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AFFDL-TR-75-155

SUPERCRITICAL WING PRELIMINARY DESIGN STUDY

GENERAL DYNAMICS
FORT WORTH DIVISION

DECEMBER 1975

TECHNICAL REPORT AFFDL-TR-75-155
FINAL REPORT FOR PERIOD APRIL-OCTOBER 1975

Prepared For
AIR FORCE FLIGHT DYNAMICS LABORATORY
AIR FORCE WRIGHT AERONAUTICAL LABORATORIES
Air Force Systems Command
Wright-Patterson Air Force Base, Ohio 45433

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This technical report has been reviewed and is approved for publication.

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Buy-to-Fly Ratio	Fracture Allowable	Repairability
Damage Tolerance	Graphite Epoxy	Structural Efficiency
Design-to-Cost	Inspectability	Structural Integrity
Durability	Maintainability	Supercritical Airfoil

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

This analytical effort was applied to a supercritical wing box with provisions for variable camber leading and trailing edge devices. The wing geometry and criteria are consistent with the requirements for the FB-111 aircraft or its growth versions, of this strategic aircraft. Cost and weight reduction of the wing box was realized thru concept innovation and application of a systematic design approach that utilizes a quantative evaluation

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20. Abstract (Continued)

system for selecting the most promising concepts from a broad array of alternate designs.

Twenty-one metallic and twelve composite concepts including two baseline concepts were defined.as one inch cross-section sketches. Cost and weight screening of these resulted in the selection and definition of fourteen metallic concepts, five composite concepts and a baseline on analytical assembly drawings as 48 inch long, constant section analytical models. From these, two metallic concepts and one composite concept were selected and developed into preliminary designs of complete wing boxes. Evaluation of the three designs showed weight savings of up to 27% and cost savings of up to 12.3% when compared to a baseline of the same size but configured to FB-111 construction and materials.

The three advanced designs meet static strength, fatigue, fracture, thermal and flutter requirements for the FB-111 aircraft.

FOREWORD

The analytical structural study reported in this document was sponsored by the Air Force Flight Dynamics Laboratory (AFFDL). This work was performed under contract F33615-75-C-3104, AFFDL Project Number 1368, Task Number 136802, Work Unit Number 13680223, "Supercritical Wing Preliminary Design Study".

Mr. Charles L. Ramsey (AFFDL/FBS) was the Air Force Project Engineer.

This study was performed at General Dynamics Fort Worth Division with D. F. Davis as Program Manager. Other principal participants in the program were: E. W. Gomez, Stress Analysis; W. C. Rister, Fatigue and Fracture; Olin E. Weiss, Structural Design (Composites); R. W. McAnally, Structural Design (Metals); C. J. Sawey, Manufacturing Engineering; R. L. Haller, Flutter Analysis; and H. E. Bratton, Information Transfer.

The study was conducted April through October of 1975.

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SECTION I

INTRODUCTION AND SUMMARY

This document reports the procedure and results of the analytical work accomplished under contract F33615-75-C-3104, "Supercritical Wing Preliminary Design Study".

This study involved the development of preliminary design definitions and evaluation of optimum metallic and composite wing box designs for a variable camber supercritical wing designated as ATW-4. The ATW-4 wing is sized and configured for the FB-111 aircraft or various growth versions of the FB-111. Results of the study analytically demonstrate the feasibility of significantly reducing the cost and weight of the wing box component while maintaining strength, fatigue and fracture characteristics consistent with requirements of the FB-111 aircraft.

The cost and weight advantages of the advanced designs developed during the study when compared to the baseline (633RW000) give the following results:

633RW001 - Laminated Skin Y-Spar Wing Box

Weight Savings 15%
Cost Savings 12.3%

633RW002 - Laminated Skin Canted Spar Wing Box

Weight Savings 12%
Cost Savings 10.7%

633RW003 - Composite Skin & Y-Spar Wing Box

Weight Savings 27%
Cost Savings -29% to -4.4% (Depending on Assumed 1980 Gr/Ep Cost)

Figure 1 Program Flow Diagram, outlines the approach taken and shows the sequence of tasks accomplished to complete the ATW-4 wing box study. The main tasks completed during the program are summarized below:

1. Assembled baseline loads, ATW-4 geometry and criteria and reduced to a usable form.

2. Selected materials for consideration in the study and developed fatigue and fracture allowable stress curves for each material.

3. Assembled an array of 31 metallic and composite wing box concepts from other programs and through innovation of new concepts. These were defined on cross-section sketeches, sized, weighed, and costed with the most promising selected for analytical assembly iteration.

4. Defined alternate concepts plus a baseline on 48 inch span analytical assembly drawings. These were analyzed, evaluated and two metallic and one composite concept were selected for input into the preliminary design iteration.

5. Preliminary design drawings were prepared defining the three selected concepts plus the baseline for the entire ATW-4 wing box from pivot to tip.

6. Static strength, fatigue, fracture and flutter analyses was conducted for each of the preliminary wing box designs.

7. Evaluative data for each design parameter in the AFFDL Merit Rating System was computed for each of the preliminary designs plus the baseline. The preliminary designs were then scored and ranked.

8. A follow-on plan that would provide the proof-of-concept was developed.

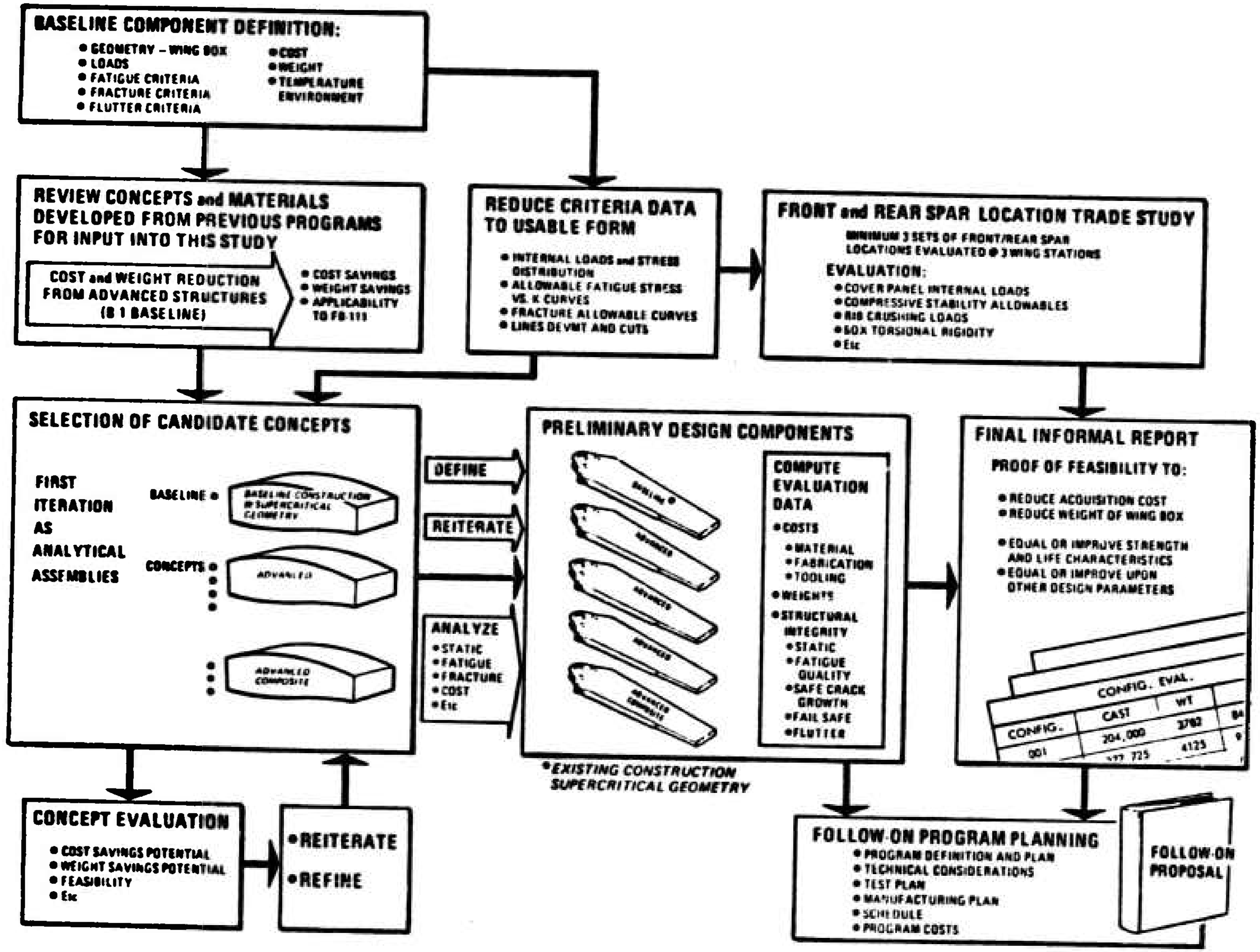


Figure 1 Program Flow Diagram for Supercritical Wing Box Study

SECTION II

BASELINE DEFINITION

The baseline article is the wing box structure from pivot to tip for a supercritical wing configuration designated as ATW-4. The ATW-4 configuration incorporates variable camber leading and trailing edge devices and provides a planform area of 725.7 square feet. The planform is shown in Figure 2.

2.1 BASELINE DESCRIPTION

The wing box is defined as the primary wing structure from the wing pivot fitting outboard to the wing tip splice. It consists of seven spars, upper and lower one-piece skins, and eight primary bulkheads. The outer section is spliced to the wing pivot fitting between center spar stations 97.7 and 106.8. All wing box loads are transferred to the pivot fitting through this connection. The configuration was developed in this program by revising the F-111F wing box to the planform and airfoil for the ATW-4 configuration, deleting provisions for the external stores, and conducting trade studies to optimize the number of spars. The concept for manufacturing each element of the box assembly for the F-111F was retained in that the skins are tapered and etched and the spars and bulkheads are designed as integrally stiffened machined members. The materials used in the F-111F wing box were retained in the new baseline, such as 2024 aluminum for skins, spars, and bulkheads, and D6ac for the wing pivot fitting. The baseline structure is shown in Figures 3 and 4.

