CR-184002

TWR-18736
Revision A

SPACE SHUTTLE
Solid Rocket Motors
Thiokol Corporation

Igniter Adapter-to-Igniter Chamber Deflection Test Final Report

June 1990

Contract No. NAS8-30490
DR. No. 5-3 Type 2
WBS No. 4B102 10 06
ECS No. SS1985

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Publications No. 90623

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Igniter Adapter-to-Igniter Chamber Deflection Test Final Report

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REVISION DESCRIPTION

REV LTR	DATE	DESCRIPTION
Basic	24 Jan 89	
A	6 June 90	The primary reasons for this revision are: Initial data interpretation was incorrect. Thiokol Engineering has re-evaluated the initial data interpretation and decided to delete all Launch Commit Criteria (LCC) references with respect to the igniter adapter-to-igniter chamber joint temperature during motor ignition. Only the maximum igniter adapter-to-igniter chamber joint deflection will be reported in Revision A of this report. A major recommendation of this report is that future analysis be performed to evaluate the igniter adapter-to-igniter chamber joint LCC temperature using the maximum deflection value determined during this test. Test objectives listed and addressed in the basic version of this report were not the objectives from the test plan WTP-0178. Revision A addresses the objectives from the test plan. Test No. 1 was considered a "non-test," and all data collected from that test were invalid. The data from Test No. 1 is not included in Revision A. Editorial changes were also made throughout the text.

ABSTRACT

Testing to determine the maximum RSRM igniter adapter-to-igniter chamber joint deflection, at the crown of the inner joint primary seal, was performed on 9 and 20 September 1988. The deflection data was gathered to support igniter inner joint gasket resiliency predictions which led to launch commit criteria temperature determinations.

The proximity (deflection) gage holes for the first test (Test No. 1) were incorrectly located; therefore, the test was declared a "non-test." Prior to Test No. 2, test article configuration was modified with the correct proximity gage locations. Deflection data were successfully acquired during Test No. 2. However, the proximity gage deflection measurements were adversely affected by temperature increases. Deflections measured after the temperature rise at the proximity gages were considered unreliable. An analysis was performed to predict the maximum deflections based on the reliable data measured before the detectable temperature rise. Deflections to the primary seal crown location were adjusted to correspond to the time of maximum expected operating pressure (2,159 psi) to account for proximity gage bias, and to account for maximum attach and special bolt relaxation. The maximum joint deflection for the igniter inner joint at the crown of the primary seal, accounting for all significant correction factors, was 0.0031 in. (3.1 mil).

Since the predicted (0.003 in.) and tested maximum deflection values were sufficiently close, the launch commit criteria was not changed as a result of this test. Data from this test should be used to determine if the igniter inner joint gasket seals are capable of maintaining sealing capability at a joint displacement of (1.4) x (0.0031 in.) = 0.00434 inches. Additional testing should be performed to increase the database on igniter joint deflections and address launch commit criteria temperatures.

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ACRONYMS

LCC	launch commit criteria
S&A	safe and arm
NBR	nitrile butadiene rubber (insulation)
B-KNO_3	boron-potassium nitrate
B-B	barrier-booster
GFE	government-furnished equipment
PIC	pyrotechnic initiator controller
JES	joint environment simulator
CEI	contract end item
MEOP	maximum expected operating pressure
kips	thousand pounds
kps	thousands of pound-seconds
RH	relative humidity
Hg	mercury
ms	milliseconds

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INTRODUCTION

This report documents the procedures, performance, and results obtained from the Igniter Adapter-to-Igniter Chamber Deflection Test. Tests were performed on 9 and 20 Sep 1988 at the Thiokol Small Motor Conditioning and Firing Bay, T-11. Testing was performed in accordance with WTP-0178, Test Plan for the Igniter Adapter-to-Igniter Chamber Deflection Test.

The purpose of the test was to determine the maximum igniter adapter-to-igniter chamber joint (igniter inner joint) deflection at the crown of the inner joint primary seal during motor ignition (Figure 1). Joint deflection rate (from pressure measurements) and temperature near the inner joint primary seal during motor ignition were also to be determined. The igniter inner joint is subjected to the largest deflection of the three ignition system joints; the other two joints are the safe and arm (S&A)-to-igniter adapter joint (S&A joint) and the igniter adapter-to-forward dome (igniter outer joint). The igniter inner joint has a higher magnitude of joint opening due to its configuration and larger loading rate.

The purpose of determining the igniter inner joint deflection during motor ignition was to support igniter inner joint gasket resiliency predictions which led to launch commit criteria (LCC) temperature determinations. Gasket resiliency is a function of joint deflection magnitude, joint deflection rate, and gasket temperature. Contract End Item (CEI) CPW1-3600 specifies that the igniter inner gasket shall maintain, without pressure assistance, sealing capability (seal shall be in contact with both sealing surfaces) with a joint displacement of 1.4 times maximum expected displacement.

Two complete igniters were test fired for this test. Since Test No. 1 was declared a "non-test," the primary focus of this report is on the configuration and results obtained from Test No. 2.

Related structural deflection test results/analysis for the igniter inner and outer joint gaskets may be found in TWR-17265, RSRM Ignition System Structural Analysis. Previous igniter inner joint deflection tests were performed on JES-3C (TWR-18000) and TPTA-1.3 (TWR-18624).

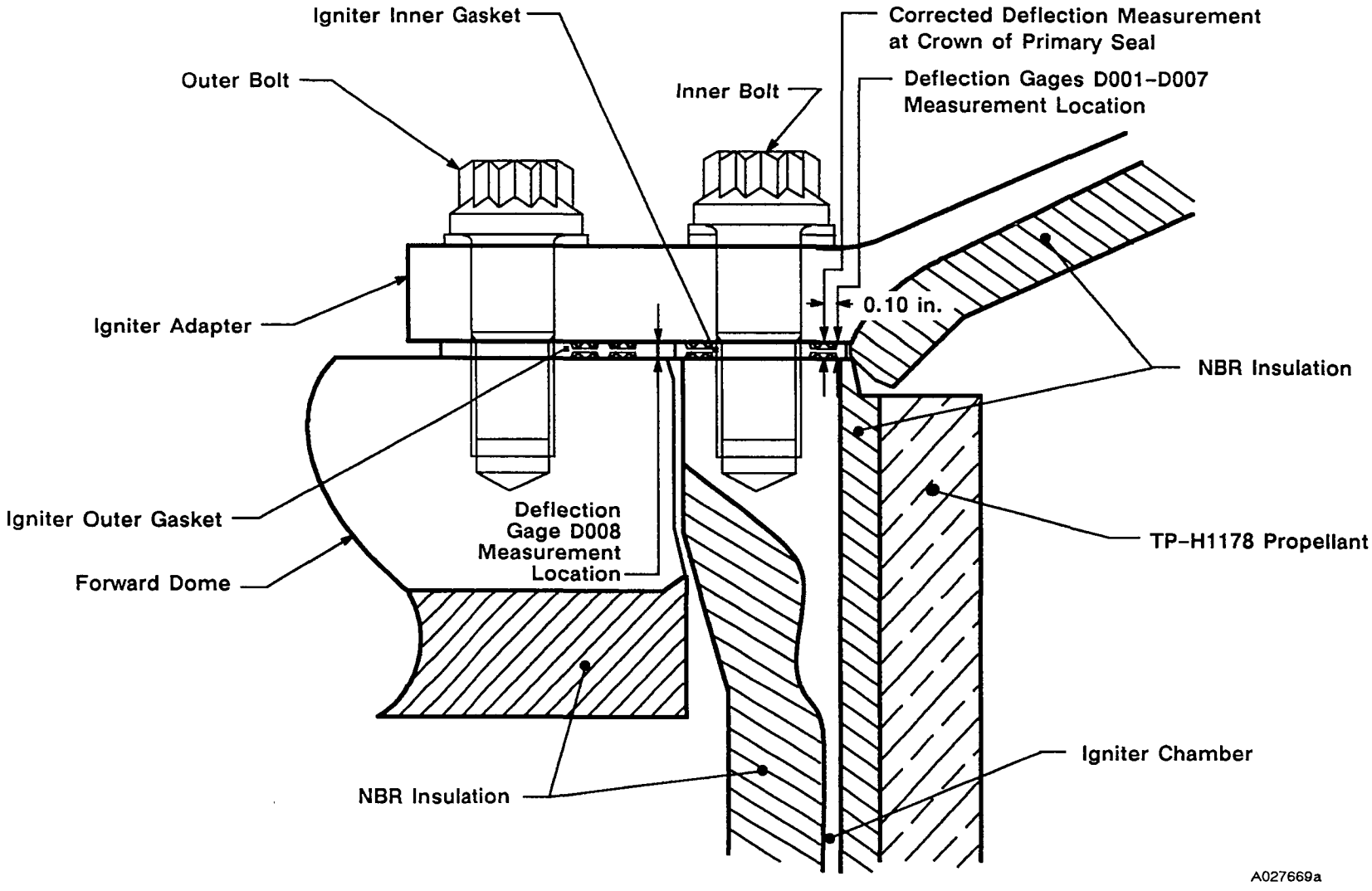

Figure 1. Test Article Configuration—Igniter Adapter-to-Igniter Chamber-to-Forward Dome Joint

1.1 TEST ARTICLE DESCRIPTION

The igniter pressure vessel test article consisted of a loaded igniter chamber (Dwg 1U51882) bolted to a modified igniter adapter (Dwg 1U50278, modified per Dwg 7U52775). Two igniter chambers were used: Serial number (S/N) 0000002, was used for Test No. 1, and S/N 0000003 was used for Test No. 2. The igniter adapters were modified to allow the use of proximity (deflection)/temperature gages. The Test No. 2 igniter adapter configuration, including locations of all proximity (deflection), temperature, and pressure gages, is shown in Figures 1 and 2.

The igniter chamber and adapter were internally insulated with asbestos-filled nitrile butadiene rubber (NBR). Insulation was vulcanized to the igniter chamber wall with Chemlok® primer adhesive. The igniter chamber was externally insulated with silicon dioxide and NBR. TP-H1178 propellant, configured in a 40-point star pattern, was used in the igniter chamber. TP-H1178 propellant, configured in a 30-point star pattern (Dwg 1U50152), was also used in the igniter initiator. A pyrotechnic booster charge of B-KNO_3 granules and pellets, contained in the pyrotechnic basket assembly of the barrier-booster (B-B) (Dwg 1U52294), was used to ignite the igniter initiator. A government-furnished equipment (GFE) pyrotechnic initiator controller (PIC) ground ordnance firing assembly (MC450-0018) was used to fire the B-B initiators. The test article did not include an S&A device, nor was putty installed in the igniter chamber-to-igniter adapter joint.

Both igniter gaskets were modified. Metal was removed from the igniter inner gasket (Dwg 7U76058) to allow for proximity gage (gages D001 through D006) measurements between metal-to-metal sealing surfaces (Figure 3). Proximity Gages D001, D002, D005, and D006 were located adjacent to the special bolt locations. Proximity Gage D007 was positioned to measure a deflection from the adapter metal sealing surface to the top of the inner joint gasket retainer surface. The igniter outer gasket (Dwg 7U76059-01) was also modified, with the same type of cutout as the inner gasket, to allow for an inner joint deflection measurement (Gage D008). Each proximity gage was positioned normal to the respective joint sealing or gasket measurement surface.

The igniter chamber and adapter were bolted to an insulated forward dome (Dwg 7U52927-02). The forward dome, previously used in joint environment simulator (JES) tests, was configured with inert propellant. Standard, new igniter attach bolts

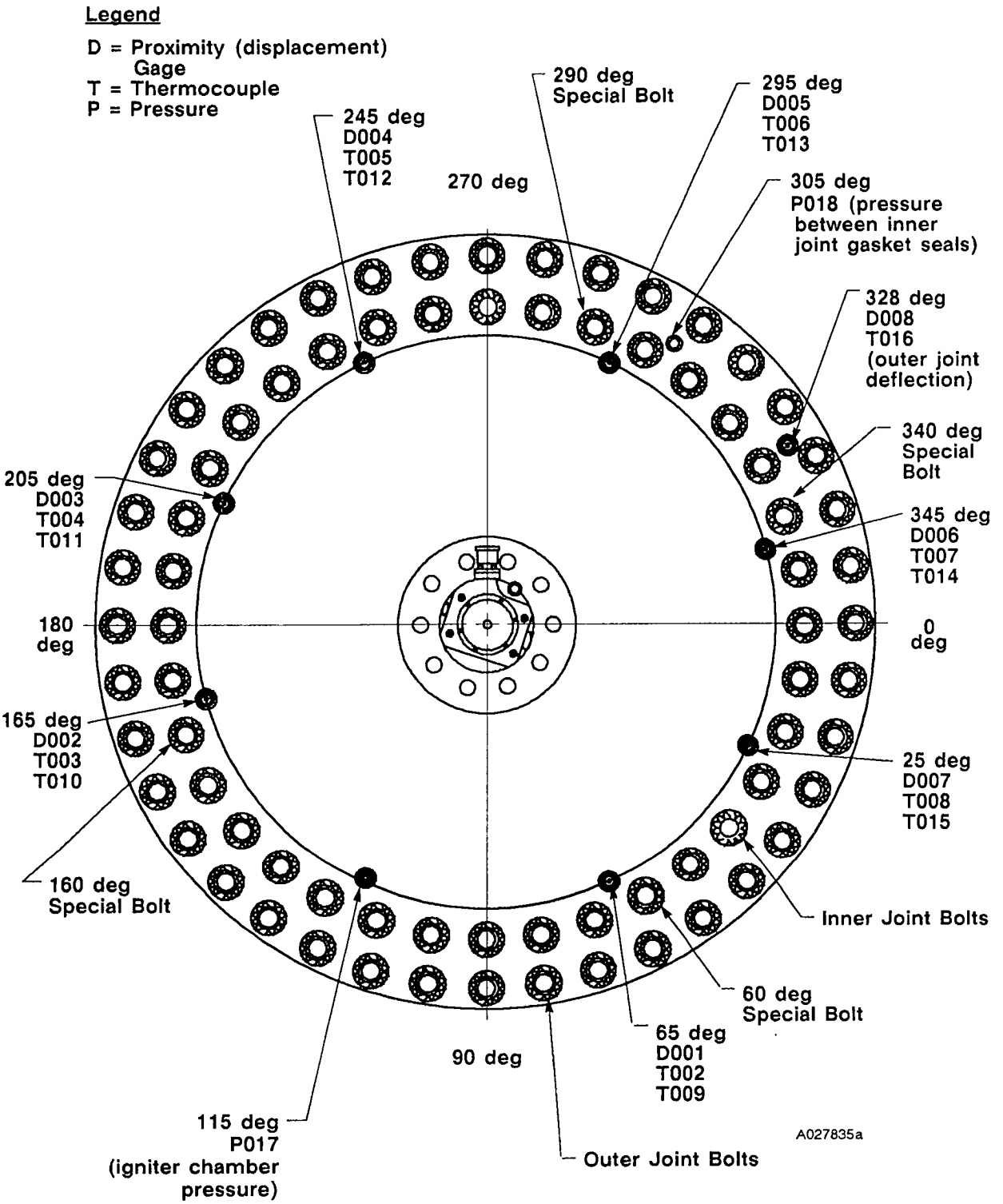

Figure 2. Test No. 2 Igniter Adapter Configuration

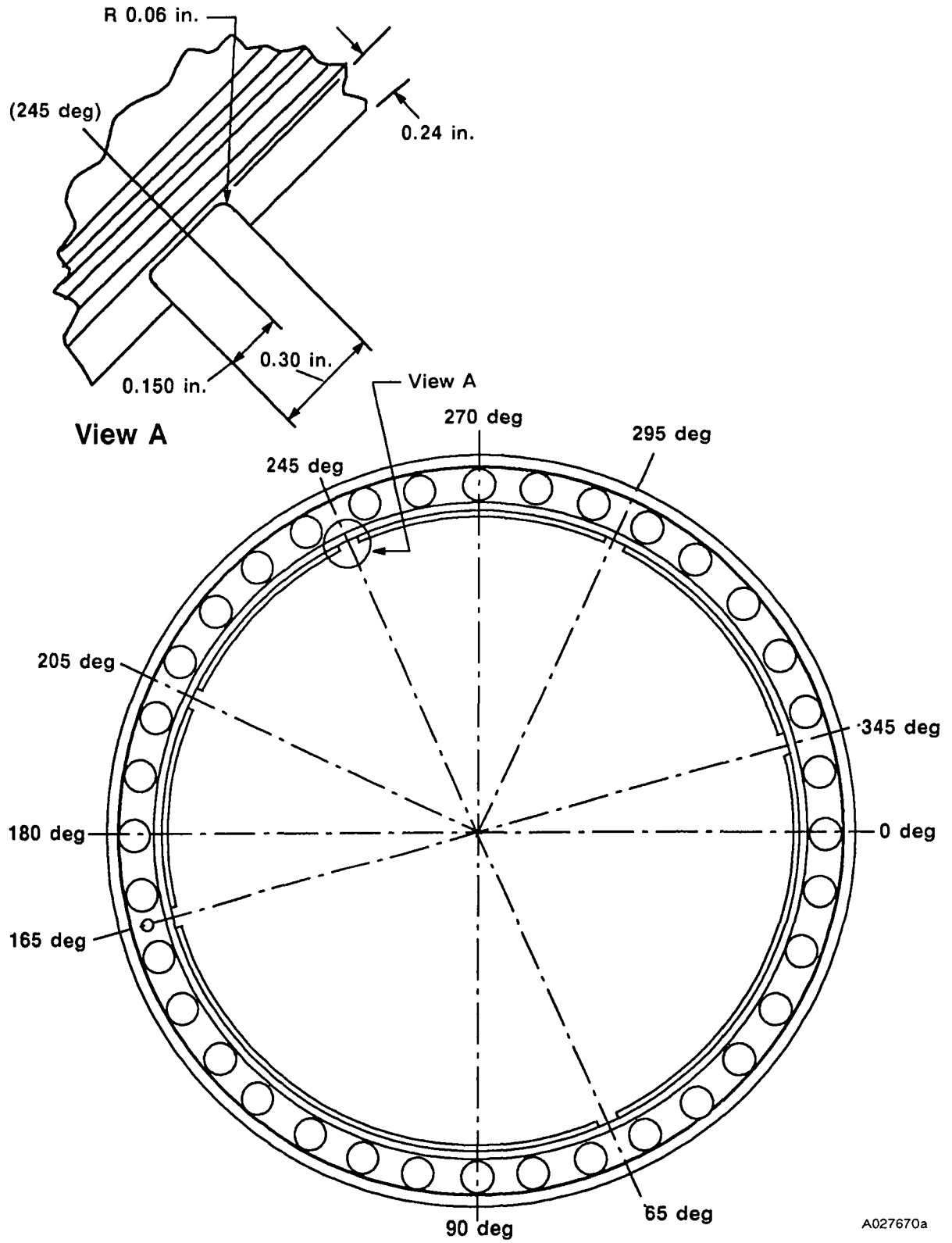

Figure 3. Modified Igniter Inner Gasket—Test No. 2

were used. Each attach bolt was preloaded to the minimum specified levels. Attach bolts at the four special bolt locations were preloaded to the lowest levels specified for special bolts. The final test article assembly was installed onto the hydrotest stand (Dwg 2U65052) with the igniter nozzle pointing up (Figures 4 and 5).

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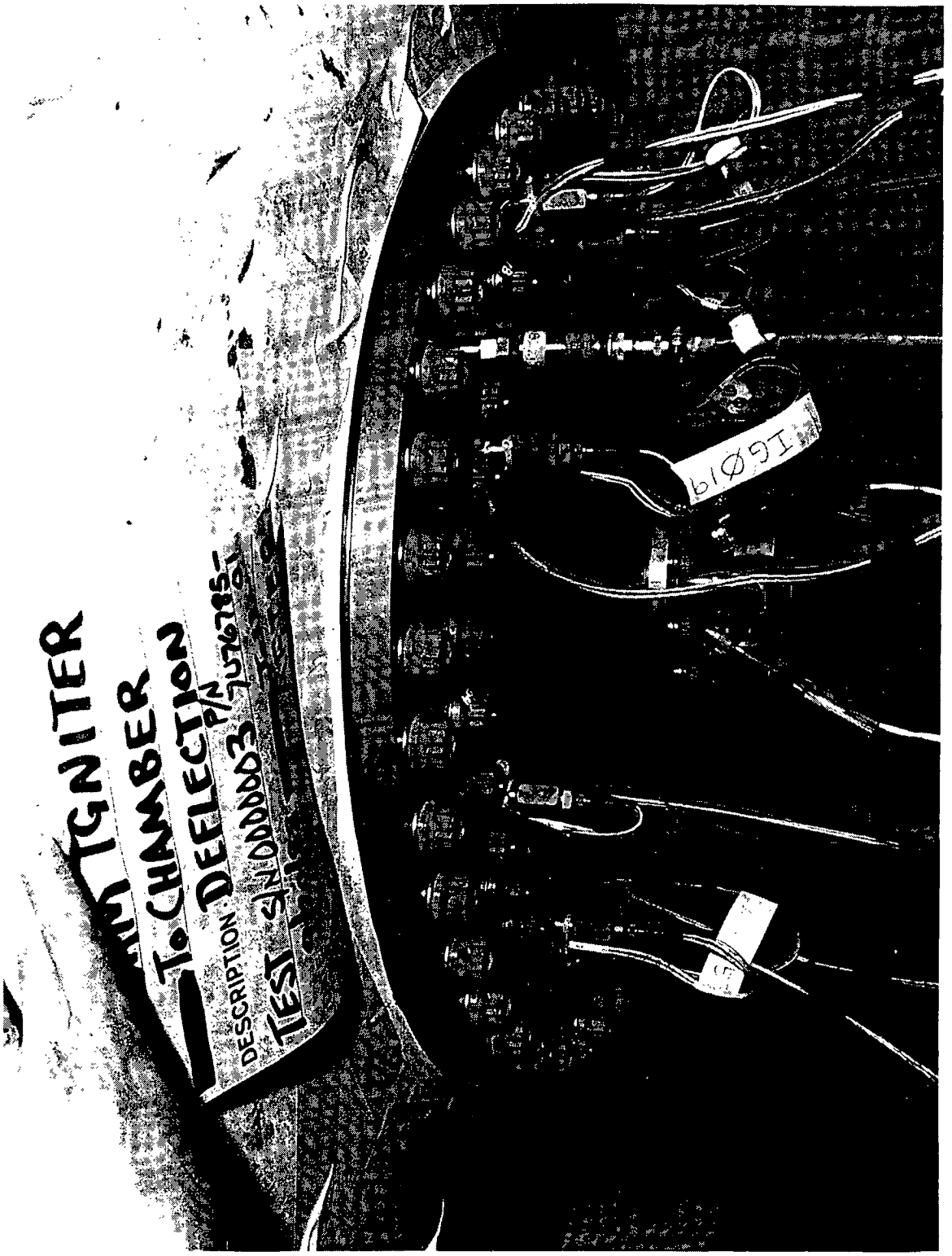

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Figure 4. Igniter Adapter Final Assembly—Test No. 2

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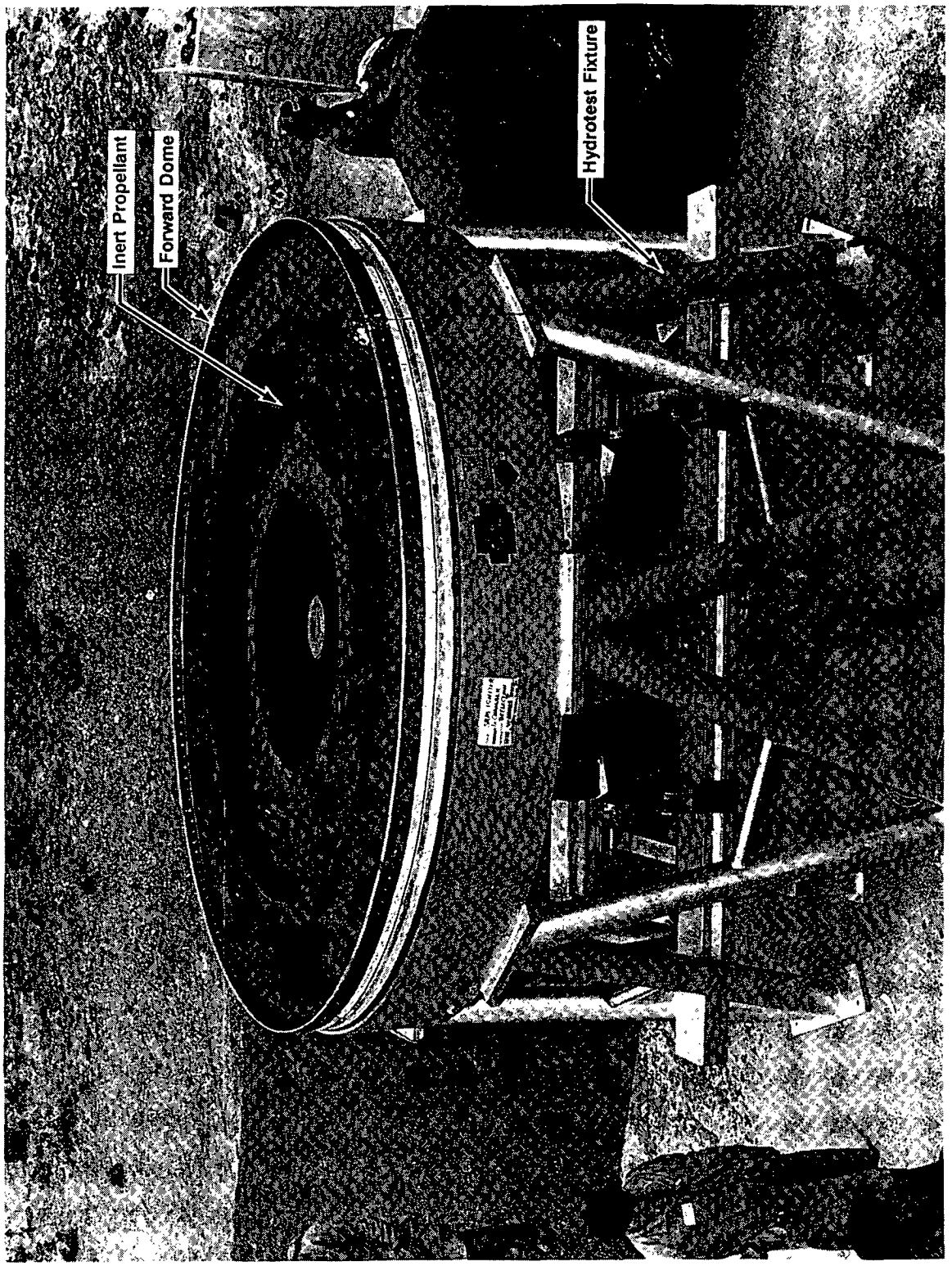

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Figure 5. Final Assembly of Test Article — Test No. 2

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OBJECTIVES

The objectives of WTP-0178 were derived from the objectives of TWR-15723 Revision D, Development and Verification Plan, to satisfy the requirement of CEI specification CPW1-3600, Paragraph 3.2.1.2.4.d. The objectives were:

A. Gather data and evidence to back up previous analysis regarding igniter inner joint gap growth during igniter action time.

B. Evaluate the sealing capability of the inner gasket primary seal at the minimum LCC temperature of 67°F.

3

EXECUTIVE SUMMARY

3.1 SUMMARY

This section contains an executive summary of the key results from test data evaluation and post-test inspection. Additional information and details can be found in Section 6, Results and Discussion.

The test articles for each test were thermally conditioned prior to test firing; the igniter inner joint was conditioned to 65°F for Test No. 1, and 50°F for Test No. 2. The maximum chamber pressure was 1,900 psia for Test No. 1, and 1,916.5 psia for Test No. 2.

Upon completion of Test No. 1, the test data was found to be in error because the proximity gage holes had been incorrectly located on the original igniter modification drawing. Data from these gages were considered invalid; therefore, Test No. 1 was declared a "non-test."

Prior to Test No. 2, test article configuration was modified with the correct proximity gage locations. Deflection data were successfully acquired during Test No. 2. Although the data from Test No. 1 were invalid, the data from Test No. 2 were more valuable because the ability of the igniter gaskets to seal decreases at lower temperatures.

Data evaluation revealed that the proximity gage deflection measurements were adversely affected by temperature increases during Test No. 2. Deflections measured after the temperature rise at the proximity gages were considered unreliable. An analysis was performed to predict the maximum deflections based on the reliable data (measured before the detectable temperature rise) that was measured during the test.

The maximum joint deflection for the igniter inner joint at the crown of the primary seal, accounting for all significant correction factors, was 0.0031 in. (3.1 mil). The maximum deflection occurred at 65 degrees, adjacent to a special bolt location. Deflections were adjusted to the primary seal crown location to correspond to the time of maximum expected operating pressure (MEOP) (2,159 psi), to account for proximity gage bias, and to account for maximum attach and special bolt relaxation.

3.2 CONCLUSIONS

The following listing is the conclusions as they relate specifically to the objectives and applicable CEI specification (CPW1-3600) paragraphs. Additional information about the conclusions can be found in Section 6, Results and Discussion.

Objective	CEI Paragraph	Conclusion
A. Gather data and evidence to back up previous analysis regarding igniter inner joint gap growth during igniter action time.	3.2.1.2.4.d. Ignition System Seals. Each seal shall maintain without pressure assistance, sealing capability with a joint displacement of 1.4 times maximum expected displacement. Displacement will be applied in direct proportion to applicable pressure time relationship.	The predicted and measured (corrected) maximum igniter inner joint deflections at the crown of the primary inner gasket seal (0.003 and 0.0031 in., respectively) were sufficiently close that this test backed up previous analysis. Data from this test should be used to determine if the igniter inner joint gasket seals are capable of maintaining sealing capability at a joint displacement of (1.4) x (0.0031 in.) = 0.00434 inches.
B. Evaluate the sealing capability of the inner gasket primary seal at the minimum LCC temperature of 67°F.	3.2.1.2.4.d. Refer to Objective A.	The LCC of 67°F was based on a predicted maximum igniter inner joint deflection at the crown of the primary seal of 0.003 in. (3 mil). This test was run to verify that this deflection was approximately 0.003 inch. The maximum corrected defection based on the measured deflection from this test was 0.0031 in. (3.1 mil). Since the predicted and tested maximum deflection values were sufficiently close, the LCC was not changed as a result of this test.

