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TEST REPORT

CRITICAL COMPOSITE JOINTS ANCILLARY DATA TEST RESULTS

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MCDONNELL DOUGLAS CORPORATION

DOUGLAS AIRCRAFT COMPANY

3855 Lakewood Boulevard Long Beach, California 90846

ACEE-26-TR-2958

10 September 1982

DRL Item Number 009

TEST REPORT

CRITICAL COMPOSITE JOINTS ANCILLARY DATA TEST RESULTS

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Prepared for Langley Research Center
Contract NAS1-16857

MCDONNELL DOUGLAS CORPORATION

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10 September 1982

DRL Item Number 009

CRITICAL COMPOSITE JOINTS ANCILLARY DATA TEST RESULTS

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TABLE OF CONTENTS

Section		Page
1.0	INTRODUCTION	1
2.0	SPECIMEN DESCRIPTION	2
2.1	Unloaded Hole Specimens	3
2.2	Double Shear Specimens	4
2.3	Single Shear Specimens	4
3.0	TEST SETUP AND PROCEDURE	5
4.0	TEST RESULTS	7
4.1	Unloaded Hole Tests	8
4.1.1	Unloaded Hole Tension Tests	8
4.1.2	Unloaded Hole Compression Tests	9
4.2	Double Shear Tests	9
4.2.1	Double Shear Tension Tests	9
4.2.2	Double Shear Compression Tests	11
4.3	Single Shear Tension and Compression Tests	11
5.0	BASIC MECHANICAL PROPERTY TESTS	13
6.0	SUMMARY AND CONCLUSIONS	14
7.0	REFERENCES	15
8.0	APPENDICES	
	A - UNLOADED HOLE - DRAWING ZJ011266	A-1
	B - DOUBLE SHEAR - DRAWING ZJ011268	B-1
	C - SINGLE SHEAR - DRAWING ZJ011267	C-1

LIST OF ILLUSTRATIONS

Figure		Page
1	Unloaded Hole Tension Specimens	16
2	Unloaded Hole Tension Specimens	17
3	Unloaded Hole Tension Specimens	18
4	Unloaded Hole Compression Specimens	19
5	Unloaded Hole Compression Specimens	20
6	Unloaded Hole Compression Specimens	21
7	Double Shear Tension Specimens	22
8	Double Shear Tension Specimens	23
9	Double Shear Compression and Tension Specimens	24
10	Double Shear Compression Specimens	25
11	Double Shear Compression Specimens	26
12	Double Shear Compression Specimens	27
13	Single Shear Specimens	28
14	Single Shear Specimens	29
15	Single Shear Specimens	30
16	Bolt Head Angle Change Measurement	31
17	Test Set-up - Double Shear Tension Test	32
18	Single Shear Test Set-up	33
19	Definition of Relative Deflection Measurement	34
20	Deflection Measurement Device	35
21	Single Shear Test - Measurement System for Bolt Head Rotation	36
22	Unloaded Hole Tension Test - Net-Section Failures	37

LIST OF ILLUSTRATIONS (CONT'D)

Figure		Page
23	Unloaded Hole Tension Test - Bonded Doubler Failure . .	38
24	Unloaded Hole Tension Test - Net-Section Failure . . .	39
25	Unloaded Hole Tension Test - (w/d = 6) - Net Section Failure	40
26	Unloaded Hole Tension Test - Bonded Doubler and End Hole Failure	41
27	Unloaded Hole Compression Test - Net-Section Failure . .	42
28	Double Shear Tension Tests - Net-Section Failures . . .	43
29	Double Shear Tension Tests - Net-Section Failures . . .	44
30	Double Shear Tension Tests - Bolt Bending Failure . . .	45
31	Double Shear Tension Tests - Bearing Failure	46
32	Double Shear Tension Tests - Bonded Doubler Failure . .	47
33	Double Shear Tension Tests - Net-Section Failure . . .	48
34	Double Shear Compression Test - Bearing Failure . . .	49
35	Double Shear Compression Test - Bolt Bending Failure . .	50
36	Specimen Configurations - Mechanical Property Tests . .	51
37	Unnotched Compression Specimen	52
38	Unnotched Tension Specimens	53

LIST OF TABLES

Table		Page
1	Ancillary Test Specimen Coding	54
2	Unloaded Hole Ancillary Test Specimen	55
3	Double Shear Ancillary Tension Specimen	56
4	Double Shear Ancillary Compression Specimen	57
5	Single Shear Ancillary Tension Specimen	58
6	Single Shear Ancillary Compression Specimen	59
7	Ancillary Test Specimen Loading Rates	60
8	Unloaded Hole Tension Specimens, Fiber Pattern A, U.S. Customary Units	61
9	Unloaded Hole Tension Specimens, Fiber Pattern B, U.S. Customary Units	62
10	Unloaded Hole Tension Specimens, Fiber Pattern A, S.I. Units	63
11	Unloaded Hole Tension Specimens, Fiber Pattern B, S.I. Units	64
12	Unloaded Hole Compression Specimens, Fiber Pattern A, U.S. Customary Units	65
13	Unloaded Hole Compression Specimens, Fiber Pattern B, U.S. Customary Units	66
14	Unloaded Hole Compression Specimens, Fiber Pattern A, S.I. Units	67
15	Unloaded Hole Compression Specimens, Fiber Pattern B, S.I. Units	68
16	Double Shear Tension Specimens, Fiber Pattern A, U.S. Customary Units	69
17	Double Shear Tension Specimens, Fiber Pattern B, U.S. Customary Units	70

LIST OF TABLES (CONT'D)

Table		Page
18	Double Shear Tension Specimens, Fiber Pattern A, S.I. Units	71
19	Double Shear Tension Specimens, Fiber Pattern B, S.I. Units	72
20	Double Shear Compression Specimens, Fiber Pattern A, U.S. Customary Units	73
21	Double Shear Compression Specimens, Fiber Pattern B, U.S. Customary Units	74
22	Double Shear Compression Specimens, Fiber Pattern A, S.I. Units	75
23	Double Shear Compression Specimens, Fiber Pattern B, S.I. Units	76
24	Single Shear Tension Specimens, Fiber Pattern A, U.S. Customary Units	77
25	Single Shear Tension Specimens, Fiber Pattern B, U.S. Customary Units	78
26	Single Shear Tension Specimens, Fiber Pattern A, S.I. Units	79
27	Single Shear Tension Specimens, Fiber Pattern B, S.I. Units	80
28	Single Shear Compression Specimens, Fiber Pattern A, U.S. Customary Units	81
29	Single Shear Compression Specimens, Fiber Pattern B, U.S. Customary Units	82
30	Single Shear Compression Specimens, Fiber Pattern A, S.I. Units	83
31	Single Shear Compression Specimens, Fiber Pattern B, S.I. Units	84
32	Unnotched Tension Test Results & Unnotched Compression Test Results	85

1.0 INTRODUCTION

The design and anlaysis of bolted joints in fibrous composite structures continues to be an area of concern with respect to the safe and efficient use of composite materials in aircraft structures. Work is in progress at Douglas Aircraft Company under NASA Contract NAS1-16857 for the development of critical joint technology. This contract research effort includes a large mechanical testing program including ancillary and subcomponent test specimens (reference 1). This report contains an account of the test specimens, procedures, and results for the ancillary test program.

There were two primary objectives of the ancillary test program. For loaded hole specimens, data was obtained for load-deflection behavior of single bolt joints in graphite epoxy including the effect of bolt bending and shear deformations and local bearing deformations in the joint members. In addition to load-deflection data, all specimens were loaded to failure to obtain ultimate strength and stress concentration data for loaded and unloaded hole configurations. This report is limited to experimental results, and no theoretical predictions or inferences are offered. Some general conclusions will be drawn with regard to the actual test results.

2.0 SPECIMEN DESCRIPTION

A total of 180 specimens was fabricated and tested at the Douglas Aircraft Company in Long Beach, California. These included a variety of configurations and geometries selected to generate a sufficient data base to support analysis methods.

Tension and compression tests were performed on three types of specimens: Double Shear Tension and Compression (DST and DSC), Single Shear Tension and Compression (SST and SSC), and Unloaded Hole Tension and Compression (UHT and UHC). Figures 1 through 15 present dimensioned drawings of each specimen type. The hole or bolt diameters were limited to 0.25 in. (6.35 mm), 0.50 in. (12.70 mm), and 0.75 in. (19.05 mm). Laminate widths and thicknesses were varied among specimen groups and will be discussed in subsequent sections.

Load was introduced to the tension specimens and single shear compression specimens through pin-loaded holes at each end which were reinforced with graphite/epoxy doublers. These doublers were constructed using the same layup pattern as the base laminate. Potted ends were used on double shear and unloaded hole compression specimens for the introduction of load. The ends were machined flat and parallel to stabilize and align the specimens.

Critical dimensions of each specimen were measured and recorded before testing. Specimens were visually inspected for any flaws or damage which could affect test results. Three identical specimens were tested for each configuration. Table 1 lists the coding or numbering system for all of the ancillary test specimens.

The material system used in this program is the Ciba-Geigy Fiberdux 914/Toray T-300 graphite epoxy. The 914 resin is a so-called "toughened resin". The basic epoxy is modified with a polysulfone thermoplastic to create a more flexible, impact resistant matrix relative to established composite material systems. The Toray T-300 (hereafter T-300) was provided as a "thick ply" tape (approximately

0.01 in/ply). This consisted of two plies of 5 mil dry tape which were combined during the vendor preimpregnation process.

There were two fiber patterns used to build the laminates from which test specimens were made. Pattern A was (25% 0°, 50% ±45°, 25% 90°) and Pattern B was (37.5% 0°, 50% ±45°, 12.5% 90°). Laminates were inspected by C-scan for voids and delaminations prior to fabrication of test specimens.

Test laminate balanced layup sequences provided zero degree fibers at the surfaces of all parts. Only ±45 degree angle changes were allowed between adjacent interior plies. There were no stacked plies except two (2) 45-degree plies at the laminate mid-plane of symmetry and no 0°/90° interfaces except at the mid-plane of the 24-ply, 37.5 percent zero degree pattern (with 8-ply unit sequencing).

2.1 Unloaded Hole Specimens

Table 2 lists the nominal dimensions and characteristics of the unloaded hole specimens shown on Douglas Drawing ZJ011266. The narrow specimens had a w/d (width/hole diameter) ratio of 2.0, while for the wide specimens the w/d ratio was 8.0 with one exception. For the unloaded hole tension tests, the -533 specimens (UHT 16, 17, 18) were cut down from w = 6.0 in. (152.4 mm) to w = 4.5 in. (114.3 mm) giving a w/d ratio of 6.0 (to prevent recurrent doubler failure).

Figures 1 through 6 present dimensioned drawings for the unloaded hole specimens. The central holes were filled with 1/16 in. (1.59 mm) undersized bolts and tightened to moderate torque values. This provided some clamp-up effect at the hole without allowing load transfer through the bolt itself. All the unloaded hole specimens were fabricated from 24-ply laminates. Sixteen-ply tapered doublers were bonded to all UHT specimens for reinforcement at the load introduction holes, with one exception. As noted in Figure 2, the -531 specimens were inadvertently fabricated with 24-ply instead of 16-ply doublers.

2.2 Double Shear Specimens

Tables 3 and 4 depict the double shear tension and compression specimens per DAC Drawing ZJ011268. The narrow and wide specimens maintained w/d ratios of 3.0 and 8.0 respectively, but again with one exception. The -529 compression specimens (DSC 10, 11, 12) had (inadvertently drilled) 0.50 in. (12.7 mm) central holes with a w/d ratio of 4.0. Torque levels for the three bolt sizes were:

Diameter	Torque
0.25 in. (6.35 mm)	25-30 in.-lb. (2.82-3.39 N-m)
0.50 in. (12.7 mm)	50-60 in.-lb. (5.65-6.78 N-m)
0.75 in. (19.05 mm)	75-90 in.-lb. (8.47-10.17 N-m)

Figures 7 through 12 contain dimensioned drawings of all double shear test specimens. In some cases there were slight clearances between the blade and the clevis plates and shims were used to eliminate the gap.

2.3 Single Shear Specimens

A general description of the single shear specimens is presented in Tables 5 and 6, including nominal dimensions. These specimens utilize a special aluminum fitting for one side of the joint (Figure 16) to reduce possible joint rotation due to eccentric loading and to assure the shear load application at the interface.

All of the single shear specimens had a w/d ratio of 8.0 and were generally free of flaws and defects. Bolts were torqued to the same values presented for the double shear specimens. Figures 13 through 15 contain dimensioned drawings of these specimens, per DAC Drawing ZJ011267.

The bolts are installed in cup-shaped retainers in the loading fixture ZJ111270, rather than in a simple through-the-thickness hole, so that any fastener rotation would be more representative of a composite-to-composite single-shear joint.

3.0 TEST SETUP AND PROCEDURE

All ancillary test specimens were tested in a 100,000 pound capacity servo-hydraulic MTS test machine. For the double shear and unloaded hole tests, load was applied to the DST and UHT tension specimens through the combination of pin loading and clamping forces on the end fittings. Compression specimens for the DSC and UHC tests were loaded directly through the potted ends. A spherical support was used for alignment of the compression specimens to minimize eccentric loads. Stabilizing plates were mounted to those compression specimens susceptible to premature buckling failure. Figure 17 shows a double shear tension specimen mounted in the MTS machine.

The single shear specimens (tension and compression) were loaded through bookend loading clevises. One clevis attached directly to the end of the specimen. The other clevis was attached to the steel test fixture which was then bolted to the test specimen. Figure 18 displays a single shear specimen and test fixture mounted in the MTS machine.

All specimens were loaded to failure using the stroke control (machine head travel) mode of loading. For the narrow specimens ($w/d = 2$ and $w/d = 3$) the stroke loading rate was varied between different configurations to induce a strain rate of 0.003 in./min. The wider, bearing critical specimens ($w/d = 8$) were loaded at one-half the rate of the narrow specimens. Loading rates for the ancillary tests are presented in Table 7, which appeared in TAD ZCA10193 (reference 2).

For the single shear and double shear tests a load-deflection (P-δ) plot was continuously recorded to failure for each specimen. The deflection measurement for the double shear specimens is a record of the relative movement between the clevis and the blade at the side edge of the specimen at the centerline of the central hole (Figure 19). The single shear deflection measurement is essentially the same except that the relative movement is between the test specimen and the aluminum test fixture (Figure 19).

The deflection recorded for the unloaded hole tests is head travel of the MTS machine.

Deflection measurements were recorded using MTS clip gages which were attached to specially designed adapters mounted on the specimens. These adapters attached to the specimens at the mid-thickness of each plate at the bolt centerline and were designed to insure that the true relative deflection was measured (Figure 20). These devices were used for both the single shear and double shear tests. Load versus deflection or load versus head travel plots were continuously recorded using a Hewlett-Packard X-Y plotter.

For the single shear tests, bolt head rotation (versus load and/or deflection) was also recorded. A laser beam was reflected from the bolt head to a graduated scale, from which readings were taken throughout each test. This data was then converted to angle change or rotation of the bolt head. The test setup is shown in Figure 21 (and Figure 16).

4.0 TEST RESULTS

The ancillary test program was primarily intended to provide the data necessary for the anlaysis of multi-row bolted joints (fabricated with Ciba-Geigy 914/T300) using the A4EJ computer program (reference 3). The development of a sufficient data base to facilitate strength predictions at individual bolt locations in a bolted joint was of primary importance. This required a variety of specimens designed to exhibit a variety of failure modes. The three modes of failure to be examined were unloaded hole net-section failure, loaded hole net-section failure, and loaded hole bearing failure. Tension and compression specimens were tested for all cases.

In addition to strength data, the load-deflection behavior of bolted joint in both single and double shear was also examined. The prediction or determination of bolt load distributions in multi-row bolted joints is dependent upon the joint flexibility at each bolt location within the joint both in the linear (elastic) and non-linear (plastic) range.

Although most of the tests proceeded to failure as expected, many specimens displayed failure modes contrary to what had been planned. This was primarily the result of tapered bonded doublers attached to the specimens at the load introduction holes which occasionally failed prior to failure at the center test section. This occurred on both the double shear and unloaded hole tests as noted in the data and was, of course, limited to tension specimens. However, the basic problem was relatively steep machined tapers on the doublers. In a few instances, use of inadequate bond surface preparation and/or use of EA934 rather than higher strain to failure EA9320 adhesive was at fault. Subsequent analytic investigation provided design guidelines for future bonded and tapered doubler design, reference 4.

The load-deflection curves are contained in Appendices 1 through 3. Relative deflection measurements for the loaded hole tests were generally successful. The regions of elastic and plastic deformation are clearly defined along with

the transition point between the two behavior modes. The test data are summarized in Tables 8 through 31. Bearing, net-section, and gross-section stresses at failure are calculated for all loaded hole specimens regardless of the failure mode noted. The area used in bearing was the specimen thickness times the hole diameter. For the double-shear tests, virtually all of the failures occurred in the outer clevis members. Stress calculations were made using the thickness of the two outer members.

4.1 Unloaded Hole Tests

4.1.1 Unloaded Hole Tension Tests

Most of the unloaded hole tension tests resulted in net-section tension failures. However, out of 36 total UHT specimens, 13 of them failed in the tapered doublers and progressively through the net-section at the load introduction hole. All of the narrow specimens (w/d = 2) failed in net-tension through the central hole (Figure 22). The ultimate loads attained by these specimens were somewhat lower than expected, possibly as a result of the side edge effects involved in such narrow coupons. It has been concluded that a w/d ratio of 3 would be a more appropriate minimum for any future tests. The tapered doubler failures occurred in the wider (w/d = 8) specimens which resulted in 13 out of 18 specimens failing in this mode (Figure 23). Those that did fail in net-tension through the center experienced excessive delaminations and fiber separations at failure (Figure 24). These specimens also reached comparatively high load levels at failure, indicating relatively high bypass strength for this material system. Three of the wide specimens (UHT 16, 17, 18) were cut down in width from 6.0 in. to 4.5 in. to prevent early doubler failure. With 0.75 in. diameter central holes, these specimens then had a w/d ratio of 6.0 and all three failed in net-tension at the central hole (Figure 25). On three other specimens (UHT 34, 35, 36) the end holes were relocated and "C" clamps were mounted at the ends of the tapered doublers to add resistance to the high peel forces. Despite this modification, all three specimens failed in the doublers and end holes (Figures 23 and 26).

The load-deflection curves for the unloaded hole tension tests are presented in Appendix 1. The test data are summarized in Tables 8 through 11.

4.1.2 Unloaded Hole Compression Tests

The unloaded hold compression specimens all failed through the net-section at the central hole (Figure 27). All tests proceeded without difficulties except for the UHC 13, 14, 15 series of three specimens. A malfunction in the data acquisition system occurred during the testing of UHC-13, with the result that no data was recorded for that specimen. Stabilizing plates were mounted on all wide (w/d = 8) specimens to prevent premature buckling failure. These plates were inadvertently omitted during the testing of UHC-14 and UHC-15. Both specimens failed at a much lower ultimate load than expected due to compressive buckling failures at the central hole net-section.

Plots of load versus head travel for the UHC tests are contained in Appendix 1. Tables 12 through 15 summarize the test data.

4.2 Double Shear Tests

4.2.1 Double Shear Tension Tests

The double shear tension tests resulted in a variety of failure modes for both the narrow (w/d = 3) and wide (w/d = 8) specimens. Figures 28 through 33 show several of the failed specimens with different modes of failure.

The narrow specimens were intended to provide data regarding loaded hole net-section strength. Approximately 50 percent of these specimens resulted in net-tension failures (Figure 28). Nearly all of the w/d = 3 specimens with 0.75 in. diameter bolts failed the tapered doublers at the end fittings, followed by a net-tension failure at the load introduction hole (Figure 29). Some of the narrow specimens also failed in bearing, and those that did fail in tension were working to a relatively high bearing stress.

The wider specimens were designed to fail in bearing and did so with reasonable consistency (Figure 30). The specimens with 0.25 in. diameter bolts actually failed in bolt bending with minor bearing deformation due to the bending of the bolts (Figure 31). The load-deflection curves for these specimens display a smooth transition from elastic to plastic behavior, clearly representative of the bolt bending failure. One wide specimen (DST 14) resulted in an adhesive failure of the bonded doubler between the two clevises, but not before the ultimate bearing strength had essentially been reached.

For virtually all the specimens that failed in net-tension or in bearing, the ultimate failure occurred in the two outer members (Figure 32). For this reason, the thicknesses of the two outer plates were used for stress calculations. In all cases the outer laminates were one-half the number of plies of the central member. The buckling and delamination of outer plies (in the strap members) associated with bearing failures was restricted in the central member due to clamp-up effects. This phenomenon contributed to the bearing deformation occurring predominantly in the outer members. In addition, any eccentricities causing unequal loading between the outer plates would result in failure of those members prior to the central blade.

One area of concern was the apparently high level of scatter between the slopes of the load deflection curves for identical specimens. In response to this, a number of steps were taken to ensure that the data acquisition system was not the cause of this scatter. More frequent checks were made to ensure that load and deflection scales on the plotter correctly represented the actual measurements. A total of 12 runs were made with DST specimen 14, all within the elastic range of behavior (see Appendix B). Sets of 3 runs were made with the extensometer adapter mounted on the plate centerline, 1/8 in. over the centerline, 1/8 in. under the centerline, and with the bolt torque increased from 50 to 90 in.-lb. The load-deflection curves yielded very consistent results throughout the repeated loadings despite these varied conditions. Suggesting the cause of this scatter would still be speculation at this time.

Appendix 2 contains the load-deflection curves for the double shear tension tests. A summary of the test data is presented in Tables 16 through 19.

4.2.2 Double Shear Compression Tests

The double shear compression tests were completed without any deviations from the anticipated behavior. Approximately 50 percent of the narrow (w/d = 3) specimens failed in compression, the remainder consisting of bearing failures (Figure 34). Compression failures for these specimens usually consisted of a shear/buckling failure occurring immediately at the boundary of the washer at the central hole. All of the specimens that failed in compression were working to a very high bearing stress. The remainder of the narrow specimens did, in fact, fail in bearing.

Most of the wide specimens (w/d = 8) resulted in bearing failures. The only exceptions were the three wide specimens with 0.25 in. diameter bolts (DSC-28, 29, 30) which failed in bolt bending with some minor bearing damage (Figure 35). Three specimens (DSC 10, 11, 12) which had 0.50 in. rather than the planned 0.25 in. holes also failed in bearing at a w/d ratio of 4.0. As was the case for the DST tests, failures occurred consistently in the outer clevis plates of the DSC specimens.

The slopes of the load deflection curves for the DSC tests were notably more consistent among identical specimens than they were for the DST tests. The load-deflection curves are presented in Appendix 2. The test data are summarized in Tables 20 through 23.

4.3 Single Shear Tension & Compression Tests

The single shear test results were consistent for both tension and compression tests. All the single shear specimens had a w/d ratio of 8.0 and all failed in bearing. Examination of the load deflection curves clearly indicates the yield point at which plastic bearing deformation begins. This change in

stiffness was generally less severe than that observed for the double shear tests. Bearing strengths were fairly consistent between SST and SSC tests of the same geometry.

The plastic range of bearing deformation was also clearly audible from the initial ply failures through to ultimate load.

Measurements of bolt head rotation were taken for all single shear tests. Although readings of the laser beam deflection were taken incrementally, the variation of bolt head rotation with load appeared essentially bilinear and analogous to the path of each load-deflection curve. These data were gathered in anticipation of their potential significance to the load-deflection characteristics of single-shear joints. A measurable amount of permanent bearing deformation was sustained by the aluminum bushings as well as the graphite plates. The aluminum bushing bearing areas were the same as the graphite for each hole. Bearing yield deformation of both members must be considered when making use of the load-deflection data.

The load-deflection curves for the single-shear tests are presented in Appendix 3. The test data are summarized in Tables 24 through 31.

5.0 BASIC MECHANICAL PROPERTY TESTS

The ancillary test program included a series of tests to determine basic laminate strength allowables and modulus values. A total of six (6) tension and six (6) compression tests was fabricated as in Figure 36. Among each set of specimens, three (3) consisted of layup Pattern A, and three (3) of layup Pattern B.

The tension tests were run using self-tightening friction grips at the ends with an extensometer attached to the specimen along the constant section to measure Young's Modulus. One specimen of each group (Pattern A, B) had strain gauges at the minimum section. The extensometer was removed from each specimen at approximately 2/3 the anticipated failure load, and the test was then continued to failure.

The compression tests provided ultimate compression strength data only. The specimens were made with potted ends similar to all previous compression specimens (Figure 37).

Table 32 summarizes the results for the tension and compression tests. Ultimate tension stresses are calculated based on the minimum width section. In addition, these stress values are multiplied by the appropriate stress concentration factor associated with this type of specimen.

Several tension specimens failed at some distance away from the minimum cross-section (Figure 38). This result suggests that the stresses presented in Table 32 may be considered minimum allowable stresses in tension.

6.0 SUMMARY AND CONCLUSIONS

Basic unloaded hole and single bolt loaded hole test data are presented to support the analysis of bolted joints in thick ply graphite fiber/toughened epoxy composites. The load-deflection curves indicate that bolted joints in composites may exhibit distinct regions of linear-elastic and non-linear (plastic) behavior. This non-linear behavior is the result of bolt bending and bolt shear deformations and bearing deformation in the joint members. The possibility of bolt bending failures must be considered for low values of d/t.

The high gross stresses attained by the wide unloaded hole tension and compression failures indicate the presence of substantially improved bypass strength for the Ciba-Geigy 914/T300 over 5208/T300. The extensive delaminations and splitting at failure suggest that interlaminar forces play an important role in the behavior and strength characteristics of this thick-ply material system. The delamination failure behavior may correlate with that reported in Reference 5, where large immediate extension of delaminations through the specimen width was noted for edge delamination specimens fabricated with relatively thick ply toughened epoxy composites.

Because of loading end failures, an incomplete matrix of data was obtained to fulfill desired Ancillary Test Program objectives; however, the tapered bonded doubler failure data is useful to support analysis work extending the state of the art of doubler design.

It is recommended that additional Ancillary Test work be accomplished with improved specimens in order to fill in test matrix gaps and provide data at intermediate w/d values.

Data presented in this report allow completion of the subsequent Subcomponent Test Specimen analysis task within the current overall contracted program.

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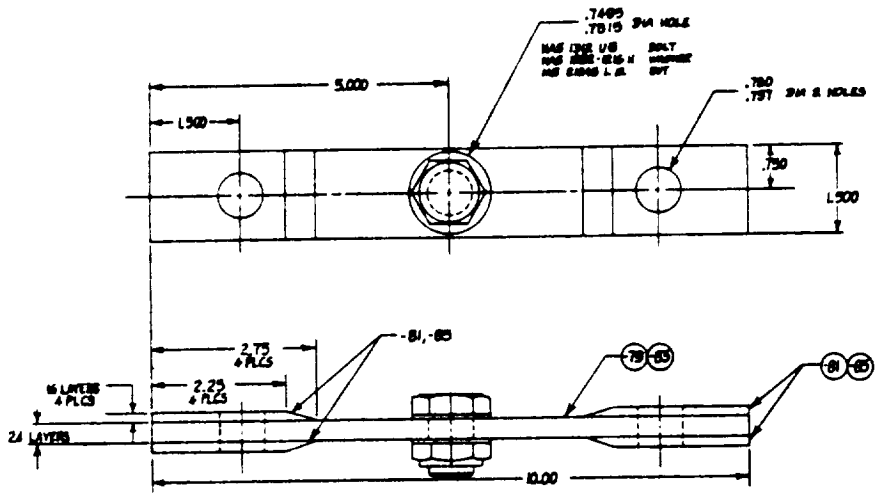
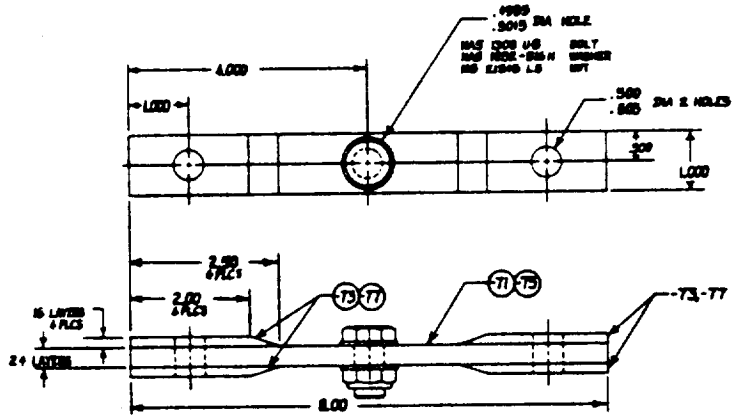
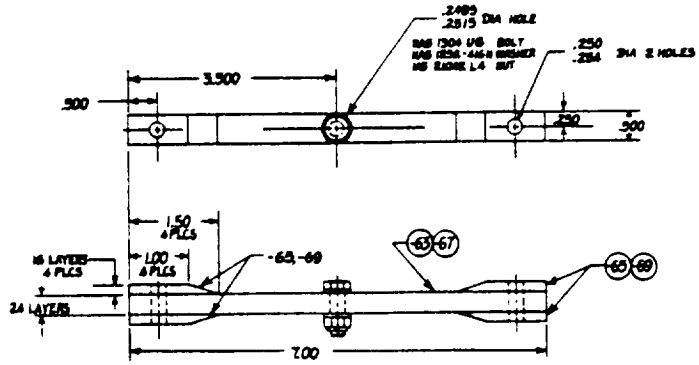


- 527 (UHT 7,8,9)
- 539 (UHT 25,26,27)

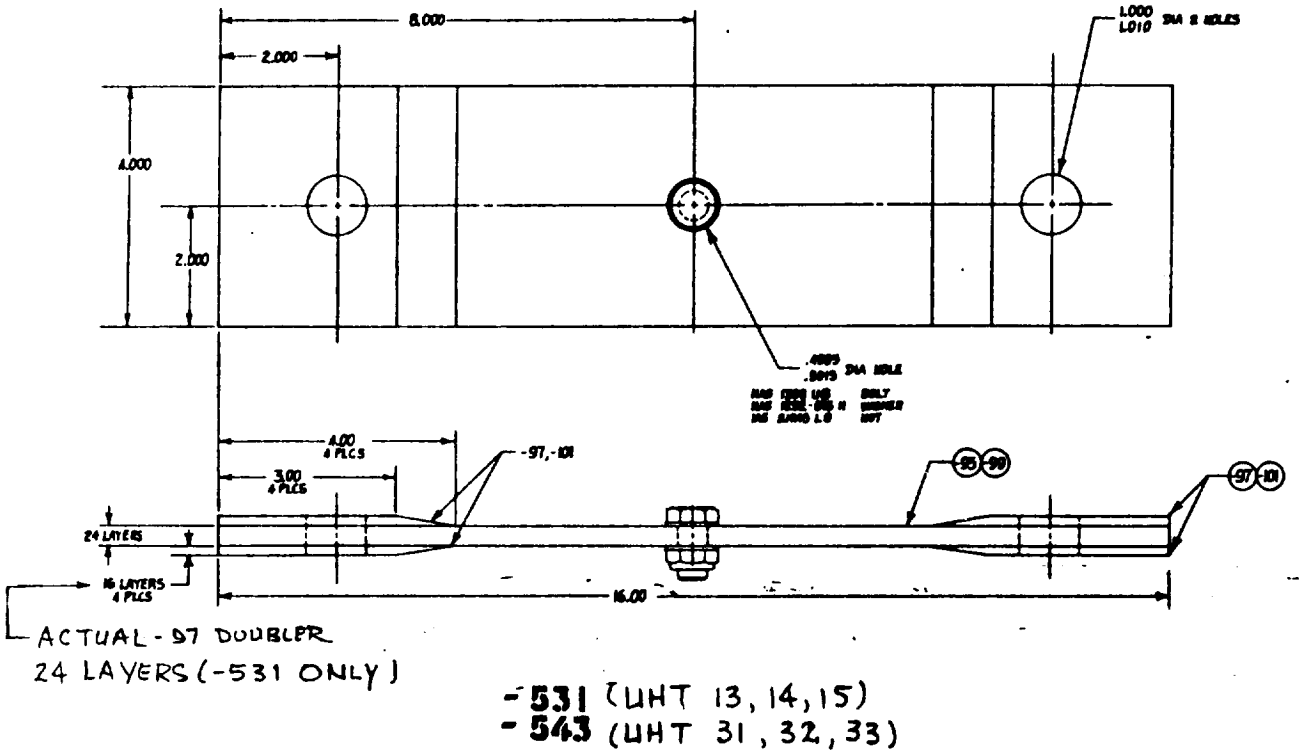


- 525 (UHT 4,5,6)
- 537 (UHT 22,23,24)



- 523 (UHT 1,2,3)
- 535 (UHT 19,20,21)

FIGURE 1 - UNLOADED HOLE TENSION SPECIMENS



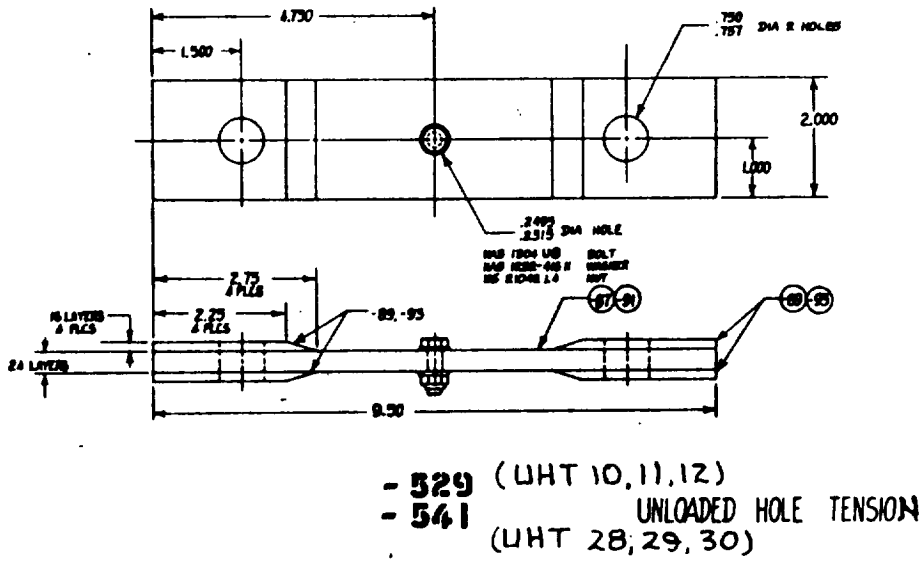


FIGURE 2 - UNLOADED HOLE TENSION SPECIMENS

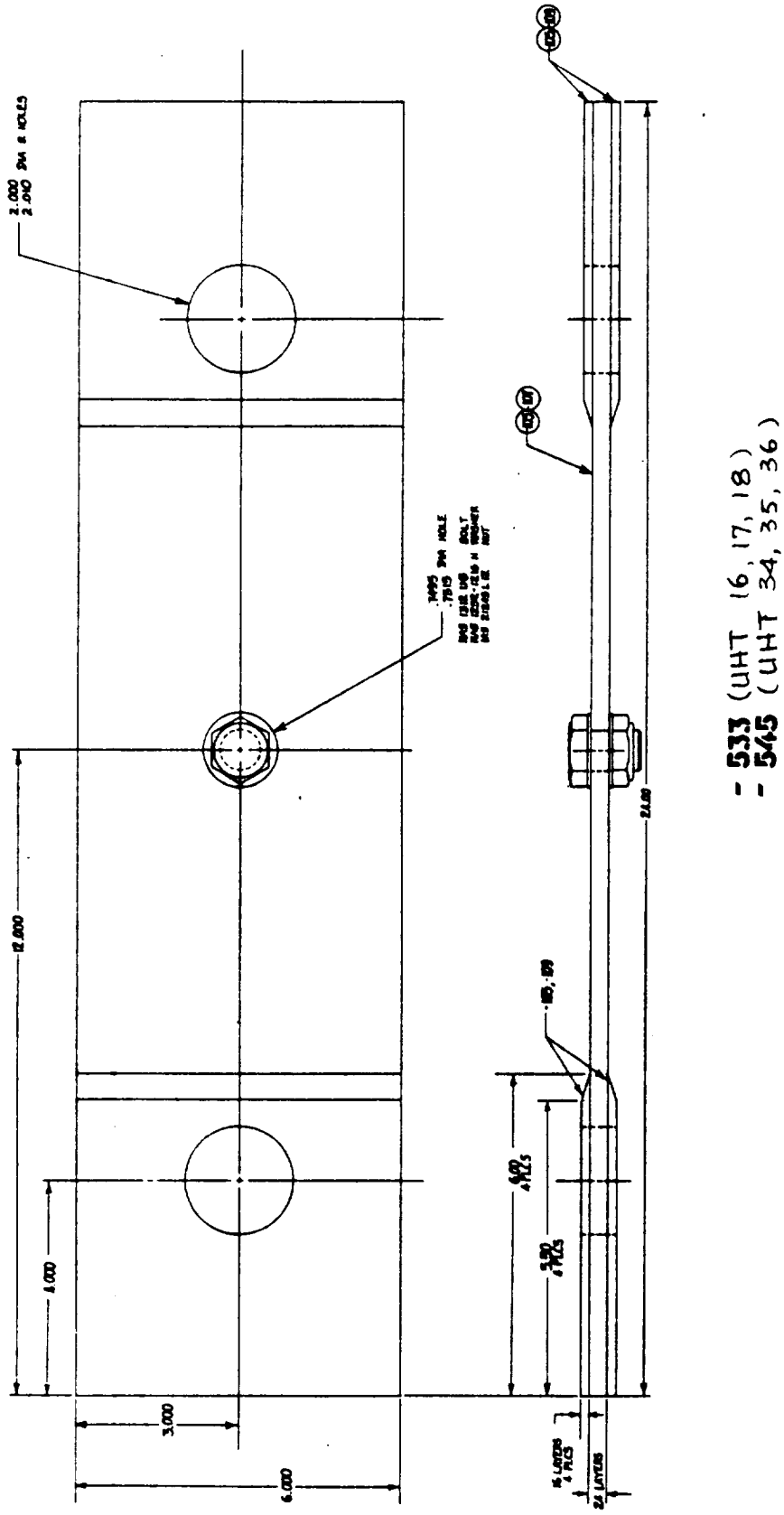
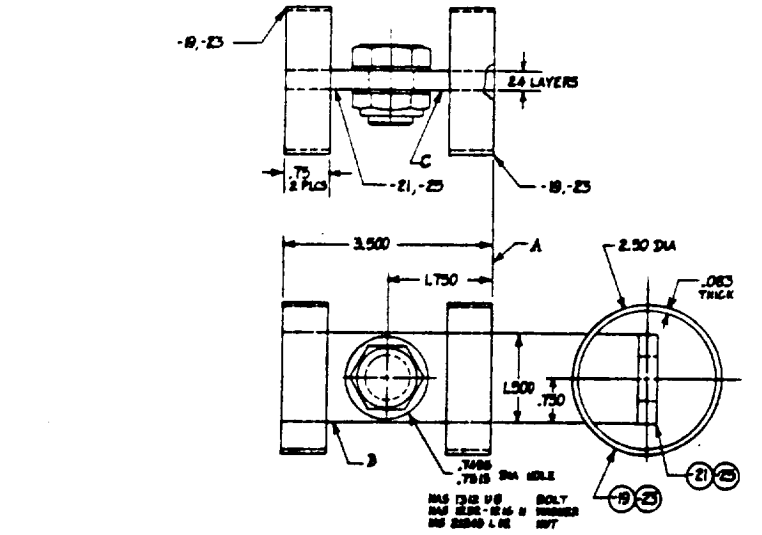
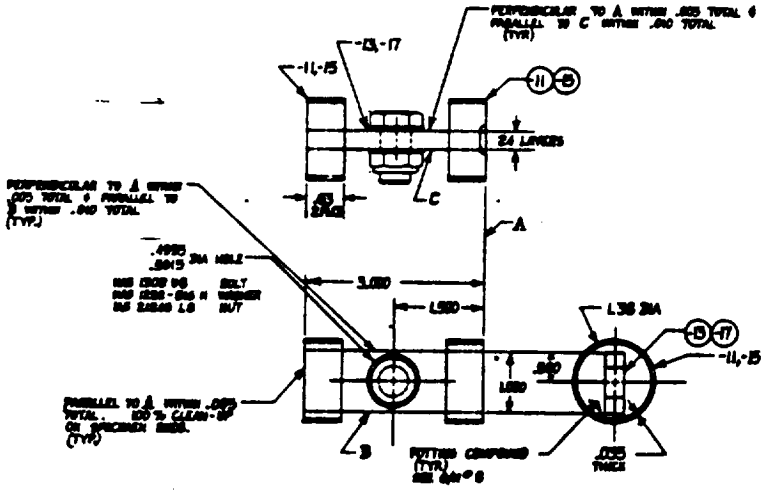


FIGURE 3 - UNLOADED HOLE TENSION SPECIMEN





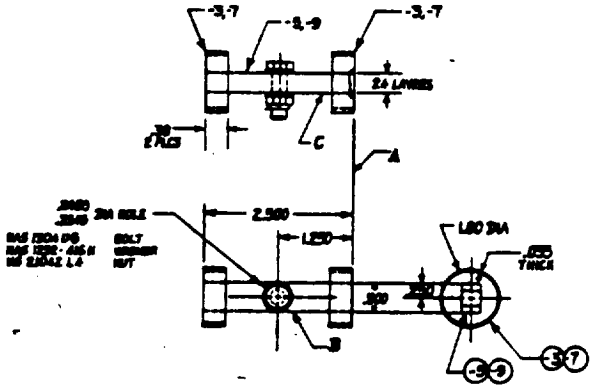
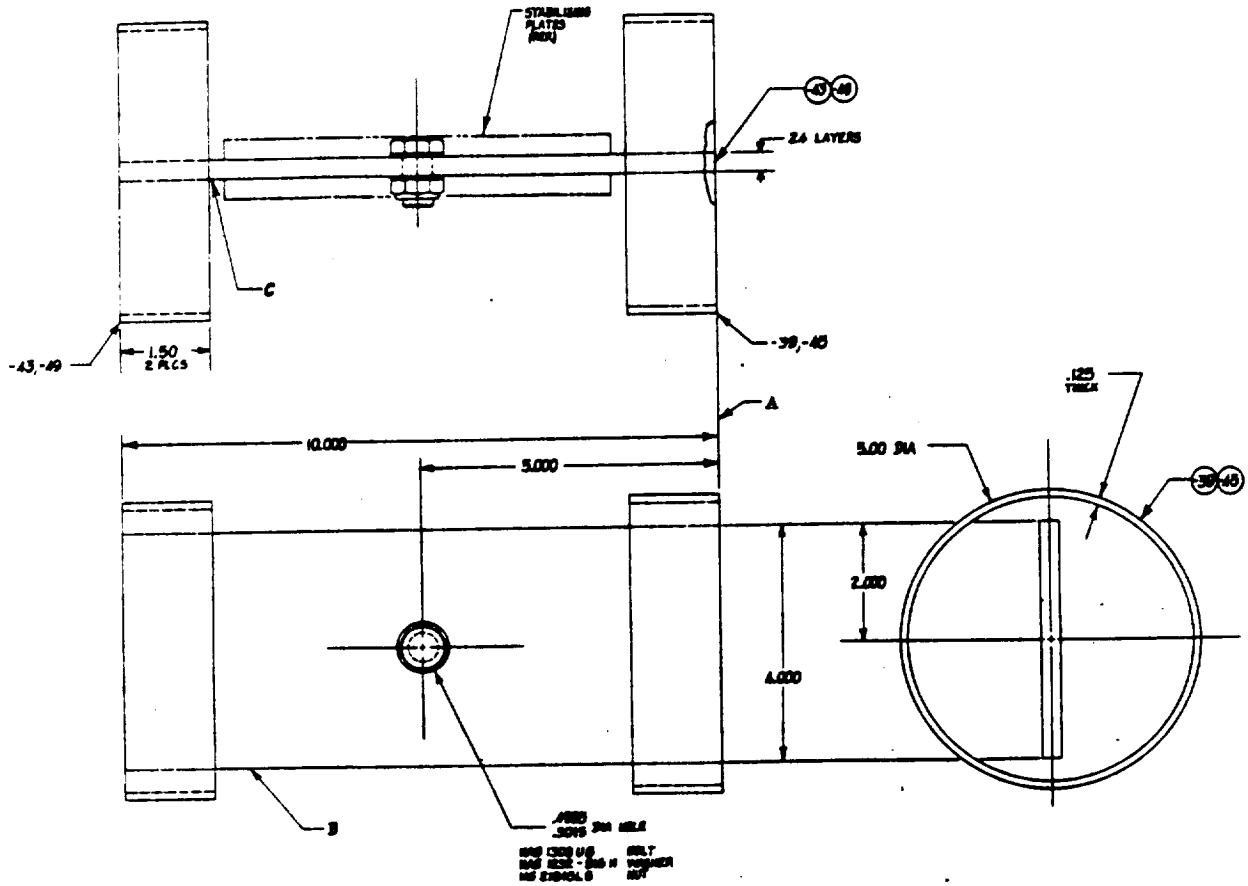
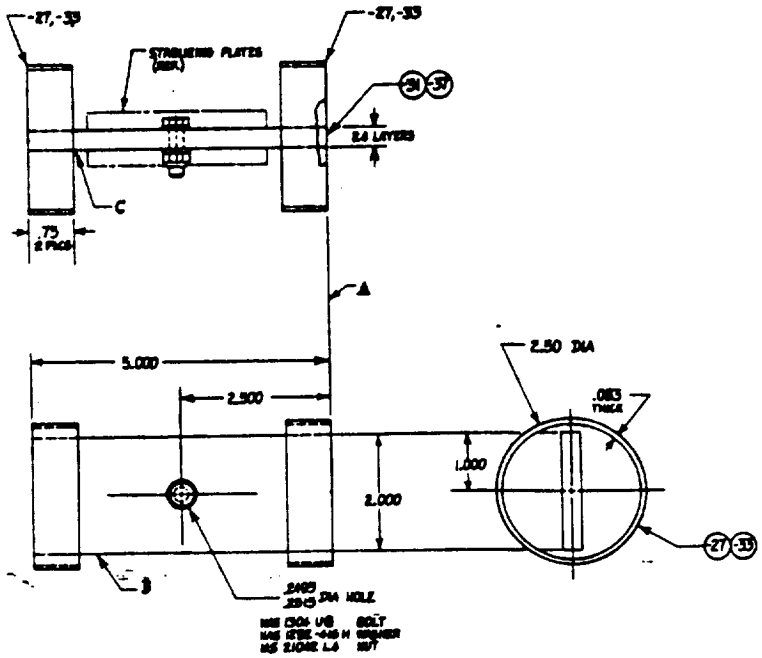


FIGURE 4 - UNLOADED HOLE COMPRESSION SPECIMENS

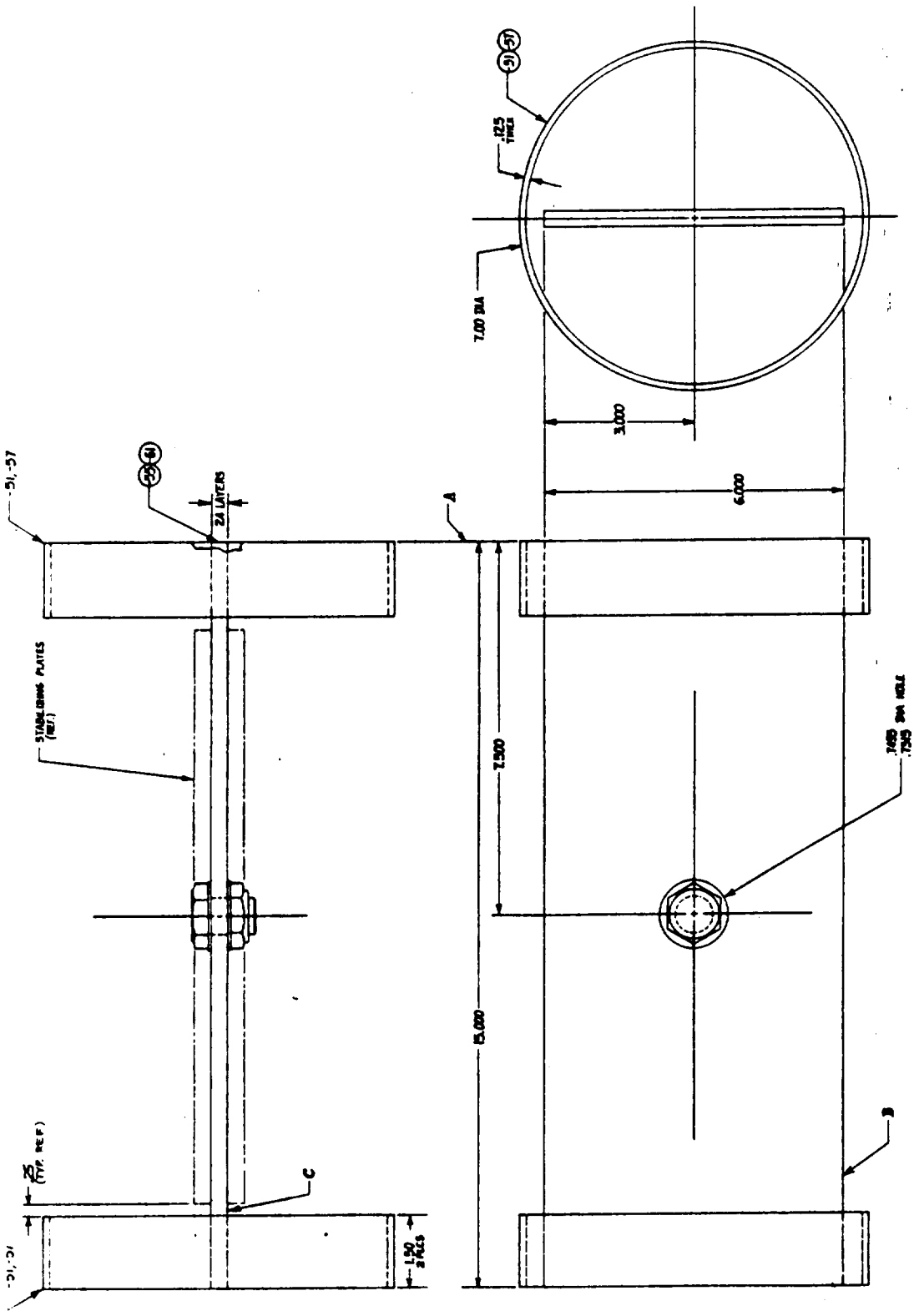


-507 (UHC 13, 14, 15)
-519 (UHC 31, 32, 33)



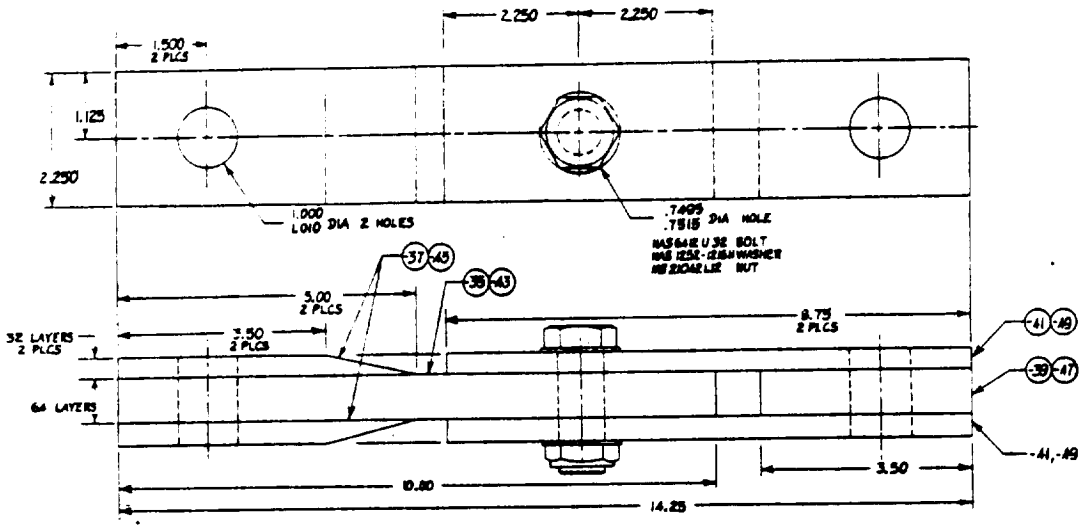
-505 (UHC 10, 11, 12) UNLOADED HOLE COMPRESS
-517 (UHC 28, 29, 30)

FIGURE 5 - UNLOADED HOLE COMPRESSION SPECIMENS

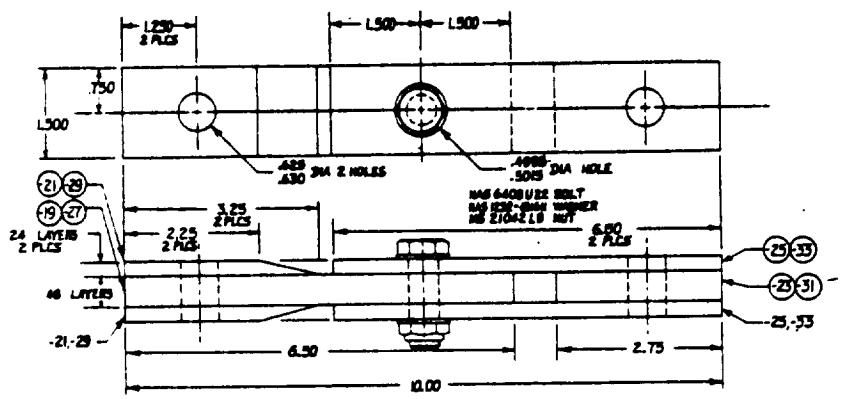


-509 (UHC 16,17,18)
-521 (UHC 34,35,36)

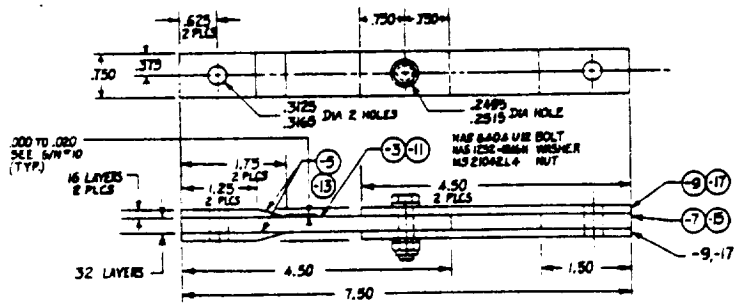
FIGURE 6 - UNLOADED HOLE COMPRESSION SPECIMEN



-503 (DST 7, 8, 9)
-515 (DST 25, 26, 27)

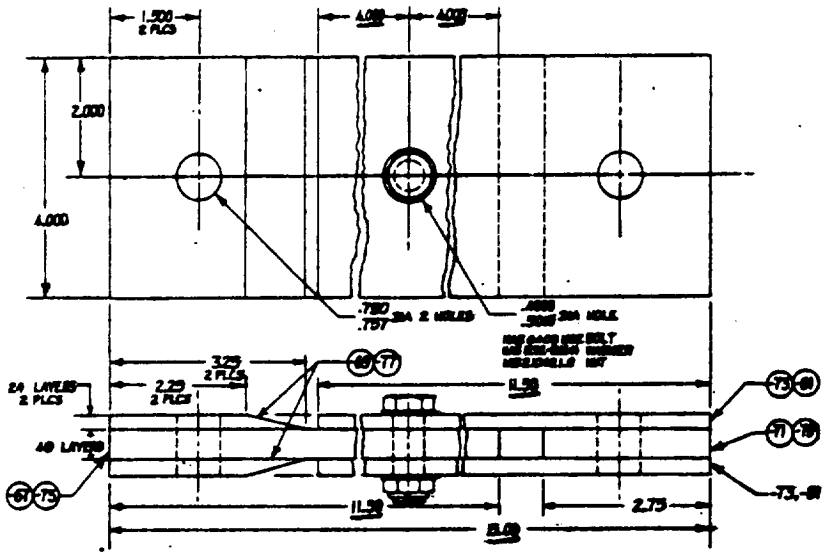


-501 (DST 4, 5, 6)
-513 (DST 22, 23, 24)

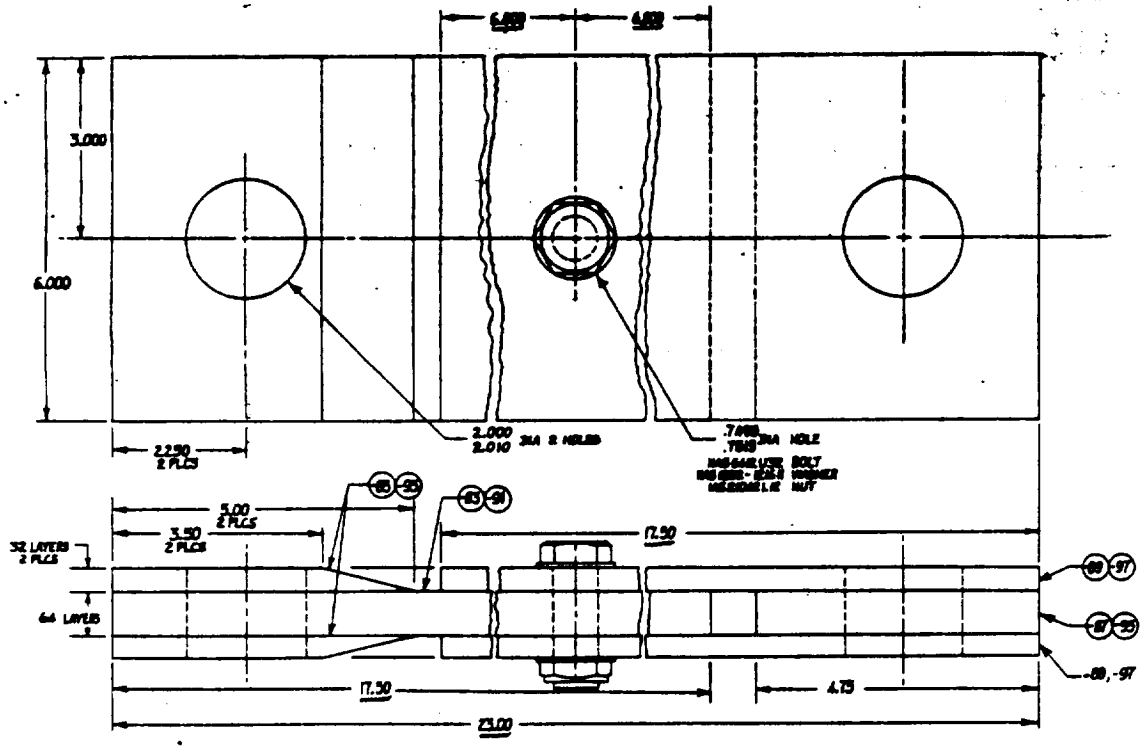


-1 (DST 1, 2, 3)
-511 (DST 19, 20, 21)

FIGURE 7 - DOUBLE SHEAR TENSION SPECIMENS

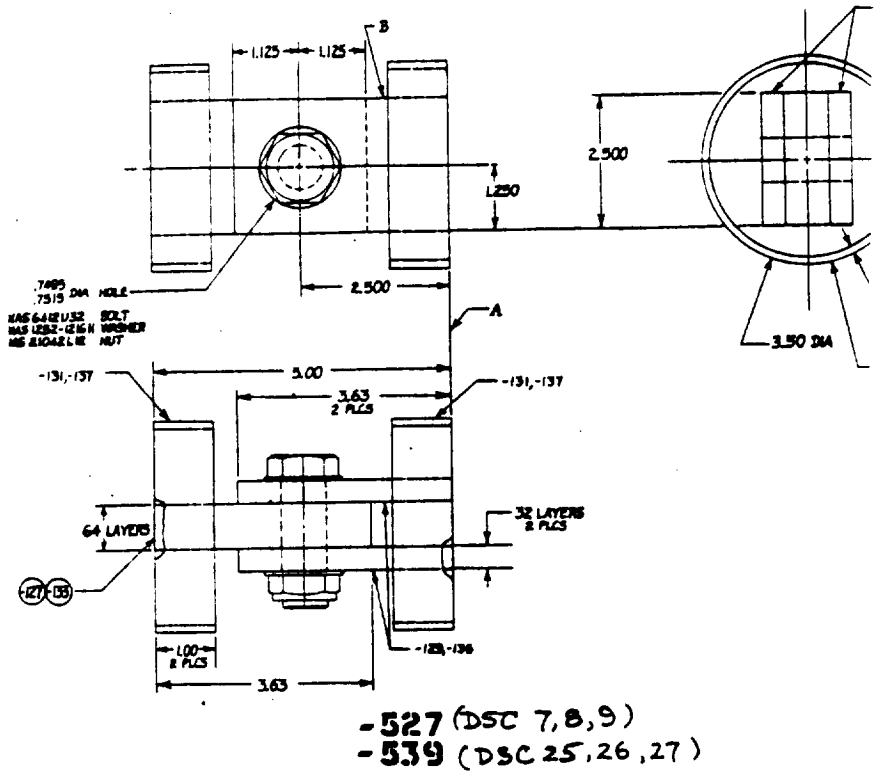


-507 (DST 13,14,15)
-519 (DST 31,32,33)



-509 (DST 16,17,18)
-521 (DST 34,35,36)

FIGURE 8 - DOUBLE SHEAR TENSION SPECIMENS



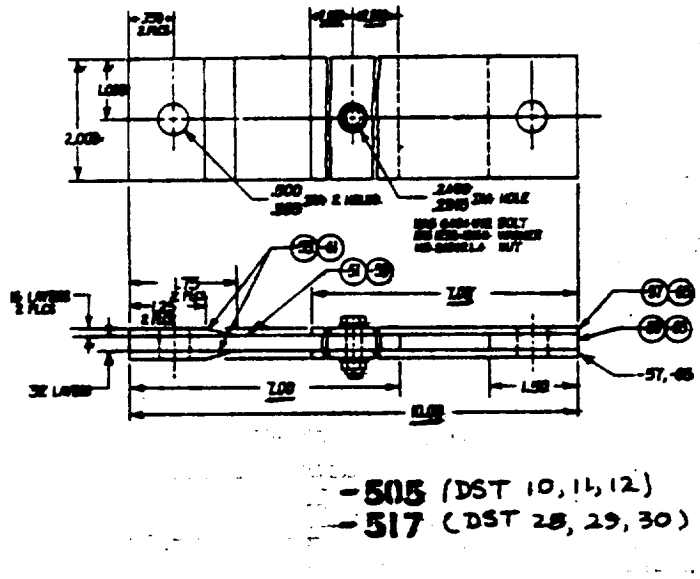


FIGURE 9 - DOUBLE SHEAR COMPRESSION AND TENSION SPECIMENS

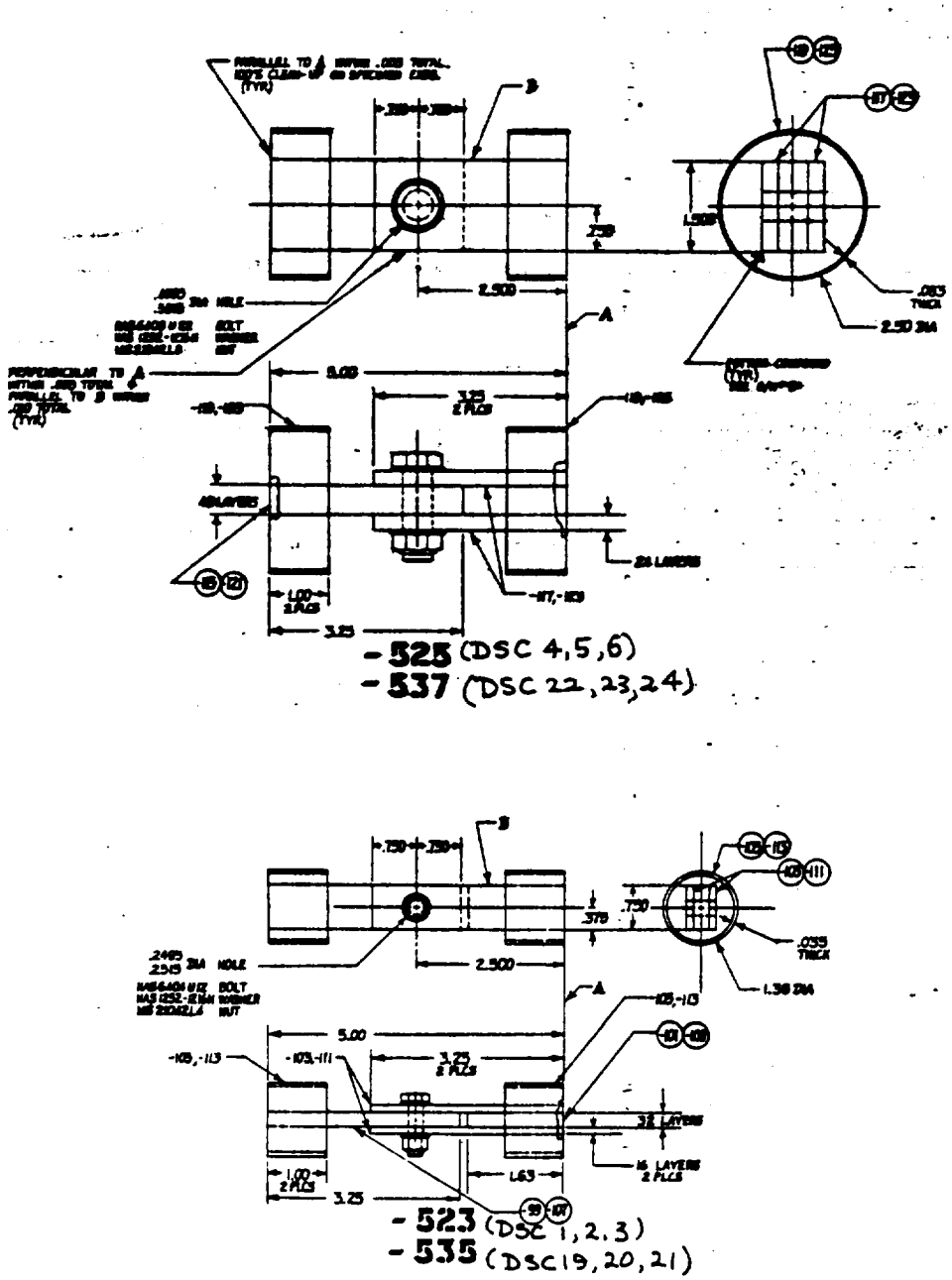
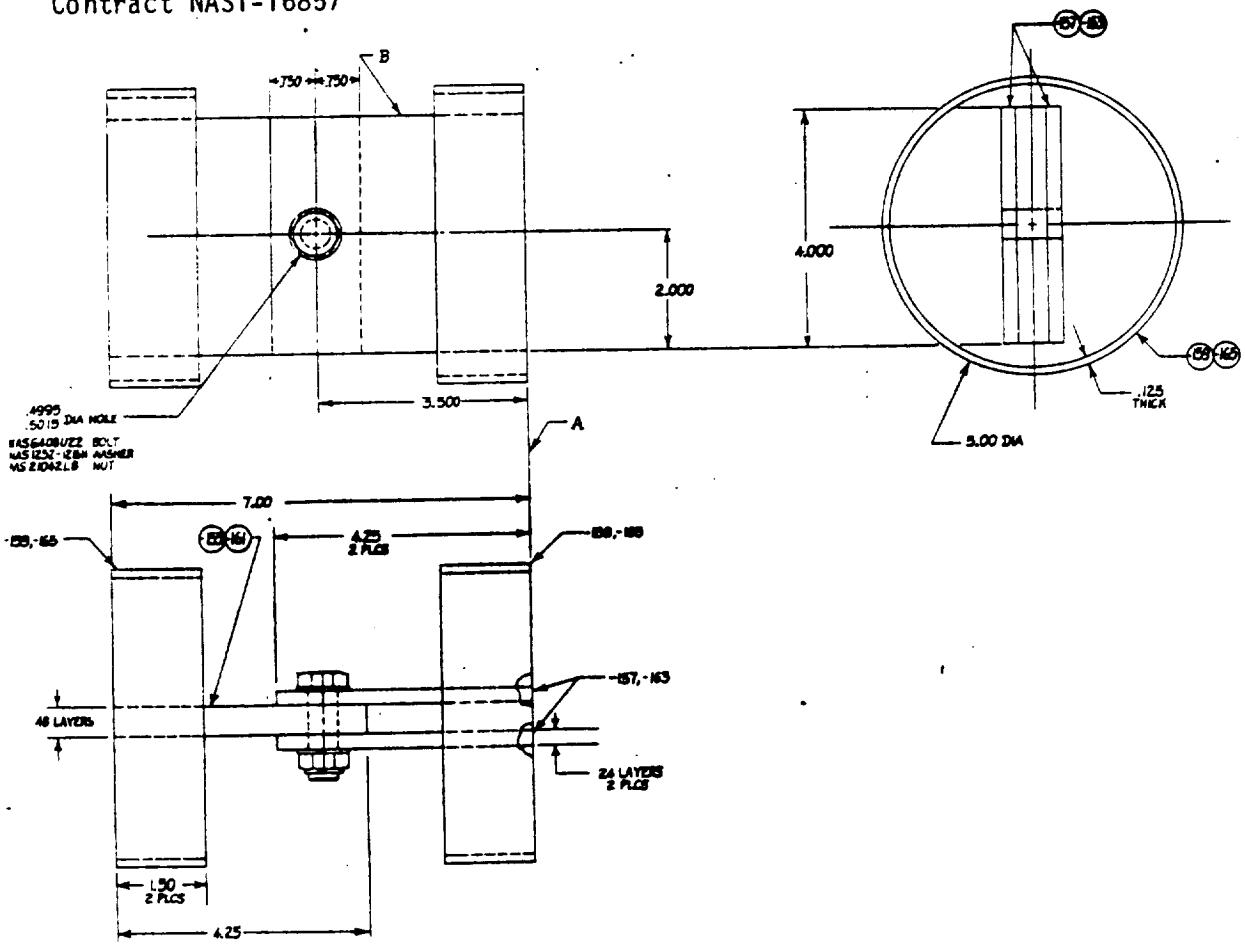
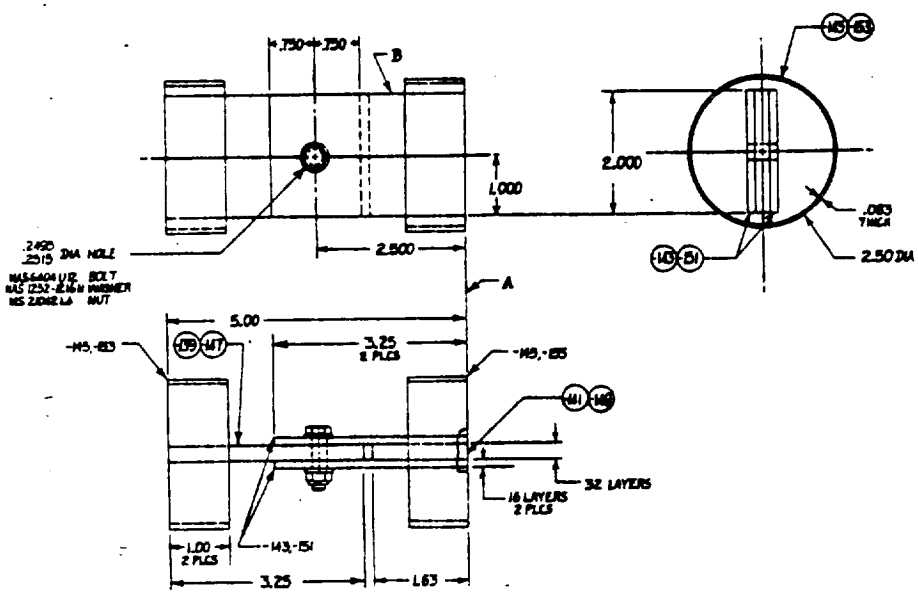


FIGURE 10 - DOUBLE SHEAR COMPRESSION SPECIMENS

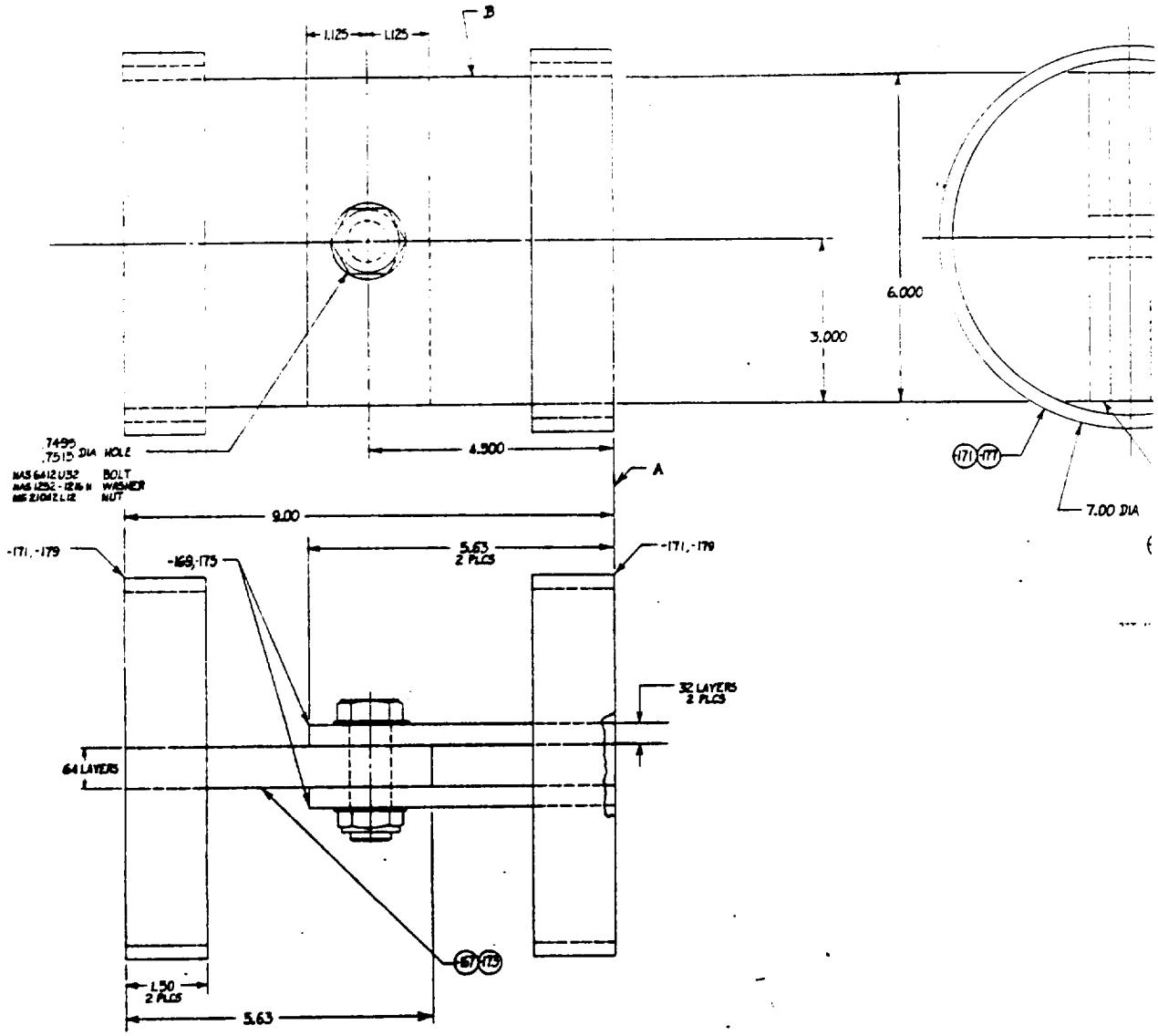


-531 (DSC 13, 14 & 15)
-543 (DSC 31, 32, 33)



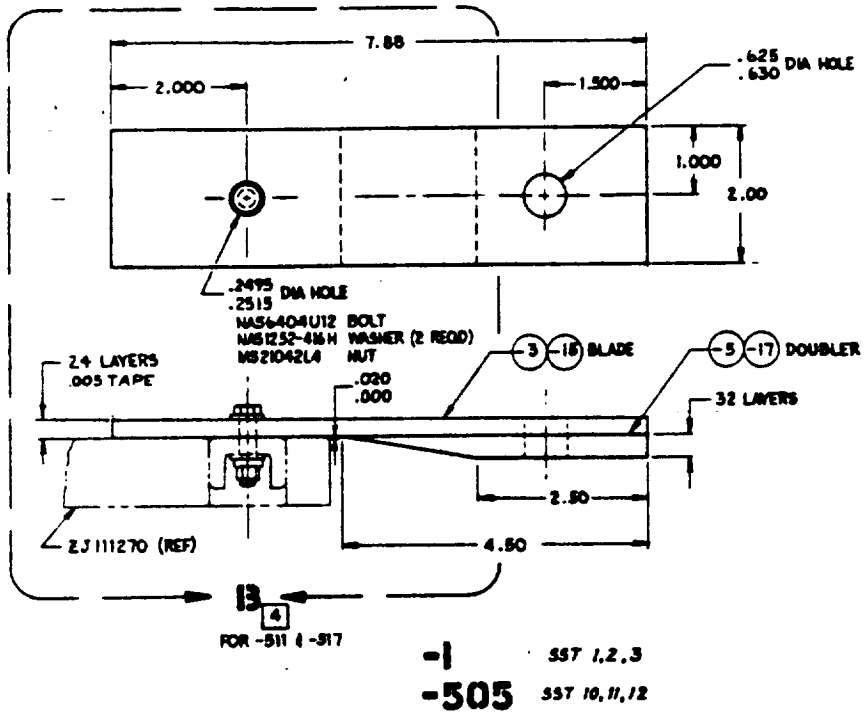
-529 (DSC 10, 11, 12)
-541 (DSC 28, 29, 30)

FIGURE 11 - DOUBLE SHEAR COMPRESSION SPECIMENS



-533 (DSC 16, 17, 18)
-545 (DSC 34, 35, 36)

FIGURE 12 - DOUBLE SHEAR COMPRESSION SPECIMEN



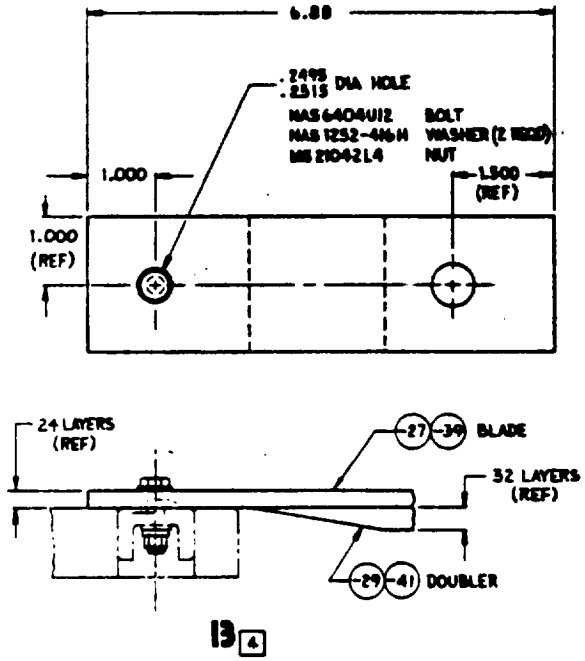
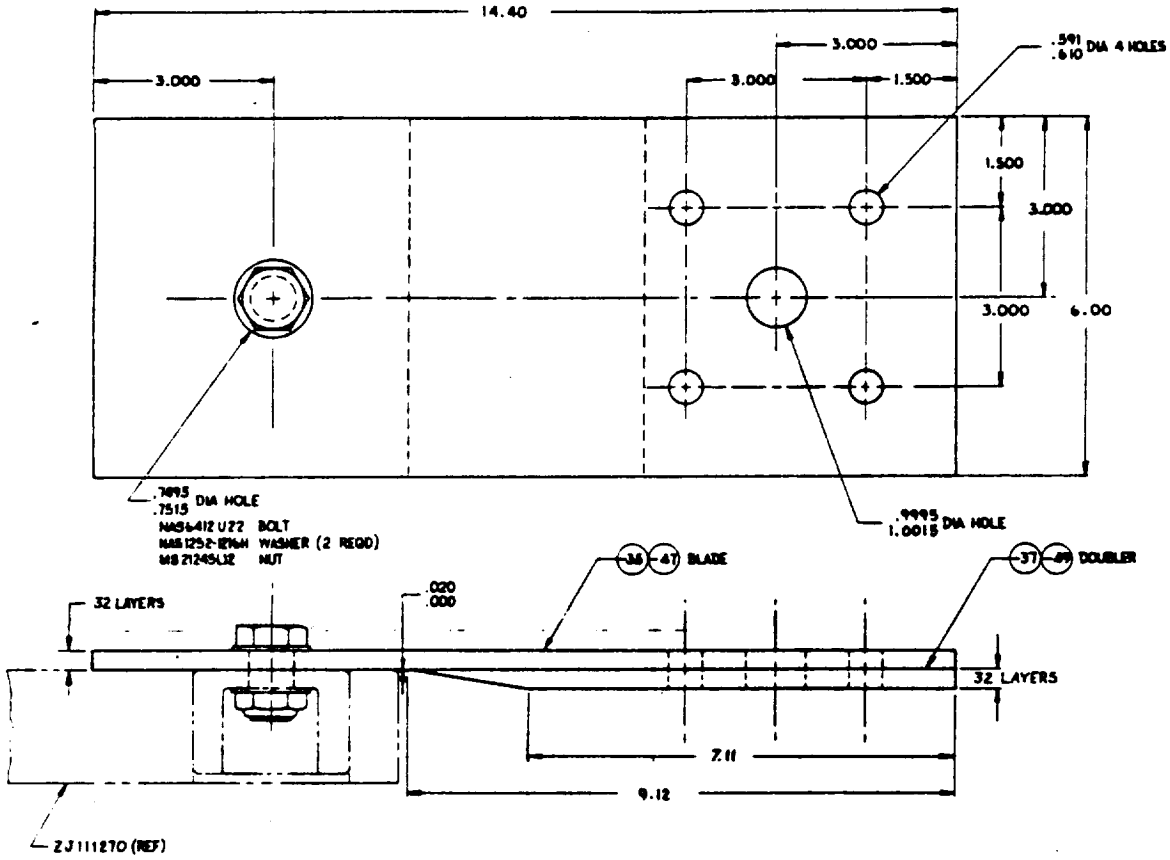
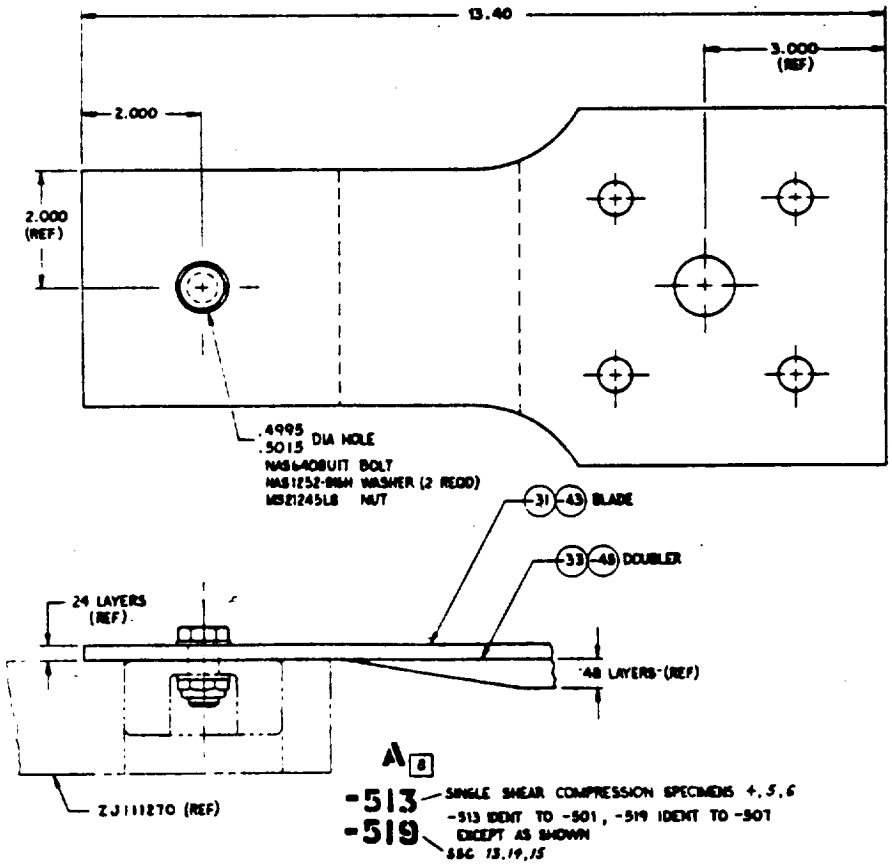


FIGURE 13 - SINGLE SHEAR SPECIMENS



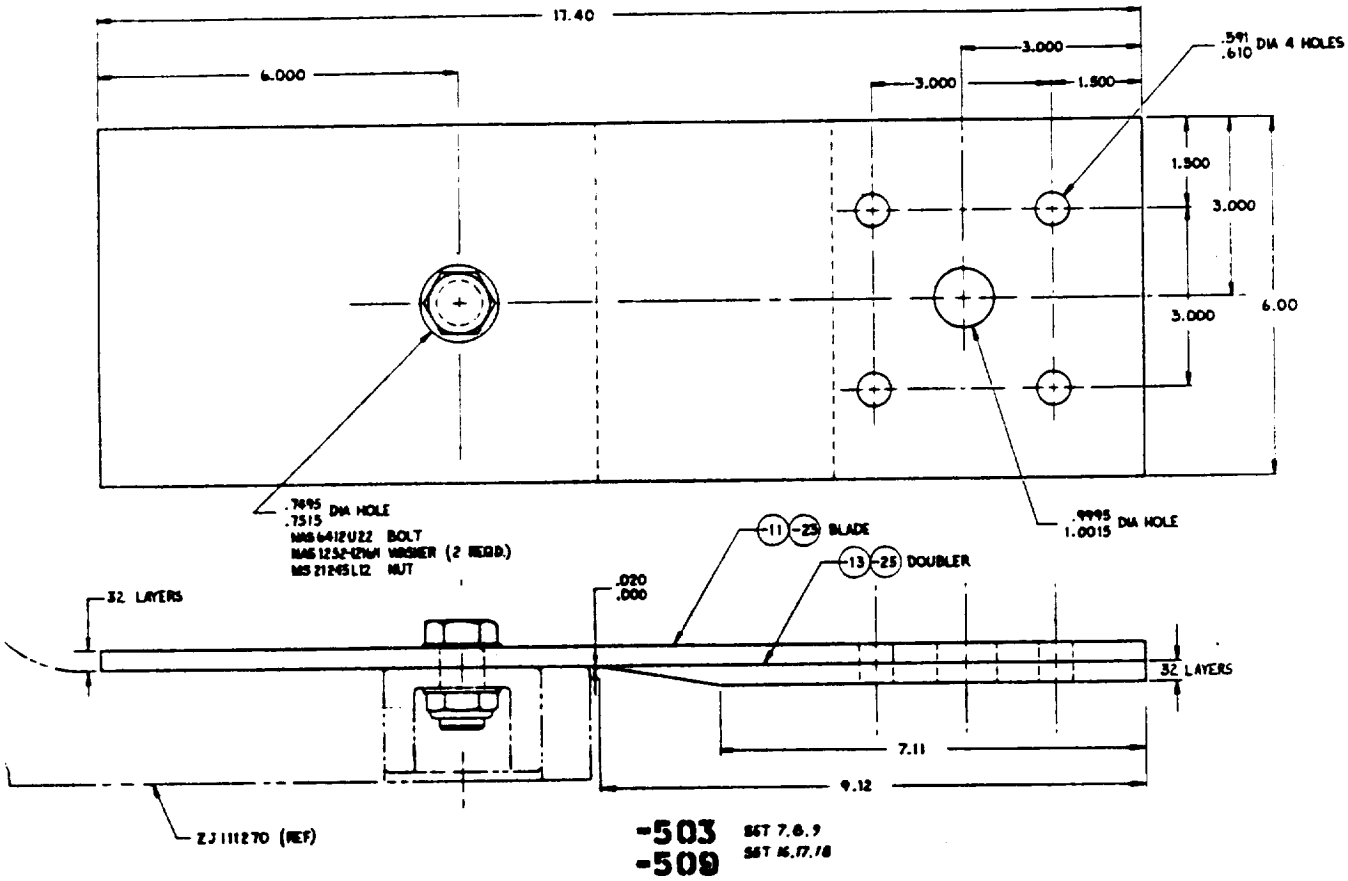
-515 SSC 7, 8, 9
-521 SSC 16, 17, 18



A 8

-513 SINGLE SHEAR COMPRESSION SPECIMENS 4, 5, 6
-519 -513 IDENT TO -501, -519 IDENT TO -507 EXCEPT AS SHOWN
SSC 13, 14, 15

FIGURE 14 - SINGLE SHEAR SPECIMENS



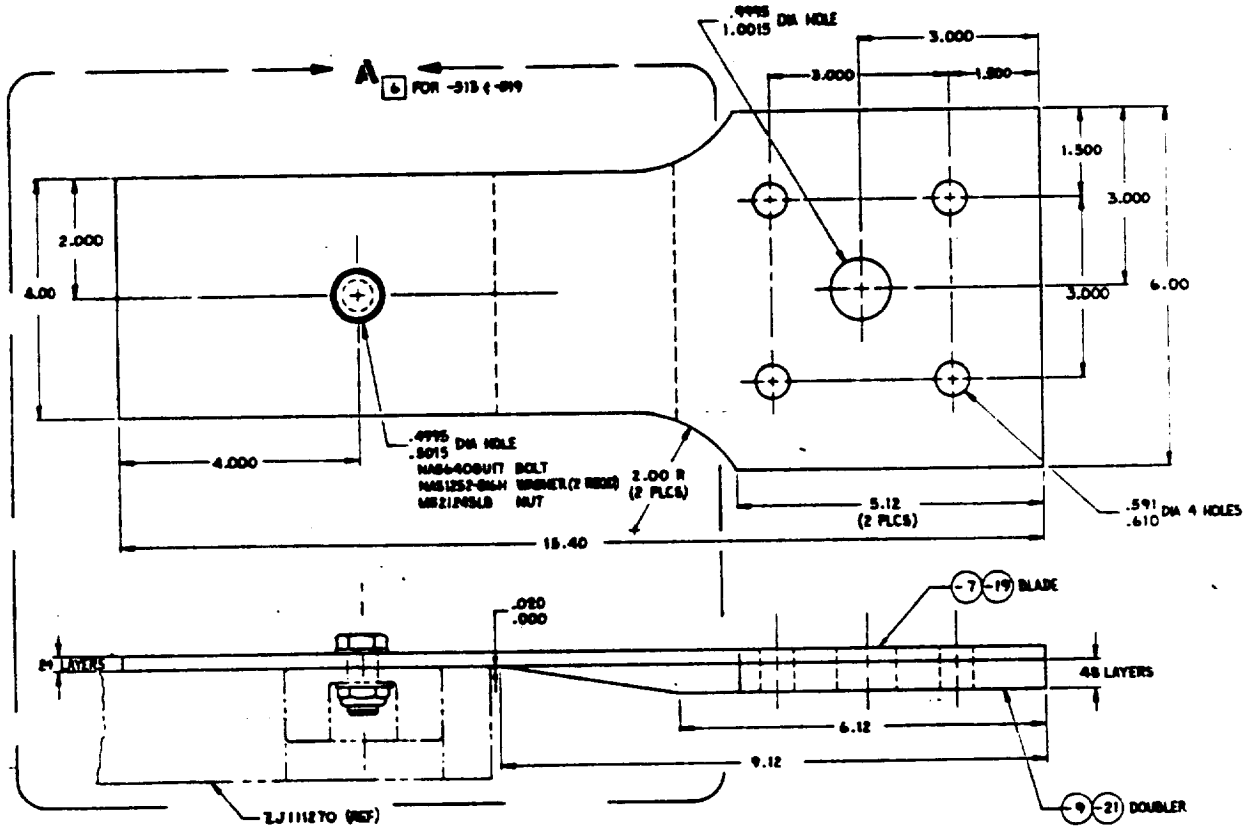


FIGURE 15 - SINGLE SHEAR SPECIMENS

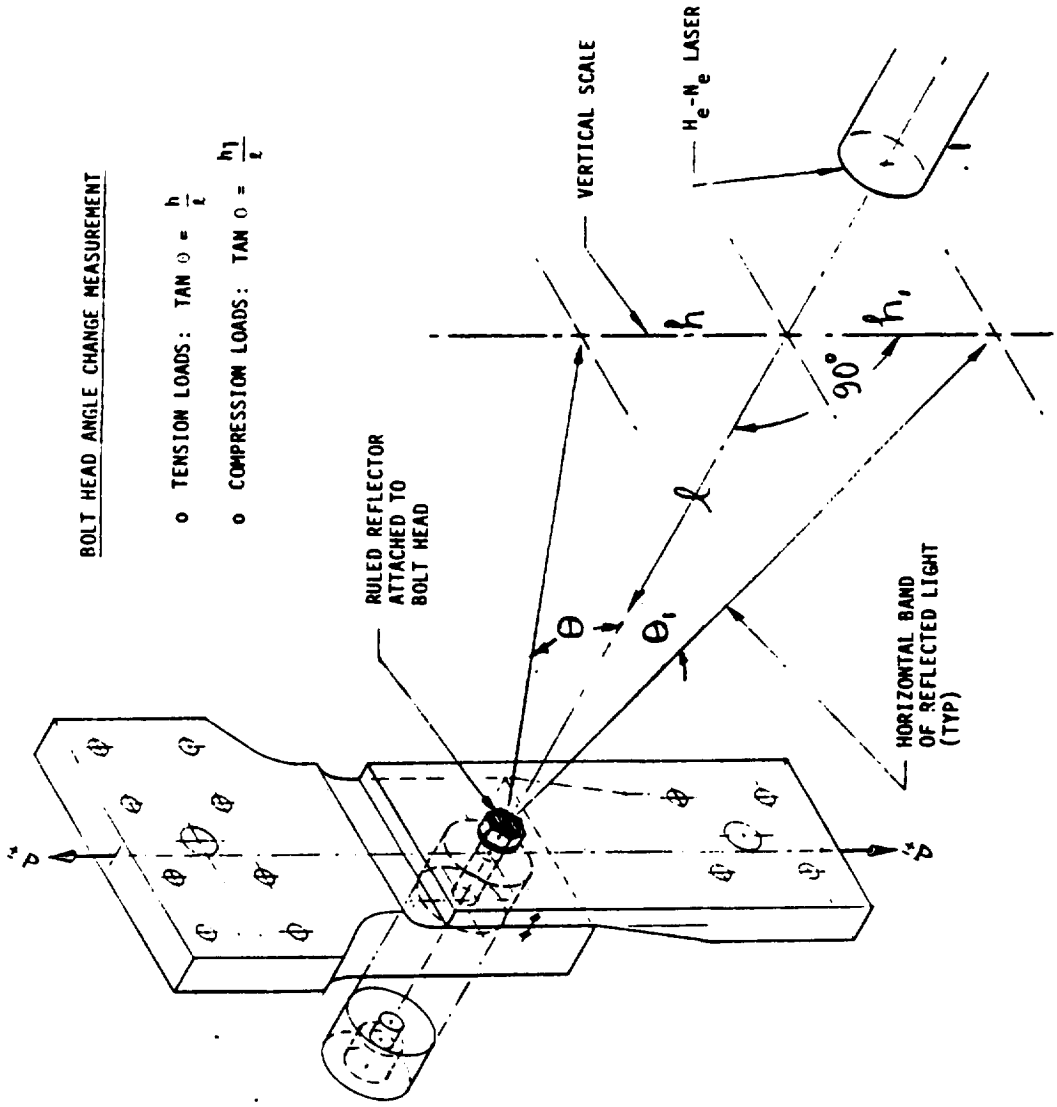


FIGURE 16 - BOLT HEAD ANGLE CHANGE MEASUREMENT

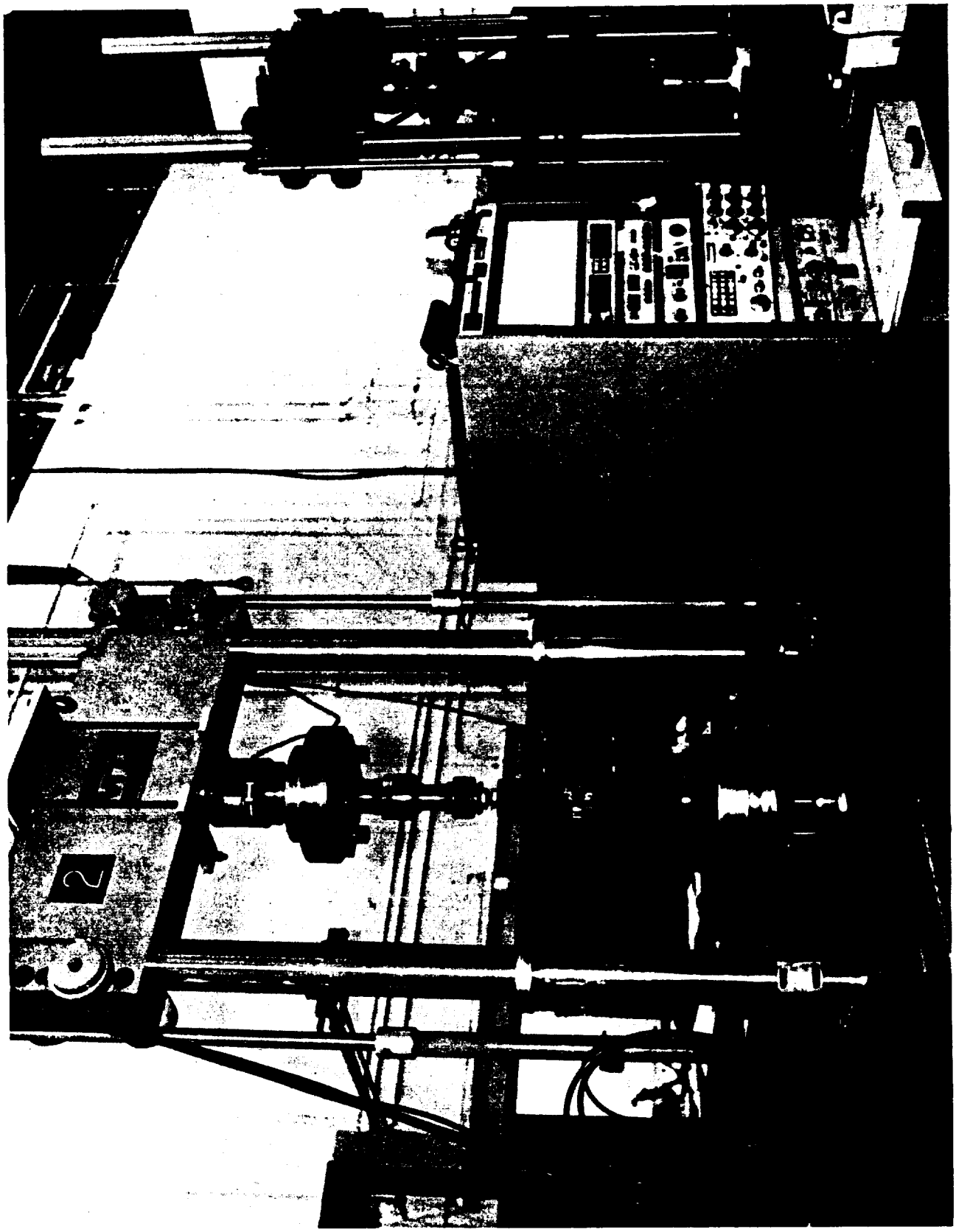


FIGURE 17. TEST SET-UP - DOUBLE SHEAR TENSION TEST

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FIGURE 18. SINGLE SHEAR TEST SET-UP

ORIGINAL PAGE
BLACK AND WHITE PHOTOGRAPH

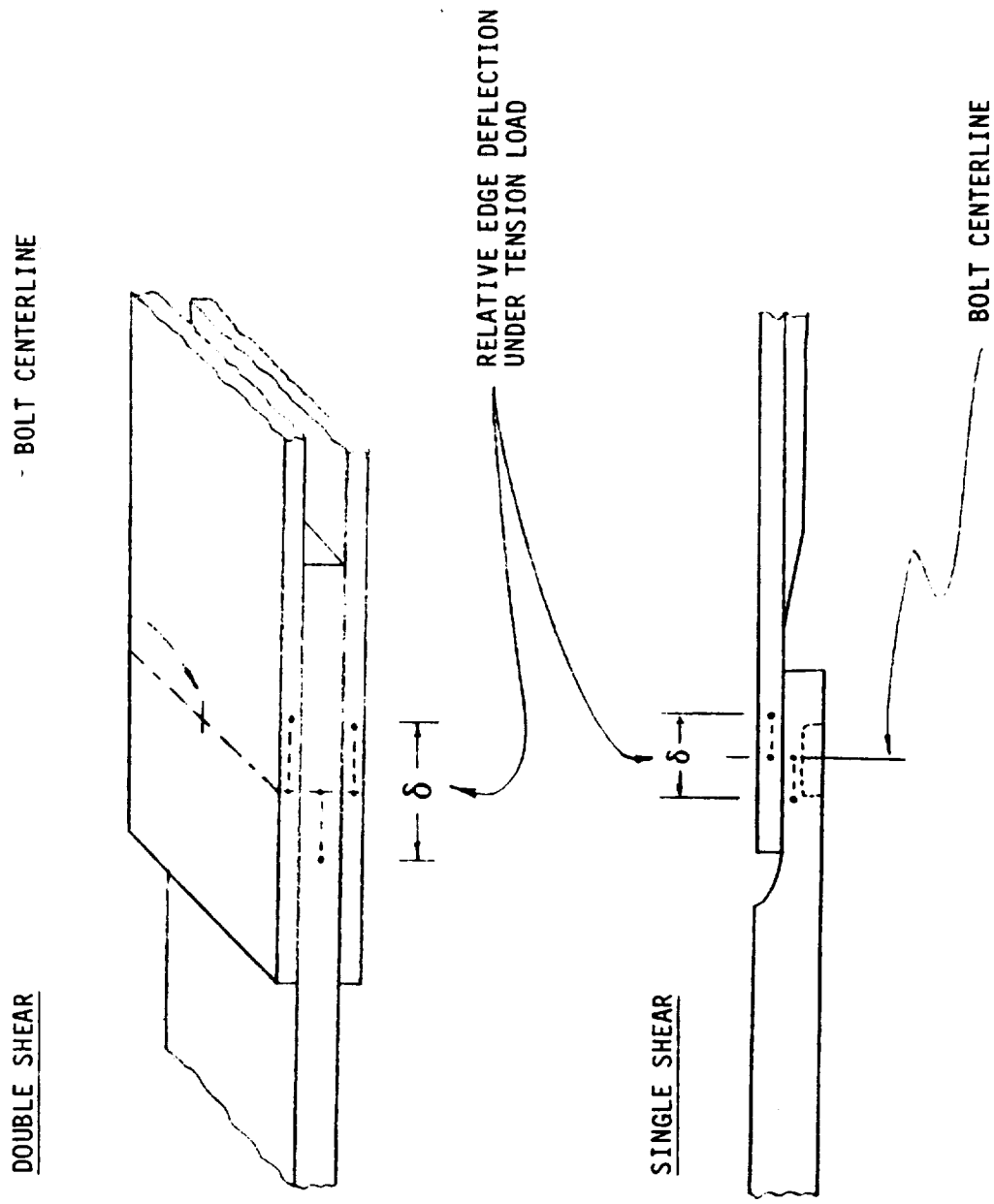

FIGURE 19
DEFINITION OF RELATIVE DEFLECTION MEASUREMENT

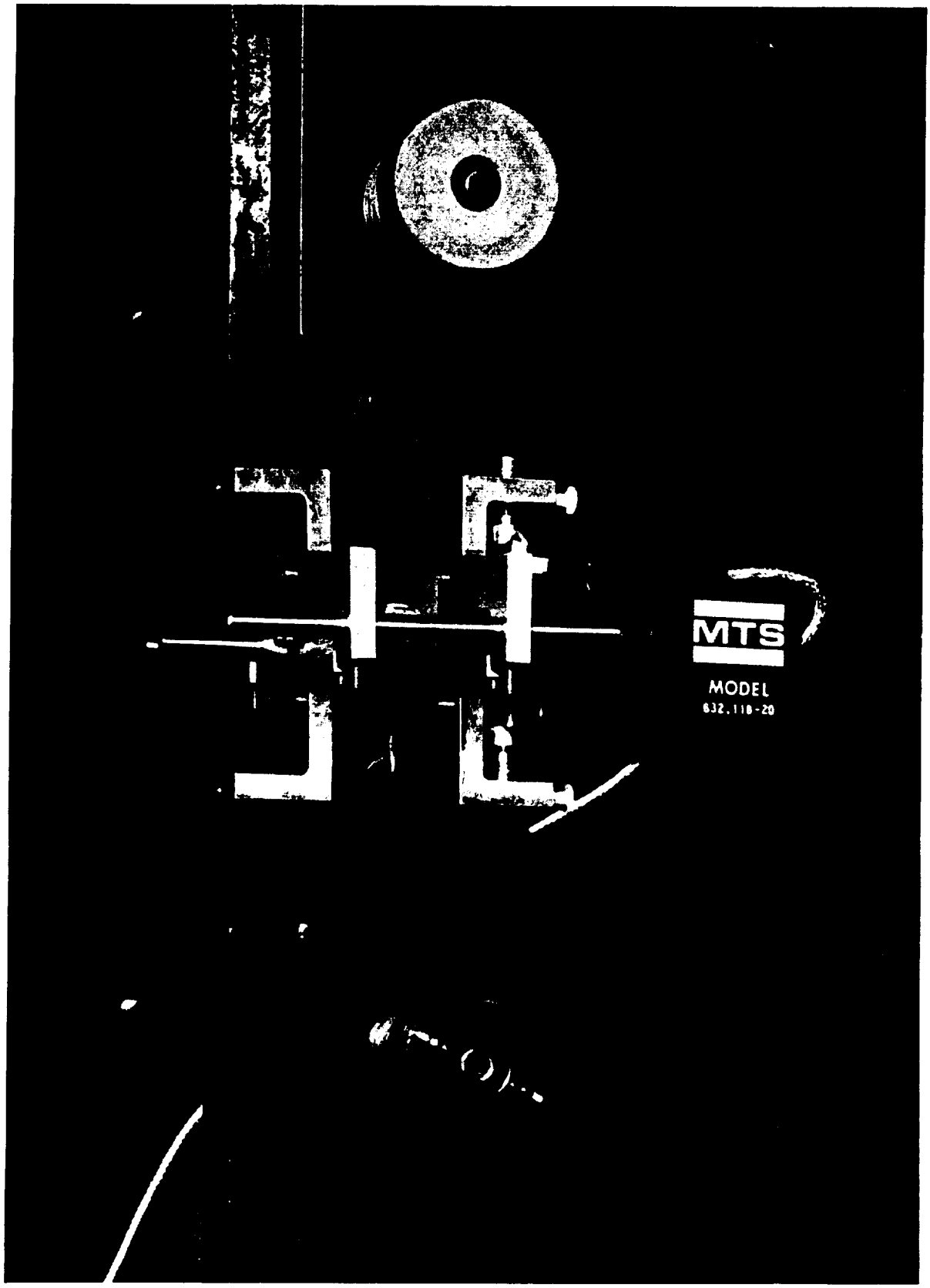

FIGURE 20. DEFLECTION MEASUREMENT DEVICE

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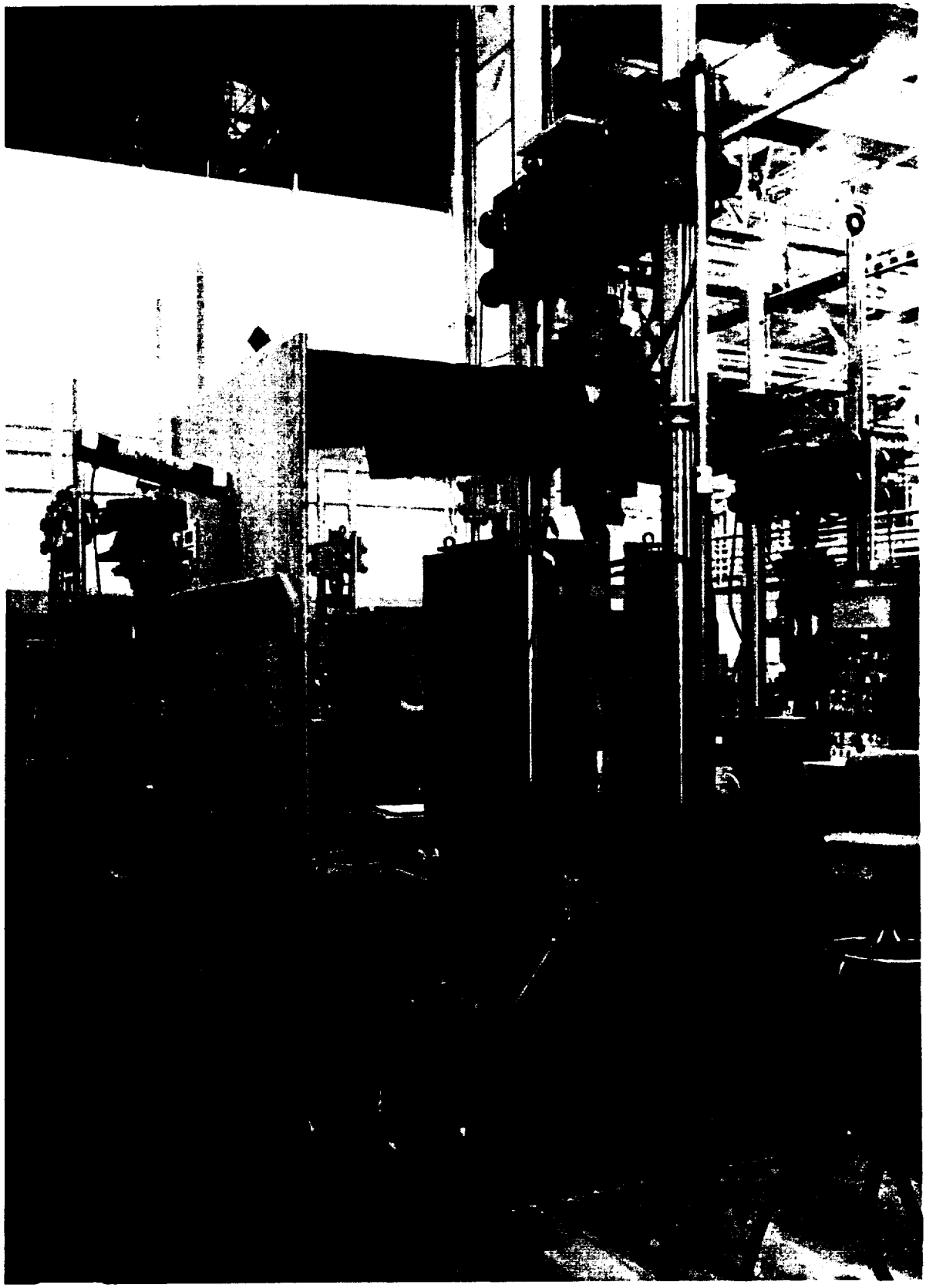

FIGURE 21. SINGLE SHEAR TEST -
MEASUREMENT SYSTEM FOR BOLT HEAD ROTATION

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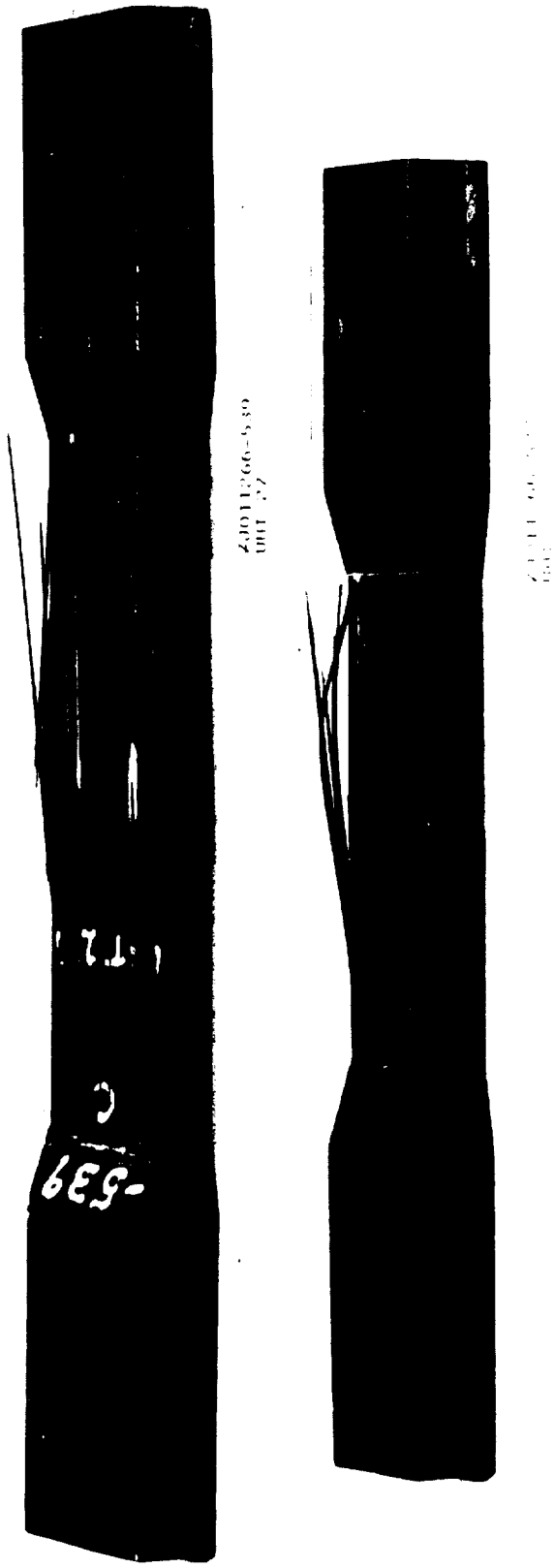