The baseline criteria includes the requirements of the FB111 aircraft, but in addition, imposes the requirements of MIL-STD-1530 and MIL-STD-83444. External loads and fatigue spectrum for the ATW-4 wing differ from those for the FB111 wing. The ATW-4 loads and fatigue spectrum are defined in FZM-12-6466 which was developed under Contract No. F33615-75-C-3018 and is included in Appendix A of this report.

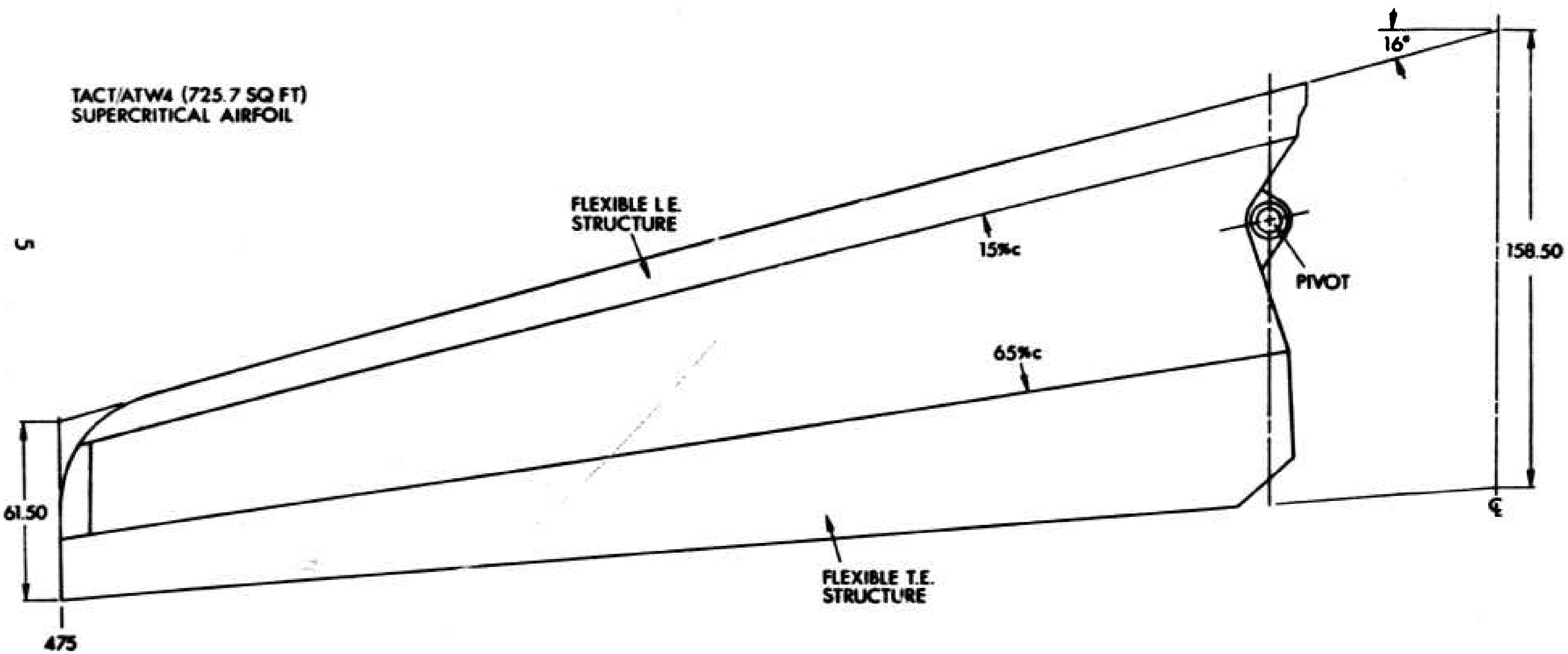
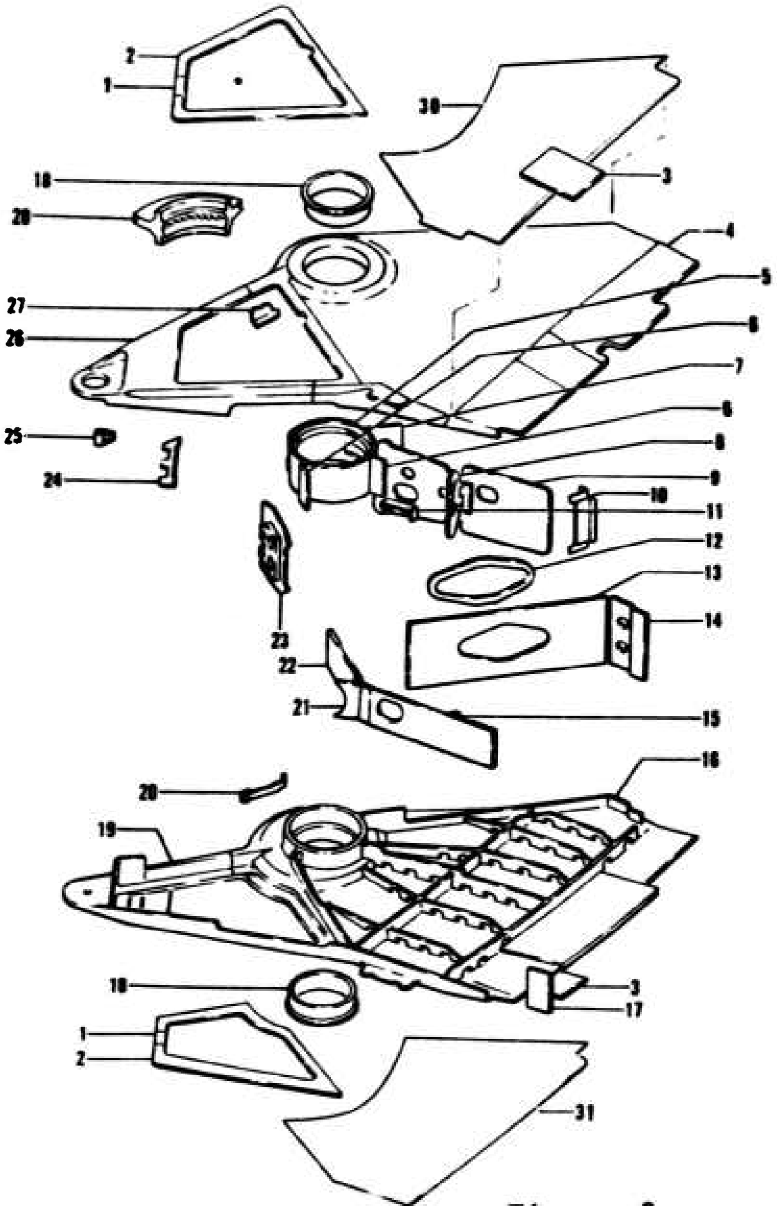
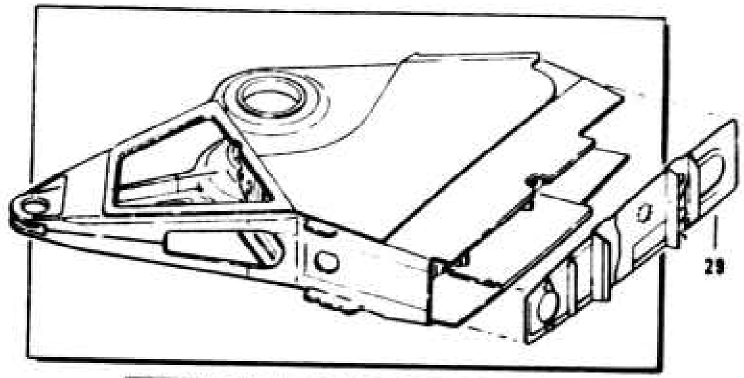


Figure 2 ATW-4 Wing Planform





1.	12W473	Shim (F-111E, F-111A)
2.	12W473	Shim
3.	12W474	Shim (F-111A, FB-111A)
4	12W475	Plate, Upper (F-111A, FB-111A)
4.	12W503	Plate, Upper (F-111E)
5.	12W478	Ring
6.	12W472	Flange
7.	12W472	Flange (F-111A, FB-111A)
8.	12W406	Stiffener (F-111A, FB-111A)
8.	12W529	Stiffener (F-111E)
9.	12W490	Web, Center (F-111A, FB-111A)
9.	12W527	Web, Center (F-111E)
10.	12W984	Bracket (F-111A, FB-111A)
10.	12W528	Bracket (F-111E)
11.	12P581	Bracket (F-111A)
12.	12W473	Seal
13.	12W492	Web (F-111A, FB-111A)
13.	12W592	Web (F-111E)
14.	12W477	Web (F-111A, FB-111A)
14.	12W498	Web (F-111E)
15.	12W477	Web
16.	12W476	Plate, Lower (F-111A, FB-111A)
16.	12W504	Plate, Lower (F-111E)
17.	12W474	Shim (F-111A, FB-111A)
17.	12W502	Shim (F-111E)
18.	12W426	Bushing
19.	12W476	Arm, Lower (F-111A, FB-111A)
19.	12W504	Arm, Lower (F-111E)
20.	12W427	Bracket
21.	12W477	Web
22.	12W477	Web (F-111A, FB-111A)
22.	12W588	Web (F-111E)
23.	12W491	Plate
24.	12W6401	Retainer
25.	12W433	Bracket
26.	12W475	Arm, Upper (F-111A, FB-111A)
26.	12W503	Arm, Upper (F-111E)
27.	12W427	Bracket
28.	12W412	Shear Lug
29.	12W911	Bulkhead
30	12W494	Panel, Wing Pivot, Upper
31.	12W495	Panel, Wing Pivot, Lower

