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STRUCTURAL SIZING OF THE EDIN0620 BODY COMPONENTS USING THE APAS STRUCTURAL SYNTHESIS COMPUTER PROGRAM.

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PREFACE

This report concerns the use of a structural synthesis computer program to design components for a heavy lift launch vehicle defined by a study designated EDIN0620. Each stage of the two-stage vehicle was divided into three components: nose structure, tank walls and aft skirt. A loads program was used to determine vehicle shears, bending moments and axial loads. Two design loading conditions were considered: (1) maximum dynamic pressure during launch and (2) staging. A comparison has been made between results from the structures program and the results of a weight estimating program which used historical data in determining component weights. This study was performed under contract NAS9-14520 under the supervision of Mr. Robert W. Abel.

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STRUCTURAL SIZING OF THE EDIN0620 BODY COMPONENTS USING THE APAS STRUCTURAL SYNTHESIS COMPUTER PROGRAM.

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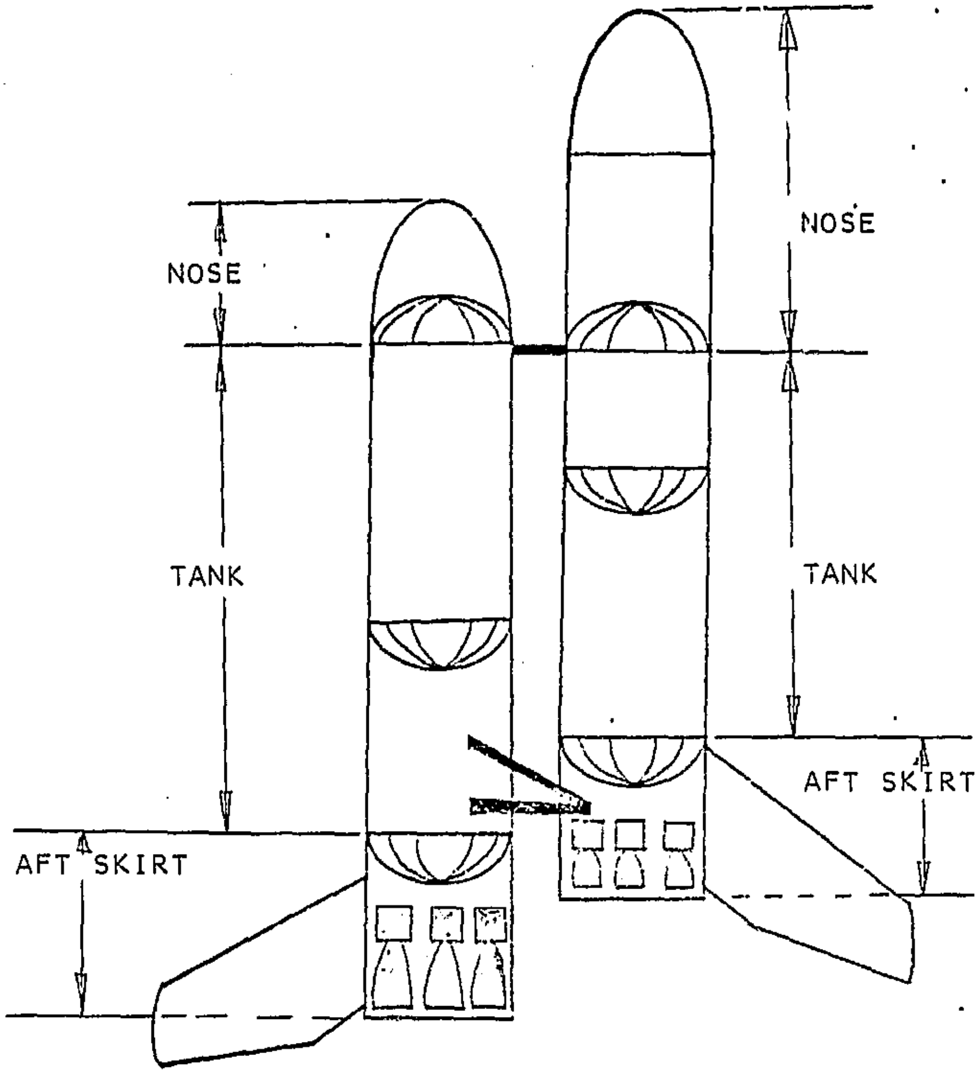
SUMMARY AND INTRODUCTION

A study designated EDIN0620 has been conducted to define a heavy lift launch vehicle for the Solar Power Satellite System (Reference 1). This system would require the launch vehicle fleet to deliver approximately 500,000,000 pounds to a low earth assemble orbit for each power satellite.

The configuration investigated was a two stage (belly to belly configuration) series burn, winged vehicle with a payload capability of 1,000,000 pounds. The booster was a heat sink non-powered flyback stage that required fourteen LOX/C_3H_8 high chamber pressure engines for boost. Landing speed for both the booster and second stage was 220 knots. The second stage was powered by eight uprated shuttle type main engines and its wings were sized to permit un-powered glide back to the launch site after one orbit. Weight estimating relations (WER's) based on a 1995 technology level (reference 2), were used in determining component weights.

This report concerns the use of a structural synthesis program, APAS (reference 3), to design components for the EDIN0620 configurations. Two loading conditions - max $\underline{q}$ and staging - were used as the design conditions. A loads program (reference 4) was used in determining vehicle shears, bending moments and axial loads at these two conditions and the resulting load distributions were then input into APAS. Each stage was divided into three components: nose structure, tank walls and aft skirt. Each component was designed separately to allow for various pressure differentials.

The resulting component weights have been included in this report and a comparison has been made between the WER results and the APAS results. A discussion of the difference between these two results is also included. Figure 1 contains a summary of the results for each stage.



STAGE 1

COMPONENT	WER EST.	APAS EST.
NOSE STRUCTURE	10463.	4080.34
TANK	96790.	158966.68
AFT SKIRT	103653.	77411.28

STAGE 2

COMPONENT	WER EST.	APAS EST.
PAYLOAD BAY	64376.	15345.8
TANK	119487.	67868.0
AFT SKIRT	23374.	19701.2

FIGURE 1 SUMMARY OF RESULTS.

ASSUMPTIONS AND FLIGHT CONDITIONS

APAS, a structural synthesis program of reference 3, has been used to size structural elements and to determine basic component weights for EDIN0620. Those components designed included nose structures, tank walls and aft skirt of the first and second stage. The design was based on two loading conditions: (1) maximum dynamic pressure during launch and (2) staging (maximum g-loading). Although the trajectory calls for a zero lift launch, an angle of attack of 5° was assumed. This was to account for gust loads. Aluminum 2024-T6 was the design material assuming a temperature of 80°F. Skin stiffners were integral tee as illustrated below.

ALUMINUM 2024-T6 MATERIAL PROPERTIES AT ROOM TEMPERATURE (80°)

ULTIMATE TENSILE STRENGTH - 62.KSI

COMPRESSIVE YIELD STRENGTH - 49.KSI

ULTIMATE SHEAR STRENGTH - 37.KSI

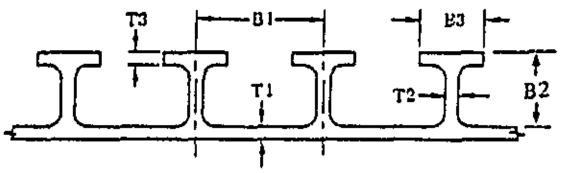
MODULUS OF ELASTICITY IN COMPRESSION - 10 MSI

MODULUS OF ELASTICITY IN TENSION - 10.2 MSI

SHEAR MODULUS - 4.0 MSI

DENSITY - 0.1 LBS./IN.^{3}

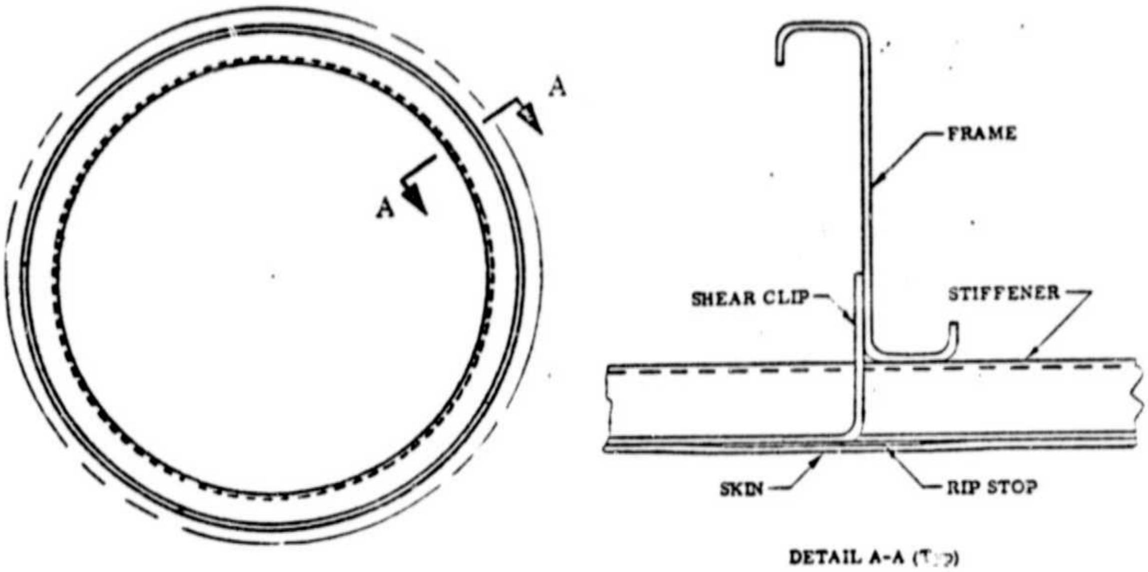
TYPE 2 INTEGRAL TEE



The thickness variables (T's) and spacing variables (B's) were optimized using a two step procedure. First, the T's and B's were adjusted until each element had a zero margin of safety or until a minimum gage constraint was encountered. Second, margins of safety were maximized while holding structural weight constant. This process continued until convergence was obtained for the two static strength load conditions.