3.3 RECOMMENDATIONS

The following recommendations have been made as a result of this test:

A. Data from this test should be used to determine if the igniter inner joint gasket seals are capable of maintaining sealing capability at the CPW1-3600 specified joint displacement of 0.00434 inches. This deflection was determined by multiplying the maximum deflection determined in this test (0.0031 in.) by 1.4. Data from the test should also be used to support igniter adapter-to-igniter chamber joint temperature LCC.

B. Additional testing should be performed to increase the database on igniter joint deflections, particularly at lower temperatures. In future deflection testing, proximity gages should not be used where temperature might affect them; only temperature compensated (or temperature insensitive) deflection gages should be used. Additional testing should also address LCC temperatures.

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INSTRUMENTATION

All test instruments were electrically zeroed and operationally verified to requirements traceable to the National Institute of Standards and Technology. Test instrumentation met the system requirements of MIL-STD-45662. Test instrumentation is listed in Table 1.

Figure 2 shows the location of each proximity (deflection), temperature, and pressure gage on the modified igniter adapter. Figure 1 provides additional information on proximity gage locations.

Deflection and Temperature Measuring Instrumentation. The joint deflection and temperature measurements were taken with proximity/thermocouple combination (2-in-1) gages (Figure 6) that were a variation of the Dwg 7U76436 proximity/temperature/pressure combination (3-in-1) gage. Each proximity gage consisted of two coils mounted in series within the gage probes. The inner coil was a reference coil, while the outer coil was a measurement coil. Once a proximity gage is calibrated against a movable surface, any surface movement will change the inductance of the outer coil. This alters the relative inductance between the two coils, and this ratio indicates the value surface movement (Beckwith, Buck, and Marangoni, *Mechanical Measurements*, Third Edition), pp 101 - 102).

Pressure Measuring Instrumentation. Igniter chamber pressure transducer P-017 was used to correlate peak pressure and time of maximum joint deflection. Pressure transducer P-018 was installed between the inner joint gasket seals to verify that the gasket maintained sealing capability.

Current Measuring Instrumentation. The SII firing current measurements did not apply specifically to the joint deflection test, but were installed to ensure that adequate current was applied to the SIIs.

Table 1. Instrumentation List

Designation	Measurement	Range and Accuracy
D001-D008	Joint deflection	0-0.1 in. ±5%
P017	Igniter pressure	0-3,000 psi ±2%
P018	Igniter seal pressure	0-3,000 psi ±2%
T001-T016	Joint temperature	0-1,000°F ±5%
I001, I002	SII firing current	0-30 amp ±1 amp

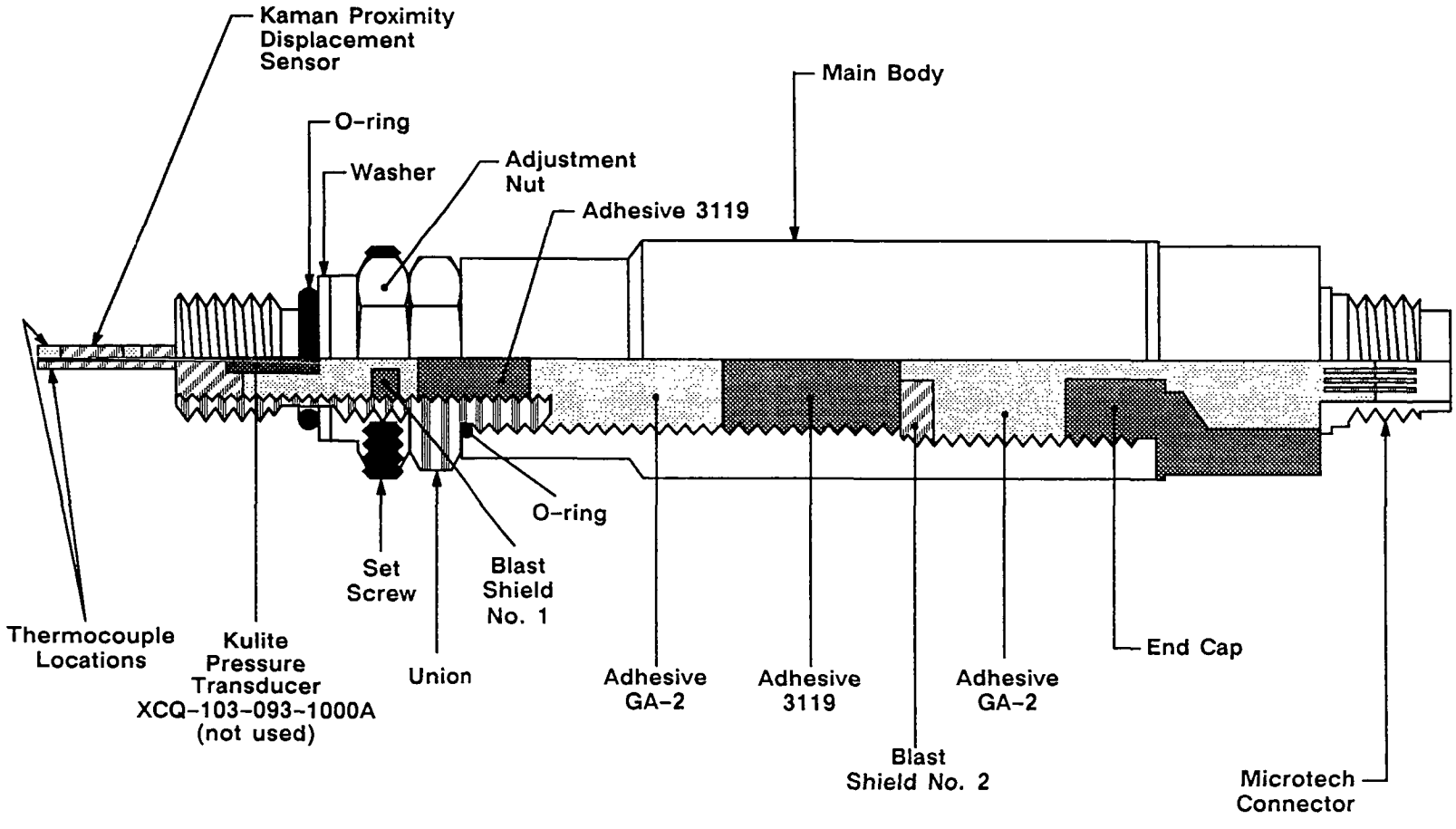

Figure 6. Three-in-One Gage—Cutaway View

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PHOTOGRAPHY

Still color photographs were taken during assembly, test, and disassembly. Copies of the photographs taken (Series 105992 and 106223) are available from the Thiokol Photographic Services Department.

6

RESULTS AND DISCUSSION

6.1 TEST ARTICLE ASSEMBLY

Igniter Adapter Modifications. The original igniter modification drawing (7U52775), which specified the location, size, and angles for the proximity gage installation holes, incorrectly identified a proximity gage installation hole size. Because the proximity gages would not fit into their respective holes, the igniter was disassembled and the adapter holes were machined to the correct dimensions.

Igniter Attach and Special Bolt Installations. The igniter chamber and adapter were attached under the requirements of Dwg 7U76751. The igniter chamber and adapter were installed onto the forward dome under the requirements of Dwg 7U76785. Standard, new igniter attach bolts were ultrasonically preloaded to the lower end of the specified load range (52 to 54 kips) to allow for maximum joint deflection. Flight configuration igniter adapters incorporate four special bolt/pressure transducers for measurement of motor pressure. The attach bolts that were located at the special bolt locations were ultrasonically preloaded to the lower end of the specified load range (27 to 29 kips) to allow for maximum joint deflection. The attach bolts were ultrasonically preloaded per STW7-3680. Ultrasonic preloadings for the attach bolts that were adjacent to proximity gages are listed in Table 2. Average attach bolt preloadings and stresses are listed in Table 3. Attach bolt preloadings were verified on the day of each test firing.

The proximity/temperature gages were installed per test area procedures. The gages were then electronically calibrated and the gage probe tips were adjusted to ensure that the gages would measure within the specified range. (Prior to testing, calibrations were verified on scrap igniter hardware and calibration blocks.)

Prior to testing, the igniter inner and outer joint seals were leak tested per STW7-2692.

The test article assembly was installed onto the hydrotest stand. Following installation of the igniter-to-forward dome in the test stand, the B-B assembly was manually armed.

Table 2. Ultrasonic Preload on Igniter Attach Bolts That Were Adjacent to Deflection Gages—Test No. 2

Gage Number	D001	D002	D003	D004	D005	D006	D007	D008
Gage Location (deg)	65	165	205	245	295	345	25	157
Adjacent Bolt Preloadings:								
Special Bolt (kps)	29.3	27.6			27.6	28.4		
Attach Bolt (kps)	52.1	52.9	51.4	52.1	52.9	52.9	51.4	*
Attach Bolt (kps)			52.9	51.4			52.9	*

*The igniter outer joint bolts were torqued to the minimum specified 275 ft-lb.

Table 3. Average Bolt Preload and Stress

Parameter	Test No. 1	Test No. 2
Average Inner Bolt Preload (lb)	52,998.50	52,998.53
Average Special Bolt Preload (lb)	28,259.75	28,068.50
Average Inner Bolt Stress (psi)	142,102.25	142,102.34
Average Special Bolt Stress (psi)	75,771.33	75,258.55

6.2 TEST

The test articles for each test were thermally conditioned underneath a shroud prior to test firing (Figure 7). Test conditions are listed in Table 4. The maximum chamber pressure was 1,900 psia for Test No. 1, and 1,916.5 psia for Test No. 2 (Gage P017).

6.2.1 Test No. 1 Results

Upon completion of Test No. 1, the test data was found to be in error. Investigation revealed that the proximity gage holes had been incorrectly located on the original igniter modification Dwg 7U52775. The holes were too far inboard, and the tips of the proximity gages rested on the edge of the igniter chamber-to-insulation interface. The data from these gages were considered invalid; therefore, Test No. 1 was declared a "non-test."

Prior to Test No. 2, Dwg 7U52775 and the igniter adapter configuration were modified, with special attention placed on location, size, and angle of the deflection gage holes. The proximity gage holes from Test No. 1 were plugged with port plugs which incorporated O-rings. Each deflection gage hole for Test No. 2 was re-drilled, and a hole for Gage D008 was added for igniter inner joint deflection measurement.

6.2.2 Test No. 2 Results

Deflection data were successfully acquired during Test No. 2. Although the data from Test No. 1 were invalid, the data from Test No. 2 were more valuable because the ability of the igniter gaskets to seal decreases at lower temperatures. Data plots from Test No. 2 are included in Appendix A. Pressure between the igniter inner joint seals, measured by Gage P018, was maintained. No deflection was detected at the igniter outer joint (D008). The measured deflections from Test No. 2 are listed in Table 5.

An unexpected deflection measurement problem was discovered in the deflection results for Gages D001 through D007. In most cases, the deflection traces did not correspond to the continuous curve of the igniter chamber pressure trace from Gage P017. Sporadic measurements for each deflection measurement occurred at the same time that temperature was detected at the corresponding temperature gages. A good example of this can be seen when comparing the deflection trace from Gage D005 with its corresponding temperature trace from Gage T006. A downward spike in the deflection trace occurred at approximately the same time that temperature was

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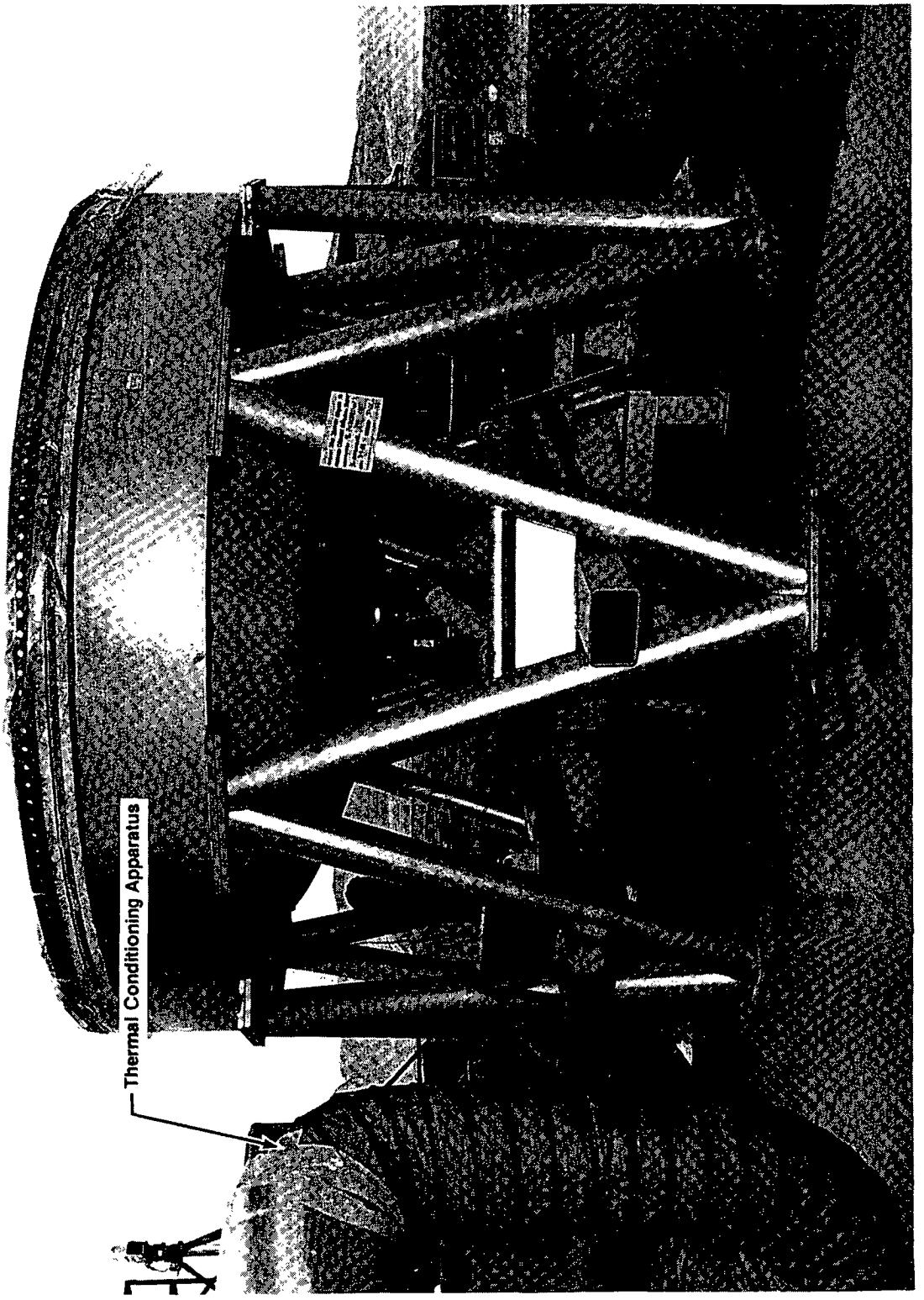

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Figure 7. Thermal Conditioning of Test Article

Table 4. Test Conditions

Parameter	Test No. 1	Test No. 2
Inner Joint Temperature (°F)	65	50
Ambient Temperature (°F)	82	42
Relative Humidity (%)	18	68
Barometric Pressure (in. Hg)	25.37	25.32

Table 5. Test No. 2 Maximum Measured Igniter Adapter-Igniter Chamber Joint Deflections*

Gage Number	D001	D002	D003	D004	D005	D006	D007	D008
Gage Location (deg)	65	165	205	245	295	345	25	157
Maximum Measured Deflection at Gage ($\times 10^{-3}$ in.)	2.8	2.7	2.4	1.0	1.7	1.4	0.6	0.0

*Measured just prior to a temperature rise at the gage.

recorded on the temperature trace. The first temperature readings, and the initial deflection spikes, were detected between 40 to 50 ms.

The sporadic deflection measurements were most likely caused by proximity gage probe tip heating during the test firing. Initially, the temperature of the proximity gage outer coil was raised, while the inner coil was unaffected. The increased temperature of the outer coil changed its inductance. This unbalanced the inductance ratio between the two coils and caused a displacement reading change that was not a result of a deflection. Deflection data measured after the temperature rise at the proximity gages were considered unreliable. An analysis was performed to predict the maximum deflections based on the reliable data that was measured during the test.

6.2.2.1 Test No. 2 Data Evaluation. As calculated in the analysis presented below, the maximum corrected joint deflection for the igniter inner joint at the crown of the primary seal was 0.0031 in. (3.1 mil). The maximum corrected deflection values from each proximity gage are listed in Table 6.

Analysis for corrected joint deflection for proximity Gages D001 and D002 is presented below.

Calculated Joint Deflection at the Primary Seal Crown, Proximity Gage D001:

Each calculation is based on the previous calculation(s).

- Actual time that the proximity gage temperature began increasing (temperature changes at the proximity gage caused the deflection measurements to be unreliable), measured by Thermocouple T009 (this measurement was taken from digital data, Table 7)
  = 46 ms
- Actual deflection reading at 46 ms (digital data, Figure 8)
  = 0.0028 in.
- Corrected maximum joint deflection. This value was interpolated from the time temperature began to affect the gage reading (46 ms) to the time that MEOP was reached (joint deflection versus pressure was considered linear, based on analysis documented in TWR-17265, Figure 203):
  = (measured deflection at 46 ms) x $\frac{\text{(MEOP)}}{\text{(pressure at 46 ms)}}$

Table 6. Test No. 2 Maximum Corrected Igniter Adapter-to-Igniter Chamber Joint Deflections*

Gage Number	D001	D002	D003	D004	D005	D006	D007
Gage Location (deg)	65	165	205	245	295	345	25
Maximum Corrected Deflection at Gage Degree Location ($\times 10^{-3}$ in.)	3.1	2.9	2.8	1.2	2.0	1.7	0.9

*Deflections were adjusted to the primary seal crown location to correspond to the time of MEOP (2,159 psi), to account for proximity gage bias, and to account for maximum attach and special bolt relaxation.

Table 7. Test No. 2 Digital Data — Proximity Gages D001 and D002

Line	Sample	Time	D001	D002	T009	T010	P017
1	1	0.000	0.0000	0.0000	49.7381	51.6678	-0.0525
2	2	0.002	0.0000	0.0000	47.9487	51.6678	-0.0525
3	3	0.004	0.0000	0.0001	49.7381	51.6678	-0.0525
4	4	0.006	0.0001	0.0000	49.7381	51.6678	0.7905
5	5	0.008	0.0000	0.0000	49.7381	51.6678	6.6919
6	6	0.010	0.0000	0.0001	49.7381	51.6678	23.5532
7	7	0.012	0.0000	0.0001	49.7381	51.6678	48.0020
8	8	0.014	0.0000	0.0000	51.5422	51.6678	74.9797
9	9	0.016	0.0000	0.0000	51.5422	51.6678	87.6257
10	10	0.018	0.0001	0.0001	51.5422	51.6678	99.4285
11	11	0.020	0.0001	0.0001	51.5422	51.6678	109.5452
12	12	0.022	0.0001	0.0001	49.7381	51.6678	126.4065
13	13	0.024	0.0001	0.0001	49.7381	51.6678	148.3259
14	14	0.026	0.0002	0.0001	49.7381	51.6678	182.0483
15	15	0.028	0.0001	0.0001	49.7381	51.6678	228.4165
16	16	0.030	0.0002	0.0002	49.7381	51.6678	298.3906
17	17	0.032	0.0003	0.0003	51.5422	51.6678	404.6160
18	18	0.034	0.0006	0.0005	51.5422	51.6678	564.7971
19	19	0.036	0.0010	0.0008	51.5422	51.6678	757.8894
20	20	0.038	0.0014	0.0011	49.7381	51.6678	934.6460
21	21	0.040	0.0017	0.0016	51.5422	51.6678	1085.1853
22	22	0.042	0.0019	0.0019	49.7381	51.6678	1209.5068
23	23	0.044	0.0023	0.0023	51.5422	51.6678	1310.9937
24	24	0.046	0.0028	0.0026	51.5422	51.6678	1394.7205
25	25	0.048	0.0032	0.0027	53.3490	51.6678	1467.4529
26	26	0.050	0.0032	0.0030	53.3490	53.4725	1530.9773
27	27	0.052	0.0030	0.0034	53.3490	53.4725	1586.9553
28	28	0.054	0.0028	0.0034	56.9626	53.4725	1635.2998
29	29	0.056	0.0028	0.0035	55.1558	53.4725	1678.5557
30	30	0.058	0.0026	0.0036	58.7694	53.4725	1715.0261
31	31	0.060	0.0027	0.0037	58.7694	53.4725	1746.4080
32	32	0.062	0.0026	0.0039	58.7694	55.2772	1771.8523
33	33	0.064	0.0026	0.0038	60.5768	57.0819	1793.9043
34	34	0.066	0.0026	0.0042	60.5768	57.0819	1812.5637
35	35	0.068	0.0027	0.0042	64.1904	58.8866	1826.9822
36	36	0.070	0.0027	0.0039	64.1904	57.0819	1840.5527
37	37	0.072	0.0027	0.0039	64.1904	60.6913	1852.4268
38	38	0.074	0.0028	0.0040	67.8039	58.8866	1860.9084
39	39	0.076	0.0029	0.0045	69.6107	60.6913	1869.3899
40	40	0.078	0.0031	0.0046	71.4182	62.4960	1876.1750
41	41	0.080	0.0033	0.0046	69.6107	60.6913	1881.2639
42	42	0.082	0.0034	0.0043	69.6107	62.4960	1887.2012
43	43	0.084	0.0035	0.0046	69.6107	62.4960	1892.2900
44	44	0.086	0.0037	0.0045	71.4182	62.4960	1894.8345
45	45	0.088	0.0037	0.0045	73.2250	64.3007	1899.0752
46	46	0.090	0.0036	0.0046	75.0306	64.3007	1900.7715
47	47	0.092	0.0037	0.0047	73.2250	62.4960	1902.4678
48	48	0.094	0.0037	0.0047	78.5174	66.1054	1903.3159
49	49	0.096	0.0039	0.0047	76.7740	64.3007	1902.4678
50	50	0.098	0.0038	0.0046	82.0042	67.9094	1902.4678

- Actual pressure reading at 46 ms, as measured by Pressure Gage P017 (digital data, Figure 8)
  = 1,394 psi
- MEOP is 2,159 psi
  = (0.0028 in.) x $\frac{(2{,}159 \text{ psi})}{(1{,}394 \text{ psi})}$
  = 0.0043 in.

- Corrected maximum joint deflection at the crown of the primary inner gasket seal. The location correction factor used to determine this deflection was derived from predicted deflections taken at the same location (relative to a special bolt) as Proximity Gage D001. (The predicted joint deflections were based on analysis documented in TWR-17265, Figure 200. The analysis was performed using minimum bolt preloadings to produce maximum deflections. The analysis did not show a linear deflection increase from the seal crown to the proximity gage location.)
  = (deflection at gage) x (location correction factor)
  = (deflection at gage) x $\frac{\text{(predicted deflection at gage)}}{\text{(predicted deflection at seal crown)}}$
  = (0.0043 in.) x $\frac{0.0034 \text{ in.})}{(0.0046 \text{ in.})}$
  = (0.0043 in.) x (0.74)
  = 0.0032 in.

- Corrected joint deflection, with proximity gage bias correction factor. This correction factor adjusts the deflection value by the maximum amount of gage bias. This correction factor was determined in proximity gage comparison testing with linear variable displacement transformer/transducers (LVDT). The comparison testing was performed, as a result of questionable data obtained during JES-3, to verify the measurement accuracy of the proximity gages relative to LVDTs. The results of this comparison testing (Memo L224:FY89:107) are included in Appendix B. The gage bias correction factor, at approximately 46 ms after the start of deflection, was conservatively determined to be 12 percent high. Determination of the bias is explained on the plot for Test S/N IG008, Run 1 (Appendix B). Test IG008, Run 1 gave the worst-case bias of the six comparisons. The primary cause of the bias was expected to be surface (measured surface) movement that was not normal to gage.

= (joint deflection) - (joint deflection) x (proximity gage bias correction factor)
= (0.0032 in.) - (0.0032 in.) x (0.12)
= 0.0028 in.

- Corrected joint deflection, with bolt relaxation (bolt preload loss) correction factor. This correction factor was based on NSTS-08307, Criteria for Preloaded Bolts. NSTS-08307 states that the amount of preload loss for joints with metal-to-metal contact is five percent of the minimum preload, over time (all bolt preloadings were verified on the day of the test). For a conservative analysis, five percent of the maximum preload was subtracted from the minimum preload. This equated to a loss of 2.8 kips at the attach bolts and 2.2 kips at the special bolts. Applying these preload losses to the structural analysis documented in TWR-17265, Figure 202, worst-case attach and special bolt relaxation effects would increase the deflection by 0.0003 inch.
  = (corrected joint deflection) + (deflection increase due to worst case bolt relaxation effects)
  = (0.0028 in.) + (0.0003 in.)
  = 0.0031 in.; the maximum joint deflection for the igniter inner joint at the crown of the primary seal (65 degrees), accounting for all significant correction factors.

Calculated Joint Deflection at the Primary Seal Crown, Proximity Gage D002:

Each calculation is based on the previous calculation(s).

- Actual time that the proximity gage temperature began increasing, measured by Thermocouple T010 (this measurement was taken from digital data, Figure 8)
  = 48 ms
- Actual deflection reading at 48 ms (digital data, Figure 8)
  = 0.0027 in.
- Corrected maximum joint deflection.
  = (measured deflection at 48 ms) x $\frac{\text{(MEOP)}}{\text{(pressure at 46 ms)}}$
  - Actual pressure reading at 48 ms, as measured by Pressure Gage P017 (digital data, Figure 8)
    = 1,467 psi

- MEOP is 2,159 psi
  = (0.0027 in.) x $\frac{(2{,}159 \text{ psi})}{(1{,}467 \text{ psi})}$
  = 0.0040 in.

- Corrected maximum joint deflection at the crown of the primary inner gasket seal.
  = (deflection at gage) x (location correction factor)
  = (deflection at gage) x $\frac{\text{(predicted deflection at gage)}}{\text{(predicted deflection at seal crown)}}$
  = (0.0040 in.) x $\frac{(0.0034 \text{ in.})}{(0.0046 \text{ in.})}$
  = (0.0040 in.) X (0.74)
  = 0.0029 in.

- Corrected joint deflection, with proximity gage bias correction factor.
  = (joint deflection) - (joint deflection) x (proximity gage bias correction factor)
  = (0.0029 in.) - (0.0029 in.) x (0.12)
  = 0.0026 in.

- Corrected joint deflection, with bolt relaxation (bolt preload loss) correction factor.
  = (corrected joint deflection) + (deflection increase due to worst-case bolt relaxation effects)
  = (0.0026 in.) + (0.0003 in.)
  = 0.0029 in., the maximum joint deflection for the igniter inner joint at the crown of the primary seal (165 degrees), accounting for all significant correction factors.

7

APPLICABLE DOCUMENTS

Document No.	Title
CPW1-3600	Prime Equipment Contract End Item (CEI) Detail Specifications
L224:FY89:107	Memo on JES-3C Igniter Deflections Validation Testing
NSTS-08307	Criteria for Preloaded Bolts
TWR-15723	Development and Verification Plan
TWR-17265	RSRM Ignition System Structural Analysis
TWR-18000	Joint Environment Simulator 3C (JES-3C) Final Test Report
TWR-18624	Transient Pressure Test Article 1.3 (TPTA 1.3) Final Test Report
STW7-2692	Leak Testing, Ignition System Seals, Space Shuttle SRM
STW7-3680	Igniter Attach Bolts Ultrasonic Inspection
WTP-0178	Test Plan for Igniter Adapter-to-Igniter Chamber Deflection Test

Military Standards	Title
MC450-0018	Pyrotechnic Initiator Controller (PIC) Ground Ordnance Firing Assembly
MIL-STD-45662	Calibration System Requirements

Drawing No.	Title
1U50152	Chamber Assembly, Igniter Initiator - Loaded
1U50278	Adapter, Igniter
1U51882	Chamber Assembly - Igniter, Loaded
1U52294	Barrier Booster Assembly S/A Device - Loaded
7U52775	Adapter, Igniter
7U52927	FWD Dome, Insulated Inert
2U65052	Base Stand - Hydrotest and Hydroburst
7U76058	Gasket-Inner, Modified
7U76059	Gasket - Outer, Modified

7U76436	Gage Assembly, Three In One Combination
7U76751	Igniter Deflection Test Configuration
7U76785	Igniter-Forward Dome Deflection Test Configuration

Books

Mechanical Measurements, Third Edition; T.G. Beckwith, N.L. Book, and R.D. Marangoni; Addison-Wesley Publishing Co.; Copyright 1982

APPENDIX A

Data from Test No. 2

MORTON THIOKOL, INC.
Aerospace Group
Support Services

TEST REPORT

TITLE: Deflection Test Igniter to Forward Dome

PROJECT: HQ301-06-07 DATE: 27 September 1988

TEST DATE: 20 September 1988 REPORT NO. TE-12674

PREPARED BY: Scott Cook

Scott Cook
Test Engineer

APPROVED BY: B. O. Tams

B. O. Tams, Manager
Test Engineering

DISTRIBUTION:

Pat McCluskey
Brian Russell
Dan Cooper

FORM TC 7155 (REV 10-87)

MORTON THIOKOL INC
SUPPORT SERVICES

TABLE OF CONTENTS

MORTON THIOKOL INC.
SUPPORT SERVICES

1.0 SUMMARY

This report contains the results of the second igniter adapter-to-igniter chamber Deflection test. The test article was an SRM Igniter installed in a forward dome. Part number 7U76785-01, serial number 0000003.

