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A Study Of Man's Physical Capabilities On The Moon

VOLUME II, PART 2

BIOMECHANICS RESEARCH PROGRAM APPENDICES

By W. Kuehnegger

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for

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

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FOREWORD

This volume contains the Appendices to the biomechanics research program conducted in "A Study of Man's Physical Capabilities on the Moon", under NASA contract NAS 1-4449. This contract was administered by Langley Research Center, with Mr. William Letko serving as NASA Technical Monitor.

The study was performed by Northrop Space Laboratories in association with Case Institute of Technology, Cleveland, Ohio. Dr. Walter Kuehnegger served as the Principal Investigator for NSL. Professor James B. Reswick, Director of the Case Institute Engineering Design Center, guided and directed the work conducted at Case under subcontract.

In view of the complexity and scope of the work performed under this contract, the final report has been organized in four separate volumes (numbered I thru IV). Since the work itself was broken down into phases it was possible to treat each phase individually and document them correspondingly. The four volumes which comprise this report are identified as follows:

CR-66115 Volume I, Part 1 - Lunar Gravity Simulation Facility

CR-66116 Volume I, Part 2 - Instrumentation

CR-66117 Volume II, Part 1 - Biomechanics Research Program

CR-66118 Volume II, Part 2 - Biomechanics Research Program

CR-66119 Volume III - Work Physiology Research Program

CR-66120 Volume IV - Investigation of Lunar Gravity Simulation Techniques

Volumes I thru III were produced by NSL and have been assigned Northrop Space Laboratories' document number NSL 65-153. Volume IV was prepared from material contributed by Case Institute and reports on their portion of the contract effort. The total report (all four volumes) summarizes the performance during the contract period from 2 November 1964 to 30 September 1966.

The author of this report (Volume II, Part 2) wishes to express his appreciation to Mr. Ken Forsen for his endless and thorough effort in the establishment of a series of complex computer programs and to Mr. R. Fortney for his critique and verification of these programs.

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A STUDY OF MAN'S PHYSICAL CAPABILITIES ON THE MOON

ABSTRACT

A study was made to compare man's energy expenditure and gait characteristics, during self locomotion at various rates, in earth and in simulated lunar gravity conditions. The tests were made for the subject walking and running on the level and on grades up to 30° while in shirt sleeves and while wearing a suit pressurized to 3.5 psig. The results, presented in four volumes, may be useful for the design of space suits and life support systems and the planning of lunar exploration missions and their logistics.

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APPENDIX A

SUBJECT DATA

By W. Kuehnegger

The purpose of the detailed subject data acquisition effort represented herein was not only to record certain physical properties important to conduct the study program but also to contribute to the establishment of dependent variables capable of defining correlations with the different characteristics that make up the physical constitution of healthy human beings in the performance of work or locomotion. The ultimate goal of correlative indices is then the establishment of a meaningful unit model of man.

GENERAL DESCRIPTION OF UNIT MODEL

The immense number of human subjects required to produce statistically valid experimental data would in most cases eliminate the possibility of such research, while experiments conducted with a relatively small number of subjects produces data of limited value for extrapolation and future applications. For such future applications data from relatively few subjects cannot be used to predict quantitative characteristics of specific untested subjects with any degree of confidence. A baseline reference such as a UNIT MODEL of man with respect to the particular nature of the investigation must then be established. To create a useful research tool this model must possess the following properties.

(1) Correlation factors or indices must be found to reduce the experimental data to the model.

(2) The model itself must represent singular experimental values.

(3) For future applications these values must be reconvertible by similar correlation factors or indices to specific untested subjects resulting in realistic predictions for their characteristics and performance.

Such precise data on the subject, except for the biomechanical analysis, will mean very little unless other investigators in this field of human research are hereby encouraged to record similarly accurate information on their subjects. Better still, pertinent investigators should be requested to adhere to standard type of subject data forms. With the eventual accumulation of such data it should be possible to find the correlative indices referred to in the unit model. Once this has been accomplished, there will be no limit to the possible applications of such a model. It is foreseen that this model will represent a cross-breeding of the general subject information with the percentile-man, the Link-Joint-System and the Somatotype.

The somatotype of Olympic athletes for specific athletic events has already been the suject of an investigation by Tanner (Ref. 1) while Sills (Ref. 2) included the importance of anthropometry and the somatotype in relation to physical performance. Grim (Ref. 3) on the other hand indicated the mesomorphic predominance in the somatotype distribution of lumber jacks.

Testing is not performed for the sake of testing, but for the derivation of data useful in the understanding and quantification of human performance and useful for the confident prediction of results for subjects under investigation but not tested.

The unit model will provide a common denominator for all human performance investigations. The final benefits will include the establishment of physiological relationships in the assessment of human performance and fatigue. This detailed subject data is presented in the following sequence.

(1) General subject information

(2) Percentile man comparison

(3) Determination of body segment weights

(4) Determination of centers of gravity

(5) Moment of inertia of body segments

(6) Link joint system

(7) Biomechanics subject data

General Subject Information

Three subjects (A, B, and C) were used in the experiments conducted on the LGS. Not all tests however were conducted by each subject under the contractual requirements. Subject A performed most of the shirtsleeve Mode 1000 experiments and some important selected experiments in the pressure suited 2000 and 3000 Modes for verification. Subject B performed experiments in the shirtsleeve Mode 1000 only. Subject C performed all the tests in the 1000, 2000, and 3000 Modes. General subject information is presented in Tables A1 through A3, while Figures A1 through A3 show the overall anthropometry of the subjects.

TABLE A1. — SUBJECT A, GENERAL INFORMATION

Subject	A
Sex	male
Age	38 years
Ethnic Classification	Caucasian
Height	5 ft 7.75 in (172.08 cm)
Weight	186.25 lb (84.481 kg)
Surface Area	21.18 sq ft (1.97 sq m)
Percentile Man	28
Profession	Senior Scientist

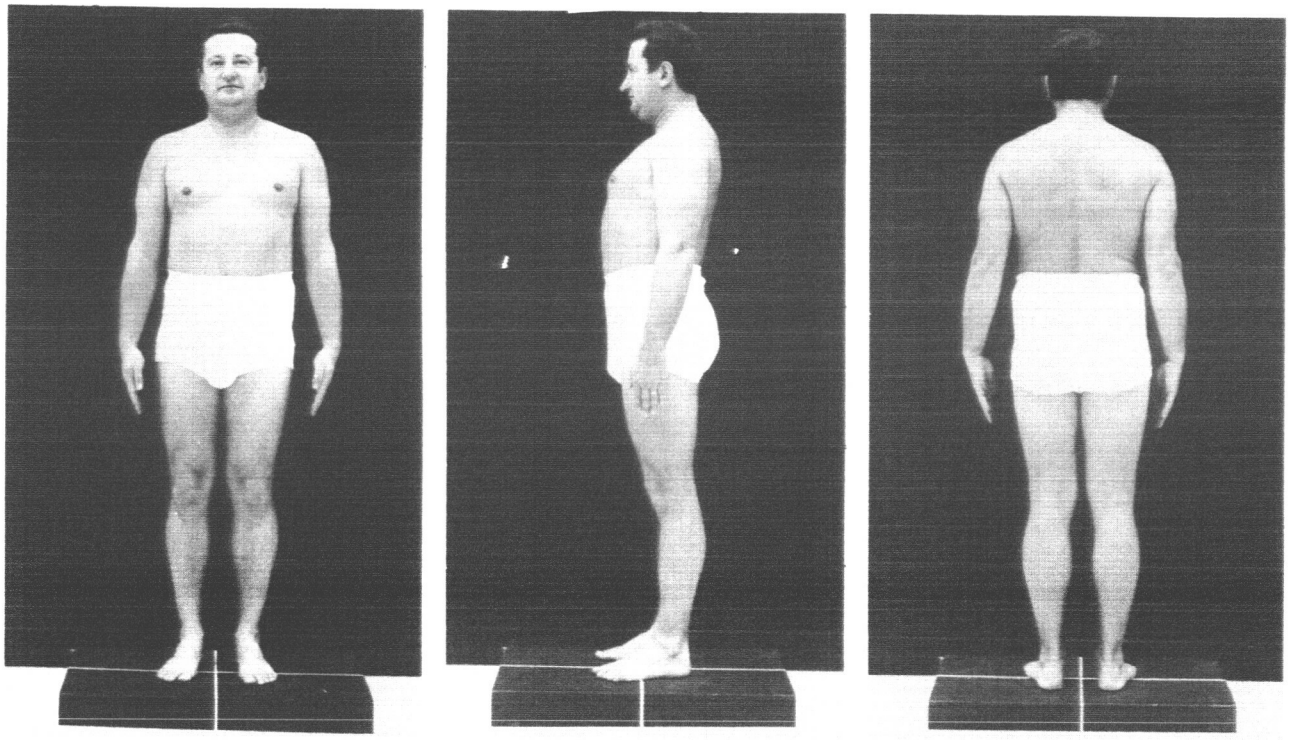


Figure A1. - Subject A, anthropometry

TABLE A2. — SUBJECT B, GENERAL INFORMATION

Subject	B
Sex	male
Age	32 years
Ethnic Classification	Caucasian
Height	5 ft 8.50 in (174.00 cm)
Weight	185.01 lb (83.92 kg)
Surface Area	21.39 sq ft (1.99 sq m)
Percentile Man	40
Profession	Flight equipment specialist

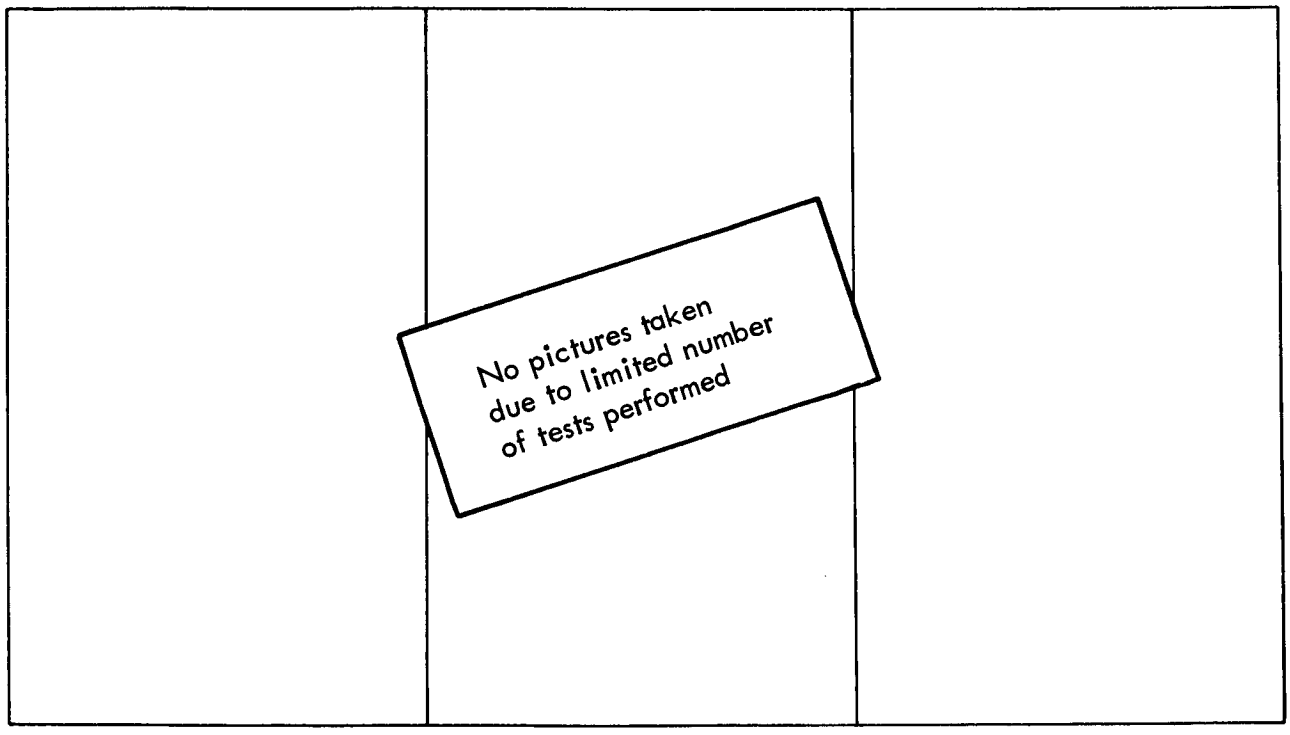


Figure A2. - Subject B, anthropometry

TABLE A3. — SUBJECT C, GENERAL INFORMATION

Subject	C
Sex	male
Age	30 years
Ethnic Classification	Caucasian
Height	5 ft 8.00 in (172.72 cm)
Weight	155.00 lb (70.306 kg)
Surface Area	19.78 sq ft (1.84 sq m)
Percentile Man	32
Profession	Biology student

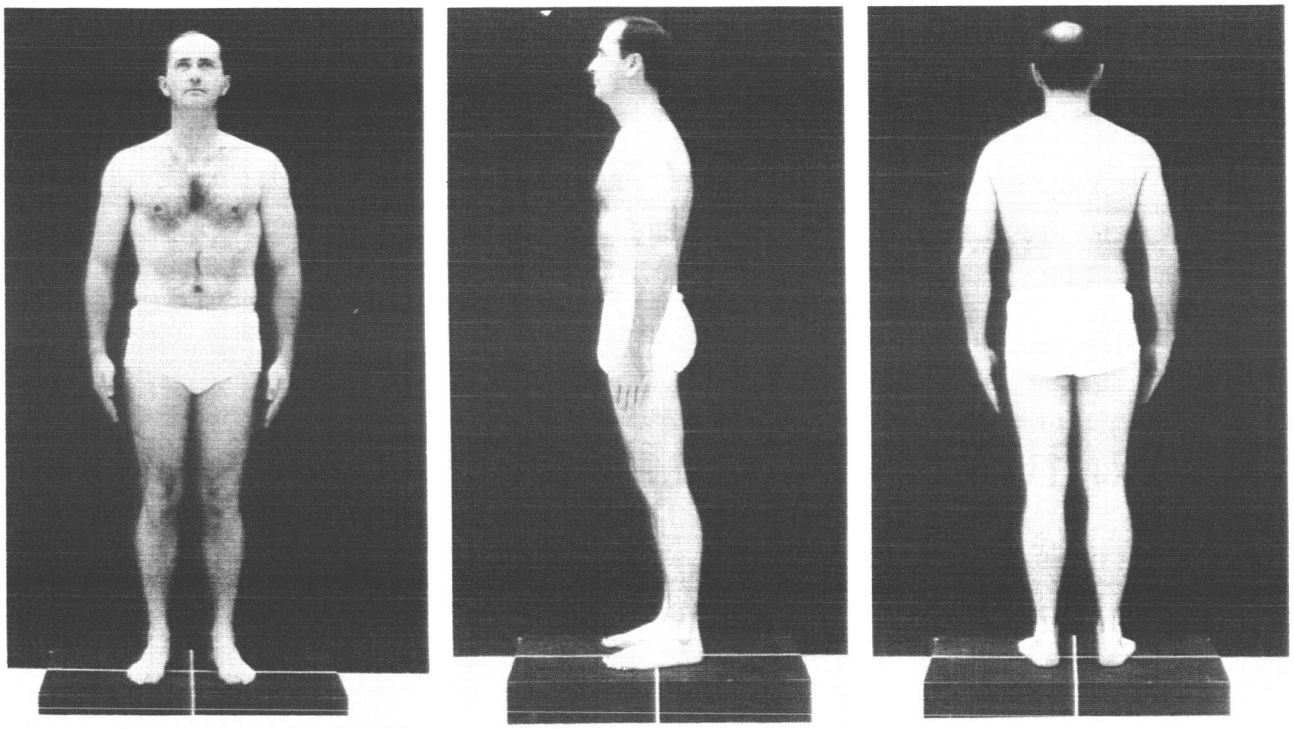


Figure A3. - Subject C, anthropometry

Percentile Man Comparison

The true percentile man does not exist. Such a quantification is based on statistical values resulting from a survey (Ref. 4). Even so, the percentile man concept serves a very useful purpose and was utilized as a basis for the anthropometric comparison of subjects used in this program. The stature of a subject can be expressed as that of a certain percentile man while other body dimensions can be randomly distributed according to the variation in the physique of the subject. The comparison is made by the determination of the percentile man from the subject's stature which is followed by a listing (see Tables A4 through A7) of the theoretical percentile dimensions compared to those measured. The theoretical percentile dimensions and those measured were based on the consideration of their usefulness for the physical performance of man. Conventional anthropometric instruments were used in measuring the total body and body segment dimensions. The locations of the dimensions are illustrated in Figures A4 through A6.

TABLE A4. DIMENSIONS OF SUBJECTS VS PERCENTILE MAN

Location no.	Body measurement	Subject A		Subject C	
		Percentile man	Measured (cm)	Percentile man	Measured (cm)
1	Stature	28	172.08	32	172.72
2	Cervicale Height	43	149.23	28	146.685
3	Shoulder Height	57	144.78	40	142.24
4	Elbow Height	13	105.41	28	107.95
5	Waist Height	17	102.55	24	103.51
6	Wrist Height	44	84.77	41	84.455
7	Knuckle Height	41	75.565	42	73.34
8	Crotch Height (Inseam)	21	80.01	39	82.23
9	Kneecap Height	65	52.39	24	49.53
10	Buttock-Knee Length	55	60.325	38	59.215
11	Buttock-Leg Length	22	104.44	9	101.75
12	Shoulder-Elbow Length	66	37.13	45	36.195
13	Forearm-Hand Length	8	45.085	11	45.403
14	Span	18	173.025	35	177.165
15	Maximum Reach from Wall	1	87.15	1	86.51

TABLE A4. DIMENSIONS OF SUBJECTS VS PERCENTILE MAN (Continued)

Location no.	Body measurement	Subject A		Subject C	
		Percentile man	Measured (cm)	Percentile man	Measured (cm)
16	Elbow-to-Elbow Breadth	92	49.21	78	46.67
17	Hip Breadth, Standing	15	33.32	13	33.09
18	Knee-to-Knee Breadth, Sitting	88	21.75	52	20.16
19	Biocromial Diameter	0	33.81	0	34.59
20	Shoulder Breadth	93	48.89	88	48.26
21	Chest Breadth	80	32.23	83	32.54
22	Waist Breadth	99	33.49	88	30.00
23	Hip Breadth	48	33.32	42	33.09
24	Chest Depth	99	28.575	73	24.13
25	Waist Depth	99	28.397	44	19.68
26	Buttock Depth	80	24.288	48	8.75
27	Neck Circumference	92	40.64	39	37.46
28	Chest Circumference	84	104.77	72	101.85
29	Waist Circumference	98	100.01	63	83.18
30	Thigh Circumference	85	62.55	35	55.25
31	Lower Thigh Circumference	41	43.18	5	38.10
32	Calf Circumference	80	38.74	69	36.83

TABLE A4. DIMENSIONS OF SUBJECTS VS PERCENTILE MAN (Continued)

Location no.	Body measurement	Subject A		Subject C	
		Percentile man	Measured (cm)	Percentile man	Measured (cm)
33	Ankle Circumference	56	22.86	22	21.59
34	Axillary Arm Circumference	90	35.56	56	32.05
35	Biceps Circumference (Flexed)	94	36.83	59	33.02
36	Lower Arm Circumference (Flexed)	89	31.59	31	28.24
37	Wrist Circumference	45	17.30	41	17.15
38	Sleeve Inseam	4	45.24	4	45.56
39	Anterior Neck Length	80	10.00	98	12.07
	FOOT				
40	Foot Length	16	25.55	50	26.27
41	Instep Length	17	18.57	41	19.21
42	Foot Breadth	55	9.68	55	9.68
43	Heel Breadth	65	6.83	65	6.83
44	Lateral Malleolus Height	99	8.41	95	7.94
45	Medial Malleolus Height	79	9.21	98	9.84
46	Ball of Foot Circumference	26	23.81	53	24.61
	HAND				
47	Hand Length	24	18.42	67	19.37

TABLE A4. DIMENSIONS OF SUBJECTS VS PERCENTILE MAN (Continued)

Location no.	Body measurement	Subject A		Subject C	
		Percentile man	Measured (cm)	Percentile man	Measured (cm)
48	Hand Breadth at Metacarpale	71	9.05	71	9.05
49	Thickness at Metacarpale III	89	3.175	96	3.27
50	Palm Length	31	10.48	65	10.95
	HEAD AND FACE				
51	Head Length	7	18.73	30	19.37
52	Head Breadth	23	15.03	93	16.19
53	Larynx to Wall	24	16.83	33	17.15
54	Head Circumference	36	56.52	43	56.83

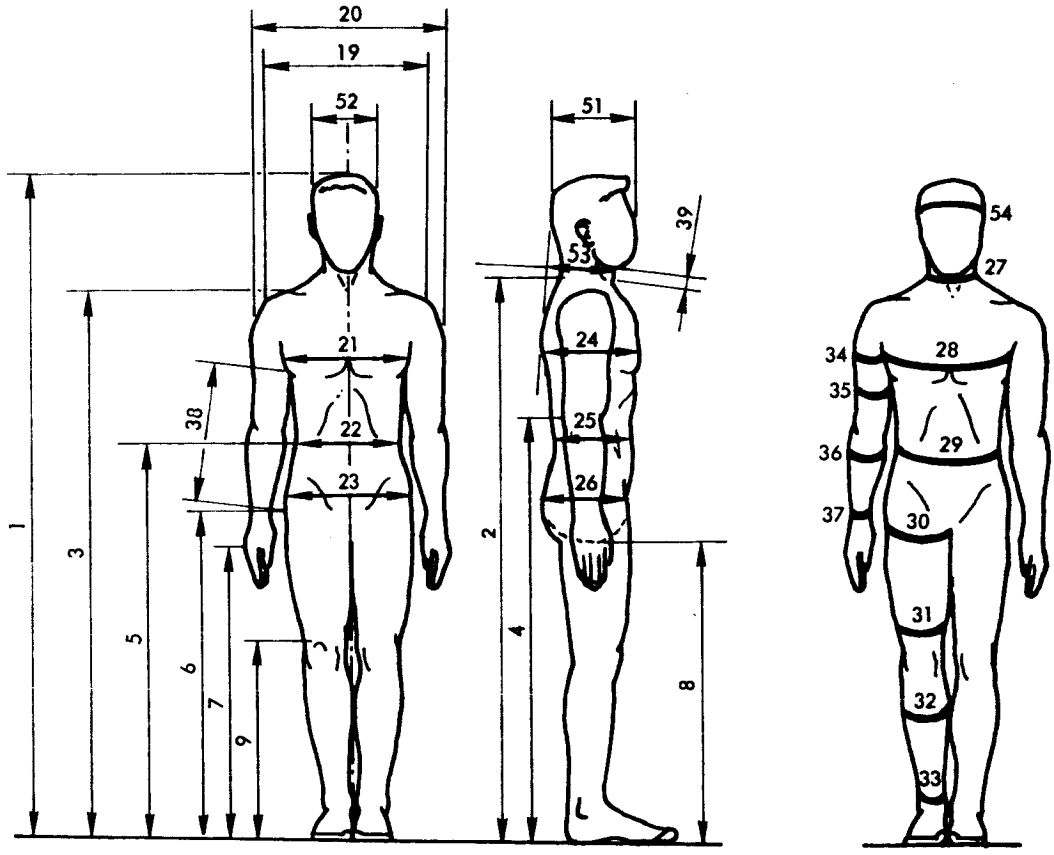


Figure A4. - Subject anthropometry, anatomical positions

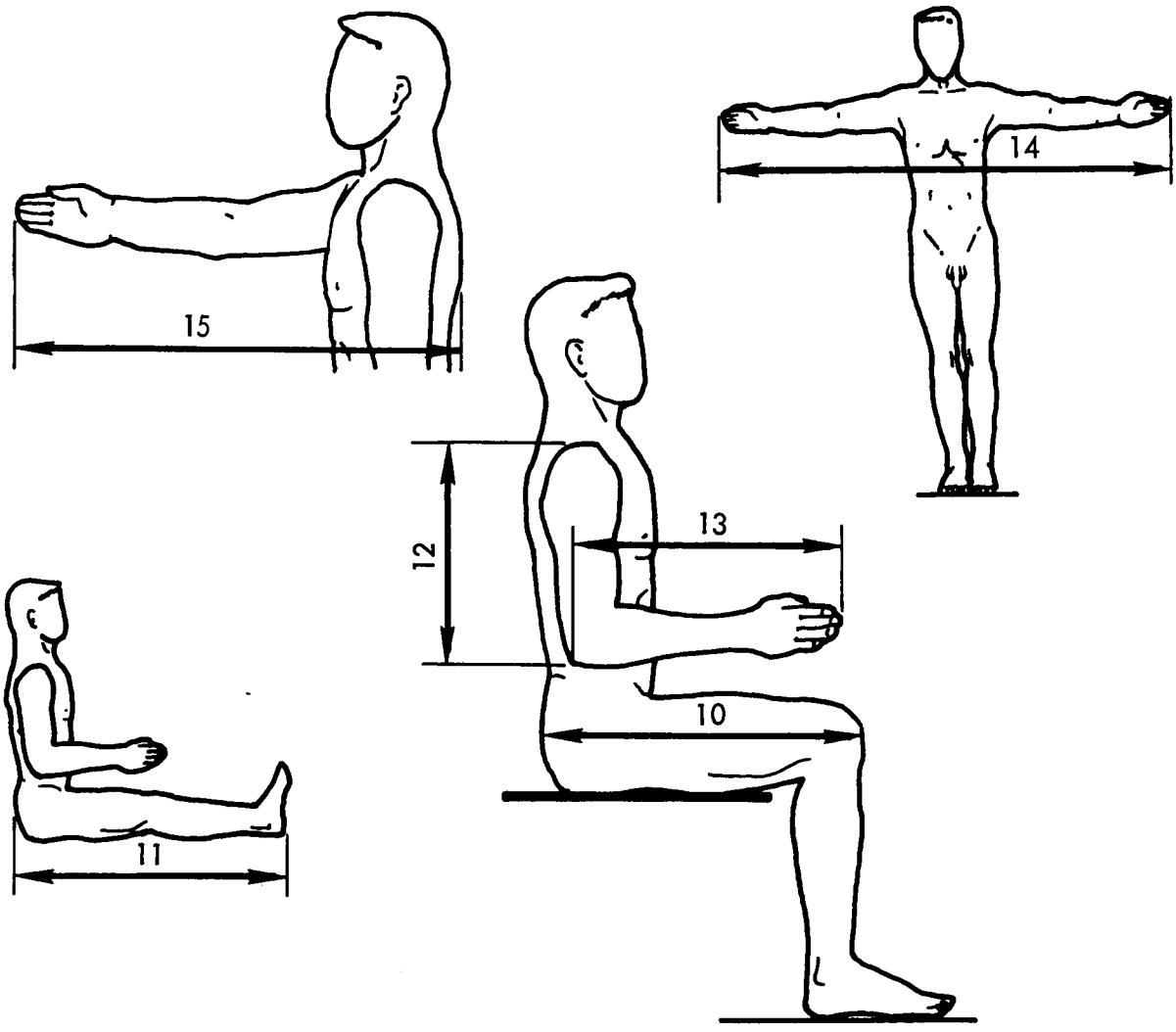


Figure A5. - Subject anthropometry, articulated positions

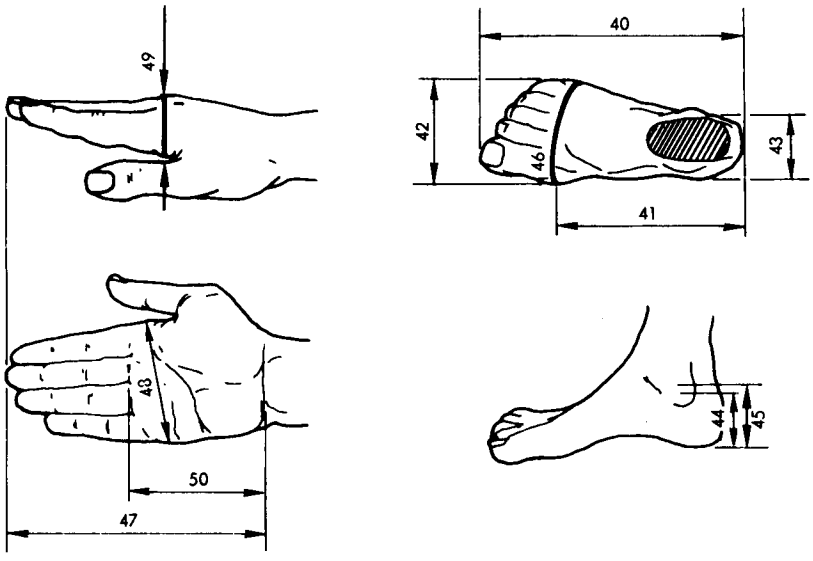


Figure A6. - Subject anthropometry, extremity details

Determination of Body Segment Weights

The body was divided into the six body segments as listed in Table A8.

TABLE A5. – BODY SEGMENTS

Segment no.	Segment
1	Head and Neck
2	Trunk
3	Upper Arm
4	Lower Arm and Hand
5	Thigh
6	Lower Leg and Foot

These segments are further illustrated in Figure A4, A5, and A6 of this report. The immersion method discussed earlier under Biomechanics Motion Analysis was used to determine the volume displaced by the body segments. Since the specific volume of water varies with pressure and temperature it was necessary to conduct the determination of body segment volumes by immersion in water at controlled conditions. This was achieved by maintaining a constant water temperature of 80°F throughout the immersion test procedure which included the measurement of the displaced volume. The determined volumes were then multiplied by the specific gravity (taken from Ref. 5) of a particular segment, to compute the segment weight. A verification of the sum of the computed segment with that of the actual body weight was made. Slight differences for both subject A and C were corrected by using the ratio K to recompute the segment weight. This is shown by the computations in Tables A6 and A7.

TABLE A6. — DETERMINATION OF BODY SEGMENT WEIGHTS, SUBJECT A

Segment No.	Body Segment	Volume Displaced Liter	Specific Gravity	Segment Weight, Kg. = Vol. x Spec. Gr.	Corrected Weight Kg, (K = .97897)
1	Head and Neck	4.725	1.110	5.244	5.136
2	Trunk*	45.783**	1.030	47.156	46.164
3	Upper Arm - Left	1.940	1.070	2.075	2.032
	Upper Arm - Right	1.978	1.070	2.116	2.072
4	Forearm - Left	1.180	1.125	1.327	1.300
	Forearm - Right	1.310	1.125	1.473	1.443
	Hand - Left	.383	1.155	.442	.433
	Hand - Right	.398	1.155	.459	.450
5	Thigh - Left	7.550	1.050	7.927	7.761
	Thigh - Right	8.378	1.050	8.796	8.612
6	Leg - Left	3.440	1.090	3.749	3.671
	Leg - Right	3.270	1.090	3.564	3.489
	Foot - Left	.898	1.095	.983	.962
	Foot - Right	.892	1.095	.976	.955
	TOTAL BODY	82.125***		86.296****	84.480

* Determined by subtraction after total body immersion

** Includes subtraction for estimated residual respiratory volume of 1.470 liter.

*** Total body volume in the expired condition.

**** If total is not equal to actual body weight determine ratio K and recompute for last column

$$K = \frac{\text{Actual body weight}}{\text{Computed body weight}} = \frac{84.481}{86.296} = .97897$$

TABLE A7. — DETERMINATION OF BODY SEGMENT WEIGHTS SUBJECT C

Segment No.	Body Segment	Volume Displaced Liter	Specific Gravity	Segment Weight, Kg =Vol. x Spec. Gr.	Corrected Weight Kg, (K = .9671
1	Head and Neck	2.955	1.110	3.280	3.172
2	Trunk*	38.004**	1.030	39.144	37.856
3	Upper Arm - Left	1.980	1.070	2.119	2.049
	Upper Arm - Right	1.752	1.070	1.875	1.813
4	Forearm - Left	1.050	1.125	1.181	1.142
	Forearm - Right	1.000	1.125	1.125	1.088
	Hand - Left	.398	1.155	.460	.445
	Hand - Right	.388	1.155	.448	.433
5	Thigh - Left	6.820	1.050	7.161	6.925
	Thigh - Right	6.980	1.050	7.329	7.088
6	Leg - Left	2.900	1.090	3.161	3.057
	Leg - Right	3.230	1.090	3.521	3.405
	Foot - Left	.828	1.095	.907	.877
	Foot - Right	.902	1.095	.988	.955
	TOTAL BODY	69.227***		72.699****	70.307

*Determined by subtraction after total body immersion.

**Includes subtraction for estimated residual respiratory volume of 1.470 liter.

***Total body volume in the expired condition.

****If total is not equal to actual body weight determine ratio K and recompute for last column

$$K = \frac{\text{Actual body weight}}{\text{Computed body weight}} = \frac{70.306}{72.699} = .9671$$

Body density verification. — This was made by using the empirical densitometric method of Pascale (Ref. 6) outlined earlier in this report to verify the actual computed density.

TABLE A8. — DETERMINATION OF BODY DENSITY

Subject	Total Volume Displaced, liter*	Body Weight, kg**	Body Density, D_{air}, grams/cu cm	Specific Gravity $\frac{D_{air}}{D_{water}} = \frac{D_{air}}{1.000}$
A	82.125	84.481	1.029	1.029
C	69.227	70.306	1.016	1.016

* from Tables A6 and A7.
** from Tables A1 and A3

According to Boyd (Ref. 7) the specific gravity of approximately 1.038 may be accepted as a representative average while the specific gravity for respiratory states may range from less than 1.00 to several hundreds more than the figure quoted. As such, the specific gravity of Subjects A and C falls within representative average limits.

After the determination of body density by immersion, three skinfold tests were performed by skinfold calipers on each subject in the respective locations. These were recorded and averaged out in Table A9.

TABLE A9. — DETERMINATION OF AVERAGE SKINFOLD THICKNESS**

Subject	Location*	Test 1	Test 2	Test 3	Total	Average
A	T	26.0	26.0	25.5	77.5	25.83
	M	30.0	31.0	25.5	86.5	28.83
	A	11.5	13.5	12.0	37.0	12.33
C	T	8.5	8.7	8.5	25.7	8.57
	M	18.5	14.5	15.7	48.7	16.23
	A	12.0	8.5	13.4	33.9	11.30

* These locations are defined under Methods of this report.

** Skinfold calipers were used at standard specific pressure setting of 10 gram/sq mm.

With skinfold thicknesses in mm, the body density was derived by the following empirical equation:

$$D = 1.088468 - 0.0007123T - 0.0004834M - 0.0005513A \qquad \text{(A1)}$$

Using the average skinfold values established in Table A12 the densities for each subject were computed. For subject A

$$D = 1.088468 - (0.0007123)(25.83) - (0.0004834)(28.83) - (0.0005513)(12.33)$$
$$= 1.088468 - 0.018398 - 0.013936 - 0.006797 = 1.049337$$

while for subject C

$$D = 1.088468 - (0.0007123)(8.57) - (0.0004834)(16.23) - (0.0005513)(11.3)$$

$$= 1.088468 - 0.006102 - 0.007846 - 0.006238 = 1.068282$$

Comparing these values to those determined by the immersion technique, the following variability was computed:

$$\text{Subject A, Variability} = \frac{1.0493 - 1.029}{1.029} \times 100 = 1.973\%$$

$$\text{Subject C, Variability} = \frac{1.0683 - 1.016}{1.016} \times 100 = 5.14\%$$

The above results show a very good correlation for subject A, while that for subject C was less desirable, but still within an acceptable range.

Determination of Centers of Gravity

Having been established as shown in Tables A9 through A10, the corrected segment weights were then used to determine the location of the segment centers of gravity. This was performed by applying different experimental and analytical techniques.

Total body c.g. location.– The center of gravity of the total body in the z-plane was determined as follows The subject was placed on the weighing board with sharp wedge supports on either end. His position is shown in Figure A7 from which the corresponding analysis was made.

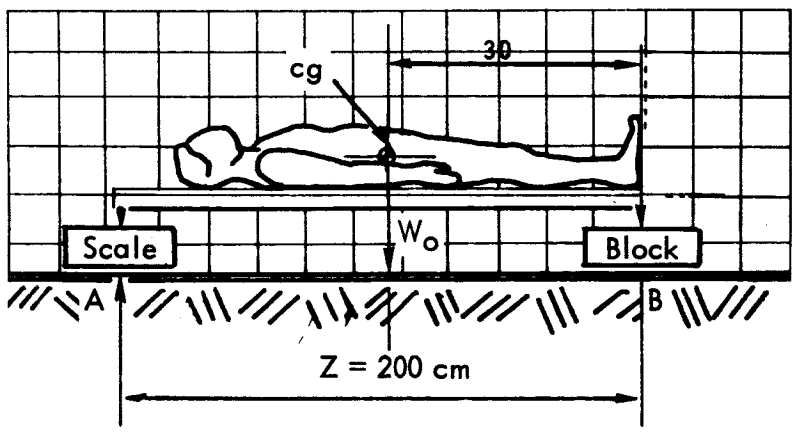


Figure A7. - Total body c.g. determination in z-plane

A' was defined as the scale reaction due to the board weight alone. The term A represented the total scale reaction due to total body and board weight. A_0 was the net scale reaction due to total body weight. The following relationship may then be stated,

$$A_0 = A - A' \tag{A2}$$

Now the sum of the moments about "B" must be zero to satisfy this condition

$$\Sigma M_B = 0$$

then

$$+A_0 Z - W_0 z_0 = 0$$

and

$$z_0 = \frac{A_0 Z}{W_0} \tag{A3}$$

The scale reaction due to board weight was A' = 6.577 kg and used in the computation given in Table A10.

TABLE A10.– COMPUTATION FOR TOTAL BODY CG LOCATION IN Z-PLANE

Computation	Subject	
	A	C
Subject in position,		
reaction A , kg	49.555	41.390
- A' , kg	- 6.577	- 6.577
Net reaction due to body weight		
$A_0 = A - A'$, kg	42.978	34.813
and $A_0 z/W_0$, cm	42.978 x 200/84.481	34.81 x 200/70.306
c.g. position , cm	101.74	99.02

The center of gravity of the total body in the x-plane was determined by the following method: With the subject placed in the position shown in Figure A8, the subsequent equations were derived. Similarly to the c.g. determination in the z-plane, the net reaction due to the body weight

$$A_0 = A - A'$$

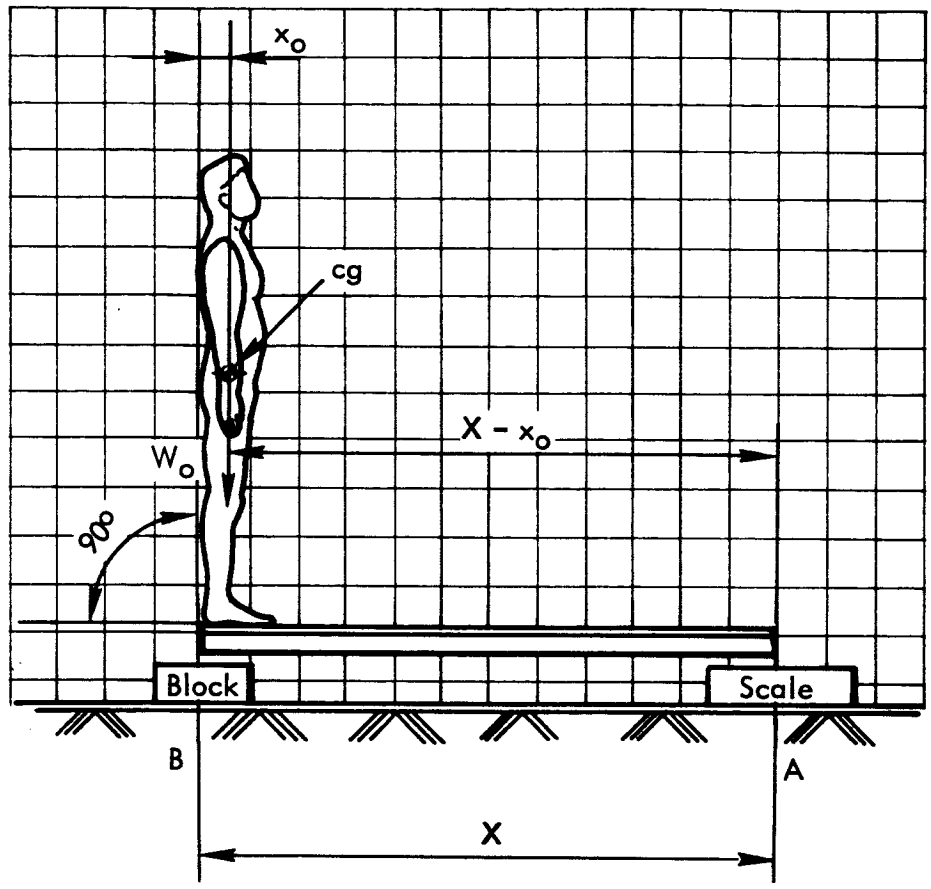


Figure A8. - The body c.g. determination in x-plane

Again the sum of the moments about "B" must be zero

$$\Sigma M_B = 0$$

Then

$$+ A_0 X - W_0 x_0 = 0$$

and

$$x_0 = \frac{A_0 X}{W_0} \tag{A4}$$

The scale reaction due to the board weight was recorded as A' = 6.577 kg and was used in the computation given in Table A11.

The centers of gravity for the extremities were found in the z-plane by the differential weighing technique described and illustrated earlier in this report.

TABLE A11. – COMPUTATION FOR TOTAL BODY CG LOCATION IN X-PLANE

Computation	Subject	
	A	B
Subject in position shown		
reaction A , kg	10.829	9.525
- A' , kg	- 6.577	-6.577
Net reaction due to body weight		
$A_0 = A - A'$	4.252	2.948
and $A_0 X/W_0$	4.252 x 200/84.481	2.94 x 200/70.306
c.g. position , x_0, cm	10.07	8.39

Segment No. 4 lower arm and hand cg location. — In the differential weighing technique for this segment, the subject remained in his relative position on the weighing board but was told to flex both forearms and hands 90° to position C shown in Figure A9. The reaction at the scale was increased to A_4 due to this new position. This increase in moment is

$$A_4 Z - A Z = Z (A_4 - A) \tag{A5}$$

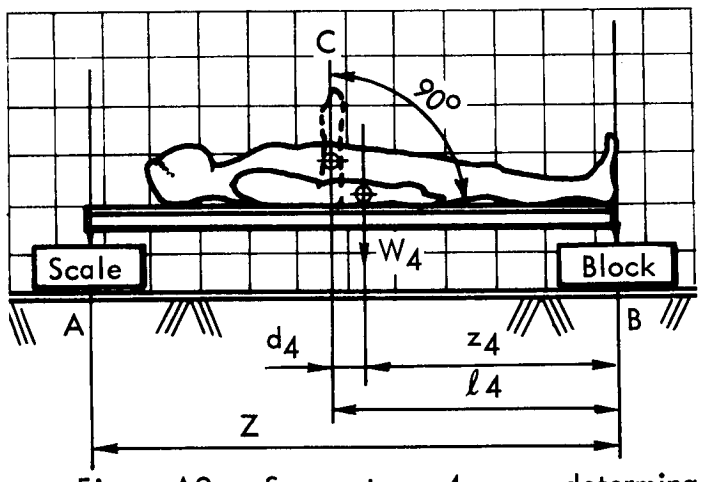


Figure A9. - Segment no. 4, c.g. determination

which represents the net moment due to this displacement. The center of gravity position of the hands and forearms W_4 thus had shifted through distance d_4 from the undetermined position of z_4 to $z_4 + d_4$ and the net moment produced by this displacement

$$= W_4 (z_4 + d_4) - W_4 z_4 = W_4 (z_4 + d_4 - z_4) = W_4 d_4 \tag{A6}$$

which is equivalent to Equation (A5)

$$Z (A_4 - A)$$

and

$$z(A_4 - A) = W_4 d_4$$

From this relation

$$d_4 = \frac{Z(A_4 - A)}{W_4} \tag{A7}$$

where d_4 defines the center of gravity position of hands and forearms.

The segment weights given in Tables A12 and A13 were taken from Tables A6 and A7.

TABLE A12. — SEGMENT NO. 4 WEIGHT DISTRIBUTION

Body Segment No. 4	Segment Weight, kg	
	Subject A	Subject C
Forearm - left	1.300	1.142
Forearm - right	1.443	1.088
Hand - left	.433	.445
Hand - right	.450	.433
Total Segment Weight W_4	3.626	3.108

TABLE A13. — COMPUTATION FOR SEGMENT NO. 4 CG LOCATION IN z PLANE

Computation			Subject	
			A	C
Reaction A	,	kg	49.328	41.447
Reaction A_4	,	kg	49.668	41.787
$A_4 - A$	,	kg	.340	.340
$Z(A_4 - A)$	,	kg cm	68.00	68.00
$Z(A_4 - A)/W_4$	,	cm	68.00/3.626	68.00/3.108
d_4		cm	18.75	21.88
ℓ_4 measured on board,		cm	109.20	109.22
$\ell_4 - d_4$	,	cm	109.20 - 18.75	109.22 - 21.88
z_4	,	cm	90.45	87.34

Segment No. 6, leg and foot c.g. location. — In determining the center of gravity location for the leg and foot, the subject was placed on the board flexing both legs and feet according to Figure A10. The reaction A in the unflexed position was made identical to the one previously recorded for the determination of z_0. Then both legs and feet were flexed to the 90° position and reaction A_6 was recorded. The net moment due to the displacement of these body segments was

$$Z(A_6 - A)$$

and similarly to equation (A7)

$$d_6 = \frac{Z(A_6 - A)}{W_6}$$

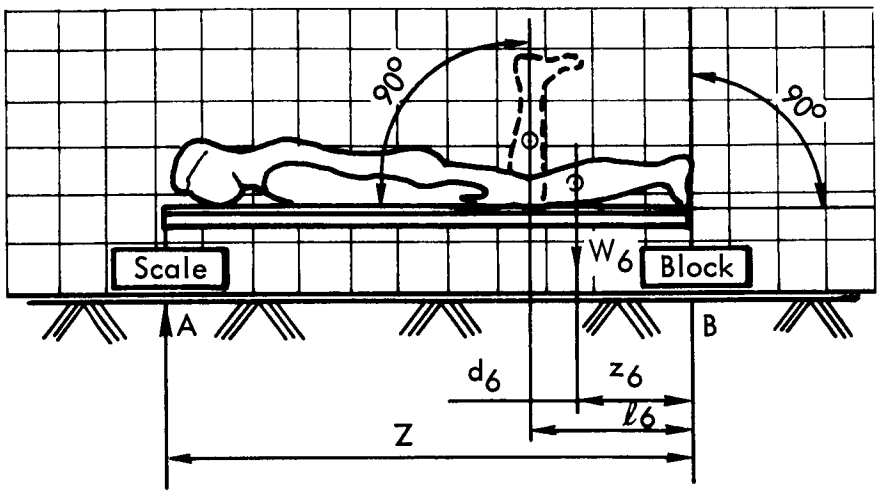


Figure A10. - Segment no. 6, c.g. determination

The individual weights of these segment components were taken from Tables A6 and A7 and relisted in Table A14. The total segment weight was then used in the computation given in Table A15.

TABLE A14. — SEGMENT NO. 6, WEIGHT DISTRIBUTION

Body Segment No. 6	Segment Weight, kg	
	Subject A	Subject C
Leg - left	3.671	3.057
Leg - right	3.489	3.405
Foot - left	.962	.877
Foot - right	.955	.955
Total Segment Weight W_6	9.077	8.294

TABLE A15. — COMPUTATION OF SEGMENT NO. 6, CG LOCATION IN z PLANE

Computation			Subject	
			A	C
Reaction A	,	kg	49.555	41.39
Reaction A_6	,	kg	50.745	42.64
$A_6 - A$	,	kg	1.190	1.25
$Z(A_6 - A)$	,	kg cm	238.00	250.00
$Z(A_6 - A)/W_6$	,	cm	238.00/9.077	250.00/8.294
d_6	,	cm	26.22	30.14
ℓ_6 measured on board,		cm	49.00	49.15
$\ell_6 - d_6$	,	cm	49.00-26.22	49.15-30.14
z_6	,	cm	22.78	19.01

Segment no. 1, head and neck c.g. location. — The center of gravity of the head and neck was determined by positioning the subject according to Figure A11. The segment mark had to fall in line with the edge of the board at "B" producing a cantilever support arrangement.

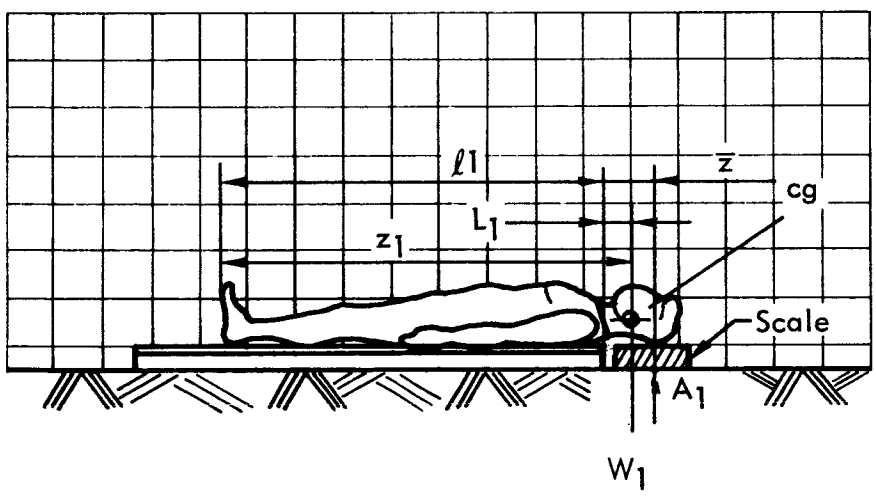


Figure A11. - Segment no. 1, c.g. determination

For moments about support B, $\Sigma M_B = 0$. Then

$$+A_1 \bar{z} - W_1 L_1 = 0$$

from which

$$L_1 = \frac{A_1 \bar{z}}{W_1} \tag{A8}$$

and

$$z_1 = \ell_1 + L_1 \tag{A9}$$

Equations (A8) and (A9) were then used in the computation given in Table A16.

TABLE A16.— COMPUTATION FOR SEGMENT NO. 1 C. G. LOCATION IN Z-PLANE

Computation		Subject	
		A	C
Weight, W_1,	kg	5.136*	3.172**
Distance, $\bar{z}$,	cm	20.00	16.30
Reaction, A_1,	kg	3.456	2.431
Moment, $A_1 \bar{z}$	kg cm	3.456 x 20.00	2.431 x 16.30
, $A_1 \bar{z}/W_1$	cm	69.12/5.136	39.62/3.172
L_1	cm	13.458	12.49
ℓ_1 Measured on board,	cm	145.40	149.70
$\ell_1 + L_1$,		145.40 + 13.50	149.70 + 12.49
z_1,	cm	158.90	162.19

* from Table A6

** from Table A7

Segments no. 3, upper arm and no. 5, thigh, c. g. location. — A very close agreement between the weight values of segment no. 3, the upper arm and segment no. 5, the thigh from Tables A6 and A7 and those computed for the LJS in Table A20 was observed. This observation then justified the use of the analytical method for the determination of the corresponding c. g. locations. The c. g. locations were expressed in relation to the total body height (Table A21) and were computed in Table A17.

TABLE A17. - COMPUTATION FOR SEGMENTS NO. 3 AND NO. 5 C. G. LOCATION IN Z-PLANE

Segment No.	Computation	Subject	
		A	C
3	Total body height H, cm	172.08	172.70
	z_3 = .7366 H , cm	126.76	127.22
5	z_5 = .4197 H , cm	72.22	72.49

This established the c.g. location in the z-plane for segments 1, 3, 4, 5, 6, and the total body; leaving the c.g. location for segment 2, the trunk, undetermined.

Segment no. 2, trunk c.g. location. – The center of gravity of the trunk can then be determined analytically by computation since the location of the remaining body segment weight centers have been identified. The subject was assumed in the position shown in Figure A12.

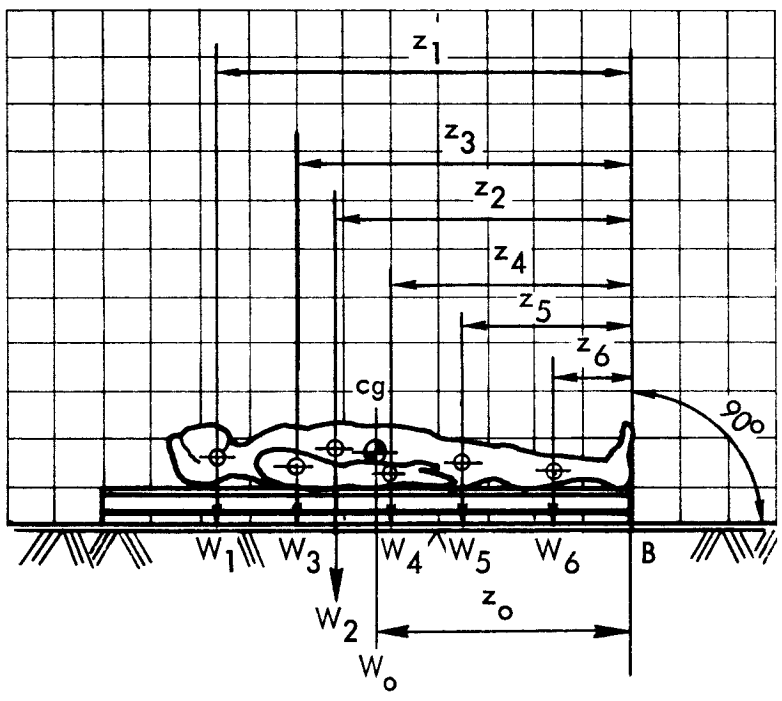


Figure A12. - Segment no. 2, c.g. determination

Taking the moments about support B

$$\sum_{1}^{6} W_n z_n - W_0 z_0 = 0$$

or

$$W_0 z_0 = \sum_1^6 W_n z_n \tag{A10}$$

from which

$$W_0 z_0 = W_1 z_1 + W_2 z_2 + W_3 z_3 + W_4 z_4 + W_5 z_5 + W_6 z_6$$

Since W_2 = weight of trunk and z_2 = c. g. location of trunk, then

$$W_0 z_0 - W_1 z_1 - \sum_3^6 W_n z_n = W_2 z_2$$

and

$$z_2 = \frac{W_0 z_0 - W_1 z_1 - \sum_3^6 W_n z_n}{W_2} \tag{A11}$$

where the segment weight W_2 was found by

$$W_2 = W_0 - W_1 - \sum_3^6 W_n \tag{A12}$$

This determination according to equations A11 and A12 was computed in tabular form (see Table A18), the segment weight values being taken from Tables A6 and A7.

TABLE A18. - SEGMENT WEIGHT AND C. G. LOCATION SUMMARY

Segment		Subject A			Subject C		
No.	Name	Weight, W_n kg	CG Location, z_n, cm	Segment Moment $W_n z_n$ kg cm	Weight, W_n kg	CG Location z_n cm	Segment Moment $W_n z_n$, kg cm
1	Head and Neck	5.136	158.90	816.11	3.172	162.19	514.47
2	Trunk	46.164	120.04		37.857	119.15	
3	Upper Arm	4.104	126.76	520.22	3.862	127.22	491.32
4	Forearm and Hand	3.626	90.45	327.97	3.108	87.34	271.45
5	Thigh	16.373	72.22	1182.46	14.013	72.49	1015.80
6	Lower Leg and Foot	9.077	22.78	206.77	8.294	19.01	157.67
0	Total Body	84.481	101.74	8595.10	70.306	99.02	6961.70
2	Trunk	46.164		-3053.53	37.857		-2450.71
	Computation		120.04	5541.57		119.15	4510.99

The values for W_2 and z_2 were then inserted in the Table A18 providing a complete summary of body segment data for subjects A and C.

The c.g. location for the body segments in the x-plane were determined visually on the subject. This completed the analysis and established the respective location of biomechanics targets on the body segments.

Moment of Inertia of Body Segments

The moments of inertia of subject body segments were determined by the computer analysis developed in Appendix E. This analysis was performed for subjects A and C in the shirtsleeve and pressure suit mode and is presented in Table A19.

TABLE A19. - SEGMENTS, WEIGHTS, AND CORRESPONDING MOMENTS OF INERTIA

Subject A			Subject C	
Shirt Sleeve				
Segment	Weight (kg.)	IYY (kg. cm^2)	Weight (kg.)	IYY (kg. cm^2)
1	6.05*	.475	4.09*	.327
2	46.16	21.646	37.86	15.277
3	2.05	.135	1.93	.131
4	1.81	.257	1.55	.263
5	8.19	1.242	7.01	.773
6	4.54	1.152	4.15	1.411
Pressure Suit				
1	8.10	.732	6.14	.543
2	48.33	23.231	40.03	15.863
3	2.24	.147	2.12	.139
4	2.15	.319	1.89	.322
5	8.52	1.262	7.33	.808
6	5.76	1.678	5.45	1.810

* The segment weights for the subject were taken from Table A18 and those for the pressure suit from Table 9 of Part 1, of this report. Segment 1 in Table A19 also includes the shirt sleeve helmet weight of 0.916 kg. The weights for segment No. 3, 4, 5, and 6 were averaged out to present mean values in Table A19. These results were based on the geometric solids assumed in Table 1 of Part 1 of the biomechanics motion analysis where they were utilized further.

The Link Joint System

The link joint system (LJS) is explained in great detail in Reference 5. One of its practical applications is discussed in Reference 8. The LJS concept projects an anatomical structure in terms of an engineering structure consisting of links and joints. The LJS concept divides the body into structural segments (see Figure A13). Figure A13 shows the stick-like structure which is continuously used in the biomechanics analysis. The joints are marked by open circles while the segment mass (weight) centers are identified by a full circle.

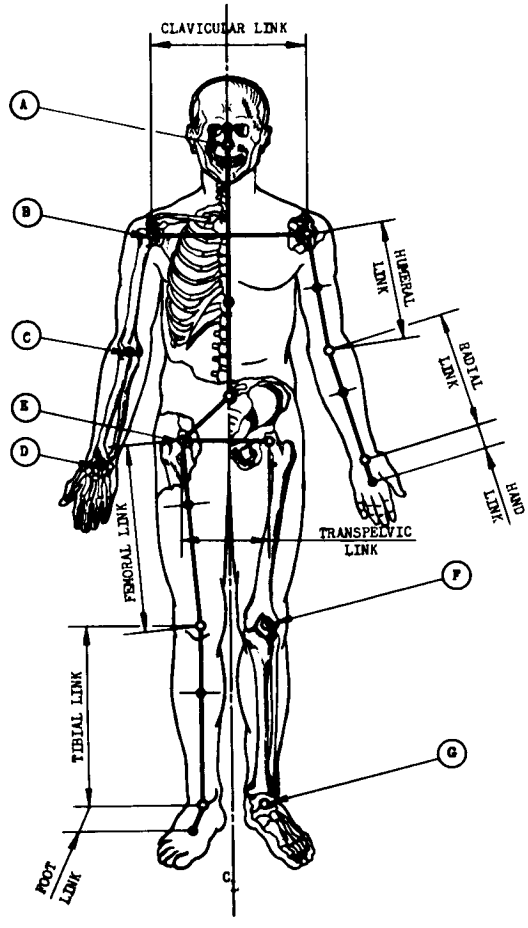


Figure A13. - Link joint system structure

Certain assumptions had to be made during this interpretation of the anatomical structure that links are rigid members terminating in a joint or in between joint centers. Bones, however, are not rigid bodies (Refs. 5 and 9). Furthermore, joints cannot be measured directly from surface landmarks. Approximate mean joint center positions can be estimated by the bending and testing of joints.

Link dimensions are not static correlates with bone lengths. They are only true for mean dimensions based upon the mean-center position of joint axes since joint axes shift during the performance of motion and a link may become longer or shorter than the dimensions taken for their mean centers. As such, a link dimension is a functional dimension. Approximations of nominal link dimensions, however, have practical application in determining the basic structure of man in the biomechanical analysis of working motions.

The LJS utilized in Reference 8 establishes a man model which is reworked and compared to the actual subject data and in so doing relates the subject to the LJS. This relationship for the link weights and link center of gravity coordinates are shown in Tables A20 and A21 based on the data derived in Table A19.

TABLE A20.— COMPARISON BETWEEN SUBJECT WEIGHTS AND LJS WEIGHTS

Segment		Theoretical segment f (W)		Subject A		Subject C	
No.	Name			Measured segment weight, kg	Measured segment weight, f (W)	Measured segment weight, kg	Measured segment weight, f (W)
1	Head and neck	.079		5.136	.061	3.172	.045
2	Trunk	.514		46.164	.546	37.857	.538
3	Upper arm	.053		4.104	.049	3.862	.055
4	Forearm	.031	.043	3.626	.043	3.108	.044
	Hands	.012					
5	Thighs	.193		16.373	.194	14.013	.199
6	Legs	.090	.118	9.077	.107	8.294	.118
	Feet	.028					
0	Total body	1.000		84.481	1.000	70.306	1.000

TABLE A21.— COMPARISON BETWEEN SEGMENT CG AND LJS COORDINATES

Segment		Theoretical segment height, f (H)		Subject A, H=172.08cm		Subject C, H=172.70cm	
No.	Name			Measured segment height, cm	Measured segment height, f (H)	Measured segment height, cm	Measured segment height, f (H)
1	Head and neck	.9233		158.90	.9234	162.19	.9391
2	Trunk	.6820		120.04	.6975	119.15	.6899
3	Upper arm	.7366		126.76	.7366	127.22	.7366
4	Forearm	.5734	.5380	90.45	.5256	87.34	.5057
	Hands	.4466					
5	Thigh	.4197		72.22	.4197	72.49	.4197
6	Legs	.1788	.1406	22.78	.1324	19.01	.1101
	Feet	.0178					
0	Total body	.5832		101.74	.5912	99.02	.5734

The results in Tables A19 and A20 show fairly good correlation between the LJS coordinates and those established for the subjects. It should be noted that only the cg coordinates for segments 3 and 5 were obtained from this LJS and consequently show the identical value in Table A20.

SUBJECT GROSS ANTHROPOMETRY

A series of biomechanics data pictures were taken against the corrected vertical grid which produced a 10 x 10 cm reference plane through the center line of the subject. Pertinent anthropometric as well as biomechanics data was verified by these pictures. Side views of the subjects in the different modes were used very frequently in the verification and reconstruction of subjects during the reduction of biomechanics data recordings. The following Figures A14 thru A23 are arranged according to their mode of operation on the LGS which were identified in the Summary section of this report.

Mode 1000 and mode 6000

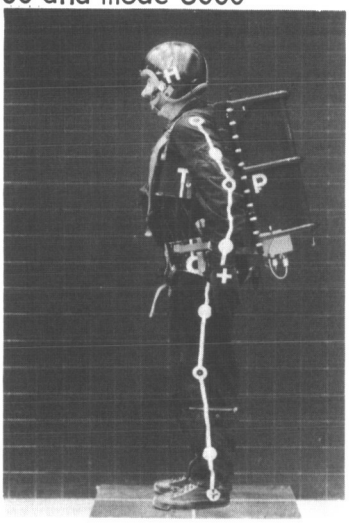


Figure A14. - Subject A, side view

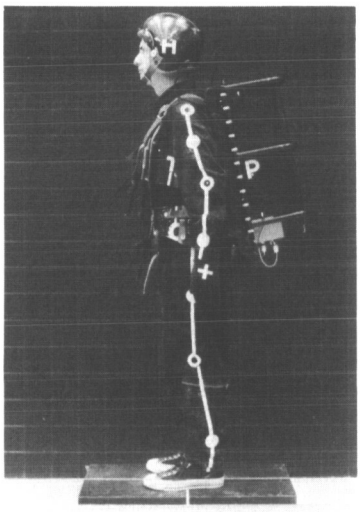


Figure A15. - Subject C, side view

Mode 2000 and mode 7000

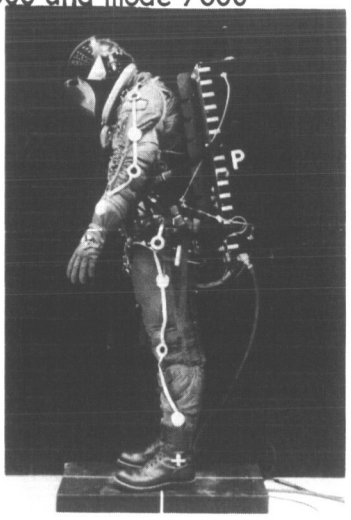


Figure A16. - Subject A, side view

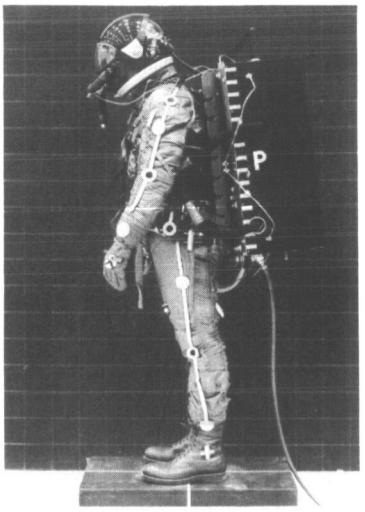


Figure A17. - Subject C, side view

Mode 3000 and mode 8000

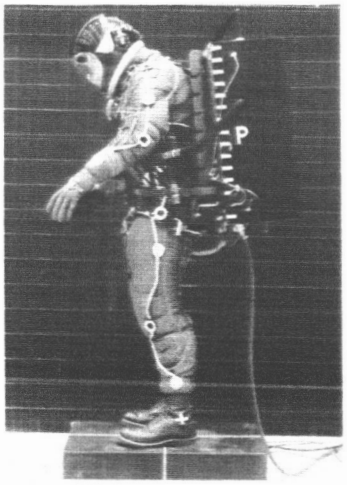


Figure A18. - Subject A, side view

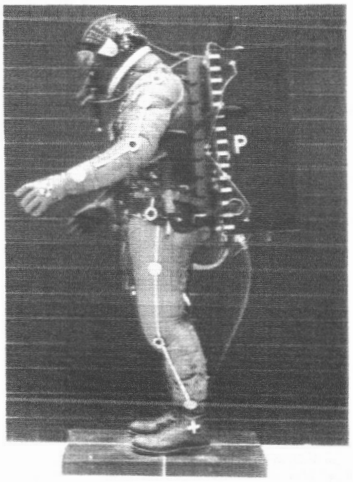


Figure A19. - Subject C, side view

Mode 5000 and mode 6500

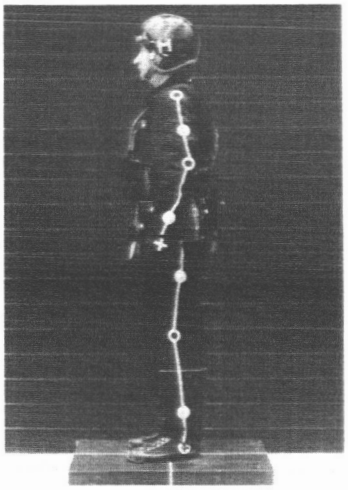


Figure A20. - Subject A, side view

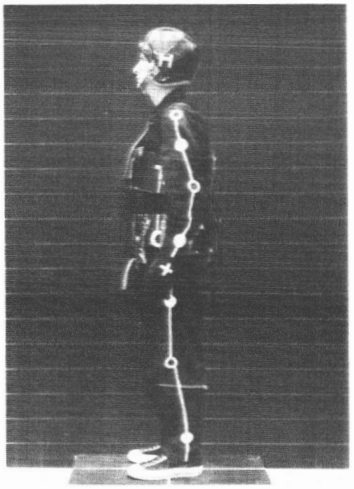


Figure A21. - Subject C, side view

Mode 5500

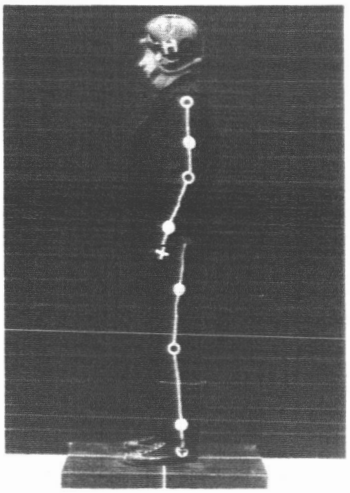


Figure A22. - Subject A, side view

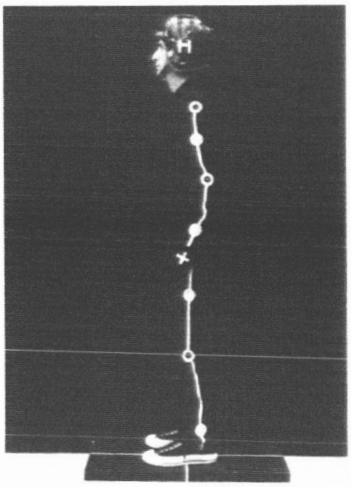


Figure A23. - Subject C, side view

APPENDIX B

DEVELOPMENT OF BIOMECHANICS DATA RECORDING EQUIPMENT

by W. Kuehnegger

To achieve the objectives of this study, it was necessary to develop a method whereby a complete recording of body segment motions of the subject in one plane on the Lunar Gravity Simulator (LGS) could be obtained. Several of the known recording methods discussed below were reviewed and investigated for possible adaptation.

(1) Mechanical methods by which the subject could transmit his movement to a recorder by a cable, pulley, or lever. This method, though relatively simple, was considered more practical for the investigation of one or two specific segment motions instead of those produced by the complete body.

(2) Electrical methods whereby the subject's motion could be used to change the electrical current in a recording circuit. This concept was abandoned due to excessive complexity.

(3) Pneumatic methods that worked by the pressure changes produced during the subject's motion were discarded and considered impractical for this application.

(4) Combinations of electromechanical and electropneumatic methods were rejected since they only multiplied the problem of complexity.

(5) Finally, optical methods using photometric recordings of the subject's motion were considered. This technique appeared to provide the most acceptable solutions.

Various optical methods were analyzed in great depth and the results are presented in Table B1.

TABLE B1. - REVIEW OF PHOTOMETRIC METHODS

Photometric Method	Applicable Experimental Activity	Effort Required in Data Reduction
Motion Picture	Complete range of fine to gross - motor activities	Extremely time consuming
Interrupted Light	For gross - motor activities	Estimated at about 1/4 time for that of motion pictures
Stroboscopic flash series	For semi-gross and gross motor activities	Also estimated at about 1/4 time for that of motion pictures
Gliding Cyclograph	For repetitive semi-gross motor activities	Estimated at about 1/2 time for that of motion pictures

The results as shown in Table B1 clearly indicate that it would not be practical to use any one of the photometric methods alone for the recording of the experiments that were to be conducted on the LGS. Therefore, the following combination of methods was selected for their specific applicability.

(1) Motion pictures were to be used primarily for documentary purposes though they could be used in special cases for the verification of some gross-motor activities such as walking, running, etc.

(2) The interrupted light technique was selected as the primary method for the recording of gross-motor activities.

(3) The stroboscopic flash series was eliminated in light of requirements for outdoor tests and also because of the great distances between the subject and the test set up of the LGS from the camera.

(4) The gliding cyclograph was considered as the primary solution for recording repetitive semi-gross motor activities.

TECHNIQUE DESCRIPTION

The motion picture techniques used during the program involved conventional color and black and white silent photography. Due to the general understanding of this method it will not be described in detail. The interrupted light technique is not well known and consequently deserves a detailed description.

The interrupted light technique had been used successfully by a few investigators for the analysis of the lower extremities in the walking cycle, as well as for the dynamics of the upper extremities. These investigations, however, were conducted under very fully controlled and well illuminated laboratory conditions at fairly short distances. A thorough discussion of the principle involved (ref. 10) provided the basic background for development of the data recording camera used in this program. The basic principle of the camera device embodies a slotted disc rotating at a constant speed in front of the camera lens. As the subject enters the field of vision, the shutter is opened and left open as for a single exposure still picture. Each time one of the slots on the disc passes the lens, the instantaneous subject image is recorded by the camera. The disc then obscures the open lens for a time period dependent on its speed until the next slot allows another image of the subject to be recorded. During the time period the lens is closed, however, the subject has moved further along his path of motion. The resulting composite still picture reveals a sequence of these intermittent exposures which can be used for data analysis. An illustration of a typical data recording is shown in Figure B1. The selected method then produced the necessary results when the subject was moving in the field of a stationary recording camera.

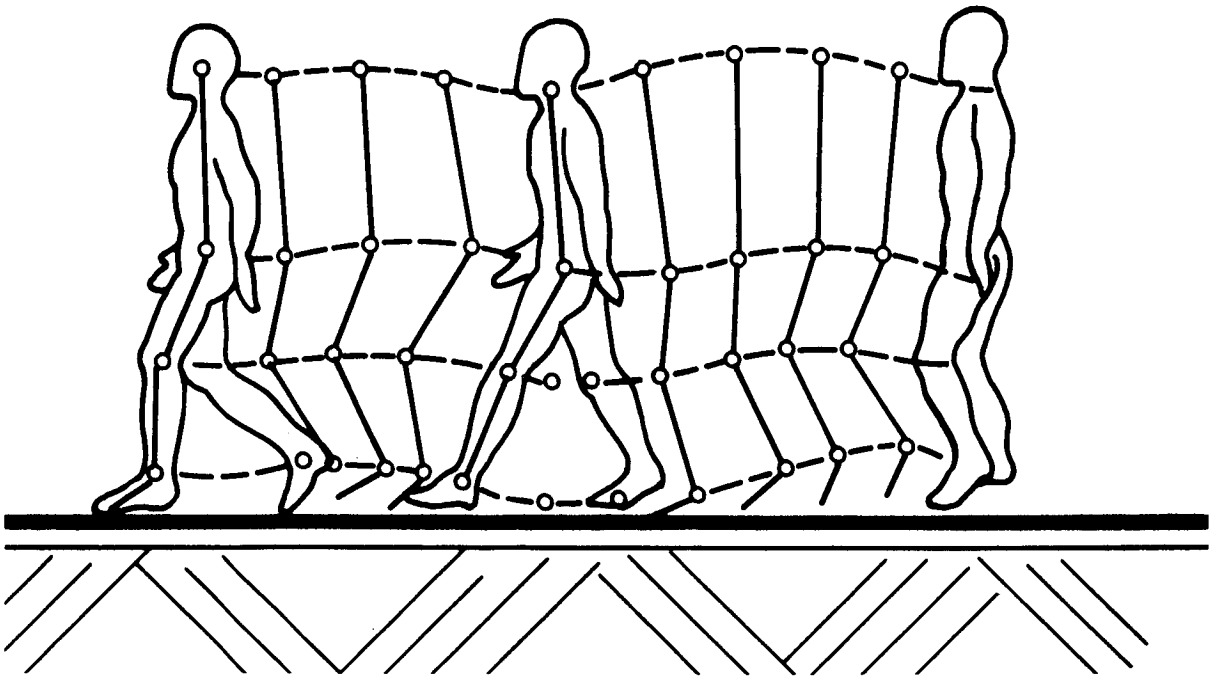


Figure B1. - Interrupted light data recording

The gliding cyclograph is basically an extension of the interrupted light technique. This method was introduced by Bernstein (Ref. 11) and Drillis (Ref. 10), who, in addition to the rotating disc, had driven the film across the opened shutter. In the repetitive local segment motions occurring during semi-gross motor activities the subject does not traverse the camera field but remains relatively stationary. Using the interrupted light technique in this case would have resulted in a recording of obliterated and overlapping segment images impossible to analyze. However, moving the film across the open lens at the same time results in a spreading out of the segment images very clearly revealing their relative positions to one another. In the analysis of such recordings the distance covered by the moving film during the interrupted exposures must be considered.

DATA CAMERA DESIGN REQUIREMENTS

Based on the close relationship between the interrupted light method and the technique used by the gliding cyclograph, a decision was made to incorporate both optometric techniques in the design of one camera. First, the interrupted light camera was to be developed in such a way as to provide for the addition of the cyclographic drive. Then a dimensional envelope was estimated for the experiments to be recorded on the LGS center test section which determined the field for the camera. To reduce parallel and swing out distortions, the camera was to be located as near as possible to the passing dolly from which the subject was suspended. This determined the camera location at the window level on the fifth floor of the adjacent building. Thus two of the main design requirements were established. The field of the test area to be covered at one end and the location of the data camera at the other end.

DATA CAMERA I - DESIGN AND FABRICATION

To produce adequate data recordings at the distances involved, a film size of 70 mm was selected. Further, it was desired that recordings should be made in the shade as well as under sunlit conditions. A 7.5 in. lens was then selected to meet the above design requirements. The box frame of a Beattie, 70 mm Varatron camera was obtained on loan from USAF and modified with slight changes. At first a synchronous 1/20 hp motor running at 1800 rpm was used for a 1 : 1 disc drive by mounting the disc directly on the motor shaft. This motor was later replaced by a 1/15 hp motor possessing variable speed control. Since the operation of this camera took place under daylight conditions never before tried, a completely enclosed disc housing was designed (See Figure B2). This disc housing, made from aluminum, was attached to the front casting of the drive motor. The disc diameter was set at 16.75 inches (42.55 cm). Then the ıted motor was mounted on a separate aluminum cantilever structure to avoid transmission of vibration to the camera. At one point, however, the disc housing had to be connected to the lens hood of the camera to avoid the admission of stray light. This was achieved by a black boot with sewn elastic at either end to ensure quick access for refocusing. The two separate cantilevers, one supporting the camera and the other the disc drive motor and the disc housing, can be seen in Figure B3, which shows a number of components. The window mounting bracket was made from 1/4 in. aluminum sheet, formed and reinforced by welding in two cross members. The disc drive motor was calibrated stroboscopically and calibration curves, Figure B4, and a table were prepared to be used in the operation of the camera. To provide verification for the total activity cycle durations or any portions thereof, the time periods t occurring between the stick recordings at various disc speed settings were listed in Table B2.

TABLE B2. - DISC SPEED CONTROL

Disc Speed Setting, %	Time Period Between Stick Recordings, t, sec.
35	.08711
40	.06612
45	.05321
50	.04697
55	.03810
60	.03166
65	.02709
70	.02348

This table was constructed from the values of the calibration curve with the speed switch in the low position.

$$N \text{ images/sec} = \frac{\text{disc rpm}}{60} \times 2\,(\text{slots}) = \frac{\text{disc rpm}}{30}$$

$$\text{and } t = \frac{1.00}{N} = \frac{30}{\text{disc rpm}} \qquad \text{(B1)}$$

Figure B2. - Disc housing

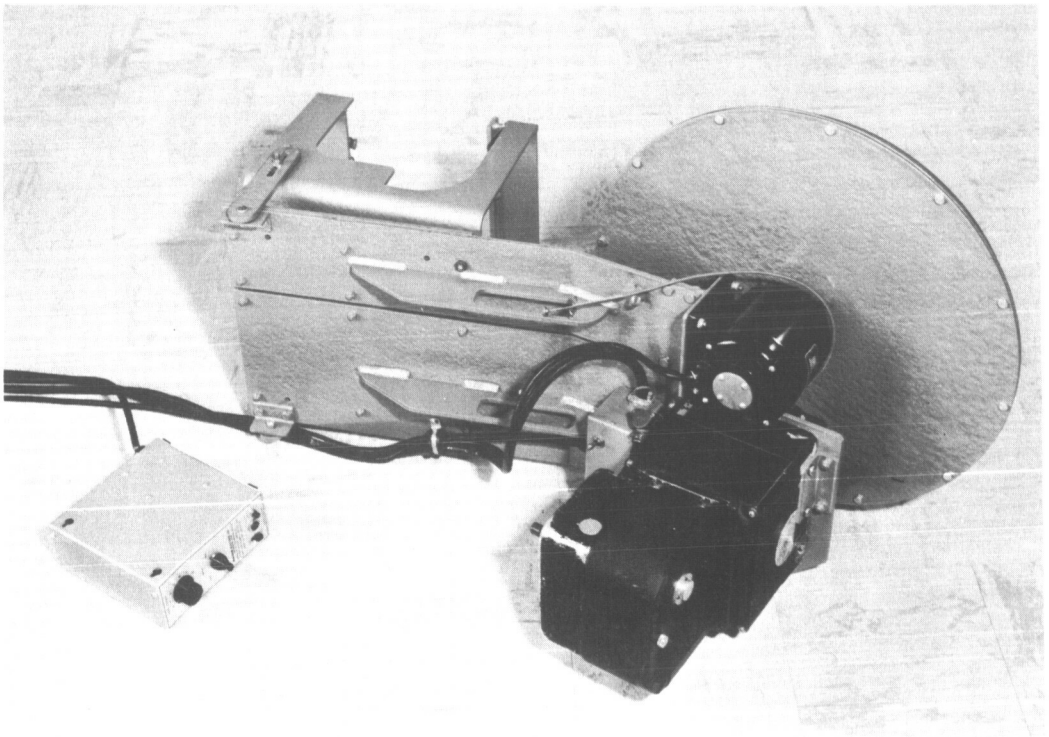


Figure B3. - Data camera I, overall view

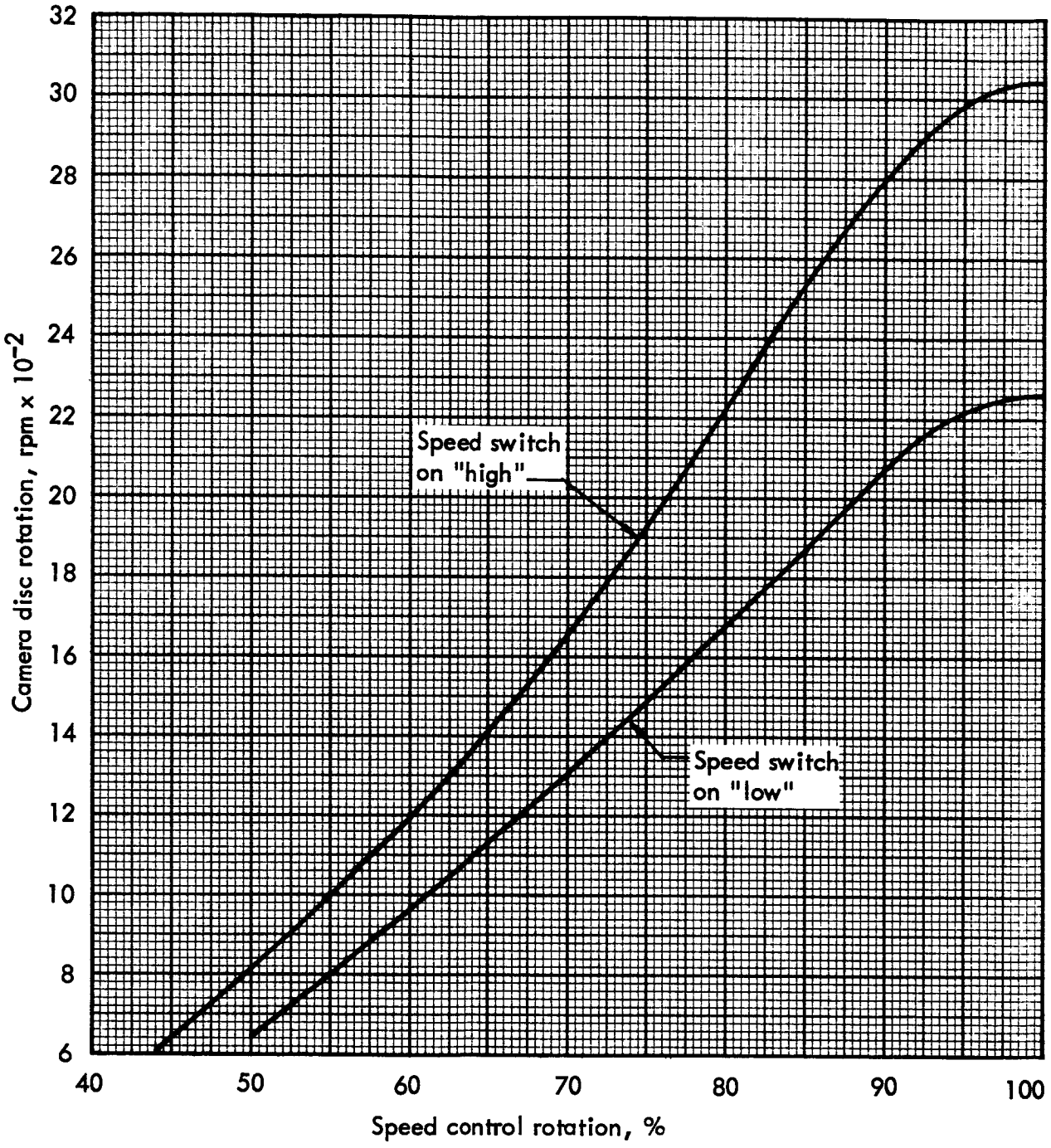


Figure B4. - Calibration curves for disc drive motor

Figure B5 shows the actual installation of the data camera I on the window sill.

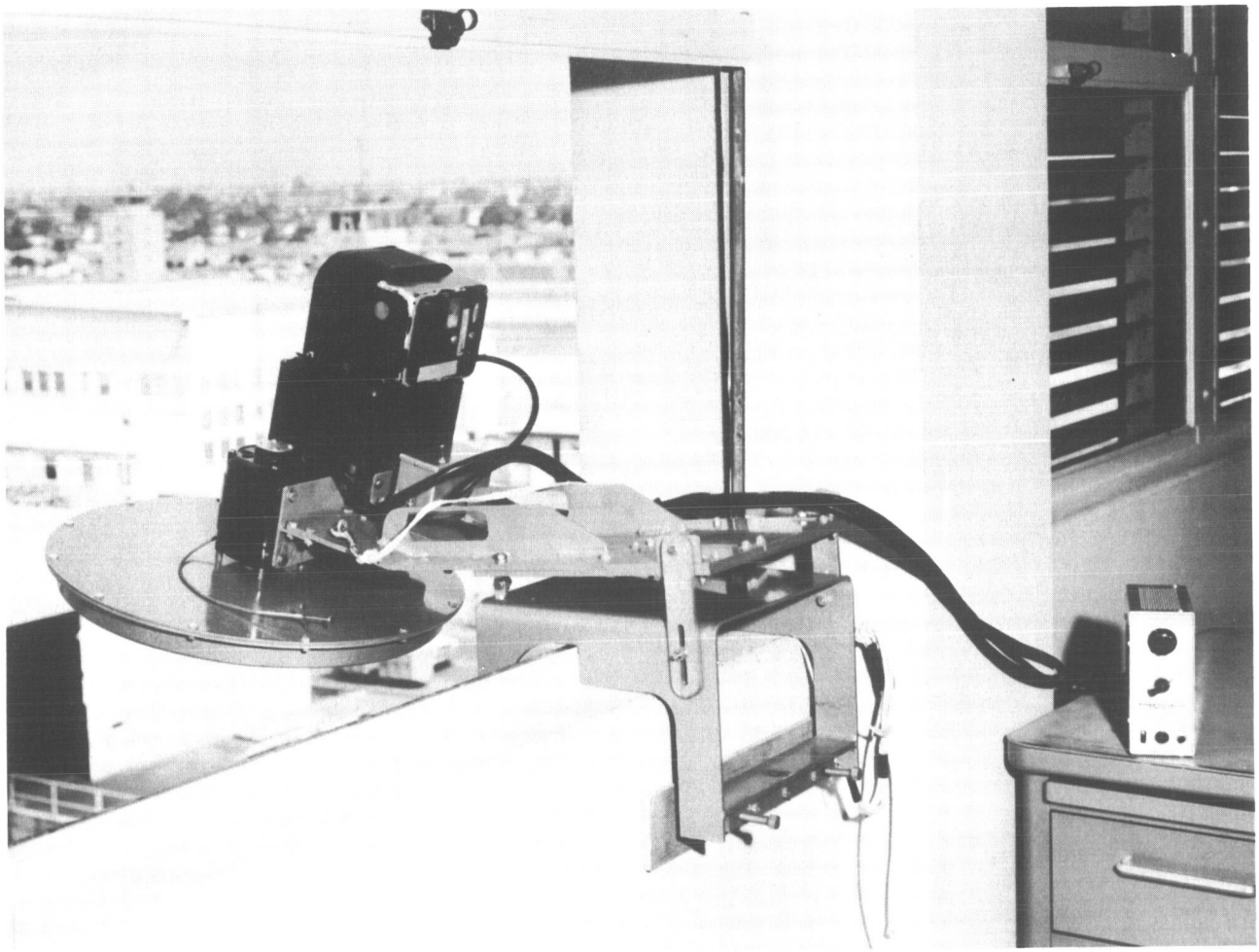


Figure B5. – Data camera model I, installation

DATA CAMERA I TESTING

The initial camera tests were conducted simultaneously to provide information on the grid system. A grid system consisting mainly of 0.5 in. (1.27 cm) but some 0.75 in. (1.91 cm) wide masking tape was constructed. Large grid squares of 50 x 50 cm, to small 10 x 10 cm squares were used in tests 1 through 5. At the same time, 8.5 x 11 in. (21.59 x 27.94 cm) flat, black sheets containing samples of tapes in different colors and widths were placed on the center test section to investigate their properties. Furthermore, the subject was instrumented with white segment targets of different configurations and sizes to determine their properties for data reduction. Samples of these are shown in Figure B6. A total of 13 primary tests were conducted, and the corresponding results listed and illustrated below.

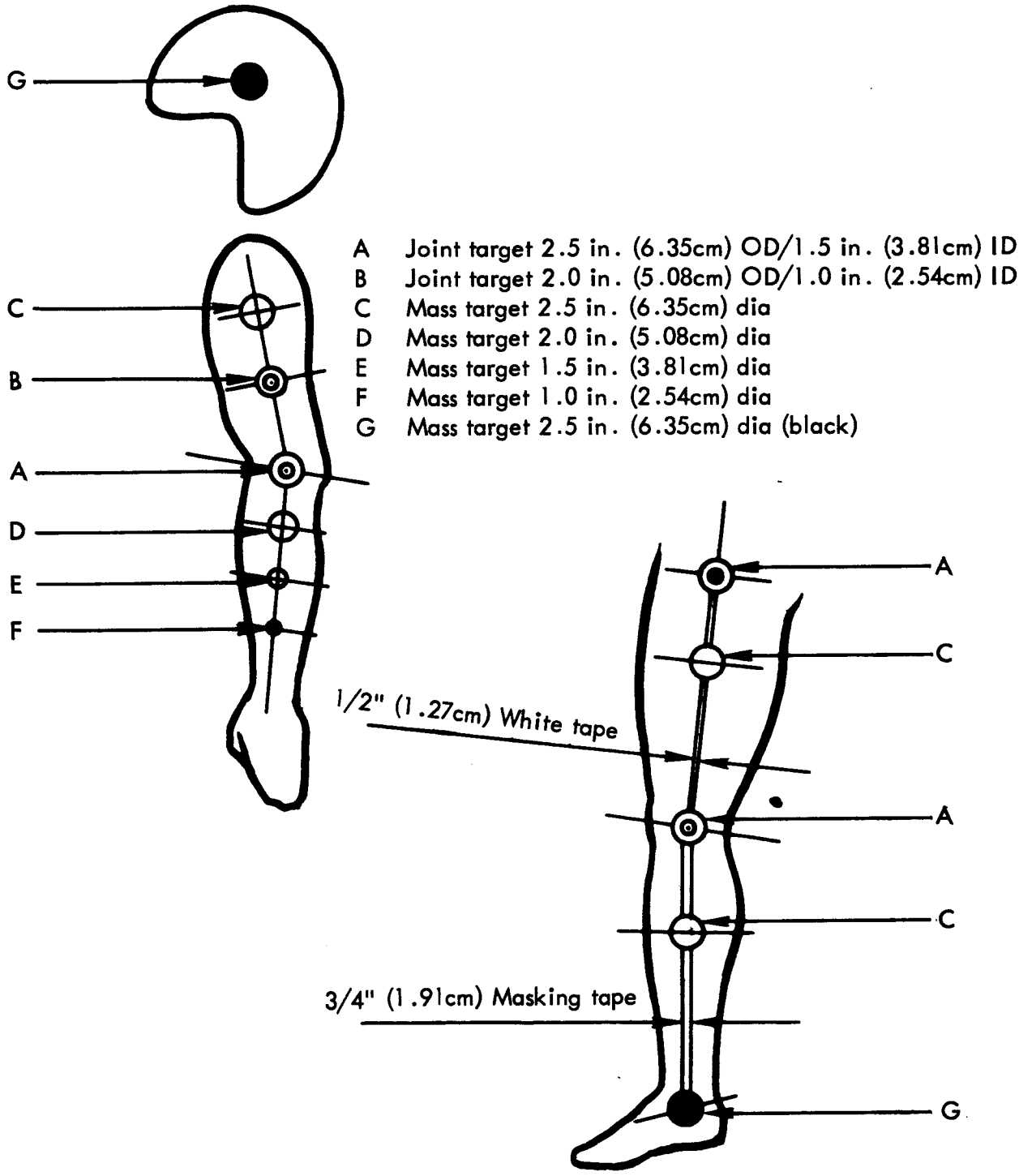


Figure B6. – Biomechanics test targets

Test 1

Test 1 was performed with the synchronous-motor driving disc A with 2-10° slot openings. Some targets were recorded, but were far too weak and the grid was too pronounced (See Figure B7)

Test 2

Disc B, with only one slot, was used at the same synchronous speed of 1800 rpm. Data points were more defined and the unfinished leg support bar can be seen in Figure B8.

Test 3

The synchronous motor was replaced by a motor with speed control from 0 - 100% speed range. The complete disc speed spectrum from 30 - 100% was used to determine optimal speed - experiments of crawling, walking, running, leaping, junping, and back-flip. Test lines for the grid were added. Optimal speeds were between 70% and 90% except for crawling which was 50%. Results, shown on Figure B9, were satisfactory in general, but the data point recording still needed improvement.

Test 4

Targets were changed from white to reflective types in places and the tests were rerun at the optimal speeds. The result was a degradation in data recording (See Figure B10), eliminating these types of targets.

Test 5

Fluorescent type targets replacing the reflective types, but of the same size, were used in the shade to determine their suitability. The same testing sequence and optimal disc speeds were used; a red filter was added to increase the target image. The result was completely blurred data except for one picture taken without the red filter (See Figure B11). Camera vibration was experienced during optimal speed levels. Analysis of this test also showed a recording of the black pencil line drawn in to mark the center of the test section.

Test 6

This test consisted of a vibration test on the equipment alone. Static balancing of various discs did not reduce the vibration.

Test 7

A new disc, D, with two slots of 10° openings was used and the speeds were reduced to about one-half of the previous optimal speeds because of the two slot openings. The usual experiments were conducted from 20% to 55% at 5% increments resulting in no vibration but also no recordings (See Figure B12). The reason was insufficient slot openings for the wide lens openings required in shady conditions.

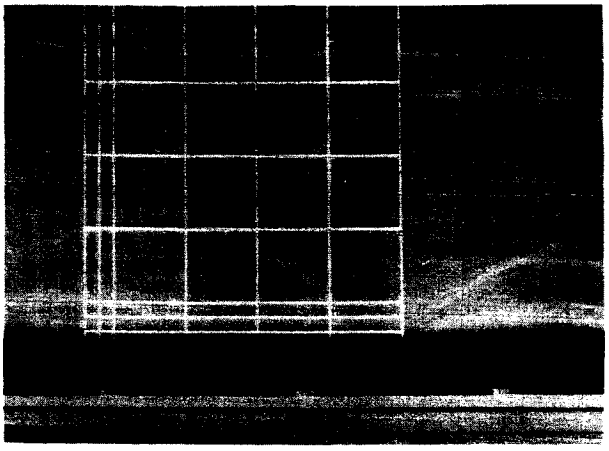


Figure B7. – Test 1, loping

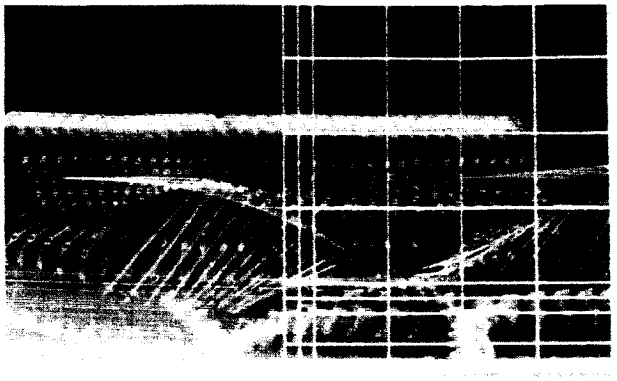


Figure B8. – Test 2, running

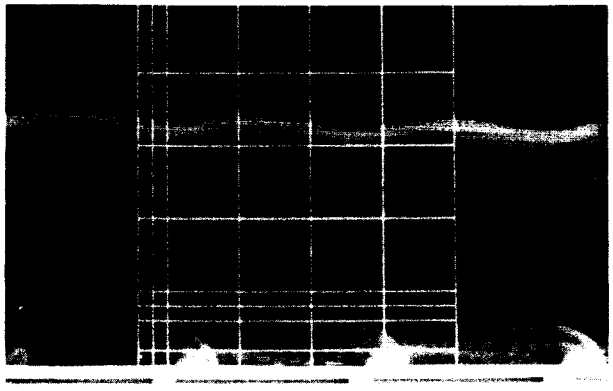


Figure B9. – Test 3, walking at 90% disc speed

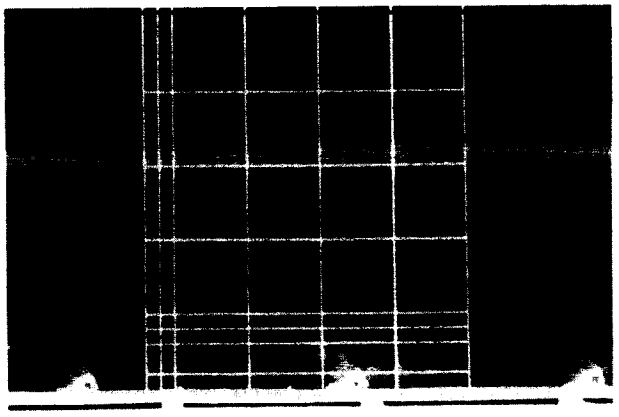


Figure B10. – Test 4, running at 80% disc speed

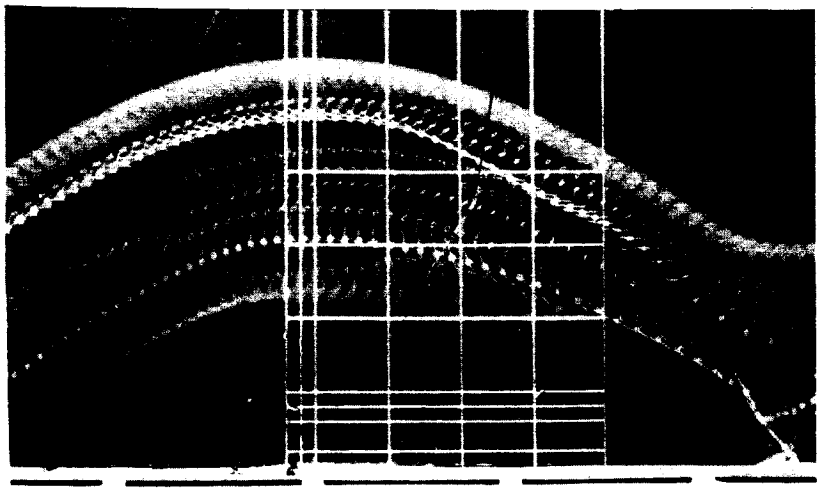


Figure B11. – Test 5, jumping at 80% disc speed

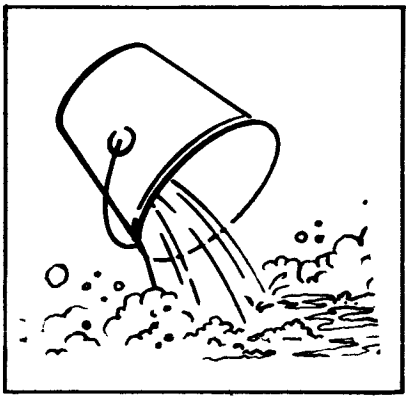


Figure B12. – Test 7, washout

Test 8

Test 7 was rerun with a different film and filter which required less lens opening. The data reappeared but not as clearly defined as desired (See Figure B13). A few preliminary gridlines were installed by using 0.02-in. (.0508 cm) stainless steel wire which showed considerable improvement but did not yet provide the desired strength.

Test 9

Disc D was increased to a 25° slot opening to determine correct slot openings, a red filter was also used during some of the experiments (See Figure B14). The data produced was best with a red filter, but the slot was now too wide for rapid body segment. No grid lines were used on this test.

Test 10

The slot opening on disc D was reduced to 20° and disc speed was set at 40%. The results for walking were excellent, but at higher speeds of body motion images of targets and sticks became blurred; the reason was not enough disc speed. The preliminary gridline system constructed from 0.02-in. (.0508 cm) Monel wire was found to produce the desired contrast between the subject's data recording and the grid.

Test 11

The same slot opening on the disc D as in Test 10 was used. A complete spectrum of disc speeds from 40% to 60% was run at 5% increments. The best data records were obtained at 55% and 60% disc speed. The camera was not refocussed after installation producing some blurred images.

Test 12

The same disc D as above was used with test run at 55% and 60% speed. This produced excellent data as seen by typical jumping example in Figure B15. Test fabrics of different fluorescent materials were added parallel to the humerus link. As a result it was decided to stay with the previous stick-on type fluorescent tape. The gridline system was completed at this time and proved itself in use.

Test 13

Test 13 was conducted under the same conditions as Test 12. The only change was in the biomechanics targets which had been positioned correctly on Subject A. The quality of the data recording remained the same as in previous test.

A total of 115 successful data recordings were taken during the testing period resulting in certain disc speed recommendations for a given subject velocity. These recommendations are listed in Table B2.

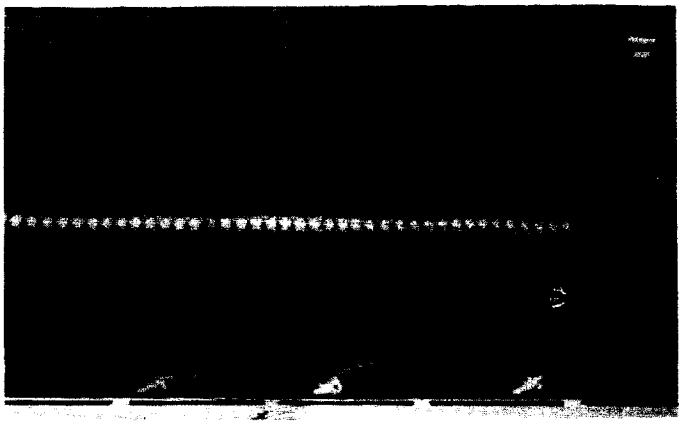


Figure B13. – Test 8, running at 50% disc speed

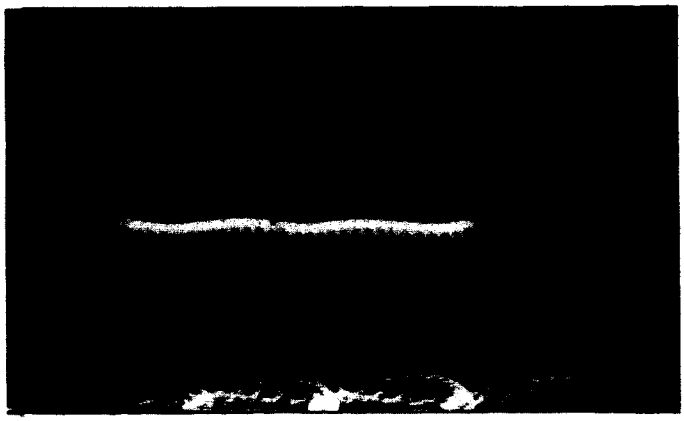


Figure B14. – Test 9, walking at 40% disc speed

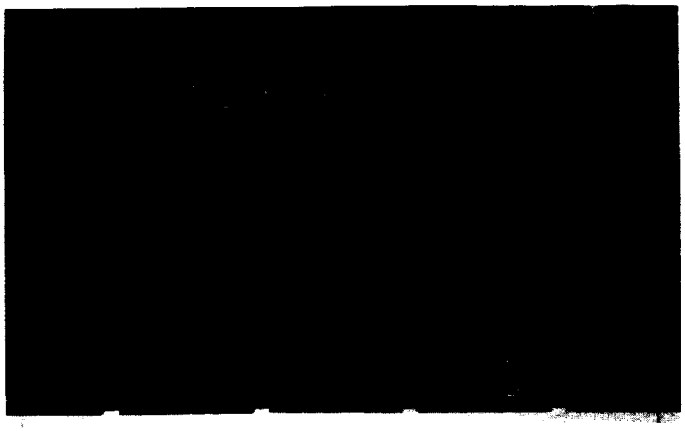


Figure B15. – Test 12, jumping at 55% disc speed

TABLE B3.- RECOMMENDED DISC SPEEDS VERSUS SUBJECT VELOCITY

Subject Velocity, mph	Disc Speed, %
0.5	35
1.0	40
2.0	50
3.0	50
4.0	55
5.0	60
6.0	60
7.0	65
8.0	65

DATA CAMERA II - DESIGN AND FABRICATION

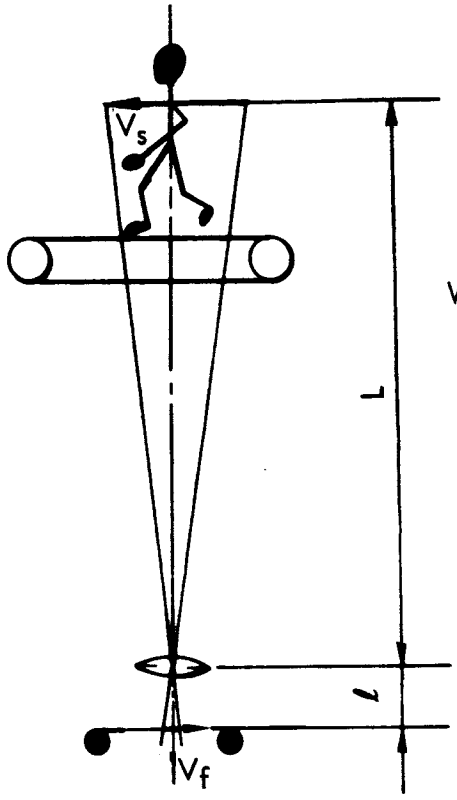
Originally, the addition of the cylographic drive was only intended for recording repetitive semi-gross motor working activities on the LGS. While testing, however, it was discovered that it was impossible for the subject to locomote past the camera field under a specified velocity after stepping off the one sixth g treadmill. Upon completion of the work physiological test on this treadmill, the subject was supposed to attempt to duplicate this same treadmill velocity by the time he reached the center test section for the recording of his biomechanics data by camera I. At lower treadmill velocities up to 5 mph, this method appeared to be feasible. However, stepping off the treadmill moving at 8 mph on to the LGS walkway and trying to reach this same velocity for the data recording was almost physically impossible. This presented a considerable problem since the recording of work physiological and biomechanical data had to be performed under identical conditions in the production of meaningful data. Utilization of the modified gliding cyclograph provided the necessary solution to this problem. The primary application of this technique was in the area of local repetitive activities of an otherwise stationary subject. A theory was then developed to provide a film drive at a velocity which represents the subject's velocity on the treadmill. The relationship between the two velocities is indicated by Figure B16. From Figure B16 the following geometric relationship was evident.

$$\frac{0.5\ V_f}{\ell} = \frac{0.5\ V_s}{L}$$

from which $V_f = V_s \frac{\ell}{L}$

where Focal length = 7.5776 in. = 0.63147 ft.

and camera range = 60.94 ft.



Where V_s = Subject velocity
V_f = Film velocity
L = Camera range
ℓ = Focal length

Figure B16. – Velocity relationship of subject versus film

Based on this constant relationship it was possible to determine the film velocity for any given subject velocity; $V_f = V_s \times 0.01036$. The subject velocity at 1 mph $= \frac{5280 \times 12}{60 \times 60} =$ 17.6 in/sec from which $V_{f\,(in/sec)} = V_{s\,(mph)} \times 17.6 \times 0.01036 = V_{s\,(mph)} \times 0.1823$ (B2)

A variable-speed 1/15 hp motor with built-in gear reduction of 6:1 was selected. This reduction was not sufficient and had to be geared down further because of the extremely small ratio of the focal length/camera range. Even with this further reduction it was possible to only record data produced by subject velocities in excess of 1.5 mph. A close-up view of this film drive system is shown in Figure B17. This complete film drive was installed in the existing camera magazine and calibrated. The calibration was recorded in a curve and table for various subject velocities. An additional support bracket for the film drive motor had to be installed because of the torque produced by the weight of the motor. During preliminary testing, this torque had caused local buckling in the magazine track which permitted light to enter. The addition of more components required for the gliding cyclograph increased the weight of the complete data camera assembly to the point where manual installation or removal was impossible. An industrial cart was then modified upon which the new camera was mounted. The extreme overhang required for the camera position made it necessary to counterbalance the cart at the opposite end with a 150-pound lead weight in the bottom shelf.

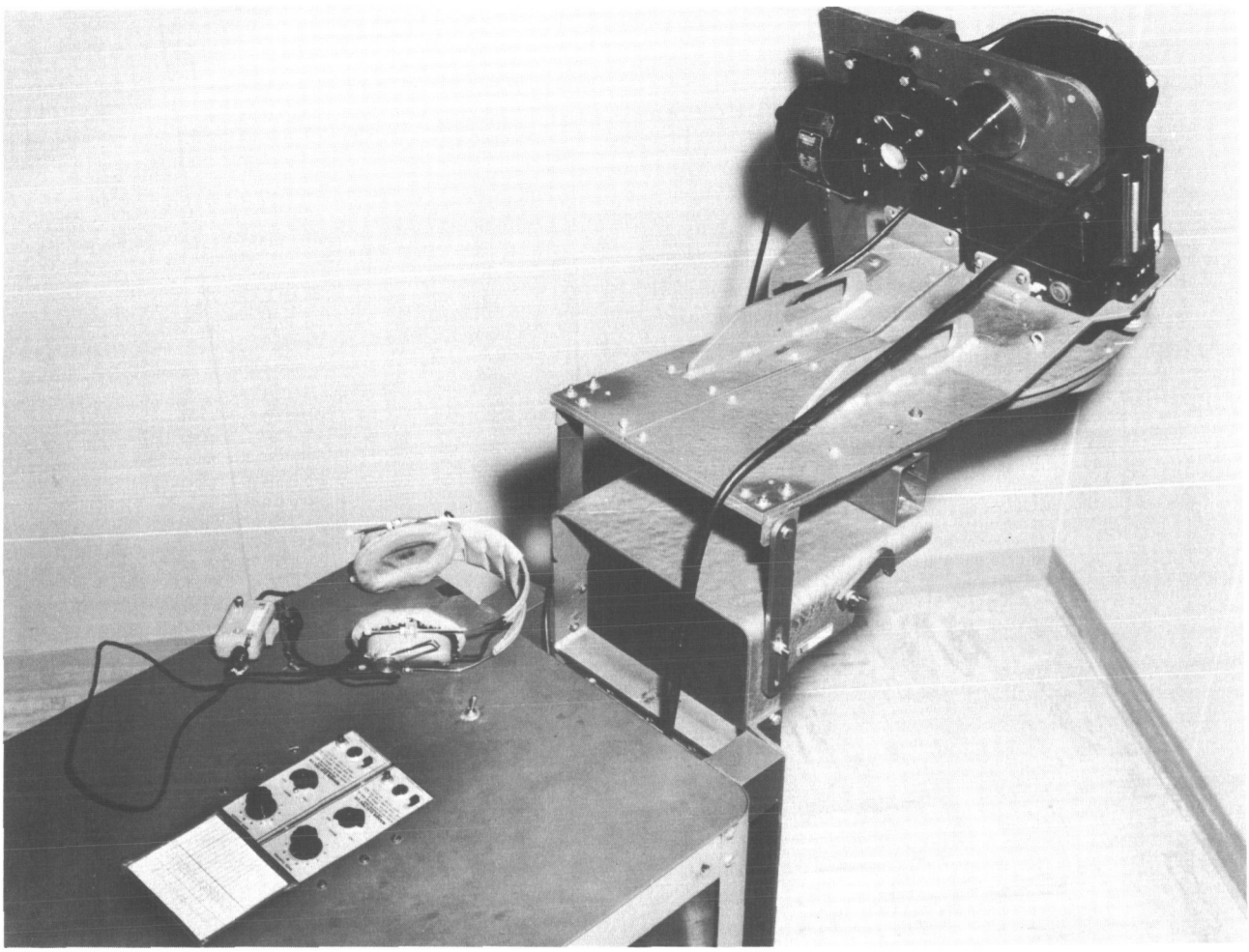


Figure B17. – Film drive system

The Off/On switch and the two speed control units with their calibration tables were installed on the top surface of the camera cart. Figure B18 shows the calibration curve obtained.

Local modifications were then made on the original window mounting bracket to enable the camera to be moved into the window sill position. The cantilevers were raised by the installation of a box section. New adjustment links were made and two locking hooks were installed on the mounting bracket. With the camera in position, these hooks, one on each side of the bracket, were lowered to engage on the outside of the window frame and locked in position by wing nuts. This arrangement secured the complete camera cart to the specified window position each time the camera was used. After testing, the camera cart was moved into the data recording office and consequently removed from the influence of weather and the local atmosphere which had caused some problems earlier with data camera I. Further illustrations of data camera II are given in Figures B19 and B20.

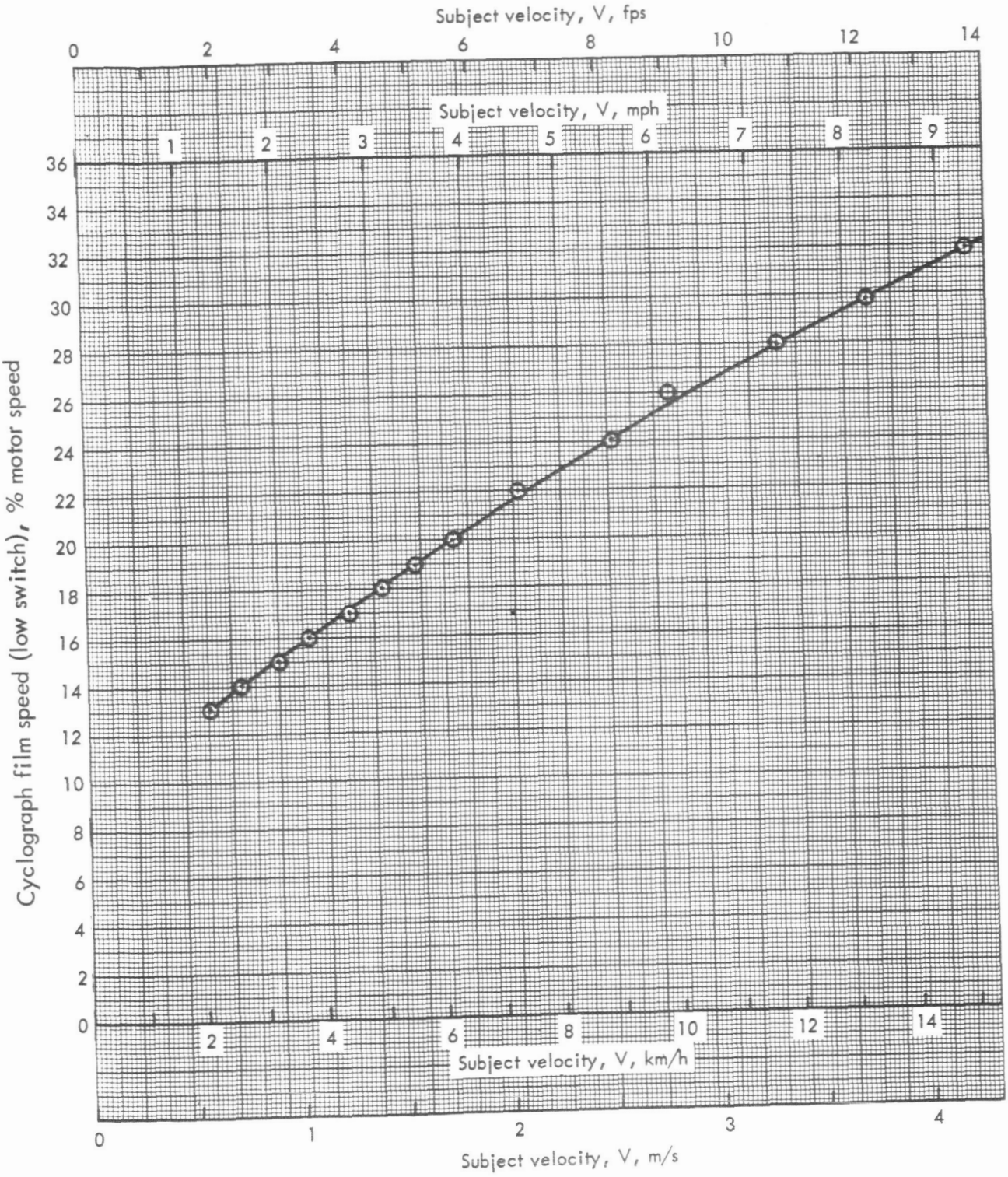


Figure B18. – Subject velocity versus cyclograph film speed calibration curve

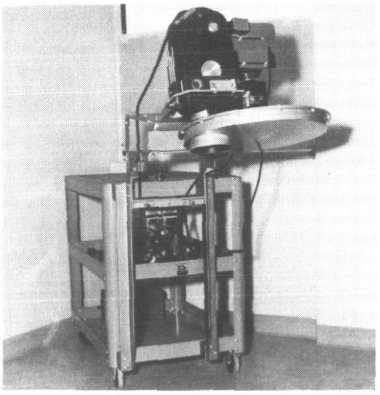


Figure B19. – Front view of data camera II

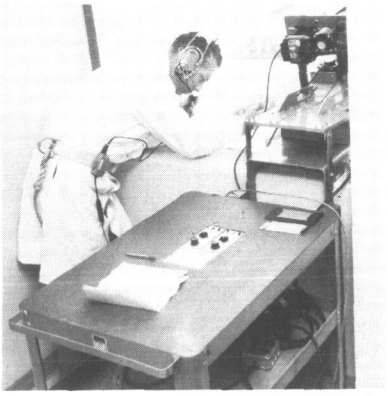


Figure B20. – Operation of data camera II

DATA CAMERA II - TESTING

The data camera was positioned in its new location over the center line of the treadmill test section which was aligned by a transit. Another grid system had to be provided behind the test subject. The vertical lines of this grid system, otherwise identical to the one on the center test section, had to be left off because of the camera technique. Instead, only the centerline was marked on the backdrop. The data recorded in this position consisted of repetitive exposures of the horizontal guidelines while the single grid center line was only exposed once and then transported across during the interval between the exposures in much the same way as the subject's data image. Thus the horizontal gridlines were constructed on the same material as in the center test section while the vertical gridline had to be more pronounced and was made from 1/8 inch (.318 cm), heat-resistant masking tape. Similarly, new test numbers identifying the data recording had to be developed. They had to be arranged vertically to avoid their overlapping and obliteration. The thickness of letters and numbers also had to be increased for single exposure strength.

The provisions for data camera II testing were then complete. Tests of subject speeds ranging from 2 to 10 mph were performed and analyzed. One typical test result of data camera II over the treadmill section is compared with another one taken by data camera I in the center test section. Their close agreement in Figures B21 and B22 verifies the usefulness and applicability of the latter camera technique while recording subject data on the treadmill.

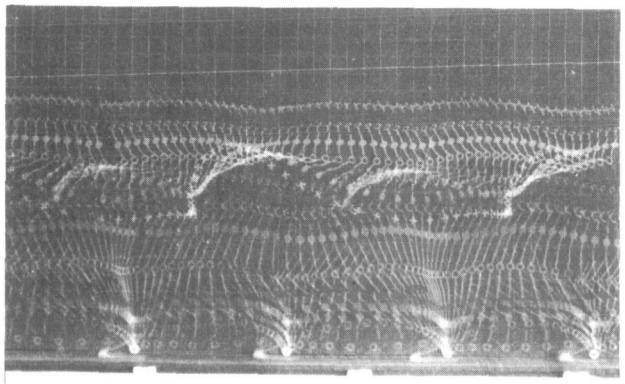


Figure B21. – Recording by data camera I, subject walking at 3 mph

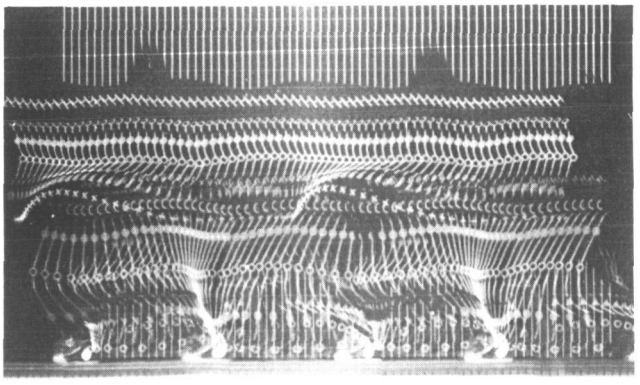


Figure B22. – Recording by data camera II, subject walking at 3 mph

APPENDIX C

ANALYSIS OF GRID SYSTEMS

By W. Kuehnegger

PART I

ANALYSIS OF LUNAR GRAVITY SIMULATOR GRID

The following discussion describes the development of gridline system for the LGS backdrop. The prime objective was to achieve a gridline system which would avoid repetitive and lengthy analysis for correcting biomechanical data recorded by the camera. This correction would ordinarily have been necessary due to two distorting factors (see Figure C1); (1) the geometric arc traversed by the subject during motion along the z plane, and (2) the parallax error produced by the camera in the x and z plane. An attempt was made to correct both distortions by compensating the gridline system for them in advance. This would permit direct scaling and motion analysis from the biomechanics camera recording. To perform this compensation, pertinent and constant geometric data of the Lunar Gravity Simulator had to be determined first.

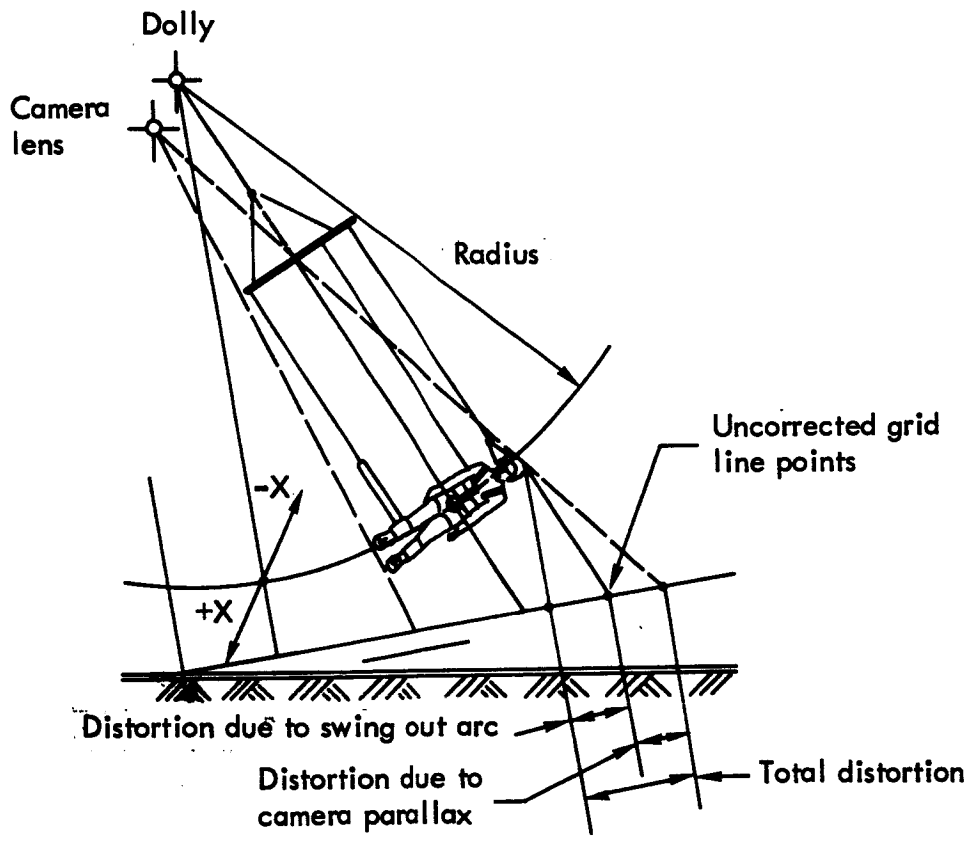


Figure C1. - Biomechanical data distortion

Determination of Radius R

Figure C2 was used in establishing the geometry of the LGS in relation to the adjacent building from which the suspension dolly originated. The known values from the geometry were:

$$\theta = 9^\circ\ 36'$$

$$\ell_R = 19.98 \text{ in. } (50.75 \text{ cm})$$

$$H_R = 828.17 \text{ in. } (2103.55 \text{ cm})$$

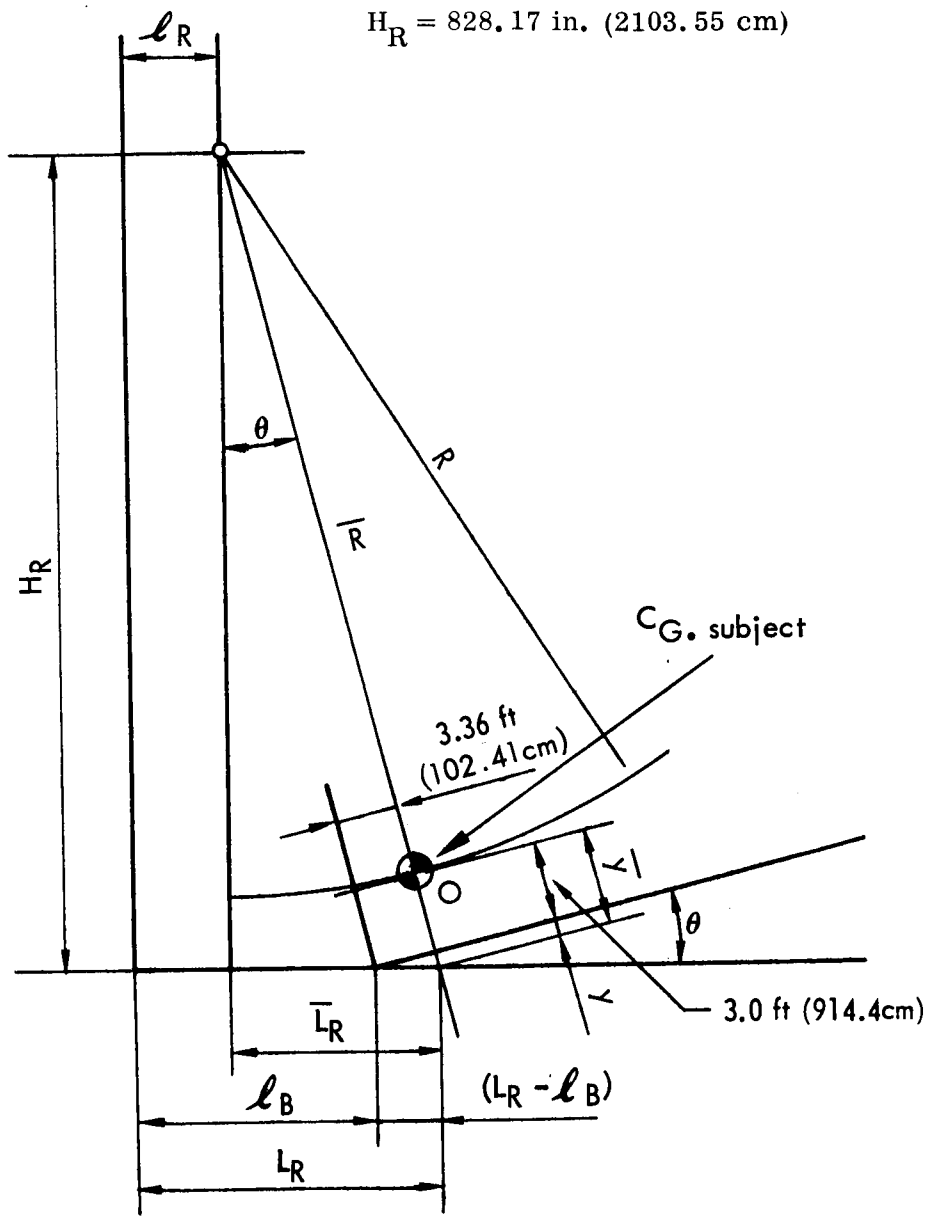


Figure C2. - LGS Geometry

It can be seen that

$$\cos\theta = \frac{H_R}{\overline{R}} \text{ and } \overline{R} = \frac{H_R}{\cos\theta} = \frac{828.17}{0.9860} = 839.62 \text{ in. } (2132.63 \text{ cm}) \qquad \text{(C1)}$$

also that

$$\tan\theta = \frac{\overline{L}_R}{H_R} \text{ from which } \overline{L}_R = H_R \tan\theta = 828.17 \times 0.16914 = 140.0 \text{ in. } (355.6 \text{ cm}) \qquad \text{(C2)}$$

where

$$L_R = \overline{L}_R + \ell_R = 140.00 + 19.98 = 159.98 \text{ in. } (406.35 \text{ cm})$$

then

$$\tan\theta = \frac{y}{40.32} \text{ from which } y = \tan\theta\, 40.32 = 0.16914 \times 40.32 = 6.82 \text{ in. } (17.32 \text{ cm}) \qquad \text{(C3)}$$

and

$$\overline{y} = 3.0 \text{ (ft)} + y = 36.00 + 6.82 = 42.82 \text{ in. } (108.76 \text{ cm})$$

$$R = \overline{R} - \overline{y} = 839.62 - 42.82 = 796.80 \text{ in. } (2023.87 \text{ cm})$$

Determination of Starting Point 0

Starting point 0 had to be determined prior to defining any point P_z along the arc of R and is defined as the point of intersection between the arc of radius R and the walkway floor of the LGS. This starting point 0 also represents an imaginary longitudinal line along the walkway whose value z = 0. The geometric details for the dimensions involved are are shown in Figure C3.