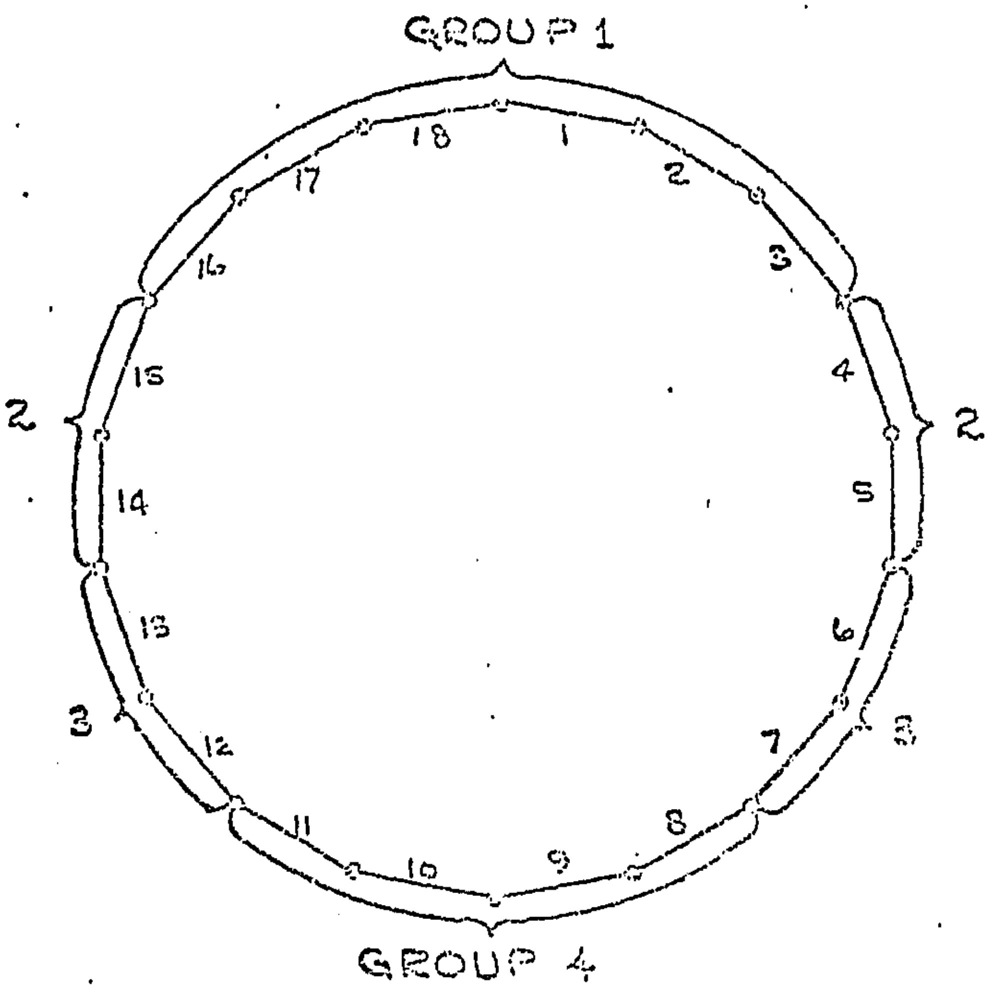
The minimum gage constraints for the T's was 0.01 inches and the minimum for the B's was 1.0 inch.

Zee type rings were employed with a 25 inch frame spacing as illustrated below:



ZEE TYPF RING FRAME

Symmetry grouping was used to allow all panels in a group to have the same design. In this manner, fuselage symmetry was maintained. The symmetry grouping used for EDIN0620 is shown in the following sketch:



EDIN0620 Symmetry Grouping

EDIN0620's unique belly to belly configuration required determination of the forces in the attach pins. This was done by summing forces and moments at the two loading conditions. The results were as follows:

```
1ST ATTACH PIN AT X= 53.05
    AXIAL FORCE=  -.1468+08
    NORMAL FORCE=  -.3463+07
2ND ATTACH PIN AT X=168.99
    NORMAL FORCE=   .1077+08
```

MAX Q ∿ 2.02 g's

```
1ST ATTACH PIN AT X= 53.05
    AXIAL FORCE=  -.2355+08
    NORMAL FORCE=  -.3525+07
2ND ATTACH PIN AT X=168.99
    NORMAL FORCE=   .1097+08
```

STAGGING ∿ 3.24 g's

X, in this case, is referenced from the nose of the second stage. The negative normal force at the first pin indicates tension while the second pin is in compression. The negative axial force is the result of the booster thrust acting on the second stage.

Air load distributions were also used in determining vehicle loads (see figures 2 and 3). The curves were integrated by hand and the results are tabulated below:

AIRLOAD DISTRIBUTION - 2nd. STAGE

DIST. FROM NOSE (FEET)	$N/q\ \alpha$
5.	1.75
15.	5.0
25.	8.0
35.	10.75
45.	6.0
50.	0.0
55.	5.025
65.	10.75
75.	11.00
85.	9.5
95.	5.5
105.	1.375
115.	-1.125
125.	-2.0
135.	-1.5
145.	-0.625
155	

AIRLOAD DISTRIBUTION - 1st. STAGE

DIST. FROM NOSE (FEET)	$\frac{N}{q\ \alpha}$	$\frac{N_O}{q\ \alpha}$
5.	1.75	-10.
15.	5.25	-29.5
25.	8.5	-48.5
35.	10.75	-64.5
42.5	5.625	-34.0
47.5	2.75	-16.25

Finally, inclusion of the inertial loads produced the overall shear, bending moment and axial loads for each stage. Diagrams of these loads are shown in figures 4 through 15 as follows:

FIGURE	STAGE	LOADING CONDITION	LOAD
4	2	Maximum Dynamic Pressure	Shear
5	2	Staging	Shear
6	2	Maximum Dynamic Pressure	Moment
7	2	Staging	Moment
8	2	Maximum Dynamic Pressure	Axial
9	2	Staging	Axial
10	1	Maximum Dynamic Pressure	Shear
11	1	Staging	Shear
12	1	Maximum Dynamic Pressure	Moment
13	1	Staging	Moment
14	1	Maximum Dynamic Pressure	Axial
15	1	Staging	Axial