Figure 3 Baseline Pivot Fitting

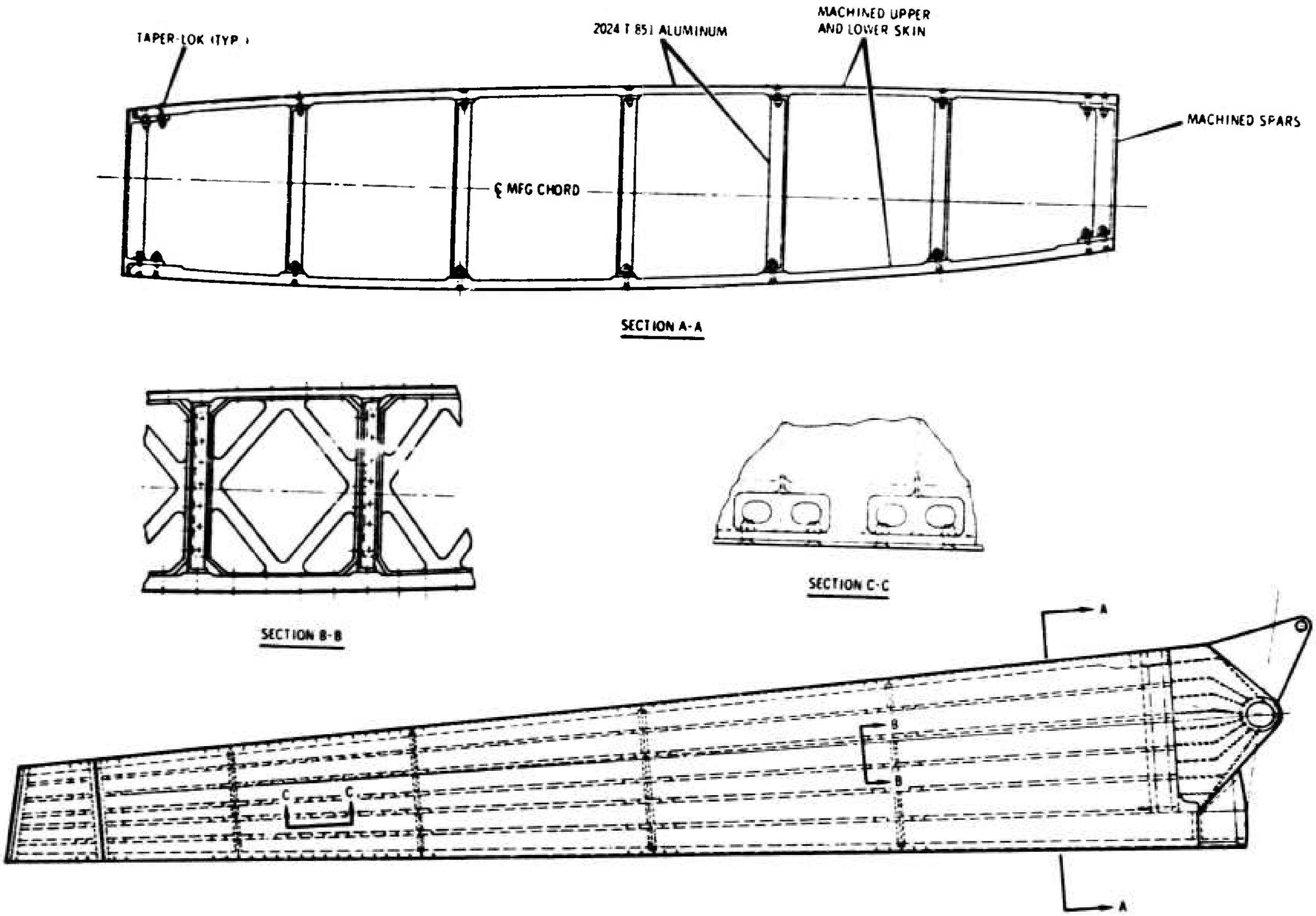


Figure 4 ATW-4 Wing Box Baseline

SECTION III

DESIGN

Design definition and analysis was conducted in sufficient detail to determine the applicability of innovative and advanced structural concepts to the main wing box of a supercritical variable camber wing configuration.

3.1 DESIGN APPROACH AND EVALUATION SYSTEM

A systematic iterative design method was applied that utilizes the AFFDL merit rating system to quantitatively evaluate each design parameter of each alternate concept after each iteration for scoring and selecting concepts for the succeeding iteration.

3.1.1 Design Approach

A methodical system developed on previous contracts (F33615-72-C-2149 and F33165-74-C-3026) was used in this program which allows a large number of ideas to be evaluated for potential application to the final design. In this process, ideas are developed into one inch span cross-section drawings; the cross-sections are analyzed and ranked; highest ranking cross-sections are further developed into forty eight inch span analytical assemblies; the analytical assemblies are analyzed and ranked; the highest ranking analytical assemblies are then drawn up as preliminary designs of full wing boxes; and finally, these preliminary designs are analyzed and ranked for final selection of the highest potential concept. Details of each step of this methodology are discussed in the following paragraphs.

3.1.1.1 Cross-Section Concept

The use of one inch span cross-sections provide a valuable iterative step in the overall design process leading to an optimum design. Advantages of the cross-section methodology are as follows: (a) the cross-section sketches provide a work sheet for integrating element concepts into workable wing designs; (b) by considering only one inch length a large variety of designs can be economically weighed, costed, and evaluated; and (c) by configuring all concepts at a specific wing station and to the identical static load, fatigue spectrum, and fracture criteria that occurs at that station, a meaningful and equitable evaluation will result.

The initial design effort was sizing and defining applicable concepts from previous programs as one inch span cross-section analytical specimens with geometry and load taken at Load Reference Axis (LRA) Sta. 140.0. Innovative effort produced several new concepts which were also sized and defined as one inch span cross-section specimens. The one inch span cross-section concepts were weighed, costed and scored (see paragraph 3.2.1).

3.1.1.2 Analytical Assembly Design

Advantages of the analytical assembly designs as a preliminary design tool are as follows:

- o Provides on a single drawing a definition of the configuration and the critical numerical values that measure weight, cost, strength/stress levels, fatigue quality, damage tolerance and overall desirability of a design concept.
- o Serves as an instrument to coordinate the technical efforts of the various disciplines necessary to optimize and effect a complex design concept.
- o Promotes concept reiteration by showing up promising elements of one assembly that can be comined with promising elements from other assemblies to provide a new assembly with the best collection of elements.
- o The concept data block provides detailed evaluation data on each configuration of each part or element, such as a spar or skin, for better visibility as to which element is the principal driver for cost, weight, etc.
- o Provides valid data for evaluating a number of design concepts to specified design parameters on a completely uniform, equitable basis.

From the one inch cross-section concepts, fourteen metallic concepts and five composite concepts were selected for definition on analytical assembly drawings. The analytical assembly models are 48 inch span constant section wing box assemblies designed to the geometry and loads that occur at LRA Sta. 140.0. These assemblies were sized to static strength, fatigue and fracture allowable stresses. Weights and costs were computed and other parameters evaluated. Scores and rank were computed for each concept in accordance with the AFFDL merit rating system (see paragraph 3.2.2).

3.1.1.3 Preliminary Design

After having gone through the screening of the cross-section concepts and the analytical assembly designs, the next step is to develop preliminary designs of the highest ranking analytical assemblies. These drawings are much more complex and complete than the previous drawings. The advantage of the methodology has its greatest pay-off at this point in that the concepts reviewed at this stage are all high potential ideas. The time required to develop the preliminary design for ideas that have limited potential has been avoided by the screening process. Also, the possibility that a good idea will emerge late in the program has been minimized because of the large number of concepts evaluated in the system.

Two of the most promising metallic concepts and one composite concept were selected and developed into complete wing box preliminary designs capable of meeting all specified criteria. Weights, and costs were computed and other parameters evaluated. Scores and rank were computed for each design (see paragraph 3.2.3).

3.1.2 Merit Rating System

The design parameters that were evaluated and the "weighing" value applied to each parameter in computing a weighted score was specified by AFFDL. The merit rating system is shown in Table I.

3.1.3 Evaluation and Ranking of Concepts

An important part of the design methodology used in this program was the evaluation and ranking of design concepts via a formal rating system. The objective of the rating system is to minimize personal opinion and to ensure that each area of responsibility has an opportunity to influence the design configuration chosen for the production effort.

The basic elements of the rating system are shown in Table I. The approach used to implement this system is discussed in the following paragraphs.

3.1.3.1 Structural Efficiency (40%)

Two parameters were used to evaluate the structural efficiency of a concept; cost and weight, sixty percent of the structural efficiency score is assigned to cost (24% of total ranking) and forty percent is assigned to the weight (16% of total ranking). Use of these parameters is discussed below:

Cost - Cost was computed for each concept by estimating and summing the material cost, the tooling recurring cost, and the fabrication costs. The cost score recorded in the Evaluation Summaries are:

$$\text{Cost Score} = \frac{\text{Cost of lowest cost concept}}{\text{Cost of concept being scored}} \times .24$$

Weight - Weight was computed for each concept which has been sized to the controlling criteria of static loads, fatigue, or fracture. The weight score recorded in Evaluation Summaries are:

$$\text{Weight Score} = \frac{\text{Weight of lightest concept}}{\text{Weight of concept being scored}} \times .16$$

TABLE I   MERIT RATING SYSTEM

STRUCTURAL EFFICIENCY (.4)	TECHNOLOGY IMPROVEMENT (.1)	DAMAGE TOLERANCES (.2)	ABILITIES (.3)
COST (.6)	CONCEPTS (.5)	SAFE CRACK (.4)	INSPECTABILITY (.2)
WEIGHT (.4)	MATERIALS (.2)	FAIL SAFE (.6)	MANUFACTURABILITY (.2)
	MFG. (.3)		MAINTAINABILITY (.2)
			REPAIRABILITY (.2)
			*DURABILITY (.2)

*DURABILITY IS DEFINED AS THE ABILITY TO RESIST FATIGUE, THERMAL DEGRADATION, CORROSION, STRESS CORROSION, HYDROGEN CRACKING, WEAR, AND FOREIGN OBJECT DAMAGE -- MINIMIZES REPAIR AND MAINTENANCE.

