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ANALYTICAL MODELLING OF LOAD-DEFLECTION BEHAVIOR INTERVERTEBRAL--ETC(U)

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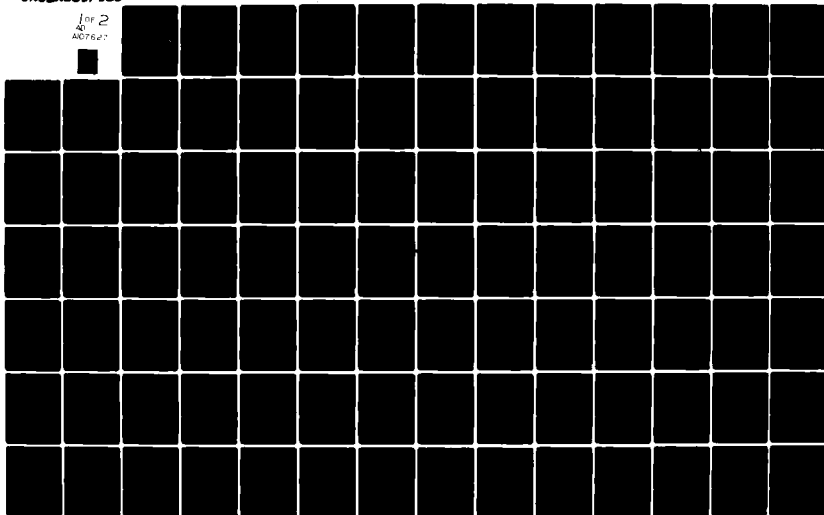
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Final Research Report

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ANALYTICAL MODELLING OF LOAD-DEFLECTION BEHAVIOR OF
INTERVERTEBRAL DISCS SUBJECTED TO AXIAL COMPRESSION
BY EXACT PARAMETRIC SOLUTIONS OF KELVIN-SOLID MODELS

by

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ABSTRACT

Results of analytical modelling of creep response phenomena of human and rhesus monkey intervertebral discs subjected to a constant axial compressive load by utilizing Kelvin-solid models are presented. Experimental datum from forty-seven human intervertebral joints were analyzed by 2-, 3-, and 4-parameter-solid models employing the Burns-Kaleps "exact analysis scheme". Results for the three and four-parameter models were excellent with an average error for the model predicted strain values from the experimental data ranging from .465% to 11.4% (collective average of 2.31%) for the former model and 1.29% to 19.9% (collective average of 4.44%) for the latter on the 47-human spinal segments considered. The 3-parameter model strain predictions were very nearly a "best fit" to the experimental data, while the values for the mechanical properties (Young's moduli and viscosity coefficients) of the 4-parameter model were obviously not optimized to the observed data. In spite of the "lack of optimization", the results suggest the latter model as being more appropriate for predicting compressive creep behavior of human spinal segments over the entire time range. Experimental datum from 59-rhesus monkey intervertebral joints were also analyzed, but by only the 2-parameter-solid model. Results were mixed with the average error per specimen ranging from 1.55% to 35%, but by comparison with the same model predictions for the human datum, the results clearly indicate superior results should be obtainable by a 3-parameter-solid model analysis. Consequently, correlation of the mechanical properties and spinal behavior of human and rhesus monkey specimens appears possible, which should allow dynamic vertical acceleration tests on rhesus monkey specimens to give valuable behavior probability data on human spinal columns.

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RESEARCH AREA AND OBJECTIVES

An understanding of the mechanical properties and behavior of the spinal column is of general interest to a variety of researchers. Of particular interest to this investigation and the AFOSR is the biomechanical modelling of human and rhesus monkey intervertebral joint response to constant axial compressive loads, where an intervertebral joint is taken to be a spinal disc and adjoining vertebrae. Nachemson (1960), Hirsch (1965), and Rolander (1966) performed experimental investigations to determine the load-deflection behavior of the intervertebral disc subjected to axial loading. Kazarian (1975) reported creep characteristics for human spinal segments subjected to a constant axial stress, where the typical experimental data of strain $\epsilon(t)$, as illustrated by the dotted curve in Fig. 1, was observed to exhibit behavior similar to that of a Kelvin solid. Capitalizing on this observation, Kazarian and Kaleps (1979) illustrated the determination of Young's moduli and a viscosity coefficient for a three-parameter-solid model based on Kazarian's (1975) data. Their method of analysis, which employed various approximations and optimization schemes, was recently displaced by a more accurate and successful "exact analysis scheme" by Burns and Kaleps (1980). The latter scheme allowed for unique model identification by employing exact parameter solutions for the one-Kelvin-unit model, the three-parameter-solid model, and the two-Kelvin-unit model, with an illustrated method by which the associated Young's moduli and viscosity coefficients for an identified model are calculable.

The research supported by Grant No. AFOSR-80-0115 has been concerned with the modelling of compressive creep phenomena of human and rhesus monkey intervertebral joints that are subjected to a constant axial loading. The creep behavior of experimental strain data reported in the literature by Leon E. Kazarian (BED Branch Chief, Wright-Patterson Air Force Base) and others prompted the development of the "exact analysis scheme" by Marshall L. Burns in close collaboration with Ints Kaleps (BED Branch Chief, Wright-Patterson Air Force Base), which constituted the theoretical basis for this investigation. The scheme employs exact parametric solution equations for the two-, three-, four-, and five-parameter-solid models in analyzing

Kazarian's human and rhesus monkey experimental data, resulting in the most appropriate model of the four being identified for the data associated with a particular intervertebral joint. Most importantly, the method allows for the determination of the mechanical properties (Young's moduli and viscosity coefficients) associated with an "identified model", once the values for the "model parameters" are uniquely determined from the experimental strain data of a particular spinal segment.

The general objectives of the research were to refine previously developed (Grant No. AFOSR-78-3578) computer programs concerned with the smoothing and interpolation of experimental strain data, and to reformulate and employ computer programs representing the "exact analysis scheme" for the four previously indicated solid-models on all of Dr. Leon E. Kazarian's human and rhesus monkey experimental data. Specifically, prior to its inception on March 1, 1980 the original research embodied the following activities:

- (a) refine the computer programs utilized to smooth and interpolate Kazarian's experimental strain data,
- (b) reformulate a unified modelling theory associated with the Burns-Kaleps "exact analysis scheme" for the 2-, 3-, 4-, and 5-parameter-solid models,
- (c) chain the necessary computer programs for the 2-, 3-, 4-, and 5-parameter-solid models for the quick and efficient analysis of experimental data,
- (d) initiate the smoothing, interpolation, and analysis computer programs on Kazarian's human strain data,
- (e) initiate the loading of Kazarian's experimental data from rhesus monkey spinal segments into computer files,
- (f) submit all available modelling results to Ints Kaleps and Leon E. Kazarian during a mid-August meeting at Wright-Patterson Air Force Base in Dayton, Ohio,
- (g) complete the modelling analysis on all available experimental data by mid-December,
- (h) submit all modelling results and discuss the research progress with Ints Kaleps and Leon E. Kazarian at our annual meeting in December at WPAFB in Dayton, Ohio,
- (i) prepare research publications for the Journal of Biomechanics (Burns, Kaleps, and Kazarian) and the Journal of Biomechanical Engineering (Burns and Kaleps),
- (j) prepare final research report for the AFOSR.

Although continuous effort was expended and steady progress maintained towards the timely completion of the research activities, it was obvious by mid-November that these objectives were overly optimistic for the originally granted twelve-month time frame. This was the result in part from two major modifications of the original proposal and progress was further inhibited from October through mid-January by several unanticipated developments.

GRANT MODIFICATIONS AND RESEARCH ENCUMBRANCES

The intent of the original proposal was modified in two significant ways, including (1) computer equipment and (2) experimental data format. With regards to the first modification, the principal investigator's letter dated 19th February, 1980 requested the purchase of a TRS-80 Model II micro-computer system, which would be utilized in the "computer analysis" of Dr. Kazarian's experimental strain data. This equipment was intended to reduce the research dependence on Tuskegee Institute's HP-2000 system and minimize that system's costs for "terminal time sharing" and "programs/data files storage". The TRS-80 Model II system, including a peripheral printer and acoustic coupler, was functional by late June and has been found completely capable of satisfying the original objectives detailed in the afore mentioned "request letter".

The second significant modification of the proposed research effort involved the "format" of the available experimental data. It was assumed in the original proposal that Dr. Kazarian's experimental strain datum for approximately 400 inter-vertebral joints were available on IBM computer cards, as was the situation for the effort supported by Grant No. AFOSR-78-3578A. Unlike the previous research, where the experimental strain data could be immediately loaded into a data-file on an HP-2000 disk via a card-reader, the "new" experimental data was available in digital form on "thermal printer rolls", which necessitated it being hand-typed into the Model II system and programmatically stored in appropriate data-files. Obviously, the availability of the experimental datum on computer cards was essential for the timely completion of the research objectives, as the "time allotted" for data entry

was minimal in the original proposal. This unexpected "data format" was further frustrated by not having the "area data" associated with the time-deformation data for the sixty rhesus monkey spinal segments. In fact it was mid-April before the "area data" was available for inclusion with the time-deformation datum. It should be understood that the "exact analysis scheme" utilizes the "area data" in predicting the "mechanical properties" of a spinal segment, once a particular model is identified from the analysis of the experimental strain data.

Essentially, there were four significant delays in the research progress through mid-January, which resulted from the following:

- (1) unavailability of the funded one-sixth release time for a computer assistant during the spring, 1980 semester,
- (2) unanticipated time-demands required by the new equipment (Model II system) purchase and the incompatibility of the HP-2000 and the TRS-80 Model II BASIC computer languages,
- (3) increased time-demands resulting from the "format" of Dr. Nazarian's rhesus monkey experimental strain datum,
- (4) unavailability of the funded one-third release time for the principal investigator during a large portion of the fall, 1980 semester.

Each of these delays and their consequential impact on the research effort were fully discussed in the December 3rd, 1980 "Progress Report and Time Extension Request" and, as such, will not be detailed herein. However, one additional objective stated in that request, which was not contained in the original proposal, is indicated below for completeness:

- (5) develop and implement a computer program on the TRS-80 Model II system for "optimizing" the values of the mechanical properties predicted by any one of the four solid-models.

RESEARCH PROGRESS AND RESULTS

Although the above time-delays impeded the research accomplishments on items 1 and 4 of the original objectives, all other objectives were successfully completed. After recognizing the inhibiting effect of the "format" of Dr. Nazarian's experimental strain data, the modelling efforts were reduced to the analysis of the strain from 47-human and 50-rhesus monkey intervertebral joints.

The research accomplishments on these "two" sets of data" will be detailed separately, as the human intervertebral joint data was fully analyzed on the HP-2000 system, while the rhesus monkey data was initiated for analysis on the TRS-80 Model II system.

Three remote terminals of the HP-2000 system were simultaneously utilized in analyzing the human experimental data and displaying the results (chaned analysis programs involving the two-, three-, and four-parameter solid models; programatic plot involving error analysis of the experimental and model (2, 3, 4) predicted strain-time values; real time plot of original and model (2, 3, 4) predicted strain-time values) for each set of experimental strain data of the 47-human intervertebral joints. Superior results were obtained from this effort and are partially illustrated in Tables I, II, III, and IV. Table I simply offers an overview of the prediction capability and accuracy of the three models for each of the 47-human spinal segments. Table II clearly illustrates the ineptness of the two-parameter-solid model (one-Melvin-unit) in predicting the observed compressive creep behavior, even though four spinal segments (I.D. No. 2, 8, 53, and 56) had acceptable average errors of 5% or less. It should be noted that the "average of the absolute percent error", denoted as AVERAGE ABS (% ERROR) in the tables, is defined in terms of the experimental, $\epsilon(t_i)_{exp}$, and model predicted, $\epsilon(t_i)_{cal}$, strain values as

$$\bar{\epsilon} = (1/N) \sum_{i=1}^N \text{ABS} \{ 10^2 \cdot [\epsilon(t_i)_{exp} - \epsilon(t_i)_{cal}] / \epsilon(t_i)_{exp} \},$$

where N is the number of experimental data values. As can be seen in the real-time plots comparing the experimental compressive creep response for the 47-human intervertebral joints, by Kazarian, with the two-parameter-solid model predictions by the Burns-Haleps exact analysis scheme (six 141-page copies of these real-time plots accompany this report under separate cover), the model is incapable of closely predicting the initial behavior of the experimental strain-time response. It is for this reason that the average % error is excessive, although some improvement is obviously possible by employing an "optimization scheme" on the model parameters.

The three-parameter and four-parameter-solid models yielded superior modelling

results, as is illustrated by Tables III and IV, respectively. As observed in Table III, the three-parameter-solid model yields calculated strain values that have collectively an average error of 3.314% from the experimentally measured (Kazarian) values for the 47-human intervertebral joints; whereas, the four-parameter-solid model (Table IV) illustrates a collective average error of 4.416%. It should be emphasized that in "general" the four-parameter model is capable of predicting the entire range of experimental strain values better than the three-parameter model. This is quickly perceived by viewing Figure I (or the real-time plots under separate cover) and realizing that the three-parameter-solid model (3PSM) values are essentially "optimized"; whereas, the values representative of the four-parameter-solid model (4PSM) are not optimized. Most importantly, however, the four-parameter model is capable of predicting the observed strain-time behavior at values of time that are close to $t = 0$, while by design the three-parameter model is seriously lacking in this predictability. It should be noted that the research supported by Grant No. APOSR-78-35784, on which the Burns and Kaleps (1980) publication was based, was only partially successful in modelling Kazarian's (1975) human intervertebral joint data. In fact the two-parameter and four-parameter-solid models were completely unsuccessful during that effort, while the three-parameter-solid model yielded good results on only twenty of the forty-seven human spinal segments. The effort expended during the current research investigation on improving the "smoothing", "interpolation", and "modelling" computer programs is primarily responsible for the superior results obtained. It bears stating that an average absolute-percent-error of approximately 2% (as defined by the above equation) is exceptionally good, since the observed strain-time data probably has as large or greater experimental error.

The modelling of the 59-rhesus monkey spinal segments (identified in Table V) was initiated on the TRS-80 Model II system. Due to the "time-delays" and unavailable "raw data" as discussed previously, the analysis effort was continuously delayed and ultimately inhibited by the "lack of grant supported" release time for the principal investigator. The analysis at this time is only partially completed,

as only the two-parameter-solid model has been utilized. The computer results for this model are fully illustrated in Table VI for the 59-rhesus monkey spinal segments with mixed but encouraging predictions. The data represented in Table VI is "grouped" together for each of the 59-specimens, with the first line identifying the experimental spinal segment. In the first group of results per specimen, A1 and B1 are the "model parameters" predicted by the Burns-Kaleps "exact analysis scheme" (detailed in the Burns and Kaleps (1980) publication), while E1 and N1 (CGS units) are the model predicted material properties (Young's modulus and viscosity coefficient, respectively). The number of experimental "creep" data points analyzed is represented by N, while T1 and T2 represent the initial and final times (in minutes) for the data range. R1 is the AVERAGE % ERROR, R2 is the AVERAGE ABS (% ERROR), and in this context R1 indicates the "goodness of fit" while R2 represents the "quality of fit". Ideally, R1 would be very close to zero and R2 would be less than 5%, if the model is appropriate for the experimental data analyzed. Whereas the "first group" of results per specimen is representative of the "model predictions", the "second group" illustrates the "optimization" of the 1st group's model parameter values A1 and B1 (and hence the mechanical properties E1 and N1). These results clearly illustrate the advantage of the "exact analysis scheme" in that the values of the mechanical properties predicted by the model analysis are very close to the "optimized" values. The results are most encouraging and surprising because twenty-four of the 59 spinal segments analyzed yielded results under 10% for the AVERAGE-ABSOLUTE % ERROR, with nine of these being 6% or less. Clearly, the two-parameter-solid model is appropriate for RN57, since the AVERAGE-ABSOLUTE % ERROR over all of the data points is only 1.55%. By comparing the results of Table VI with those obtained by the same model for the 47-human spinal segments (Table II), it appears that a correlation is possible between human and rhesus monkey spinal behavior and that the three-parameter-solid model should yield superior results for all of the rhesus monkey data. Unfortunately the analysis results utilizing this model are not available, as the research release time for the principal investigator has expired without a continuation of grant support.

In fact the results detailed herein for the two-parameter-solid model were obtained by the principal investigator after the grant expiration date of May 14, 1981. The complete analysis of the Nazarian experimental strain data for the 51-rhesus monkey intervertebral joints will be finished in the near future, at which time the results will be made available to the "concerned parties" at Wright-Patterson Air Force Base in Dayton, Ohio.

RESEARCH PRESENTATIONS AND PUBLICATIONS

The following presentation and publication have occurred during the past year:

"Simulating Compressive Creep Phenomena of Intervertebral Discs Under Axial Loading by Exact Parametric Solutions of Kelvin-Solid Models", M. L. Burns, Review of Air Force Sponsored Research in Environmental Physiology and Biomechanics, 23-25 Sept., 31 (1980).

"Analysis of Load-Deflection Behavior of Intervertebral Discs Under Axial Compression Using Exact Parametric Solutions of Kelvin-Solid Models", M. L. Burns, I. Kaleps, J. Biomechanics, 13/11, 959 (1980).

The details of the articles cited below are "nearly" completed and will be submitted for publication in the year indicated. Collectively, they will represent a very definitive resource in this area of research, becoming primary references for other investigators in related areas.

"Analysis of Load-Deflection Behavior of Human Intervertebral Discs Under Axial Compression Using Exact Parametric Solutions for the 2-, 3-, and 4-Parameter-Solid Models", M. L. Burns, I. Kaleps, L. E. Nazarian, J. Biomechanics, (submission pending), (1981).

"Analysis of Compressive Creep Behavior of Rhesus Monkey Intervertebral Discs Subjected to Axial Loading Using Exact Parametric Solutions for the 2- and 3-Parameter-Solid Models", M. L. Burns, I. Kaleps, L. E. Nazarian, J. Biomechanics, (submission pending), (1982).

"Analytical Modelling of Compressive Creep Phenomena Using Exact Parametric Solutions of Kelvin-Solid and Maxwell-Fluid Models", M. L. Burns, I. Kaleps, J. Biomechanical Engineering, (submission pending), (1982).

CONCLUSION

The research effort expended and the progress attained by the principal investigator on Grant No. AFOSR-80-0115B has been presented along with alluding remarks on the many technical difficulties and unanticipated delays. The investigation not only yielded superior modelling results, but in addition it is the only

investigatory effort known to date that has successfully modelled creep response datum of human spinal segments by a four-parameter-solid model. The results tend to suggest that the four-parameter model and the mechanical properties calculated thereby are more appropriate than those predicted by the "celebrated" three-parameter-solid model for human spinal segments. Although the analysis results for the rhesus monkey datum are incomplete, the results illustrated from the two-parameter-solid model are most encouraging. The three-parameter-solid model analysis of rhesus monkey datum is expected to yield excellent results, thereby allowing a correlation of the mechanical properties and spinal behavior between human and rhesus monkey specimens. These results add considerable support to the continuation of this research effort and the continued utilization and development of the Burns-Maleps "exact analysis scheme" in modelling the creep behavior of experimental datum from biological tissues (bone, ligaments, spinal segments, and tendons).

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Figure I

A comparison of the experimental compressive creep response for the human T7 - T8 intervertebral joint, by Kazarian, with the predictions of a three-parameter-solid model (3PSM) and a four-parameter-solid model (4PSM), by the Burns-Kaleps exact analysis scheme.

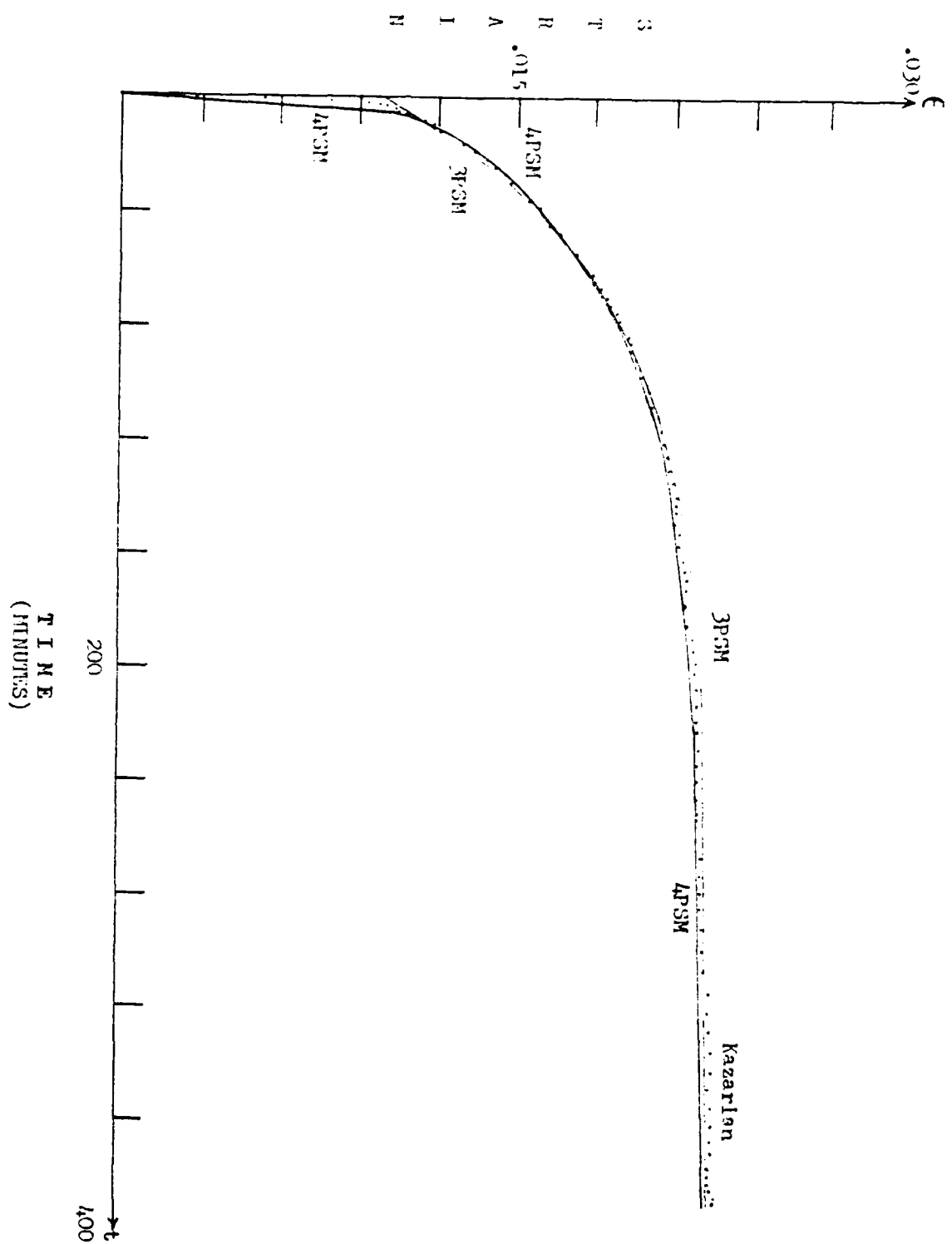


Table I

A comparison of the 2-, 3-, and 4-parameter-solid models in their ability to predict Kazarian's experimental datum for 47 human intervertebral joints.

Comparison of the 2-, 3-, and 4-Parameter-Solid Models

Test I.D. No.	Spinal Segments	AVERAGE ABS(% ERROR)		
		2-Parameter Model	3-Parameter Model	4-Parameter Model
1	T1 - T2	19.92	4.840	4.440
2	T2 - T3	5.735	.6767	3.572
4	T4 - T5	12.15	2.418	3.980
5	T5 - T6	11.99	.9041	1.473
6	T6 - T7	15.66	2.345	4.194
7	T7 - T8	11.81	1.913	2.372
8	T8 - T9	5.510	2.420	10.51
9	T9 - T10	25.52	2.009	6.044
10	T10 - T11	14.56	1.603	4.405
16	T2 - T3	19.28	11.35	6.953
17	T3 - T4	13.15	1.265	6.212
18	T4 - T5	15.80	1.721	3.029
19	T5 - T6	19.51	1.830	5.649
20	T6 - T7	18.87	1.452	3.148
21	T7 - T8	19.85	2.457	4.834
22	T8 - T9	18.89	1.604	2.634
23	T9 - T10	19.02	1.805	3.136
24	T10 - T11	20.82	1.647	2.527
25	T11 - T12	17.09	1.383	3.518
26	T12 - L1	17.33	1.006	5.138
27	L1 - L2	15.93	2.412	2.674
28	L2 - L3	23.24	2.400	4.280
29	L3 - L4	18.52	.9755	2.543
30	L4 - L5	16.38	1.770	6.223
31	L5 - S1	16.58	3.986	8.015
42	L5 - S1	10.86	1.714	3.028
44	L3 - L4	5.849	1.883	3.222
45	L2 - L3	15.00	2.910	5.435
47	T11 - T12	12.87	2.438	9.346
48	T12 - L1	11.25	1.524	1.895
49	T9 - T10	11.95	2.880	19.88
50	T10 - T11	7.026	1.958	4.710
51	T8 - T9	9.671	2.793	3.796
52	T7 - T8	20.84	2.448	6.532
53	T4 - T5	3.085	.4655	2.732
54	T6 - T7	6.415	.4647	2.935
56	T5 - T6	4.474	1.624	2.350
57	T2 - T3	24.41	2.362	2.267
59	T9 - T10	12.92	1.185	1.287
60	T4 - T5	14.09	3.745	3.137
61	T5 - T6	15.71	2.302	3.075
62	T6 - T7	15.55	1.771	4.843
63	T11 - T12	23.72	3.405	3.743
64	T7 - T8	14.49	3.933	3.447
65	T10 - T11	12.44	4.218	3.838
66	T8 - T9	14.69	2.837	2.656
68	T12 - L1	24.54	1.699	3.321

Table II

Young's modulus and the viscosity coefficient predicted by the two-parameter-solid model from Kazarian's datum on 47 human intervertebral joints. A comparison of the predicted strain values, $\epsilon(t_1)_{cal}$, of the Burns-Kaleps exact analysis scheme with the strain values obtained experimentally, $\epsilon(t_2)_{exp}$, by Kazarian is represented as an "average of the absolute % error" for each disc.

2-Parameter-Solid Model

Test I.D. No.	Spinal Segments	Area (sq cm)	Height (cm)	Young's Modulus ($\times 10^8$ g/cm-s ²)	Viscosity Coef. ($\times 10^{11}$ g/cm-s)	Average ABS(% Error)
1	T1 - T2	4.148	2.445	.9839	6.998	19.92
2	T2 - T3	5.619	2.515	1.314	.6806	5.735
3	T3 - T5	5.181	2.280	2.188	5.944	12.15
4	T5 - T6	5.568	2.085	1.132	4.486	11.99
5	T6 - T7	6.490	2.670	.5785	2.840	15.66
6	T7 - T8	7.632	2.755	1.080	2.232	11.81
7	T8 - T9	8.123	1.194	.5713	.1215	5.510
8	T9 - T10	7.781	2.240	1.044	7.015	15.52
9	T10 - T11	8.961	3.920	1.197	6.115	14.56
10	T12 - T3	5.787	2.431	.5518	2.096	19.28
11	T3 - T4	5.148	2.585	1.840	10.61	13.15
12	T4 - T5	5.310	2.445	.9504	4.754	15.80
13	T5 - T6	5.800	2.240	4.037	18.78	19.51
14	T6 - T7	6.123	2.340	1.881	6.215	18.87
15	T7 - T8	8.161	2.670	.4123	.9647	19.85
16	T8 - T9	8.032	2.615	.4930	2.208	18.89
17	T9 - T10	9.123	2.670	.6828	4.804	19.02
18	T10 - T11	10.329	2.795	.5257	2.985	20.82
19	T11 - T12	11.800	3.515	.6598	3.498	17.09
20	L1 - L2	11.181	3.725	.8273	3.617	17.33
21	L2 - L3	11.813	3.900	.8351	3.778	15.93
22	L3 - L4	14.219	3.535	.3185	2.117	23.24
23	L4 - L5	14.168	3.165	.5822	5.297	18.52
24	L5 - L6	17.219	3.160	.4841	2.195	16.38
25	L6 - S1	25.613	3.760	.1748	.6159	16.58
26	L5 - S1	19.213	4.350	.3960	1.158	10.86
27	L3 - L4	19.639	4.090	1.478	1.116	5.849
28	L2 - L3	18.523	2.635	.3239	1.266	15.00
29	T11 - T12	19.348	2.789	.4131	1.932	12.87
30	T12 - L1	24.181	2.340	.4953	1.136	11.25
31	T9 - T10	19.987	2.171	.2778	1.027	11.95
32	T10 - T11	18.256	2.180	.4156	2.700	7.026
33	T8 - T9	17.110	2.163	.4054	.7523	9.671
34	T7 - T8	16.213	2.645	.3927	2.645	20.84
35	T7 - T5	14.032	1.965	.9167	.2130	3.085
36	T6 - T7	11.858	2.600	.5589	.8911	6.415
37	T5 - T6	14.729	1.980	.4440	.2414	4.474
38	T2 - T3	9.929	2.160	.4317	.3973	24.41
39	T3 - T10	16.813	2.775	.2558	.6613	12.92
40	T4 - T5	11.142	2.240	.2596	1.306	14.09
41	T5 - T6	10.432	1.895	.3594	2.064	15.71
42	T6 - T7	12.329	1.850	.3356	1.422	15.55
43	T11 - T12	16.503	2.975	.3777	6.587	23.72
44	T7 - T8	13.690	2.660	1.035	3.519	14.49
45	T10 - T11	14.561	2.765	.5848	3.470	12.44
46	T8 - T9	16.329	2.705	.6893	1.905	14.69
47	T12 - L1	16.503	2.935	.3881	7.376	24.54

Table III

Young's moduli and the viscosity coefficient predicted by the three-parameter-solid model from Kazarian's datum on forty-seven human intervertebral joints. A comparison of the predicted strain values, $\epsilon(t_1)_{cal}$, of the Burns-Kaleps exact analysis scheme with the strain values obtained experimentally, $\epsilon(t_1)_{exp}$, by Kazarian is represented as an "average of the absolute percent error" for each of the 47 spinal segments.

3-Parameter-Solid Model

Test I.D. No.	Spinal Segments	Area (sq cm)	Height (cm)	Young's Moduli ($\times 10^8$ g/cm-s ²)		Viscosity Coef. ($\times 10^{12}$ g/cm-s) η_1	Average ABS(% Error)
				E_1	E_2		
1	T1 - T2	4.148	2.445	1.537	2.516	1.737	4.840
2	T2 - T3	5.619	2.515	3.494	2.041	.4972	.6767
4	T4 - T5	5.181	2.280	6.520	3.261	3.644	2.418
5	T5 - T6	5.568	2.085	2.006	2.515	1.312	.9041
6	T6 - T7	6.490	2.670	1.089	1.195	.9668	2.345
7	T7 - T8	7.632	2.755	1.847	2.375	.6643	1.913
8	T8 - T9	8.123	1.194	1.609	.6174	9.951	2.420
9	T9 - T10	7.781	2.240	1.574	2.156	2.931	2.009
10	T10 - T11	8.961	3.920	1.684	2.406	2.728	1.603
16	T2 - T3	5.787	2.431	1.709	.7219	2.701	11.35
17	T3 - T4	5.148	2.585	2.425	4.729	3.171	1.265
18	T4 - T5	5.310	2.445	1.589	1.991	1.661	1.721
19	T5 - T6	5.800	2.240	15.61	4.933	20.98	1.830
20	T6 - T7	6.123	2.340	6.213	2.462	8.357	1.452
21	T7 - T8	8.161	2.670	1.528	.5934	.5397	2.457
22	T8 - T9	8.032	2.615	.9229	.9479	.8675	1.604
23	T9 - T10	9.123	2.670	.9761	1.732	1.337	1.805
24	T10 - T11	10.329	2.795	1.089	1.002	1.068	1.647
25	T11 - T12	11.800	3.515	1.347	.9843	3.436	1.383
26	T12 - L1	11.181	3.725	2.304	1.132	3.248	1.006
27	L1 - L2	11.813	3.900	1.992	1.261	2.964	2.412
28	L2 - L3	14.219	3.535	.5875	.5786	1.028	2.400
29	L3 - L4	14.168	3.165	.8527	1.359	1.606	.9755
30	L4 - L5	17.219	3.160	.9414	.8826	.9423	1.770
31	L5 - S1	25.613	3.760	.4162	.2935	.2475	3.986

3-Parameter-Solid Model

Test I.D. No.	Spinal Segments	Area (sq cm)	Height (cm)	Young's Moduli ($\times 10^8$ g/cm-s ²)		Viscosity Coef. ($\times 10^{12}$ g/cm-s)	Average ABS(% Error)
				E ₁	E ₂	1	
42	L5 - S1	19.213	4.350	.8581	.6434	.5912	1.714
44	L3 - L4	19.639	4.090	20.73	1.623	7.291	1.883
45	L2 - L3	18.523	2.635	.001476	.4073	2.988	2.910
47	T11 - T12	19.348	2.789	.7506	.9850	.4332	2.438
48	T12 - L1	24.181	2.340	2.468	.5968	2.016	1.524
49	T9 - T10	19.987	2.171	.5375	.5850	.2535	2.880
50	T10 - T11	18.256	2.180	.4967	2.519	.3836	1.958
51	T8 - T9	17.110	2.163	.7211	.8103	.2403	2.793
52	T7 - T8	16.213	2.645	.6098	1.282	.2995	2.448
53	T4 - T5	14.032	1.965	6.312	1.037	1.262	.4655
54	T6 - T7	11.858	2.600	1.333	.9210	.4274	.4647
56	T5 - T6	14.729	1.980	1.212	.6726	.1634	1.624
57	T2 - T3	9.929	2.160	.7696	1.138	.6707	2.362
59	T9 - T10	16.813	2.775	.6256	.3378	1.067	1.185
60	T4 - T5	11.142	2.240	.5680	.4761	.4915	3.745
61	T5 - T6	10.432	1.895	.5837	.8969	.5810	2.466
62	T6 - T7	12.329	1.850	.5383	.7909	.4042	1.771
63	T11 - T12	16.503	2.975	.7111	.8390	1.805	3.405
64	T7 - T8	13.690	2.660	3.126	1.343	4.711	3.933
65	T10 - T11	14.561	2.765	.6621	1.126	1.961	4.218
66	T8 - T9	16.329	2.705	11.10	.7764	7.435	2.837
68	T12 - L1	16.503	2.935	.6645	1.076	1.767	1.699

Table IV

Young's moduli and the viscosity coefficients predicted by the four-parameter-solid model from Kazarian's datum on forty-seven human intervertebral joints. A comparison of the predicted strain values, $\{t_1\}_{cal}$, of the Burns-Kaleps exact analysis scheme with the experimental strain values, $\{t_1\}_{exp}$, obtained by Kazarian is represented as an "average of the absolute percent error" for each of the forty-seven spinal segments.

4-Parameter-Solid Model

Test S.L. No.	Spinal Segments	Area (sq. cm.)	Height (cm.)	Young's Moduli ($\times 10^8$ g/cm-s ²)		Viscosity Coef. ($\times 10^{11}$ g/cm-s)		Average ABS(% Error)
				E ₁	E ₂	η_1	η_2	
1	T1 - T2	4.148	2.445	2.558	1.530	.6985	16.95	4.440
2	T2 - T3	5.619	2.515	5.736	1.705	10.74	.3868	3.572
3	T3 - T4	5.181	2.280	3.430	6.289	.9441	25.86	3.980
4	T4 - T5	5.568	2.085	2.114	2.392	14.52	.1575	1.473
5	T5 - T6	6.490	2.670	1.172	1.134	10.60	.2066	4.194
6	T6 - T7	7.632	2.755	2.052	2.165	7.847	.2524	2.372
7	T7 - T8	8.123	1.194	6.630	.5956	124.9	.4400	10.51
8	T8 - T9	7.781	2.240	2.091	1.518	1.131	32.68	6.044
9	T9 - T10	8.961	3.920	1.831	2.497	24.85	.8423	4.405
10	T10 - T11	5.787	2.431	.9584	1.222	.4252	9.279	6.953
11	T11 - T12	5.148	2.585	2.772	4.482	32.75	3.883	6.212
12	T12 - L1	5.310	2.445	1.909	1.523	.3870	18.65	3.029
13	T13 - T14	5.800	2.240	5.254	12.95	1.615	163.1	5.649
14	T14 - T15	6.123	2.340	2.673	6.724	.1584	37.91	3.148
15	T15 - T16	8.161	2.670	.5474	1.752	.09549	9.706	4.834
16	T16 - T17	8.032	2.615	.8481	.8358	.1262	13.66	2.634
17	T17 - T18	9.123	2.670	1.609	.9772	.3226	15.00	3.136
18	T18 - T19	10.329	2.795	.9136	1.260	.1495	13.51	2.527
19	T19 - T20	11.800	3.515	.9414	1.709	.2547	33.37	3.518
20	T20 - L1	11.181	3.725	1.097	2.537	.3273	34.22	5.138
21	L1 - L2	11.813	3.900	1.240	2.436	.1467	26.92	2.674
22	L2 - L3	14.219	3.535	.6255	.5622	10.41	.1194	4.280
23	L3 - L4	14.168	3.165	1.301	.7765	.3745	18.38	2.543
24	L4 - L5	17.219	3.160	.8185	.7433	.4024	14.36	6.223
25	L5 - S1	25.613	3.760	.2354	.4411	.1848	7.761	8.015

4-Parameter-Solid Model

Test No. No.	Spiral Segments	Area (sq cm)	Height (cm)	Young's Moduli ($\times 10^8$ g/cm-s ²)		Viscosity Coef. ($\times 10^{11}$ g/cm-s)		Average ABS (% Error)
				L ₁	L ₂	η_1	η_2	
42	15 - 21	19.213	4.350	.5533	1.109	.2977	10.50	3.028
44	19 - 24	19.639	4.090	9.795	1.585	201.6	.4873	3.222
45	11 - 13	18.523	4.835	.1158	.4131	27.24	.2856	5.425
47	T11 - T12	19.348	2.789	1.071	.5904	1.412	5.202	9.346
48	T12 - 11	24.181	2.340	.5883	1.692	.1107	27.77	1.895
49	T9 - T10	19.987	2.171	.6339	.5035	3.522	2.319	19.88
50	T10 - T11	18.256	2.180	2.530	.4843	4.562	3.836	4.710
51	T8 - T9	17.110	2.163	.6925	.6709	.03540	3.775	3.796
52	T7 - T8	16.213	2.645	.6118	.7744	.9187	14.86	6.532
53	T4 - T5	14.032	1.965	22.13	.9653	34.31	.05332	2.732
54	T6 - T7	11.858	2.600	1.454	.9422	3.630	.08159	2.935
56	T5 - T6	14.729	1.980	1.356	.6109	2.812	.06332	2.350
57	T2 - T3	9.929	2.160	1.065	.7299	.1457	8.153	2.267
59	T9 - T10	16.813	2.775	.3280	.6477	.07844	12.64	1.287
60	T4 - T5	11.142	2.240	.4424	.5541	.1525	6.862	3.137
61	T5 - T6	10.432	1.895	.8086	.5288	.2247	7.303	3.075
62	T6 - T7	12.329	1.850	.5694	.7587	4.124	.2068	4.843
63	T11 - T12	18.503	2.975	.7793	.7690	.5481	20.69	3.743
64	T7 - T8	13.690	2.660	1.559	2.970	.2139	12.93	3.447
65	T10 - T11	14.561	2.765	.9871	.5945	.3767	24.58	3.836
66	T8 - T9	16.329	2.705	13.35	.7622	44.69	.02962	2.656
68	T11 - 11	18.503	2.935	.6523	1.021	19.40	.3047	3.321

Table V

Identification of Dr. Leon E. Kazarian's rhesus monkey
datum for fifty-nine intervertebral joints.

*1 Page deleted because it was
illegible.*

DTIC DDA 2

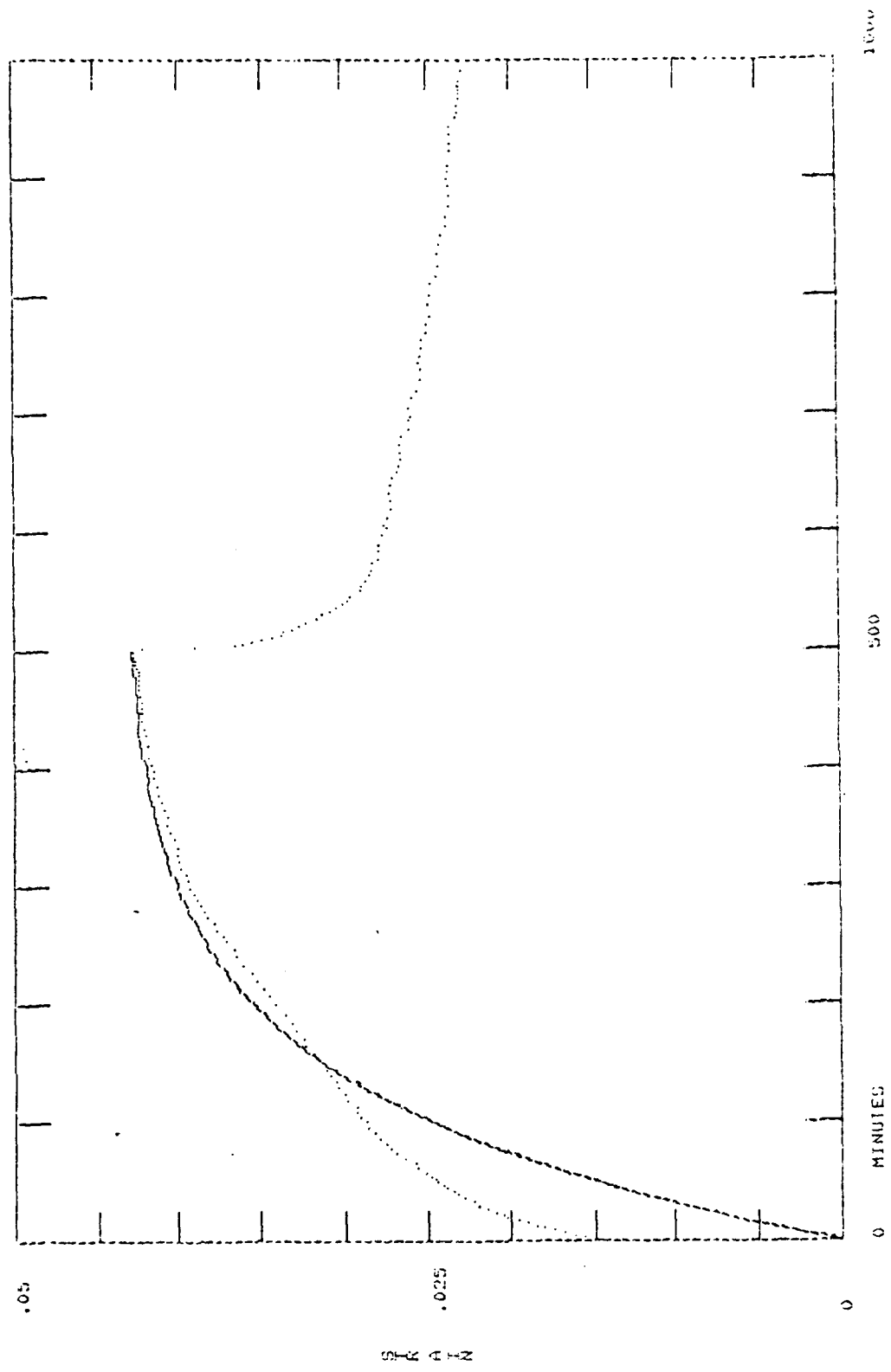
13 Nov 81

Table VI

Mechanical properties and error results (as defined on p. 8) predicted by the two-parameter-solid model analysis of Dr. Leon E. Kazarian's datum on fifty-nine rhesus monkey spinal segments.

*15 pages' deleted because they
were not reproducible.*

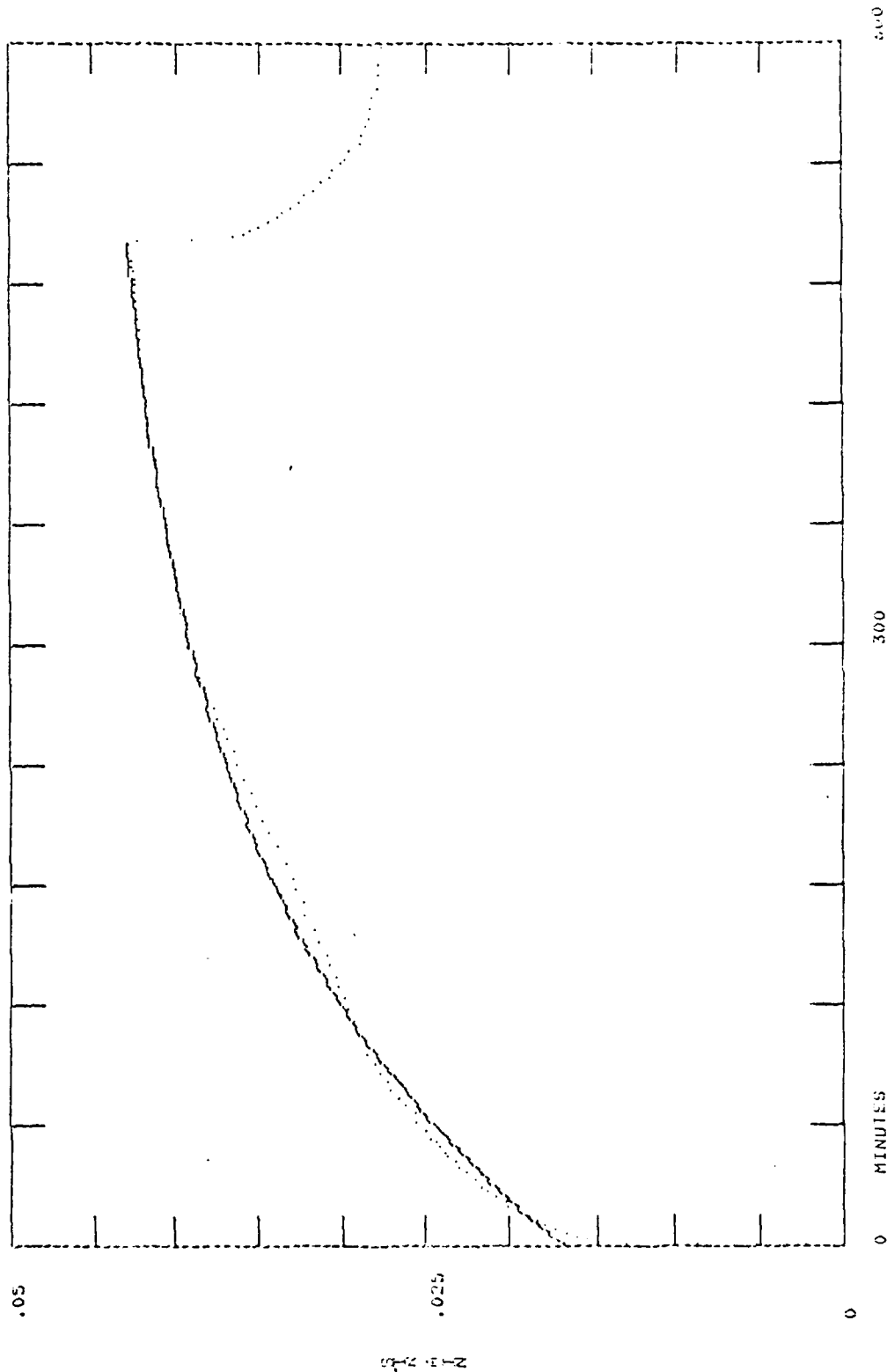
*DTIC-DDA-2
13 Nov 81*



2-PARAMETER SOLID MODEL WITH VALUES OF
 $Q1 = 0.043574$, $R1 = 0.433561$, $Q2 = 0$
 DELTA TIME = 30
 ERROR (USING ALL POINTS) : 2.886%
 ERROR (USING FIRST 3 POINTS) : 2.257%

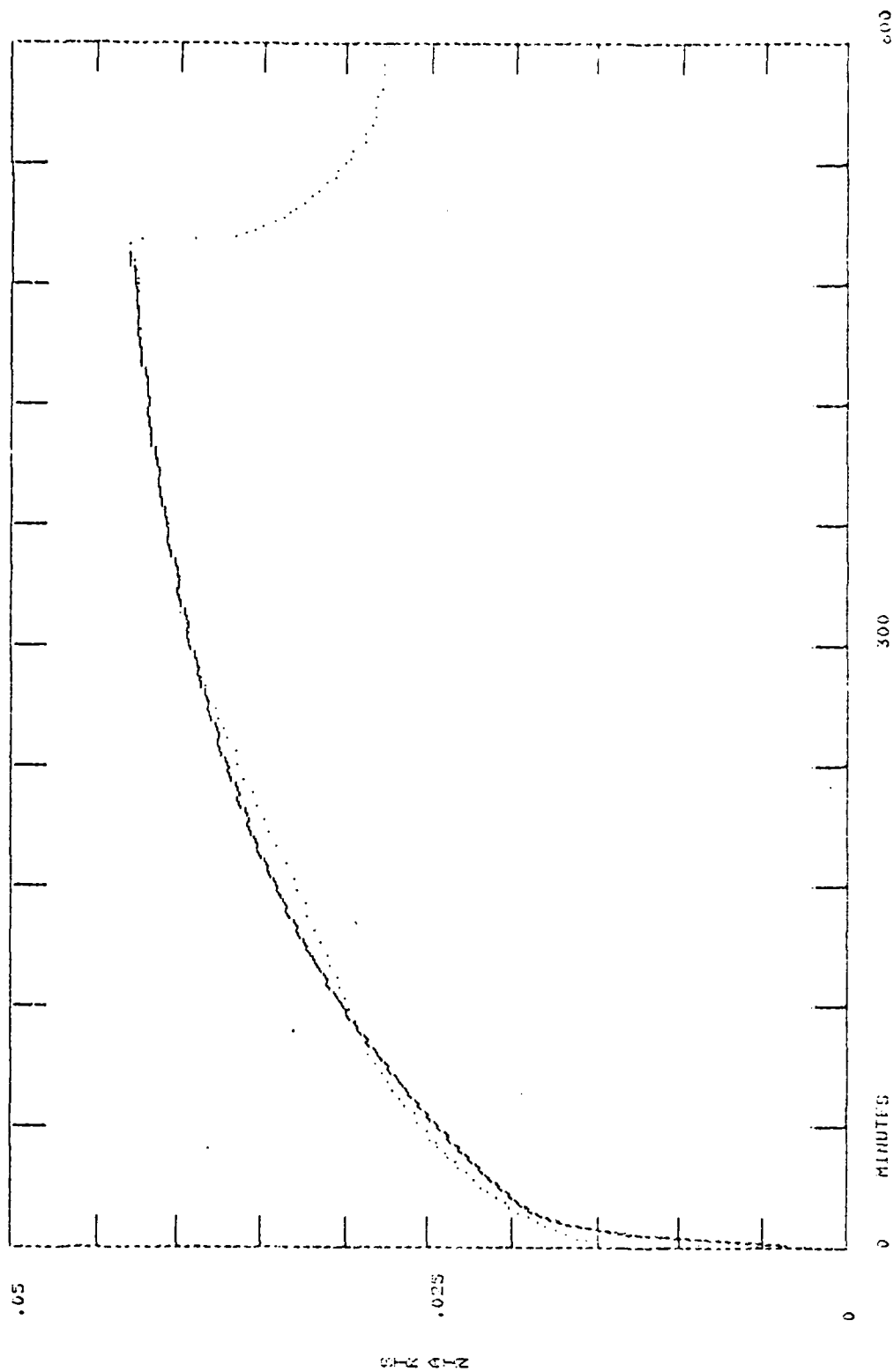
LN-01 T1-T2 19 MAY 75 AREA = 4.15 SQ CM HEIGHT = 2.445 CM
 DOTTED LINE: ORIGINAL DATA HEAVY LINE: MODEL PREDICTION

1



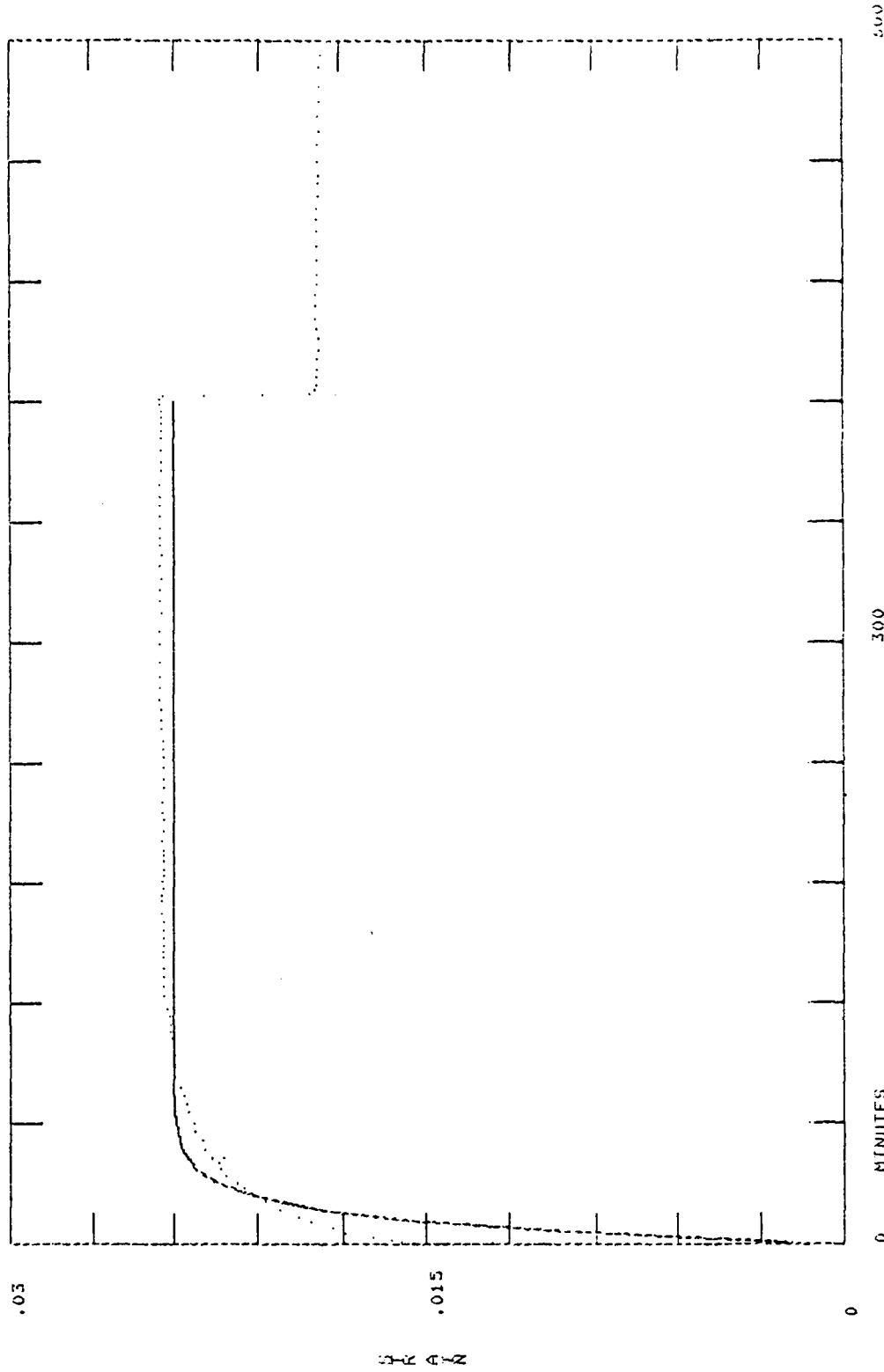
3-PARAMETER SOLID MODEL WITH VALUES OF
 $\alpha_1 = .044939$, $\alpha_2 = 5.3088E-03$, $\alpha_3 = .017039$
 DELTA TIME = 4
 ERROR CURSING ALL POINTS: -2.047%
 ERROR CURSING FIRST 3 POINTS: -1.184%

18-01 11-12 19 MAY 75 AREA = 4.15 SQ CM HEIGHT = 2.445 CM
 DOTTED LINE: ORIGINAL DATA HEAVY LINE: MODEL PREDICTION



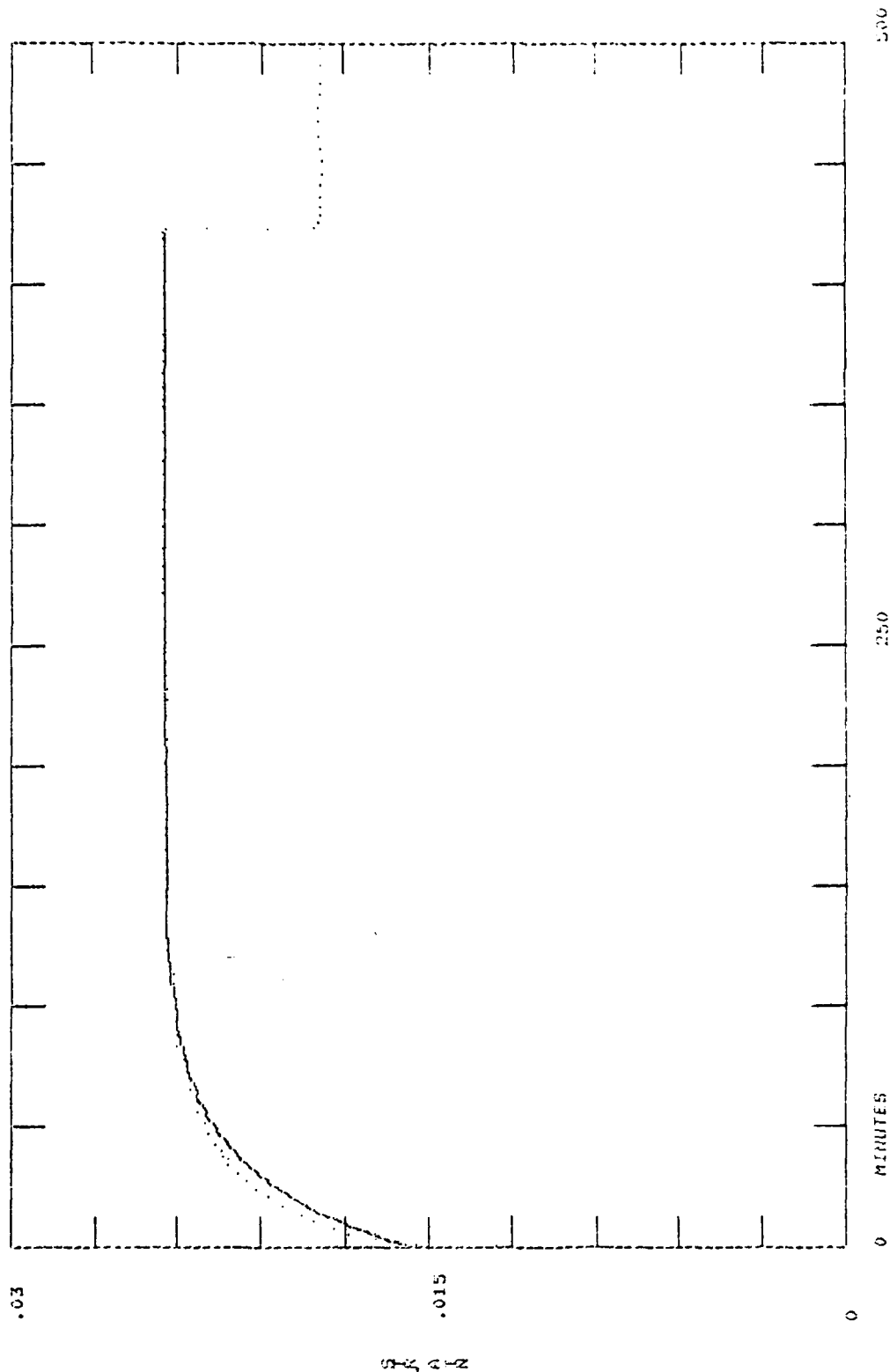
4-PARAMETER SOLID MODEL WITH VALUES OF
 A1 = .016266, B1 = .21977, A2 = .028039, B2 = 5.4144E-03
 TIME = 4
 ERROR CUSING ALL POINTS: 1.140%
 ERROR CUSING FIRST 3 POINTS: 1.143%

LN-01 11-12 19 MAY 75 AREA = 4.15 SQ CM HEIGHT = 2.445 CM
 DOTTED LINE: ORIGINAL DATA HEAVY LINE: MODEL PREDICTION



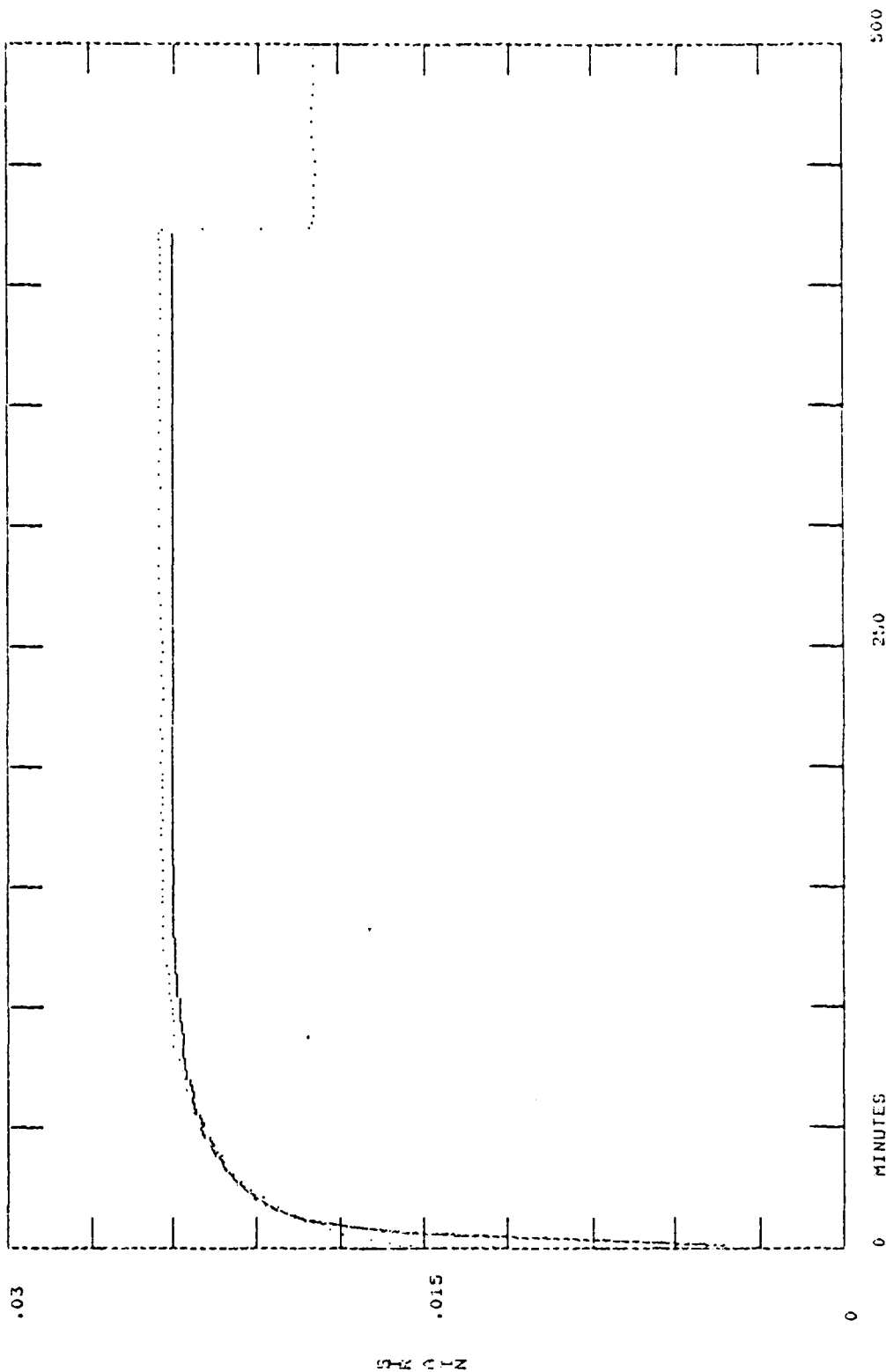
2-PARAMETER SOLID MODEL WITH VALUES OF
 $A1 = .024093$, $B1 = .089526$, $A2 = 0$
 DELTA TIME COUNTING ALL POINTS: 4.3332%
 ERROR COUNTING FIRST 3 POINTS: 3.6992%

LN-02 T2-13 21 MAY 75 AREA = 5.62 SQ CM HEIGHT = 2.515 CM
 DOTTED LINE: ORIGINAL DATA HEAVY LINE: MODEL PREDICTION



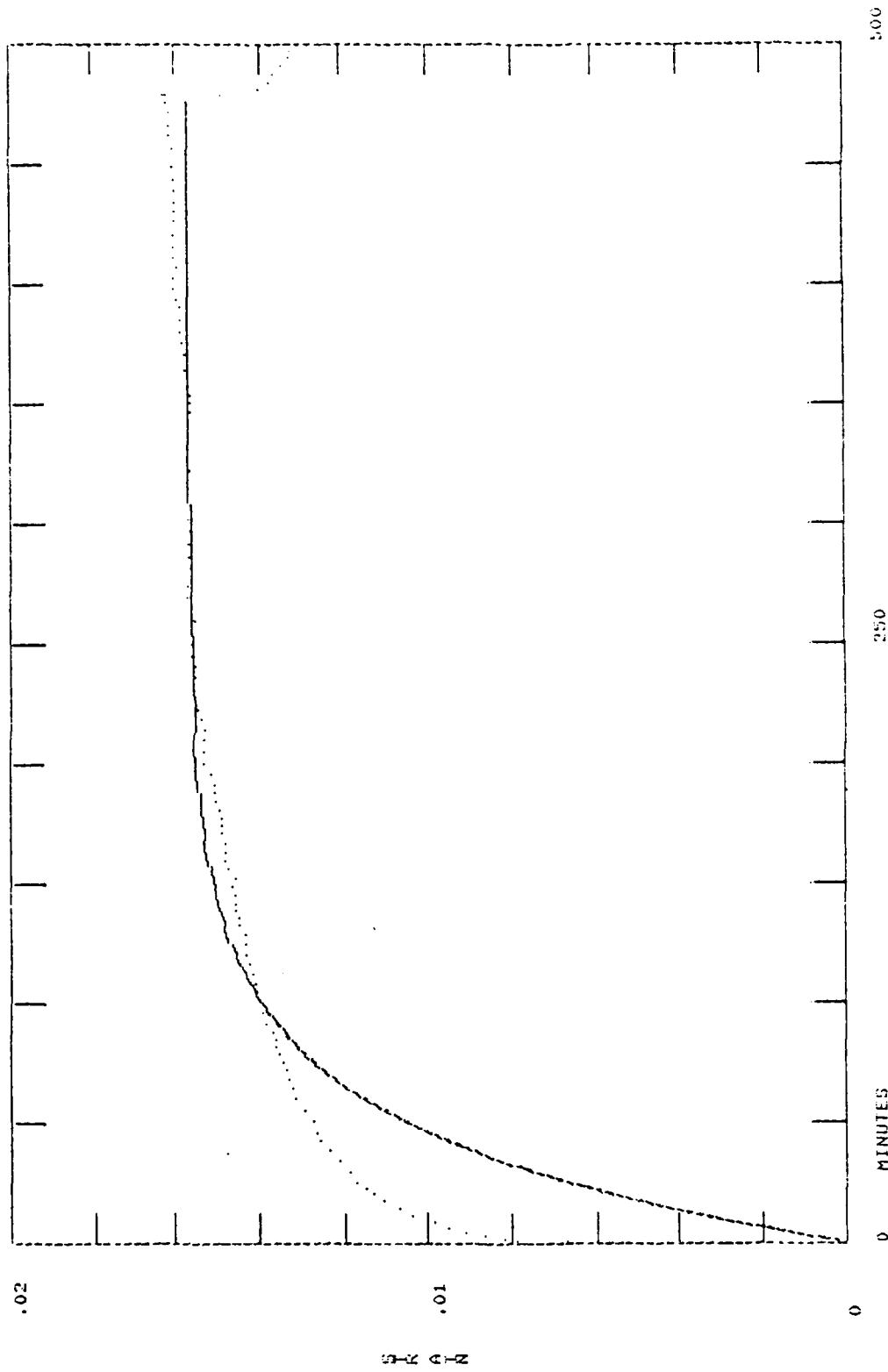
LA-02 12-13 21 MAY 75 AREA = 5.62 50 CM HEIGHT = 2.515 CM

DOTTED LINE: ORIGINAL DATA HEAVY LINE: MODEL PREDICTION



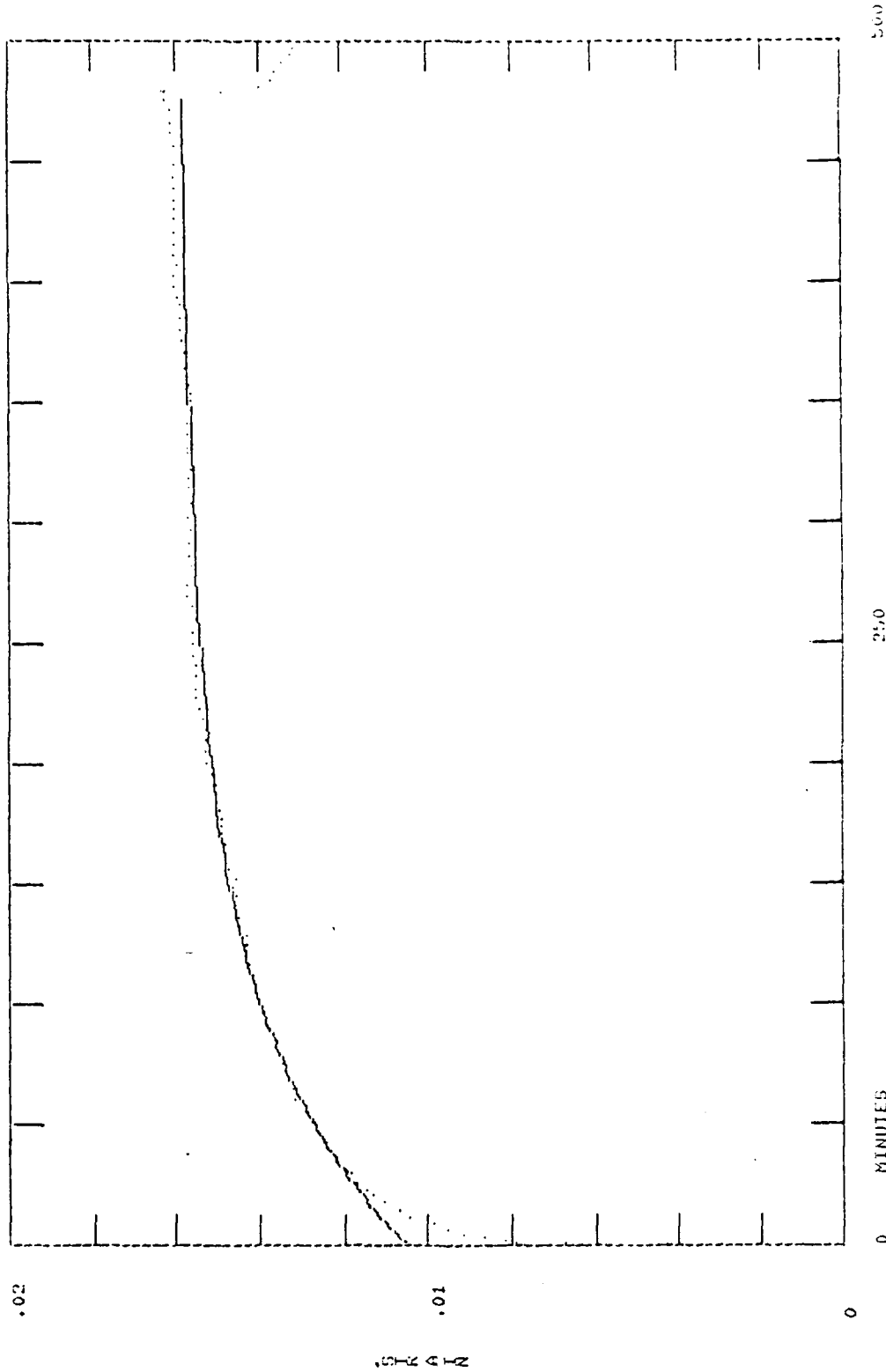
4-PARAMETER SOLID MODEL WITH VALUES OF
 A1 = 5.5199E-03, B1 = .032035, A2 = .018576, B2 = .26439
 DELTA TIME = 8
 ERROR (USING ALL POINTS): 3.301%
 ERROR (USING FIRST 3 POINTS): 2.757%

LK-02 12-13 21 MAY 75 AREA = 5.62 SQ CM HEIGHT = 2.515 CM
 DOTTED LINE: ORIGINAL DATA HEAVY LINE: MODEL PREDICTION

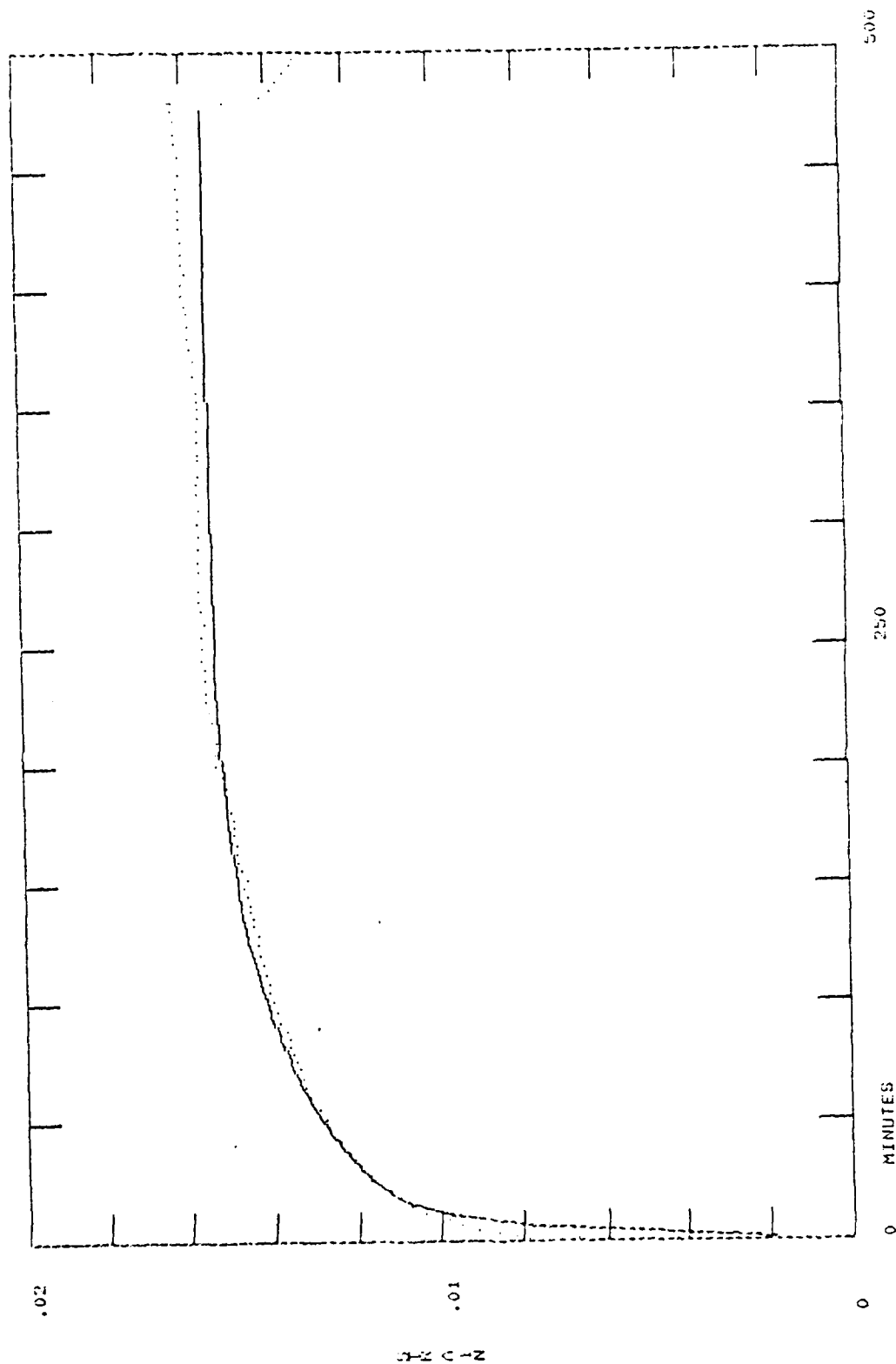


2-PARAMETER SOLID MODEL WITH VALUES OF
 A1 = .015593, R1 = .022087, A2 = 0
 DELETED TIME = 18
 ERROR (USING ALL POINTS): 6.835%
 ERROR (IGNORING FIRST 3 POINTS): 6.500%

LK-04 14-15 04 SEP 75 ARL - 5.10 50 CM HEIGHT - 2.28 CM
 DOTTED LINE: ORIGINAL DATA HEAVY LINE: MODEL PREDICTION

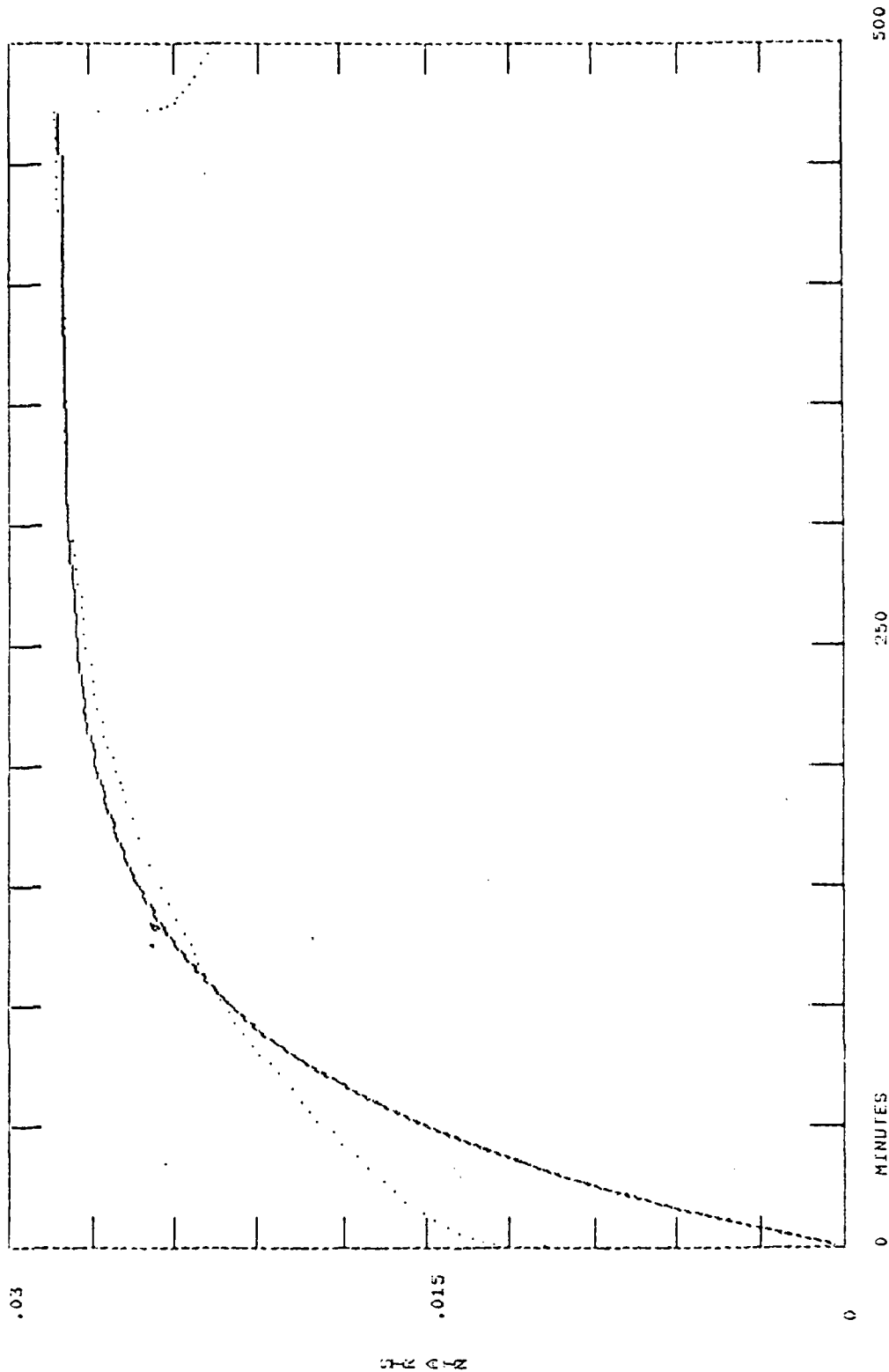


5--PARAMETER SOLVER MODEL WITH VALUES OF
 A1 = .015802, B1 = .010736, A2 = .010534
 DELTA TIME = 4
 ERROR CUSTING ALL POINTS : 1.265%
 ERROR CUSTING FIRST 3 POINTS : 0.424%
 LN-04 T4 15 04 SLP 75 AREA = 5.18 SQ CM HEIGHT = 2.28 CM
 DOTTED LINE: ORIGINAL DATA
 HEAVY LINE: MODEL PREDICTION