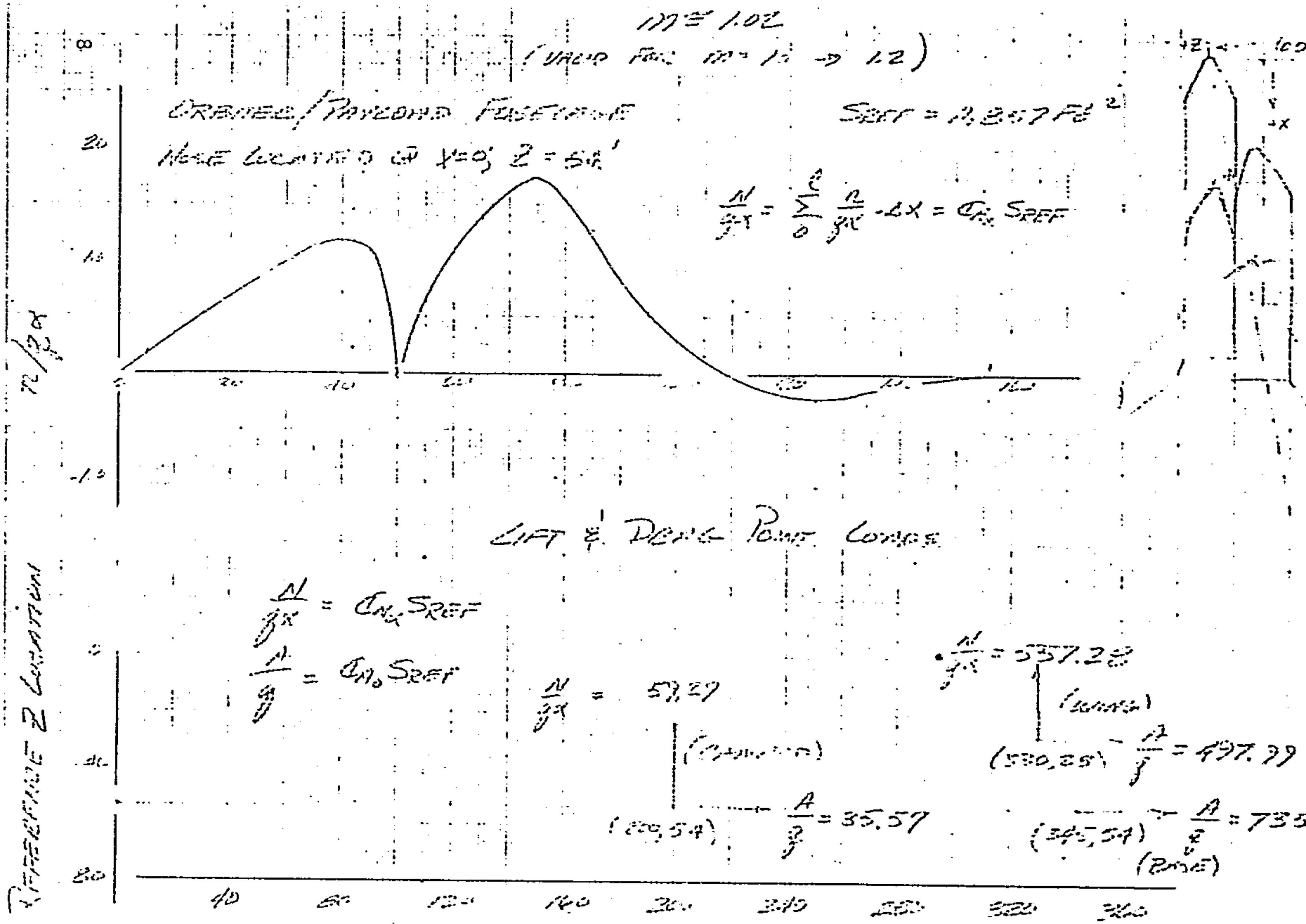


FIGURE 2 PRELIMINARY AIRLOAD DISTRIBUTION - STAGE 2

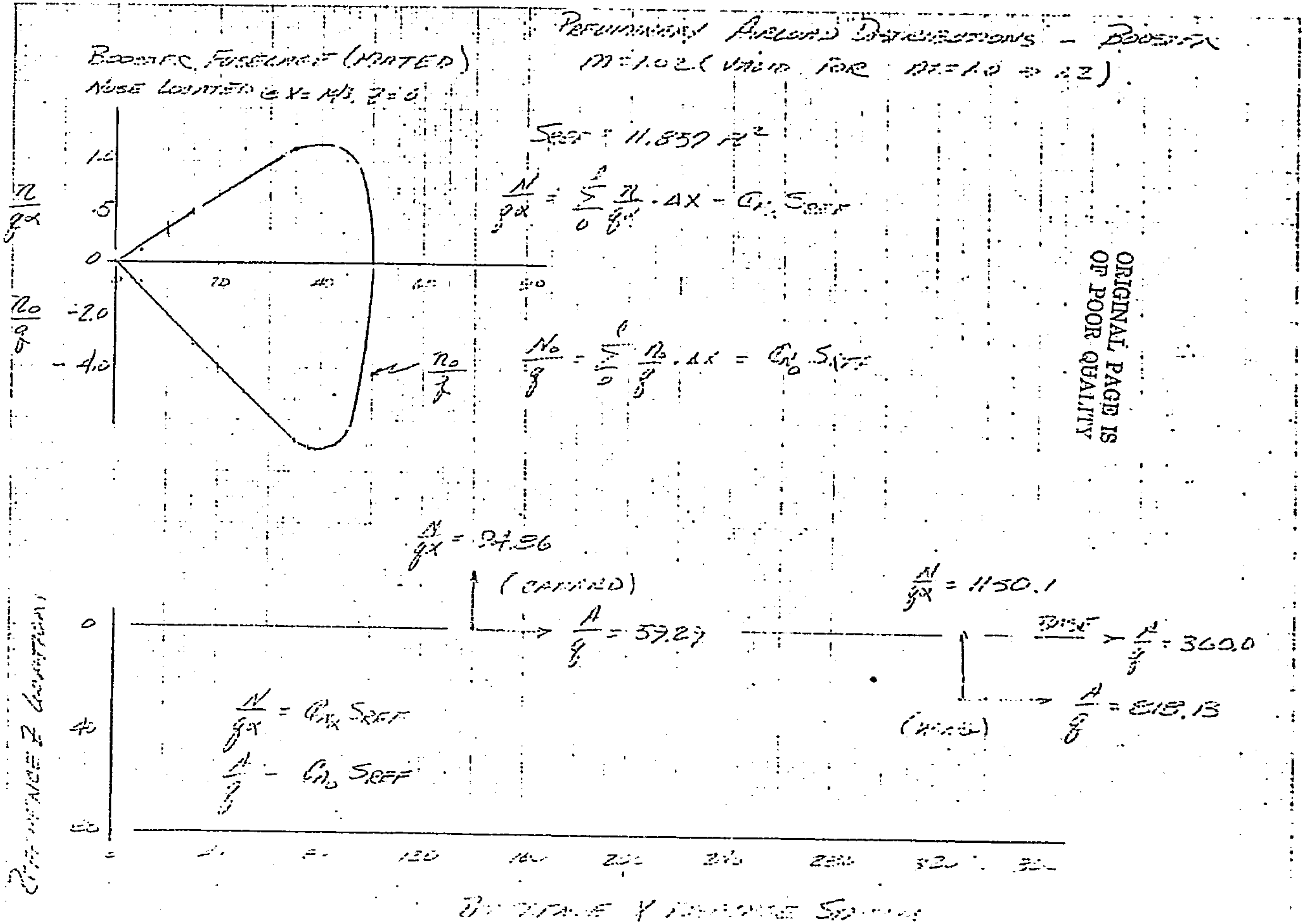


FIGURE 3 PRELIMINARY AIRLOAD DISTRIBUTION - STAGE 1.

STRUCTURAL SYNTHESIS RESULTS

Second Stage

Nose Structure. - The second stage nose structure extended from station 0.0 to station 636.59. Structural synthesis was done at every ring frame giving a total of 27 synthesized stations. Load condition one - max q - was the designing load condition in most instances. Panel running weight varied from 1.96 lbs./inch at the front of the nose to 61.12 lbs./inch at the end of the nose structure. The total weight was 15,345.8 lbs.

The EDIN0620 stage 2 weight statement gave the payload bay structural weight as 64,376. lbs. The differences in these two weights can be accounted for by realizing that the structures program designed a nose shroud only. The result from the weight estimating relations includes all payload bay structural weight - doors, hatches, decks, bolts, etc.

Tank Structure. - The second stage tank walls extended from station 636.59 to station 1801.25. Only tank walls were designed. End domes were not included due to the different nature of their design and construction. Synthesis was done at every frame giving a total of 48 stations. Internal tank pressure was assumed to be 40.0 psi. Panel running weight varied from 76.77 lbs./inch to 53.01 lbs./inch. Total tank weight (excluding bulkheads) was 67,868.0 lbs.

EDIN0620 WER's gave a total tank structural weight of 119,487. lbs. The difference in these two weights is due in part to the exclusion of the end domes. Also, the WER's gave an estimate for the entire structure including hatches, bolts, fittings, etc.

Aft Skirt. - The aft skirt extends from station 1801.25 to station 2558.9. A synthesis was done at every frame producing a total of 32 stations. Panel running weight varied from 6.021 lbs./inch to 61.129 lbs./inch. Total weight for the aft skirt was 19,701.2 lbs. The WER's gave a total weight of 23,374. lbs. which included the thrust structure.

First Stage

Nose Structure. - The first stage nose structure extended from station 0.0 to station 457.15. Synthesis was done at every frame for a total of 20 stations. Panel running weights varied from 1.08 lbs./inch to 91.79 lbs./inch. Total weight of the shroud was 4,080.34 lbs. The stage 1 weight statement gave a nose structure weight of 10,463. lbs. This estimate included all hatches, fittings, bolts, etc.

Tank Structure. - The first stage tank walls extended from station 457.15 to station 1955.62. Only tank walls were designed. End domes were not included due to the different nature of their design and construction. Synthesis was done at every frame for a total of 61 stations. Panel running weights varied from 74.4 lbs./inch to 163.1 lbs./inch. Internal tank pressure was assumed to be 40. psi. Total tank weight (excluding bulkheads) was 158,966.68 lbs.

The WER's gave a total tank structural weight of 96,790 lbs. including end domes. The differences in these two weights may be accounted for by realizing that the structural synthesis took into account the loads from the attach pins. Both pins were assumed to go through the tank creating large shears and bending moments. The WER's did not account for any loads but were based on tank volume and therefore gave a lower weight estimate.

Aft Skirt. - The aft skirt extended from station 1955.62 to station 2507.42. Synthesis was done at every frame for a total of 24 stations. Panel running weight varied from 176.03 lbs./inch to 4.85 lbs./inch at the end of the vehicle. Total weight was 77,411.28 lbs. EDIN0620 WER's gave a total weight of 103,653 lbs. which included the thrust structure.