The following trigonometric relationships were derived from Figures C2, C3, and C4.

$$\text{cotan}\,\theta = \frac{H_B}{\ell_B} \qquad \ell_B = \text{known} = 120 \text{ in. } (304.8 \text{ cm})$$

$$H_B = \ell_B \text{ cotan}\,\theta = 120 \times 5.9123 = 709.48 \text{ in. } (1802.08 \text{ cm}) \qquad \text{(C4)}$$

$$H_R = \text{known} = 828.17 \text{ in. } (2103.55 \text{ cm})$$

$$\tan\beta = \frac{\ell_R}{H_R - H_B} = \frac{19.98}{828.17 - 709.48} = 0.16834 \qquad \text{(C5)}$$

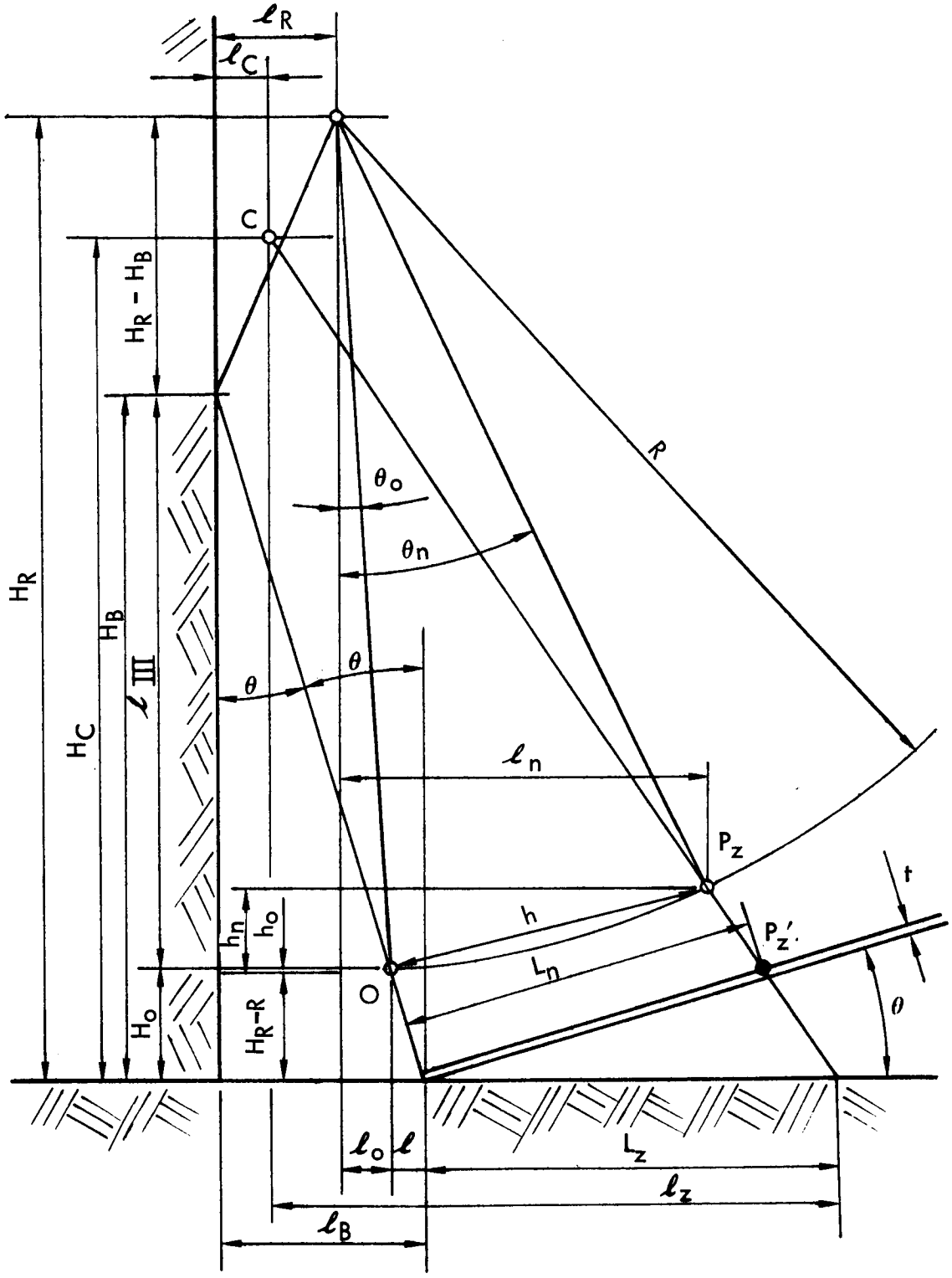


Figure C3. - Geometric details for z correction

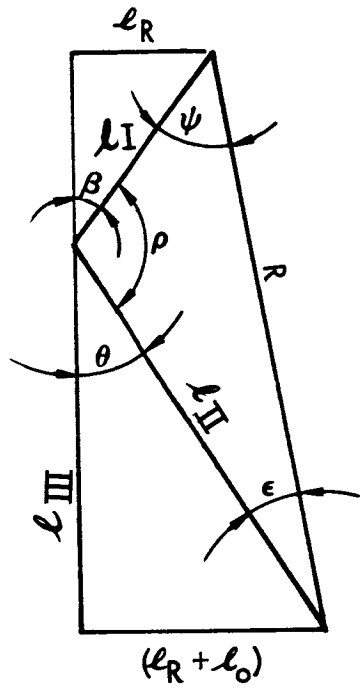


Figure C4. - Geometry detail

from which $\beta = 9° - 33' - 20''$

$$\text{angle } \rho = 180° - (\theta + \beta) = 180 - [(9° - 36') + (9° - 33' - 20'')] \tag{C6}$$

$$= (179° - 60') - (19° - 19' - 20'') = 160° - 40' - 40''$$

From figure C 4 $\qquad \sin\beta = \dfrac{\ell_R}{\ell_I}$

$$\ell_I = \frac{\ell R}{\sin\beta} = \frac{19.98}{0.16600} = 120.36 \text{ in. } (305.71 \text{ cm}) \tag{C7}$$

$$\frac{R}{\sin\rho} = \frac{\ell_I}{\sin\epsilon}$$

and $\qquad \sin\epsilon = \dfrac{\ell_I}{R}\sin\rho = \dfrac{120.36}{796.80}\,0.33097 = 0.04999 \qquad$ (C8)

$$\epsilon = 2^\circ - 52'$$

$$\text{angle } \psi = 180 - (\rho + \epsilon) \tag{C9}$$

$$= 180 - [(160^\circ - 40' - 40'') + (2^\circ - 52')] = 16^\circ - 27' - 20''$$

and again in the solution of this oblique triangle

$$\frac{\ell_I}{\sin \epsilon} = \frac{\ell_{II}}{\sin \psi}$$

where $\ell_{II} = \ell_I \dfrac{\sin \psi}{\sin \epsilon} = 120.36 \dfrac{0.28327}{0.04999} = 682.02$ in. (1732.33 cm) (C10)

and $\cos \alpha = \dfrac{\ell_{III}}{\ell_{II}}$

determining $\ell_{III} = \ell_{II} \cos \theta = 682.02 \times 0.98600 = 672.47$ in. (1708.07 cm) (C11)

From Figure C3

$$H_o = H_B - \ell_{III} = 709.48 - 672.47 = 37.01 \text{ in. } (94.01 \text{ cm}) \tag{C12}$$

$$h_o = H_o - (H_R - R) = H_o - H_R + R = 37.01 + 796.80 - 828.17 = 5.64 \text{ in. } (14.33 \text{ cm})$$

$$\sin \theta = \frac{(\ell_R + \ell_o)}{\ell_{II}} \tag{C13}$$

and $(\ell_R + \ell_o) = \ell_{II} \sin \theta$

$$\ell_o = \ell_{II} \sin \theta - \ell_R = 682.02 \times 0.16677 - 19.98 = 93.76 \text{ in. } (238.15 \text{ cm}) \tag{C14}$$

Before resolving starting point 0 any further it will be necessary to define the relation between h_o and ℓ_o as f (θ_o) (see Figure C5).

where $\ell_o = R \sin \theta_o$

and $\sin \theta_o = \dfrac{\ell_o}{R} = \dfrac{93.76}{796.80} = 0.11767$ (C15)

from which $\theta_o = 6^\circ - 45' - 27''$

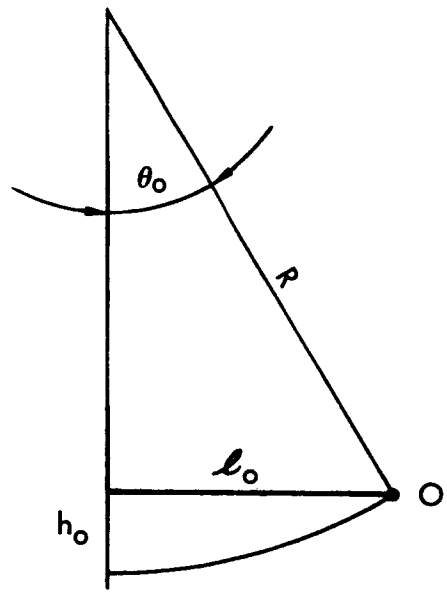


Figure C5. - Radius versus θ_o relationship

Starting point 0 was then located by

$$H_o = 37.01 \text{ in. } (94.01 \text{ cm})$$

by

$$(\ell_o + \ell_R) = (93.76 + 19.98) = 113.74 \text{ in. } (288.90 \text{ cm})$$

and in direction by the angle θ_o.

Determination of Geometric Arc and Camera Parallax Distortion in z-Plane

The previous analysis was performed by using the actual dimensions. This was necessary to establish the constants for the subsequent analysis. This analysis, however, was made to derive the general equations for any one point.

Using a true finite length (height) along the arc of radius R to point P_z, the camera projection on the backdrop was defined by length L_n. This finite arc length was called z representing a displacement in the z-plane shown by Figure C6. First, the existing arc z_o produced by h_o and ℓ_o had to be found. z for the complete circle = $2\pi R$.

then

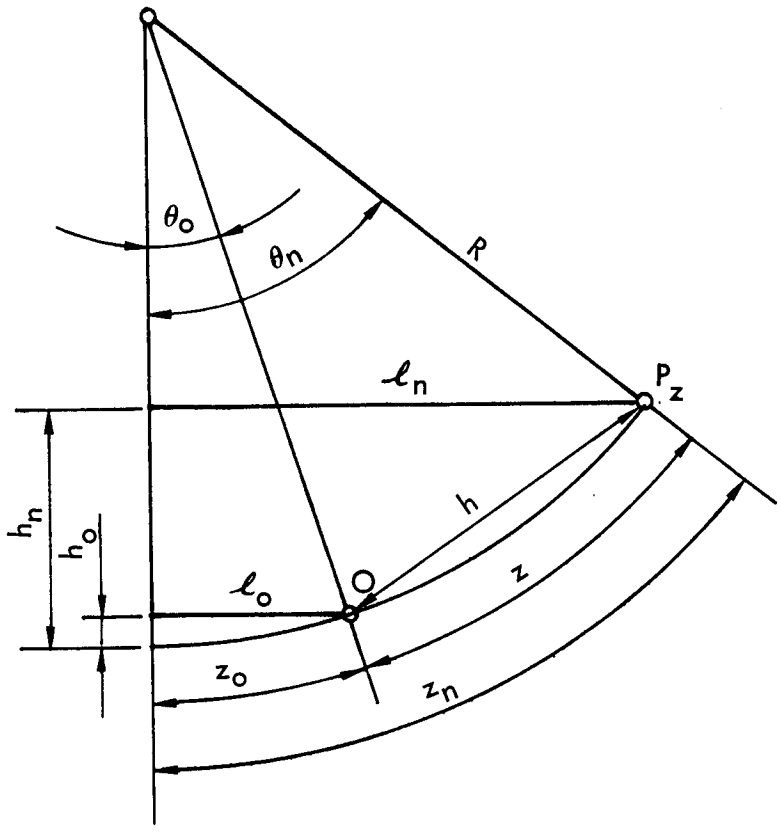


Figure C6. - Details of arcs for z displacement

$$z_o = \frac{\theta_o}{360} 2\pi R = \frac{\theta_o}{180} \pi R$$

where

z_o remained constant

while

z_n represented the total arc to point P_n

$$z_n = z_o + z \tag{C16}$$

since

$$z = \frac{\theta}{180} \pi R$$

$$z_n = \frac{\theta_n}{180} \pi R \tag{C17}$$

z_n being a known value θ_n was determined $\theta_n = z_n \frac{180}{\pi R}$ where $\left(\frac{180}{\pi R}\right)$ was a constant. Figure C6 shows that $\cos \theta_n = \frac{R-h_n}{R}$ and $R \cos \theta_n = R-h_n$ from which

$$h_n = R - R \cos \theta_n$$

or

$$h_n = R\ (1 - \cos \theta_n) \tag{C18}$$

while

$$\sin \theta_n = \frac{\ell n}{R} \text{ and } \ell_n = R \sin \theta_n \tag{C19}$$

Now ℓ_n and h_n were incorporated for the formation of the camera triangle as shown in Figure C7.

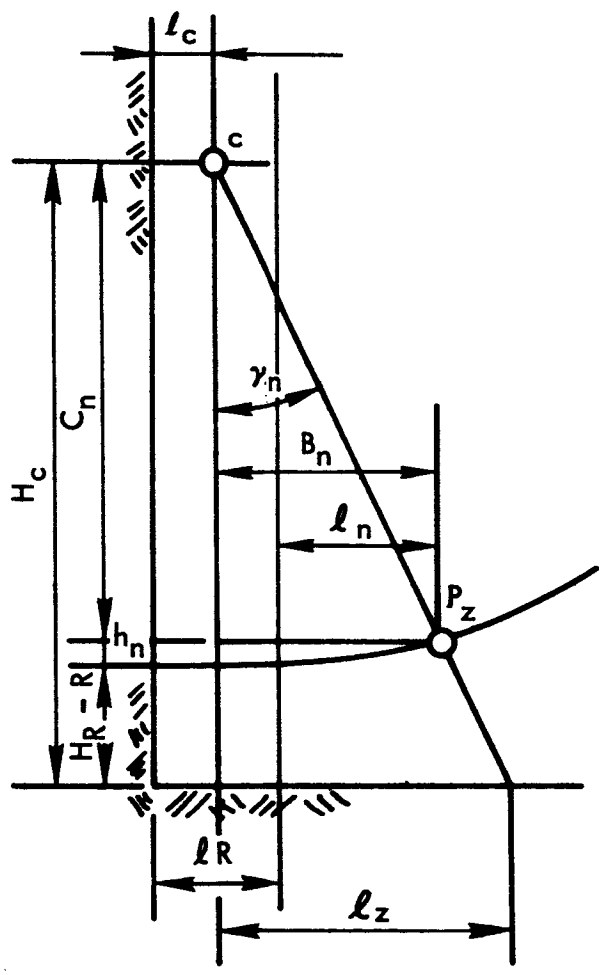


Figure C7. - Details of camera geometry

Determination of Camera Geometry

The base of the camera triangle

$$B_n = \ell_n + \ell_R - \ell_c \tag{C20}$$

and

$$C_n = H_c - (H_R - R) - h_n = H_c - H_R + R - h_n \tag{C21}$$

thus

$$\tan \gamma_n = \frac{B_n}{C_n} \tag{C22}$$

from which the angle γ_n was found. From the relation of the two triangles

$$\frac{B_n}{C_n} = \frac{\ell_z}{H_c}$$

where

$$\ell_z = \frac{H_c B_n}{C_n} \tag{C23}$$

and

L_z from Figure C3

$$L_z = \ell_z + \ell_c - \ell_B \tag{C24}$$

Reduction to Backdrop Surface

Since L_z is the established projection of P_z against floor level it had to be reduced to the backdrop surface. The geometry identifying the trigonometric relationships is shown in Figure C8. It can be seen that

$$\text{angle } \xi = 180 - 90 - \gamma_n = 90 - \gamma_n \tag{C25}$$

and that

$$\text{angel } \phi = 180 - (\theta + \xi) \tag{C26}$$

Solving this oblique triangle

$$\frac{L_m}{\sin \xi} = \frac{L_z}{\sin \phi}$$

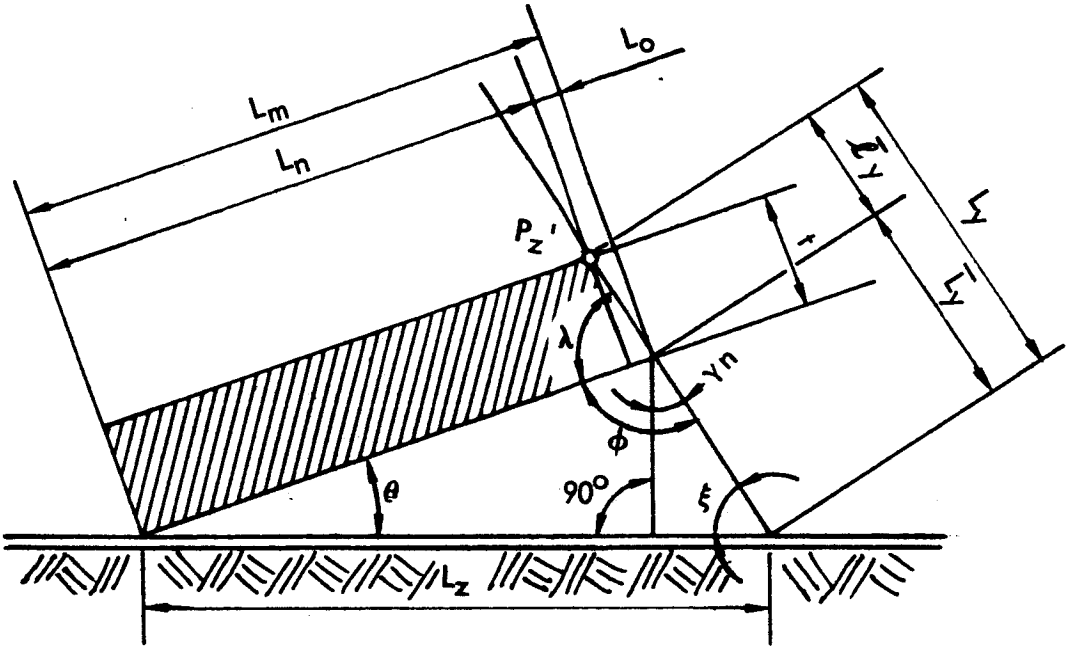


Figure C8. - Back drop surface geometry

from which

$$L_m = L_z \frac{\sin \xi}{\sin \phi} \tag{C27}$$

Then

$$\text{angle } \lambda = 180 - \phi \tag{C28}$$

and

$$\text{cotan } \lambda = \frac{L_o}{t}$$

where t = thickness of backdrop surface.

Then

$$L_o = t \text{ cotan } \lambda \tag{C29}$$

and

$$L_n = L_m - L_o \tag{C30}$$

Note: L_o was only negative for those conditions where $\sphericalangle \phi > 90^\circ$. When conditions ocurred where $\sphericalangle \phi < 90^\circ$ $\sphericalangle \lambda$ then became $> 90^\circ$ and the change of this trigonometric function in the second quadrant produced a positive L_o in the determination of L_n.

This completed the derivations for the correction of an arbitrary point P_z to its projection P_z'. A table was then constructed using Δz increments of 10 cm along the arc of radius R to establish the correspondingly corrected z-grid on the backdrop surface.

CORRECTION ANALYSIS FOR X GRID

This analysis utilized the applicable relationships derived in the z correction. A point P_x was selected for the definition of its correction to point P_x'. Their respective positions and associated geometry are shown in Figure C9.

Where ℓ_x is of a given value, in this case assumed of unit length, then;

$$\tan \theta_x = \frac{\ell_x}{H_c - (H_R - R + h_n)} = \frac{\ell_x}{(H_c - H_R + R - h_n)}$$

or

$$\tan \theta_x = \frac{\ell_x}{(H_c + R - H_R - h_n)} \tag{C31}$$

and from the triangle relation of:

$$\frac{\ell_x}{(H_c + R - H_R - h_n)} = \frac{\bar{L}_x}{H_c}$$

$$\bar{L}_x = \frac{H_c \, \ell_x}{(H_c + R - H_R - h_n)} \tag{C32}$$

From Figure C8 it can be seen that

$$\frac{\bar{L}_y}{\sin \theta} = \frac{L_m}{\sin \xi}$$

from which

$$\bar{L}_y = L_m \frac{\sin \theta}{\sin \xi} \tag{C33}$$

To allow for the backdrop thickness t

$$\sin \lambda = \frac{t}{\bar{\ell}_y} \text{ and } \bar{\ell}_y = \frac{t}{\sin \lambda} \tag{C34}$$

then

$$L_y = \bar{L}_y + \bar{\ell}_y \tag{C35}$$

$$\ell_N = \sqrt[2]{\ell_x^{\,2} + H_c^{\,2}} \tag{C36}$$

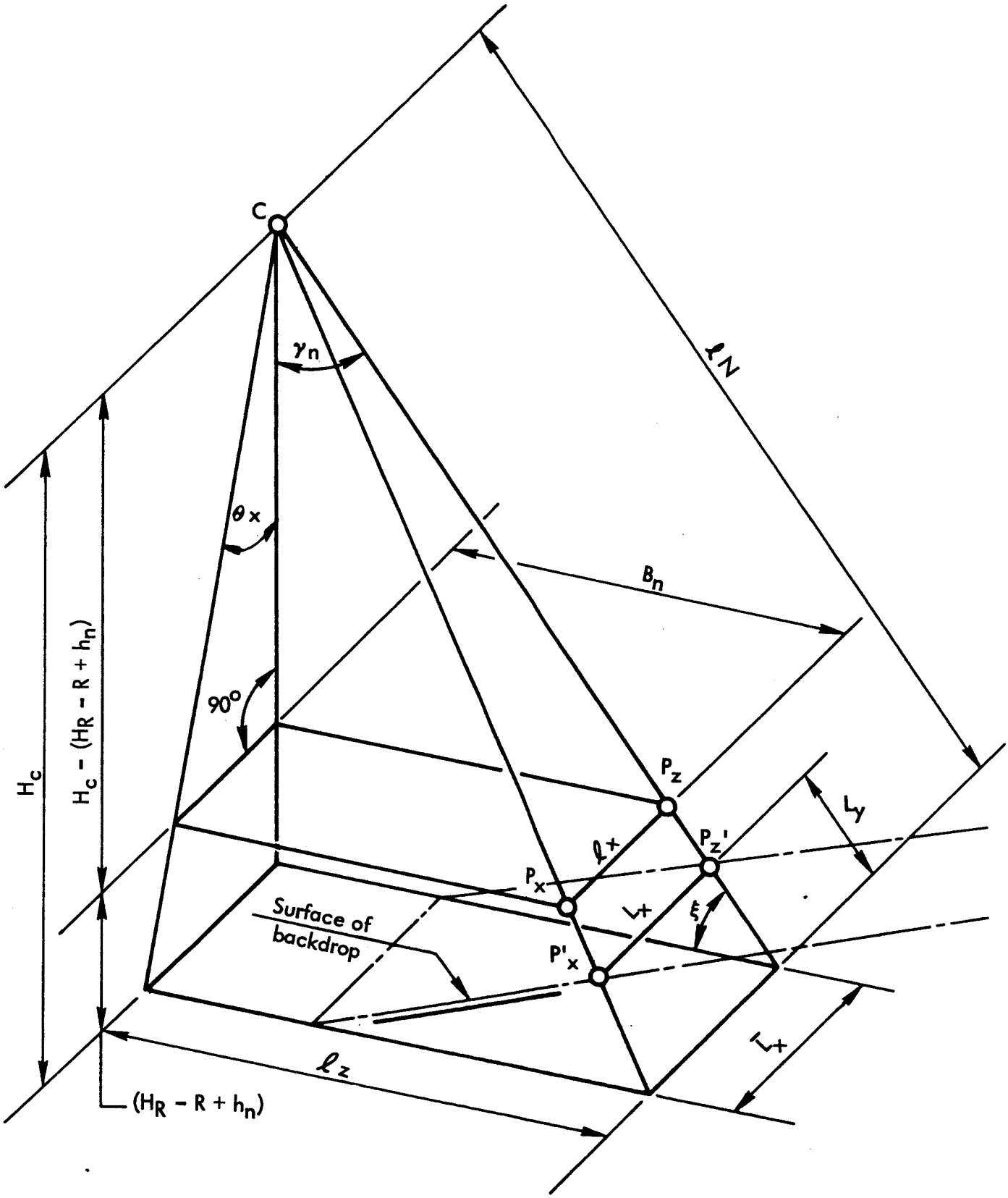


Figure C9. - Geometric details for x correction

and from the relation of

$$\frac{\bar{L}_x}{\ell_N} = \frac{L_x}{(\ell_N - L_y)}$$

$$L_x = \bar{L}_x\left(\frac{\ell_N - L_y}{\ell_N}\right) \tag{C37}$$

from which point P_x' has been established.

A table was constructed similarly to the procedure of the z-correction using Δx increments of 10 cm to establish the corrected x-grid on the backdrop surface. This table indicated not only the complexity of the computation to be performed but also the tremendous number of computations necessary to cover the complete backdrop of the center test section. This resulted in the decision to analyze the corrections by a computer program. Subsequently a program was set up which utilized the equations derived in this Appendix. This program is discussed in greater depth in Appendix E, Part 2 entitled Grid Correction. An exaggerated illustration of the grid variation is shown in Figure C10.

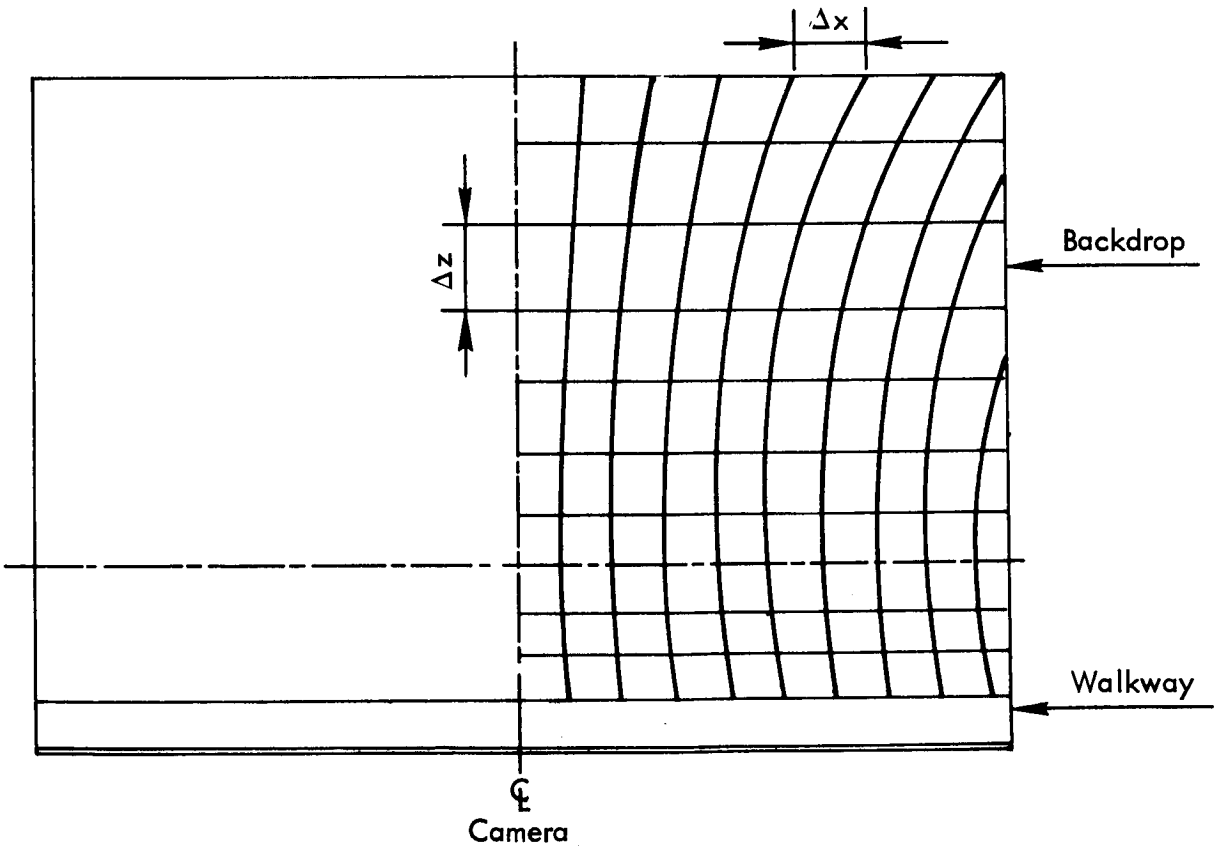
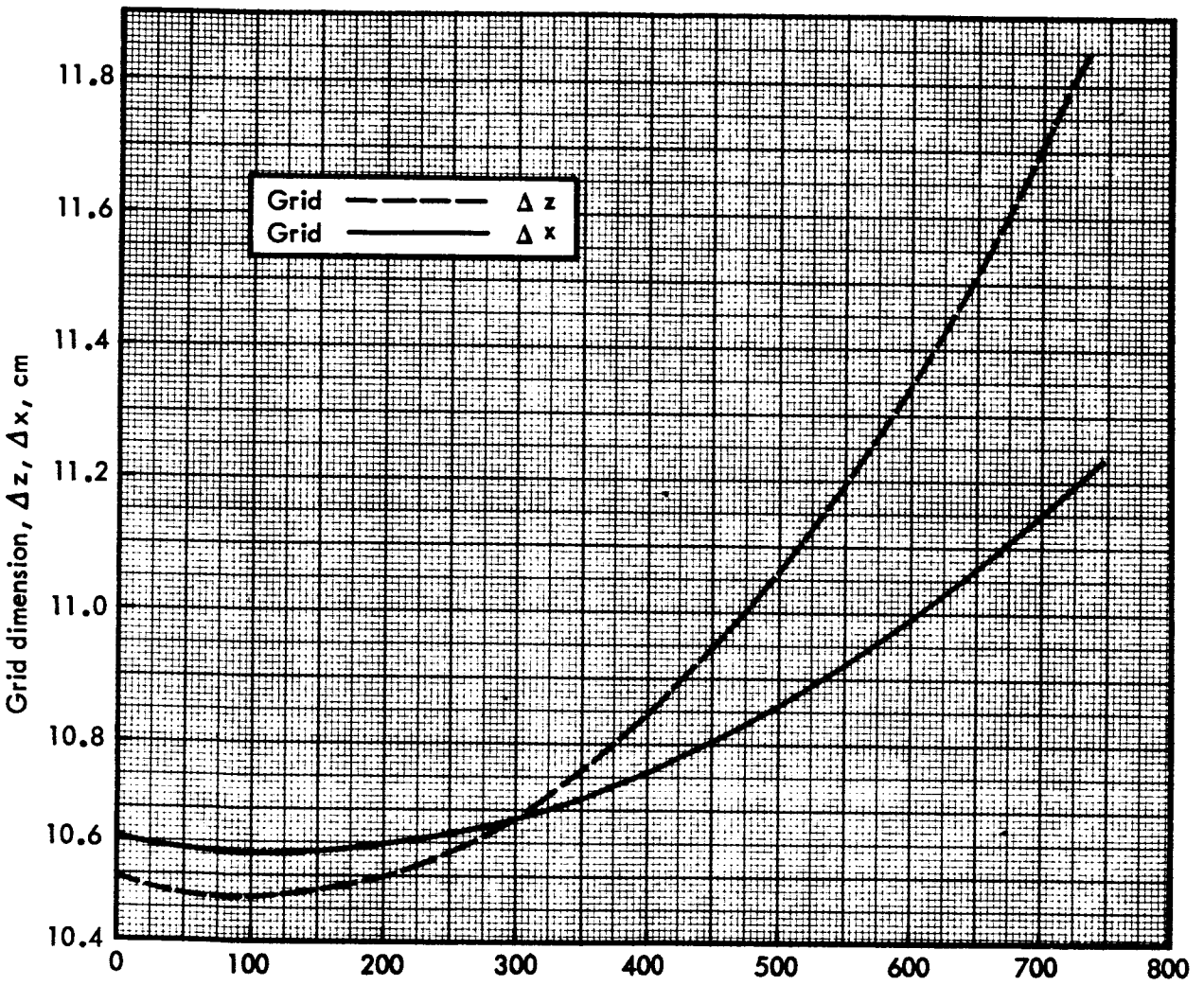


Figure C10. - Grid correction on center test section

The data from the computer program produced the Δz and Δx dimensions for the actual backdrop grid. A plot of these values is shown by Figure C11. Δz is plotted against the distance from the walkway/suspension (Point 0) arc intersection while Δx is plotted against the z_n value which was originally expected to be variable, but remained constant along the z_n line from the center line of the camera. This investigation has revealed the importance of this correction since Δz can reach almost 11.8 cm. Comparing this value to the actual 10.0 cm traversed by the subject, an error of 18% would have been overlooked.



For Δz = distance from walkway/suspension arc intersect, z, cm

For Δx = distance from camera center line at corresponding, z, cm

Figure C11. - Corrected grid dimensions

APPENDIX C

ANALYSIS OF GRID SYSTEMS

By W. Kuehnegger

PART 2

ANALYSIS OF VERTICAL GRID

A small scale gridded vertical backdrop for biomechanics and anthropometric recordings was developed for use with the test subject under earth-gravity conditions. Since test activities were conducted in a plane in front of this backdrop, a certain parallax error would normally have been produced by the camera. To eliminate subsequent corrections and the reduction of the test activity or anthropometric picture to the actual plane, a correction analysis was made to incorporate this correction into the gridded backdrop itself, similar to the full size grid developed for the LGS under Part 1 of this Appendix. This correction was made for the z and the x plane. Its development is described by the analysis of the parallax correction for the z plane first followed by that for the x plane.

PARALLAX CORRECTION FOR Z PLANE

Figure C12 has been drawn to illustrate the dimensional relationships involved. The following values were pre-established: ℓ, Lc, ℓc and $h_{z'}$. In fixing the lens height z_c of the camera,

$$\frac{h_{z'}}{\ell} = \frac{z_c}{L_c} \quad \text{from which } z_c = h_{z'} \frac{L_c}{\ell} \tag{C38}$$

Thus, the point z = 0 will become fixed at the intersection between the floor and the gridded backdrop of the z-plane.

$$\ell_{z'} = z_c - h_{z'} - z' \tag{C39}$$

where z' is of a predetermined length then from the relation of

$$\frac{\ell_z}{L_c} = \frac{\ell_{z'}}{\ell_c} \qquad \ell_z = \ell_{z'} \frac{L_c}{\ell_c} \tag{C40}$$

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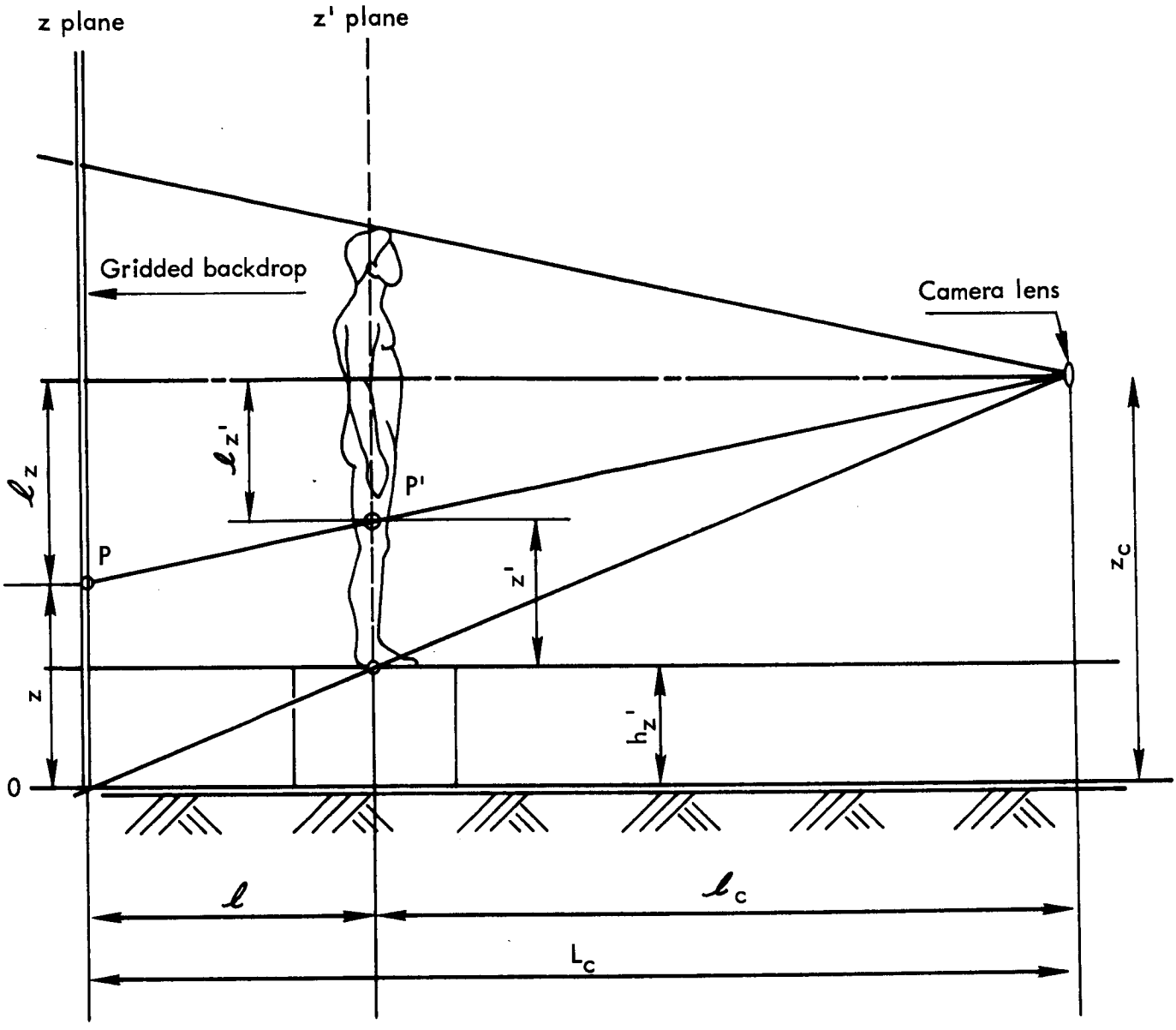

Figure C12. - Parallax correction for z - plane

and

$$z = z_c - \ell_z \tag{C41}$$

Note: According to Figure C12 $z = z_c$ when $\ell_z = 0$.

The pre-established dimensions were:

$h_{z'} = 9.60$ in. (24.38 cm)	$\ell = 36.00$ in. (91.44 cm)
$\ell_c = 144.00$ in. (365.76 cm)	$L_c/\ell_c = 1.25$
$L_c = 180.00$ in. (457.20 cm)	$y_c = 48.00$ in. (121.91 cm)

These values were then used in the determination of an imaginary 10 cm Δz grid through the center line of the subject. The computations revealed that Δz of 12.5 cm remained constant and did not vary as a function of z. This was expected since the z-plane was parallel to the z'-plane.

PARALLAX CORRECTION FOR X PLANE

Again an illustration was constructed (see Figure C13) to reveal the geometric and dimensional relationships that were added by investigating the second plane. Figure C13 shows that there is no relation between z or z' to the x and x' projection.

thus

$$\frac{x'}{\ell_c} = \frac{x}{L_c}$$

and

$$x = x' \frac{L_c}{\ell_c} \tag{C42}$$

As such, this remained constant for all z values.

x', similar to z', was of a predetermined length. The computation was made by using the pre-established values for the determination of an imaginary 10 cm Δx grid. This grid was investigated from the center line of the subject to one side of the backdrop only because of the symmetrical arrangement. Δx, as expected, did not vary with x and remained constant at 12.5 cm.

Thus, the grid system on the backdrop consisted of 12.5 x 12.5 cm squares. This arrangement achieved the desired parallax correction which concluded the photogrammetric correction.

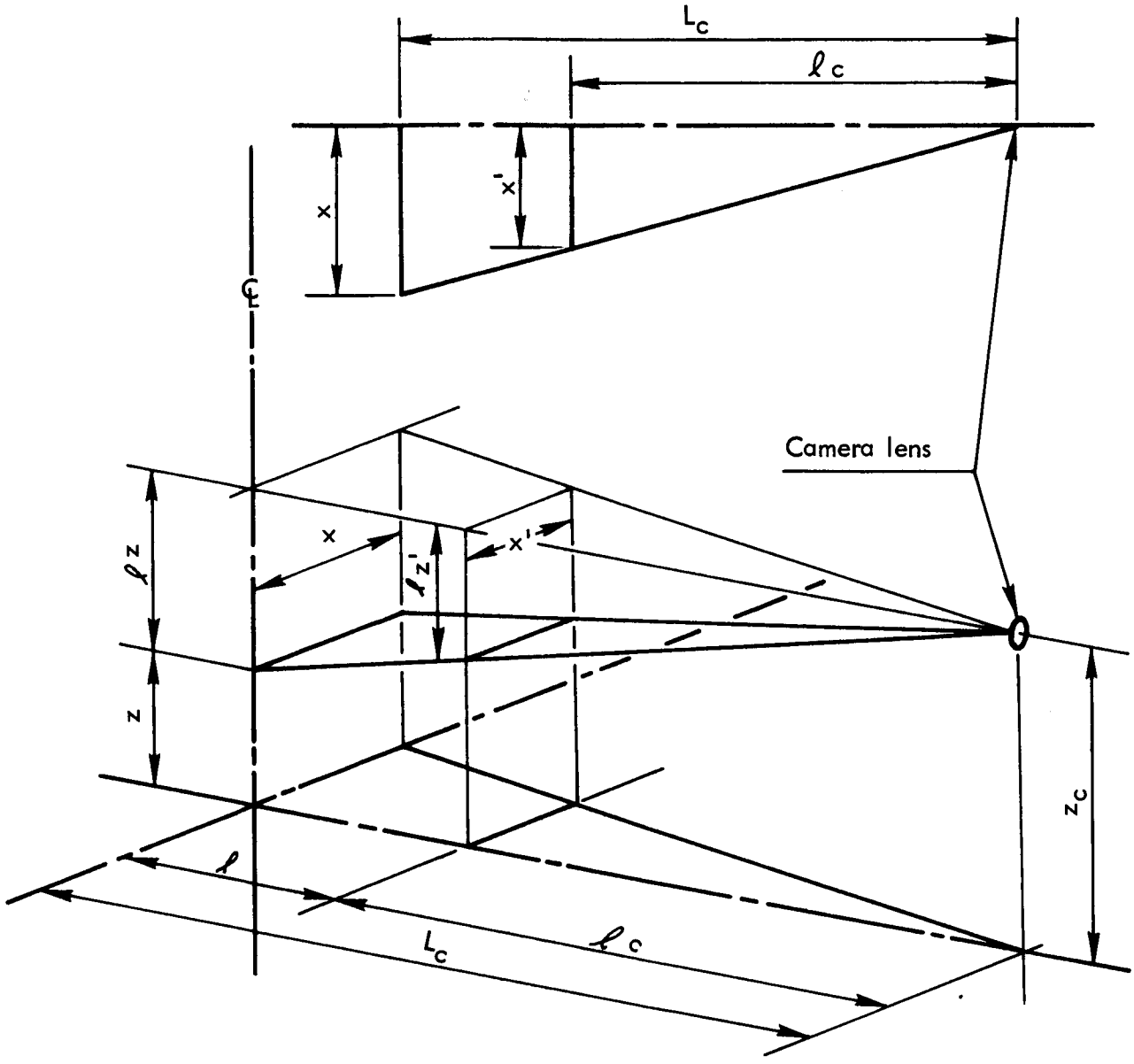

Figure C13. - Parallax correction for x (y) - plane

APPENDIX D

DETERMINATION OF "n" SUIT PRESSURE

by W. Kuehnegger

The full pressure suits used for the experiments in this study were the Navy MK IV type. Since this type of suit will not be used for any lunar exploration, it became necessary to establish its properties for subsequent evaluations of the experiments conducted. This had to be done to provide a basis for comparison with those pressure suits that will be used for lunar exploration. Only under the establishment of such a basis can the conducted experiments be used to predict the physical performance of man in a lunar suit.

A study of the bending moments of the MK IV suit had already been performed under the analysis of secondary energy effects which formed the static baseline data of the suits used. The dynamic baseline data was established by the performance of two different series of tests. The first series investigated was for the vertical jump height performance while the second series determined the maximum running performance of the MK IV suit. The results of the dynamic baseline data were used to equate the performance of the MK IV suit to that of the Apollo suit under the two conditions described.

Originally it was felt that by reducing the operating pressure of the MK IV suit an equivalent Apollo suit performance would be achieved.

PERFORMANCE BASELINE FOR VERTICAL JUMP HEIGHT

Shirtsleeve

Because of the jumping heights involved, this series of tests was performed in the center section test area of the LGS. The biomechanics data camera was used to record these tests. A typical example of one of the data recordings is presented in Figure D1. For each test, the measurement of the highest z-position of the mass center of Segment 1 represented by H (see Figure D2) was taken. The maximum jump height recorded on the LGS in the shirt sleeve mode was as follows. For Subject A, z_1 max = 142.9 in. (363.0 cm) and for Subject C, z_1 max = 150.0 in. (381.0 cm). Since these heights were based on the data obtained on the LGS, they had to be corrected for the influence of the gravity gradient to produce the actual lunar jumping height. This was done by using the correction curve shown in Figure D3. The corresponding correction factors and results were obtained.

Using Figure D1 for reference, from which

$$\text{cg Jump Height} = z_1 \max - (z_1 - z_o) - z_o = z_1 \max - z_1 + z_o - z_o$$

$$= z_1 \max - z_1 \qquad \text{(D1)}$$

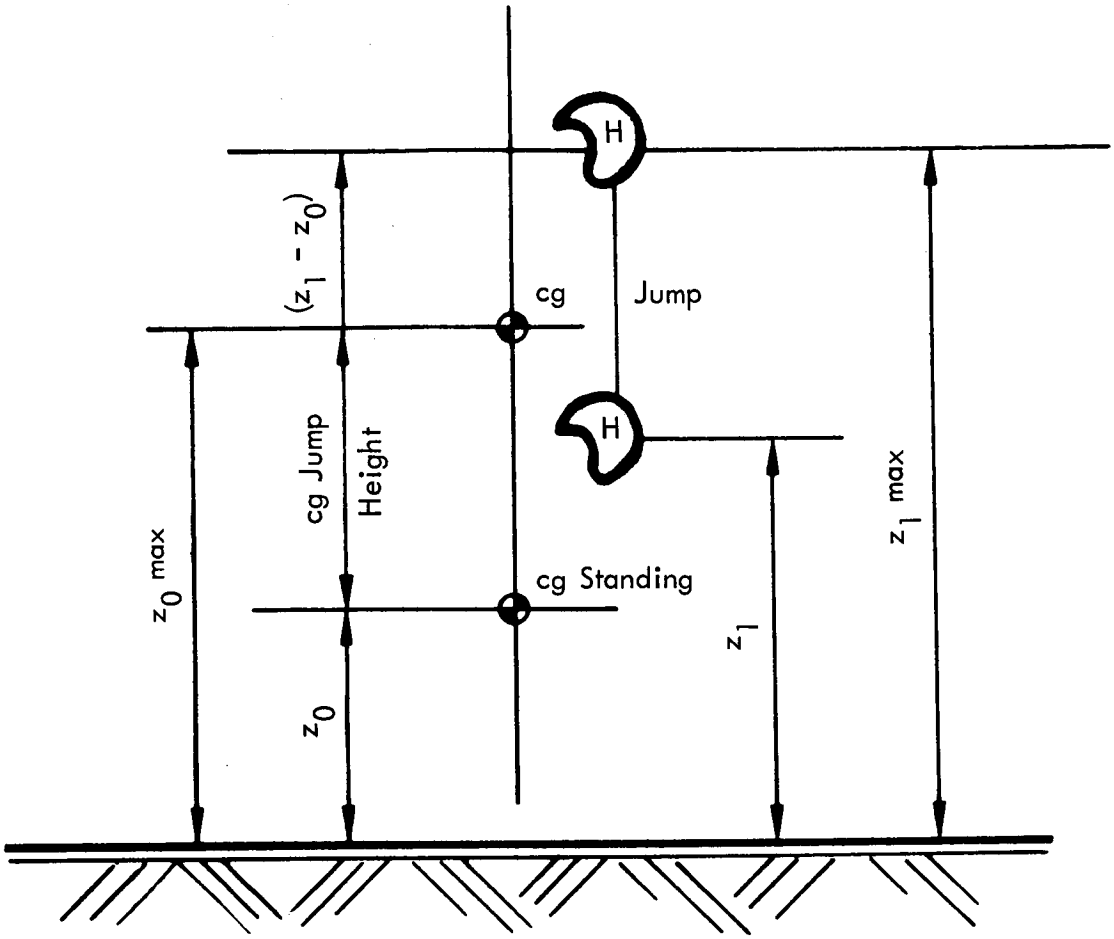

Figure D1. - Determination of vertical jump height

Then for	Subject A	Subject C
z_1 max (ref. Figure D2)	11 ft 10.9 in. (363.0 cm)	12 ft 6.0 in. (381.0 cm)
$-z_1$ (from Table A18)	-5 ft 2.5 in. (158.9 cm)	-5 ft 3.8 in. (162.2 cm)
cg Jump Height =	6 ft 8.4 in. (204.1 cm)	7 ft 2.2 in. (218.8 cm)

From Figure D3

Corrected Lunar Jump Height	8 ft 7.2 in. (262.0 cm)	9 ft 5.0 in. (287.0 cm)

This correction was necessary as it reduces the data of the LGS to a common denominator from which comparisons and predictions can be made for either the actual lunar environment or the performance on another simulator.

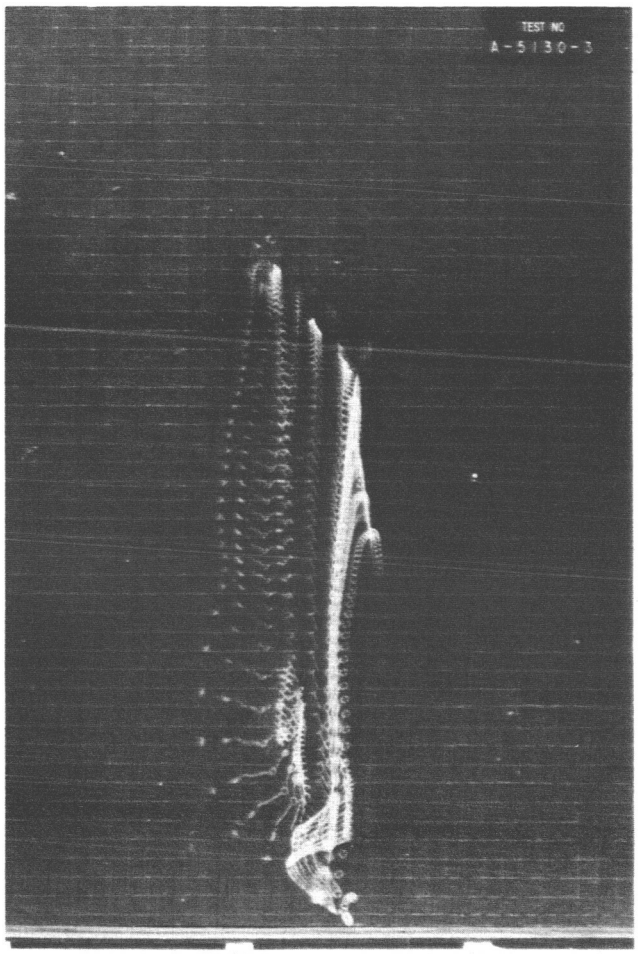

Figure D2. - Data recording of shirtsleeve jump

Full Pressure Suit

Tests with the full pressure suit were conducted over the treadmill section of the LGS. The subject did not wear any of the instrument packs. Pressurization was therefore achieved by an arrangement which involved the pressure suit test kit and a portable respirator unit. Oxygen was supplied by the seondary umbilical. This test arrangement can be seen in Figure D4. The test procedure demanded six (6) individual maximum vertical jumping attempts from each subject, first in the vent flow condition followed by .5 psig increments to 3.5 psig. Each subject then performed a total of 48 jumps in this phase. Figure D5 shows a typical data recording taken during this test series. This figure shows a curve rather than the straight recording of a vertical jump as in Figure D2. This recording is still that of a vertical jump, but the curve was produced by driving the data film across similarly to a cyclographic recording to provide a more accurate data analysis.

The analysis of the biomechanics data generated by these pressure suited tests was performed in the same manner as those for the previous shirt sleeve tests. The resulting data for the vertical jump heights is seen plotted against the suit pressure in Figure

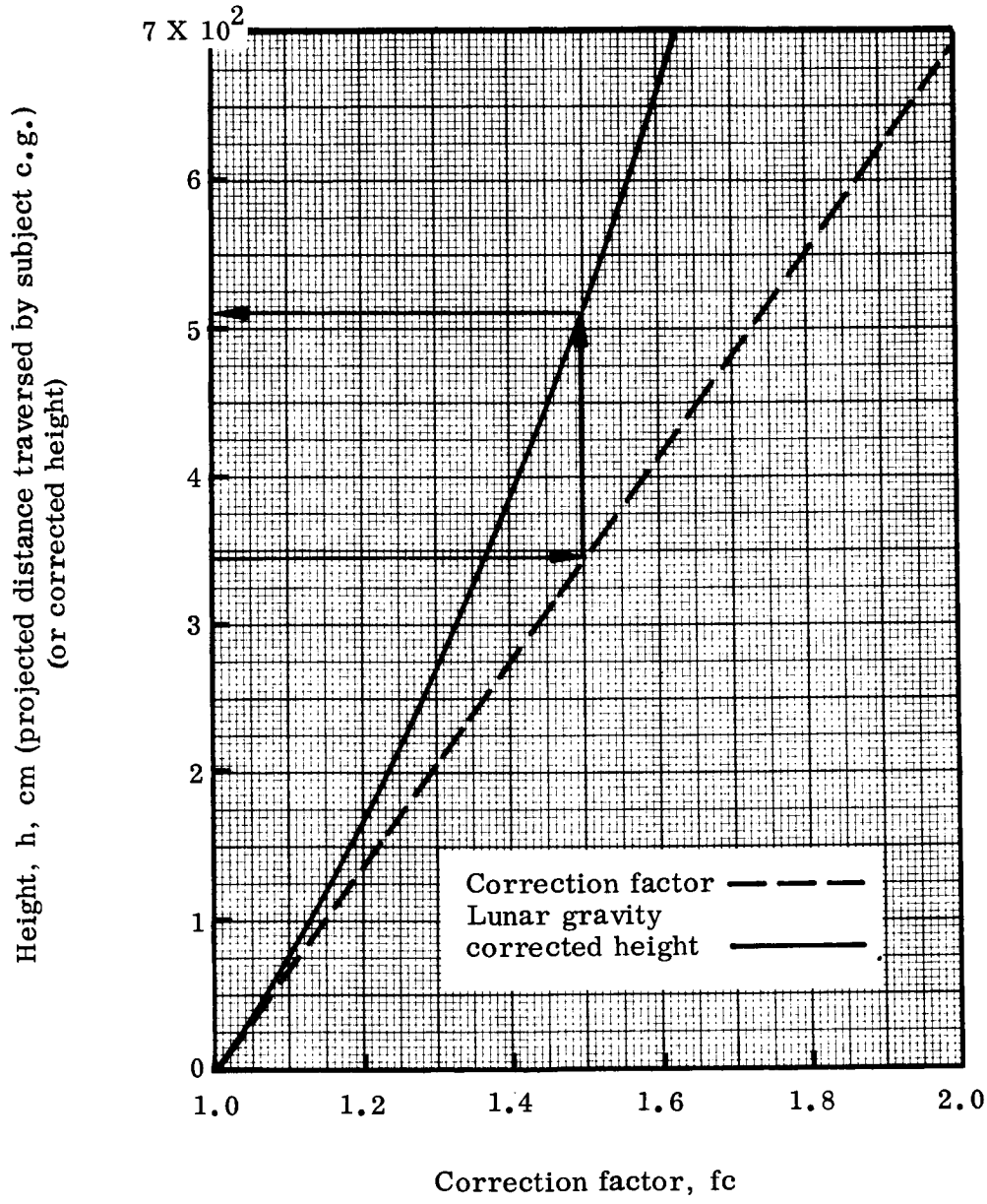

Figure D3. - Height versus correction factor

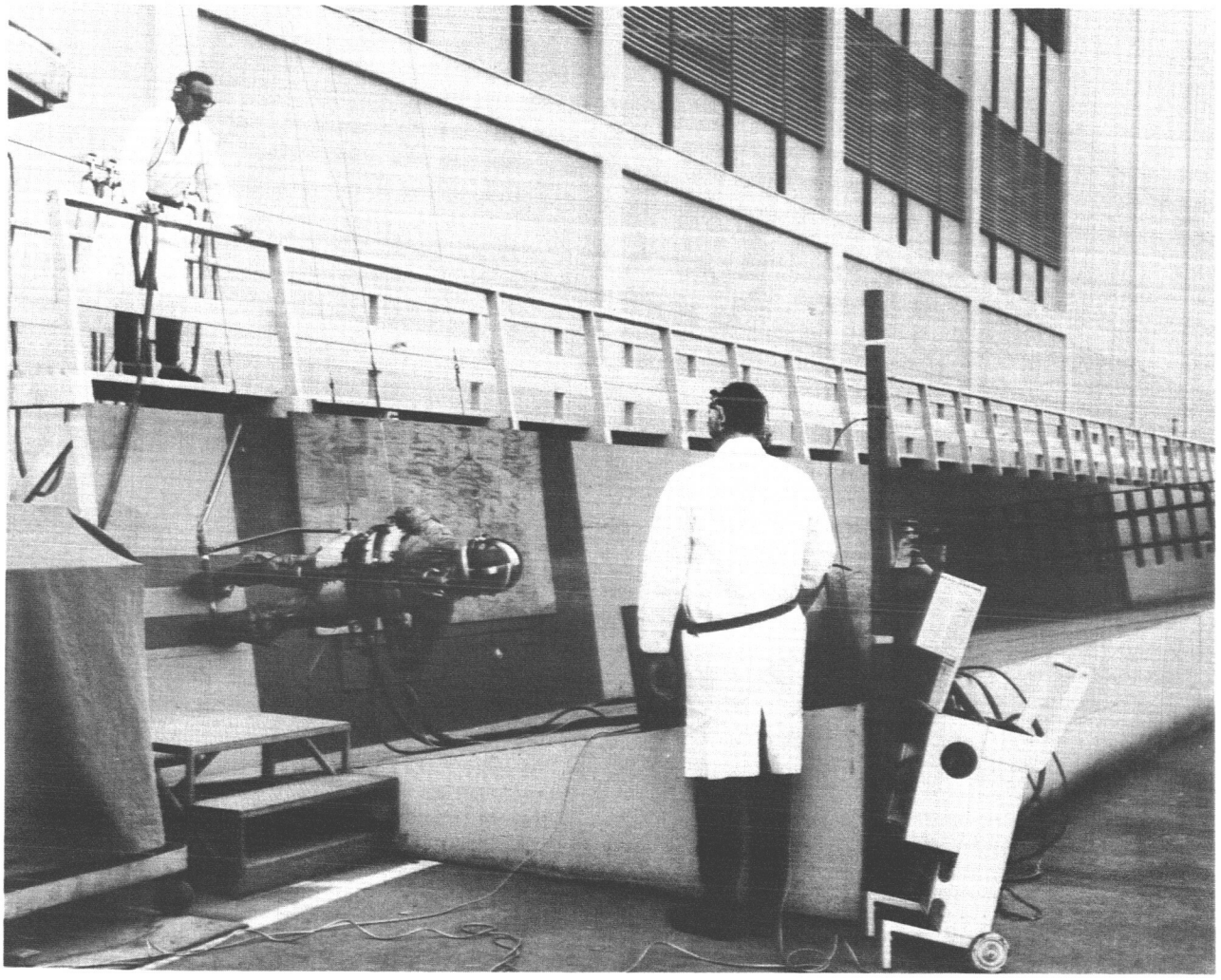

Figure D4. - Test arrangement for vertical jump test

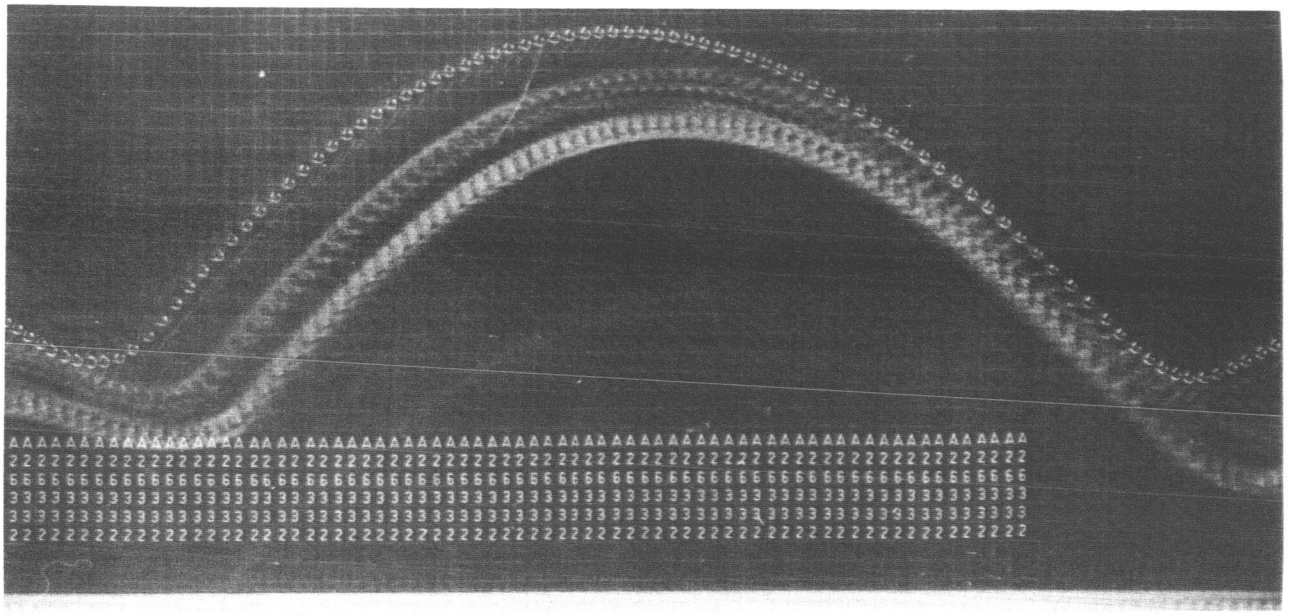

Figure D5. - Data recording of jumping in pressure suit

D6 for subject A and Figure D7 for subject B. These figures show two curves for each subject. One curve was constructed representing the average value of the six attempts while the top curve was shown to represent the maximum value found within the six attempts.

PERFORMANCE COMPARISON

The purpose of this comparison was to indicate and quantify the performance differences between; (1) the subjects, (2) the lunar gravity simulation facilities, and (3) the full pressure suits. The differences between the subjects are discussed simultaneously with those of the lunar gravity simulation facilities and those of the full pressure suits.

Data obtained from the NASA Langley Research Center LGS facility indicated that nominal vertical jumping heights of 154 in. (391.16 cm) for subjects in normal clothing (without pack) were obtained. This height was reduced to 141 in. (358.1 cm) by the Apollo suit in vent flow and further to 88 in. (223.52 cm) when pressurized at 3.7 psig. These values have already been corrected for the gravity gradient of the LRC LGS facility and can thus be used directly for comparison. Tables D1 and D2 summarize the data and its analysis for the final determination of "n" pressure. The final values for the LGS jump heights developed in Table D2 were compared to Figure D5 for subject A and Figure D6 for subject C. It was noted that neither of the subjects could achieve the equivalent Apollo suit performance in the vent flow condition. Subject A fell short by 9.4 in. (24.0 cm) and subject C by 4.3 in. (11.0 cm). In the pressurized condition, however, the results were very satisfactory showing equivalent Apollo suit performance pressure "n" at 3.5 psig using the maximum height curve.

TABLE D1

DATA COMPARISON

NASA Langley Research Center, LGS Data	
Corrected lunar jumping height in shirtsleeve (no instrument pack)	= 12 ft, 10 in. (391.16 cm)
Corrected lunar jumping height in Apollo suit (vent flow - 0 psig)	= 11 ft, 9 in. (358.14 cm)
Corrected lunar jumping height in Apollo suit (3.7 psig)	= 7 ft, 4 in. (223.52 cm)
Vent flow ratio $= \frac{358.14}{391.16} = .9156$	Pressure ratio $= \frac{223.52}{391.16} = .5714$

Northrop Space Laboratories, LGS, Data, cm	Subject A	Subject C
Jumping height in shirtsleeve (no instrument pack)	204.1	218.8
Corrected lunar jumping height in shirtsleeve (no instrument pack)	262.0	287.0
Ratioed jumping height for Apollo equivalent vent flow reduction	240.0	262.8
Ratioed jumping height for Apollo equivalent pressurized (3.7 psig) reduction	149.8	164.2

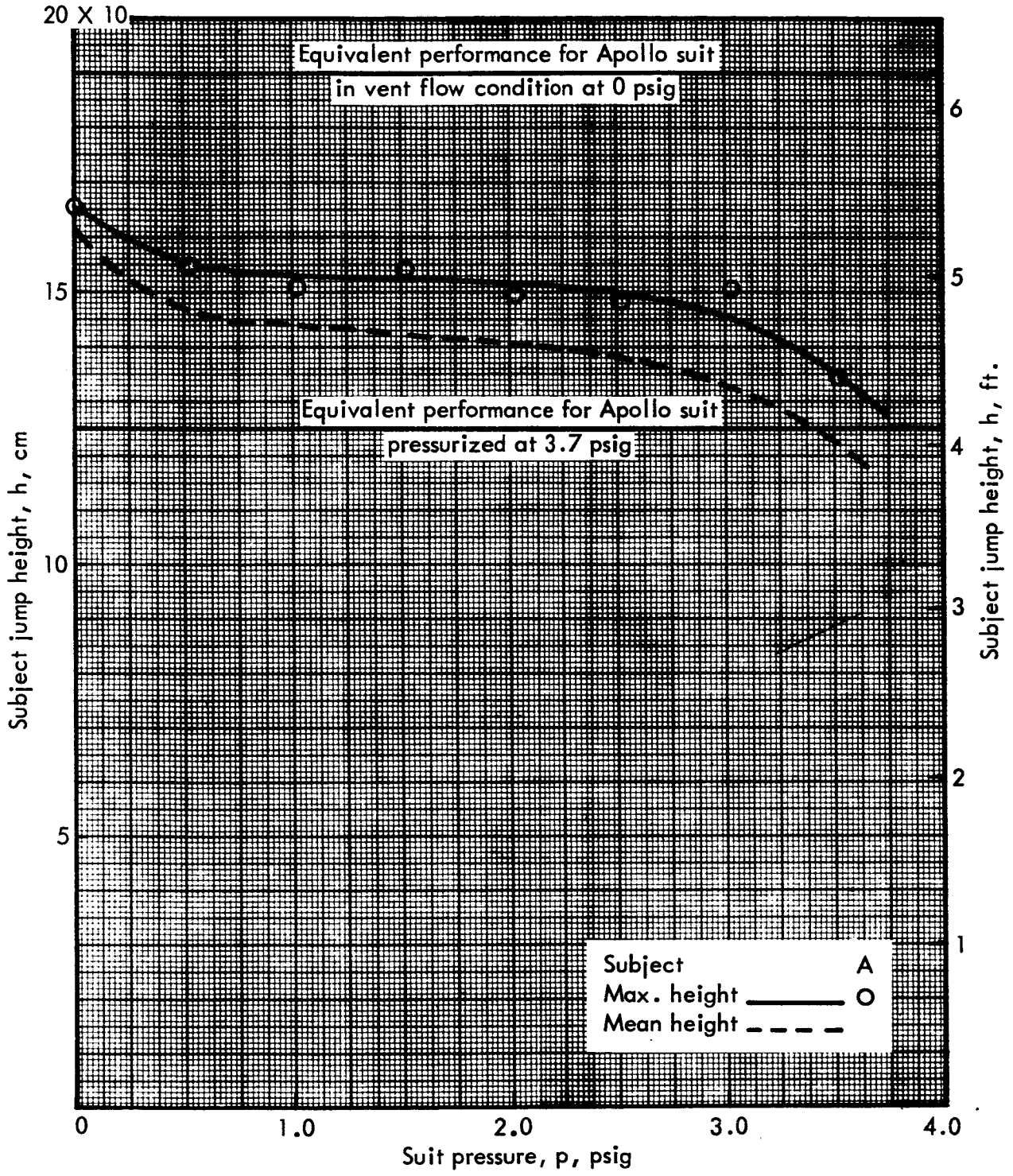

Figure D6. - Navy MK IV suit pressure versus subject jump height

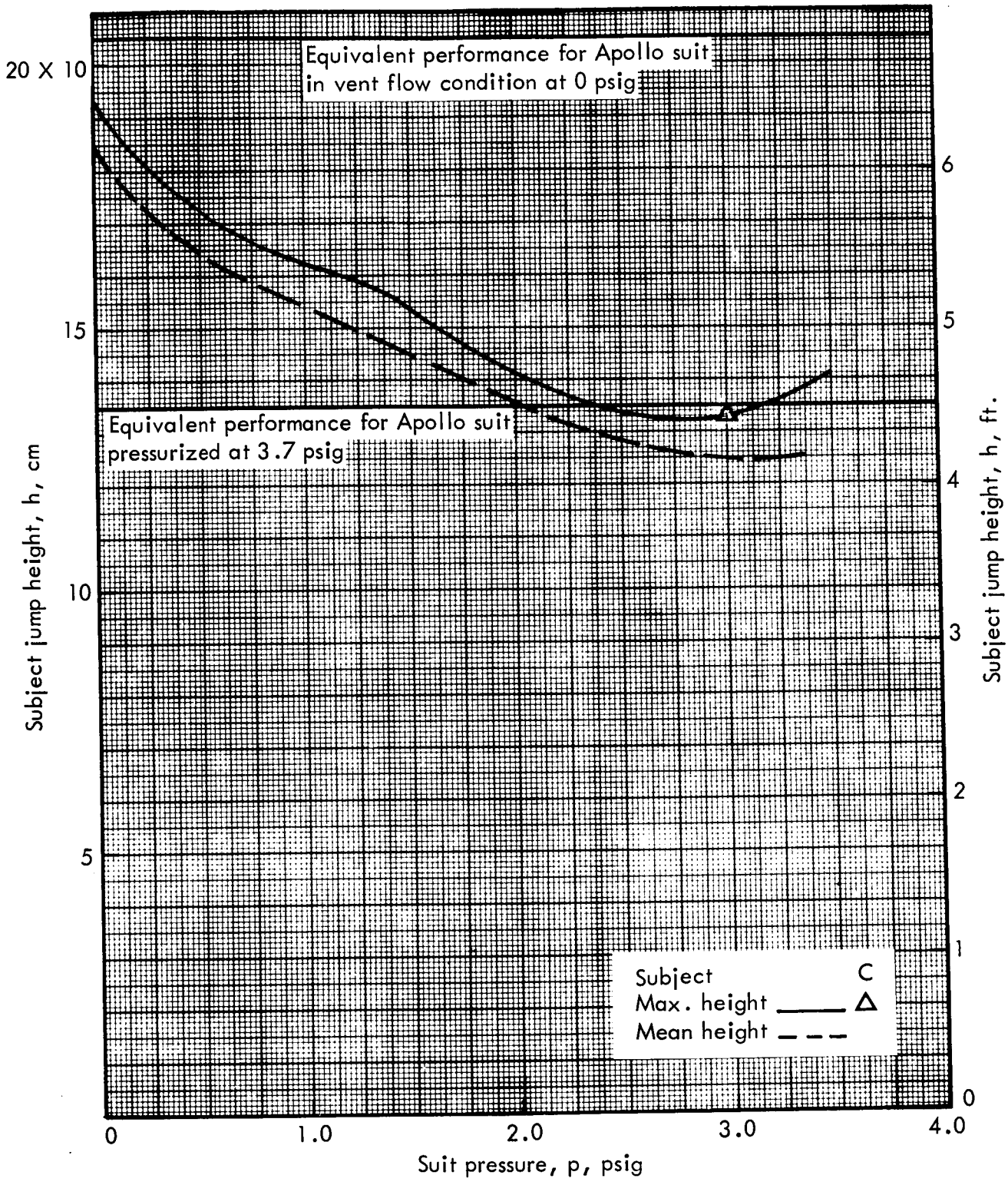

Figure D7. - Navy MK IV suit pressure versus subject jump height

TABLE D2. DETERMINATION OF EQUIVALENT APOLLO PERFORMANCE

Height Computations, cm	Subject A		Subject C	
	Vent flow, 0 psig	Pressurized "n" psig	Vent flow, 0 psig	Pressurized "n" psig
Ratioed jumping heights for Apollo equivalent	240.0	149.8	262.8	164.2
LGS jump height (from Fig. D3)	190.0	125.0	205.0	135.0

PERFORMANCE BASELINE FOR MAXIMUM RUNNING

Running on the LGS is achieved with very little displacement in the z-plane. It was therefore considered unnecessary to apply a gravity gradient correction. Furthermore, since the LRC and the NSL LGS facilities were based on the same principle, it was possible to compare the running data directly. One test series consisting of several attempts to reach V maximum was conducted by subject C only. A typical data recording is shown in Figure D7 with the results indicated in Figure D8. These results were then compared to the performance obtained in the NASA LRC simulation and are shown in Table D3.

TABLE D3. — COMPARISON OF PRESSURE SUIT PERFORMANCE

NASA LRC LGS Apollo suit performance		NSL LGS Navy Mark IV suit performance	
Vent flow, 0 psig	15.5 fps		13.73 fps
Pressurized at 3.7 psig	12.5 fps	at 3.5 psig	8.37 fps

CONCLUSIONS

The Navy MK IV suit at 3.5 psig has been shown to be comparable to the Apollo suit at 3.7 psig under the maximum activities investigated.

In pressurized maximum running activities the Navy MK IV suit was inferior but approached the Apollo suit properties in the vent flow condition. Furthermore, it should be mentioned that due to the limitation of the 100 foot (3048 cm) walkway on the NSL LGS it was not always possible to achieve maximum velocities.

These considerations and the quantified comparison between the two suits have justified the use of the Navy MK IV suit for the tests conducted on the NSL LGS as part of this program.

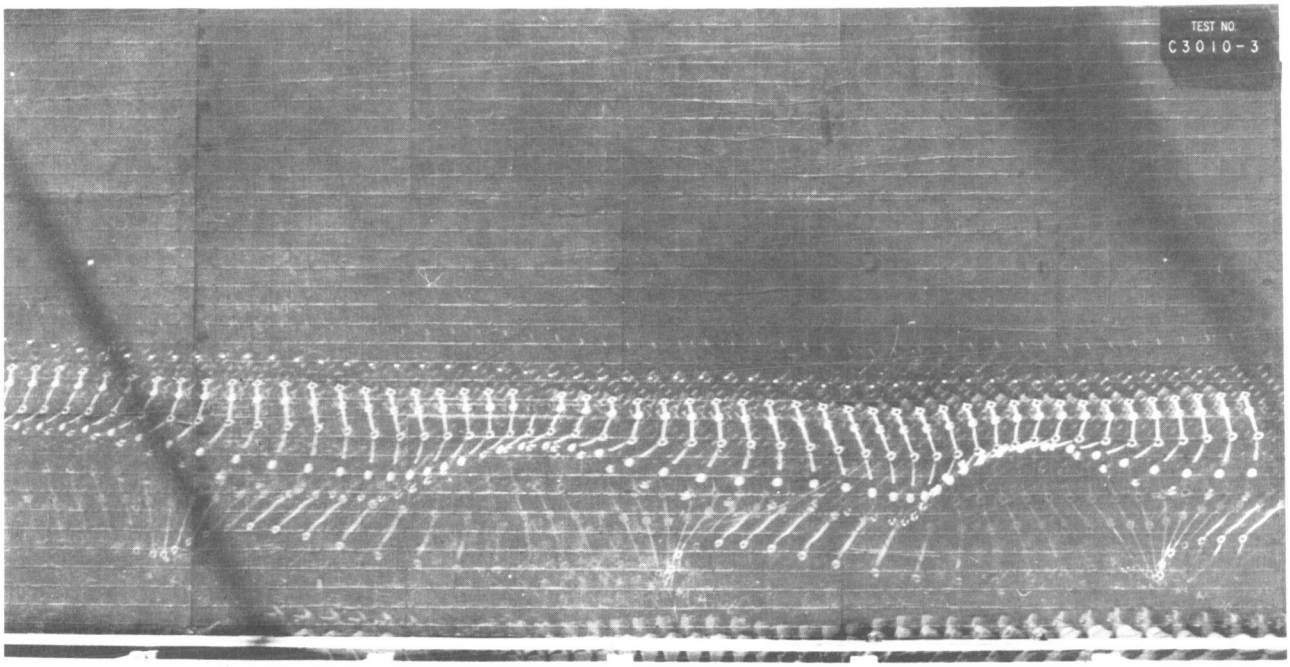

Figure D8. - Data recording of running in pressure suit

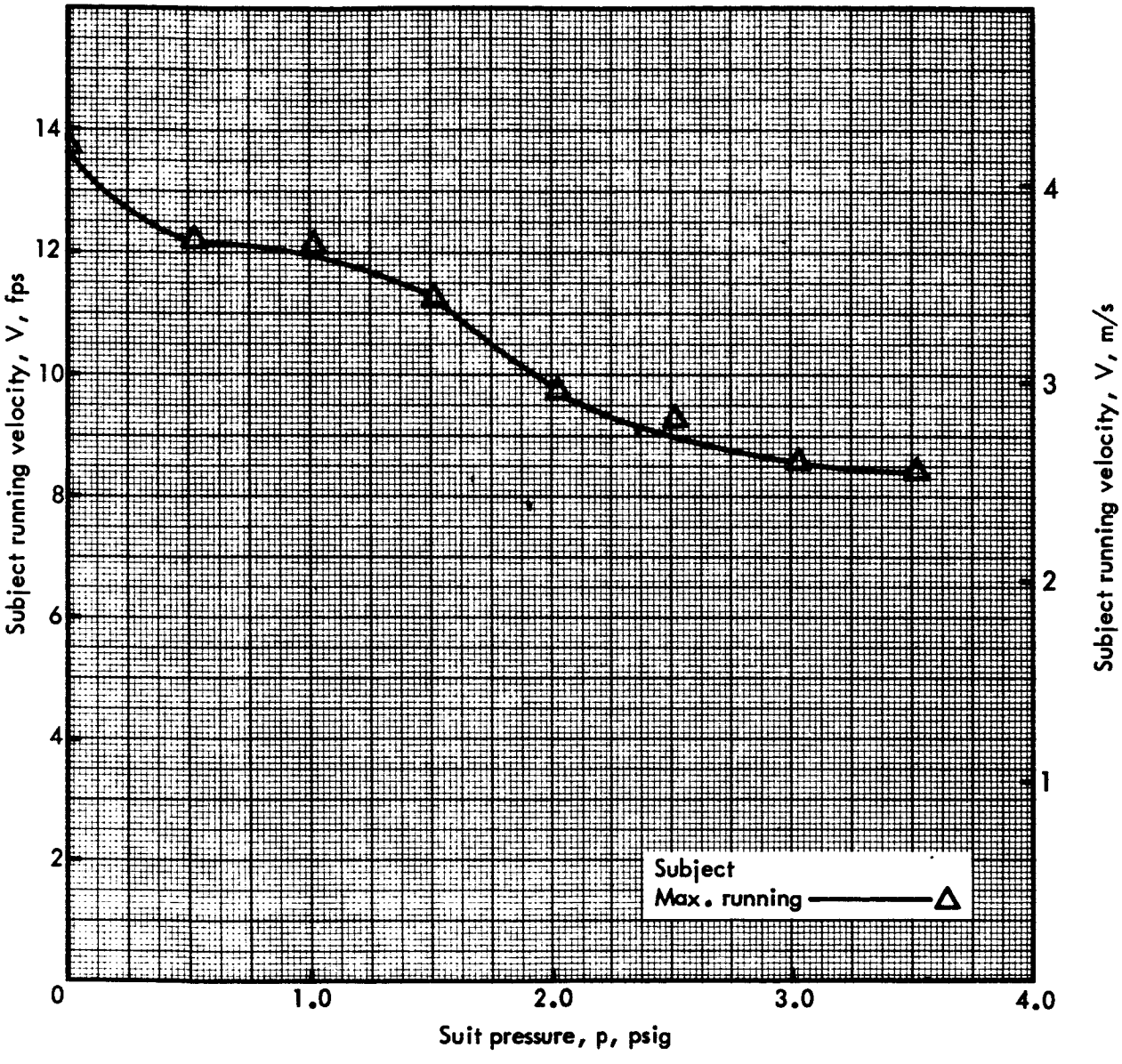

Figure D9. - Navy MK IV suit pressure versus subject velocity

APPENDIX E

COMPUTER PROGRAMS

PART I

COMPUTER PROGRAM FOR BIOMECHANICS MOTION ANALYSIS

By K. L. Forsen

The following discussion concerns the development of a computer program to analyze the biomechanical properties of man as derived from tests conducted during "A Study of Man's Physical Capabilities on the Moon". Data reduction and analysis was performed by writing a Fortran IV program entitled "MOM". The program was utilized by means of an IBM 7090 Computer and a Stromberg-Carlson SC-4020 Plotter.

The overall objective of the computer program was to develop a mathematical model of the biomechanical characteristics of man under simulated lunar gravity conditions. Several analytical considerations were involved in the establishment of such a mathematical model. These were as follows.

(1) Analysis of the kinetic energy

(2) Analysis of the moment of inertia

(3) Analysis of gravity gradient

(4) Analysis of potential energy

(5) Analysis of pressure suit torque

The data derived from these analyses were not necessarily used in the sequence shown, but were applied whenever called for in the main program.

This main program develops an equation of motion for seven separate segments. These segments are listed below.

(1) Segment 1 The Head and Neck

(2) Segment 2 The Trunk

(3) Segment 3 The Upper Arm

(4) Segment 4 The Lower Arm and Hand

(5) Segment 5 The Thigh

(6) Segment 6 The Lower Leg and Foot

(7) Segment 7 The Instrument Pack (considered as a separate entity)

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Each segment is treated in three different components versus time. These components are the analysis of curvilinear motion in the rectilinear coordinates of x and z and the rotational component of θ. For each one of these components an equation of motion is developed by using a numerical calculation known as the Method of Least Squares. From this equation of motion, subsequent equations are derived for the following: velocity (the first derivative of the equation of motion) and acceleration (the second derivative of the equation of motion).

The force generated by a given segment was determined by the acceleration times the mass of the segment. This is true only for the x and z components. In the θ or rotational component, the moment of inertia is substituted for the mass of the segment and is multiplied by the angular acceleration, producing the torque of the given segment.

The power is derived by the multiplication of the first derivative times the force or torque of the segment being analyzed. The work of each one of these components was then derived by the absolute integration of the power produced for the given cycle duration except for the z component which is explained under Subroutine WORK subsection. Further, in the z component a gravity gradient determination is developed from the equation of motion. From this determination the power of potential energy was developed. The work of the power of potential energy was then obtained by integrating its value over the cycle duration, recognizing positive and negative powers.

The sum of each component's work for a given segment is the total work developed by that segment. With segments 3, 4, 5, and 6 the total work of these segments is doubled since they represent the upper and lower extremities.

The summation of work expended by segments one through six is the total body work. Addition of the work expended by the instrument pack results in the sum total of all work produced for one activity cycle duration.

The original equations used for computer analysis were derived in the biomechanical motion analysis of this report.

For each component, curves are plotted by the SC-4020 Plotter against a common base of time for one activity cycle. These curves, representing the final biomechanics data, are found under the previous Results Section of this report.

A computer symbol listing accompanied by a definition and its function is not given, due to the complexity of the total Biomechanics Program.

MOM COMPUTER PROGRAM

MOM program was set up to function as the main computer program. This program performed the calling of eight subroutines that contributed to the making of the total program. It read all data and printed out the calculated equations and tabulated data versus a common base of time in seconds. Each of the body segments was treated as a complete computing cycle. This cycle was made up of the time base readings in seconds, abscissa (x) readings in centimeters, ordinate (z) readings in centimeters, or a rotational reading (θ) in degrees. The degree readings were converted into radian measurements by the computer before the computation of the rotational component began.

The computing cycle commenced as follows.

(1) The control data card P(I) card is read in. This card is discussed later in the section Arrangement of Program and Data Cards for Computer Analysis.

(2) The M(I) card is the next card to be read. This card contains the total number of points used for a given segment. This value is recorded in Columns 4 and 5 on the M(I) card.

(3) Following the reading of the M(I) card, the cards containing the time readings are read in and are held in storage until a new segment is about to be analyzed.

(4) The first component analyzed versus time was the abscissa data; the second component, the ordinate data z, and the third component was the rotational data θ. After completion of the θ analysis, a new set of data for the subsequent segments was read in, repeating the cycle.

(5) Plotting of the original abscissa data versus the time base was executed by the calling of subroutine CUPLOT.

(6) After the plotting of the original data versus time, a Least Square Curve Fit Method was utilized to develop an equation of motion, by the calling of subroutine CURFIT. The curve fit solved a set of equations from the first degree to the tenth degree. The print out of only one of these equations was executed. The method of selection of this equation is explained in detail later in this appendix under Subroutine CURFIT. The equation of motion selected is used throughout the computing cycle for one component. At this point the equation of motion was printed out.

(7) From this equation of motion mentioned above, the first and second derivatives of the component being analyzed are determined. The coefficients of the first and second derivative are redefined for future determinations that will be carried on later in the program. This redefinition of the coefficients is necessary in order to preserve the original coefficients of the equation of motion.

Up to this point, relatively similar computations have been used for all component cycles. However, when the rotational component was to be determined for each cycle, it first had to be converted from degree readings into radian measurements.

The determination of the component forces was performed in the following manner. The force values for the x and z components were determined by multiplying the second derivative by the weight of the segment divided by G. The determination of the torque component was then performed by multiplying the moment of inertia of the segment times the second derivative of θ. These three processes were performed for each time interval throughout the activity cycle from beginning to end. A curve plot versus time was generated by the calling of subroutine CUPLOT for each of these forces and torque.

The power determination for the rectilinear components x and z, respectively, was accomplished by multiplying the force of the given segment by its own first derivative. The power for the rotational component θ was computed by multiplying the torque times

its first derivative. Again, these three processes were performed for each time interval throughout the activity cycle from beginning to end. For each activity cycle the power was printed out versus time in tabular form. A curve plot was generated for each power table by recalling subroutine CUPLOT.

The gravity gradient was developed from the equation of motion for the z component. This must be taken into consideration during the actual determination of the z component. The gravity gradient takes into account the changing effects of gravity in the z component acting upon the body and its segments. The gravity gradient as defined by this analysis is a unitless value. For each time period of the segment motion cycle, a gravity gradient value was determined. This determination was executed from the beginning to the end of the activity cycle.

In addition to the previous kinetic analysis, the power of potential energy was determined by multiplying the weight of the segment being examined by the gravity gradient times the first derivative of the equation of motion. This was performed for each time period and was repeated from the beginning to the end of the activity cycle. A table for time versus gravity gradient and time versus power of potential energy was printed out covering a complete activity cycle. For both the gravity gradient and power of potential energy determinations subroutine CUPLOT was called and a plot of their respective values versus a common base of time was plotted for a given activity cycle.

During the analysis of a pressure suited mode, a pressure suit moment distribution was taken into account for segments 3 through and including 6. This analysis was needed to determine the amount of work the test subject must perform in torque to overcome the resistance moment of the pressure suit.

The determination of the suit moment was developed in the following manner. Experimental data was obtained for the aforementioned segments for a given test subject in the pressure suited condition. A curve fit of the data obtained experimentally for the previously mentioned segments was made apart from the biomechanics program. Thus, for each test subject a set of coefficients for segments 3 through 6 in the pressure suited conditions was obtained from the curve fit of the experimental data and used for the analysis of tests conducted in the pressure suited mode. The coefficients obtained from these curve fits were then punched onto data cards. At the beginning of the execution of a complete biomechanical test cycle, a computer test was made to determine if this test was performed in a pressure suited mode. When the computer test was positive, the following procedure was carried out. After the computation was completed for the equation of motion for segment number 2 in the θ coordinate, its coefficients were redefined and stored in the computer memory for future use. Once the computation for the θ component was completed for segment number 3, its coefficients were redefined and saved from its equation of motion. Depending upon the results of another computer test, the corresponding coeffficients obtained from the curve fit of the experimental data were then subtracted from the coefficients of segment number 3. From this determination, a pressure suited moment was created for any time period during the cycle. This was achieved by multiplying the newly created moment by a given time period. This procedure was applied to the activity cycle from the beginning to the end. Then a table of time versus the pressure suit torque was printed out and a curve plot was generated by again calling subroutine CUPLOT. This was carried out from the beginning to the end of the activity cycle. The power developed by the pressure suit torque was determined by multiplying the pressure suit torque by the first derivative of the original equation of motion for the θ component of the segment being analyzed. Once again, a table and

curve plot were generated in terms of time from the beginning to the end of the activity cycle. The work expended by the pressure suited mode was determined by calling subroutine PSWK. This same procedure was carried out for segment number 4, except that its equation of motion coefficients were reduced by subtracting the coefficients saved from the segment number 3. Segment 5 was treated in a manner similar to segment 3. After the computation for segment 5 was completed, its equation of motion θ coefficients were redefined and stored in memory.

The pressure suit torque for Segment 6 was computed by reducing the equation of motion θ coefficients for Segment 6 by subtracting the coefficients for Segment 5. This again was carried out from the beginning to the end of the activity cycle.

After Segment 6 was completely analyzed, the work expended for segments 1 through 6 of the x, z, and θ components were added together. Also added to this quantity was the expended work from the power of potential energy and the work expended by the suit power, in the case of a pressure suited test. The sum of these additions were printed out to give the total body work expended by the test subject over a given activity cycle.

The instrument pack was treated as a separate segment apart from the body. Its computer analysis was conducted in the same manner as for any other segment in the shirt sleeve mode. The three components of x, z, and θ were taken into account and calculated as mentioned above. The total work of the instrument pack was added to the total body work. A print out of the total body weight plus the instrument pack was given.

SUBROUTINES

The main program contained two basic types of contributory programs: namely, subroutines (5 each) and function subroutines (3 each).

Subroutines

Subroutines, referenced by a call statement in the main program, return a specified source of information when called upon to do so. The subroutines used are briefly described in the paragraphs that follow.

Subroutine CURFIT. - The purpose of this subroutine program was to supply a single polynomial from the first through the tenth order supplied by the Least Square Curve Fit subroutine called LTSQS, each time CURFIT is called by the main program.

Subroutine LTSQS. - This subroutine developed the polynomial coefficients for a given equation that had to be developed. LTSQS utilized the technique of the Lease Square Curve Fit Method (Reference 12). The residuals to determine the polynomials were also developed in this subroutine.

Subroutine MATNIV. - This was a matrix inverter program used to solve the residual equations required by LTSQS. MATNIV transmitted its data to LTSQS, which in turn developed the polynomials for CURFIT. LTSQS then transmitted the required polynomials to CURFIT which delivered the equation of motion to the main program.

This process was repeated for first through the tenth order equations each time CURFIT was called by the main program. The polynomial showing the least amount of error was used. The coefficients for this polynomial were then returned from CURFIT to the main program showing the absolute error, the overall percentage error, and degree of the equation returned.

Subroutine CUPLOT. - The following procedure took place when CUPLOT was called by the program:

(1) The abscissa title of time was labeled.

(2) The ordinate title, depending on what coordinate, and derivation being executed by the main program was determined and labeled.

(3) The main heading was determined and labeled as shown in the previous step.

(4) CUPLOT analyzed the data to be plotted versus time and set up the graphic grid system based on its determination.

(5) The data was then plotted versus a common base of time.

The above operations were recorded on magnetic tape by the 7090 computer to be processed later by the SC 4020 Plotter. The SC 4020 Plotter transmitted the data via the magnetic tape onto an oscilloscope displaying the grid system and the plotted data. A 35 mm film picture was taken when the graph was displayed on the scope. Subsequently, an enlarged 8-1/2 x 11 inch graph of the activity was developed.

Subroutine ISIA. - This subroutine was an integration program based on Simpson's Integration Rule (Reference 12). Data for this subroutine was supplied by a function routine. These function routines may be either WORK, PAPE, or PSWK. ISIA continued to integrate until it converged to within three significant figures to the right of the decimal point. ISIA was capable of converging to a greater degree of accuracy, but for the purposes of this program the convergence limit was set at three. Based on the results of ISIA, this operation required anywhere from 4 interval integrating steps up to 1000 integrating steps. When the convergence requirement of three significant figures was met, the result was returned to the main program.

Function Subroutines

A function subroutine was referenced by an arithmetic expression containing the function's name. It returns a single valued result to the calling program (ISIA) for every time interval (T). The function subroutines used by the subroutine ISIA were as follows.

Function subroutine PSWK. - This program calculated the values of power, which were called by ISIA to integrate the power of a segment, and arrived at the absolute work expended by the segment being analyzed over a given time cycle. PSWK was used only for segments three through six for the rotational component when the pressure suit mode was being examined.

Function subroutine PAPE. - PAPE calculated the gravity gradient and power of potential energy values for ISIA. From PAPE, ISIA integrated the power of potential

energy and arrived at the work expended by the segment over a given time cycle. PAPE was used only during the determination of the z component.

Function subroutine WORK. - WORK calculated the values for the first and second derivatives and multiplied these values by the mass or moment of inertia of the segment depending upon which component of the given segment was being examined. The power value for the x or θ component was called by ISIA and the absolute work of the segment over a given time cycle was determined and then returned to the main program. During the determination of the z component, the gravity gradient was created which resulted in the acceleration projected in the z plane. A computer test was then made to determine the magnitude of the second derivative of z at a given time. When the second derivative exceeded the value of the projected z acceleration computed previously, the difference was used to determine the net force applied in the z plane. When the second derivative of z did not exceed the projected acceleration, the resulting z force remained the same in the curve plots and the print outs for time versus force and power. However, when setting up WORK for the integration of the power in the z component by ISIA, the negative forces were not taken into consideration.

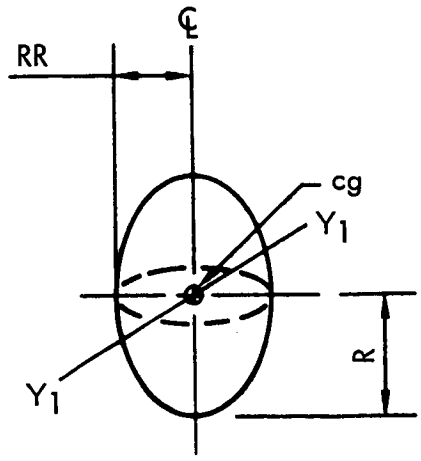
The net forces and powers discussed earlier in the case where the second derivative of z exceeded the projected acceleration, the integration of power to determine the work expended did include the portion produced by the net forces and powers which was then returned to the main program.

MOMENT OF INERTIA PROGRAM (IYY)

A numerical value defined as Moment of Inertia is derived from the following program which is separate and apart from the main program. It is introduced as IYY. The moments of inertia about the y axis determined herein are used as input data to the main program.

The Segment Mass Moment of Inertia (IYY) program was based upon the following equations. Equations E1, E8 (Reference 13), Equations E2-E7 (Reference 14), and Equation E10 (Reference 15) were modified for their application to this program.

Segment No. 1, Head and Neck, was treated as a right circular ellipsoid of revolution as shown in Figure E1. The neck could have been expressed in terms of a frustum of a cone separately, however this assumption would have been incorrect for the pressure suited operation.



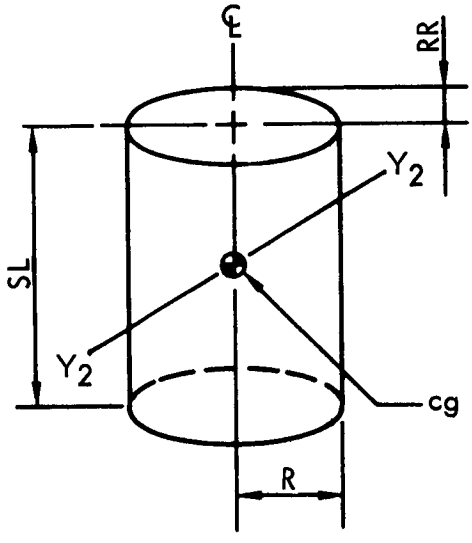
RR = smaller radius, ft. (cm)
R = larger radius, ft. (cm)
SM = mass of segment, slugs (kg sec^2/cm)

Figure E1. - Model of head

The equation (IYY) for Segment No. 1 is:

$$SIYY1 = 0.2\ SM\ (R^2 + RR^2),\ \text{Slug-ft}^2\ (\text{kg cm}^2) \tag{E1}$$

Segment No. 2, Trunk, was treated as a right elliptical cylinder as shown in Figure E2.



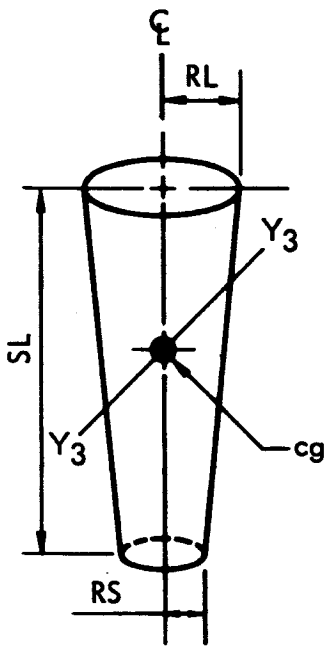
R = .5 segment breadth, ft. (cm)
RR = .5 segment depth, ft. (cm)
SL = segment length, ft. (cm)
SM = mass of segment, slugs (kg sec^2/cm)

Figure E2. - Model of trunk

The equation for Segment No. 2 is:

$$SIYY2 = \frac{SM}{12} \left[3\,(RR)^2 + (SL)^2 \right] \text{ slugs ft}^2 \text{ (kg cm}^2\text{)} \tag{E2}$$

Segment No. 3, the Upper Arm, was treated as a frustum of a right circular cone as shown in Figure E3.



RL = larger end radius, ft. (cm)
RS = smaller end radius, ft. (cm)
SL = segment length, ft. (cm)
D = density of the segment, lb/ft^3 (kg/cm^3)
SM = mass of segment, slugs (kg sec^2/cm)

Figure E3. - Model of upper arm

The equation (IYY) for a frustum of a right circular cone is as follows:

$$U = RS/RL \tag{E3}$$

$$UU = (1 + U + U^2) \tag{E4}$$

$$A = \frac{9}{20\ PI} \left[\frac{UU + U^3 + U^4}{UU^2} \right] \tag{E5}$$

$$C = \frac{3}{80} \left[\frac{1 + 4U + 10U^2 + 4U^3 + U^4}{UU^2} \right] \tag{E6}$$

$$SIYY = SM \left[A\left(\frac{SM}{DxSL}\right) + C \times SL^2 \right], \text{ slug-ft}^2 \text{ (kg cm}^2\text{)} \tag{E7}$$

The equation for the mass moment of inertia for the Upper Arm is SIYY3 = SIYY.

Segment No. 4, Lower Arm and Hand, was treated as a combination of a frustum of a right circular cone and a sphere, and are correspondingly shown in Figure E4.

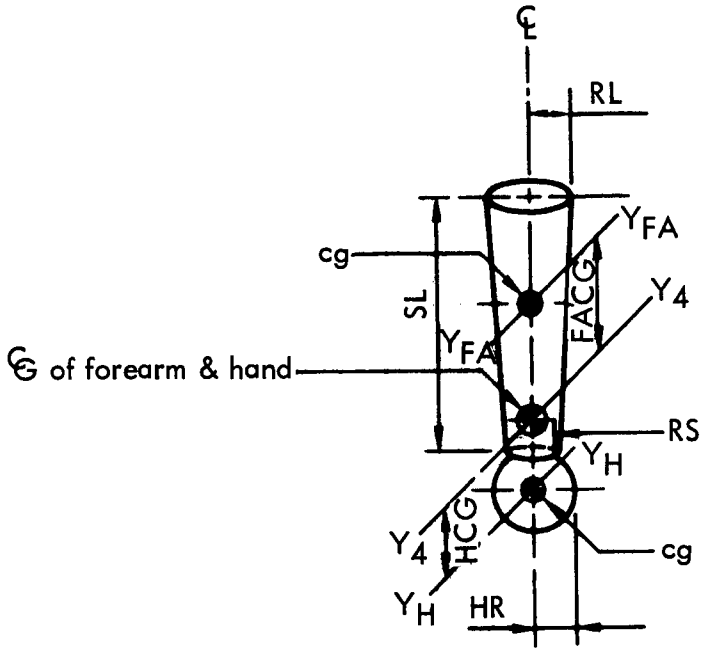


Figure E4. - Model of forearm and hand

The moment of inertia of the forearm SIYYFA was treated as illustrated in Segment No. 3, (Eq E3-E7).

The (IYY) for the hand was determined as follows:

SM = Mass of the forearm, slugs (kg sec^2/cm)

SMH = Mass of the hand, slugs (kg sec^2/cm)

HR = First radius, ft (cm)

SIYYH = $.4SM(HR)^2$, slug-ft^2 (kg cm^2)

FAC.G. = distance from the C.G. of the forearm to the C.G. of Segment No. 4.

HC.G. = distance from the C.G. of the hand to the C.G. of Segment No. 4.

FAC.G. and HC.G. are predetermined values and are both entered as data.

The moment of inertia for Segment No. 4 is

$$SIYY4 = SIYYFA + (SMxFAC.G.^2) + SIYYH + (SMHxHC.G.^2), \text{slug-ft}^2 \ (\text{kg cm}^2) \quad (E8)$$

Segment No. 5, Thigh, was also treated as a frustum of a right circular cone as indicated in Figure E5.

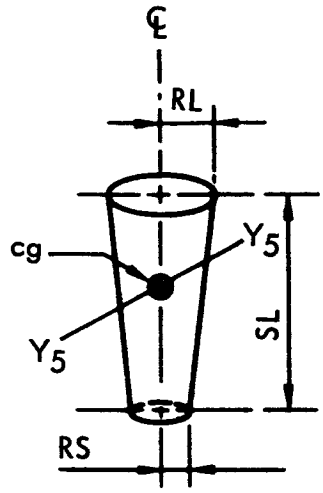


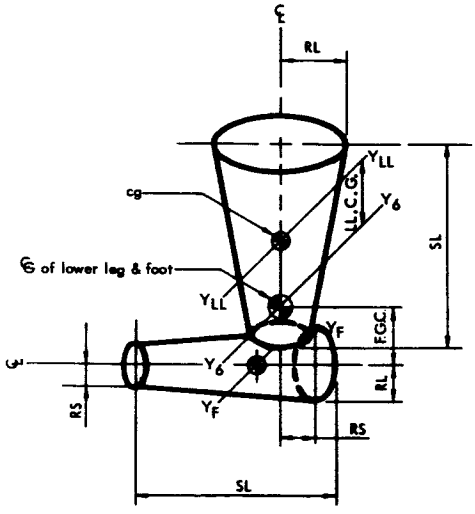
Figure E5. - Model of thigh

The Moment of Inertia for the thigh, SIYY5, was thus treated in the same manner as that for Segment 3 (Eq E7).

Segment No. 6, Lower Leg and Foot, was treated as a combination of the two separate frustums of right circular cones shown in Figure E6.

The equations used for Segment 3 were again employed for both a frustum for the lower leg, SIYYLL, and a frustum for the foot, SIYYF (Eq E3-E7).

The distances LL. C. G. and F. C. G. were predetermined values and consequently treated as data. In determining the combined mass moments of inertia, SIYY6, the combination of the lower leg and foot is treated in the same manner as that shown for the determination of Segment No. 4 (Eq E8).



SML = Segment mass of lower leg, slugs (kg sec^2/cm)

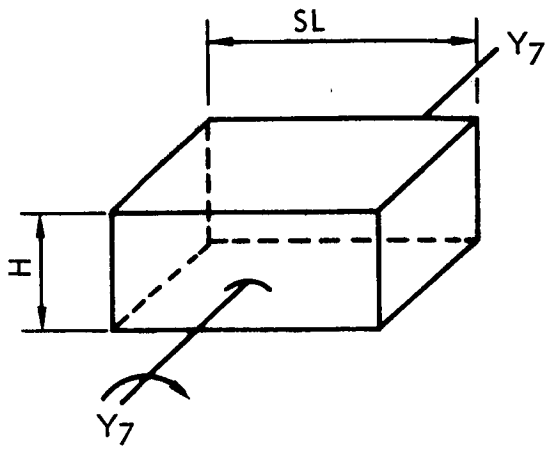
SMF = Segment mass of foot, slugs (kg sec^2/cm)

Figure E6. - Model of lower leg and foot

The moment of inertia for Segment No. 6 is

$$SIYY6 = SIYYLL + (SMLxL.L.C.G.^2) + SIYYF + (SMFxF.C.G.^2), \text{ slug-ft}^2 \text{ (kg cm}^2) \quad (E9)$$

Segment No. 7, Instrument Pack, where the mass moment of inertia was treated as that for a prism (see Figure E7).



H = height, ft. (cm)
SL = length, ft. (cm)
SM = segment mass, slugs (kg sec^2/cm)

Figure E7. - Model of instrument pack

$$SIYY7 = SM\left[\frac{(.5SL)^2}{3} + \frac{H^2}{12}\right], \text{ slug-ft}^2 \text{ (kg cm}^2) \quad (E10)$$

(Reference 15)

A mass moment of inertia (IYY) program notation record is listed in Table E1 which explains each field length of the input data. Accompanying the notation record for (IYY) is a general purpose key punch form showing the layout of this data to be entered onto the punched cards (Figure E8). A listing of the (IYY) program is also given in Figure E9.

TABLE E1.- IYY COMPUTER PROGRAM NOTATION RECORD

ITEM	UNITS	B(I) SHIRT-SLEEVE		P(I) PRESSURE SUIT	INPUT FIELD LENGTH
Segment No. 1 - Head and Neck					
Head and helmet weight	(kg.)	B(1)	=	P(2)	F 6.2
Helmet, small circumference	(cm.)	B(2)	=	P(1)	F 6.2
Length from top of helmet to middle of neck	(cm.)	B(3)	=	P(28)	F 6.2
Segment No. 2 - Trunk					
Trunk weight	(kg.)	B(4)	=	P(4)	F 6.2
Chest breadth	(cm.)	B(5)	=	P(3)	F 6.2
Trunk length	(cm.)	B(6)			F 6.2
*Trunk depth, stated below, B(38)					
Segment No. 3 - Upper Arm					
Upper arm weight	(kg.)	B(7)	=	P(5)	F 5.2
Upper arm length	(cm.)	B(8)			F 6.2
Larger end circumference	(cm.)	B(9)	=	P(6)	F 6.2
Smaller end circumference	(cm.)	B(10)	=	P(7)	F 6.2
Density of upper arm	(kg./cm^3)	B(11)			F 5.2
Segment No. 4 - Forearm and Hand					
Forearm weight	(kg.)	B(12)	=	P(10)	F 5.2
Elbow circumference	(cm.)	B(13)	=	P(8)	F 6.2
Wrist circumference	(cm.)	B(14)	=	P(9)	F 6.2
Forearm length	(cm.)	B(15)			F 6.2
Density of forearm	(kg./cm^3)	B(16)			F 5.2
Hand weight	(kg.)	B(17)	=	P(11)	F 6.2
Fist circumference	(cm.)	B(18)	=	P(12)	F 6.2
Forearm C.G. to segment C.G., length	(cm.)	B(19)			F 6.2
Hand C.G. to segment C.G., length	(cm.)	B(20)			F 6.2
Segment No. 5 - Thigh					
Larger end circumference	(cm.)	B(21)	=	P(13)	F 6.2
Smaller end circumference	(cm.)	B(22)	=	P(14)	F 6.2
Density of thigh	(kg./cm^3)	B(23)			F 5.2
Thigh weight	(kg.)	B(24)	=	P(15)	F 6.2
Thigh length	(cm.)	B(25)			F 6.2

TABLE E1.- IYY COMPUTER PROGRAM NOTATION RECORD (Continued)

ITEM	UNITS	B(I) SHIRT-SLEEVE		P(I) PRESSURE SUIT	INPUT FIELD LENGTH
Segment No. 6 - Lower Leg and Foot					
Leg weight	(kg)	B(26)	=	P(16)	F 5.2
Ankle circumference	(cm.)	B(27)	=	P(17)	F 6.2
Knee circumference	(cm.)	B(28)	=	P(18)	F 6.2
Density of lower leg	(kg./cm^3)	B(29)			F 5.2
Length of lower leg	(cm.)	B(30)			F 6.2
Foot weight	(kg.)	B(31)	=	P(19)	F 6.3
Foot length	(cm.)	B(32)	=	P(20)	F 6.2
Larger end circumference	(cm.)	B(33)	=	P(21)	F 6.2
Smaller end circumference	(cm.)	B(34)	=	P(22)	F 6.2
Lower leg C.G. to segment C.G., length	(cm.)	B(35)			F 6.2
Foot C.G. to segment C.G., length	(cm.)	B(36)			F 6.2
Density of foot	(kg./cm^3)	B(37)			F 5.2
*Trunk depth (part of segment #2)	(cm.)	B(38)	=	P(23)	F 6.2
Subject letter				P(24)	A 1
Month				P(25)	A 2
Day				P(26)	A 2
Year				P(27)	A 2
Segment No. 7 - Instrument Pack #1					
Blank	Unitless			P(29)	F 5.1
Height of pack	(cm.)			P(30)	F 5.1
Length of pack	(cm.)			P(31)	F 5.1
Weight of pack	(kg.)			P(32)	F 5.1
Segment No. 7 - Instrument Pack #2					
Blank	Unitless			P(33)	F 5.1
Height of pack	(cm.)			P(34)	F 5.1
Length of pack	(cm.)			P(35)	F 5.1
Weight of pack	(kg.)			P(36)	F 5.1
Segment No. 7 - Instrument Pack #3					
Blank	Unitless			P(37)	F 5.1
Height of pack	(cm.)			P(38)	F 5.1
Length of pack	(cm.)			P(39)	F 5.1
Weight of pack	(kg.)			P(40)	F 5.1

KEY PUNCH FORM - GENERAL PURPOSE

Form 20-708 (R.1-60)

JOB TITLE	ENGINEER	PAGE
MASS MOMENT OF INERTIA PROGRAM	K. FORSEN	OF

NC CODE	DIV.	SALES ORDER	DASH	EWO NO.	FOR ORGN. NO.	ANALYST	DATE
				30 S 07772	2473		

NOTE:

1. All figures are right adjusted
2. B(I) is shirtsleeve data
3. P(I) is pressure suit and test subject data

B(1)	B(2)	B(3)	B(4)	B(5)	B(6)	B(7)	B(8)	B(9)	B(10)	B(11)	B(12)	B(I)
B(13)	B(14)	B(15)	B(16)	B(17)	B(18)	B(19)	B(20)	B(21)	B(22)	B(23)	B(24)	B(I)
B(25)	B(26)	B(27)	B(28)	B(29)	B(30)	B(31)	B(32)	B(33)	B(34)	B(35)	B(36)	B(I)
B(37)	B(38)											B(I)

P(1)	P(2)	P(3)	P(4)	P(5)	P(6)	P(7)	P(8)	P(9)	P(10)	P(11)	P(12)	P(I)
P(13)	P(14)	P(15)	P(16)	P(17)	P(18)	P(19)	P(20)	P(21)	P(22)	P(23)		P(I)
P(28)	P(29)	P(30)	P(31)	P(32)	P(33)	P(34)	P(35)	P(36)	P(37)	P(38)	P(39)	P(40)	P(I)

P(24) P(25) P(26) P(27)

Figure E8. - Format layout

```
$IBFTC IYY      REF
      DIMENSION B(45),P(45)
   10 FORMAT(1H624X71HDETERMINATION OF SEGMENT MASS MOMENT OF INERTIA (I
     1YY), 10-65, K. FORSEN)
   15 FORMAT(1H113HTEST SUBJECT A1,39H  DATE SEGMENT MEASUREMENTS WERE T
     1AKEN A2,1H-A2,1H-A2///)
   25 FORMAT(1H 50X16HSHIRT SLEEVE IYY)
   30 FORMAT(6F6.2,F5.2,3F6.2,2F5.2/3F6.2,F5.2,6F6.2,F5.2,F6.2/F6.2,F5.2
     1,2F6.2,F5.2,F6.2,F6.3,5F6.2/F5.2,F6.2)
   32 FORMAT(1HL37HSEGMENT NO. 7, INSTRUMENT PACK 1 IYY=1PE14.6,21H, (KG
     1.-SEC.*SEC.-CM.))
   35 FORMAT(1H037HSEGMENT NO. 7, INSTRUMENT PACK 2 IYY=1PE14.6,21H, (KG
     1.-SEC.*SEC.-CM.))
   39 FORMAT(1H037HSEGMENT NO. 7, INSTRUMENT PACK 3 IYY=1PE14.6,21H, (KG
     1.-SEC.*SEC.-CM.))
   40 FORMAT(4F6.2,F5.2,4F6.2,F5.2,2F6.2/3F6.2,F5.2,2F6.2,F6.3,4F6.2,A1,
     13A2/F6.2,11F5.1)
   60 FORMAT(1H033HSEGMENT NO. 1, HEAD AND NECK IYY=1PE14.5,21H, (KG.-SE
     1C.*SEC.-CM.))
   65 FORMAT(1H025HSEGMENT NO. 2, TRUNK IYY=1PE14.5,21H, (KG.-SEC.*SEC.-
     1CM.))
   68 FORMAT(1H028HSEGMENT NO. 3 UPPER ARM IYY=1PE14.6,21H, (KG.-SEC.*SE
     1C.-CM.))
   70 FORMAT(1H038HSEGMENT NO. 4, LOWER ARM AND HAND IYY=1PE14.6,21H, (K
     1G.-SEC.*SEC.-CM.))
   72 FORMAT(1H025HSEGMENT NO. 5, THIGH IYY=1PE14.6,21H, (KG.-SEC.*SEC.-
     1CM.))
   74 FORMAT(1H038HSEGMENT NO. 6, LOWER LEG AND FOOT IYY=1PE14.6,21H, (K
     1G.-SEC.*SEC.-CM.)//)
   76 FORMAT(1HL51X17HPRESSURE SUIT IYY)
      WRITE(6,10)
  105 DO16 I=1,38
   16 B(I)=0.0
      DO18 I=1,40
   18 P(I)=0.0
      READ(5,30)(B(I),I=1,38)
      READ(5,40)(P(I),I=1,39)
      WRITE(6,15)(P(24),P(25),P(26),P(27))
      WRITE(6,25)
      KK=0
C     HEAD AND NECK IYY DETERMINATION
 125  RR=B(2)/6.283
      R=.5*B(3)
      SIYY1=(.2*B(1)/980.67)*(R**2+RR**2)
      WRITE(6,60)SIYY1
C     TRUNK IYY DETERMINATION
      R=.5*B(5)
      RR=.5*B(38)
      SM=B(4)/980.67
      SL=B(6)
      SIYY2=(SM/12.)*(3.*(RR**2)+SL**2)
```

Figure E9. - IYY listing

```
      WRITE(6,65)SIYY2
C     UPPER ARM IYY DETERMINATION
      K=1
      SM=B(7)/980.67
      D=B(11)
      RS=B(10)/6.283
      RL=B(9)/6.283
      SW=B(7)
      SL=B(8)
      GOTO 150
   80 SIYY3=SIYY
      WRITE(6,68)SIYY3
      K=2
C     FORARM IYY DETERMINATION
      SM=B(12)/980.67
      D=B(16)
      RS=B(14)/6.283
      SL=B(15)
      RL=B(13)/6.283
      SW=B(12)
      GOTO 150
   81 SIYYFA=SIYY
C     HAND IYY DETERMINATION
      SMH=B(17)/980.67
      HR=B(18)/6.283
      SIYYH=.4*SMH*(HR**2)
C     FORARM AND HAND IYY DETERMINATION
      SIYY4=((SIYYFA+SM*(B(19)**2))+(SIYYH+SMH*(B(20)**2)))
      WRITE(6,70)SIYY4
      K=3
C     THIGH IYY DETERMINATION
      SW=B(24)
      D=B(23)
      RS=B(22)/6.283
      RL=B(21)/6.283
      SL=B(25)
      SM=B(24)/980.67
      GOTO 150
   82 SIYY5=SIYY
      WRITE(6,72)SIYY5
      K=4
C     LOWER LEG IYY DETERMINATION
      SML=B(26)/980.67
      D=B(29)
      RS=B(27)/6.283
      RL=B(28)/6.283
      SL=B(30)
      SM=B(26)/980.67
      GOTO 150
   83 SIYYLL=SIYY
      K=5
```

Figure E9. - IYY listing (continued)

```
C     FOOT IYY DETERMINATION
      SMF=B(31)/980.67
      D=B(37)
      RS=B(34)/6.283
      RL=B(33)/6.283
      SL=B(32)
      SM=B(31)/980.67
      GOTO 150
   84 SIYYF=SIYY
C     LOWER LEG AND FOOT IYY DETERMINATION
      SIYY6=((SIYYLL+SML*(B(35)**2))+(SIYYF+SMF*(B(36)**2)))
      WRITE(6,74)SIYY6
      IF(KK.EQ.1.AND.P(29).EQ.0.)GOTO 105
      IF(KK.EQ.1.AND.P(29).GT.0.)GOTO 174
      WRITE(6,76)
      B(1)=P(2)
      B(2)=P(1)
      B(3)=P(28)
      B(4)=P(4)
      B(5)=P(3)
      B(7)=P(5)
      B(9)=P(6)
      B(10)=P(7)
      B(12)=P(10)
      B(13)=P(8)
      B(14)=P(9)
      B(17)=P(11)
      B(18)=P(12)
      B(21)=P(13)
      B(22)=P(14)
      B(24)=P(15)
      B(26)=P(16)
      B(27)=P(17)
      B(28)=P(18)
      B(31)=P(19)
      B(32)=P(20)
      B(33)=P(21)
      B(34)=P(22)
      B(38)=P(23)
      KK=1
      GOTO 125
  150 U=RS/RL
      UU=1.+U+U**2
      A=.14324*((UU+U**3+U**4)/UU**2)
      C=.0375*((1.+4.*U+10.*U**2+4.*U**3+U**4)/UU**2)
      SIYY=SM*((A*(SM/D*SL))+C*SL**2)
      GOTO (80,81,82,83,84),K
  174 KK=2
      SM=P(32)/980.67
      SL=P(31)
      H=P(30)
      GOTO 175
```

Figure E9. - IYY listing (continued)

```
 31 SM=P(36)/980.67
    SL=P(35)
    H=P(34)
    KK=3
    GOTO 175
 34 SM=P(39)/980.67
    SL=P(38)
    H=P(37)
    KK=4
175 SL=.5*SL
    SIYY=SM*((SL**2/3.)+(H**2/12.))
    GOTO (174,213,214,215),KK
213 SIYY7=SIYY
    WRITE(6,32)SIYY7
    GOTO 31
214 SIYY8=SIYY
    WRITE(6,35)SIYY8
    GOTO 34
215 SIYY9=SIYY
    WRITE(6,39)SIYY9
    GOTO 105
    END
```

Figure E9. - IYY listing (continued)

MATHEMATICAL DISCUSSION

The development of the equation of motion was based upon the Principle of Least Squares, as mentioned under Subroutine LTSQS. This principle indicated that the best or most probable value obtainable from a set of measurements or observations of equal precision (in this report, data points) is that value for which the sum of the squares of the errors is a minimum.

In the discussion of Subroutine LTSQS earlier, residuals were also mentioned. A residual is the difference between the most probable measurement and any particular measurement of data for a given data measurement (Reference 12).

Two to three data points were read before and after the activity cycle for each segment. These data points and the data points inside the activity cycle were the total number of points analyzed by the computer in arriving at the equation of motion. Only the data points at time zero, inside the activity cycle and the last data point which is the data reading at the end of the activity cycle was used in the results of the biomechanical analysis. The data points outside the activity cycle were needed to prevent a vector curl at the ends of the curve fitted equation of motion. The vector curl being a characteristic of the Method of Least Squares.

The cyclic effects that appeared in the first and second derivatives of the equation of motion did not always act as a true cycle. This was due to the noise in the recorded data. When the differentiation of this noise was attempted the errors (noise) in the data were magnified and thus a true time cycle did not occur. The difficulty can be illustrated by the fact that even a sudden change in the force will cause but a slight disturbance in the displacement. Smoothing of the original data by the Method of Least Squares tended to lessen the effects of these errors, but the second derivative may have been altered to a very noticeable amount. This effect of noise upon the derivative of a function showed that noise did not share with ordinary analytical functions the property of smoothness and differentiability.

A suggestion for improving the reliability of the second derivative would be to develop the equation of motion by employing Fourier Series. The use of Fourier Series does not treat the data in the same manner as the Method of Least Squares. It considers the entire set of data as one unified whole, which tends to separate out the effects of noise. The Method of Least Squares treats each individual data point with respect to its neighbor readings (Reference 16).

ARRANGEMENT OF PROGRAM AND DATA CARDS FOR COMPUTER ANALYSIS

This section explains the sequence of the control cards used for loading of the program and the subsequent input data into the computer; for the biomechanical analysis of the data reduced from a complete activity cycle for a given test (See Figure E10).

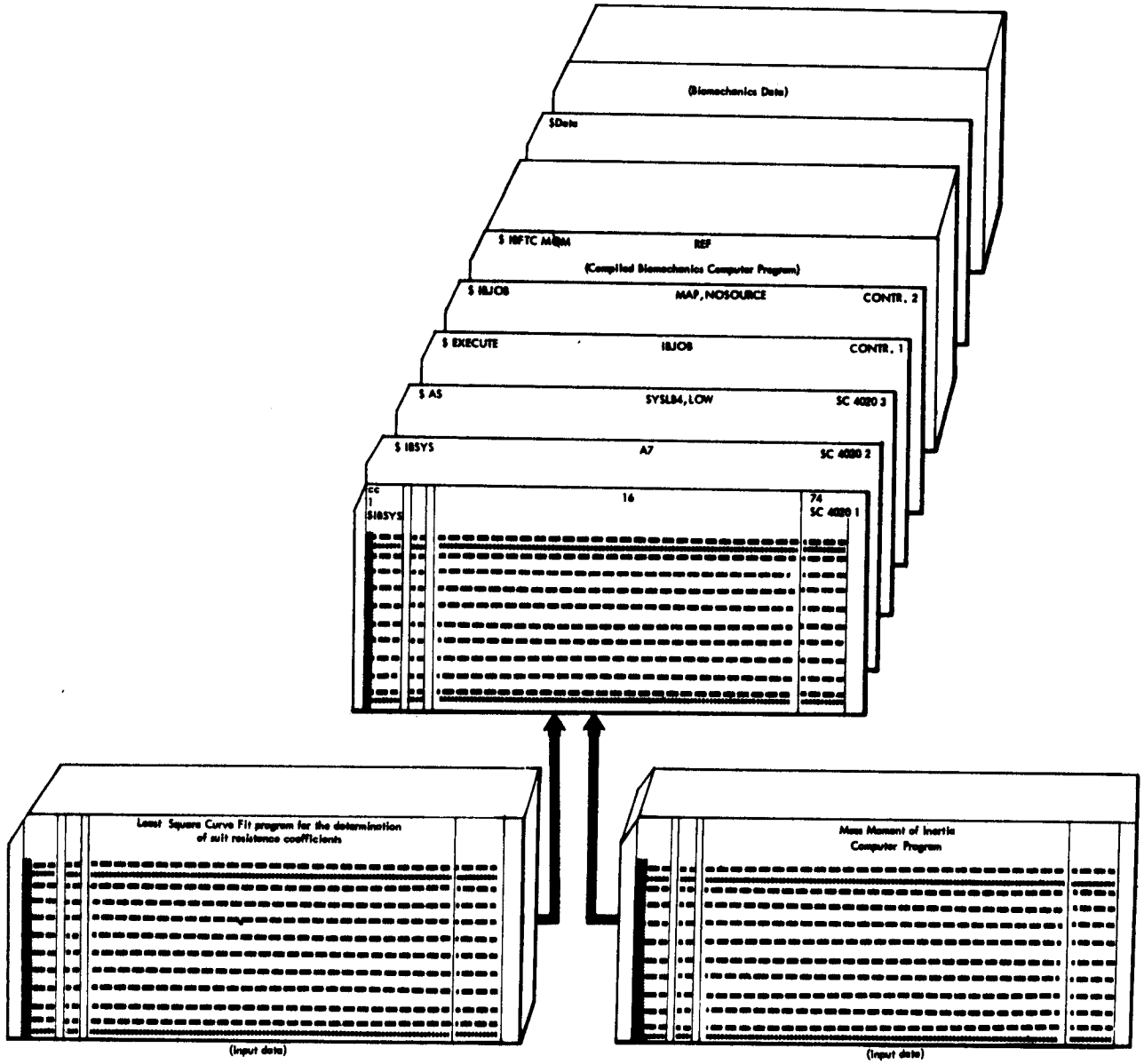


Figure E10. - Arrangement of card sequence for computer processing

The computer program notation record is listed in Table E2 explaining each field length of the input data. Accompanying the notation record is a general purpose key punch form showing the layout of this data to be entered on the punched cards (See Figure E11). A flow chart of the biomechanical motion analysis program is given in Figure E12. A listing (Figure E13) is given followed by a typical test printout (Figure E14). This printout for test No. C-3007-2 corresponds to the curve plots included in the this analysis.

TABLE E2. MOM COMPUTER PROGRAM NOTATION RECORD

DATA CARD CODE	ITEM	INPUT FIELD LENGTH
T (I)	Time (seconds, readings)	F 12.0
X (I)	X (X, coordinate readings, Cm.)	F 12.0
X (I)	Z (Z, coordinate readings, Cm.)	F 12.0
X (I)	TH (Theta, angle readings in degrees)	F 12.0
C (1)	X, letter	A 1
C (2)	Z, letter	A 1
M (I)	Number of points used	I 5
P (I)		
P(1)	Moment of Inertia of Mass (I_o), of segment, Kg cm^2	F 7.3
P(2)	Weight of segment, Kg	F 7.2
P(3)	Subject letter	A 1
P(4)	Test No. (xxxx)	A 4
P(5)	Baseline	A 1
P(6)	Month	A 2
P(7)	Day	A 2
P(8)	Year	A 2
P(9)	Segment name, (number)	F 2.0
P(10)	Minimum degree, (Min. degree equation fitted)	F 2.0
P(11)	Maximum degree, (Max. degree equation fitted)	F 2.0
P(12)	NOPT, (type of curve fit used)	F 2.0
P(13)	N, (total number of points read in)	F 2.0
P(14)	NS, (first value used in curve fit)	F 2.0
P(15)	NL, (last value used in curve fit)	F 2.0
P(16)	NS1, (first curve fit value used for % of error)*	F 2.0
P(17)	NL1, (last curve fit value used for % of error)*	F 2.0
P(18)	Cycle length, (cm)	F 5.2
P(19)	Activity cycle frequency, (min)	F 5.2
P(20)	Activity cycle duration, (sec)	F 5.3
P(21)	Test duration time, (min.)	F 4.1

*Same numerical value as P(14) and P(15) respectfully

KEY PUNCH FORM - GENERAL PURPOSE

Form 20-708 (R.1-60)

JOB TITLE	ENGINEER	PAGE
MAN'S PHYSICAL CAPABILITIES ON THE MOON PROGRAM (MOM)	K. Forsen	OF
A/C CODE / DIV. / SALES ORDER / DASH — EWO NO. 30 S 07772 — FOR ORGN. NO. 2473	ANALYST	DATE

1. Coordinate Letters: T, (Time, sec.)
   X or Z, (Ordinate, cm.)
   R, (Rotation, degrees)
2. All figures are right adjusted.

