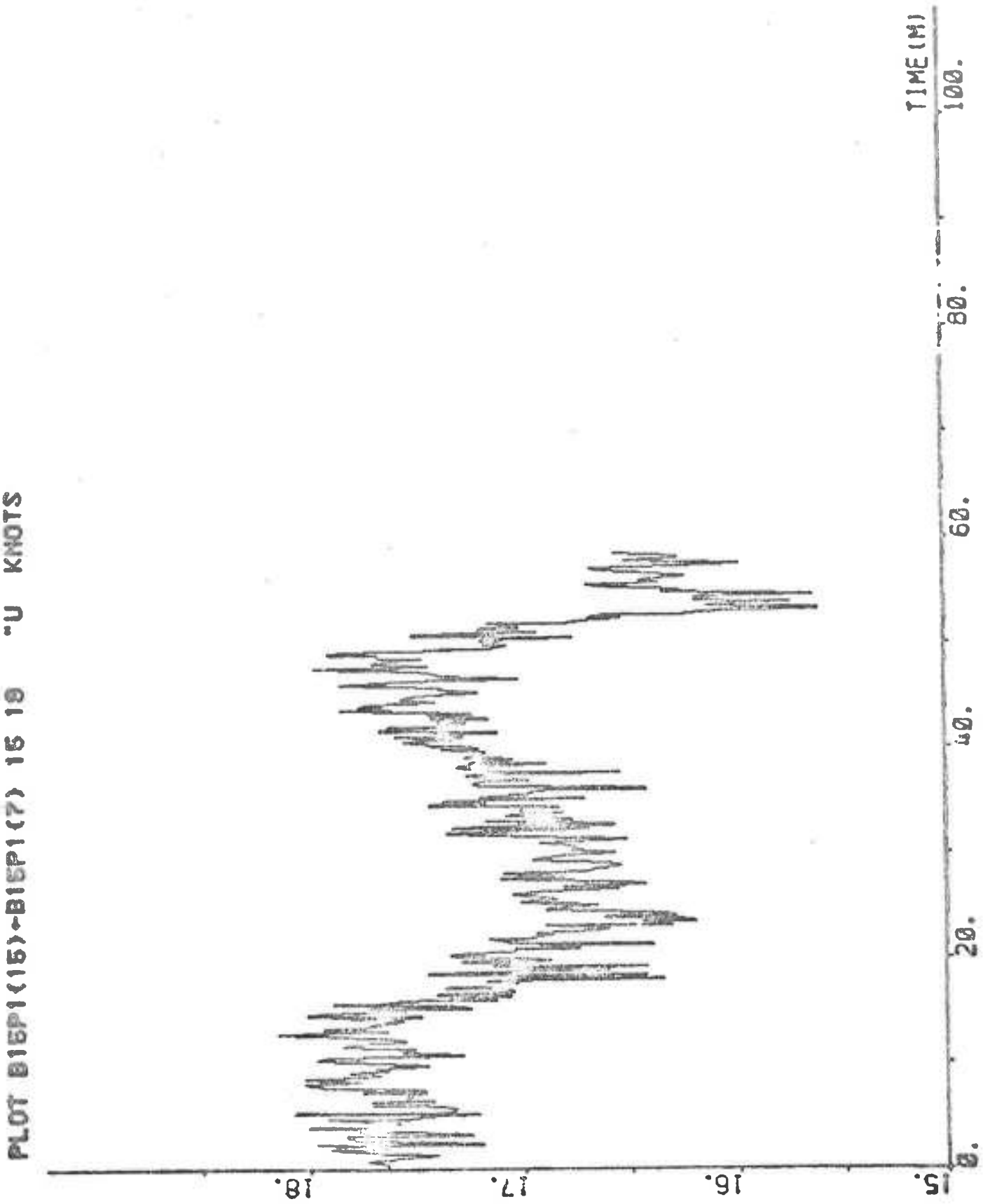

PLOT B16P1(16)-HP B16P1(1) ZERO -20 20 "DELCOC DEG
TIME(M)
0.
20.
40.
60.
80.
100.
-20.
-10.
0.
10.

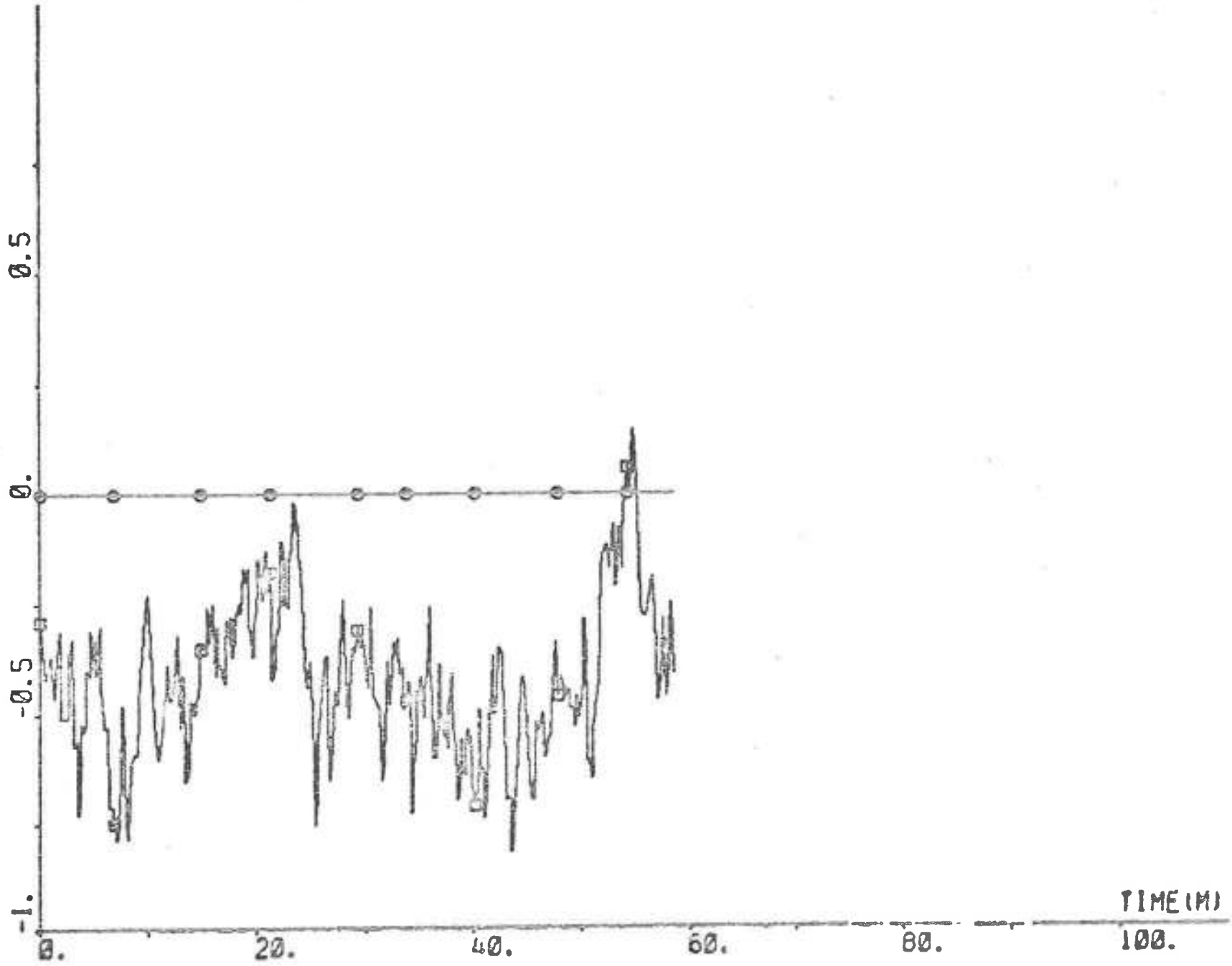

PLOT B15P1(15)-B15P1(3) ZERO -20 20 "DELTAS DEG
10.
0.
-10.
-20.
0.
20.
40.
60.
80.
100.
TIME(H)

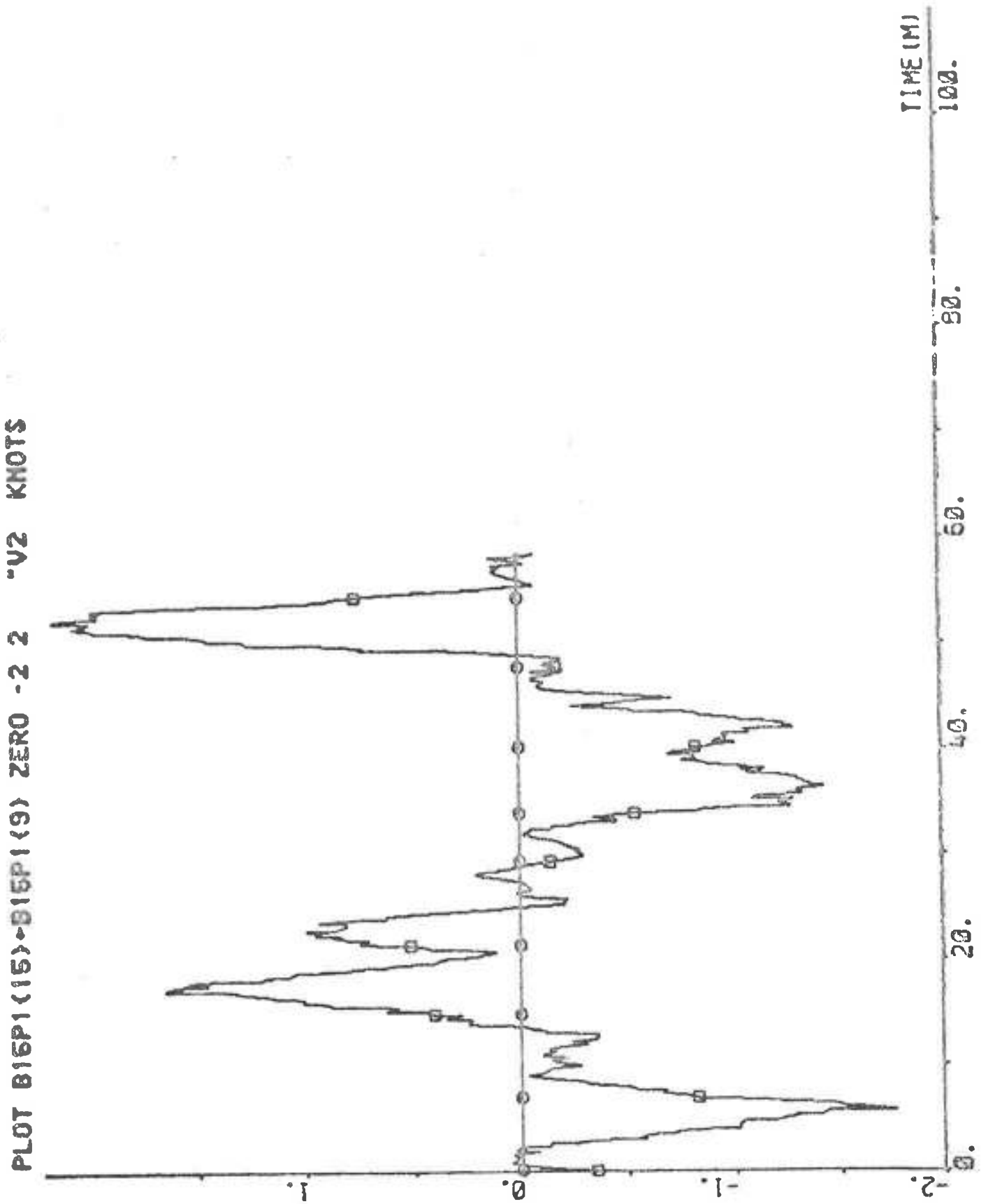

PLOT B15P1(15)-B15P1(4) ZERO -20 20 "DELTA DEG
10.
0.
-10.
-20.
0.
20.
40.
60.
80.
100.
TIME(M)

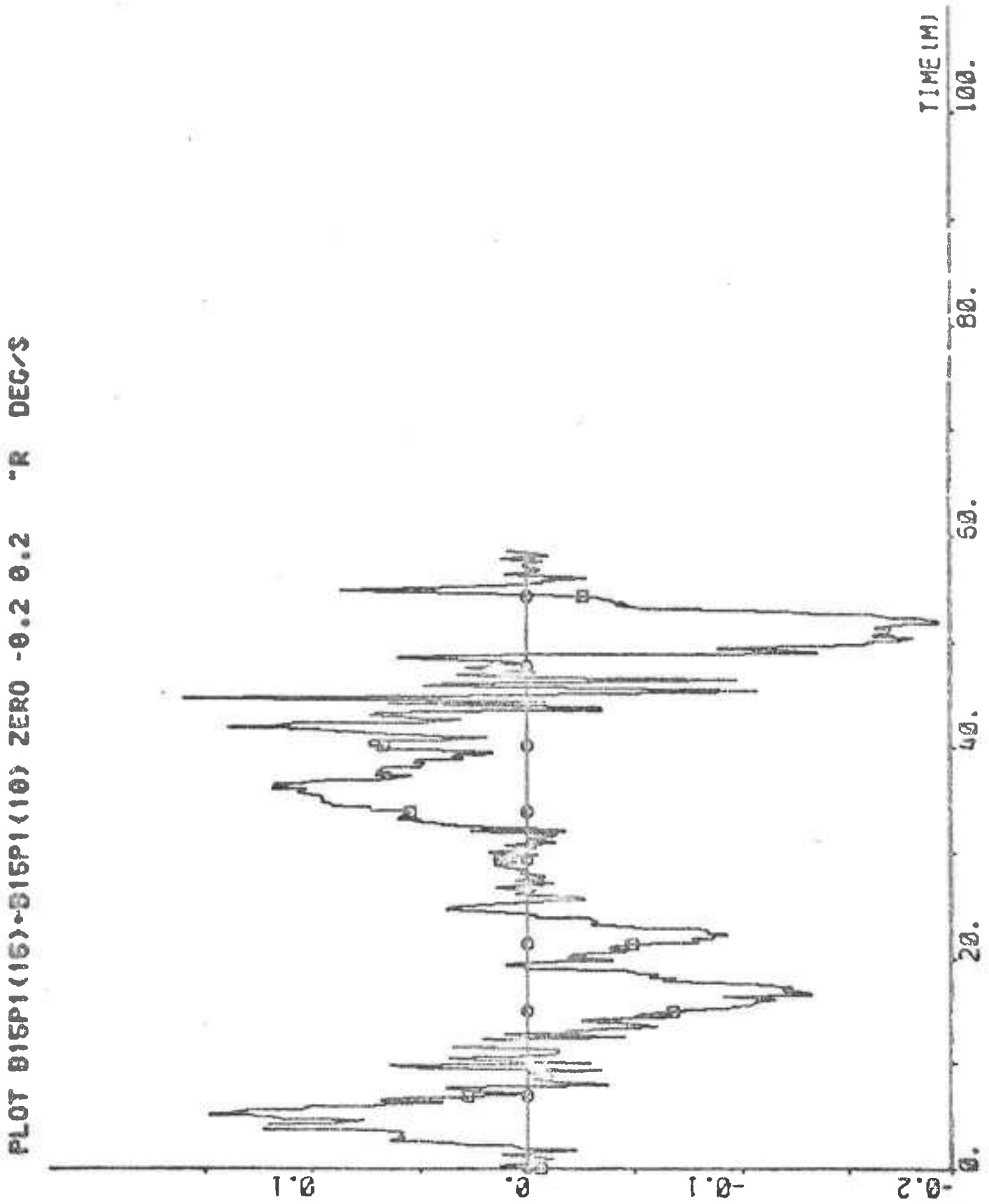

PLOT B16P1(16)-B16P1(5) ZERO -0.4 0.4 "PP DEG/S
0.2
0.
-0.2
-0.4
0.
20.
40.
60.
80.
100.
TIME(M)

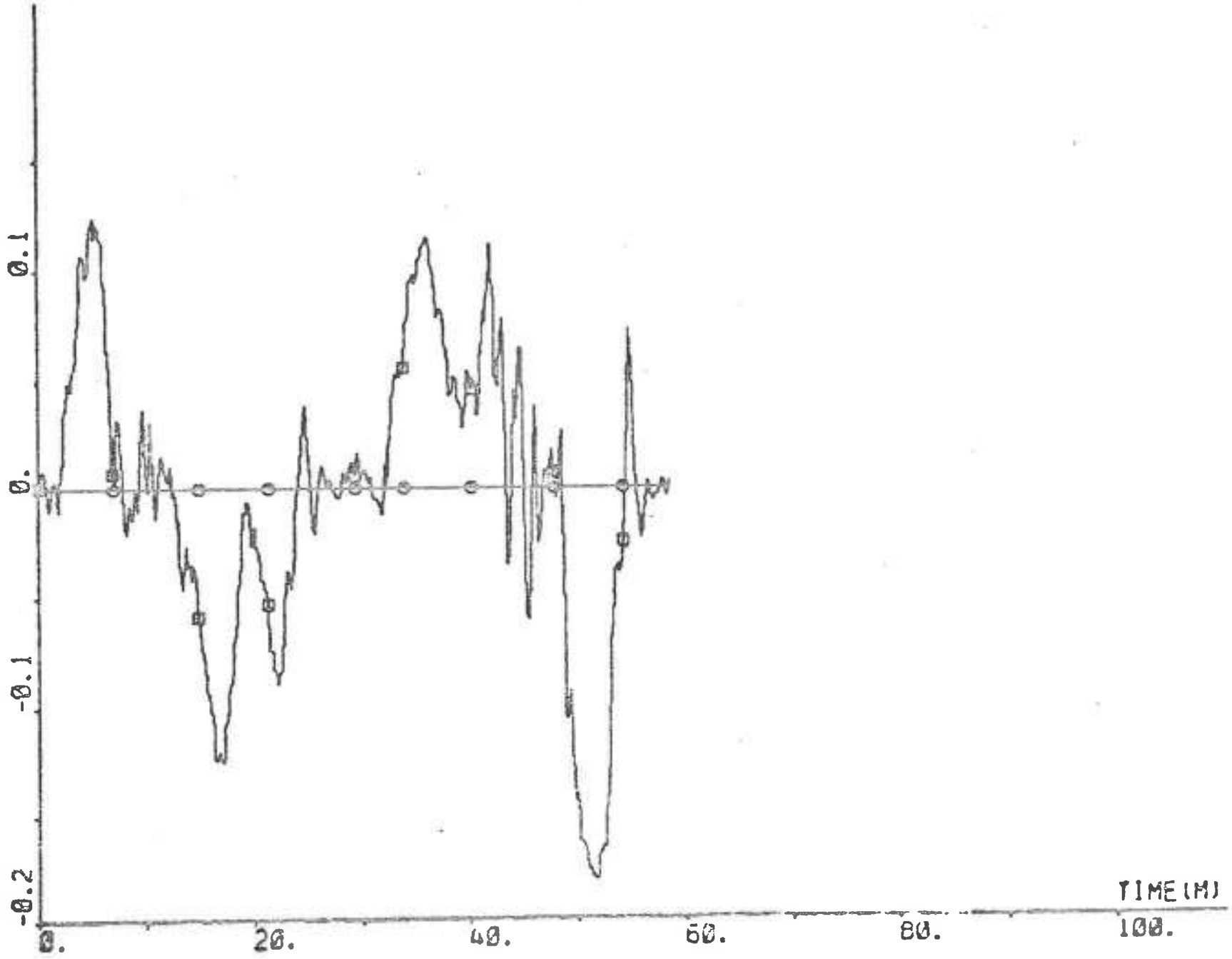

PLOT B15P1(15)-B15P1(6) 82 90 "AN RPM
88.
86.
84.
82.
0.
20.
40.
60.
80.
100.
TIME(M)

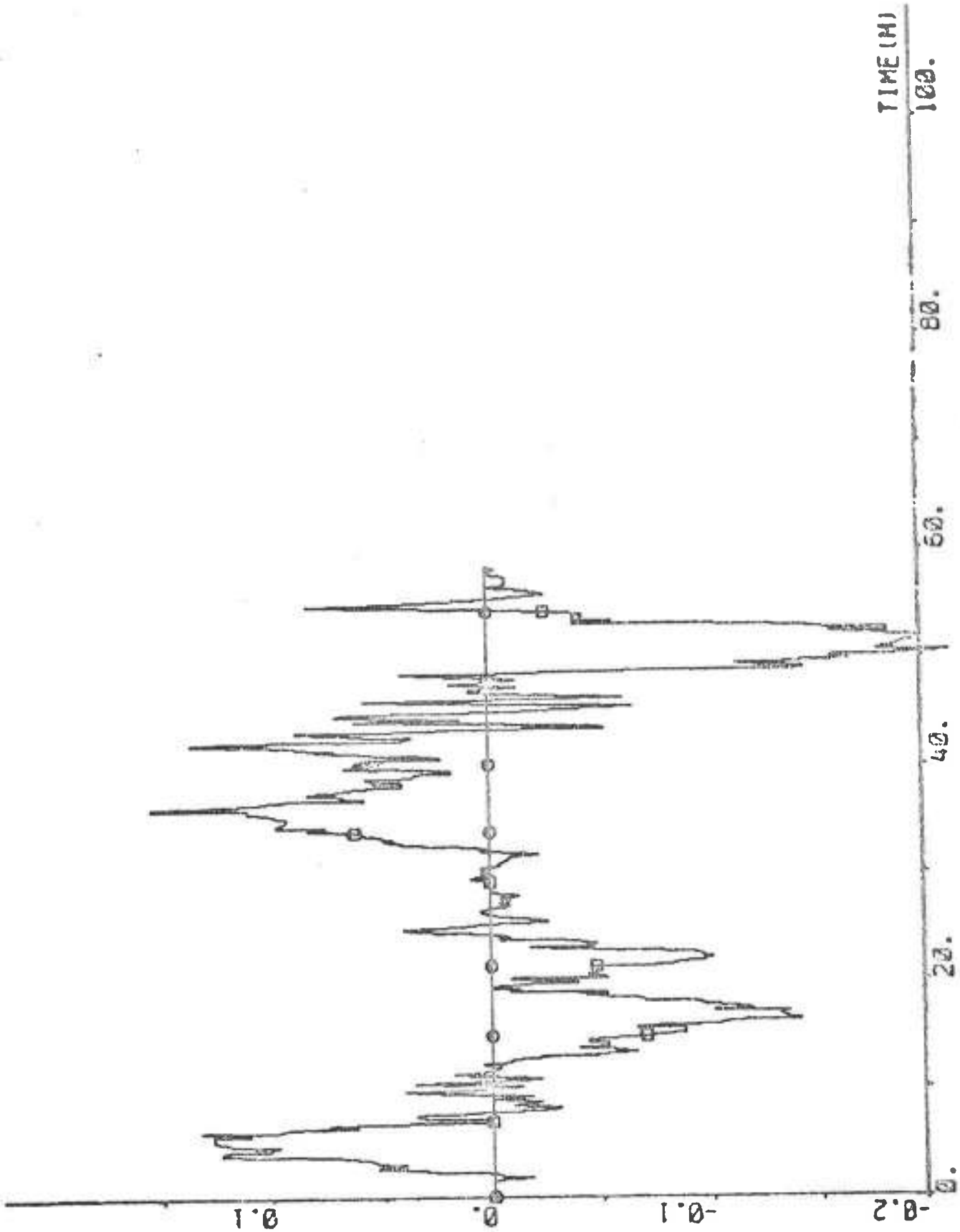

PLOT B1SP1(15)-B1SP1(7) 15 10 "U KNOTS
TIME(M)
0.
20.
40.
60.
80.
100.
15.
16.
17.
18.

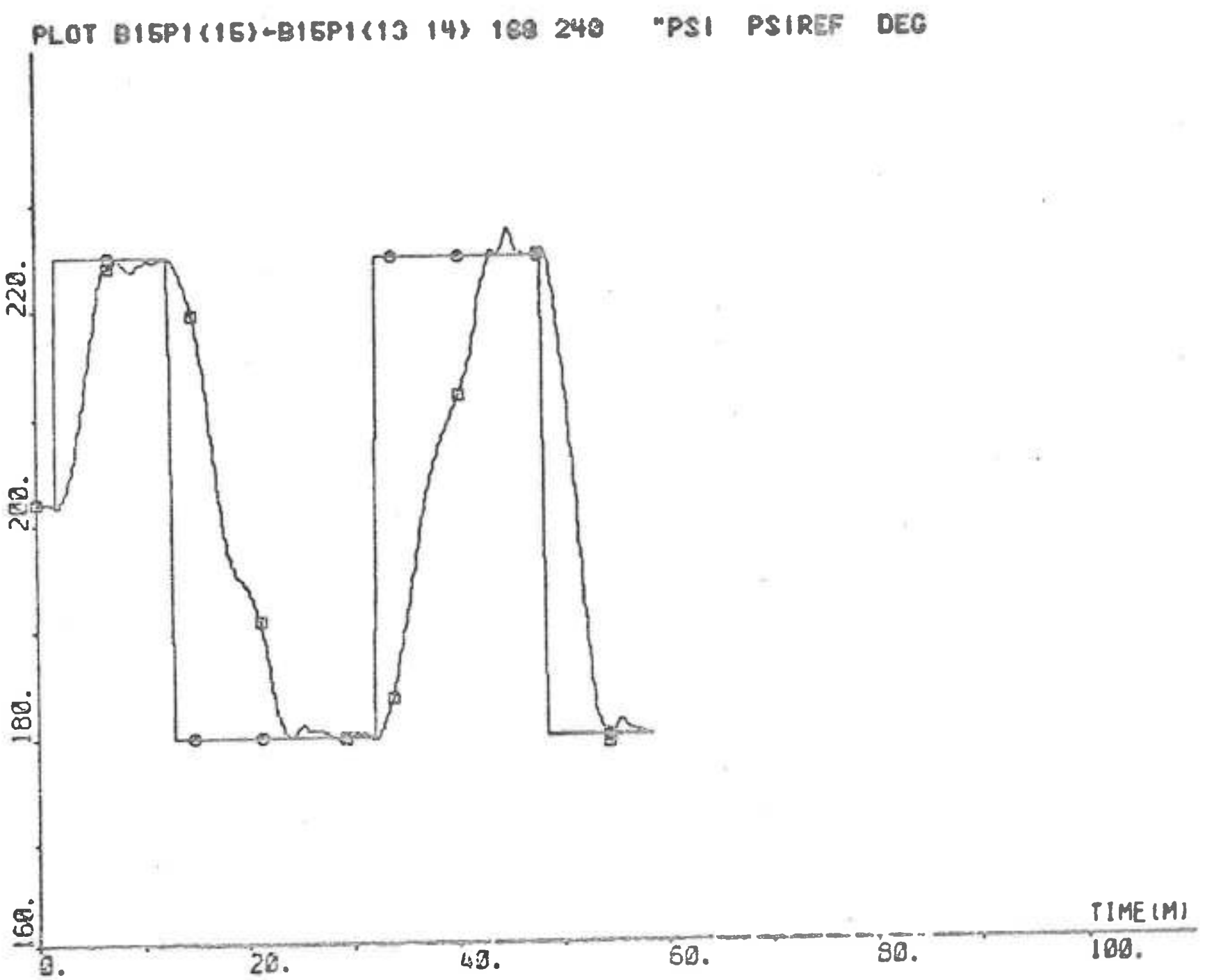

PLOT B16P1(15)-B16P1(0) ZERO -1 1 "V1 KNOTS
0.5
0.
-0.5
-1.
0.
20.
40.
60.
80.
100.
TIME(M)

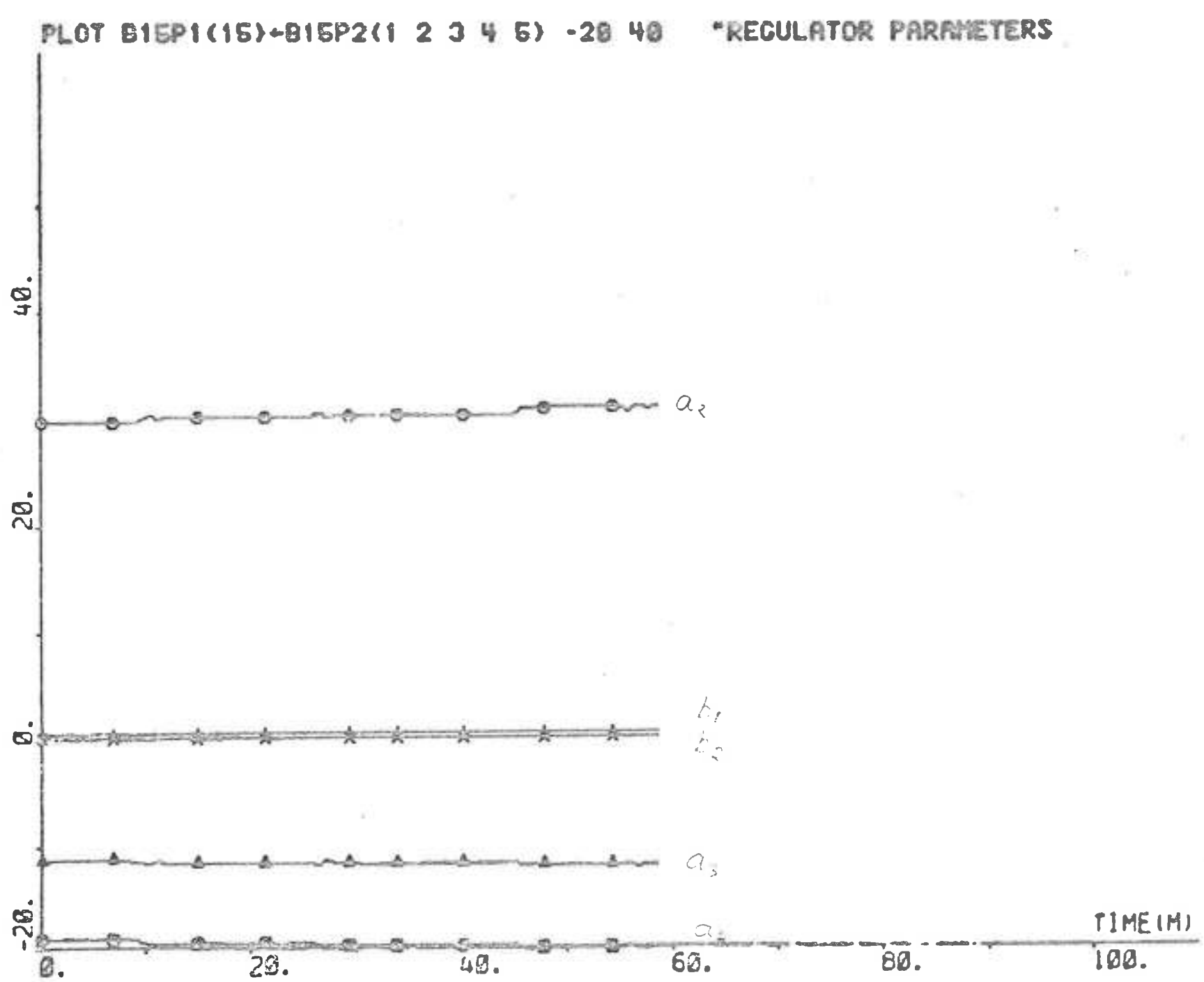

PLOT B16P1(15)-B16P1(9) ZERO -2 2 "V2 KNOTS
1.
0.
-1.
-2.
0.
20.
40.
60.
80.
100.
TIME(M)


PLOT B15P1(15)-B15P1(10) ZERO -0.2 0.2 "R DEG/S
TIME(M)
0.
20.
40.
60.
80.
100.
0.2
0.1
0.
-0.1
-0.2

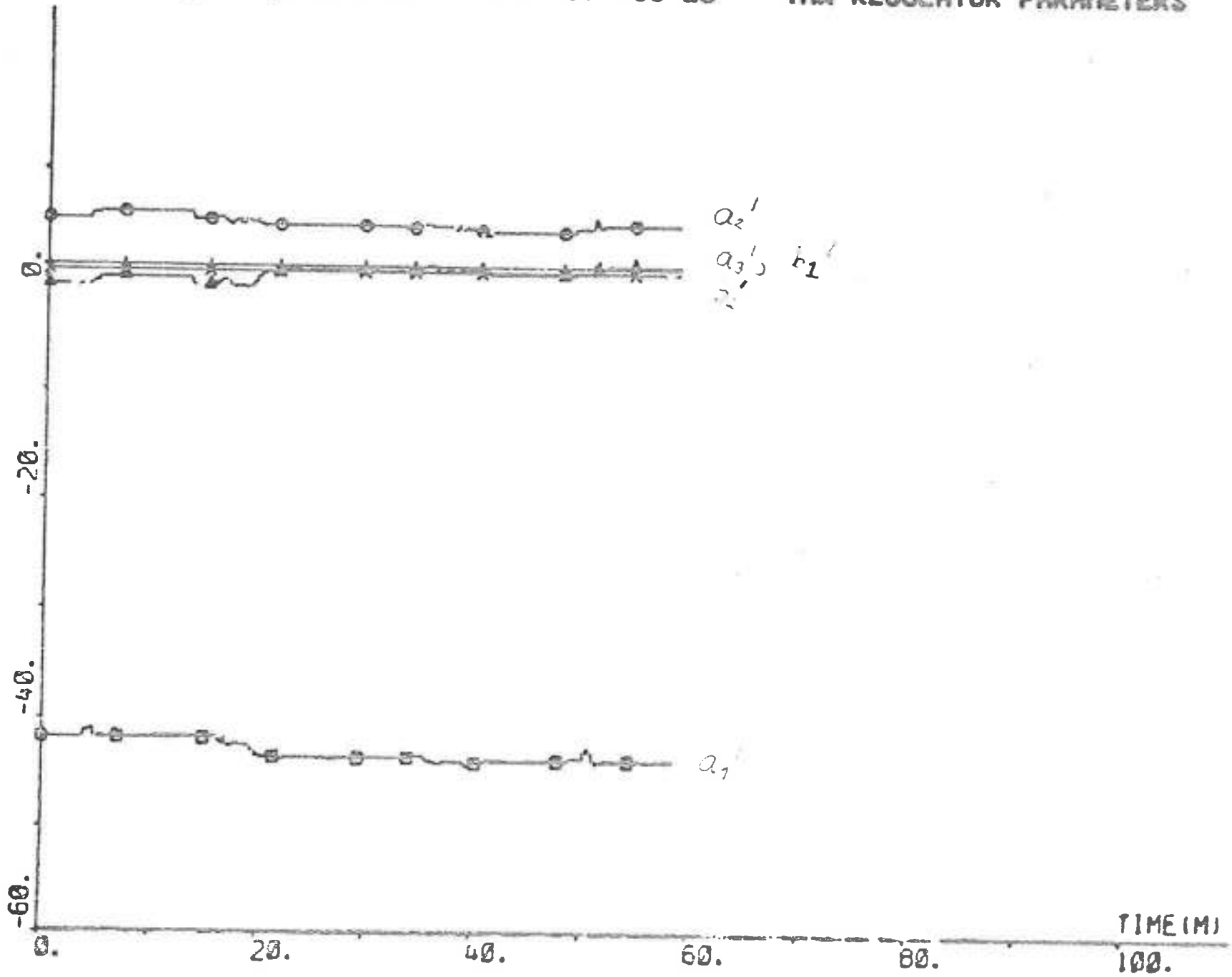

PLOT B15P1(16)-B15P1(11) ZERO -0.2 0.2 "AVR DEG/S (BR=0.2)
0.1
0.
-0.1
-0.2
0.
20.
40.
60.
80.
100.
TIME(M)

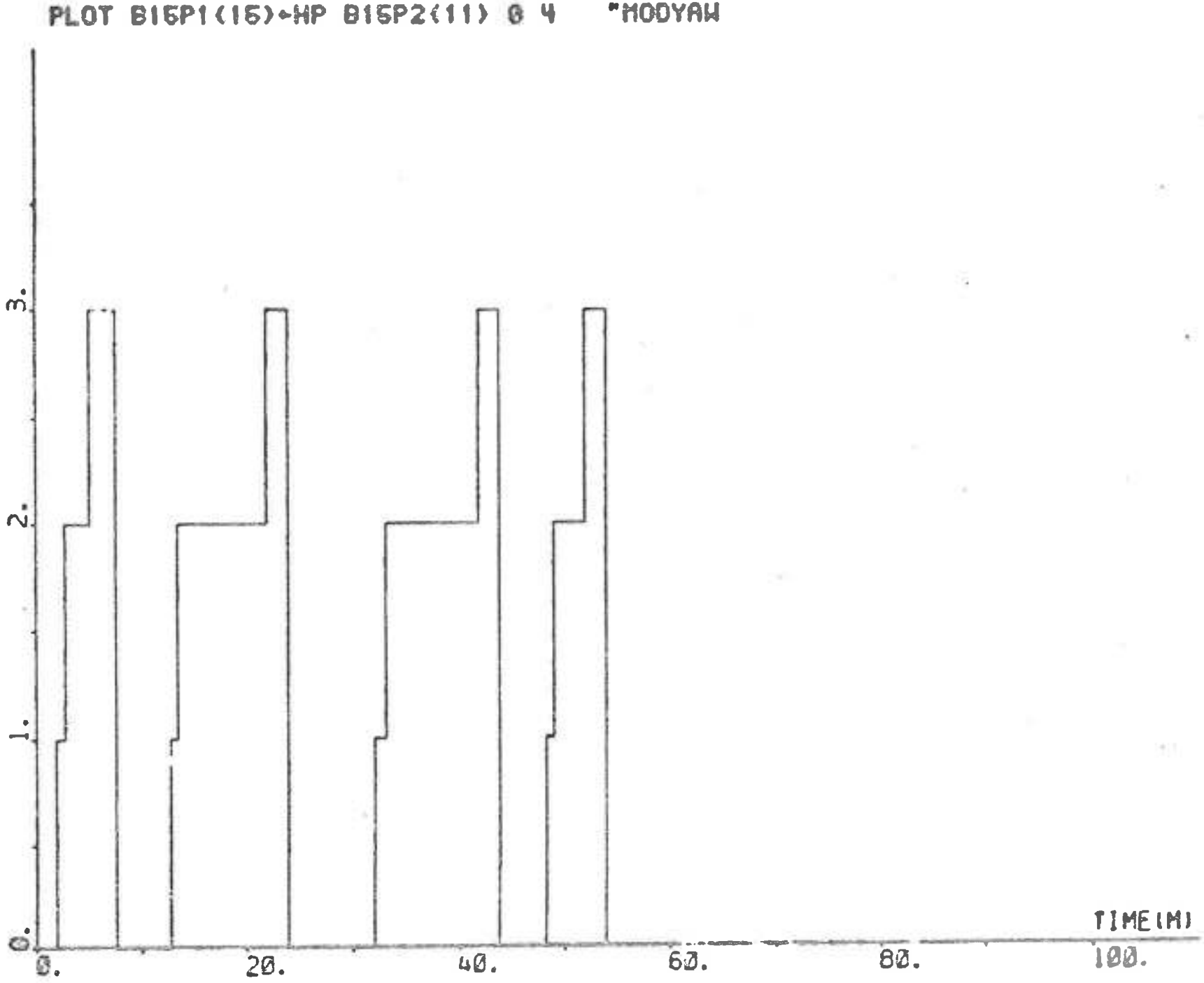

PLOT B16P1(16)-B15P1(12) ZERO -0.2 0.2 "DPSIDT DEG/S (10PSI*5)
TIME(H)
0.
20.
40.
60.
80.
100.
0.1
0.
-0.1
-0.2


PLOT B15P1(15)-B15P1(13 14) 160 240 "PSI PSIREF DEG
220.
200.
180.
160.
0.
20.
40.
60.
80.
100.
TIME(M)


PLOT B15P1(15)-B15P2(1 2 3 4 5) -20 40 *REGULATOR PARAMETERS
40.
20.
0.
-20.
0.
20.
40.
60.
80.
100.
TIME(M)
a2
b1
b2
a3
a1

PLOT B15P1(15)-B15P2(6 7 8 9 10) -60 20 *YAW REGULATOR PARAMETERS




PLOT B16P1(16)-HP B16P2(11) 0 4 "MODYAW
3.
2.
1.
0.
0.
20.
40.
60.
80.
100.
TIME(M)

EXPERIMENT C1

Date	1974-10-16
Time	10.35
Duration	33 min
Position	S 00° 27' E 48° 50'
Water depth	deep
Forward draught	20.2 m
Aft draught	20.2 m
Wind direction	S (8; see Appendix A)
Wind velocity	3-4 Beaufort (4-8 m/s, gentle to moderate breeze)
Wave height	4 m
PSIREF	208°
Rudder limit	Not active

Probably misleading measurements of U, V1 and V2 due to air-bubbles below the doppler logs. The yaw rate signal R was limited to ±0.03 deg/s.

Parameter values of the PID-regulator

$k_P = 0.5$ $k_D = 135$ s $k_I = 1/135$ s^{-1} $T_s = 15$ s

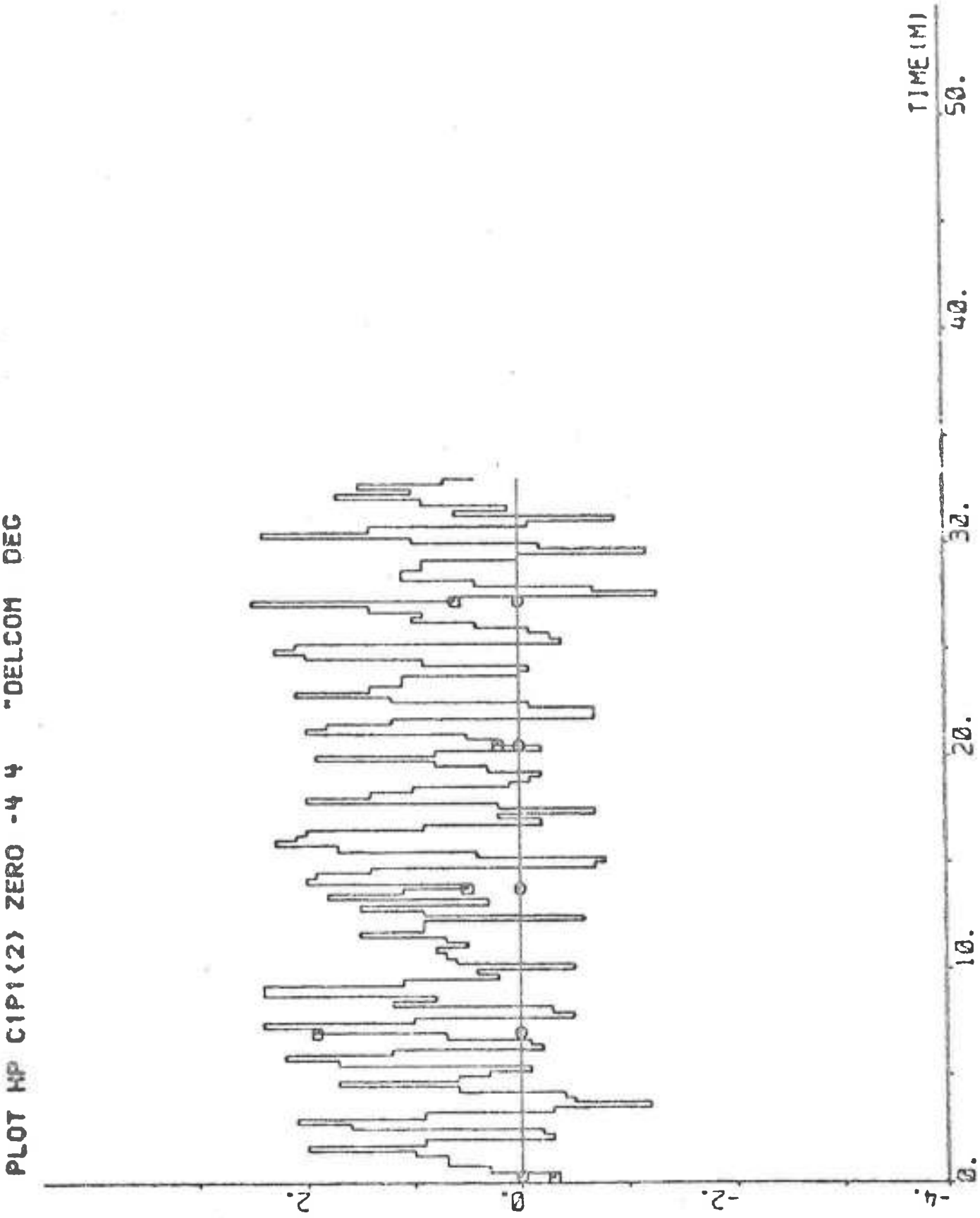
The parameters were manually tuned before the experiment started.

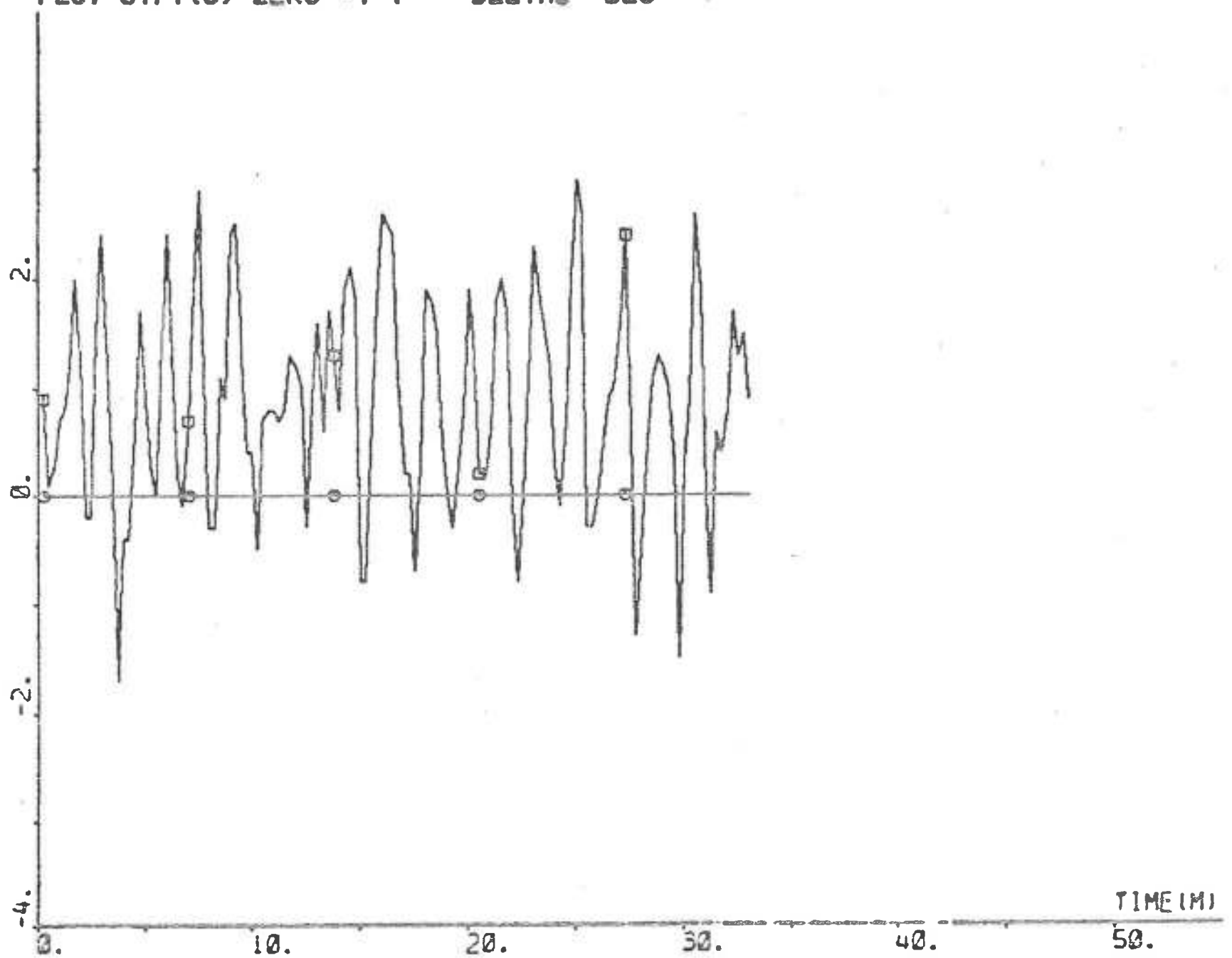
Statistics (mean value and standard deviation)

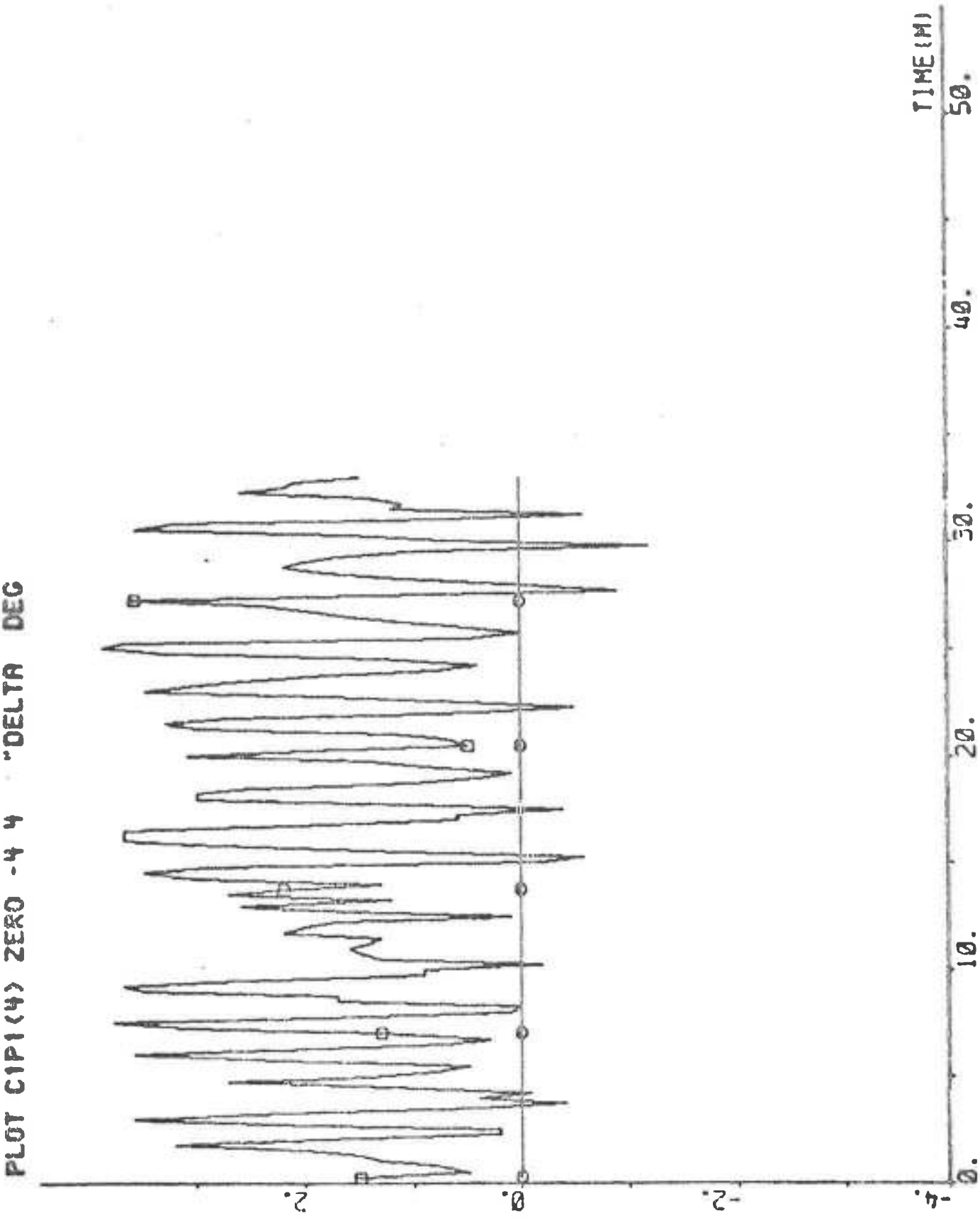
DELTA	1.60 ± 1.21 deg
PSI-PSIREF	0.024 ± 0.252 deg
AN	85.65 ± 0.26 rpm
U	19.25 ± 0.10 knots