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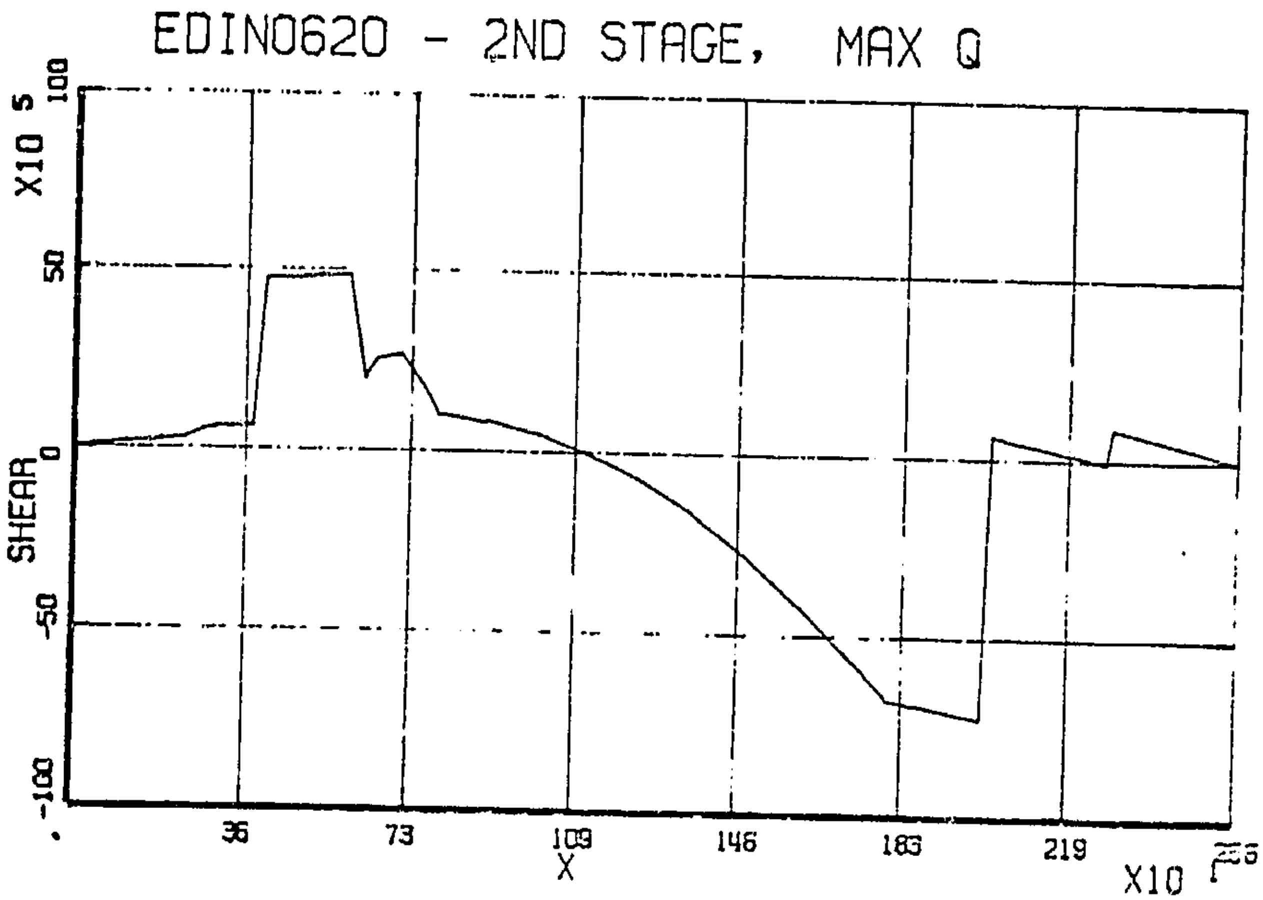

FIGURE 4 SHEAR DIAGRAM - STAGE 2.