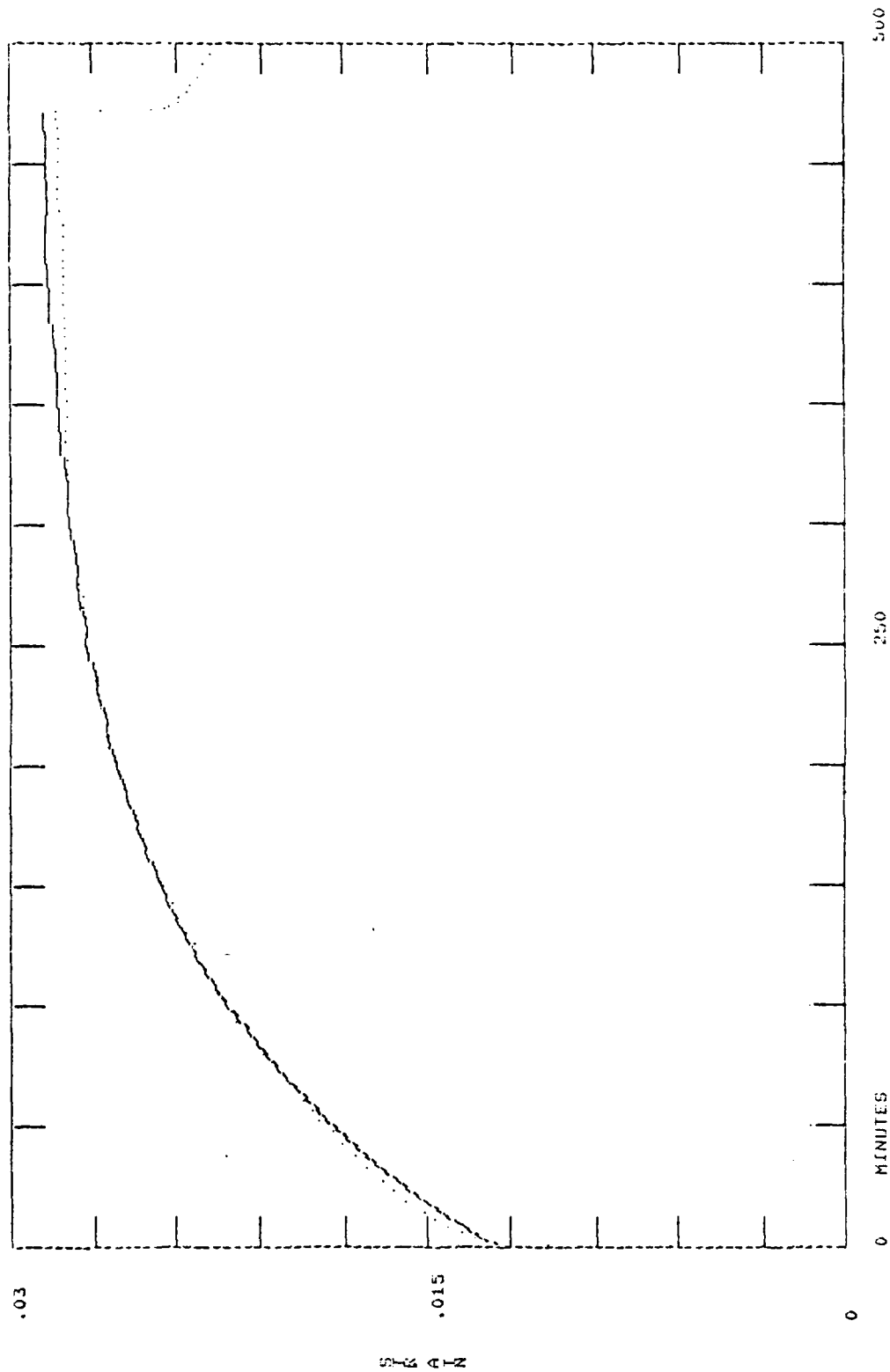
4-PROGRAMMER SOLID MODEL WITH VALUES OF
 A1 = .010011, B1 = .218, A2 = 5.4608E-03, B2 = .014589
 DELTA TIME = 8
 ERROR CUSING ALL POINTS:
 ERROR CUSING FIRST 3 POINTS:
 2.5852%
 2.5852%

1K-04 14-15 04 SEP 75 AREA = 5.10 50 CM HEIGHT = 2.20 CM
 DOTTED LINE: ORIGINAL DATA HEAVY LINE: MODEL PREDICTION



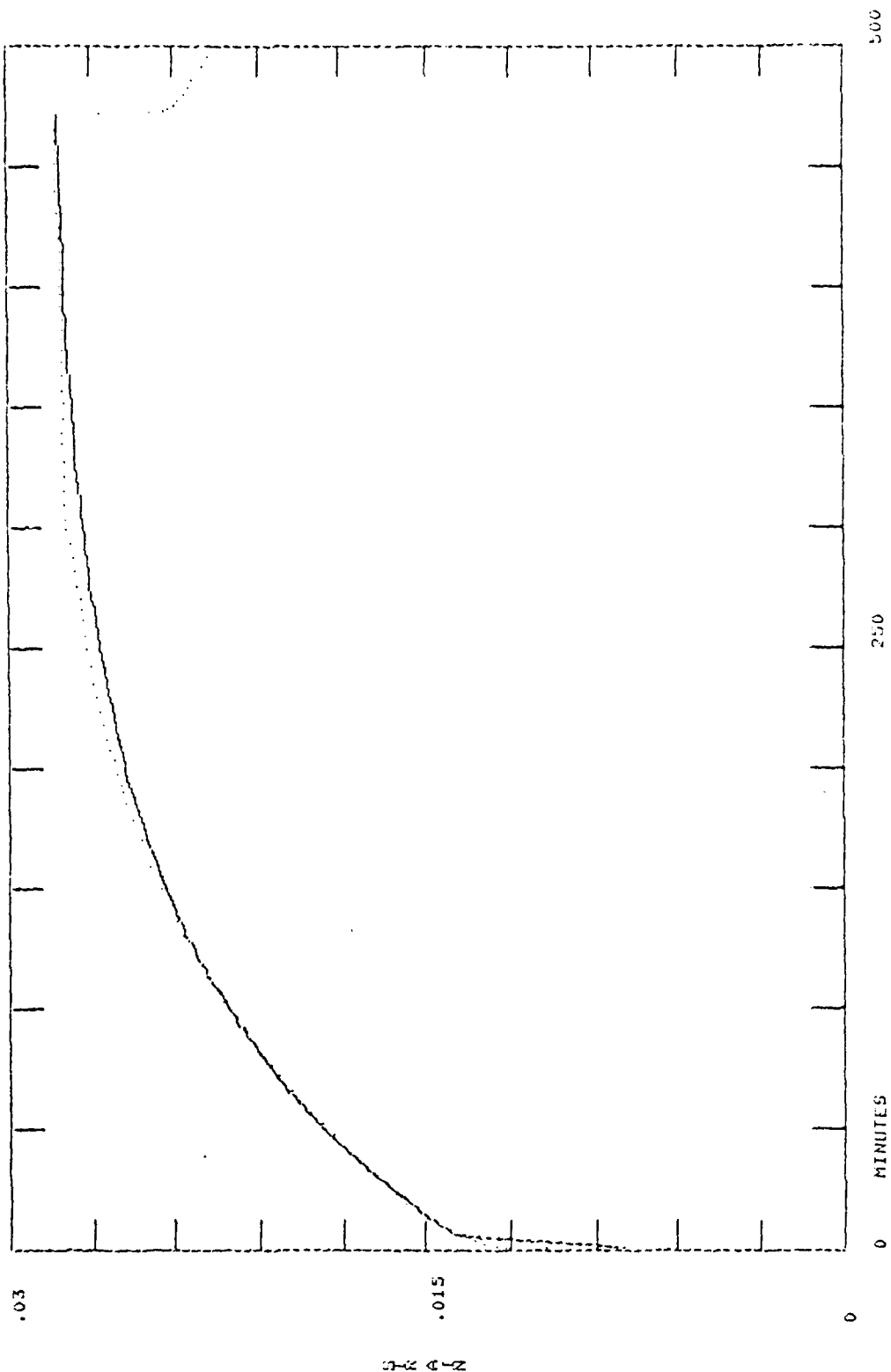
2-PARAMETER SOLID MODEL WITH VALUES OF
 $a_1 = .028229$, $b_1 = .019133$, $a_2 = 0$
 DELTA TIME = 16
 ERROR (USING ALL POINTS): 6.419%
 ERROR (IGNORING FIRST 3 POINTS): 6.073%

LA-05 15-16 28 AUG 75 AREA = 5.57 SQ CM HEIGHT = 2.005 CM
 DOTTED LINE: ORIGINAL DATA HEAVY LINE: MODEL PREDICTION



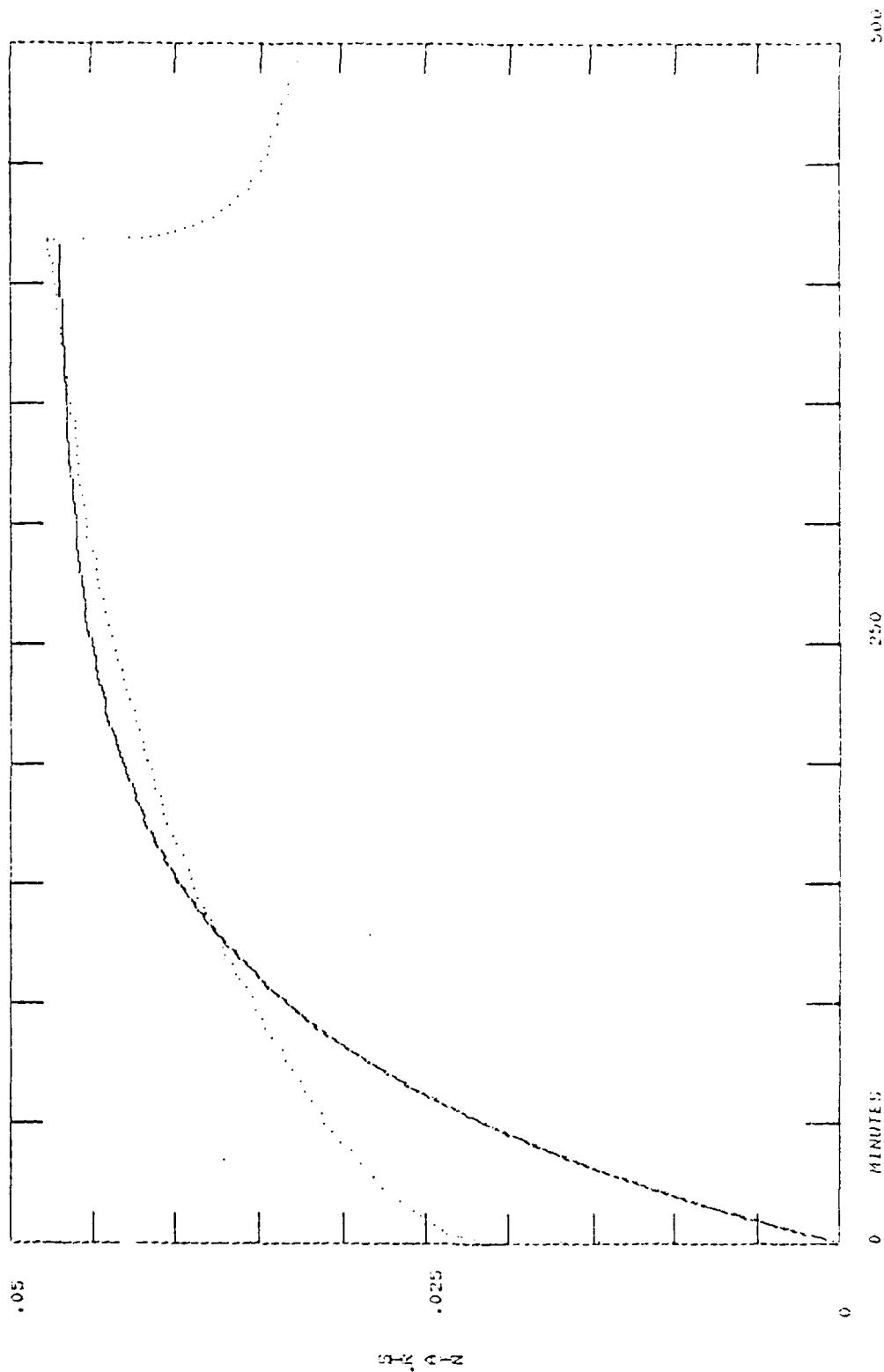
3-PARAMETER SOLID MODEL WITH VALUES OF
 $\alpha_1 = .029165$, $\alpha_2 = 8.5903E-03$, $\alpha_3 = .012632$
 DELTA TIME = 4
 ERROR USING ALL POINTS: -1.139%
 ERROR USING FIRST 3 POINTS: -0.457%

LN-05 15-T6 28 AUG 75 AREA = 5.57 SQ CM. HEIGHT = 2.085 CM
 DOTTED LINE: ORIGINAL DATA HEAVY LINE: MODEL PREDICTION



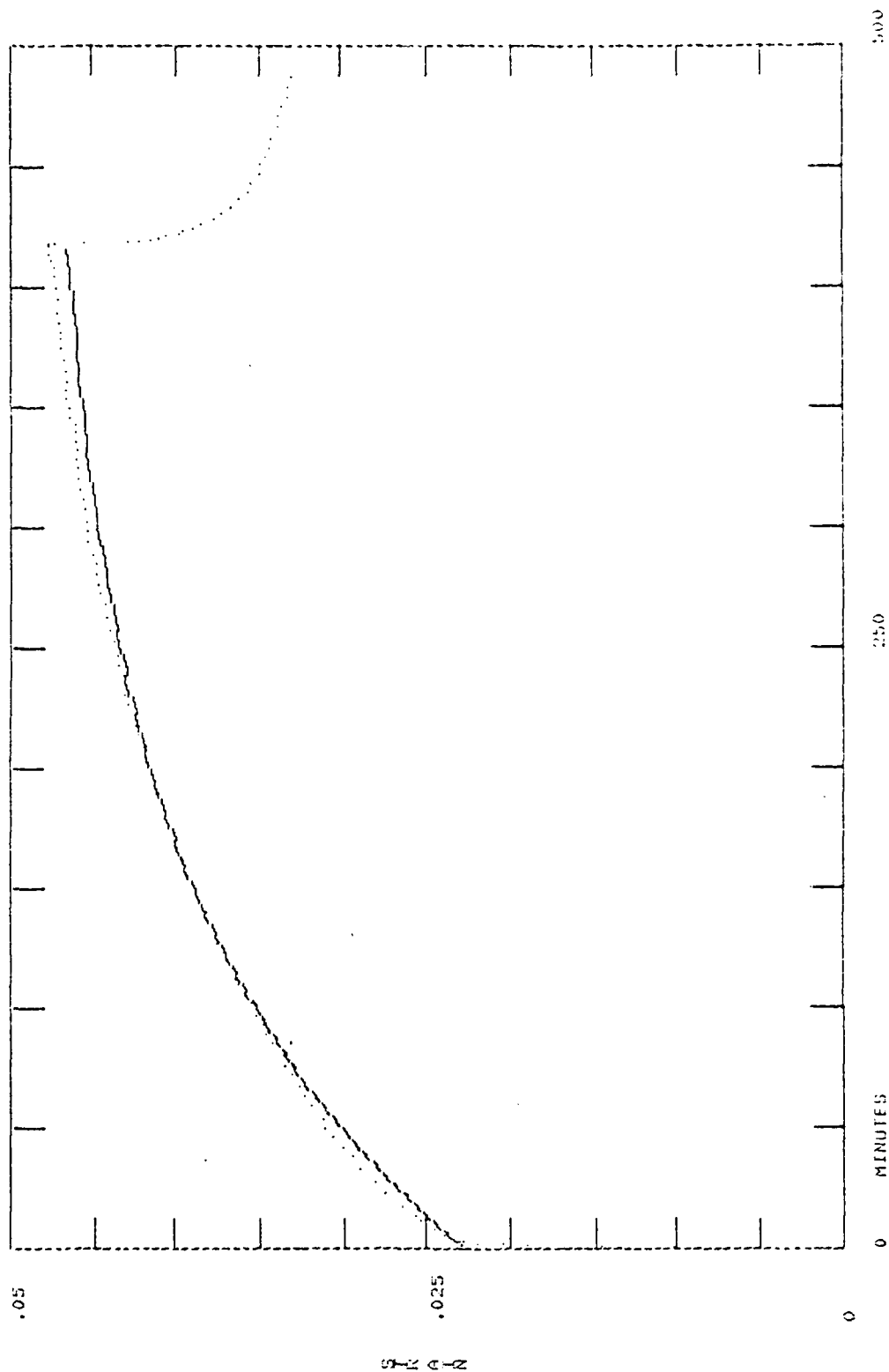
A PARAMETER SOLTD MODEL WITH VALUES OF
 Q1 = .01516 * R1 = 8.7356E-03 * Q2 = .0133561 * R2 = .91083
 DELTA TIME = 4
 ERROR USING ALL POINTS : 1.114%
 ERROR USING FIRST 3 POINTS : 1.134%

LN-05 T5-T6 28 AUG 75 AFCA 5.57 50 CM HEIGHT = 2.005 CM
 DOTTED LINE: ORIGINAL DATA HEAVY LINE: MODEL PREDICTION



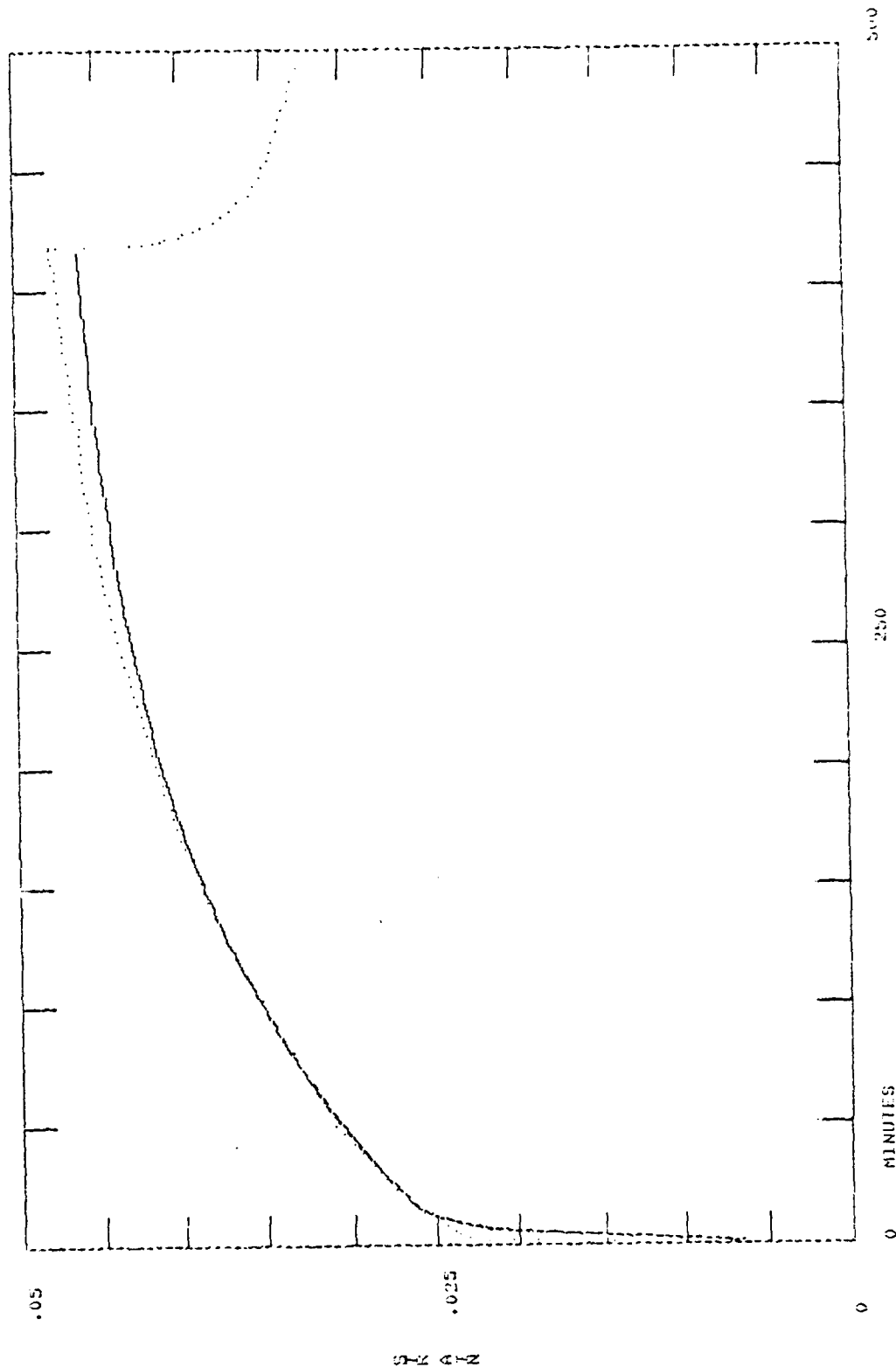
2-PARAMETER SOLID MODEL WITH VALUES OF
 $Q_1 = .0473894$ $Q_2 = .0122224$ $Q_3 = 0$
 DELTA TIME = 1.6
 ERROR CLOSING ALL POINTS : 8.2672%
 ERROR CLOSING FIRST 3 POINTS : 7.9833%

LN-05 16-17 29 MAY 75 AREA = 6.49 50 CM HEIGHT = 2.67 CM
 BOTTOM LINE: ORIGINAL DATA HEADY LINE: MODEL PREDICTION



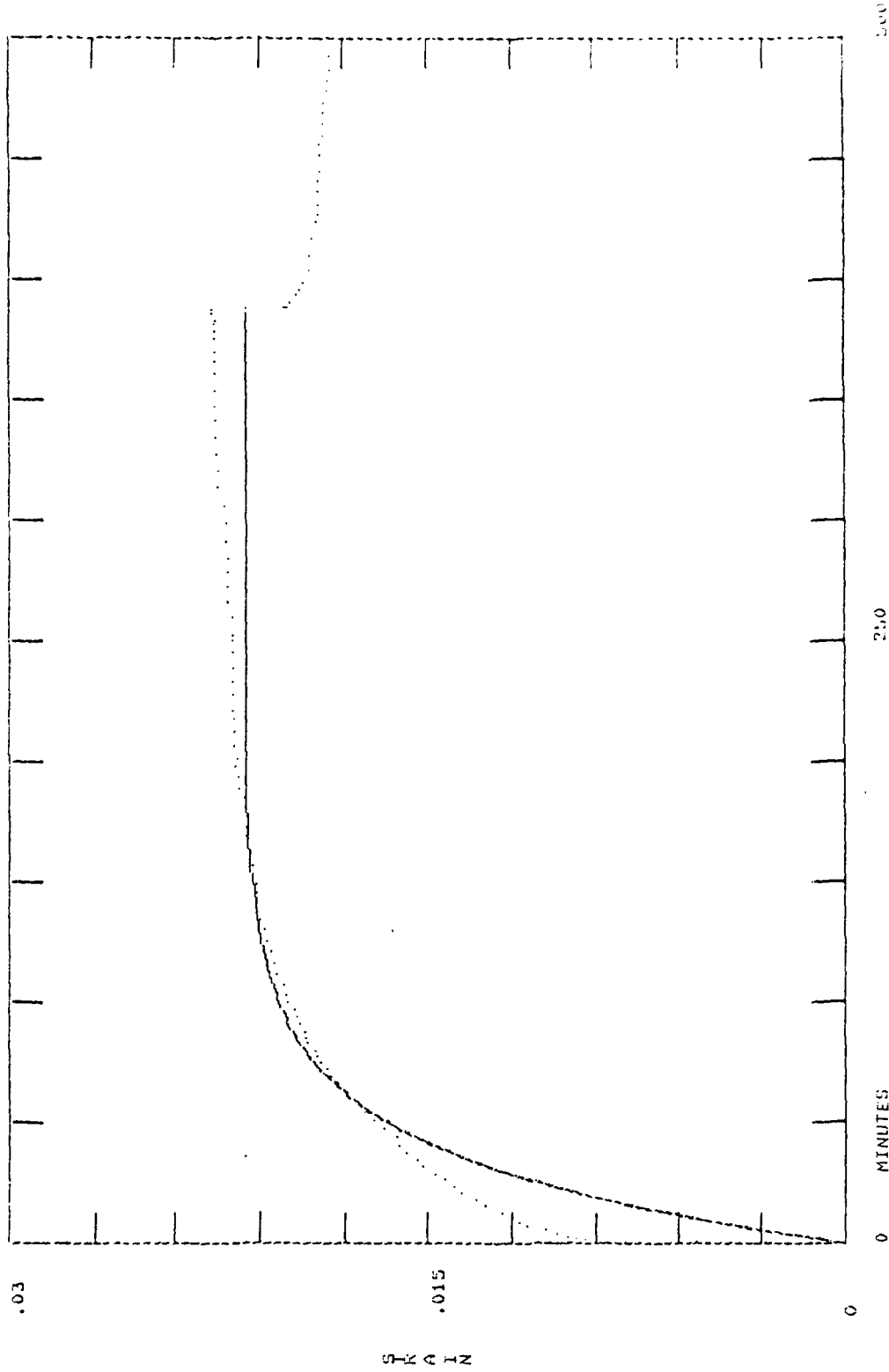
3-PARAMETER SOLID MODEL WITH VALUES OF
 DELTA = 0.0314, 131 = 6.7899E-03, 62 = 0.02945
 TIME = 4
 CUSING ALL POINTS
 ERROR CUSING FIRST 3 POINTS : 0.072%
 ERROR CUSING FIRST 3 POINTS : 0.657%

LN-06 16-17 29 MAY 75 AREA = 6.49 SQ CM HEIGHT = 2.67 CM
 DOTTED LINE: ORIGINAL DATA HEAVY LINE: MODEL PREDICTION



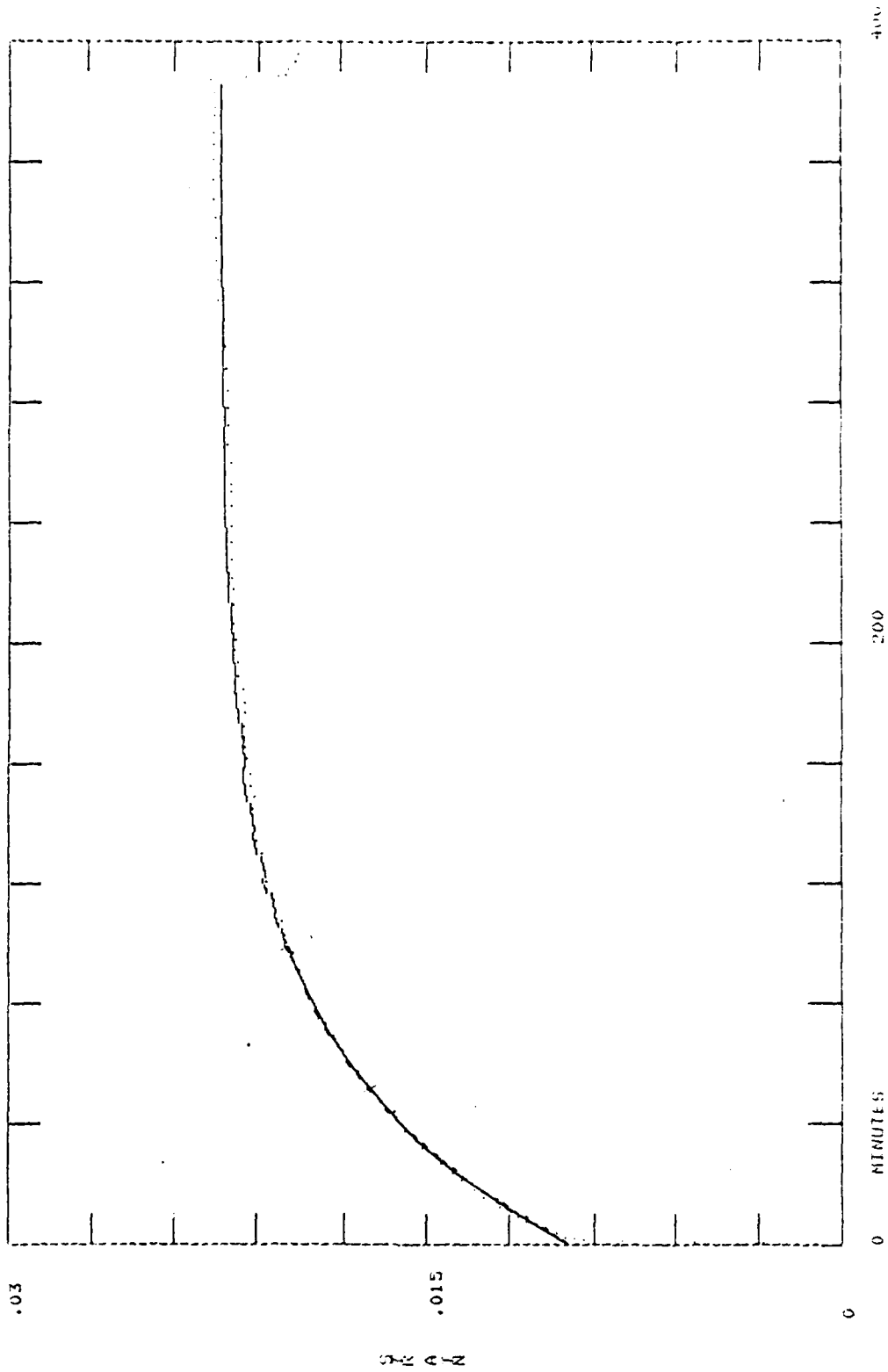
PARAMETER SOLID MODEL WITH VALUES OF
 A1 = .023583, K1 = 6.6349E-03, A2 = .024179, K2 = .329222
 TIME COSTNO ALL POINTS : 3.0832%
 ERROR COSTNO FIRST 3 POINTS : 2.9337%

IN-06 16-17 29 MAY 75 AREA = 6.49 SQ CM HEIGHT = 2.67 CM
 DOTTED LINE: ORIGINAL DATA HEAVY LINE: MODEL PREDICTION



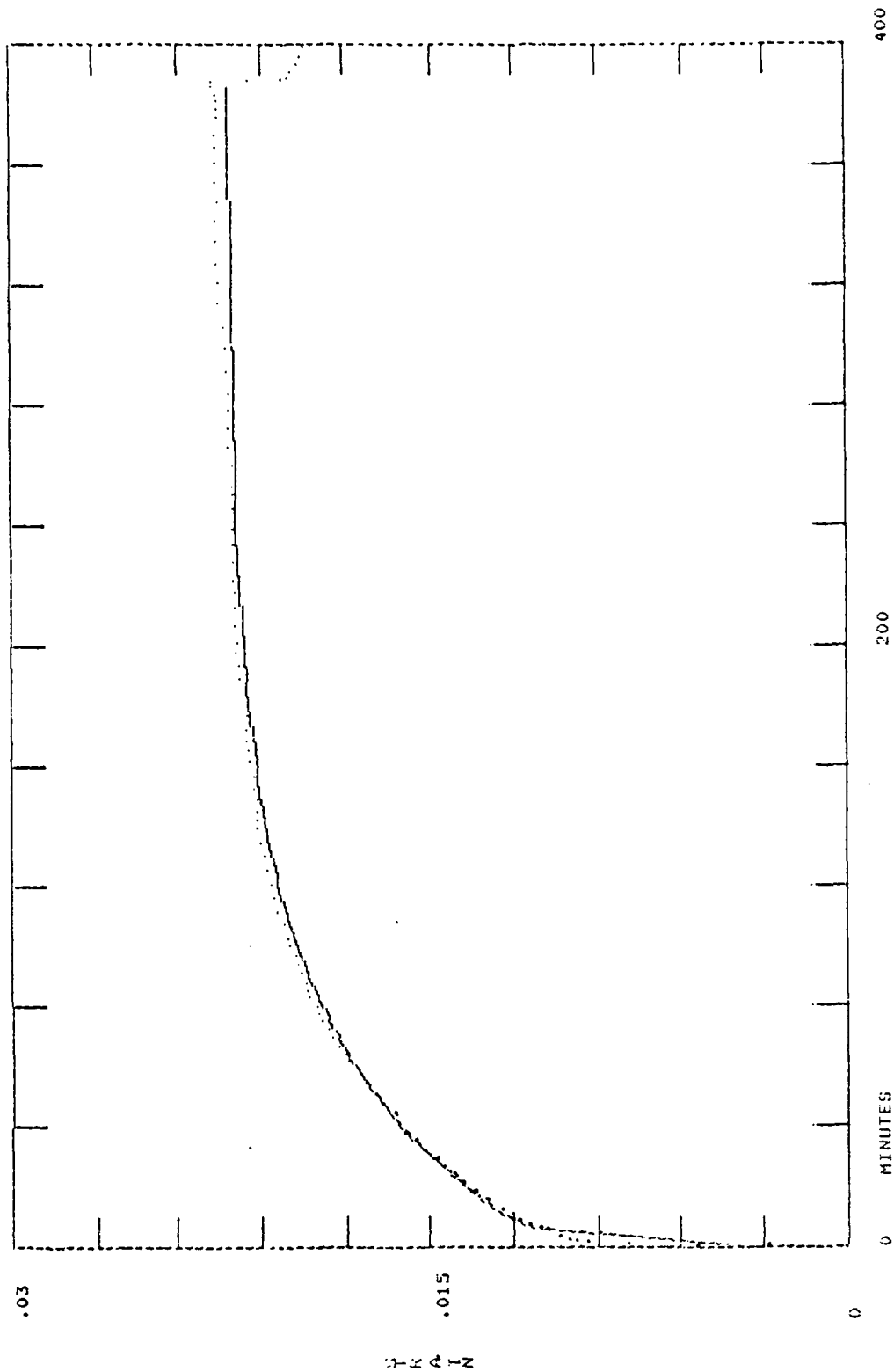
2-PARAMETER SOLID MODEL WITH VALUES OF
 $\alpha_1 = .021595$, $\alpha_2 = .029033$, $\alpha_3 = 0$
 DELTA TIME = 8
 ERROR (USING ALL POINTS): 6.854%
 ERROR (USING FIRST 3 POINTS): 6.701%

LA-07 17-18 08 SEP 75 AREA = 7.63 SQ CM HEIGHT = 2.755 CM
 DOTTED LINE: ORIGINAL DATA HEAVY LINE: MODEL PREDICTION



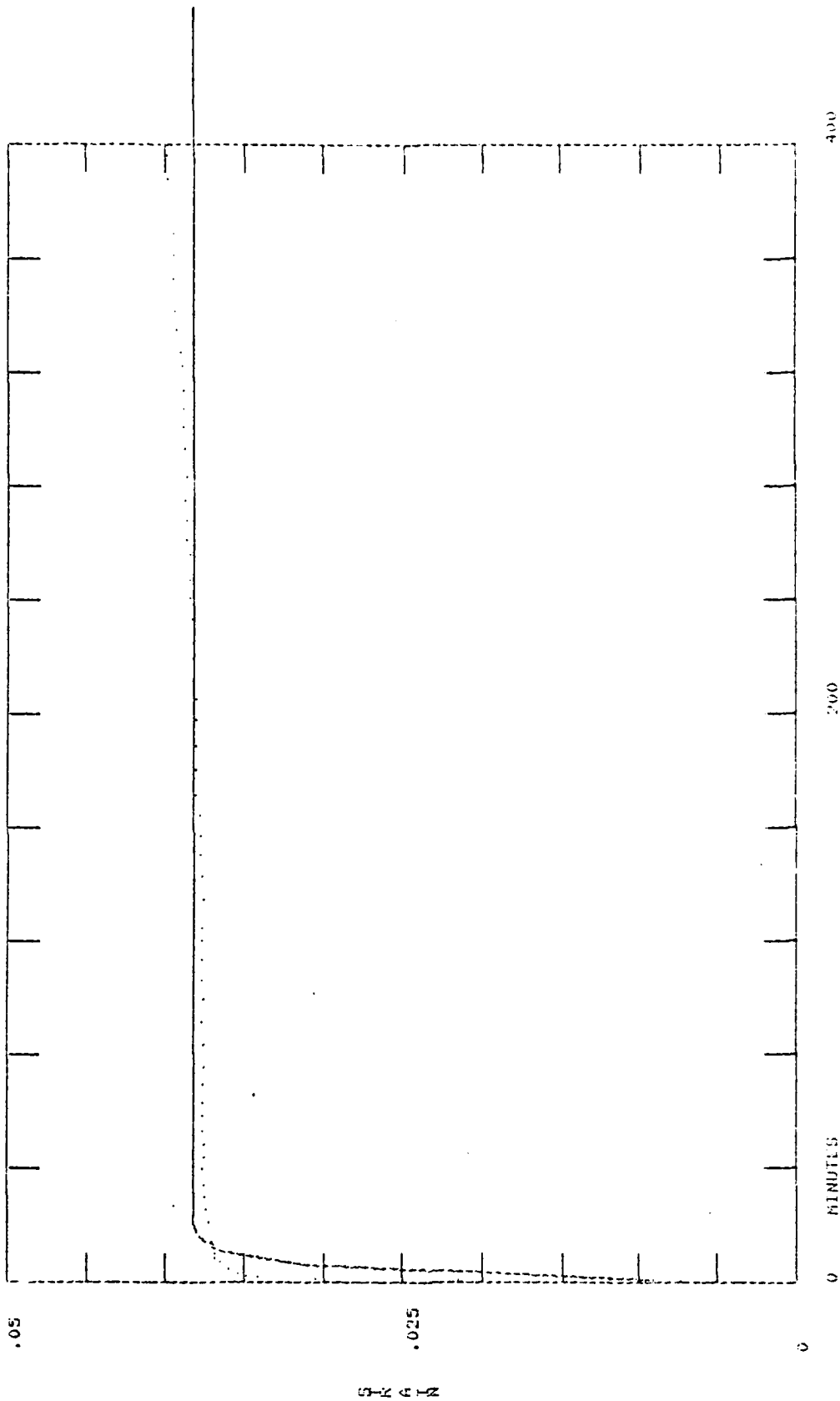
3-PARAMETER SOLID MODEL WITH VALUES OF
 A1 = .022442, A2 = .016687, A3 = 9.8199E-03
 DELTA TIME = 4
 ERROR (USING ALL POINTS) = 1.302%
 ERROR (USING FIRST 3 POINTS) = 0.485%

LN-07 17-18 08 SEP 75 AREA = 7.63 SQ CM HEIGHT = 2.755 CM
 DOTTED LINE: ORIGINAL DATA HEAVY LINE: MODEL PREDICTION



4-PARAMETER SOLID MODEL WITH VALUES OF
 A1 = .01359, A2 = .015692, A3 = .01077, A4 = .51459
 DELTA TIME = 8
 ERROR CLUSTERING ALL POINTS
 ERROR CLUSTERING FIRST 3 POINTS

LN-07 T7-18 OB SET 75 AREA = 7.63 SQ CM HEIGHT = 2.755 CM
 DOTTED LINE: ORIGINAL DATA HEAVY LINE: MODEL PREDICTION



2-1 PARAMETER SOLID MODEL WITH VALUES OF

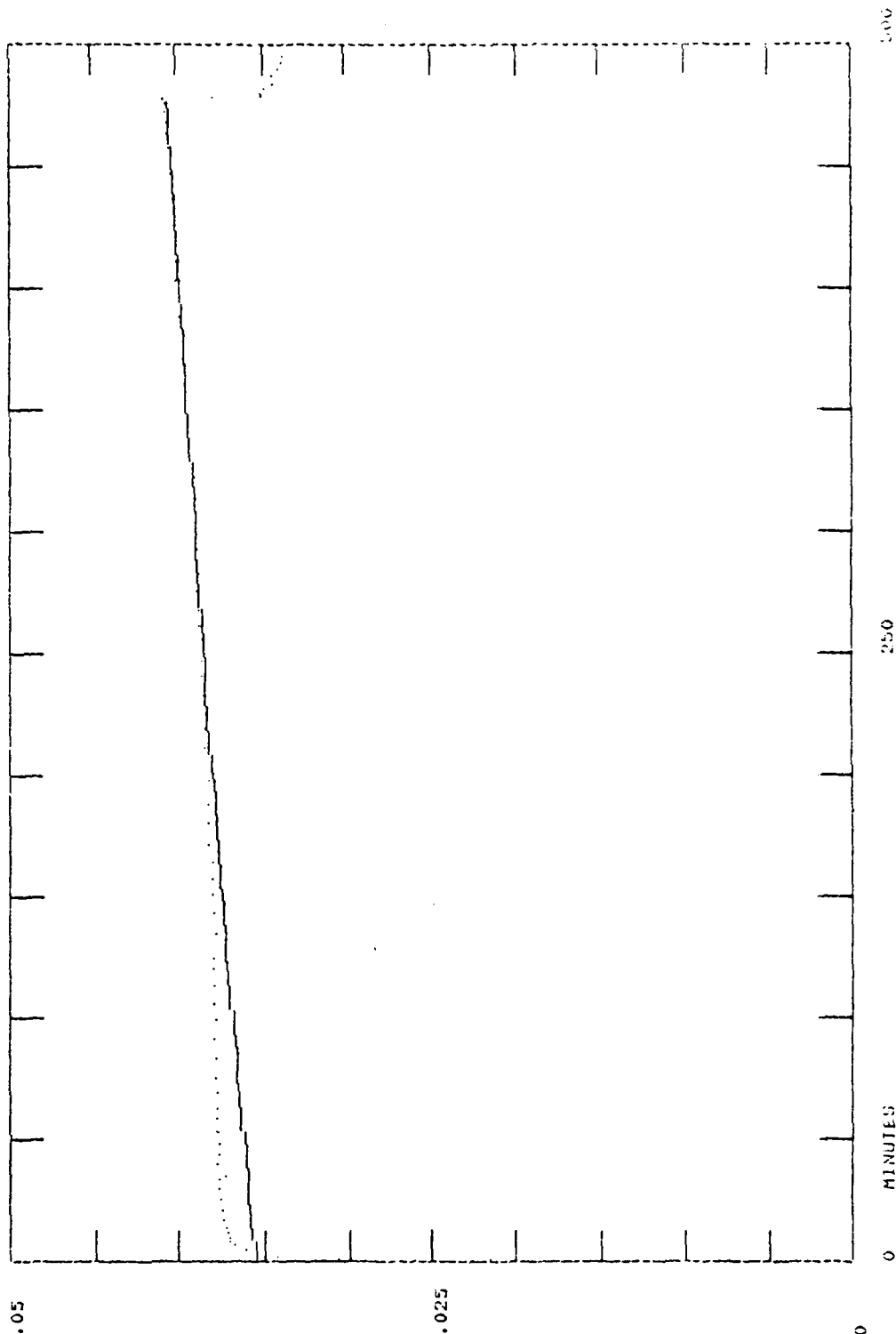
AL = 0.03333, AT = 0.28211, AM = 0

DELTA TIME = 0

ERROR (USING ALL POINTS): 0.0000

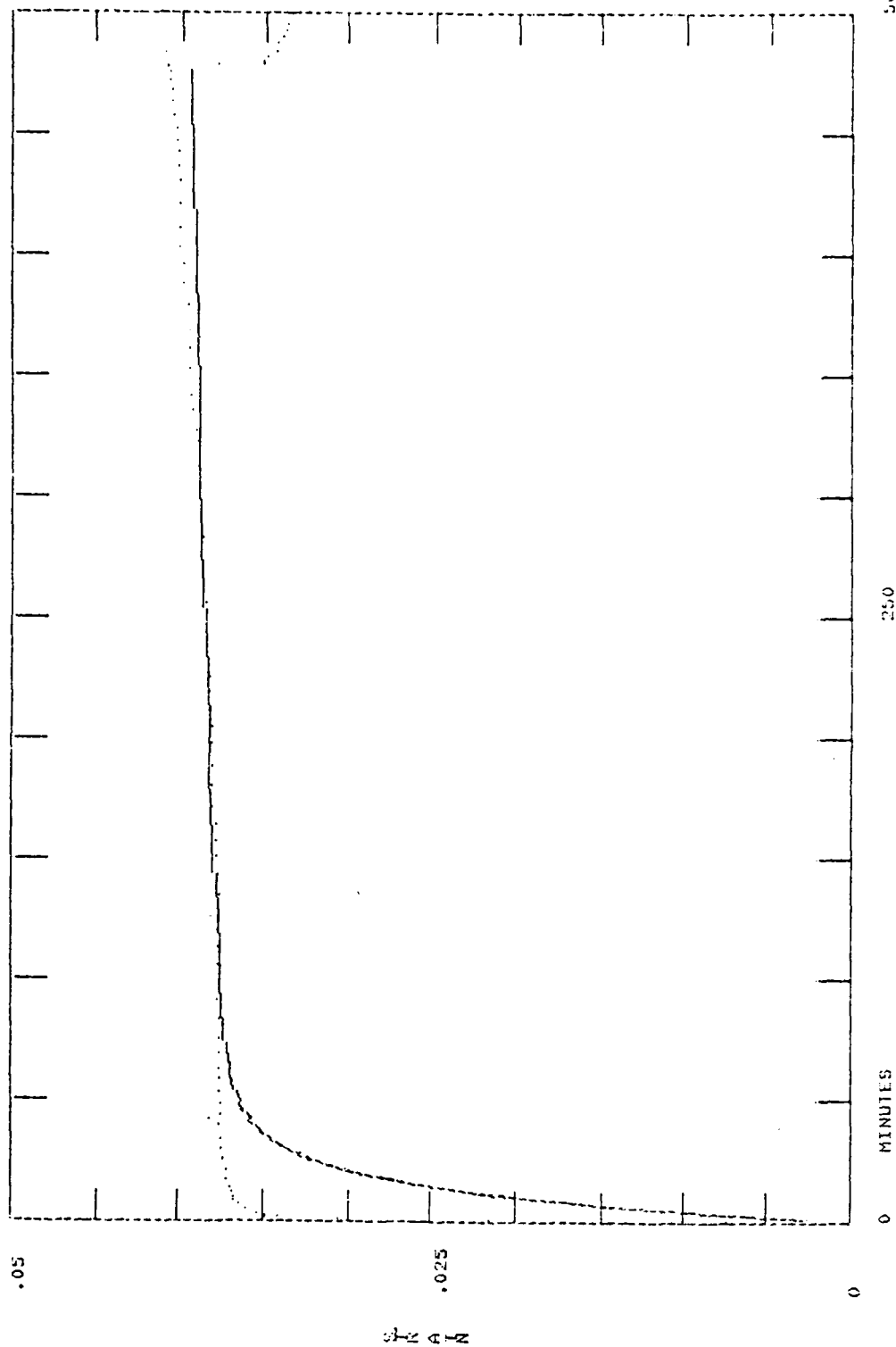
ERROR (IGNORING FIRST 3 POINTS): 0.0000

LN-08 10-19 22 AUG 75 AREA = 0.12 SQ CM HEIGHT = 1.194 CM
 DOTTED LINE: ORIGINAL DATA HEAVY LINE: MODEL PREDICTION



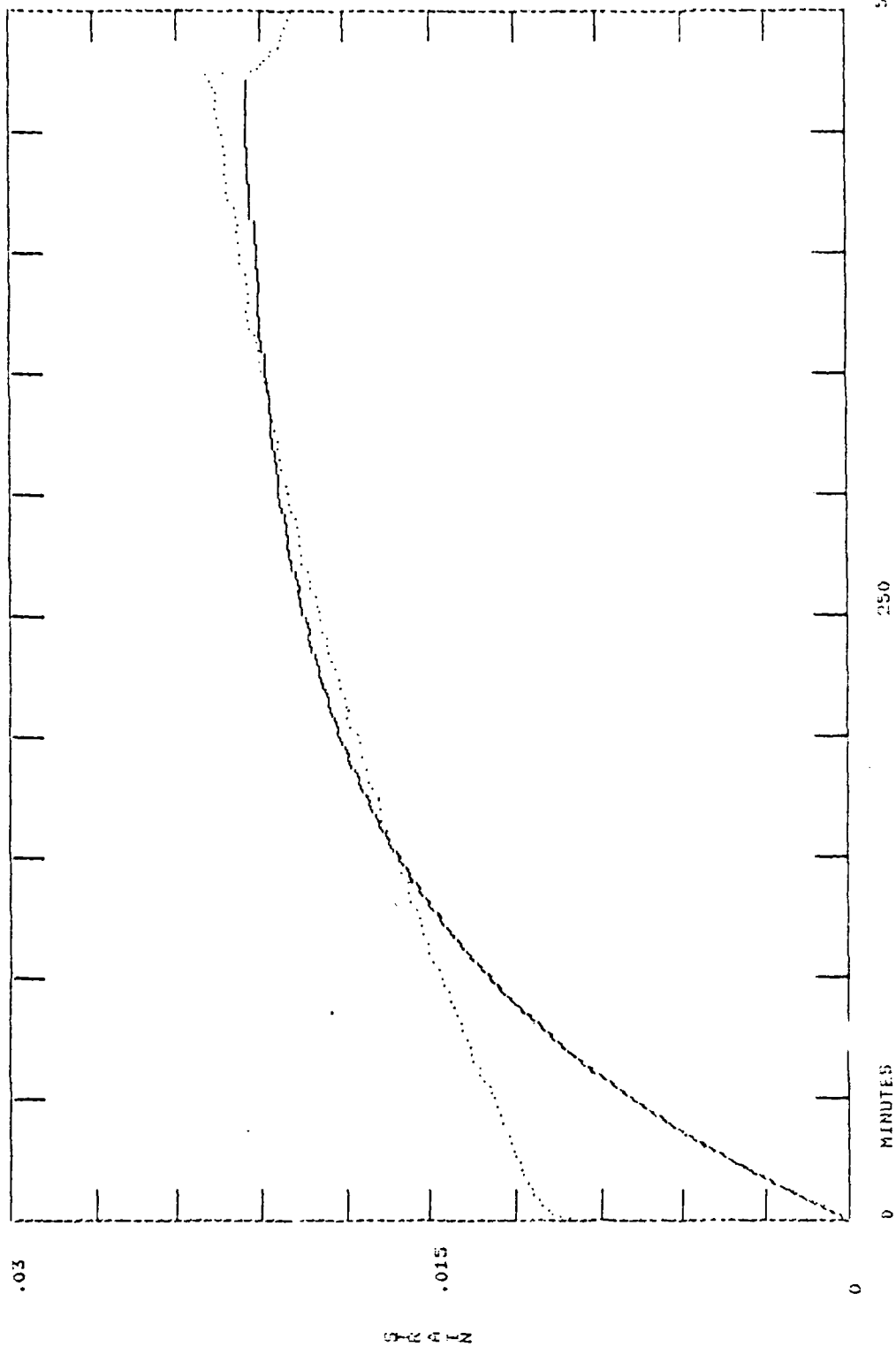
3-PARAMETER SOLID MODEL WITH VALUES OF
 A1 = .00491, G1 = 9.703E-04, A2 = .038491
 DELETE TIME = 8
 ERROR COUNTING ALL POINTS: -0.312%
 ERROR COUNTING FIRST 3 POINTS: 1.024%

LN-08 18-19 22 AUG 75 AREA = 6.12 SQ CM HEIGHT = 1.194 CM
 DOTTED LINE: ORIGINAL DATA HEAVY LINE: MODEL PREDICTION



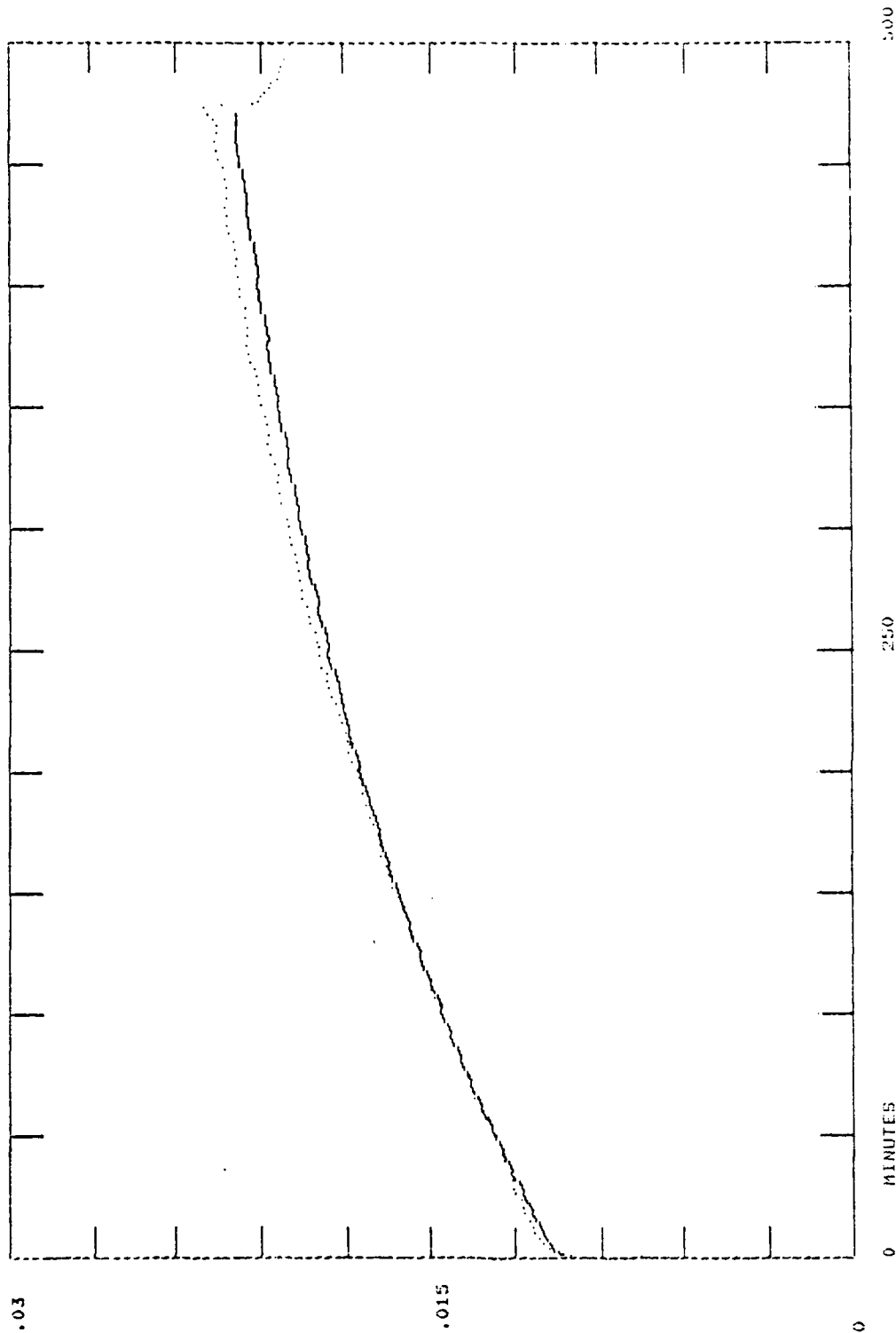
4. PARAMETER SOLID MODEL WITH VALUES OF
 A1 = 3.3037E-03, B1 = 3.1859E-03, A2 = .036773, B2 = .031224
 DELTA TIME = 30
 ERROR COUNTING ALL POINTS: 9.501%
 ERROR COUNTING FIRST 3 POINTS: 8.794%

LK-08 10-19 22 AUG 75 AREA = 0.12 SQ CM HEIGHT = 1.194 CM
 DOTTED LINE: ORIGINAL DATA HEAVY LINE: MODEL PREDICTION



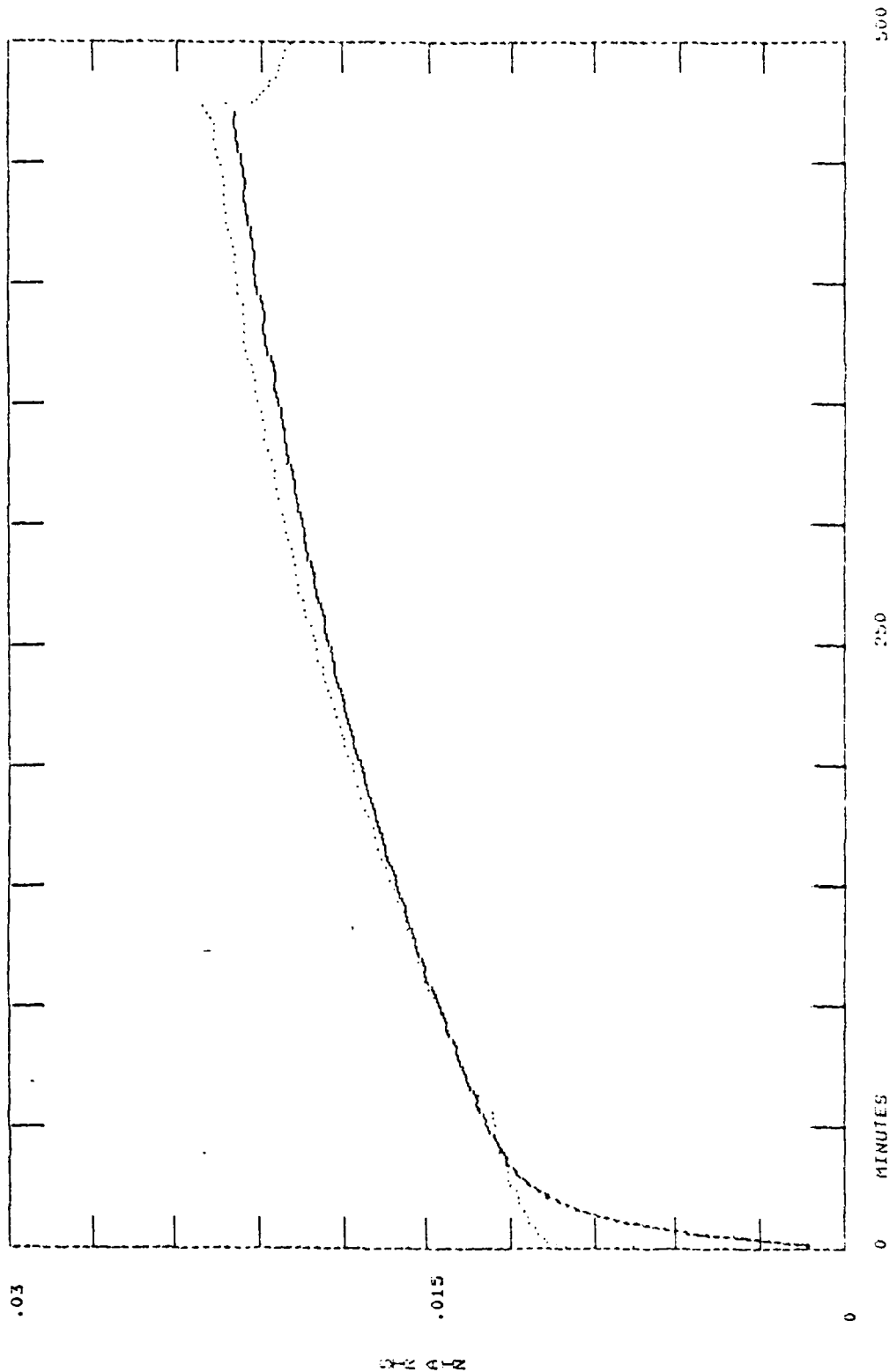
2-PARAMETER SOLID MODEL WITH VALUES OF
 $\alpha_1 = .021876 \times 10^4 = 8.9334E-03$, $\alpha_2 = 0$
 DELTA TIME = 16
 ERROR USING ALL POINTS: 9.698%
 ERROR USING FIRST 3 POINTS: 9.485%

LN-09 19-110 21 AUG 75 AREA = 7.70 SQ CM HEIGHT = 2.24 CM
 DOTTED LINE: ORIGINAL DATA HEAVY LINE: MODEL PREDICTION



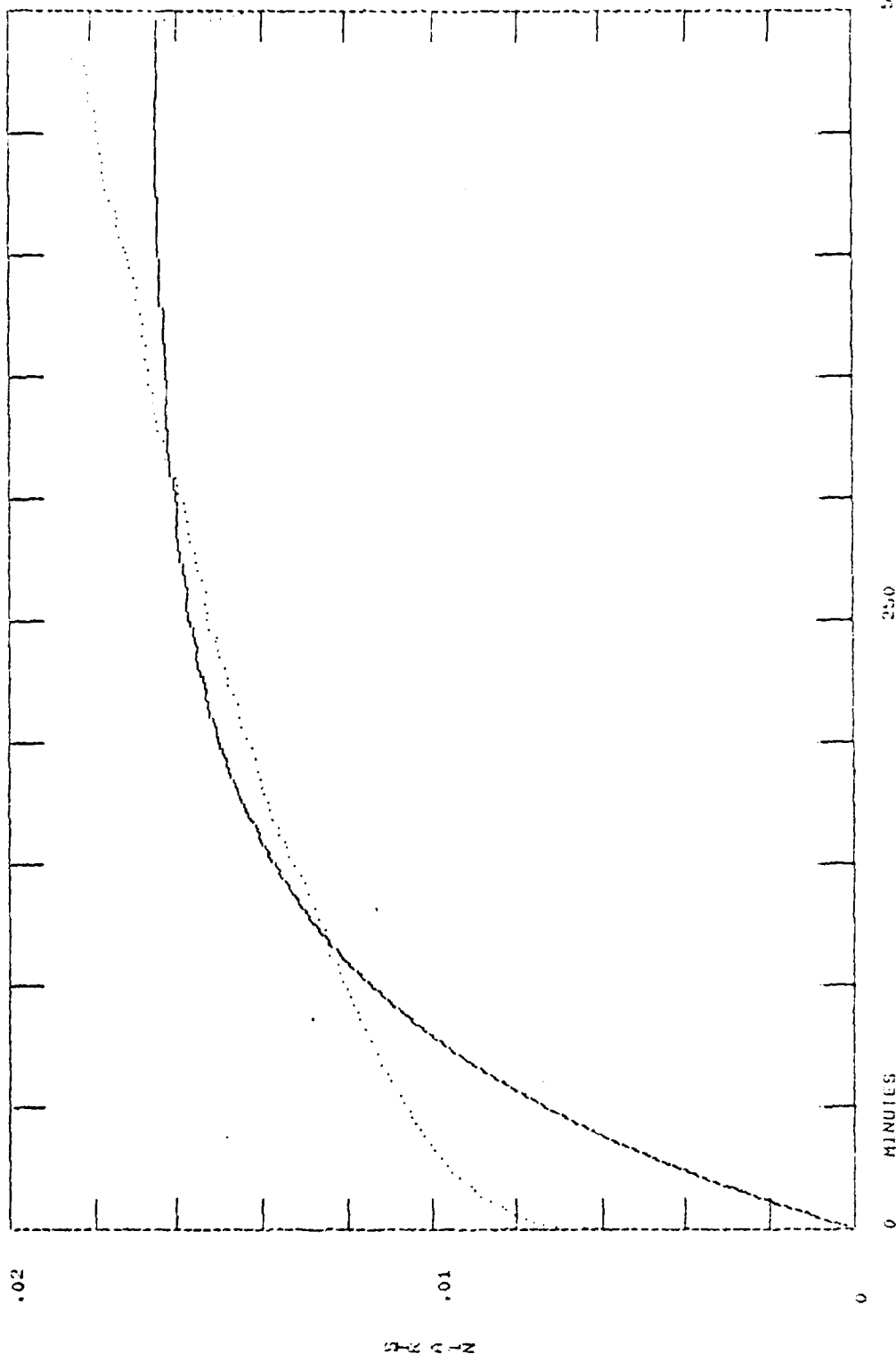
3-PARAMETER SOLID MODEL WITH VALUES OF
 A1 = .028143, B1 = 3.2212E-03, A2 = .010609
 DELTA TIME = 30
 ERROR USING ALL POINTS: 1.098%
 ERROR USING FIRST 5 POINTS: 1.718%

LK-09 T9-110 21 AUG 75 AREA = 7.78 SQ CM HEIGHT = 2.24 CM
 DOTTED LINE: ORIGINAL DATA
 HEAVY LINE: MODEL PREDICTION



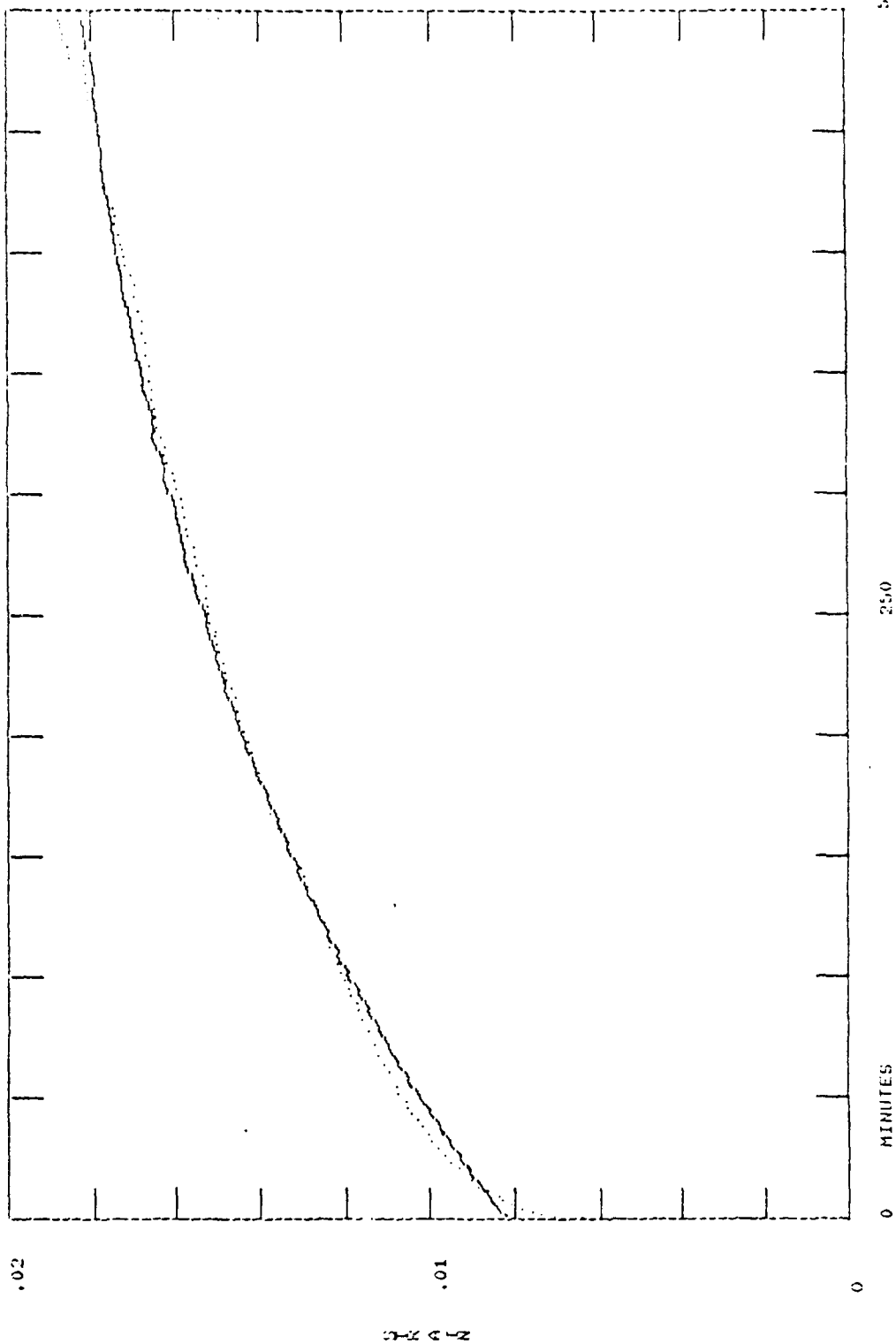
4-PARAMETER SOLID MODEL WITH VALUES OF
 A1 = .010934, B1 = .11098, A2 = .015064, B2 = 2.7868E-03
 INITIAL TIME CUSING ALL POINTS: 16 4.795%
 ERROR (CONJUG FIRST 3 POINTS): 4.610%

IX-09 19-110 21 AUG 75 AREA = 7.78 50 CM HEIGHT = 2.24 CM
 DOTTED LINE: ORIGINAL DATA HEAVY LINE: MODEL PREDICTION



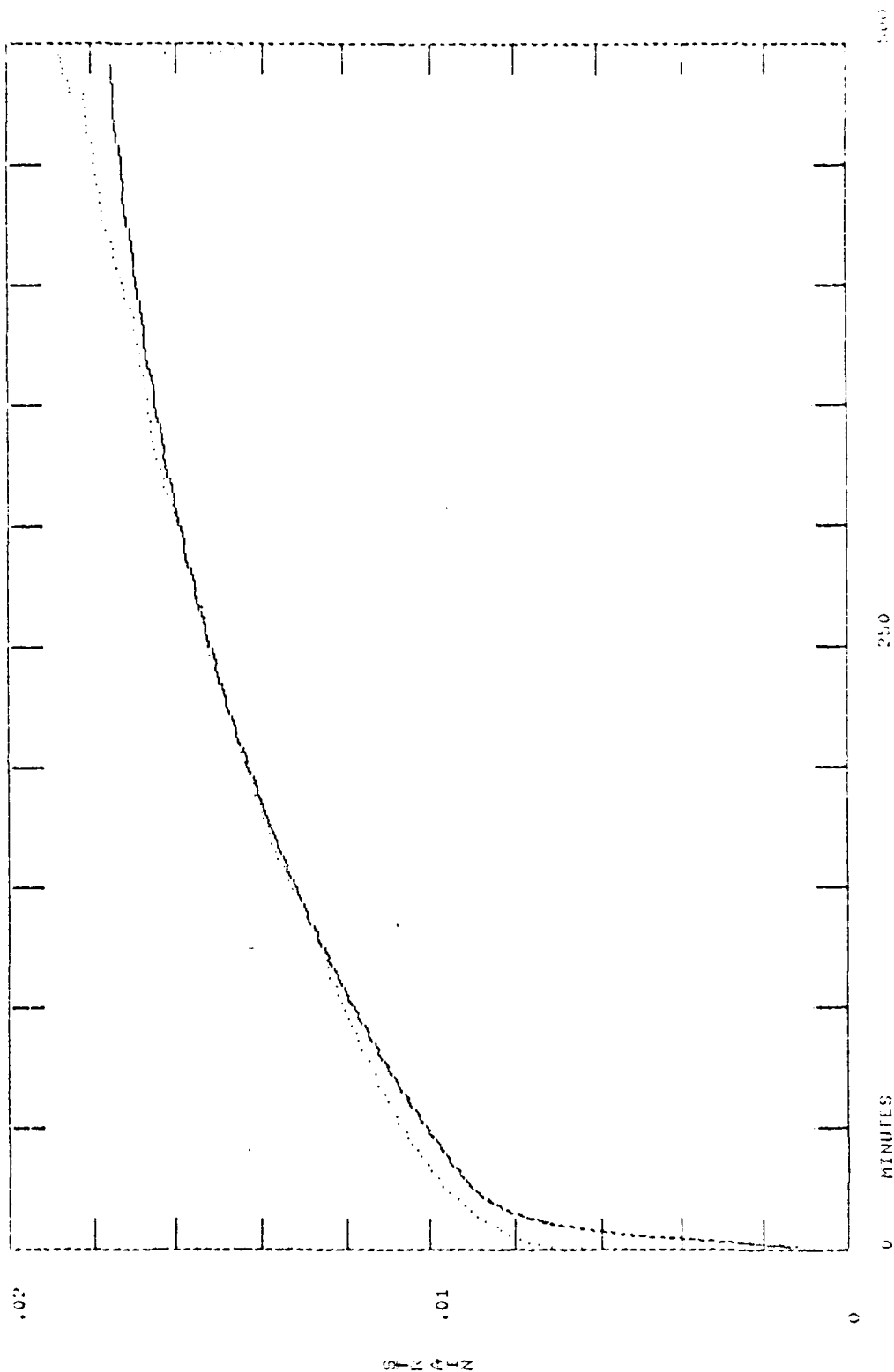
2-PROGRAMETER SOLID MODEL WITH VALUES OF
 $\alpha_1 = .016593$, $\alpha_2 = .011743$, $\alpha_3 = 0$
 DELTA TIME CURSING ALL POINTS:
 ERROR (IGNORING FIRST 3 POINTS):
 2.0000%
 3.6200%

LN-10 110-111 04 AUG 75 ARE = 0.96 50 CM HEIGHT = 3.92 CM
 DOTTED LINE: ORIGINAL DATA HEAVY LINE: MODEL PREDICTION



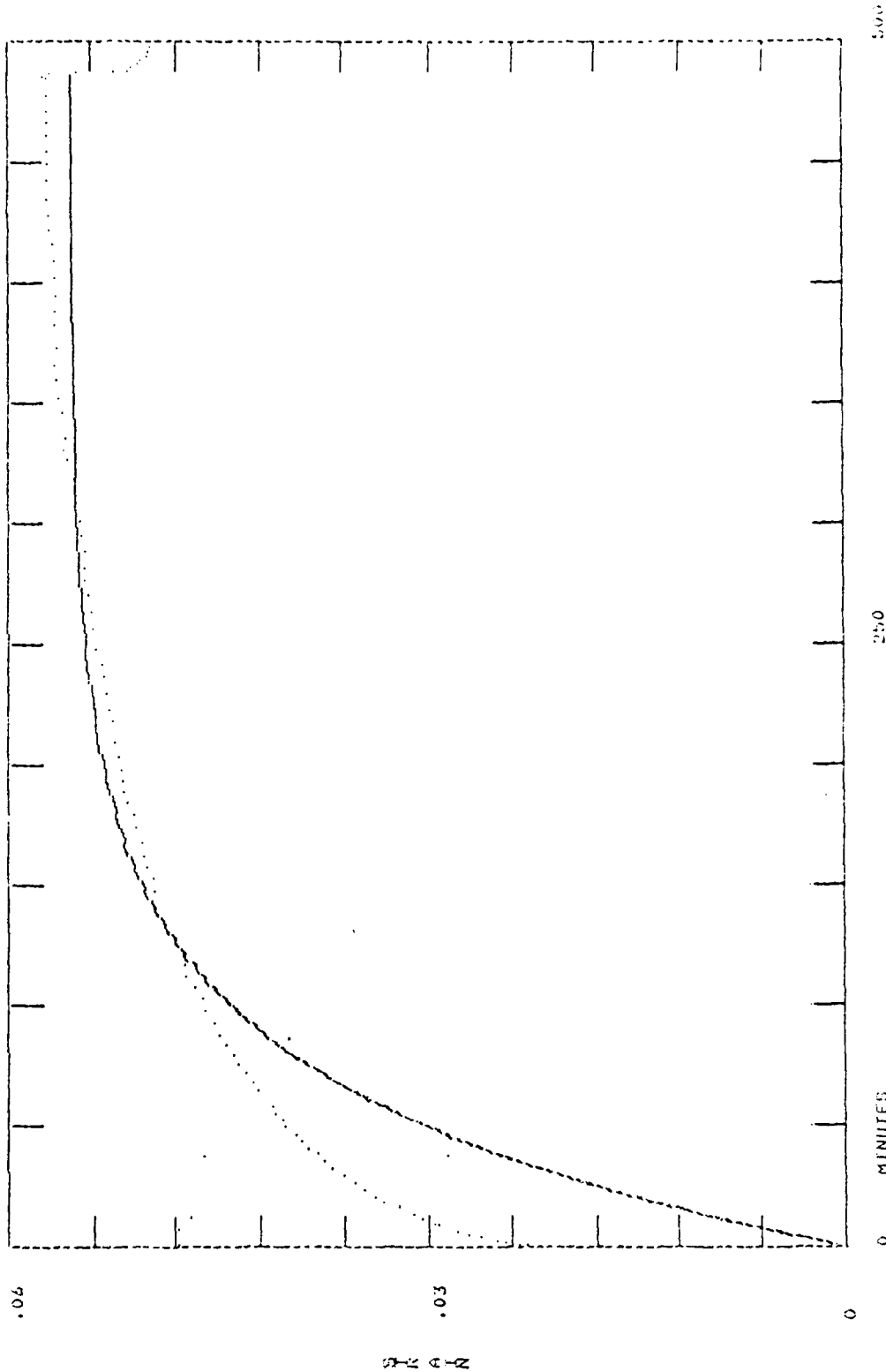
3-PARAMETER SOLID MODEL WITH VALUES OF
 A1 = .020049, A2 = 3.7028E-03, A3 = .008254
 DELTA TIME = 30
 ERROR USING ALL POINTS: -0.339%
 ERROR (IGNORING FIRST 3 POINTS): 0.031%