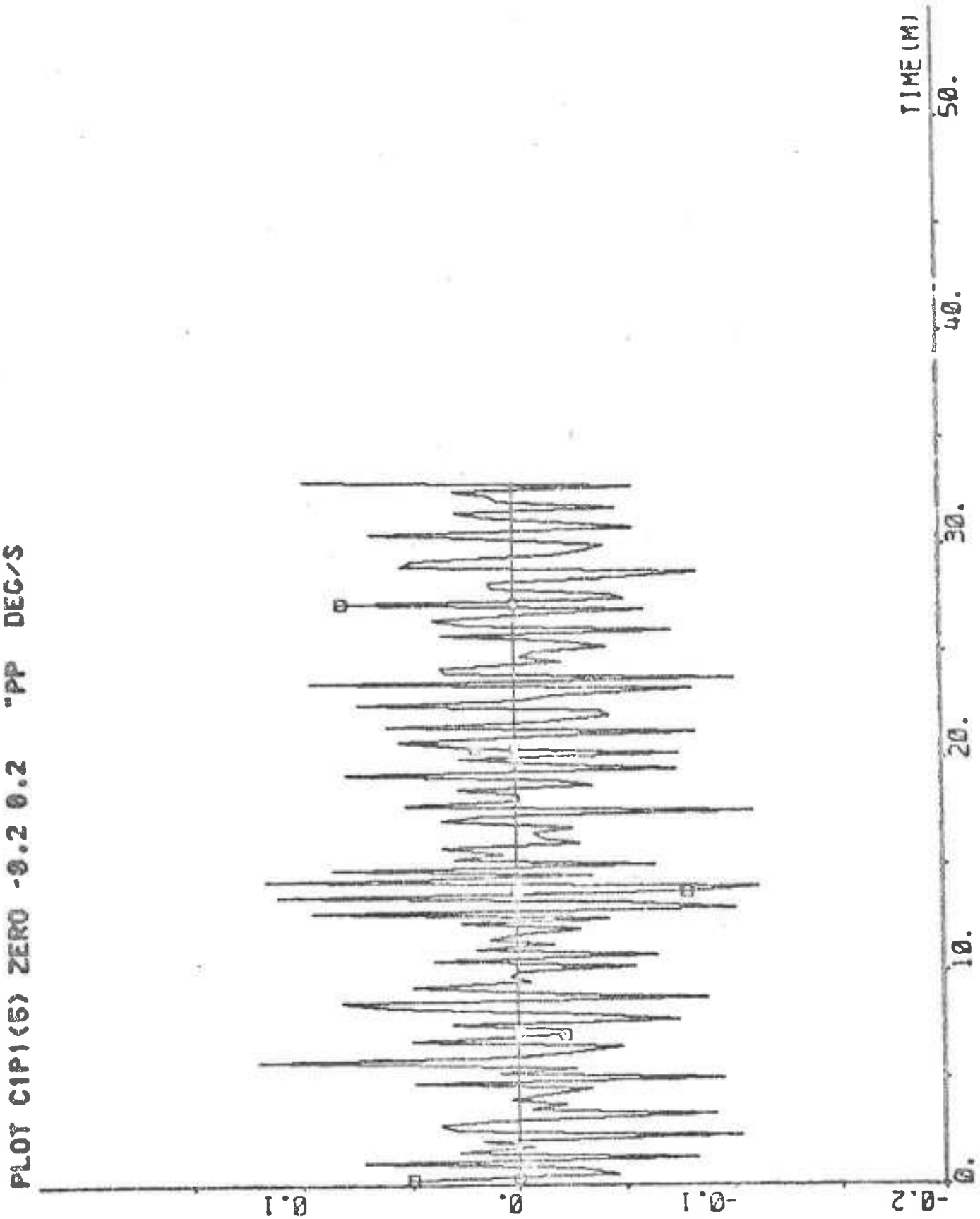
$V_1 = 0.466$

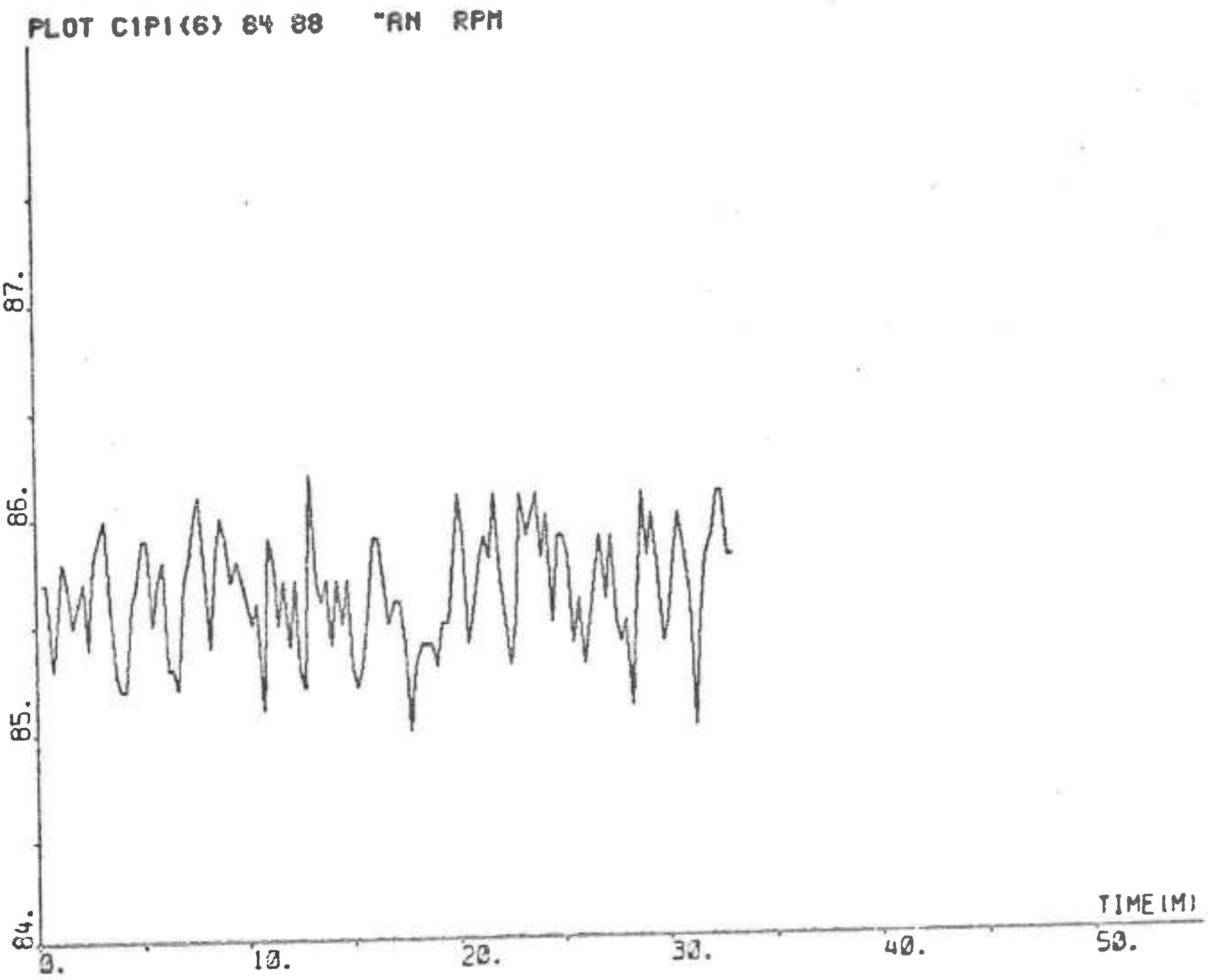
$V_2 = 0.210$

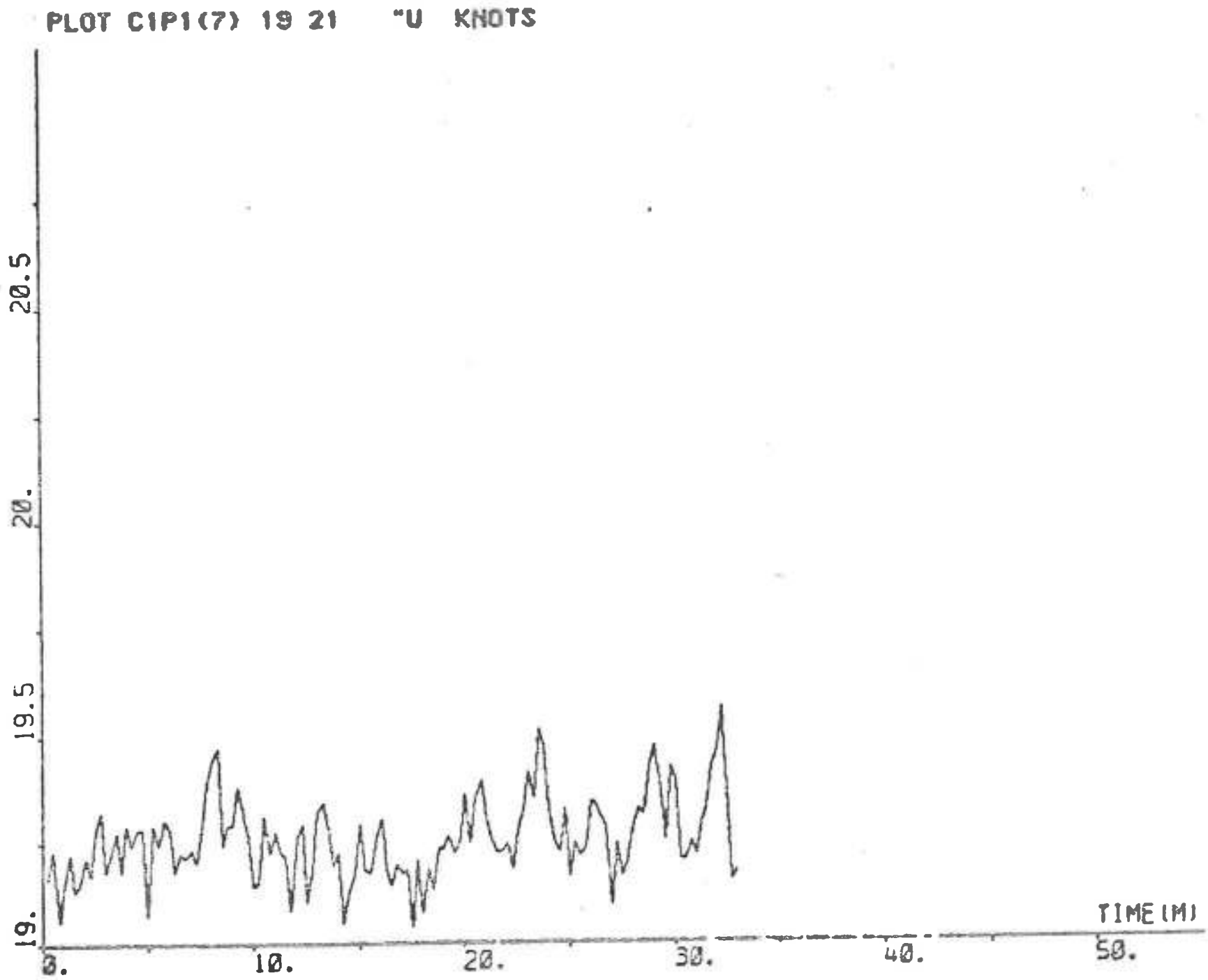

PLOT HP C1P1(2) ZERO -4 4 "DELCOM DEG
TIME(M)
0.
10.
20.
30.
40.
50.
2.
0.
-2.
-4.


PLOT C1P1(3) ZERO -4 4 °DELTAS DEG
2.
0.
-2.
-4.
0.
10.
20.
30.
40.
50.
TIME(M)

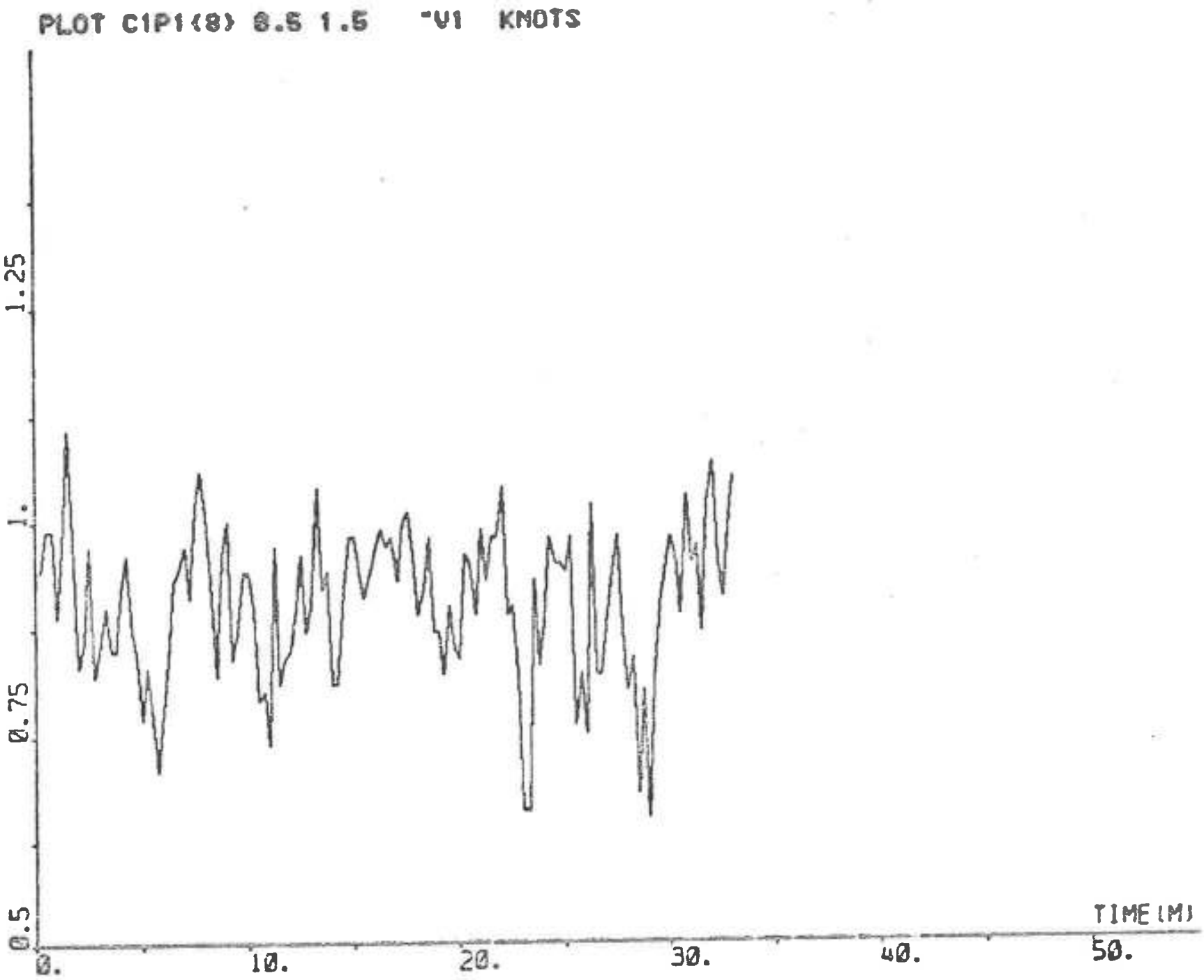

PLOT C1P1(4) ZERO -4 4 "DELTA DEG
TIME(M)
0.
10.
20.
30.
40.
50.
4.
2.
0.
-2.

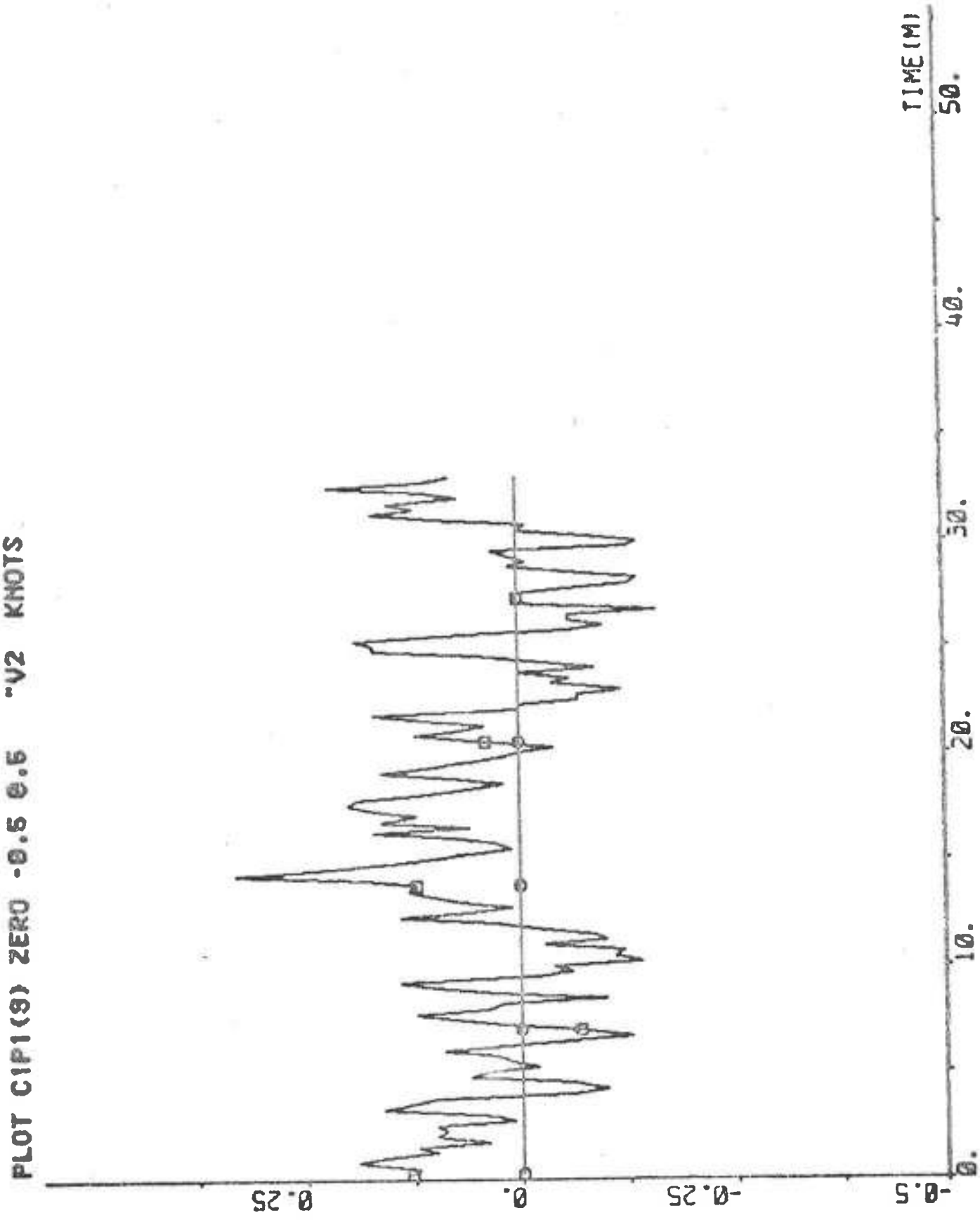

PLOT C1P1(5) ZERO -0.2 0.2 "PP DEG/S
TIME(M)
0.
10.
20.
30.
40.
50.
-0.2
-0.1
0.
0.1

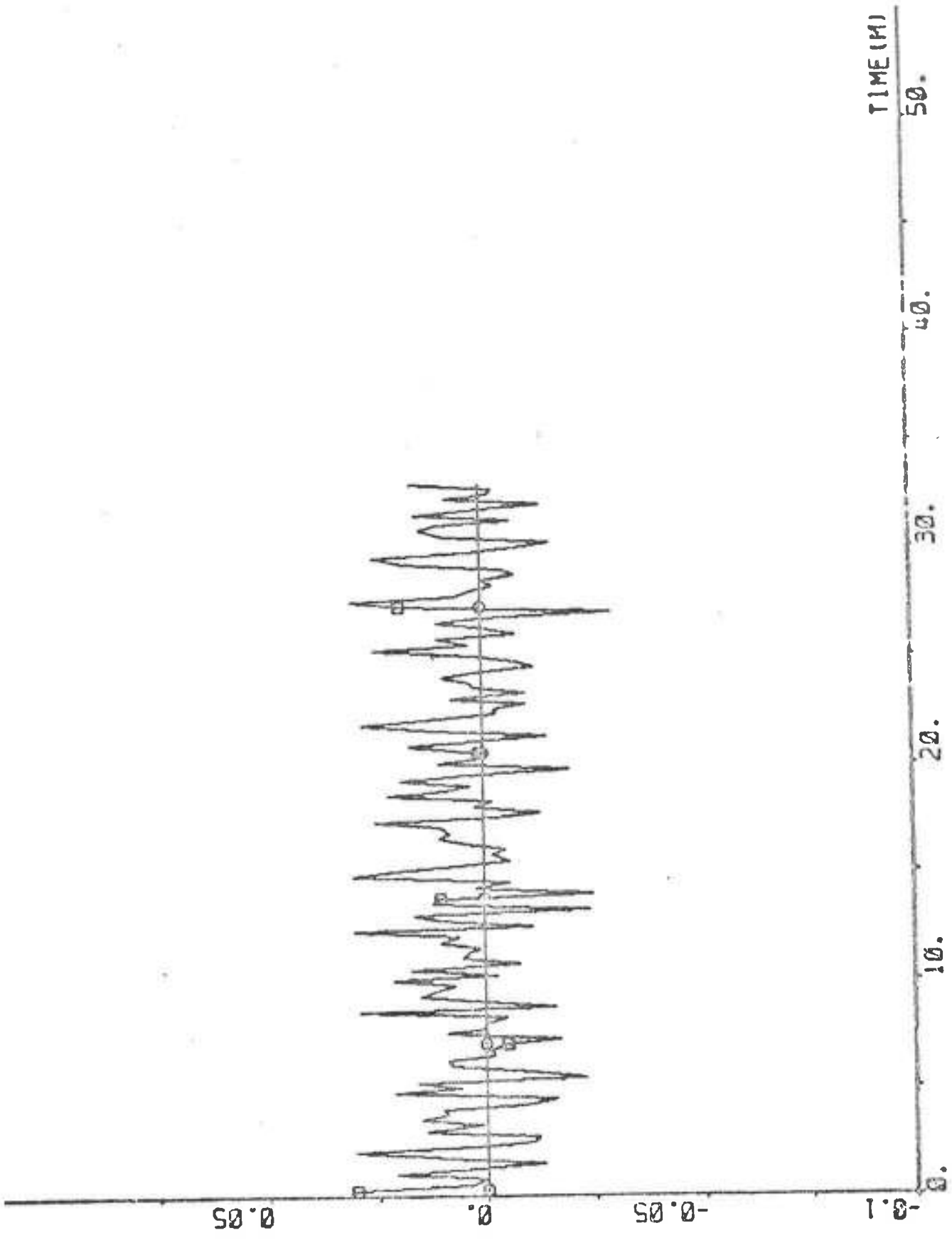

PLOT C1P1(6) 64 88 "AN RPM
87.
86.
85.
84.
0.
10.
20.
30.
40.
50.
TIME(M)

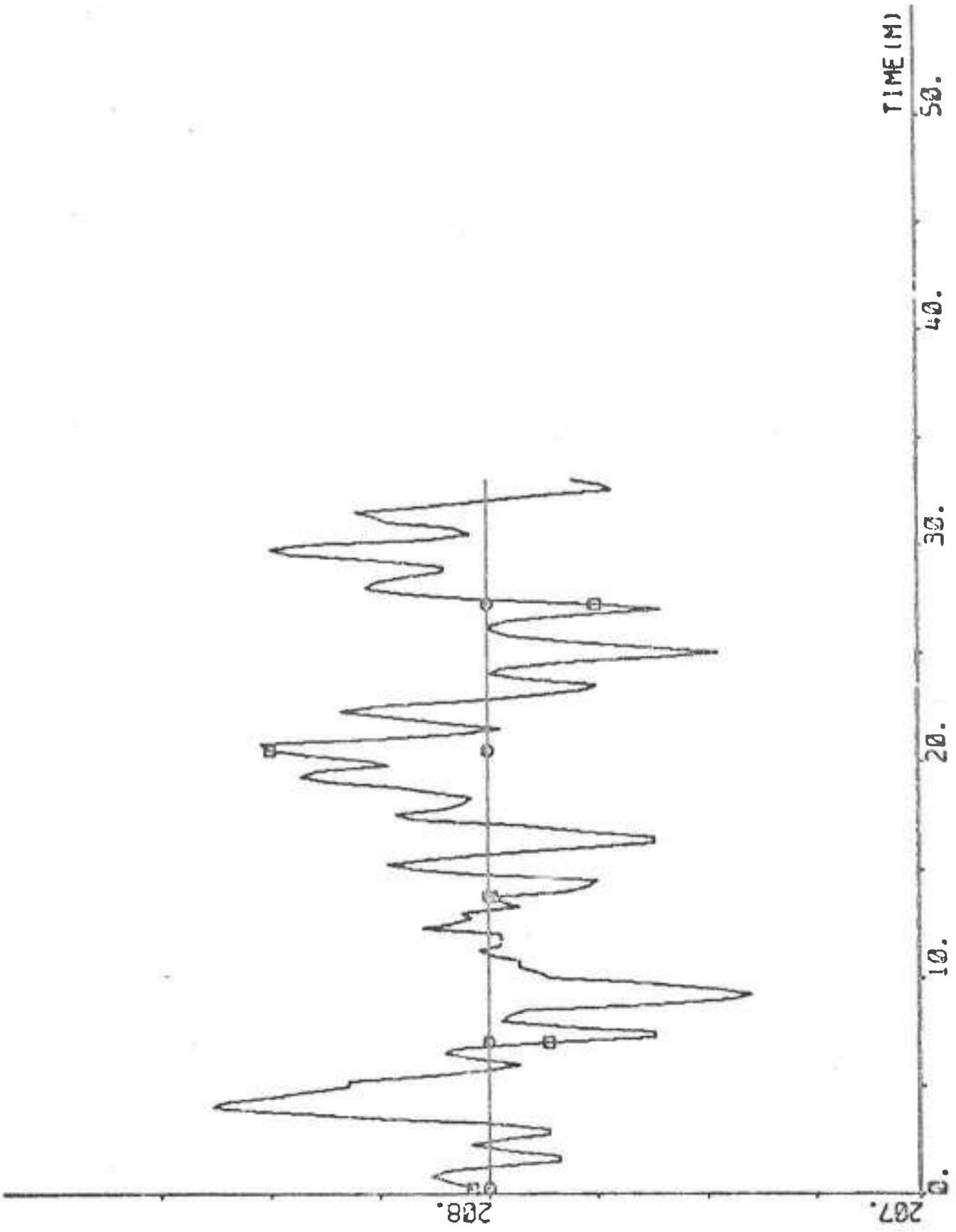


.968.


PLOT C1P1(8) 0.5 1.5 "V1 KNOTS
1.25
1.
0.75
0.5
0.
10.
20.
30.
40.
50.
TIME(M)


PLOT C1P1(9) ZERO -0.5 0.5 "V2 KNOTS
0.25
0.
-0.25
-0.5
0.
10.
20.
30.
40.
50.
TIME(M)


PLOT C1P1(10) ZERO -0.1 0.1 "R DEG/S
0.05
0.
-0.05
-0.1
0.
10.
20.
30.
40.
50.
TIME(M)


PLOT CIP1(13 14) 207 208 "PSI PSIREF DEG
TIME(M)
0.
10.
20.
30.
40.
50.
207.
208.

EXPERIMENT C2

Date	1974-10-17
Time	16.50
Duration	37 min
Position	S 07^{o} 40' E 45^{o} 06'
Water depth	deep
Forward draught	20.2 m
Aft draught	20.2 m
Wind direction	SE (7; see Appendix A)
Wind velocity	3-4 Beaufort (4-8 m/s, gentle to moderate breeze)
Wave height	3 - 5 m
PSIREF	208^{o}
Rudder limit	Not active

The yaw rate signal R was limited to ±0.03 deg/s.

Parameter values of the PID-regulator.

$k_P = 1.3$ $k_D = 105$ s $k_I = 1/105$ s^{-1} $T_s = 15$ s

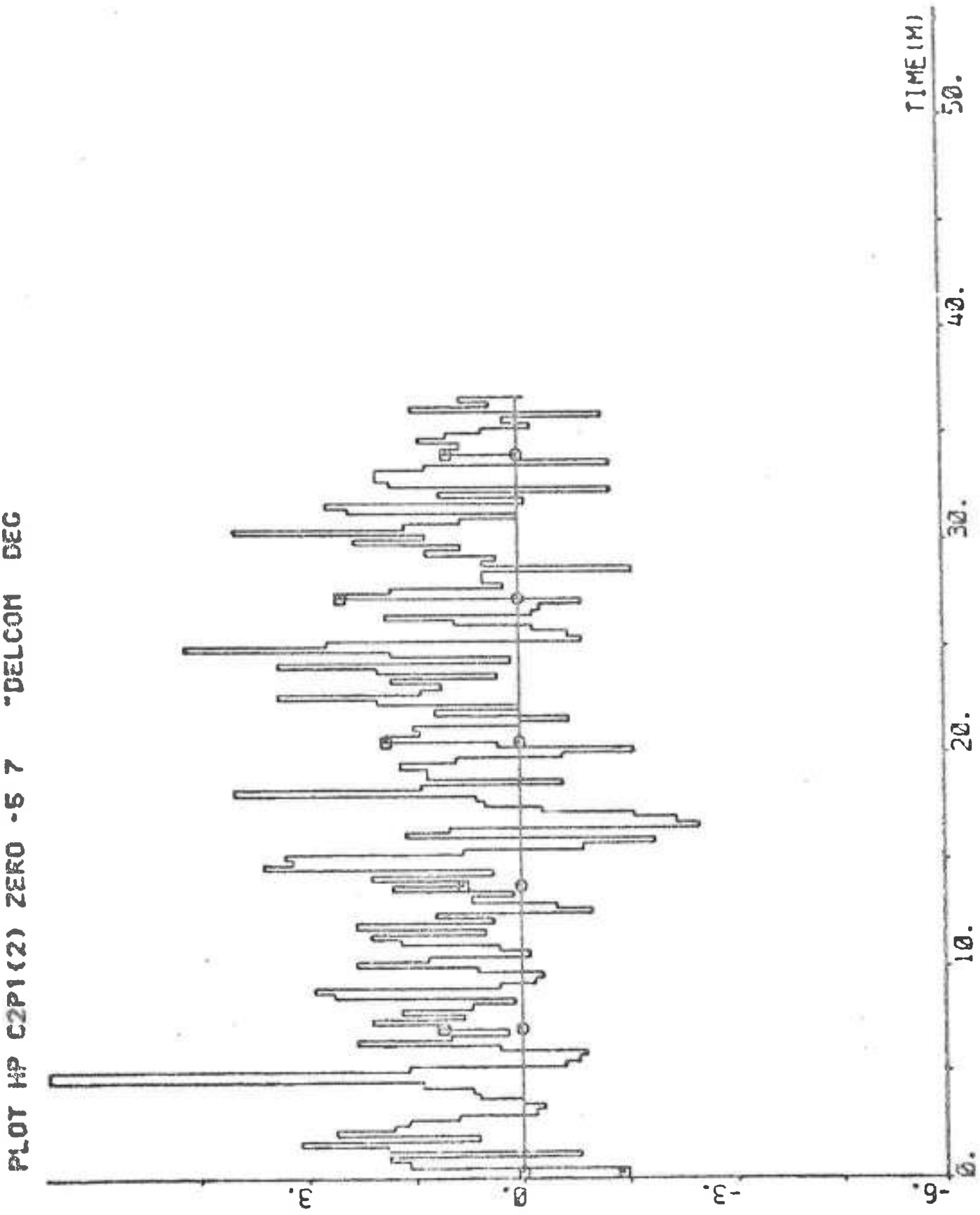
The parameters were manually tuned before the experiment started.

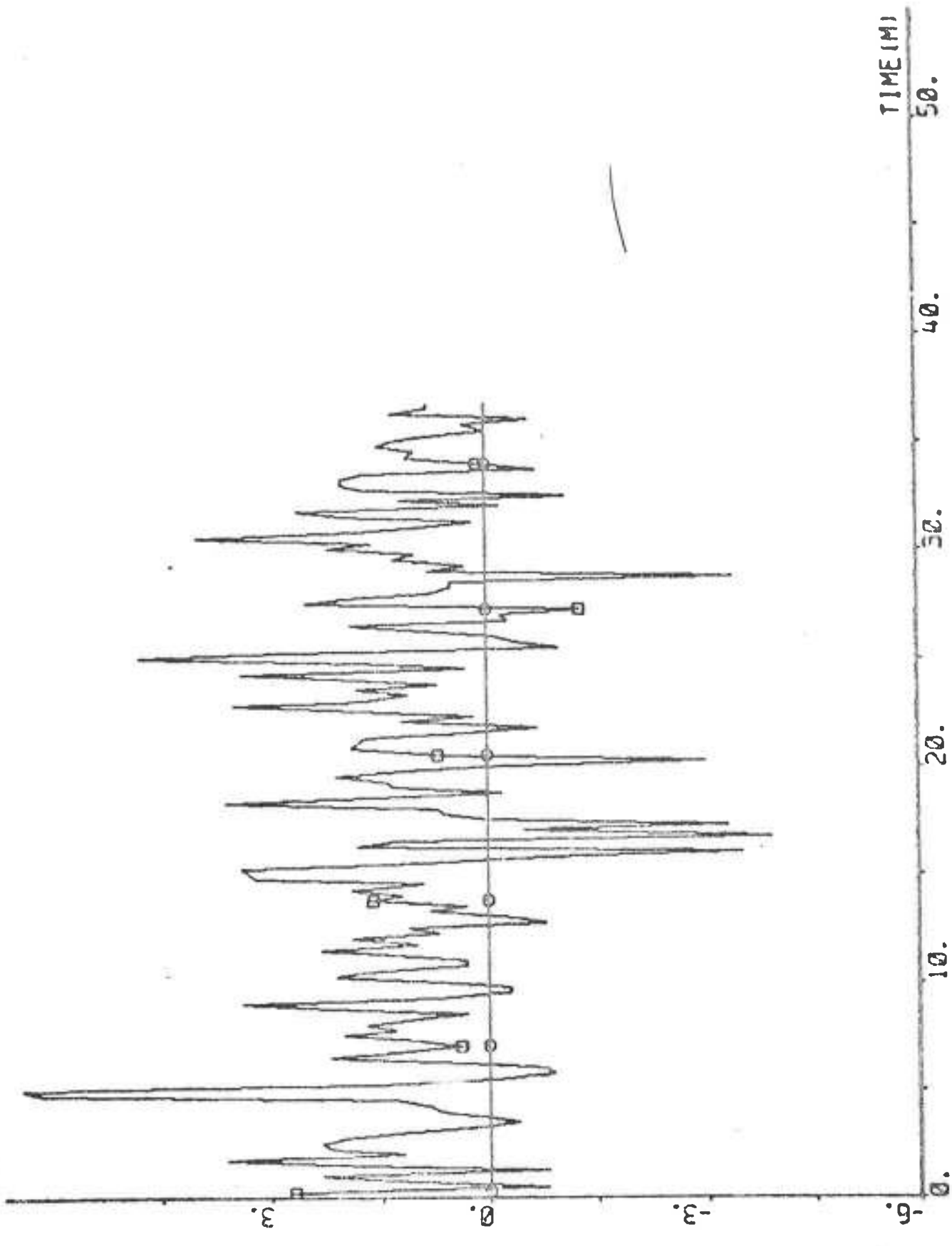
Statistics (mean value and standard deviation)

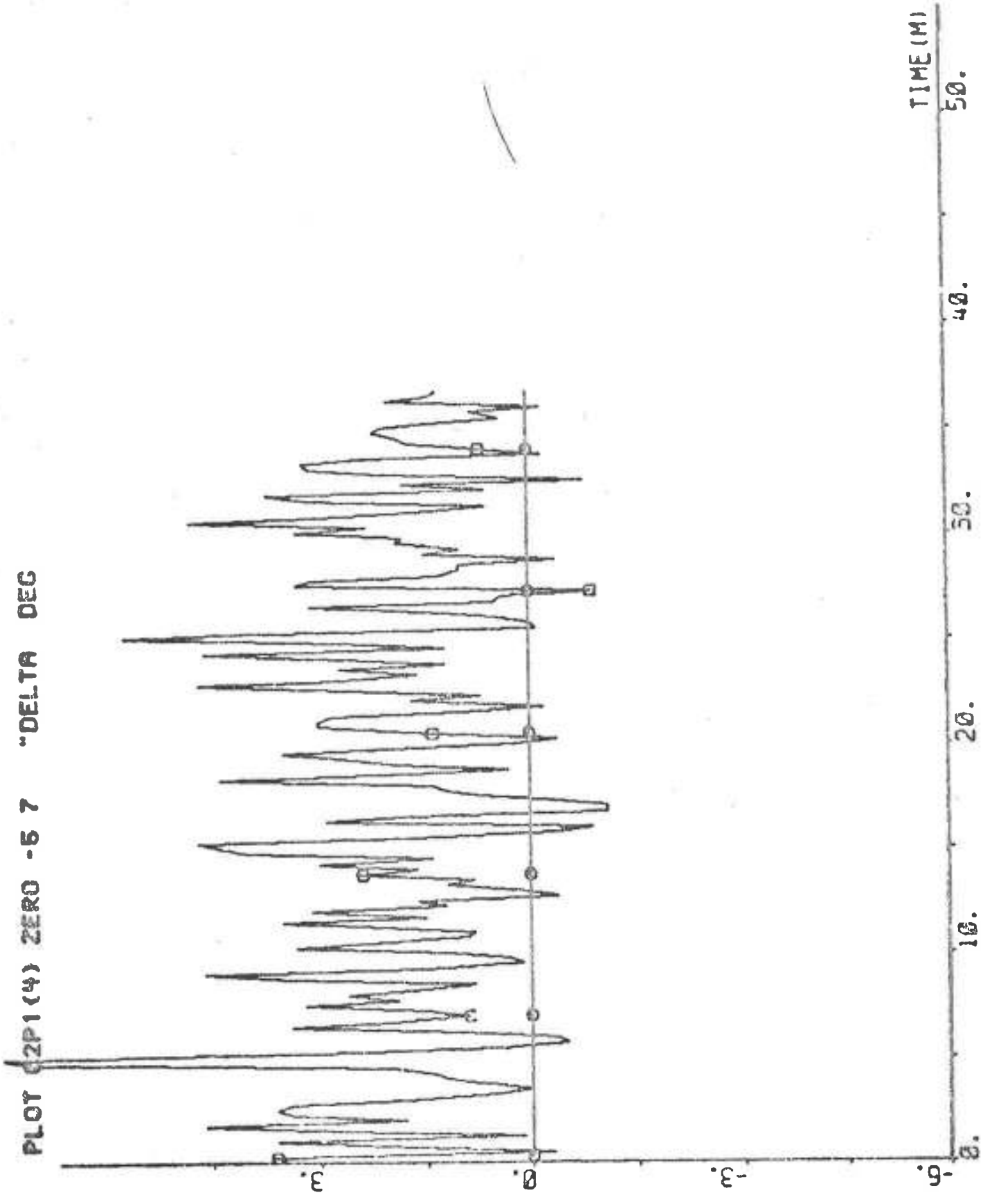
DELTA	1.83 ± 1.58 deg
PSI-PSIREF	0.026 ± 0.397 deg
AN	85.97 ± 0.27 rpm
U	16.52 ± 0.20 knots

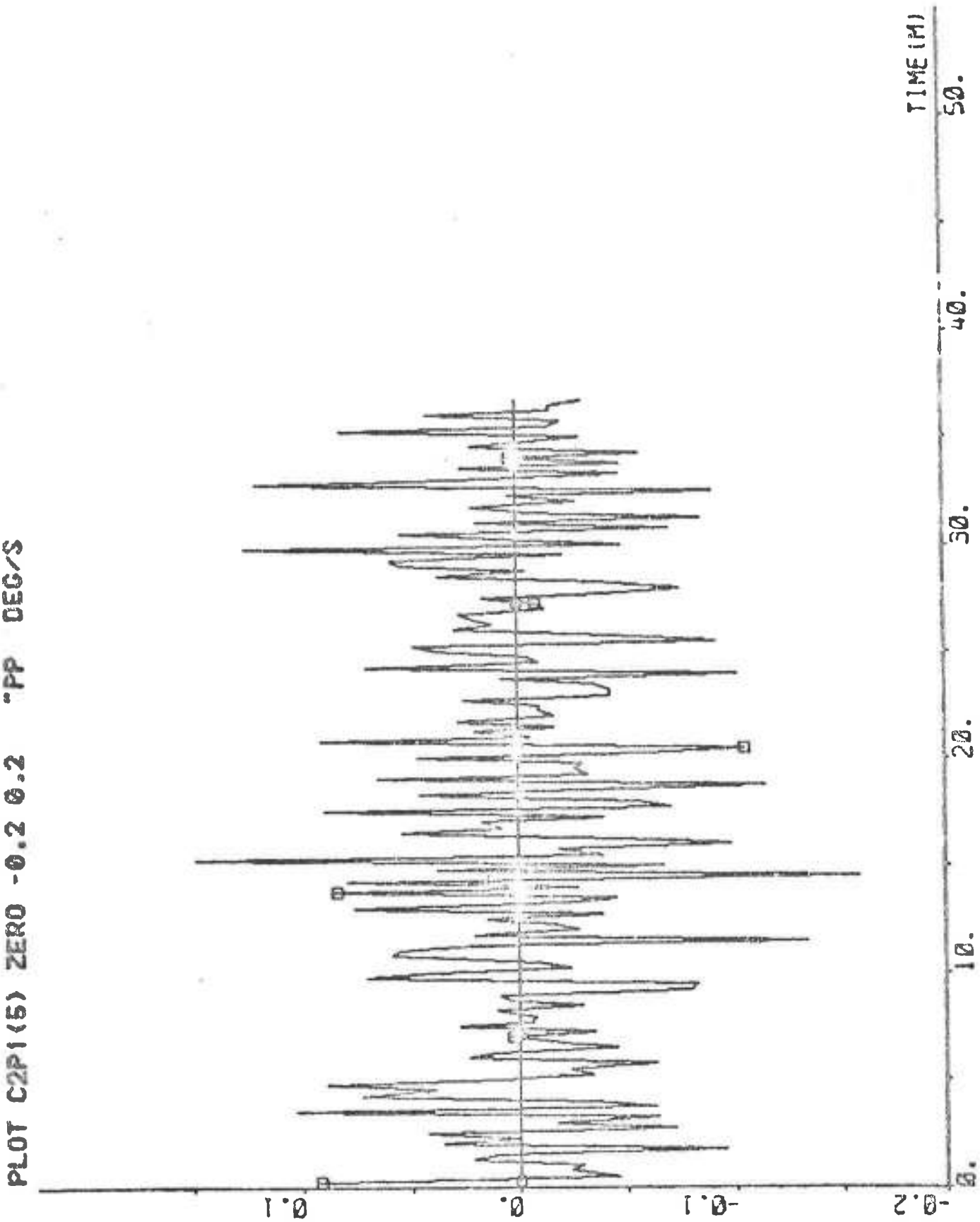
$V_1 = 0.743$

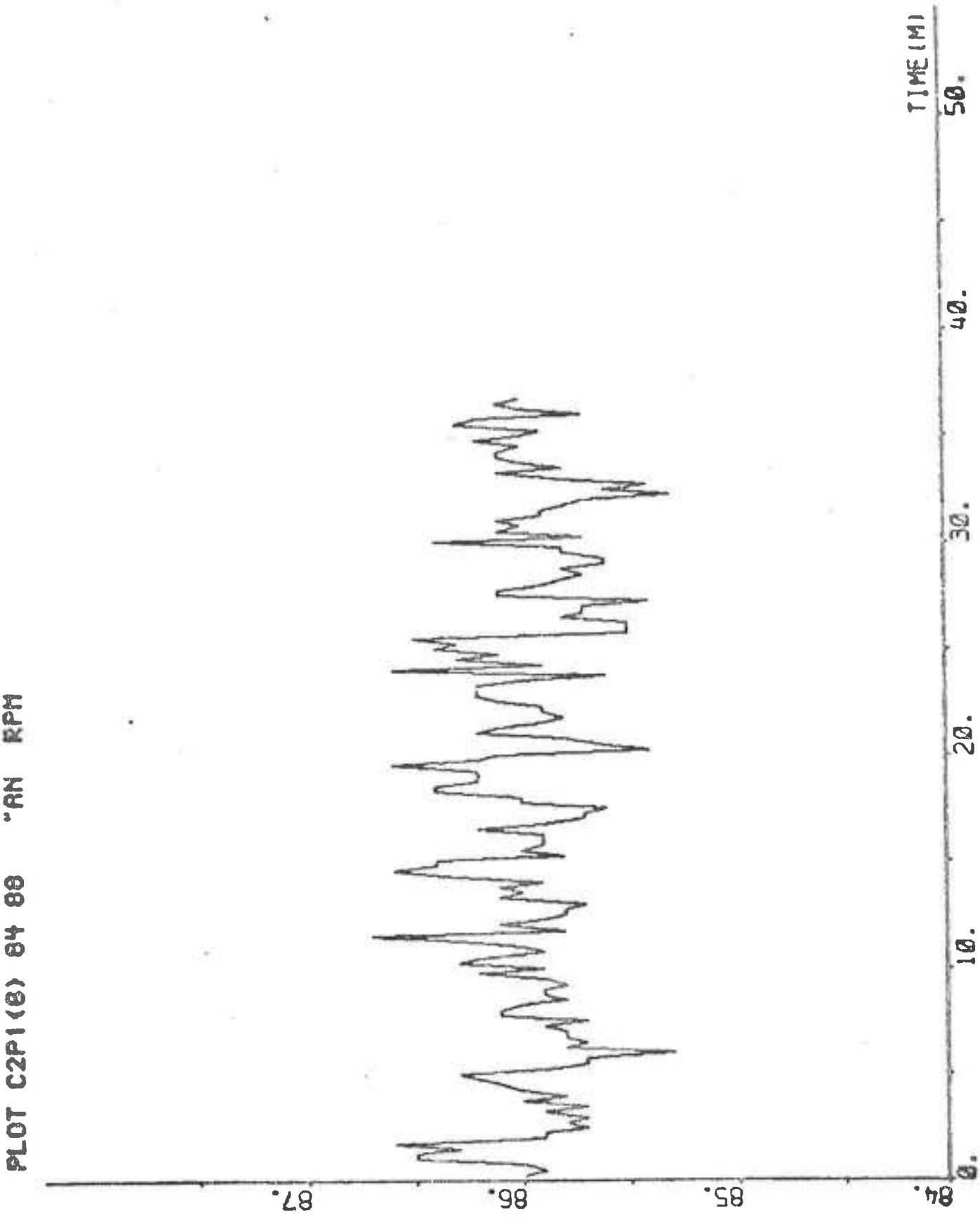
$V_2 = 0.408$

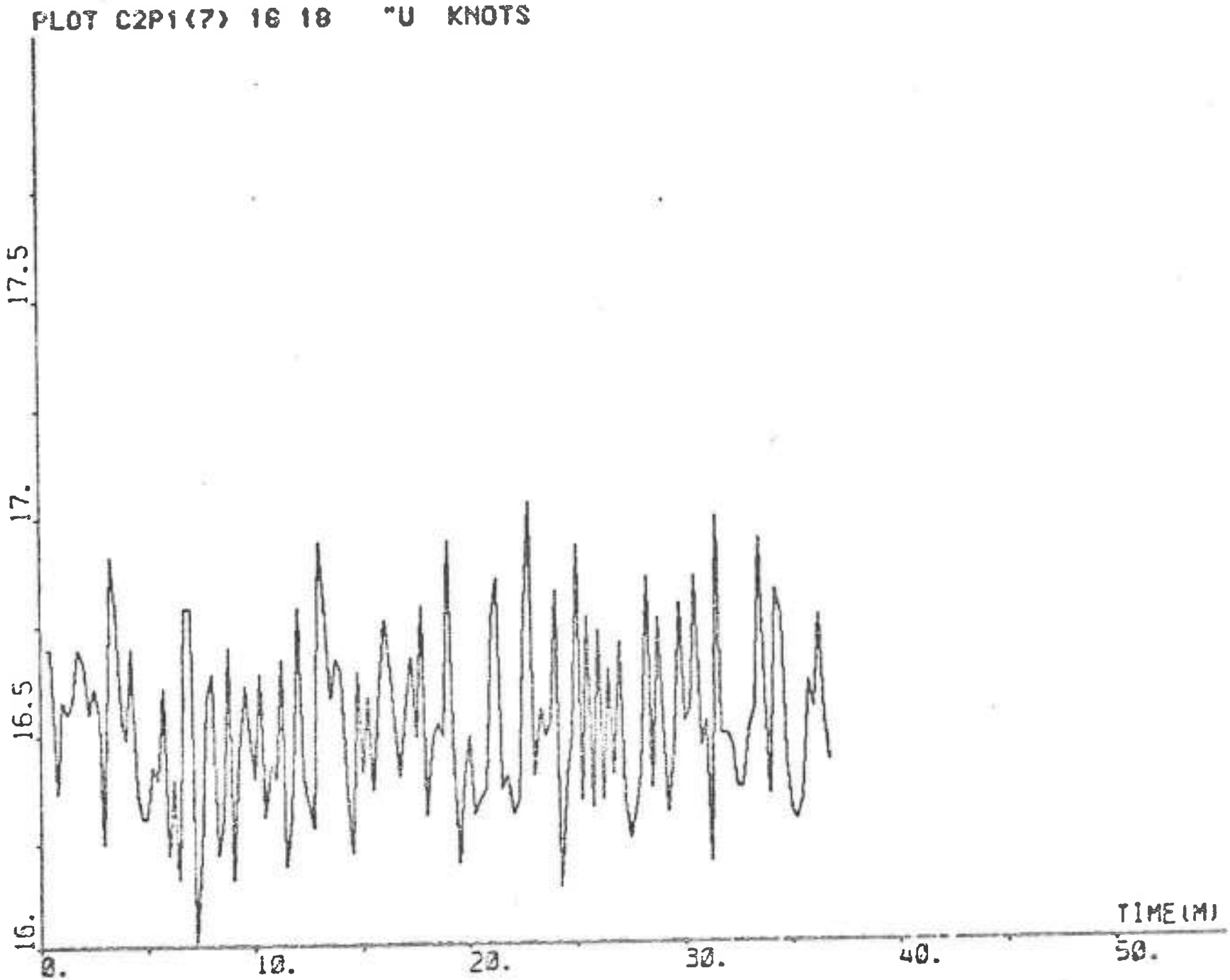

PLOT HP C2P1(2) ZERO -6 7 "DELCOM DEG
TIME(MI)
0.
10.
20.
30.
40.
50.
-6.
-3.
0.
3.