3.1.3.2 Technology Improvement (10%)

The weighted technology improvement score is made up of the sum of the weighted scores from Concepts, Manufacturing Technology and Materials Technology. The weighted scores for each of the three technology parameters is defined below:

Concept Technology - The weighted concept technology score was computed for each concept by counting the number of innovations embodied in each concept and rationing the scores such that the highest ranking score equals .05.

Manufacturing Technology - The weighted score for manufacturing technology was computed by scoring the concept from 0% to 100% on the degree to which it will advance manufacturing technology and multiplying the percent value by .03.

Materials Technology - The weighted score for materials technology was determined by identifying the number of new materials and processes used in a concept and rationing the scores such that the concept using the greatest number of new materials and processes receives, the highest score of .02.

3.1.3.3 Damage Tolerances (20%)

The parameters assessed during this portion of the rating system were safe crack growth and fail safe characteristics as discussed below:

Safe Crack - Safe crack is interpreted as referring to the maximum stress in the fatigue stress spectrum consistent with stable crack growth. Each design concept was analyzed for cracks starting at both surface flaws and at holes (unless the concept was free of holes). There are four damage tolerance categories: (1) fail-safe, hole free structure; (2) fail-safe structure with holes; (3) slow crack growth (not fail-safe) structure; and (4) slow crack growth structure with holes.

The critical crack growth stress level, F_{cr}, is controlled by the damage tolerance category and the type of material in accordance with MIL-STD-1530. The ratio of the critical crack growth stress to the maximum static tension stress is considered a measure of excess damage tolerance capability. The ratios are then divided by the maximum such ratio and multiplied by .08 to obtain the final weighted values.

Fail Safe - A count was made of the maximum number of individual structural elements in a concept that could be failed without impairing load capability. By dividing all such counts by the number in the concept with the highest number and multiplying this number by .12 the weighted score is obtained.

3.1.3.4 Abilities (30%)

The parameters that were evaluated to arrive at the abilities weighted scores are inspectability, manufacturability, repairability, and durability. All concepts were ranked on a 0% to 100% scale for each parameter by specialists in the area defined by the parameter. The score for each concept was obtained by multiplying these % numbers by .06 for the corresponding parameter.

3.2 WING BOX DESIGN

The contents of this paragraph summarizes the design work accomplished and the evaluation summary charts for this work.

3.2.1 Cross Section Iteration

Figures 5 thru 37 show the structural concepts defined as cross-section sketches. Table II, Wing Box Metallic Cross Section Concept Scoring and Ranking Summary and Table III Wing Box Composite Cross Section Concept Scoring and Ranking Summary summarizes the data used in selecting concepts for input into the analytical assembly iteration.

3.2.1.1 Metallic Cross-Section Concepts

The nineteen metallic cross-section concepts defined and evaluated embody several promising ideas to reduce cost, reduce weight, improve fatigue life and improve damage tolerance characteristics.

Alternate aluminum lower skin concepts defined and studied include the following:

- o Monolithic skin with fastener penetrations
- o Laminated lower skins with & without fastener penetrations
- o Planked (fail safe) laminated & non-planked (not fail safe).

Alternate spar concepts included several configurations to increase the allowable compressive buckling stress of the upper skin, and at the same time achieve low weight and cost for the spars. These concepts are as follows:

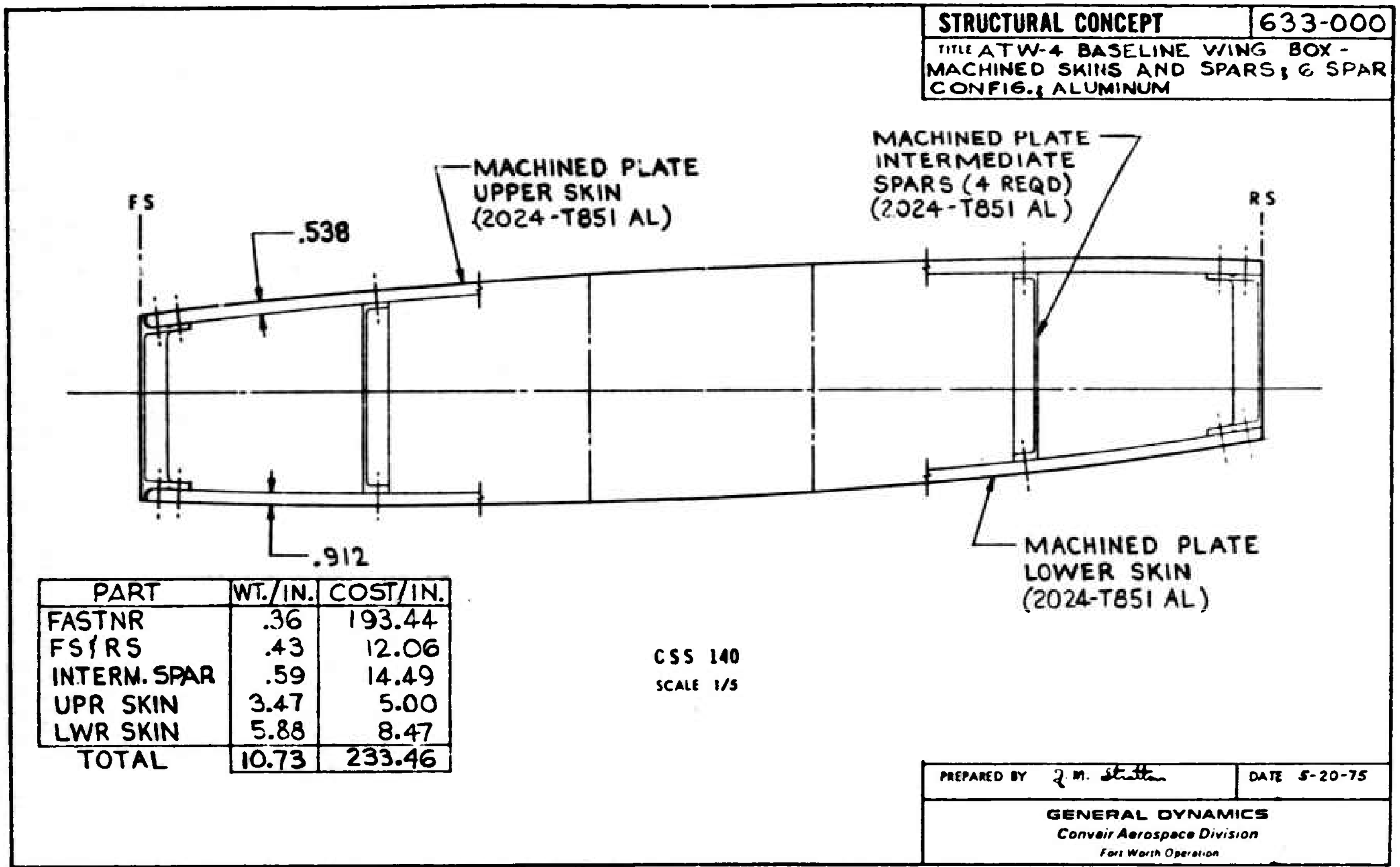
- o Extruded and built-up sheet metal "Y" spars
- o Corrugated sheet metal spars with wide extruded caps
- o Conventional integrally machined spars
- o Inverted "A" sheet metal spars
- o Slanting sheet metal spar web having stabilizing intercostals with two upper extruded caps.

The upper wing box skin configurations included:

- o Machine pocketed aluminum plate
- o Non-pocketed aluminum plate
- o Aluminum honey comb sandwich panel.

The concepts showing the best total score (scoring cost at a weighting value of .60 and weight at a weighting value of .40) were as follows:

- o Laminated aluminum sheet lower skins without fastener penetrations where these skins are planked to fall into the "fail safe catagory of MIL-A-83444.
- o Spar designs that provide a broad area of support for the upper skin member in a manner that increases the upper skin compressive buckling stress allowable over the base spar concept.
- o Configurations of sheet metal or extrusions in lieu of parts integrally machined from heavy plate. Reducing the ratio of starting material to finished material achieves a cost savings in material and fabrication.