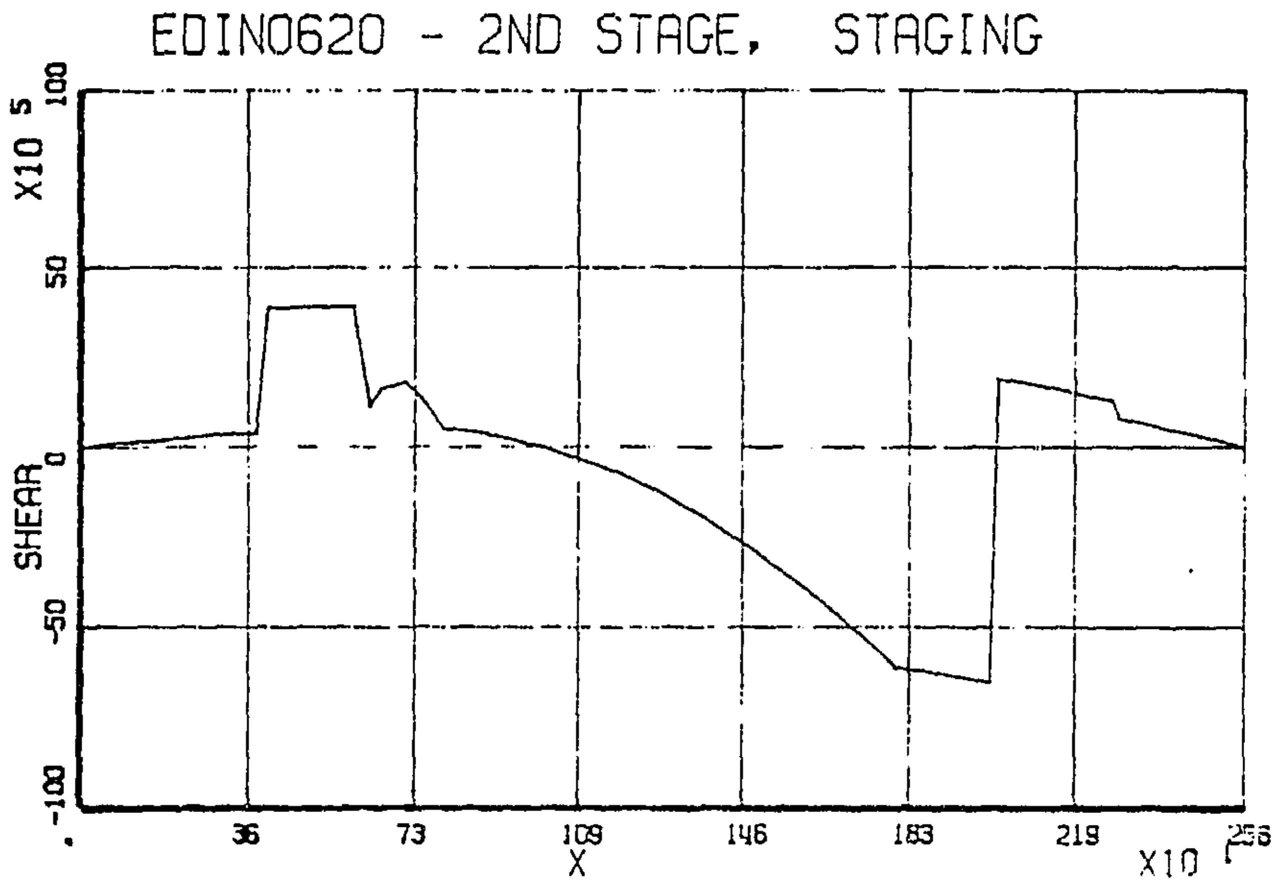

FIGURE 5 SHEAR DIAGRAM - STAGE 2

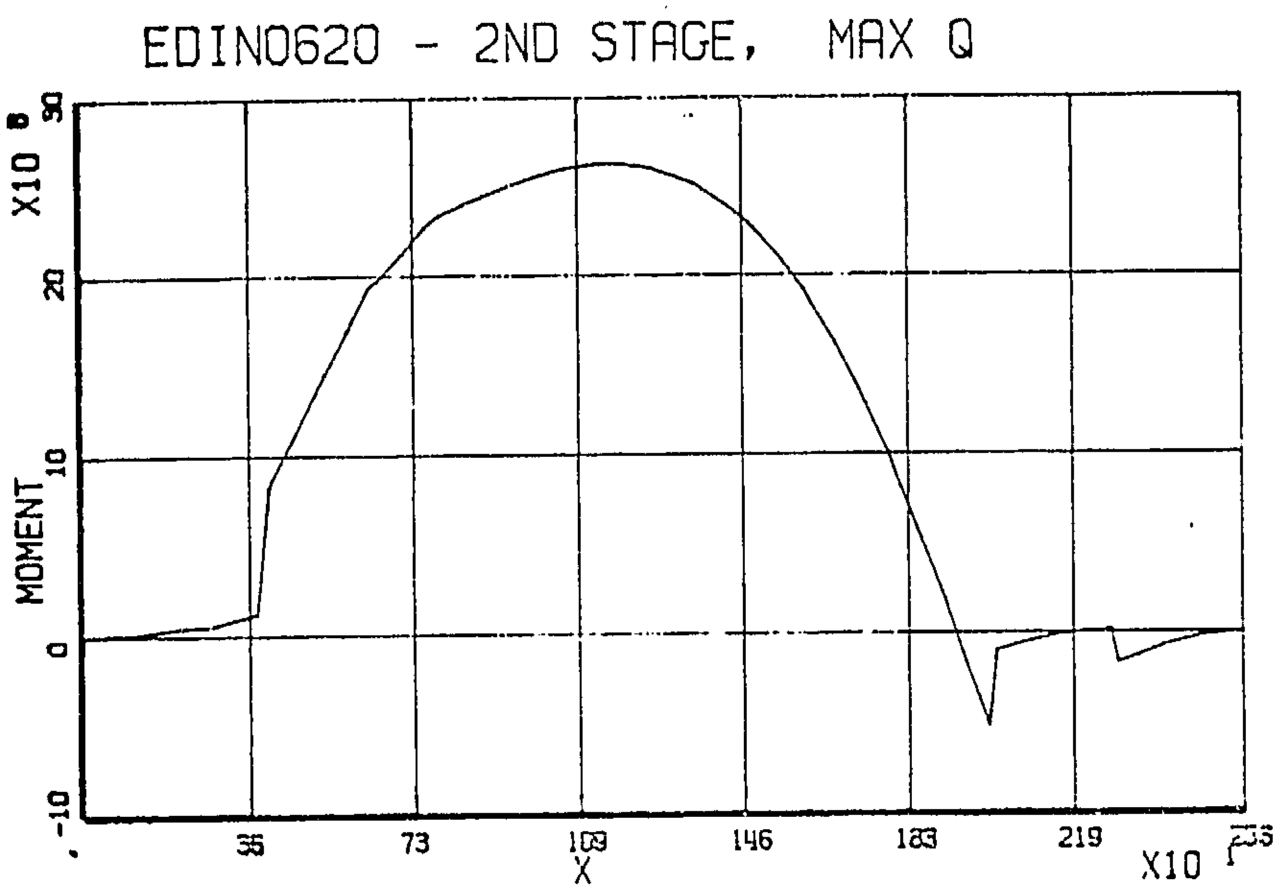

FIGURE 6 MOMENT DIAGRAM - STAGE 2

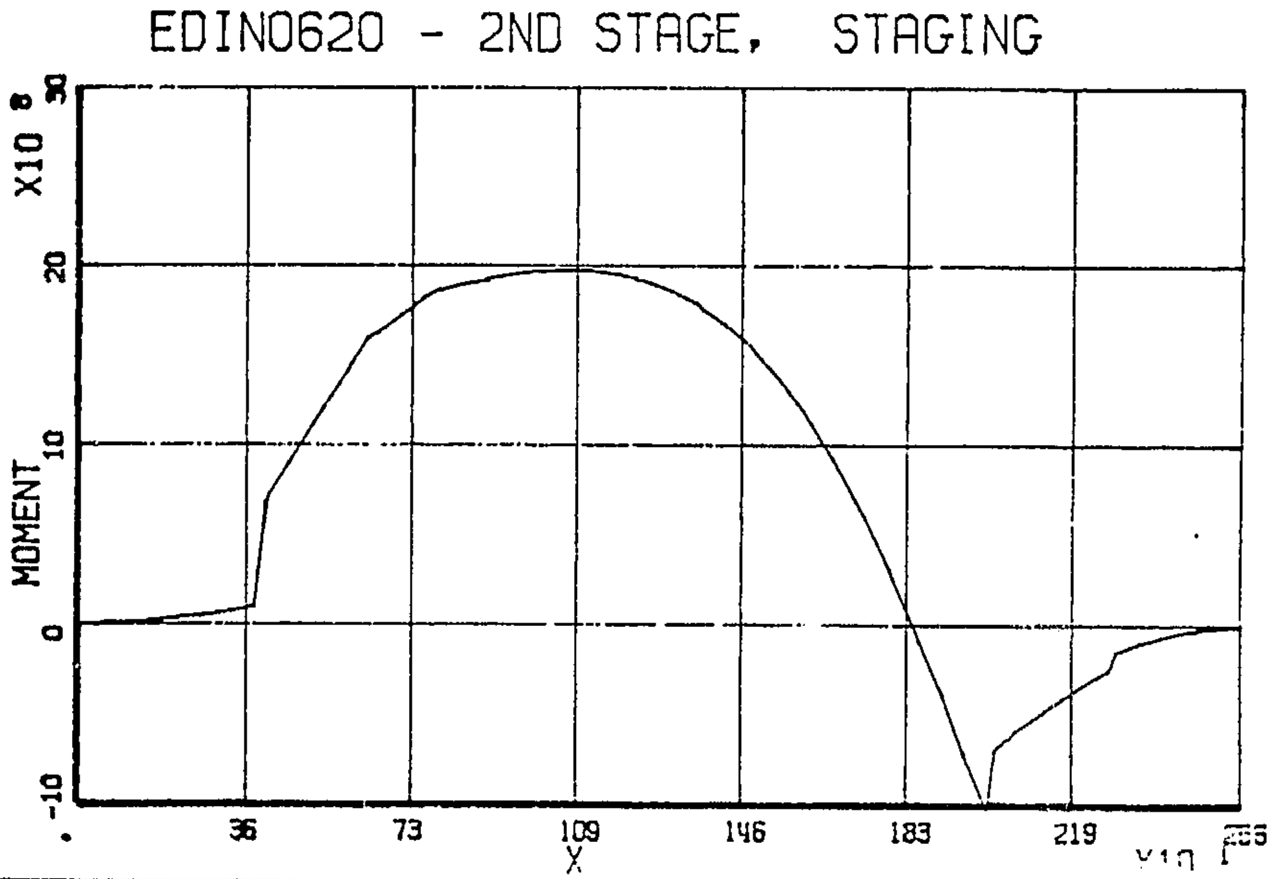

FIGURE 7 MOMENT DIAGRAM - STAGE 2

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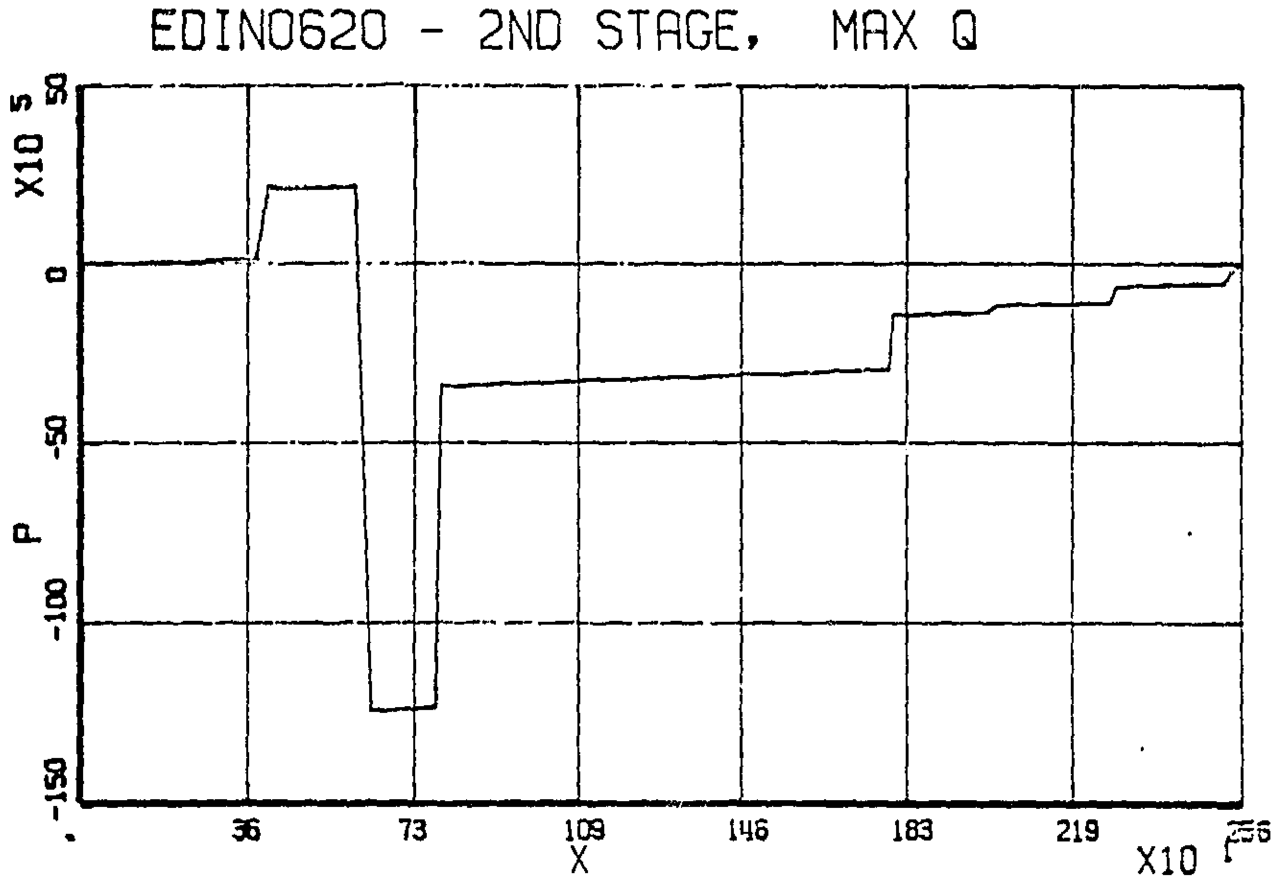