LN-10 T10-T11 04 AUG 75 AREA = 0.96 SQ CM HEIGHT = 3.92 CM
 DOTTED LINE: ORIGINAL DATA HEAVY LINE: MODEL PREDICTION



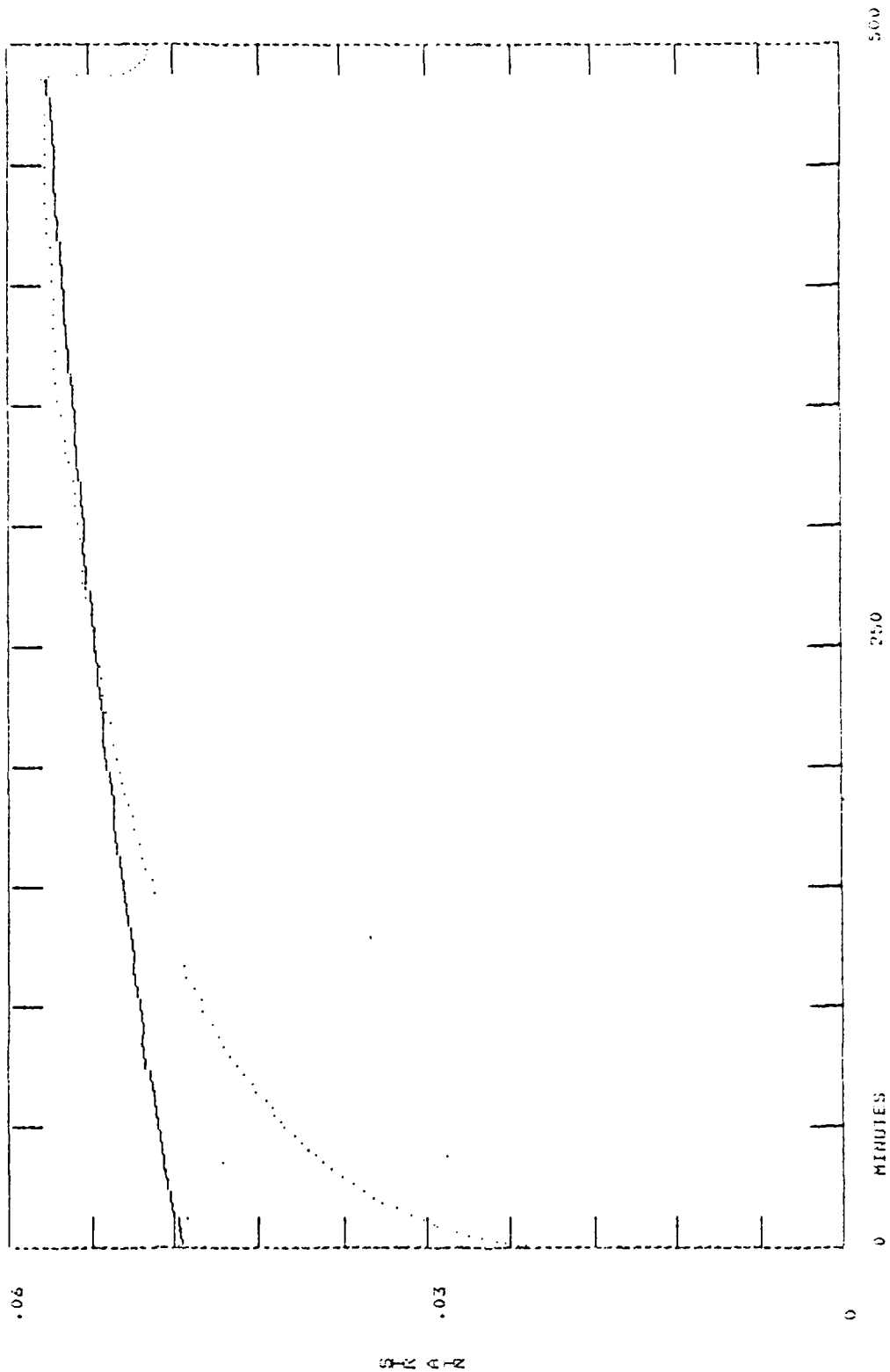
4--PARAMETER SOLID MODEL WITH VALUES OF
 AT = .010845, RT = 4.4204E-03, R2 = 7.9511E-03, R3 = .17039
 DELTA TIME = 16
 ERROR CURING ALL POINTS: 3.6522%
 ERROR CURING FIRST 3 POINTS: 3.3501%

LN-10 110-111 04 AUG 75 AREA = 8.96 SQ CM HEIGHT = 3.92 CM
 DOTTED LINE: ORIGINAL DATA HEAVY LINE: MODEL PREDICTION



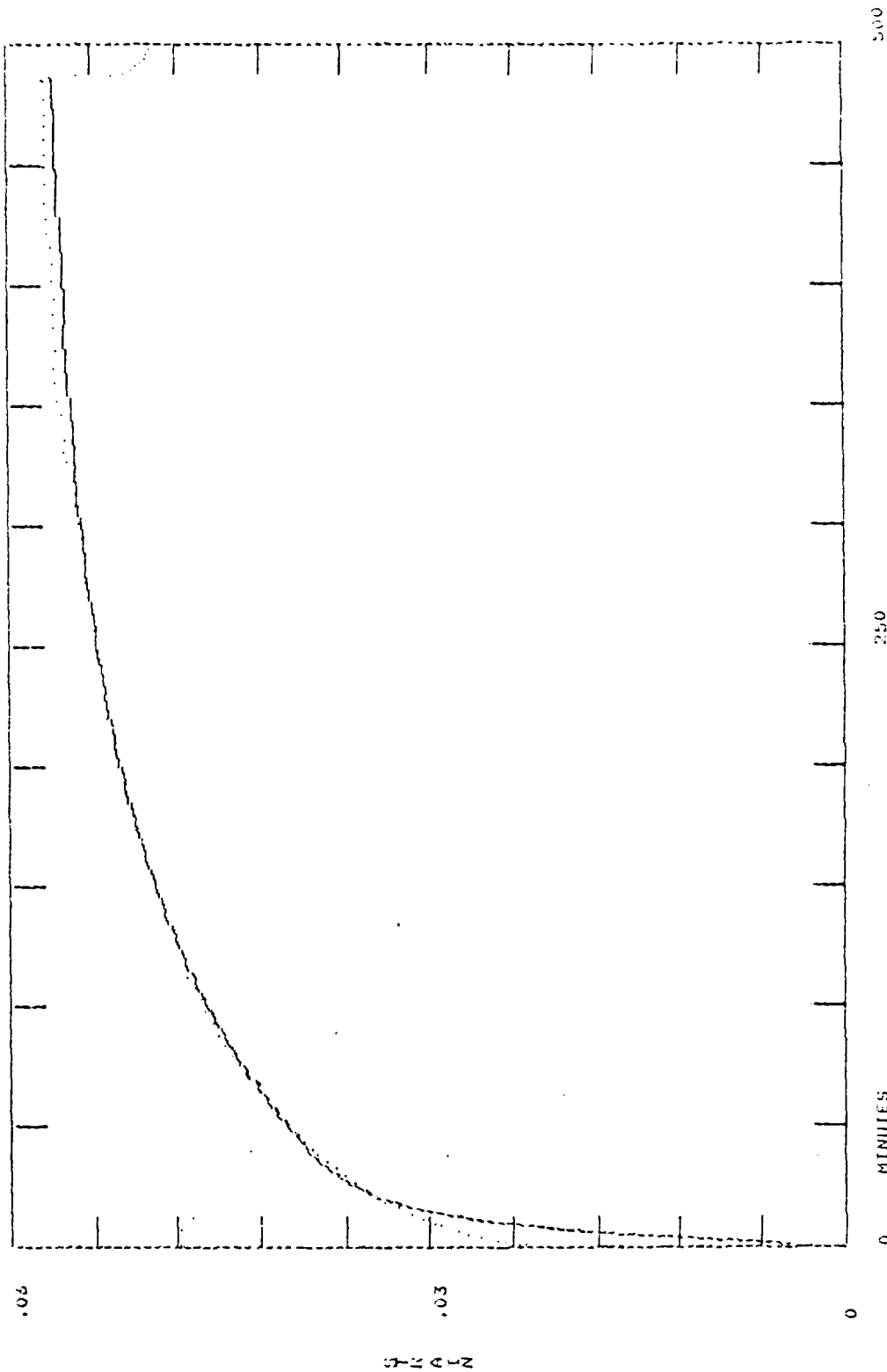
2-PARAMETER SOLID MODEL WITH VALUES OF
 A1 = .055687, B1 = .015795, A2 = 0
 DELTA TIME = 800 ALL POINTS :
 ERROR CORRECTING FIRST 3 POINTS :
 ERROR CORRECTING FIRST 3 POINTS :
 15.589%
 15.240%

LN-16 12-13 06 JUN 75 AREA = 5.79 SQ CM HEIGHT = 2.43 CM
 DOTTED LINE: ORIGINAL DATA HEAVY LINE: MODEL PREDICTION



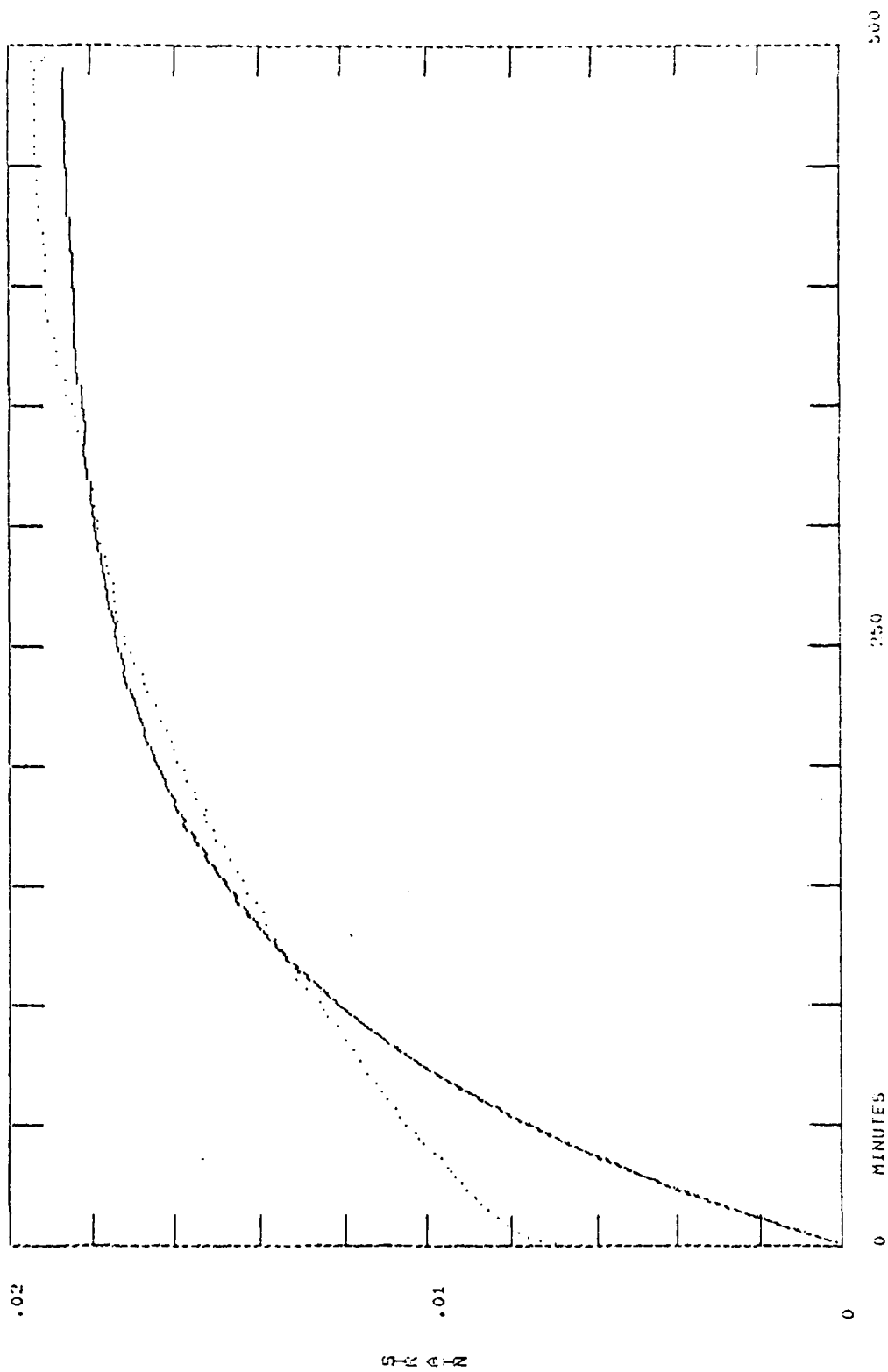
3-PARAMETER SOLID MODEL WITH VALUES OF
 AT = .0025 BT = 2.1097E-03 = .047768
 DELTA TIME = 3
 ERROR USING ALL POINTS = 2.6922%
 ERROR IGNORING FIRST 3 POINTS = 3.355%

LN-16 12-13 06 JUN 75 AREA = 5.79 SQ CM HEIGHT = 2.43 CM
 DOTTED LINE: ORIGINAL DATA HEAVY LINE: MODEL PREDICTION



4-PARAMETER SOLID MODEL WITH VALUES OF
 $a_1 = .032081$, $b_1 = .13525$, $a_2 = .025168$, $b_2 = 2.89994E-03$
 DELTA TIME = 4
 ERROR USING ALL POINTS : 6.247%
 ERROR IGNORING FIRST 3 POINTS : 6.319%

LN-16 12-73 06 JUN 75 AREA = 5.79 SQ CM HEIGHT = 2.43 CM
 DOTTED LINE: ORIGINAL DATA HEAVY LINE: MODEL PREDICTION



2--PARAMETER SOLID MODEL WITH VALUES OF

A1 = .018781, A2 = .010401, A3 = 0

DELTA TIME = 1.0

ERROR (USING ALL POINTS) :

2.901%

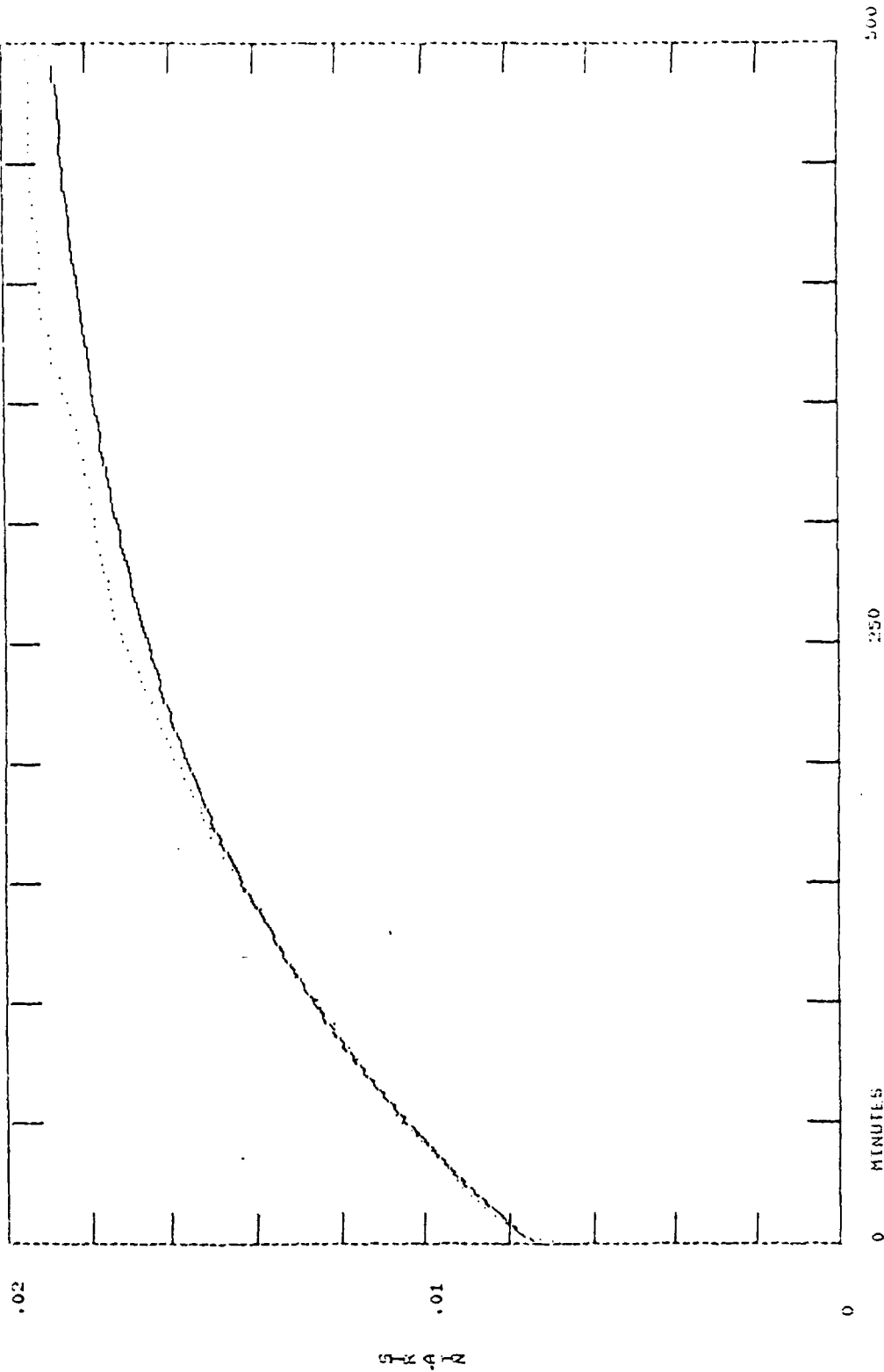
ERROR (USING FIRST 3 POINTS) :

5.951%

LN-17 TS-14 09 SEP 75 AREA = 5.15 SQ CM HEIGHT = 2.585 CM

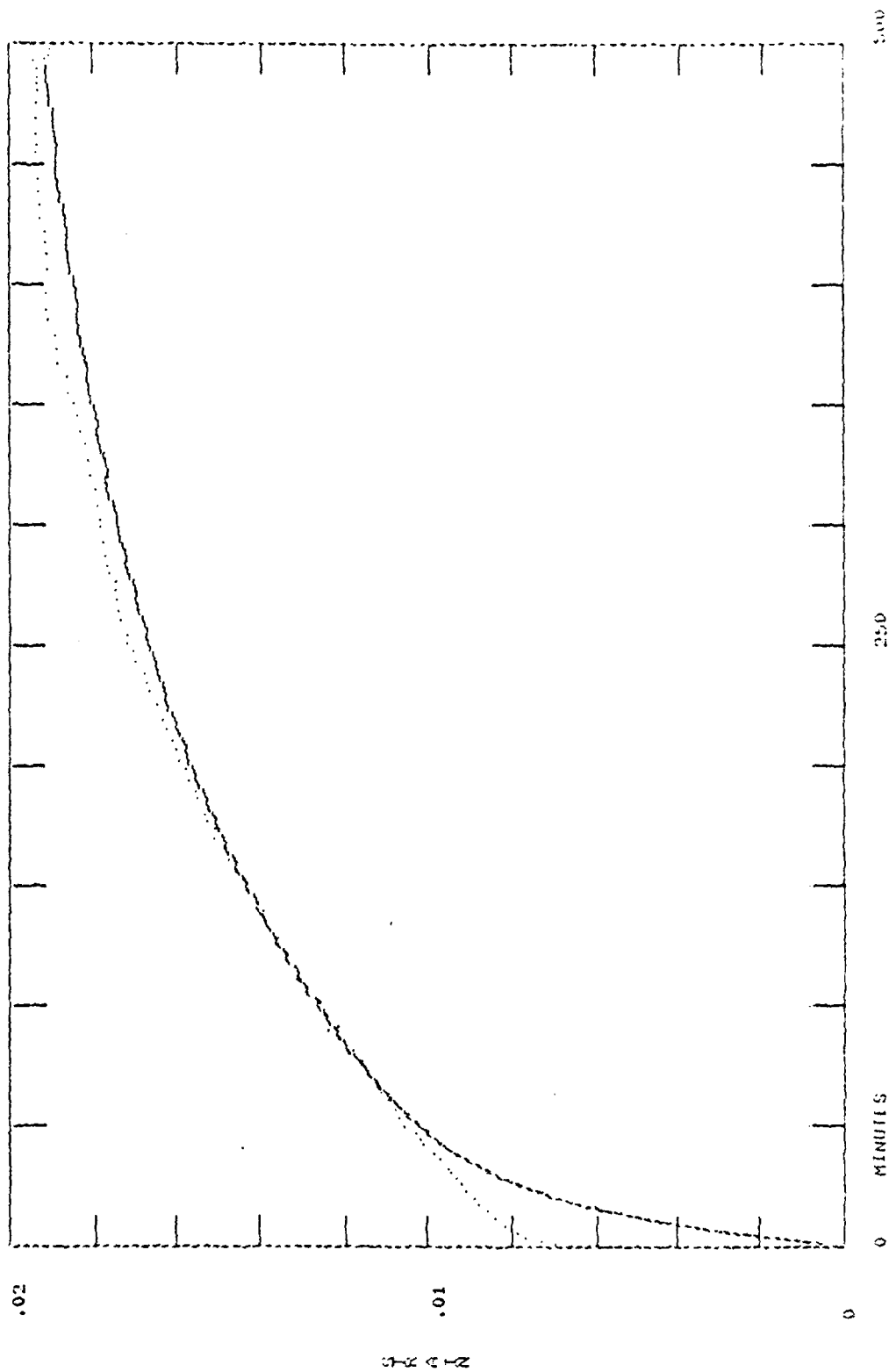
DOTTED LINE: ORIGINAL DATA

HEAVY LINE: MODEL PREDICTION



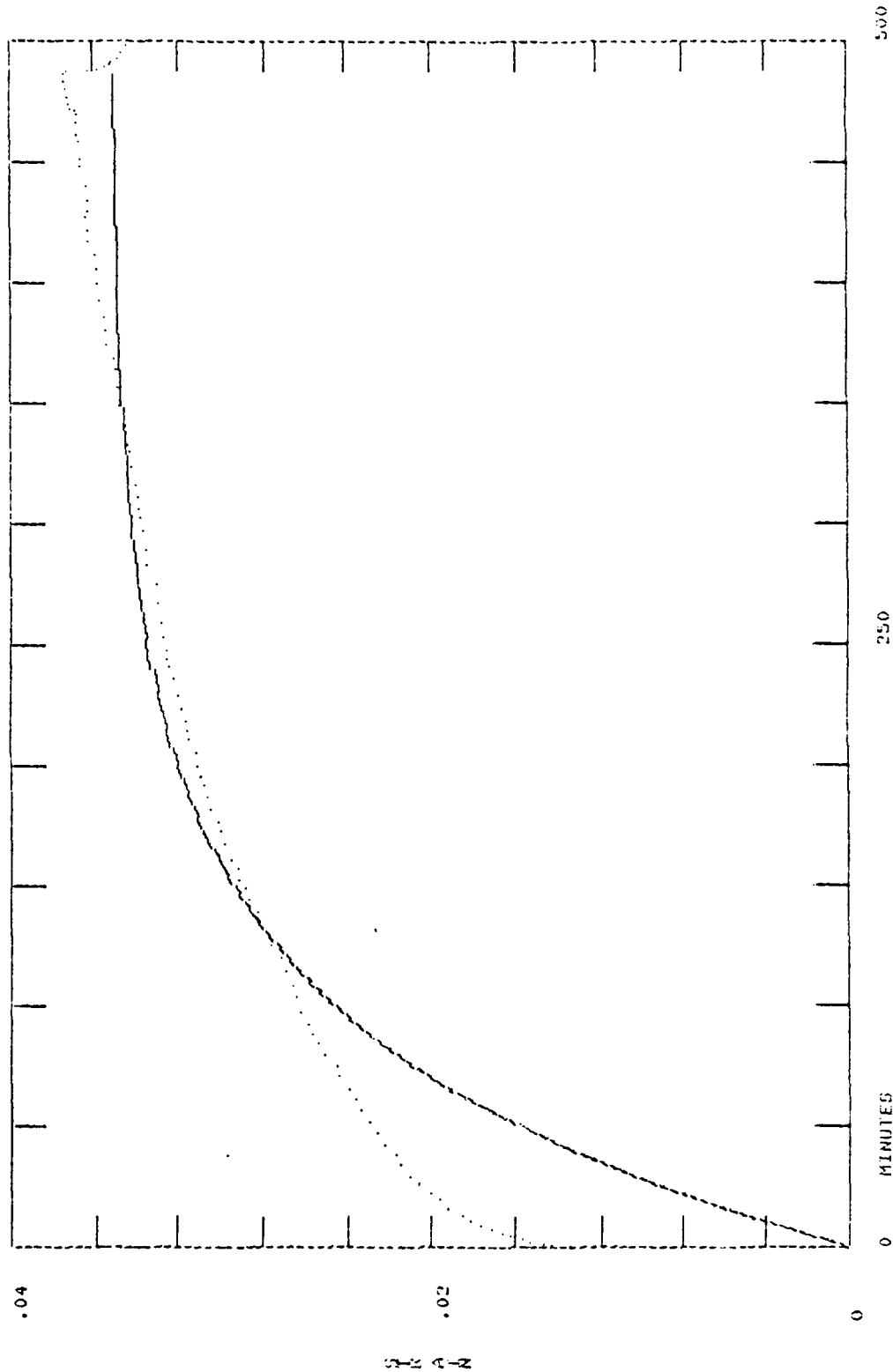
3-PARAMETER SOLID MODEL WITH VALUES OF
 A1 = .019618, A2 = 5.5538E-03, A3 = 7.4902E-03
 DELTA TIME = 4
 ERROR (USING ALL POINTS): 1.8722%
 ERROR (IGNORING FIRST 3 POINTS): 2.2322%

LN-17, T3-14, 09 SEP 75, AREA = 5.15 SQ CM, HEIGHT = 2.585 CM
 DOTTED LINE: ORIGINAL DATA, HEAVY LINE: MODEL PREDICTION



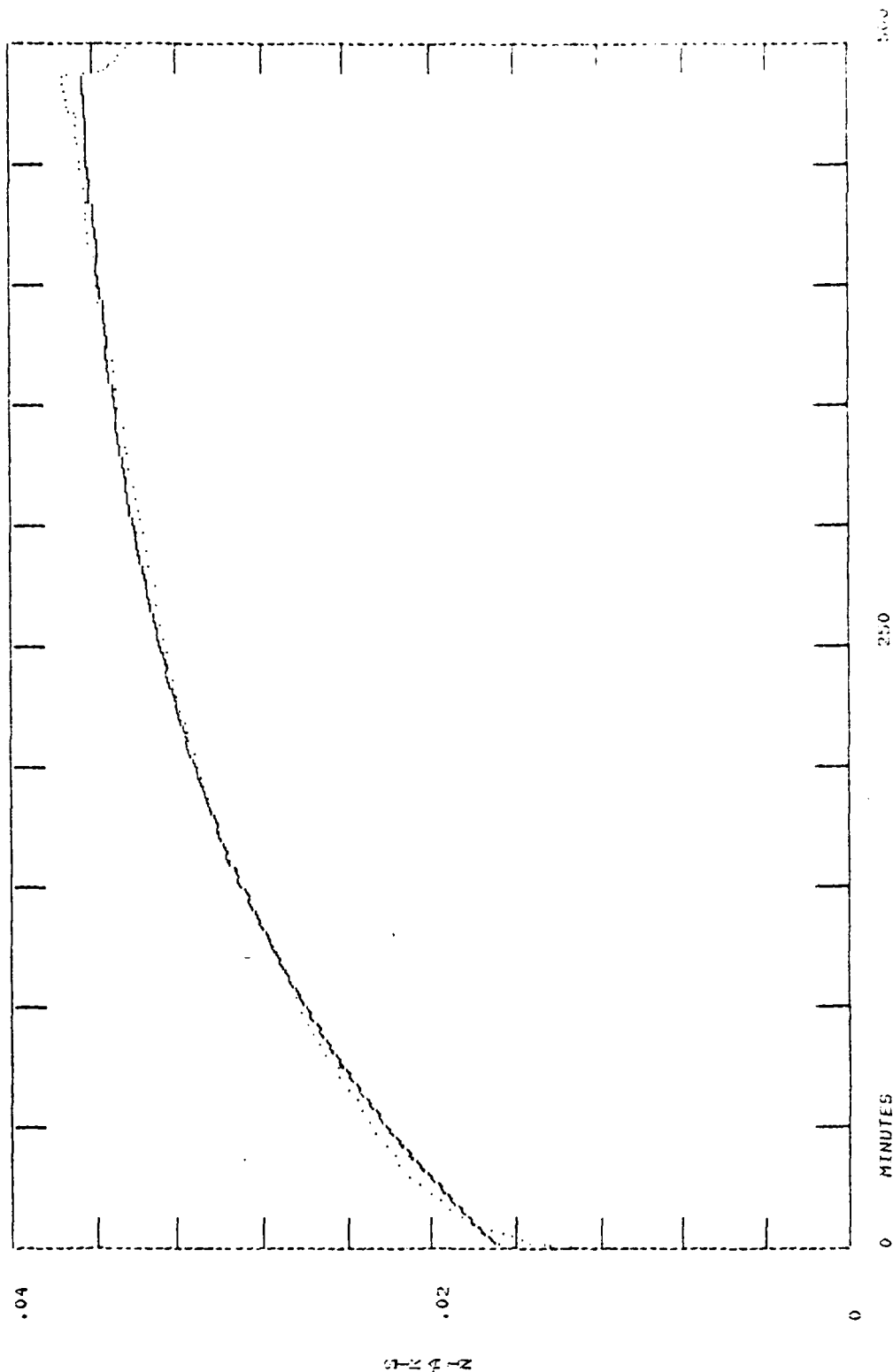
4-PARAMETER SOLID MODEL WITH VALUES OF
 $\alpha_1 = .012466$, $\alpha_2 = 5.0291E-03$, $\alpha_3 = 2.7114E-03$, $\alpha_4 = .009240$
 DELTA TIME = 16
 ERROR COSTING ALL POINTS: 4.5982%
 ERROR COSTING FIRST 3 POINTS: 4.1512%

LN-17 13-14 09 SEP 75 AREA = 5.15 50 CM HEIGHT = 2.505 CM
 DOTTED LINE: ORIGINAL DATA HEAVY LINE: MODEL PREDICTION

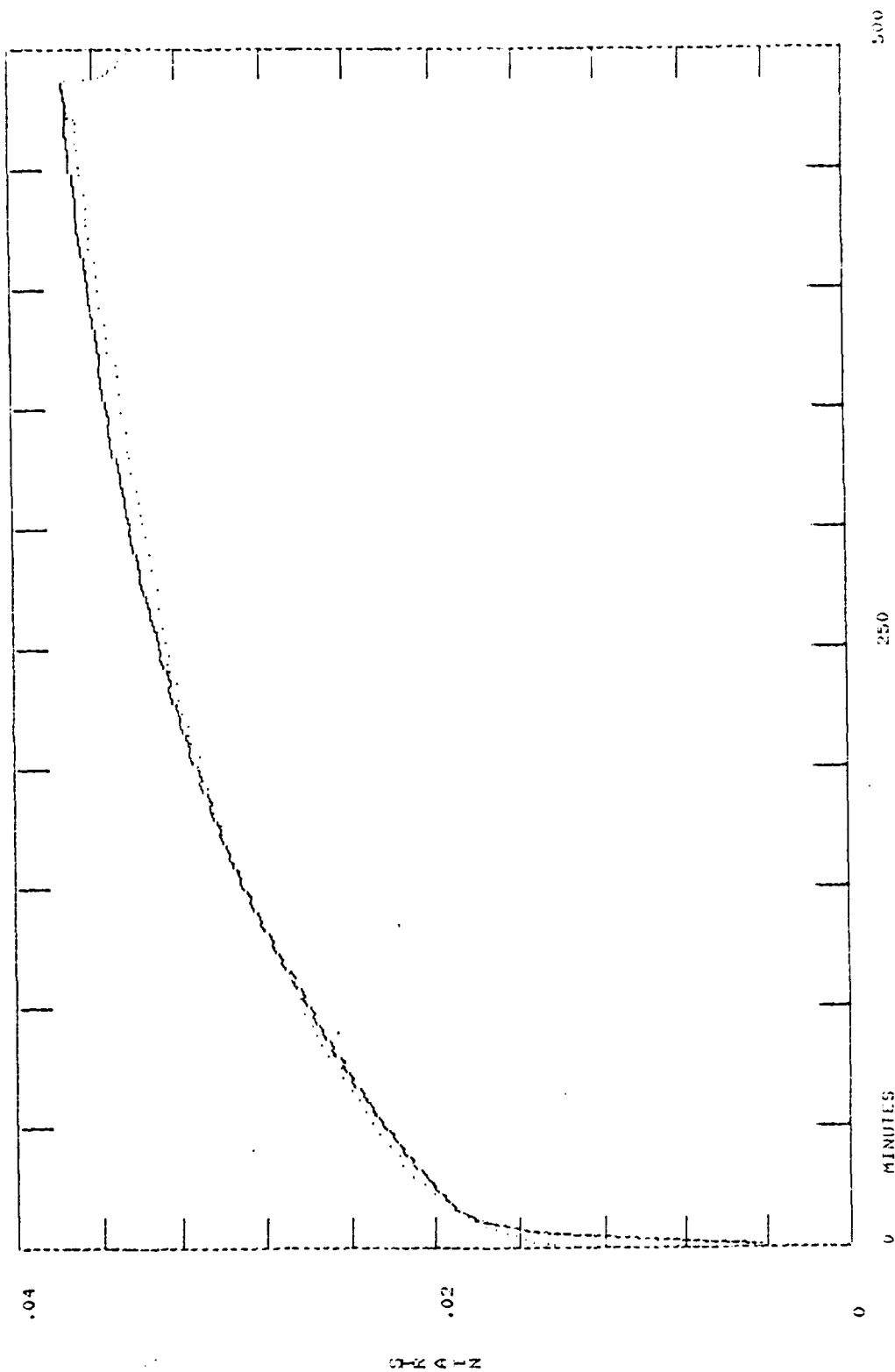


2-PPAROMETER SOLID MODEL WITH VALUES OF
 $\Delta t = .035256$, $B_1 = .011995$, $A_2 = 0$
 DELTA TIME = 16
 ERROR USING ALL POINTS: 9.830%
 ERROR (CONSIDERING FIRST 3 POINTS): 9.196%

LN-18 14-15 12 AUG 75 AREA = 5.31 SQ CM HEIGHT = 2.445 CM
 DOTTED LINE: ORIGINAL DATA HEAVY LINE: MODEL PREDICTION



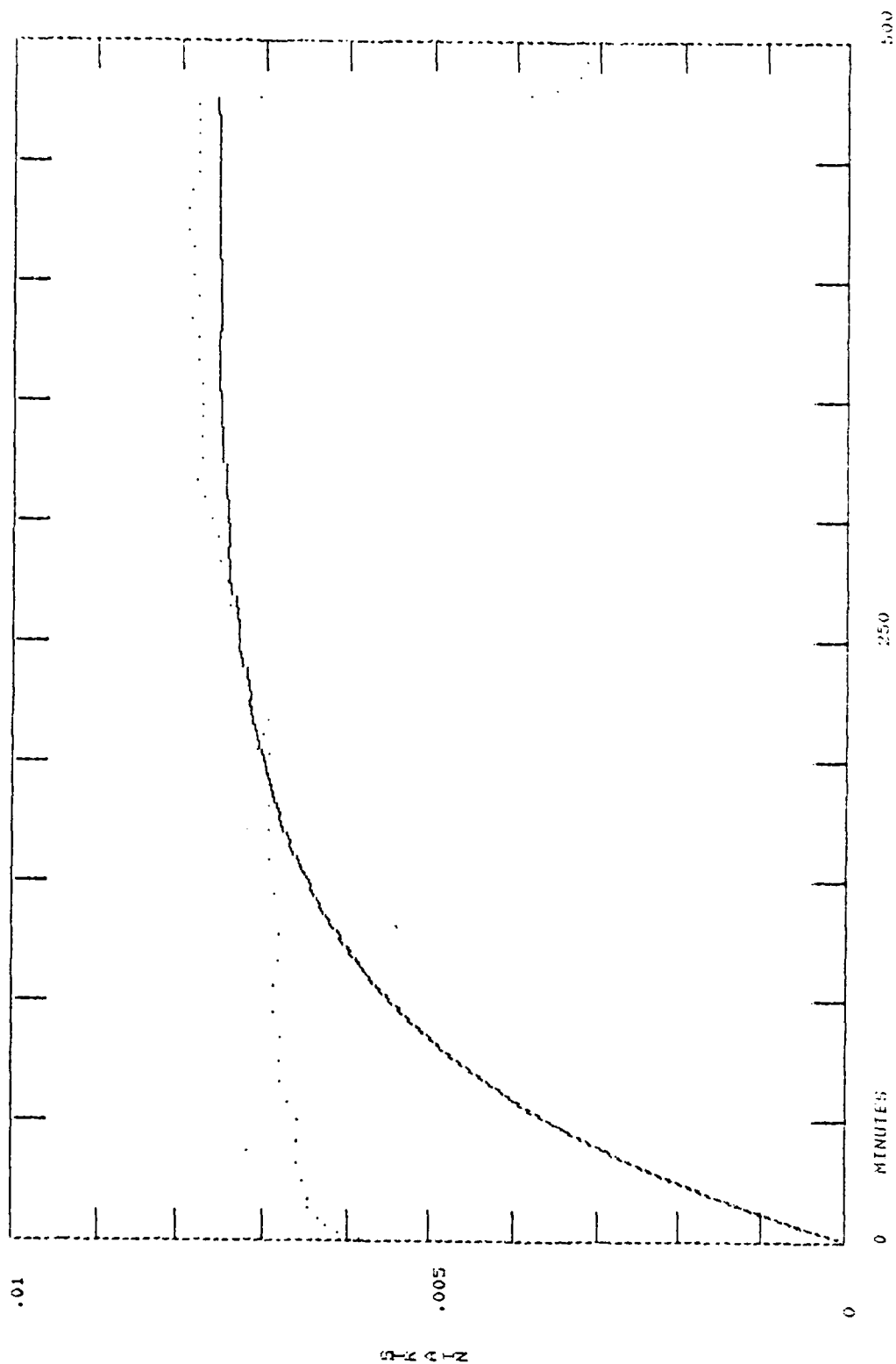
LK-18 T4-T5 12 AUG 75 AREA = 5.31 SQ CM HEIGHT = 2.445 CM
 DOTTED LINE: ORIGINAL DATA
 HEAVY LINE: MODEL PREDICTION



4-PROGRAMMER'S SOLUTION MODEL WITH VALUES OF
 A1 = .012501, A2 = .29601, A3 = .022004, B2 = 4.8998E-03
 TOTAL TIME = 4
 COSTING ALL POINTS: 0.909%
 COSTING FIRST 3 POINTS: 0.342%

LN-18 14-15 12 AUG 75 AREA = 5.31 50 CM HEIGHT = 2.445 CM
 BOTTOM LINE: ORIGINAL DATA HEAVY LINE: MODEL PREDICTION

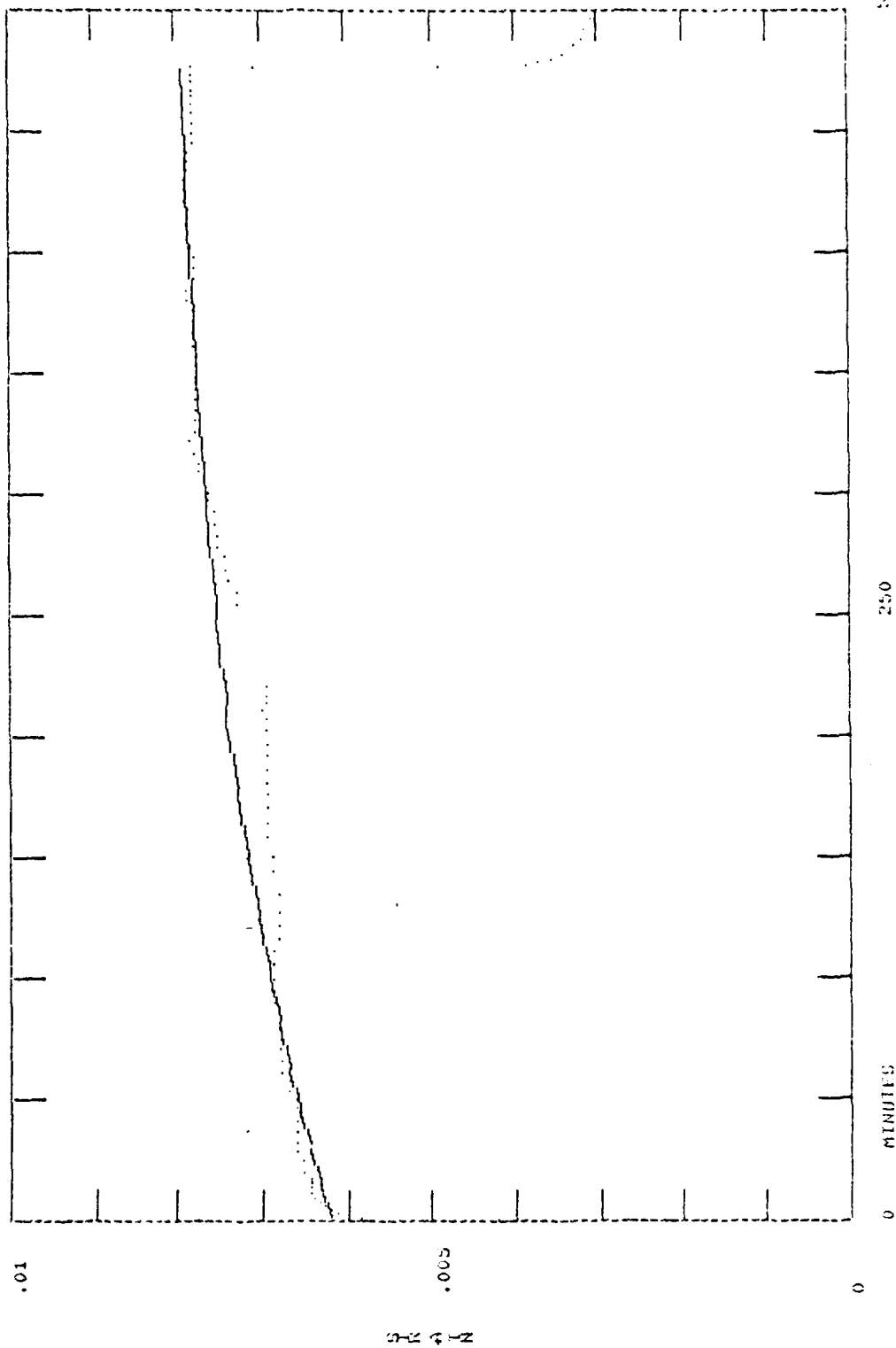
35



2-PARAMETER SOLID MODEL WITH VALUES OF
 $\alpha_1 = 7.5984E-03$, $\beta_1 = .0129$
 DELTA TIME = 4
 ERROR (USING ALL POINTS): 18.291%
 ERROR (USING FIRST 3 POINTS): 15.865%

LN-19 15-16 11 AUG 75 AREA = 5.8 50 CM WEIGHT = 2.24 CM
 DOTTED LINE: ORIGINAL DATA HEAVY LINE: MODEL PREDICTION

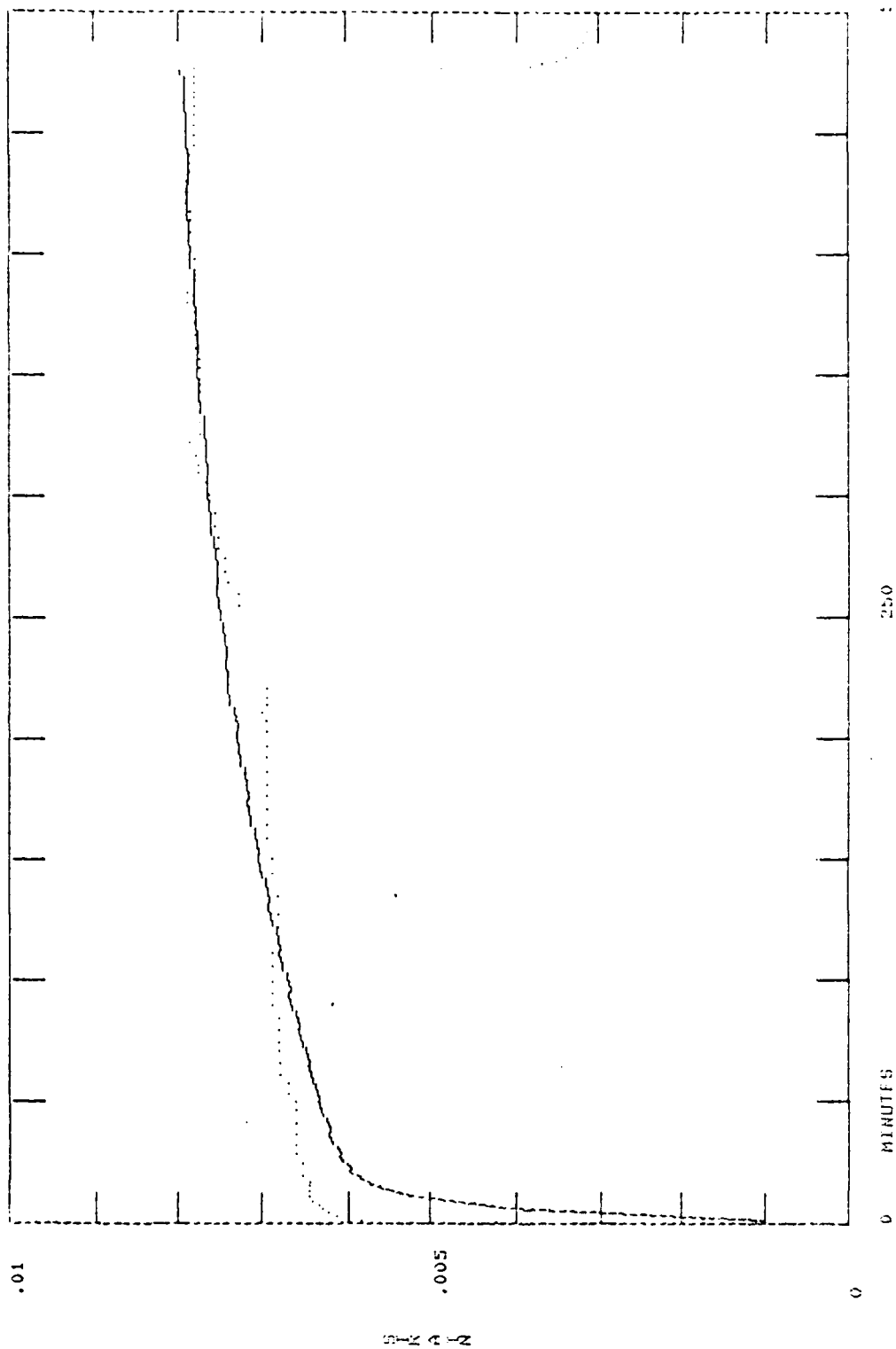
17



3-PARAMETER SOLID MODEL WITH VALUES OF
 A1 = 8.1845E-03, B1 = 4.4625E-03, A2 = .006219
 DELTA TIME = 4
 ERROR (USING ALL POINTS): -1.941%
 ERROR (IGNORING FIRST 3 POINTS): -1.139%

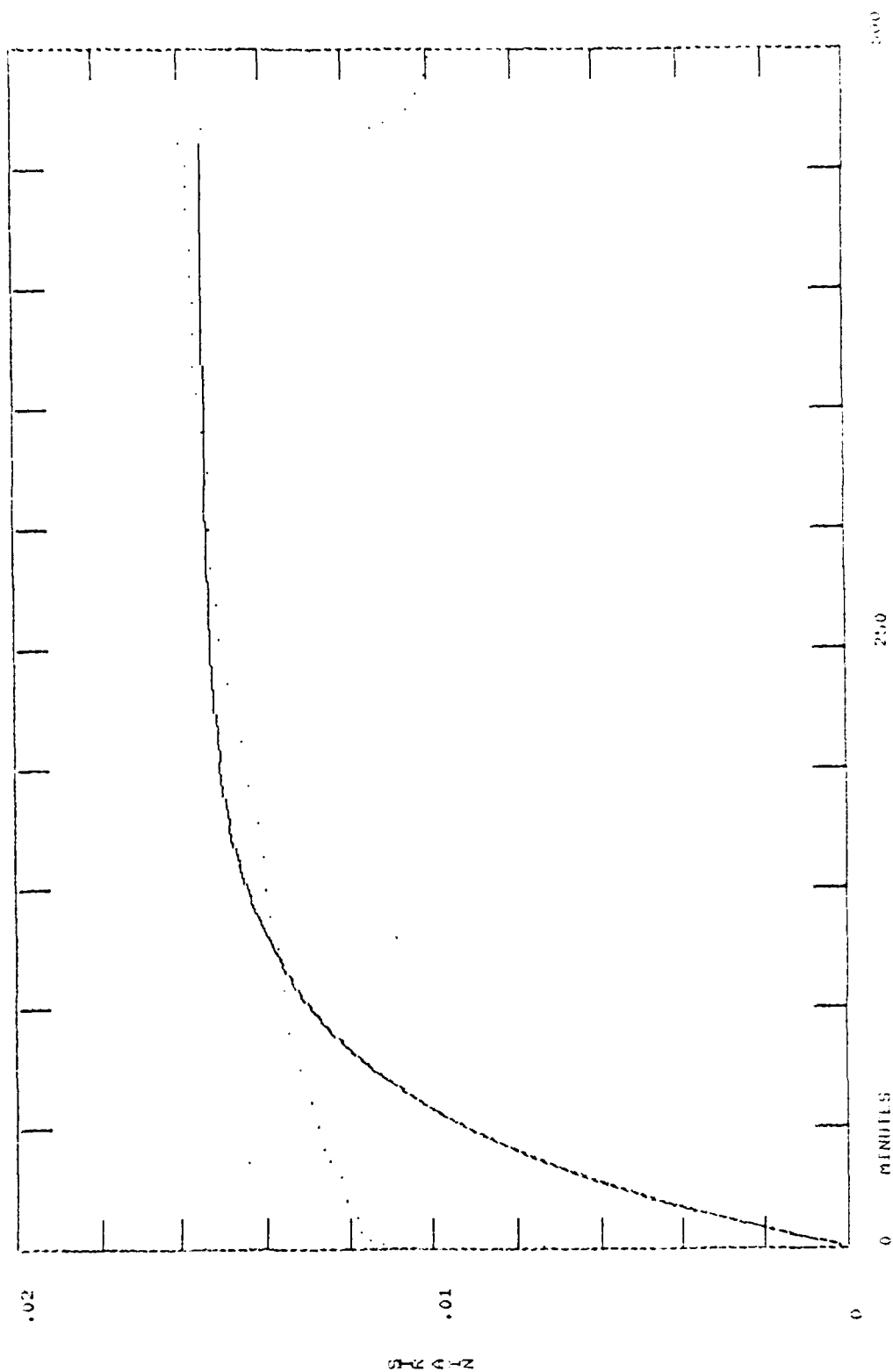
LN-19 15-T6 11 AUG 75 AREA = 5.0 SQ CH HEIGHT = 2.24 CH
 DOTTED LINE: ORIGINAL DATA HEAVY LINE: MODEL PREDICTION

37



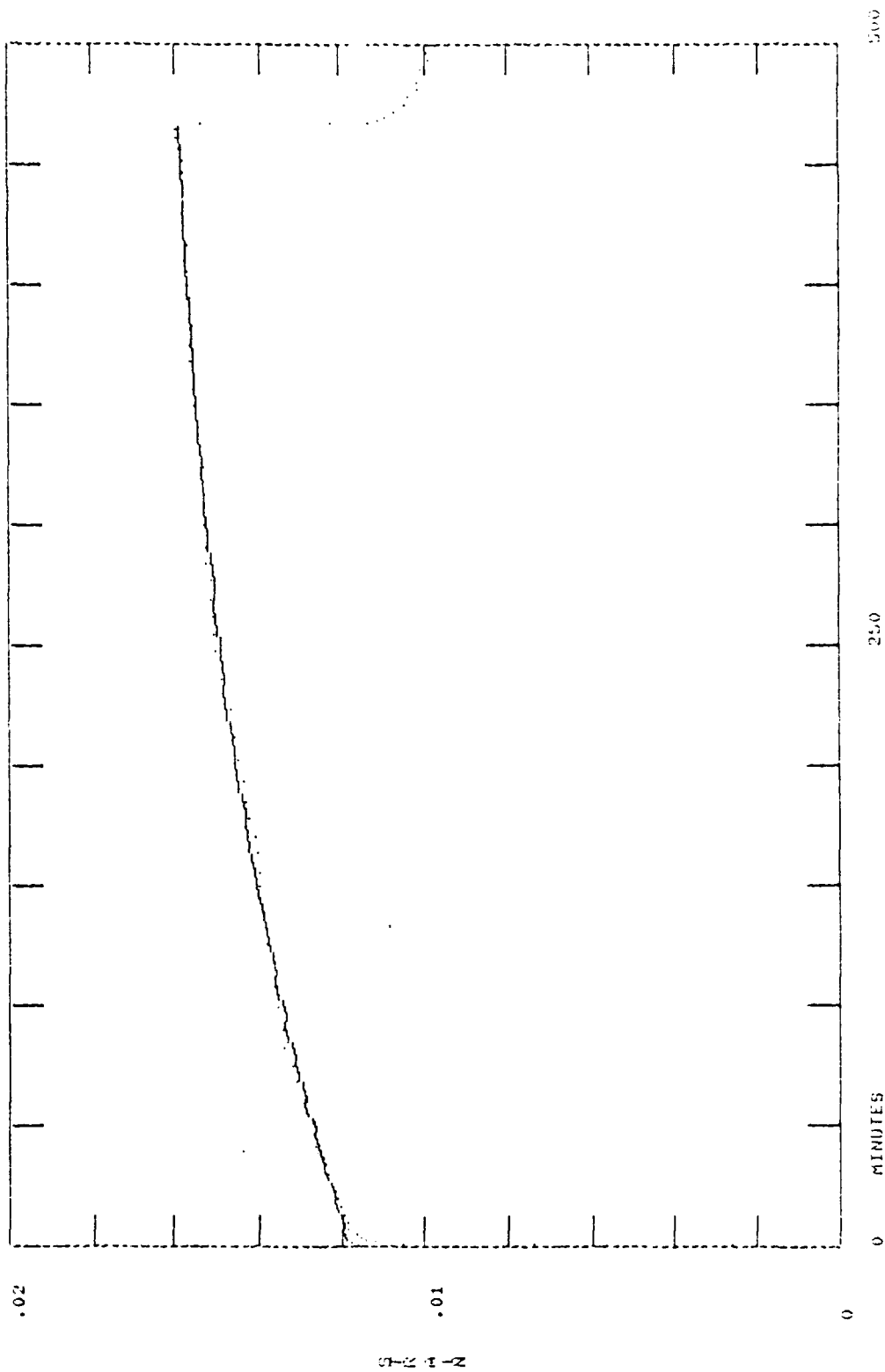
4-PARAMETER SOLID MODEL WITH VALUES OF
 A1 = 5.8383E-03, B1 = .19519, A2 = 2.3692E-03, B2 = 4.7623E-03
 DELTA TIME = 4
 ERROR CUSING ALL POINTS: 3.7962%
 ERROR CUSING FIRST 3 POINTS: 3.1322%

IN-19 15.14 11 AUG 75 AREA = 5.0 SQ CM HEIGHT = 2.24 CM
 DOTTED LINE: ORIGINAL DATA HEAVY LINE: MODEL PREDICTION



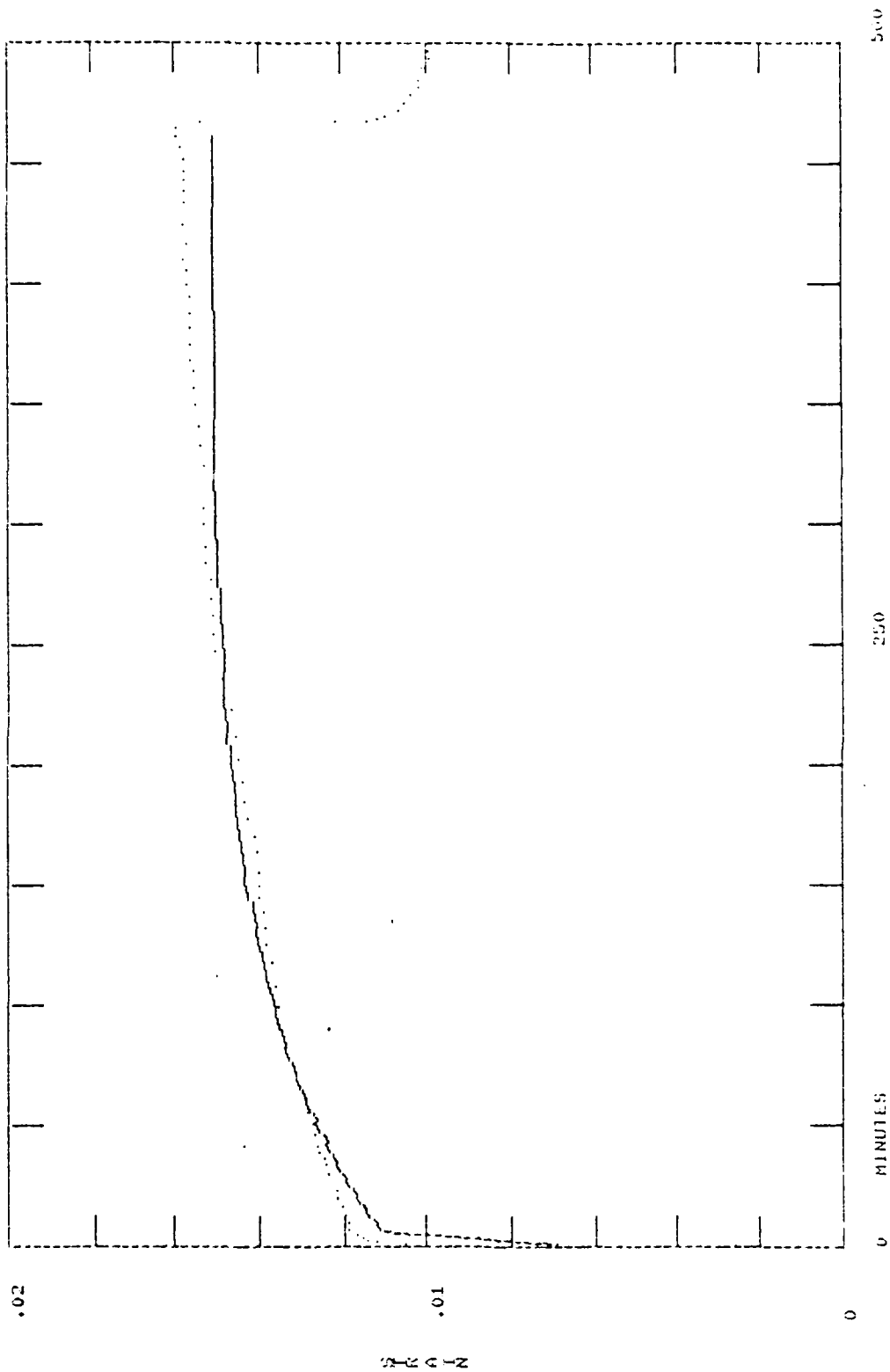
2-PARAMETER SOLID MODEL WITH VALUES OF
 Q1 = .01846, Q2 = .018154
 DELTA T = 8
 CUSING ALL POINTS:
 ERROR FIRST 3 POINTS:
 14.74%
 11.84%

IN 29 16 17 07 500 75 AREA = 6.12 50 CM HEIGHT = 2.34 CM
 BOTTLE LINE: ORIGINAL DATA BLOW LINE: MODEL PREDICTION



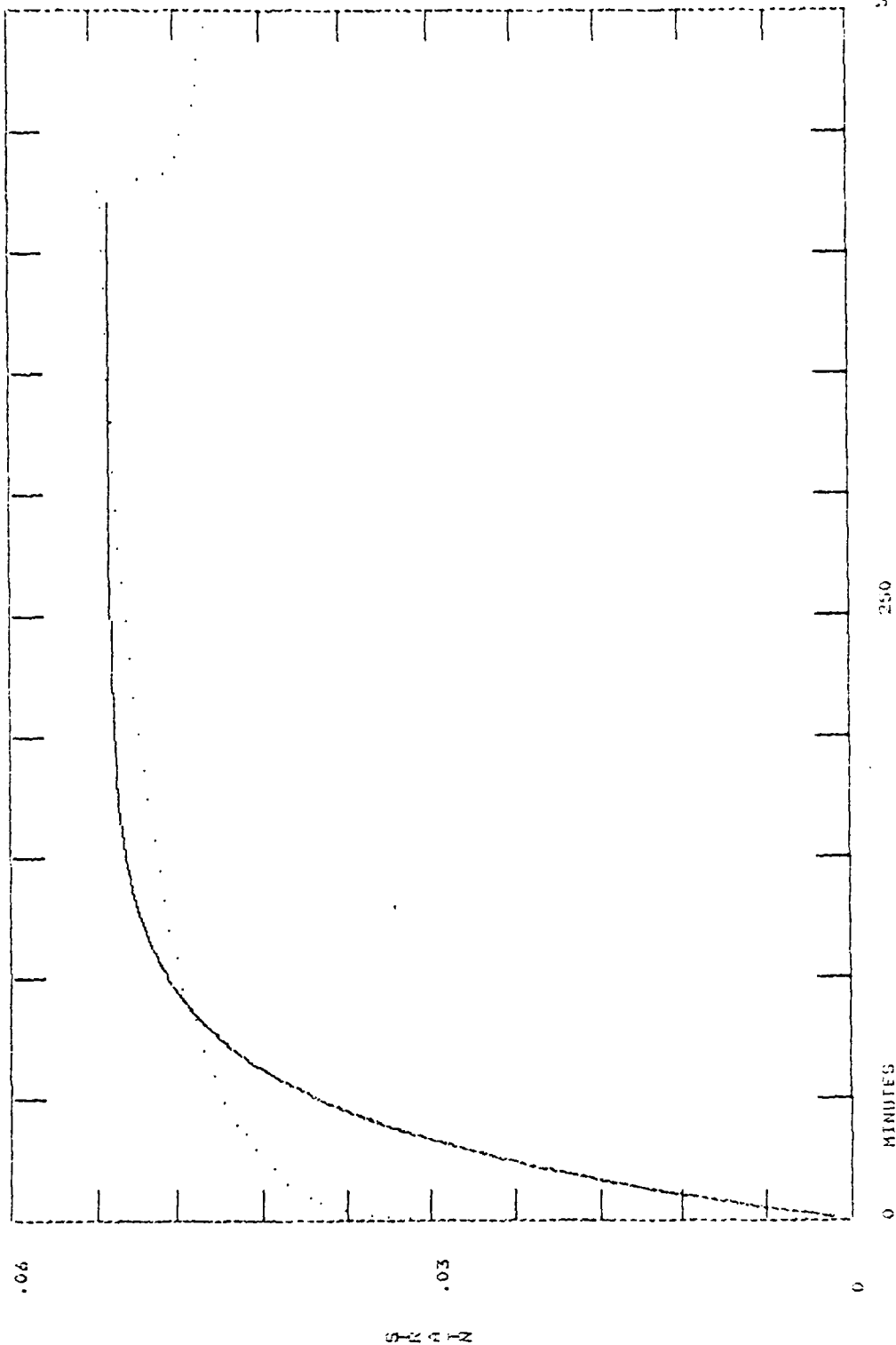
3-PARAMETER SOLID MODEL WITH VALUES OF
 A1 = .0164867 A2 = 4.4607E-03 A3 = .011807
 DELTA TIME = 8
 ERROR CUSING ALL POINTS : -2.3312%
 ERROR CUSING FIRST 3 POINTS : -1.0452%

LN-20 16-1/ 07 AUG 75 AREA = 6.12 SQ CM HEIGHT = 2.34 CM
 DOTTED LINE: ORIGINAL DATA HEAVY LINE: MODEL PREDICTION



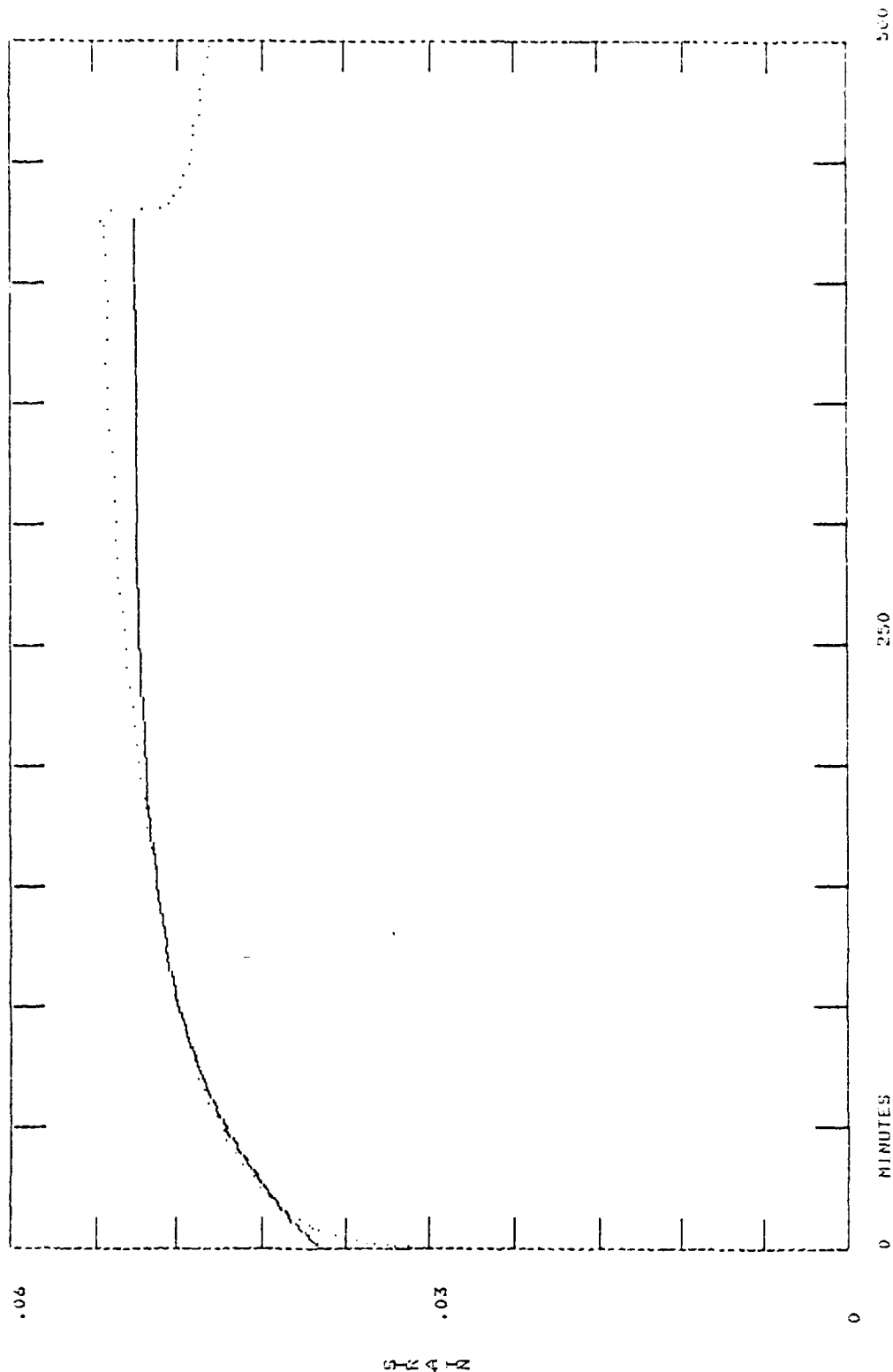
4-PARAMETER SOLID MODEL WITH VALUES OF
 AREA = 0.01069, RT = 1.0125, Q2 = 4.3217E-03, R2 = 0.010691
 DELTA TIME = 4
 CUSING ALL POINTS: 1.8242%
 CUSING FIRST 3 POINTS: 2.2522%

IN-20 16-17 67 606 75 AREA = 6.12 50 CM HEIGHT = 2.34 CM
 DOTTED LINE: ORIGINAL DATA HEAVY LINE: MODEL PREDICTION



2-PARAMETER SOLID MODEL WITH VALUES OF
 $A_1 = .052387$, $B_1 = .025643$
 DELTA TIME = 1.6
 USING ALL POINTS: 10:5502%
 USING FIRST 3 POINTS: 10:5502%

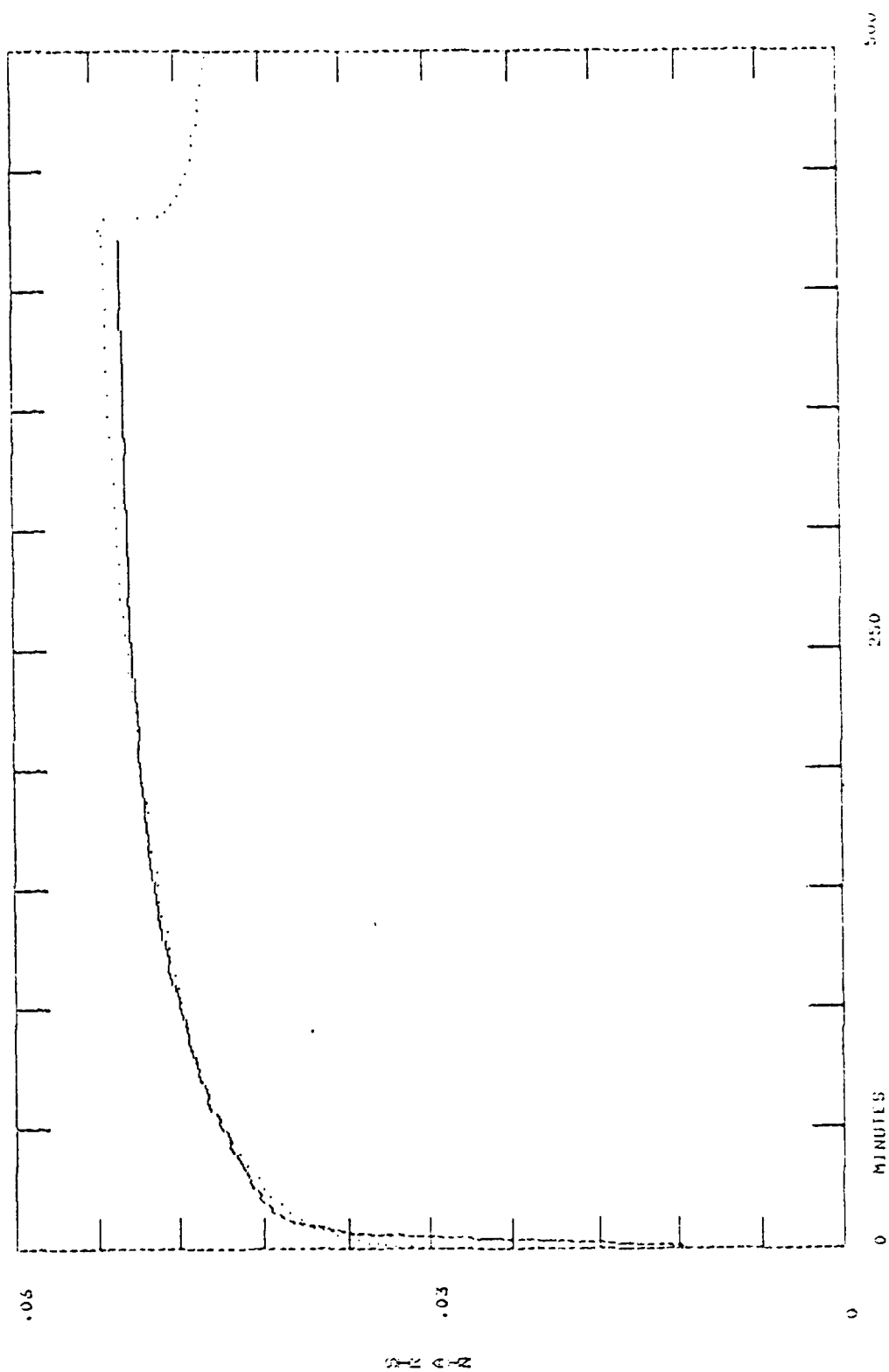
LN-21 17-18 10 SEP 75 AREA = 0.16 SQ CM HEIGHT = 2.57 CM
 DOTTED LINE: ORIGINAL DATA HEAVY LINE: MODEL PREDICTION



3-PARAMETER SOLID MODEL WITH VALUES OF
 A1 = .051179, B1 = .013867, C2 = .037977
 DELTA TIME = 30
 ERROR (USING ALL POINTS) : -0.742%
 ERROR (IGNORING FIRST 3 POINTS) : 0.424%

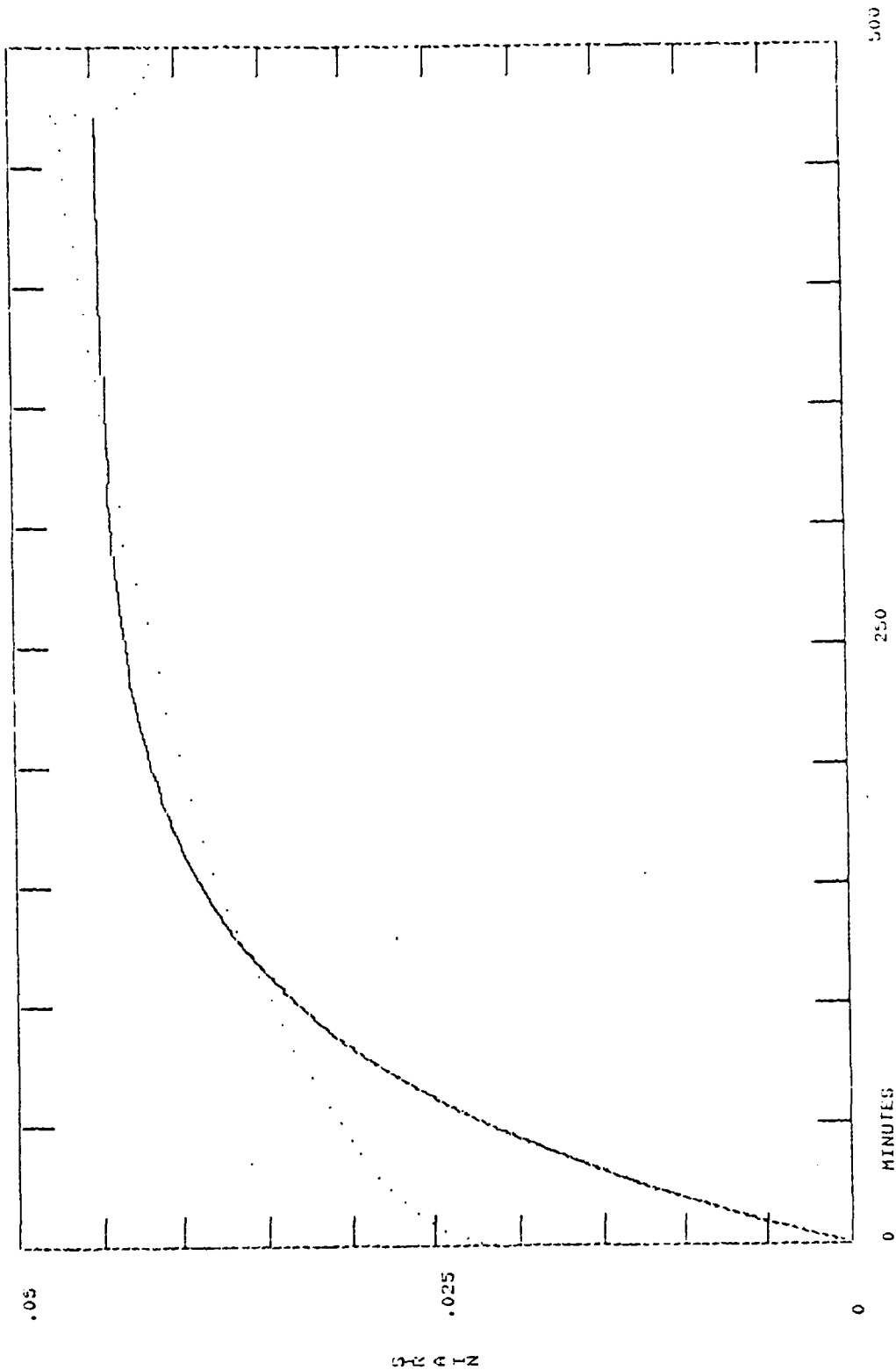
IN-21 17-18 10 SEP 75 AREA = 8.16 SQ CM HEIGHT = 2.67 CM
 BOTTLE LINE: ORIGINAL DATA HEAVY LINE: MODEL PREDICTION

47



4-PROGRAMMER SOLID MODEL WITH VALUES OF
 A1 = .039829, B1 = .34394, A2 = .01244, 102 = .010828
 DELTA TIME = 4
 ERROR CUSING ALL POINTS : 3.6492%
 ERROR CUSING FIRST 3 POINTS : 3.0922%

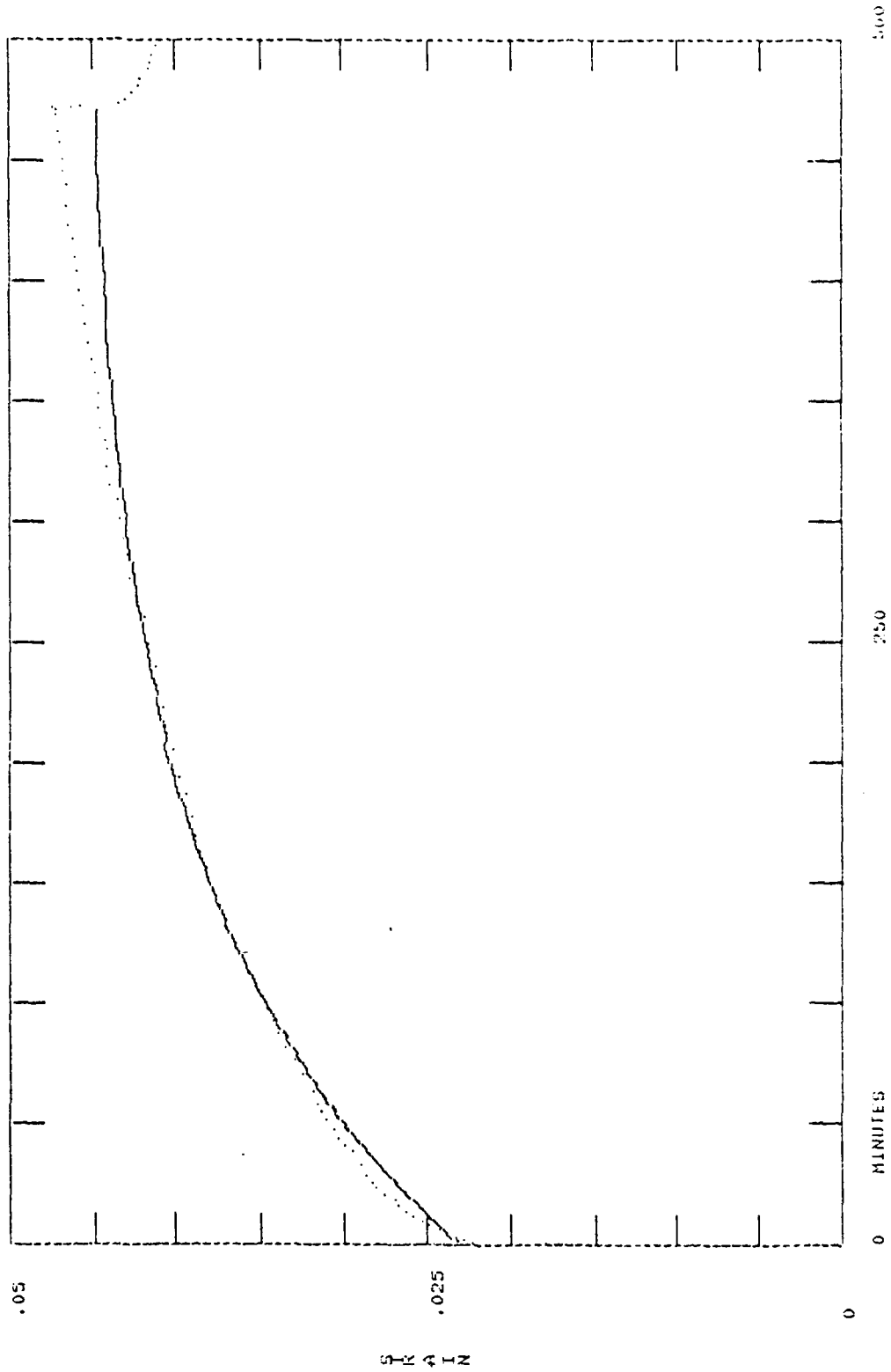
1A-21 17 18 10 SEP 75 AREA = 0.16 SQ CM HEIGHT = 2.67 CM
 DOTTED LINE: ORIGINAL DATA HEAVY LINE: MODEL PREDICTION



2-PARAMETER SOLID MODEL WITH VALUES OF
 $\alpha_1 = .044945$, $\beta_1 = .013895$
 DELTA TIME = 30
 ERROR USING ALL POINTS: 13.120%
 ERROR USING FIRST 3 POINTS: 10.217%