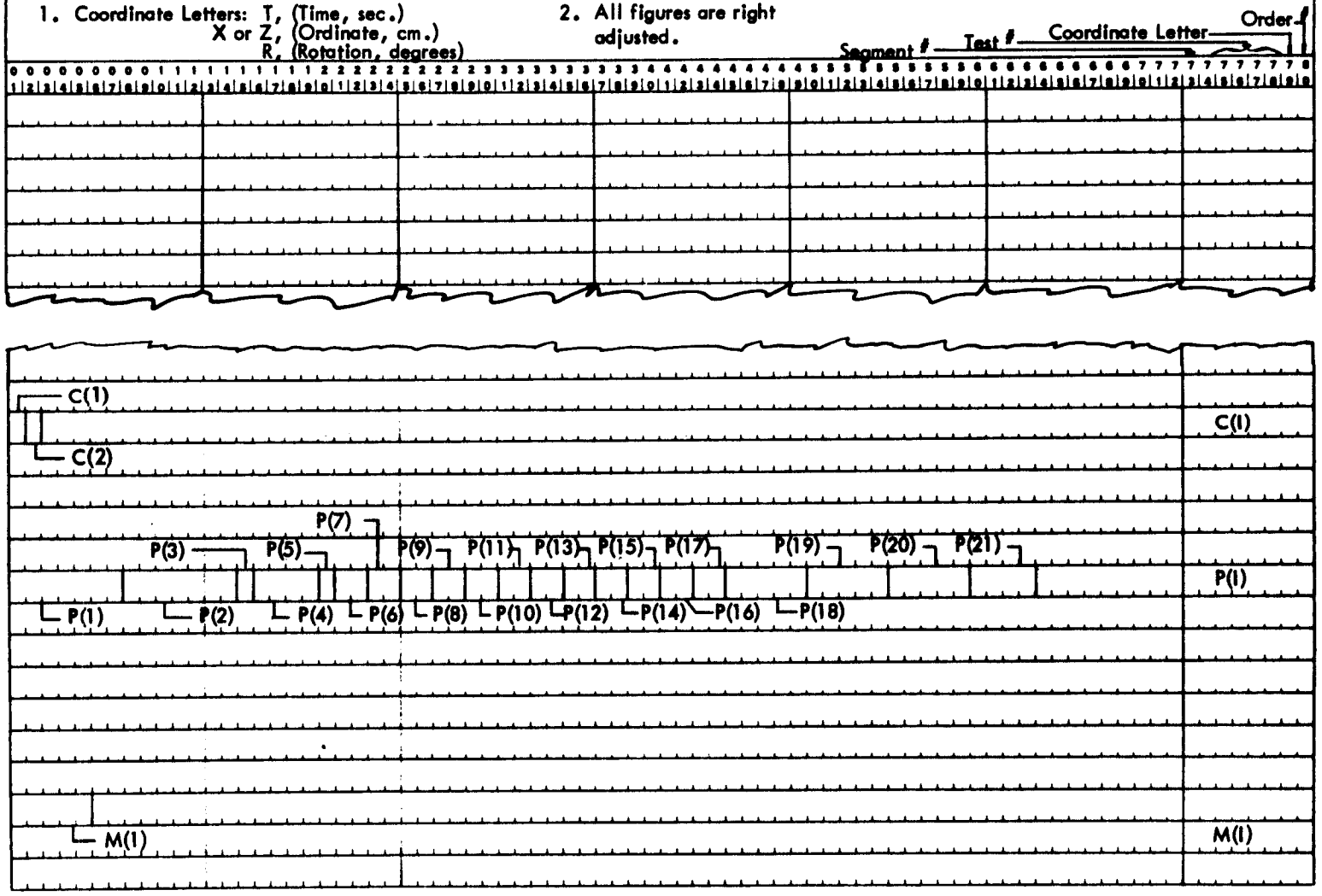


Figure E11. - MOM control data card layout

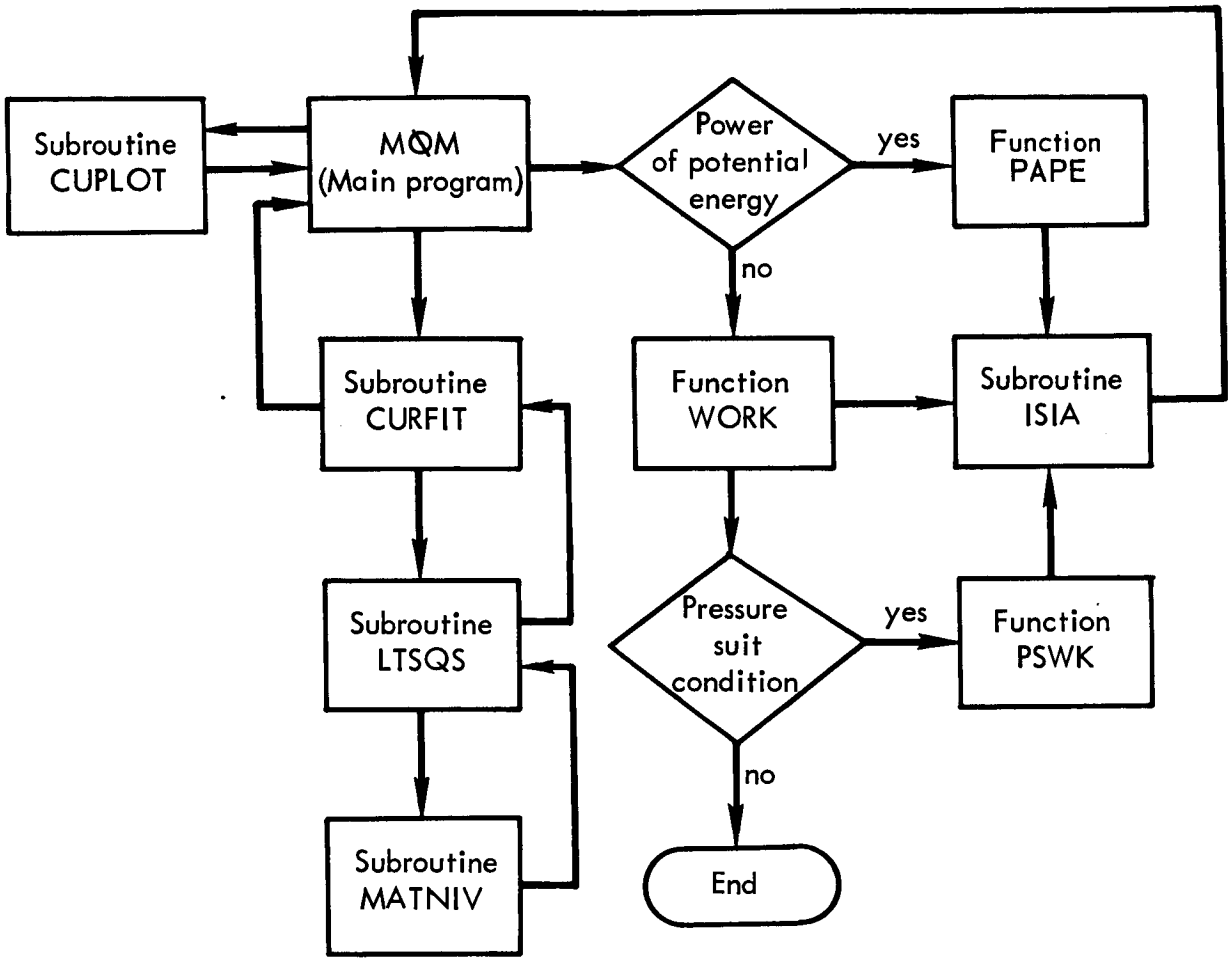


Figure E12. - Biomechanics motion analysis flow chart

```
      DIMENSIONP(30),T(50),X(50),Y(50),TH(50),A(11),B(50),FDER(50),SDER(
     150),F(50),PR(50),C(20),WK(50),ZN(50),Z(11),ZZ(11),W(200),WAKUX(10)
     2,WAKUZ(10),WAKUTH(10),WAKUPE(10),WAKUP(10),GR(50),PPE(50),R(2,4,11
     3),TM(50),PS(50),AB(11),AC(11),THB(50),AD(11)
      COMMON MINDEG,MAXDEG,NQPT,N  ,NS,NL,NS1,NL1,P,A,R,NN,AC,AB,K,KVFPS
     1,AD
      DATA T1,T2,T3,T4,T5,T6,T7/4H2000,4H4999,4H7000,4H8999,4H6000,4H300
     10,4H8000/
      EXTERNAL WORK
      EXTERNAL PAPE
      EXTERNAL PSWK
      READ (5,101)C(1),C(2)
      WRITE(6,8)
      BOB=0.0
  200 READ(5,2)(P(I),I=1,21)
      IF(P(4).GE.T6.AND.P(4).LE.T2.OR.P(4).GE.T7.AND.P(4).LE.T4)GOTO 600
      GOTO 500
  600 IF(BOB.EQ.P(3))GOTO 500
      DO48 KR=1,4
   48 READ(5,3)(R(1,KR,JR),JR=1,11)

      BOB=P(3)
  500 CONTINUE
      K=P(9)
      NN=1
    4 READ(5,1)M
      READ(5,3)(T(I),I=1,M)
      KI=P(9)
      IF(K.NE.1)GOTO 201
      WRITE(6,7)(P(I),I=3,5),P(21),(P(I),I=6,8),P(19),P(20),P(18)

    1 FORMAT(6I5)
    2 FORMAT(F7.3,F7.2,A1,A4,A1,3A2,9F2.0,2F5.2,F5.3,F4.1)
    3 FORMAT(6F12.0)
    5 FORMAT(2A1)
    6 FORMAT(1H065HPOWER OF POTENTIAL ENERGY=G-GRADIENT*G*MASS*DZ/DT  (K
     1G.-CM./SEC.))
    7 FORMAT(1H 9HTEST NO. A1,1H-A4,1H-A1,28H  TEST DURATION TIME (MIN.)
     1 F4.1,7H  DATE A2,1H-A2,1H-A2,27H  ACTIVITY CYCLE FREQUENCY F7.2,5
     2H/MIN./1H 29HACTIVITY CYCLE DURATION TIME F7.3,29H SEC.  ACTIVITY
     3CYCLE LENGTH F7.2,4H CM.//)
    8 FORMAT(1H68X101HBIOMECHANICS MOTION ANALYSIS FOR THE STUDY OF MANS
     1 PHYSICAL CAPABILITIES ON THE MOON, 9-65, K. FORSEN/1H1)
    9 FORMAT(1H044HWORK P-SUIT TORQUE= INTERGRATION OF POWER TH)
  201 GOTO(11,12,13,14,15,16,17),K
   11 WRITE(6,21)
   21 FORMAT(1H028HSEGMENT-NO. 1, HEAD AND NECK)
      GO TO 30
   12 WRITE(6,22)
   22 FORMAT(1H020HSEGMENT-NO. 2, TRUNK)
      GO TO 30
   13 WRITE(6,23)
```

Figure E13. - Biomechanics motion analysis program (MOM) listing

```
23 FORMAT(1H024HSEGMENT-NO. 3, UPPER ARM)
   GO TO 30
14 WRITE(6,24)
24 FORMAT(1H033HSEGMENT-NO. 4, LOWER ARM AND HAND)
   GO TO 30
15 WRITE(6,25)
25 FORMAT(1H020HSEGMENT-NO. 5, THIGH)
   GO TO 30
16 WRITE(6,26)
26 FORMAT(1H027HSEGMENT-NO. 6, LEG AND FOOT)
   GOTO 30
17 WRITE(6,27)
27 FORMAT(1H030HSEGMENT-NO. 7, INSTRUMENT PACK)
30 IF(K.NE.1)GOTO 91
31 FORMAT(1H032HWORK TH=INTERGRATION OF POWER TH)
32 FORMAT(1H 1PE10.3,2H+(E10.3,4H)T+(E10.3,7H)T**2+(E10.3,7H)T**3+(E1
  10.3,7H)T**4+(E10.3,5H)T**5/1H 2H+(E10.3,7H)T**6+(E10.3,7H)T**7+(E1
  20.3,7H)T**8+(E10.3,7H)T**9+(E10.3,6H)T**10)
33 FORMAT(1H 1PE10.3,2H+(E10.3,4H)T+(E10.3,7H)T**2+(E10.3,7H)T**3+(E1
  10.3,5H)T**4/1H 2H+(E10.3,7H)T**5+(E10.3,7H)T**6+(E10.3,7H)T**7+(E1
  20.3,7H)T**8+(E10.3,5H)T**9)
34 FORMAT(1H 1PE10.3,2H+(E10.3,4H)T+(E10.3,7H)T**2+(E10.3,7H)T**3+(E1
  10.3,5H)T**4/1H 2H+(E10.3,7H)T**5+(E10.3,7H)T**6+(E10.3,7H)T**7+(E1
  20.3,5H)T**8)
35 FORMAT(1H 37HP-SUIT MOMENT DISTRIBUTION, UPPER ARM)
37 FORMAT(1H 46HP-SUIT MOMENT DISTRIBUTION, LOWER ARM AND HAND)
38 FORMAT(1H 33HP-SUIT MOMENT DISTRIBUTION, THIGH)
39 FORMAT(1H 40HP-SUIT MOMENT DISTRIBUTION, LEG AND FOOT)
40 FORMAT (1H0A1,26H,(F)T,(SEC.), MOTION, CMS.)
41 FORMAT  (1H01HD,A1,24H/DT, VELOCITY (CM./SEC.))
42 FORMAT(1H029HTH,(F)T,(SEC.), MOTION, RADS.)
43 FORMAT  (1H02HDD,A1,34H/DDT, ACCELERATION (CM./SEC.*SEC.))
44 FORMAT(1H028HDTH/DT, VELOCITY (RAD./SEC.))
45 FORMAT  (1H0A1,5H=M(DD,A1,18H/DDT), FORCE (KG.))
46 FORMAT(1H039HDDTH/DDT, ACCELERATION (RAD./SEC.*SEC.))
47 FORMAT  (1H01HP,A1,8H=FORCE(D,A1,25H/DT), POWER (KG.CM./SEC.))
49 FORMAT(1H044HMOMENT OF INERTIA(DDTH/DDT) TORQUE (KG.-CM.))
50 FORMAT(1H 3X4HTIME,5X6HTORQUE,9X4HTIME,5X6HTORQUE,9X4HTIME,5X6HTOR
  1QUE,9X4HTIME,5X6HTORQUE,9X4HTIME,5X6HTORQUE//)
51 FORMAT(1H020HPOWER,(KG.-CM./SEC.))
52 FORMAT (1H05HWORK A1,23H=INTERGRATION OF POWER A1)
53 FORMAT(1H 5HWORK=1PE13.3,17H (KG.CM.)  CHECK=0PF7.1,27H, NUMBER OF
  1 INCREMENTS USED)
57 FORMAT(1H016HTOTAL BODY WORK=1PE13.3,11H, (KG.-CM.))
58 FORMAT(1H 3X4HTIME,5X5HFORCE,10X4HTIME,5X5HFORCE,10X4HTIME,5X5HFOR
  1CE,10X4HTIME,5X5HFORCE,10X4HTIME,5X5HFORCE//)
59 FORMAT(5(0PF9.3,1PE13.3,2X))
72 FORMAT(1H054HPRESSURE SUIT MOMENT, TIME (SEC.) VS. TORQUE (KG.-CM.
  1))
76 FORMAT(1H1)
79 FORMAT(1H 3X4HTIME,5X6HP.P.E., 9X4HTIME,5X6HP.P.E., 9X4HTIME,5X6HP
  1.P.E., 9X4HTIME,5X6HP.P.E., 9X4HTIME,5X6HP.P.E.//)
```

Figure E13. - Biomechanics motion analysis program (MOM) listing (continued)

```
 80 FORMAT(1H062HPOTENTIAL ENERGY=INTERGRATION OF THE POWER OF POTENTI
   1AL ENERGY)
 81 FORMAT(1H 17HPOTENTIAL ENERGY=1PE13.3,17H(KG.-CM.)  CHECK=OP
   1F7.1,27H, NUMBER OF INCREMENTS USED)
 93 FORMAT(1H030HTOTAL WORK OF INSTRUMENT PACK=1PE13.3,11H, (KG.-CM.))
 94 FORMAT(1H046HTOTAL BODY WORK+TOTAL WORK OF INSTRUMENT PACK=1PE13.3
   1,11H, (KG.-CM.))
100 FORMAT(1H 3X4HTIME,5X5HPOWER,10X4HTIME,5X5HPOWER,10X4HTIME,5X5HPOW
   1ER,10X4HTIME,5X5HPOWER,10X4HTIME,5X5HPOWER//)
101 FORMAT(2A1                                  )
160 FORMAT(1H026HG-GRADIENT (F)T (UNITLESS))
161 FORMAT(1H 3X4HTIME,5X6HG-GRAD, 9X4HTIME,5X6HG-GRAD, 9X4HTIME,5X6HG
   1-GRAD, 9X4HTIME,5X6HG-GRAD, 9X4HTIME,5X6HG-GRAD//)
198 FORMAT(1H 34HFROM THE EQUATION OF MOTION Z,(F)T)
 91 MINDEG=P(10)
    MAXDEG=P(11)
    NOPT=P(12)
    N=P(13)
    NS=P(14)
    NL=P(15)
    NS1=P(16)
    NL1=P(17)
 90 READ(5,3)(X(I),I=1,M)
    KEN=0
180 D=1.0
    IF(NN.EQ.4)D=.01745
    DO176I=1,M
176 B(I)=(X(I)*D)
    IF(KEN.EQ.3)GOTO 185
    KEN=1
185 CALL CUPLOT(T,B,C,P,KEN,NN,NS,NL)
    IF(KEN.EQ.3)GOTO 68
    IF(NN.EQ.4)GOTO 186
    WRITE(6,40)C(NN)
    GOTO 187
186 WRITE(6,42)
187 NS=1
    NL=N
    DO193I=1,11
193 A(I)=0.0
    CALL CURFIT(T,B,W)
    NS=P(14)
    NL=P(15)
    WRITE(6,32)(A(I),I=1,11)
    M=NL+1
    DO36I=1,M
    E=T(I)
    IF(I.EQ.M)E=P(20)
    FDER(I)=A(2)+2.*A(3)*E+3.*A(4)*E**2+4.*A(5)*E**3+5.*A(6)*E**4+6.*A
   1(7)*E**5+7.*A(8)*E**6+8.*A(9)*E**7+9.*A(10)*E**8+10.*A(11)*E**9
 36 SDER(I)=2.*A(3)+6.*A(4)*E+12.*A(5)*E**2+20.*A(6)*E**3+30.*A(7)*E**
   14+42.*A(8)*E**5+56.*A(9)*E**6+72.*A(10)*E**7+90.*A(11)*E**8
```

Figure E13. - Biomechanics motion analysis program (MOM) listing (continued)

```
      IF(NN.EQ.4)GOTO 188
      WRITE(6,41)C(NN)
      GOTO 189
  188 WRITE(6,44)
  189 Z(1)=A(2)
      Z(2)=2.*A(3)
      Z(3)=3.*A(4)
      Z(4)=4.*A(5)
      Z(5)=5.*A(6)
      Z(6)=6.*A(7)
      Z(7)=7.*A(8)
      Z(8)=8.*A(9)
      Z(9)=9.*A(10)
      Z(10)=10.*A(11)
      WRITE(6,33)(Z(I),I=1,10)
      IF(NN.EQ.4)GOTO 190
      WRITE(6,43)C(NN)
      GOTO 191
  190 WRITE(6,46)
  191 ZZ(1)=2.*A(3)
      ZZ(2)=6.*A(4)
      ZZ(3)=12.*A(5)
      ZZ(4)=20.*A(6)
      ZZ(5)=30.*A(7)
      ZZ(6)=42.*A(8)
      ZZ(7)=56.*A(9)
      ZZ(8)=72.*A(10)
      ZZ(9)=90.*A(11)
      WRITE(6,34)(ZZ(I),I=1,9)
      IF(NN.EQ.4)GOTO 69
      WRITE(6,45)C(NN),C(NN)
      DO98I=NS,M
      F(I)=SDER(I)*P(2)/980.67
   98 PR(I)=(FDER(I)*F(I))
      WRITE(6,58)
      WRITE(6,59)(T(I),F(I),I=NS,NL),(P(20),F(M))

      WRITE(6,47)C(NN),C(NN)
      WRITE(6,100)
      WRITE(6,59)(T(I),PR(I),I=NS,NL),(P(20),PR(M))

      WRITE(6,52)C(NN),C(NN)
      CALL ISIA (P(20),T(NS),3.0,CHECK,ANS,WORK)
      IF(K.GT.2.AND.K.LT.7)ANS=2.*ANS
      WRITE(6,53)ANS,CHECK
      GOTO(71,54),NN
   71 WAKUX(KI)=ANS
      GOTO 56
   54 WAKUZ(KI)=ANS
   56 CONTINUE
   69 J=1
   68 DO61 L=NS,M
```

Figure E13. - Biomechanics motion analysis program (MOM) listing (continued)

```
      GOTO(62,63,64,65,66,67),J
   62 B(L)=W(L)
      KEN=2
      GOTO 60
   63 B(L)=FDER(L)
      KEN=4
      GOTO 60
   64 B(L)=SDER(L)
      KEN=5
      GOTO 60
   65 IF(NN.EQ.4)GOTO 70
      B(L)=F(L)
      KEN=6
      GOTO 60
   66 B(L)=PR(L)
      KEN=7
   60 IF(L.EQ.M)CALL CUPLOT(T,B,C,P,KEN,NN,NS,NL)
      IF(KEN.EQ.3)J=J+1
      IF(KEN.EQ.3)GOTO 180
   61 CONTINUE
      J=J+1
      GOTO 68
   67 NN=NN+1
      IF(NN.NE.3)GOTO 99
      WRITE(6,76)
      WRITE(6,198)
      WRITE(6,160)
      WRITE(6,161)
      DO 199I=NS,M
      E=T(I)
      IF(I.EQ.M)E=P(20)
      ZN(I)=A(1)+(A(2)*E)+(A(3)*E**2)+(A(4)*E**3)+(A(5)*E**4)+(A(6)*E**5
     1)+(A(7)*E**6)+(A(8)*E**7)+(A(9)*E**8)+(A(10)*E**9)+(A(11)*E**10)+2
     227.
      ZN(I)=ZN(I)*.02831
      GR(I)=SIND(ZN(I))
  199 PPE(I)=GR(I)*P(2)*FDER(I)
      WRITE(6,59)(T(I),GR(I),I=NS,NL),(P(20),GR(M))

      WRITE(6,6)
      WRITE(6,79)
      WRITE(6,59)(T(I),PPE(I),I=NS,NL),(P(20),PPE(M))

      JK=1
   87 DO 85 I=NS,M
      GOTO(83,84,86),JK
   83 B(I)=GR(I)
      KEN=10
      GOTO 82
   84 B(I)=PPE(I)
      KEN=11
   82 IF(I.EQ.M)CALL CUPLOT(T,B,C,P,KEN,NN,NS,NL)
```

Figure E13. - Biomechanics motion analysis program (MOM) listing (continued)

```
 85 CONTINUE
    JK=JK+1
    GOTO 87
 86 WRITE(6,80)
    CALL ISIA(P(20),T(NS),3.0,CHECK,ANS,PAPE)
    IF(K.GT.2.AND.K.LT.7)ANS=2.*ANS
    WRITE(6,81)ANS,CHECK
    WAKUPE(KI)=ANS
    NN=NN+1
 99 M=N
    WRITE(6,76)
    GOTO 90
 70 DO73I=NS,M
    TH(I)=SDER(I)*P(1)
 73 B(I)=TH(I)
    KEN=6
    CALL CUPLOT(T,B,C,P,KEN,NN,NS,NL)
    WRITE(6,49)
    WRITE(6,50)
    WRITE(6,59)(T(I),TH(I),I=NS,NL),(P(20),TH(M))

    DO77I=NS,M
    PR(I)=TH(I)*FDER(I)
 77 B(I)=PR(I)
    KEN=7
    CALL CUPLOT(T,B,C,P,KEN,NN,NS,NL)
    WRITE(6,51)
    WRITE(6,100)
    WRITE(6,59)(T(I),PR(I),I=NS,NL),(P(20),PR(M))

    WRITE(6,31)
    CALL ISIA (P(20),T(NS),3.0,CHECK,ANS,WORK)
    IF(K.GT.2.AND.K.LT.7)ANS=2.*ANS
    WRITE(6,53)ANS,CHECK
    WAKUTH(KI)=ANS
    IF(K.EQ.7)GOTO 92
    WK(KI)=WAKUX(KI)+WAKUZ(KI)+WAKUTH(KI)+WAKUPE(KI)
    IF(P(4).GE.T6.AND.P(4).LE.T2.OR.P(4).GE.T7.AND.P(4).LE.T4)GOTO 601
    GOTO 78
601 WRITE(6,76)
    IF(K-2)55,402,403
402 DO405 I=1,11
405 AB(I)=A(I)
    GOTO 55
403 K1=1
    K2=4
    KVFPS=1
    DO413 J=NS,M
    GOTO(55,55,415,417,419,434,55),K
415 DO421 I=1,11
421 AC(I)=A(I)
419 TH3=A(1)-AB(1)
```

Figure E13. - Biomechanics motion analysis program (MOM) listing (continued)

```
      DO426 I=2,11
  426 TH3=TH3+(A(I)-AB(I))*T(J)**(I-1)
      THB(J)=TH3
      IF(K.NE.5)GOTO 430
      DO432 I=1,11
  432 AD(I)=A(I)
      GOTO 430
  417 TH4=A(1)-AC(1)
      DO437 I=2,11
  437 TH4=TH4+(A(I)-AC(I))*T(J)**(I-1)
      THB(J)=TH4
      GOTO 430
  434 TH6=A(1)-AD(1)
      DO436 I=2,11
  436 TH6=TH6+(A(I)-AD(I))*T(J)**(I-1)
      THB(J)=TH6
  430 TP=R(KVFPS,K-2,1)
      DO440 I=2,11
  440 TP=TP+R(KVFPS,K-2,I)*THB(J)**(I-1)
      TM(J)=TP
  413 CONTINUE
      DO74 J=NS,M
   74 B(J)=TM(J)
      KEN=12
      CALL CUPLOT(T,B,C,P,KEN,NN,NS,NL)
      IF(K.EQ.3)WRITE(6,35)
      IF(K.EQ.4)WRITE(6,37)
      IF(K.EQ.5)WRITE(6,38)
      IF(K.EQ.6)WRITE(6,39)
      WRITE(6,72)
      WRITE(6,50)
      WRITE(6,59)(T(J),TM(J),J=NS,NL),(P(20),TM(M))

      WRITE(6,51)
      WRITE(6,100)
      DO75 J=NS,M
      PS(J)=TM(J)*FDER(J)
   75 B(J)=PS(J)
      WRITE(6,59)(T(J),PS(J),J=NS,NL),(P(20),PS(M))

      KEN=13
      CALL CUPLOT(T,B,C,P,KEN,NN,NS,NL)
      WRITE(6,9)
      CALL ISIA(P(20),T(NS),3.0,CHECK,ANS,PSWK)
      IF(K.GT.2.AND.K.LT.7)ANS=2.*ANS
      WRITE(6,53)ANS,CHECK
      WAKUP(KI)=ANS
      IF(KI.EQ.6)WKPS=WAKUP(3)+WAKUP(4)+WAKUP(5)+WAKUP(6)
   78 IF(KI.LT.6)GOTO 55
      IF(P(4).GE.T6.AND.P(4).LE.T2.OR.P(4).GE.T7.AND.P(4).LE.T4)GOTO 602
      WKPS=0.0
  602 WKK=WK(1)+WK(2)+WK(3)+WK(4)+WK(5)+WK(6)+WKPS
```

Figure E13. - Biomechanics motion analysis program (MOM) listing (continued)

```
      WRITE(6,57)WKK
      IF(K.EQ.6)GOTO 55
   92 WKBP=WAKUX(7)+WAKUZ(7)+WAKUPE(7)+WAKUTH(7)
      WRITE(6,93)WKBP
      IF(P(4).GT.T2.AND.P(4).LT.T5)WKBP=0.
      TWK=WKK+WKBP
      WRITE(6,94)TWK
   55 WRITE(6,76)
      GOTO 200
      END
```

```
      SUBROUTINE CURFIT (X,Y,W)
      DIMENSION X(50),Y(50),B(11),POLY(200),D(200),A(11,11),CC(11),W(200
     1),P(30)
      COMMON MINDEG,MAXDEG,NOPT,NUM,NS,NL,NS1,NL1,P,CC
      DUMMY=0.0
      J=0
      J=J+1
      N=NL-NS+1
      K=0
      DO 1 I=1,NUM
      IF(I-NS)1,2,2
2     IF(I-NL)3,3,4
3     K=K+1
      X(K)=X(I)
      Y(K)=Y(I)
1     CONTINUE
4     MS=MINDEG+1
      ML=MAXDEG+1
      EMIN=100000.
      DO34I=1,11
   34 CC(I)=0.0
      DO 55 M=MS,ML
      PERER=0.0
      VARER=0.0
      MM=M-1
      MIN=12-M
      DO 6 K=1,N
      IF(NOPT)11,6,7
7     X(K)=ALOG(X(K))
6     Y(K)=ALOG(Y(K))
11    CONTINUE
      CALL LTSQS(A,B,DETERM,Y,X,MM,N,RMS)
      DO 30 K=1,N
      POLY(K)=B(1)
      DO 5 M1=2,M
5     POLY(K)=POLY(K)+B(M1)*X(K)**(M1-1)
      D(K)=POLY(K)-Y(K)
      VARER=VARER+D(K)**2
      IF(NOPT)8,9,10
10    X(K)=EXP(X(K))
9     Y(K)=EXP(Y(K))
```

Figure E13. - Biomechanics motion analysis program (MOM) listing (continued)

```
      POLY(K)=EXP(POLY(K))
8     D(K)=100.0*(POLY(K)-Y(K))/Y(K)
      IF(K-NS1)30,28,28
28    IF(K-NL1)29,29,30
29    PERER=PERER+D(K)**2
30    CONTINUE
      PERVAR=SQRT(PERER/FLOAT(NL1-NS1))
      VAR=SQRT(VARER/FLOAT(N-1))
      IF(VAR.GT.EMIN)GOTO 32
      DO41I=1,N
   41 W(I)=POLY(I)
      DO33I=1,M
   33 CC(I)=B(I)
      MO=MM
      VAA=VAR
      PERVAA=PERVAR
      EMIN=VAR
   32 CONTINUE
55    CONTINUE
      WRITE(6,300)(VAA,PERVAA,MO)
  300 FORMAT(1H09X10HVAR ERROR=E12.5,9X14HPERCENT ERROR=E12.5,9X6H ORDER
     1I2)
      W(N+1)=CC(1)
      MM=MO+1
      DO60 I=2,MM
   60 W(N+1)=W(N+1)+CC(I)*P(20)**(I-1)
      RETURN
      END
```

```
      SUBROUTINE LTSQS(A,B,DETERM,THETA,T,M,N,RMSE)
      COMMON NDUM
      DIMENSION A(11,11),B(11),THETA(50),T(50),R(200),NDUM(217)
      COMMON/RESID/RES(200)
      DO2K=1,11
      DO1J=1,11
      A(J,K)=0.0
1     DETERM=0.0
2     CONTINUE
      DO3K=1,11
3     B(K)=0.0
      KM=M+1
      DO7K=1,N
      DO5J=1,KM
      DO4I=1,KM
      R(K)=T(K)
      IF(I+J.EQ.2)R(K)=1.0
4     A(I,J)=A(I,J)+R(K)**(I+J-2)
5     CONTINUE
      DO6I=1,KM
      R(K)=T(K)
      IF(I.EQ.1)R(K)=1.0
6     B(I)=B(I)+THETA(K)*R(K)**(I-1)
```

Figure E13. - Biomechanics motion analysis program (MOM) listing (continued)

```
 7    CONTINUE
      CALL MATINV(A,KM,B,1,DETERM)
COMPUTE THE RESIDUALS AND THE ROOT MEAN SQUARE ERROR
      RMSET=0.0
      DO9I=1,N
      RES(I)=0.0
      DO8J=1,KM
      R(I)=T(I)
      IF(J.EQ.1)R(I)=1.0
 8    RES(I)=RES(I)+B(J)*R(I)**(J-1)
      RES(I)=THETA(I)-RES(I)
 9    RMSET=RMSET+RES(I)**2
      RMSE=SQRT(RMSET/FLOAT(N))
      RETURN
      END
```

```
      SUBROUTINE MATINV(A,N,B,M,DETERM)
      DIMENSION IPIVOT(11),A(11,11),B(11,1),INDEX(11,2),PIVOT(11),NDUM(1
     173)
      COMMON NDUM
      COMMON PIVOT, INDEX, IPIVOT
      EQUIVALENCE (IROW,JROW), (ICOLUM,JCOLUM), (AMAX, T, SWAP)
   10 DETERM=1.0
   15 DO 20 J=1,N
   20 IPIVOT(J)=0
   30 DO 550 I=1,N
   40 AMAX=0.0
   45 DO 105 J=1,N
   50 IF (IPIVOT(J)-1) 60, 105, 60
   60 DO 100 K=1,N
   70 IF (IPIVOT(K)-1) 80, 100, 740
   80 IF (ABS (AMAX)-ABS (A(J,K))) 85, 100, 100
   85 IROW=J
   90 ICOLUM=K
   95 AMAX=A(J,K)
  100 CONTINUE
  105 CONTINUE
  110 IPIVOT(ICOLUM)=IPIVOT(ICOLUM)+1
  130 IF (IROW-ICOLUM) 140, 260, 140
  140 DETERM=-DETERM
  150 DO 200 L=1,N
  160 SWAP=A(IROW,L)
  170 A(IROW,L)=A(ICOLUM,L)
  200 A(ICOLUM,L)=SWAP
  205 IF(M) 260, 260, 210
  210 DO 250 L=1, M
  220 SWAP=B(IROW,L)
  230 B(IROW,L)=B(ICOLUM,L)
  250 B(ICOLUM,L)=SWAP
  260 INDEX(I,1)=IROW
  270 INDEX(I,2)=ICOLUM
```

Figure E13. - Biomechanics motion analysis program (MOM) listing (continued)

```
  310 PIVOT(I)=A(ICOLUM,ICOLUM)
  320 DETERM=DETERM*PIVOT(I)
  330 A(ICOLUM,ICOLUM)=1.0
  340 DO 350 L=1,N
  350 A(ICOLUM,L)=A(ICOLUM,L)/PIVOT(I)
  355 IF(M) 380, 380, 360
  360 DO 370 L=1,M
  370 B(ICOLUM,L)=B(ICOLUM,L)/PIVOT(I)
  380 DO 550 L1=1,N
  390 IF(L1-ICOLUM) 400, 550, 400
  400 T=A(L1,ICOLUM)
  420 A(L1,ICOLUM)=0.0
  430 DO 450 L=1,N
  450 A(L1,L)=A(L1,L)-A(ICOLUM,L)*T
  455 IF(M) 550, 550, 460
  460 DO 500 L=1,M
  500 B(L1,L)=B(L1,L)-B(ICOLUM,L)*T
  550 CONTINUE
  600 DO 710 I=1,N
  610 L=N+1-I
  620 IF (INDEX(L,1)-INDEX(L,2)) 630, 710, 630
  630 JROW=INDEX(L,1)
  640 JCOLUM=INDEX(L,2)
  650 DO 705 K=1,N
  660 SWAP=A(K,JROW)
  670 A(K,JROW)=A(K,JCOLUM)
  700 A(K,JCOLUM)=SWAP
  705 CONTINUE
  710 CONTINUE
  740 RETURN
      END
```

```
      SUBROUTINE CUPLOT(T,B,C,P,KEN,NN,NS,NL)
      DIMENSION B(50),T(50),C(20),P(30)
C     POLYNOMIAL EVALUATOR FOR LINEAR, SEMI LN, AND LN LN    4-29-65
      IF(KEN.NE.3)NK=0
      IF(KEN.GT.1)GOTO 205
      CALL SIMULA(0)
      CALL CAMRAV(35)
      CALL FRAMEV
  205 NK=NK+1
      KJ=0
      Z=C(NN)
      ML=NL
      IF(KEN.EQ.3.AND.NK.EQ.3)GOTO 36
      XL=T(NS)
      XR=T(NS)
      NS1=NS+1
      DO 30 K=NS1,NL
      XL=AMIN1(XL,T(K))
   30 XR=AMAX1(XR,T(K))
      XR=AMAX1(XR,P(20))
```

Figure E13. - Biomechanics motion analysis program (MOM) listing (continued)

```
      YB=B(NS)
      YT=B(NS)
      IF(KEN.GT.1)ML=NL+1
      DO31 K=NS1,ML
      YB=AMIN1(YB,B(K))
   31 YT=AMAX1(YT,B(K))
      IF(KEN.EQ.1)UT=YT
      IF(KEN.EQ.2)UT=AMAX1(UT,YT)
32    IF(XL.LT.0.0) XL=XL-1.0
      XL=AINT(XL)
      XR=1.0+AINT(XR)
      IF(NOPT.GT.-1) GO TO 35
      IF(YB.LT.0.0) YB=YB-1.0
      YB=AINT(YB)
      YT=1.0+AINT(YT)
   35 CONTINUE
      CALL DXDYV(1,XL,XR,DX,N,I,NX,20.0,IERR)
      IF(IERR.EQ.0) GO TO 40
      WRITE(6,800)
      GO TO 8
40    IF(NOPT.GE.0) GO TO 41
      CALL DXDYV(2,YB,YT,DY,M,J,NY,20.0,IERR)
      IF(IERR.EQ.0) GO TO 41
      WRITE(6,801)
      GO TO 8
800   FORMAT(1H010X38HERROR DURING CALCULATION OF DX,N,I,$NX)
801   FORMAT(1H010X38HERROR DURING CALCULATION OF DY,M,J,$NY)
   41 CALL SETMIV(24,10,24,60)
   45 IF(KEN.EQ.3)YT=UT
      CALL GRID1V(1,XL,XR,YB,YT,DX,DY,N,M,I,J,NX,NY)
      NUM=1+NL-NS
      CALL APLOTV(NUM,T(NS),B(NS),1,1,1,63,IERR)
      IF(KEN.EQ.1)GOTO 91
      IF(KEN.EQ.3)NK=NK+1
      CALL APLOTV(1,P(20),B(NL+1),1,1,1,63,IERR)
   91 IF(IERR.EQ.0)GO TO 37
      CALL PRINTV(-15,15HPOINTS OFF GRID,900,7)
      ERR=IERR
      CALL LABLV(ERR,852,7,5,1,0)
      GOTO 37
   36 CALL APLOTV  (NUM,T(NS),B(NS),1,1,1,38,IERR)
      GOTO 88
   37 CALL PRINTV(-11,11HTIME (SEC.),479,7)
      IF(KEN.EQ.10)GOTO 55
      IF(KEN.EQ.11)GOTO 56
      IF(KEN.EQ.12)GOTO 57
      IF(KEN.EQ.13)GOTO 58
      IF(NN.EQ.4)GOTO 70
      GOTO(60,61,62,63,64,65,66),KEN
   70 GOTO(51,52,53,54,59,67,68),KEN
   60 CALL APRNTV(0,-12,-5,5HDATA ,10,527)
      CALL APRNTV(0,-12,1,Z,10,463)
```

Figure E13. - Biomechanics motion analysis program (MOM) listing (continued)

```
      GOTO 69
   61 CALL APRNTV(0,-12,-10,10HCURVE FIT ,10,530)
      CALL APRNTV(0,-12,1,Z,10,409)
      GOTO 69
   62 CALL APRNTV(0,-12,-15,15HDATA/CURVE FIT ,10,560)
      CALL APRNTV(0,-12,1,Z,10,379)
      GOTO 69
   63 CALL APRNTV(0,-12,-9,9HVELOCITY ,10,536)
      CALL APRNTV(0,-12,1,Z,10,428)
      GOTO 69
   64 CALL APRNTV(0,-12,-13,13HACCELERATION ,10,539)
      CALL APRNTV(0,-12,1,Z,10,378)
      GOTO 69
   65 CALL APRNTV(0,-12,-6,6HFORCE ,10,533)
      CALL APRNTV(0,-12,1,Z,10,455)
      GOTO 69
   66 CALL APRNTV(0,-12,-6,6HPOWER ,10,533)
      CALL APRNTV(0,-12,1,Z,10,455)
      GOTO 69
   51 CALL APRNTV(0,-12,-7,7HDATA TH,10,527)
      GOTO 69
   52 CALL APRNTV(0,-12,-12,12HCURVE FIT TH,10,530)
      GOTO 69
   53 CALL APRNTV(0,-12,-17,17HDATA/CURVE FIT TH,10,560)
      GOTO 69
   54 CALL APRNTV(0,-12,-11,11HVELOCITY TH,10,536)
      GOTO 69
   59 CALL APRNTV(0,-12,-15,15HACCELERATION TH,10,539)
      GOTO 69
   67 CALL APRNTV(0,-12,-9,9HTORQUE TH,10,521)
      GOTO 69
   68 CALL APRNTV(0,-12,-8,8HPOWER TH,10,518)
      GOTO 69
   55 CALL APRNTV(0,-12,-12,12HG GRADIENT Z,10,530)
      GOTO 69
   56 CALL APRNTV(0,-12,-27,27HPOWER OF POTENTIAL ENERGY Z,10,615)
      GOTO 69
   57 CALL APRNTV(0,-12,-16,16HP/SUIT MOMENT TH,10,565)
      GOTO 69
   58 CALL APRNTV(0,-12,-15,15HP/SUIT POWER TH,10,560)
   69 CONTINUE
      ZX= P(3)
      ZY= P(4)
      ZZ= P(5)
      CALL PRINTV(-9,9HTEST NO. ,374,1002)
      CALL PRINTV(1,ZX,440,1002)
      CALL PRINTV(-1,1H-,447,1002)
      CALL PRINTV(4,ZY,453,1002)
      CALL PRINTV(-1,1H-,484,1002)
      CALL PRINTV(1,ZZ,490,1002)
      K=P(9)
      GOTO(71,72,73,74,75,76,78),K
```

Figure E13. - Biomechanics motion analysis program (MOM) listing (continued)

```
71 CALL PRINTV(-26,28HSEGMENT-NO. 1, HEAD AND NECK,503,1002)
   GOTO 77
72 CALL PRINTV(-20,20HSEGMENT-NO. 2, TRUNK,503,1002)
   GOTO 77
73 CALL PRINTV(-24,24HSEGMENT-NO. 3, UPPER ARM,503,1002)
   GOTO 77
74 CALL PRINTV(-33,33HSEGMENT-NO. 4, LOWER ARM AND HAND,503,1002)
   GOTO 77
75 CALL PRINTV(-20,20HSEGMENT-NO. 5, THIGH,503,1002)
   GOTO 77
76 CALL PRINTV(-27,27HSEGMENT-NO. 6, LEG AND FOOT,503,1002)
   GOTO 77
78 CALL PRINTV(-30,30HSEGMENT-NO. 7, INSTRUMENT PACK,503,1002)
77 CONTINUE
   IF(KEN.EQ.10)GOTO 95
   IF(KEN.EQ.11)GOTO 96
   IF(KEN.EQ.12)GOTO 92
   IF(KEN.EQ.13)GOTO 93
   IF(NN.EQ.4)GOTO 90
   GOTO(79,80,81,82,83,84,85),KEN
79 CALL PRINTV(-11,11HDATA (CMS.),475,977)
   GOTO 88
80 CALL PRINTV(-25,25HEQUATION OF MOTION (CMS.),433,977)
   GOTO 88
81 CALL PRINTV(-34,34HDATA AND EQUATION OF MOTION (CMS.),394,977)
   GOTO 88
82 CALL PRINTV(-19,19HVELOCITY (CM./SEC.),451,977)
   GOTO 88
83 CALL PRINTV(-28,28HACCELERATION (CM./SEC.XSEC.),412,977)
   GOTO 88
84 CALL PRINTV(-11,11HFORCE (KG.),451,977)
   GOTO 88
85 CALL PRINTV(-19,19HPOWER (KG.CM./SEC.),427,977)
   GOTO 88
90 GOTO(42,46,47,48,49,86,85),KEN
42 CALL PRINTV(-12,12HDATA (RADS.),472,977)
   GOTO 88
46 CALL PRINTV(-26,26HEQUATION OF MOTION (RADS.),430,977)
   GOTO 88
47 CALL PRINTV(-35,35HDATA AND EQUATION OF MOTION (RADS.),391,977)
   GOTO 88
48 CALL PRINTV(-21,21HVELOCITY (RADS./SEC.),447,977)
   GOTO 88
49 CALL PRINTV(-30,30HACCELERATION (RADS./SEC.XSEC.),406,977)
   GOTO 88
86 CALL PRINTV(-16,16HTORQUE (KG.-CM.),433,977)
   GOTO 88
92 CALL PRINTV(-37,37HPRESSURE SUIT MOMENT-TORQUE (KG.-CM.),385,977)
   GOTO 88
93 CALL PRINTV(-34,34HPRESSURE SUIT POWER (KG.-CM./SEC.),397,977)
   GOTO 88
95 CALL PRINTV(-21,21HG-GRADIENT (UNITLESS),440,977)
```

Figure E13. - Biomechanics motion analysis program (MOM) listing (continued)

```
      GOTO 88
   96 CALL PRINTV(-40,40HPOWER OF POTENTIAL ENERGY (KG.-CM./SEC.),376,97
     17)
   88 CONTINUE
      IX1=NXV(T(NS))
      IY1=NYV(B(NS))
      DO50 KK=NS,ML
      IX2=NXV(T(KK))
      IF(KK.NE.ML)GO TO 5
      IF(KEN.GT.1.AND.NK.LT.3) IX2=NXV(P(20))
    5 IY2=NYV(B(KK))
      CALL LINEV(IX1,IY1,IX2,IY2)
      IX1=IX2
      IY1=IY2
50    CONTINUE
      IF(NK.EQ.1.AND.KEN.EQ.2)KEN=3
      IF(KEN.EQ.3.AND.NK.EQ.1)GOTO 45
    8 CONTINUE
      RETURN
      END
```

```
      SUBROUTINE ISIA (XU,XL,EPSI,CHECK,ANS,FUN)
      CMAX=1000.0
      CHECK=4.0
      M2=4
      H=(XU-XL)/2.0
      H3=H/3.0
      T1=FUN(XL)+FUN(XU)
      ST3=FUN(XL+H)
      A1=H3*(T1+4.0*ST3)
      H=H/2.0
      H3=H/3.0
      ST2=FUN(XL+H)+FUN(XL+3.0*H)
      A2=H3*(T1+4.0*ST2+2.0*ST3)
5     IF(EPSI-1.0)4,8,8
8     IF(A1*A2.LT.0.0)GOTO10
      IF(A1.NE.0.0)GOTO16
      AL1=0.0
      GOTO 18
   16 AL1=ALOG10(ABS(A1))
   18 IF(A2.NE.0.0)GOTO 15
      AL2=0.0
      GOTO 17
   15 AL2=ALOG10(ABS(A2))
   17 N1=EPSI
      X1=-1.0
      IF(AL1.LE.-1.0) X1=0.0
      N1=N1+IFIX(-AL1+X1)
      N2=EPSI
      X2=-1.0
      IF(AL2.LE.-1.0) X2=0.0
      N2=N2+IFIX(-AL2+X2)
```

Figure E13. - Biomechanics motion analysis program (MOM) listing (continued)

```
      D =ABS(A1*10.0**N1-A2*10.0**N2)
      IF(D-1.)100,2,2
10    D=ABS(A1-A2)
      IF(D-.01)100,100,2
4     D=ABS(A1/A2-1.0)
      IF(D-EPSI)100,100,2
2     CONTINUE
      ST3=ST3+ST2
      T2=0.0
      A1=A2
      H=H/2.0
      H3=H/3.0
      M2=2*M2
      IMAX=M2-1
      DO7I=1,IMAX,2
      C=I
7     T2=T2+FUN(XL+C*H)
      ST2=T2
      T2=4.0*T2
      T3=2.0*ST3
      CHECK=M2
      A2=H3*(T1+T2+T3)
      IF(CHECK-CMAX)5,6,6
6     WRITE (6,1000)A1,A2,D,EPSI,CHECK
100   ANS=A2
1000  FORMAT(38HOMAXIMUM NUMBER OF INCREMENTS EXCEEDED
     15E15.6)
      RETURN
      END
```

```
      FUNCTION WORK(T)
      DIMENSION P(30),A(11),R(2,4,11)
      COMMON MINDEG,MAXDEG,NOPT,N,NS,NL,NS1,NL1,P,A,R,NN
      FDER=A(2)+2.*A(3)*T+3.*A(4)*T**2+4.*A(5)*T**3+5.*A(6)*T**4+6.*A(7)
     1*T**5+7.*A(8)*T**6+8.*A(9)*T**7+9.*A(10)*T**8+10.*A(11)*T**9
      SDER=2.*A(3)+6.*A(4)*T+12.*A(5)*T**2+20.*A(6)*T**3+30.*A(7)*T**4+4
     12.*A(8)*T**5+56.*A(9)*T**6+72.*A(10)*T**7+90.*A(11)*T**8
      IF(NN.EQ.2)GOTO 18
      IF(NN.EQ.4)GOTO 15
      GOTO 19
   18 ZN=A(1)+A(2)*T+A(3)*T**2+A(4)*T**3+A(5)*T**4+A(6)*T**5+A(7)*T**6+A
     1(8)*T**7+A(9)*T**8+A(10)*T**9+A(11)*T**10+227.
      ZN=ZN*.02831
      GR=SIND(ZN)
      B=GR*980.67
      IF(SDER.LT.0.0.AND.SDER.GT.-B)SDER=0.0
      IF(SDER.LT.-B)SDER=SDER+B
   19 WORK=ABS(P(2)*SDER*FDER/980.67)
      GOTO 20
   15 WORK=ABS(P(1)*FDER*SDER)
   20 RETURN
      END
```

Figure E13. - Biomechanics motion analysis program (MOM) listing (continued)

```
      FUNCTION PAPE(T)
      DIMENSION P(30),A(11)
      COMMON MINDEG,MAXDEG,NOPT,N,NS,NL,NS1,NL1,P,A
      FDER=A(2)+2.*A(3)*T+3.*A(4)*T**2+4.*A(5)*T**3+5.*A(6)*T**4+6.*A(7)
     1*T**5+7.*A(8)*T**6+8.*A(9)*T**7+9.*A(10)*T**8+10.*A(11)*T**9
      ZN=A(1)+A(2)*T+A(3)*T**2+A(4)*T**3+A(5)*T**4+A(6)*T**5+A(7)*T**6+A
     1(8)*T**7+A(9)*T**8+A(10)*T**9+A(11)*T**10+227.
      ZN=ZN*.02831
      GR=SIND(ZN)
      PAPE=GR*FDER*P(2)/980.67
      RETURN
      END
```

```
      FUNCTION PSWK(T)
      DIMENSION P(30),A(11),R(2,4,11),AC(11),AB(11),AD(11)
      COMMON MINDEG,MAXDEG,NOPT,NUM,NS,NL,NS1,NL1,P,A,R,NN,AC,AB,K,KVFPS
     1,AD
      GOTO(55,55,15,9,15,8,55),K
   15 TH3=A(1)-AB(1)
      DO5I=2,11
    5 TH3=TH3+(A(I)-AB(I))*T**(I-1)
      GOTO 6
    9 TH4=A(1)-AC(1)
      DO13 I=2,11
   13 TH4=TH4+(A(I)-AC(I))*T**(I-1)
      TH3=TH4
      GOTO 6
    8 TH6=A(1)-AD(1)
      DO 18 I=2,11
   18 TH6=TH6+(A(I)-AD(I))*T**(I-1)
      TH3=TH6
    6 TM=R(KVFPS,K-2,1)
      DO7 I=2,11
    7 TM=TM+R(KVFPS,K-2,I)*TH3**(I-1)
      FDER=A(2)+2.*A(3)*T+3.*A(4)*T**2+4.*A(5)*T**3+5.*A(6)*T**4+6.*A(7)
     1*T**5+7.*A(8)*T**6+8.*A(9)*T**7+9.*A(10)*T**8+10.*A(11)*T**9
      PSWK=ABS(TM*FDER)
   55 RETURN
      END
```

Figure E13. - Biomechanics motion analysis program (MOM) listing

```
TEST NO. C-3007-2  TEST DURATION TIME (MIN.)  3.0  DATE 12- 8-65  ACTIVITY CYCLE FREQUENCY   51.50/MIN.
ACTIVITY CYCLE DURATION TIME   1.165 SEC.  ACTIVITY CYCLE LENGTH  260.30 CM.


SEGMENT-NO. 1, HEAD AND NECK

X,(F)T,(SEC.), MOTION, CMS.

          VAR ERROR= 0.57601E 00          PERCENT ERROR= 0.68068E 00          ORDER 9
-9.211E-02+( 2.155E 02)T+( 1.749E 01)T**2+(-1.606E 01)T**3+( 4.186E 01)T**4+(-8.557E 01)T**5
+( 5.467E 01)T**6+( 3.312E 01)T**7+(-5.774E 01)T**8+( 2.038E 01)T**9+( 0.       )T**10

DX/DT, VELOCITY (CM./SEC.)
 2.155E 02+( 3.497E 01)T+(-4.817E 01)T**2+( 1.675E 02)T**3+(-4.278E 02)T**4
+( 3.280E 02)T**5+( 2.318E 02)T**6+(-4.619E 02)T**7+( 1.834E 02)T**8+( 0.       )T**9

DDX/DDT, ACCELERATION (CM./SEC.*SEC.)
 3.497E 01+(-9.634E 01)T+( 5.024E 02)T**2+(-1.711E 03)T**3+( 1.640E 03)T**4
+( 1.391E 03)T**5+(-3.233E 03)T**6+( 1.467E 03)T**7+( 0.       )T**8

X=M(DDX/DDT), FORCE (KG.)
   TIME      FORCE          TIME      FORCE          TIME      FORCE          TIME      FORCE          TIME      FORCE

   0.        2.414E-01      0.029     2.248E-01      0.058     2.123E-01      0.087     2.027E-01      0.116     1.947E-01
   0.145     1.873E-01      0.175     1.795E-01      0.204     1.713E-01      0.233     1.621E-01      0.262     1.516E-01
   0.291     1.399E-01      0.320     1.271E-01      0.349     1.133E-01      0.378     9.880E-02      0.407     8.393E-02
   0.436     6.899E-02      0.466     5.379E-02      0.495     3.961E-02      0.524     2.615E-02      0.553     1.358E-02
   0.582     1.957E-03      0.611    -8.709E-03      0.640    -1.849E-02      0.670    -2.782E-02      0.698    -3.596E-02
   0.727    -4.397E-02      0.757    -5.194E-02      0.786    -5.936E-02      0.815    -6.637E-02      0.844    -7.258E-02
   0.873    -7.726E-02      0.902    -7.923E-02      0.931    -7.673E-02      0.960    -6.728E-02      0.989    -4.750E-02
   1.018    -1.297E-02      1.047     4.201E-02      1.077     1.281E-01      1.106     2.487E-01      1.135     4.171E-01
   1.164     6.467E-01      1.165     6.559E-01

PX=FORCE(DX/DT), POWER (KG.CM./SEC.)
   TIME      POWER          TIME      POWER          TIME      POWER          TIME      POWER          TIME      POWER

   0.        5.202E 01      0.029     4.866E 01      0.058     4.616E 01      0.087     4.424E 01      0.116     4.266E 01
   0.145     4.119E 01      0.175     3.962E 01      0.204     3.794E 01      0.233     3.600E 01      0.262     3.378E 01
   0.291     3.126E 01      0.320     2.846E 01      0.349     2.543E 01      0.378     2.222E 01      0.407     1.891E 01
   0.436     1.557E 01      0.466     1.215E 01      0.495     8.954E 00      0.524     5.916E 00      0.553     3.073E 00
   0.582     4.430E-01      0.611    -1.971E 00      0.640    -4.184E 00      0.670    -6.292E 00      0.698    -8.127E 00
   0.727    -9.930E 00      0.757    -1.172E 01      0.786    -1.338E 01      0.815    -1.494E 01      0.844    -1.632E 01
   0.873    -1.735E 01      0.902    -1.777E 01      0.931    -1.718E 01      0.960    -1.504E 01      0.989    -1.061E 01
   1.018    -2.895E 00      1.047     9.379E 00      1.077     2.864E 01      1.106     5.580E 01      1.135     9.418E 01
   1.164     1.474E 02      1.165     1.496E 02

WORK X=INTERGRATION OF POWER X
WORK=     2.905E 01 (KG.CM.)  CHECK=   32.0, NUMBER OF INCREMENTS USED
```

Figure E14. - Biomechanics motion analysis printout

```
Z,(F)T,(SEC.), MOTION, CMS.

        VAR ERROR= 0.68190E 00          PERCENT ERROR= 0.42065E-00          ORDER 9
 1.523E 02+(-8.440E 00)T+( 3.980E 02)T**2+(-1.284E 03)T**3+( 9.937E 02)T**4+( 6.581E 02)T**5
+(-5.290E 02)T**6+(-9.845E 02)T**7+( 9.980E 02)T**8+(-2.379E 02)T**9+( 0.       )T**10

DZ/DT, VELOCITY (CM./SEC.)
-8.440E 00+( 7.960E 02)T+(-3.852E 03)T**2+( 3.975E 03)T**3+( 3.291E 03)T**4
+(-3.174E 03)T**5+(-6.892E 03)T**6+( 7.984E 03)T**7+(-2.141E 03)T**8+( 0.       )T**9

DDZ/DDT, ACCELERATION (CM./SEC.*SEC.)
 7.960E 02+(-7.703E 03)T+( 1.192E 04)T**2+( 1.316E 04)T**3+(-1.587E 04)T**4
+(-4.135E 04)T**5+( 5.589E 04)T**6+(-1.713E 04)T**7+( 0.       )T**8

Z=M(DDZ/DDT), FORCE (KG.)
   TIME      FORCE          TIME      FORCE          TIME      FORCE          TIME      FORCE          TIME      FORCE

   0.         5.495E 00     0.029      4.024E 00     0.058      2.704E 00     0.087      1.544E 00     0.116      5.509E-01
   0.145     -2.714E-01     0.175     -9.424E-01     0.204     -1.421E 00     0.233     -1.739E 00     0.262     -1.907E 00
   0.291     -1.938E 00     0.320     -1.848E 00     0.349     -1.656E 00     0.378     -1.382E 00     0.407     -1.046E 00
   0.436     -6.719E-01     0.466     -2.681E-01     0.495      1.159E-01     0.524      4.725E-01     0.553      7.825E-01
   0.582      1.029E 00     0.611      1.198E 00     0.640      1.279E 00     0.670      1.264E 00     0.698      1.156E 00
   0.727      9.516E-01     0.757      6.502E-01     0.786      2.856E-01     0.815     -1.319E-01     0.844     -5.773E-01
   0.873     -1.020E 00     0.902     -1.425E 00     0.931     -1.750E 00     0.960     -1.950E 00     0.989     -1.976E 00
   1.018     -1.774E 00     1.047     -1.290E 00     1.077     -4.313E-01     1.106      8.015E-01     1.135      2.486E 00
   1.164      4.672E 00     1.165      4.756E 00

PZ=FORCE(DZ/DT), POWER (KG.CM./SEC.)
   TIME      POWER          TIME      POWER          TIME      POWER          TIME      POWER          TIME      POWER

   0.        -4.637E 01     0.029      4.629E 01     0.058      6.917E 01     0.087      5.318E 01     0.116      2.137E 01
   0.145     -1.067E 01     0.175     -3.450E 01     0.204     -4.488E 01     0.233     -4.329E 01     0.262     -3.278E 01
   0.291     -1.757E 01     0.320     -1.989E 00     0.349      1.046E 01     0.378      1.758E 01     0.407      1.866E 01
   0.436      1.442E 01     0.466      6.300E 00     0.495     -2.761E 00     0.524     -1.066E 01     0.553     -1.558E 01
   0.582     -1.655E 01     0.611     -1.363E 01     0.640     -7.851E 00     0.670     -7.265E-01     0.698      5.040E 00
   0.727      8.392E 00     0.757      8.018E 00     0.786      4.089E 00     0.815     -1.933E 00     0.844     -7.604E 00
   0.873     -1.001E 01     0.902     -6.628E 00     0.931      3.590E 00     0.960      1.926E 01     0.989      3.594E 01
   1.018      4.641E 01     1.047      4.217E 01     1.077      1.578E 01     1.106     -2.882E 01     1.135     -7.262E 01
   1.164     -6.712E 01     1.165     -6.509E 01

WORK Z=INTEGRATION OF POWER Z
WORK=     1.452E 01 (KG.CM.)  CHECK=  256.0, NUMBER OF INCREMENTS USED
```

Figure E14. - Biomechanics motion analysis printout (continued)

FROM THE EQUATION OF MOTION Z,(F)T

G-GRADIENT (F)T (UNITLESS)

TIME	G-GRAD	TIME	G-GRAD	TIME	G-GRAD	TIME	G-GRAD	TIME	G-GRAD
0.	1.863E-01	0.029	1.864E-01	0.058	1.866E-01	0.087	1.871E-01	0.116	1.876E-01
0.145	1.881E-01	0.175	1.887E-01	0.204	1.892E-01	0.233	1.896E-01	0.262	1.899E-01
0.291	1.901E-01	0.320	1.901E-01	0.349	1.901E-01	0.378	1.900E-01	0.407	1.897E-01
0.436	1.895E-01	0.466	1.891E-01	0.495	1.888E-01	0.524	1.885E-01	0.553	1.882E-01
0.582	1.879E-01	0.611	1.877E-01	0.640	1.876E-01	0.670	1.875E-01	0.698	1.876E-01
0.727	1.877E-01	0.757	1.878E-01	0.786	1.880E-01	0.815	1.882E-01	0.844	1.884E-01
0.873	1.886E-01	0.902	1.887E-01	0.931	1.887E-01	0.960	1.886E-01	0.989	1.884E-01
1.018	1.881E-01	1.047	1.877E-01	1.077	1.872E-01	1.106	1.867E-01	1.135	1.862E-01
1.164	1.859E-01	1.165	1.859E-01						

POWER OF POTENTIAL ENERGY=G-GRADIENT*G*MASS*DZ/DT (KG.-CM./SEC.)

TIME	P.P.E.	TIME	P.P.E.	TIME	P.P.E.	TIME	P.P.E.	TIME	P.P.E.
0.	-1.065E 01	0.029	1.451E 01	0.058	3.232E 01	0.087	4.362E 01	0.116	4.925E 01
0.145	5.007E 01	0.175	4.677E 01	0.204	4.045E 01	0.233	3.195E 01	0.262	2.210E 01
0.291	1.167E 01	0.320	1.385E 00	0.349	-8.129E 00	0.378	-1.636E 01	0.407	-2.291E 01
0.436	-2.752E 01	0.466	-3.009E 01	0.495	-3.044E 01	0.524	-2.879E 01	0.553	-2.536E 01
0.582	-2.046E 01	0.611	-1.445E 01	0.640	-7.794E 00	0.670	-7.300E-01	0.698	5.538E 00
0.727	1.120E 01	0.757	1.568E 01	0.786	1.822E 01	0.815	1.867E 01	0.844	1.680E 01
0.873	1.252E 01	0.902	5.943E 00	0.931	-2.621E 00	0.960	-1.261E 01	0.989	-2.321E 01
1.018	-3.331E 01	1.047	-4.155E 01	1.077	-4.636E 01	1.106	-4.544E 01	1.135	-3.683E 01
1.164	-1.808E 01	1.165	-1.722E 01						

POTENTIAL ENERGY=INTERGRATION OF THE POWER OF POTENTIAL ENERGY
POTENTIAL ENERGY= -1.012E-03(KG.-CM.) CHECK= 8.0, NUMBER OF INCREMENTS USED

TH,(F)T,(SEC.), MOTION, RADS.

VAR ERROR= 0.51967E-01 PERCENT ERROR= 0.53766E 01 ORDER 9
-8.553E-01+(-2.344E 00)T+(-2.759E 00)T**2+(7.532E 01)T**3+(-1.971E 02)T**4+(1.722E 02)T**5
+(-3.378E 01)T**6+(1.661E 01)T**7+(-5.012E 01)T**8+(2.203E 01)T**9+(0.)T**10

DTH/DT, VELOCITY (RAD./SEC.)
-2.344E 00+(-5.517E 00)T+(2.260E 02)T**2+(-7.886E 02)T**3+(8.608E 02)T**4
+(-2.027E 02)T**5+(1.163E 02)T**6+(-4.009E 02)T**7+(1.982E 02)T**8+(0.)T**9

DDTH/DDT, ACCELERATION (RAD./SEC.*SEC.)
-5.517E 00+(4.519E 02)T+(-2.366E 03)T**2+(3.443E 03)T**3+(-1.013E 03)T**4
+(6.977E 02)T**5+(-2.807E 03)T**6+(1.586E 03)T**7+(0.)T**8

Figure E14. - Biomechanics motion analysis printout (continued)

MOMENT OF INERTIA(DDTH/DDT) TORQUE (KG.-CM.)

TIME	TORQUE	TIME	TORQUE	TIME	TORQUE	TIME	TORQUE	TIME	TORQUE
0.	-2.996E 00	0.029	3.085E 00	0.058	7.275E 00	0.087	9.832E 00	0.116	1.101E 01
0.145	1.105E 01	0.175	1.014E 01	0.204	8.563E 00	0.233	6.521E 00	0.262	4.202E 00
0.291	1.782E 00	0.320	-5.802E-01	0.349	-2.747E 00	0.378	-4.601E 00	0.407	-6.052E 00
0.436	-7.031E 00	0.466	-7.503E 00	0.495	-7.423E 00	0.524	-6.828E 00	0.553	-5.756E 00
0.582	-4.273E 00	0.611	-2.467E 00	0.640	-4.457E-01	0.670	1.736E 00	0.698	3.719E 00
0.727	5.575E 00	0.757	7.123E 00	0.786	8.113E 00	0.815	8.474E 00	0.844	8.100E 00
0.873	6.925E 00	0.902	4.930E 00	0.931	2.159E 00	0.960	-1.264E 00	0.989	-5.115E 00
1.018	-9.057E 00	1.047	-1.261E 01	1.077	-1.520E 01	1.106	-1.580E 01	1.135	-1.348E 01
1.164	-6.929E 00	1.165	-6.610E 00						

POWER,(KG.-CM./SEC.)

TIME	POWER	TIME	POWER	TIME	POWER	TIME	POWER	TIME	POWER
0.	7.022E 00	0.029	-7.197E 00	0.058	-1.490E 01	0.087	-1.558E 01	0.116	-1.126E 01
0.145	-4.740E 00	0.175	1.622E 00	0.204	5.668E 00	0.233	6.954E 00	0.262	5.687E 00
0.291	2.697E 00	0.320	-8.964E-01	0.349	-3.996E 00	0.378	-5.784E 00	0.407	-5.874E 00
0.436	-4.352E 00	0.466	-1.613E 00	0.495	1.381E 00	0.524	3.884E 00	0.553	5.220E 00
0.582	5.027E 00	0.611	3.349E 00	0.640	6.399E-01	0.670	-2.431E 00	0.698	-4.684E 00
0.727	-5.630E 00	0.757	-4.680E 00	0.786	-2.008E 00	0.815	1.682E 00	0.844	5.221E 00
0.873	7.267E 00	0.902	6.752E 00	0.931	3.372E 00	0.960	-2.007E 00	0.989	-7.261E 00
1.018	-9.424E 00	1.047	-5.786E 00	1.077	4.814E 00	1.106	1.825E 01	1.135	2.631E 01
1.164	1.746E 01	1.165	1.674E 01						

WORK TH=INTERGRATION OF POWER TH
WORK= 7.134E 00 (KG.CM.) CHECK= 128.0, NUMBER OF INCREMENTS USED

SEGMENT-NO. 2, TRUNK

X,(F)T,(SEC.), MOTION, CMS.

```
        VAR ERROR= 0.39891E-00          PERCENT ERROR= 0.68743E 00          ORDER 9
 2.158E-01+( 2.250E 02)T+(-3.893E 01)T**2+( 9.164E 01)T**3+( 1.139E 02)T**4+(-4.374E 02)T**5
+( 2.520E 02)T**6+( 2.030E 02)T**7+(-2.529E 02)T**8+( 6.952E 01)T**9+( 0.        )T**10

DX/DT, VELOCITY (CM./SEC.)
 2.250E 02+(-7.785E 01)T+( 2.749E 02)T**2+( 4.555E 02)T**3+(-2.187E 03)T**4
+( 1.512E 03)T**5+( 1.421E 03)T**6+(-2.023E 03)T**7+( 6.257E 02)T**8+( 0.        )T**9

DDX/DDT, ACCELERATION (CM./SEC.*SEC.)
-7.785E 01+( 5.498E 02)T+( 1.366E 03)T**2+(-8.748E 03)T**3+( 7.559E 03)T**4
+( 8.524E 03)T**5+(-1.416E 04)T**6+( 5.005E 03)T**7+( 0.        )T**8
```

Figure E14. - Biomechanics motion analysis printout (continued)

X=M(DDX/DDT), FORCE (KG.)

TIME	FORCE	TIME	FORCE	TIME	FORCE	TIME	FORCE	TIME	FORCE
0.	-3.178E 00	0.029	-2.489E 00	0.058	-1.755E 00	0.087	-1.019E 00	0.116	-3.195E-01
0.145	3.140E-01	0.175	8.749E-01	0.204	1.309E 00	0.233	1.626E 00	0.262	1.822E 00
0.291	1.900E 00	0.320	1.866E 00	0.349	1.732E 00	0.378	1.512E 00	0.407	1.223E 00
0.436	8.864E-01	0.466	5.085E-01	0.495	1.362E-01	0.524	-2.226E-01	0.553	-5.493E-01
0.582	-8.275E-01	0.611	-1.044E 00	0.640	-1.188E 00	0.670	-1.255E 00	0.698	-1.241E 00
0.727	-1.150E 00	0.757	-9.827E-01	0.786	-7.623E-01	0.815	-5.003E-01	0.844	-2.159E-01
0.873	6.868E-02	0.902	3.298E-01	0.931	5.432E-01	0.960	6.863E-01	0.989	7.392E-01
1.018	6.878E-01	1.047	5.258E-01	1.077	2.469E-01	1.106	-1.108E-01	1.135	-5.173E-01
1.164	-9.130E-01	1.165	-9.255E-01						

PX=FORCE(DX/DT), POWER (KG.CM./SEC.)

TIME	POWER	TIME	POWER	TIME	POWER	TIME	POWER	TIME	POWER
0.	-7.150E 02	0.029	-5.549E 02	0.058	-3.886E 02	0.087	-2.247E 02	0.116	-7.030E 01
0.145	6.908E 01	0.175	1.929E 02	0.204	2.895E 02	0.233	3.614E 02	0.262	4.073E 02
0.291	4.273E 02	0.320	4.222E 02	0.349	3.940E 02	0.378	3.456E 02	0.407	2.809E 02
0.436	2.042E 02	0.466	1.174E 02	0.495	3.148E 01	0.524	-5.144E 01	0.553	-1.268E 02
0.582	-1.906E 02	0.611	-2.397E 02	0.640	-2.719E 02	0.670	-2.861E 02	0.698	-2.817E 02
0.727	-2.601E 02	0.757	-2.215E 02	0.786	-1.714E 02	0.815	-1.122E 02	0.844	-4.839E 01
0.873	1.539E 01	0.902	7.393E 01	0.931	1.220E 02	0.960	1.544E 02	0.989	1.667E 02
1.018	1.554E 02	1.047	1.191E 02	1.077	5.597E 01	1.106	-2.513E 01	1.135	-1.172E 02
1.164	-2.064E 02	1.165	-2.092E 02						

```
WORK X=INTERGRATION OF POWER X
WORK=     2.465E 02 (KG.CM.)  CHECK=  128.0, NUMBER OF INCREMENTS USED

Z,(F)T,(SEC.), MOTION, CMS.

          VAR ERROR= 0.56315E 00          PERCENT ERROR= 0.45792E-00          ORDER10
 1.239E 02+( 2.130E 01)T+( 4.213E 02)T**2+(-2.127E 03)T**3+( 2.977E 03)T**4+(-5.481E 02)T**5
+(-8.241E 02)T**6+(-1.172E 03)T**7+( 1.800E 03)T**8+(-5.141E 02)T**9+(-3.130E 01)T**10

DZ/DT, VELOCITY (CM./SEC.)
 2.130E 01+( 8.426E 02)T+(-6.381E 03)T**2+( 1.191E 04)T**3+(-2.740E 03)T**4
+(-4.945E 03)T**5+(-8.204E 03)T**6+( 1.440E 04)T**7+(-4.627E 03)T**8+(-3.130E 02)T**9

DDZ/DDT, ACCELERATION (CM./SEC.*SEC.)
 8.426E 02+(-1.276E 04)T+( 3.573E 04)T**2+(-1.096E 04)T**3+(-2.472E 04)T**4
+(-4.923E 04)T**5+( 1.008E 05)T**6+(-3.702E 04)T**7+(-2.817E 03)T**8
```

Figure E14. - Biomechanics motion analysis printout (continued)

Z=M(DDZ/DDT), FORCE (KG.)

TIME	FORCE	TIME	FORCE	TIME	FORCE	TIME	FORCE	TIME	FORCE
0.	3.440E 01	0.029	2.050E 01	0.058	8.989E 00	0.087	-2.451E-01	0.116	-7.319E 00
0.145	-1.237E 01	0.175	-1.566E 01	0.204	-1.716E 01	0.233	-1.721E 01	0.262	-1.605E 01
0.291	-1.392E 01	0.320	-1.105E 01	0.349	-7.699E 00	0.378	-4.106E 00	0.407	-4.997E-01
0.436	2.905E 00	0.466	6.012E 00	0.495	8.448E 00	0.524	1.020E 01	0.553	1.116E 01
0.582	1.131E 01	0.611	1.062E 01	0.640	9.137E 00	0.670	6.868E 00	0.698	4.200E 00
0.727	1.047E 00	0.757	-2.412E 00	0.786	-5.701E 00	0.815	-8.675E 00	0.844	-1.107E 01
0.873	-1.262E 01	0.902	-1.309E 01	0.931	-1.230E 01	0.960	-1.012E 01	0.989	-6.523E 00
1.018	-1.610E 00	1.047	4.359E 00	1.077	1.115E 01	1.106	1.760E 01	1.135	2.290E 01
1.164	2.573E 01	1.165	2.576E 01						

PZ=FORCE(DZ/DT), POWER (KG.CM./SEC.)

TIME	POWER	TIME	POWER	TIME	POWER	TIME	POWER	TIME	POWER
0.	7.326E 02	0.029	8.337E 02	0.058	4.584E 02	0.087	-1.323E 01	0.116	-3.744E 02
0.145	-5.451E 02	0.175	-5.268E 02	0.204	-3.754E 02	0.233	-1.651E 02	0.262	3.669E 01
0.291	1.806E 02	0.320	2.418E 02	0.349	2.199E 02	0.378	1.345E 02	0.407	1.719E 01
0.436	-9.740E 01	0.466	-1.817E 02	0.495	-2.116E 02	0.524	-1.874E 02	0.553	-1.199E 02
0.582	-3.064E 01	0.611	5.443E 01	0.640	1.114E 02	0.670	1.244E 02	0.698	9.213E 01
0.727	2.493E 01	0.757	-5.625E 01	0.786	-1.165E 02	0.815	-1.327E 02	0.844	-9.117E 01
0.873	2.928E 00	0.902	1.235E 02	0.931	2.280E 02	0.960	2.690E 02	0.989	2.125E 02
1.018	5.723E 01	1.047	-1.509E 02	1.077	-3.227E 02	1.106	-3.288E 02	1.135	-9.604E 01
1.164	3.416E 02	1.165	3.583E 02						

WORK Z=INTERGRATION OF POWER Z
WORK= 1.571E 02 (KG.CM.) CHECK= 64.0, NUMBER OF INCREMENTS USED

FROM THE EQUATION OF MOTION Z,(F)T

G-GRADIENT (F)T (UNITLESS)

TIME	G-GRAD	TIME	G-GRAD	TIME	G-GRAD	TIME	G-GRAD	TIME	G-GRAD
0.	1.725E-01	0.029	1.729E-01	0.058	1.736E-01	0.087	1.743E-01	0.116	1.751E-01
0.145	1.758E-01	0.175	1.763E-01	0.204	1.767E-01	0.233	1.770E-01	0.262	1.770E-01
0.291	1.769E-01	0.320	1.766E-01	0.349	1.763E-01	0.378	1.759E-01	0.407	1.754E-01
0.436	1.749E-01	0.466	1.744E-01	0.495	1.740E-01	0.524	1.737E-01	0.553	1.735E-01
0.582	1.734E-01	0.611	1.734E-01	0.640	1.736E-01	0.670	1.738E-01	0.698	1.741E-01
0.727	1.744E-01	0.757	1.747E-01	0.786	1.750E-01	0.815	1.753E-01	0.844	1.755E-01
0.873	1.755E-01	0.902	1.755E-01	0.931	1.753E-01	0.960	1.749E-01	0.989	1.745E-01
1.018	1.740E-01	1.047	1.735E-01	1.077	1.731E-01	1.106	1.727E-01	1.135	1.726E-01
1.164	1.726E-01	1.165	1.726E-01						

Figure E14. - Biomechanics motion analysis printout (continued)

POWER OF POTENTIAL ENERGY=G-GRADIENT*G*MASS*DZ/DT (KG.-CM./SEC.)

TIME	P.P.E.	TIME	P.P.E.	TIME	P.P.E.	TIME	P.P.E.	TIME	P.P.E.
0.	1.471E 02	0.029	2.815E 02	0.058	3.544E 02	0.087	3.767E 02	0.116	3.586E 02
0.145	3.099E 02	0.175	2.374E 02	0.204	1.548E 02	0.233	6.797E 01	0.262	-1.619E 01
0.291	-9.192E 01	0.320	-1.548E 02	0.349	-2.016E 02	0.378	-2.307E 02	0.407	-2.415E 02
0.436	-2.347E 02	0.466	-2.110E 02	0.495	-1.745E 02	0.524	-1.278E 02	0.553	-7.461E 01
0.582	-1.881E 01	0.611	3.559E 01	0.640	8.468E 01	0.670	1.260E 02	0.698	1.528E 02
0.727	1.663E 02	0.757	1.631E 02	0.786	1.431E 02	0.815	1.073E 02	0.844	5.787E 01
0.873	-1.631E 00	0.902	-6.627E 01	0.931	-1.300E 02	0.960	-1.862E 02	0.989	-2.276E 02
1.018	-2.476E 02	1.047	-2.405E 02	1.077	-2.004E 02	1.106	-1.292E 02	1.135	-2.896E 01
1.164	9.174E 01	1.165	9.610E 01						

POTENTIAL ENERGY=INTERGRATION OF THE POWER OF POTENTIAL ENERGY
POTENTIAL ENERGY= 1.768E-03(KG.-CM.) CHECK= 16.0, NUMBER OF INCREMENTS USED

TH,(F)T,(SEC.), MOTION, RADS.

VAR ERROR= 0.11561E-01 PERCENT ERROR= 0.37133E 01 ORDER 9

```
-3.315E-01+( 1.622E-01)T+(-8.560E-01)T**2+( 8.591E-02)T**3+( 5.558E 00)T**4+(-8.145E 00)T**5
+( 1.601E 00)T**6+( 1.703E 00)T**7+( 7.062E-01)T**8+(-8.289E-01)T**9+( 0.       )T**10
```

DTH/DT, VELOCITY (RAD./SEC.)

```
 1.622E-01+(-1.712E 00)T+( 2.577E-01)T**2+( 2.223E 01)T**3+(-4.073E 01)T**4
+( 9.606E 00)T**5+( 1.192E 01)T**6+( 5.650E 00)T**7+(-7.460E 00)T**8+( 0.       )T**9
```

DDTH/DDT, ACCELERATION (RAD./SEC.*SEC.)

```
-1.712E 00+( 5.154E-01)T+( 6.669E 01)T**2+(-1.629E 02)T**3+( 4.803E 01)T**4
+( 7.152E 01)T**5+( 3.955E 01)T**6+(-5.968E 01)T**7+( 0.       )T**8
```

MOMENT OF INERTIA(DDTH/DDT) TORQUE (KG.-CM.)

TIME	TORQUE	TIME	TORQUE	TIME	TORQUE	TIME	TORQUE	TIME	TORQUE
0.	-2.716E 01	0.029	-2.609E 01	0.058	-2.362E 01	0.087	-2.009E 01	0.116	-1.584E 01
0.145	-1.119E 01	0.175	-6.262E 00	0.204	-1.648E 00	0.233	2.585E 00	0.262	6.245E 00
0.291	9.176E 00	0.320	1.126E 01	0.349	1.242E 01	0.378	1.262E 01	0.407	1.188E 01
0.436	1.022E 01	0.466	7.659E 00	0.495	4.486E 00	0.524	7.945E-01	0.553	-3.218E 00
0.582	-7.331E 00	0.611	-1.130E 01	0.640	-1.488E 01	0.670	-1.789E 01	0.698	-1.984E 01
0.727	-2.074E 01	0.757	-2.027E 01	0.786	-1.833E 01	0.815	-1.484E 01	0.844	-9.806E 00
0.873	-3.348E 00	0.902	4.286E 00	0.931	1.269E 01	0.960	2.129E 01	0.989	2.928E 01
1.018	3.561E 01	1.047	3.896E 01	1.077	3.753E 01	1.106	2.937E 01	1.135	1.209E 01
1.164	-1.716E 01	1.165	-1.842E 01						

Figure E14. - Biomechanics motion analysis printout (continued)

POWER,(KG.-CM./SEC.)

TIME	POWER	TIME	POWER	TIME	POWER	TIME	POWER	TIME	POWER
0.	-4.406E 00	0.029	-2.957E 00	0.058	-1.599E 00	0.087	-5.547E-01	0.116	8.423E-02
0.145	3.365E-01	0.175	2.916E-01	0.204	8.859E-02	0.233	-1.366E-01	0.262	-2.789E-01
0.291	-2.793E-01	0.320	-1.308E-01	0.349	1.264E-01	0.378	4.193E-01	0.407	6.621E-01
0.436	7.778E-01	0.466	7.132E-01	0.495	4.679E-01	0.524	8.677E-02	0.553	-3.444E-01
0.582	-7.139E-01	0.611	-9.077E-01	0.640	-8.376E-01	0.670	-4.503E-01	0.698	1.642E-01
0.727	9.446E-01	0.757	1.715E 00	0.786	2.201E 00	0.815	2.235E 00	0.844	1.700E 00
0.873	6.216E-01	0.902	-7.926E-01	0.931	-2.152E 00	0.960	-2.947E 00	0.989	-2.694E 00
1.018	-1.152E 00	1.047	1.417E 00	1.077	4.115E 00	1.106	5.051E 00	1.135	2.556E 00
1.164	-3.585E 00	1.165	-3.828E 00						

WORK TH=INTERGRATION OF POWER TH
WORK= 1.404E 00 (KG.CM.) CHECK= 256.0, NUMBER OF INCREMENTS USED

SEGMENT-NO. 3, UPPER ARM

X,(F)T,(SEC.), MOTION, CMS.

VAR ERROR= 0.47624E-00 PERCENT ERROR= 0.73919E 00 ORDER 9
4.121E-01+(2.199E 02)T+(-1.907E 01)T**2+(1.367E 02)T**3+(-1.981E 02)T**4+(-6.107E 00)T**5
+(1.283E 02)T**6+(8.906E 01)T**7+(-1.991E 02)T**8+(7.298E 01)T**9+(0.)T**10

DX/DT, VELOCITY (CM./SEC.)
2.199E 02+(-3.815E 01)T+(4.100E 02)T**2+(-7.924E 02)T**3+(-3.053E 01)T**4
+(7.700E 02)T**5+(6.234E 02)T**6+(-1.593E 03)T**7+(6.568E 02)T**8+(0.)T**9

DDX/DDT, ACCELERATION (CM./SEC.*SEC.)
-3.815E 01+(8.200E 02)T+(-2.377E 03)T**2+(-1.221E 02)T**3+(3.850E 03)T**4
+(3.741E 03)T**5+(-1.115E 04)T**6+(5.255E 03)T**7+(0.)T**8

X=M(DDX/DDT), FORCE (KG.)

TIME	FORCE	TIME	FORCE	TIME	FORCE	TIME	FORCE	TIME	FORCE
0.	-8.507E-02	0.029	-3.650E-02	0.058	3.200E-03	0.087	3.423E-02	0.116	5.696E-02
0.145	7.190E-02	0.175	7.988E-02	0.204	8.122E-02	0.233	7.723E-02	0.262	6.892E-02
0.291	5.735E-02	0.320	4.363E-02	0.349	2.883E-02	0.378	1.397E-02	0.407	1.335E-05
0.436	-1.222E-02	0.466	-2.232E-02	0.495	-2.909E-02	0.524	-3.260E-02	0.553	-3.274E-02
0.582	-2.963E-02	0.611	-2.360E-02	0.640	-1.519E-02	0.670	-4.790E-03	0.698	5.604E-03
0.727	1.604E-02	0.757	2.532E-02	0.786	3.167E-02	0.815	3.437E-02	0.844	3.257E-02
0.873	2.566E-02	0.902	1.349E-02	0.931	-3.527E-03	0.960	-2.424E-02	0.989	-4.656E-02
1.018	-6.724E-02	1.047	-8.165E-02	1.077	-8.324E-02	1.106	-6.339E-02	1.135	-1.187E-02
1.164	8.451E-02	1.165	8.882E-02						

Figure E14. - Biomechanics motion analysis printout (continued)

```
PX=FORCE(DX/DT), POWER (KG.CM./SEC.)
   TIME      POWER            TIME      POWER            TIME      POWER            TIME      POWER            TIME      POWER

   0.       -1.871E 01        0.029    -7.999E 00        0.058     7.006E-01        0.087     7.503E 00        0.116     1.252E 01
   0.145     1.586E 01        0.175     1.771E 01        0.204     1.809E 01        0.233     1.728E 01        0.262     1.549E 01
   0.291     1.293E 01        0.320     9.868E 00        0.349     6.534E 00        0.378     3.171E 00        0.407     3.032E-03
   0.436    -2.772E 00        0.466    -5.060E 00        0.495    -6.585E 00        0.524    -7.367E 00        0.553    -7.385E 00
   0.582    -6.671E 00        0.611    -5.305E 00        0.640    -3.411E 00        0.670    -1.075E 00        0.698     1.258E 00
   0.727     3.603E 00        0.757     5.693E 00        0.786     7.132E 00        0.815     7.756E 00        0.844     7.362E 00
   0.873     5.811E 00        0.902     3.059E 00        0.931    -7.998E-01        0.960    -5.494E 00        0.989    -1.053E 01
   1.018    -1.516E 01        1.047    -1.832E 01        1.077    -1.859E 01        1.106    -1.409E 01        1.135    -2.632E 00
   1.164     1.878E 01        1.165     1.974E 01

WORK X=INTERGRATION OF POWER X
WORK=     1.960E 01 (KG.CM.)  CHECK=  256.0, NUMBER OF INCREMENTS USED

Z,(F)T,(SEC.), MOTION, CMS.

          VAR ERROR= 0.56174E 00          PERCENT ERROR= 0.36336E-00          ORDER 9
 1.407E 02+( 2.347E 01)T+( 3.873E 02)T**2+(-2.060E 03)T**3+( 3.224E 03)T**4+(-1.392E 03)T**5
+(-9.505E 01)T**6+(-1.143E 03)T**7+( 1.549E 03)T**8+(-4.905E 02)T**9+( 0.        )T**10

DZ/DT, VELOCITY (CM./SEC.)
 2.347E 01+( 7.747E 02)T+(-6.181E 03)T**2+( 1.290E 04)T**3+(-6.958E 03)T**4
+(-5.703E 02)T**5+(-7.998E 03)T**6+( 1.239E 04)T**7+(-4.414E 03)T**8+( 0.        )T**9

DDZ/DDT, ACCELERATION (CM./SEC.*SEC.)
 7.747E 02+(-1.236E 04)T+( 3.869E 04)T**2+(-2.783E 04)T**3+(-2.852E 03)T**4
+(-4.799E 04)T**5+( 8.674E 04)T**6+(-3.531E 04)T**7+( 0.        )T**8

Z=M(DDZ/DDT), FORCE (KG.)
   TIME      FORCE            TIME      FORCE            TIME      FORCE            TIME      FORCE            TIME      FORCE

   0.        1.728E 00        0.029     9.991E-01        0.058     4.066E-01        0.087    -5.949E-02        0.116    -4.092E-01
   0.145    -6.529E-01        0.175    -8.055E-01        0.204    -8.686E-01        0.233    -8.609E-01        0.262    -7.949E-01
   0.291    -6.830E-01        0.320    -5.378E-01        0.349    -3.712E-01        0.378    -1.952E-01        0.407    -2.045E-02
   0.436     1.429E-01        0.466     2.906E-01        0.495     4.052E-01        0.524     4.863E-01        0.553     5.302E-01
   0.582     5.346E-01        0.611     4.998E-01        0.640     4.277E-01        0.670     3.183E-01        0.698     1.902E-01
   0.727     3.877E-02        0.757    -1.277E-01        0.786    -2.871E-01        0.815    -4.328E-01        0.844    -5.525E-01
   0.873    -6.343E-01        0.902    -6.666E-01        0.931    -6.398E-01        0.960    -5.468E-01        0.989    -3.842E-01
   1.018    -1.534E-01        1.047     1.380E-01        1.077     4.869E-01        1.106     8.444E-01        1.135     1.185E 00
   1.164     1.460E 00        1.165     1.468E 00
```

Figure E14. - Biomechanics motion analysis printout (continued)

PZ=FORCE(DZ/DT), POWER (KG.CM./SEC.)

TIME	POWER	TIME	POWER	TIME	POWER	TIME	POWER	TIME	POWER
0.	4.055E 01	0.029	4.101E 01	0.058	2.035E 01	0.087	-3.104E 00	0.116	-2.005E 01
0.145	-2.741E 01	0.175	-2.583E 01	0.204	-1.833E 01	0.233	-8.428E 00	0.262	8.215E-01
0.291	7.299E 00	0.320	1.003E 01	0.349	9.125E 00	0.378	5.516E 00	0.407	6.066E-01
0.436	-4.122E 00	0.466	-7.526E 00	0.495	-8.649E 00	0.524	-7.544E 00	0.553	-4.697E 00
0.582	-1.013E 00	0.611	2.436E 00	0.640	4.680E 00	0.670	5.091E 00	0.698	3.653E 00
0.727	8.032E-01	0.757	-2.570E 00	0.786	-5.000E 00	0.815	-5.503E 00	0.844	-3.467E 00
0.873	9.451E-01	0.902	6.670E 00	0.931	1.188E 01	0.960	1.441E 01	0.989	1.248E 01
1.018	5.531E 00	1.047	-4.999E 00	1.077	-1.561E 01	1.106	-1.976E 01	1.135	-1.204E 01
1.164	1.043E 01	1.165	1.145E 01						

WORK Z=INTERGRATION OF POWER Z
WORK= 1.457E 01 (KG.CM.) CHECK= 32.0, NUMBER OF INCREMENTS USED

FROM THE EQUATION OF MOTION Z,(F)T

G-GRADIENT (F)T (UNITLESS)

TIME	G-GRAD	TIME	G-GRAD	TIME	G-GRAD	TIME	G-GRAD	TIME	G-GRAD
0.	1.807E-01	0.029	1.811E-01	0.058	1.818E-01	0.087	1.825E-01	0.116	1.832E-01
0.145	1.839E-01	0.175	1.844E-01	0.204	1.848E-01	0.233	1.850E-01	0.262	1.851E-01
0.291	1.850E-01	0.320	1.848E-01	0.349	1.845E-01	0.378	1.841E-01	0.407	1.837E-01
0.436	1.833E-01	0.466	1.829E-01	0.495	1.825E-01	0.524	1.823E-01	0.553	1.821E-01
0.582	1.820E-01	0.611	1.821E-01	0.640	1.822E-01	0.670	1.824E-01	0.698	1.826E-01
0.727	1.829E-01	0.757	1.832E-01	0.786	1.835E-01	0.815	1.837E-01	0.844	1.838E-01
0.873	1.838E-01	0.902	1.838E-01	0.931	1.836E-01	0.960	1.832E-01	0.989	1.828E-01
1.018	1.823E-01	1.047	1.818E-01	1.077	1.813E-01	1.106	1.809E-01	1.135	1.807E-01
1.164	1.807E-01	1.165	1.807E-01						

POWER OF POTENTIAL ENERGY=G-GRADIENT*G*MASS*DZ/DT (KG.-CM./SEC.)

TIME	P.P.E.	TIME	P.P.E.	TIME	P.P.E.	TIME	P.P.E.	TIME	P.P.E.
0.	9.274E 00	0.029	1.626E 01	0.058	1.990E 01	0.087	2.082E 01	0.116	1.964E 01
0.145	1.689E 01	0.175	1.294E 01	0.204	8.529E 00	0.233	3.961E 00	0.262	-4.183E-01
0.291	-4.323E 00	0.320	-7.538E 00	0.349	-9.917E 00	0.378	-1.138E 01	0.407	-1.192E 01
0.436	-1.156E 01	0.466	-1.036E 01	0.495	-8.522E 00	0.524	-6.184E 00	0.553	-3.529E 00
0.582	-7.540E-01	0.611	1.941E 00	0.640	4.360E 00	0.670	6.380E 00	0.698	7.672E 00
0.727	8.286E 00	0.757	8.062E 00	0.786	6.988E 00	0.815	5.108E 00	0.844	2.522E 00
0.873	-5.991E-01	0.902	-4.022E 00	0.931	-7.454E 00	0.960	-1.056E 01	0.989	-1.299E 01
1.018	-1.438E 01	1.047	-1.440E 01	1.077	-1.271E 01	1.106	-9.259E 00	1.135	-4.015E 00
1.164	2.823E 00	1.165	3.082E 00						

POTENTIAL ENERGY=INTERGRATION OF THE POWER OF POTENTIAL ENERGY
POTENTIAL ENERGY= -1.824E-03(KG.-CM.) CHECK= 4.0, NUMBER OF INCREMENTS USED

Figure E14. - Biomechanics motion analysis printout (continued)

P-SUIT MOMENT DISTRIBUTION, UPPER ARM

PRESSURE SUIT MOMENT, TIME (SEC.) VS. TORQUE (KG.-CM.)

TIME	TORQUE	TIME	TORQUE	TIME	TORQUE	TIME	TORQUE	TIME	TORQUE
0.	2.785E 02	0.029	2.799E 02	0.058	2.847E 02	0.087	2.920E 02	0.116	3.007E 02
0.145	3.101E 02	0.175	3.197E 02	0.204	3.283E 02	0.233	3.358E 02	0.262	3.417E 02
0.291	3.459E 02	0.320	3.482E 02	0.349	3.488E 02	0.378	3.478E 02	0.407	3.453E 02
0.436	3.418E 02	0.466	3.373E 02	0.495	3.325E 02	0.524	3.276E 02	0.553	3.230E 02
0.582	3.187E 02	0.611	3.152E 02	0.640	3.125E 02	0.670	3.105E 02	0.698	3.096E 02
0.727	3.095E 02	0.757	3.101E 02	0.786	3.112E 02	0.815	3.127E 02	0.844	3.143E 02
0.873	3.157E 02	0.902	3.167E 02	0.931	3.172E 02	0.960	3.168E 02	0.989	3.157E 02
1.018	3.139E 02	1.047	3.114E 02	1.077	3.086E 02	1.106	3.060E 02	1.135	3.039E 02
1.164	3.029E 02	1.165	3.035E 02						

POWER,(KG.-CM./SEC.)

TIME	POWER	TIME	POWER	TIME	POWER	TIME	POWER	TIME	POWER
0.	3.696E 01	0.029	6.970E 01	0.058	9.124E 01	0.087	1.035E 02	0.116	1.078E 02
0.145	1.053E 02	0.175	9.650E 01	0.204	8.342E 01	0.233	6.723E 01	0.262	4.943E 01
0.291	3.149E 01	0.320	1.471E 01	0.349	1.456E-01	0.378	-1.150E 01	0.407	-1.988E 01
0.436	-2.498E 01	0.466	-2.710E 01	0.495	-2.661E 01	0.524	-2.428E 01	0.553	-2.081E 01
0.582	-1.693E 01	0.611	-1.328E 01	0.640	-1.045E 01	0.670	-8.907E 00	0.698	-9.078E 00
0.727	-1.111E 01	0.757	-1.522E 01	0.786	-2.097E 01	0.815	-2.805E 01	0.844	-3.579E 01
0.873	-4.328E 01	0.902	-4.939E 01	0.931	-5.289E 01	0.960	-5.255E 01	0.989	-4.736E 01
1.018	-3.676E 01	1.047	-2.079E 01	1.077	3.677E-01	1.106	2.320E 01	1.135	4.492E 01
1.164	6.029E 01	1.165	6.075E 01						

WORK P-SUIT TORQUE= INTERGRATION OF POWER TH
WORK= 9.171E 01 (KG.CM.) CHECK= 128.0, NUMBER OF INCREMENTS USED

SEGMENT-NO. 4, LOWER ARM AND HAND

X,(F)T,(SEC.), MOTION, CMS.

```
        VAR ERROR= 0.45879E-00          PERCENT ERROR= 0.18044E 01          ORDER10
 4.209E-01+( 2.236E 02)T+( 2.487E 01)T**2+(-2.869E 02)T**3+( 1.153E 03)T**4+(-1.683E 03)T**5
+( 6.082E 01)T**6+( 2.299E 03)T**7+(-2.374E 03)T**8+( 9.266E 02)T**9+(-1.185E 02)T**10

DX/DT, VELOCITY (CM./SEC.)
 2.236E 02+( 4.974E 01)T+(-8.606E 02)T**2+( 4.612E 03)T**3+(-8.416E 03)T**4
+( 3.649E 02)T**5+( 1.609E 04)T**6+(-1.899E 04)T**7+( 8.339E 03)T**8+(-1.185E 03)T**9

DDX/DDT, ACCELERATION (CM./SEC.*SEC.)
 4.974E 01+(-1.721E 03)T+( 1.384E 04)T**2+(-3.366E 04)T**3+( 1.825E 03)T**4
+( 9.656E 04)T**5+(-1.329E 05)T**6+( 6.671E 04)T**7+(-1.066E 04)T**8
```

Figure E14. - Biomechanics motion analysis printout (continued)

```
TH,(F)T,(SEC.), MOTION, RADS.

        VAR ERROR= 0.10140E-01          PERCENT ERROR= 0.20552E 01          ORDER10
 4.611E-01+( 1.327E-01)T+( 2.437E 00)T**2+(-1.046E 01)T**3+( 1.380E 01)T**4+(-3.262E 00)T**5
+(-2.519E 00)T**6+(-5.567E 00)T**7+( 7.204E 00)T**8+(-1.145E 00)T**9+(-5.884E-01)T**10

DTH/DT, VELOCITY (RAD./SEC.)
 1.327E-01+( 4.875E 00)T+(-3.138E 01)T**2+( 5.519E 01)T**3+(-1.631E 01)T**4
+(-1.511E 01)T**5+(-3.897E 01)T**6+( 5.763E 01)T**7+(-1.031E 01)T**8+(-5.884E 00)T**9

DDTH/DDT, ACCELERATION (RAD./SEC.*SEC.)
 4.875E 00+(-6.277E 01)T+( 1.656E 02)T**2+(-6.524E 01)T**3+(-7.556E 01)T**4
+(-2.338E 02)T**5+( 4.034E 02)T**6+(-8.246E 01)T**7+(-5.296E 01)T**8
```

MOMENT OF INERTIA(DDTH/DDT) TORQUE (KG.-CM.)

TIME	TORQUE	TIME	TORQUE	TIME	TORQUE	TIME	TORQUE	TIME	TORQUE
0.	6.776E-01	0.029	4.437E-01	0.058	2.471E-01	0.087	8.604E-02	0.116	-4.139E-02
0.145	-1.375E-01	0.175	-2.067E-01	0.204	-2.473E-01	0.233	-2.654E-01	0.262	-2.642E-01
0.291	-2.474E-01	0.320	-2.186E-01	0.349	-1.814E-01	0.378	-1.392E-01	0.407	-9.561E-02
0.436	-5.356E-02	0.466	-1.460E-02	0.495	1.633E-02	0.524	3.890E-02	0.553	5.199E-02
0.582	5.514E-02	0.611	4.858E-02	0.640	3.323E-02	0.670	9.822E-03	0.698	-1.674E-02
0.727	-4.625E-02	0.757	-7.547E-02	0.786	-9.876E-02	0.815	-1.135E-01	0.844	-1.161E-01
0.873	-1.037E-01	0.902	-7.409E-02	0.931	-2.655E-02	0.960	3.787E-02	0.989	1.157E-01
1.018	2.001E-01	1.047	2.808E-01	1.077	3.437E-01	1.106	3.629E-01	1.135	3.128E-01
1.164	1.569E-01	1.165	1.492E-01						

POWER,(KG.-CM./SEC.)

TIME	POWER	TIME	POWER	TIME	POWER	TIME	POWER	TIME	POWER
0.	8.992E-02	0.029	1.105E-01	0.058	7.918E-02	0.087	3.051E-02	0.116	-1.485E-02
0.145	-4.667E-02	0.175	-6.238E-02	0.204	-6.283E-02	0.233	-5.313E-02	0.262	-3.822E-02
0.291	-2.253E-02	0.320	-9.237E-03	0.349	-7.568E-05	0.378	4.606E-03	0.407	5.505E-03
0.436	3.914E-03	0.466	1.173E-03	0.495	-1.306E-03	0.524	-2.882E-03	0.553	-3.351E-03
0.582	-2.928E-03	0.611	-2.046E-03	0.640	-1.111E-03	0.670	-2.817E-04	0.698	4.907E-04
0.727	1.660E-03	0.757	3.704E-03	0.786	6.653E-03	0.815	1.018E-02	0.844	1.322E-02
0.873	1.421E-02	0.902	1.155E-02	0.931	4.428E-03	0.960	-6.280E-03	0.989	-1.735E-02
1.018	-2.344E-02	1.047	-1.874E-02	1.077	4.095E-04	1.106	2.753E-02	1.135	4.624E-02
1.164	3.123E-02	1.165	2.985E-02						

```
WORK TH=INTERGRATIUN UF POWER TH
WORK=    4.869E-02 (KG.CM.)  CHECK=  128.0, NUMBER OF INCREMENTS USED
```

Figure E14. - Biomechanics motion analysis printout (continued)

```
X=M(DDX/DDT), FORCE (KG.)
   TIME      FORCE          TIME      FORCE          TIME      FORCE          TIME      FORCE          TIME      FORCE

   0.         9.789E-02     0.029     2.095E-02      0.058    -1.975E-02      0.087    -3.330E-02      0.116    -2.803E-02
   0.145     -1.127E-02     0.175     1.159E-02      0.204     3.391E-02      0.233     5.272E-02      0.262     6.549E-02
   0.291      7.083E-02     0.320     6.832E-02      0.349     5.843E-02      0.378     4.227E-02      0.407     2.152E-02
   0.436     -1.821E-03     0.466    -2.639E-02      0.495    -4.831E-02      0.524    -6.643E-02      0.553    -7.907E-02
   0.582     -8.497E-02     0.611    -8.342E-02      0.640    -7.428E-02      0.670    -5.740E-02      0.698    -3.594E-02
   0.727     -9.595E-03     0.757     1.967E-02      0.786     4.715E-02      0.815     7.089E-02      0.844     8.789E-02
   0.873      9.540E-02     0.902     9.107E-02      0.931     7.341E-02      0.960     4.204E-02      0.989    -1.843E-03
   1.018     -5.506E-02     1.047    -1.120E-01      1.077    -1.655E-01      1.106    -1.996E-01      1.135    -1.999E-01
   1.164     -1.454E-01     1.165    -1.422E-01

PX=FORCE(DX/DT), POWER (KG.CM./SEC.)
   TIME      POWER          TIME      POWER          TIME      POWER          TIME      POWER          TIME      POWER

   0.         2.189E 01     0.029     4.700E 00      0.058    -4.432E 00      0.087    -7.458E 00      0.116    -6.264E 00
   0.145     -2.515E 00     0.175     2.585E 00      0.204     7.580E 00      0.233     1.182E 01      0.262     1.474E 01
   0.291      1.601E 01     0.320     1.552E 01      0.349     1.332E 01      0.378     9.670E 00      0.407     4.934E 00
   0.436     -4.177E-01     0.466    -6.047E 00      0.495    -1.105E 01      0.524    -1.513E 01      0.553    -1.792E 01
   0.582     -1.916E 01     0.611    -1.870E 01      0.640    -1.657E 01      0.670    -1.275E 01      0.698    -7.955E 00
   0.727     -2.121E 00     0.757     4.349E 00      0.786     1.045E 01      0.815     1.577E 01      0.844     1.966E 01
   0.873      2.147E 01     0.902     2.062E 01      0.931     1.671E 01      0.960     9.607E 00      0.989    -4.218E-01
   1.018     -1.258E 01     1.047    -2.543E 01      1.077    -3.724E 01      1.106    -4.437E 01      1.135    -4.383E 01
   1.164     -3.150E 01     1.165    -3.081E 01

WORK X=INTERGRATION OF POWER X
WORK=     3.257E 01 (KG.CM.)  CHECK=  128.0, NUMBER OF INCREMENTS USED

Z,(F)T,(SEC.), MOTION, CMS.

          VAR ERROR= 0.66105E 00          PERCENT ERROR= 0.54404E 00          ORDER 9
 1.187E 02+( 2.733E 01)T+( 2.282E 02)T**2+(-5.171E 02)T**3+(-1.951E 03)T**4+( 5.567E 03)T**5
+(-1.636E 03)T**6+(-6.267E 03)T**7+( 6.313E 03)T**8+(-1.760E 03)T**9+( 0.        )T**10

DZ/DT, VELOCITY (CM./SEC.)
 2.733E 01+( 4.564E 02)T+(-1.551E 03)T**2+(-7.802E 03)T**3+( 2.784E 04)T**4
+(-9.819E 03)T**5+(-4.387E 04)T**6+( 5.050E 04)T**7+(-1.584E 04)T**8+( 0.        )T**9

DDZ/DDT, ACCELERATION (CM./SEC.*SEC.)
 4.564E 02+(-3.103E 03)T+(-2.341E 04)T**2+( 1.113E 05)T**3+(-4.909E 04)T**4
+(-2.632E 05)T**5+( 3.535E 05)T**6+(-1.267E 05)T**7+( 0.        )T**8
```

Figure E14. - Biomechanics motion analysis printout (continued)

Z=M(DDZ/DDT), FORCE (KG.)

TIME	FORCE	TIME	FORCE	TIME	FORCE	TIME	FORCE	TIME	FORCE
0.	8.983E-01	0.029	6.877E-01	0.058	4.305E-01	0.087	1.548E-01	0.116	-1.146E-01
0.145	-3.574E-01	0.175	-5.636E-01	0.204	-7.080E-01	0.233	-7.920E-01	0.262	-8.136E-01
0.291	-7.751E-01	0.320	-6.823E-01	0.349	-5.443E-01	0.378	-3.722E-01	0.407	-1.792E-01
0.436	2.075E-02	0.466	2.198E-01	0.495	3.908E-01	0.524	5.284E-01	0.553	6.224E-01
0.582	6.652E-01	0.611	6.526E-01	0.640	5.837E-01	0.670	4.563E-01	0.698	2.928E-01
0.727	8.856E-02	0.757	-1.448E-01	0.786	-3.739E-01	0.815	-5.863E-01	0.844	-7.609E-01
0.873	-8.767E-01	0.902	-9.143E-01	0.931	-8.579E-01	0.960	-6.976E-01	0.989	-4.323E-01
1.018	-7.233E-02	1.047	3.566E-01	1.077	8.249E-01	1.106	1.231E 00	1.135	1.491E 00
1.164	1.475E 00	1.165	1.468E 00						

PZ=FORCE(DZ/DT), POWER (KG.CM./SEC.)

TIME	POWER	TIME	POWER	TIME	POWER	TIME	POWER	TIME	POWER
0.	2.455E 01	0.029	2.688E 01	0.058	2.039E 01	0.087	8.003E 00	0.116	-5.956E 00
0.145	-1.731E 01	0.175	-2.331E 01	0.204	-2.260E 01	0.233	-1.646E 01	0.262	-7.225E 00
0.291	2.245E 00	0.320	9.345E 00	0.349	1.240E 01	0.378	1.100E 01	0.407	6.029E 00
0.436	-7.224E-01	0.466	-7.246E 00	0.495	-1.111E 01	0.524	-1.142E 01	0.553	-8.135E 00
0.582	-2.340E 00	0.611	4.086E 00	0.640	9.010E 00	0.670	1.069E 01	0.698	8.434E 00
0.727	2.803E 00	0.757	-4.525E 00	0.786	-1.025E 01	0.815	-1.190E 01	0.844	-7.851E 00
0.873	1.606E 00	0.902	1.384E 01	0.931	2.429E 01	0.960	2.784E 01	0.989	2.090E 01
1.018	3.774E 00	1.047	-1.788E 01	1.077	-3.393E 01	1.106	-3.184E 01	1.135	-8.310E 00
1.164	2.466E 01	1.165	2.563E 01						

WORK Z=INTERGRATION OF POWER Z
WORK= 2.026E 01 (KG.CM.) CHECK= 128.0, NUMBER OF INCREMENTS USED

FROM THE EQUATION OF MOTION Z,(F)T

G-GRADIENT (F)T (UNITLESS)

TIME	G-GRAD	TIME	G-GRAD	TIME	G-GRAD	TIME	G-GRAD	TIME	G-GRAD
0.	1.700E-01	0.029	1.704E-01	0.058	1.711E-01	0.087	1.718E-01	0.116	1.725E-01
0.145	1.732E-01	0.175	1.739E-01	0.204	1.744E-01	0.233	1.748E-01	0.262	1.750E-01
0.291	1.750E-01	0.320	1.749E-01	0.349	1.746E-01	0.378	1.743E-01	0.407	1.738E-01
0.436	1.733E-01	0.466	1.728E-01	0.495	1.724E-01	0.524	1.720E-01	0.553	1.718E-01
0.582	1.717E-01	0.611	1.717E-01	0.640	1.718E-01	0.670	1.721E-01	0.698	1.725E-01
0.727	1.729E-01	0.757	1.734E-01	0.786	1.738E-01	0.815	1.741E-01	0.844	1.744E-01
0.873	1.744E-01	0.902	1.743E-01	0.931	1.740E-01	0.960	1.735E-01	0.989	1.729E-01
1.018	1.722E-01	1.047	1.714E-01	1.077	1.708E-01	1.106	1.703E-01	1.135	1.701E-01
1.164	1.701E-01	1.165	1.701E-01						

Figure E14. - Biomechanics motion analysis printout (continued)

POWER OF POTENTIAL ENERGY=G-GRADIENT*G*MASS*DZ/DT (KG.-CM./SEC.)

TIME	P.P.E.	TIME	P.P.E.	TIME	P.P.E.	TIME	P.P.E.	TIME	P.P.E.
0.	8.965E 00	0.029	1.286E 01	0.058	1.564E 01	0.087	1.713E 01	0.116	1.730E 01
0.145	1.619E 01	0.175	1.388E 01	0.204	1.074E 01	0.233	7.011E 00	0.262	2.999E 00
0.291	-9.783E-01	0.320	-4.623E 00	0.349	-7.679E 00	0.378	-9.945E 00	0.407	-1.129E 01
0.436	-1.165E 01	0.466	-1.099E 01	0.495	-9.459E 00	0.524	-7.175E 00	0.553	-4.334E 00
0.582	-1.166E 00	0.611	2.075E 00	0.640	5.120E 00	0.670	7.785E 00	0.698	9.590E 00
0.727	1.056E 01	0.757	1.045E 01	0.786	9.195E 00	0.815	6.824E 00	0.844	3.472E 00
0.873	-6.166E-01	0.902	-5.091E 00	0.931	-9.508E 00	0.960	-1.336E 01	0.989	-1.613E 01
1.018	-1.734E 01	1.047	-1.659E 01	1.077	-1.356E 01	1.106	-8.504E 00	1.135	-1.829E 00
1.164	5.490E 00	1.165	5.735E 00						

POTENTIAL ENERGY=INTERGRATION OF THE POWER OF POTENTIAL ENERGY
POTENTIAL ENERGY= -1.335E-06(KG.-CM.) CHECK= 8.0, NUMBER OF INCREMENTS USED

TH,(F)T,(SEC.), MOTION, RADS.

VAR ERROR= 0.19312E-01 PERCENT ERROR= 0.17289E 01 ORDER 9

```
 1.192E 00+( 1.129E-01)T+( 1.805E 00)T**2+(-1.743E 00)T**3+(-2.588E 01)T**4+( 6.030E 01)T**5
+(-1.292E 01)T**6+(-7.508E 01)T**7+( 7.448E 01)T**8+(-2.108E 01)T**9+( 0.       )T**10
```

DTH/DT, VELOCITY (RAD./SEC.)

```
 1.129E-01+( 3.611E 00)T+(-5.229E 00)T**2+(-1.035E 02)T**3+( 3.015E 02)T**4
+(-7.751E 01)T**5+(-5.255E 02)T**6+( 5.958E 02)T**7+(-1.897E 02)T**8+( 0.       )T**9
```

DDTH/DDT, ACCELERATION (RAD./SEC.*SEC.)

```
 3.611E 00+(-1.046E 01)T+(-3.106E 02)T**2+( 1.206E 03)T**3+(-3.876E 02)T**4
+(-3.153E 03)T**5+( 4.171E 03)T**6+(-1.517E 03)T**7+( 0.       )T**8
```

MOMENT OF INERTIA(DDTH/DDT) TORQUE (KG.-CM.)

TIME	TORQUE	TIME	TORQUE	TIME	TORQUE	TIME	TORQUE	TIME	TORQUE
0.	1.163E 00	0.029	9.902E-01	0.058	7.047E-01	0.087	3.568E-01	0.116	-8.233E-03
0.145	-3.527E-01	0.175	-6.555E-01	0.204	-8.743E-01	0.233	-1.007E 00	0.262	-1.048E 00
0.291	-1.000E 00	0.320	-8.710E-01	0.349	-6.744E-01	0.378	-4.284E-01	0.407	-1.538E-01
0.436	1.273E-01	0.466	4.010E-01	0.495	6.273E-01	0.524	7.972E-01	0.553	8.961E-01
0.582	9.140E-01	0.611	8.468E-01	0.640	6.964E-01	0.670	4.627E-01	0.698	1.878E-01
0.727	-1.335E-01	0.757	-4.764E-01	0.786	-7.854E-01	0.815	-1.038E 00	0.844	-1.199E 00
0.873	-1.237E 00	0.902	-1.125E 00	0.931	-8.480E-01	0.960	-4.033E-01	0.989	1.897E-01
1.018	8.857E-01	1.047	1.605E 00	1.077	2.245E 00	1.106	2.584E 00	1.135	2.411E 00
1.164	1.419E 00	1.165	1.366E 00						

Figure E14. - Biomechanics motion analysis printout (continued)

POWER,(KG.-CM./SEC.)

TIME	POWER	TIME	POWER	TIME	POWER	TIME	POWER	TIME	POWER
0.	1.313E-01	0.029	2.088E-01	0.058	2.028E-01	0.087	1.199E-01	0.116	-2.895E-03
0.145	-1.182E-01	0.175	-1.885E-01	0.204	-1.907E-01	0.233	-1.336E-01	0.262	-4.138E-02
0.291	5.343E-02	0.320	1.204E-01	0.349	1.405E-01	0.378	1.106E-01	0.407	4.376E-02
0.436	-3.638E-02	0.466	-1.046E-01	0.495	-1.344E-01	0.524	-1.193E-01	0.553	-6.523E-02
0.582	8.546E-03	0.611	7.560E-02	0.640	1.110E-01	0.670	9.899E-02	0.698	4.555E-02
0.727	-3.273E-02	0.757	-1.032E-01	0.786	-1.254E-01	0.815	-7.986E-02	0.844	2.950E-02
0.873	1.674E-01	0.902	2.734E-01	0.931	2.824E-01	0.960	1.575E-01	0.989	-7.613E-02
1.018	-3.129E-01	1.047	-3.868E-01	1.077	-1.350E-01	1.106	4.138E-01	1.135	9.401E-01
1.164	8.088E-01	1.165	7.844E-01						

WORK TH=INTERGRATION OF POWER TH
WORK= 3.799E-01 (KG.CM.) CHECK= 128.0, NUMBER OF INCREMENTS USED

P-SUIT MOMENT DISTRIBUTION, LOWER ARM AND HAND

PRESSURE SUIT MOMENT, TIME (SEC.) VS. TORQUE (KG.-CM.)

TIME	TORQUE	TIME	TORQUE	TIME	TORQUE	TIME	TORQUE	TIME	TORQUE
0.	1.012E 01	0.029	1.012E 01	0.058	1.011E 01	0.087	1.011E 01	0.116	1.010E 01
0.145	1.010E 01	0.175	1.010E 01	0.204	1.010E 01	0.233	1.008E 01	0.262	1.007E 01
0.291	1.004E 01	0.320	1.000E 01	0.349	9.952E 00	0.378	9.893E 00	0.407	9.828E 00
0.436	9.761E 00	0.466	9.694E 00	0.495	9.640E 00	0.524	9.603E 00	0.553	9.588E 00
0.582	9.598E 00	0.611	9.632E 00	0.640	9.688E 00	0.670	9.761E 00	0.698	9.837E 00
0.727	9.916E 00	0.757	9.989E 00	0.786	1.005E 01	0.815	1.009E 01	0.844	1.012E 01
0.873	1.013E 01	0.902	1.012E 01	0.931	1.009E 01	0.960	1.005E 01	0.989	9.992E 00
1.018	9.929E 00	1.047	9.872E 00	1.077	9.835E 00	1.106	9.838E 00	1.135	9.885E 00
1.164	9.968E 00	1.165	1.006E 01						

POWER,(KG.-CM./SEC.)

TIME	POWER	TIME	POWER	TIME	POWER	TIME	POWER	TIME	POWER
0.	1.143E 00	0.029	2.134E 00	0.058	2.910E 00	0.087	3.395E 00	0.116	3.552E 00
0.145	3.385E 00	0.175	2.905E 00	0.204	2.202E 00	0.233	1.338E 00	0.262	3.974E-01
0.291	-5.363E-01	0.320	-1.382E 00	0.349	-2.073E 00	0.378	-2.555E 00	0.407	-2.797E 00
0.436	-2.789E 00	0.466	-2.529E 00	0.495	-2.065E 00	0.524	-1.437E 00	0.553	-6.979E-01
0.582	8.974E-02	0.611	8.599E-01	0.640	1.544E 00	0.670	2.088E 00	0.698	2.386E 00
0.727	2.431E 00	0.757	2.165E 00	0.786	1.604E 00	0.815	7.764E-01	0.844	-2.489E-01
0.873	-1.370E 00	0.902	-2.458E 00	0.931	-3.361E 00	0.960	-3.925E 00	0.989	-4.009E 00
1.018	-3.508E 00	1.047	-2.379E 00	1.077	-5.914E-01	1.106	1.576E 00	1.135	3.854E 00
1.164	5.681E 00	1.165	5.778E 00						

WORK P-SUIT TORQUE= INTERGRATION OF POWER TH
WORK= 4.995E 00 (KG.CM.) CHECK= 64.0, NUMBER OF INCREMENTS USED

Figure E14. - Biomechanics motion analysis printout (continued)

```
SEGMENT-NO. 5, THIGH

X,(F)T,(SEC.), MOTION, CMS.

         VAR ERROR= 0.47579E-00          PERCENT ERROR= 0.21443E 01          ORDER 9
 1.470E-01+( 2.111E 02)T+(-3.418E 01)T**2+( 3.064E 02)T**3+(-4.802E 02)T**4+( 2.287E 02)T**5
+(-6.306E 01)T**6+( 1.659E 02)T**7+(-1.396E 02)T**8+( 3.017E 01)T**9+( 0.        )T**10

DX/DT, VELOCITY (CM./SEC.)
 2.111E 02+(-6.836E 01)T+( 9.193E 02)T**2+(-1.921E 03)T**3+( 1.143E 03)T**4
+(-3.783E 02)T**5+( 1.161E 03)T**6+(-1.117E 03)T**7+( 2.715E 02)T**8+( 0.        )T**9

DDX/DDT, ACCELERATION (CM./SEC.*SEC.)
-6.836E 01+( 1.839E 03)T+(-5.763E 03)T**2+( 4.574E 03)T**3+(-1.892E 03)T**4
+( 6.968E 03)T**5+(-7.818E 03)T**6+( 2.172E 03)T**7+( 0.        )T**8

X=M(DDX/DDT), FORCE (KG.)
   TIME      FORCE          TIME      FORCE          TIME      FORCE          TIME      FORCE          TIME      FORCE

   0.       -5.279E-01      0.029    -1.527E-01      0.058     1.526E-01      0.087     3.931E-01      0.116     5.736E-01
   0.145     6.992E-01      0.175     7.766E-01      0.204     8.059E-01      0.233     7.958E-01      0.262     7.519E-01
   0.291     6.794E-01      0.320     5.842E-01      0.349     4.717E-01      0.378     3.475E-01      0.407     2.171E-01
   0.436     8.584E-02      0.466    -4.559E-02      0.495    -1.636E-01      0.524    -2.685E-01      0.553    -3.566E-01
   0.582    -4.248E-01      0.611    -4.710E-01      0.640    -4.937E-01      0.670    -4.918E-01      0.698    -4.672E-01
   0.727    -4.202E-01      0.757    -3.513E-01      0.786    -2.692E-01      0.815    -1.771E-01      0.844    -8.179E-02
   0.873     8.971E-03      0.902     8.587E-02      0.931     1.383E-01      0.960     1.543E-01      0.989     1.207E-01
   1.018     2.310E-02      1.047    -1.541E-01      1.077    -4.388E-01      1.106    -8.299E-01      1.135    -1.353E 00
   1.164    -2.028E 00      1.165    -2.054E 00

PX=FORCE(DX/DT), POWER (KG.CM./SEC.)
   TIME      POWER          TIME      POWER          TIME      POWER          TIME      POWER          TIME      POWER

   0.       -1.114E 02      0.029    -3.204E 01      0.058     3.202E 01      0.087     8.289E 01      0.116     1.220E 02
   0.145     1.504E 02      0.175     1.693E 02      0.204     1.781E 02      0.233     1.783E 02      0.262     1.706E 02
   0.291     1.560E 02      0.320     1.355E 02      0.349     1.104E 02      0.378     8.184E 01      0.407     5.137E 01
   0.436     2.036E 01      0.466    -1.082E 01      0.495    -3.875E 01      0.524    -6.337E 01      0.553    -8.373E 01
   0.582    -9.914E 01      0.611    -1.091E 02      0.640    -1.135E 02      0.670    -1.121E 02      0.698    -1.057E 02
   0.727    -9.433E 01      0.757    -7.833E 01      0.786    -5.971E 01      0.815    -3.915E 01      0.844    -1.803E 01
   0.873     1.977E 00      0.902     1.894E 01      0.931     3.056E 01      0.960     3.419E 01      0.989     2.681E 01
   1.018     5.137E 00      1.047    -3.423E 01      1.077    -9.698E 01      1.106    -1.815E 02      1.135    -2.905E 02
   1.164    -4.225E 02      1.165    -4.274E 02

WORK X=INTEGRATION OF POWER X
WORK=     2.138E 02 (KG.CM.)  CHECK=    64.0, NUMBER OF INCREMENTS USED
```

Figure E14. - Biomechanics motion analysis printout (continued)

```
Z,(F)T,(SEC.), MOTION, CMS.

        VAR ERROR= 0.67631E 00          PERCENT ERROR= 0.86406E 00          ORDER 9
 7.689E 01+( 2.366E 01)T+( 3.390E 02)T**2+(-1.768E 03)T**3+( 2.598E 03)T**4+(-8.689E 02)T**5
+(-2.125E 02)T**6+(-1.046E 03)T**7+( 1.341E 03)T**8+(-4.012E 02)T**9+( 0.        )T**10

DZ/DT, VELOCITY (CM./SEC.)
 2.366E 01+( 6.780E 02)T+(-5.304E 03)T**2+( 1.039E 04)T**3+(-4.345E 03)T**4
+(-1.275E 03)T**5+(-7.323E 03)T**6+( 1.073E 04)T**7+(-3.611E 03)T**8+( 0.        )T**9

DDZ/DDT, ACCELERATION (CM./SEC.*SEC.)
 6.780E 02+(-1.061E 04)T+( 3.117E 04)T**2+(-1.738E 04)T**3+(-6.375E 03)T**4
+(-4.394E 04)T**5+( 7.512E 04)T**6+(-2.889E 04)T**7+( 0.        )T**8

Z=M(DDZ/DDT), FORCE (KG.)
```

TIME	FORCE	TIME	FORCE	TIME	FORCE	TIME	FORCE	TIME	FORCE
0.	5.235E 00	0.029	3.059E 00	0.058	1.267E 00	0.087	-1.617E-01	0.116	-1.252E 00
0.145	-2.029E 00	0.175	-2.533E 00	0.204	-2.764E 00	0.233	-2.774E 00	0.262	-2.599E 00
0.291	-2.274E 00	0.320	-1.835E 00	0.349	-1.319E 00	0.378	-7.606E-01	0.407	-1.947E-01
0.436	3.473E-01	0.466	8.522E-01	0.495	1.261E 00	0.524	1.570E 00	0.553	1.764E 00
0.582	1.833E 00	0.611	1.773E 00	0.640	1.587E 00	0.670	1.270E 00	0.698	8.752E-01
0.727	3.862E-01	0.757	-1.763E-01	0.786	-7.411E-01	0.815	-1.289E 00	0.844	-1.779E 00
0.873	-2.169E 00	0.902	-2.416E 00	0.931	-2.478E 00	0.960	-2.318E 00	0.989	-1.906E 00
1.018	-1.219E 00	1.047	-2.508E-01	1.077	1.038E 00	1.106	2.529E 00	1.135	4.204E 00
1.164	5.974E 00	1.165	6.035E 00						

```
PZ=FORCE(DZ/DT), POWER (KG.CM./SEC.)
```

TIME	POWER	TIME	POWER	TIME	POWER	TIME	POWER	TIME	POWER
0.	1.239E 02	0.029	1.196E 02	0.058	5.971E 01	0.087	-7.938E 00	0.116	-5.799E 01
0.145	-8.130E 01	0.175	-7.883E 01	0.204	-5.830E 01	0.233	-2.949E 01	0.262	-1.274E 00
0.291	1.978E 01	0.320	3.018E 01	0.349	2.952E 01	0.378	2.000E 01	0.407	5.469E 00
0.436	-9.653E 00	0.466	-2.168E 01	0.495	-2.703E 01	0.524	-2.526E 01	0.553	-1.728E 01
0.582	-5.503E 00	0.611	6.760E 00	0.640	1.613E 01	0.670	2.001E 01	0.698	1.721E 01
0.727	8.519E 00	0.757	-3.962E 00	0.786	-1.538E 01	0.815	-2.183E 01	0.844	-1.983E 01
0.873	-8.009E 00	0.902	1.201E 01	0.931	3.526E 01	0.960	5.404E 01	0.989	5.970E 01
1.018	4.545E 01	1.047	1.006E 01	1.077	-4.015E 01	1.106	-8.108E 01	1.135	-8.182E 01
1.164	-2.163E 00	1.165	2.509E 00						

```
WORK Z=INTERGRATION OF POWER Z
WORK=    5.166E 01 (KG.CM.)  CHECK=  128.0, NUMBER OF INCREMENTS USED
```

Figure E14. - Biomechanics motion analysis printout (continued)

FROM THE EQUATION OF MOTION Z,(F)T

G-GRADIENT (F)T (UNITLESS)

TIME	G-GRAD	TIME	G-GRAD	TIME	G-GRAD	TIME	G-GRAD	TIME	G-GRAD
0.	1.496E-01	0.029	1.500E-01	0.058	1.507E-01	0.087	1.514E-01	0.116	1.520E-01
0.145	1.526E-01	0.175	1.532E-01	0.204	1.535E-01	0.233	1.538E-01	0.262	1.538E-01
0.291	1.538E-01	0.320	1.536E-01	0.349	1.533E-01	0.378	1.530E-01	0.407	1.526E-01
0.436	1.522E-01	0.466	1.518E-01	0.495	1.515E-01	0.524	1.512E-01	0.553	1.510E-01
0.582	1.509E-01	0.611	1.509E-01	0.640	1.510E-01	0.670	1.512E-01	0.698	1.515E-01
0.727	1.518E-01	0.757	1.521E-01	0.786	1.524E-01	0.815	1.527E-01	0.844	1.529E-01
0.873	1.530E-01	0.902	1.530E-01	0.931	1.528E-01	0.960	1.526E-01	0.989	1.522E-01
1.018	1.517E-01	1.047	1.511E-01	1.077	1.506E-01	1.106	1.500E-01	1.135	1.497E-01
1.164	1.495E-01	1.165	1.495E-01						

POWER OF POTENTIAL ENERGY=G-GRADIENT*G*MASS*DZ/DT (KG.-CM./SEC.)

TIME	P.P.E.	TIME	P.P.E.	TIME	P.P.E.	TIME	P.P.E.	TIME	P.P.E.
0.	2.680E 01	0.029	4.443E 01	0.058	5.375E 01	0.087	5.625E 01	0.116	5.333E 01
0.145	4.632E 01	0.175	3.609E 01	0.204	2.453E 01	0.233	1.238E 01	0.262	5.710E-01
0.291	-1.013E 01	0.320	-1.913E 01	0.349	-2.599E 01	0.378	-3.046E 01	0.407	-3.246E 01
0.436	-3.203E 01	0.466	-2.924E 01	0.495	-2.459E 01	0.524	-1.843E 01	0.553	-1.120E 01
0.582	-3.430E 00	0.611	4.356E 00	0.640	1.162E 01	0.670	1.804E 01	0.698	2.256E 01
0.727	2.535E 01	0.757	2.589E 01	0.786	2.395E 01	0.815	1.957E 01	0.844	1.290E 01
0.873	4.276E 00	0.902	-5.758E 00	0.931	-1.646E 01	0.960	-2.693E 01	0.989	-3.610E 01
1.018	-4.282E 01	1.047	-4.592E 01	1.077	-4.411E 01	1.106	-3.643E 01	1.135	-2.206E 01
1.164	-4.099E-01	1.165	4.707E-01						

POTENTIAL ENERGY=INTERGRATION OF THE POWER OF POTENTIAL ENERGY
POTENTIAL ENERGY= -8.049E-04(KG.-CM.) CHECK= 4.0, NUMBER OF INCREMENTS USED

TH,(F)T,(SEC.), MOTION, RADS.

```
        VAR ERROR= 0.20712E-01          PERCENT ERROR= 0.57466E 02          ORDER10
 1.970E-01+(-1.481E 00)T+( 2.880E 00)T**2+( 1.253E 00)T**3+(-6.624E 00)T**4+( 4.312E 00)T**5
+( 2.165E 00)T**6+(-7.850E-01)T**7+(-2.766E 00)T**8+( 8.311E-01)T**9+( 3.835E-01)T**10
```

DTH/DT, VELOCITY (RAD./SEC.)

```
-1.481E 00+( 5.761E 00)T+( 3.758E 00)T**2+(-2.650E 01)T**3+( 2.156E 01)T**4
+( 1.299E 01)T**5+(-5.495E 00)T**6+(-2.213E 01)T**7+( 7.480E 00)T**8+( 3.835E 00)T**9
```

DDTH/DDT, ACCELERATION (RAD./SEC.*SEC.)

```
 5.761E 00+( 7.515E 00)T+(-7.949E 01)T**2+( 8.623E 01)T**3+( 6.494E 01)T**4
+(-3.297E 01)T**5+(-1.549E 02)T**6+( 5.984E 01)T**7+( 3.451E 01)T**8
```

Figure E14. - Biomechanics motion analysis printout (continued)

MOMENT OF INERTIA(DDTH/DDT) TORQUE (KG.-CM.)

TIME	TORQUE	TIME	TORQUE	TIME	TORQUE	TIME	TORQUE	TIME	TORQUE
0.	4.655E 00	0.029	4.778E 00	0.058	4.805E 00	0.087	4.745E 00	0.116	4.612E 00
0.145	4.417E 00	0.175	4.165E 00	0.204	3.885E 00	0.233	3.582E 00	0.262	3.268E 00
0.291	2.954E 00	0.320	2.650E 00	0.349	2.364E 00	0.378	2.101E 00	0.407	1.868E 00
0.436	1.665E 00	0.466	1.487E 00	0.495	1.343E 00	0.524	1.221E 00	0.553	1.112E 00
0.582	1.006E 00	0.611	8.908E-01	0.640	7.510E-01	0.670	5.644E-01	0.698	3.360E-01
0.727	2.888E-02	0.757	-3.793E-01	0.786	-8.732E-01	0.815	-1.472E 00	0.844	-2.177E 00
0.873	-2.980E 00	0.902	-3.865E 00	0.931	-4.801E 00	0.960	-5.741E 00	0.989	-6.620E 00
1.018	-7.348E 00	1.047	-7.810E 00	1.077	-7.852E 00	1.106	-7.279E 00	1.135	-5.875E 00
1.164	-3.365E 00	1.165	-3.255E 00						

POWER,(KG.-CM./SEC.)

TIME	POWER	TIME	POWER	TIME	POWER	TIME	POWER	TIME	POWER
0.	-6.894E 00	0.029	-6.267E 00	0.058	-5.474E 00	0.087	-4.592E 00	0.116	-3.688E 00
0.145	-2.816E 00	0.175	-1.991E 00	0.204	-1.295E 00	0.233	-7.139E-01	0.262	-2.495E-01
0.291	1.044E-01	0.320	3.600E-01	0.349	5.336E-01	0.378	6.426E-01	0.407	7.041E-01
0.436	7.331E-01	0.466	7.418E-01	0.495	7.381E-01	0.524	7.271E-01	0.553	7.088E-01
0.582	6.796E-01	0.611	6.319E-01	0.640	5.550E-01	0.670	4.309E-01	0.698	2.618E-01
0.727	2.270E-02	0.757	-2.958E-01	0.786	-6.616E-01	0.815	-1.054E 00	0.844	-1.416E 00
0.873	-1.664E 00	0.902	-1.685E 00	0.931	-1.346E 00	0.960	-5.235E-01	0.989	8.667E-01
1.018	2.808E 00	1.047	5.118E 00	1.077	7.441E 00	1.106	8.890E 00	1.135	8.580E 00
1.164	5.485E 00	1.165	5.318E 00						

WORK TH=INTERGRATION OF POWER TH
WORK= 4.931E 00 (KG.CM.) CHECK= 64.0, NUMBER OF INCREMENTS USED

P-SUIT MOMENT DISTRIBUTION, THIGH

PRESSURE SUIT MOMENT, TIME (SEC.) VS. TORQUE (KG.-CM.)

TIME	TORQUE	TIME	TORQUE	TIME	TORQUE	TIME	TORQUE	TIME	TORQUE
0.	2.444E 02	0.029	2.182E 02	0.058	1.975E 02	0.087	1.813E 02	0.116	1.687E 02
0.145	1.591E 02	0.175	1.519E 02	0.204	1.472E 02	0.233	1.444E 02	0.262	1.432E 02
0.291	1.435E 02	0.320	1.449E 02	0.349	1.473E 02	0.378	1.506E 02	0.407	1.546E 02
0.436	1.592E 02	0.466	1.646E 02	0.495	1.705E 02	0.524	1.771E 02	0.553	1.844E 02
0.582	1.925E 02	0.611	2.016E 02	0.640	2.118E 02	0.670	2.238E 02	0.698	2.363E 02
0.727	2.509E 02	0.757	2.677E 02	0.786	2.857E 02	0.815	3.049E 02	0.844	3.249E 02
0.873	3.447E 02	0.902	3.629E 02	0.931	3.779E 02	0.960	3.878E 02	0.989	3.906E 02
1.018	3.851E 02	1.047	3.704E 02	1.077	3.461E 02	1.106	3.156E 02	1.135	2.814E 02
1.164	2.469E 02	1.165	2.152E 02						

Figure E14. - Biomechanics motion analysis printout (continued)

POWER,(KG.-CM./SEC.)

TIME	POWER	TIME	POWER	TIME	POWER	TIME	POWER	TIME	POWER
0.	-3.620E 02	0.029	-2.861E 02	0.058	-2.251E 02	0.087	-1.755E 02	0.116	-1.349E 02
0.145	-1.014E 02	0.175	-7.260E 01	0.204	-4.906E 01	0.233	-2.877E 01	0.262	-1.093E 01
0.291	5.069E 00	0.320	1.969E 01	0.349	3.326E 01	0.378	4.605E 01	0.407	5.826E 01
0.436	7.009E 01	0.466	8.211E 01	0.495	9.370E 01	0.524	1.054E 02	0.553	1.175E 02
0.582	1.300E 02	0.611	1.430E 02	0.640	1.565E 02	0.670	1.708E 02	0.698	1.842E 02
0.727	1.972E 02	0.757	2.088E 02	0.786	2.164E 02	0.815	2.183E 02	0.844	2.114E 02
0.873	1.925E 02	0.902	1.582E 02	0.931	1.060E 02	0.960	3.536E 01	0.989	-5.115E 01
1.018	-1.472E 02	1.047	-2.427E 02	1.077	-3.279E 02	1.106	-3.854E 02	1.135	-4.109E 02
1.164	-4.024E 02	1.165	-3.517E 02						

WORK P-SUIT TORQUE= INTERGRATION OF POWER TH
WORK= 3.487E 02 (KG.CM.) CHECK= 32.0, NUMBER OF INCREMENTS USED

SEGMENT-NO. 6, LEG AND FOOT

X,(F)T,(SEC.), MOTION, CMS.

VAR ERROR= 0.10007E 01 PERCENT ERROR= 0.44593E 01 ORDER 8

```
-7.093E-01+( 6.164E 01)T+( 1.951E 02)T**2+( 6.756E 02)T**3+(-2.530E 03)T**4+( 3.624E 03)T**5
+(-1.573E 03)T**6+(-7.253E 02)T**7+( 5.284E 02)T**8+( 0.       )T**9+( 0.       )T**10
```

DX/DT, VELOCITY (CM./SEC.)

```
 6.164E 01+( 3.903E 02)T+( 2.027E 03)T**2+(-1.012E 04)T**3+( 1.812E 04)T**4
+(-9.440E 03)T**5+(-5.077E 03)T**6+( 4.227E 03)T**7+( 0.       )T**8+( 0.       )T**9
```

DDX/DDT, ACCELERATION (CM./SEC.*SEC.)

```
 3.903E 02+( 4.053E 03)T+(-3.036E 04)T**2+( 7.248E 04)T**3+(-4.720E 04)T**4
+(-3.046E 04)T**5+( 2.959E 04)T**6+( 0.       )T**7+( 0.       )T**8
```

X=M(DDX/DDT), FORCE (KG.)

TIME	FORCE	TIME	FORCE	TIME	FORCE	TIME	FORCE	TIME	FORCE
0.	2.117E 00	0.029	2.626E 00	0.058	2.912E 00	0.087	3.027E 00	0.116	3.016E 00
0.145	2.919E 00	0.175	2.766E 00	0.204	2.596E 00	0.233	2.430E 00	0.262	2.285E 00
0.291	2.173E 00	0.320	2.104E 00	0.349	2.079E 00	0.378	2.096E 00	0.407	2.149E 00
0.436	2.227E 00	0.466	2.322E 00	0.495	2.409E 00	0.524	2.474E 00	0.553	2.498E 00
0.582	2.460E 00	0.611	2.341E 00	0.640	2.124E 00	0.670	1.778E 00	0.698	1.332E 00
0.727	7.385E-01	0.757	-1.939E-02	0.786	-8.855E-01	0.815	-1.869E 00	0.844	-2.945E 00
0.873	-4.080E 00	0.902	-5.226E 00	0.931	-6.318E 00	0.960	-7.280E 00	0.989	-8.013E 00
1.018	-8.400E 00	1.047	-8.304E 00	1.077	-7.523E 00	1.106	-5.914E 00	1.135	-3.247E 00
1.164	7.258E-01	1.165	8.893E-01						

Figure E14. - Biomechanics motion analysis printout (continued)

P-SUIT MOMENT DISTRIBUTION, LEG AND FOOT

PRESSURE SUIT MOMENT, TIME (SEC.) VS. TORQUE (KG.-CM.)

TIME	TORQUE	TIME	TORQUE	TIME	TORQUE	TIME	TORQUE	TIME	TORQUE
0.	4.606E 01	0.029	4.919E 01	0.058	5.307E 01	0.087	5.788E 01	0.116	6.377E 01
0.145	7.079E 01	0.175	7.915E 01	0.204	8.802E 01	0.233	9.727E 01	0.262	1.064E 02
0.291	1.149E 02	0.320	1.223E 02	0.349	1.283E 02	0.378	1.327E 02	0.407	1.351E 02
0.436	1.354E 02	0.466	1.335E 02	0.495	1.293E 02	0.524	1.230E 02	0.553	1.147E 02
0.582	1.047E 02	0.611	9.346E 01	0.640	8.174E 01	0.670	7.003E 01	0.698	6.027E 01
0.727	5.180E 01	0.757	4.476E 01	0.786	3.922E 01	0.815	3.449E 01	0.844	3.032E 01
0.873	2.675E 01	0.902	2.397E 01	0.931	2.223E 01	0.960	2.172E 01	0.989	2.254E 01
1.018	2.468E 01	1.047	2.803E 01	1.077	3.250E 01	1.106	3.758E 01	1.135	4.344E 01
1.164	5.016E 01	1.165	5.700E 01						

POWER,(KG.-CM./SEC.)

TIME	POWER	TIME	POWER	TIME	POWER	TIME	POWER	TIME	POWER
0.	-1.330E 02	0.029	-1.424E 02	0.058	-1.539E 02	0.087	-1.670E 02	0.116	-1.810E 02
0.145	-1.949E 02	0.175	-2.072E 02	0.204	-2.144E 02	0.233	-2.143E 02	0.262	-2.044E 02
0.291	-1.828E 02	0.320	-1.490E 02	0.349	-1.036E 02	0.378	-4.828E 01	0.407	1.404E 01
0.436	7.961E 01	0.466	1.462E 02	0.495	2.048E 02	0.524	2.531E 02	0.553	2.875E 02
0.582	3.055E 02	0.611	3.067E 02	0.640	2.929E 02	0.670	2.674E 02	0.698	2.384E 02
0.727	2.072E 02	0.757	1.761E 02	0.786	1.470E 02	0.815	1.186E 02	0.844	9.089E 01
0.873	6.491E 01	0.902	4.149E 01	0.931	2.044E 01	0.960	2.685E-01	0.989	-2.168E 01
1.018	-4.846E 01	1.047	-8.229E 01	1.077	-1.246E 02	1.106	-1.692E 02	1.135	-2.108E 02
1.164	-2.379E 02	1.165	-2.695E 02						

WORK P-SUIT TORQUE= INTERGRATION OF POWER TH
WORK= 3.655E 02 (KG.CM.) CHECK= 64.0, NUMBER OF INCREMENTS USED

TOTAL BODY WORK= 3.425E 03, (KG.-CM.)

SEGMENT-NO. 7, INSTRUMENT PACK

X,(F)T,(SEC.), MOTION, CMS.

```
        VAR ERROR= 0.45835E-00          PERCENT ERROR= 0.12807E 01          ORDER 9
 2.525E-01+( 2.172E 02)T+( 8.006E 00)T**2+( 9.012E 01)T**3+(-2.769E 02)T**4+( 2.453E 02)T**5
+(-4.511E 01)T**6+( 6.256E 01)T**7+(-1.311E 02)T**8+( 5.399E 01)T**9+( 0.       )T**10

DX/DT, VELOCITY (CM./SEC.)
 2.172E 02+( 1.601E 01)T+( 2.703E 02)T**2+(-1.107E 03)T**3+( 1.227E 03)T**4
+(-2.707E 02)T**5+( 4.379E 02)T**6+(-1.049E 03)T**7+( 4.859E 02)T**8+( 0.       )T**9
```

Figure E14. - Biomechanics motion analysis printout (continued)

PX=FORCE(DX/DT), POWER (KG.CM./SEC.)