Test was conducted in accordance with test plan WTP-0178 and shop traveler HR80E, Revision 02. All test objectives were met except the thermocouple reference oven was at 147° F not 150° F.

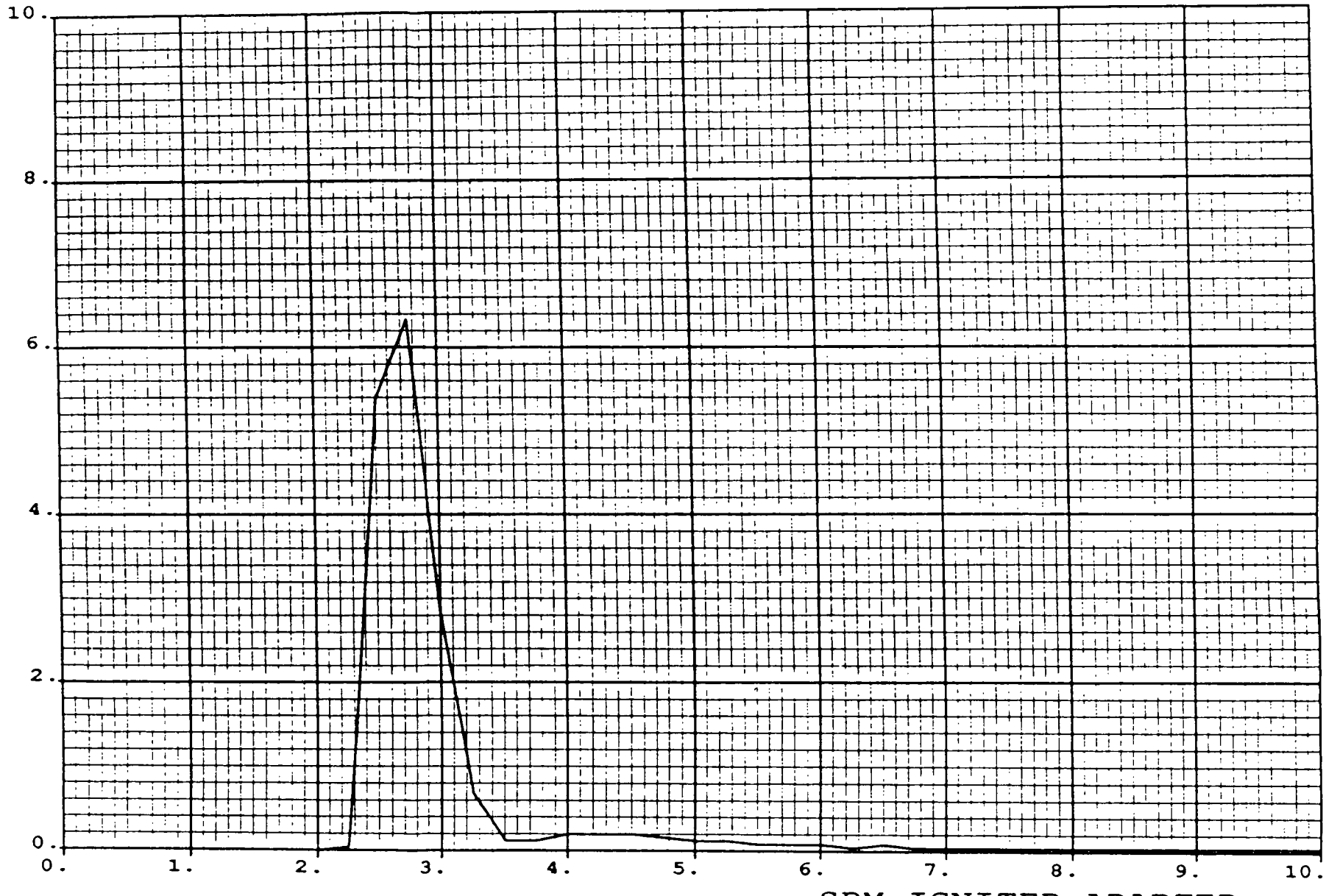
2.0 DEFLECTION TEST

Deflection test took place on 20 September 1988 at T-11. The test article 7U76785-01, Serial Number 0000003 was installed in the 2U65052-04 Hydrotest Stand with the igniter nozzle pointing up. Igniter was fired under the following conditions.

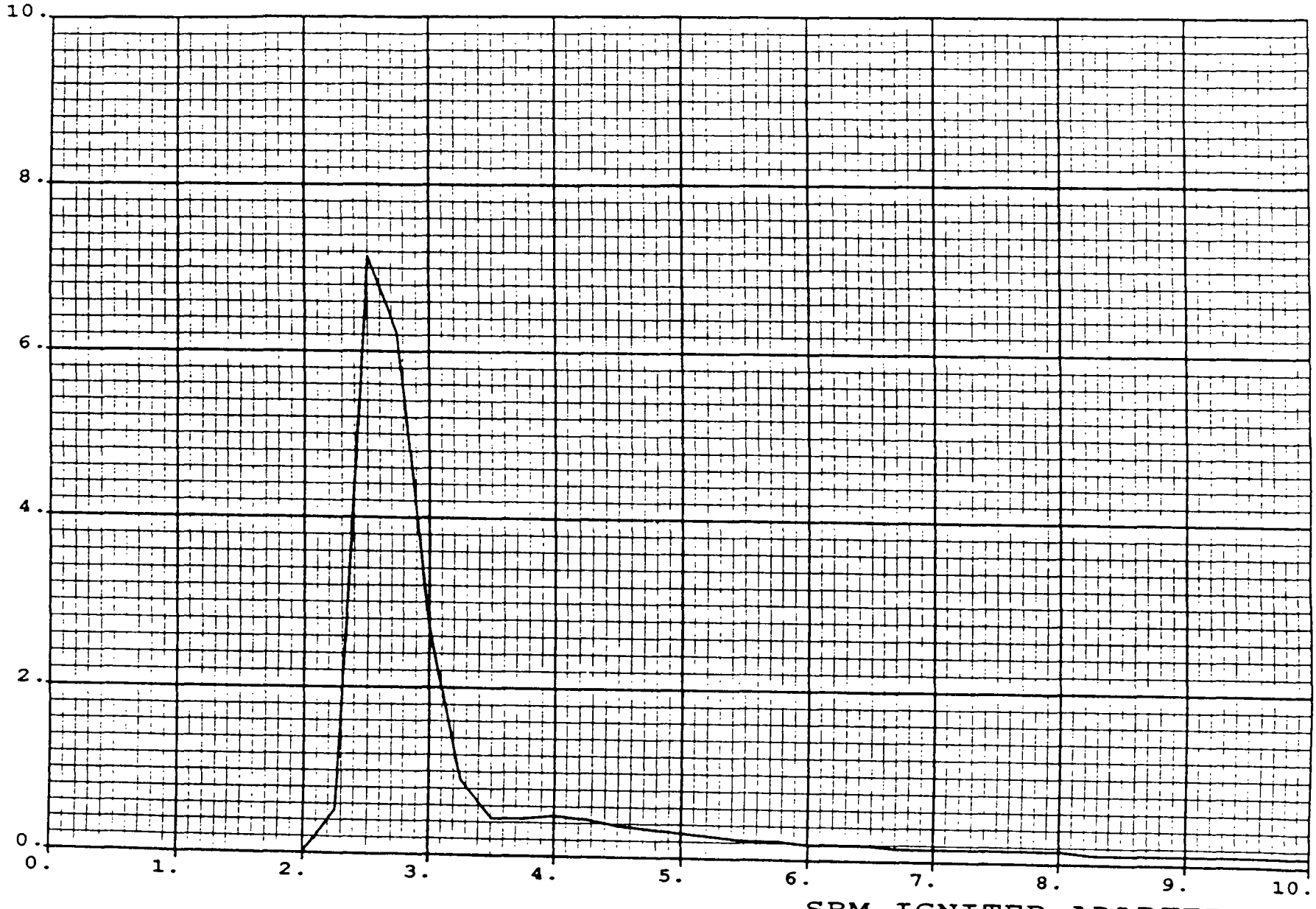
Average Inter-joint Temperature	50° F
Ambient Temperature	42° F
Humidity	68%
Barometer Pressure	25.32" HG

3.0 DATA

Time Versus Amps	I001
Time Versus Amps	I002
Time Versus PSIA	P017
Time Versus PSIA	P018
Time Versus Inches	D001
Time Versus Inches	D002
Time Versus Inches	D003
Time Versus Inches	D004
Time Versus Inches	D005
Time Versus Inches	D006
Time Versus Inches	D007
Time Versus Inches	D008
Time Versus Temperature	T002
Time Versus Temperature	T003
Time Versus Temperature	T005
Time Versus Temperature	T006
Time Versus Temperature	T007
Time Versus Temperature	T008
Time Versus Temperature	T009
Time Versus Temperature	T010
Time Versus Temperature	T011
Time Versus Temperature	T012
Time Versus Temperature	T013
Time Versus Temperature	T014
Time Versus Temperature	T015
Time Versus Temperature	T016



SRM IGNITER ADAPTER-TO-IGNITER CHAMBER DELFECTION TEST S/N 003
20 SEPTEMBER 1988



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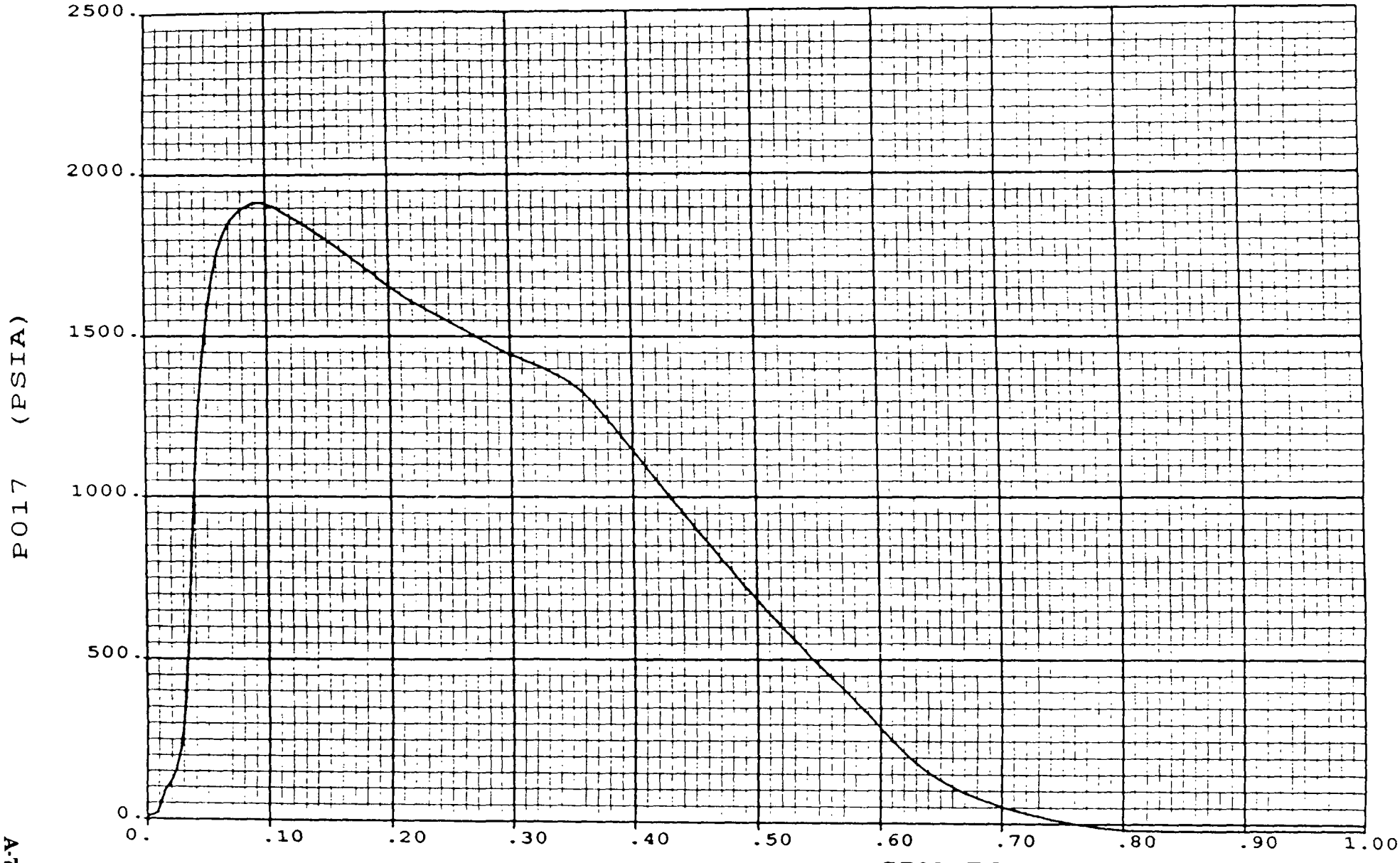

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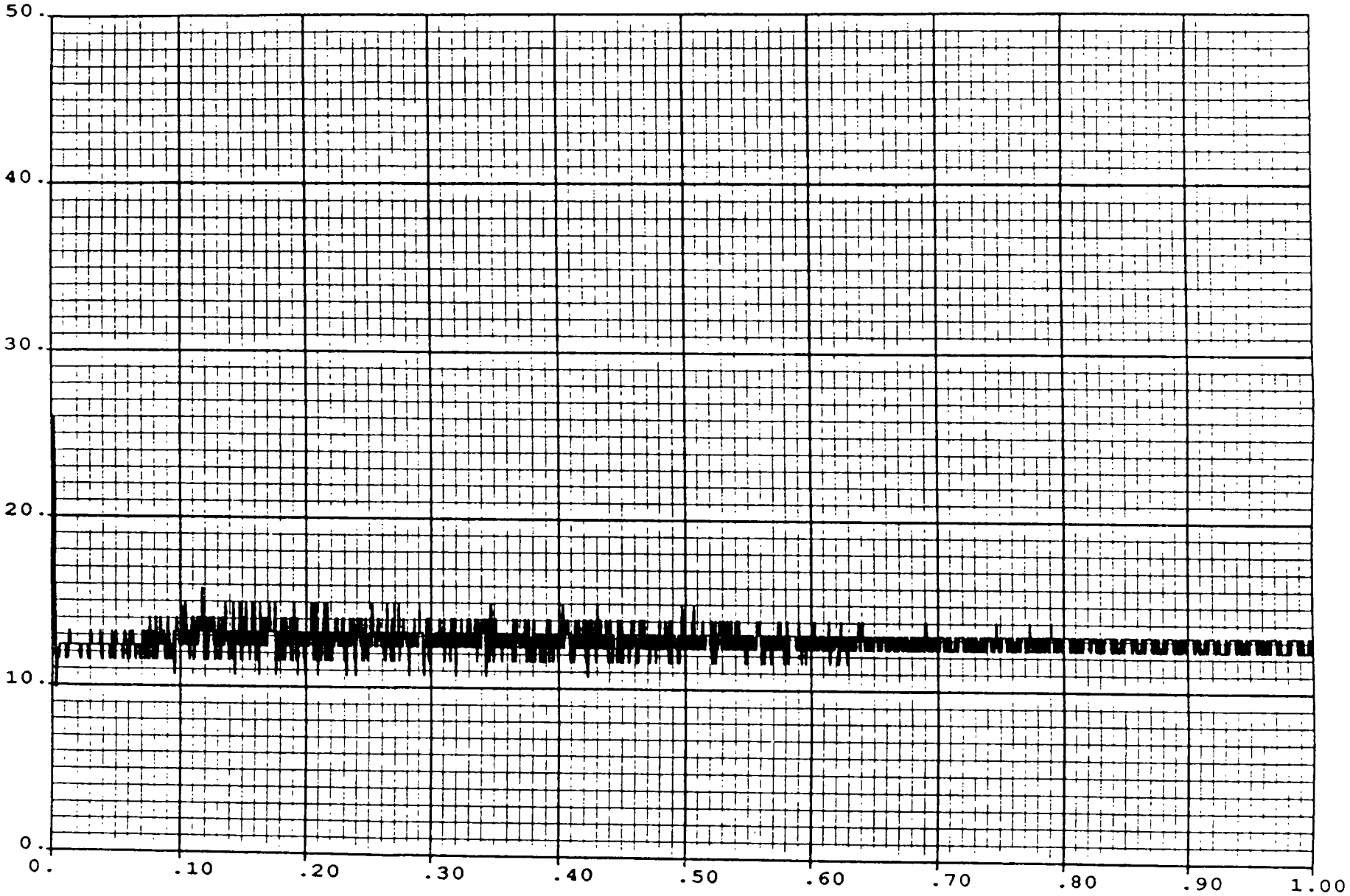

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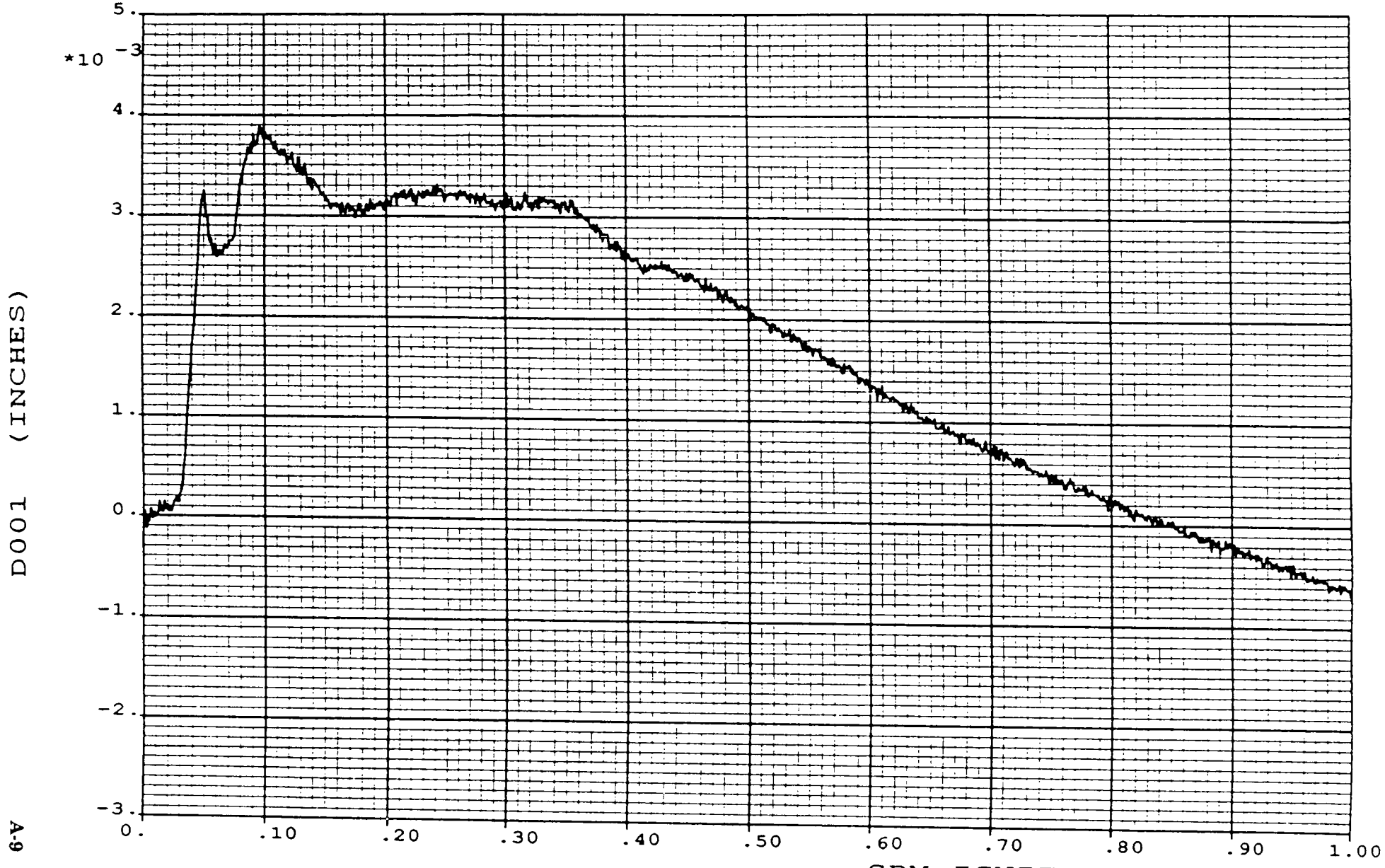

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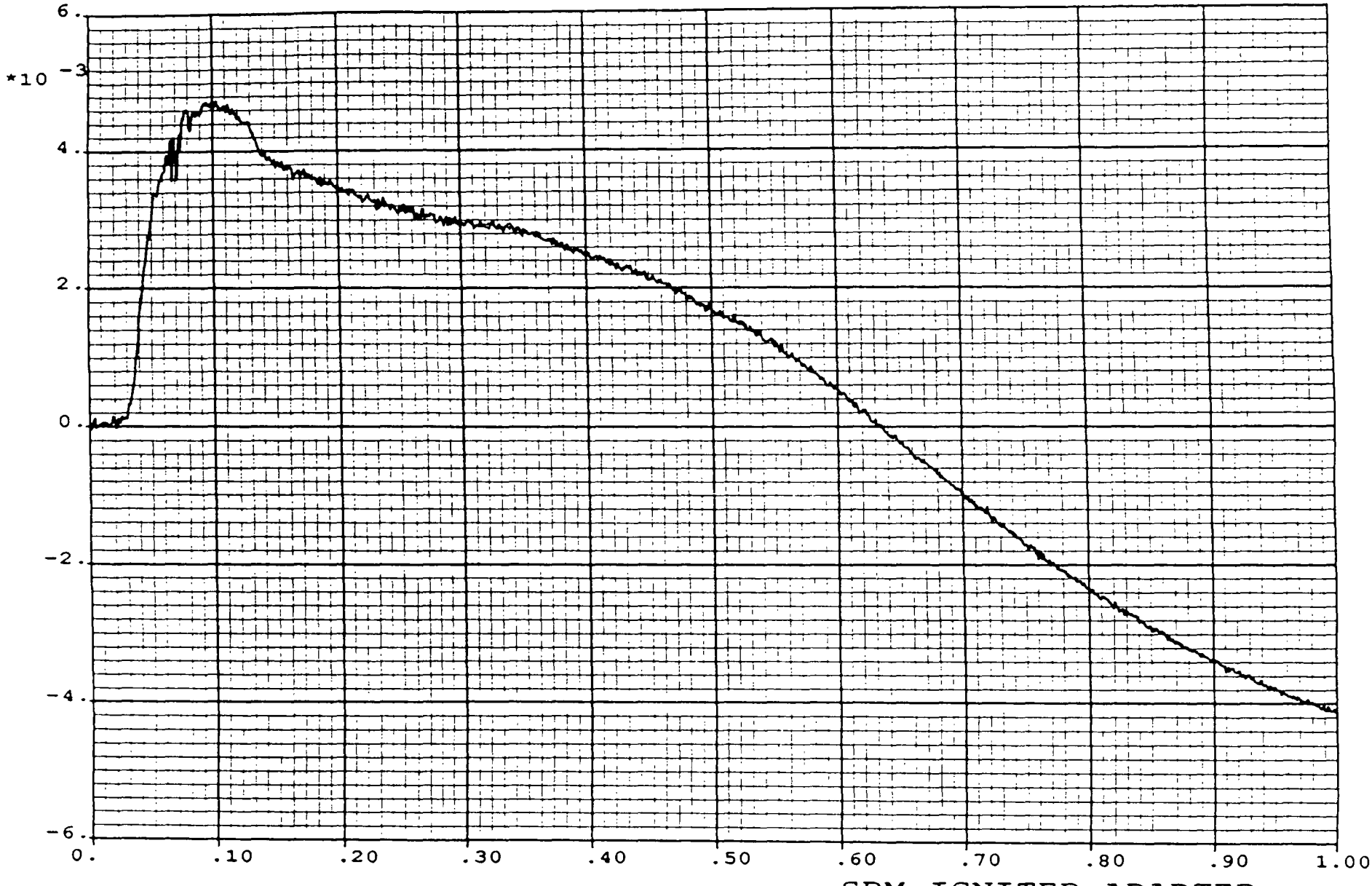

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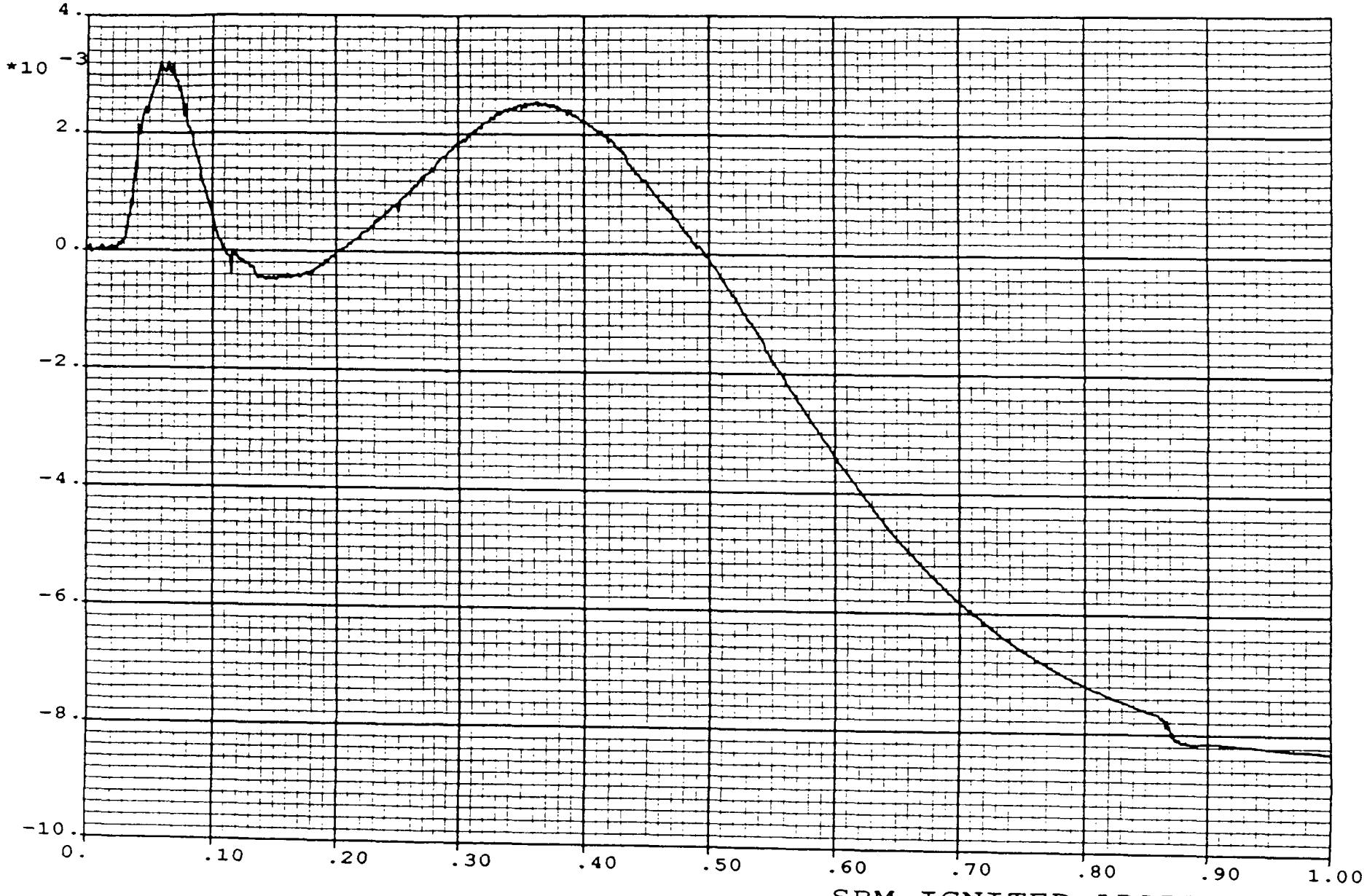