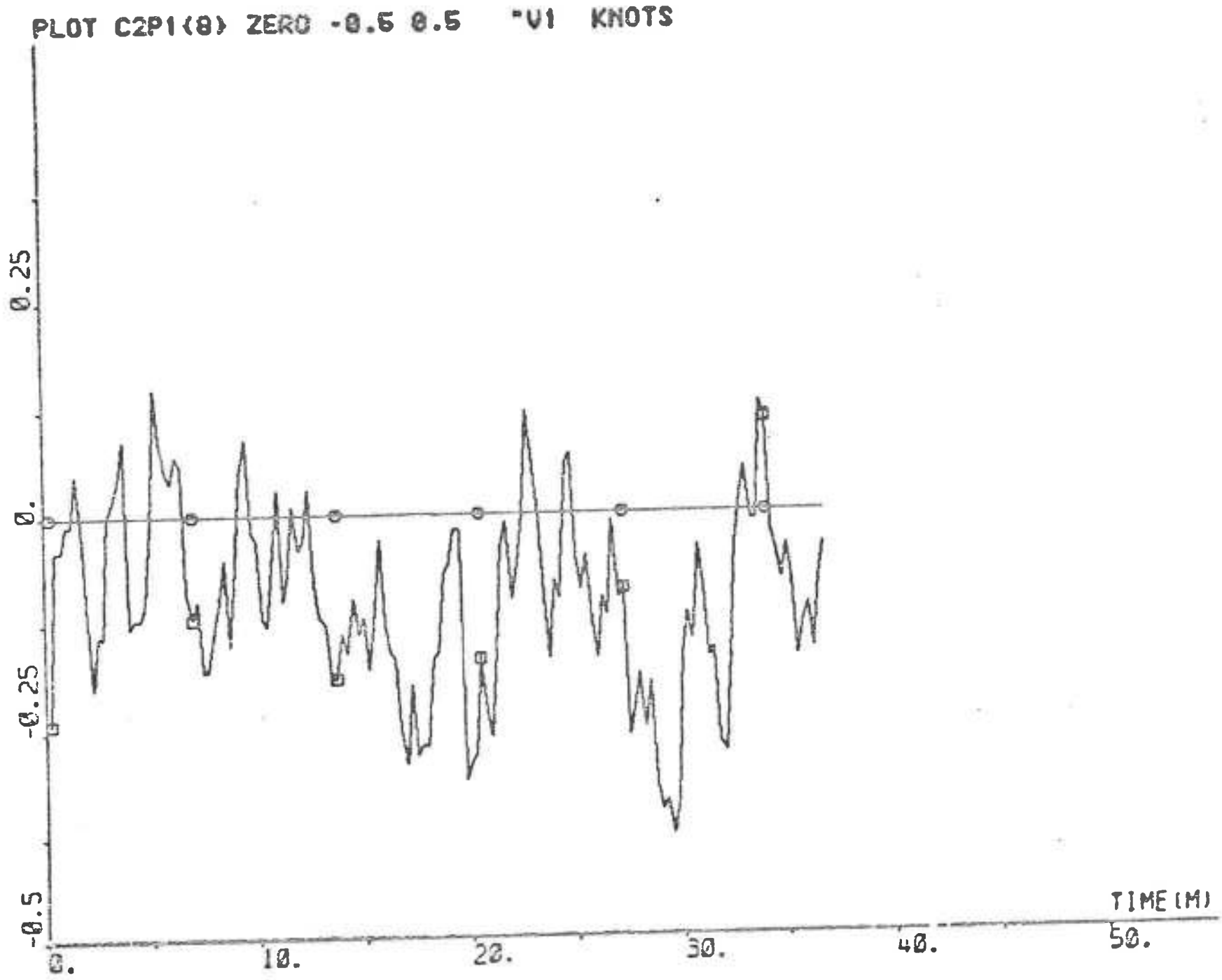

PLOT C2P1(3) ZERO -S 7 "DELTAS DEC
3.
0.
-3.
-6.
0.
10.
20.
30.
40.
50.
TIME(M)

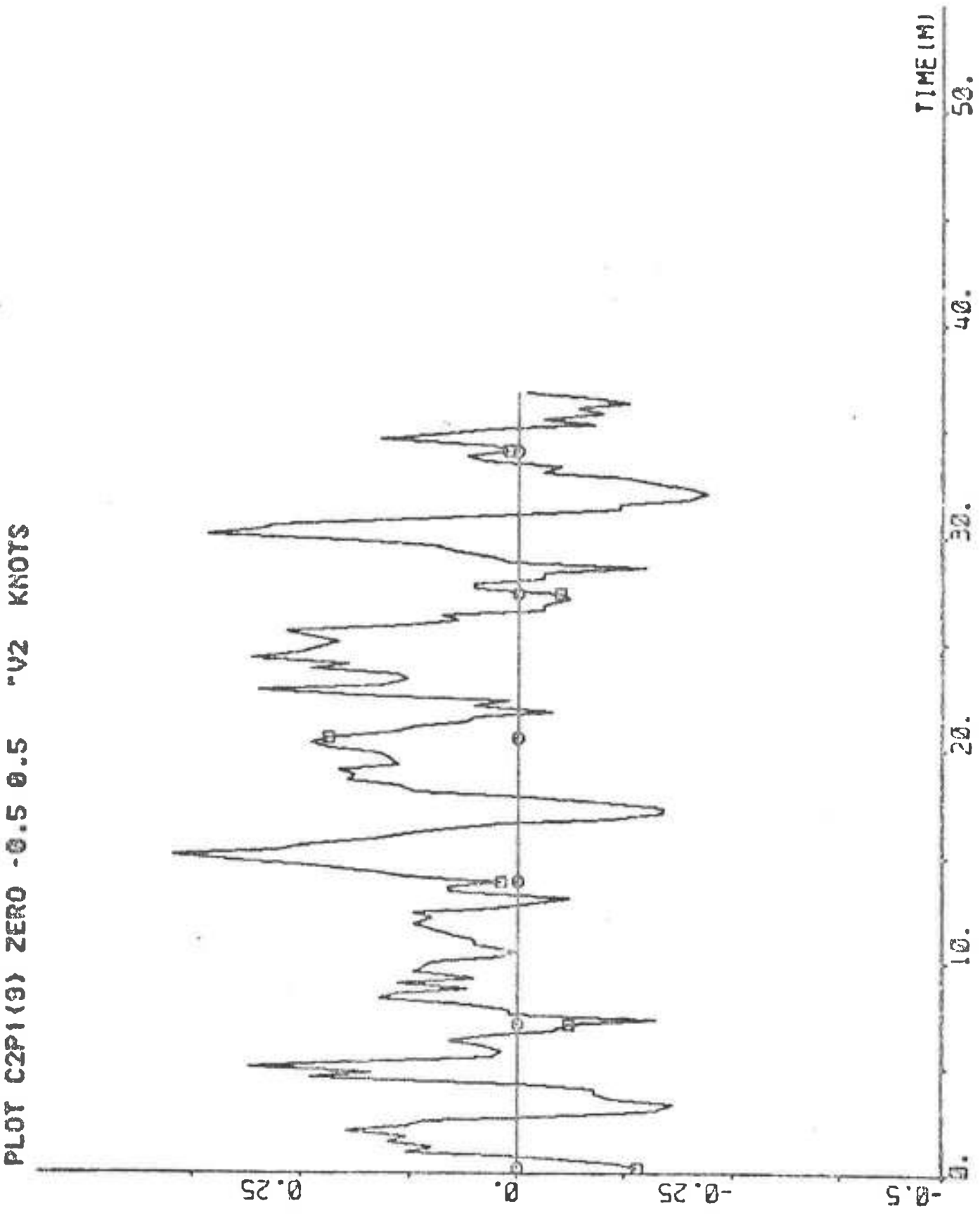

PLOT (2P1(4) ZERO -5 7 "DELTA DEC
3.
0.
-3.
-6.
0.
10.
20.
30.
40.
50.
TIME(M)

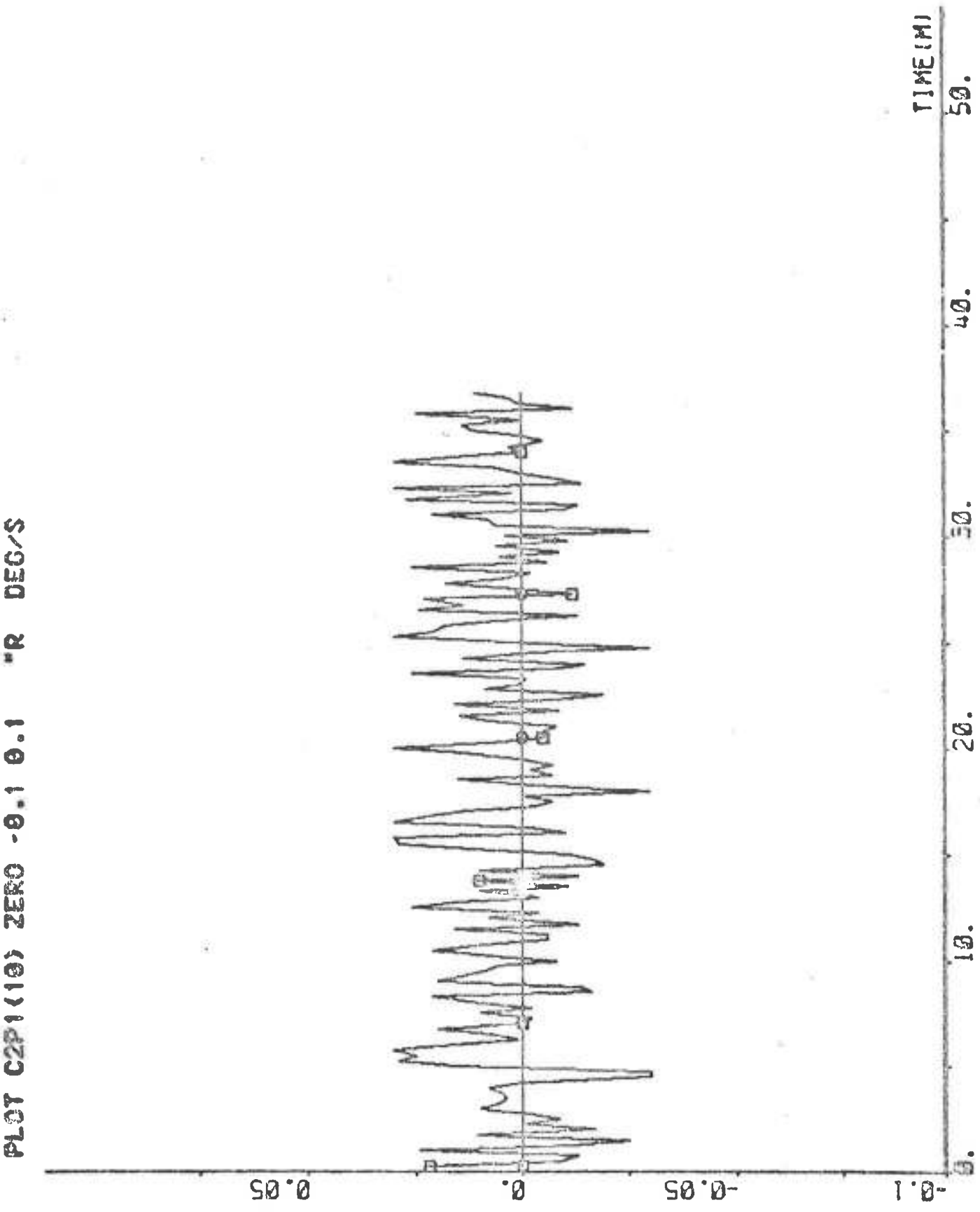

PLOT C2P1(S) ZERO -0.2 0.2 "PP DEG/S
0.1
0.
-0.1
-0.2
0.
10.
20.
30.
40.
50.
TIME(M)

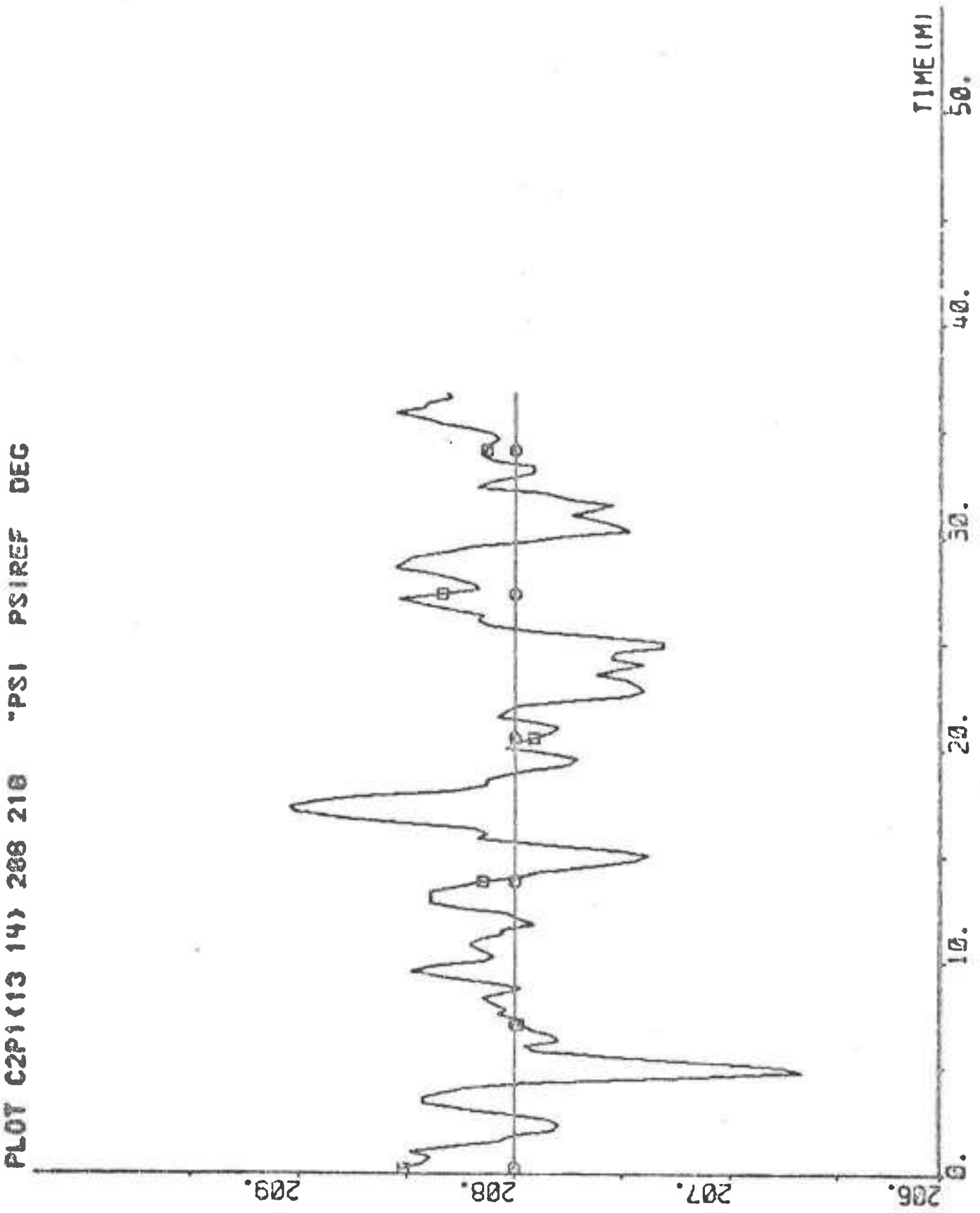

PLOT C2P1(8) 84 88 'AN RPM
84.
85.
86.
87.
0.
10.
20.
30.
40.
50.
TIME(M)


PLOT C2P1(7) 16 18 "U KNOTS
17.5
17.
16.5
16.
0.
10.
20.
30.
40.
50.
TIME(M)


PLOT C2P1(8) ZERO -0.5 0.5 *V1 KNOTS
0.25
0.
-0.25
-0.5
0.
10.
20.
30.
40.
50.
TIME(M)


PLOT C2P1(3) ZERO -0.5 0.5 "V2 KNOTS
0.25
0.
-0.25
-0.5
0.
10.
20.
30.
40.
50.
TIME(M)


PLOT C2P1(10) ZERO -0.1 0.1 °R DEG/S
0.05
0.
-0.05
-0.1
0.
10.
20.
30.
40.
50.
TIME(M)


PLOT C2P1(13 14) 208 210 "PSI PSIREF DEG
206.
207.
208.
209.
0.
10.
20.
30.
40.
50.
TIME(M)

EXPERIMENT C3

Date	1974-10-21
Time	12.58
Duration	87 min
Position	S 29° 05' E 32° 19'
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	215°
Rudder limit	Not active

The yaw rate signal R was limited to ±0.03 deg/s.

Parameter values of the PID-regulator

Initial values:

$k_P = 1.9$ $k_D = 150$ s $k_I = 1/150$ s^{-1} $T_S = 15$ s

Final values:

$k_P = 1.6$ $k_D = 105$ s $k_I = 1/105$ s^{-1} $T_S = 15$ s

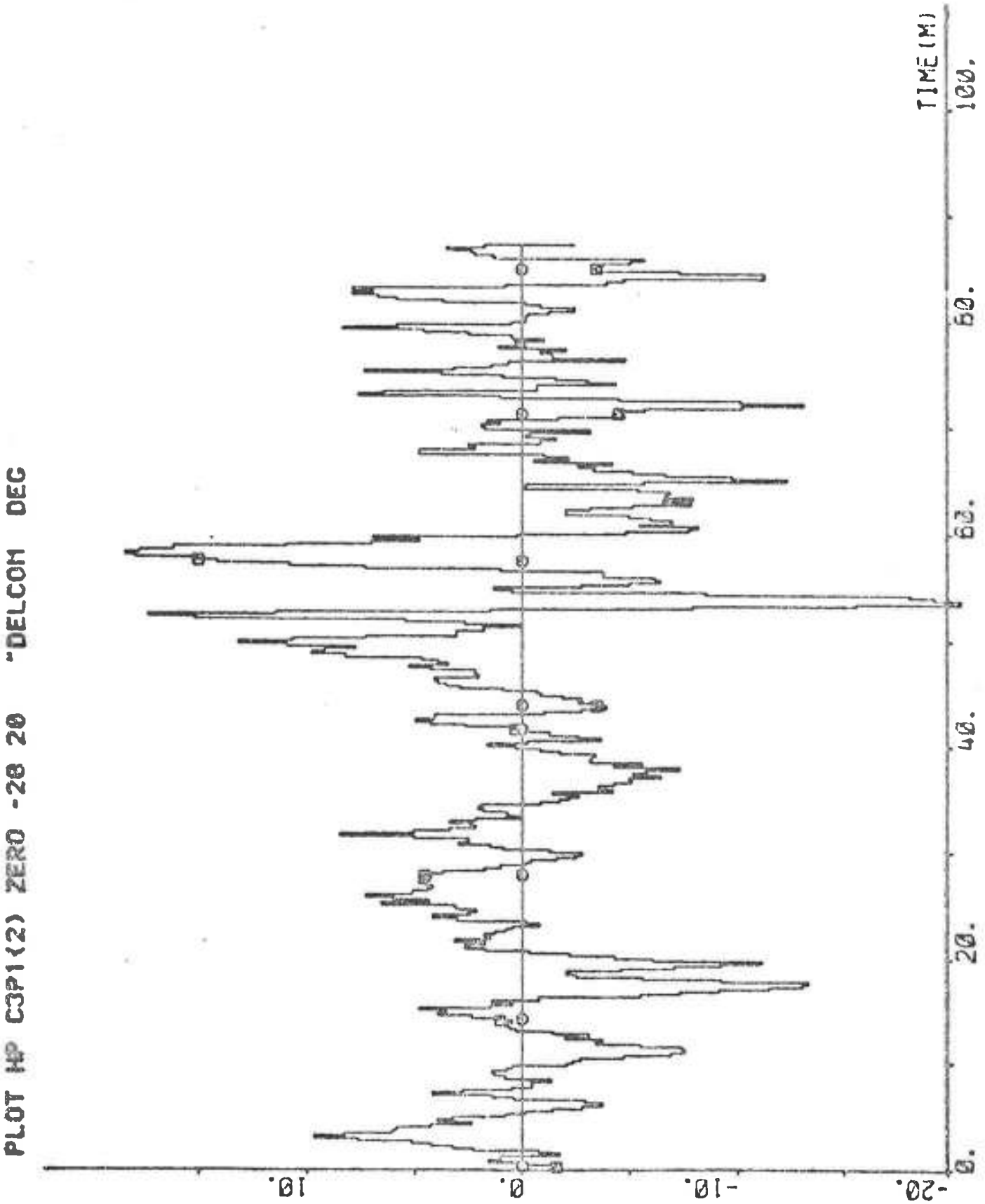
The parameters were changed several times during the experiment.

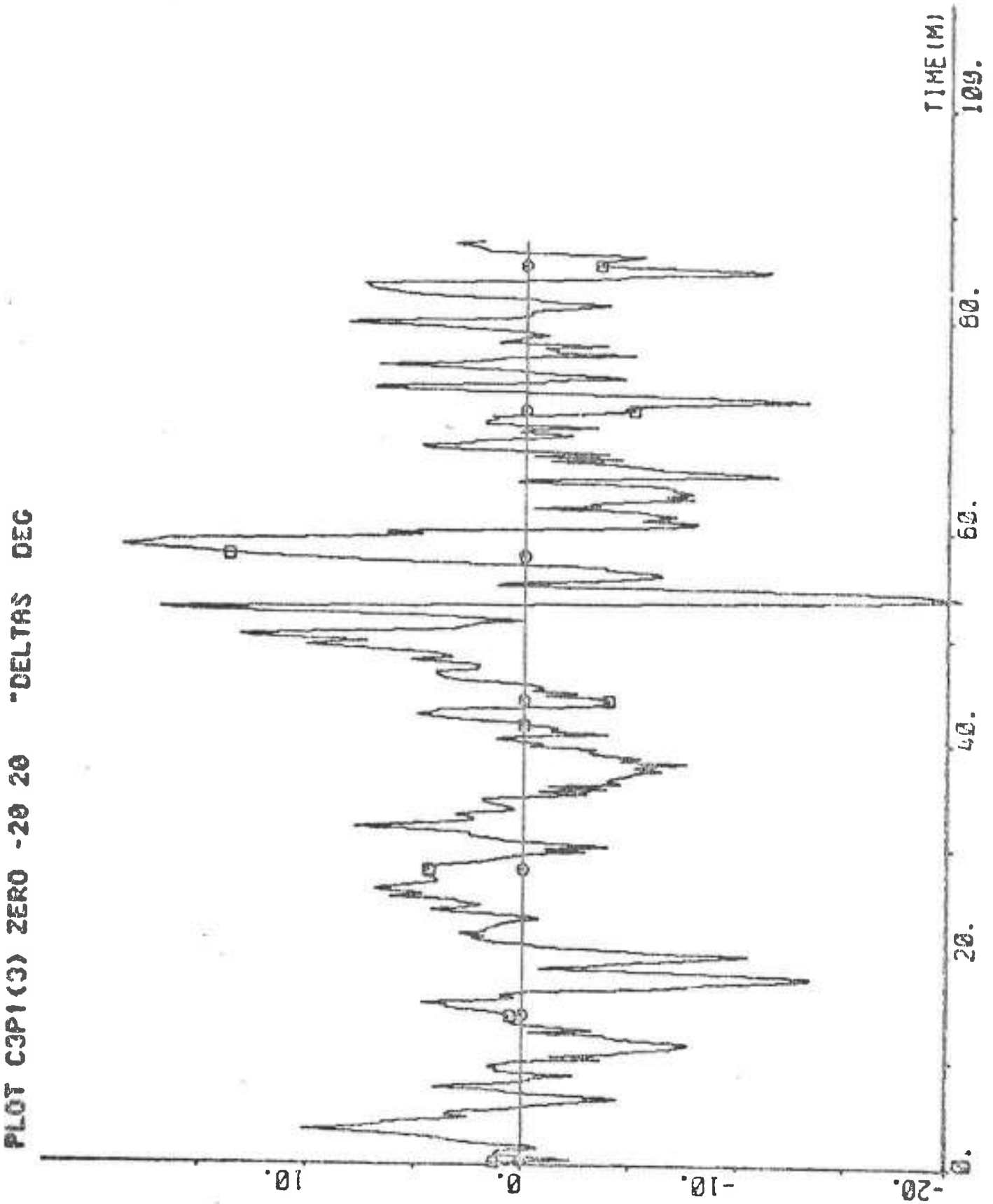
Statistics (mean value and standard deviation)

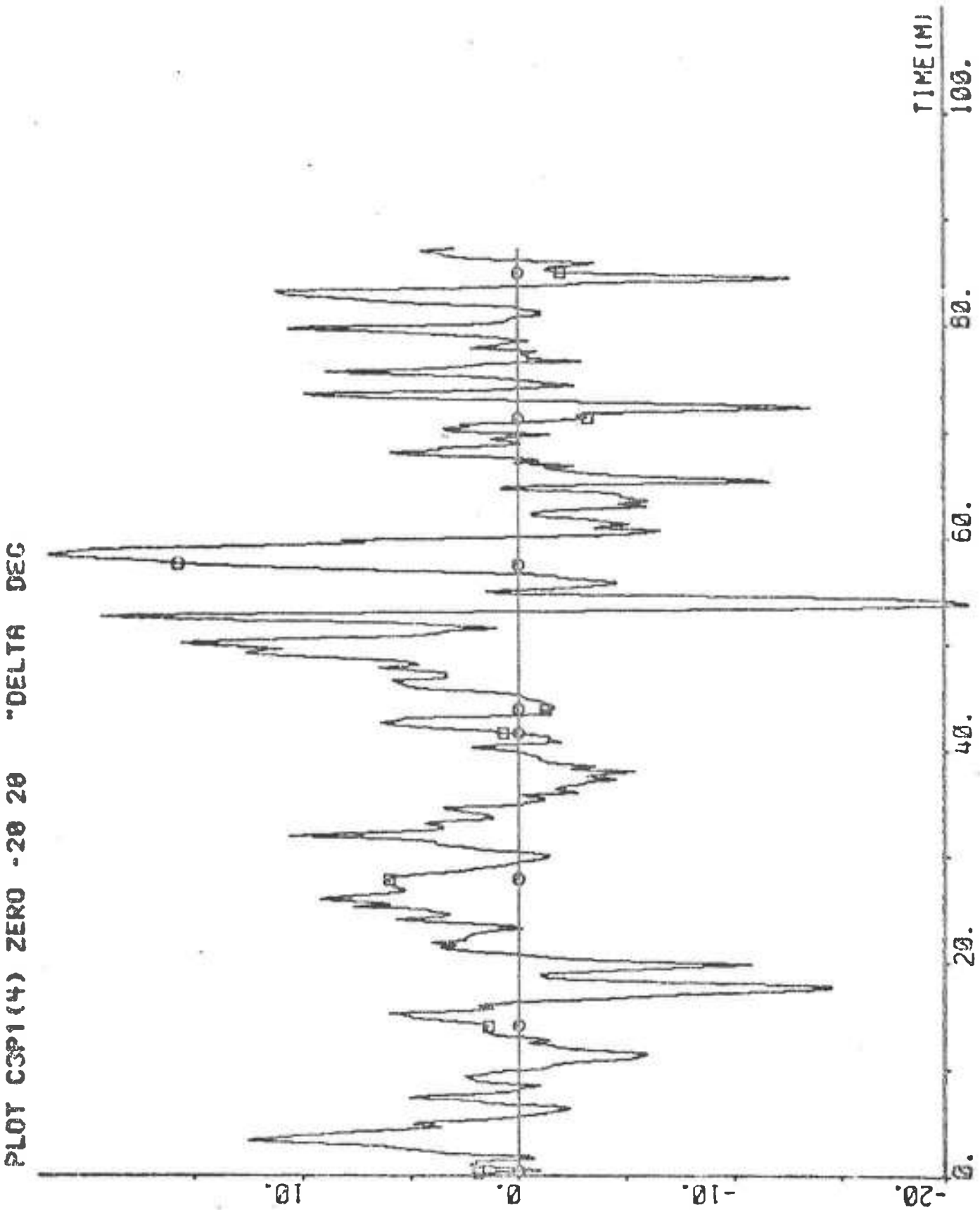
DELTA	1.31 ± 6.11 deg
PSI-PSIREF	0.203 ± 1.510 deg
AN	48.75 ± 0.71 rpm
U	4.55 ± 0.31 knots

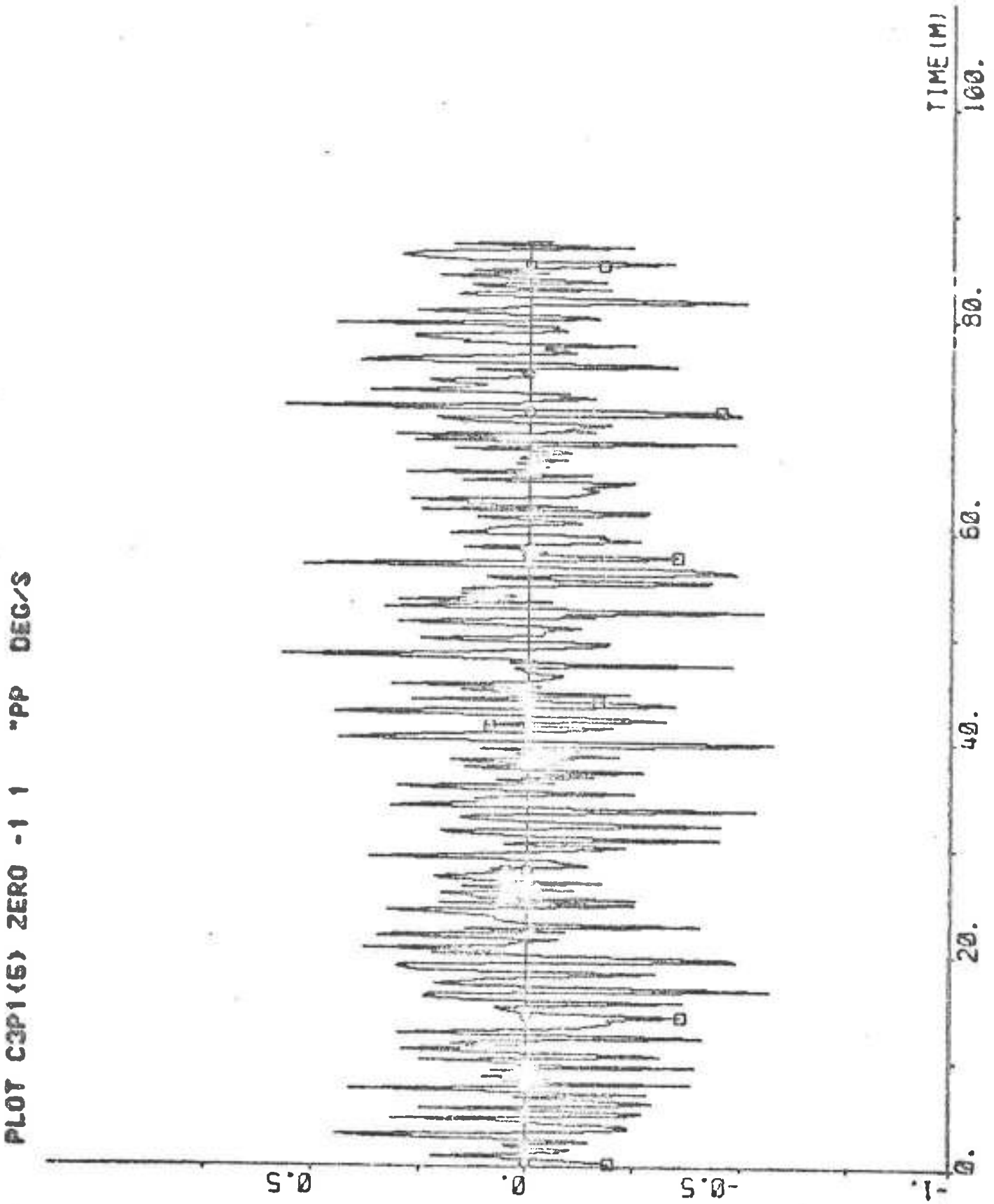
$V_1 = 6.226$

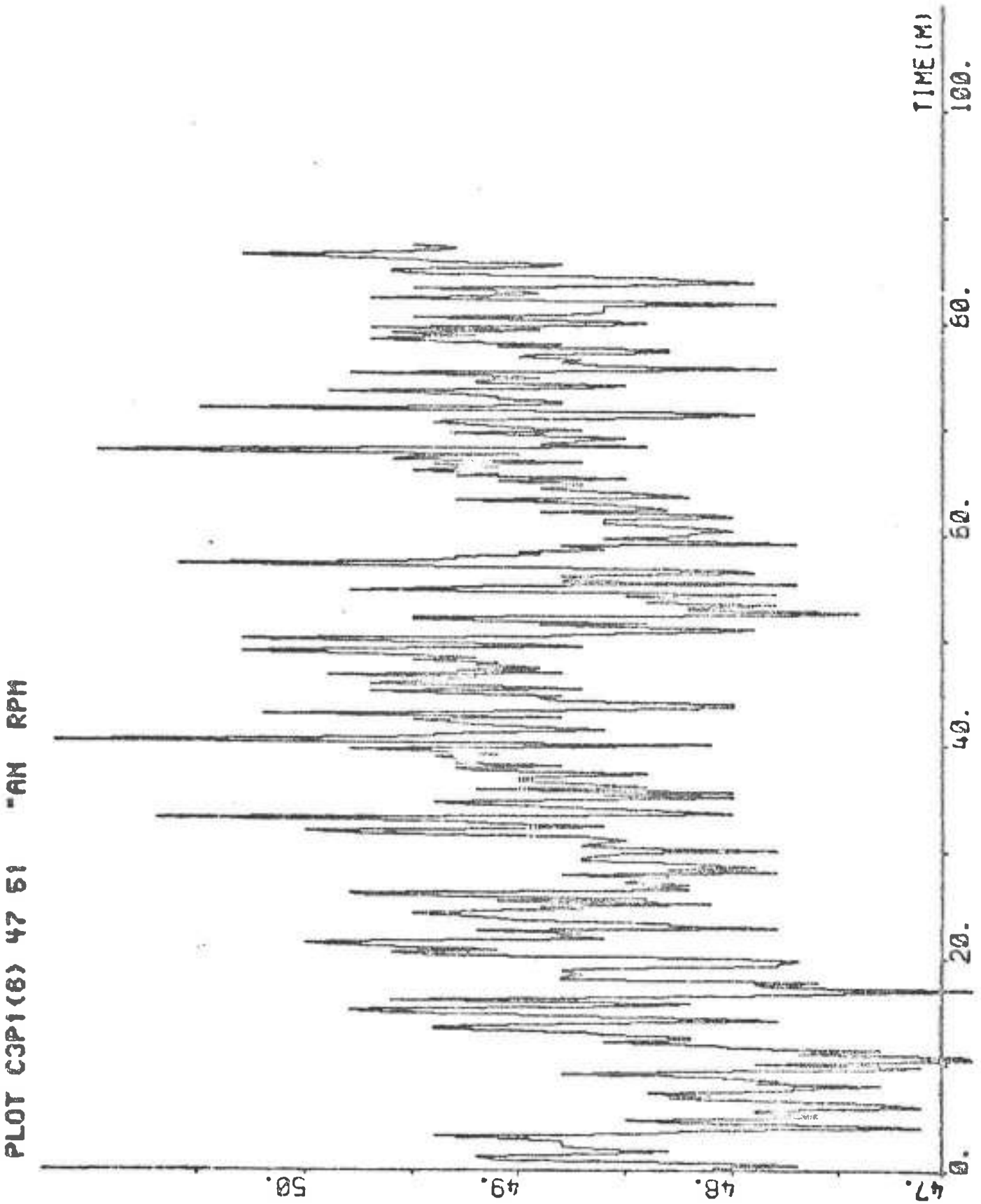
$V_2 = 6.055$

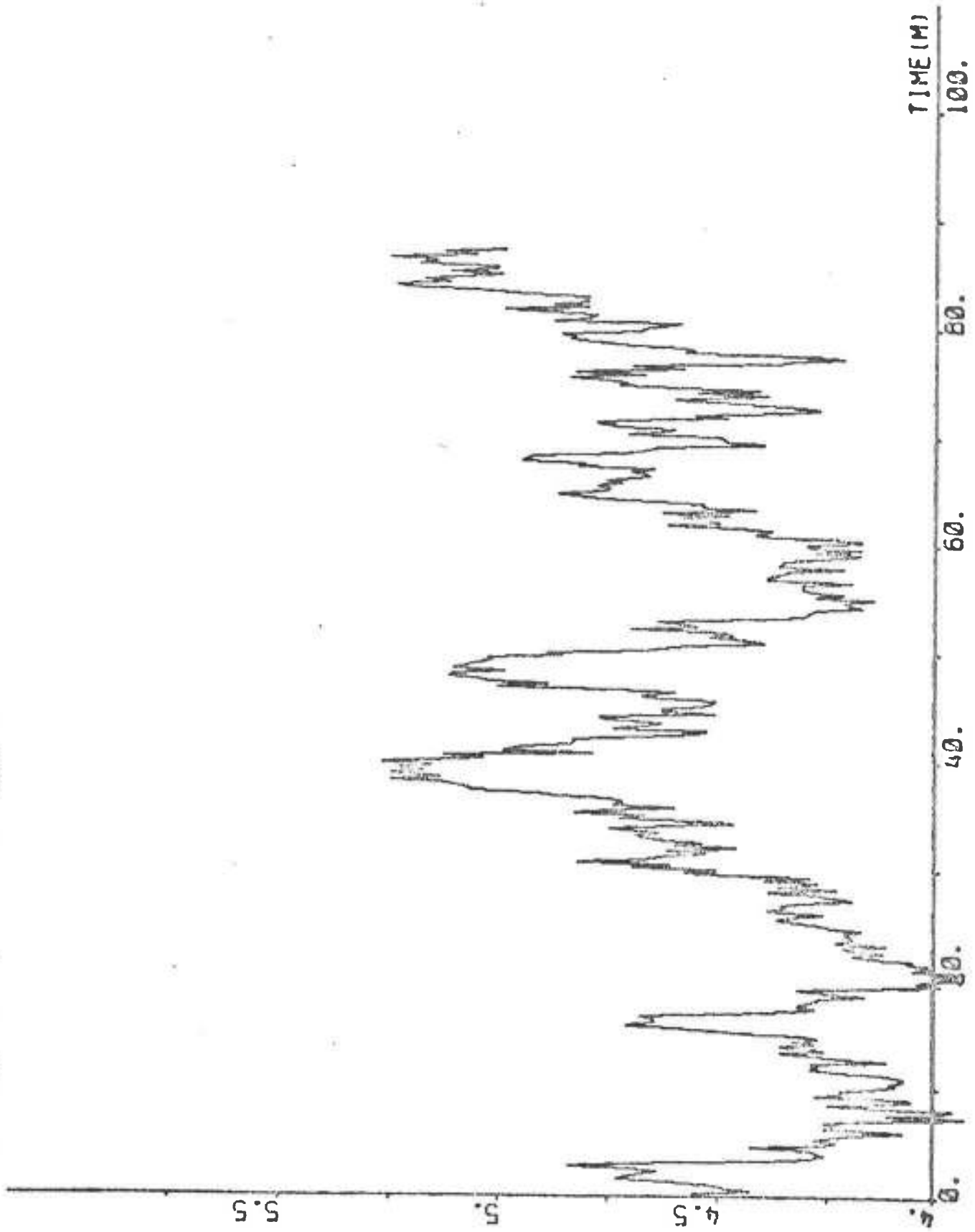

PLOT HP C3P1(2) ZERO -20 20 "DELCOM DEC
TIME(M)
0.
20.
40.
60.
80.
100.
-20.
-10.
0.
10.

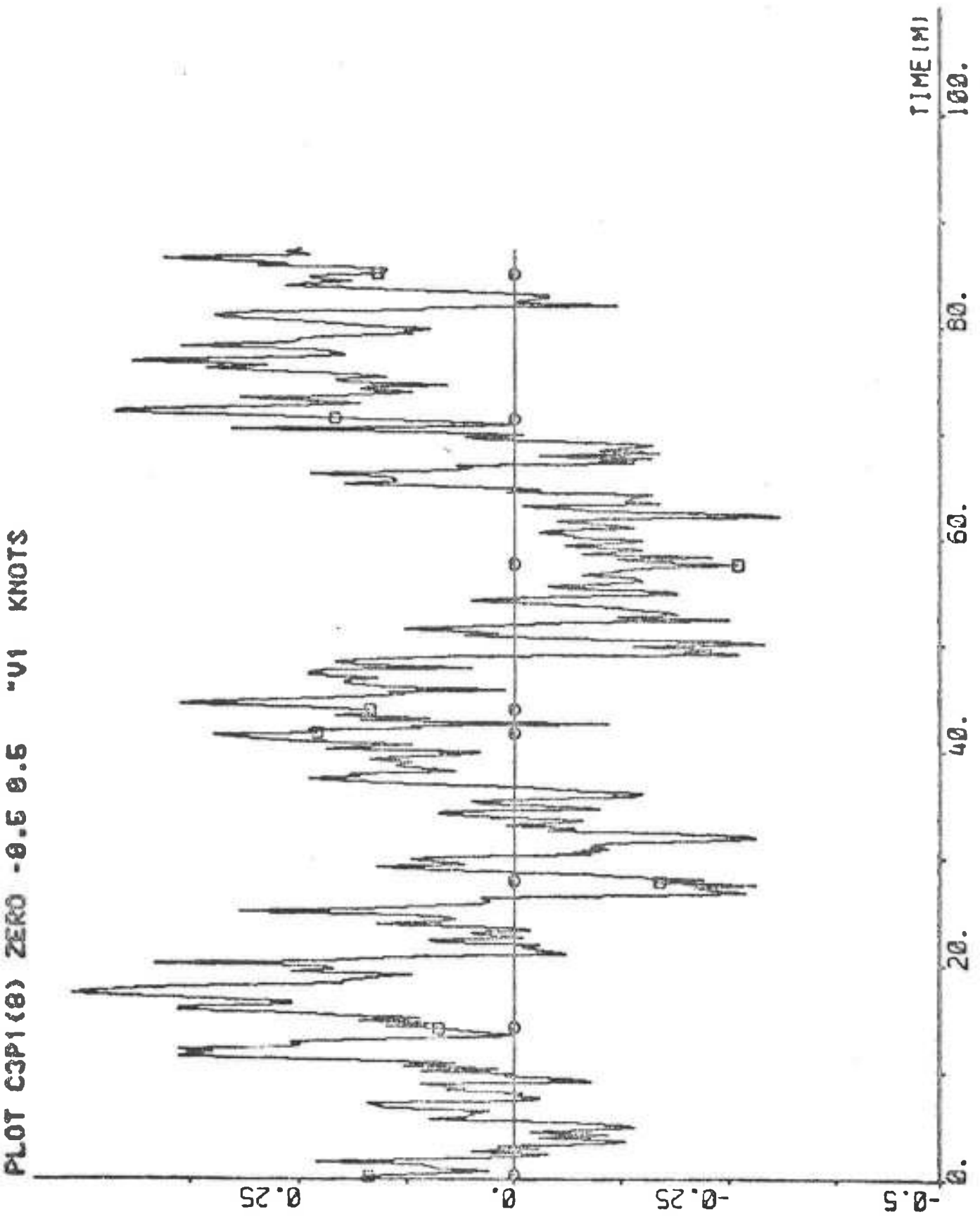

PLOT C3P1(3) ZERO -20 20 "DELTAS DEG
10.
0.
-10.
-20.
0.
20.
40.
60.
80.
100.
TIME(M)

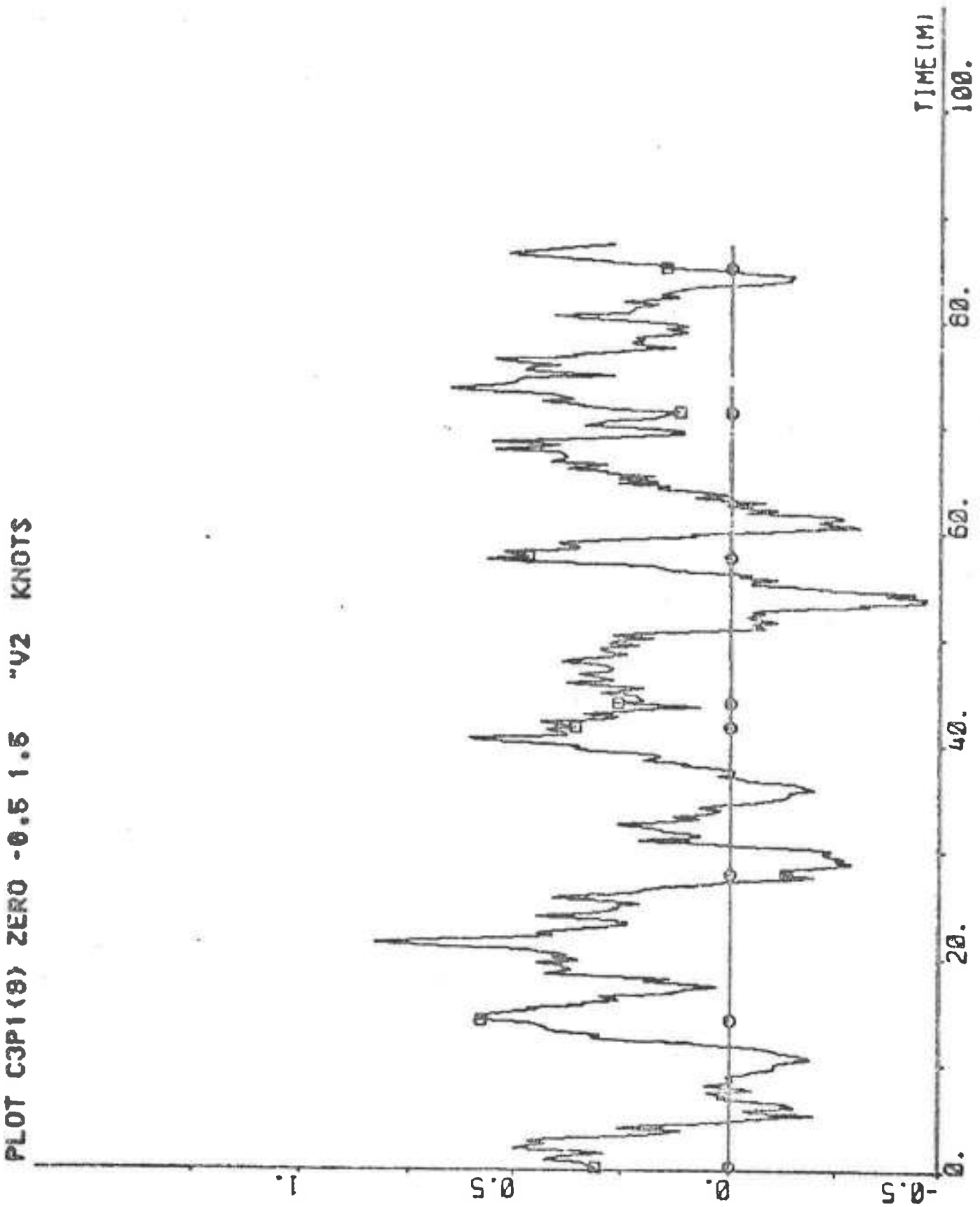

PLOT C3P1(4) ZERO -20 20 "DELTA DEC
10.
0.
-10.
-20.
0.
20.
40.
60.
80.
100.
TIME(M)

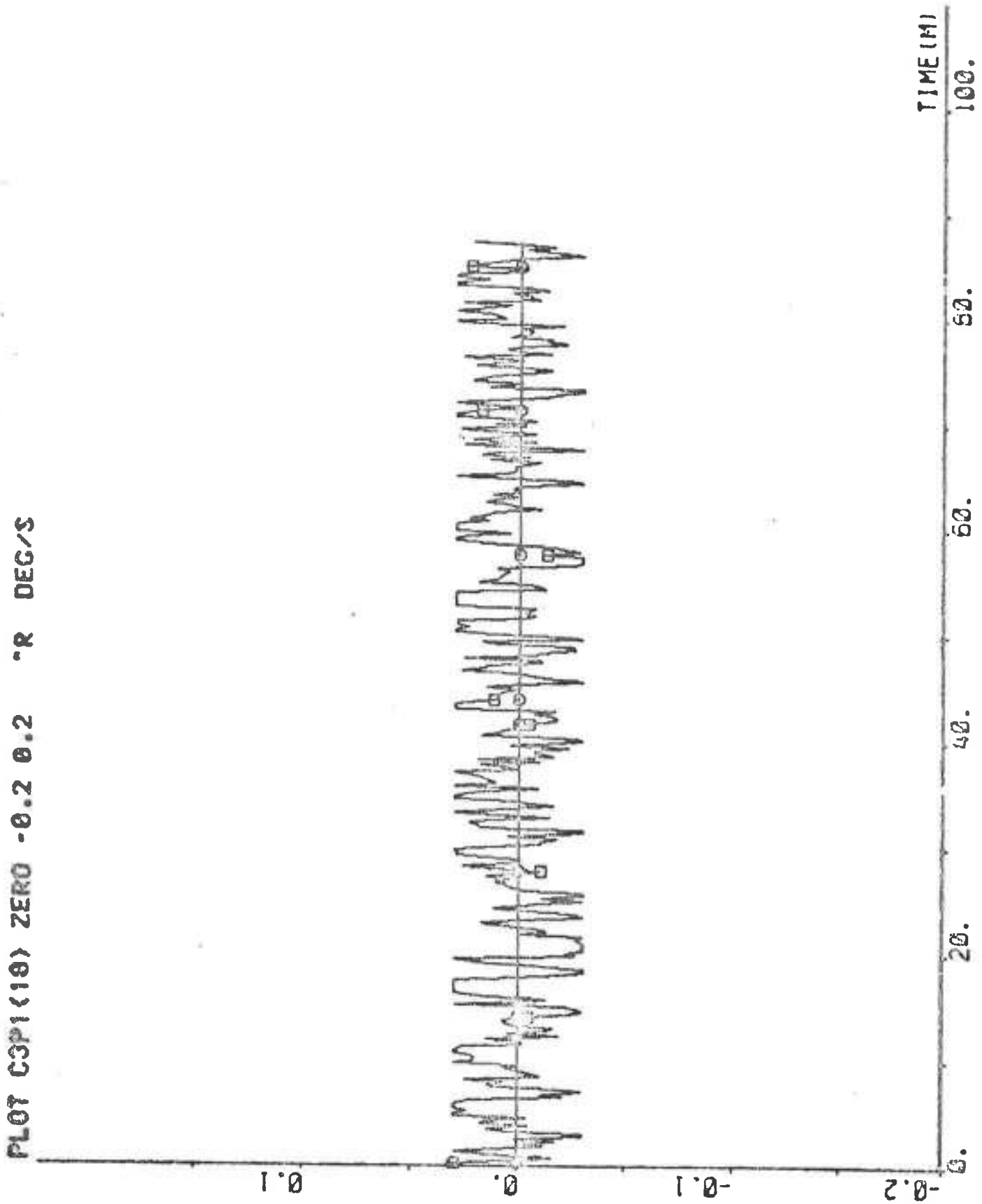

PLOT C3P1(5) ZERO -1 1 "PP DEG/S
0.5
0.
-0.5
-1.
0.
20.
40.
60.
80.
100.
TIME(M)

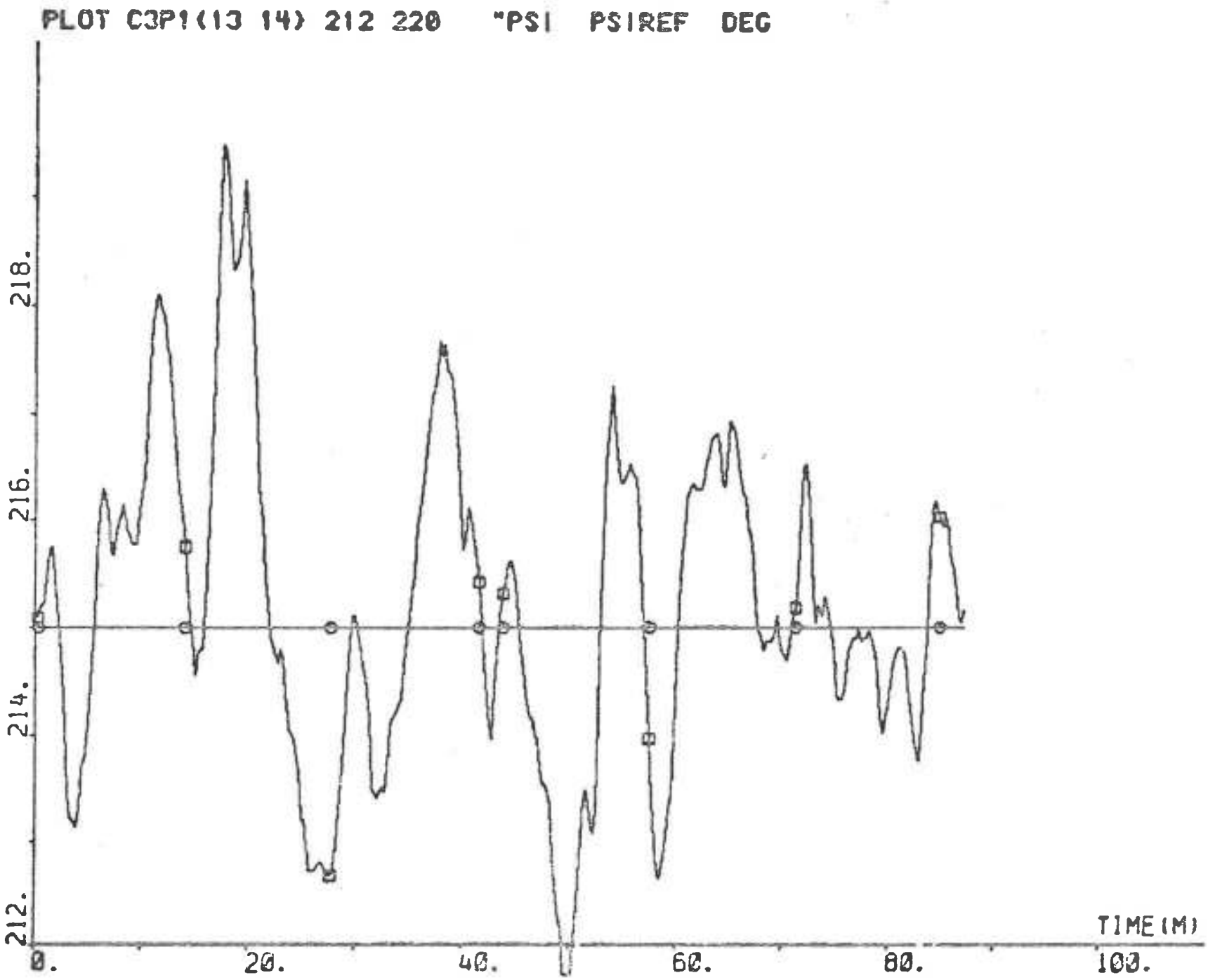

PLOT C3P1(8) 47 51 *AM RPM
47.
48.
49.
50.
0.
20.
40.
60.
80.
100.
TIME(M)


PLOT C3P1(7) 4 8 "U KNOTS
4.
4.5
5.
5.5
0.
20.
40.
60.
80.
100.
TIME(M)


PLOT C3P1(8) ZERO -0.5 0.5 "V1 KNOTS
0.25
0.
-0.25
-0.5
0.
20.
40.
60.
80.
100.
TIME(M)


PLOT C3P1(8) ZERO -0.5 1.5 "V2 KNOTS
TIME(M)
0.
20.
40.
60.
80.
100.
-0.5
0.
0.5
1.


PLOT C3P1(10) ZERO -0.2 0.2 'R DEG/S
0.1
0.
-0.1
-0.2
0.
20.
40.
60.
80.
100.
TIME(M)


PLOT C3P1(13 14) 212 220 "PSI PSIREF DEG
218.
216.
214.
212.
0.
20.
40.
60.
80.
100.
TIME(M)

EXPERIMENT D1

Date	1974-10-19
Time	11.00
Duration	62 min
Position	S 18° 29' E 39° 34'
Water depth	deep
Forward draught	20.2 m
Aft draught	20.2 m
Wind direction	N (4, 5; see Appendix A)
Wind velocity	3-4 Beaufort (4-8 m/s, gentle to moderate breeze)
Wave height	3 - 4 m
PSIREF	180°, 225°, 195°, 190°, 189°, 191°, 195°, 205°, 209°, 210°, 210.3°
RREF	0.07 deg/s
Rudder limit	Not active
Approximate mean value of AN	85.5 rpm
Approximate mean value of U	18.0 knots

The signal R-RREF was limited to ±0.03 deg/s. The first yaw was interrupted because of the motion of another ship. The Sailmaster was switched on after 57 min. of the experiment.