TIME	POWER	TIME	POWER	TIME	POWER	TIME	POWER	TIME	POWER
0.	1.305E 02	0.029	1.954E 02	0.058	2.601E 02	0.087	3.186E 02	0.116	3.663E 02
0.145	4.009E 02	0.175	4.234E 02	0.204	4.346E 02	0.233	4.394E 02	0.262	4.419E 02
0.291	4.463E 02	0.320	4.560E 02	0.349	4.738E 02	0.378	5.010E 02	0.407	5.380E 02
0.436	5.837E 02	0.466	6.377E 02	0.495	6.921E 02	0.524	7.432E 02	0.553	7.835E 02
0.582	8.043E 02	0.611	7.956E 02	0.640	7.471E 02	0.670	6.447E 02	0.698	4.939E 02
0.727	2.779E 02	0.757	-7.337E 00	0.786	-3.330E 02	0.815	-6.890E 02	0.844	-1.048E 03
0.873	-1.376E 03	0.902	-1.632E 03	0.931	-1.778E 03	0.960	-1.783E 03	0.989	-1.634E 03
1.018	-1.343E 03	1.047	-9.547E 02	1.077	-5.329E 02	1.106	-2.040E 02	1.135	-3.080E 01
1.164	1.529E 00	1.165	2.006E 00						

WORK X=INTERGRATION OF POWER X
WORK= 1.532E 03 (KG.CM.) CHECK= 128.0, NUMBER OF INCREMENTS USED

Z,(F)T,(SEC.), MOTION, CMS.

VAR ERROR= 0.11068E 01 PERCENT ERROR= 0.36853E 01 ORDER 9
2.181E 01+(4.537E 01)T+(6.930E 02)T**2+(-2.421E 03)T**3+(1.849E 03)T**4+(9.875E 02)T**5
+(-7.007E 02)T**6+(-1.645E 03)T**7+(1.551E 03)T**8+(-3.559E 02)T**9+(0.)T**10

DZ/DT, VELOCITY (CM./SEC.)
4.537E 01+(1.386E 03)T+(-7.263E 03)T**2+(7.395E 03)T**3+(4.938E 03)T**4
+(-4.204E 03)T**5+(-1.151E 04)T**6+(1.241E 04)T**7+(-3.203E 03)T**8+(0.)T**9

DDZ/DDT, ACCELERATION (CM./SEC.*SEC.)
1.386E 03+(-1.453E 04)T+(2.218E 04)T**2+(1.975E 04)T**3+(-2.102E 04)T**4
+(-6.909E 04)T**5+(8.686E 04)T**6+(-2.562E 04)T**7+(0.)T**8

Z=M(DDZ/DDT), FORCE (KG.)

TIME	FORCE	TIME	FORCE	TIME	FORCE	TIME	FORCE	TIME	FORCE
0.	7.519E 00	0.029	5.337E 00	0.058	3.373E 00	0.087	1.637E 00	0.116	1.374E-01
0.145	-1.120E 00	0.175	-2.167E 00	0.204	-2.936E 00	0.233	-3.476E 00	0.262	-3.798E 00
0.291	-3.918E 00	0.320	-3.857E 00	0.349	-3.637E 00	0.378	-3.284E 00	0.407	-2.823E 00
0.436	-2.285E 00	0.466	-1.677E 00	0.495	-1.069E 00	0.524	-4.692E-01	0.553	9.553E-02
0.582	6.017E-01	0.611	1.029E 00	0.640	1.360E 00	0.670	1.590E 00	0.698	1.693E 00
0.727	1.687E 00	0.757	1.563E 00	0.786	1.344E 00	0.815	1.045E 00	0.844	6.921E-01
0.873	3.185E-01	0.902	-3.602E-02	0.931	-3.246E-01	0.960	-4.942E-01	0.989	-4.860E-01
1.018	-2.360E-01	1.047	3.236E-01	1.077	1.304E 00	1.106	2.713E 00	1.135	4.649E 00
1.164	7.183E 00	1.165	7.282E 00						

Figure E14. - Biomechanics motion analysis printout (continued)

PZ=FORCE(DZ/DT), POWER (KG.CM./SEC.)

TIME	POWER	TIME	POWER	TIME	POWER	TIME	POWER	TIME	POWER
0.	3.411E 02	0.029	4.251E 02	0.058	3.468E 02	0.087	1.900E 02	0.116	1.659E 01
0.145	-1.322E 02	0.175	-2.357E 02	0.204	-2.791E 02	0.233	-2.705E 02	0.262	-2.213E 02
0.291	-1.472E 02	0.320	-6.447E 01	0.349	1.232E 01	0.378	7.204E 01	0.407	1.081E 02
0.436	1.188E 02	0.466	1.056E 02	0.495	7.512E 01	0.524	3.491E 01	0.553	-7.200E 00
0.582	-4.422E 01	0.611	-7.108E 01	0.640	-8.523E 01	0.670	-8.655E 01	0.698	-7.775E 01
0.727	-6.213E 01	0.757	-4.346E 01	0.786	-2.686E 01	0.815	-1.418E 01	0.844	-6.166E 00
0.873	-1.976E 00	0.902	1.970E-01	0.931	2.102E 00	0.960	4.314E 00	0.989	5.560E 00
1.018	3.184E 00	1.047	-4.341E 00	1.077	-1.189E 01	1.106	3.791E 00	1.135	9.683E 01
1.164	3.747E 02	1.165	3.896E 02						

WORK Z=INTERGRATION OF POWER Z
WORK= 1.908E 02 (KG.CM.) CHECK= 128.0, NUMBER OF INCREMENTS USED

FROM THE EQUATION OF MOTION Z,(F)T

G-GRADIENT (F)T (UNITLESS)

TIME	G-GRAD	TIME	G-GRAD	TIME	G-GRAD	TIME	G-GRAD	TIME	G-GRAD
0.	1.226E-01	0.029	1.235E-01	0.058	1.248E-01	0.087	1.264E-01	0.116	1.281E-01
0.145	1.298E-01	0.175	1.315E-01	0.204	1.329E-01	0.233	1.342E-01	0.262	1.351E-01
0.291	1.358E-01	0.320	1.362E-01	0.349	1.363E-01	0.378	1.361E-01	0.407	1.357E-01
0.436	1.350E-01	0.466	1.342E-01	0.495	1.332E-01	0.524	1.322E-01	0.553	1.311E-01
0.582	1.301E-01	0.611	1.291E-01	0.640	1.281E-01	0.670	1.273E-01	0.698	1.266E-01
0.727	1.260E-01	0.757	1.255E-01	0.786	1.252E-01	0.815	1.249E-01	0.844	1.248E-01
0.873	1.247E-01	0.902	1.246E-01	0.931	1.245E-01	0.960	1.244E-01	0.989	1.243E-01
1.018	1.241E-01	1.047	1.239E-01	1.077	1.237E-01	1.106	1.236E-01	1.135	1.238E-01
1.164	1.243E-01	1.165	1.243E-01						

POWER OF POTENTIAL ENERGY=G-GRADIENT*G*MASS*DZ/DT (KG.-CM./SEC.)

TIME	P.P.E.	TIME	P.P.E.	TIME	P.P.E.	TIME	P.P.E.	TIME	P.P.E.
0.	2.960E 01	0.029	5.234E 01	0.058	6.829E 01	0.087	7.808E 01	0.116	8.228E 01
0.145	8.149E 01	0.175	7.610E 01	0.204	6.722E 01	0.233	5.554E 01	0.262	4.190E 01
0.291	2.715E 01	0.320	1.211E 01	0.349	-2.455E 00	0.378	-1.589E 01	0.407	-2.765E 01
0.436	-3.735E 01	0.466	-4.494E 01	0.495	-4.983E 01	0.524	-5.233E 01	0.553	-5.259E 01
0.582	-5.085E 01	0.611	-4.743E 01	0.640	-4.270E 01	0.670	-3.686E 01	0.698	-3.092E 01
0.727	-2.469E 01	0.757	-1.856E 01	0.786	-1.331E 01	0.815	-9.018E 00	0.844	-5.913E 00
0.873	-4.116E 00	0.902	-3.625E 00	0.931	-4.288E 00	0.960	-5.777E 00	0.989	-7.563E 00
1.018	-8.907E 00	1.047	-8.840E 00	1.077	-6.002E 00	1.106	9.192E-01	1.135	1.372E 01
1.164	3.450E 01	1.165	3.539E 01						

POTENTIAL ENERGY=INTERGRATION OF THE POWER OF POTENTIAL ENERGY
POTENTIAL ENERGY= 4.622E-03(KG.-CM.) CHECK= 64.0, NUMBER OF INCREMENTS USED

Figure E14. - Biomechanics motion analysis printout (continued)

```
TH,(F)T,(SEC.), MOTION, RADS.

        VAR ERROR= 0.42379E-01          PERCENT ERROR= 0.17186E 03          ORDER 9
-5.244E-01+(-2.888E 00)T+(-4.578E-02)T**2+(-3.121E 00)T**3+( 3.636E 01)T**4+(-4.355E 01)T**5
+( 2.104E 01)T**6+( 6.555E 00)T**7+(-1.536E 01)T**8+( 6.564E 00)T**9+( 0.        )T**10

DTH/DT, VELOCITY (RAD./SEC.)
-2.888E 00+(-9.157E-02)T+(-9.364E 00)T**2+( 1.455E 02)T**3+(-2.428E 02)T**4
+( 1.262E 02)T**5+( 4.588E 01)T**6+(-1.229E 02)T**7+( 5.908E 01)T**8+( 0.        )T**9

DDTH/DDT, ACCELERATION (RAD./SEC.*SEC.)
-9.157E-02+(-1.873E 01)T+( 4.364E 02)T**2+(-9.711E 02)T**3+( 6.311E 02)T**4
+( 2.753E 02)T**5+(-8.601E 02)T**6+( 4.726E 02)T**7+( 0.        )T**8
```

MOMENT OF INERTIA(DDTH/DDT) TORQUE (KG.-CM.)

TIME	TORQUE	TIME	TORQUE	TIME	TORQUE	TIME	TORQUE	TIME	TORQUE
0.	-1.080E-01	0.029	-3.433E-01	0.058	1.275E-01	0.087	1.156E 00	0.116	2.608E 00
0.145	4.362E 00	0.175	6.379E 00	0.204	8.425E 00	0.233	1.048E 01	0.262	1.247E 01
0.291	1.433E 01	0.320	1.600E 01	0.349	1.744E 01	0.378	1.859E 01	0.407	1.942E 01
0.436	1.990E 01	0.466	1.998E 01	0.495	1.964E 01	0.524	1.885E 01	0.553	1.760E 01
0.582	1.586E 01	0.611	1.362E 01	0.640	1.088E 01	0.670	7.519E 00	0.698	3.904E 00
0.727	-2.931E-01	0.757	-5.073E 00	0.786	-1.004E 01	0.815	-1.526E 01	0.844	-2.057E 01
0.873	-2.582E 01	0.902	-3.077E 01	0.931	-3.512E 01	0.960	-3.851E 01	0.989	-4.051E 01
1.018	-4.058E 01	1.047	-3.806E 01	1.077	-3.192E 01	1.106	-2.164E 01	1.135	-5.997E 00
1.164	1.625E 01	1.165	1.715E 01						

POWER,(KG.-CM./SEC.)

TIME	POWER	TIME	POWER	TIME	POWER	TIME	POWER	TIME	POWER
0.	3.121E-01	0.029	9.939E-01	0.058	-3.697E-01	0.087	-3.335E 00	0.116	-7.405E 00
0.145	-1.201E 01	0.175	-1.670E 01	0.204	-2.052E 01	0.233	-2.309E 01	0.262	-2.396E 01
0.291	-2.281E 01	0.320	-1.950E 01	0.349	-1.407E 01	0.378	-6.765E 00	0.407	2.018E 00
0.436	1.170E 01	0.466	2.189E 01	0.495	3.109E 01	0.524	3.878E 01	0.553	4.410E 01
0.582	4.629E 01	0.611	4.471E 01	0.640	3.901E 01	0.670	2.871E 01	0.698	1.544E 01
0.727	-1.173E 00	0.757	-1.995E 01	0.786	-3.764E 01	0.815	-5.244E 01	0.844	-6.167E 01
0.873	-6.267E 01	0.902	-5.325E 01	0.931	-3.229E 01	0.960	-4.761E-01	0.989	3.898E 01
1.018	7.966E 01	1.047	1.117E 02	1.077	1.224E 02	1.106	9.741E 01	1.135	2.910E 01
1.164	-7.705E 01	1.165	-8.109E 01						

```
WORK TH=INTERGRATION OF POWER TH
WORK=     7.750E 01 (KG.CM.)  CHECK=  256.0, NUMBER OF INCREMENTS USED
```

Figure E14. - Biomechanics motion analysis printout (continued)

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DDX/DDT, ACCELERATION (CM./SEC.*SEC.)
 1.601E 01+( 5.407E 02)T+(-3.322E 03)T**2+( 4.907E 03)T**3+(-1.353E 03)T**4
+( 2.627E 03)T**5+(-7.340E 03)T**6+( 3.887E 03)T**7+( 0.        )T**8

X=M(DDX/DDT), FORCE (KG.)
   TIME      FORCE          TIME      FORCE          TIME      FORCE          TIME      FORCE          TIME      FORCE

   0.        5.481E-01      0.029     9.933E-01      0.058     1.271E 00      0.087     1.406E 00      0.116     1.420E 00
   0.145     1.336E 00      0.175     1.169E 00      0.204     9.525E-01      0.233     7.013E-01      0.262     4.344E-01
   0.291     1.692E-01      0.320    -7.883E-02      0.349    -2.961E-01      0.378    -4.715E-01      0.407    -5.962E-01
   0.436    -6.644E-01      0.466    -6.725E-01      0.495    -6.199E-01      0.524    -5.113E-01      0.553    -3.531E-01
   0.582    -1.546E-01      0.611     7.197E-02      0.640     3.123E-01      0.670     5.577E-01      0.698     7.667E-01
   0.727     9.446E-01      0.757     1.068E 00      0.786     1.112E 00      0.815     1.068E 00      0.844     9.251E-01
   0.873     6.797E-01      0.902     3.351E-01      0.931    -9.522E-02      0.960    -5.861E-01      0.989    -1.097E 00
   1.018    -1.571E 00      1.047    -1.930E 00      1.077    -2.069E 00      1.106    -1.846E 00      1.135    -1.107E 00
   1.164     3.500E-01      1.165     4.158E-01

PX=FORCE(DX/DT), POWER (KG.CM./SEC.)
   TIME      POWER          TIME      POWER          TIME      POWER          TIME      POWER          TIME      POWER

   0.        1.190E 02      0.029     2.164E 02      0.058     2.782E 02      0.087     3.092E 02      0.116     3.140E 02
   0.145     2.970E 02      0.175     2.613E 02      0.204     2.137E 02      0.233     1.578E 02      0.262     9.796E 01
   0.291     3.819E 01      0.320    -1.780E 01      0.349    -6.682E 01      0.378    -1.062E 02      0.407    -1.341E 02
   0.436    -1.490E 02      0.466    -1.505E 02      0.495    -1.383E 02      0.524    -1.139E 02      0.553    -7.850E 01
   0.582    -3.435E 01      0.611     1.598E 01      0.640     6.939E 01      0.670     1.242E 02      0.698     1.711E 02
   0.727     2.115E 02      0.757     2.401E 02      0.786     2.511E 02      0.815     2.420E 02      0.844     2.105E 02
   0.873     1.551E 02      0.902     7.662E 01      0.931    -2.178E 01      0.960    -1.339E 02      0.989    -2.499E 02
   1.018    -3.560E 02      1.047    -4.343E 02      1.077    -4.621E 02      1.106    -4.092E 02      1.135    -2.438E 02
   1.164     7.699E 01      1.165     9.147E 01

WORK X=INTERGRATION OF POWER X
WORK=     2.137E 02 (KG.CM.)  CHECK=  128.0, NUMBER OF INCREMENTS USED

Z,(F)T,(SEC.), MOTION, CMS.

         VAR ERROR= 0.23270E 01          PERCENT ERROR= 0.16048E 01          ORDER 8
 1.362E 02+( 2.938E 01)T+( 3.681E 02)T**2+(-2.408E 03)T**3+( 5.308E 03)T**4+(-5.142E 03)T**5
+( 1.409E 03)T**6+( 9.516E 02)T**7+(-5.185E 02)T**8+( 0.        )T**9+( 0.        )T**10

DZ/DT, VELOCITY (CM./SEC.)
 2.938E 01+( 7.362E 02)T+(-7.224E 03)T**2+( 2.123E 04)T**3+(-2.571E 04)T**4
+( 8.455E 03)T**5+( 6.661E 03)T**6+(-4.148E 03)T**7+( 0.        )T**8+( 0.        )T**9

DDZ/DDT, ACCELERATION (CM./SEC.*SEC.)
 7.362E 02+(-1.445E 04)T+( 6.370E 04)T**2+(-1.028E 05)T**3+( 4.227E 04)T**4
+( 3.997E 04)T**5+(-2.904E 04)T**6+( 0.        )T**7+( 0.        )T**8
```

Figure E14. - Biomechanics motion analysis printout (continued)

Z=M(DDZ/DDT), FORCE (KG.)

TIME	FORCE	TIME	FORCE	TIME	FORCE	TIME	FORCE	TIME	FORCE
0.	2.520E 01	0.029	1.261E 01	0.058	3.181E 00	0.087	-3.551E 00	0.116	-8.034E 00
0.145	-1.068E 01	0.175	-1.188E 01	0.204	-1.191E 01	0.233	-1.113E 01	0.262	-9.813E 00
0.291	-8.178E 00	0.320	-6.417E 00	0.349	-4.682E 00	0.378	-3.091E 00	0.407	-1.726E 00
0.436	-6.375E-01	0.466	1.758E-01	0.495	6.669E-01	0.524	8.988E-01	0.553	9.226E-01
0.582	8.049E-01	0.611	6.238E-01	0.640	4.636E-01	0.670	4.108E-01	0.698	5.426E-01
0.727	9.316E-01	0.757	1.658E 00	0.786	2.701E 00	0.815	4.072E 00	0.844	5.723E 00
0.873	7.559E 00	0.902	9.424E 00	0.931	1.110E 01	0.960	1.228E 01	0.989	1.259E 01
1.018	1.154E 01	1.047	8.551E 00	1.077	2.649E 00	1.106	-6.636E 00	1.135	-2.044E 01
1.164	-3.991E 01	1.165	-4.070E 01						

PZ=FORCE(DZ/DT), POWER (KG.CM./SEC.)

TIME	POWER	TIME	POWER	TIME	POWER	TIME	POWER	TIME	POWER
0.	7.404E 02	0.029	5.693E 02	0.058	1.643E 02	0.087	-1.822E 02	0.116	-3.716E 02
0.145	-4.080E 02	0.175	-3.354E 02	0.204	-2.154E 02	0.233	-9.212E 01	0.262	6.154E 00
0.291	6.757E 01	0.320	9.270E 01	0.349	8.963E 01	0.378	6.930E 01	0.407	4.219E 01
0.436	1.621E 01	0.466	-4.502E 00	0.495	-1.682E 01	0.524	-2.206E 01	0.553	-2.192E 01
0.582	-1.853E 01	0.611	-1.398E 01	0.640	-1.018E 01	0.670	-8.868E 00	0.698	-1.151E 01
0.727	-1.920E 01	0.757	-3.234E 01	0.786	-4.775E 01	0.815	-6.039E 01	0.844	-6.123E 01
0.873	-3.840E 01	0.902	1.996E 01	0.931	1.202E 02	0.960	2.553E 02	0.989	3.953E 02
1.018	4.818E 02	1.047	4.311E 02	1.077	1.472E 02	1.106	-3.593E 02	1.135	-8.797E 02
1.164	-7.152E 02	1.165	-6.814E 02						

WORK Z=INTERGRATION OF POWER Z
WORK= 1.453E 02 (KG.CM.) CHECK= 64.0, NUMBER OF INCREMENTS USED

FROM THE EQUATION OF MOTION Z,(F)T

G-GRADIENT (F)T (UNITLESS)

TIME	G-GRAD	TIME	G-GRAD	TIME	G-GRAD	TIME	G-GRAD	TIME	G-GRAD
0.	1.785E-01	0.029	1.791E-01	0.058	1.797E-01	0.087	1.805E-01	0.116	1.812E-01
0.145	1.818E-01	0.175	1.823E-01	0.204	1.826E-01	0.233	1.828E-01	0.262	1.828E-01
0.291	1.828E-01	0.320	1.826E-01	0.349	1.824E-01	0.378	1.821E-01	0.407	1.817E-01
0.436	1.814E-01	0.466	1.810E-01	0.495	1.806E-01	0.524	1.803E-01	0.553	1.799E-01
0.582	1.796E-01	0.611	1.793E-01	0.640	1.790E-01	0.670	1.787E-01	0.698	1.784E-01
0.727	1.781E-01	0.757	1.778E-01	0.786	1.775E-01	0.815	1.773E-01	0.844	1.771E-01
0.873	1.770E-01	0.902	1.770E-01	0.931	1.771E-01	0.960	1.773E-01	0.989	1.777E-01
1.018	1.782E-01	1.047	1.788E-01	1.077	1.796E-01	1.106	1.804E-01	1.135	1.811E-01
1.164	1.815E-01	1.165	1.815E-01						

Figure E14. - Biomechanics motion analysis printout (continued)

POWER OF POTENTIAL ENERGY=G-GRADIENT*G*MASS*DZ/DT (KG.-CM./SEC.)

TIME	P.P.E.	TIME	P.P.E.	TIME	P.P.E.	TIME	P.P.E.	TIME	P.P.E.
0.	1.761E 02	0.029	2.714E 02	0.058	3.116E 02	0.087	3.108E 02	0.116	2.813E 02
0.145	2.332E 02	0.175	1.727E 02	0.204	1.108E 02	0.233	5.077E 01	0.262	-3.849E 00
0.291	-5.069E 01	0.320	-8.856E 01	0.349	-1.172E 02	0.378	-1.370E 02	0.407	-1.491E 02
0.436	-1.548E 02	0.466	-1.556E 02	0.495	-1.530E 02	0.524	-1.486E 02	0.553	-1.435E 02
0.582	-1.388E 02	0.611	-1.349E 02	0.640	-1.320E 02	0.670	-1.295E 02	0.698	-1.270E 02
0.727	-1.232E 02	0.757	-1.164E 02	0.786	-1.054E 02	0.815	-8.827E 01	0.844	-6.361E 01
0.873	-3.019E 01	0.902	1.258E 01	0.931	6.440E 01	0.960	1.237E 02	0.989	1.872E 02
1.018	2.496E 02	1.047	3.026E 02	1.077	3.350E 02	1.106	3.279E 02	1.135	2.616E 02
1.164	1.092E 02	1.165	1.020E 02						

POTENTIAL ENERGY=INTERGRATION OF THE POWER OF POTENTIAL ENERGY
POTENTIAL ENERGY= 3.841E-02(KG.-CM.) CHECK= 64.0, NUMBER OF INCREMENTS USED

TH,(F)T,(SEC.), MOTION, RADS.

VAR ERROR= 0.96239E-02 PERCENT ERROR= 0.26137E 01 ORDER 9

```
-3.948E-01+( 8.890E-02)T+(-1.810E 00)T**2+( 7.621E 00)T**3+(-1.218E 01)T**4+( 8.521E 00)T**5
+(-3.588E 00)T**6+( 2.141E 00)T**7+(-8.035E-01)T**8+(-2.645E-02)T**9+( 0.       )T**10
```

DTH/DT, VELOCITY (RAD./SEC.)

```
 8.890E-02+(-3.620E 00)T+( 2.286E 01)T**2+(-4.871E 01)T**3+( 4.261E 01)T**4
+(-2.153E 01)T**5+( 1.499E 01)T**6+(-6.428E 00)T**7+(-2.380E-01)T**8+( 0.       )T**9
```

DDTH/DDT, ACCELERATION (RAD./SEC.*SEC.)