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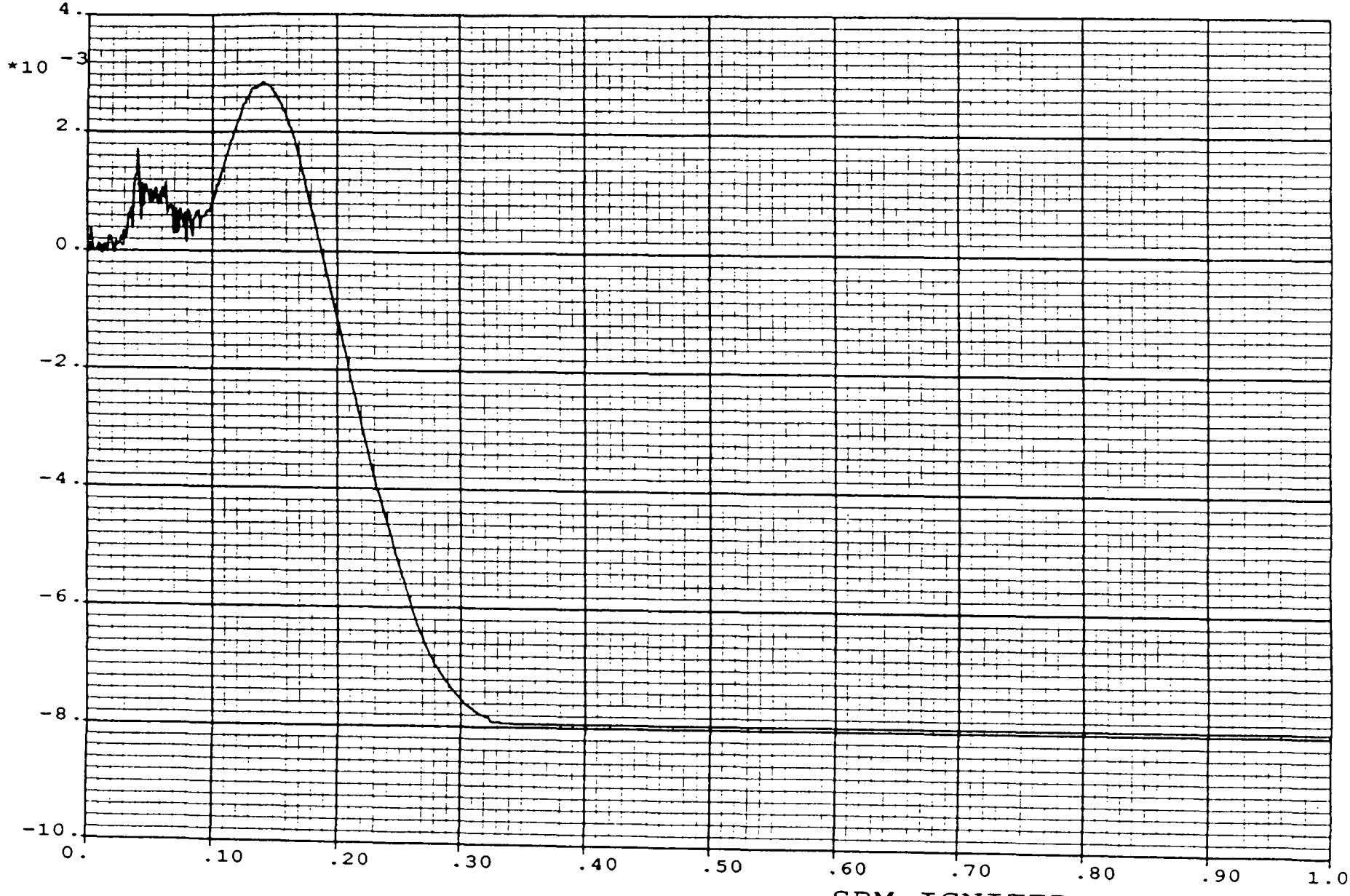

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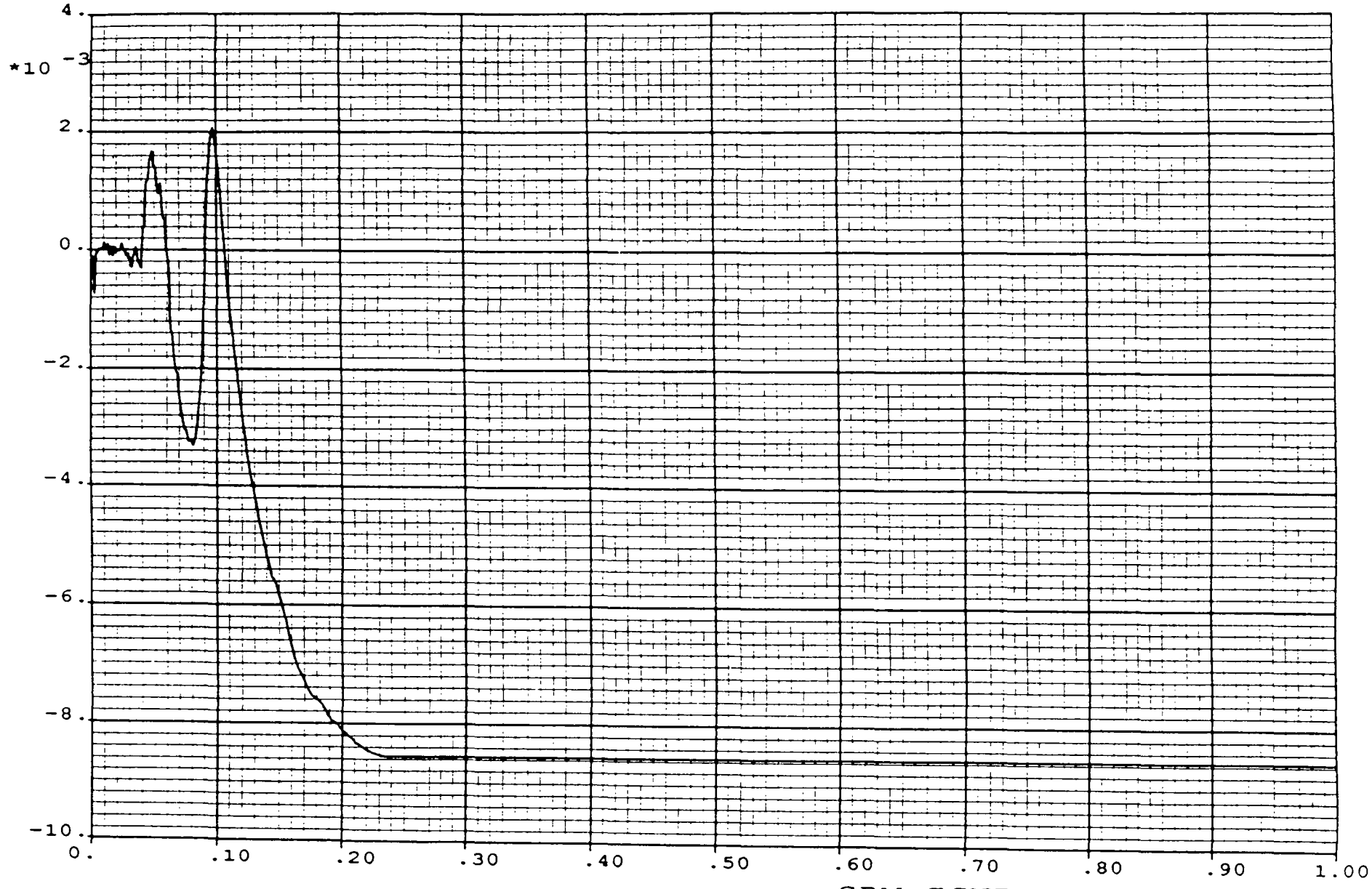

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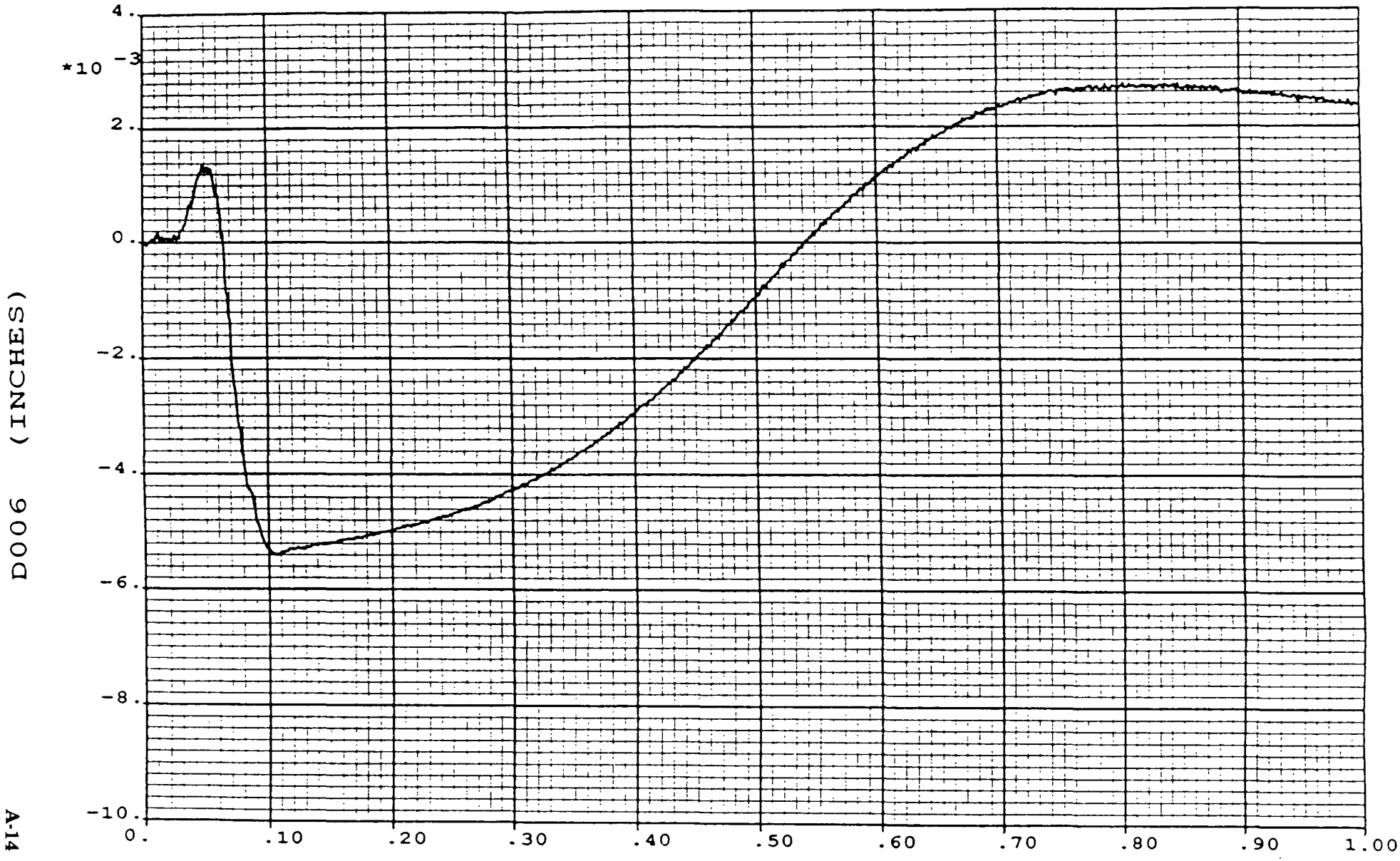

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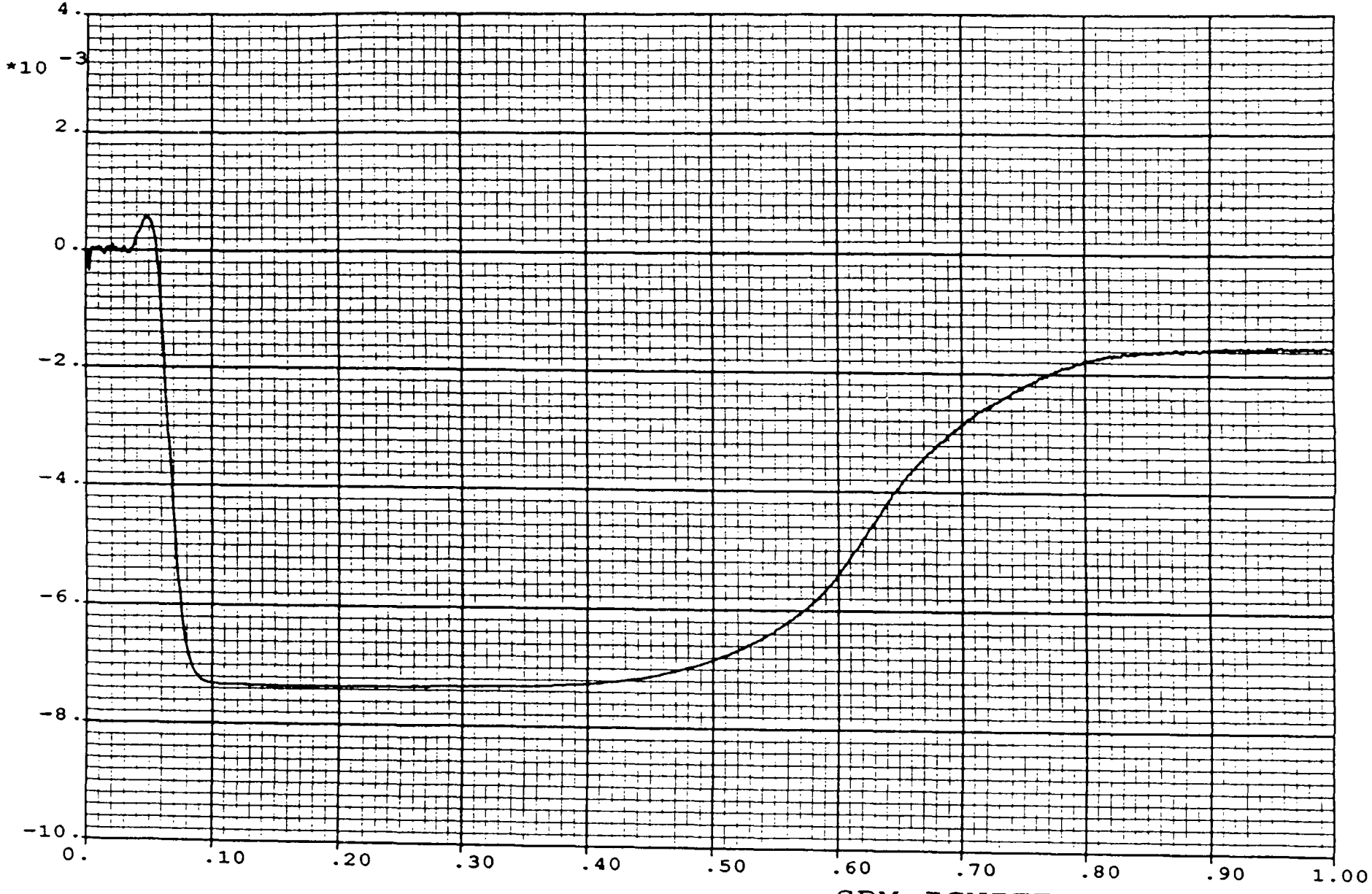

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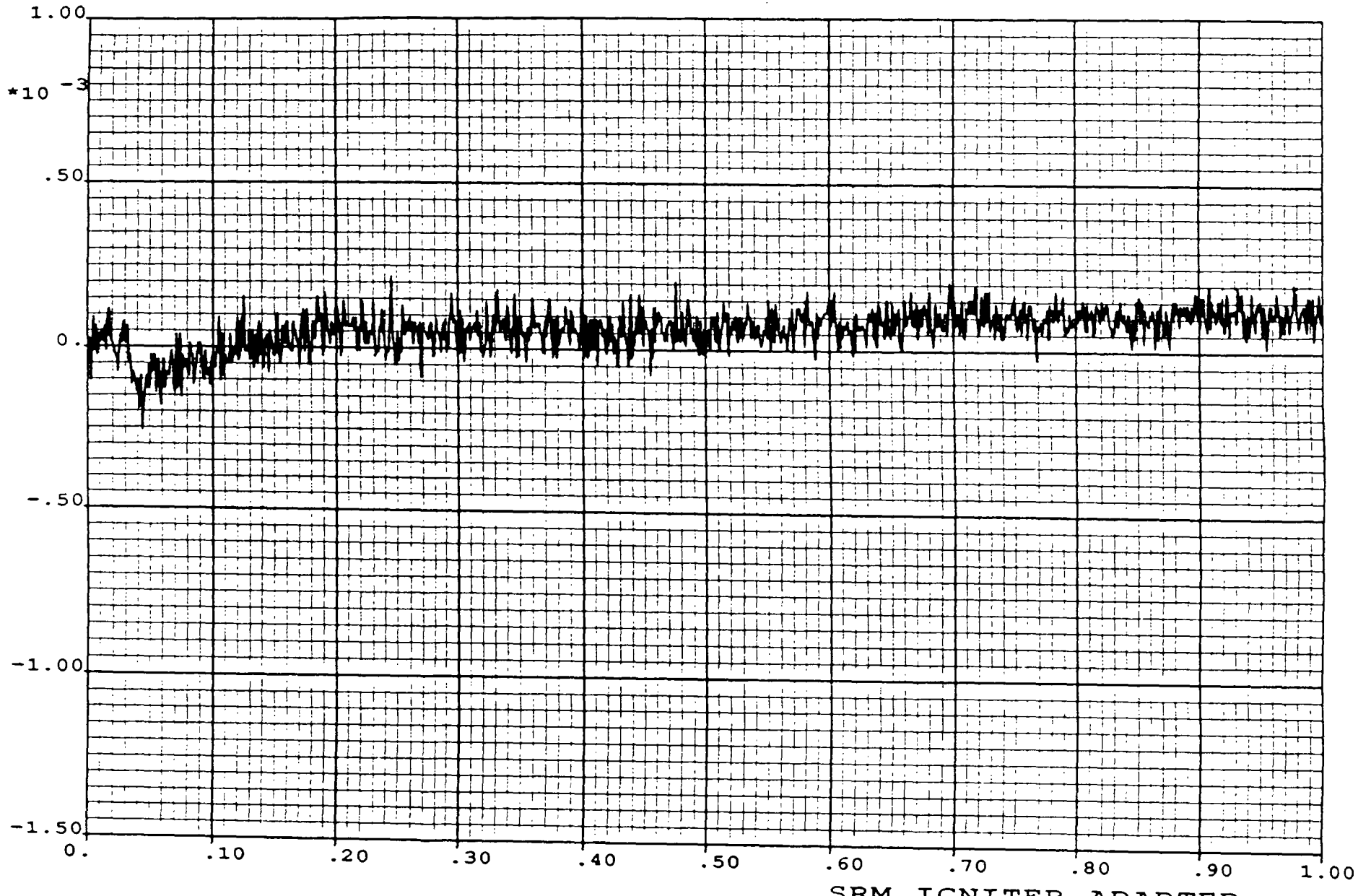

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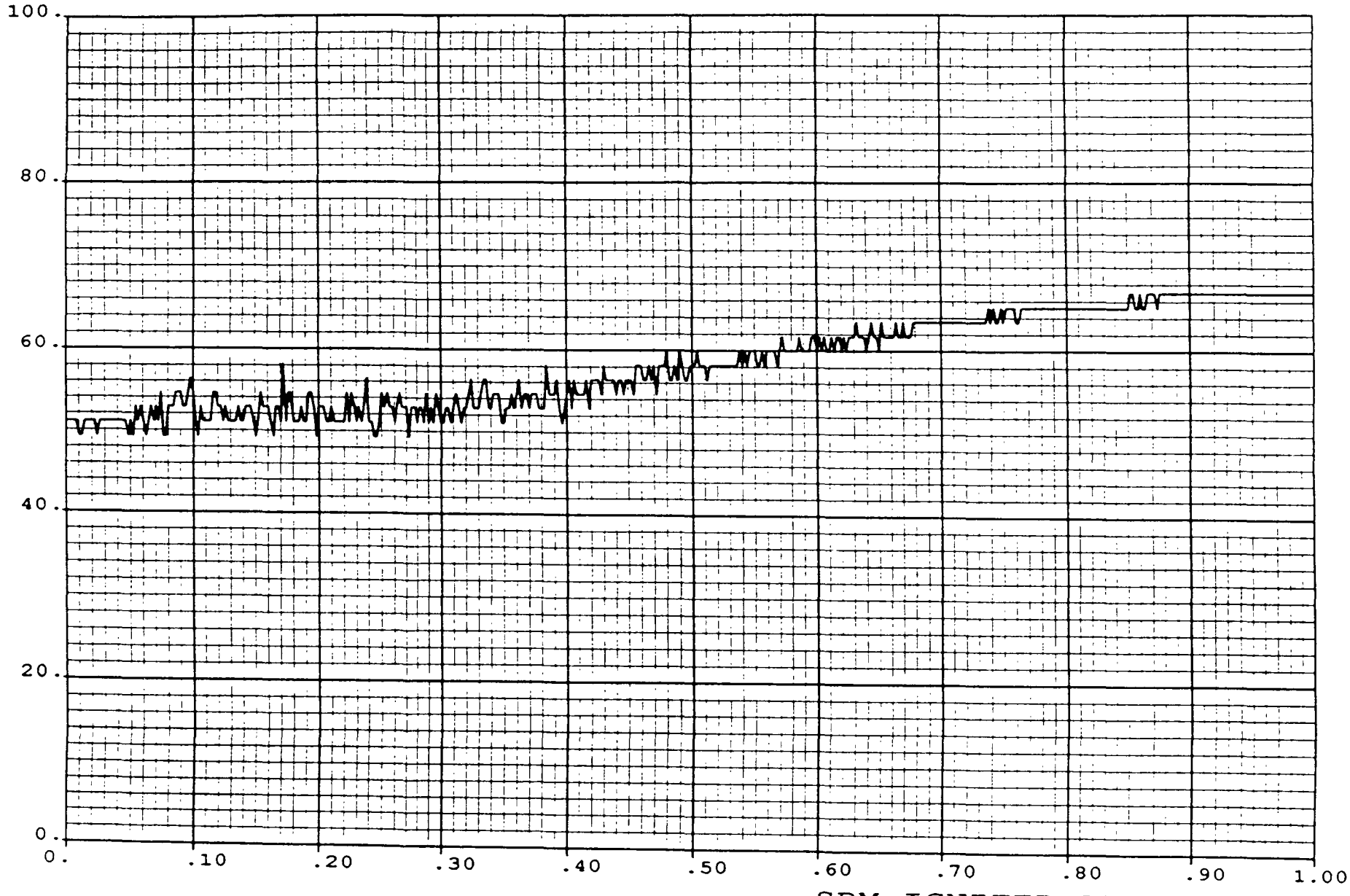

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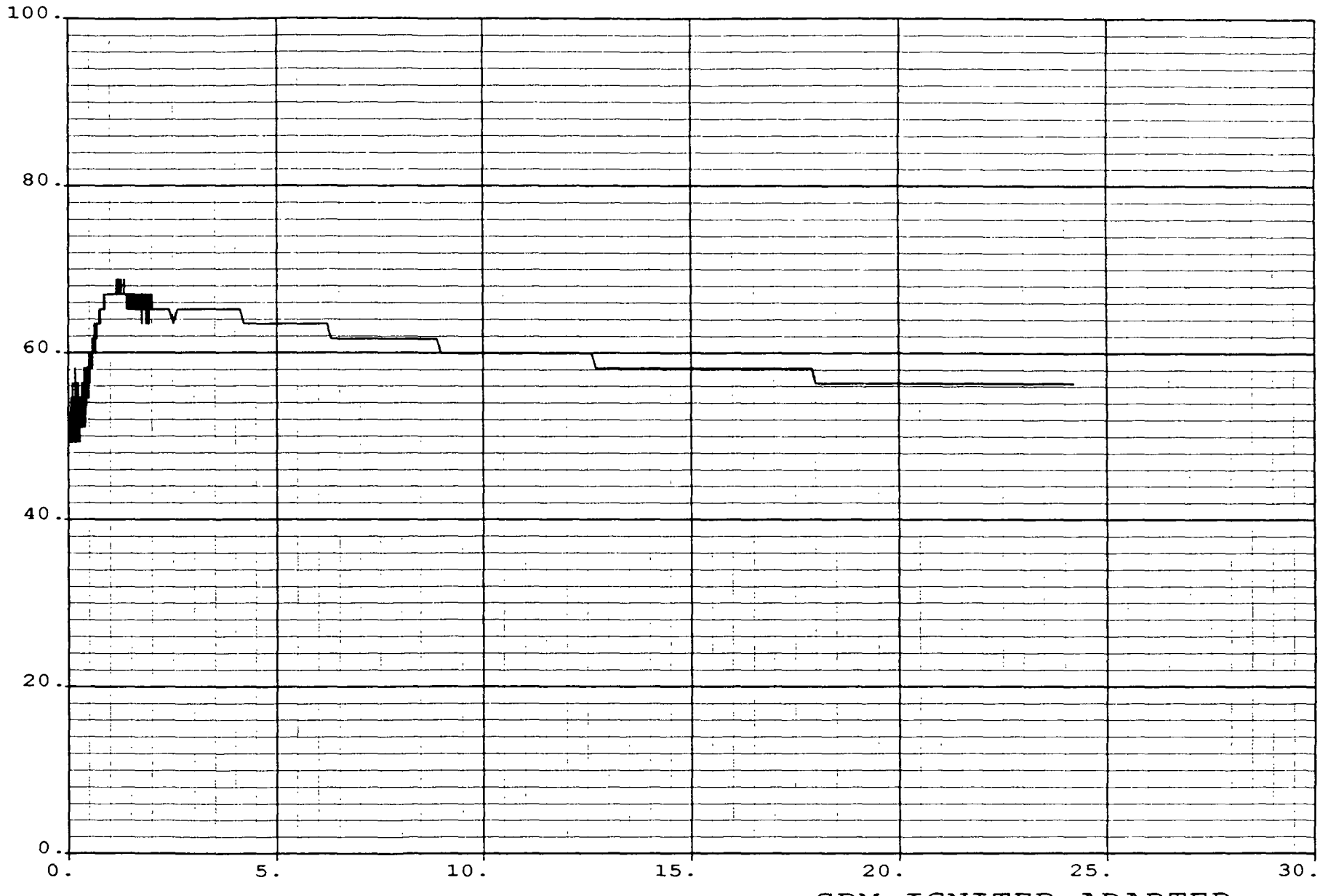

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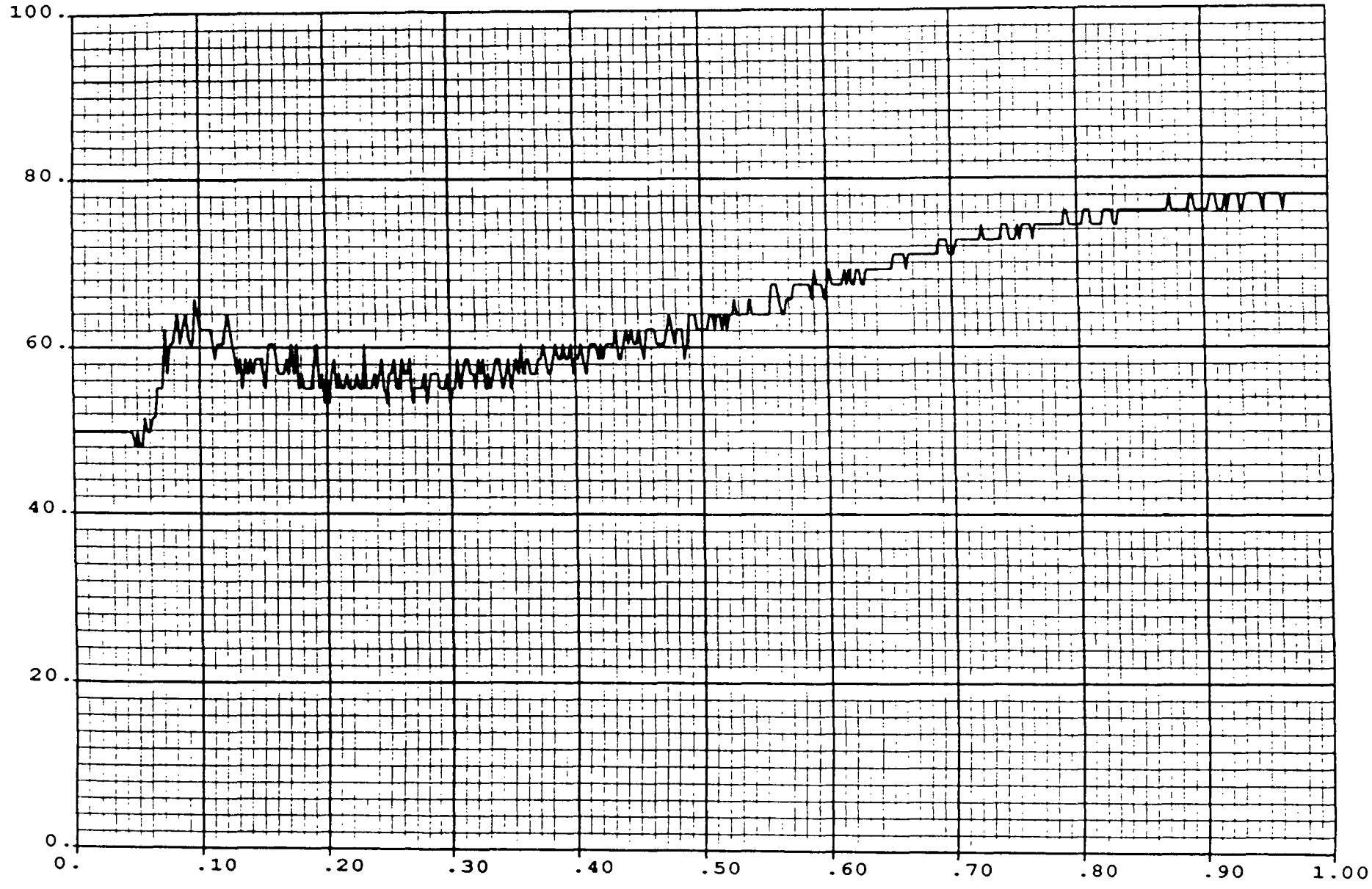