Parameter values of the PID-regulator.

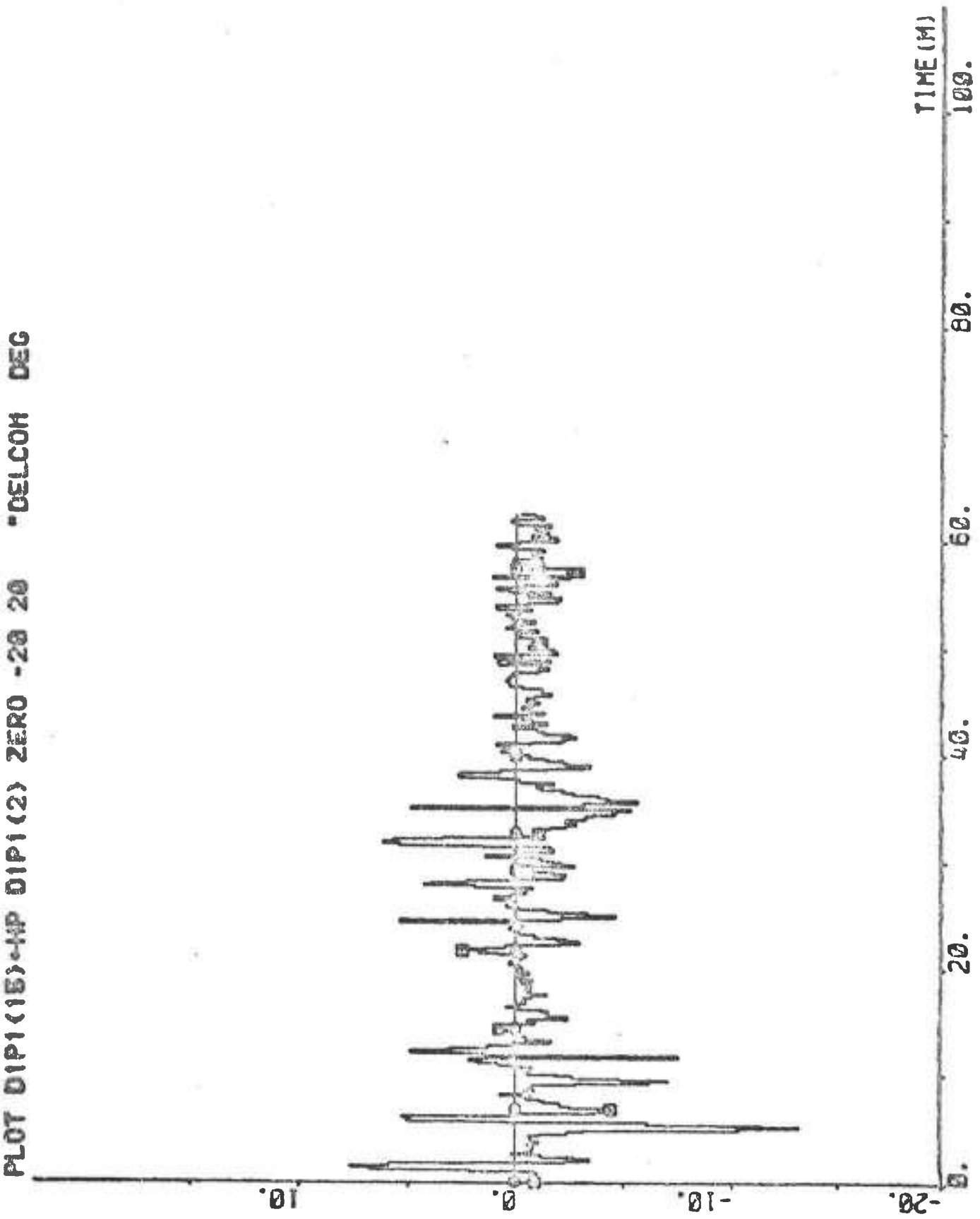
Straight course keeping:

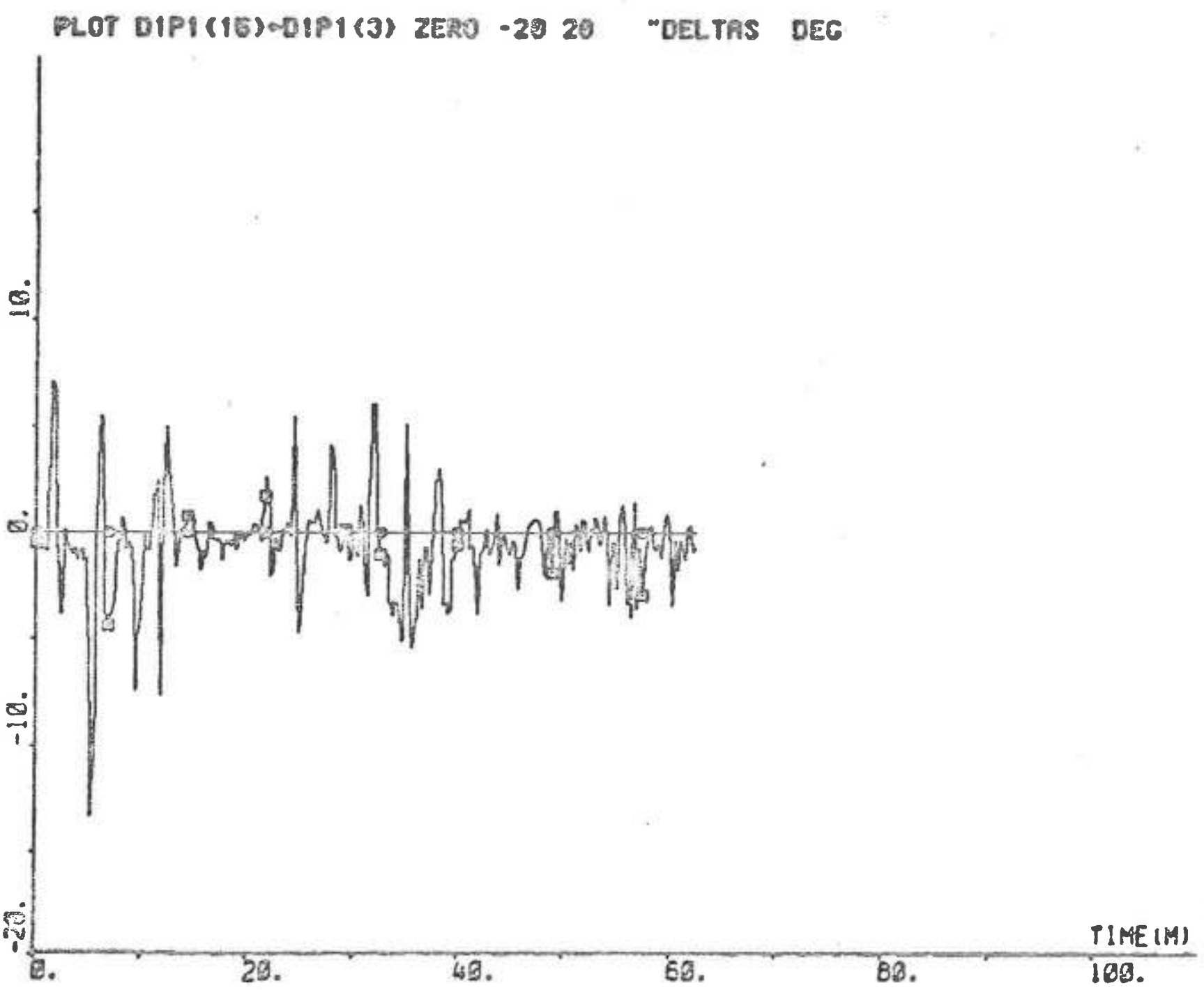
$k_P = 1.7$ $k_D = 120$ s $k_I = 1/120$ s^{-1} $T_S = 15$ s

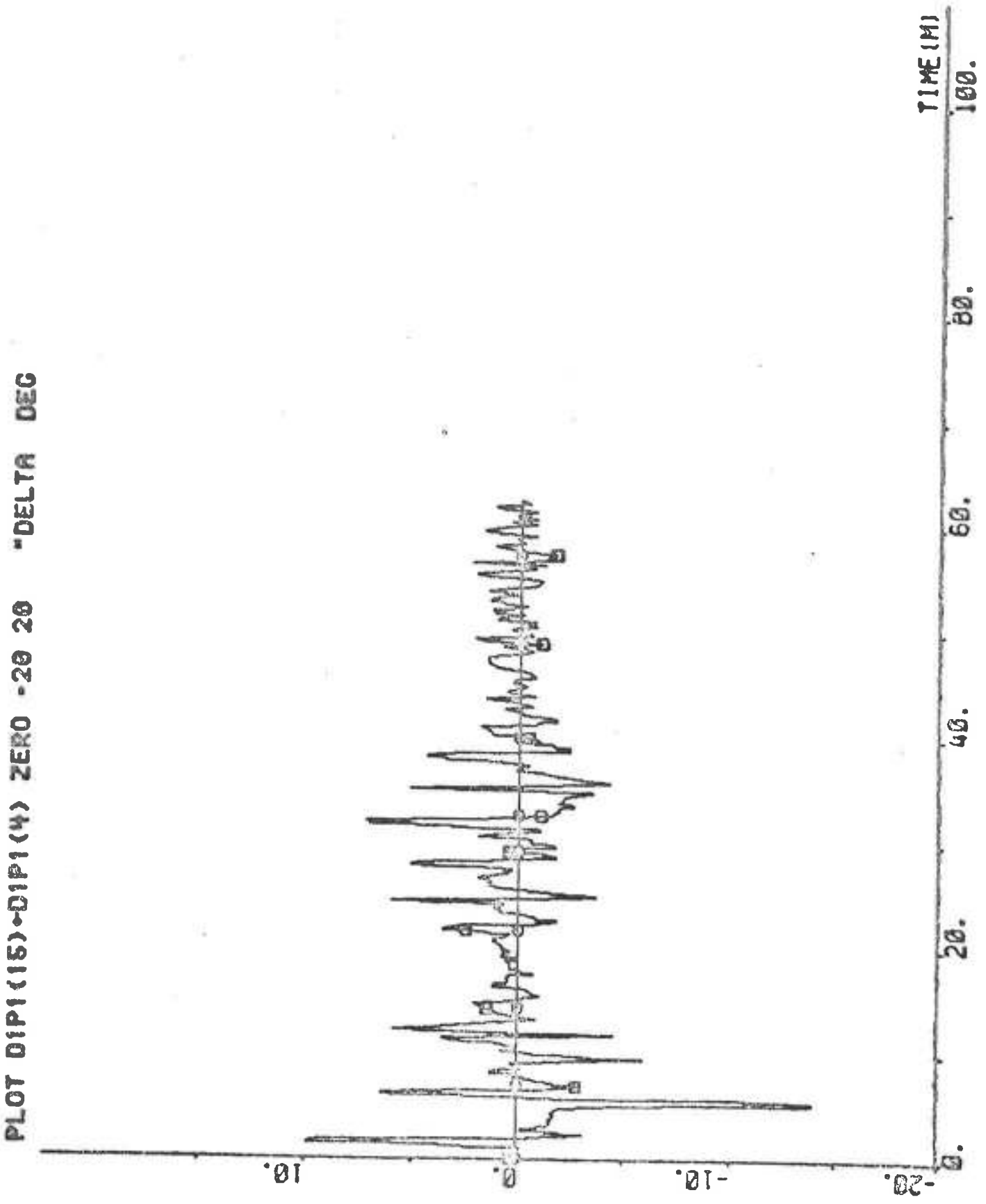
Yawing:

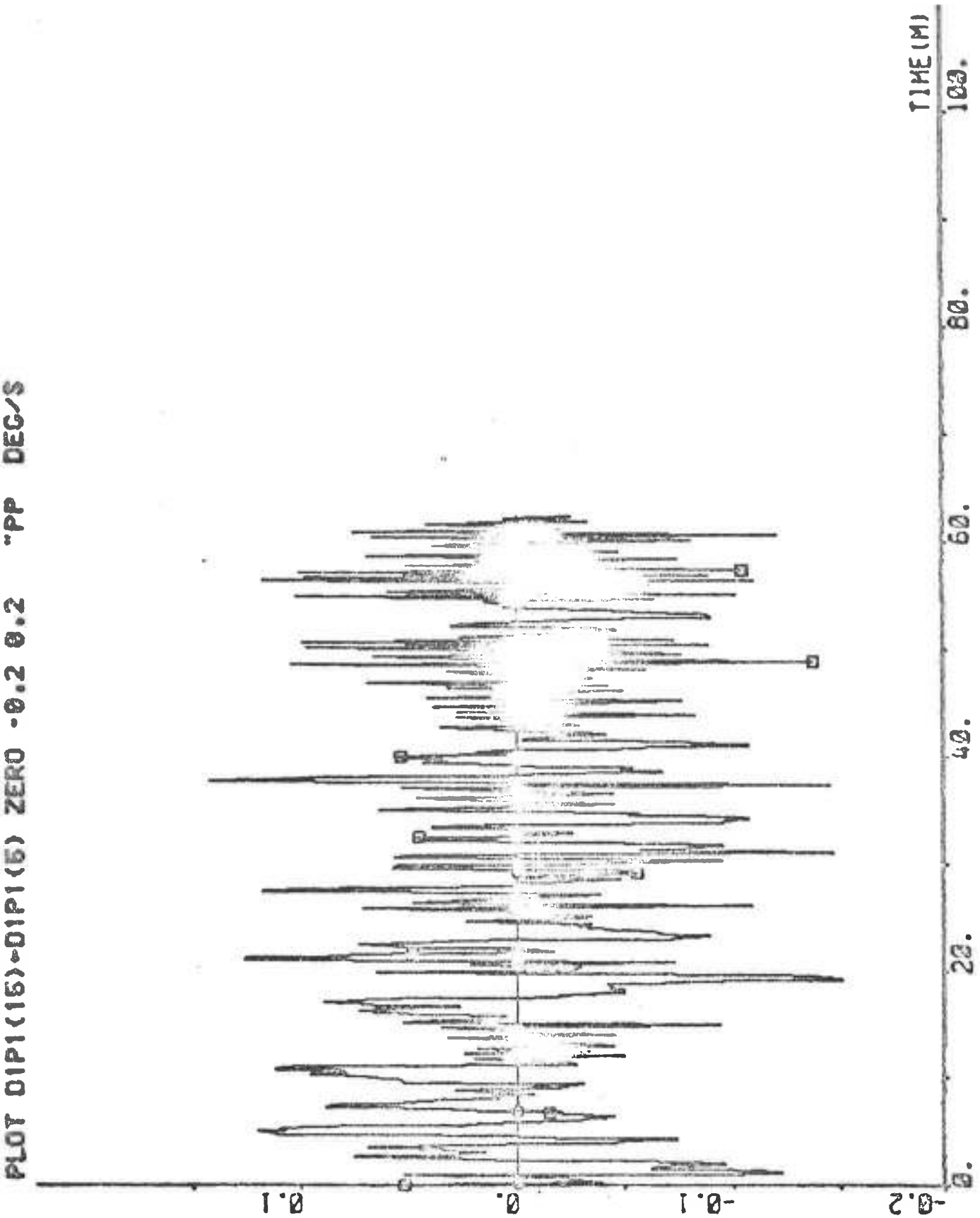
$k_P = 1.2$ $k_D = (1+3|R|)\cdot 120$ s $k_I = 1/4\ k_D$ s^{-1}

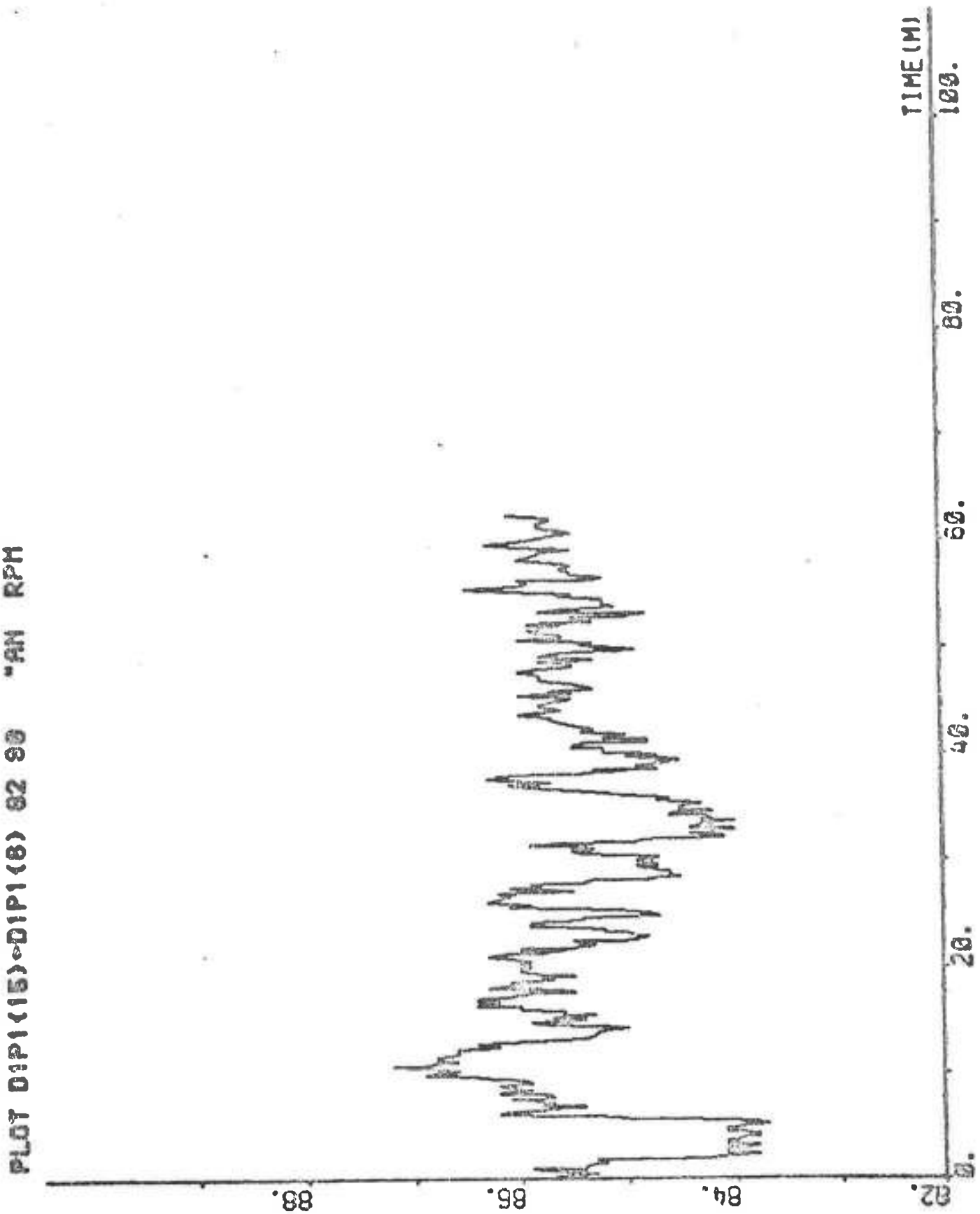
$T_S = 10$ s

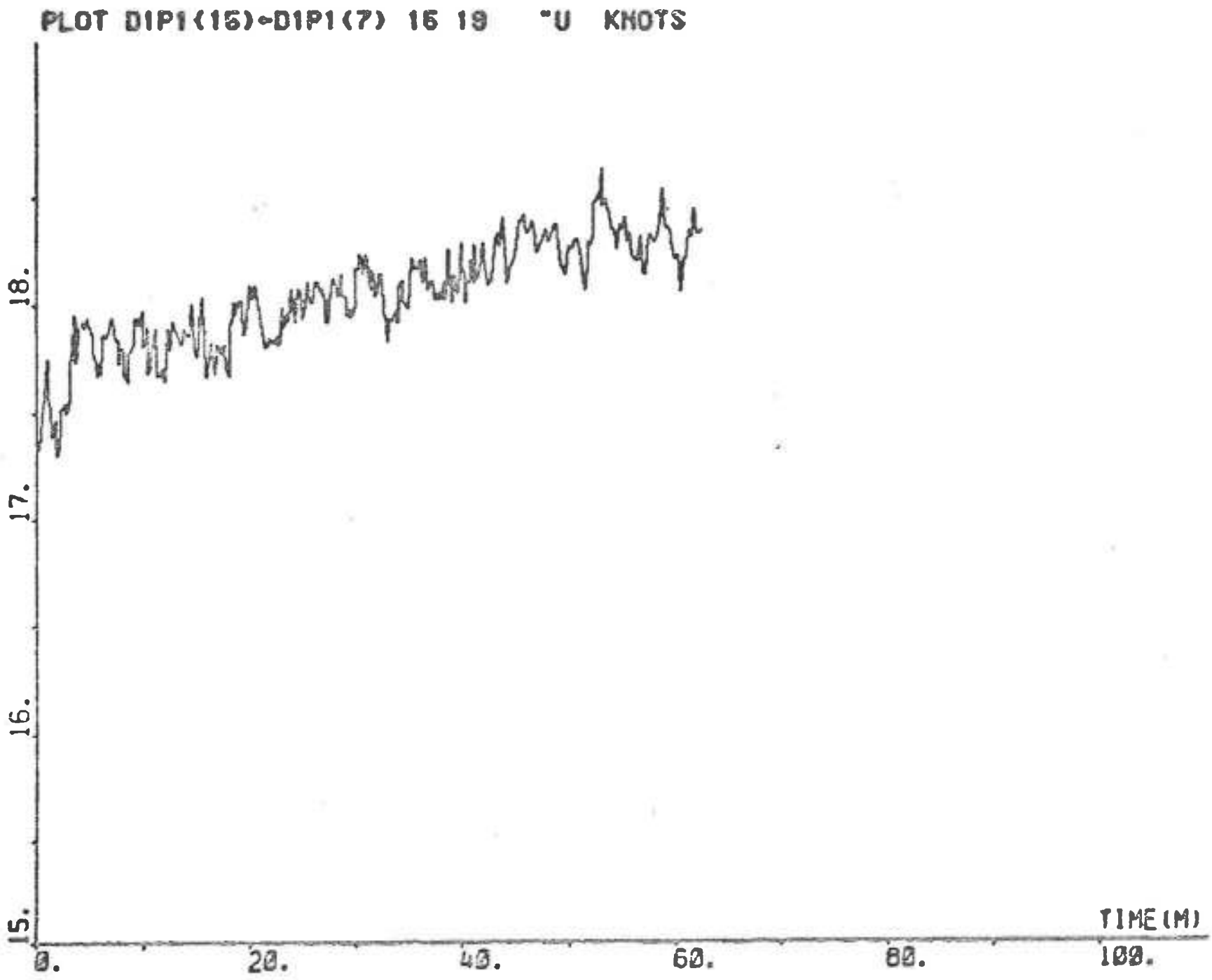

PLOT DIP1(15)-HP DIP1(2) ZERO -20 20 *DELCOH DEG
TIME(M)
0.
20.
40.
60.
80.
100.
-20.
-10.
0.
10.

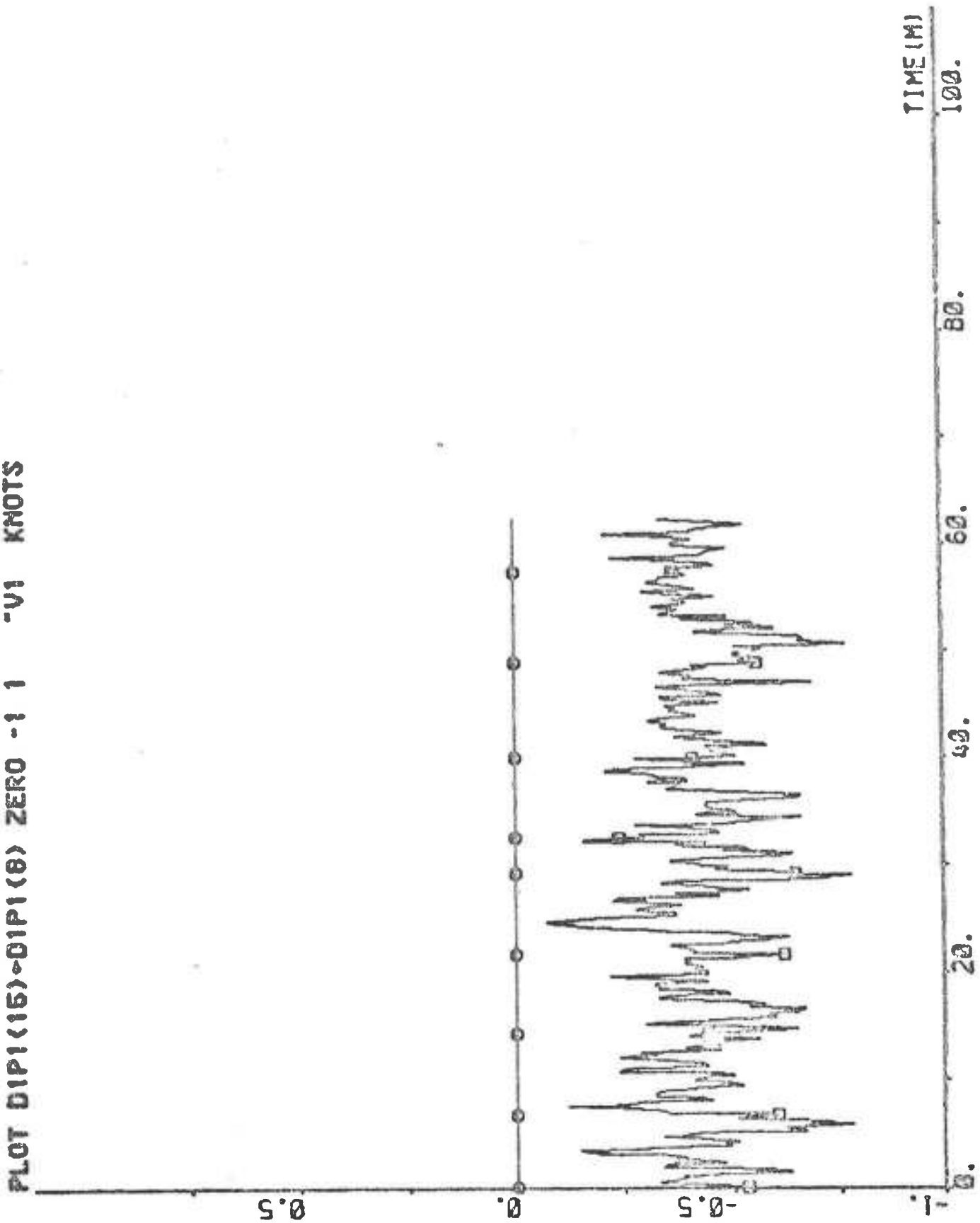

PLOT D1P1(16)-D1P1(3) ZERO -20 20 "DELTRS DEC
10.
0.
-10.
-20.
0.
20.
40.
60.
80.
100.
TIME(M)

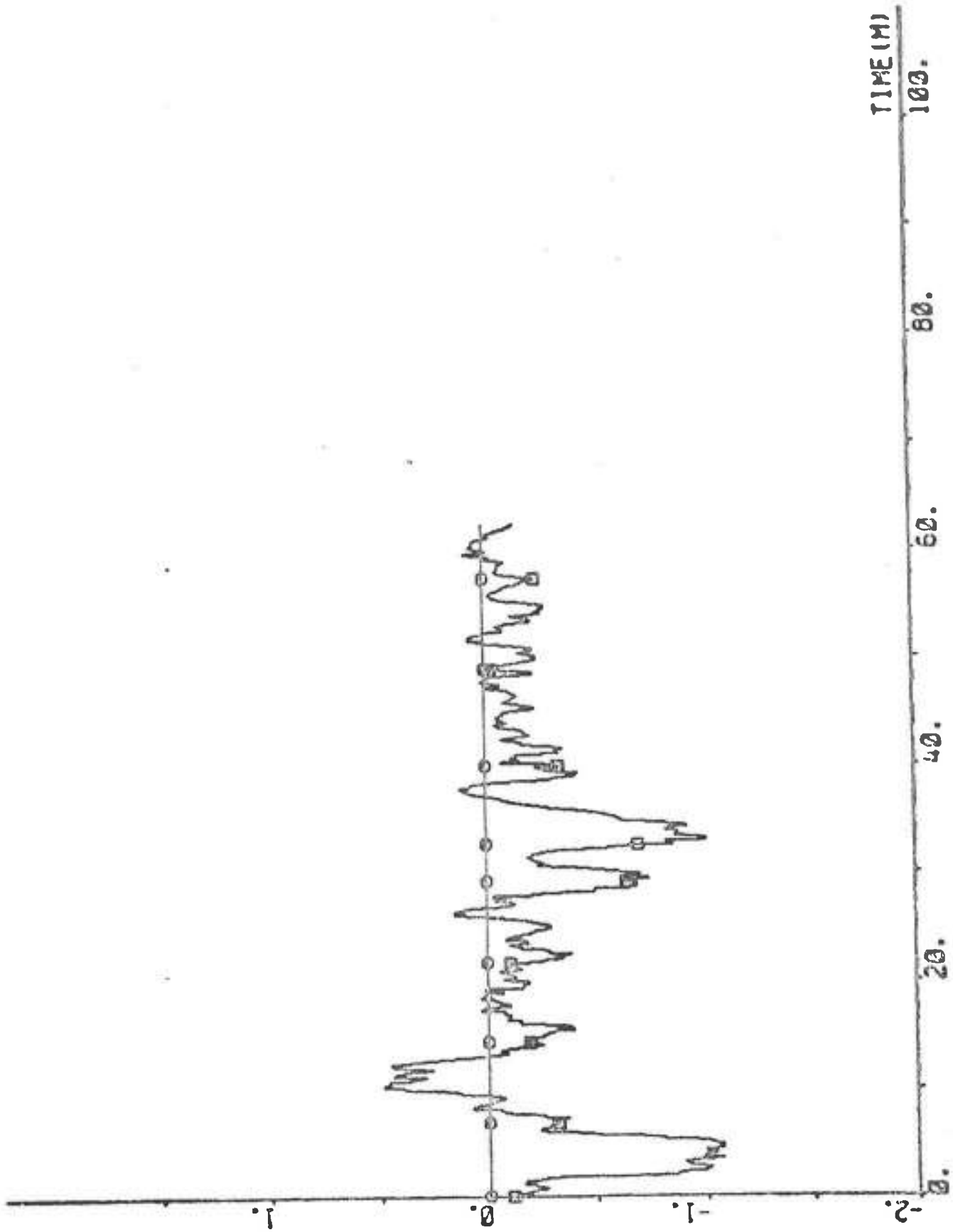

PLOT DIP1(15)-DIP1(4) ZERO -20 20 "DELTA DEC
10.
0.
-10.
-20.
0.
20.
40.
60.
80.
100.
TIME(M)

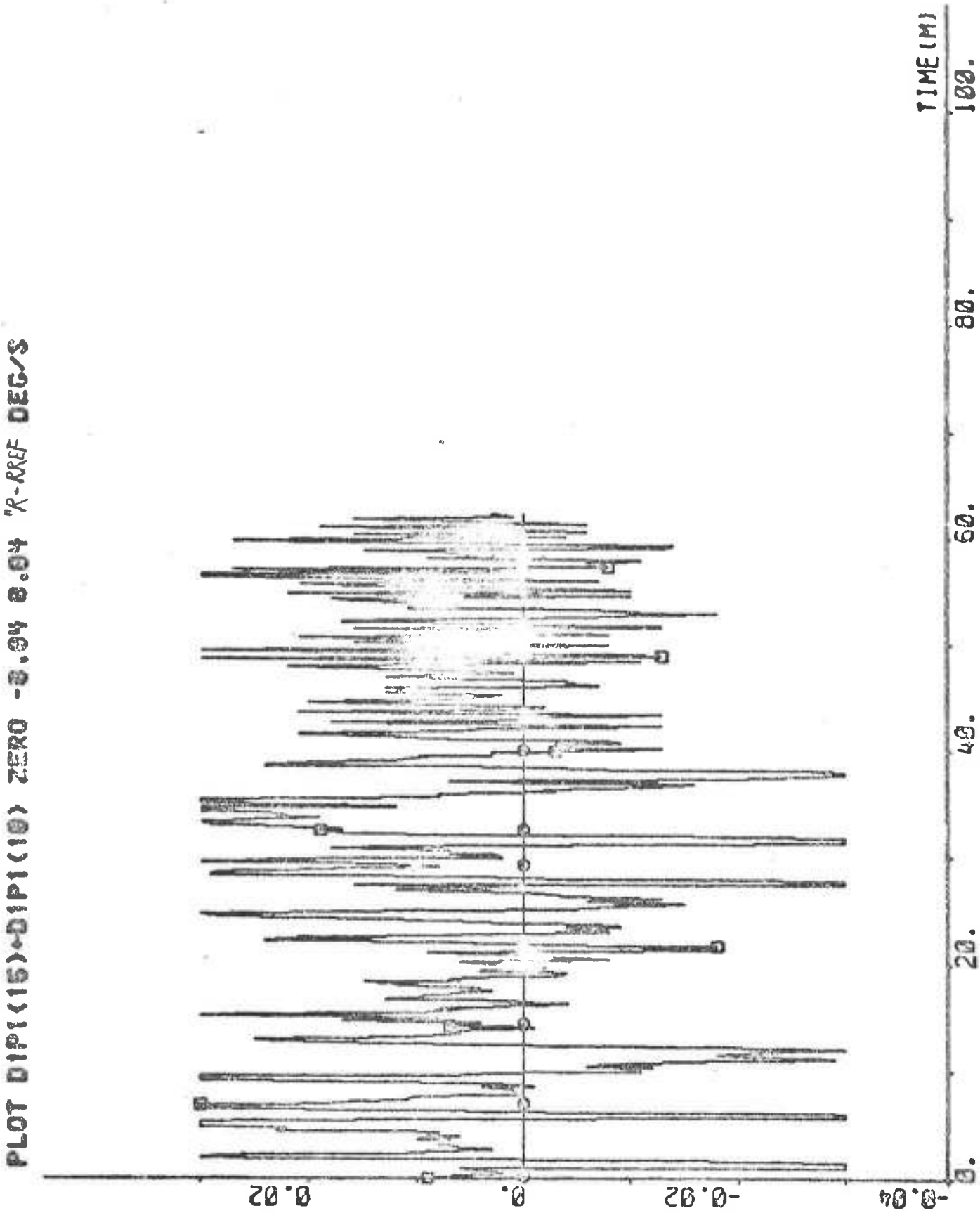

PLOT DIP1(15)-DIP1(5) ZERO -0.2 0.2 "PP DEG/S
TIME(M)
0.
22.
40.
60.
80.
100.
0.2
0.1
0.
-0.1
-0.2

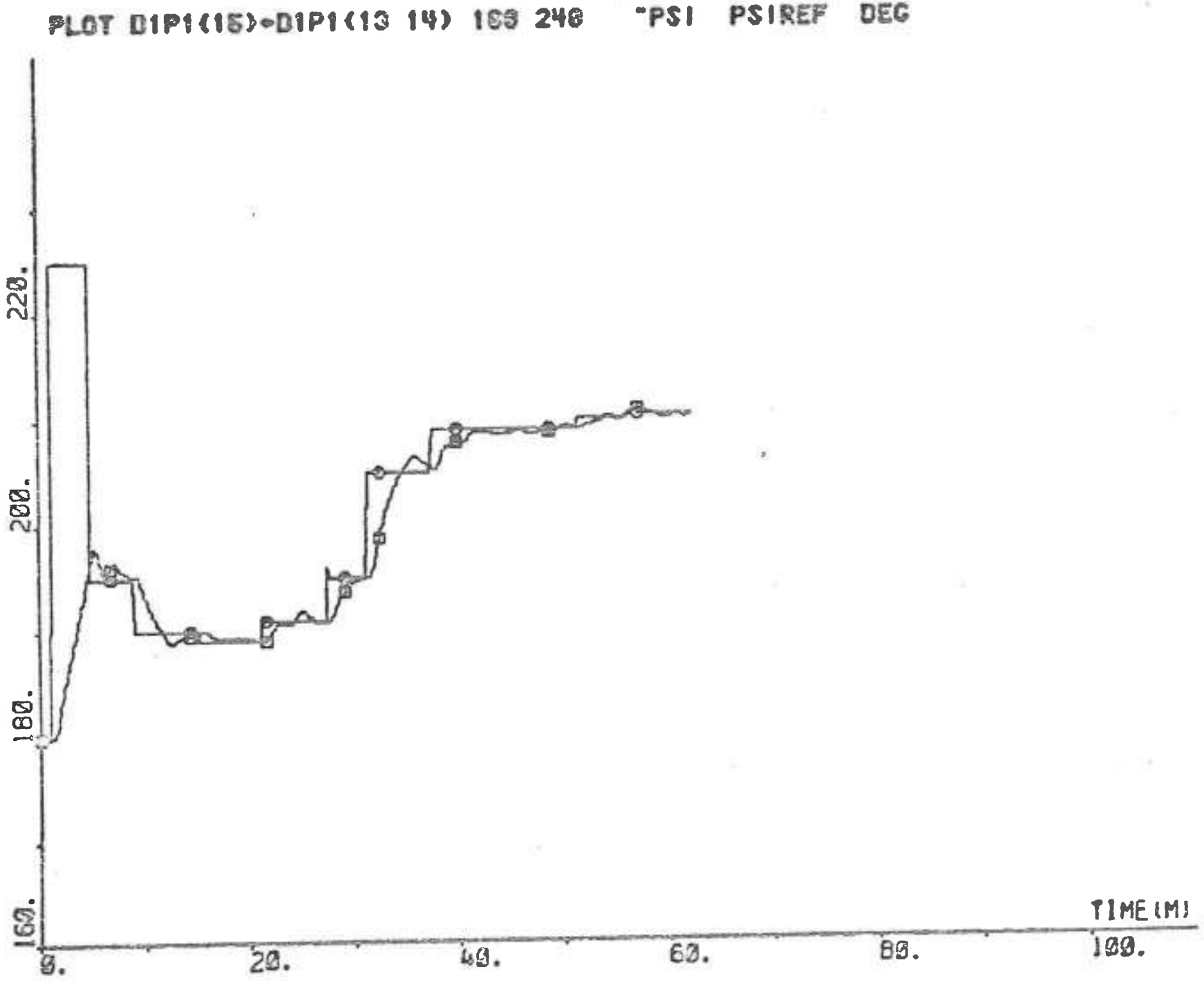

PLOT DIP1(15)-DIP1(8) 82 88 "AN RPM
82.
84.
86.
88.
0.
20.
40.
60.
80.
100.
TIME(M)


PLOT DIP1(15)-DIP1(7) 15 19 *U KNOTS
18.
17.
16.
15.
TIME(M)
0.
20.
40.
60.
80.
100.


PLOT D1P1(16)-D1P1(8) ZERO -1 1 "V1 KNOTS
TIME(M)
0.
20.
40.
60.
80.
100.
1.
0.5
0.
-0.5


PLOT DIP1(15)-DIP1(8) ZERO -2 2 "V2 KNOTS
TIME(M)
0.
20.
40.
60.
80.
100.
1.
0.
-1.
-2.


PLOT DIP1(15)-DIP1(10) ZERO -0.04 0.04 R-REF DEG/S
-0.04
-0.02
0.
0.02
0.
20.
40.
60.
80.
100.
TIME(M)


PLOT D1P1(15)-D1P1(13 14) 160 240 "PSI PSIREF DEG
220.
200.
180.
160.
TIME(M)
0.
20.
40.
60.
80.
100.

1006.

EXPERIMENT D2

Date	1974-10-19
Time	13.21
Duration	66 min
Position	S 19° 08' E 39° 14'
Water depth	deep
Forward draught	20.2 m
Aft draught	20.2 m
Wind direction	N (4, 5; see Appendix A)
Wind velocity	3 Beaufort (4-5.5 m/s, gentle breeze)
Wave height	4 m
PSIREF	210°, 225°, 180°, 225°, 210.5°, 210.6°
RREF	0.07 deg/s (0-32 min),
	0.14 deg/s (32-50 min),
	0.07 deg/s (50-66 min)
Rudder limit	Not active
Approximate mean value of AN	85.5 rpm
Approximate mean value of U	17.2 knots

The signal R-RREF was limited to ±0.03 deg/s. The Sailmaster was switched on after 52 min of the experiment.

Parameter values of the PID-regulator.

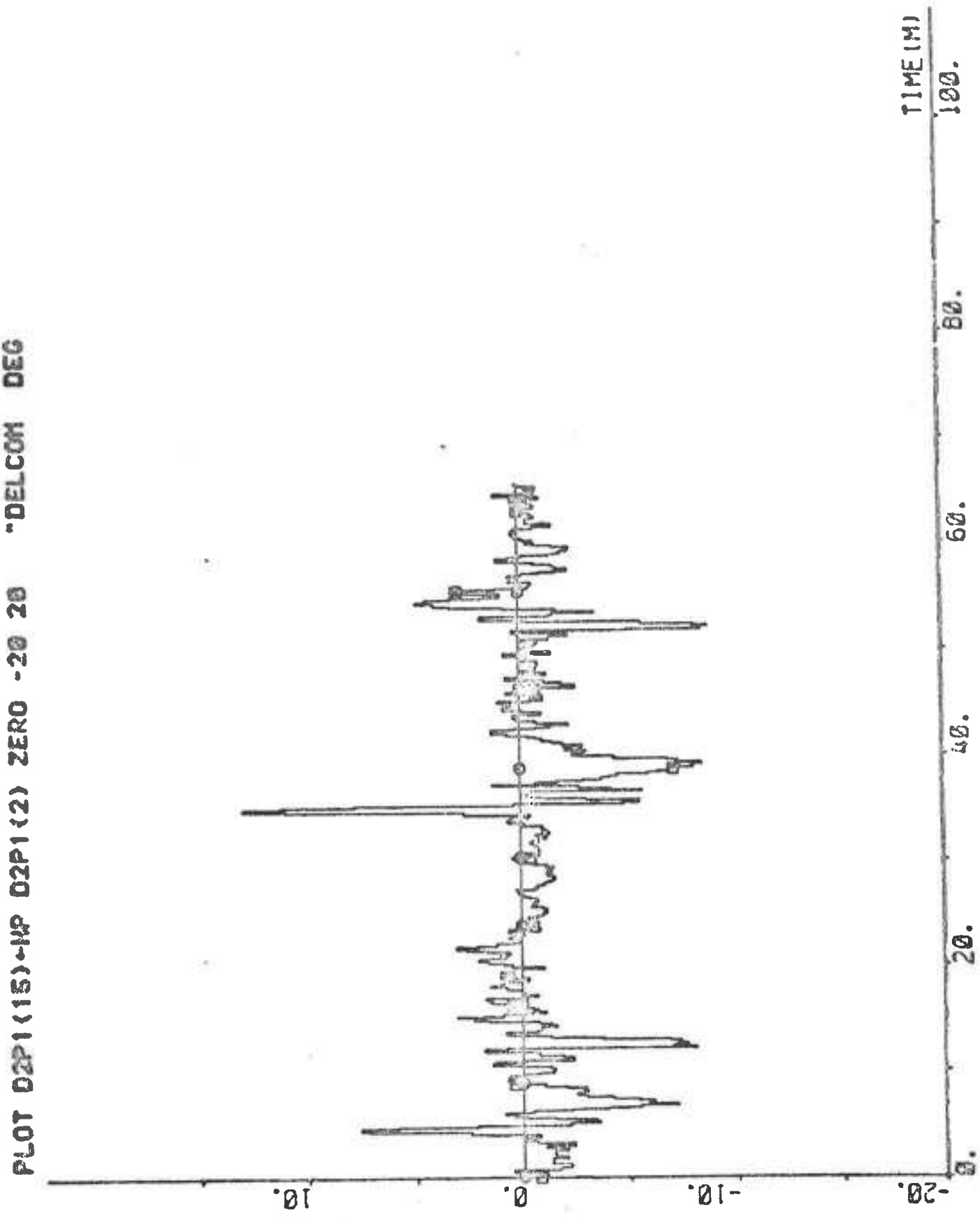
Straight course keeping:

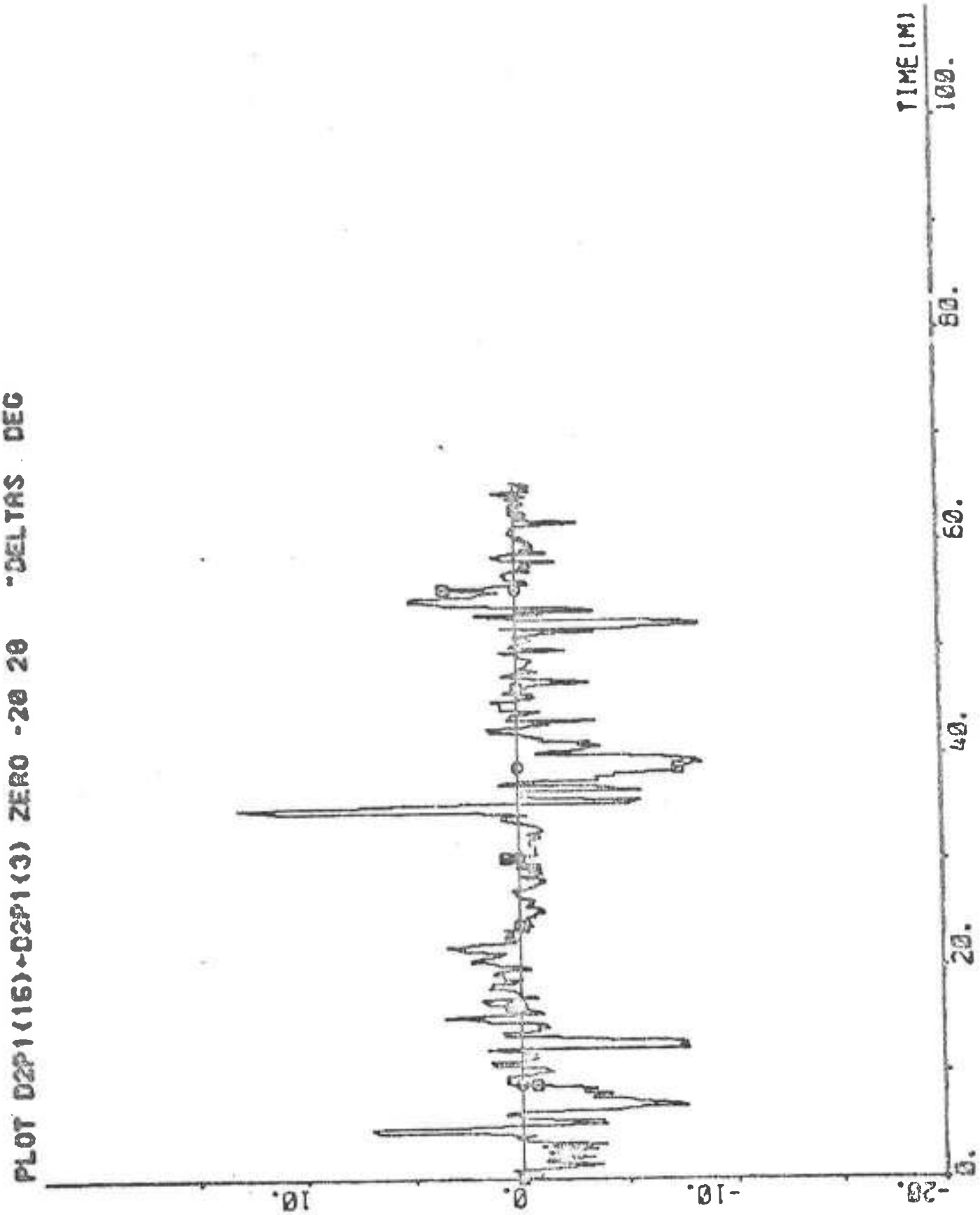
$k_P = 1.7$ $k_D = 120$ s $k_I = 1/120$ s^{-1} $T_s = 15$ s

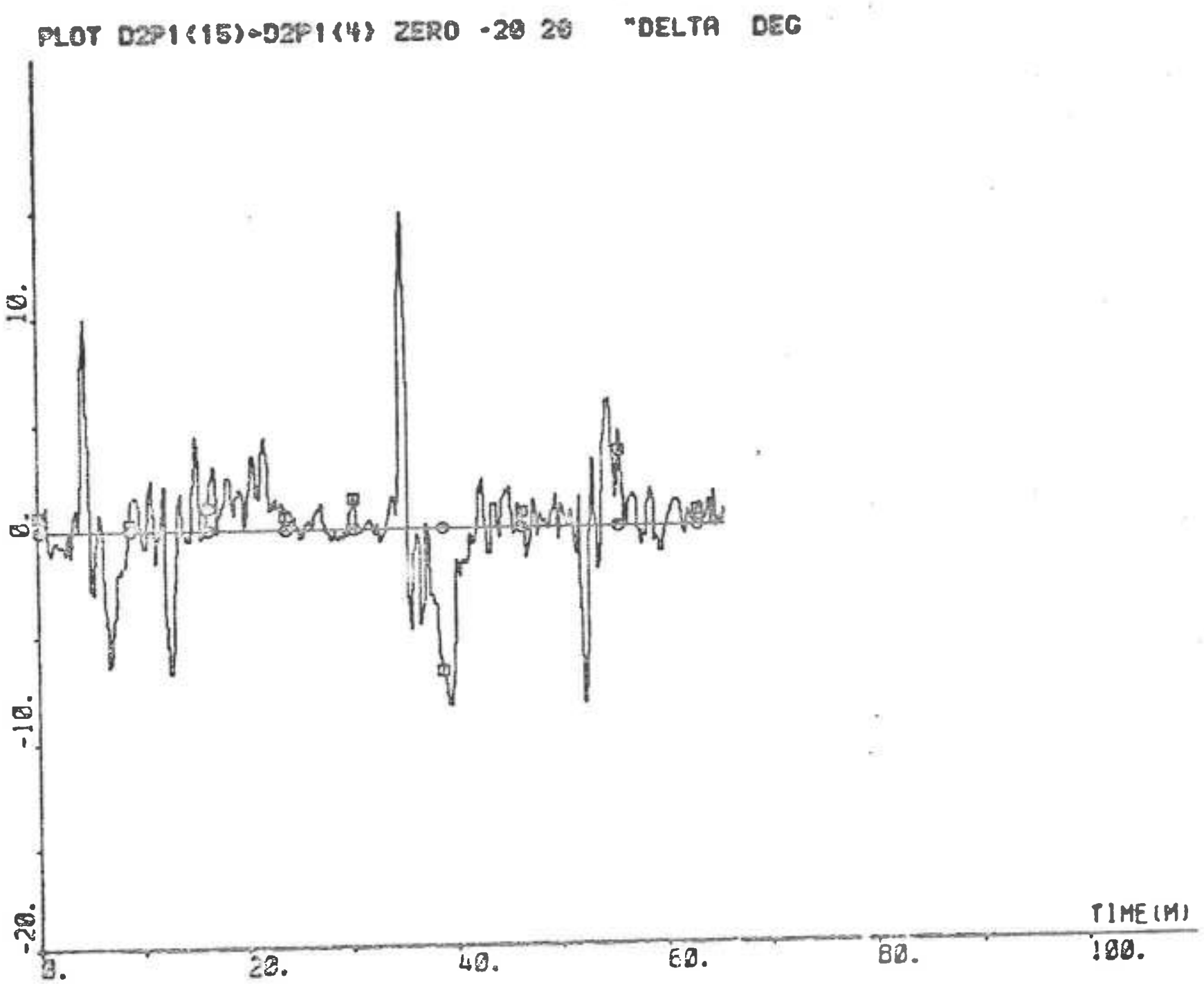
Yawing:

$k_P = 1.2$ $k_D = (1+3|R|)\cdot 120$ s $k_I = 1/4\ k_D$ s^{-1} $T_s = 10$ s

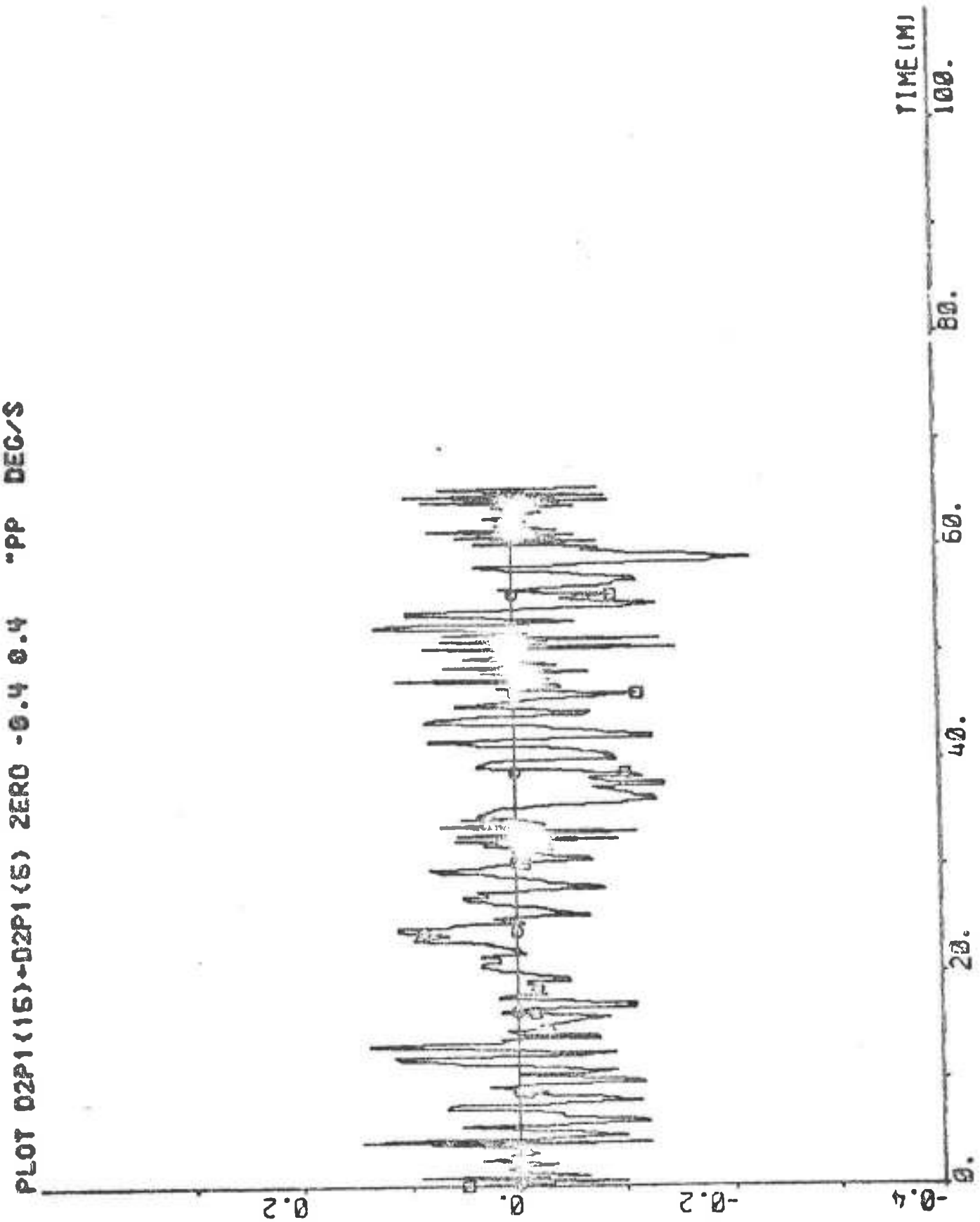
The value of k_P for yawing was changed to 1.7 after 44 min of the experiment.