IN-22 10-19 16 JUN 75 AREA = 0.03 50 CM HEIGHT = 2.615 CM
 EDITED LINE: ORIGINAL DATA HEAVY LINE: MODEL PREDICTION

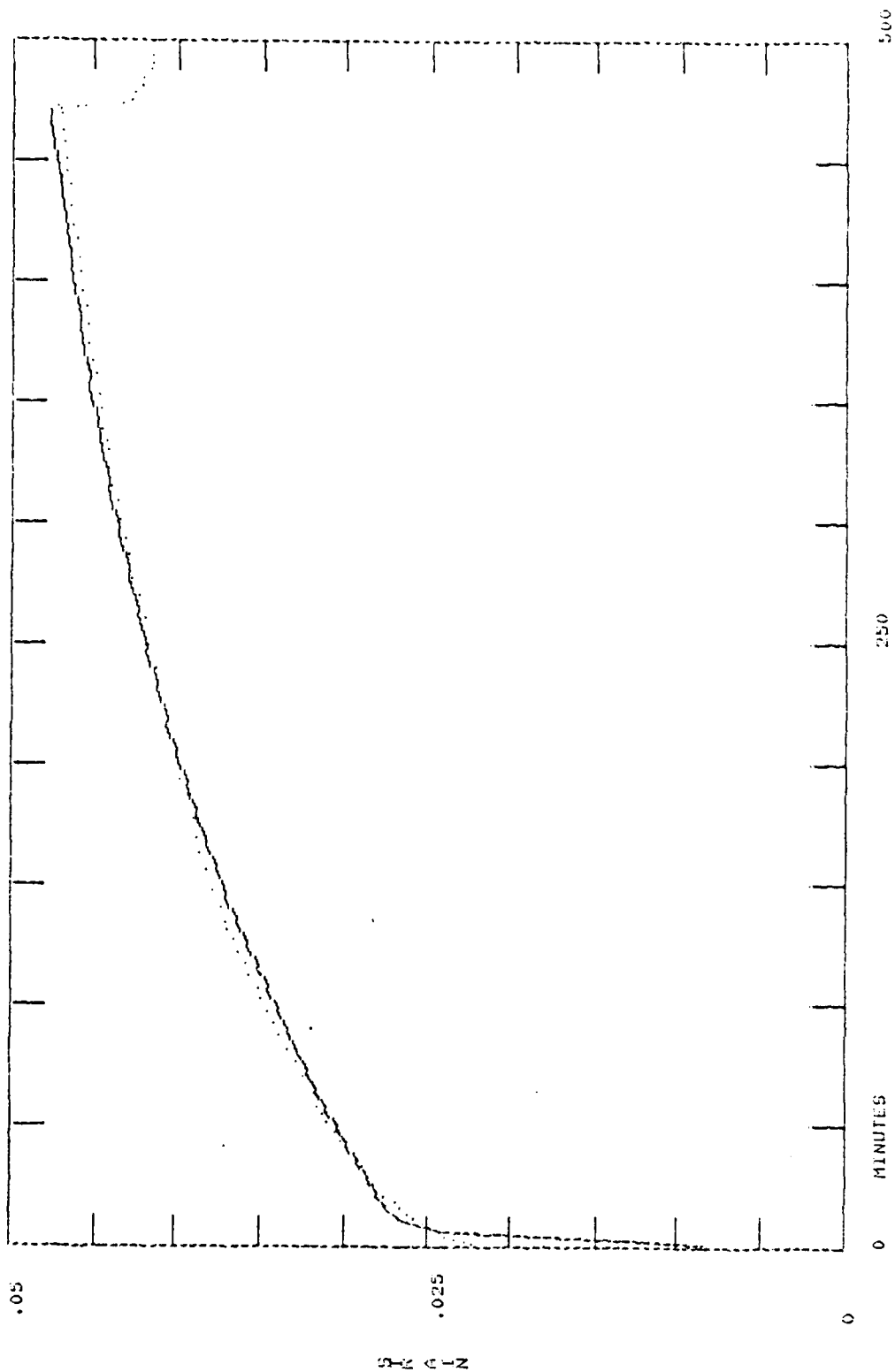
11



3-PARAMETER SOLID MODEL WITH VALUES OF
 A1 = .045255, B1 = 7.1614E-03, C2 = .003252
 DELTA TIME = 4
 ERROR CUSING ALL POINTS: 1.1878%
 ERROR CUSING FIRST 3 POINTS: 1.278%

18-22 TO 19 16 JDR ZS AREA = 0.03 50 CM HEIGHT = 2.615 CM
 DOTTED LINE: ORIGINAL DATA HEAVY LINE: MODEL PREDICTION

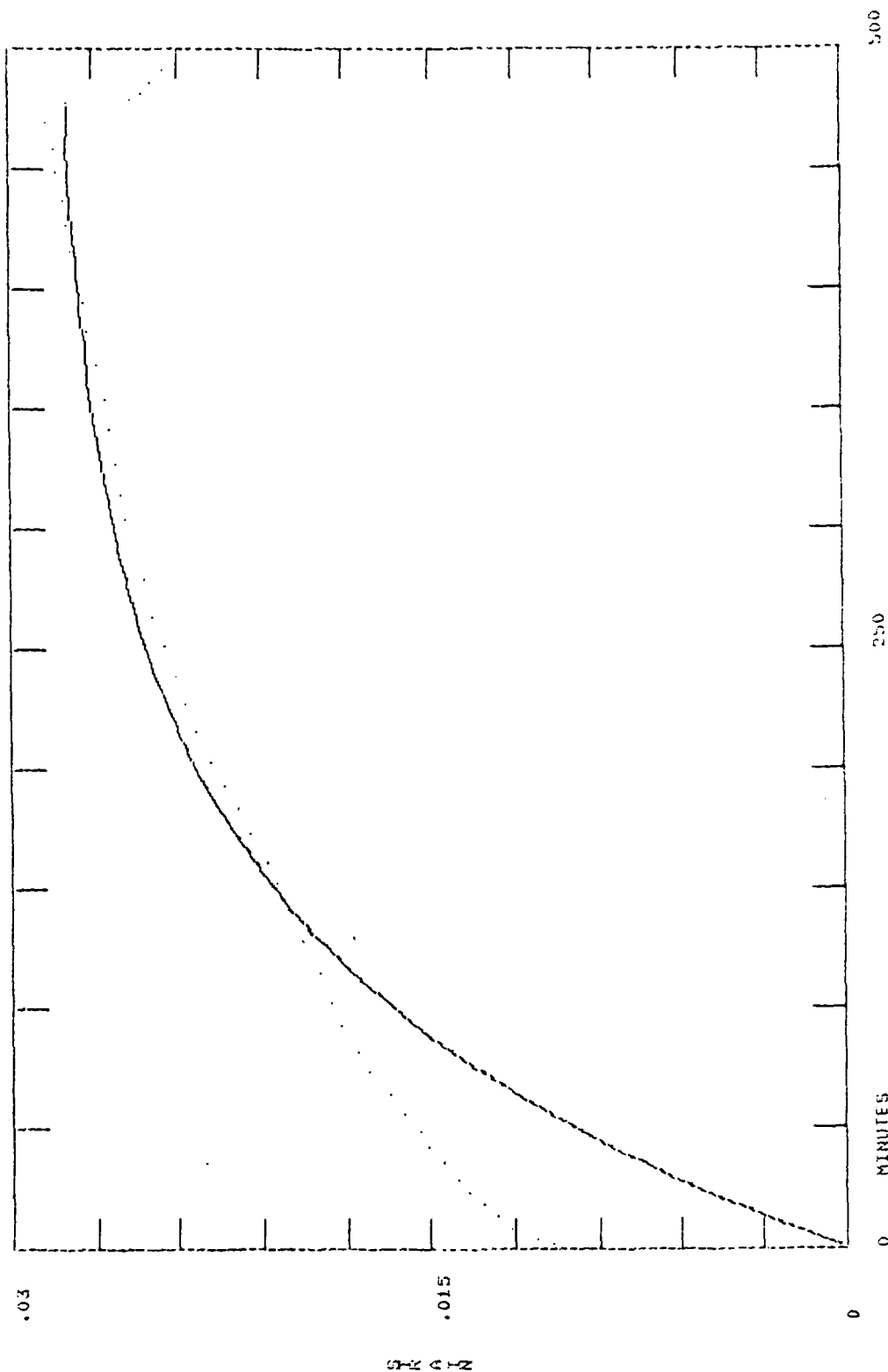
4.7



4- PARAMETER SOLID MODEL WITH VALUES OF
 AT = .02512, BT = .4031, CT = .025504, DT = 3.6708E-03
 DELTA TIME = 4
 ERROR USING ALL POINTS: 1.2492
 ERROR USING FIRST 3 POINTS: 0.6692

LN-22 18-IV 16 JUN 75 AREA = 8.03 SQ CM HEIGHT = 2.615 CM
 DOTTED LINE: ORIGINAL DATA HEAVY LINE: MODEL PREDICTION

48



2-PARAMETER SOLID MODEL WITH VALUES OF

$\alpha_1 = .02857$, $\alpha_2 = .008528$

DELTA TIME = 8

ERROR COSTING ALL POINTS:

ERROR COSTING FIRST 3 POINTS:

11.172%

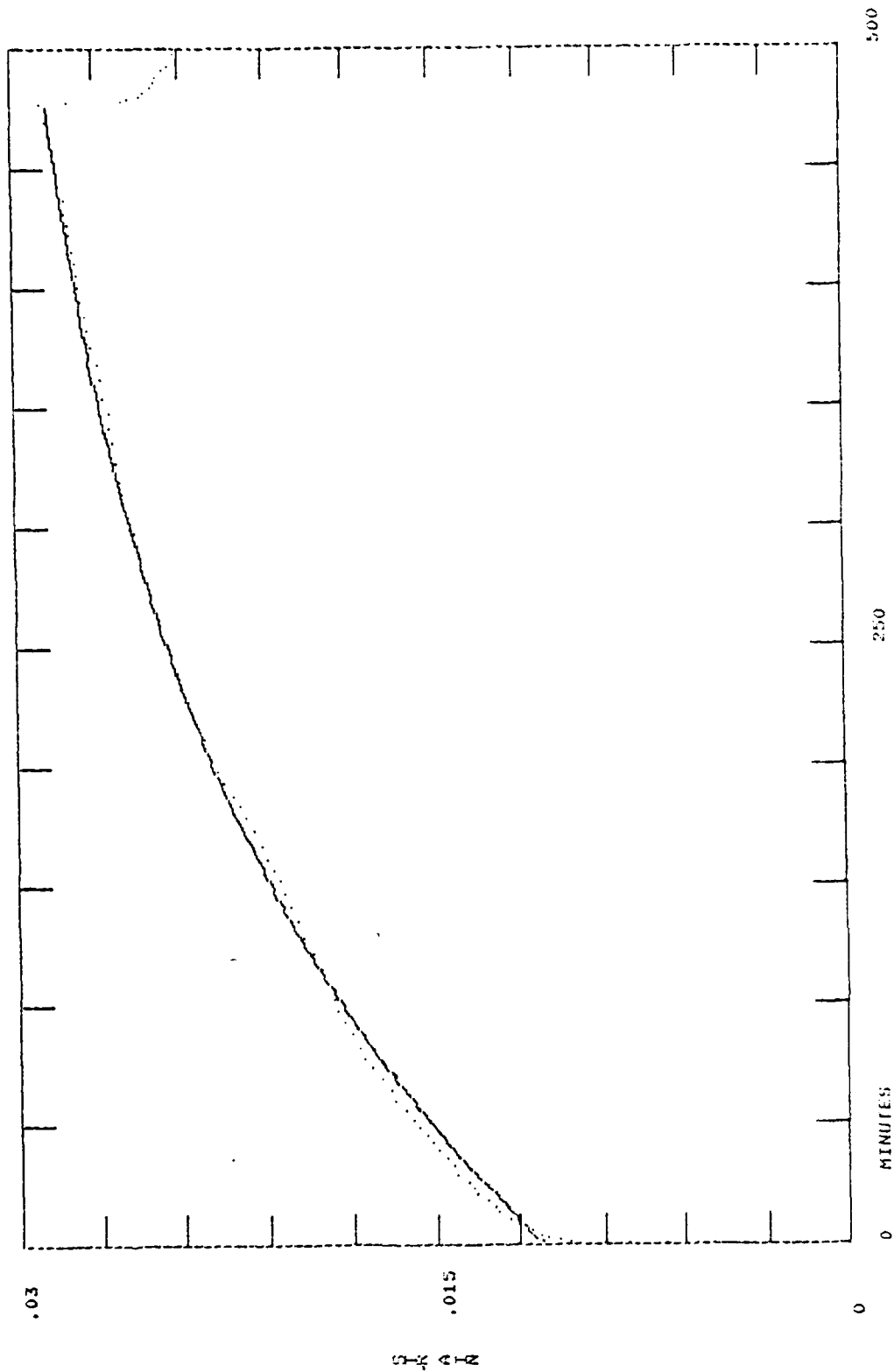
9.227%

LN-23 19-110 06 AUG 75 AREA = 9.12 SQ CM HEIGHT = 2.67 CM

DOTTED LINE: ORIGINAL DATA

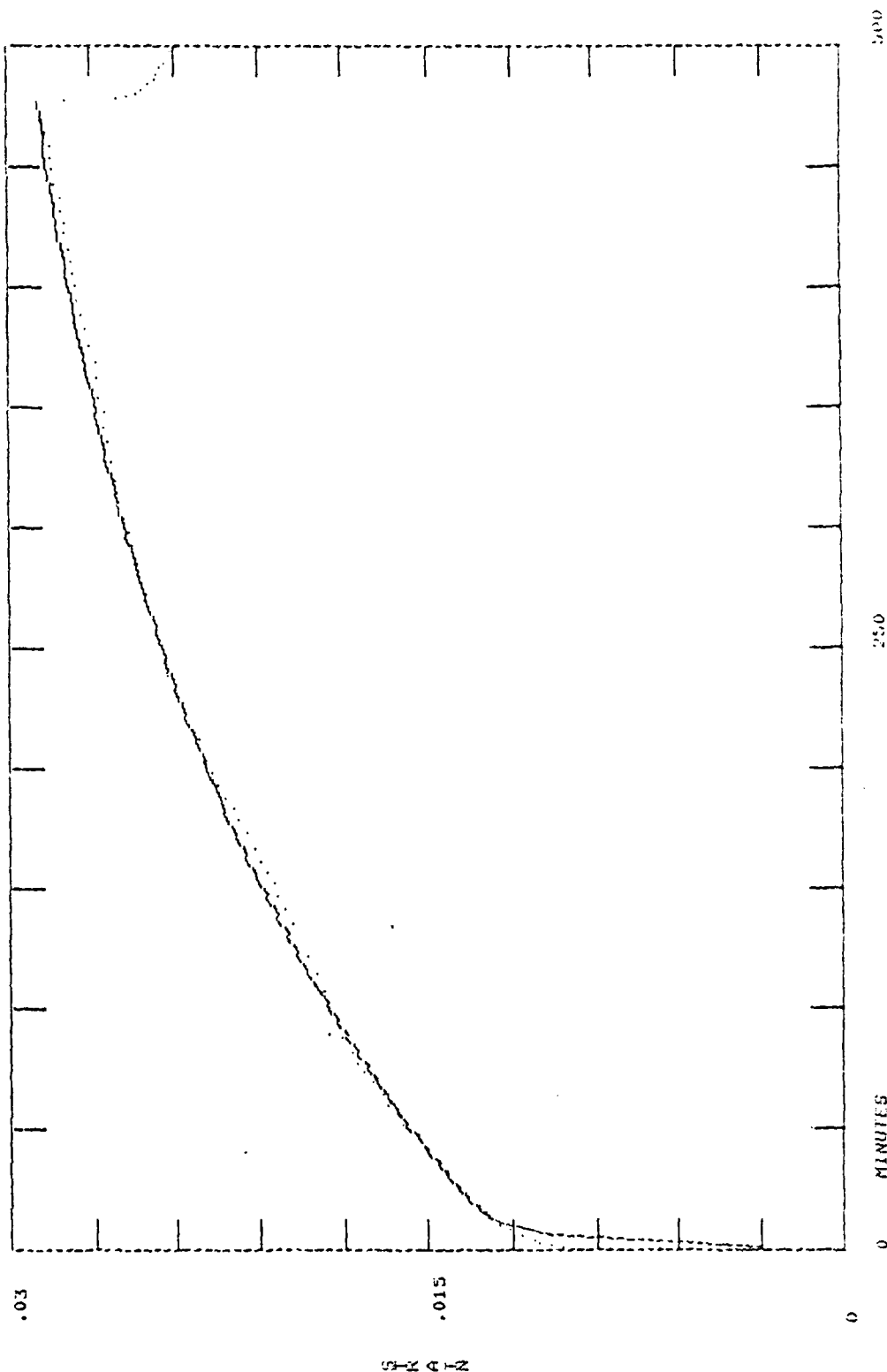
HEAVY LINE: MODEL PREDICTION

11



3-PARAMETER SOLID MODEL WITH VALUES OF
 A1 = .03125, B1 = 4.5816E-03, A2 = .011253
 DELTA TIME = 4
 ERROR DURING ALL POINTS: 0.6282%
 ERROR DURING FIRST 3 POINTS: 0.024%

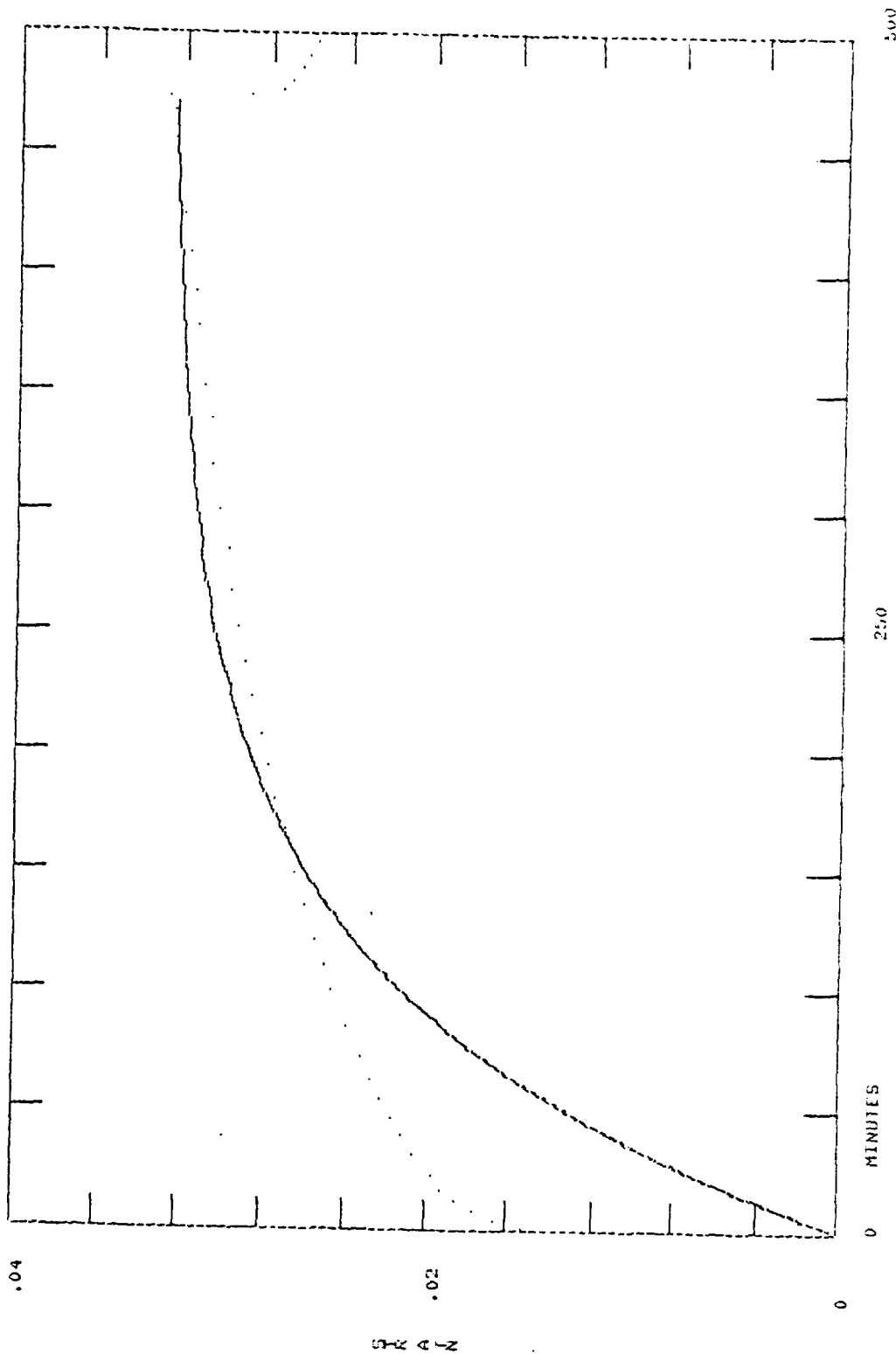
LN-23 19-110 06 AUG 75 AREA = 9.12 SQ CM HEIGHT = 2.67 CM
 DOTTED LINE: ORIGINAL DATA HEAVY LINE: MODEL PREDICTION



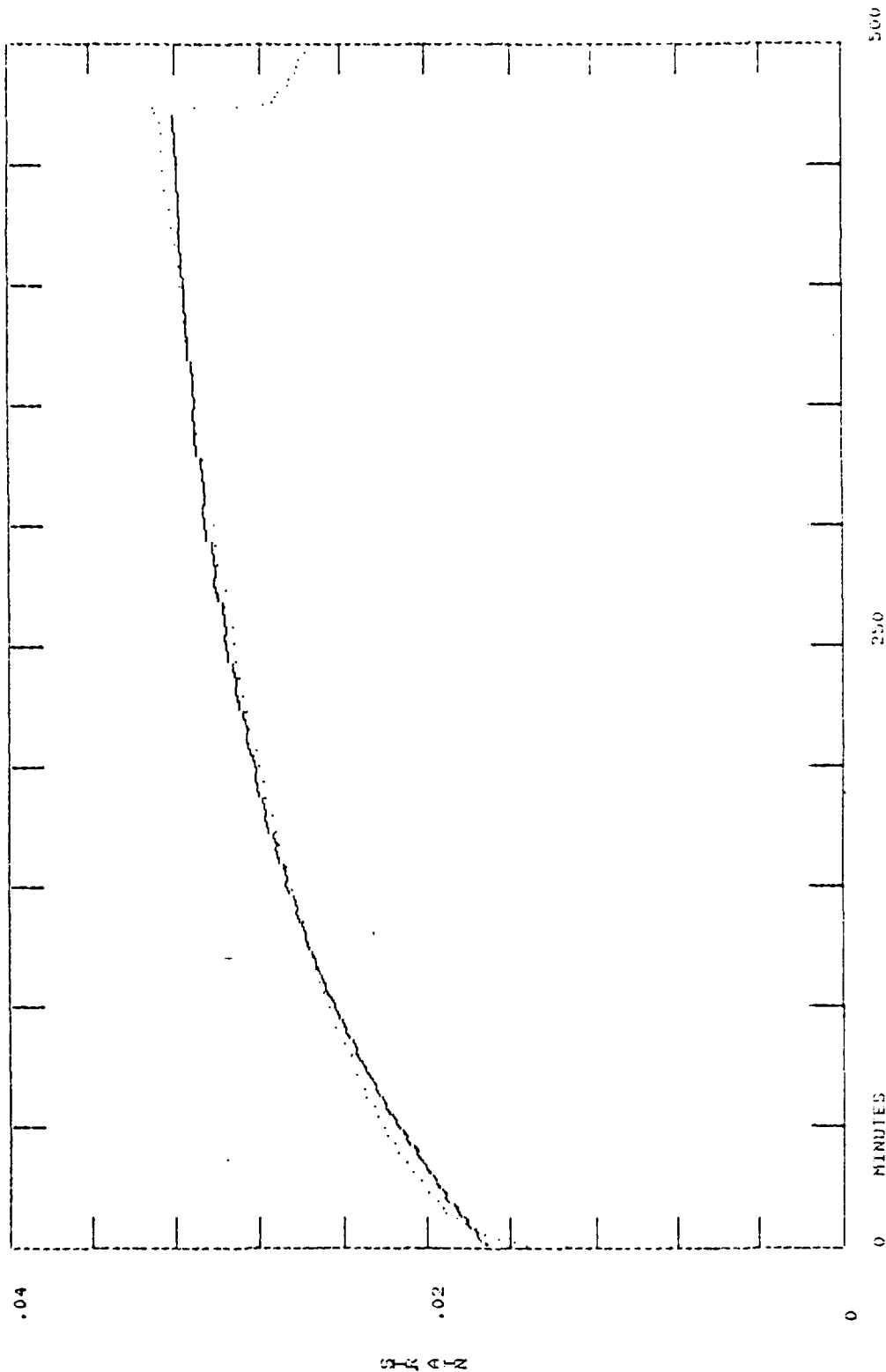
9-10-68
 12

PARAMETER SOLID MODEL WITH VALUES OF
 Q1 = .01212, Q2 = .29929, Q3 = .01999, Q4 = 3.9087E-03
 Q5 = .01212, Q6 = .29929, Q7 = .01999, Q8 = 3.9087E-03
 ERROR COSTING ALL POINTS: 0.904%
 ERROR COSTING FIRST 5 POINTS: 0.904%

1A-23 19-110 06 500 75 AREA = 9.12 50 CM HEIGHT = 2.67 CM
 BOTH LINES: ORIGINAL DATA HEAVY LINE: MODEL PREDICTION



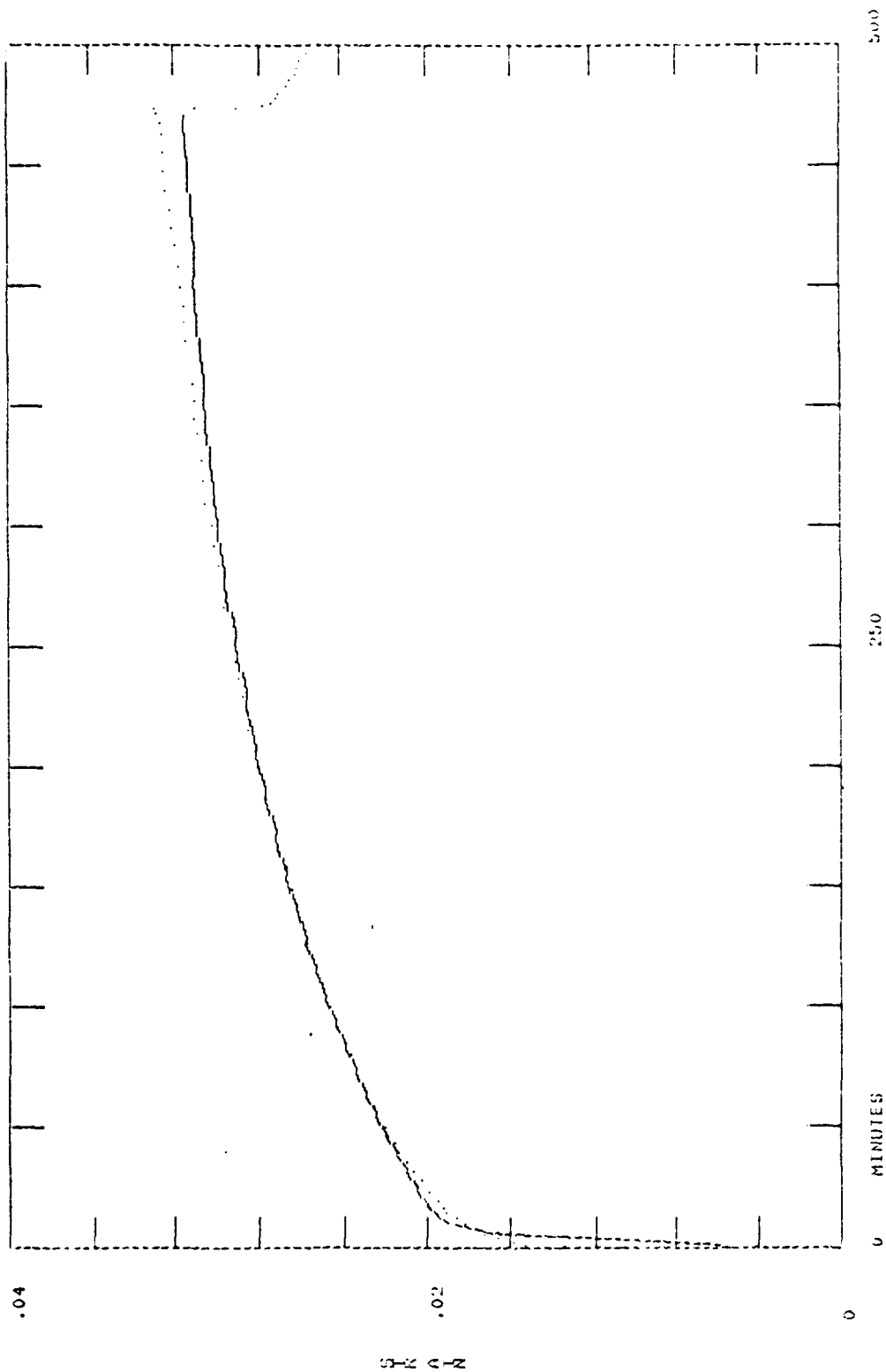
LN-24 110-111 18 JUN 75 AREA = 10.53 SQ CM HEIGHT = 2.795 CM
 DOTTED LINE: ORIGINAL DATA HEAVY LINE: MODEL PREDICTION



3-PROGRAMMER SOLTD MODEL WITH VALUES OF
 A1 = .0333, B1 = 6.1208E-03, A2 = .012187
 DELTA TIME = 4
 ERROR COSTING ALL POINTS: -0.202%
 ERROR COSTING FIRST 3 POINTS: -0.432%

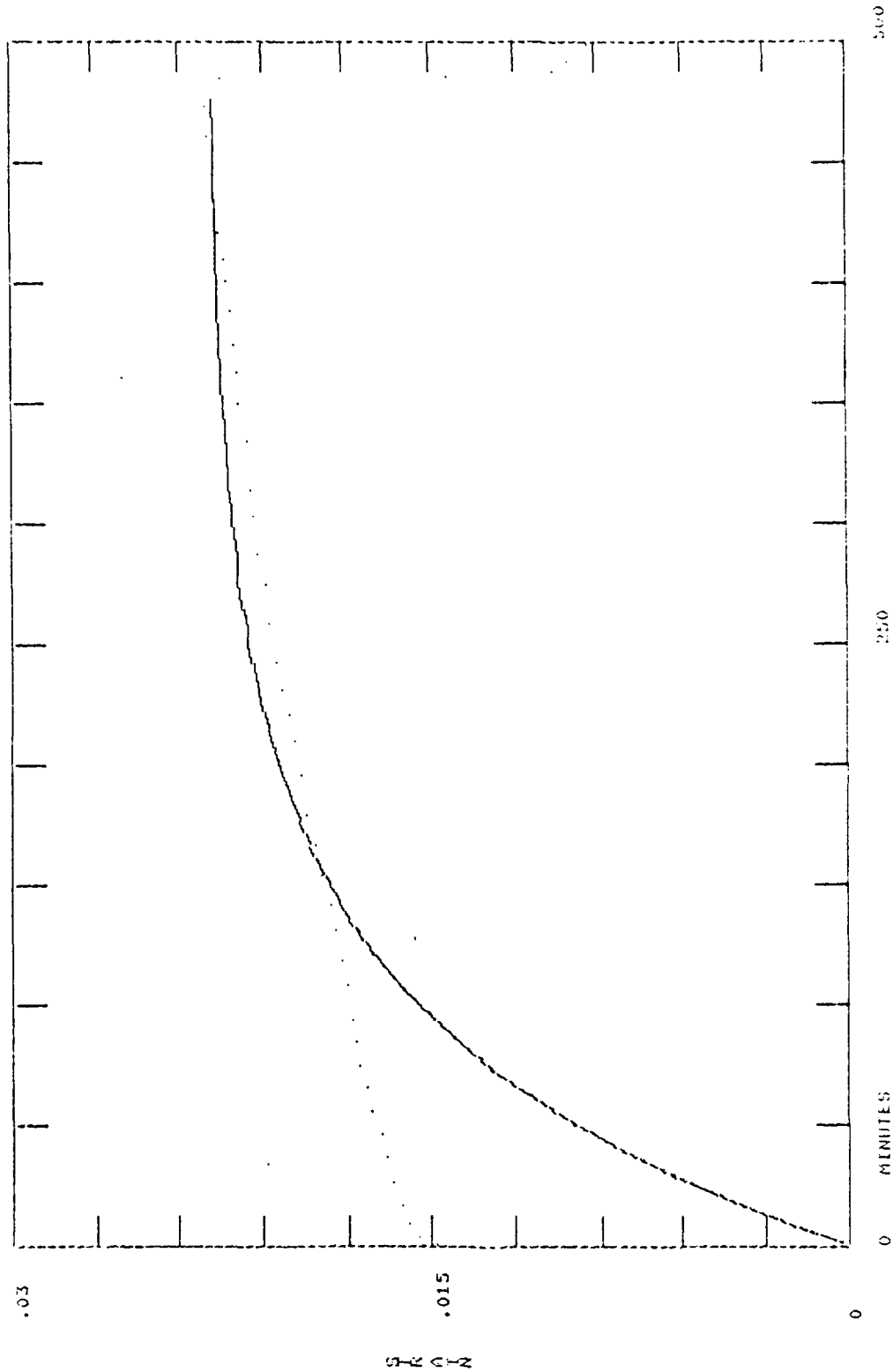
LN-24 110-111 18 JUN 75 AREA = 10.33 SQ CM HEIGHT = 2.795 CM
 DOTTED LINE: ORIGINAL DATA HEAVY LINE: MODEL PREDICTION

1.5



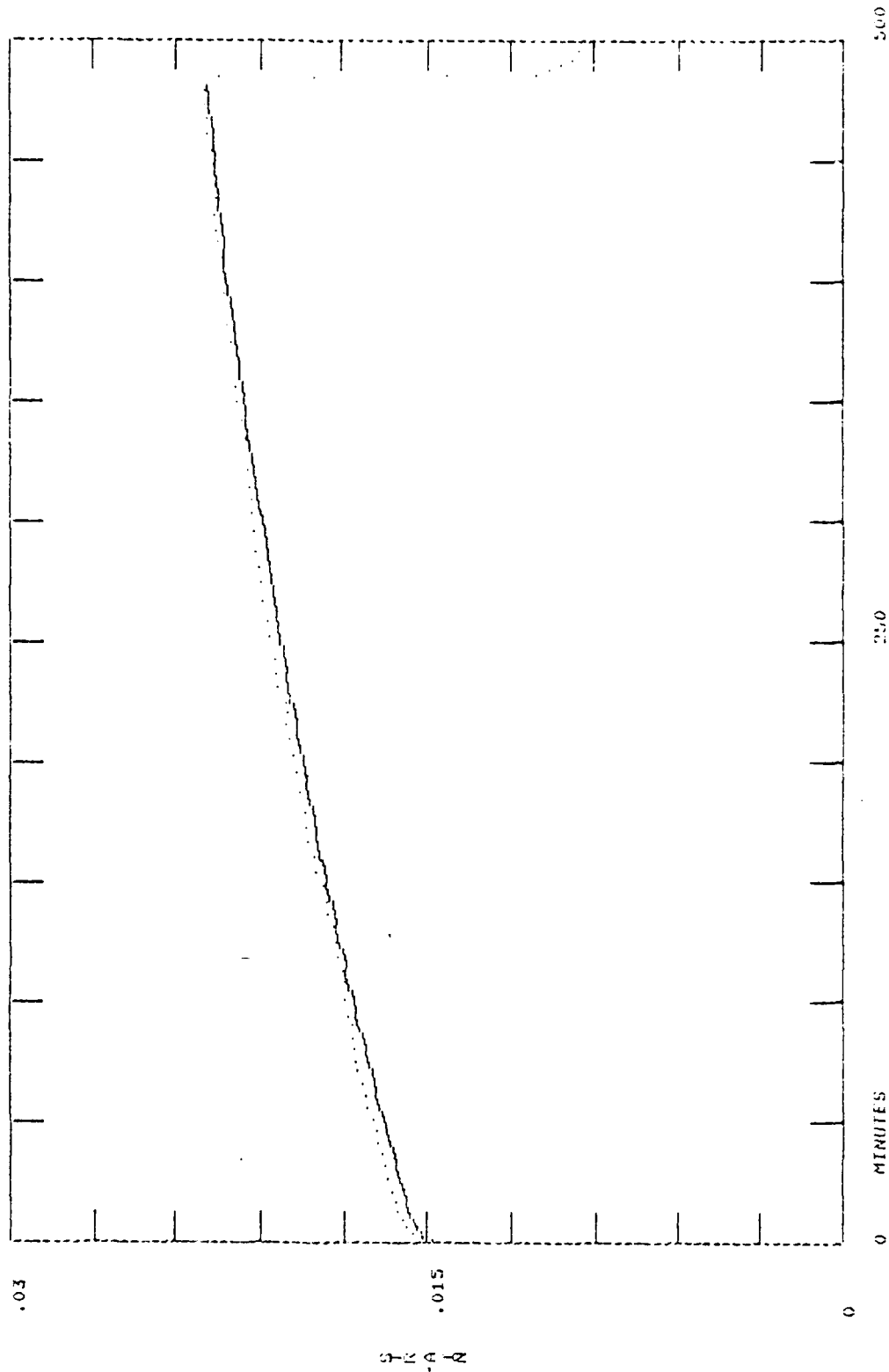
4-PARAMETER SOLID MODEL WITH VALUES OF
 A1 = .018899, B1 = .386784, C1 = .013676, D2 = 5.59561E-03
 DELTA TIME = 4
 ERROR COSTNO ALL POINTS: 12.0682
 ERROR COSTNO FIRST 3 POINTS: 1.3592

LN 24 110-111 18 JUN 75 AREA = 10.33 SQ CM HEIGHT = 2.795 CM
 DOTTED LINE: ORIGINAL DATA HEAVY LINE: MODEL PREDICTION



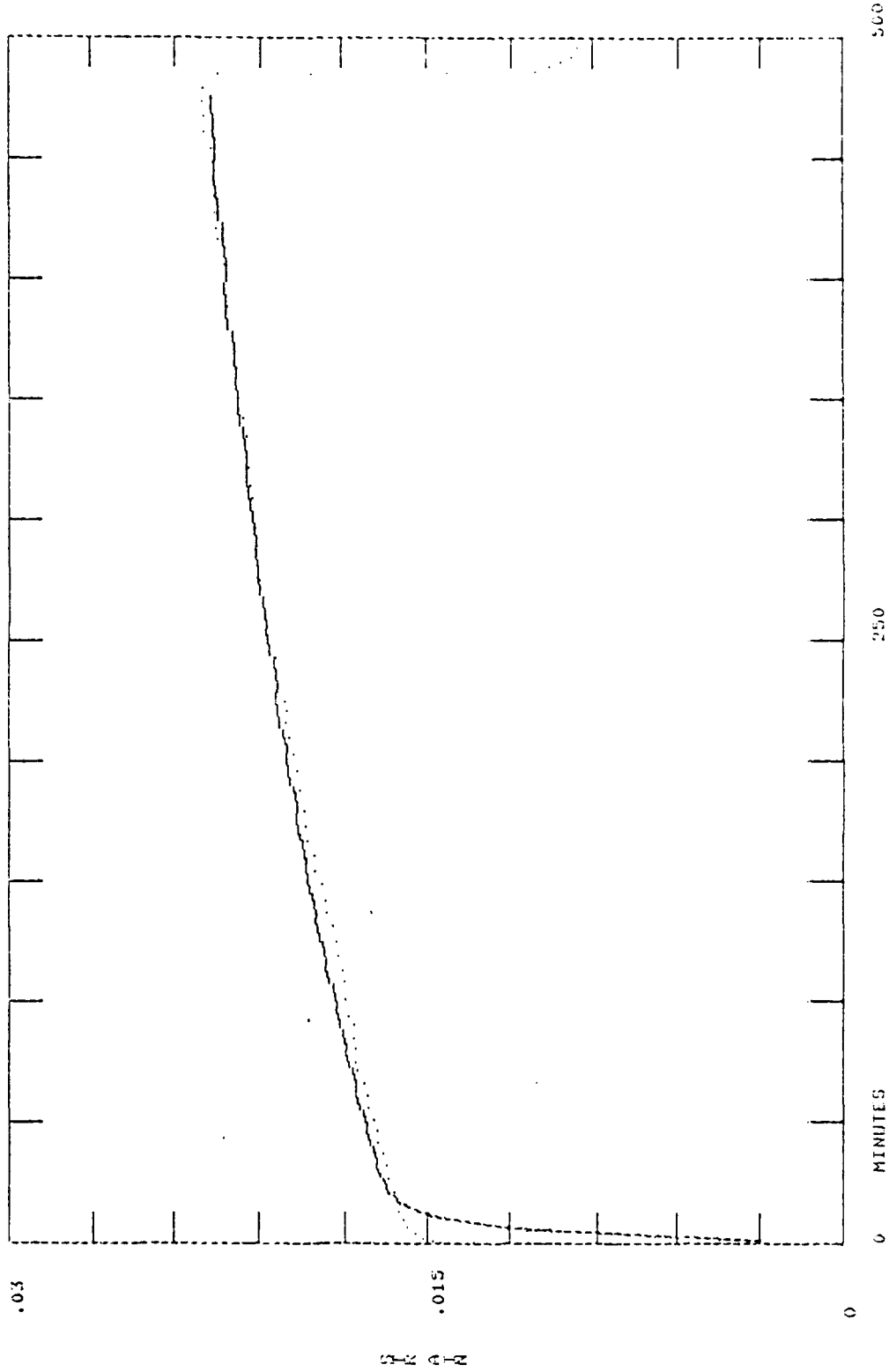
2-PARAMETER SOLID MODEL WITH VALUES OF
 $\Delta t = .0228851$ $kl = .011317$
 $\Delta t = .0228851$ $kl = .011317$
 ERROR CURSING ALL POINTS:
 ERROR CURSING FIRST 3 POINTS:
 12.57%
 13.75%

UN-25 11-112 19 JUN 79 AREA = 1.0 SR CH HEIGHT = 3.515 CM
 DOTTED LINE: ORIGINAL DATA HEAVY LINE: MODEL PREDICTION



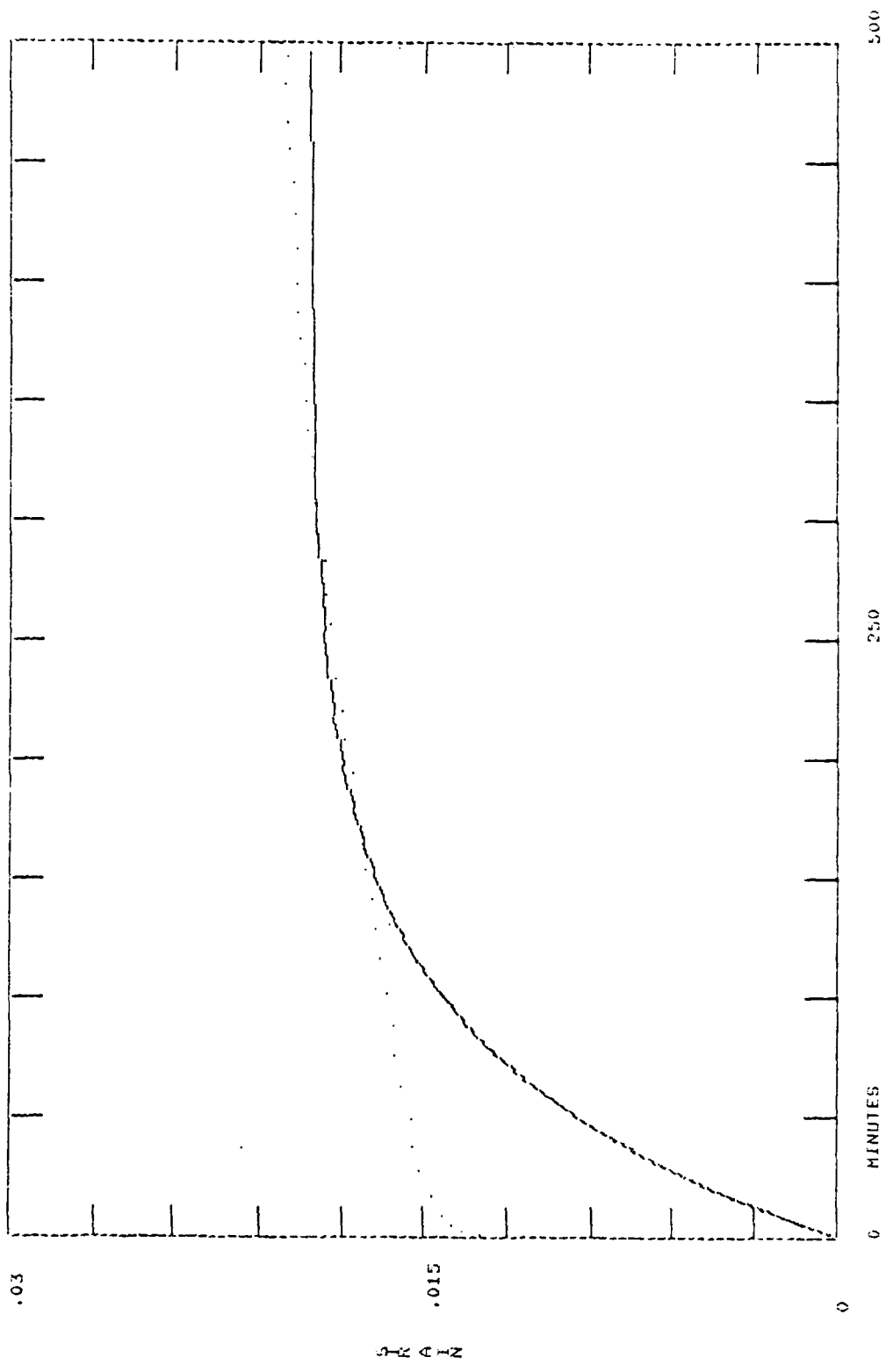
3-PARAMETER SOLID MODEL WITH VALUES OF
 Q1 = .026515, K1 = 2.3513E-03, A2 = .015318
 DELTA TIME = 4
 DENSIN CONDENS ALL POINTS : 0.2432
 ERROR CONDENS FIRST 3 POINTS : 0.9892

LA-25, 711-712 19 JUN 75 AREA = 11.8 SQ CM HEIGHT = 3.515 CM
 DOTTED LINE: ORIGINAL DATA HEAVY LINE: MODEL PREDICTION



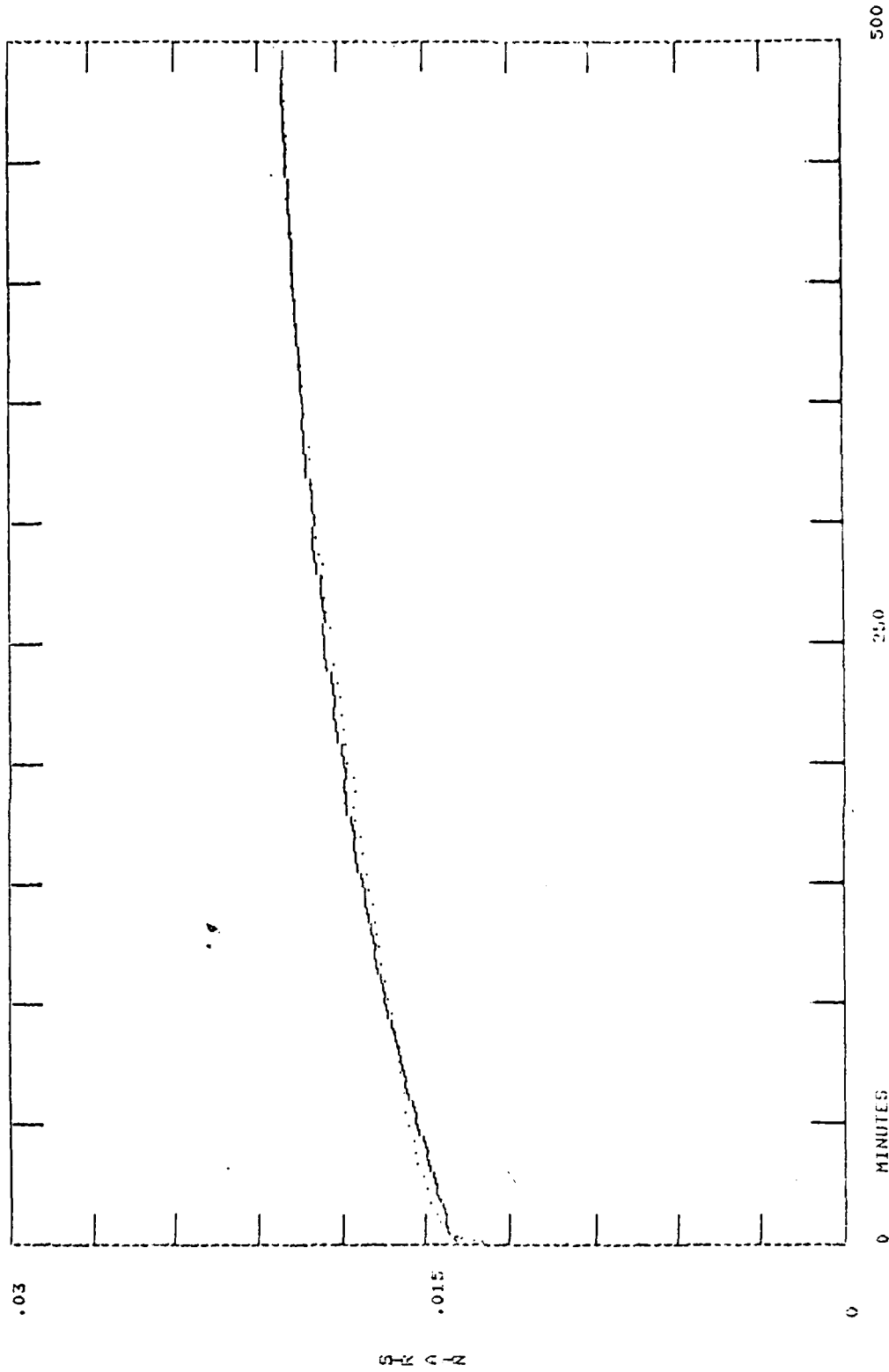
4-PARAMETER SOLID MODEL WITH VALUES OF
 A1 = .016016, A2 = .2218, A3 = 8.3228E-03, A4 = 3.0732E-03
 DELTA TIME CUSING ALL POINTS: 2.1192
 ERROR CUSING FIRST 5 POINTS: 1.2152

LN-25 111-112 19 JUN 75 AREA = 11.8 50 CM HEIGHT = 3.515 CM
 DOTTED LINE: ORIGINAL DATA HEAVY LINE: MODEL PREDICTION



2-PARAMETER SOLID MODEL WITH VALUES OF
 $Q_1 = .019236$, $Q_2 = .013725$
 DELTA TIME = 1.6
 ERROR (USING ALL POINTS): 15.239%
 ERROR (IGNORING FIRST 3 POINTS): 11.515%

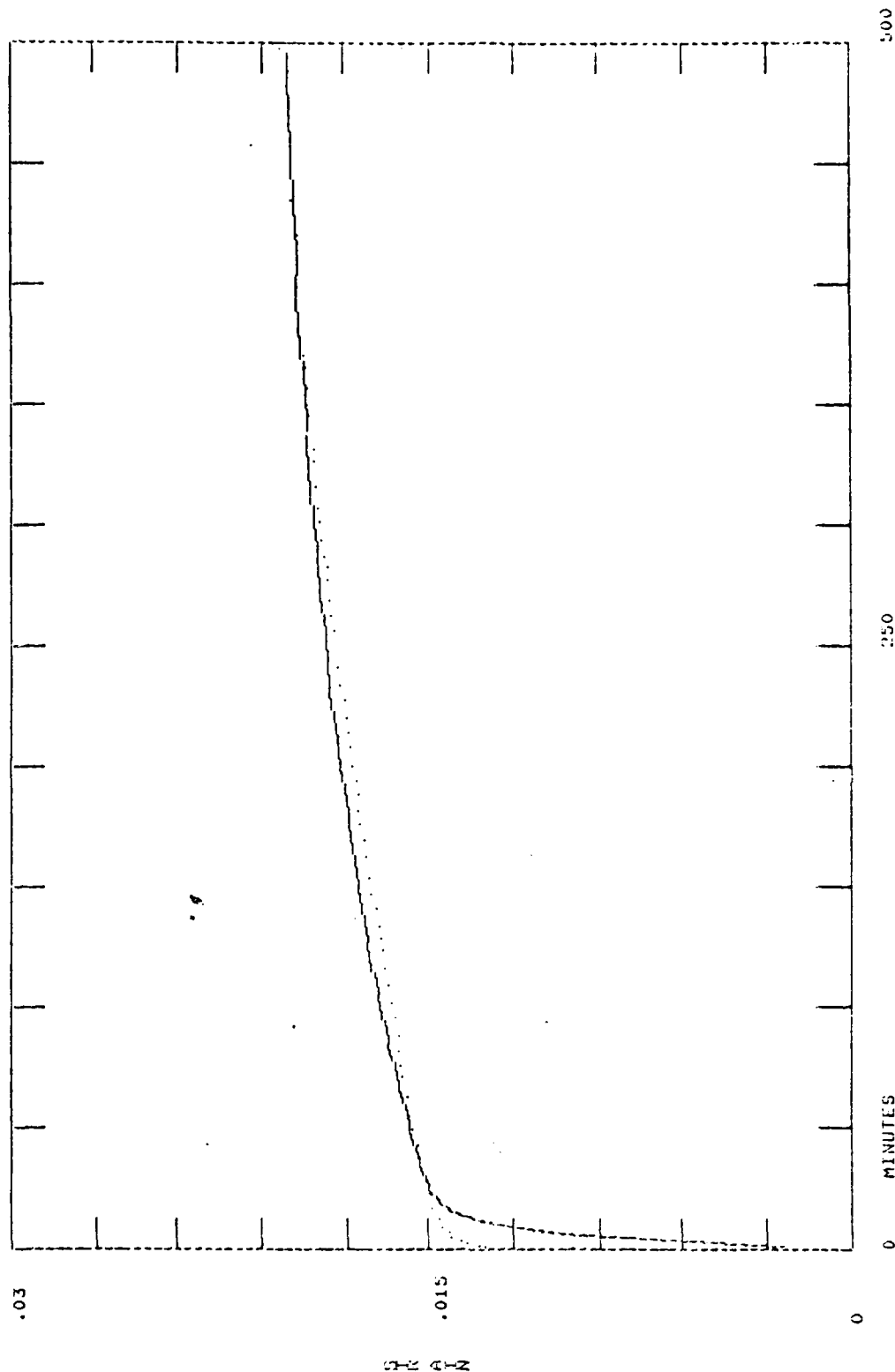
LN-26 112-11 01 AUG 75 AREA = 11.18 SQ CM HEIGHT = 3.725 CM
 DOTTED LINE: ORIGINAL DATA
 HEAVY LINE: MODEL PREDICTION



3-PARAMETER SOLID MODEL WITH VALUES OF
 Q1 = .02097, R1 = 4.2554E-03, Q2 = .014062
 DELTA TIME = 4
 CLOSING ALL POINTS: -1.256%
 CLOSING FIRST 3 POINTS: -0.378%

LA-25 112-11 01 AUG 75 AREA = 11.18 SQ CM HEIGHT = 3.725 CM
 SOLID LINE: ORIGINAL DATA HEAVY LINE: MODEL PREDICTION

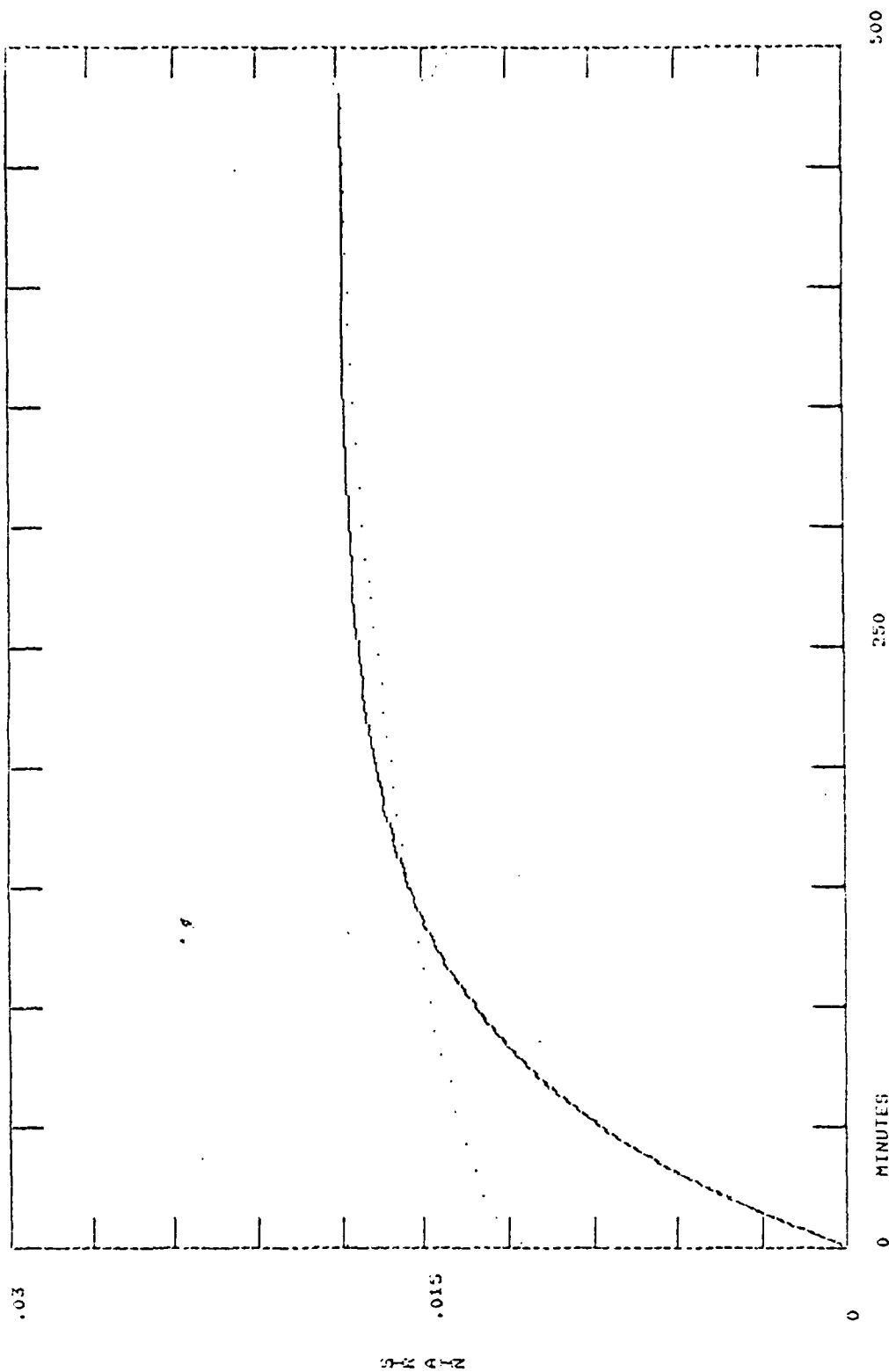
51



4-PARAMETER SOLID MODEL WITH VALUES OF
 $\alpha_1 = .014512$, $\alpha_2 = .20104$, $\alpha_3 = 6.2734E-03$, $\alpha_4 = 4.4473E-03$
 DELTA TIME = 8
 ERROR (USING ALL POINTS): 2.8851%
 ERROR (USING FIRST 3 POINTS): 2.0856%

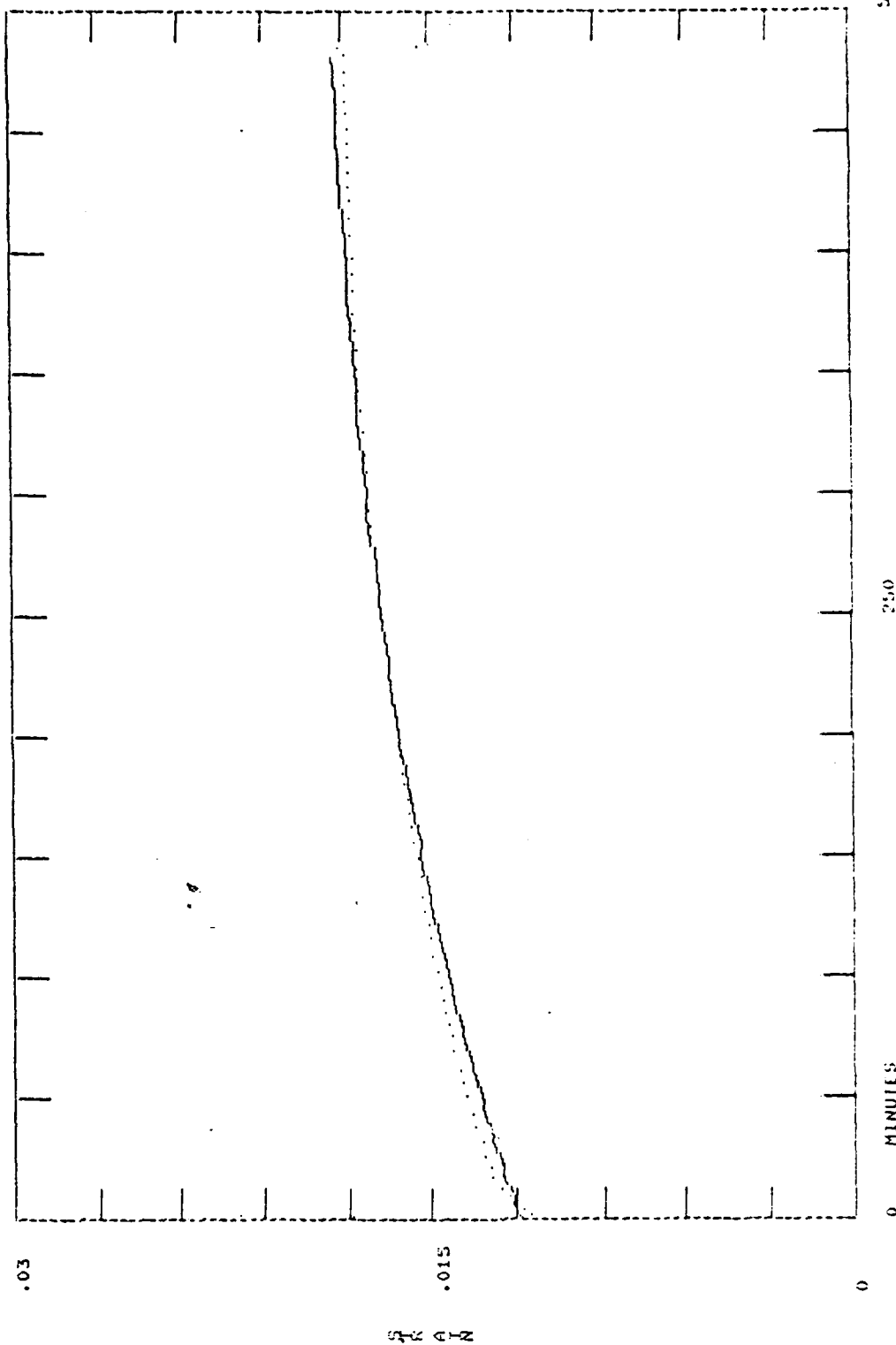
LA-26 T12-L1 01 AUG 75 AREA = 11.18 SQ CM HEIGHT = 3.725 CM
 DOTTED LINE: ORIGINAL DATA HEAVY LINE: MODEL PREDICTION

(-)



2-PARAMETER SOLID MODEL WITH VALUES OF
 $\alpha_1 = .0180417$ $\alpha_2 = .013264$
 DELTA TIME = 1.6
 ERROR USING ALL POINTS: 11.939%
 ERROR USING FIRST 3 POINTS: 7.388%

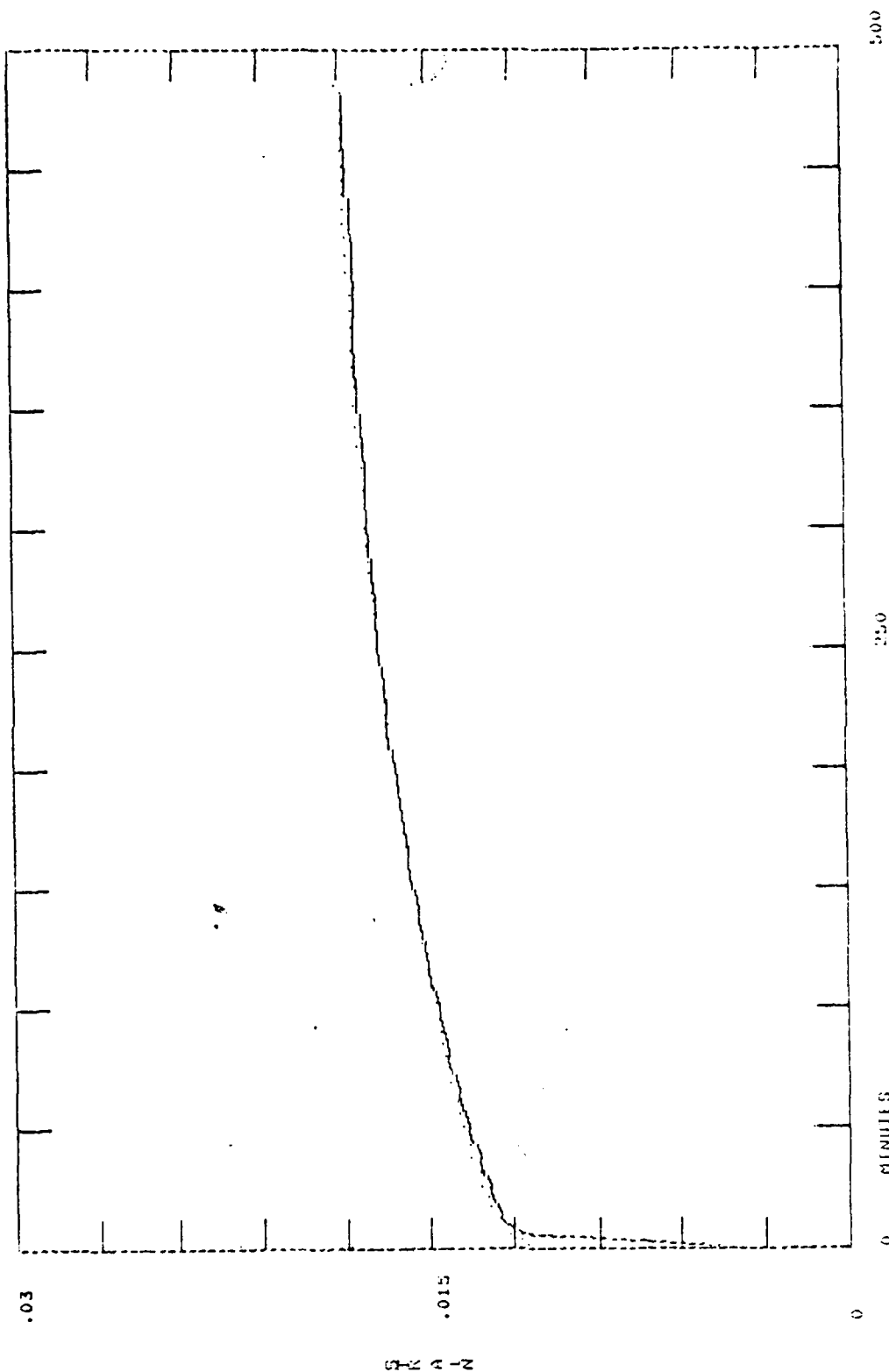
LR-27 11-12 11 SLP 75 AREA = 11.01 SQ CM HEIGHT = 3.9 CM
 DOTTED LINE: ORIGINAL DATA HEAVY LINE: MODEL PREDICTION



3. PARAMETER SOL. TO MODEL WITH VALUES OF
 C1 = .0125, C2 = 4.0529E-03, C3 = .011948
 DELTA TIME = 4
 CUSTNO ALL POINTS : 0.000%
 ERROR CIGNORE FIRST 3 POINTS : 1.131%

18-27 11-12 11 SEP 75 AREA = 11.01 50 CM HEIGHT = 3.9 CM
 DOTTED LINE: ORIGINAL DATA HEAVY LINE: MODEL PREDICTION

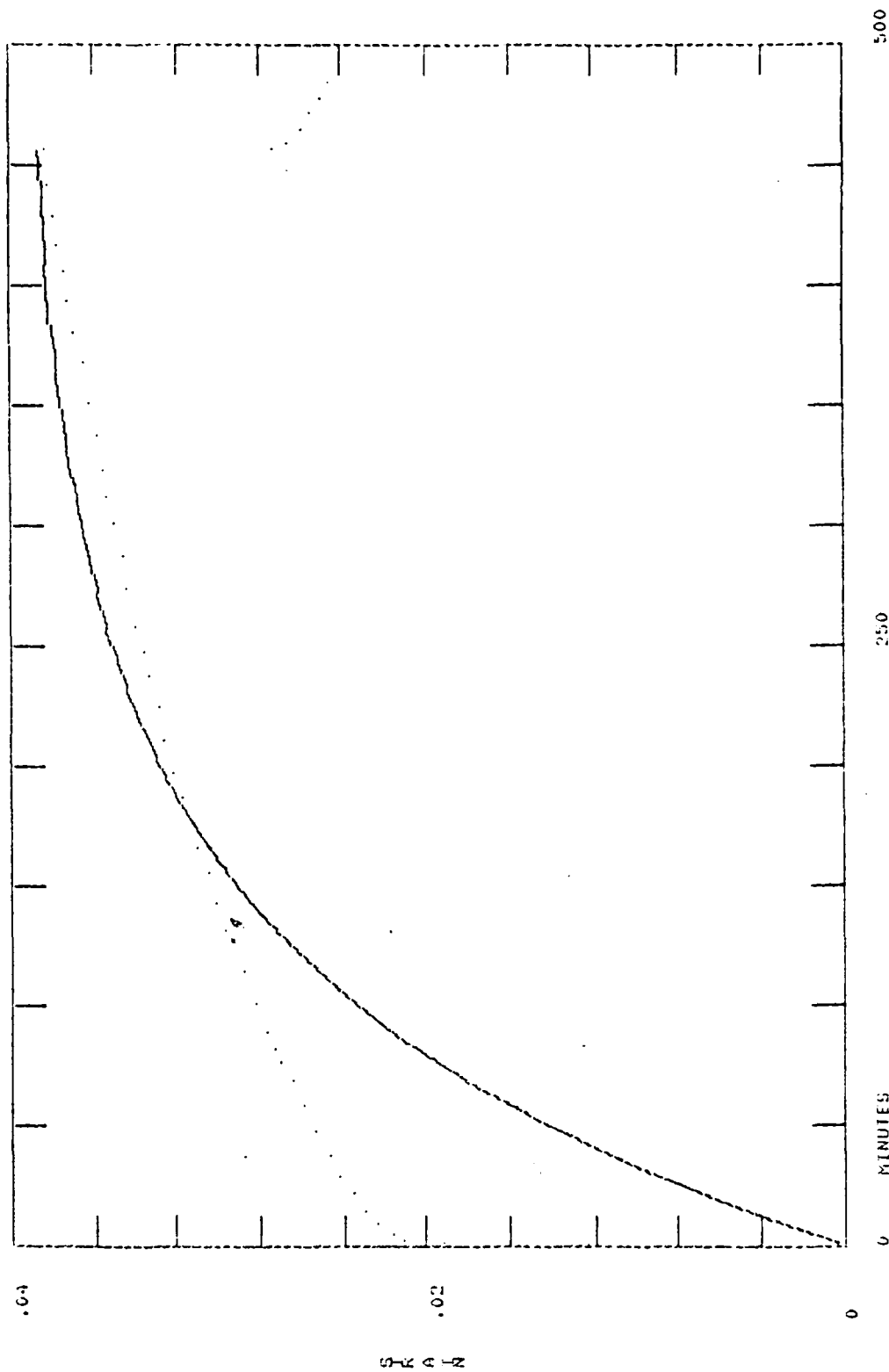
6.2



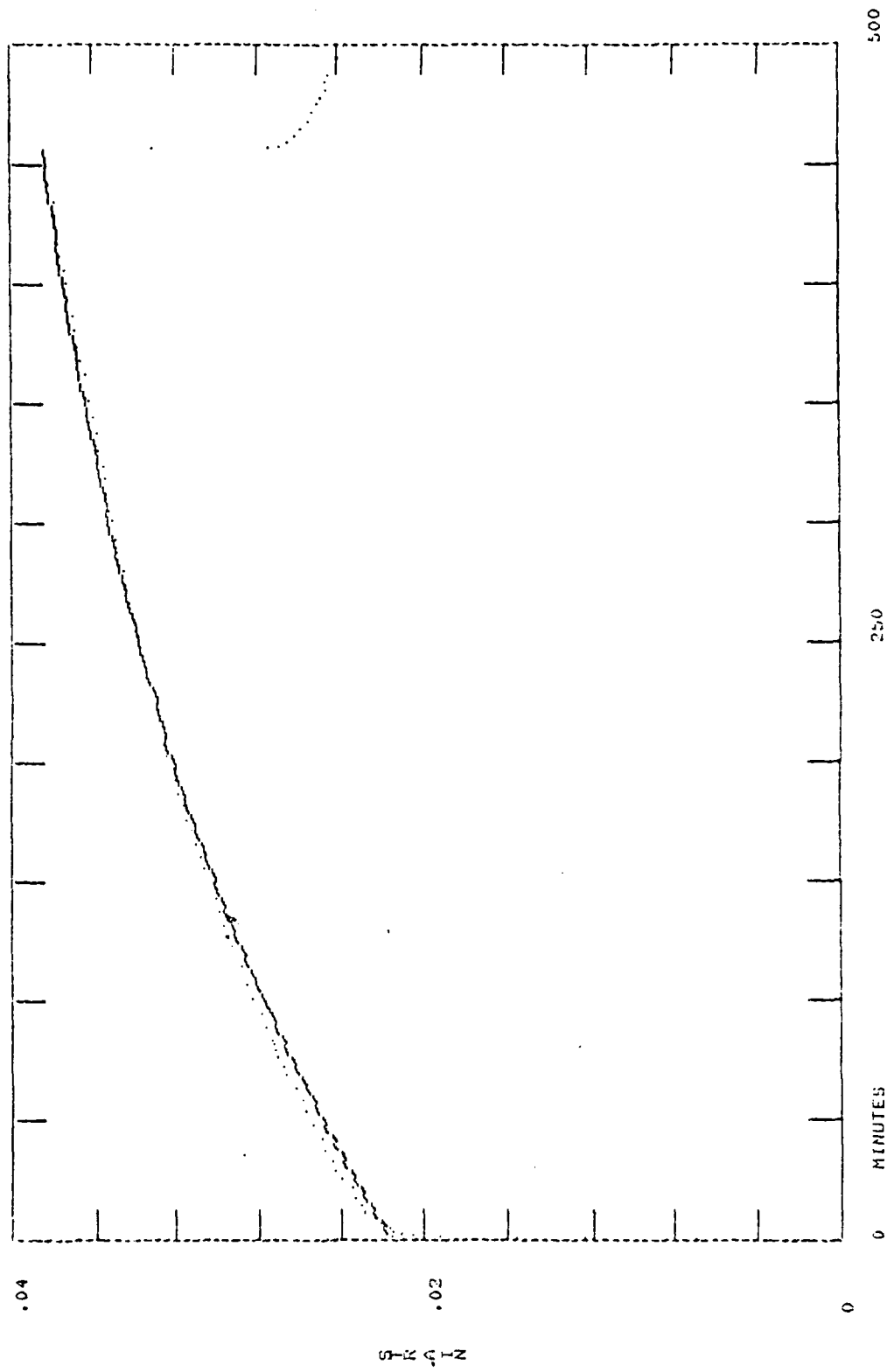
4-PARAMETER SOLID MODEL WITH VALUES OF
 AT = .012144, RT = .8072, AR = 6.1838E-03, R2 = .005429
 DELTA TIME = 8
 ERROR USING ALL POINTS : 3.584%
 ERROR USING FIRST 3 POINTS : 2.867%

IN-27 11-12 11 SEP 75 AREA = 11.01 50 CM HEIGHT = 3.9 CM
 DOTTED LINE: ORIGINAL DATA HEAVY LINE: MODEL PREDICTION

63



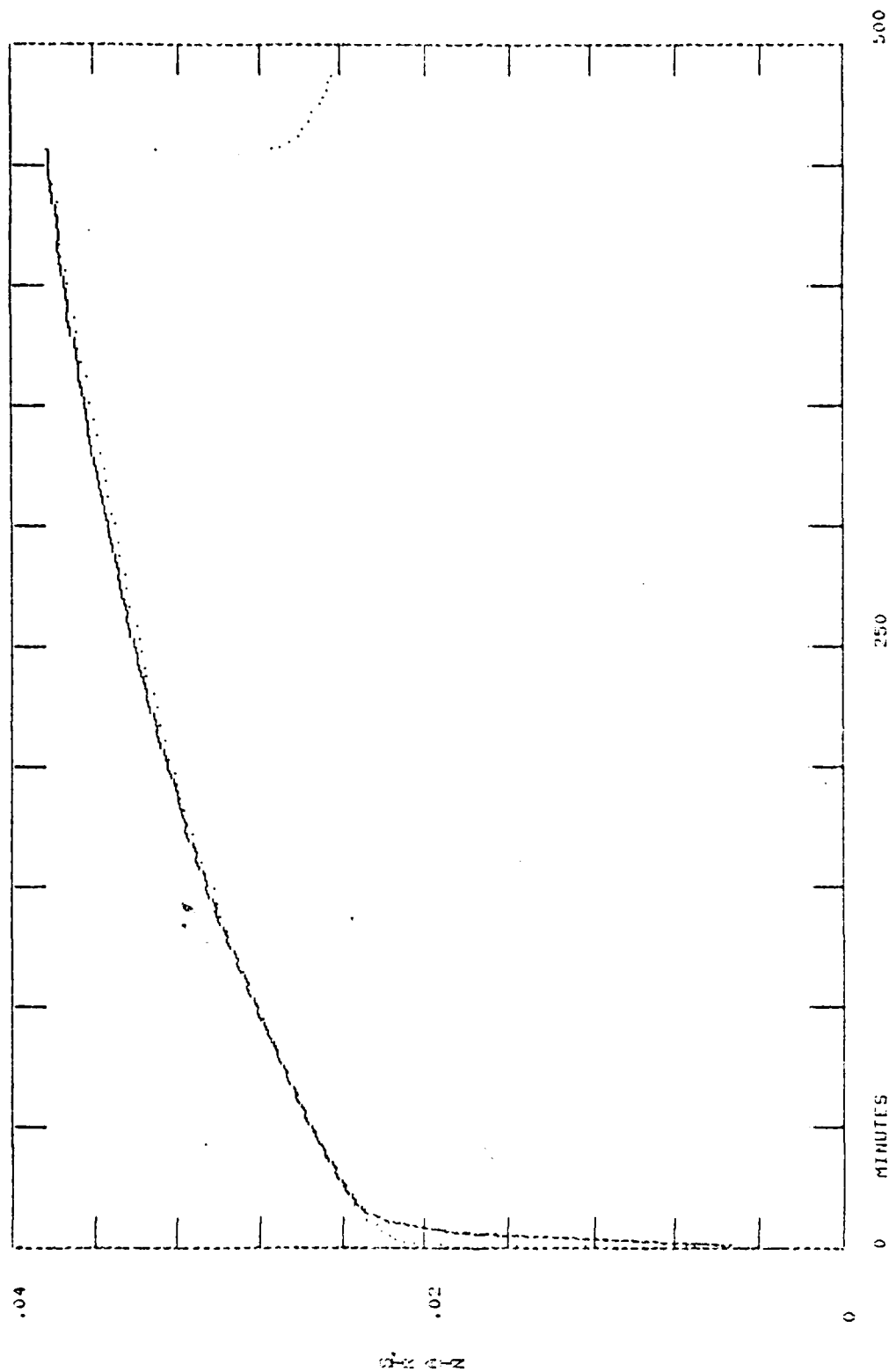
IN-28 L2-13 31 JUN 79 AREA = 14.22 SQ CM HEIGHT = 3.535 CM
 DOTTED LINE: ORIGINAL DATA HEAVY LINE: MODEL PREDICTION