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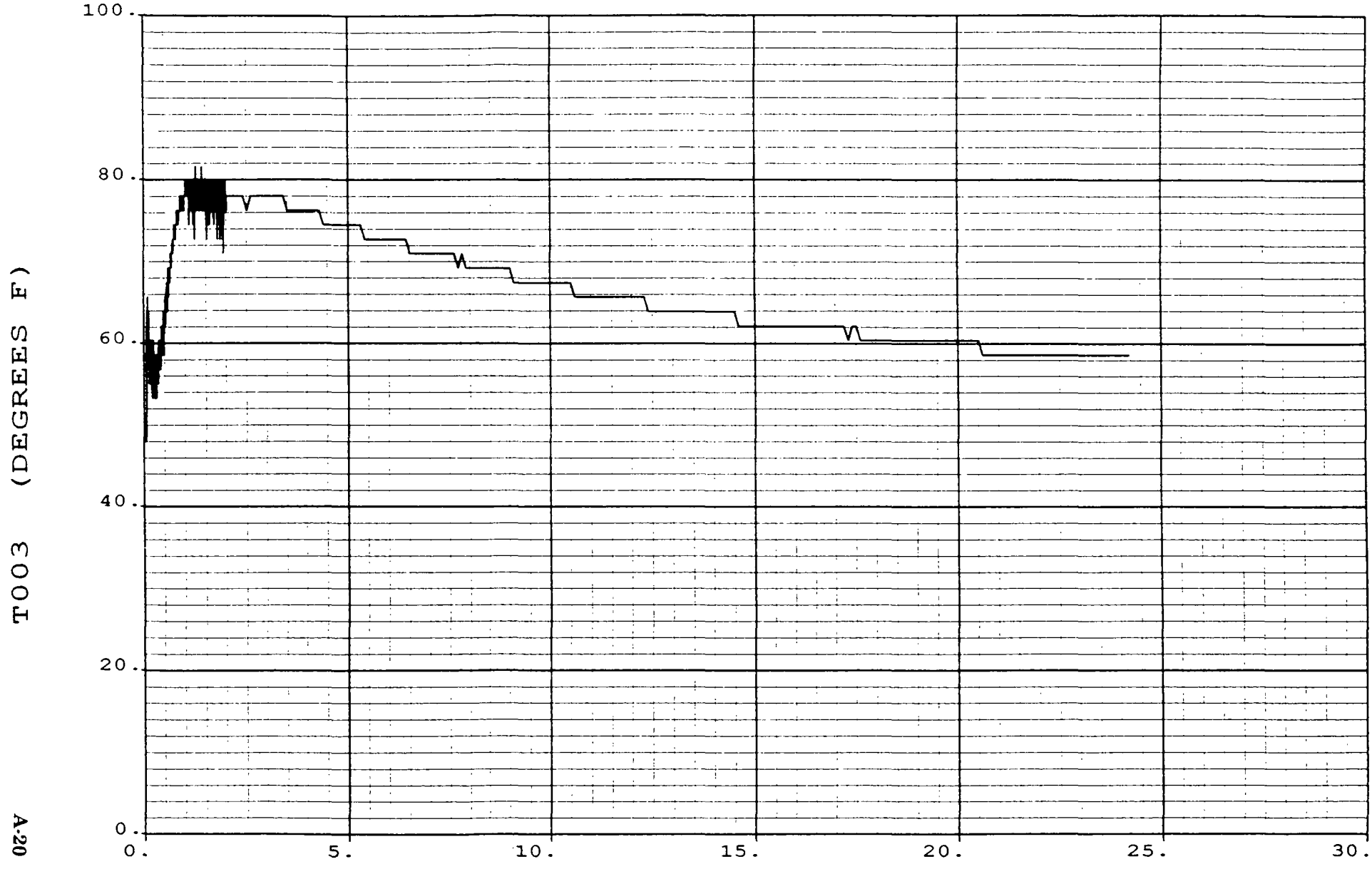

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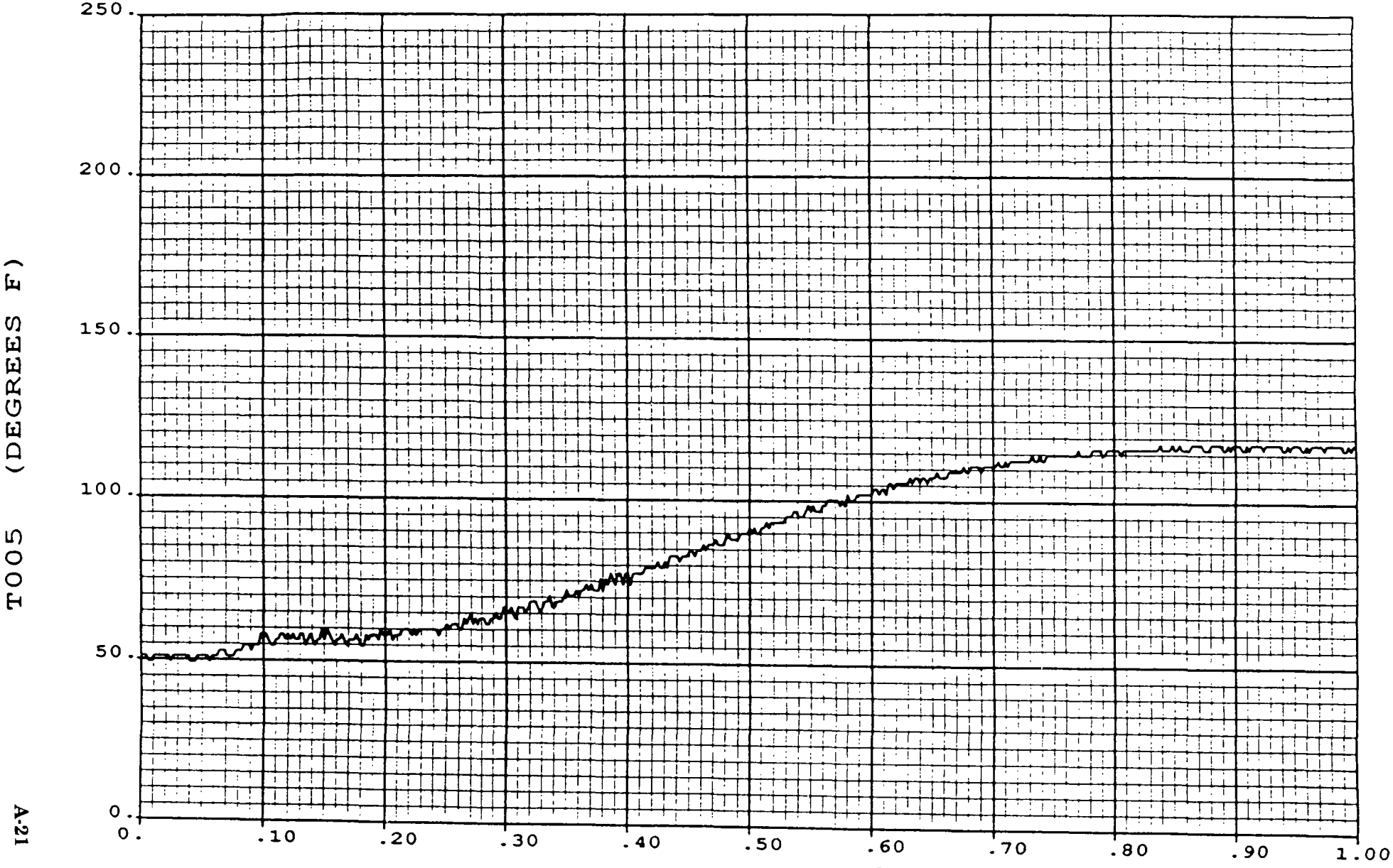

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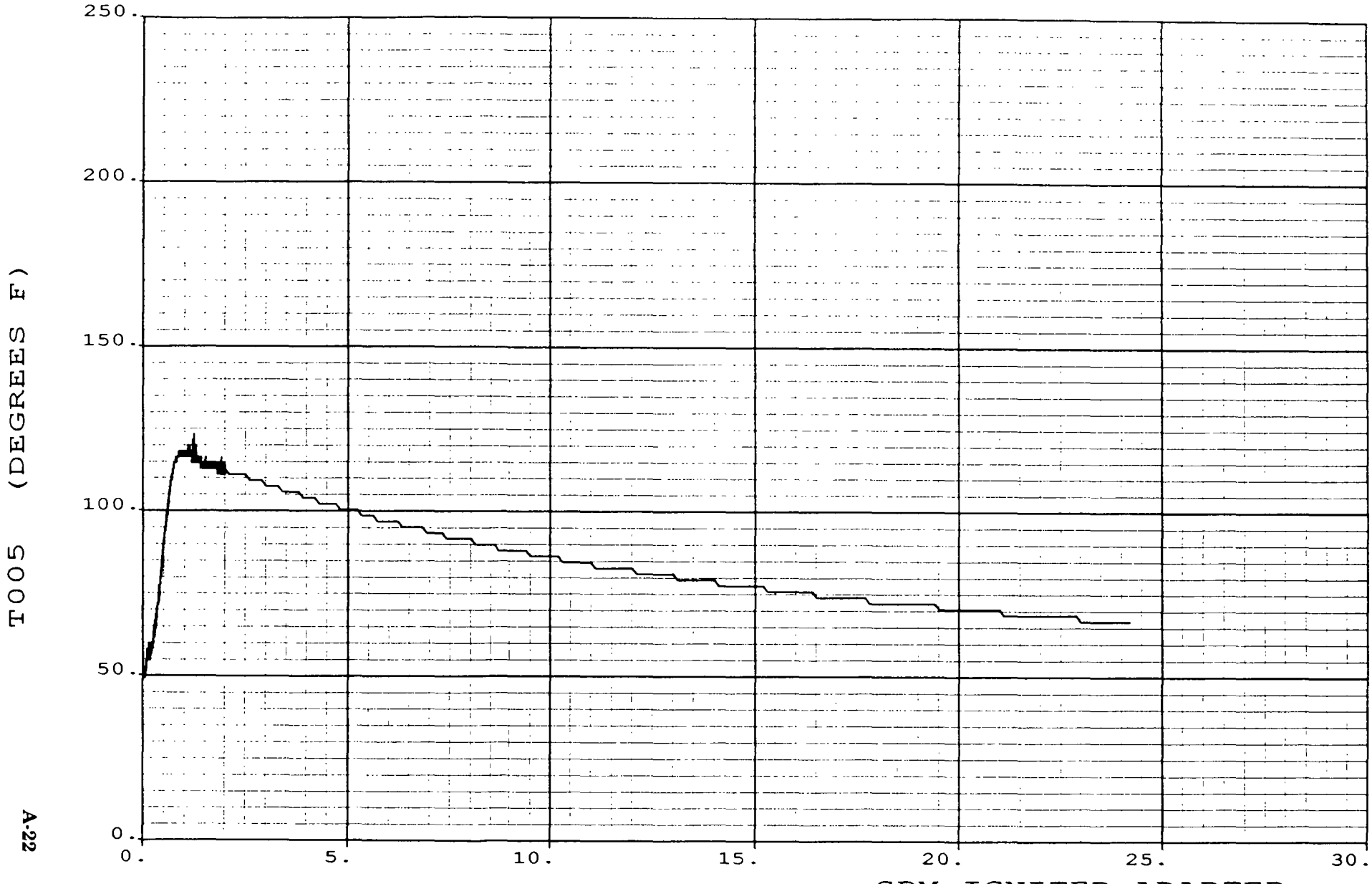

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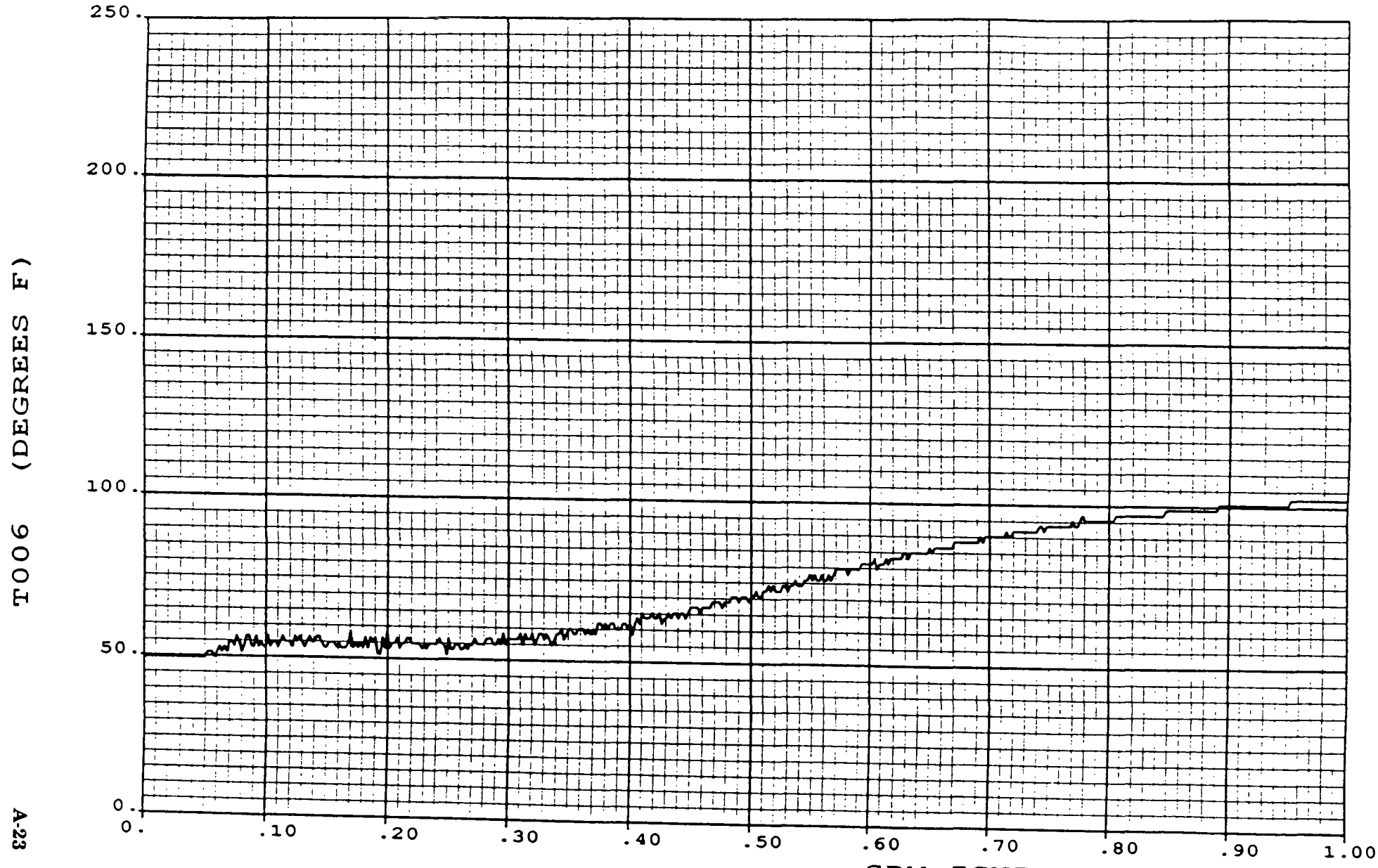

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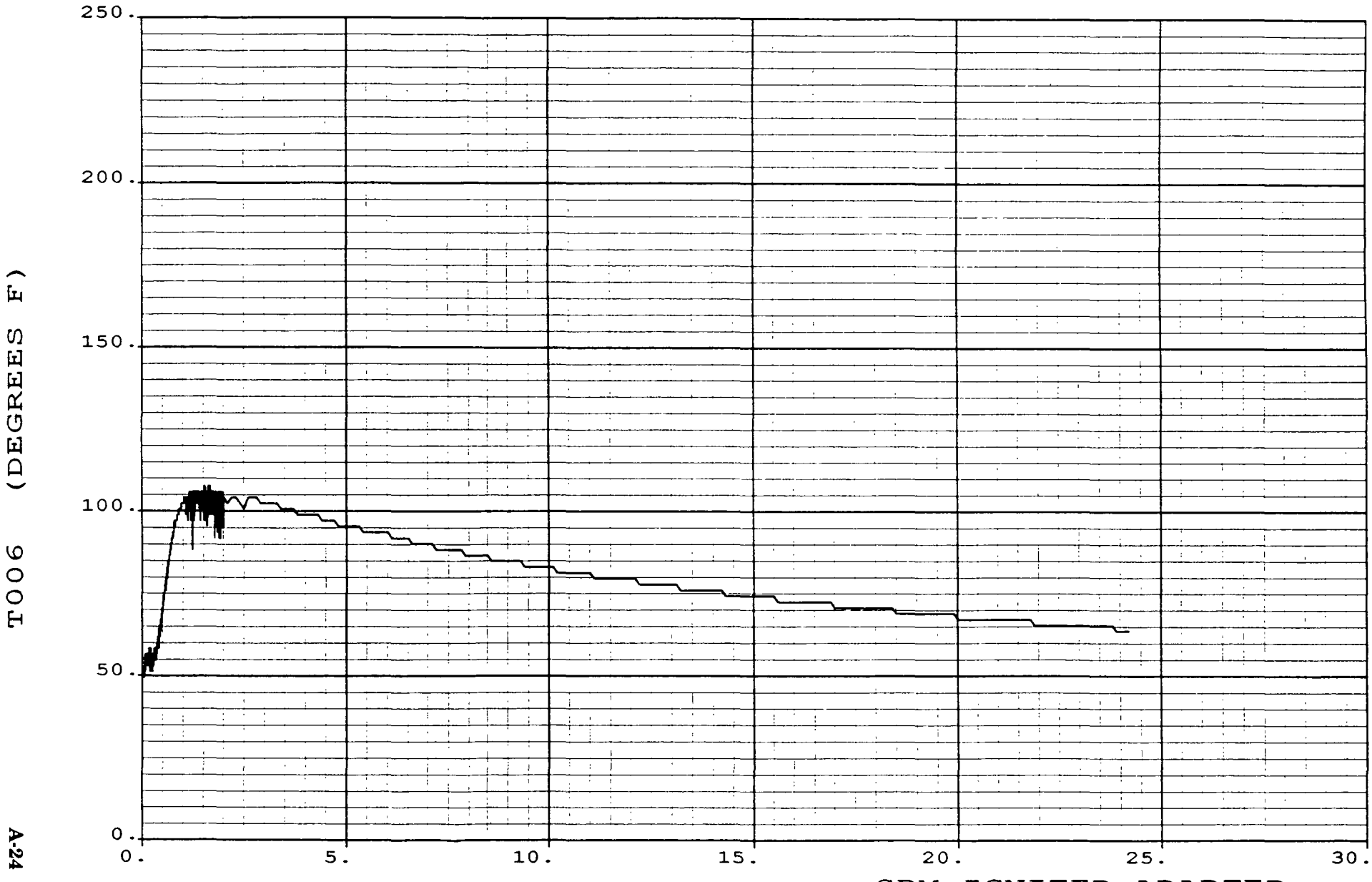

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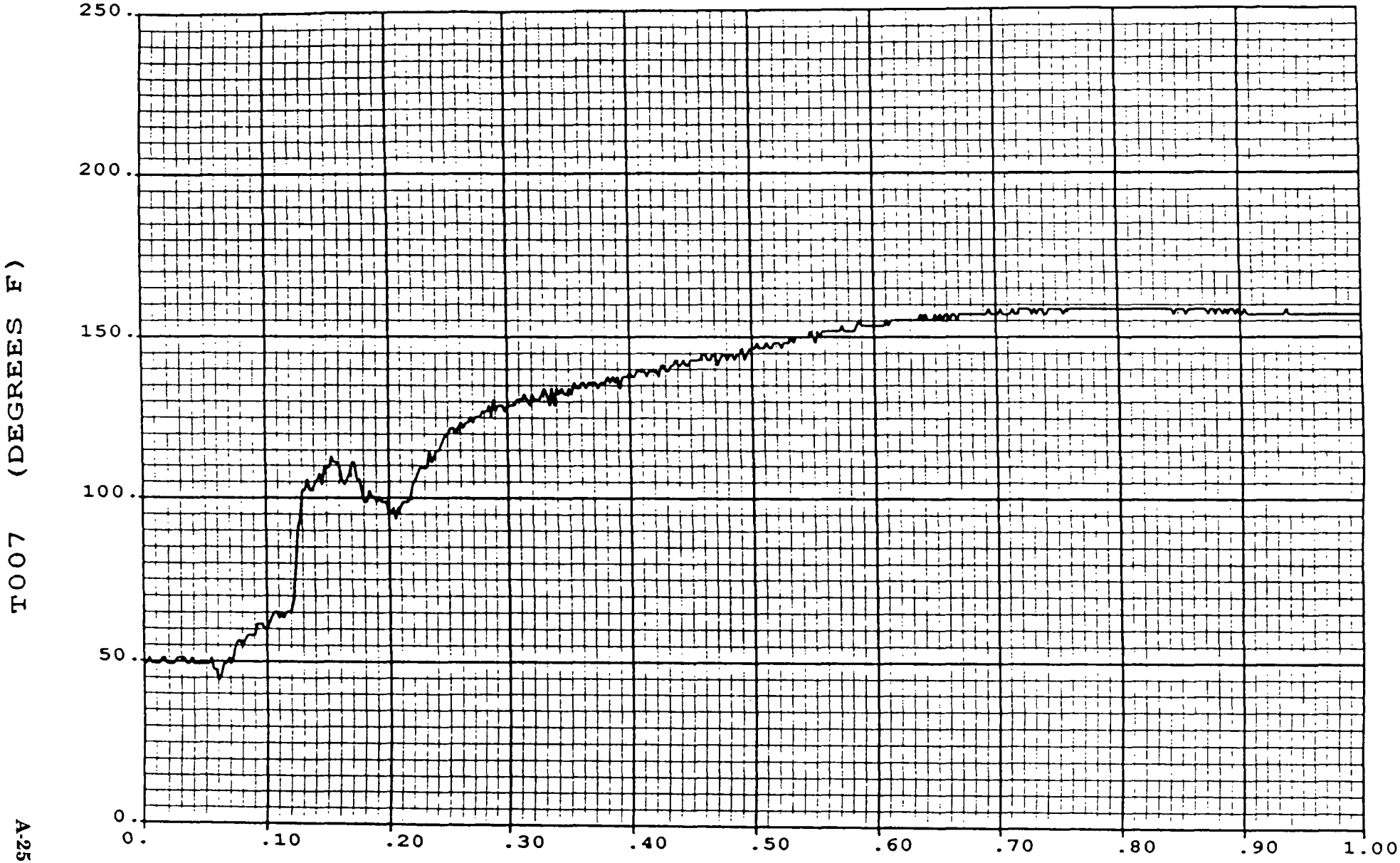

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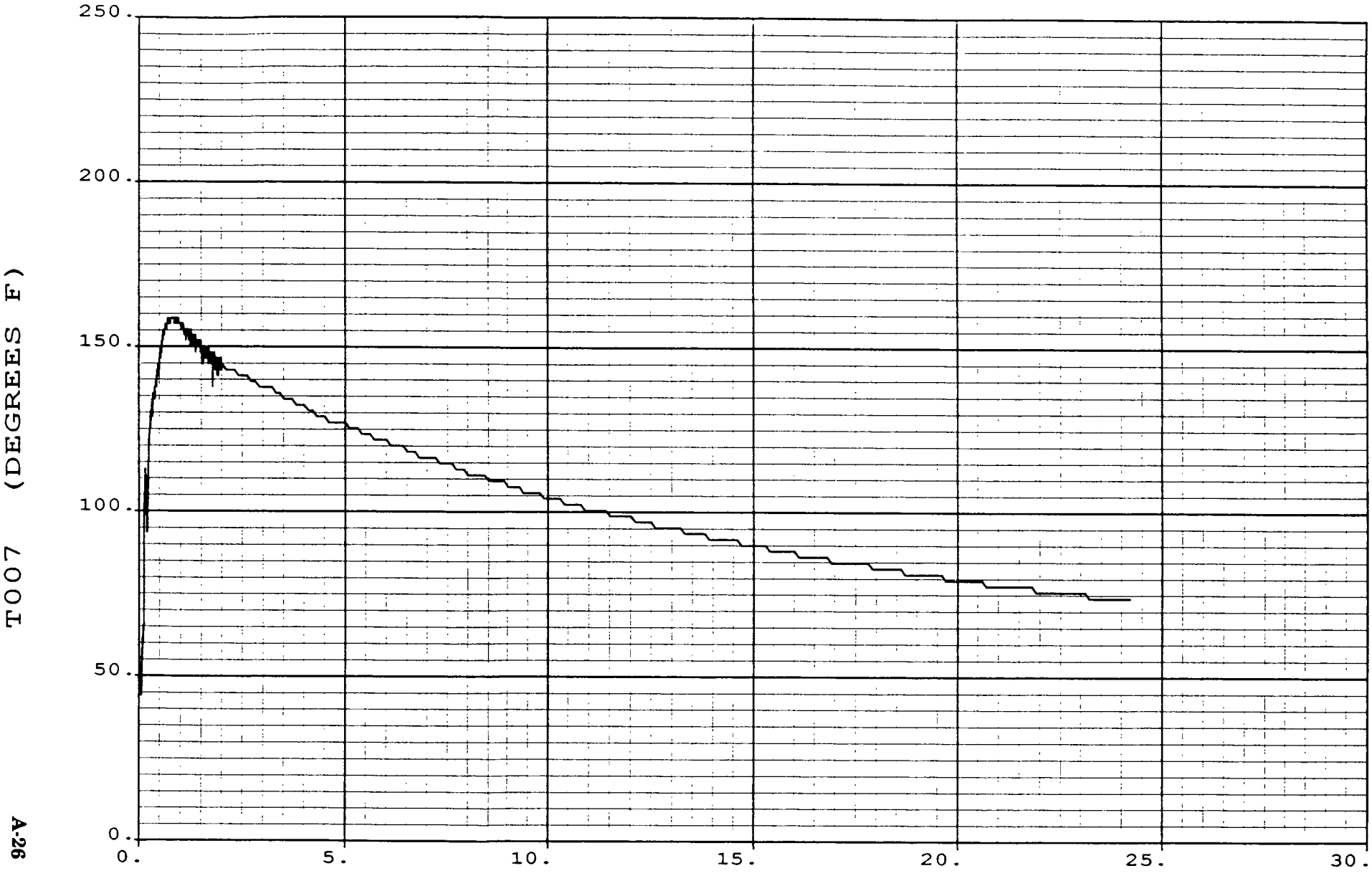

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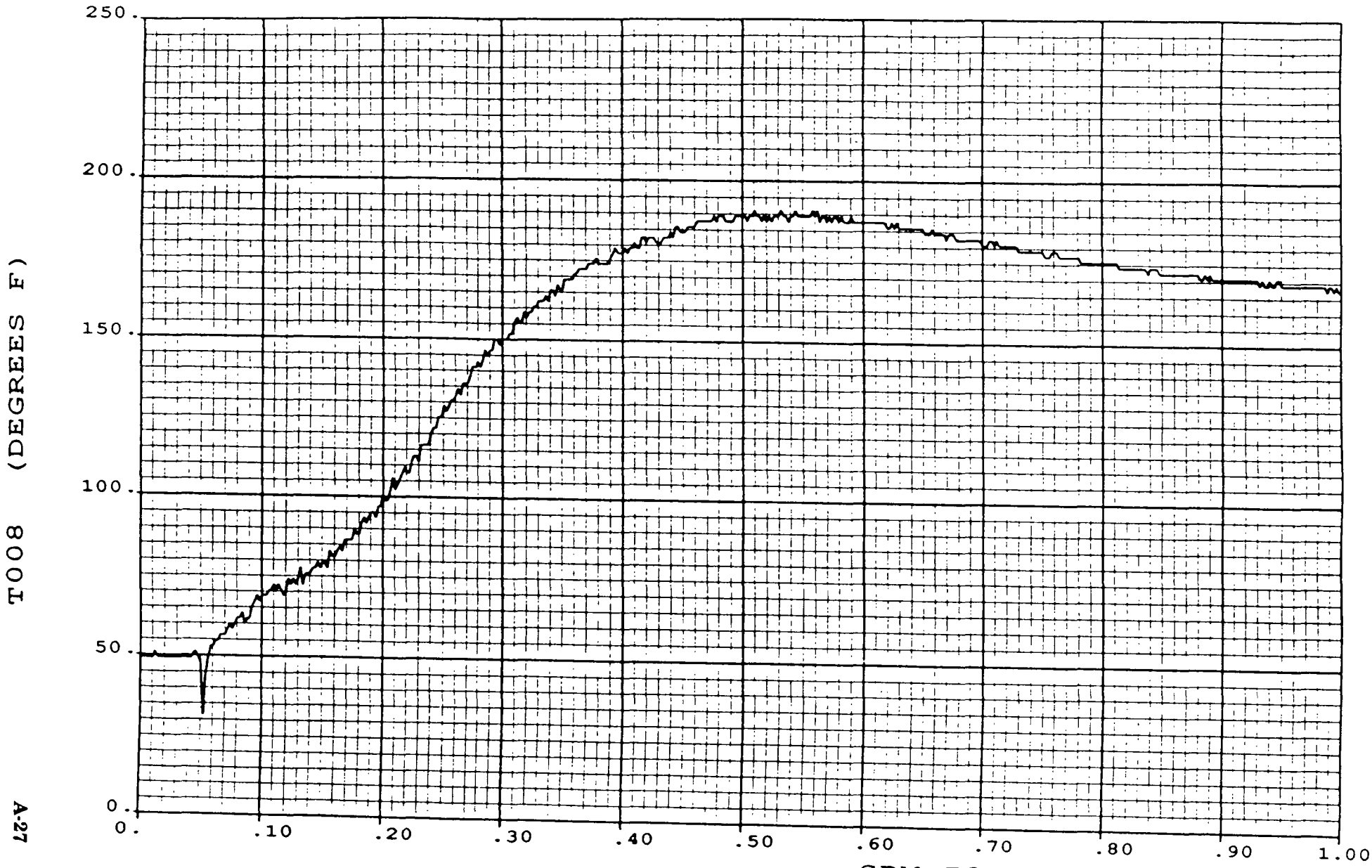