```
-3.620E 00+( 4.573E 01)T+(-1.461E 02)T**2+( 1.704E 02)T**3+(-1.076E 02)T**4
+( 8.993E 01)T**5+(-4.500E 01)T**6+(-1.904E 00)T**7+( 0.       )T**8
```

MOMENT OF INERTIA(DDTH/DDT) TORQUE (KG.-CM.)

TIME	TORQUE	TIME	TORQUE	TIME	TORQUE	TIME	TORQUE	TIME	TORQUE
0.	-5.491E 01	0.029	-3.659E 01	0.058	-2.165E 01	0.087	-9.725E 00	0.116	-5.093E-01
0.145	6.301E 00	0.175	1.112E 01	0.204	1.389E 01	0.233	1.508E 01	0.262	1.492E 01
0.291	1.364E 01	0.320	1.148E 01	0.349	8.648E 00	0.378	5.343E 00	0.407	1.765E 00
0.436	-1.900E 00	0.466	-5.596E 00	0.495	-8.908E 00	0.524	-1.181E 01	0.553	-1.417E 01
0.582	-1.587E 01	0.611	-1.681E 01	0.640	-1.692E 01	0.670	-1.610E 01	0.698	-1.446E 01
0.727	-1.189E 01	0.757	-8.342E 00	0.786	-4.158E 00	0.815	6.285E-01	0.844	5.823E 00
0.873	1.117E 01	0.902	1.637E 01	0.931	2.101E 01	0.960	2.465E 01	0.989	2.672E 01
1.018	2.660E 01	1.047	2.354E 01	1.077	1.637E 01	1.106	4.585E 00	1.135	-1.309E 01
1.164	-3.787E 01	1.165	-3.887E 01						

Figure E14. - Biomechanics motion analysis printout (continued)

POWER,(KG.-CM./SEC.)

TIME	POWER	TIME	POWER	TIME	POWER	TIME	POWER	TIME	POWER
0.	-4.881E 00	0.029	-7.287E-02	0.058	1.151E 00	0.087	8.044E-01	0.116	4.690E-02
0.145	-5.431E-01	0.175	-7.628E-01	0.204	-6.173E-01	0.233	-2.489E-01	0.262	1.844E-01
0.291	5.434E-01	0.320	7.346E-01	0.349	7.204E-01	0.378	5.169E-01	0.407	1.828E-01
0.436	-1.965E-01	0.466	-5.372E-01	0.495	-7.311E-01	0.524	-7.345E-01	0.553	-5.279E-01
0.582	-1.335E-01	0.611	3.860E-01	0.640	9.364E-01	0.670	1.419E 00	0.698	1.684E 00
0.727	1.686E 00	0.757	1.351E 00	0.786	7.235E-01	0.815	-1.115E-01	0.844	-9.978E-01
0.873	-1.733E 00	0.902	-2.107E 00	0.931	-1.951E 00	0.960	-1.208E 00	0.989	1.037E-02
1.018	1.377E 00	1.047	2.359E 00	1.077	2.299E 00	1.106	7.397E-01	1.135	-2.018E 00
1.164	-4.043E 00	1.165	-4.052E 00						

WORK TH=INTERGRATION OF POWER TH
WORK= 1.150E 00 (KG.CM.) CHECK= 128.0, NUMBER OF INCREMENTS USED

TOTAL WORK OF INSTRUMENT PACK= 3.601E 02, (KG.-CM.)

TOTAL BODY WORK+TOTAL WORK OF INSTRUMENT PACK= 3.785E 03, (KG.-CM.)

Figure E14. - Biomechanics motion analysis printout (continued)

Result curves for motion dynamics and external work performed for sample test C-3007-2 follow.

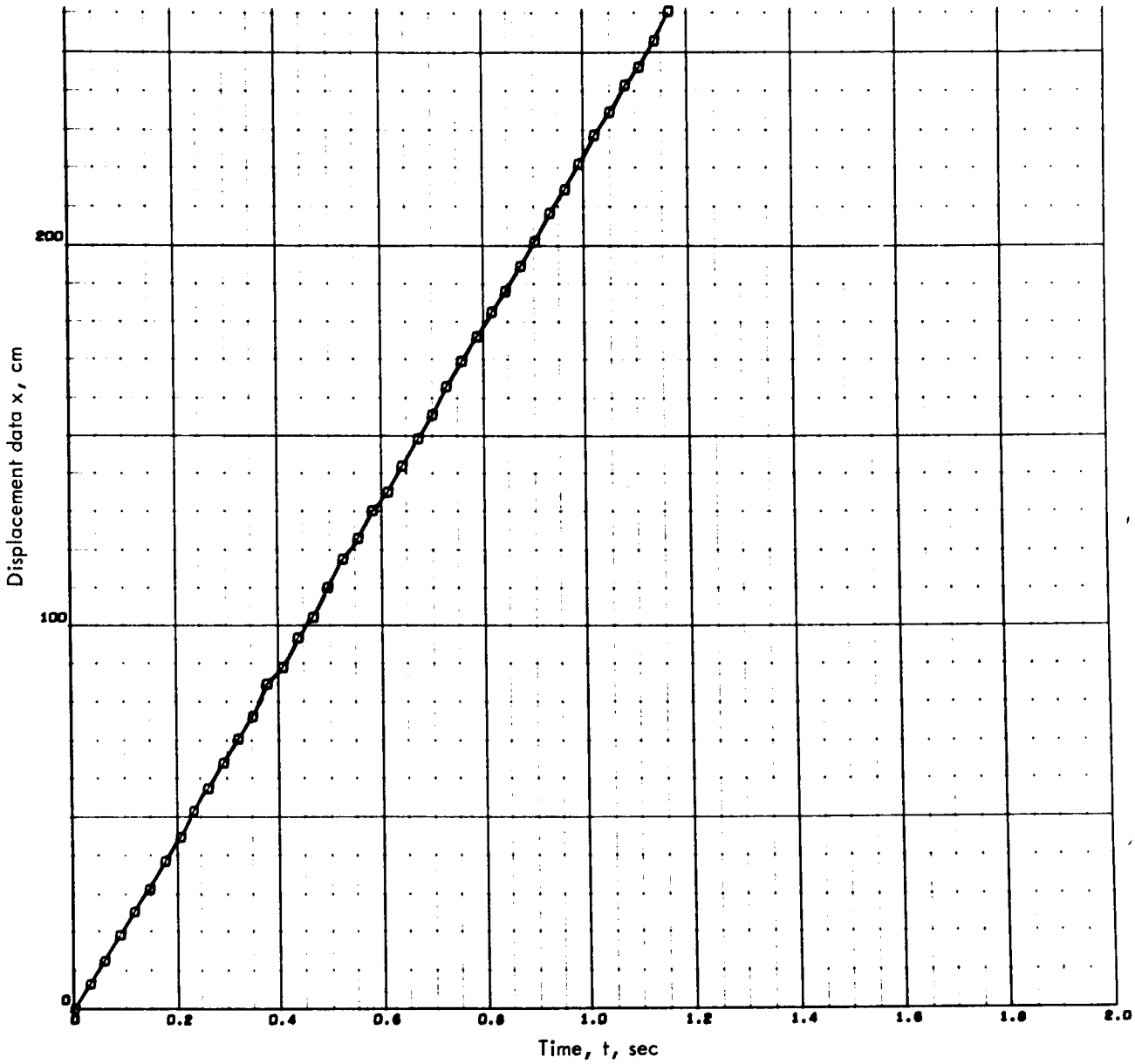

Figure E15. - Displacement data x versus time for segment no. 1, head and neck

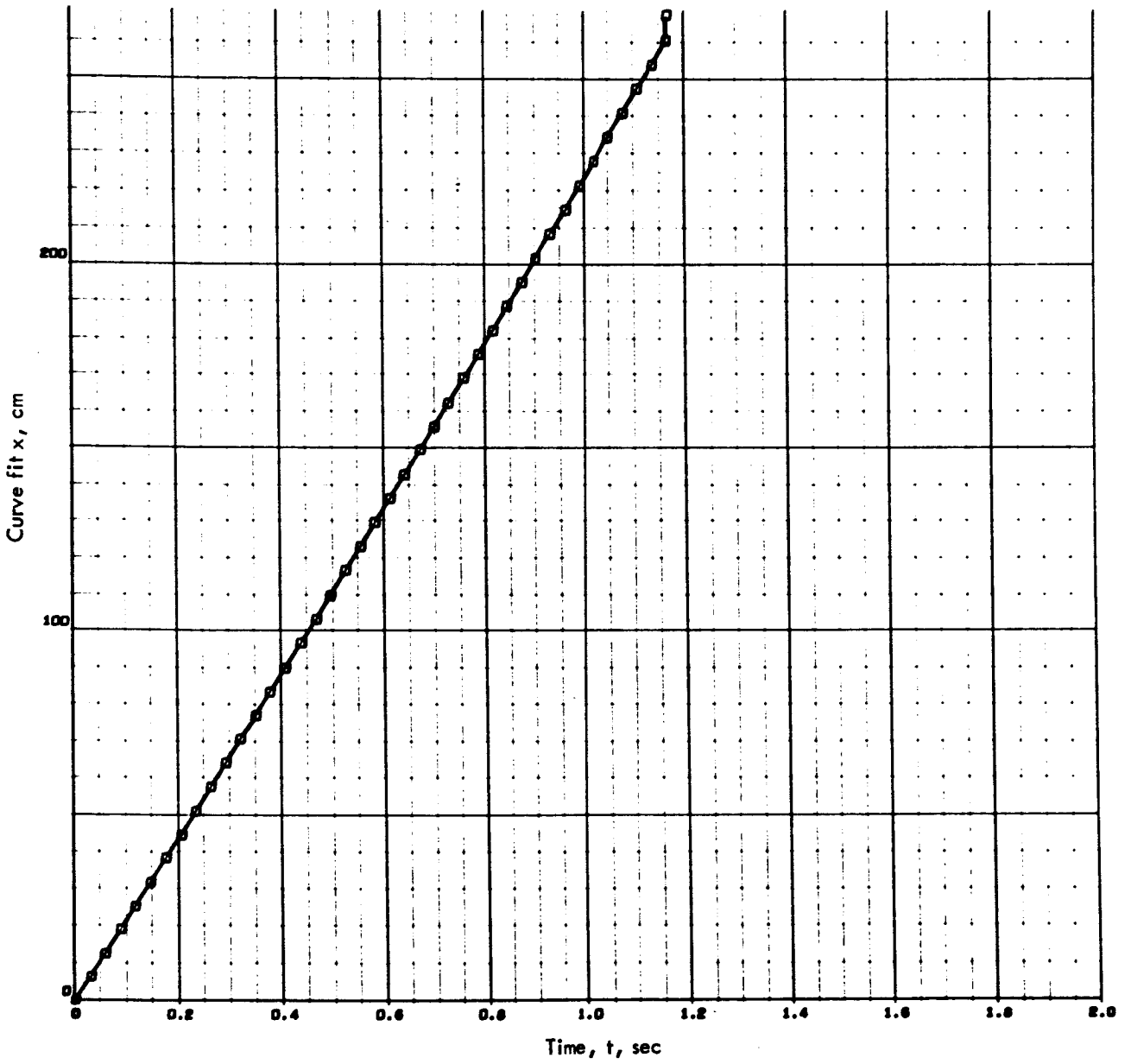

Figure E16. - Curve fit x versus time for segment no. 1, head and neck

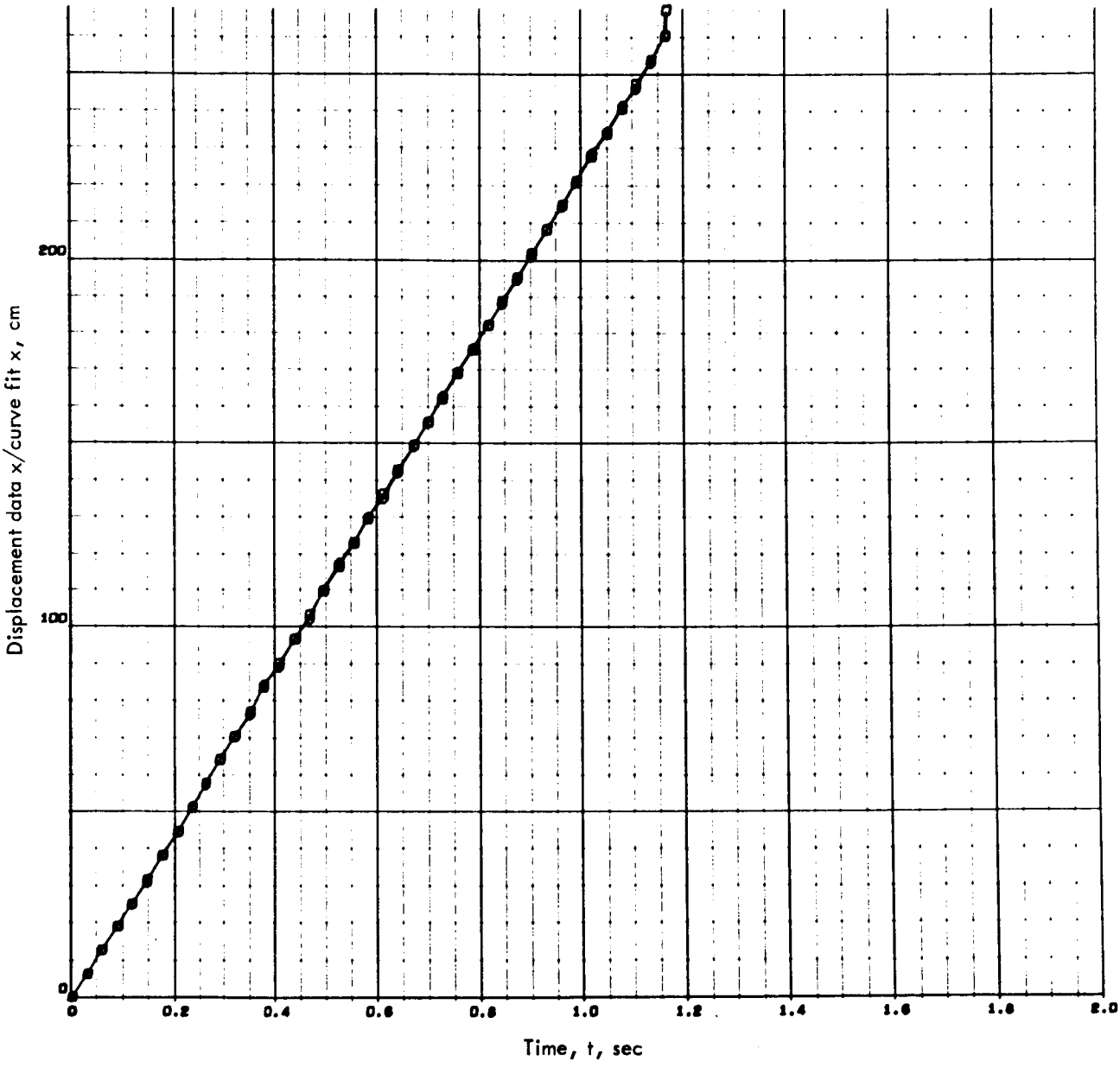

Figure E17. - Displacement data x/curve fit x versus time for segment no. 1, head and neck

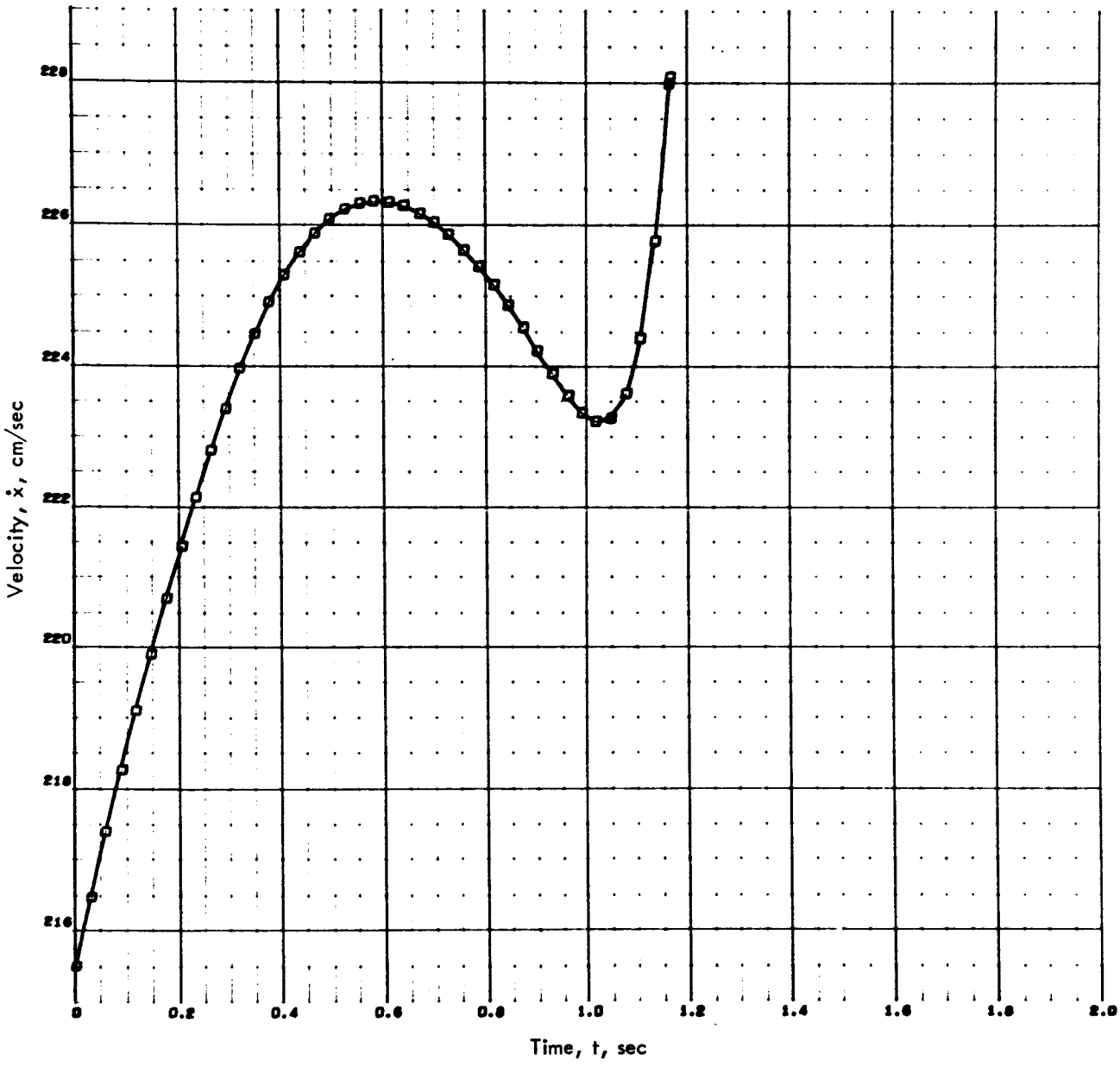

Figure E18. - Velocity $\dot{x}$ versus time for segment no. 1, head and neck

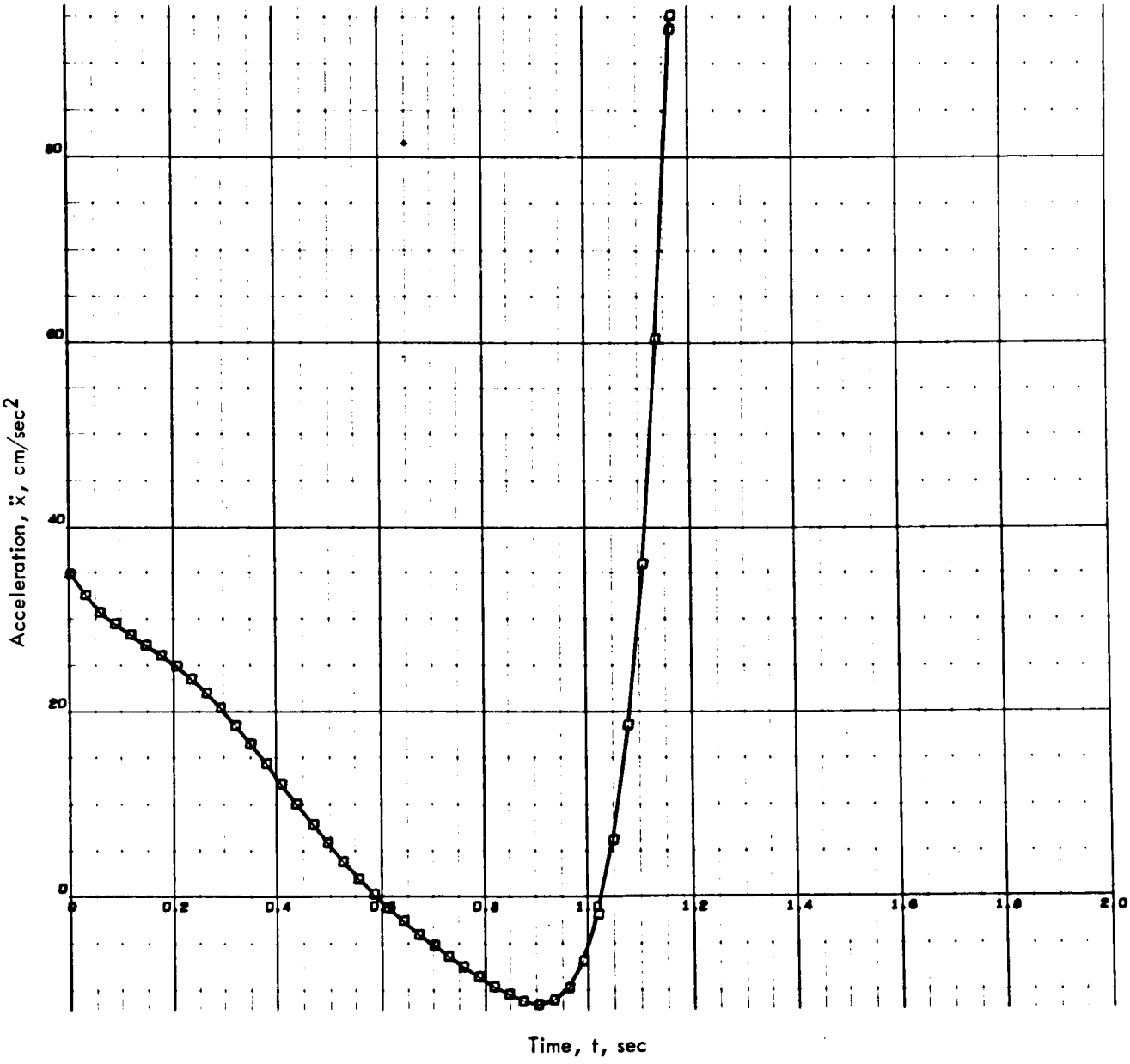

Figure E19. - Acceleration $\ddot{x}$ versus time for segment no. 1, head and neck

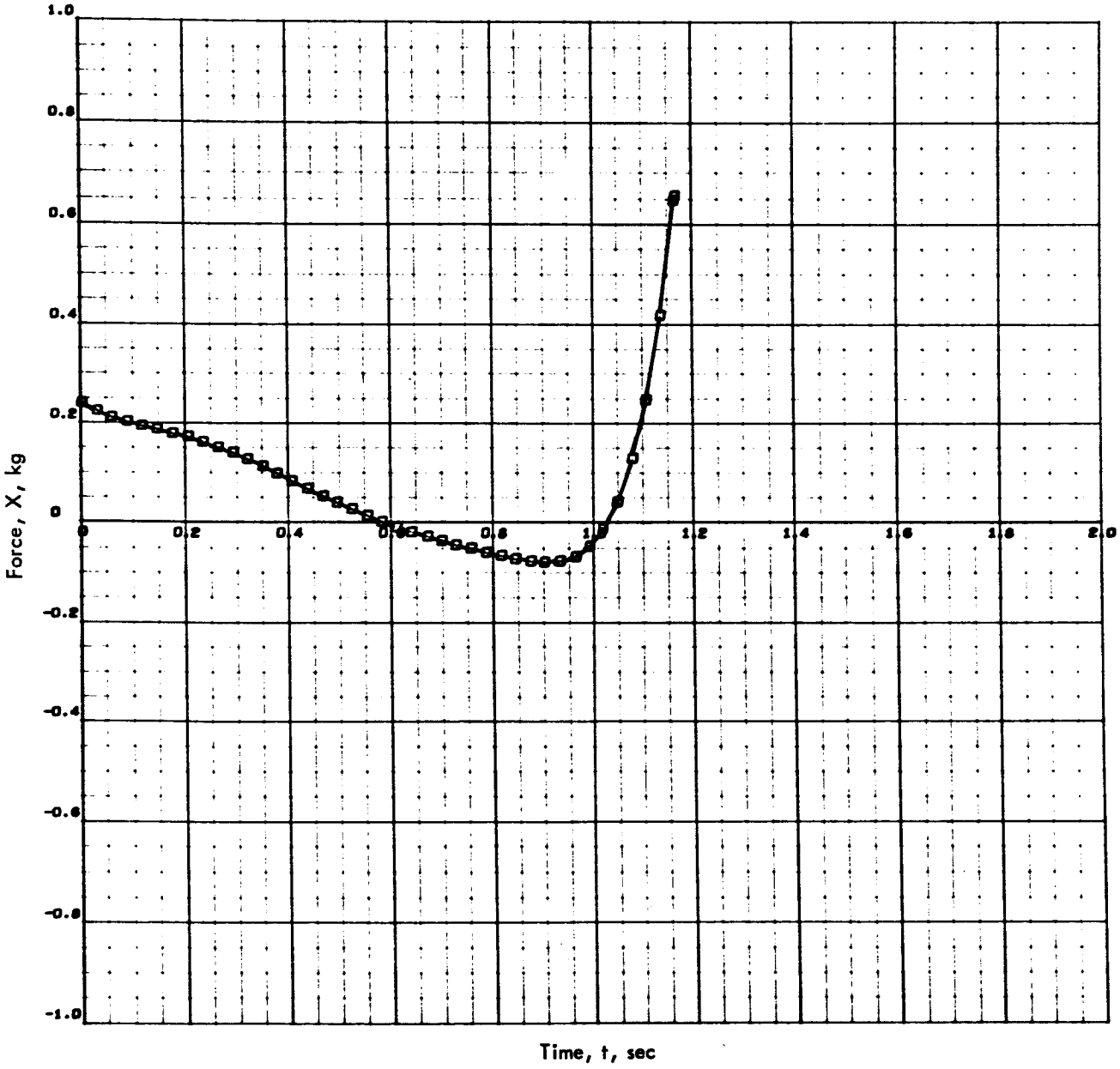

Figure E20. - Force X versus time for segment no. 1, head and neck

Figure E21. - Power P_x versus time for segment no. 1, head and neck

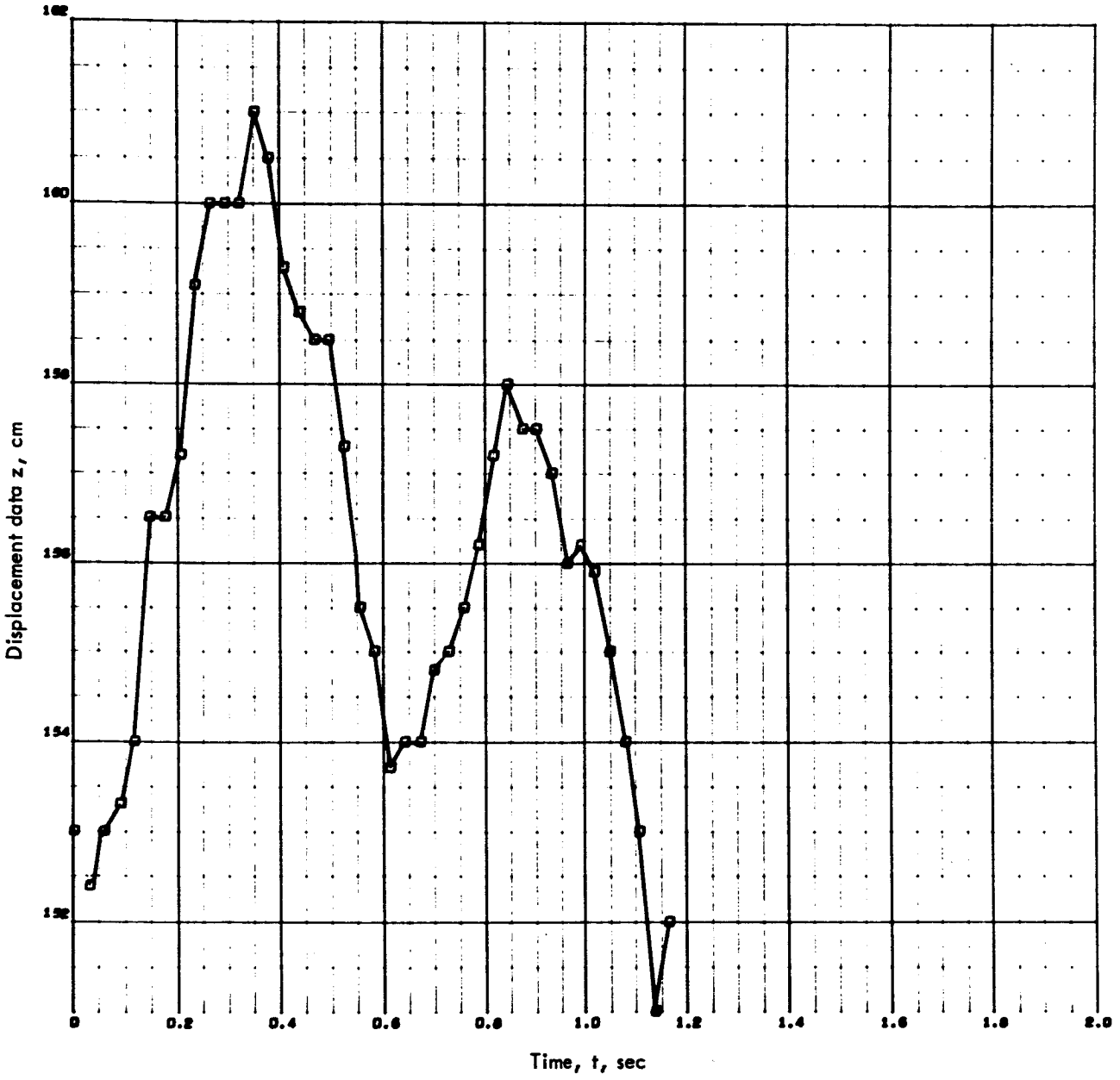

Figure E22. - Displacement data z versus time for segment no. 1, head and neck

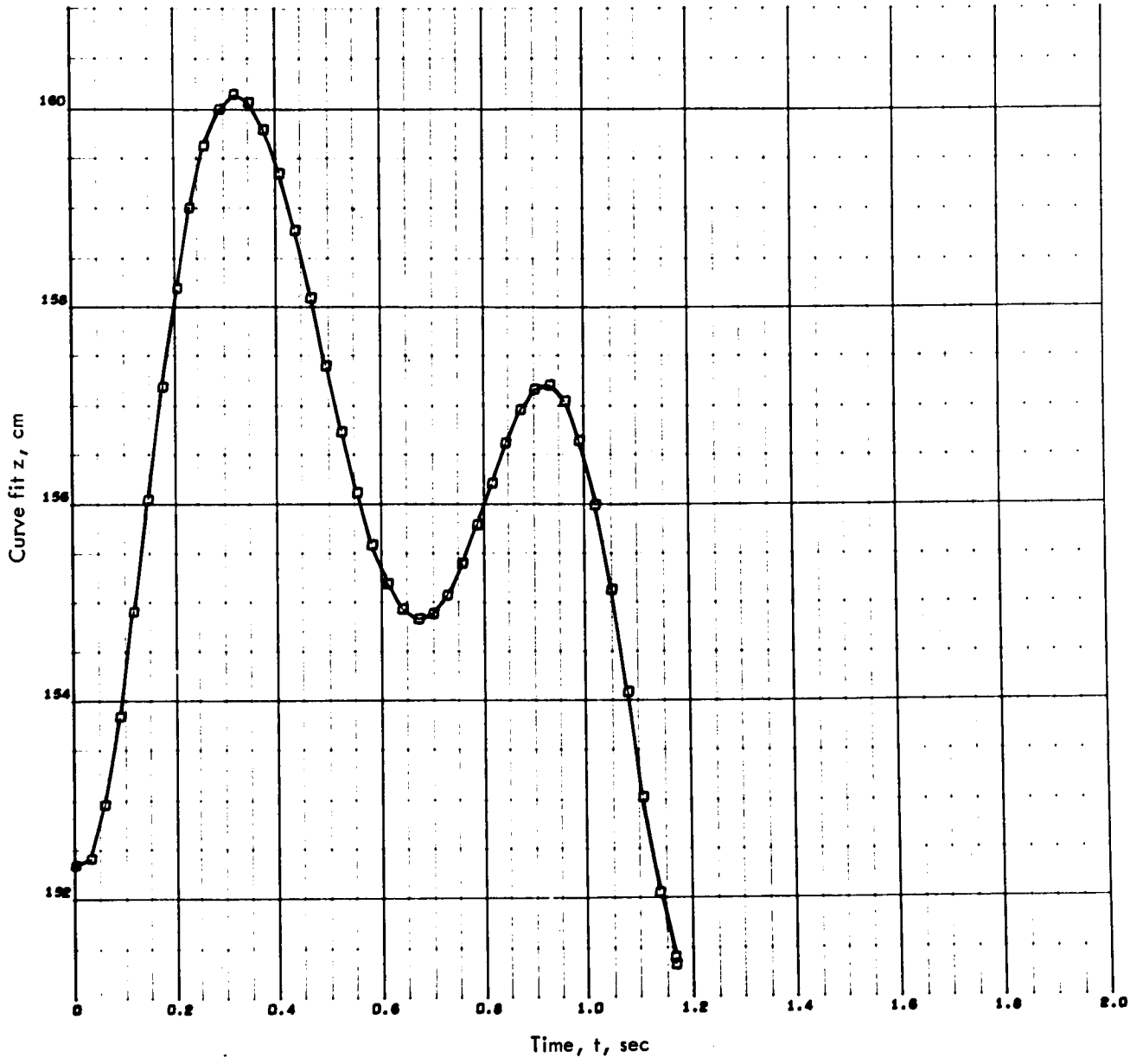

Figure E23. - Curve fit z versus time for segment no. 1, head and neck

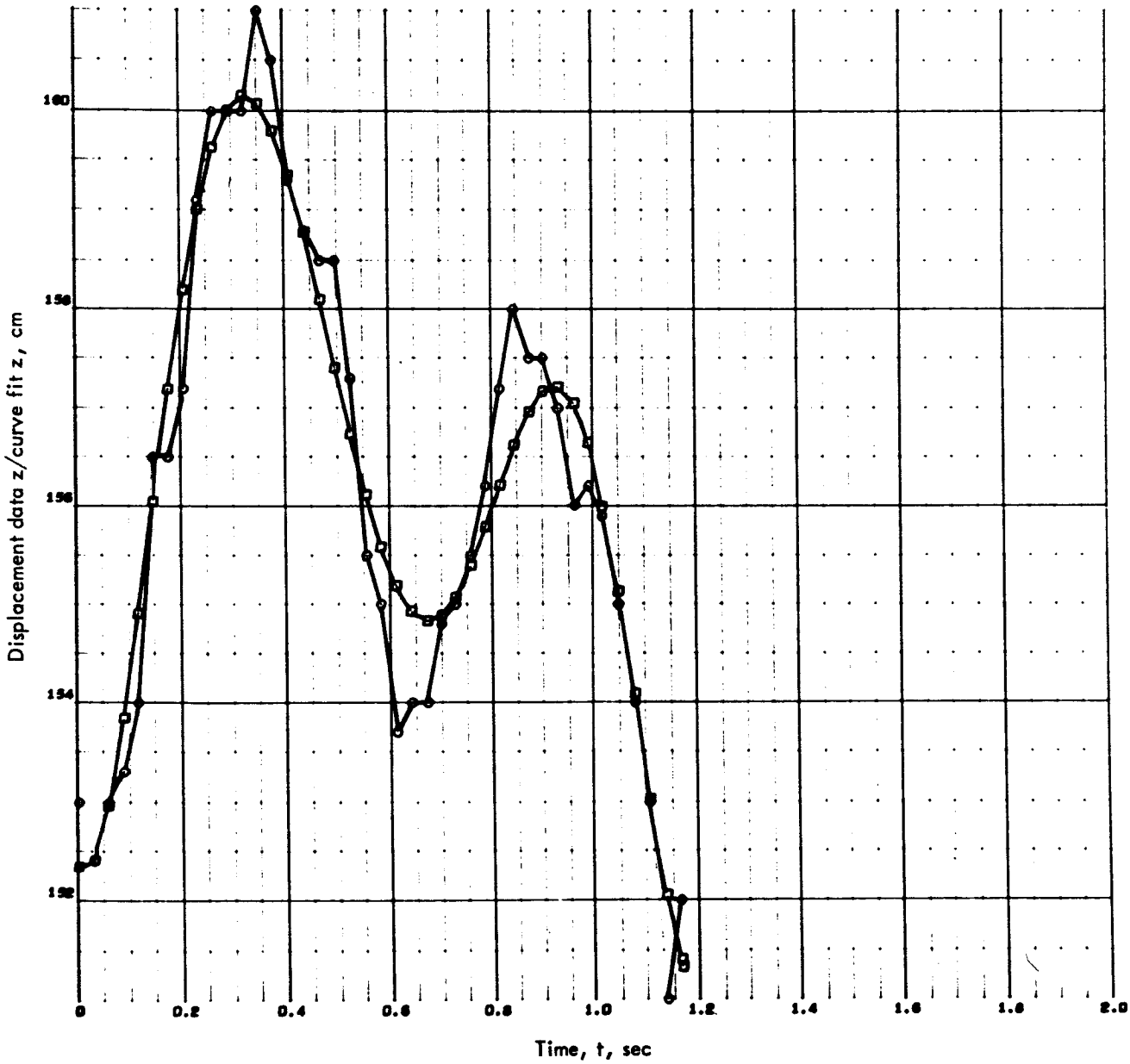

Figure E24. - Displacement data z/curve fit z versus time for segment no. 1, head and neck

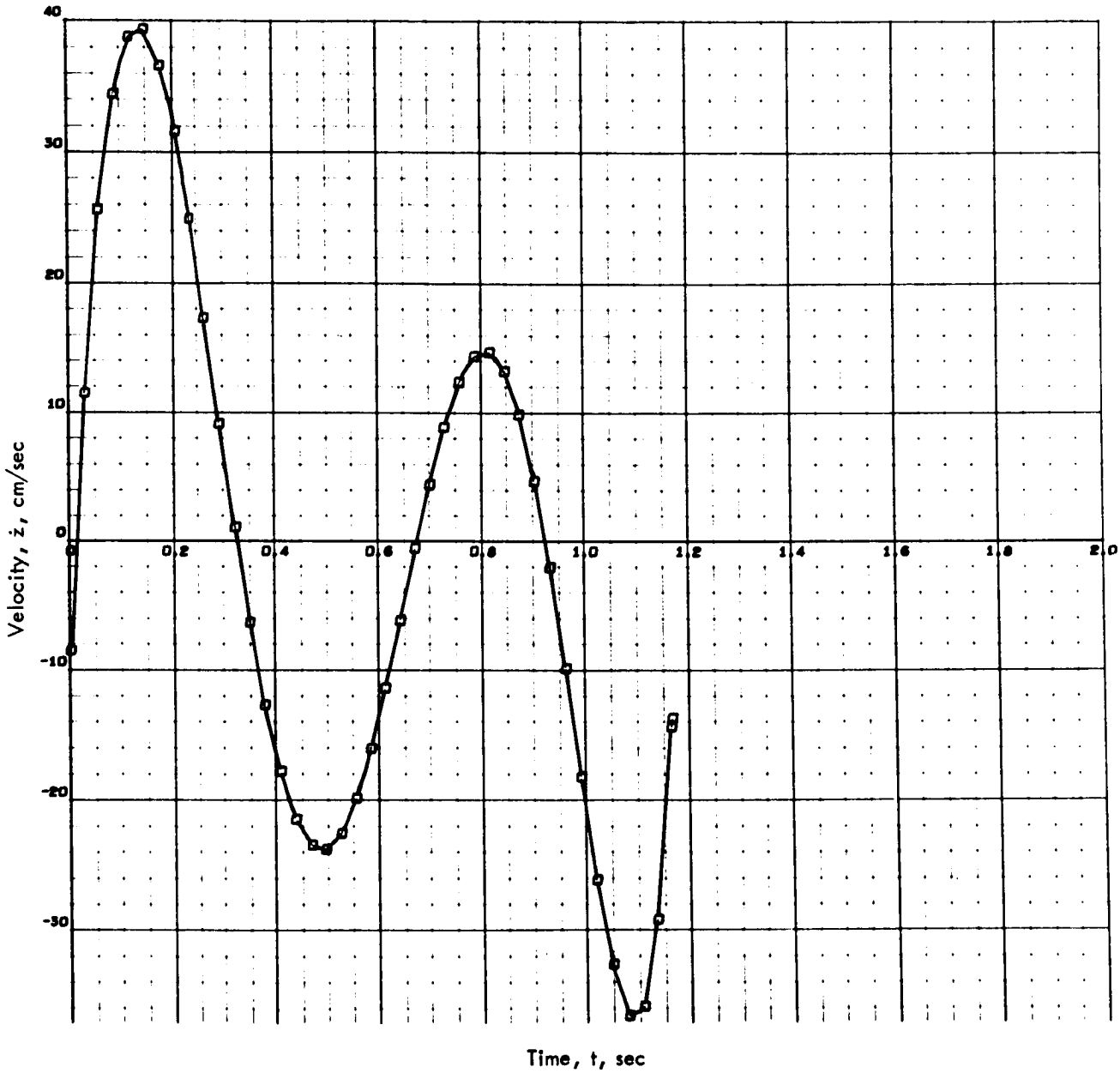

Figure E25. - Velocity ż versus time for segment no. 1, head and neck

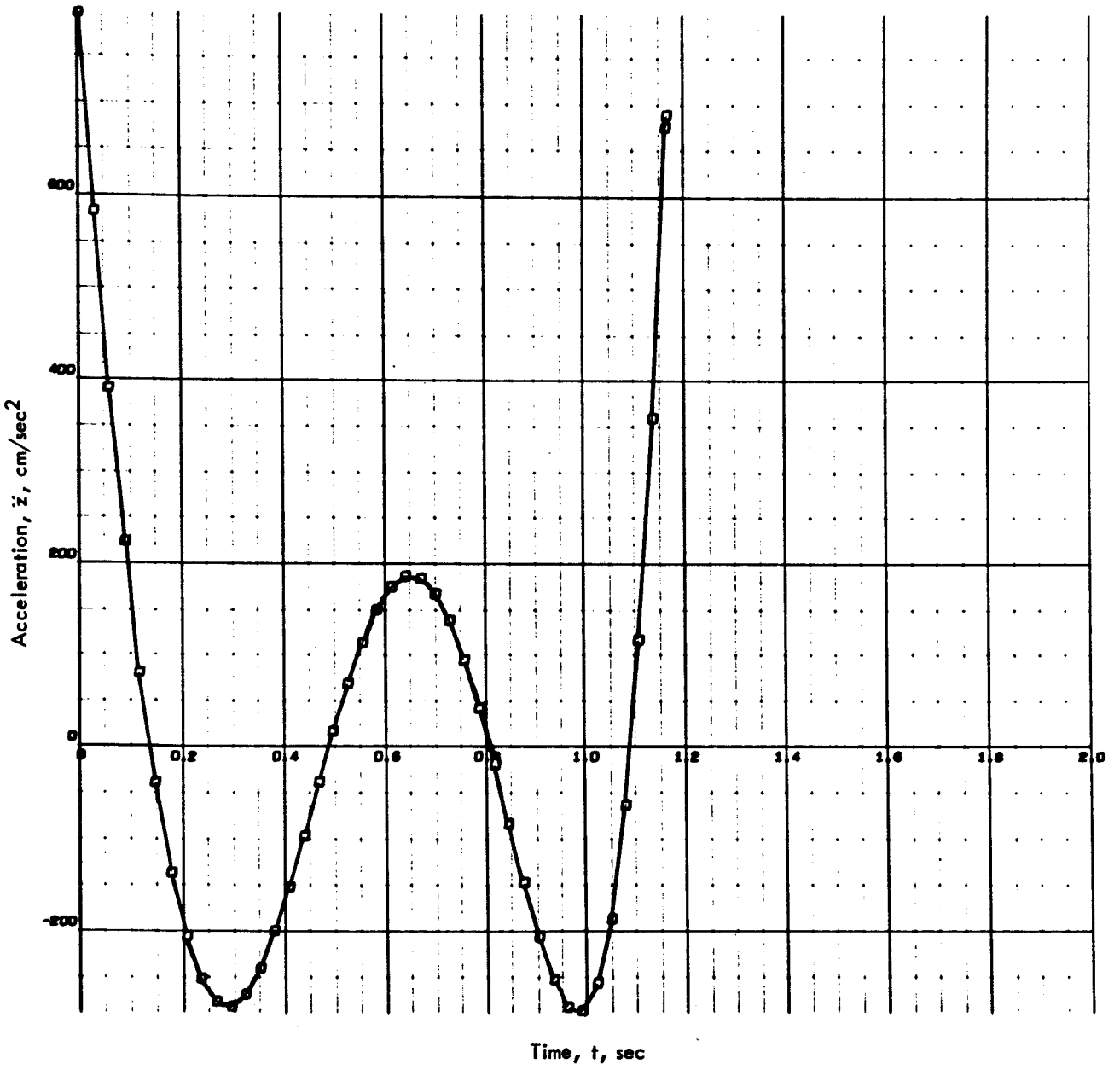

Figure E26.- Acceleration ẍ versus time for segment no. 1, head and neck

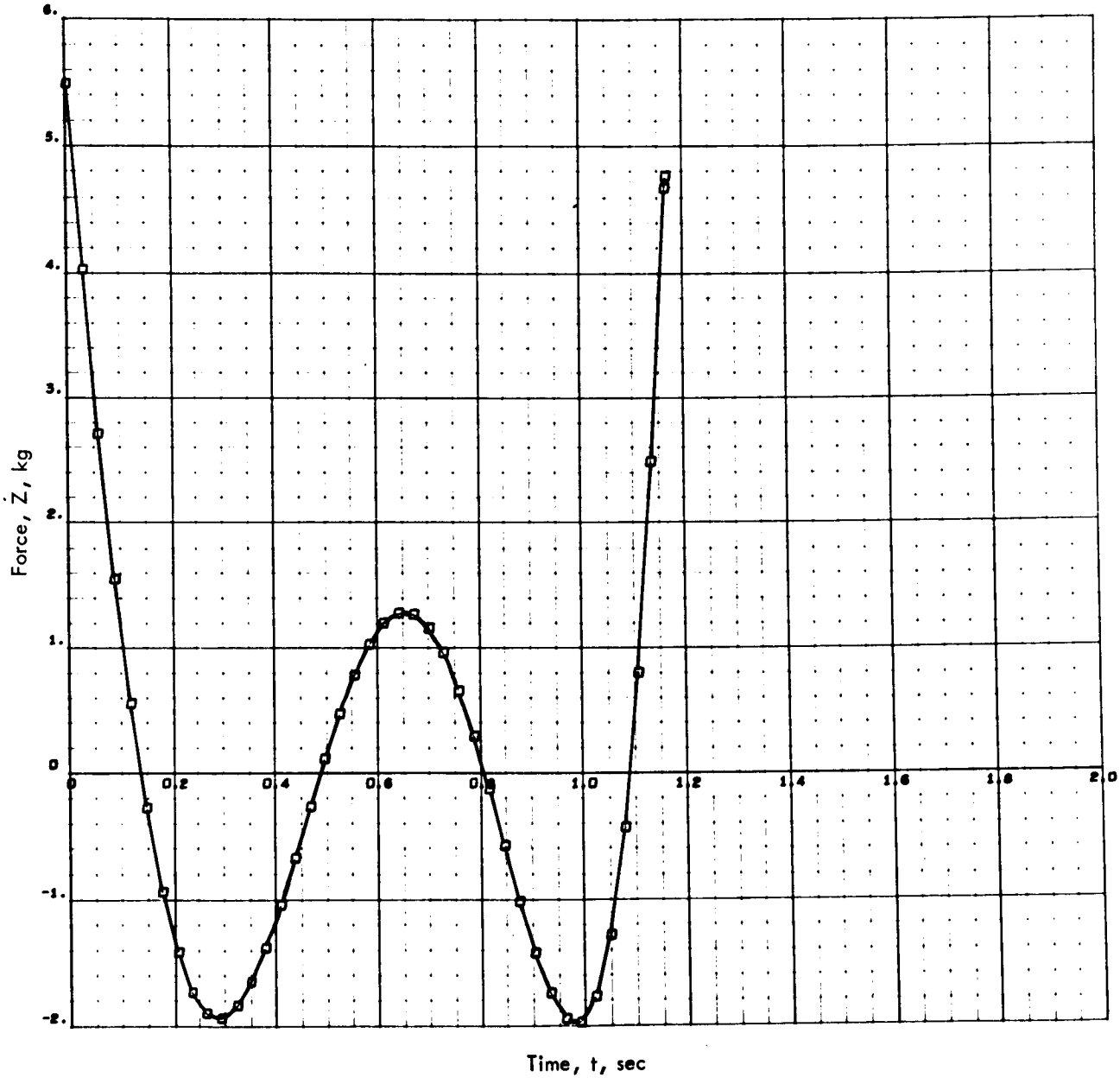

Figure E27. - Force Z versus time for segment no. 1, head and neck

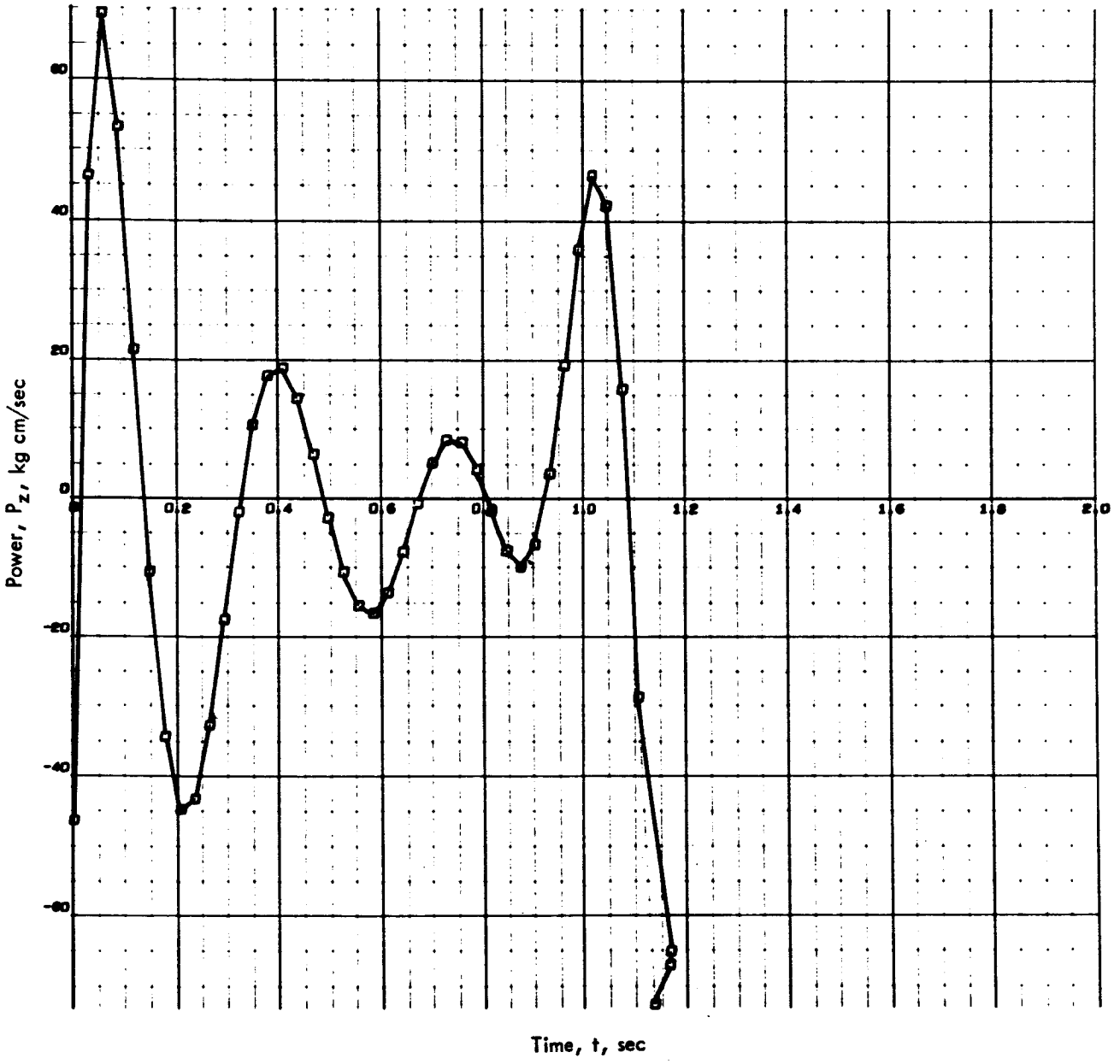

Figure E28. - Power P_z versus time for segment no. 1, head and neck

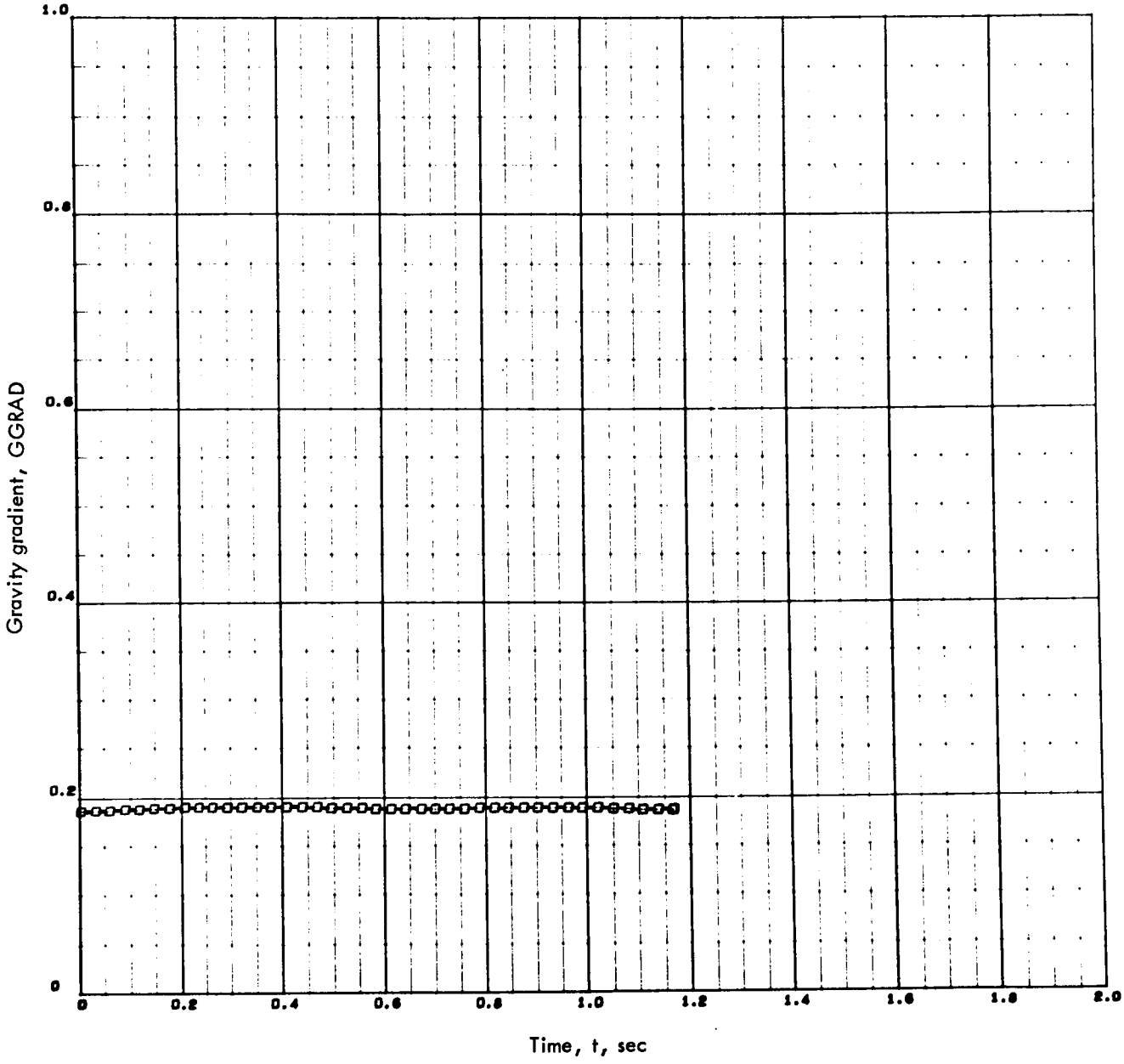

Figure E29. - Gravity gradient versus time for segment no. 1, head and neck

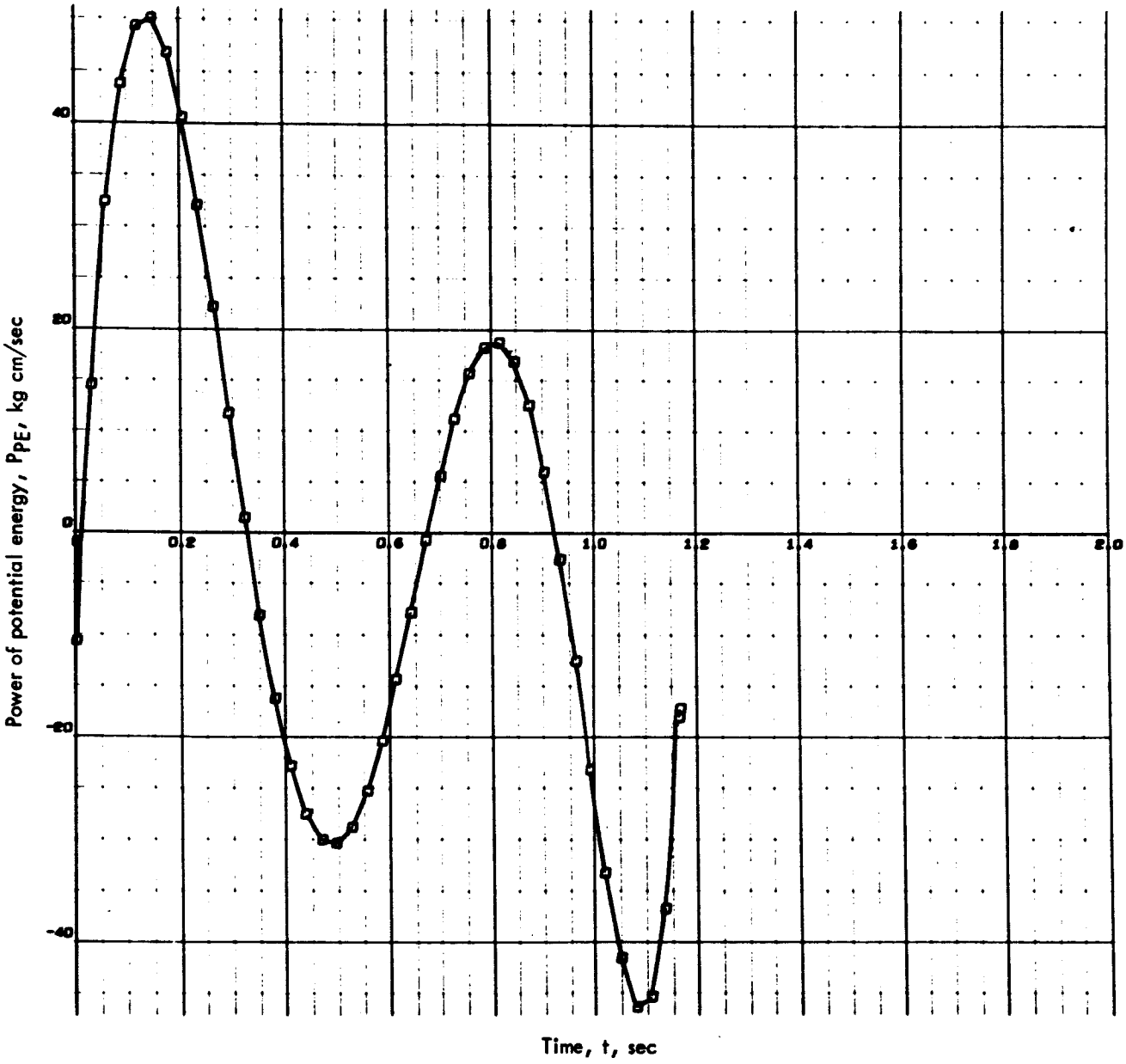

Figure E30.- Power of potential energy versus time for segment no. 1, head and neck

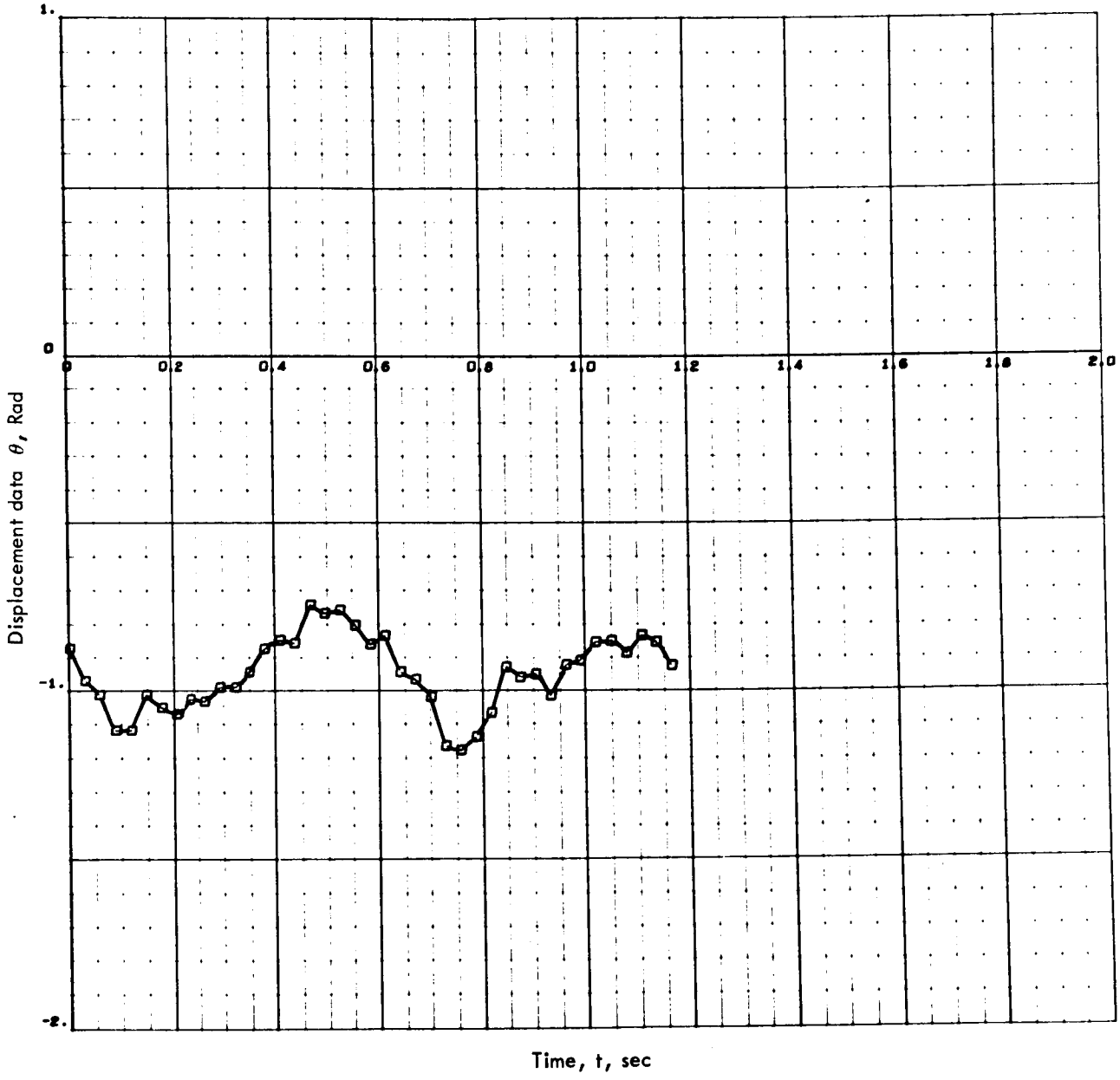

Figure E31. - Displacement data θ versus time for segment no. 1, head and neck

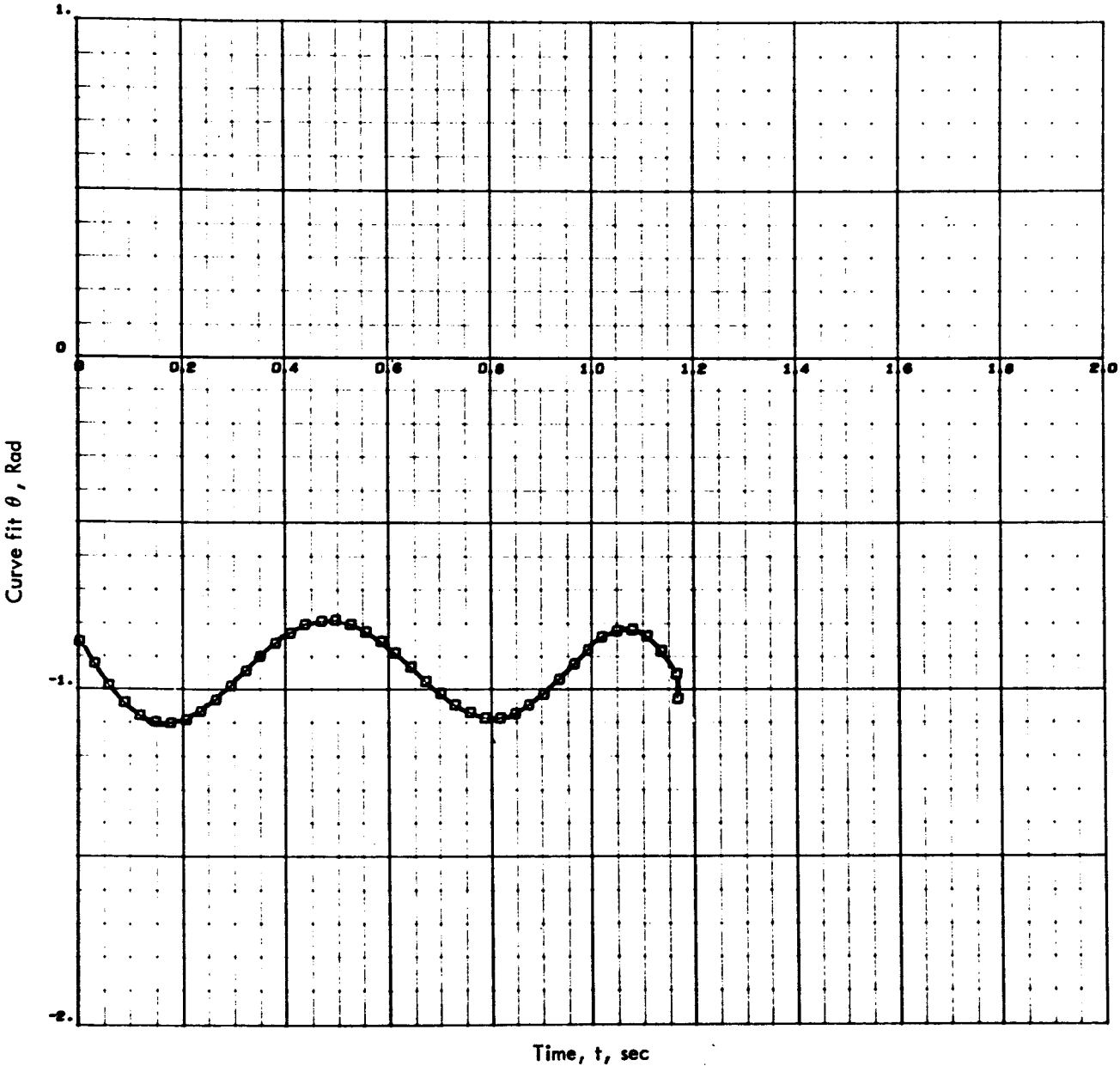

Figure E32. - Curve fit θ versus time for segment no. 1, head and neck

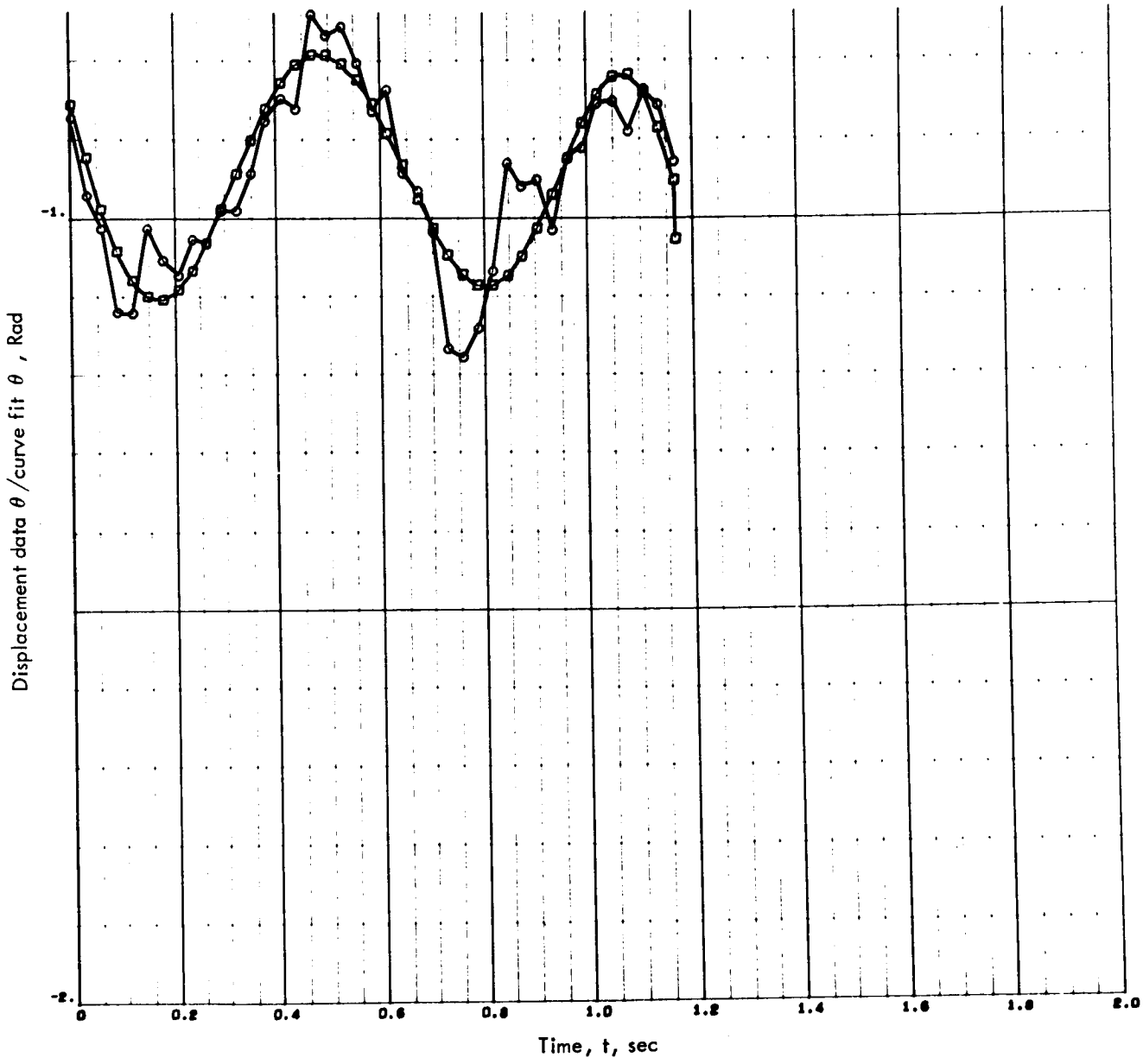

Figure E33. - Displacement data θ /curve fit θ versus time for segment no. 1, head and neck

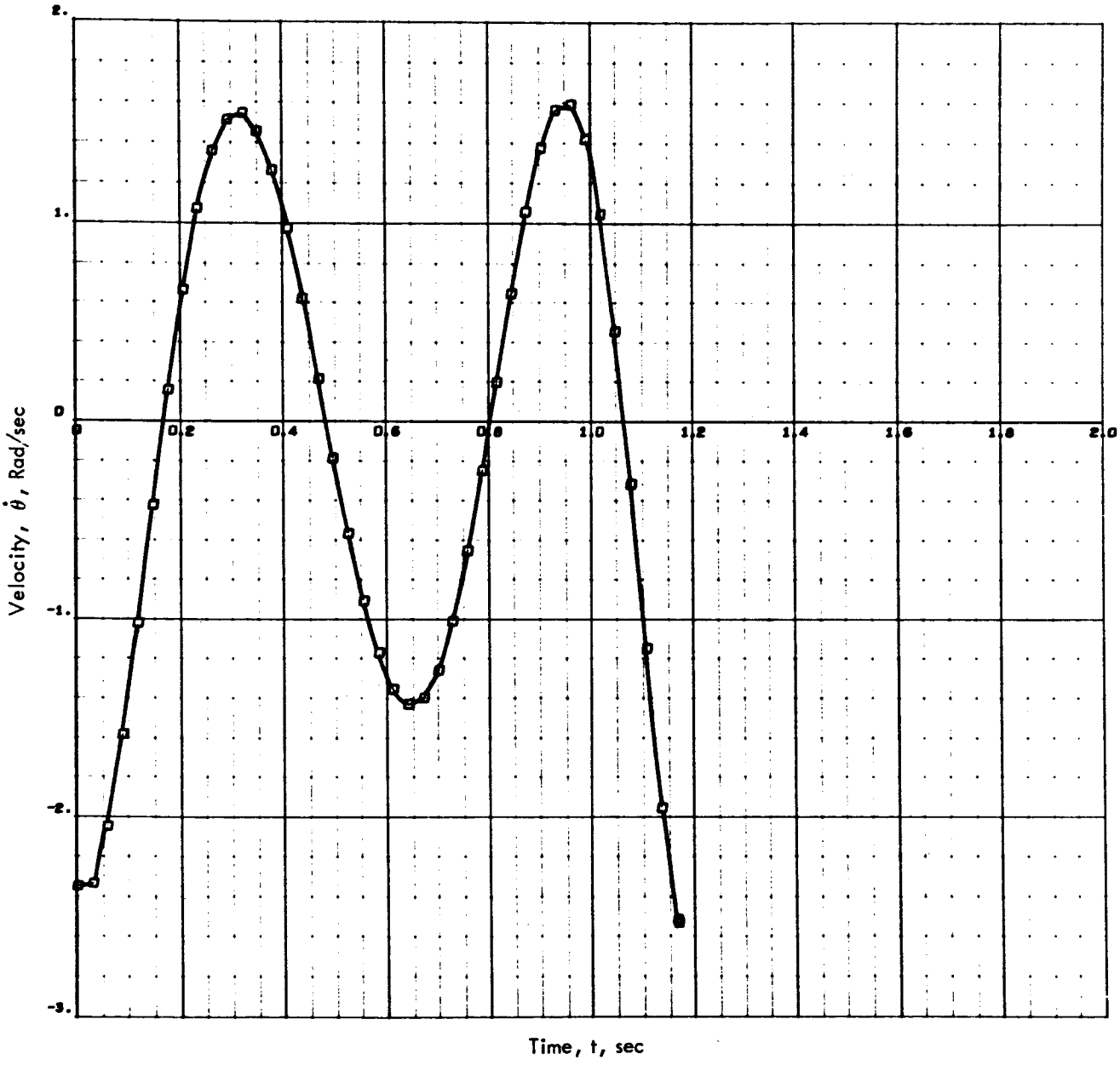

Figure E34. - Velocity $\dot{\theta}$ versus time for segment no. 1, head and neck

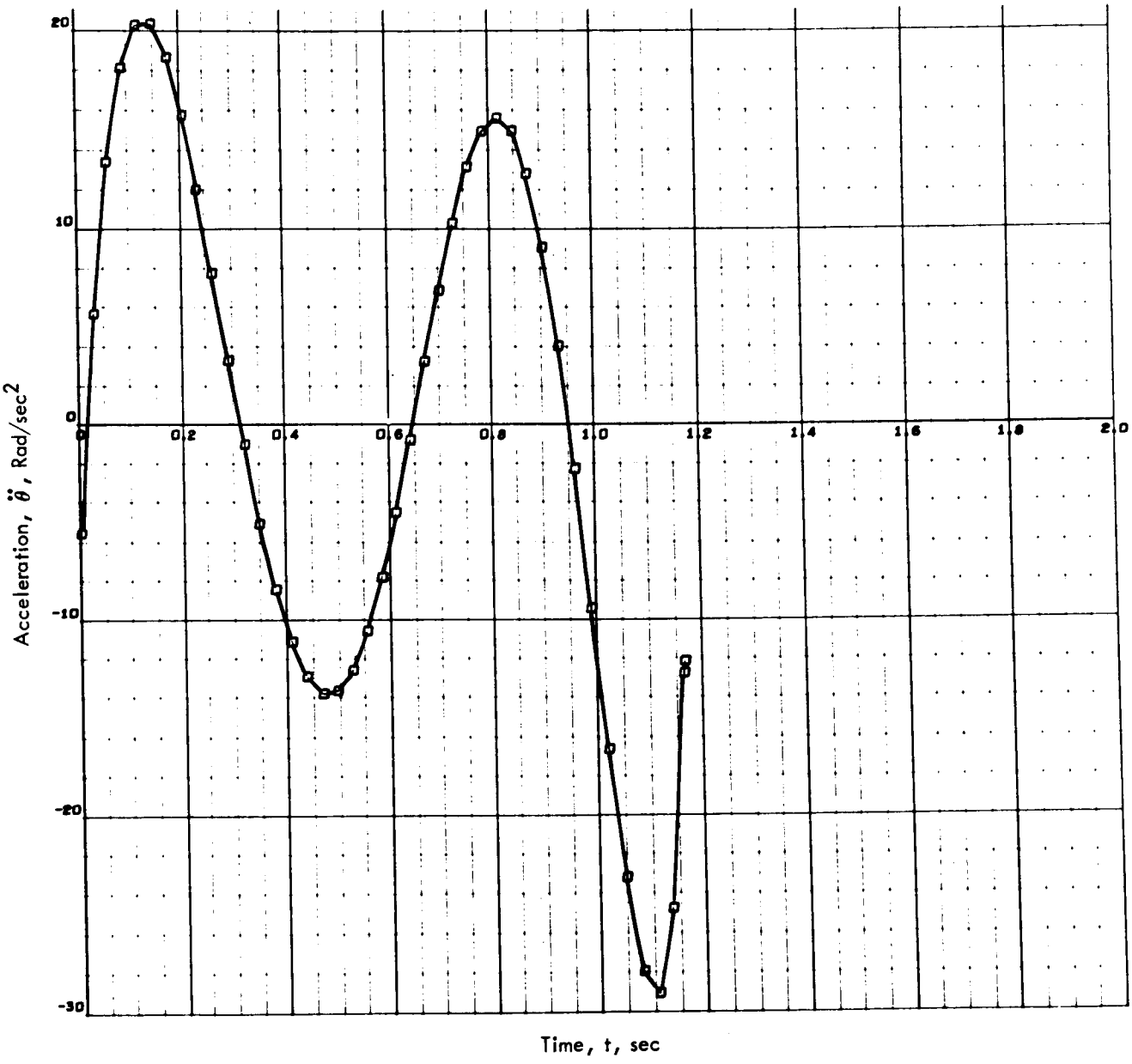

Figure E35. - Acceleration $\ddot{\theta}$ versus time for segment no. 1, head and neck

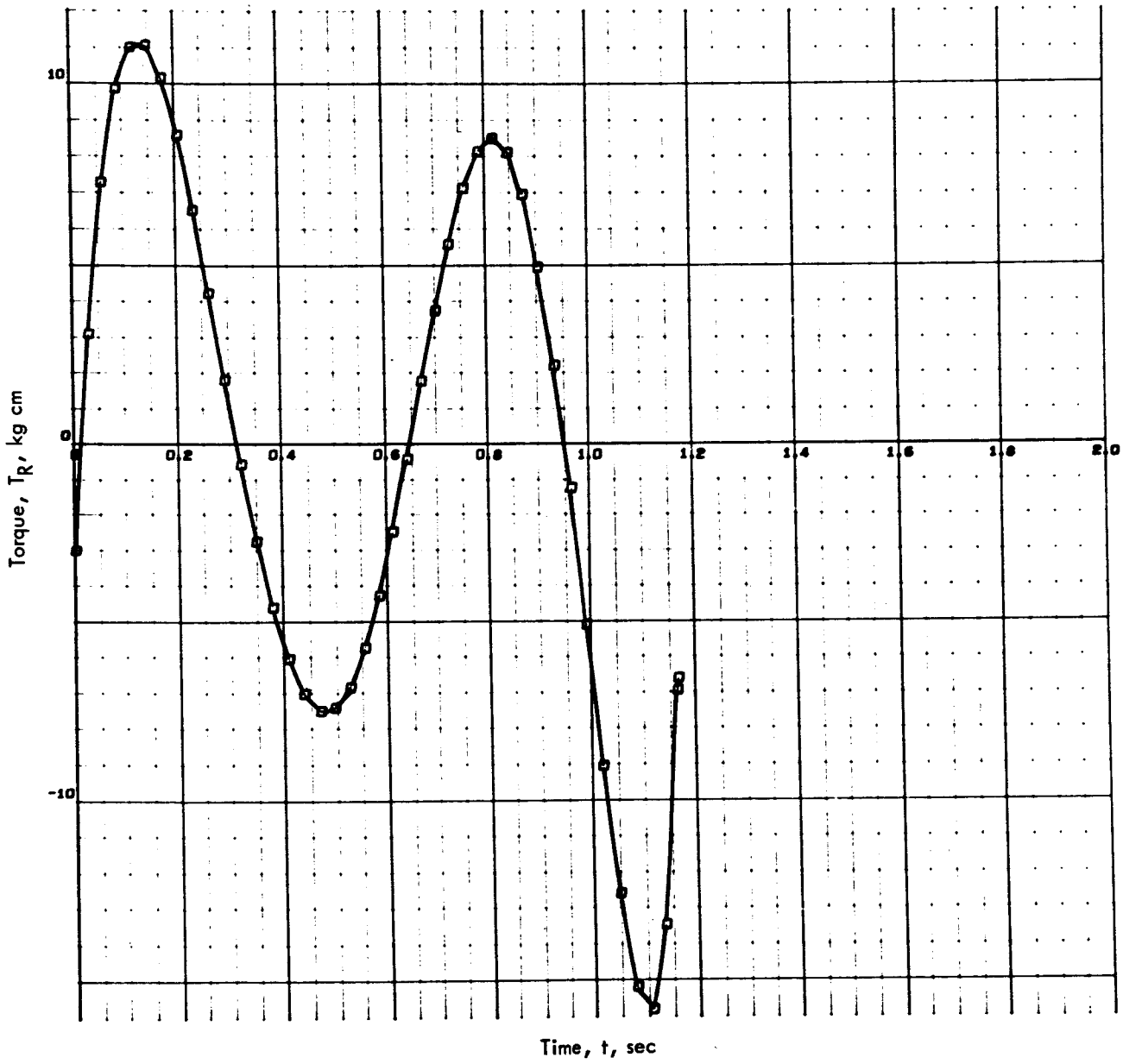

Figure E36.- Torque T_R versus time for segment no. 1, head and neck

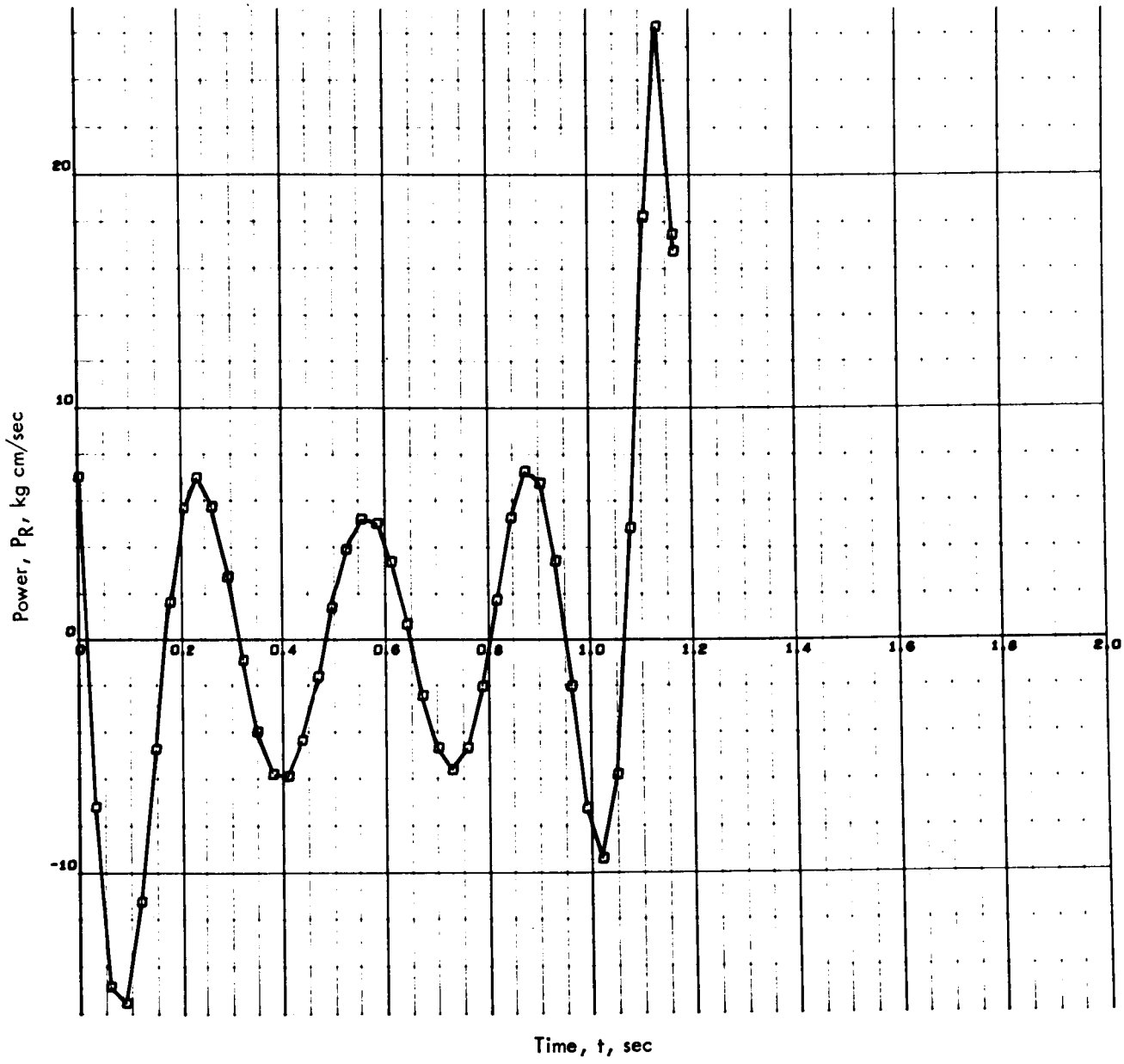

Figure E37.- Power P_R versus time for segment no. 1, head and neck

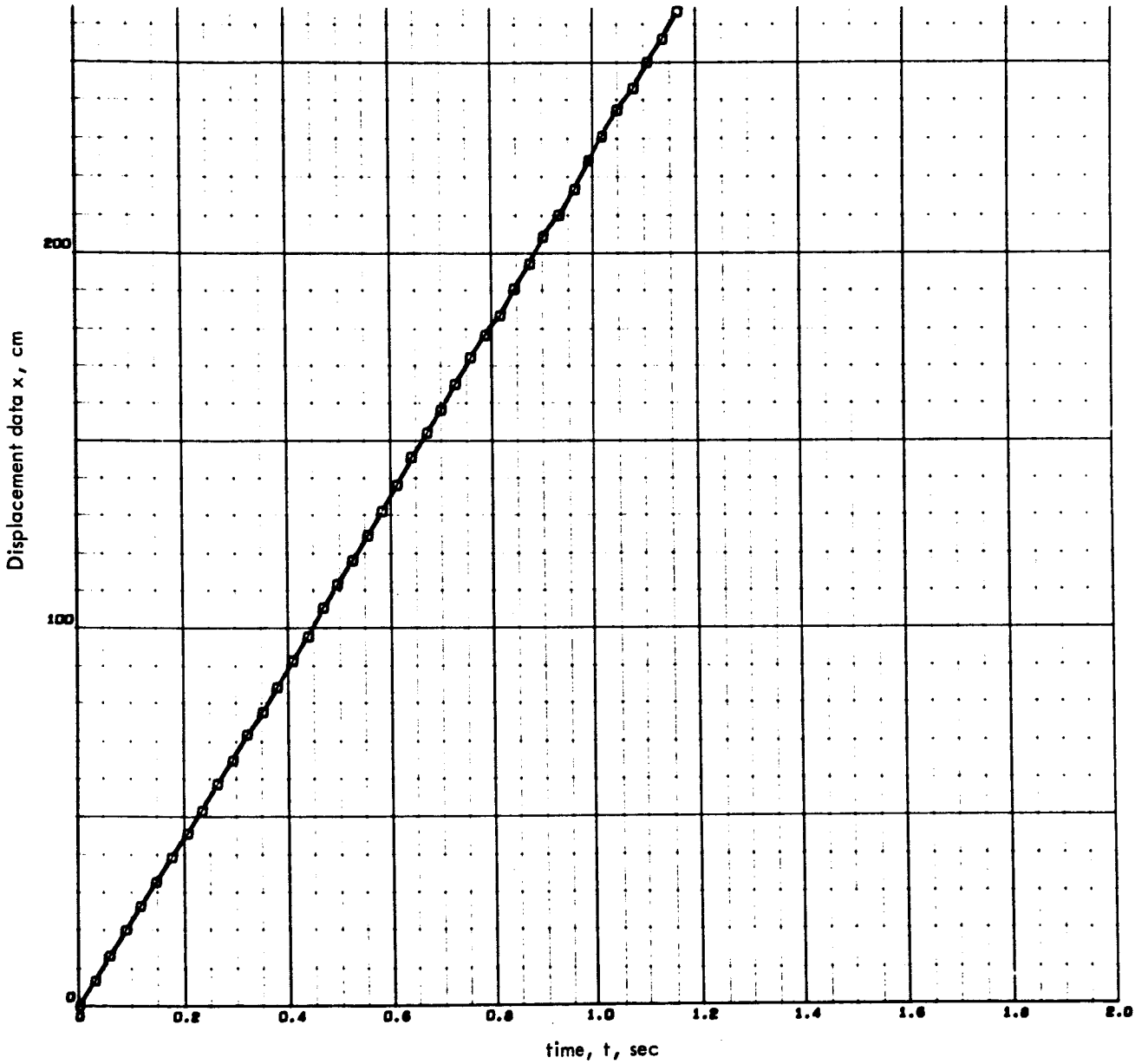

Figure E38.- Displacement data x versus time for segment no. 2, trunk

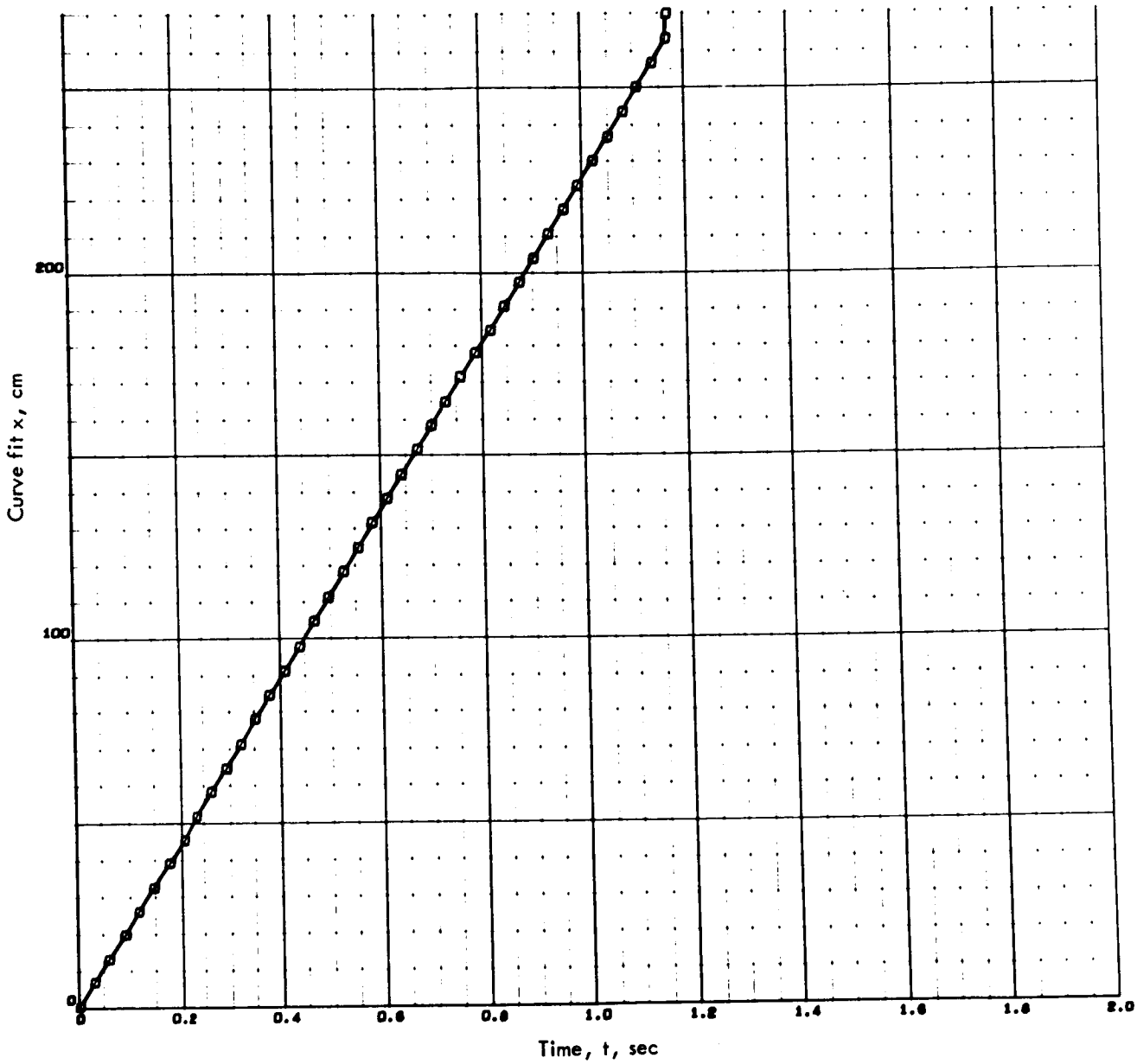

Figure E39 - Curve fit x versus time for segment no. 2, trunk

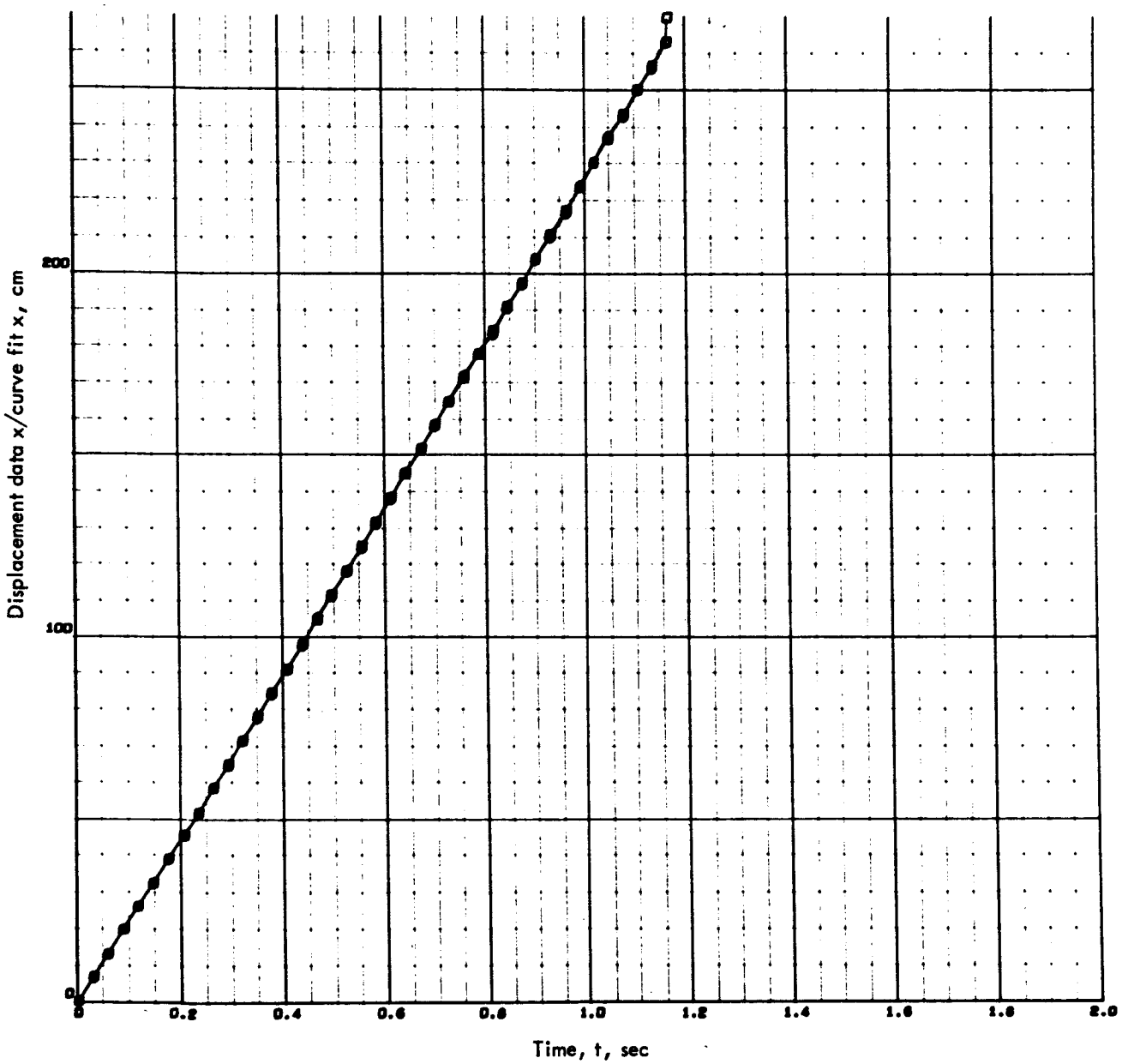

Figure E40. - Displacement data x/curve fit x versus time for segment no. 2, trunk

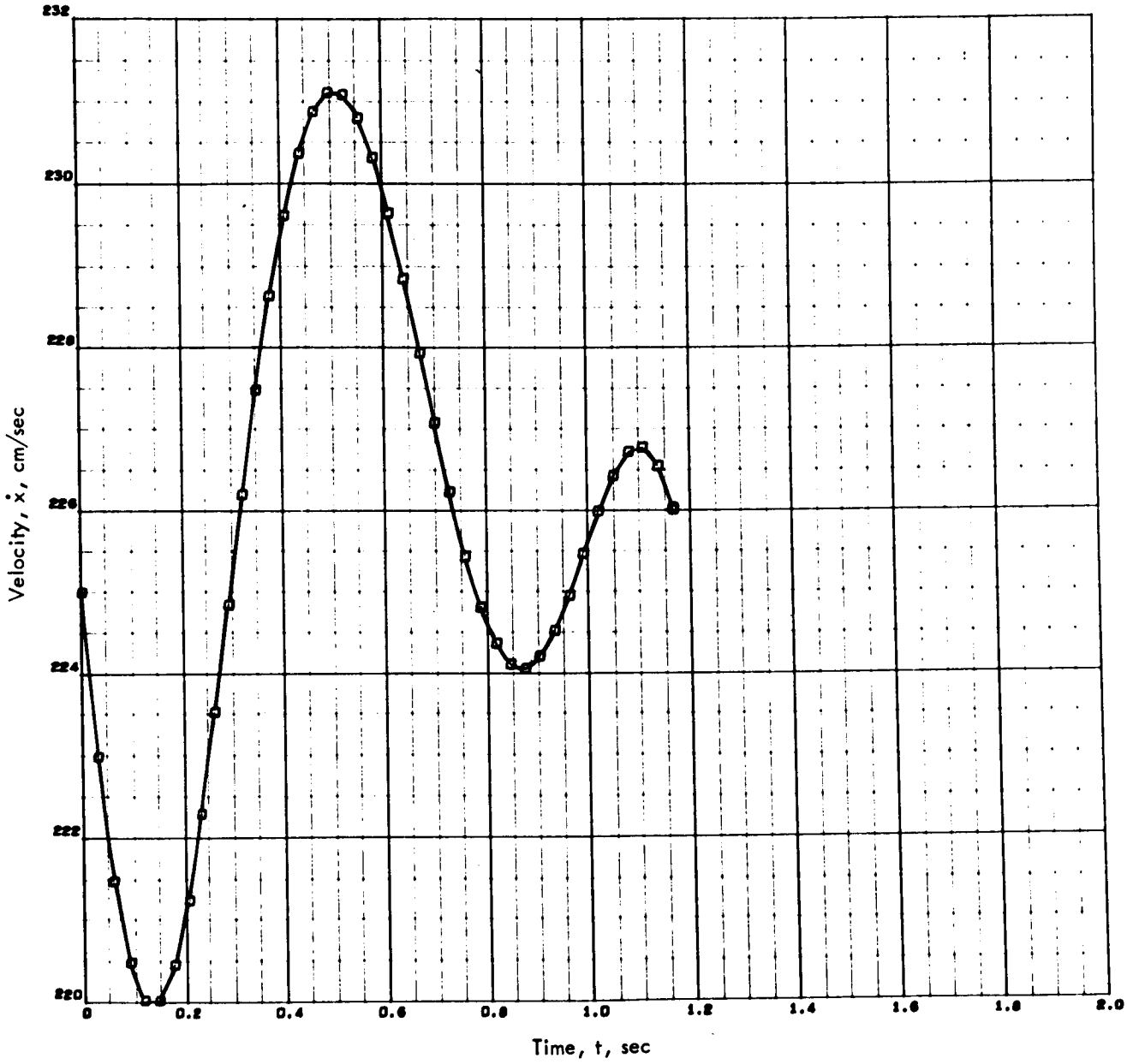

Figure E41. - Velocity $\dot{x}$ versus time for segment no. 2, trunk

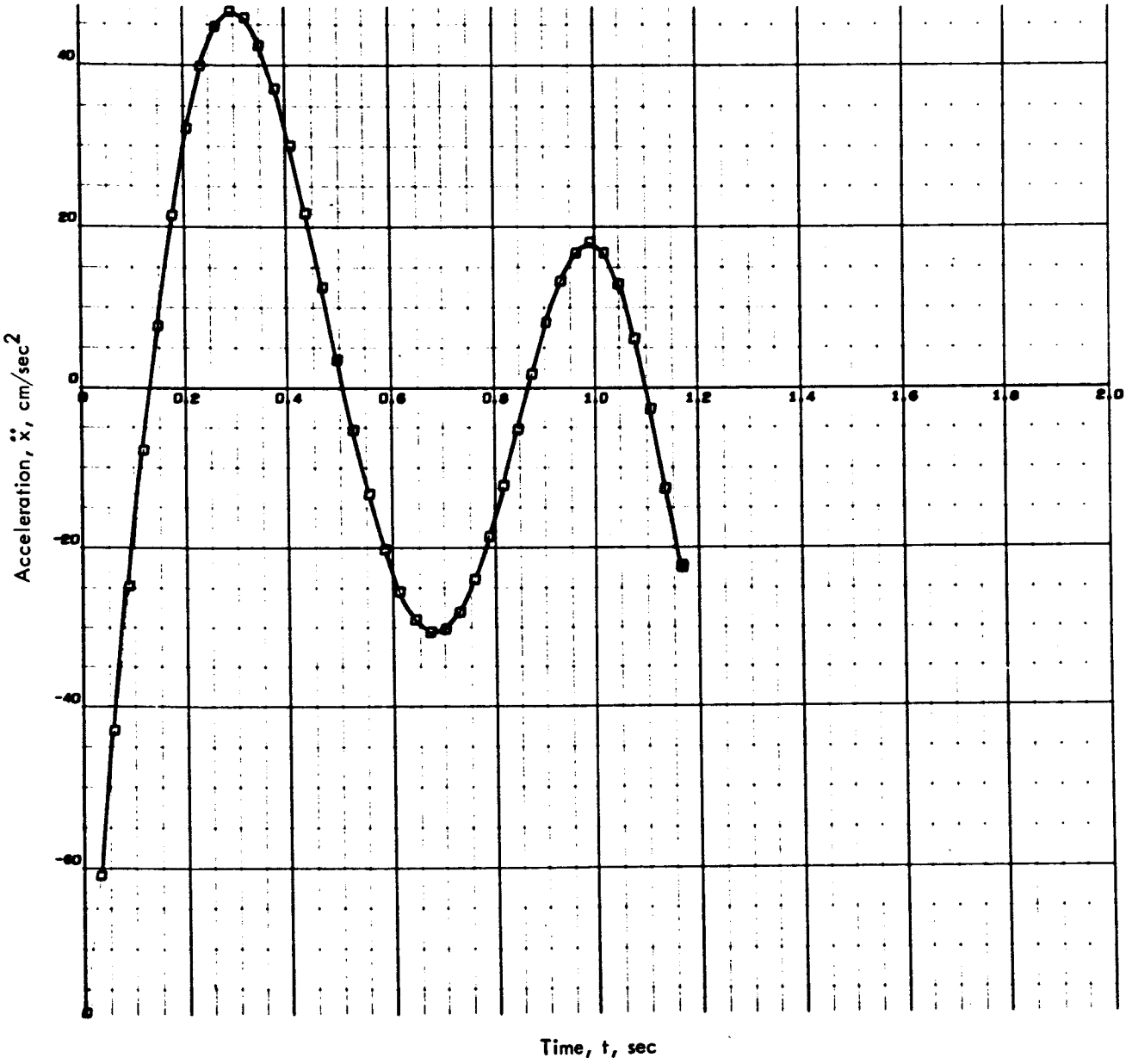

Figure E42. - Acceleration $\ddot{x}$ versus time for segment no. 2, trunk

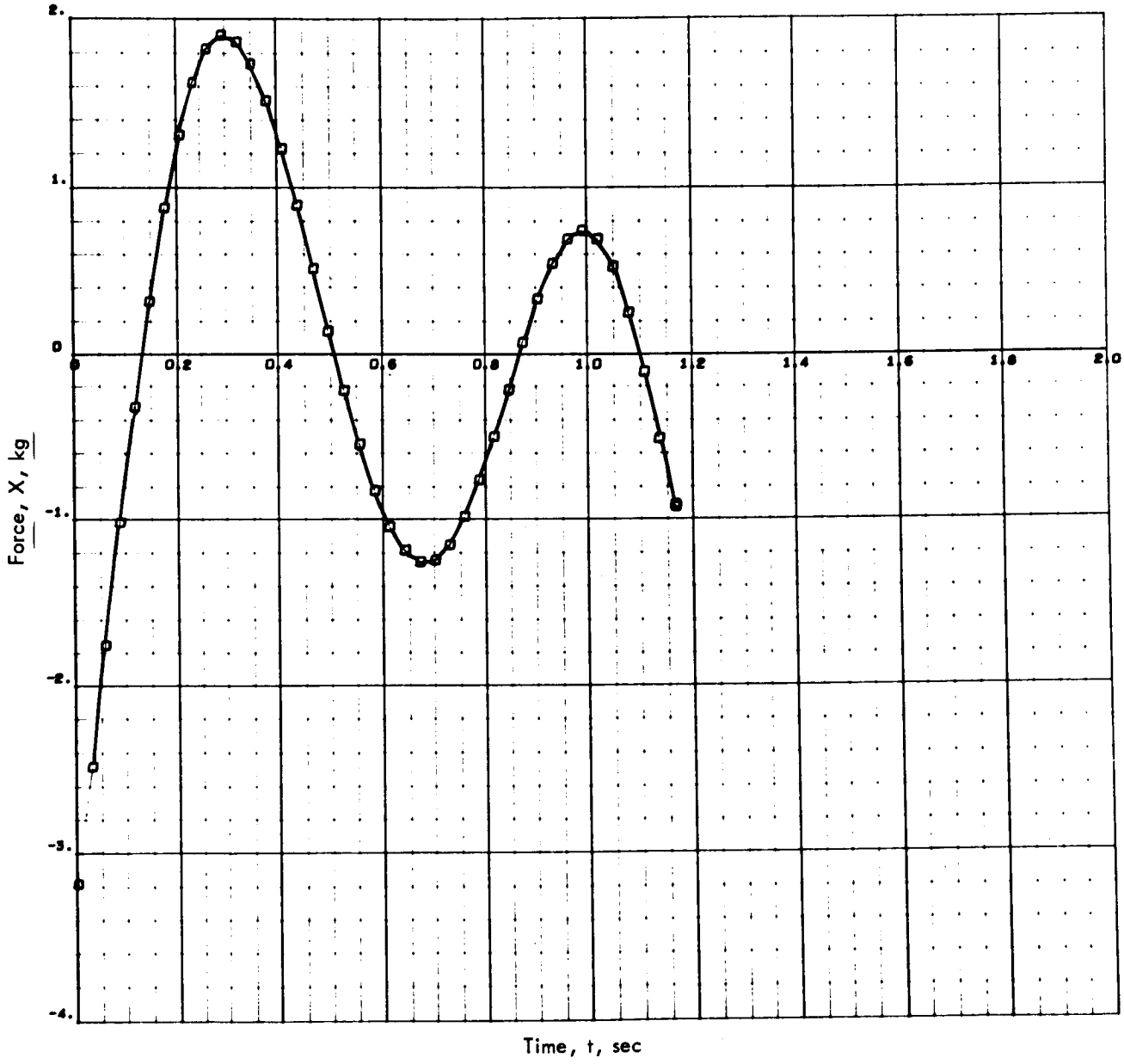

Figure E43.- Force X versus time for segment no. 2, trunk

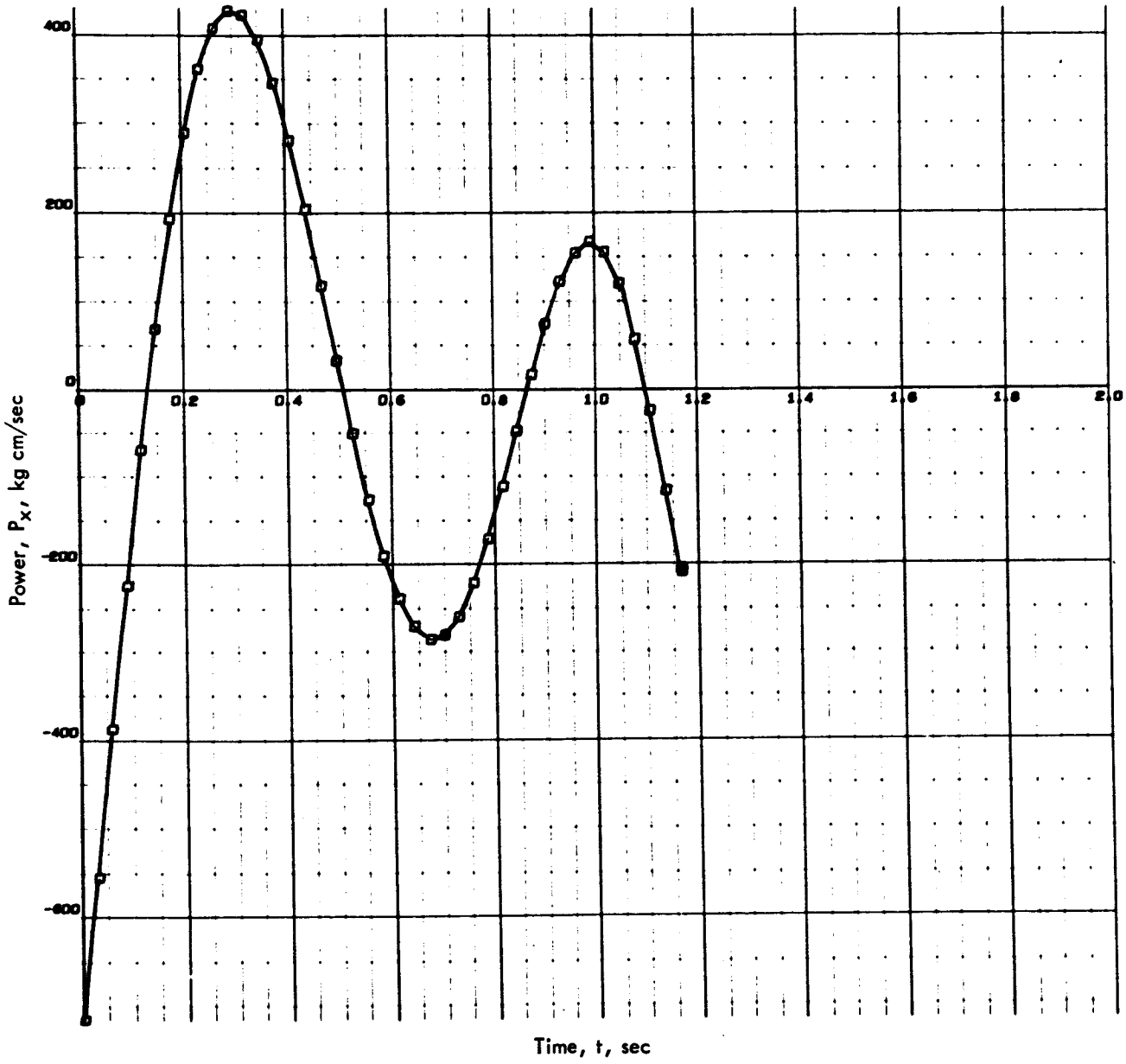

Figure E44. - Power P_x versus time for segment no. 2, trunk

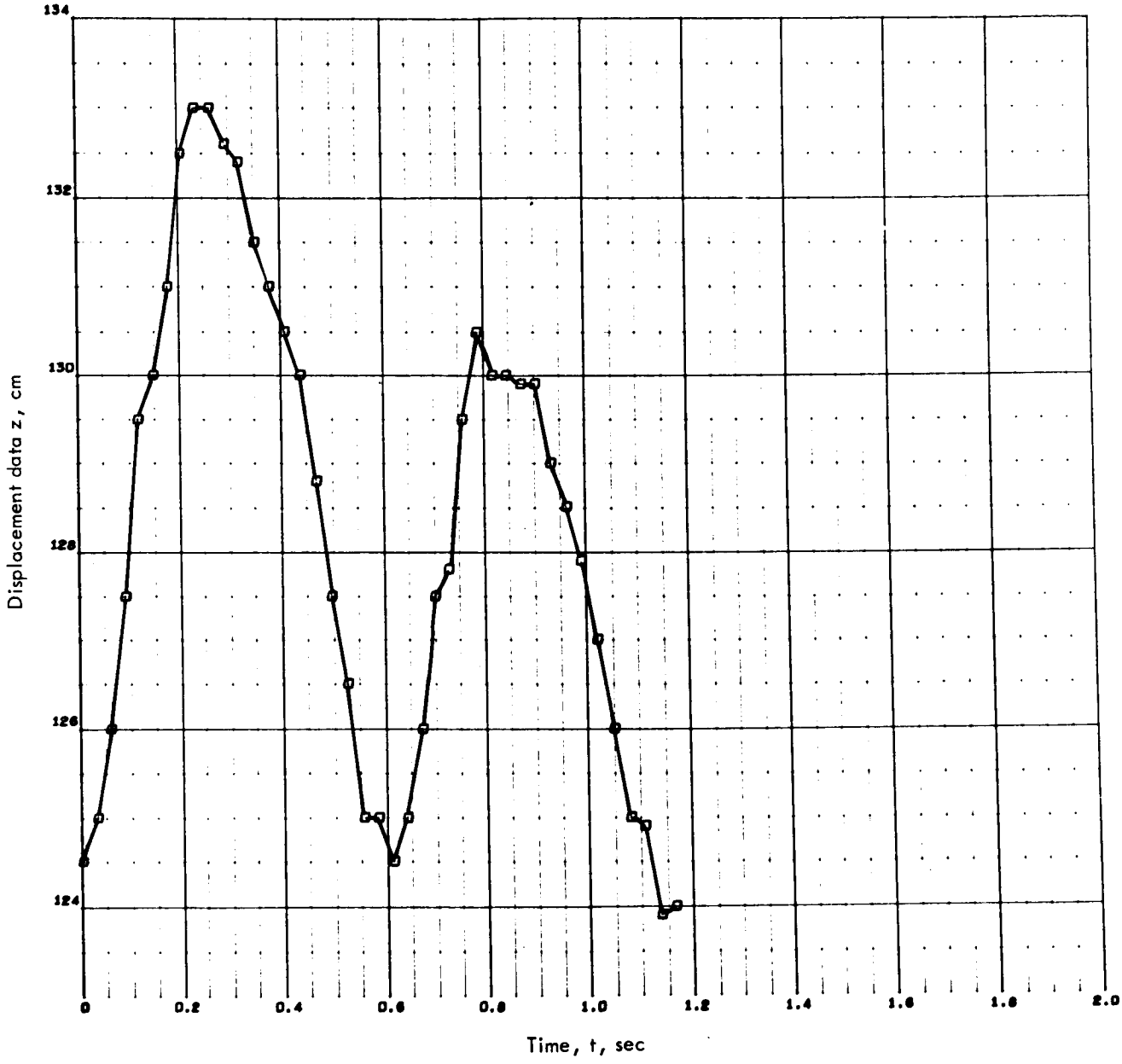

Figure E45. - Displacement data z versus time for segment no. 2, trunk

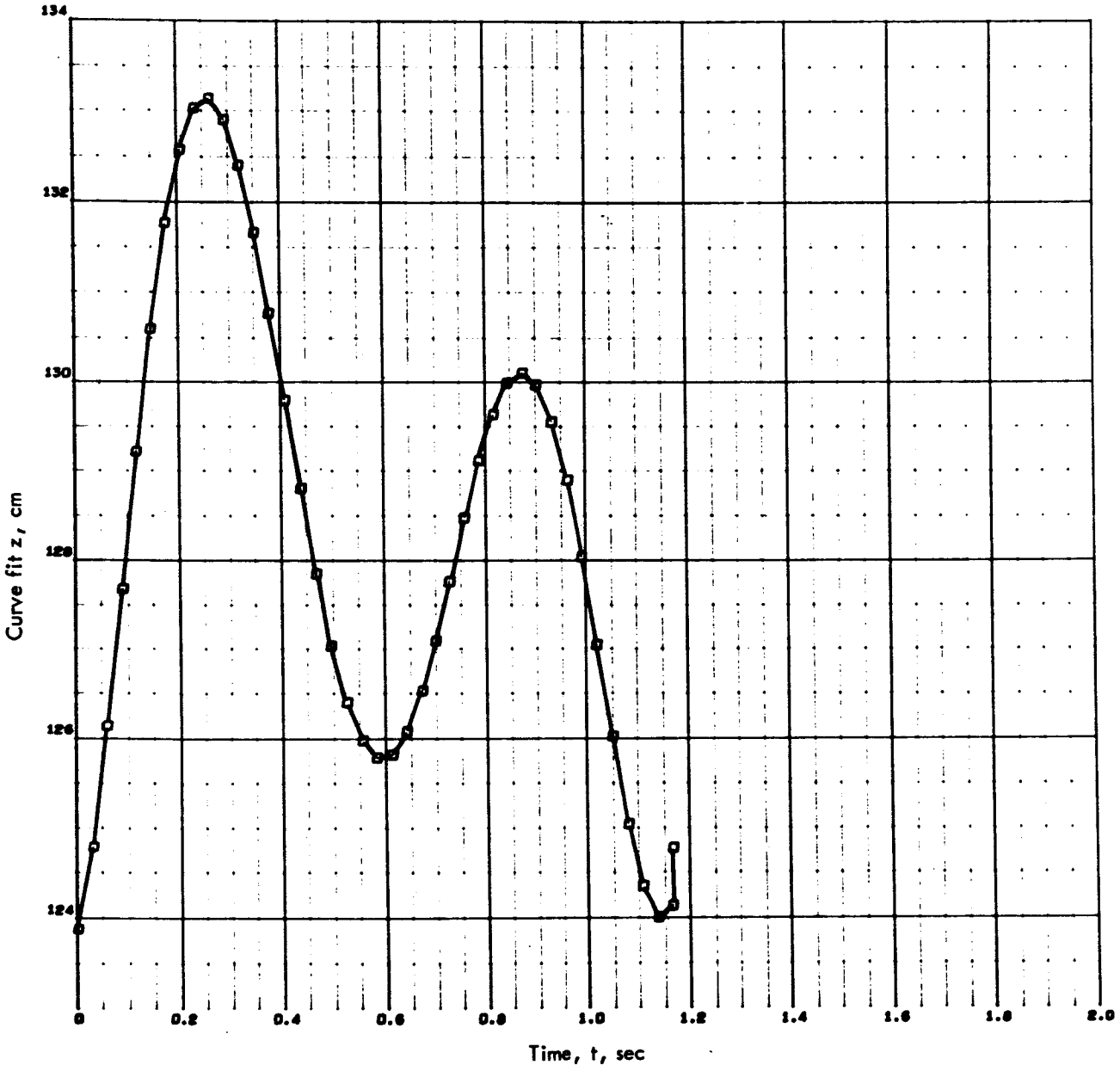

Figure E46. - Curve fit z versus time for segment no. 2, trunk

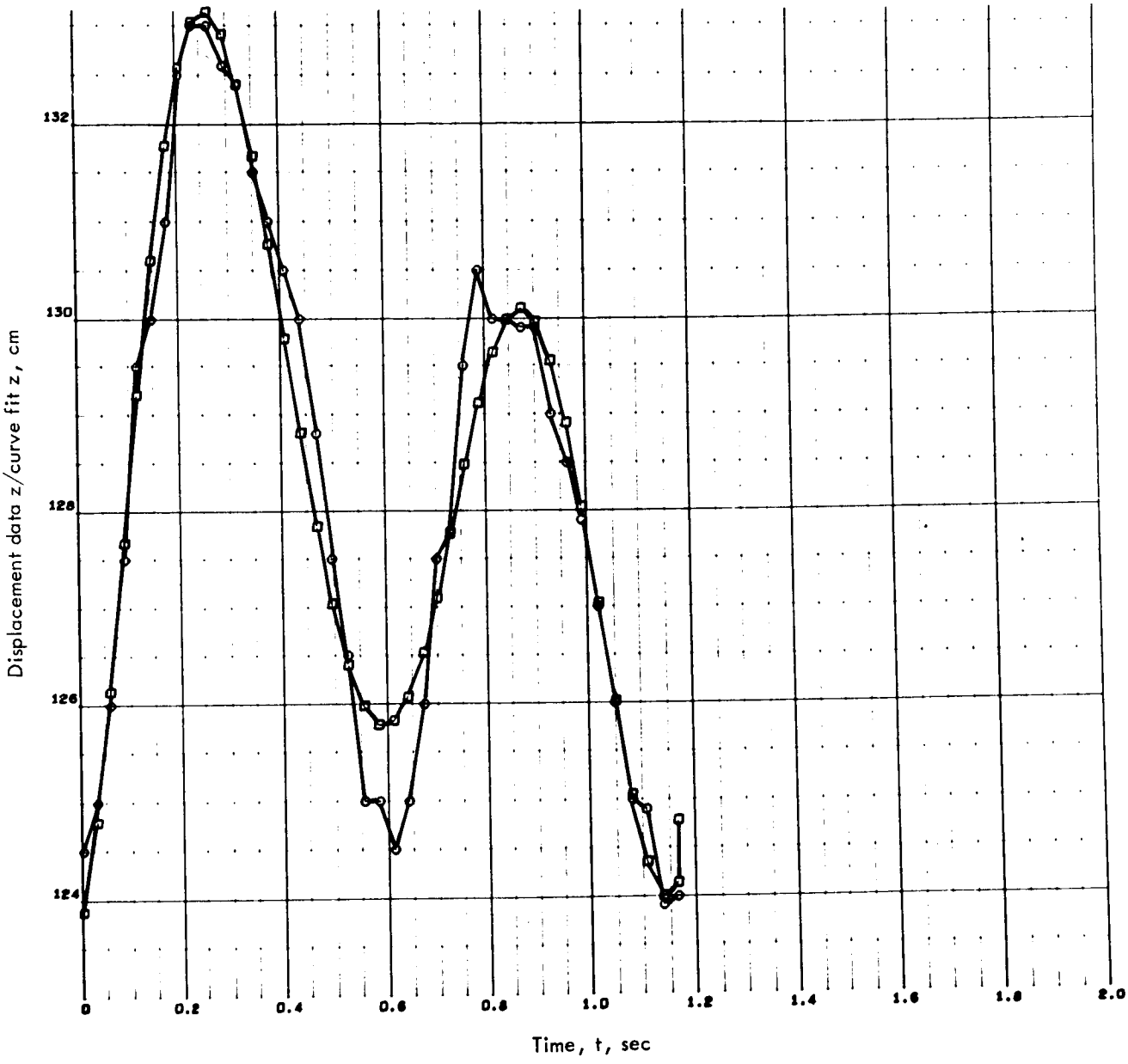

Figure E47. - Displacement data z/curve fit z versus time for segment no. 2, trunk

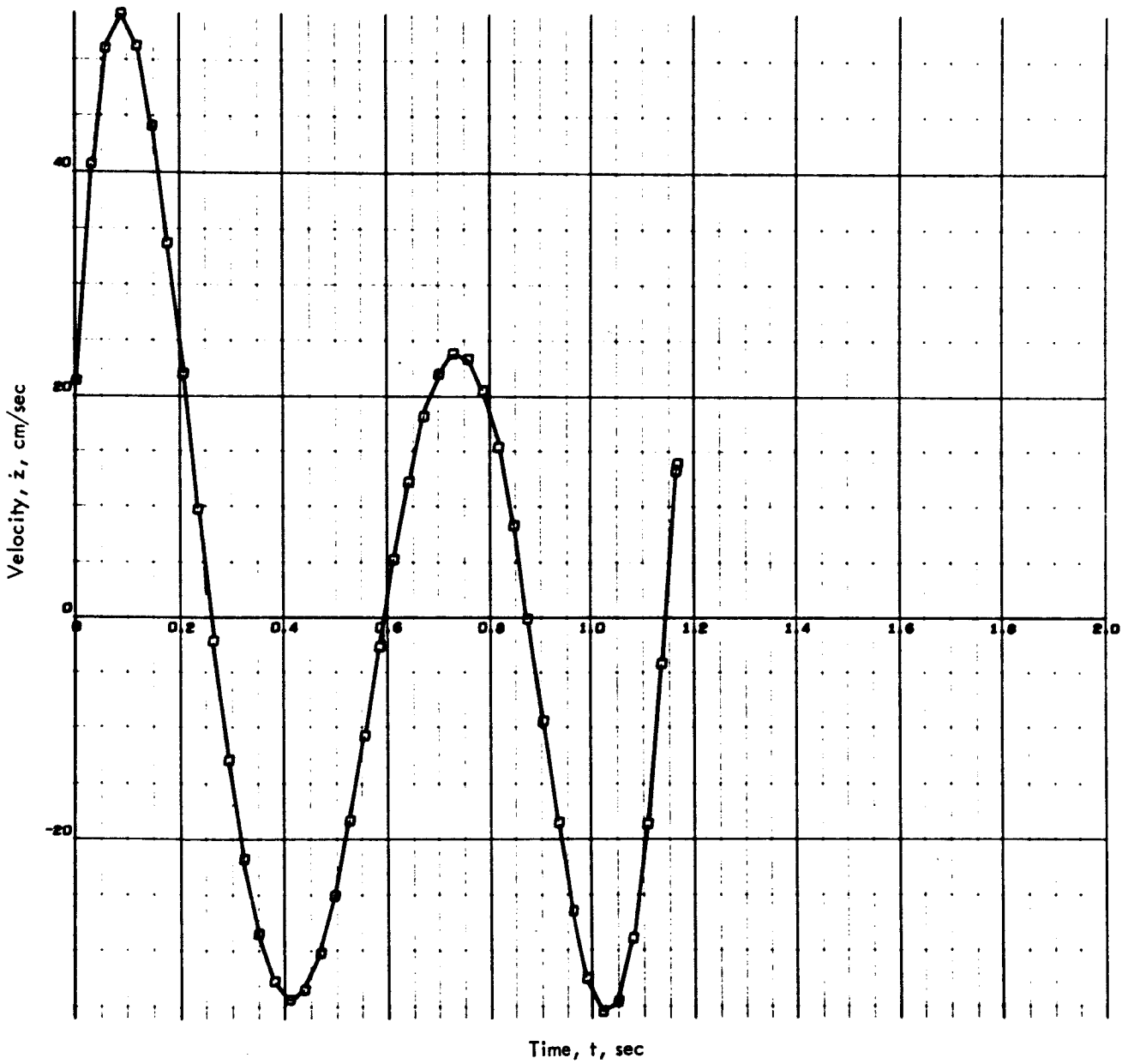

Figure E48. - Velocity ż versus time for segment no. 2, trunk

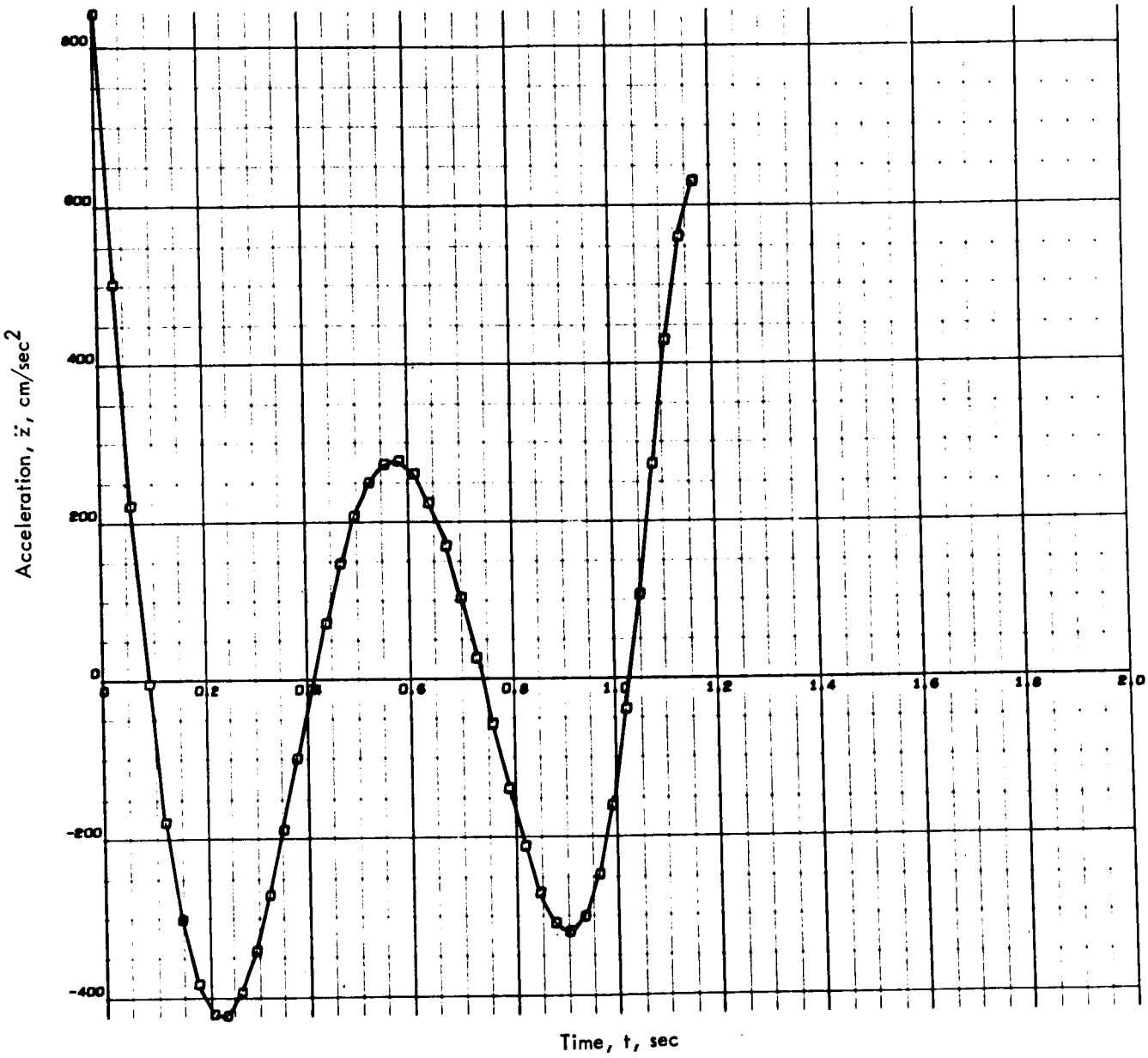

Figure E49. - Acceleration $\ddot{z}$ versus time for segment no. 2, trunk

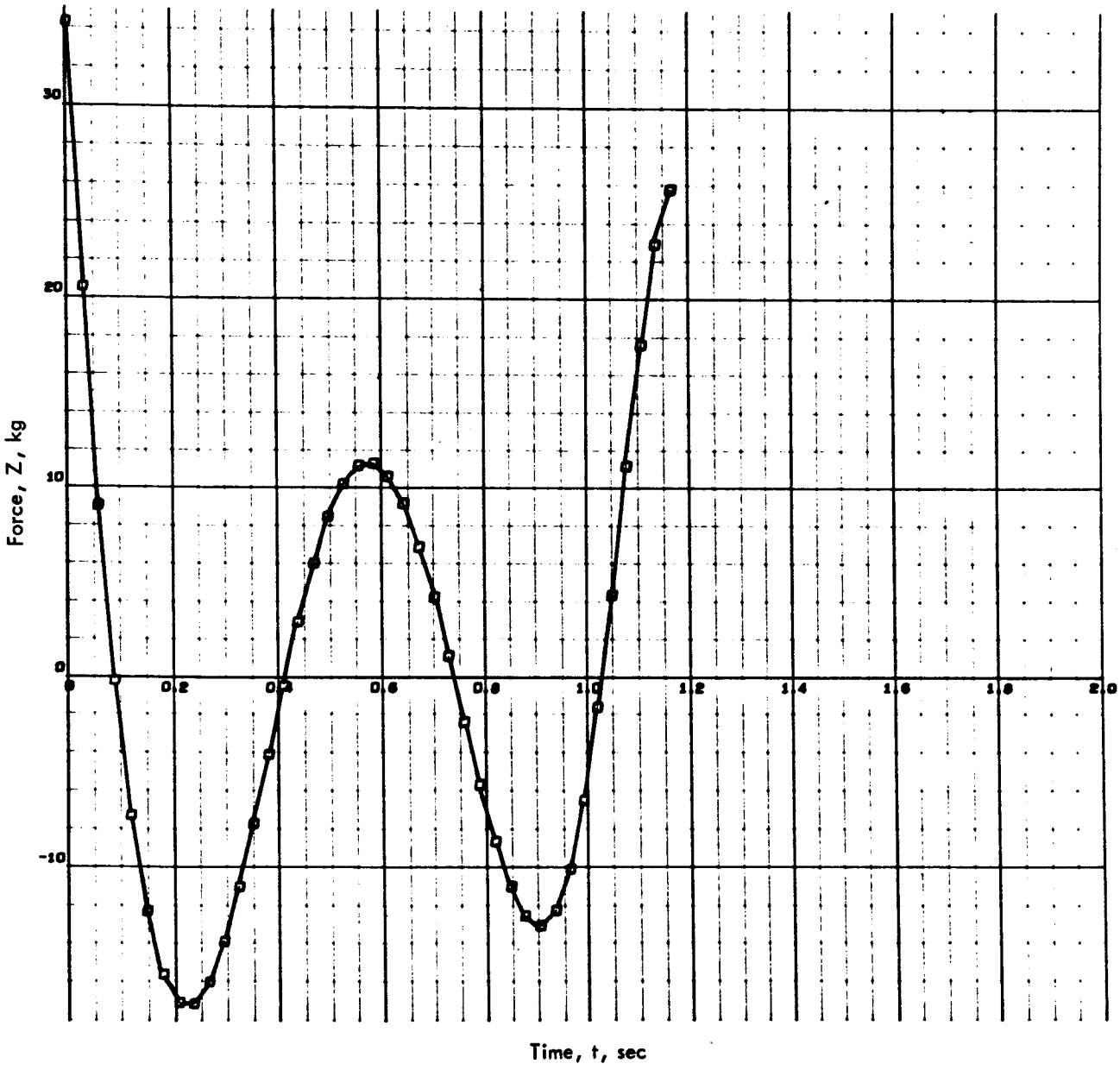

Figure E50. - Force Z versus time for segment no. 2, trunk

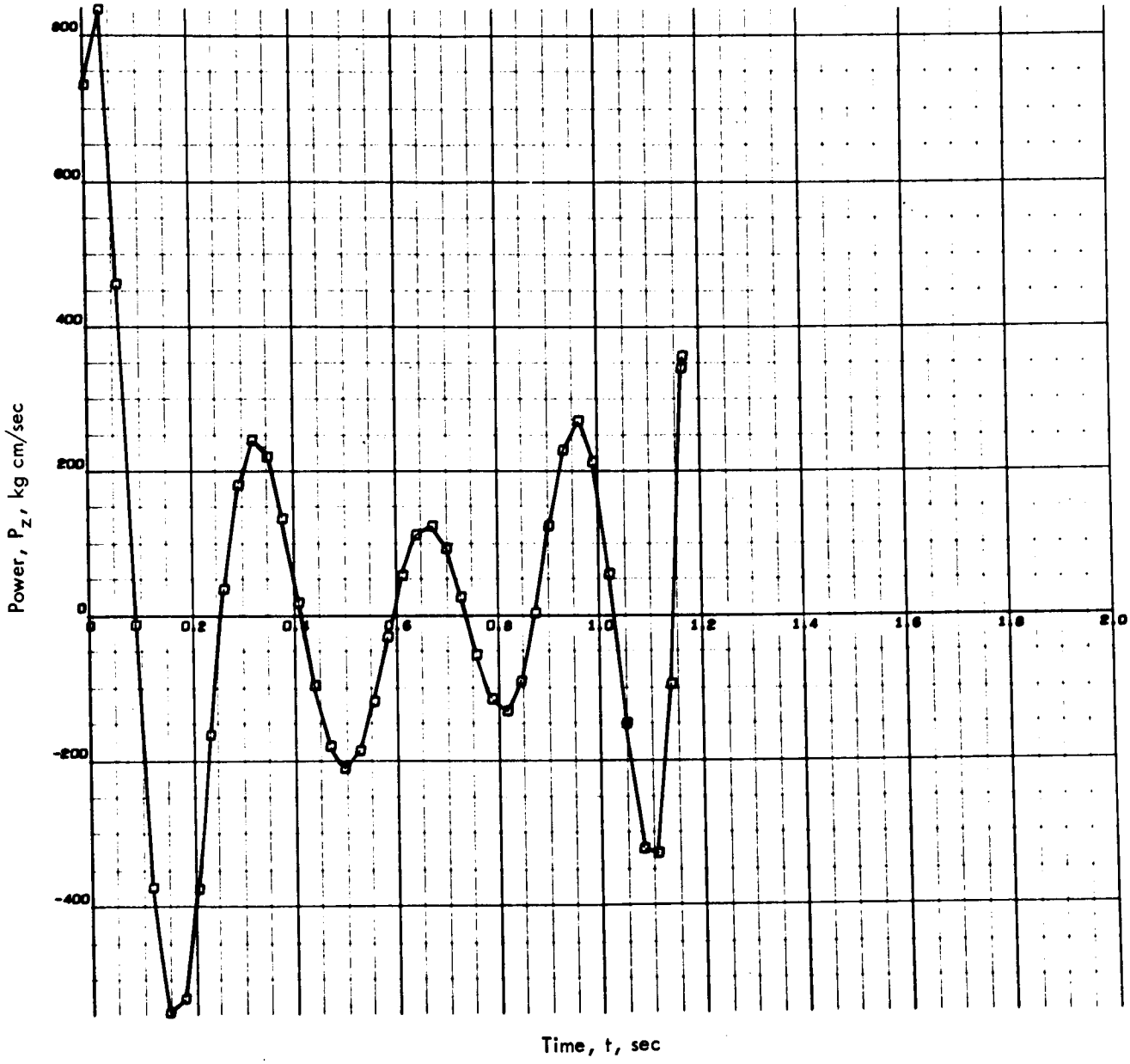

Figure E51. - Power P_z versus time for segment no. 2, trunk

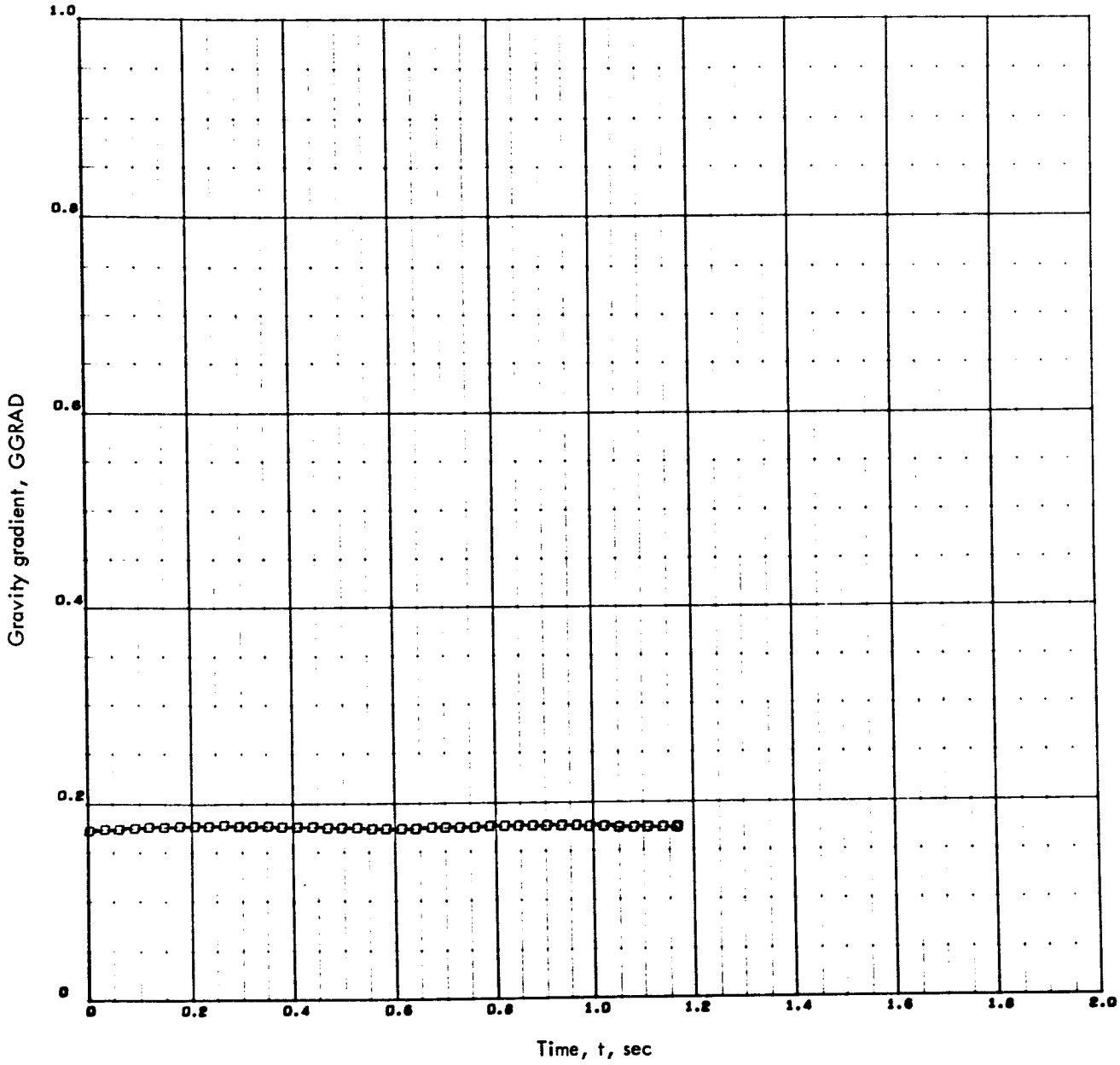

Figure E52. - Gravity gradient versus time for segment no. 2, trunk

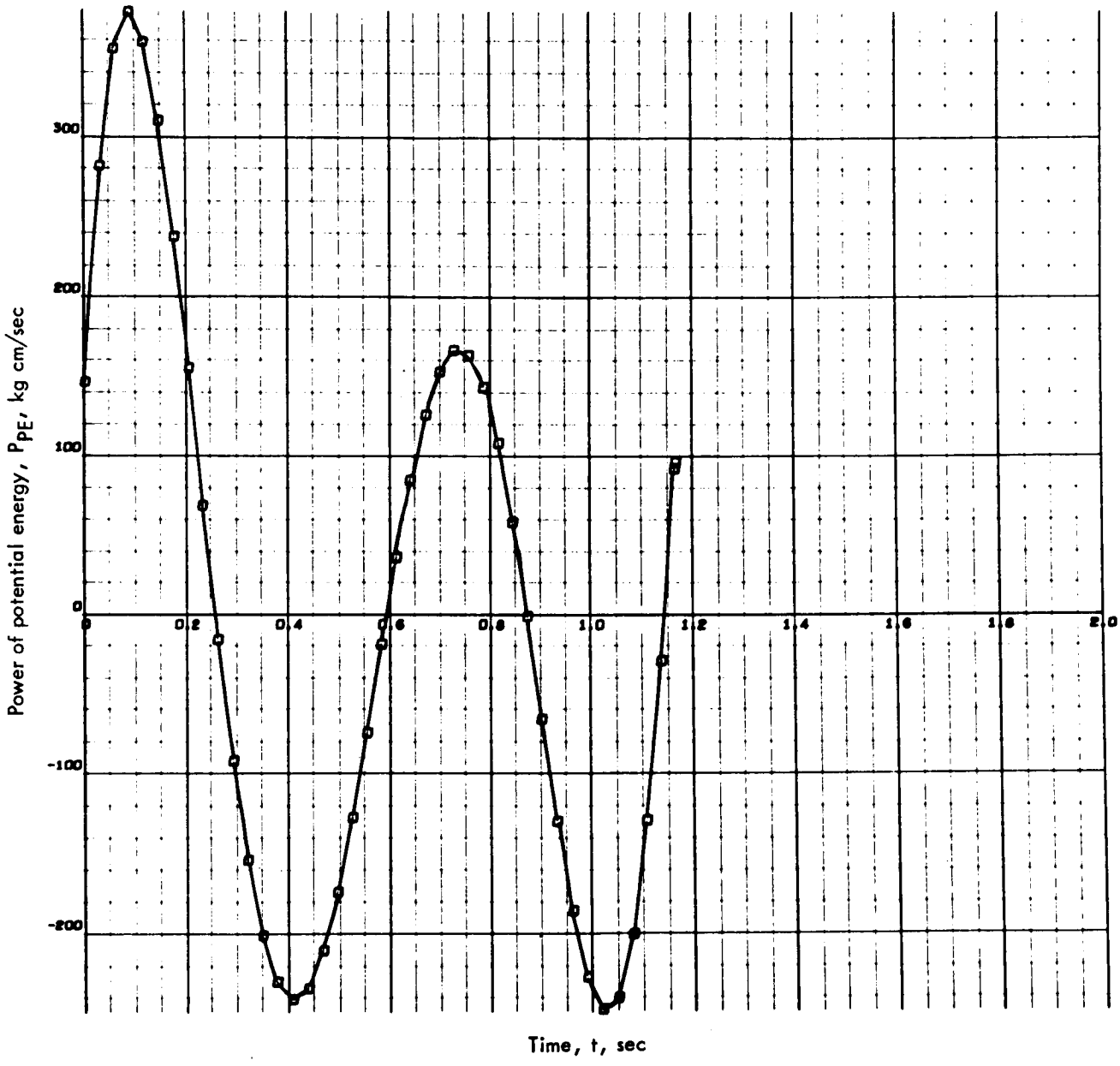

Figure E53. - Power of potential energy versus time for segment no. 2, trunk

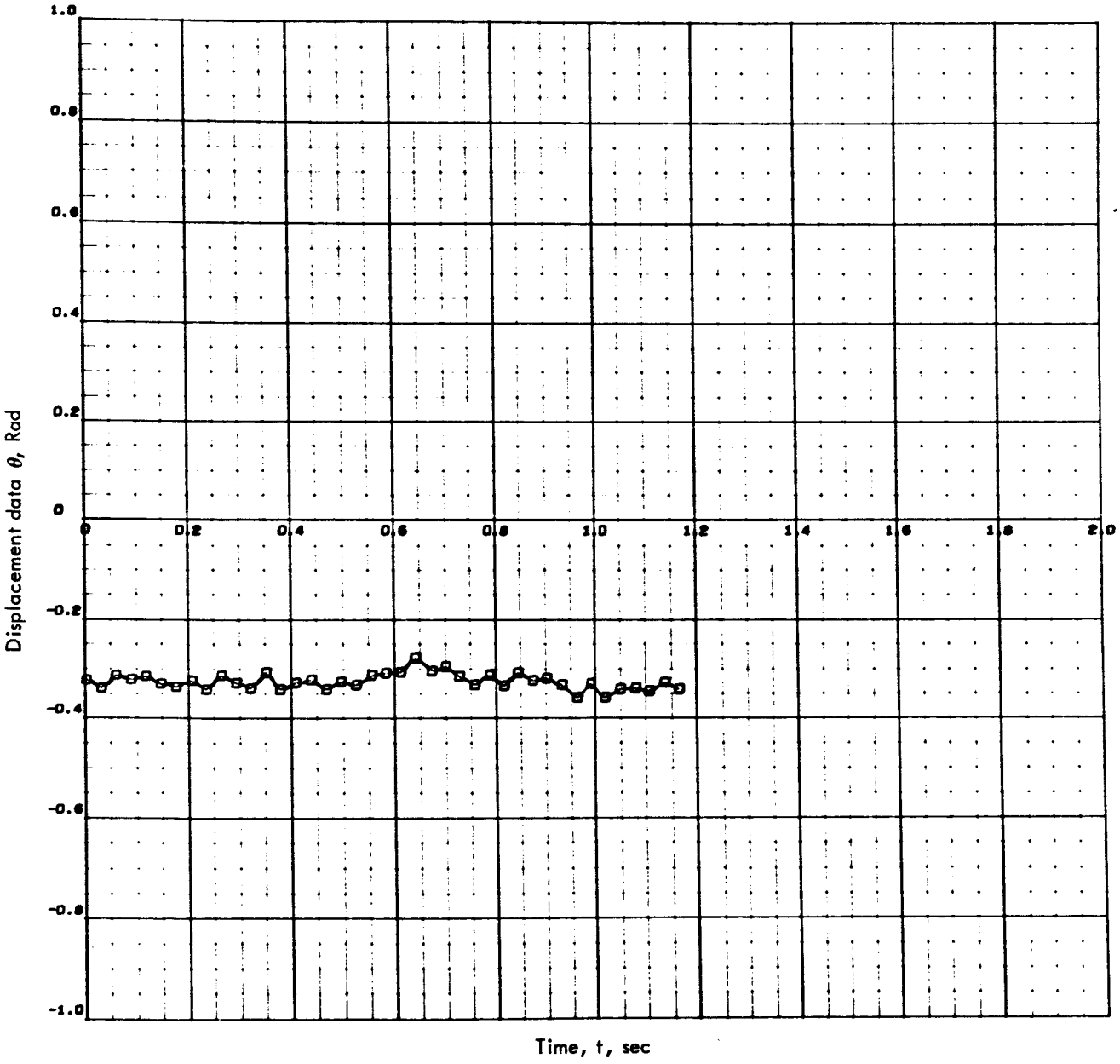

Figure E54. - Displacement data θ versus time for segment no. 2, trunk

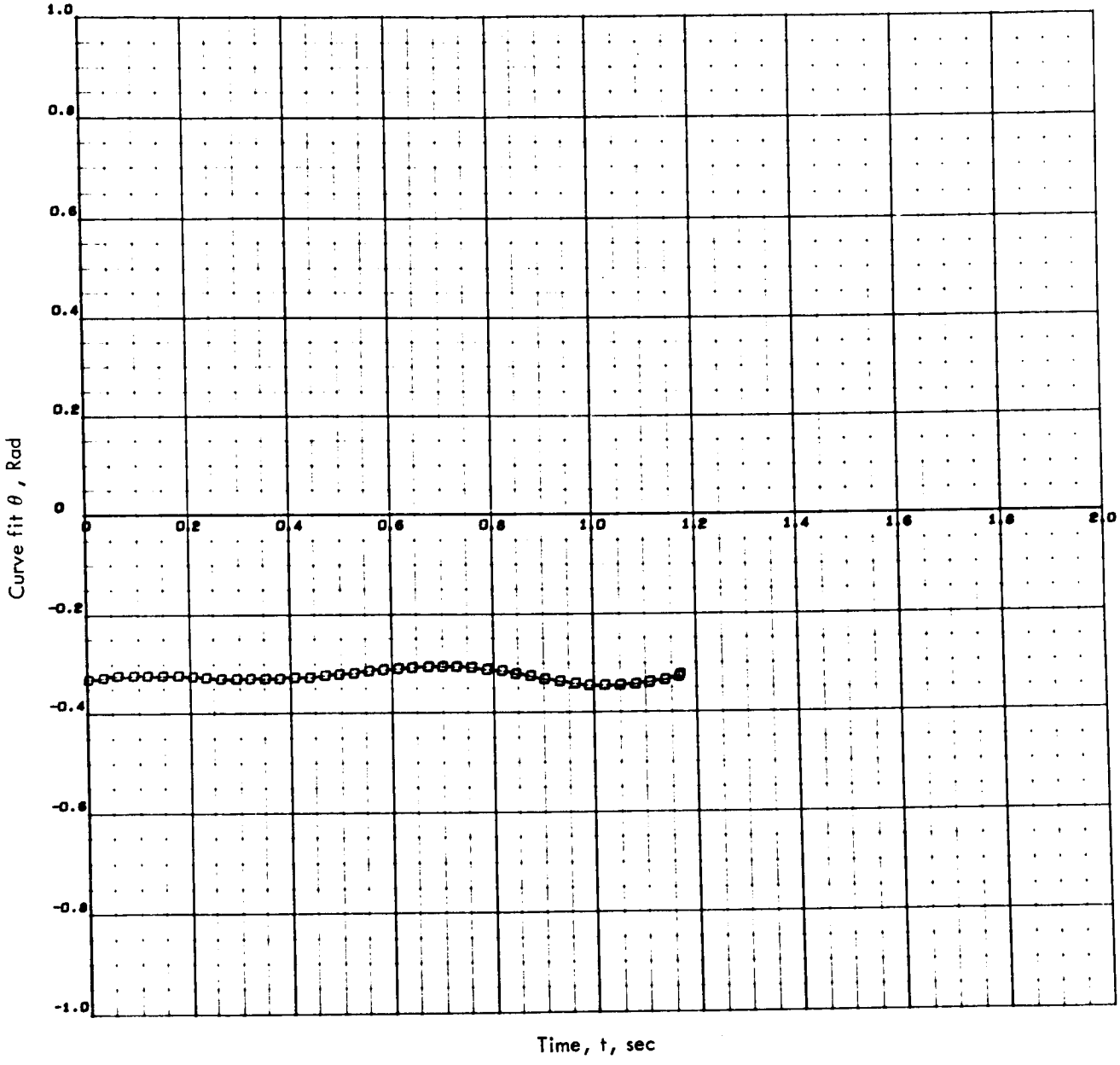

Figure E55. - Curve fit θ versus time for segment no. 2, trunk

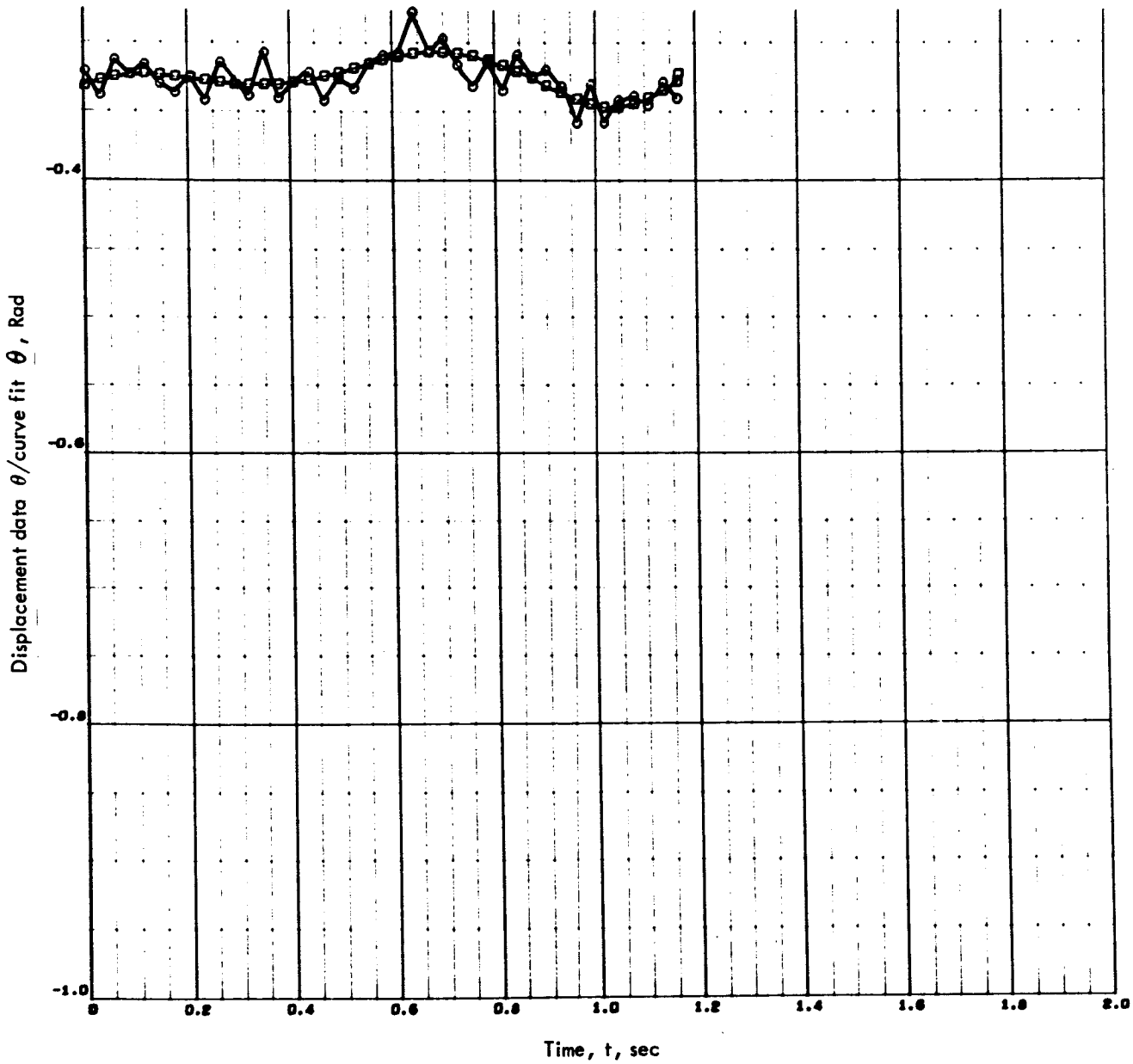

Figure E56.- Displacement data θ/curve fit θ versus time for segment no. 2, trunk

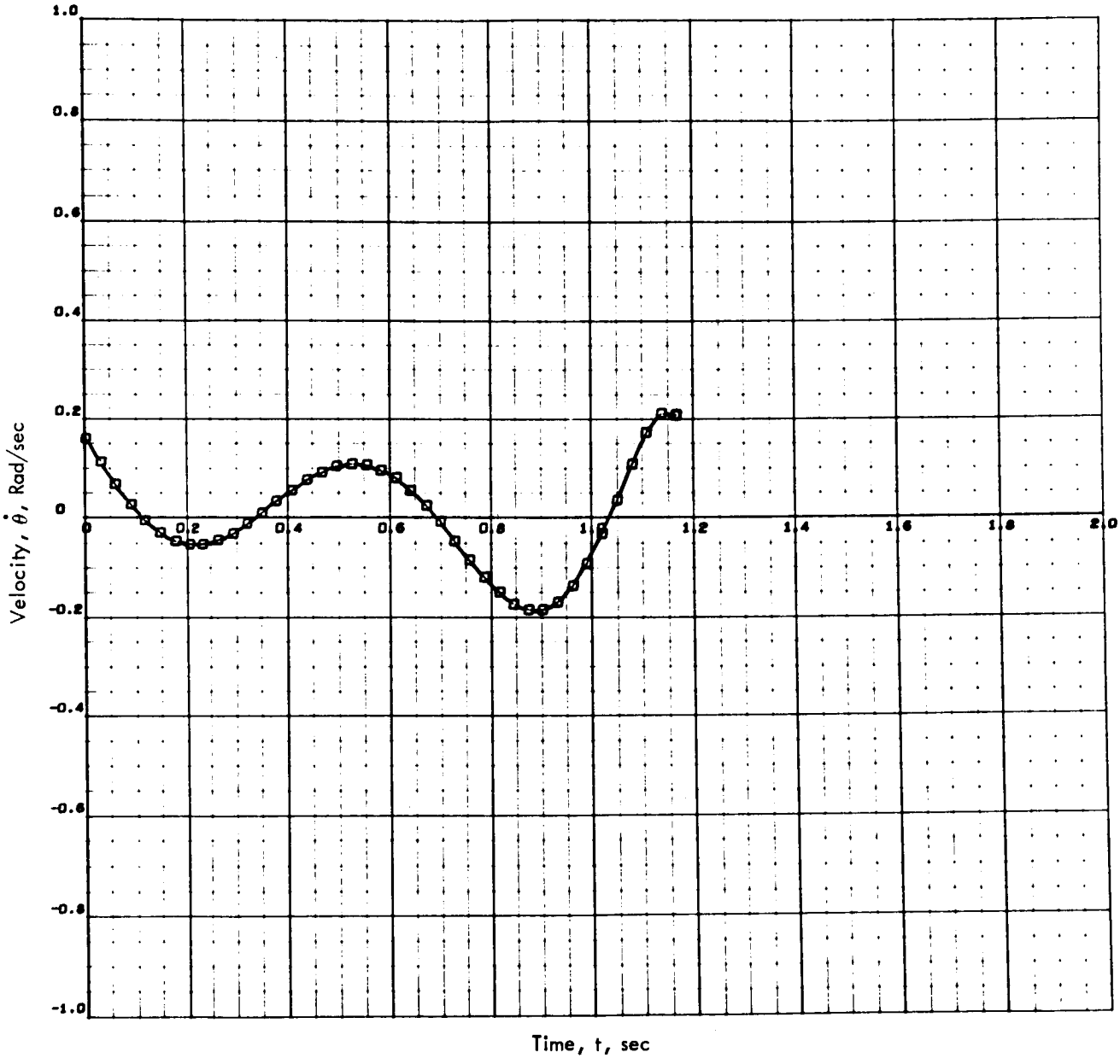

Figure E57. - Velocity $\dot{\theta}$ versus time for segment no. 2, trunk

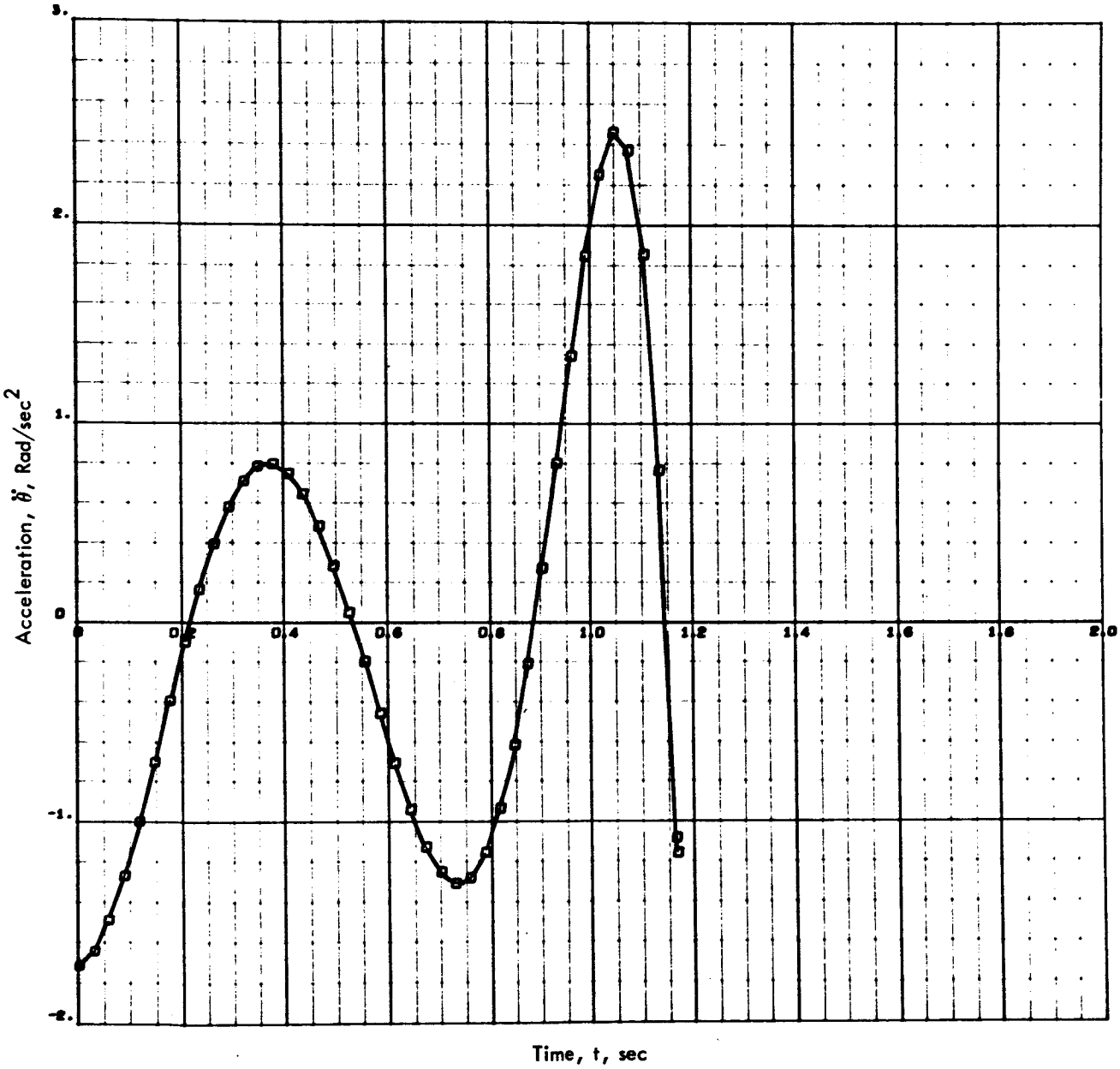

Figure E58. - Acceleration $\ddot{\theta}$ versus time for segment no. 2, trunk

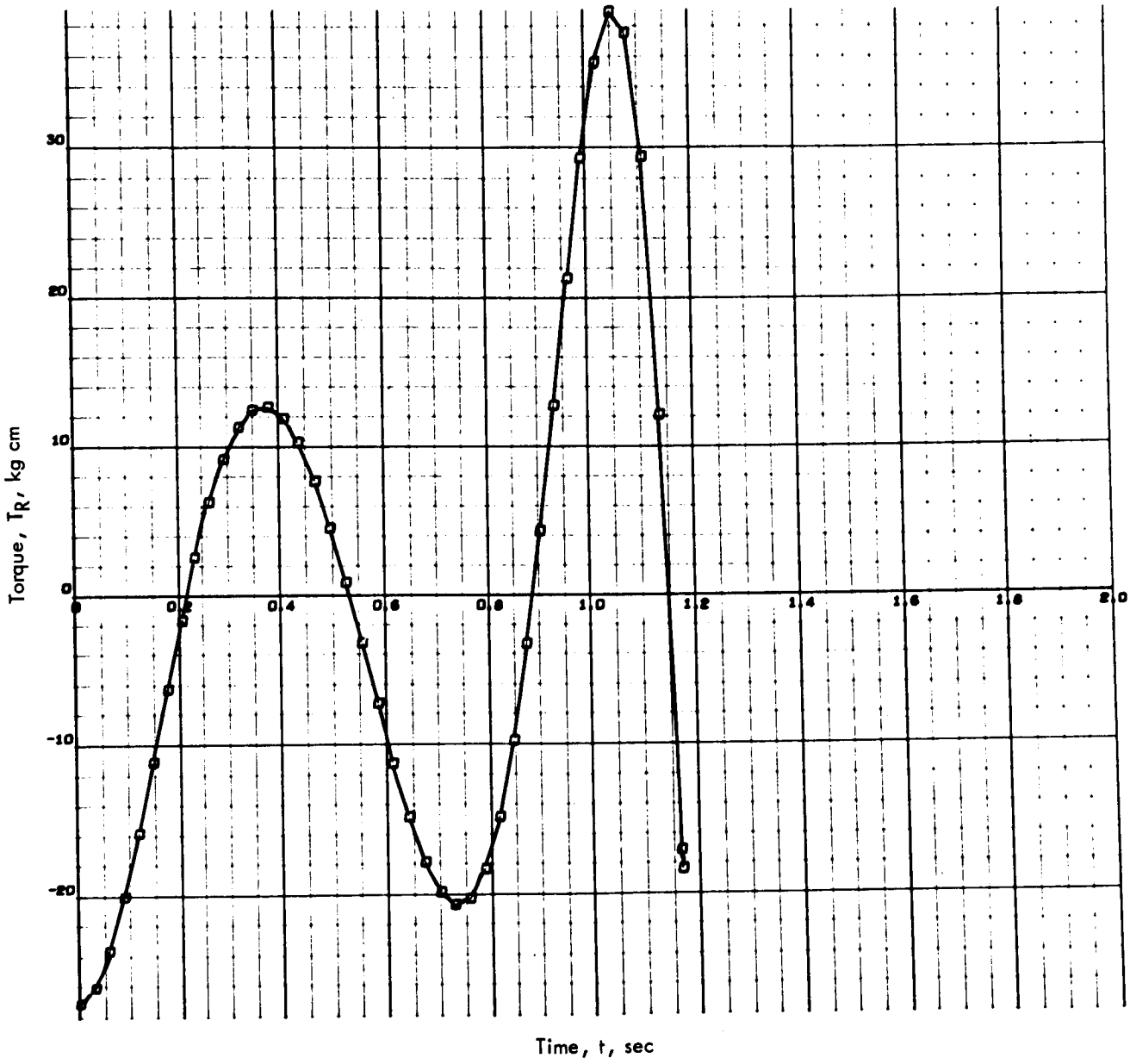

Figure E59. - Torque T_R versus time for segment no. 2, trunk

Figure E60. - Power P_R versus time for segment no. 2, trunk

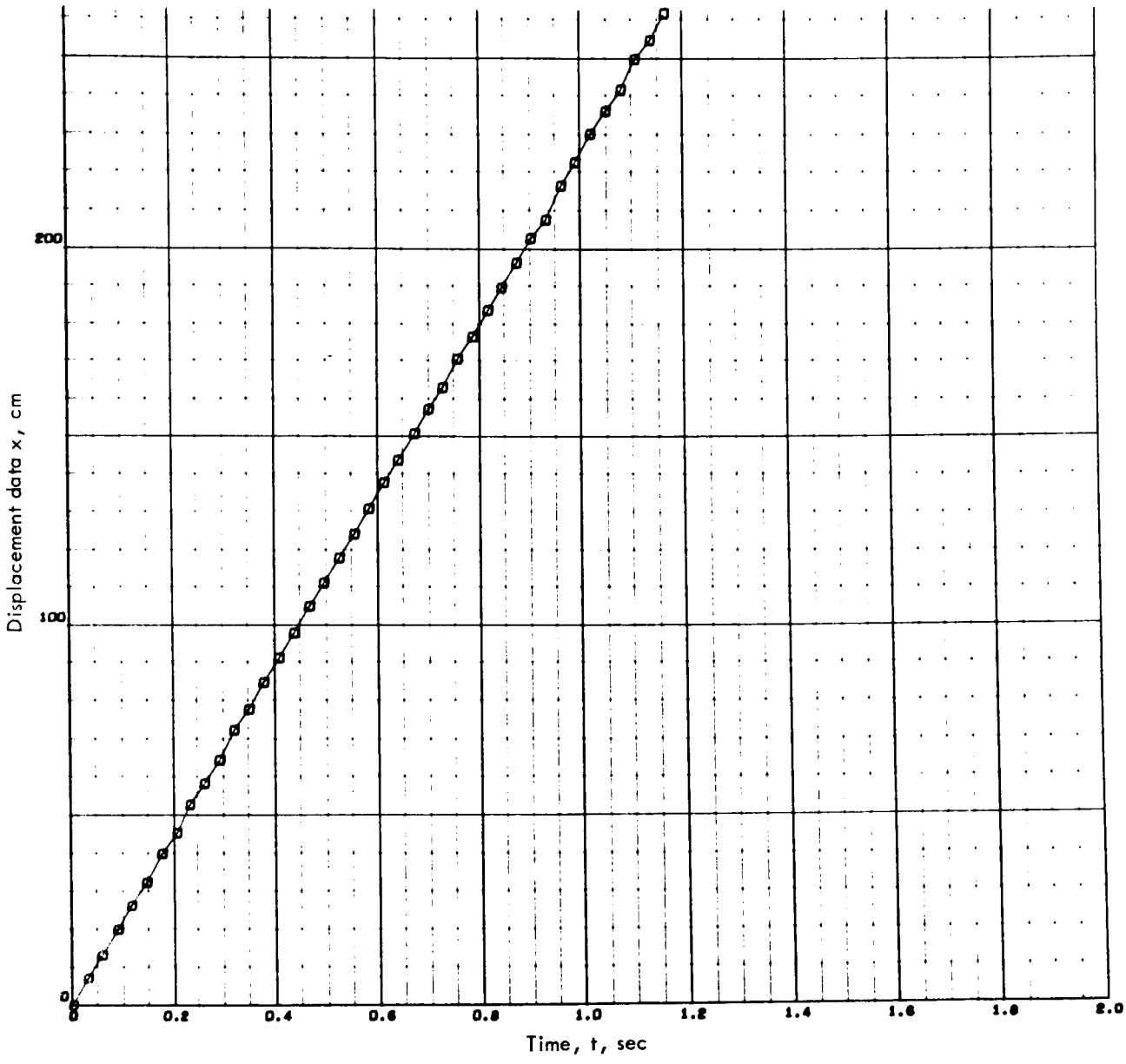

Figure E61. - Displacement data x versus time for segment no. 3, upper arm

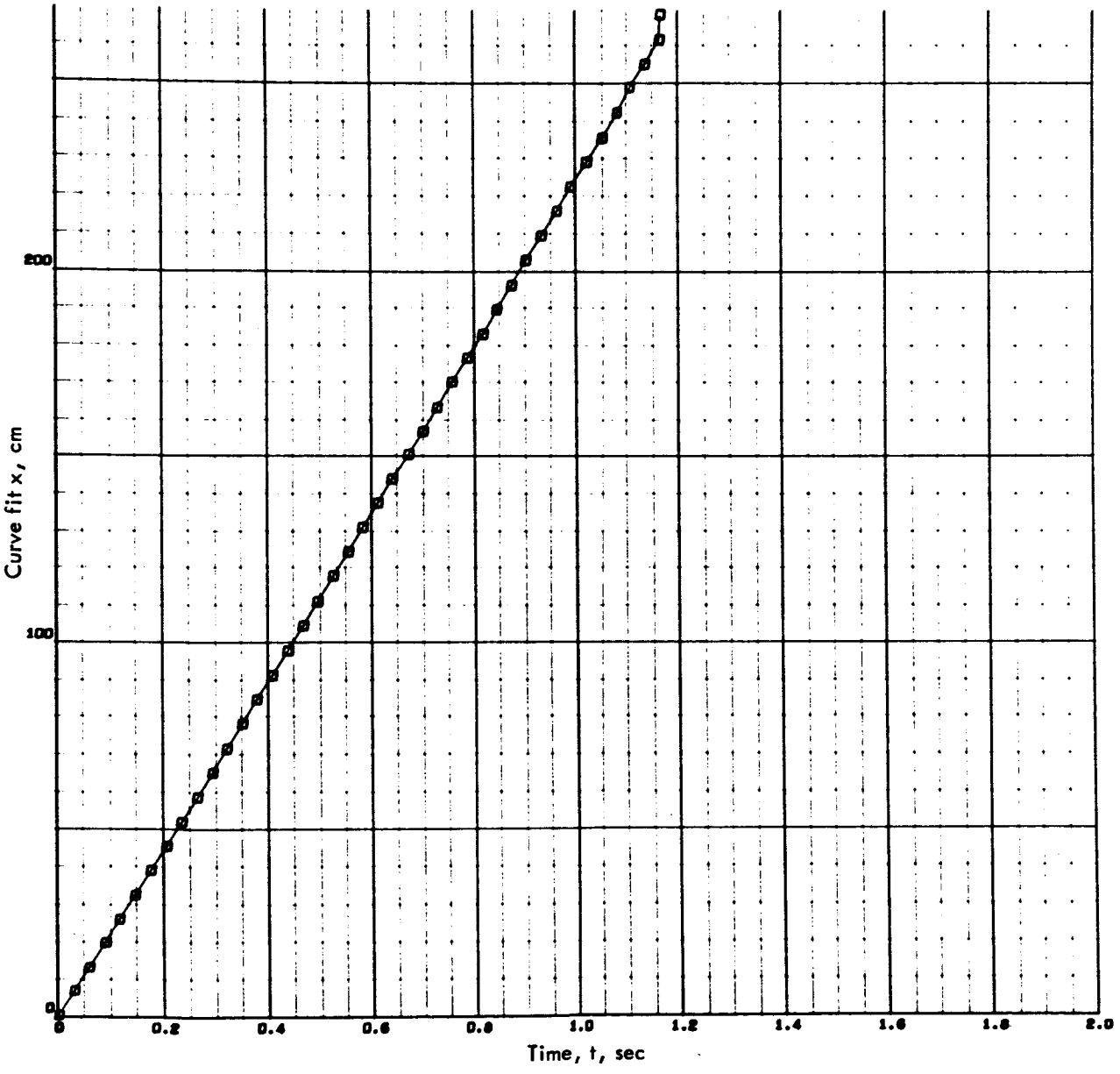

Figure E62. - Curve fit x versus time for segment no. 3, upper arm

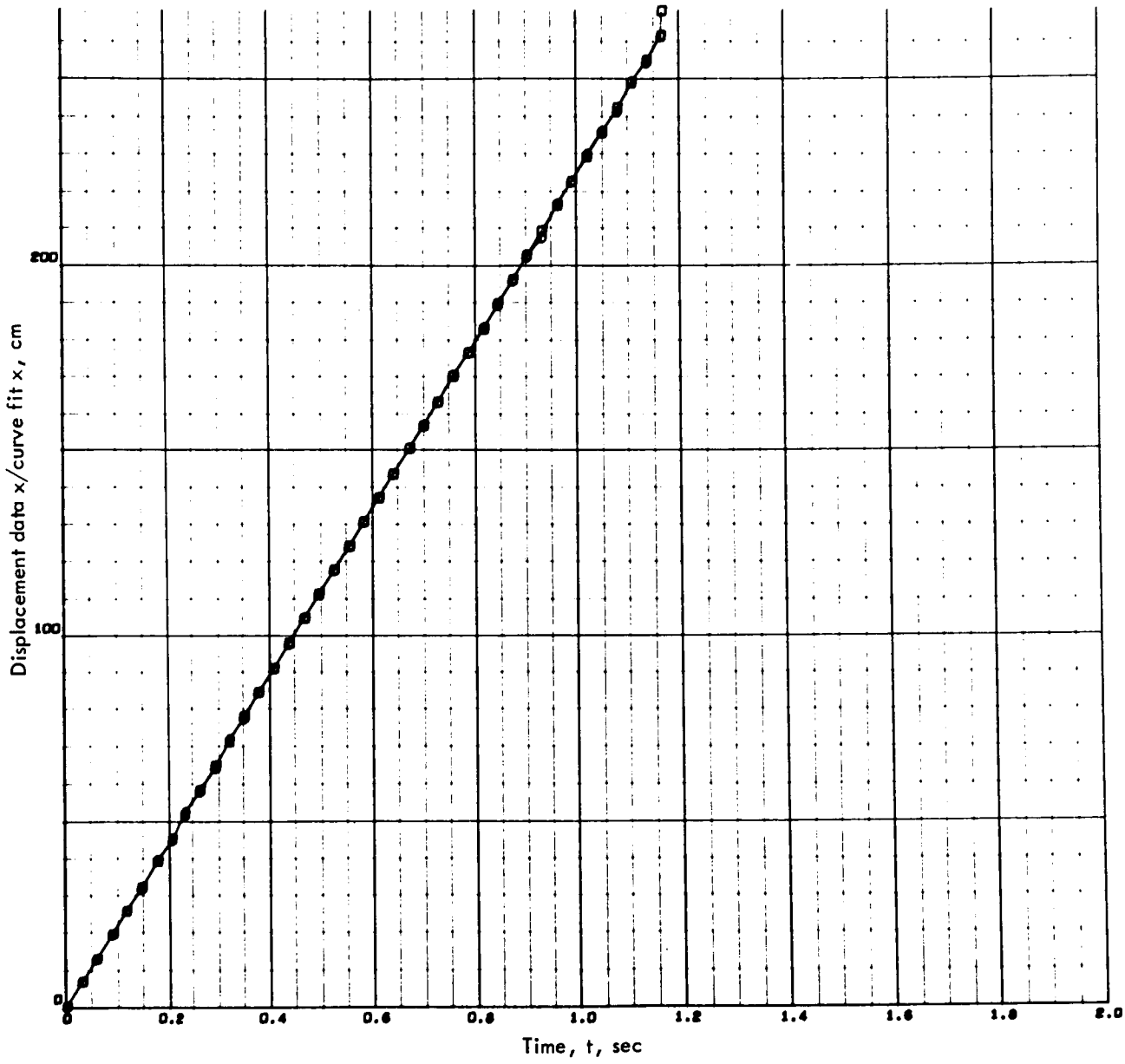

Figure E63. - Displacement data x/curve fit x versus time for segment no. 3, upper arm

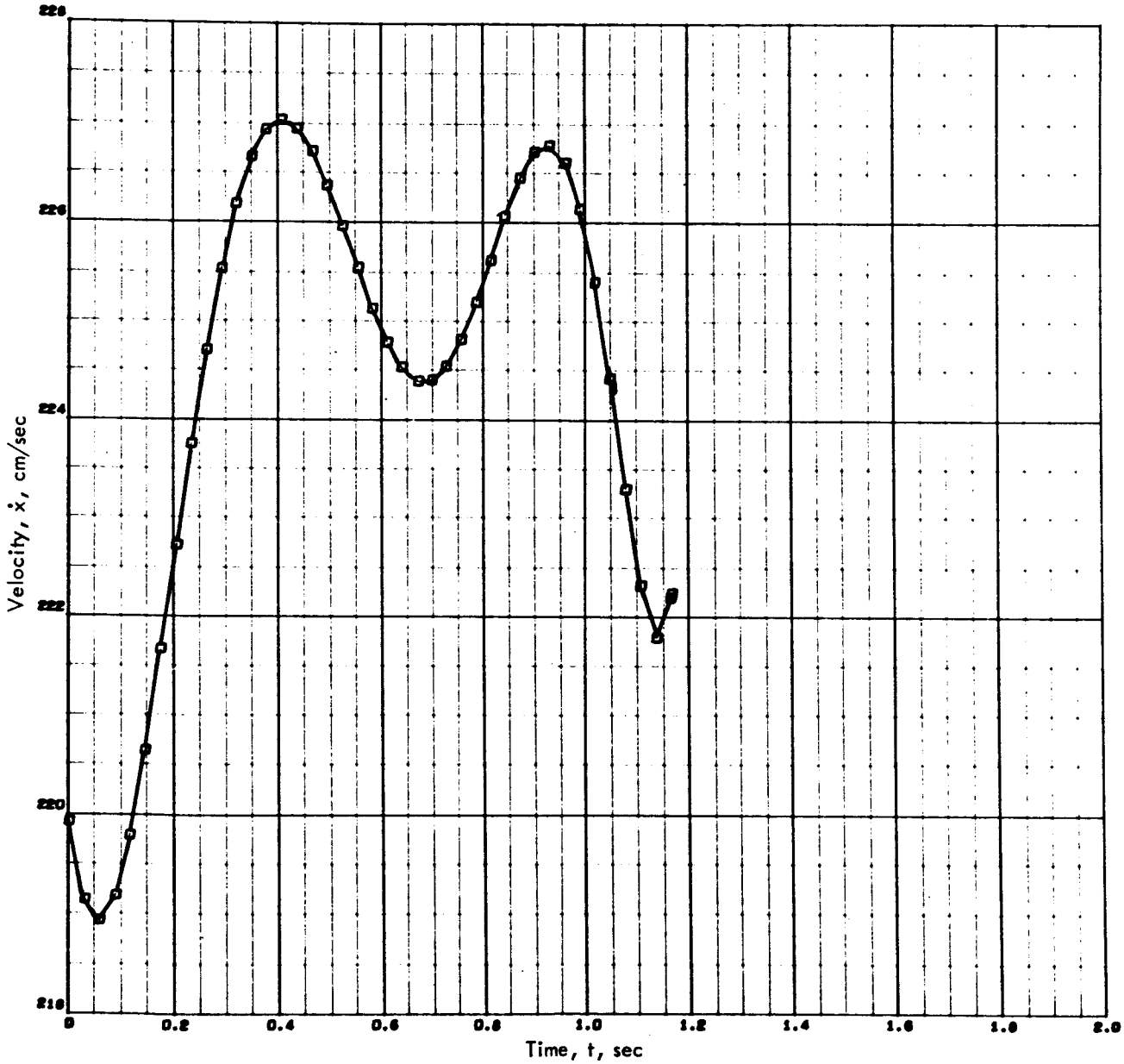

Figure E64. - Velocity $\dot{x}$ versus time for segment no. 3, upper arm

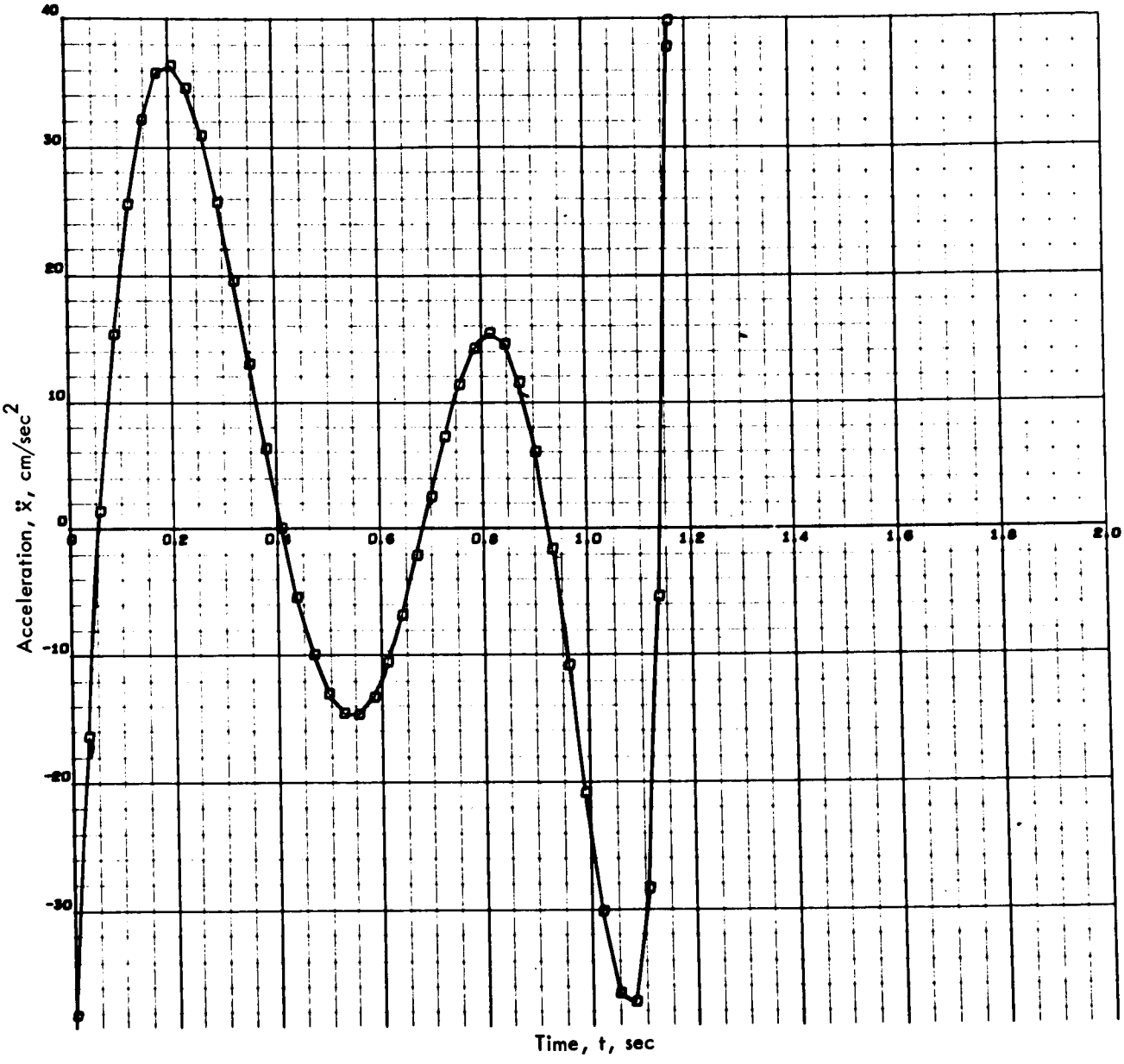

Figure E65. - Acceleration $\ddot{X}$ versus time for segment no. 3, upper arm

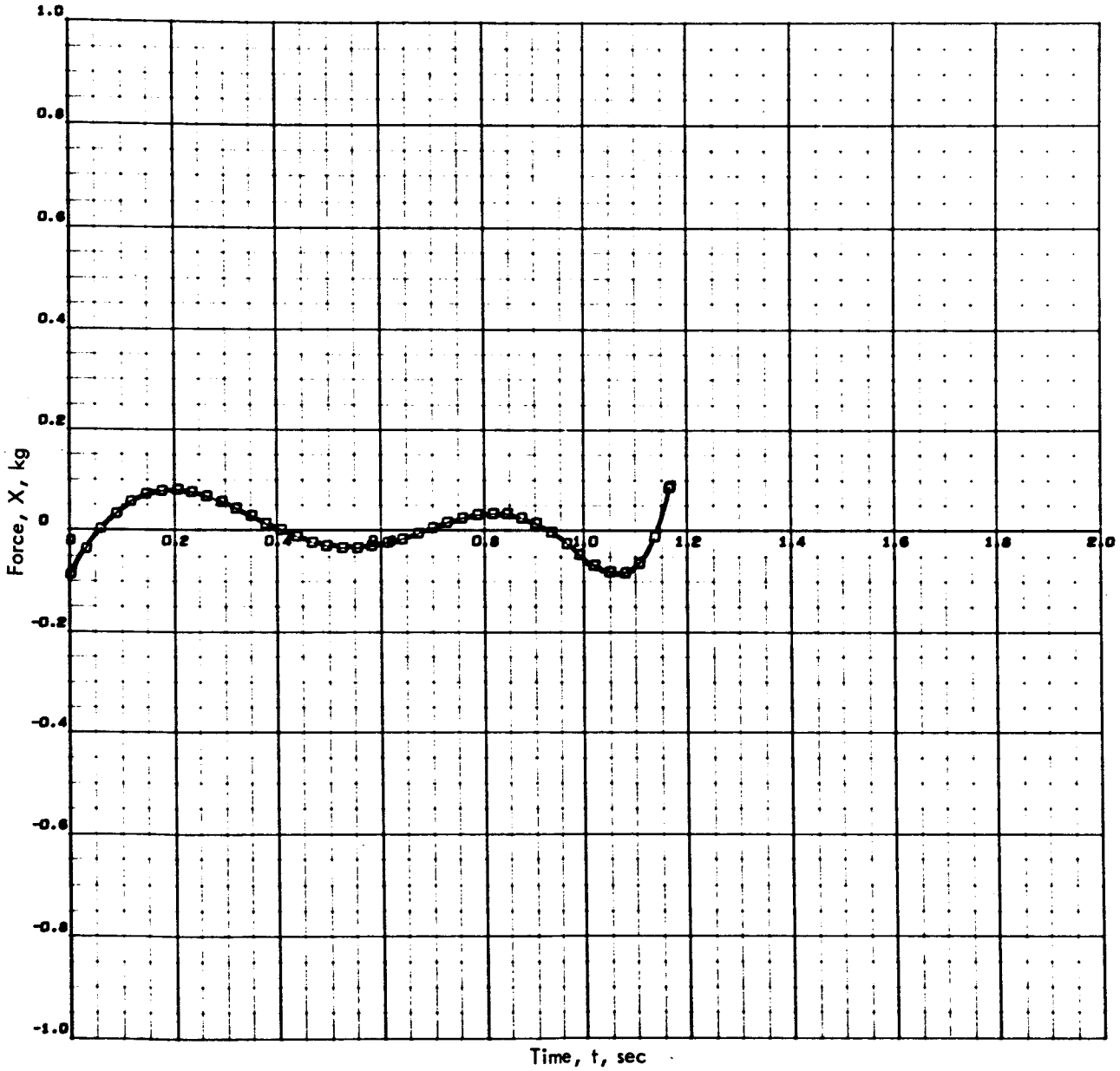

Figure E66. - Force X versus time for segment no. 3, upper arm

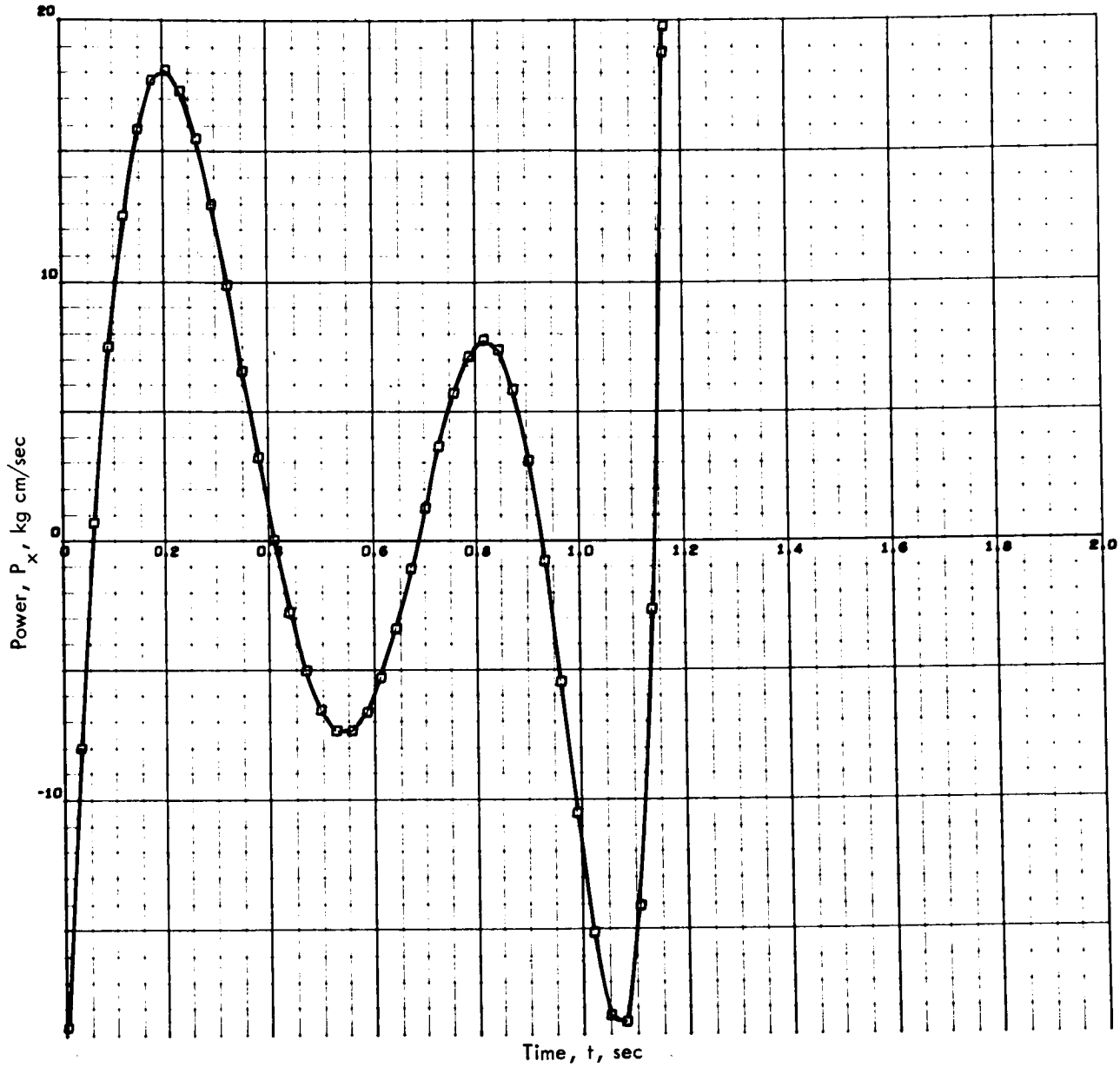

Figure E67. - Power P_x versus time for segment no. 3, upper arm

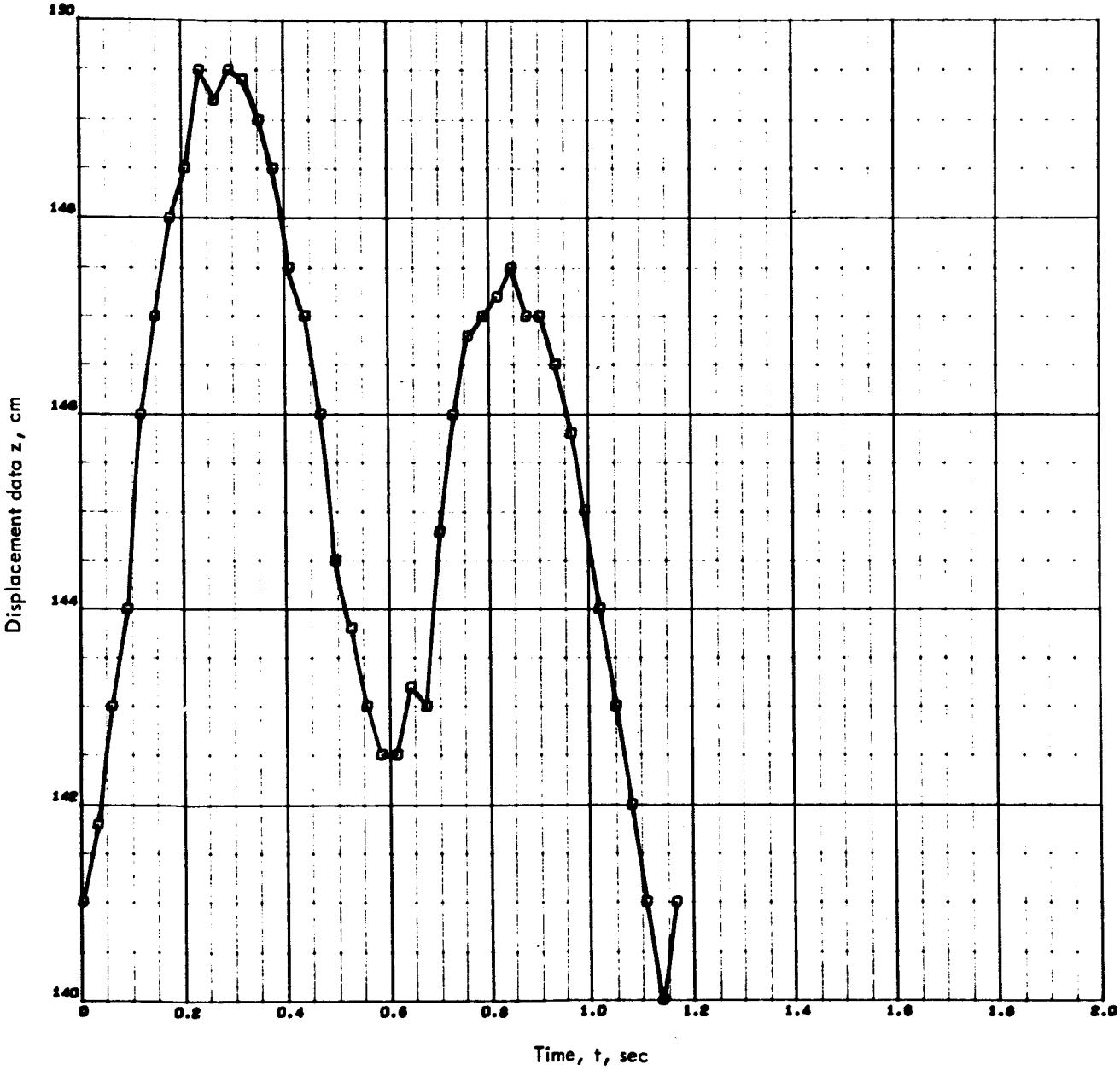

Figure E68. - Displacement data z versus time for segment no. 3, upper arm

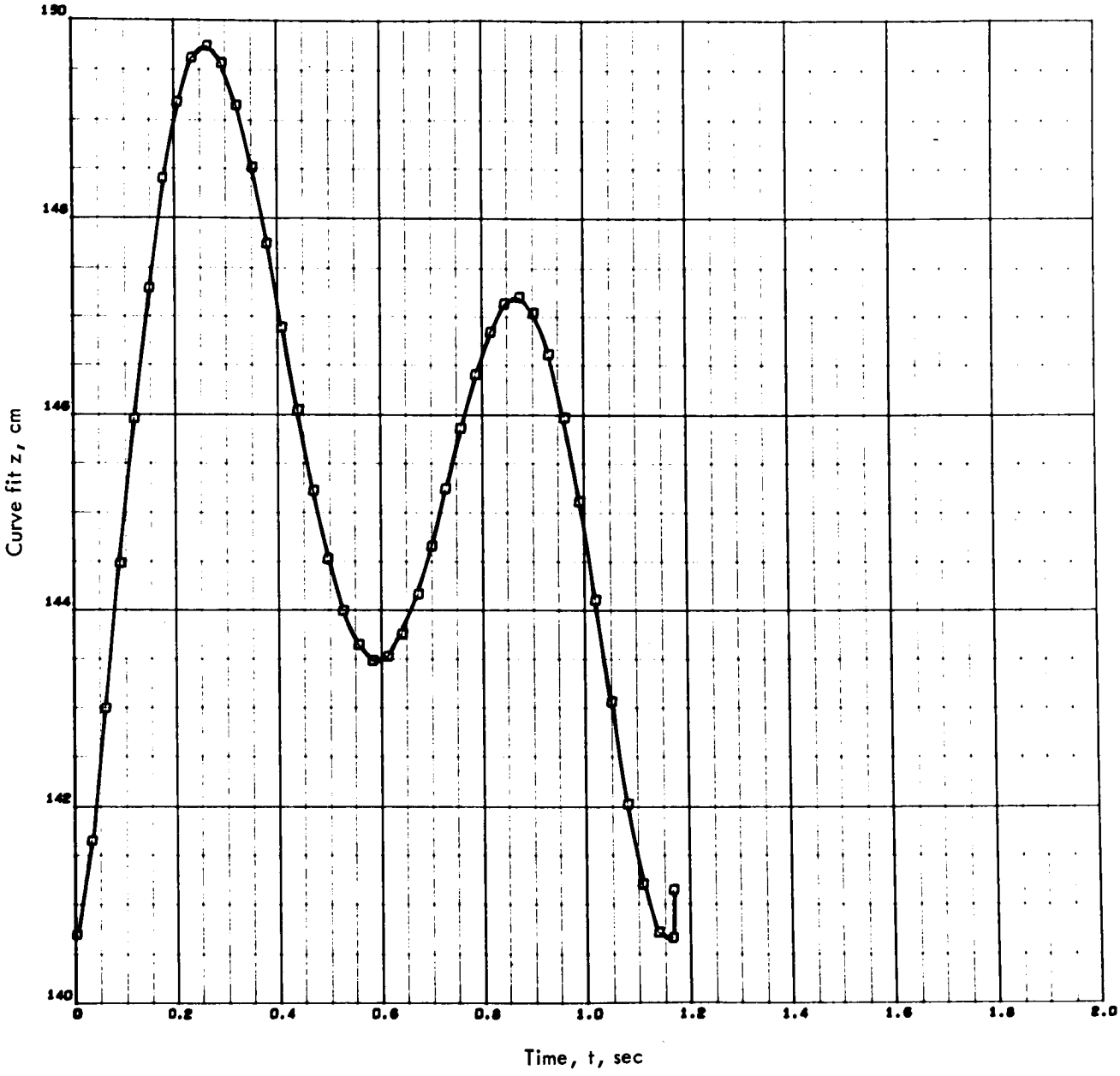

Figure E69. - Curve fit z versus time for segment no. 3, upper arm

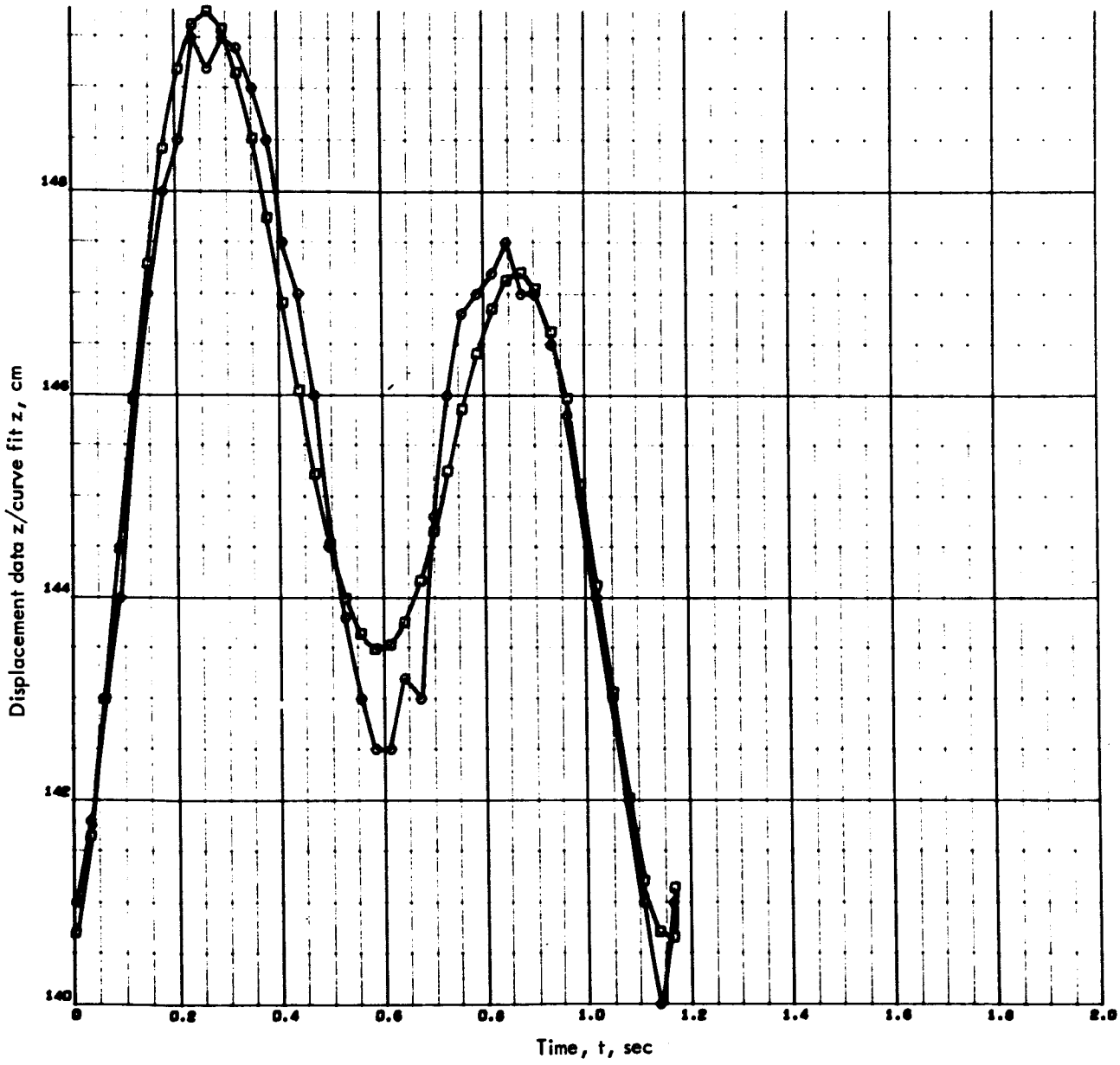

Figure E70. - Displacement data z/curve fit z versus time for segment no. 3, upper arm

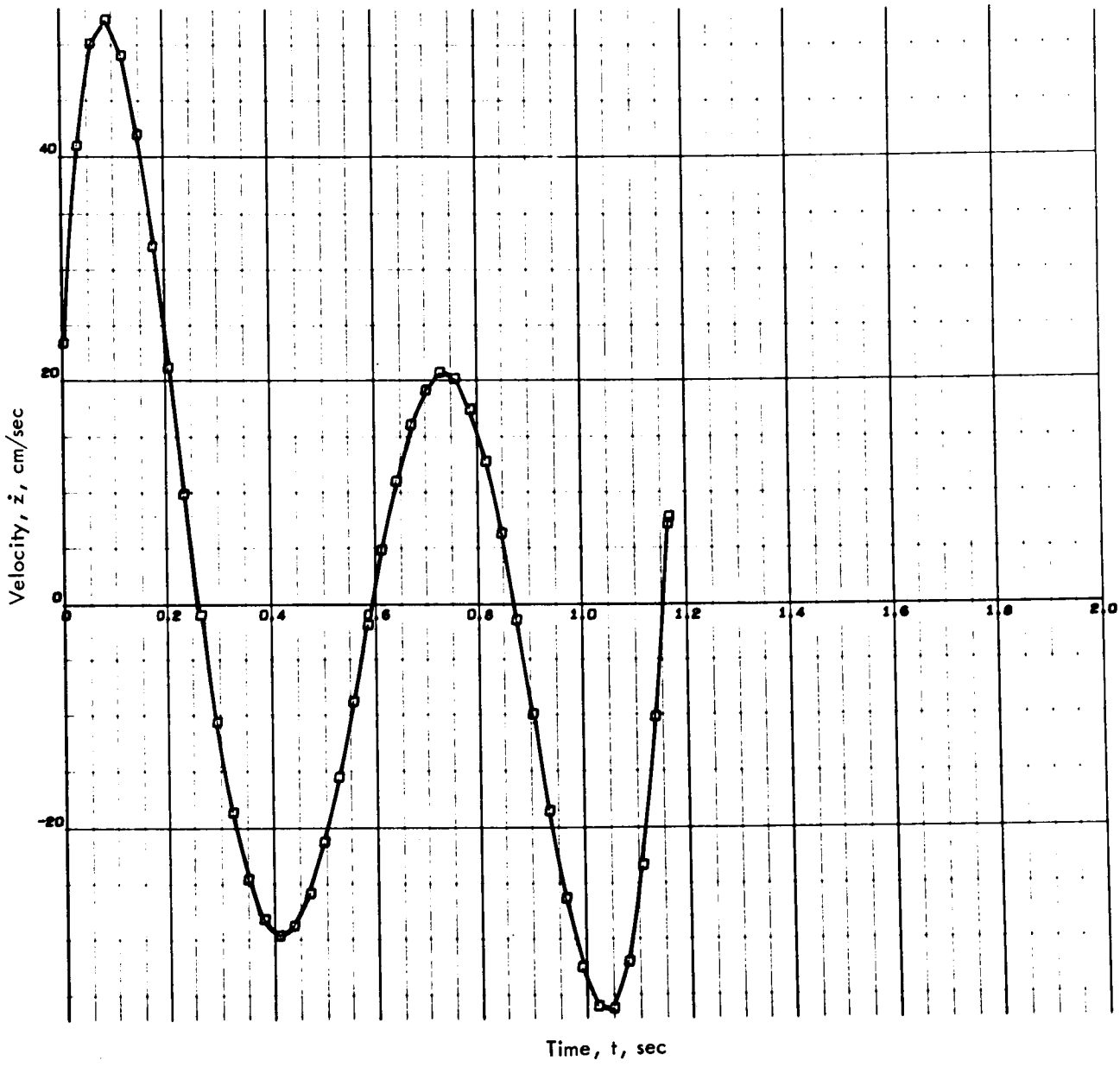

Figure E71. - Velocity ż versus time for segment no. 3, upper arm

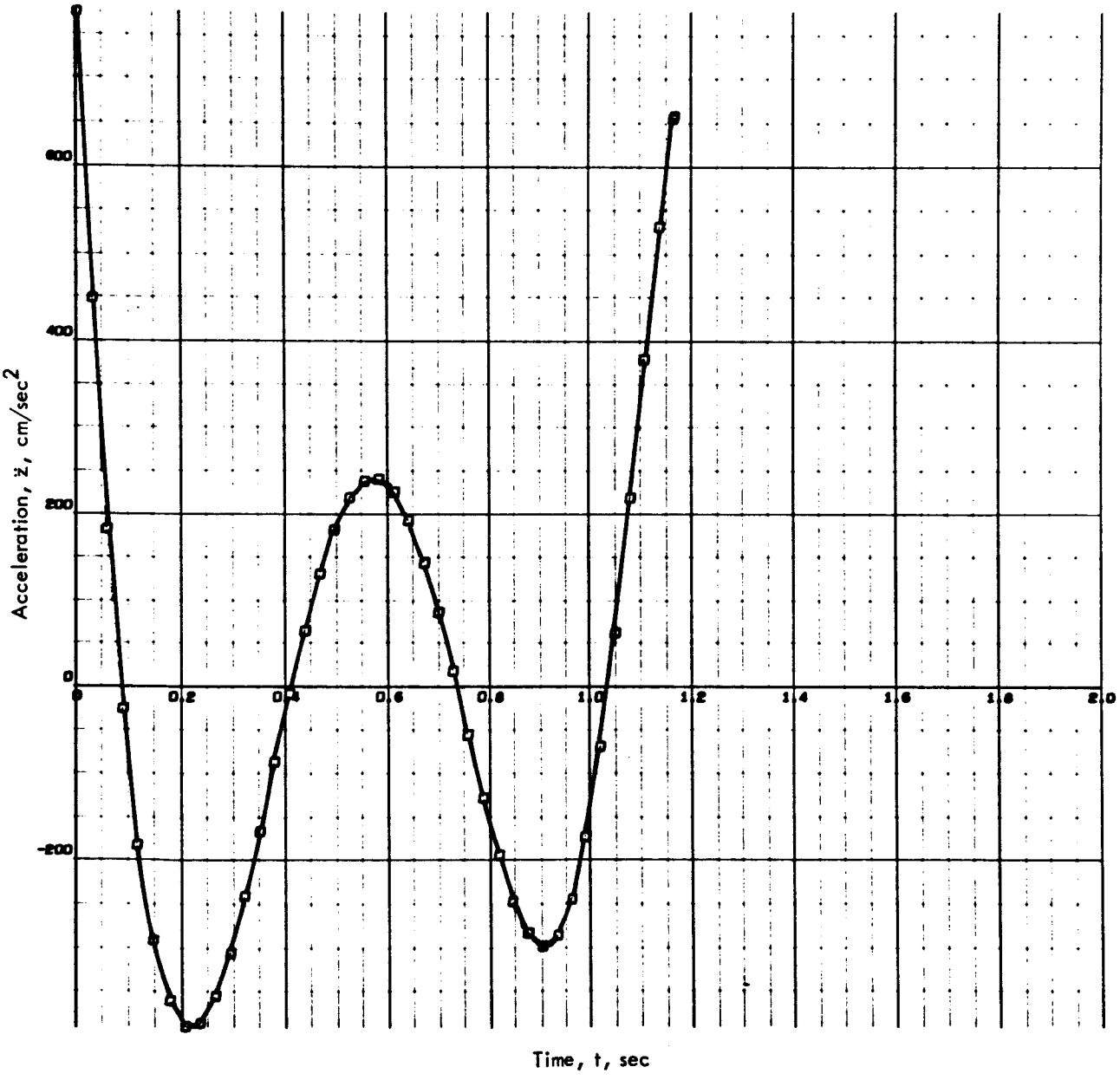

Figure E72. - Acceleration ẍ versus time for segment no. 3, upper arm

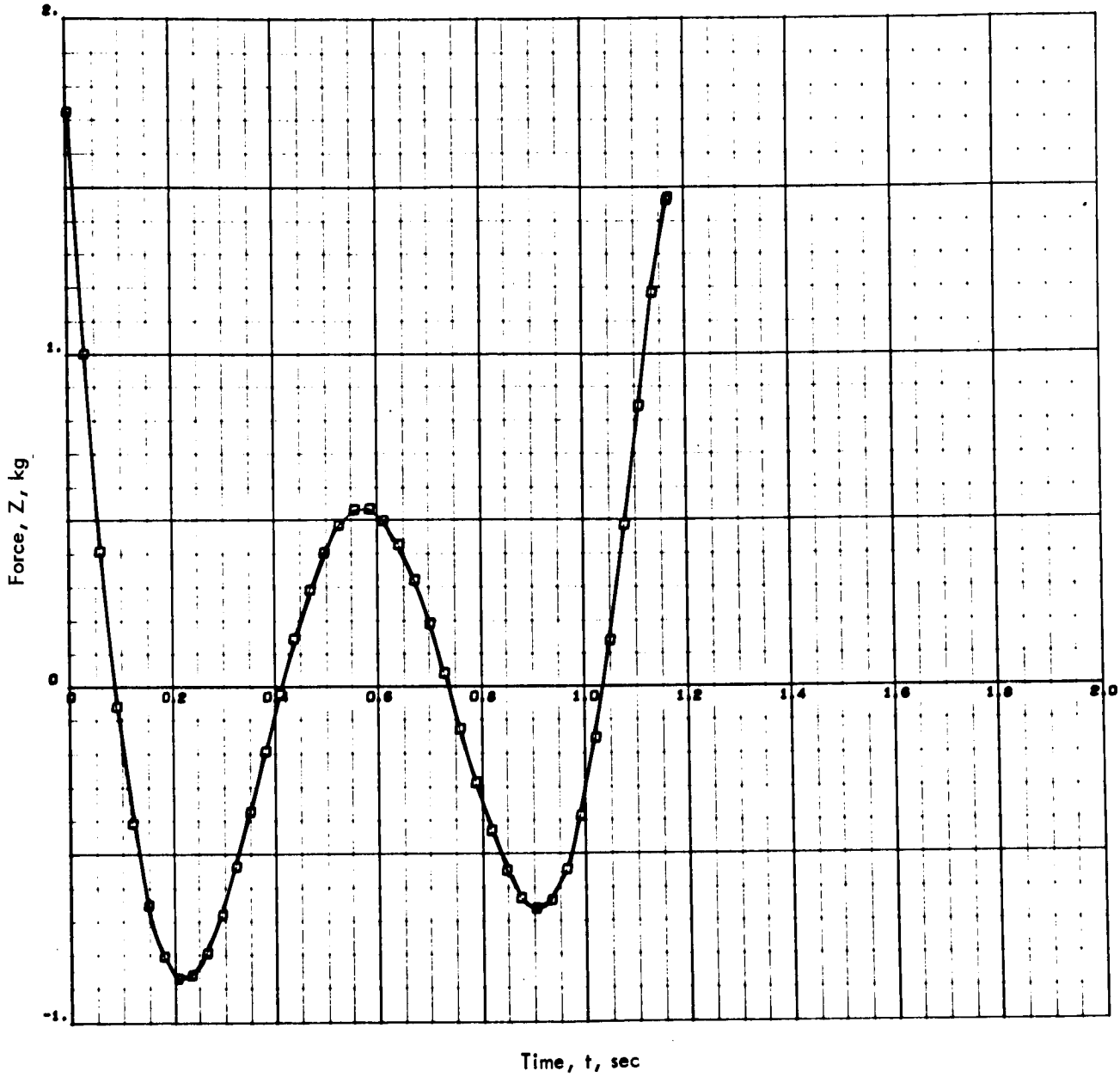

Figure E73. - Force Z versus time for segment no. 3, upper arm

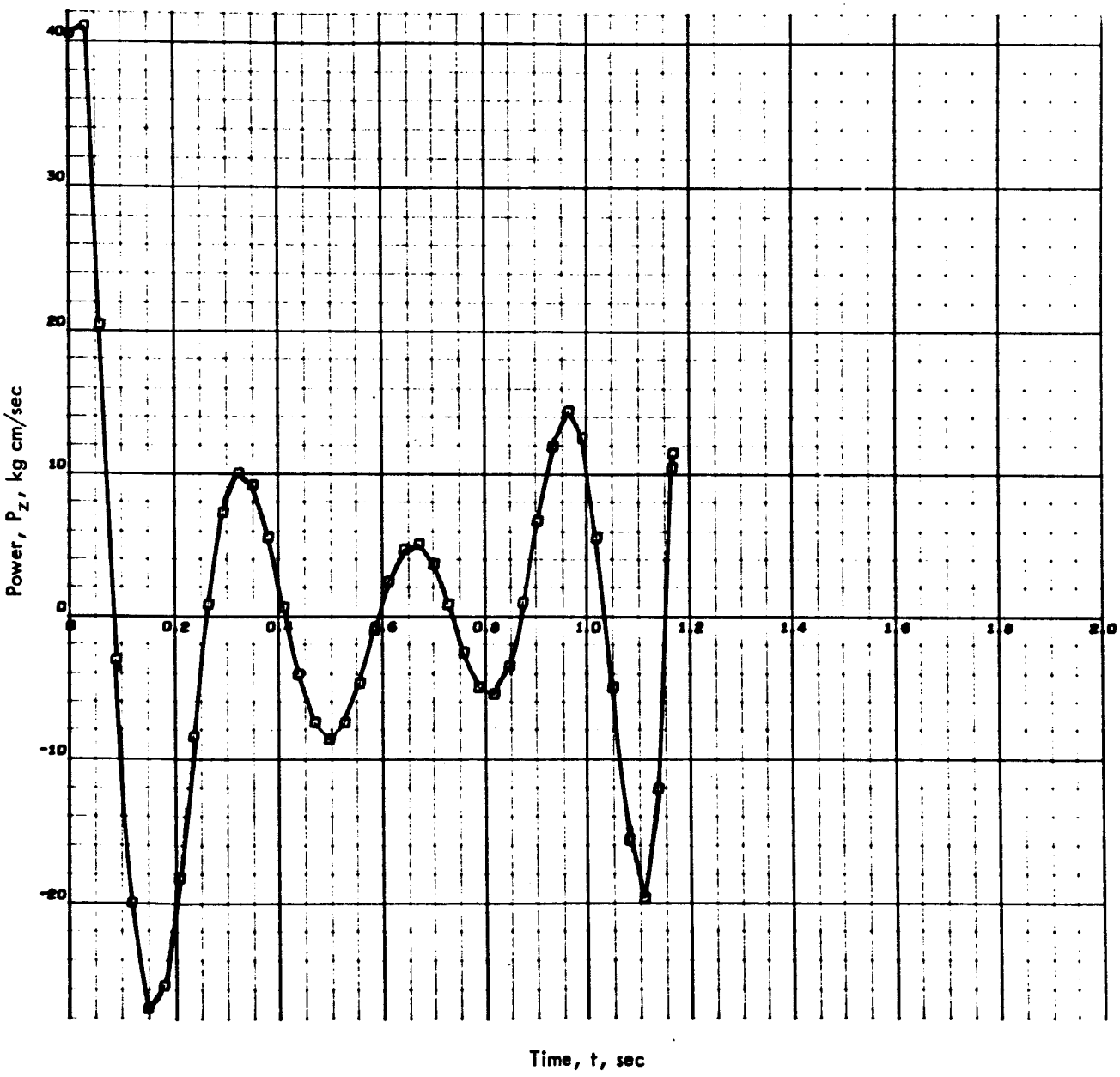

Figure E74. - Power P_z versus time for segment no. 3, upper arm

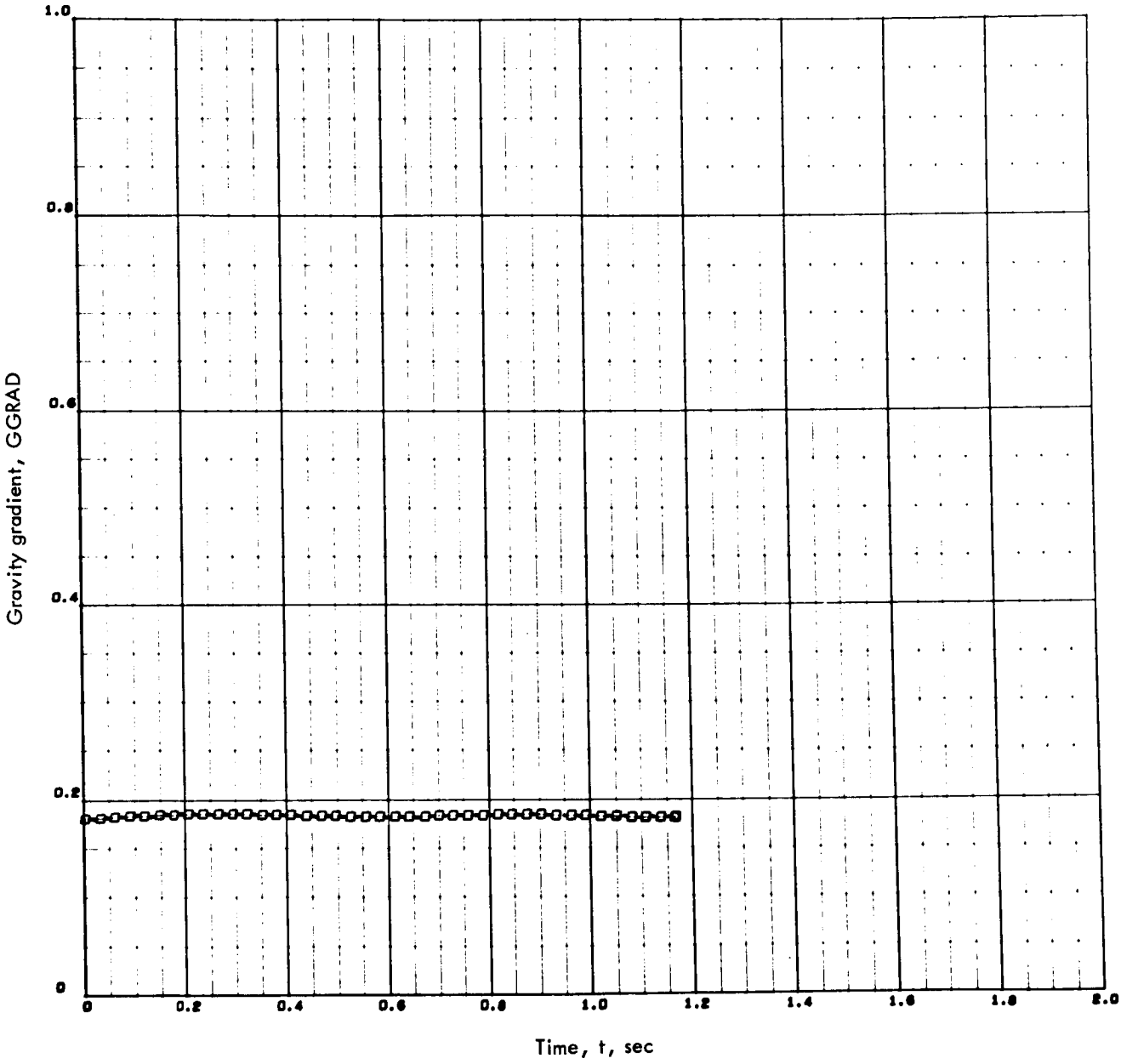

Figure E75. - Gravity gradient versus time for segment no. 3, upper arm

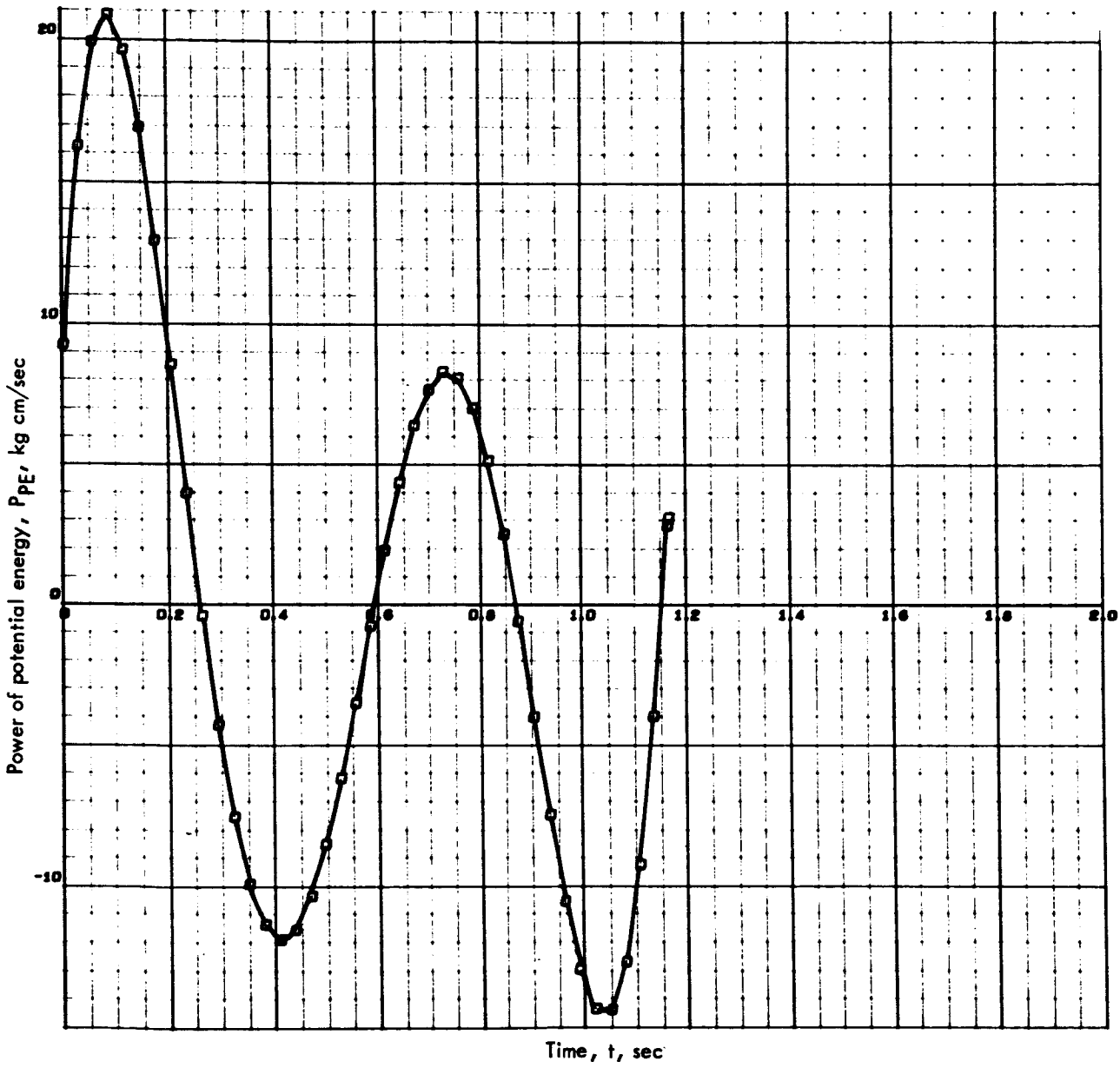

Figure E76. - Power of potential energy versus time for segment no. 3, upper arm

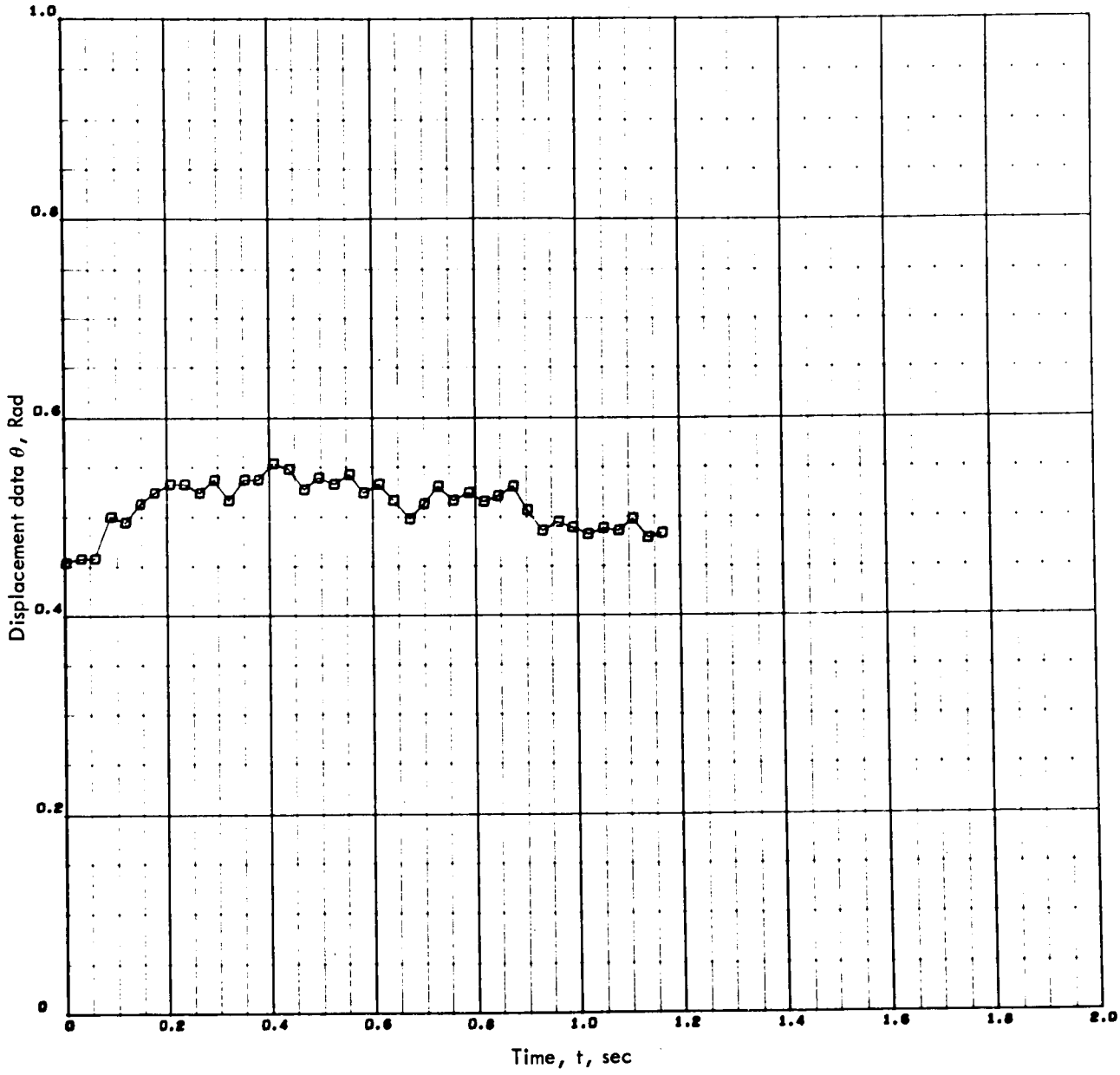

Figure E77. - Displacement data θ versus time for segment no. 3, upper arm

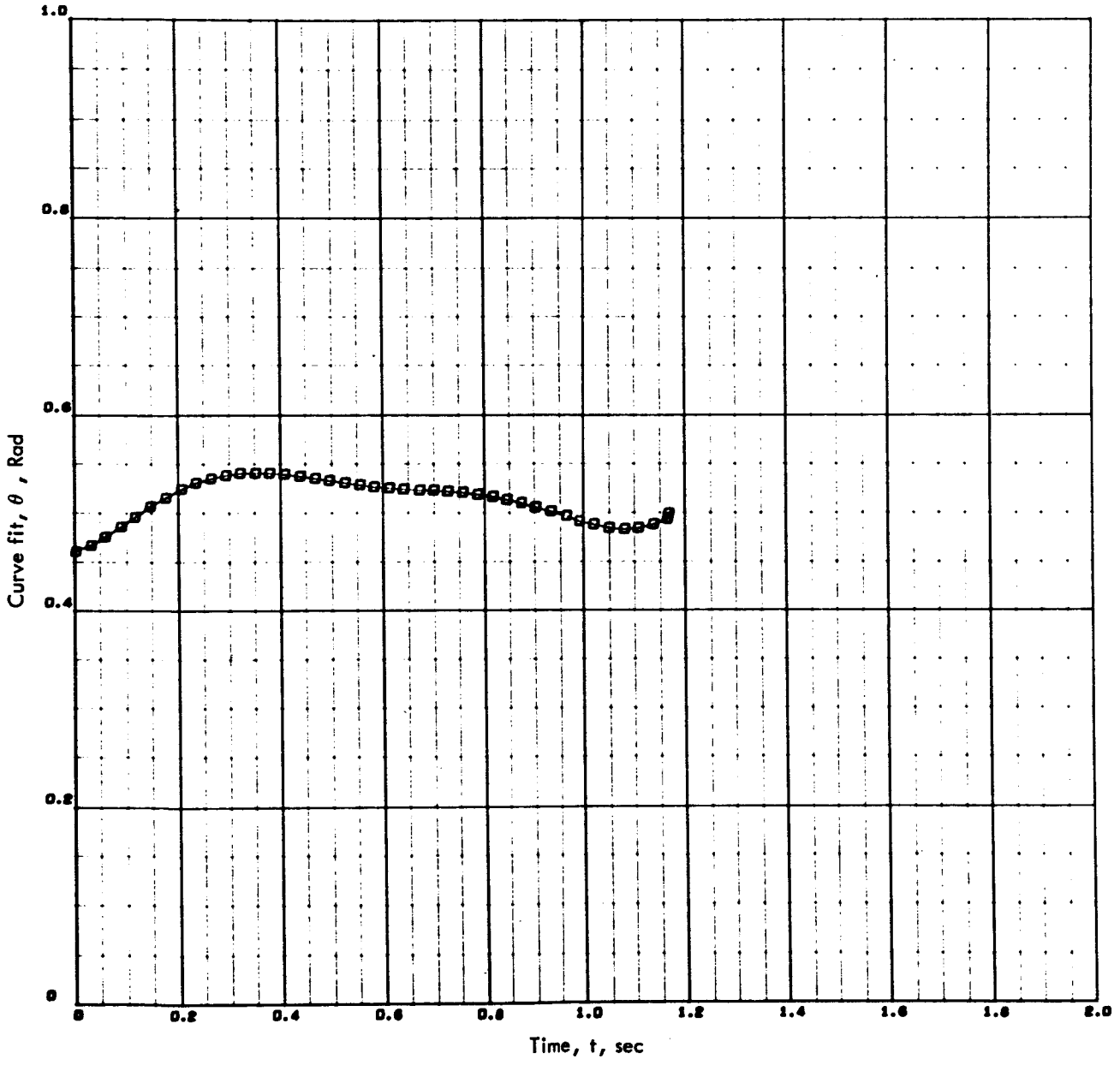

Figure E78. - Curve fit θ versus time for segment no. 3, upper arm

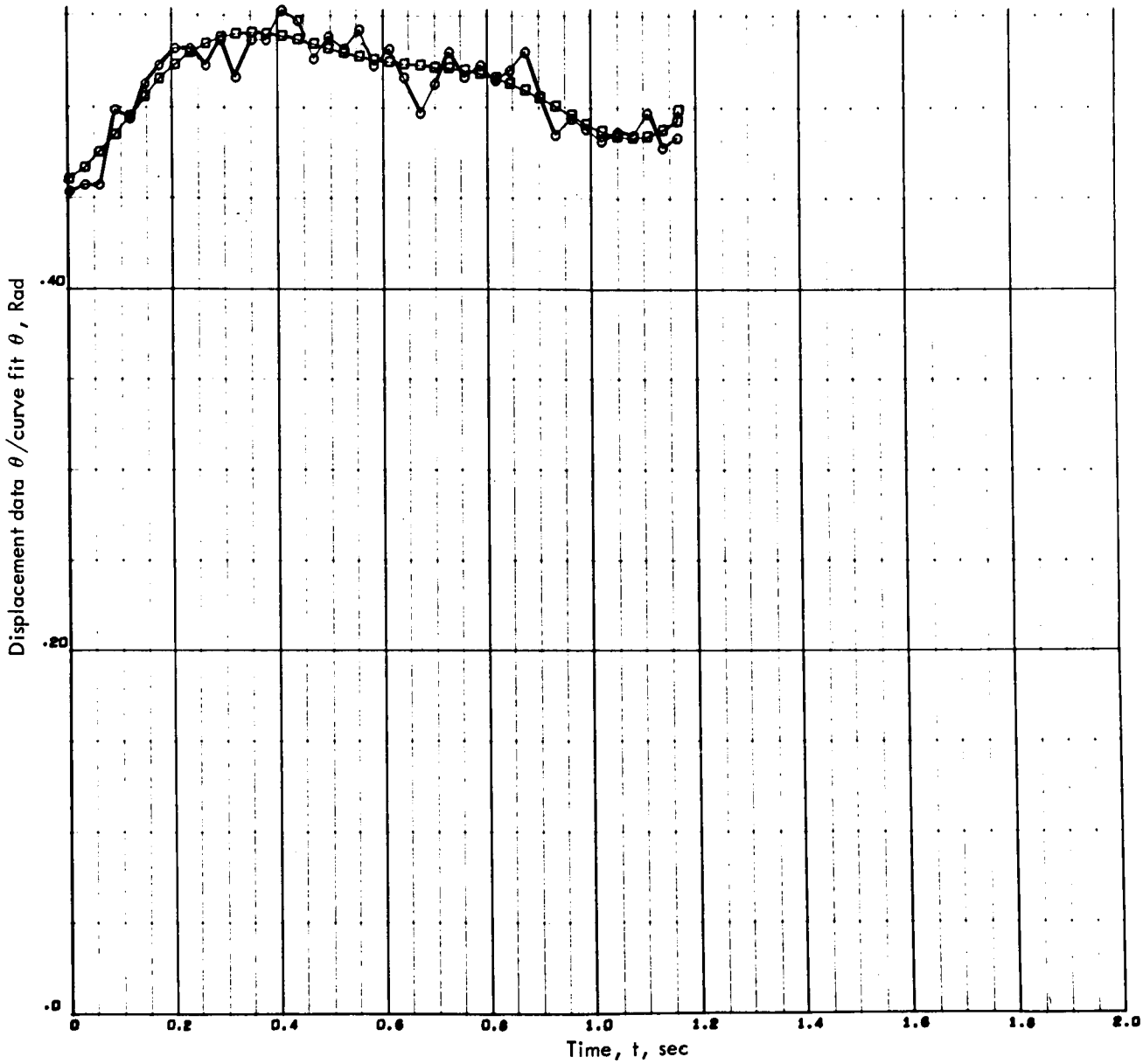

Figure E79.- Displacement θ /curve fit θ versus time for segment no. 3, upper arm

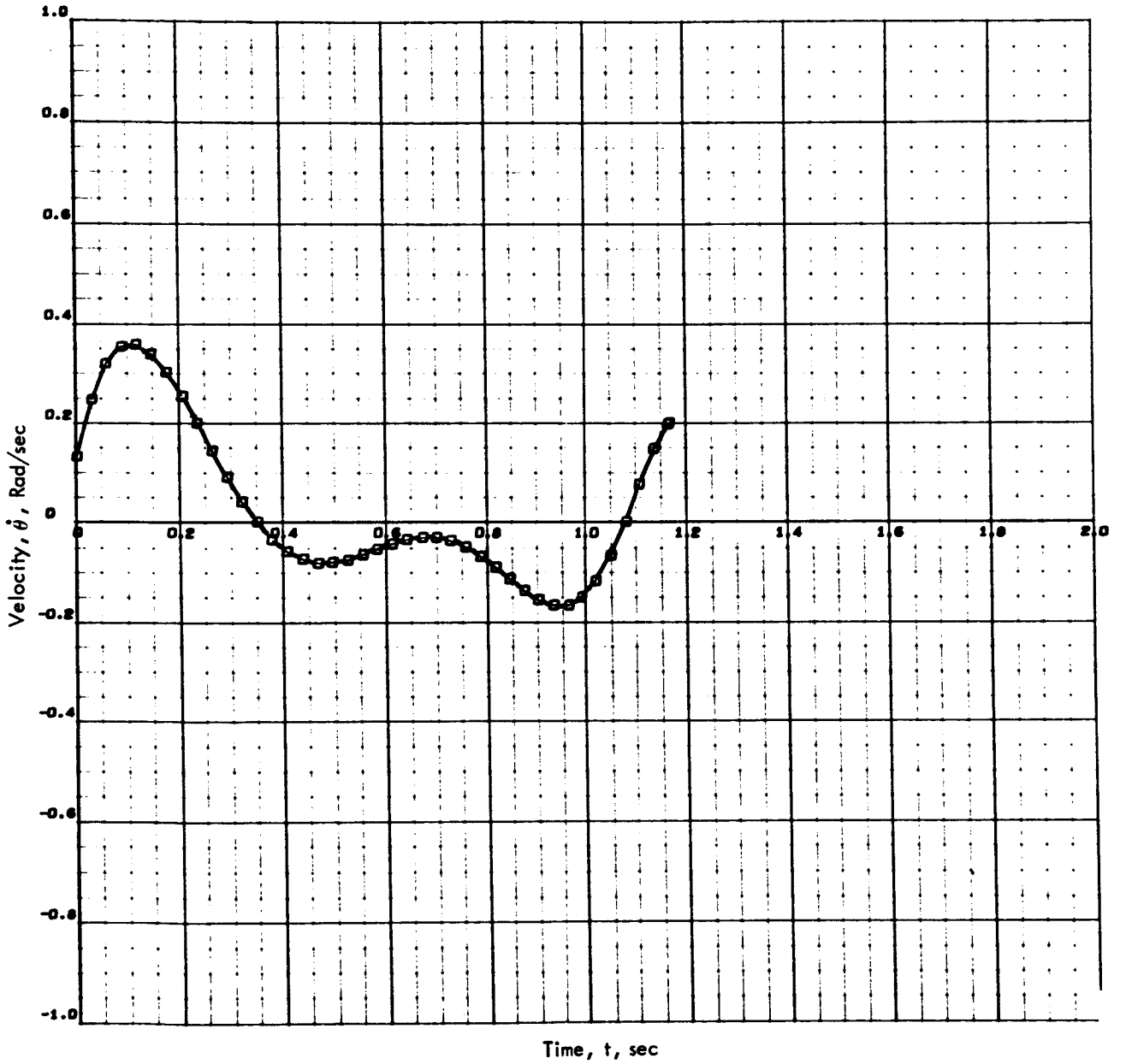

Figure E80. - Velocity $\dot{\theta}$ versus time for segment no. 3, upper arm

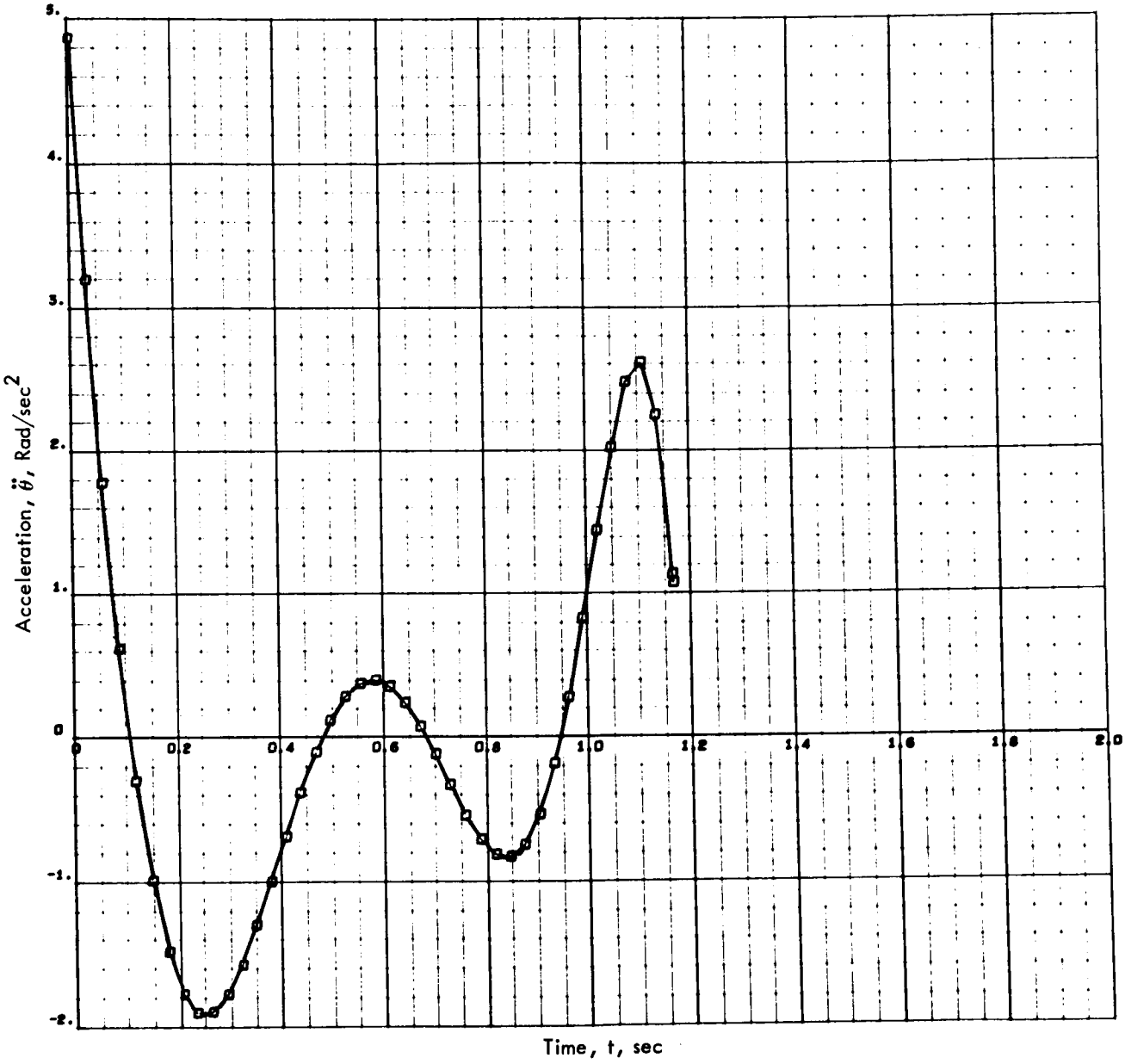

Figure E81. - Acceleration $\ddot{\theta}$ versus time for segment no. 3, upper arm

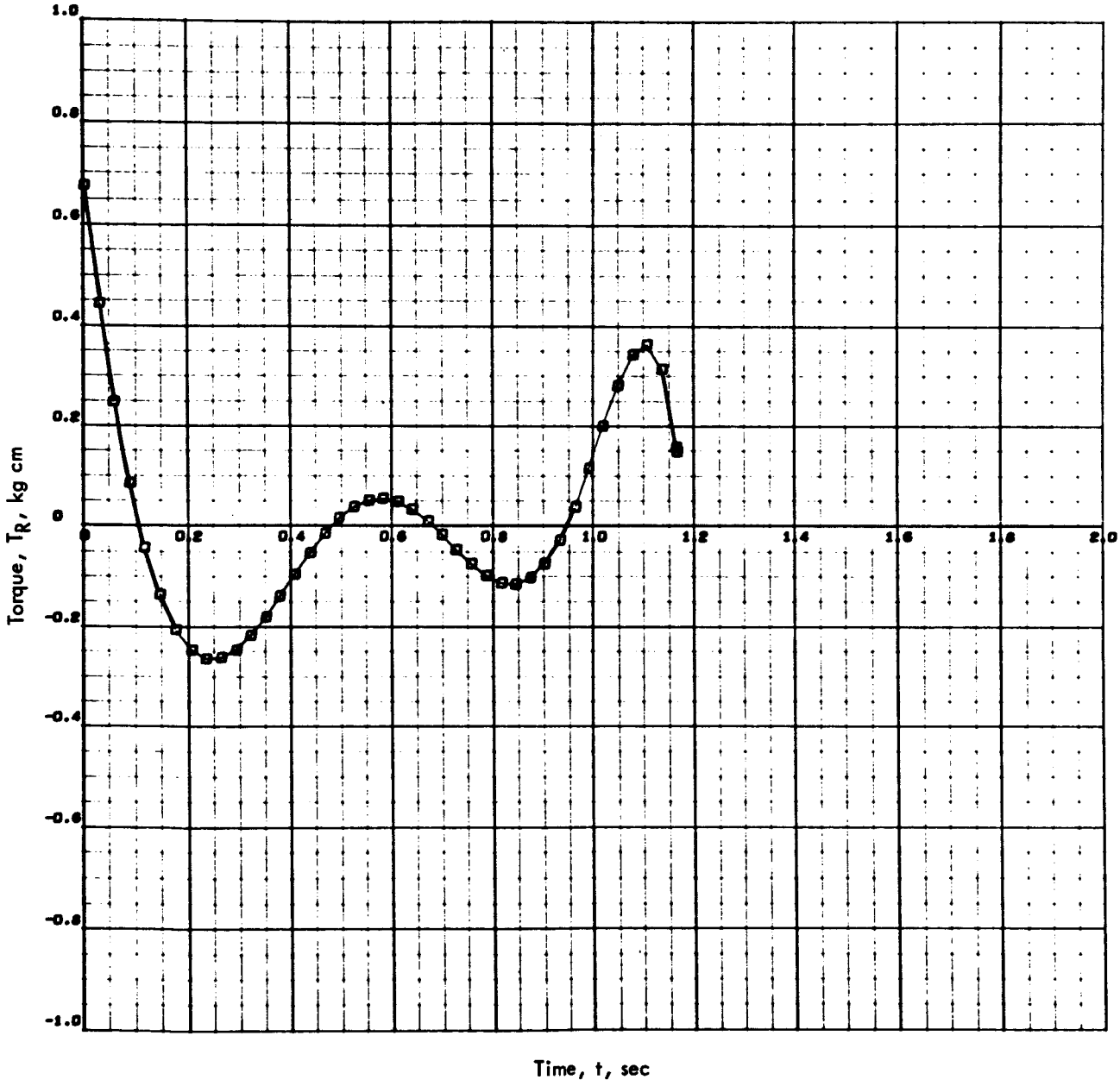

Figure E82.- Torque T_R versus time for segment no. 3, upper arm

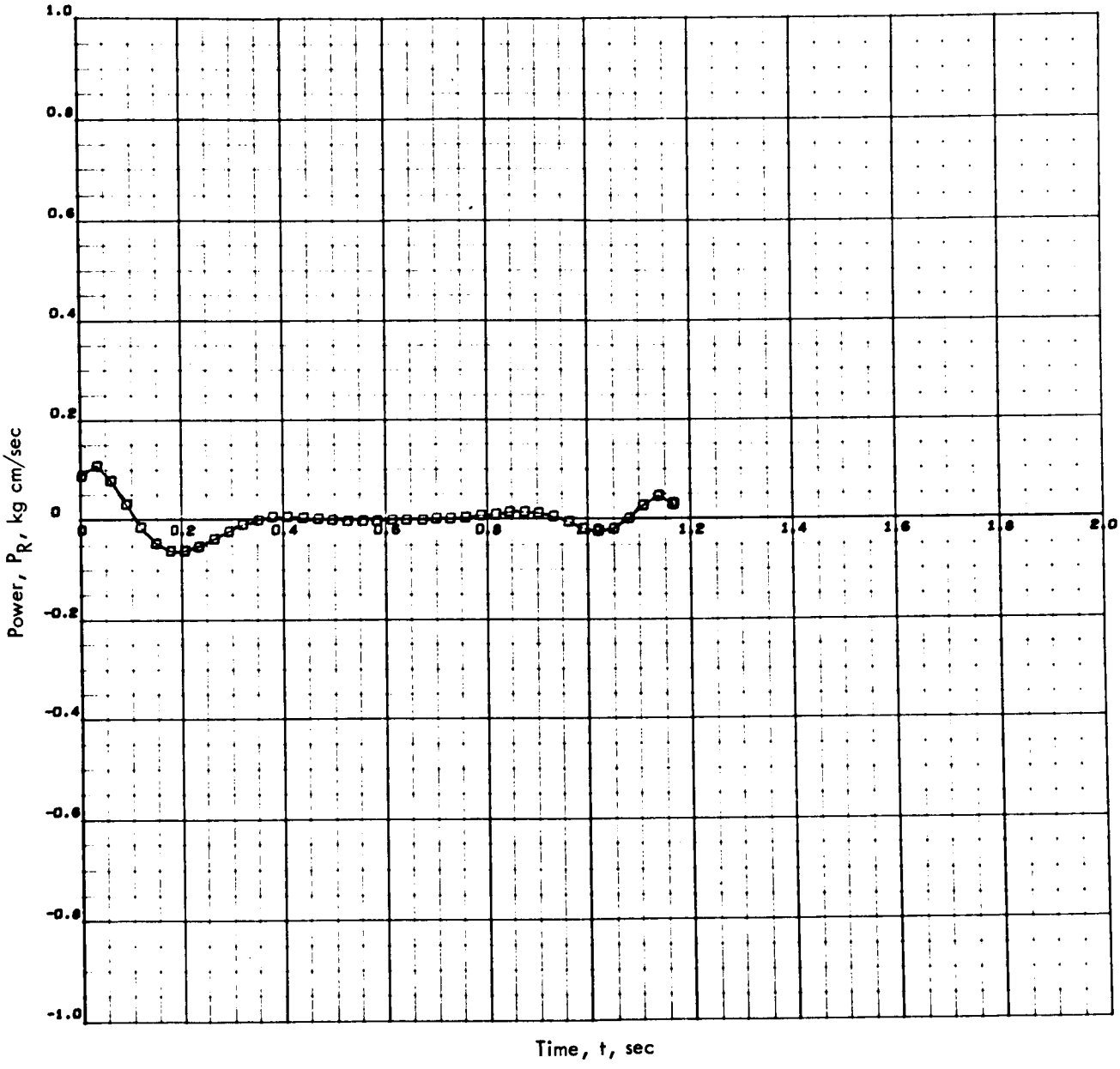

Figure E83. - Power P_R versus time for segment no. 3, upper arm

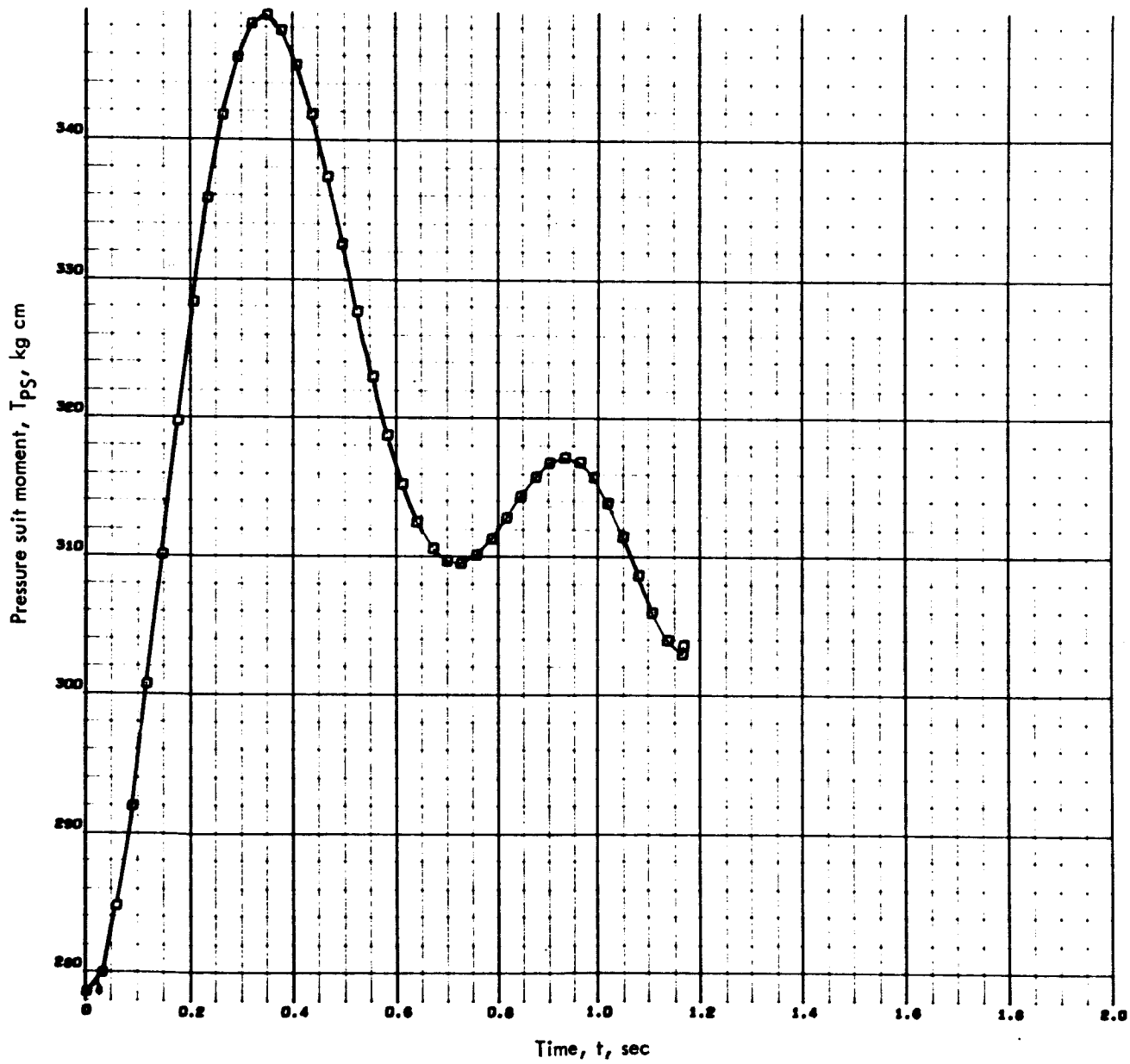

Figure E84. - Pressure suit moment T_{PS} versus time for segment no. 3, upper arm

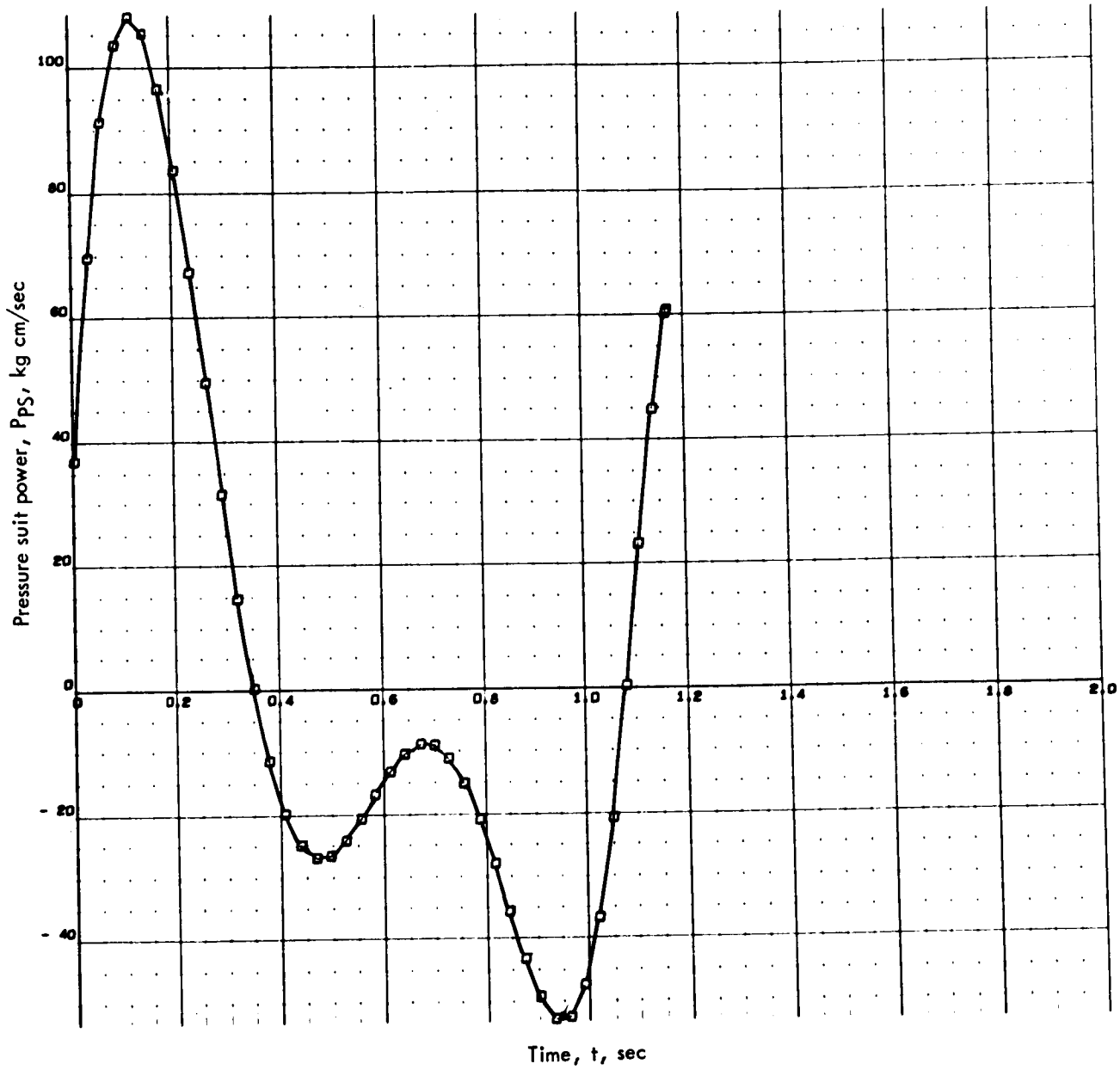

Figure E85. - Pressure suit power P_{PS} versus time for segment no. 3, upper arm

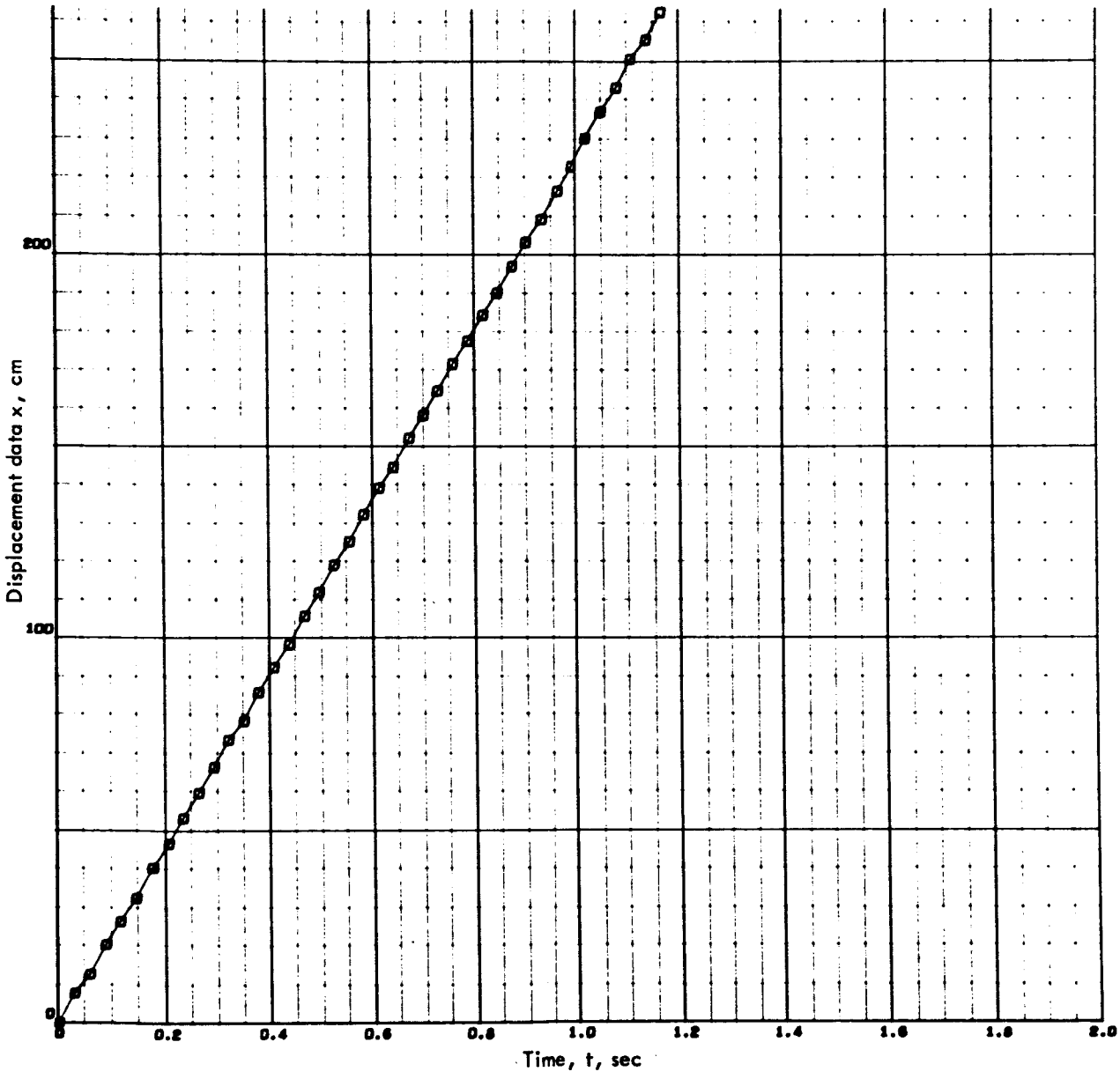

Figure E86.- Displacement data x versus time for segment no. 4, lower arm and hand

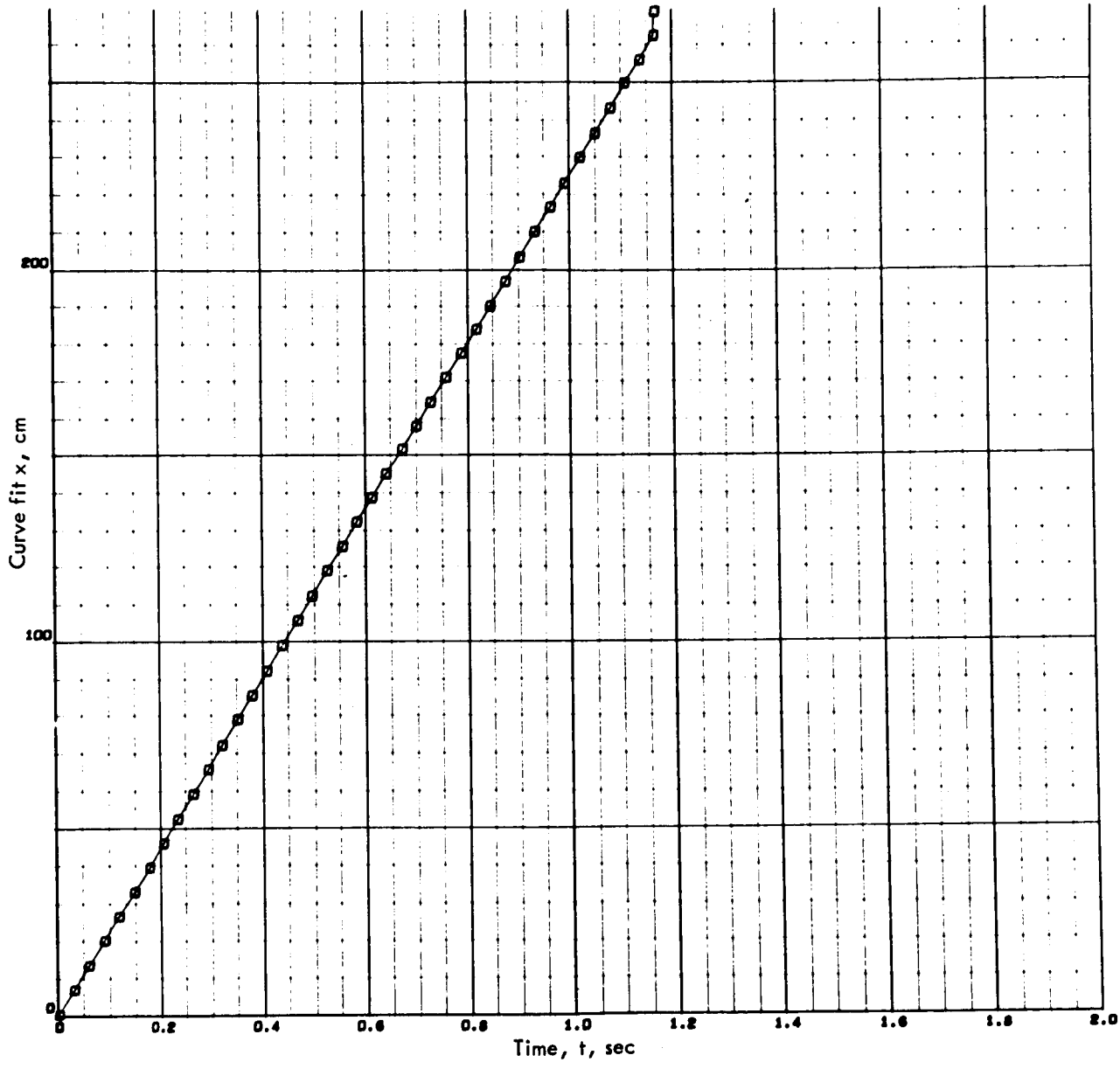

Figure E87. - Curve fit x versus time for segment no. 4, lower arm and hand

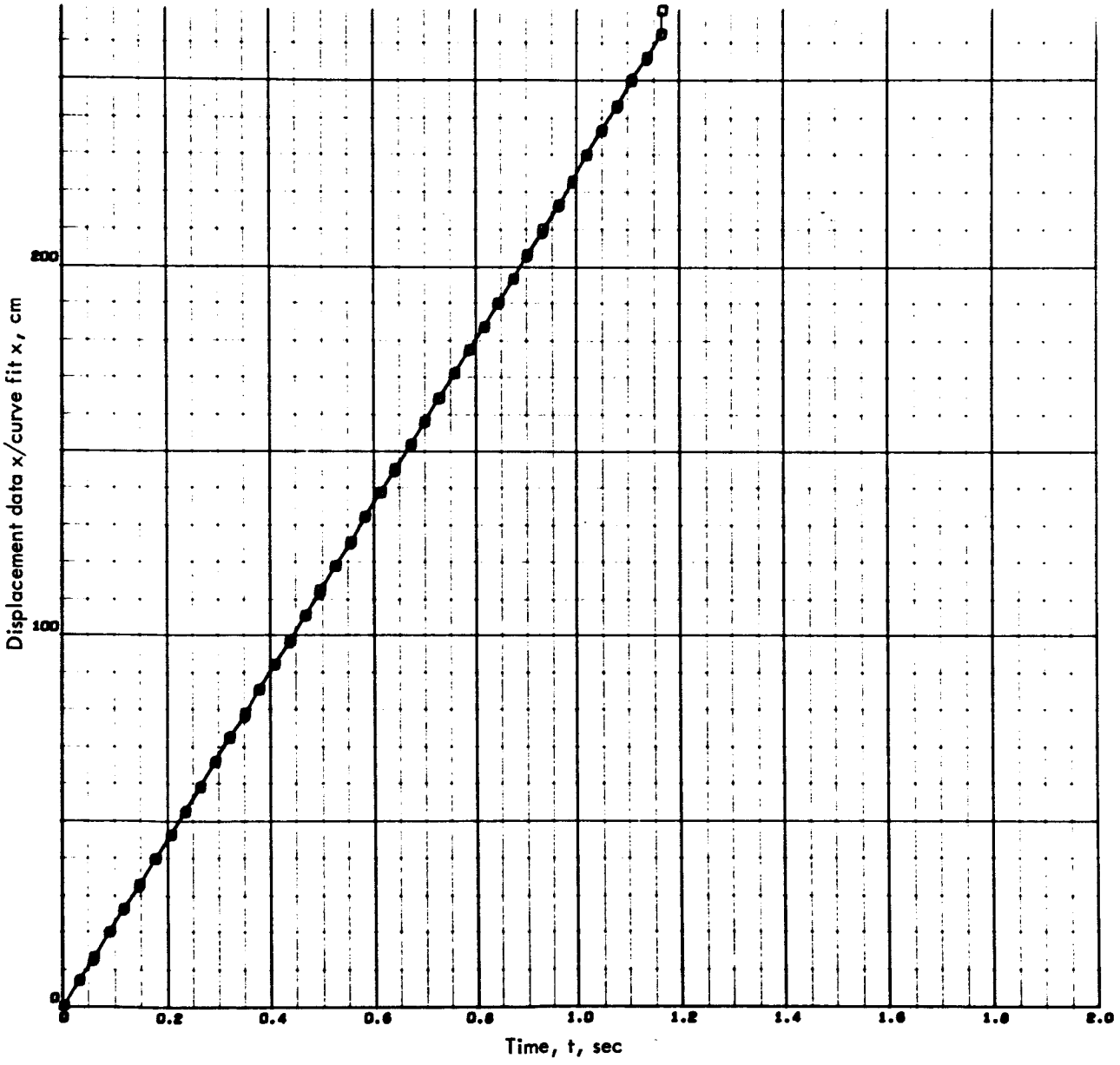

Figure E88. - Displacement data x/curve fit x versus time for segment no. 4, lower arm and hand

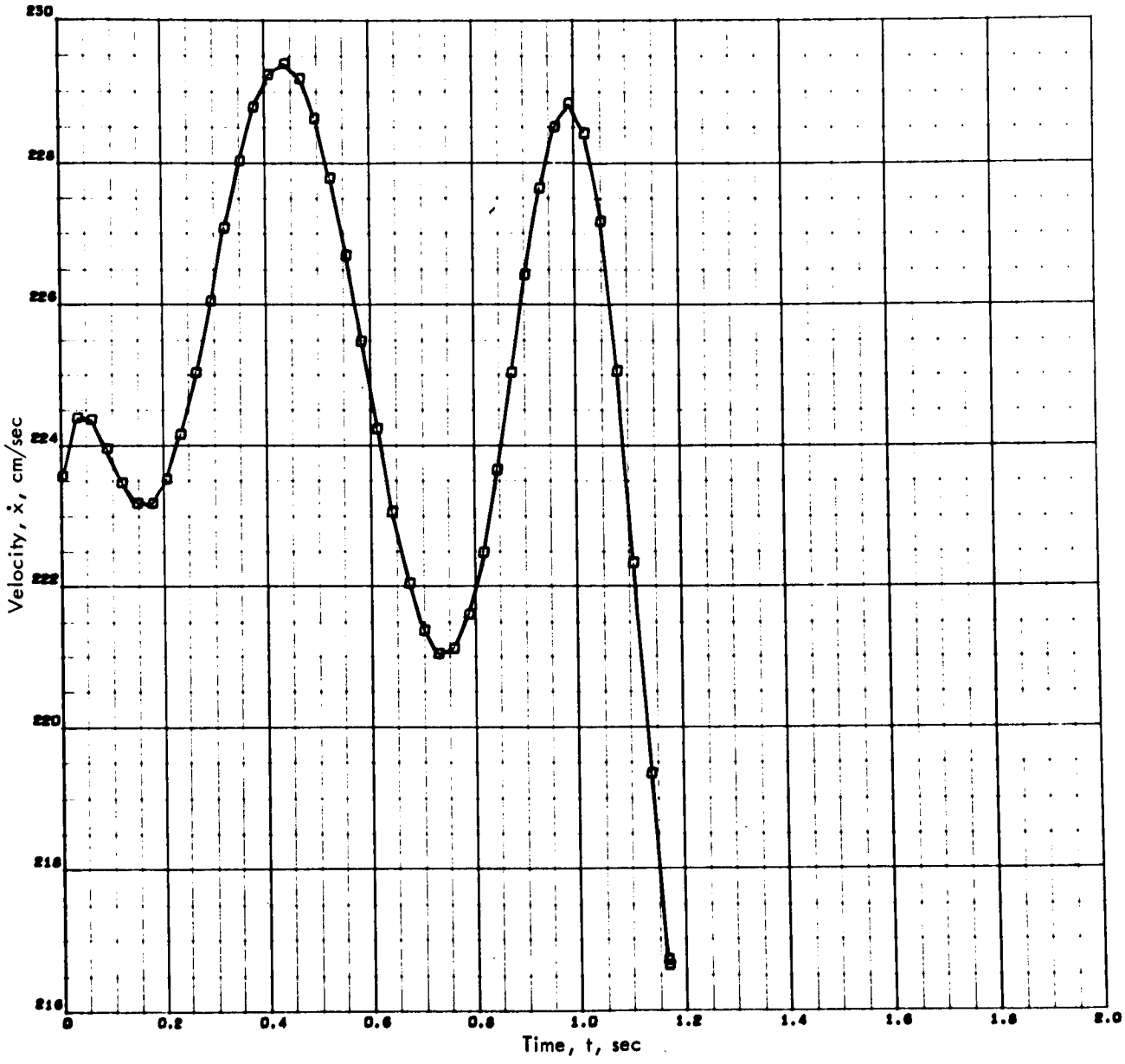

Figure E89. - Velocity $\dot{x}$ versus time for segment no. 4, lower arm and hand

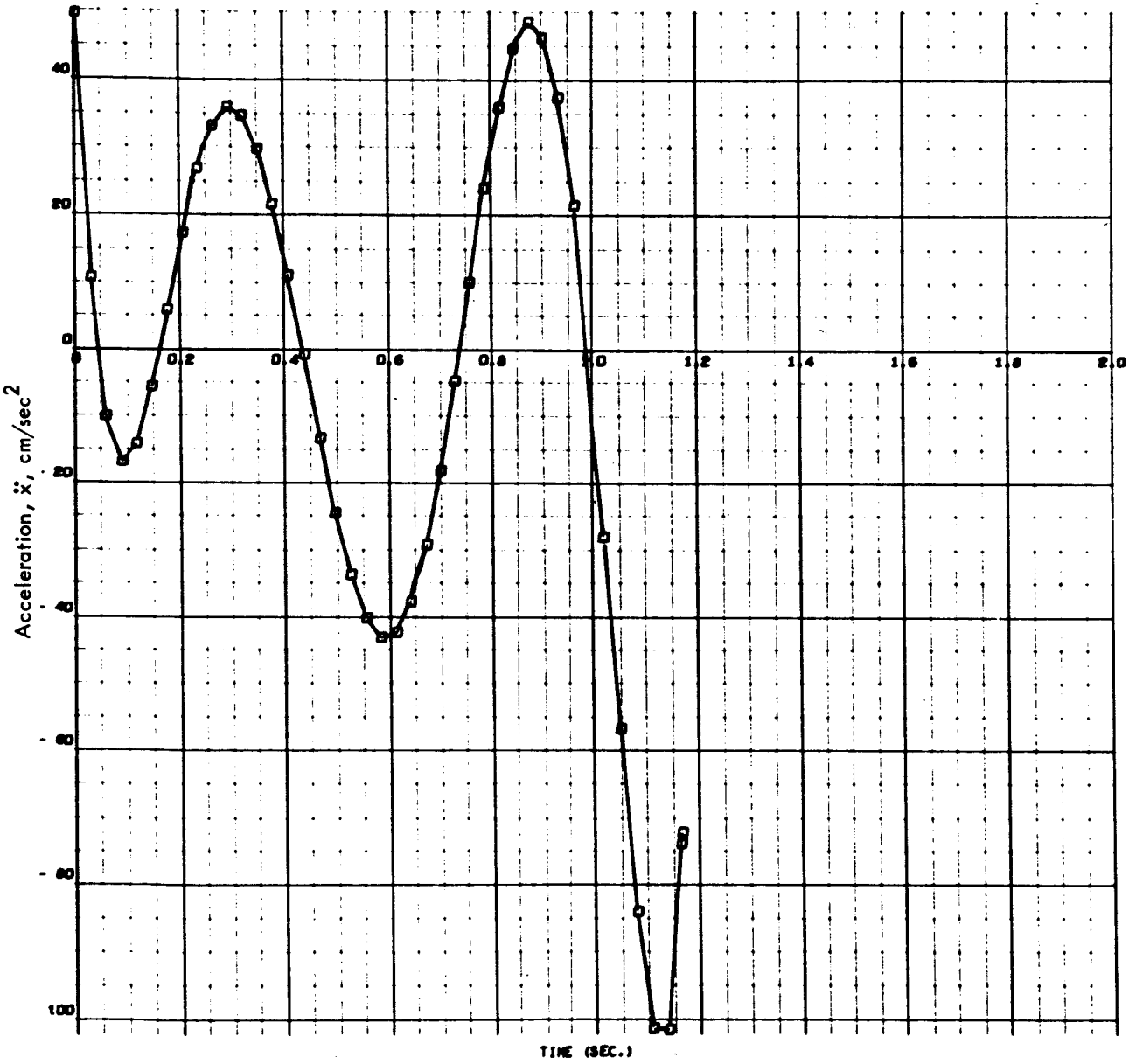

Figure E90. - Acceleration $\ddot{x}$ versus time for segment no. 4, lower arm and hand

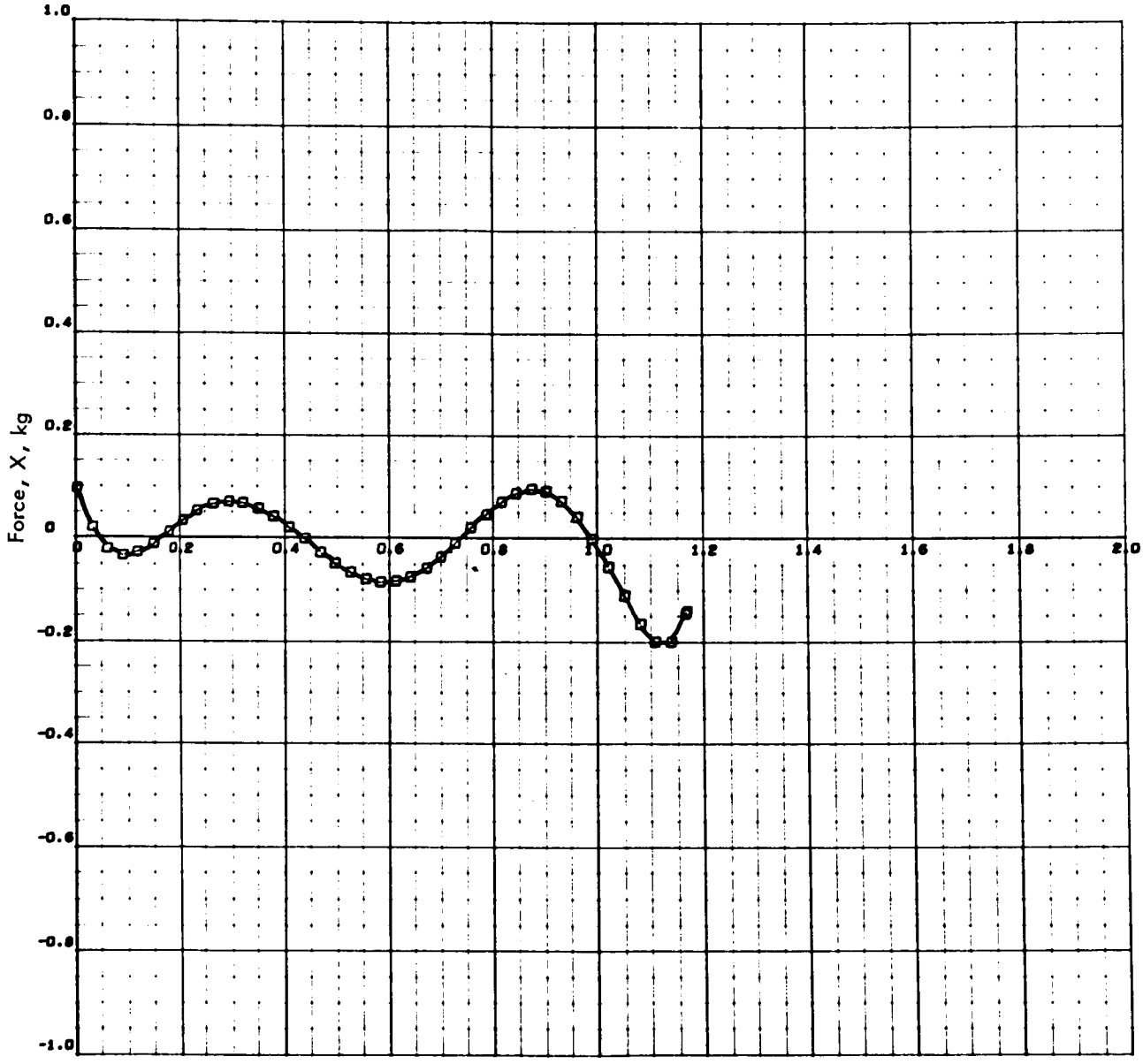

Figure E91. - Force X versus time for segment no. 4, lower arm and hand

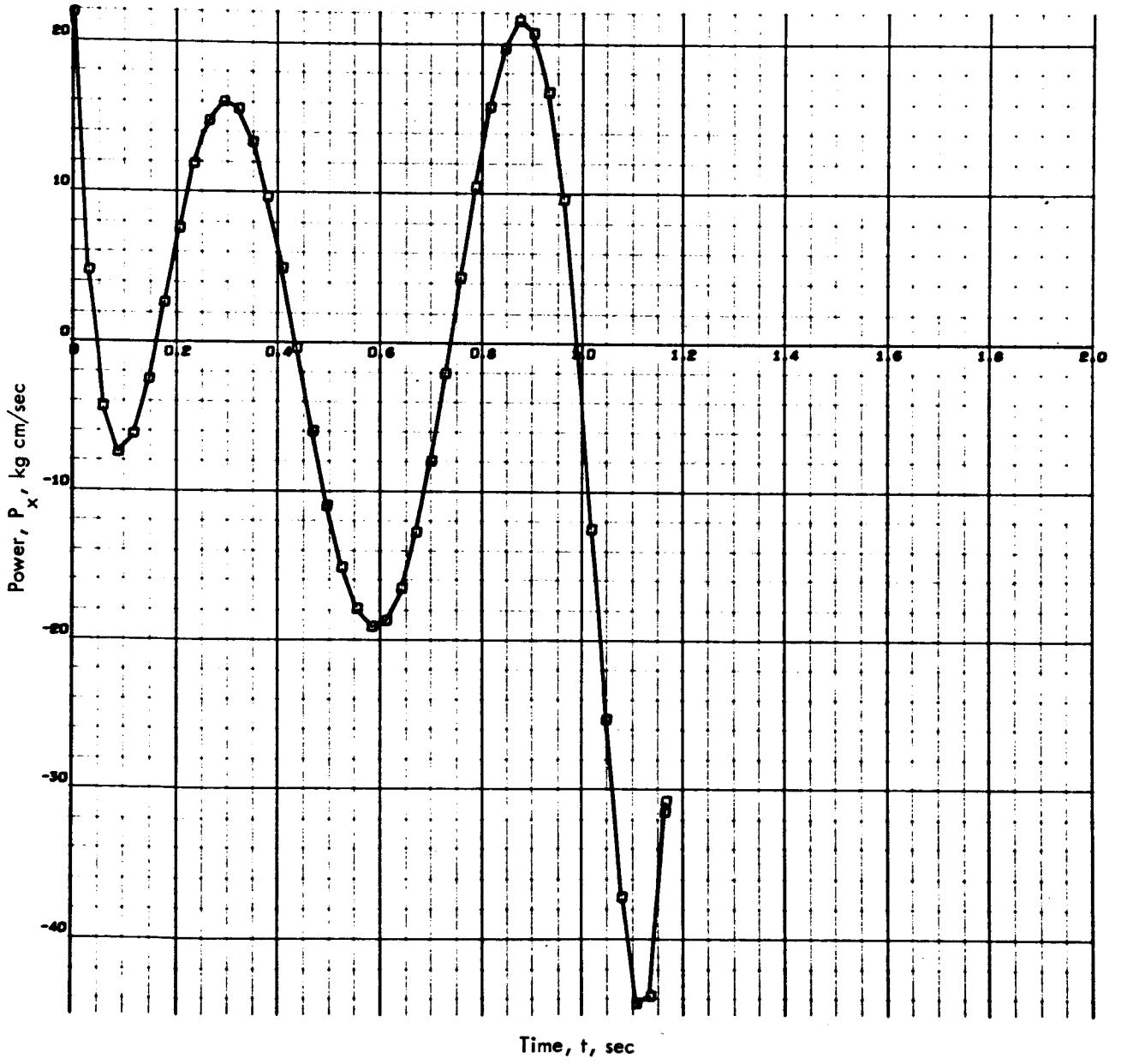

Figure E92. - Power P_x versus time for segment no. 4, lower arm and hand

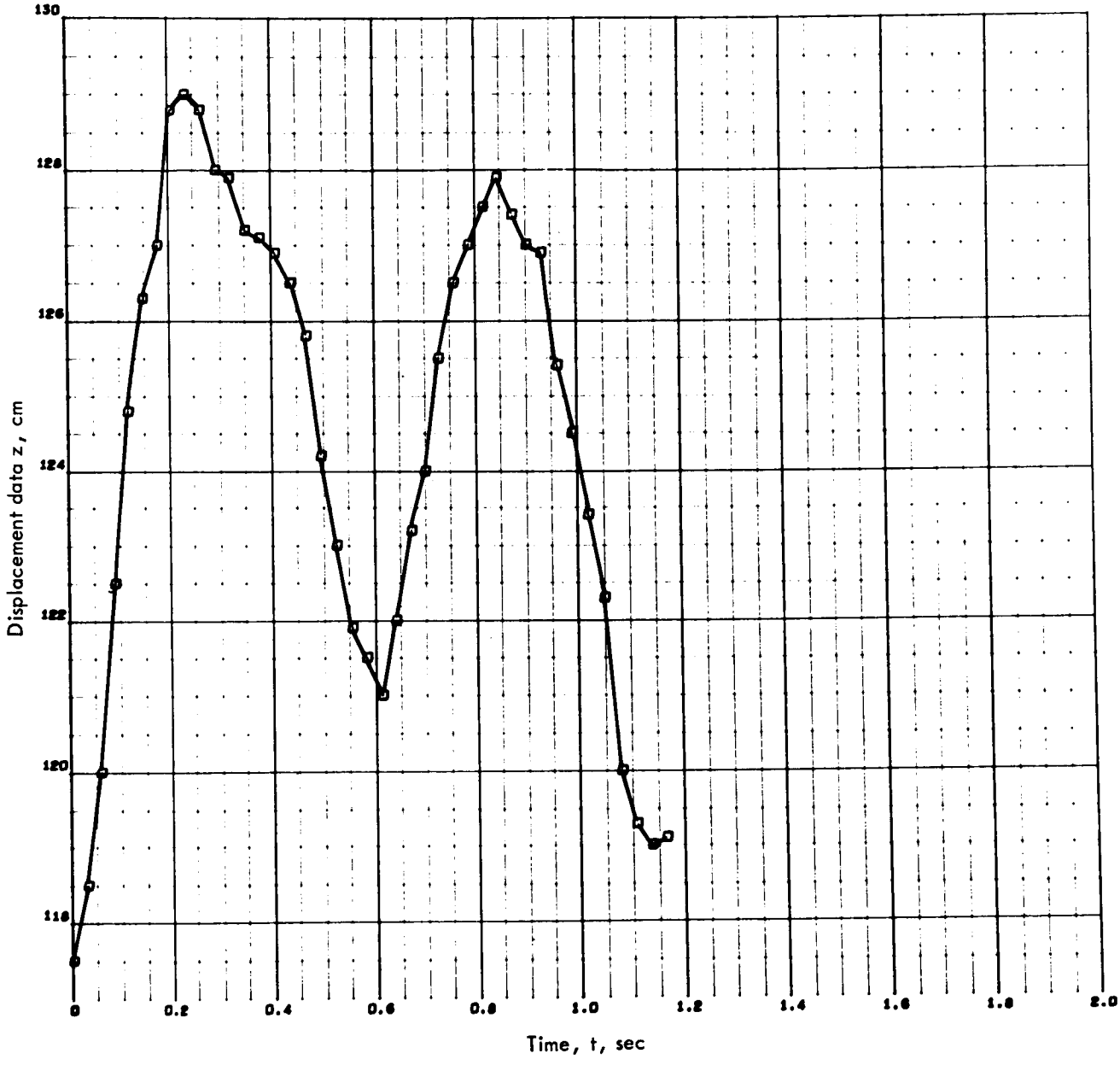

Figure E93. - Displacement data z versus time for segment no. 4, lower arm and hand

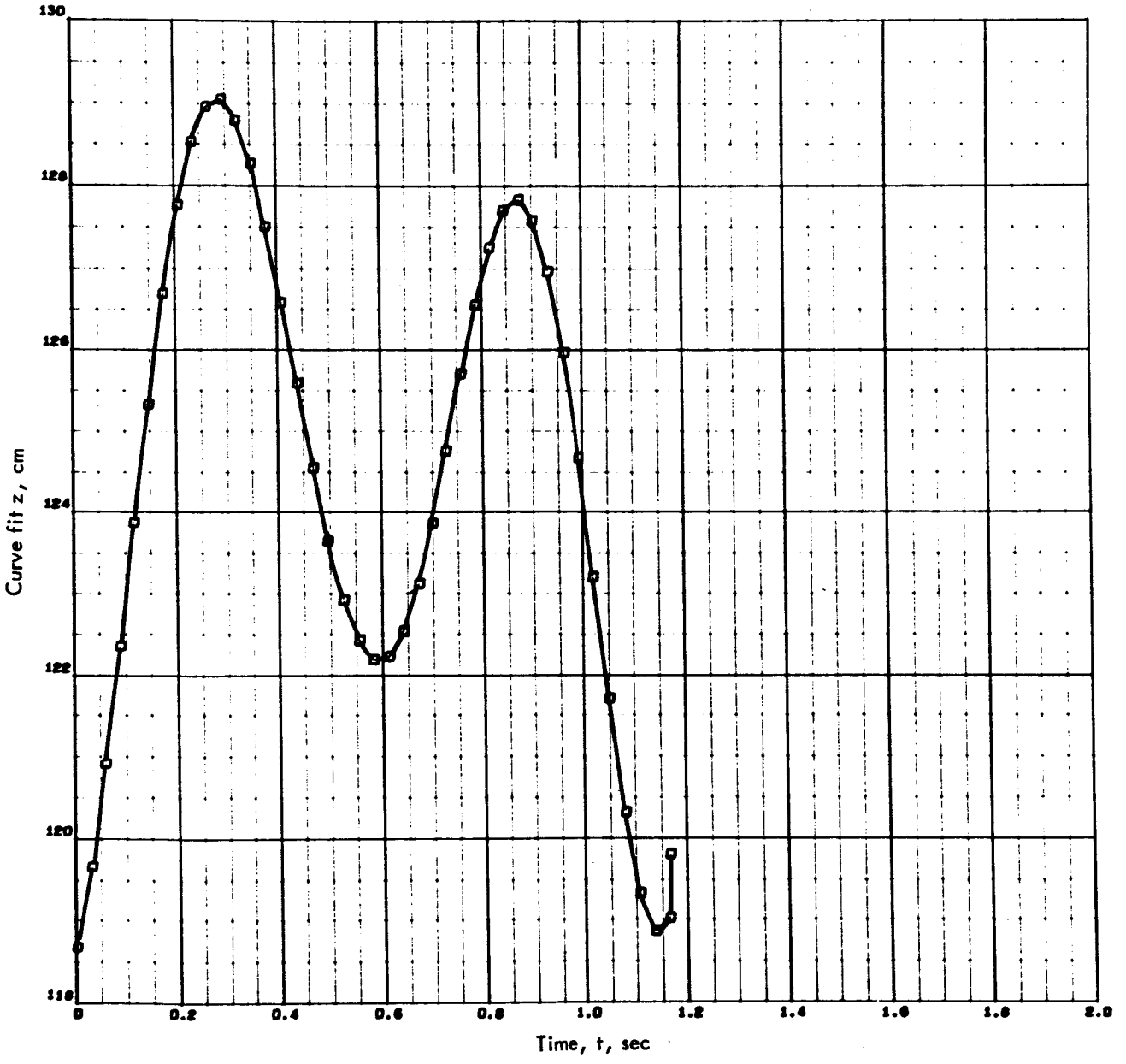

Figure E94. - Curve fit z versus time for segment no. 4, lower arm and hand

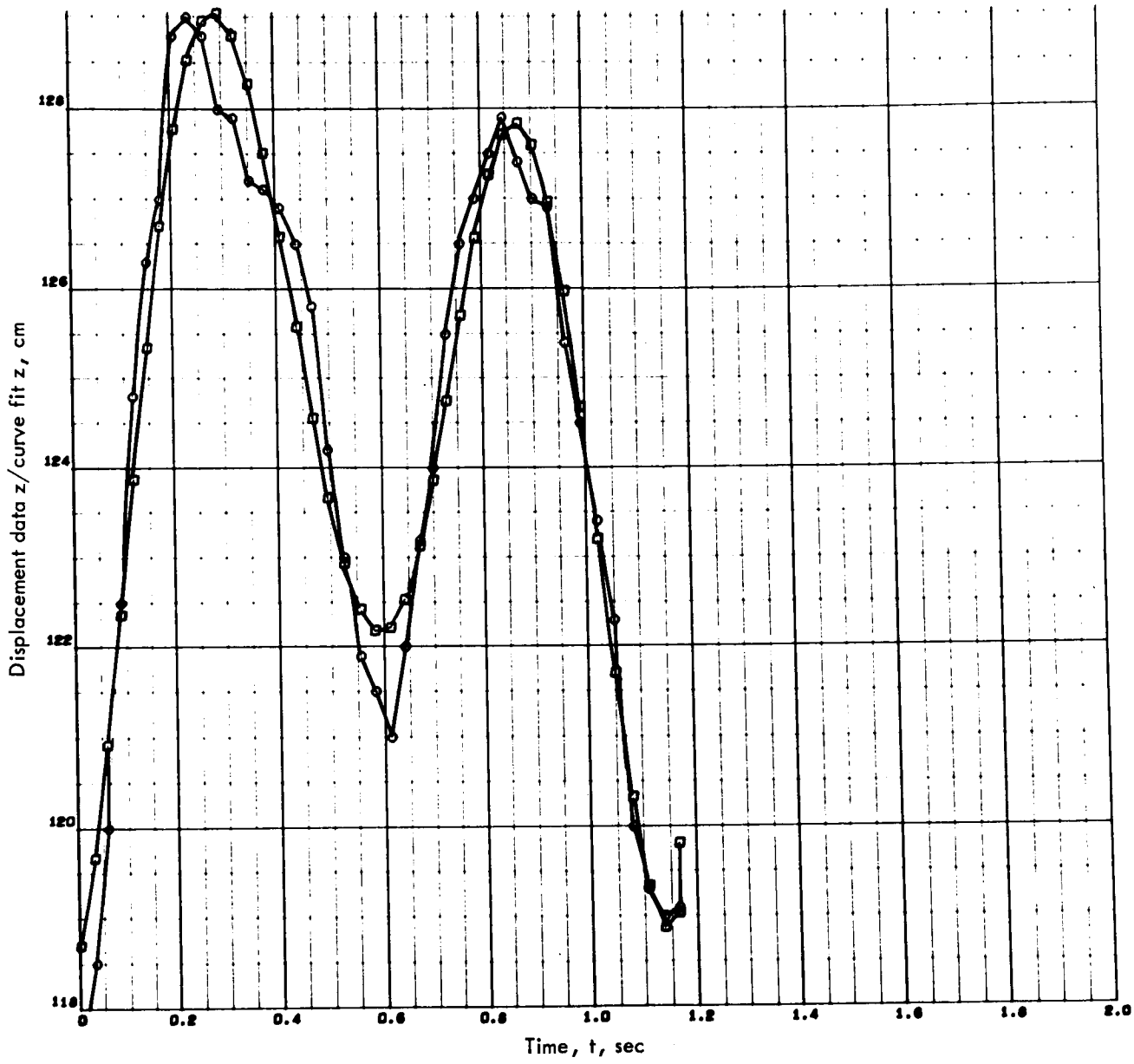

Figure E95. - Displacement data z/curve fit z versus time for segment no. 4, lower arm and hand

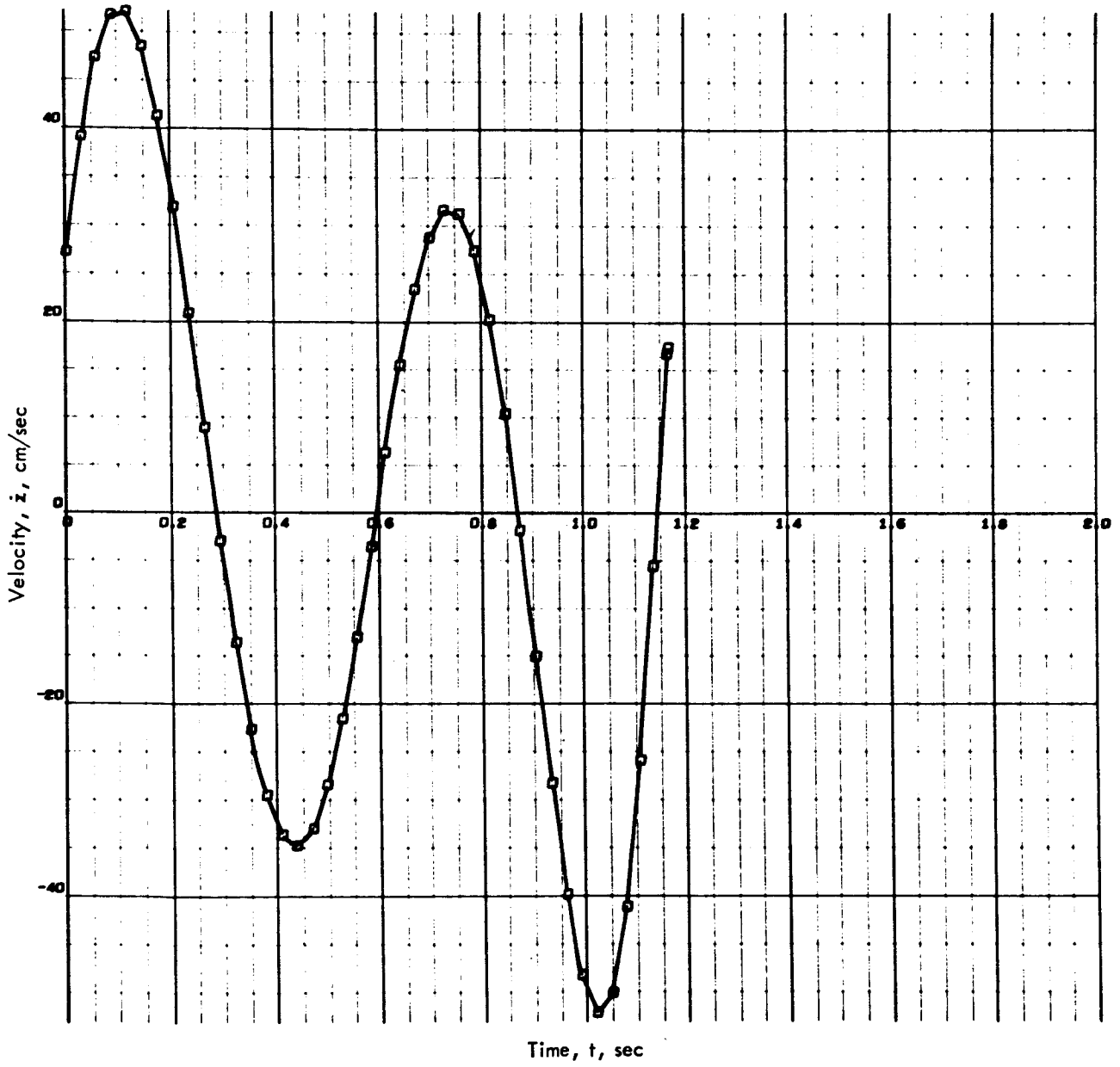

Figure E96. - Velocity ż versus time for segment no. 4, lower arm and hand

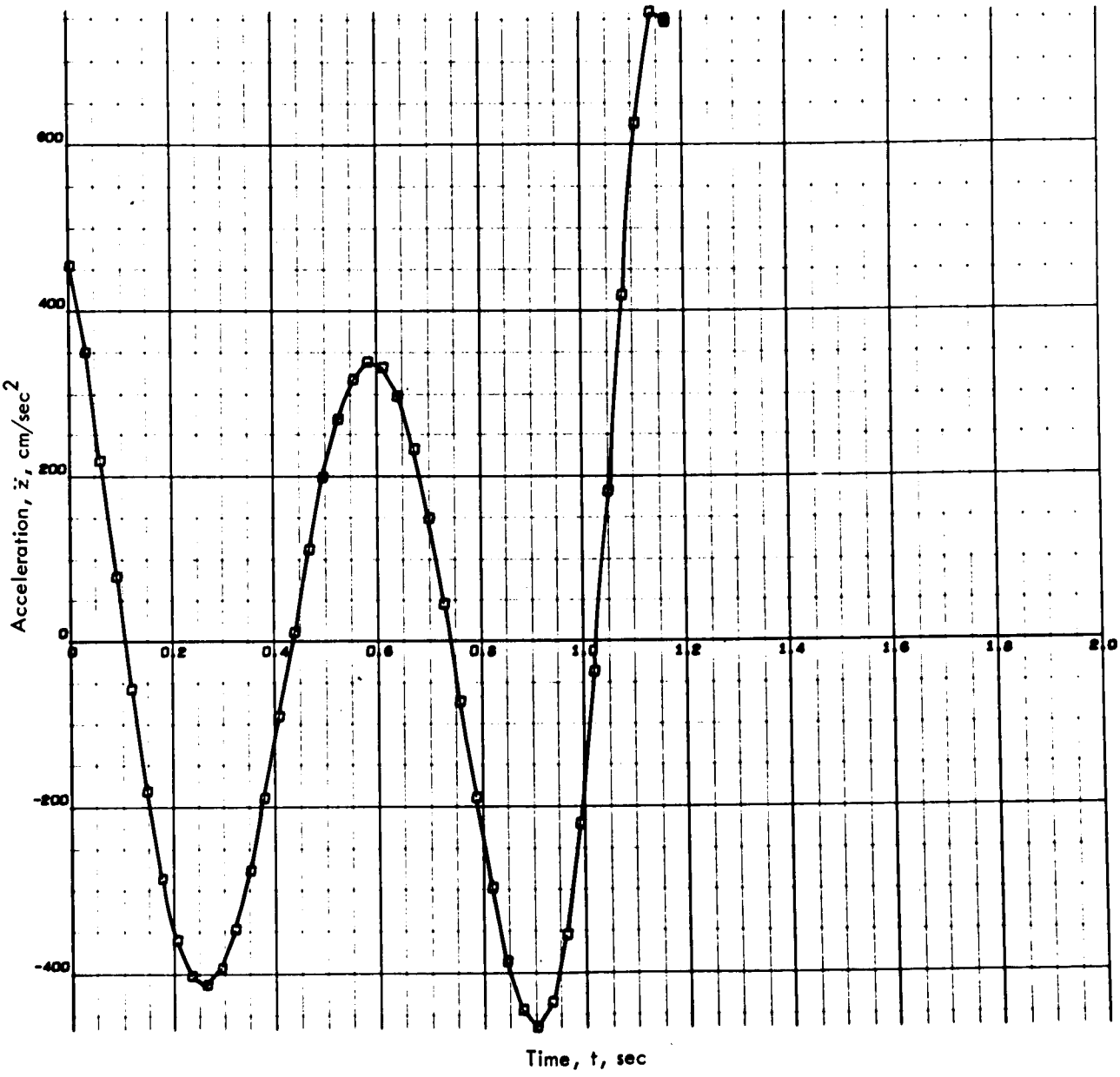

Figure E97. - Acceleration $\ddot{z}$ versus time for segment no. 4, lower arm and hand

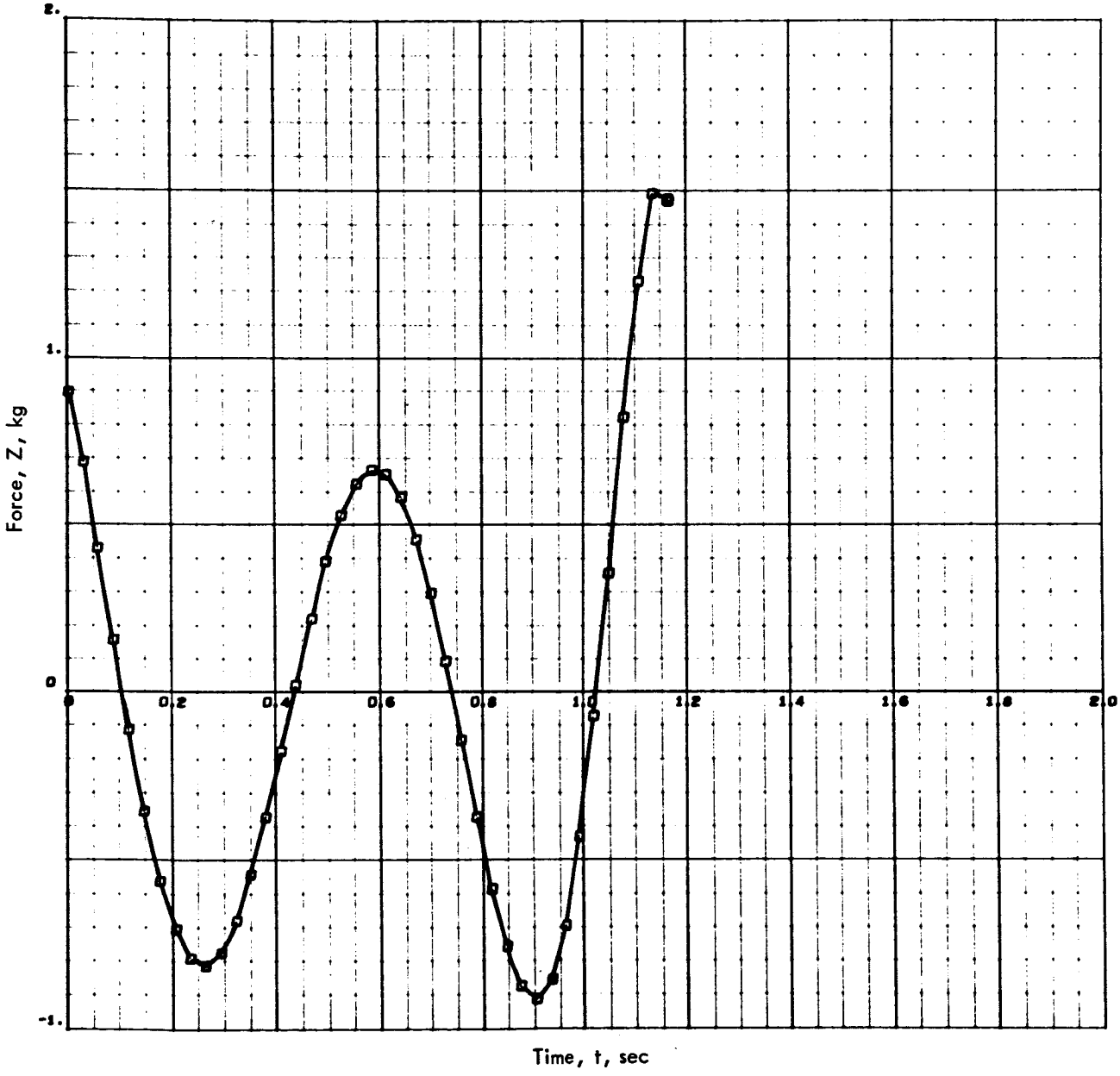

Figure E98. - Force Z versus time for segment no. 4, lower arm and hand

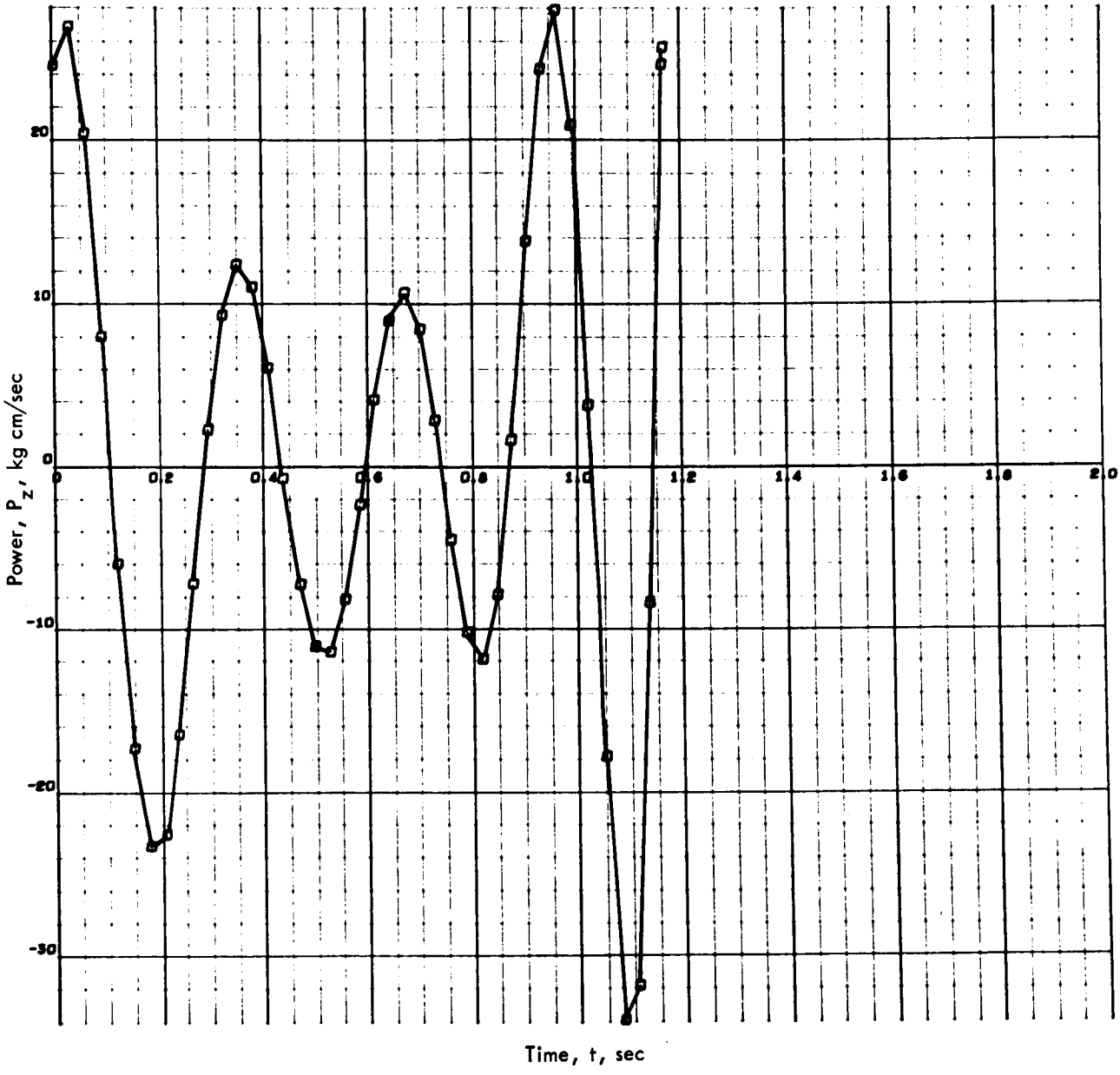

Figure E99. - Power P_z versus time for segment no. 4, lower arm and hand

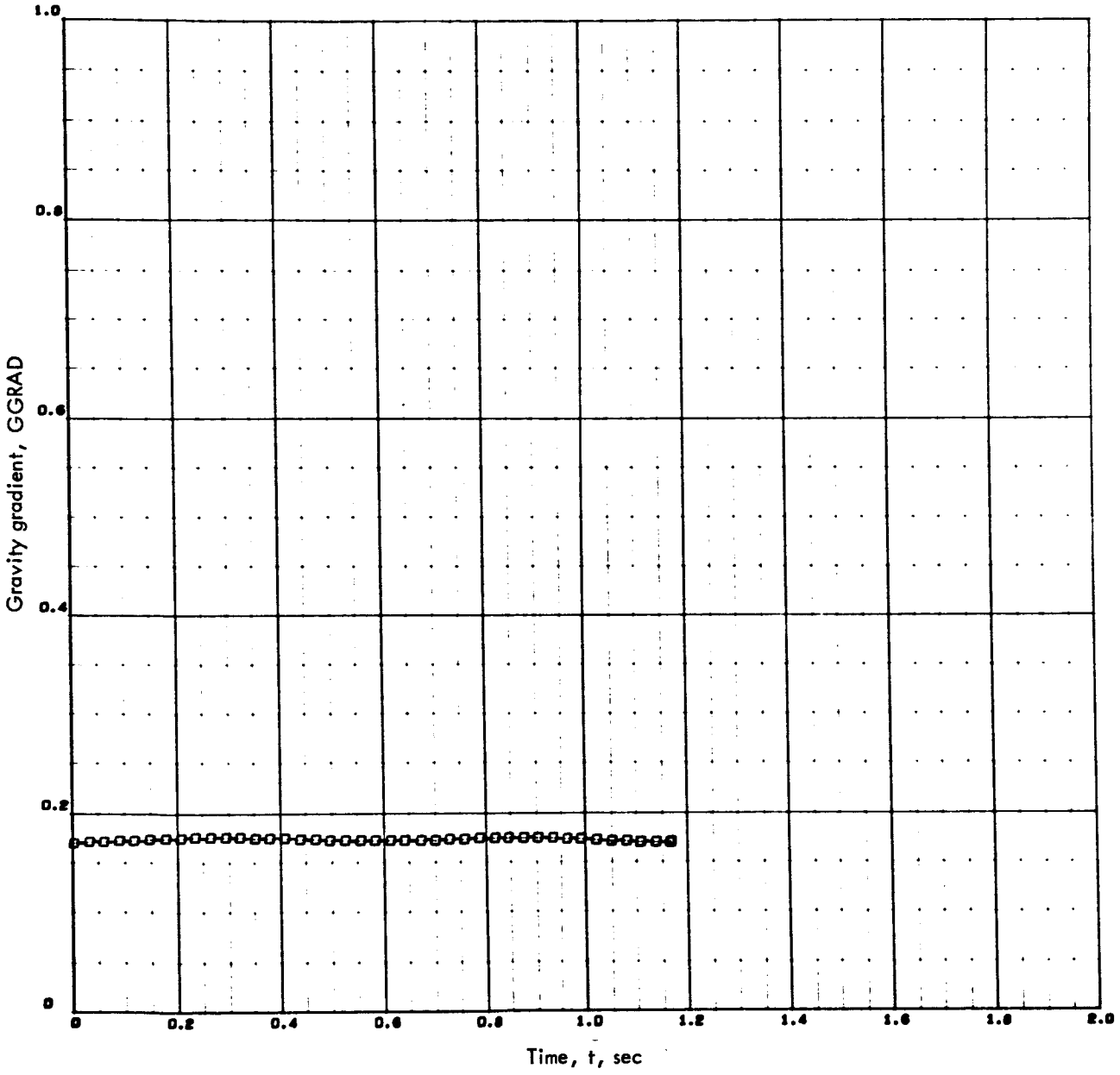

Figure E100.- Gravity gradient versus time for segment no. 4, lower arm and hand

Figure E101. - Power of potential energy versus time for segment no. 4, lower arm and hand