FIGURE 8 AXIAL LOAD - STAGE 2

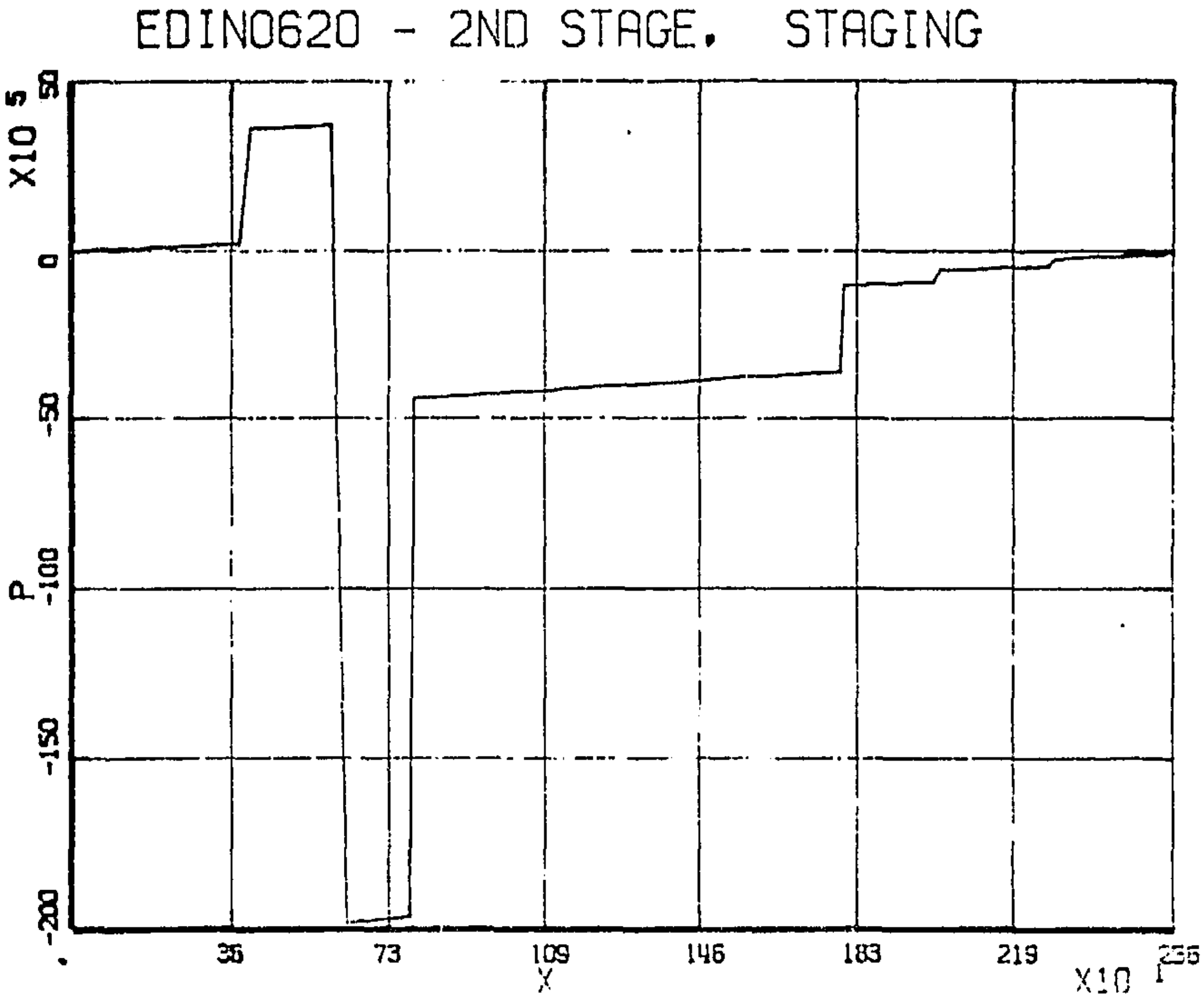

FIGURE 9 AXIAL LOAD - STAGE 2

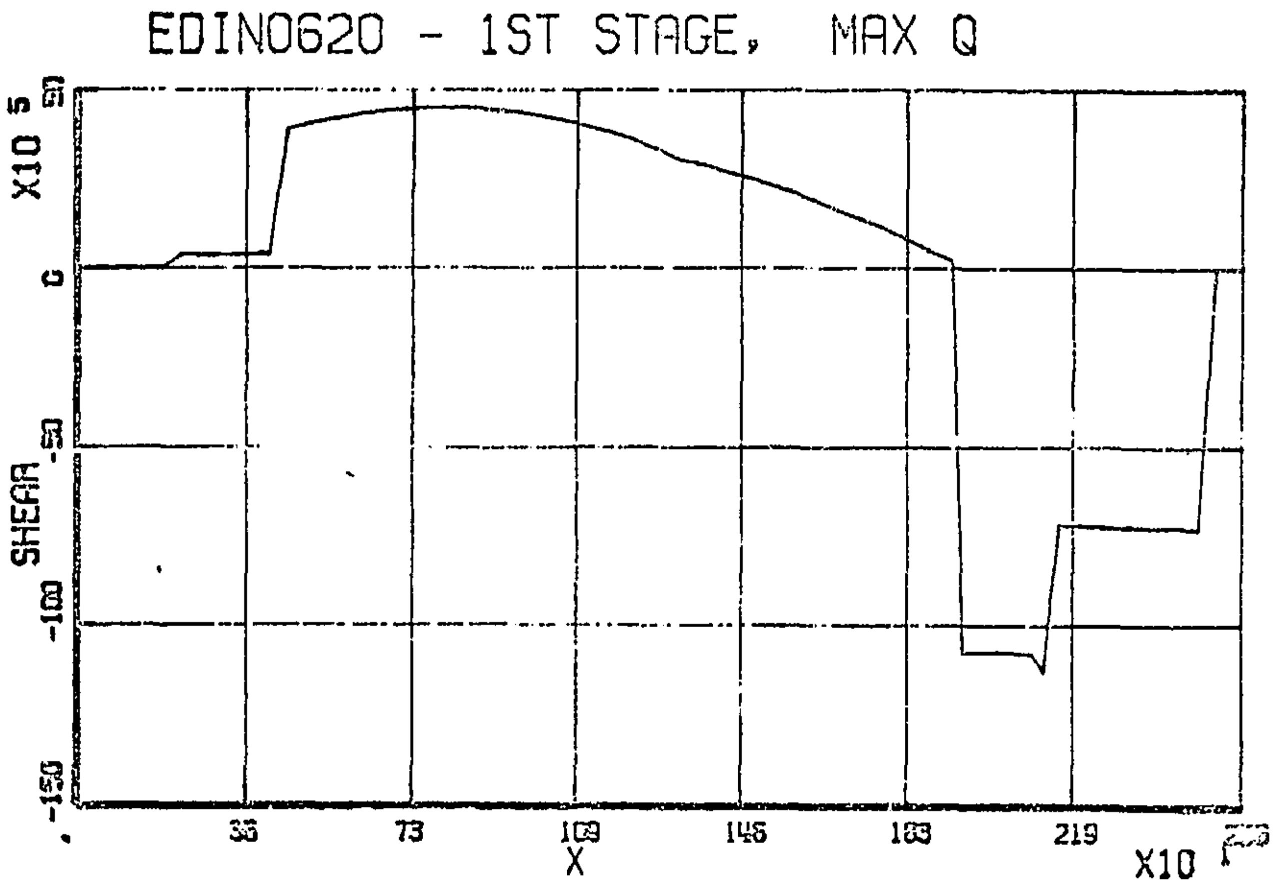

FIGURE 10 SHEAR DIAGRAM - STAGE 1

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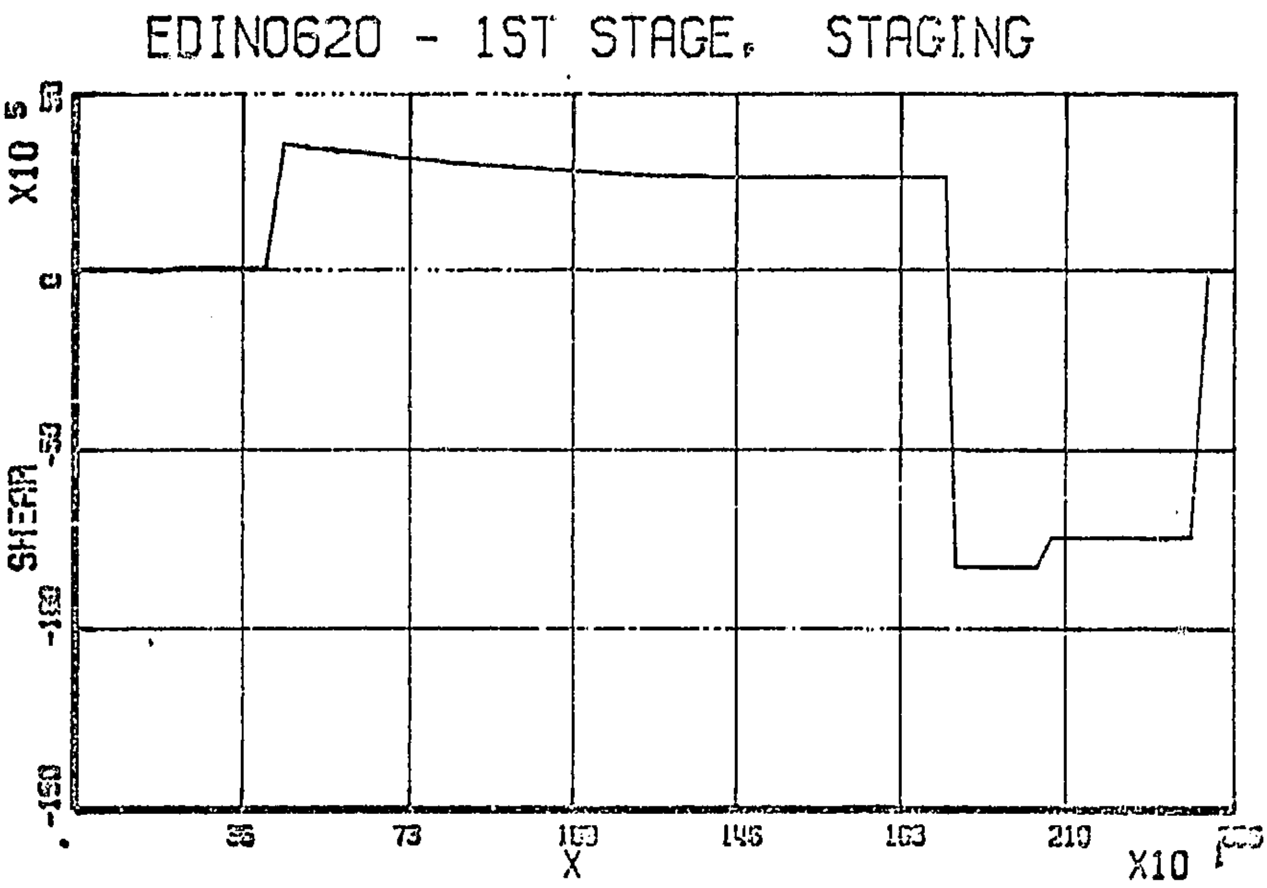