FIGURE 22. UNLOADED HOLE TENSION TEST - NET-SECTION FAILURES

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OF POOR QUALITY

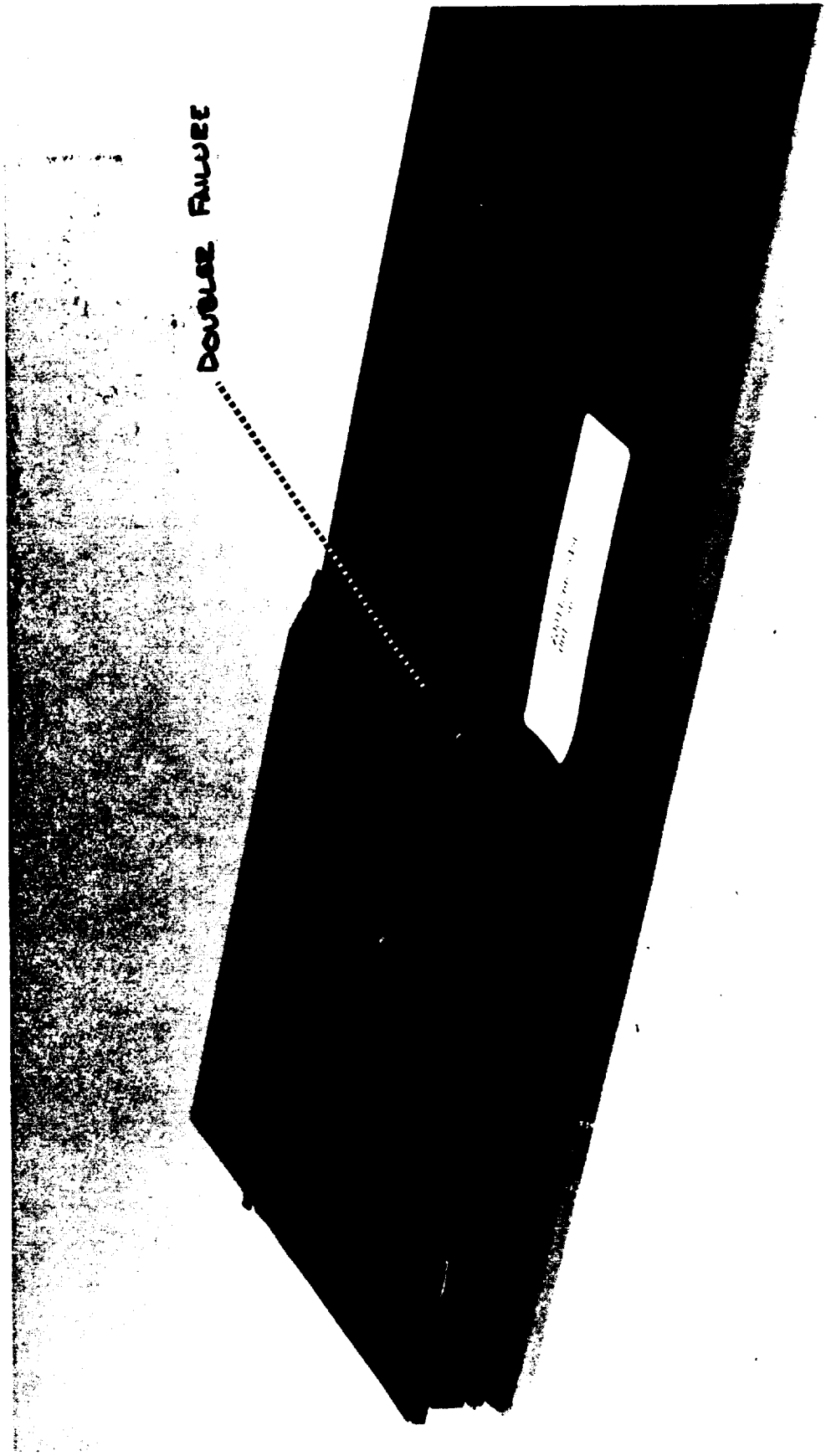

FIGURE 23. UNLOADED HOLE TENSION TEST - BONDED DOUBLER FAILURE

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OF POOR QUALITY

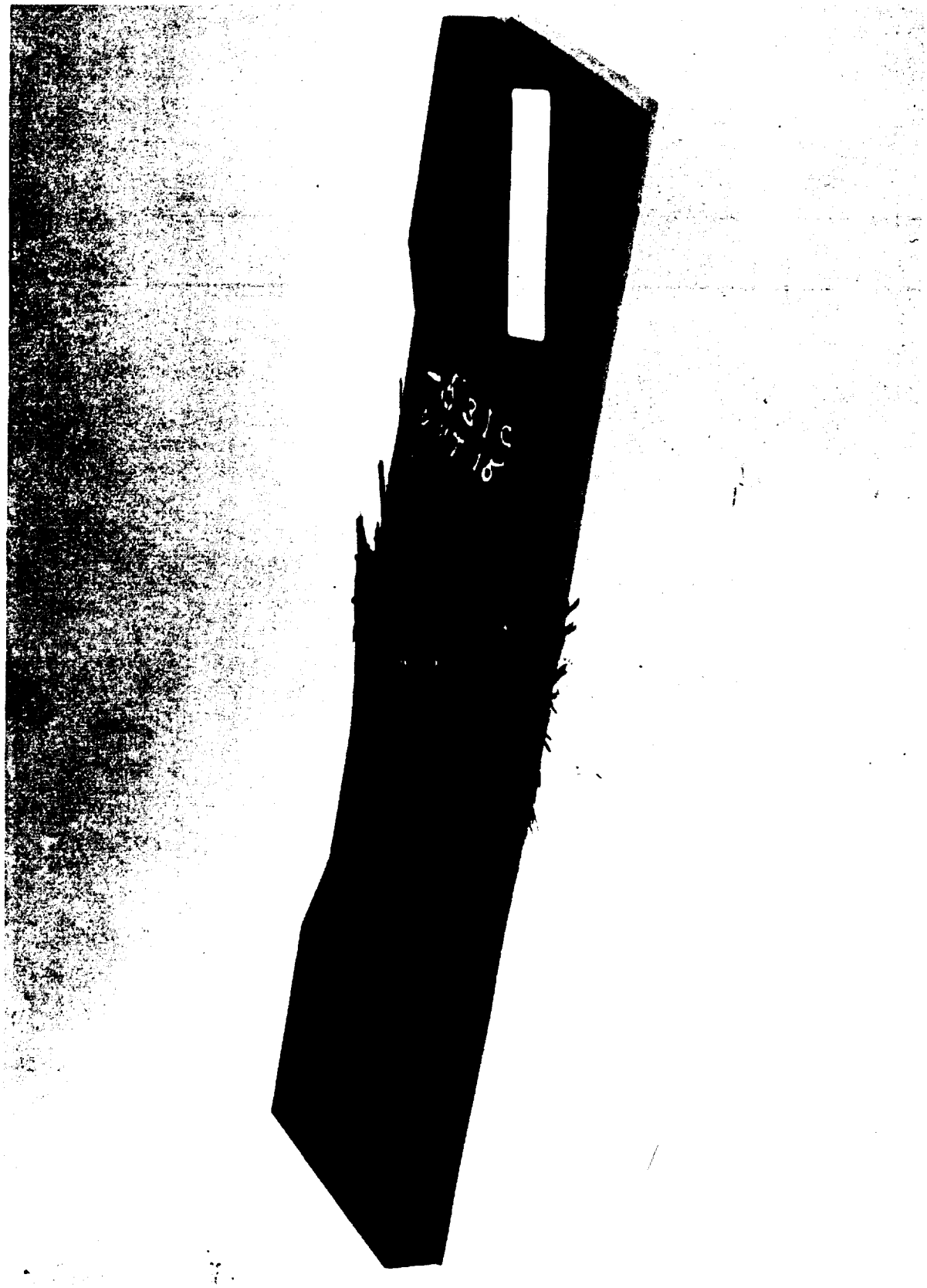

FIGURE 24. UNLOADED HOLE TENSION TEST - NET-SECTION FAILURE

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OF POOR QUALITY

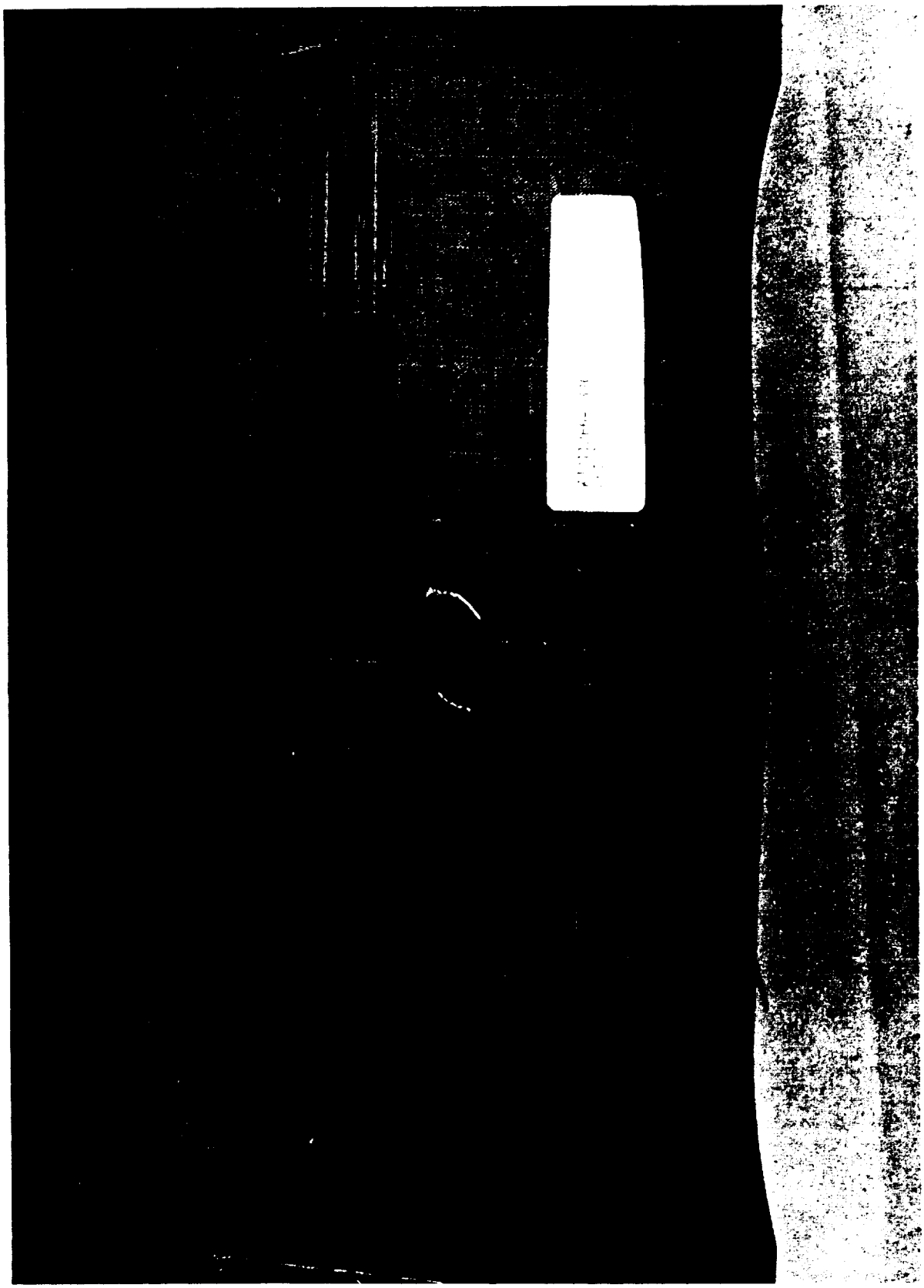

FIGURE 25. UNLOADED HOLE TENSION TEST - (w/d = 6) - NET-SECTION FAILURE

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BLACK AND WHITE PHOTOGRAPH

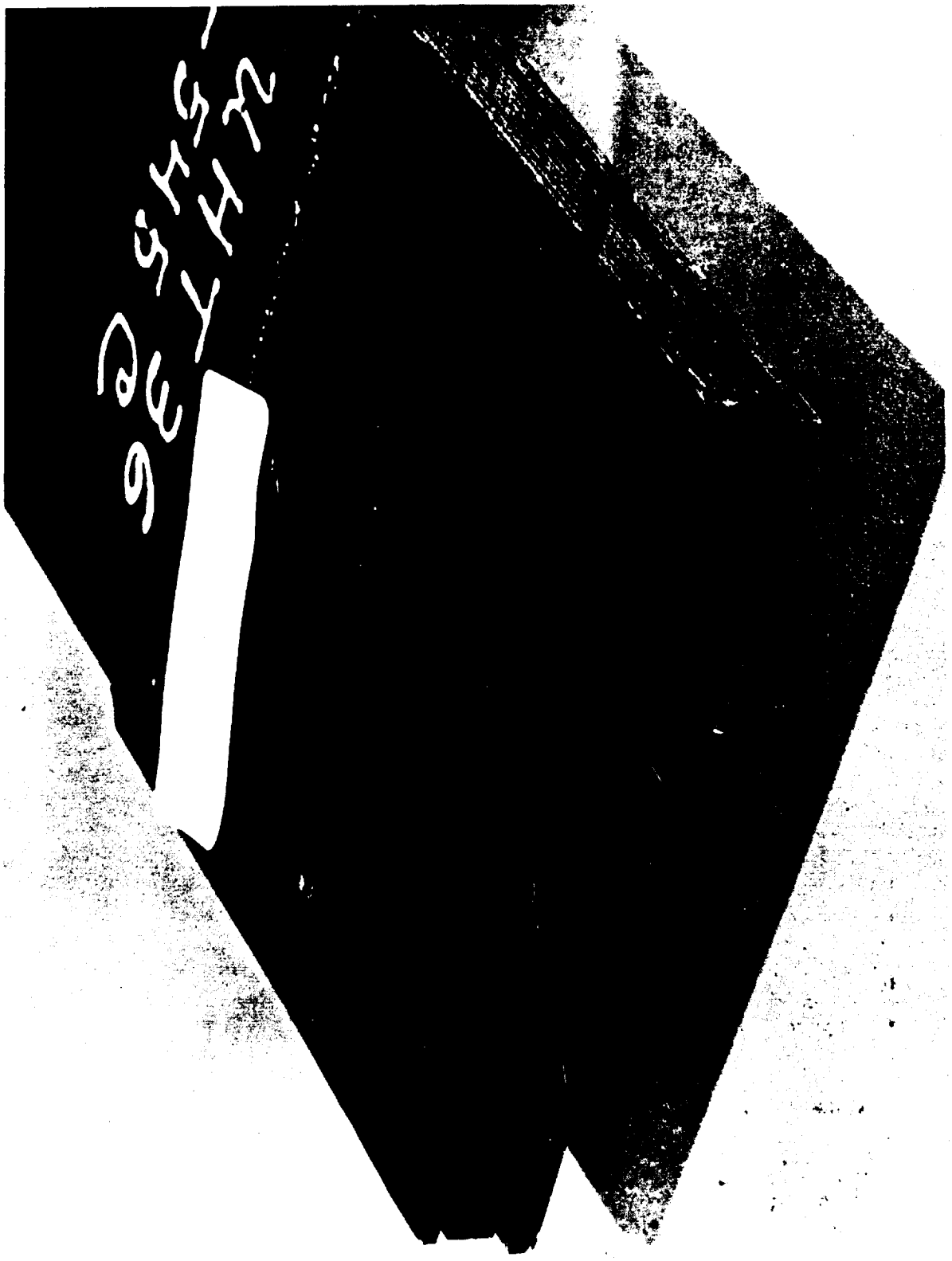

FIGURE 26. UNLOADED HOLE TENSION TEST - BONDED DOUBLER AND END HOLE FAILURE

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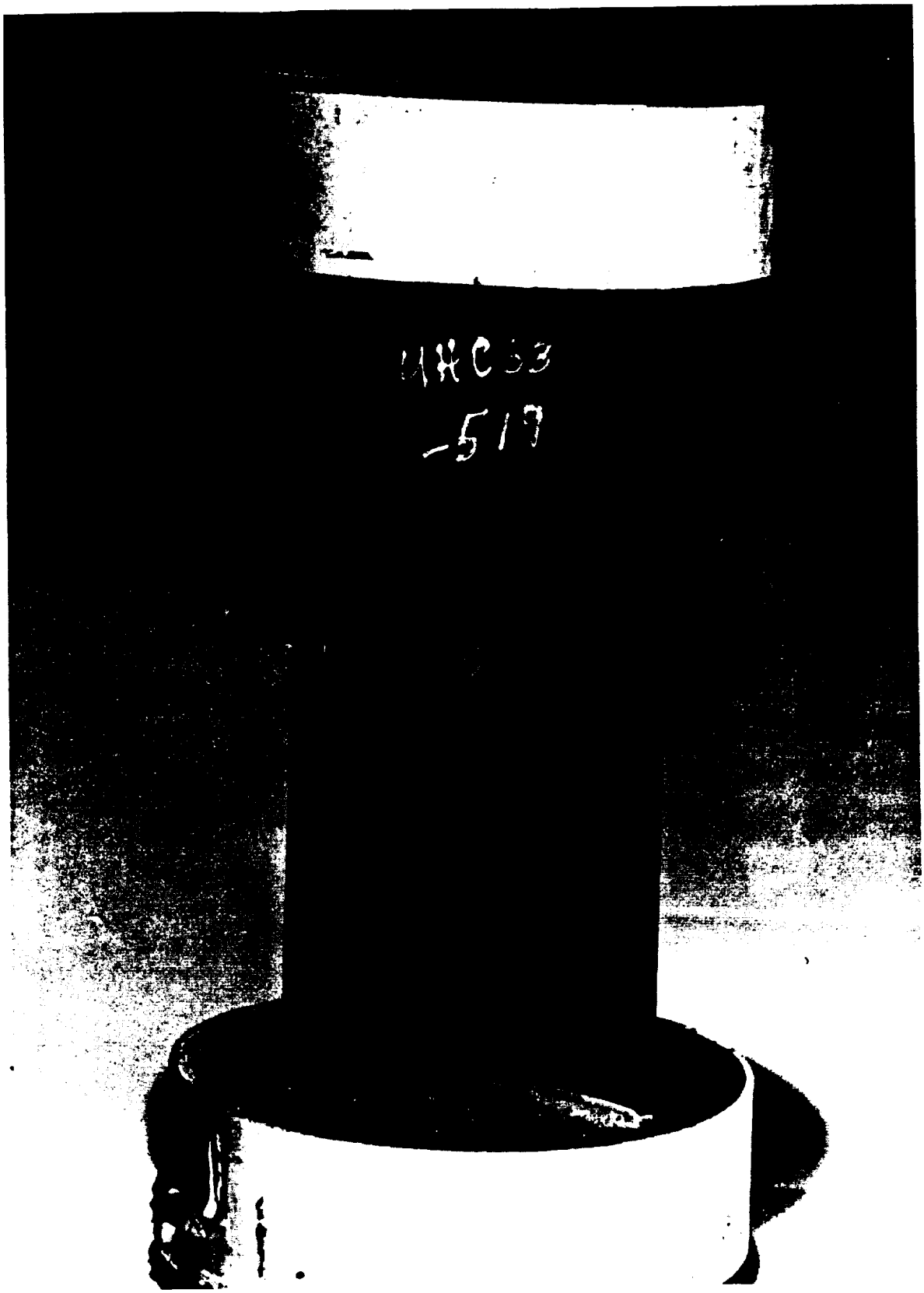

FIGURE 27. UNLOADED HOLE COMPRESSION TEST - NET-SECTION FAILURE

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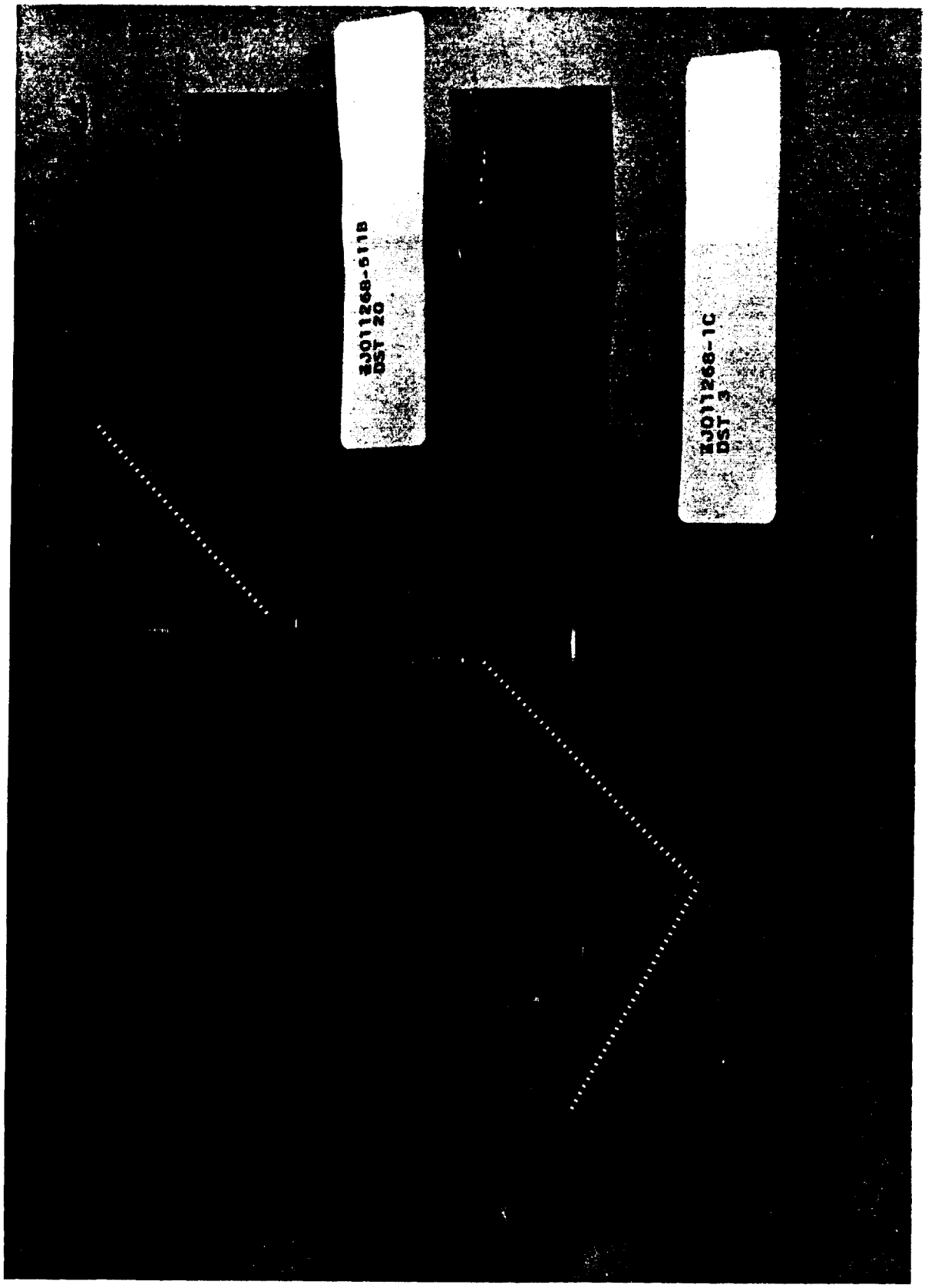

FIGURE 28. DOUBLE SHEAR TENSION TESTS - NET-SECTION FAILURES

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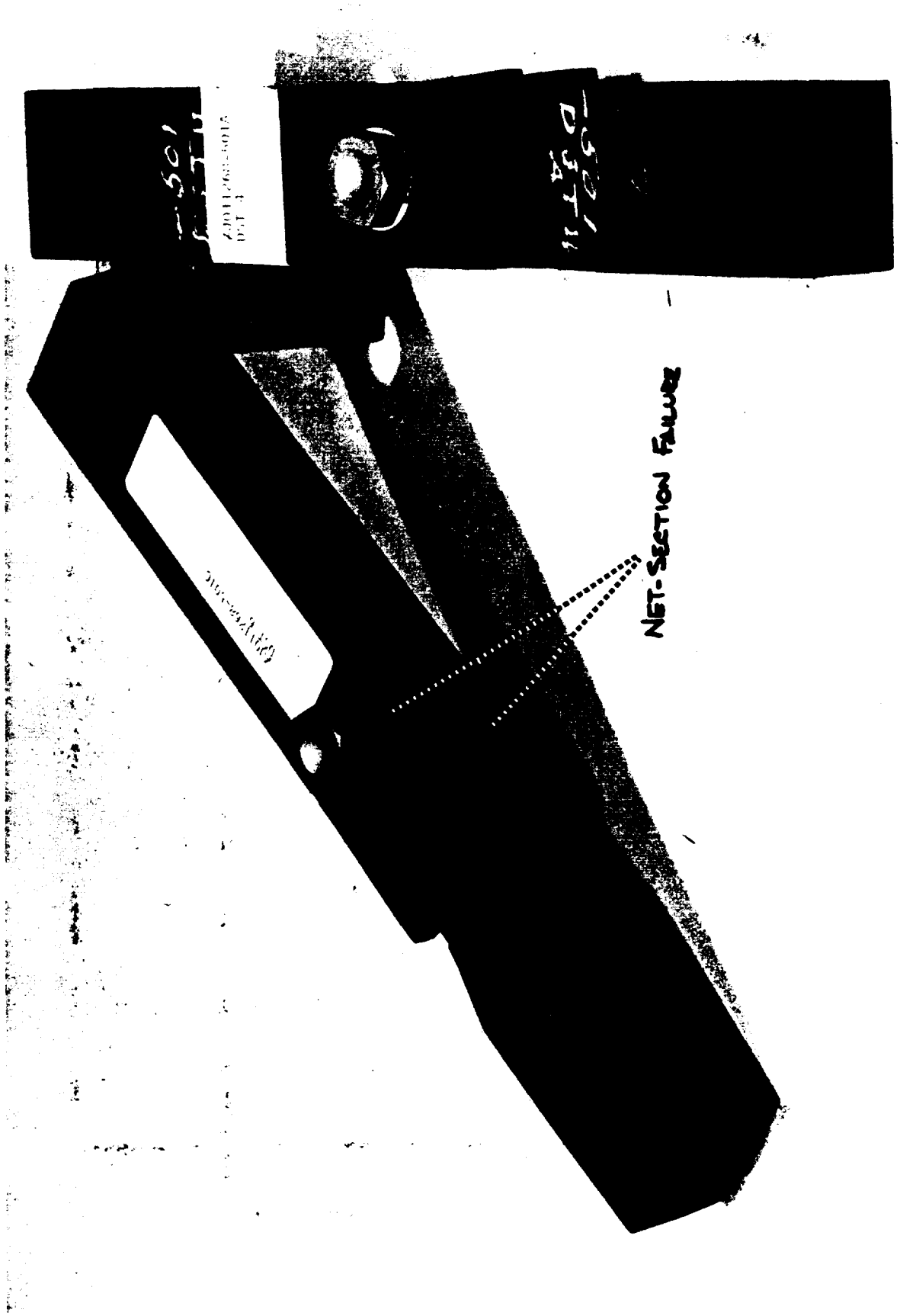

FIGURE 29. DOUBLE SHEAR TENSION TESTS - NET-SECTION FAILURES

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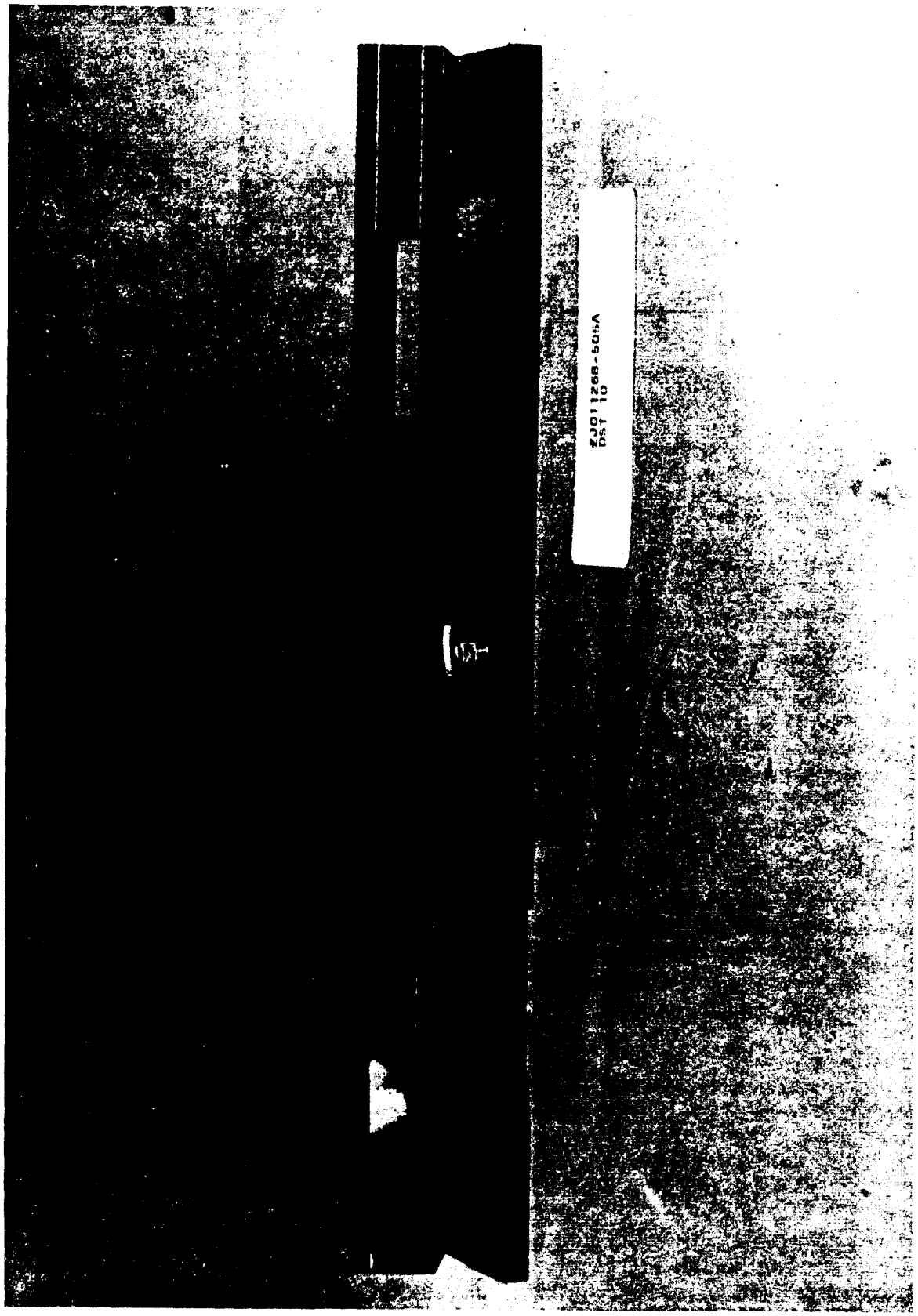

FIGURE 30. DOUBLE SHEAR TENSION TESTS - BOLT BENDING FAILURE

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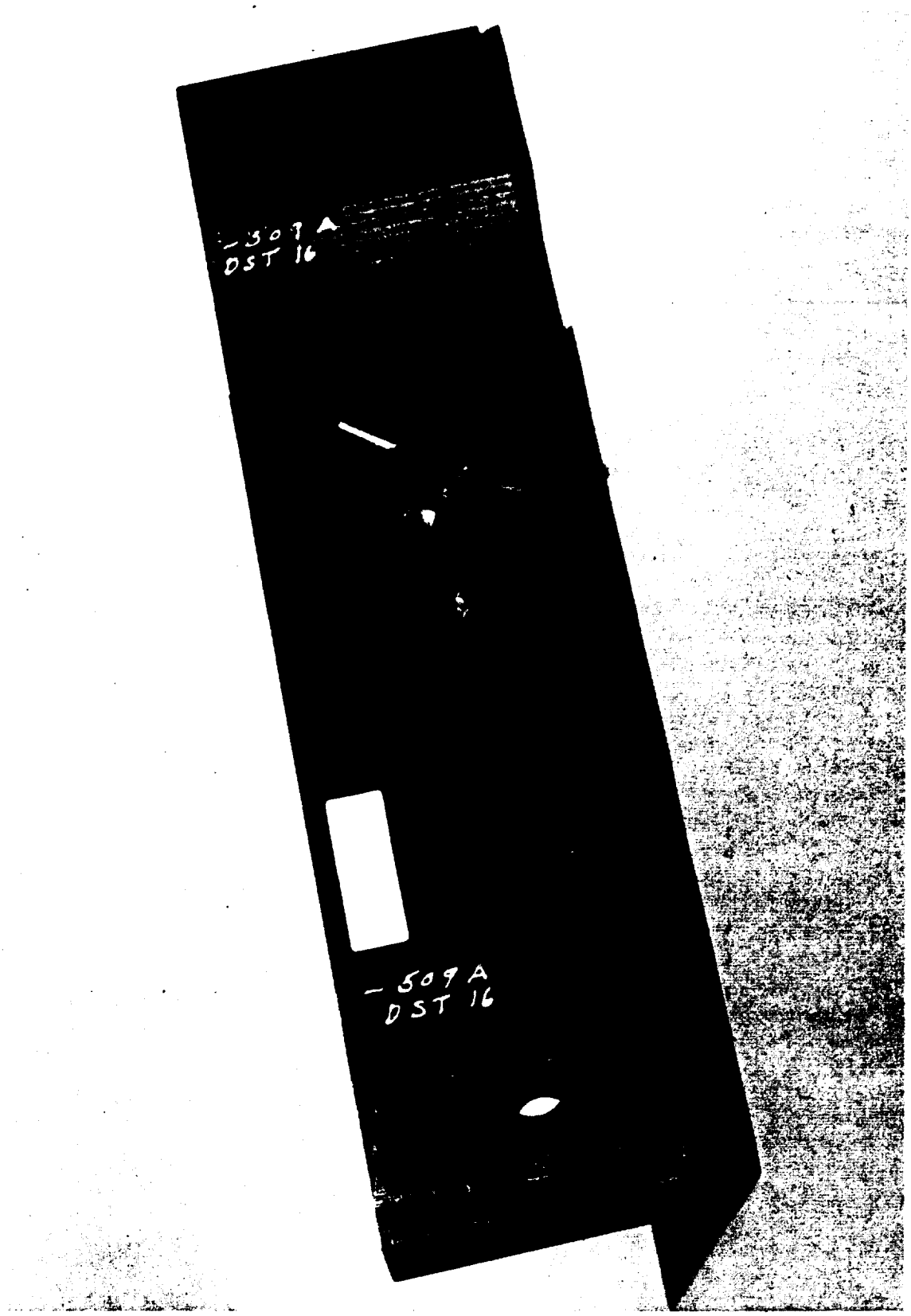

FIGURE 31. DOUBLE SHEAR TENSION TESTS - BEARING FAILURE

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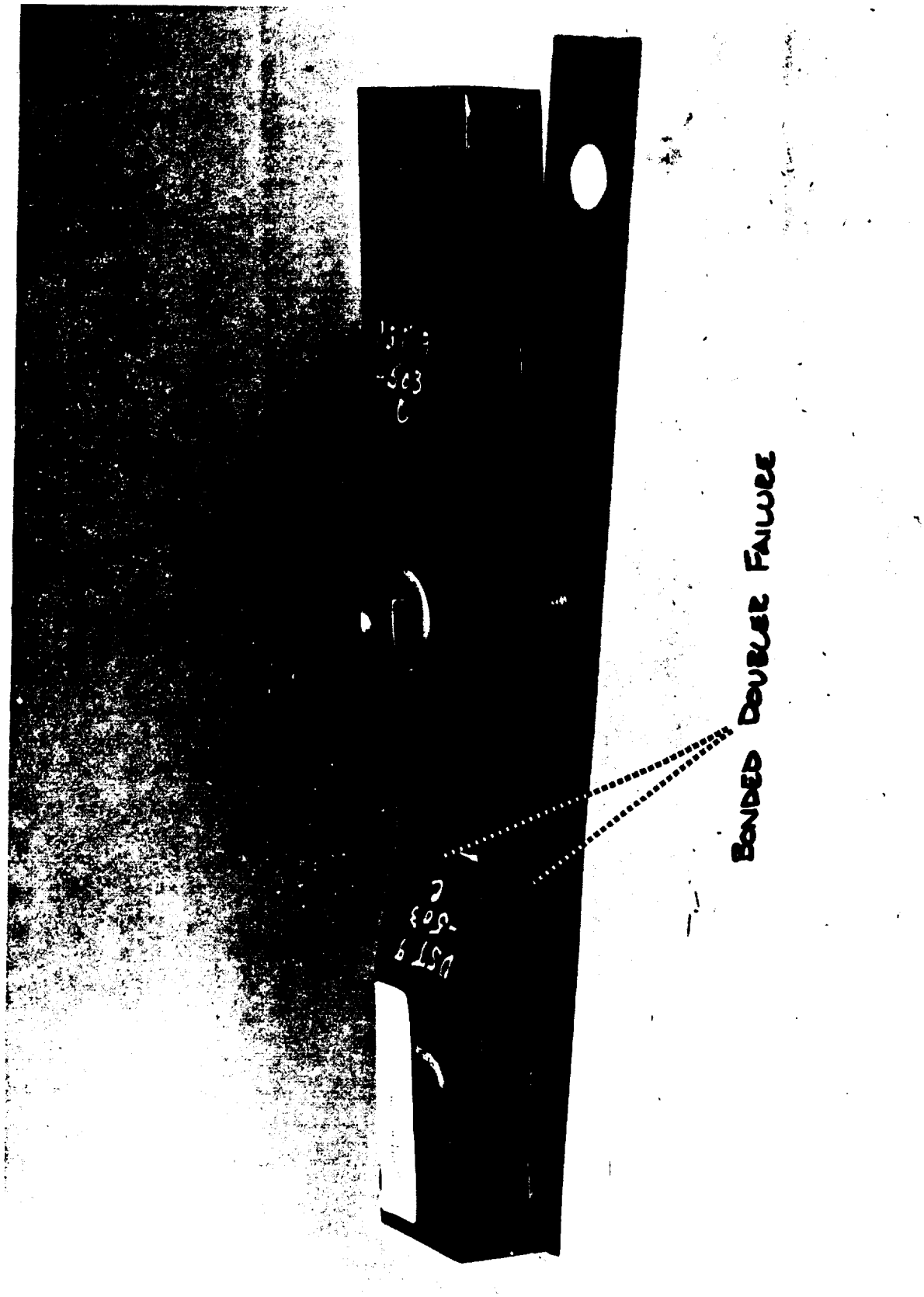

FIGURE 32. DOUBLE SHEAR TENSION TESTS - BONDED DOUBLER FAILURE

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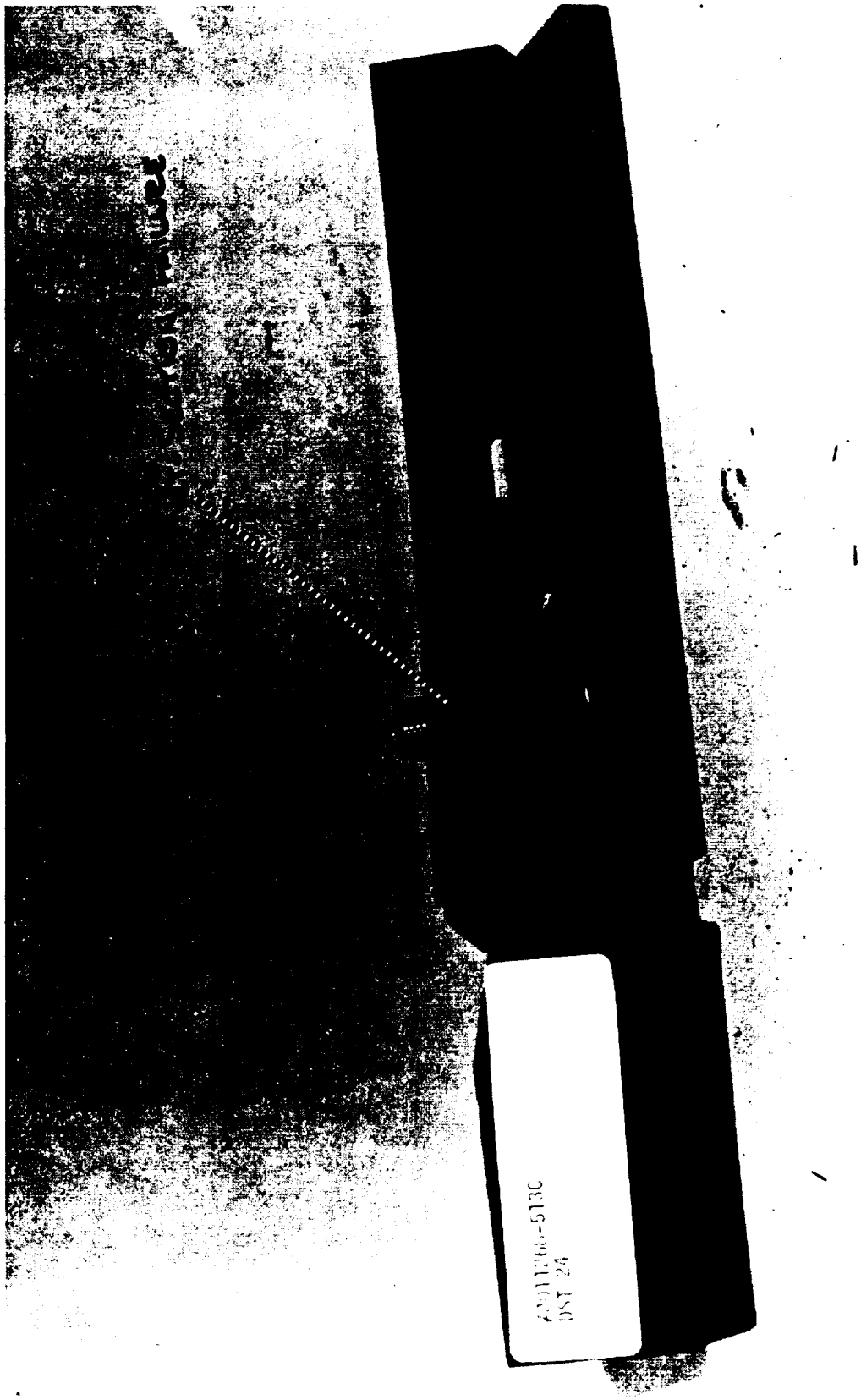

FIGURE 33. DOUBLE SHEAR TENSION TESTS - NET-SECTION FAILURE

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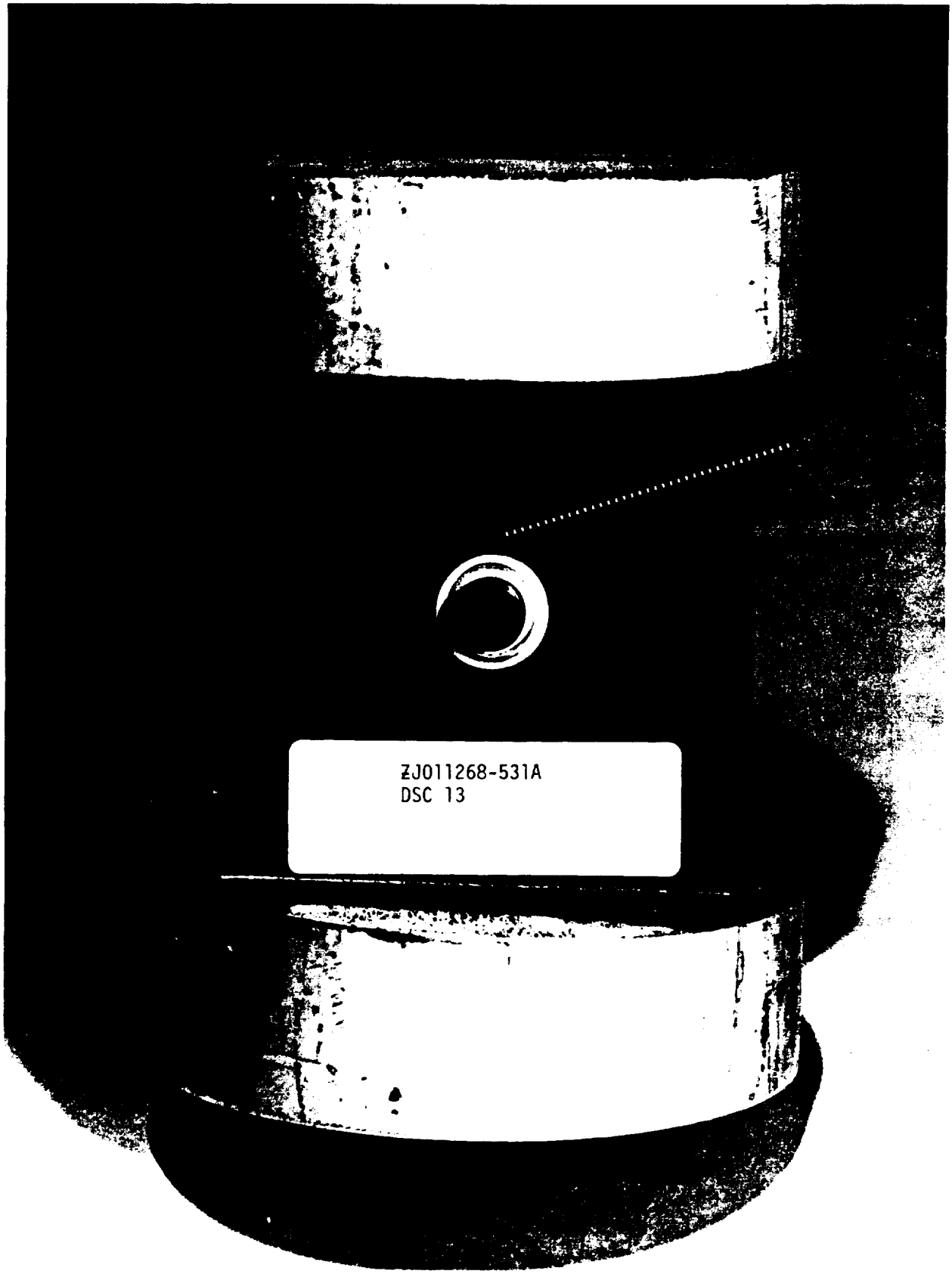

FIGURE 34. DOUBLE SHEAR COMPRESSION TEST - BEARING FAILURE

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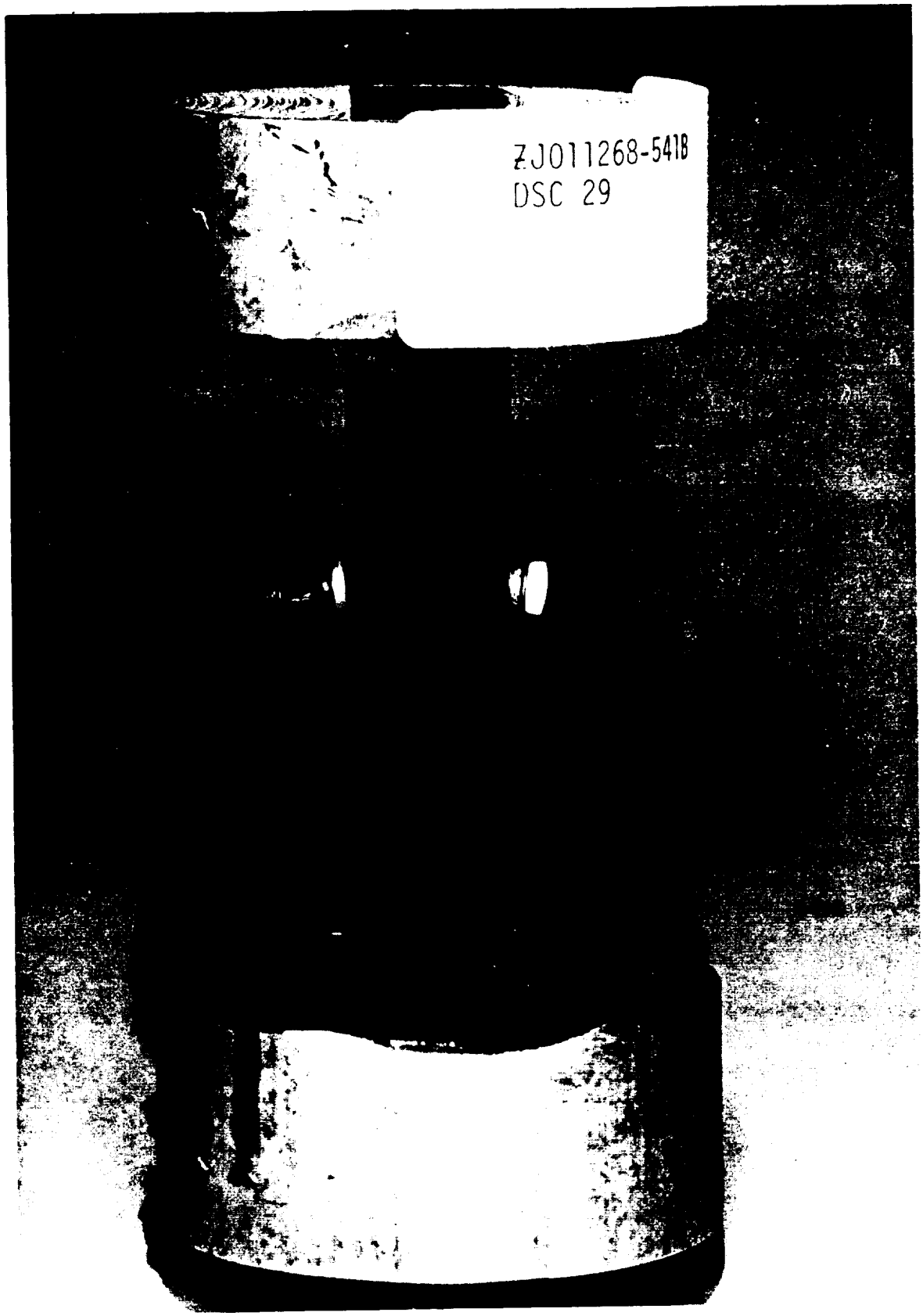

FIGURE 35. DOUBLE SHEAR COMPRESSION TEST - BOLT BENDING FAILURE

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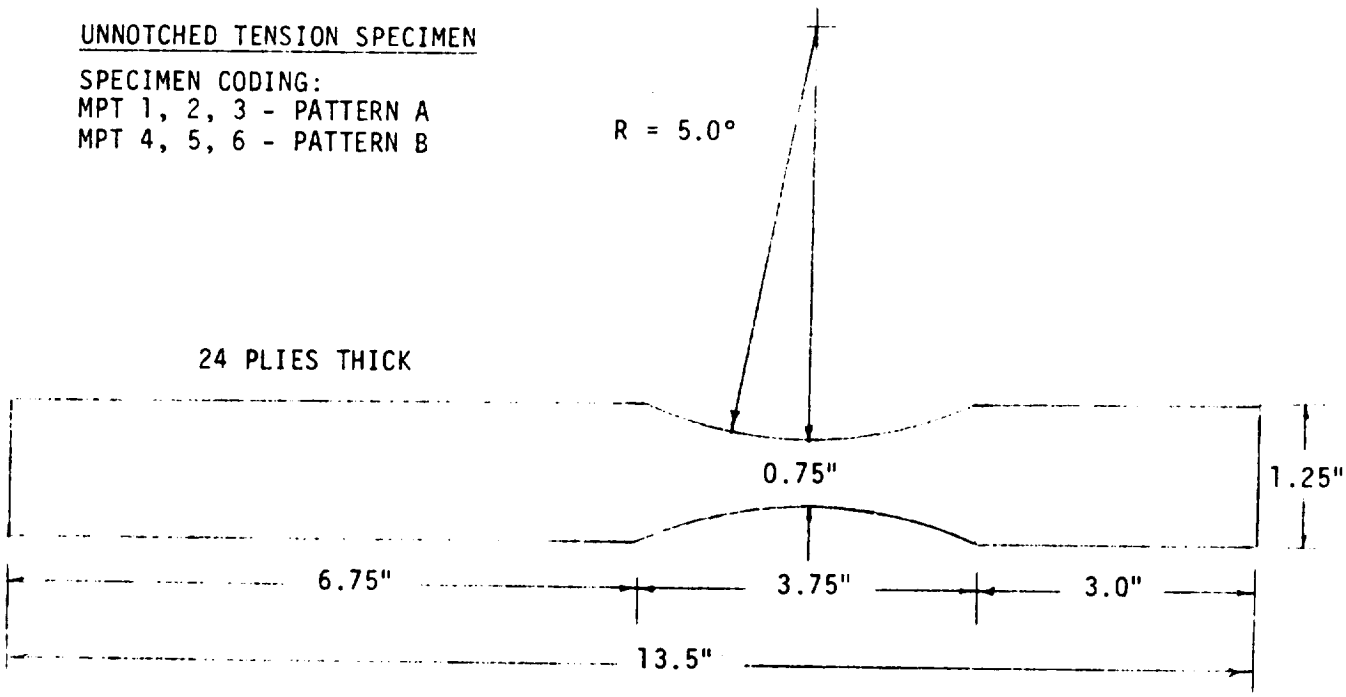
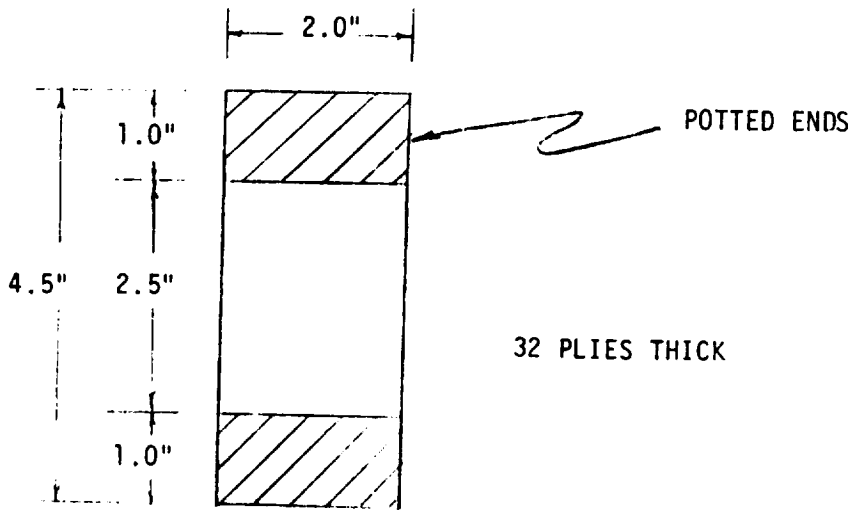
UNNOTCHED TENSION SPECIMEN

SPECIMEN CODING:
MPT 1, 2, 3 - PATTERN A
MPT 4, 5, 6 - PATTERN B





UNNOTCHED COMPRESSION SPECIMEN

SPECIMEN CODING: MPC 1, 2, 3, - PATTERN A
MPT 4, 5, 6, - PATTERN B

FIGURE 36
SPECIMEN CONFIGURATIONS - MECHANICAL PROPERTY TESTS

FIGURE 37. UNNOTCHED COMPRESSION SPECIMEN

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FIGURE 38. UNNOTCHED TENSION SPECIMENS

ORIGINAL PAGE
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Table 1. Ancillary Test Specimen Coding

Specimen Coding	Drawing Number	Conf. No.	Layup Patt.
DST 1,2,3	ZJ011268	-1	
4,5,6		-501	
7,8,9		-503	
10,11,12		-505	A
13,14,15		-507	
16,17,18		-509	
19,20,21		-511	
22,23,24		-513	
25,26,27		-515	B
28,29,30		-517	
31,32,33		-519	
34,35,36		-521	
DSC 1,2,3		-523	
4,5,6		-525	
7,8,9		-527	A
10,11,12		-529	
13,14,15		-531	
16,17,18		-533	
19,20,21		-535	
22,23,24		-537	
25,26,27		-539	B
28,29,30		-541	
31,32,33		-543	
34,35,36	ZJ011268	-545	

Specimen Coding	Drawing Number	Conf. No.	Layup Patt.
SST 1,2,3	ZJ011267	-1	
4,5,6		-501	A
7,8,9		-503	
10,11,12		-505	
13,14,15		-507	B
16,17,18		-509	
SSC 1,2,3		-511	
4,5,6		-513	A
7,8,9		-515	
10,11,12		-517	
13,14,15		-519	B
16,17,18	ZJ011267	-521	

SST - Single Shear Tension
SSC - Single Shear Compression

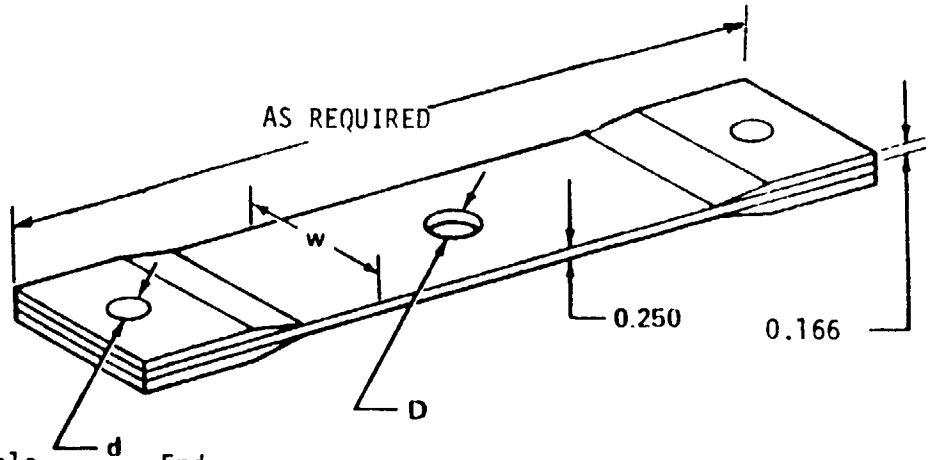
Layup Pattern A
0°, ±45°, 90°
25%, 50%, 25%

Layup Pattern B
0°, ±45°, 90°
37.5%, 50%, 12.5%

Specimen Coding	Drawing Number	Conf. No.	Layup Patt.
UHC 1,2,3	ZJ011266	-1	
4,5,6		-501	
7,8,9		-503	
10,11,12		-505	A
13,14,15		-507	
16,17,18		-509	
19,20,21		-511	
22,23,24		-513	
25,26,27		-515	B
28,29,30		-517	
31,32,33		-519	
34,35,36		-521	
UHT 1,2,3		-523	
4,5,6		-525	
7,8,9		-527	A
10,11,12		-529	
13,14,15		-531	
16,17,18		-533	
19,20,21		-535	
22,23,24		-537	
25,26,27		-539	
28,29,30		-541	B
31,32,33		-543	
34,35,36	ZJ011266	-545	

DST - Double Shear Tension
DSC - Double Shear Compression

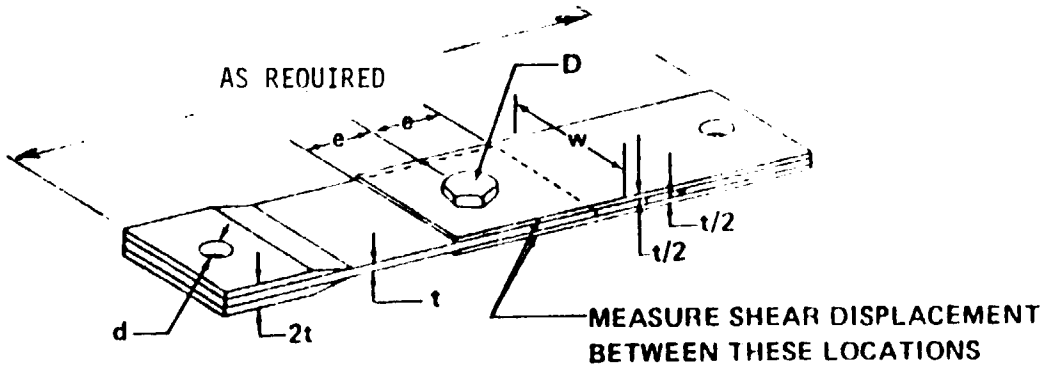
UHT - Unloaded Hole Tension
UHC - Unloaded Hole Compression



No. Specimens	Hole Diameter (D)	End Attachment (d)	Thickness (t)	Width (w)	Layup Pattern	Load Direction
6	0.250	0.250	0.250	0.500	0°, 45°, 90°	
	0.500	0.500		1.000	25%, 50%, 25%	
	0.750	0.750		1.500		
	0.250	0.750		2.00		
	0.500	1.000		4.00		
	0.750	2.000		6.00	0°, 45°, 90°	
					25%, 50%, 25%	Tension and Compression
	0.250	0.250		0.500	0°, 45°, 90°	
	0.500	0.500		1.000	37.5%, 50%, 12.5%	
	0.750	0.750		1.500		
	0.250	0.750		2.000		
	0.500	1.000		4.000		
6	0.750	2.000	0.250	6.000	0°, 45°, 90°	
					37.5%, 50%, 12.5%	
72	TOTAL					

Table 2

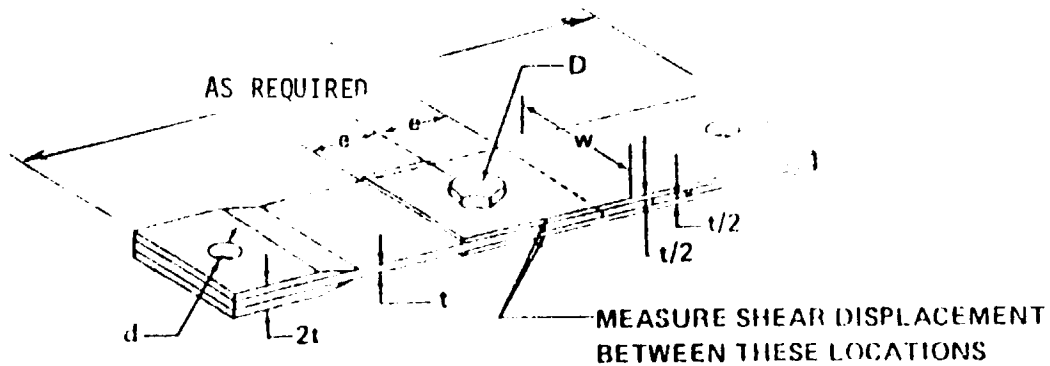
Unloaded Hole Ancillary Test Specimen
Dimensions in Customary Units (Inches)
Tension Specimen Shown



No. Specimens	Edge Distance (e)	Center Attachment Diameter (D)	End Attachment Diameter (d)	Thickness (t)	Width (w)	Layup Pattern	Load Direction
3	0.75	0.250	0.312	0.333	0.75	0°, 45°, 90°	
	1.50	0.500	0.625	0.500	1.50	25%, 50%, 25%	
	2.25	0.750	1.000	0.666	2.25		
	2.00	0.250	0.500	0.333	2.00		
	4.00	0.500	0.750	0.500	4.00		
	6.00	0.750	2.000	0.666	6.00	0°, 45°, 90°	
						25%, 50%, 25%	Tension
	0.75	0.250	0.312	0.333	0.75	0°, 45°, 90°	
	1.50	0.500	0.625	0.500	1.50	37.5%, 50%, 12.5%	
	2.25	0.750	1.000	0.666	2.25		
	2.00	0.250	0.500	0.333	2.00		
	4.00	0.500	0.750	0.500	4.00		
3	6.00	0.750	2.000	0.666	6.00	0°, 45°, 90°	
						37.5%, 50%, 12.5%	
36	Total						

Table 3.

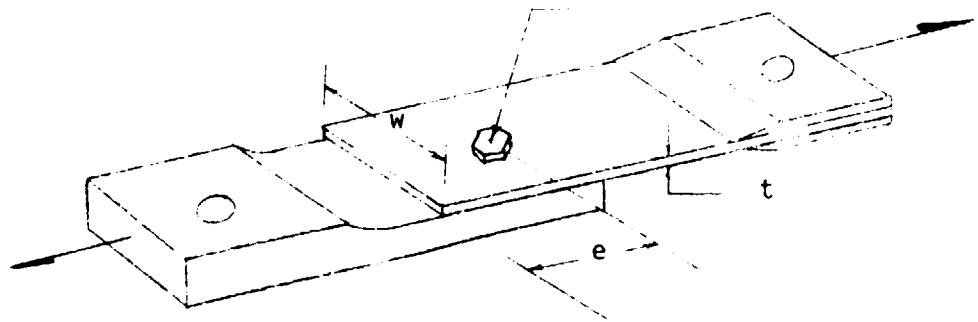
Double Shear Ancillary Tension Specimen
Dimensions Shown in Customary Units (Inches)
(Tension Specimen Shown)



No. Specimens	Edge Distance (e)	Center Attachment Diameter (D)	Thickness (t)	Width (w)	Layup Pattern	Load Direction
3	0.750	0.250	0.333	0.75	0°, 45°, 90°	
	0.750	0.500	0.500	1.50	25%, 50%, 25%	
	1.125	0.750	0.666	2.25		
	0.750	0.250	0.333	2.00		
	0.750	0.500	0.500	4.00		
	1.125	0.750	0.666	6.00	0°, 45°, 90°	
					25%, 50%, 25%	Compression
	0.750	0.250	0.333	0.75	0°, 45°, 90°	
	0.750	0.500	0.500	1.50	37.5%, 50%, 12.5%	
	1.125	0.750	0.666	2.25		
	0.750	0.250	0.333	2.00		
	0.750	0.500	0.500	4.00		
3	1.125	0.750	0.666	6.00	0°, 45°, 90°	
					37.5%, 50%, 12.5%	
36	TOTAL					

Table 4.

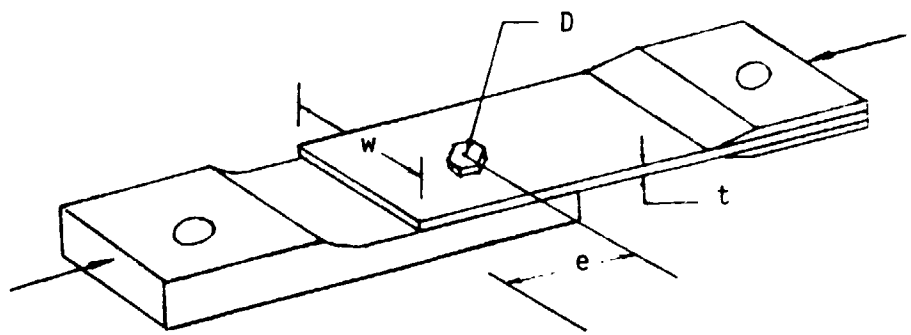
Double Shear Ancillary Compression Specimen
Dimensions Shown in Customary Units (Inches)
(Tension Specimen Shown)



No. Specimens	Edge Distance (e)	Attachment Diameter (D)	Thickness (t)	Width (w)	Layup Pattern	Load Direction
3	2.00	0.250	0.333	2.00	0°, 45°, 90° 25%, 50%, 25%	Tension
	4.00	0.500	0.500	4.00		
	6.00	0.750	0.666	6.00	0°, 45°, 90° 25%, 50%, 25%	
	2.00	0.250	0.333	2.00	0°, 45°, 90° 37.5%, 50%, 12.5%	
	4.00	0.500	0.500	4.00		
3	6.00	0.750	0.666	6.00	0°, 45°, 90° 37.5%, 50%, 12.5%	
18	Total					

Table 5

Single Shear Ancillary Tension Specimen
Dimensions Shown in Customary Units (Inches)



No. Specimens	Edge Distance (e)	Attachment Diameter (D)	Thickness (t)	Width (w)	Layup Pattern	Load Direction
3	1.00	0.250	0.333	2.00	0°, 45°, 90° 25%, 50%, 25%	Compression
	2.00	0.500	0.500	4.00		
	3.00	0.750	0.666	6.00	0°, 45°, 90° 25%, 50%, 25%	
	1.00	0.250	0.333	2.00	0°, 45°, 90° 37.5%, 50%, 12.5%	
	2.00	0.500	0.500	4.00		
3	3.00	0.750	0.666	6.00	0°, 45°, 90° 37.5%, 50%, 12.5%	
18	TOTAL					

Table 6

Single Shear Ancillary Compression Specimen
Dimensions Shown in Customary Units (Inches)

Table 7. Ancillary Test Specimen Loading Rates

Double Shear ZJ011268			Single Shear ZJ011267			Unloaded Hole ZJ011266		
Config.	δ (in/min)	P (lb/min)	Config.	δ (in/min)	P (lb/min)	Config.	δ (in/min)	P (lb/min)
-1	.02	6,000	-1	.010	4,360	-1	.007	3,000
-501	.022	18,000	-501	.021	17,500	-501	.009	6,000
-503	.034	36,000	-503	.024	35,000	-503	.010	9,000
-505	.018	12,000	-505	.010	4,368	-505	.015	12,000
-507	.027	35,000	-507	.021	17,500	-507	.03	24,000
-509	.044	70,000	-509	.024	35,000	-509	.056	36,000
-511	.02	7,500	-511	.010	4,368	-511	.007	3,750
-513	.022	22,500	-513	.021	17,500	-513	.009	7,500
-515	.034	45,000	-515	.024	35,000	-515	.010	11,250
-517	.015	12,000	-517	.010	4,368	-517	.015	15,000
-519	.022	35,000	-519	.021	17,500	-519	.03	30,000
-521	.035	70,000	-521	.024	35,000	-521	.045	45,000
-523	.015	6,000				-523	.018	3,000
-525	.015	18,000				-525	.018	6,000
-527	.015	36,000				-527	.021	9,000
-529	.011	12,000				-529	.019	12,000
-531	.015	35,000				-531	.036	24,000
-533	.015	70,000				-533	.048	36,999
-535	.015	7,500				-535	.018	3,750
-537	.015	22,500				-537	.018	7,500
-539	.015	45,000				-539	.021	11,250
-541	.009	12,000				-541	.019	15,000
-543	.013	35,000				-543	.036	30,000
-545	.016	70,000				-545	.048	45,000

δ : is the stroke loading rate - inches per minute

P : is the estimated rate of applied load in pounds per minute for the specified δ

TABLE 8

UNLOADED HOLE TENSION SPECIMENS

FIBER PATTERN A - (25% 0°,50% ±45°,25% 90°)

U.S. CUSTOMARY UNITS

SPECIMEN NUMBER	HOLE DIAM. IN.	PANEL WIDTH IN.	W/D RATIO	PANEL THICK. IN.	FAILURE LOAD LB	FAILURE MODE	NET-SECT. STRESS KSI	GROSS-SECT. STRESS KSI
UHT- 1	0.250	0.503	2.0	0.254	3040.0	TENS	47.31	23.79
UHT- 2	0.250	0.503	2.0	0.254	3220.0	TENS	50.11	25.20
UHT- 3	0.250	0.503	2.0	0.254	3160.0	TENS	49.17	24.73
UHT- 4	0.500	0.995	2.0	0.245	5680.0	TENS	46.34	23.30
UHT- 5	0.500	0.995	2.0	0.240	6000.0	TENS	50.51	25.13
UHT- 6	0.500	0.998	2.0	0.245	6075.0	TENS	49.79	24.85
UHT- 7	0.750	1.493	2.0	0.247	8965.0	TENS	48.85	24.31
UHT- 8	0.750	1.493	2.0	0.247	9510.0	TENS	51.82	25.79
UHT- 9	0.750	1.493	2.0	0.244	8700.0	TENS	47.99	23.88
UHT-10	0.250	2.001	8.0	0.245	27200.0	TENS	63.40	55.48
UHT-11	0.250	2.005	8.0	0.250	23000.0	DBLR	52.42	45.89
UHT-12	0.250	2.000	8.0	0.250	25625.0	DBLR	58.57	51.25
UHT-13	0.500	4.002	8.0	0.244	32100.0	DBLR	37.57	32.87
UHT-14	0.500	4.000	8.0	0.244	38500.0	DBLR	45.08	39.45
UHT-15	0.500	4.000	8.0	0.243	50000.0	TENS	58.79	51.44
UHT-16	0.750	4.500	6.0	0.245	49300.0	TENS	53.66	44.72
UHT-17	0.750	4.500	6.0	0.244	51100.0	TENS	55.85	46.54
UHT-18	0.750	4.500	6.0	0.245	50600.0	TENS	55.07	45.90

TENS = TENSION
COMP = COMPRESSION
BRNG = BEARING
B/B = BOLT BENDING
DBLR = DOUBLER

TABLE 9

UNLOADED HOLE TENSION SPECIMENS

FIBER PATTERN B - (37.5% 0°, 50% ±45°, 12.5% 90°)

U.S. CUSTOMARY UNITS

SPECIMEN NUMBER	HOLE DIAM. IN.	PANEL WIDTH IN.	W/D RATIO	PANEL THICK. IN.	FAILURE LOAD LB	FAILURE MODE	NET-SECT. STRESS KSI	GROSS-SECT. STRESS KSI
UHT-19	0.250	0.485	2.0	0.251	4190.0	TENS	71.04	34.42
UHT-20	0.250	0.490	2.0	0.251	4500.0	TENS	74.70	36.59
UHT-21	0.250	0.495	2.0	0.251	4500.0	TENS	73.18	36.22
UHT-22	0.500	0.999	2.0	0.242	8470.0	TENS	70.14	35.04
UHT-23	0.500	1.000	2.0	0.242	8600.0	TENS	71.07	35.54
UHT-24	0.500	0.995	2.0	0.240	8520.0	TENS	71.72	35.68
UHT-25	0.750	1.446	2.0	0.246	12500.0	TENS	73.01	35.14
UHT-26	0.750	1.445	2.0	0.243	12900.0	TENS	76.38	36.74
UHT-27	0.750	1.444	2.0	0.246	12820.0	TENS	75.09	36.09
UHT-28	0.250	1.995	8.0	0.246	20750.0	DBLR	48.34	42.28
UHT-29	0.250	1.998	8.0	0.242	25400.0	DBLR	60.05	52.53
UHT-30	0.250	2.000	8.0	0.244	28650.0	DBLR	67.10	58.71
UHT-31	0.500	4.000	8.0	0.240	49350.0	DBLR	58.75	51.41
UHT-32	0.500	3.999	8.0	0.241	47300.0	DBLR	56.09	49.08
UHT-33	0.500	4.002	8.0	0.239	53000.0	DBLR	63.32	55.41
UHT-34	0.750	5.993	8.0	0.240	66800.0	DBLR	53.09	46.44
UHT-35	0.750	5.992	8.0	0.243	49300.0	DBLR	38.70	33.86
UHT-36	0.750	5.996	8.0	0.244	70500.0	DBLR	55.08	48.19

TENS = TENSION
COMP = COMPRESSION
BRNG = BEARING
B/B = BOLT BENDING
DBLR = DOUBLER

TABLE 10

UNLOADED HOLE TENSION SPECIMENS

FIBER PATTERN 4 - (25% 0°, 50% ±45°, 25% 90°)

S.I. UNITS

SPECIMEN NUMBER	HOLE DIAM. MM.	PANEL WIDTH MM.	W/D RATIO	PANEL THICK. MM.	FAILURE LOAD KNEWTON	FAILURE MODE	NET-SECT. STRESS MPASCAL	GROSS-SECT. STRESS MPASCAL
UHT- 1	6.35	12.78	2.0	6.45	13.63	TENS	326.2	164.1
UHT- 2	6.35	12.78	2.0	6.45	14.43	TENS	345.5	173.8
UHT- 3	6.35	12.78	2.0	6.45	14.16	TENS	339.0	170.5
UHT- 4	12.70	25.27	2.0	6.22	25.46	TENS	322.9	160.6
UHT- 5	12.70	25.27	2.0	6.10	26.89	TENS	348.2	173.2
UHT- 6	12.70	25.35	2.0	6.22	27.23	TENS	343.3	171.3
UHT- 7	19.05	37.92	2.0	6.27	40.18	TENS	336.8	167.6
UHT- 8	19.05	37.92	2.0	6.27	42.63	TENS	357.3	177.8
UHT- 9	19.05	37.92	2.0	6.20	39.00	TENS	330.9	164.7
UHT-10	6.35	50.83	8.0	6.22	121.92	TENS	437.2	382.5
UHT-11	6.35	50.93	8.0	6.35	103.09	DBLR	361.4	316.4
UHT-12	6.35	50.80	8.0	6.35	114.86	DBLR	403.8	353.4
UHT-13	12.70	101.65	8.0	6.20	143.88	DBLR	259.0	226.7
UHT-14	12.70	101.60	8.0	6.20	172.56	DBLR	310.6	272.0
UHT-15	12.70	101.60	8.0	6.17	224.11	TENS	405.3	354.7
UHT-16	19.05	114.30	6.0	6.22	220.97	TENS	370.0	308.3
UHT-17	19.05	114.30	6.0	6.20	229.04	TENS	385.1	320.9
UHT-18	19.05	114.30	6.0	6.22	226.80	TENS	379.7	316.4

TENS = TENSION
COMP = COMPRESSION
BRNG = BEARING
B/B = BOLT BENDING
DBLR = DOUBLER

TABLE 11

UNLOADED HOLE TENSION SPECIMENS

FIBER PATTERN B - (37.5% 0°,50% ±45°,12.5% 90°)

S.I. UNITS

SPECIMEN NUMBER	HOLE DIAM. MM.	PANEL WIDTH MM.	W/D RATIO	PANEL THICK. MM.	FAILURE LOAD KNEWTON	FAILURE MODE	NET-SECT. STRESS MPASCAL	GROSS-SECT. STRESS MPASCAL
UHT-19	6.35	12.32	2.0	6.38	18.78	TENS	489.8	237.3
UHT-20	6.35	12.45	2.0	6.38	20.17	TENS	515.0	252.3
UHT-21	6.35	12.57	2.0	6.38	20.17	TENS	504.5	249.7
UHT-22	12.70	25.37	2.0	6.15	37.96	TENS	483.6	241.6
UHT-23	12.70	25.40	2.0	6.15	38.55	TENS	490.0	245.0
UHT-24	12.70	25.27	2.0	6.10	38.19	TENS	494.5	246.0
UHT-25	19.05	36.73	2.0	6.25	56.03	TENS	503.4	242.3
UHT-26	19.05	36.70	2.0	6.17	57.82	TENS	526.6	253.3
UHT-27	19.05	36.68	2.0	6.25	57.46	TENS	517.7	248.8
UHT-28	6.35	50.67	8.0	6.25	93.01	DBLR	333.3	291.5
UHT-29	6.35	50.75	8.0	6.15	113.85	DBLR	414.0	362.2
UHT-30	6.35	50.80	8.0	6.20	128.42	DBLR	462.6	404.8
UHT-31	12.70	101.60	8.0	6.10	221.20	DBLR	405.1	354.4
UHT-32	12.70	101.57	8.0	6.12	212.01	DBLR	386.7	338.4
UHT-33	12.70	101.65	8.0	6.07	237.56	DBLR	436.6	382.0
UHT-34	19.05	152.22	8.0	6.10	299.41	DBLR	366.0	320.2
UHT-35	19.05	152.20	8.0	6.17	220.97	DBLR	266.8	233.4
UHT-36	19.05	152.30	8.0	6.20	316.00	DBLR	379.7	332.2

TENS = TENSION
COMP = COMPRESSION
BRNG = BEARING
B/B = BOLT BENDING
DBLR = DOUBLER

TABLE 12

UNLOADED HOLE COMPRESSION SPECIMENS

FIBER PATTERN A - (25% 0°,50% ±45°,25% 90°)

U.S. CUSTOMARY UNITS

SPECIMEN NUMBER	HOLE DIAM. IN.	PANEL WIDTH IN.	W/D RATIO	PANEL THICK. IN.	FAILURE LOAD LB	FAILURE MODE	NET-SECT. STRESS KSI	GROSS-SECT. STRESS KSI	
UHC- 1	0.250	0.510	2.0	0.246	4490.0	COMP	70.20	35.79	
UHC- 2	0.250	0.507	2.0	0.253	4320.0	COMP	66.44	33.68	
UHC- 3	0.250	0.505	2.0	0.253	3490.0	COMP	54.10	27.32	
UHC- 4	0.500	1.003	2.0	0.255	7350.0	COMP	57.30	28.74	
UHC- 5	0.500	1.001	2.0	0.255	8100.0	COMP	63.40	31.73	
UHC- 6	0.500	1.002	2.0	0.254	7900.0	COMP	61.96	31.04	
UHC- 7	0.750	1.490	2.0	0.253	9700.0	COMP	51.81	25.73	
UHC- 8	0.750	1.491	2.0	0.255	10340.0	COMP	54.72	27.20	
UHC- 9	0.750	1.489	2.0	0.254	9600.0	COMP	51.14	25.38	
UHC-10	0.250	1.998	8.0	0.253	26250.0	COMP	59.36	51.93	
UHC-11	0.250	1.996	8.0	0.254	25250.0	COMP	56.94	49.80	
UHC-12	0.250	2.002	8.0	0.253	25400.0	COMP	57.30	50.15	
UHC-13	0.500	3.995	8.0	0.252	0.0	COMP	0.00	0.00	*
UHC-14	0.500	3.995	8.0	0.251	26550.0	COMP	30.27	26.48	**
UHC-15	0.500	3.997	8.0	0.253	26000.0	COMP	29.39	25.71	**
UHC-16	0.750	5.993	8.0	0.252	65000.0	COMP	49.20	43.04	
UHC-17	0.750	5.999	8.0	0.253	67300.0	COMP	50.68	44.34	
UHC-18	0.750	5.995	8.0	0.252	58700.0	COMP	44.41	38.86	

TENS = TENSION
COMP = COMPRESSION
BRNG = BEARING
B/B = BOLT BENDING
DBLR = DOUBLER

* Malfunction of data acquisition system
** Anti-buckling plates omitted during test

TABLE 13

UNLOADED HOLE COMPRESSION SPECIMENS

FIBER PATTERN 8 - (37.5% 0°,50% ±45°,12.5% 90°)

U.S. CUSTOMARY UNITS

SPECIMEN NUMBER	HOLE DIAM. IN.	PANEL WIDTH IN.	W/D RATIO	PANEL THICK. IN.	FAILURE LOAD LB	FAILURE MODE	NET-SECT. STRESS KSI	GROSS-SECT. STRESS KSI
UHC-19	0.250	0.509	2.0	0.252	4520.0	COMP	69.25	35.24
UHC-20	0.250	0.506	2.0	0.251	4670.0	COMP	72.68	36.77
UHC-21	0.250	0.508	2.0	0.250	5070.0	COMP	78.60	39.92
UHC-22	0.500	1.030	2.0	0.254	8770.0	COMP	65.15	33.52
UHC-23	0.500	1.020	2.0	0.250	9020.0	COMP	69.38	35.37
UHC-24	0.500	1.020	2.0	0.254	8700.0	COMP	65.37	33.58
UHC-25	0.750	1.500	2.0	0.251	12880.0	COMP	68.42	34.21
UHC-26	0.750	1.504	2.0	0.251	12930.0	COMP	68.32	34.25
UHC-27	0.750	1.504	2.0	0.254	12980.0	COMP	67.78	33.98
UHC-28	0.250	2.120	8.0	0.254	33450.0	COMP	70.42	62.12
UHC-29	0.250	2.130	8.0	0.251	30950.0	COMP	65.59	57.89
UHC-30	0.250	2.150	8.0	0.254	28500.0	COMP	59.06	52.19
UHC-31	0.500	4.090	8.0	0.258	53400.0	COMP	57.65	50.61
UHC-32	0.500	4.090	8.0	0.256	43900.0	COMP	53.21	46.70
UHC-33	0.500	4.090	8.0	0.256	47500.0	COMP	51.68	45.37
UHC-34	0.750	6.050	8.0	0.257	72200.0	COMP	53.01	46.44
UHC-35	0.750	6.000	8.0	0.252	72100.0	COMP	54.50	47.69
UHC-36	0.750	6.030	8.0	0.249	67200.0	COMP	51.11	44.76

TENS = TENSION
COMP = COMPRESSION
BRNG = BEARING
B/B = BOLT BENDING
DBLR = DOUBLER

TABLE 14

UNLOADED HOLE COMPRESSION SPECIMENS

FIBER PATTERN A - (25% 0°,50% ±45°,25% 90°)

S.I. UNITS

SPECIMEN NUMBER	HOLE DIAM. MM.	PANEL WIDTH MM.	W/D RATIO	PANEL THICK. MM.	FAILURE LOAD KNEWTON	FAILURE MODE	NET-SECT. STRESS MPASCAL	GROSS-SECT. STRESS MPASCAL
UHC- 1	6.35	12.95	2.0	6.25	20.13	COMP	484.0	246.8
UHC- 2	6.35	12.83	2.0	6.43	19.36	COMP	455.1	232.2
UHC- 3	6.35	12.83	2.0	6.43	15.64	COMP	373.0	188.3
UHC- 4	12.70	25.48	2.0	6.48	32.94	COMP	395.1	198.1
UHC- 5	12.70	25.43	2.0	6.48	36.31	COMP	437.1	218.6
UHC- 6	12.70	25.45	2.0	6.45	35.41	COMP	427.2	214.0
UHC- 7	19.05	37.85	2.0	6.43	43.48	COMP	357.2	177.4
UHC- 8	19.05	37.87	2.0	6.48	46.35	COMP	377.3	187.5
UHC- 9	19.05	37.82	2.0	6.45	43.03	COMP	352.6	175.0
UHC-10	6.35	50.75	8.0	6.43	117.66	COMP	409.2	353.0
UHC-11	6.35	50.70	8.0	6.45	113.18	COMP	392.6	343.4
UHC-12	6.35	50.85	8.0	6.43	113.85	COMP	395.1	345.8
UHC-13	12.70	101.47	8.0	6.40	0.00	COMP	0.0	0.0 *
UHC-14	12.70	101.47	8.0	6.38	119.00	COMP	208.7	182.6 **
UHC-15	12.70	101.52	8.0	6.43	116.54	COMP	202.6	177.3 **
UHC-16	19.05	152.22	8.0	6.40	291.34	COMP	339.2	296.7
UHC-17	19.05	152.37	8.0	6.43	301.65	COMP	349.4	305.7
UHC-18	19.05	152.27	8.0	6.40	263.11	COMP	306.2	267.9

TENS = TENSION
COMP = COMPRESSION
BRNG = BEARING
B/B = BOLT BENDING
DBLR = DOUBLER

* Malfunction of data acquisition system
** Anti-buckling plates omitted during test

TABLE 15

UNLOADED HOLE COMPRESSION SPECIMENS

FIBER PATTERN B - (37.5% 0°, 50% ±45°, 12.5% 90°)

S.I. UNITS

SPECIMEN NUMBER	HOLE DIAM. MM.	PANEL WIDTH MM.	W/D RATIO	PANEL THICK. MM.	FAILURE LOAD KILONEWTON	FAILURE MODE	NET-SECT. STRESS MPASCAL	GROSS-SECT. STRESS MPASCAL
UHC-19	6.35	13.93	2.0	6.40	20.26	COMP	477.5	243.0
UHC-20	6.35	13.85	2.0	6.38	20.93	COMP	501.1	255.5
UHC-21	6.35	12.90	2.0	6.35	22.72	COMP	542.0	275.2
UHC-22	12.70	26.16	2.0	6.45	39.31	COMP	449.2	231.1
UHC-23	12.70	25.91	2.0	6.35	40.43	COMP	473.4	243.9
UHC-24	12.70	25.91	2.0	6.45	39.00	COMP	454.2	231.5
UHC-25	19.05	38.10	2.0	6.38	57.73	COMP	471.78	235.89
UHC-26	19.05	38.20	2.0	6.38	57.95	COMP	471.09	236.16
UHC-27	19.05	38.20	2.0	6.45	58.13	COMP	467.36	234.30
UHC-28	6.35	53.85	8.0	6.45	149.93	COMP	485.6	428.3
UHC-29	6.35	54.10	8.0	6.38	136.72	COMP	452.2	399.1
UHC-30	6.35	54.61	8.0	6.45	127.74	COMP	407.2	359.8
UHC-31	12.70	103.89	8.0	6.55	239.35	COMP	397.5	348.9
UHC-32	12.70	103.89	8.0	6.50	219.18	COMP	366.9	322.0
UHC-33	12.70	103.89	8.0	6.50	212.90	COMP	356.4	312.8
UHC-34	19.05	153.67	8.0	6.53	323.61	COMP	365.5	320.2
UHC-35	19.05	152.40	8.0	6.40	323.17	COMP	375.7	328.8
UHC-36	19.05	153.16	8.0	6.32	301.20	COMP	352.4	308.6

TENS = TENSION
COMP = COMPRESSION
BRNG = BEARING
B/B = BOLT BENDING
DBLR = DOUBLER

TABLE 16

DOUBLE-SHEAR TENSION SPECIMENS

FIBER PATTERN A - (25% 0°, 50% ±45°, 25% 90°)

U.S. CUSTOMARY UNITS

SPECIMEN NUMBER	HOLE DIAM. IN.	PANEL WIDTH IN.	W/D RATIO	CENTER THICK. IN.	SPLICE THICKx2 IN.	FAILURE LOAD LB	FAILURE MODE	BEARING STRESS KSI	NET-SECT. STRESS KSI	GROSS-SECT. STRESS KSI
DST- 1	0.250	0.755	3.0	0.350	0.336	7410.0	TENS	88.21	43.67	29.21
DST- 2	0.250	0.743	3.0	0.354	0.326	6380.0	TENS	84.42	42.51	28.40
DST- 3	0.250	0.752	3.0	0.352	0.326	7080.0	TENS	86.87	43.26	28.89
DST- 4	0.500	1.500	3.0	0.512	0.506	23175.0	TENS	91.60	45.80	30.53
DST- 5	0.500	1.500	3.0	0.515	0.506	23050.0	BRNG	91.11	45.55	30.37
DST- 6	0.500	1.500	3.0	0.513	0.497	23600.0	TENS	94.97	47.48	31.66
DST- 7	0.750	2.250	3.0	0.680	0.699	36900.0	DBLR	70.39	35.19	23.46
DST- 8	0.750	2.249	3.0	0.686	0.696	30800.0	DBLR	59.00	29.52	19.68
DST- 9	0.750	2.248	3.0	0.635	0.699	43800.0	DBLR	83.55	41.83	27.87
DST-10	0.250	2.005	8.0	0.349	0.337	9875.0	B/B	117.21	16.70	14.61
DST-11	0.250	2.005	8.0	0.348	0.339	8600.0	B/B	101.47	14.46	12.65
DST-12	0.250	2.006	8.0	0.346	0.339	8400.0	B/B	99.12	14.11	12.35
DST-13	0.500	4.001	8.0	0.508	0.504	27200.0	BRNG	107.94	15.42	13.49
DST-14	0.500	4.001	8.0	0.512	0.505	27500.0	DBLR	108.91	15.55	13.61
DST-15	0.500	4.000	8.0	0.508	0.509	26150.0	BRNG	102.75	14.68	12.84
DST-16	0.750	6.000	8.0	0.682	0.694	48000.0	BRNG	92.22	13.17	11.53
DST-17	0.750	6.004	8.0	0.687	0.694	51150.0	BRNG	96.27	14.03	12.28
DST-18	0.750	6.000	8.0	0.687	0.695	49500.0	BRNG	94.96	13.57	11.87

TENS = TENSION
COMP = COMPRESSION
BRNG = BEARING
B/B = BOLT BENDING
DBLR = DOUBLER

TABLE 17

DOUBLE-SHEAR TENSION SPECIMENS

FIBER PATTERN B - (37.5% 0°, 50% ±45°, 12.5% 90°)

U.S. CUSTOMARY UNITS

SPECIMEN NUMBER	HOLE DIAM. IN.	PANEL WIDTH IN.	W/D RATIO	CENTER THICK. IN.	SPLICE THICKx2 IN.	FAILURE LOAD LB	FAILURE MODE	BEARING STRESS KSI	NET-SECT. STRESS KSI	GROSS-SECT. STRESS KSI
DST-19	0.250	0.750	3.0	0.343	0.333	8090.0	TENS	97.18	48.59	32.39
DST-20	0.250	0.753	3.0	0.346	0.343	8420.0	TENS	98.19	48.80	32.60
DST-21	0.250	0.759	3.0	0.345	0.339	7700.0	TENS	90.86	44.62	29.93
DST-22	0.500	1.497	3.0	0.513	0.519	23400.0	BRNG	90.17	45.22	30.12
DST-23	0.500	1.496	3.0	0.513	0.508	20725.0	DBLR	81.59	40.96	27.27
DST-24	0.500	1.496	3.0	0.516	0.511	24850.0	TENS	97.26	48.33	32.51
DST-25	0.750	2.250	3.0	0.678	0.685	45000.0	BRNG	87.59	43.50	29.20
DST-26	0.750	2.249	3.0	0.681	0.681	26000.0	DBLR	50.91	25.49	16.98
DST-27	0.750	2.248	3.0	0.678	0.679	26500.0	DBLR	52.04	26.05	17.36
DST-28	0.250	2.003	8.0	0.344	0.342	8775.0	B/B	102.63	14.64	12.81
DST-29	0.250	2.002	8.0	0.342	0.344	8650.0	B/B	100.58	14.35	12.56
DST-30	0.250	2.003	8.0	0.342	0.343	9075.0	B/B	105.83	15.09	13.21
DST-31	0.500	3.987	8.0	0.512	0.508	25700.0	BRNG	101.18	14.51	12.69
DST-32	0.500	3.987	8.0	0.512	0.511	26250.0	BRNG	102.74	14.73	12.88
DST-33	0.500	3.987	8.0	0.511	0.508	26250.0	BRNG	103.35	14.82	12.96
DST-34	0.750	6.001	8.0	0.678	0.690	49600.0	BRNG	95.85	13.69	11.98
DST-35	0.750	6.000	8.0	0.674	0.688	50100.0	BRNG	97.09	13.87	12.14
DST-36	0.750	6.000	8.0	0.671	0.684	52700.0	BRNG	102.73	14.68	12.84

TENS = TENSION
COMP = COMPRESSON
BRNG = BEARING
B/B = BOLT BENDING
DBLR = DOUBLER

TABLE 18

DOUBLE-SHEAR TENSION SPECIMENS

FIBER PATTERN A - (25% 0°,50% ±45°,25% 90°)

S.I. UNITS

SPECIMEN NUMBER	HOLE DIAM. MM.	PANEL WIDTH MM.	W/D RATIO	CENTER THICK. MM.	SPLICE THICKx2 MM.	FAILURE LOAD KNEWTON	FAILURE MODE	BEARING STRESS MPASCAL	NET-SECT. STRESS MPASCAL	GROSS-SECT. STRESS MPASCAL
DST- 1	6.35	19.2	3.0	8.89	8.53	33.21	TENS	608.2	301.1	201.4
DST- 2	6.35	18.9	3.0	8.99	8.28	30.84	TENS	582.0	295.2	195.3
DST- 3	6.35	19.1	3.0	8.94	8.28	31.73	TENS	599.0	298.3	199.1
DST- 4	12.70	38.1	3.0	13.00	12.35	103.87	TENS	631.6	315.8	210.5
DST- 5	12.70	38.1	3.0	13.08	12.35	103.31	BRNG	628.2	314.1	209.4
DST- 6	12.70	38.1	3.0	13.03	12.62	105.78	TENS	654.8	327.4	218.3
DST- 7	19.05	57.1	3.0	17.27	17.75	165.39	DBLR	485.3	242.6	161.8
DST- 8	19.05	57.1	3.0	17.42	17.68	138.05	DBLR	406.8	203.5	135.7
DST- 9	19.05	57.1	3.0	17.40	17.75	196.32	DBLR	576.0	288.4	192.2
DST-10	6.35	50.9	8.0	8.86	8.56	44.26	B/B	808.1	115.1	100.8
DST-11	6.35	50.9	8.0	8.84	8.61	38.55	B/B	699.6	99.7	87.2
DST-12	6.35	51.0	8.0	8.79	8.61	37.65	B/B	633.4	97.3	85.2
DST-13	12.70	101.6	8.0	12.90	12.80	121.92	BRNG	744.2	106.3	93.0
DST-14	12.70	101.6	8.0	13.00	12.83	123.26	DBLR	750.9	107.2	93.8
DST-15	12.70	101.6	8.0	12.90	12.93	117.21	BRNG	708.4	101.2	88.6
DST-16	19.05	152.4	8.0	17.32	17.63	215.15	BRNG	635.8	90.8	79.5
DST-17	19.05	152.5	8.0	17.45	17.63	229.26	BRNG	677.6	96.7	84.6
DST-18	19.05	152.4	8.0	17.45	17.65	221.87	BRNG	654.8	93.5	81.8

TENS = TENSION
COMP = COMPRESSION
BRNG = BEARING
B/B = BOLT BENDING
DBLR = DOUBLER

TABLE 19

DOUBLE-SHEAR TENSION SPECIMENS

FIBER PATTERN 3 - (37.5% 0°, 50% ±45°, 12.5% 90°)

S.I. UNITS

SPECIMEN NUMBER	HOLE DIAM. MM.	PANEL WIDTH MM.	W/D RATIO	CENTER THICK. MM.	SPLICE THICKx2 MM.	FAILURE LOAD KNEWTON	FAILURE MODE	BEARING STRESS MPASCAL	NET-SECT. STRESS MPASCAL	GROSS-SECT. STRESS MPASCAL
DST-19	6.35	19.0	3.0	8.71	8.46	36.26	TENS	670.0	335.0	223.3
DST-20	6.35	19.1	3.0	8.79	8.71	37.74	TENS	677.0	336.5	224.3
DST-21	6.35	19.3	3.0	8.76	8.61	34.51	TENS	626.4	307.7	206.3
DST-22	12.70	38.0	3.0	13.03	13.18	104.98	BRNG	621.7	311.8	207.7
DST-23	12.70	38.0	3.0	13.03	12.90	92.89	DBLR	562.6	282.4	188.0
DST-24	12.70	38.0	3.0	13.11	12.98	111.38	TENS	670.6	336.6	224.1
DST-25	19.05	57.1	3.0	17.22	17.40	201.70	BRNG	603.9	302.0	201.3
DST-26	19.05	57.1	3.0	17.30	17.30	116.54	DBLR	351.0	175.7	117.1
DST-27	19.05	57.1	3.0	17.22	17.25	118.78	DBLR	358.3	179.6	119.7
DST-28	6.35	50.9	8.0	8.74	8.69	39.33	B/B	707.6	100.9	88.3
DST-29	6.35	50.9	8.0	8.69	8.74	38.77	B/B	693.5	99.0	86.6
DST-30	6.35	50.9	8.0	8.69	8.71	40.68	B/B	729.7	104.1	91.1
DST-31	12.70	101.3	8.0	13.00	12.90	115.19	BRNG	697.6	100.0	87.5
DST-32	12.70	101.3	8.0	13.00	12.98	117.66	BRNG	708.4	101.6	88.9
DST-33	12.70	101.3	8.0	12.98	12.90	117.66	BRNG	712.5	102.2	89.4
DST-34	19.05	152.4	8.0	17.22	17.53	222.32	BRNG	660.8	94.4	82.6
DST-35	19.05	152.4	8.0	17.12	17.48	224.56	BRNG	669.4	95.6	83.7
DST-36	19.05	152.4	8.0	17.04	17.37	236.21	BRNG	708.3	101.2	88.5

TENS = TENSION
COMP = COMPRESSION
BRNG = BEARING
B/B = BOLT BENDING
DBLR - DOUBLER

TABLE 20

DOUBLE-SHEAR COMPRESSION SPECIMENS

FIBER PATTERN A - (25% 0°,50% ±45°,25% 90°)

U.S. CUSTOMARY UNITS

SPECIMEN NUMBER	HOLE DIAM. IN.	PANEL WIDTH IN.	W/D RATIO	CENTER THICK. IN.	SPLICE THICKx2 IN.	FAILURE LOAD LB	FAILURE MODE	BEARING STRESS KSI	NET-SECT. STRESS KSI	GROSS-SECT. STRESS KSI
DSC- 1	0.250	0.752	3.0	0.335	0.329	8200.0	COMP	99.70	49.65	33.14
DSC- 2	0.250	0.754	3.0	0.338	0.333	8230.0	COMP	98.86	49.04	32.78
DSC- 3	0.250	0.757	3.0	0.334	0.333	8530.0	BRNG	102.46	50.52	33.84
DSC- 4	0.500	1.499	3.0	0.515	0.503	25950.0	COMP	103.18	51.64	34.42
DSC- 5	0.500	1.500	3.0	0.512	0.506	26450.0	BRNG	104.55	52.27	34.85
DSC- 6	0.500	1.500	3.0	0.513	0.507	25050.0	COMP	98.82	49.41	32.94
DSC- 7	0.750	2.490	3.0	0.654	0.676	48900.0	BRNG	96.45	41.57	29.05
DSC- 8	0.750	2.492	3.0	0.658	0.675	51700.0	BRNG	102.12	43.97	30.74
DSC- 9	0.750	2.492	3.0	0.655	0.673	51900.0	BRNG	102.82	44.27	30.95
DSC-10	0.500	2.003	4.0	0.339	0.336	16400.0	BRNG	97.62	32.47	24.37
DSC-11	0.500	2.005	4.0	0.338	0.339	16300.0	BRNG	96.17	31.95	23.98
DSC-12	0.500	2.005	4.0	0.335	0.340	18400.0	BRNG	108.24	35.96	26.99
DSC-13	0.500	4.002	8.0	0.508	0.510	26500.0	BRNG	103.92	14.84	12.99
DSC-14	0.500	4.003	8.0	0.513	0.509	27800.0	BRNG	109.23	15.59	13.64
DSC-15	0.500	4.000	8.0	0.512	0.507	28900.0	BRNG	114.00	16.29	14.25
DSC-16	0.750	5.997	8.0	0.651	0.675	54800.0	BRNG	108.25	15.47	13.54
DSC-17	0.750	5.997	8.0	0.645	0.677	53000.0	BRNG	104.38	14.92	13.05
DSC-18	0.750	5.995	8.0	0.645	0.675	52000.0	BRNG	102.72	14.69	12.85

TENS = TENSION
COMP = COMPRESSION
BRNG = BEARING
B/B = BOLT BENDING
DBLR = DOUBLER

TABLE 21

DOUBLE-SHEAR COMPRESSION SPECIMENS

FIBER PATTERN B - (37.5% 0°,50% ±45°,12.5% 90°)

U.S. CUSTOMARY UNITS

SPECIMEN NUMBER	HOLE DIAM. IN.	PANEL WIDTH IN.	W/D RATIO	CENTER THICK. IN.	SPLICE THICKx2 IN.	FAILURE LOAD LB	FAILURE MODE	BEARING STRESS KSI	NET-SECT. STRESS KSI	GROSS-SECT. STRESS KSI
DSC-19	0.250	0.761	3.0	0.335	0.337	7970.0	COMP	94.60	46.28	31.08
DSC-20	0.250	0.760	3.0	0.337	0.339	7310.0	COMP	86.25	42.28	28.37
DSC-21	0.250	0.755	3.0	0.335	0.320	7900.0	COMP	98.75	48.89	32.70
DSC-22	0.500	1.505	3.0	0.517	0.494	25200.0	COMP	102.02	50.76	33.90
DSC-23	0.500	1.503	3.0	0.518	0.500	24550.0	COMP	98.20	48.95	32.67
DSC-24	0.500	1.504	3.0	0.515	0.498	23500.0	BRNG	94.38	47.00	31.38
DSC-25	0.750	2.494	3.0	0.676	0.679	46350.0	BRNG	91.02	39.14	27.37
DSC-26	0.750	2.490	3.0	0.675	0.678	46950.0	BRNG	92.33	39.80	27.81
DSC-27	0.750	2.493	3.0	0.682	0.679	45500.0	BRNG	89.35	38.45	26.88
DSC-28	0.250	2.006	8.0	0.337	0.343	9575.0	B/B	111.66	15.90	13.92
DSC-29	0.250	2.005	8.0	0.338	0.343	9400.0	B/B	109.62	15.62	13.67
DSC-30	0.250	2.006	8.0	0.335	0.341	9440.0	B/B	110.73	15.76	13.80
DSC-31	0.500	4.005	8.0	0.510	0.477	25950.0	BRNG	108.81	15.52	13.58
DSC-32	0.500	4.000	8.0	0.513	0.492	26450.0	BRNG	107.52	15.36	13.44
DSC-33	0.500	4.003	8.0	0.510	0.500	27550.0	BRNG	110.20	15.73	13.76
DSC-34	0.750	5.996	8.0	0.650	0.676	50800.0	BRNG	100.20	14.32	12.53
DSC-35	0.750	5.996	8.0	0.652	0.678	52300.0	BRNG	102.85	14.70	12.87
DSC-36	0.750	5.997	8.0	0.655	0.678	52000.0	BRNG	102.26	14.62	12.79

TENS = TENSION
COMP = COMPRESSION
BRNG = BEARING
B/B = BOLT BENDING
DBLR = DOUBLER

TABLE 22

DOUBLE-SHEAR COMPRESSION SPECIMENS

FIBER PATTERN A - (25% 0°,50% ±45°,25% 90°)

S.I. UNITS

SPECIMEN NUMBER	HOLE DIAM. MM.	PANEL WIDTH MM.	W/D RATIO	CENTER THICK. MM.	SPLICE THICKx2 MM.	FAILURE LOAD KNEWTON	FAILURE MODE	BEARING STRESS MPASCAL	NET-SECT. STRESS MPASCAL	GROSS-SECT. STRESS MPASCAL
DSC- 1	6.35	19.1	3.0	8.51	8.36	36.75	COMP	687.4	342.3	223.5
DSC- 2	6.35	19.2	3.0	8.59	8.46	36.89	COMP	681.6	338.1	226.0
DSC- 3	6.35	19.2	3.0	8.49	8.46	38.23	BRNG	706.5	348.3	233.3
DSC- 4	12.70	38.1	3.0	13.08	12.78	116.31	COMP	711.4	356.1	237.3
DSC- 5	12.70	38.1	3.0	13.00	12.85	118.55	BRNG	720.8	360.4	240.3
DSC- 6	12.70	38.1	3.0	13.03	12.88	112.28	COMP	681.3	340.7	227.1
DSC- 7	19.05	63.2	3.0	16.61	17.17	219.18	BRNG	665.0	286.6	200.3
DSC- 8	19.05	63.3	3.0	16.71	17.15	231.73	BRNG	704.1	303.1	211.9
DSC- 9	19.05	63.3	3.0	16.64	17.09	232.63	BRNG	708.9	305.2	213.4
DSC-10	12.70	50.9	4.0	8.61	8.53	73.51	BRNG	673.1	223.9	168.0
DSC-11	12.70	50.9	4.0	8.59	8.61	73.06	BRNG	663.0	220.3	165.3
DSC-12	12.70	50.9	4.0	8.51	8.64	82.47	BRNG	746.3	247.9	186.1
DSC-13	12.70	101.7	8.0	12.90	12.96	118.78	BRNG	716.5	102.3	89.5
DSC-14	12.70	101.7	8.0	13.03	12.93	124.61	BRNG	753.1	107.5	94.1
DSC-15	12.70	101.6	8.0	13.00	12.88	129.54	BRNG	786.0	112.3	98.3
DSC-16	19.05	152.3	8.0	16.54	17.15	245.62	BRNG	746.3	106.7	93.3
DSC-17	19.05	152.3	8.0	16.38	17.20	237.56	BRNG	719.7	102.9	90.0
DSC-18	19.05	152.3	8.0	16.38	17.15	233.07	BRNG	708.2	101.3	88.6

TENS = TENSION
COMP = COMPRESSON
BRNG = BEARING
B/B = BOLT BENDING
DBLR = DOUBLER

TABLE 23

DOUBLE-SHEAR COMPRESSION SPECIMENS

FIBER PATTERN 5 - (37.5% 0°,50% ±45°,12.5% 90°)

S.I. UNITS

SPECIMEN NUMBER	HOLE DIAM. MM.	PANEL WIDTH MM.	W/D RATIO	CENTER THICK. MM.	SPLICE THICKx2 MM.	FAILURE LOAD KNEWTON	FAILURE MODE	BEARING STRESS MPASCAL	NET-SECT. STRESS MPASCAL	GROSS-SECT. STRESS MPASCAL
DSC-19	6.35	19.3	3.0	8.51	8.56	35.72	COMP	652.2	319.1	214.3
DSC-20	6.35	19.3	3.0	8.56	8.51	32.76	COMP	594.7	291.5	195.6
DSC-21	6.35	19.2	3.0	8.51	8.13	35.41	COMP	680.9	337.1	225.4
DSC-22	12.70	38.2	3.0	13.13	12.55	112.95	COMP	703.4	350.0	233.7
DSC-23	12.70	38.2	3.0	13.16	12.70	110.04	COMP	677.1	337.5	225.2
DSC-24	12.70	38.2	3.0	13.08	12.65	105.33	BRNG	650.7	324.1	216.3
DSC-25	19.05	63.3	3.0	17.17	17.25	207.75	BRNG	627.5	269.9	188.7
DSC-26	19.05	63.2	3.0	17.15	17.22	210.44	BRNG	636.6	274.4	191.7
DSC-27	19.05	63.3	3.0	17.32	17.25	203.94	BRNG	616.0	265.1	185.3
DSC-28	6.35	51.0	8.0	8.56	8.71	42.92	B/B	769.9	109.6	95.9
DSC-29	6.35	50.9	8.0	8.59	8.71	42.13	B/B	755.8	107.7	94.2
DSC-30	6.35	51.0	8.0	8.51	8.66	42.31	B/B	763.5	108.7	95.1
DSC-31	12.70	101.7	8.0	12.95	12.12	116.31	BRNG	750.2	107.0	93.7
DSC-32	12.70	101.6	8.0	13.03	12.50	118.55	BRNG	741.3	105.9	92.7
DSC-33	12.70	101.7	8.0	12.95	12.70	123.48	BRNG	759.8	108.5	94.9
DSC-34	19.05	152.3	8.0	16.51	17.17	227.70	BRNG	690.8	98.8	86.4
DSC-35	19.05	152.3	8.0	16.56	17.22	234.42	BRNG	709.1	101.4	88.7
DSC-36	19.05	152.3	8.0	16.64	17.22	233.07	BRNG	705.1	100.8	88.2

TENS = TENSION
COMP = COMPRESSION
BRNG = BEARING
B/B = BOLT BENDING
DBLR = DOUBLER

TABLE 24

SINGLE-SHEAR TENSION SPECIMENS

FIBER PATTERN A - (25% 0°, 50% ±45°, 25% 90°)

U.S. CUSTOMARY UNITS

SPECIMEN NUMBER	HOLE DIAM. IN.	PANEL WIDTH IN.	W/D RATIO	PANEL THICK IN.	FAILURE LOAD LB	FAILURE MODE	BEARING STRESS KSI	NET-SECT. STRESS KSI	GROSS-SECT. STRESS KSI
SST- 1	0.250	2.000	8.0	0.133	3100.0	BRNG	93.23	13.32	11.65
SST- 2	0.250	1.996	8.0	0.133	3600.0	BRNG	108.27	15.50	13.56
SST- 3	0.250	1.996	8.0	0.132	3710.0	BRNG	112.42	16.10	14.08
SST- 4	0.500	3.995	8.0	0.246	13725.0	BRNG	111.59	15.96	13.97
SST- 5	0.500	3.999	8.0	0.247	13400.0	BRNG	108.50	15.50	13.57
SST- 6	0.500	3.999	8.0	0.246	13025.0	BRNG	105.89	15.13	13.24
SST- 7	0.750	5.998	8.0	0.322	25700.0	BRNG	106.42	15.21	13.31
SST- 8	0.750	5.998	8.0	0.326	24320.0	BRNG	99.47	14.22	12.44
SST- 9	0.750	6.000	8.0	0.325	25350.0	BRNG	104.00	14.86	13.00

TENS = TENSION
COMP = COMPRESSION
BRNG = BEARING
B/B = BOLT BENDING
DBLR = DOUBLER

TABLE 25

SINGLE-SHEAR TENSION SPECIMENS

FIBER PATTERN B - (37.5% 0°, 50% ±45°, 12.5% 90°)