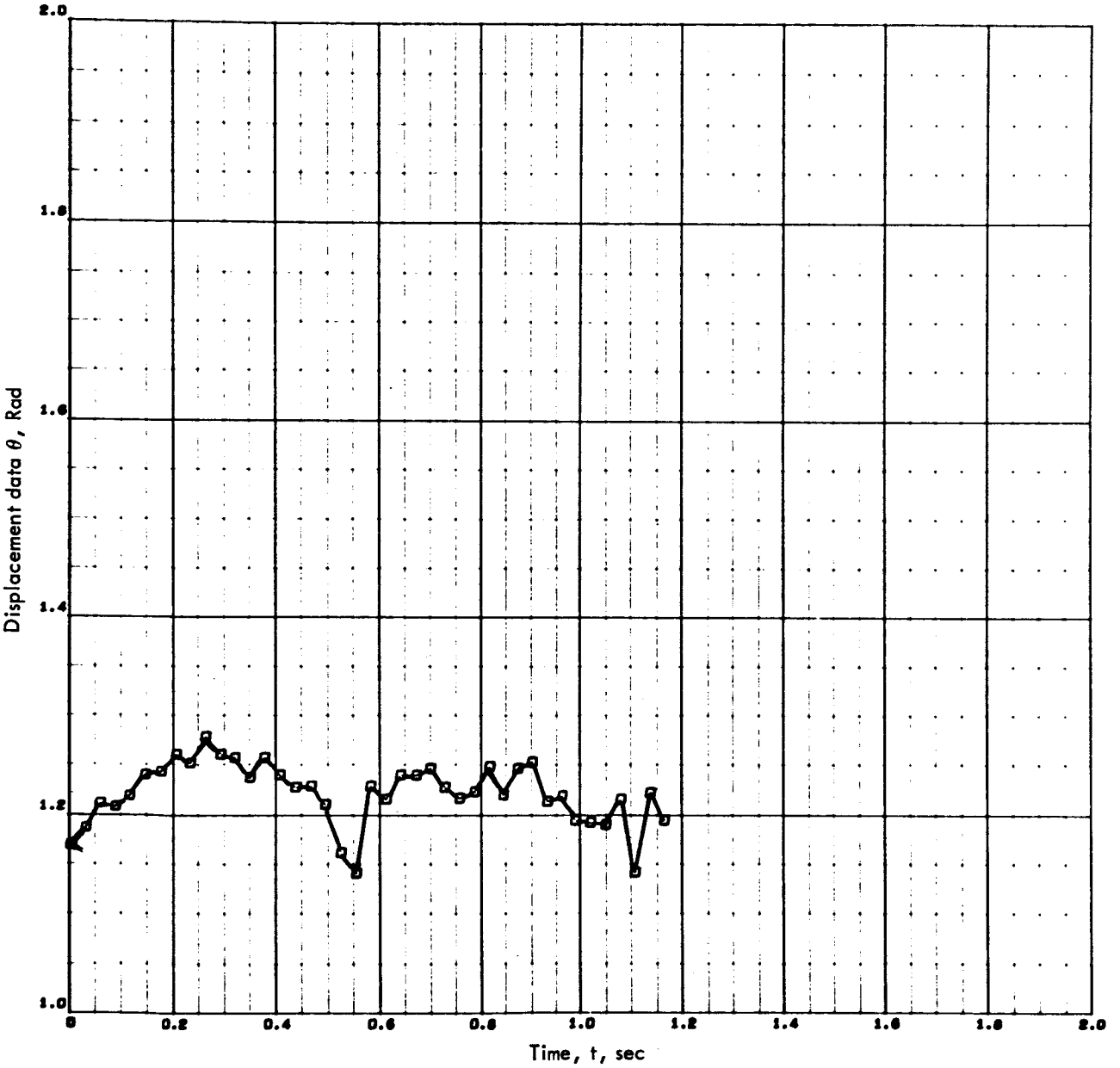

Figure E102. - Displacement data θ versus time for segment no. 4, lower arm and hand

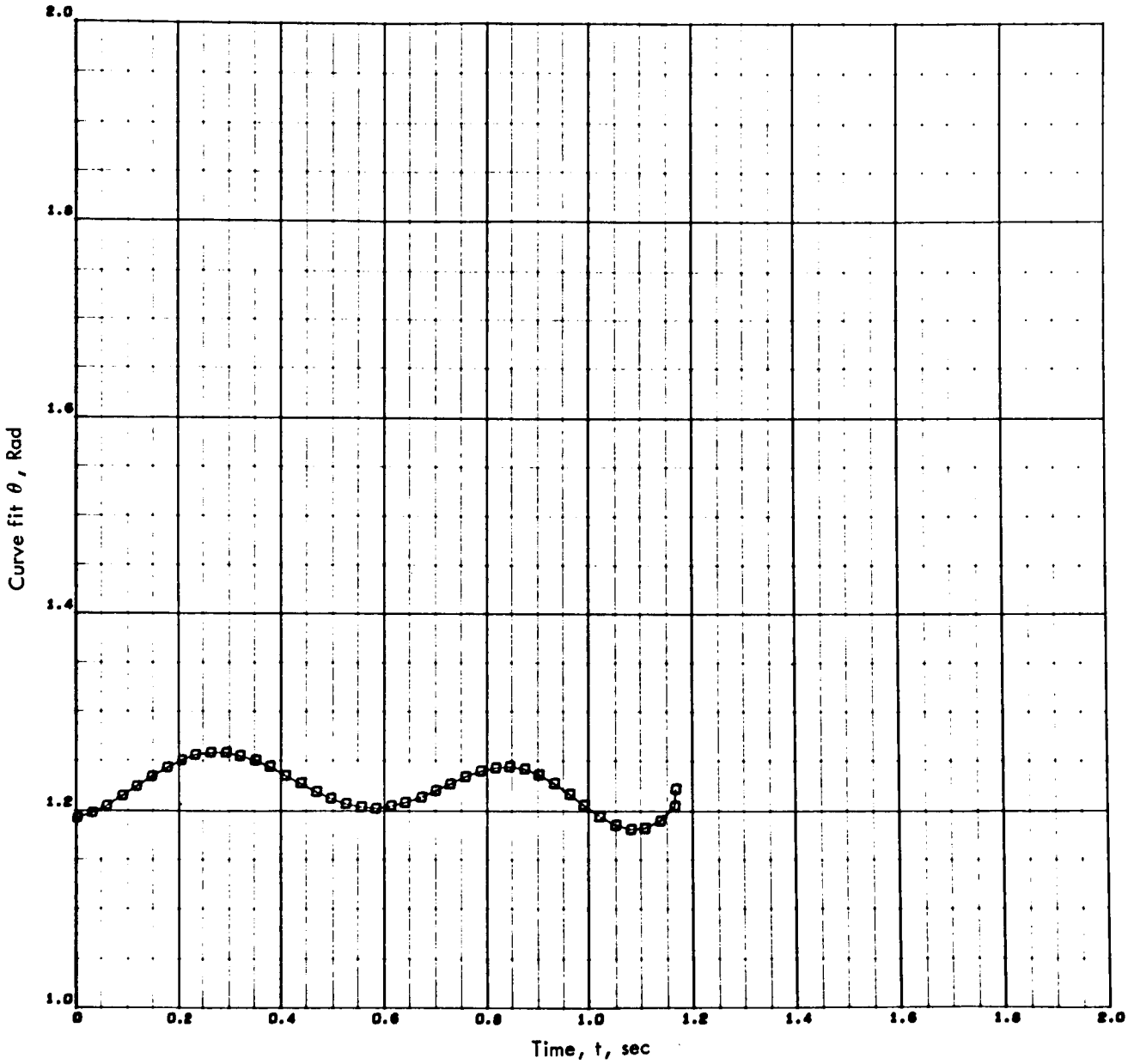

Figure E103. - Curve fit θ versus time for segment no. 4, lower arm and hand

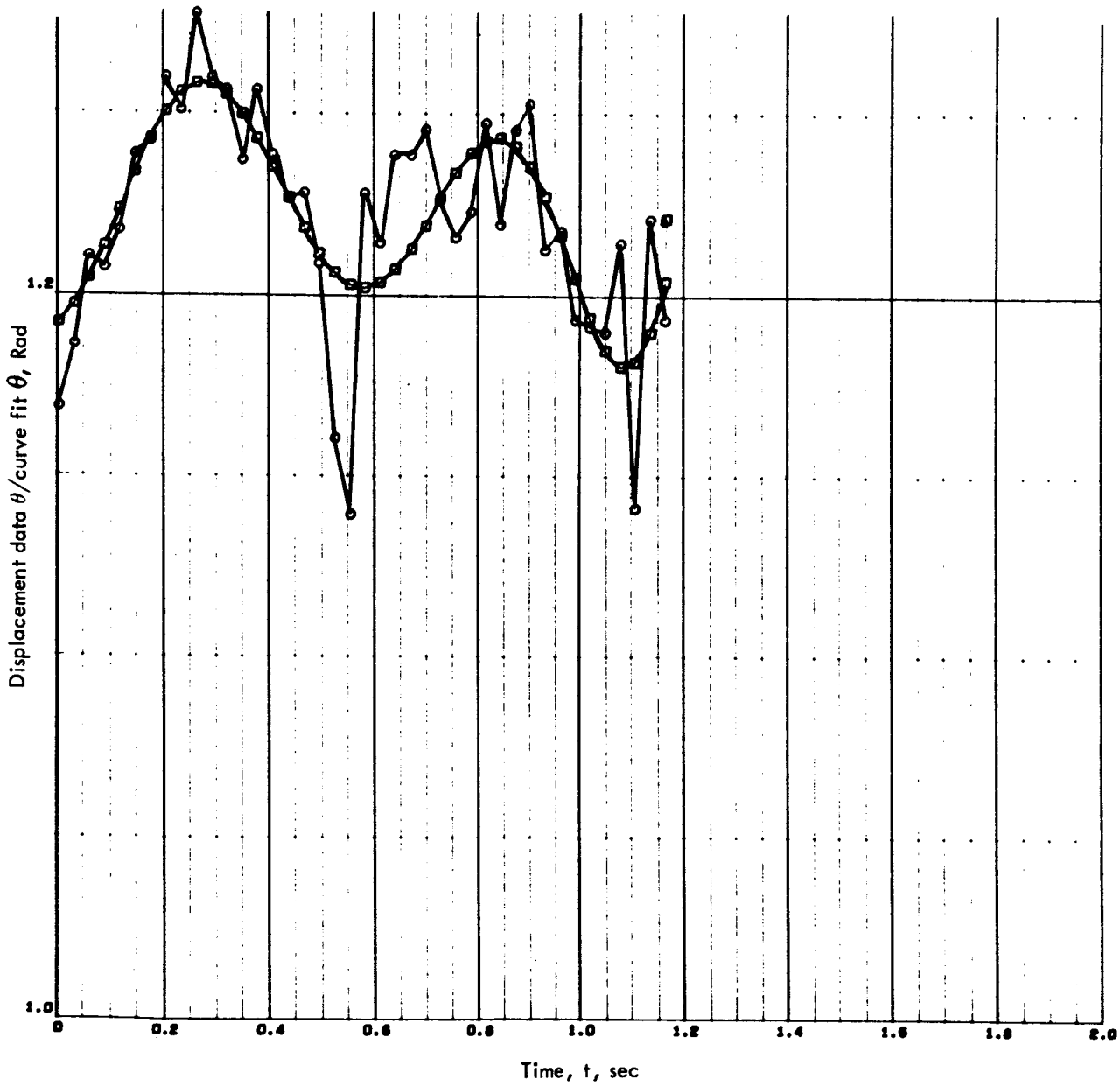

Figure E104.- Displacement data θ/curve fit θ versus time for segment no. 4, lower arm and hand

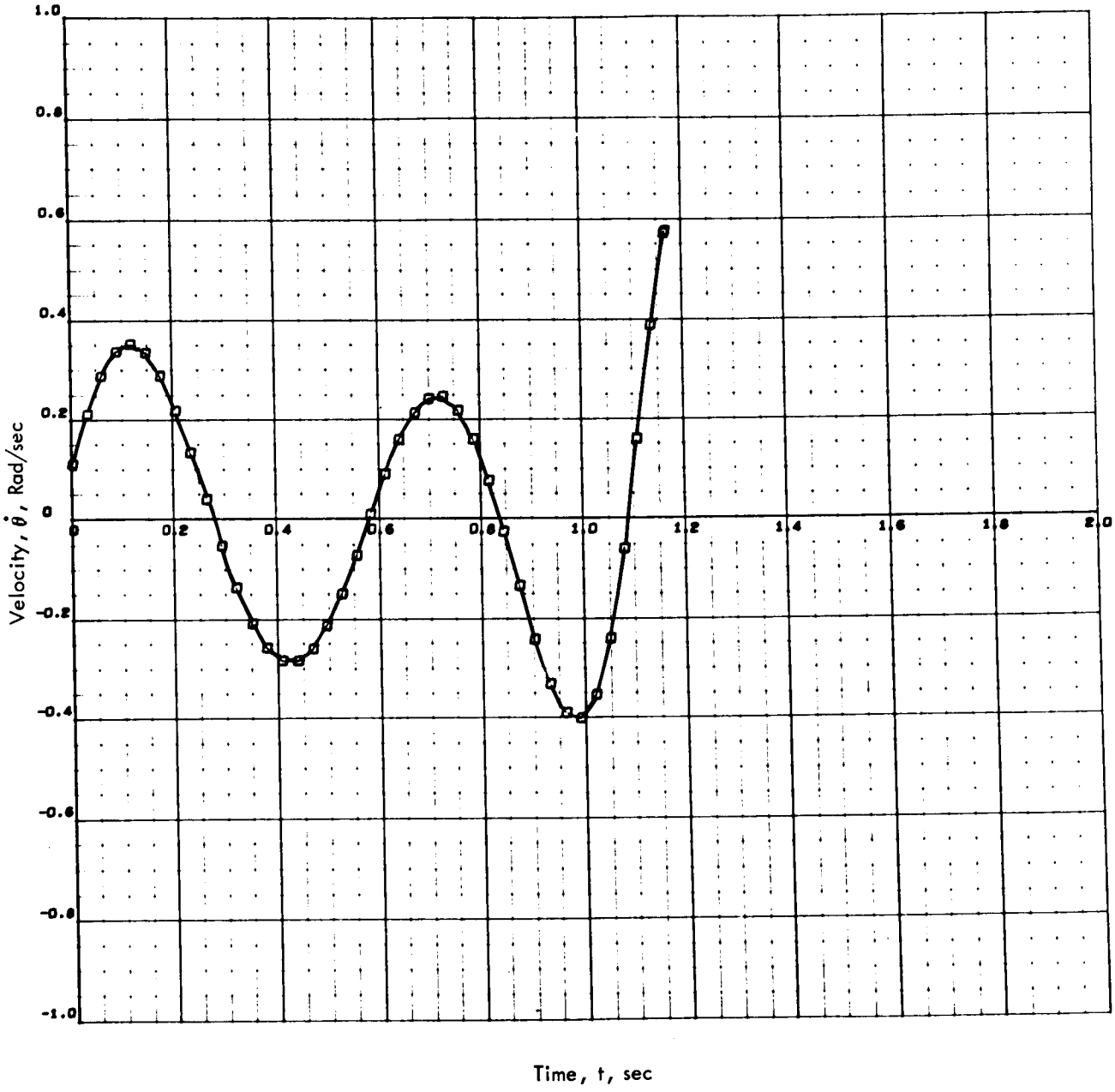

Figure E105. - Velocity $\dot{\theta}$ versus time for segment no. 4, lower arm and hand

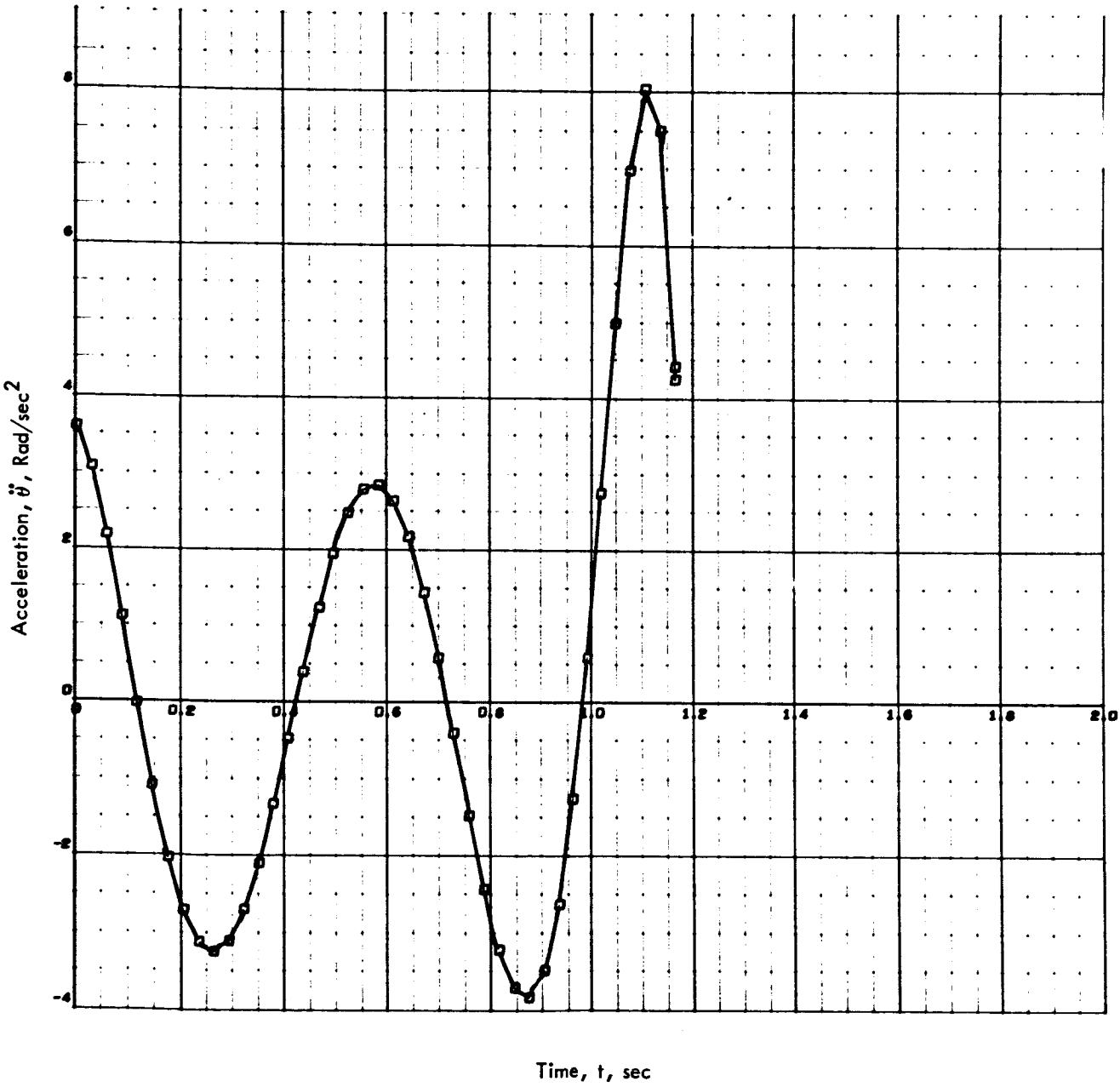

Figure E106. - Acceleration $\ddot{\theta}$ versus time for segment no. 4, lower arm and hand

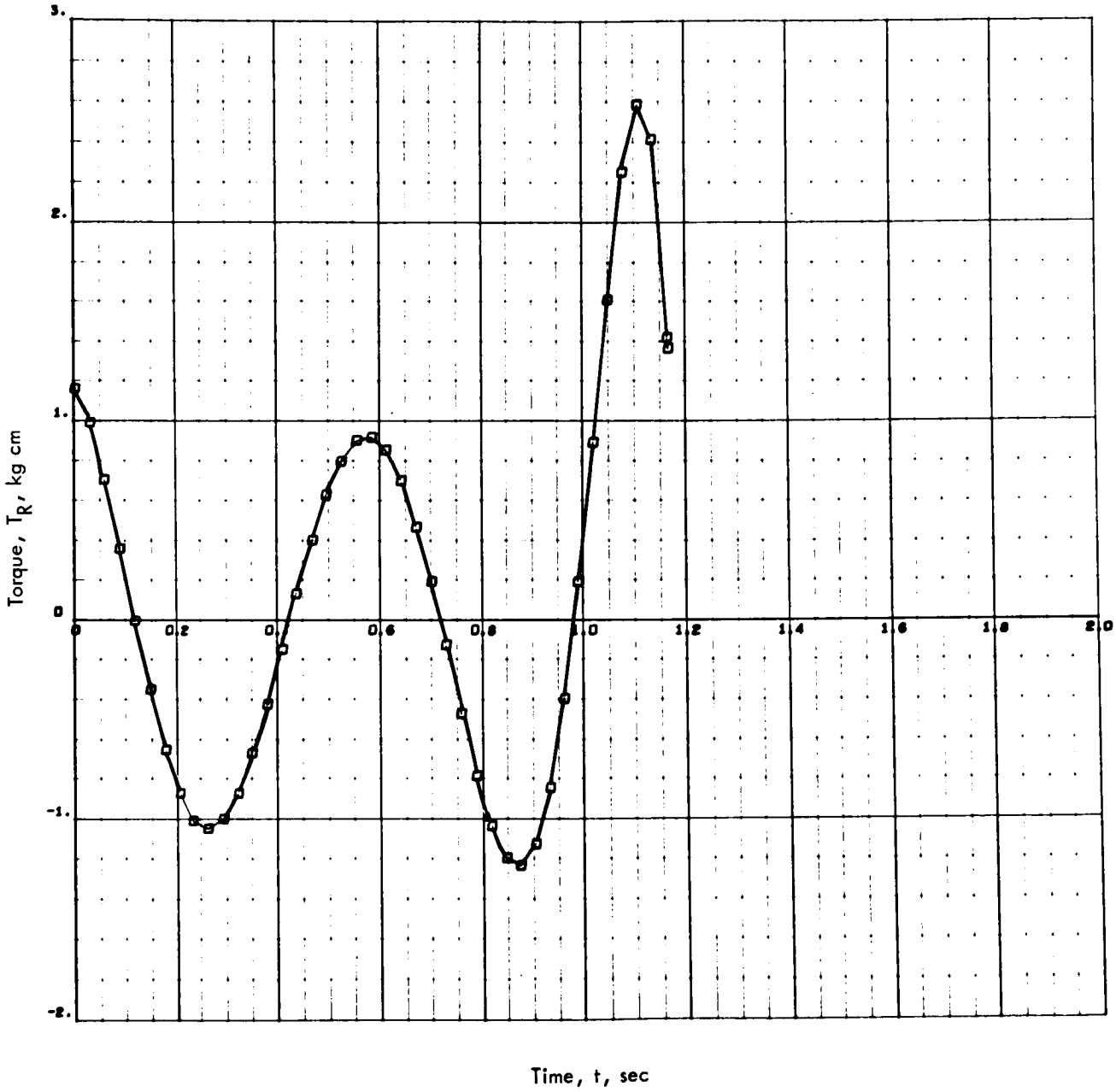

Figure E107. - Torque T_R versus time for segment no. 4, lower arm and hand

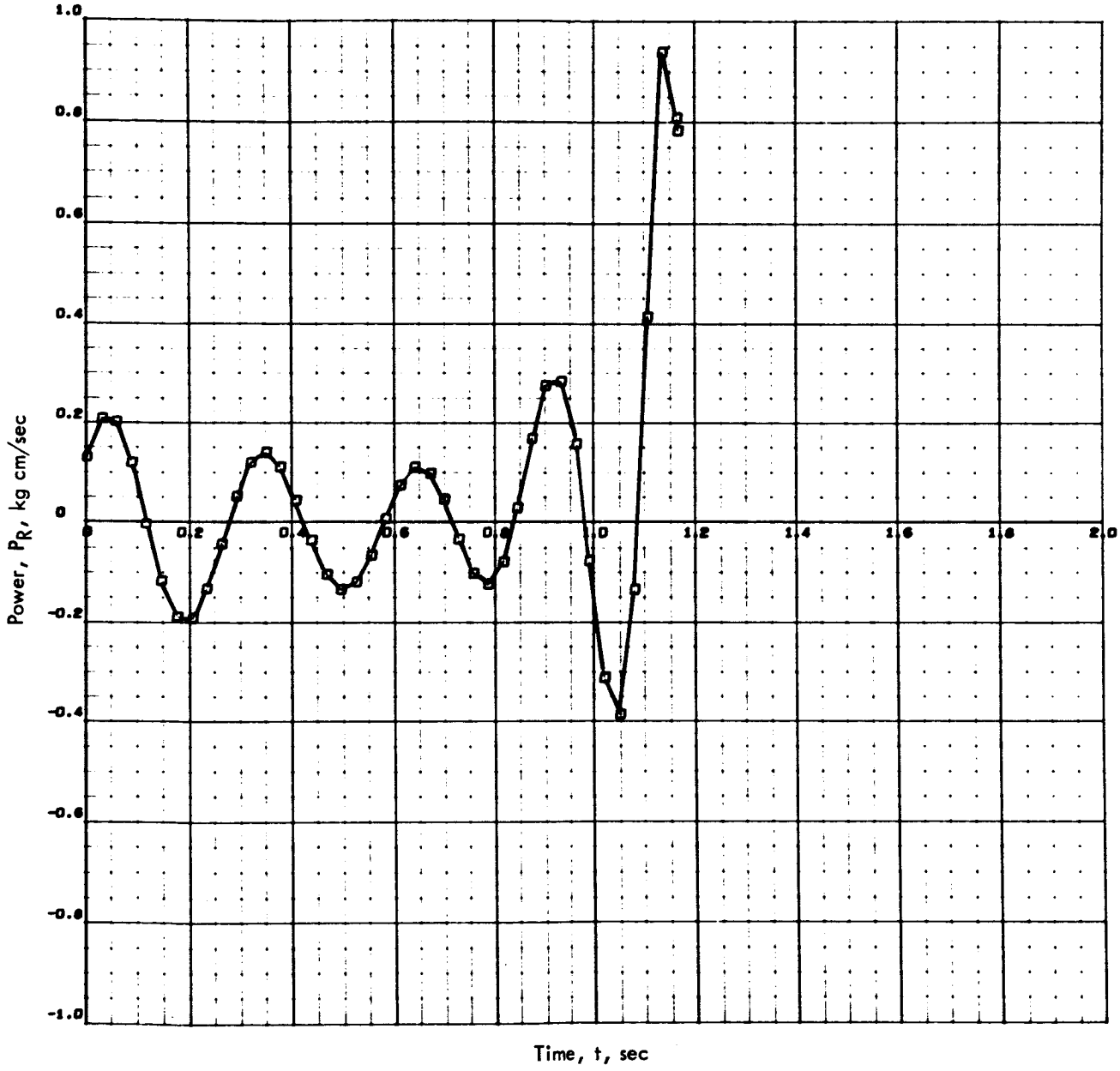

Figure E108. - Power P_R versus time for segment no. 4, lower arm and hand

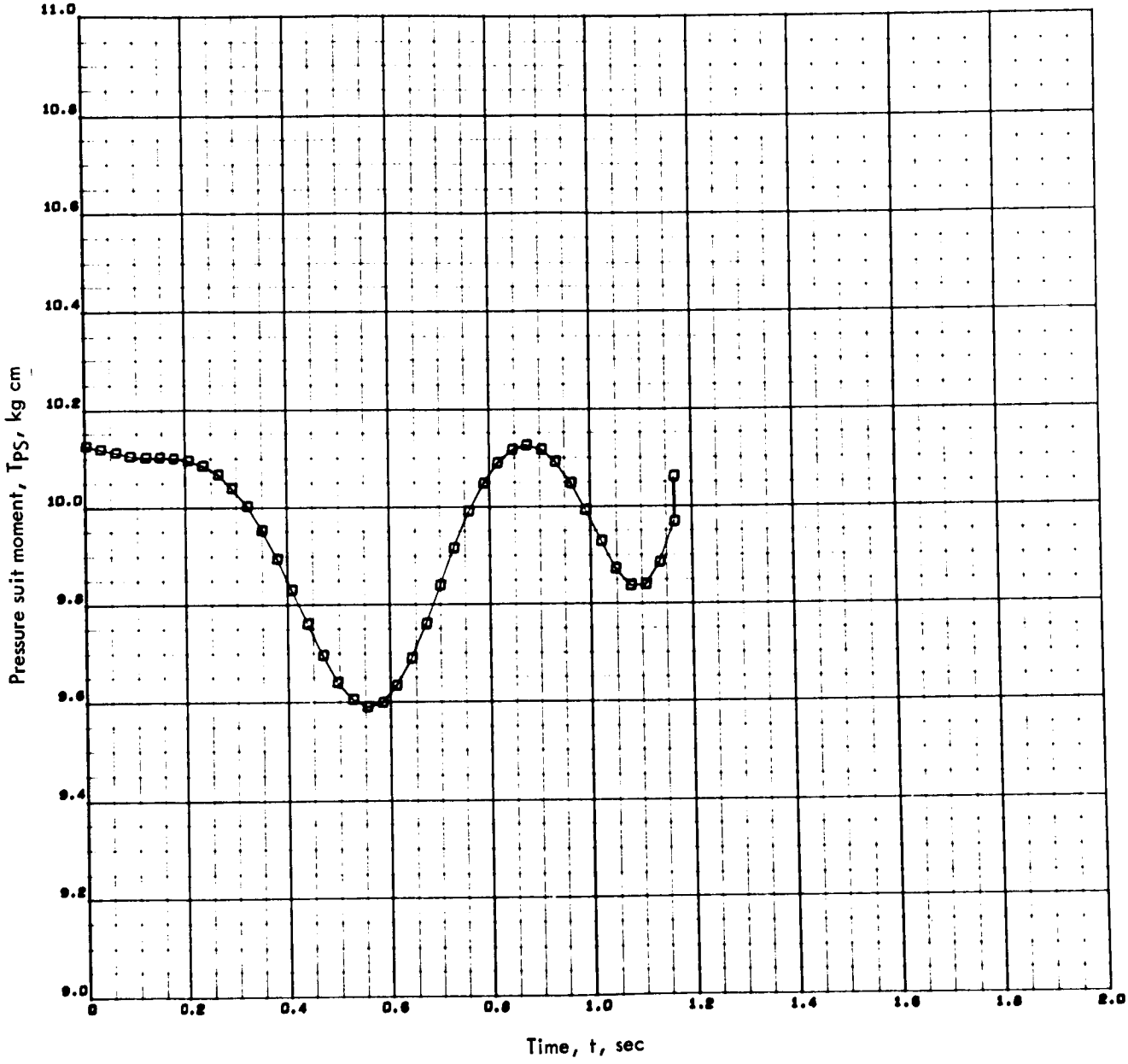

Figure E109. - Pressure suit moment T_{PS} versus time for segment no. 4, lower arm and hand

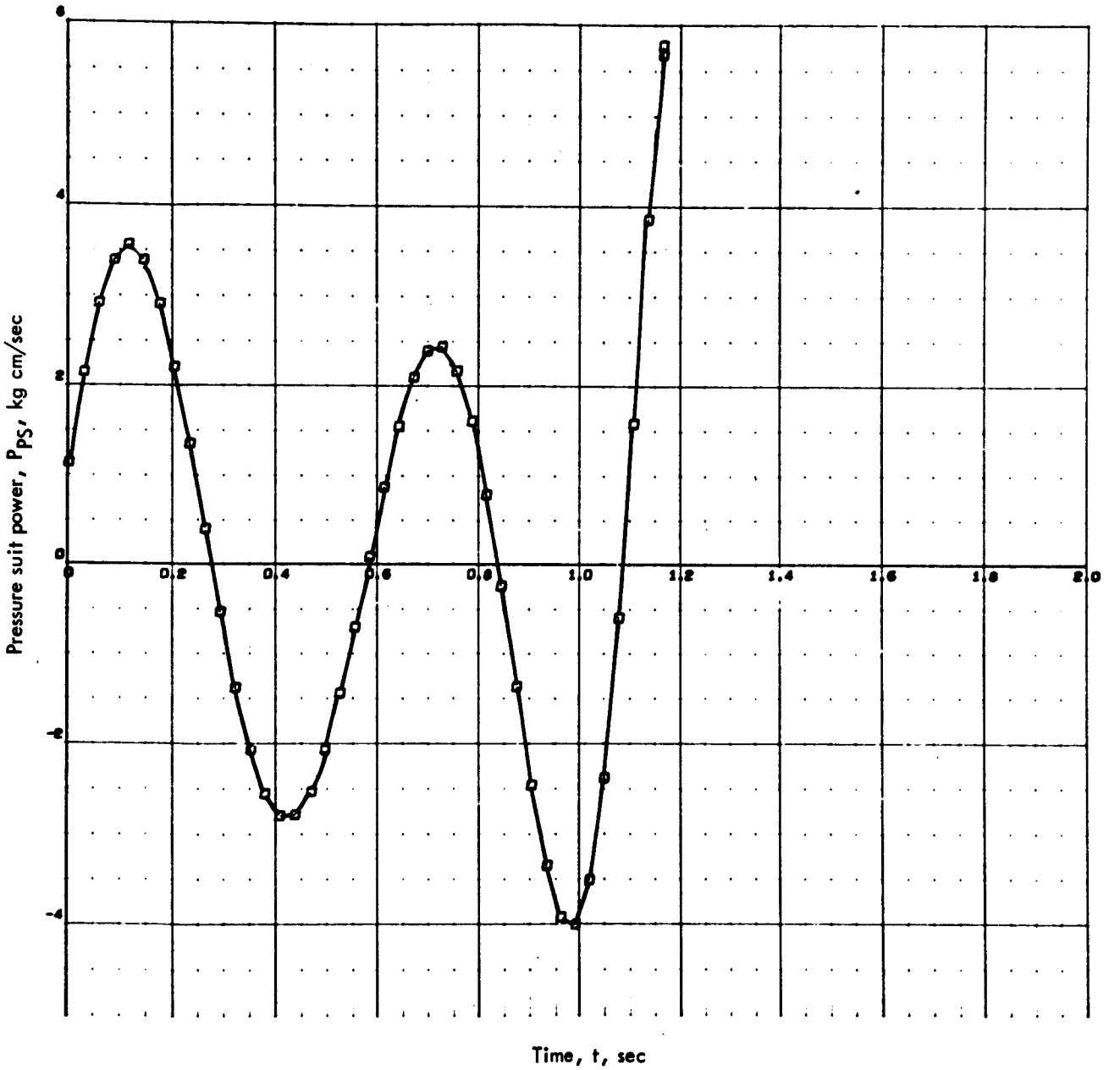

Figure E110. - Pressure suit power P_{PS} versus time for segment no. 4, lower arm and hand

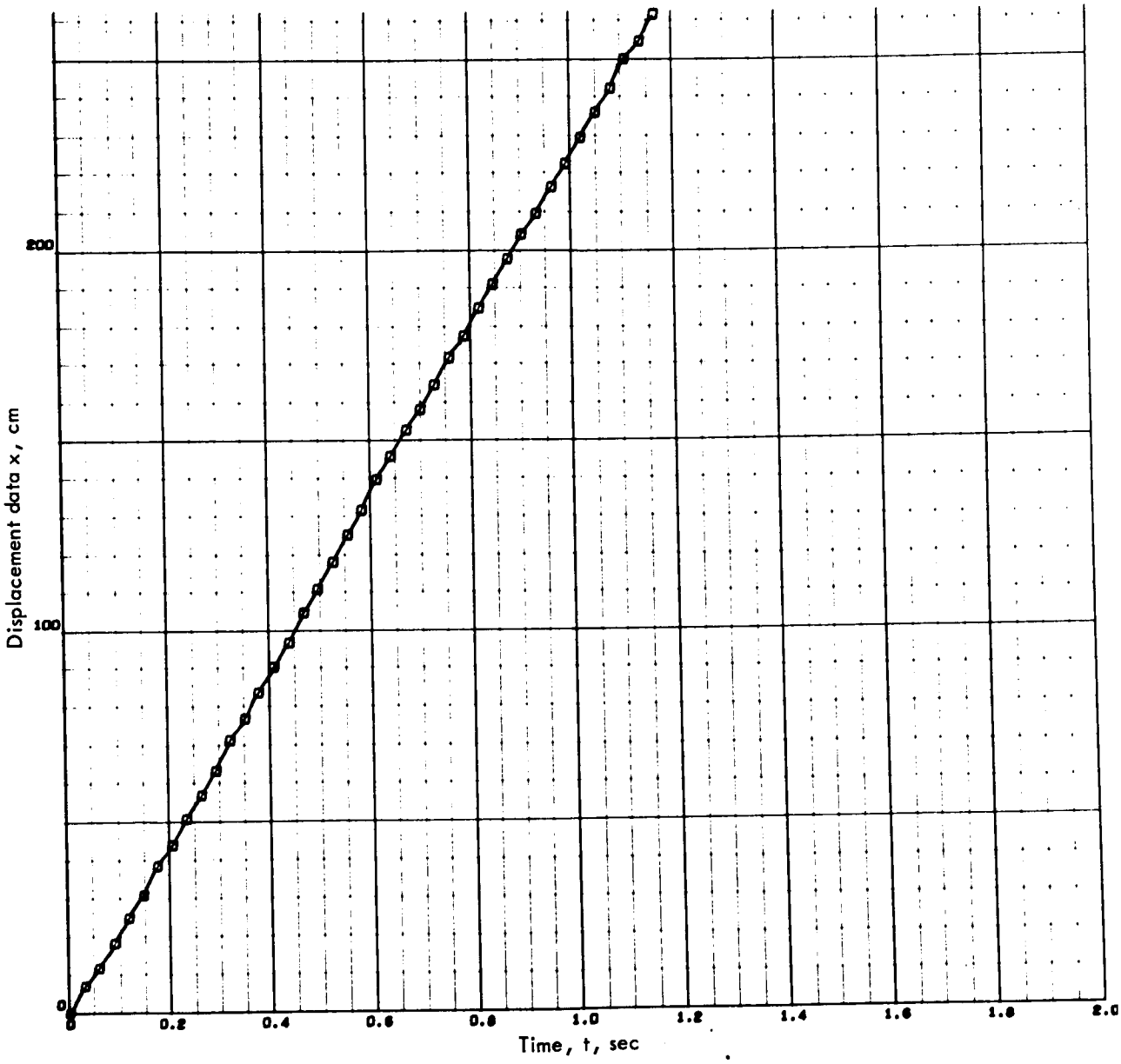

Figure E111. - Displacement data x versus time for segment no. 5, thigh

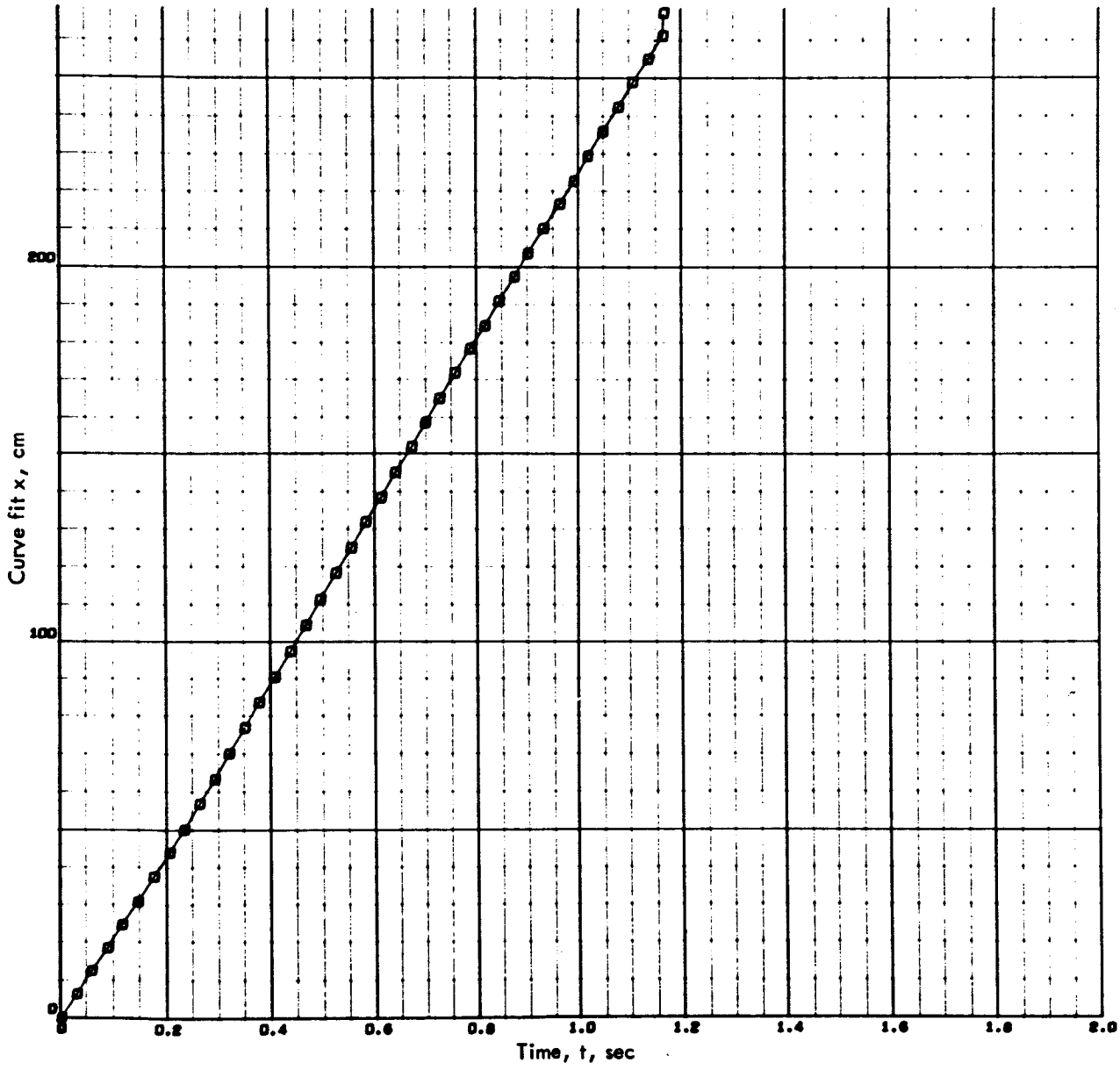

Figure E112. - Curve fit x versus time for segment no. 5, thigh

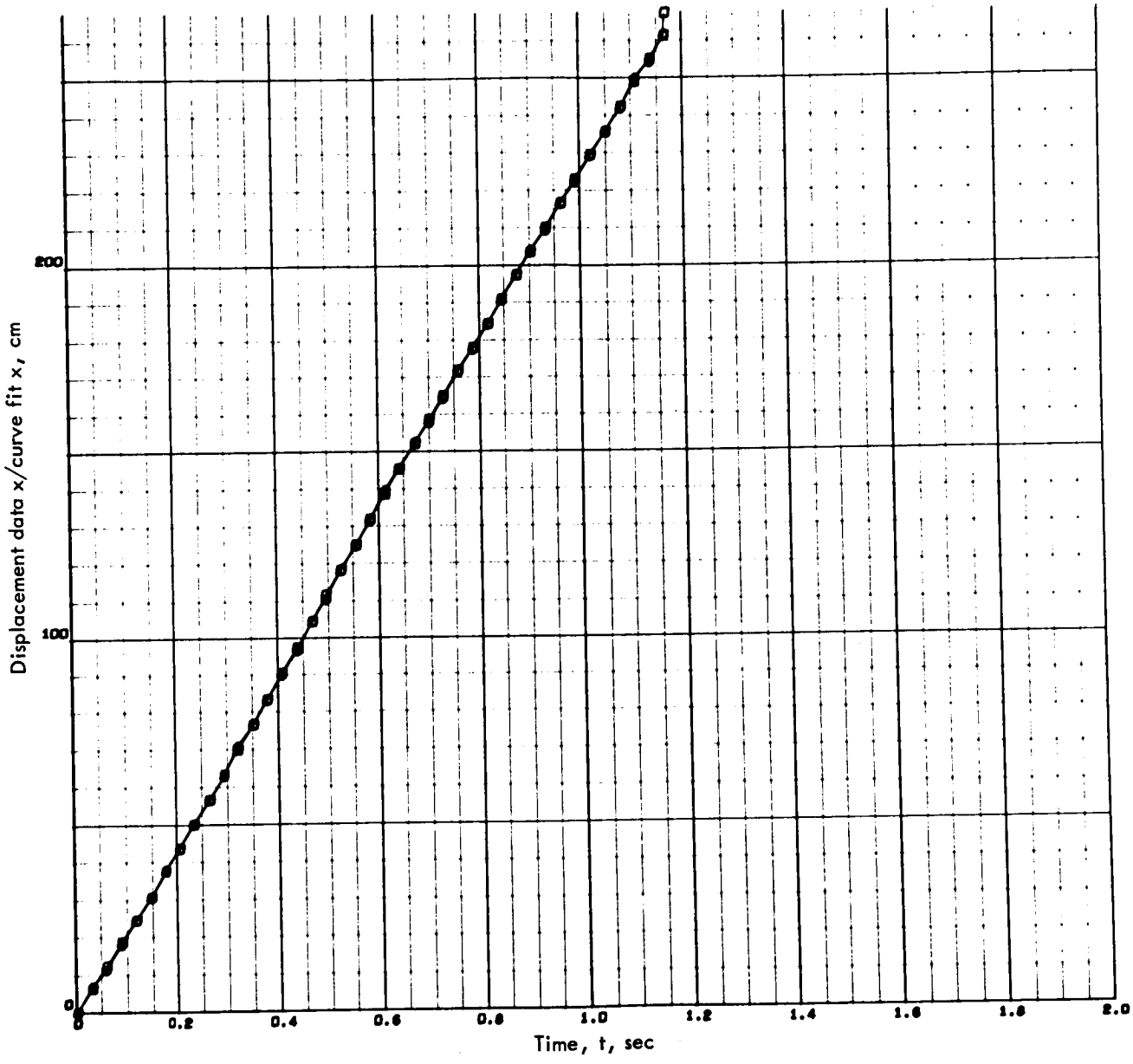

Figure E113. - Displacement data x/curve fit x versus time for segment no. 5, thigh

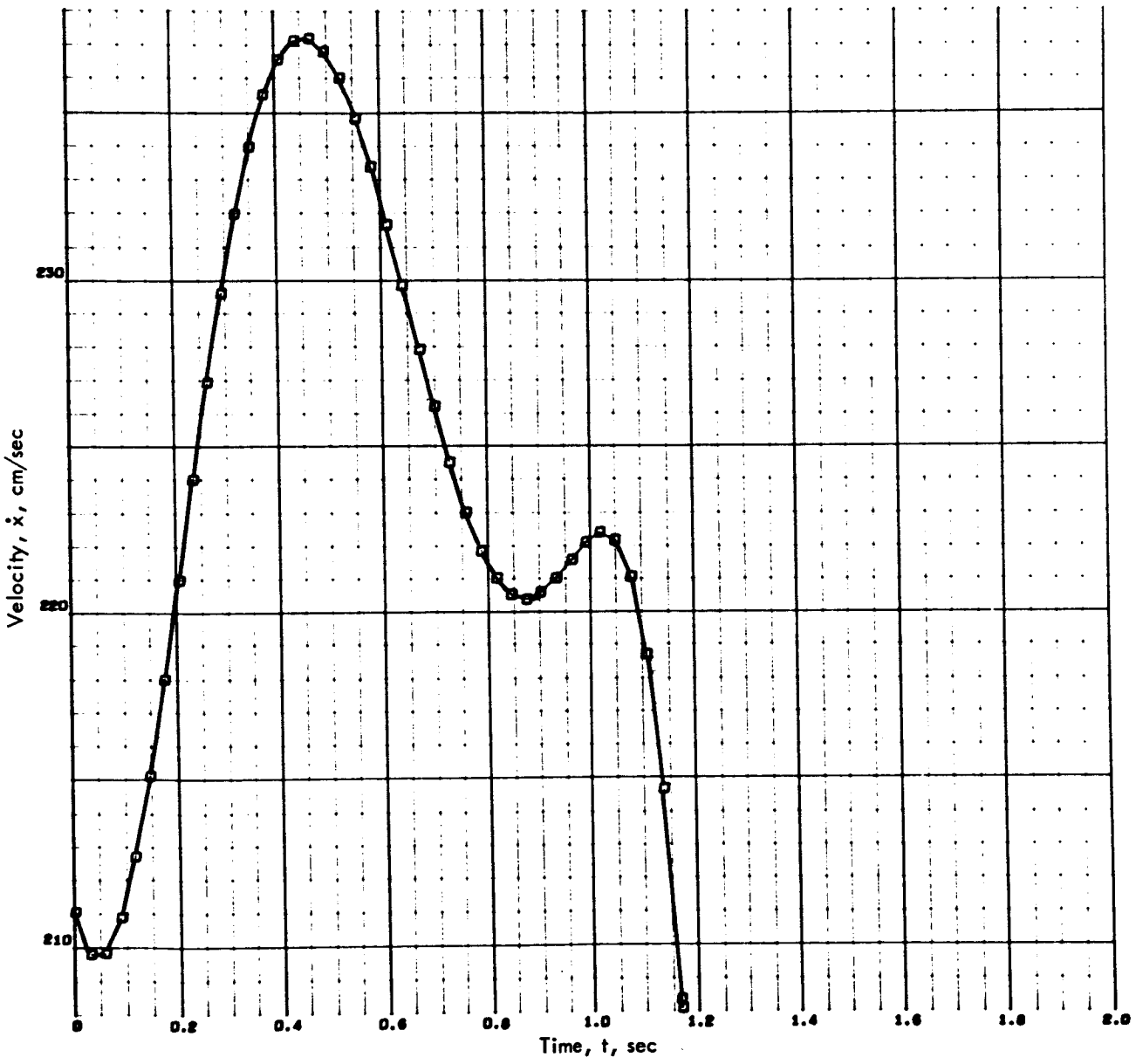

Figure E114. - Velocity $\dot{x}$ versus time for segment no. 5, thigh

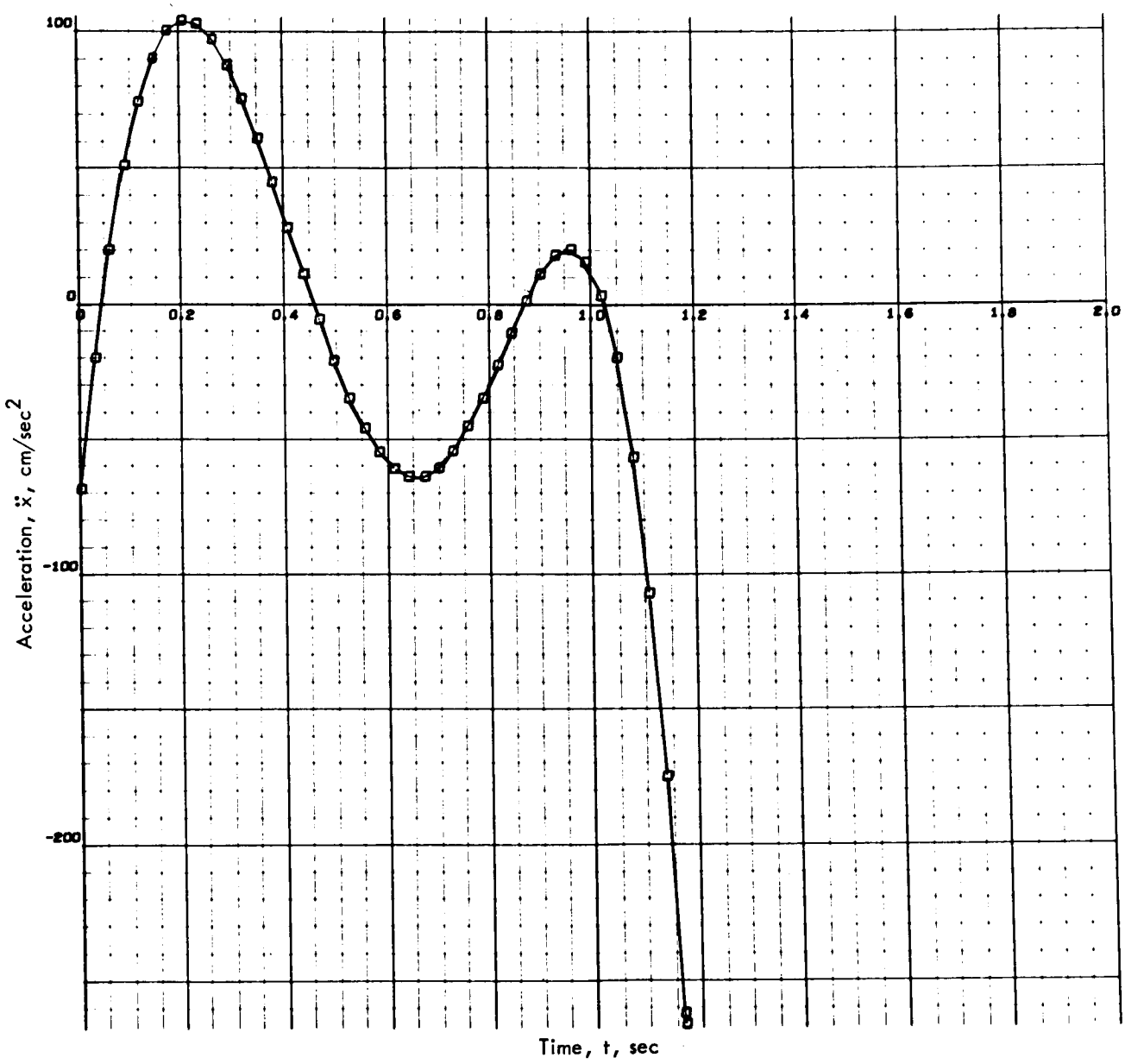

Figure E115. - Acceleration ẍ versus time for segment no. 5, thigh

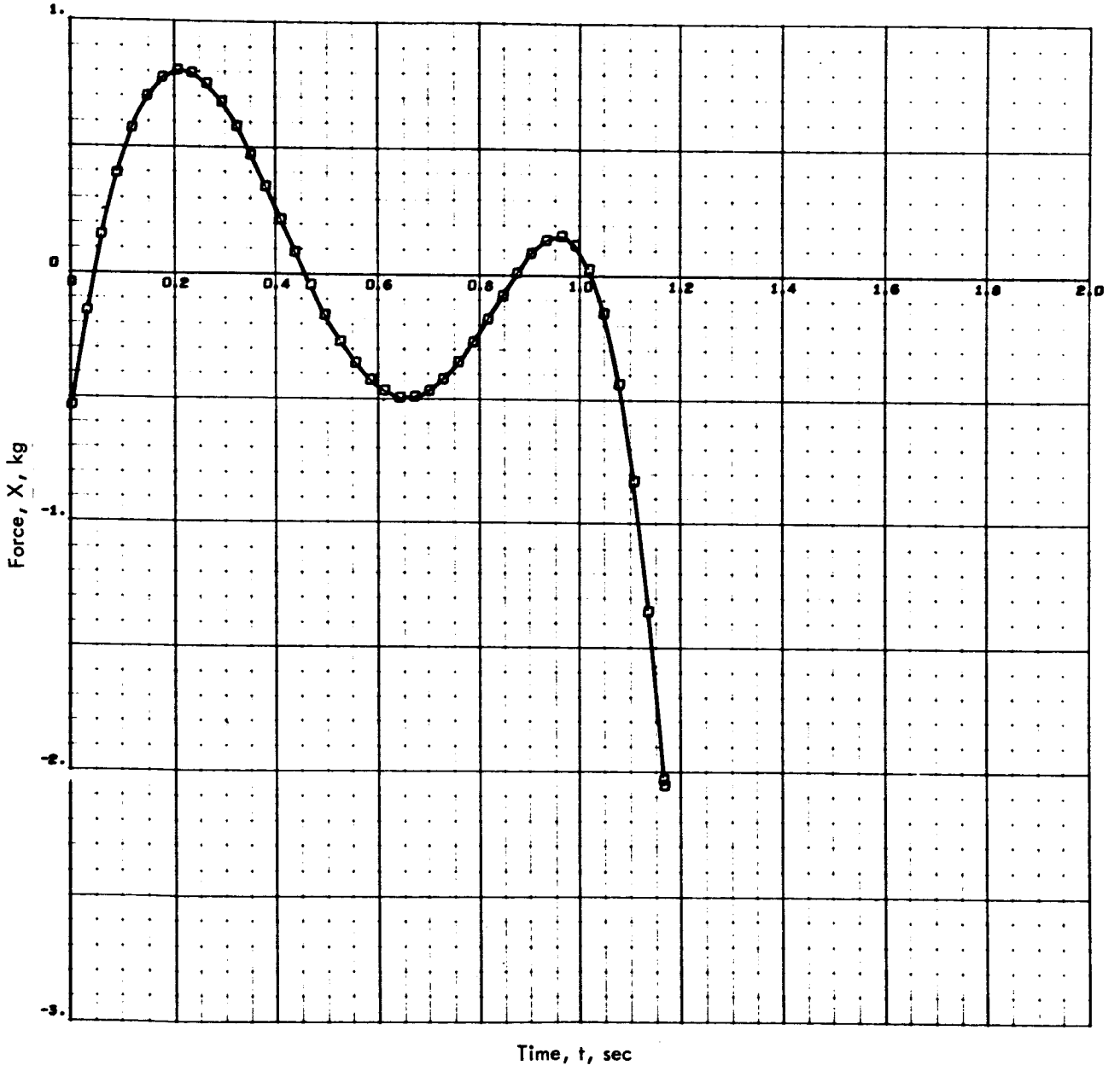

Figure E116. - Force X versus time for segment no. 5, thigh

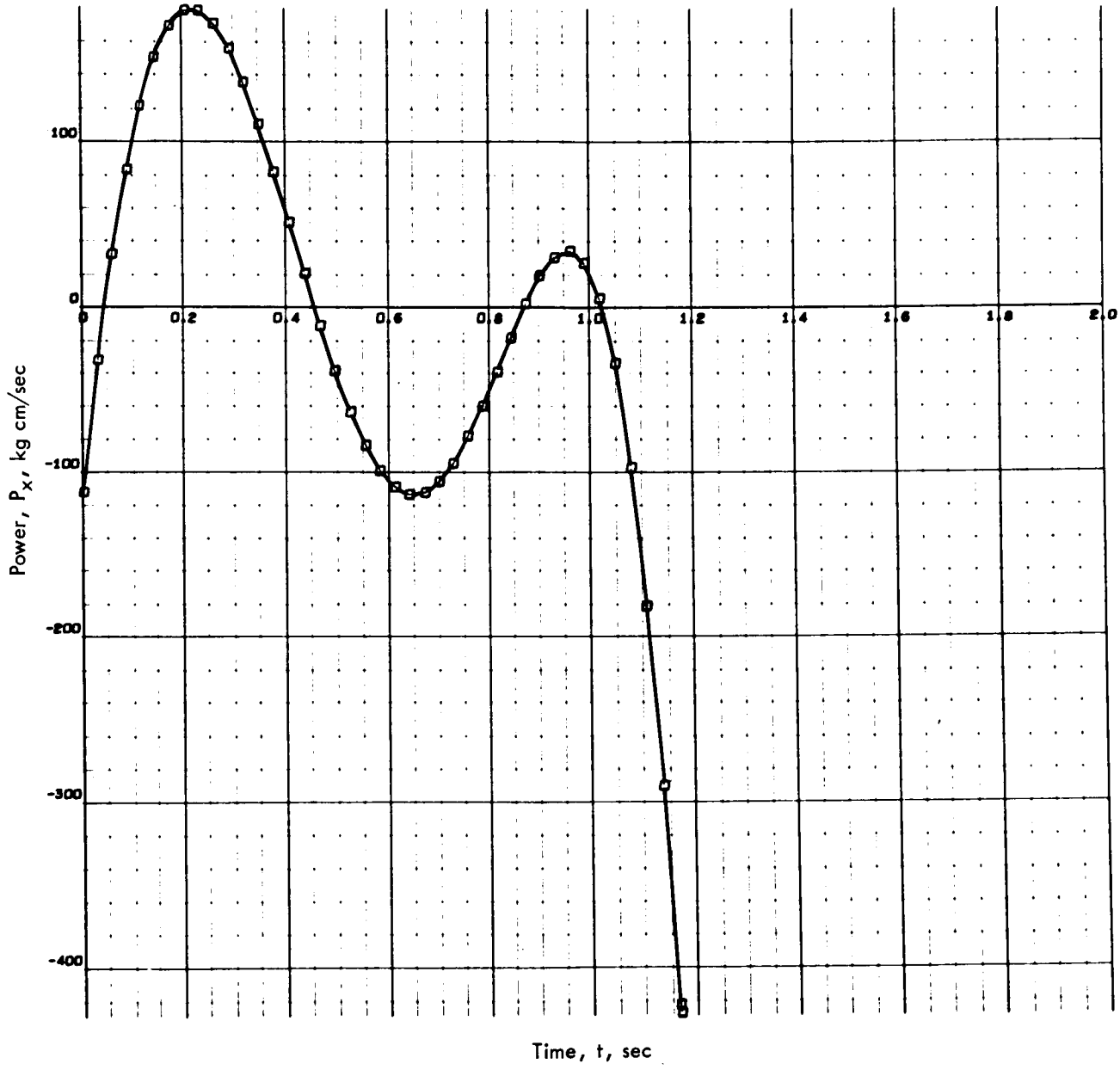

Figure E117. - Power P_x versus time for segment no. 5, thigh

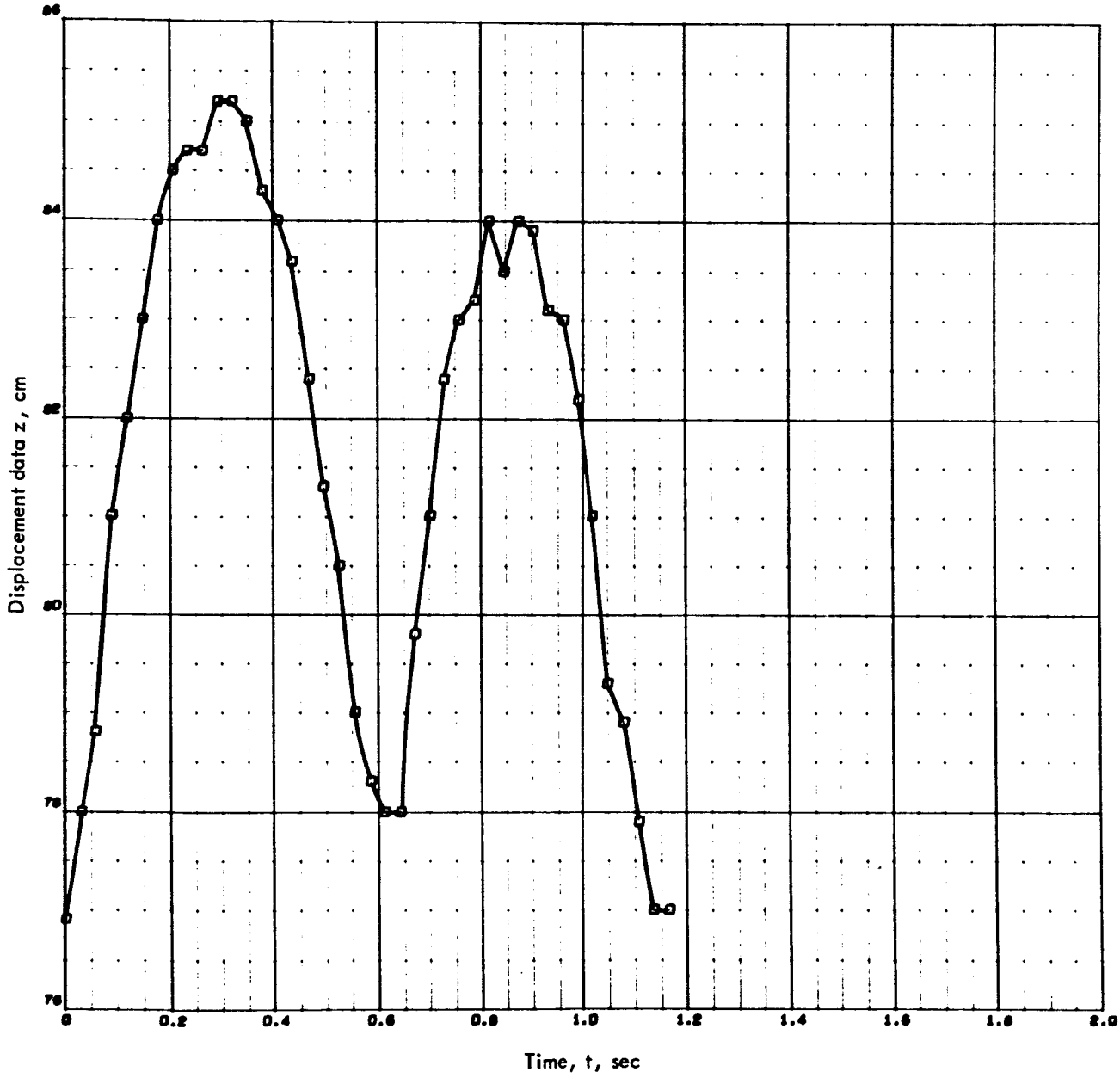

Figure E118. - Displacement data z versus time for segment no. 5, thigh

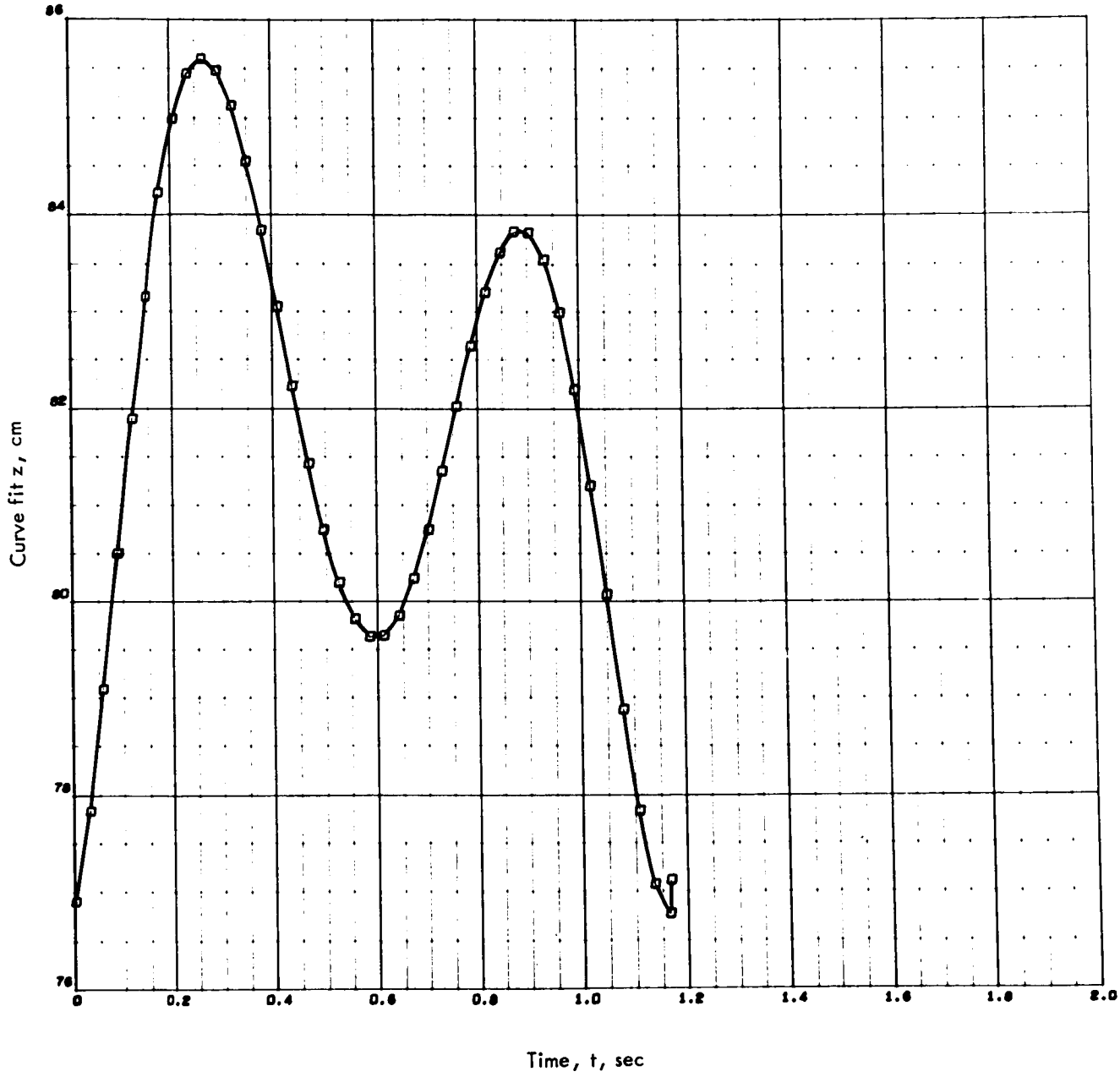

Figure E119. - Curve fit z versus time for segment no. 5, thigh

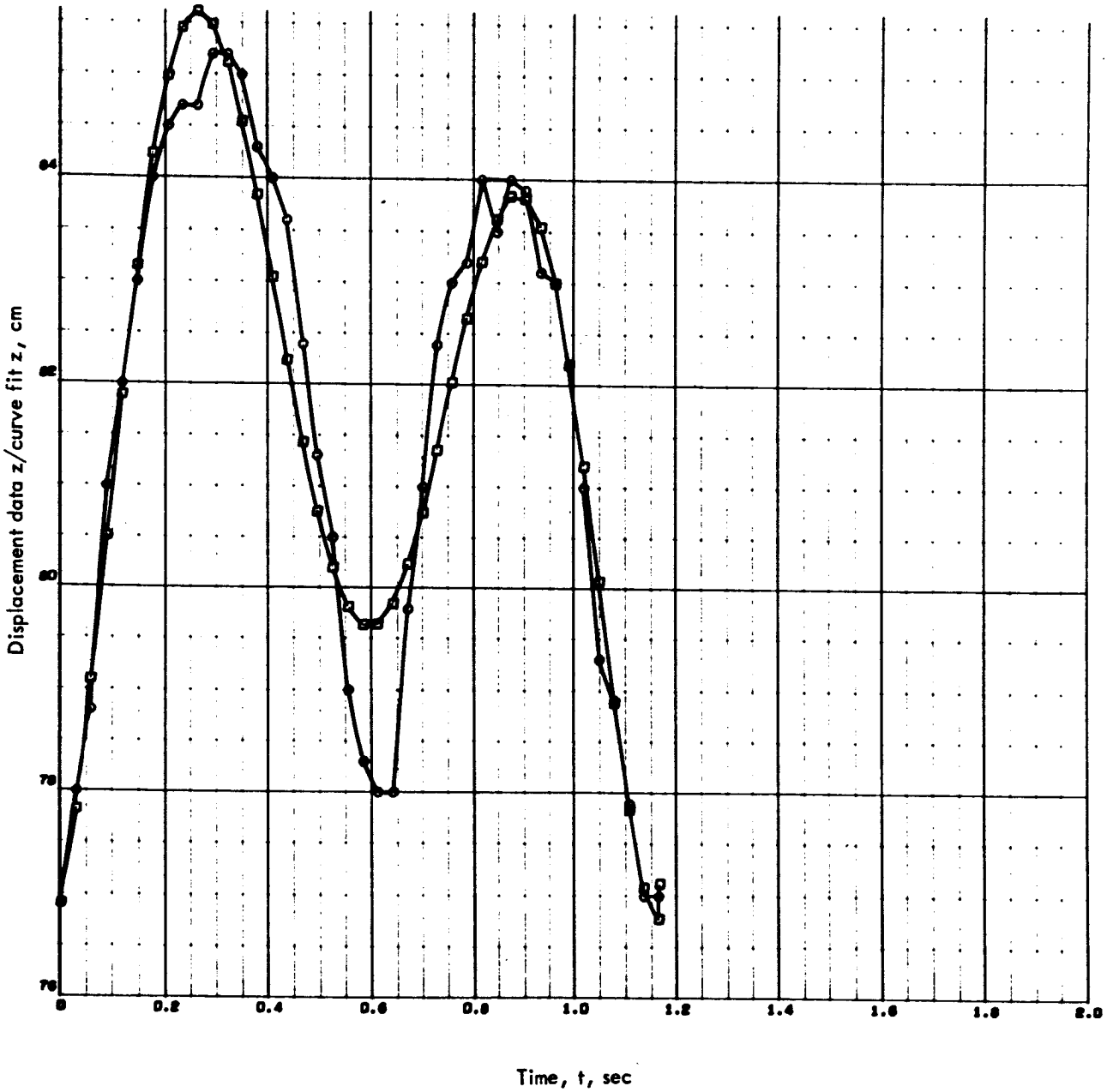

Figure E120. - Displacement data z/curve fit z versus time for segment no. 5, thigh

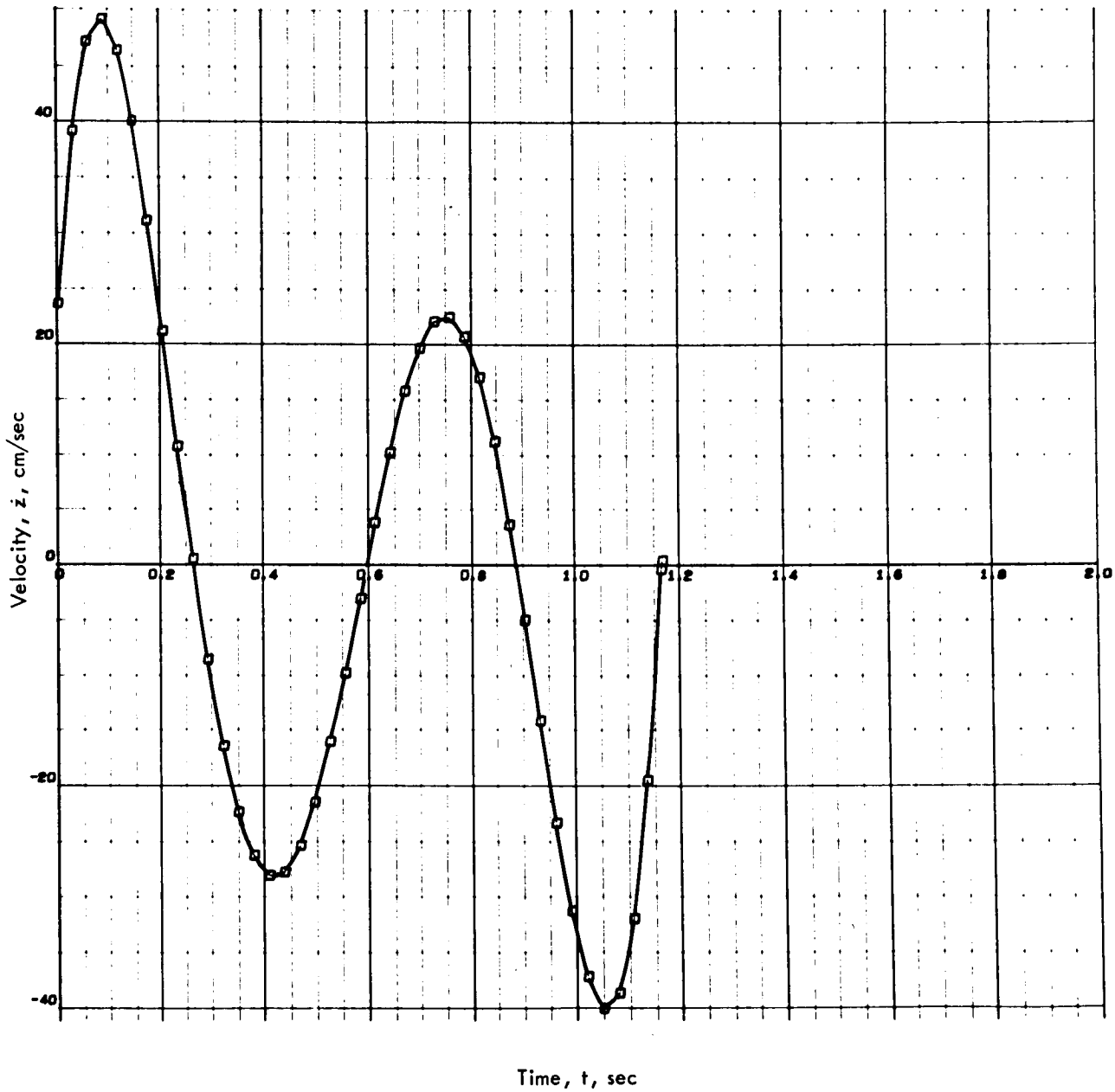

Figure E121. - Velocity ż versus time for segment no. 5, thigh

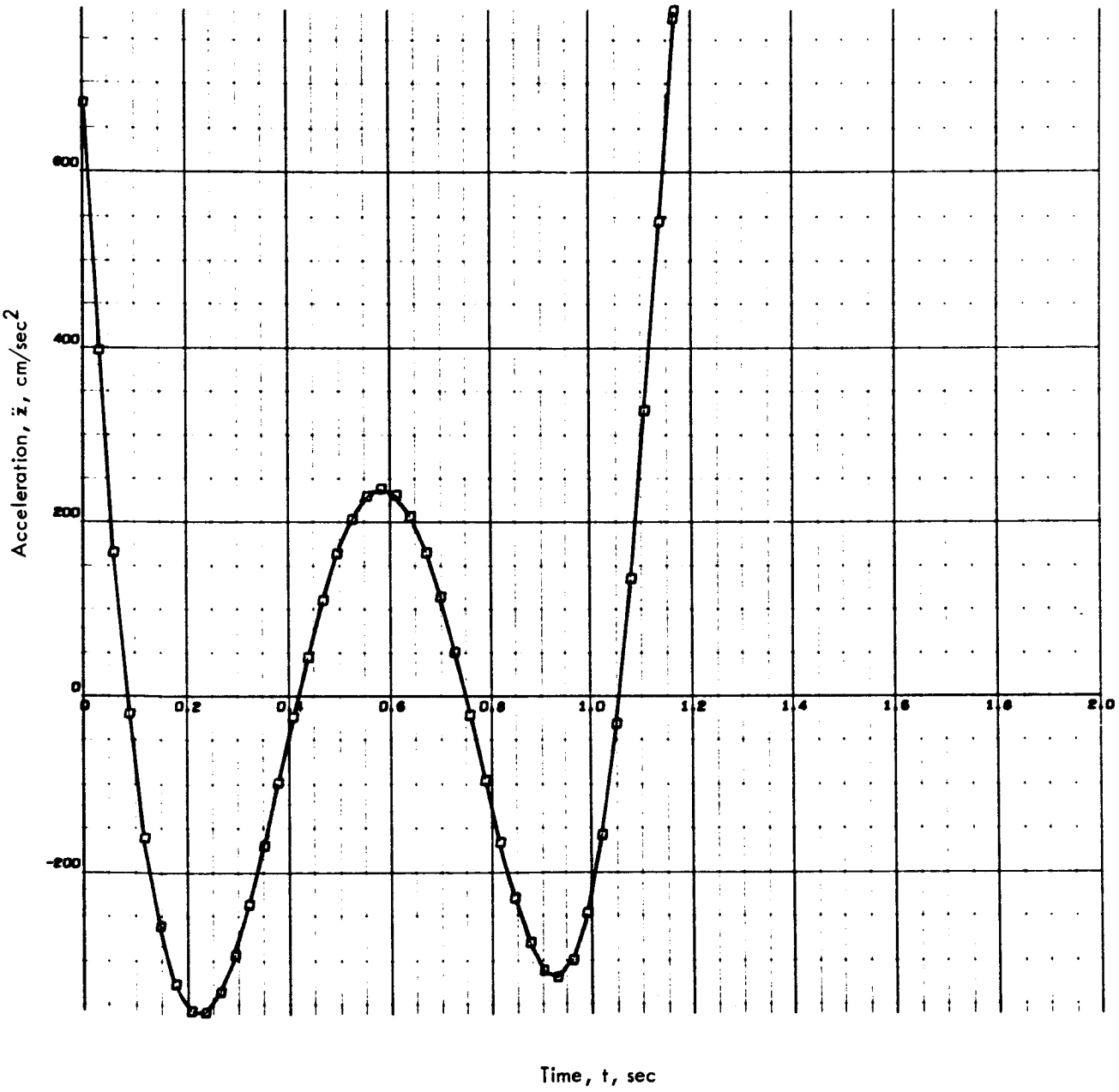

Figure E122. - Acceleration $\ddot{z}$ versus time for segment no. 5, thigh

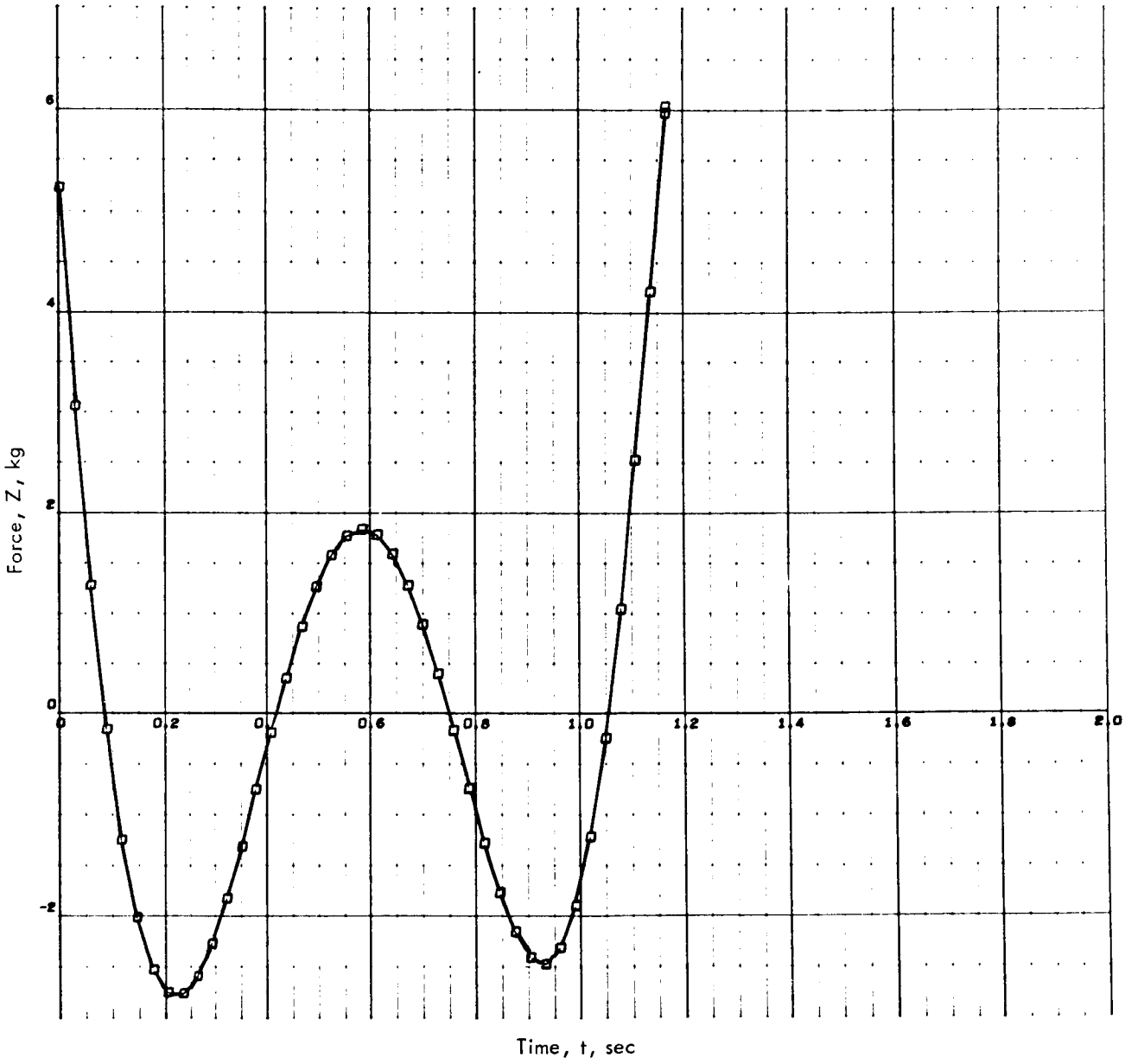

Figure E123. - Force Z versus time for segment no. 5, thigh

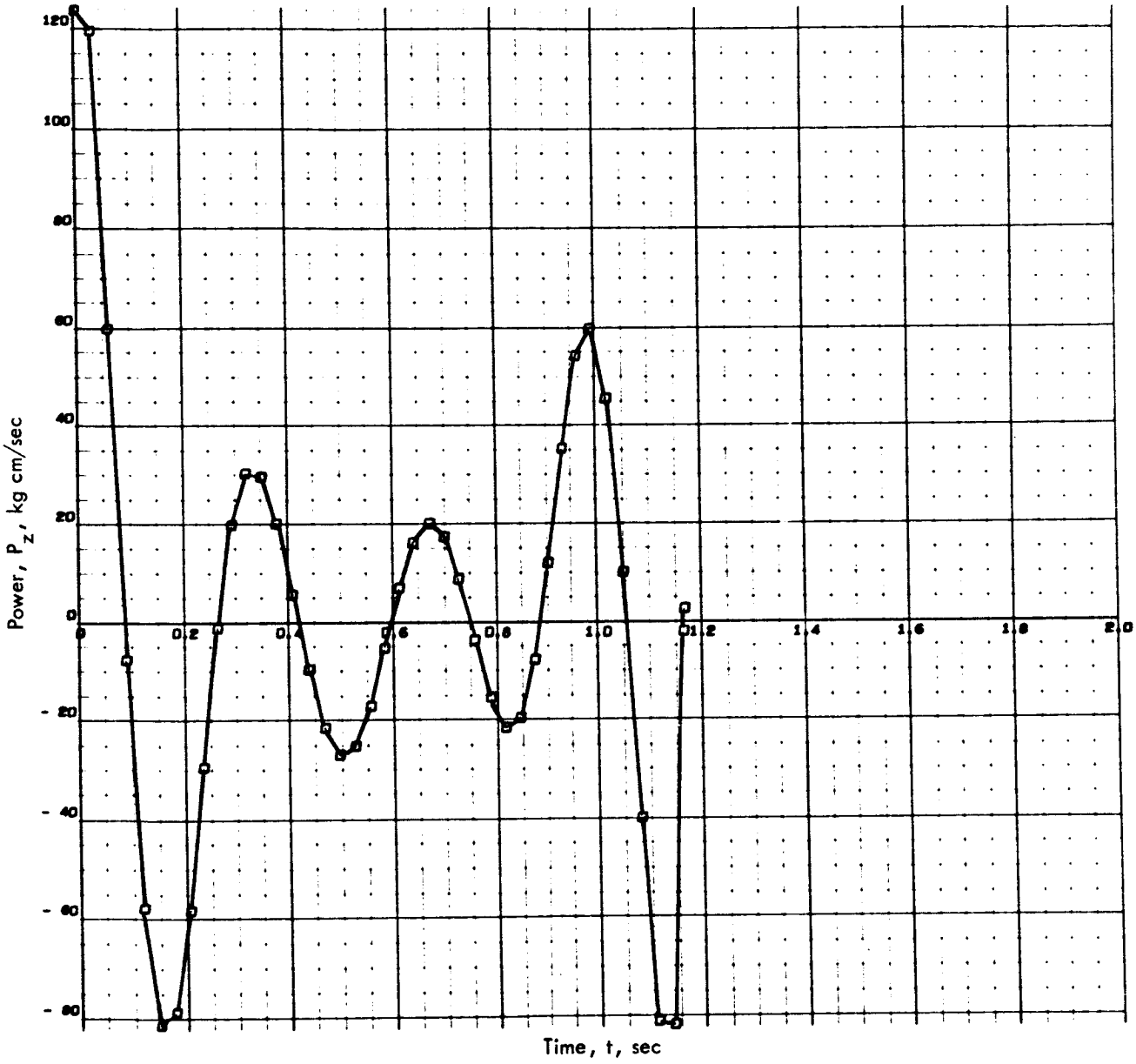

Figure E124. - Power P_z versus time for segment no. 5, thigh

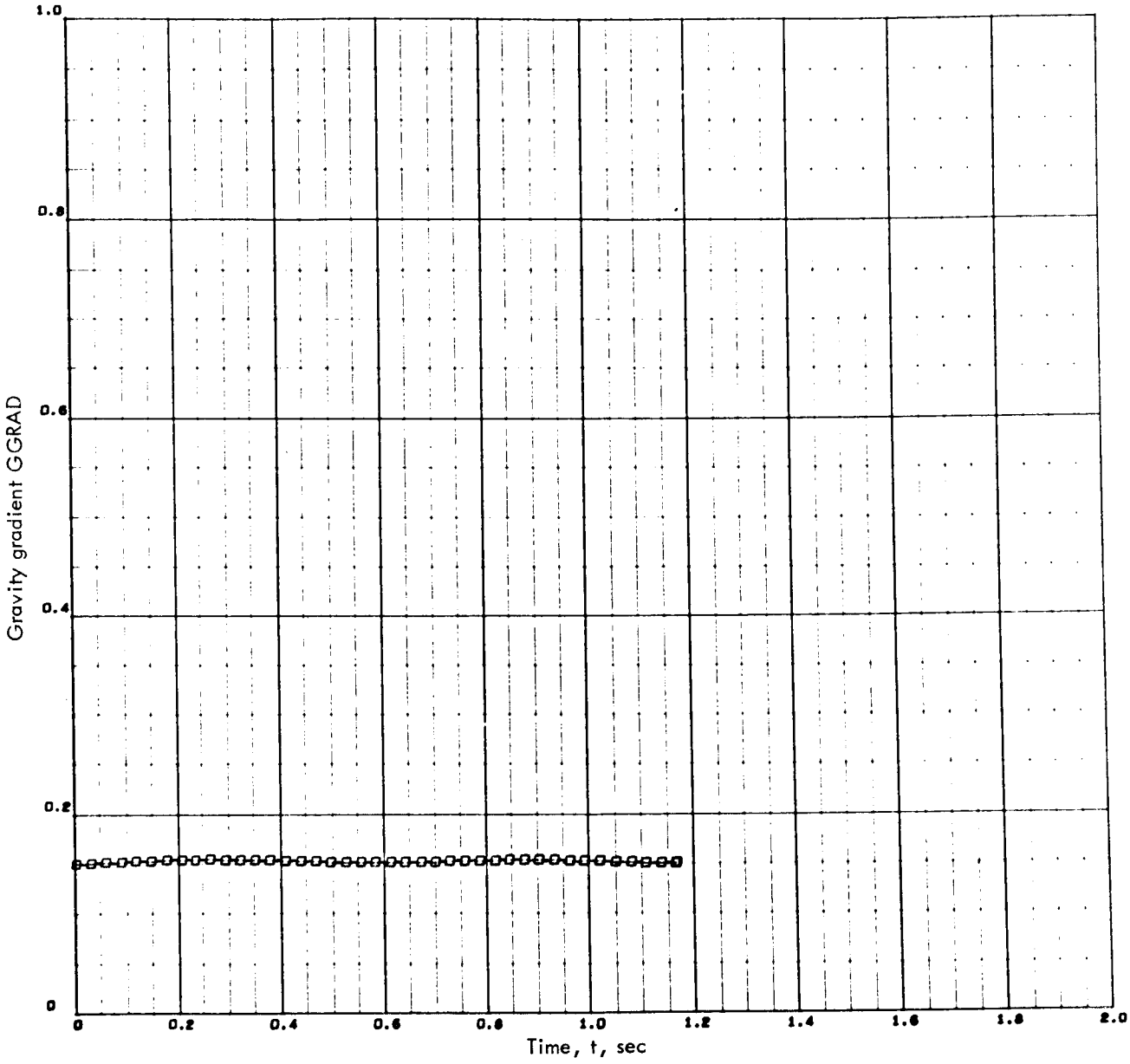

Figure E125. - Gravity gradient versus time for segment no. 5, thigh

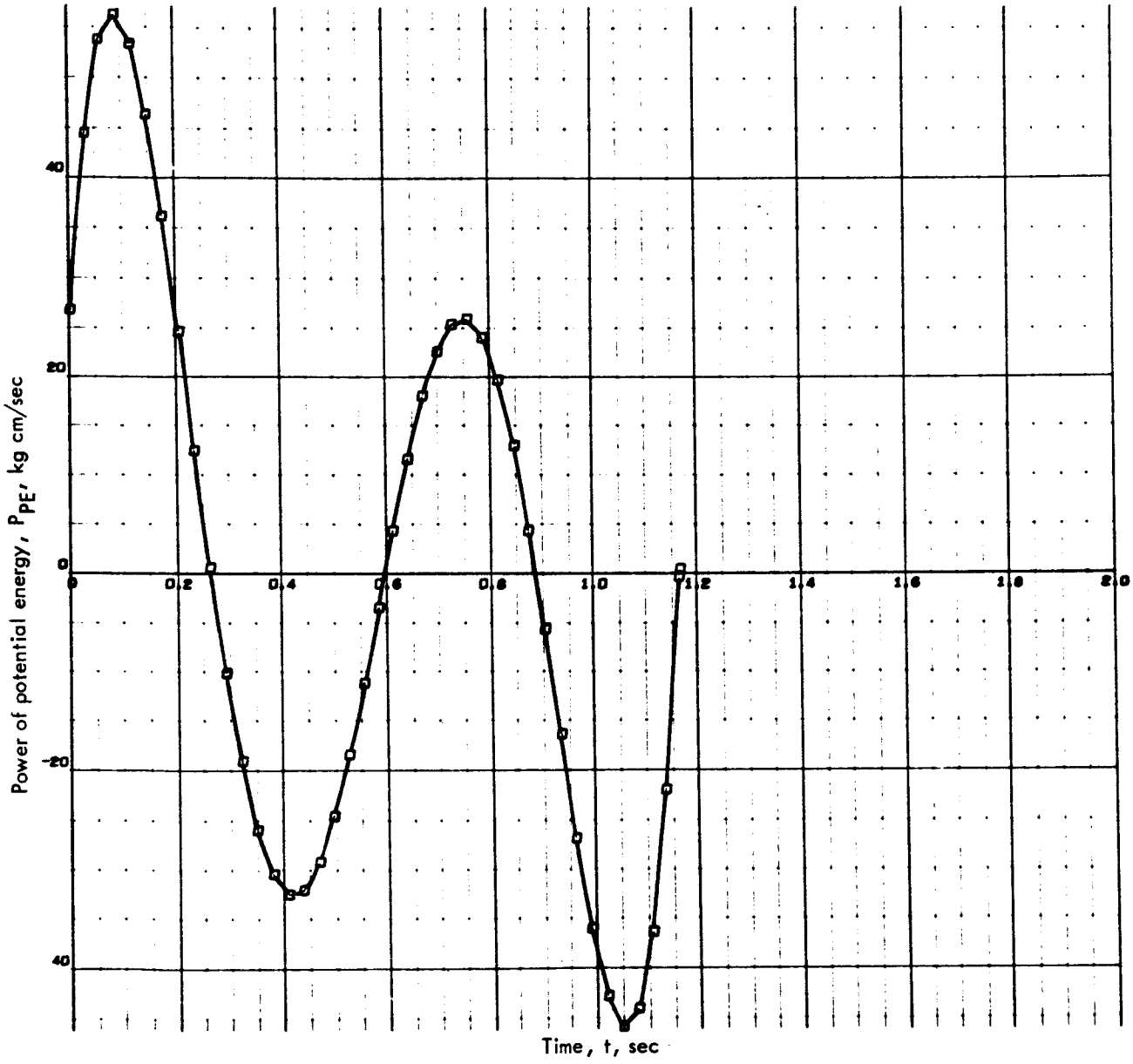

Figure E126. - Power of potential energy versus time for segment no. 5, thigh

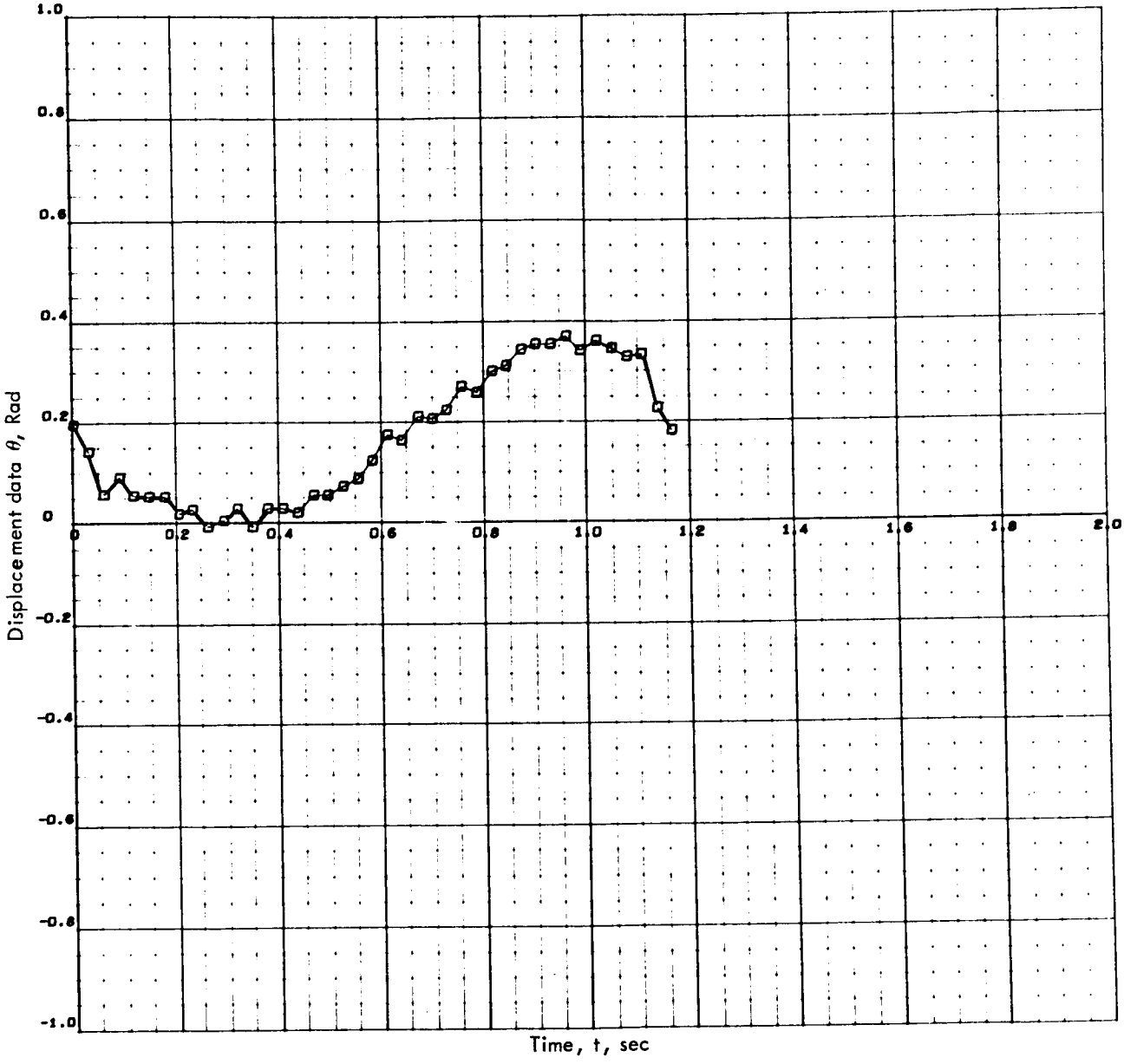

Figure E127. - Displacement data θ versus time for segment no. 5, thigh

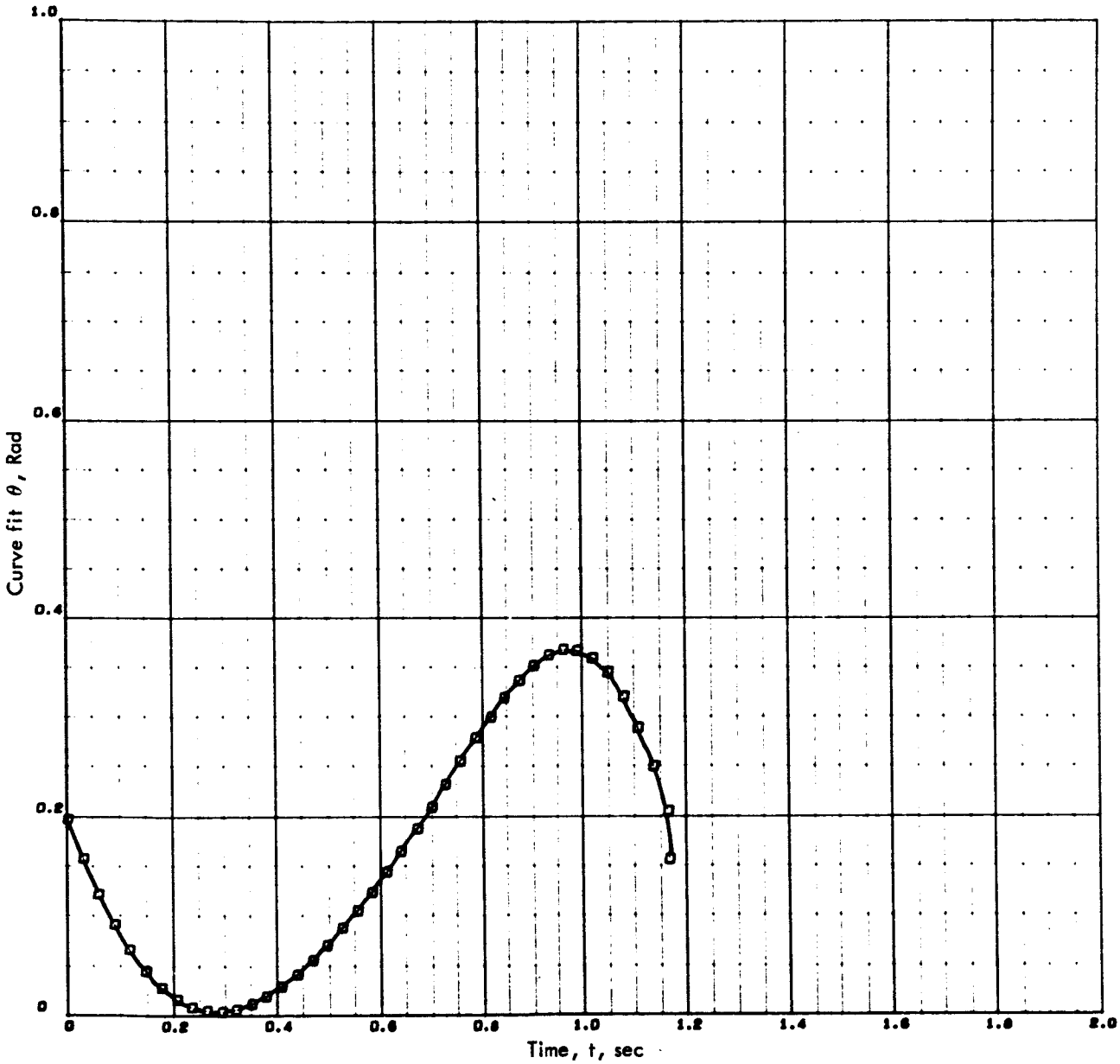

Figure E128. - Curve fit θ versus time for segment no. 5, thigh

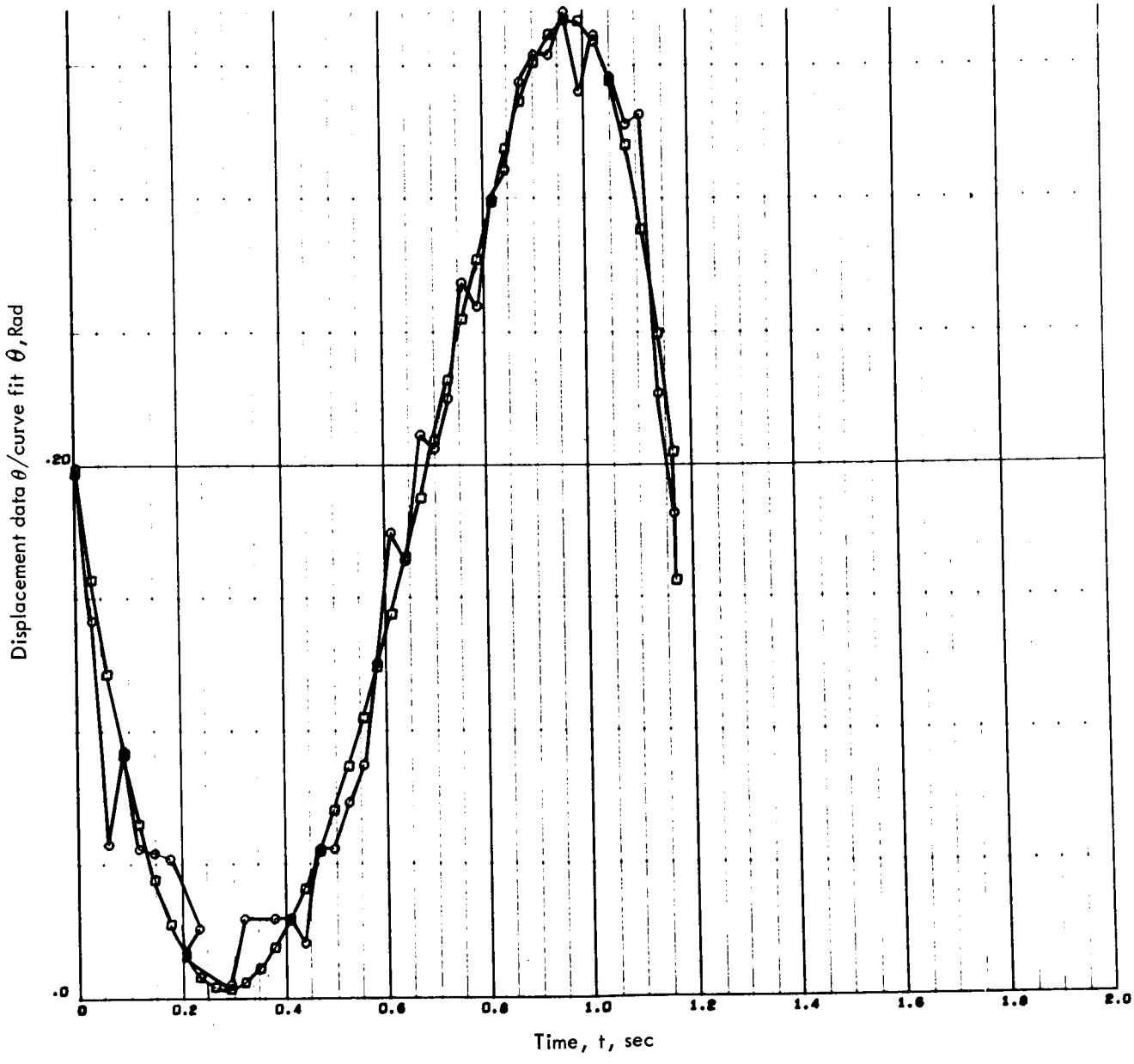

Figure E129. - Displacement data θ/curve fit θ versus time for segment no. 5, thigh

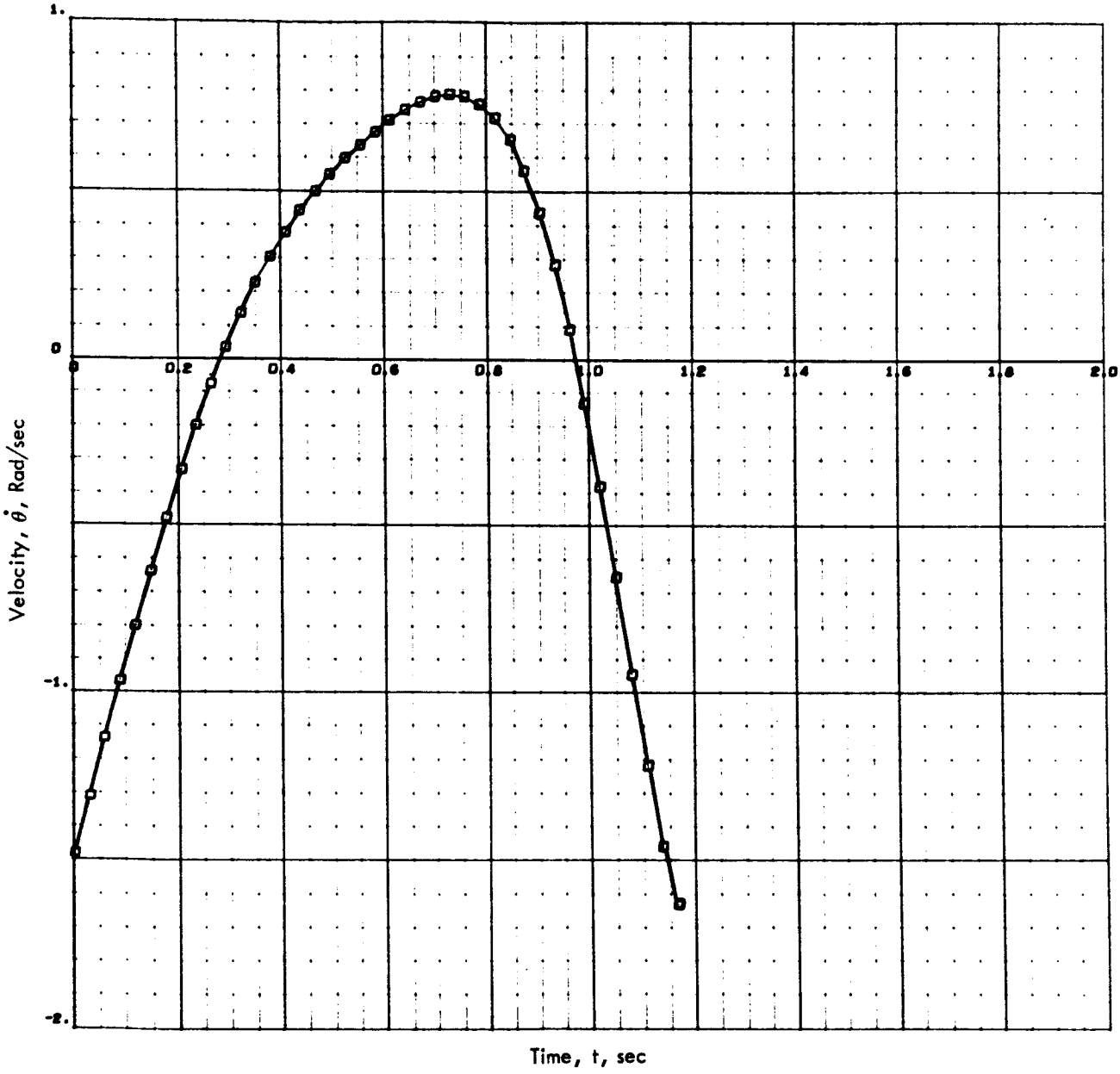

Figure E130. - Velocity $\dot{\theta}$ versus time for segment no. 5, thigh

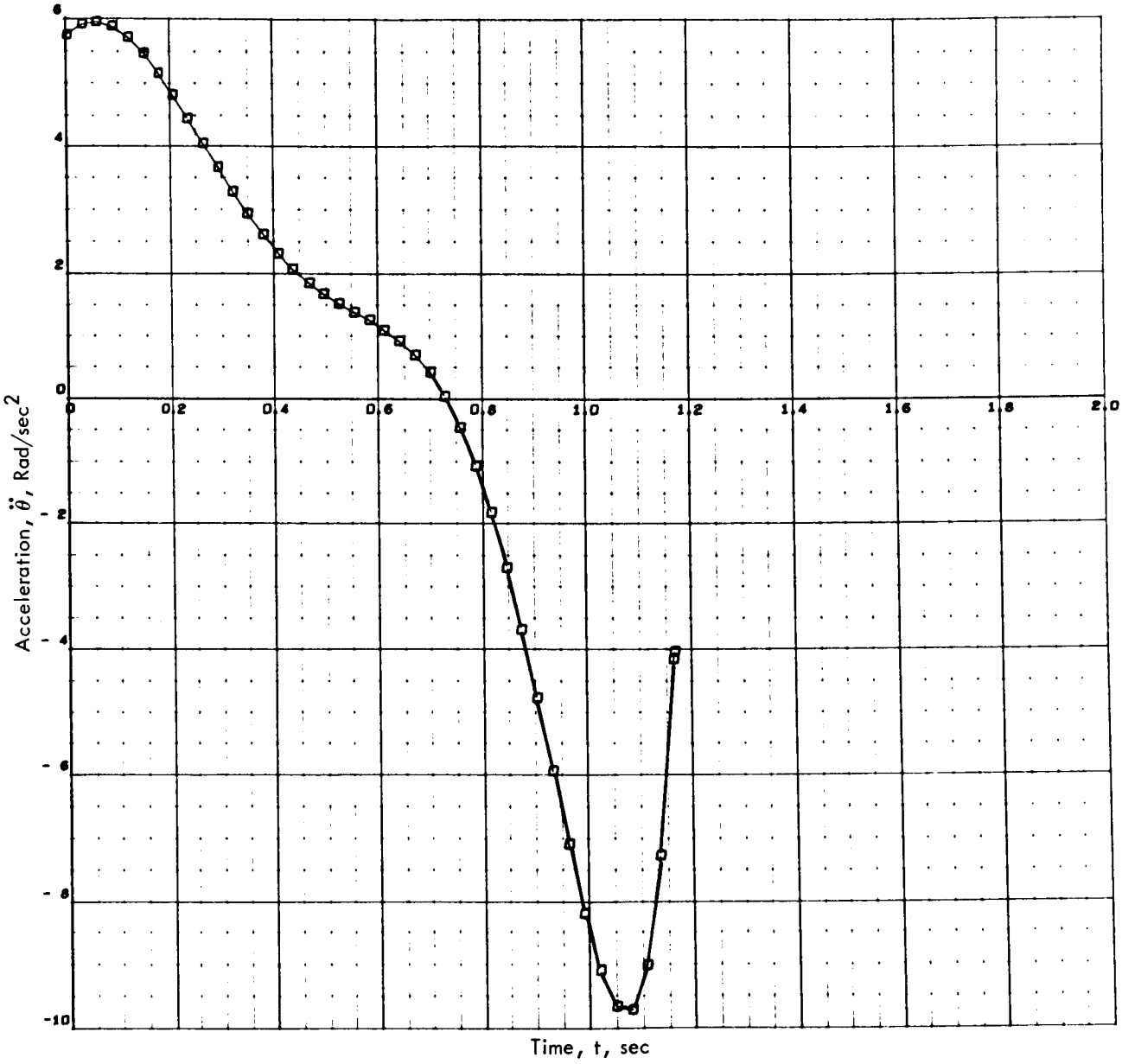

Figure E131. - Acceleration $\ddot{\theta}$ versus time for segment no. 5, thigh

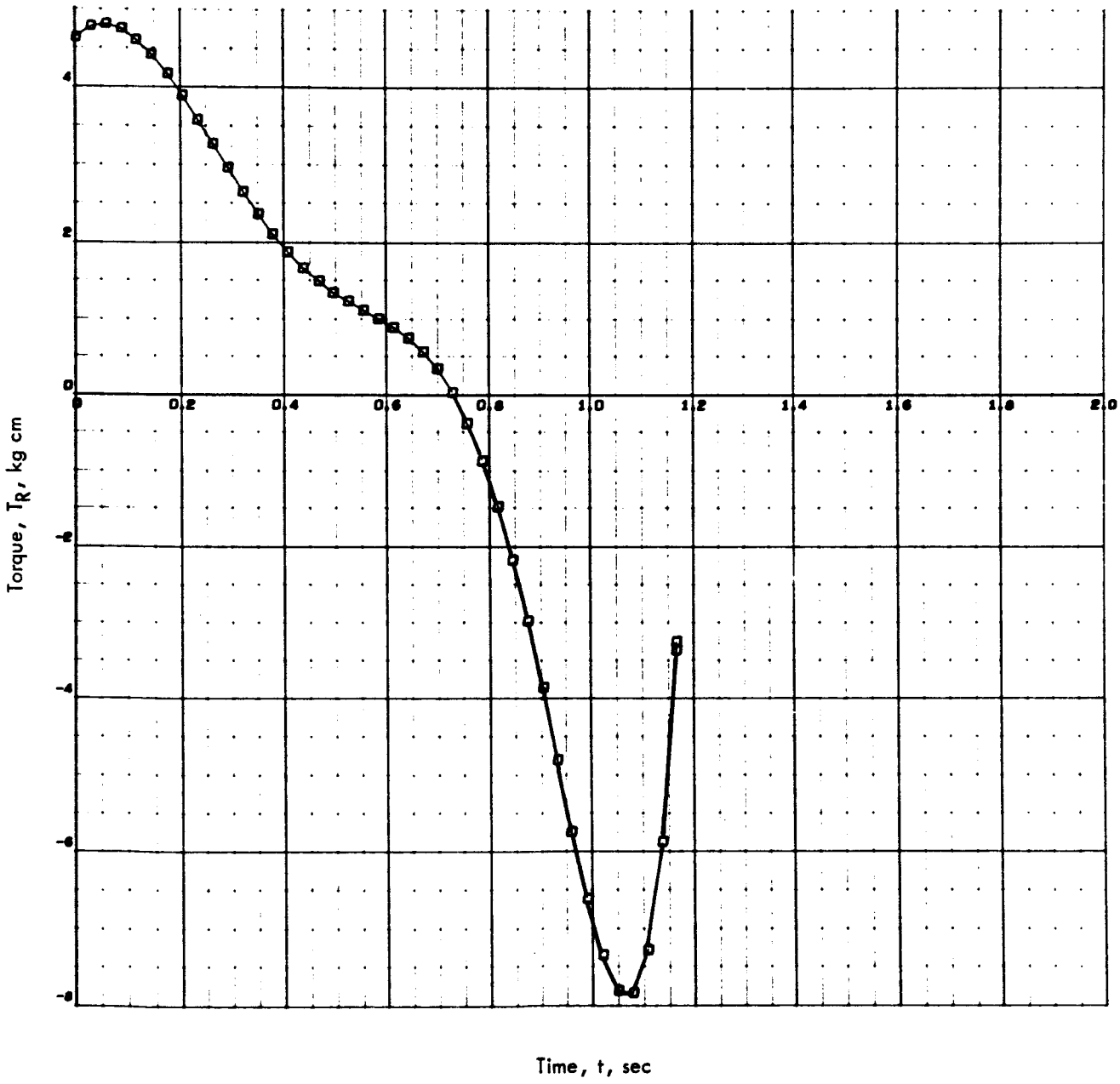

Figure E132. - Torque T_R versus time for segment no. 5, thigh

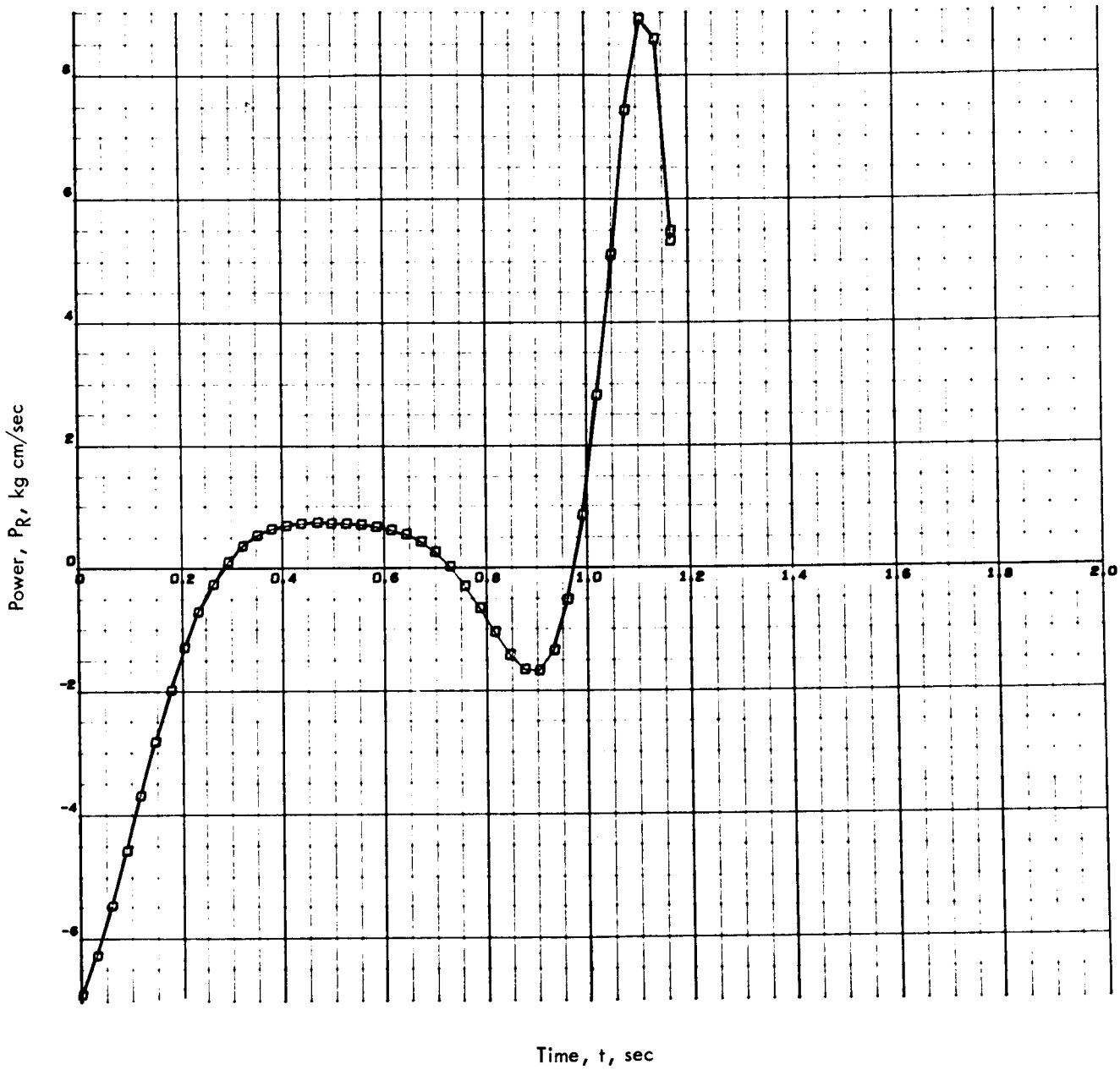

Figure E133. - Power P_R versus time for segment no. 5, thigh

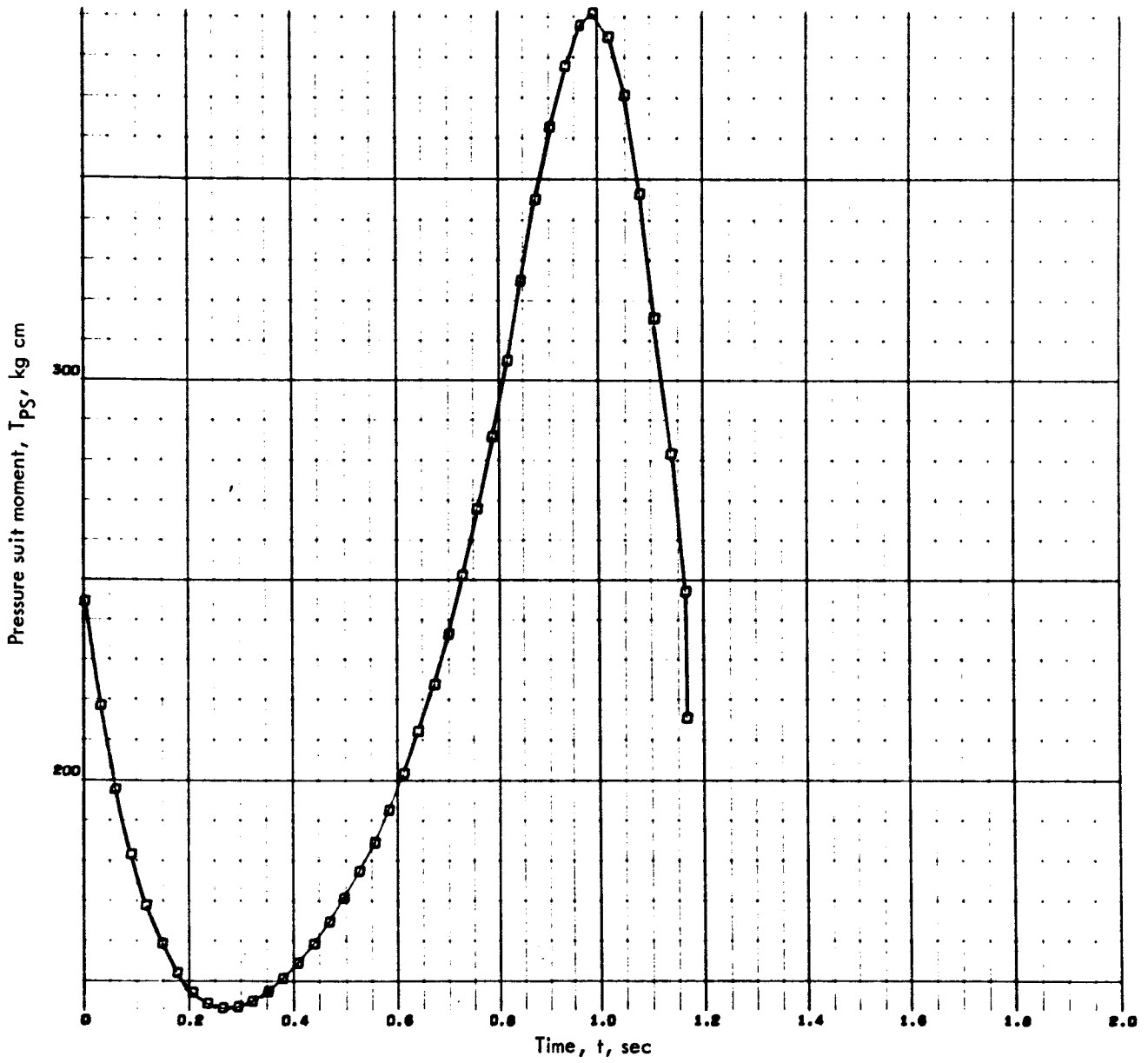

Figure E134. - Pressure suit moment T_{PS} versus time for segment no. 5, thigh

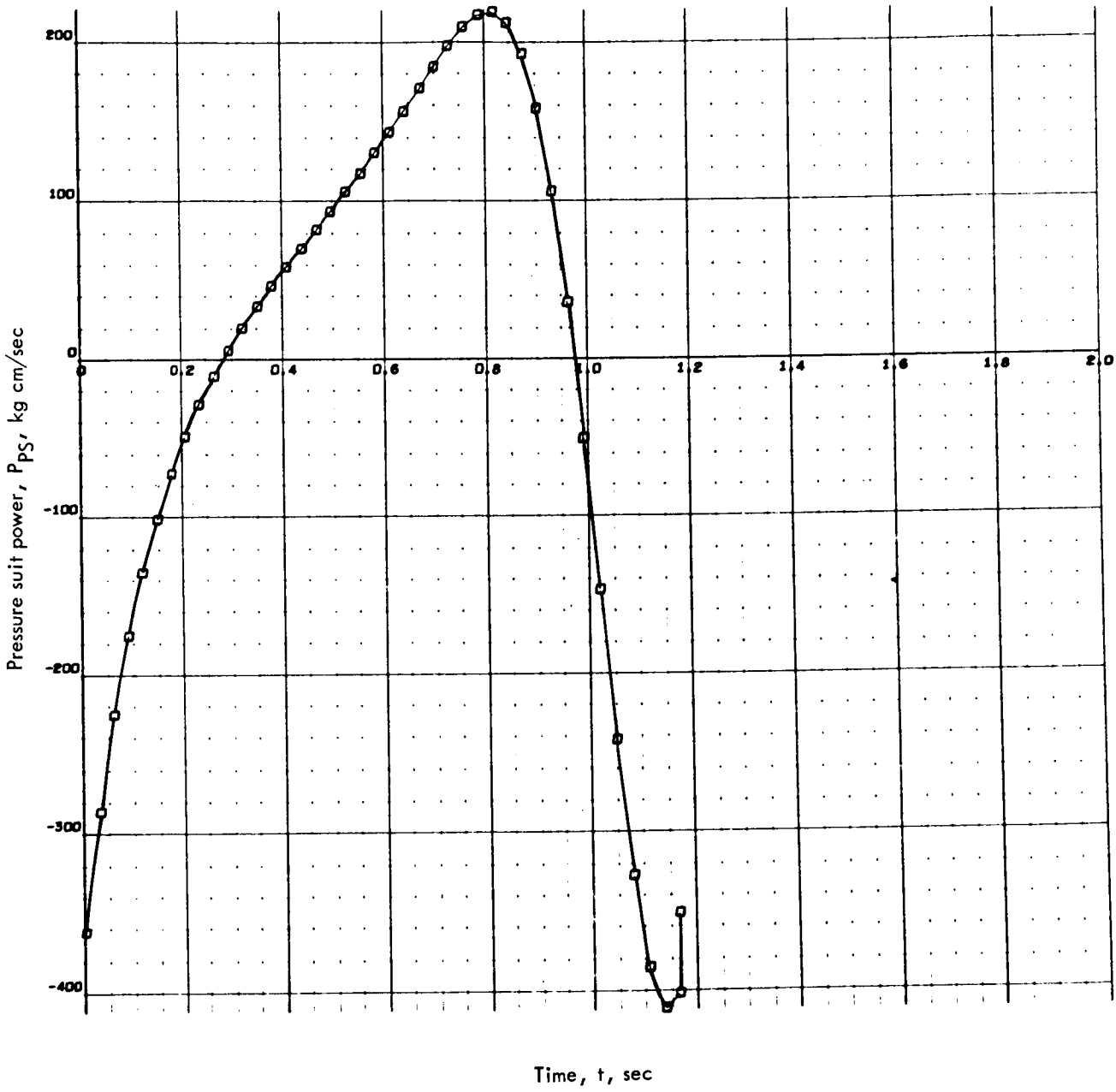

Figure E135. - Pressure suit power P_{PS} versus time for segment no. 5, thigh

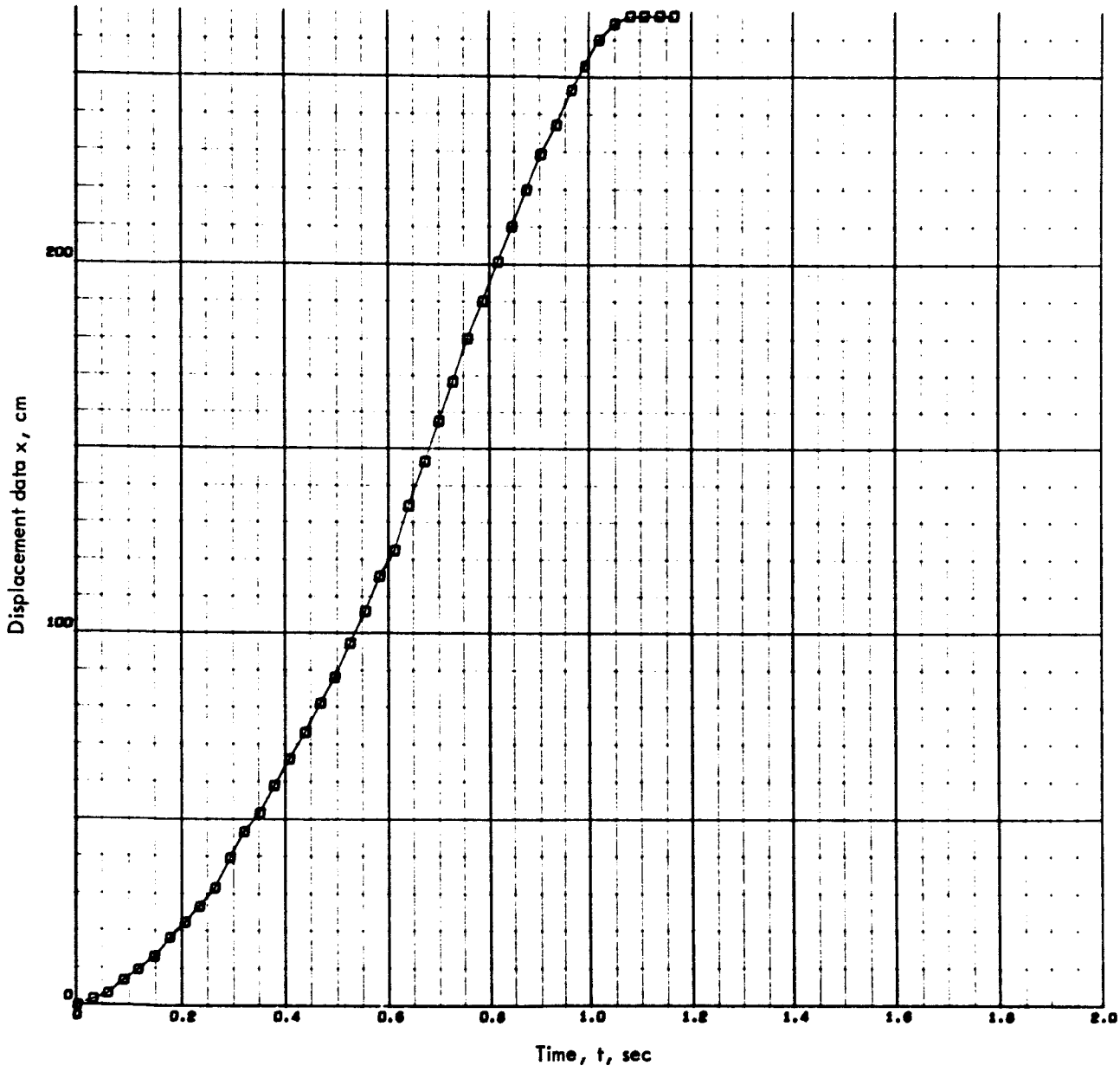

Figure E136. - Displacement data x versus time for segment no. 6, leg and foot

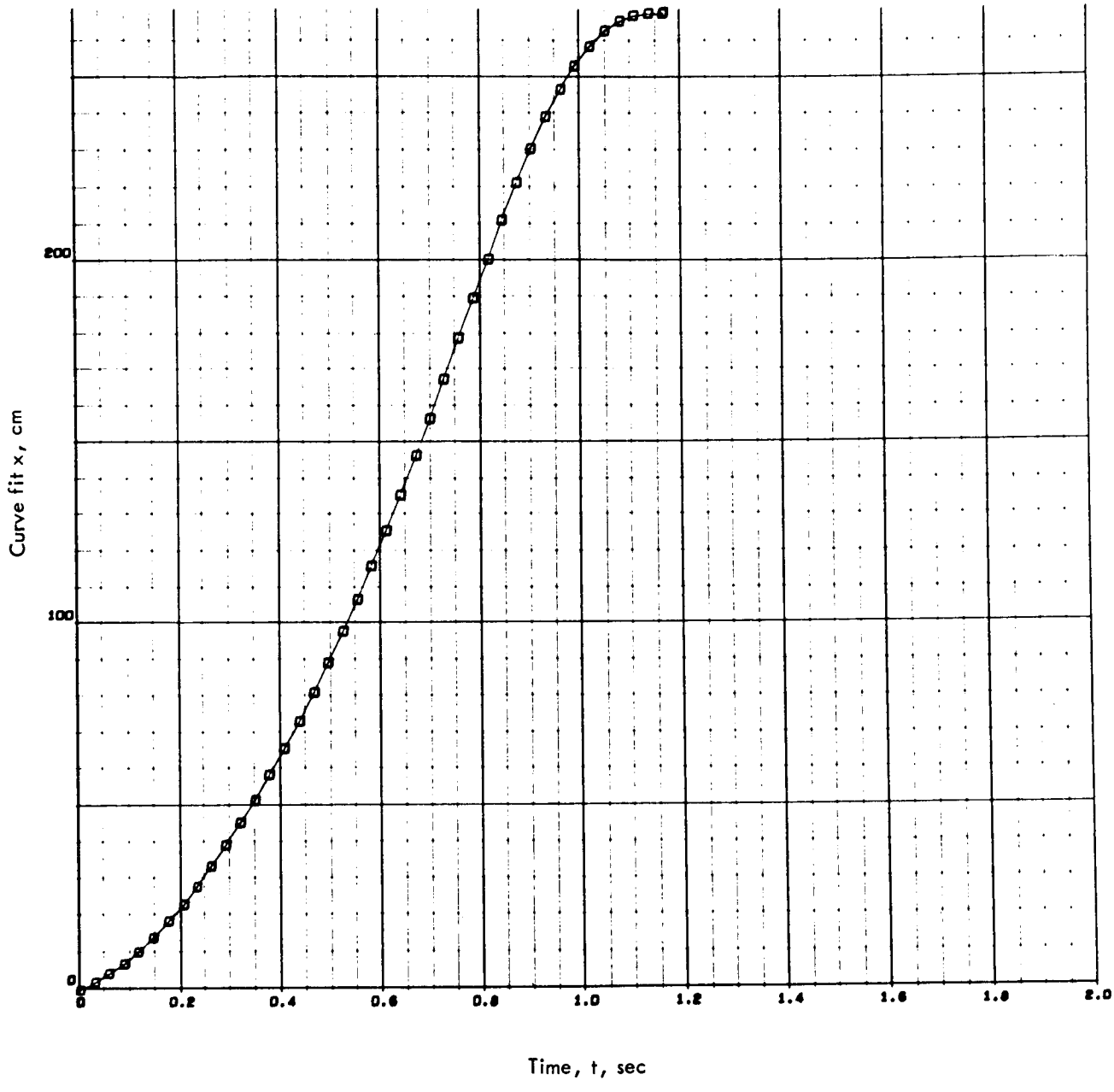

Figure E137. - Curve fit x versus time for segment no. 6, leg and foot

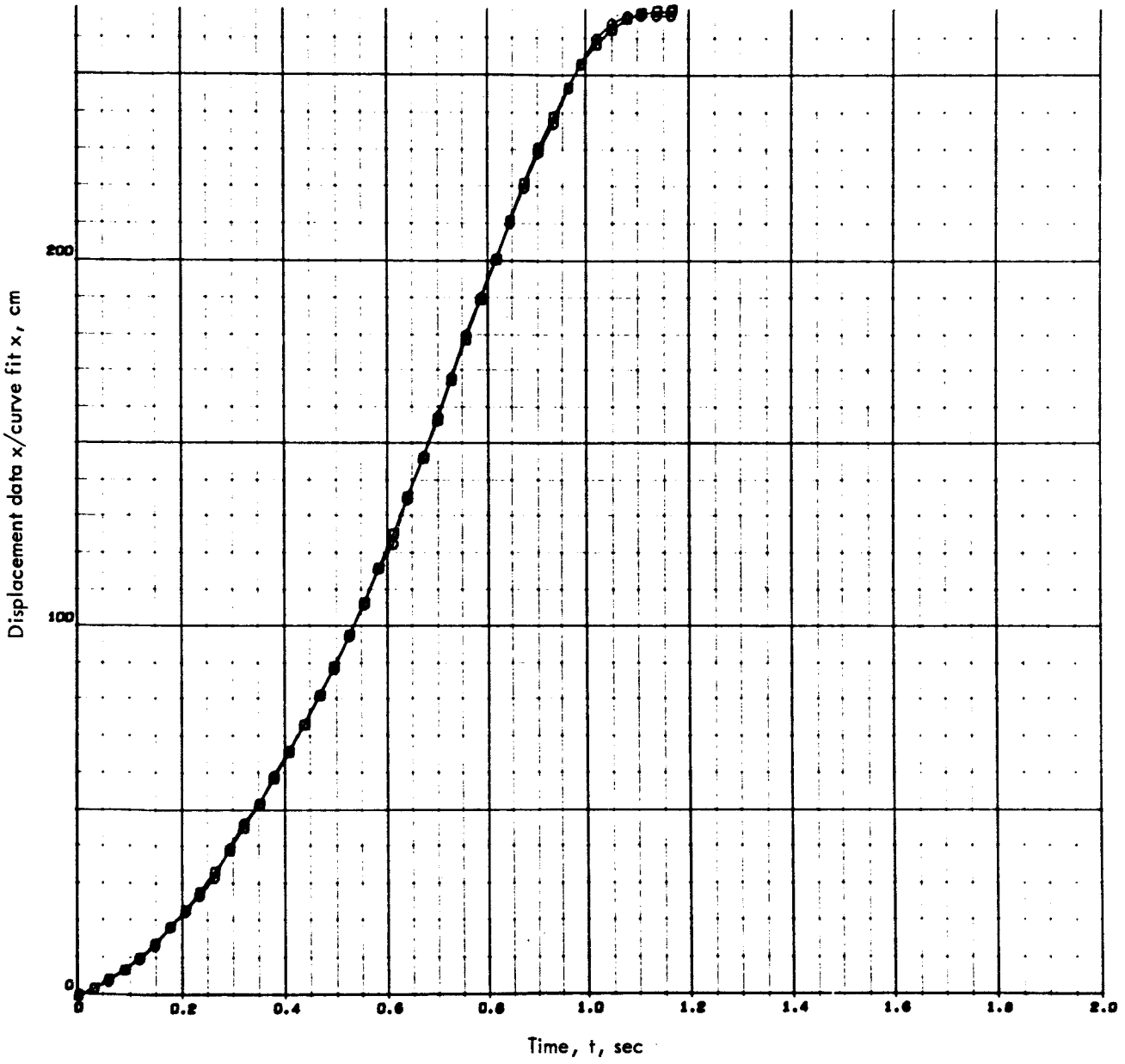

Figure E138. - Displacement data x/curve fit x versus time for segment no. 6, leg and foot

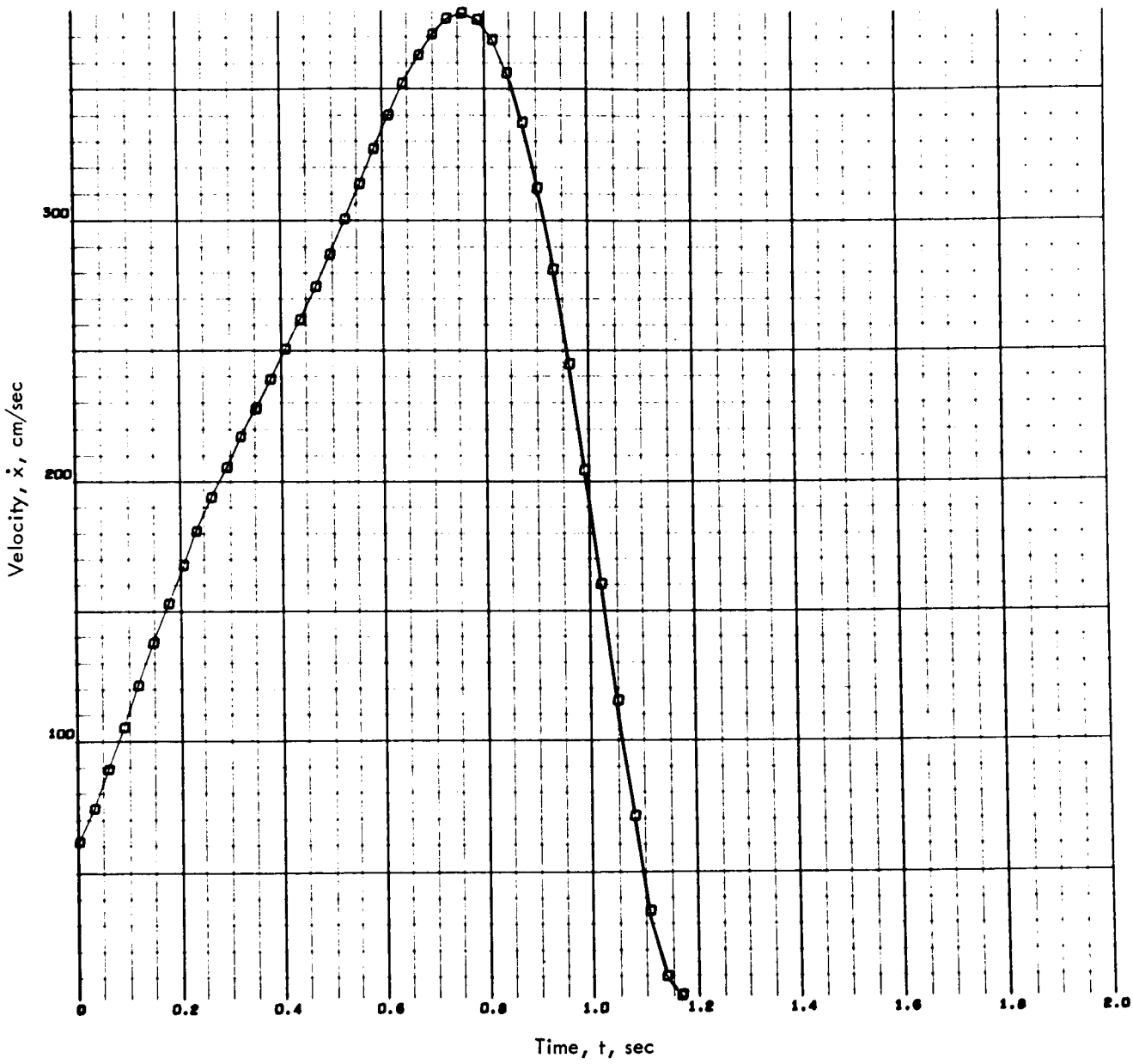

Figure E139. - Velocity $\dot{x}$ versus time for segment no. 6, leg and foot

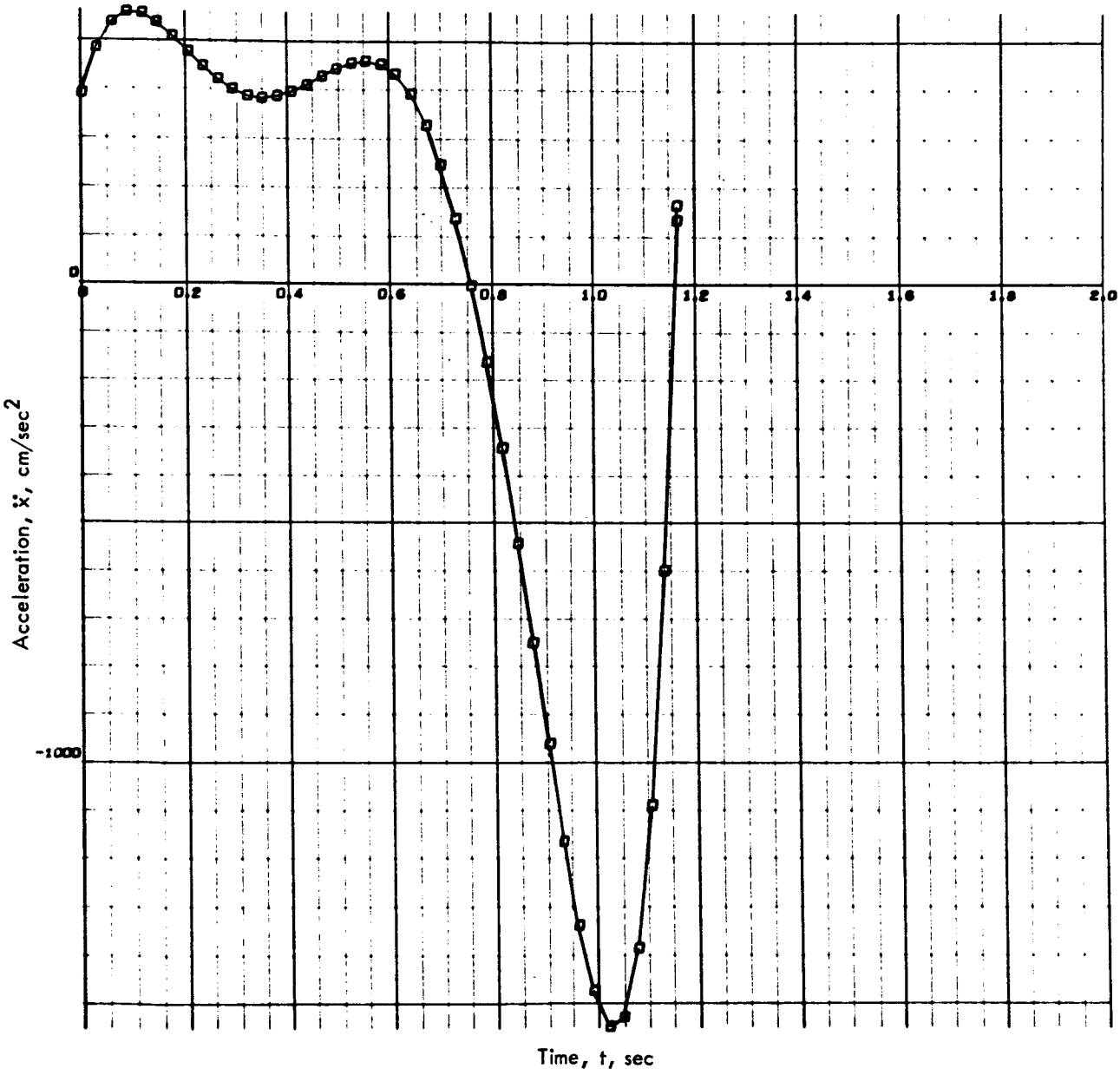

Figure E140. - Acceleration $\ddot{x}$ versus time for segment no. 6, leg and foot

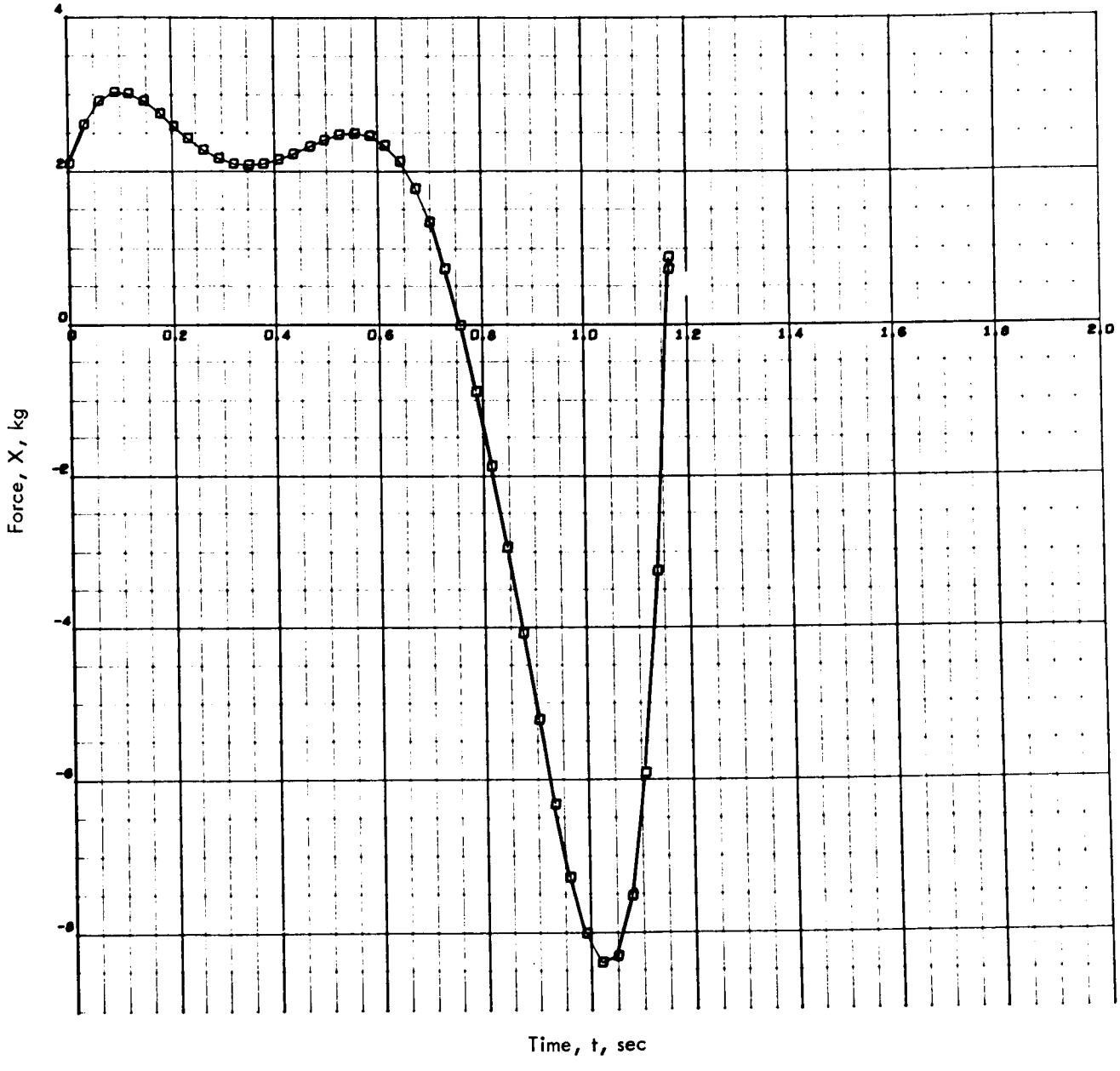

Figure E141. - Force X versus time for segment no. 6, leg and foot

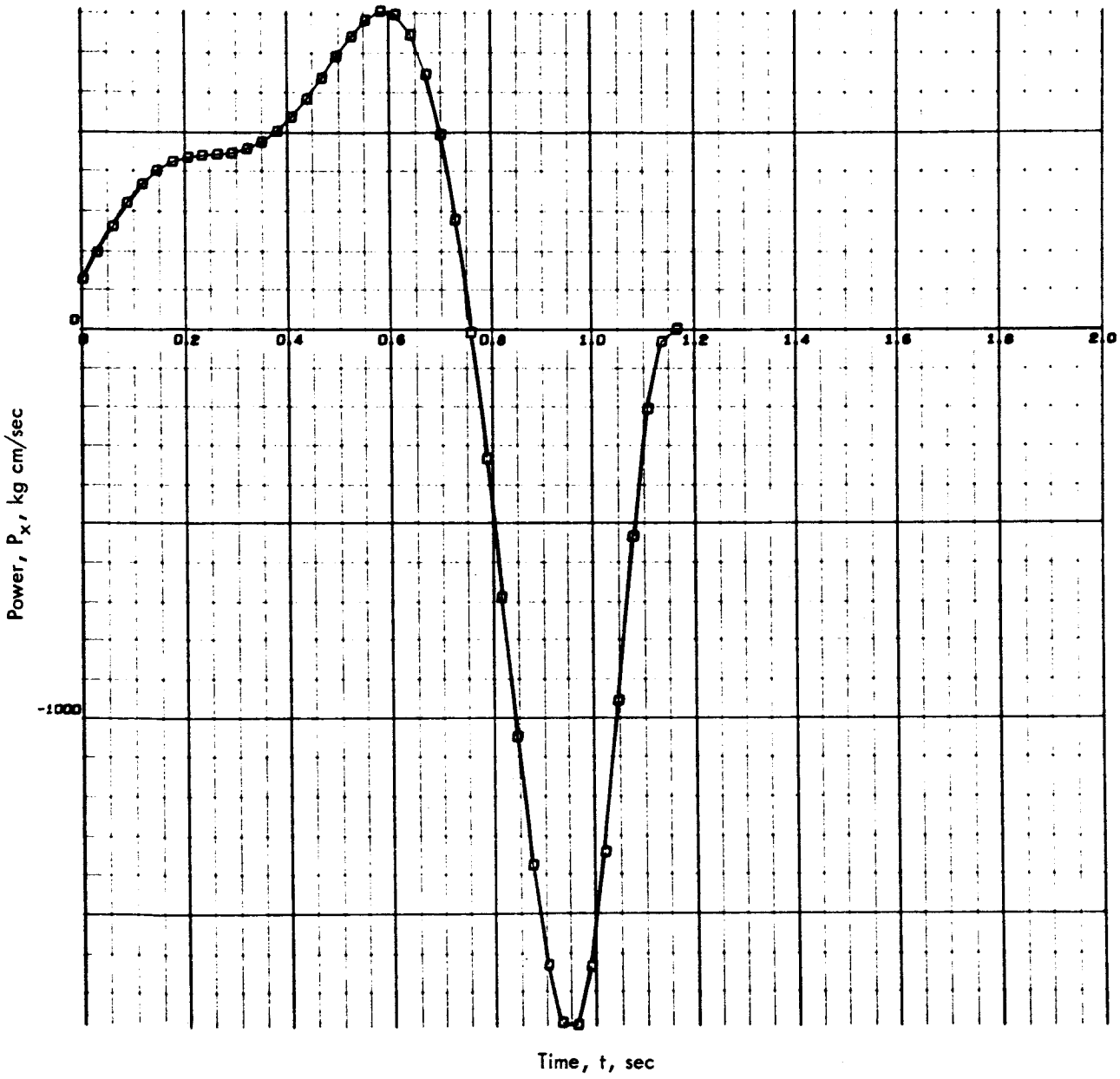

Figure E142. - Power P_x versus time for segment no. 6, leg and foot

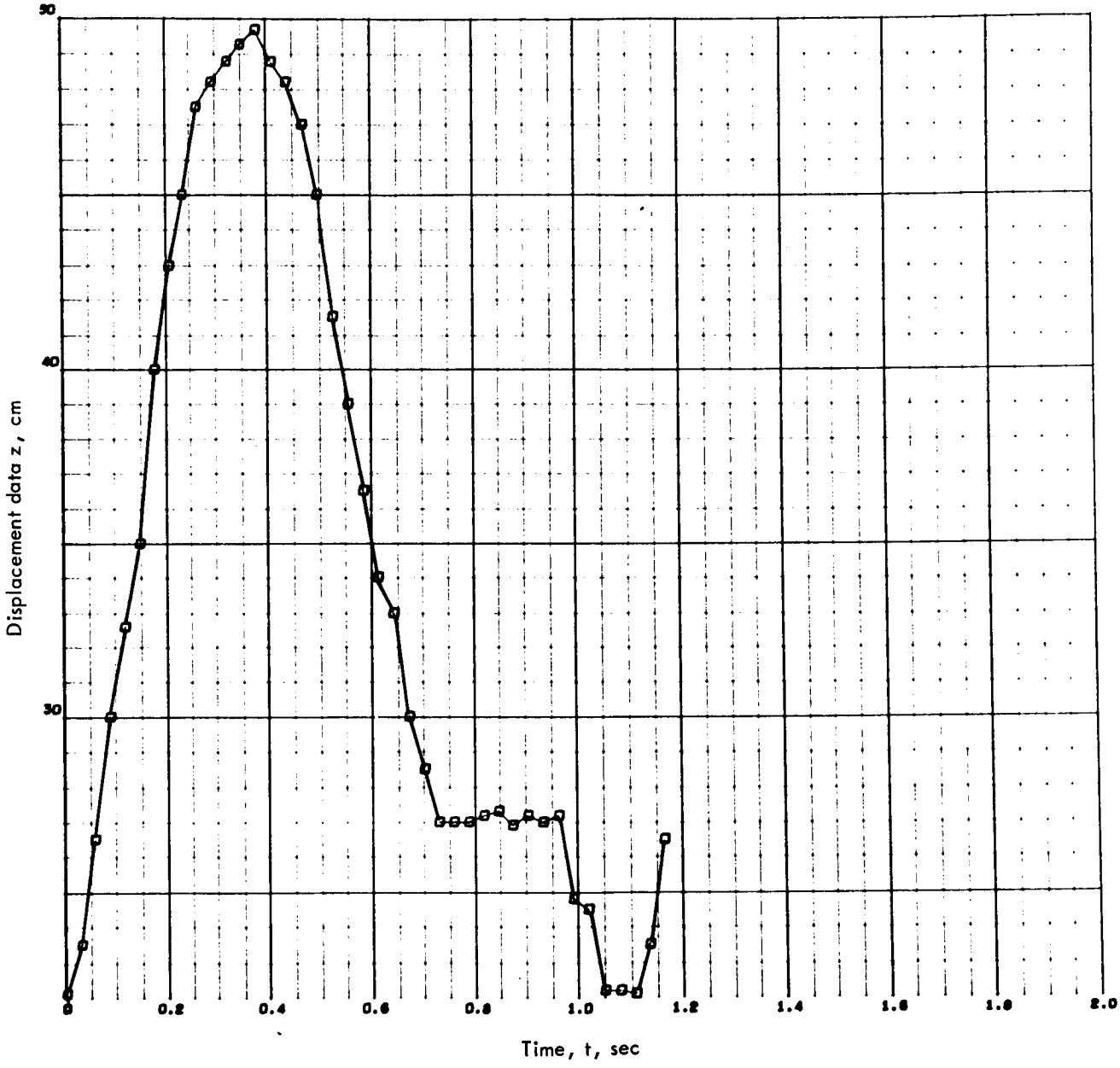

Figure E143.- Displacement data z versus time for segment no. 6, leg and foot

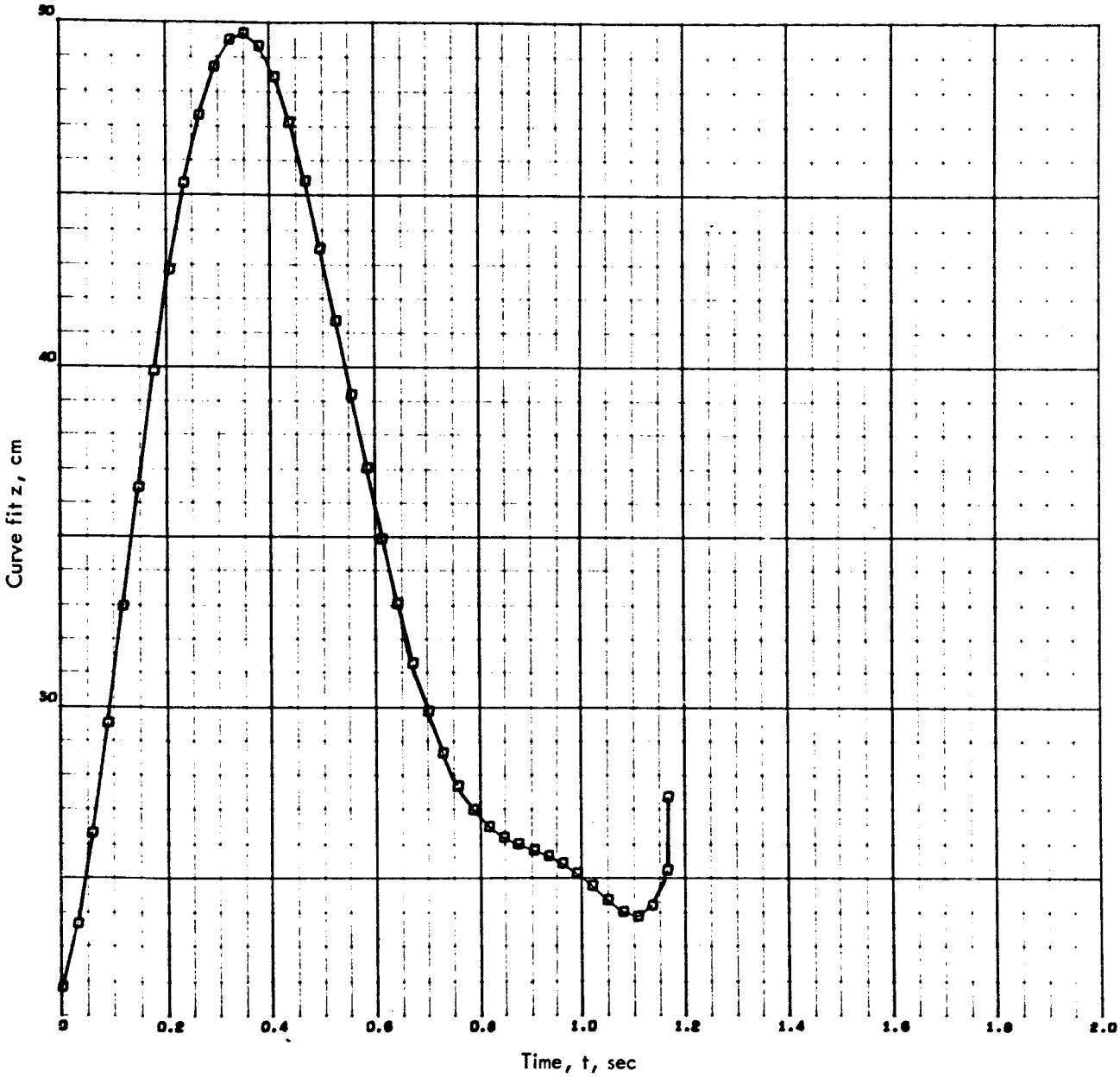

Figure E144. - Curve fit z versus time for segment no. 6, leg and foot

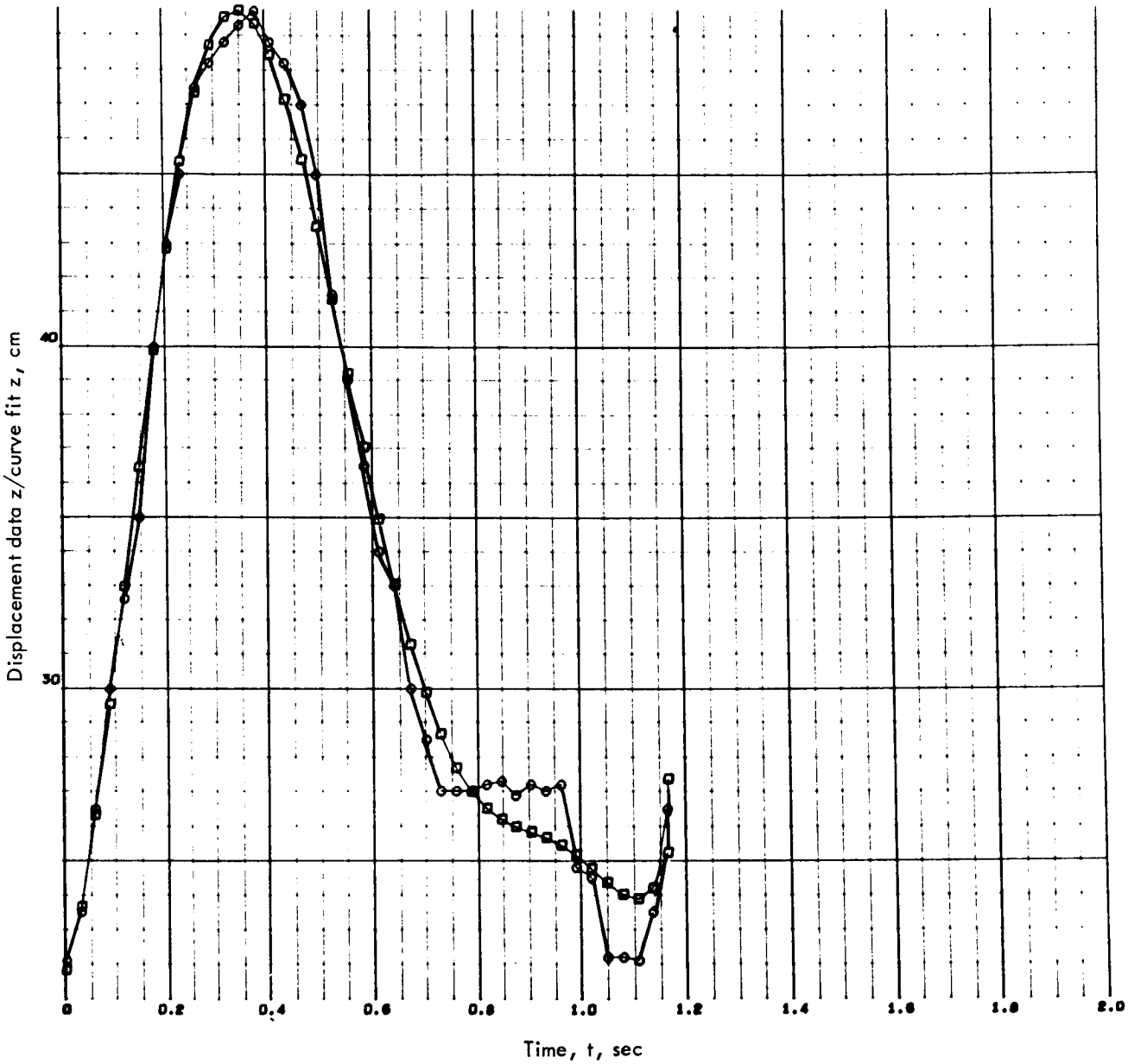

Figure E145. - Displacement data z/curvefit z versus time for segment no. 6, leg and foot

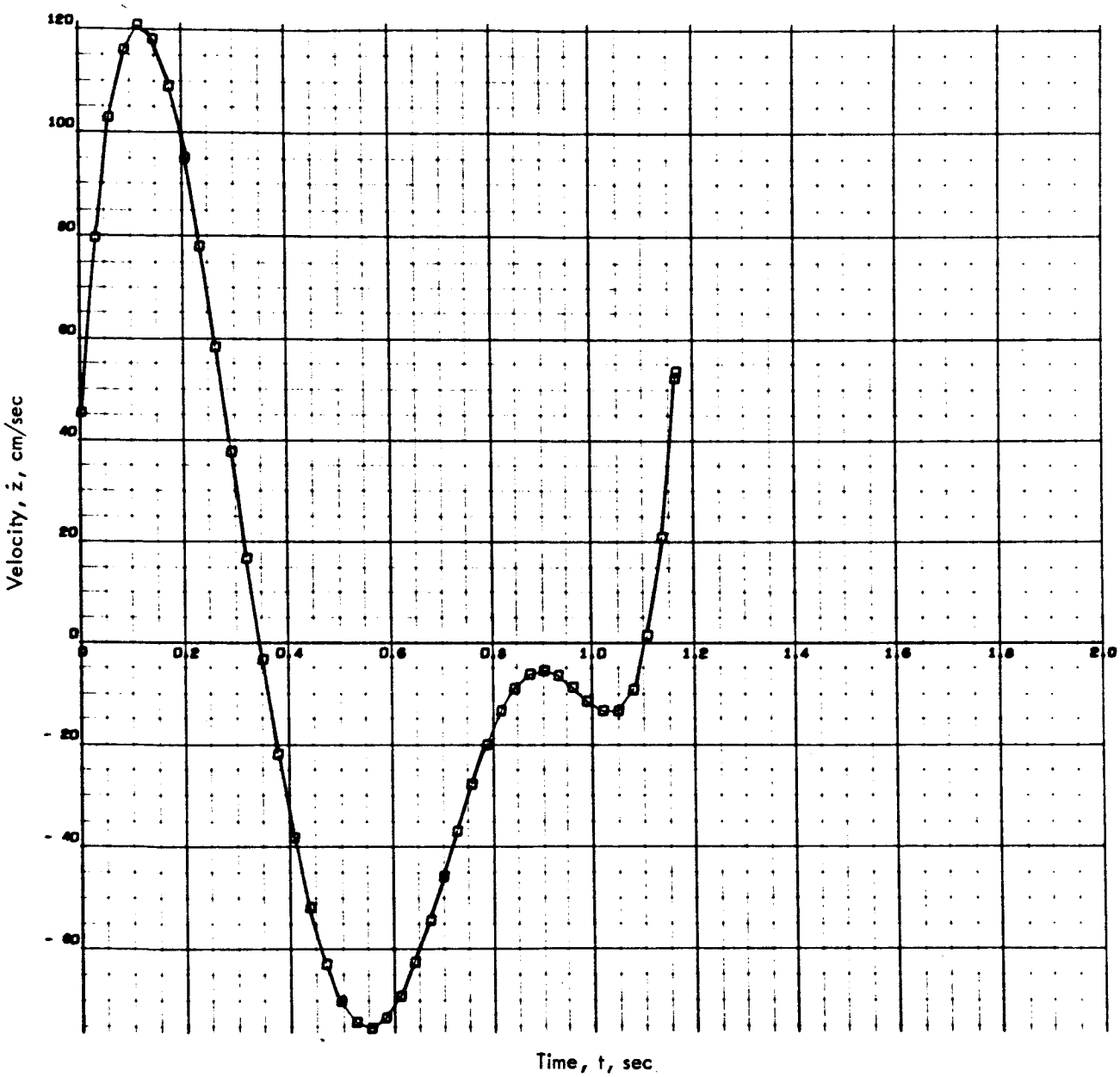

Figure E146. - Velocity ż versus time for segment no. 6, leg and foot

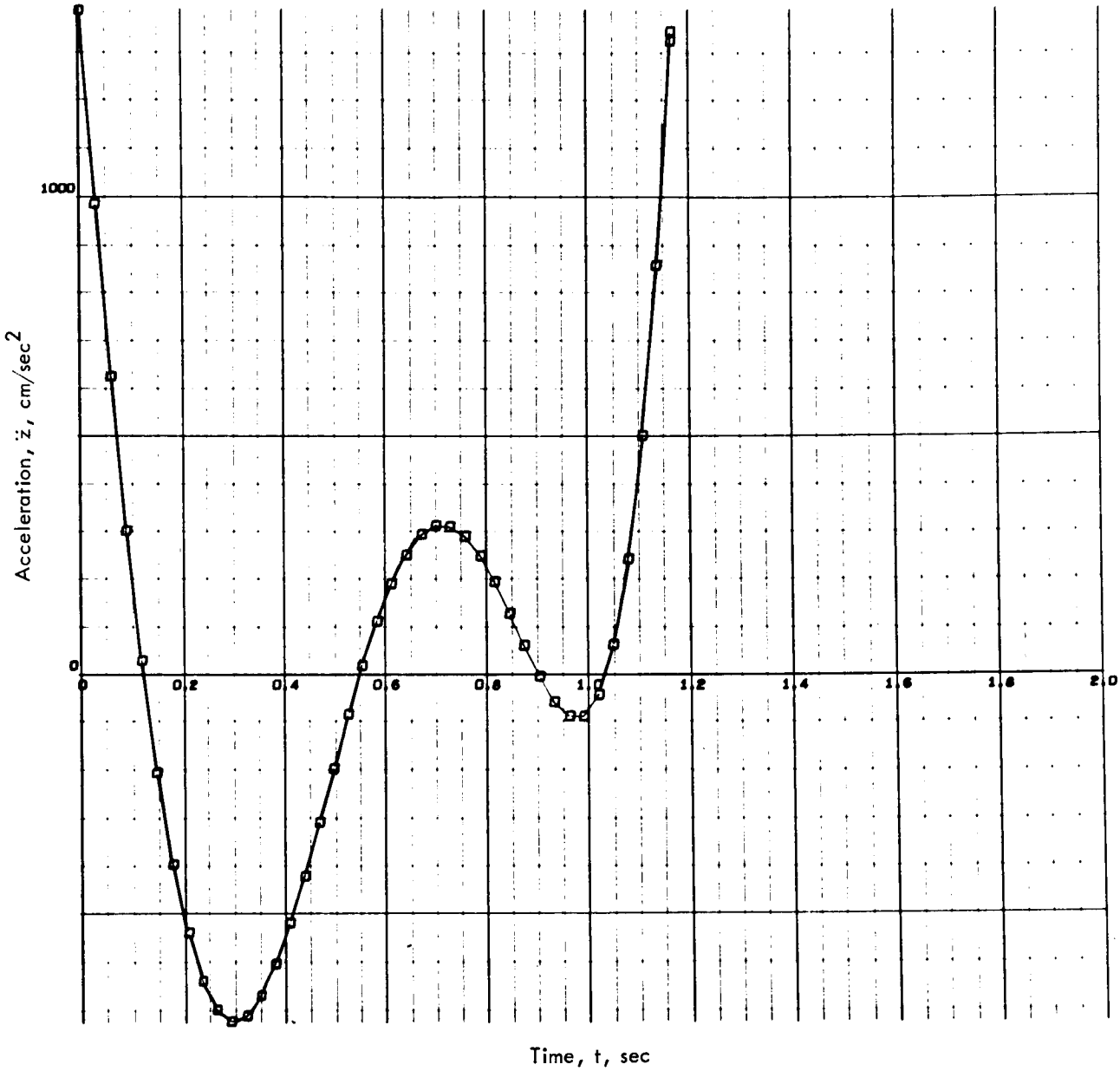

Figure E147. - Acceleration $\ddot{z}$ versus time for segment no. 6, leg and foot

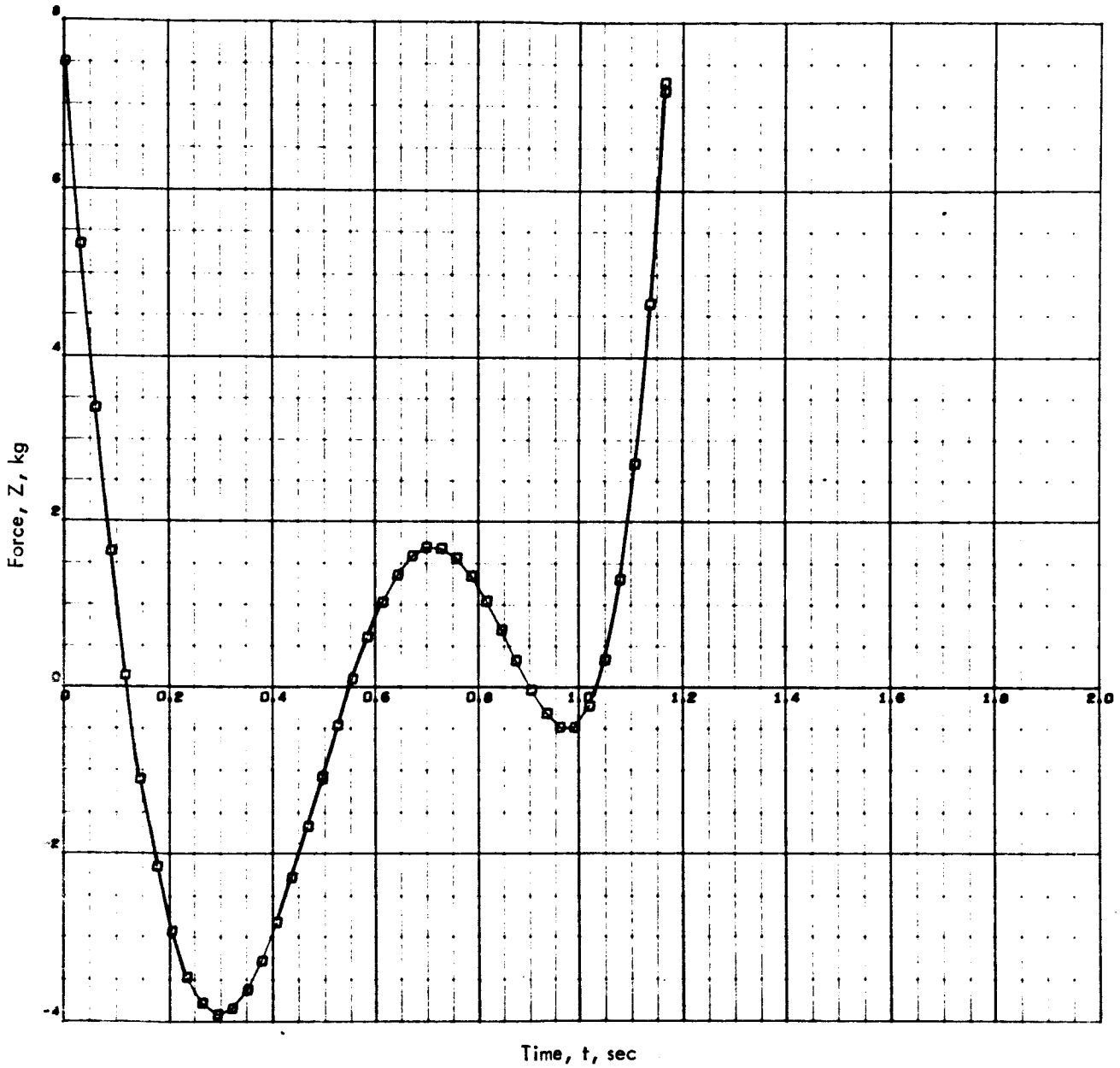

Figure E148. - Force Z versus time for segment no. 6, leg and foot

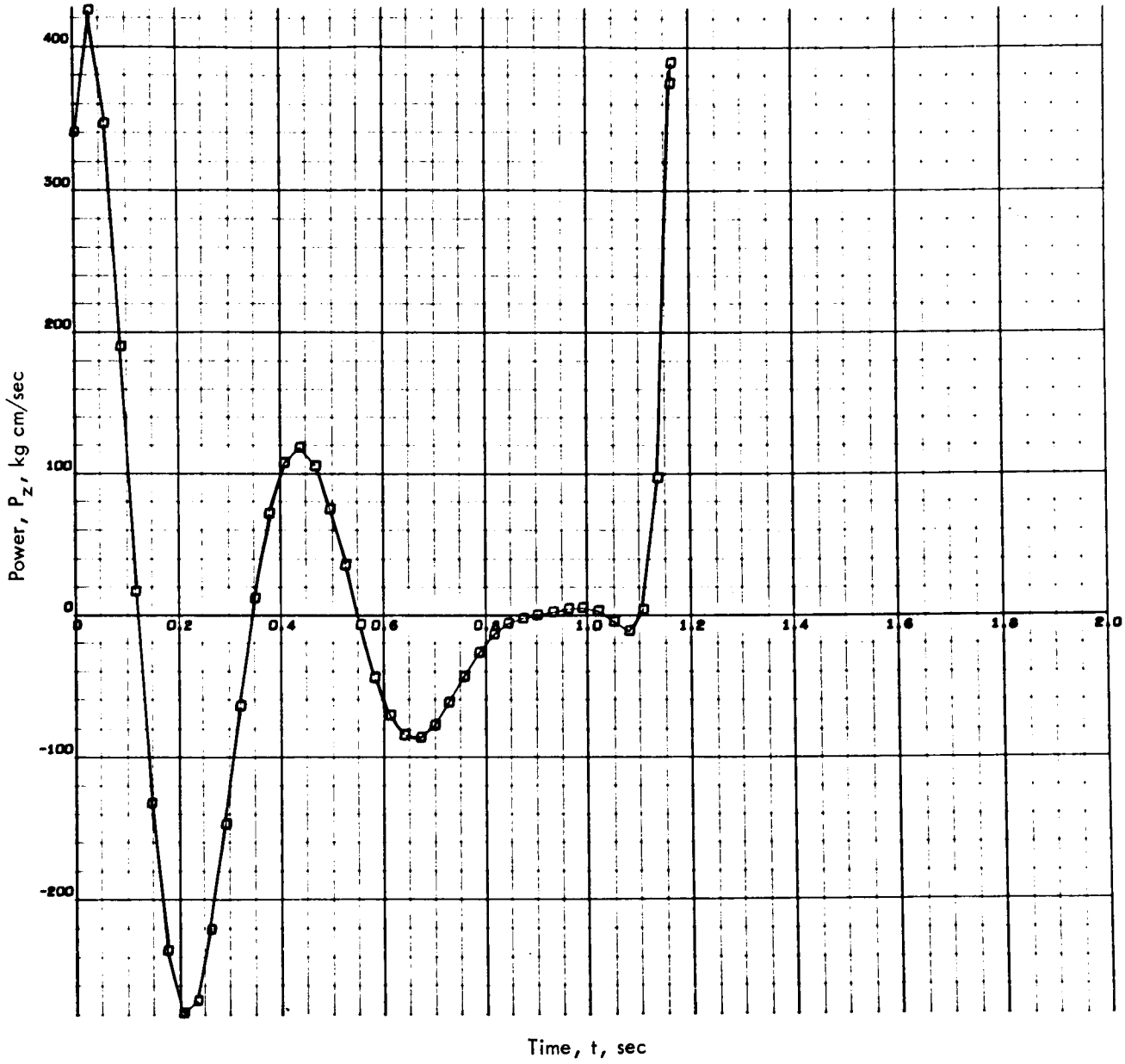

Figure E149. - Power P_z versus time for segment no. 6, leg and foot

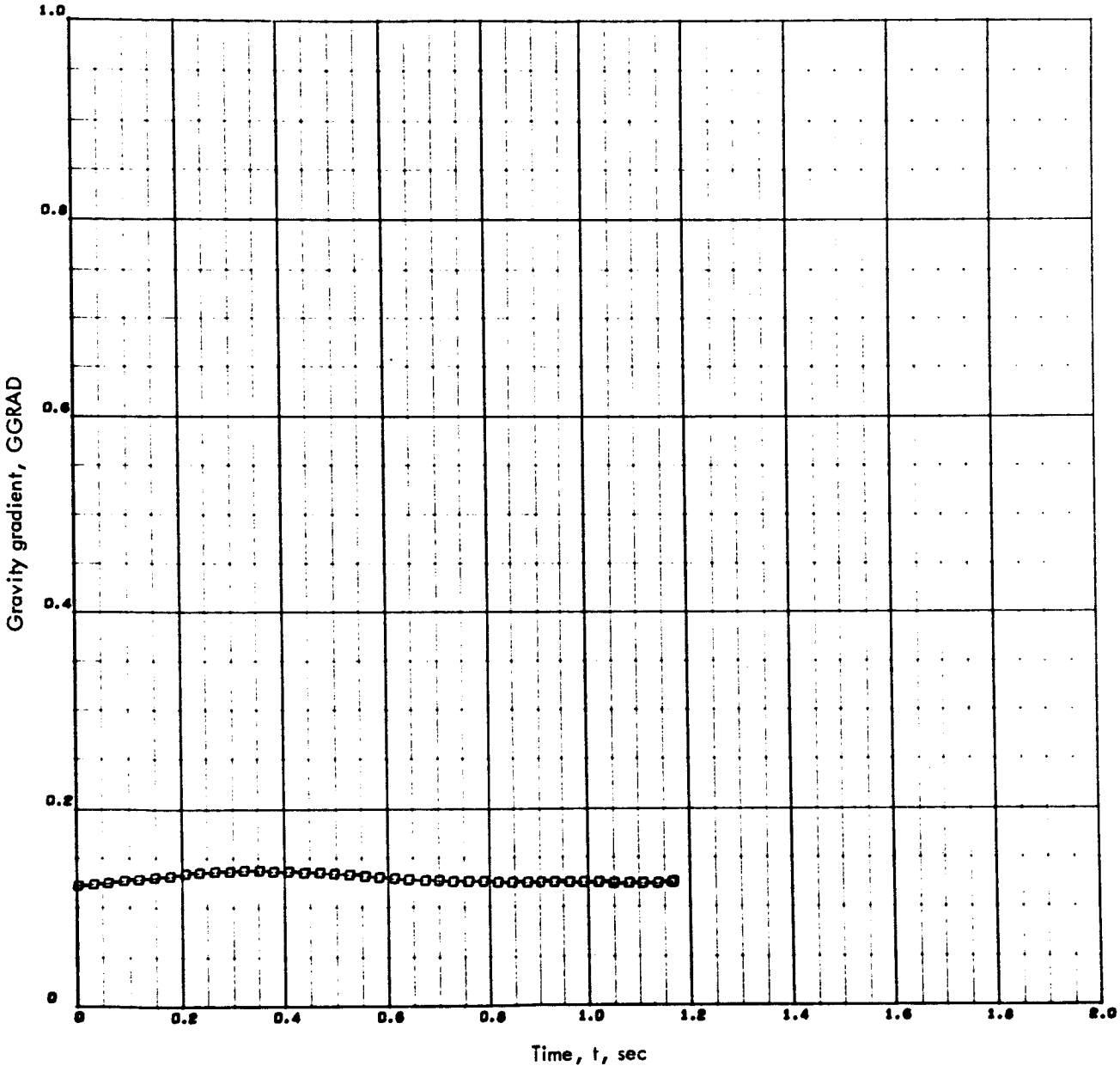

Figure E150.- Gravity gradient versus time for segment no. 6, leg and foot

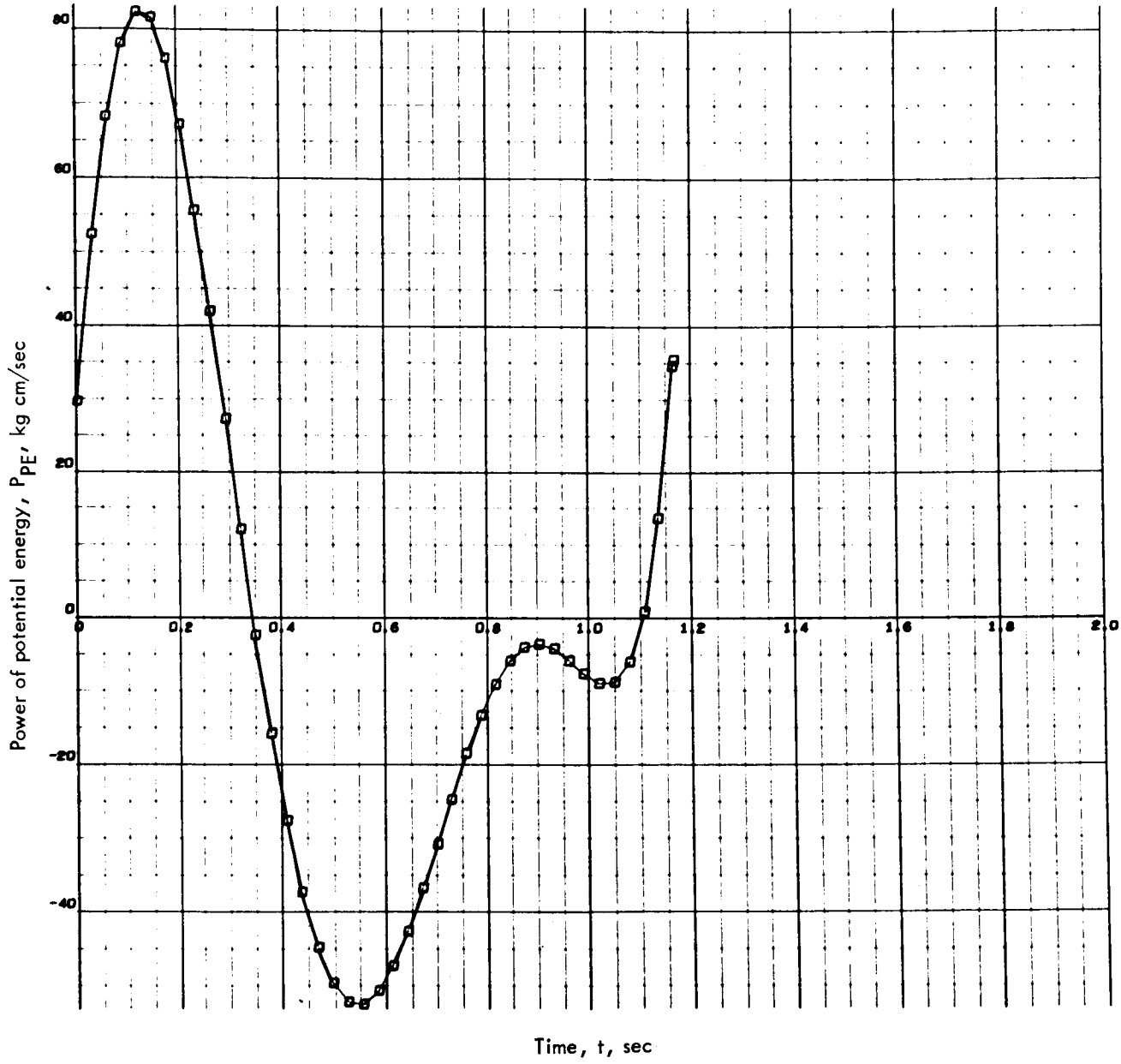

Figure E151. - Power of potential energy versus time for segment no. 6, leg and foot

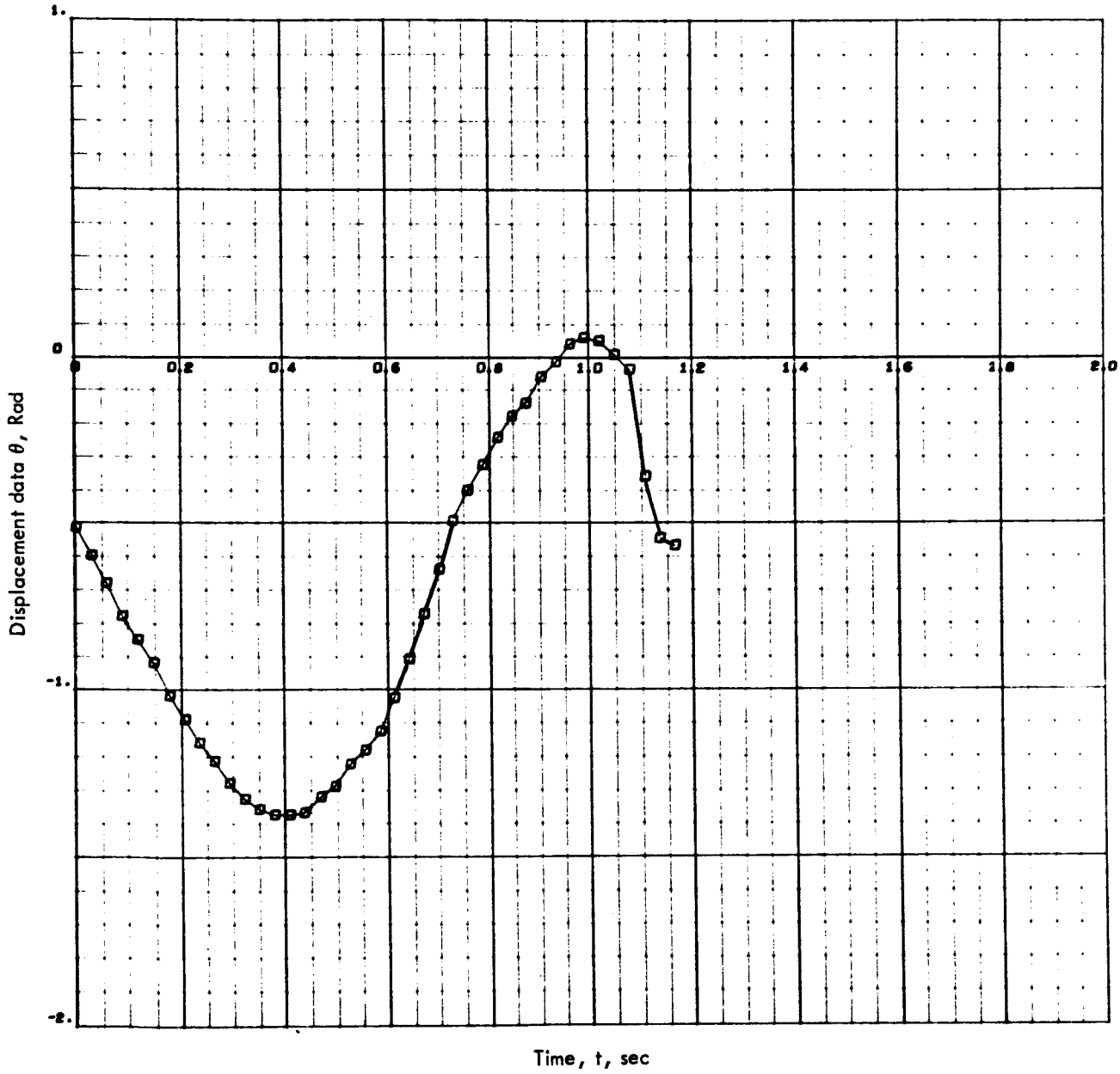

Figure E152. - Displacement data θ versus time for segment no. 6, leg and foot

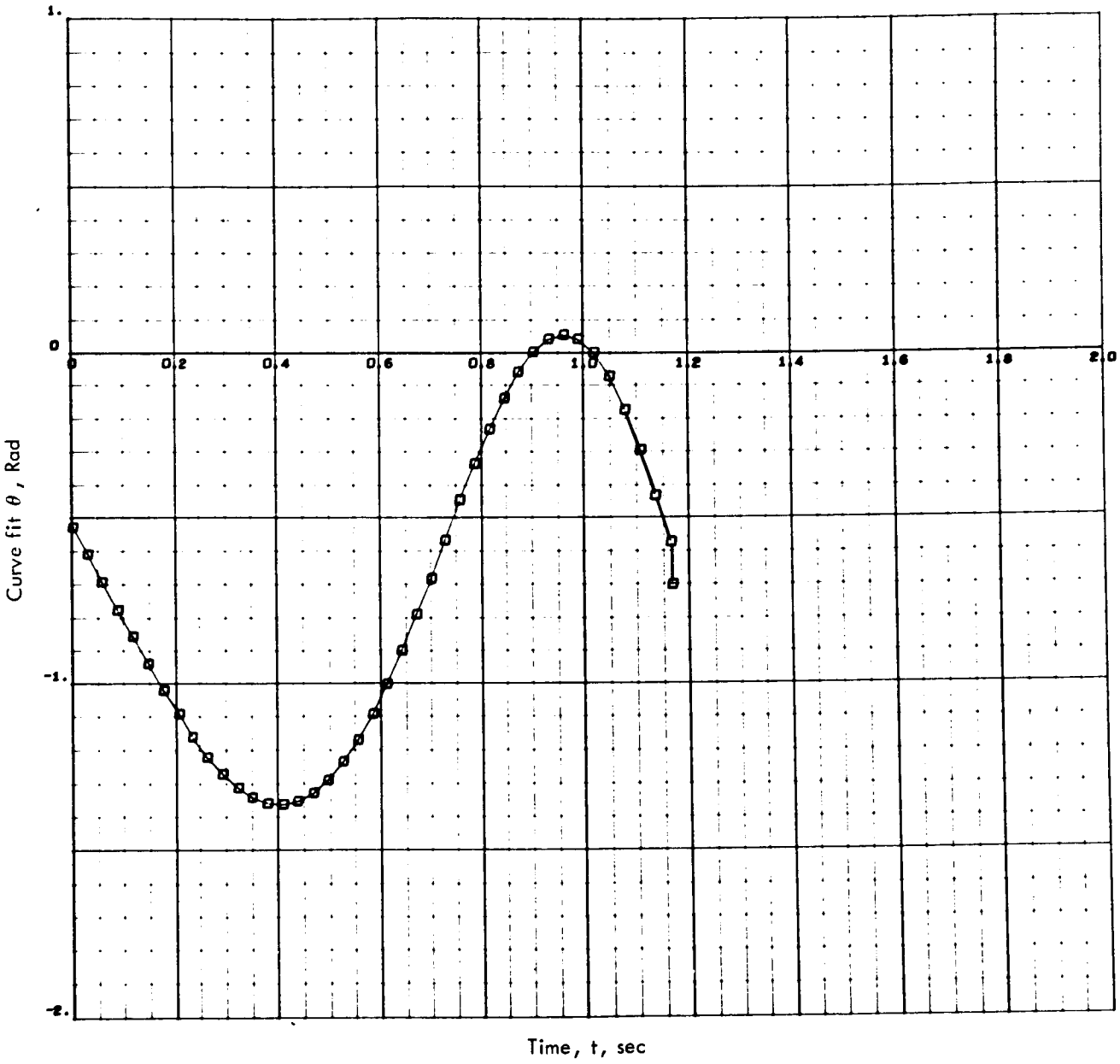

Figure E153. - Curve fit θ versus time for segment no. 6, leg and foot

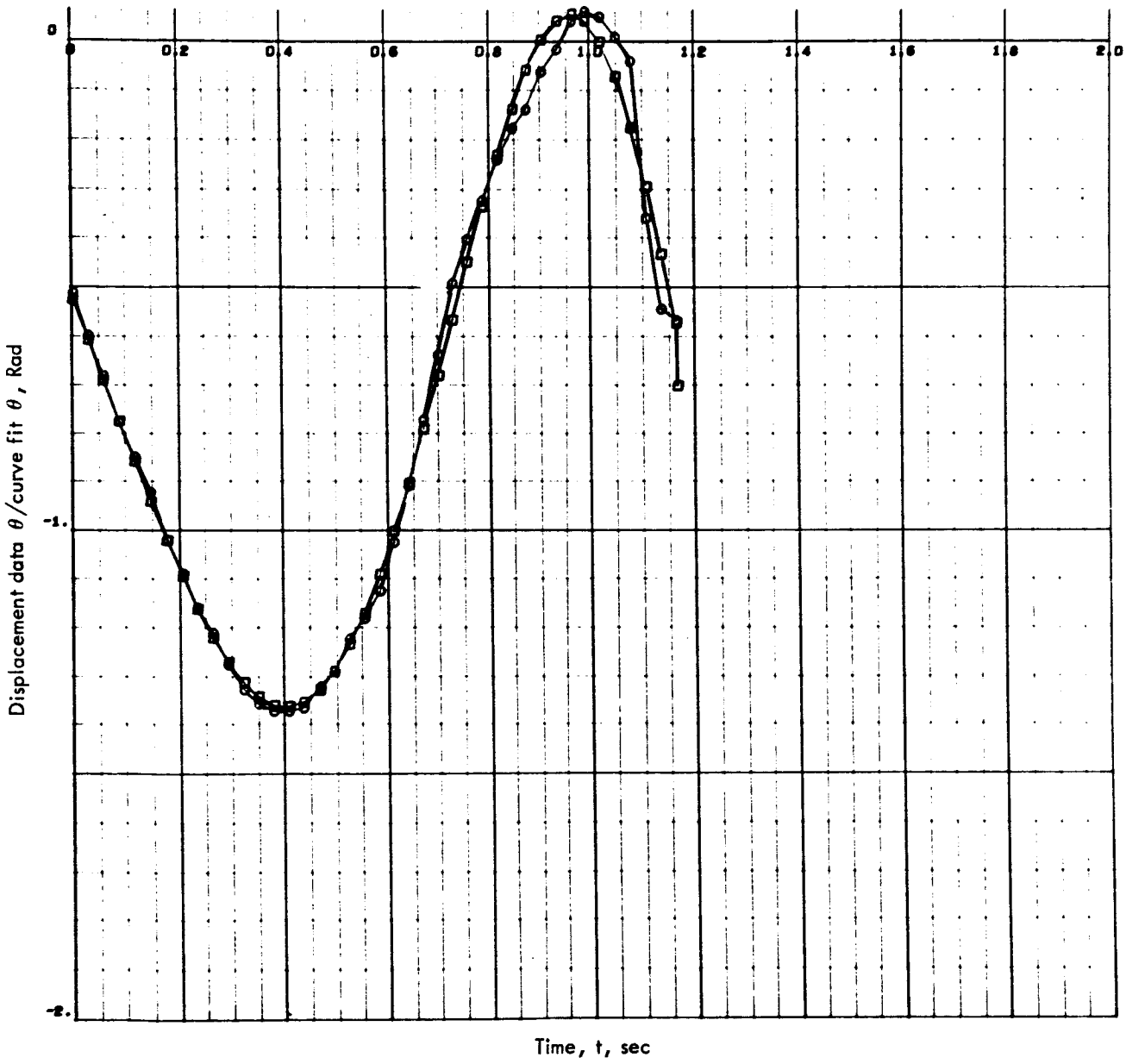

Figure E154. - Displacement data θ /curve fit θ versus time for segment no. 6, leg and foot

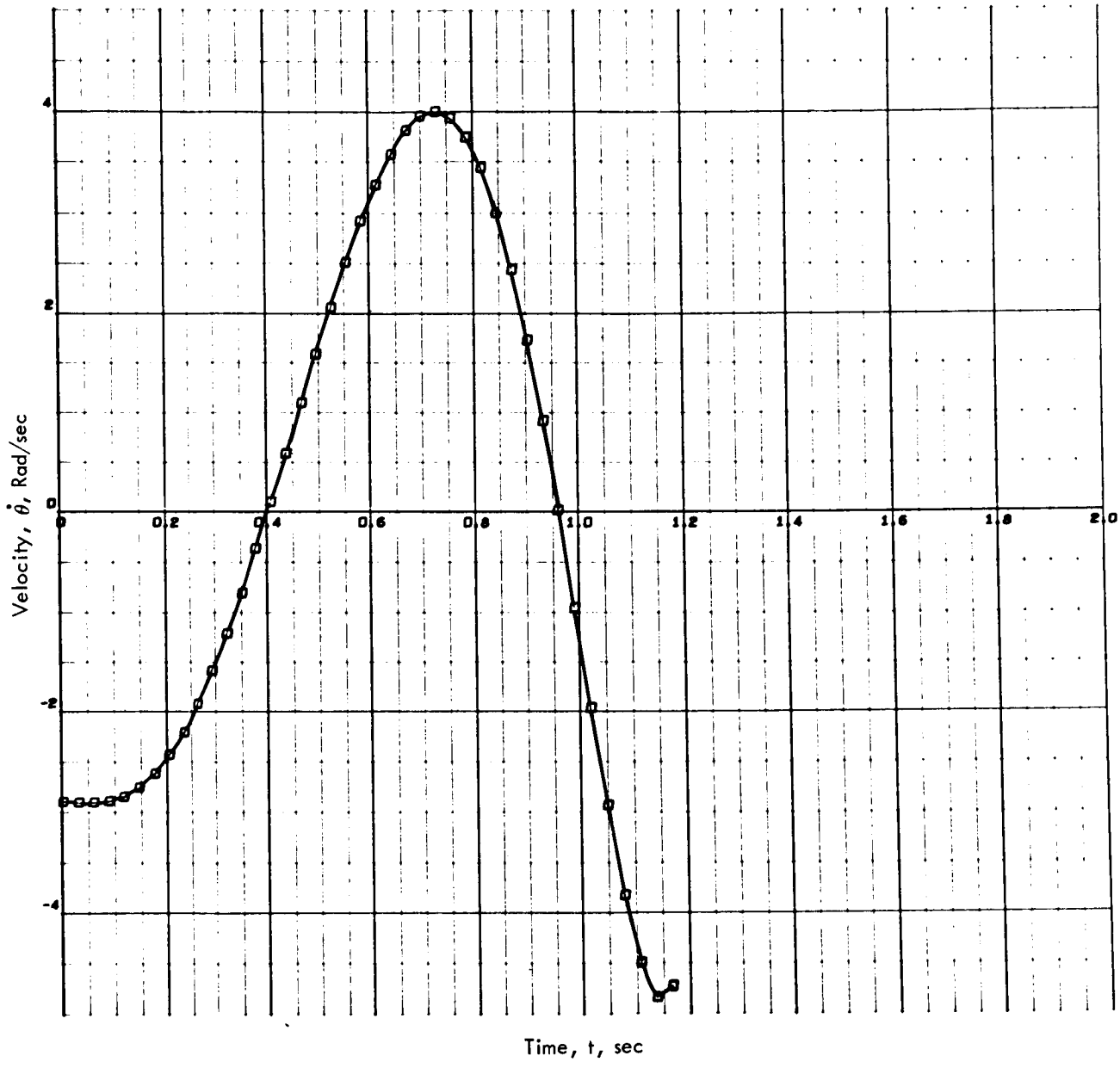

Figure E155. - Velocity $\dot{\theta}$ versus time for segment no. 6, leg and foot

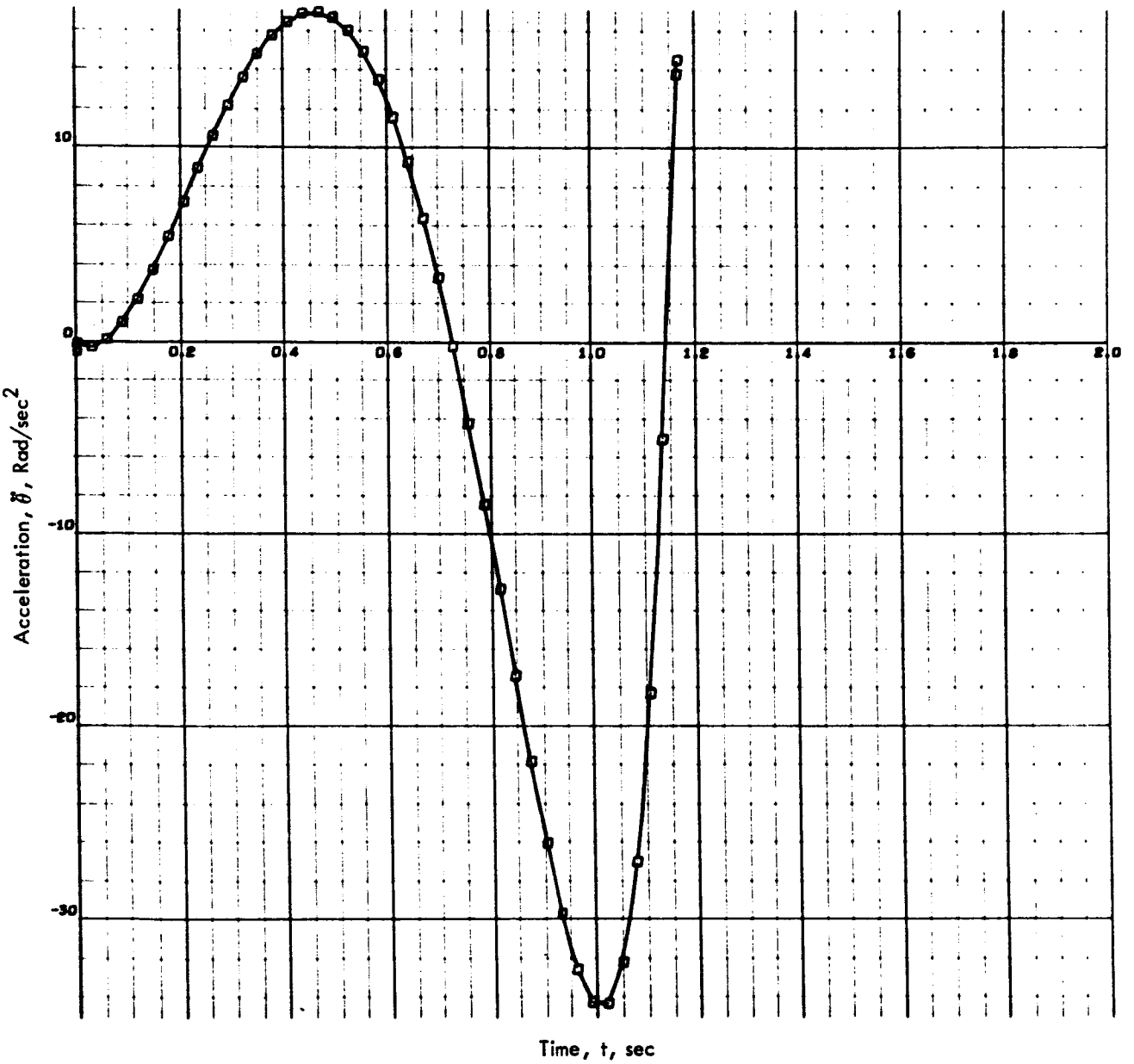

Figure E156. - Acceleration $\ddot{\theta}$ versus time for segment no. 6, leg and foot

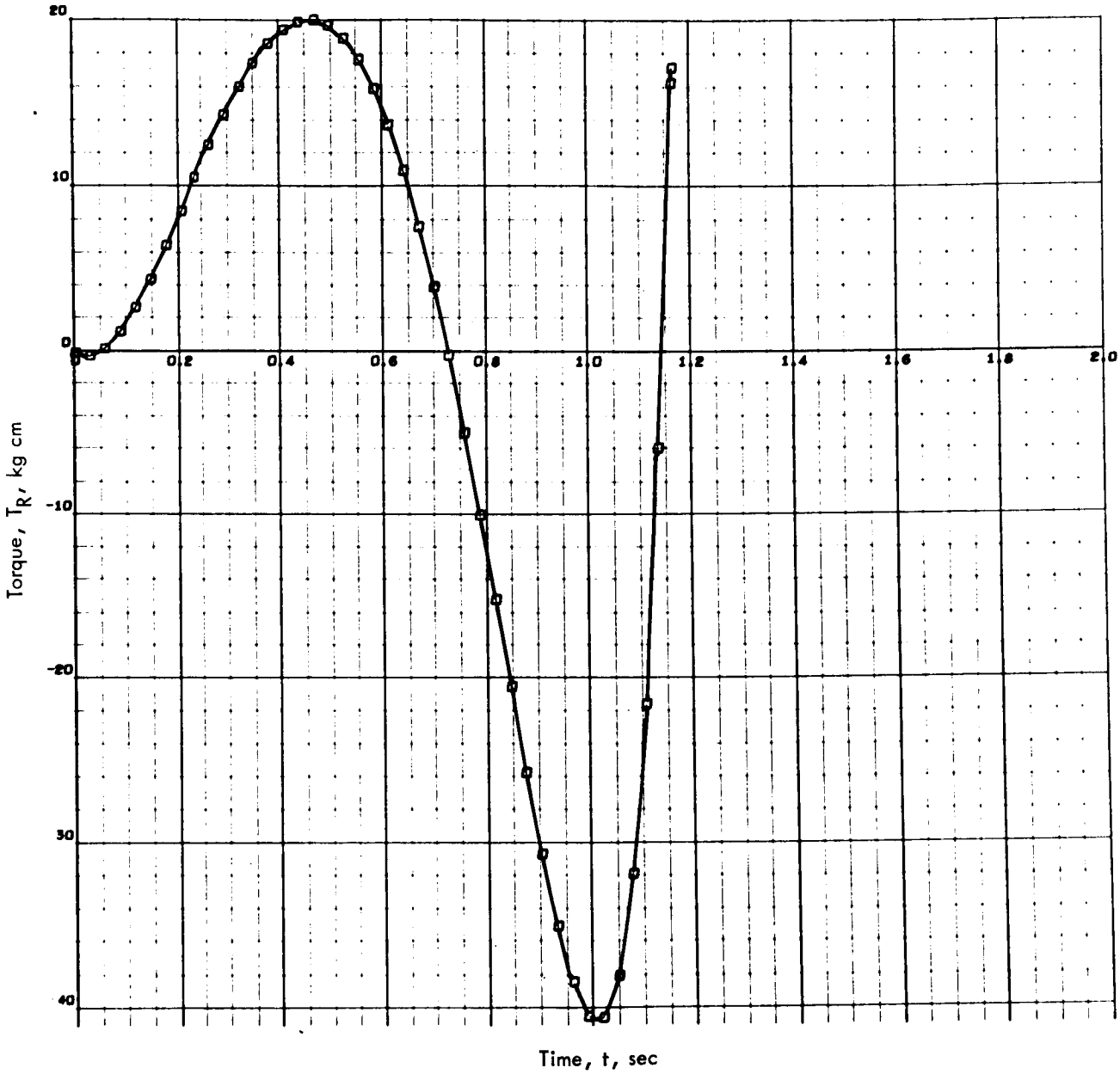

Figure E157. - Torque T_R versus time for segment no. 6, leg and foot

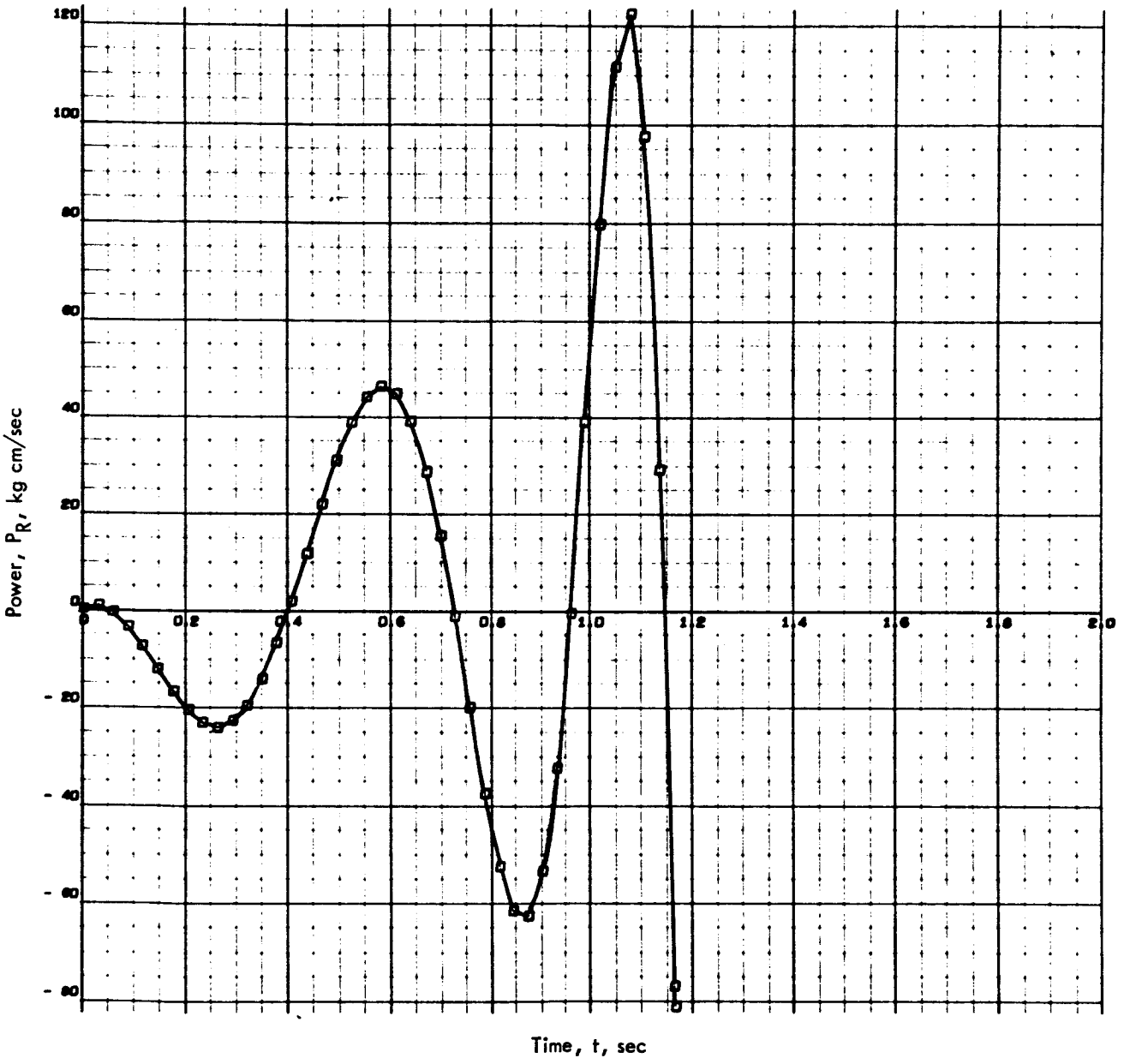

Figure E158.- Power P_R versus time for segment no. 6, leg and foot

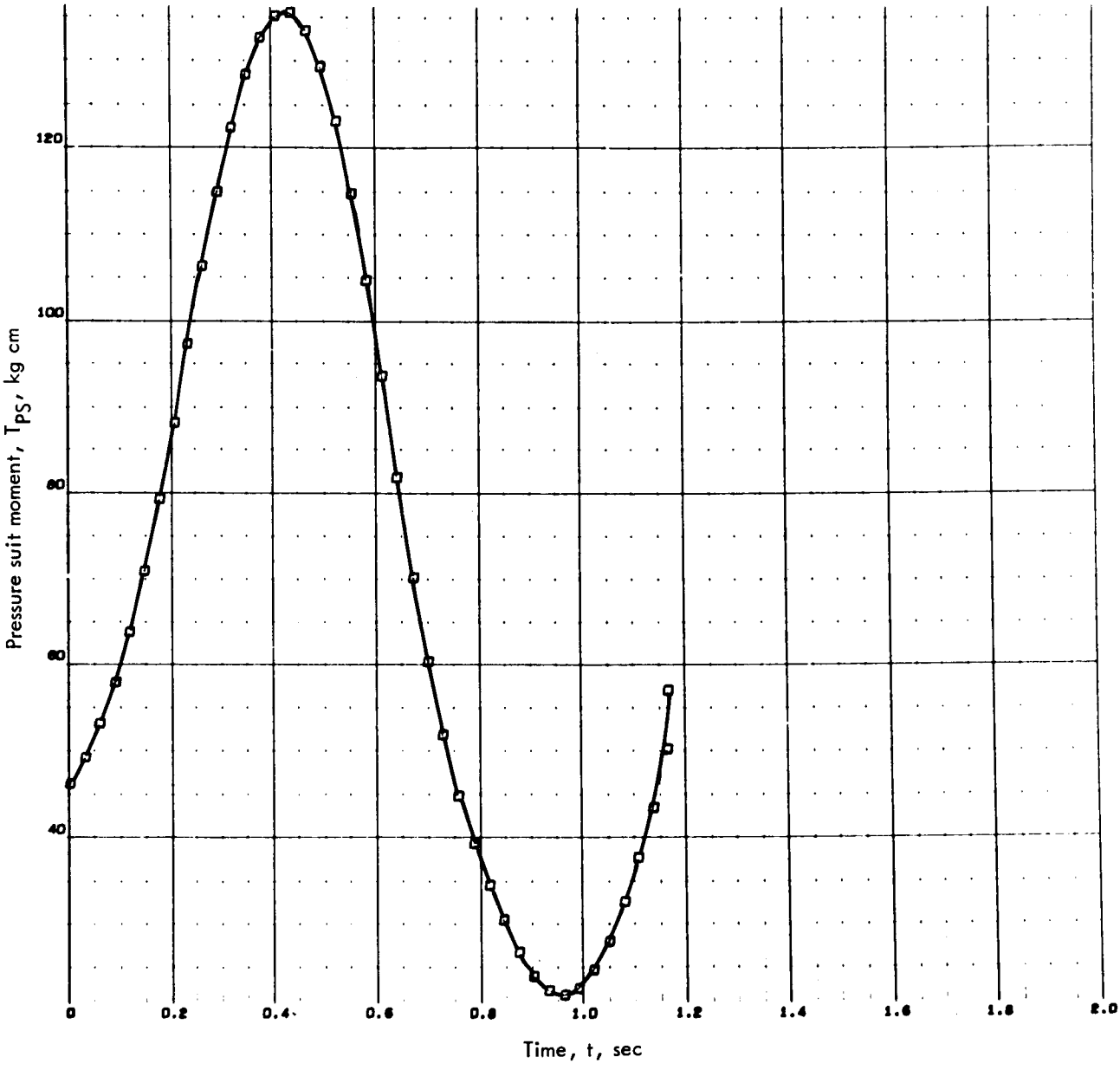

Figure E159. - Pressure suit moment T_{PS} versus time for segment no. 6, leg and foot

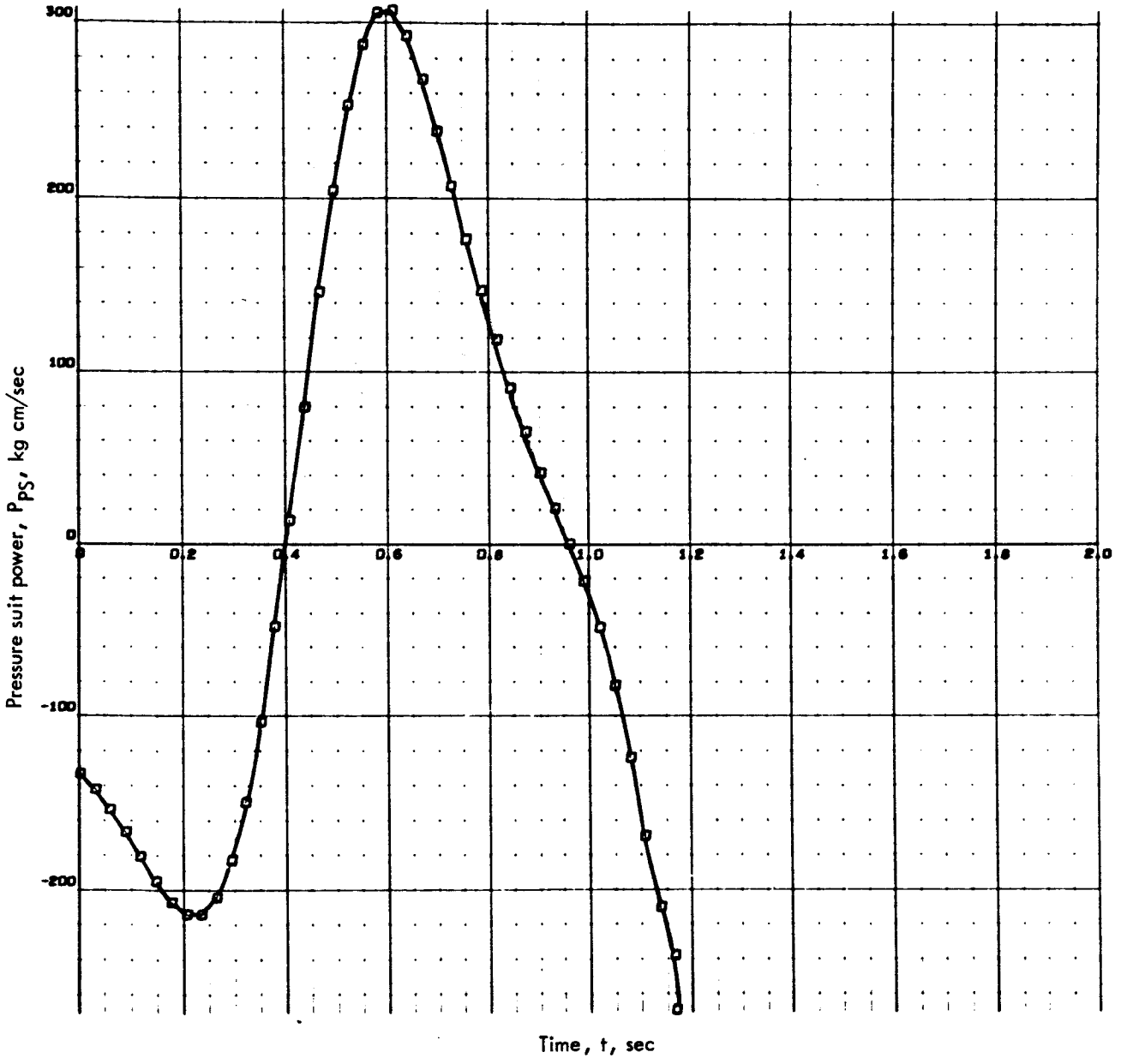

Figure E160. - Pressure suit power P_{PS} versus time for segment no. 6, leg and foot

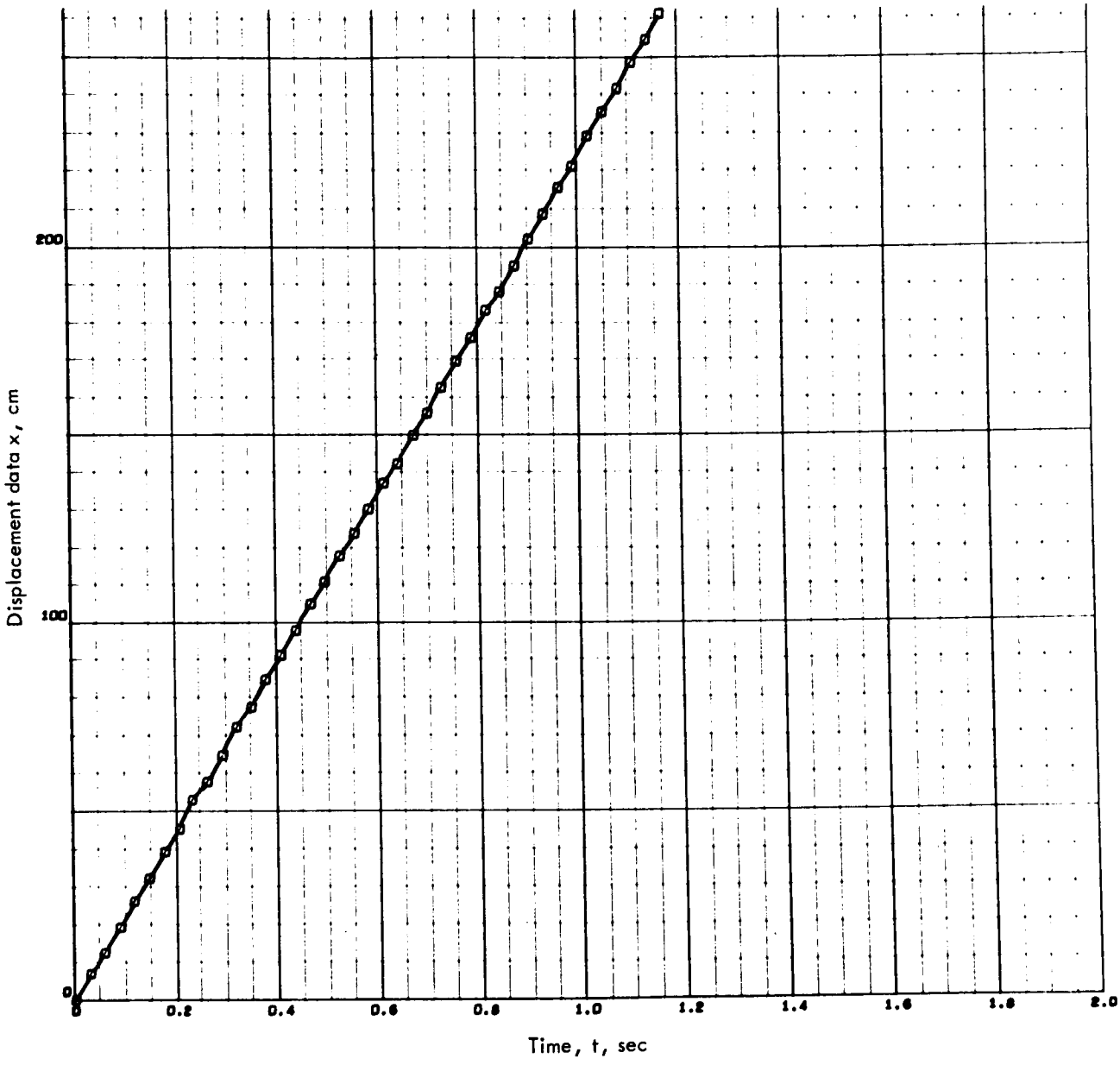

Figure E161. - Displacement data x versus time for segment no. 7, instrument pack

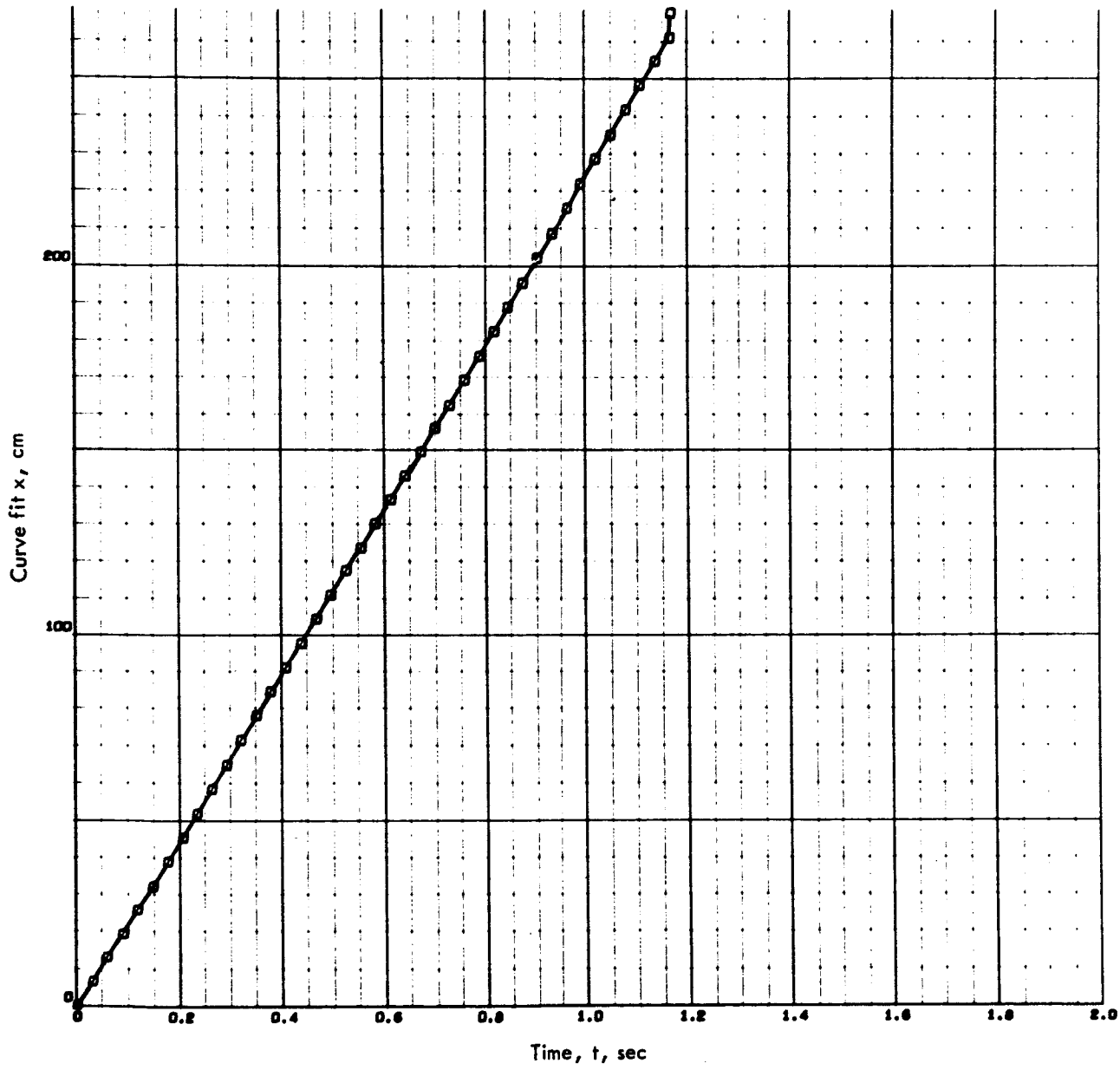

Figure E162. - Curve fit x versus time for segment no. 7, instrument pack

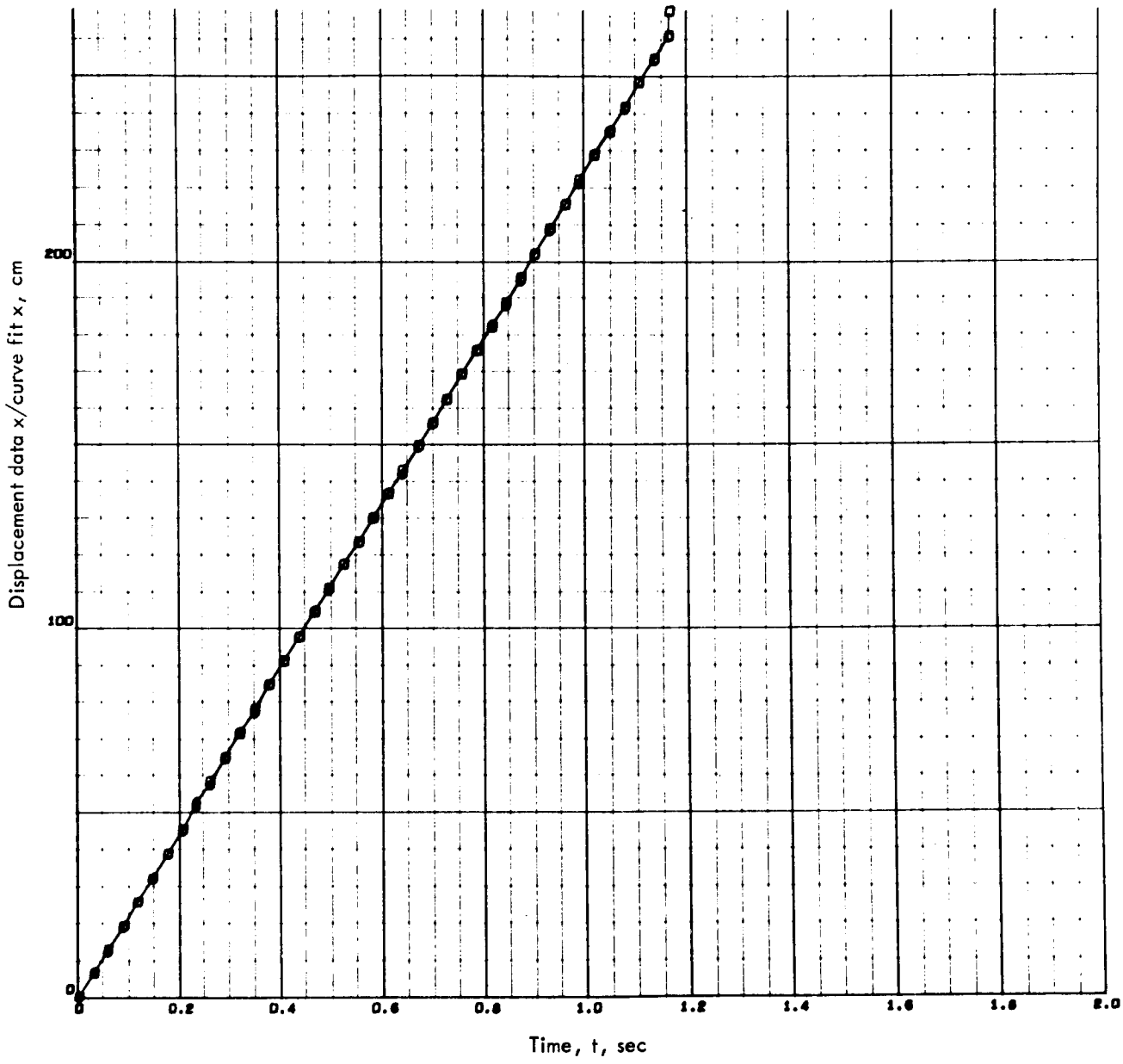

Figure E163. - Displacement data x/curve fit x versus time for segment no. 7, instrument pack

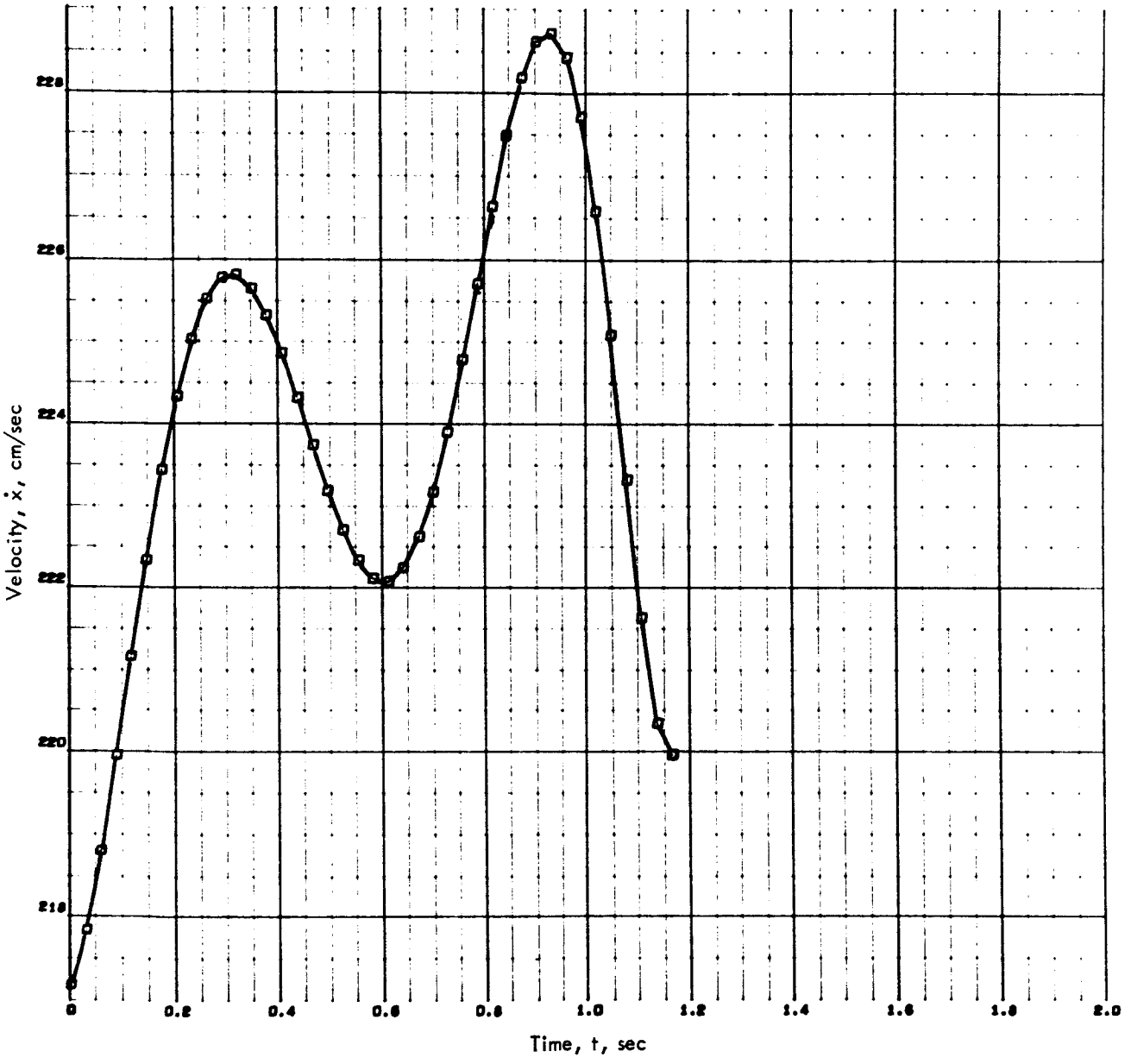

Figure E164. - Velocity $\dot{x}$ versus time for segment no. 7, instrument pack

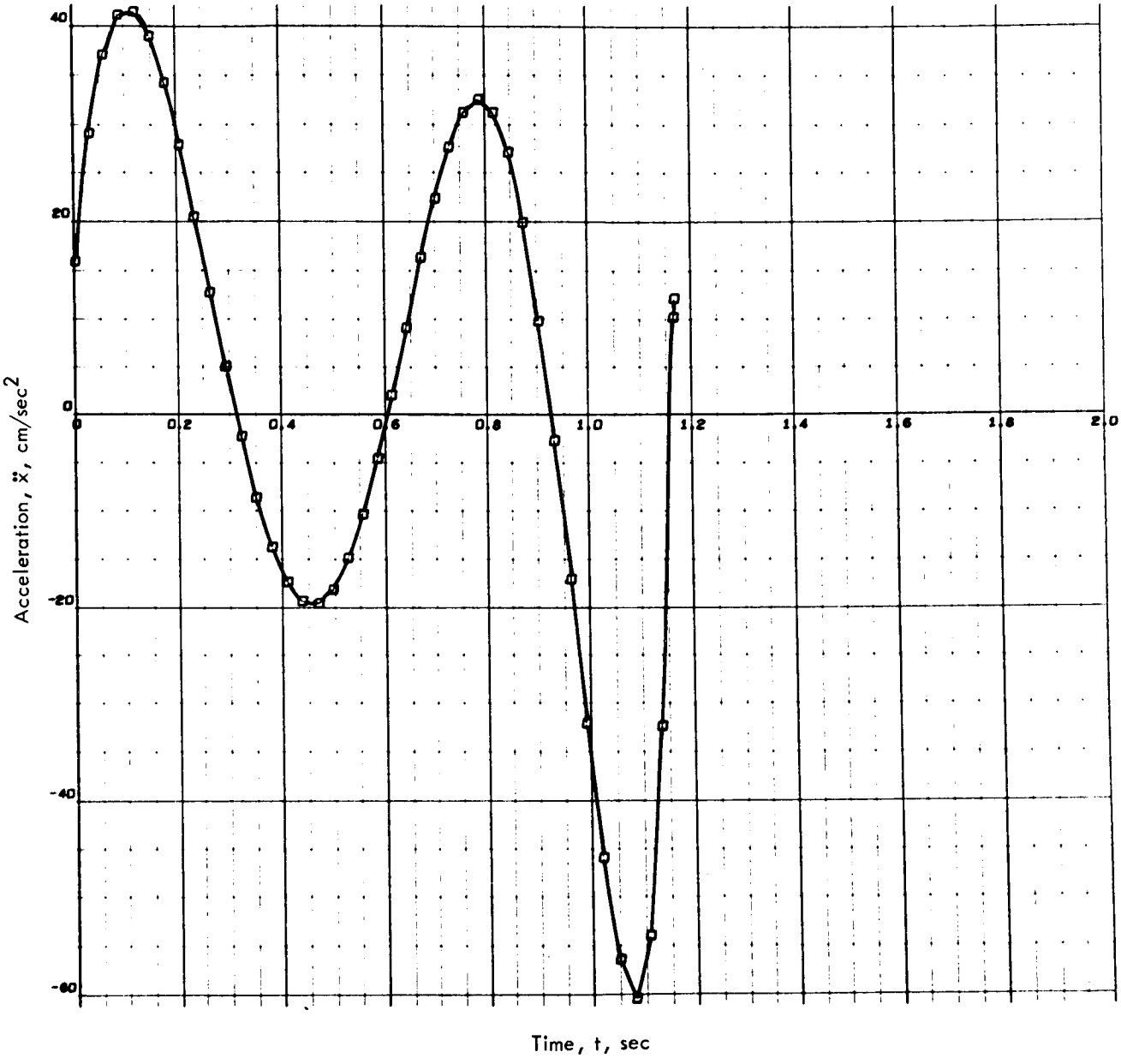

Figure E165. - Acceleration $\ddot{x}$ versus time for segment no. 7, instrument pack

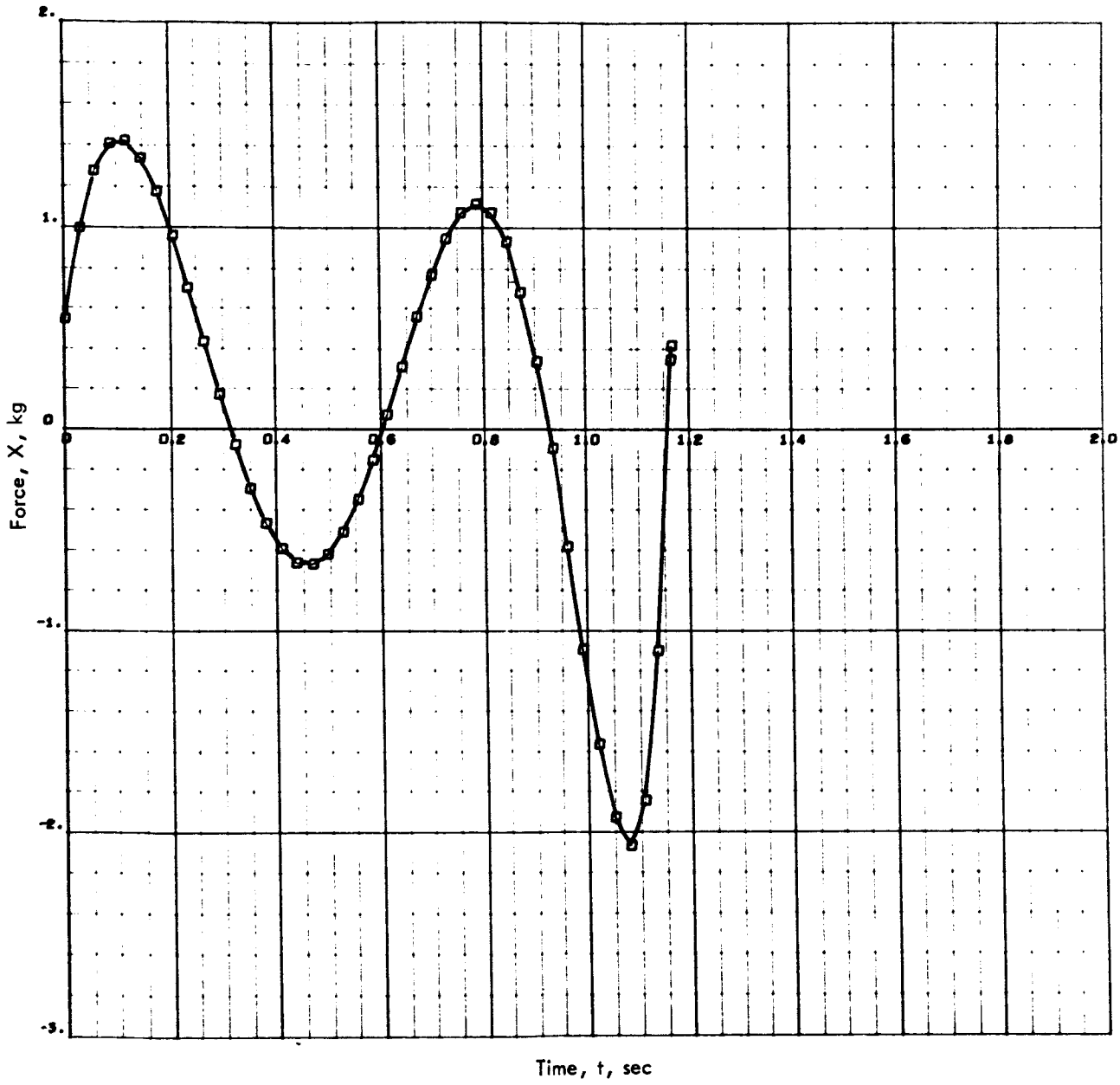

Figure E166. - Force X versus time for segment no. 7, instrument pack

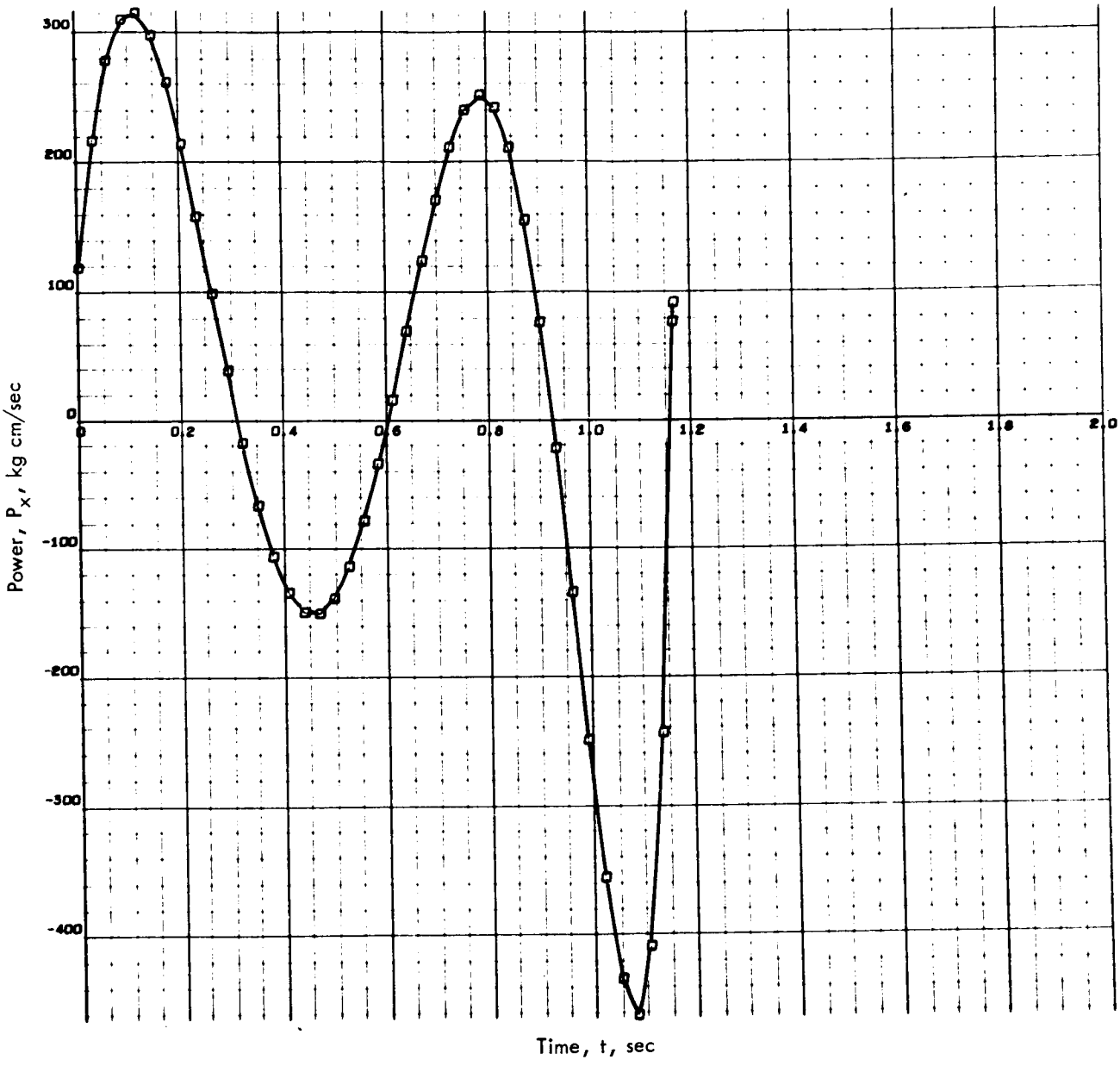

Figure E167. - Power P_x versus time for segment no. 7, instrument pack

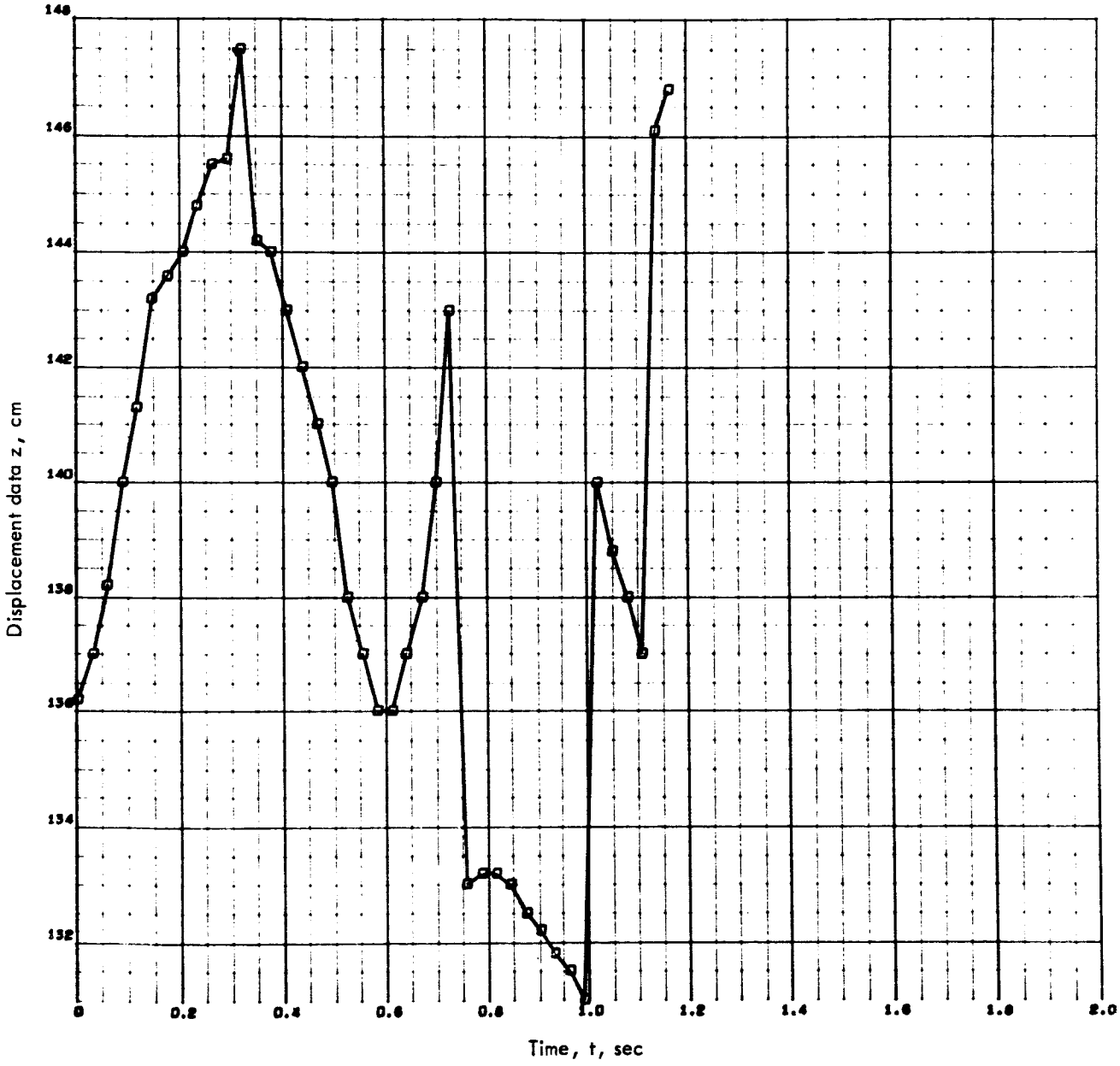

Figure E168. - Displacement data z versus time for segment no. 7, instrument pack

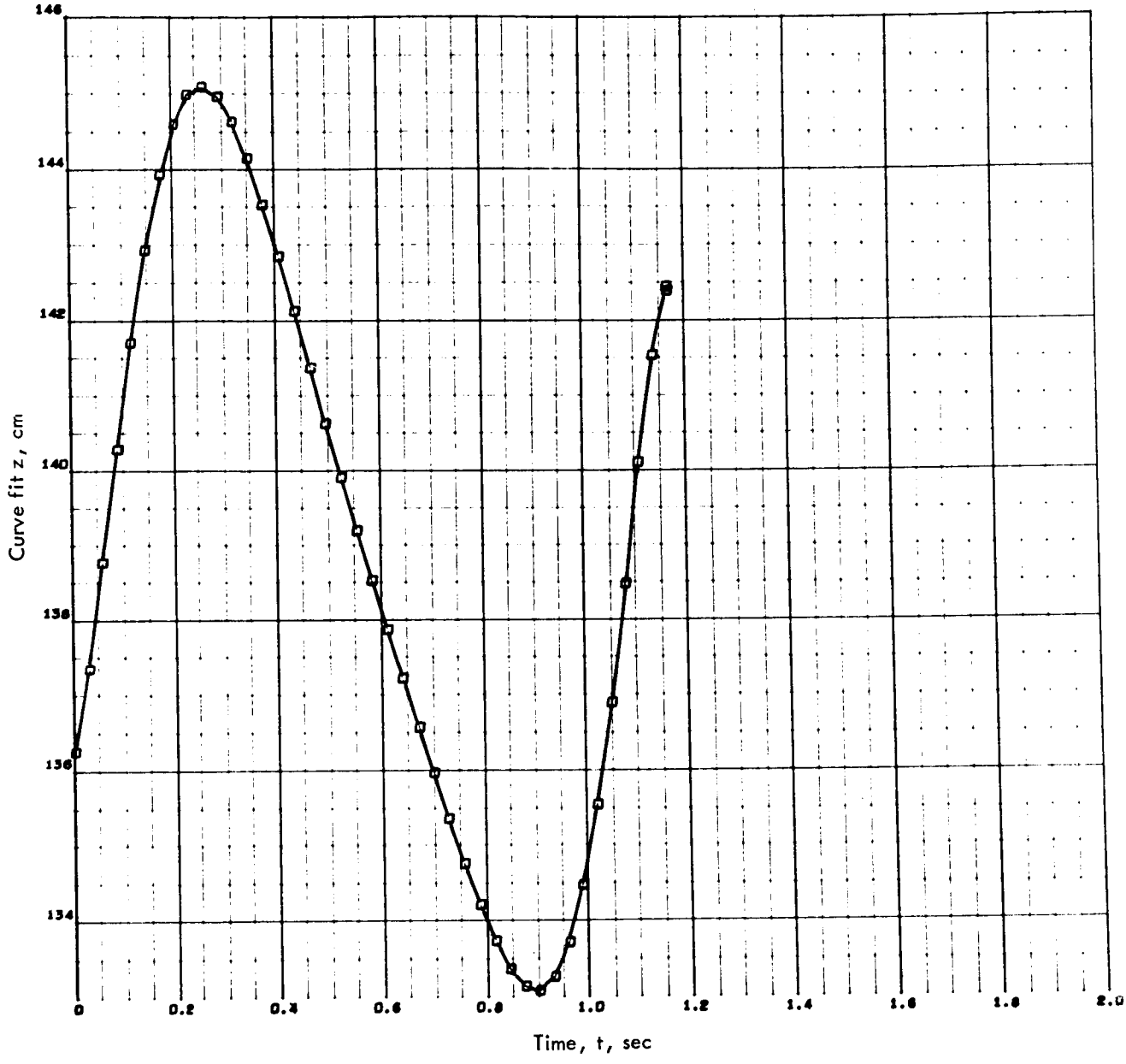

Figure E169. - Curve fit z versus time for segment no. 7, instrument pack

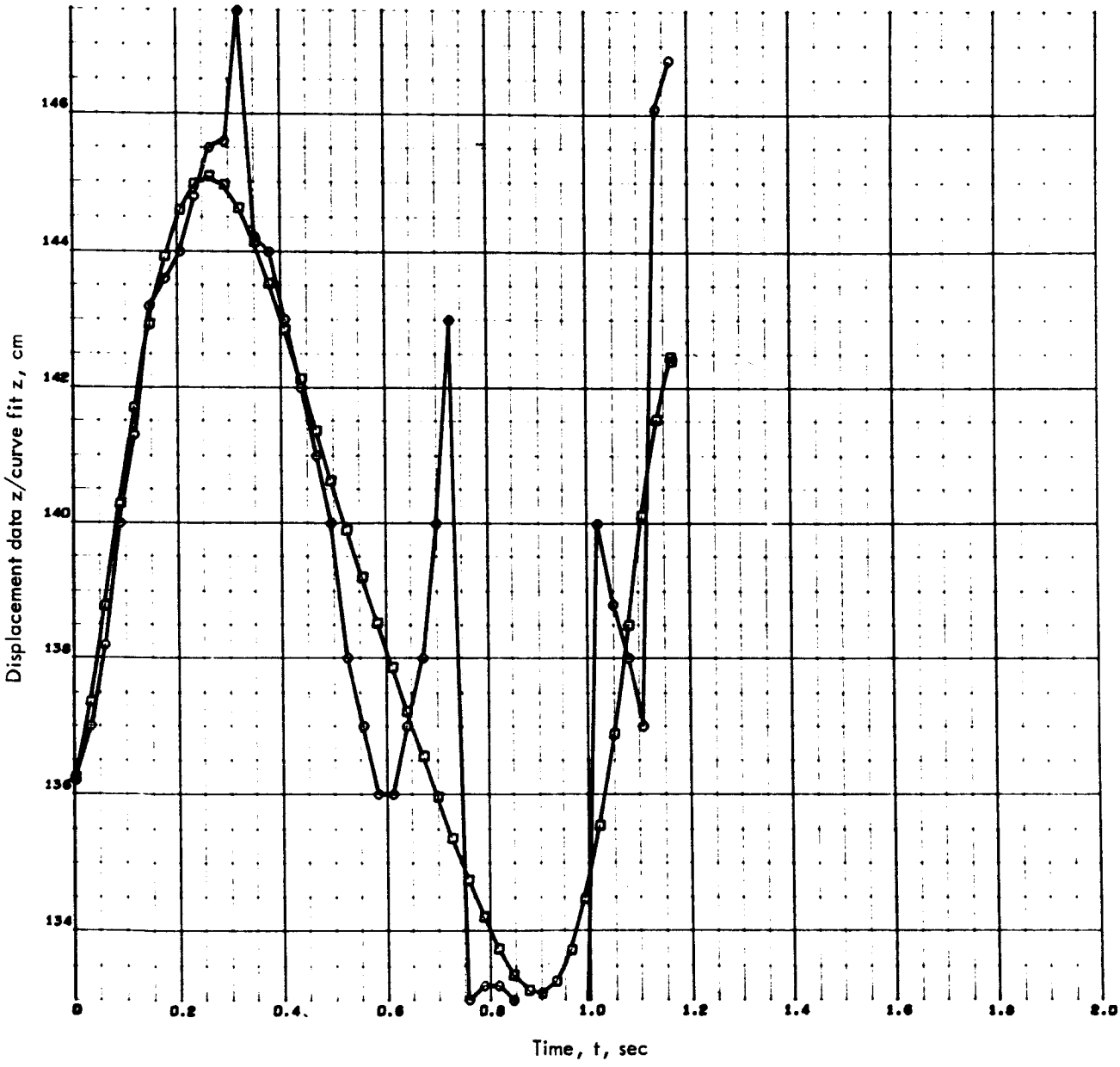

Figure E170. - Displacement data z/curve fit z versus time for segment no. 7, instrument pack

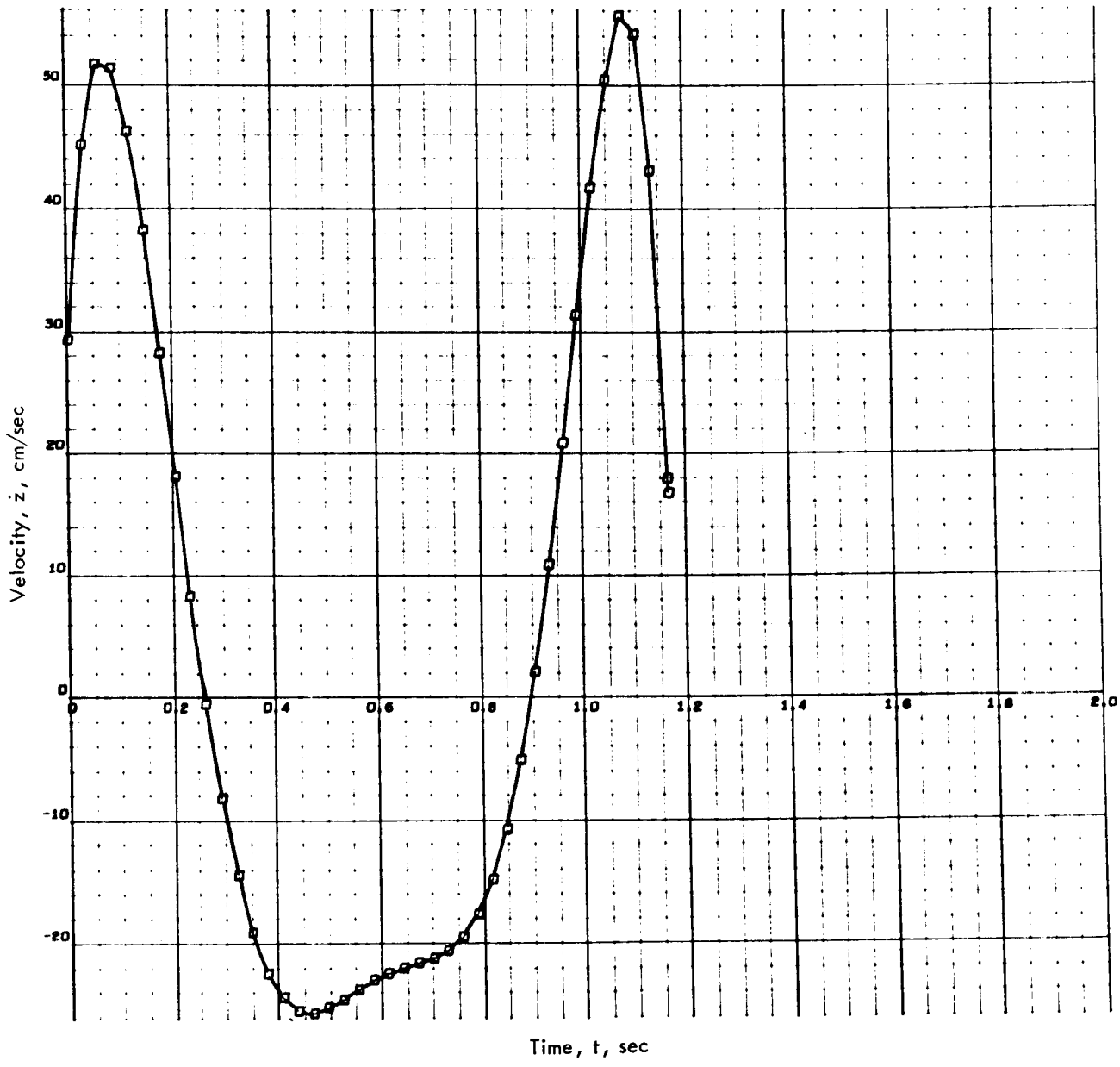

Figure E171. - Velocity ż versus time for segment no. 7, instrument pack

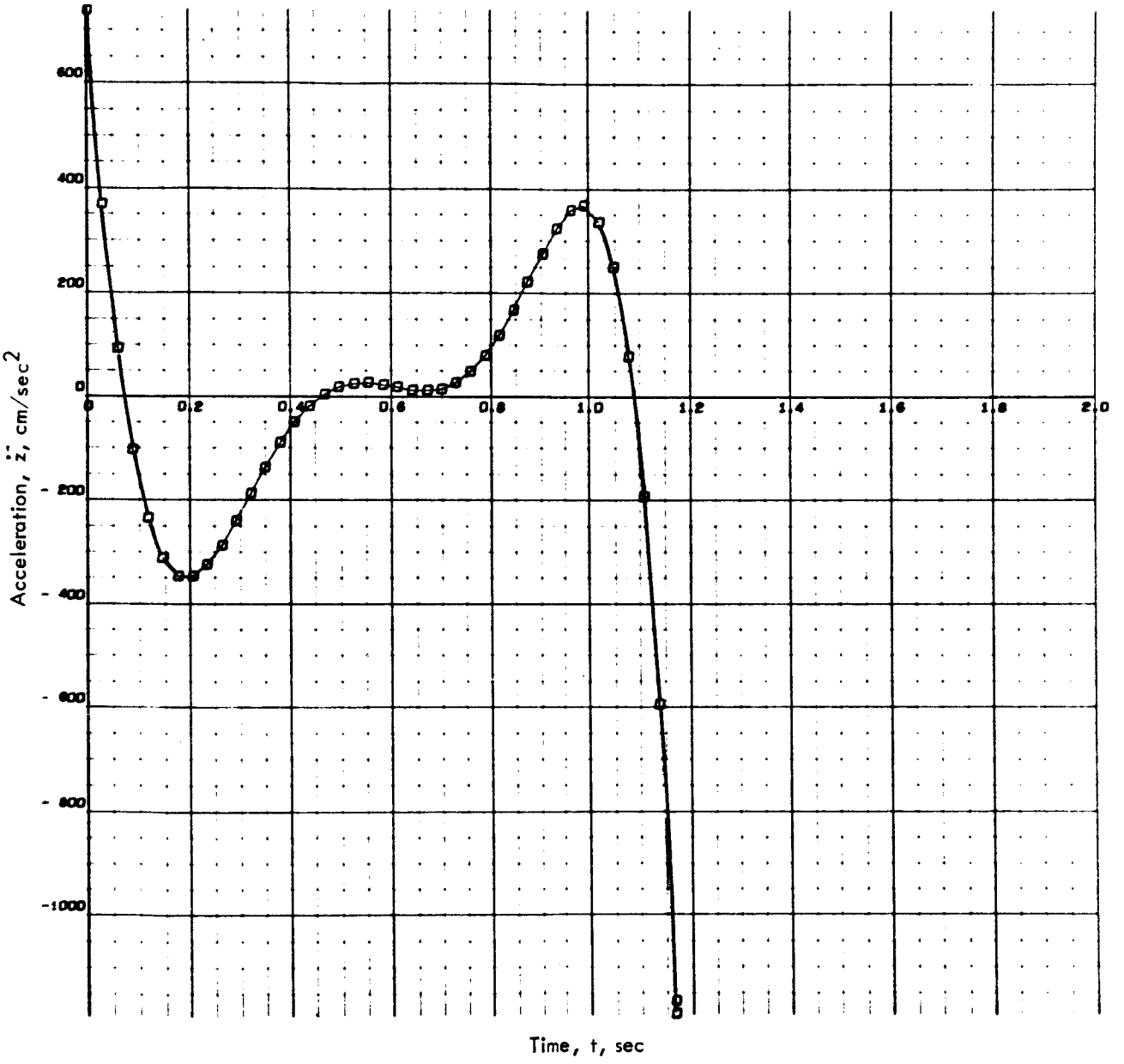

Figure E172. - Acceleration $\ddot{z}$ versus time for segment no. 7, instrument pack

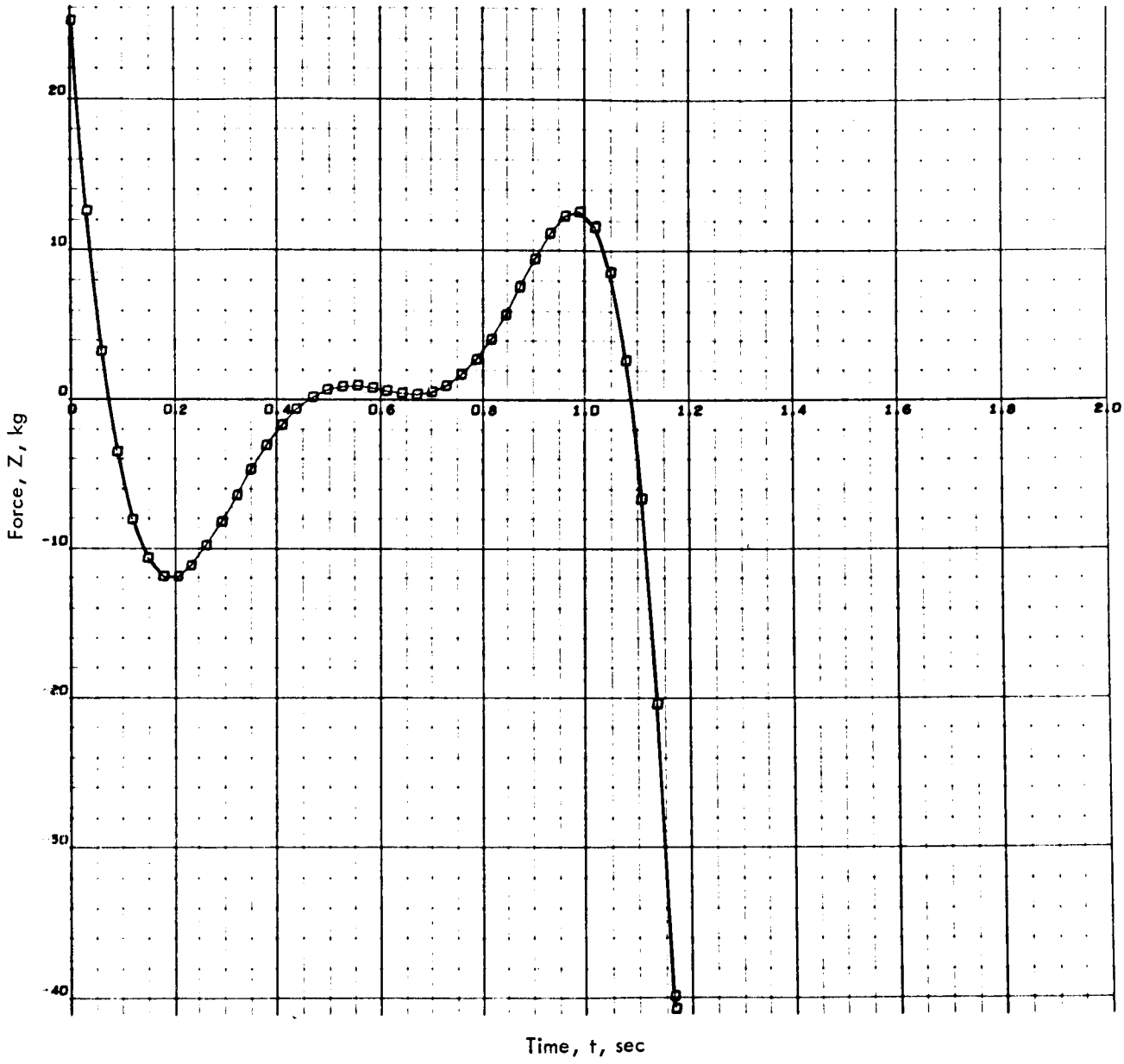

Figure E173. - Force Z versus time for segment no. 7, instrument pack

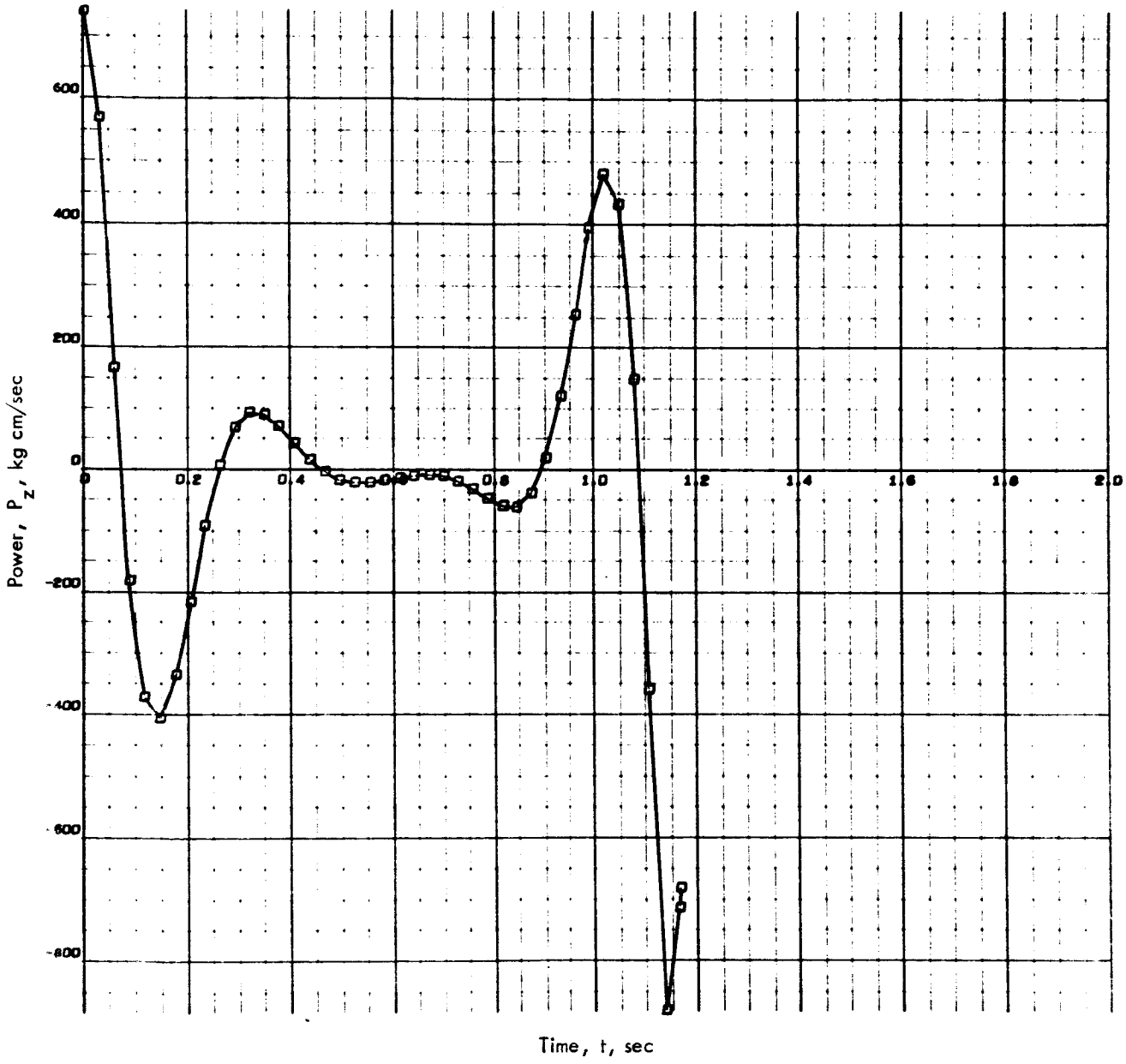

Figure E174. - Power P_z versus time for segment no. 7, instrument pack

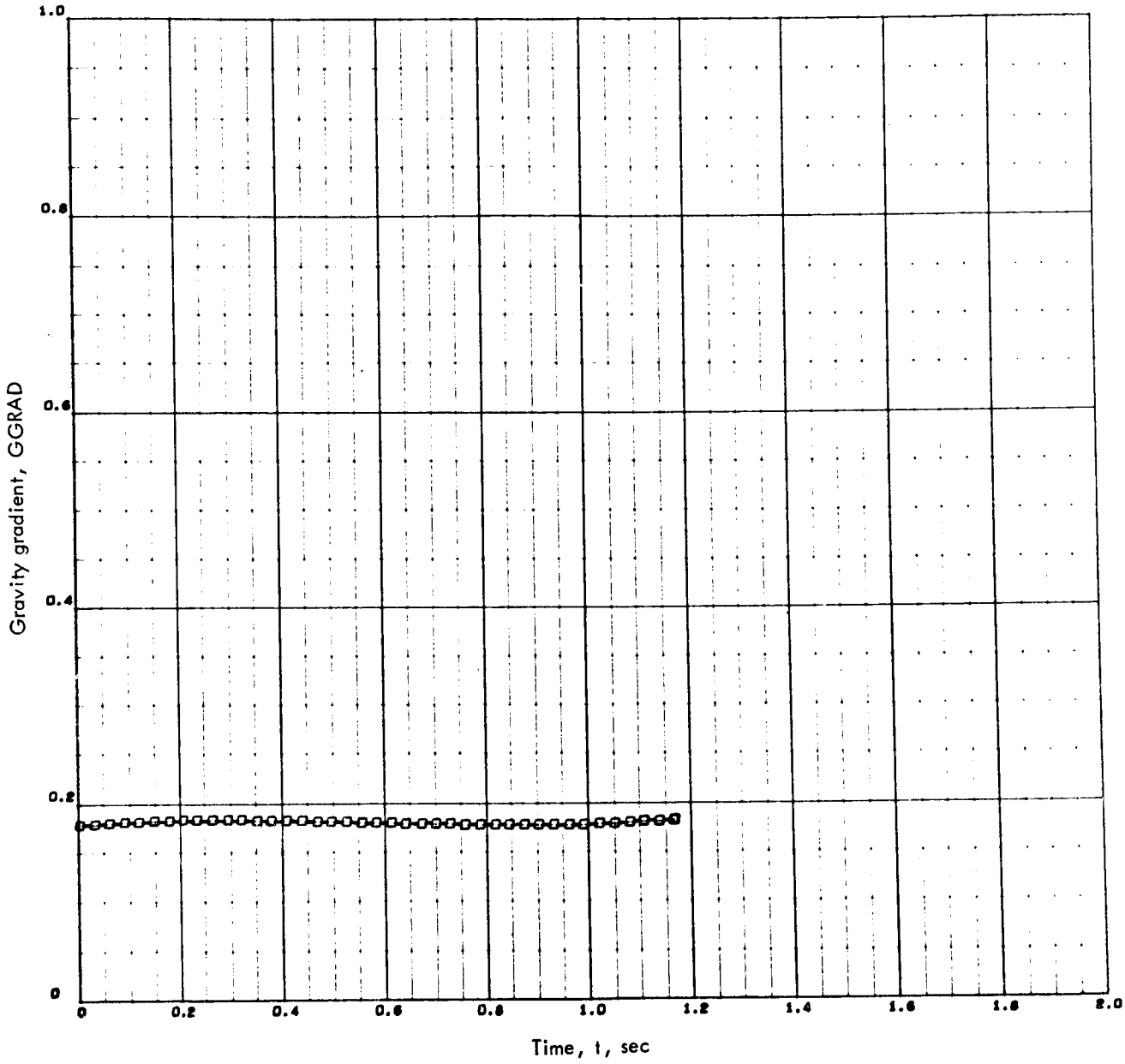

Figure E175. - Gravity gradient versus time for segment no. 7, instrument pack

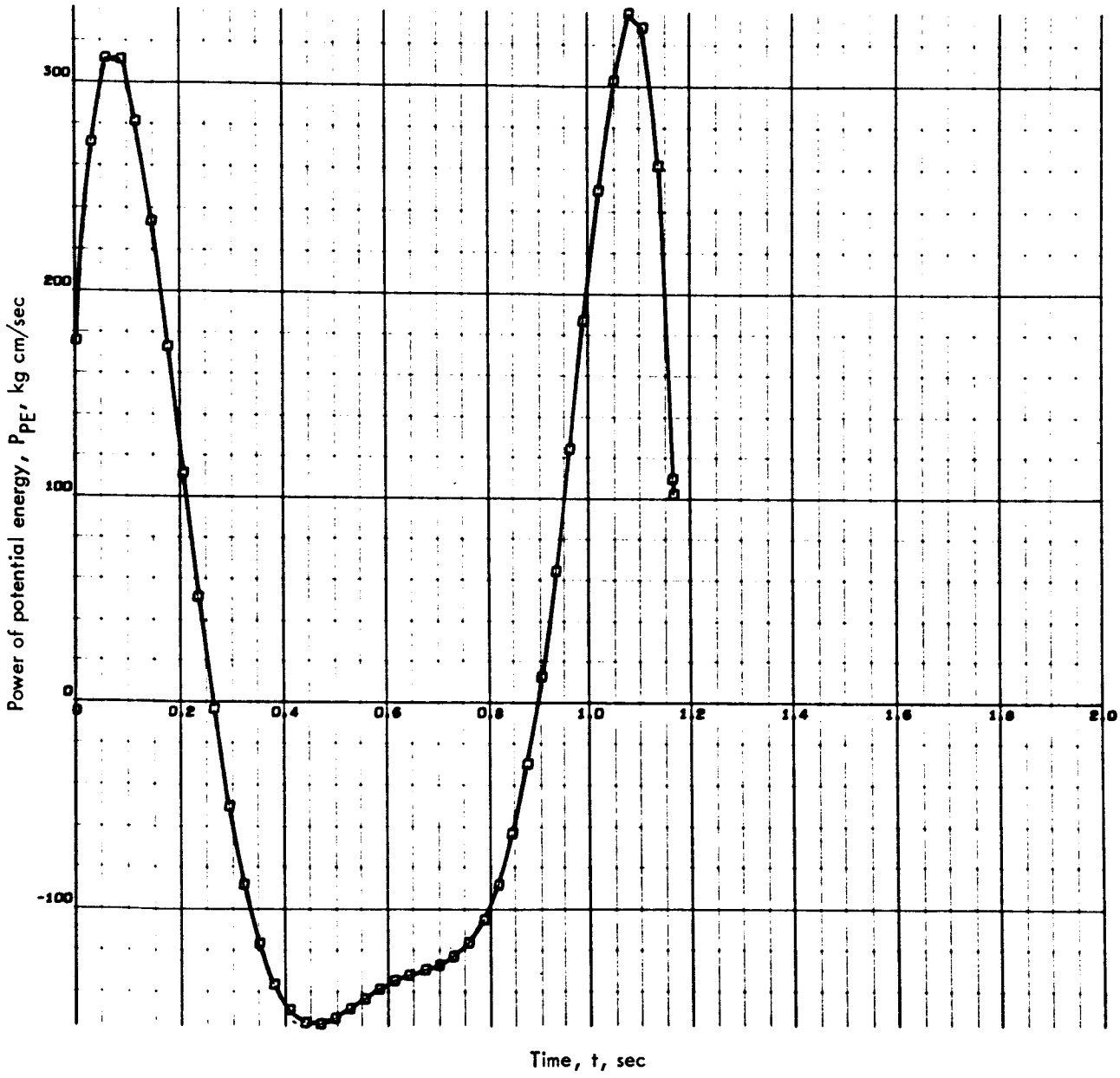

Figure E176. - Power of potential energy versus time for segment no. 7, instrument pack

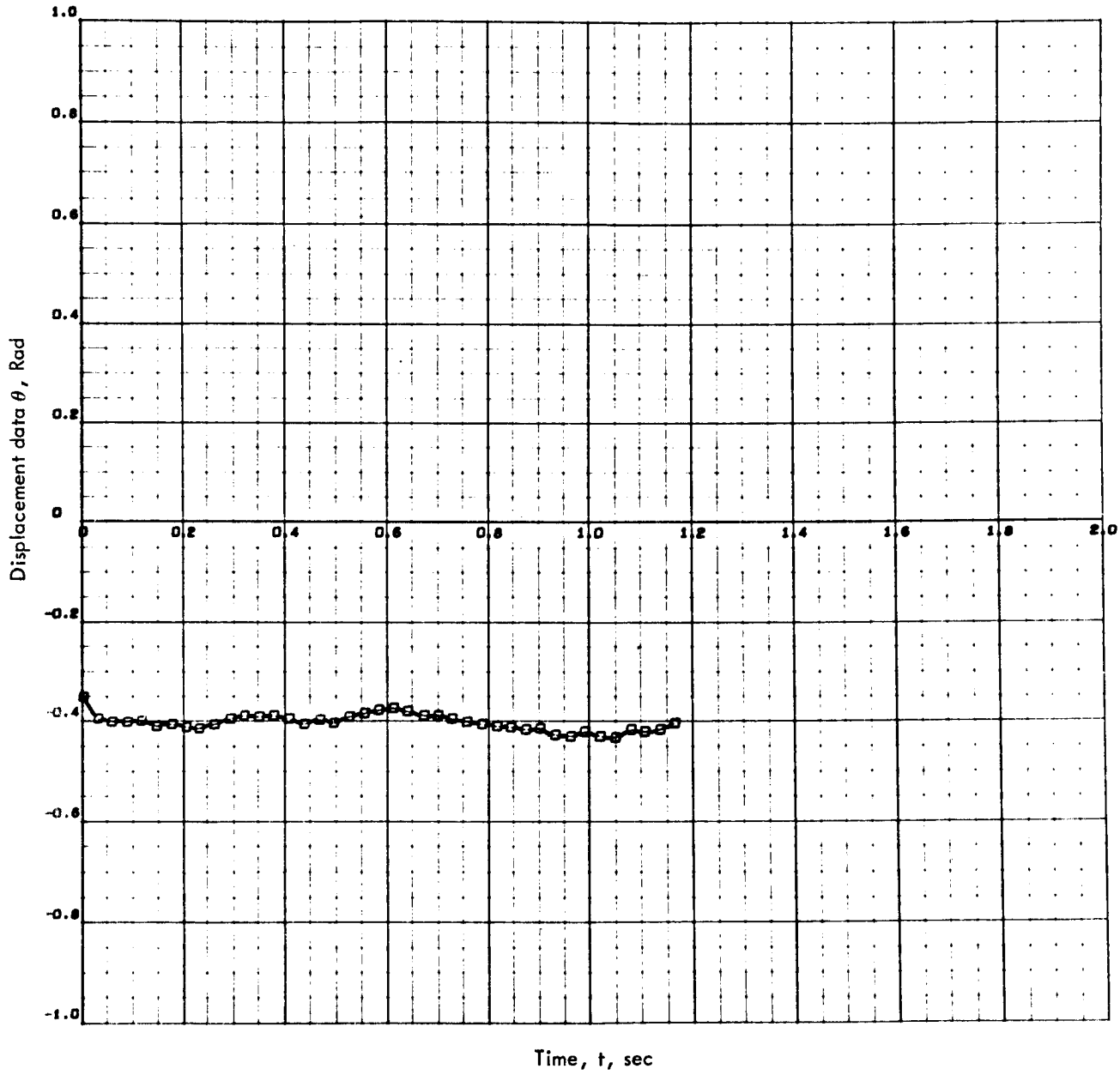

Figure E177.- Displacement data θ versus time for segment no. 7, instrument pack

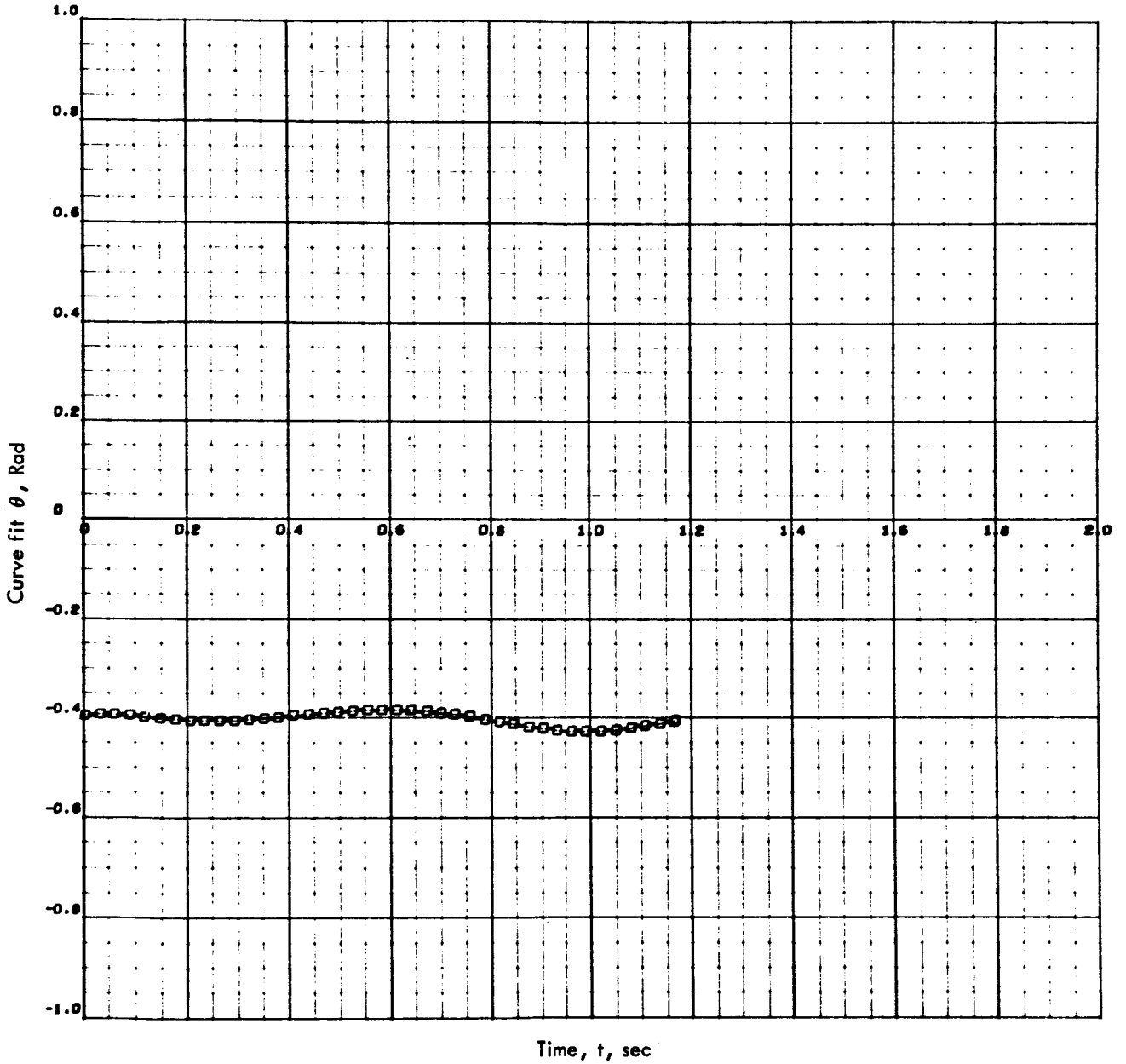

Figure E178. - Curvefit θ versus time for segment no. 7, instrument pack

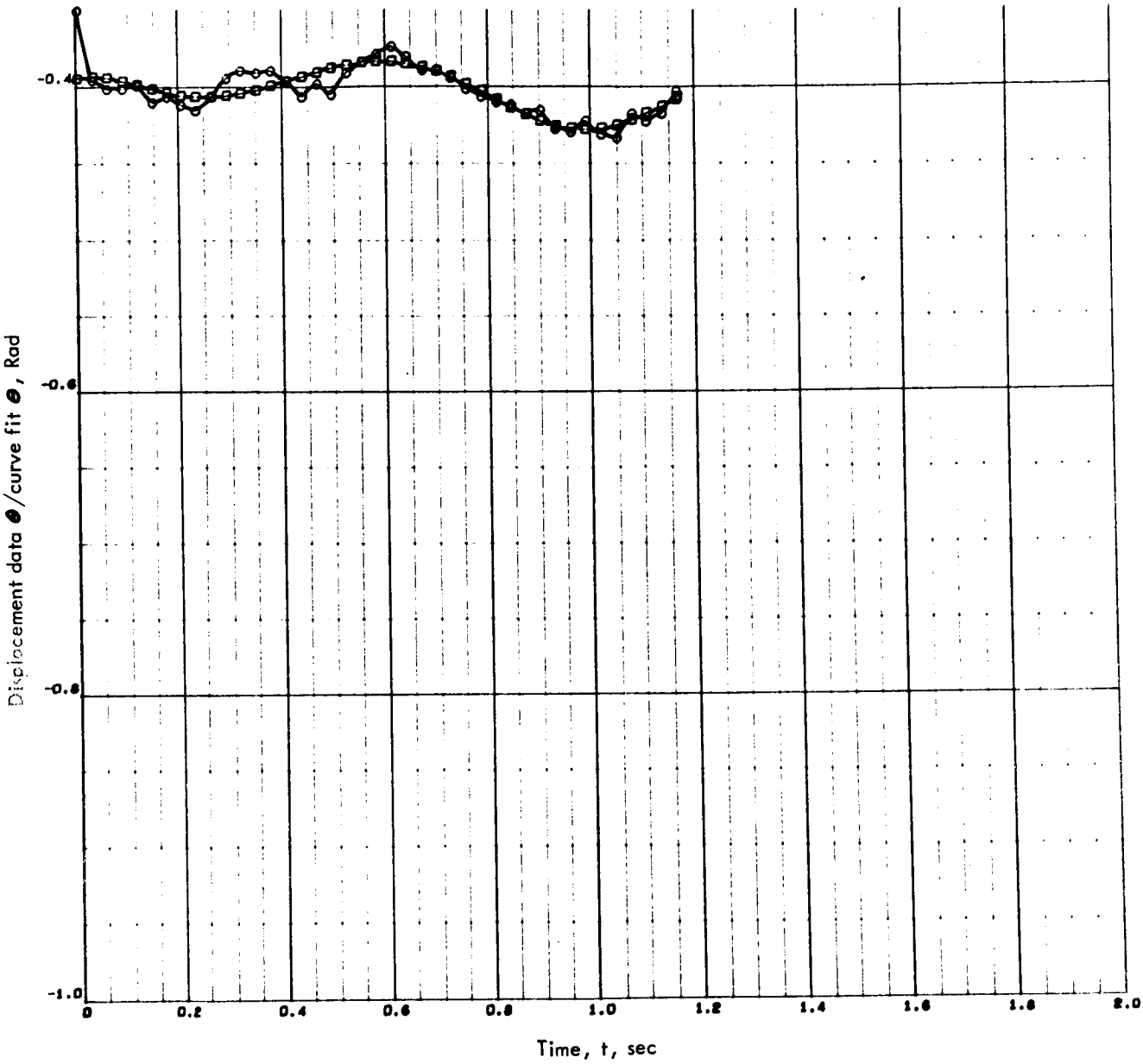

Figure E179.- Displacement data θ/curvefit θ versus time for segment no. 7, instrument pack

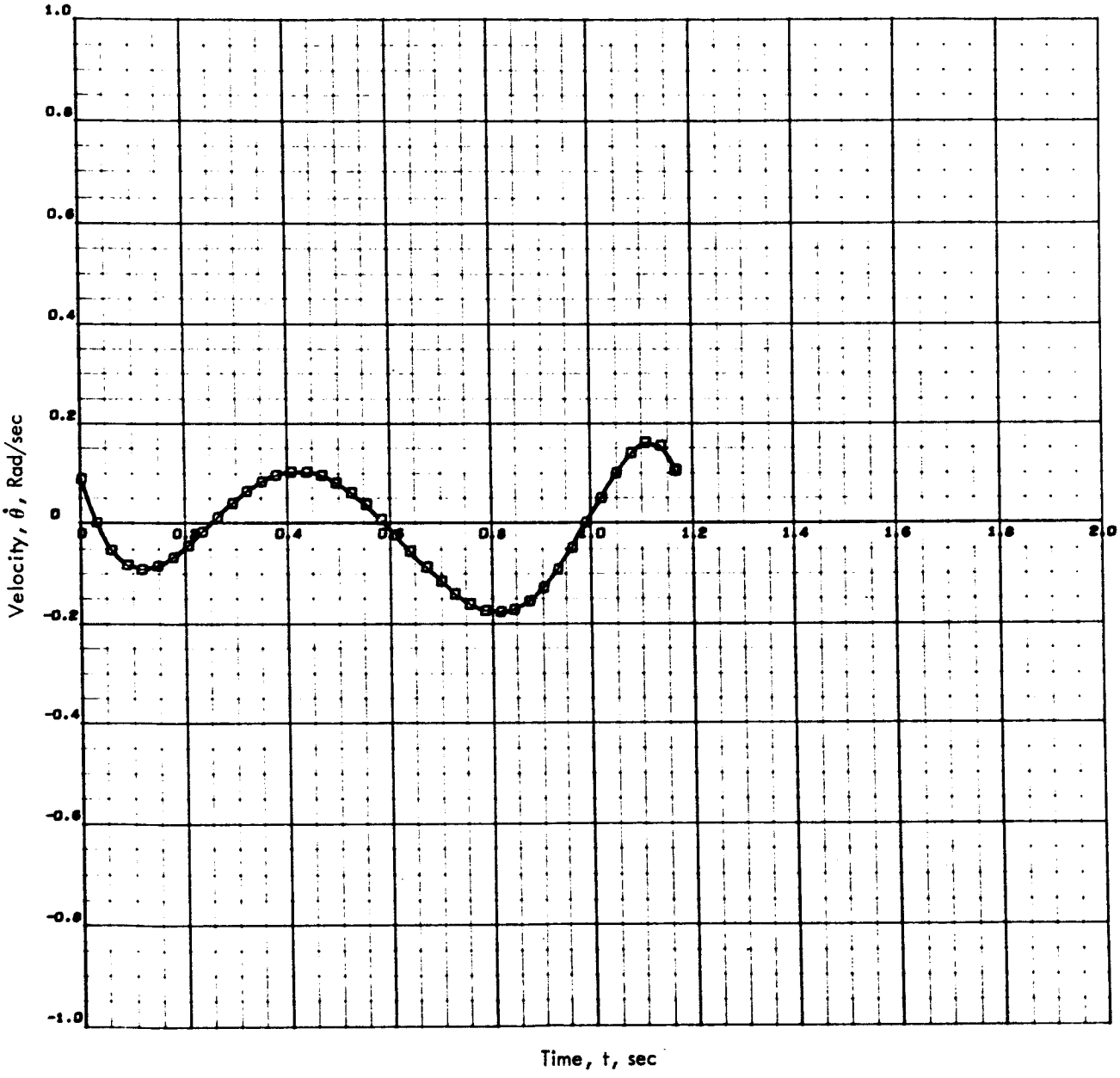

Figure E180. - Velocity $\dot{\theta}$ versus time for segment no. 7, instrument pack

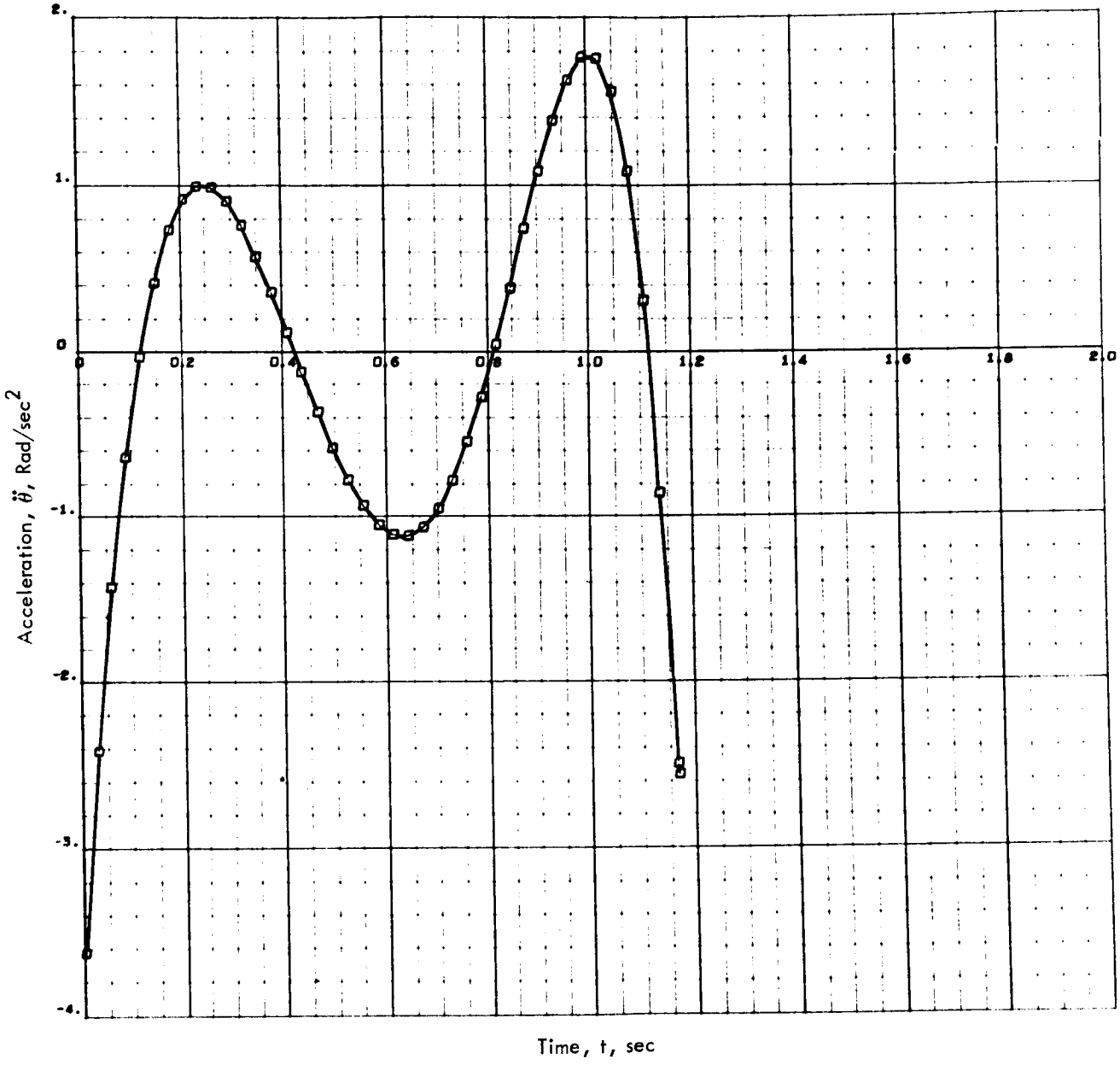

Figure E181. - Acceleration $\ddot{\theta}$ versus time for segment no. 7, instrument pack

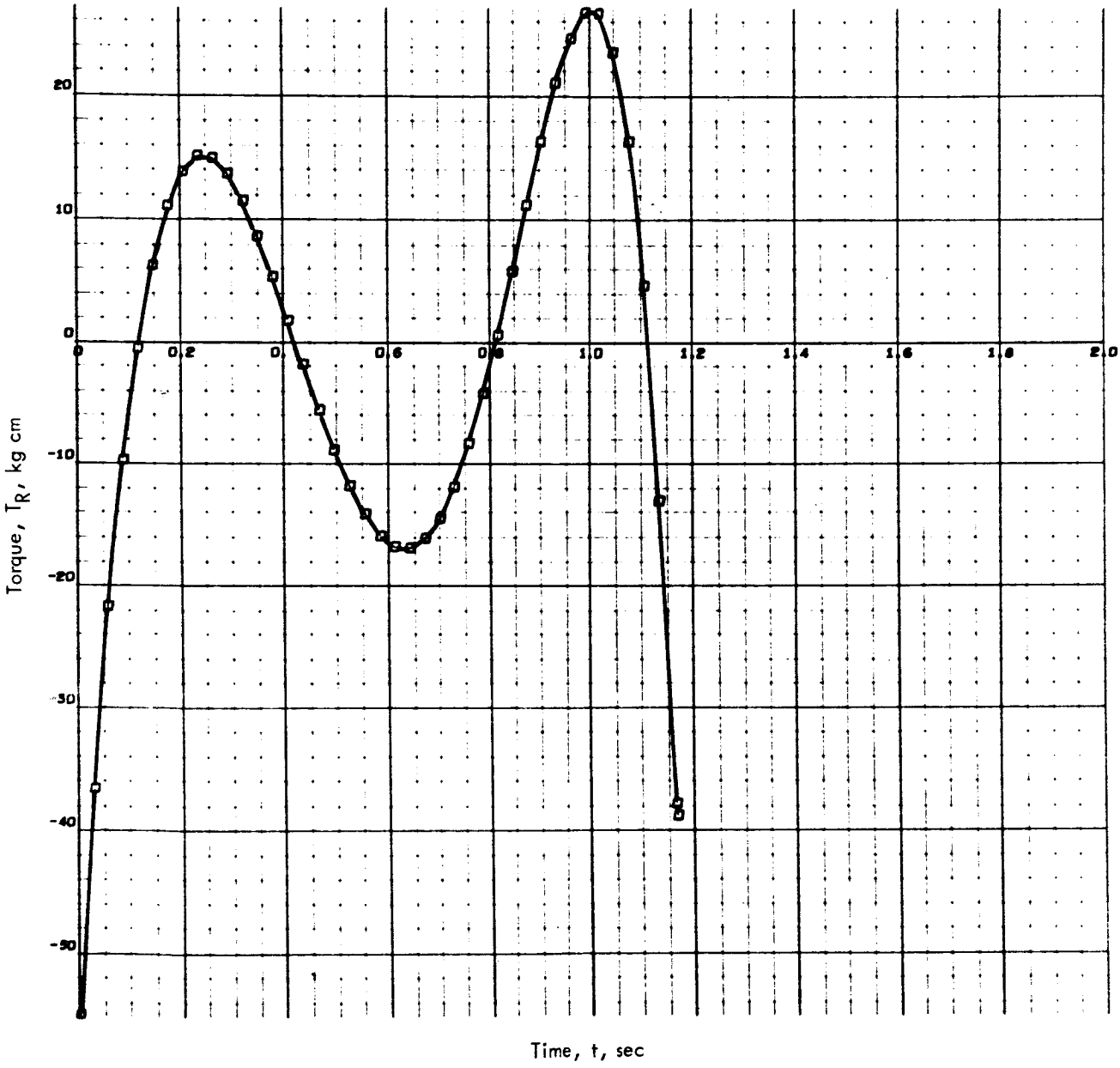

Figure E182. - Torque T_R versus time for segment no. 7, instrument pack

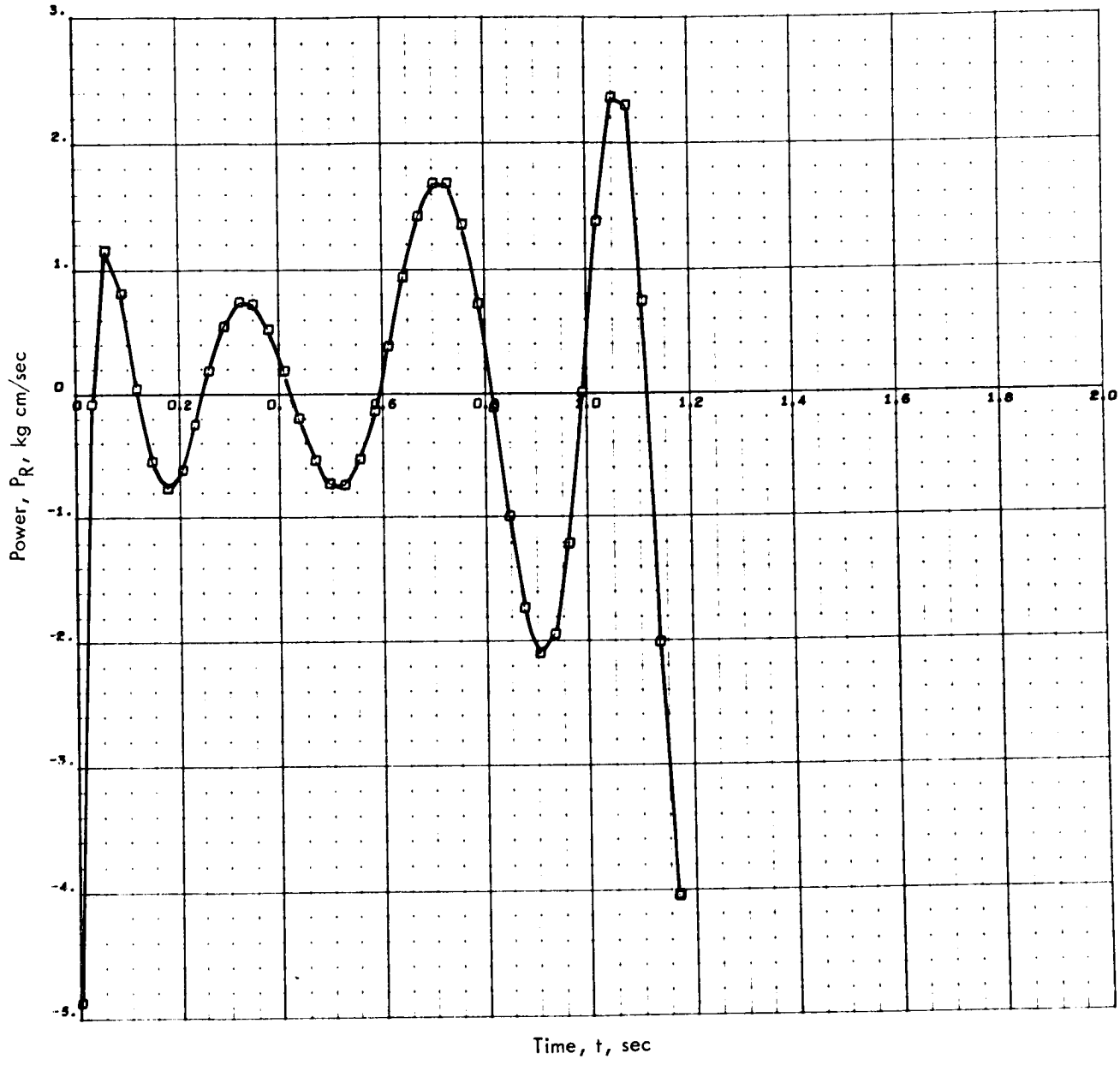

Figure E183. - Power P_R versus time for segment no. 7, instrument pack

APPENDIX E

COMPUTER PROGRAMS

PART II

GRID CORRECTION COMPUTER PROGRAM

A computer program to determine a gridline system for the Lunar Gravity Simulator backdrop was written. This grid system eliminated the necessity for repetitive and lengthy analyses to correct data recorded by the biomechanical data camera. The program was a self-contained program requiring no input data. The computer name for this Fortran IV program was GRID. The GRID program was based upon the analysis and determination of the backdrop gridline system discussed earlier in this report. GRID first determined the distance from the walkway in the x plane and then printed out the following information in 10 centimeter intervals.

(1) Arc length, Computer symbol AN.

(2) Camera height, for a given projection point. Computer symbol CN.

(3) Projection length from the camera, for a given projection point. Computer symbol BX.

(4) Distance out from the backdrop to the camera projection point. Computer symbol YLN.

(5) Distance change in the x plane for a 10-centimeter increment. Computer symbol DT.

For each increment in the x - plane, as discussed in the previous paragraph, a calculation for the z - plane was made. This calculation was executed for 0 centimeters through and including 370 centimeters at ten centimeter increments. For each z calculation the following results were printed out.

(1) The total arc length to the projection point of the camera, for a given 10 cm increment being executed. Computer symbol SNN.

(2) The tangent of the angle produced for a given unit length from the center line in the z plane: computer symbol Z.

(3) Camera height, for a given projection point: computer symbol CN.

(4) Distance on either side of the center line at a given projection point in the z - plane: computer symbol BAA.

(5) Distance change in the z - plane for a 10 centimeter increment: computer symbol DTT.

After the execution for SNN of 370, the cycle to determine the next value in the x plane was begun. This cycle was continued until SN was 730 and SNN was 370.

An illustration of these computer symbols, printed out, is given in Figure E184. A computer listing of GRID is given in Figure E185, followed by a typical sample printout (Figure E186) for one computing cycle.

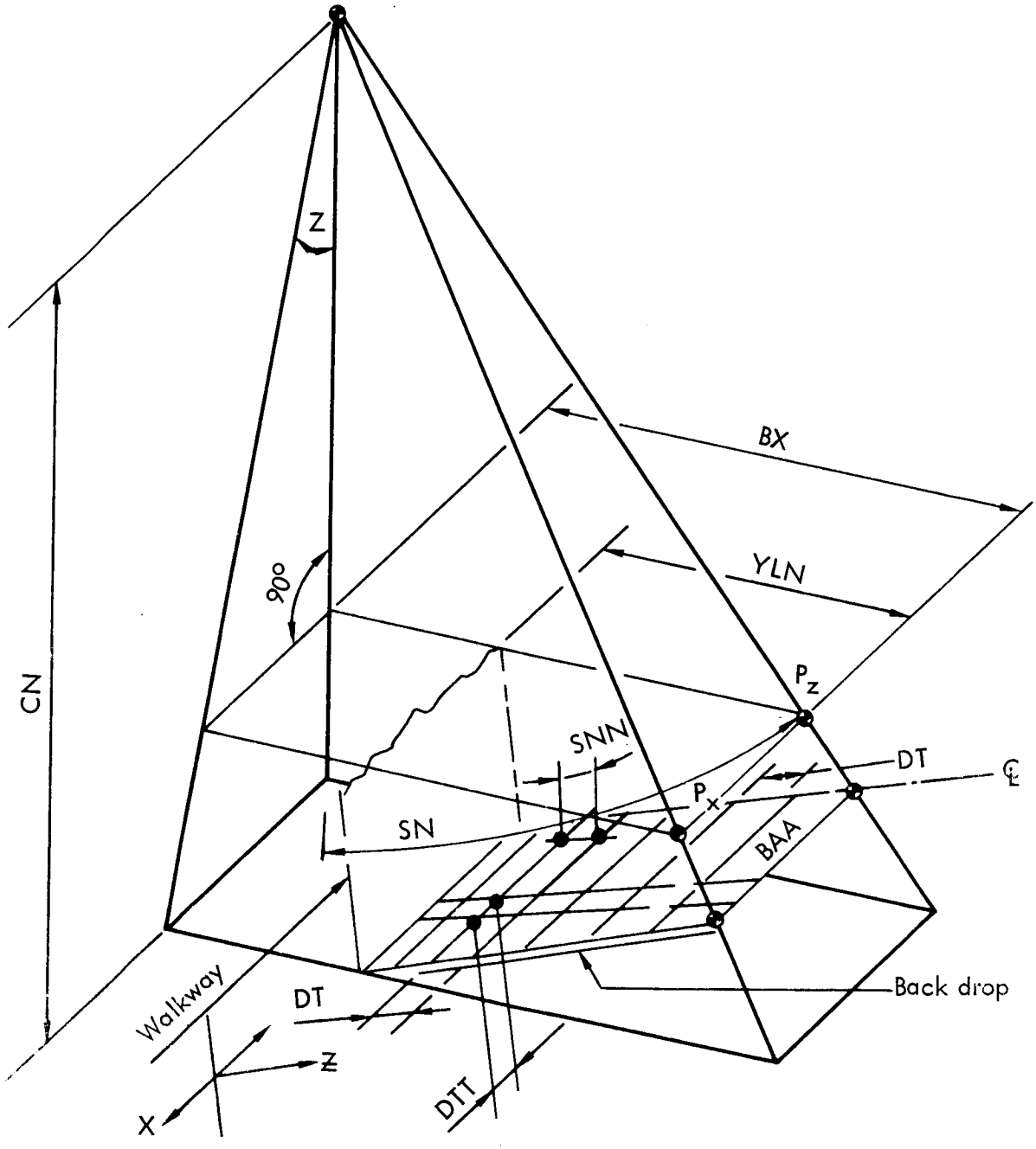

Figure E184. - Illustration of computer symbols printed out