FIGURE 11 SHEAR DIAGRAM - STAGE 1

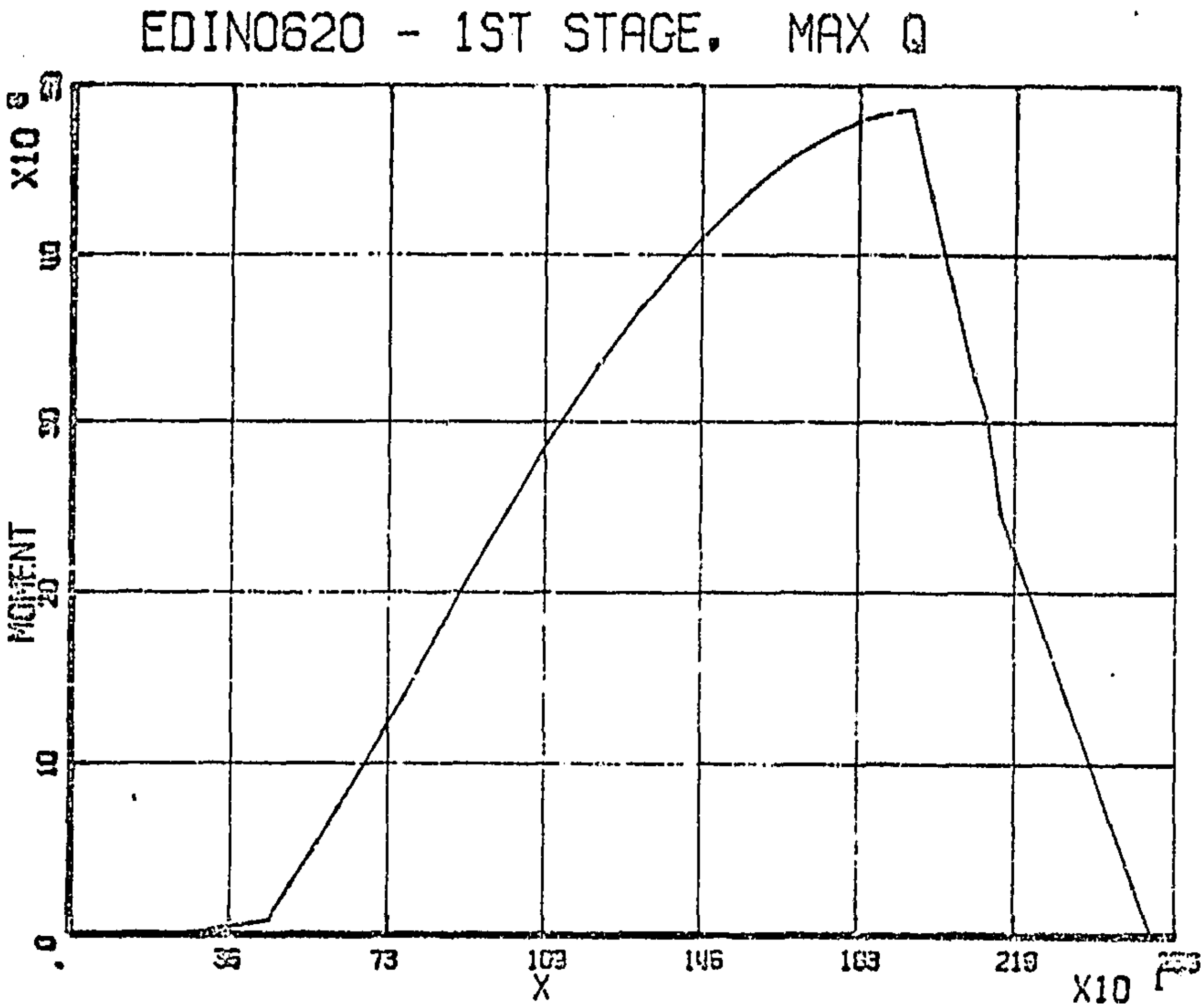

FIGURE 12 MOMENT DIAGRAM - STAGE 1

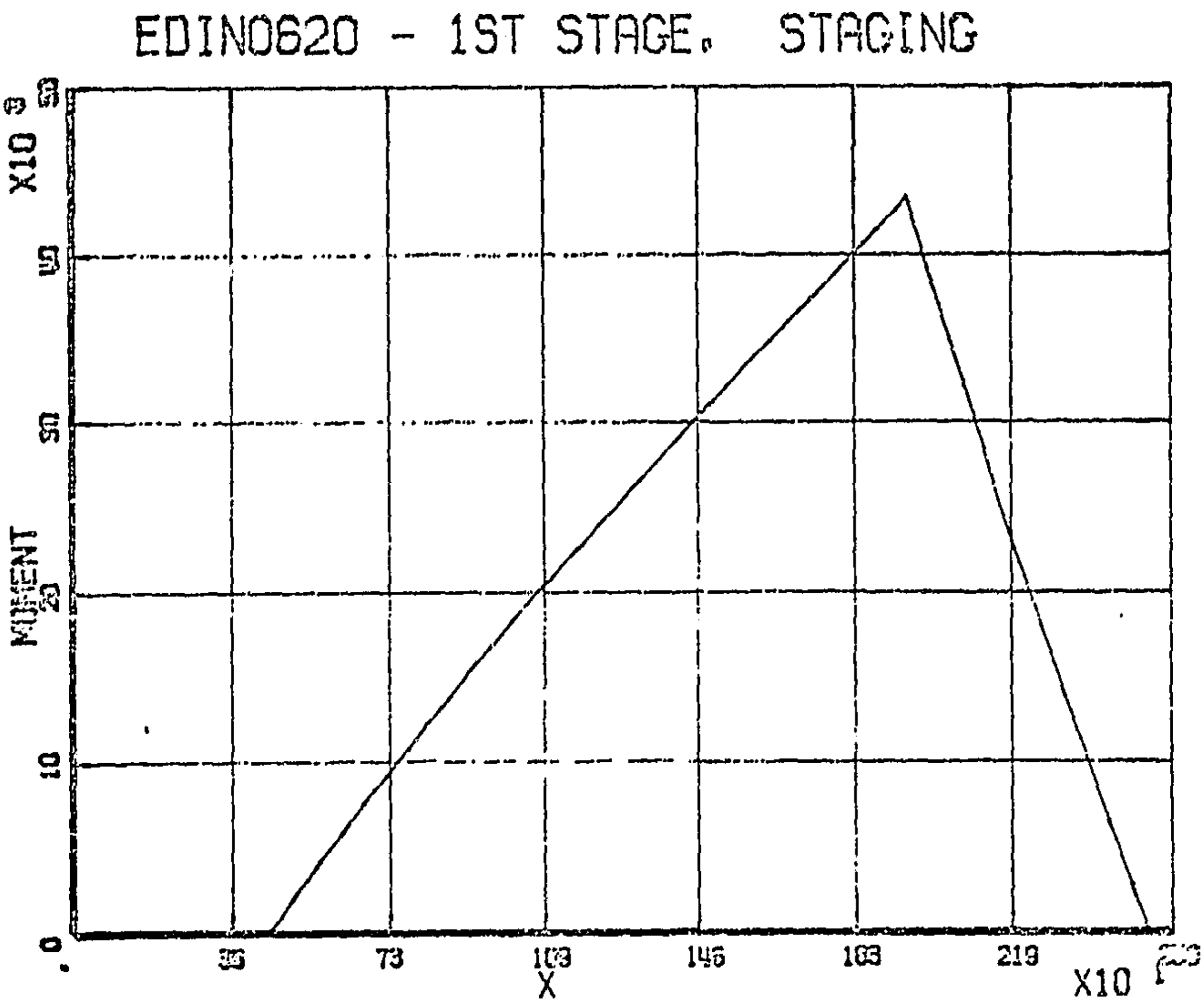

FIGURE 13 MOMENT DIAGRAM - STAGE 1