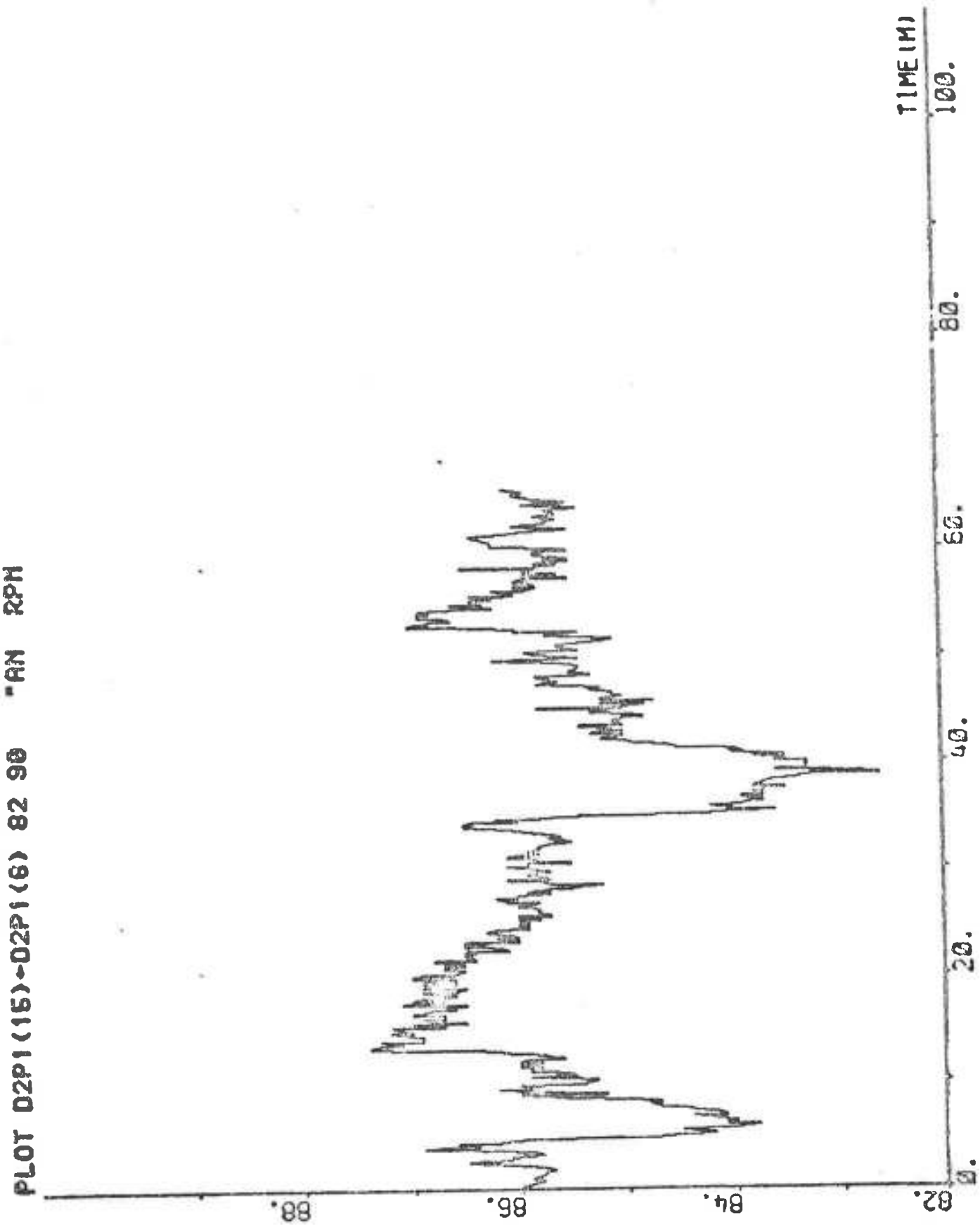

PLOT D2P1(15)-HP D2P1(2) ZERO -20 20 'DELCOM DEG
10.
0.
-10.
-20.
0.
20.
40.
60.
80.
100.
TIME(M)

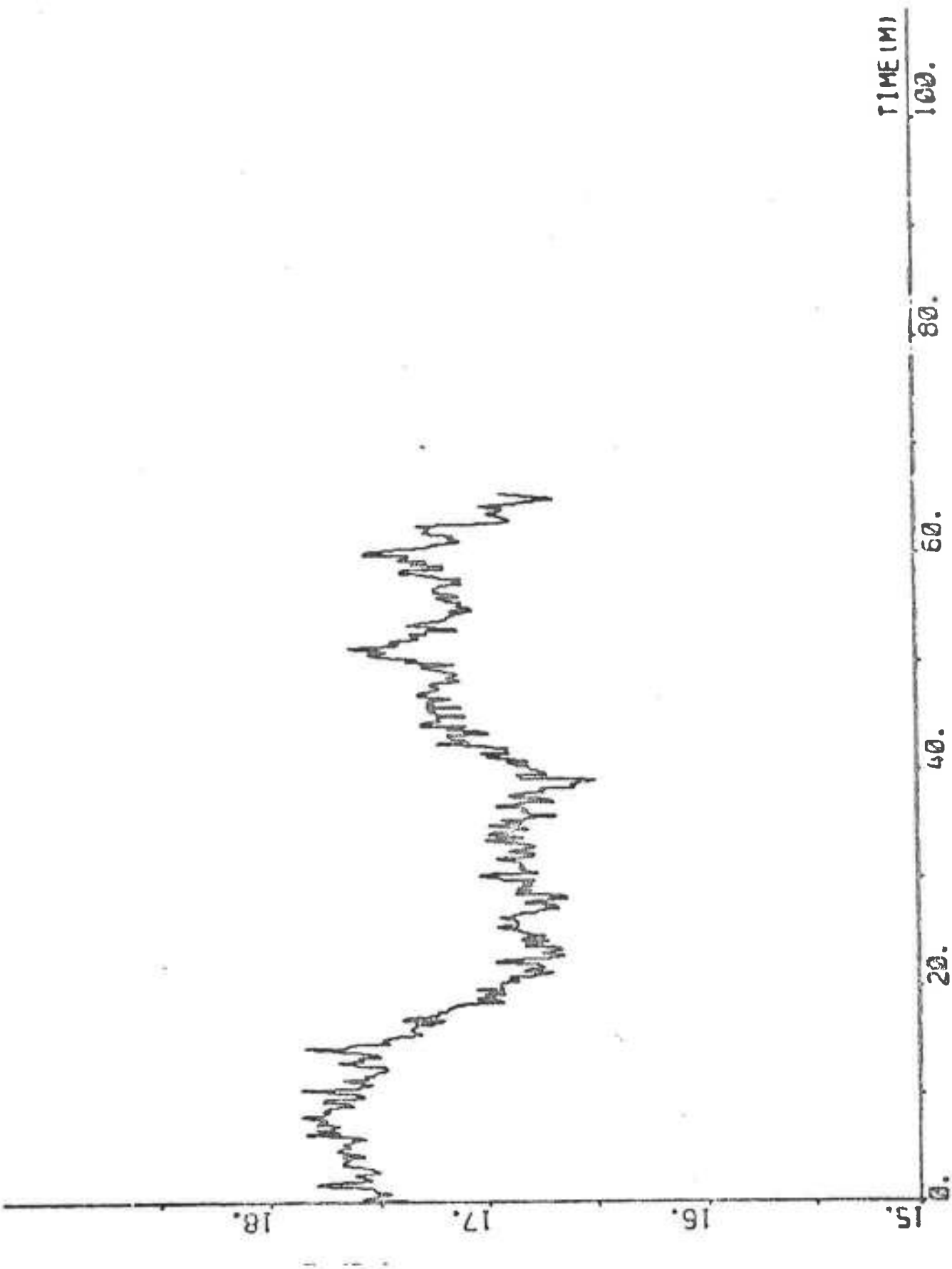

PLOT D2P1(15)-D2P1(3) ZERO -20 20 "DELTAS DEC
TIME(M)
0.
20.
40.
60.
80.
100.
-20.
-10.
0.
10.

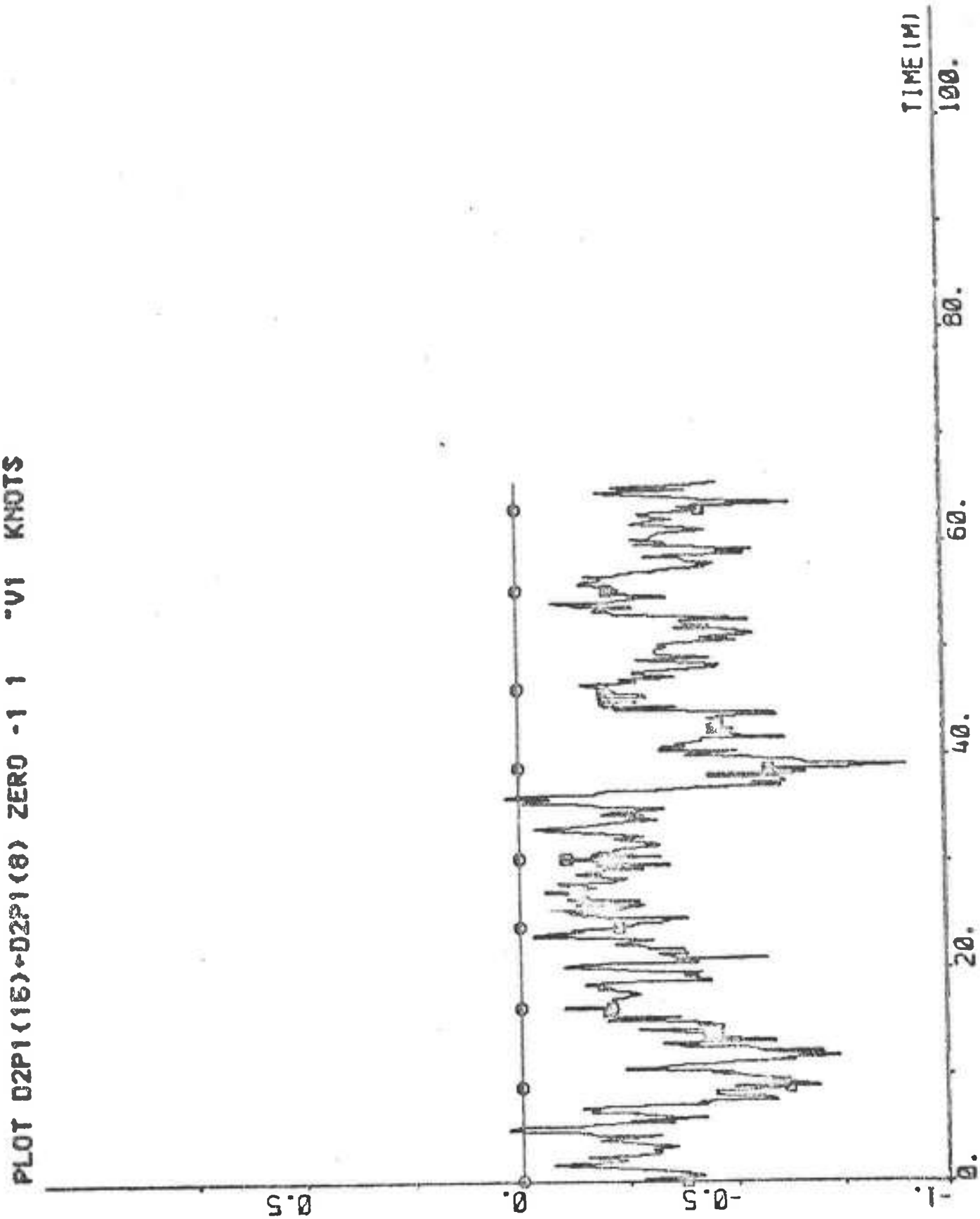

PLOT D2P1(15)-D2P1(4) ZERO -20 20 "DELTA DEG
10.
0.
-10.
-20.
0.
20.
40.
60.
80.
100.
TIME(M)

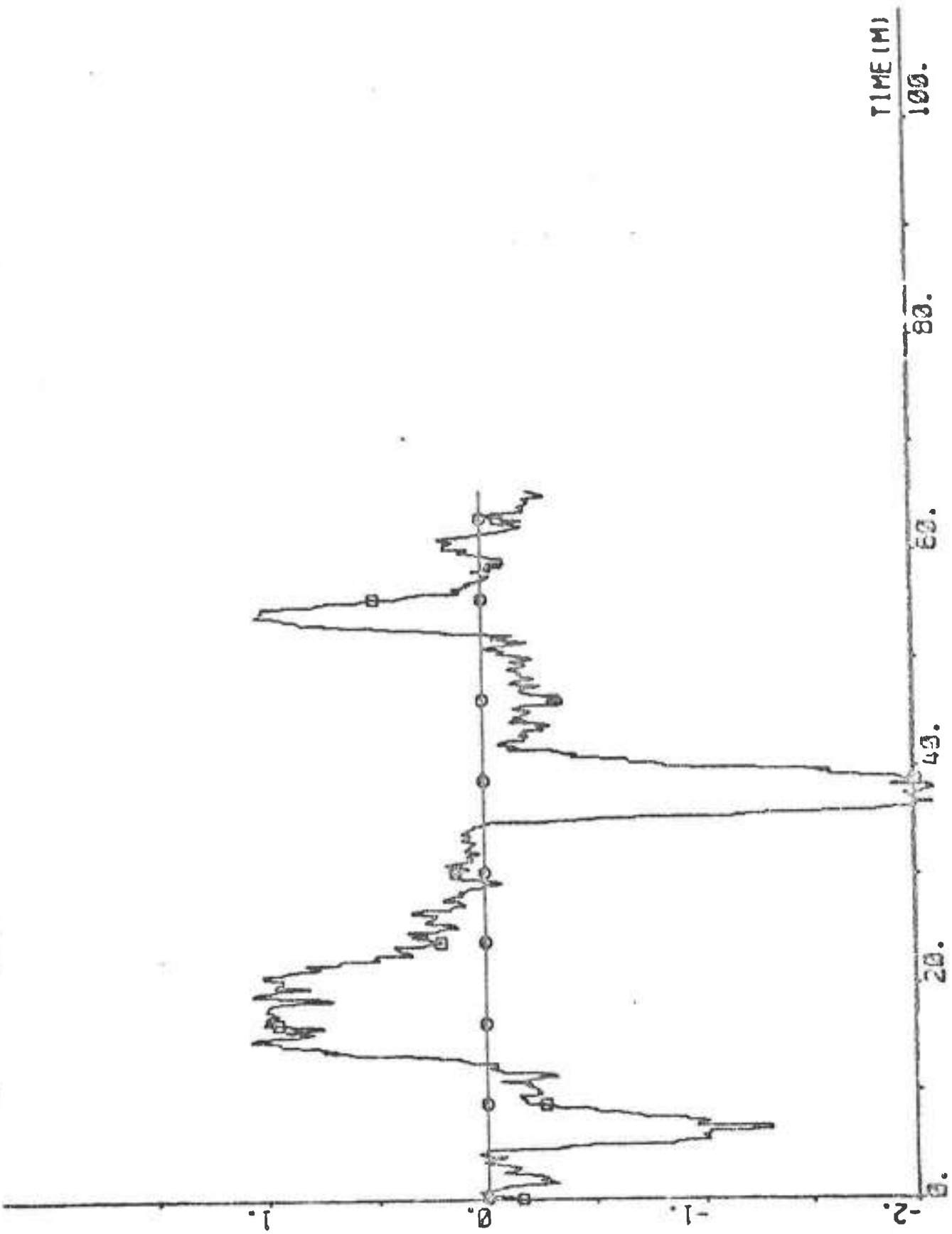
1010.

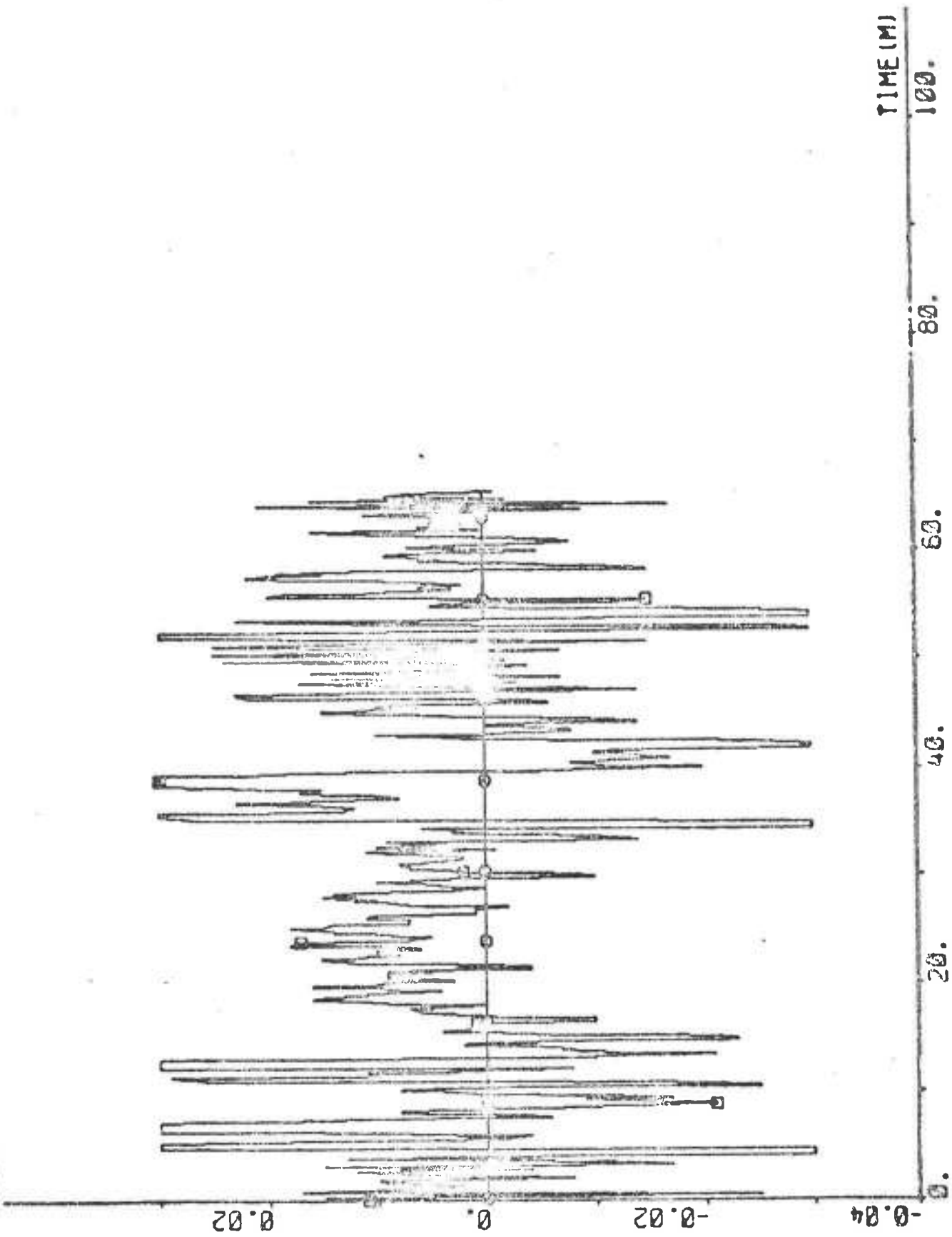

PLOT 02P1(1S)-02P1(S) ZERO -0.4 0.4 *PP DEG/S
0.2
0.
-0.2
-0.4
0.
20.
40.
60.
80.
100.
TIME(MI)

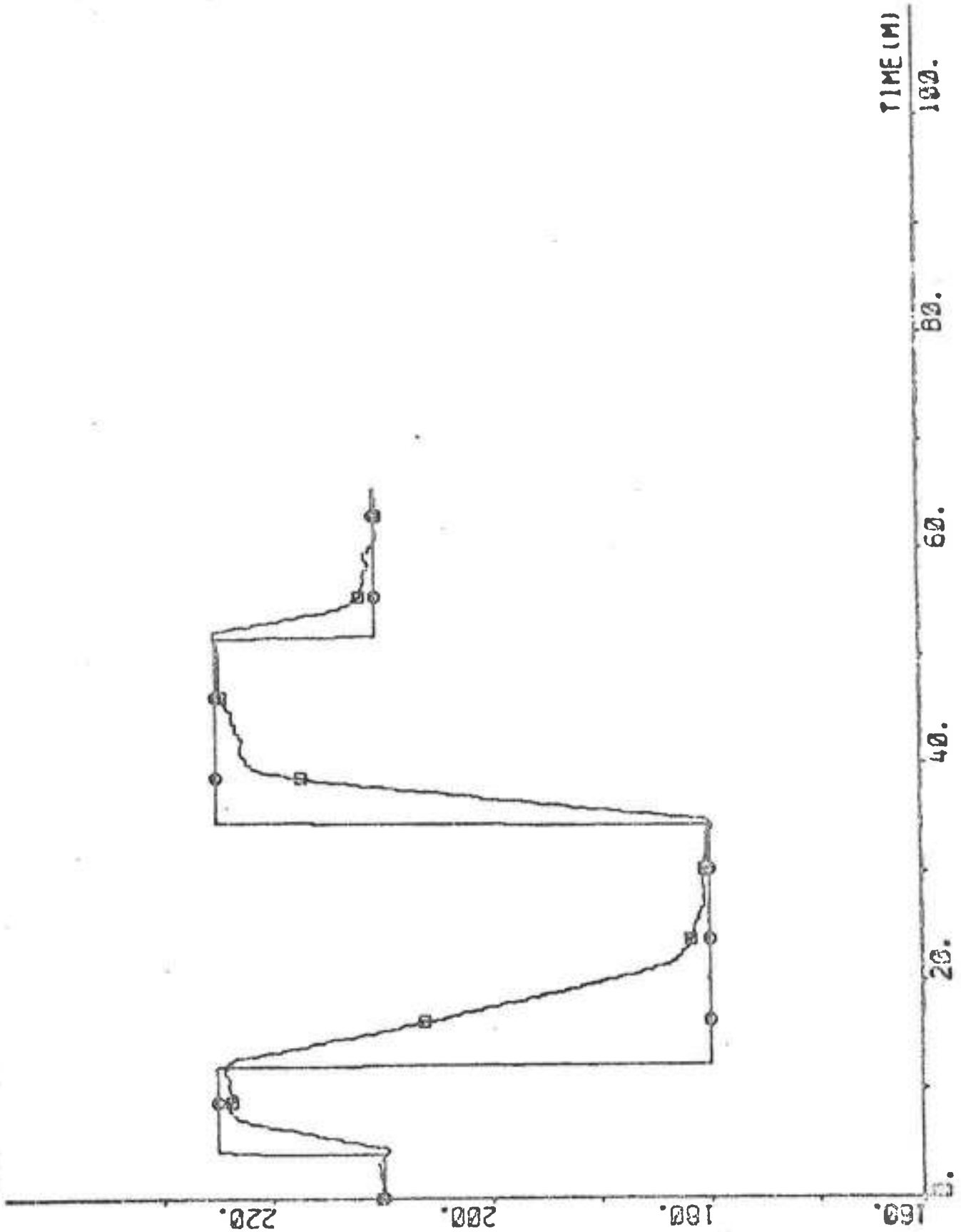

PLOT D2P1(15)-D2P1(8) 82 90 *AN RPH
TIME(M)
0.
20.
40.
60.
80.
100.
82.
84.
86.
88.


PLOT D2P1(16)-D2P1(7) 15 19 "U KNOTS
15.
16.
17.
18.
0.
20.
40.
60.
80.
100.
TIME(M)


PLOT D2P1(1E)-D2P1(8) ZERO -1 1 'V1 KNOTS
TIME(M)
0.
20.
40.
60.
80.
100.
-1.
-0.5
0.
0.5


PLOT D2P1(15)-D2P1(0) ZERO -2 2 "V2 KNOTS
TIME(M)
0.
20.
40.
60.
100.
-2.
-1.
0.
1.


PLOT D2P1(15)-D2P1(16) ZERO -0.04 0.04 "R-RREF DEG/S
TIME(M)
0.
20.
40.
60.
80.
100.
-0.04
-0.02
0.
0.02


PLOT D2P1(15)-D2P1(13 14) 160 240 "PSI PSIREF DEC
TIME(M)
0.
20.
40.
60.
80.
100.
160.
180.
200.
220.

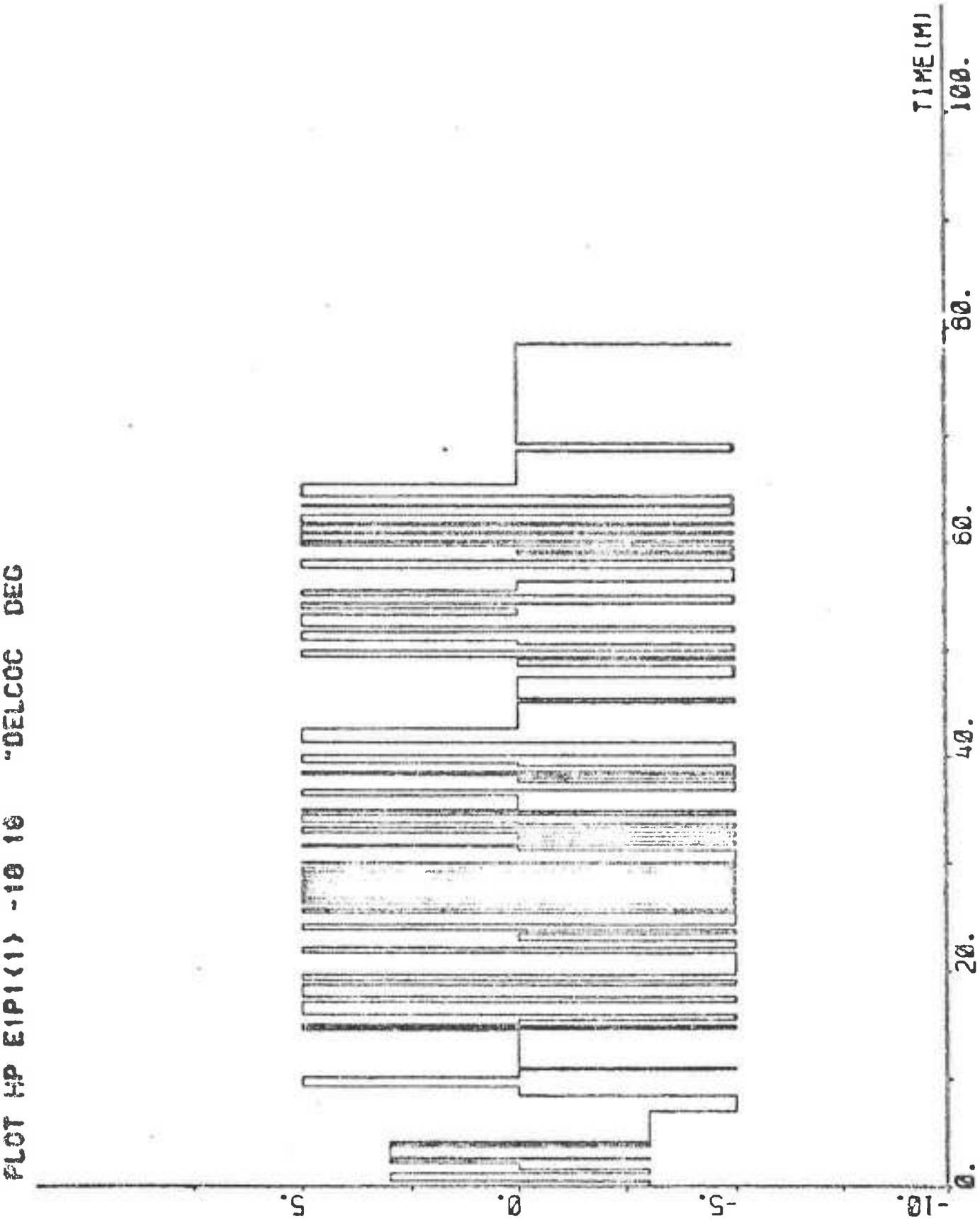
EXPERIMENT E1

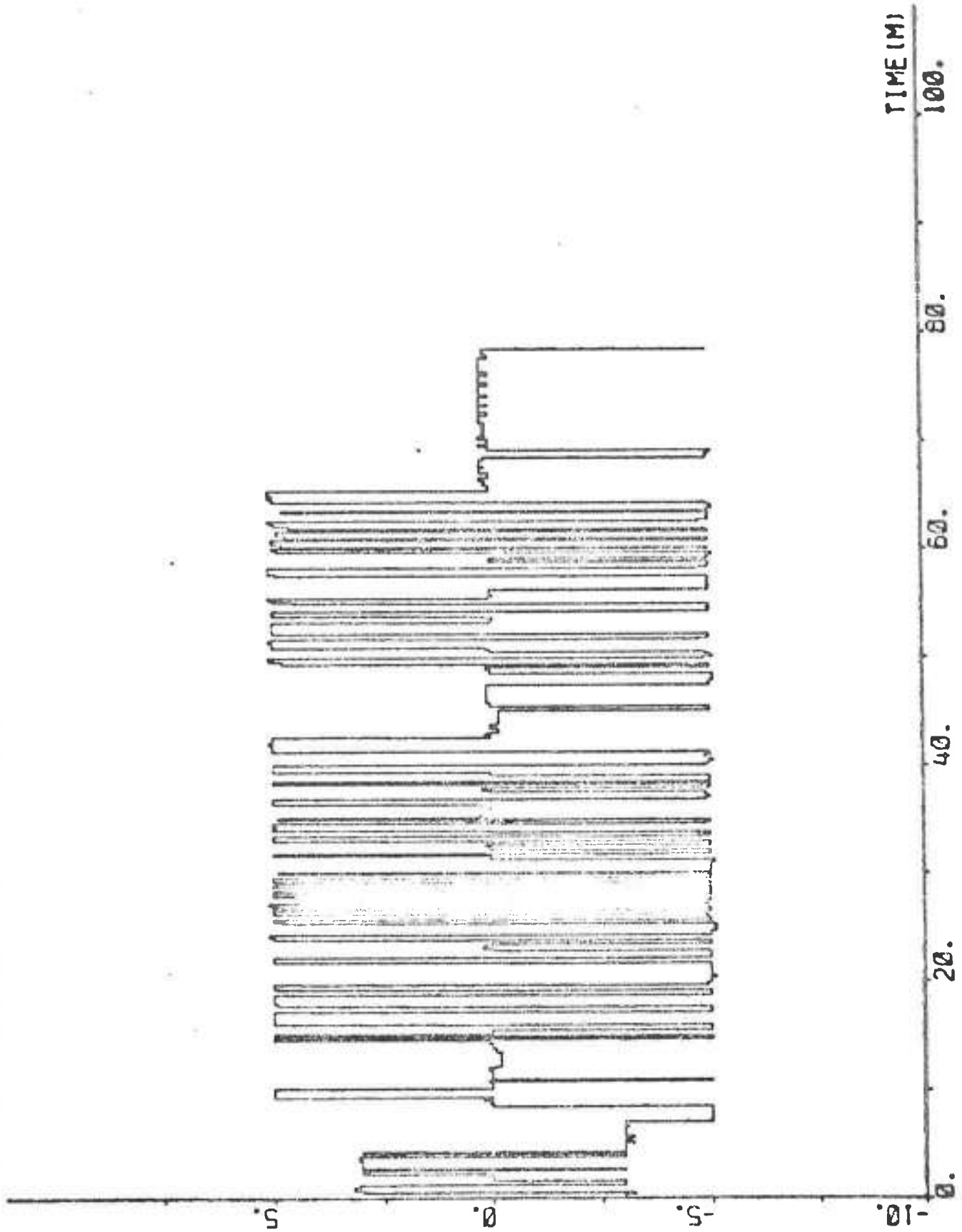
Date	1974-10-20
Time	09.40
Duration	78 min
Position	S 23° 56' E 36° 10'
Water depth	deep
Forward draught	20.2 m
Aft draught	20.2 m
Wind direction	S (8; see Appendix A)
Wind velocity	2 Beaufort (2-3.5 m/s, light breeze)
Wave height	2 - 3 m
PSIREF	215°
Rudder limit	Not active
DELAMP	3°, 5°
AKID	0
IREG	10 s

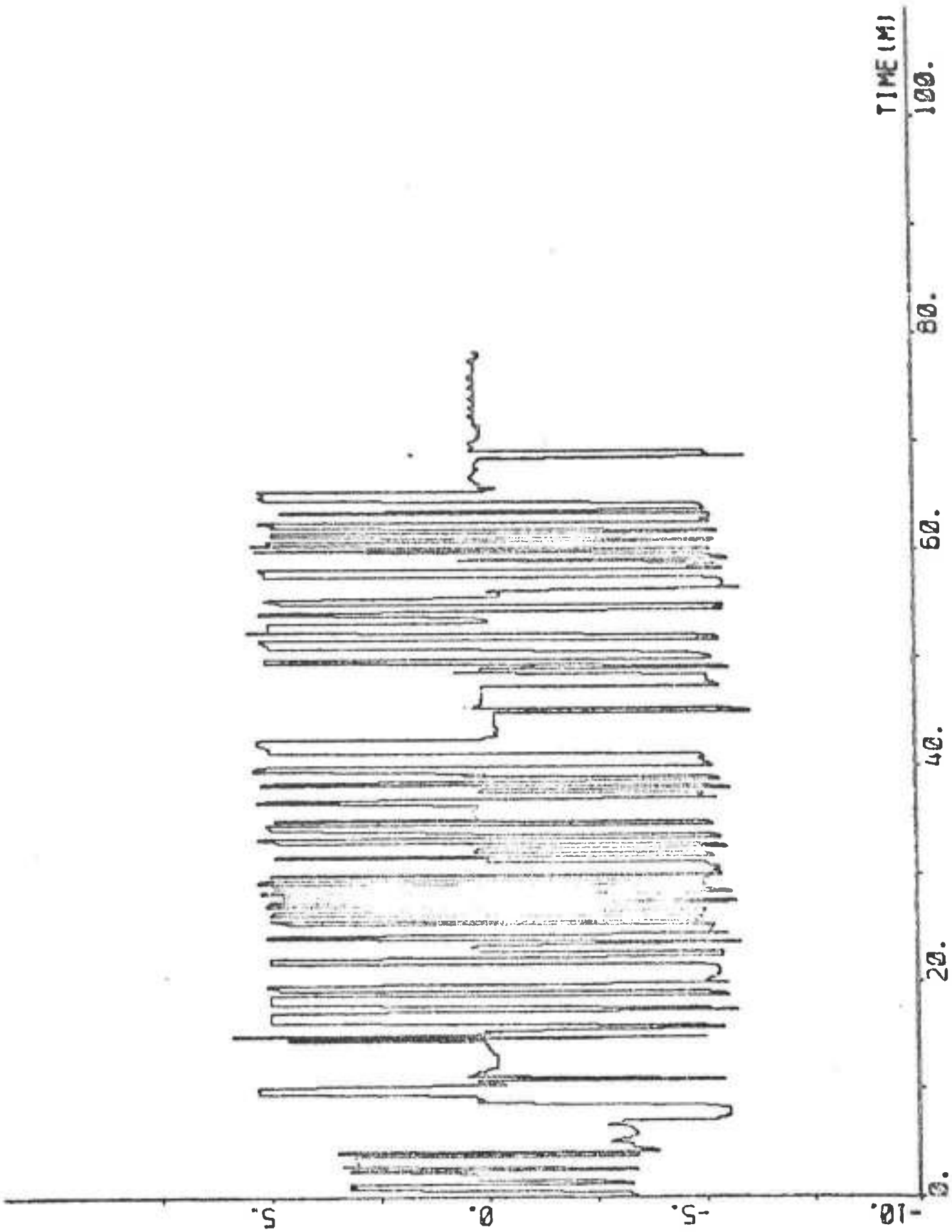
Open loop experiment for identification. Probably misleading measurements of U due to air-bubbles below the doppler log.

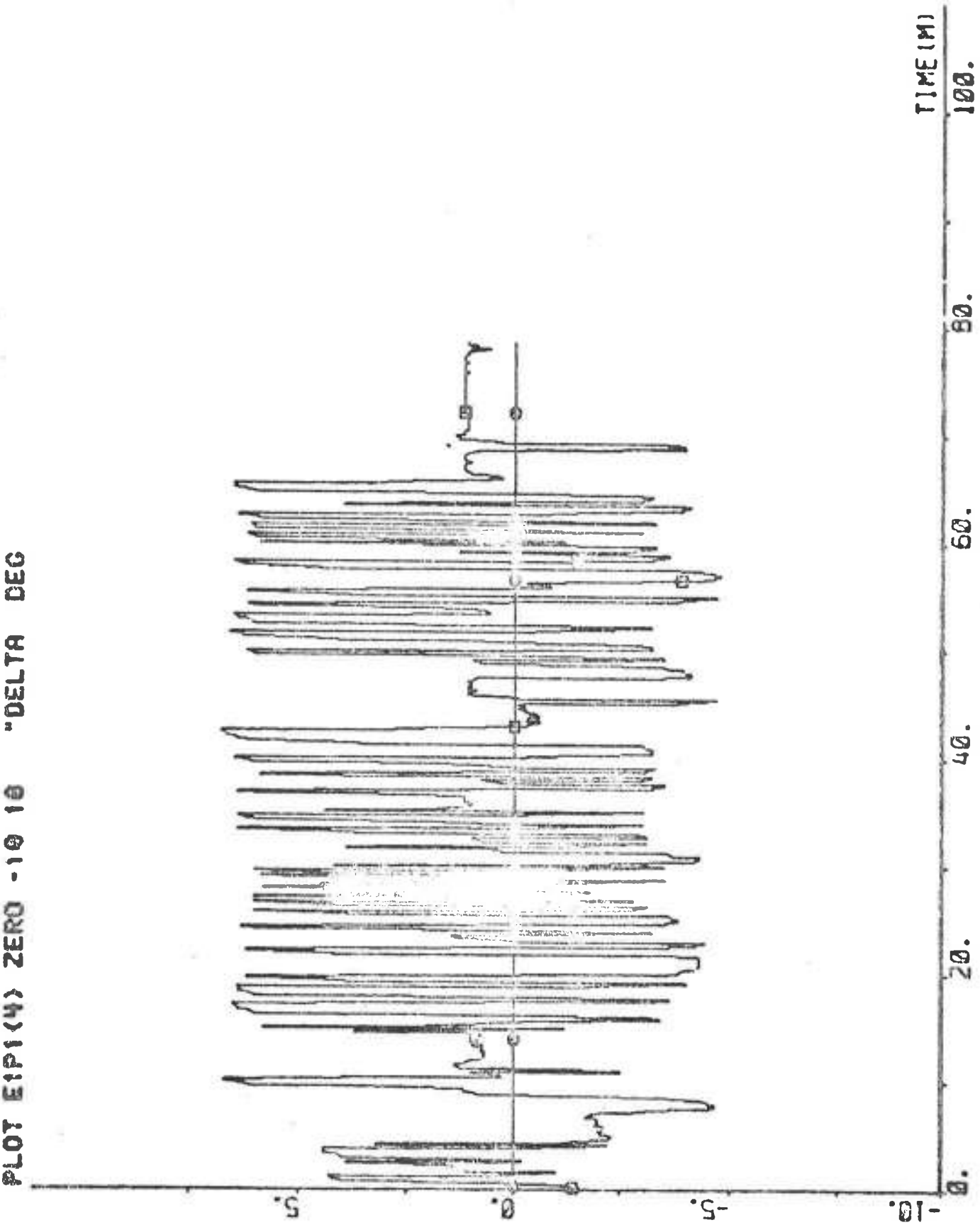
Statistics

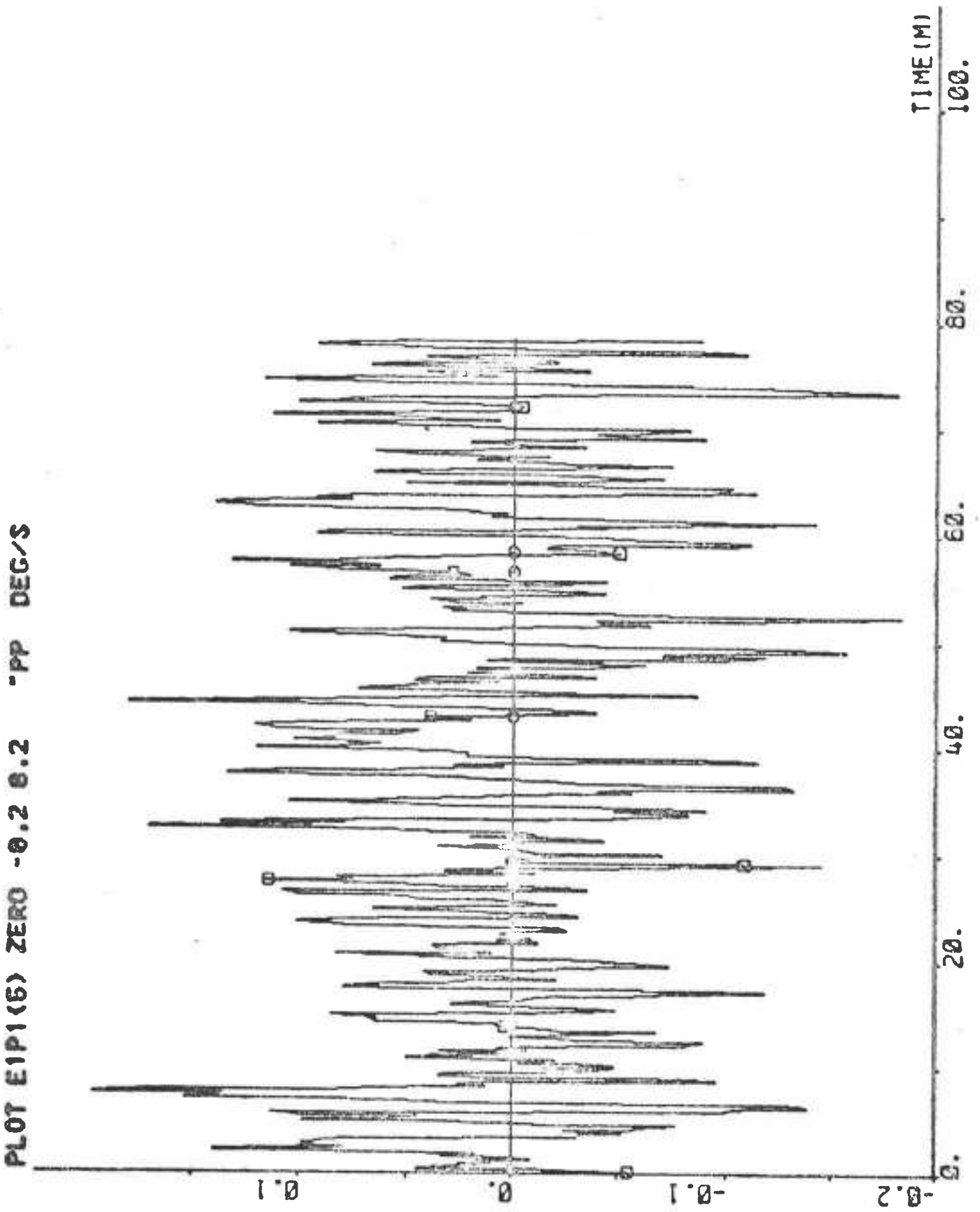
		Mean value	Standard deviation
DELCOC	deg	-0.40	3.77
DELCOM	deg	-0.39	3.76
DELTAS	deg	-0.42	3.88
DELTA	deg	0.76	3.38
PP	deg/s	0.0089	0.0652
AN	rpm	85.44	0.93
U	knots	14.33	2.98
V1	knots	-0.40	0.11
V2	knots	-0.14	0.52
R	deg/s	0.0068	0.0466
AVR	deg/s	0.0054	0.0388
DPSIDT	deg/s	0.0012	0.0429
PSI	deg	216.98	5.54

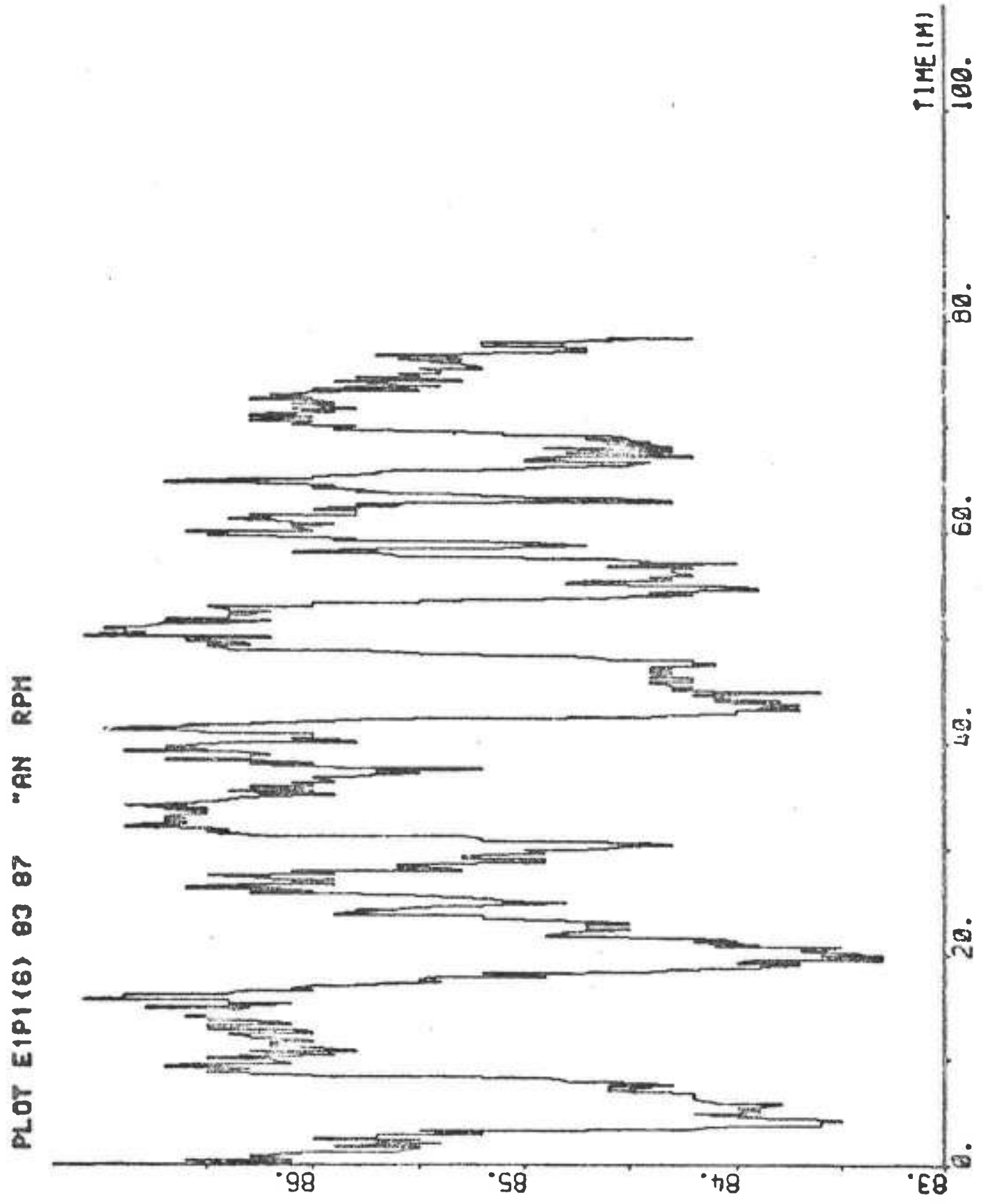

PLOT HP EIP1(1) -10 10 "DELCOC DEG
TIME(M)
0.
20.
40.
60.
80.
100.
-10.
-5.
0.
5.

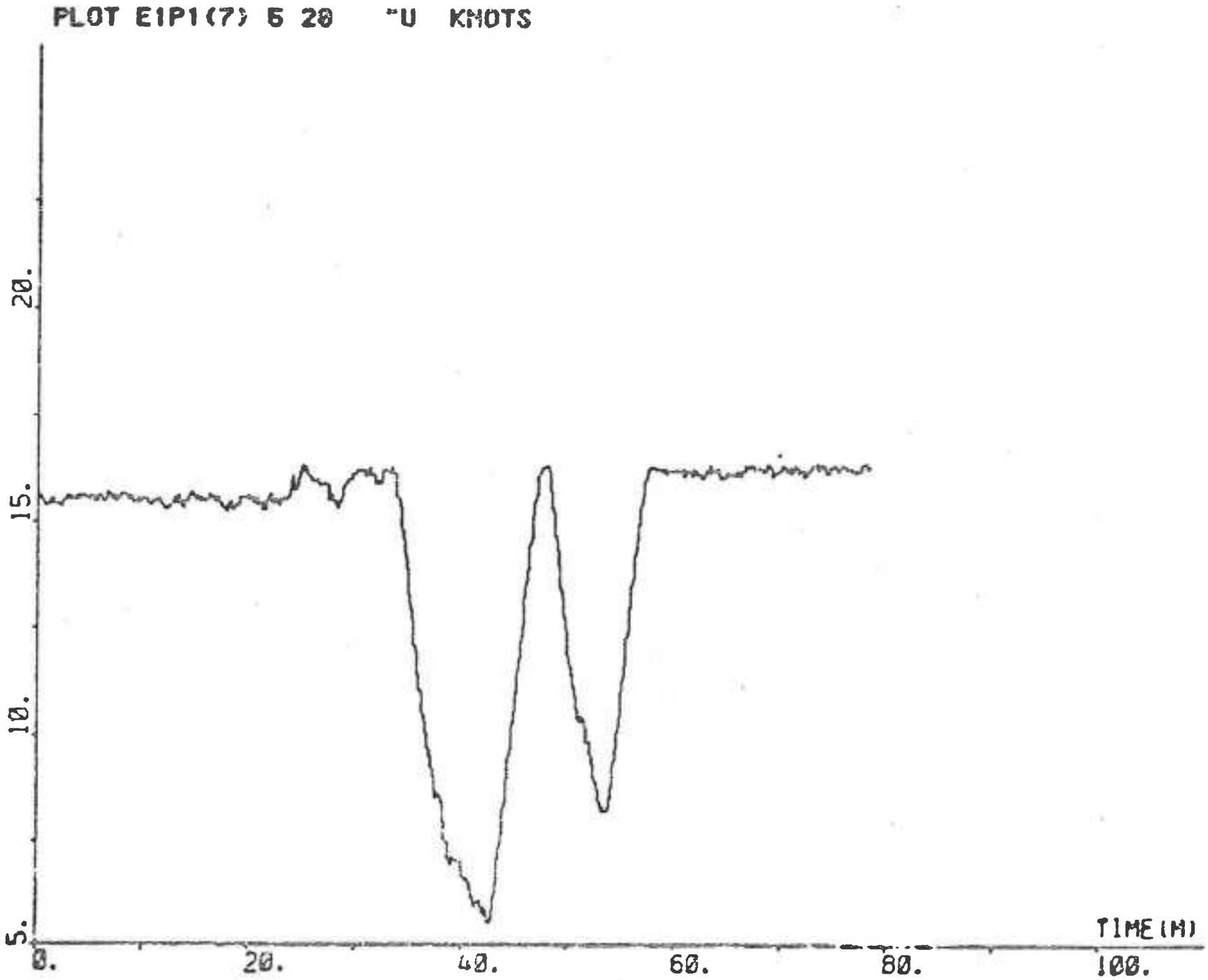

PLOT HP E1P1(2) -10 10 "DELCON DEG
TIME(M)
0.
20.
40.
60.
80.
100.
-10.
-5.
0.
5.