U.S. CUSTOMARY UNITS

SPECIMEN NUMBER	HOLE DIAM. IN.	PANEL WIDTH IN.	W/D RATIO	PANEL THICK IN.	FAILURE LOAD LB	FAILURE MODE	BEARING STRESS KSI	NET-SECT. STRESS KSI	GROSS-SECT. STRESS KSI
SST-10	0.250	1.998	8.0	0.133	3770.0	BRNG	113.39	16.22	14.19
SST-11	0.250	1.990	8.0	0.133	3160.0	BRNG	95.04	13.65	11.94
SST-12	0.250	1.999	8.0	0.134	4180.0	BRNG	124.79	17.84	15.60
SST-13	0.500	4.001	8.0	0.248	12850.0	BRNG	103.63	14.80	12.95
SST-14	0.500	4.000	8.0	0.245	14200.0	BRNG	115.92	16.56	14.49
SST-15	0.500	3.997	8.0	0.246	13620.0	BRNG	110.77	15.83	13.85
SST-16	0.750	5.997	8.0	0.327	26500.0	BRNG	108.05	15.44	13.51
SST-17	0.750	6.003	8.0	0.327	24300.0	BRNG	99.09	14.15	12.38
SST-18	0.750	6.005	8.0	0.326	24250.0	BRNG	99.19	14.16	12.39

TENS = TENSION
COMP = COMPRESSION
BRNG = BEARING
B/B = BOLT BENDING
DBLR = DOUBLER

TABLE 26

SINGLE-SHEAR TENSION SPECIMENS

FIBER PATTERN A - (25% 0°,50% ±45°,25% 90°)

S.I. UNITS

SPECIMEN NUMBER	HOLE DIAM. MM.	PANEL WIDTH MM.	W/D RATIO	PANEL THICK MM.	FAILURE LOAD KNEWTON	FAILURE MODE	BEARING STRESS MPASCAL	NET-SECT. STRESS MPASCAL	GROSS-SECT. STRESS MPASCAL
SST- 1	6.35	50.8	8.0	3.33	13.39	BRNG	642.9	91.8	80.4
SST- 2	6.35	50.7	8.0	3.38	16.14	BRNG	746.5	106.9	93.5
SST- 3	6.35	50.7	8.0	3.35	16.63	BRNG	775.1	111.0	97.1
SST- 4	12.70	101.5	8.0	6.25	61.52	BRNG	769.4	110.1	96.3
SST- 5	12.70	101.6	8.0	6.27	60.06	BRNG	748.1	106.9	93.5
SST- 6	12.70	101.6	8.0	6.25	58.38	BRNG	730.1	104.3	91.3
SST- 7	19.05	152.3	8.0	8.18	115.19	BRNG	733.7	104.9	91.7
SST- 8	19.05	152.3	8.0	8.28	109.01	BRNG	685.9	98.0	85.8
SST- 9	19.05	152.4	8.0	8.25	113.62	BRNG	717.1	102.4	89.6

TENS = TENSION
COMP = COMPRESSION
BRNG = BEARING
B/B = BOLT BENDING
DBLR = DOUBLER

TABLE 27

SINGLE-SHEAR TENSION SPECIMENS

FIBER PATTERN B - (37.5% 0°,50% ±45°,12.5% 90°)

S.I. UNITS

SPECIMEN NUMBER	HOLE DIAM. MM.	PANEL WIDTH MM.	W/D RATIO	PANEL THICK MM.	FAILURE LOAD KNEWTON	FAILURE MODE	BEARING STRESS MPASCAL	NET-SECT. STRESS MPASCAL	GROSS-SECT. STRESS MPASCAL
SST-10	6.35	50.7	8.0	3.38	16.90	BRNG	731.3	111.3	97.8
SST-11	6.35	50.5	8.0	3.38	14.16	BRNG	655.7	94.1	82.3
SST-12	6.35	50.8	8.0	3.40	18.74	BRNG	860.7	123.0	107.6
SST-13	12.70	101.6	8.0	6.30	57.60	BRNG	714.5	102.0	89.3
SST-14	12.70	101.6	8.0	6.32	63.65	BRNG	799.2	114.2	99.9
SST-15	12.70	101.5	8.0	6.25	61.05	BRNG	763.5	109.2	95.5
SST-16	19.05	152.3	8.0	8.31	116.78	BRNG	745.0	106.5	93.2
SST-17	19.05	152.5	8.0	8.31	108.92	BRNG	683.2	97.5	85.4
SST-18	19.05	152.5	8.0	8.28	108.69	BRNG	683.8	97.6	85.4

TENS = TENSION
COMP = COMPRESSION
BRNG = BEARING
B/B = BOLT BENDING
DBLR = DOUBLER

TABLE 28

SINGLE-SHEAR COMPRESSION SPECIMENS

FIBER PATTERN A - (25% 0°, 50% ±45°, 25% 90°)

U.S. CUSTOMARY UNITS

SPECIMEN NUMBER	HOLE DIAM. IN.	PANEL WIDTH IN.	W/D RATIO	PANEL THICK IN.	FAILURE LOAD LB	FAILURE MODE	BEARING STRESS KSI	NET-SECT. STRESS KSI	GROSS-SECT. STRESS KSI
SSC- 1	0.250	1.999	8.0	0.133	3740.0	BRNG	112.49	16.09	14.07
SSC- 2	0.250	2.002	8.0	0.134	2500.0	BRNG	74.63	10.65	9.32
SSC- 3	0.250	2.000	8.0	0.134	3800.0	BRNG	113.43	16.20	14.18
SSC- 4	0.500	4.001	8.0	0.238	12580.0	BRNG	105.71	15.10	13.21
SSC- 5	0.500	4.004	8.0	0.248	11820.0	BRNG	95.32	13.60	11.90
SSC- 6	0.500	4.003	8.0	0.247	12880.0	BRNG	104.29	14.89	13.03
SSC- 7	0.750	6.001	8.0	0.325	26750.0	BRNG	109.74	15.67	13.72
SSC- 8	0.750	6.000	8.0	0.327	26200.0	BRNG	106.83	15.26	13.35
SSC- 9	0.750	6.000	8.0	0.328	26600.0	BRNG	108.13	15.45	13.52

TENS = TENSION
COMP = COMPRESSION
BRNG = BEARING
B/B - BOLT BENDING
DBLR = DOUBLER

TABLE 29

SINGLE-SHEAR COMPRESSION SPECIMENS

FIBER PATTERN B - (37.5% 0°, 50% ±45°, 12.5% 90°)

U.S. CUSTOMARY UNITS

SPECIMEN NUMBER	HOLE DIAM. IN.	PANEL WIDTH IN.	W/D RATIO	PANEL THICK IN.	FAILURE LOAD LB	FAILURE MODE	BEARING STRESS KSI	NET-SECT. STRESS KSI	GROSS-SECT. STRESS KSI
SSC-10	0.250	2.002	8.0	0.133	3860.0	BRNG	116.09	16.57	14.50
SSC-11	0.250	1.997	8.0	0.135	4200.0	BRNG	124.44	17.81	15.58
SSC-12	0.250	2.003	8.0	0.133	4070.0	BRNG	122.41	17.46	15.28
SSC-13	0.500	3.996	8.0	0.249	12940.0	BRNG	103.94	14.86	13.00
SSC-14	0.500	4.001	8.0	0.246	12320.0	BRNG	100.16	14.30	12.52
SSC-15	0.500	4.003	8.0	0.255	12200.0	BRNG	95.69	13.66	11.95
SSC-16	0.750	6.002	8.0	0.326	25400.0	BRNG	103.82	14.94	12.98
SSC-17	0.750	6.001	8.0	0.326	23950.0	BRNG	97.94	13.99	12.24
SSC-18	0.750	6.000	8.0	0.326	23650.0	BRNG	96.72	13.82	12.09

TENS = TENSION
COMP = COMPRESSION
BRNG = BEARING
B/B = BOLT BENDING
DBLR = DOUBLER

TABLE 30

SINGLE-SHEAR COMPRESSION SPECIMENS

FIBER PATTERN A - (25% 0°,50% ±45°,25% 90°)

S.I. UNITS

SPECIMEN NUMBER	HOLE DIAM. MM.	PANEL WIDTH MM.	W/D RATIO	PANEL THICK MM.	FAILURE LOAD KNEWTON	FAILURE MODE	BEARING STRESS MPASCAL	NET-SECT. STRESS MPASCAL	GROSS-SECT. STRESS MPASCAL
SSC- 1	6.35	50.8	8.0	3.38	16.76	BRNG	775.5	110.9	97.0
SSC- 2	6.35	50.9	8.0	3.40	11.21	BRNG	514.5	73.4	64.3
SSC- 3	6.35	50.8	8.0	3.40	17.03	BRNG	782.1	111.7	97.8
SSC- 4	12.70	101.6	8.0	6.05	56.39	BRNG	728.2	104.1	91.1
SSC- 5	12.70	101.7	8.0	6.30	52.98	BRNG	657.2	93.8	82.1
SSC- 6	12.70	101.7	8.0	6.27	57.73	BRNG	719.1	102.6	89.8
SSC- 7	19.05	152.4	8.0	8.25	119.90	BRNG	756.7	108.1	94.6
SSC- 8	19.05	152.4	8.0	8.31	117.43	BRNG	736.6	105.2	92.1
SSC- 9	19.05	152.4	8.0	8.33	119.23	BRNG	745.5	106.5	93.2

TENS = TENSION
COMP = COMPRESSION
BRNG = BEARING
B/B = BOLT BENDING
DBLR = DOUBLER

TABLE 31

SINGLE-SHEAR COMPRESSION SPECIMENS

FIBER PATTERN B - (37.5% 0°, 50% ±45°, 12.5% 90°)

S.I. UNITS

SPECIMEN NUMBER	HOLE DIAM. MM.	PANEL WIDTH MM.	W/D RATIO	PANEL THICK MM.	FAILURE LOAD KNEWTON	FAILURE MODE	BEARING STRESS MPASCAL	NET-SECT. STRESS MPASCAL	GROSS-SECT. STRESS MPASCAL
SSC-10	6.35	50.9	8.0	3.38	17.30	BRNG	800.4	114.2	100.0
SSC-11	6.35	50.7	8.0	3.43	18.83	BRNG	858.0	122.8	107.4
SSC-12	6.35	50.9	8.0	3.38	16.24	BRNG	844.0	120.4	105.3
SSC-13	12.70	101.5	8.0	6.32	58.00	BRNG	716.5	102.5	89.7
SSC-14	12.70	101.6	8.0	6.25	55.22	BRNG	690.4	98.6	86.3
SSC-15	12.70	101.7	8.0	6.48	54.68	BRNG	659.7	94.2	82.4
SSC-16	19.05	152.5	8.0	8.28	113.65	BRNG	716.3	102.3	89.5
SSC-17	19.05	152.4	8.0	8.29	107.35	BRNG	675.4	96.5	84.4
SSC-18	19.05	152.4	8.0	8.29	106.00	BRNG	666.9	95.3	83.4

TENS = TENSION
COMP = COMPRESSION
BRNG = BEARING
B/B = BOLT BENDING
DBLR = DOUBLER

TABLE 32

UNNOTCHED TENSION TEST RESULTS

SPECIMEN NUMBER	LAYUP PATTERN	WIDTH (IN.)	THICKNESS (IN.)	FAILURE LOAD (LB)	FAILURE STRESS (PSI)	$F_{tu} \times K_t$* (PSI)	YOUNG'S MODULUS (PSI)
MPT-1	A	0.737	0.253	12,200	65,525	68,146	7.625×10^6
MPT-2	A	0.756	0.254	12,600	65,738	68,368	7.224×10^6
MPT-3	A	0.756	0.250	12,450	65,890	68,526	7.322×10^6
MPT-4	B	0.764	0.253	16,850	87,254	90,744	9.31×10^6
MPT-5	B	0.762	0.250	17,450	91,626	95,291	9.33×10^6
MPT-6	B	0.759	0.254	18,250	94,677	98,464	9.34×10^6

*$K_t = 1.04$

UNNOTCHED COMPRESSION TEST RESULTS

SPECIMEN NUMBER	LAYUP PATTERN	WIDTH (IN.)	THICKNESS (IN)	FAILURE LOAD (LB)	FAILURE STRESS (PSI)
MPC-1	A	2.0	0.333	46,850	70,362
MPC-3	A	2.0	0.332	47,850	72,139
MPC-4	A	2.0	0.332	43,000	64,827
MPC-2	B	2.0	0.325	62,200	95,692
MPC-5	B	2.0	0.325	65,500	100,769
MPC-6	B	2.0	0.325	62,150	95,615

APPENDIX A

ANCILLARY TEST DATA

SPECIMEN CODING:

UNLOADED HOLE - DRAWING ZJ011266

UHT - UNLOADED HOLE TENSION
UHC - UNLOADED HOLE COMPRESSION

FAILURE MODES

UHT	
1	Net Section Failure
2	Net-Section Failure
3	Net-Section Failure
4	Net-Section Failure
5	Net-Section Failure
6	Net-Section Failure
7	Net-Section Failure
8	Net-Section Failure
9	Net-Section Failure
10	Net-Section Failure. Visible failure along 45° lines
11	Doubler failure and net-section failure at load pin
12	Tapered doubler failure and net-section failure at load pin
13	Tapered doubler failure and net-section failure at load pin
14	Tapered doubler failure and net-section failure at load pin
15	Net-Section Failure. Vibisle along 45° line.
16	Net-Section Failure. Severe delaminations, inter-fiber failures and lateral displacement at test hole (specimen cut down to width = 4.5", (W/D = 6).
17	Net-Section Failure. Severe delaminations, inter-fiber failures and lateral displacement at test hole (specimen cut down to width = 4.5", W/D = 6).
18	Net-Section Failure. Severe delaminations, inter-fiber failures and lateral displacement at test hole (specimen cut down to width = 4.5", W/D = 6).
19	Net-Section Failure
20	Net-Section Failure
21	Net-Section Failure
22	Net-Section Failure
23	Net-Section Failure
24	Net-Section Failure
25	Net-Section Failure
26	Net-Section Failure
27	Net-Section Failure

UHT (Continued)

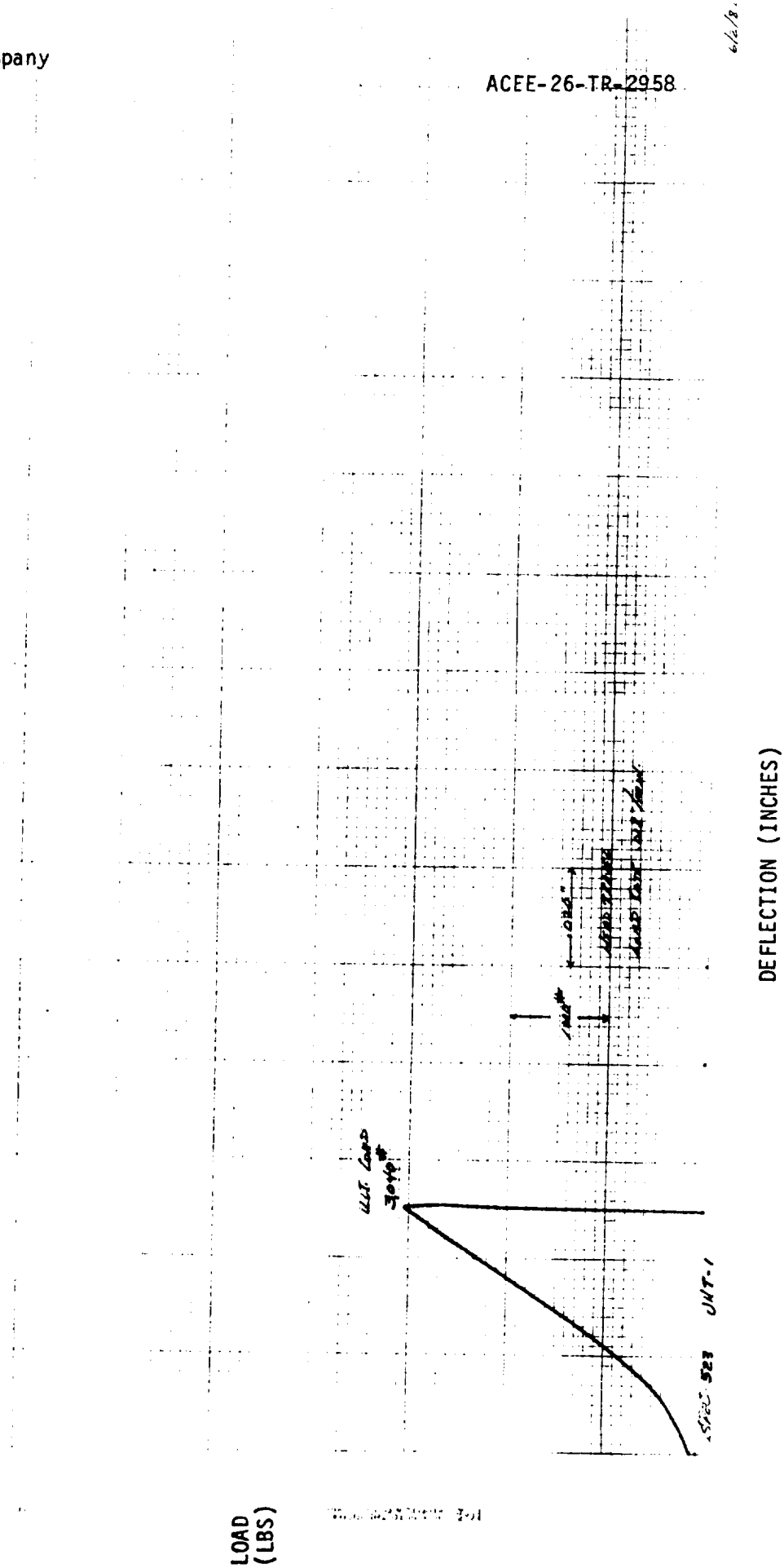
28	Tapered-Doubler Failure
29	Tapered-Doubler Failure
30	Tapered-Doubler Failure
31	Tapered Doubler Failure and net section failure at load pin primarily through 45° lines on side away from test hole
32	Tapered doubler failure and net-section failure at load pin
33	Tapered doubler failure and net section failure at load pin. Near complete failure at test hole area. Extensive delaminations along length of specimen and throughout thickness
34	Extra holes drilled at ends. Failed in bearing/shearout at outer holes for load introduction
35	Tapered doubler failure at load pin
36	Tapered doubler failure. Shearout at load pin hole. Some oneset of failure at net-section.

UHC

1	Compression failure at net-section
2	Compression failure at net-section
3	Compression failure at net-section
4	Compression failure at net-section
5	Compression failure at net-section
6	Compression failure at net-section
7	Compression failure at net-section
8	Compression failure at net-section
9	Compression failure at net-section
10	Compression failure at net-section
11	Compression failure at net-section
12	Compression failure at net-section
13	Compression failure at net-section with ply buckling and delaminations.
14	Compression failure at net-section with ply buckling and delaminations.
15	Compression failure at net-section with ply buckling and delaminations.
16	Compression failure at net-section
17	Compression failure at net-section
18	Compression failure at net-section

UHC (Continued)

19	Compression failure at net-section
20	Compression failure at net-section
21	Compression failure at net-section
22	Compression failure at net-section
23	Compression failure at net-section
24	Compression failure at net-section
25	Compression failure at net-section
26	Compression failure at net-section
27	Compression failure at net-section
28	Compression failure at net-section
29	Compression failure at net-section
30	Compression failure at net-section
31	Compression failure at net-section
32	Compression failure at net-section
33	Compression failure at net-section
34	Compression failure at net-section
35	Compression failure at net-section
36	Compression failure at net-section



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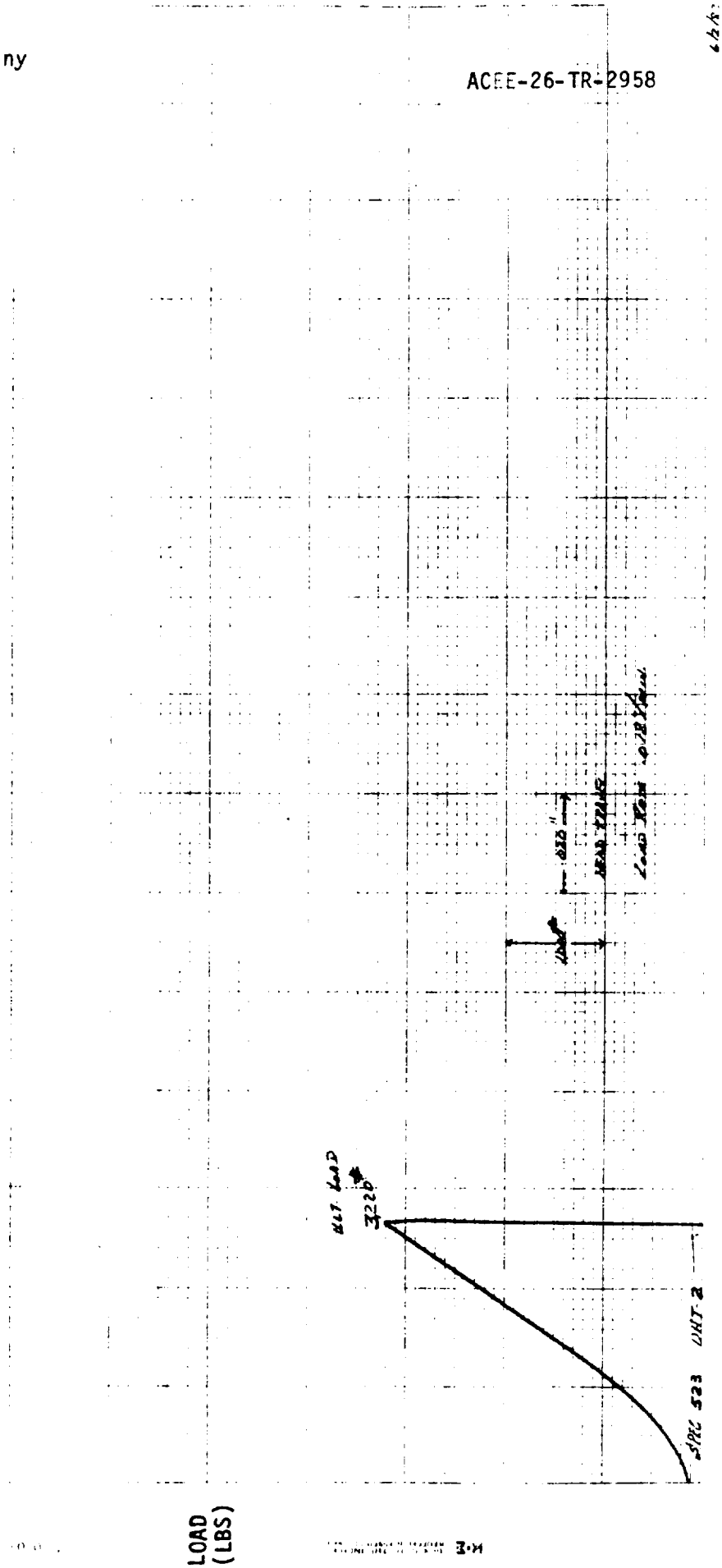
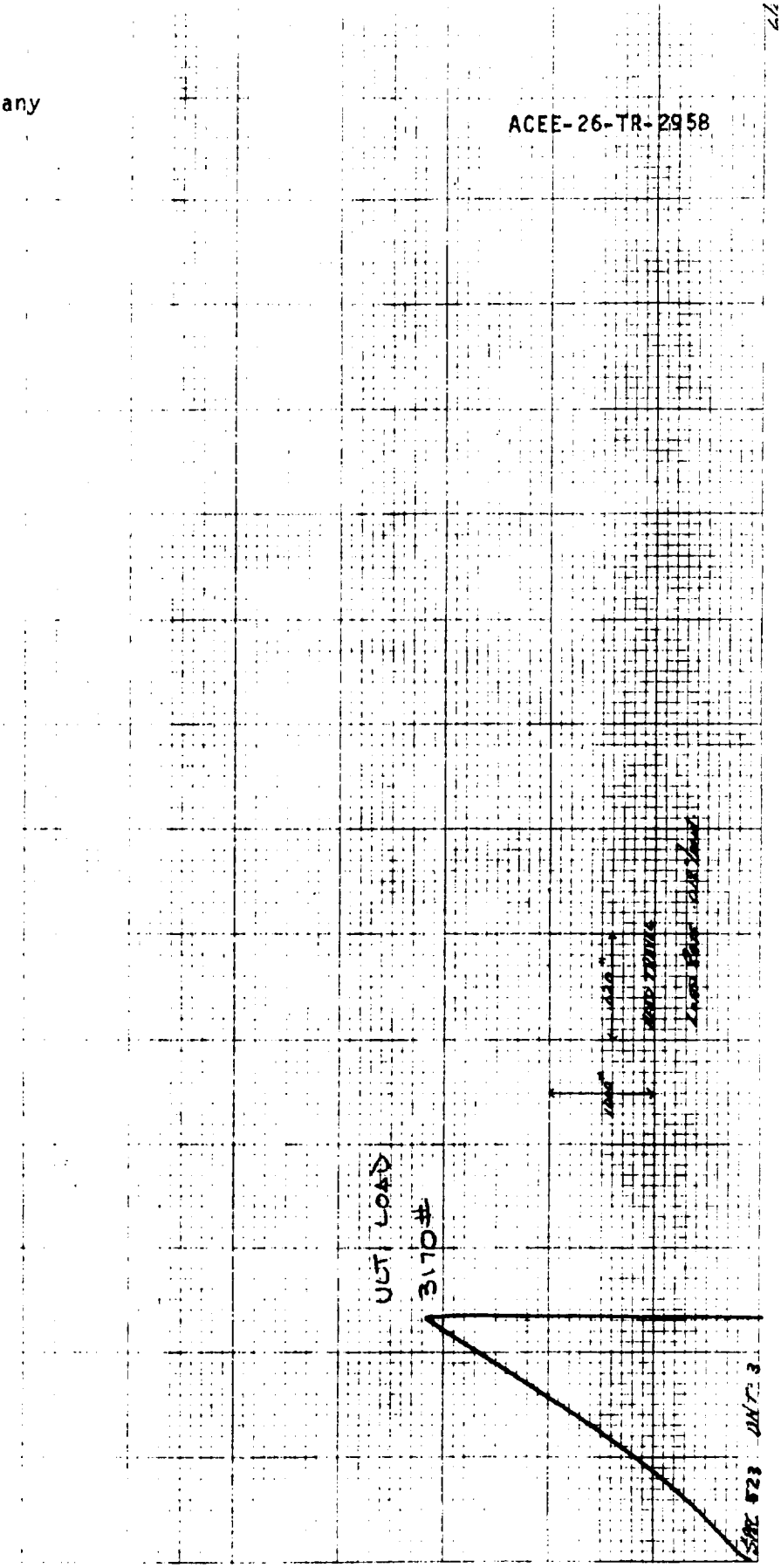
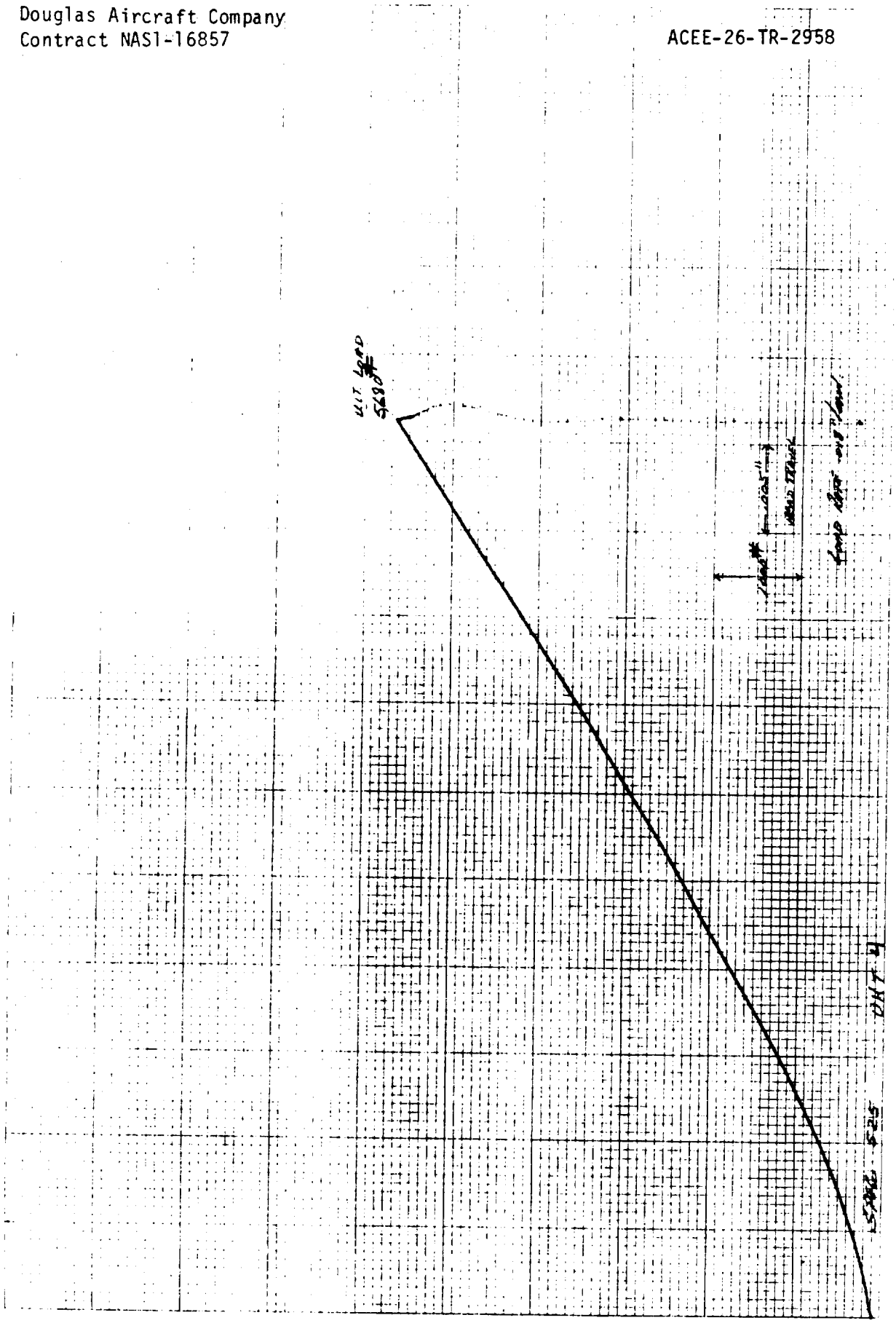
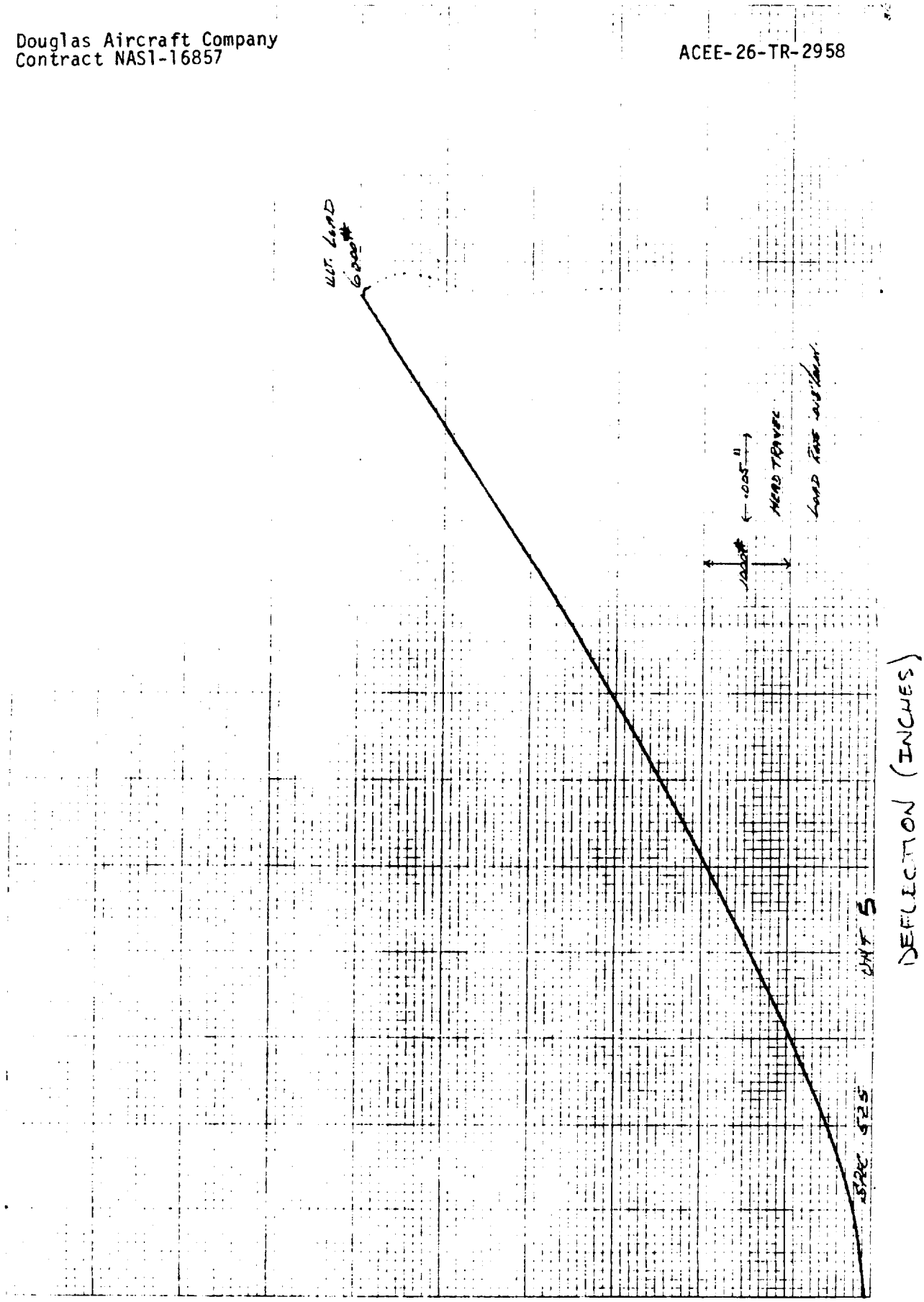

DEFLECTION (INCHES)
LOAD (LBS)
SPEC 523 UNIT 2
ULT. LOAD
3226
.036"
MEAN TRACE
LOAD TEST OBTAINED


ULT LOAD
3170#
DEFLECTION (INCHES)
LOAD
(LBS)



LOAD CASE



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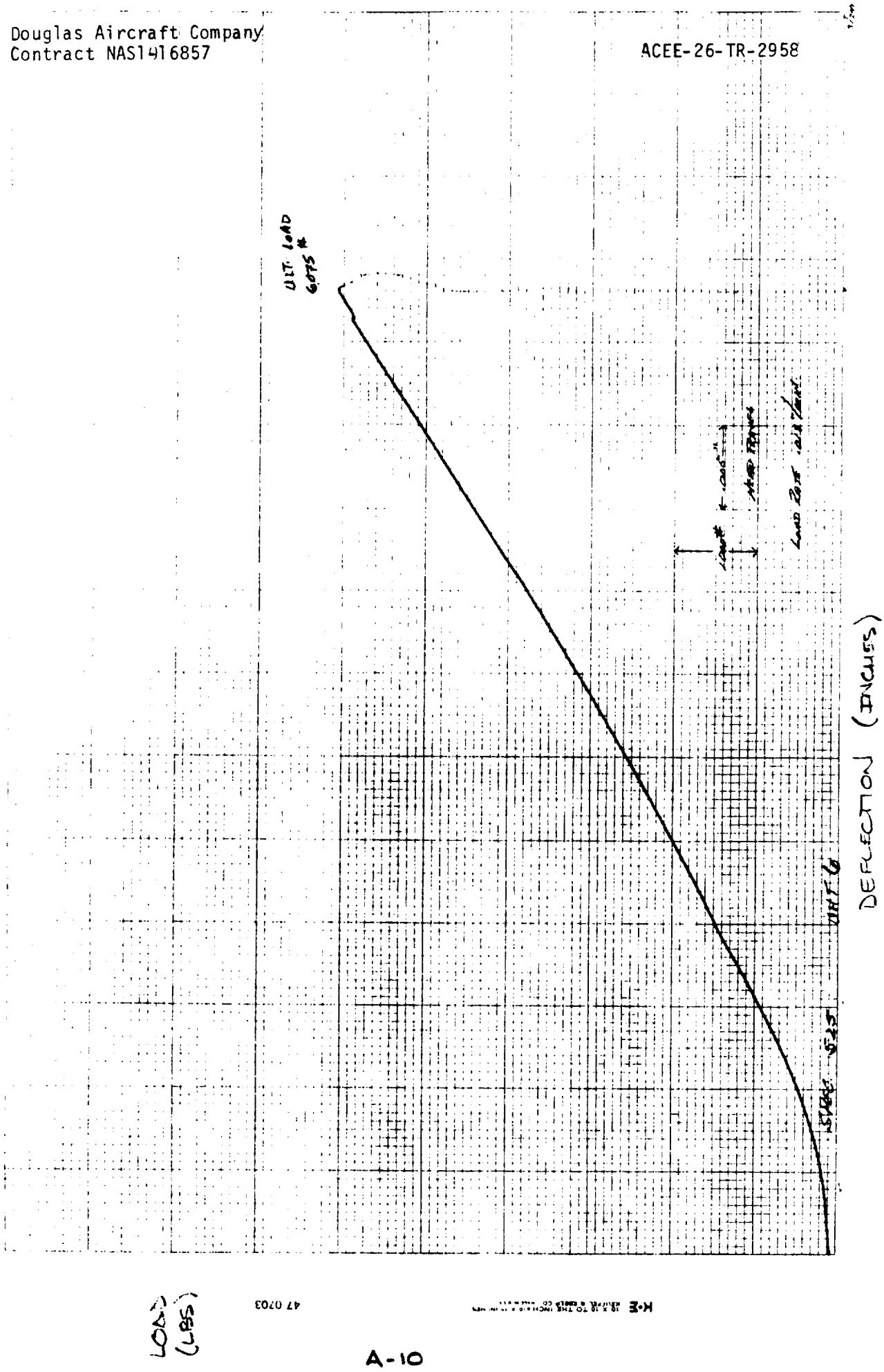
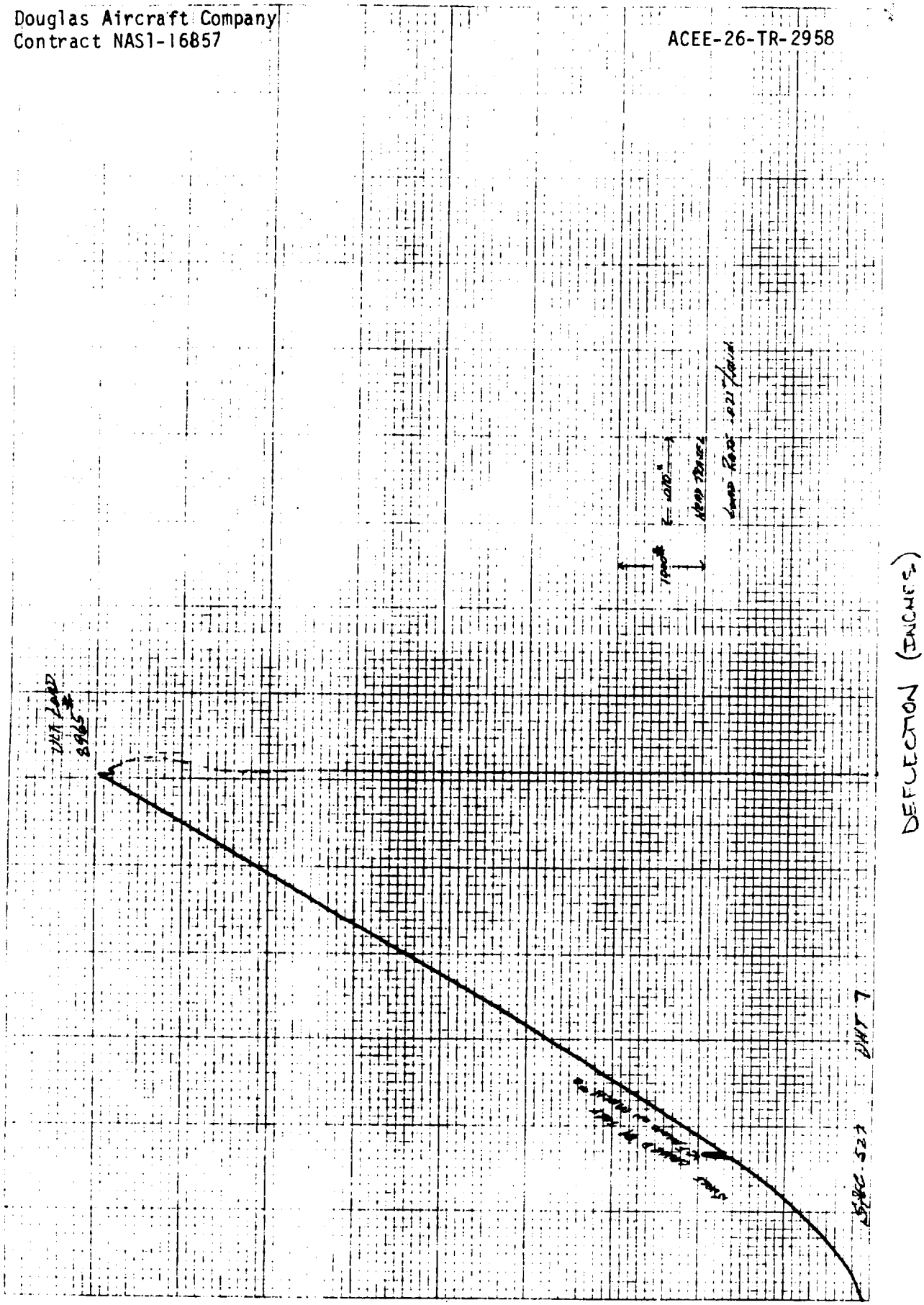
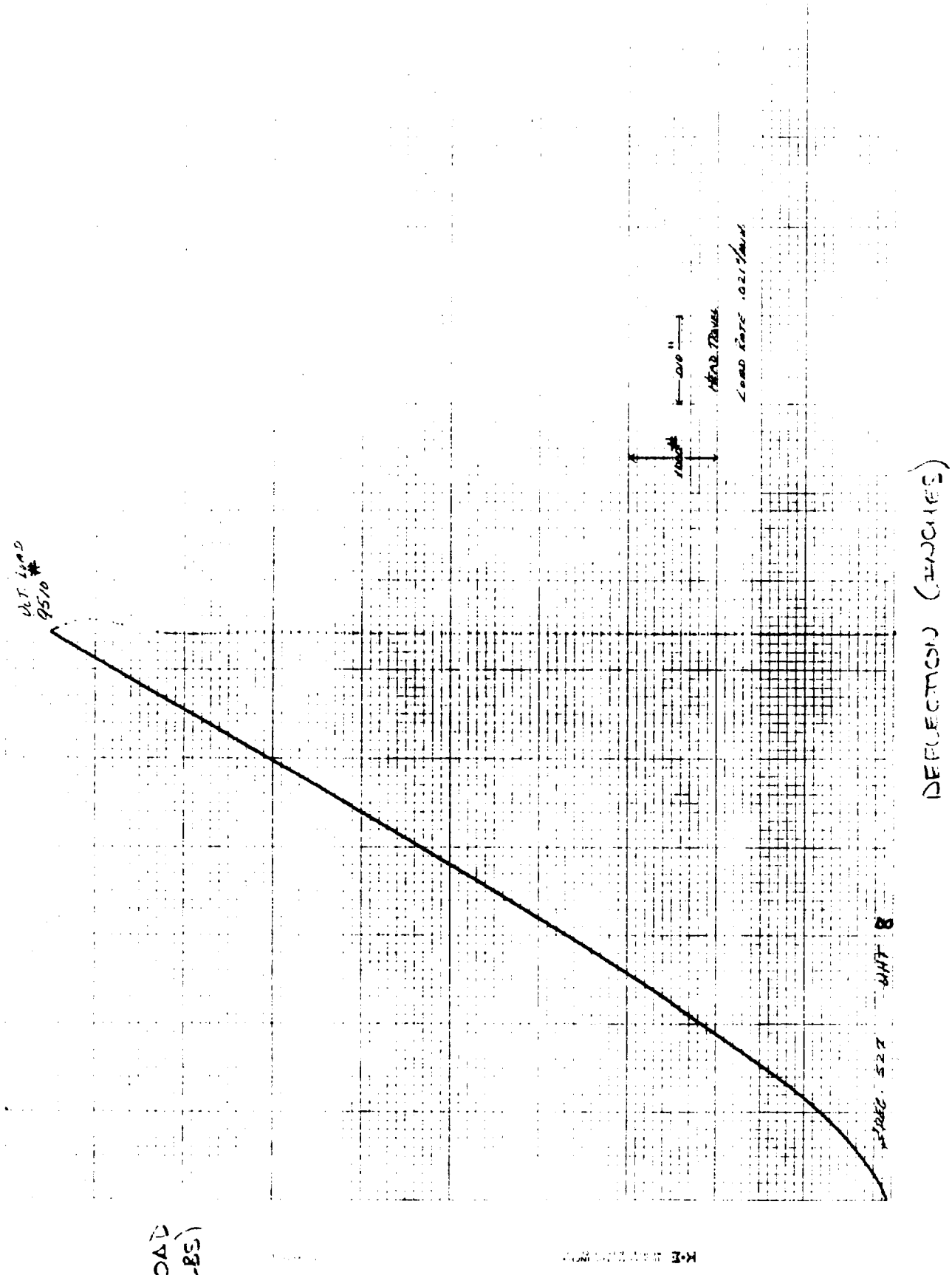
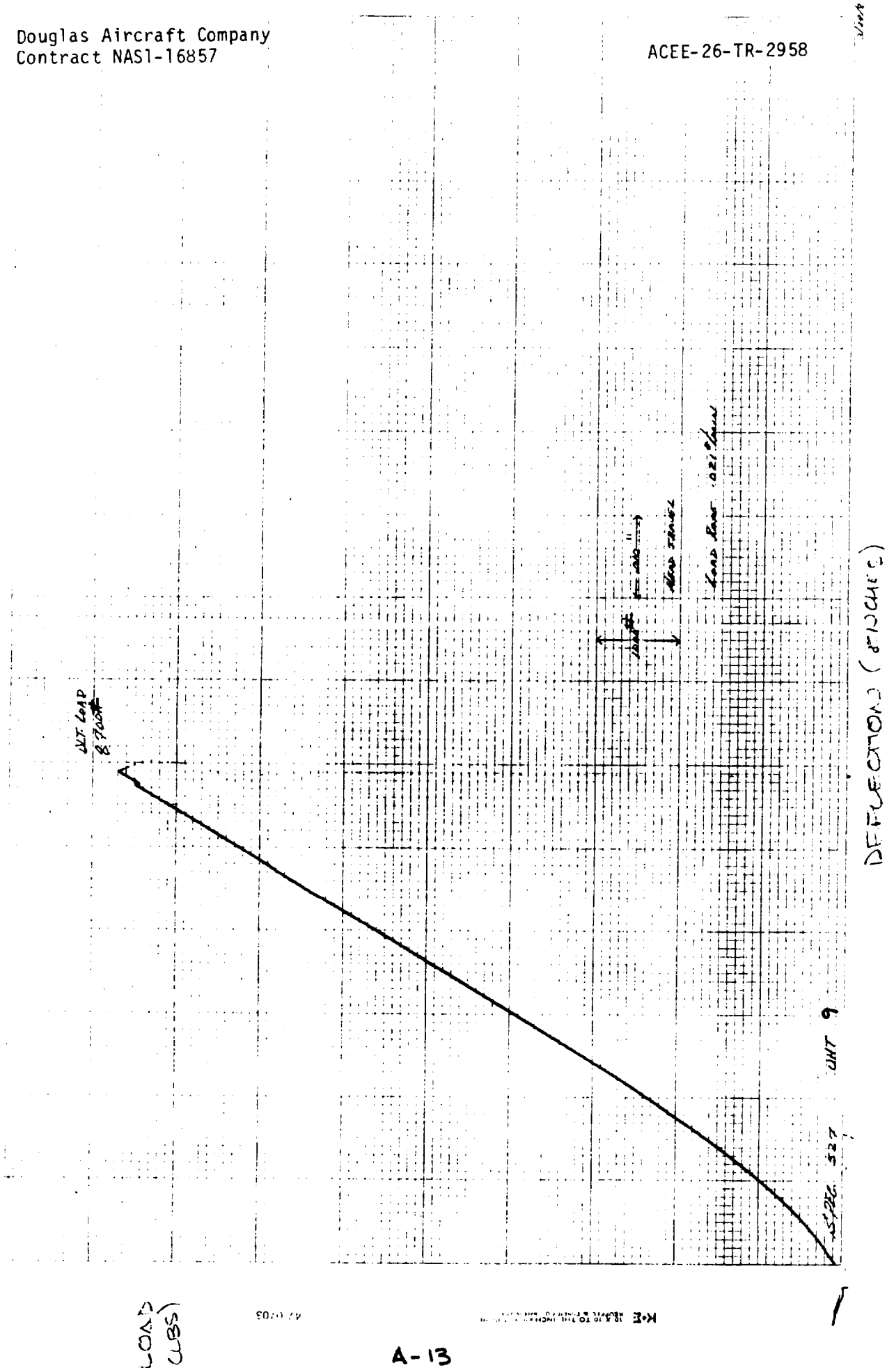
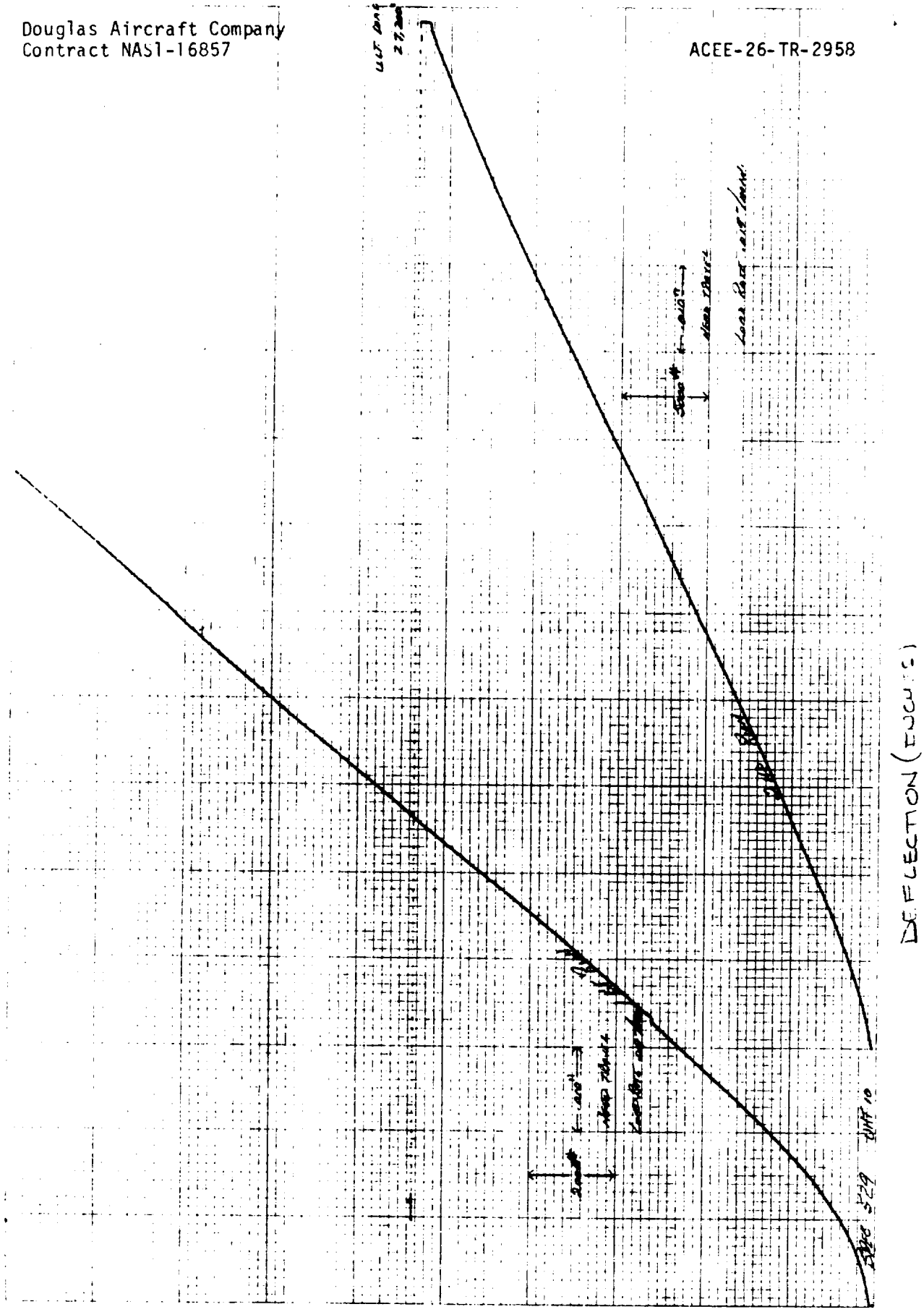
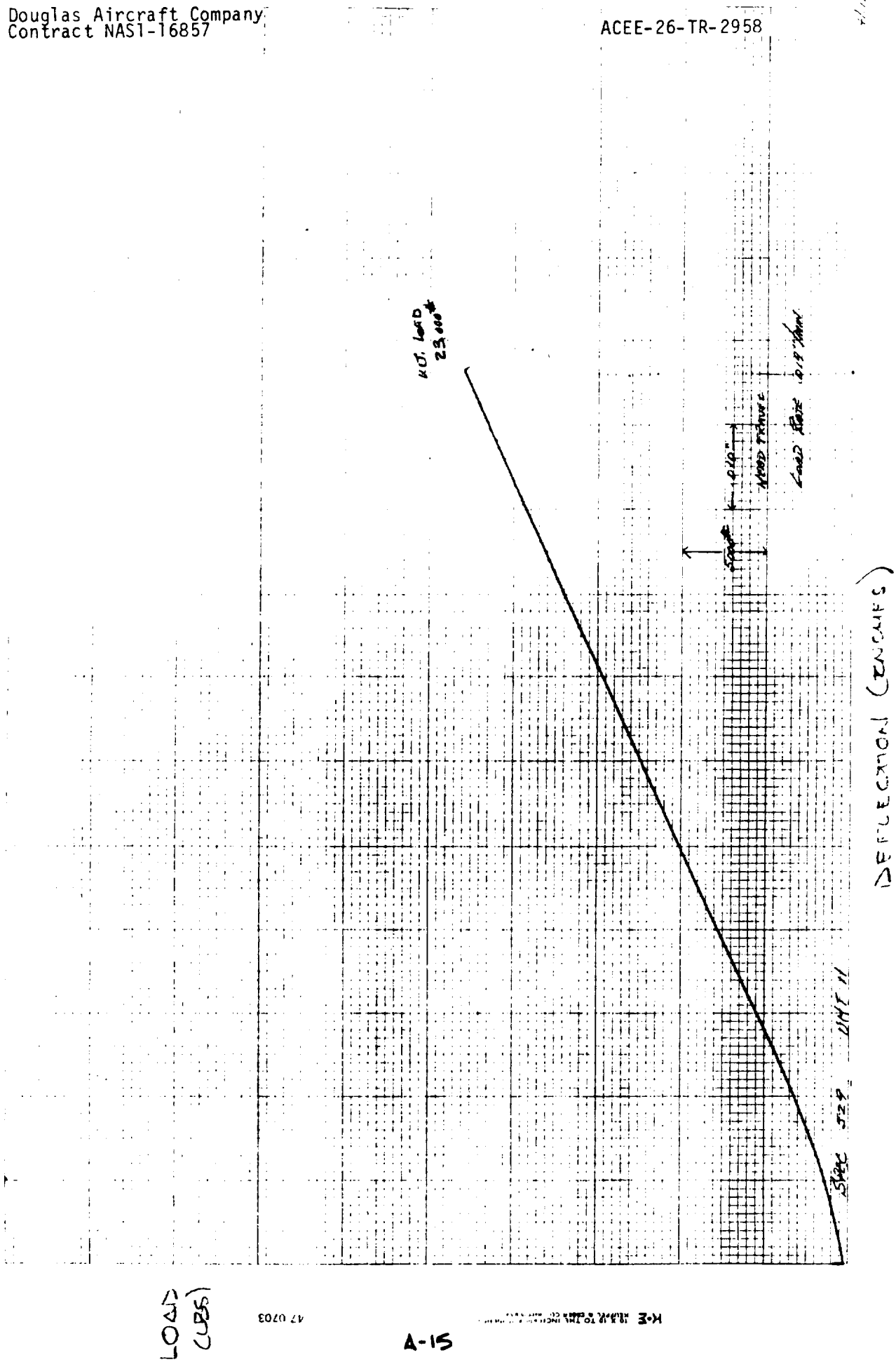

DEFLECTION (INCHES)
LOAD (LBS)

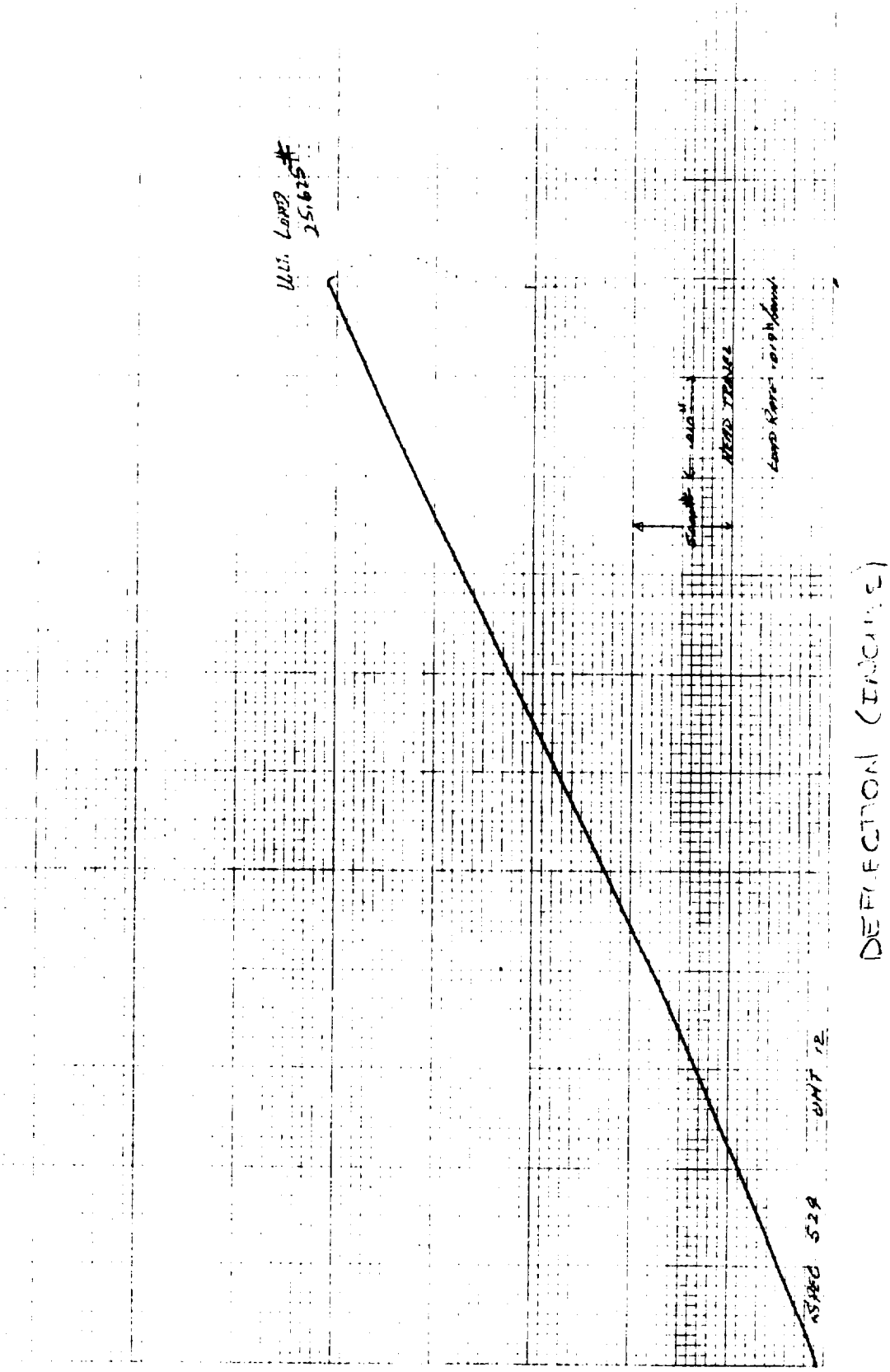

DEFLECTION (INCHES)
LOAD (LBS)
47 0703
A-11

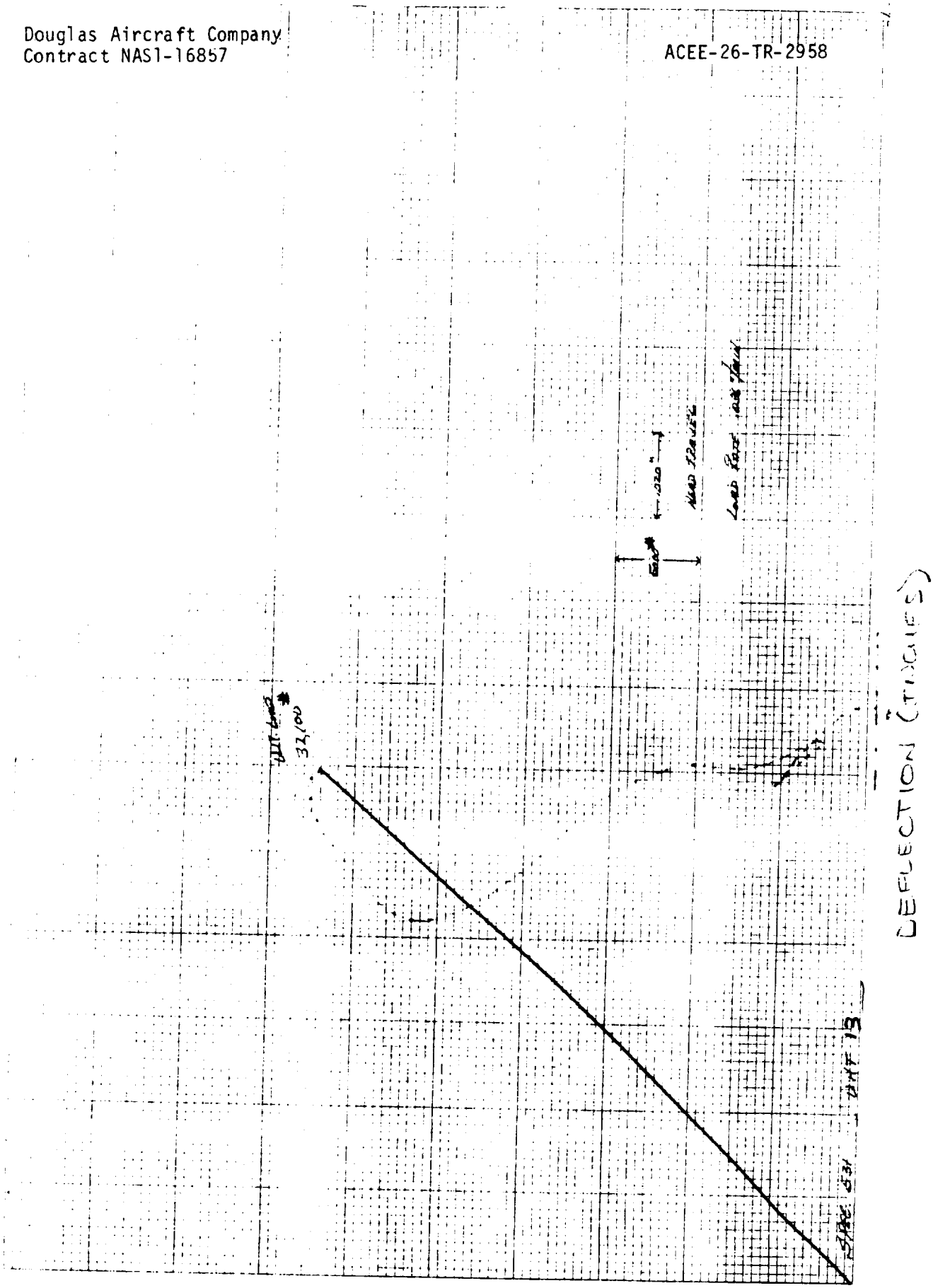

DEFLECTION (INCHES)
LOAD (LBS)

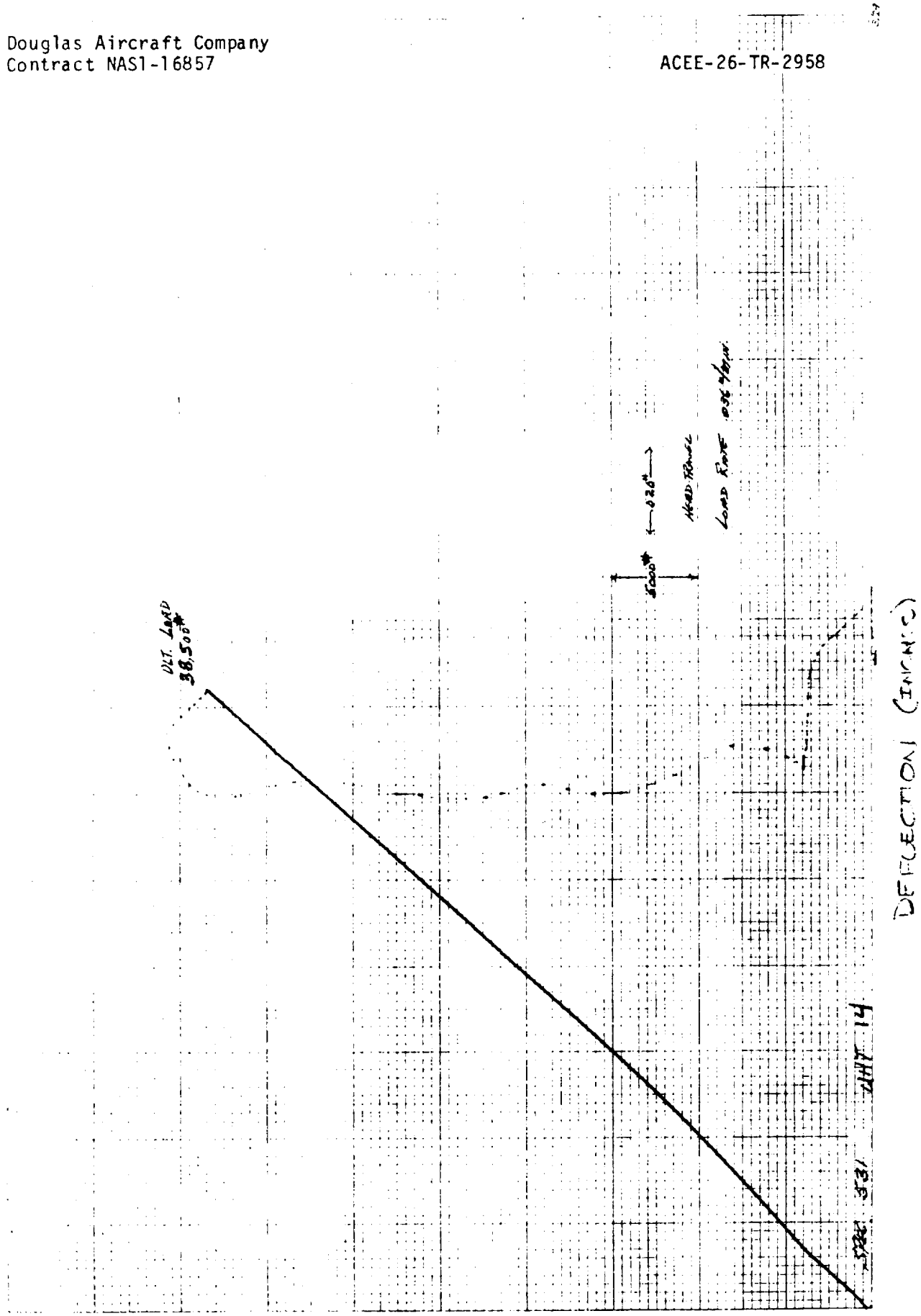

UNIT LOAD
8 FOOT
A
DEFLECTION (INCHES)
LOAD
(LBS)

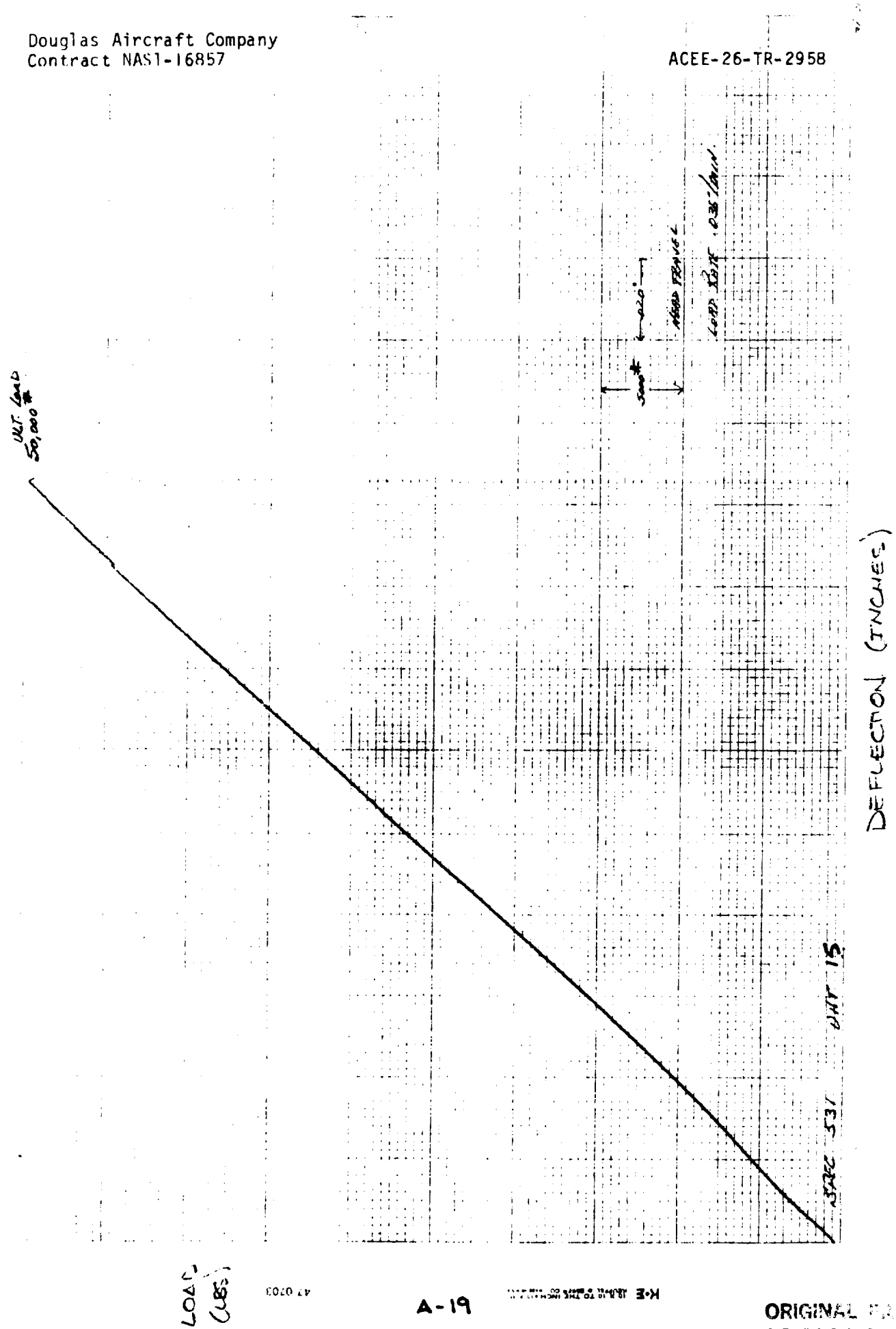

DEFLECTION (INCHES)
LOAD (LBS)


U.T. LOAD
23,000#
LOAD RAISE 0.8" MAX
WOOD FAILURE
0.10"
DEFLECTION (INCHES)
LOAD (LBS)


LOAD (LBS)
DEFLECTION (INCHES)
SPEED 529
UNIT 12
NEED TRACE


32,000
DEFLECTION (INCHES)
LOAD (LBS)


DEFLECTION (INCHES)
WT. LOAD
38,500#
5000#
0.20"
HEAD FORCE
LOAD RATE
0.56 #/sec
SHEET 14
STA. 331



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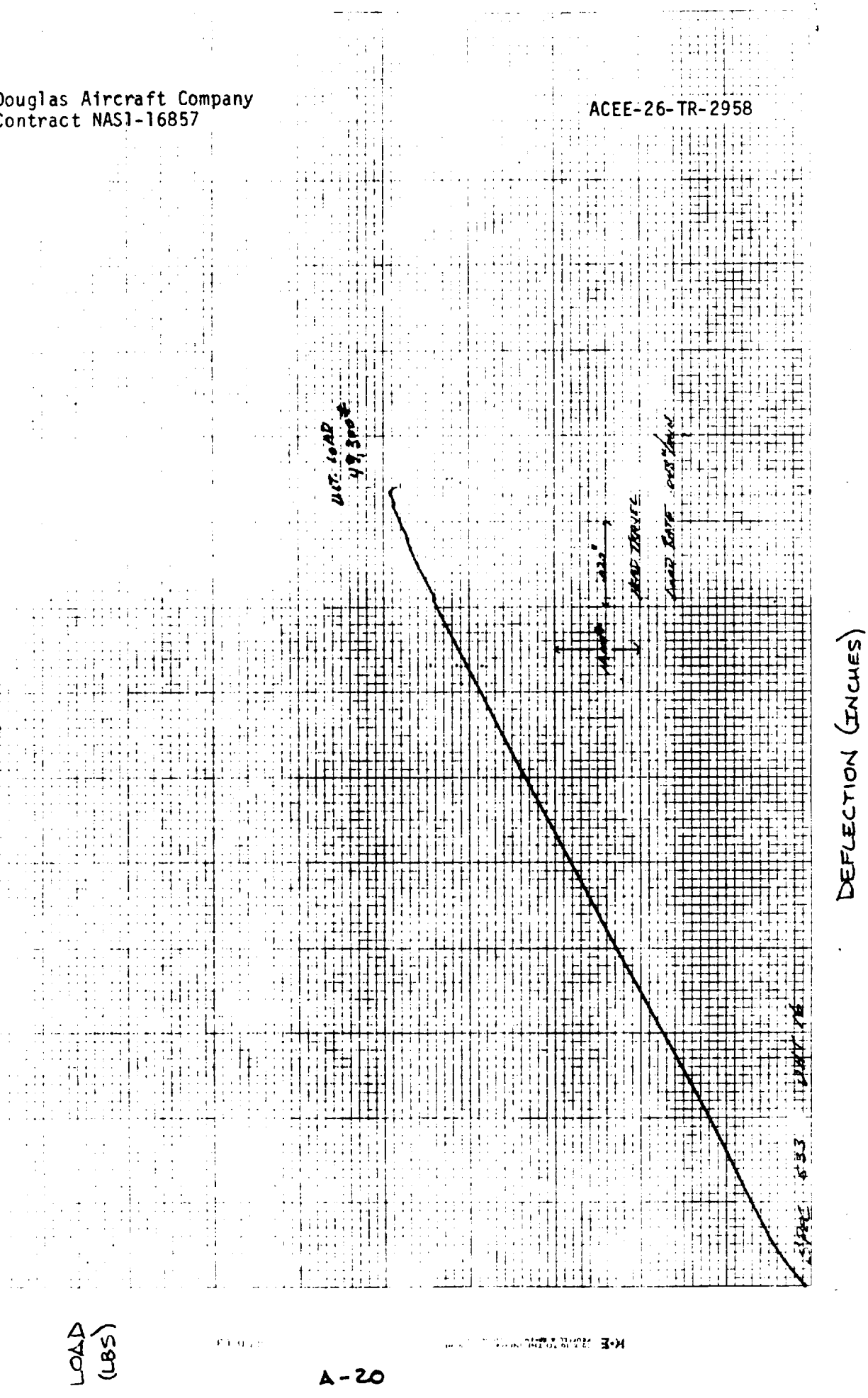
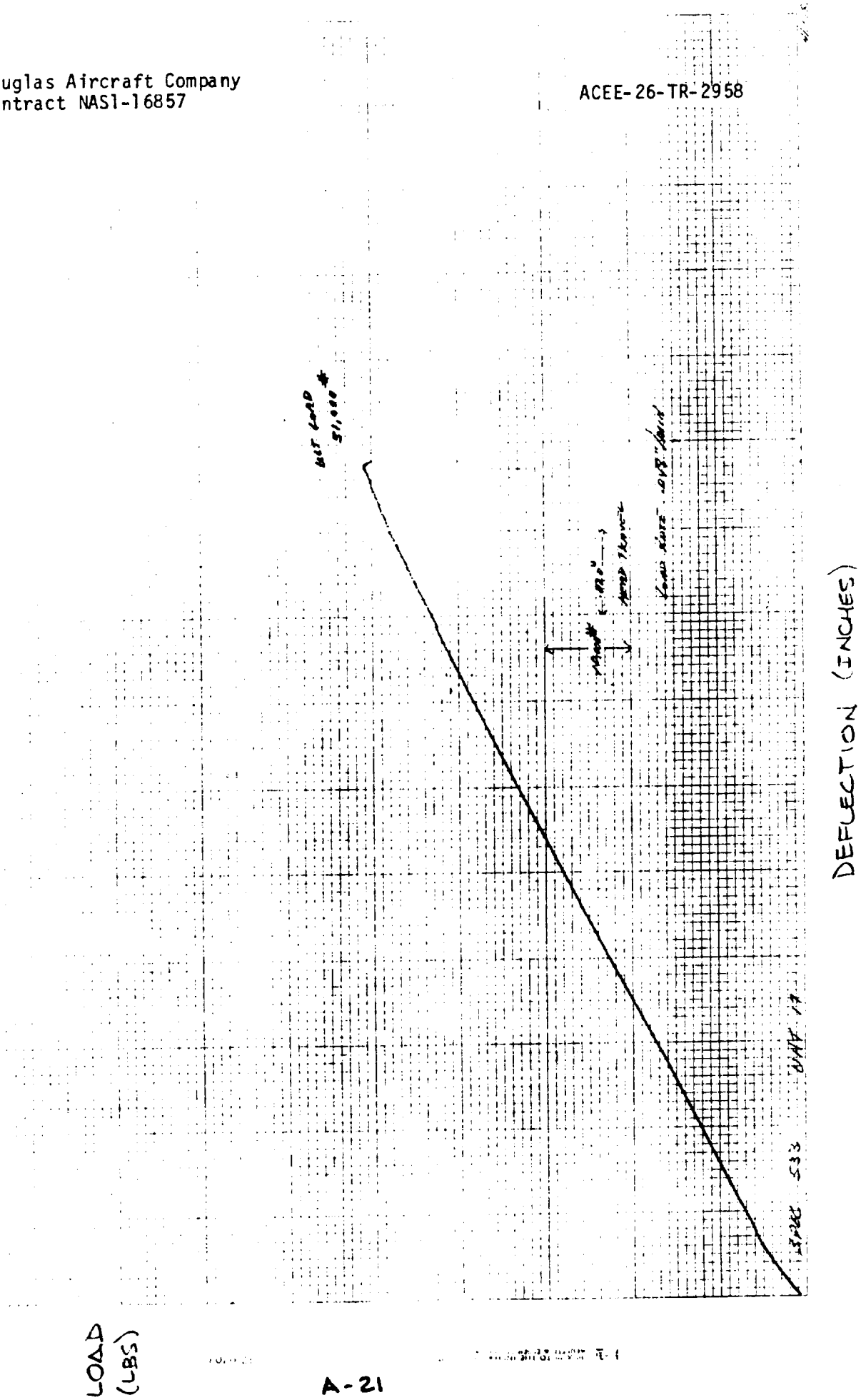
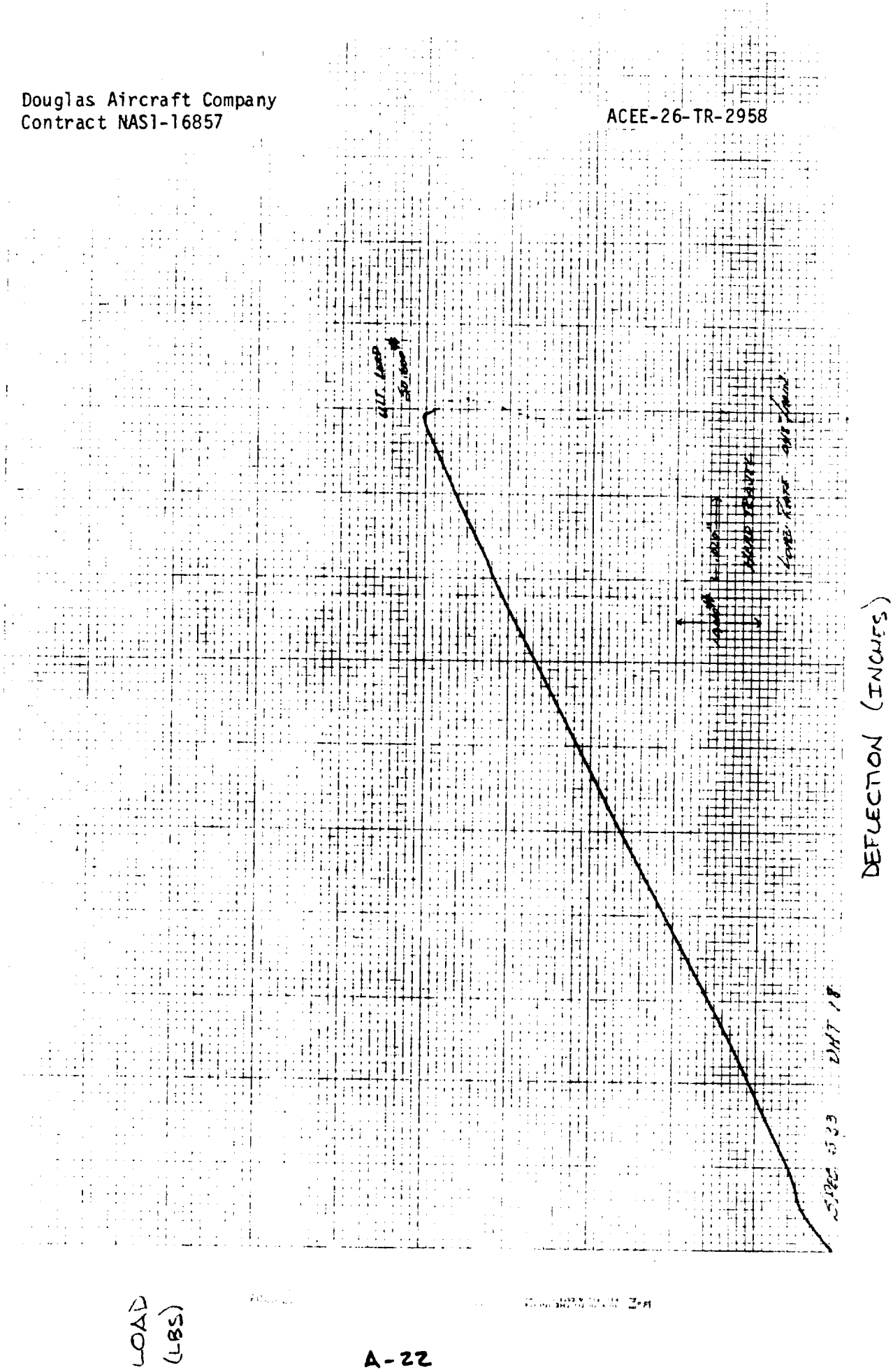
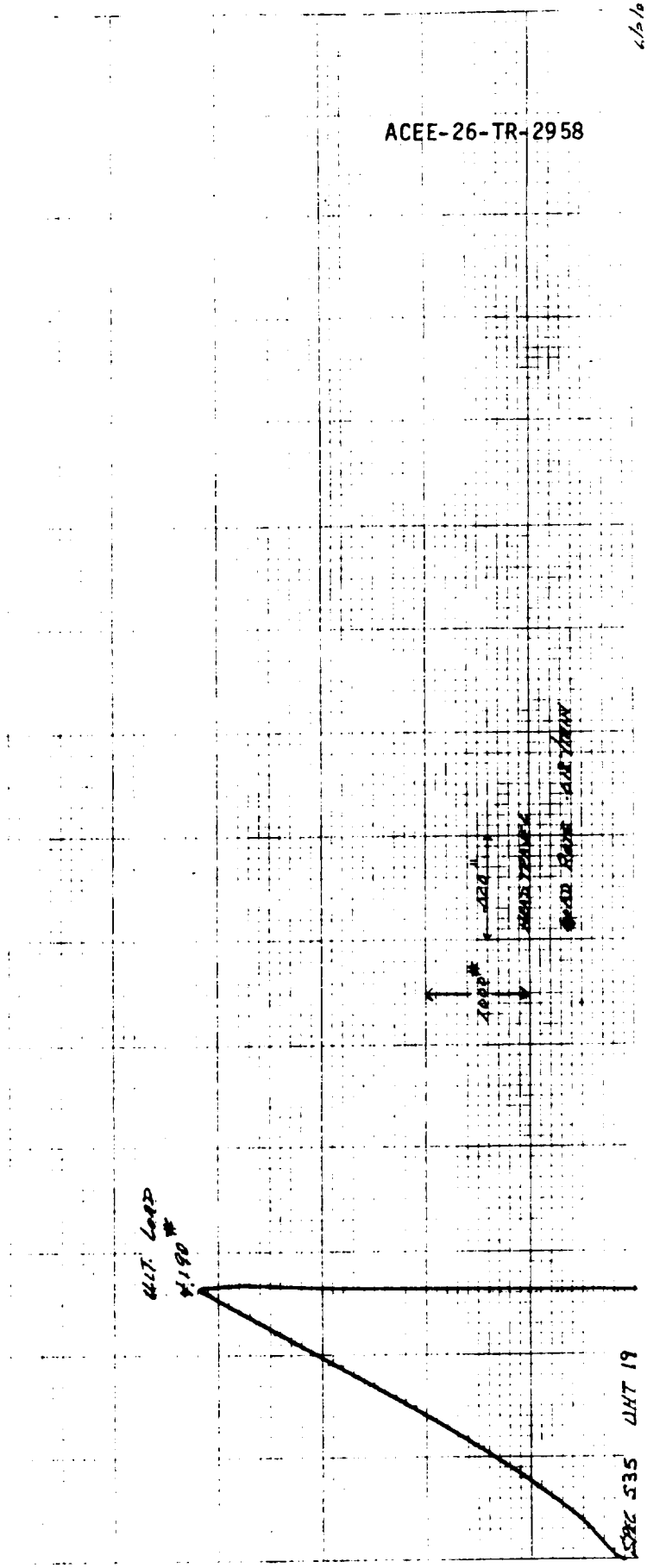
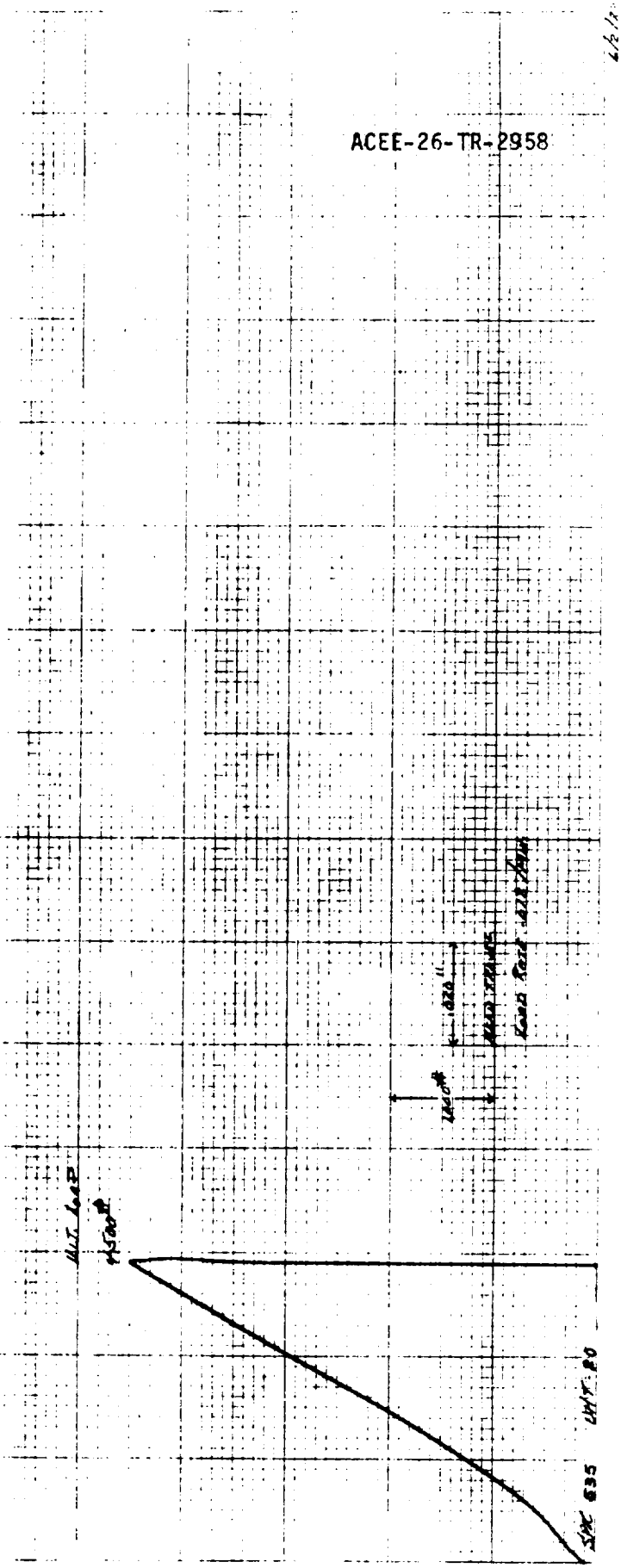
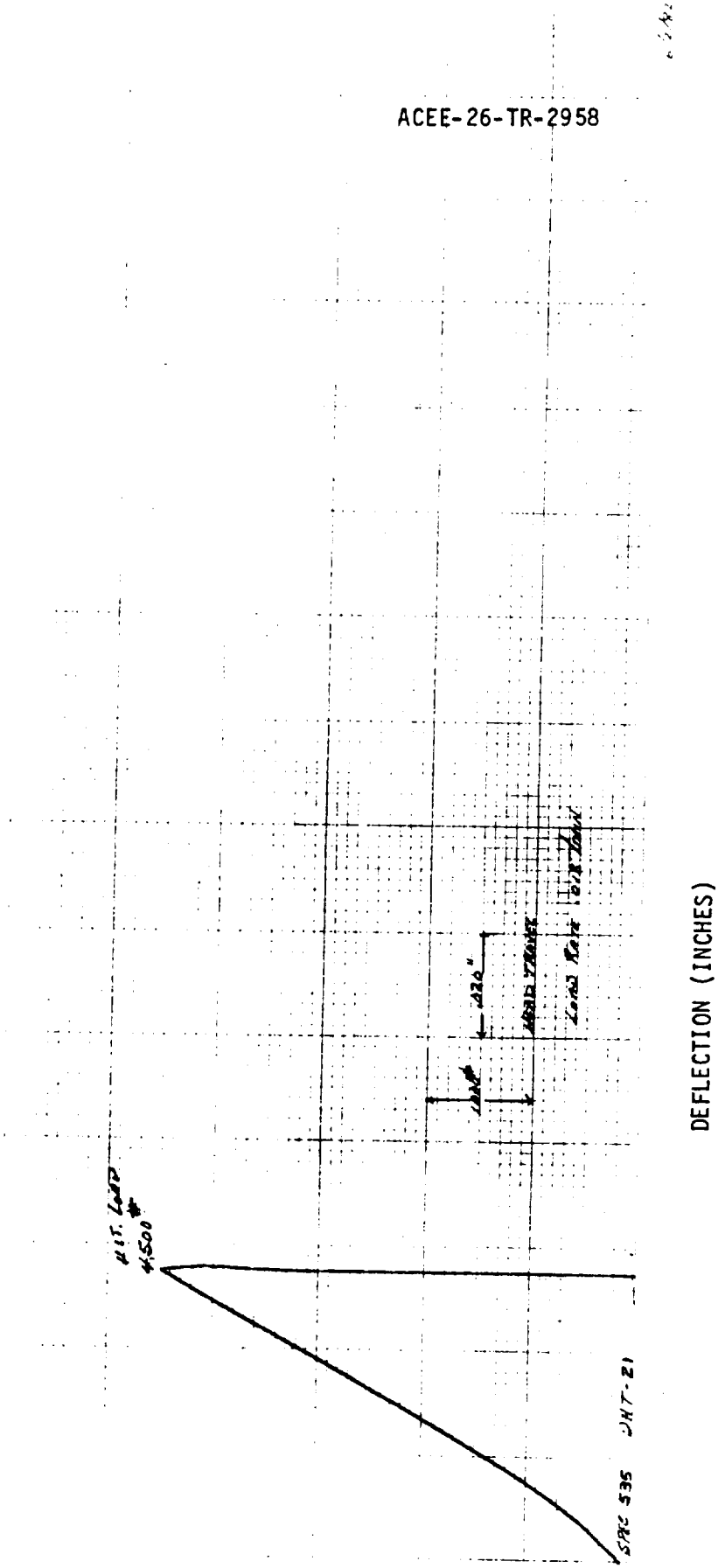

DEFLECTION (INCHES)
LOAD (LBS)

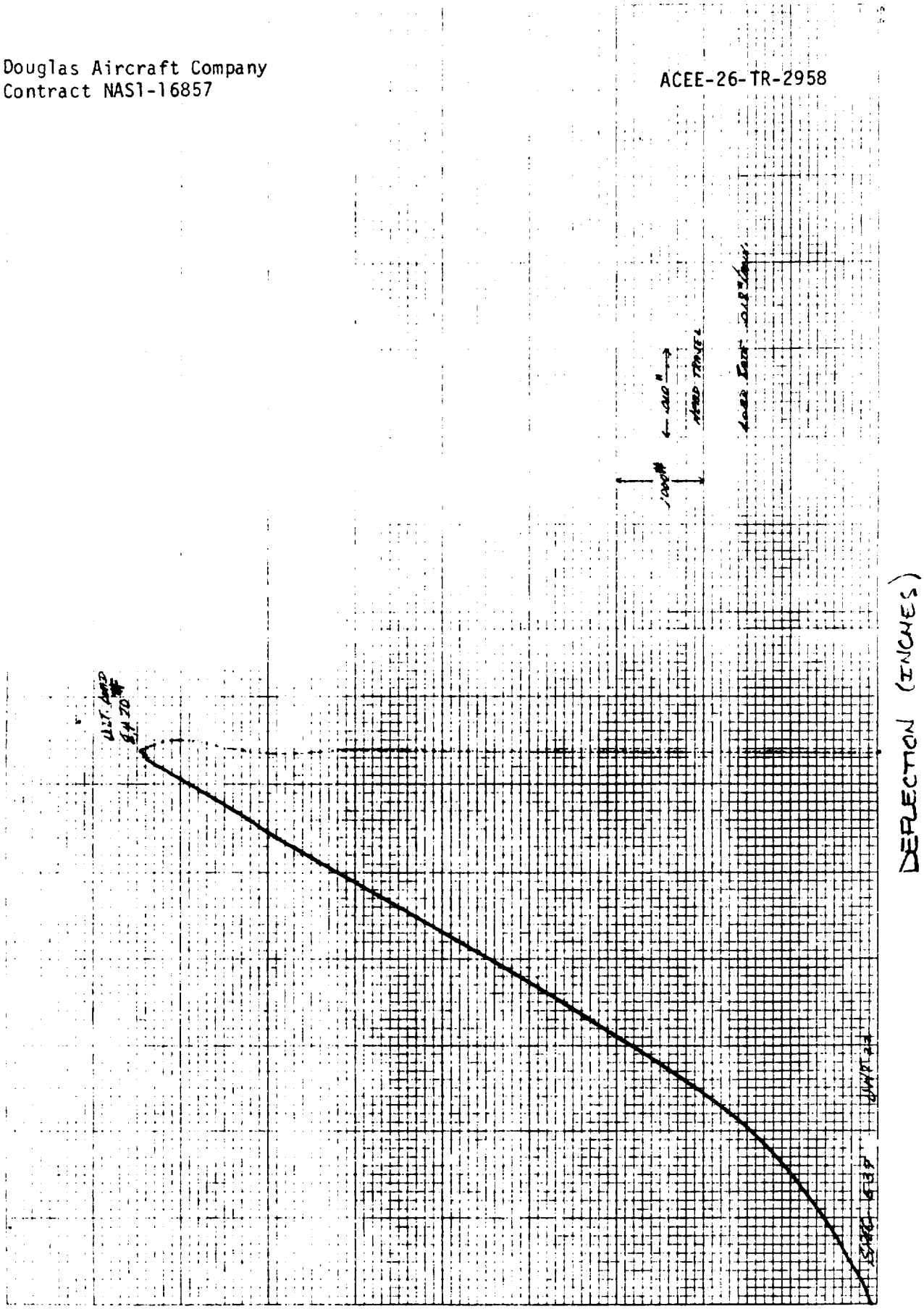

DEFLECTION (INCHES)
LOAD (LBS)

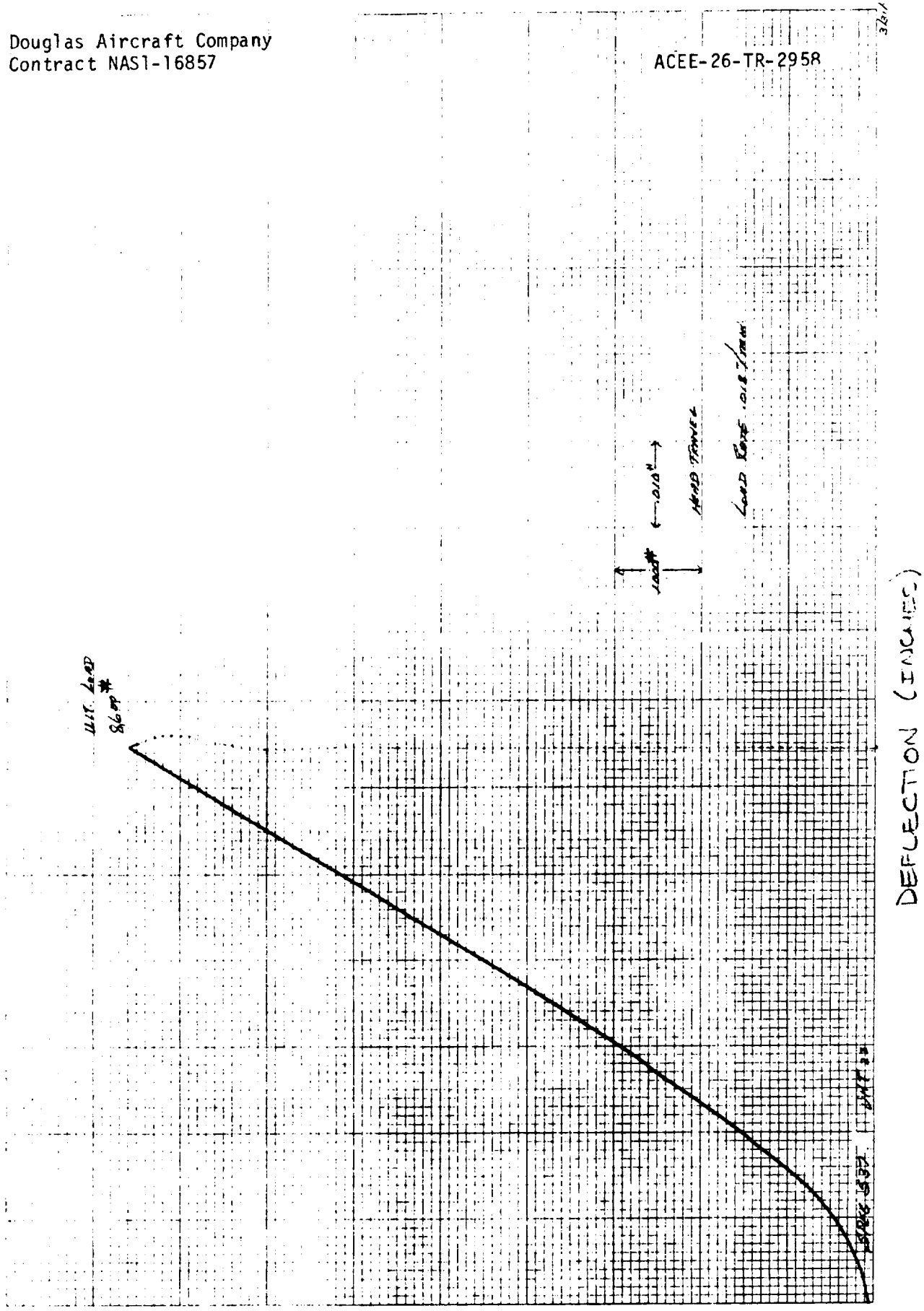

DEFLECTION (INCHES)
LOAD (LBS)

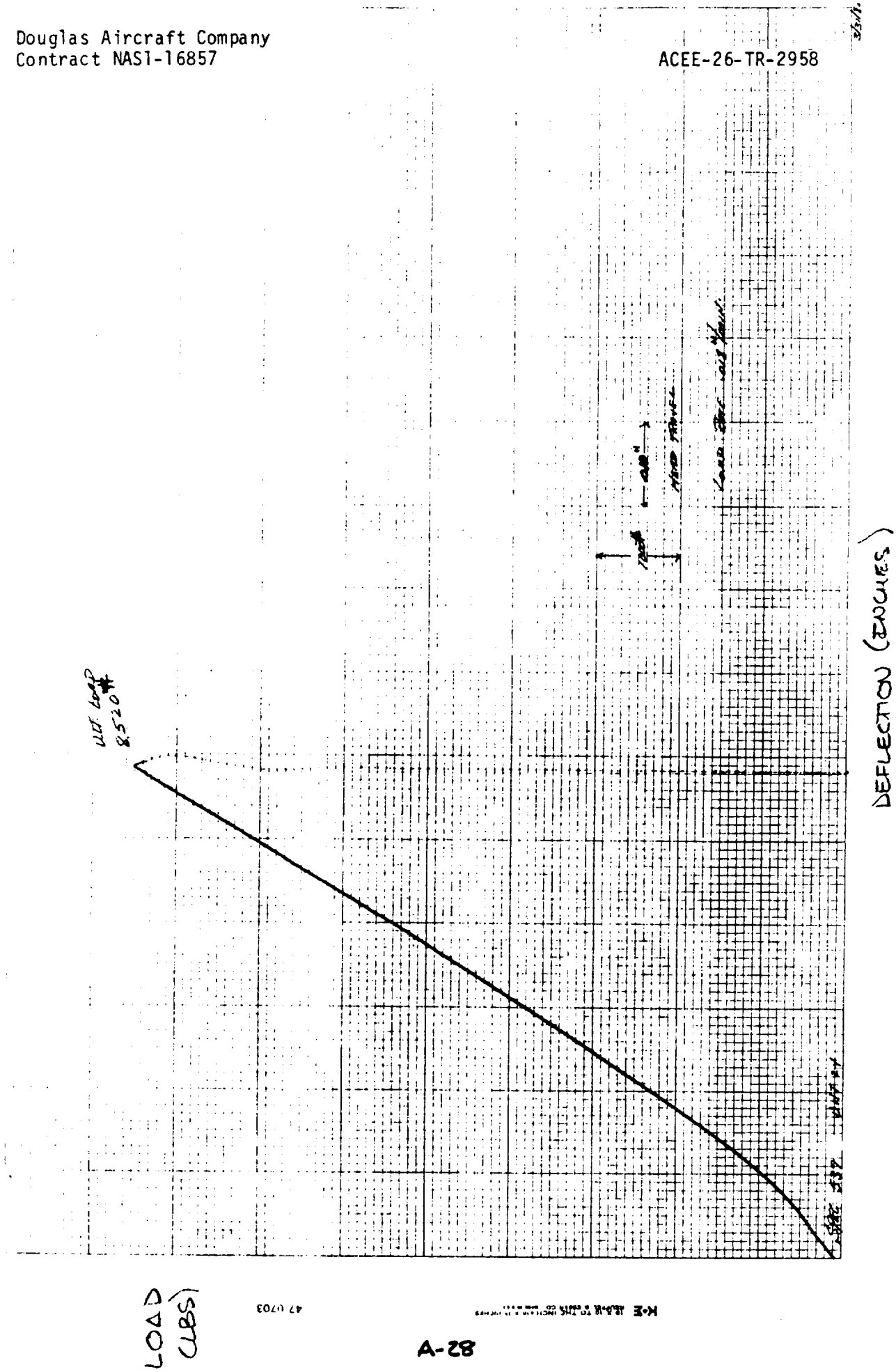

DEFLECTION (INCHES)
LOAD (LBS)

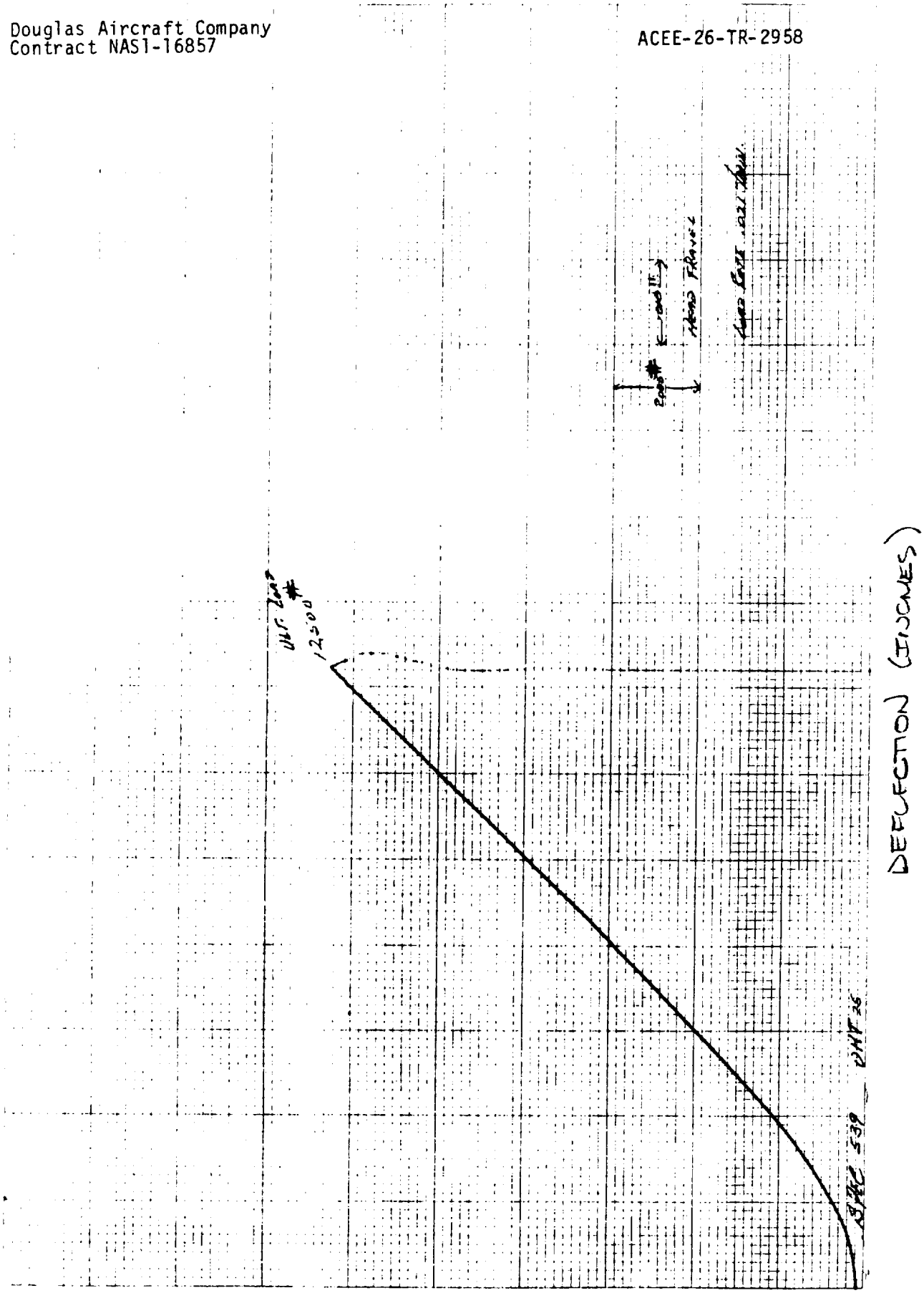

DEFLECTION (INCHES)
LOAD (LBS)


DEFLECTION (INCHES)
LOAD (LBS)
SPEC 535 JHT-21
4,500#

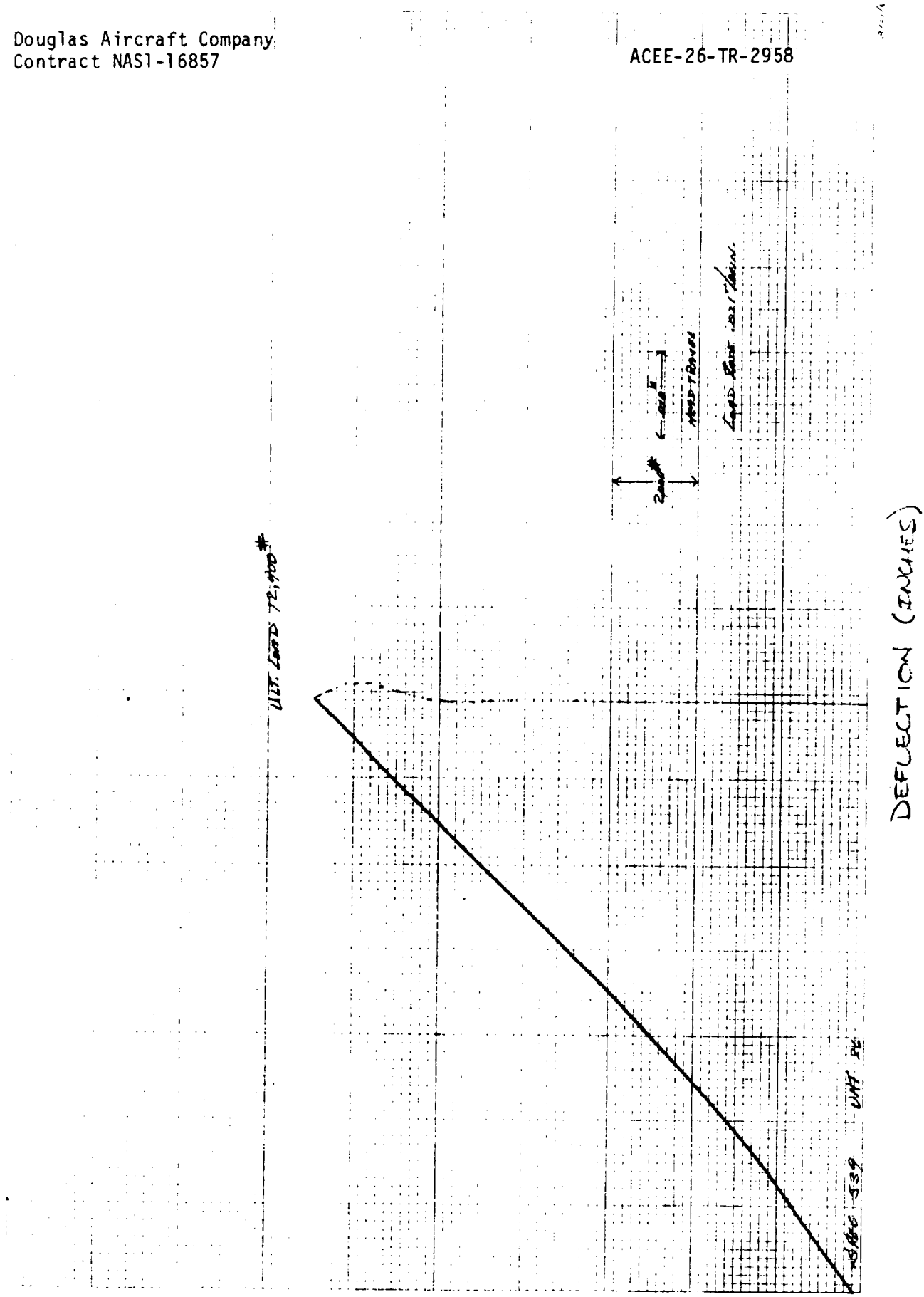

DEFLECTION (INCHES)
LOAD (LBS)