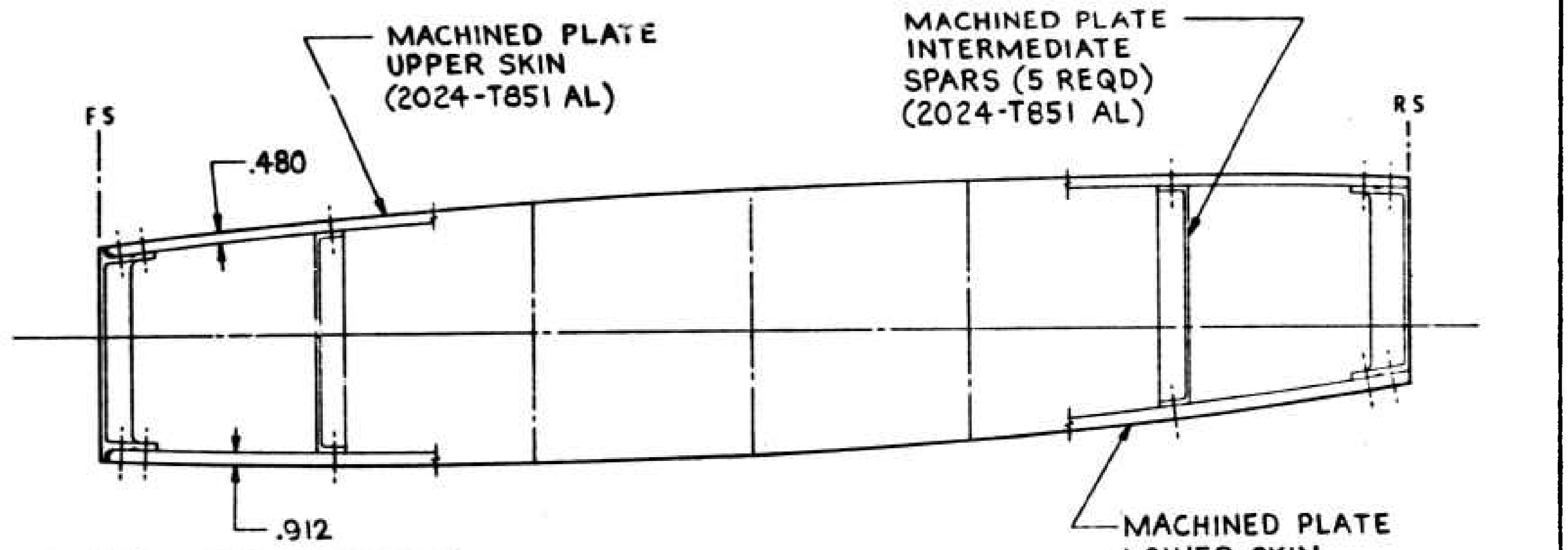


PART	WT./IN.	COST/IN.
FASTNR	.36	193.44
FS/RS	.43	12.06
INTERM. SPAR	.59	14.49
UPR SKIN	3.47	5.00
LWR SKIN	5.88	8.47
TOTAL	10.73	233.46

Figure 5 Six Spar Baseline

STRUCTURAL CONCEPT | 633-001

TITLE ATW-4 BASELINE WING BOX - MACHINED SKINS AND SPARS; 7 SPAR CONFIG.; ALUMINUM



PART	WT./IN.	COST/IN.
FASTNR	.37	194.20
FS & RS	.40	11.22
INTERM. SPAR	.71	17.44
UPR SKIN	3.10	3.38
LWR SKIN	5.88	8.47
TOTAL	10.46	234.71

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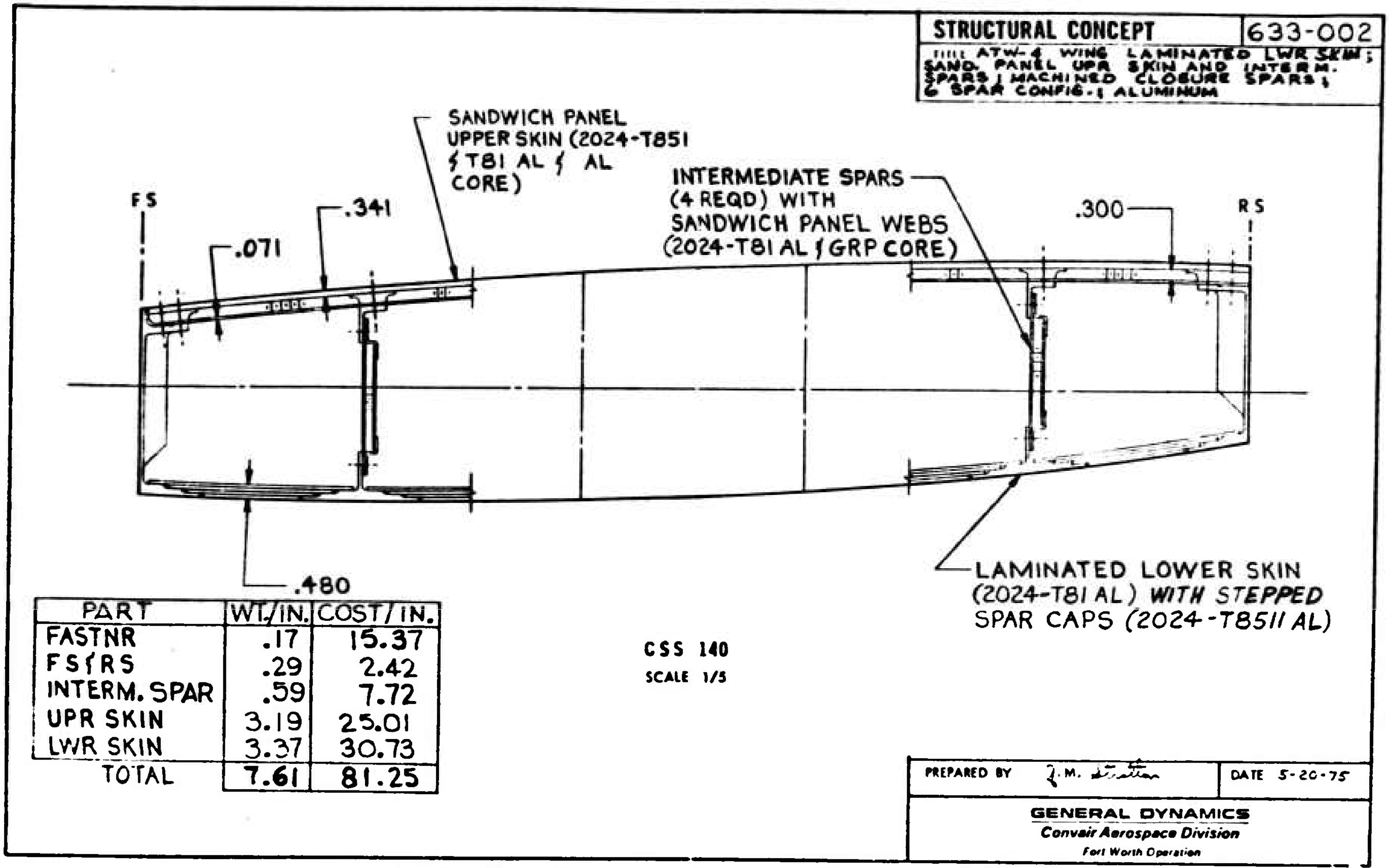
PREPARED BY J. M. Stratton | DATE 5-20-75