3-PARAMETER SOLID MODEL WITH VALUES OF
 A1 = .042922, B1 = 3.4299E-03, A2 = .021625
 DELTA TIME = 4
 ERROR CURING ALL POINTS: -1.708%
 ERROR CURING FIRST 3 POINTS: -0.515%

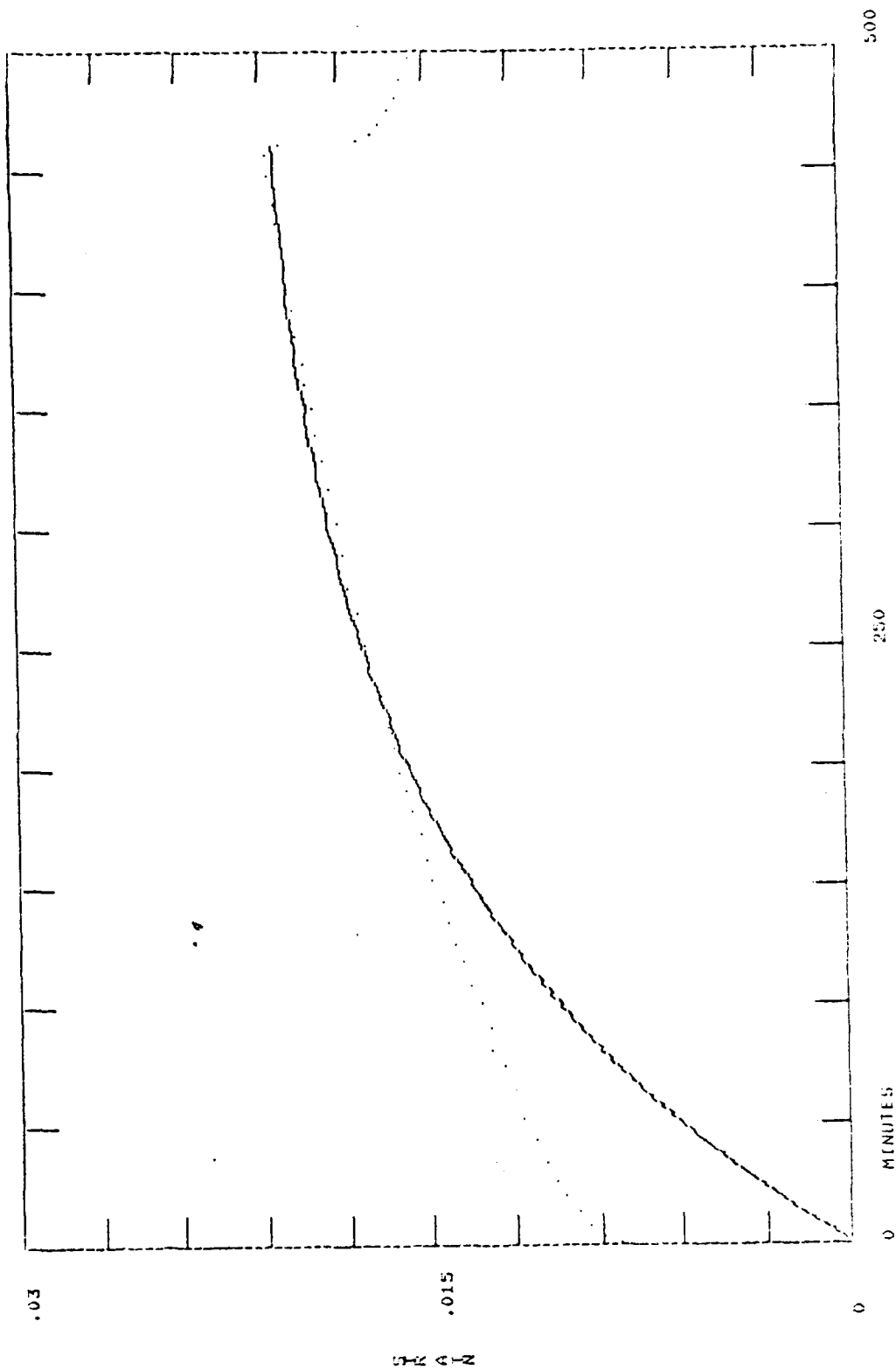
LN-2B L2-L3 31 JUN 75 AREA = 14.22 SQ CM HEIGHT = 3.535 CM
 DOTTED LINE: ORIGINAL DATA HEAVY LINE: MODEL PREDICTION

65



4-PARAMETER SOLID MODEL WITH VALUES OF
 A1 = .020006, B1 = 3.6037E-03, A2 = .022257, B2 = .28257
 DELTA TIME = 4
 ERROR USING ALL POINTS : 2.054%
 ERROR (IGNORING FIRST 3 POINTS) : 1.869%

LK-28 12-L3 31 JUN 75 AREA = 14.22 SQ CM HEIGHT = 3.535 CM
 DOTTED LINE: ORIGINAL DATA HEAVY LINE: MODEL PREDICTION



2-PARAMETER SOLID MODEL WITH VALUES OF

Q1 = .021966, R1 = 0.5944E-03

DELTA TIME = 8

ERROR (USING ALL POINTS):

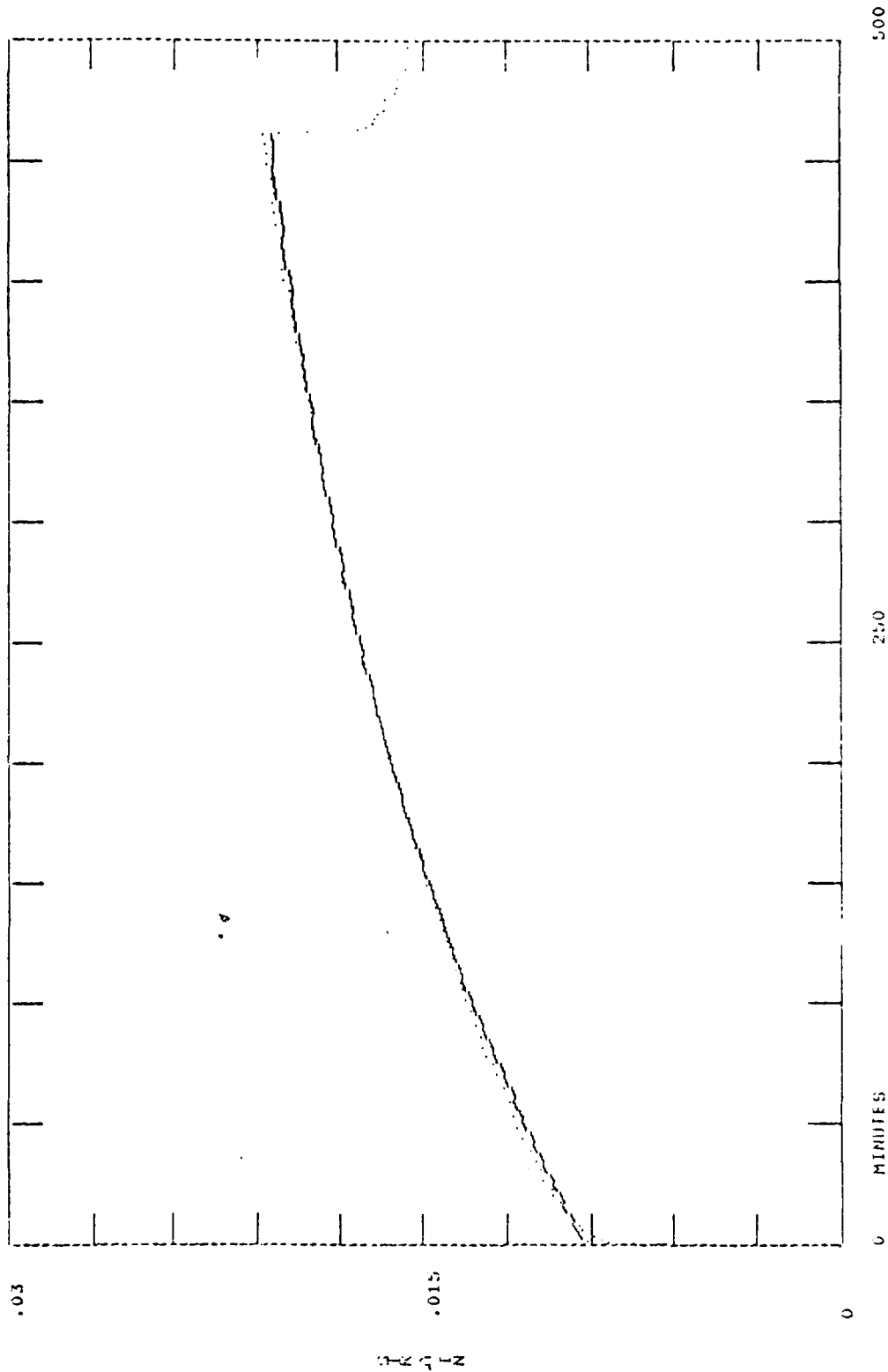
ERROR (USING FIRST 3 POINTS):

13.103%

10.760%

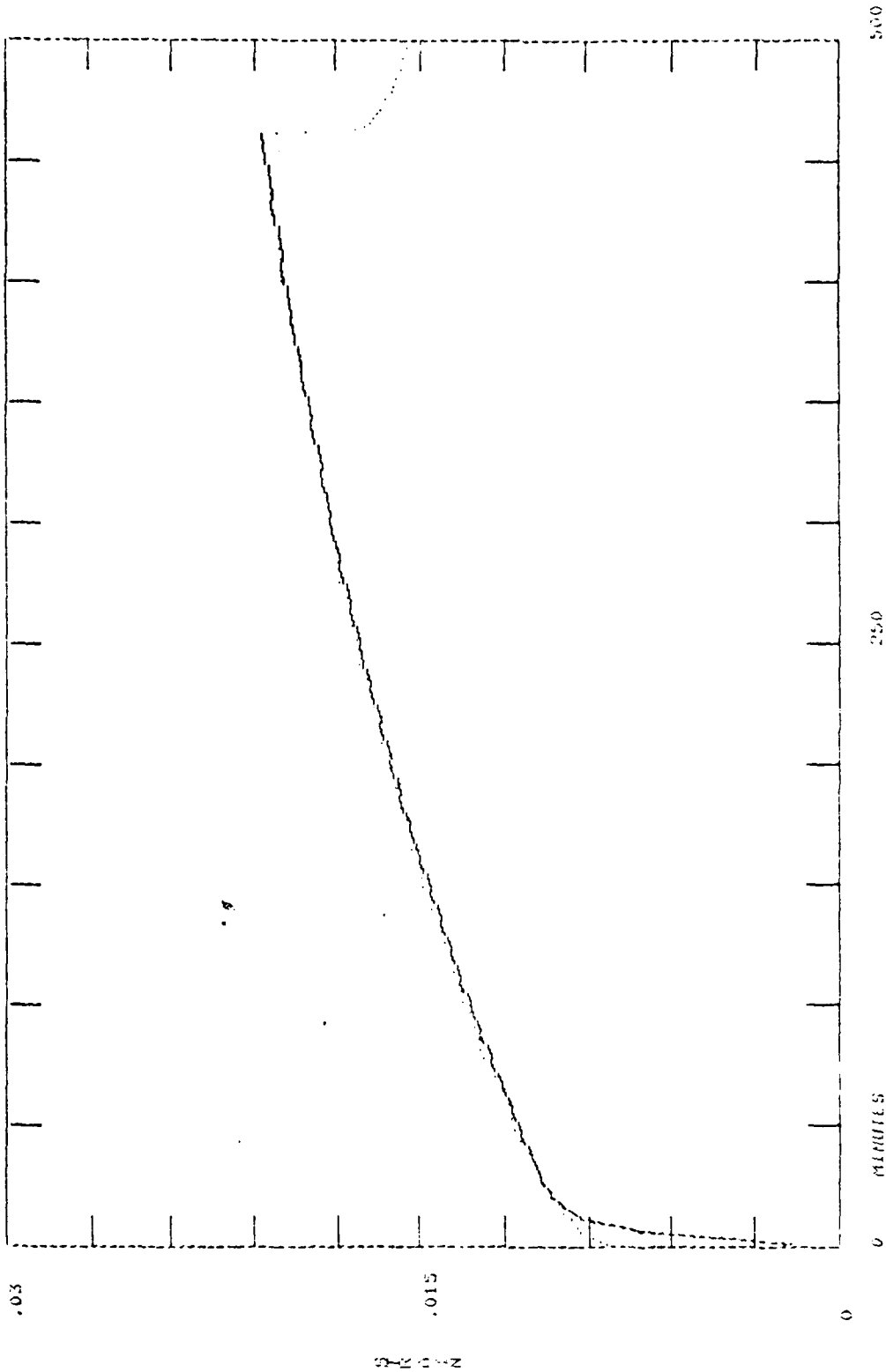
LN-29 13-14 14 AUG 75 AREA = 14.17 SQ CM HEIGHT = 3.165 CM
 DOTTED LINE: ORIGINAL DATA HEAVY LINE: MODEL PREDICTION

67



3-PARAMETER SOLID MODEL WITH VALUES OF
 A1 = .023963, B1 = 3.1864E-03, A2 = 9.2383E-03
 DELTA TIME = 4
 ERROR COUNTING ALL POINTS: .0068%
 ERROR COUNTING FIRST 3 POINTS: .0376%

LN-29 L3-L4 14 AUG 75 AREA = 14.17 SQ CM HEIGHT = 3.165 CM
 DOTTED LINE: ORIGINAL DATA HEAVY LINE: MODEL PREDICTION



4. POROMETER SOLID MODEL WITH VALUES OF
 2.1 = 9.8552E-03, R1 = .20838, R2 = .016172, R3 = 2.5349E-03
 TIME = 9
 CUSING ALL POINTS;
 CUSING FIRST 3 POINTS;
 2.127%
 1.526%

2.3.19 14 AUG 75 AREA = 14.17 SQ CM HEIGHT = 3.165 CM
 CUSING ORIGINAL DATA HEAVY LINE: MODEL PREDICTION

6.1

AD-A107 627

TUSKEGEE INST AL DEPT OF PHYSICS

F/G 6/4

ANALYTICAL MODELLING OF LOAD-DEFLECTION BEHAVIOR INTERVERTEBRAL--ETC(U)
1980 M L BURNS AFOSR-80-0115

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M. L. BURNS

AFOSR-80-0115

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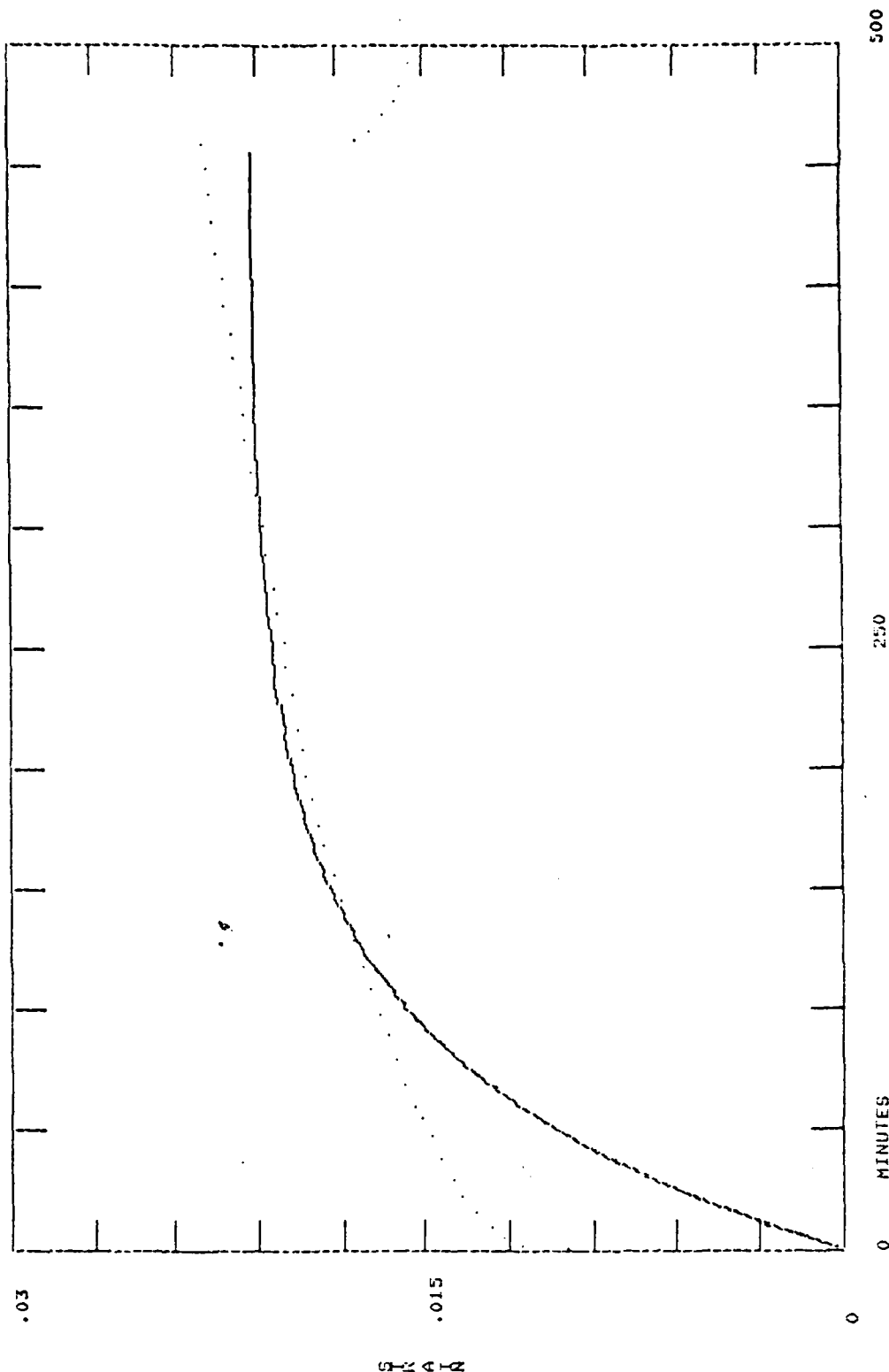
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DATE
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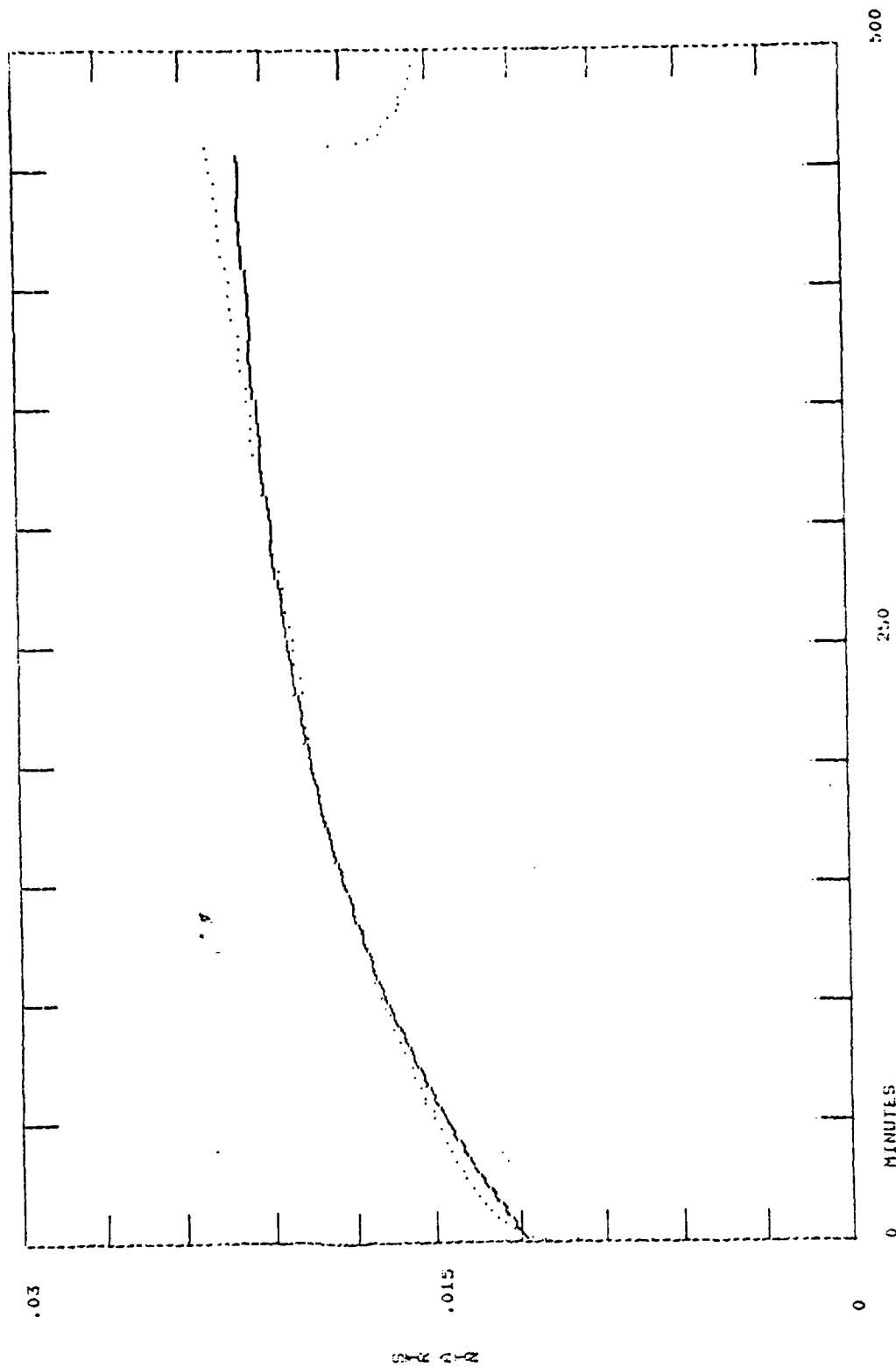
3

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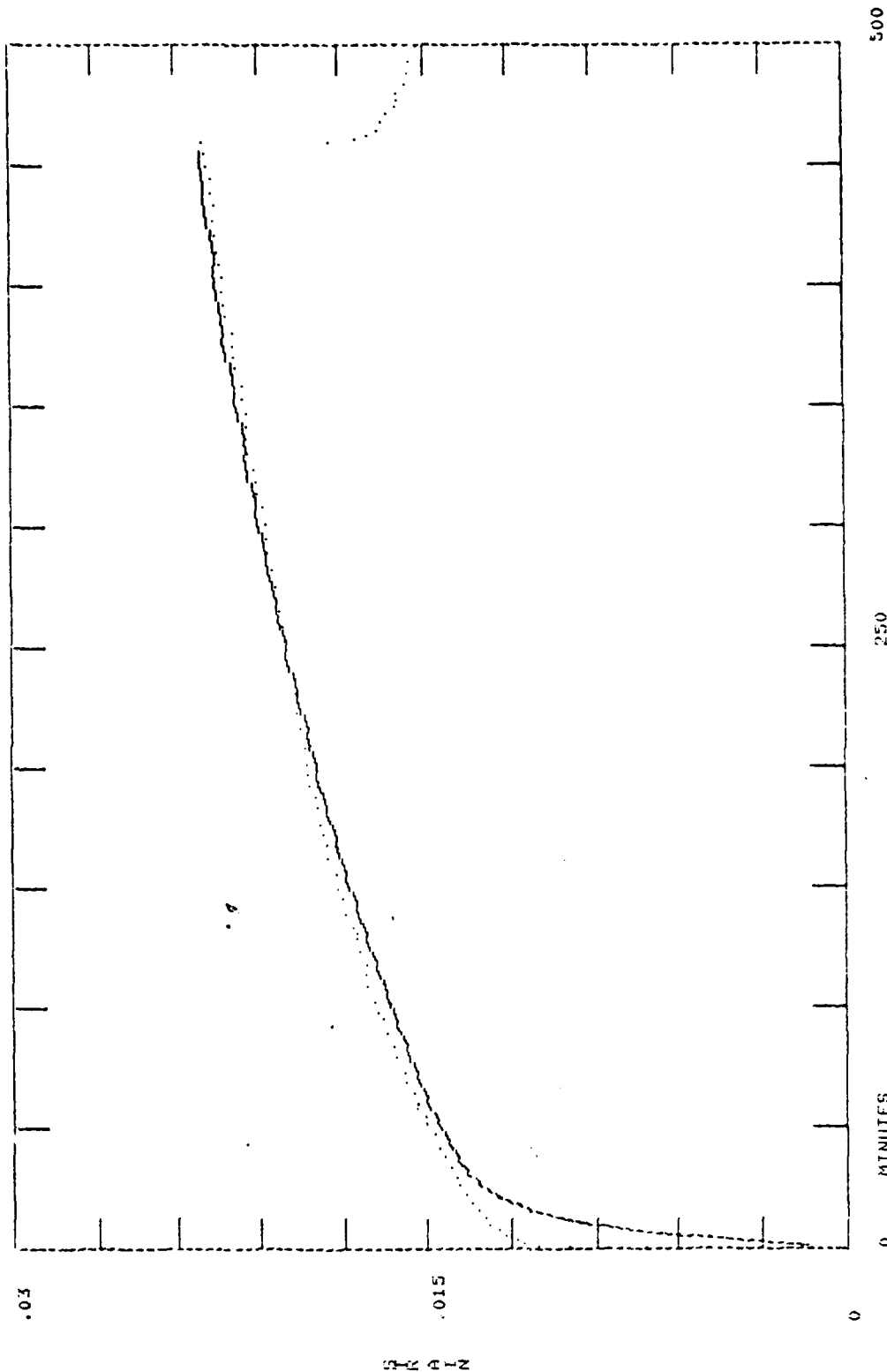
2-PARAMETER SOLID MODEL WITH VALUES OF
 AT = .021345, BT = .013233
 GEL TIME = 4
 ERROR USING ALL POINTS: 11.9332%
 ERROR IGNORING FIRST 3 POINTS: 9.274%

LN-30 14-15 16 AUG 75 AREA = 17.22 SQ CM HEIGHT = 3.16 CM
 DOTTED LINE: ORIGINAL DATA HEAVY LINE: MODEL PREDICTION



3-PARAMETER SOLID MODEL WITH VALUES OF
 A1 = .022682, B1 = 5.9945E-03, A2 = .011707
 DELTA TIME = 30
 ERROR USING ALL POINTS: 0.108%
 ERROR (IGNORING FIRST 3 POINTS): 0.932%

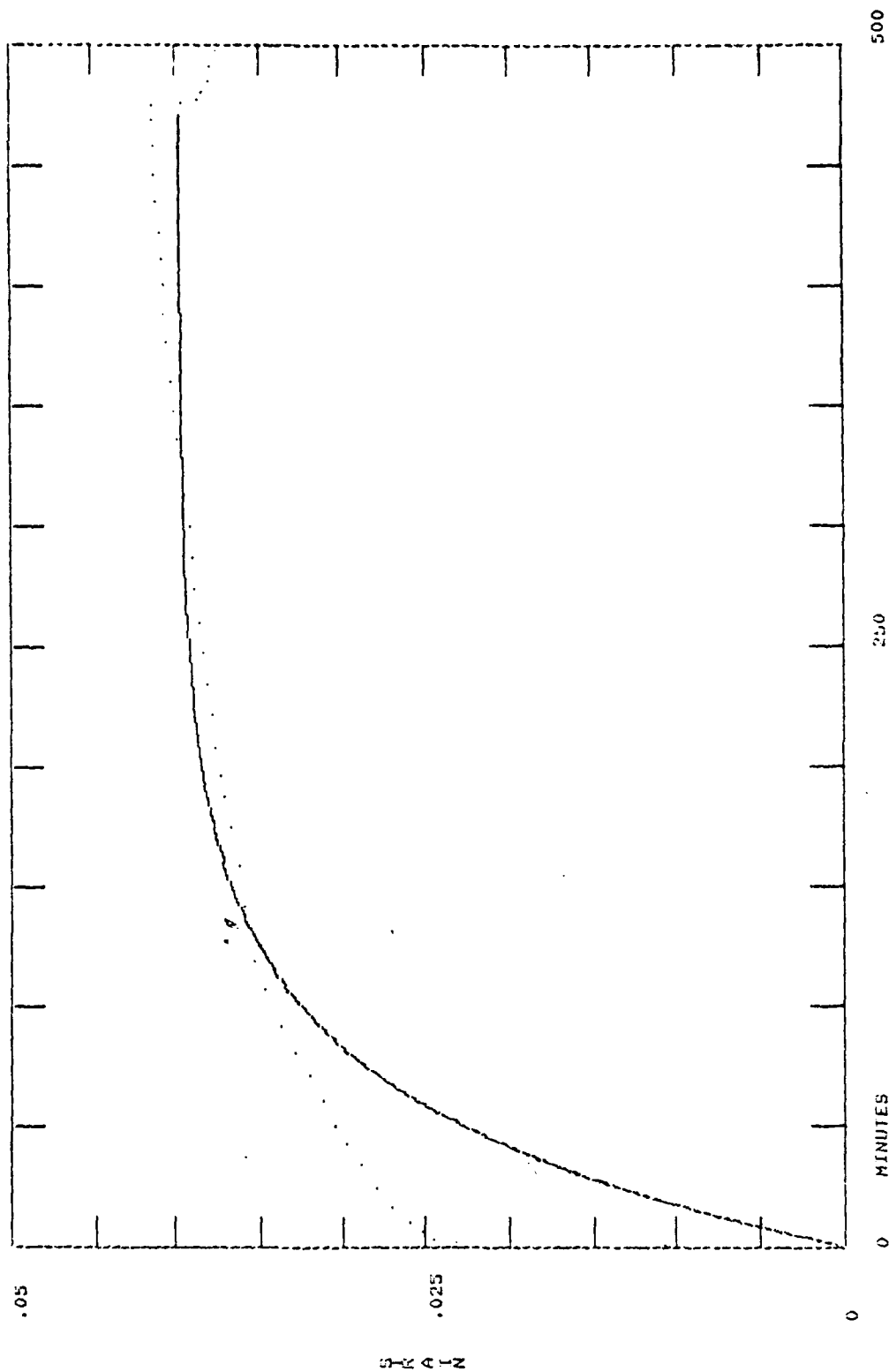
LA-30 L4-L5 16 AUG 75 AREA = 17.22 SQ CM HEIGHT = 3.16 CM
 DOTTED LINE: ORIGINAL DATA HEAVY LINE: MODEL PREDICTION



4-PARAMETER SOLID MODEL WITH VALUES OF
 $A_1 = .012624$, $B_1 = .12204$, $A_2 = .013902$, $B_2 = 3.1061E-03$
 DELTA TIME = 4
 ERROR (USING ALL POINTS): 3.980%
 ERROR (IGNORING FIRST 3 POINTS): 3.583%

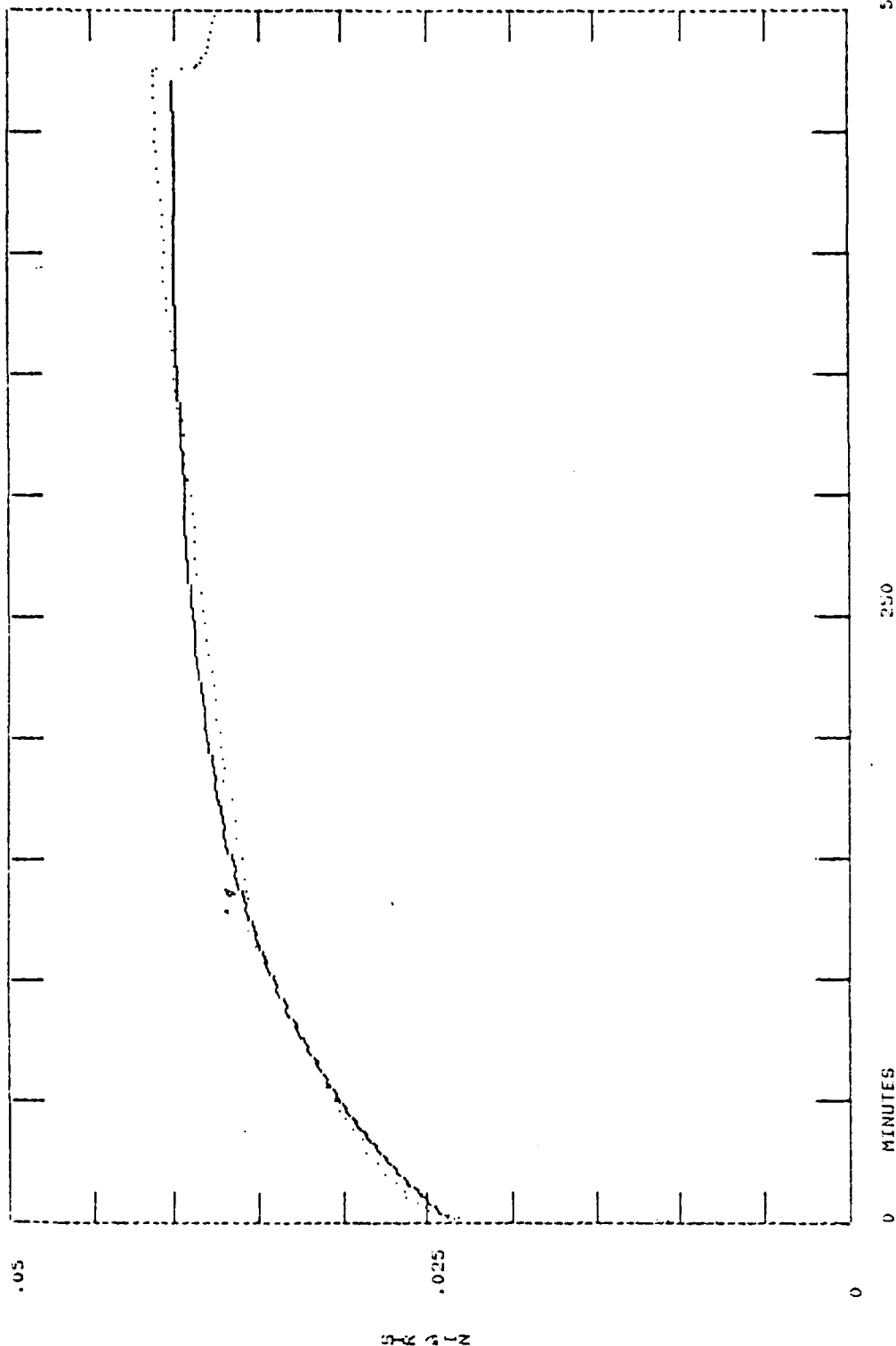
LN-30 L4-15 16 AUG 75 AREA = 17.22 SQ CM HEIGHT = 3.16 CM
 DOTTED LINE: ORIGINAL DATA
 HEAVY LINE: MODEL PREDICTION

172



2-PARAMETER SOLID MODEL WITH VALUES OF
 A1 = .039753, B1 = .017024
 DELTA TIME = 8
 ERROR (USING ALL POINTS) : 11.350%
 ERROR (IGNORING FIRST 3 POINTS) : 9.397%

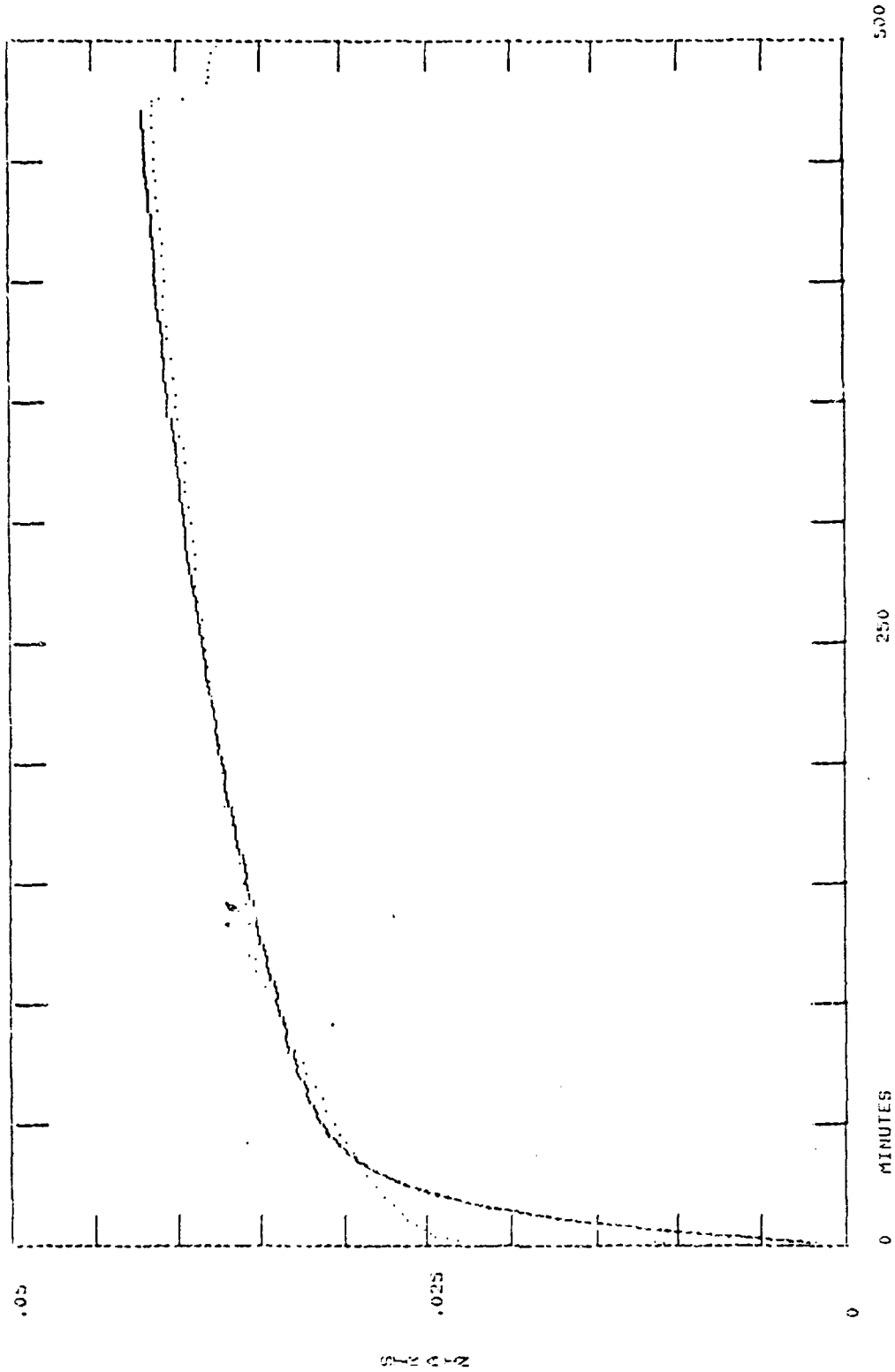
LN-31 15-51 18 AUG 75 AREA = 25.61 SQ CM HEIGHT = 3.76 CM
 DOTTED LINE: ORIGINAL DATA HEAVY LINE: MODEL PREDICTION



3-PARAMETER SOLID MODEL WITH VALUES OF
 $a_1 = .040361$, $a_2 = .010091$, $a_3 = .02367$
 DELTA TIME = 4
 ERROR (USING ALL POINTS): -1.598%
 ERROR (USING FIRST 3 POINTS): -0.487%

LN-31 15-51 18 AUG 75 AREA = 25.63 SQ CM HEIGHT = 3.76 CM
 DOTTED LINE: ORIGINAL DATA HEAVY LINE: MODEL PREDICTION

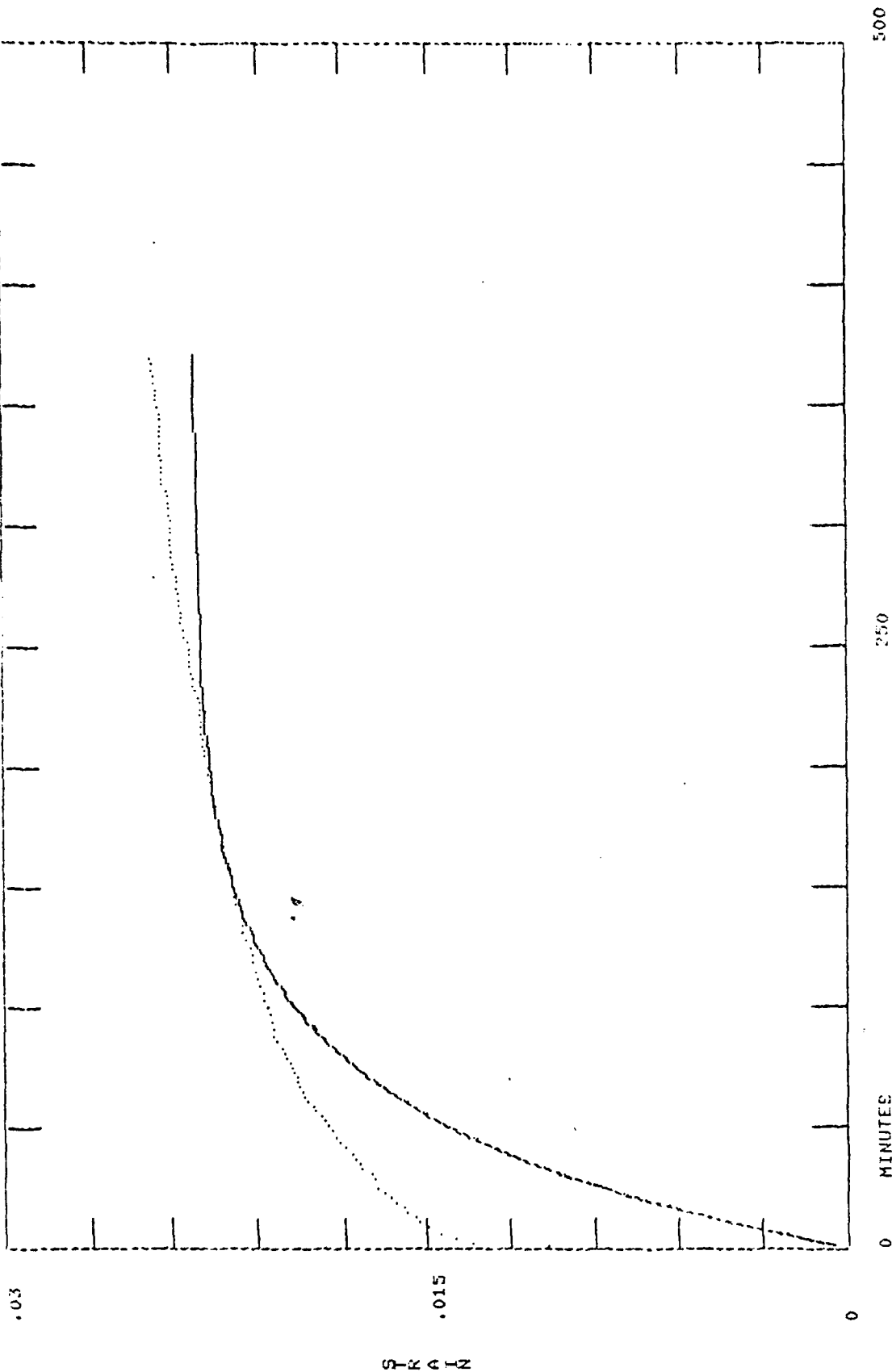
44



4-PARAMETER SOLID MODEL WITH VALUES OF
 $\Delta t = .029306$, $R1 = .076435$, $\Delta Z = .015747$, $R2 = 3.4103E-03$
 DELTA TIME = 8
 ERROR (USING ALL POINTS): 4.096%
 ERROR (IGNORING FIRST 3 POINTS): 3.794%

LN-31 15-51 18 AUG 75 AREA = 25.61 SQ CM HEIGHT = 3.76 CM
 DOTTED LINE: ORIGINAL DATA HEAVY LINE: MODEL PREDICTION

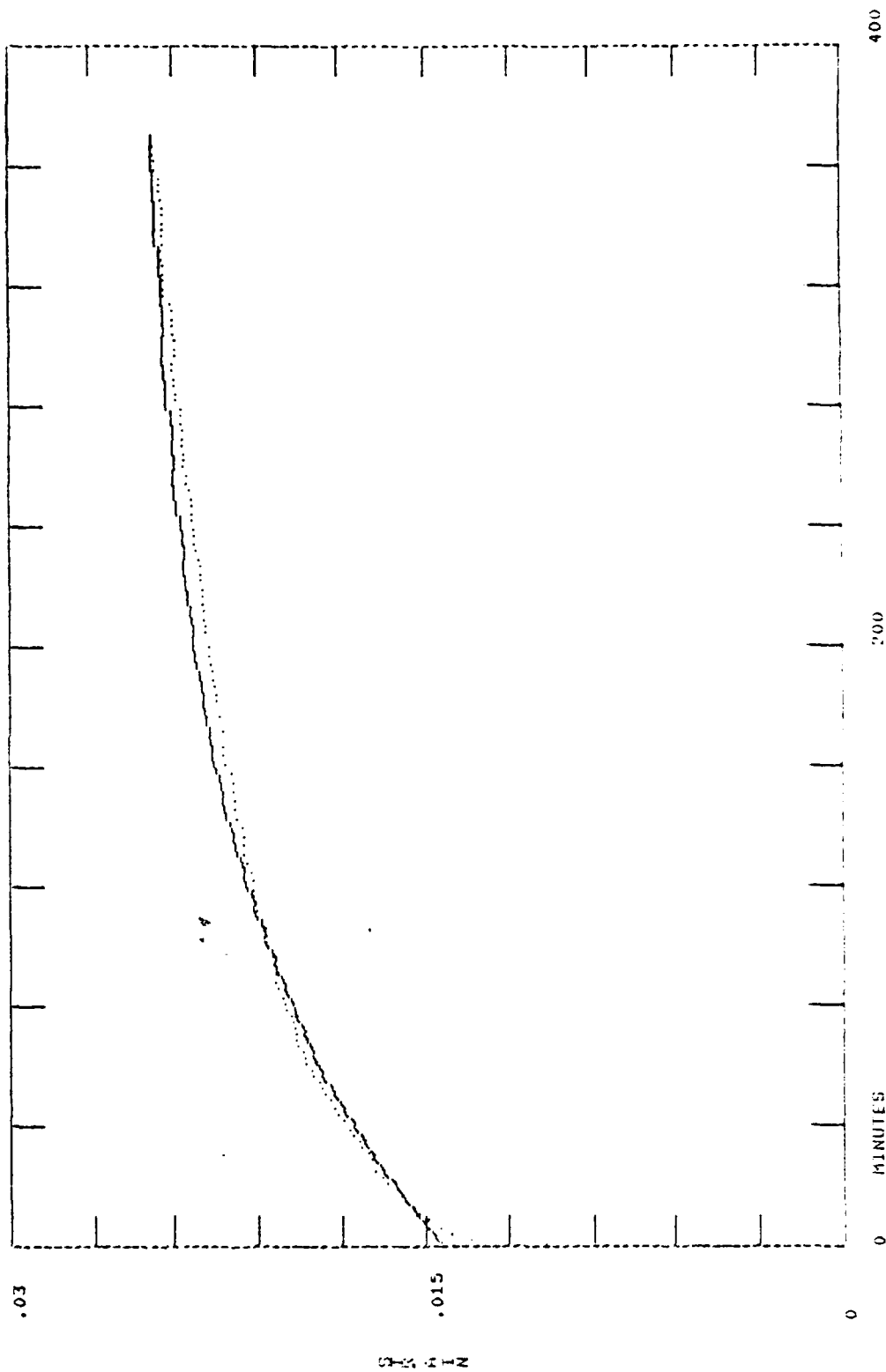
75



2-PARAMETER SOLID MODEL WITH VALUES OF
 A1 = 2.31965E-02, B1 = 1.90386E-02, A2 = 0
 B2 = 0, A3 = 0 DELTA TIME = 30
 ERROR USING ALL POINTS: 10.069%
 ERROR IGNORING FIRST 3 POINTS: 9.568%

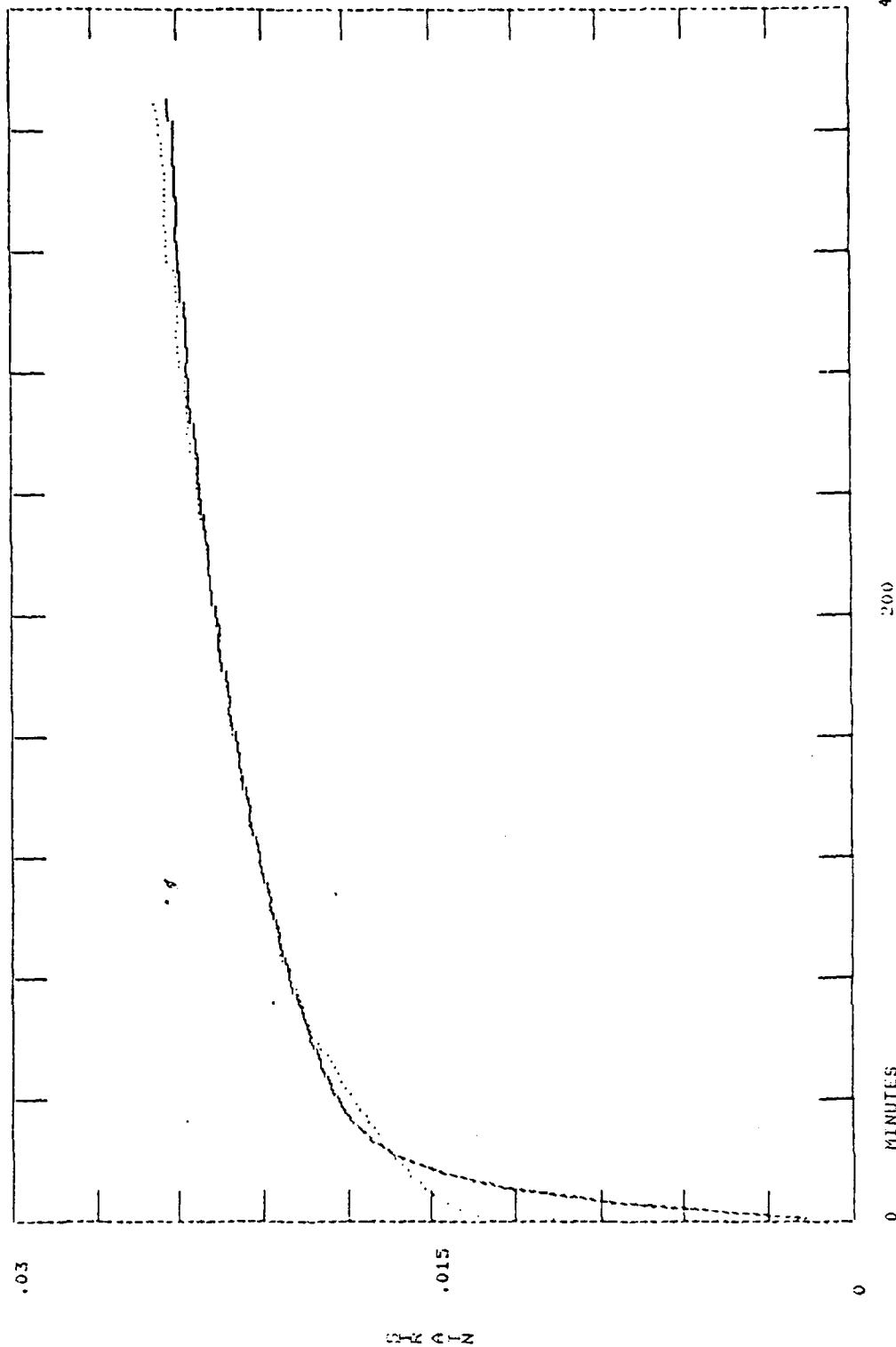
K-42 15-51 28 JAN 75 AREA = 19.21 SQ CM HEIGHT = 4.35 CM
 DOTTED LINE: ORIGINAL DATA HEAVY LINE: MODEL PREDICTION

176



3-PERFORMER SOL TO MODEL WITH VALUES OF
 AT = .0001884 AT = .0007094 AT = .0143520
 DEL TO TIME CUSING ALL POINTS: 0.7112
 PERIOD (CONSIDERING FIRST 3 POINTS): 0.8272

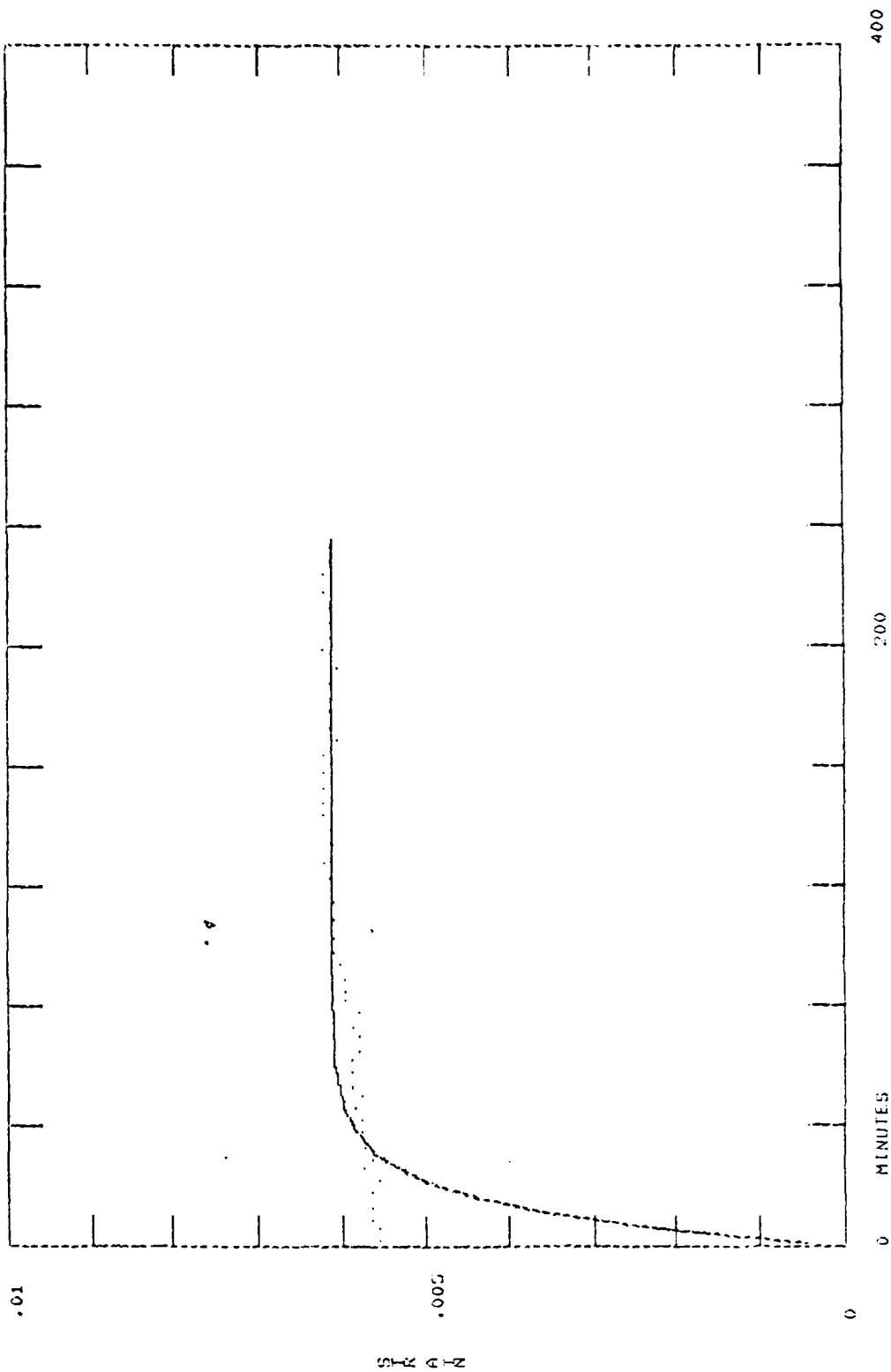
LN-42 15 51 28 JAN 75 AREA = 19.21 SQ CM HEIGHT = 4.35 CM
 DOTTED LINE: ORIGINAL DATA HEAVY LINE: MODEL PREDICTION

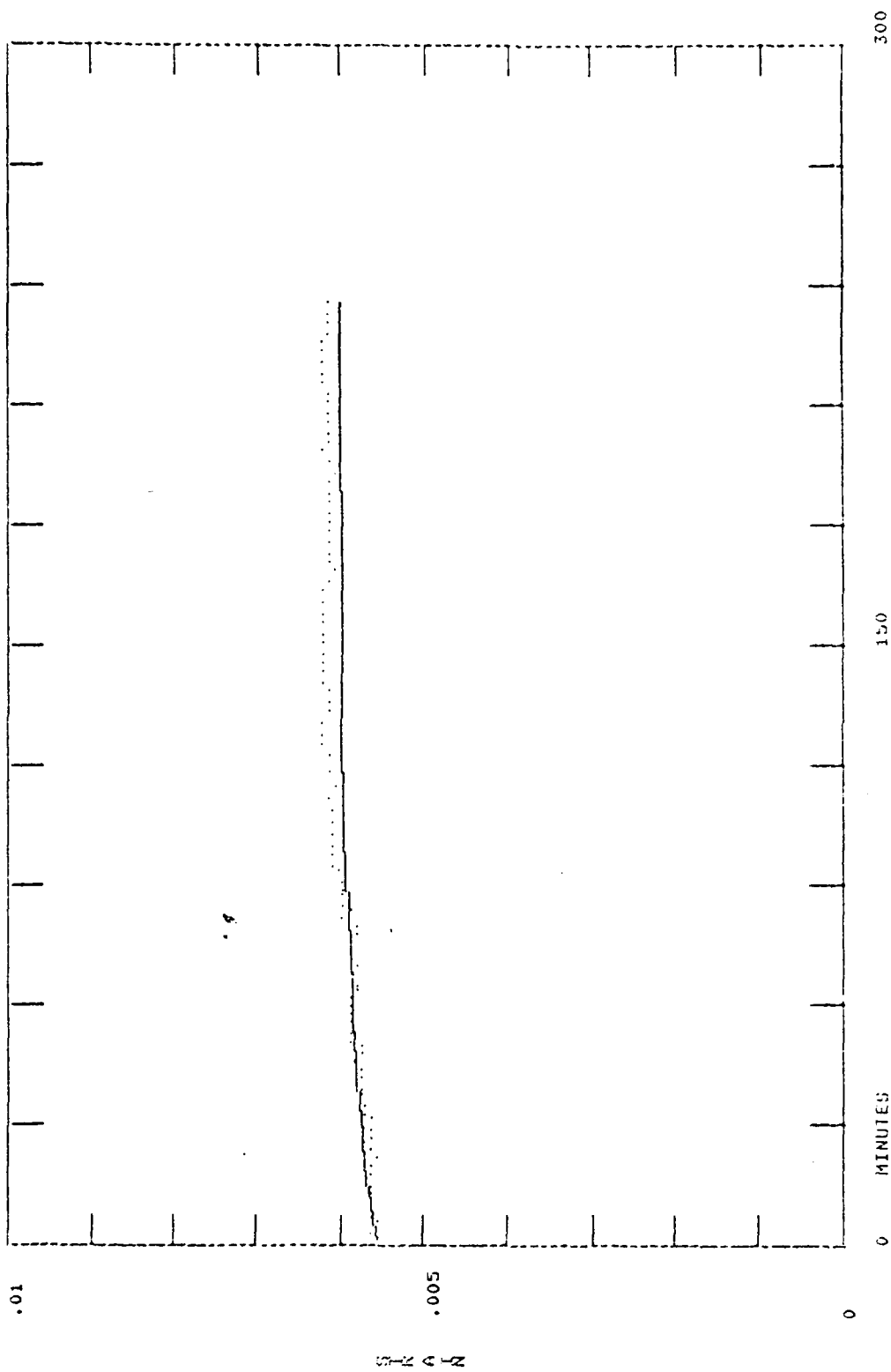


4-PARAMETER SOLID MODEL WITH VALUES OF
 A1 = .016738, B1 = .11152, A2 = .008348, B2 = 6.3364E-03
 DELTA TIME = 4
 ERROR USING ALL POINTS: 1.9282%
 ERROR IGNORING FIRST 3 POINTS: 1.4242%

177

LN-42 15-51 28 JUN 75 AREA = 19.21 SQ CM HEIGHT = 4.35 CM
 DOTTED LINE: ORIGINAL DATA HEAVY LINE: MODEL PREDICTION

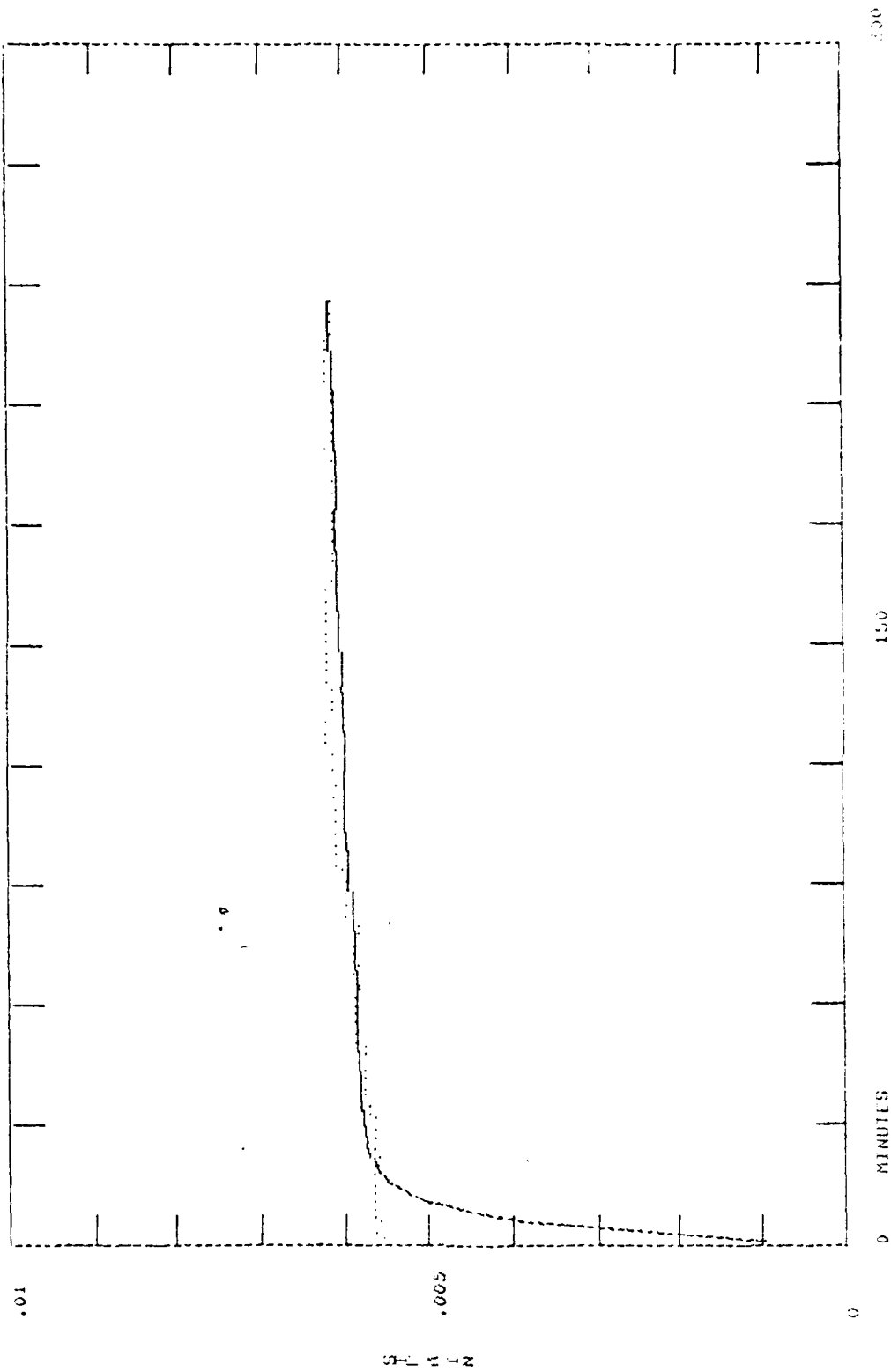




3-PARAMETER SOLID MODEL WITH VALUES OF
 A1 = 6.012E-03, A2 = .01706, A3 = 5.5012E-03
 DELTA TIME = 1.6
 ERROR USING ALL POINTS: 1.439%
 ERROR IGNORING FIRST 3 POINTS: 1.509%

LN-44 13-14 30 JAN 75 AREA = 19.64 SQ CM HEIGHT = 4.09 CM
 DOTTED LINE: ORIGINAL DATA HEAVY LINE: MODEL PREDICTION

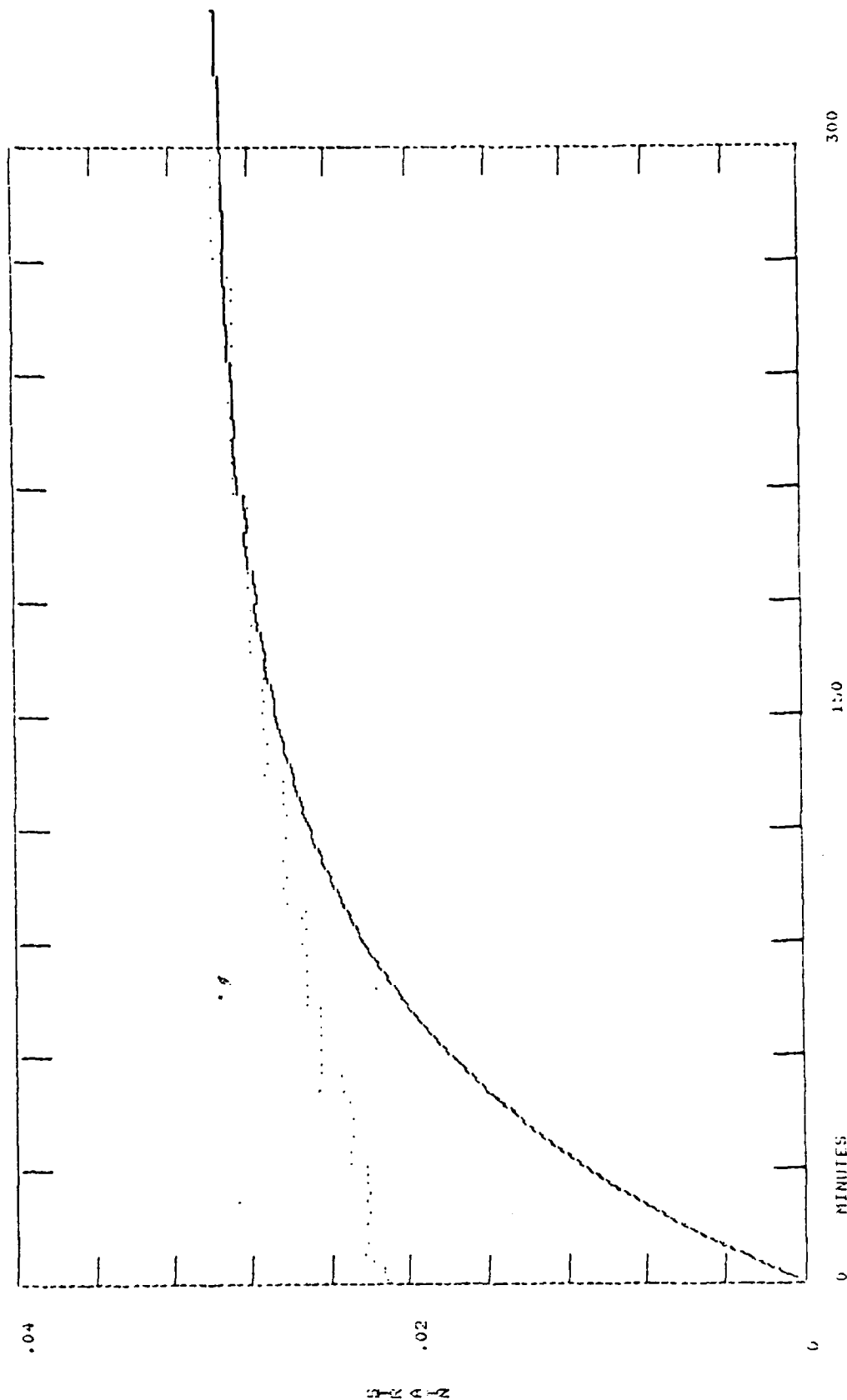
Handwritten signature or initials.