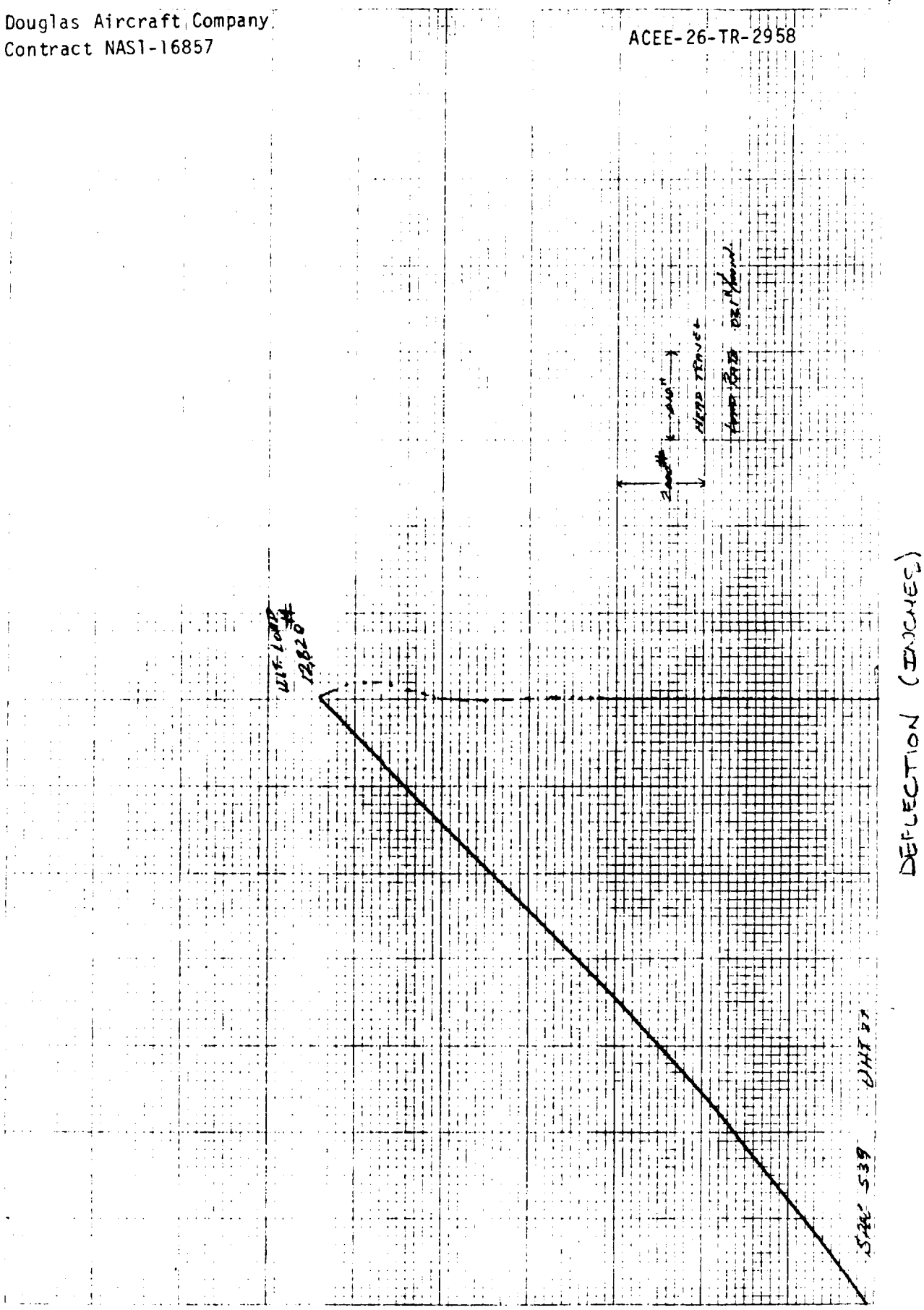

DEFLECTION (INCHES)
LOAD (LBS)
.010"
HEAD TRAVEL
LOAD RATE .018"/MIN
100#
UIT. LOAD
860#
STROKE GAP
UNIT #


LOAD (LBS)
DEFLECTION (INCHES)
ULT LOAD
8520#


DEFLECTION (INCHES)
SPEC 539
UNIT 26
ULT. LOAD
12500
2000
HEAD FRAME
FUSELAGE CAT. TEST

LOAD (LBS)


UIT. LOAD 72,000#
DEFLECTION (INCHES)
LOAD (LBS)



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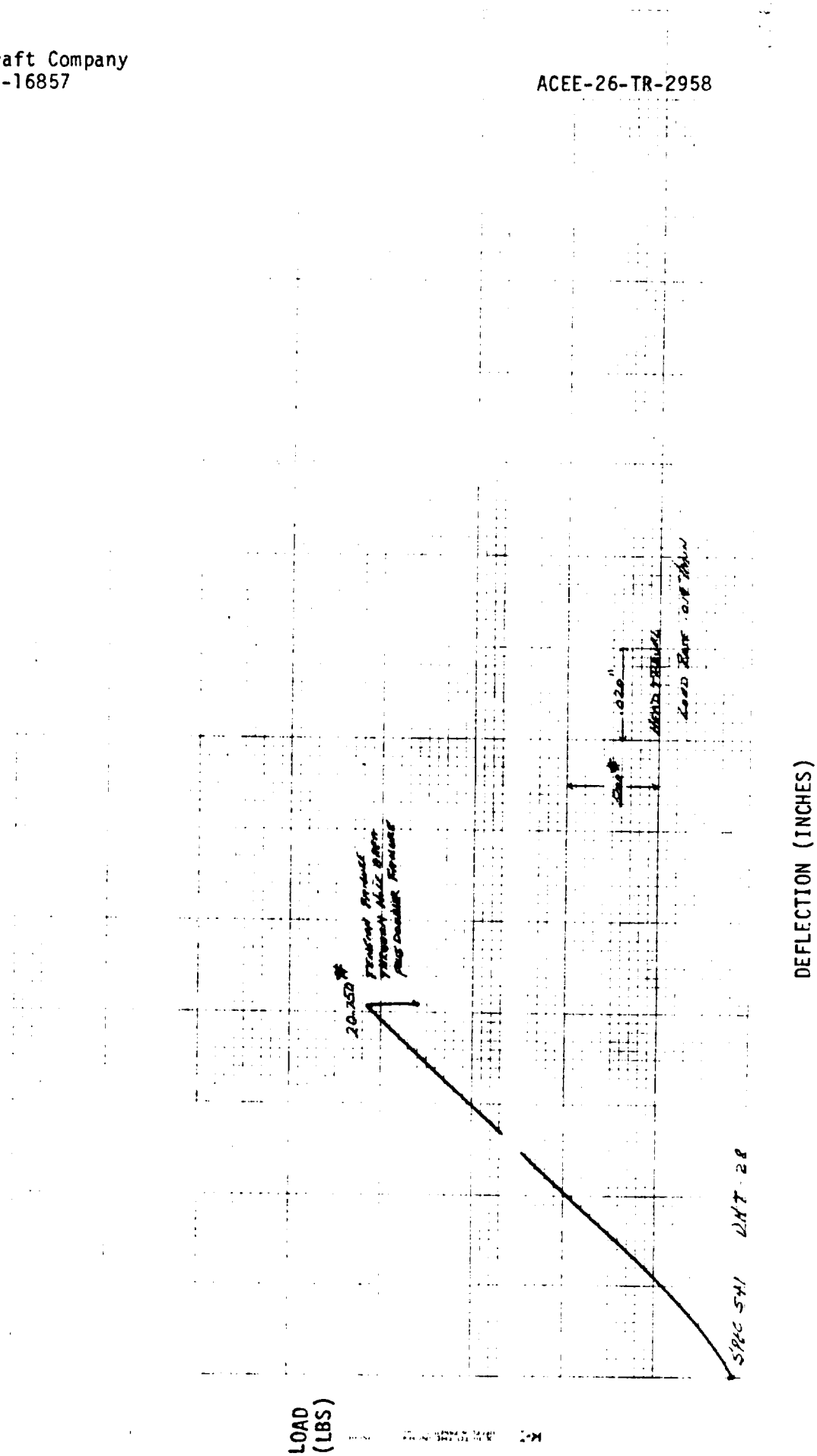
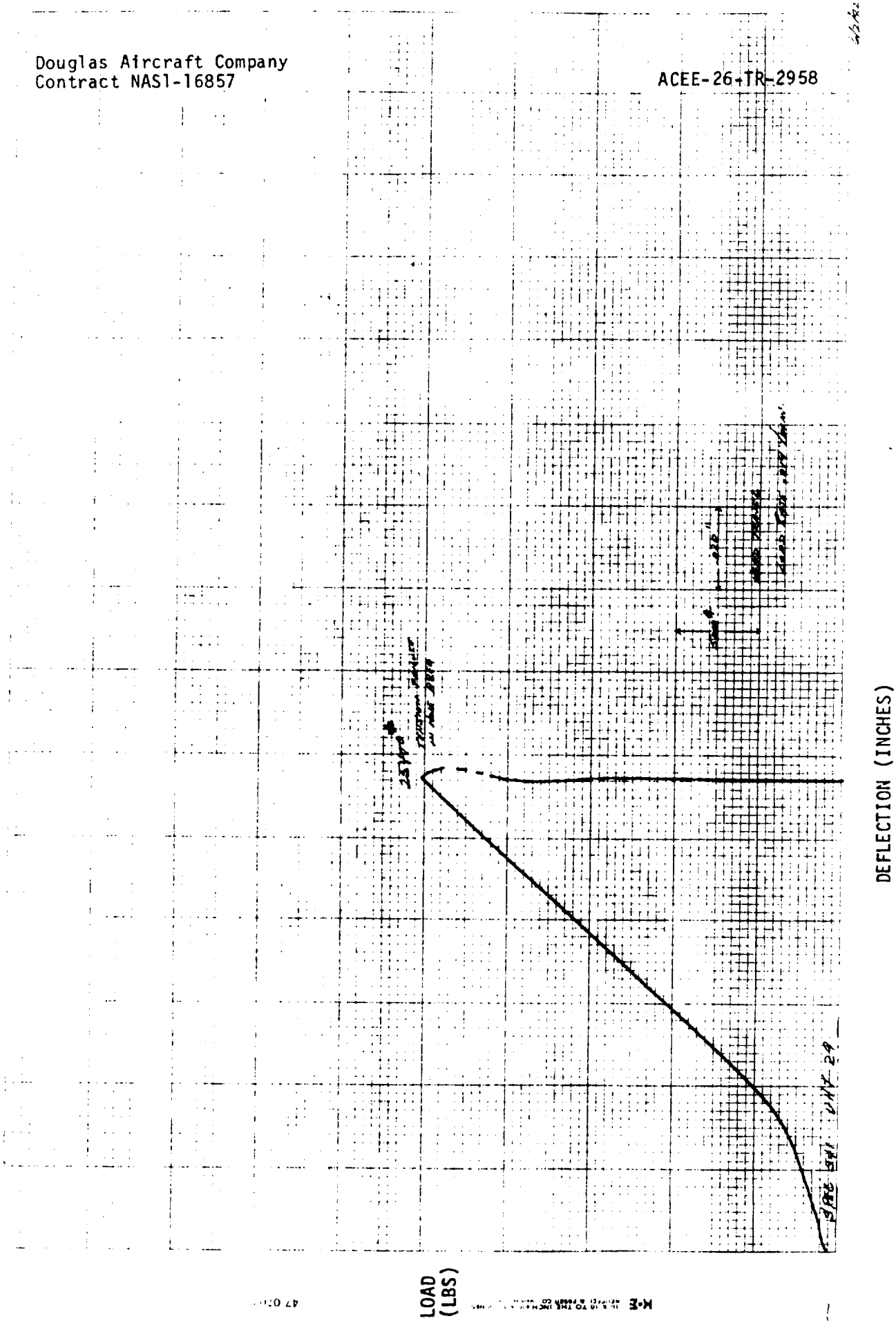
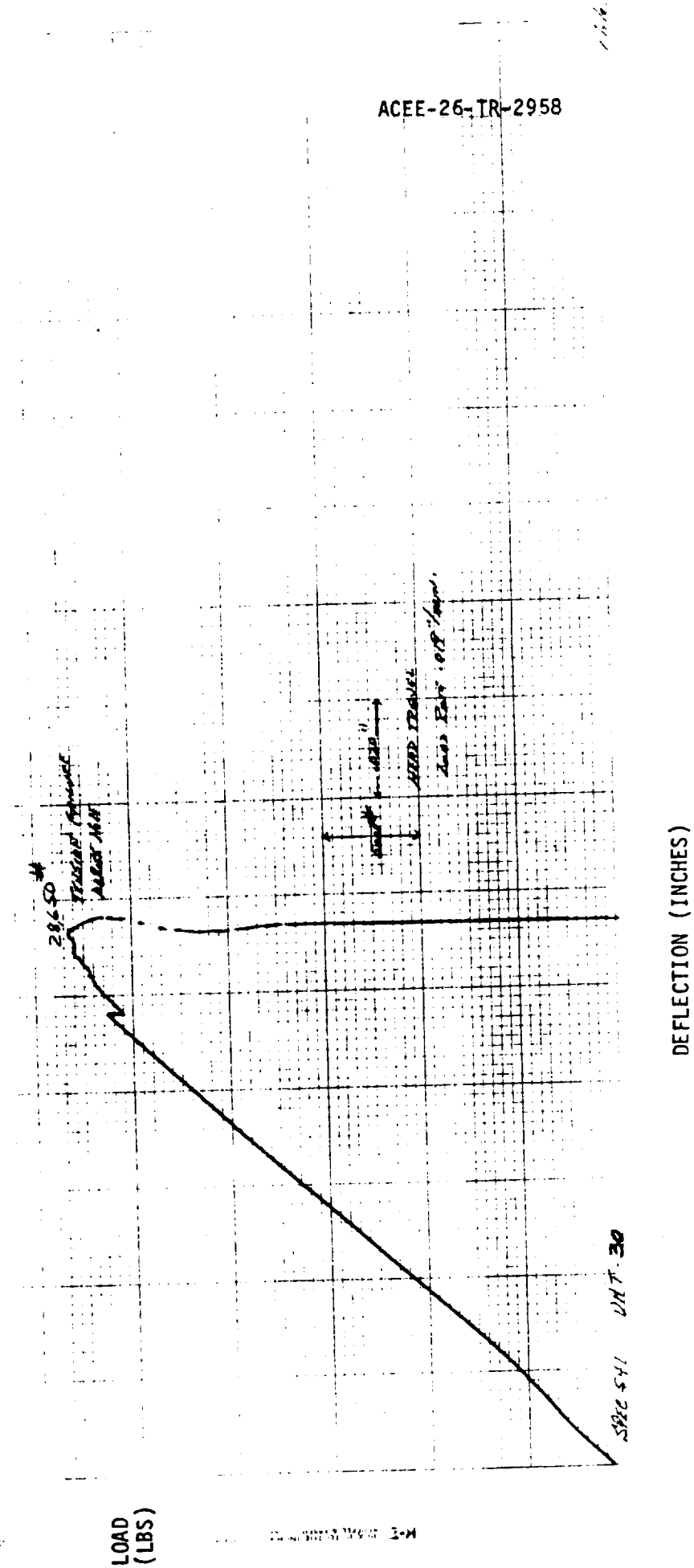
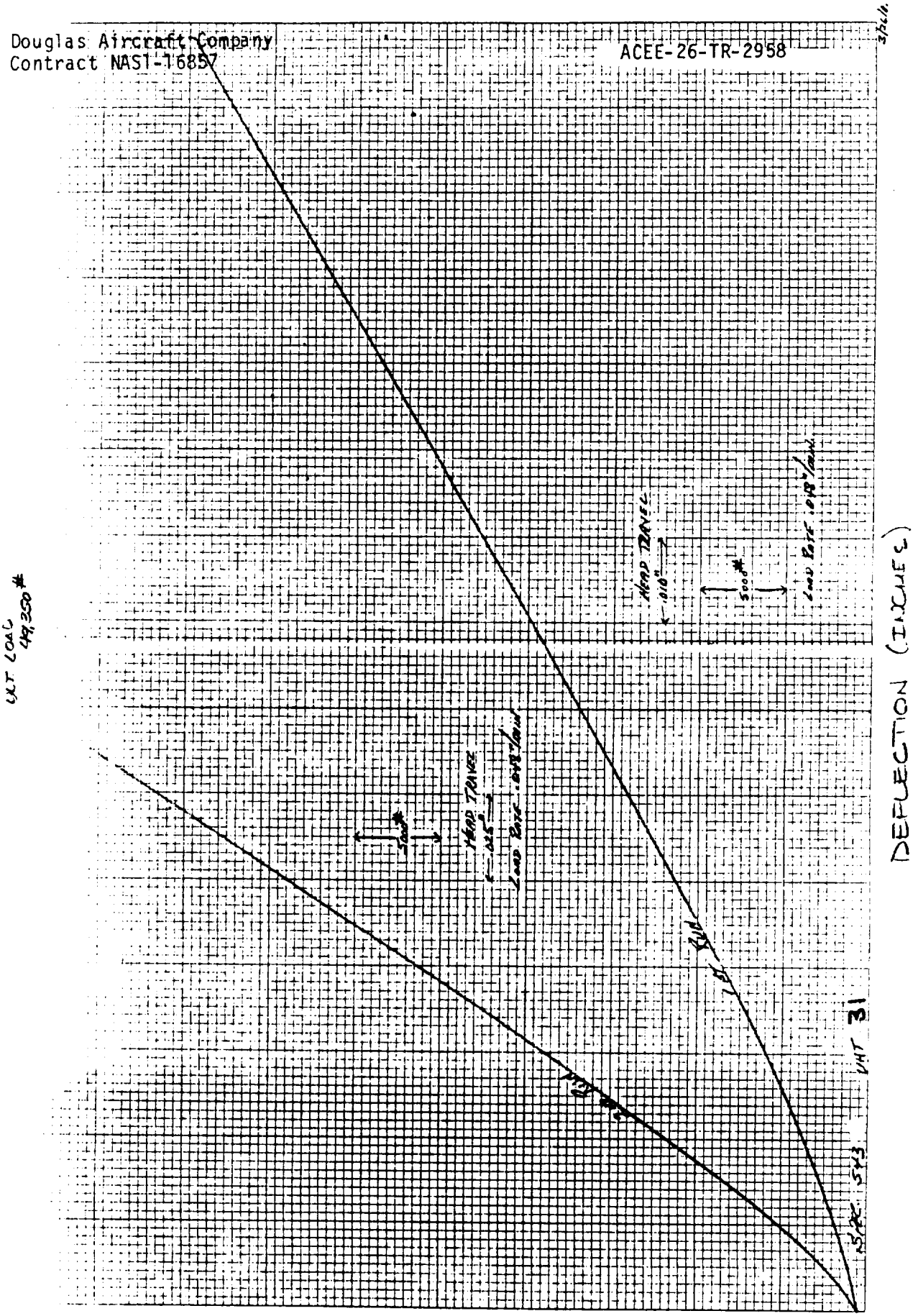
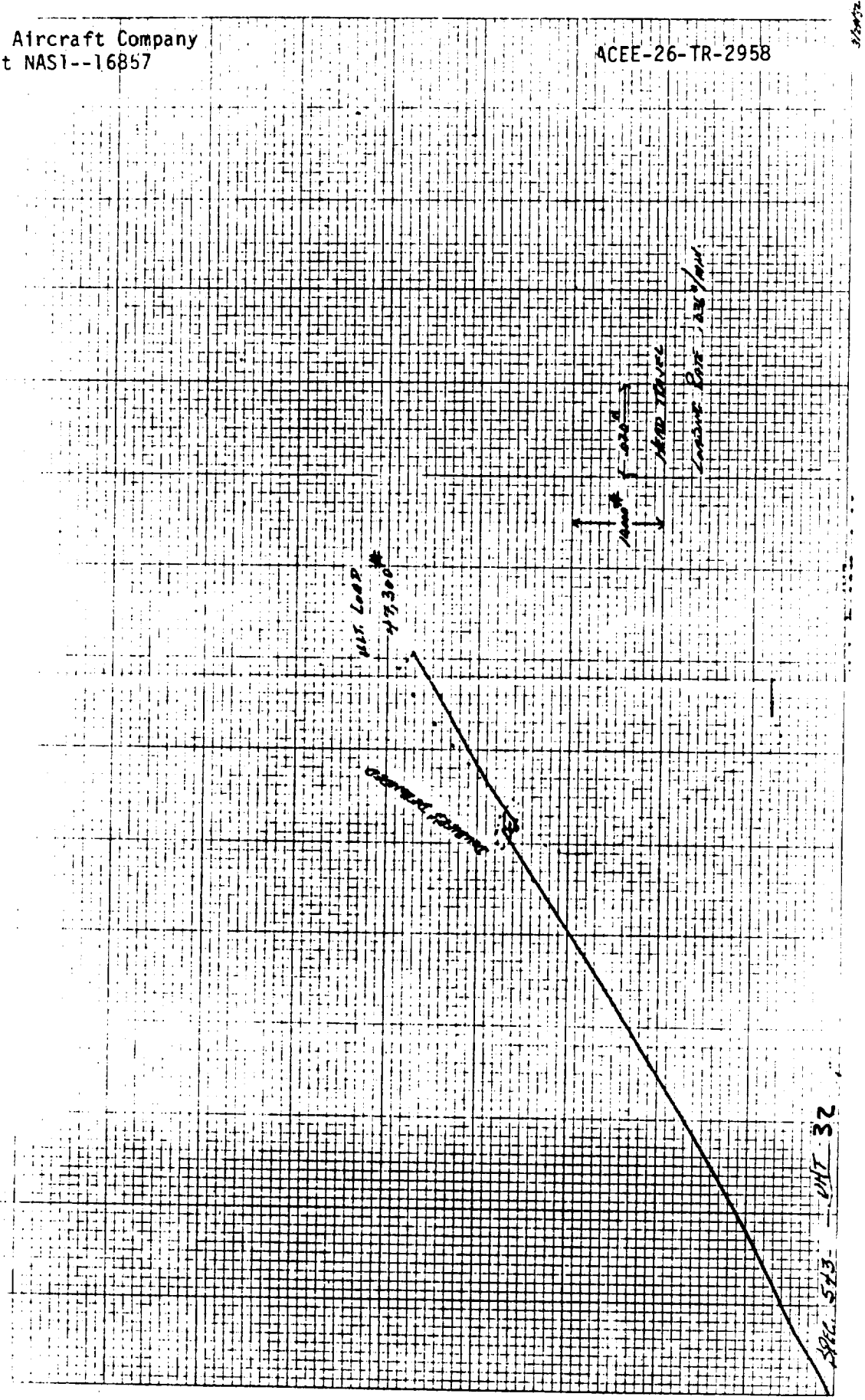
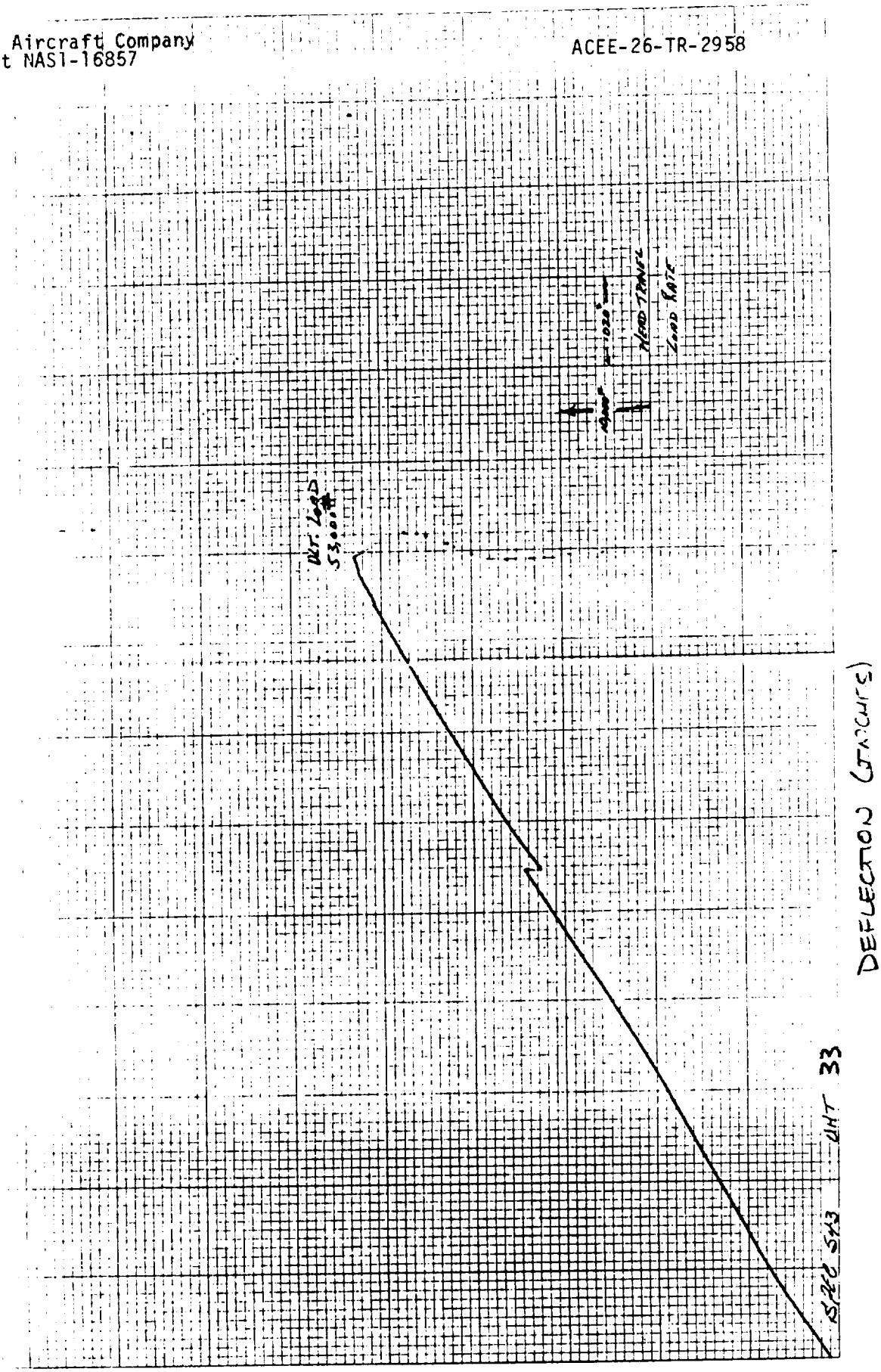

LOAD
(LBS)
DEFLECTION (INCHES)


LOAD
(LBS)
DEFLECTION (INCHES)


28650#
HEAD TRAVEL
DEFLECTION (INCHES)
LOAD (LBS)


ULT LOAD 49,350#
HEAD TRAVEL .010"
500#
LOAD RATE .018"/MIN
HEAD TRAVEL .025"
500#
LOAD RATE .018"/MIN
DEFLECTION (INCHES)
LOAD (LBS)
SPEC. STD. UNIT 31


DEFLECTION (INCHES)
LOAD (LBS)
UNIT 32
MAX. LOAD
47,300#
OBSERVED FAILURE
MAX. 0.20"
MEAN TRACE
LOWER BOUND 0.38"/INT.



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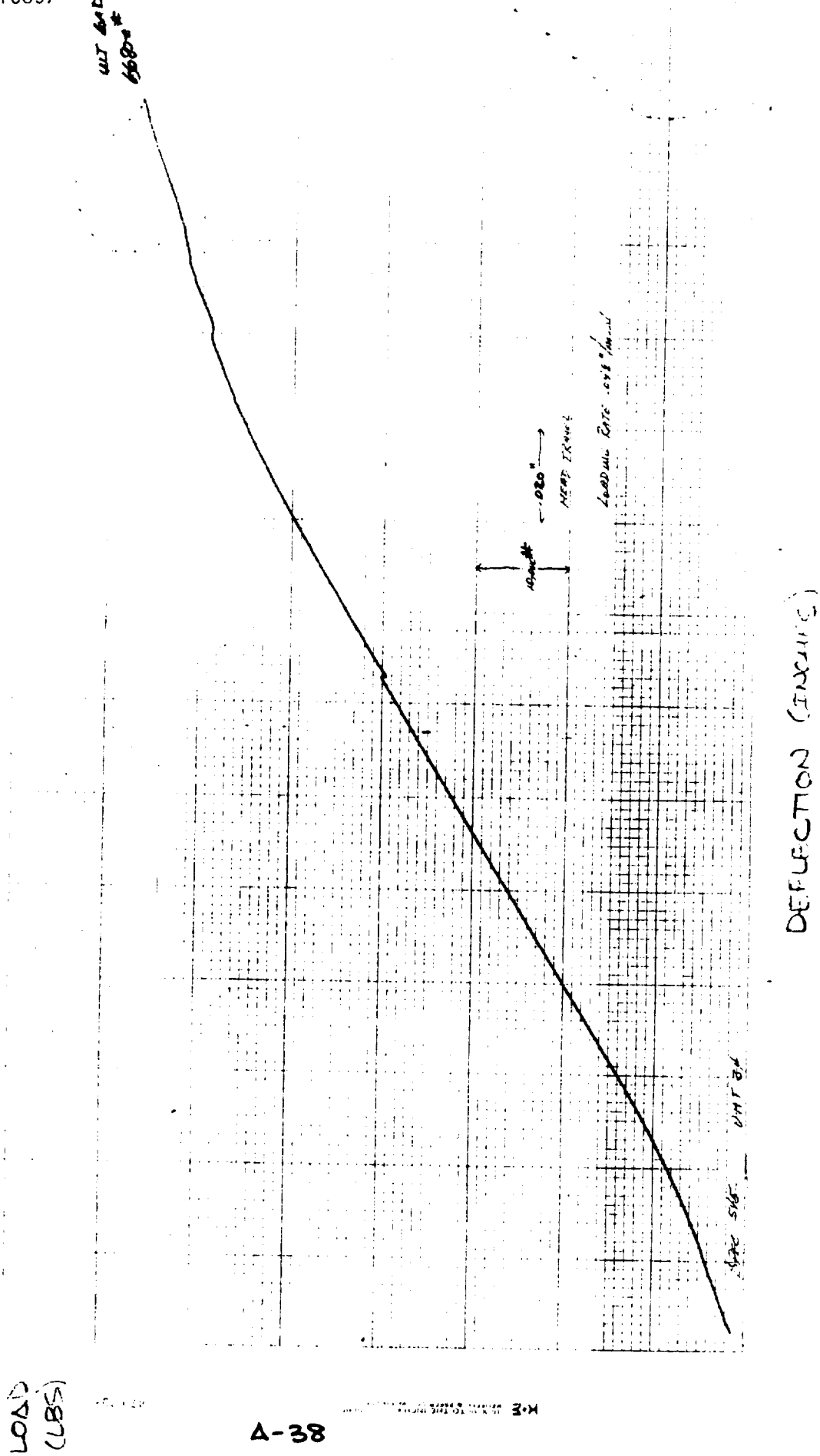
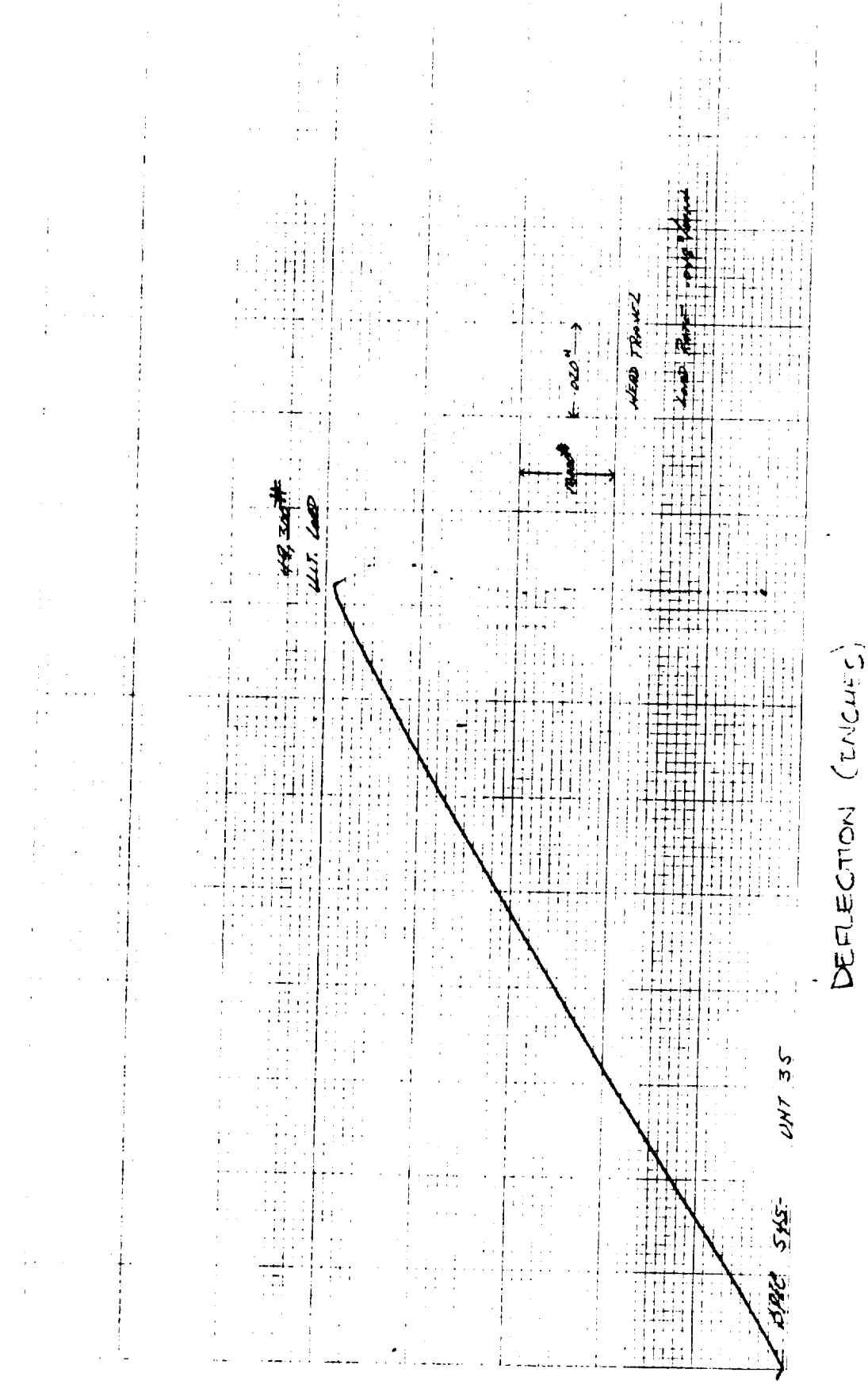
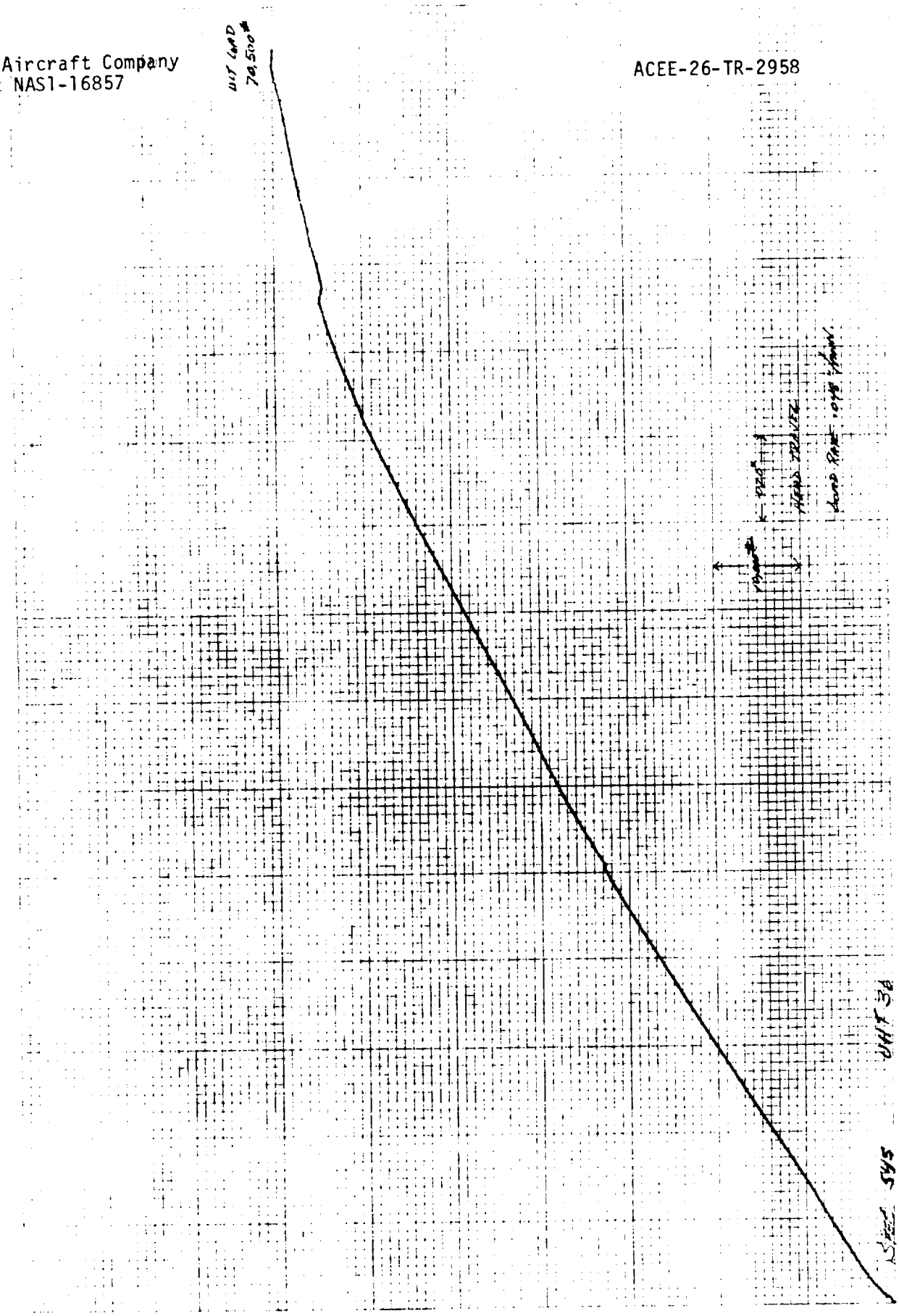
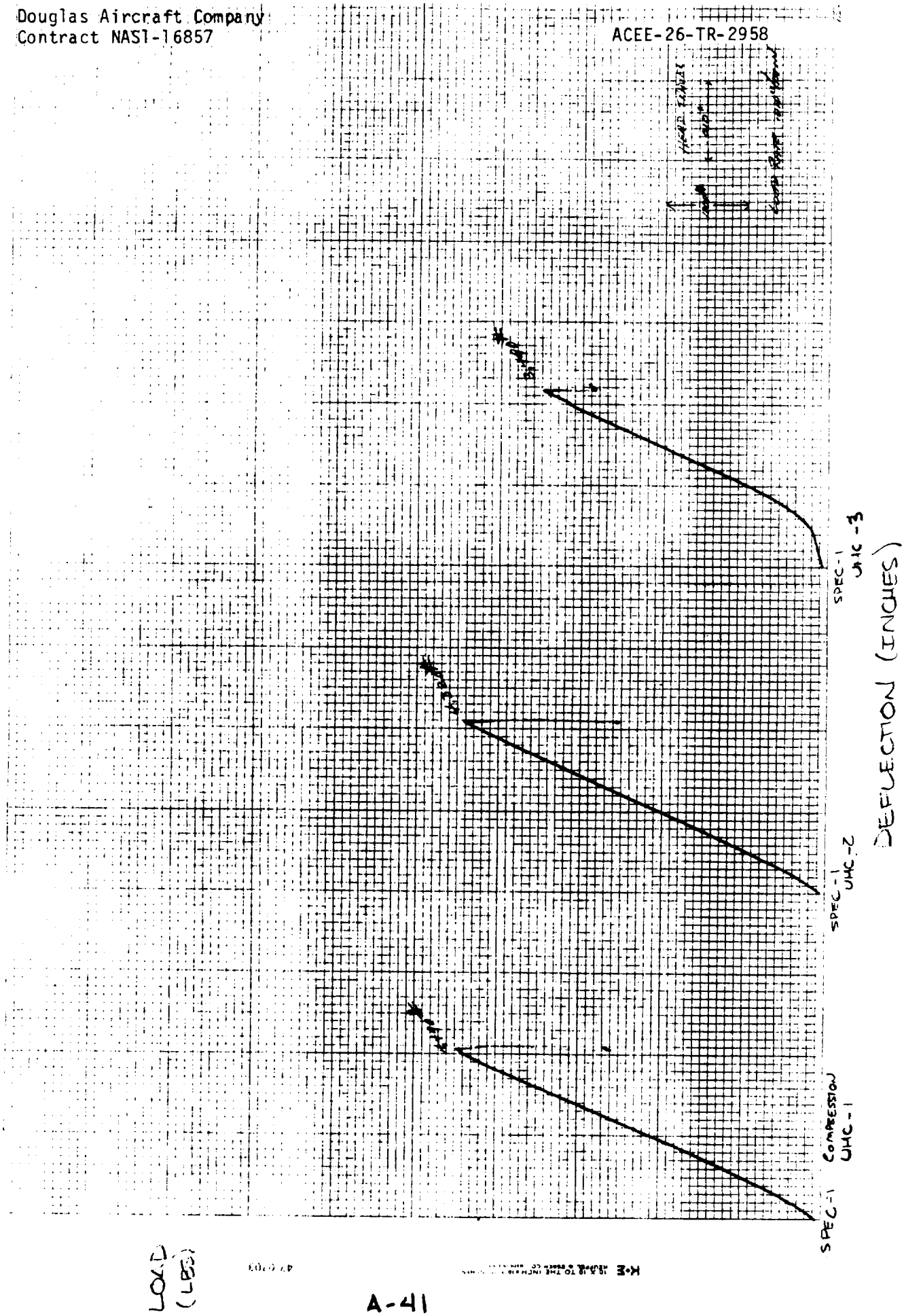
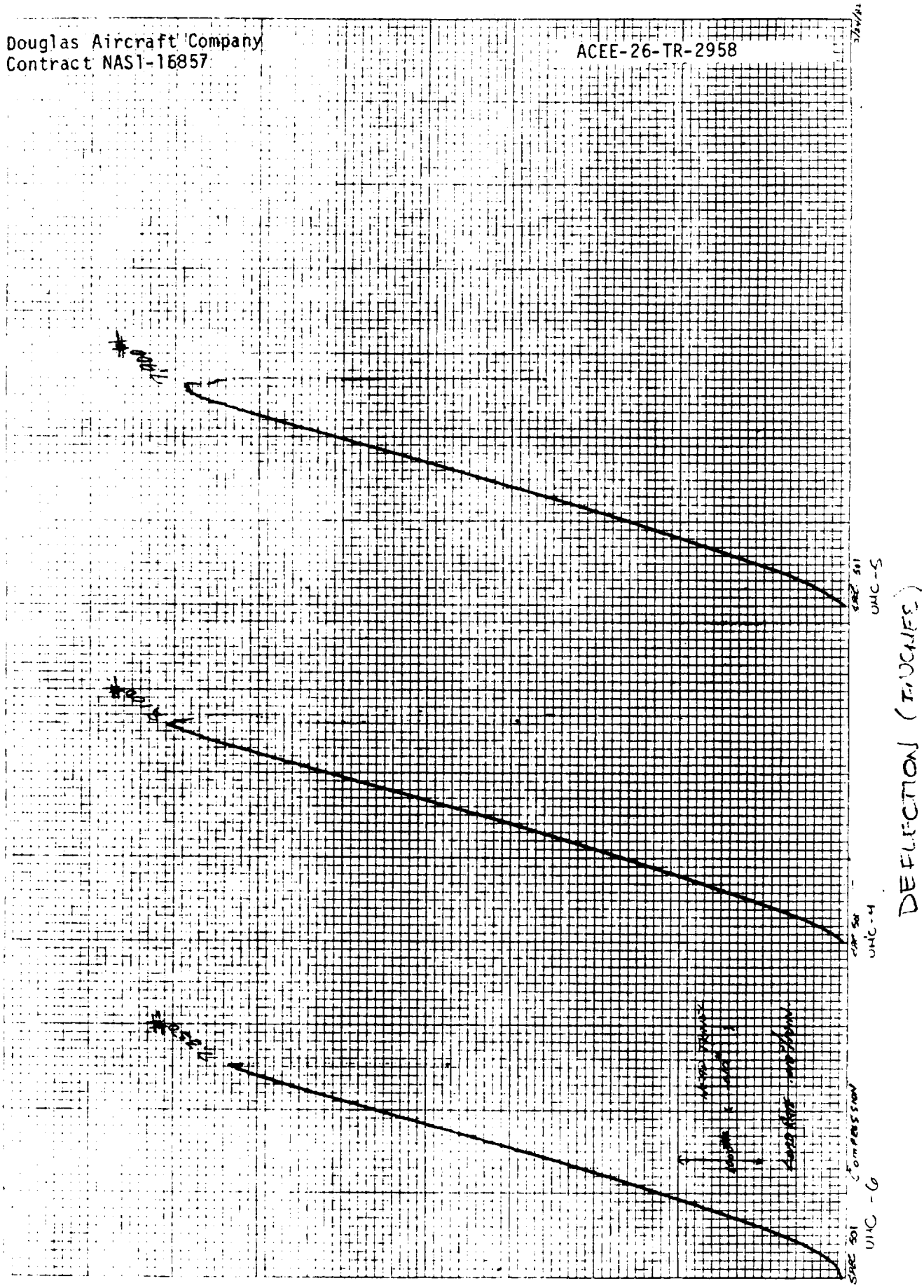

DEFLECTION (INCHES)
LOAD (LBS)

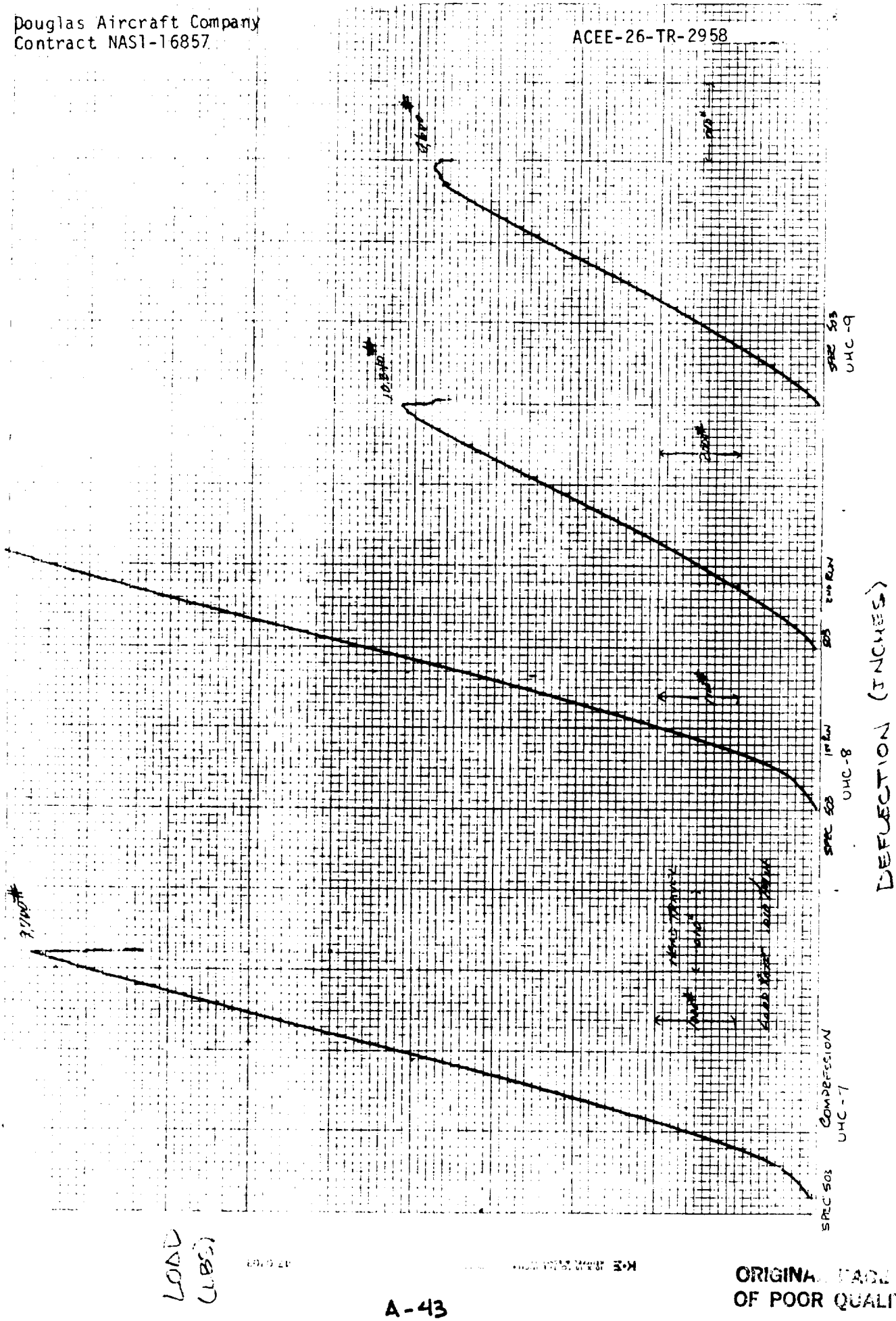

DEFLECTION (INCHES)
UNIT 35
SAS-
LOAD (LBS)



LOAD (LB)


SPEC-1
UHC-3
SPEC-1
UHC-2
COMPRESSION
UHC-1
SPEC-1
DEFLECTION (INCHES)
LOAD
(LBS)


SPEC 501
UHC-6
COMPRESSION
SPEC 501
UHC-4
SPEC 501
UHC-5
DEFLECTION (INCHES)
LOAD (LBS)



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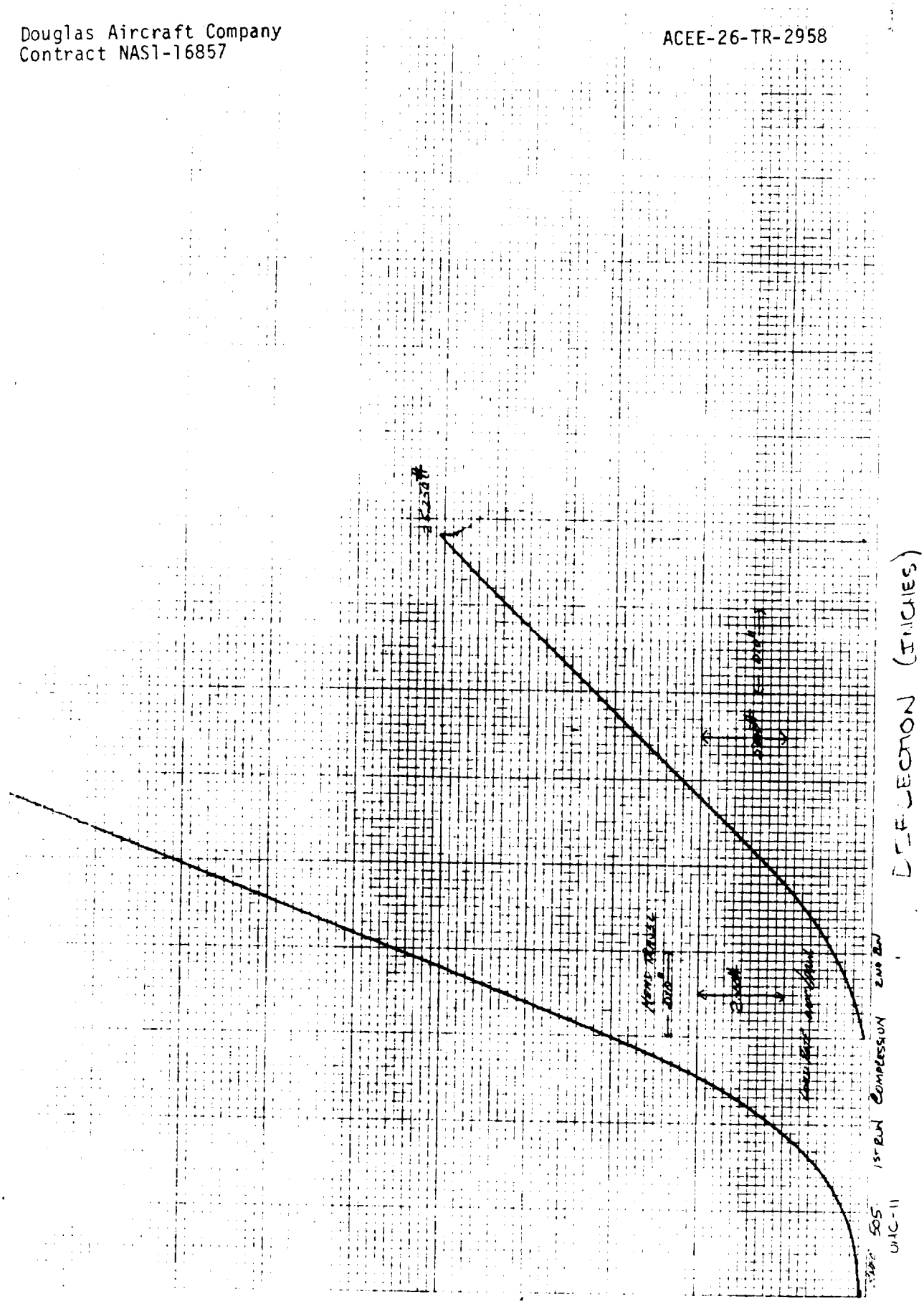
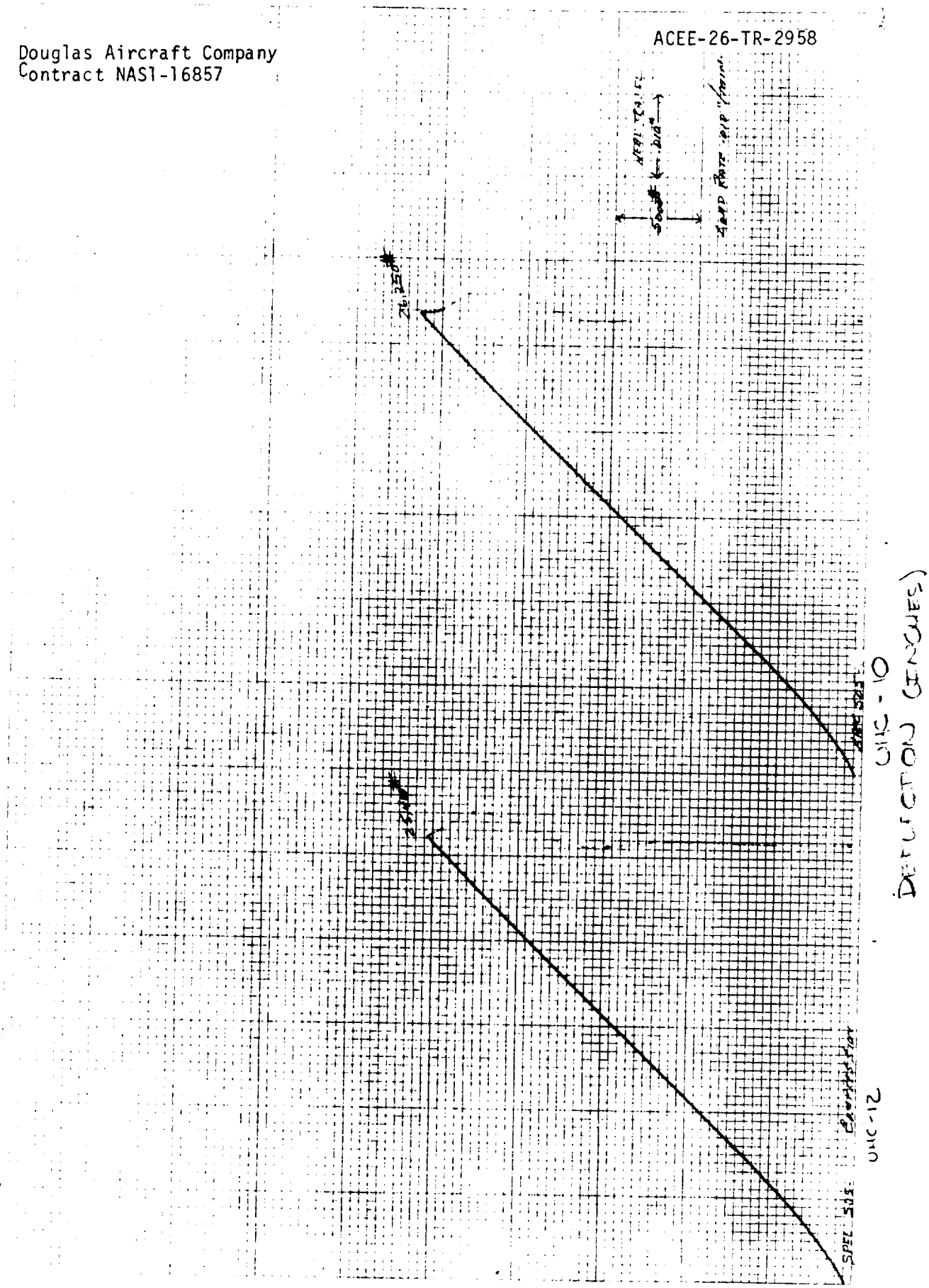
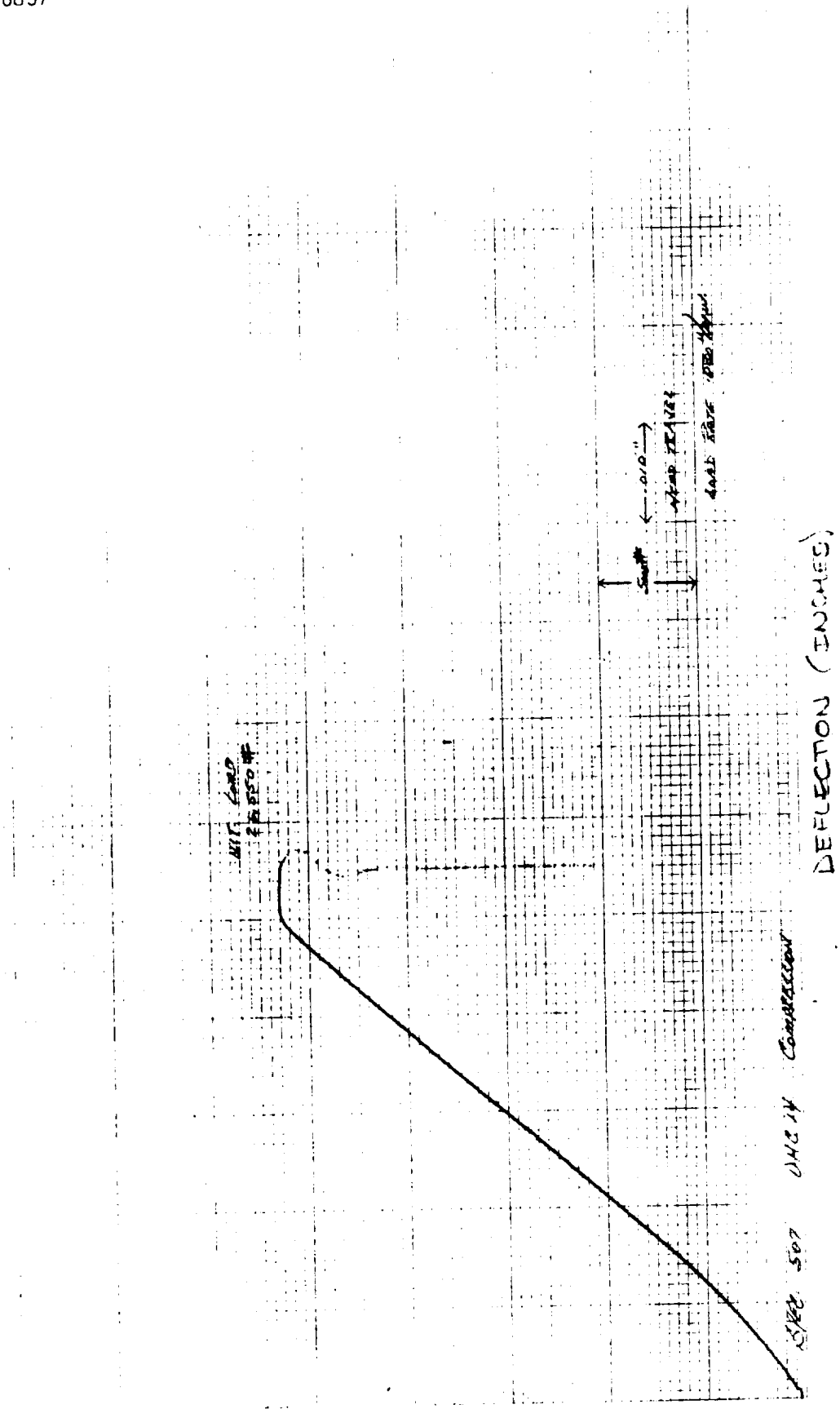
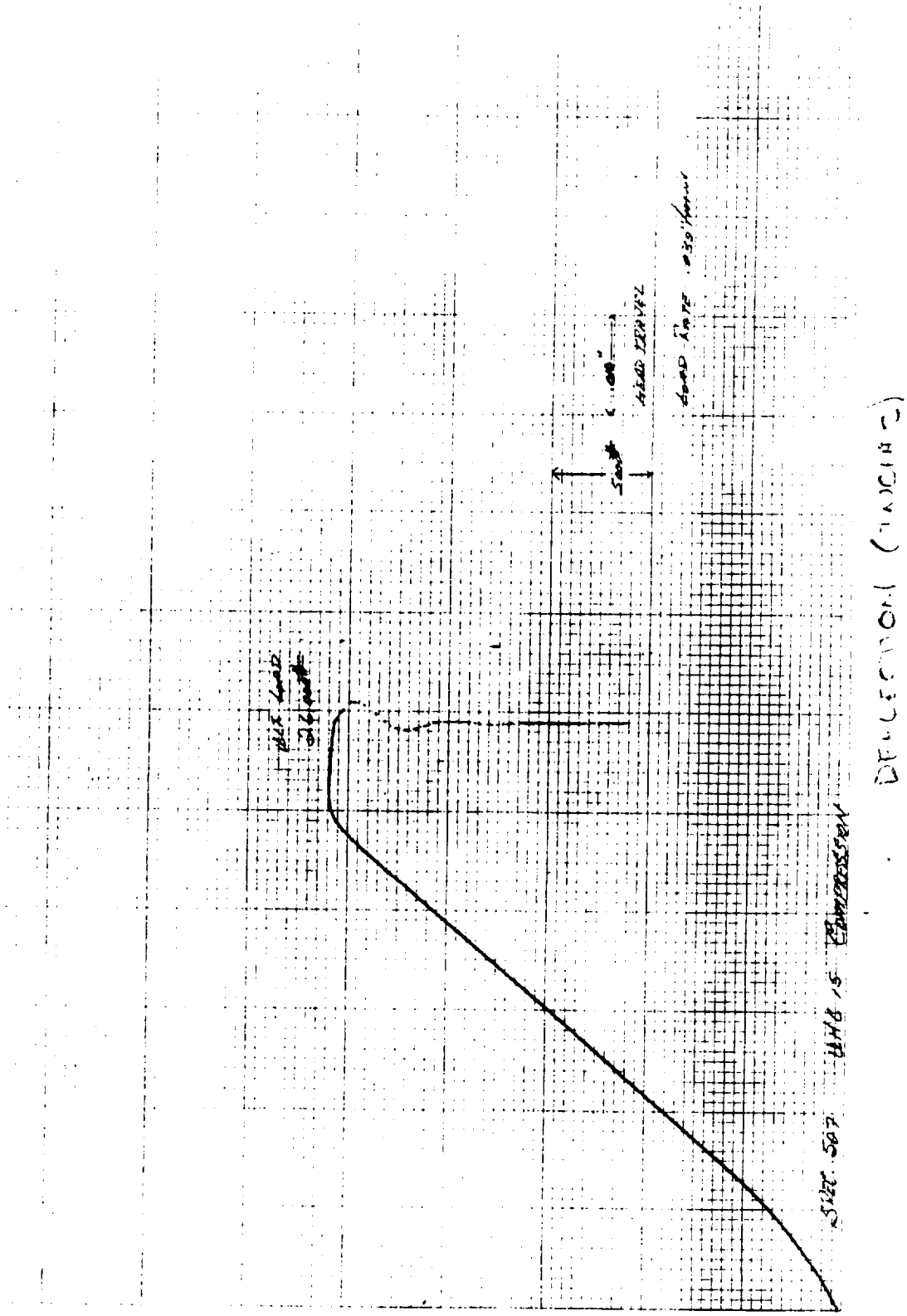

LOAD (LBS)
DEFLECTION (INCHES)
1ST RUN COMPRESSION
2ND RUN
505
UNC-11


26,250#
23,000#
UNC-10
UNC-12
DEFLECTION (INCHES)
LOAD (LBS)


DEFLECTION (INCHES)
.010"



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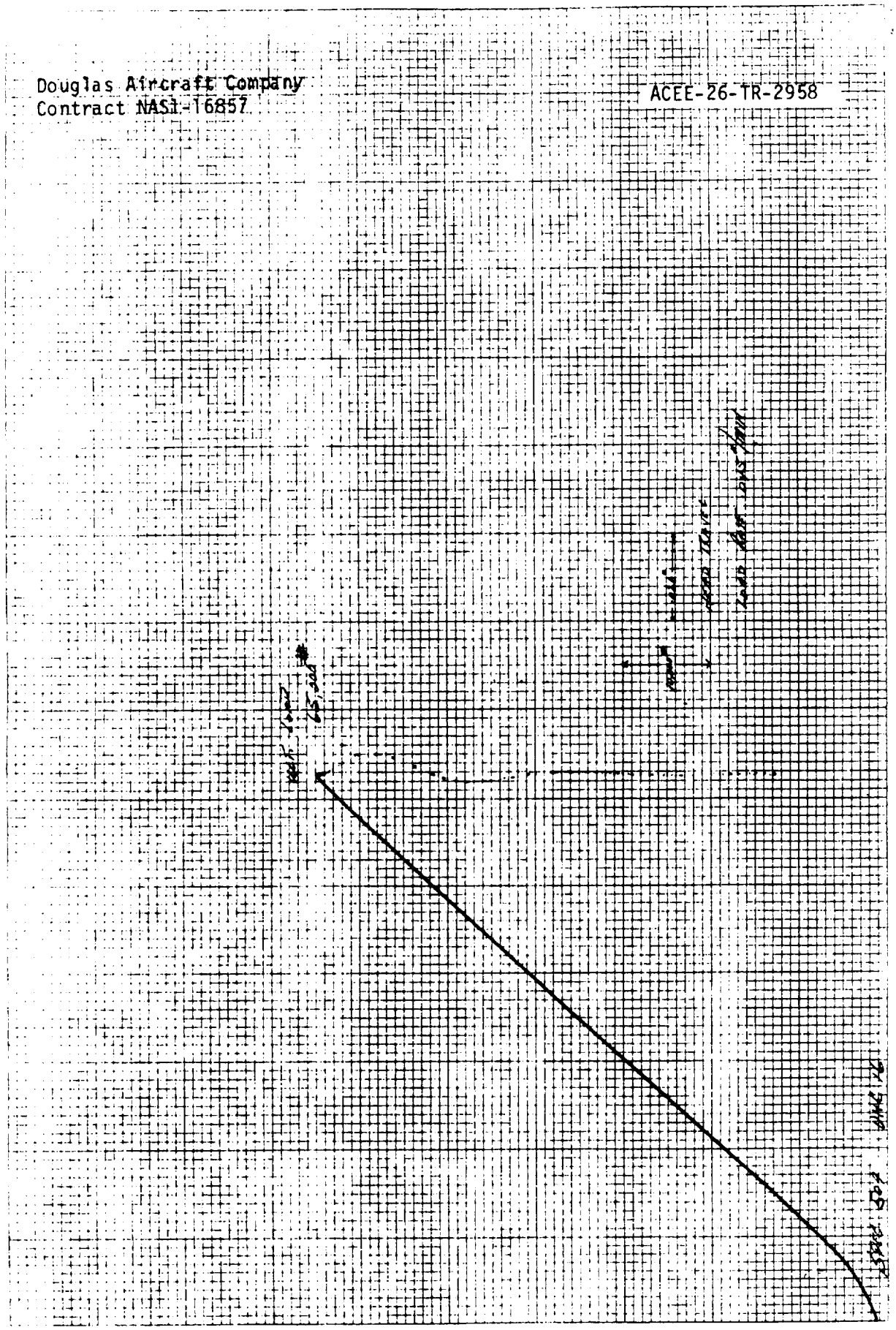
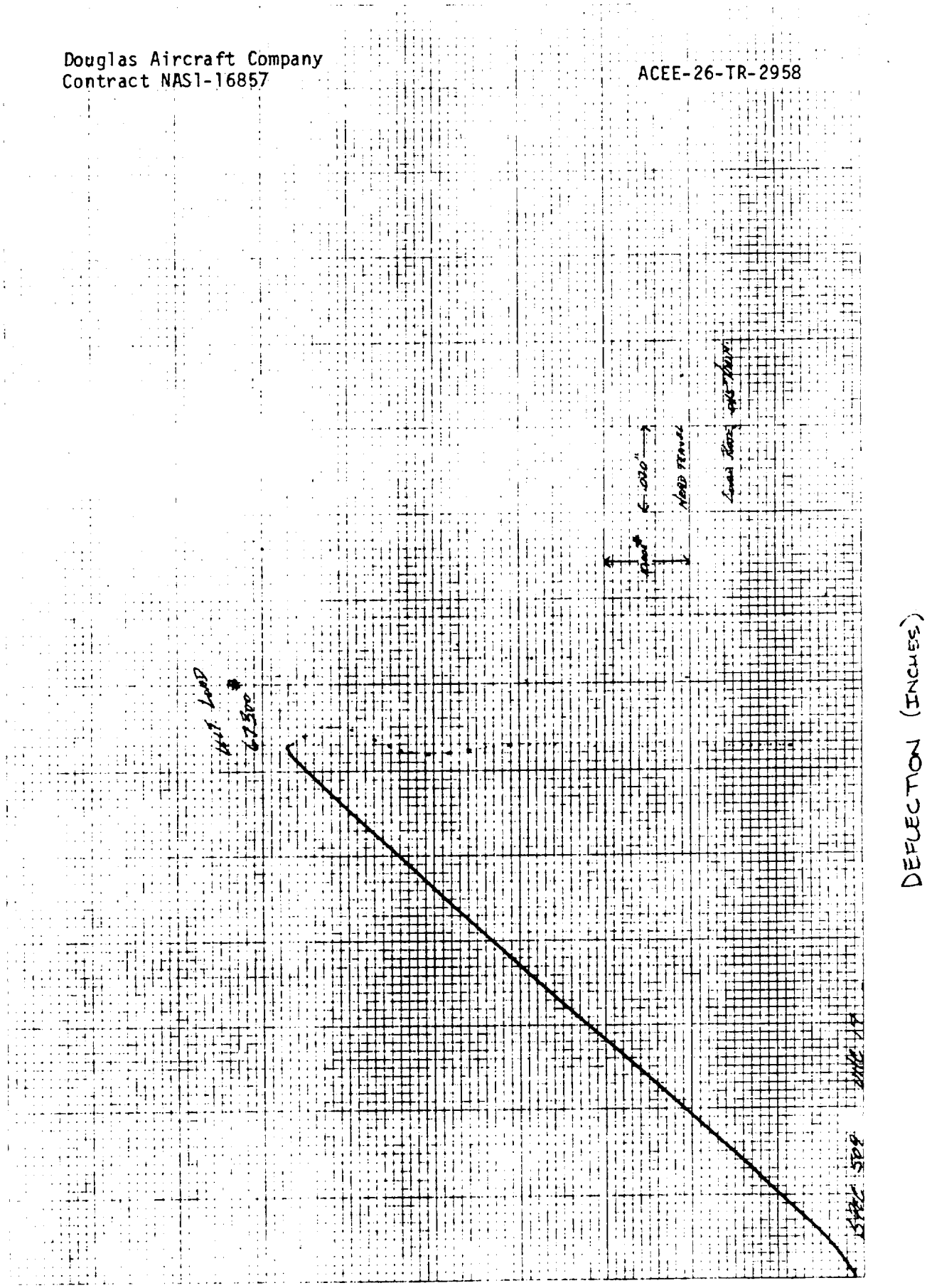
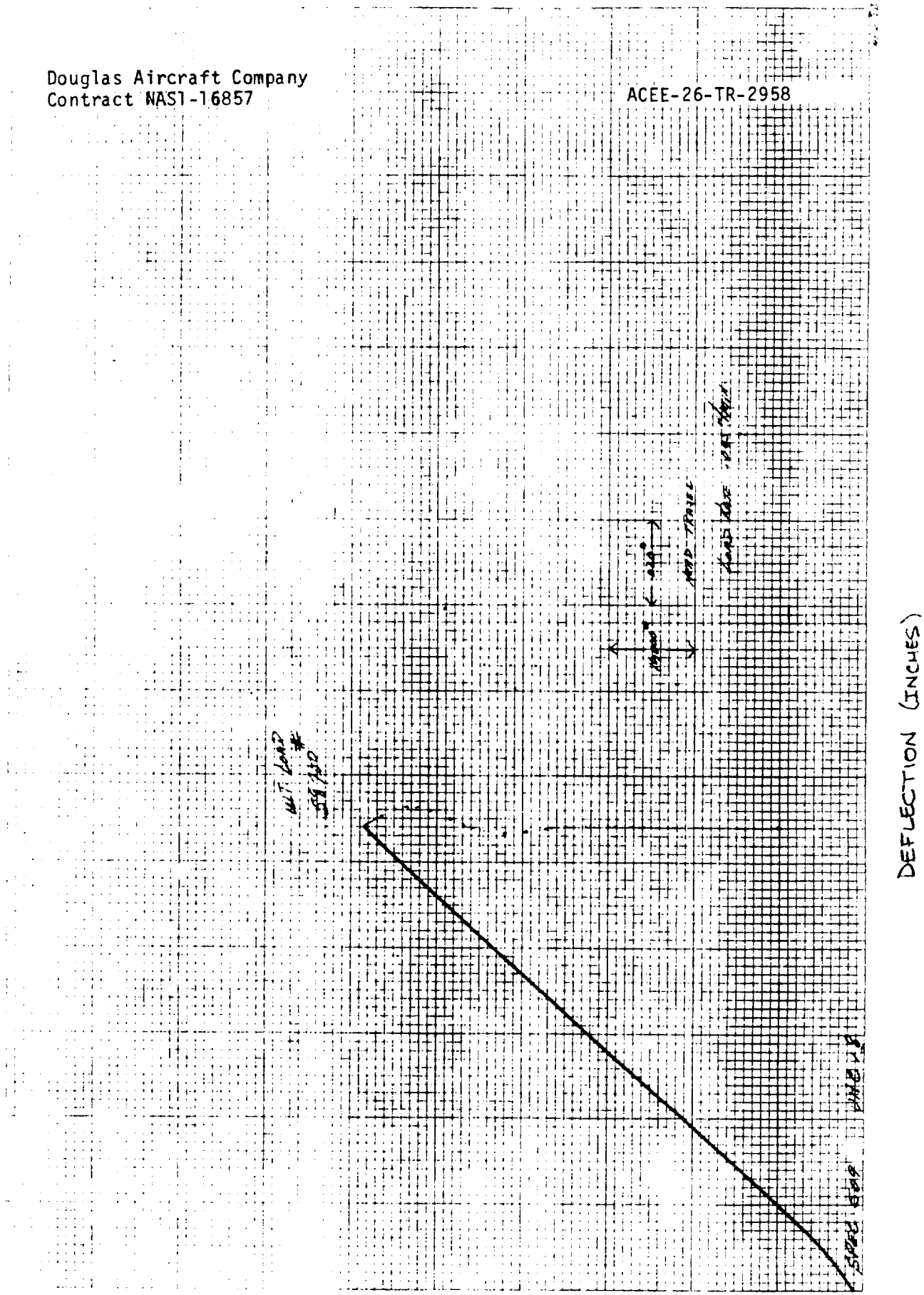
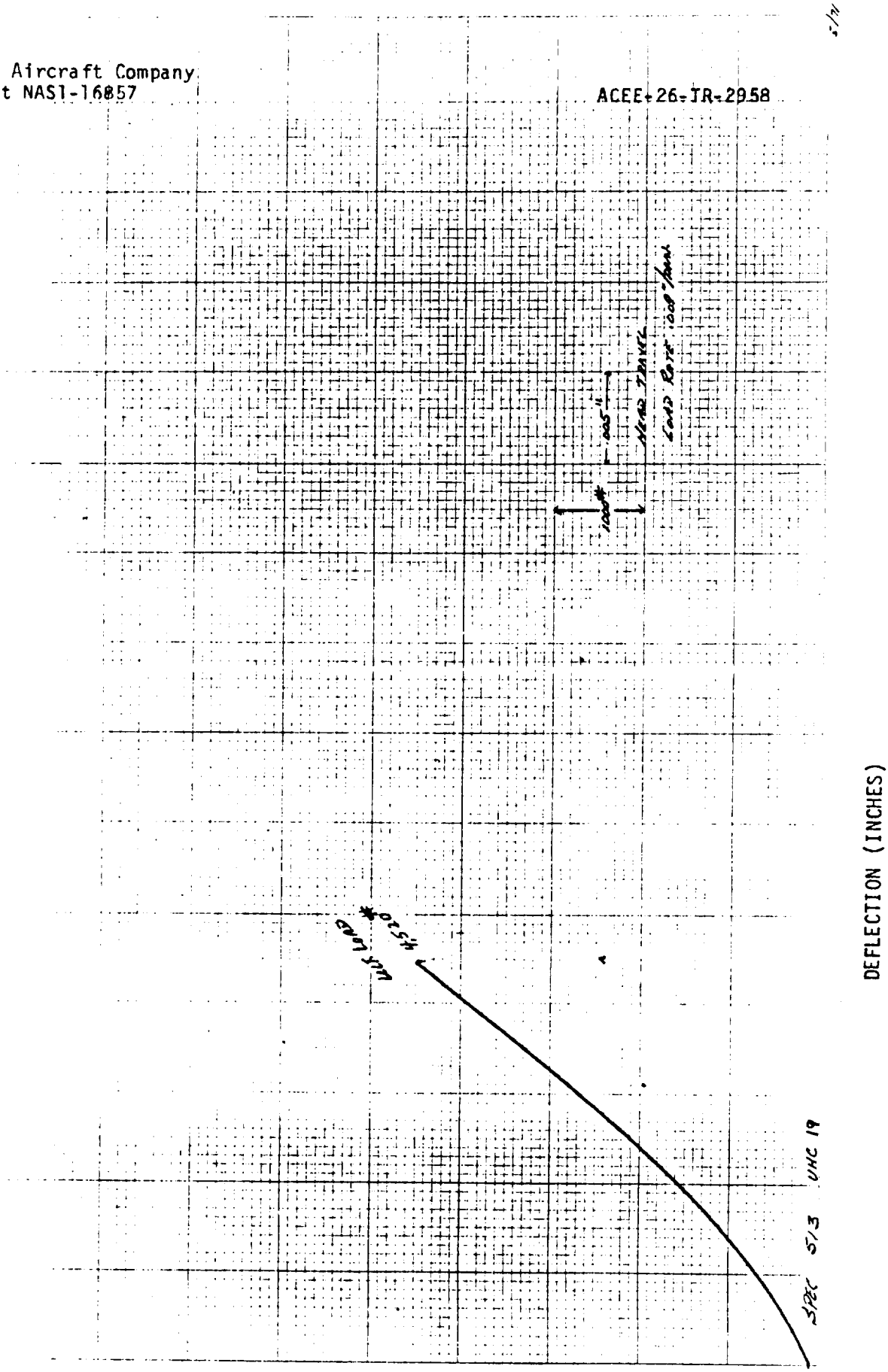

DEFLECTIONS (INCHES)
LOAD (LBS)


Hit Load
67500#
.010"
Need Travel
Load Rod
LOAD
(LBS)
DEFLECTION (INCHES)


DEFLECTION (INCHES)
LOAD (LBS)



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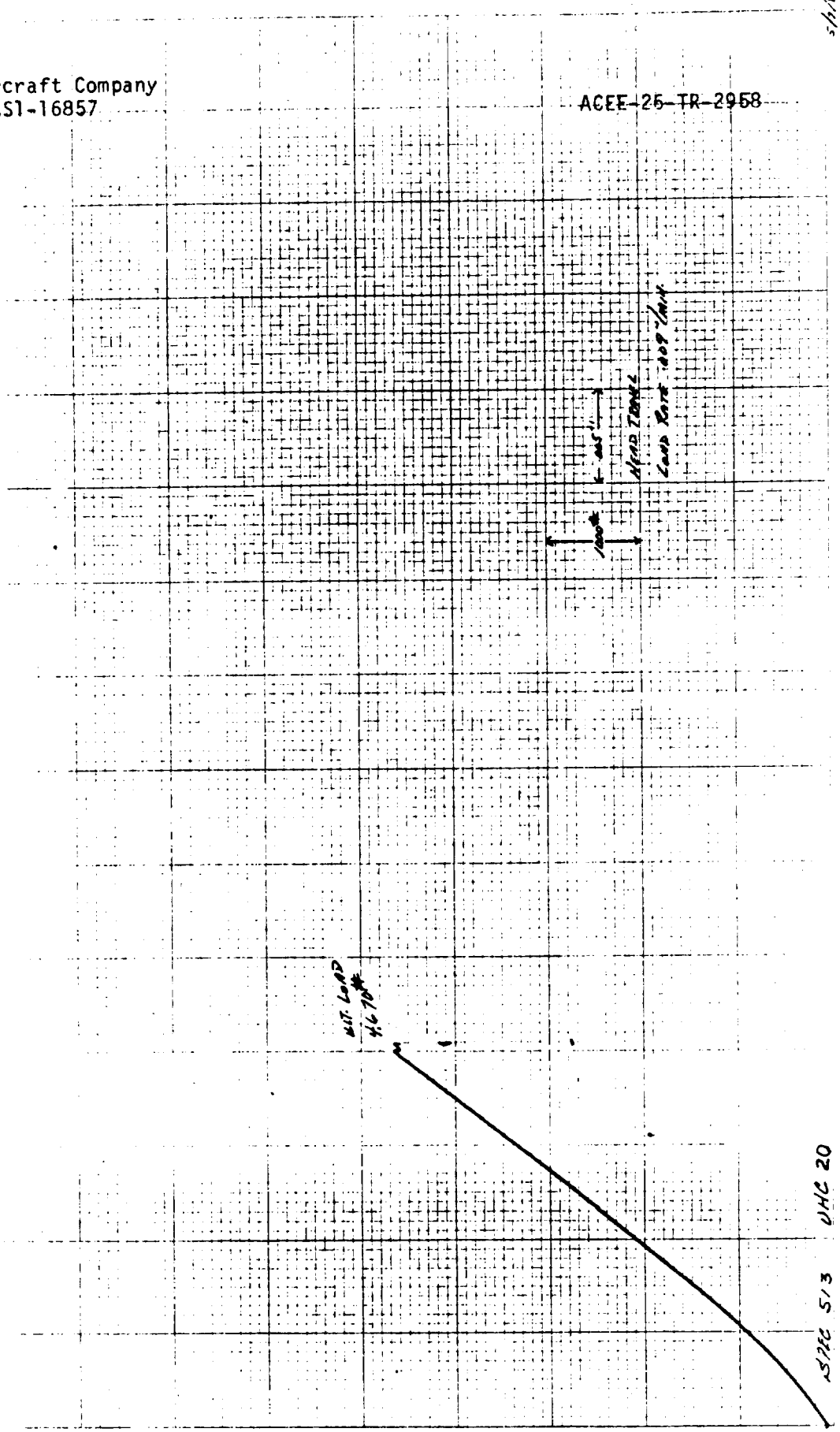
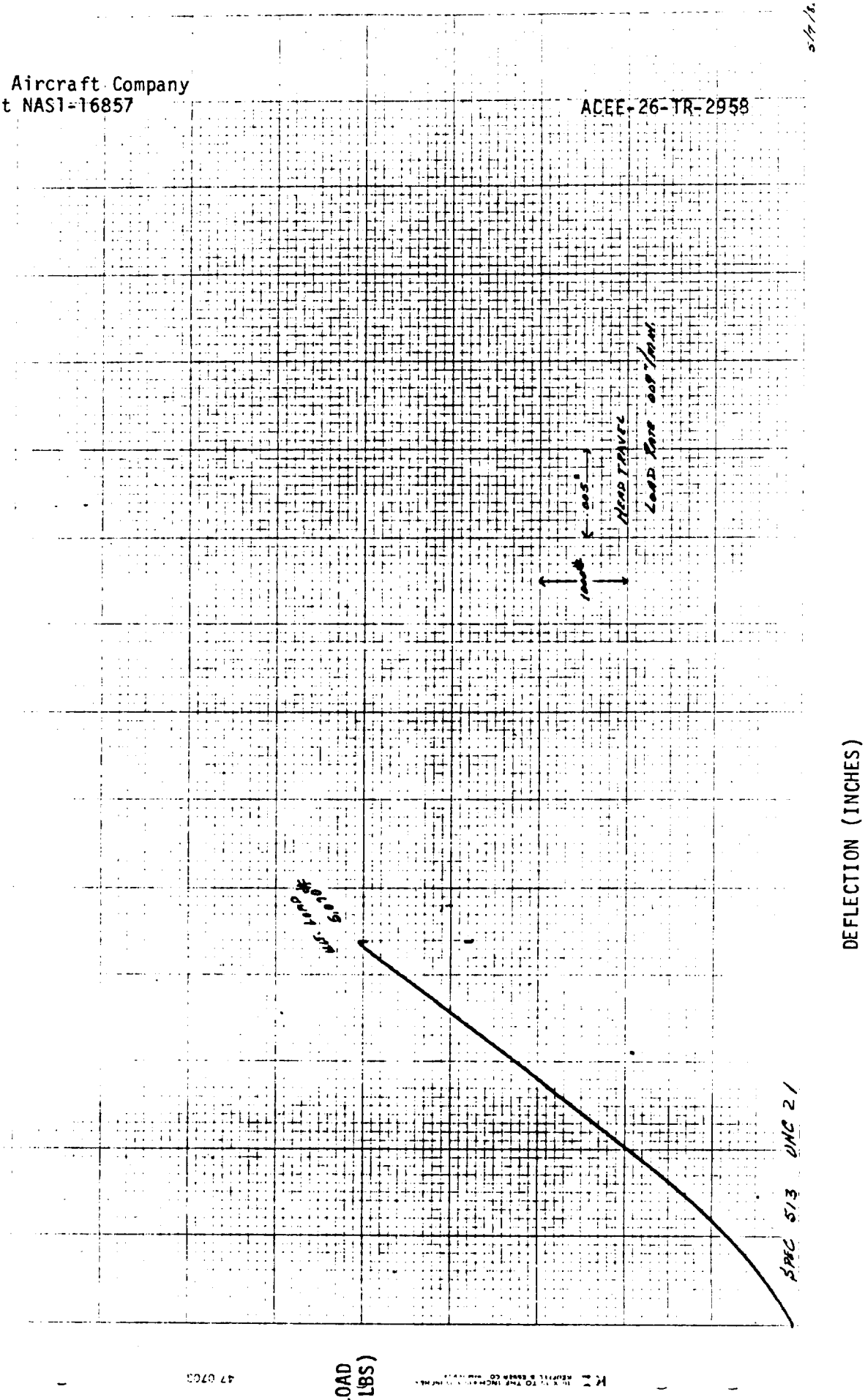
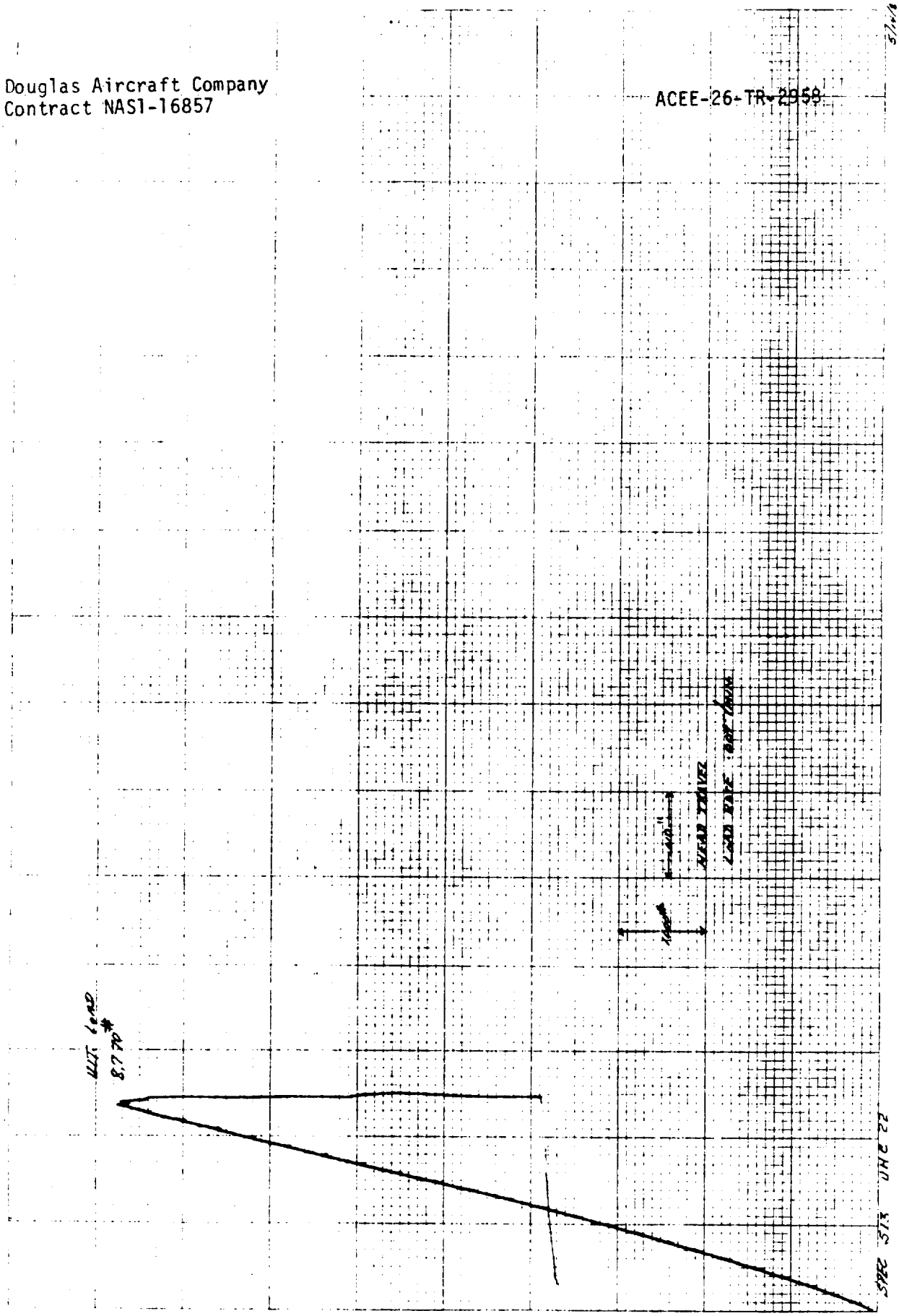

DEFLECTION (INCHES)
LOAD (LBS)
HEAD TOWARD LAND ROAD 100 L/MIN.
100#
45"
ULT. LOAD 46 70#
UHC 20
SHC 5/3


DEFLECTION (INCHES)
LOAD (LBS)
SPEC 513 UNC 21
HEAD TRAVEL
LOAD FOR .005" TRAV.
.005"
1000#
1.4 .009 .5M
47 0705



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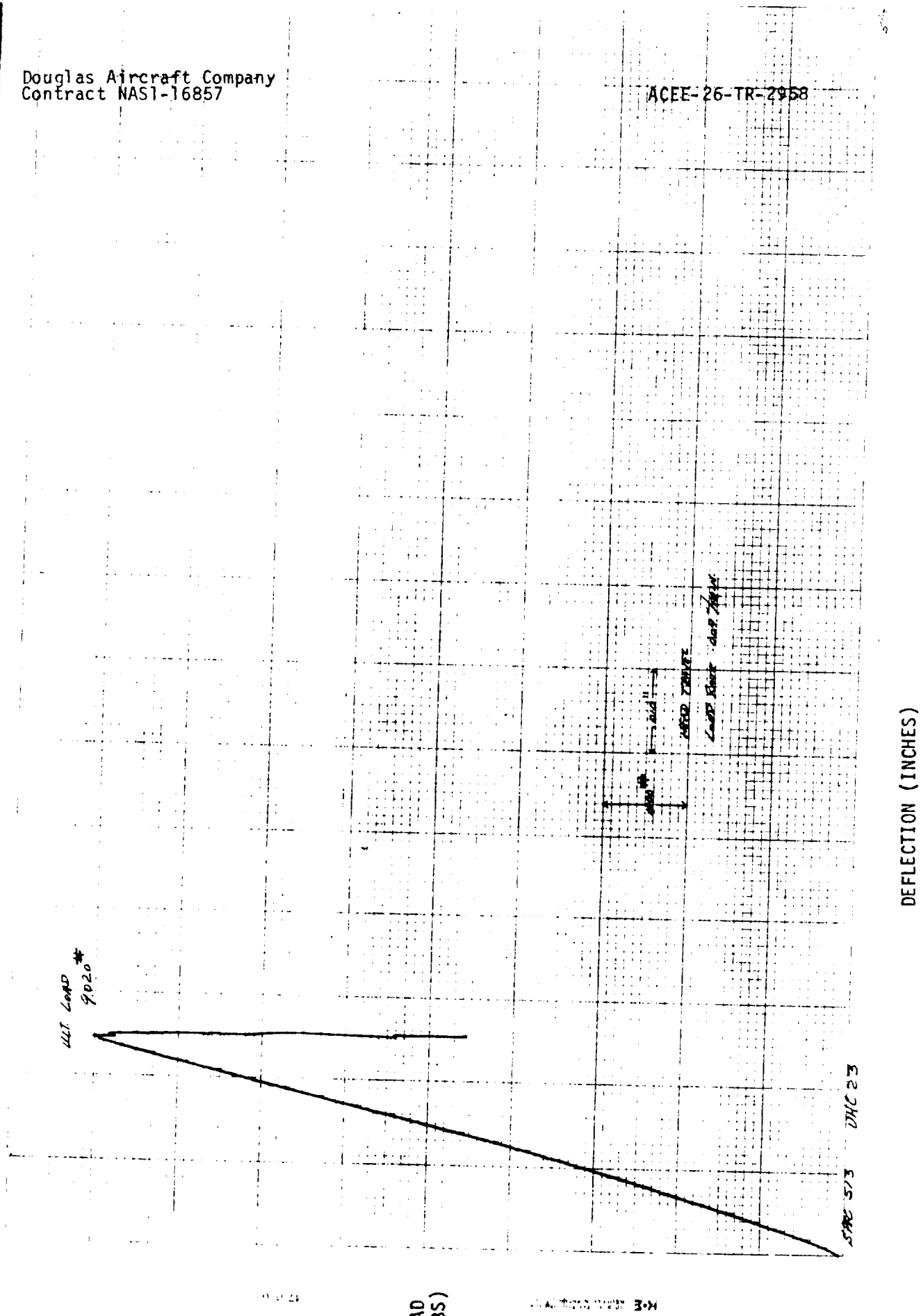

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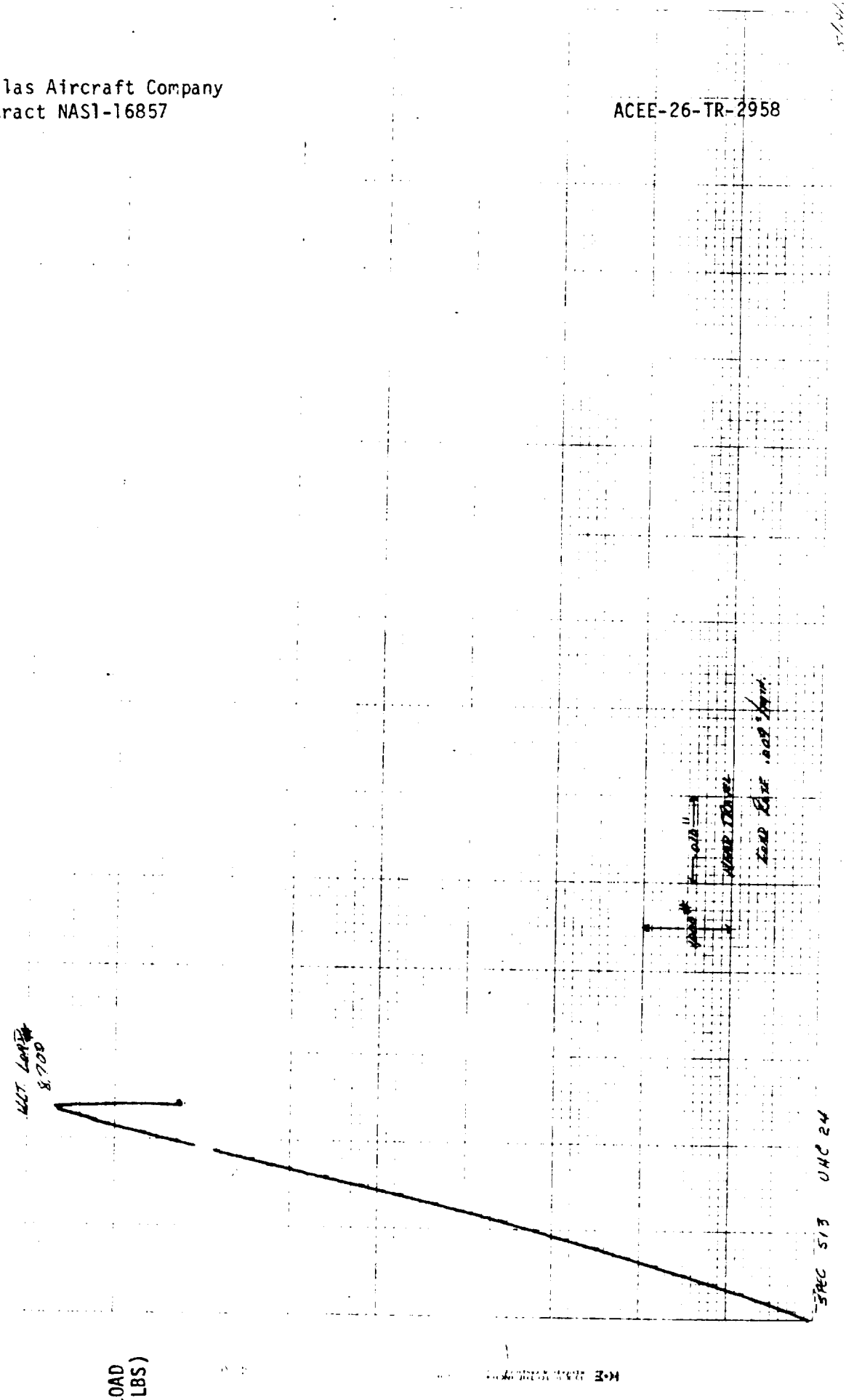
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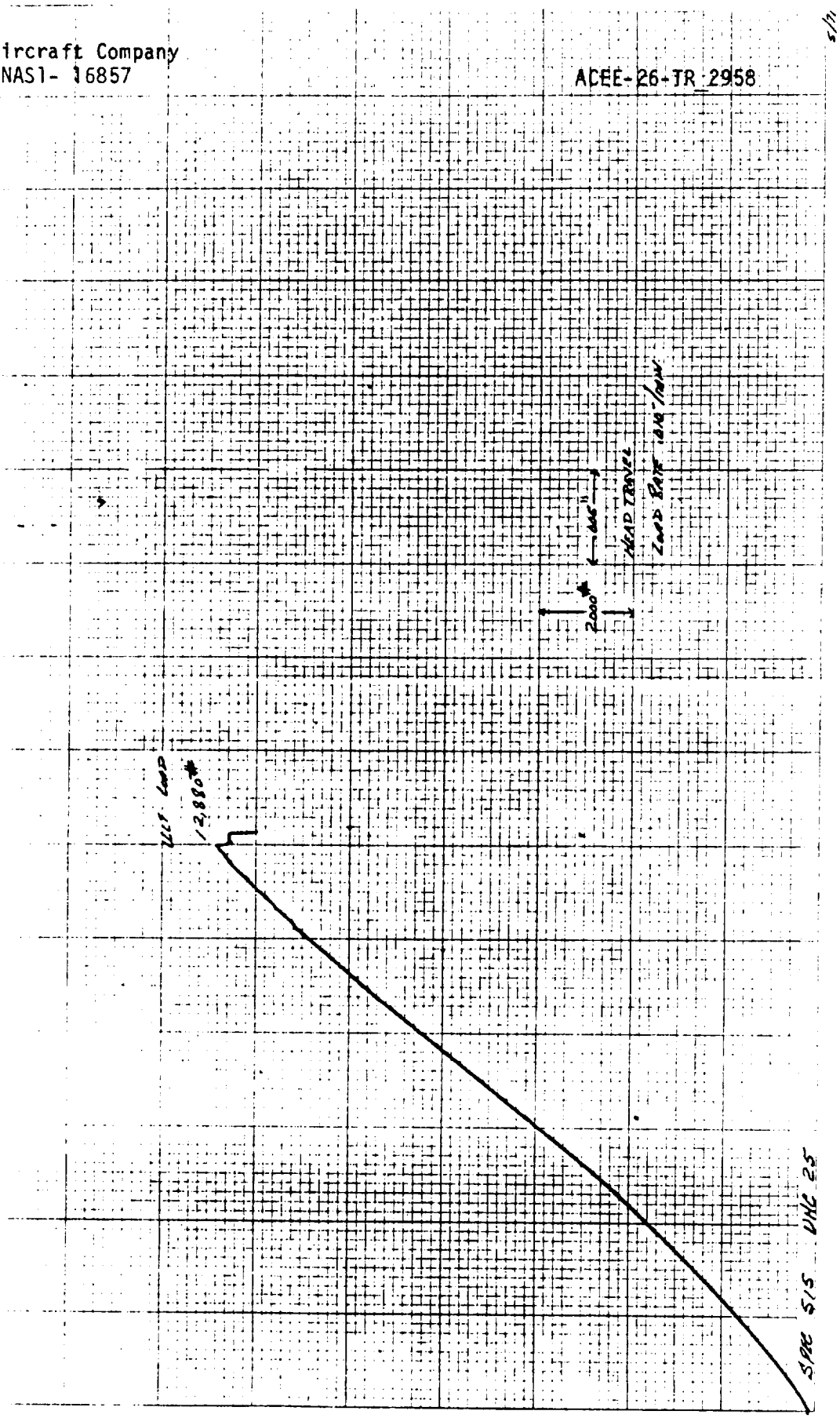

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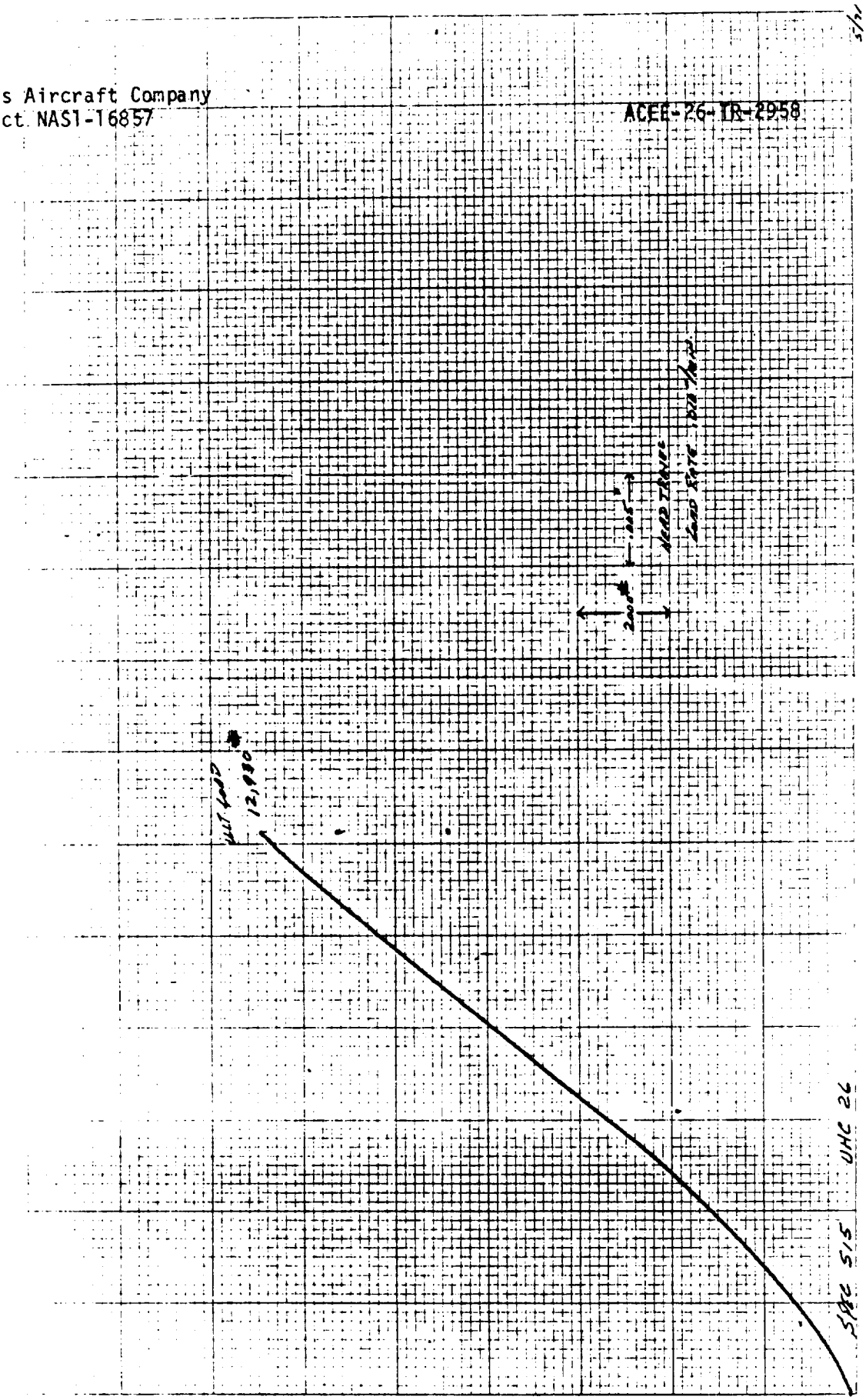
LOAD (LBS)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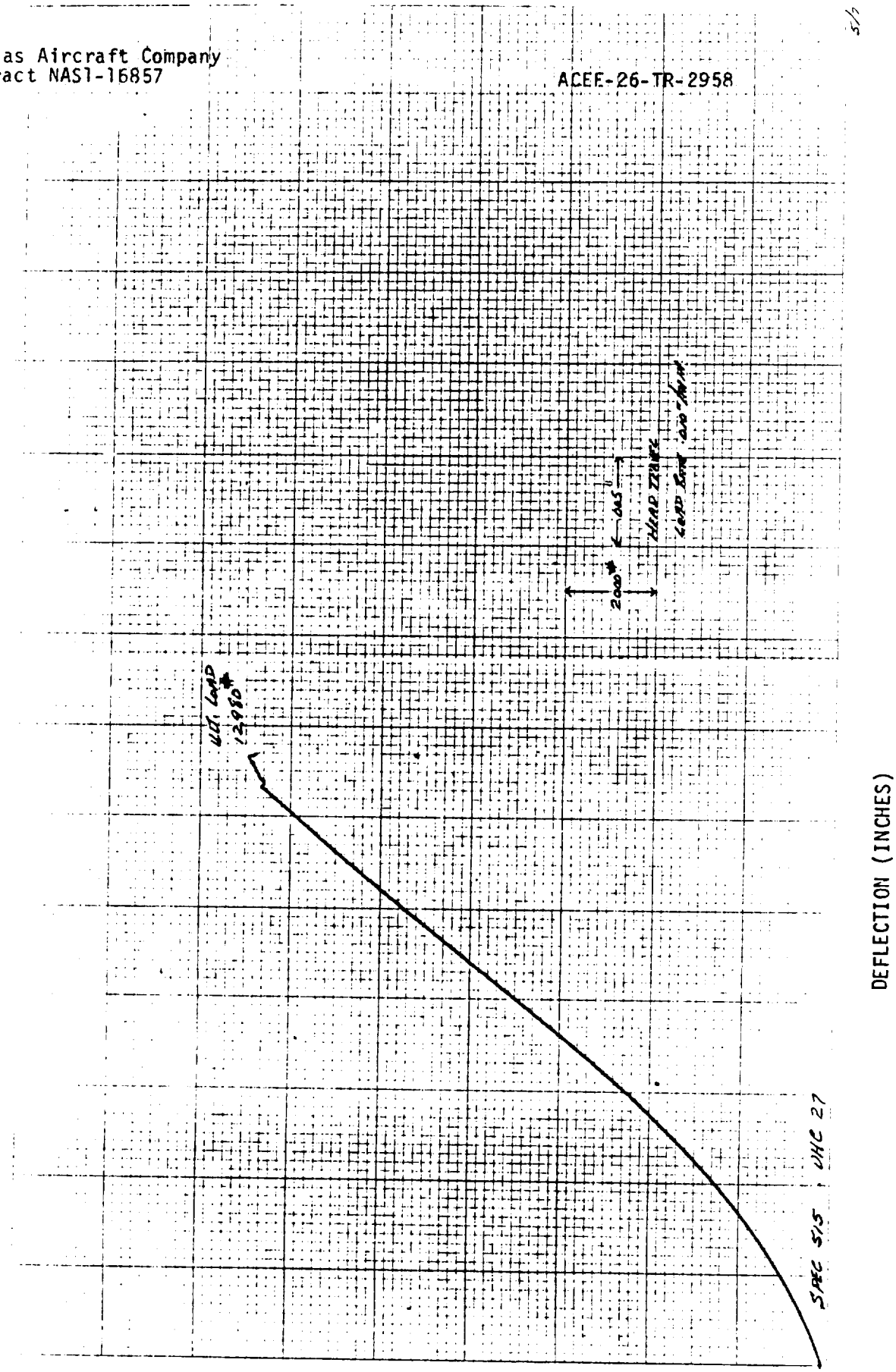
200#
.005
HEAD TRAVEL
LOAD RATE 100 #/MIN
SPEC 515 UHC 26



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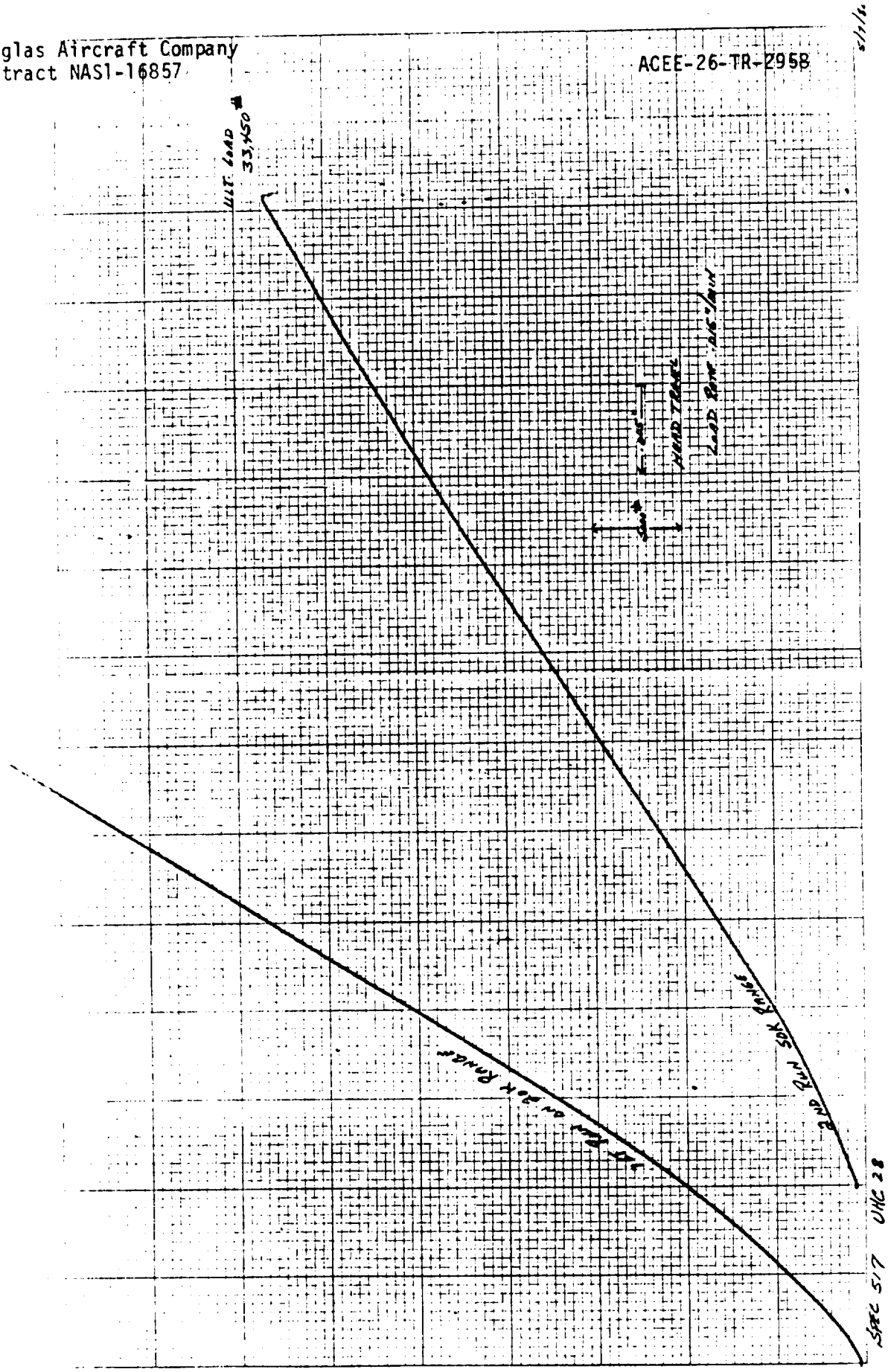