GENERAL DYNAMICS

Convair Aerospace Division

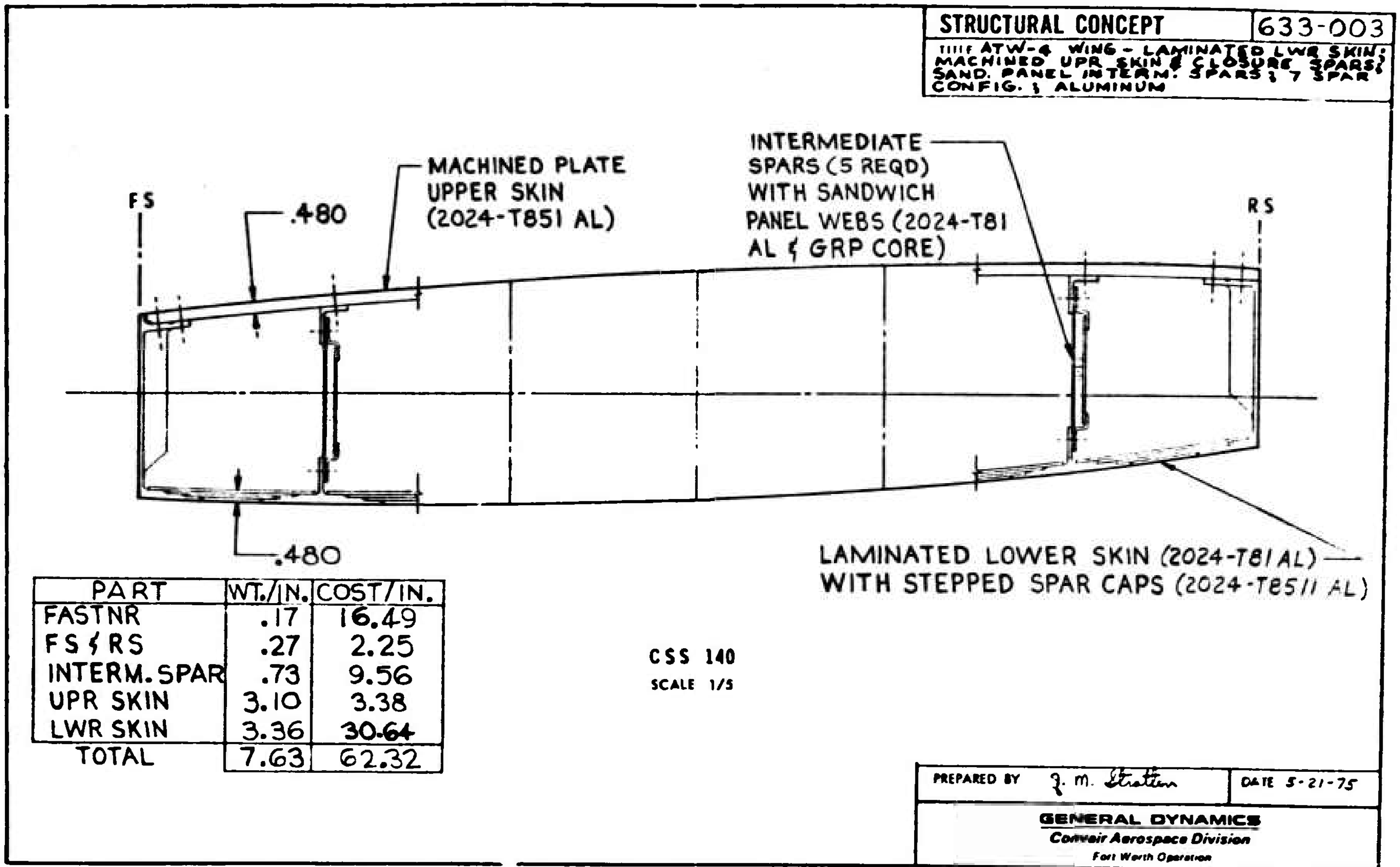
Fort Worth Operation

Figure 6 Seven Spar Baseline



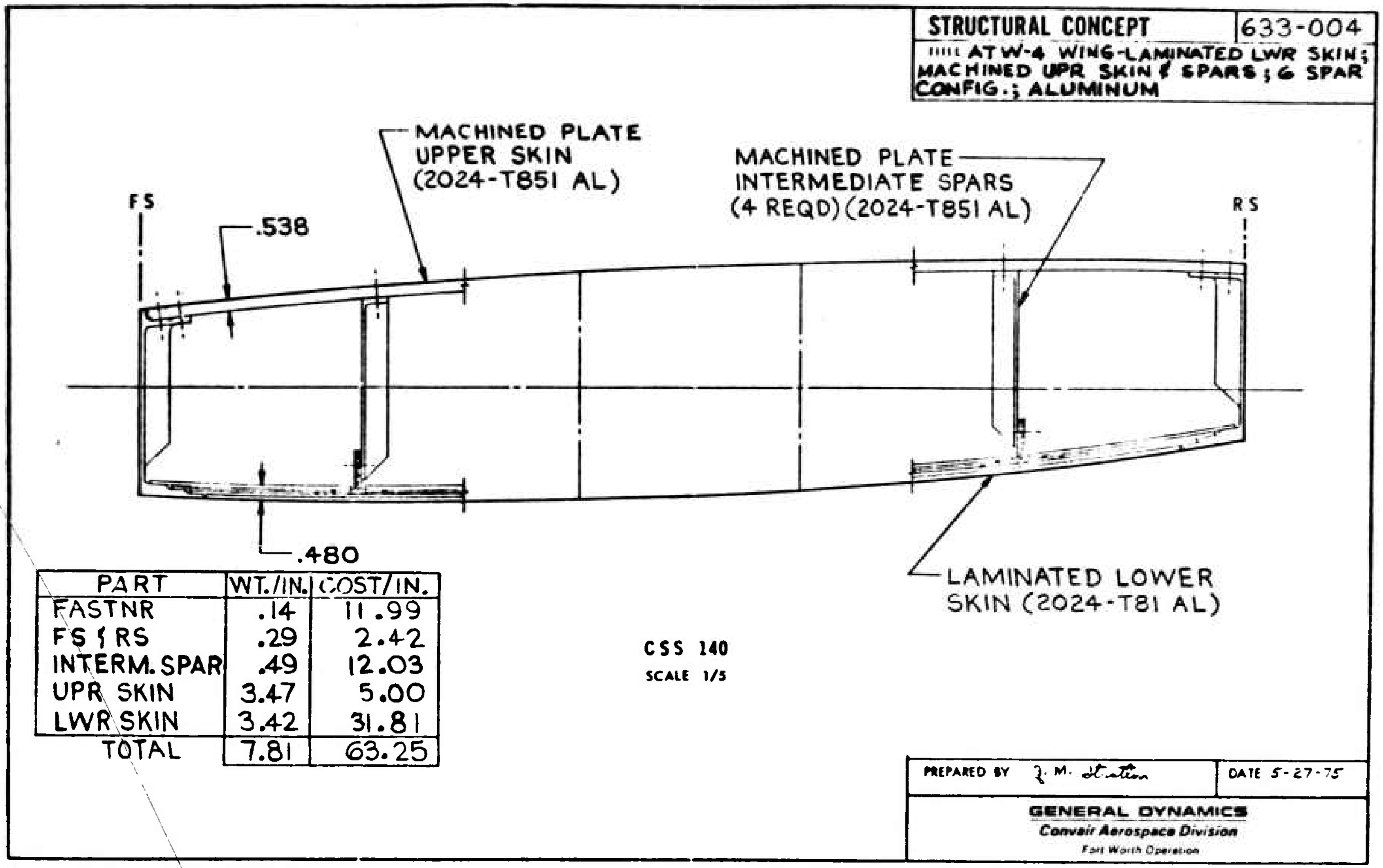
PART	WT./IN.	COST/IN.
FASTNR	.17	15.37
FS&RS	.29	2.42
INTERM. SPAR	.59	7.72
UPR SKIN	3.19	25.01
LWR SKIN	3.37	30.73
TOTAL	7.61	81.25

Figure 7 Honeycomb Spar and Upper Skin



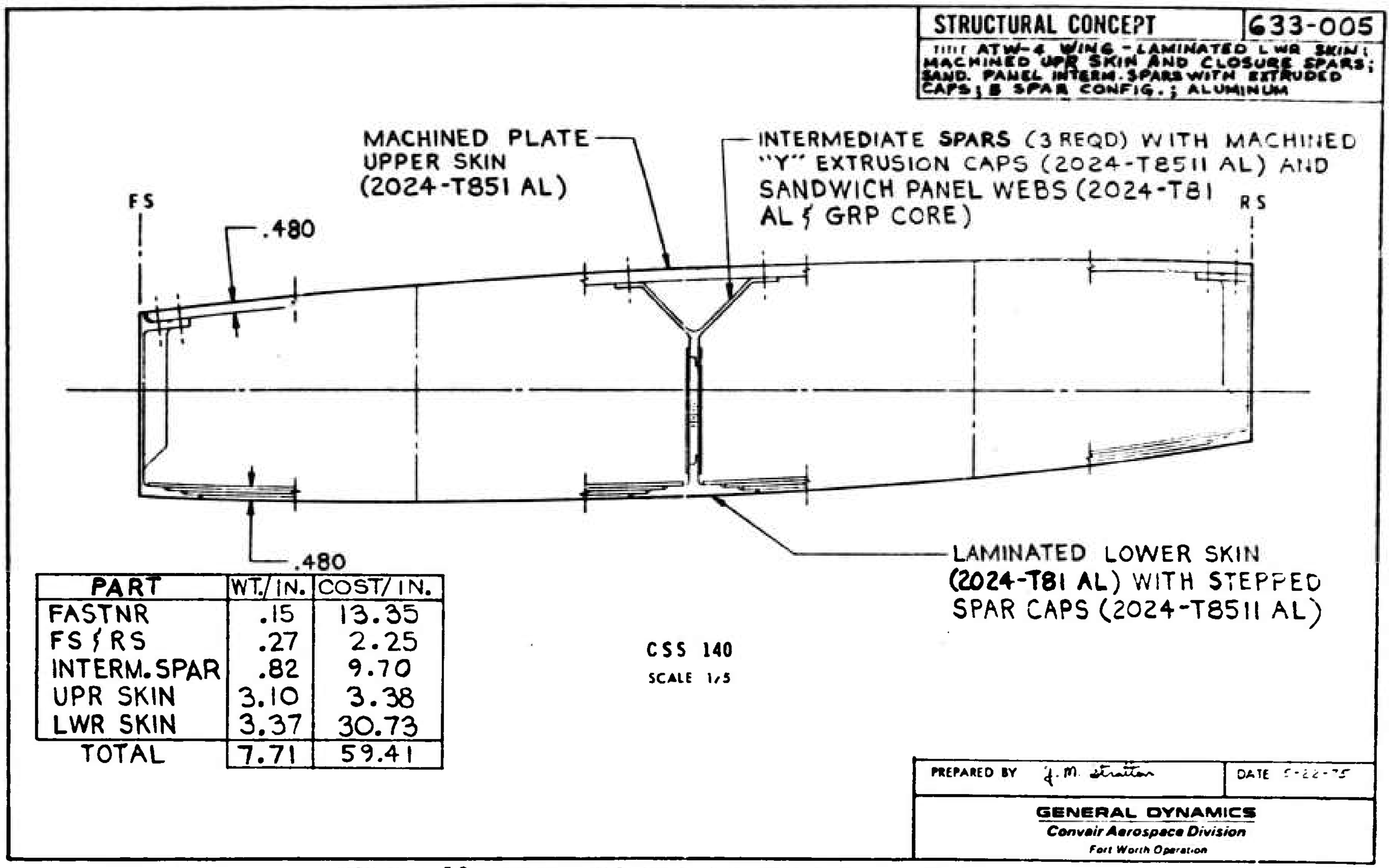
PART	WT./IN.	COST/IN.
FASTNR	.17	16.49
FS & RS	.27	2.25
INTERM. SPAR	.73	9.56
UPR SKIN	3.10	3.38
LWR SKIN	3.36	30.64
TOTAL	7.63	62.32