4-PROGRAMMETER SOLID MODEL WITH VALUES OF
 Q1 = 9.2495E-04, R1 = 2.9157E-03, Q2 = 5.7141E-03, R2 = .1952
 DELTA TIME = 1.6
 CUSTNO 011, POINTS: 2,000
 ERROR CIGNORNG FIRST 3 POINTS: 1.001%

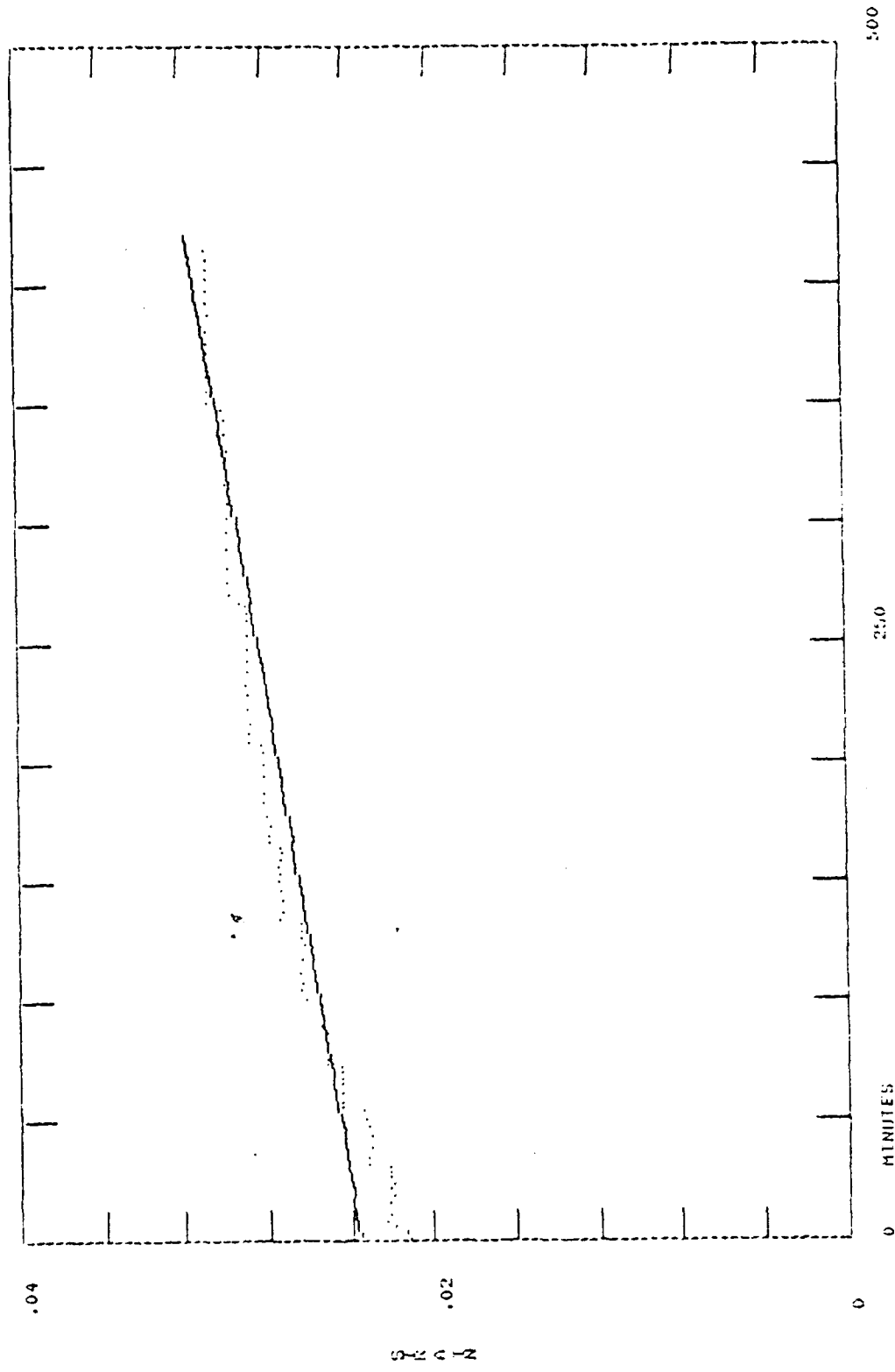
LN 44 13-14 30 JUN 75 AREA = 19.64 SQ CM HEIGHT = 4.09 CM
 BOTH LINES: ORIGINAL DATA HEAVY LINE: MODEL PREDICTION

18



2-1 PARAMETER SOLID MODEL WITH VALUES OF
 A1 = .0226567 B1 = .015358
 DELTA TIME = 4
 ERROR CUSING ALL POINTS : 18.550%
 ERROR CUSING FIRST 3 POINTS : 17.417%

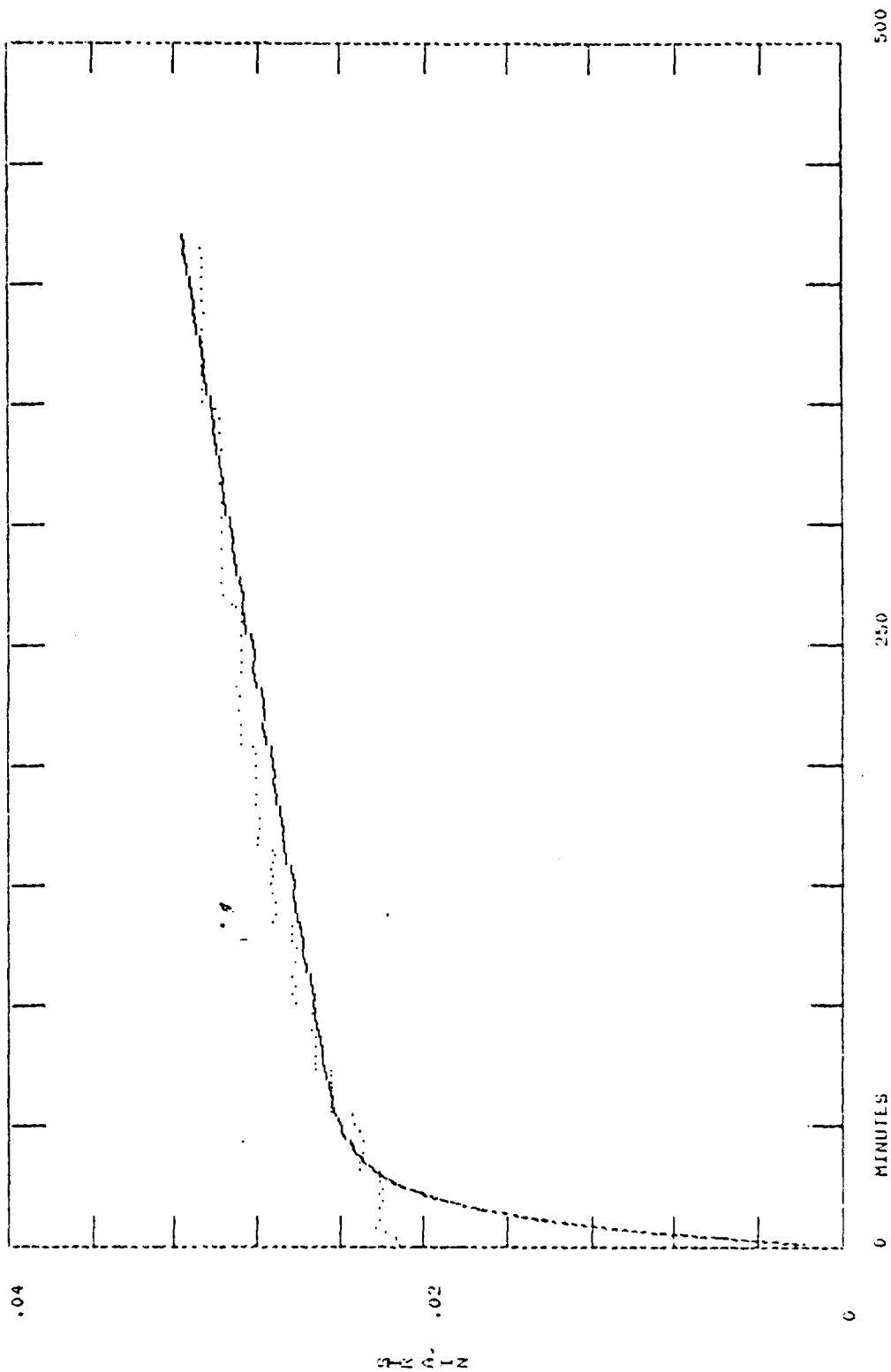
LN-45 L2-13 31 JUN 75 AREA = 18.52 SQ CM HEIGHT = 2.635 CM
 DOTTED LINE: ORIGINAL DATA HEAVY LINE: MODEL PREDICTION



3-PARAMETER SOLID MODEL WITH VALUES OF
 $\alpha_1 = 6.5512 \times 10^{-1}$ $\alpha_2 = 2.9648 \times 10^{-2}$ $\alpha_3 = .02559$
 DELTA TIME = 6
 CUSING ALL POINTS:
 ERROR CUSING FIRST 3 POINTS: 1.491%
 0.584%

1K-45 12-13 31 JAN 75 AREA = 10.52 50 CM HEIGHT = 2.635 CM
 DOTTED LINE: ORIGINAL DATA HEAVY LINE: MODEL PREDICTION

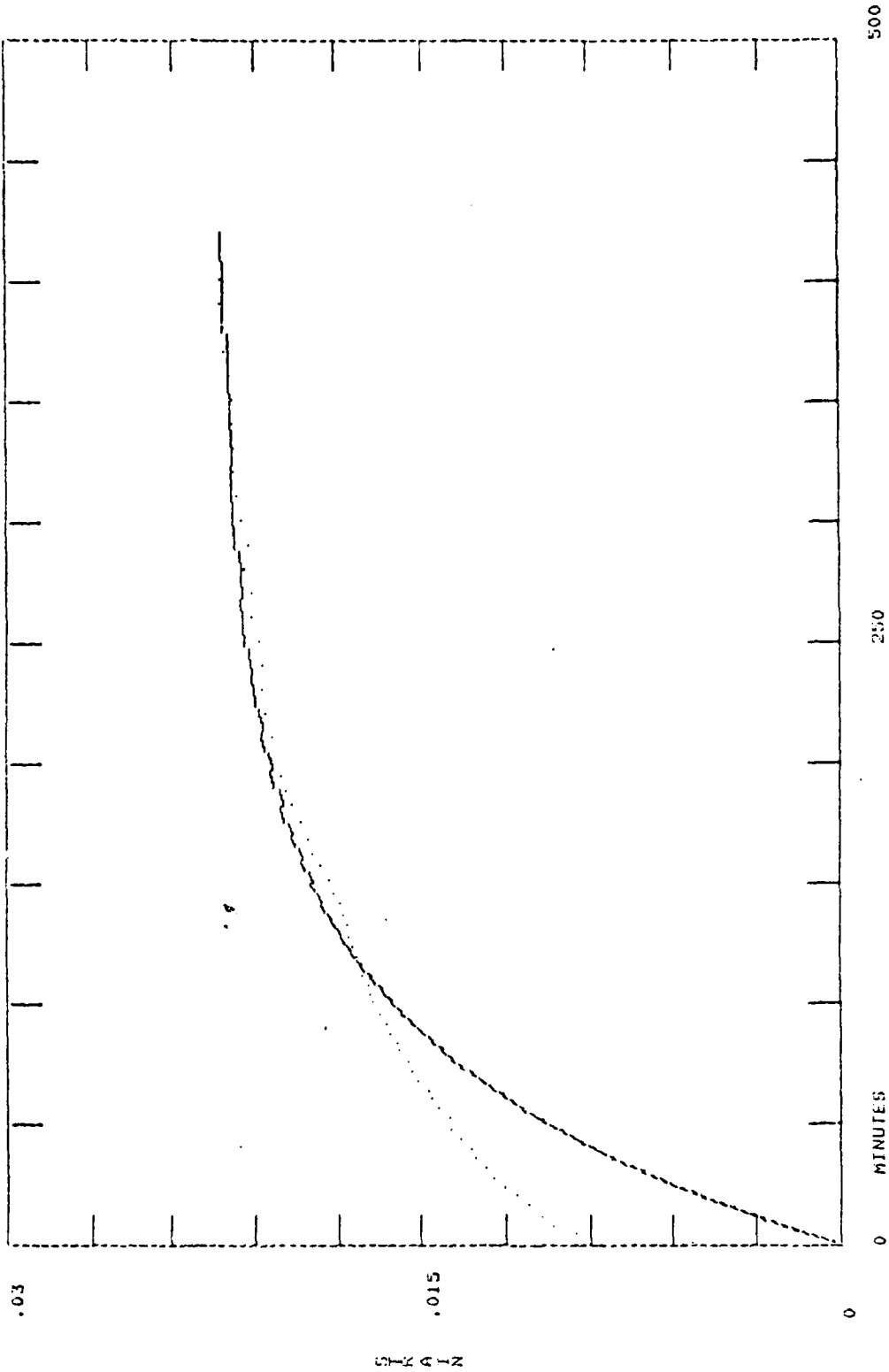
83



4 - PARAMETER SOLID MODEL WITH VALUES OF
 A1 = .082914, B1 = 2.5516E-04, A2 = .023253, B2 = .086771
 DELTA TIME = 8
 ERROR USING ALL POINTS: 5.910%
 ERROR USING FIRST 3 POINTS: 5.082%

LN-45 12-13 31 JAN 79 AREA = 19.52 SQ CM HEIGHT = 2.635 CM
 DOTTED LINE: ORIGINAL DATA HEAVY LINE: MODEL PREDICTION

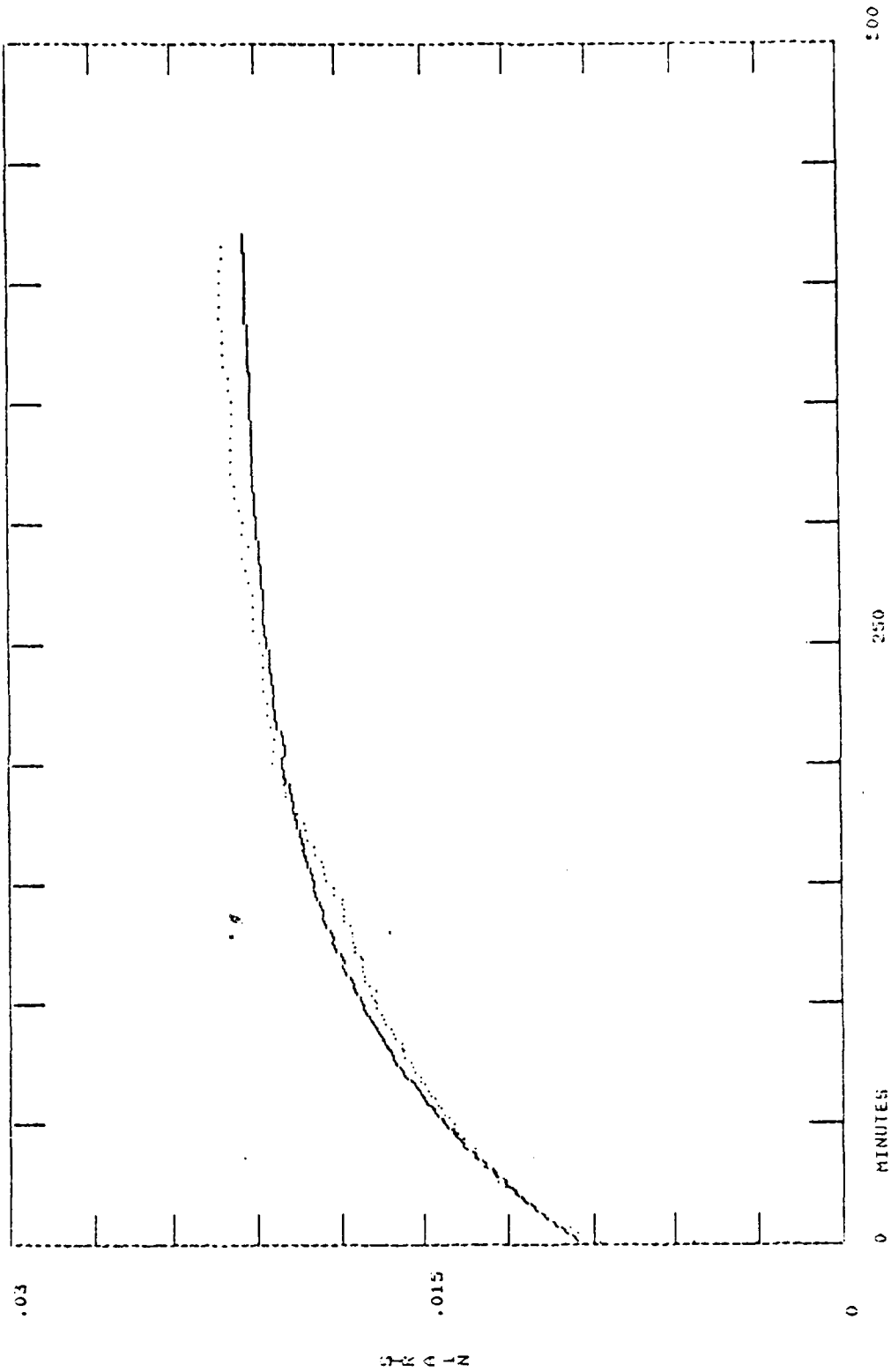
14



2-PARAMETER SOLID MODEL WITH VALUES OF
 $\alpha_1 = .022258$, $\beta_1 = .012827$
 DELTA TIME = 30
 ERROR USING ALL POINTS: 2.680%
 ERROR IGNORING FIRST 3 POINTS: 5.996%

LN-47 111-112 04 FEB 75 AREA = 19.35 SQ CM HEIGHT = 2.709 CM
 DOTTED LINE: ORIGINAL DATA HEAVY LINE: MODEL PREDICTION

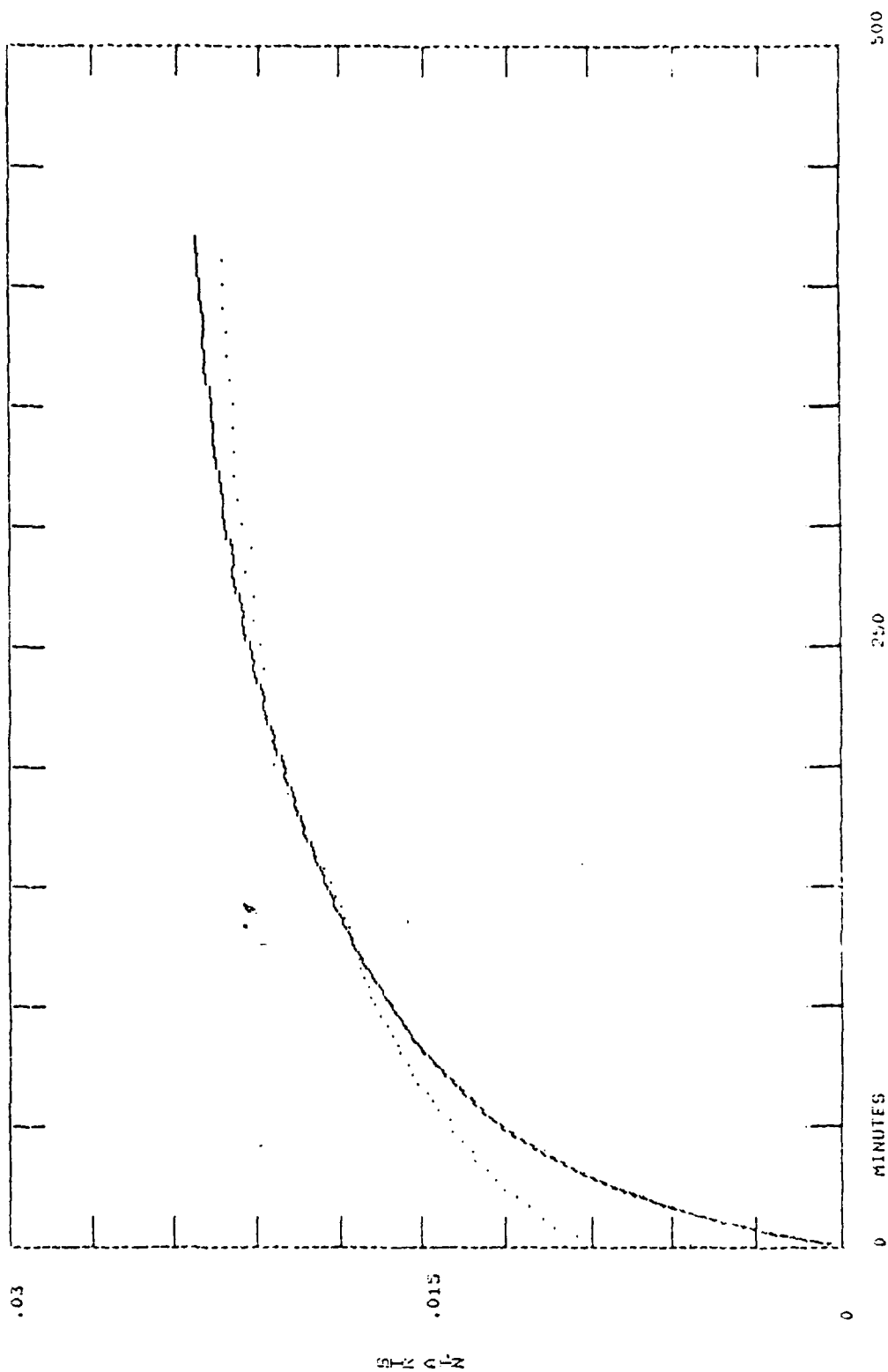
58



3-PARAMETER SOLID MODEL WITH VALUES OF
 A1 = .021585, B1 = .010397, A2 = 4.3346E-03
 DELTA TIME = 4
 ERROR (USING ALL POINTS) = 0.410%
 ERROR (CONSIDERING FIRST 3 POINTS) = 0.217%

LN-47 T11-T12 04 FEB 75 AREA = 19.35 50 CM HEIGHT = 2.789 CM
 DOTTED LINE: ORIGINAL DATA HEAVY LINE: MODEL PREDICTION

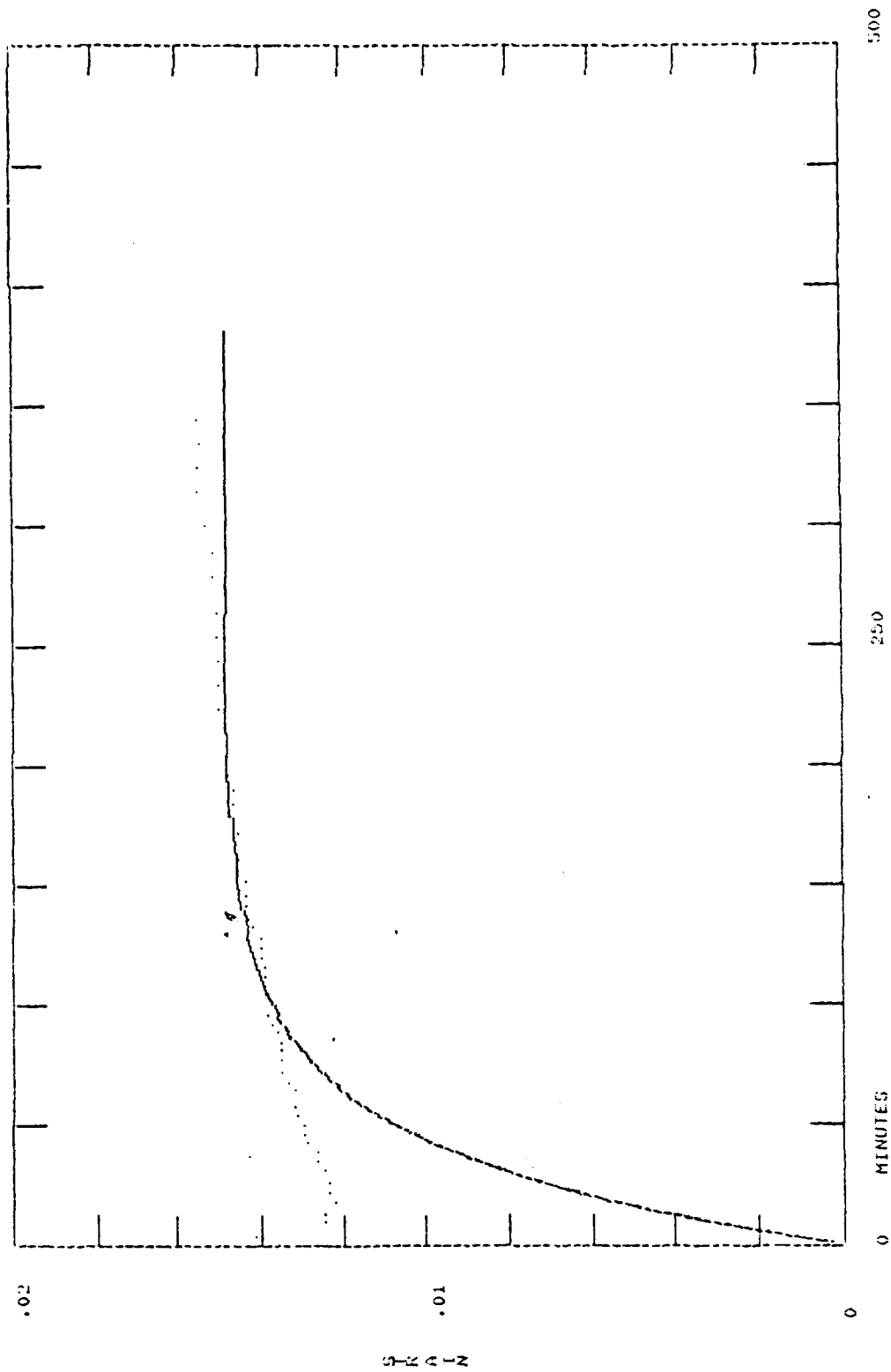
56



4-PARAMETER SOLID MODEL WITH VALUES OF
 A1 = 8.5873E-03, B1 = .048919, C2 = .018576, B2 = 6.8079E-03
 DELTA TIME = 30
 ERROR USING ALL POINTS: 4.7332%
 ERROR USING FIRST 3 POINTS: 3.186%

LR 47 111 112 04 FEB 75 AREA = 19.35 SQ CM HEIGHT = 2.789 CM
 PLOTTED LINE: ORIGINAL DATA HEAVY LINE: MODEL PREDICTION

17



2-PARAMETER SOLID MODEL WITH VALUES OF

$\alpha_1 = .014856$, $\beta_1 = .026165$

DELTA TIME = 1.6

ERROR (USING ALL POINTS):

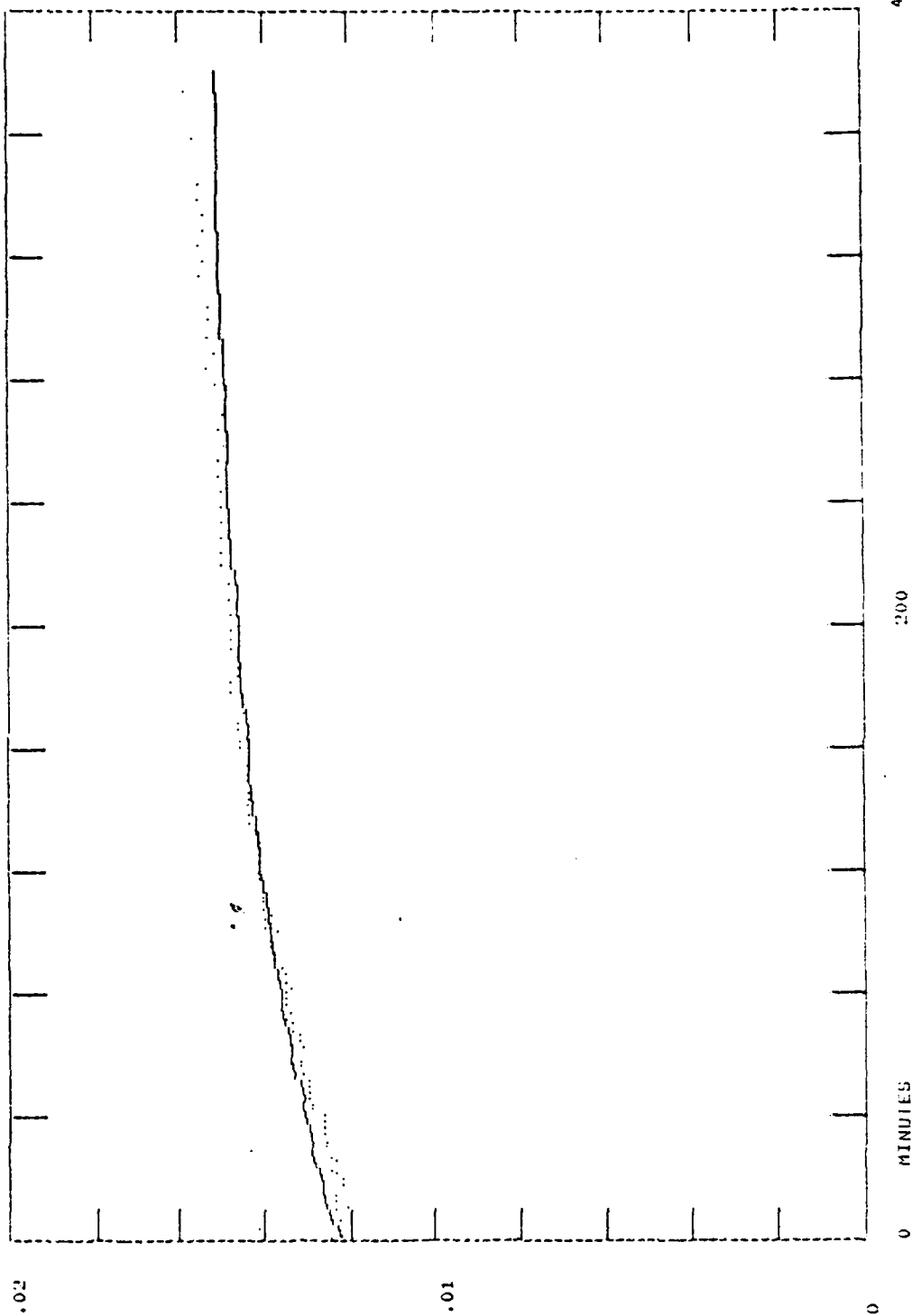
10.657%

ERROR (CONDENSING FIRST 3 POINTS):

7.323%

LK-48 112-11 5 FEB 75 ARLA = 24.18 50 CM HEIGHT = 2.34 CM

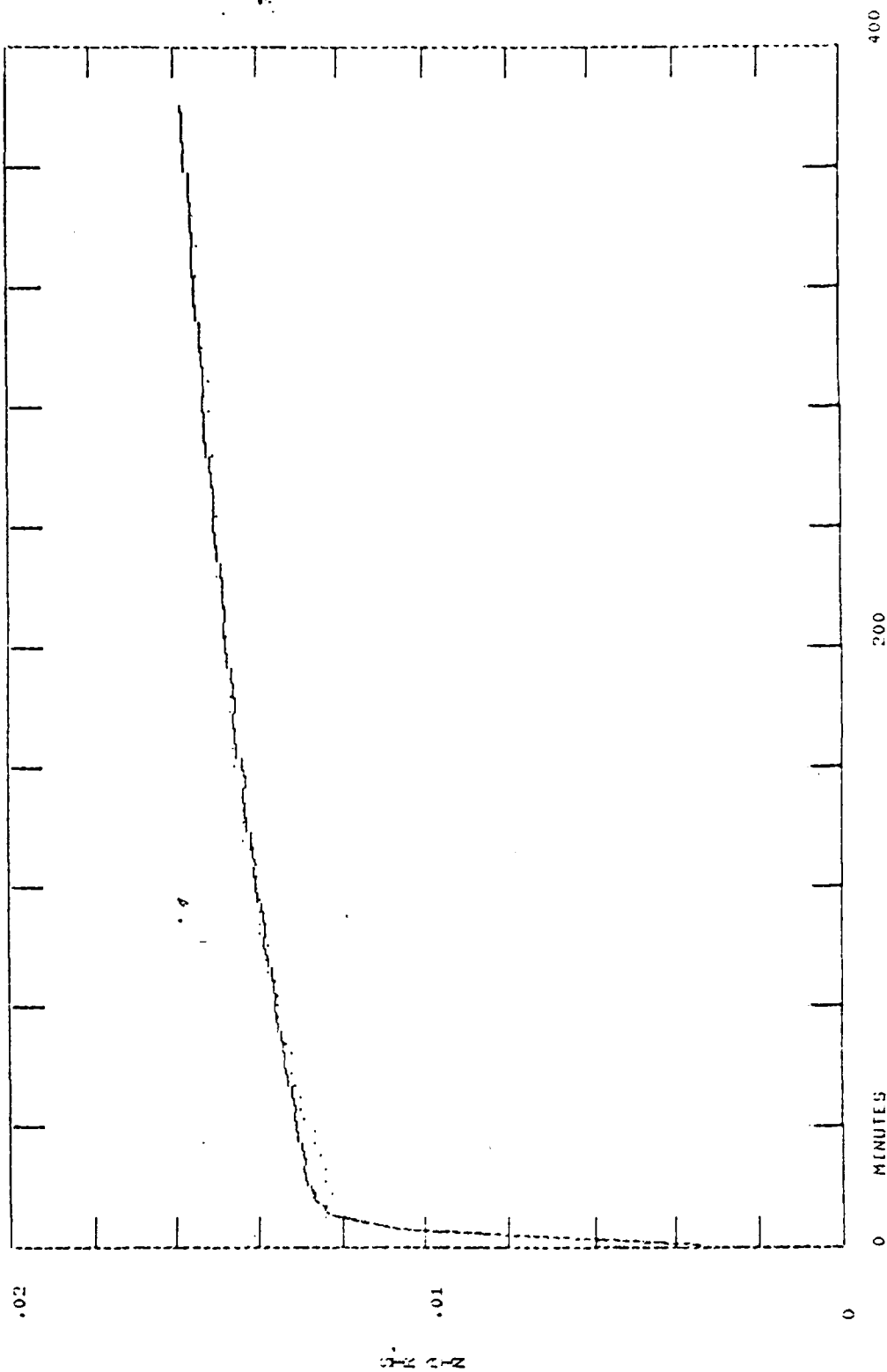
DOTTED LINE: ORIGINAL DATA HEAVY LINE: MODEL PREDICTION



3-PARAMETER SOLID MODEL WITH VALUES OF
 Q1 = .015514 Q2 = 7.3452E-05 Q3 = .012329
 DELETED TIME = 4
 CUSTING ALL POINTS;
 ERROR (CONVERTING FIRST 3 POINTS):
 0.020%
 0.012%

LN-40 112.11 5 FEB 75 AREA - 24.10 SQ CM HEIGHT - 2.34 CM
 PLOTTED TIME: ORIGINAL DATA HEAVY LINE: MODEL PREDICTION

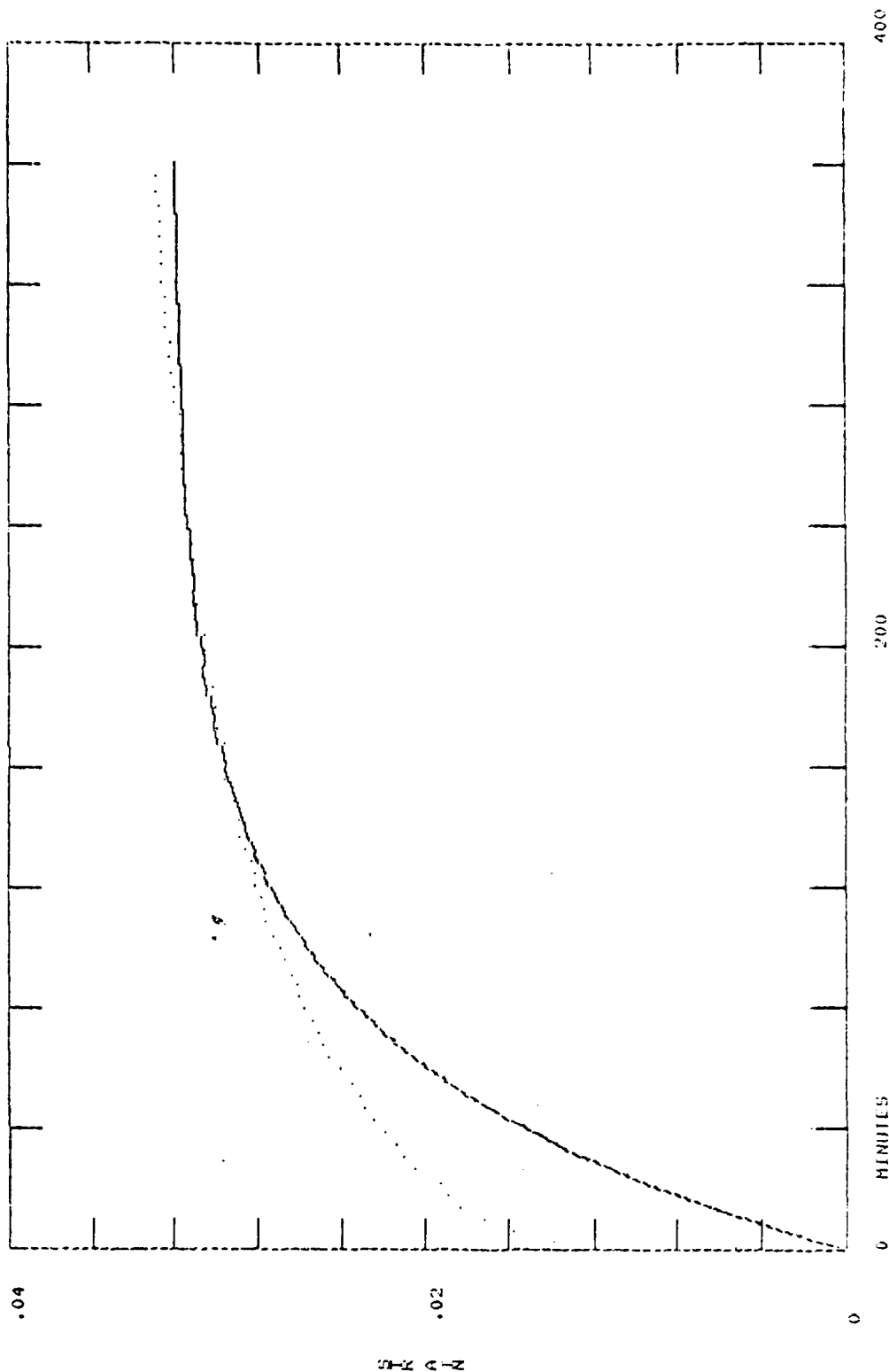
64



4-PARAMETER SOLID MODEL WITH VALUES OF
 A1 = .012508, A2 = .31876, A3 = 4.3489E-03, A4 = 3.6551E-03
 DELTA TIME = 16
 ERROR USING ALL POINTS: 1.254%
 ERROR (IGNORING FIRST 3 POINTS): 0.438%

90

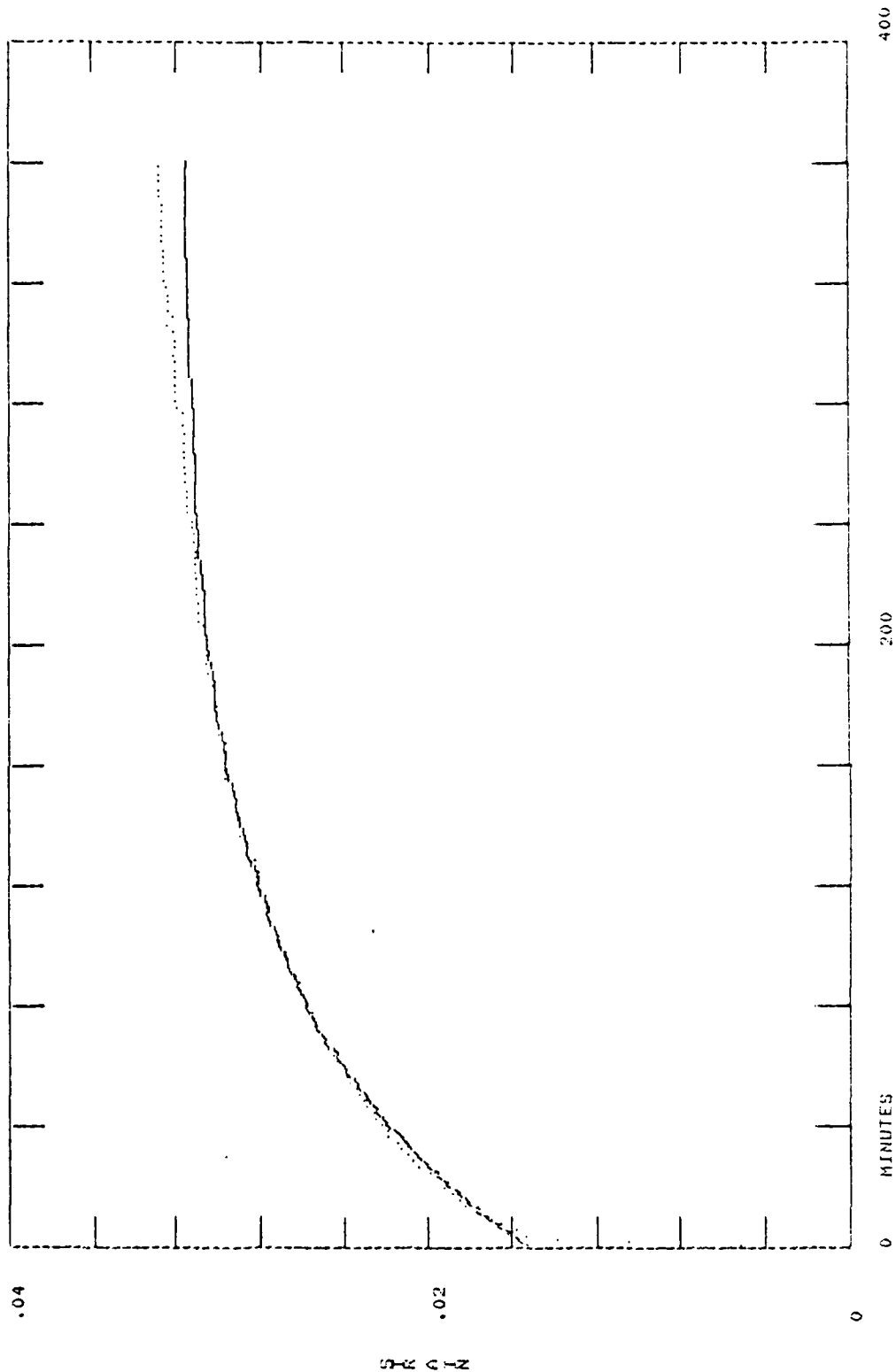
LN-48 T12-11 5 FEB 75 AREA = 24.18 SQ CM HEIGHT = 2.34 CM
 DOTTED LINE: ORIGINAL DATA HEAVY LINE: MODEL PREDICTION



2-PARAMETER SOLID MODEL WITH VALUES OF
 $\alpha_1 = .032037$, $\beta_1 = .016227$
 DELTA TIME = 16
 ERROR (USING ALL POINTS): 8.211%
 ERROR (USING FIRST 3 POINTS): 6.896%

LN-49 19-TIO 6 JUL 75 AREA = 19.99 SQ CM HEIGHT = 2.171 CM
 DOTTED LINE: ORIGINAL DATA HEAVY LINE: MODEL PREDICTION

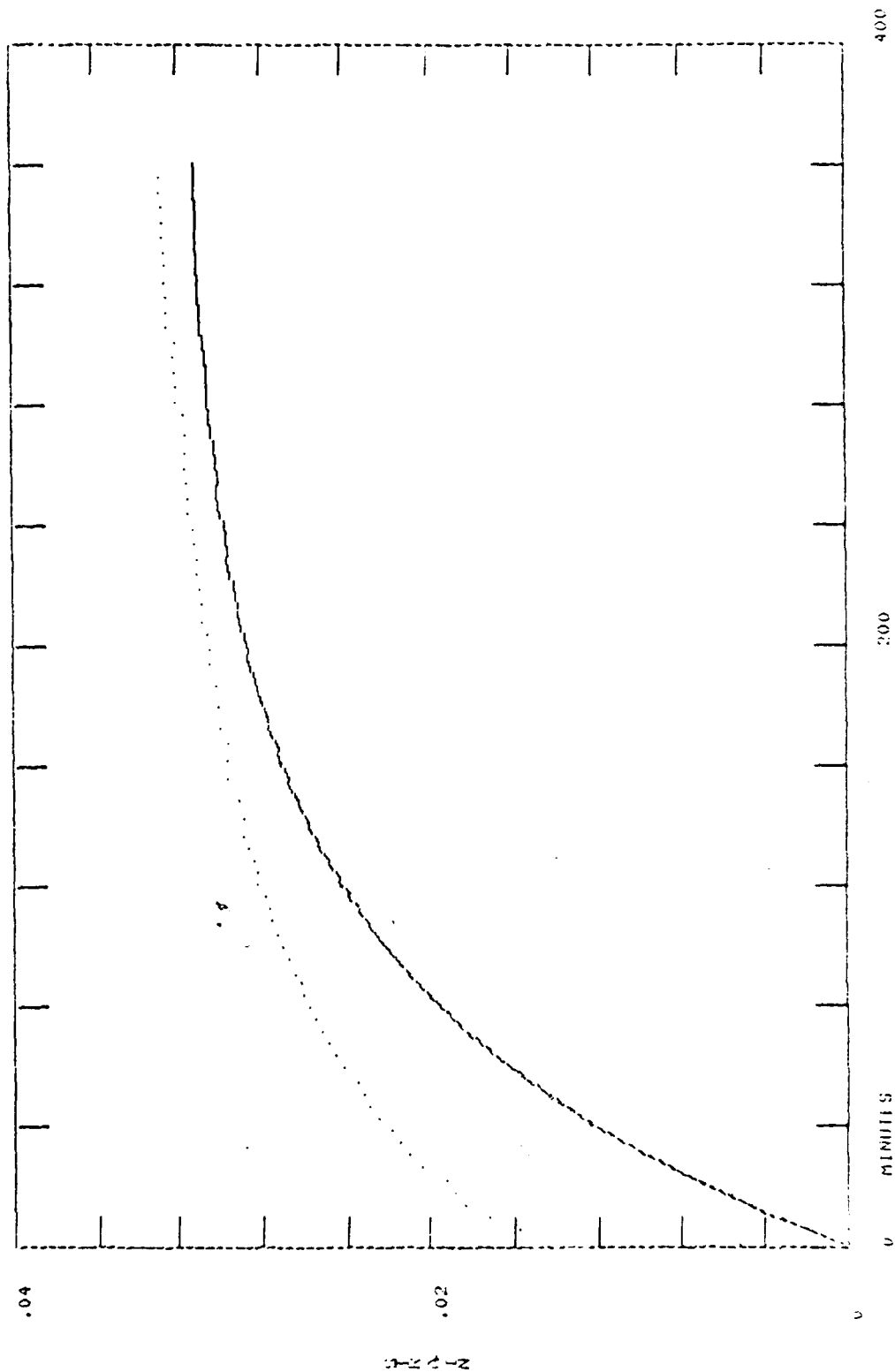
11



3-PARAMETER SOLID MODEL WITH VALUES OF
 A1 = .03172, B1 = .012725, A2 = .015214
 DELTA TIME = 4
 ERROR (USING ALL POINTS): 0.847%
 ERROR (IGNORING FIRST 3 POINTS): 1.203%

LA-49 T9-110 6 FEB 75 AREA = 19.99 SQ CM HEIGHT = 2.171 CM
 DOTTED LINE: ORIGINAL DATA HEAVY LINE: MODEL PREDICTION

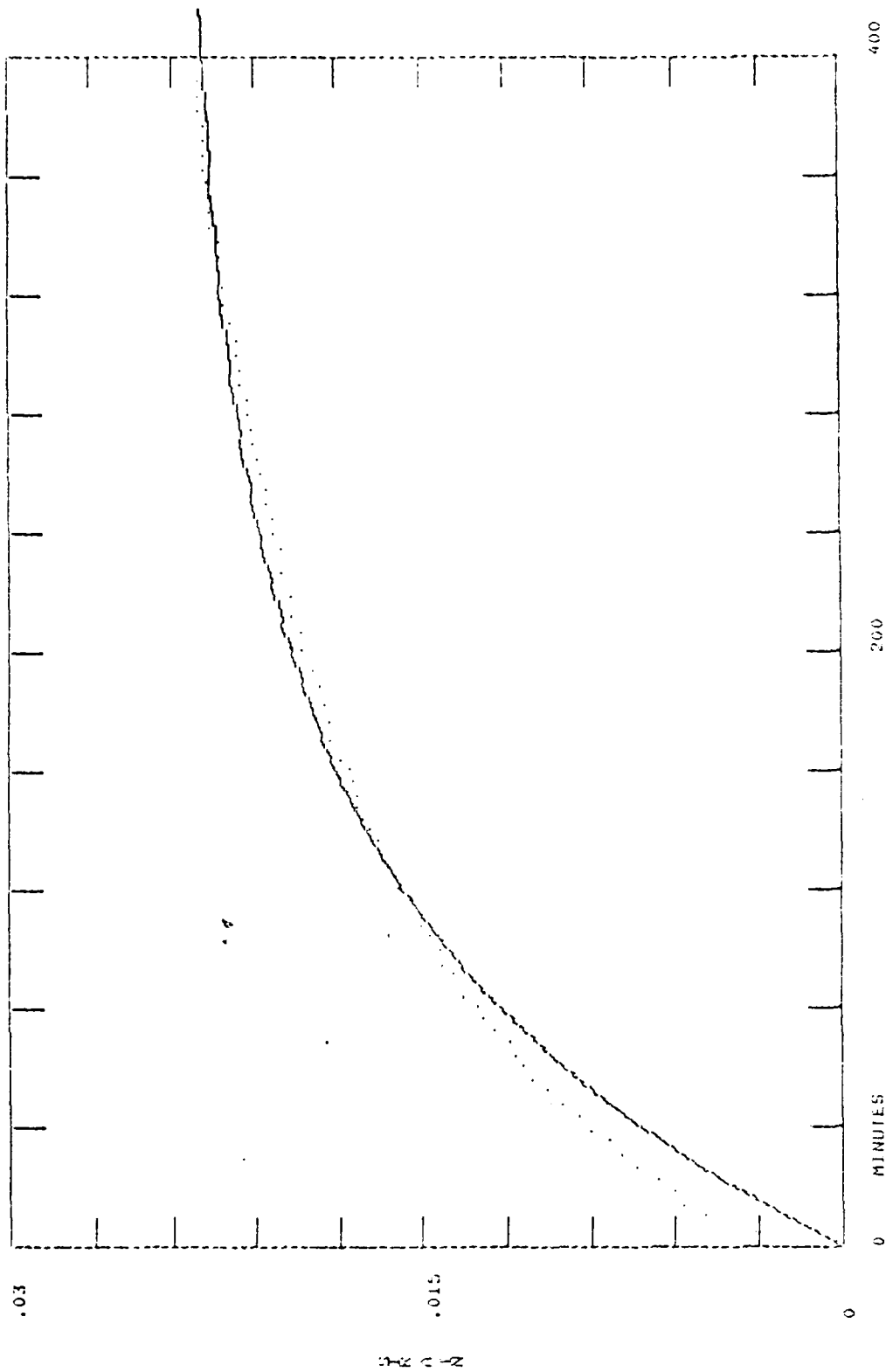
97



4- PREDICTED SOLID MODEL WITH VALUES OF
 Q1 = .014033, Q2 = .01084, Q3 = .017681, Q4 = .013027
 Q5 = .014033, Q6 = .01084, Q7 = .017681, Q8 = .013027
 Q9 = .014033, Q10 = .01084, Q11 = .017681, Q12 = .013027
 Q13 = .014033, Q14 = .01084, Q15 = .017681, Q16 = .013027
 Q17 = .014033, Q18 = .01084, Q19 = .017681, Q20 = .013027
 Q21 = .014033, Q22 = .01084, Q23 = .017681, Q24 = .013027
 Q25 = .014033, Q26 = .01084, Q27 = .017681, Q28 = .013027
 Q29 = .014033, Q30 = .01084, Q31 = .017681, Q32 = .013027
 Q33 = .014033, Q34 = .01084, Q35 = .017681, Q36 = .013027
 Q37 = .014033, Q38 = .01084, Q39 = .017681, Q40 = .013027
 Q41 = .014033, Q42 = .01084, Q43 = .017681, Q44 = .013027
 Q45 = .014033, Q46 = .01084, Q47 = .017681, Q48 = .013027
 Q49 = .014033, Q50 = .01084, Q51 = .017681, Q52 = .013027
 Q53 = .014033, Q54 = .01084, Q55 = .017681, Q56 = .013027
 Q57 = .014033, Q58 = .01084, Q59 = .017681, Q60 = .013027
 Q61 = .014033, Q62 = .01084, Q63 = .017681, Q64 = .013027
 Q65 = .014033, Q66 = .01084, Q67 = .017681, Q68 = .013027
 Q69 = .014033, Q70 = .01084, Q71 = .017681, Q72 = .013027
 Q73 = .014033, Q74 = .01084, Q75 = .017681, Q76 = .013027
 Q77 = .014033, Q78 = .01084, Q79 = .017681, Q80 = .013027
 Q81 = .014033, Q82 = .01084, Q83 = .017681, Q84 = .013027
 Q85 = .014033, Q86 = .01084, Q87 = .017681, Q88 = .013027
 Q89 = .014033, Q90 = .01084, Q91 = .017681, Q92 = .013027
 Q93 = .014033, Q94 = .01084, Q95 = .017681, Q96 = .013027
 Q97 = .014033, Q98 = .01084, Q99 = .017681, Q100 = .013027

IN 42 12 110 5 FEB 75 ORCA = 12.99 50 CM HEIGHT = 2.171 CM
 DOTTED LINE: ORIGINAL DATA HEAVY LINE: MODEL PREDICTION

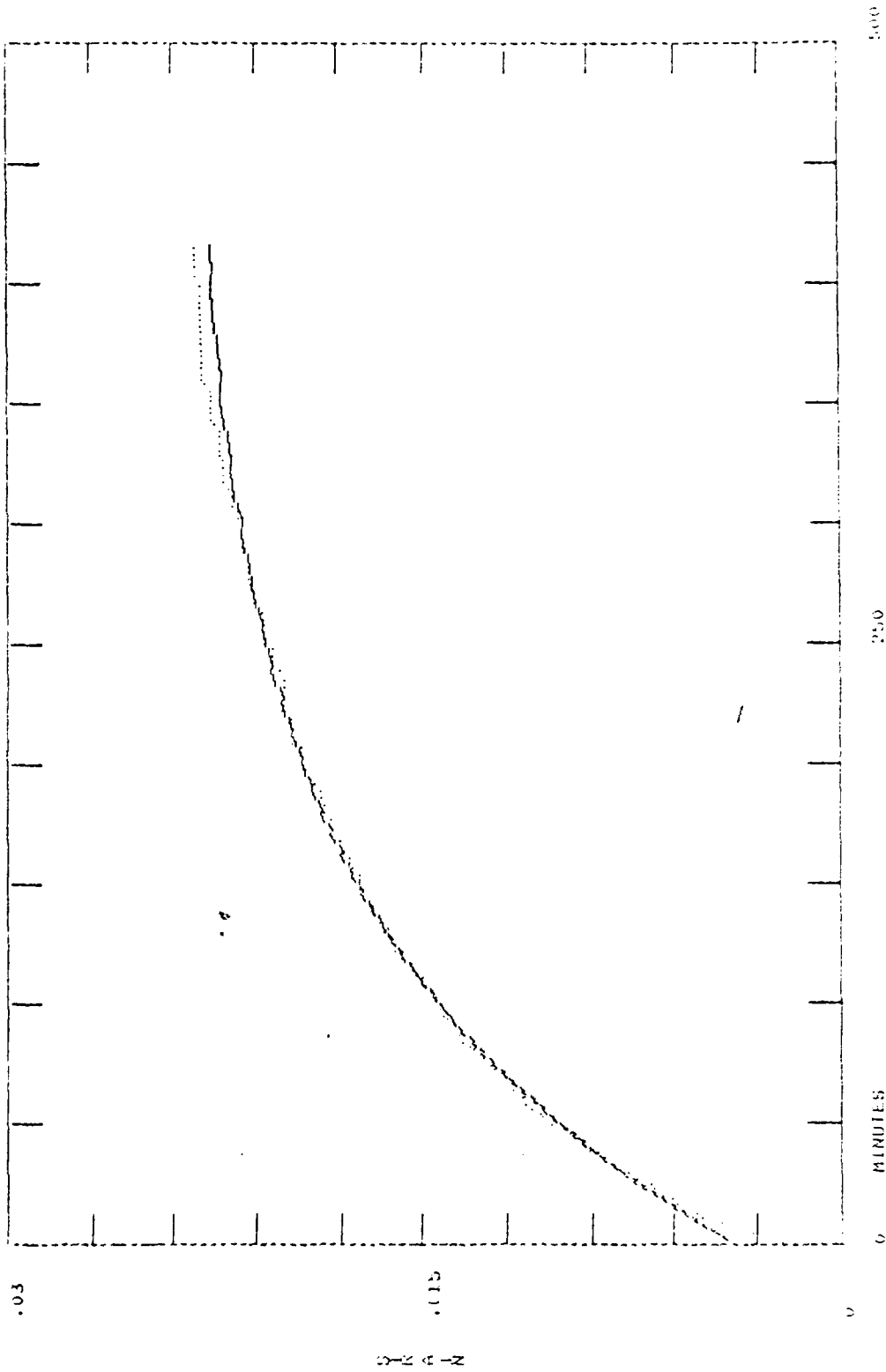
93



2-PROGRAMMER SOLID MODEL WITH VALUES OF
 Q1 = .0234434 RT = 9.2364E-03
 INITIAL TIME = 30
 ERROR CLUSTERS ALL POINTS >:
 ERROR CLUSTERING FIRST 3 POINTS >:
 1.9223%
 1.5540%

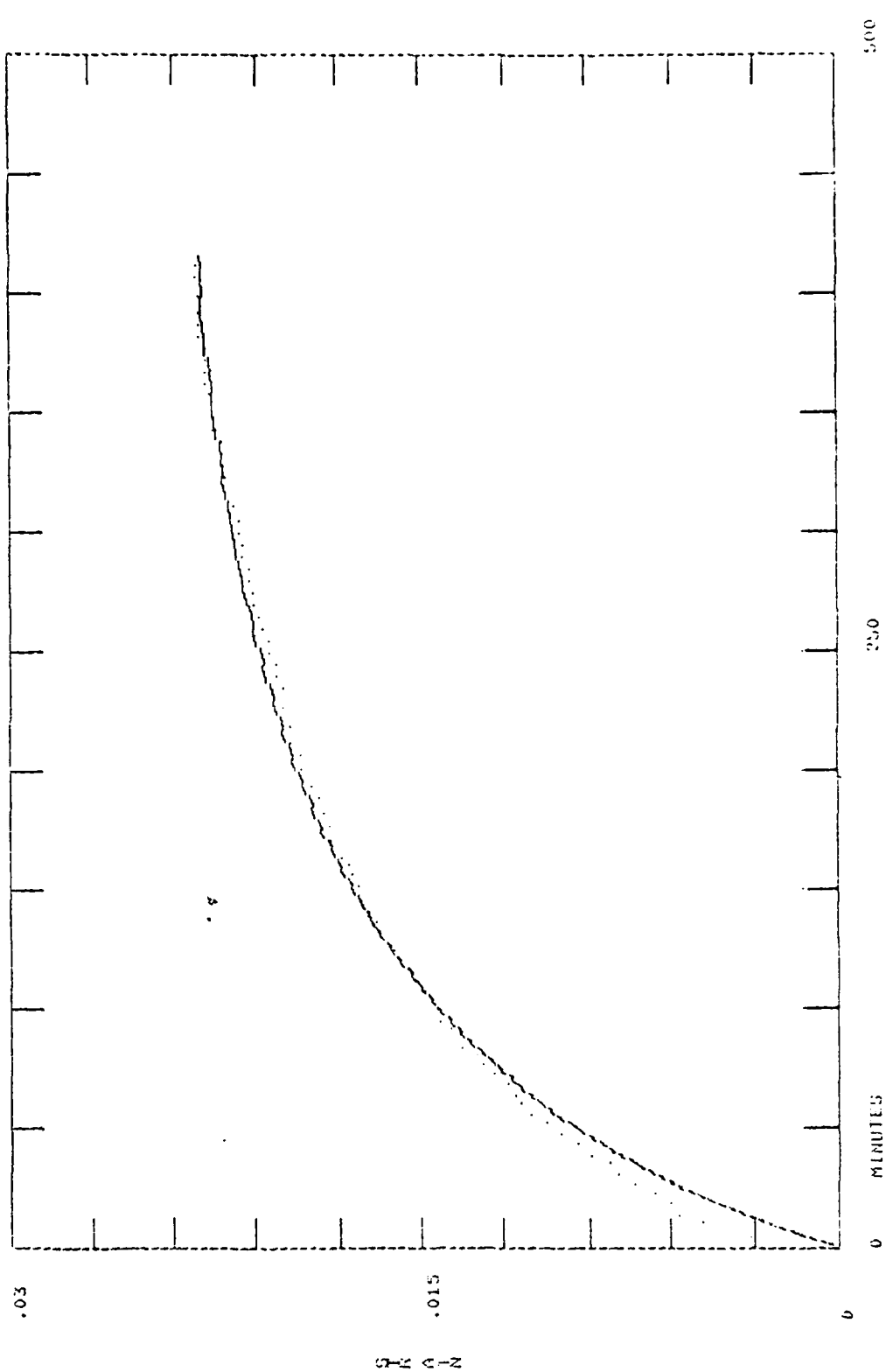
11-50 110 111 7 116 75 AREA = 10.26 50 CM HEIGHT = 2.10 CM
 DOTTED LINE: ORIGINAL DATA HEAVY LINE: MODEL PREDICTION

7.7



3. PLOTTER SOLID MODEL WITH VALUES OF
 1.0, 2.0, 3.0, 4.0, 5.0, 6.0, 7.0, 8.0, 9.0, 10.0, 11.0, 12.0, 13.0, 14.0, 15.0, 16.0, 17.0, 18.0, 19.0, 20.0, 21.0, 22.0, 23.0, 24.0, 25.0, 26.0, 27.0, 28.0, 29.0, 30.0, 31.0, 32.0, 33.0, 34.0, 35.0, 36.0, 37.0, 38.0, 39.0, 40.0, 41.0, 42.0, 43.0, 44.0, 45.0, 46.0, 47.0, 48.0, 49.0, 50.0, 51.0, 52.0, 53.0, 54.0, 55.0, 56.0, 57.0, 58.0, 59.0, 60.0, 61.0, 62.0, 63.0, 64.0, 65.0, 66.0, 67.0, 68.0, 69.0, 70.0, 71.0, 72.0, 73.0, 74.0, 75.0, 76.0, 77.0, 78.0, 79.0, 80.0, 81.0, 82.0, 83.0, 84.0, 85.0, 86.0, 87.0, 88.0, 89.0, 90.0, 91.0, 92.0, 93.0, 94.0, 95.0, 96.0, 97.0, 98.0, 99.0, 100.0

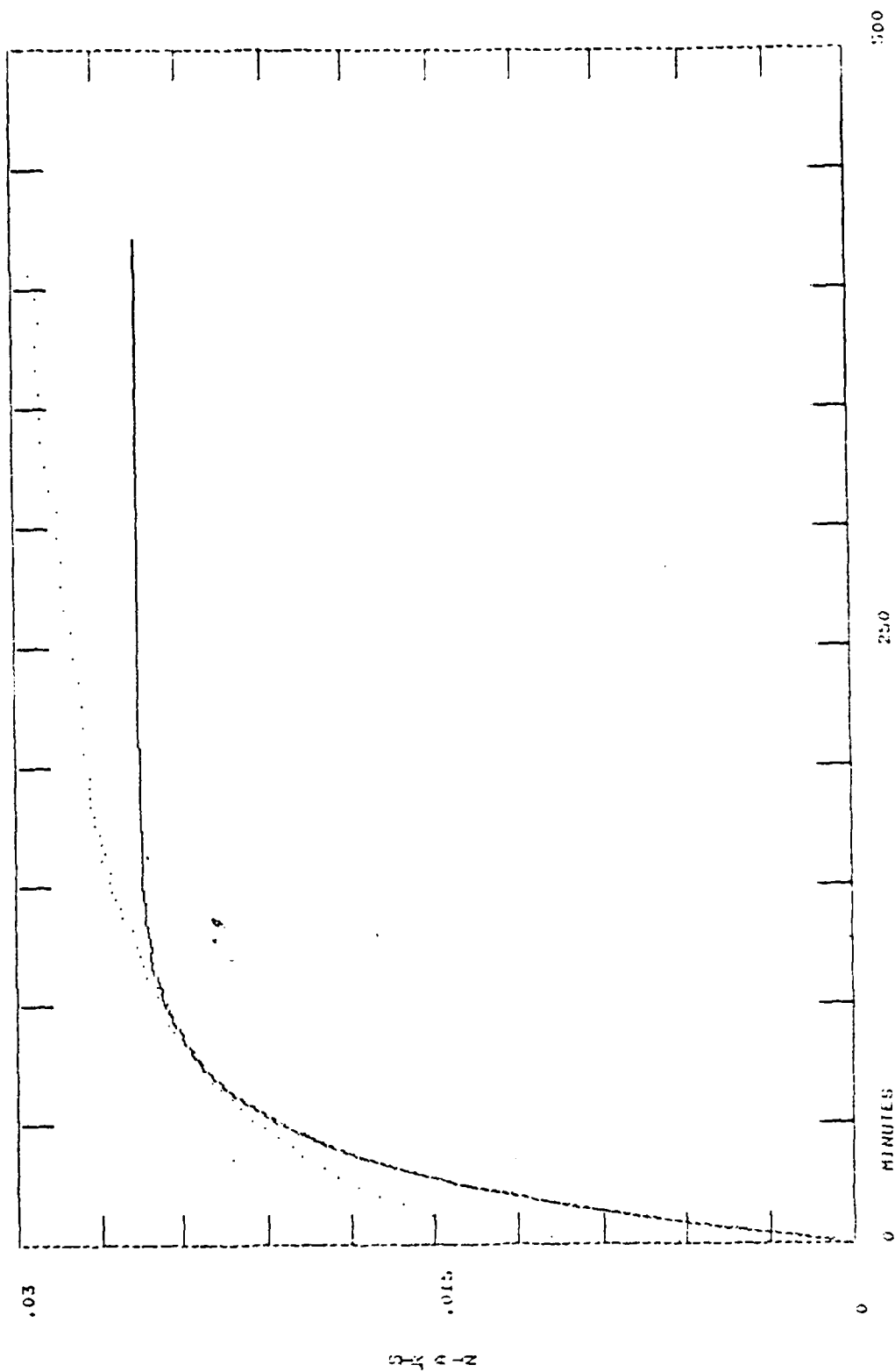
11.50 110.111 7.111.75 AREA = 10.26 50.00 HEIGHT = 2.10 CM
 DOTTED LINE: ORIGINAL DATA HEDDY LINE: MODEL PREDICTION



4-PARAMETER SOLID MODEL WITH VALUES OF
 AT = 3.88922E-03, μ_1 = .033272, μ_2 = .020125, μ_3 = 7.5746E-03
 RELAX TIME = 8
 ERROR (USING ALL POINTS): 1.1252%
 ERROR (IGNORING FIRST 3 POINTS): 0.7562%

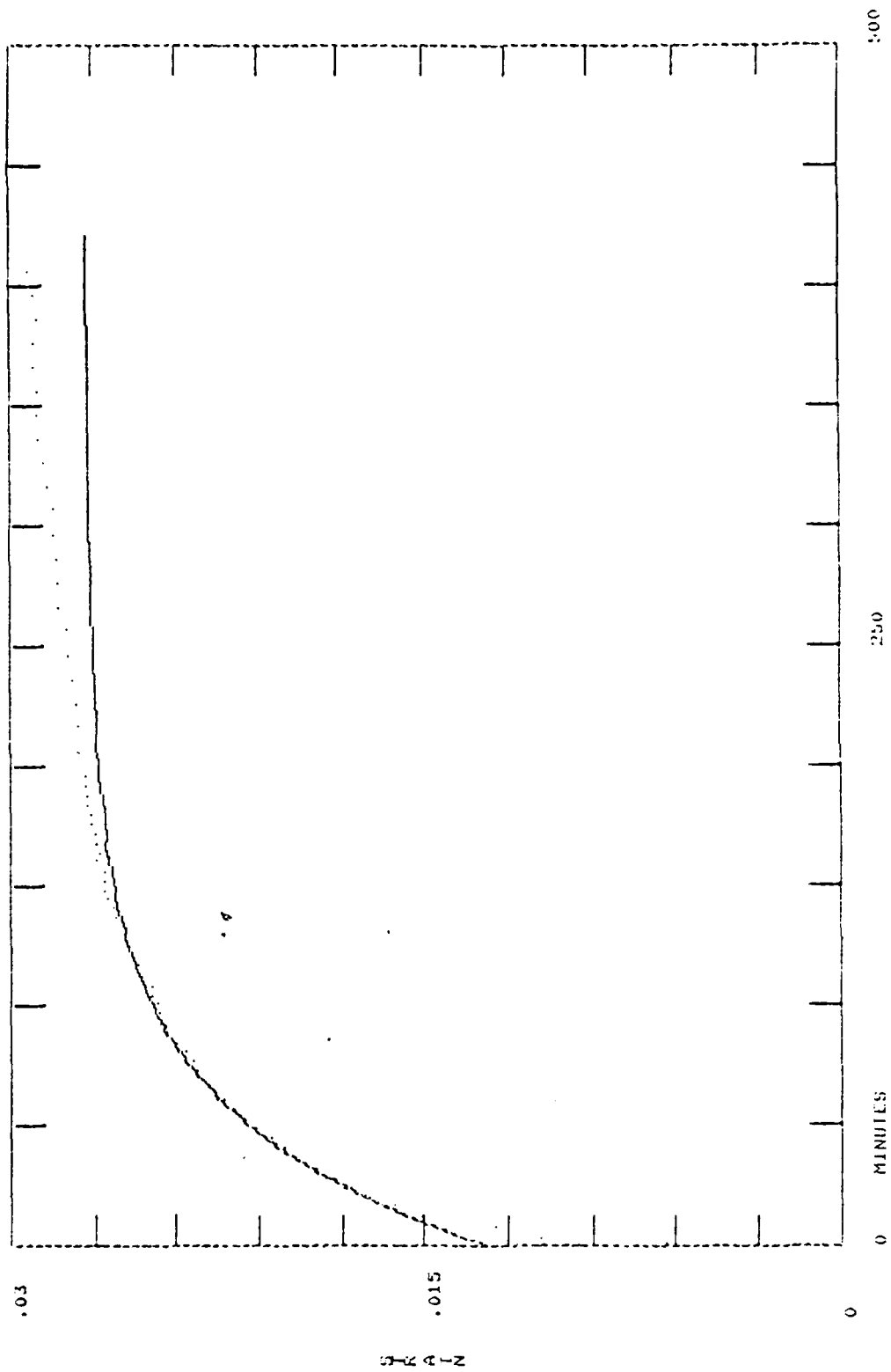
LN-50 T10-111 7 FEB 75 AREA = 10.25 SQ CM HEIGHT = 2.16 CM
 DOTTED LINE: ORIGINAL DATA HEAVY LINE: MODEL PREDICTION

110



2-PARAMETER SOLID MODEL WITH VALUES OF
 $\alpha_1 = .025648$, $\beta_1 = .032335$
 DELTA TIME = 8
 ERROR CUSING ALL POINTS: 6.886%
 ERROR CUSING FIRST 3 POINTS: 5.789%

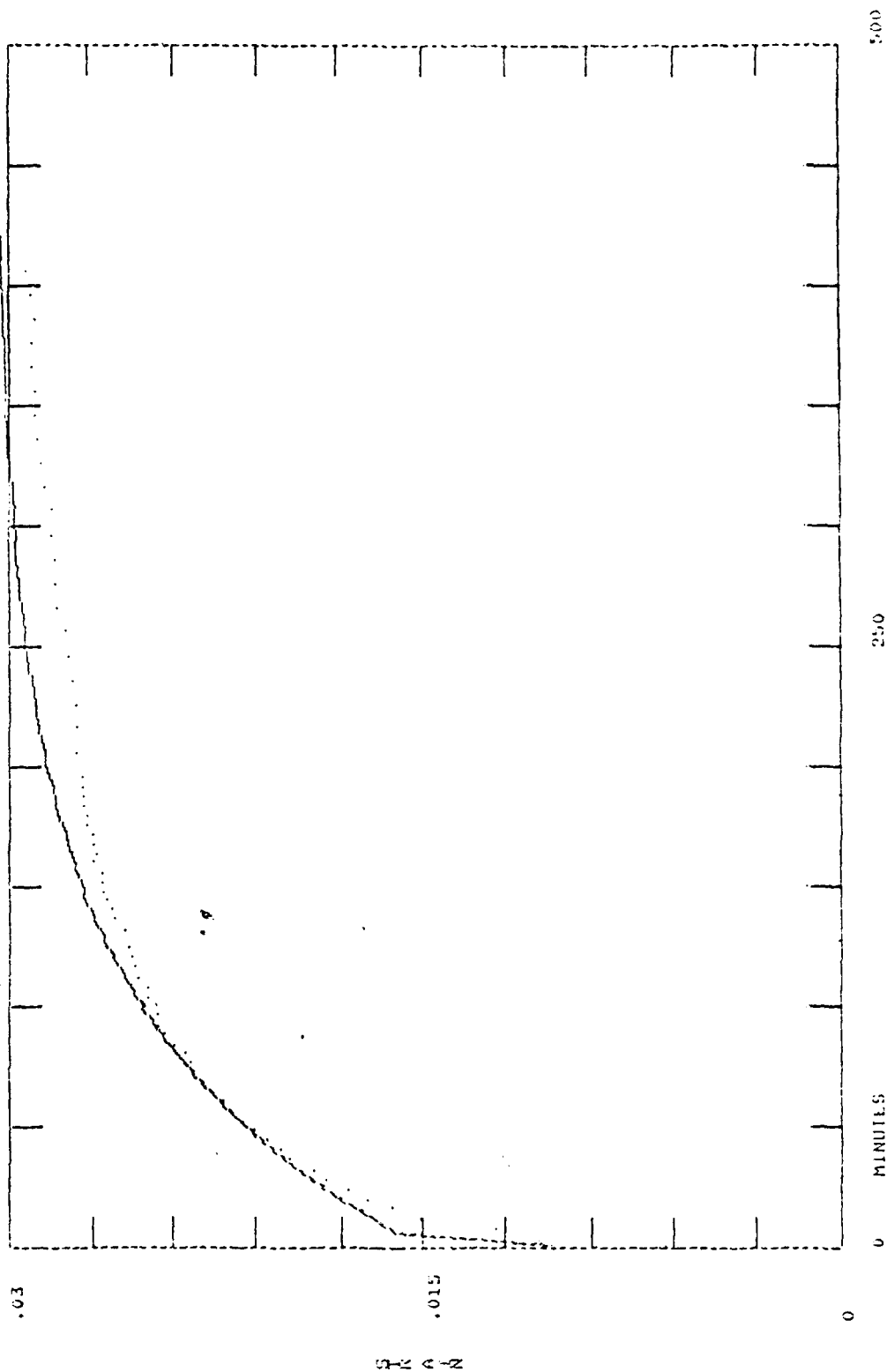
LN-51 18-19 10 FEB 75 AREA = 17.11 SQ CM HEIGHT = 2.163 CM
 DOTTED LINE: ORIGINAL DATA HEAVY LINE: MODEL PREDICTION



3-PARAMETER SOLID MODEL WITH VALUES OF
 $A_1 = .027254$, $B_1 = .018004$, $A_2 = .012833$
 INITIAL TIME = 30
 CLUSTERING ALL POINTS
 ERROR CLUSTERING FIRST 3 POINTS: 0.0599% 0.0599%

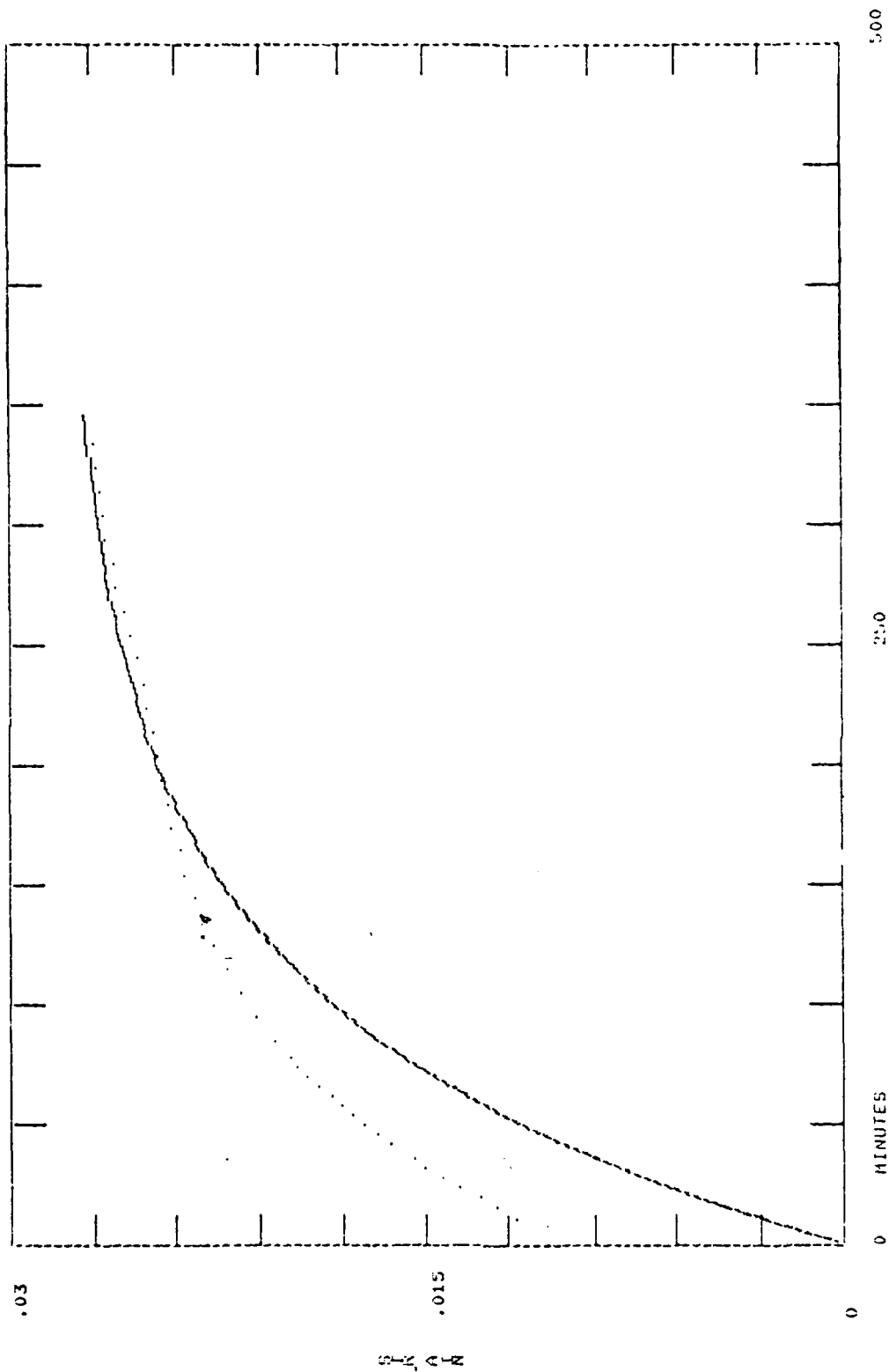
LA 51 10 19 10 FEB 75 AREA = 17.11 SQ CM HEIGHT = 2.163 CM
 DOTTED LINE: ORIGINAL DATA HEAVY LINE: MODEL PREDICTION

18



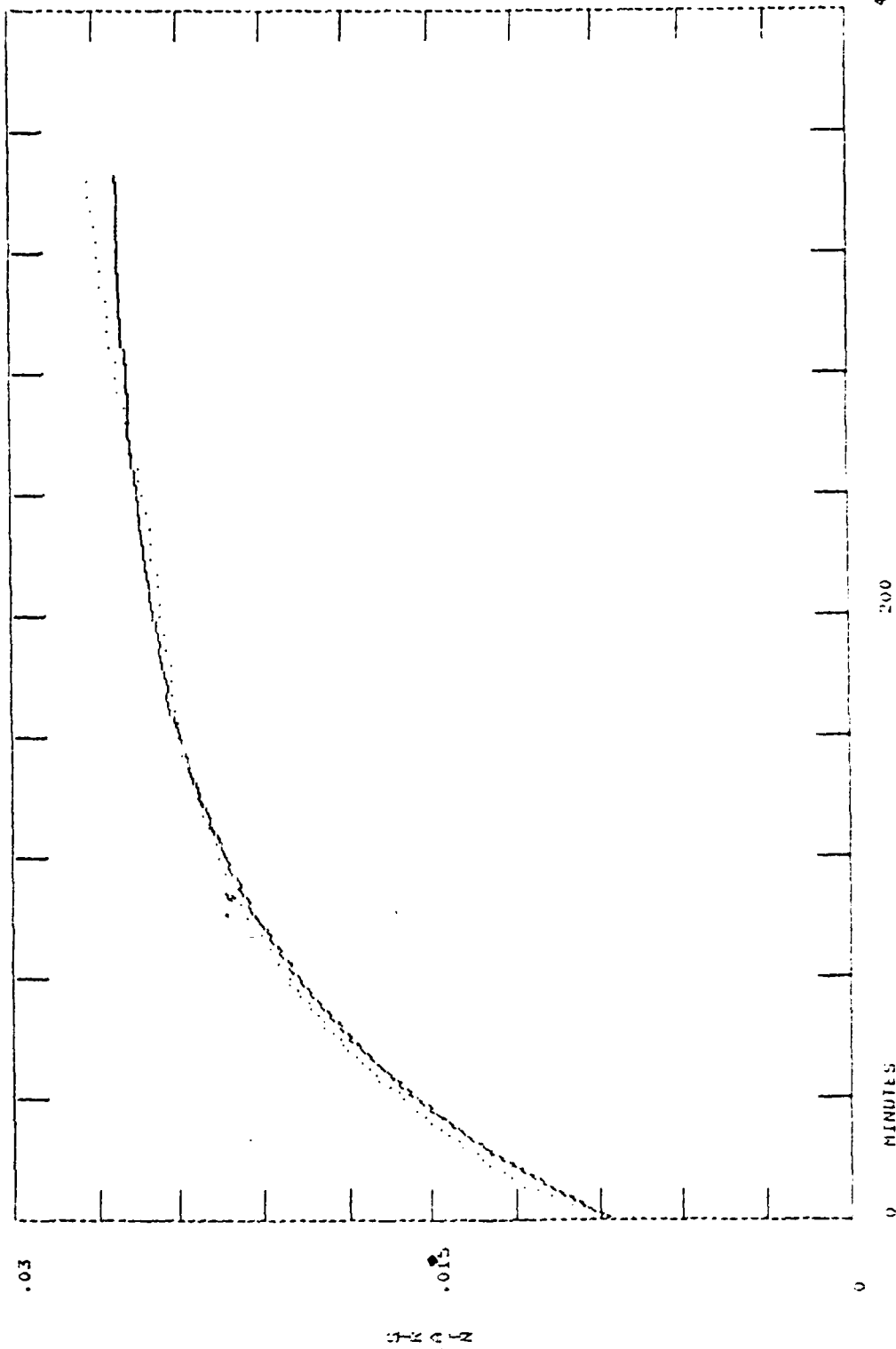
3-PARAMETER SOLID MODEL WITH VALUES OF
 A1 = .010046, B1 = 1.1736, A2 = .0155, B2 = .010662
 INITIAL TIME = 0
 ERROR USING ALL POINTS: -5.243%
 ERROR USING FIRST 5 POINTS: -4.651%

LN 51 TB 19 10 FEB 75 AREA = 17.11 SQ CM HEIGHT = 2.163 CM
 PLOT LINE: ORIGINAL DATA MODEL LINE: MODEL PREDICTION



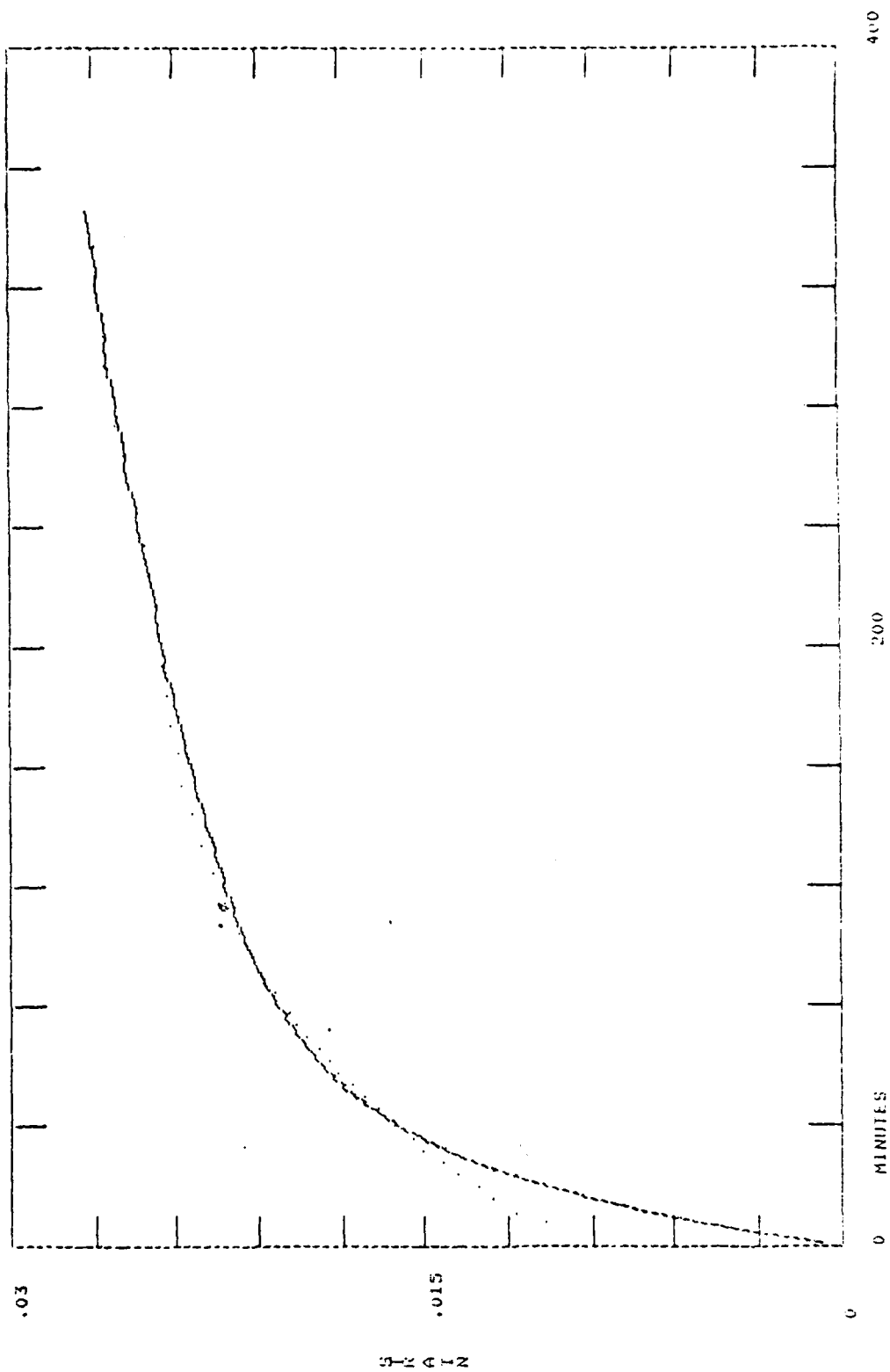
2-PARAMETER SOLID MODEL WITH VALUES OF
 $\alpha_1 = .027949$ $\beta_1 = .010751$
 DELTA TIME = 30
 ERROR USING ALL POINTS: 14.779%
 ERROR (IGNORING FIRST 3 POINTS): 12.848%

LA-52 17-18 11 FEB 75 AREA = 16.21 SQ CM HEIGHT = 2.64 CM
 SOLID LINE: ORIGINAL DATA HEAVY LINE: MODEL PREDICTION



3-POROMETER SOLID MODEL WITH VALUES OF
 AT = .022599, BT = .012213, CT = .008564
 ADJUSTED TO BE 30
 ERROR (USING ALL POINTS) : 1.283%
 ERROR (IGNORING FIRST 3 POINTS) : 1.579%

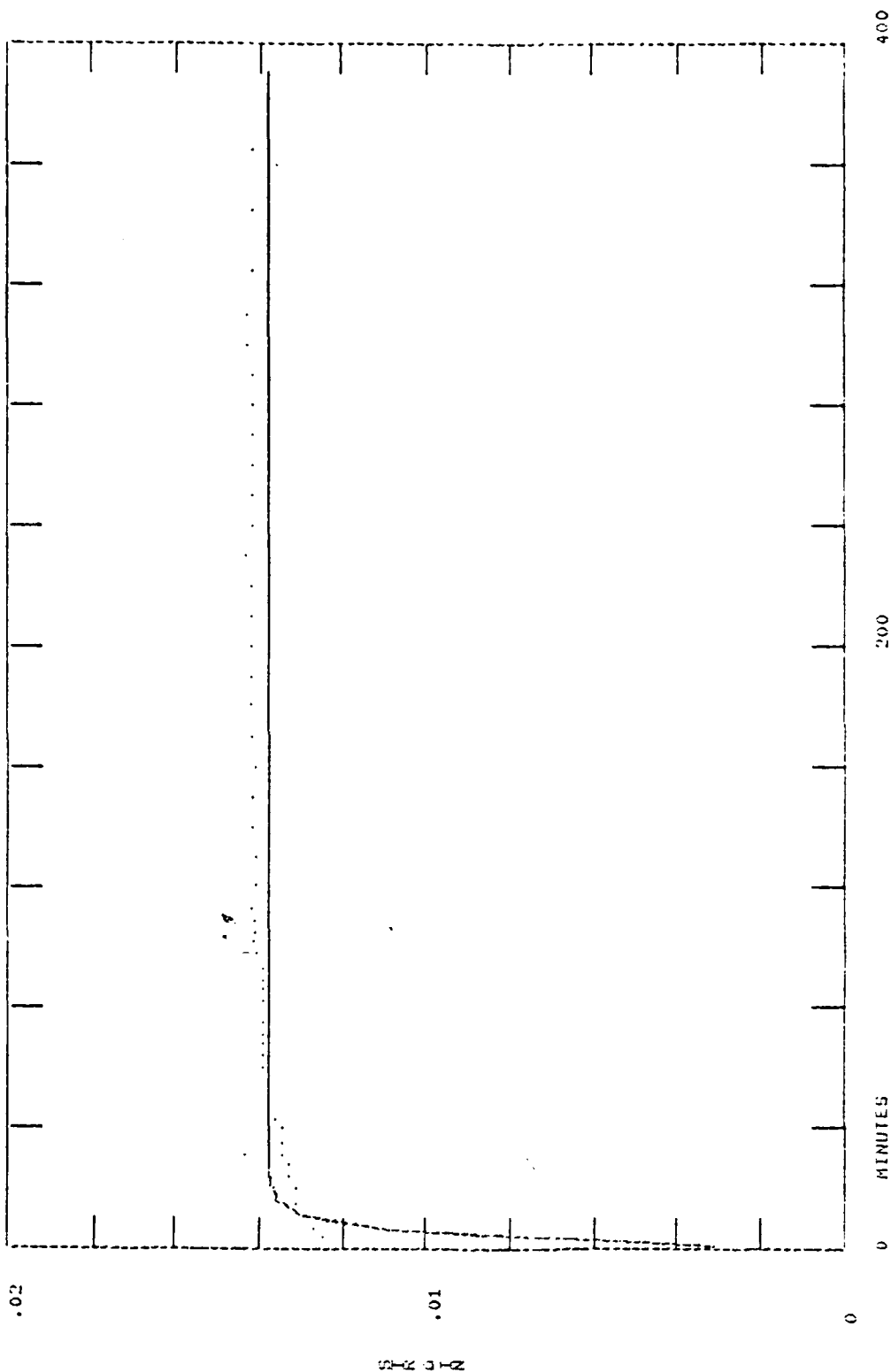
IN 22 1/10 11 FEB 75 AREA = 16.21 SQ CM HEIGHT = 2.645 CM
 HOTTED LINE: ORIGINAL DATA HEAVY LINE: MODEL PREDICTION