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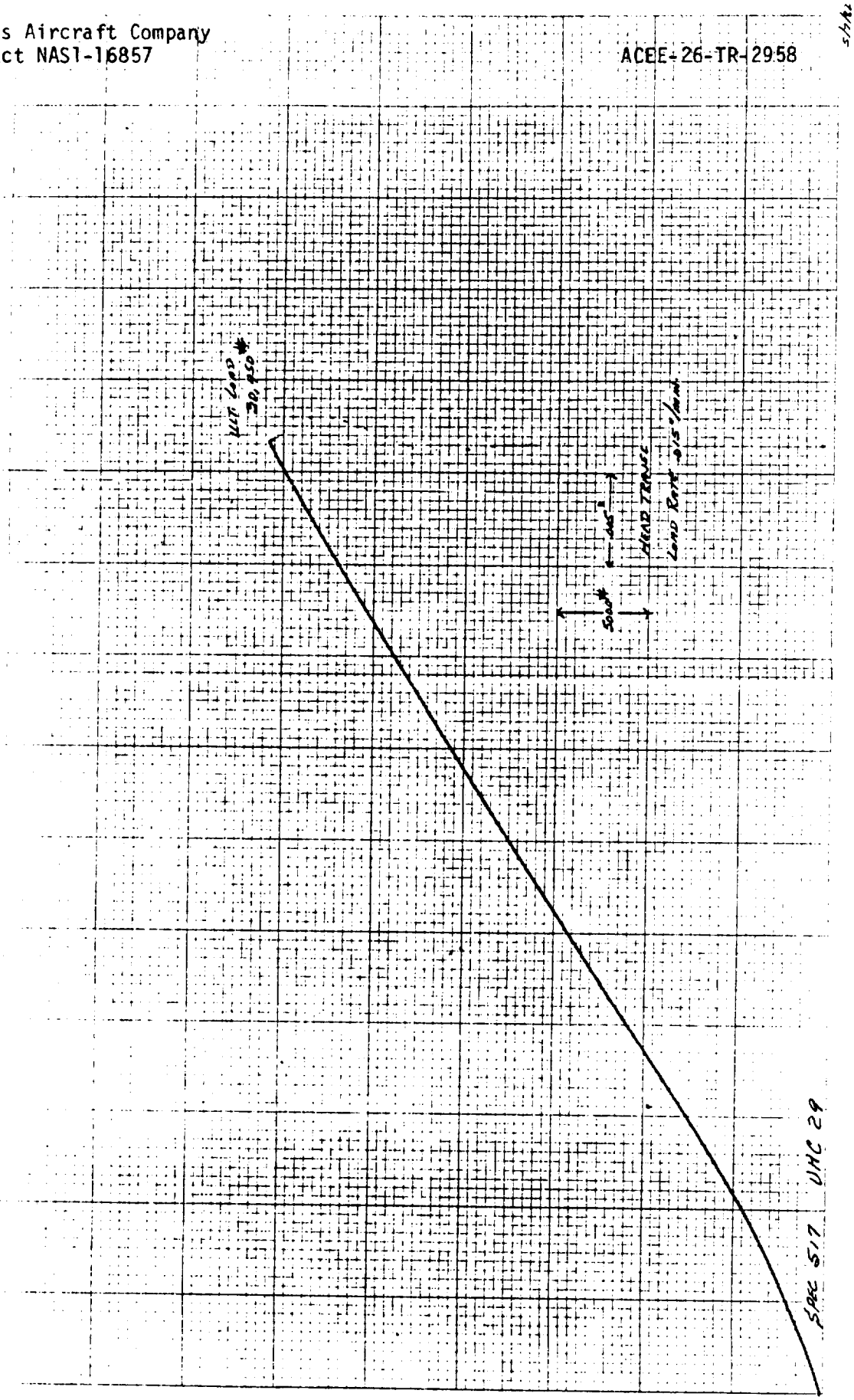
LOAD (LBS)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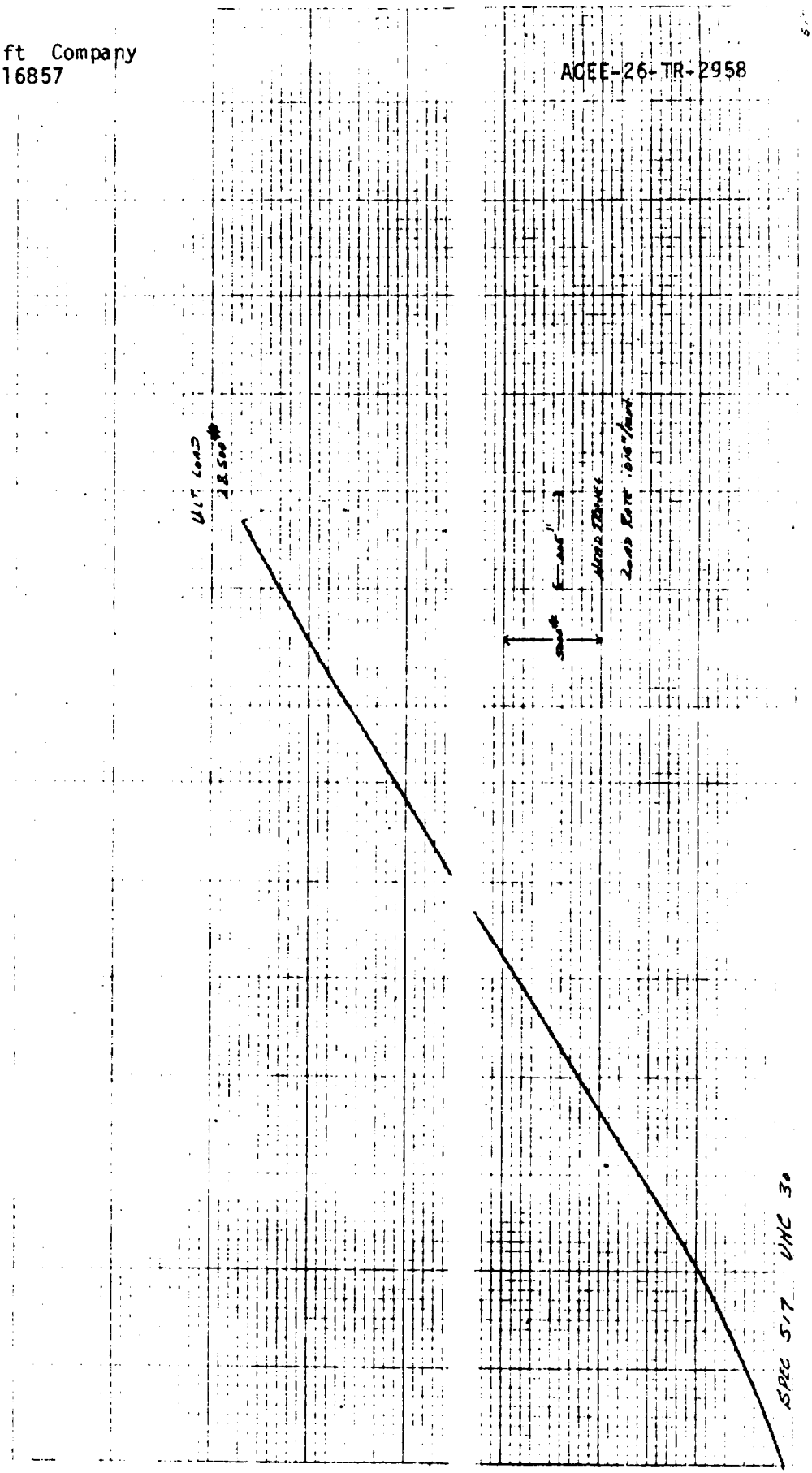
500#
HEAD TRUSS
LOAD RATE 0.5"/min.
SPEC 517 UHC 29
LOAD
(LBS)
DEFLECTION (INCHES)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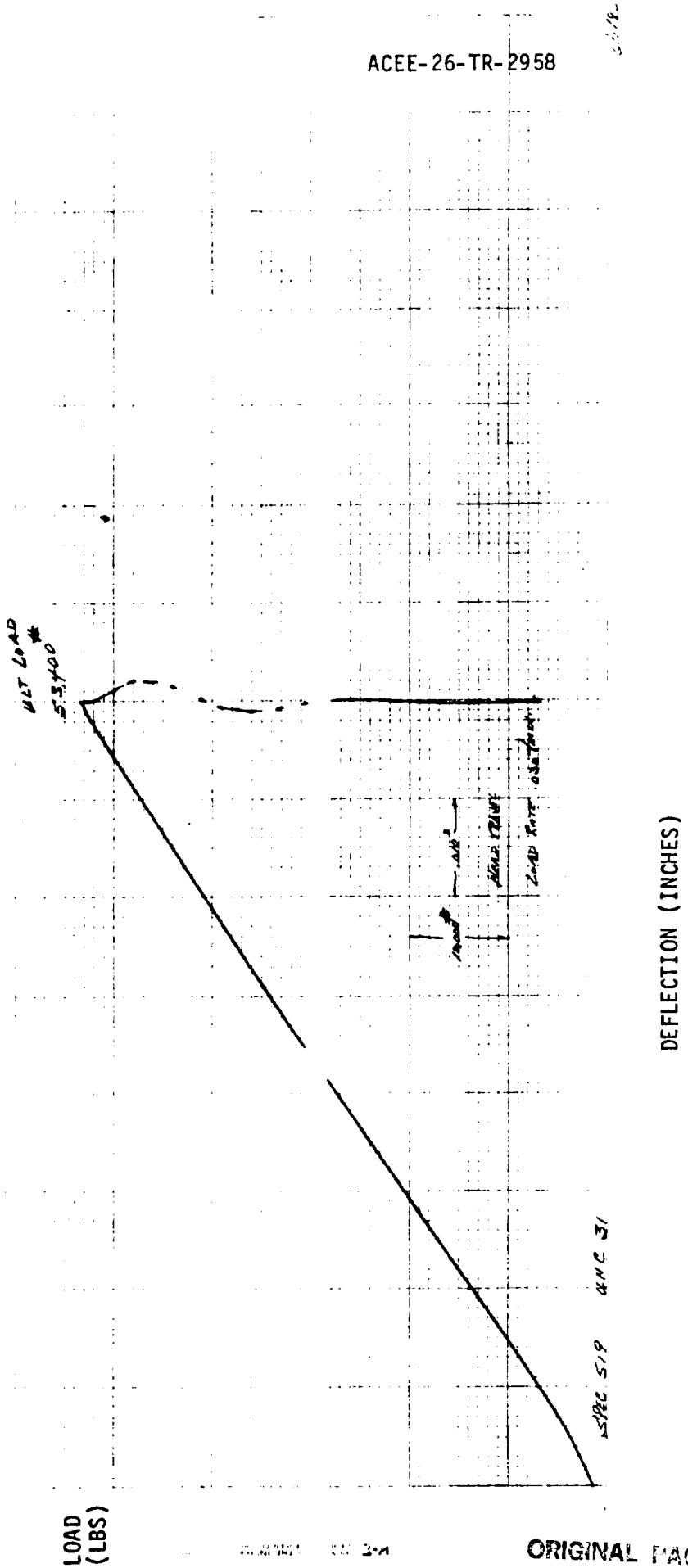
18,500#
SPEC 517 UNC 3a
DEFLECTION (INCHES)
LOAD (LBS)



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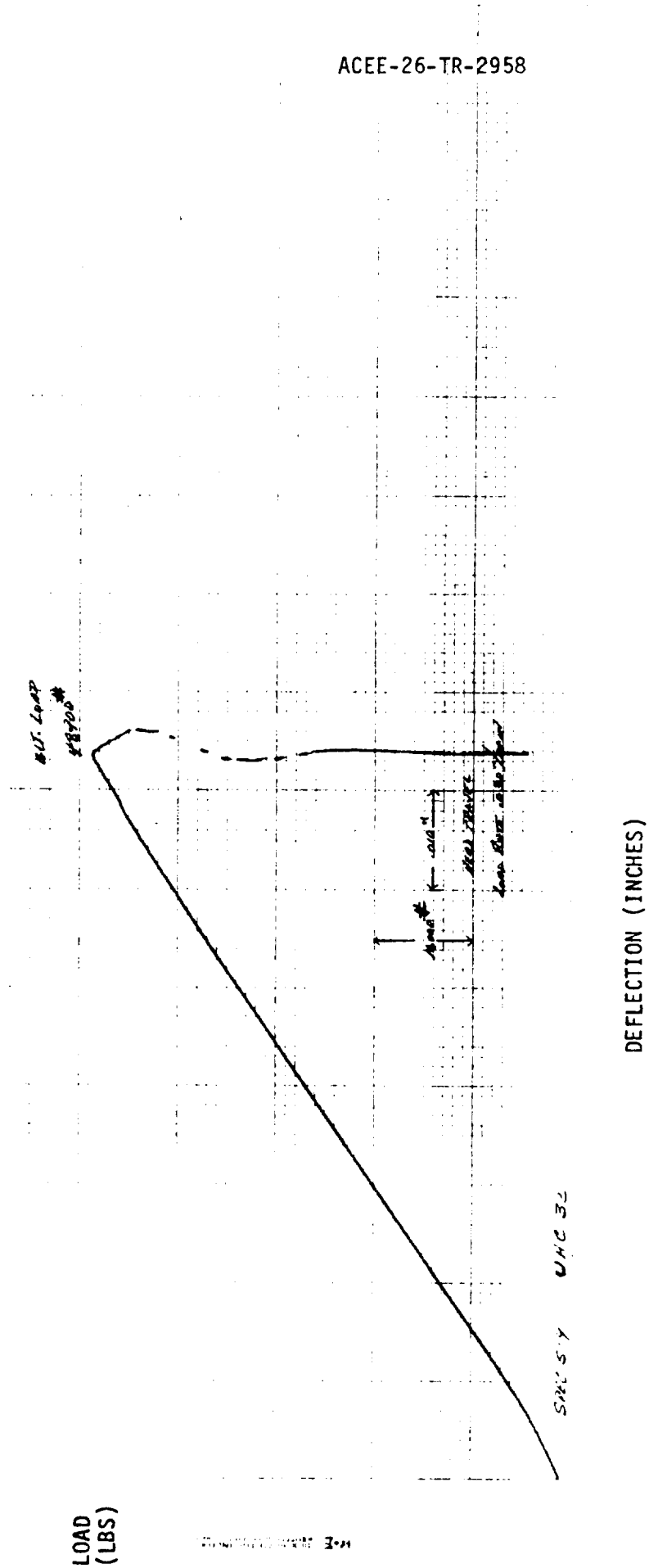
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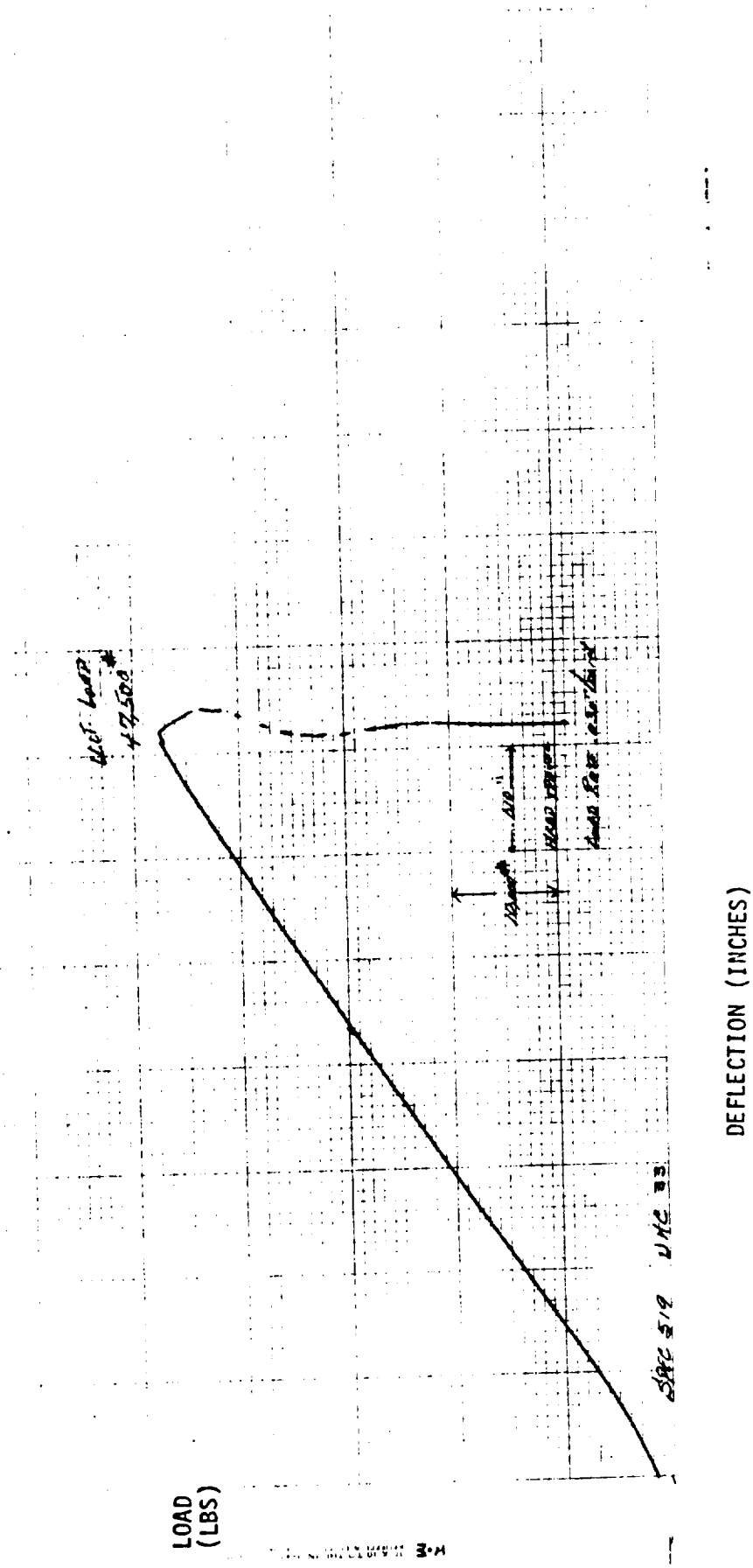
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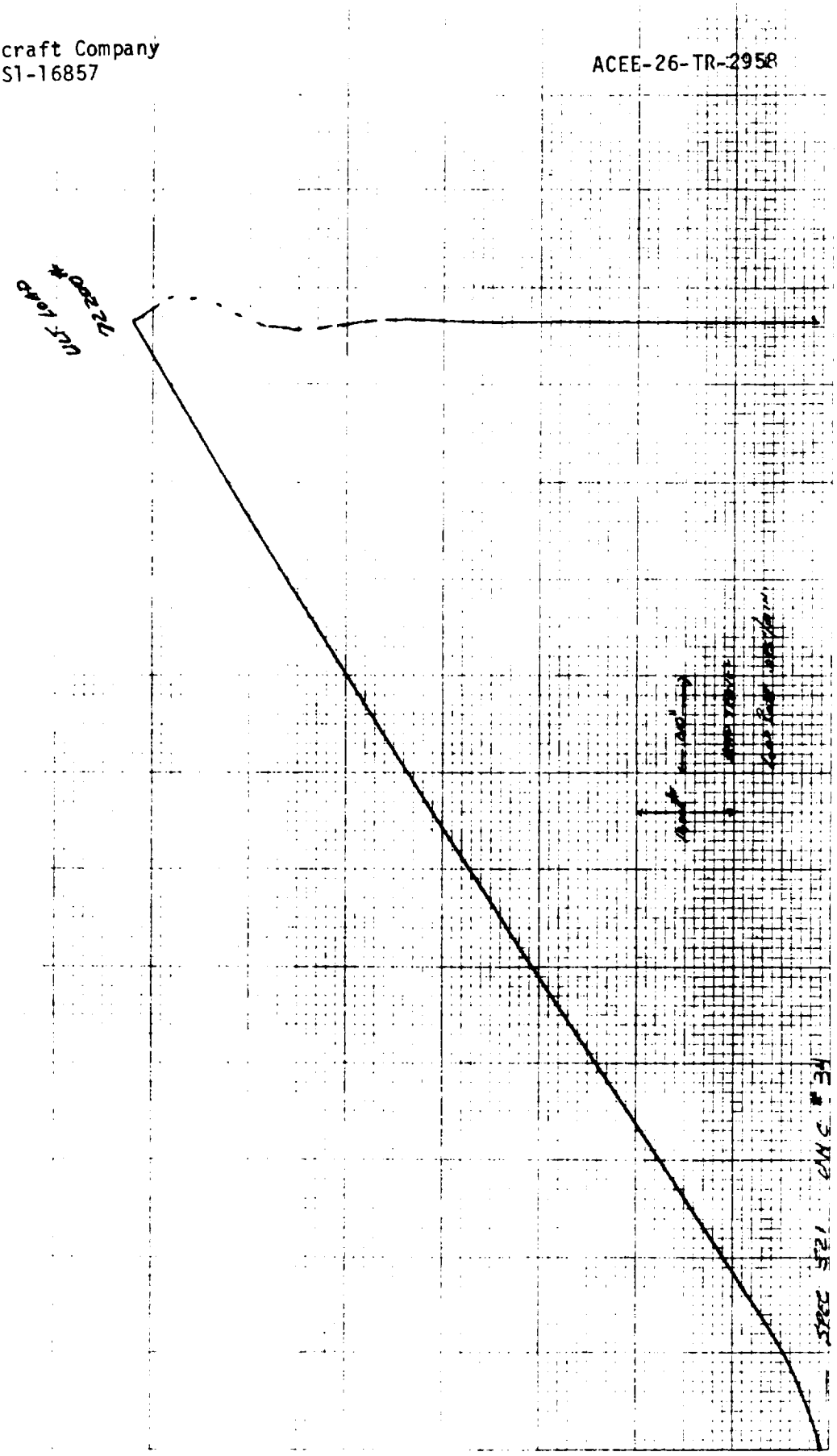

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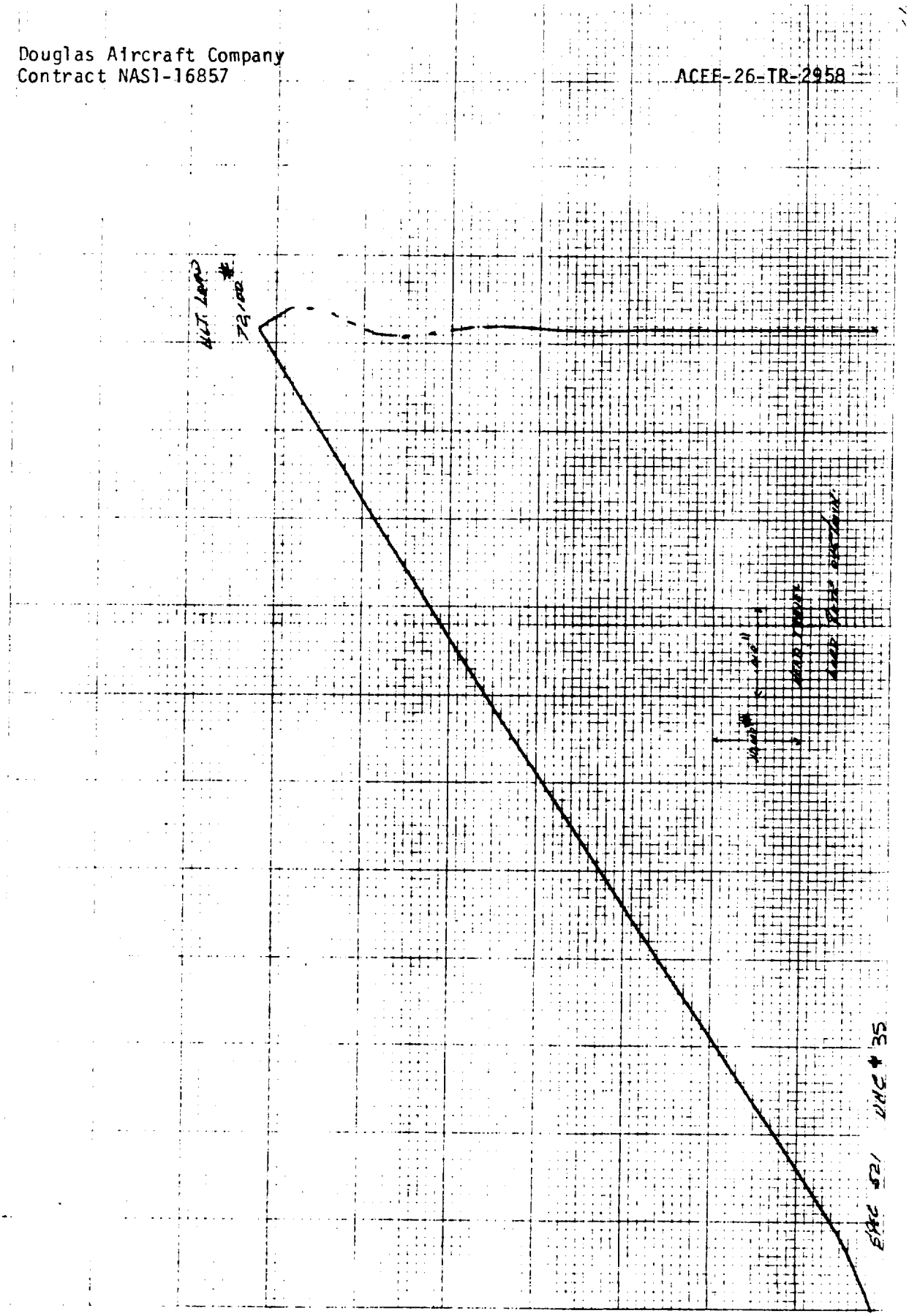

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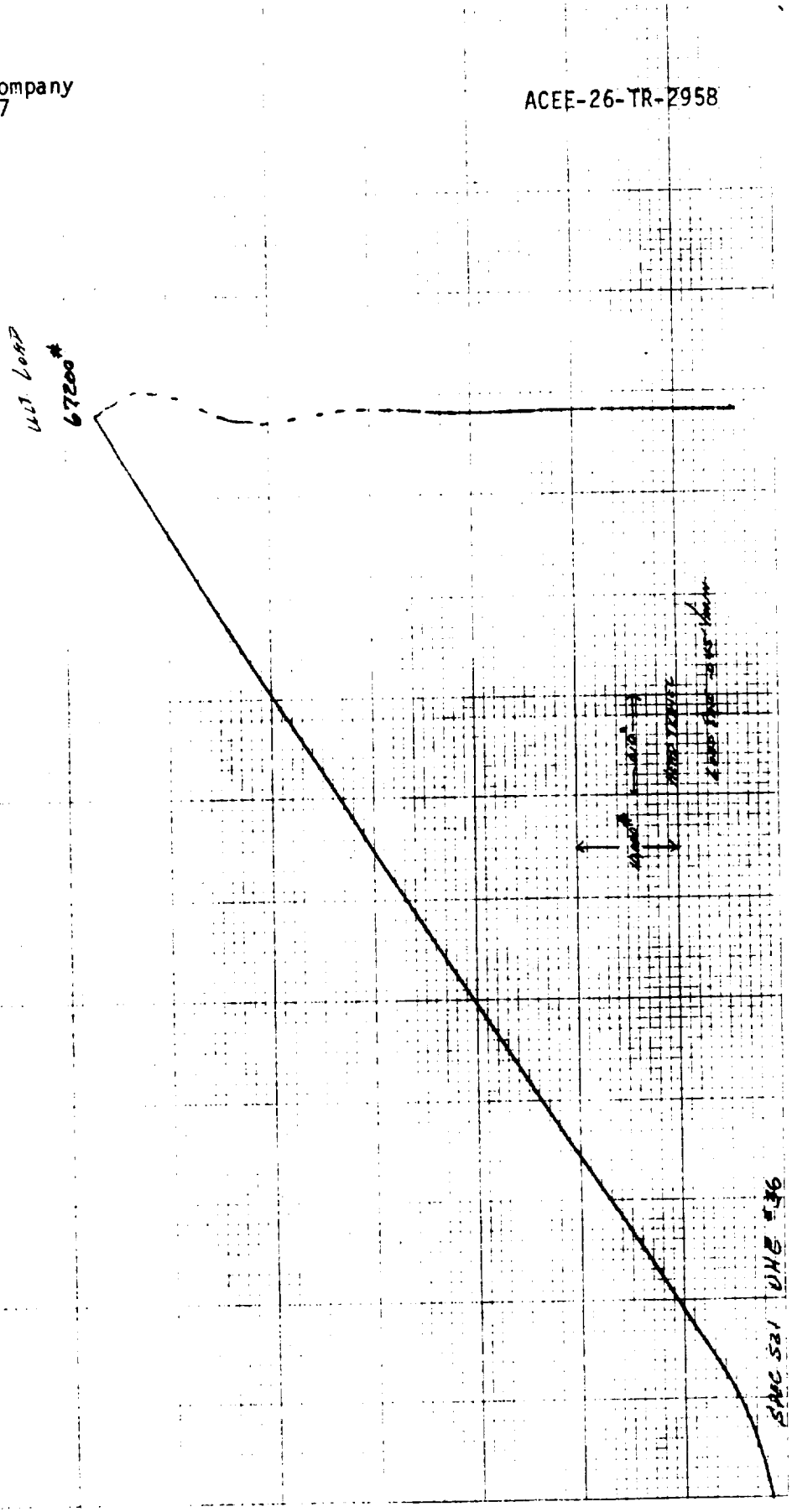

ult load
67200#
spec 521 UHB #36
LOAD
(LBS)
DEFLECTION (INCHES)

APPENDIX B

ANCILLARY TEST DATA

SPECIMEN CODING:

DOUBLE SHEAR - DRAWING ZJ011268

DST - DOUBLE SHEAR TENSION
DSC - DOUBLE SHEAR COMPRESSION

FAILURE MODES

DST	
1	Net-section failure. Most 0° plies sheared out. Cross plies failed in inter-fiber tension/shear. Some bolt bending.
2	Net-section failure. Most 0° plies sheared out. Cross plies failed in inter-fiber tension/shear. Some bolt bending.
3	1st run - doubler initiated de-bond but no catastrophic failure. 2nd run - net-section failure and doubler failure leading to net-section failure of specimen at load pin. Net-section failure at bolt occurred on nut side. Failure at load pin occurred on opposite side.
4	Net-section failure. Slightly more damage on head side of bolt. Some shear-out of 0° plies.
5	Bearing failure. Slight washer dig-in.
6	Net-section failure. Slightly more damage on head side. Some shear-out of 0° plies.
7	Tapered doubler failure and net-section failure at load pin.
8	Tapered doubler failure and net-section failure at load pin.
9	Tapered doubler failure and net-section failure at load pin. Slight buckling of plies on head side of bolt.
10	Bolt bending failure with bearing damage. Washer dig-in.
11	Bolt bending failure with bearing damage. Washer dig-in. Adhesive failure occurred on doubler (1 side) between outer plates.
12	Bolt bending and slight bearing failure
13	Bearing failure. Washer dig-in, both sides.
14	Doubler bond failure (adhesive failure). Some bearing damage in outer plates.
15	Bearing failure. Slight washer dig in. Buckling of outer plies.
16	Bearing failure. Hole elongated approximately 3d (3/4" dia). Extensive brooming and bearing damage.
17	Bearing failure. Washer dig in.
18	Bearing failure. Washer dig in.
19	Net-section failure. Bolt bending. Most of the 0° plies sheared out and cross plies failed in inter-fiber tension/shear along 45° and 90° lines.
20	Net-section failure. Bolt bending. Most of the 0° plies sheared out and cross plies failed in inter-fiber tension/shear along 45° and 90° lines.

DST (Continued)

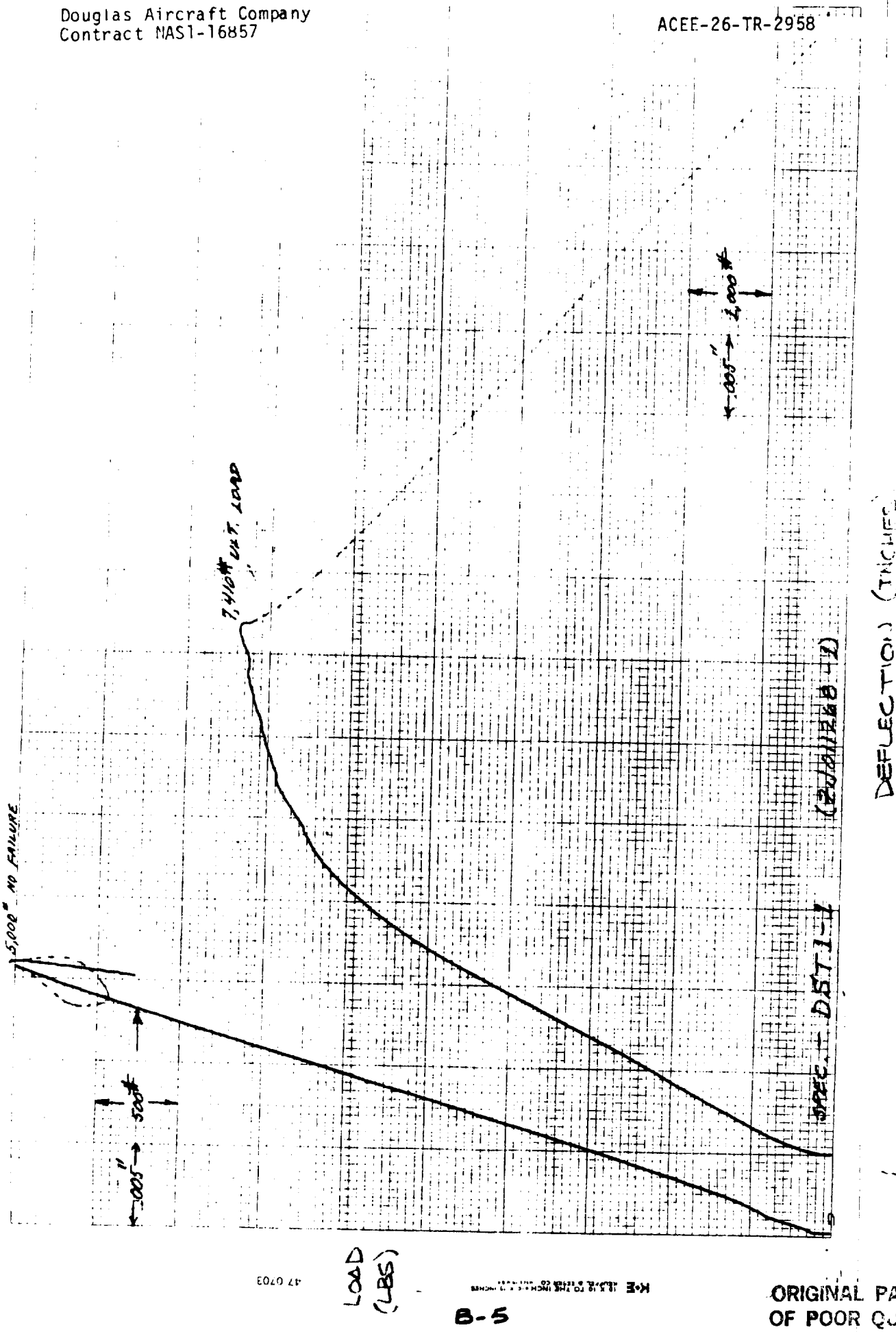
21	Net-section failure. Bolt bending. Most of the 0° plies sheared out and cross plies failed in inter-fiber tension/shear along 45° and 90° lines.
22	Apparent bearing failure. No ply buckling or delaminations on nut side. Outer ply buckling and delaminations on bolt side head. Inner ply buckling.
23	Tapered doubler failure and net-section failure at load pin
24	Net-section failure on nut side. Inner and outer 0° plies sheared out. Washer dig-in with outer buckling on head side. Also inner ply delaminations.
25	Bearing failure. Head-side - washer dig-in. Nut side - slight washer dig-in. Outer ply delaminated to edge of plate.
26	Tapered doubler failure
27	Tapered doubler failure.
28	Bolt bending failure. Slight bearing damage. Some washer dig-in.
29	Bolt bending failure. Slight bearing damage. Some washer dig-in.
30	Bolt bending failure. Slight bearing damage. Some washer dig-in.
31	Bearing failure. Not much visible damage besides cracks in outer plies and slight hole elongation.
32	Bearing failure. Washer dig-in both sides.
33	Bearing failure. Washer dig-in. Buckled plies.
34	Bearing failure. Washer dig-in. Damaged primarily in outer plates.
35	Bearing failure. Washer dig-in. Damaged primarily in outer plates.
36	Bearing failure. Washer dig-in. Damaged primarily in outer plates.

DSC

1	Failed below washer in compression on head side of outer plate. Bolt bending also occurred.
2	Failed below washer in compression on head side of outer plate. Slight bolt bending.
3	Bolt bending and some bearing damage showing.
4	Buckling of outer plies with moderate shear/buckling failure. Occurred away from hole at edge of washer.
5	Apparent bearing failure. Slight fiber splitting and delaminations of plies.
6	Buckling and delamination of outer plies with shear/buckling failure. Occurred away from hole at edge of washer.

DSC (Continued)

7	Bearing failure
8	Bearing failure
9	Bearing failure
10	Bearing failure
11	Bearing failure
12	Bearing failure
13	Bearing failure
14	Bearing failure
15	Bearing failure
16	Bearing failure
17	Bearing failure
18	Bearing failure
19	Failed in compression above bolt, somewhat along 45° line. Slight bolt bending.
20	Failed in compression above bolt, somewhat along 45° line. Slight bolt bending.
21	Failed in compression above bolt, somewhat along 45° line. Slight bolt bending.
22	Outer plates buckled, delaminated and failed in shear/buckling below bolt at edge of washer.
23	Outer plates buckled, delaminated and failed in shear/buckling below bolt at edge of washer. Damage on head side of bolt.
24	Bearing failure. Some plies failed along 45° line.
25	Bearing failure.
26	Bearing failure.
27	Bearing failure.
28	Bolt bending and bearing failure
29	Bolt bending and bearing failure
30	Bolt bending and bearing failure
31	Bearing failure
32	Bearing failure
33	Bearing failure
34	Bearing failure
35	Bearing failure
36	Bearing failure.



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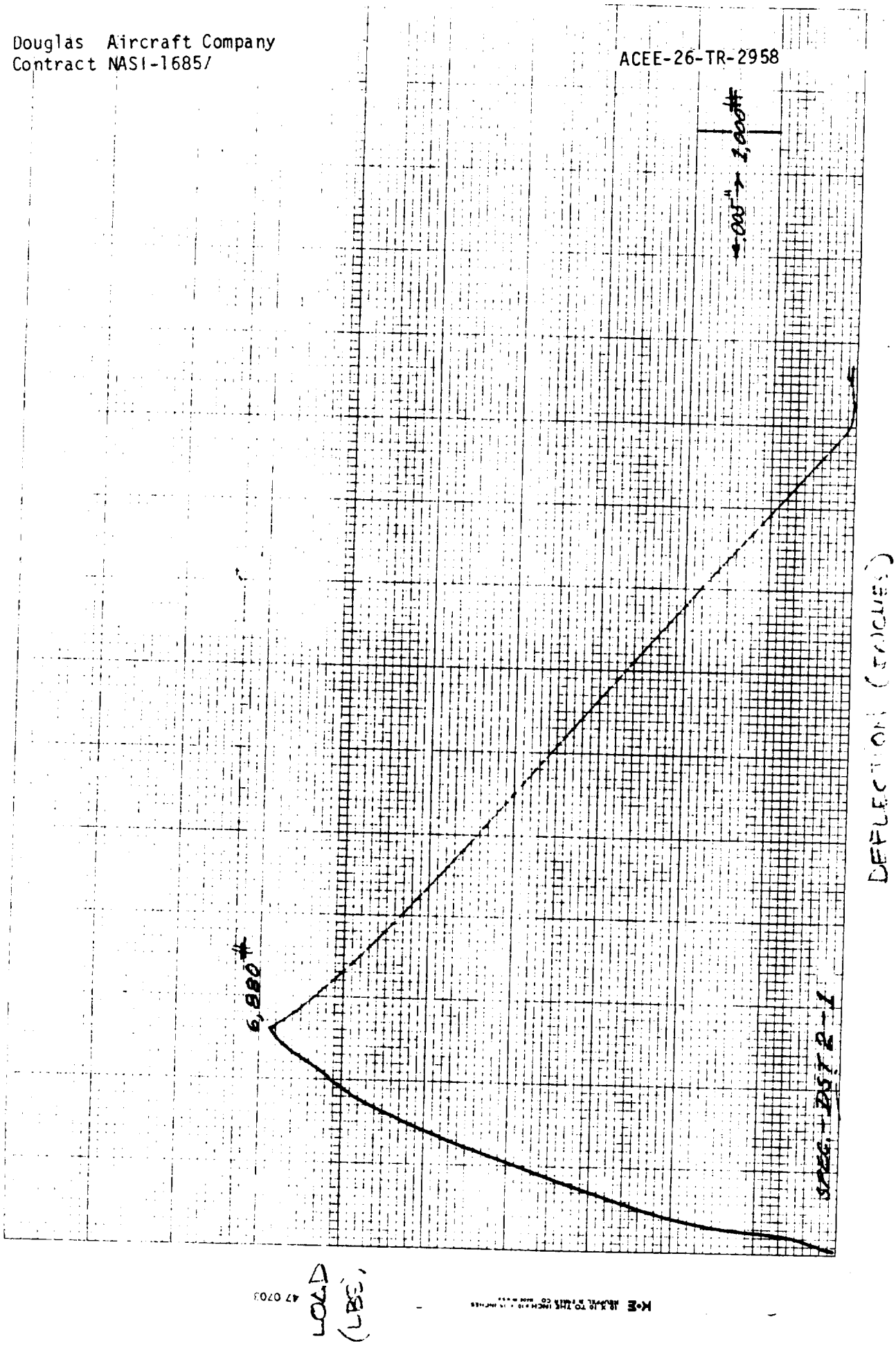
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.005"
6,880#
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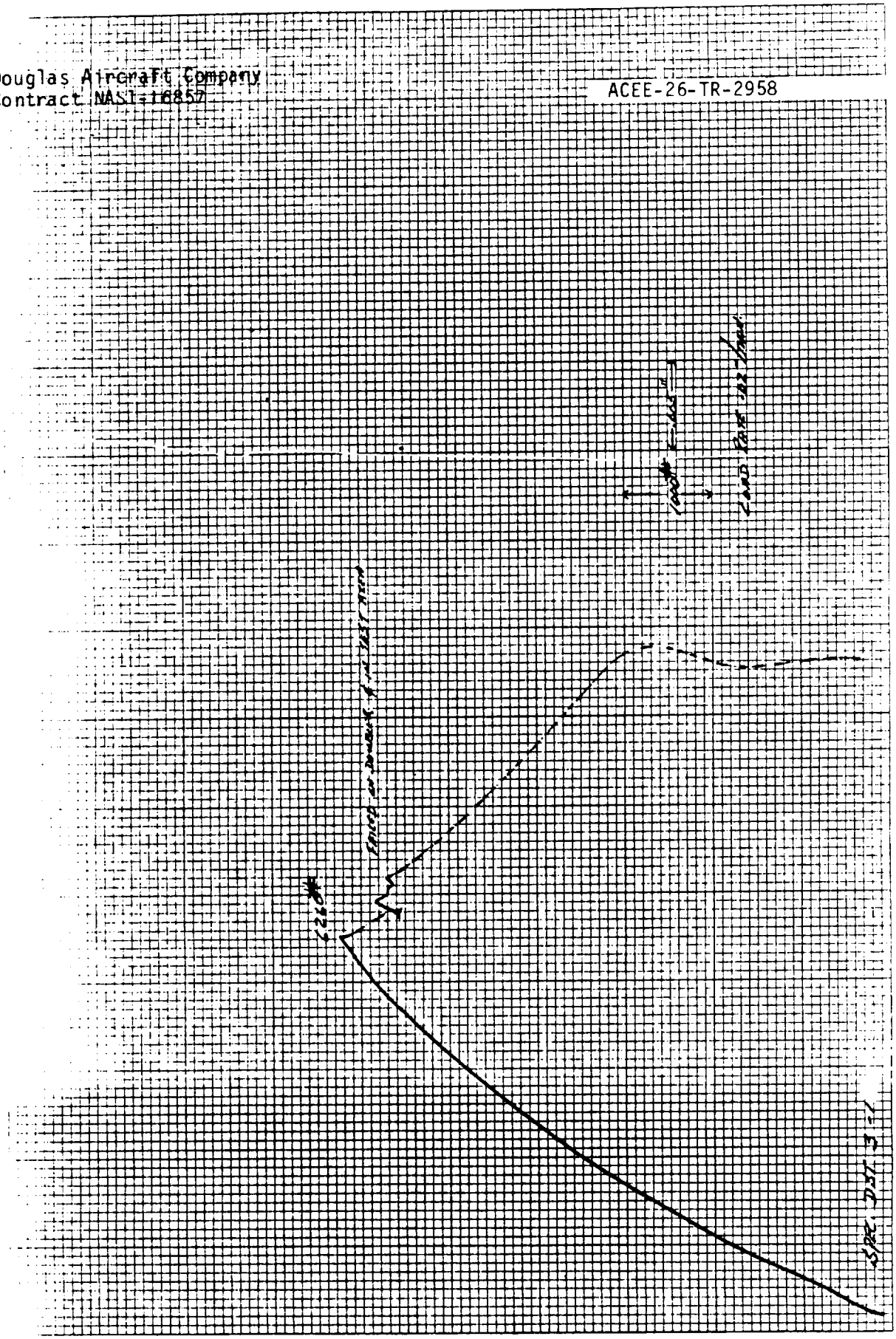
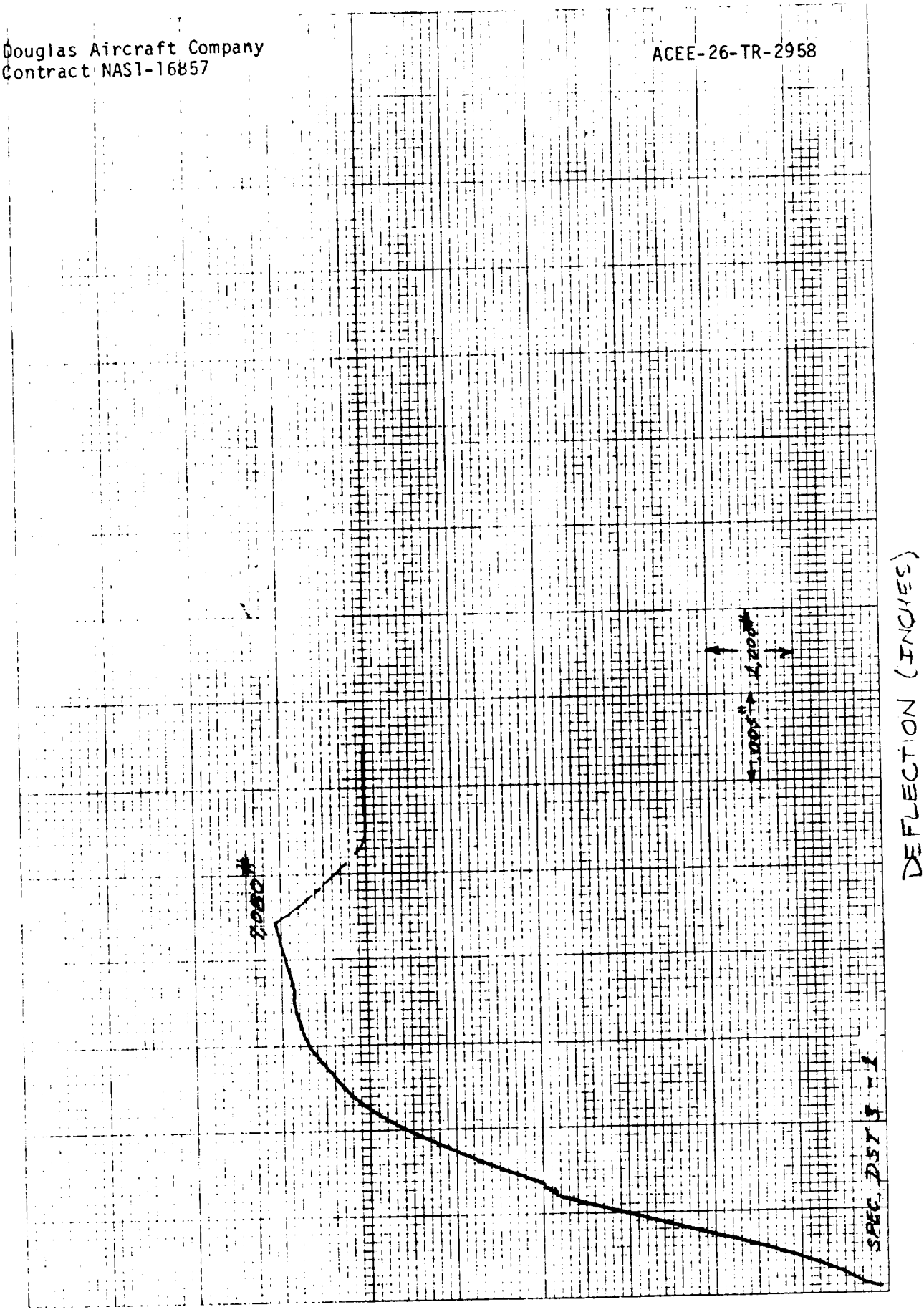
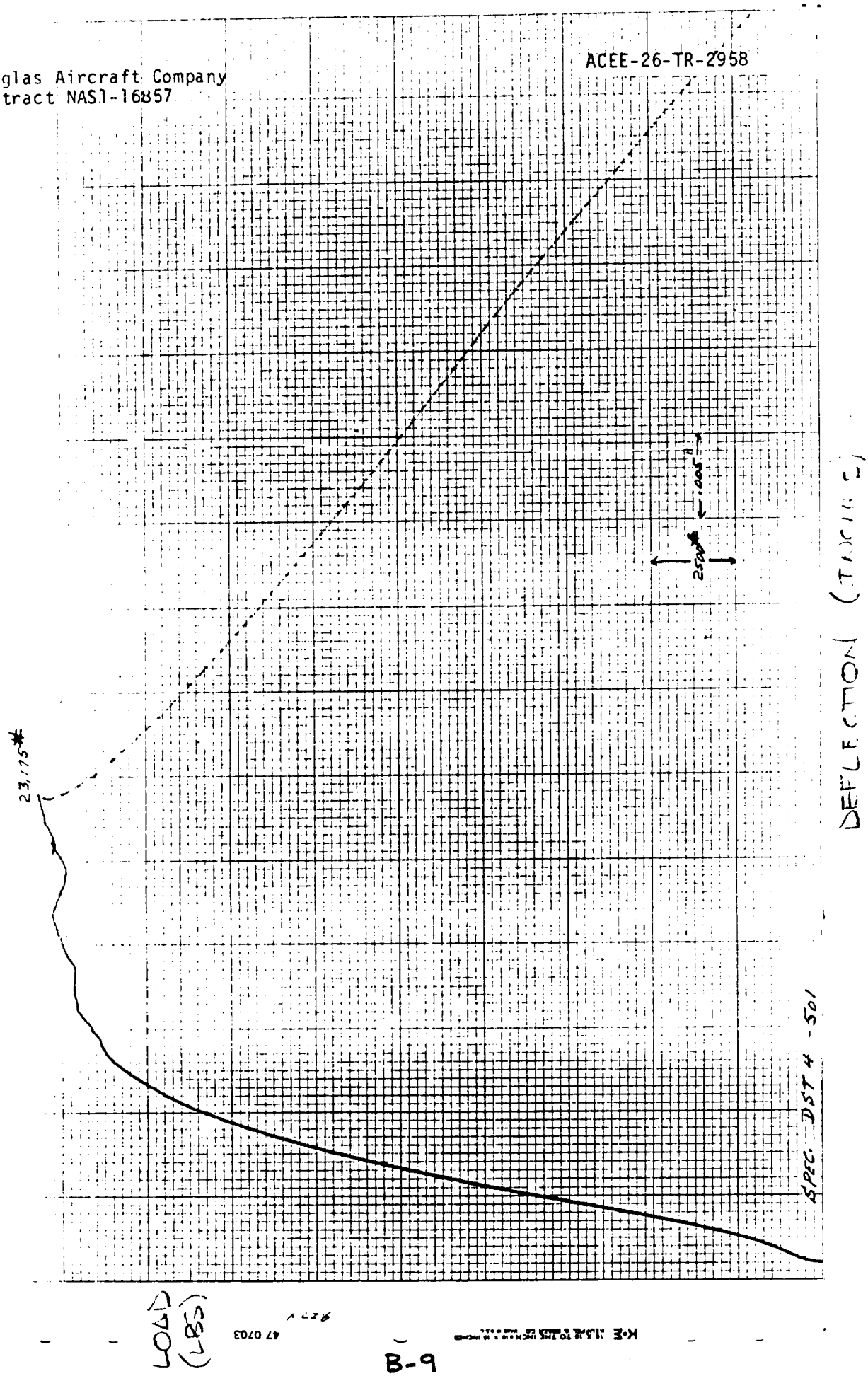
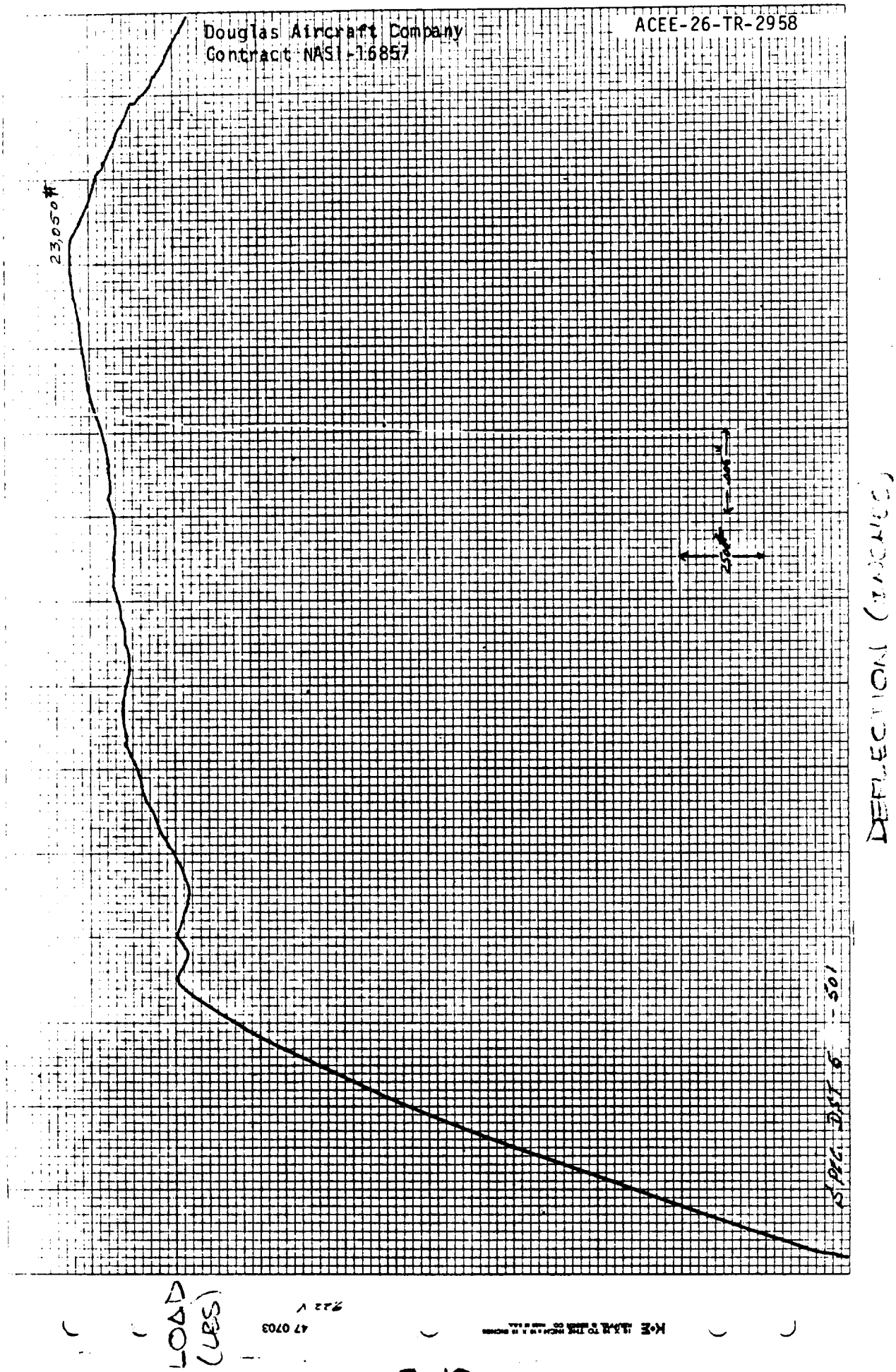
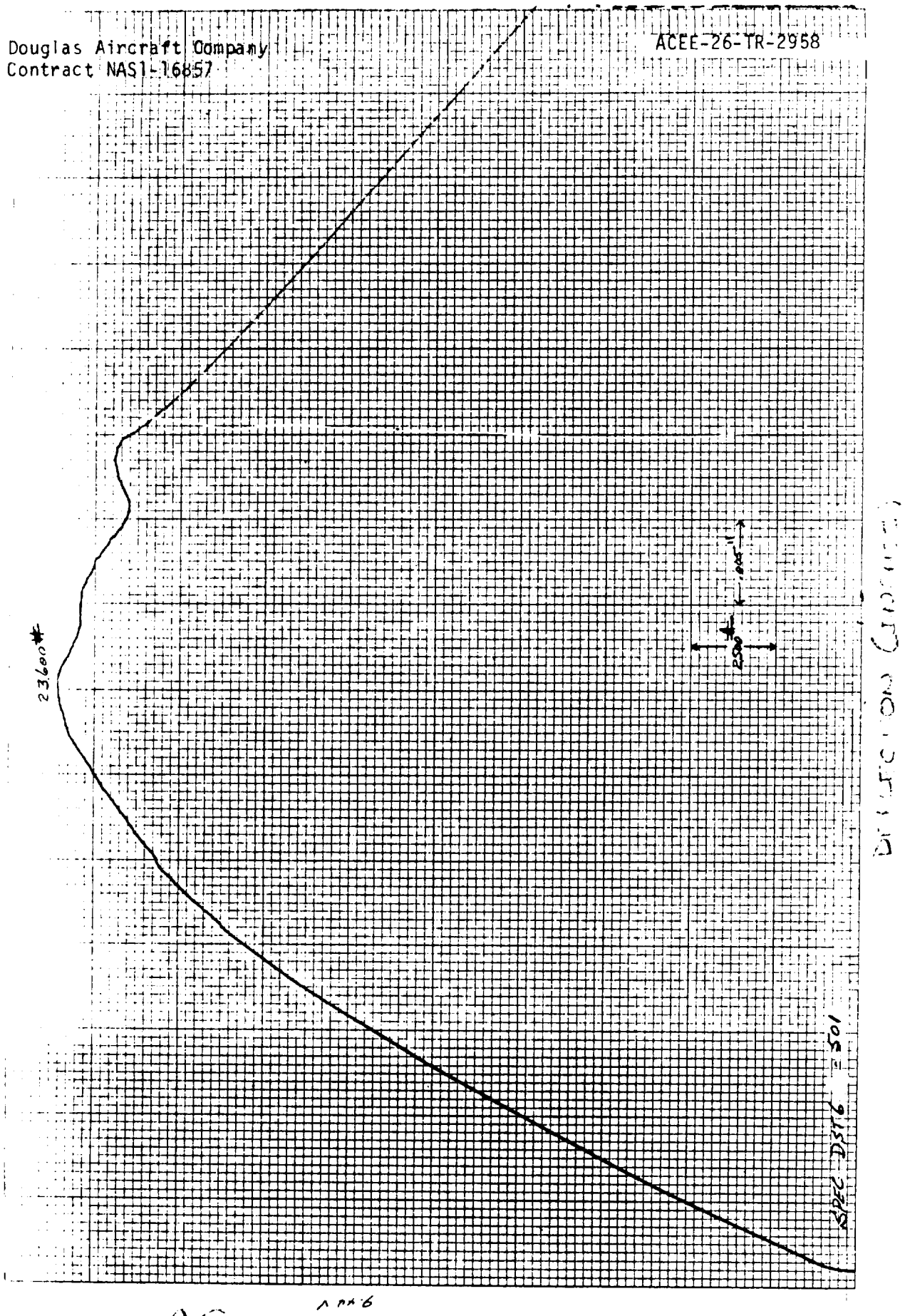

LOAD (LBS)
DEFLECTION (INCHES)
SPEC. DIST. 3"
2260#
ENTER ON DOWNWARD PART OF TEST CURVE
1000# = .045"
LOAD RATE 182 #/MIN


DEFLECTION (INCHES)
LOAD (LBS)
SPEC DST # 1
2000#
1000# ← 500# → 1000#


23,175#
2300#
.005"
LOAD (LBS)
DEFLECTION (TARGET)
SPEC. DST 4 - 501


23,050#
DEFLECTION (INCHES)
LOAD (LBS)



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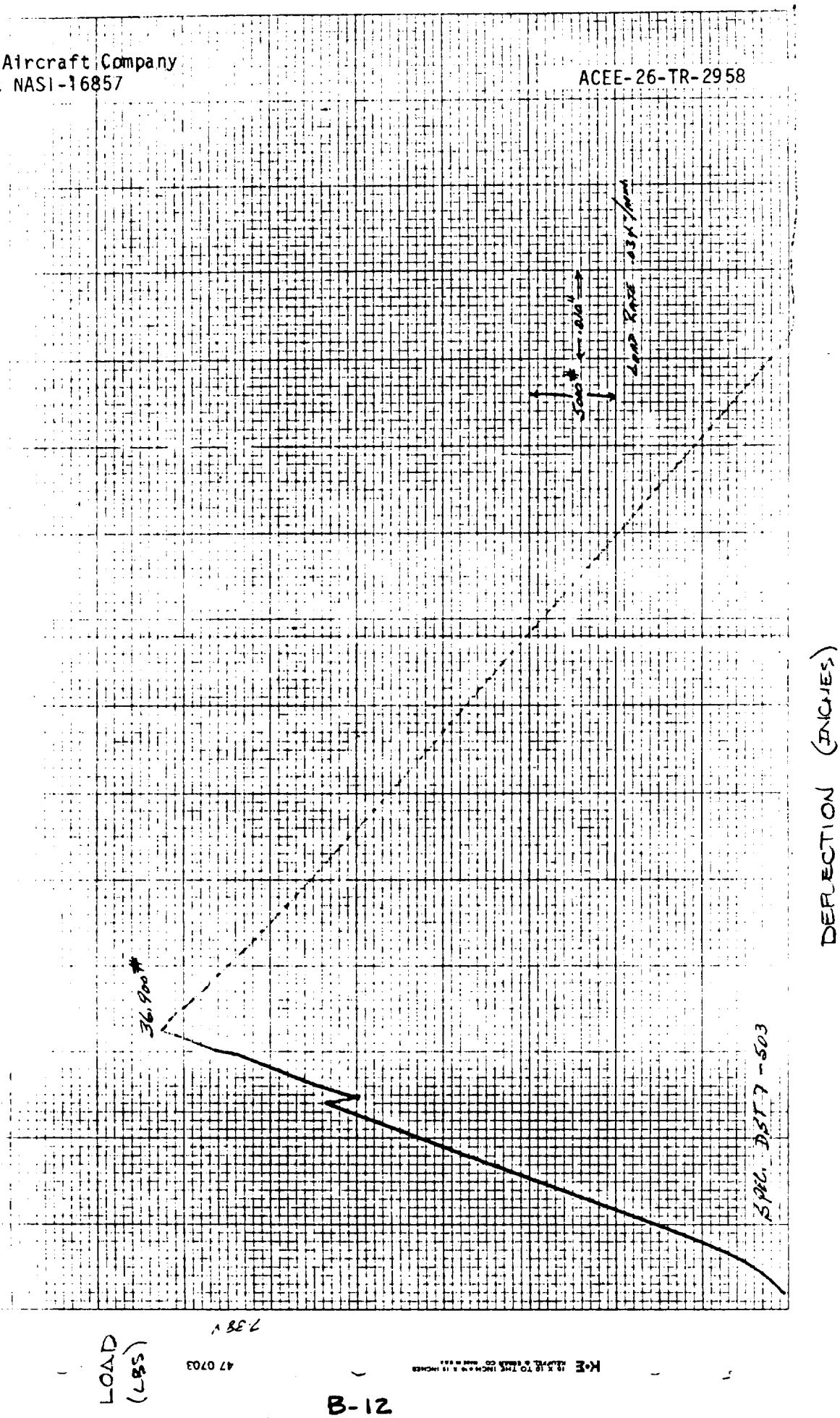
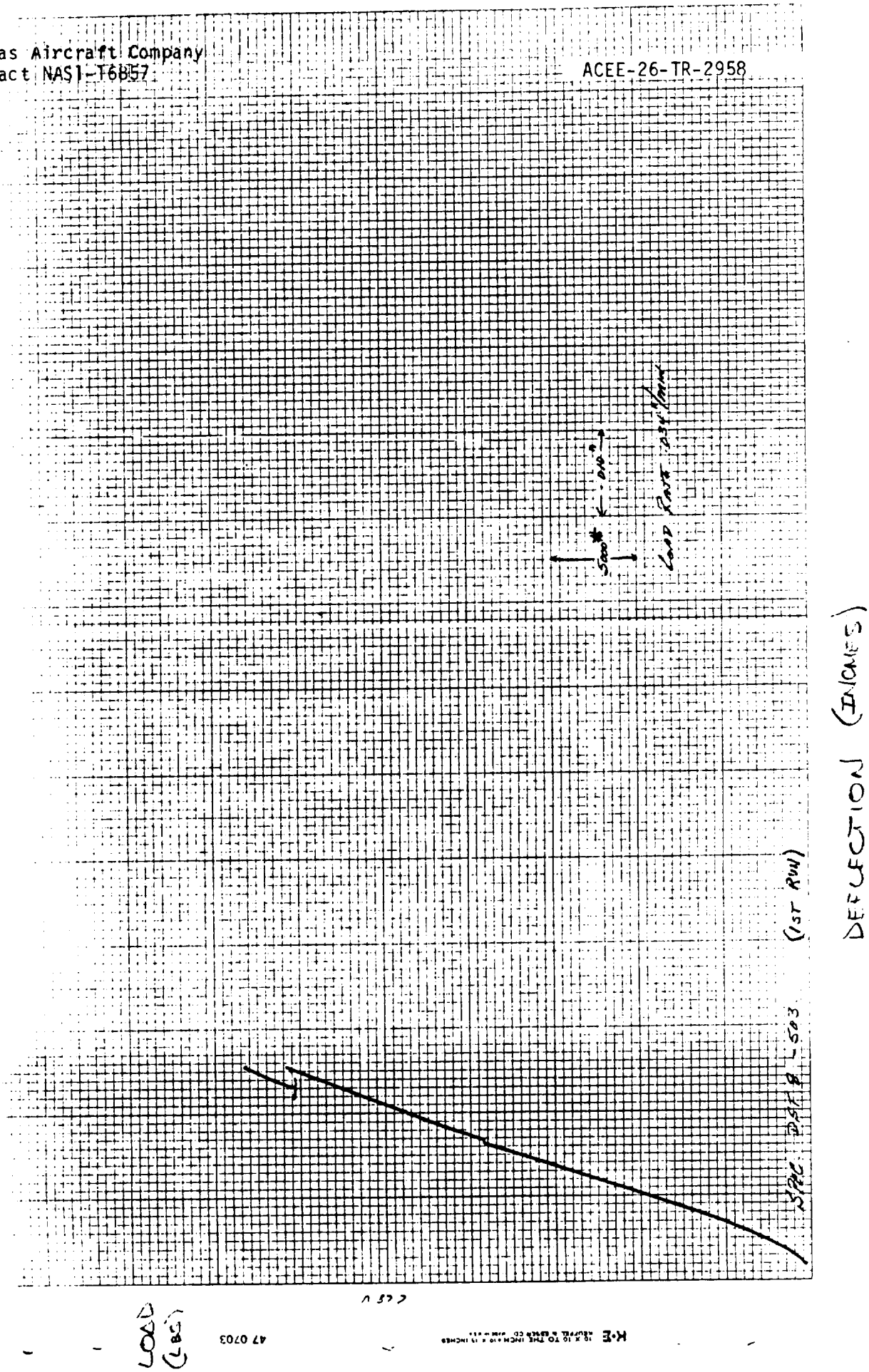
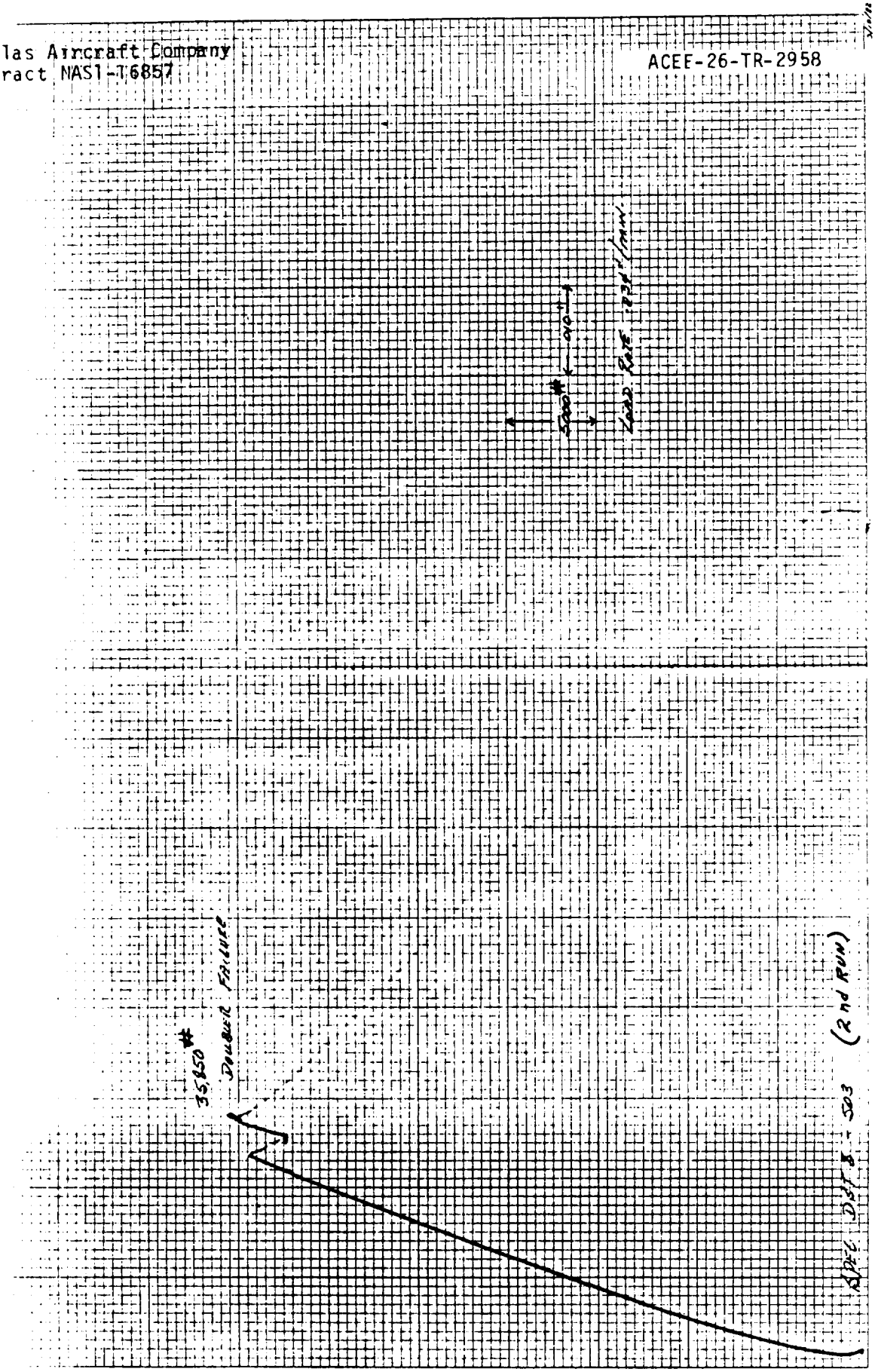
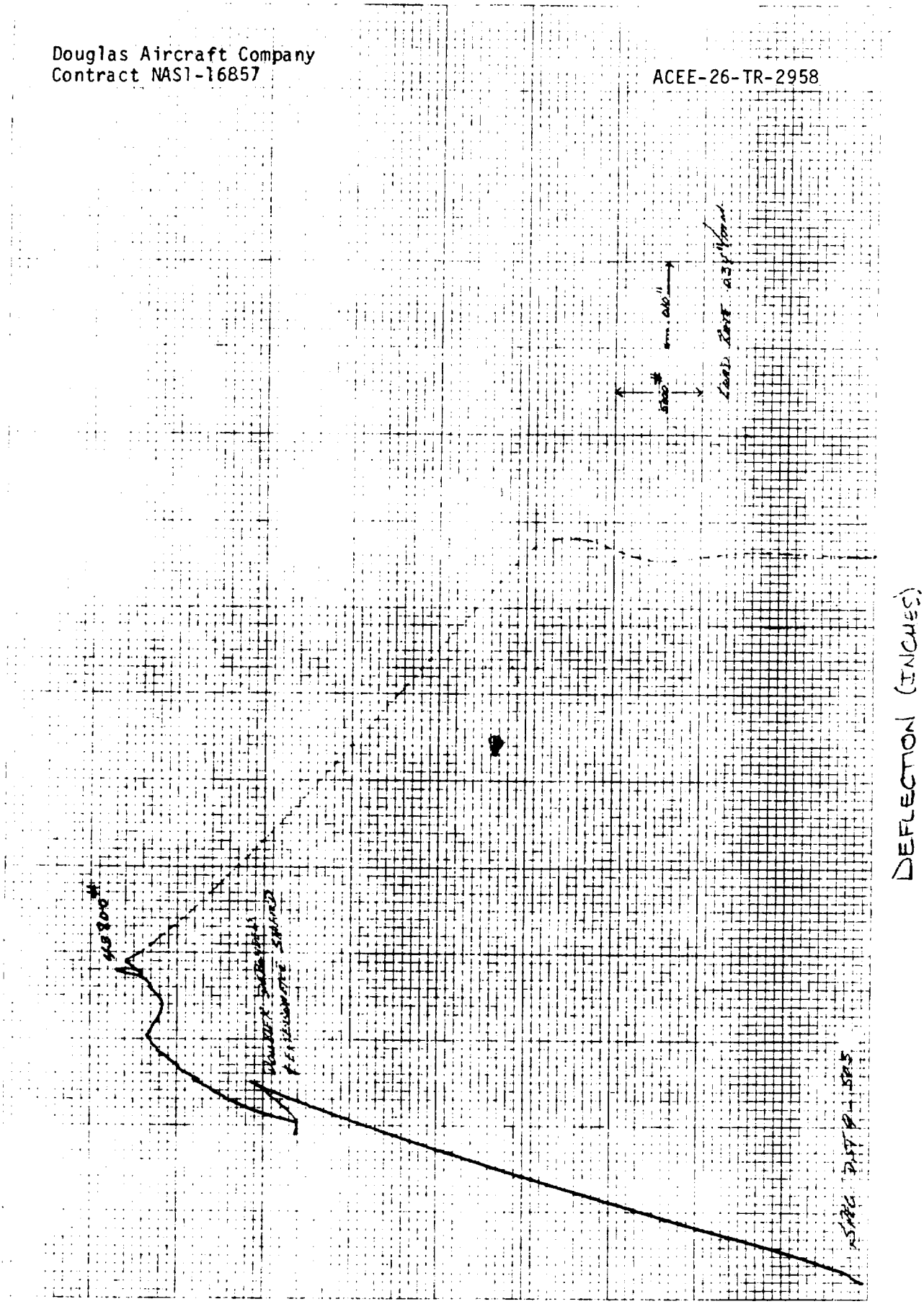

36,900#
500# ← .010" →
Load Rate .03 K/min
Spec. DST7-503
LOAD (LBS)
DEFLECTION (INCHES)


LOAD (LBS)
DEFLECTION (INCHES)
SPEC. DATA L503 (1ST RUN)
LOAD RATE .03"/MIN
500# ← .010" →
47 0703


LOAD RATE .83#/MIN.
5000 #
010
35,850 #
DOUBLE FAILURE
SPEC. DIST. - 503 (2nd RUN)
DEFLECTION (INCHES)
LOAD (LBS)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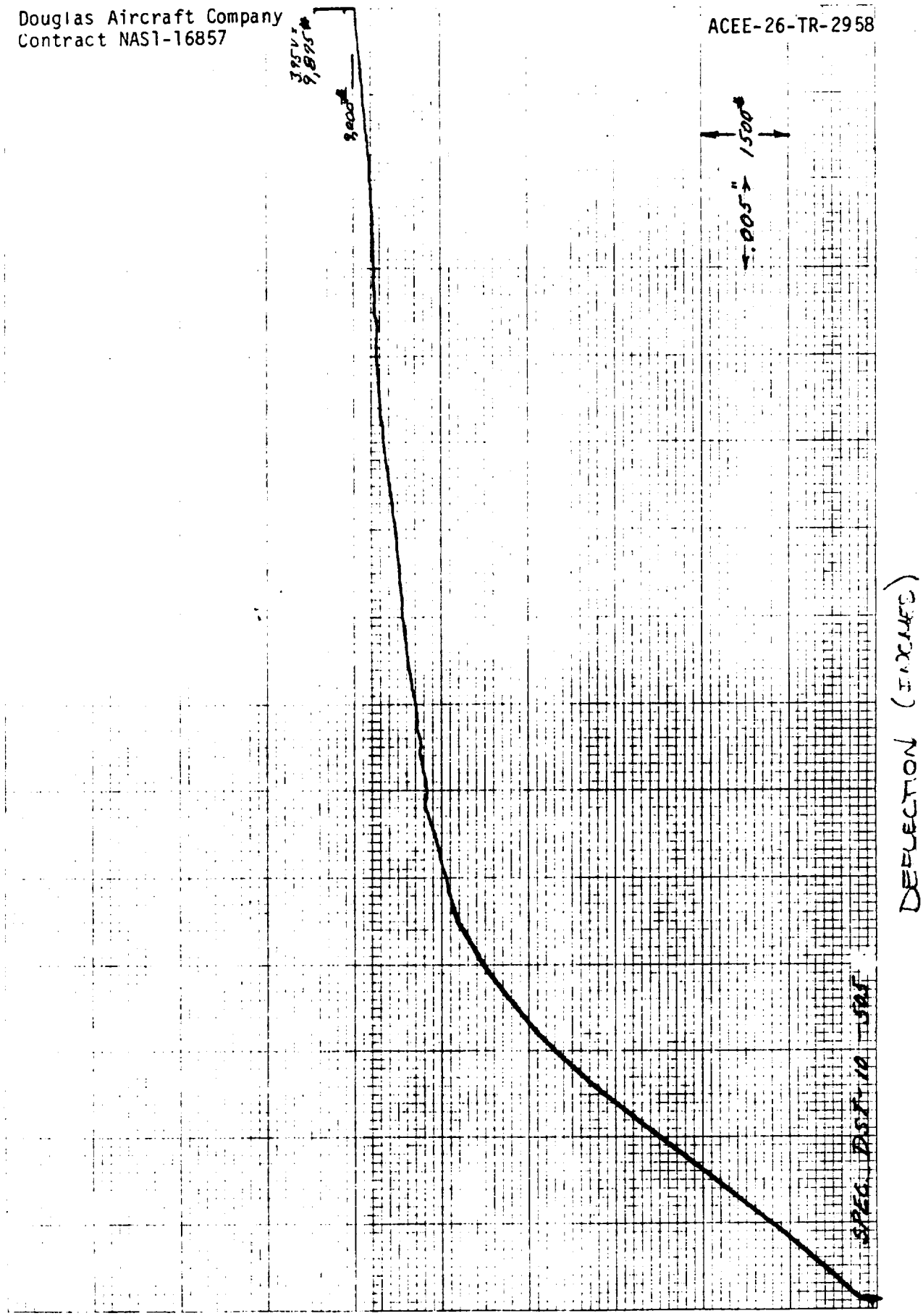
(LBS)
DEFLECTION (INCHES)



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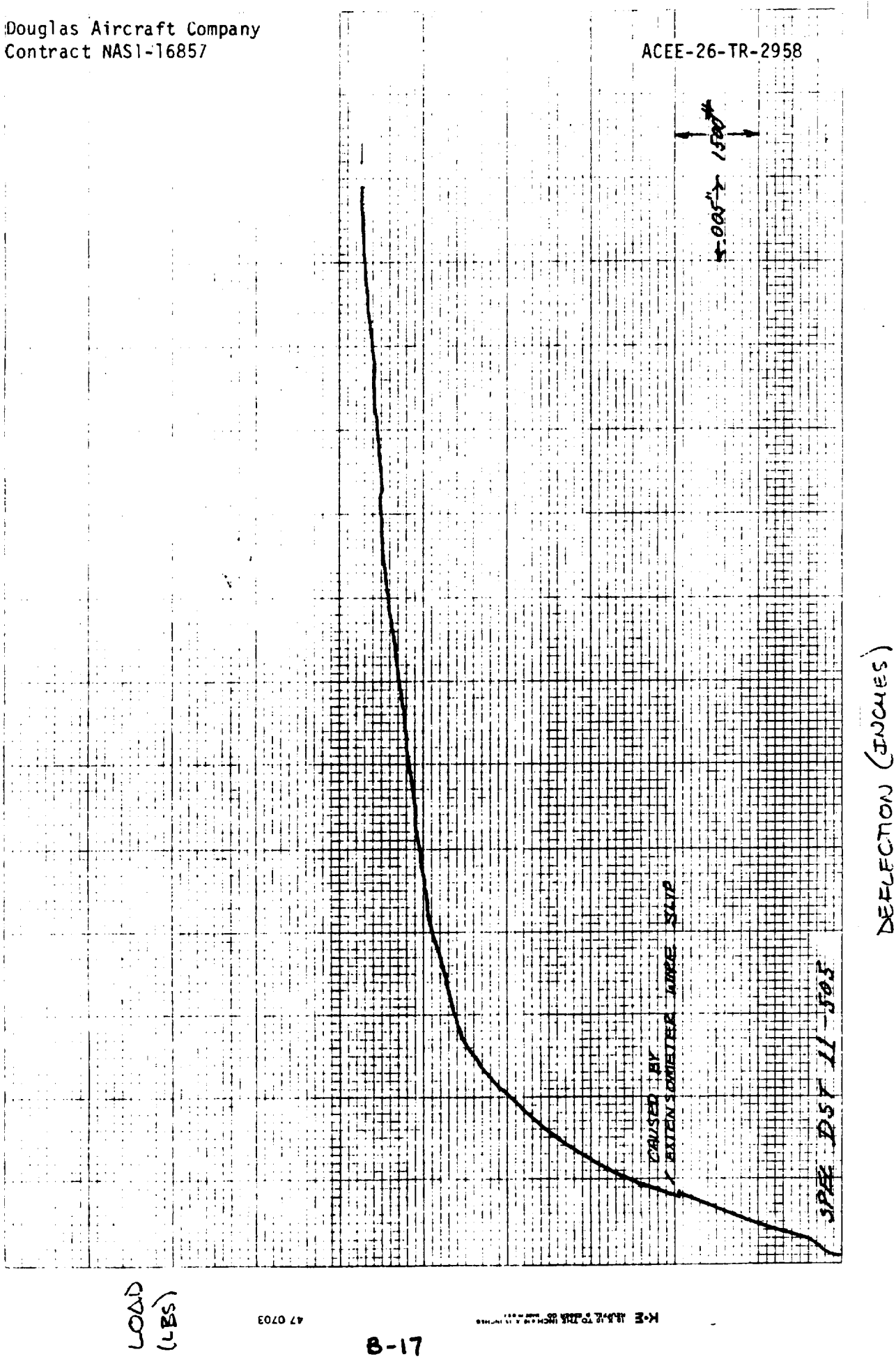
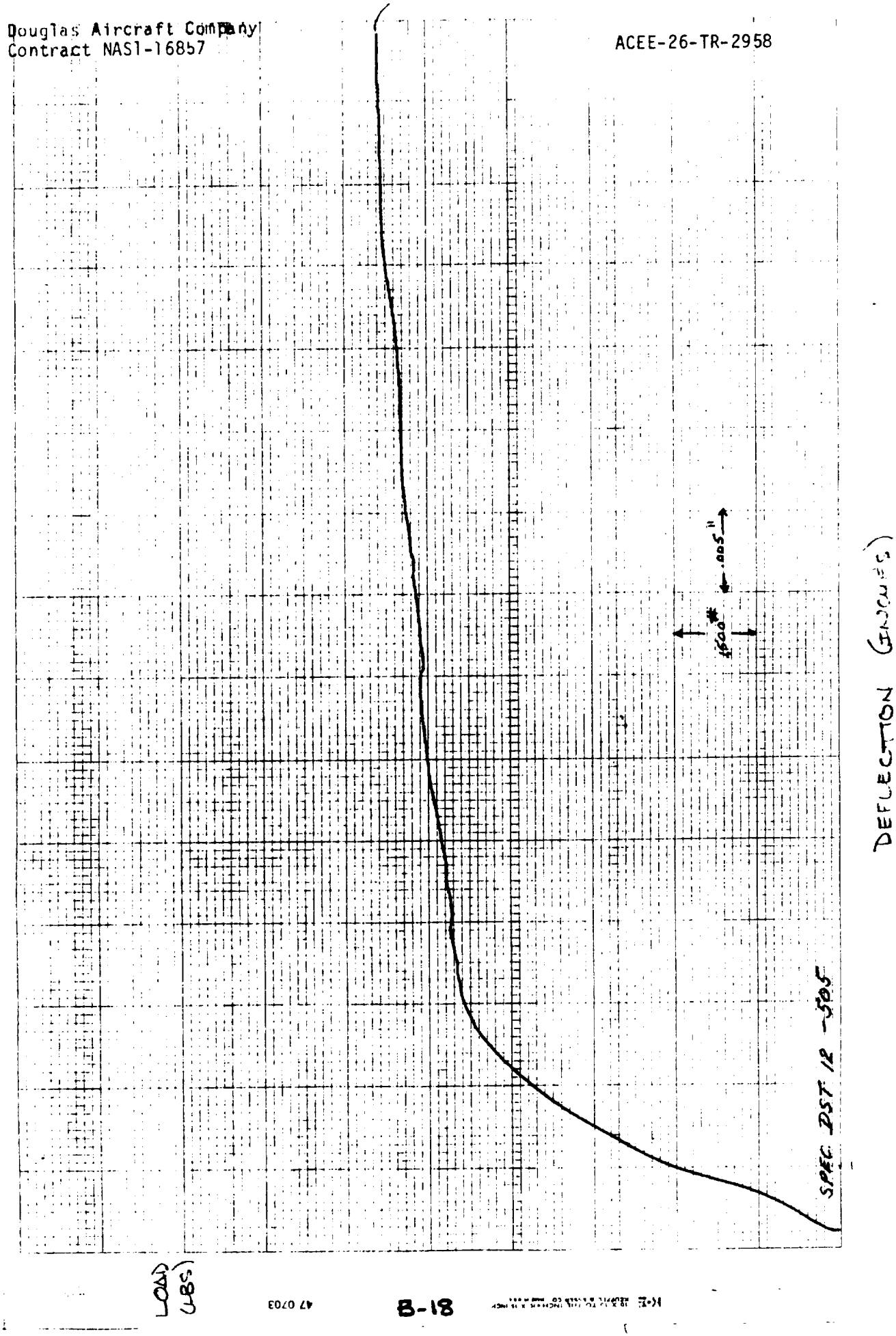

±.005" → 1500#
CAUSED BY EXTENSOMETER JAWS SLIP
SPEC. DST 11-505
LOAD (LBS)
DEFLECTION (INCHES)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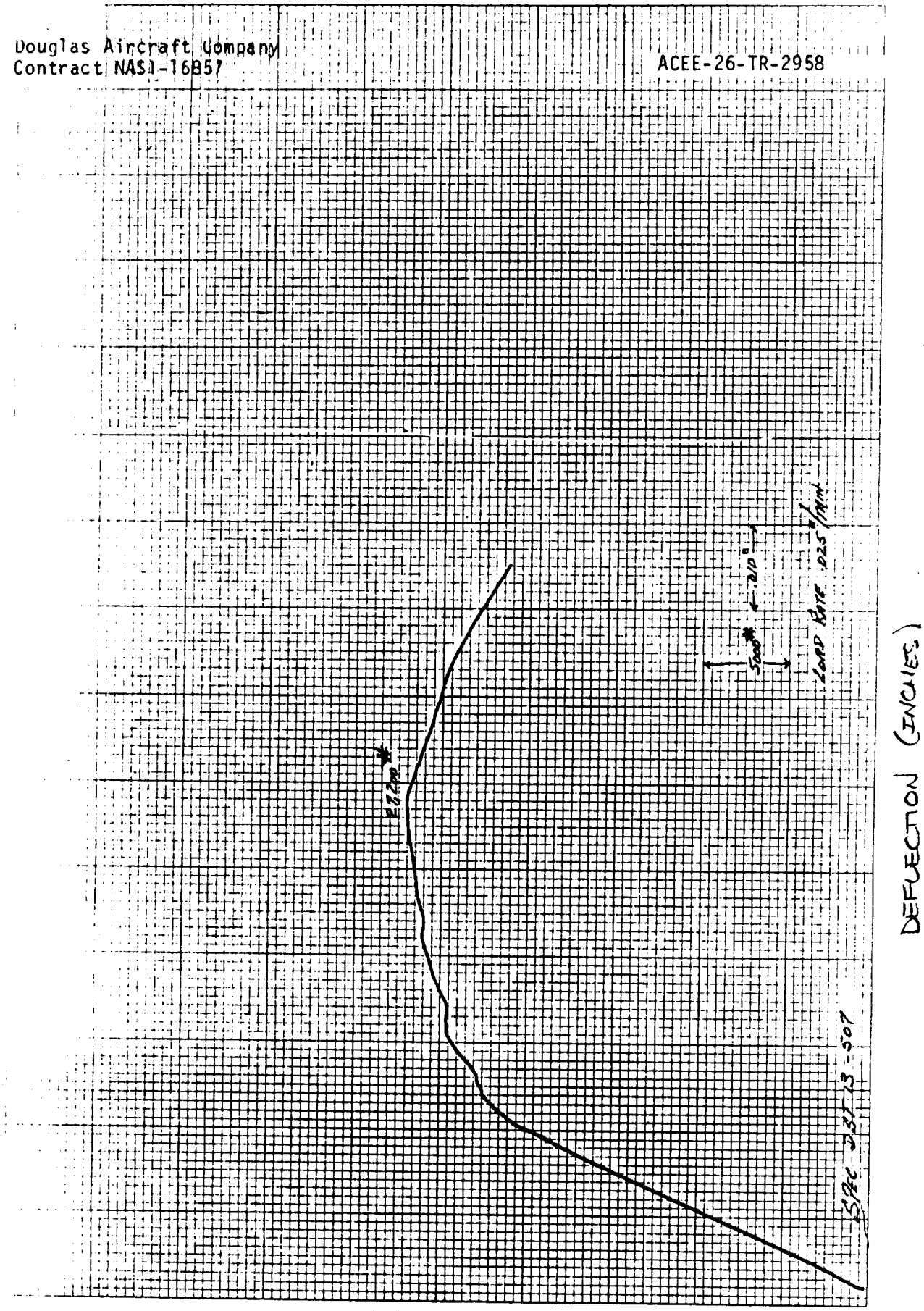
DEFLECTION (INCHES)
.005"
1500#
SPEC DST 12 -500F



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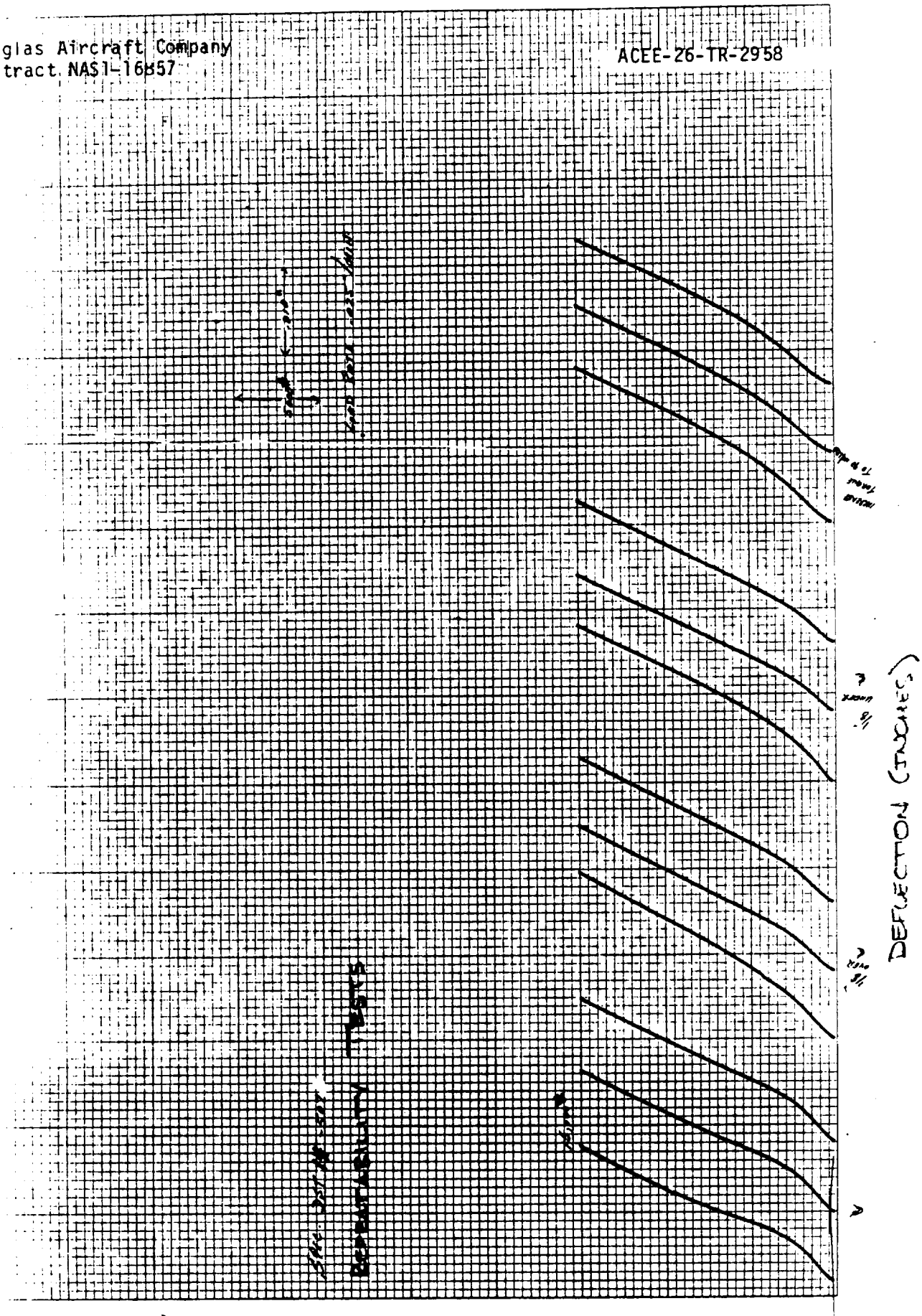
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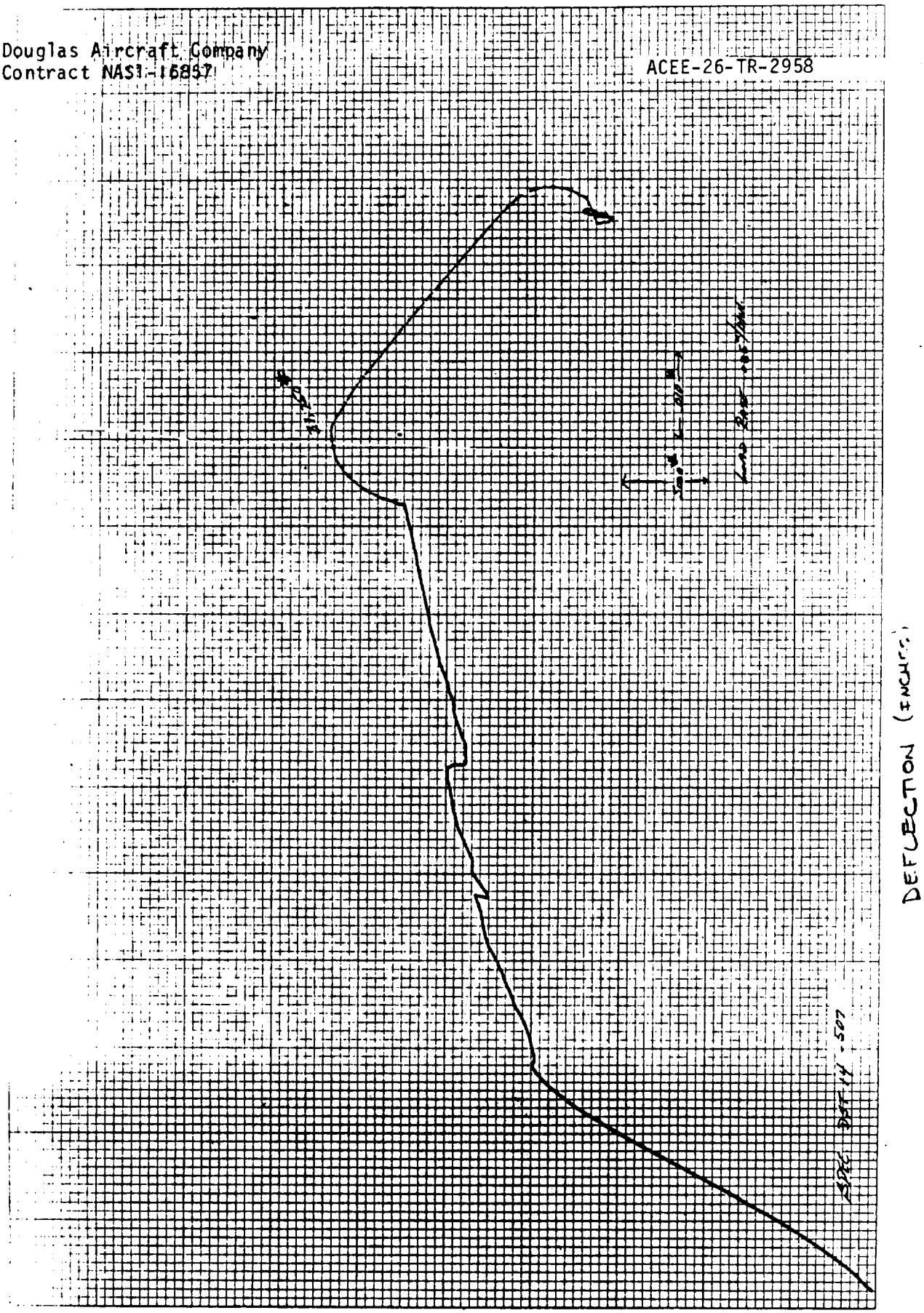
LOAD (LBS)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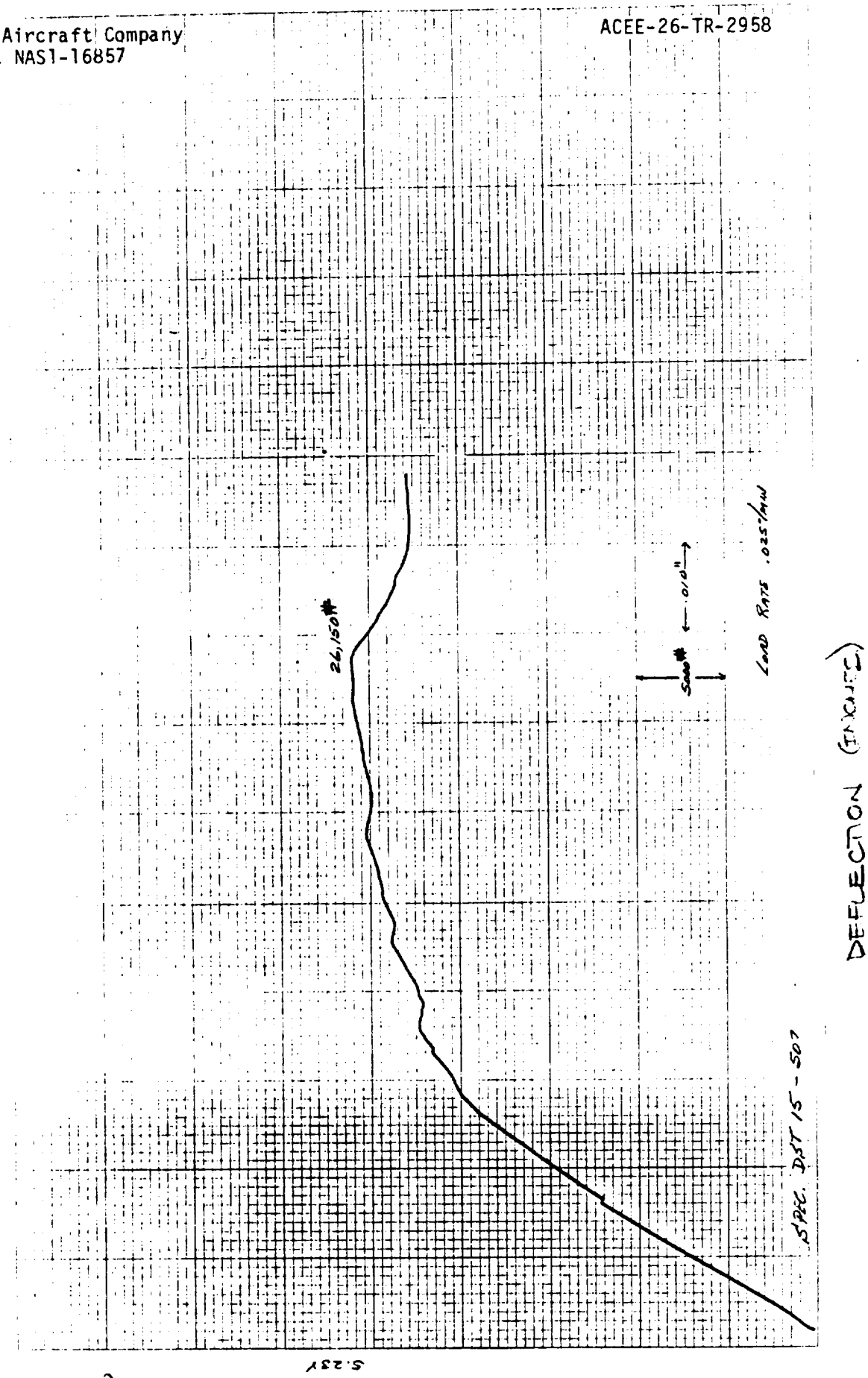
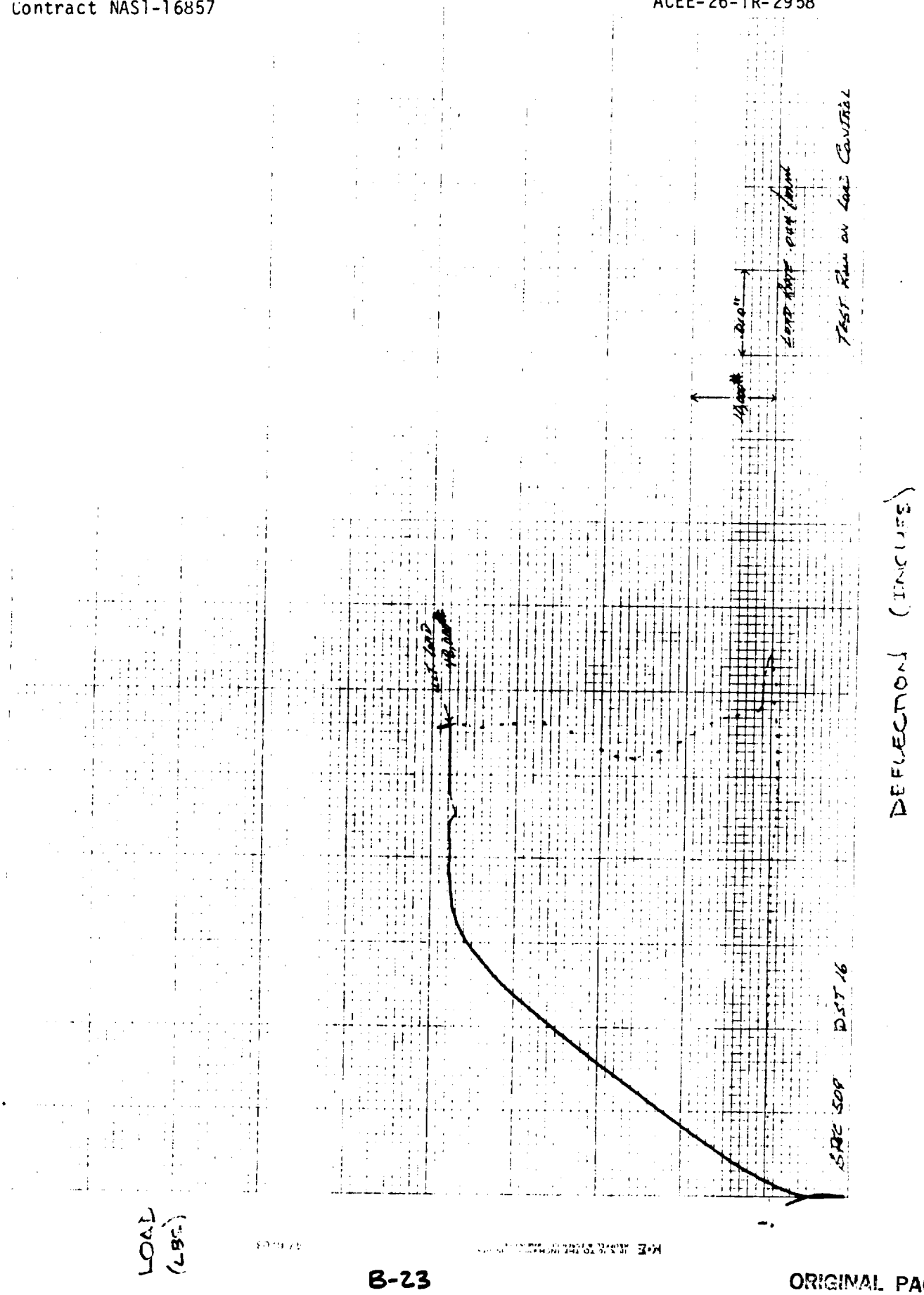
DEFLECTION (INCHES)


26,150#
500#
.010"
LOAD RATE .025"/MIN
SPEC. DST 15 - 507
DEFLECTION (INCHES)
LOAD (LBS)