Figure 8 Honeycomb Spar Plate Upper Skin



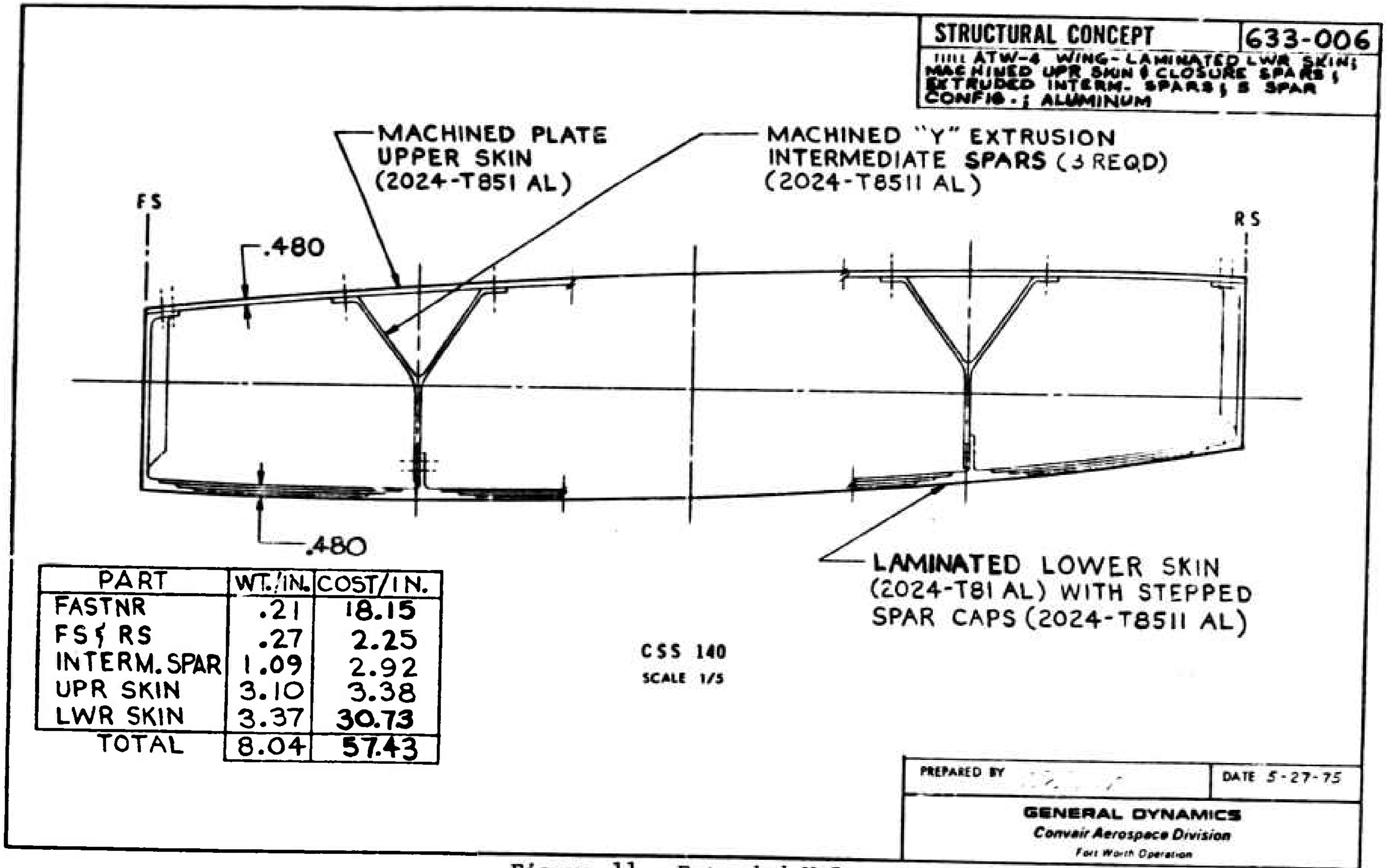
PART	WT./IN.	COST/IN.
FASTNR	.14	11.99
FS & RS	.29	2.42
INTERM. SPAR	.49	12.03
UPR SKIN	3.47	5.00
LWR SKIN	3.42	31.81
TOTAL	7.81	63.25

Figure 9 Machined Spars and Plate Upper Skin



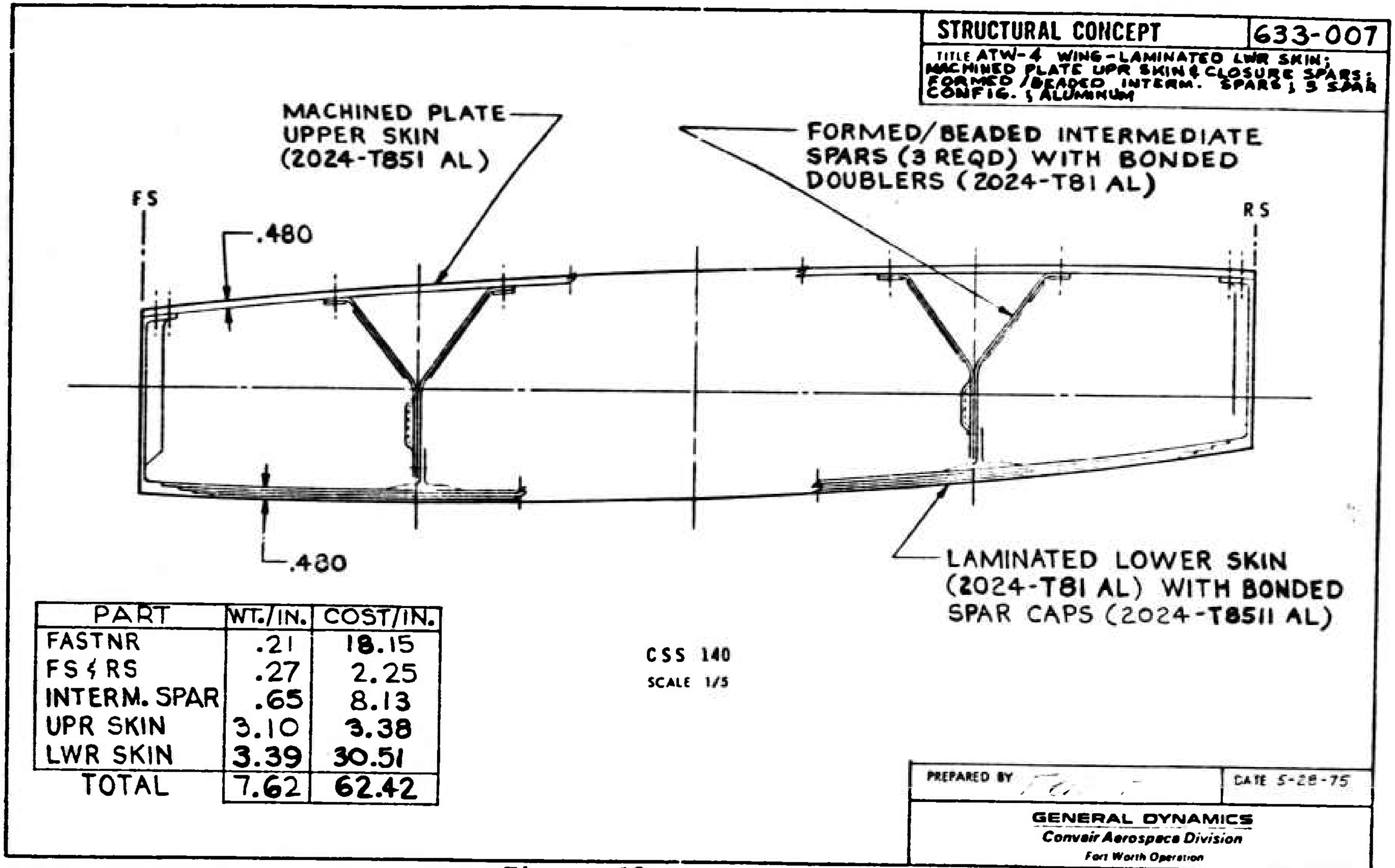
PART	WT./IN.	COST/IN.
FASTNR	.15	13.35
FS & RS	.27	2.25
INTERM. SPAR	.82	9.70
UPR SKIN	3.10	3.38
LWR SKIN	3.37	30.73
TOTAL	7.71	59.41

Figure 10 Honeycomb Y-Spars Plate Upper Skin



PART	WT./IN.	COST/IN.
FASTNR	.21	18.15
FS & RS	.27	2.25
INTERM. SPAR	1.09	2.92
UPR SKIN	3.10	3.38
LWR SKIN	3.37	30.73
TOTAL	8.04	57.43

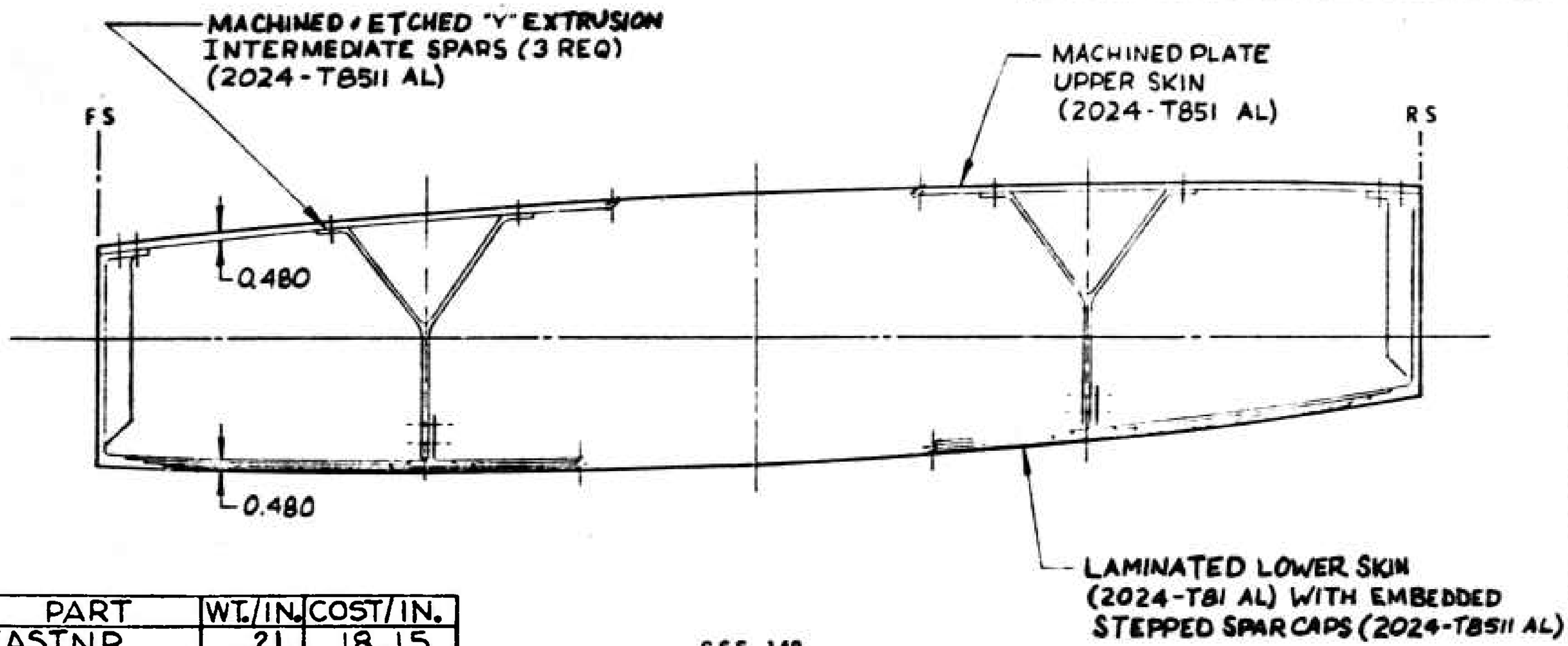
Figure 11 Extruded Y-Spar



PART	WT./IN.	COST/IN.
FASTNR	.21	18.15
FS & RS	.27	2.25
INTERM. SPAR	.65	8.13
UPR SKIN	3.10	3.38
LWR SKIN	3.39	30.51
TOTAL	7.62	62.42