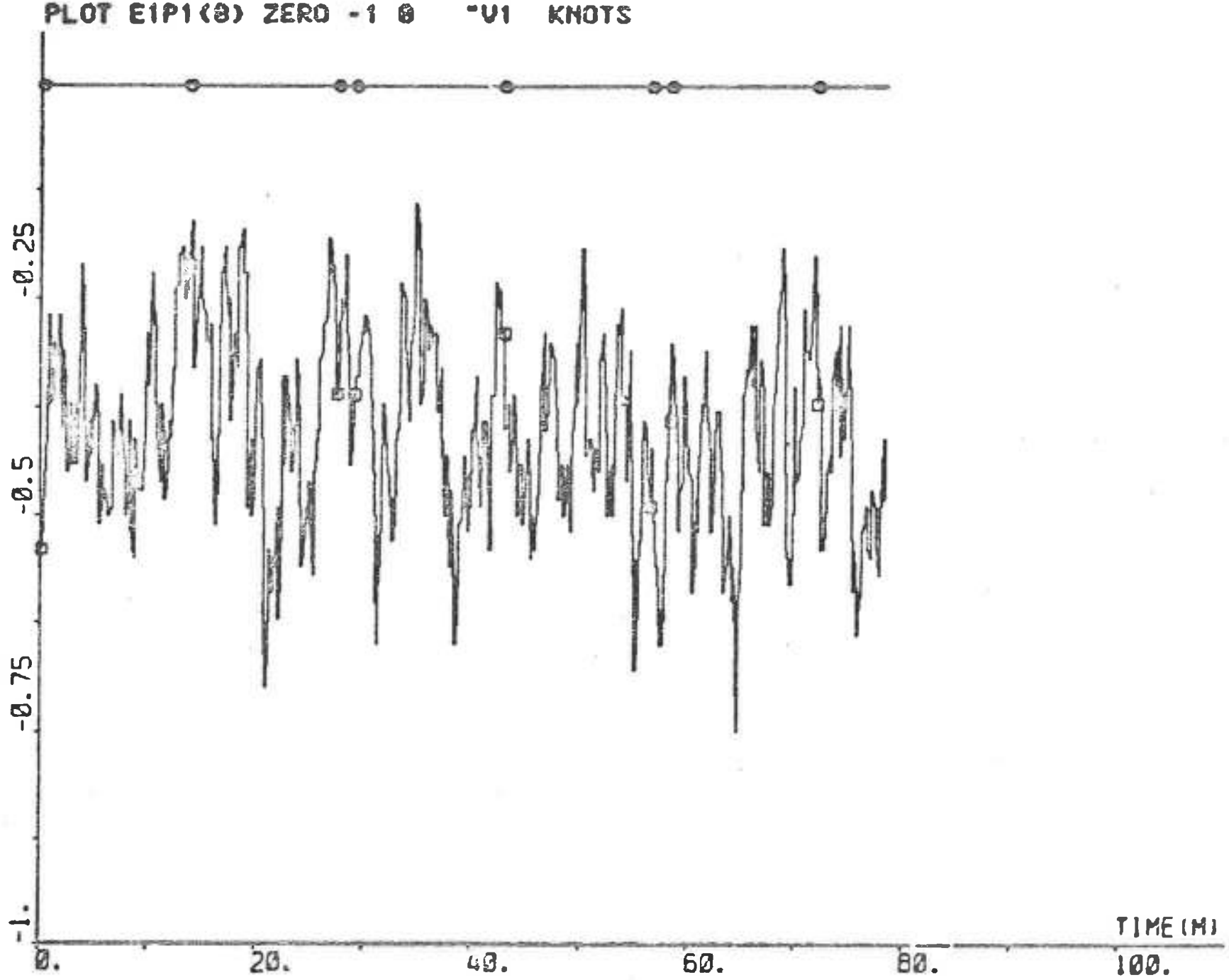

PLOT EIP1(3) -10 10 "DELTAS DEG
TIME(M)
0.
20.
40.
60.
80.
100.
-10.
-5.
0.
5.

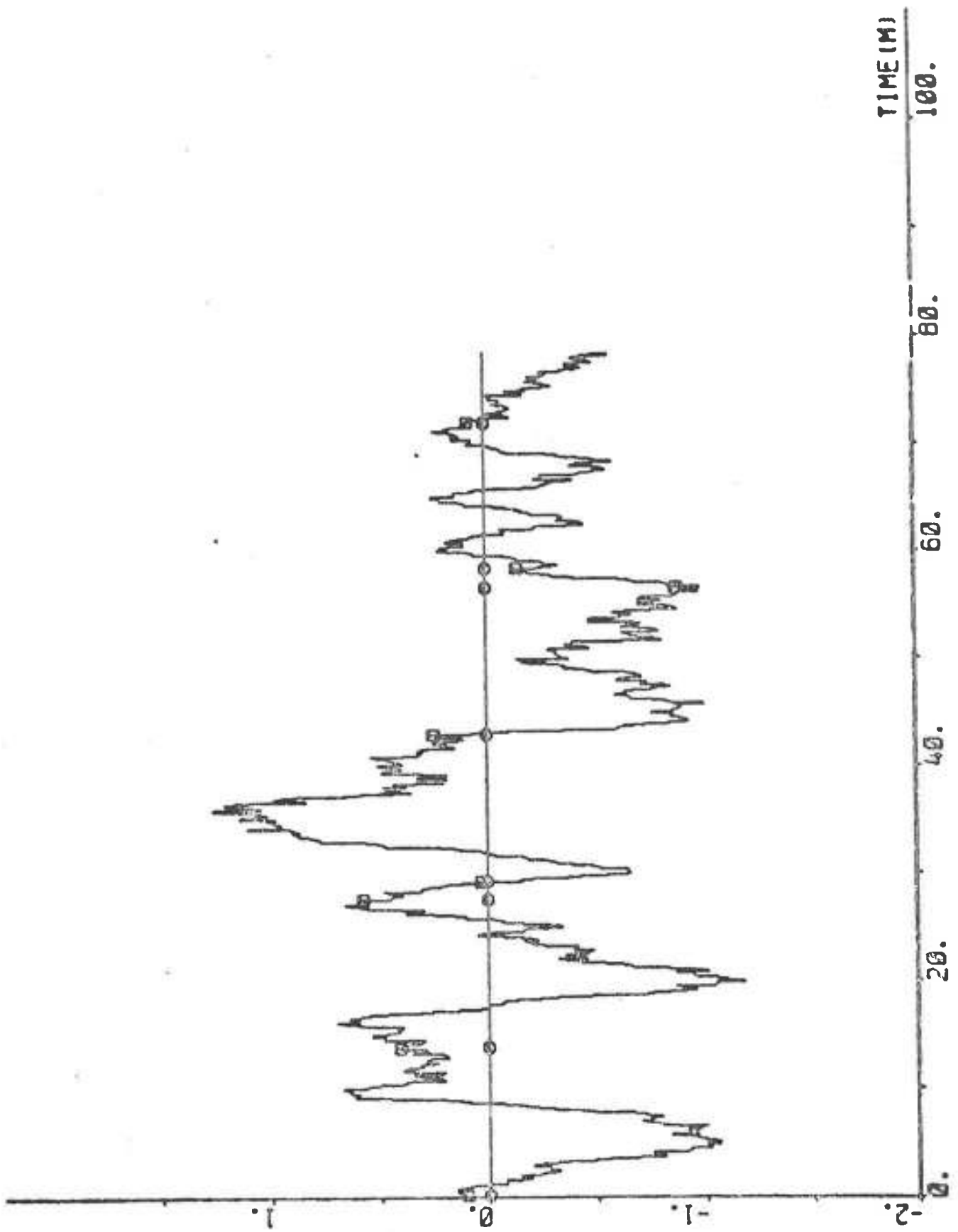

PLOT EIP1(4) ZERO -10 10 "DELTA DEG
TIME(M)
0.
20.
40.
60.
80.
100.
-10.
-5.
0.
5.

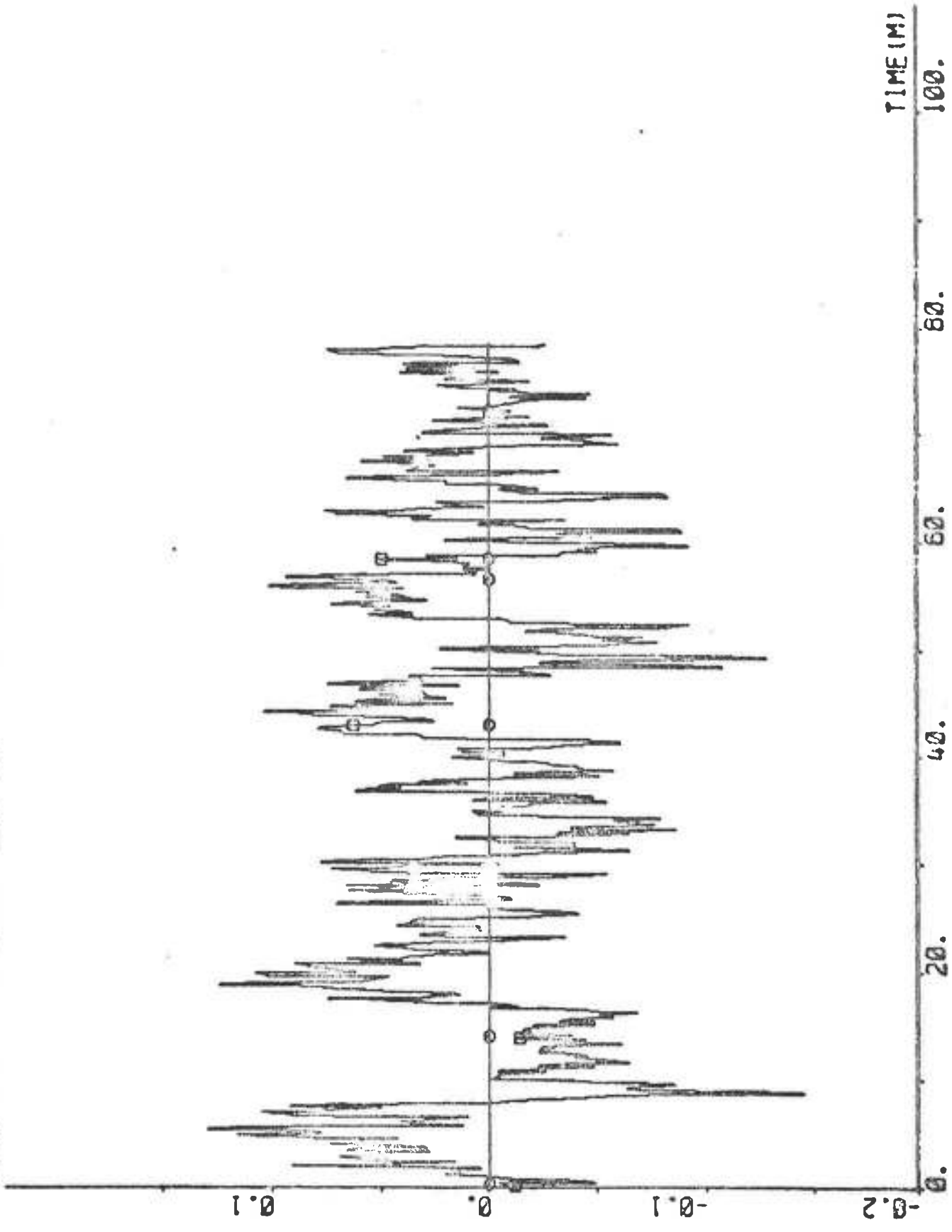

PLOT E1P1(6) ZERO -0.2 0.2 'PP DEG/S
TIME(M)
0.
20.
40.
60.
80.
100.
-0.2
-0.1
0.
0.1

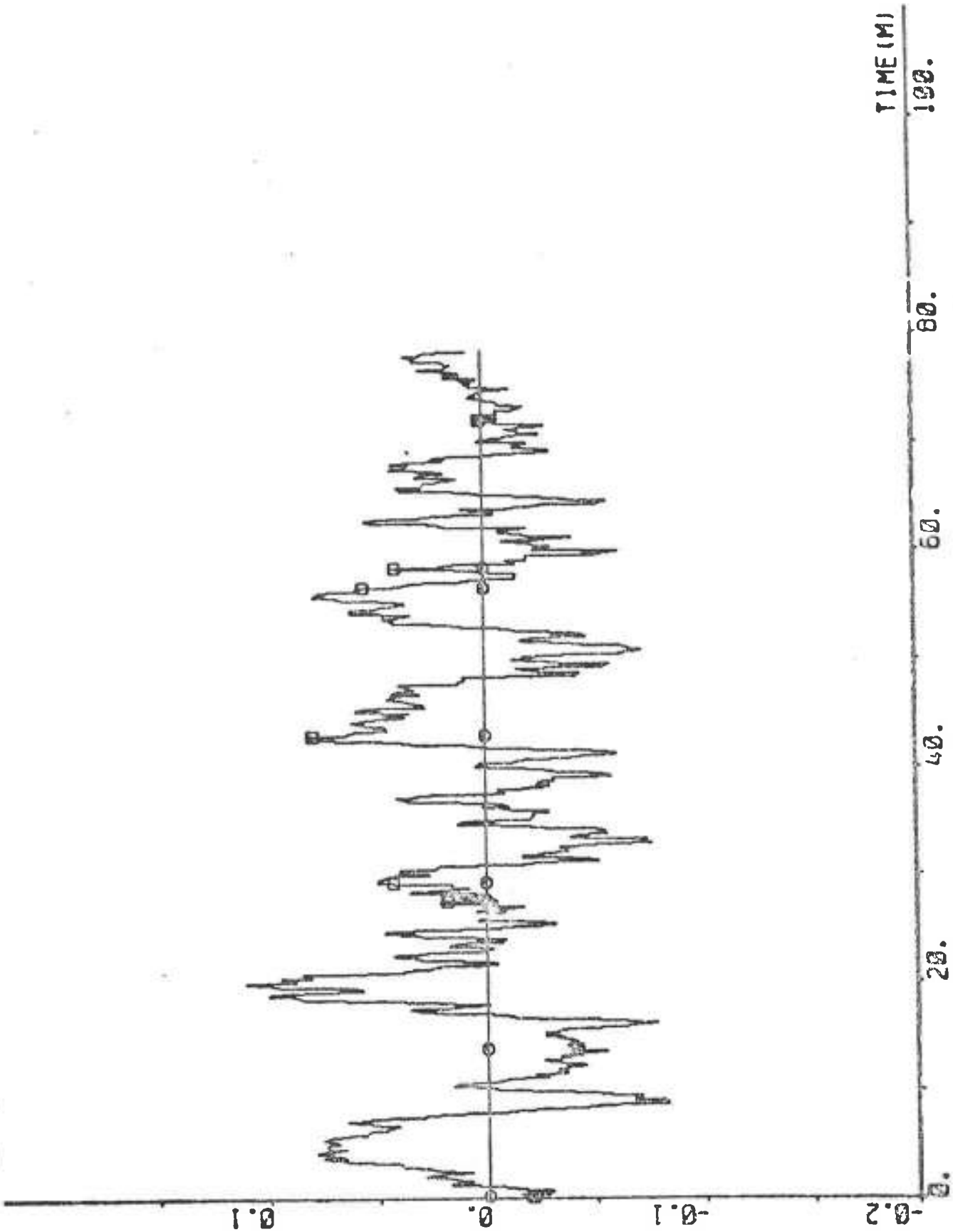

PLOT E1P1(6) 83 87 "AN RPH
83.
84.
85.
86.
0.
20.
40.
60.
80.
100.
TIME(M)

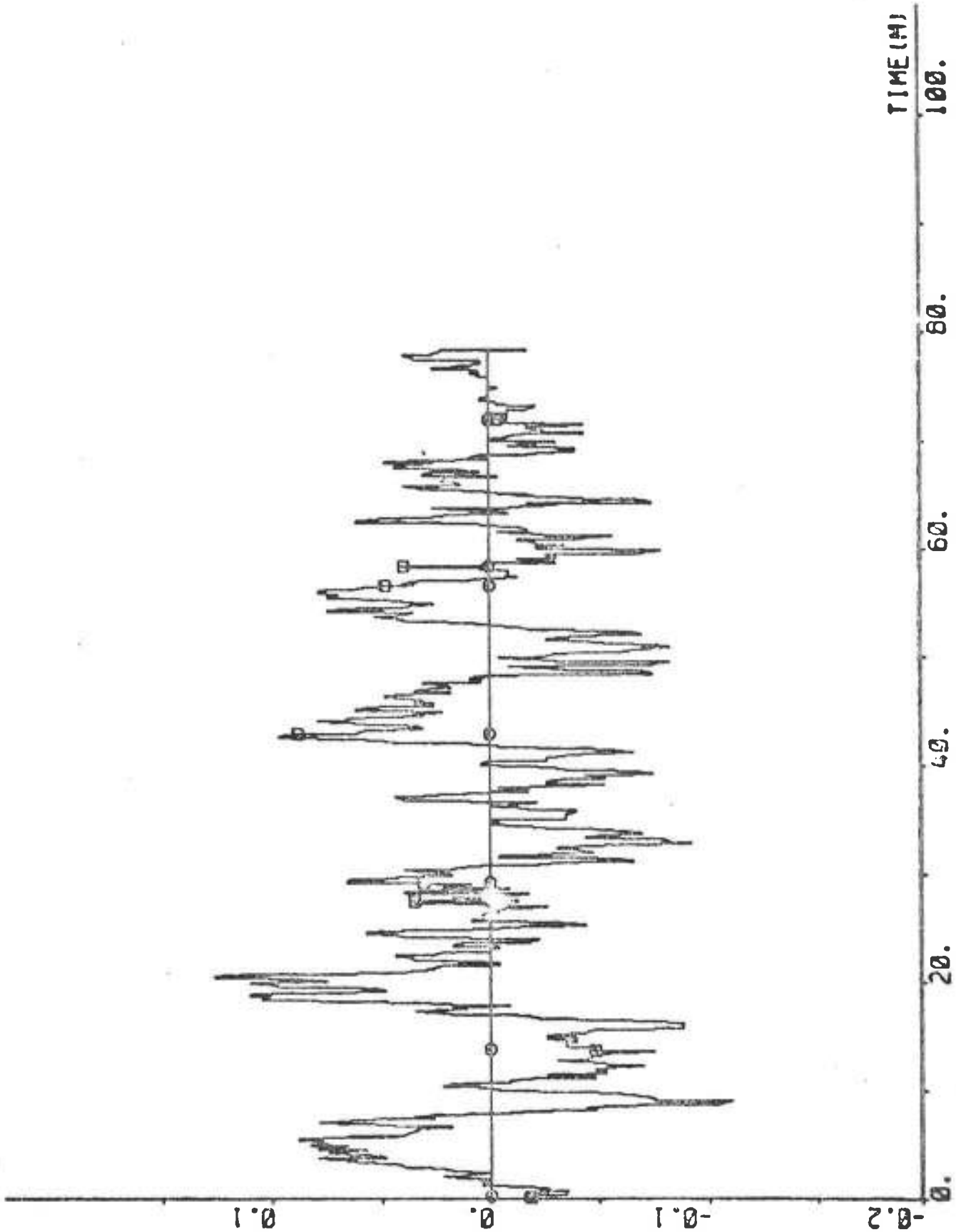

PLOT E1P1(7) 5 20 "U KNOTS
20.
15.
10.
5.
0.
20.
40.
60.
80.
100.
TIME(H)

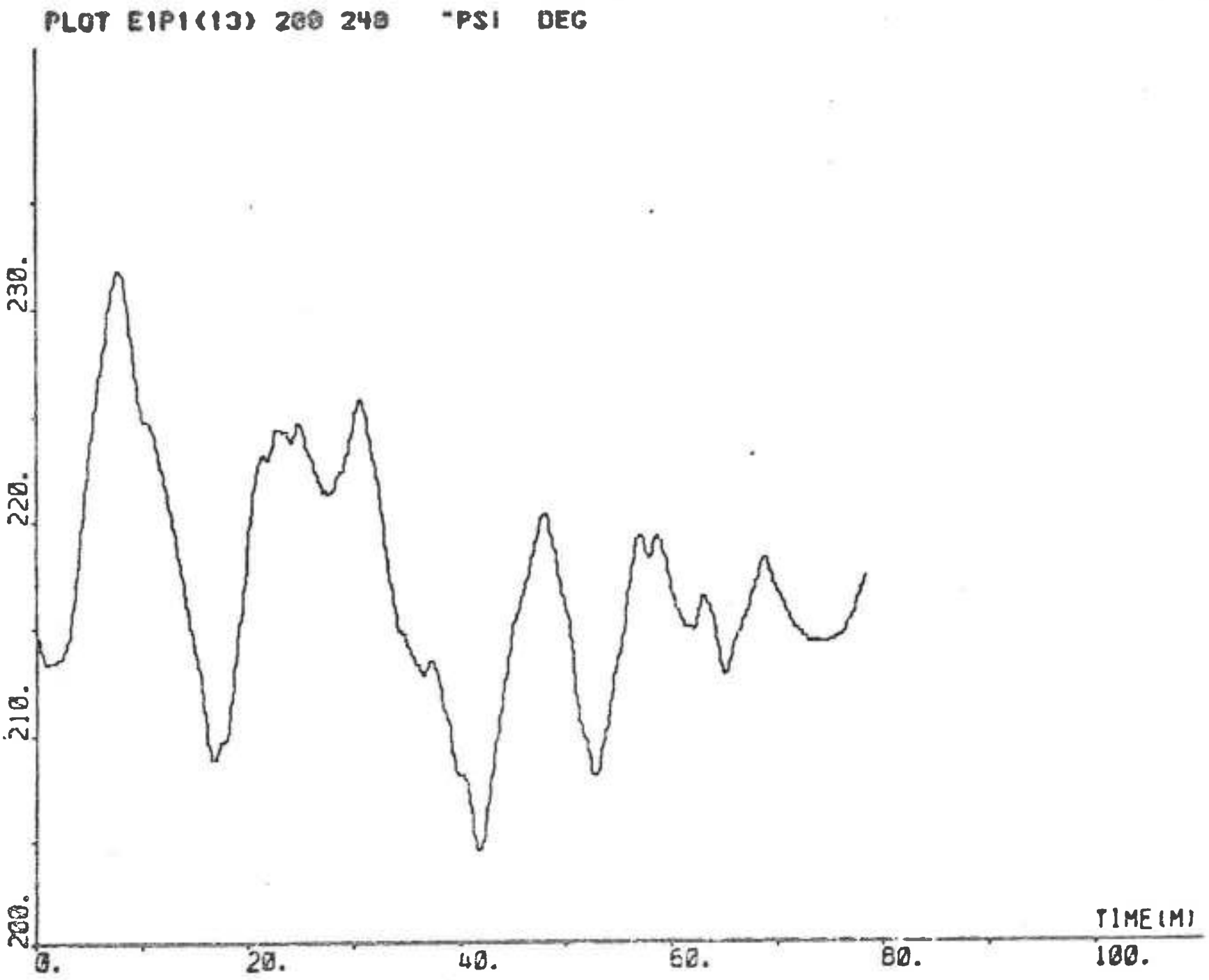

PLOT E1P1(0) ZERO -1 0 *V1 KNOTS
-0.25
-0.5
-0.75
-1.
0.
20.
40.
60.
80.
100.
TIME(M)


PLOT E1P1(8) ZERO -2 2 "V2 KNOTS
1.
0.
-1.
-2.
0.
20.
40.
60.
80.
100.
TIME(M)


PLOT EIP1(10) ZERO -0.2 0.2 "R DEG/S
0.1
0.
-0.1
-0.2
0.
20.
40.
60.
80.
100.
TIME(M)


PLOT EIP1(11) ZERO -0.2 0.2 "AVR DEG/S (BR=0.2)
0.1
0.
-0.1
-0.2
0.
20.
40.
60.
80.
100.
TIME(M)


PLOT E1P1(12) ZERO -0.2 0.2 "DPSIDT DEG/S (IDPSI=6)
0.1
0.
-0.1
-0.2
0.
20.
40.
60.
80.
100.
TIME(M)


PLOT E1P1(13) 200 240 *PSI DEG
230.
220.
210.
200.
0.
20.
40.
60.
80.
100.
TIME(M)

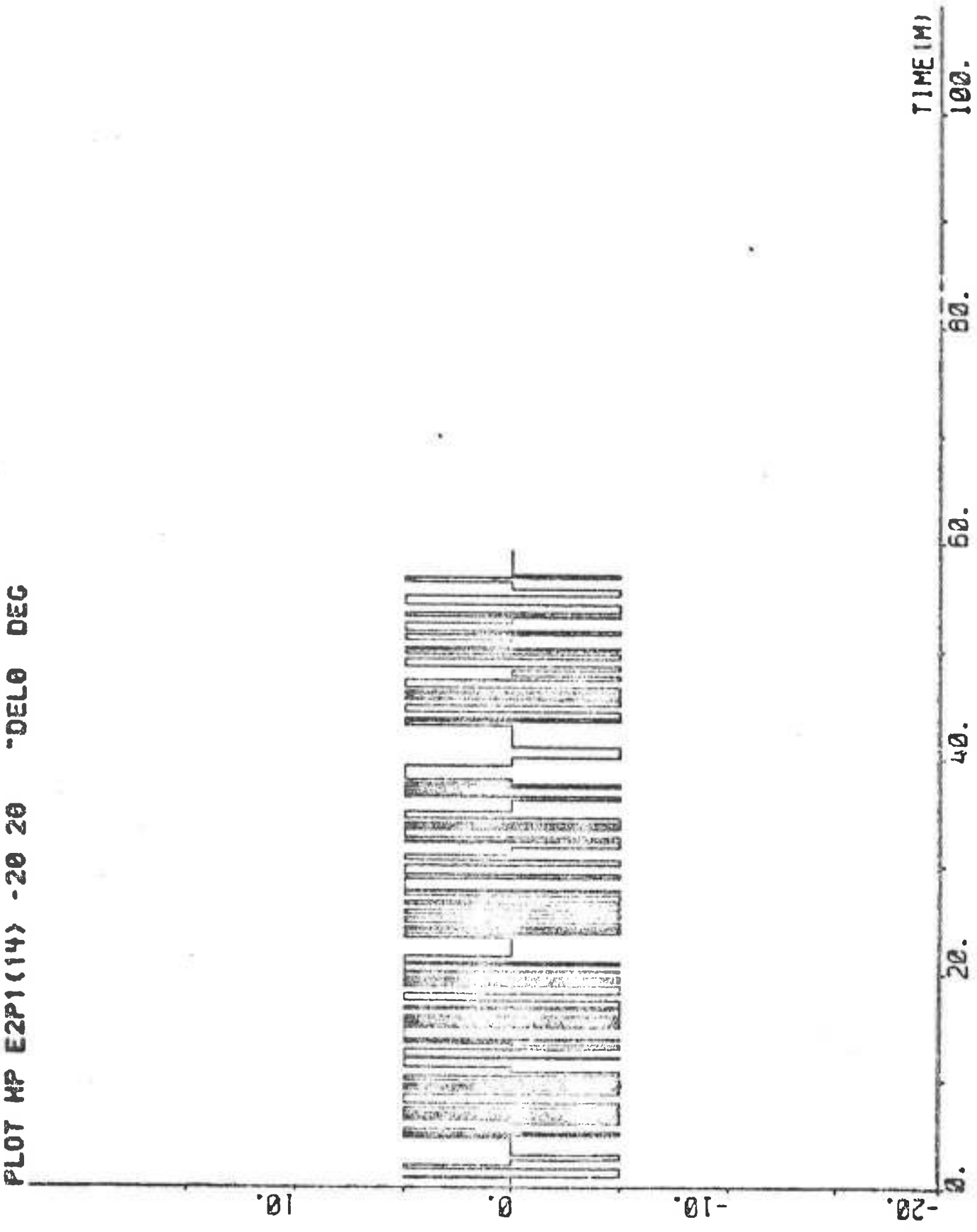
EXPERIMENT E2

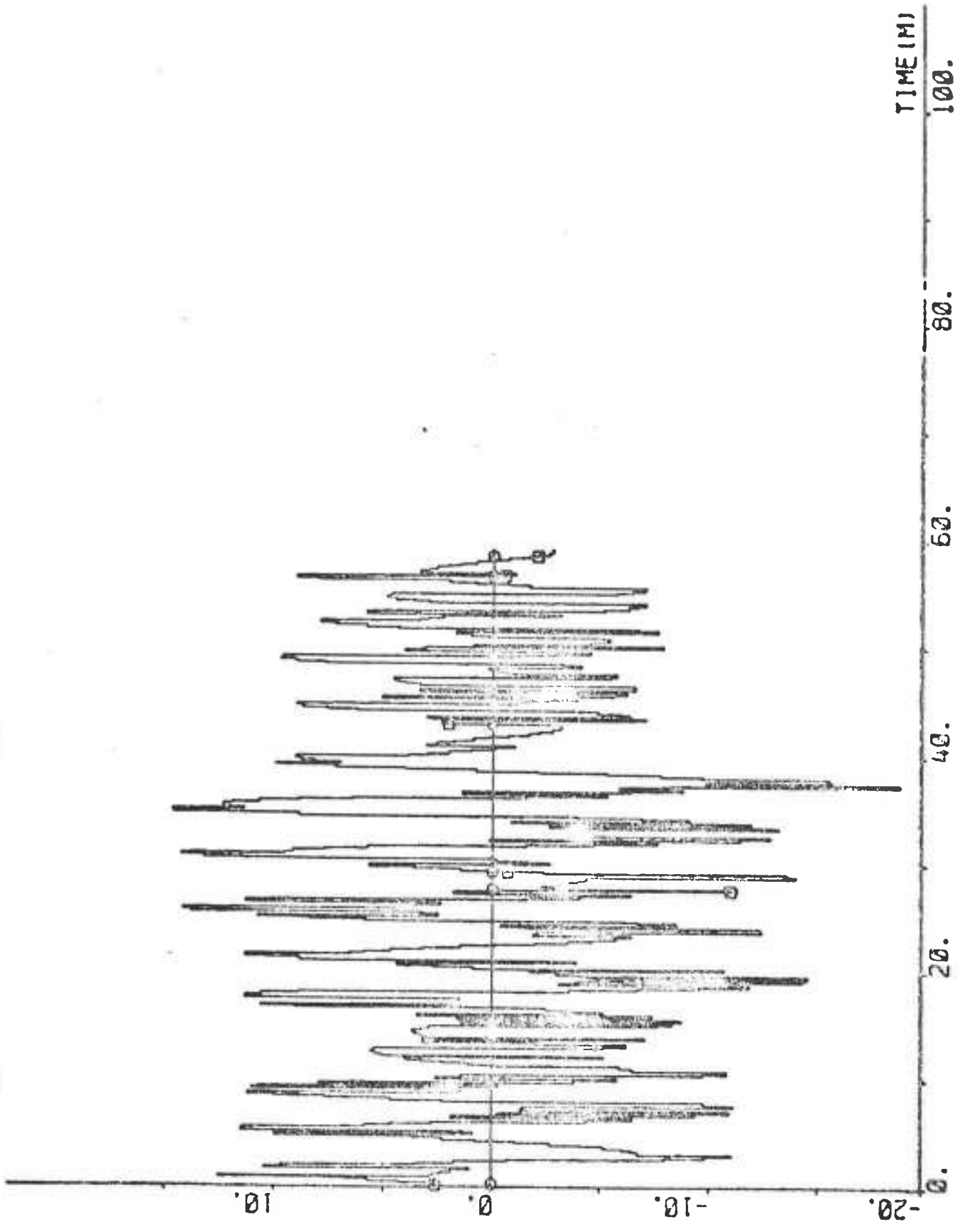
Date	1074-10-20
Time	13.08
Duration	59 min
Position	S 24° 48' E 35° 34'
Water depth	deep
Forward draught	20.2 m
Aft draught	20.2 m
Wind direction	S (8; see Appendix A)
Wind velocity	2 Beaufort (2-3.5 m/s, light breeze)
Wave height	2 m
PSIREF	212°
Rudder limit	±10°
DELAMP	5°
AKID	2
IREG	10 s

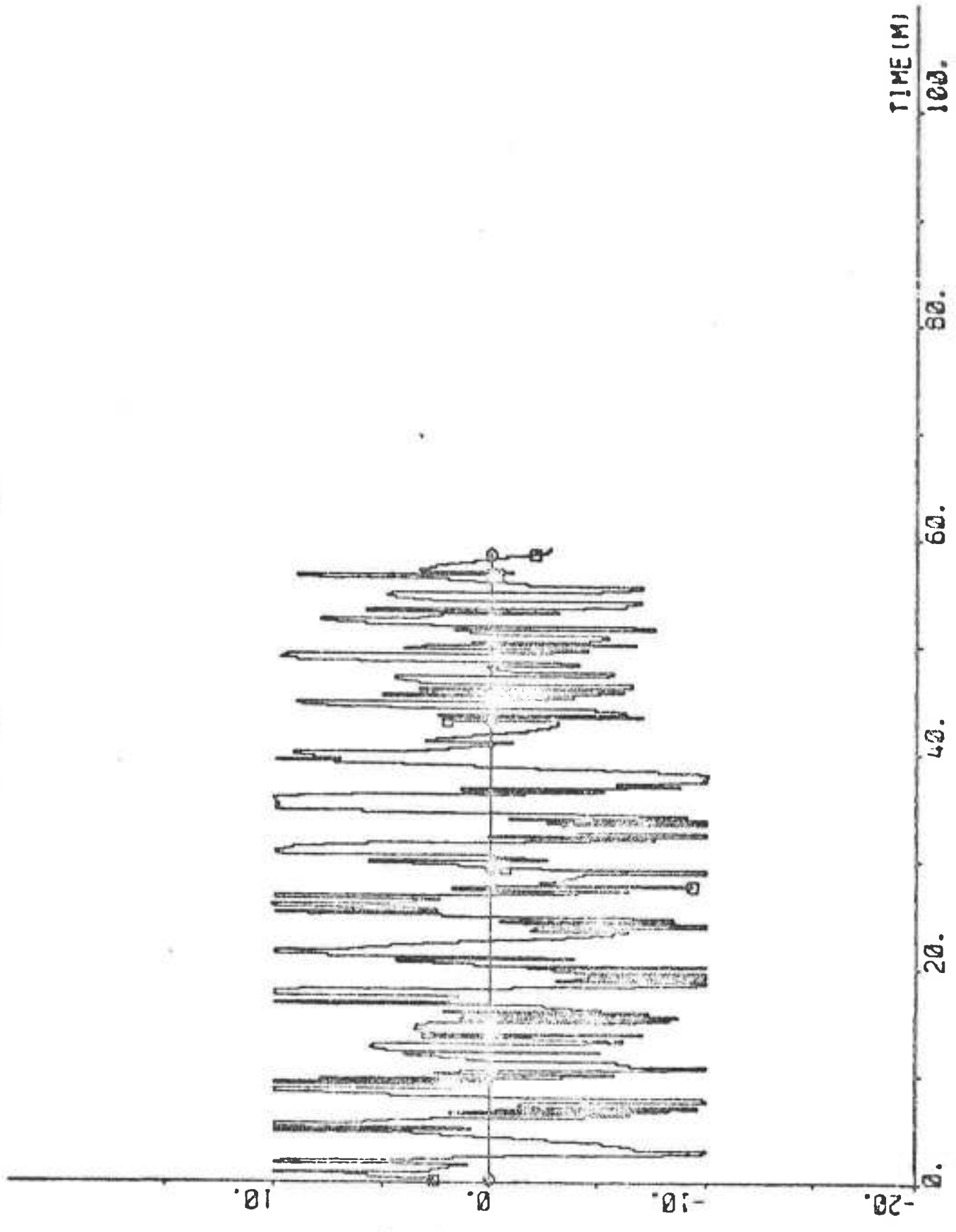
Closed loop experiment for identification using additive rudder disturbances.

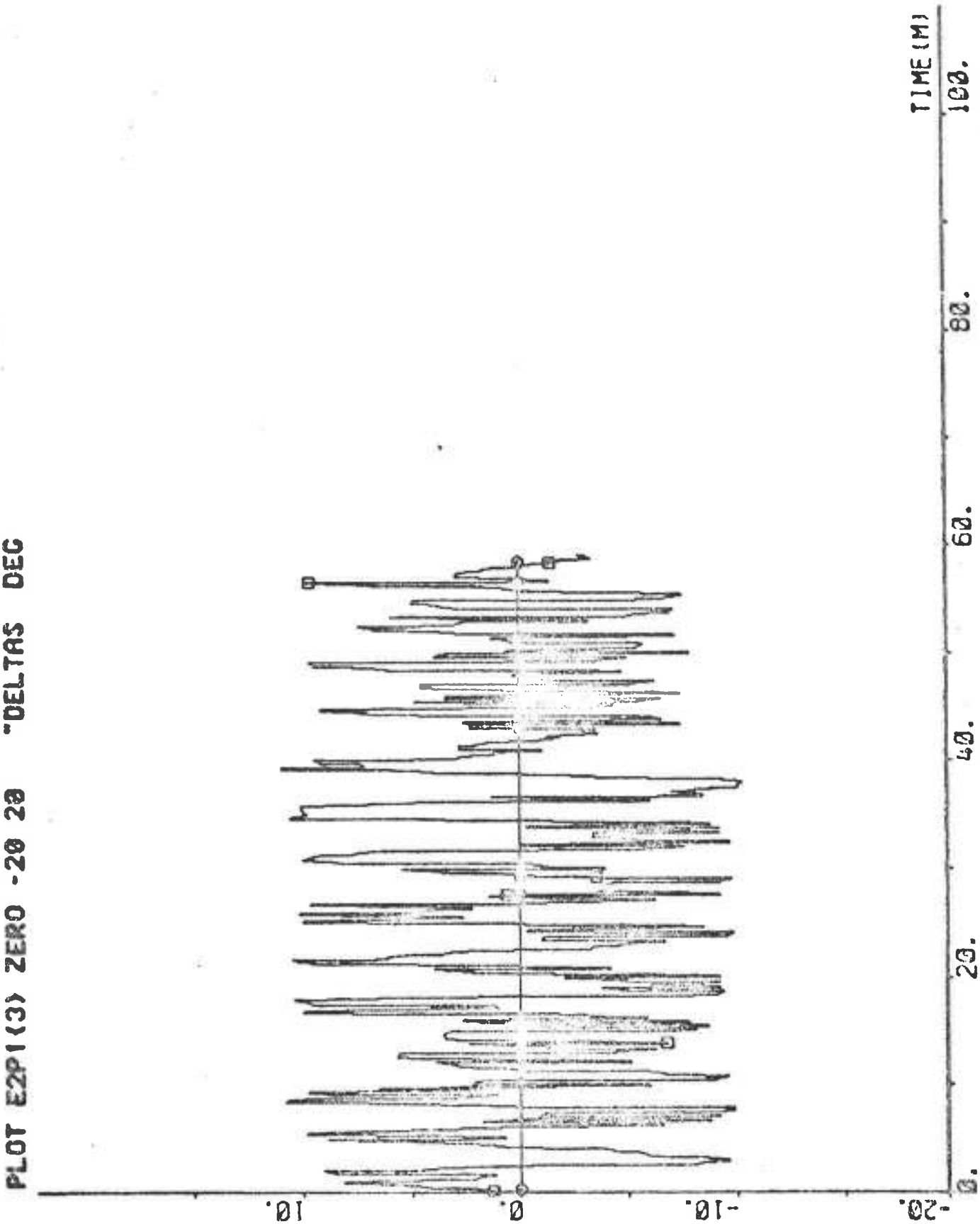
Statistics

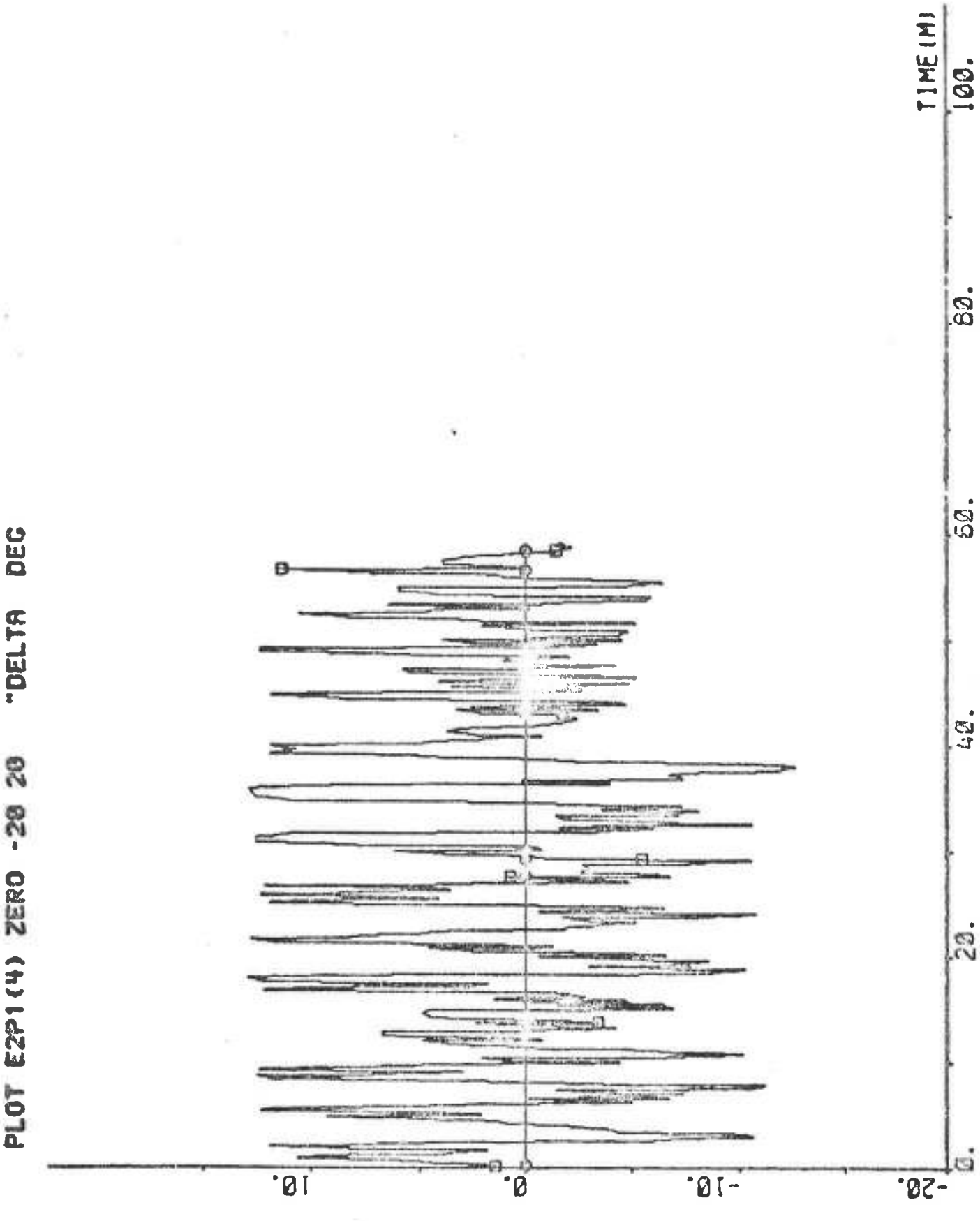
		Mean value	Standard deviation
DEL0	deg	0.40	4.25
DELCOC	deg	0.06	6.55
DELCOM	deg	0.07	5.90
DELTAS	deg	-0.02	5.92
DELTA	deg	1.15	6.30
PP	deg/s	-0.0053	0.0511
AN	rpm	85.23	1.02
U	knots	17.14	0.27
V1	knots	-0.35	0.17
V2	knots	-0.14	0.51
R	deg/s	0.0056	0.0653
AVR	deg/s	0.0046	0.0610
DPSIDT	deg/s	-0.0002	0.0669
PSI	deg	212.17	2.67

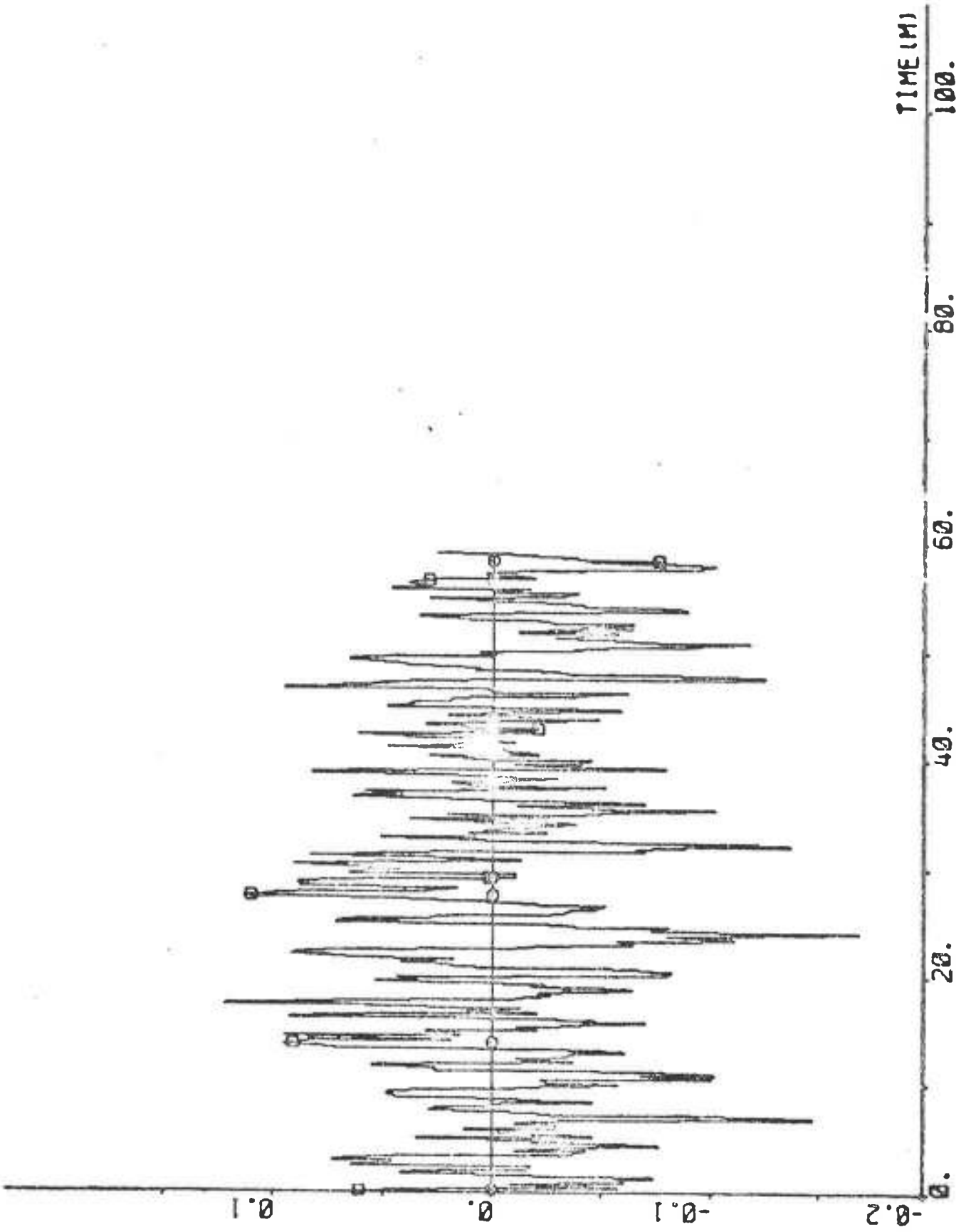

PLOT MP E2P1(14) -20 20 "DELO DEG
TIME(M)
0.
20.
40.
60.
80.
100.
-20.
-10.
0.
10.

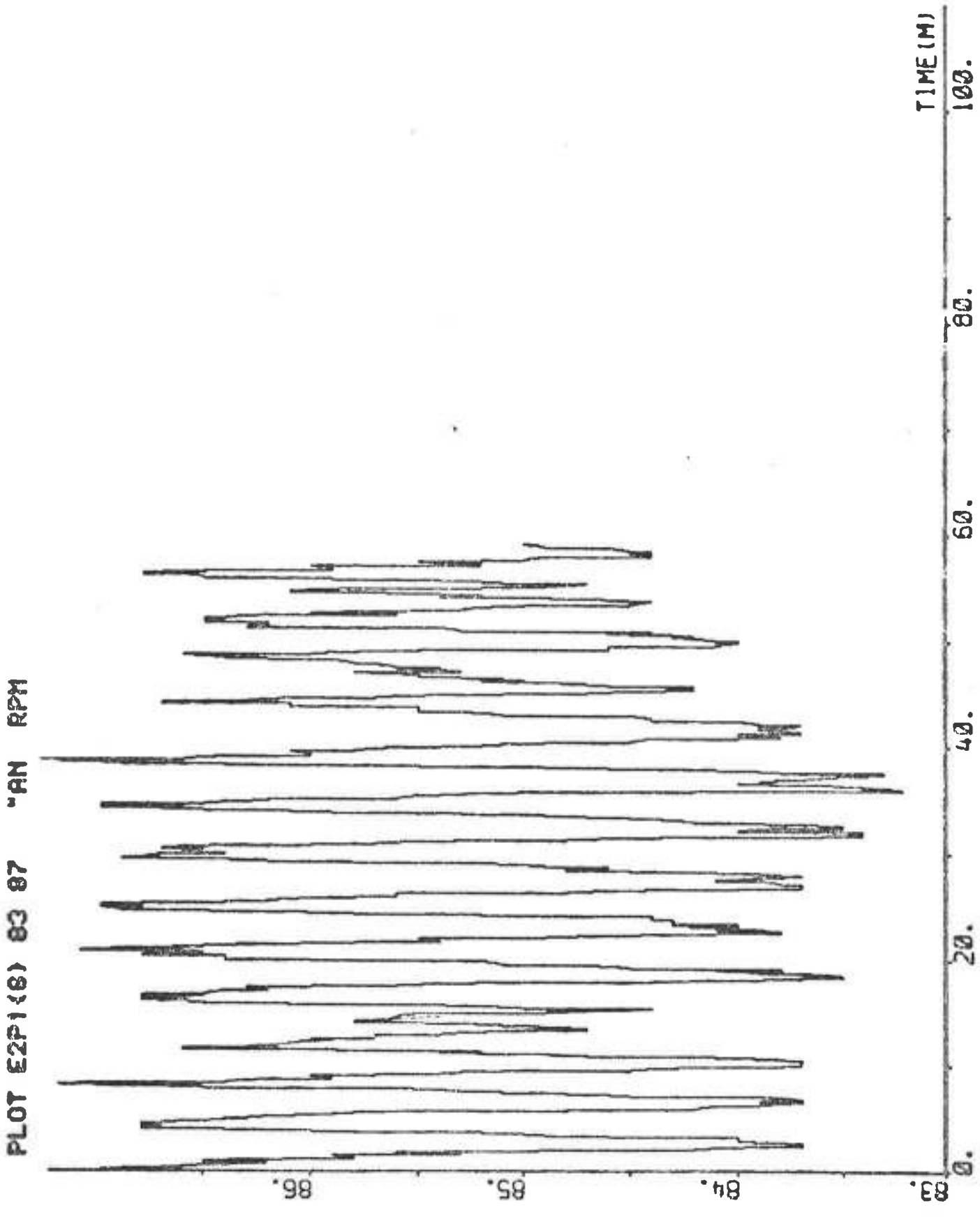

PLOT HP E2P1(1) ZERO -20 20 'DELCOC DEG
TIME(M)
0.
20.
40.
60.
80.
100.
-20.
-10.
0.
10.