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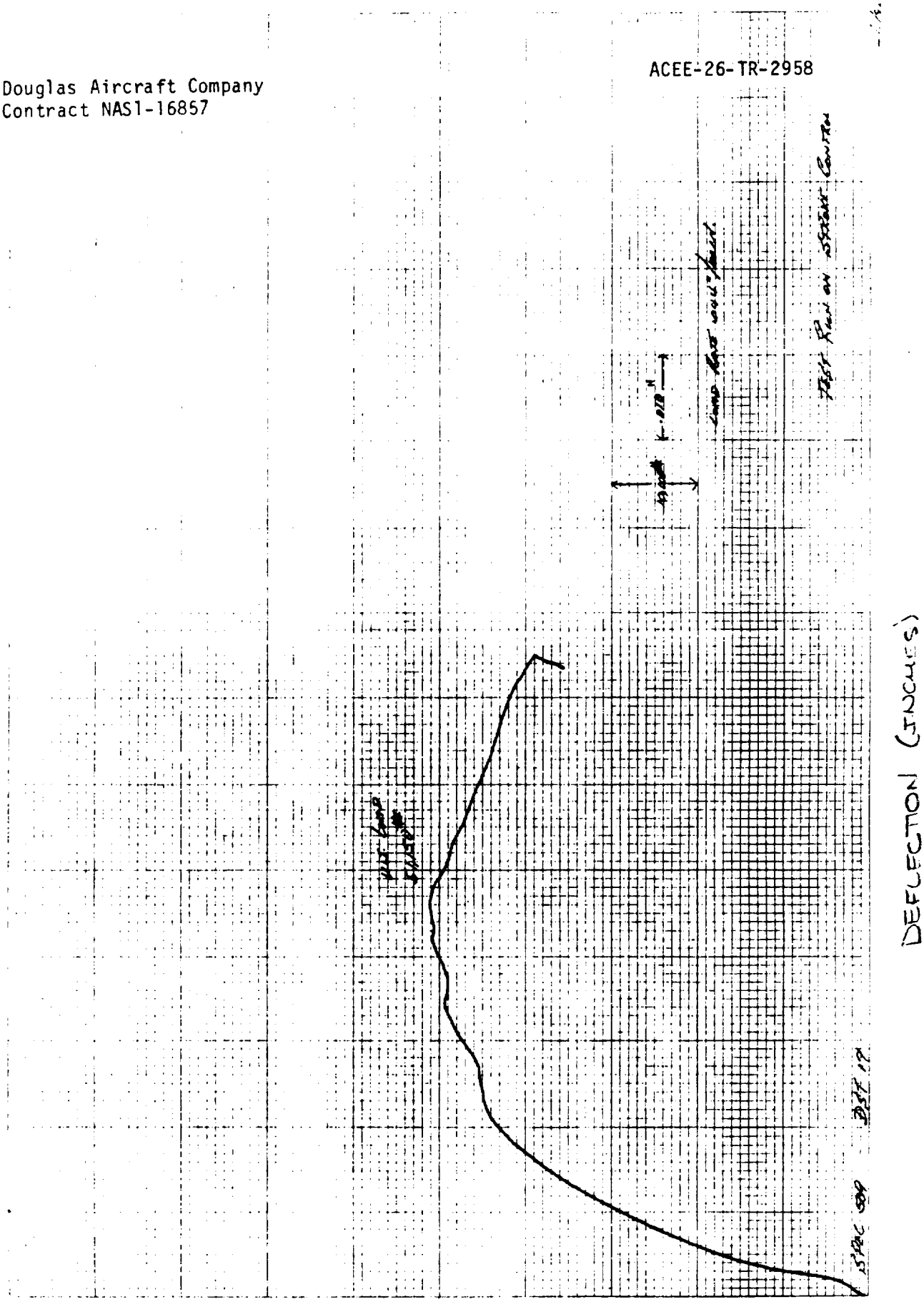
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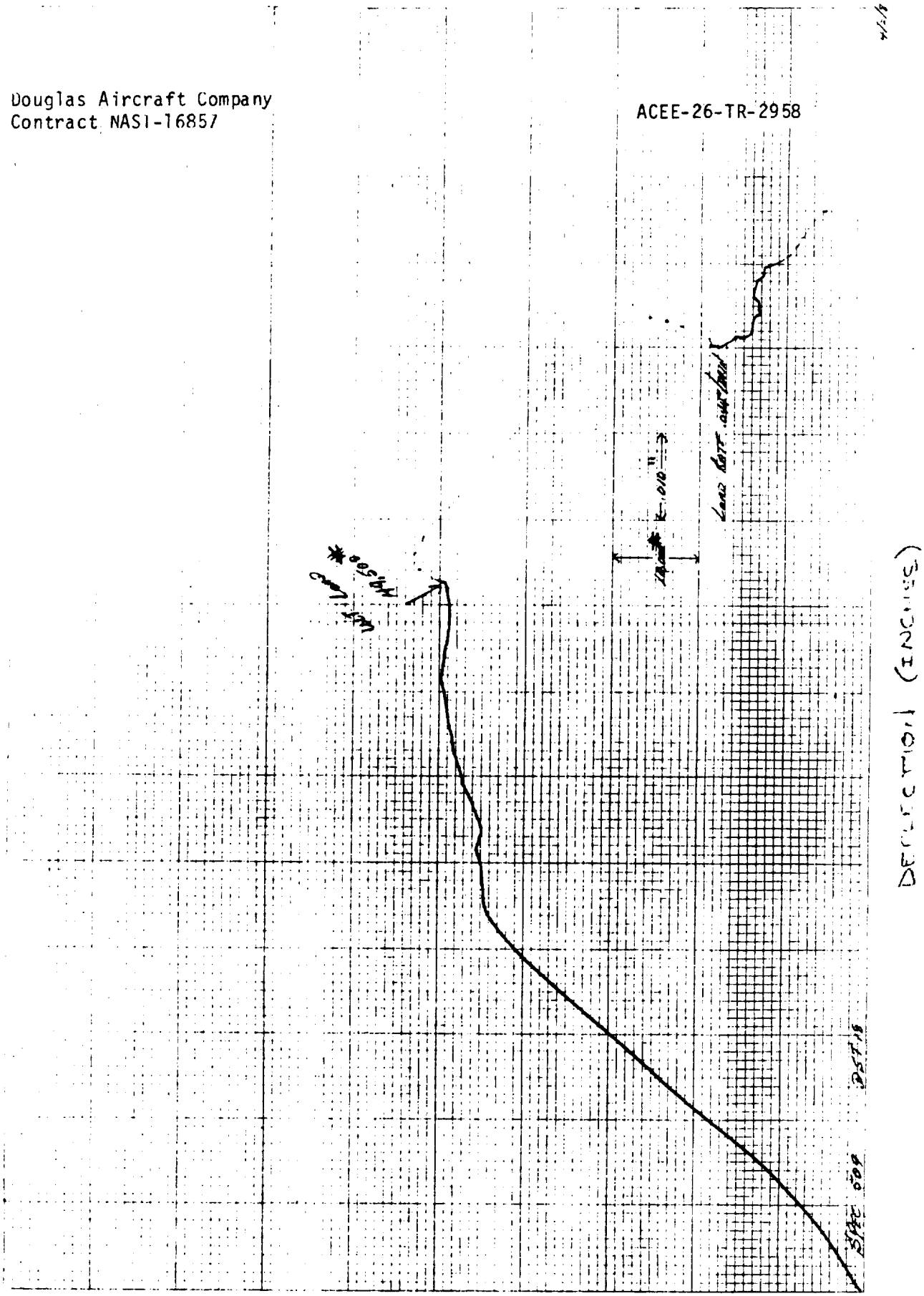
LOAD (LBS)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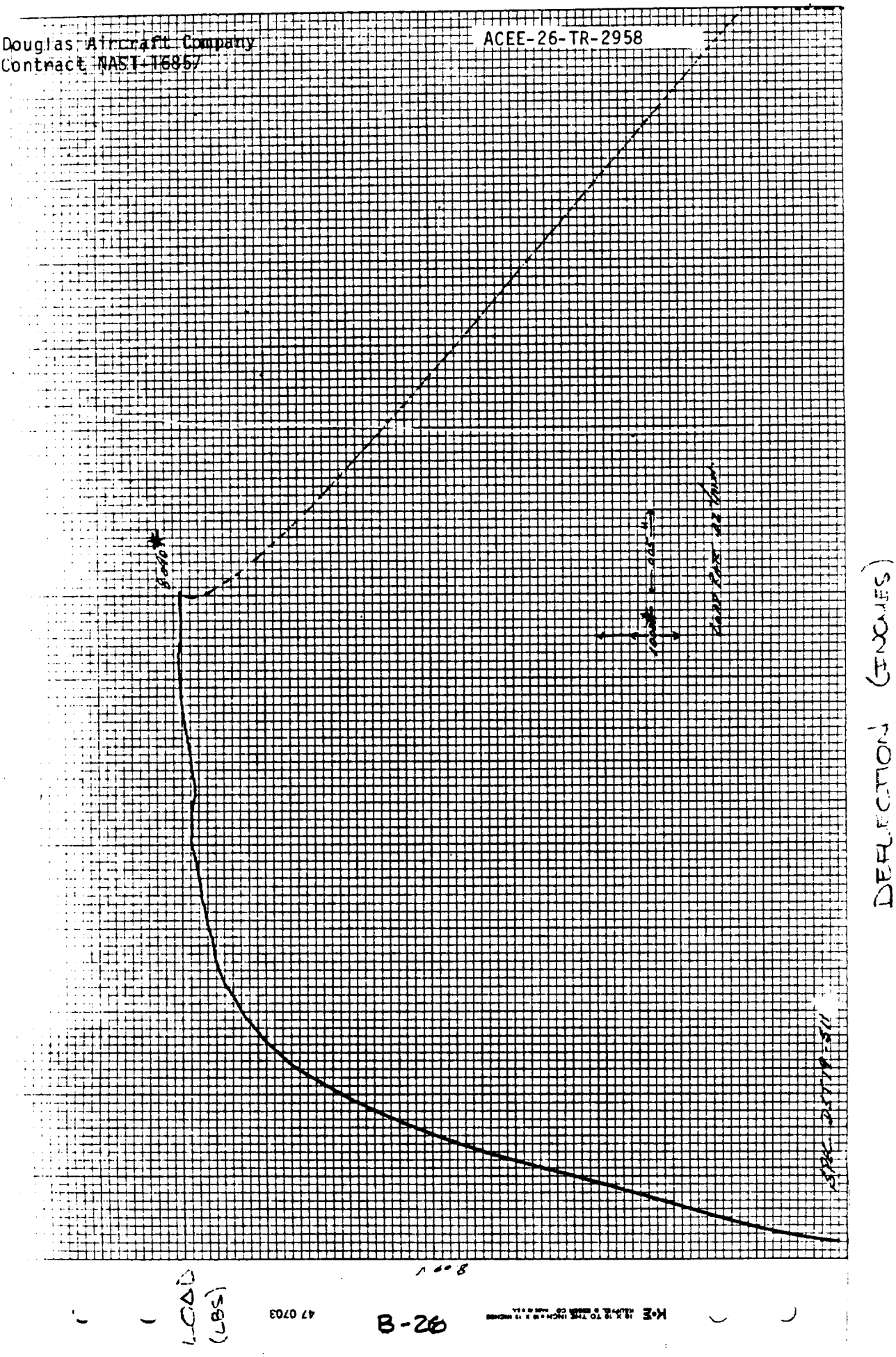
DEFLECTION (INCHES)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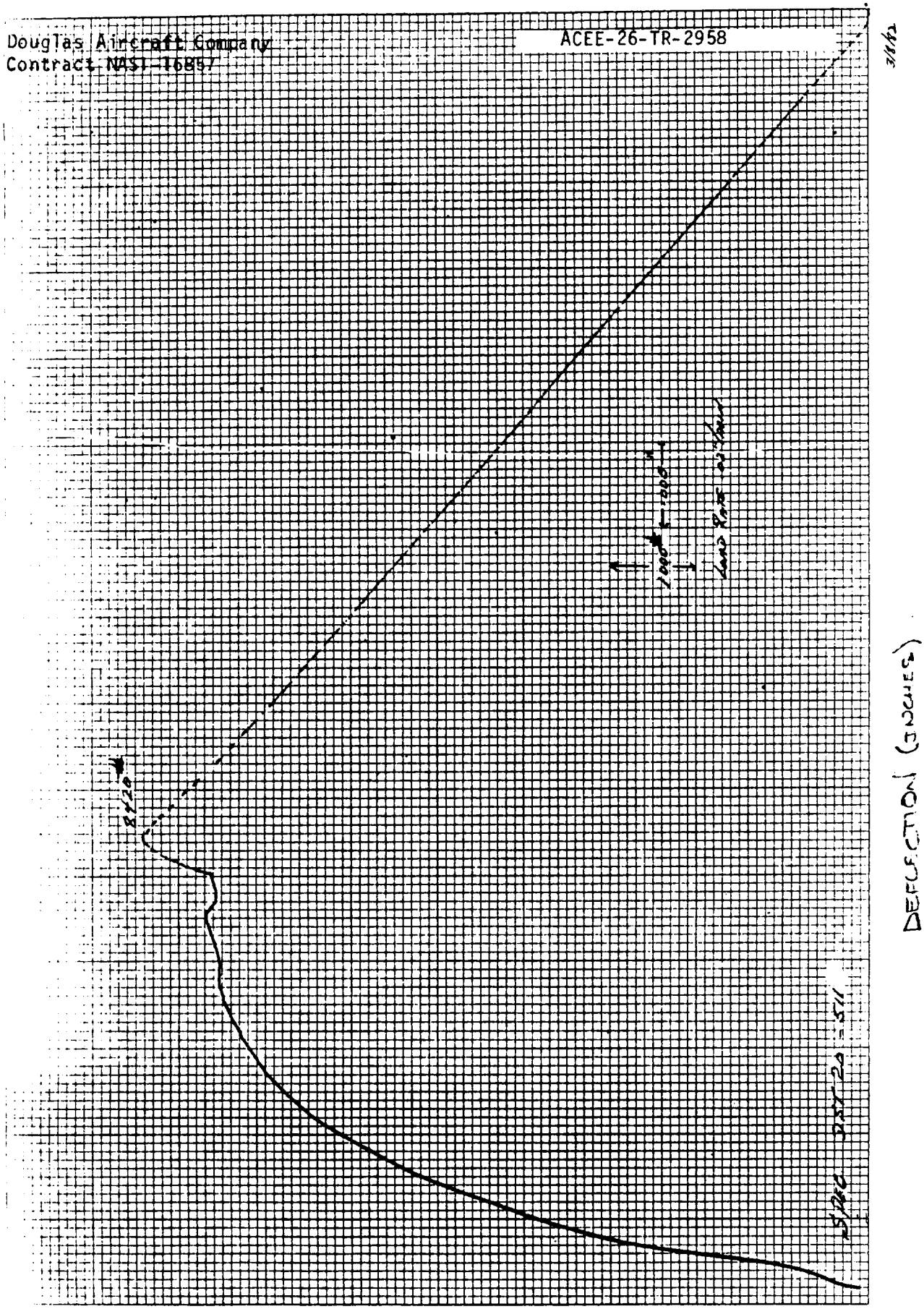
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DEFLECTION (INCHES)
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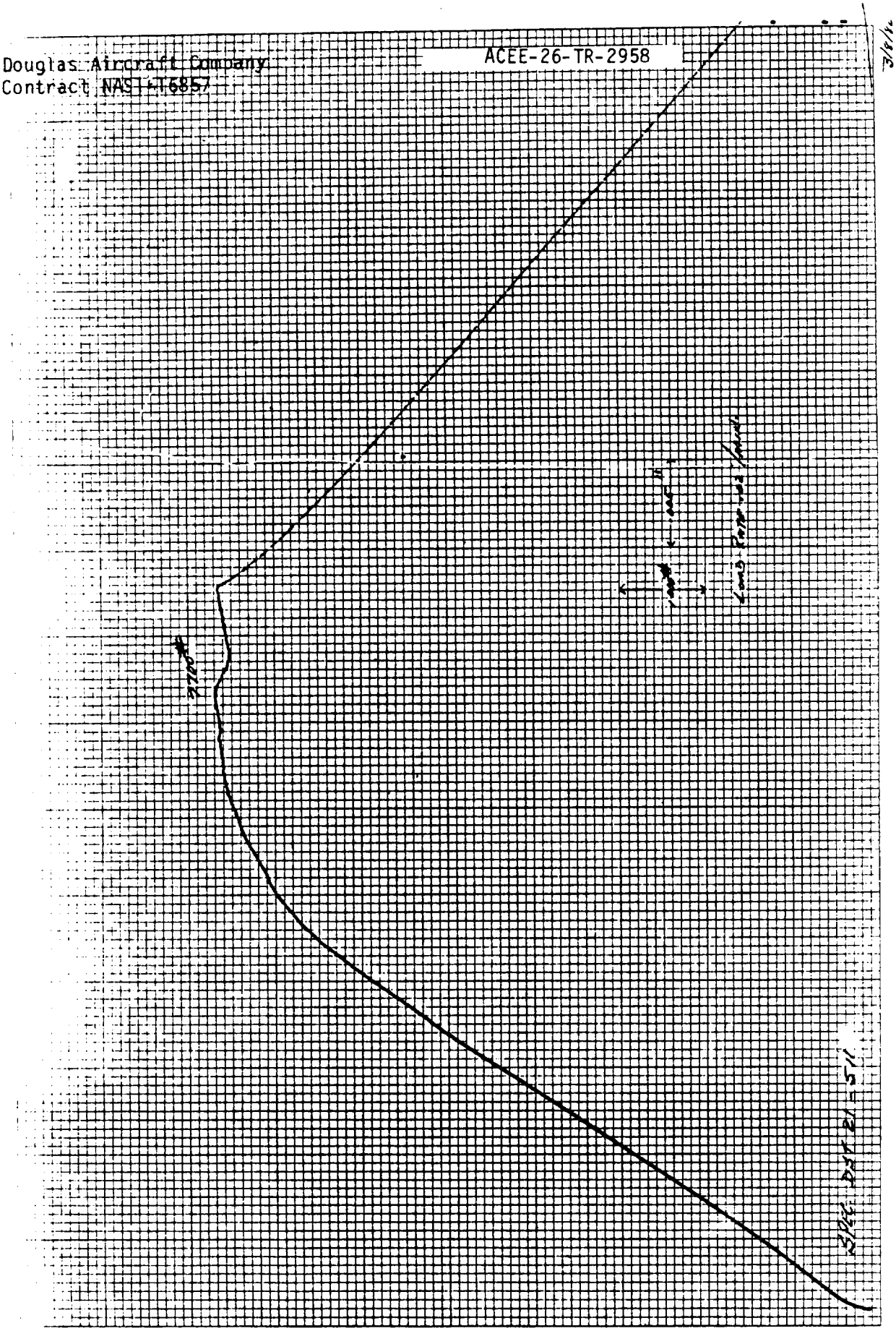
1000 LB
1000 LB
LOAD RATE 20 LB/IN
8420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LOAD (LBS)
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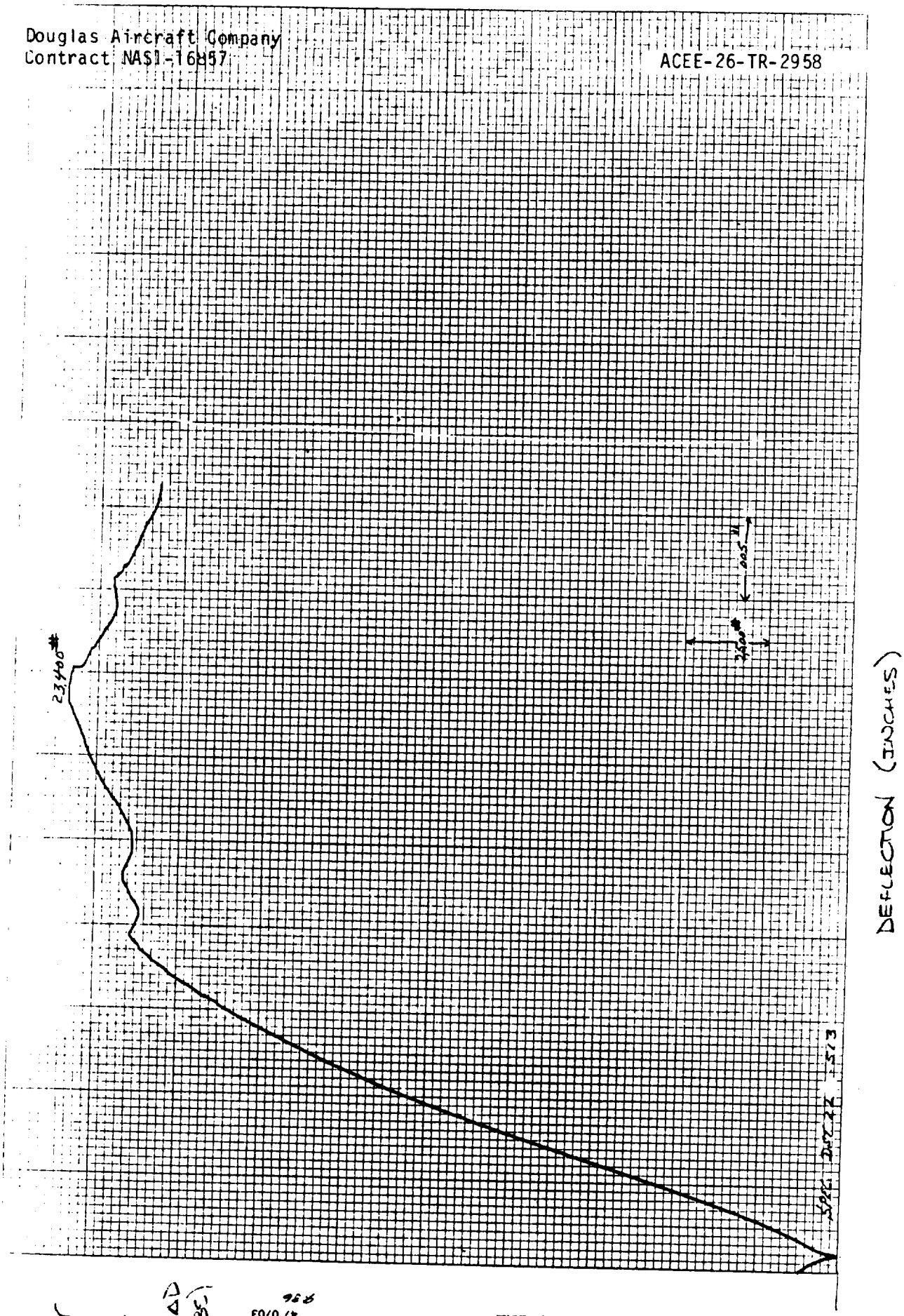
LOAD FACTOR = 1.0
LOAD FACTOR = 1.5



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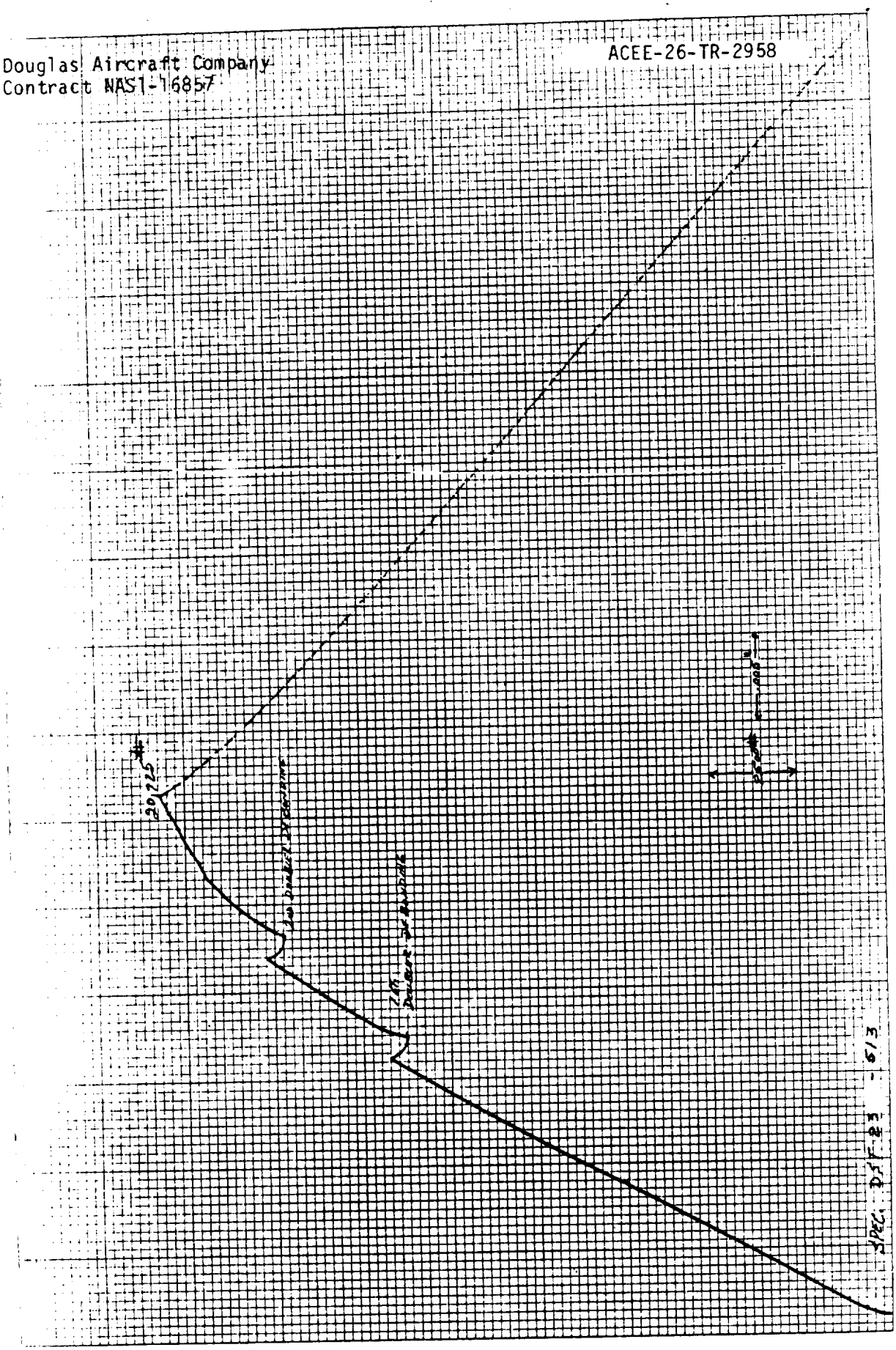
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SPEC. DSF-23 - 613
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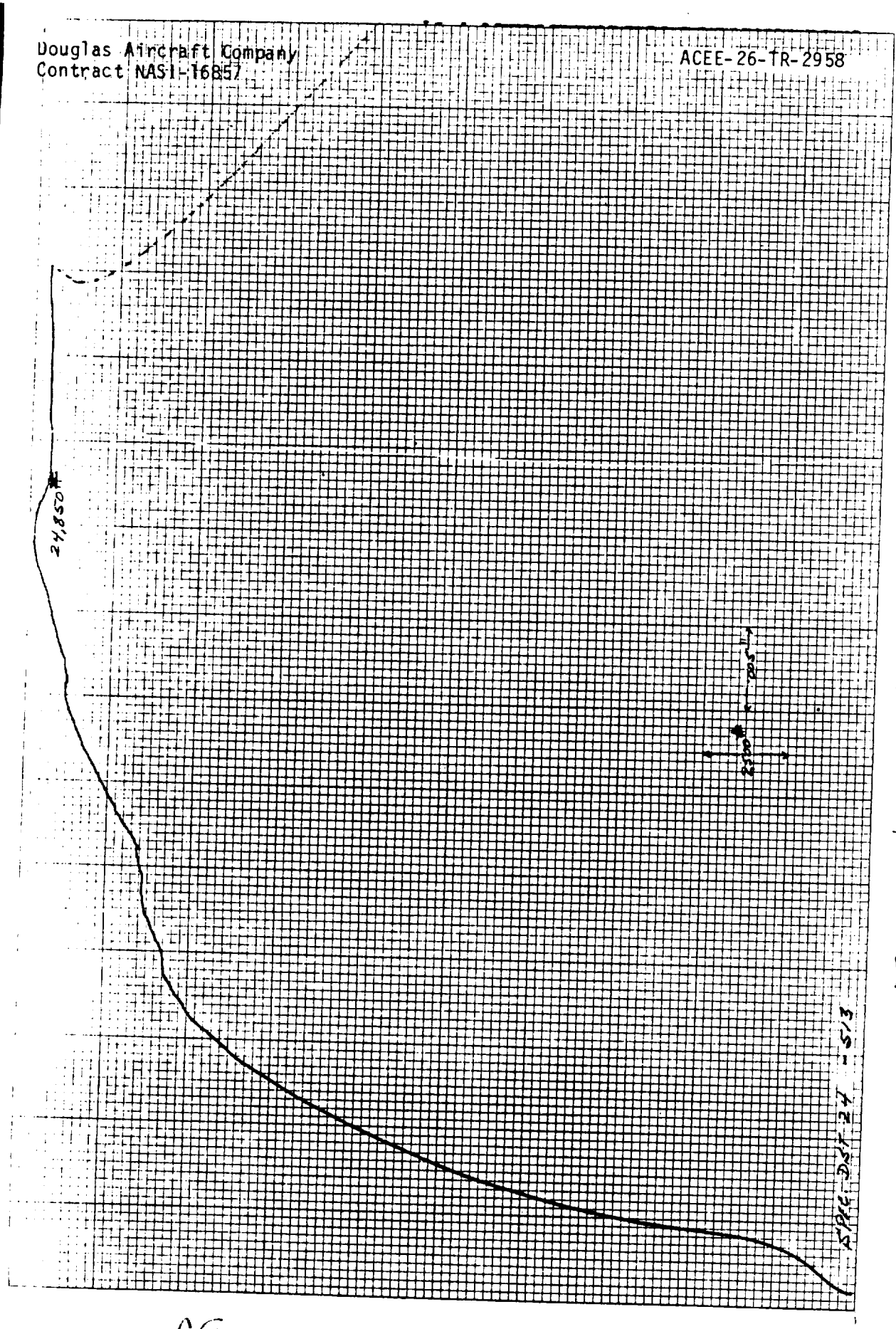
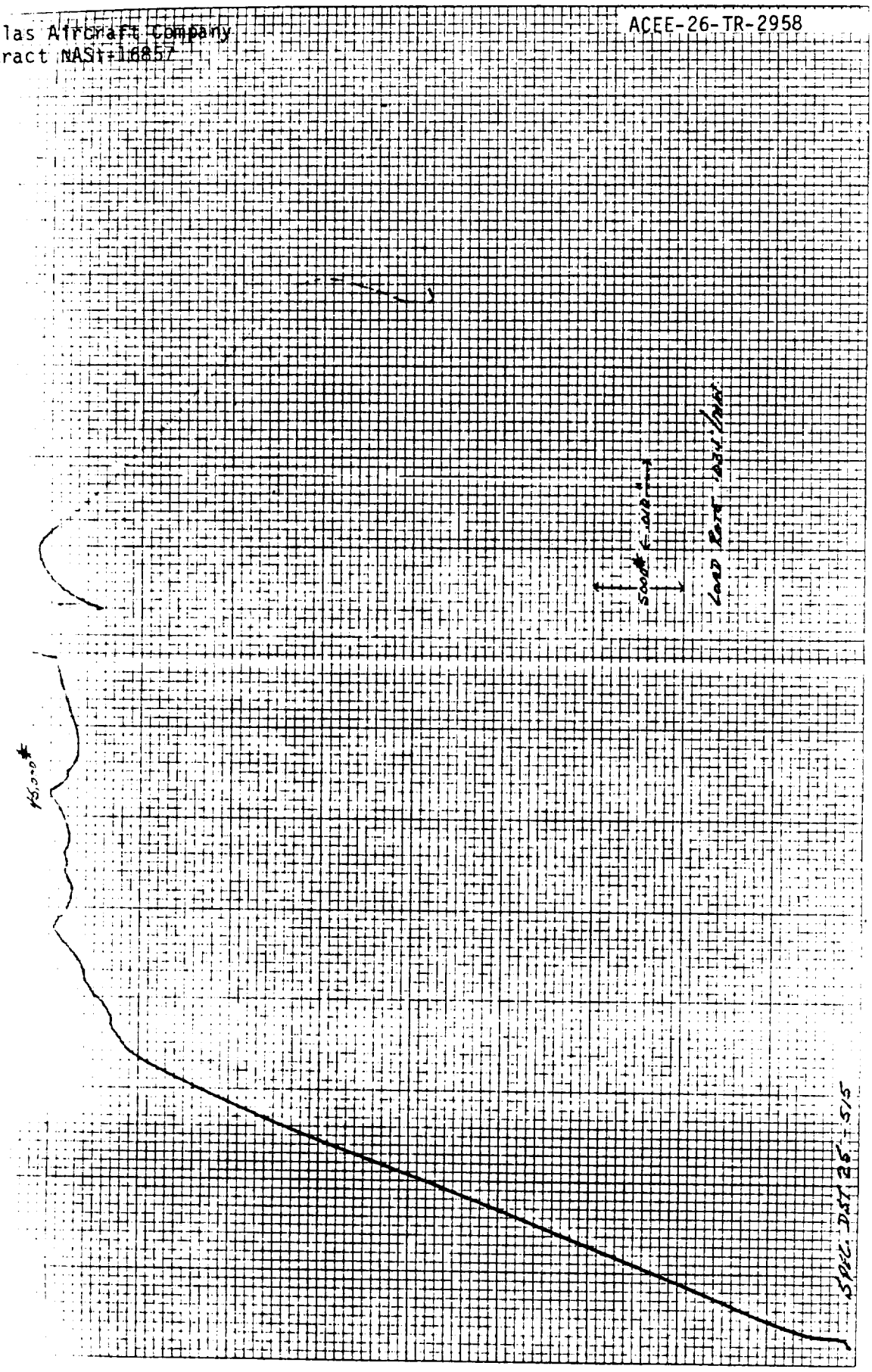
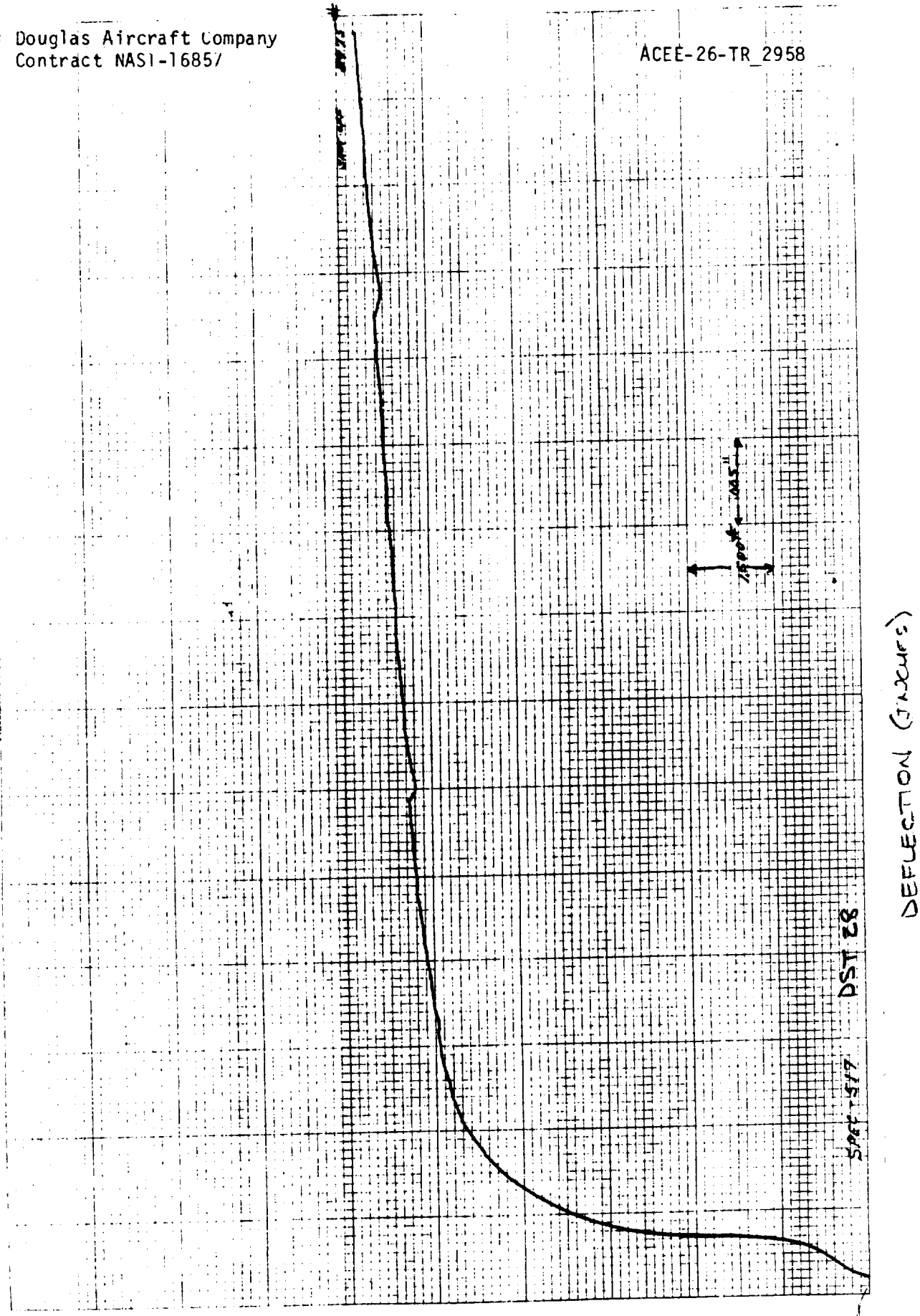
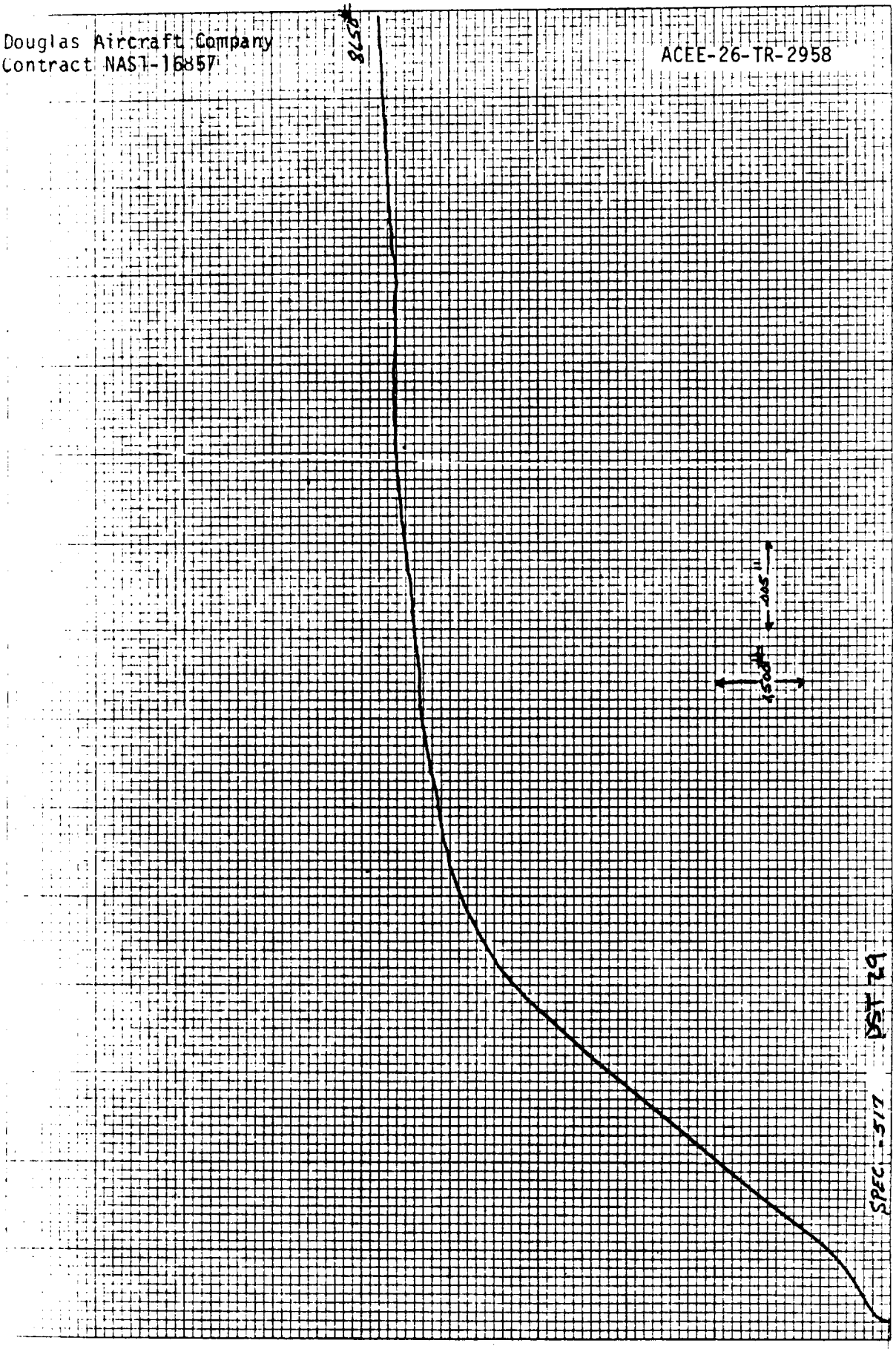
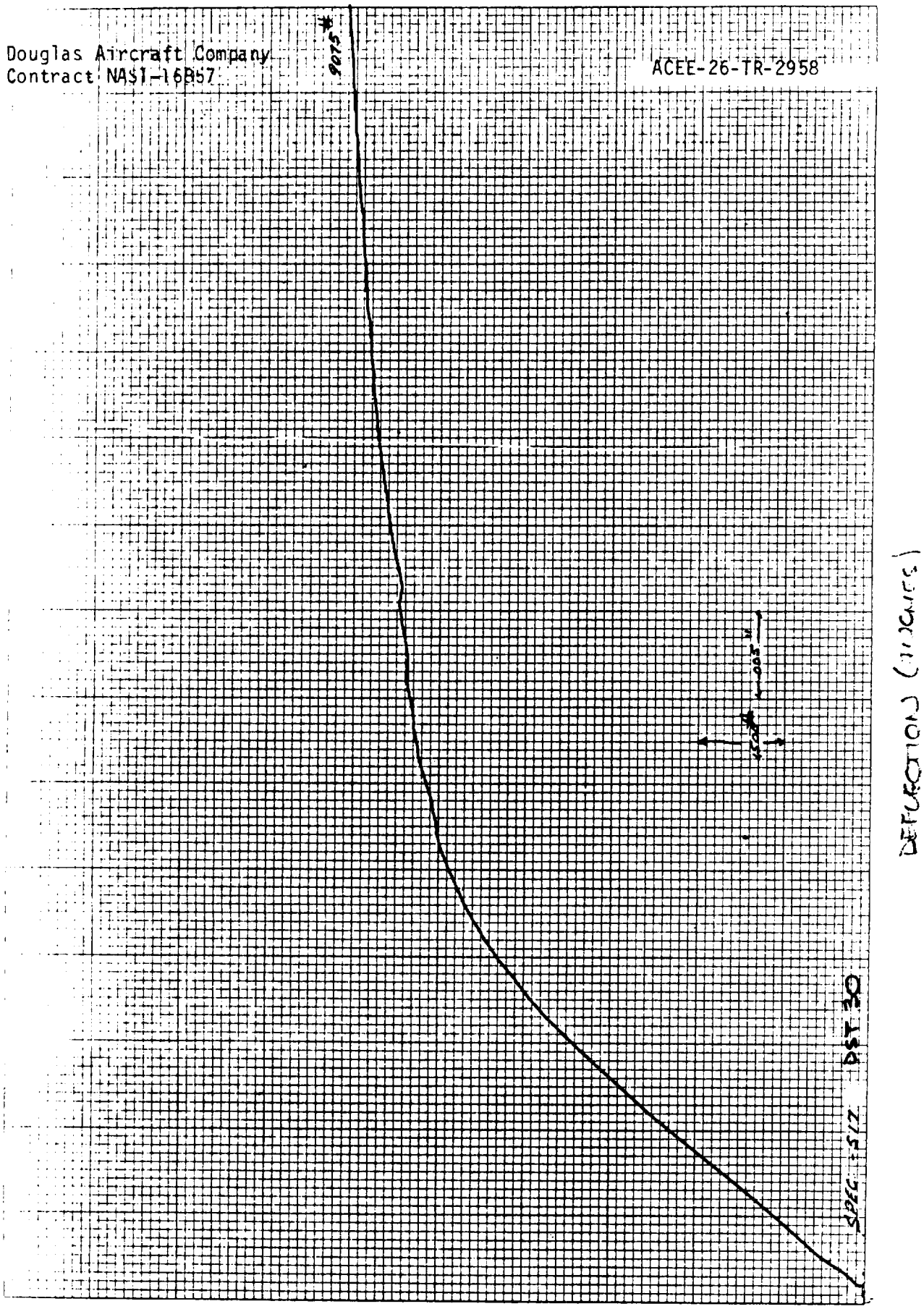
LOAD (LBS)


24,850#
DEFLECTION (INCHES)
LOAD (LBS)


500# ← 0.1 →
LOAD RATE .001/MIN
45,000#
SPEC. DIST 26 ± .5/.5
DEFLECTION (INCHES)
LOAD (LBS)


.005"
DEFLECTION (INCHES)
DST 28
SPEC-517
LOAD (LBS)


8578
.005"
.150"
SPEC. -517
DST 29
DEFLECTION (INCHES)



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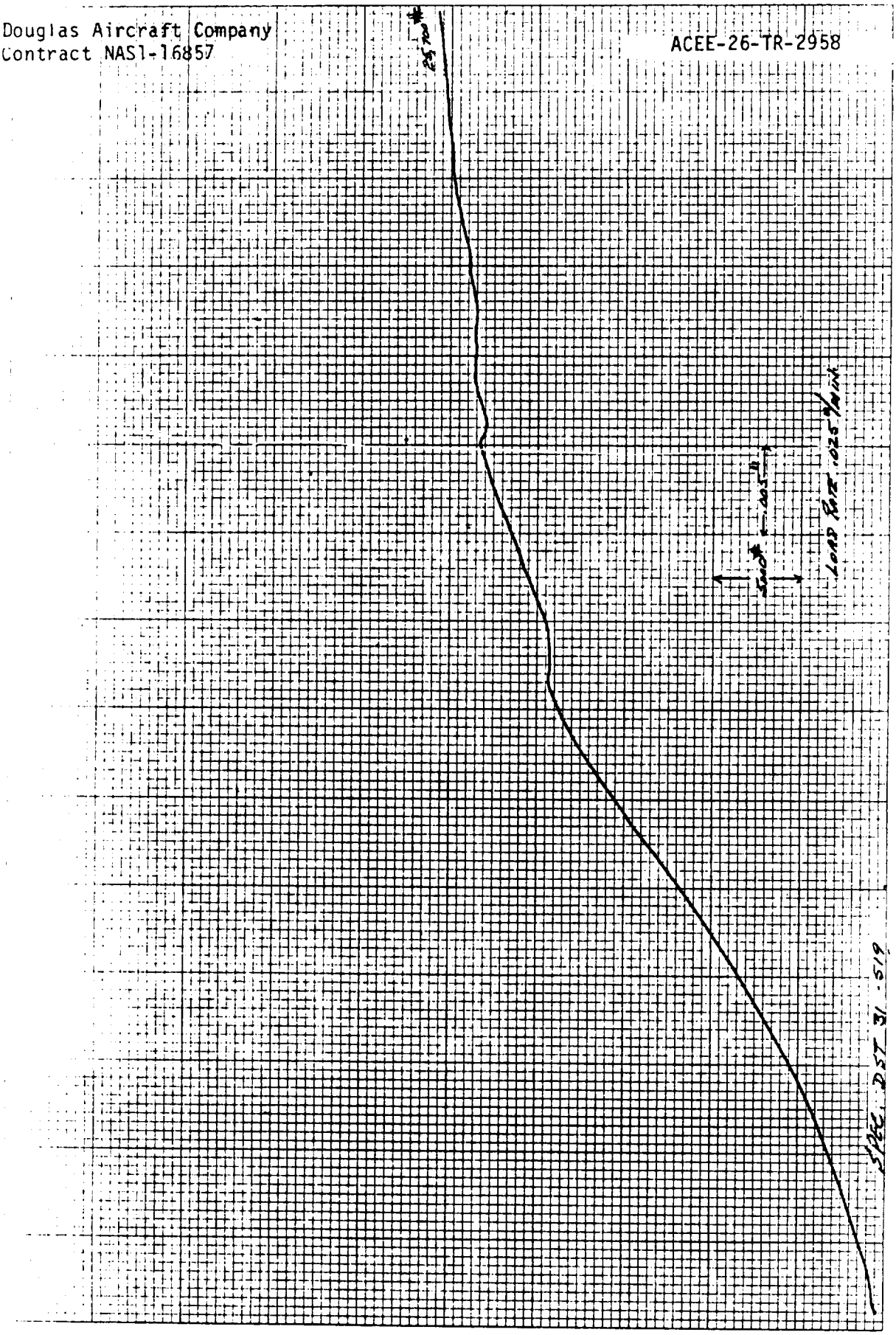
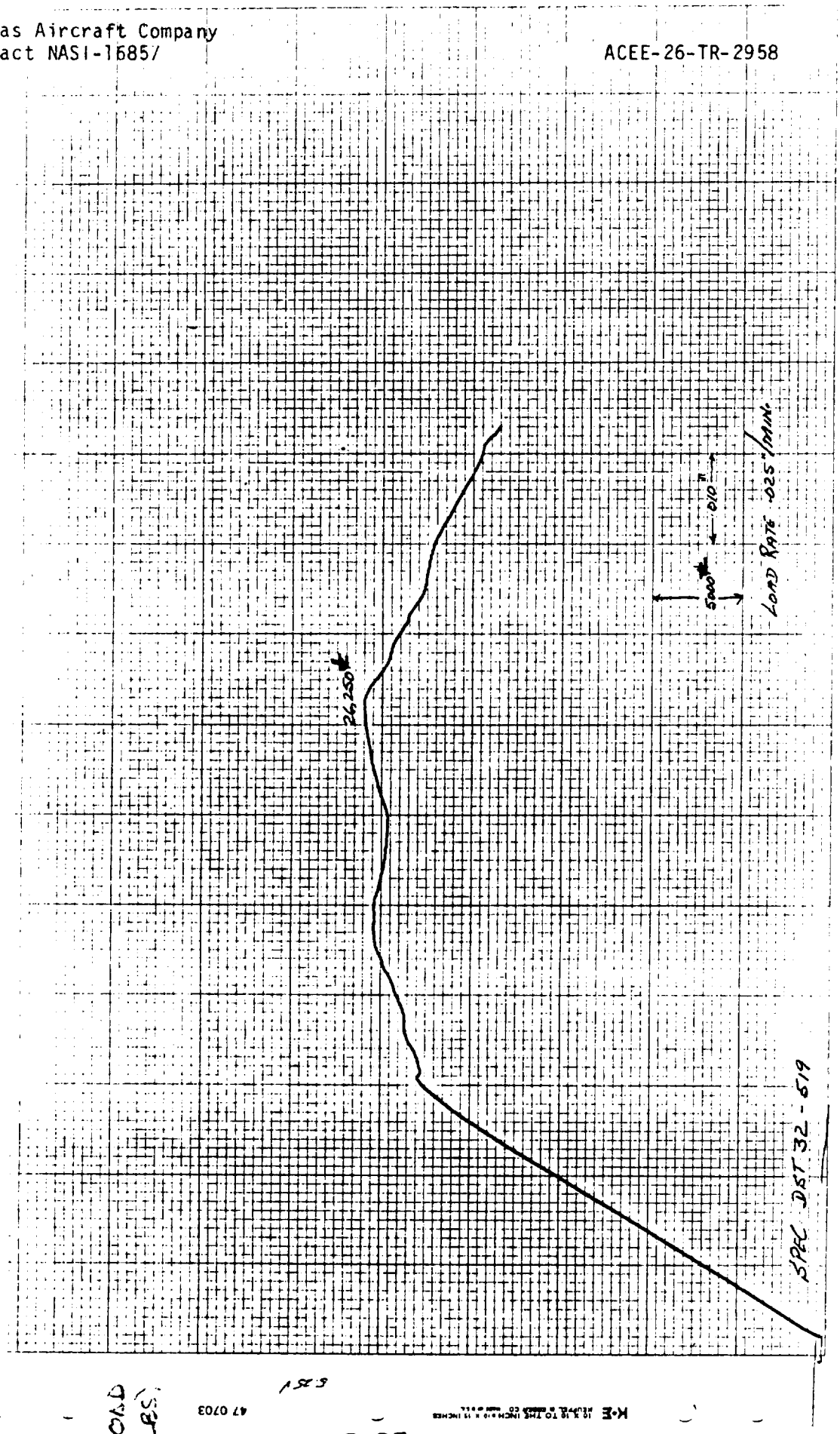
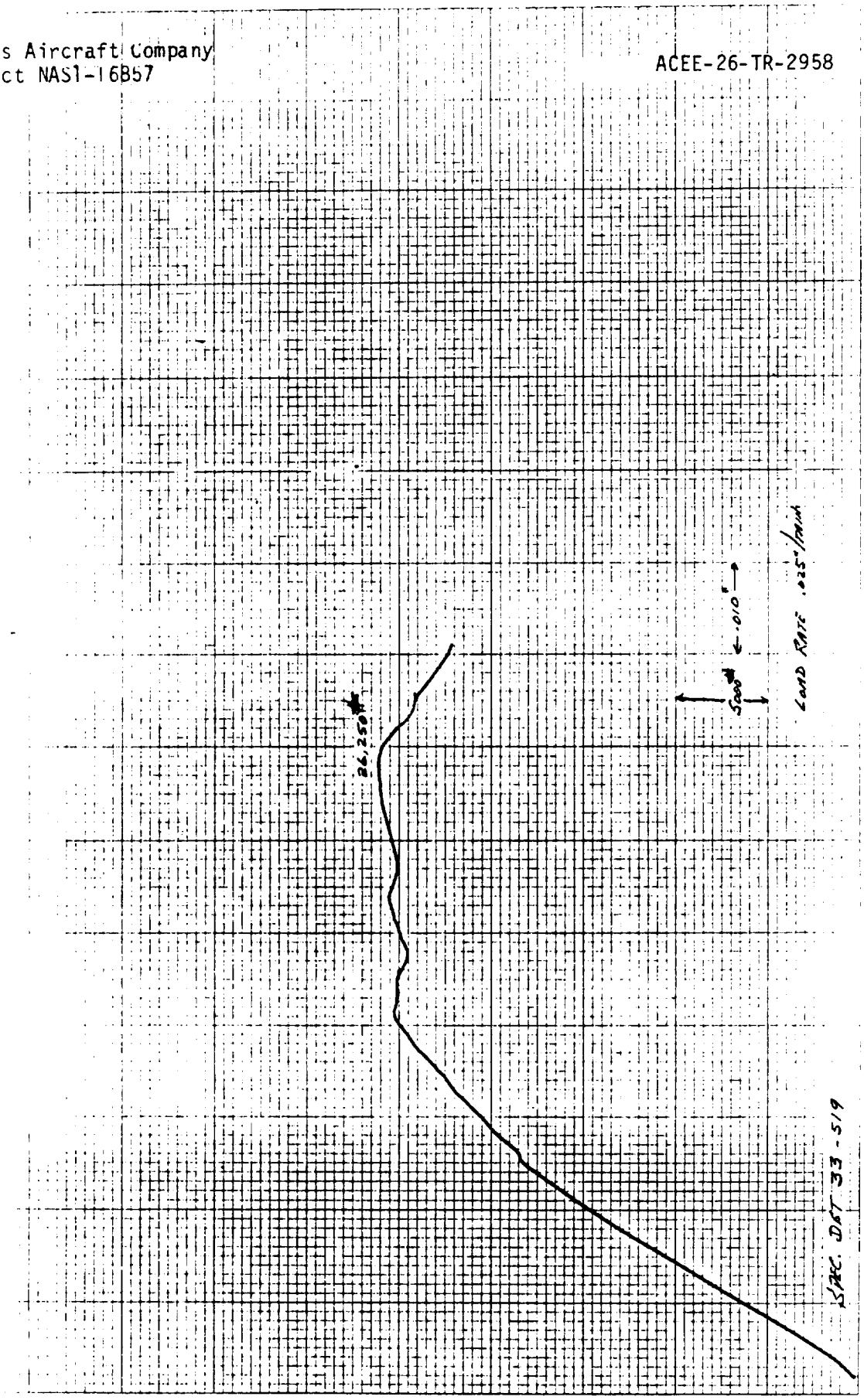
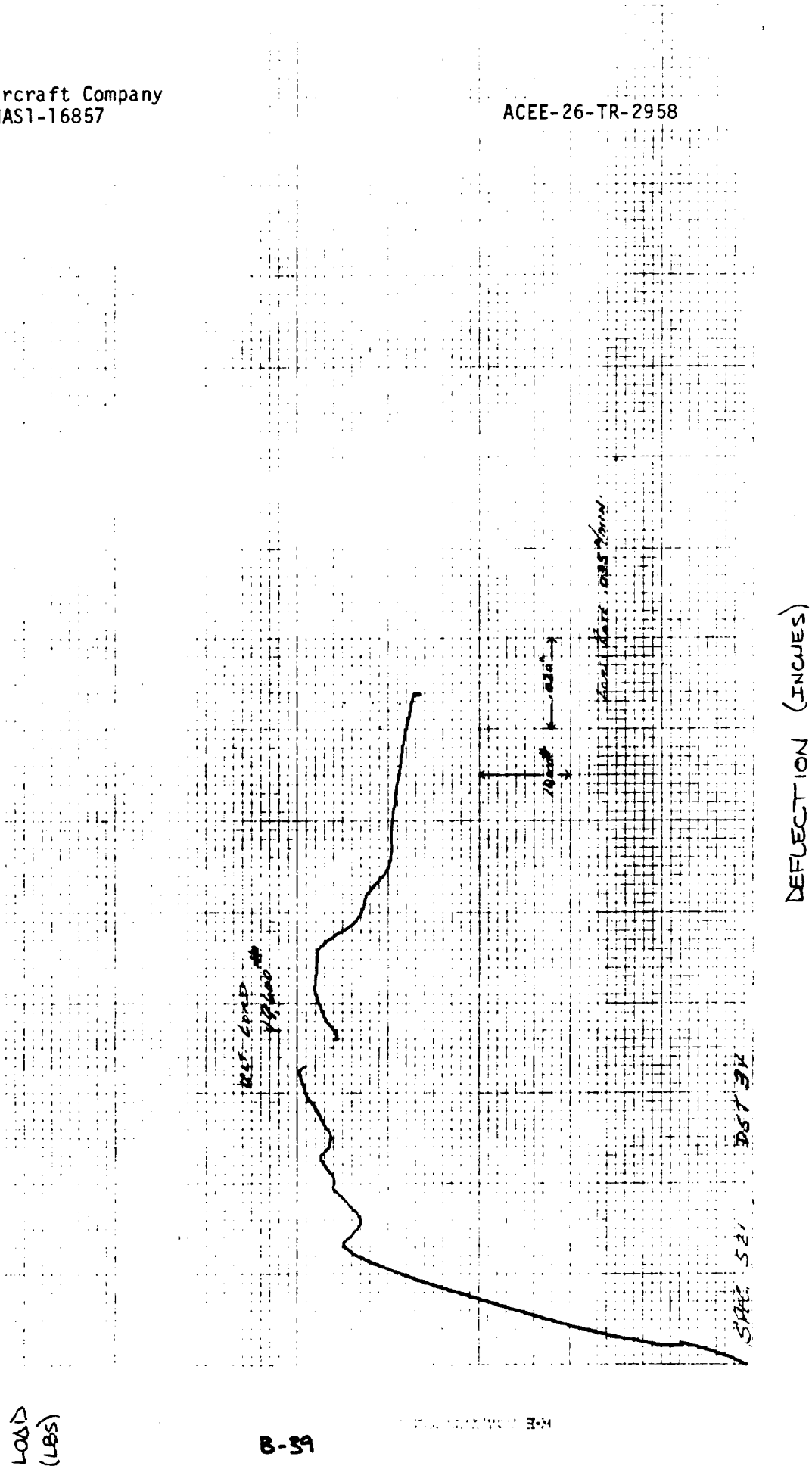
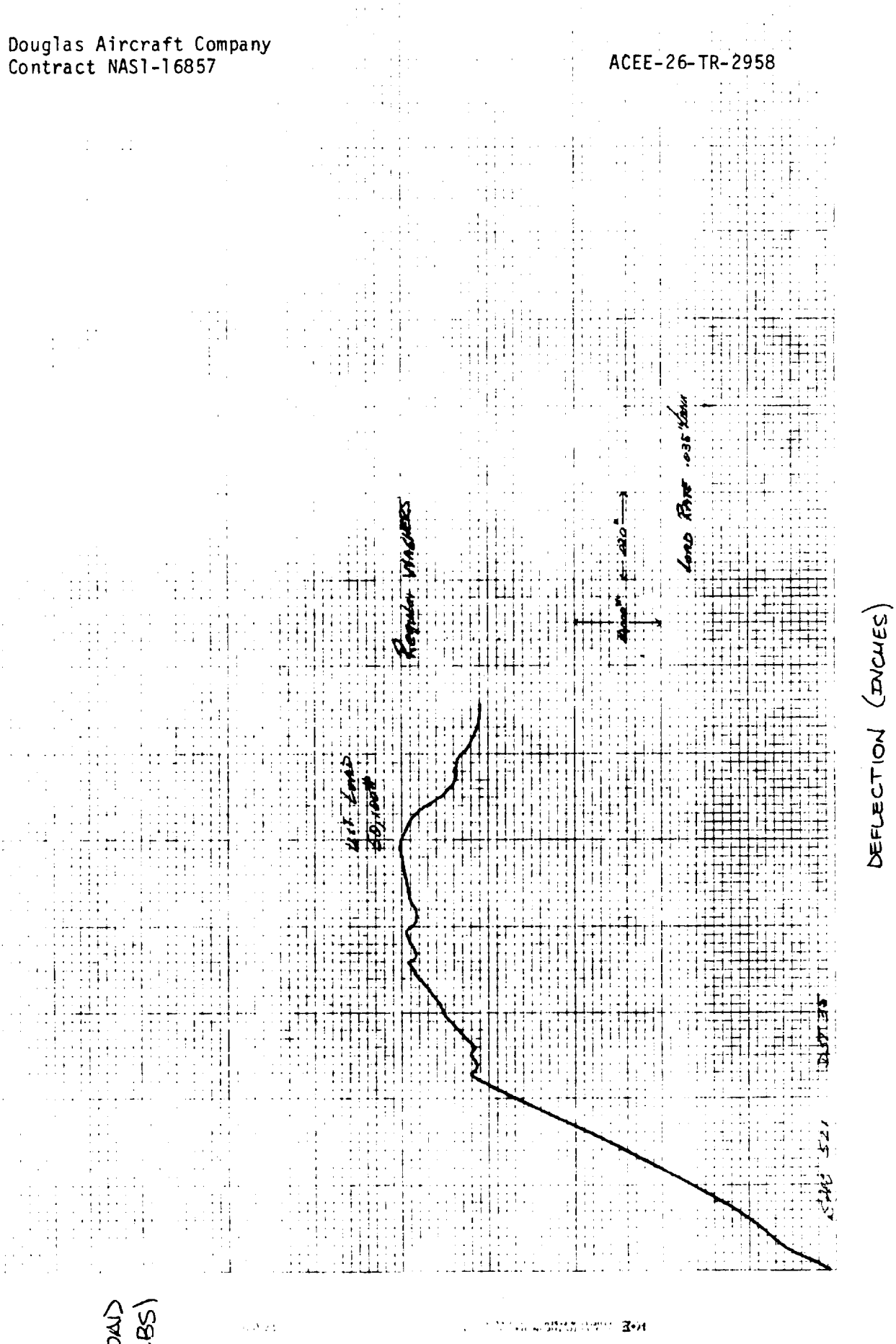
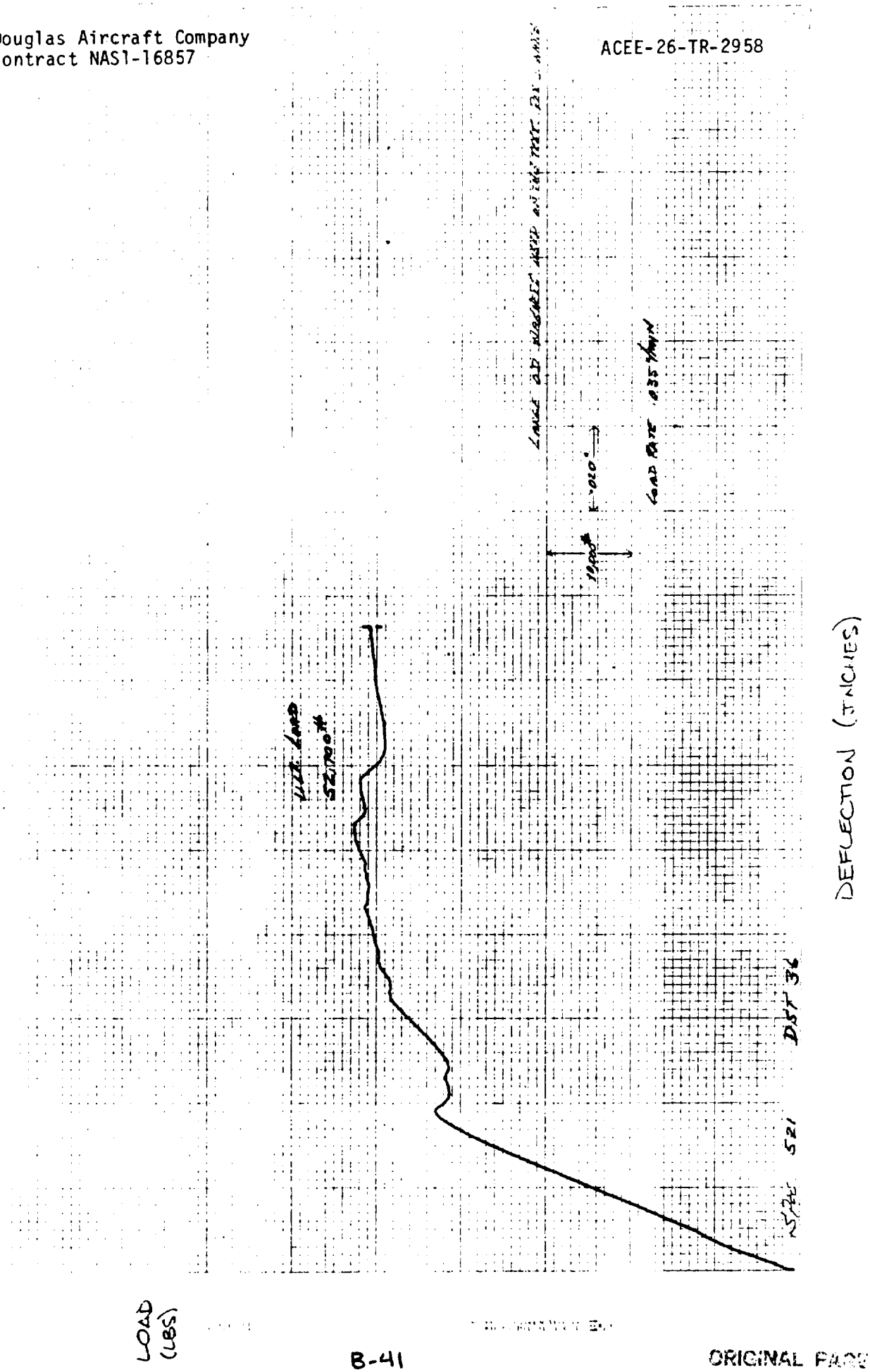

25 kip
SCALE .005"
LOAD RATE .025 #/min
SPEC. DST 31-519
LOAD (LBS)
DEFLECTION (INCHES)


26,250
5000
.010"
LOAD RATE .025"/MIN.
SPEC DST 32-519
DEFLECTION (INCHES)
LOAD (LBS)
1585
47 0703
K+E 10 X 10 TO THE INCH 10 X 15 INCHES
KEUFFEL & ESSER CO. MADE IN U.S.A.


26,250#
500#
.010"
LOAD RATE .025"/min
SPEC. DAT 33-519
DEFLECTION (INCHES)
LOAD (LBS)
625V


DEFLECTION (INCHES)
LOAD (LBS)


Regular Washers
Load Point .035" down
DEFLECTION (INCHES)
LOAD (LBS)



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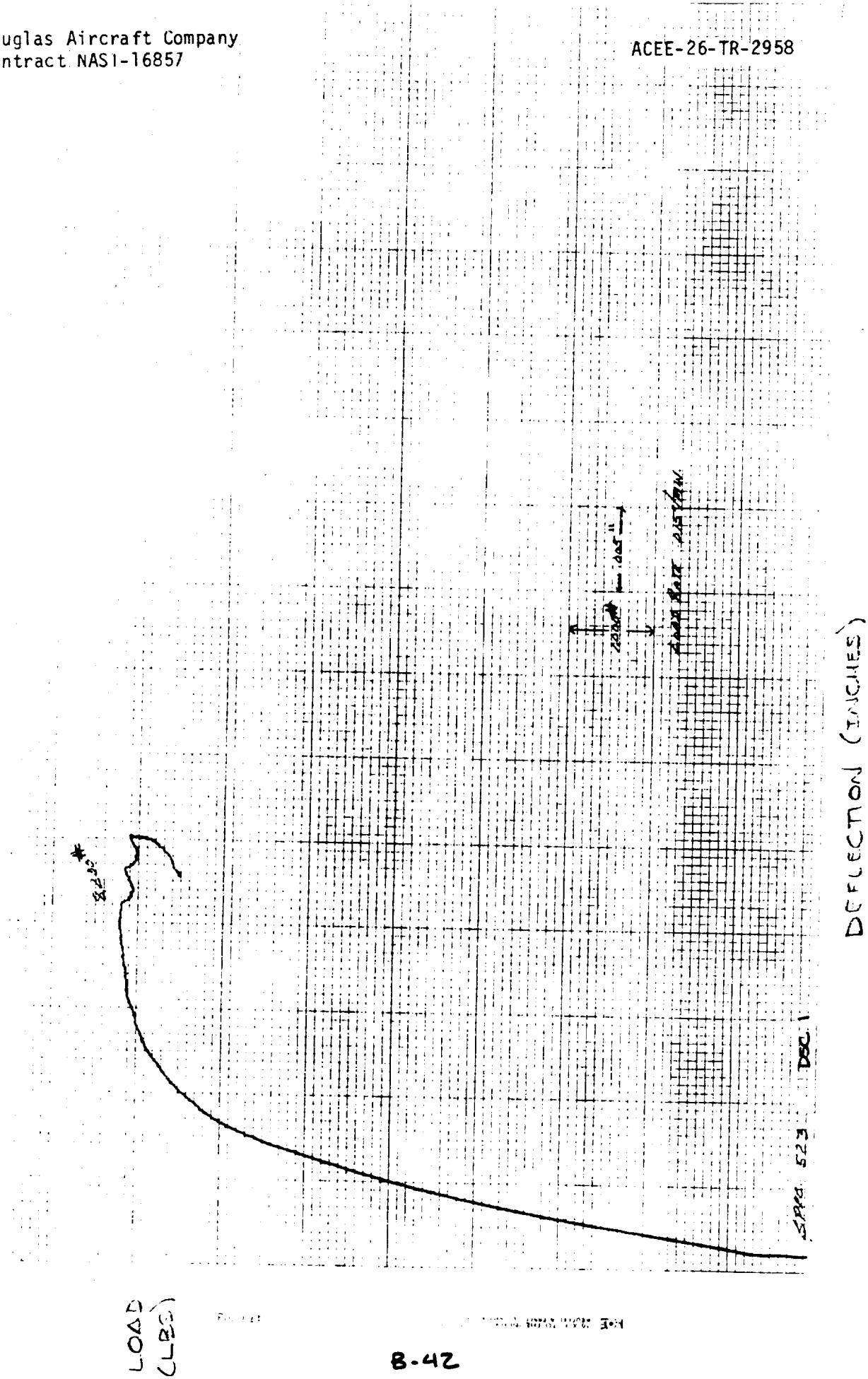
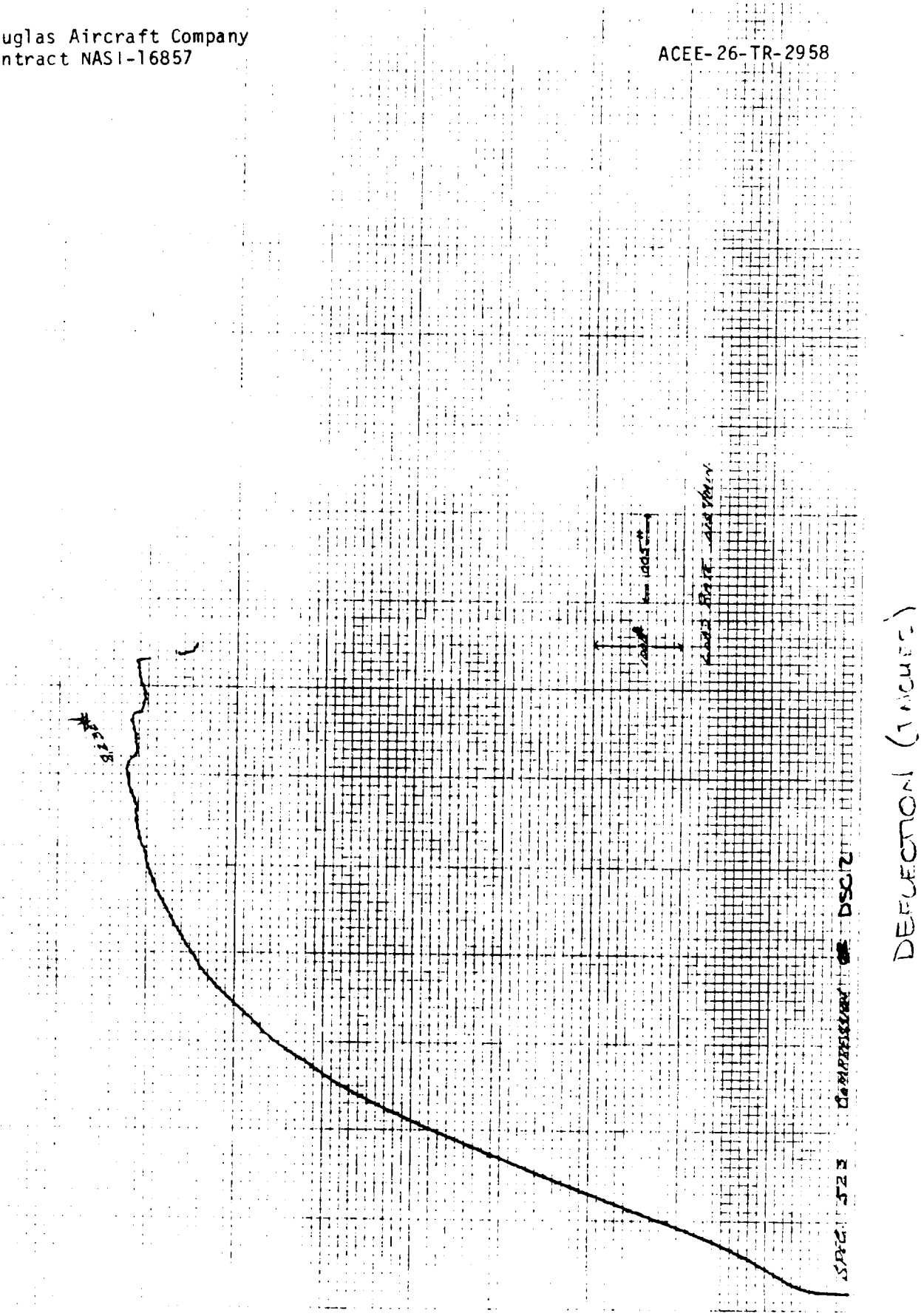

LOAD (LBS)
DEFLECTION (INCHES)
SPEC 523
DSC 1



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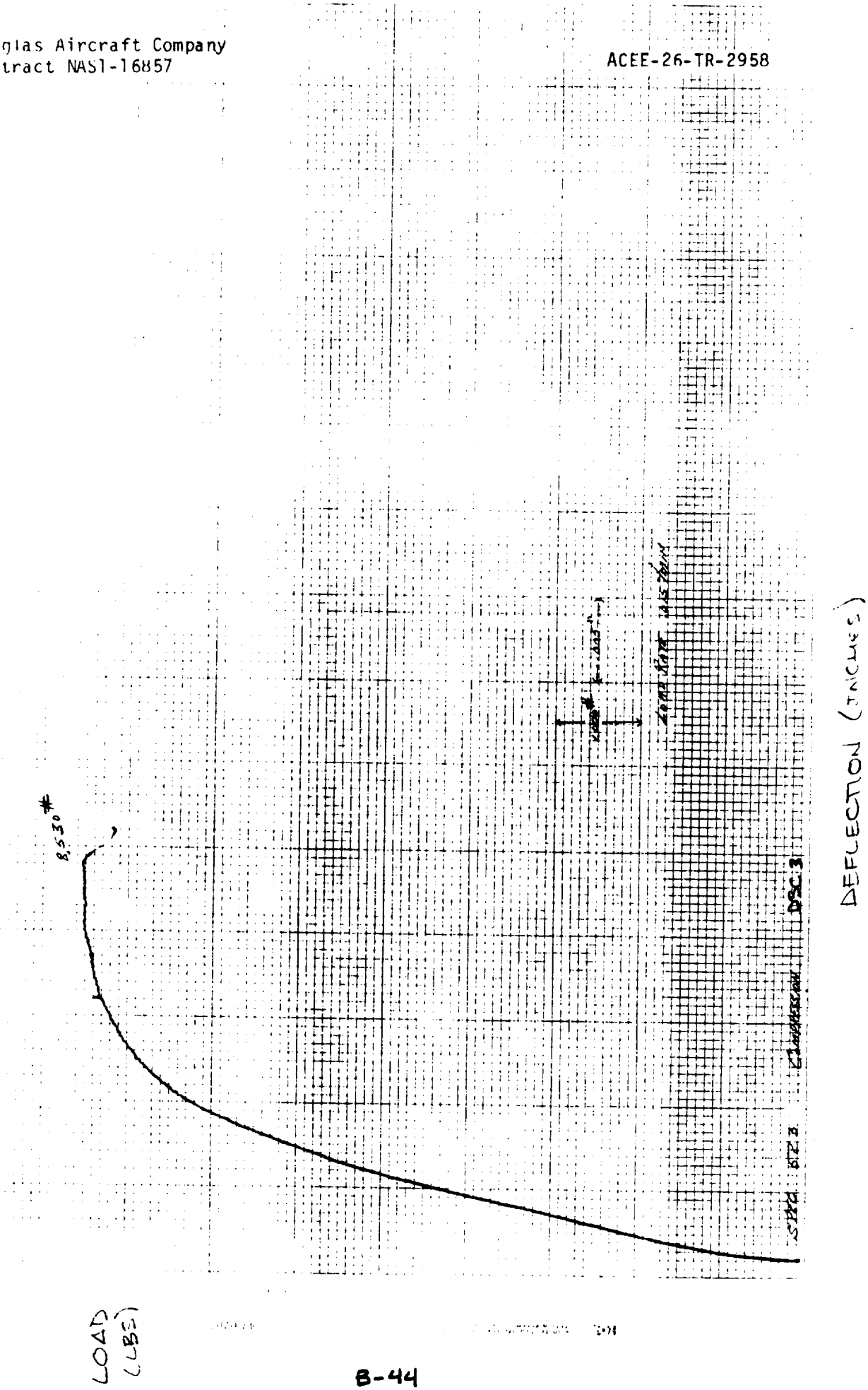
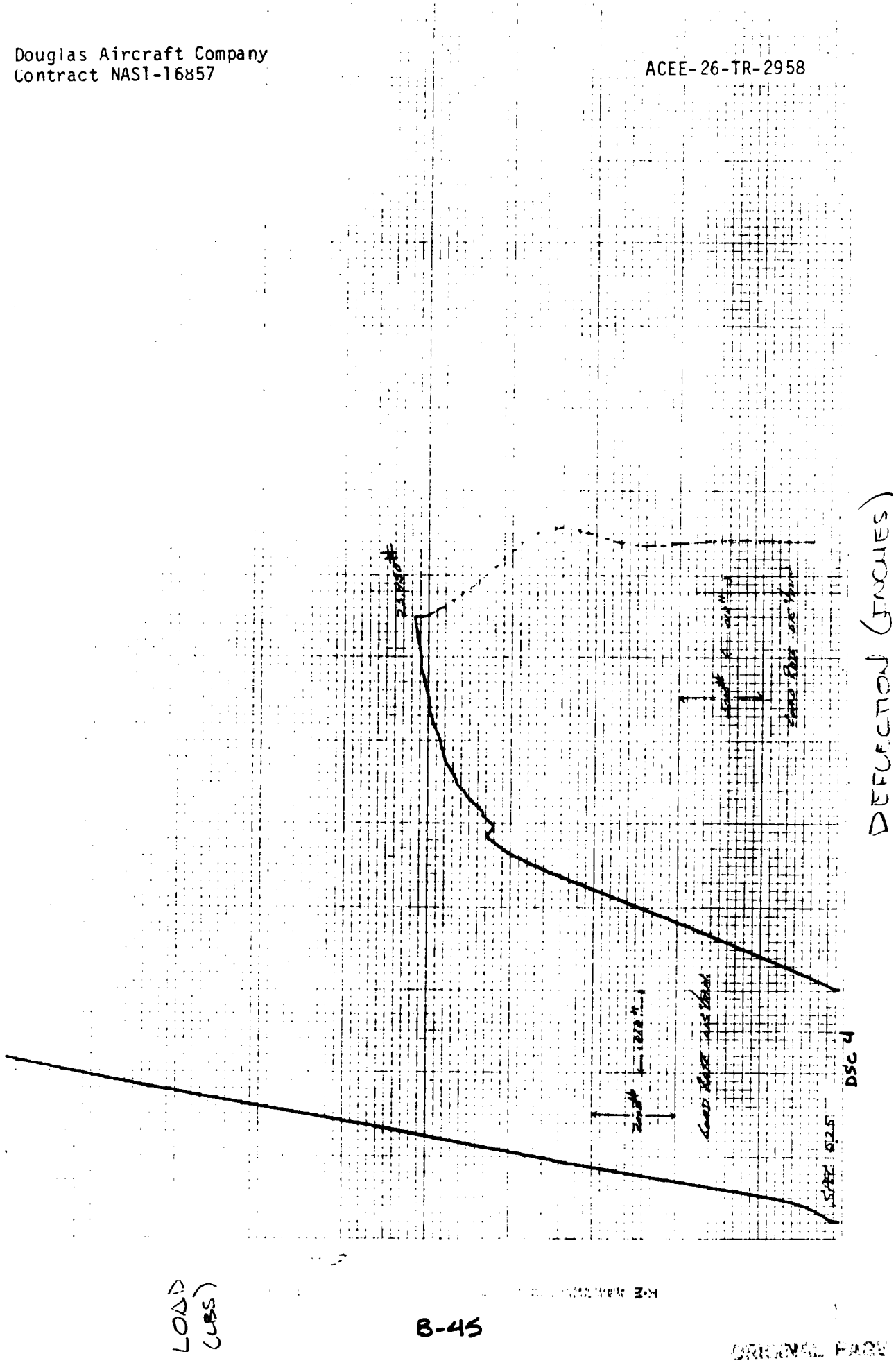

8,530#
DEFLECTION (INCHES)
LOAD (LBS)



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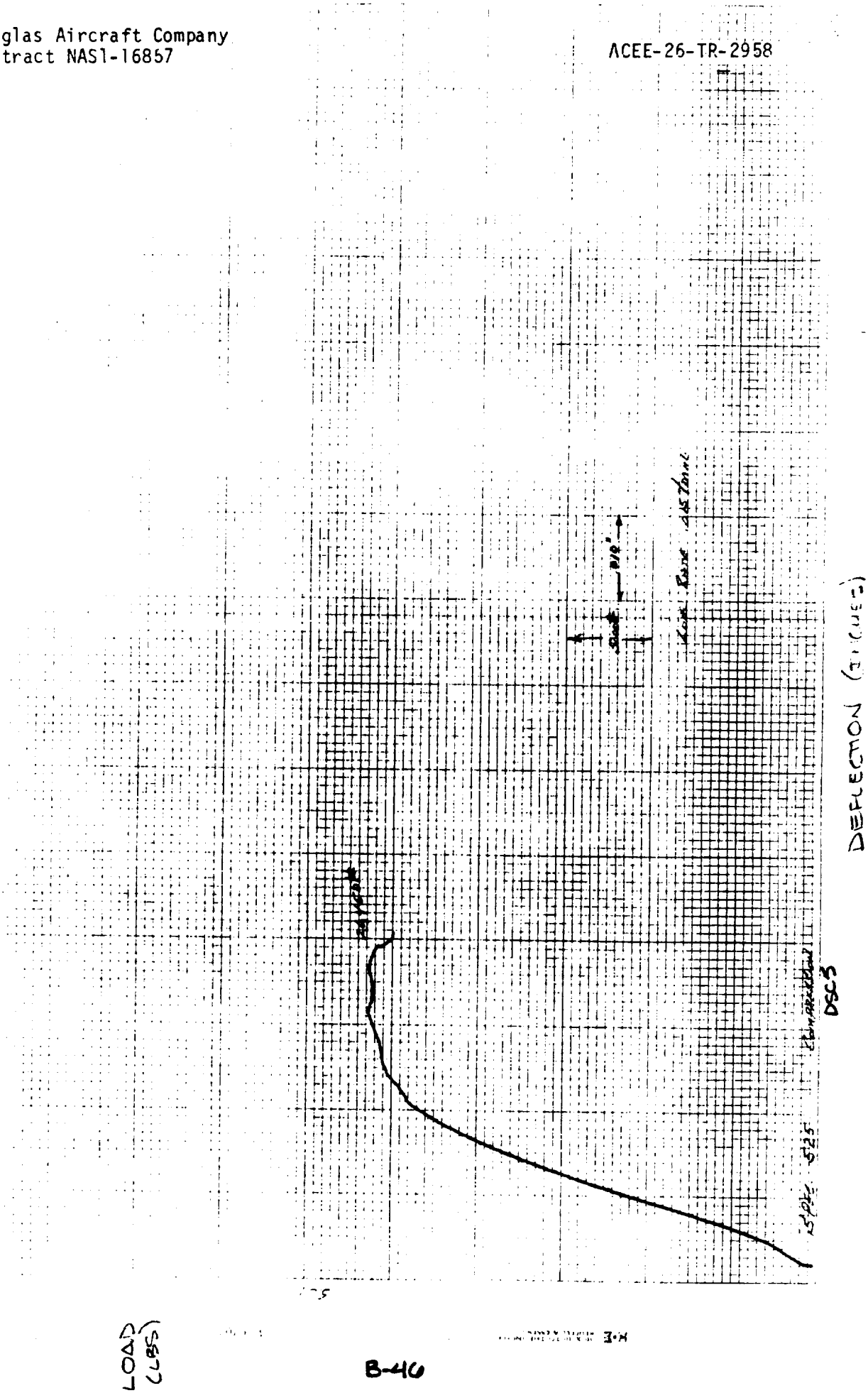
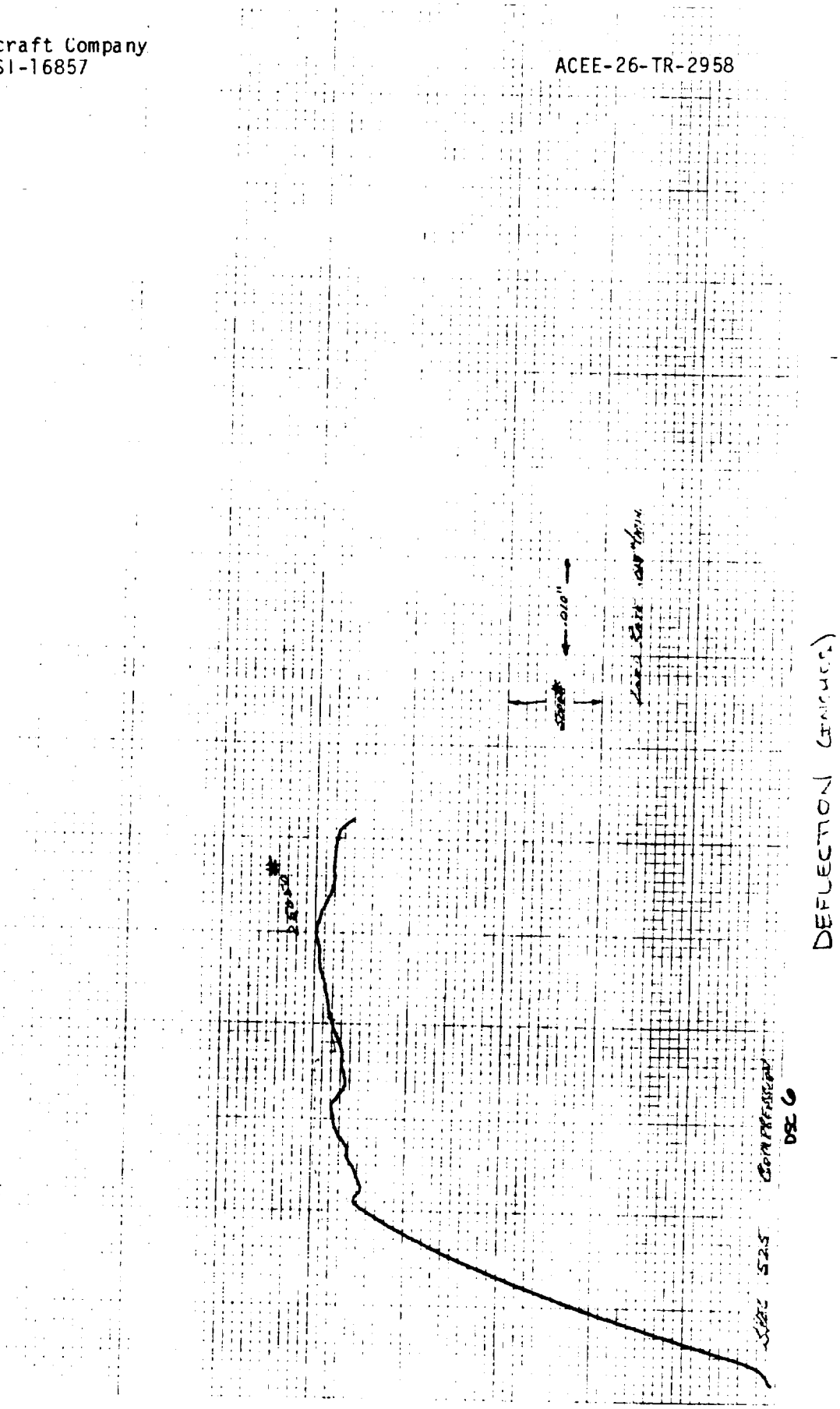

DEFLECTION (INCHES)
LOAD (LBS)
DSC3



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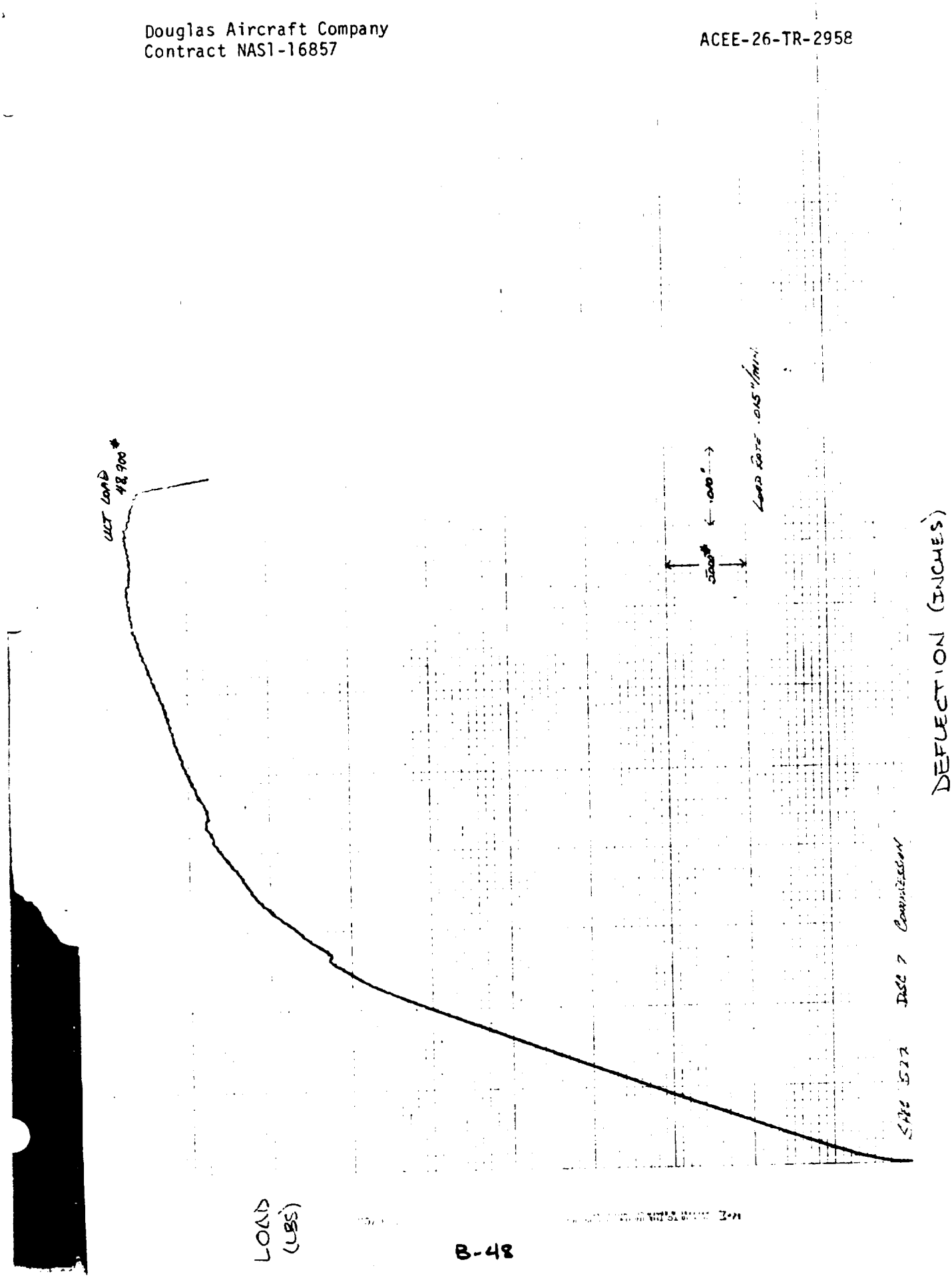
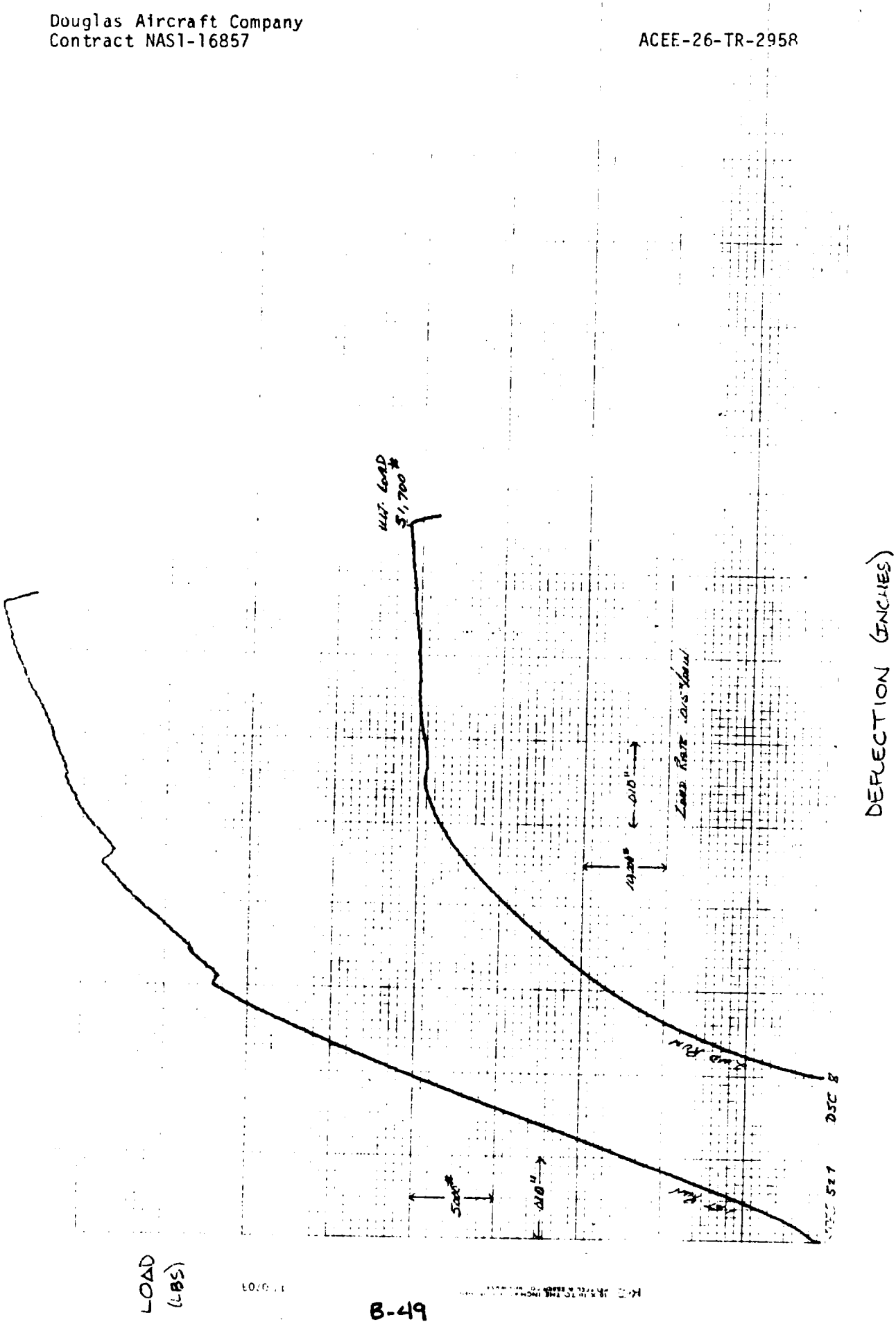
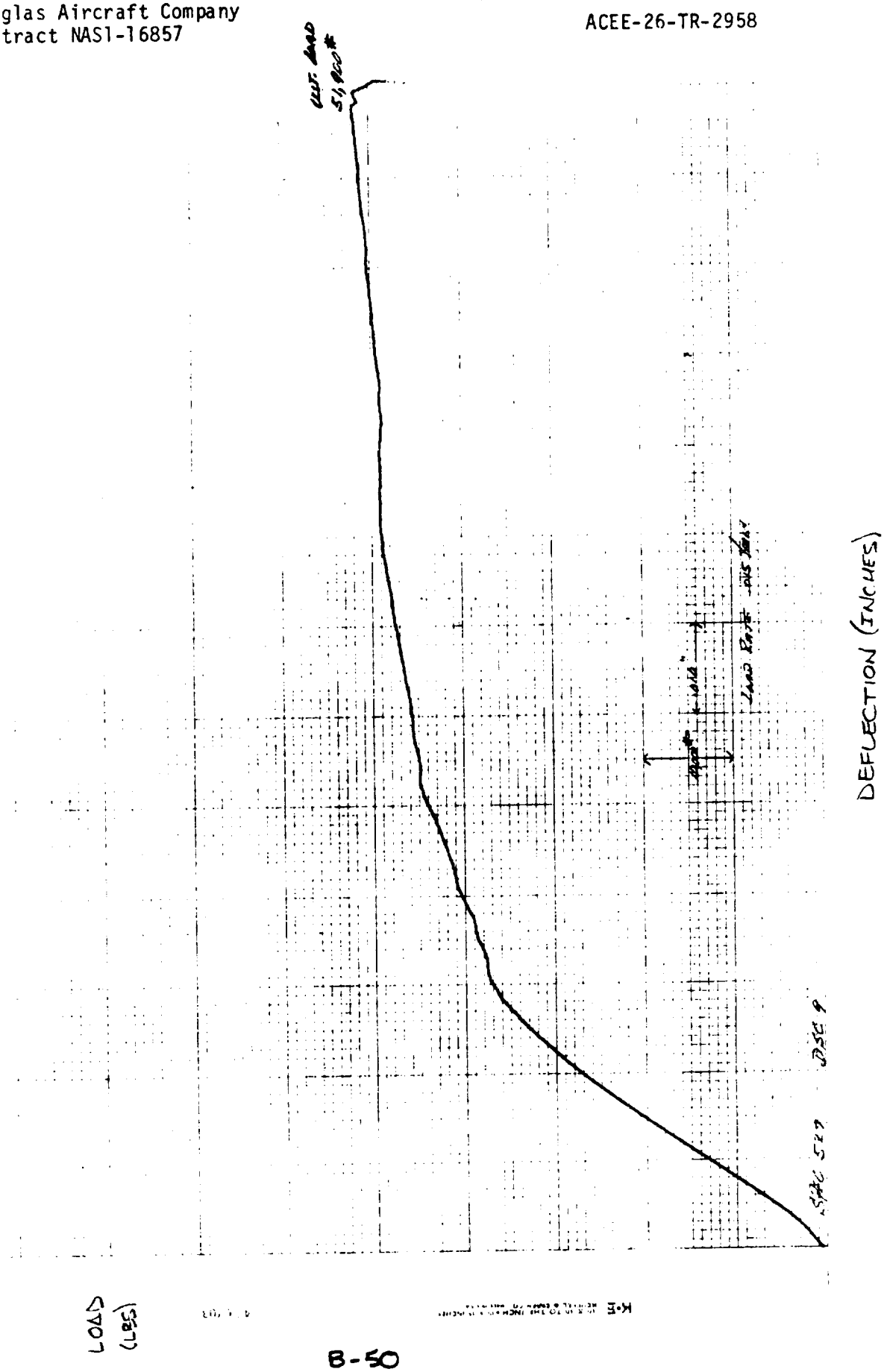
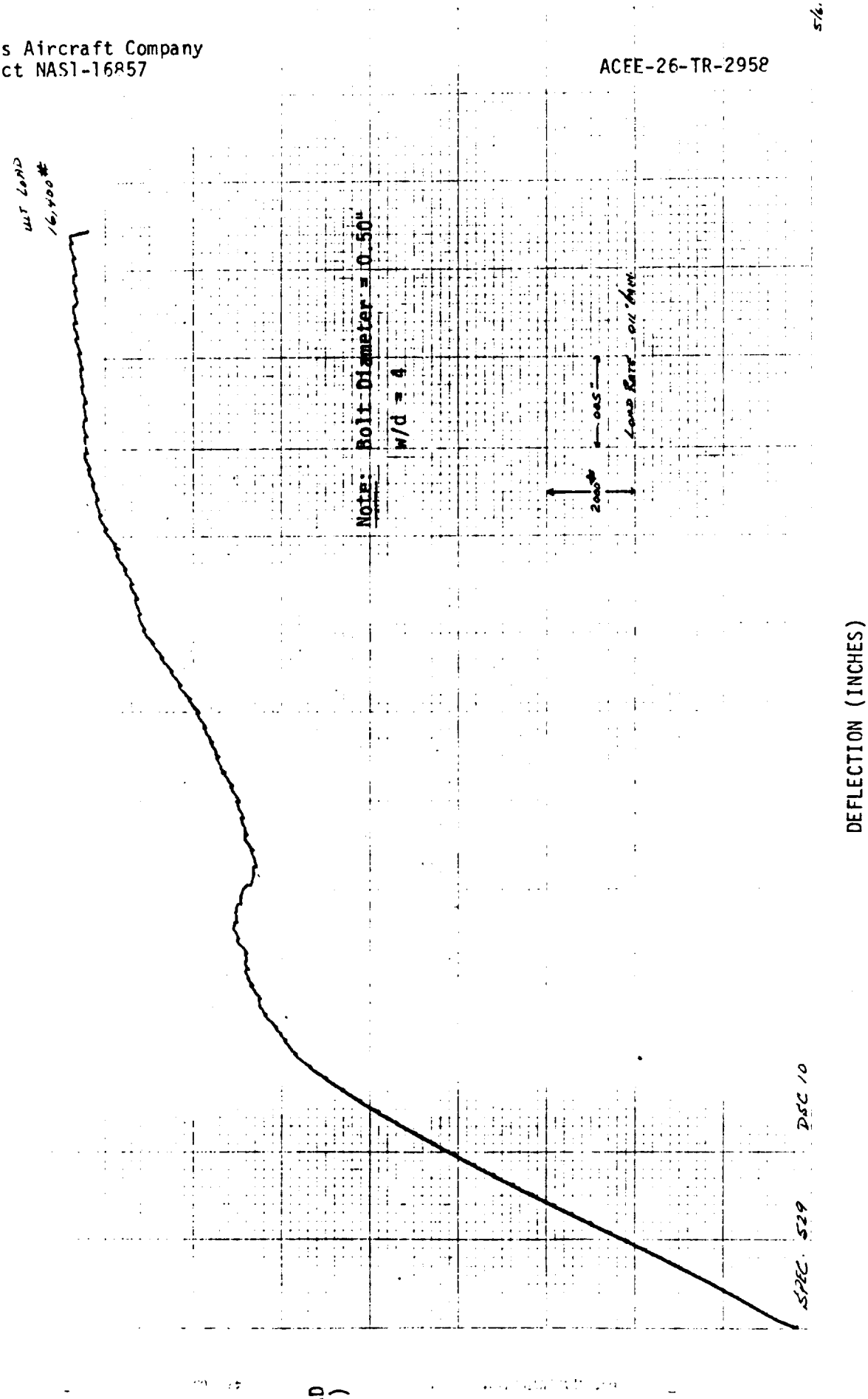

ULT LOAD
48,900#
.100"
LOAD RATE .015"/MIN
DEFLECTION (INCHES)
LOAD
(LBS)


LOAD
(LBS)
DEFLECTION (INCHES)
ULT. LOAD
51,700#
LOAD RATE 2000#/MIN
14,200#
0.10"
5200#
0.10"
DSC 8
DSC 5 & 7


DEFLECTION (INCHES)
LOAD (LBS)



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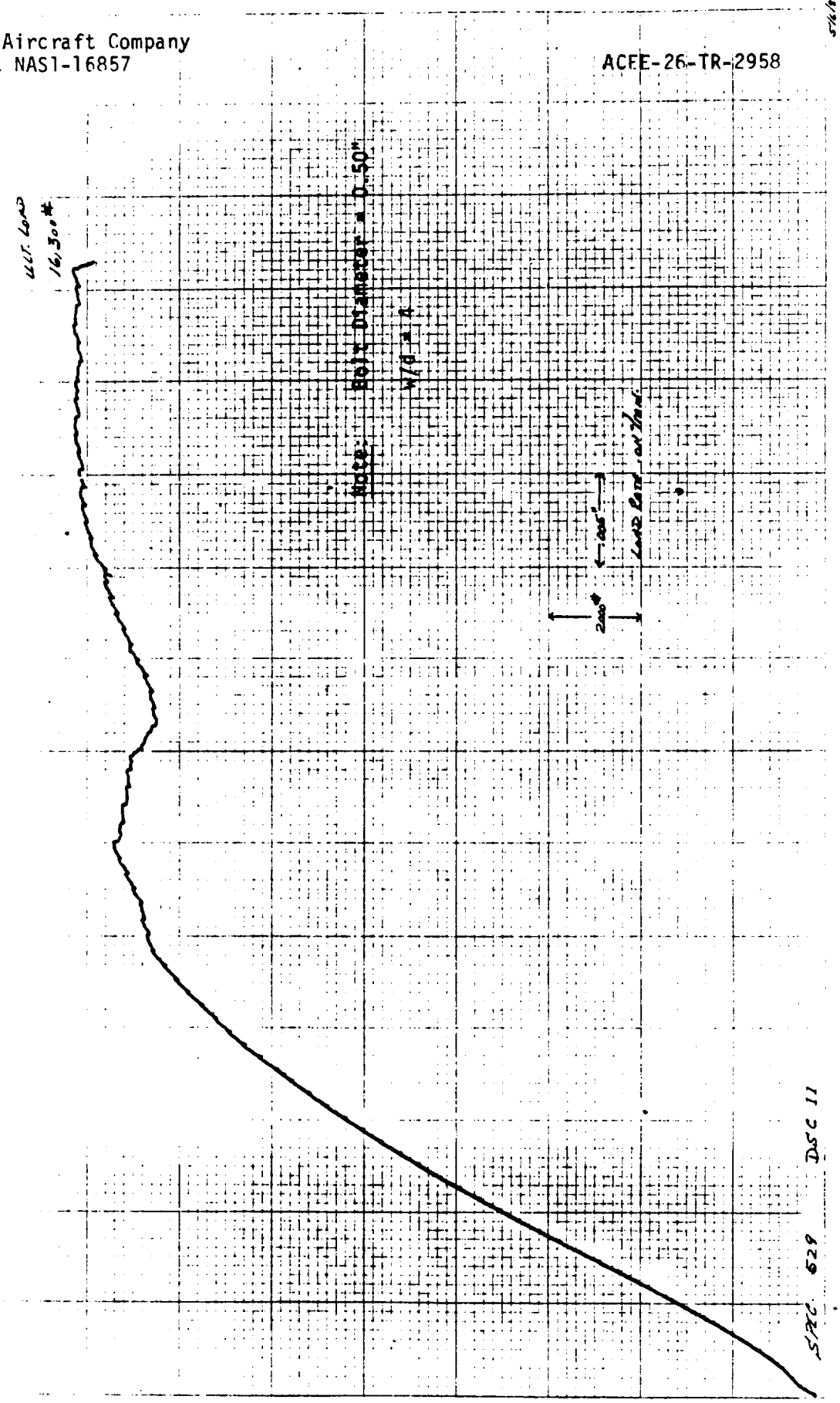
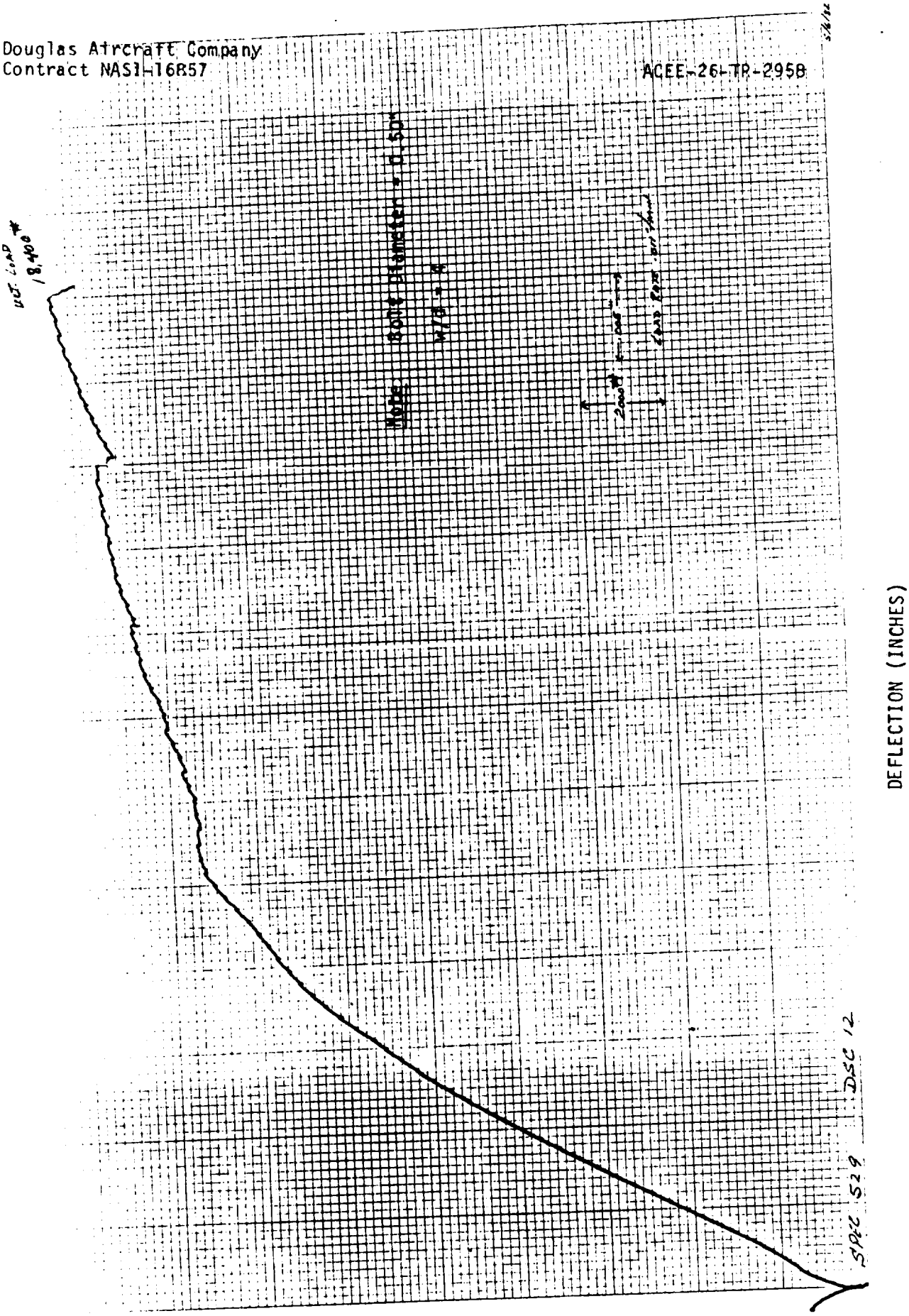

Ult. Load
16,300#
Note: Bolt Diameter = 0.50"
w/d = 4
200#
.005"
Load Band on Hand.
SPEC. 629 DSC 11
LOAD
(LB)
DEFLECTION (INCHES)