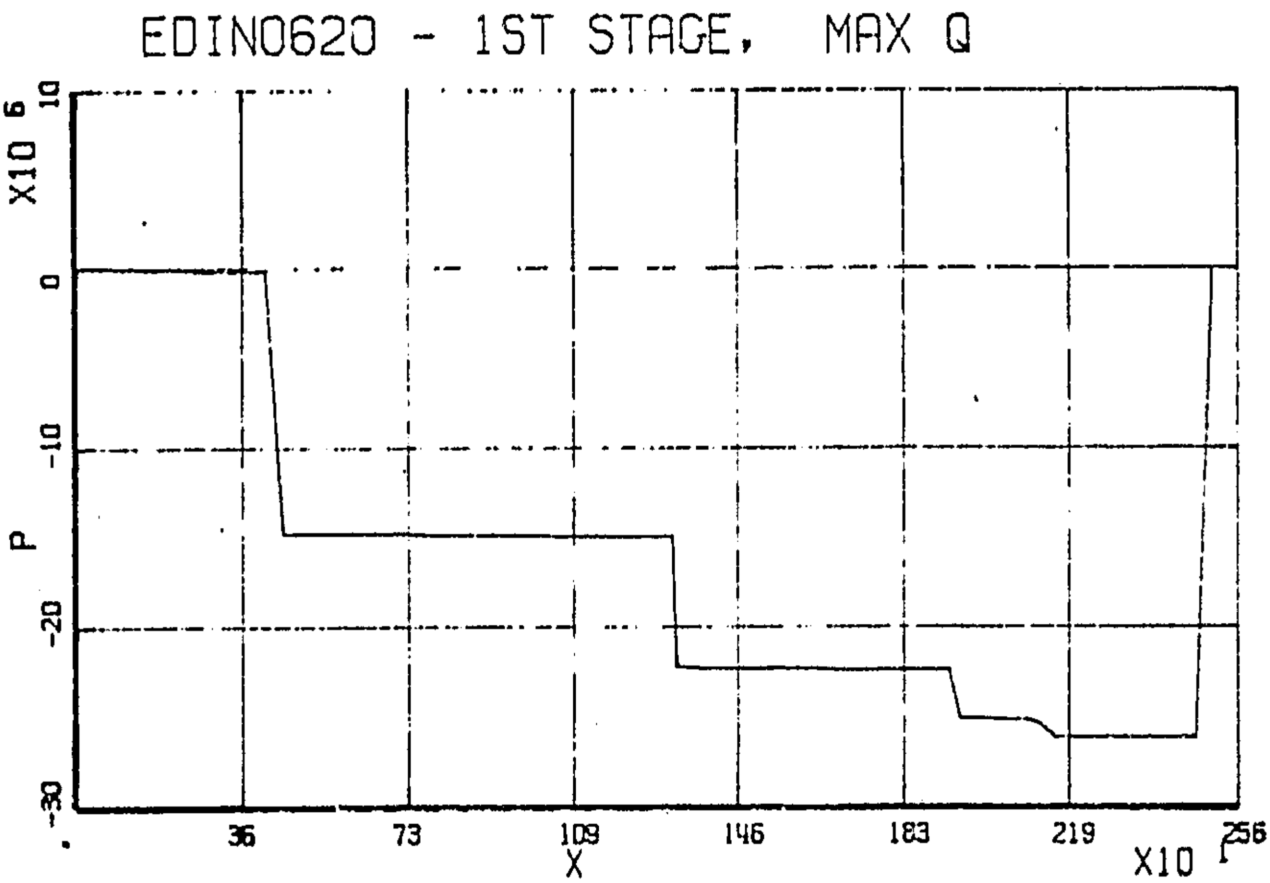

FIGURE 14 AXIAL LOAD - STAGE 1

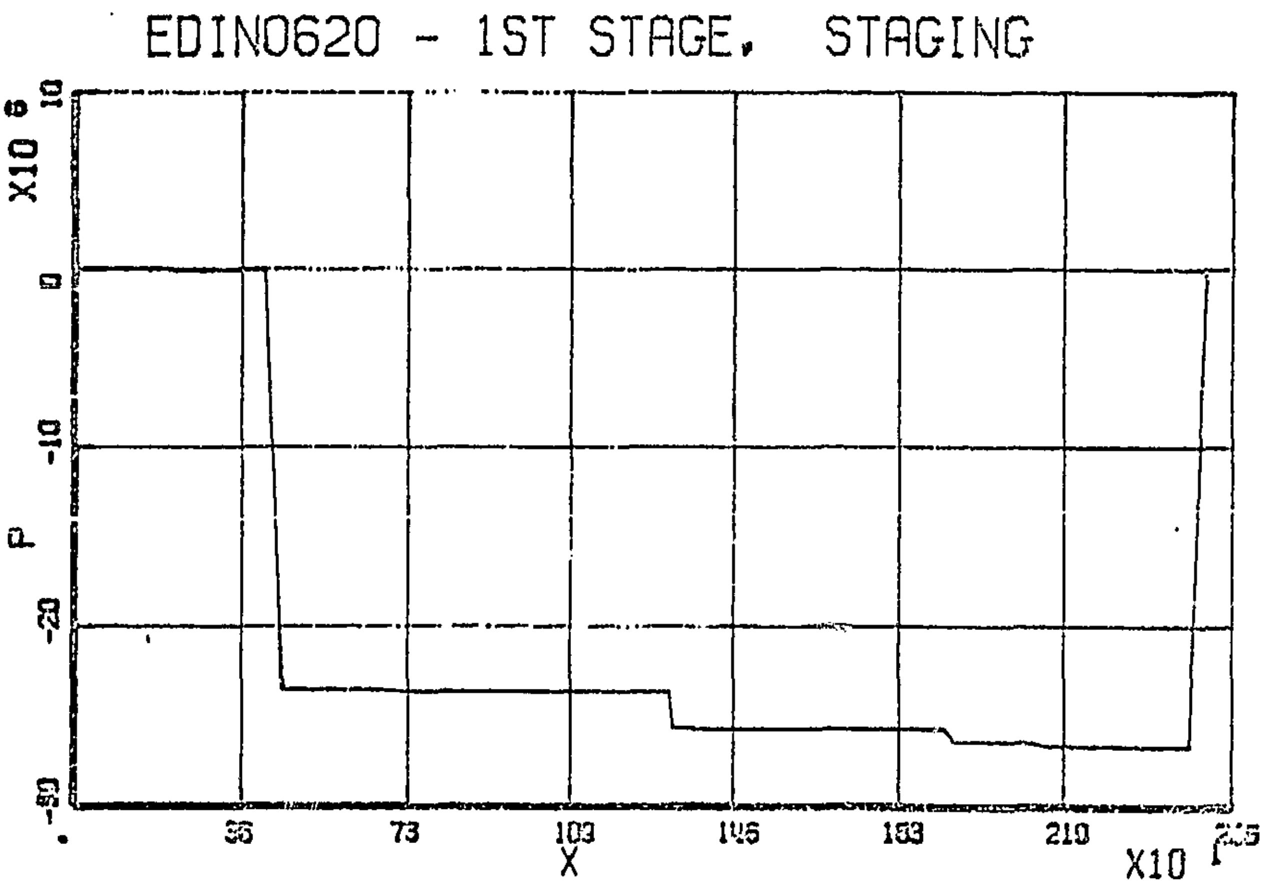

FIGURE 15 AXIAL LOAD - STAGE 1

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