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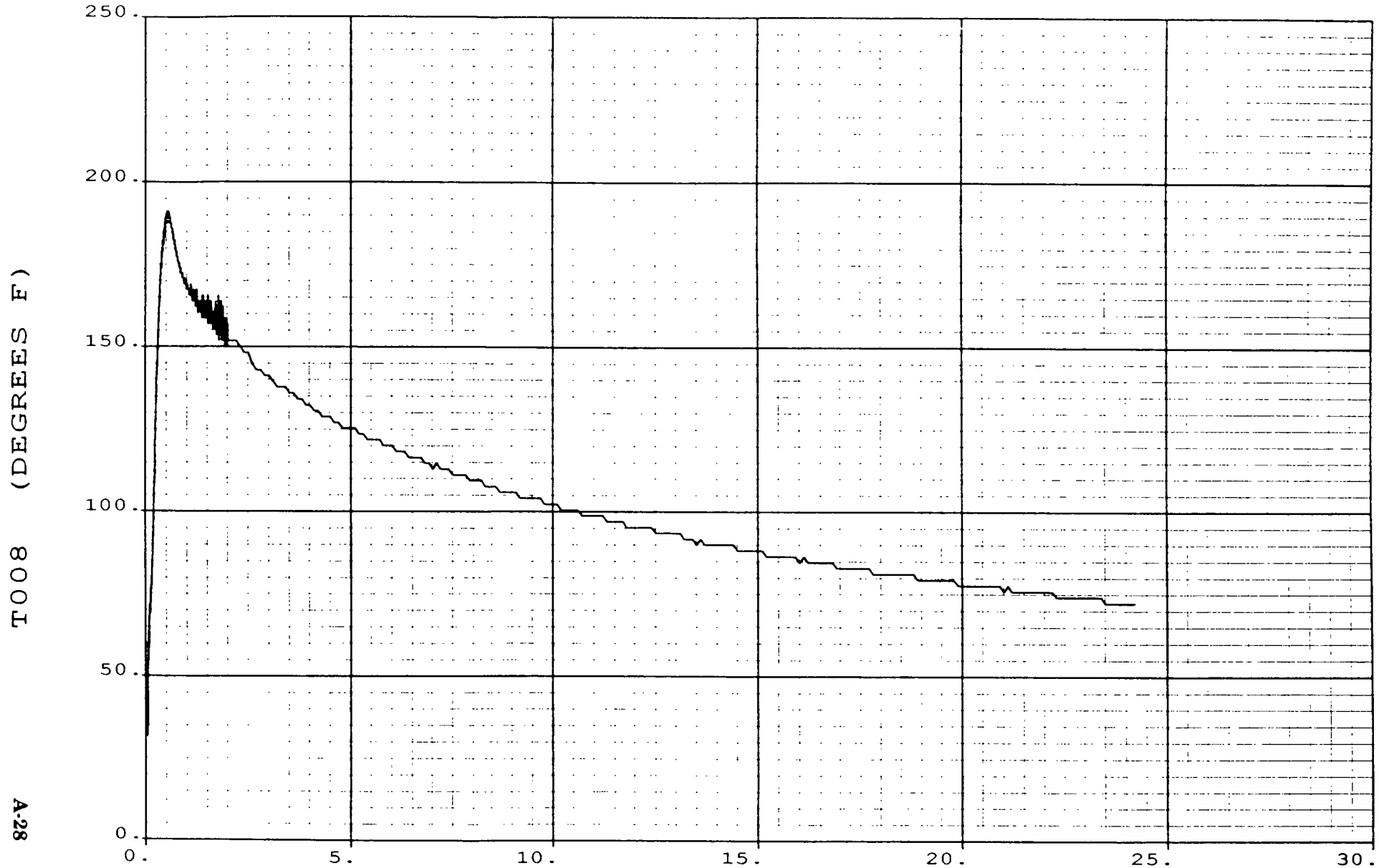

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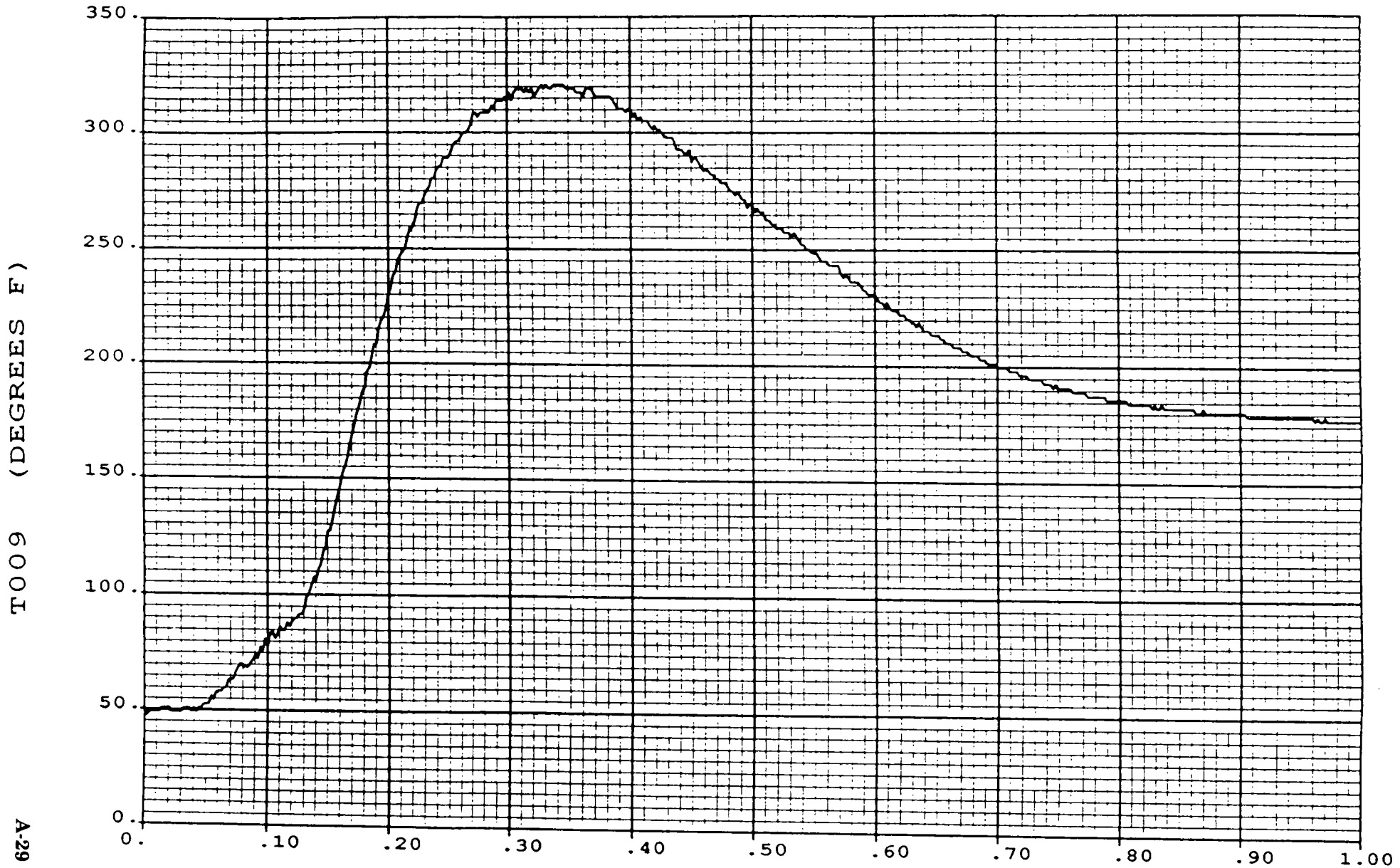

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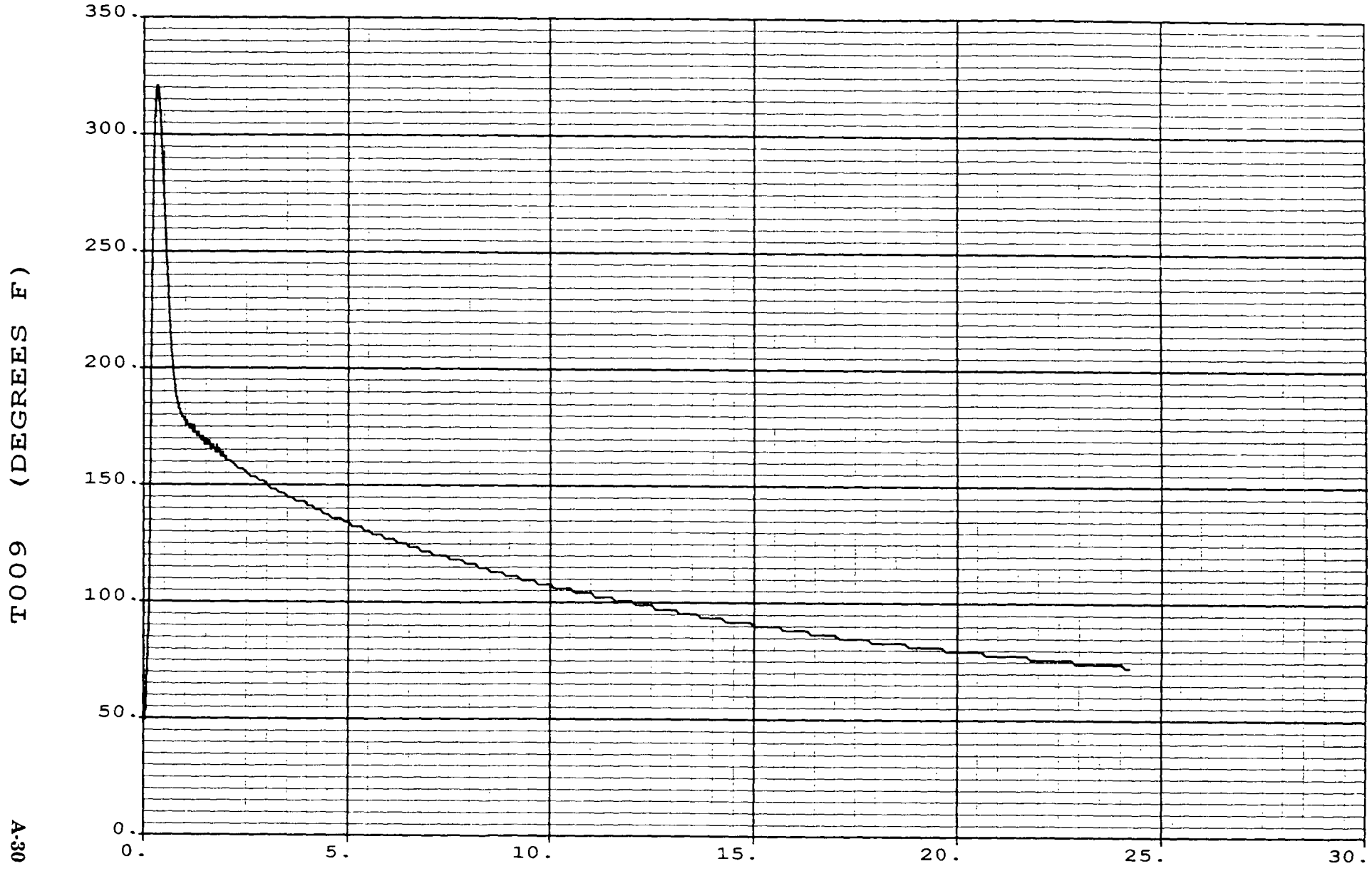

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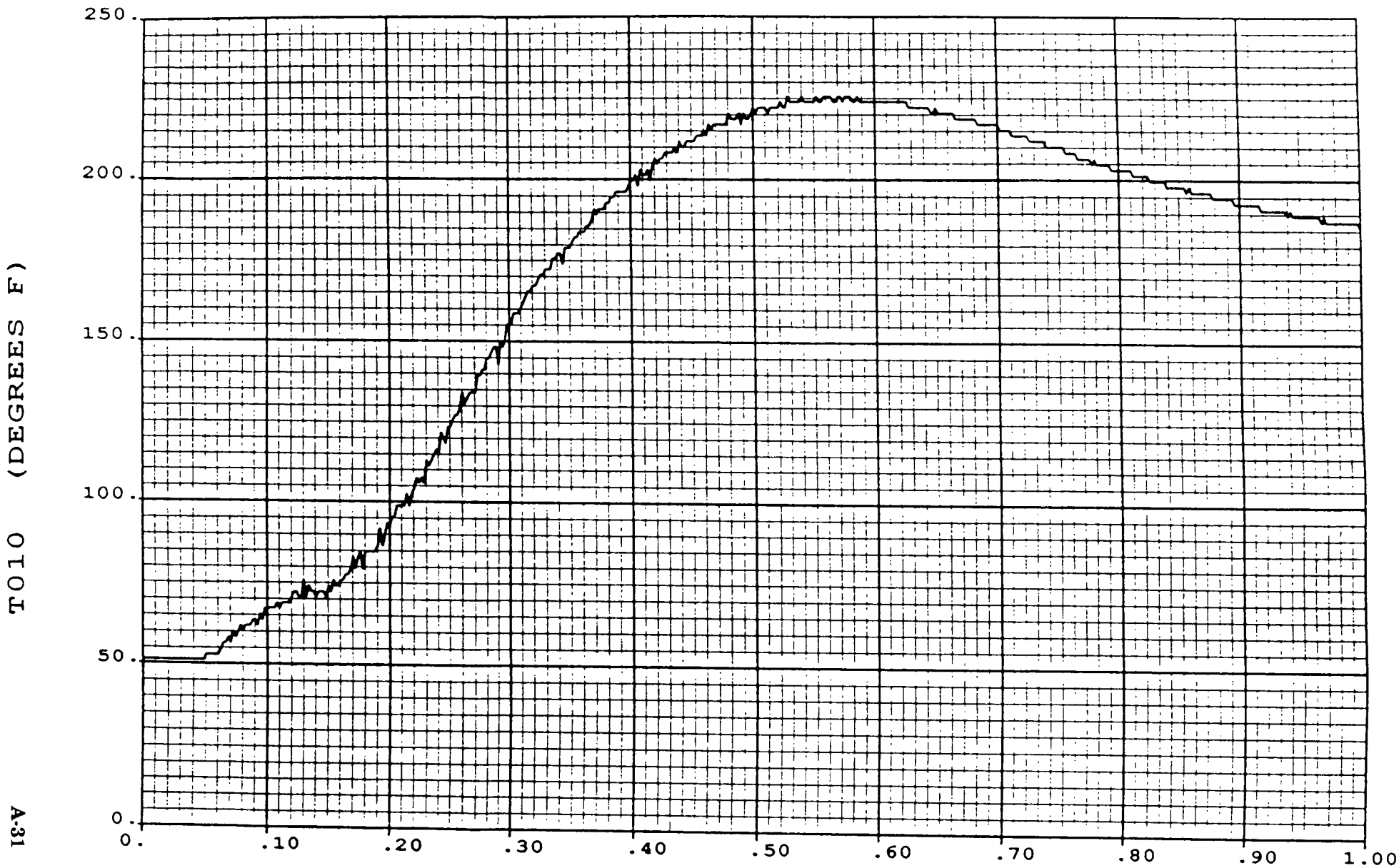

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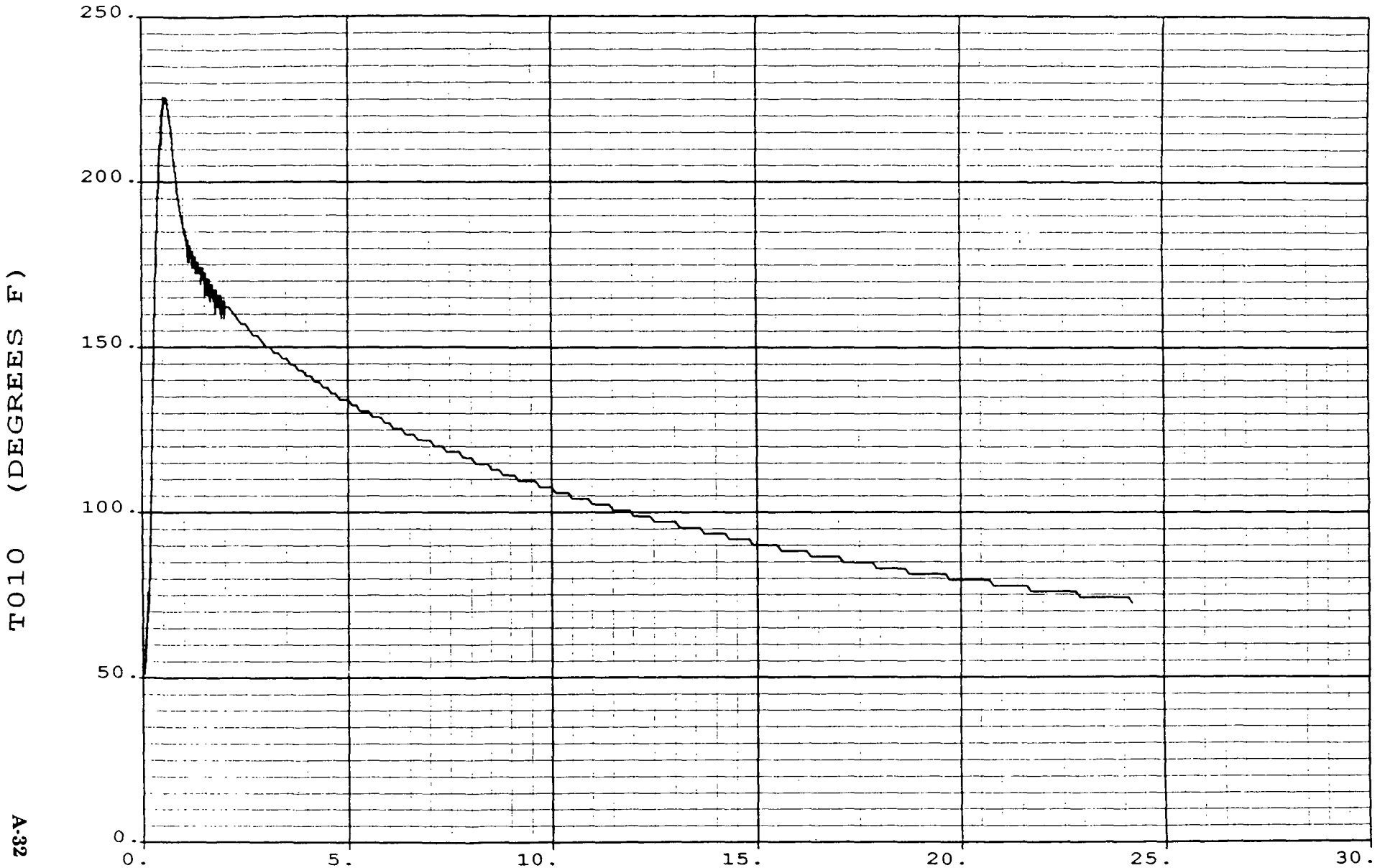

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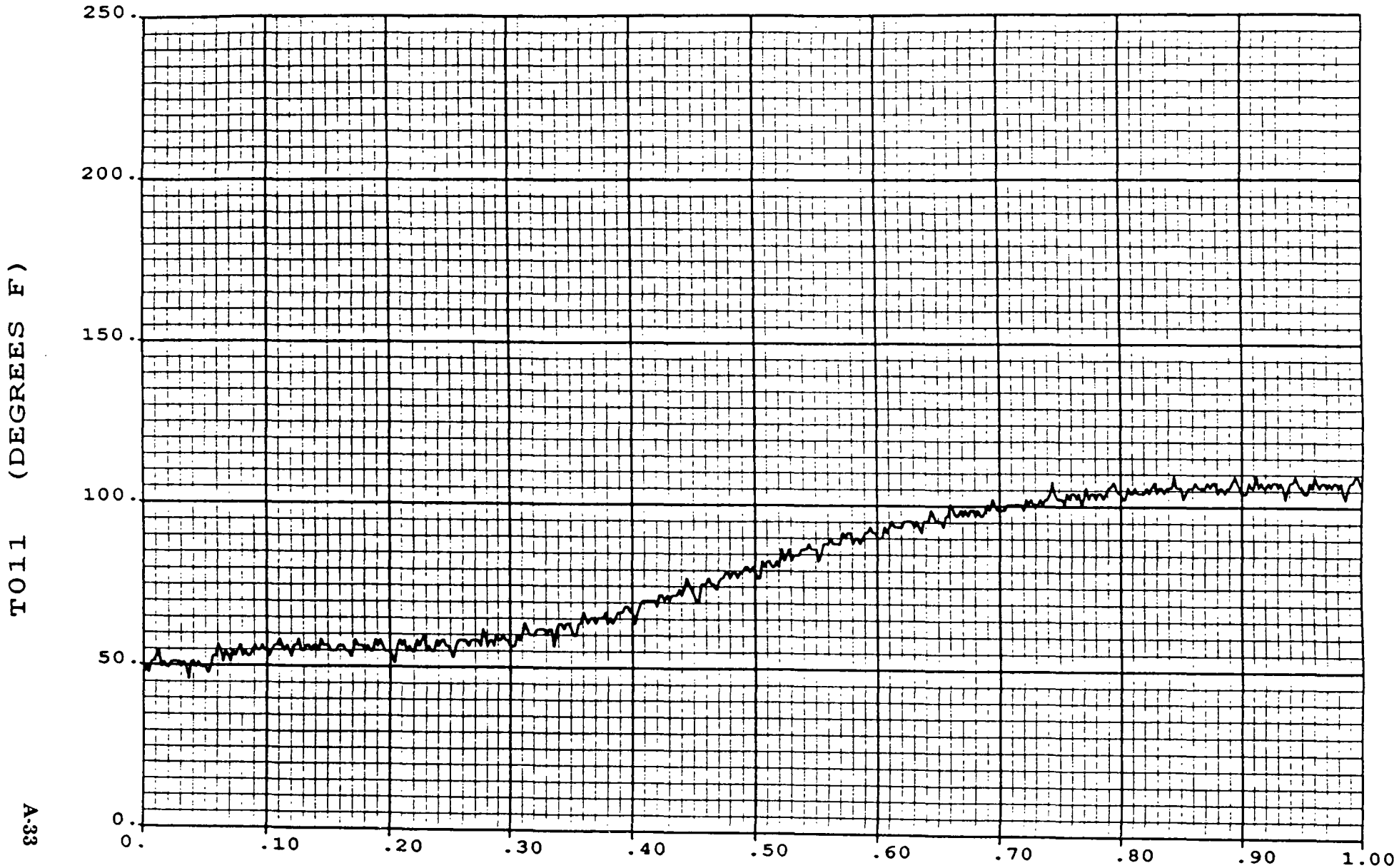

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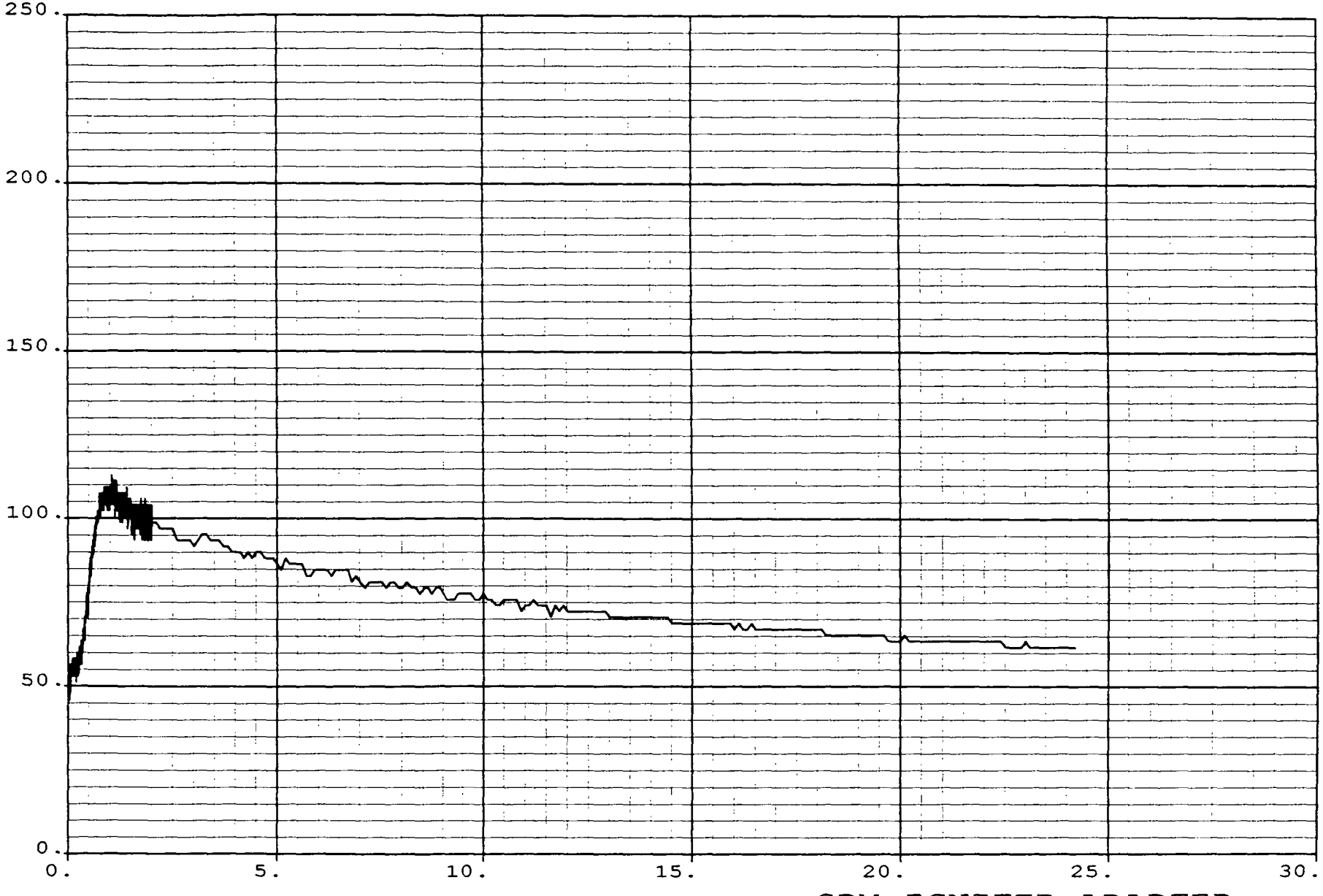

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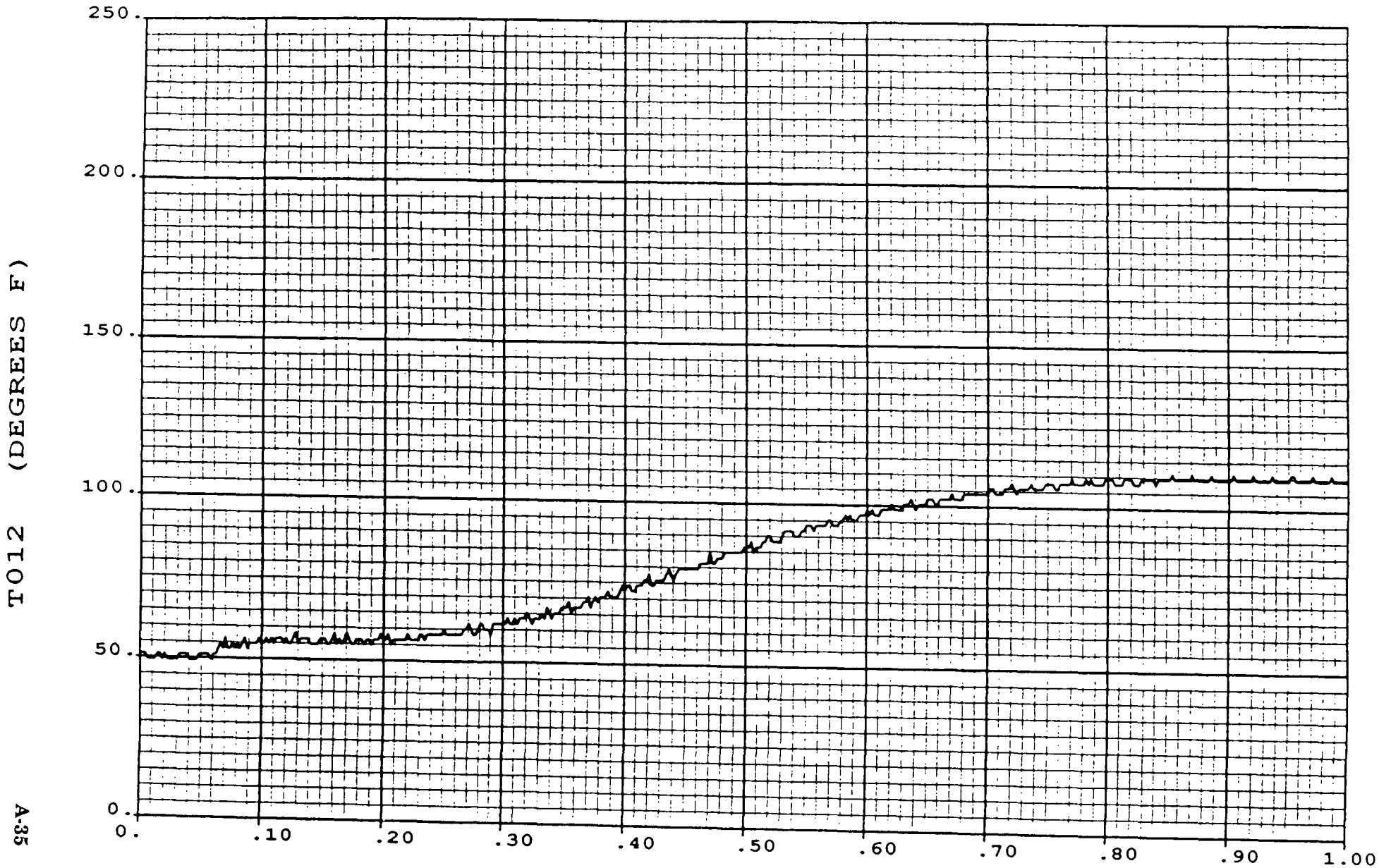
DELFECTION TEST S/N 003
20 SEPTEMBER 1988