```
$IBFTC GRID    REF
      WRITE(6,50)
   50 FORMAT(46H1DETERMINATION OF CAMERA PARALLAX IN X-Z PLANE)
      WRITE(6,75)
   75 FORMAT(39H JOB NO. 72560100 DATE 4/22/65 K.FORSEN)
      R=796.8
      AC=759.
      SN=0.
  675 AI=SN*.39370
      SSN=89.37+AI
      C=SSN*.07191
      AN=R*(1.-COSD(C))
      BM=R*(SIND(C))
      BN=BM+5.782
      CN=727.629-AN
      DN=(BN/CN)
      BX=(AC*BN)/CN
      BXX=BX-105.8
      BB=90.00-ATAND(DN)
      P=9.60
      S=180.00-(P+BB)
      BMM=BXX*(SIND(BB)/SIND(S))
      RA=2.50*(COSD(P+BB)/SIND(P+BB))
      YL =BMM-RA
      YLN=YL *2.54
      DT=(BDX-YLN)
```

Figure E 185.- Grid computer program listing

```
      BDX=YLN
      IF(SN.LT.10.)DT=0.
      WRITE(6,25)SN,CN,BX,YLN,DT
   25 FORMAT(4H1SN=,F6.0,4H CN=,F10.3,4H BX=,F10.3,5H YLN=,F10.3,4H DT=,
     1 F10.3//)
      WRITE(6,500)
  500 FORMAT(2X4H SNN,6X2H Z,9X3H CN,9X4H BAA,8X4H DTT//)
      SNN=0.
   50 AII=SNN*.39370
      Z=AII/CN
      BZZ=Z*AC
      BZY=BMM*(SIND(P)/SIND(BB))
      CYY=2.50/SIND(BB)
      BR=BZY-CYY
      BNN=(BX**2.+AC**2.)**.5
      BA =BZZ*((BNN-BR)/BNN)
      BAA=BA*2.54
   10 FORMAT(F6.0,1XF10.3,2XF10.3,2XF10.3,2XF10.3)
      IF(SNN.GE.380.)GOTO 690
      DTT=(BDY-BAA)
      BDY=BAA
      IF(SNN.LT.10.)DTT=0.
      WRITE(6,600)SNN,Z,CN,BAA,DTT
      SNN=SNN+10.
      GOTO650
  690 SN=SN+10.
```

Figure E 185.- Grid computer program listing (continued)