4-POCKNETS SOLID MODEL WITH VALUES OF
 AL = .012937, RI = .089958, QZ = .01417, 102 = 3.1278E-03
 DELTA TIME = 8
 ERROR (USING ALL POINTS) : 3.2922%
 ERROR (USING FIRST 3 POINTS) : 1.7702%

LA 52 17-10 11 FEB 75 AREA = 16.21 SQ CM HEIGHT = 2.645 CM
 DOTTED LINE: ORIGINAL DATA HEAVY LINE: MODEL PREDICTION

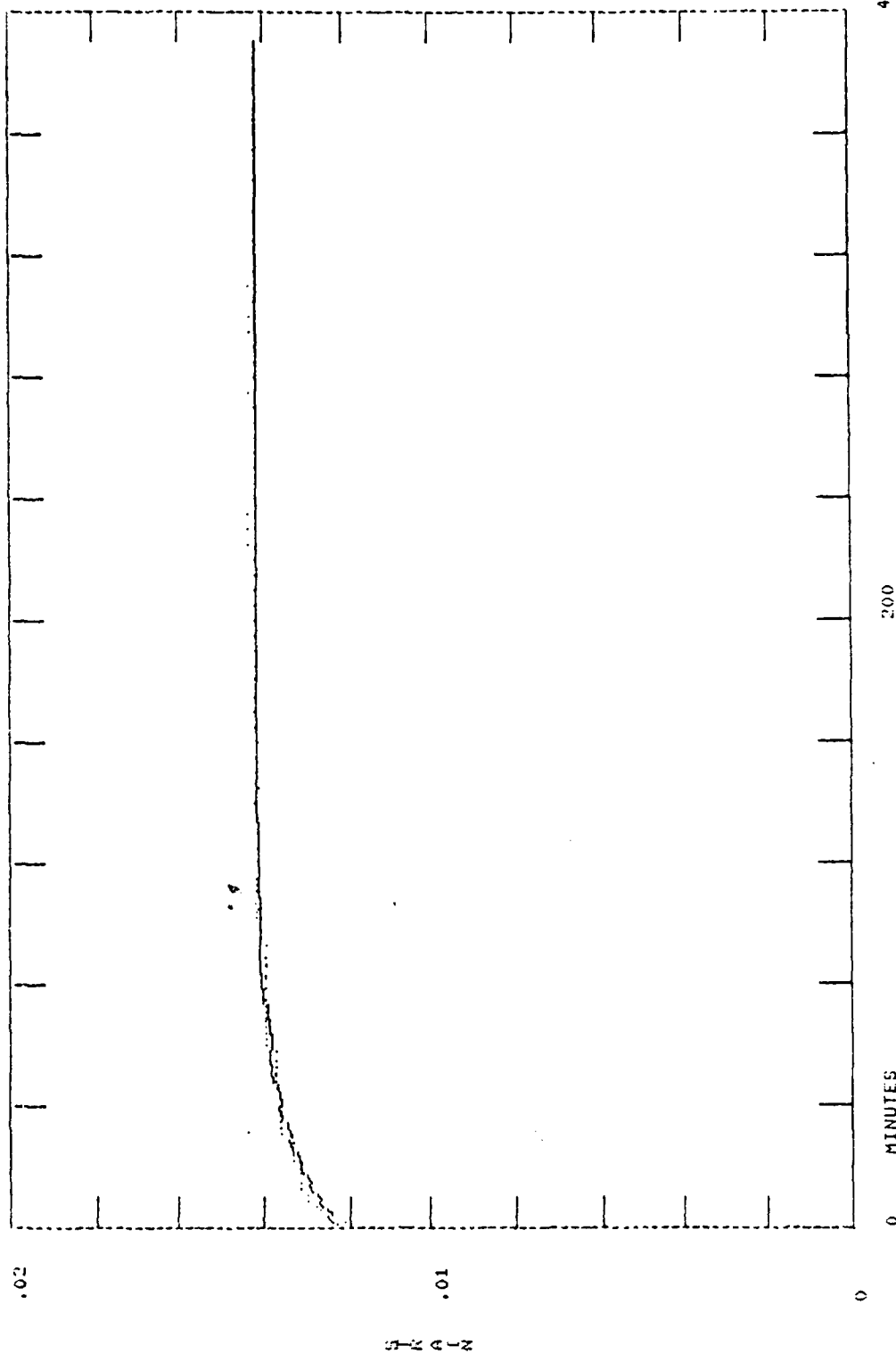
1.2



2-PARAMETER SOLID MODEL WITH VALUES OF
 A1 = .015834, B1 = .25824
 DELTA TIME = 8
 ERROR (USING ALL POINTS): 5.013%
 ERROR (IGNORING FIRST 3 POINTS): 1.299%

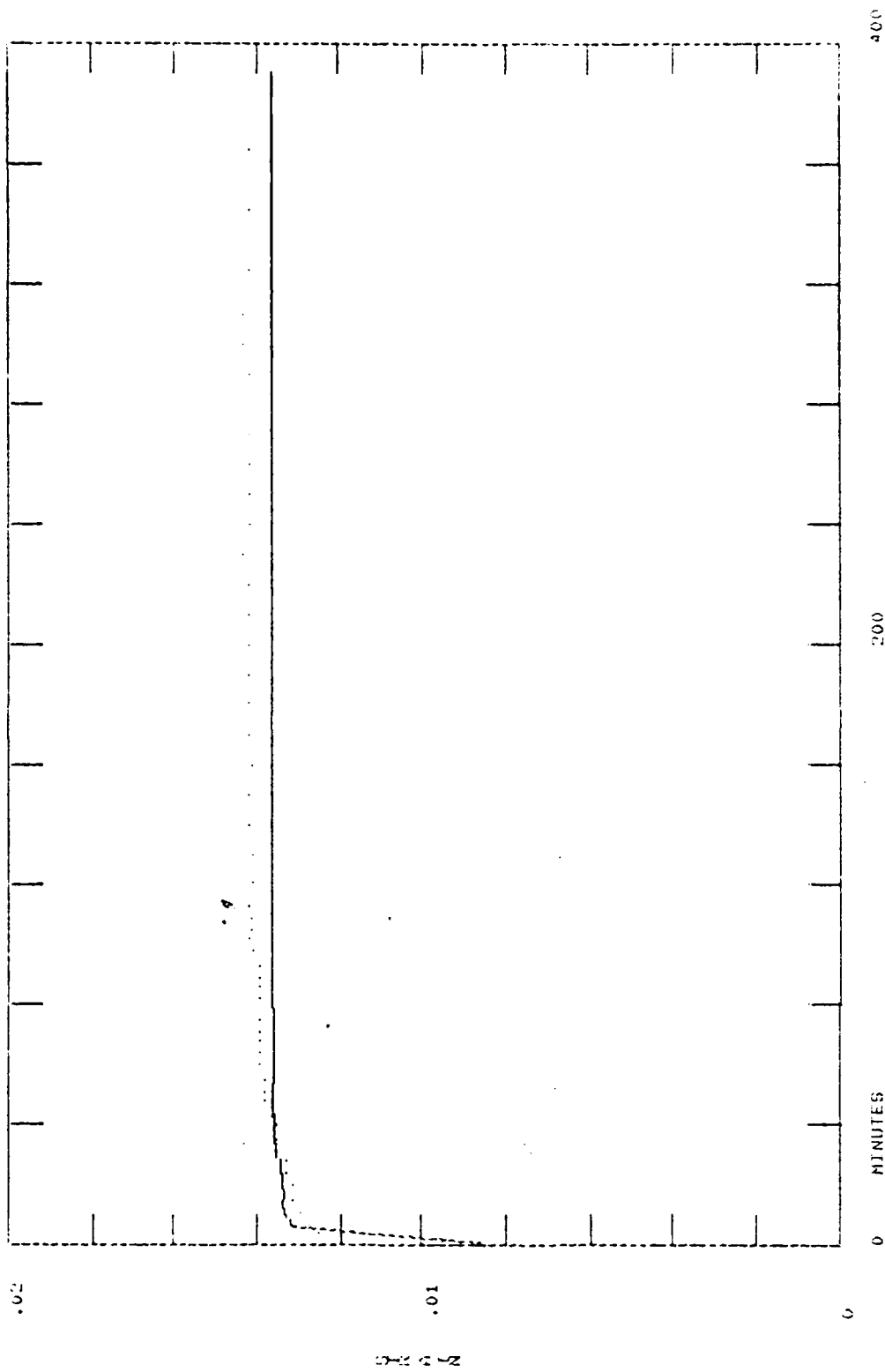
LN-53 14-15 12 FEB 75 AREA = 14.03 SQ CM HEIGHT = 1.965 CM
 DOTTED LINE: ORIGINAL DATA HEAVY LINE: MODEL PREDICTION

63



3-PARAMETER SOLID MODEL WITH VALUES OF
 $\alpha_1 = .014337$, $\alpha_2 = .030002$, $\alpha_3 = .012228$
 DELTA TIME = 4
 ERROR (USING ALL POINTS): 0.643%
 ERROR (IGNORING FIRST 3 POINTS): 0.073%

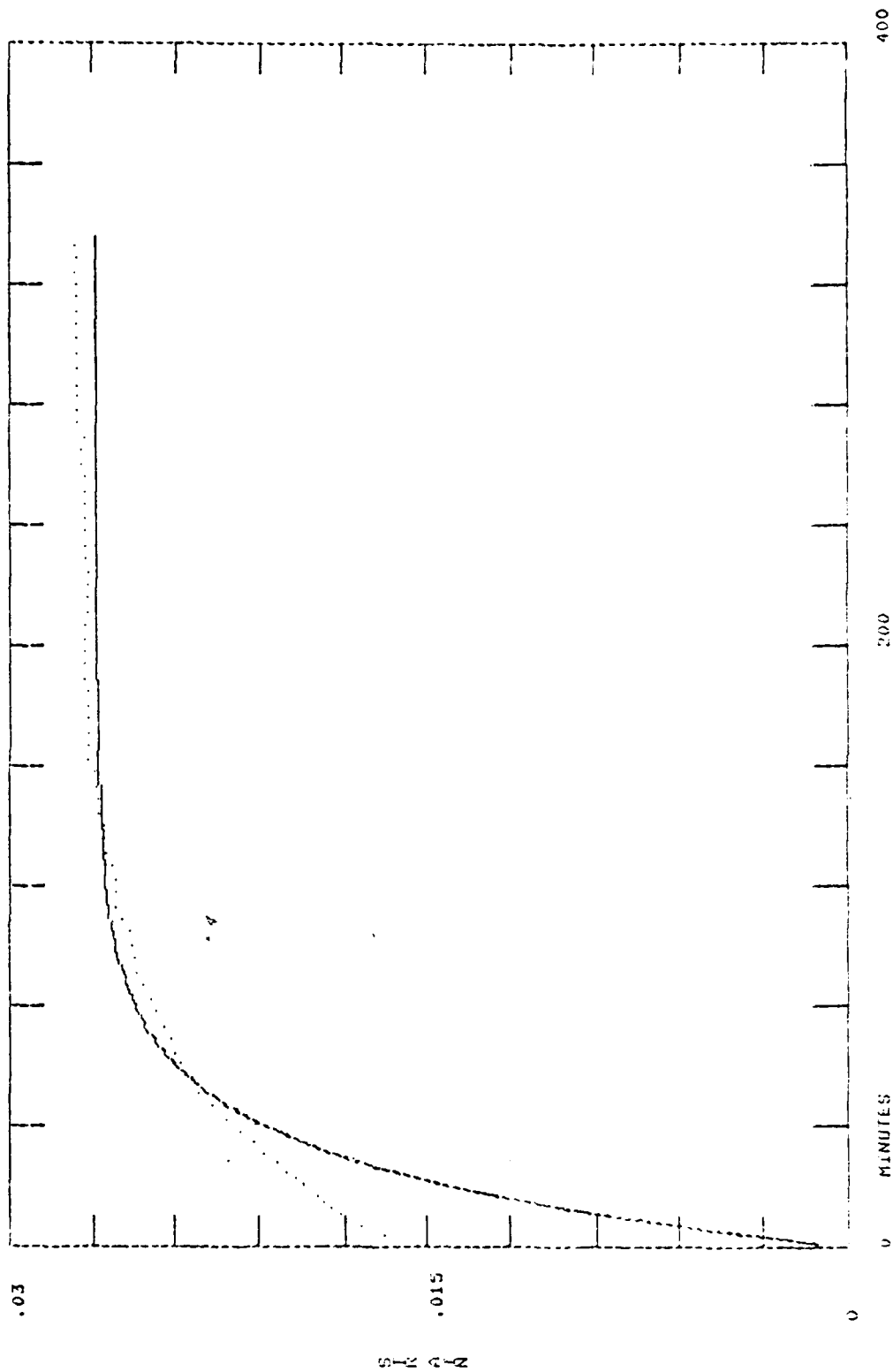
LN-53 14-15 12 FEB 75 AREA = 14.05 SQ CM HEIGHT = 1.965 CM
 DOTTED LINE: ORIGINAL DATA HEAVY LINE: MODEL PREDICTION



4-PARAMETER SOLTD MODEL WITH VALUES OF
 $\alpha_1 = 5.7307E-04$, $\alpha_2 = .0387$, $\alpha_3 = .013136$, $\alpha_4 = 1.0062$
 DELTA TIME = 4
 COSTING ALL POINTS: 2.247%
 ERROR (IGNORING FIRST 3 POINTS): 2.379%

LN-53 14-15 12 FEB 75 AREA = 14.03 SQ CM HEIGHT = 1.965 CM
 DOTTED LINE: ORIGINAL DATA HEAVY LINE: MODEL PREDICTION

105



2. PLOTTING SKAN SOLID MODEL WITH VALUES OF

AT $\alpha = 0.028342$ $\beta = 0.03763$

DELTA T TIME = 83

ERROR CUSING ALL POINTS :

5.043%

ERROR CUSING FIRST 3 POINTS :

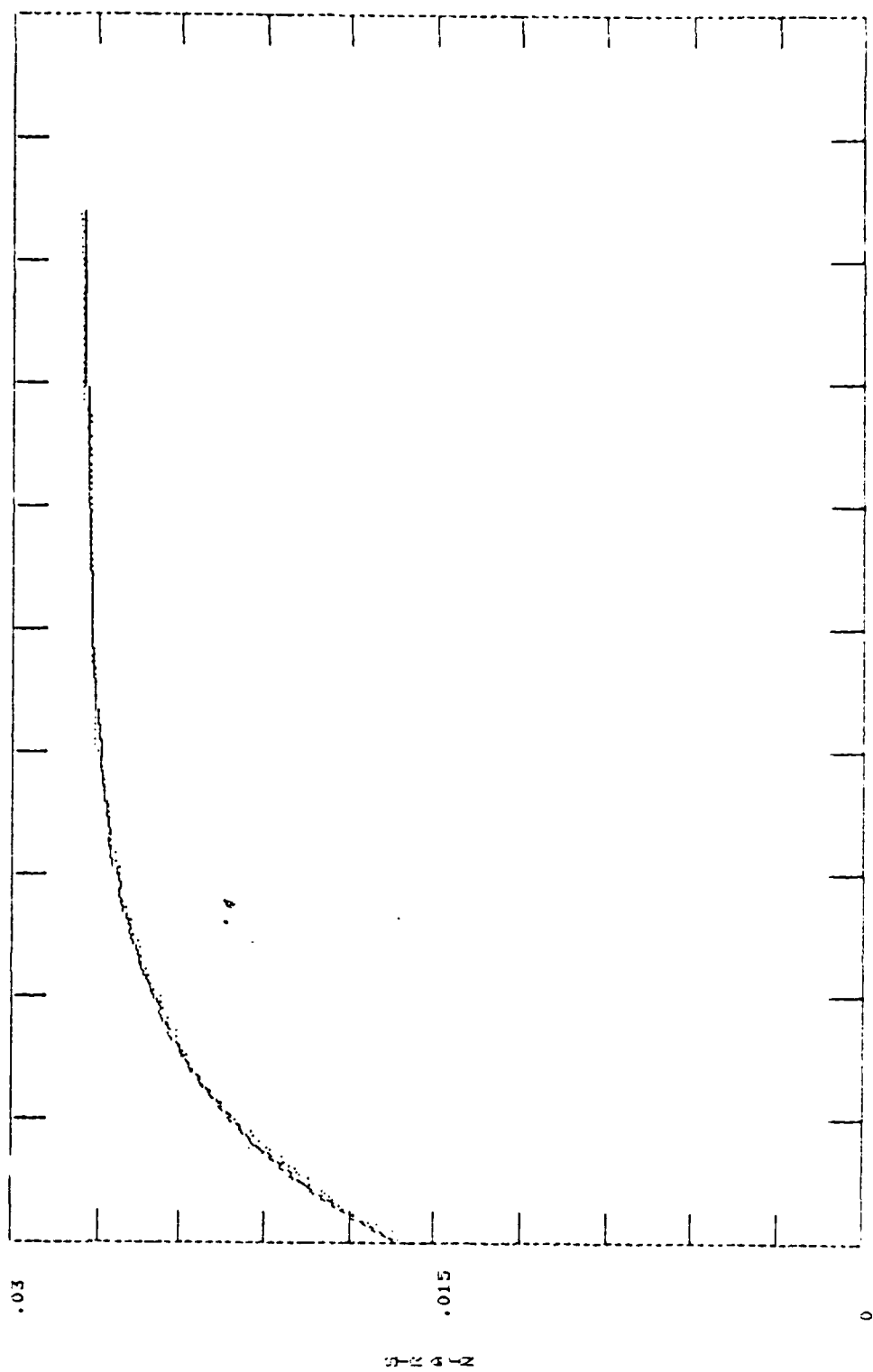
5.475%

IN 54 16 17 19 110 75 AREA = 11.06 SQ CM HEIGHT = 2.6 CM

NOTED LINE: ORIGINAL DATA

HEAVY LINE: MODEL PREDICTION

175



400

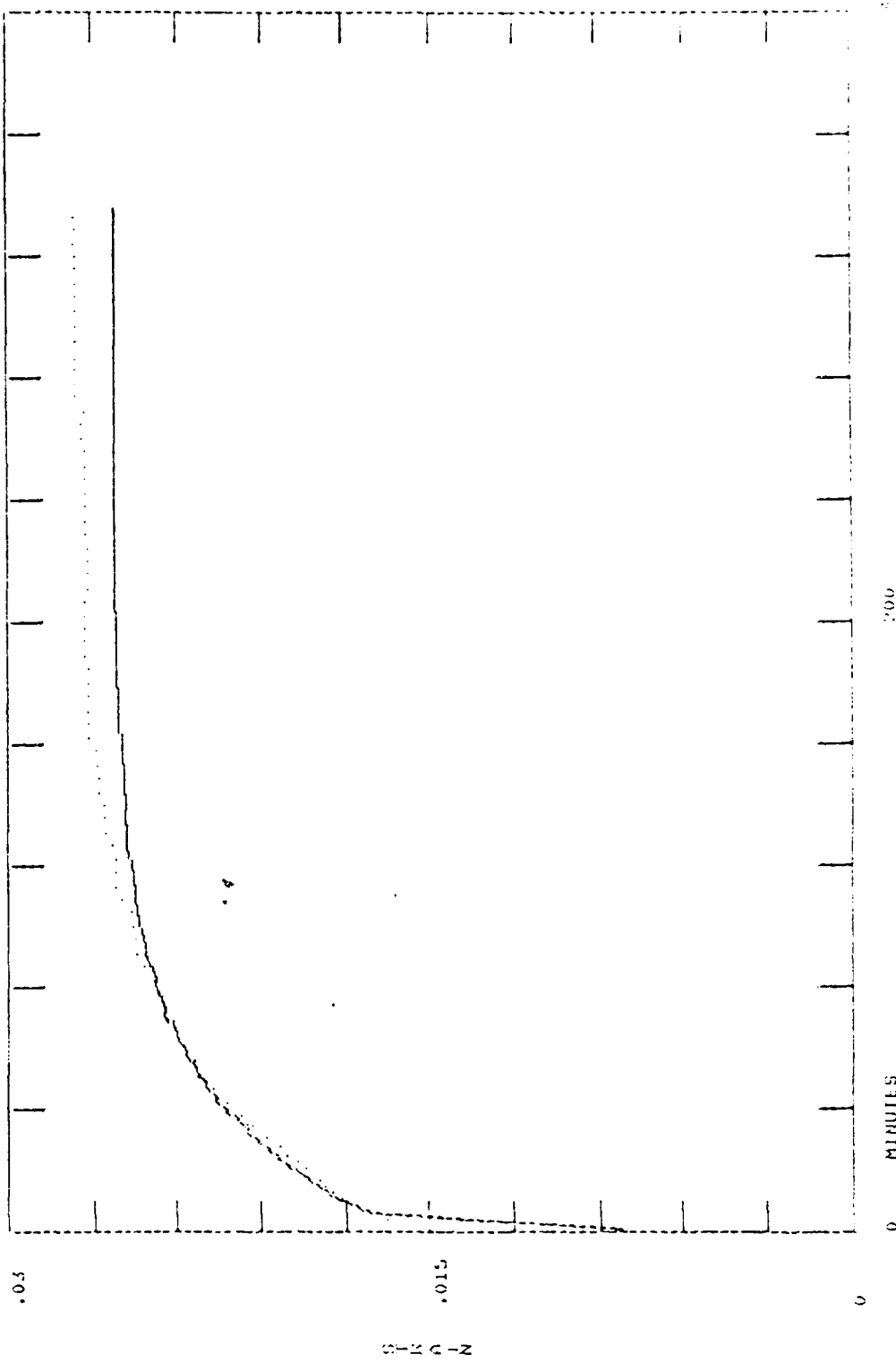
200

0 MINUTES

3-PARAMETER SOLID MODEL WITH VALUES OF
 $\alpha_1 = .0225849$, $\beta_1 = .01871$, $\alpha_2 = .016289$
 DELTA TIME = 4
 ERROR USING ALL POINTS: 0.3552%
 ERROR IGNORING FIRST 3 POINTS: -0.2661%

IN-54 16-17 19 FEB 75 AREA = 11.66 SQ CM WEIGHT = 2.6 GM
 DOTTED LINE: ORIGINAL DATA HEAVY LINE: MODEL PREDICTION

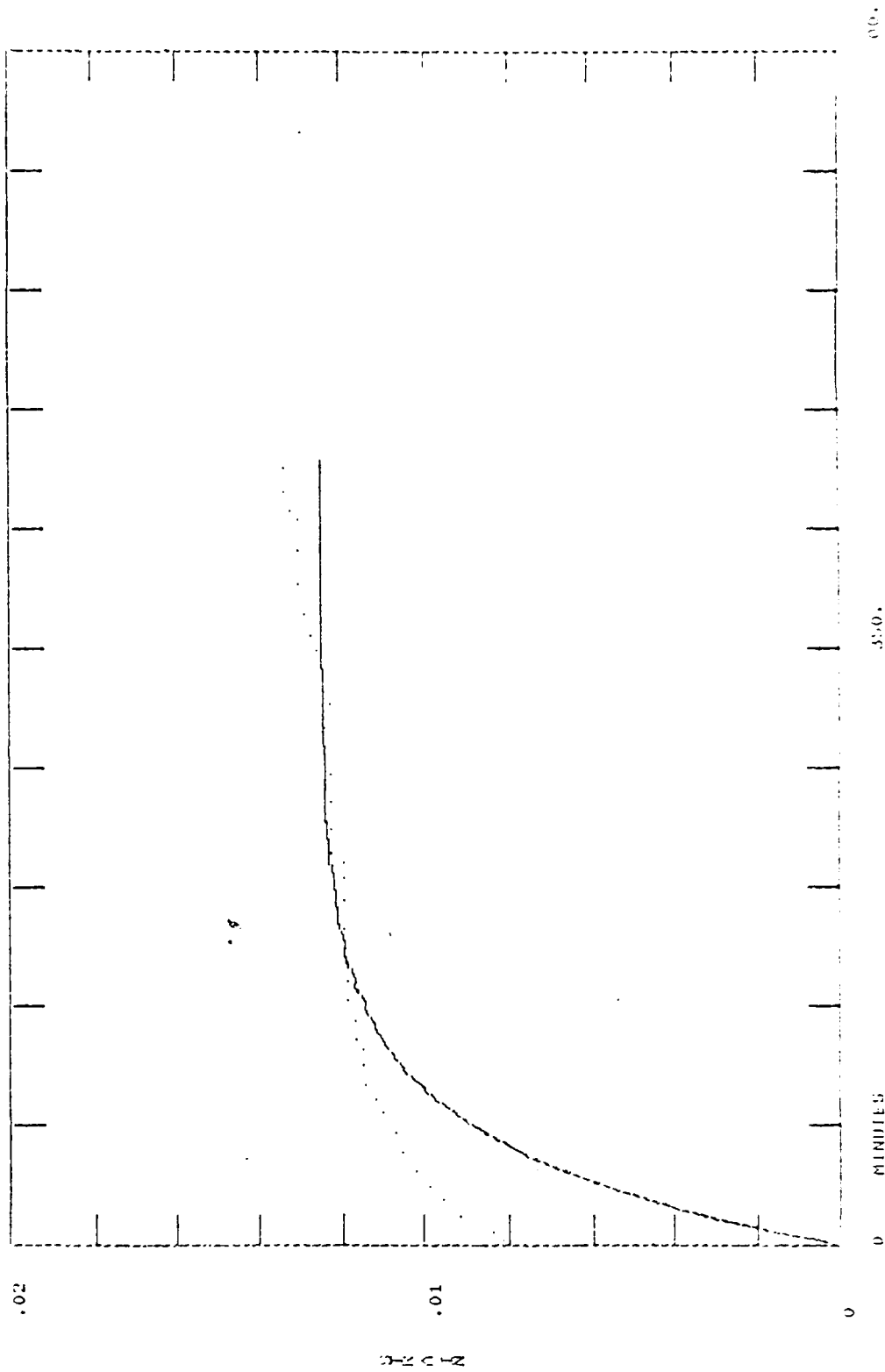
1.7



4-PARAMETER SOLID MODEL WITH VALUES OF
 AT = .0103154 RT = .023044 RD = .01092054 RTT = .692009
 GEL TO TIME = 4
 ERROR CURSING ALL POINTS: 85.1007%
 ERROR CURSING FIRST 5 POINTS: 22.744%

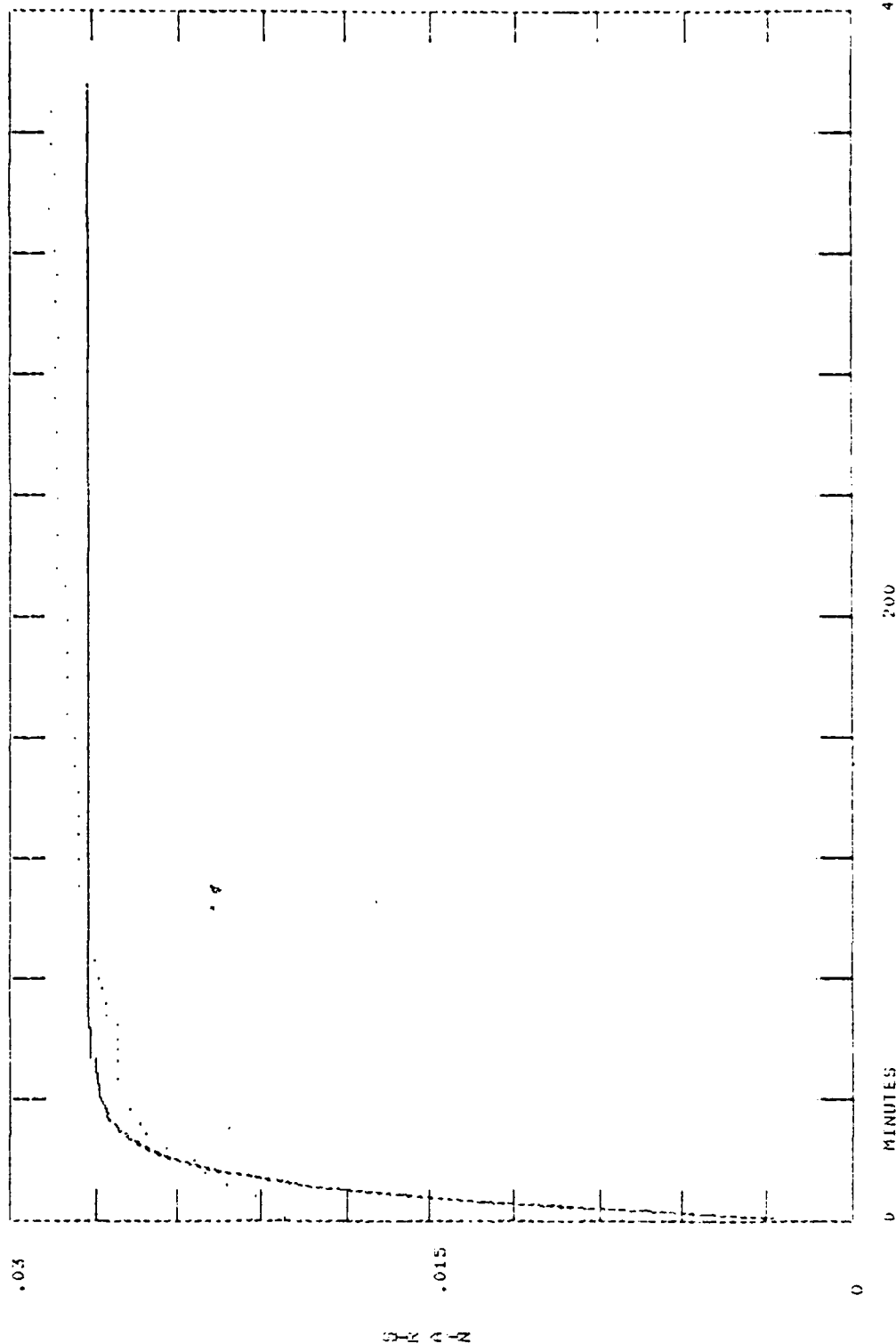
IN 54 TO 17 19 JUL 75 AREA = 11.06 SQ CM HEIGHT = 2.6 CM
 DOTTED LINE: ORIGINAL DATA HEAVY LINE: MODEL PREDICTION

3 /



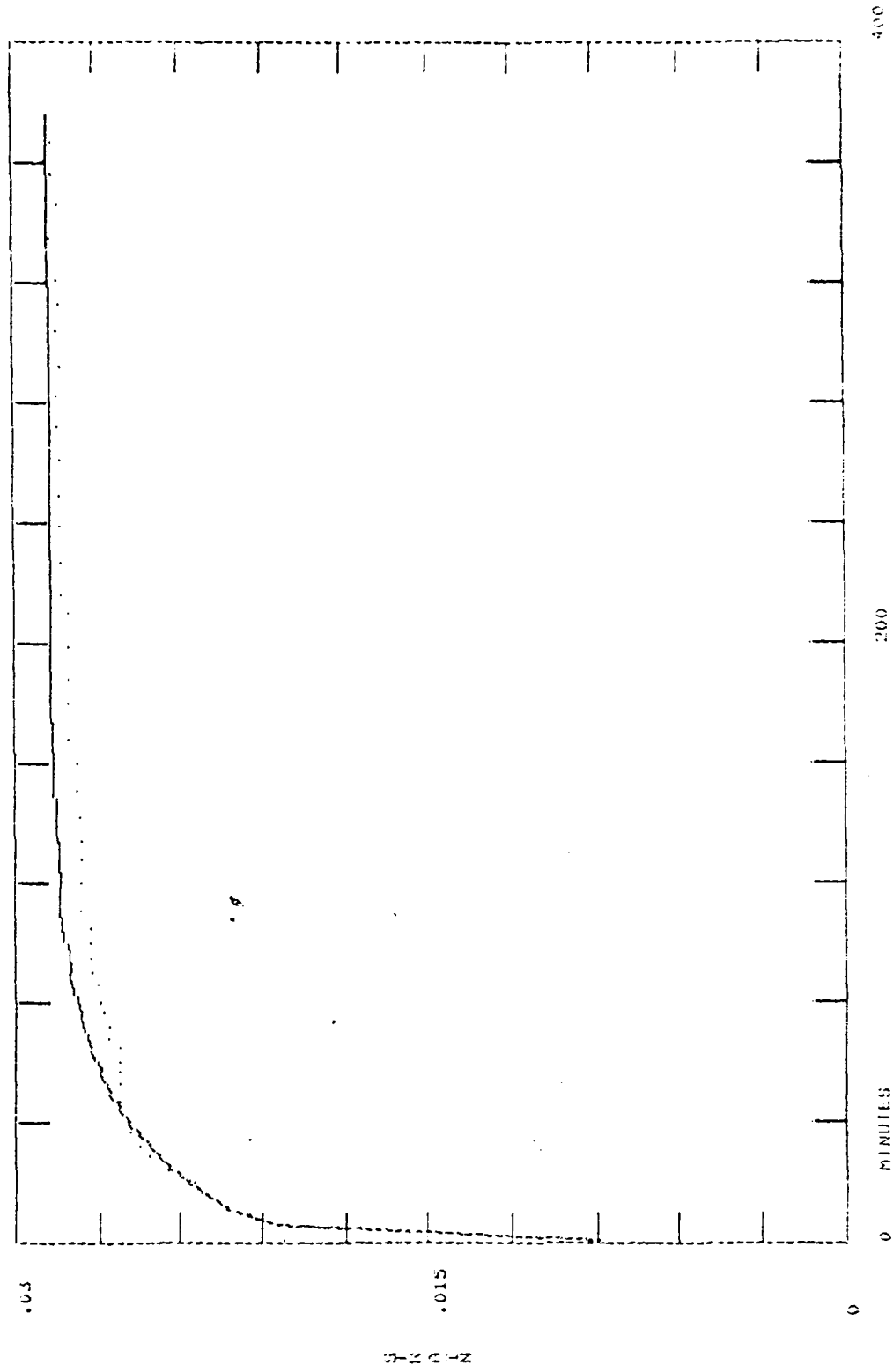
2. PASCARETTER SOLUTION MODEL WITH VALUES OF
 OF $\mu = .0125587$ AND $\mu = .0176995$
 AND TO THE $\mu = .01$
 ERROR CURSING ALL POINTS: 10.9902
 ERROR CURSING FIRST 3 POINTS: 2.0000

17.54 17.10 7.66 29.08 6.6 13.69 50.14 11.16 2.66 18
 101101101: ORIGINAL DATA 101101101: MORE PRECISION



24. PERCENTAGE SOLID MODEL WITH VALUES OF
 AT = .022204, K1 = .11038
 DELTA TIME = 4
 ERROR CURSING ALL POINTS: 0.0102
 ERROR CURSING FIRST 3 POINTS: 1.0132

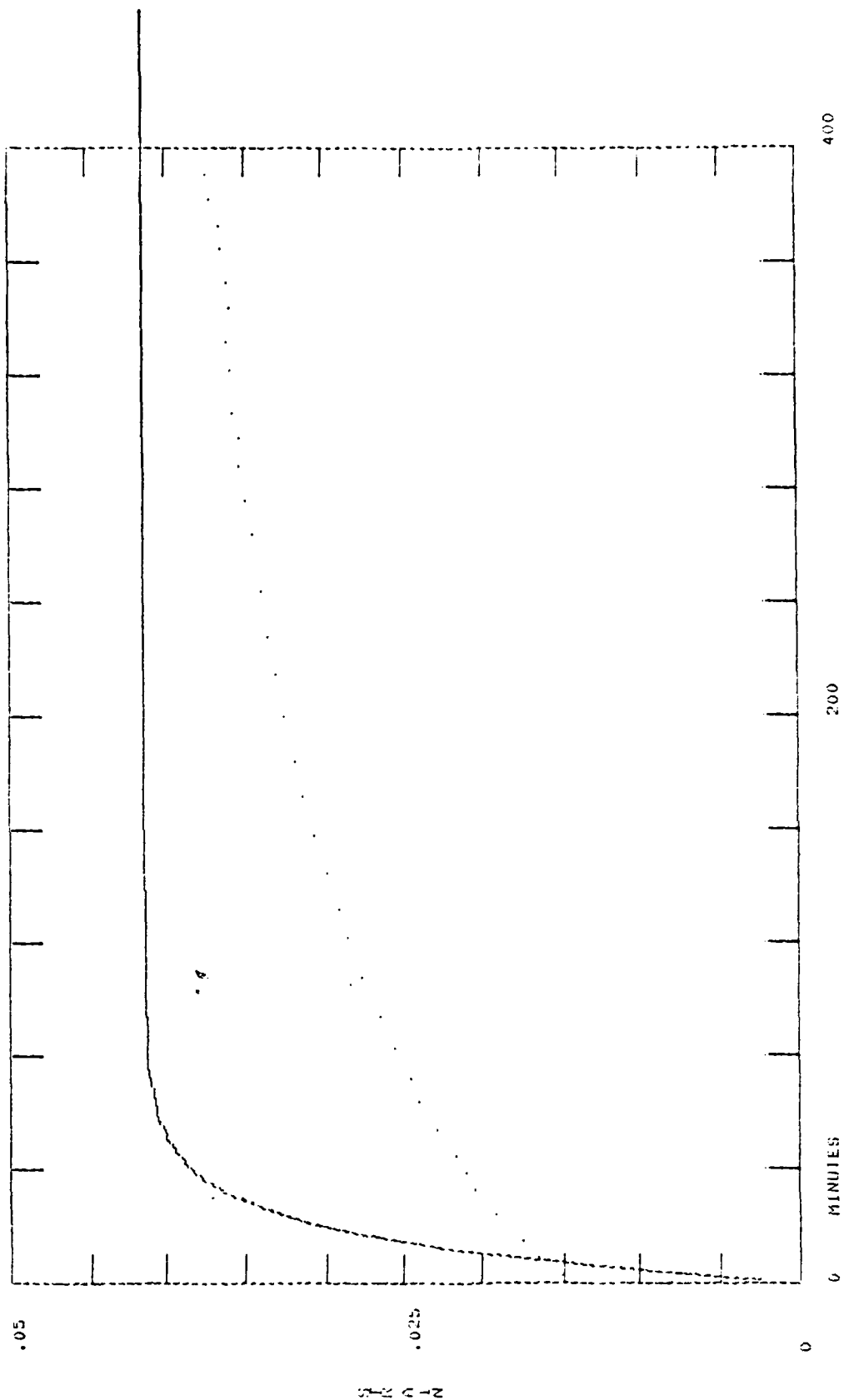
14-56 15 16 20 116 75 AREA = 14.73 SQ CM HEIGHT = 1.90 CM
 BOTH LINE: ORIGINAL DATA HEAVY LINE: MODEL PREDICTION



4 - PERFORMETER SOLID MODEL WITH VALUES OF
 A1 = 8.2089E-03, A2 = .028934, A3 = .019772, A4 = .5789
 DELTA TIME = 4
 USING ALL POINTS:
 ERROR = 0.3938%
 ERROR (CONCORDING FIRST 3 POINTS): -1.376%

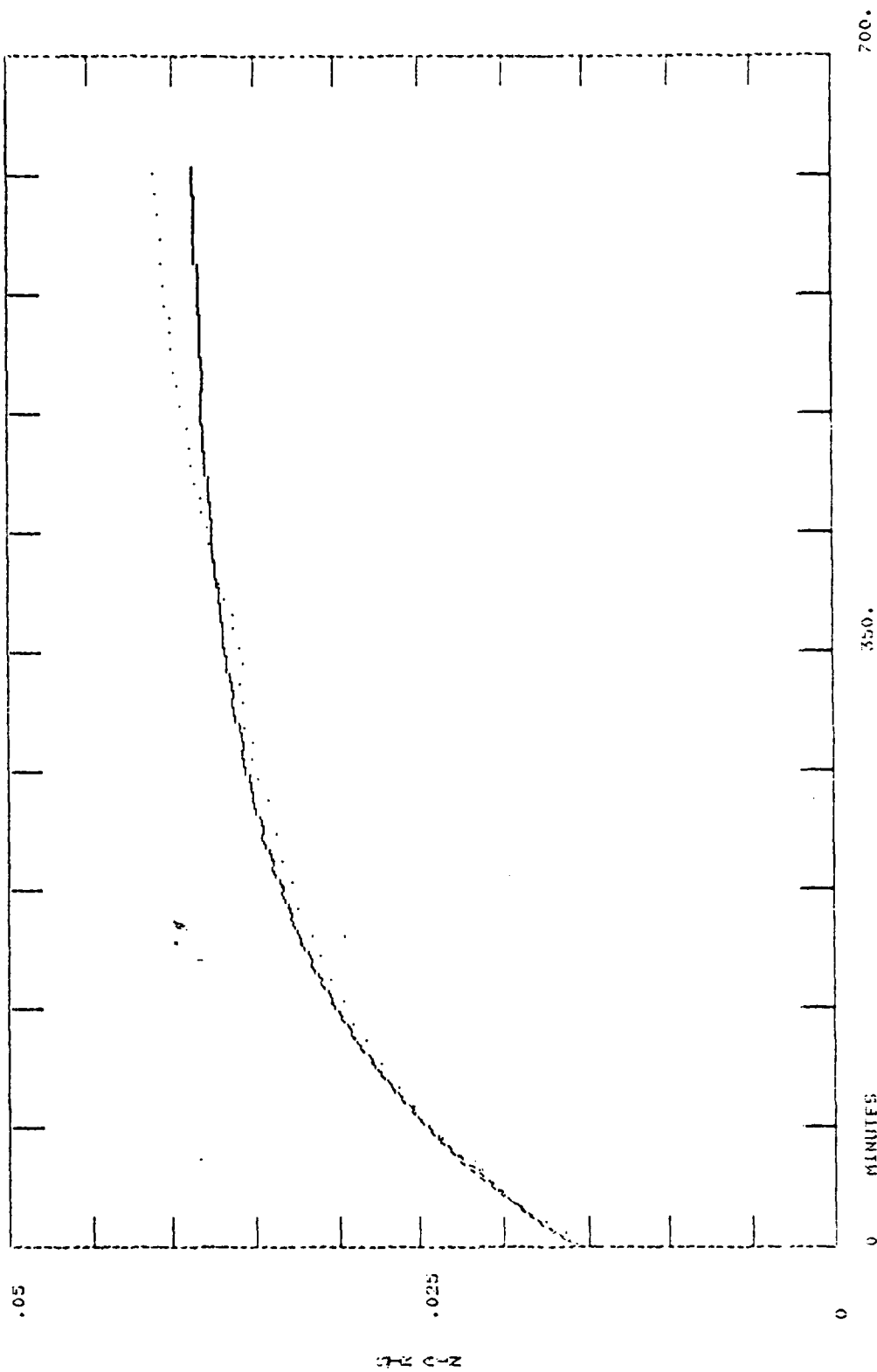
IN-26 15-16 20 FEB 75 AREA = 14.73 SQ CM HEIGHT = 1.98 CM
 DOTTED LINE: ORIGINAL DATA HEAVY LINE: ADJUSTED PRODUCTION

112



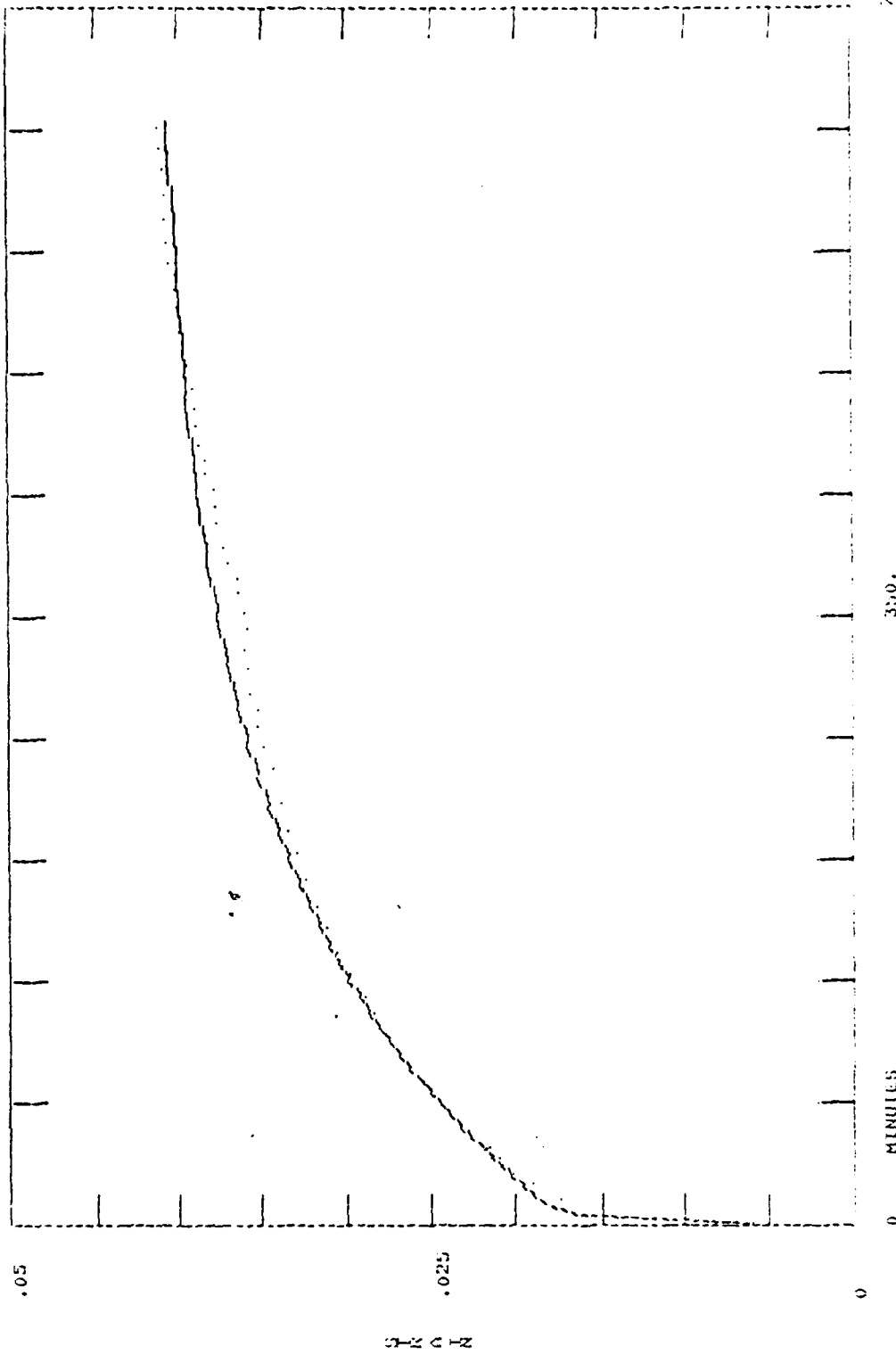
2-PARAMETER SOLID MODEL WITH VALUES OF
 A1 = .041505, B1 = .065202
 DELTA TIME = 30
 ERROR CLUSTING ALL POINTS > : -29.660%
 ERROR CLUSTING FIRST 3 POINTS > : -32.032%

18-57 12-13 13 FEB 75 AREA = 9.93 SQ CM HEIGHT = 2.16 CM
 DOTTED LINE: ORIGINAL DATA HEAVY LINE: MODEL PREDICTION



3-PARAMETER SOLID MODEL WITH VALUES OF
 A1 = .032031, A2 = 6.8847E-03, A3 = .015748
 INITIAL TIME = 16
 ERROR (USING ALL POINTS): 1.182%
 ERROR (CONFORMING FIRST 3 POINTS): 0.690%

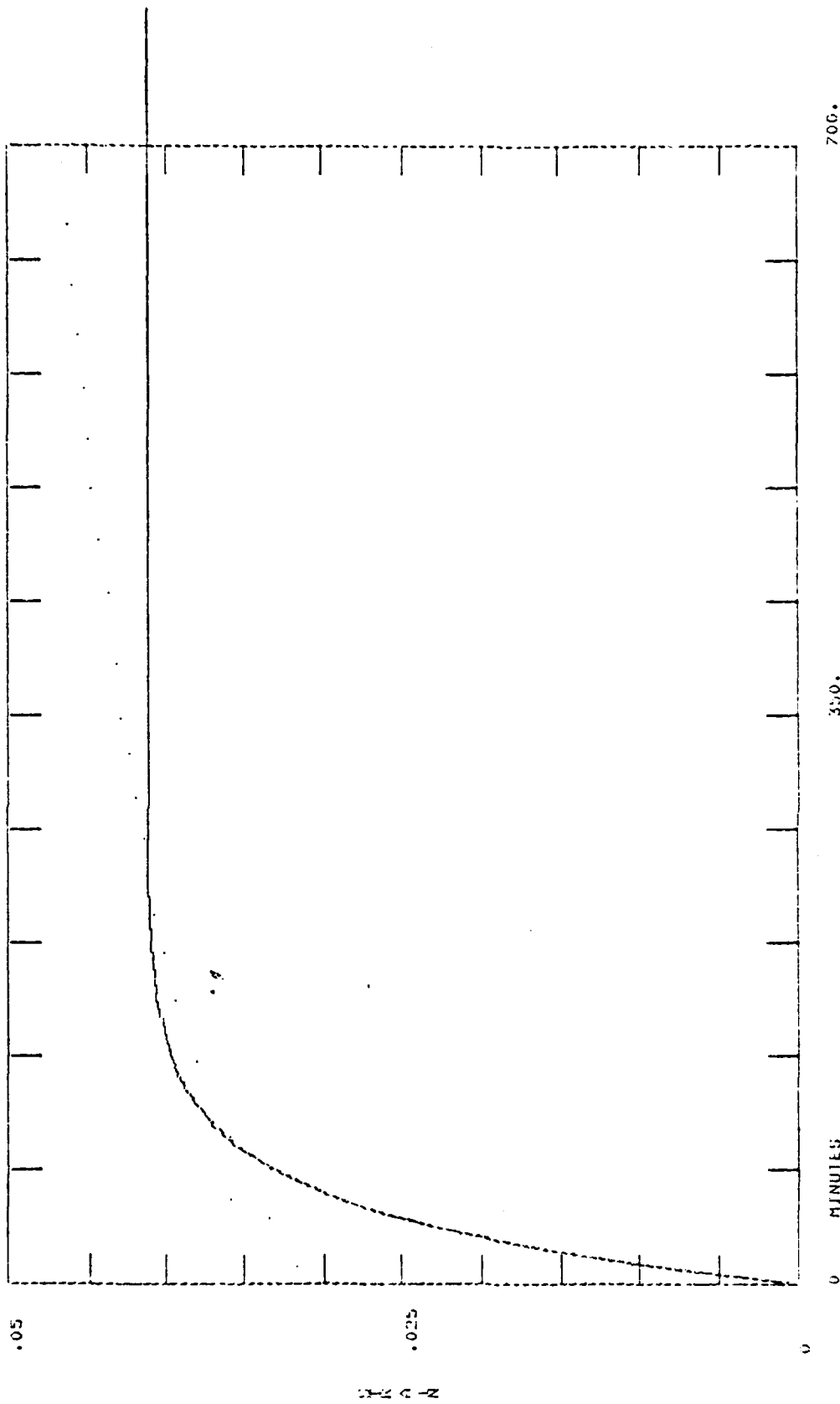
UN-5/ 12-14 13 FEB 75 AREA = 9.93 SQ CM HEIGHT = 2.16 CM
 BOTTLE LINE: ORIGINAL DATA HEAVY LINE: MODEL PREDICTION



4-PORTAMETER SOLID MODEL WITH VALUES OF
 AT = .0168247 RT = .438572 AS = .0245514 102 = 5.3715E-03
 DELTA TIME = 8
 ERROR CURSING ALL POINTS : -0.0542%
 ERROR CONORTNO FIRST 3 POINTS : -1.137%

1K-5/ 12-13 15 FEB 75 AREA = 9.93 SQ CH HEIGHT = 2.16 CM
 BOTTLED LINE: ORIGINAL DATA HEAVY LINE: MODEL PREDICTION

115



2-PROGRAMMER SOLTD MODEL WITH VALUES OF

AL = .041372, BL = .023213

DELTA TIME = 16

ERROR USING ALL POINTS :

ERROR IGNORING FIRST 3 POINTS :

9.357%

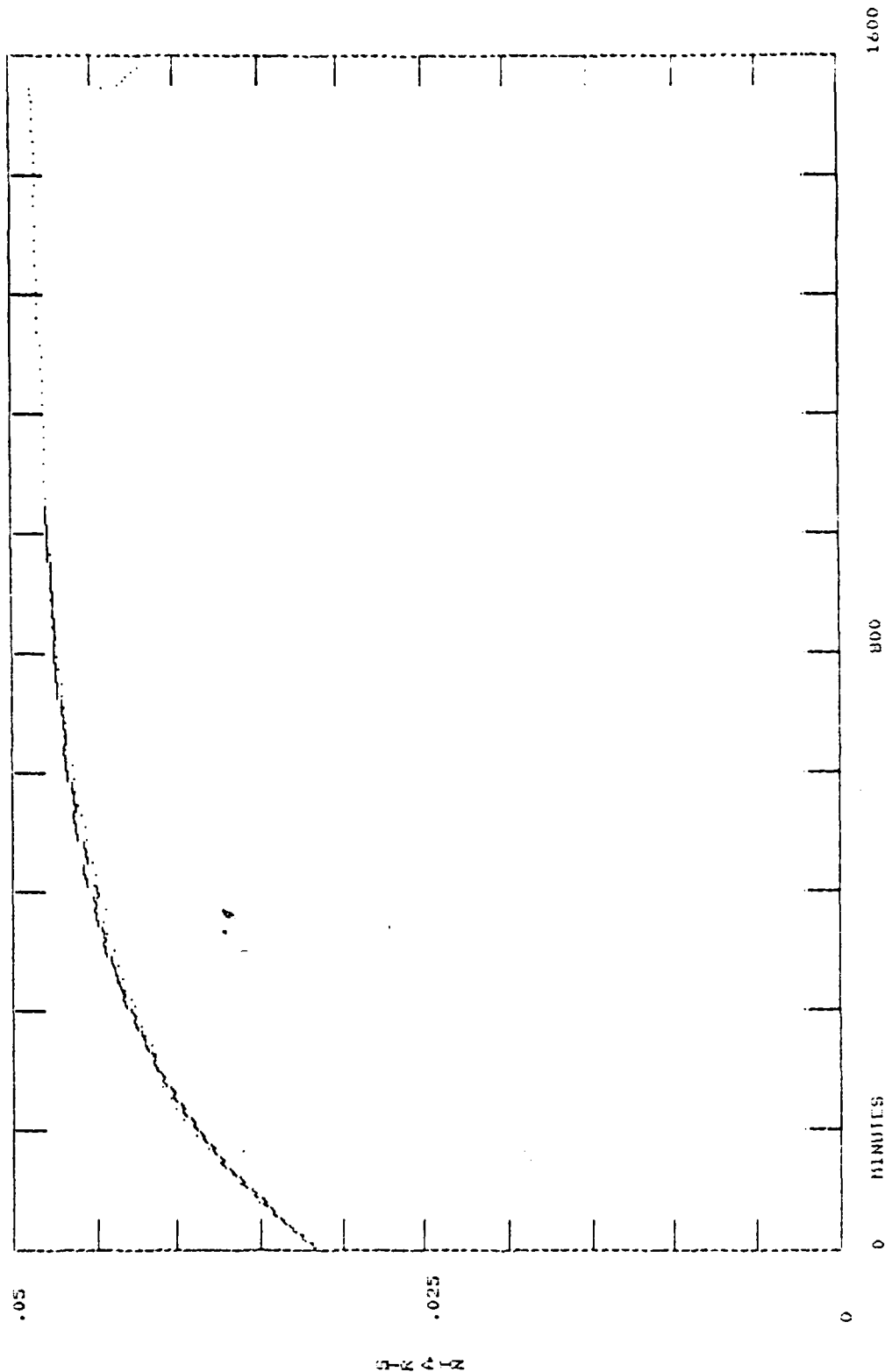
4.862%

LN-59 19-110 24 FEB 75 AREA = 16.01 SQ CM HEIGHT = 2.775 CM

BOTTLE LINE: ORIGINAL DATA

HEAVY LINE: MODEL PREDICTION

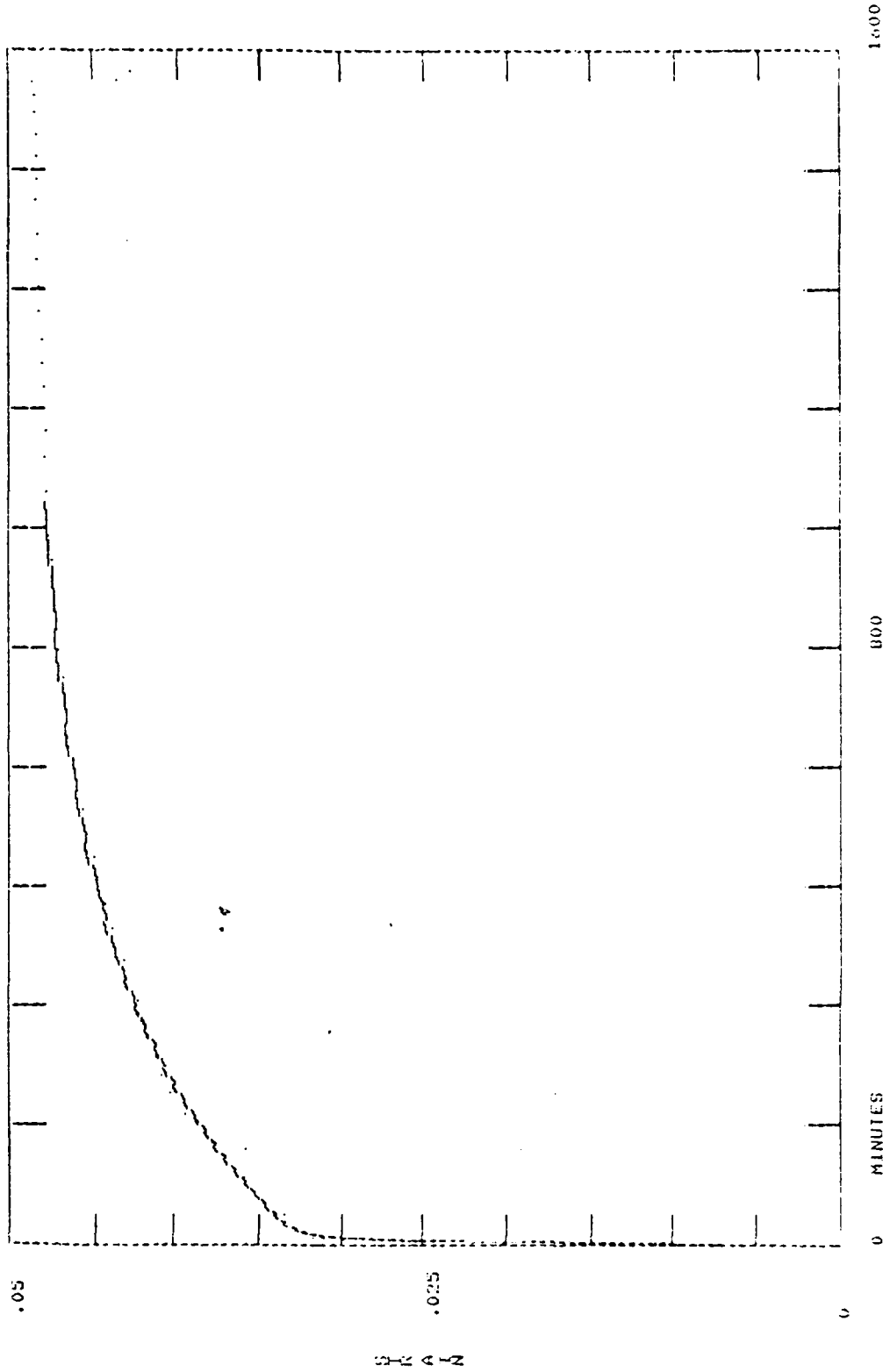
11e



3-PARAMETER SOLID MODEL WITH VALUES OF
 $\alpha_1 = .048251$, $\beta_1 = 3.5193E-05$, $\alpha_2 = .031332$
 DELTA TIME = 4
 ERROR USING ALL POINTS: 0.233%
 ERROR USING FIRST 3 POINTS: 0.044%

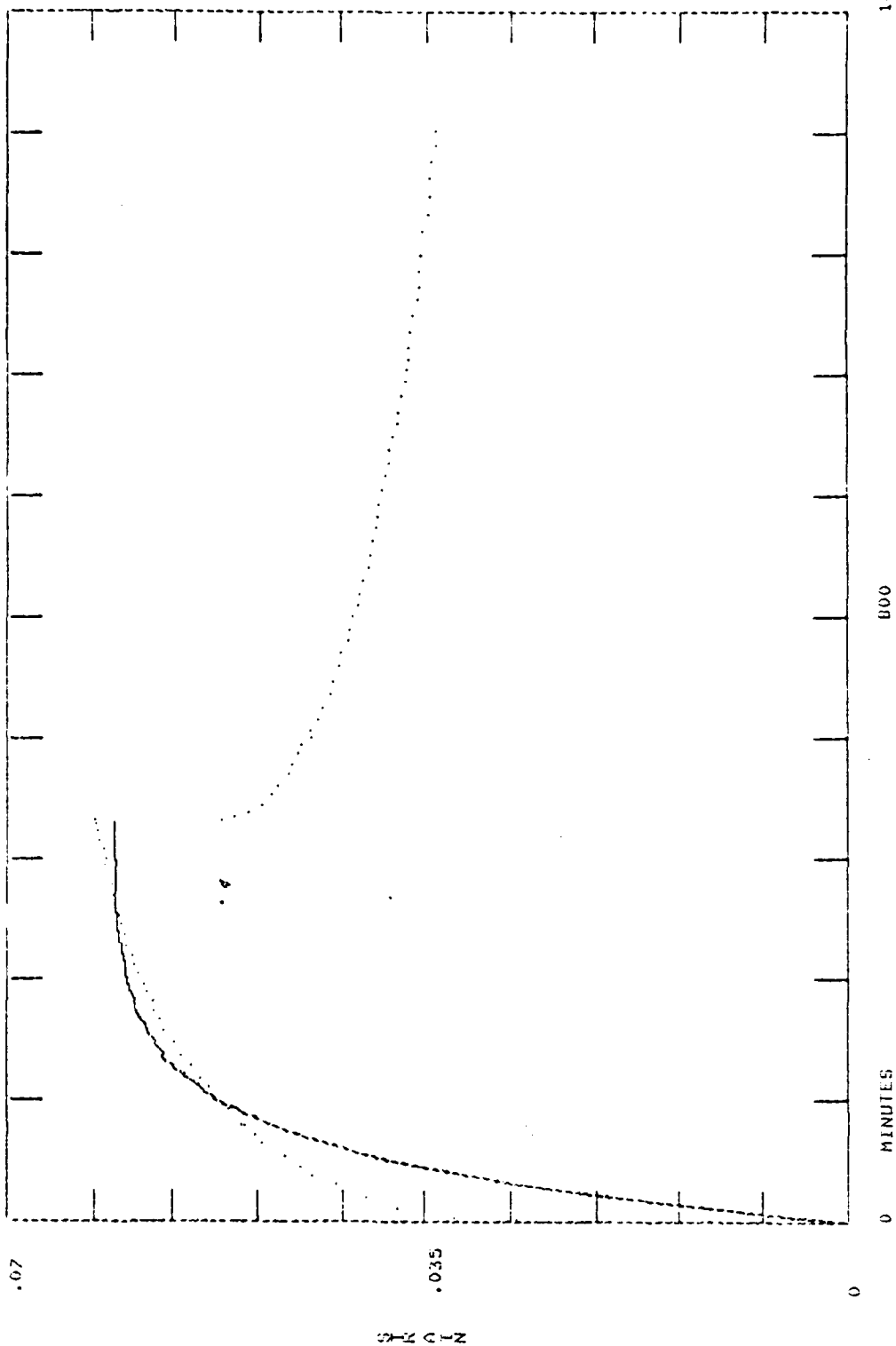
LN 59 19-110 24 FEB 75 AREA = 16.01 SQ CM HEIGHT = 2.775 CM
 DOTTED LINE: ORIGINAL DATA HEAVY LINE: MODEL PREDICTION

117



4-PROPAGATOR SOLID MODEL WITH VALUES OF
 AREA = .031251, RT = .25092, AT = .016337, RT = 3.0752E-03
 INITIAL TIME = 4 CLOSING ALL POINTS;
 ERROR CLONING FIRST 3 POINTS;
 0.0702%
 0.0392%

LA 59 19 110 24 FEB 75 AREA = 16.81 SR CM HEIGHT = 2.75 CM
 BOTTOM LINE: ORIGINAL DATA HEAVY LINE: MODI FRICTION



2-PARAMETER SOLIT MODEL WITH VALUES OF

$\Delta t = .061924$, $R1 = .01193$

DELTA TIME = 16

ERROR (IGNORING ALL POINTS):

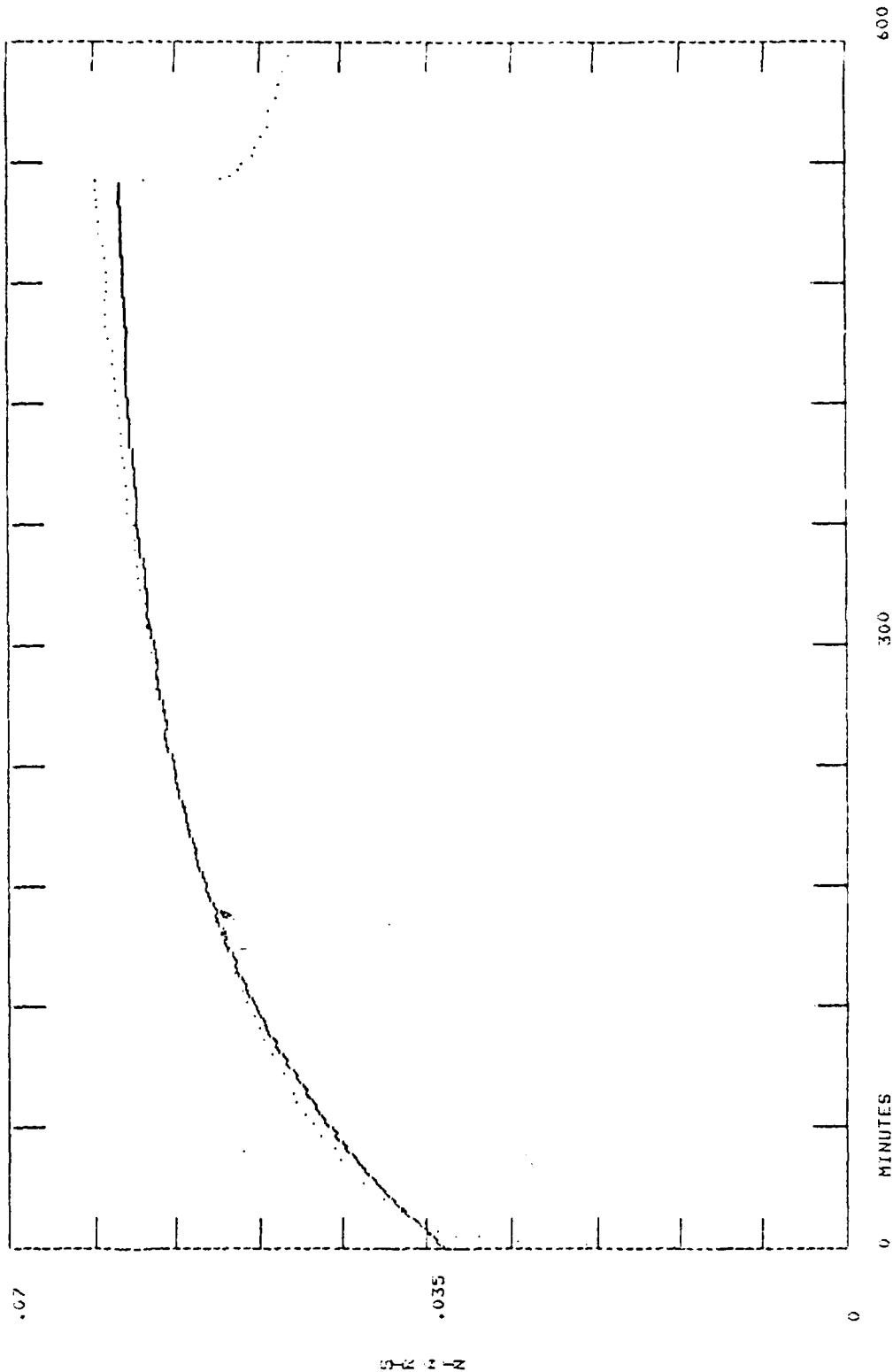
2.909%

5.166%

LR-60 14-15 26 FEB 79 AREA = 11.14 SQ CM HEIGHT = 2.24 CM

LOTTED LINE: ORIGINAL DATA HEAVY LINE: MODEL PREDICTION

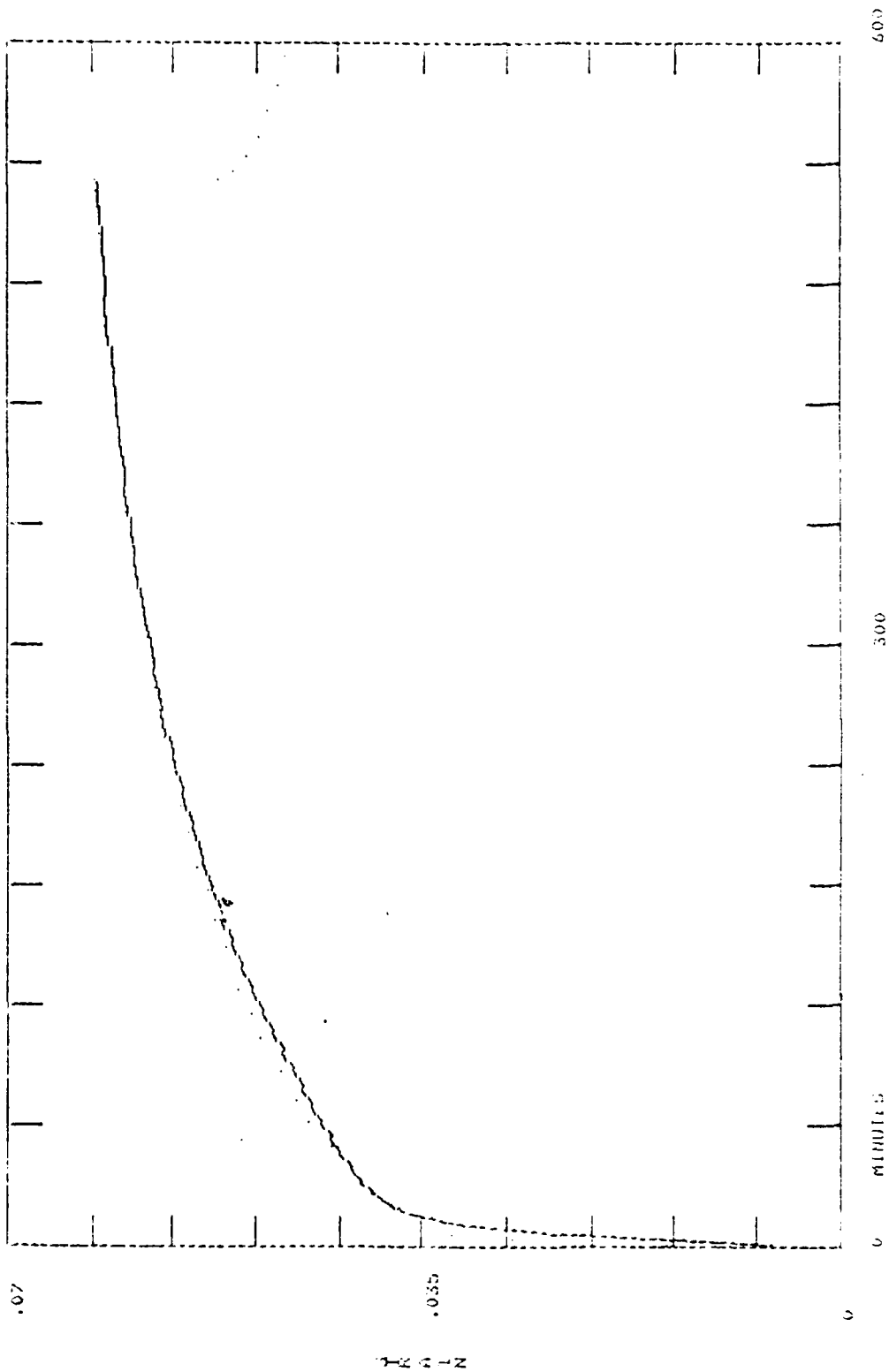
119



3-PROGRAMETER SOLTD MODEL WITH VALUES OF
 A1 = .061668, B1 = 6.9331E-03, A2 = .033548
 DELTA TIME = 4 CLOSING ALL POINTS : 0.3082%
 ERROR CLOSING FIRST 3 POINTS : 0.9722%

LN-60 14-15 28 FEB 75 AREA = 11.14 50 CM HEIGHT = 2.24 CM
 DOTTED LINE: ORIGINAL DATA HEAVY LINE: MODEL PREDICTION

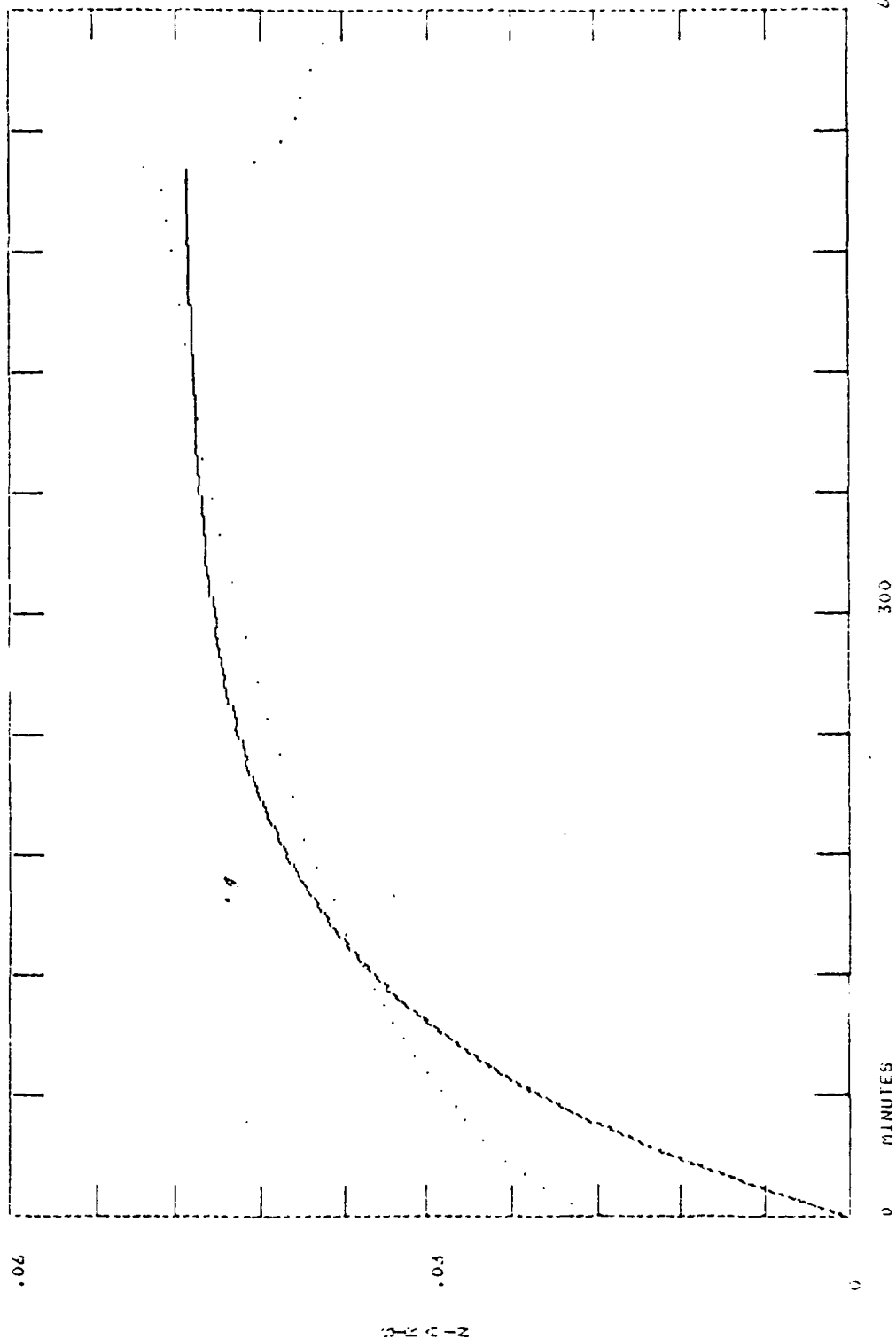
120



4-PROGRAMMER SOLID MODEL WITH VALUES OF
 Q1 = .036098, R1 = .17404, Q2 = .028821, R2 = .03445E-03
 DELTA TIME = 4
 CUSING ALL POINTS:
 ERROR CUSING FIRST 3 POINTS: 1.4702%
 0.7052%

1A-50 1A-15 20 FEB 75 AREA = 11.14 50 CM HEIGHT = 2.24 CM
 DOTTED LINE: ORIGINAL DATA HEAVY LINE: MODEL PREDICTION

121



2-PARAMETER SOLID MODEL WITH VALUES OF

$\Delta t = 0.04261$ $R_1 = 0.10447$

DELTA TIME = 1.6

ERROR (USING ALL POINTS):

ERROR (IGNORING FIRST 3 POINTS):