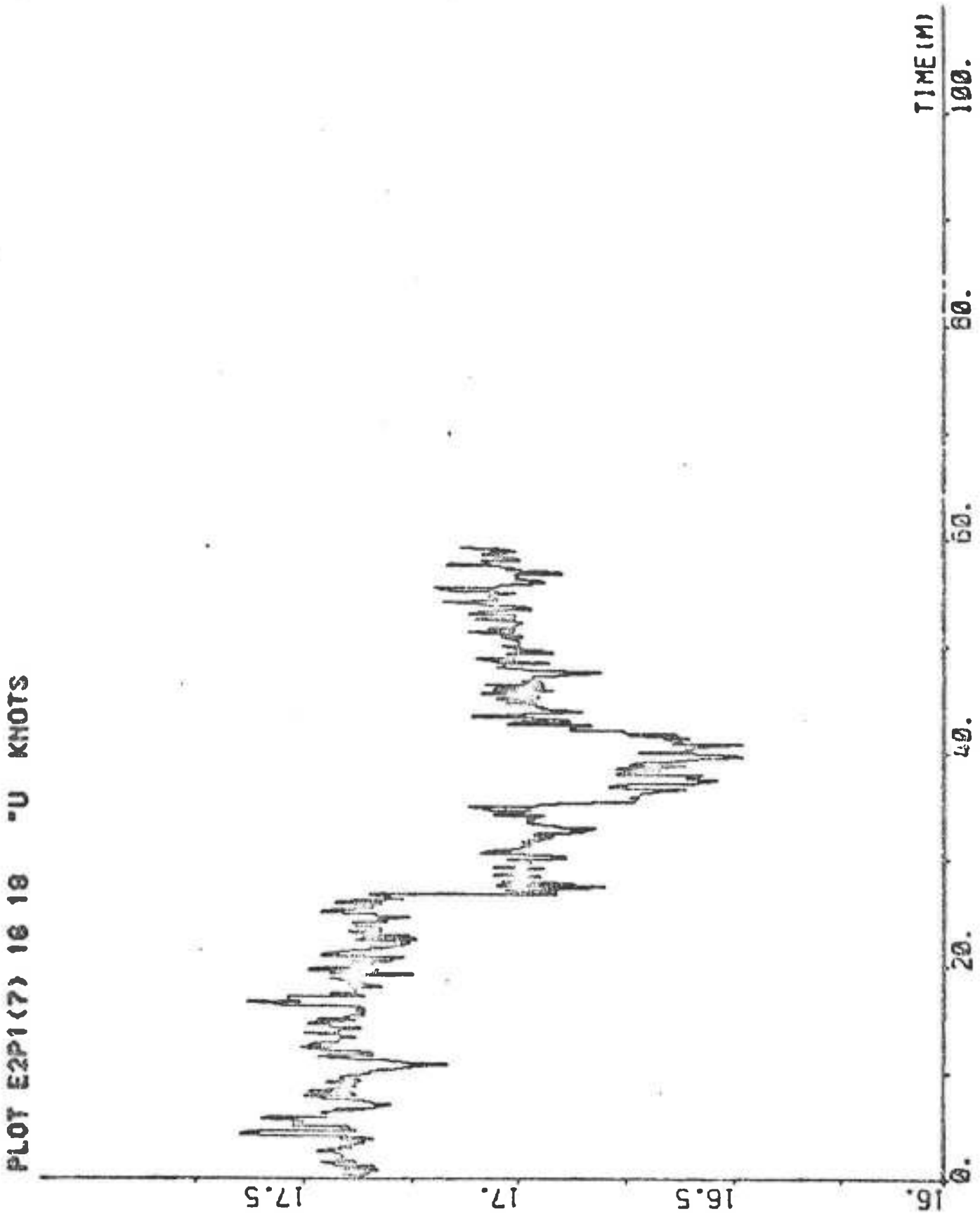

PLOT HP E2P1(2) ZERO -20 20 "DELCOM DEC
TIME(M)
0.
20.
40.
60.
80.
100.
-20.
-10.
0.
10.

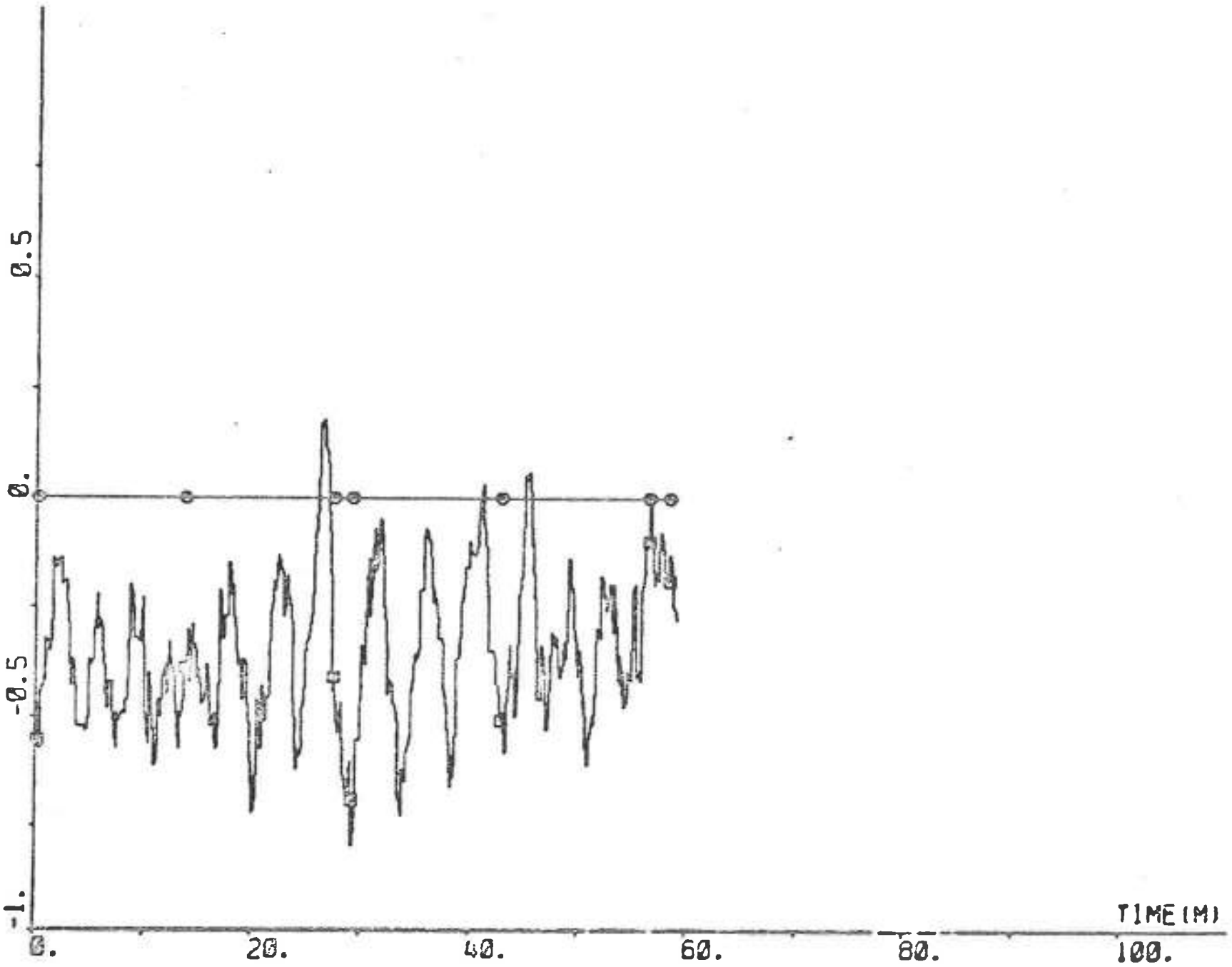

PLOT E2P1(3) ZERO -20 20 "DELTAS DEC
10.
0.
-10.
-20.
0.
20.
40.
60.
80.
100.
TIME(M)

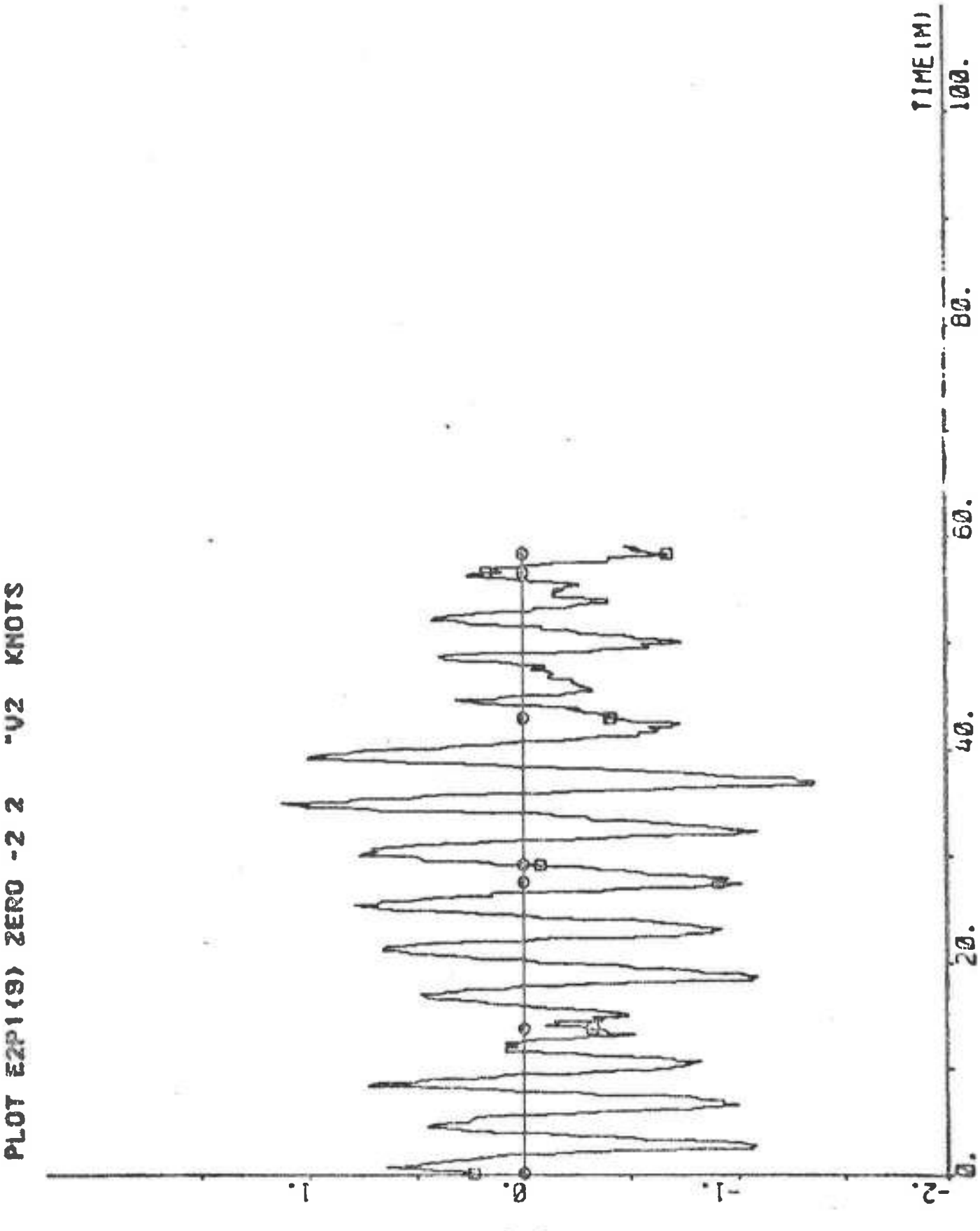

PLOT E2P1(4) ZERO -28 28 "DELTA DEC
TIME(M)
0.
20.
40.
60.
80.
100.
20.
10.
0.
-10.
-20.

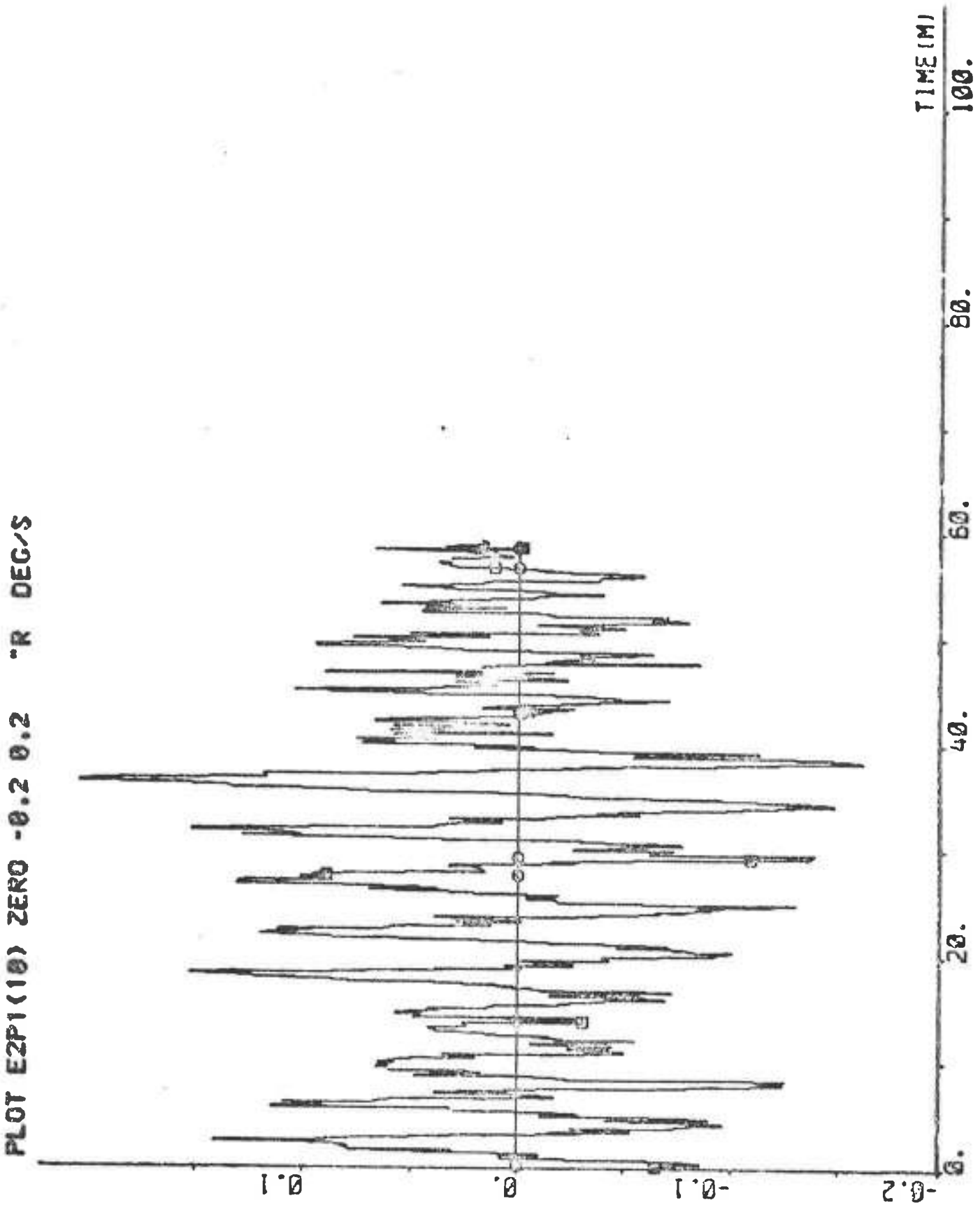

PLOT E2P1(5) ZERO -0.2 0.2 "PP DEG/S
0.1
0.
-0.1
-0.2
0.
20.
40.
60.
80.
100.
TIME(M)

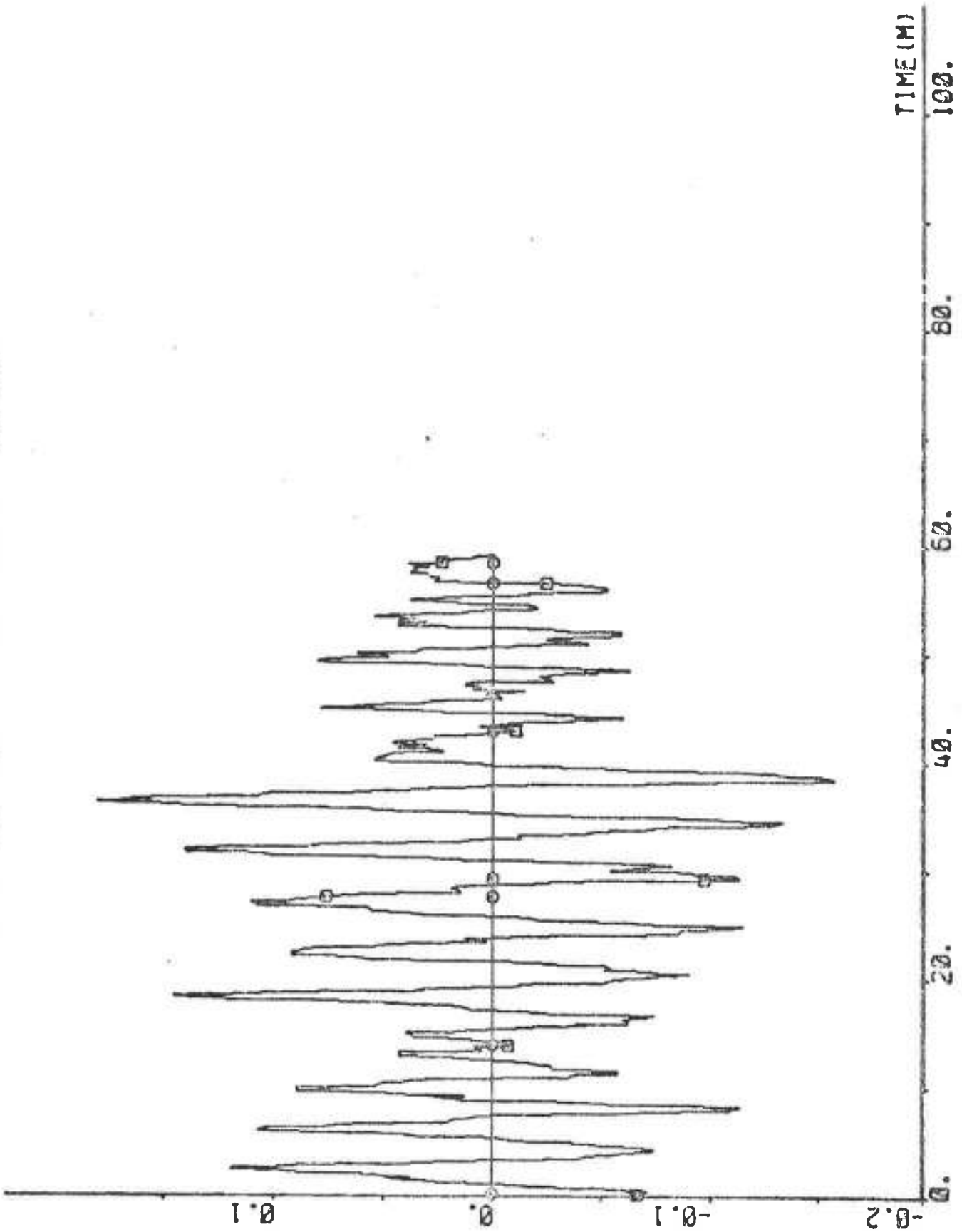

PLOT E2P1(8) 83 87 'AN RPM
TIME(M)
0.
20.
40.
60.
80.
100.
83.
84.
85.
86.

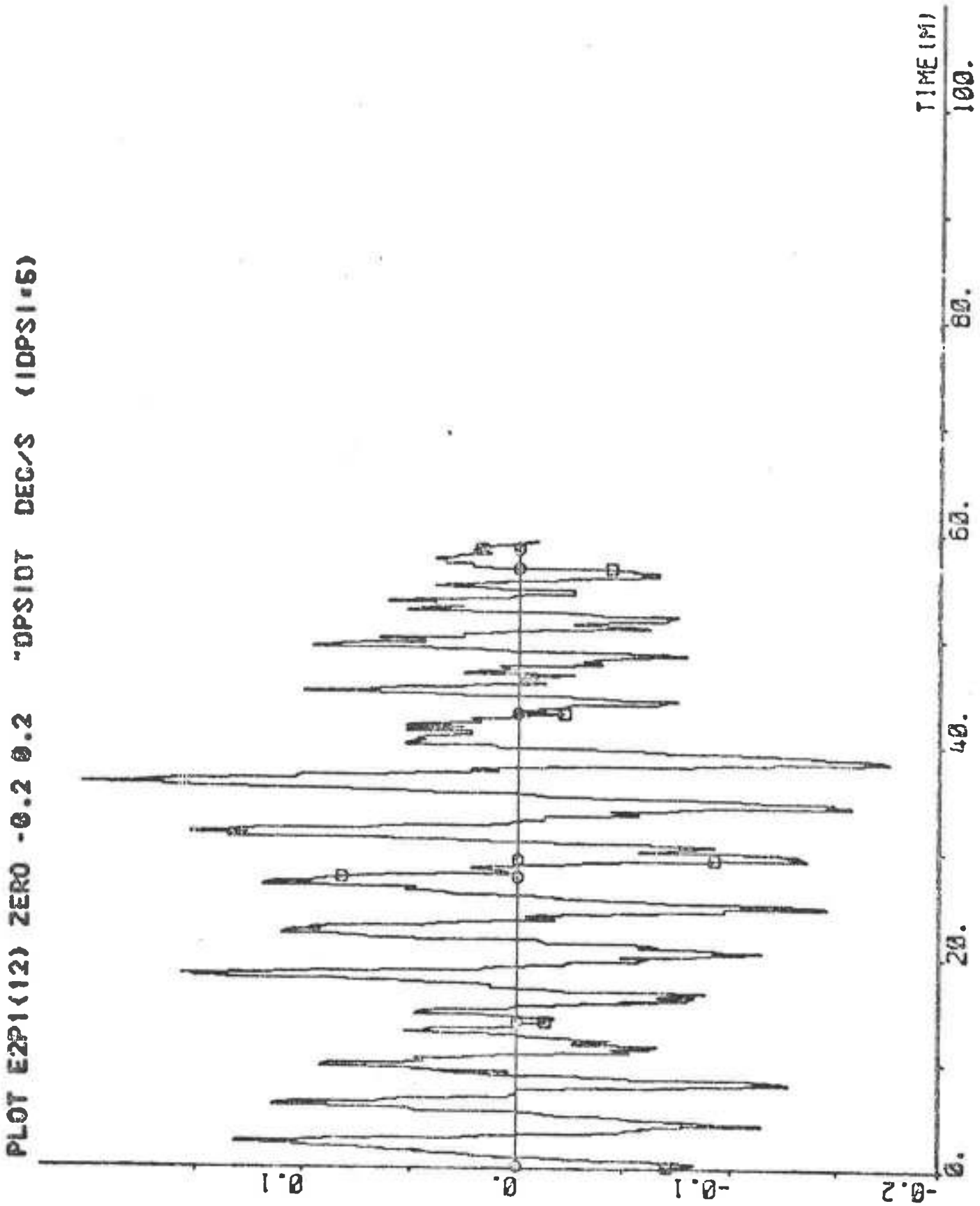

PLOT E2P1(7) 18 18 'U KNOTS
17.5
17.
16.5
16.
0.
20.
40.
60.
80.
100.
TIME(M)

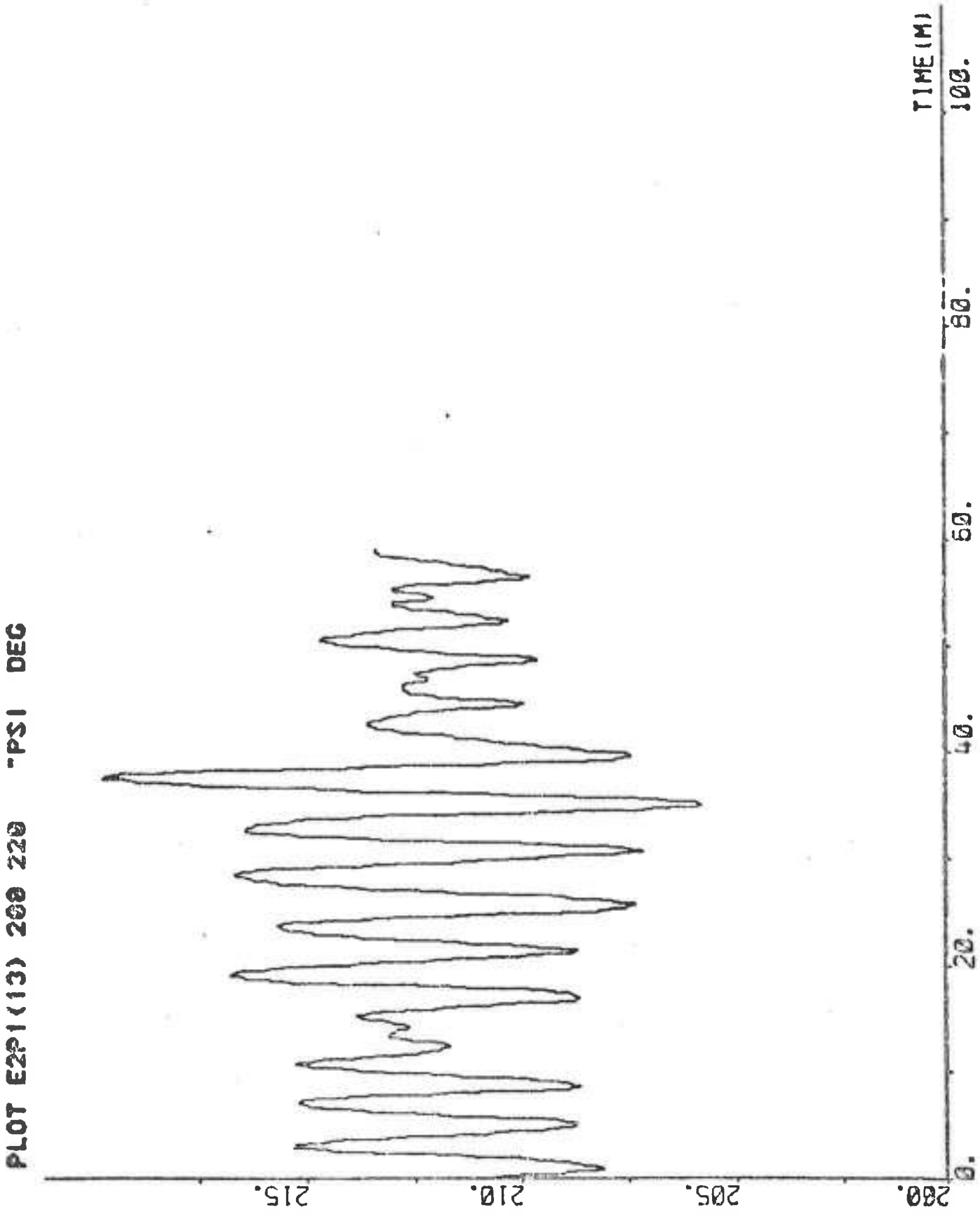

PLOT E2P1(8) ZERO -1 1 "V1 KNOTS
0.5
0.
-0.5
-1.
0.
20.
40.
60.
80.
100.
TIME(M)


PLOT E2P1(9) ZERO -2 2 'U2 KNOTS
1.
0.
-1.
-2.
0.
20.
40.
60.
80.
100.
TIME(M)


PLOT E2P1(10) ZERO -0.2 0.2 °R DEG/S
-0.2
-0.1
0.
0.1
TIME(M)
0.
20.
40.
60.
80.
100.


PLOT E2P1(11) ZERO -0.2 0.2 "AVR DEG/S (BR=0.2)
TIME(M)
0.
20.
40.
60.
80.
100.
-0.2
-0.1
0.
0.1


PLOT E2P1(12) ZERO -0.2 0.2 "DPSIDT DEG/S (IDPSI=6)
TIME(M)
0.
20.
40.
60.
80.
100.
-0.2
-0.1
0.
0.1


PLOT E2P1(13) 200 220 'PSI DEG
200.
205.
210.
215.
0.
20.
40.
60.
80.
100.
TIME(M)

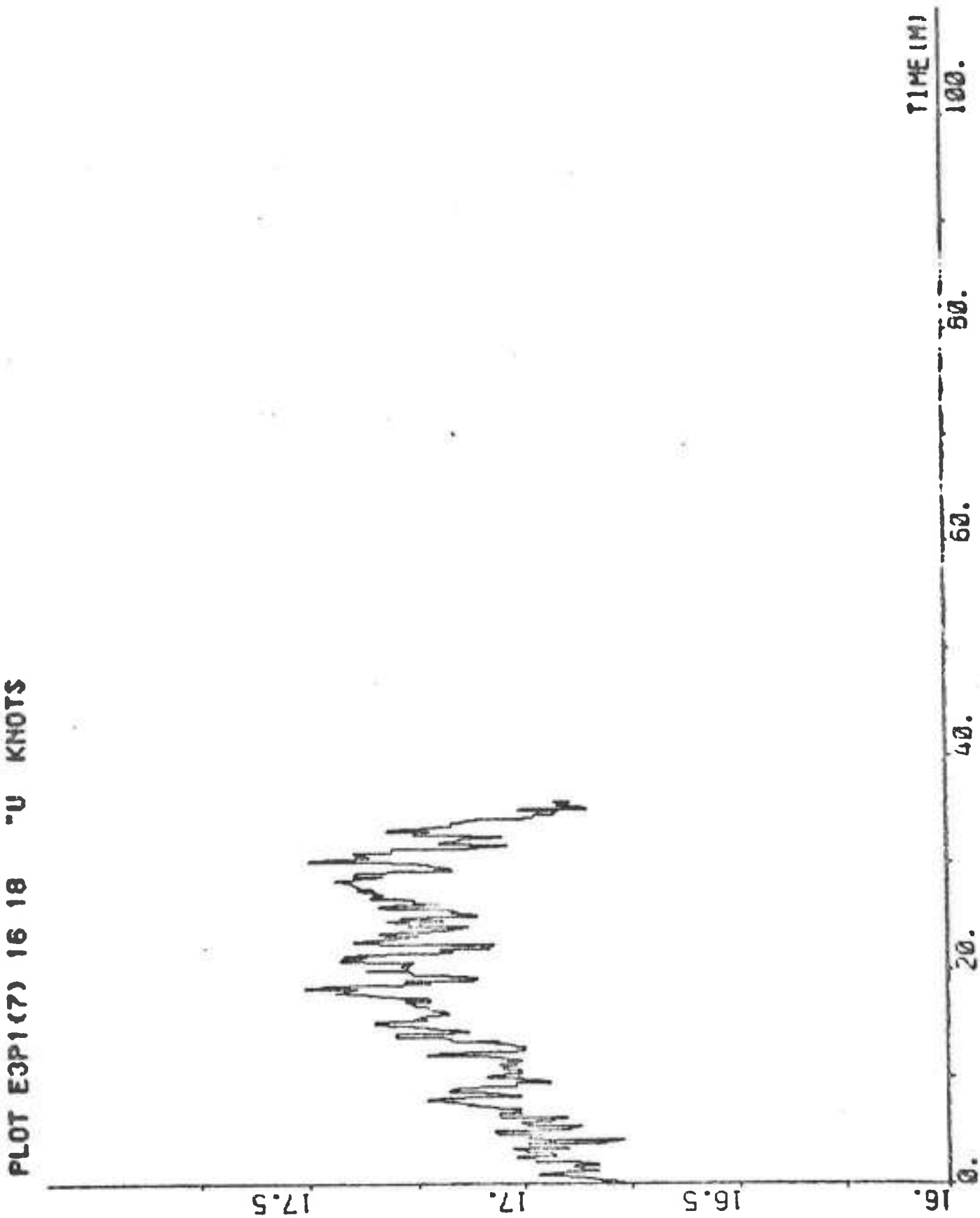
EXPERIMENT E3

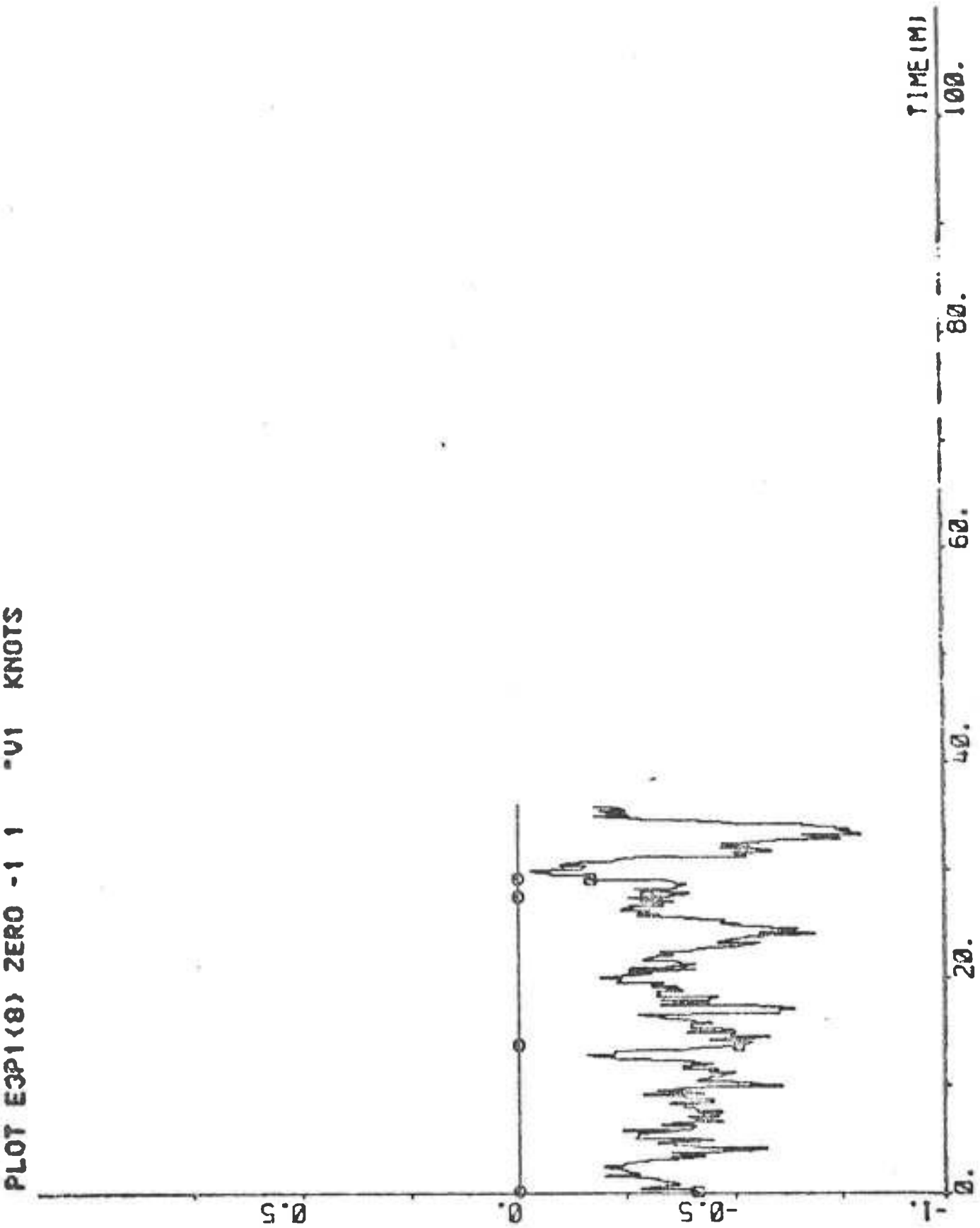
Date	1974-10-20
Time	14.29
Duration	36 min
Position	S 24° 55' E 35° 29'
Water depth	deep
Forward draught	20.2 m
Aft draught	20.2 m
Wind direction	S (8; see Appendix A)
Wind velocity	2 Beaufort (2-3.5 m/s, light breeze)
Wave height	2 m
PSIREF	212°
Rudder limit	±10°
DELAMP	0°
AKID	0.5 (0-31 min), 3 (31-36 min)
IREG	10 s

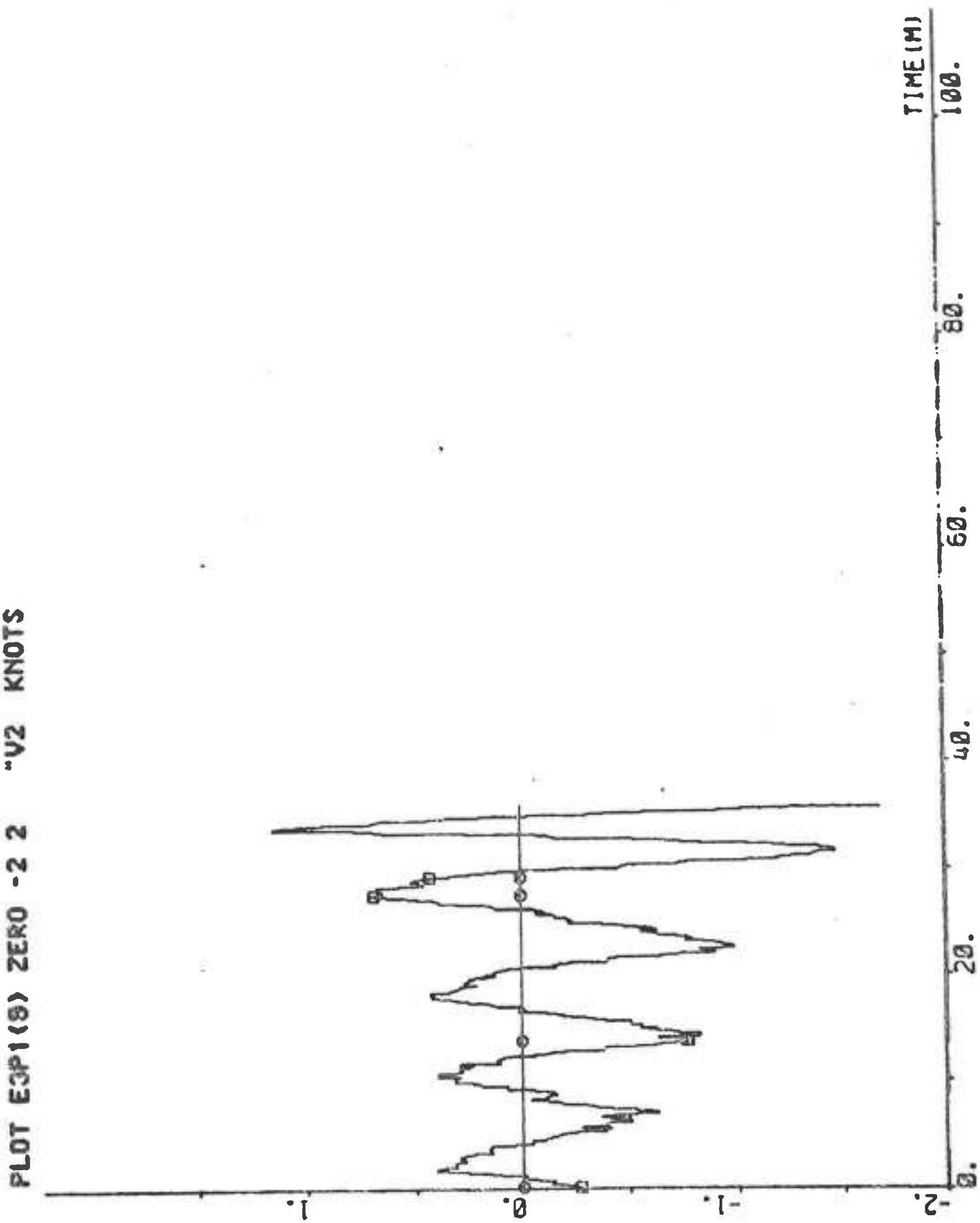
Closed loop experiment for identification not using additive rudder disturbances. The feed-back was changed after 31 min of the experiment. The experiment had to be terminated because of the large oscillations.

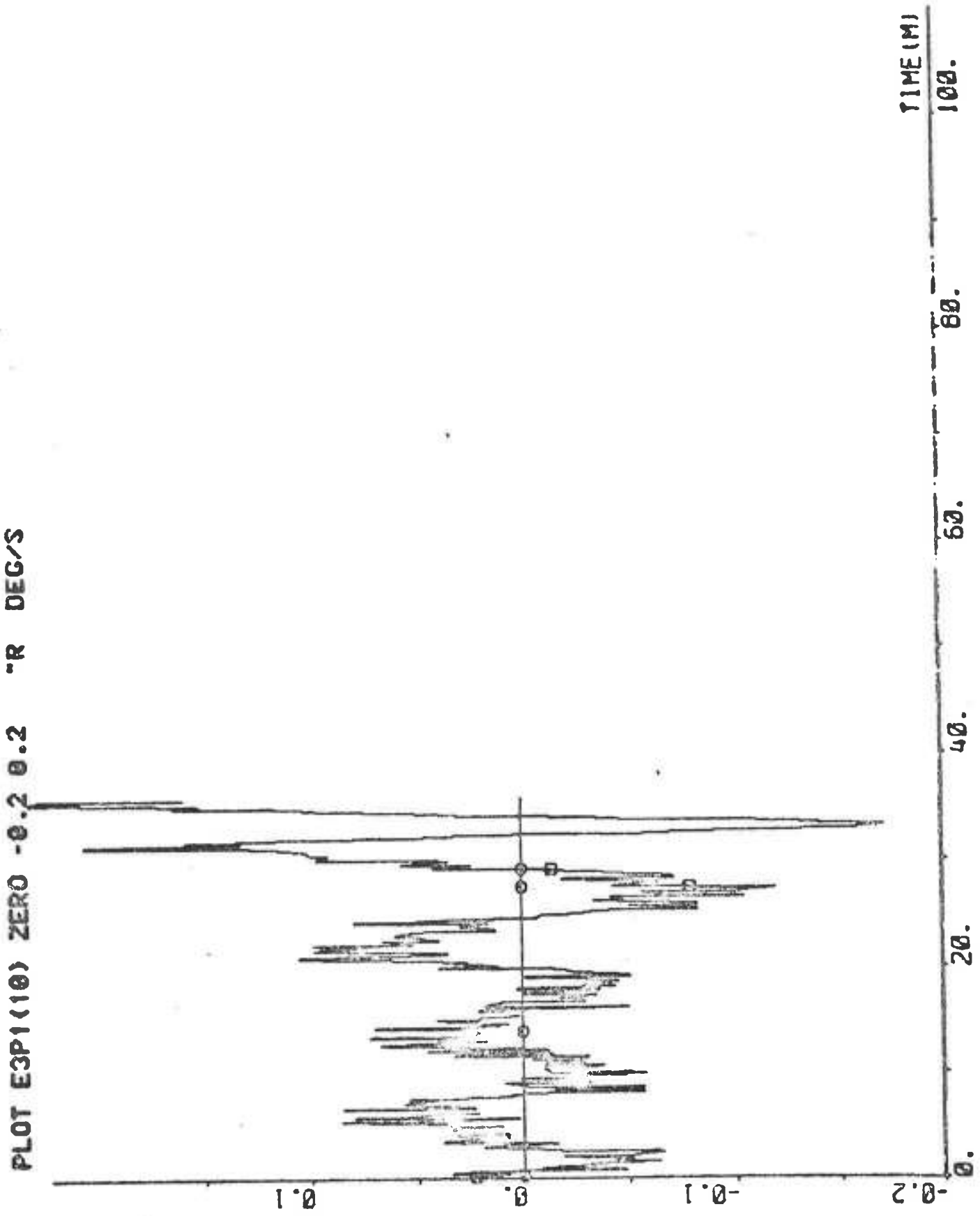
Statistics

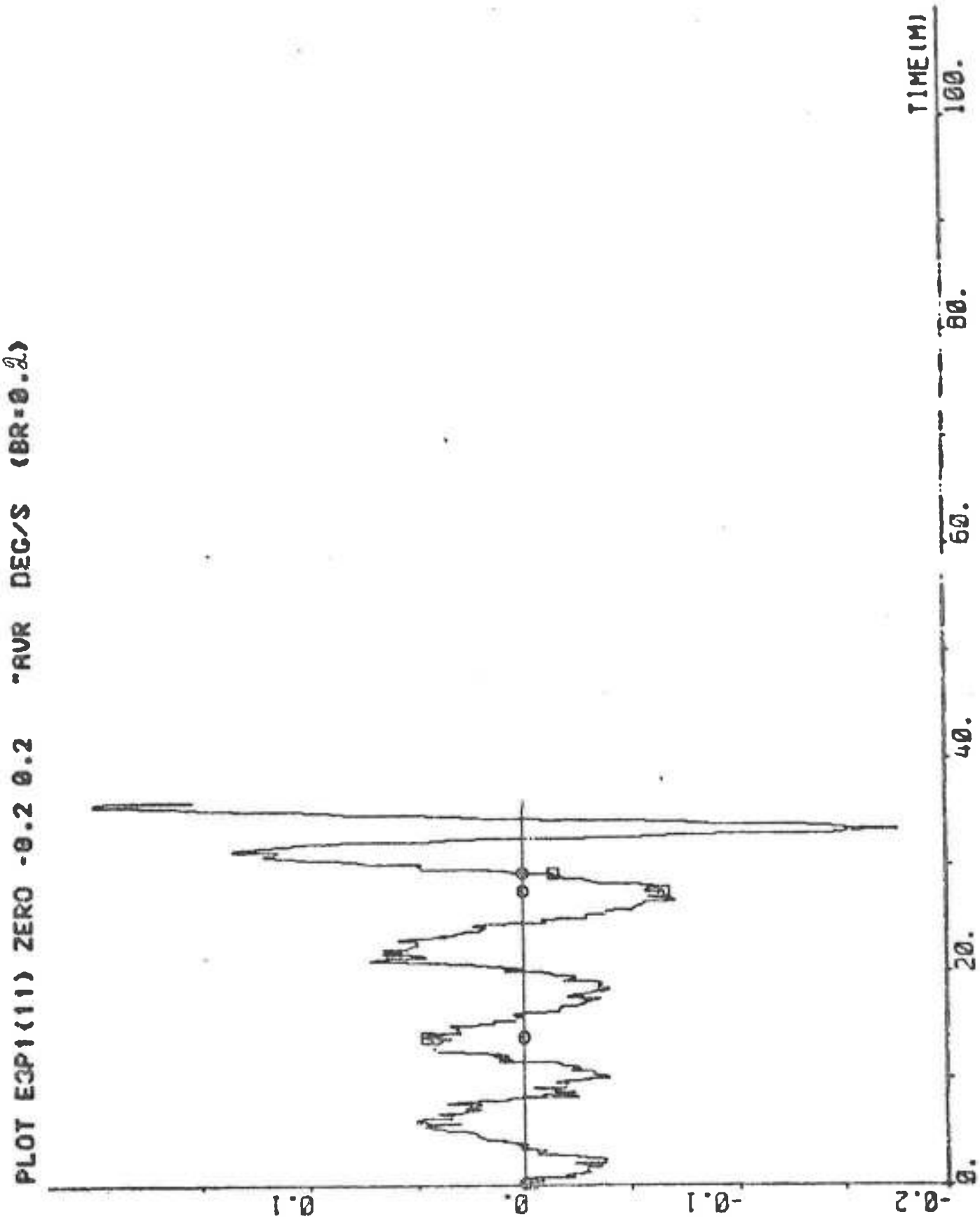
		Mean value	Standard deviation
DELCOC	deg	0.95	5.13
DELCOM	deg	0.75	3.51
DELTAS	deg	0.88	3.45
DELTA	deg	1.71	4.07
PP	deg/s	0.0015	0.0594
AN	rpm	85.63	0.98
U	knots	17.15	0.17
V1	knots	-0.39	0.14
V2	knots	-0.14	0.52
R	deg/s	0.0113	0.0660
AVR	deg/s	0.0073	0.0569
DPSIDT	deg/s	0.0032	0.0618
PSI	deg	210.43	3.48

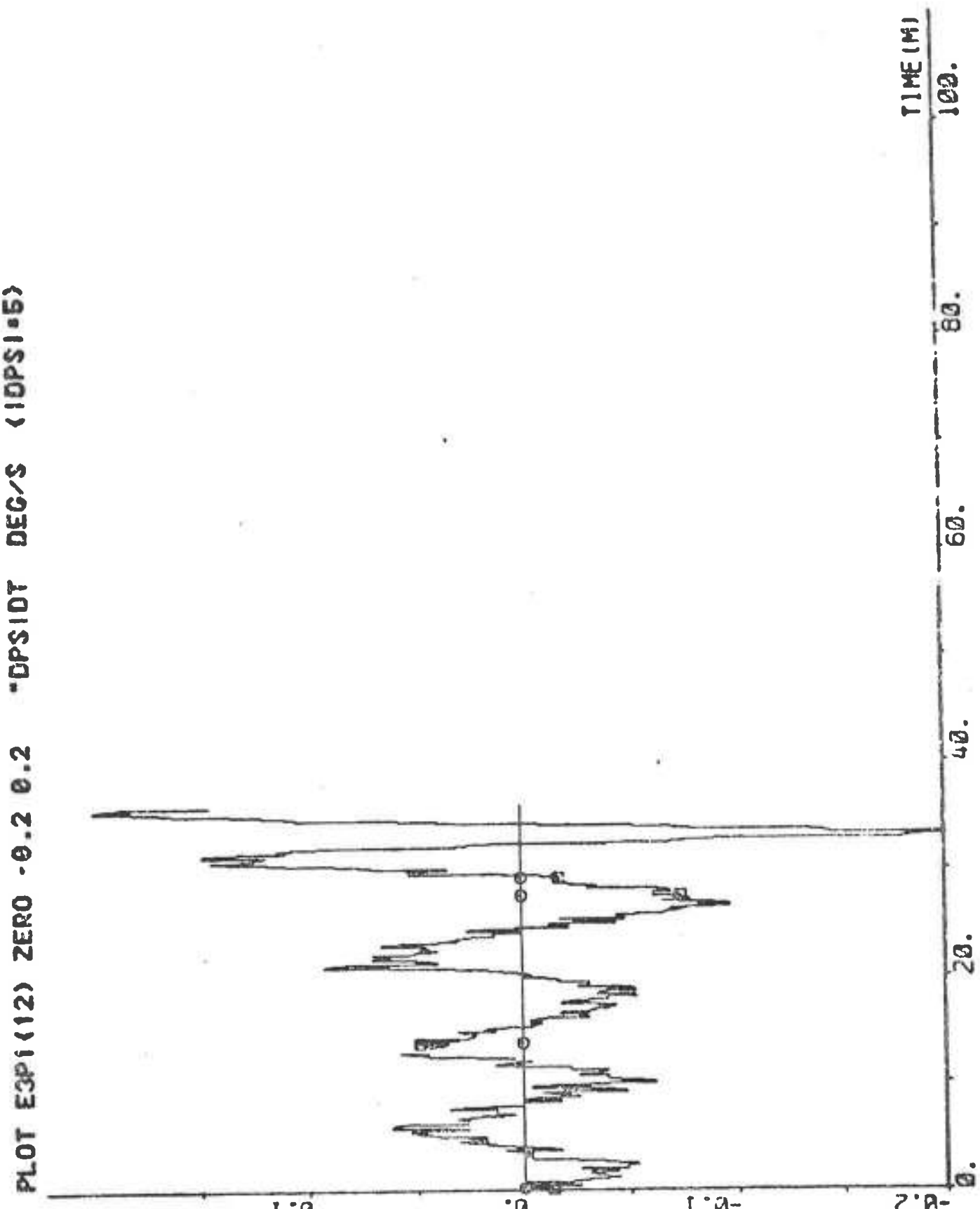

PLOT E3P1(7) 16 18 "U KNOTS
16.
16.5
17.
17.5
0.
20.
40.
60.
80.
100.
TIME(M)

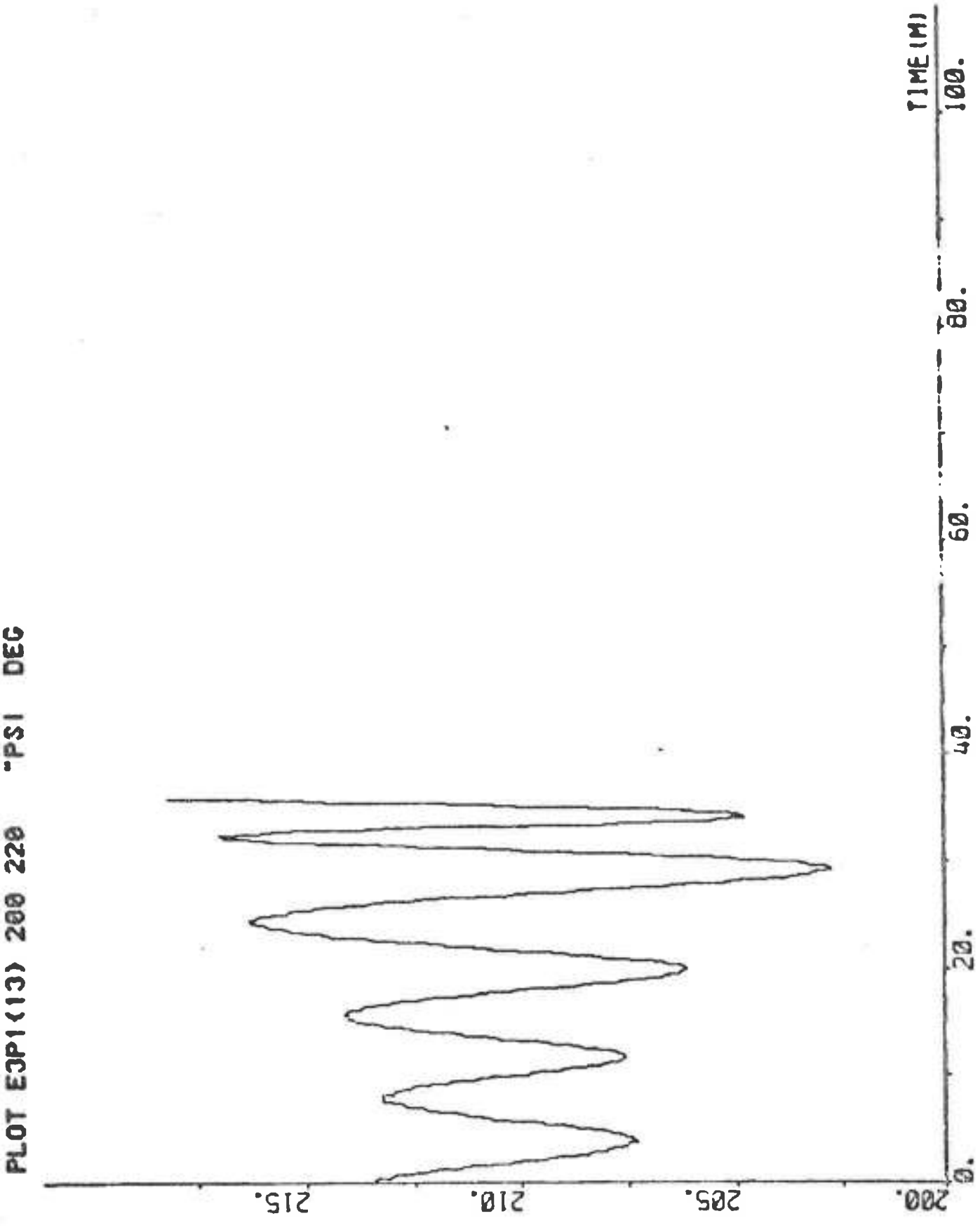

PLOT E3P1(8) ZERO -1 1 *V1 KNOTS
TIME(MI)
0.
20.
40.
60.
80.
100.
-1.
-0.5
0.
0.5


PLOT E3P1(8) ZERO -2 2 "V2 KNOTS
1.
0.
-1.
-2.
0.
20.
40.
60.
80.
100.
TIME(M)


PLOT E3P1(10) ZERO -0.2 0.2 "R DEG/S
-0.2
-0.1
0.
0.1
TIME(M)
0.
20.
40.
60.
80.
100.