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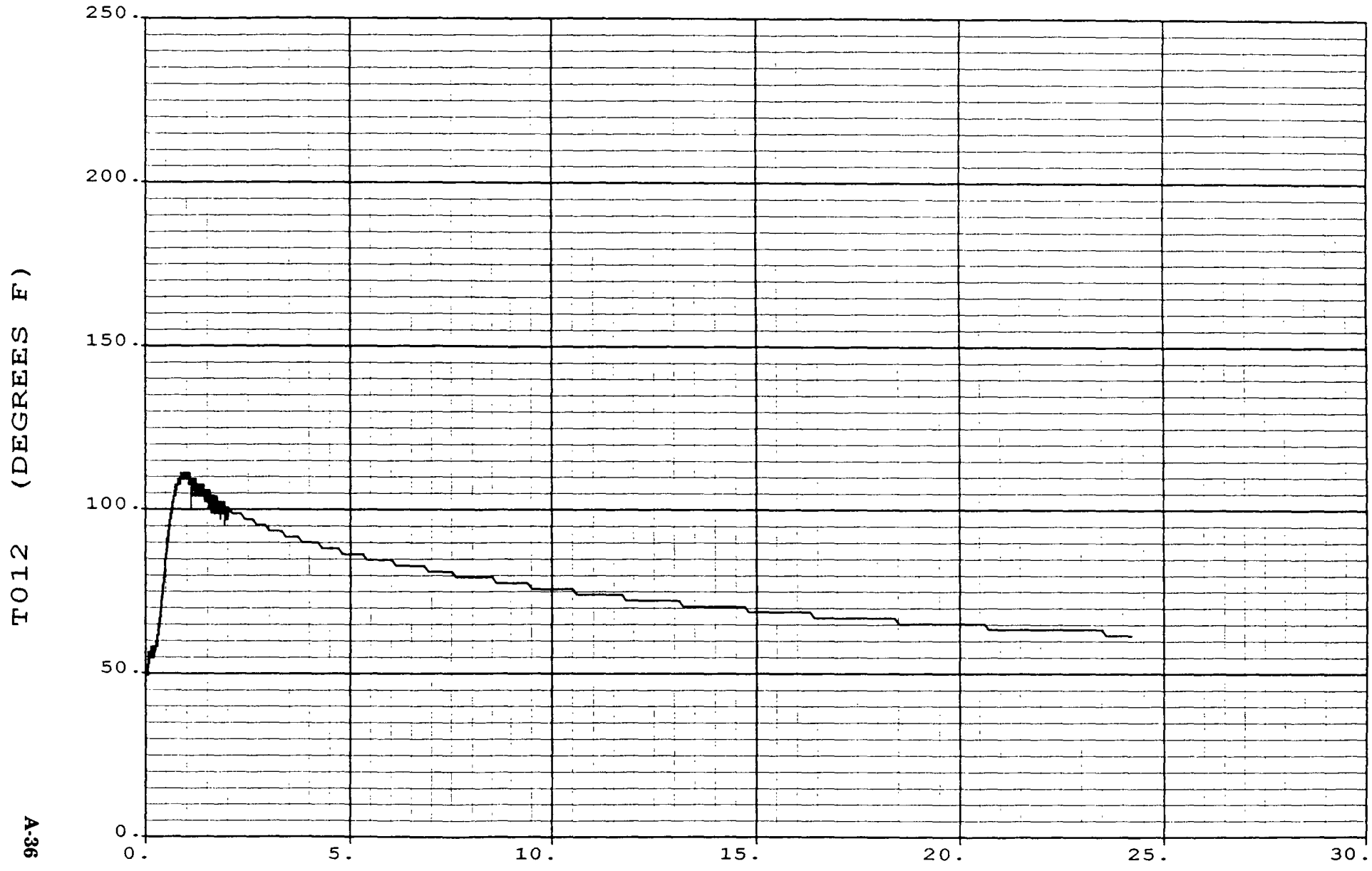
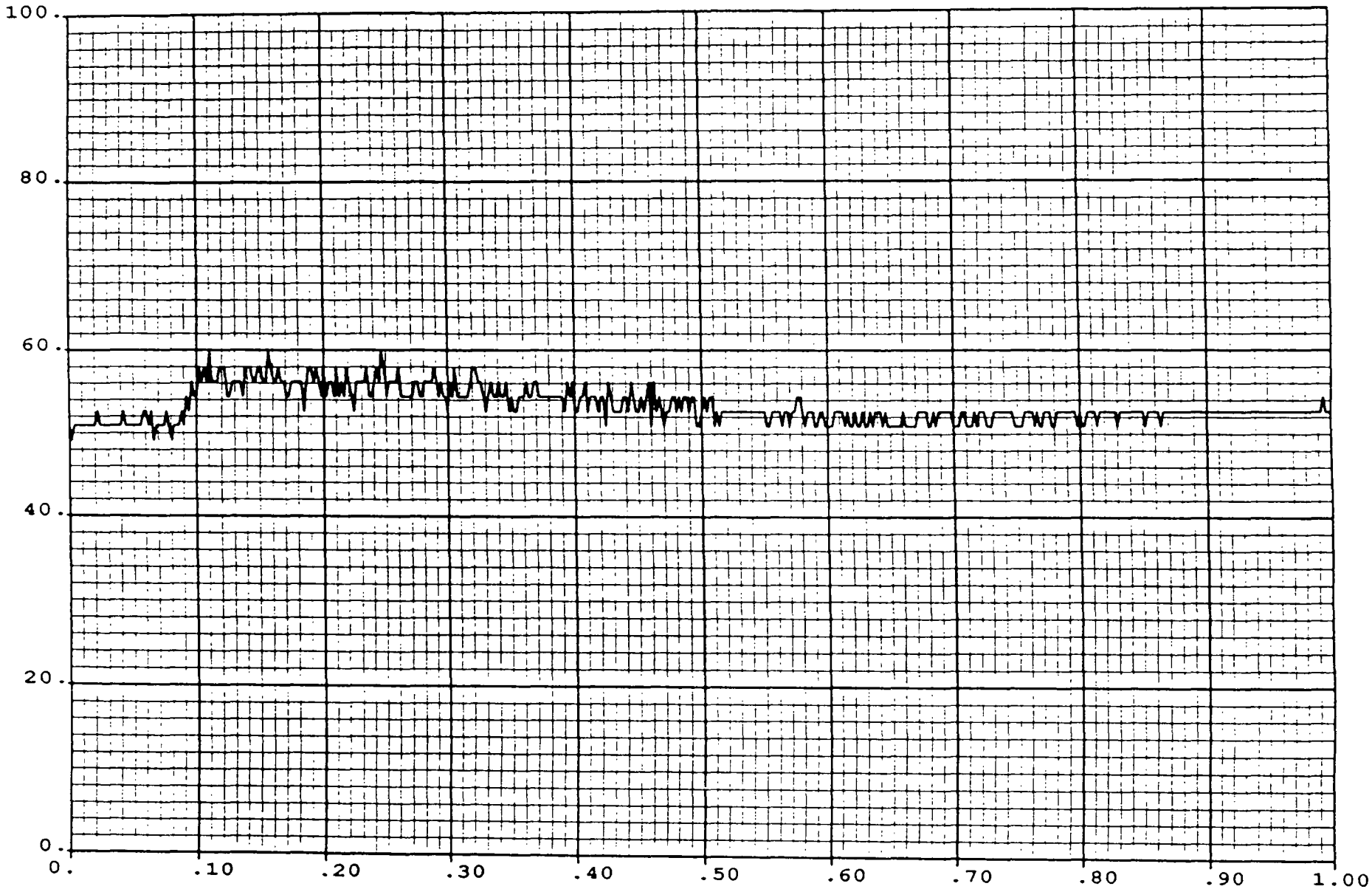
20 SEPTEMBER 1988



SRM IGNITER ADAPTER-
TO-IGNITER CHAMBER
DELFECTION TEST S/N 003
20 SEPTEMBER 1988



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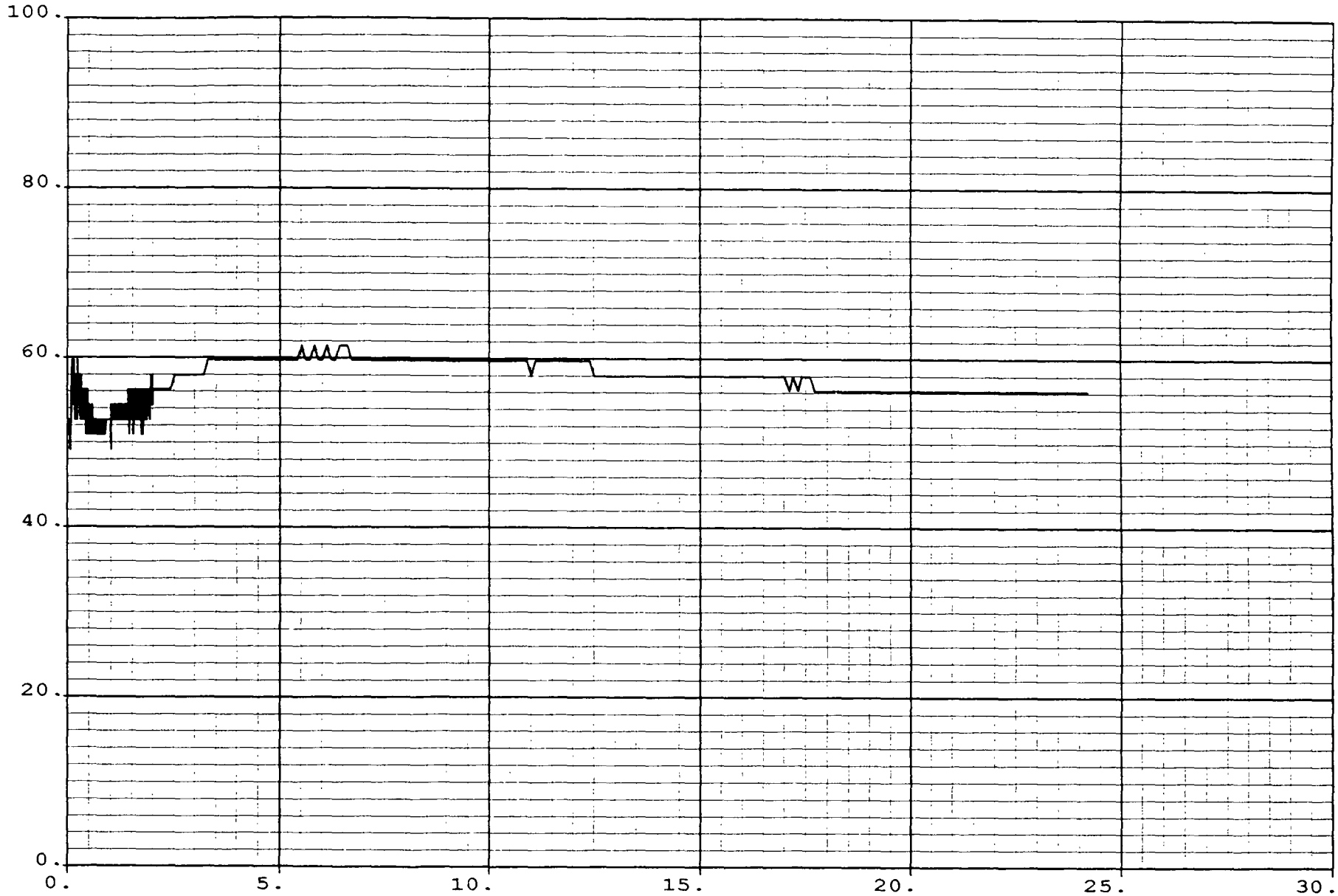

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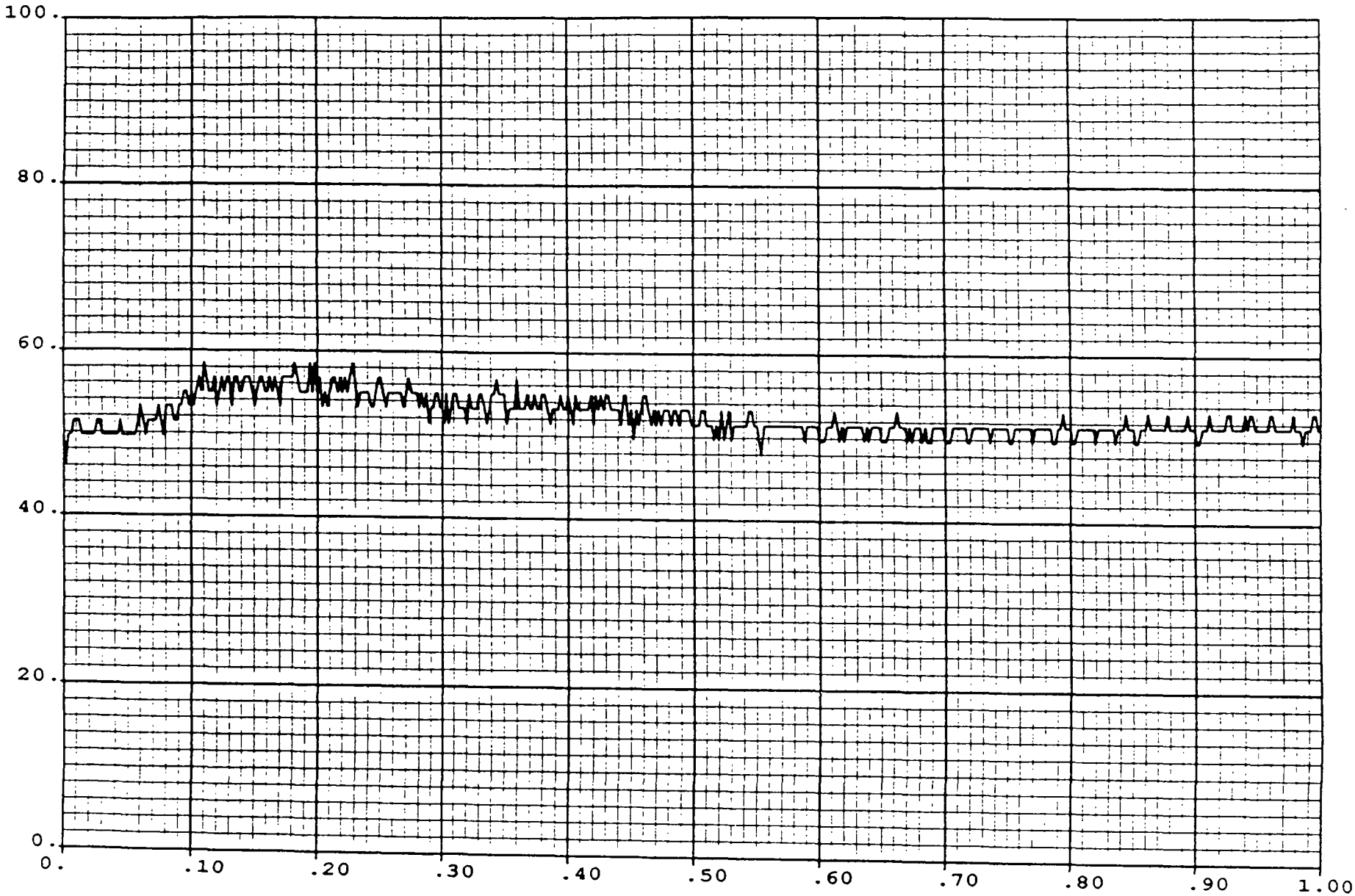

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TO-IGNITER CHAMBER
DELFECTION TEST S/N 003
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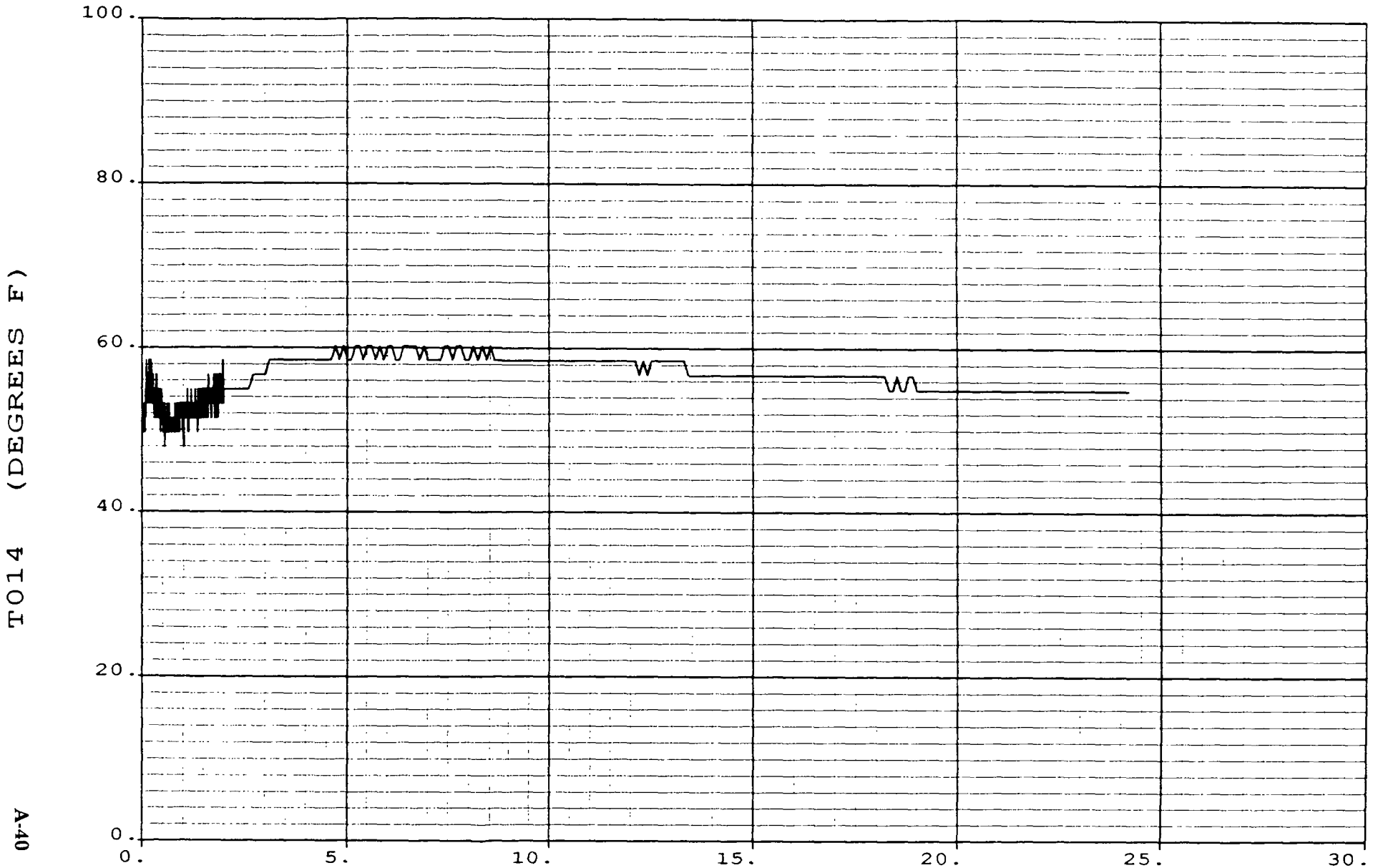

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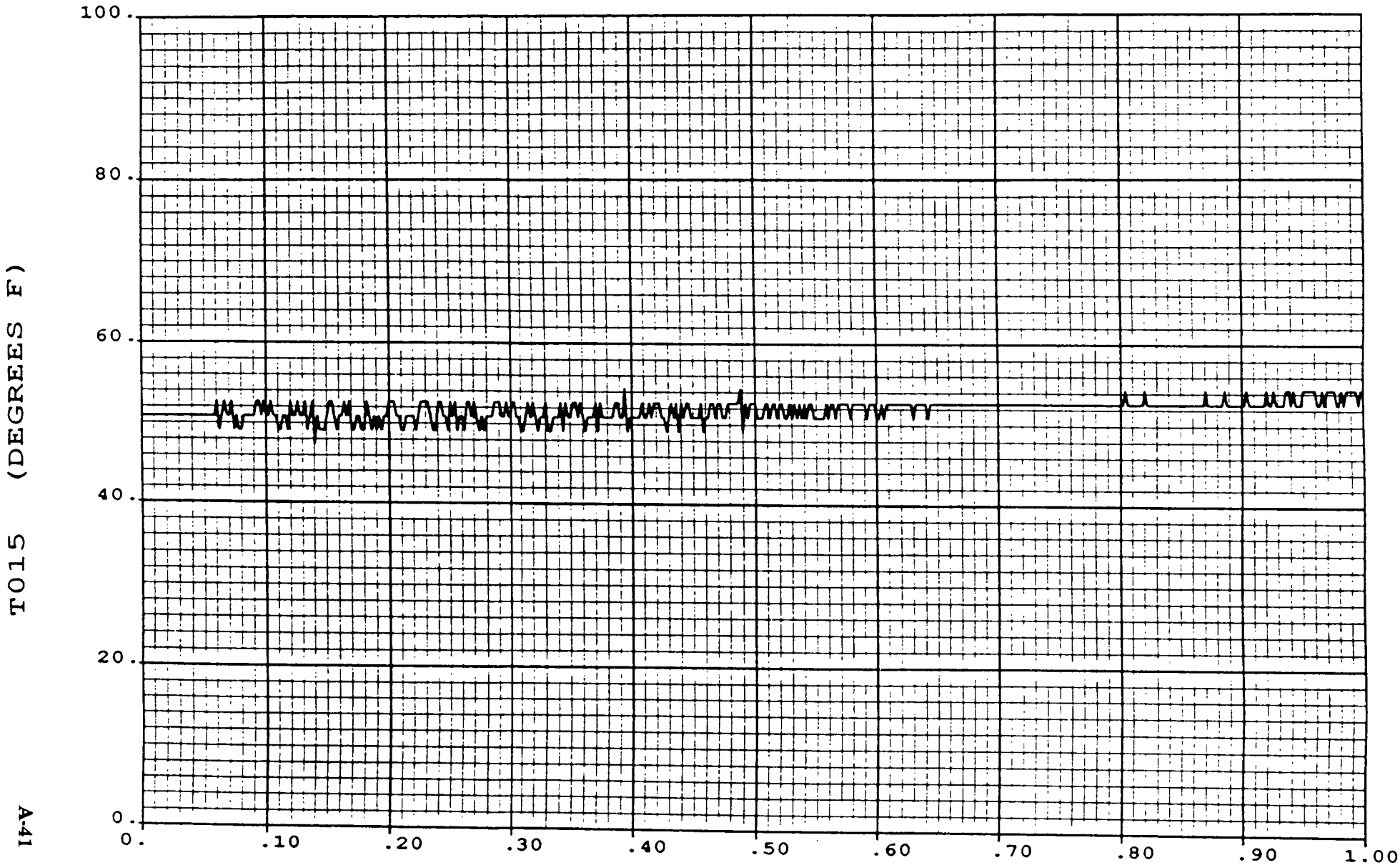

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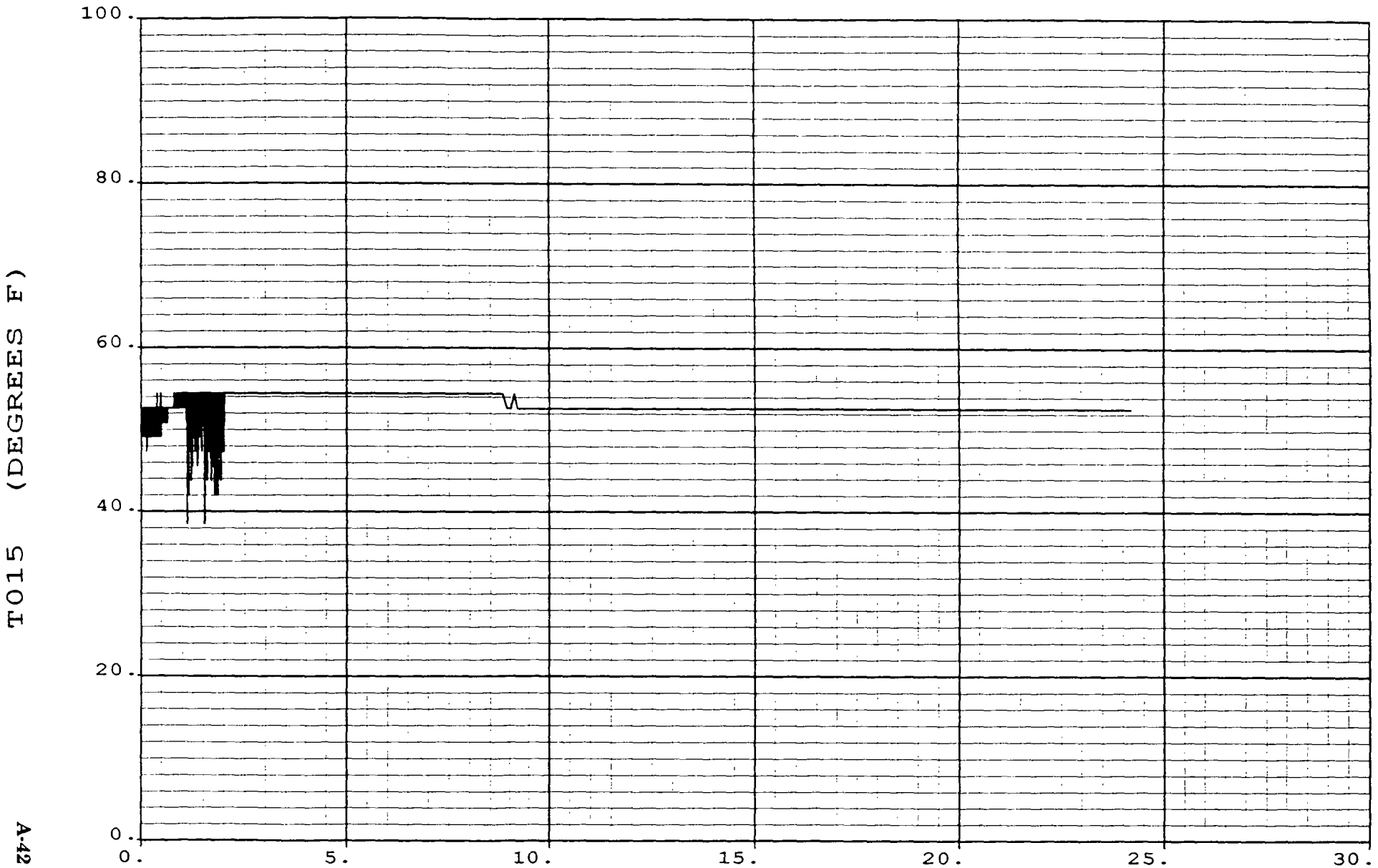

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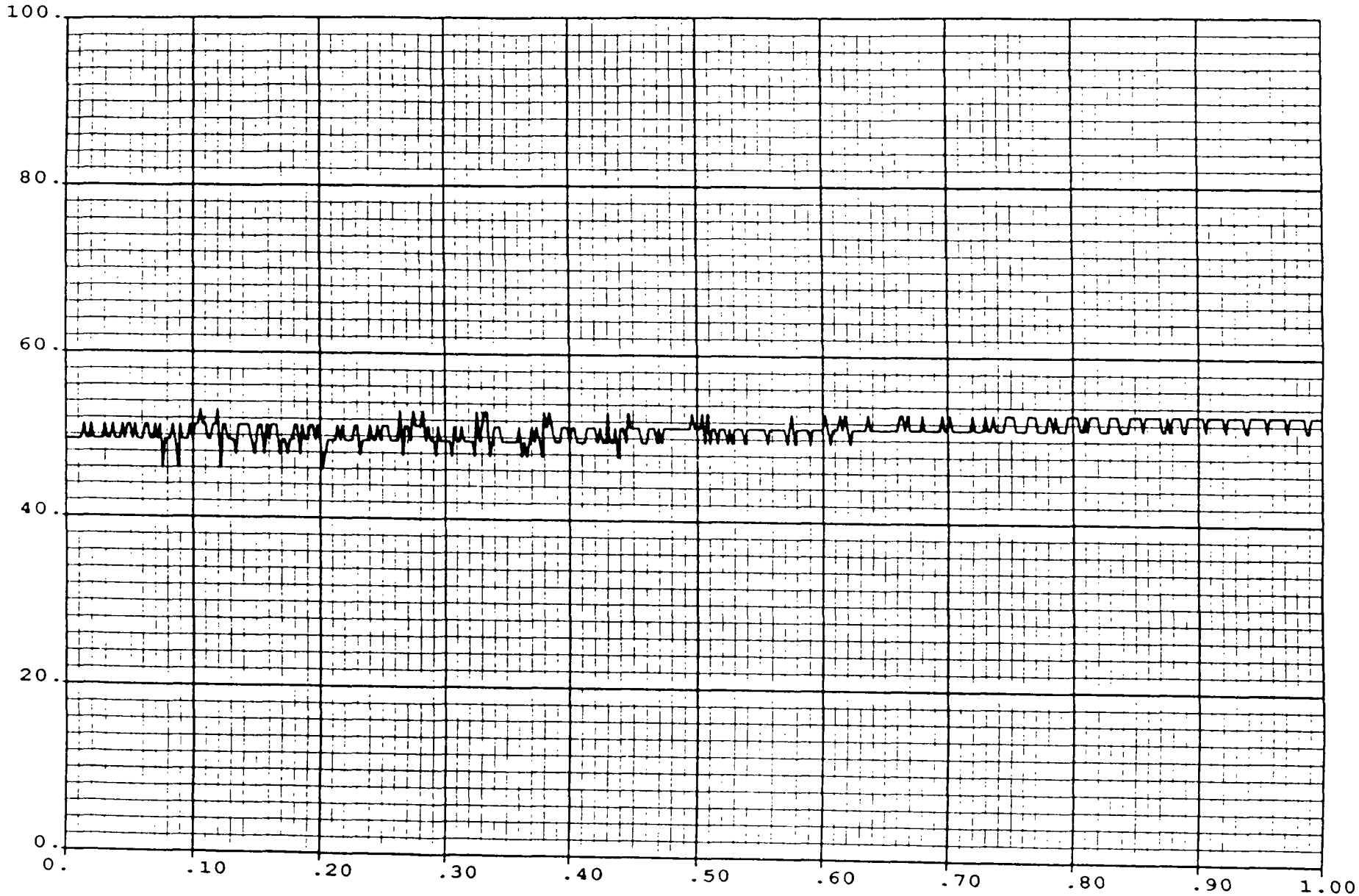

T016 9101 (DEGREES F)

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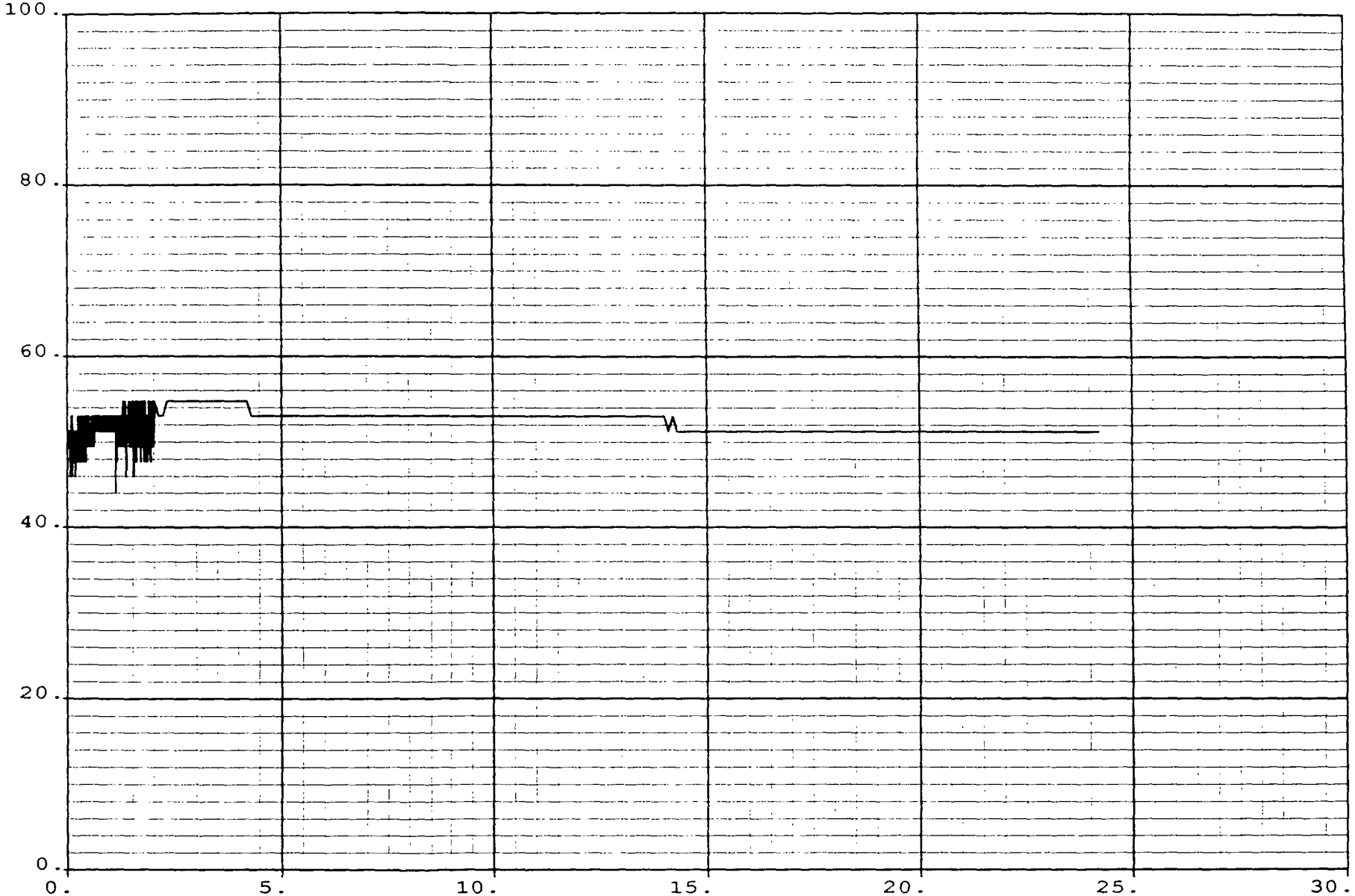
20 SEPTEMBER 1988



SRM IGNITER ADAPTER-
TO-IGNITER CHAMBER
DELFECTION TEST S/N 003
20 SEPTEMBER 1988

APPENDIX B

Memo L224:FY89:107, JES-3C Igniter Deflections Validation Testing

MORTON THIOKOL, INC.