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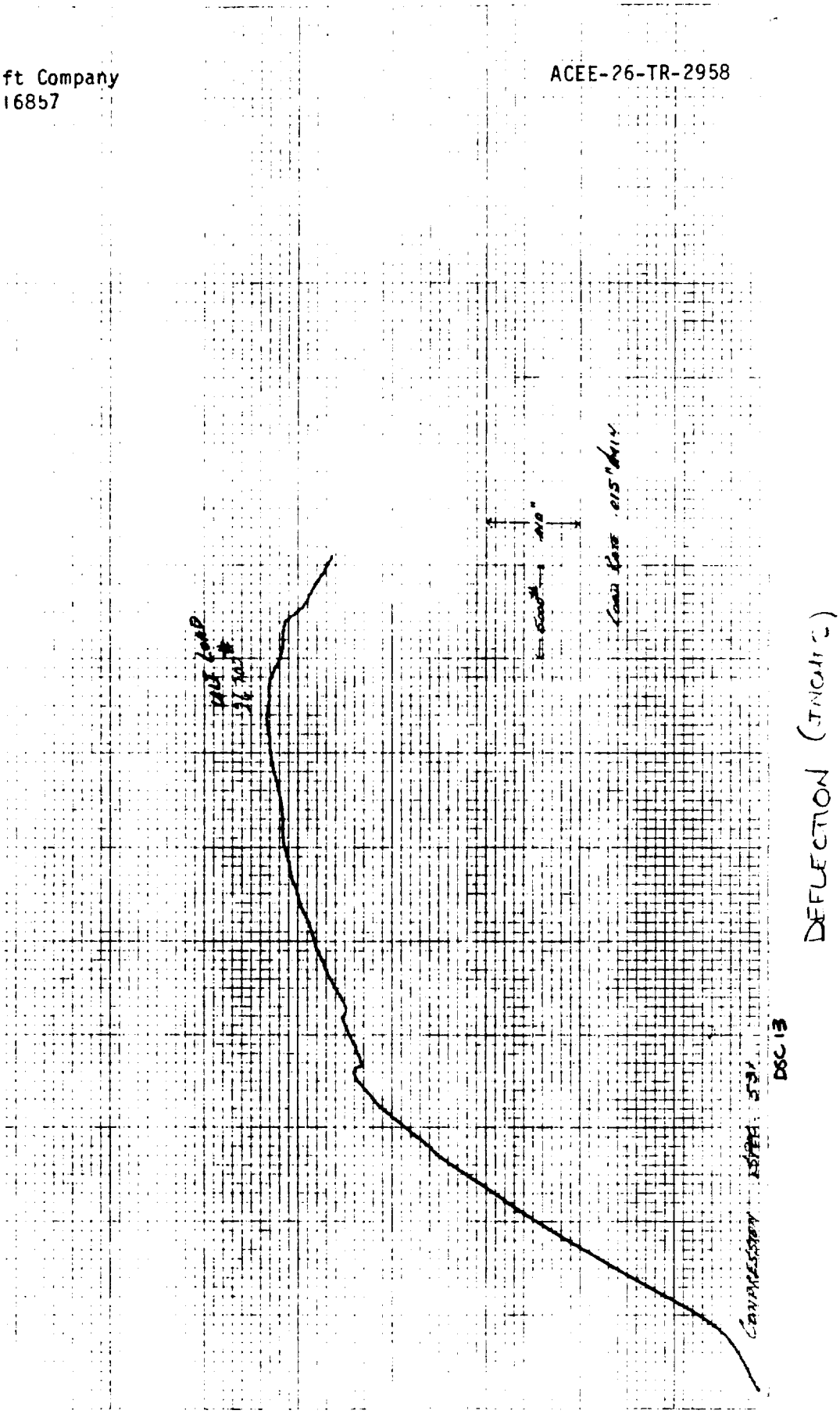
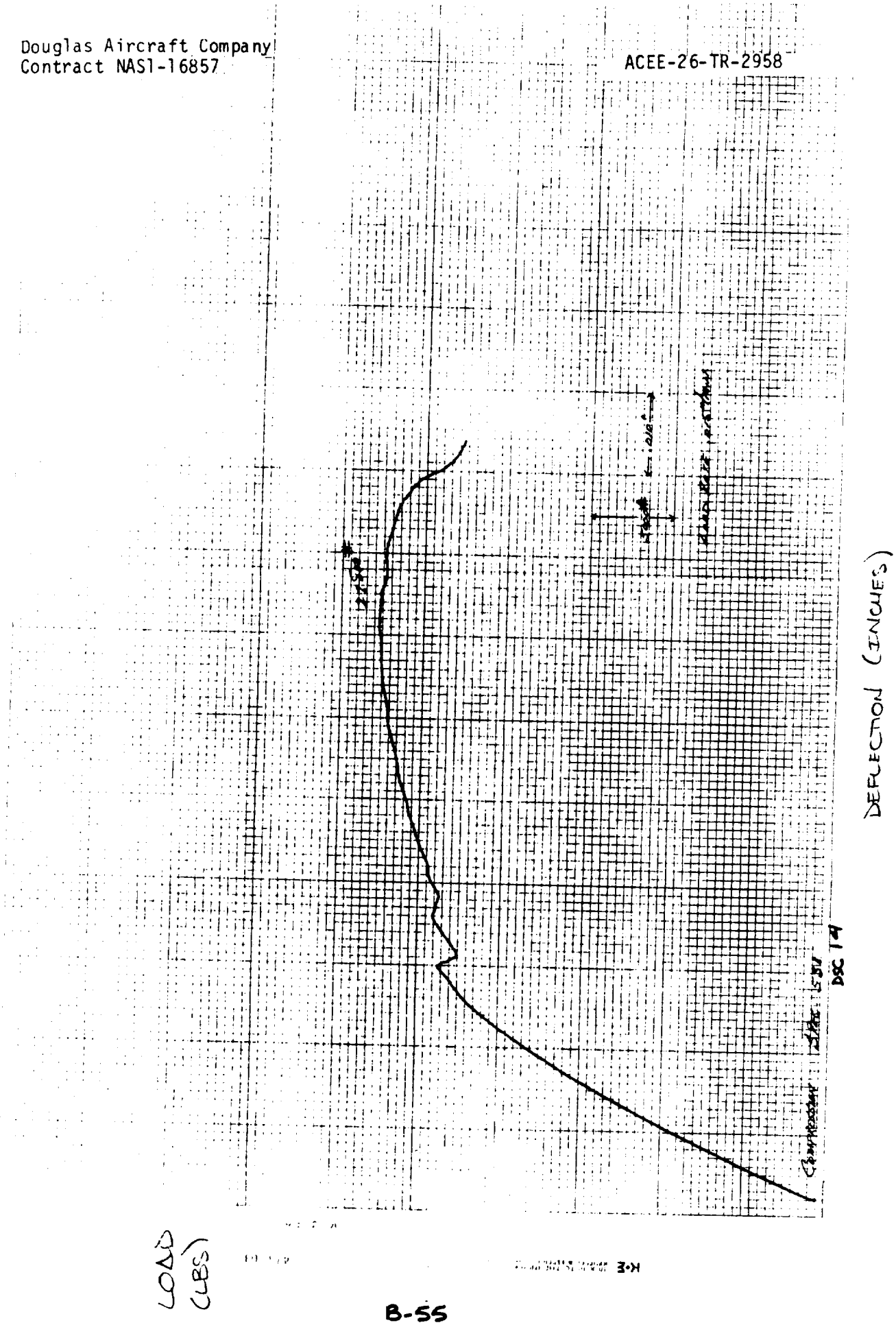
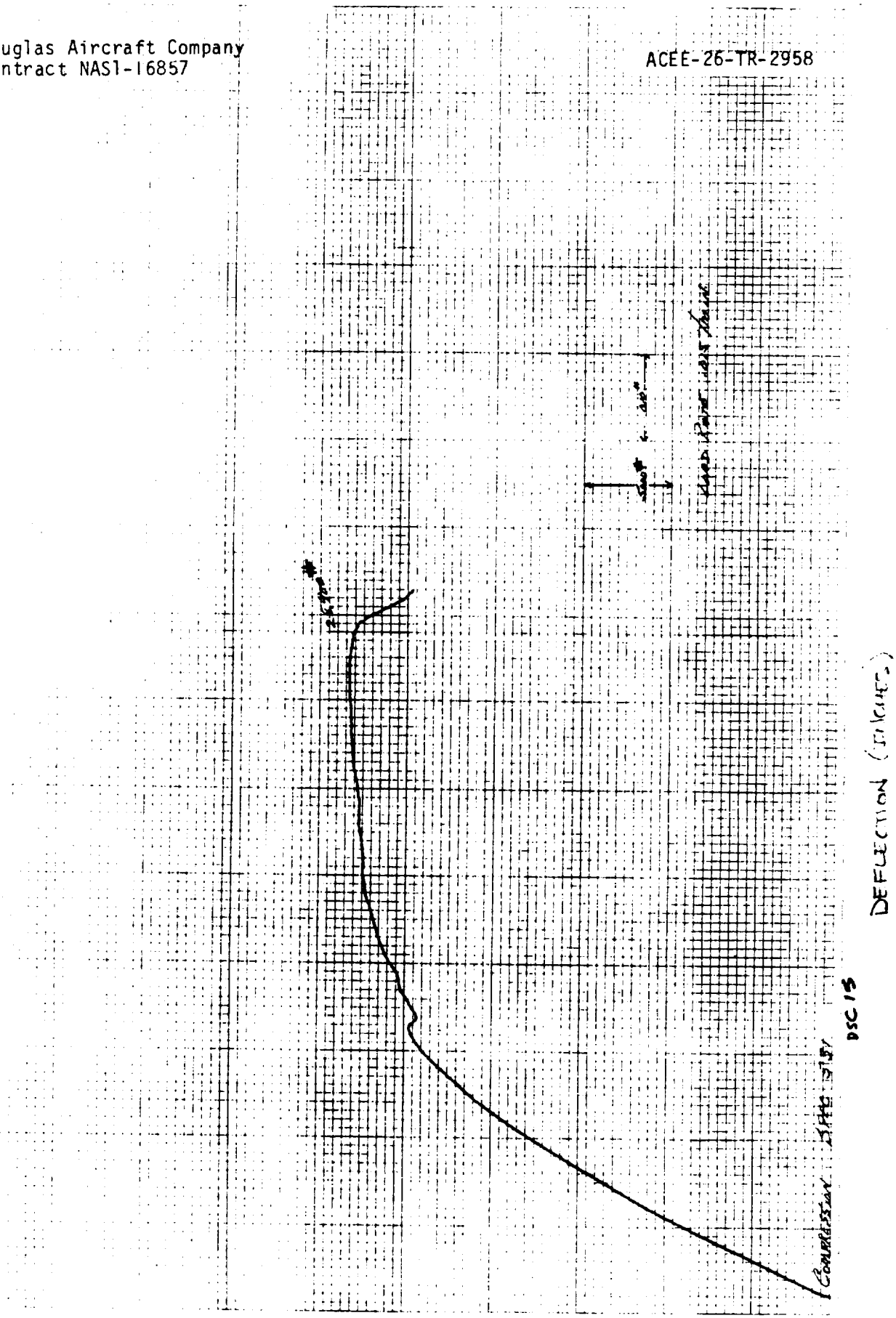
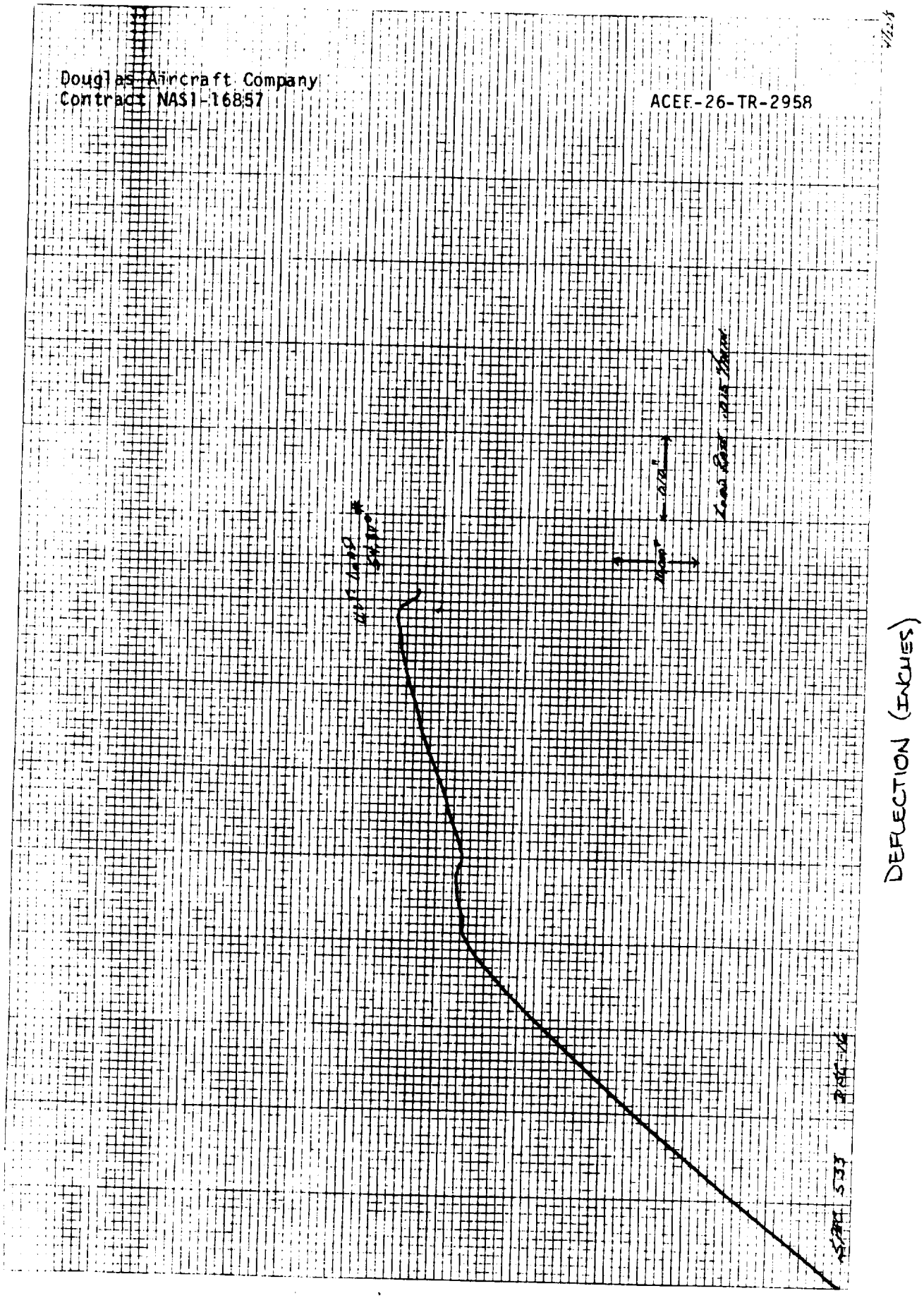

DEFLECTION (INCHES)
LOAD (LBS)
DOC 13


DEFLECTION (INCHES)
LOAD (LBS)


DEFLECTION (INCHES)
DSC 15



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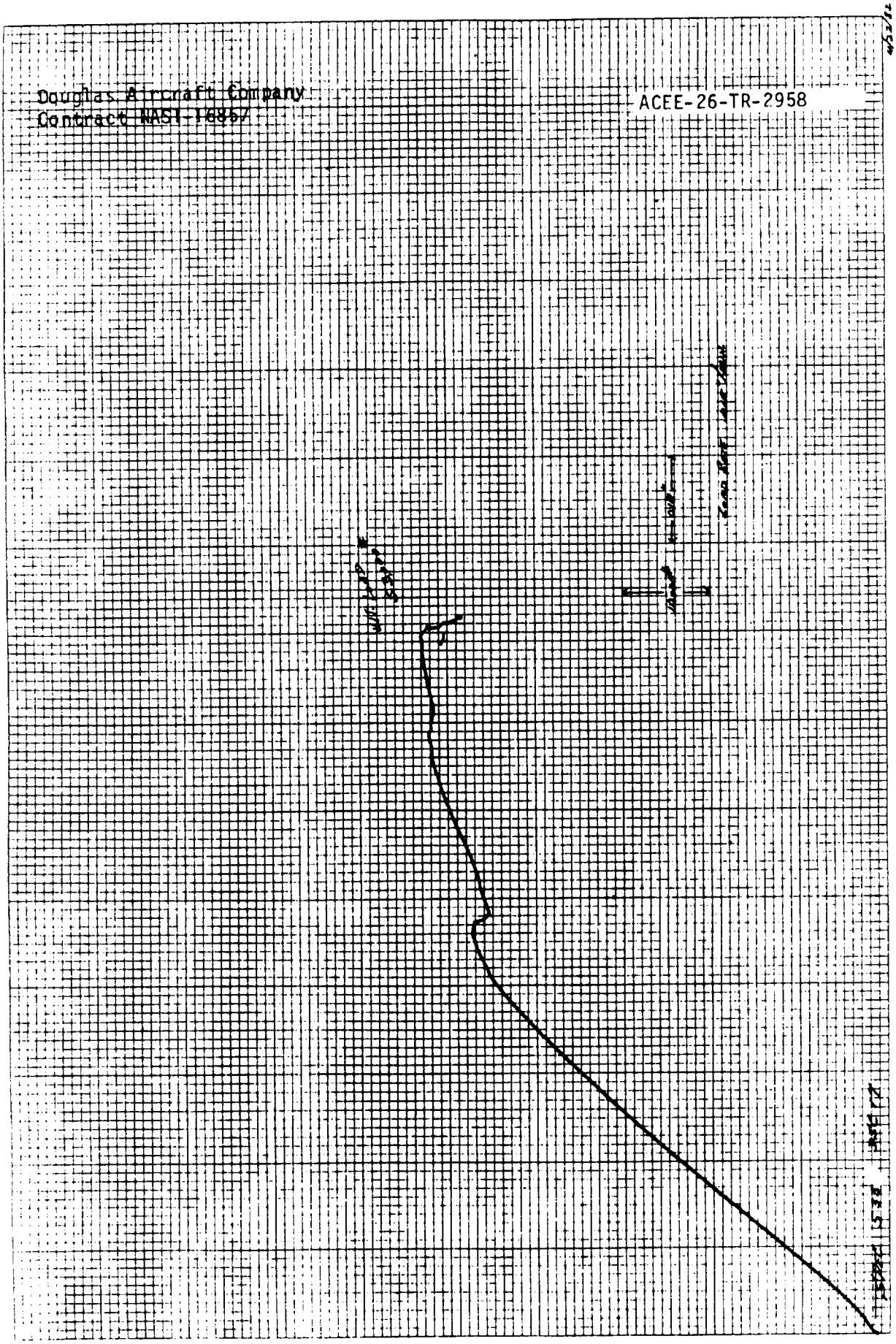
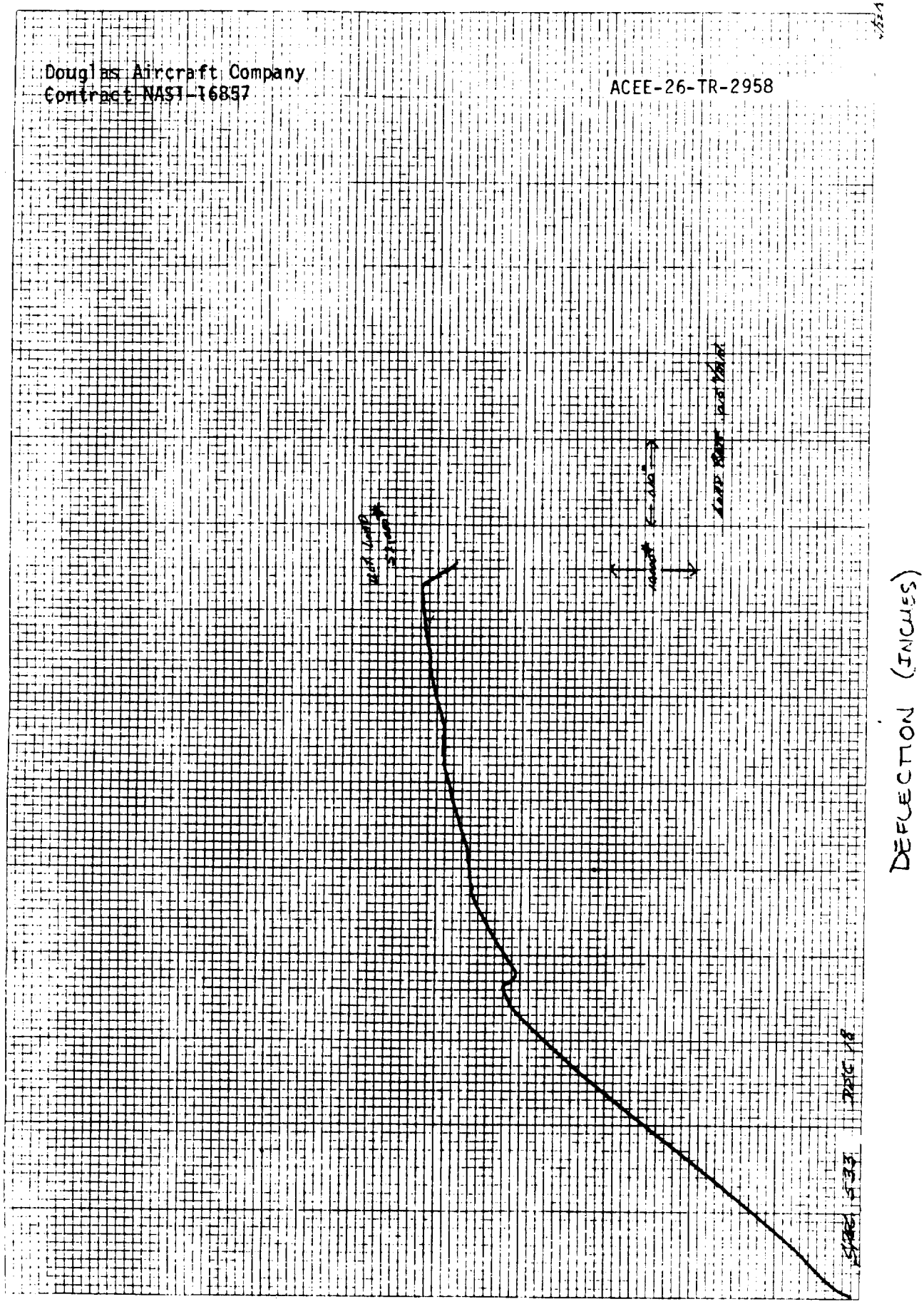
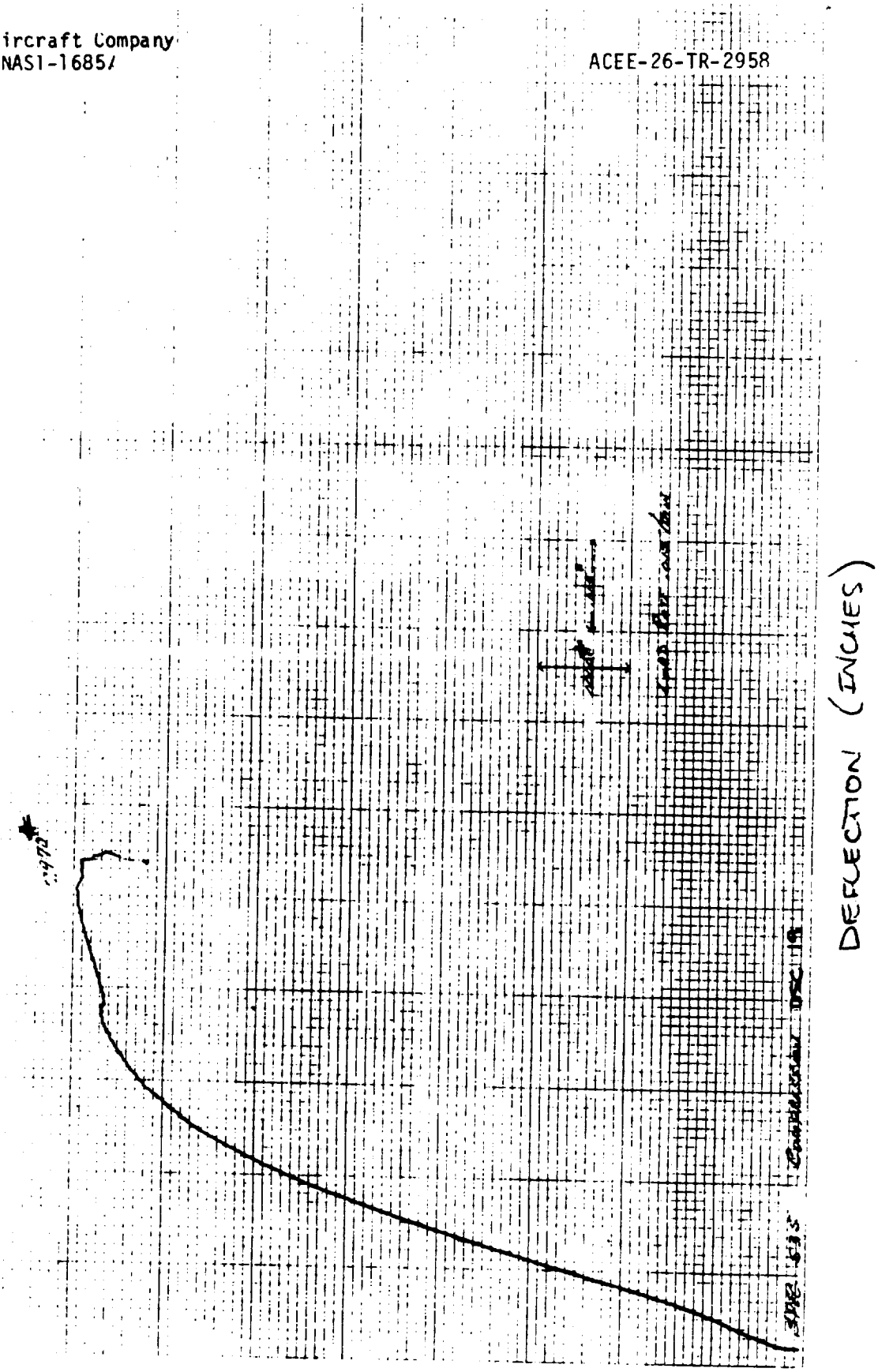
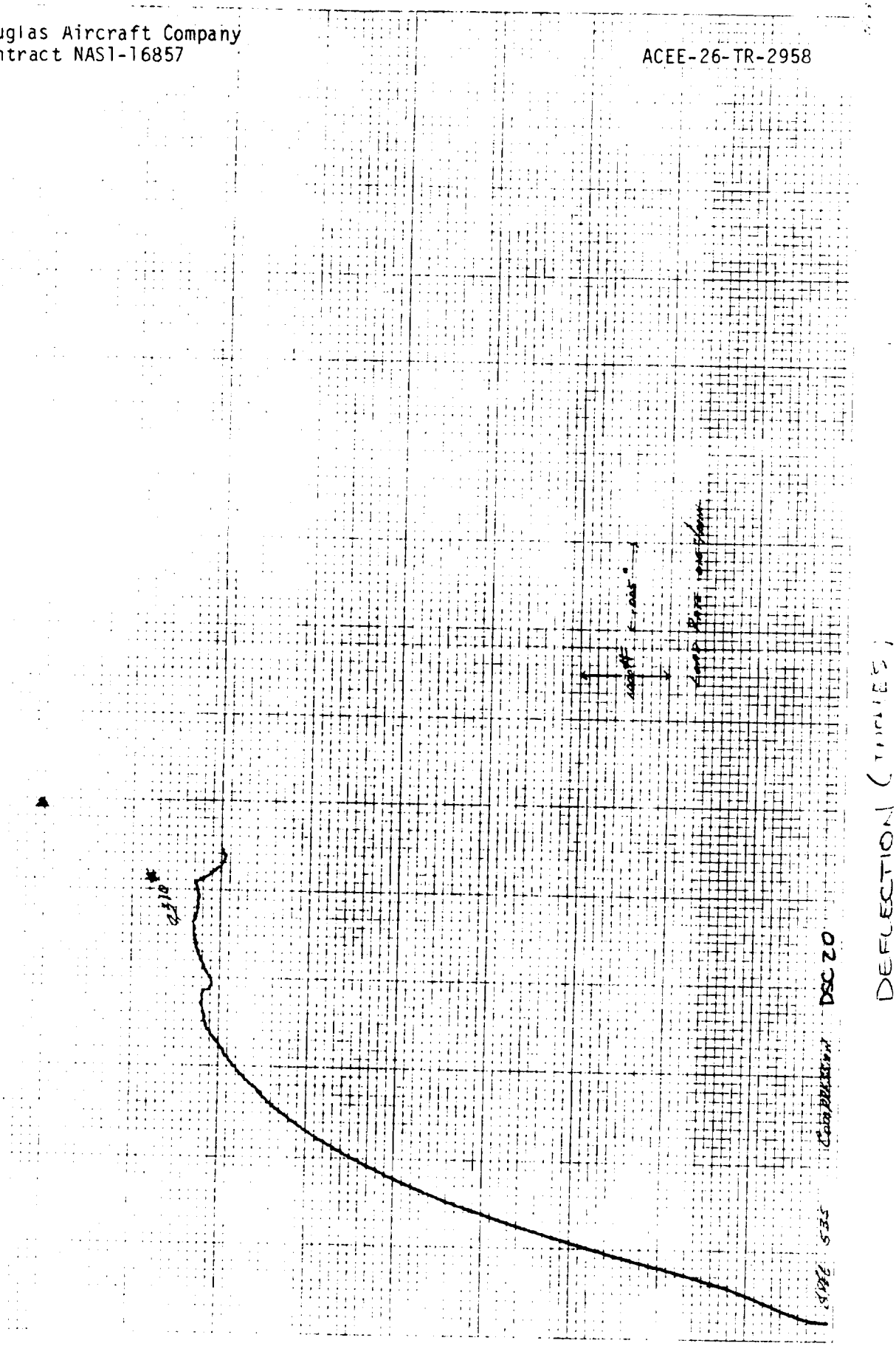
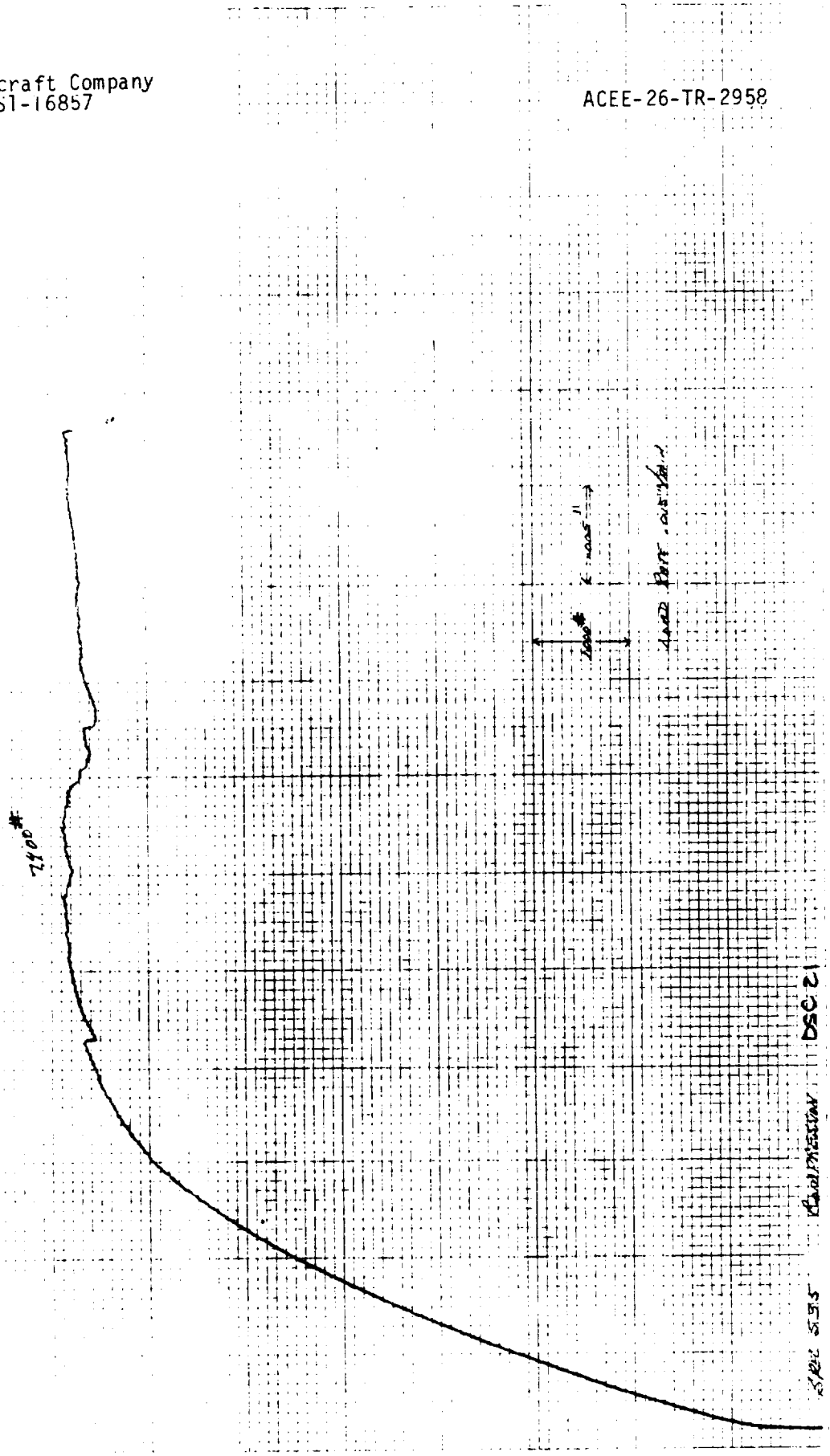
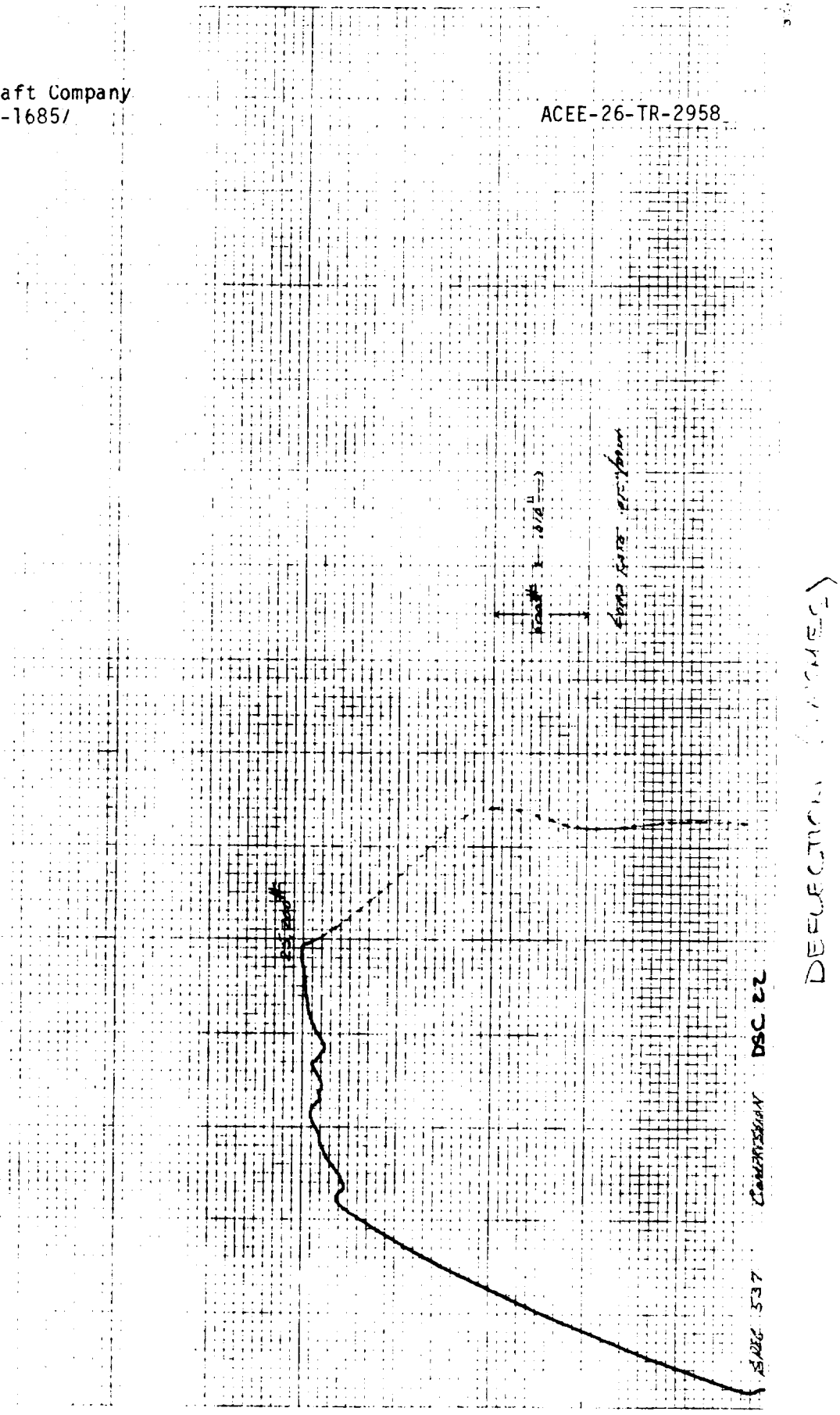

DEFLECTION (INCHES)


DEFLECTION (INCHES)
LOAD (LBS)


DEFLECTION (INCHES)


DSC 20
DEFLECTION (INCHES)


7400#
1000#
K = 1000"
LAND FORT DESIGN
DSC 21



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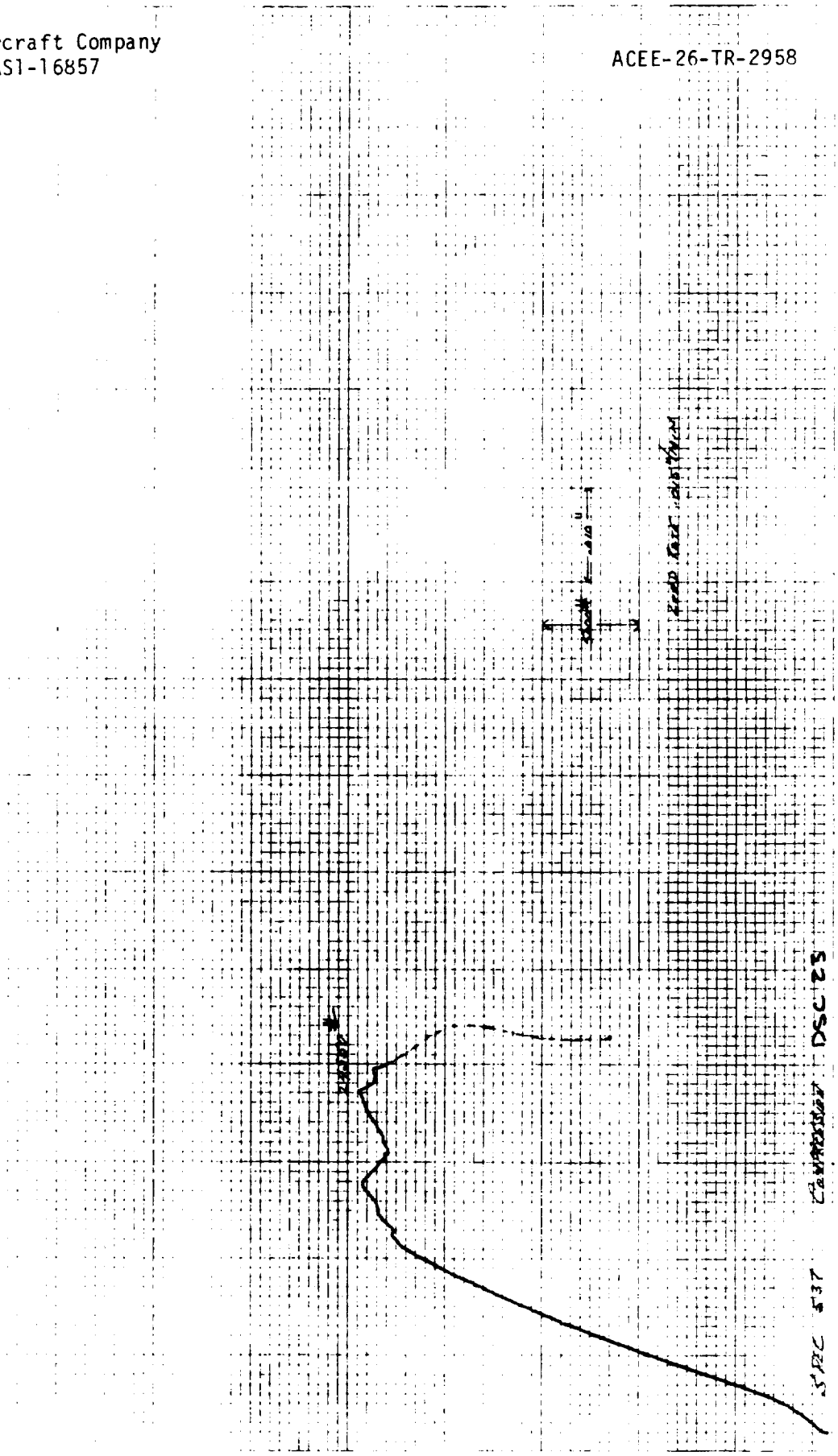
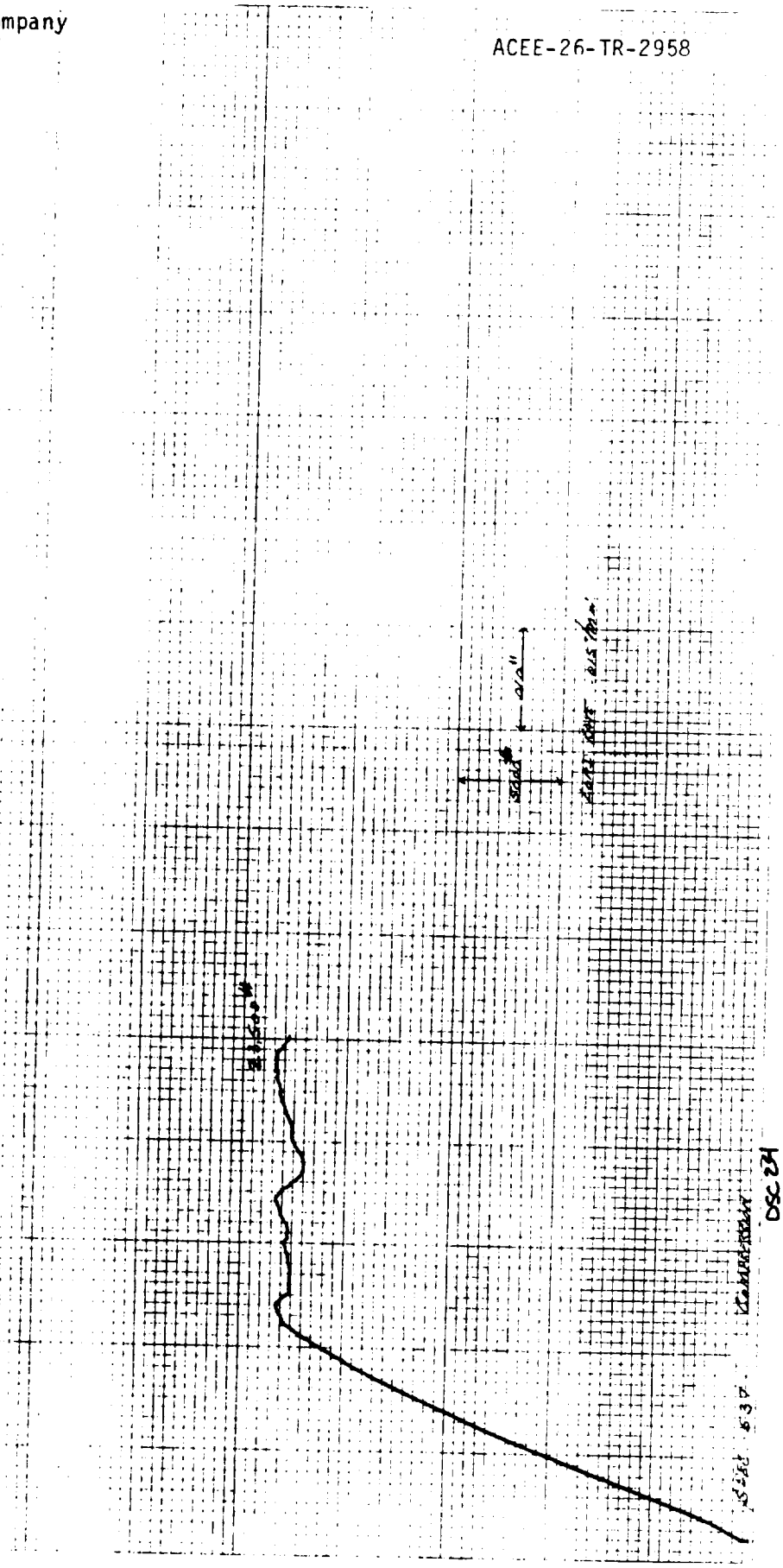
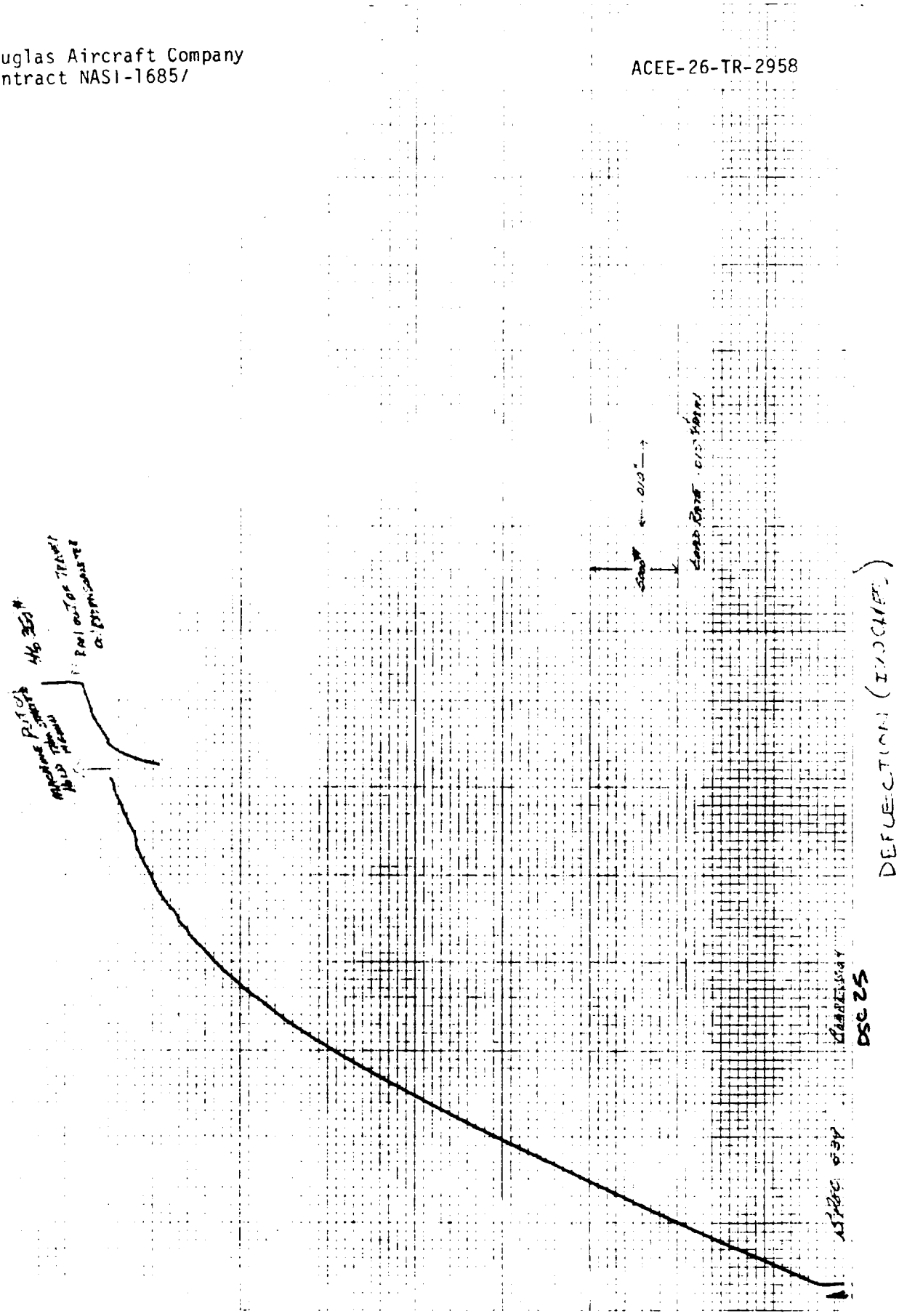
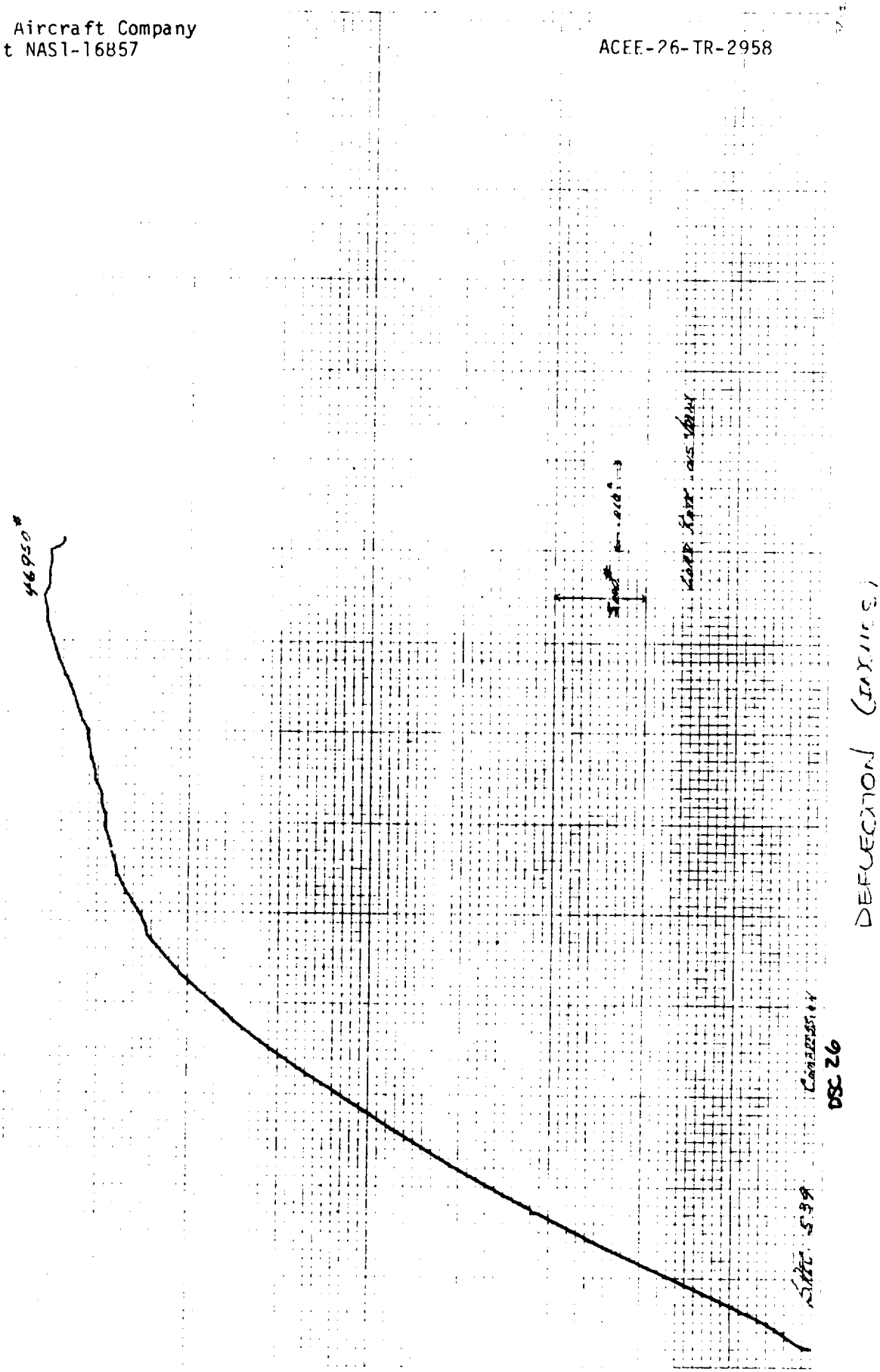

DEFLECTION (INCHES)
SPEC 537
DSC 23




DEFLECTION (INCHES)
DSC 25



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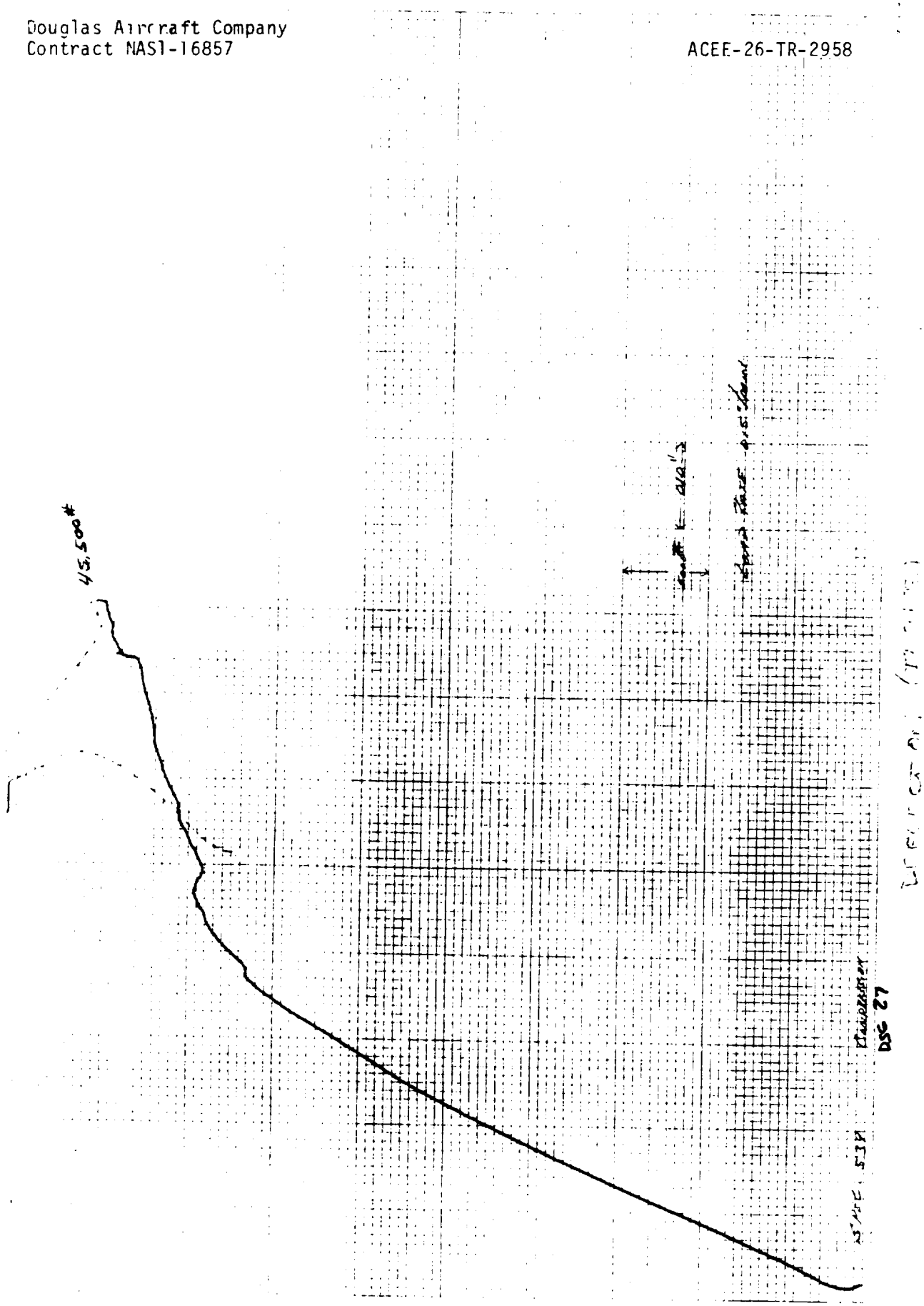
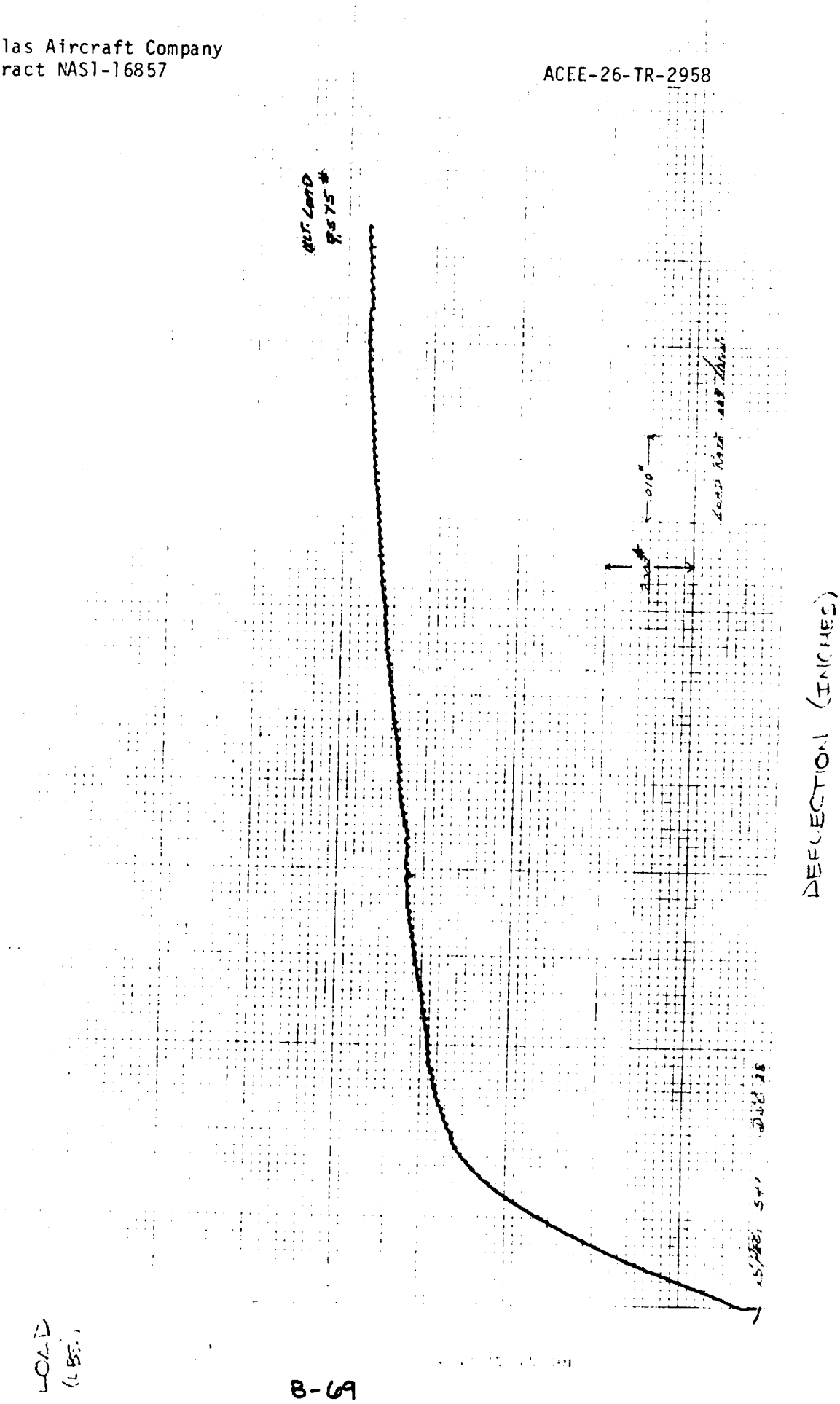
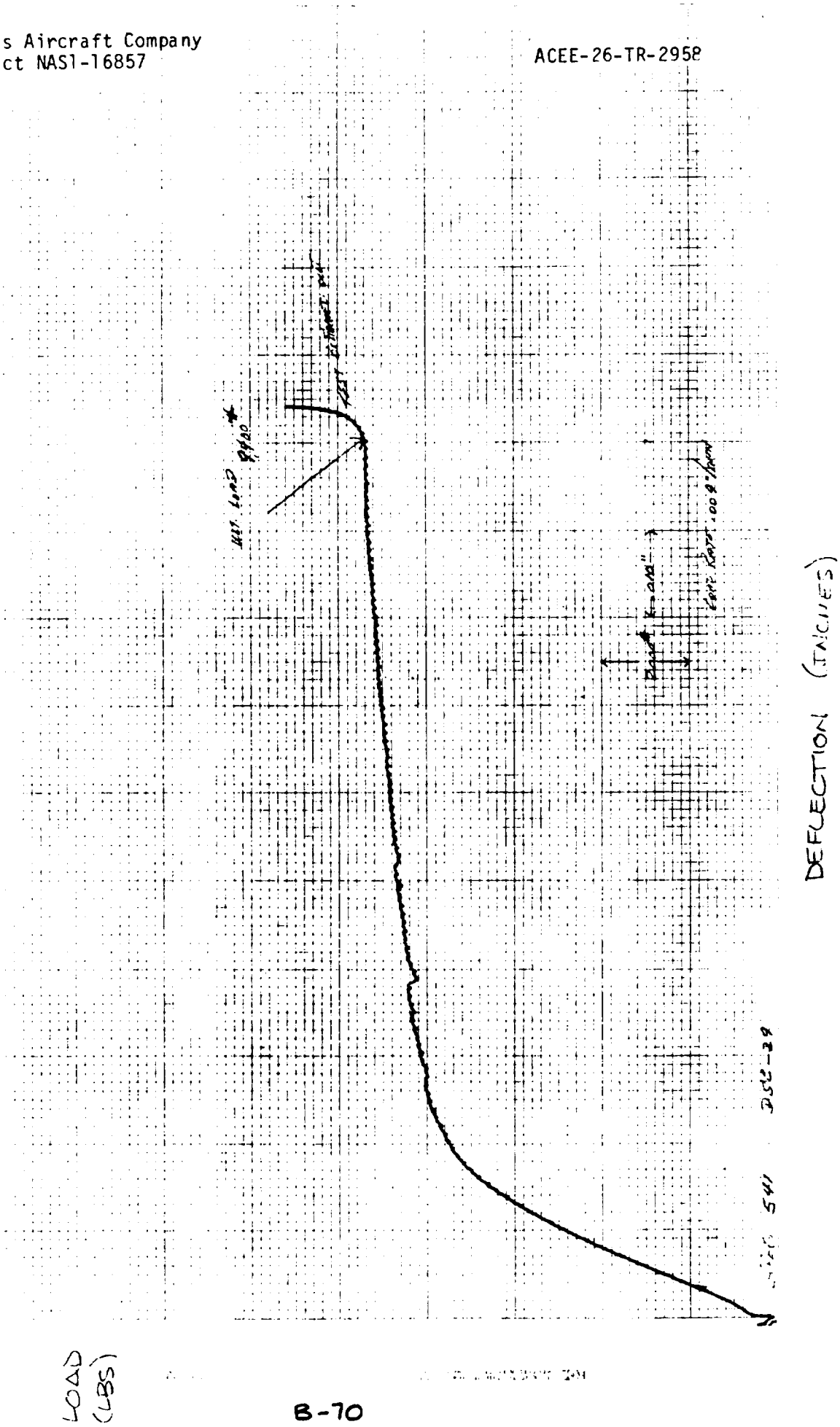
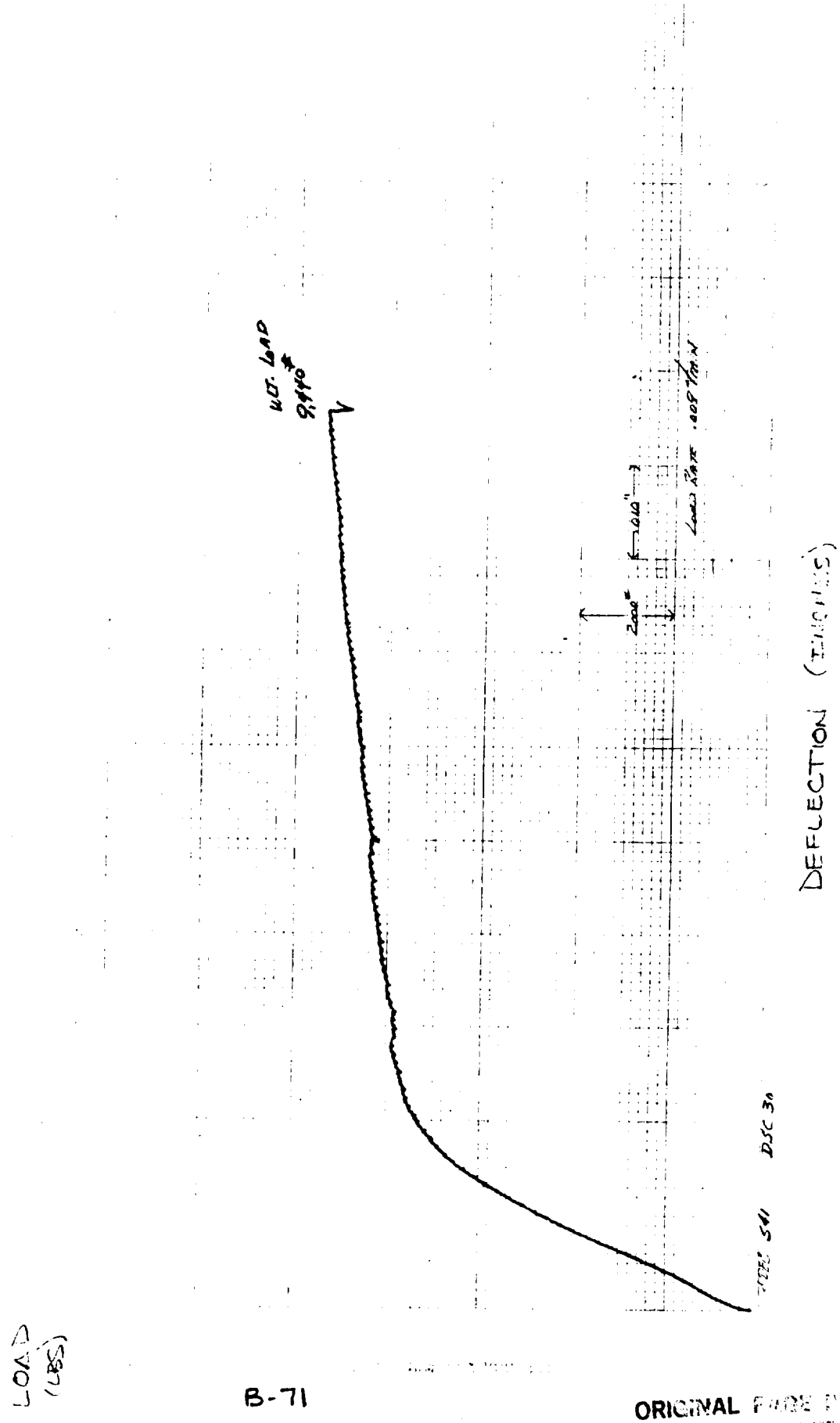

#005514
DSG 27


DEFLECTION (INCHES)
LOAD (LBS)


DEFLECTION (INCHES)
LOAD (LBS)



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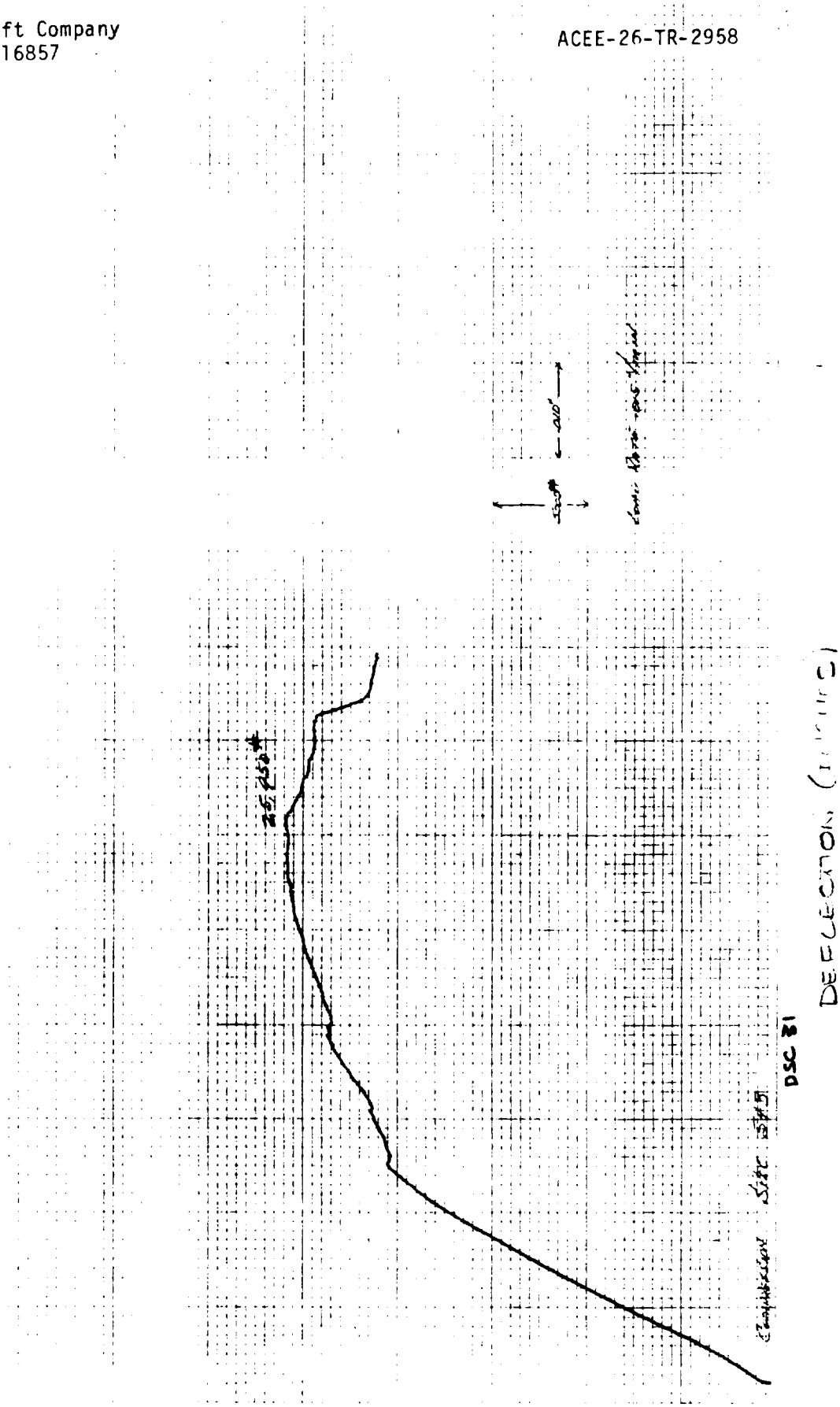
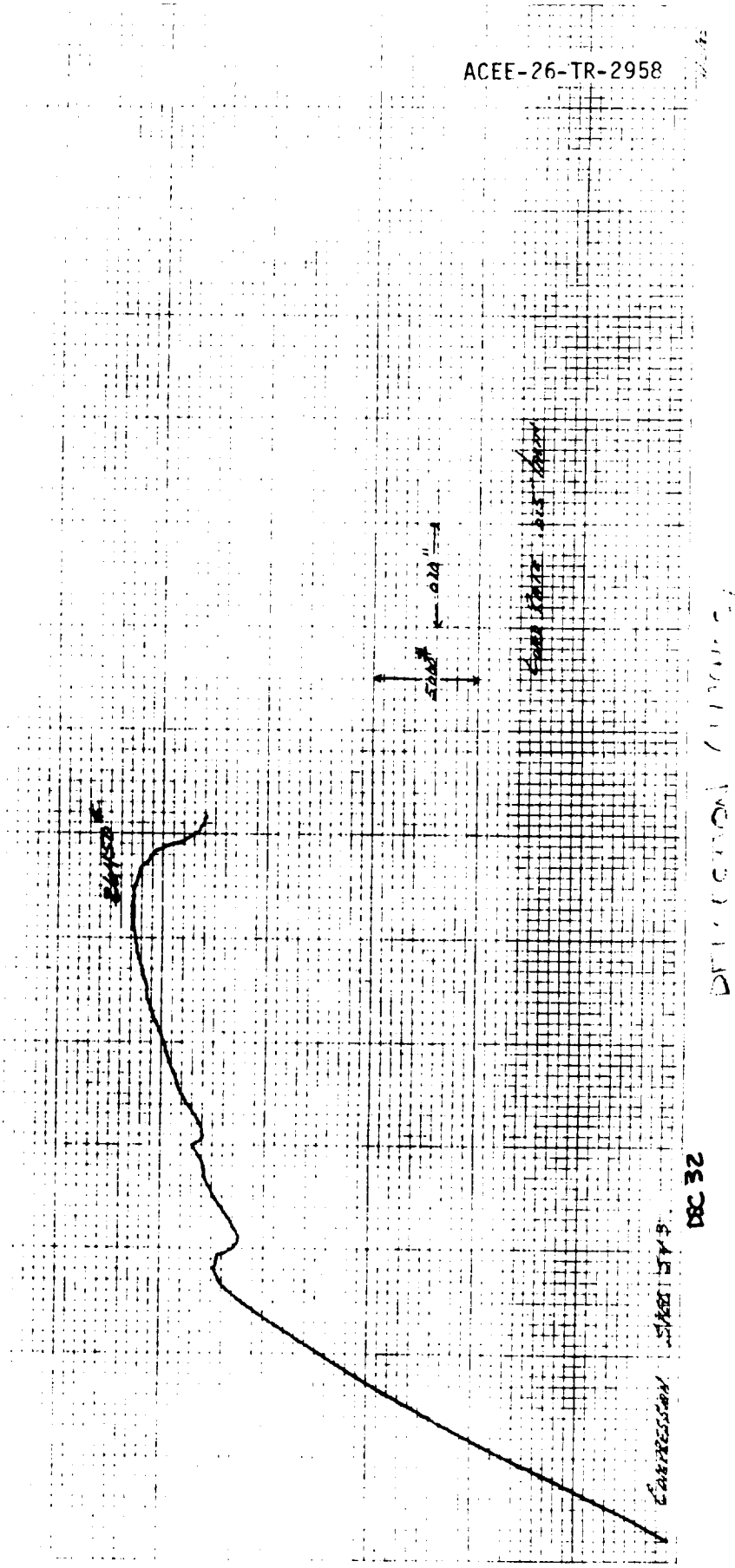
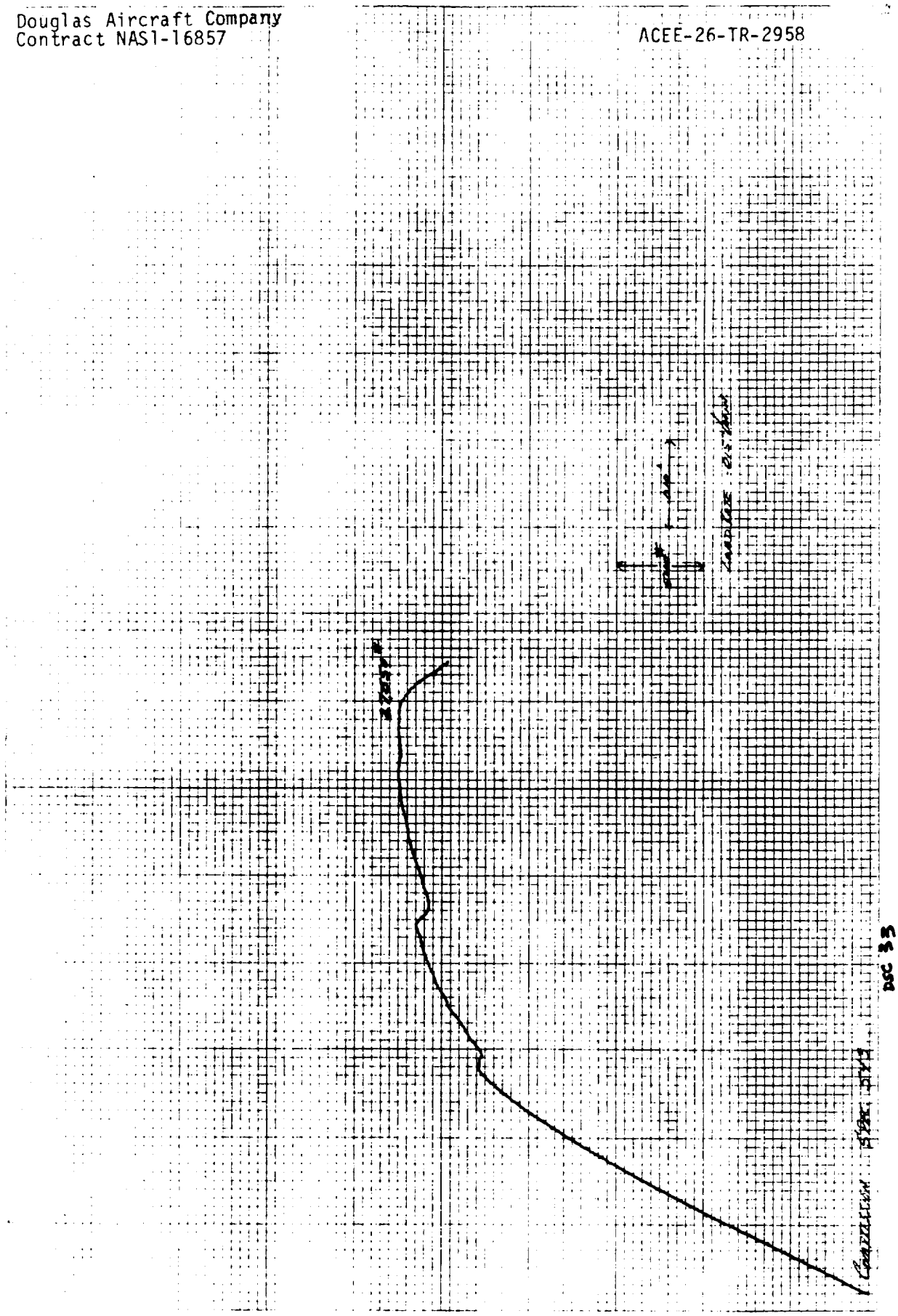
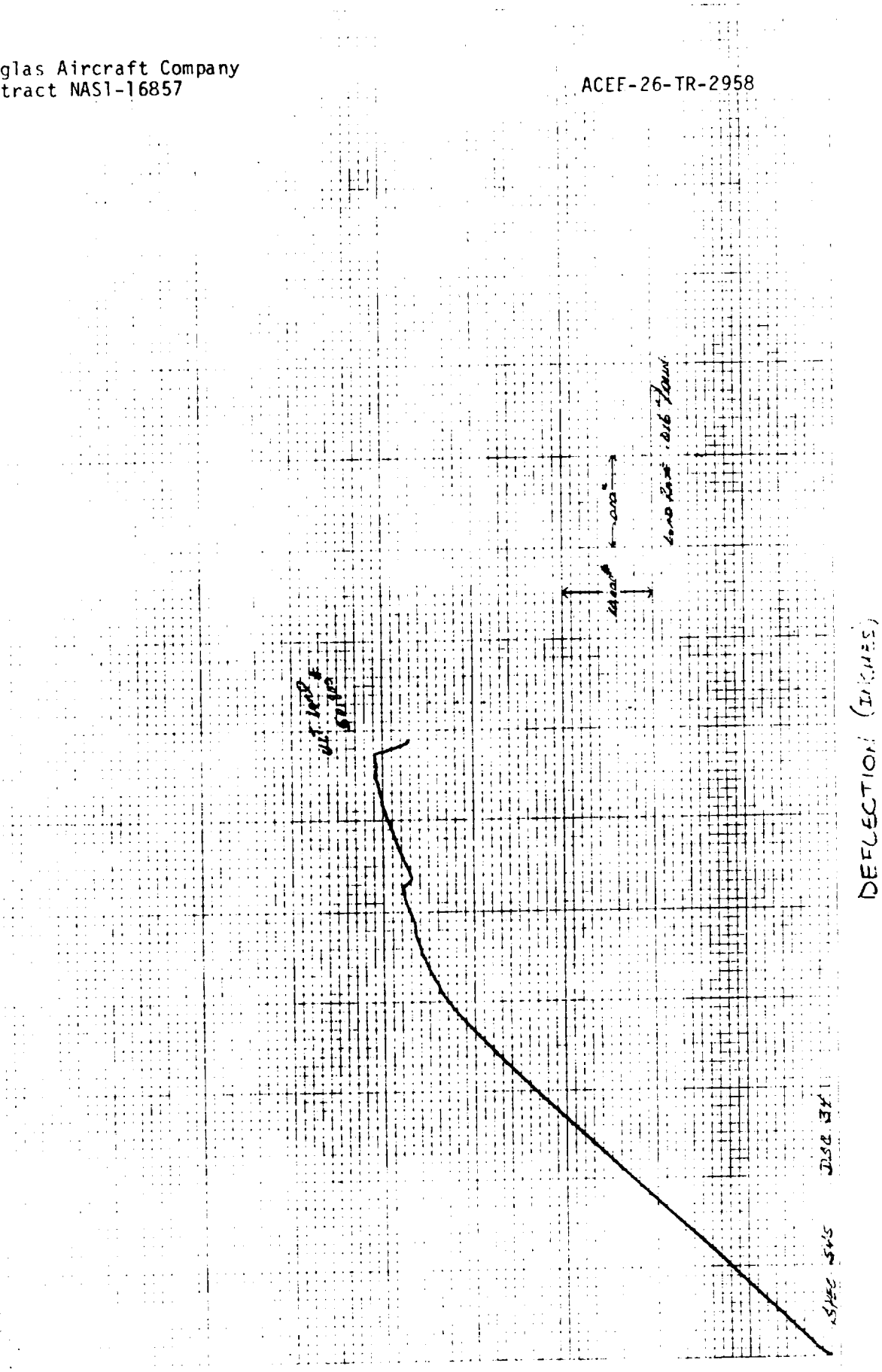

DEFLECTION
DSC 31



LOAD (LBS)


DEFLECTION (INCHES)
DOC 33
(LBF)



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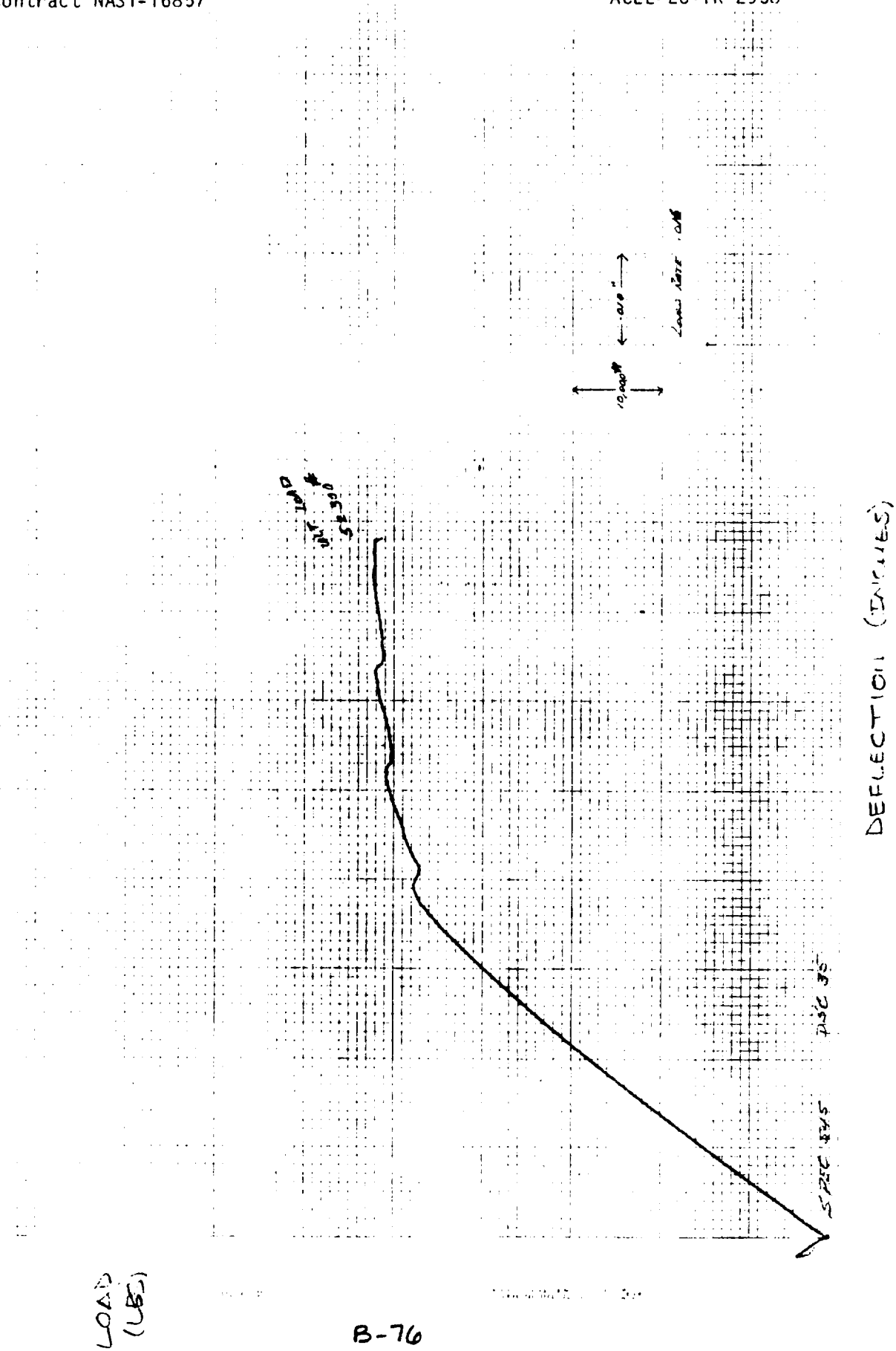
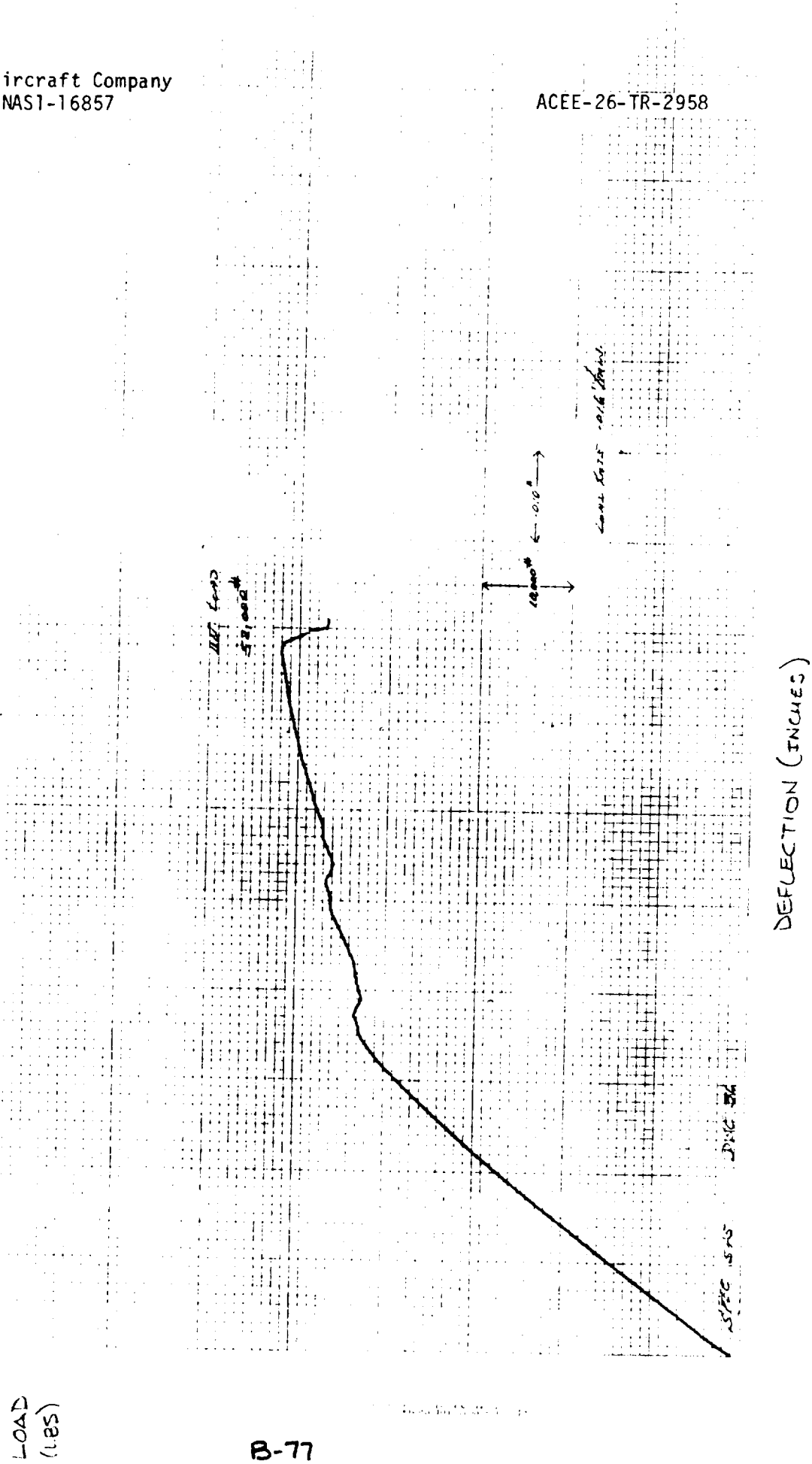

DEFLECTION (INCHES)
LOAD (LBS)


LOAD (LBS)
DEFLECTION (INCHES)

APPENDIX C

ANCILLARY TEST DATA

SPECIMEN CODING:

SINGLE SHEAR - DRAWING ZJ011267

SST - SINGLE SHEAR TENSION
SSC - SINGLE SHEAR COMPRESSION

FAILURE MODES

SST

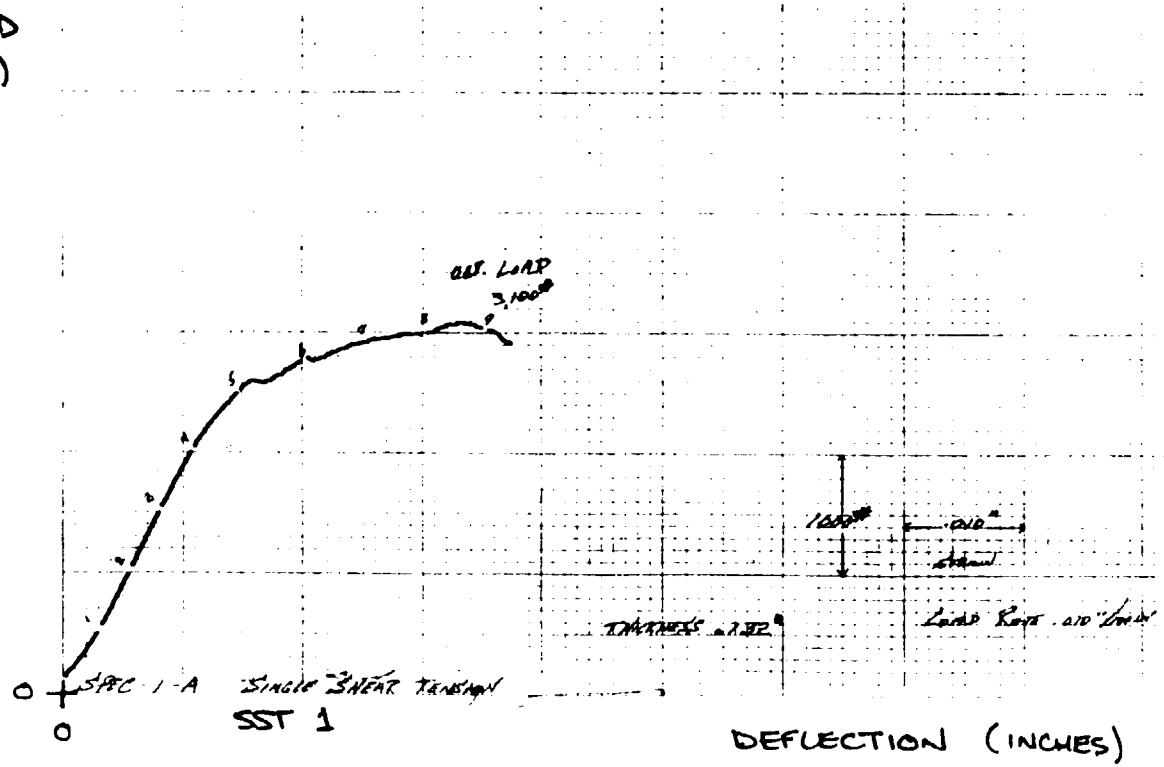
1 - 18 Bearing Failures.

SSC

1 - 18 Bearing Failures.

SST 1

Reading No.	Bolt Head Rotation (Degrees)
1	0.25
2	0.48
3	0.73
4	0.98
5	1.38
6	1.97
7	2.45
8	3.00
9	3.61



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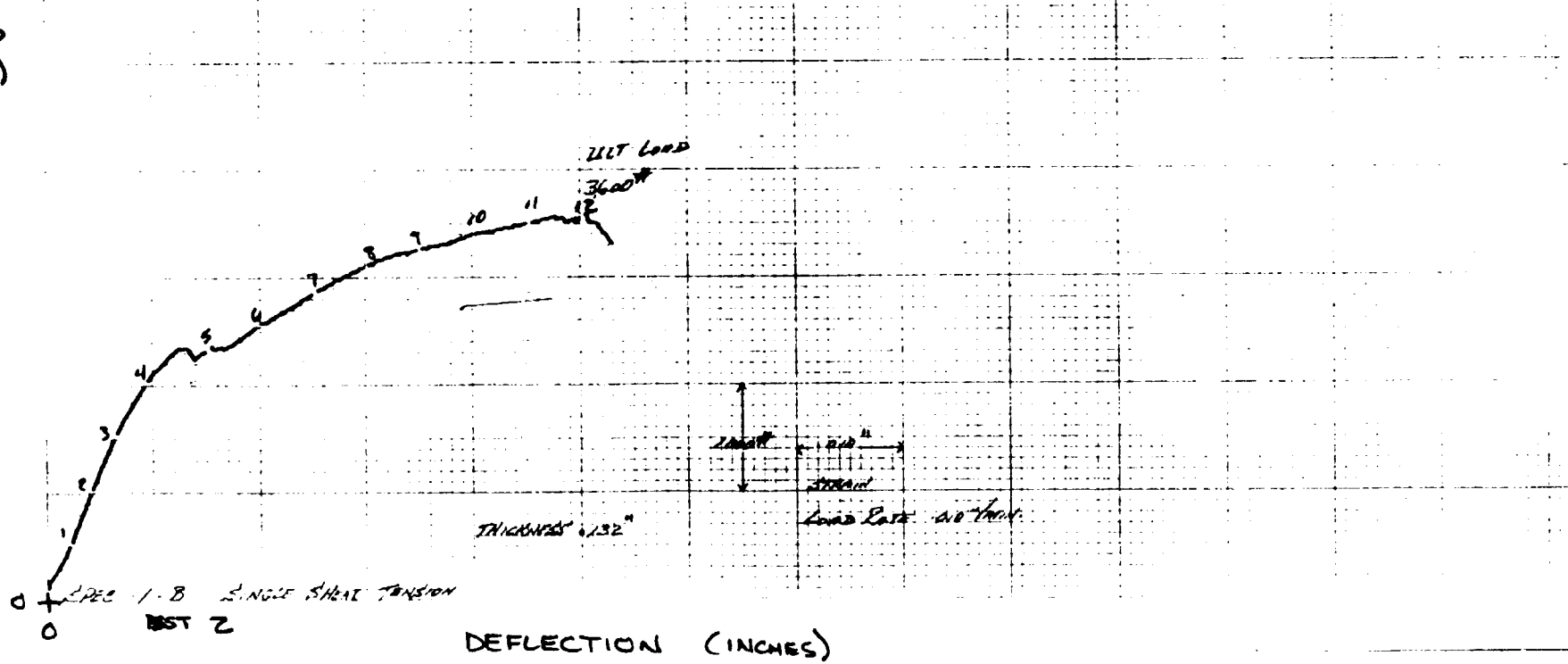
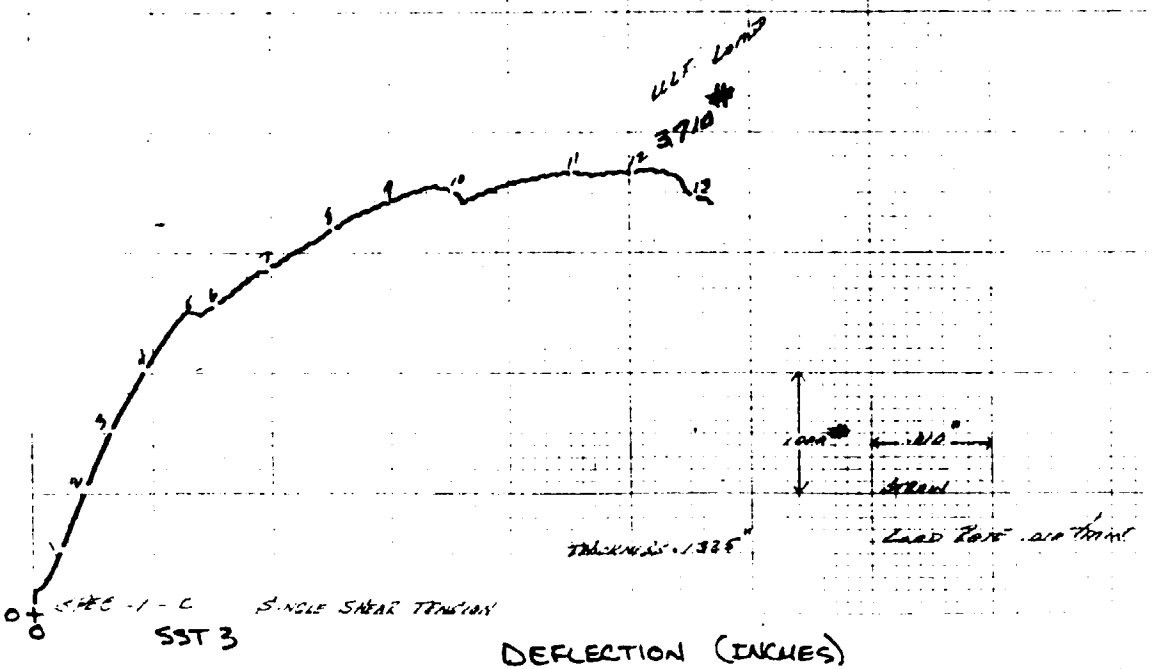
SST 2

Reading No.	Bolt Head Rotation (Degrees)
1	0.18
2	0.34
3	0.61
4	1.03
5	1.86
6	2.28
7	2.76
8	3.18
9	3.65
10	4.13
11	4.58
12	4.99

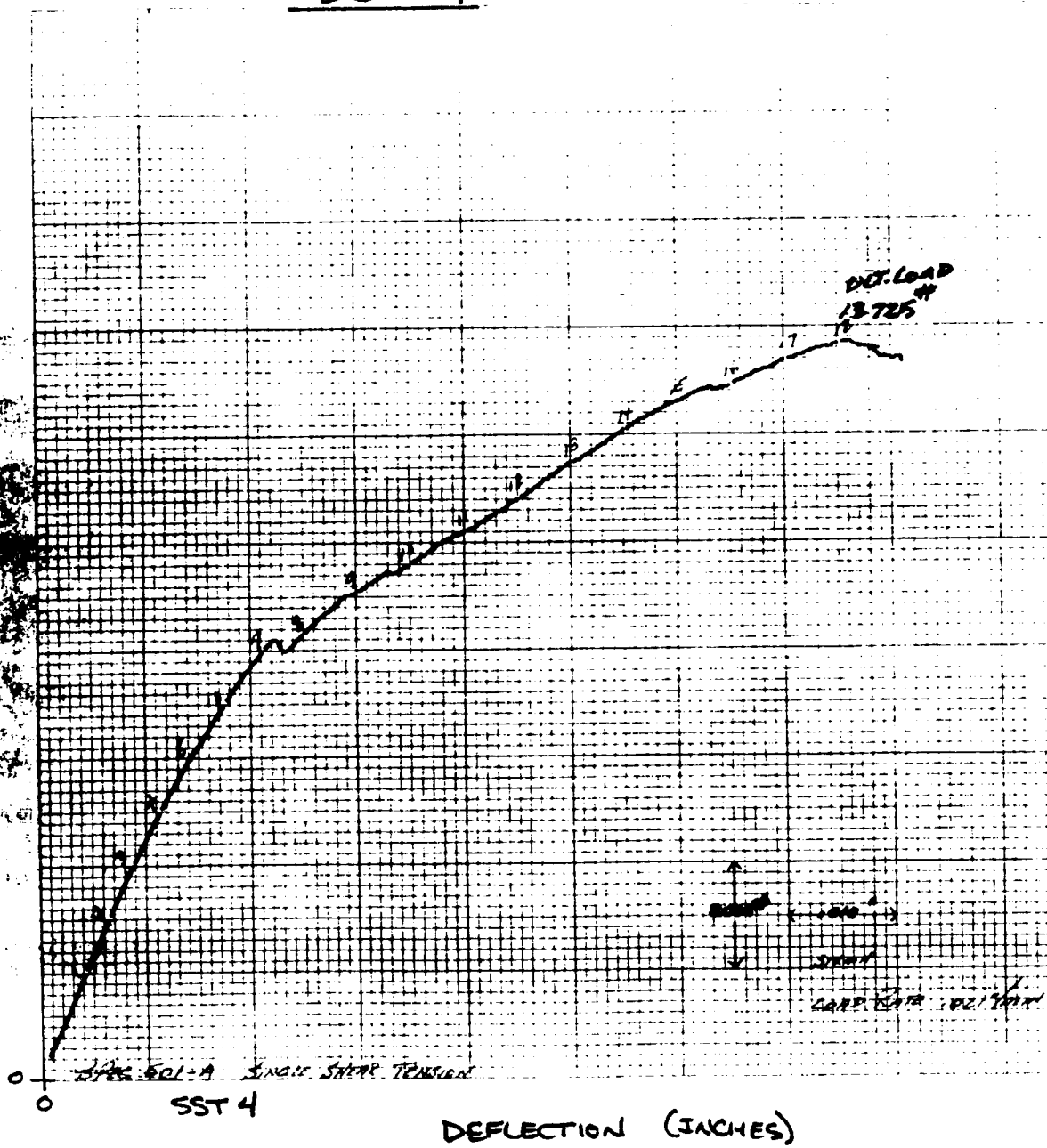


SST 3

Reading No.	Bolt Head Rotation (Degrees)
1	0.16
2	0.33
3	0.55
4	0.87
5	1.32
6	1.56
7	1.99
8	2.38
9	2.72
10	3.11
11	3.82
12	4.25
13	4.57

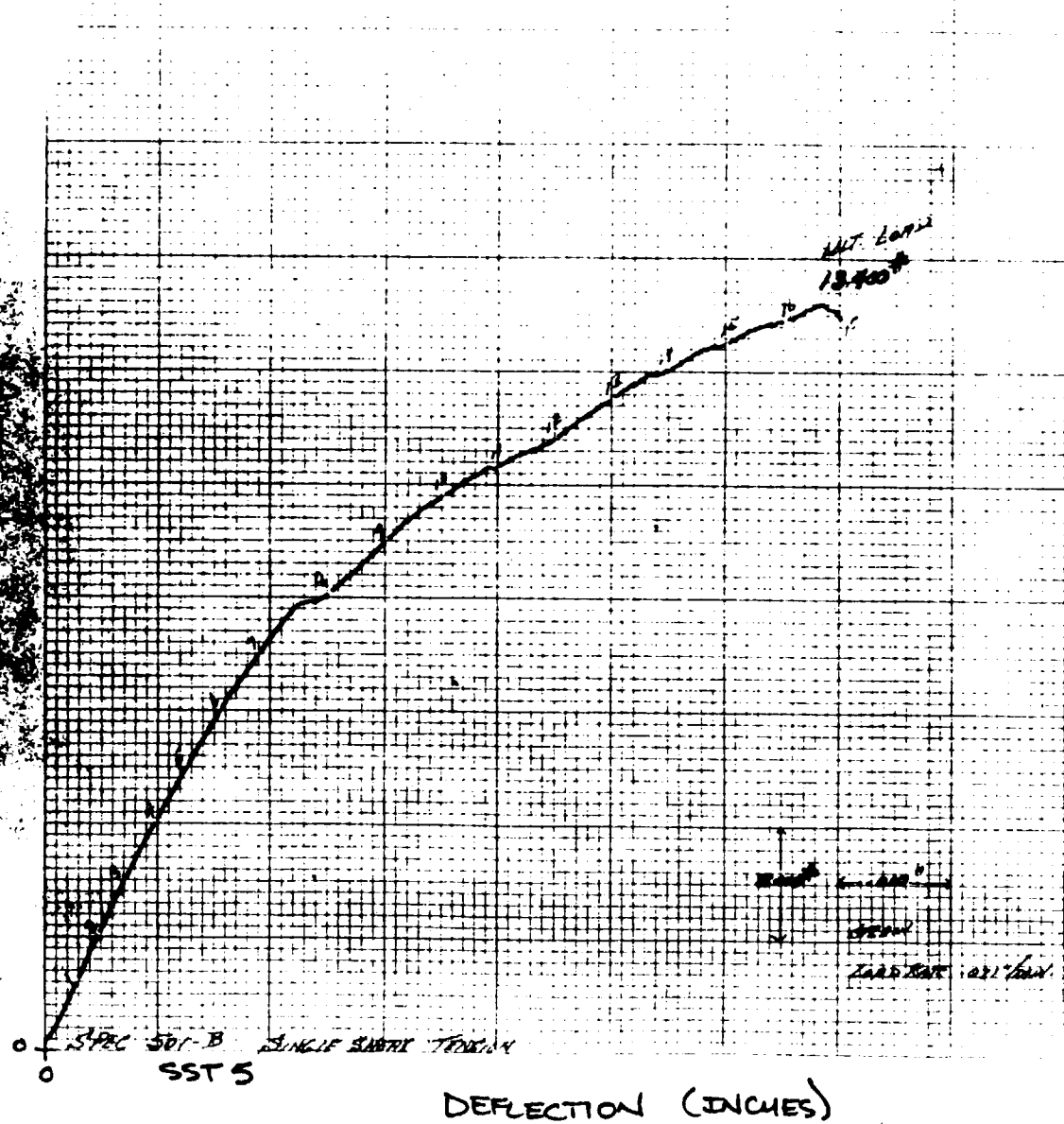


SST 4

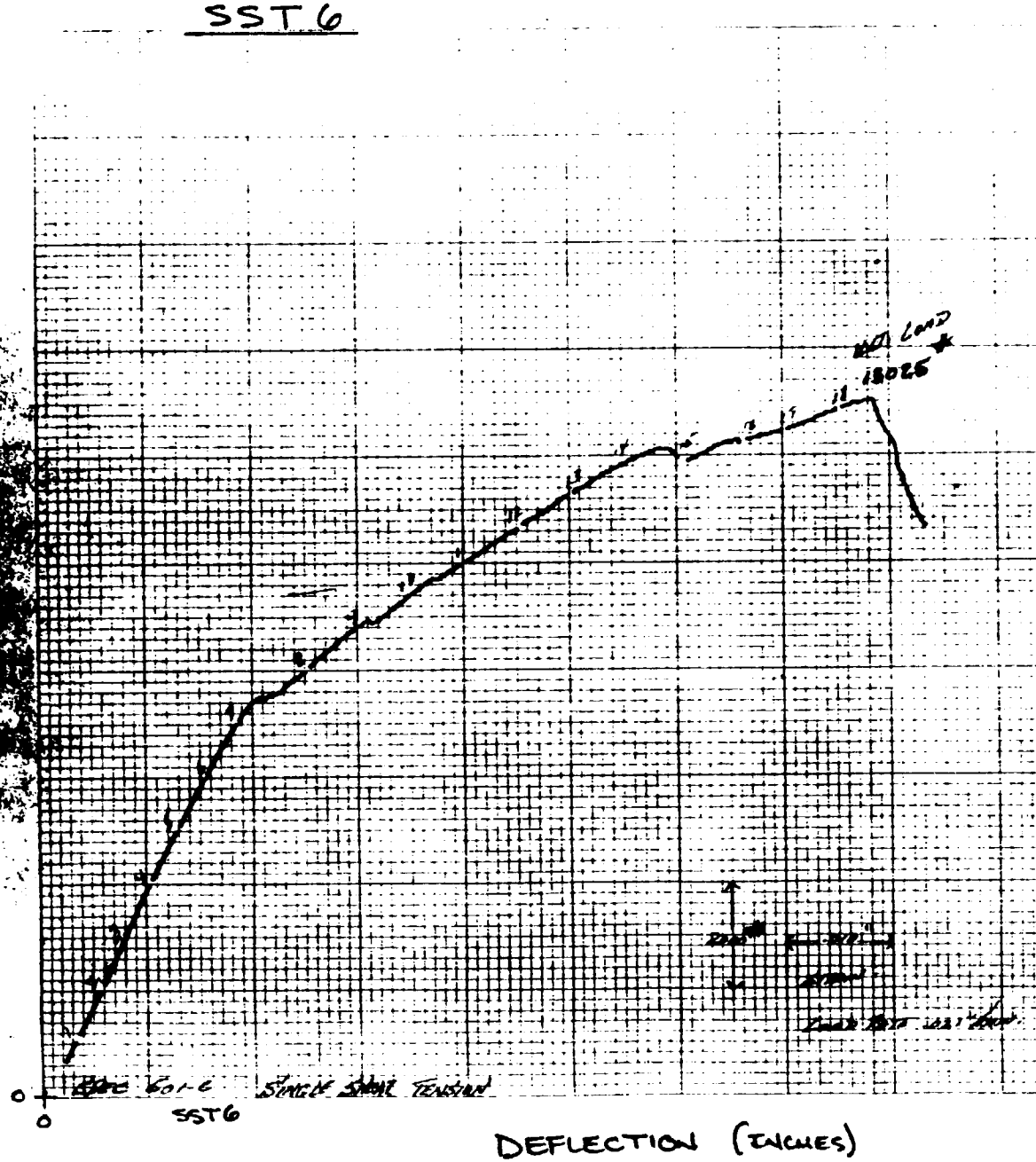


READING No.	BOLT HEAD ROTATION (DEGREES)
1	0.30
2	0.46
3	0.63
4	0.79
5	1.00
6	1.23
7	1.48
8	1.69
9	1.99
10	2.18
11	2.41
12	2.60
13	2.83
14	3.06
15	3.27
16	3.48
17	3.65
18	3.83

SST 5



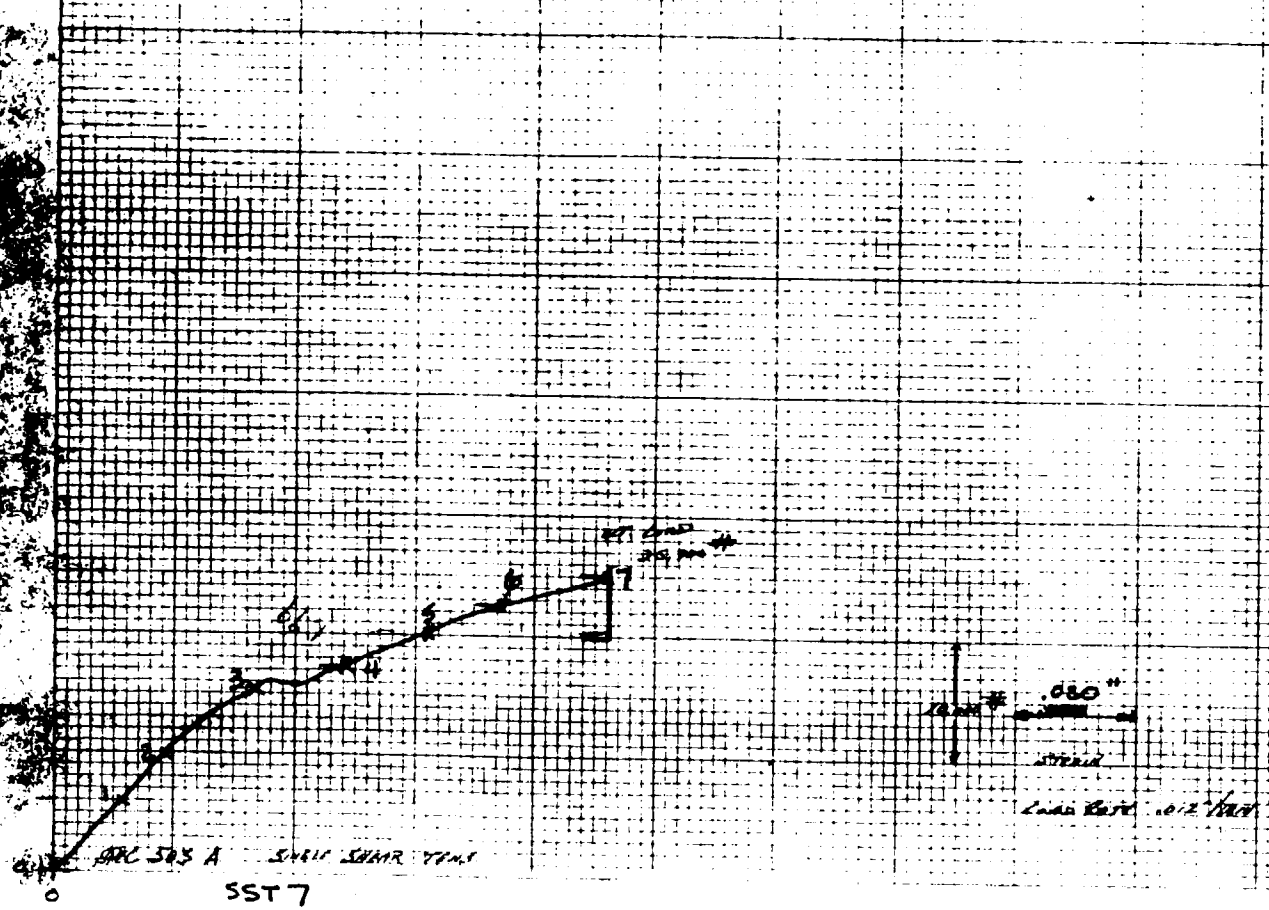
READING NO.	BOLT HEAD ROTATION (DEGREES)
1	0.16
2	0.28
3	0.42
4	0.61
5	0.79
6	1.02
7	1.23
8	1.63
9	1.95
10	2.21
11	2.42
12	2.60
13	2.81
14	3.05
15	3.23
16	3.42
17	3.61



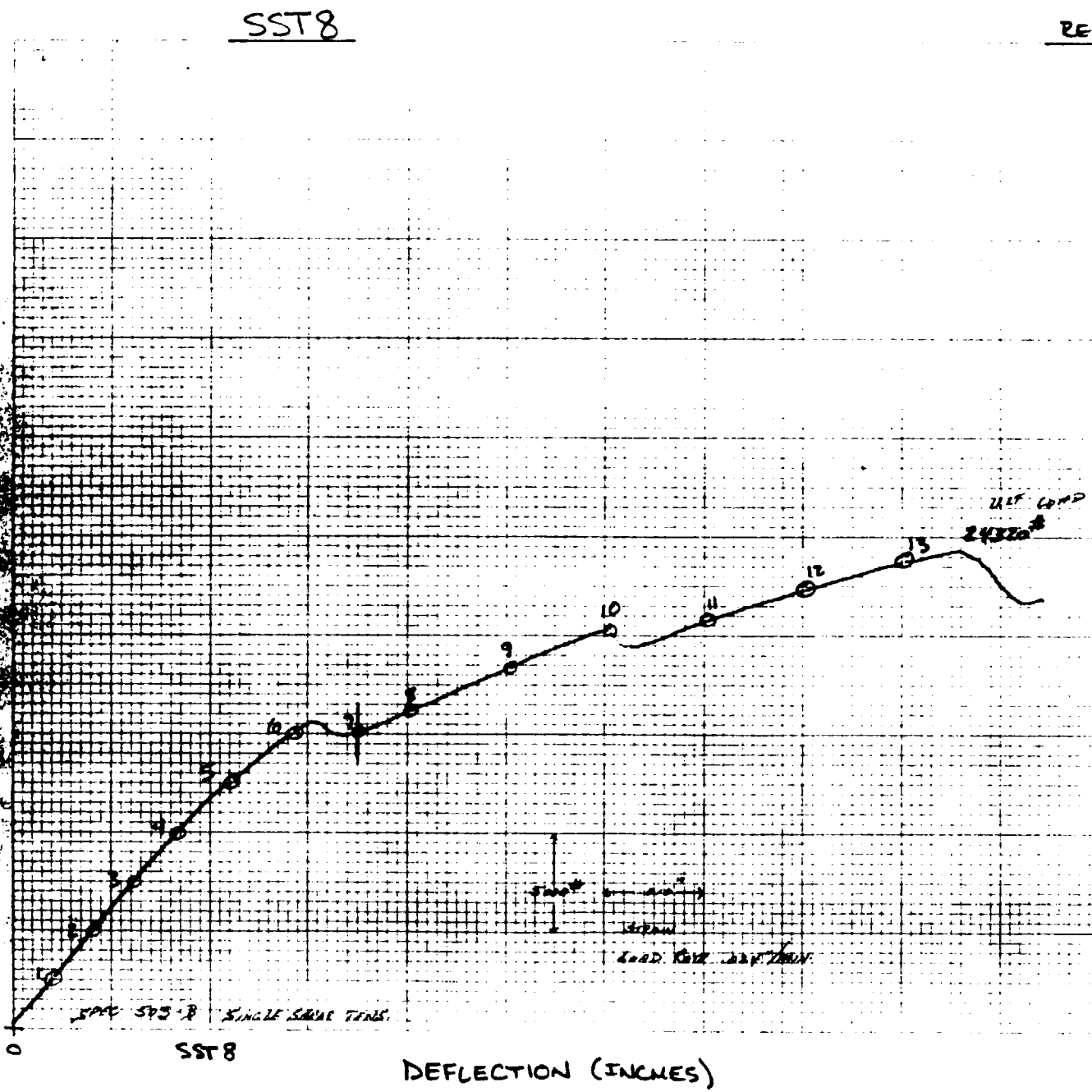
READING NO.	BOLT HEAD ROTATION (DEGREES)
1	0.16
2	0.32
3	0.49
4	0.62
5	0.81
6	0.99
7	1.18
8	1.55
9	1.80
10	1.98
11	2.17
12	2.38
13	2.59
14	2.79
15	2.98
16	3.21
17	3.35
18	3.54