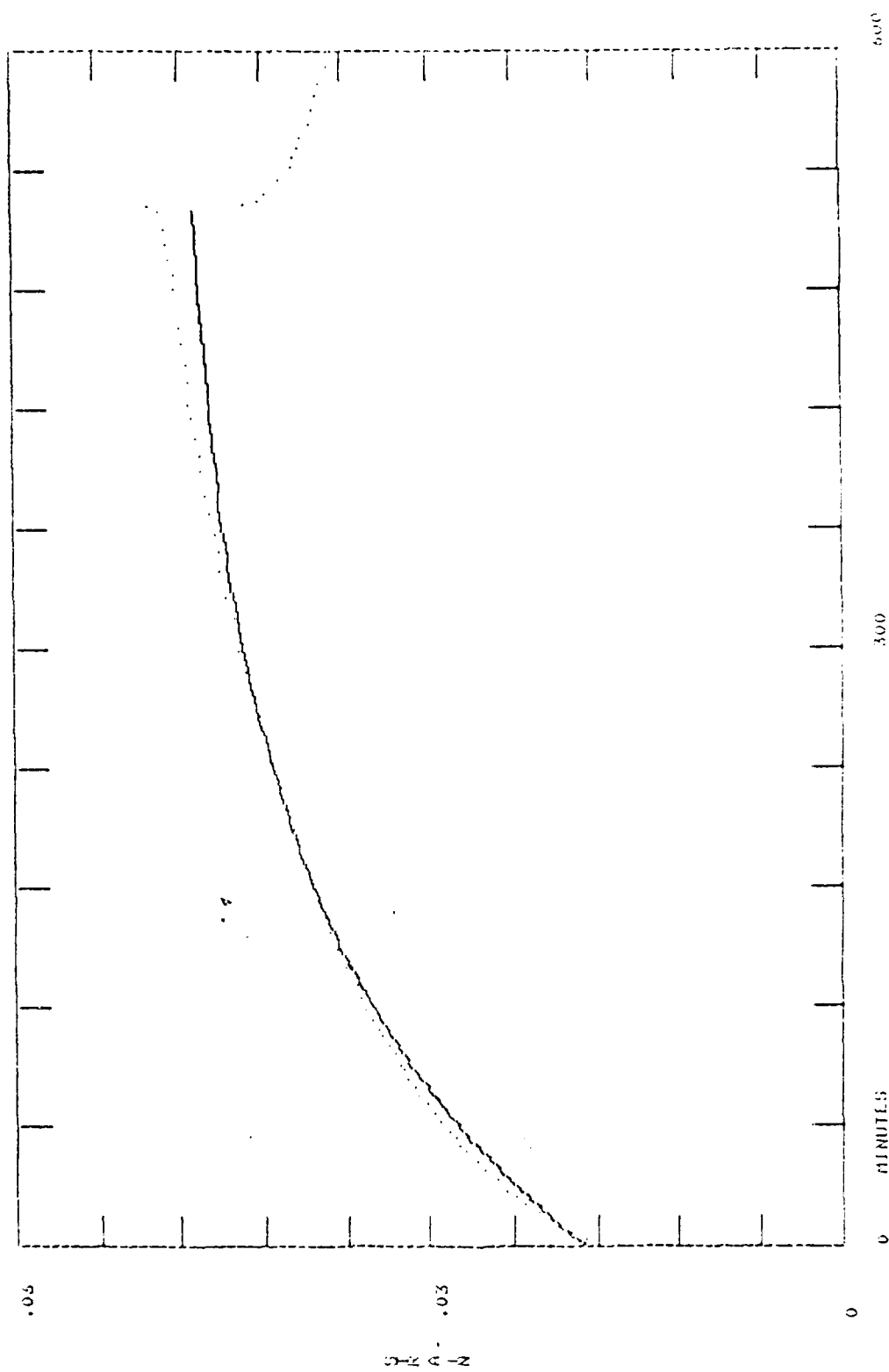
9.431%

6.264%

LN-61 15-16 5 HGT / 5 AREA = 10.43 SQ CM HEIGHT = 1.895 CM

DOTTED LINE: ORIGINAL DATA HEAVY LINE: MODEL PREDICTION

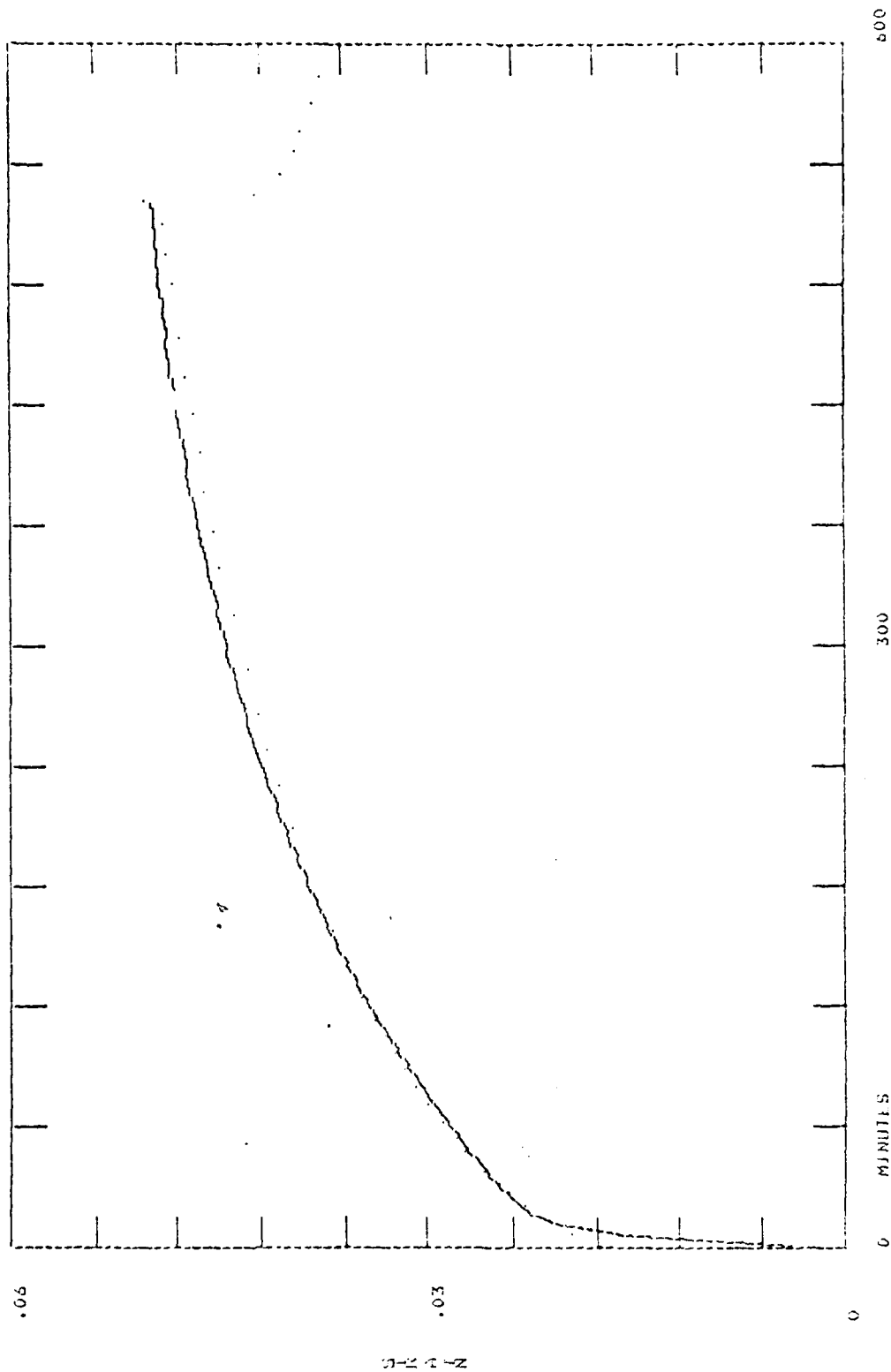
102



3-1 PARAMETER SOLID MODEL WITH VALUES OF
 A1 = .048246, B1 = 6.0272E-03, A2 = .01902
 DELTA TIME = 30
 CUSING ALL POINTS:
 ERROR CUSING FIRST 5 POINTS:
 2.088%
 2.086%

IN-61 15-16 3 HOK 75 AREA = 10.43 SQ CM HEIGHT = 1.895 CM
 DOTTED LINE: ORIGINAL DATA HEAVY LINE: MODEL PREDICTION

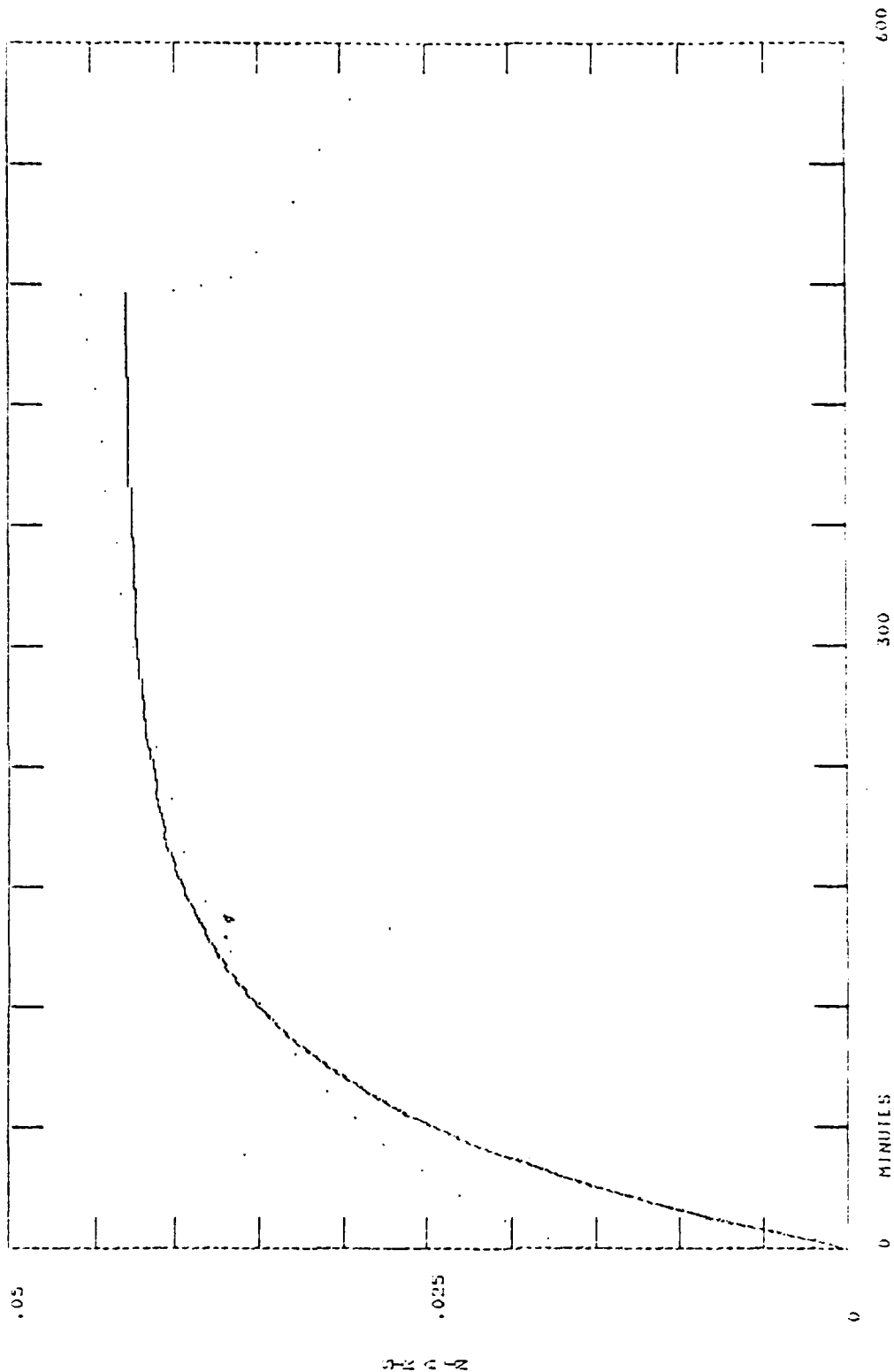
123



4 - PARABOLIC SOLID MODEL WITH VALUES OF
 AT = 0.021092, RT = 0.21503, AR = 0.032252, BR = 4.3448E-03
 DELTA TIME = 4
 ERROR (USING ALL POINTS) = 1.486%
 ERROR (USING FIRST 3 POINTS) = 0.651%

LN 61 15 14 3 HR 75 AREA = 10.43 SQ CM HEIGHT = 1.895 CM
 PLOTED LINE: ORIGINAL DATA HEAVY LINE: MODEL PREDICTION

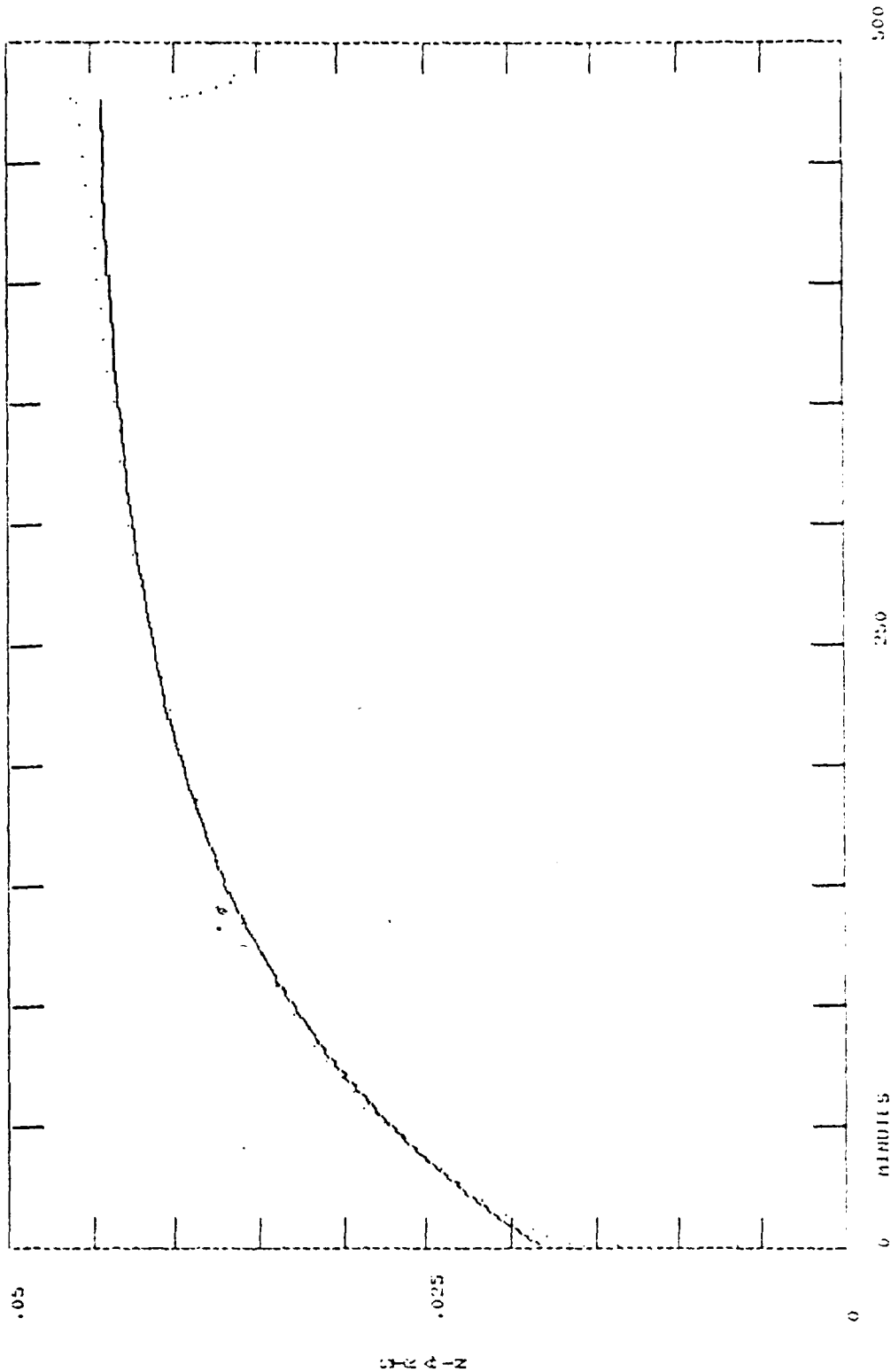
126



2. PLOT THE LINE, SOLID MODEL WITH VALUES OF
 CUTTING OFF POINTS = 0.014163
 CUTOFF TIME = 12.33
 CUTOFF POINTS = 10.299%
 CUTOFF POINTS = 6.348%

LN-62 16.17 5 MAR 75 AREA = 12.33 SQ CM HEIGHT = 1.85 CM
 DOTTED LINE: ORIGINAL DATA
 HEAVY LINE: MODEL PREDICTION

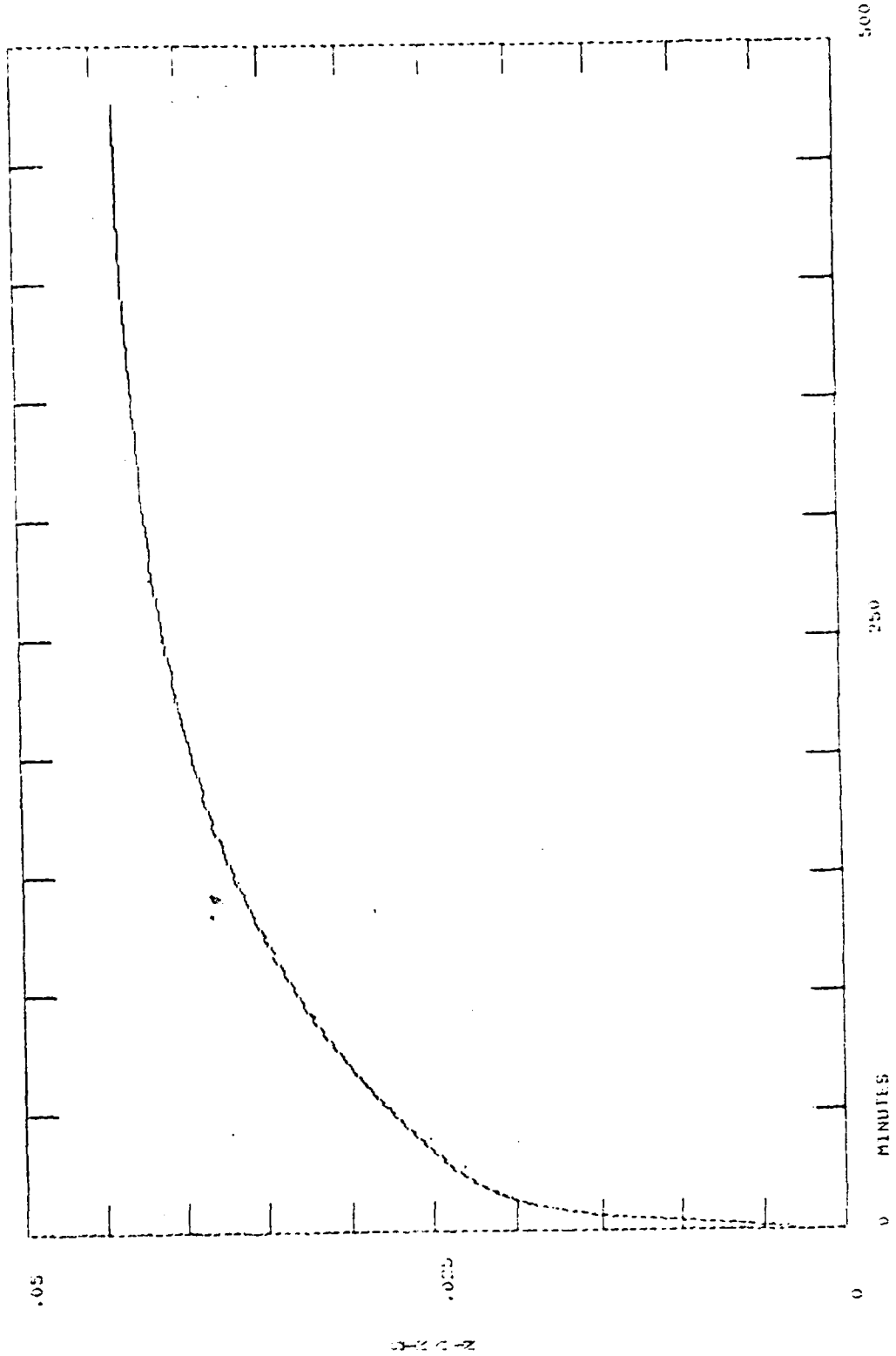
125



3-PROGRAMMER SOLTD MODEL WITH VALUES OF
 Q1 = 0.04505, Q2 = 7.9913E-03, Q3 = 0.018245
 TOTAL TIME = 0
 ERROR CUSTING ALL POINTS: 0.5592E
 ERROR CUSTING FIRST 3 POINTS: 0.5592E

LN 62 16-17 5 MCR 75 AREA = 12.55 50 CM HEIGHT = 1.05 CM
 DOTTED LINE: ORIGINAL DATA HEAVY LINE: MODEL PREDICTION

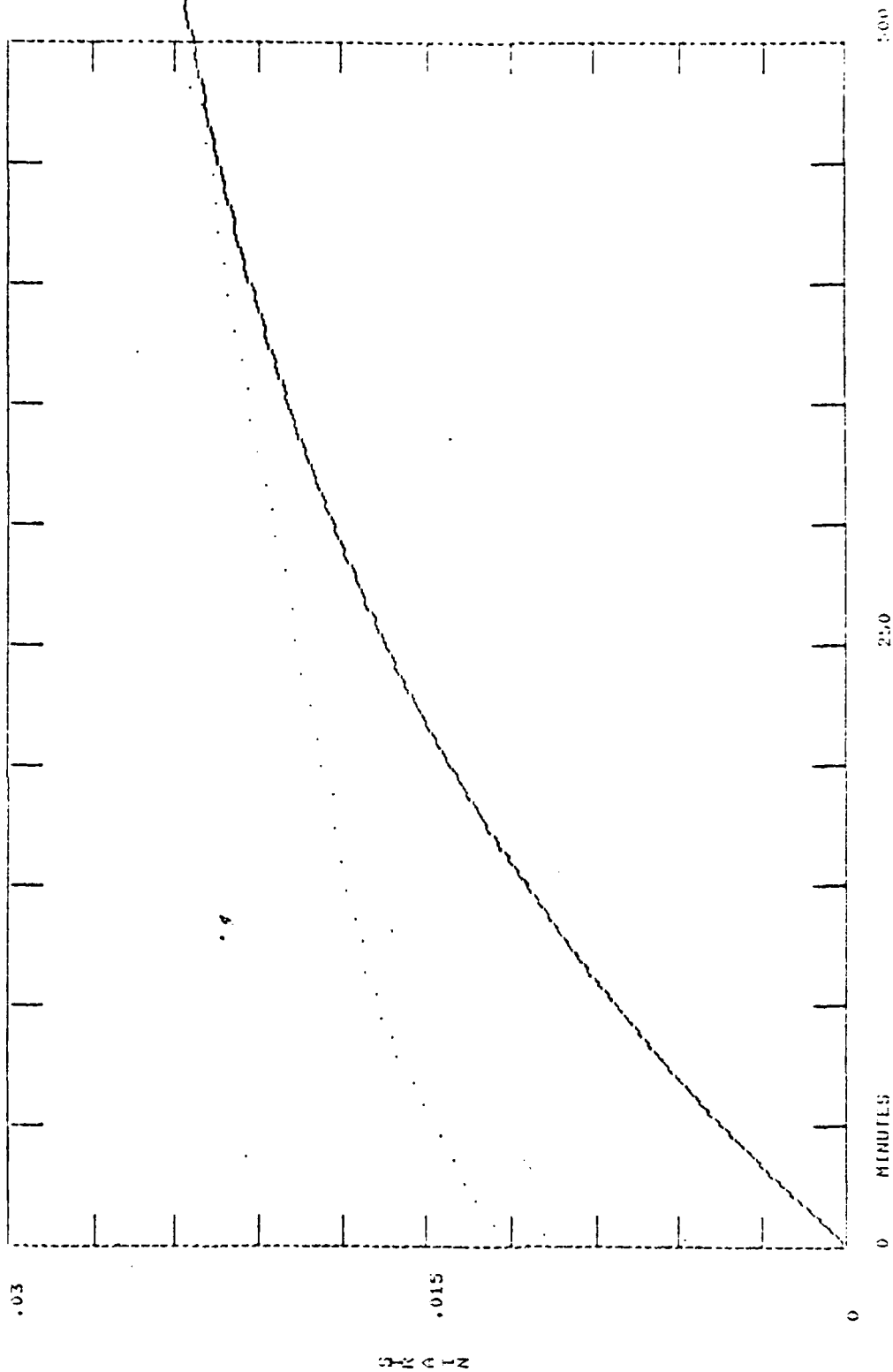
106



4- PARAGUETTES SOLID MODEL WITH VALUES OF
 C1 = .0253333, B1 = 8.2337E-03, C2 = .019021, K2 = .22008
 IN 1.16, TIME = 8
 ERROR COUNTS ALL POINTS: 5.7792
 ERROR COUNTING FIRST 5 POINTS: 1.1132

LN 62 16 17 5 808 75 AREA = 12.35 50 CM HEIGHT 1.05 CM
 TOTAL TIME: ORIGINAL DATA 01.593 TIME: ADJUSTED PRODUCTION

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2-PARAMETER SOLID MODEL WITH VALUES OF

Q1 = .020549, B1 = 35.9908E-03

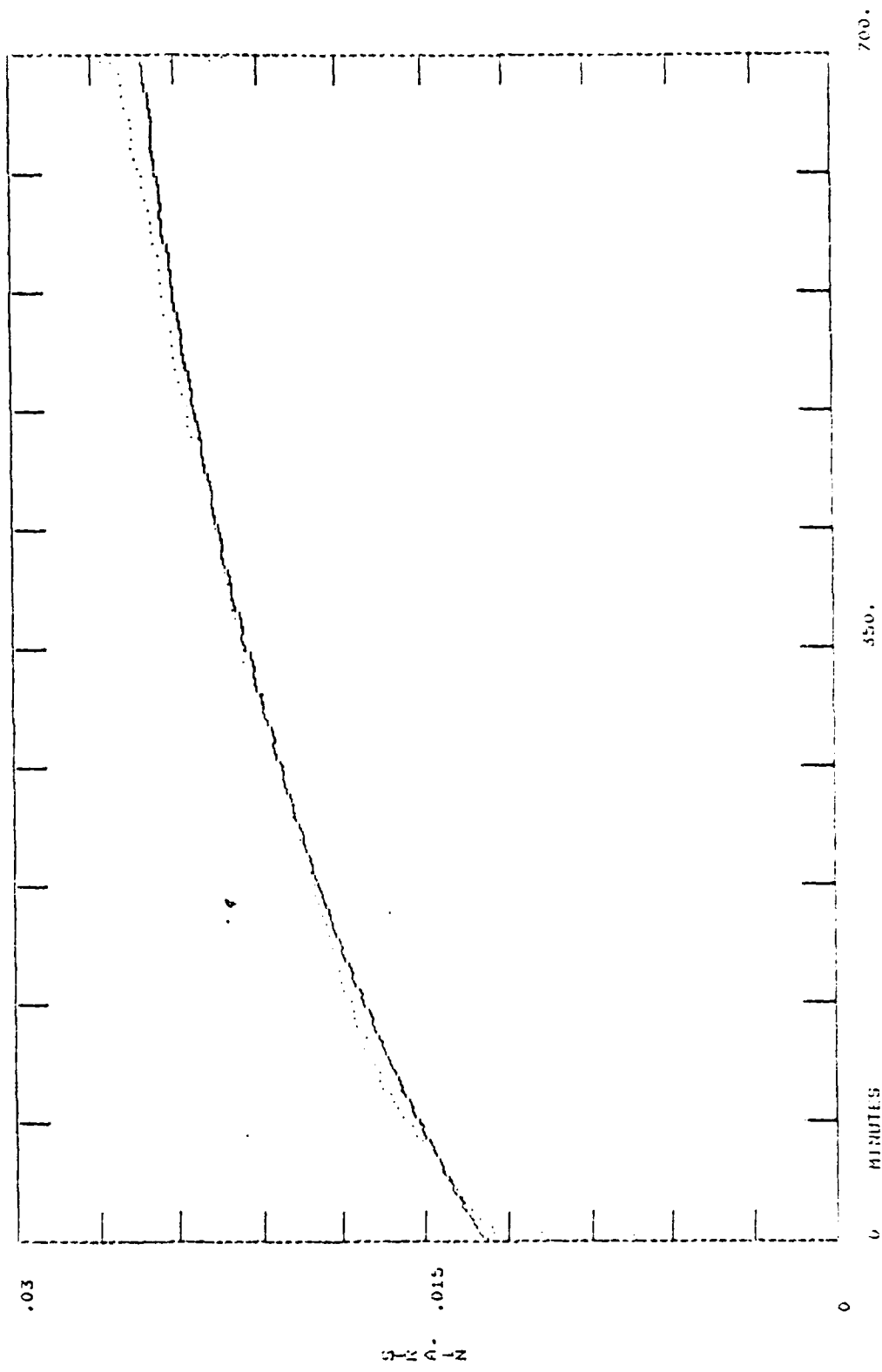
DELTA TIME = 4

ERROR (USING ALL POINTS): 20.497%

ERROR (CONORNO FIRST 3 POINTS): 22.969%

LA-63 111-112 6 MAR 75 AREA = 16.5 SQ CM HEIGHT = 2.975 CM

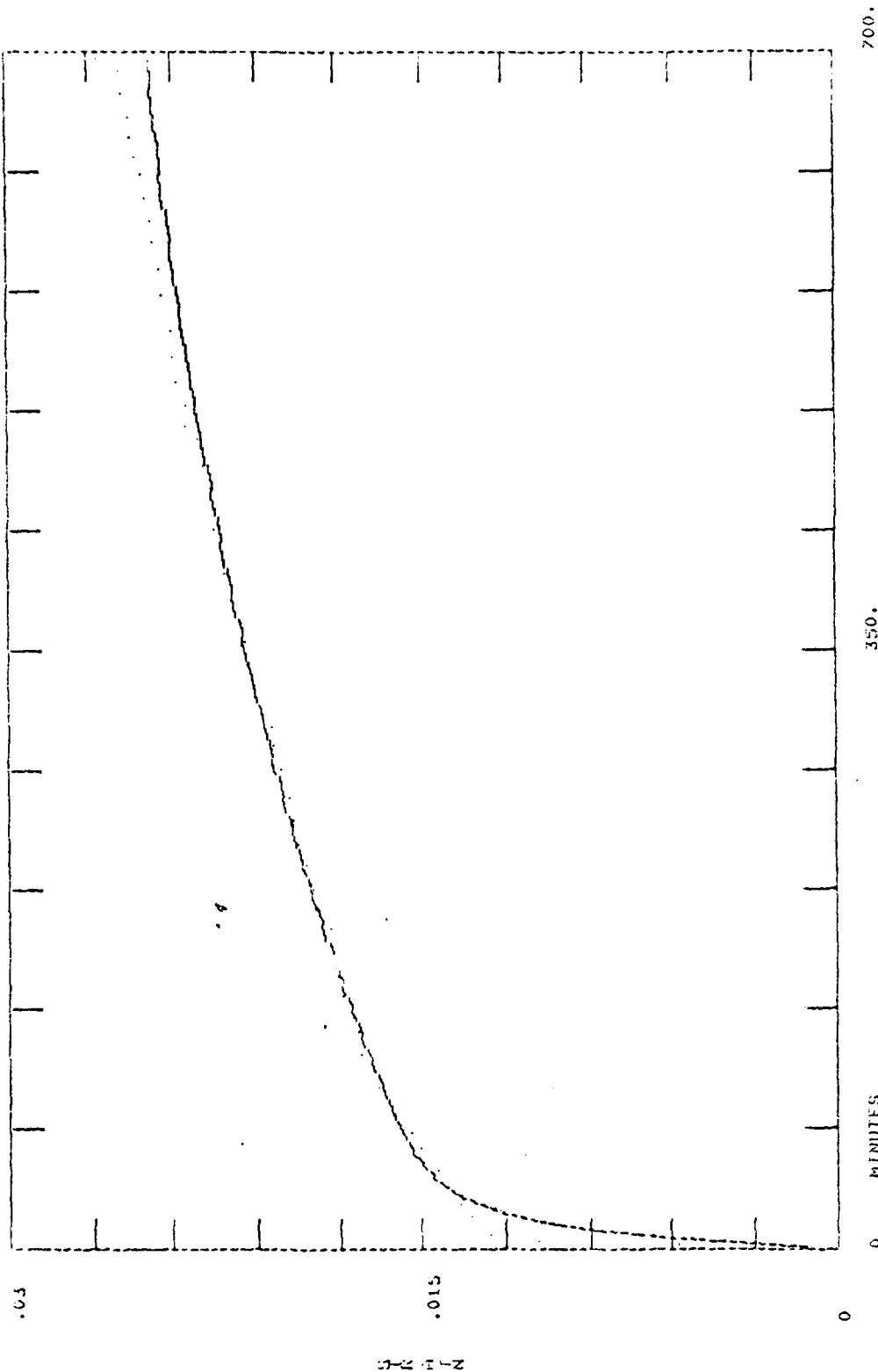
DOTTED LINE: ORIGINAL DATA HEAVY LINE: MODEL PREDICTION



3-PORT/METER SOLTD MODEL WITH VALUES OF
 Q1 = .023017, B1 = 2.3659E-03, Q2 = .012000
 DELTA T TIME = 4
 CUSING ALL POINTS:
 ERROR (CONSIDERING FIRST 3 POINTS):
 0.2402%
 1.4002%

LN-63 111-112 6 MAR 75 AREA = 16.5 50 CM HEIGHT = 2.975 CM
 DOTTED LINE: ORIGINAL DATA HEAVY LINE: MODEL PREDICTION

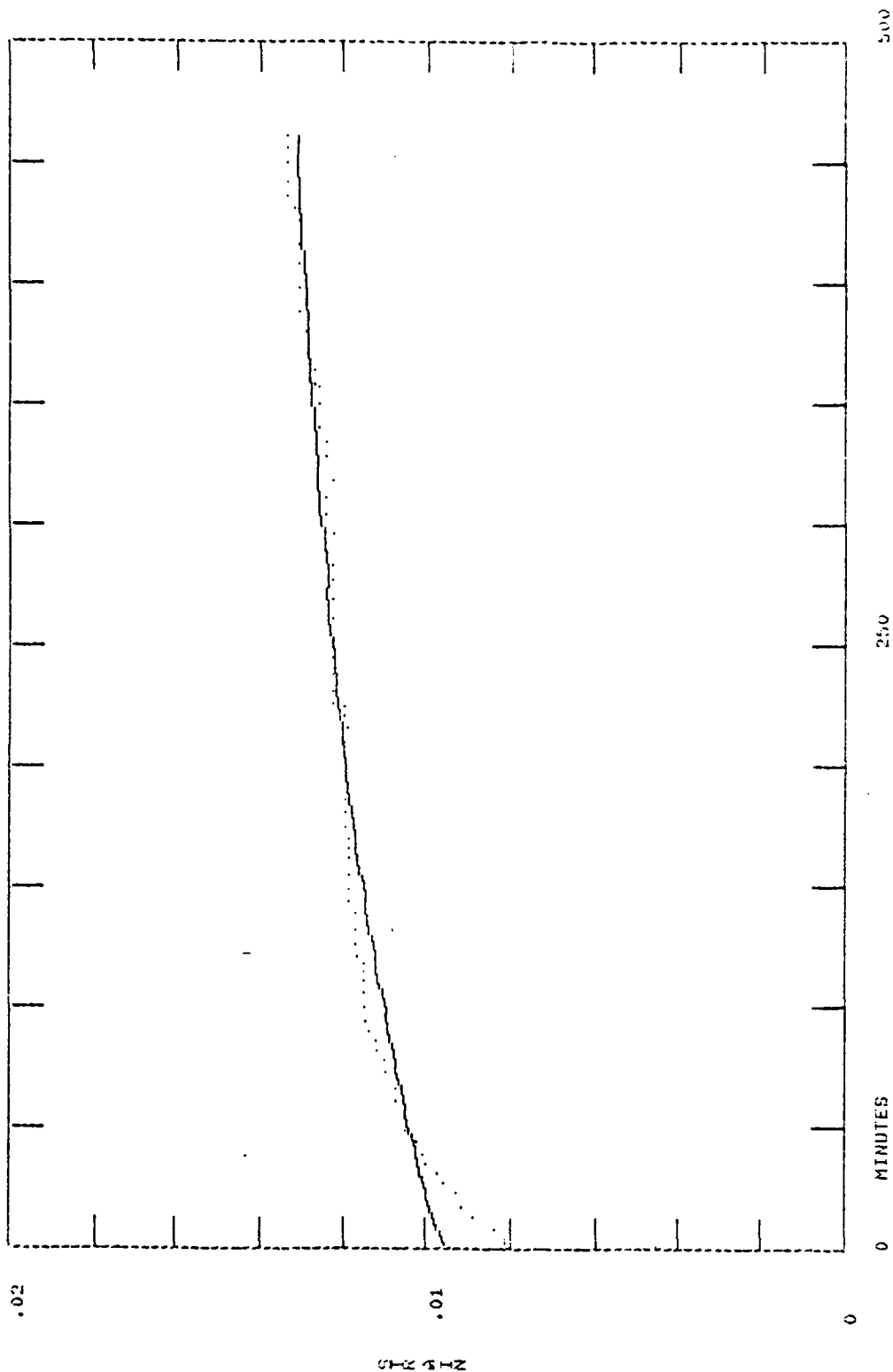
601



4-PARAMETER SOLID MODEL WITH VALUES OF
 $A1 = .013835$, $B1 = .0853$, $A2 = .01402$, $B2 = 2.2295E-03$
 DELTA TIME = 4
 ERROR USING ALL POINTS: 2.4132
 ERROR USING FIRST 3 POINTS: 1.2279%

IN-65 111-112 6 MAR 75 AREA = 16.5 50 CM HEIGHT = 2.975 CM
 DOTTED LINE: ORIGINAL DATA HEAVY LINE: MODEL PREDICTION

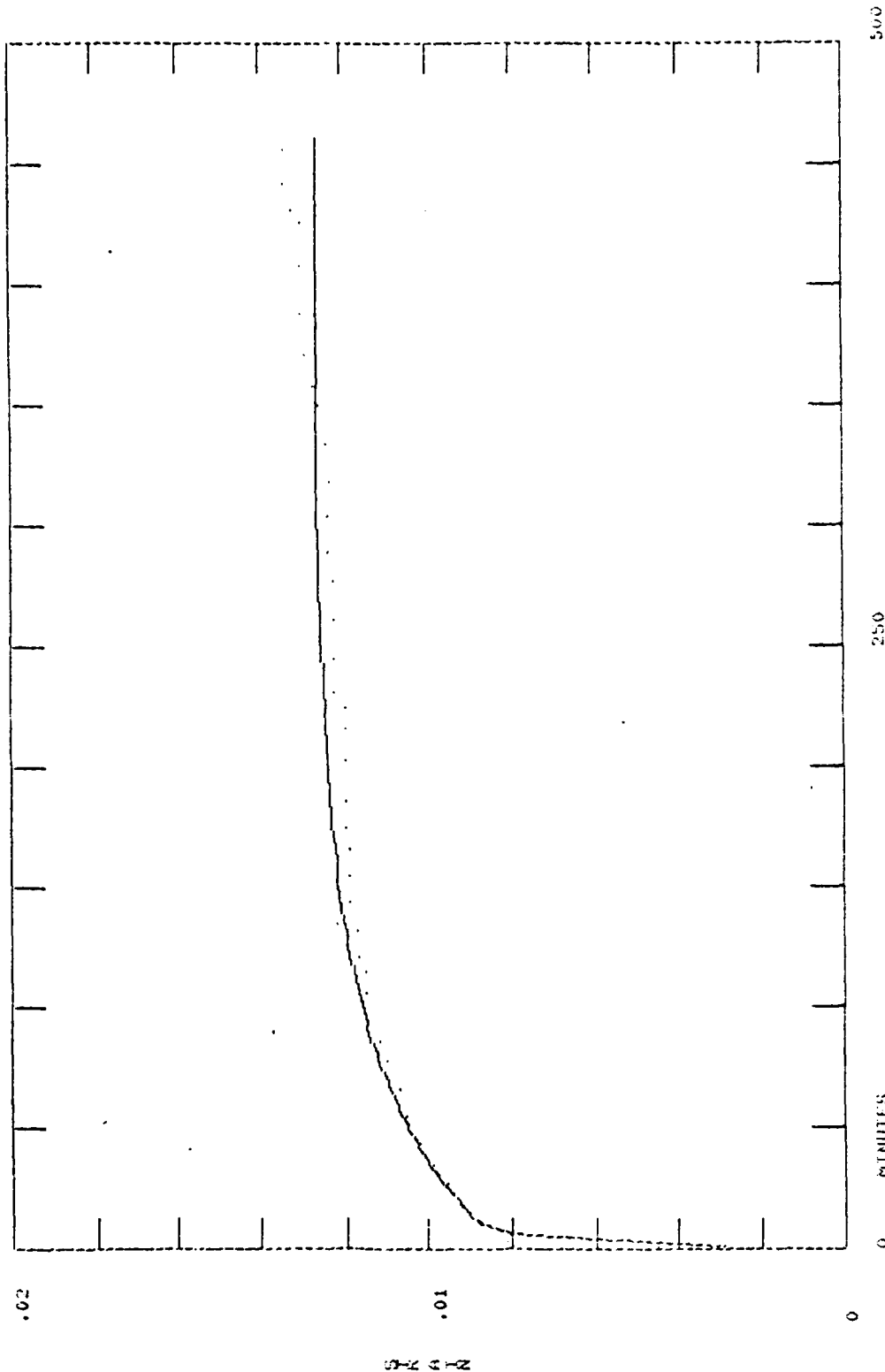
13



3-PARAMETER SOLID MODEL WITH VALUES OF
 $\alpha_1 = .013837$, $\beta_1 = 3.9809E-03$, $\alpha_2 = .009679$
 DELTA TIME = 4
 ERROR CUSING ALL POINTS: -0.729%
 ERROR CUSING FIRST 3 POINTS: -0.087%

LN-64 17-18 7 MAR 75 AREA = 13.69 SQ CM HEIGHT = 2.66 CM
 DOTTED LINE: ORIGINAL DATA HEAVY LINE: MODEL PREDICTION

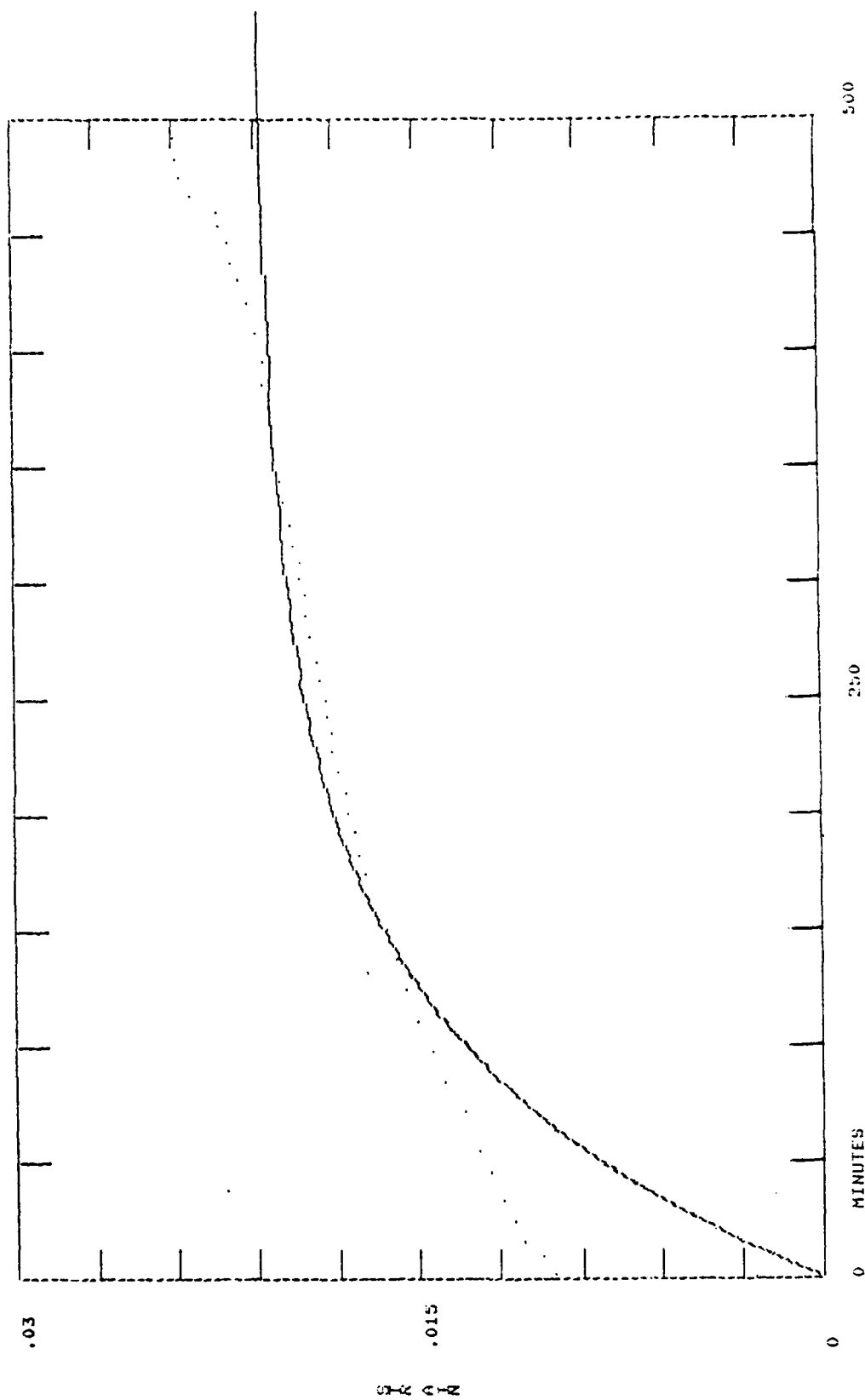
121



4-PARAMETER SOLID MODEL WITH VALUES OF
 Q1 = 8.3359E-03, Q2 = .03733, Q3 = 4.3261E-03, Q4 = .013774
 DELTA TIME = 8
 ERROR < USING ALL POINTS > : 0.144%
 ERROR < USING FIRST 3 POINTS > : 0.619%

LN 64 17-18 7 MAR 75 AREA = 13.69 SQ CM HEIGHT = 2.66 CM
 DOTTED LINE: ORIGINAL DATA HEAVY LINE: MODEL PREDICTION

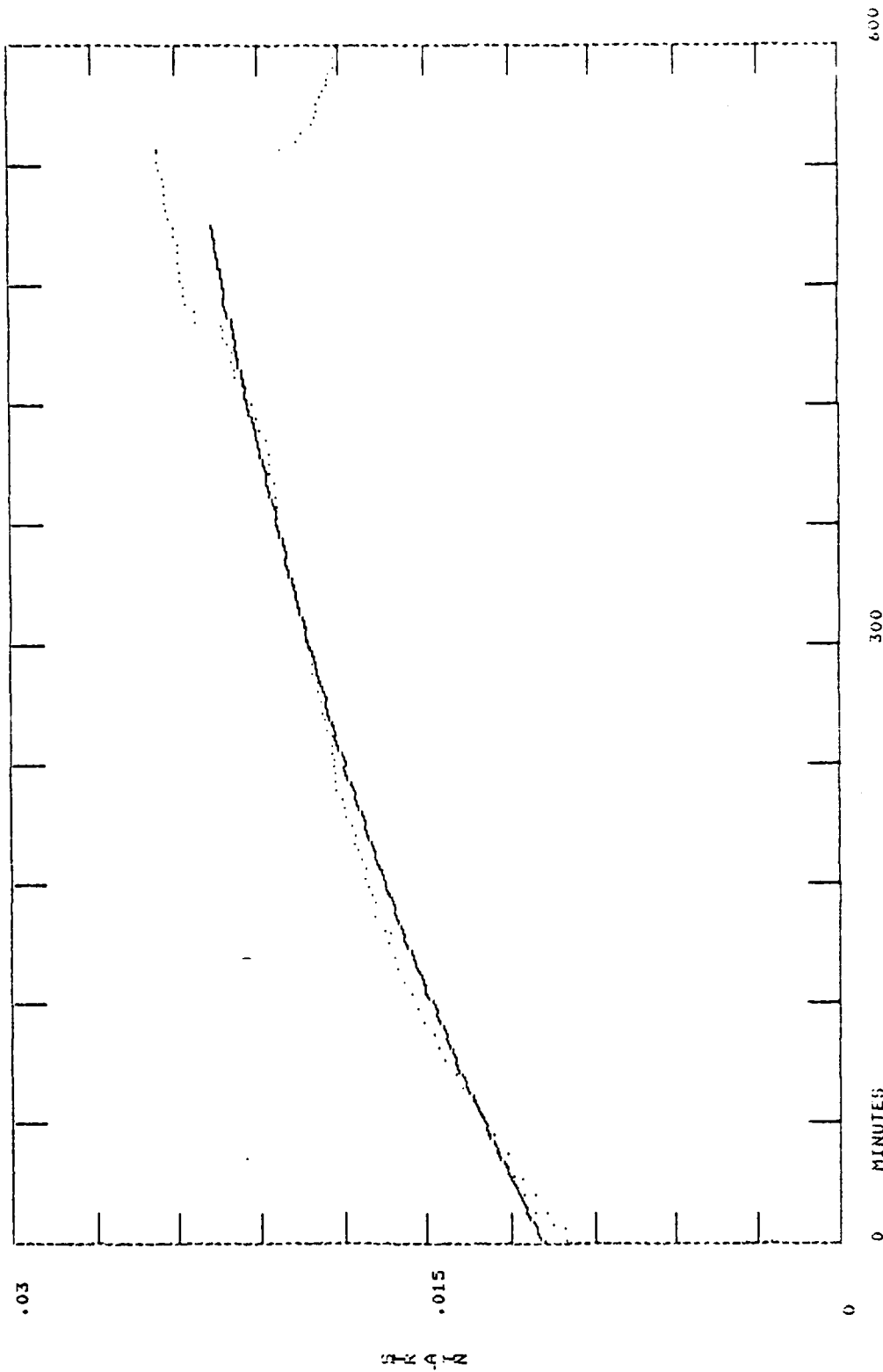
132



2-PARAMETER SOLID MODEL WITH VALUES OF
 AT = .020895, BT = .010111
 DELTA TIME = 8
 ERROR COSTING ALL POINTS: 7.2295%
 ERROR COSTING FIRST 5 POINTS: 5.2722%

LN-65 110-111 10 MAR 75 AREA = 14.56 SQ CM HEIGHT = 2.765 CM
 DOTTED LINE: ORIGINAL DATA HEAVY LINE: MODEL PREDICTION

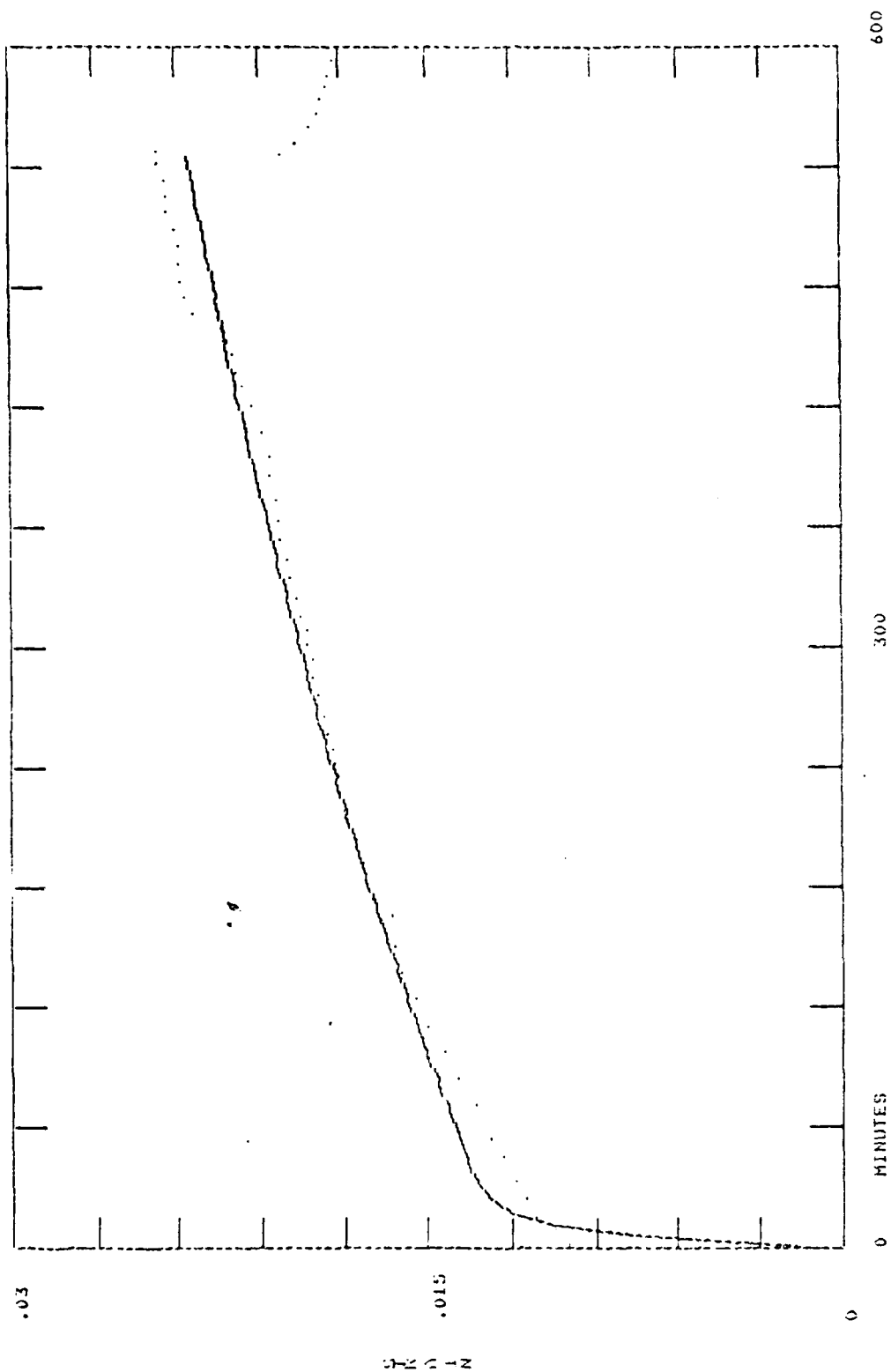
123



3-PARAMETER SOLID MODEL WITH VALUES OF
 A1 = .02293097 B1 = 2.0263E-037 A2 = .010853
 DELTA TIME = 4
 ERROR (USING ALL POINTS): 0.825%
 ERROR (USING FIRST 3 POINTS): 1.513%

LK-65 T10-T11 10 Min. 75 AREA = 14.56 SQ CM HEIGHT = 2.725 CM
 DOTTED LINE: ORIGINAL DATA HEAVY LINE: MODEL PREDICTION

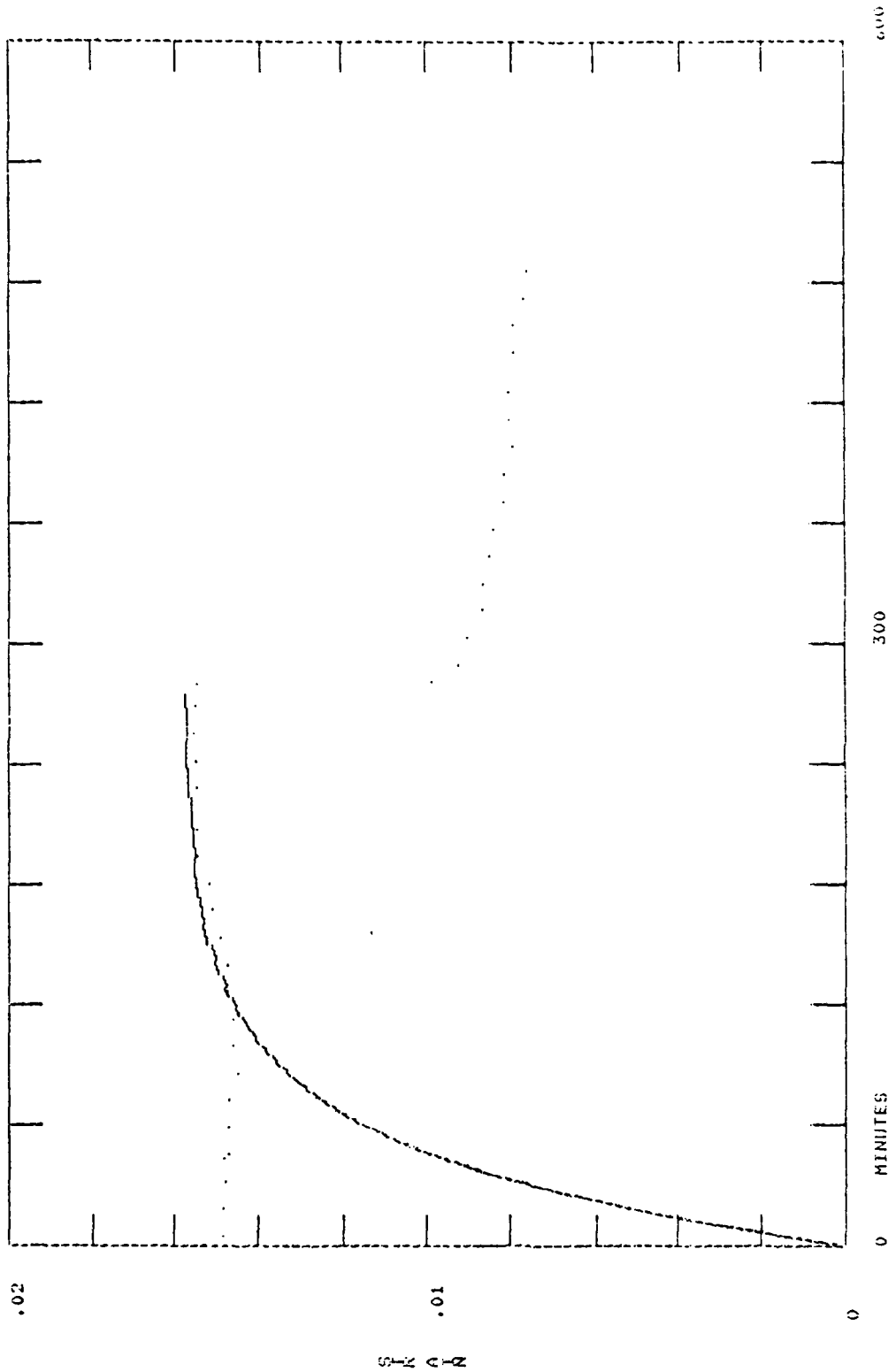
124



4-POROMETER SOLID MODEL WITH VALUES OF
 Q1 = .013379, Q2 = .13721, Q3 = .020555, Q4 = 1.4509E-03
 DELTA TIME = 8
 ERROR CUSING ALL POINTS: 0.374%
 ERROR CUSING FIRST 3 POINTS: -0.365%

LR-65 110-111 10 MAR 75 AREA = 14.56 SQ CM HEIGHT = 2.765 CM
 DOTTED LINE: ORIGINAL DATA HEAVY LINE: MODEL PREDICTION

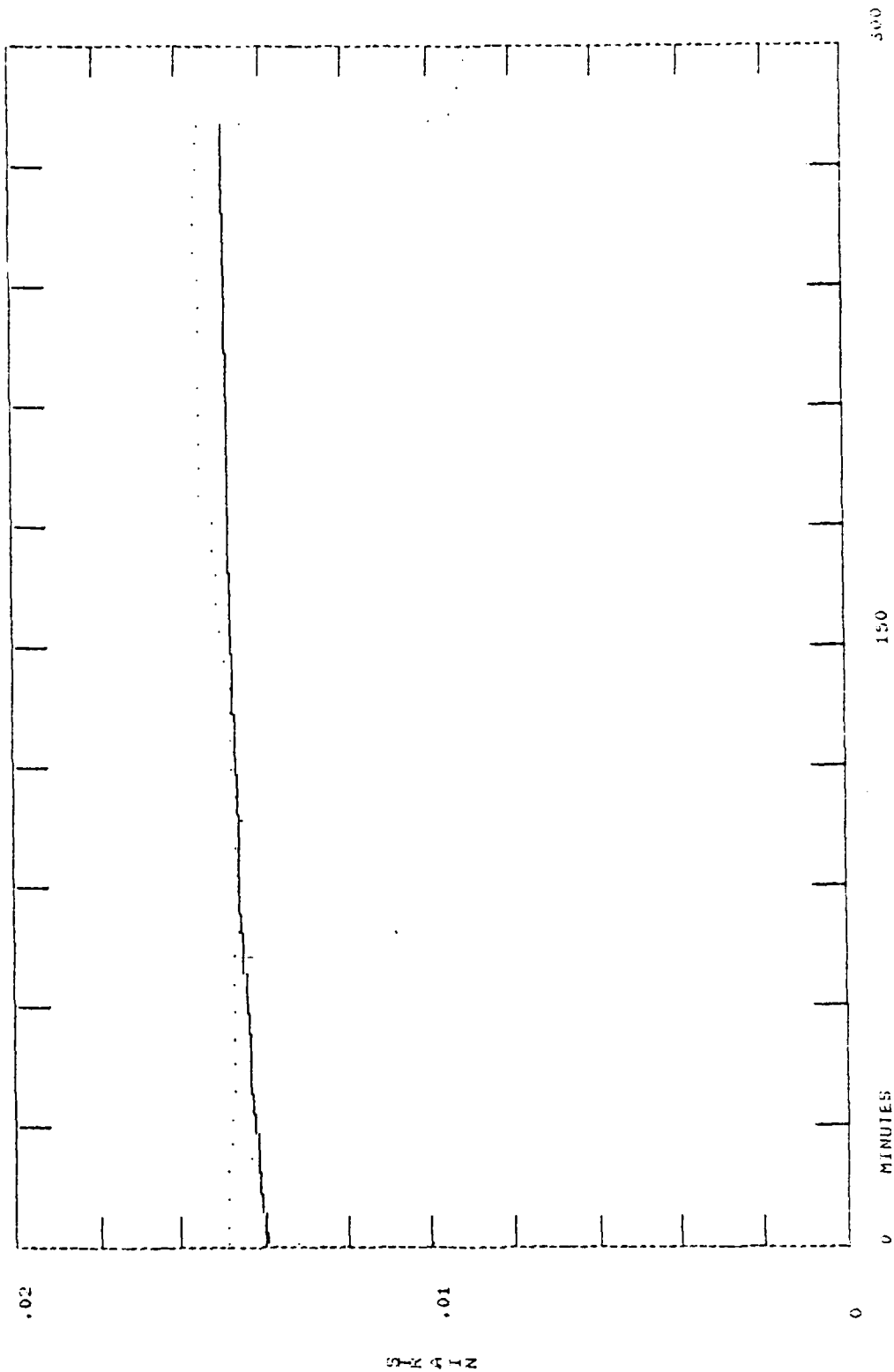
135



2-1 PARAMETER SOLID MODEL WITH VALUES OF
 $\alpha_1 = .015807$, $\beta_1 = .021706$
 MODEL TIME = 30
 ERROR COSTING ALL POINTS: 17.182%
 ERROR COSTING FIRST 5 POINTS: 0.8995%

1K-66 10-19 11 MAR 75 AREA = 16.53 SQ CM HEIGHT = 2.705 CM
 DOTTED LINE: ORIGINAL DATA HEAVY LINE: MODEL PREDICTION

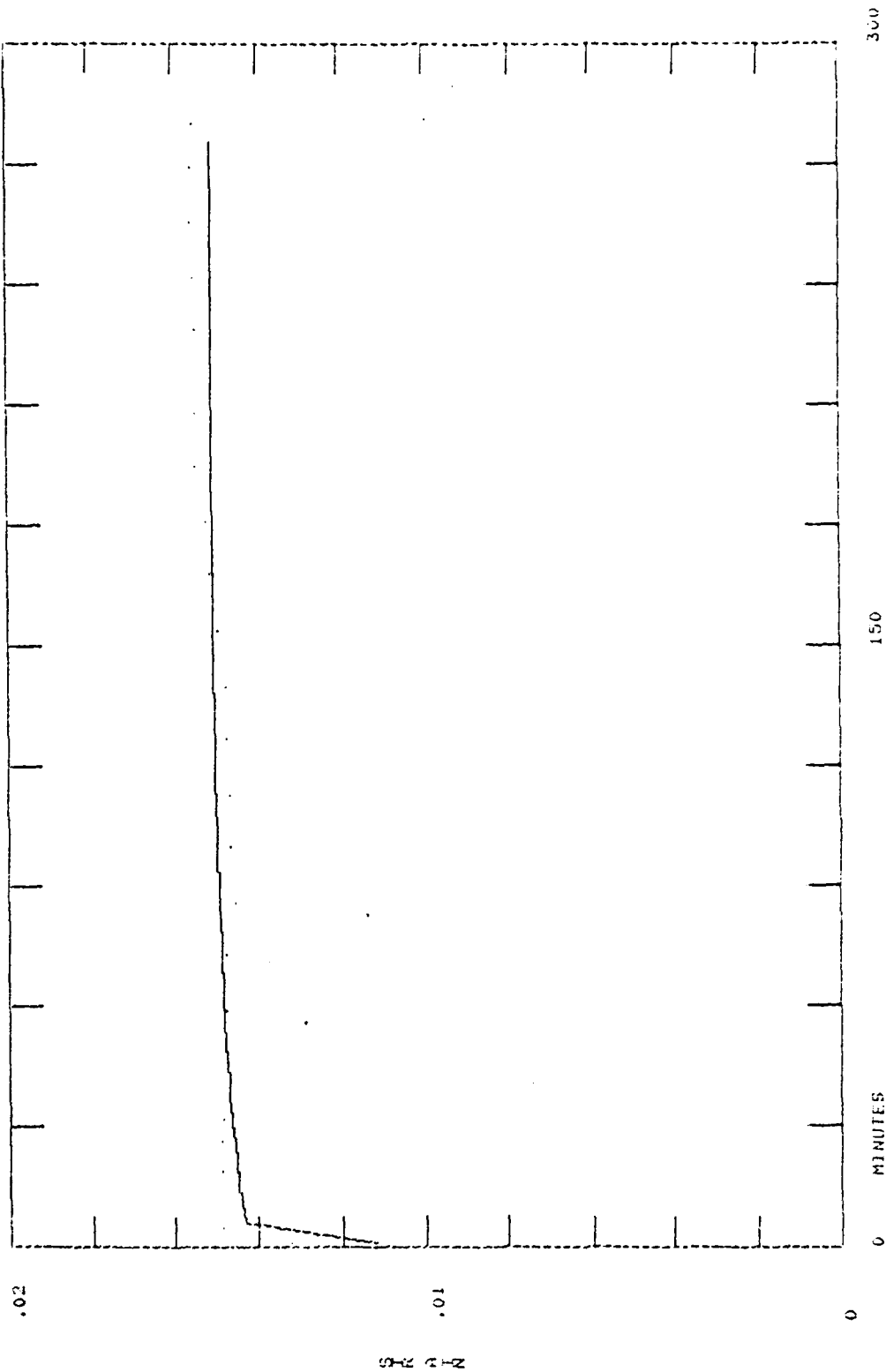
30



3-PARAMETER SOLID MODEL WITH VALUES OF
 AT = .014033 RT = 8.9532E-03 A2 = .014033
 DELTA TIME = 4
 ERROR CUSING ALL POINTS:
 ERROR CUSING FIRST 3 POINTS:
 2:58.52%
 2:59.02%

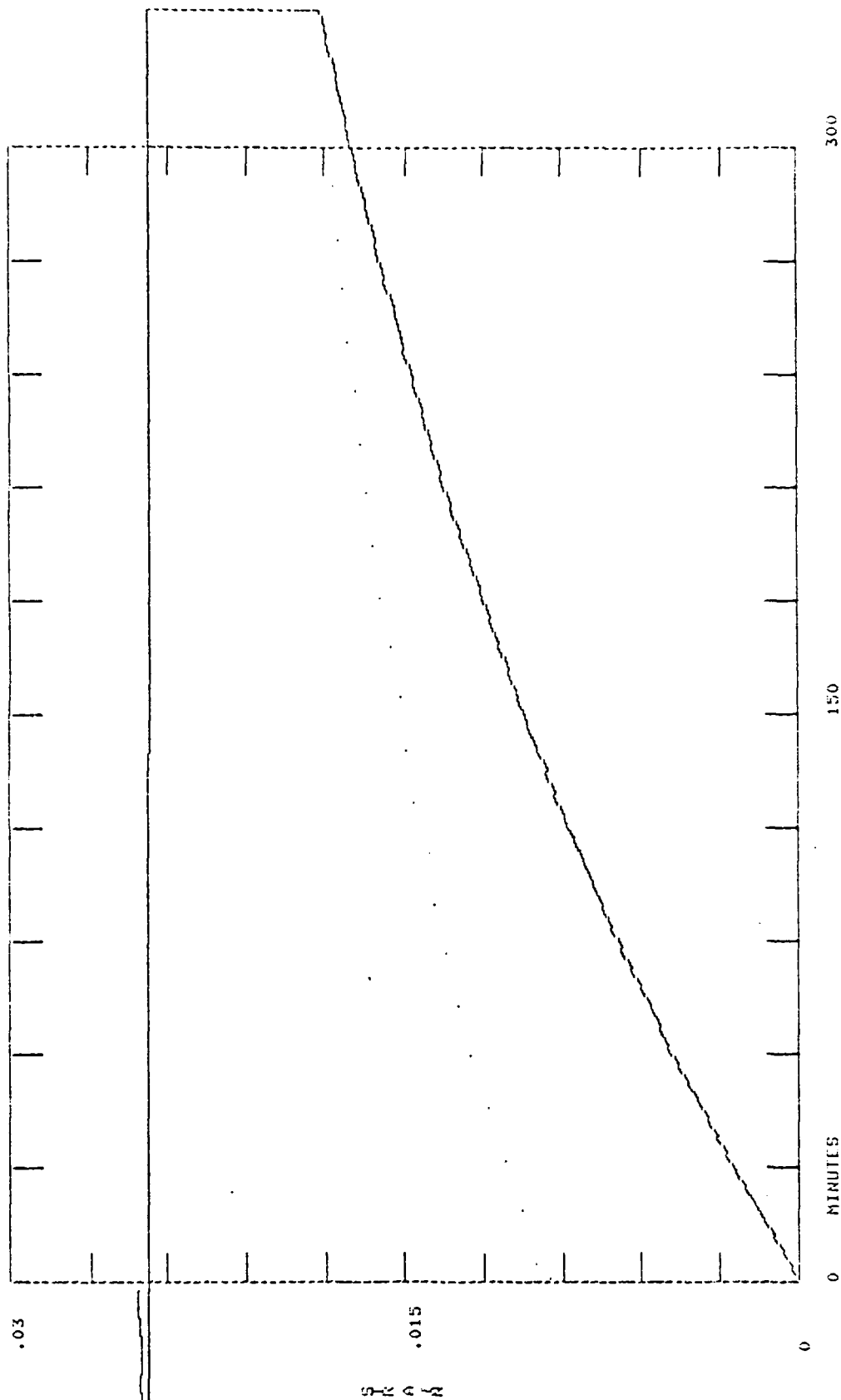
12-66 18-19 11 PER 70 AREA = 16.33 50 CM HEIGHT = 2.705 CM
 DOTTED LINE: ORIGINAL DATA HEAVY LINE: MODEL PREDICTION

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4-PROGRAMMER SOLID MODEL WITH VALUES OF
 AT = 8.163E-04 RT = 0.1792, 0.2 = 0.14295, RT = 1.544
 DELTA TIME = 4
 ERROR COUNTING ALL POINTS: 0.705%
 ERROR COUNTING FIRST 5 POINTS: 0.744%

LN-66 18-19 11 MAR 75 AREA = 16.33 SR CM HEIGHT = 2.705 CM
 DOTTED LINE: ORIGINAL DATA HEAVY LINE: MODEL PREDICTION



2-PARAMETER SOLID MODEL WITH VALUES OF

AT = .027288, BT = 3.1564E-03

DELTA T TIME = 4

ERROR COSTING ALL POINTS: 35.071%

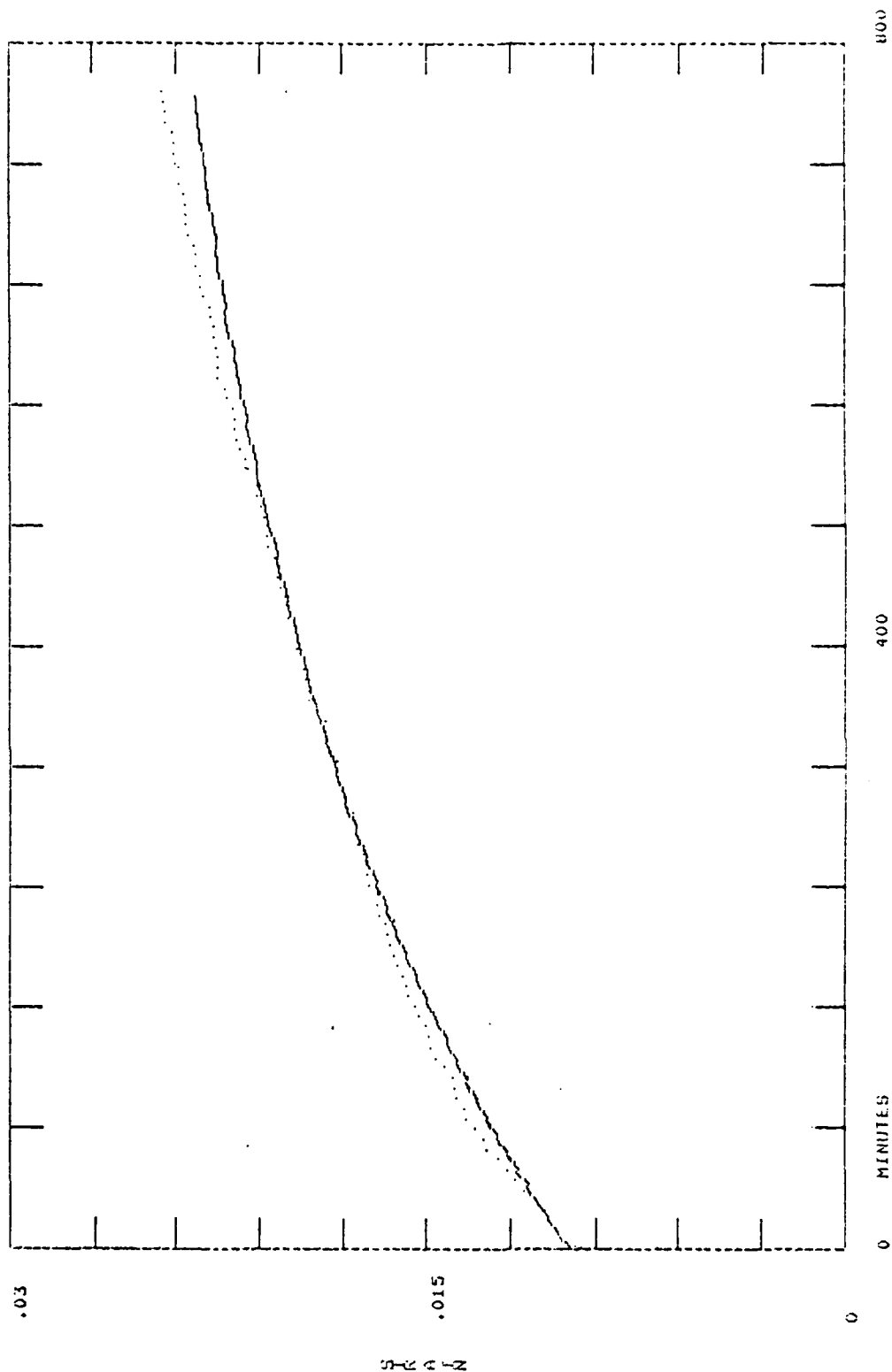
ERROR COSTING FIRST 5 POINTS: 30.734%

LR 60 112 13 MAR 75 AREA = 16.5 SQ CM HEIGHT = 2.935 CM

BOTTLE LINE: ORIGINAL DATA

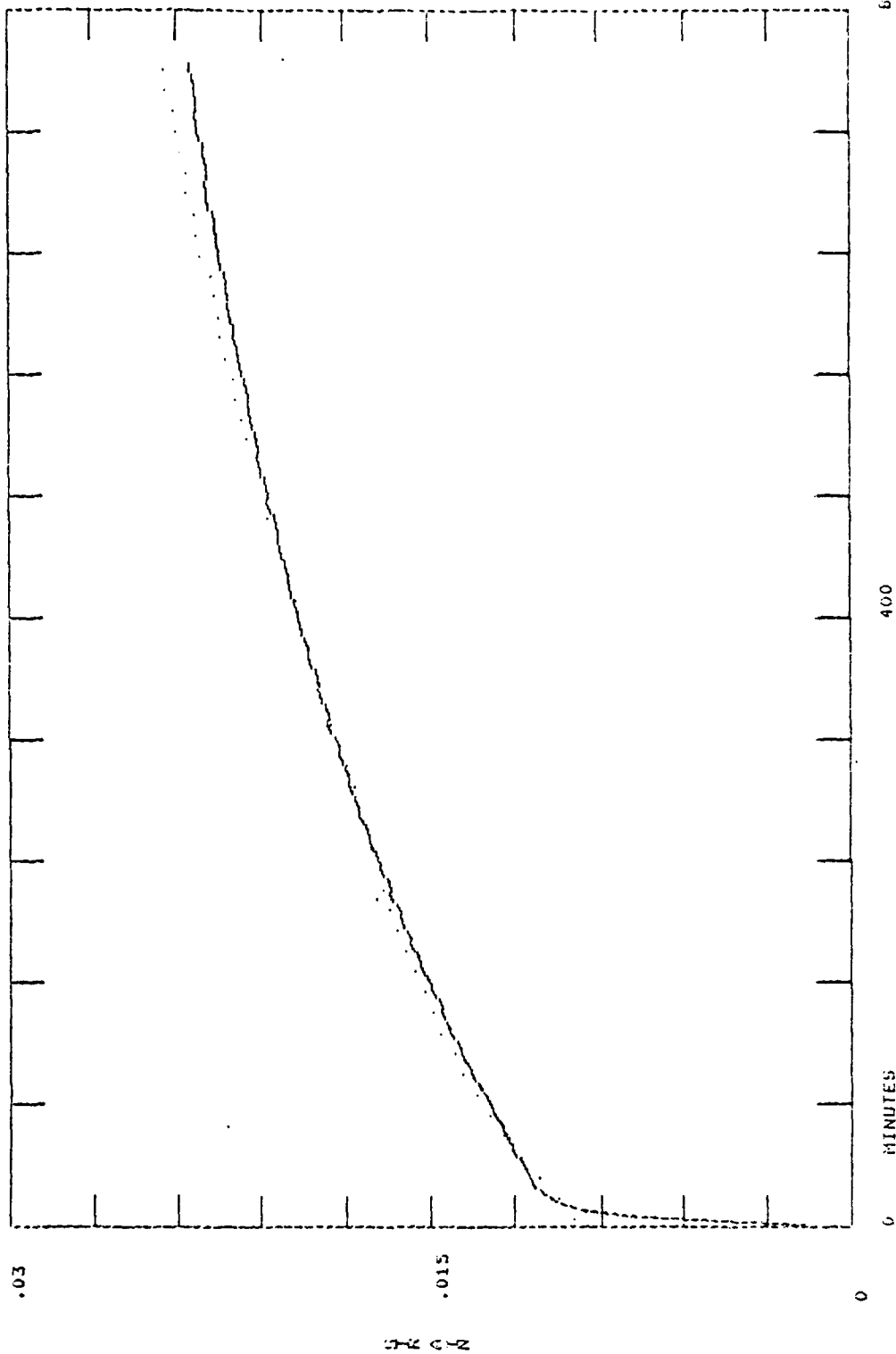
HEAVY LINE: MODEL PREDICTION

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3-PARAMETER SOLID MODEL WITH VALUES OF
 Q1 = .0262467 B1 = 2.29662E-037 A2 = .010019
 DELTA TIME = 4
 ERROR USING ALL POINTS : 2.12432
 ERROR USING FIRST 5 POINTS : 2.13392

18-68 112.11 13 MAR 75 AREA = 16.5 SQ CM HEIGHT = 2.935 CM
 DOTTED LINE: ORIGINAL DATA HEAVY LINE: MODEL PREDICTION



4-PARAMETER SOLID MODEL WITH VALUES OF
 A1 = .016528, B1 = 2.0171E-03, A2 = .010565, B2 = .20099
 DELTA TIME = 4
 ERROR USING ALL POINTS: 2.6882%
 ERROR (IGNORING FIRST 3 POINTS): 1.4422%

LA-68 112-L1 13 NOV 75 AREA = 16.5 SQ CM HEIGHT = 2.935 CM
 DOTTED LINE: ORIGINAL DATA HEAVY LINE: MODEL PREDICTION

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