Aerospace Group

Space Operations

26 July 1988
L224:FY89:107

TO: Scott R. Stein, Supervisor
Structural Applications

FROM: George Abawi
Structural Applications, Ext. 6610

Brian K. St. Aubin
Structural Applications, Ext. 4189

SUBJECT: JES-3C Igniter Deflections Validation Testing

The JES-3C igniter was modified to accommodate deflection gages to measure gap openings at the inner and outer joints. Proximity gages, 2-in-1, were used for this purpose. Because of variations in the predicted and measured deflections for the inner joint, and the limited database available for these type of gages, verification of their accuracy and response rate was necessary.

Verification tests were conducted using a subscale fixture duplicating the geometry of the igniter joints. The igniter seals resiliency test set-up was used to simulate actual inner joint deflection rise rate. Two proximity gages were investigated. Each was tested three times. For each test, two LVDTs were used to verify the proximity gage readings. Calibration factors used for the JES-3C test were maintained.

Results indicate that the proximity gages respond identical to the LVDTs. The proximity gages recorded slightly larger deflections than the LVDTs, approximately 10 percent (see attachments).

The JES-3C igniter gap openings appear to be valid. Resiliency tests are currently being conducted to determine the minimum temperature required for the igniter seals.

George Abawi

Brian K. St. Aubin

Concurrence:

Lon M. Stevens
Transducer Development

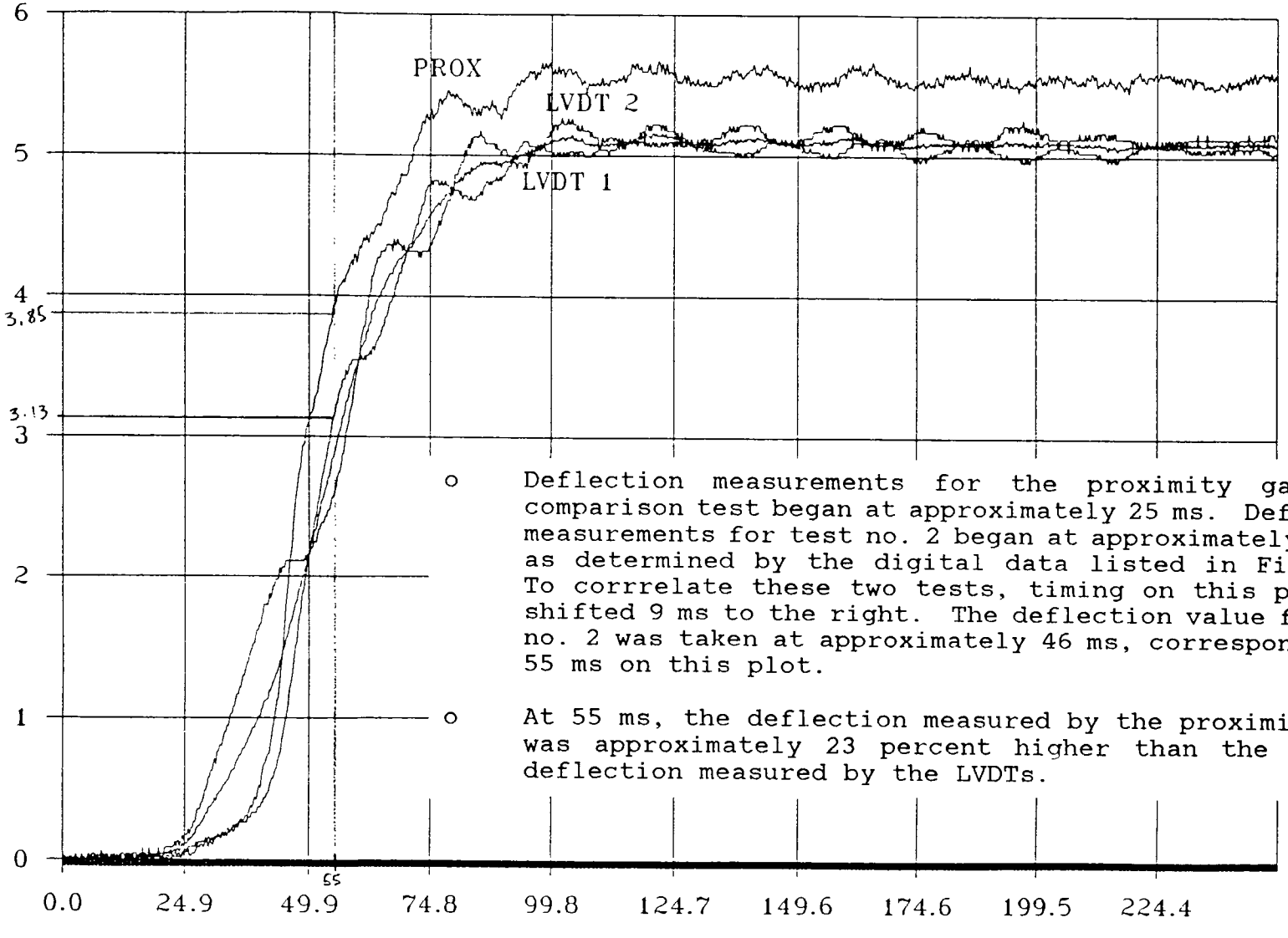
Attachments

GA/ni

cc: R. K. Parsons, T. M. Gregory, A. W. Macbeth, W. L. Miles,
G. P. Anderson, B. G. Russell, B. F. Traveller, C. A. Speak,
D. L. Rowsell, B. C. Spaulding, D. C. Cooper, M. Garcia,
P. M. McCluskey, S. B. Medrano, A. J. McDonald

IGNITOR DEFLECTION VERIFICATION TEST

S/N IG003 RUN 1

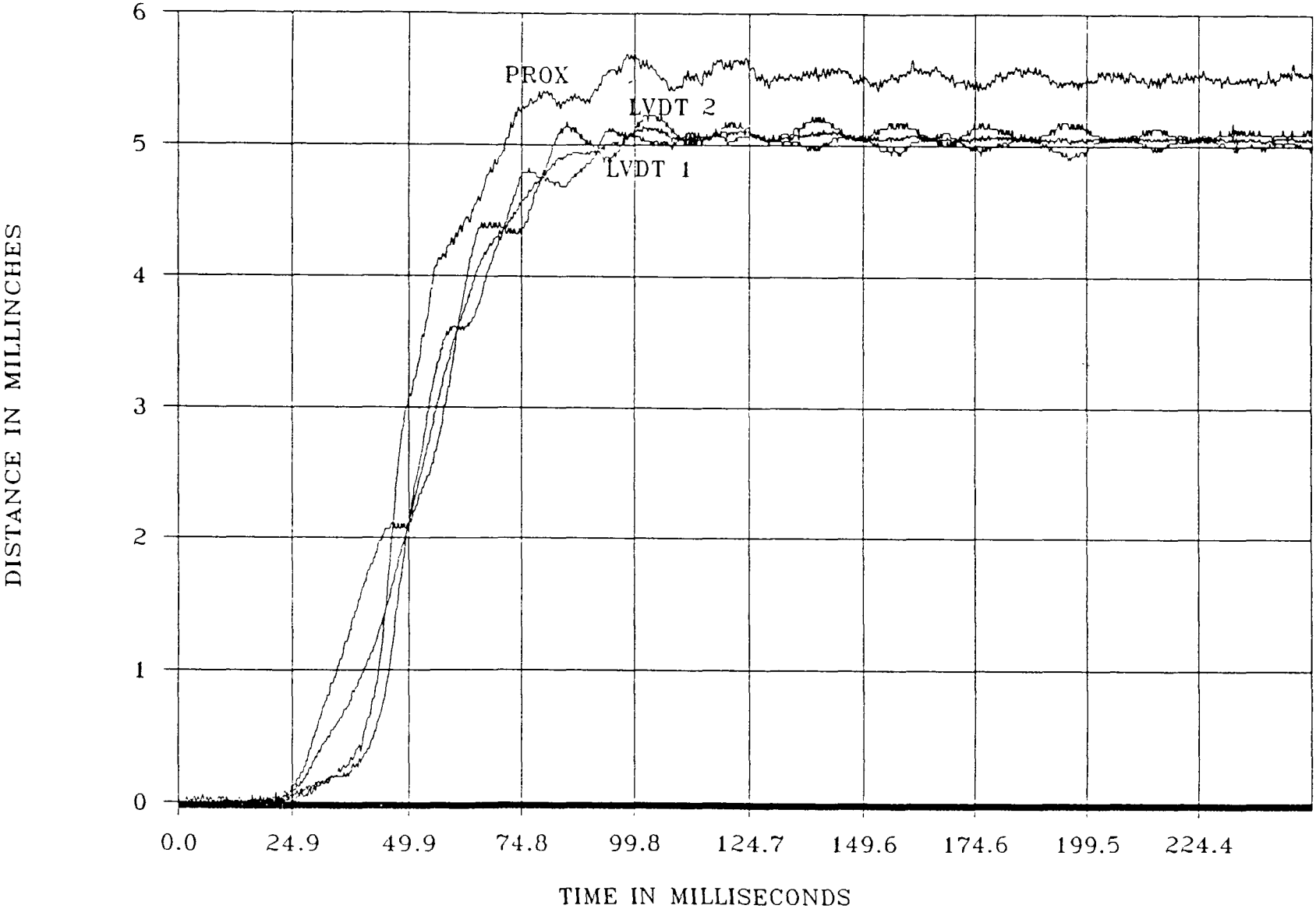


- Deflection measurements for the proximity gage/LVDT comparison test began at approximately 25 ms. Deflection measurements for test no. 2 began at approximately 16 ms, as determined by the digital data listed in Figure 8. To corrrelate these two tests, timing on this plot was shifted 9 ms to the right. The deflection value for test no. 2 was taken at approximately 46 ms, corresponding to 55 ms on this plot.

- At 55 ms, the deflection measured by the proximity gage was approximately 23 percent higher than the largest deflection measured by the LVDTs.

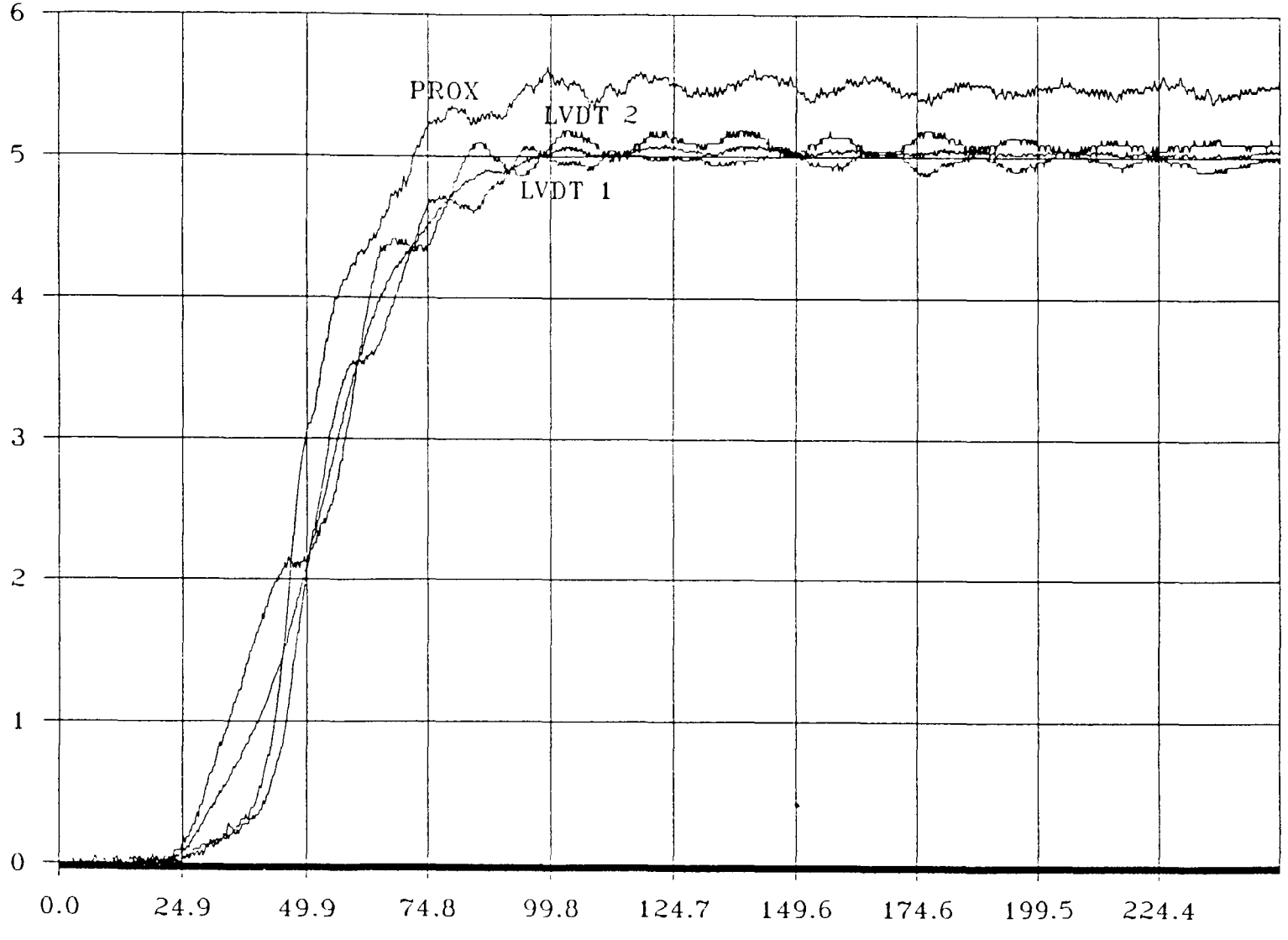
IGNITOR DEFLECTION VERIFICATION TEST

S/N IG003 RUN 2



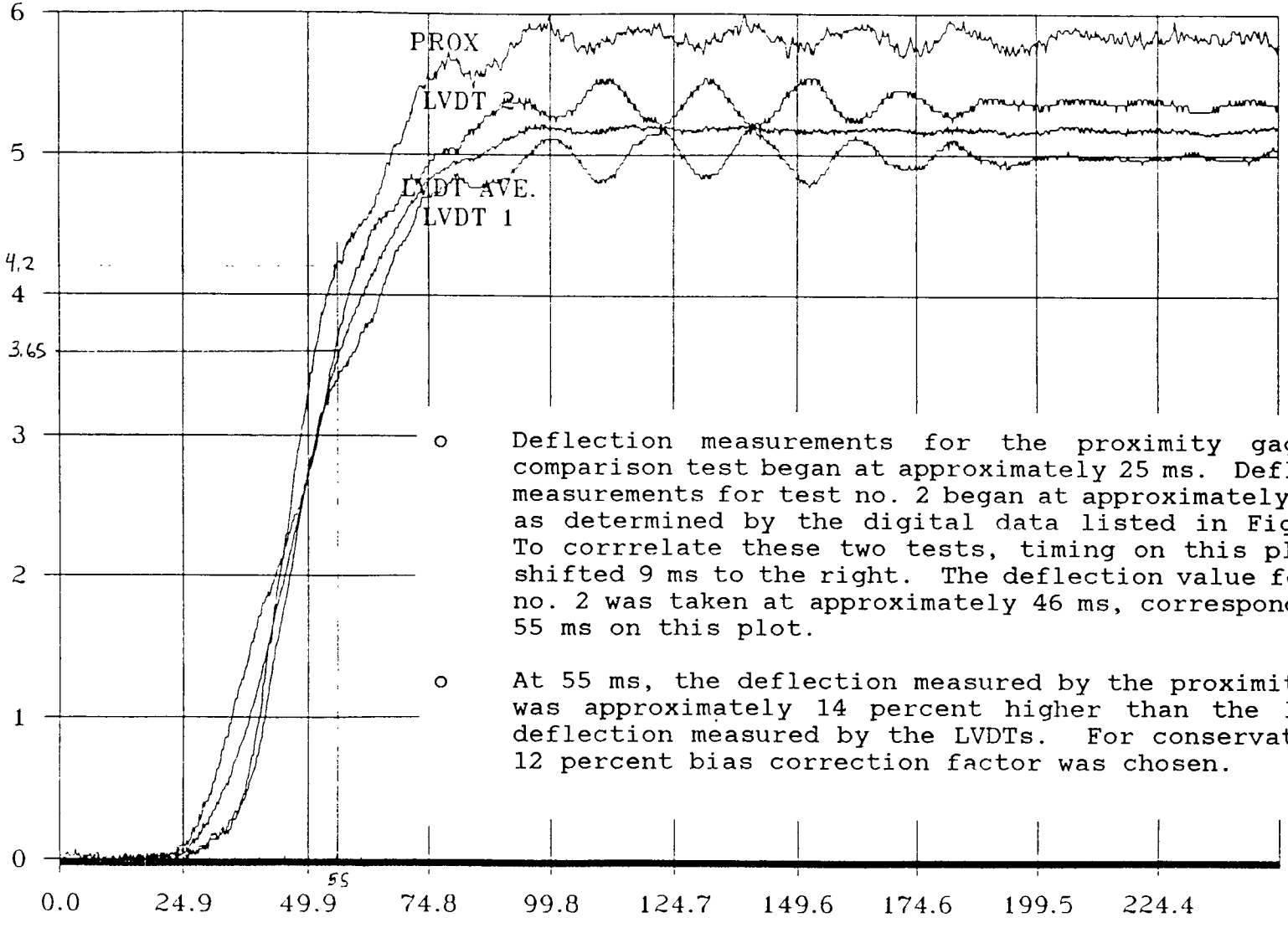
IGNITOR DEFLECTION VERIFICATION TEST

S/N IG003 RUN 3



IGNITOR DEFLECTION VERIFICATION TEST

S/N IG008 RUN1

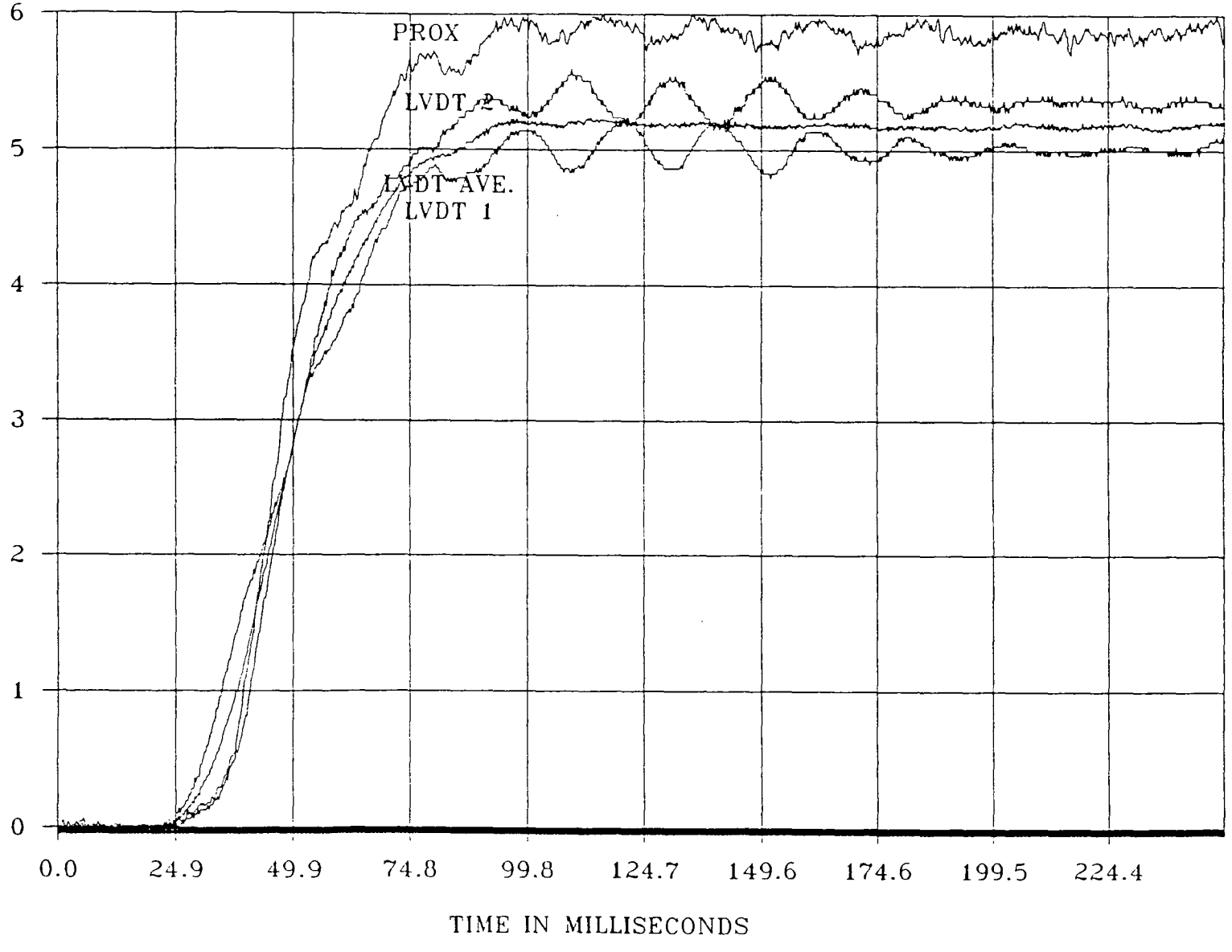


- Deflection measurements for the proximity gage/LVDT comparison test began at approximately 25 ms. Deflection measurements for test no. 2 began at approximately 16 ms, as determined by the digital data listed in Figure 8. To corrrelate these two tests, timing on this plot was shifted 9 ms to the right. The deflection value for test no. 2 was taken at approximately 46 ms, corresponding to 55 ms on this plot.

- At 55 ms, the deflection measured by the proximity gage was approximately 14 percent higher than the largest deflection measured by the LVDTs. For conservatism, a 12 percent bias correction factor was chosen.

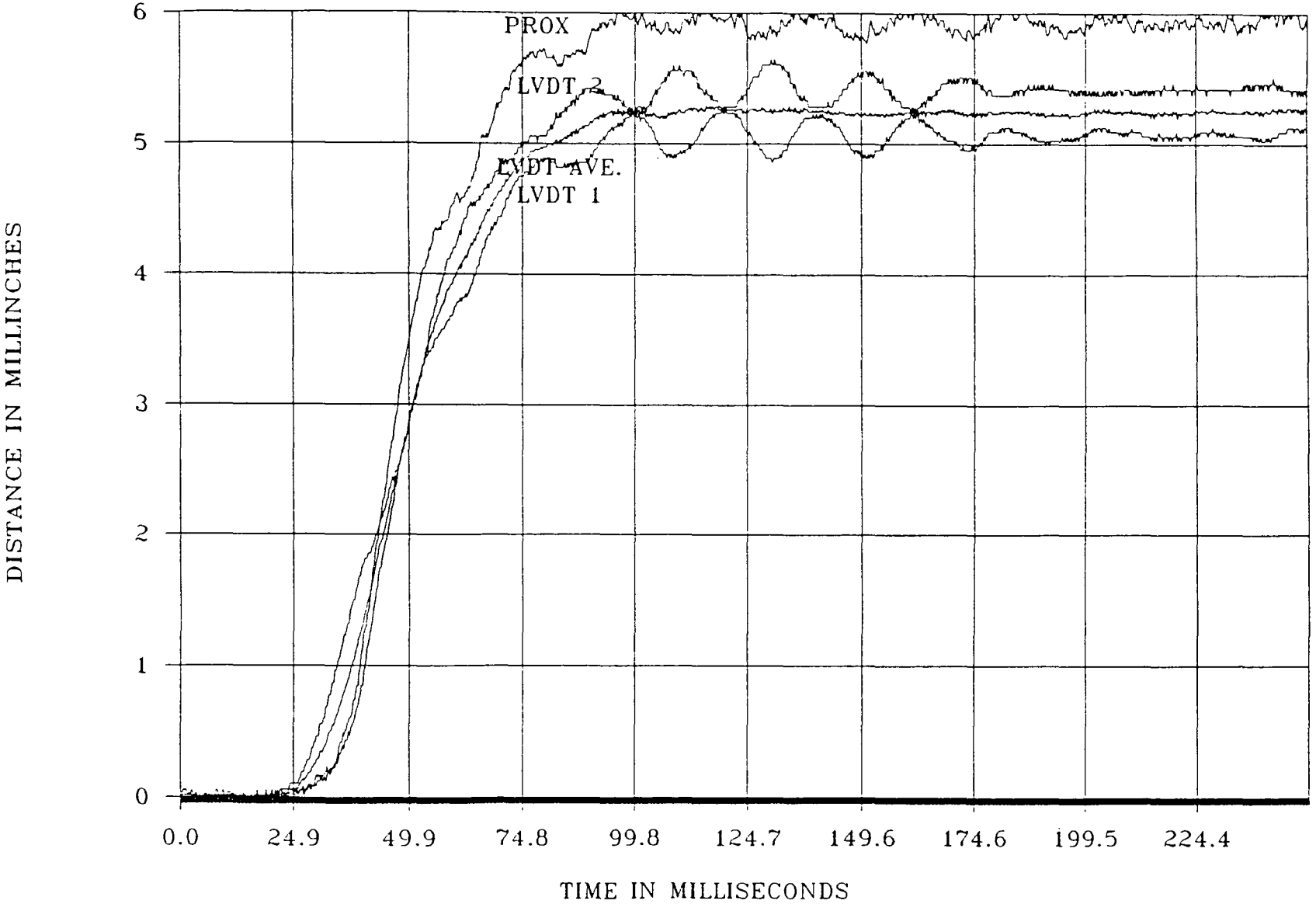
IGNITOR DEFLECTION VERIFICATION TEST

S/N IG008 RUN 2



IGNITOR DEFLECTION VERIFICATION TEST

S/N IG008 RUN 3



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