SST 7

READING NO.	BOLT HEAD ROTATION (DEGREES)
1	0.37
2	0.84
3	1.44
4	1.93
5	2.35
6	2.75
7	3.21

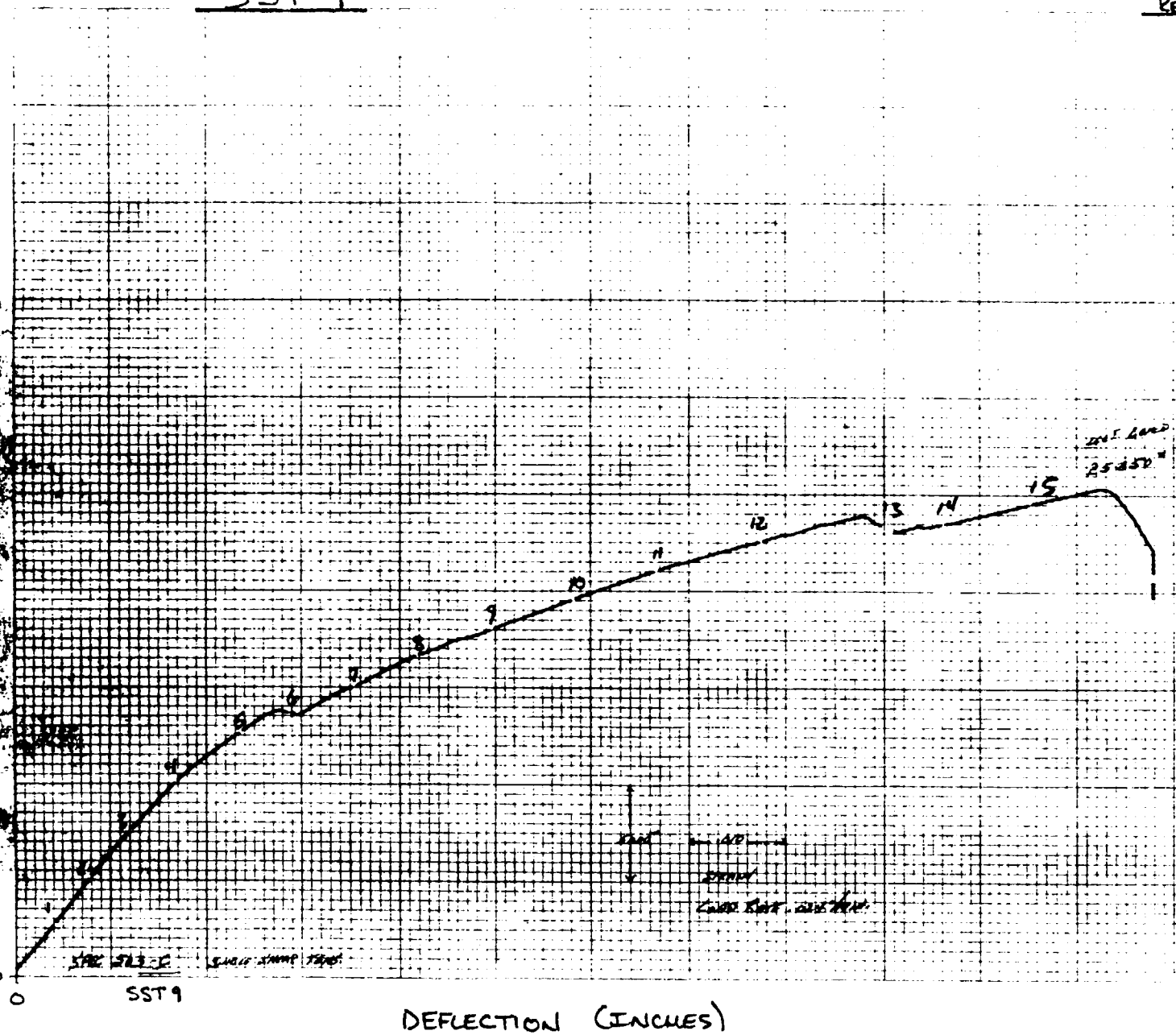


DEFLECTION (INCHES)



READING No.	BOLT HEAD ROTATION (DEGREES)
1	0.12
2	0.33
3	0.59
4	0.88
5	1.21
6	1.54
7	1.75
8	1.92
9	2.25
10	2.61
11	2.73
12	3.01
13	3.27
14	3.99

SST 9



READING NO.	BOLT HEAD ROTATION (DEGREES)
1	0.12
2	0.29
3	0.55
4	0.81
5	1.07
6	1.31
7	1.64
8	1.90
9	2.12
10	2.40
11	2.66
12	2.93
13	3.26
14	3.40
15	3.67

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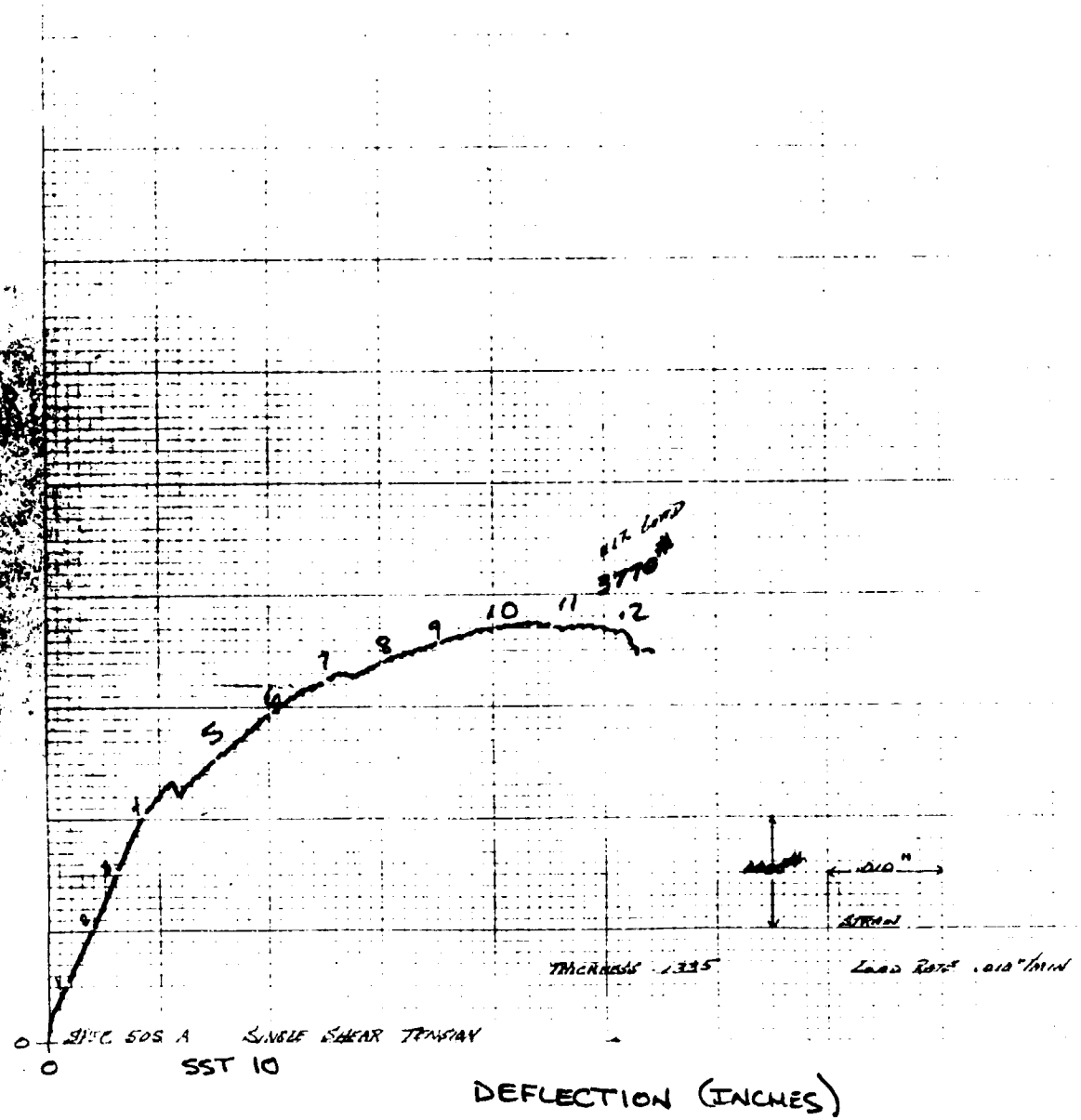
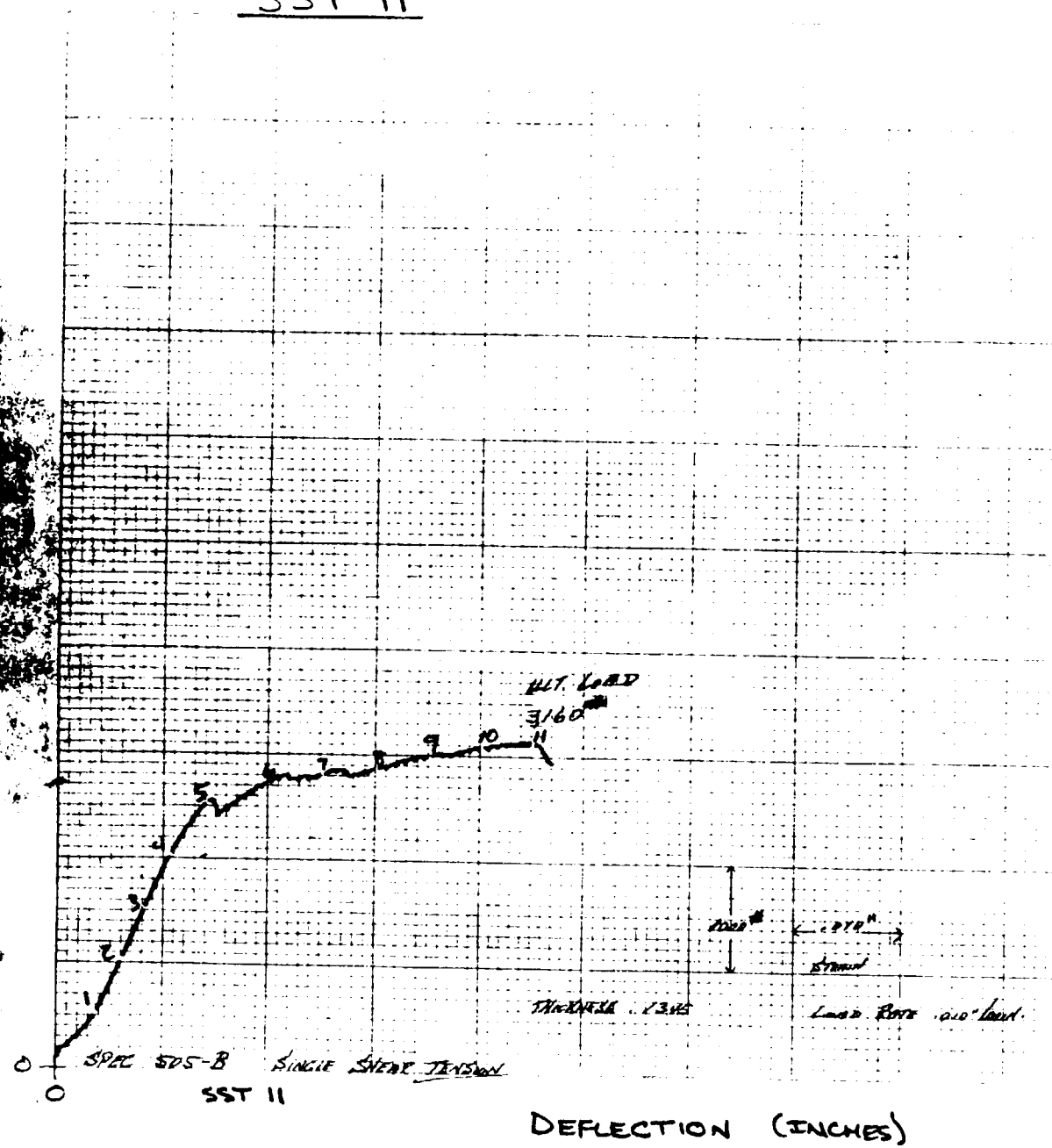
SST 10

READING NO.	BOLT HEAD ROTATION (DEGREES)
1	0.15
2	0.45
3	0.72
4	1.11
5	1.88
6	2.37
7	2.73
8	3.01
9	3.35
10	3.71
11	4.10
12	4.69



SST 11

Reading No.	Bolt Head Rotation (Degrees)
1	0.25
2	0.50
3	0.69
4	1.00
5	1.40
6	2.13
7	2.72
8	3.09
9	3.58
10	4.06
11	4.52



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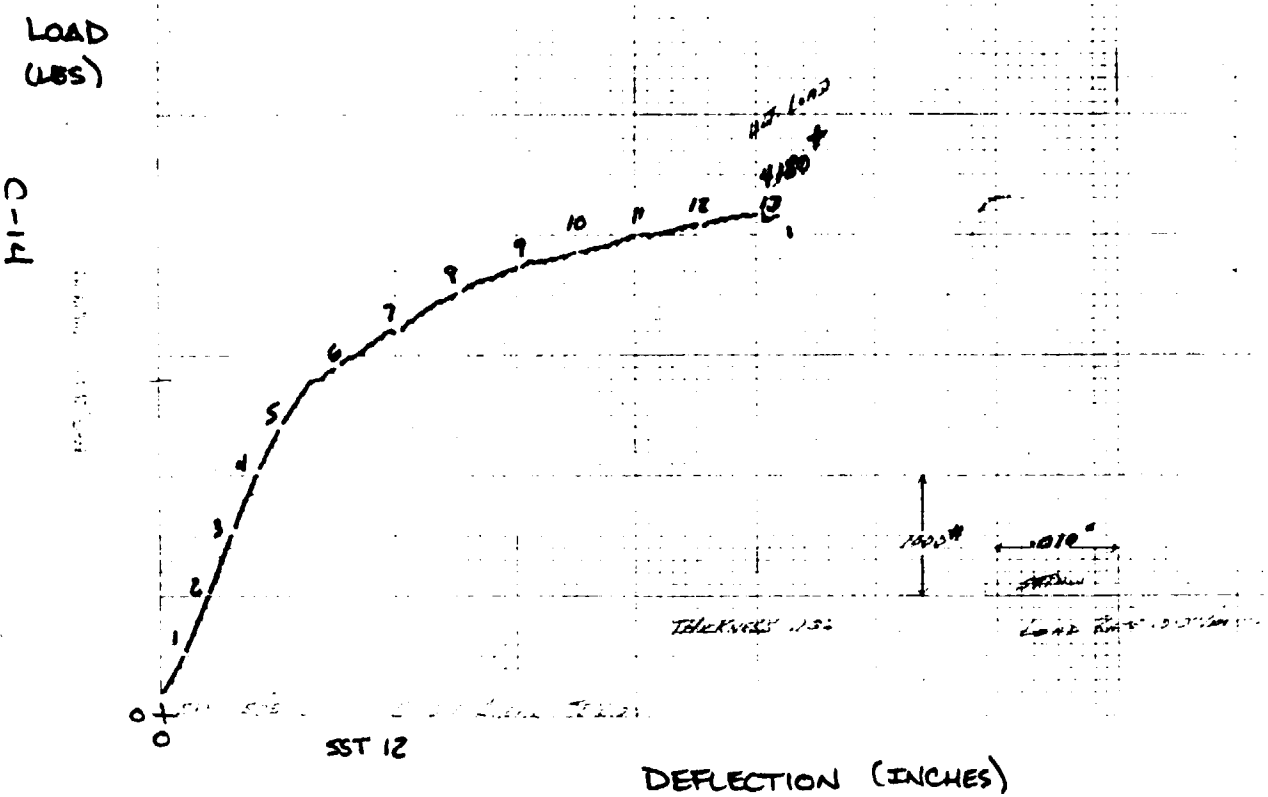
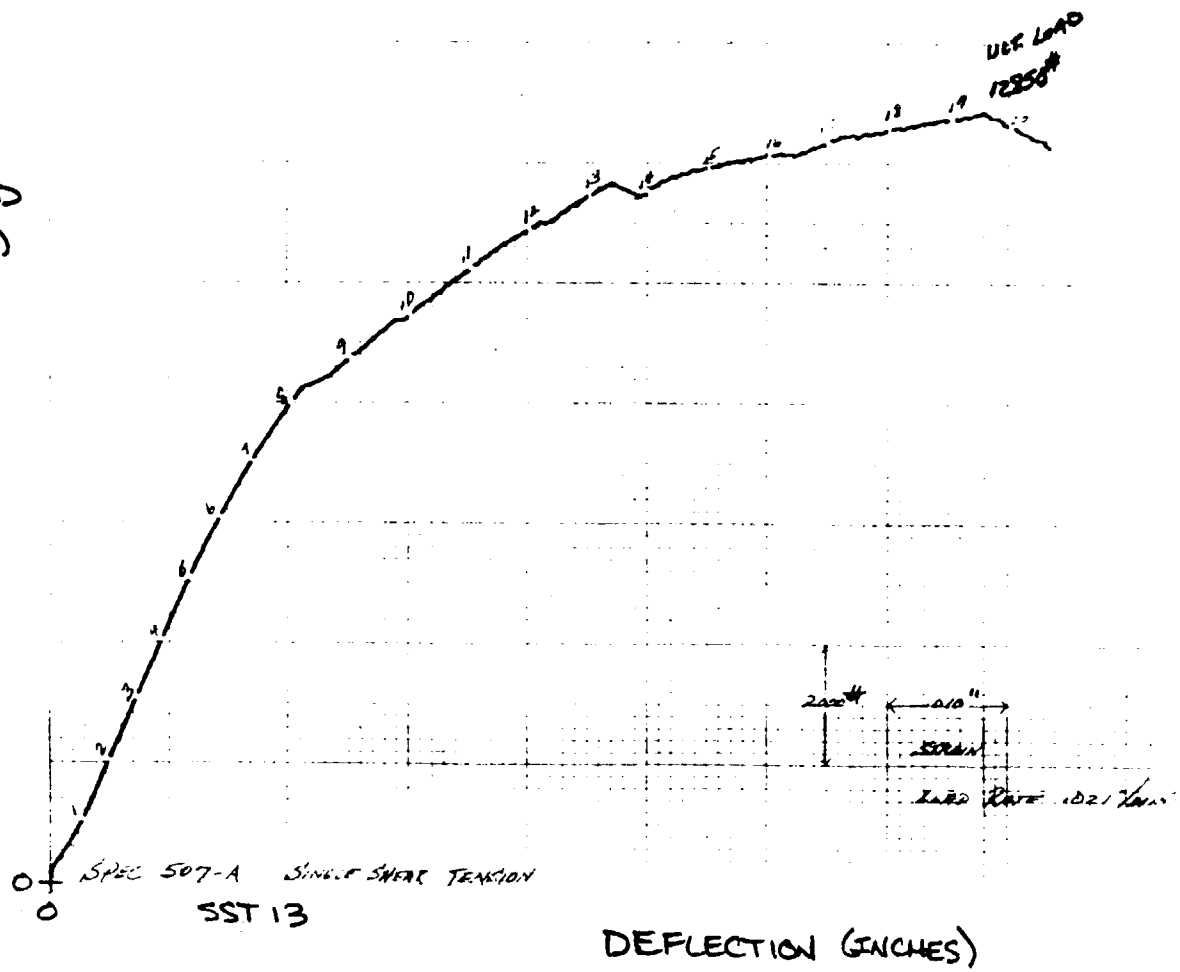
SST 12

READING NO.	BOLT HEAD ROTATION (DEGREES)
1	0.15
2	0.33
3	0.50
4	0.72
5	0.92
6	1.46
7	1.90
8	2.31
9	2.66
10	3.01
11	3.32
12	3.60
13	3.93



SST 13

Reading No.	Bolt Head Rotation (Degrees)
1	0.16
2	0.32
3	0.44
4	0.60
5	0.76
6	0.92
7	1.11
8	1.32
9	1.62
10	1.87
11	2.15
12	2.38
13	2.61
14	2.73
15	2.89
16	3.05
17	3.24
18	3.40
19	3.56
20	3.65



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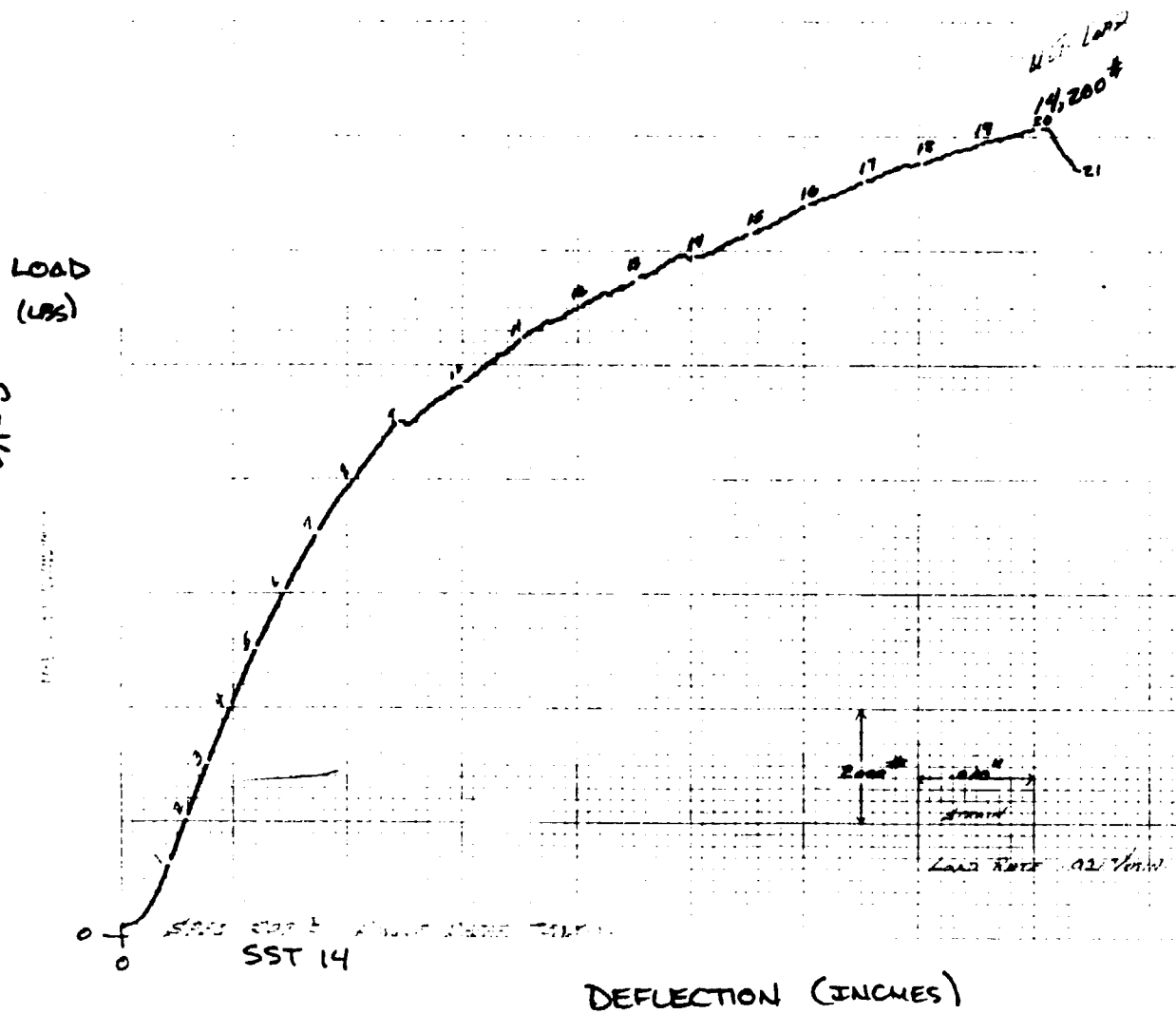
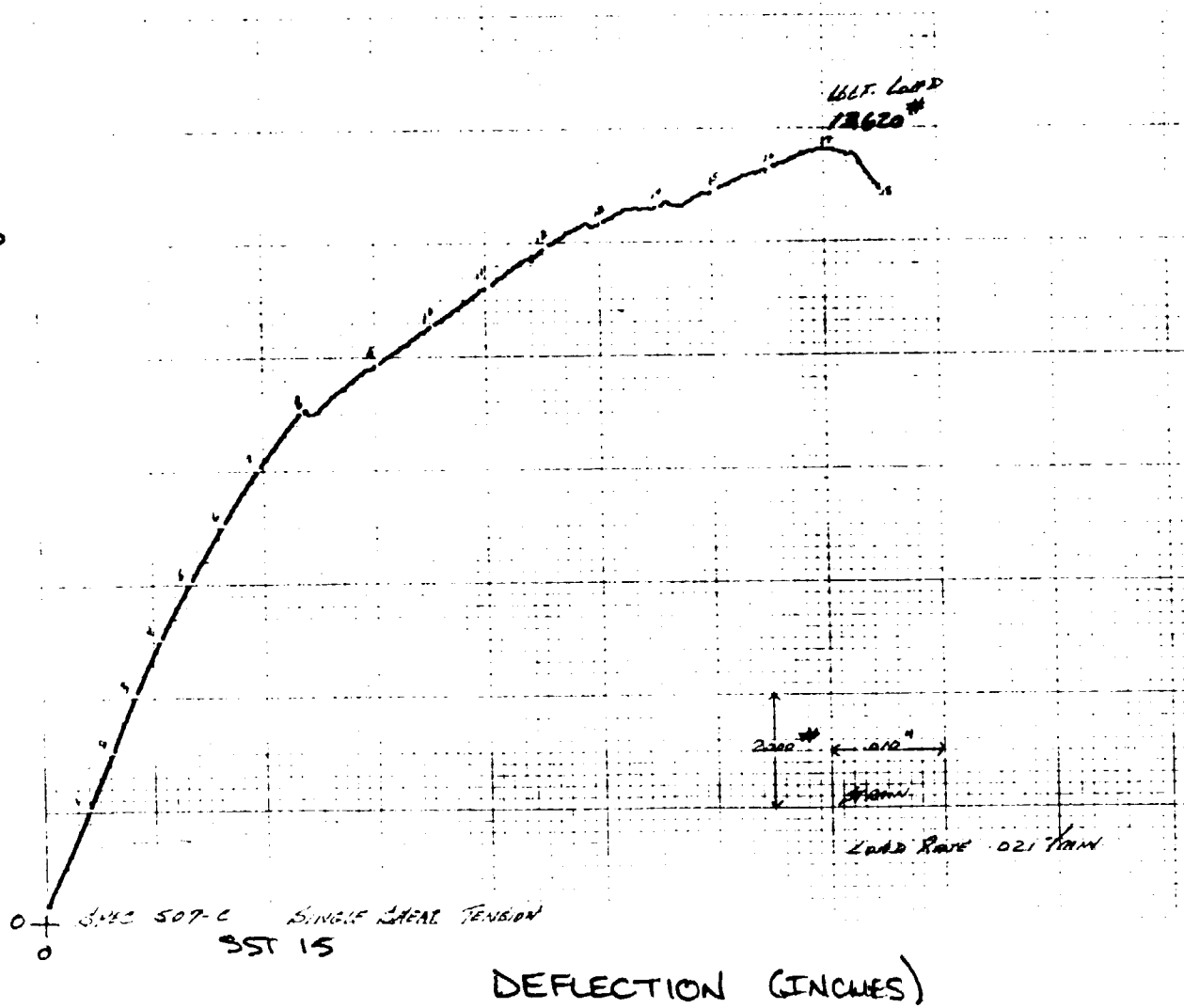
SST 14



READING No.	BOLT HEAD ROTATION (DEGREES)
1	0.20
2	0.32
3	0.43
4	0.60
5	0.76
6	0.94
7	1.13
8	1.36
9	1.59
10	1.91
11	2.19
12	2.35
13	2.51
14	2.69
15	2.88
16	3.06
17	3.27
18	3.45
19	3.64
20	3.82
21	3.87

SST 15

Reading No.	Bolt Head Rotation (Degrees)
1	0.16
2	0.60
3	0.46
4	0.64
5	0.82
6	1.03
7	1.23
8	1.46
9	1.85
10	2.12
11	2.35
12	2.58
13	2.78
14	2.92
15	3.08
16	3.26
17	3.45
18	3.54



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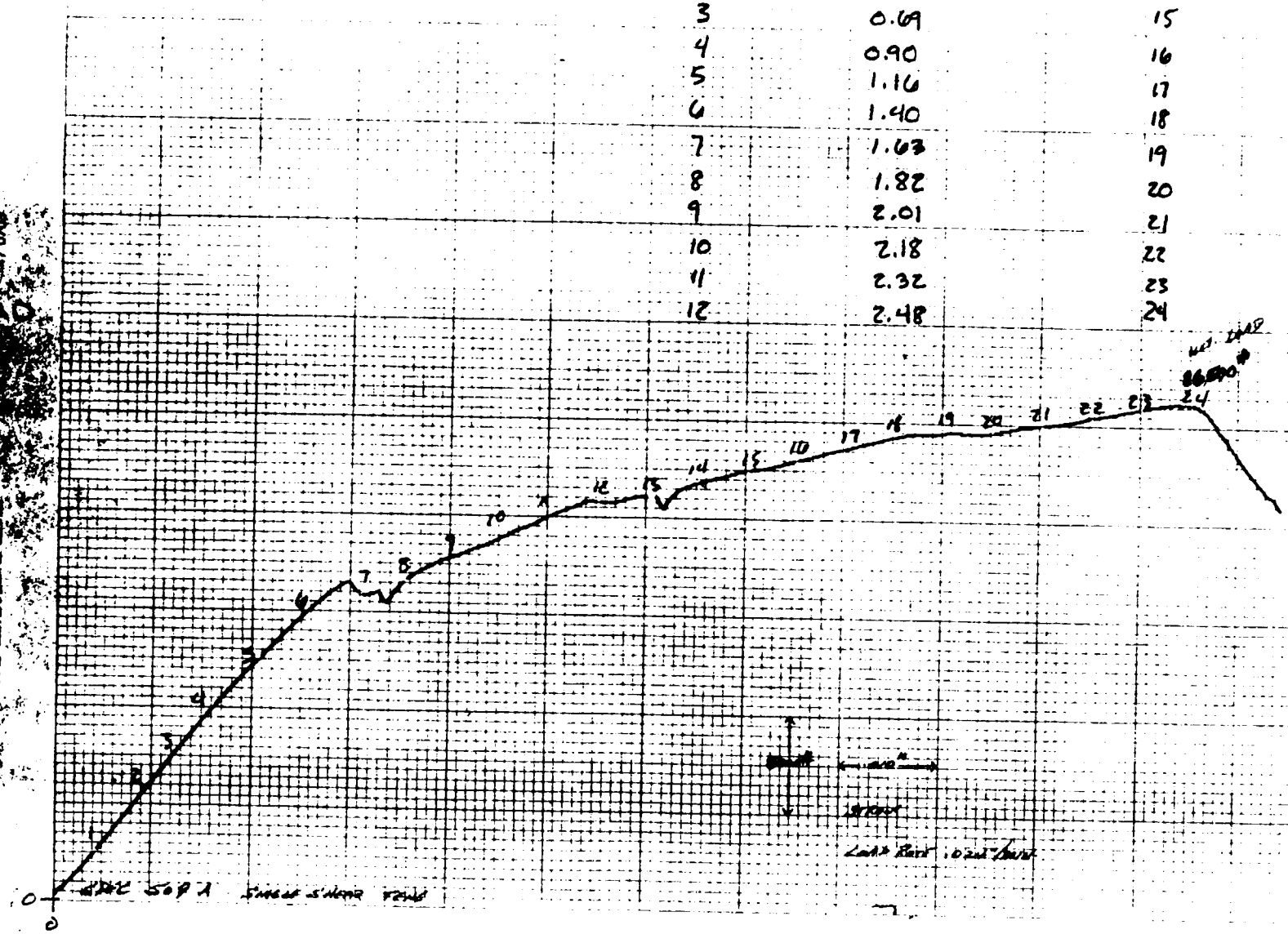
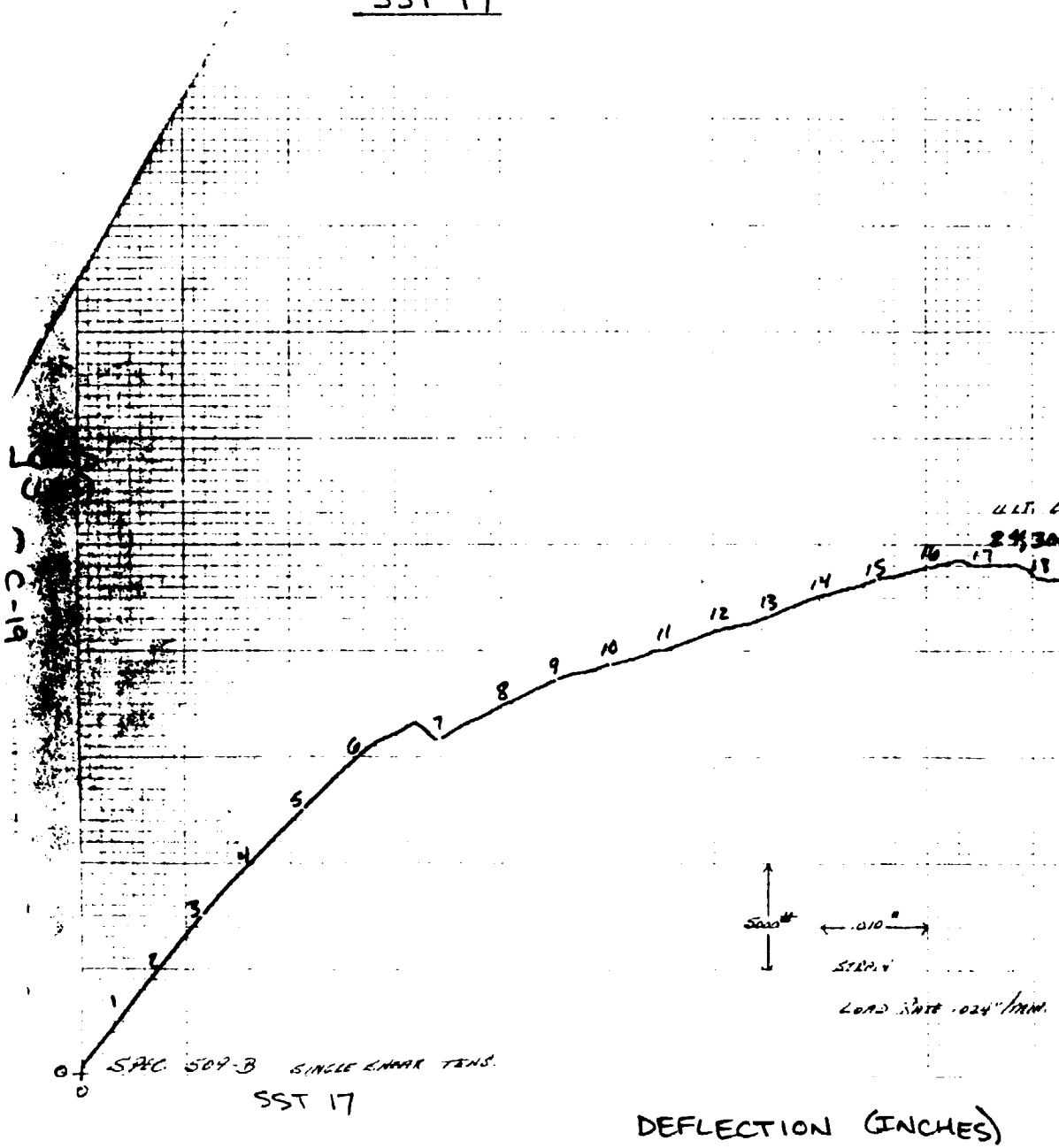
SST 16

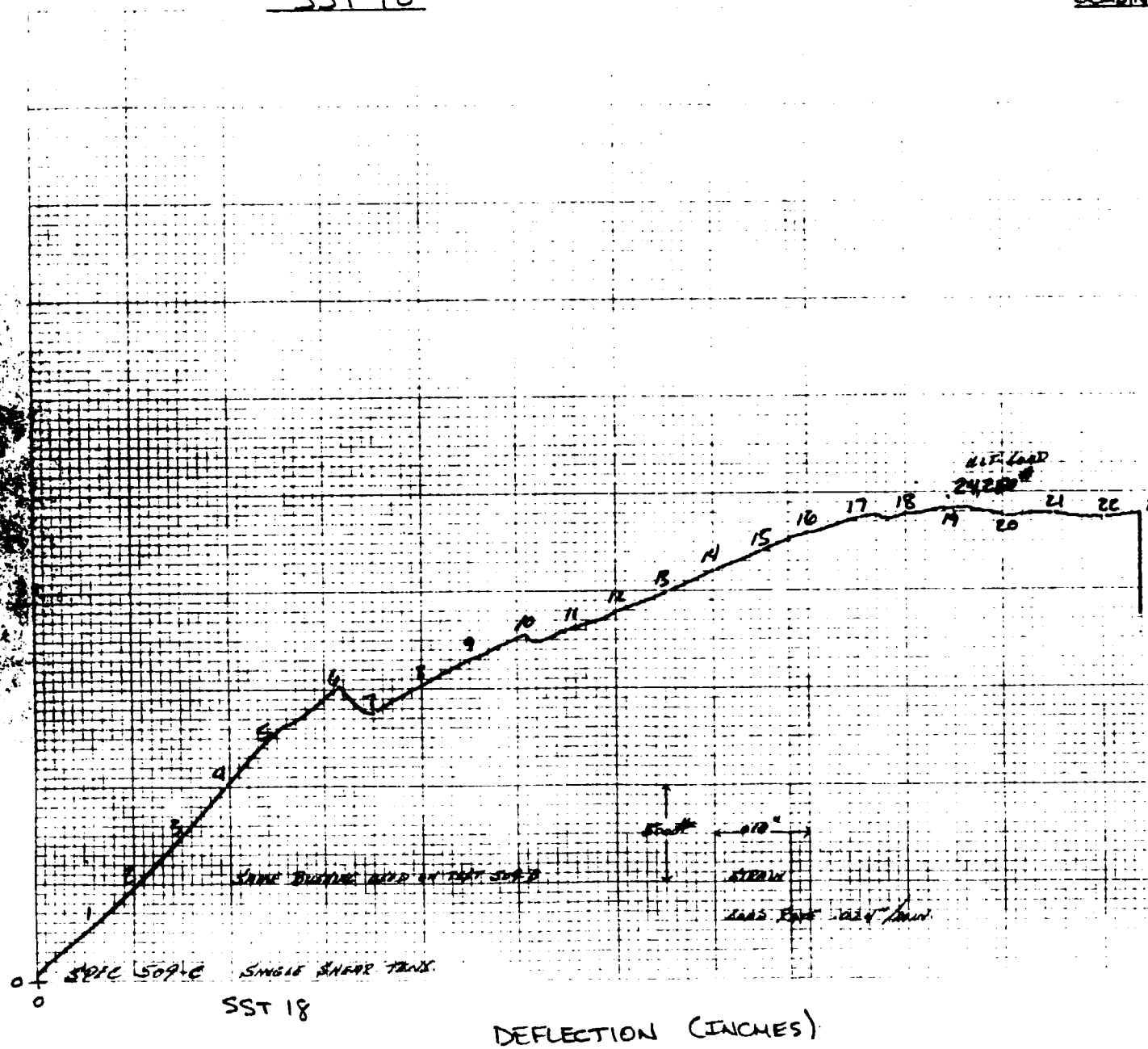
READING NO.	BOLT HEAD ROTATION (DEGREES)	READING NO.	BOLT HEAD ROTATION (DEGREES)
1	0.21	13	2.56
2	0.47	14	2.67
3	0.69	15	2.79
4	0.90	16	2.89
5	1.16	17	3.01
6	1.40	18	3.15
7	1.63	19	3.27
8	1.82	20	3.39
9	2.01	21	3.48
10	2.18	22	3.60
11	2.32	23	3.74
12	2.48	24	3.84





READING NO.	BOLT HEAD ROTATION (DEGREES)
1	0.14
2	0.35
3	0.58
4	0.86
5	1.14
6	1.45
7	1.75
8	2.05
9	2.26
10	2.88
11	2.52
12	2.66
13	2.80
14	2.96
15	3.10
16	3.25
17	3.34
18	3.46
19	3.53
20	3.64

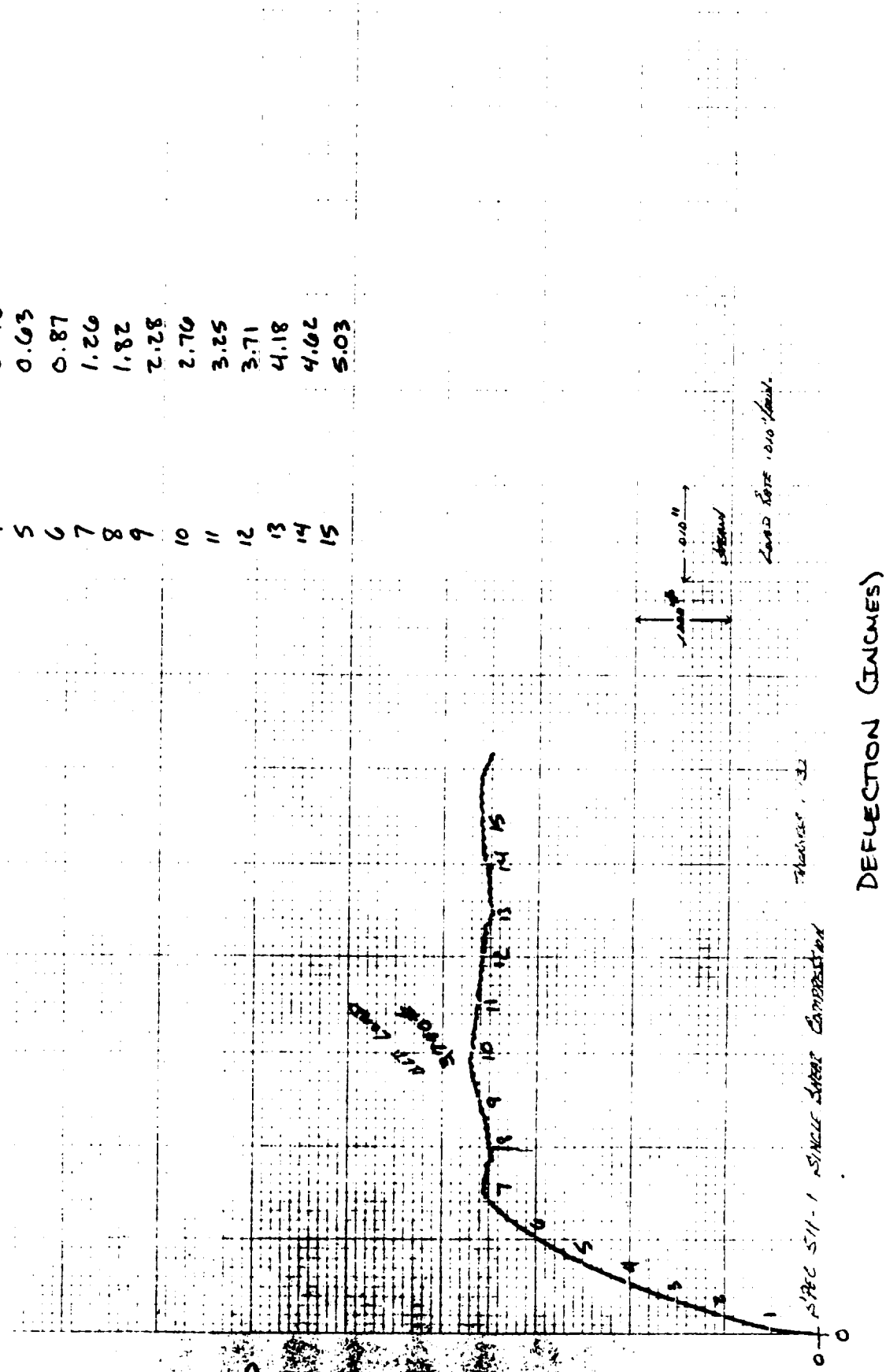
SST 18



READING No.	BOLT HEAD ROTATION (DEGREES)
1	0.35
2	0.64
3	0.94
4	1.22
5	1.50
6	1.85
7	1.92
8	2.09
9	2.30
10	2.44
11	2.51
12	2.63
13	2.77
14	2.94
15	3.08
16	3.24
17	3.36
18	3.48
19	3.57
20	3.67
21	3.74
22	3.81
23	3.86

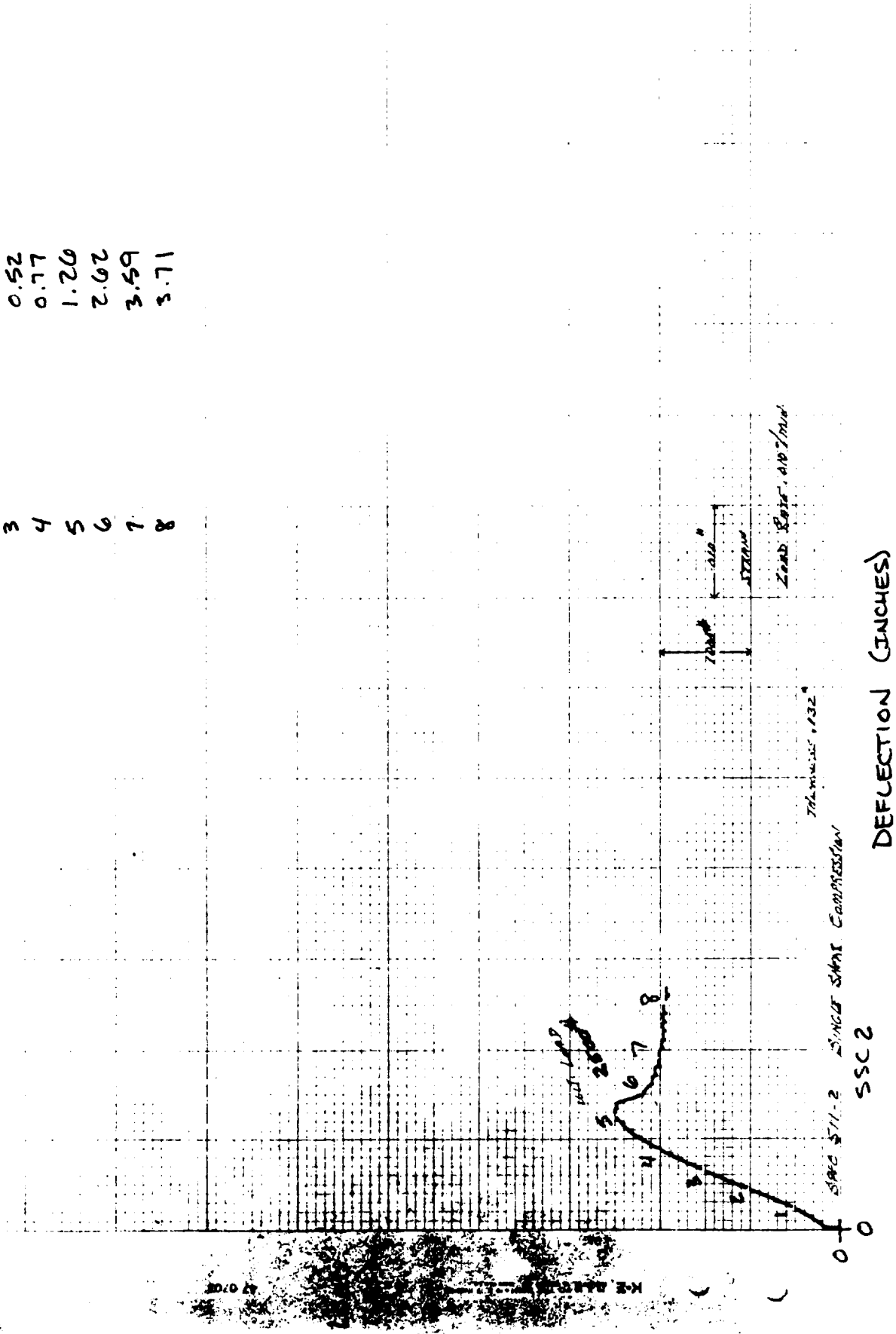
SSC 1

Reading No.	Bolt Head Rotation (Degrees)
1	0.07
2	0.17
3	0.31
4	0.48
5	0.63
6	0.87
7	1.26
8	1.82
9	2.28
10	2.76
11	3.25
12	3.71
13	4.18
14	4.62
15	5.03



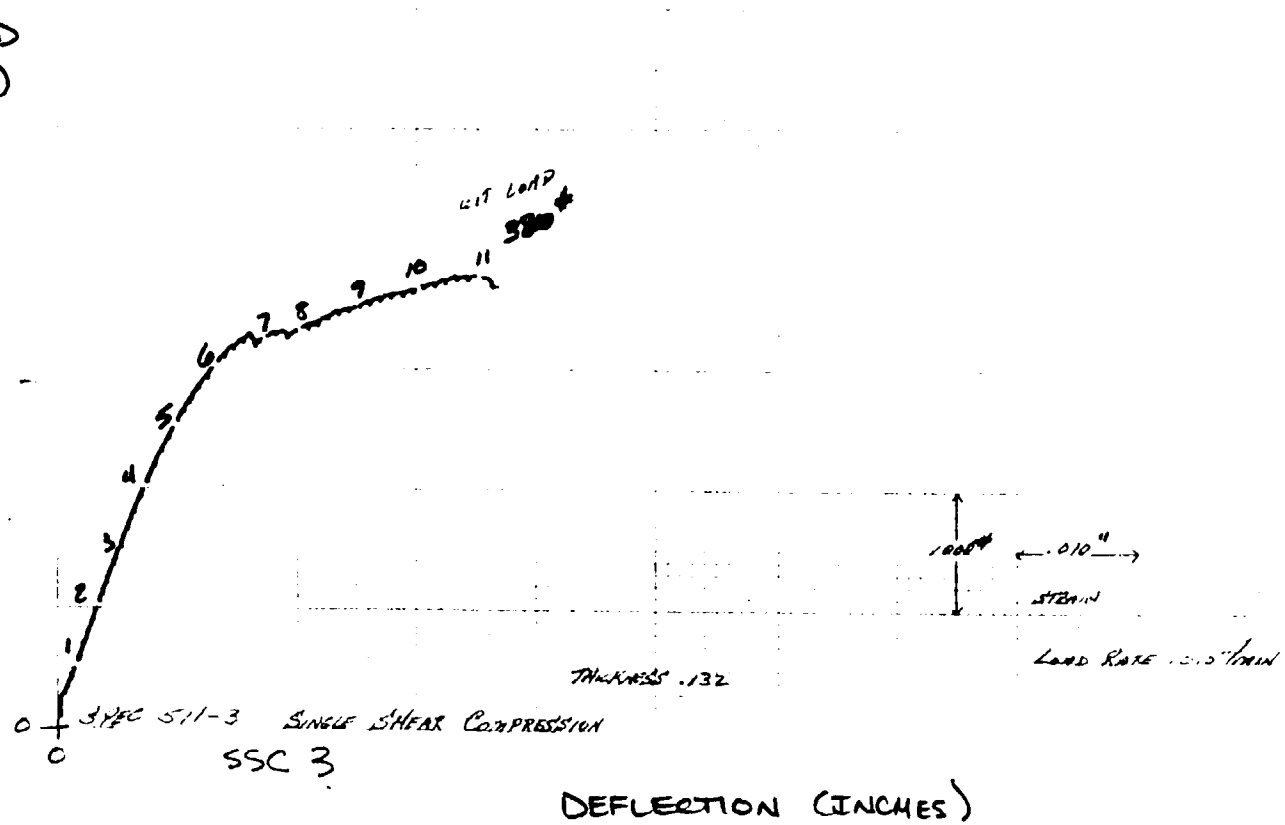
SSC 2

READING NO.	BOLT HEAD ROTATION (DEGREES)
1	0.17
2	0.32
3	0.52
4	0.77
5	1.26
6	2.62
7	3.59
8	3.71



SSC 3

READING NO.	BOLT HEAD ROTATION (DEGREES)
1	0.10
2	0.24
3	0.36
4	0.53
5	0.75
6	1.06
7	1.47
8	1.71
9	2.09
10	2.45
11	2.91



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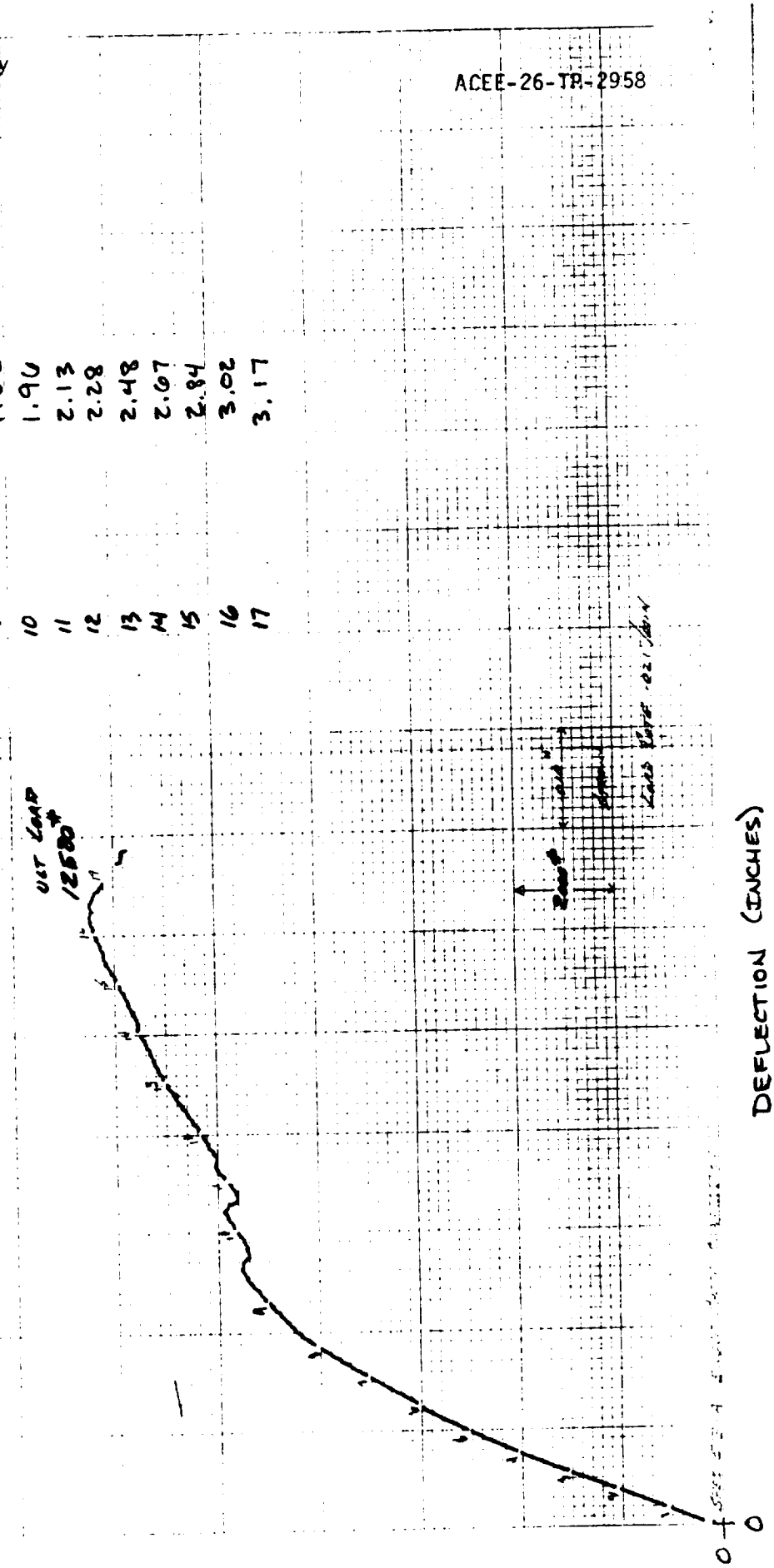
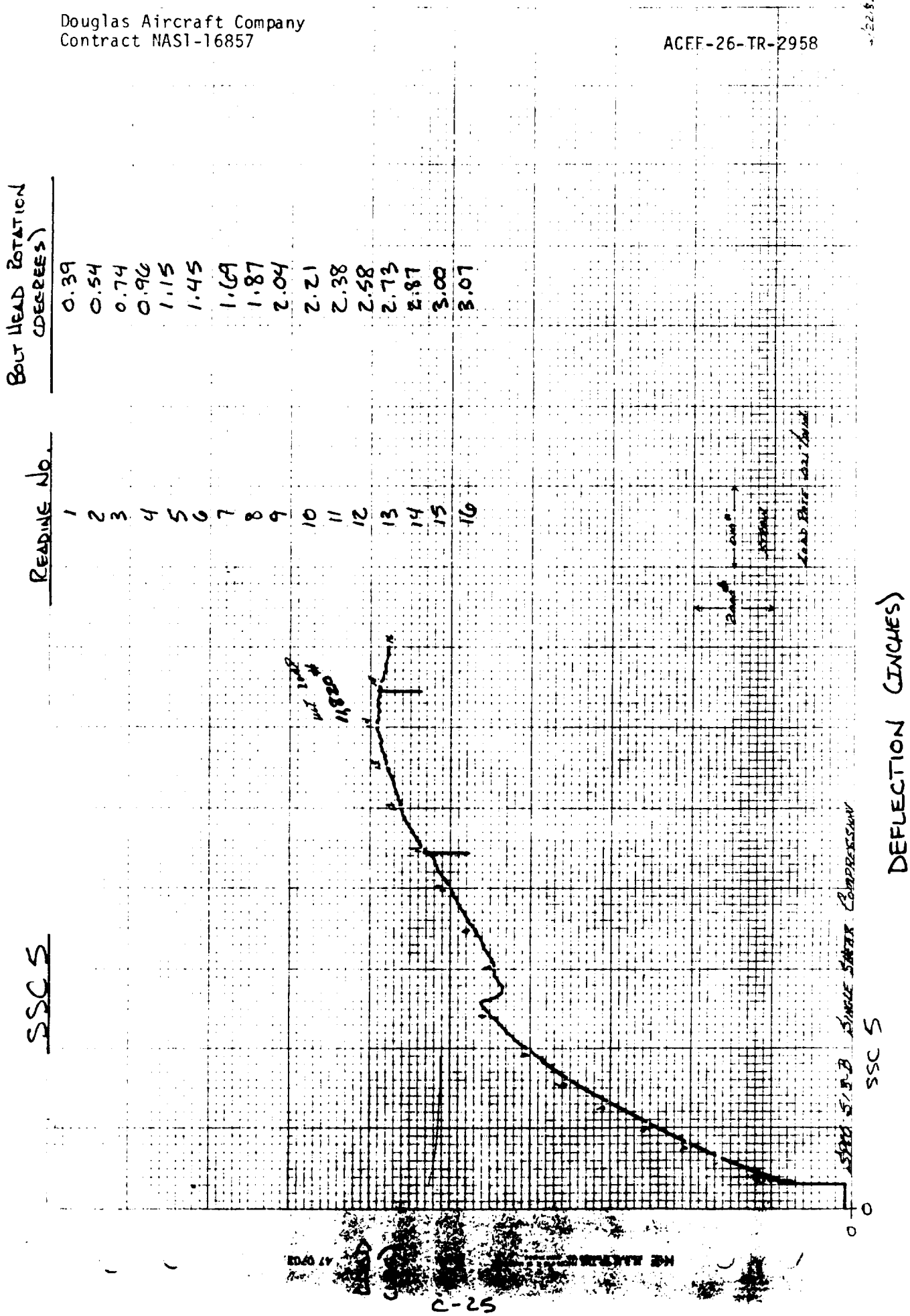
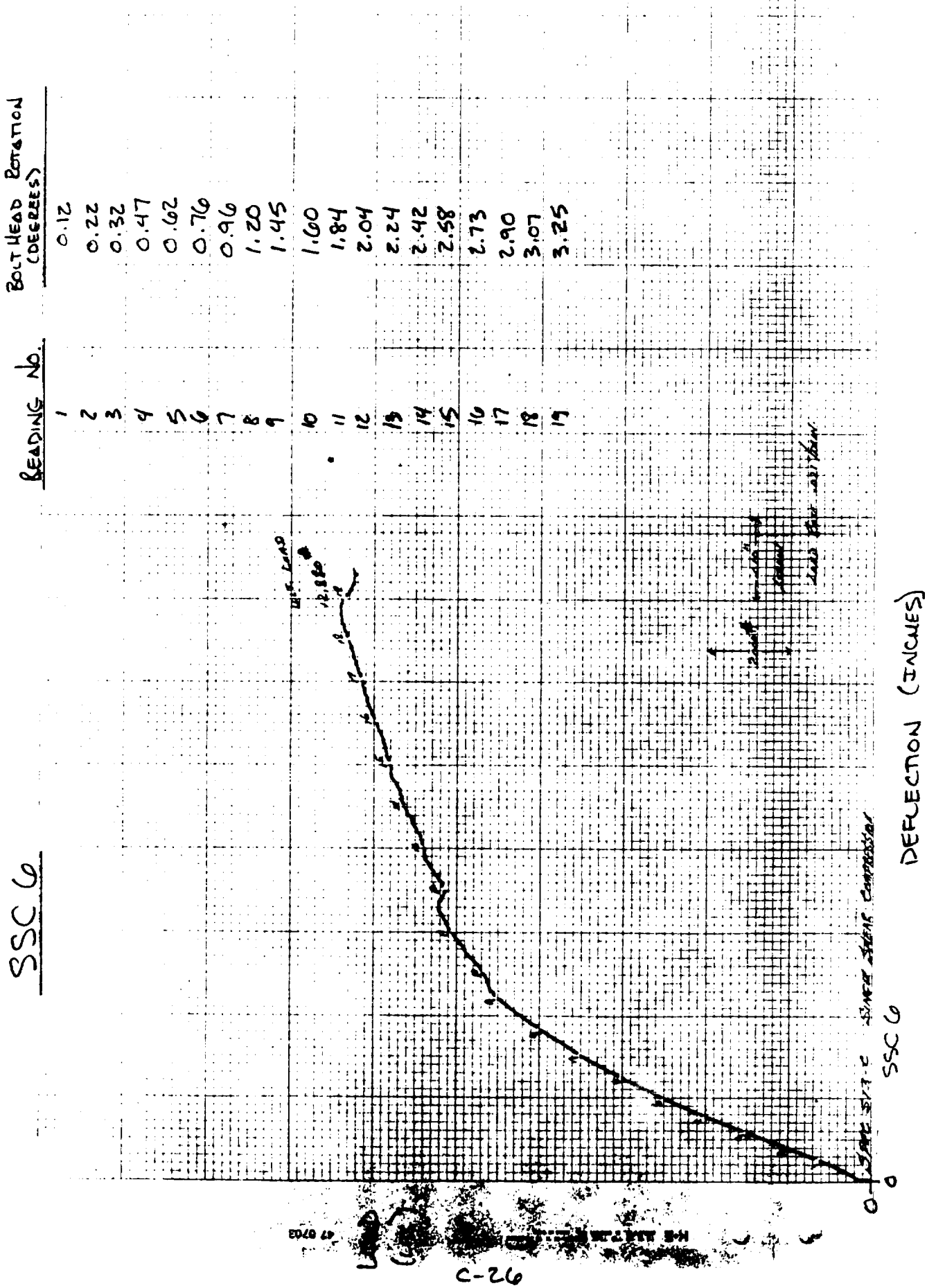
SSC 4

READING NO.	BOLT HEAD ROTATION (DEGREES)
1	0.07
2	0.20
3	0.34
4	0.49
5	0.69
6	0.88
7	1.13
8	1.35
9	1.62
10	1.90
11	2.13
12	2.28
13	2.48
14	2.67
15	2.84
16	3.02
17	3.17



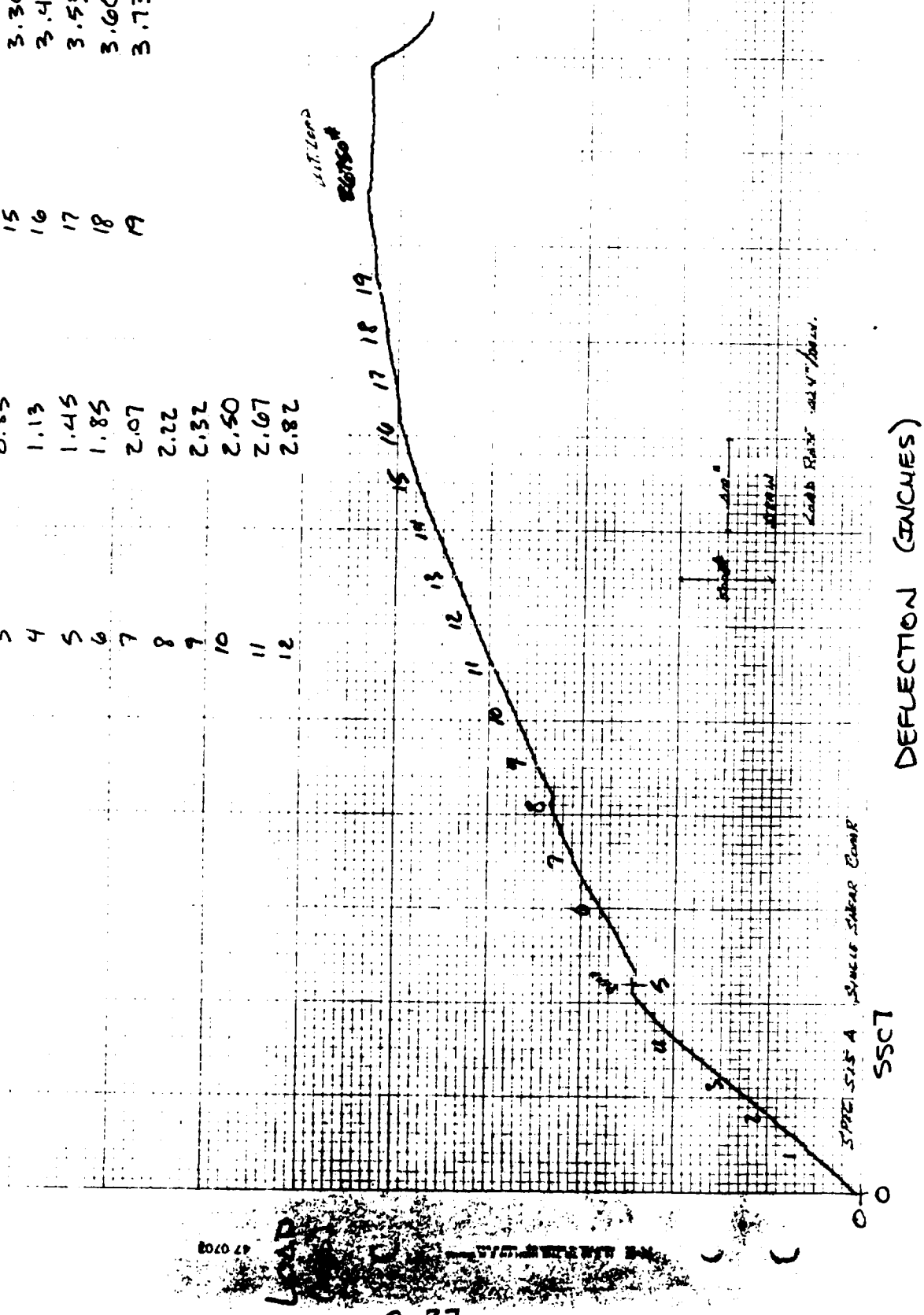

SSC 5
READING NO.
BOLT HEAD ROTATION (DEGREES)
1 0.39
2 0.54
3 0.74
4 0.96
5 1.15
6 1.45
7 1.69
8 1.87
9 2.04
10 2.21
11 2.38
12 2.58
13 2.73
14 2.87
15 3.00
16 3.07
SSC 5
DEFLECTION (INCHES)
0
0


SSC 6
READING No.
BOLT HEAD ROTATION (DEGREES)
1 0.12
2 0.22
3 0.32
4 0.47
5 0.62
6 0.76
7 0.96
8 1.20
9 1.45
10 1.60
11 1.84
12 2.04
13 2.24
14 2.42
15 2.58
16 2.73
17 2.90
18 3.07
19 3.25
0
0
SSC 6
DEFLECTION (INCHES)

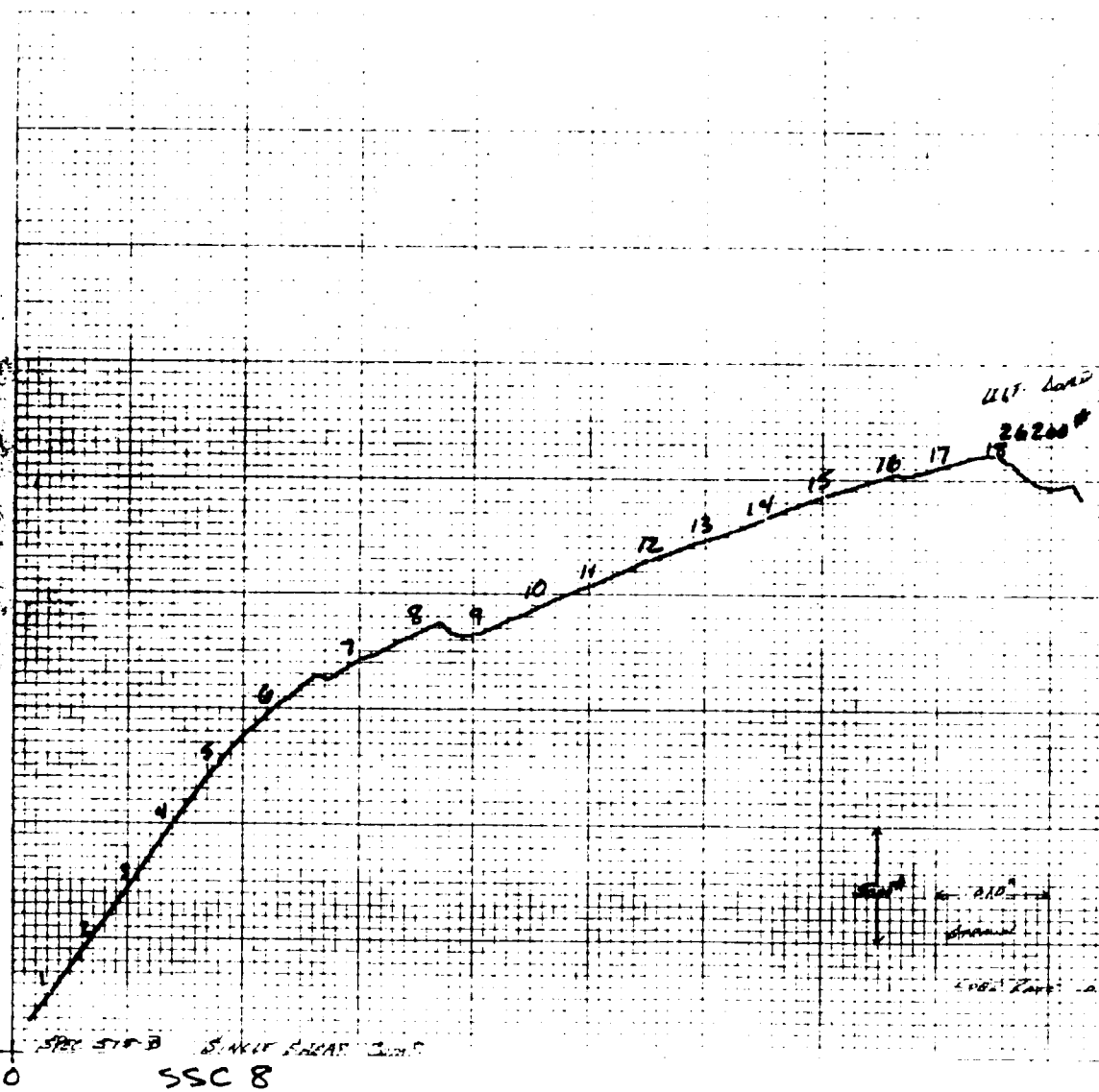
SSC 7

Reading No.	Bolt Head Rotation (Degrees)
1	0.27
2	0.58
3	0.85
4	1.13
5	1.45
6	1.85
7	2.07
8	2.22
9	2.32
10	2.50
11	2.67
12	2.82

Reading No.	Bolt Head Rotation (Degrees)
13	2.97
14	3.12
15	3.30
16	3.43
17	3.53
18	3.60
19	3.73

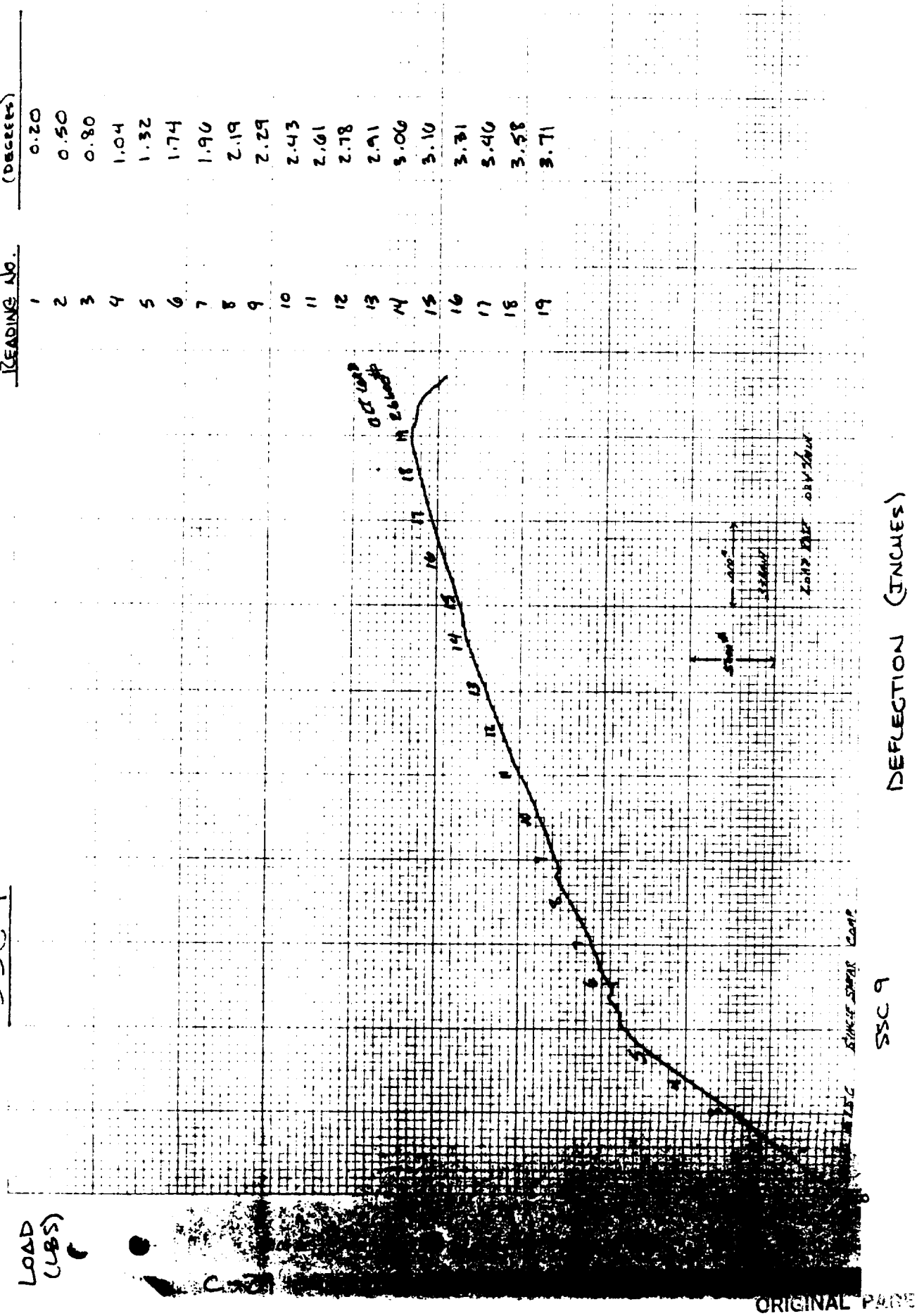


SSC 8



READING No.	BOLT HEAD ROTATION (DEGREES)
1	0.20
2	0.39
3	0.62
4	0.84
5	1.03
6	1.33
7	1.77
8	1.99
9	2.12
10	2.27
11	2.41
12	2.61
13	2.76
14	2.93
15	3.08
16	3.20
17	3.30
18	3.45

SSC 9



READING NO.	BOLT HEAD ROTATION (DEGREES)
1	0.20
2	0.50
3	0.80
4	1.04
5	1.32
6	1.74
7	1.96
8	2.19
9	2.29
10	2.43
11	2.61
12	2.78
13	2.91
14	3.06
15	3.10
16	3.31
17	3.46
18	3.58
19	3.71

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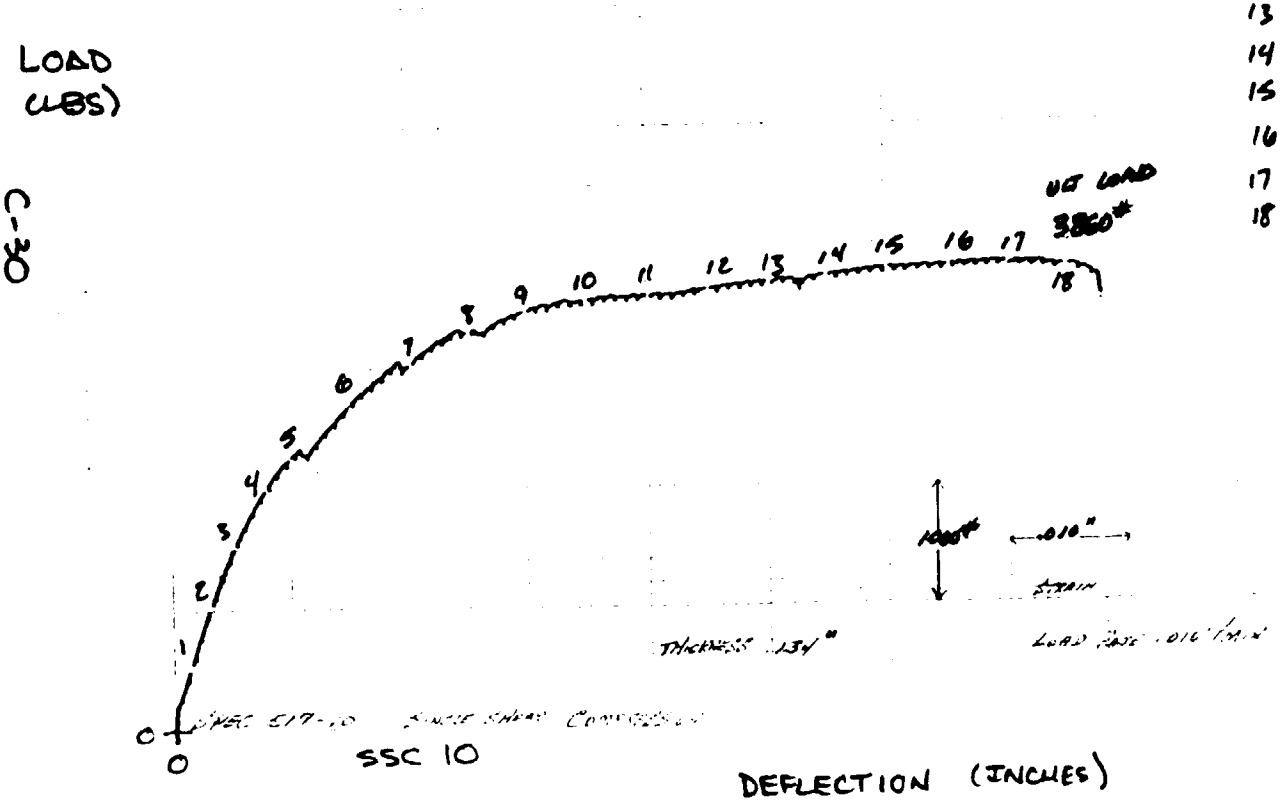
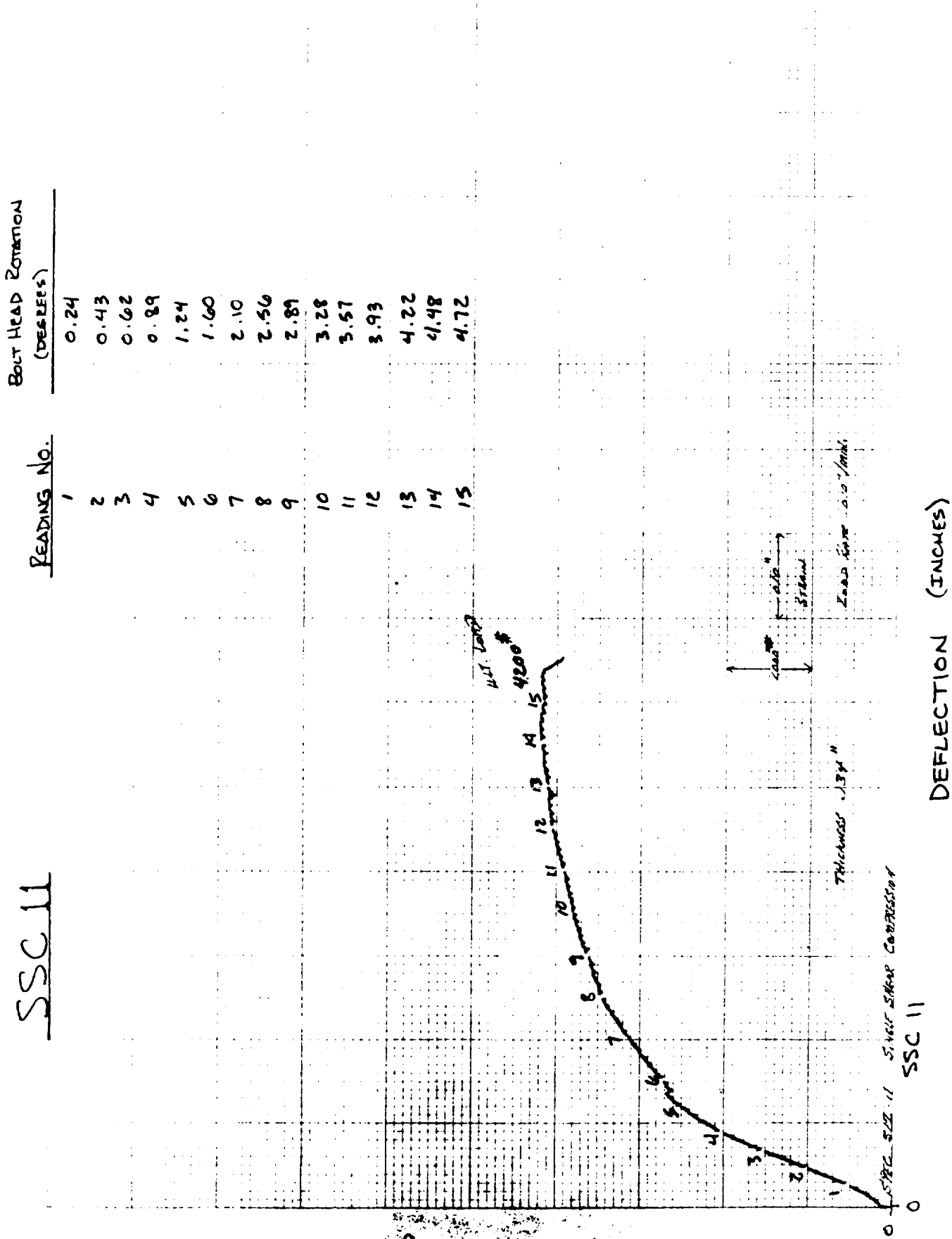
SSC 10

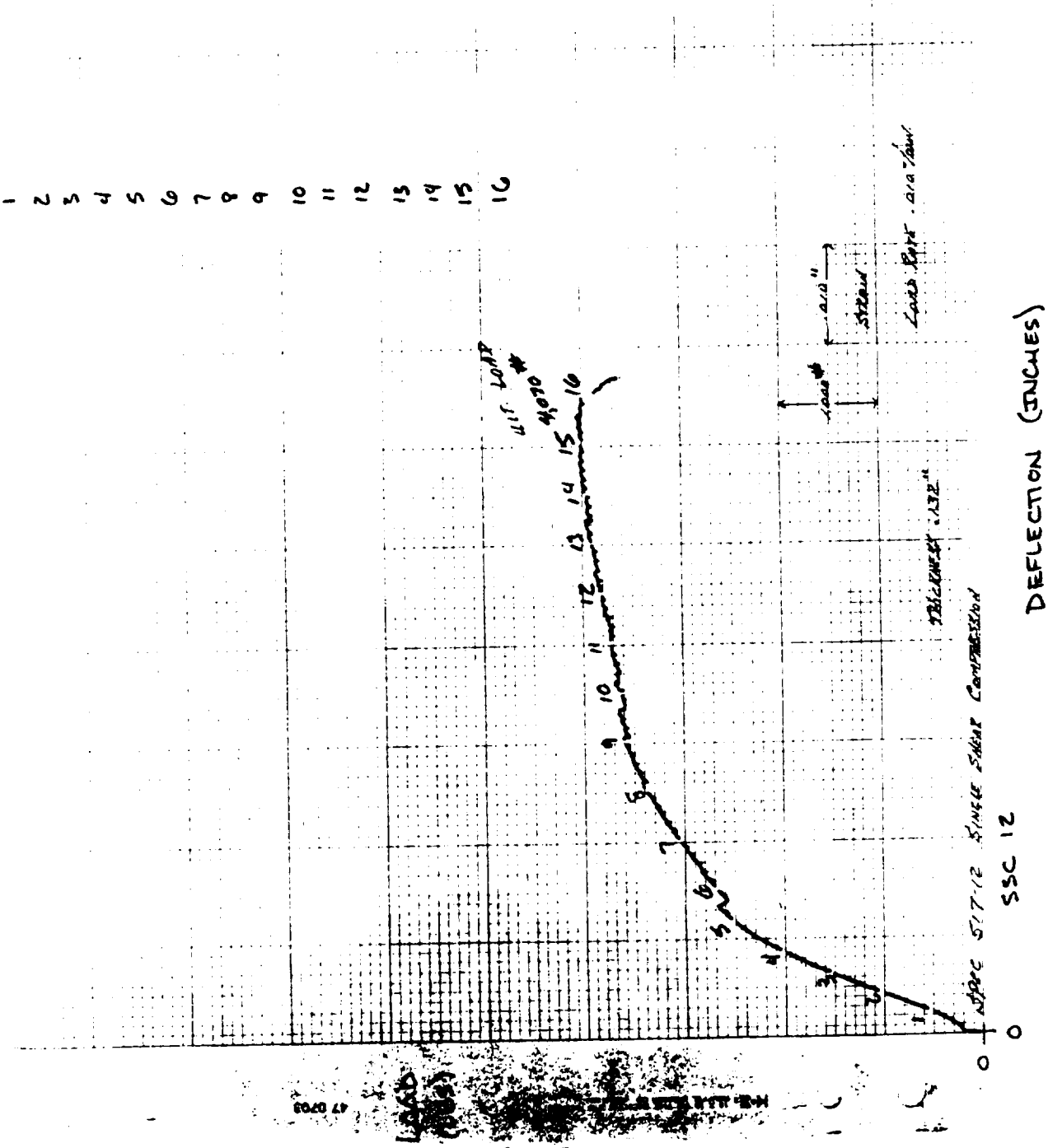
Reading No.	Bolt Head Rotation (Degrees)
1	0.15
2	0.32
3	0.58
4	0.92
5	1.22
6	1.75
7	2.21
8	2.58
9	2.85
10	3.24
11	3.63
12	3.99
13	4.41
14	4.71
15	5.08
16	5.42
17	5.74
18	6.09



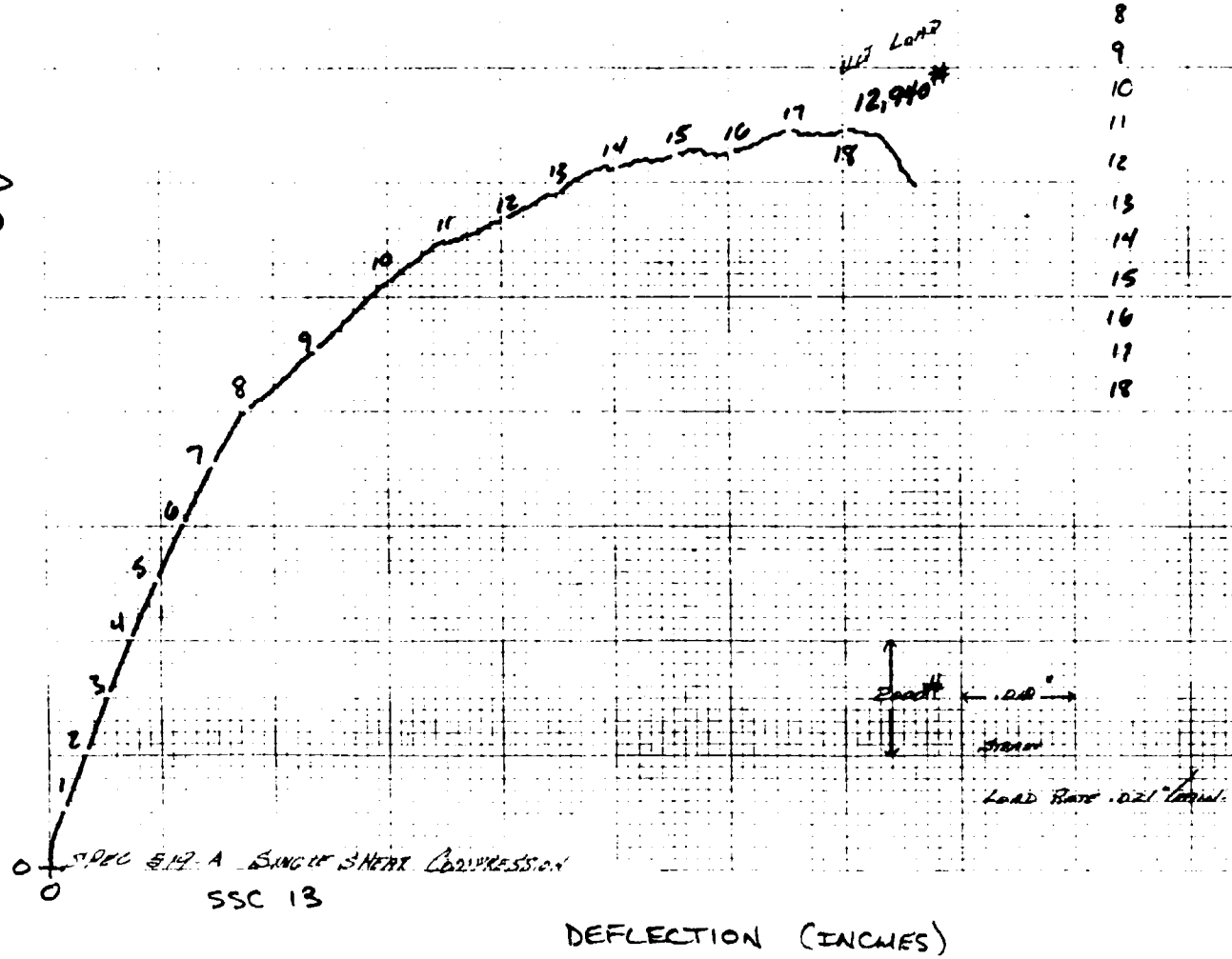

SSC 11
Bolt Head Rotation (Degrees)
Reading No.
1 0.24
2 0.43
3 0.62
4 0.89
5 1.24
6 1.60
7 2.10
8 2.56
9 2.89
10 3.28
11 3.57
12 3.93
13 4.22
14 4.48
15 4.72
1st Load
4200#
Load
Strain
Load Rate 0.10"/min.
Thickness .134"
Single Shear Compression
SSC 11
Deflection (Inches)
Load (#)
0
0

SSC 12

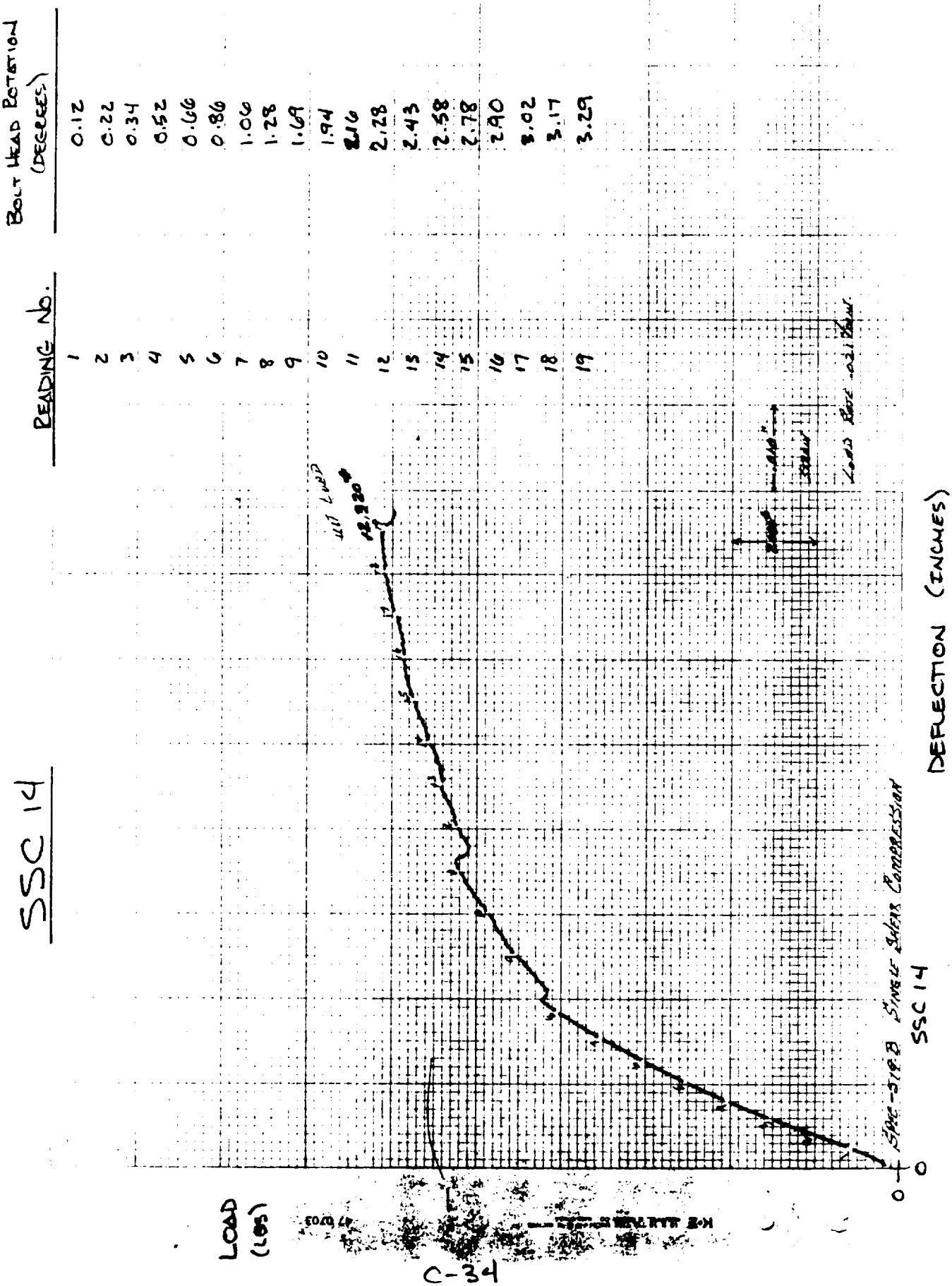
Reading No.	Bolt Head Rotation (Degrees)
1	0.19
2	0.36
3	0.58
4	0.82
5	1.23
6	1.61
7	2.07
8	2.50
9	2.84
10	3.15
11	3.42
12	3.68
13	3.95
14	4.24
15	4.58
16	4.87



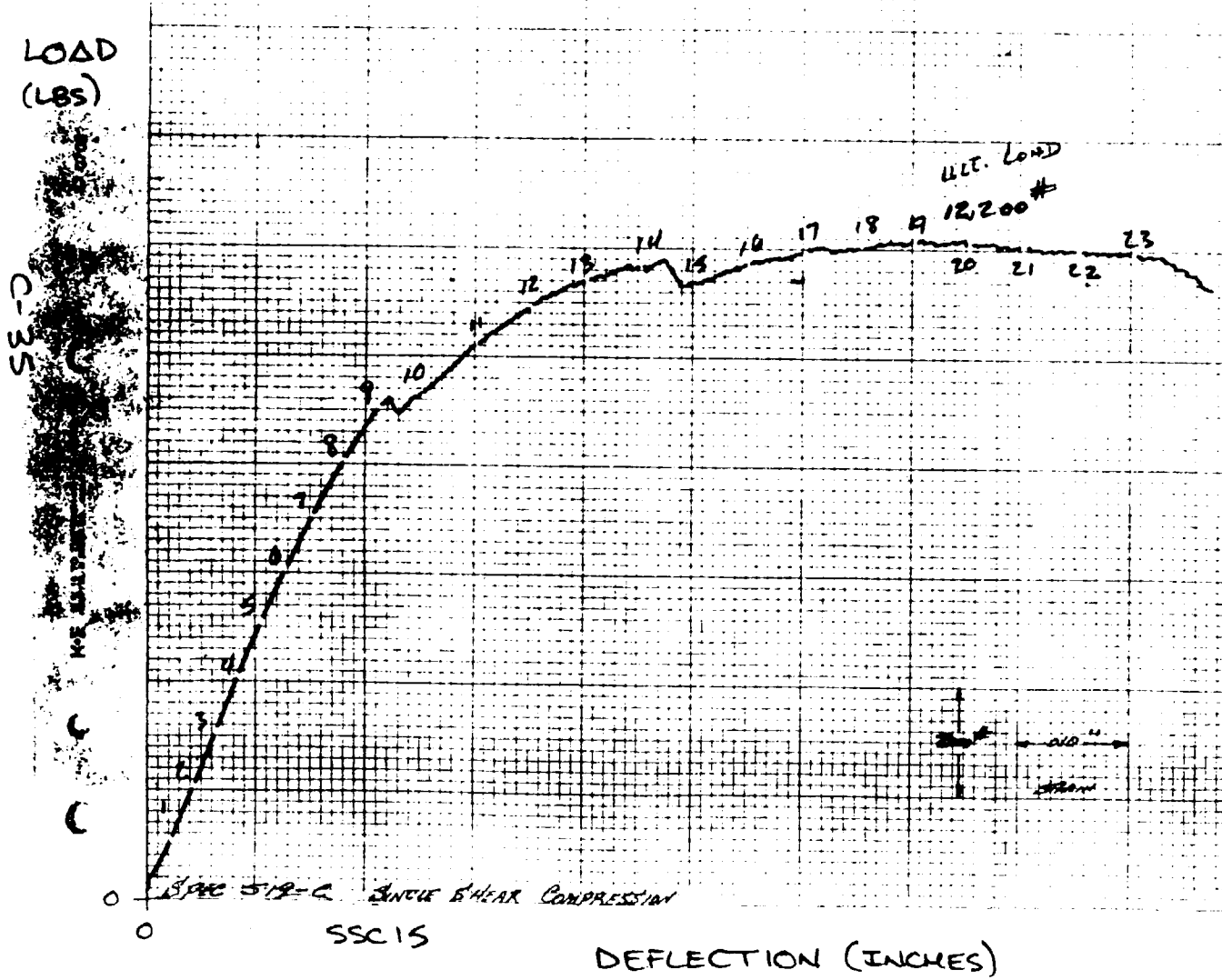
SSC 13



READING NO.	BOLT HEAD ROTATION (DEGREES)
1	0.05
2	0.17
3	0.32
4	0.49
5	0.66
6	0.83
7	1.03
8	1.25
9	1.64
10	1.99
11	2.18
12	2.33
13	2.53
14	2.70
15	2.84
16	2.97
17	3.14
18	3.24

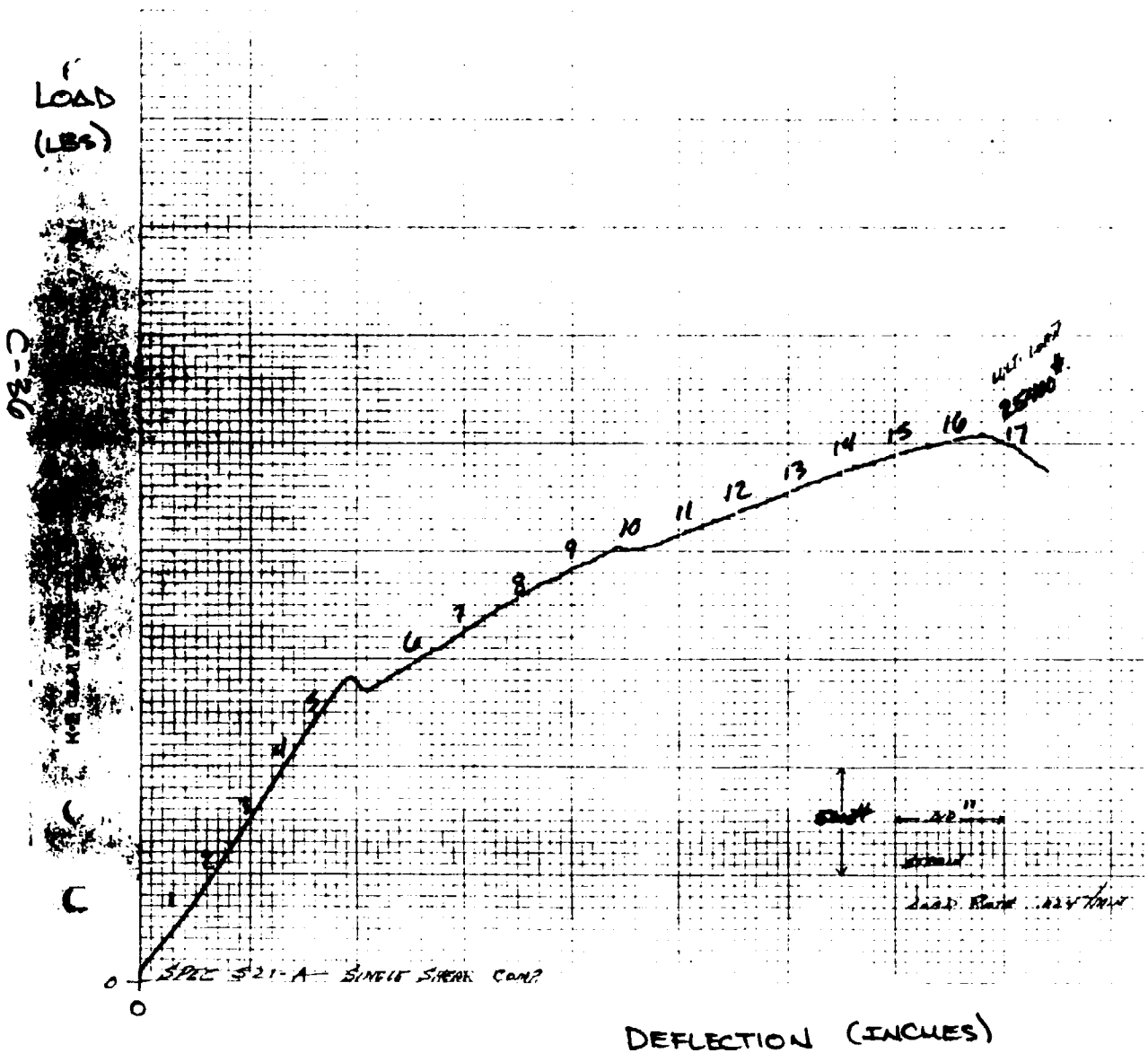

SSC 14
BOLT HEAD ROTATION (DEGREES)
READING NO.
1 0.12
2 0.22
3 0.34
4 0.52
5 0.66
6 0.86
7 1.06
8 1.28
9 1.69
10 1.94
11 2.16
12 2.28
13 2.43
14 2.58
15 2.78
16 2.90
17 3.02
18 3.17
19 3.29
LOAD (LBS)
DEFLECTION (INCHES)
0
0
SSC 14

SSC 15



READING NO.	BOLT HEAD ROTATION (DEGREES)
1	0.10
2	0.22
3	0.37
4	0.52
5	0.67
6	0.81
7	0.98
8	1.18
9	1.40
10	1.60
11	1.84
12	2.09
13	2.31
14	2.51
15	2.66
16	2.71
17	2.85
18	2.98
19	3.12
20	3.22
21	3.30
22	3.40
23	3.47

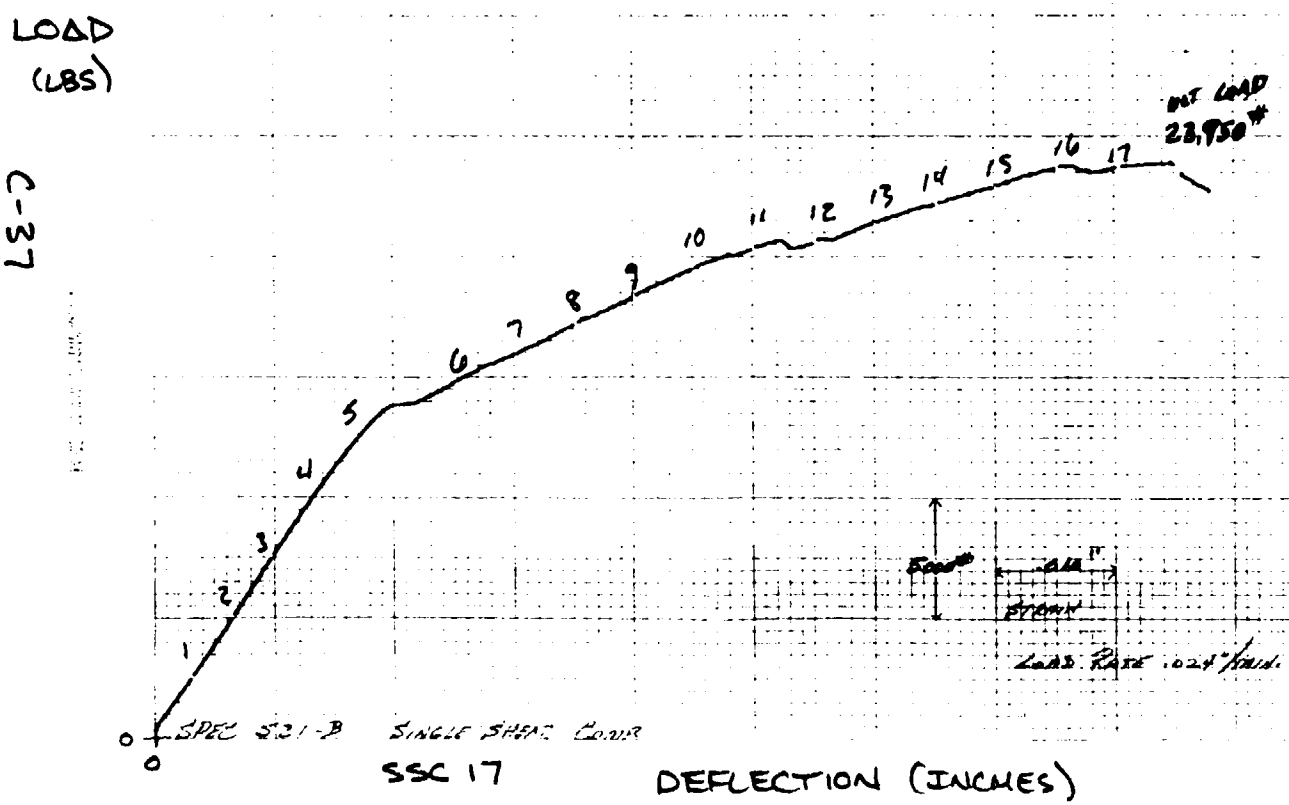
SSC 16



READING No.	BOLT HEAD ROTATION (DEGREES)
1	0.20
2	0.42
3	0.64
4	0.86
5	1.11
6	1.55
7	1.77
8	2.02
9	2.21
10	2.36
11	2.46
12	2.58
13	2.71
14	2.88
15	3.00
16	3.10
17	3.20

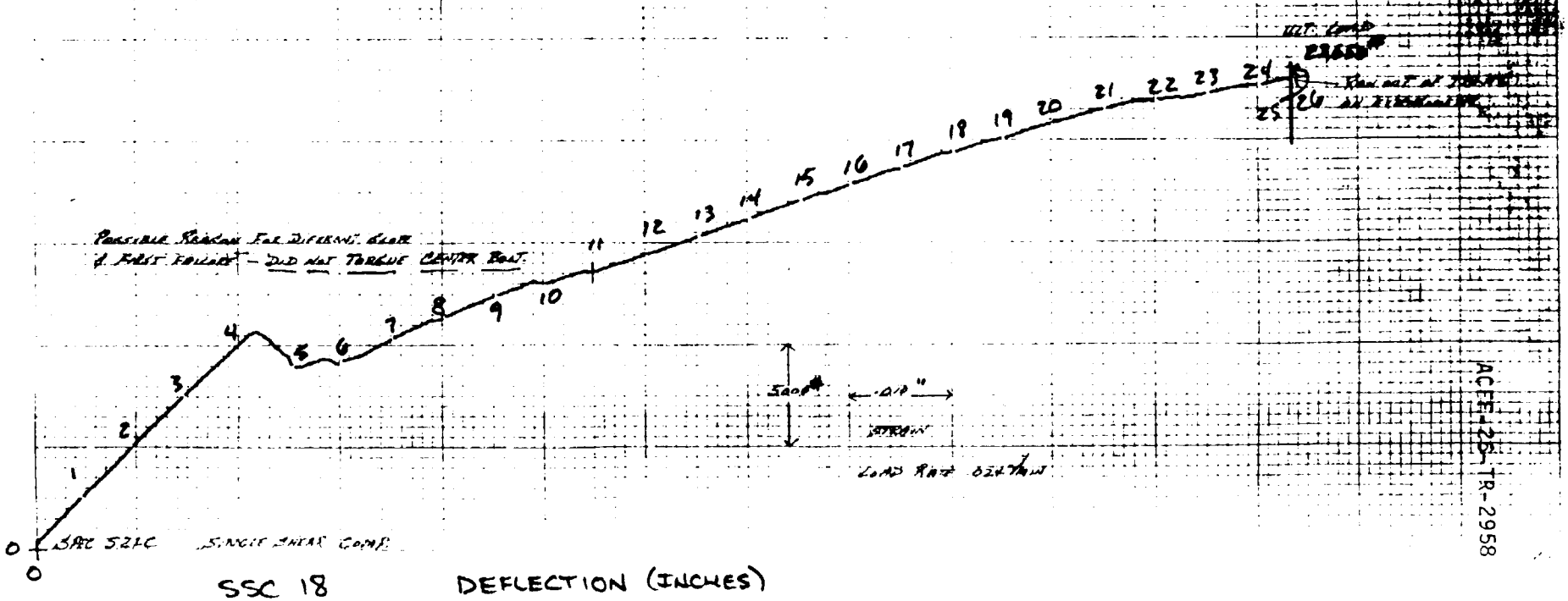
SSC 17

Reading No.	Bolt Head Rotation (Degrees)
1	0.15
2	0.35
3	0.54
4	0.79
5	1.06
6	1.48
7	1.73
8	1.93
9	2.12
10	2.30
11	2.42
12	2.50
13	2.59
14	2.74
15	2.84
16	2.99
17	3.09
18	3.19



SSC 18

READING NO.	BOLT HEAD ROTATION (DEGREES)	READING NO.	BOLT HEAD ROTATION (DEGREES)
1	0.37	14	3.48
2	0.83	15	3.58
3	1.25	16	3.71
4	1.70	17	3.83
5	2.15	18	3.96
6	2.38	19	4.11
7	2.58	20	4.21
8	2.75	21	4.36
9	2.93	22	4.46
10	3.08	23	4.56
11	3.15	24	4.64
12	3.25	25	4.79
13	3.35	26	4.97



SSC 18