PLOT E3P1(11) ZERO -0.2 0.2 "RVR DEG/S (BR=0.2)
0.1
0.
-0.1
-0.2
0.
20.
40.
60.
80.
100.
TIME(M)


PLOT E3P1(12) ZERO -0.2 0.2 "DPSIDT DEG/S (IDPSI*5)
TIME(M)
0.
20.
40.
60.
80.
100.
-0.2
-0.1
0.
0.1


PLOT E3P1(13) 200 220 "PSI DEG
200.
205.
210.
215.
0.
20.
40.
60.
80.
100.
TIME(M)

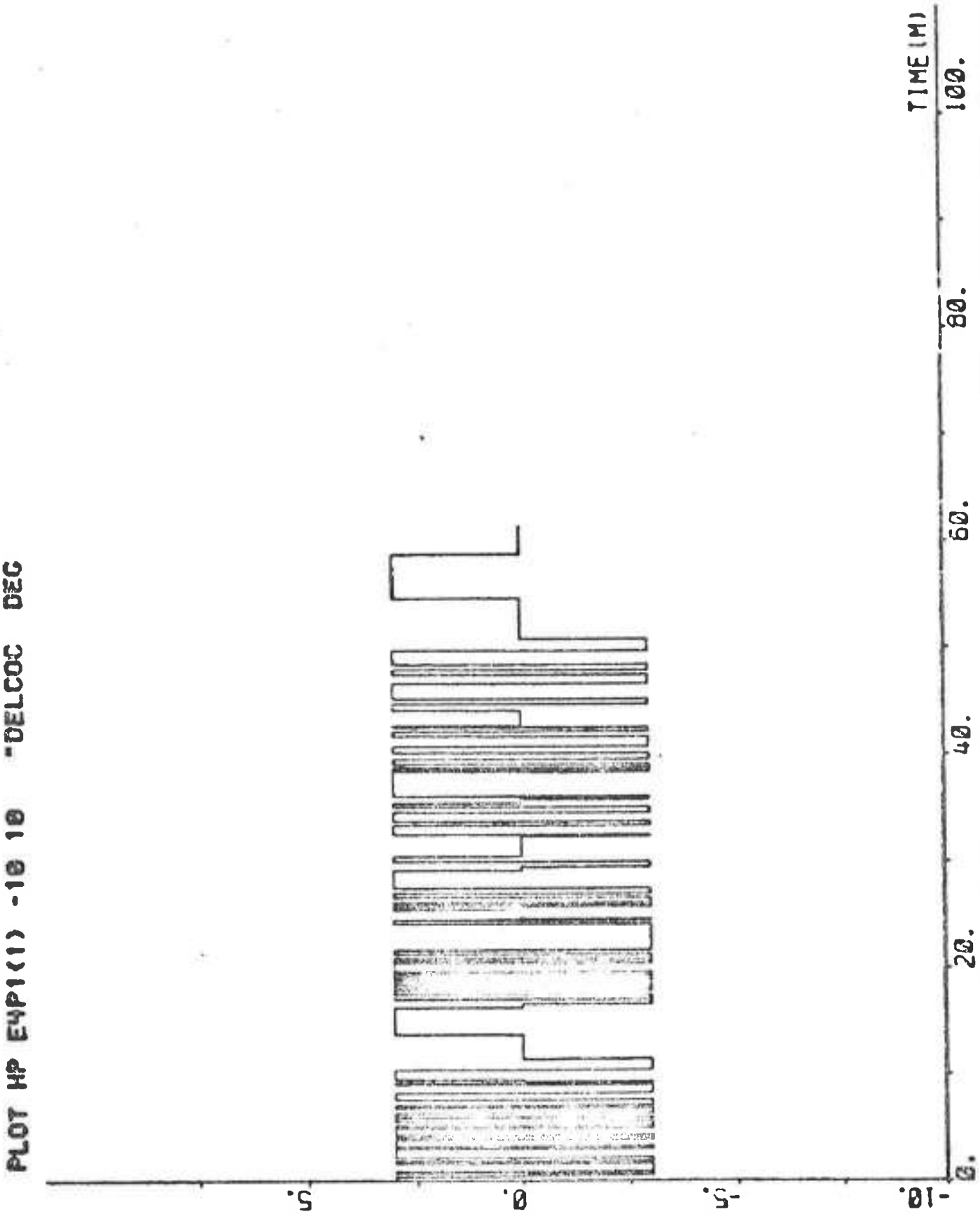
EXPERIMENT E4

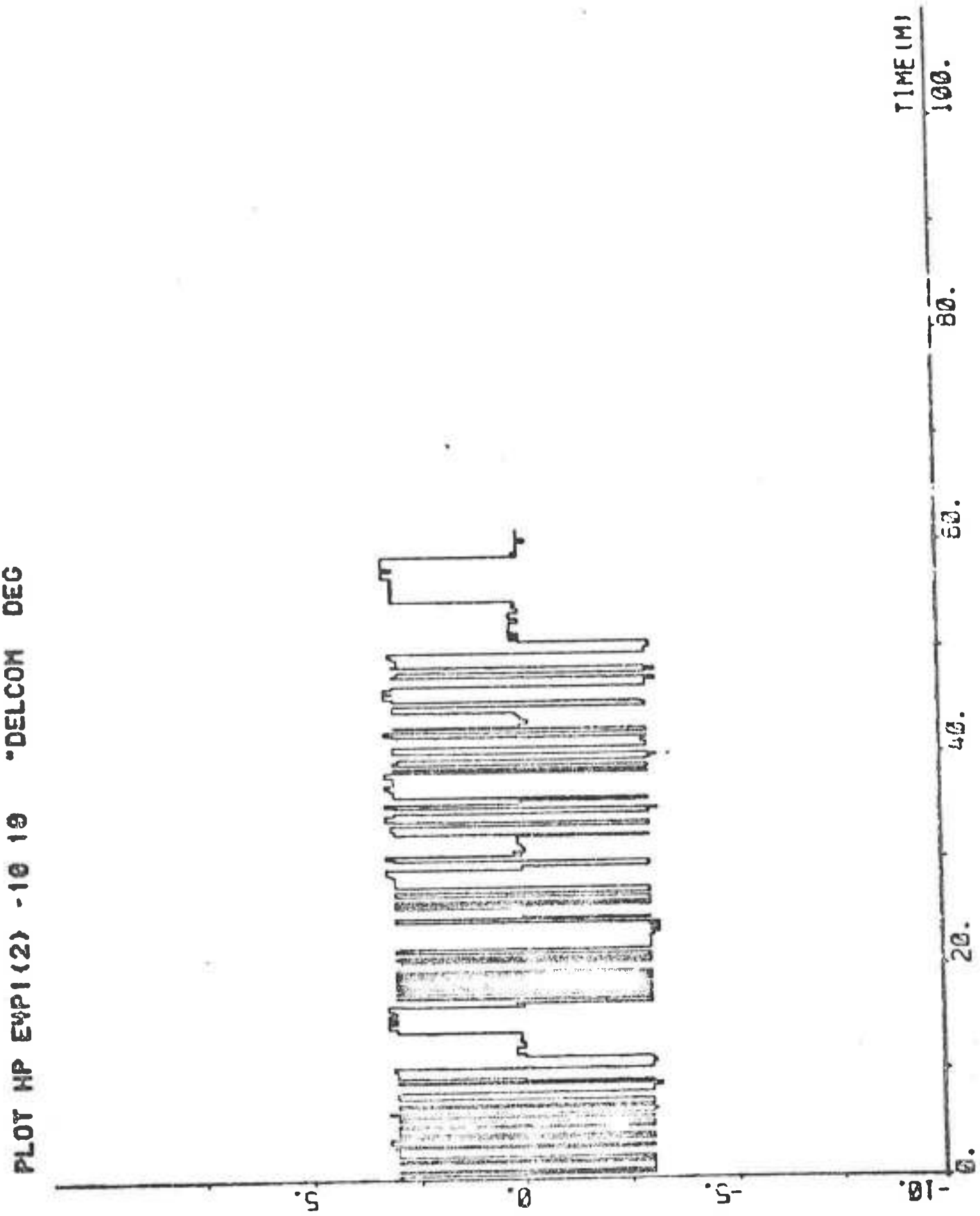
Date	1974-10-20
Time	15.29
Duration	61 min
Position	S 25° 11' E 35° 18'
Water depth	deep
Forward draught	20.2 m
Aft draught	20.2 m
Wind direction	E (6, 7; see Appendix A)
Wind velocity	2 Beaufort (2-3.5 m/s, light breeze)
Wave height	3 - 4 m (sea from S)
PSIREF	214°
Rudder limit	Not active
DELAMP	3°
AKID	0
IREG	10 s

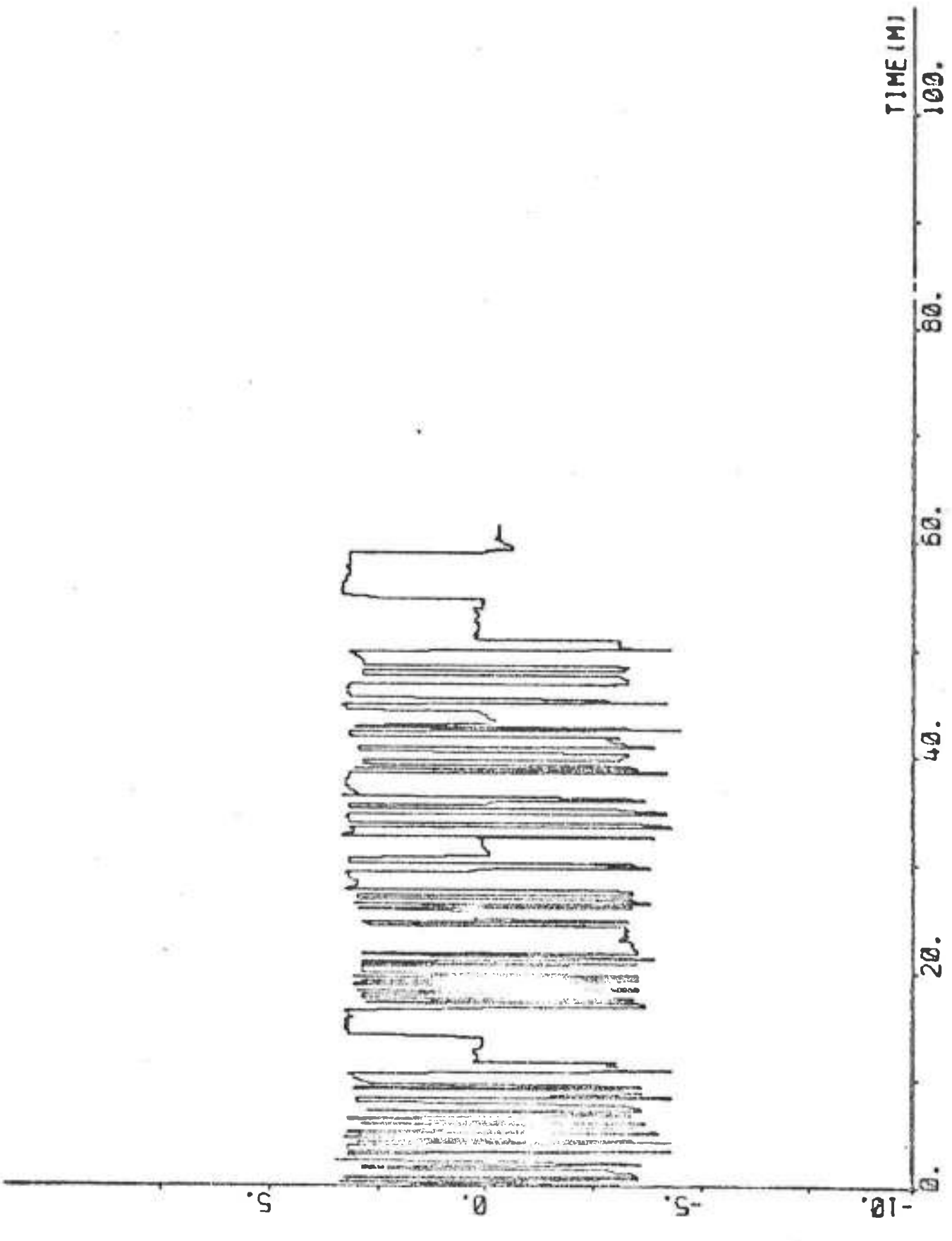
Open loop experiment for identification.

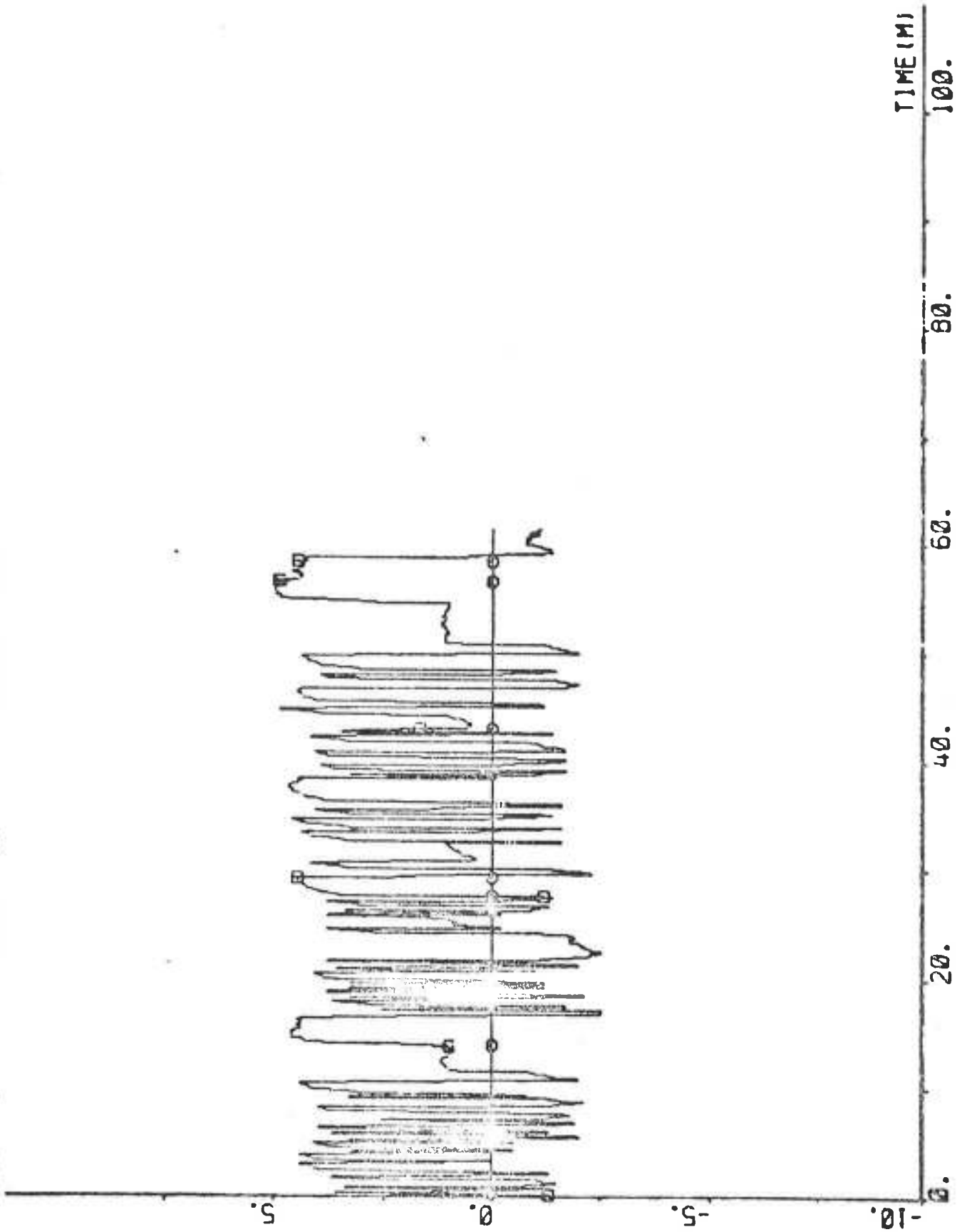
Statistics

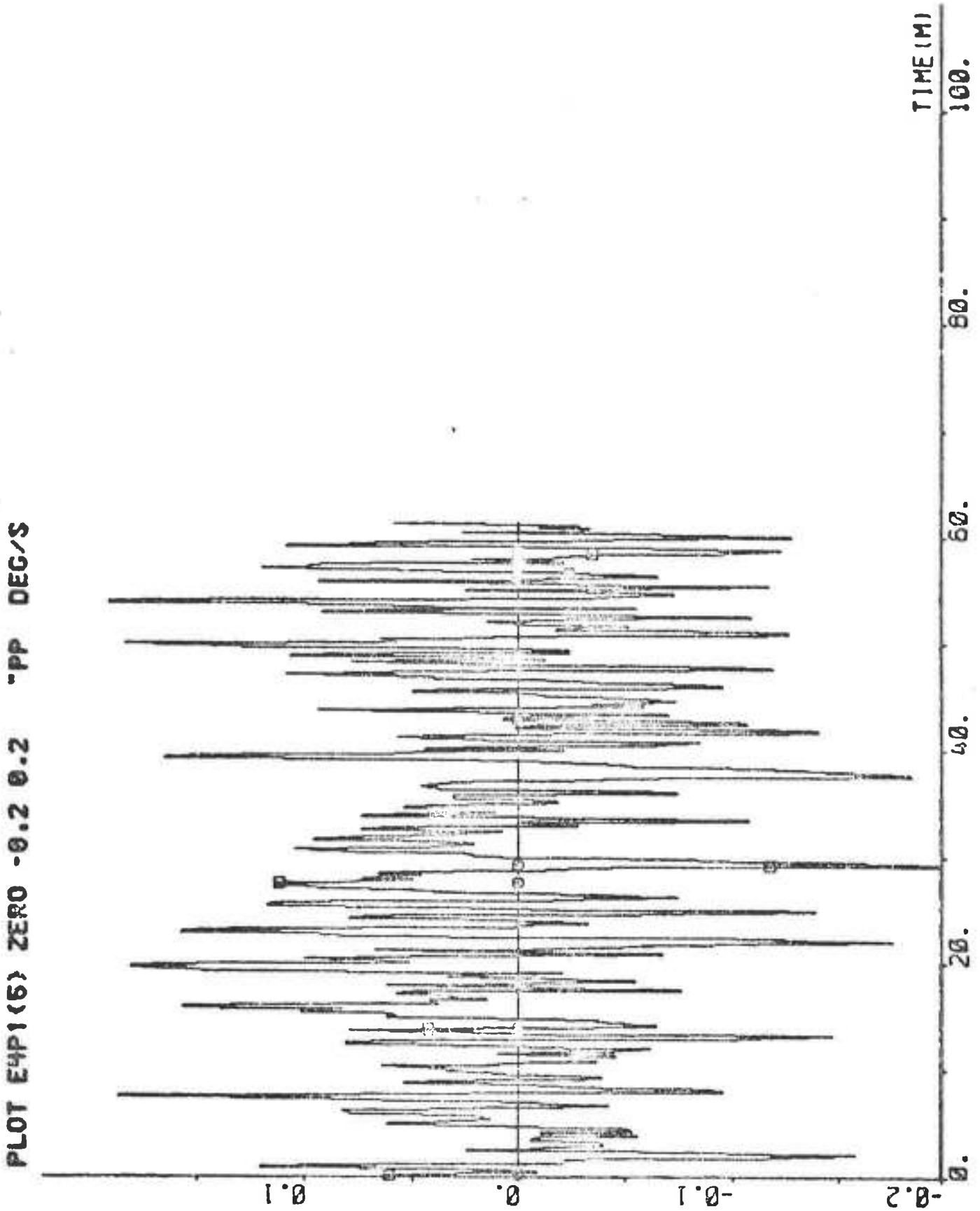
		Mean value	Standard deviation
DELCOC	deg	0.47	2.58
DELCOM	deg	0.50	2.61
DELTAS	deg	0.42	2.80
DELTA	deg	1.60	2.41
PP	deg/s	0.0041	0.0721
AN	rpm	85.78	0.95
U	knots	17.56	0.14
V1	knots	-0.40	0.13
V2	knots	-0.19	0.48
R	deg/s	0.0103	0.0502
AVR	deg/s	0.0067	0.0387
DPSIDT	deg/s	0.0038	0.0435
PSI	deg	212.98	6.89

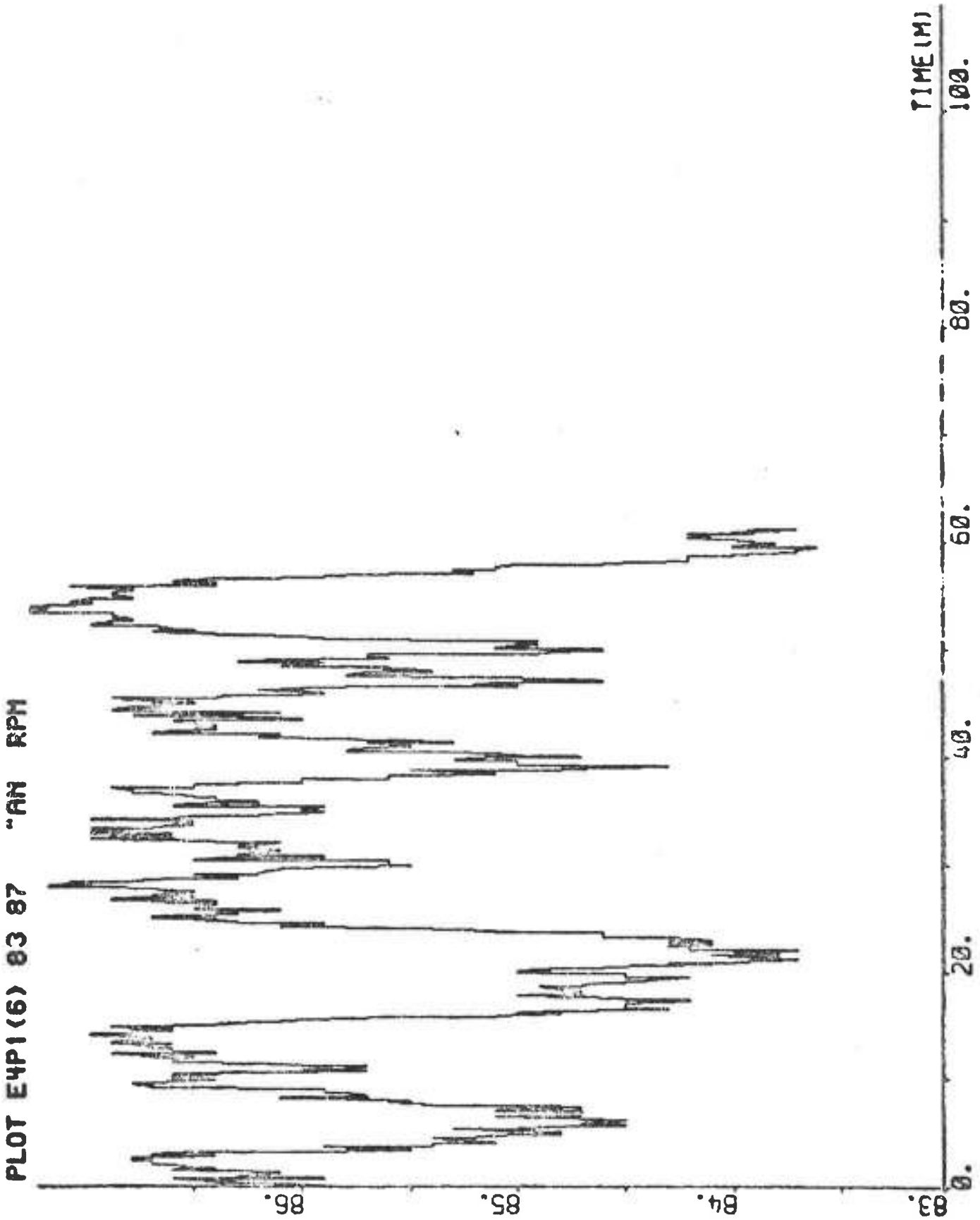

PLOT HP E4P1(1) -10 10 "DELCOC DEG
TIME(M)
0.
20.
40.
60.
80.
100.
-10.
-5.
0.
5.

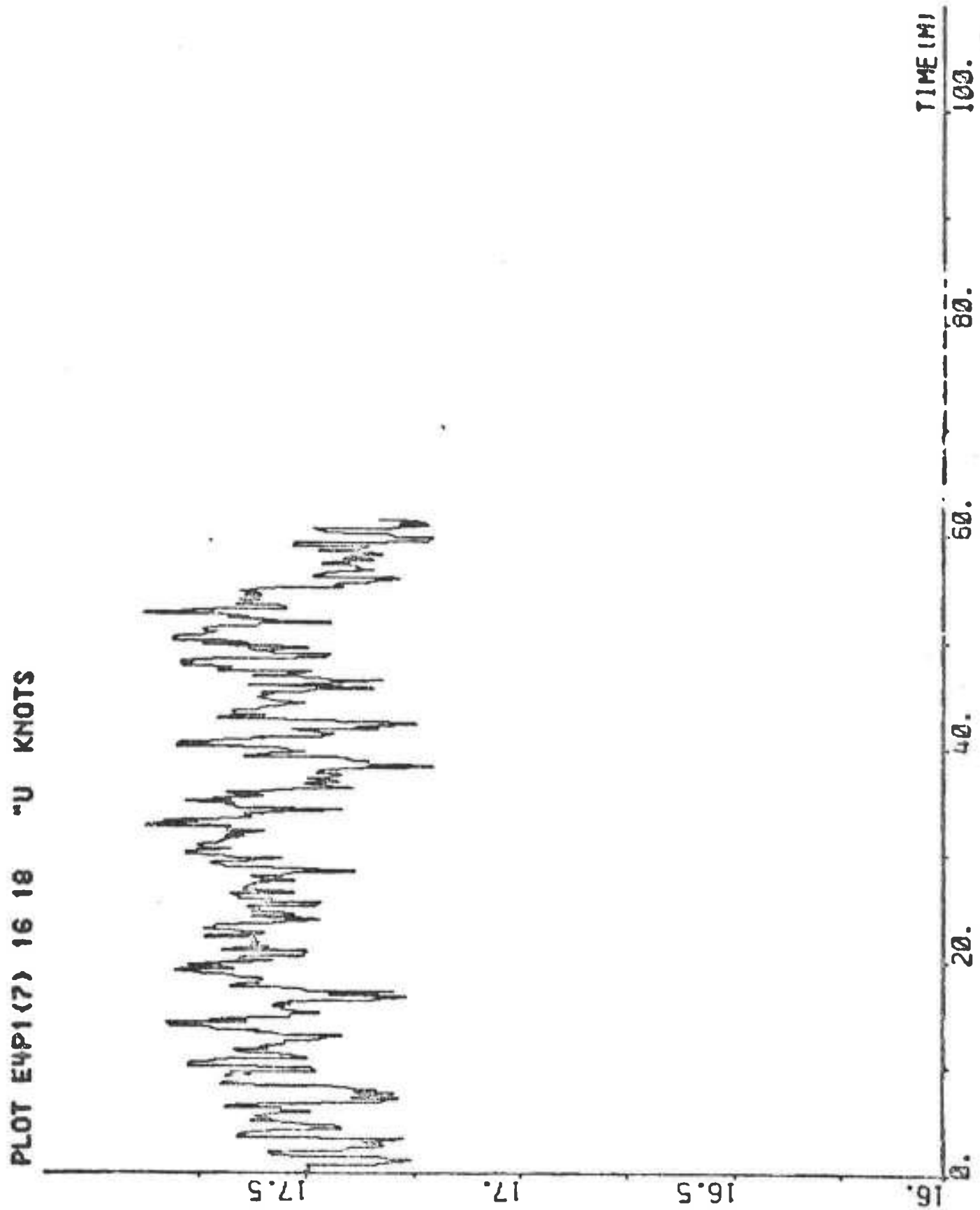

PLOT HP EMPI(2) -10 10 *DELCOM DEG
TIME(M)
0.
20.
40.
60.
80.
100.
-10.
-5.
0.
5.

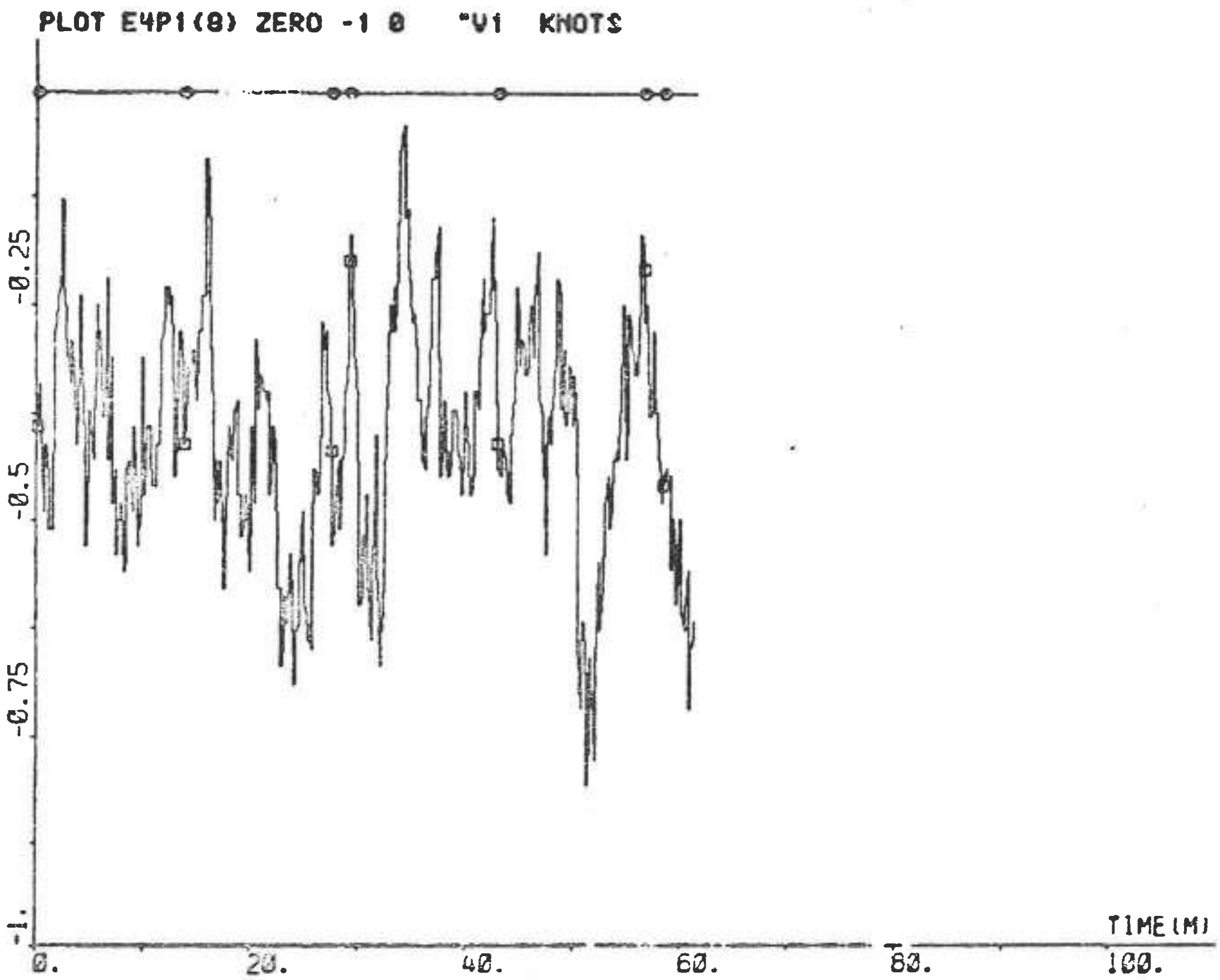

PLOT E4P1(3) -10 10 'DELTAS DEC
-10.
-5.
0.
5.
0.
20.
40.
60.
80.
100.
TIME(M)

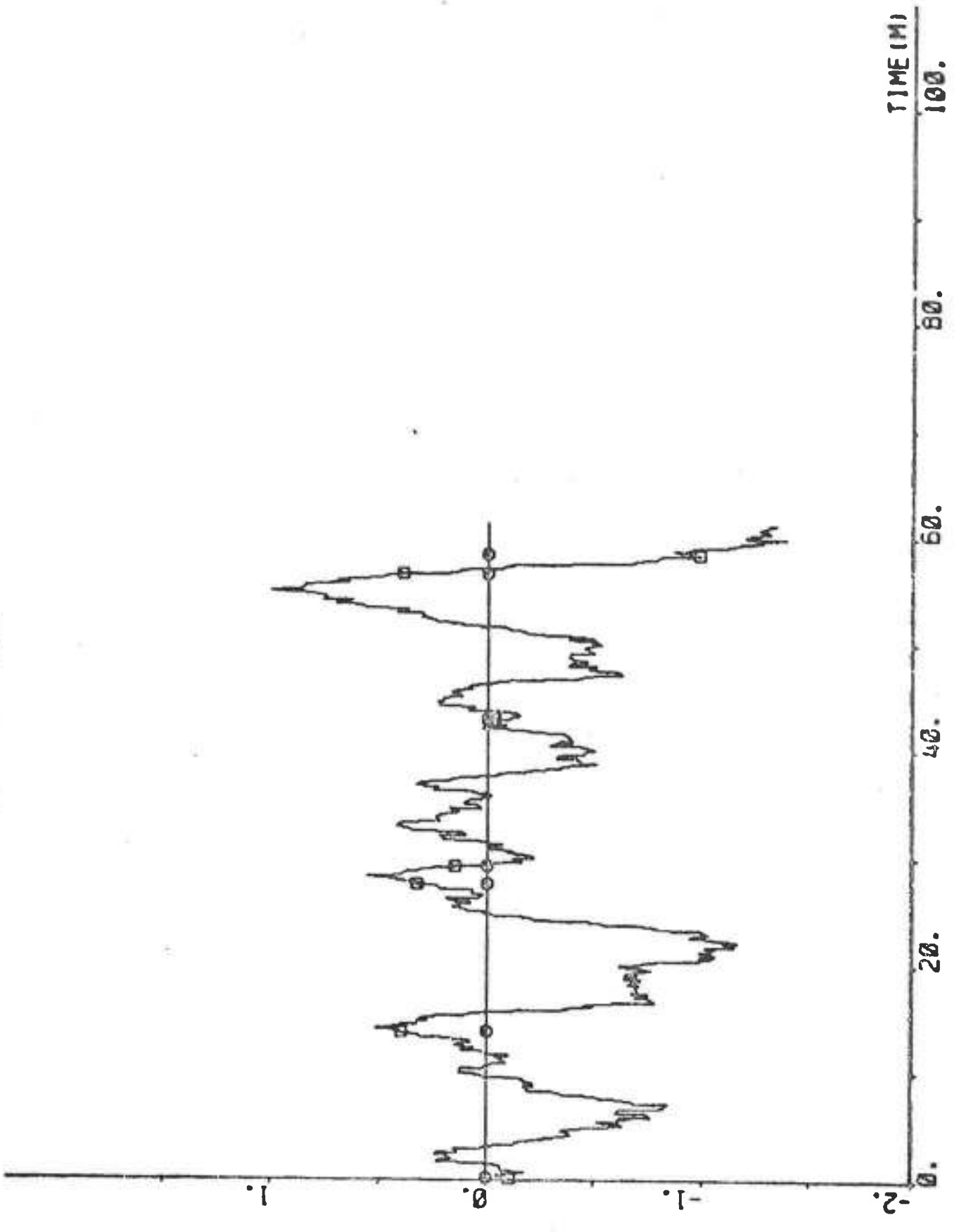

PLOT E4P1(4) ZERO -10 10 'DELTA DEG
5.
0.
-5.
-10.
0.
20.
40.
60.
80.
100.
TIME(M)

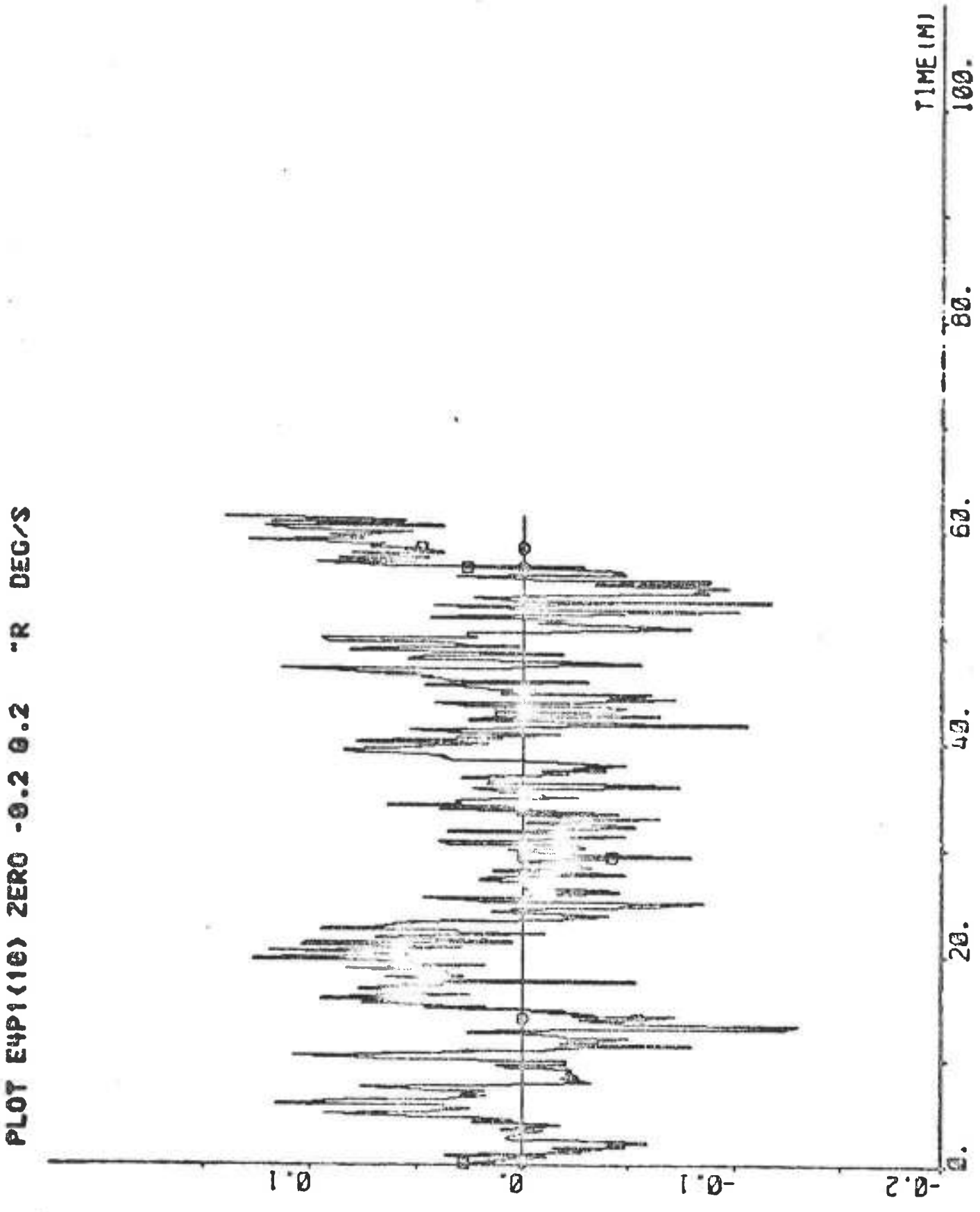

PLOT E4P1(6) ZERO -0.2 0.2 "PP DEG/S
TIME(M)
0.
20.
40.
60.
80.
100.
0.1
0.
-0.1
-0.2

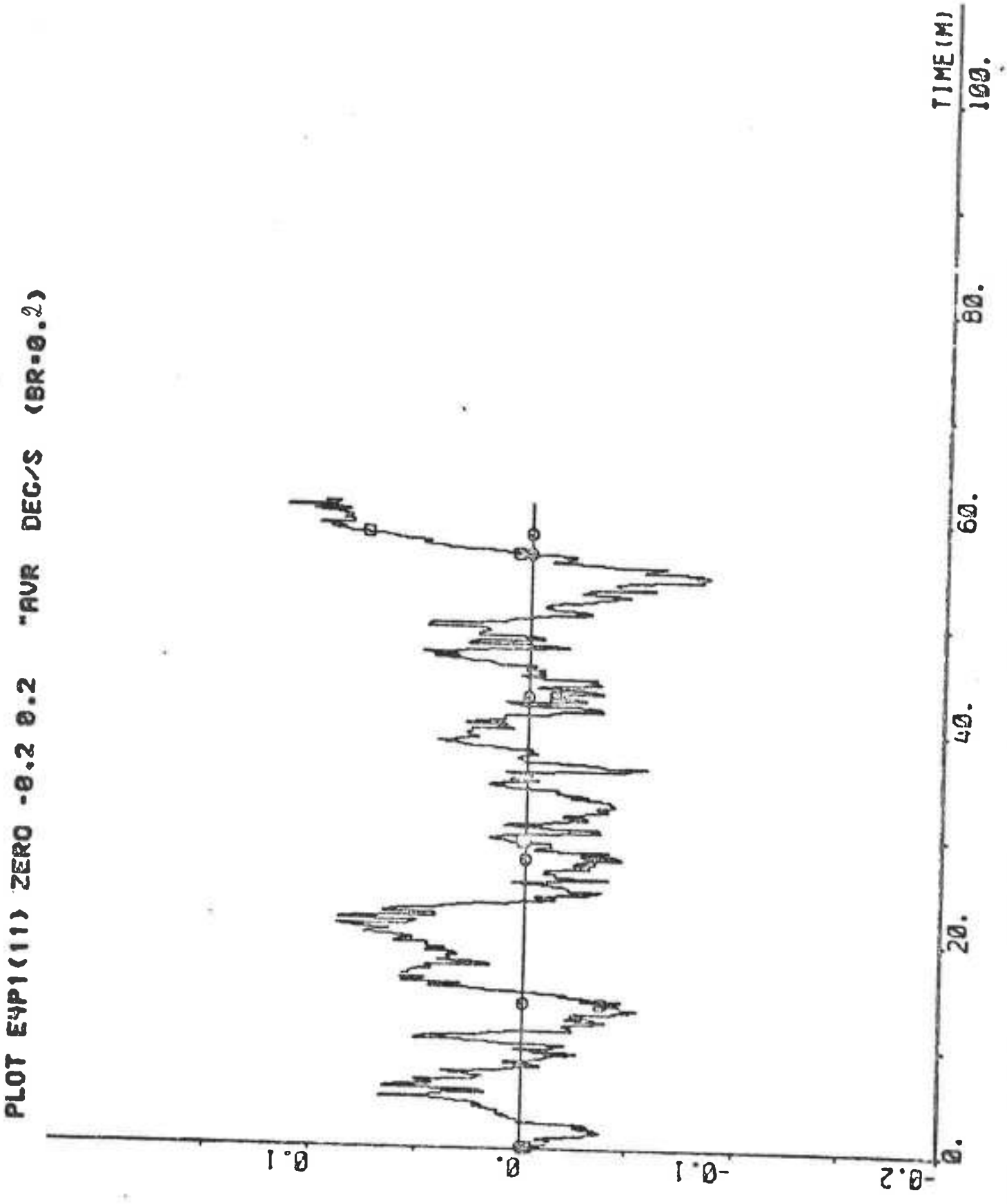

PLOT E4P1(6) 83 87 "AN RPM
83.
84.
85.
86.
0.
20.
40.
60.
80.
100.
TIME(M)

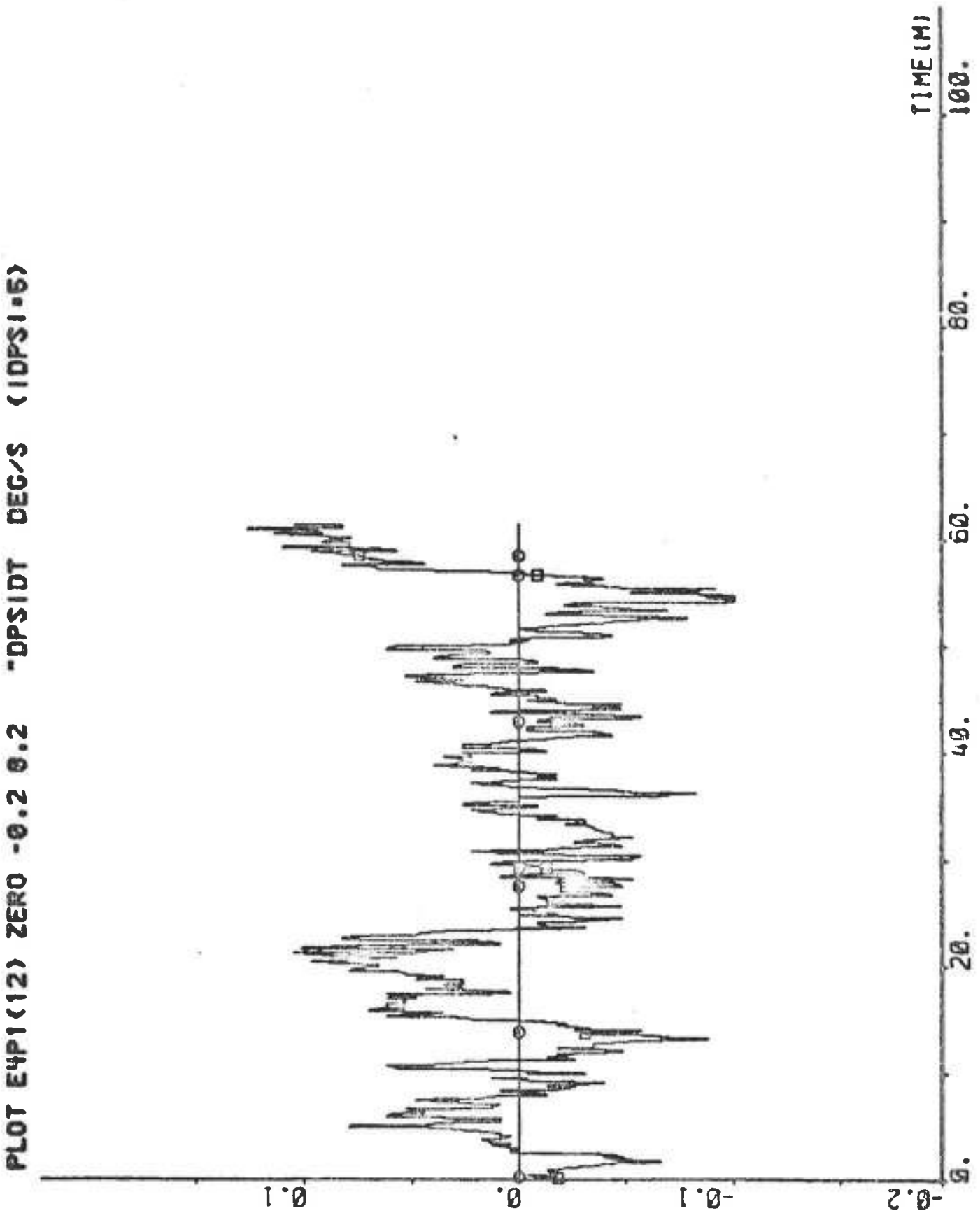

PLOT E4P1(7) 16 18 "U KNOTS
17.5
17.
16.5
16.
0.
20.
40.
60.
80.
100.
TIME(M)

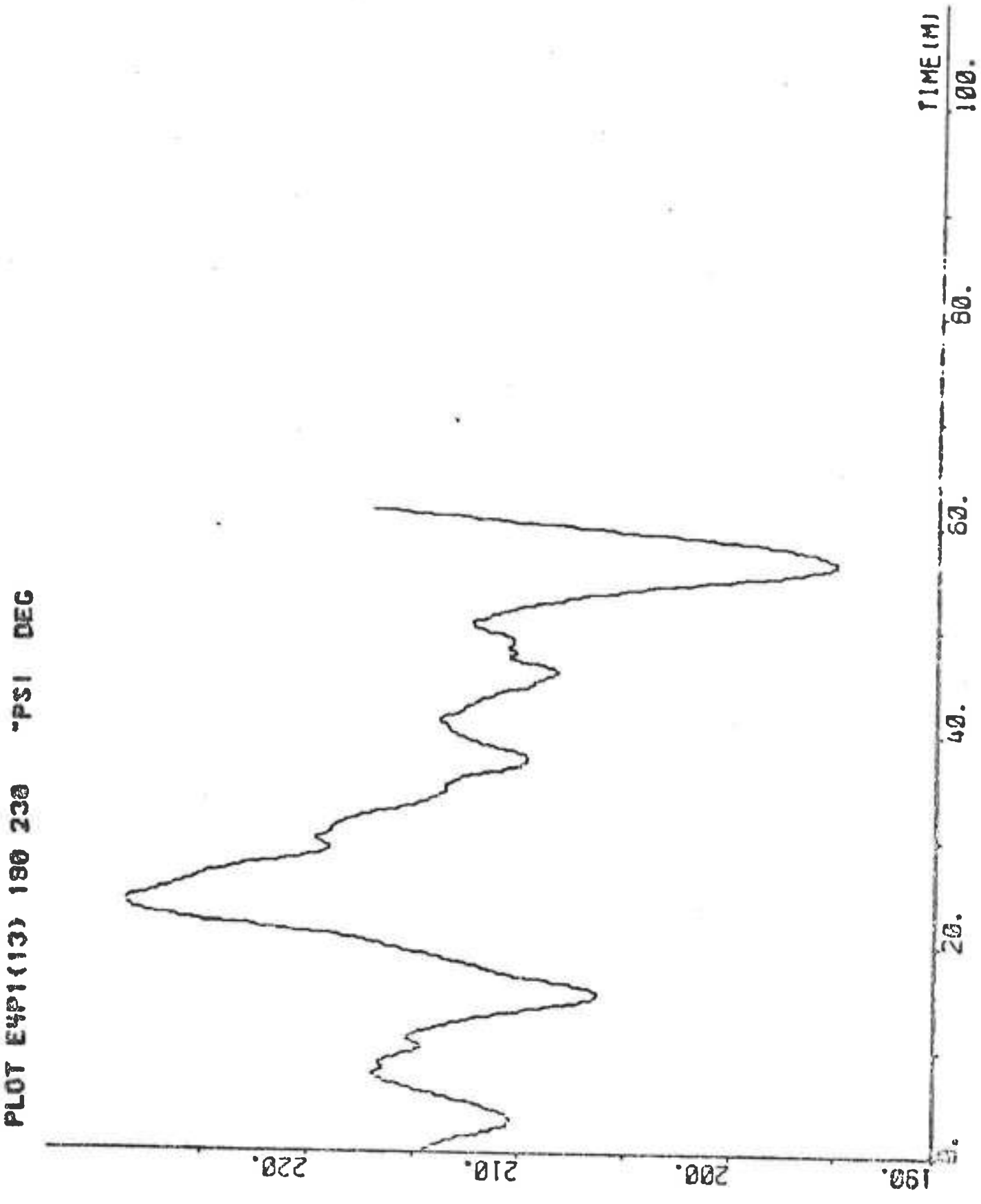

PLOT E4P1(8) ZERO -1 0 "V1 KNOTS
-0.25
-0.5
-0.75
-1.
0.
20.
40.
60.
80.
100.
TIME(M)


PLOT E4PI(8) ZERO -2 2 "V2 KNOTS
1.
0.
-1.
-2.
0.
20.
40.
60.
80.
100.
TIME(M)


PLOT E4P1(10) ZERO -0.2 0.2 "R DEG/S
0.1
0
-0.1
-0.2
0.
20.
40.
60.
80.
100.
TIME(M)


PLOT EYP1(11) ZERO -0.2 0.2 "AVR DEG/S (BR=0.2)
0.1
0.
-0.1
-0.2
0.
20.
40.
60.
80.
100.
TIME(M)


PLOT EYP1(12) ZERO -0.2 0.2 "DPSIDT DEG/S (IDPSI=5)
0.1
0.
-0.1
-0.2
0.
20.
40.
60.
80.
100.
TIME(M)


PLOT EXP1(13) 180 230 *PSI DEG
190.
200.
210.
220.
0.
20.
40.
60.
80.
100.
TIME(M)