```
IF(SN.LE.730.)GOTO 675
CALL EXIT
END
```

Figure E 185.- Grid computer program listing (continued)

SN= 450. CN= 683.461 BX= 296.936 YLN= 460.499 DT= -10.836

SNN	Z	CN	BAA	DTT
0.	0.	683.461	0.	0.
10.	0.006	683.461	10.698	-10.698
20.	0.012	683.461	21.396	-10.698
30.	0.017	683.461	32.094	-10.698
40.	0.023	683.461	42.793	-10.698
50.	0.029	683.461	53.491	-10.698
60.	0.035	683.461	64.189	-10.698
70.	0.040	683.461	74.887	-10.698
80.	0.046	683.461	85.585	-10.698
90.	0.052	683.461	96.283	-10.698
100.	0.058	683.461	106.981	-10.698
110.	0.063	683.461	117.680	-10.698
120.	0.069	683.461	128.378	-10.698
130.	0.075	683.461	139.076	-10.698
140.	0.081	683.461	149.774	-10.698
150.	0.086	683.461	160.472	-10.698
160.	0.092	683.461	171.170	-10.698
170.	0.098	683.461	181.869	-10.698
180.	0.104	683.461	192.567	-10.698
190.	0.109	683.461	203.265	-10.698
200.	0.115	683.461	213.963	-10.698
210.	0.121	683.461	224.661	-10.698
220.	0.127	683.461	235.359	-10.698
230.	0.132	683.461	246.057	-10.698
240.	0.138	683.461	256.756	-10.698
250.	0.144	683.461	267.454	-10.698
260.	0.150	683.461	278.152	-10.698
270.	0.156	683.461	288.850	-10.698
280.	0.161	683.461	299.548	-10.698
290.	0.167	683.461	310.246	-10.698
300.	0.173	683.461	320.944	-10.698
310.	0.179	683.461	331.643	-10.698
320.	0.184	683.461	342.341	-10.698
330.	0.190	683.461	353.039	-10.698
340.	0.196	683.461	363.737	-10.698
350.	0.202	683.461	374.435	-10.698
360.	0.207	683.461	385.133	-10.698
370.	0.213	683.461	395.831	-10.698

SN= 460. CN= 682.159 BX= 301.637 YLN= 471.357 DT= -10.858

Figure E 186.- Sample print-out

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