Figure 12 Beaded Y-Spar

STRUCTURAL CONCEPT	633-008
TITLE ATW-4 WING – LAMINATED LWR SKIN; MACHINED UPR SKIN & CLOSURE SPARS; EXTRUDED & ETCHED INTERM. SPARS; 5 SPAR CONFIG.; ALUMINUM	



PART	WT./IN.	COST/IN.
FASTNR	.21	18.15
FS & RS	.27	2.25
INTERM. SPAR	.86	2.56
UPR SKIN	3.10	3.38
LWR SKIN	3.37	30.67
TOTAL	7.81	57.01

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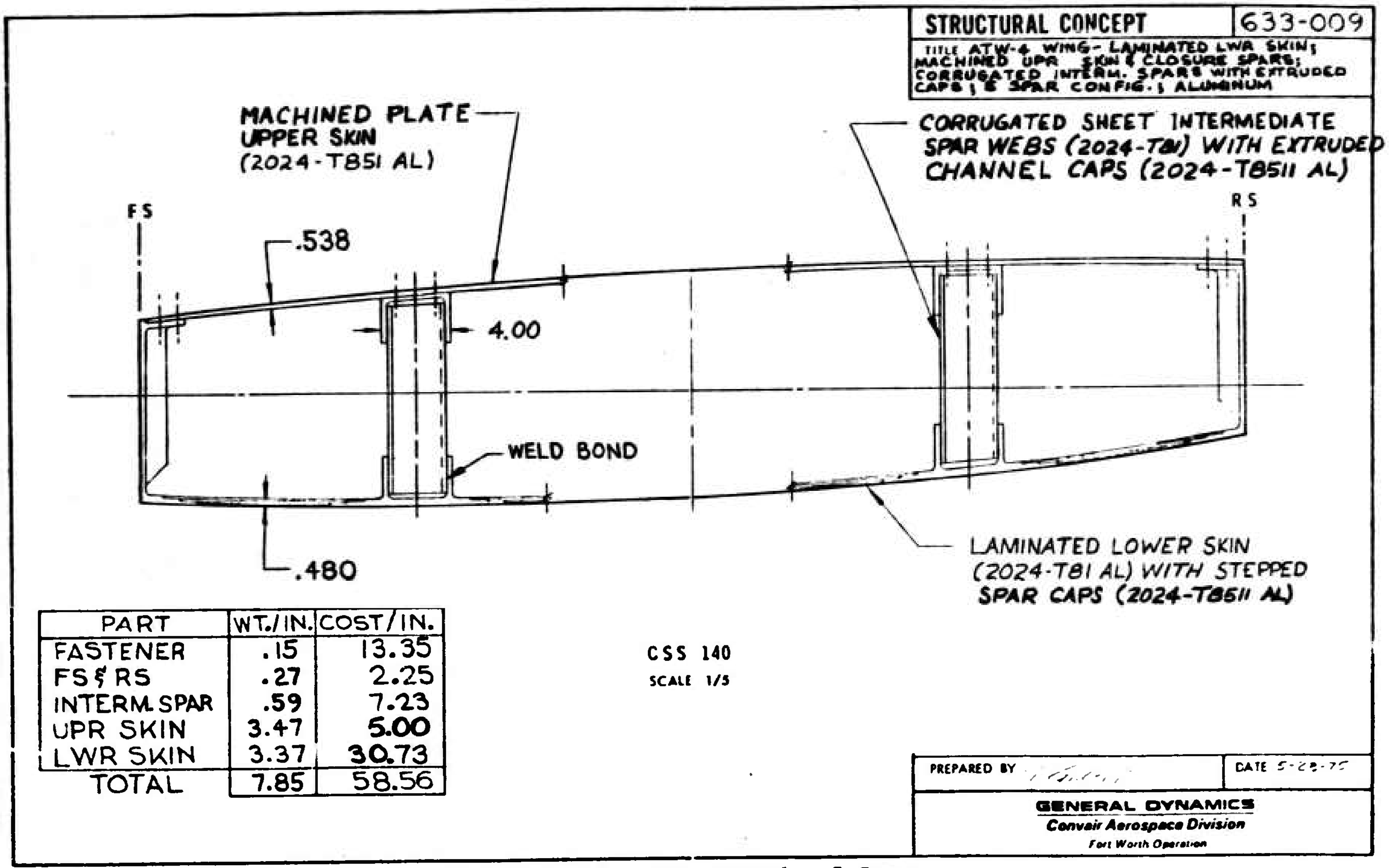
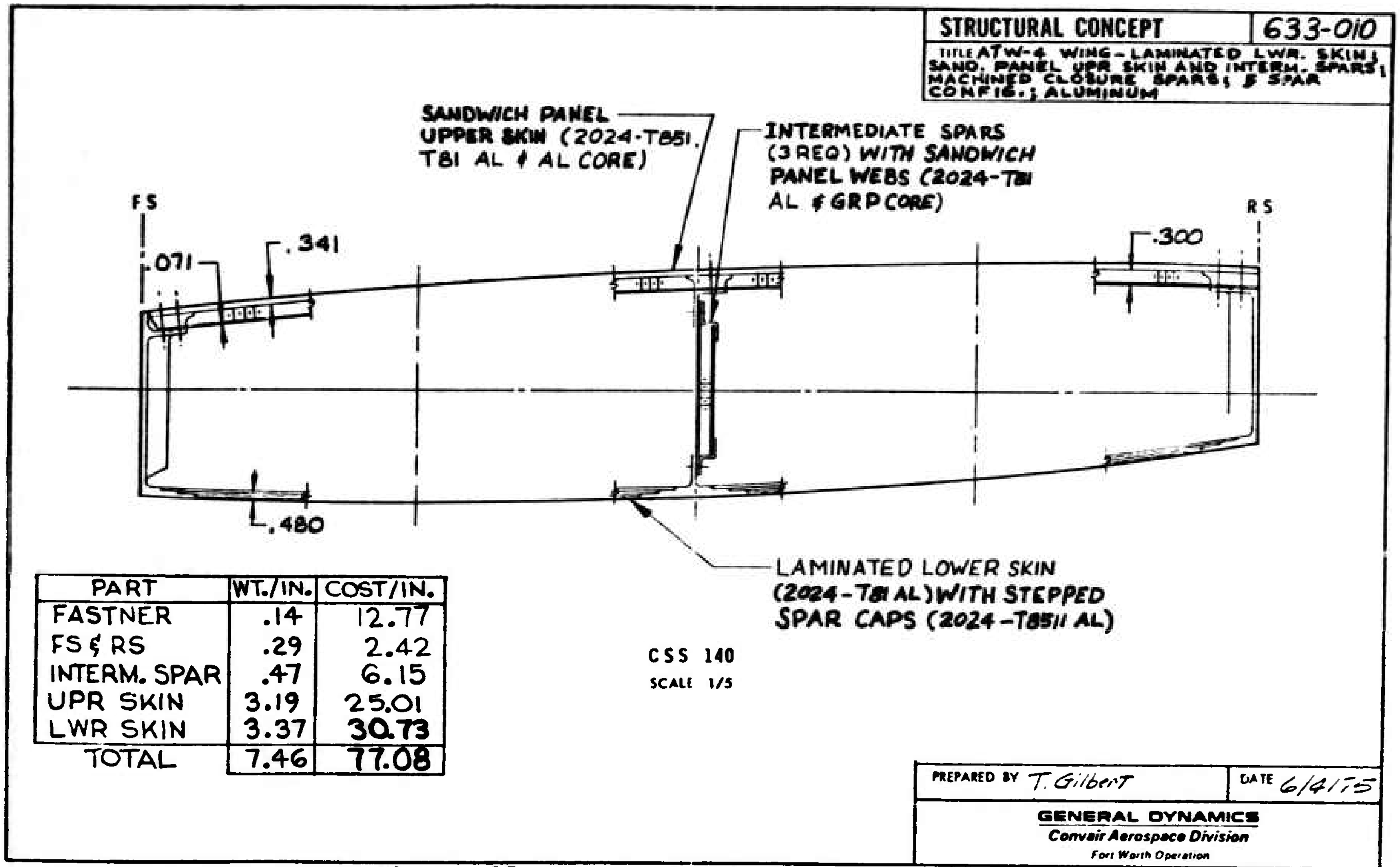
Figure 13   Extruded and Etched Y-Spar



PART	WT./IN.	COST/IN.
FASTENER	.15	13.35
FS & RS	.27	2.25
INTERM. SPAR	.59	7.23
UPR SKIN	3.47	5.00
LWR SKIN	3.37	30.73
TOTAL	7.85	58.56

Figure 14 Corrugated - 5 Spar

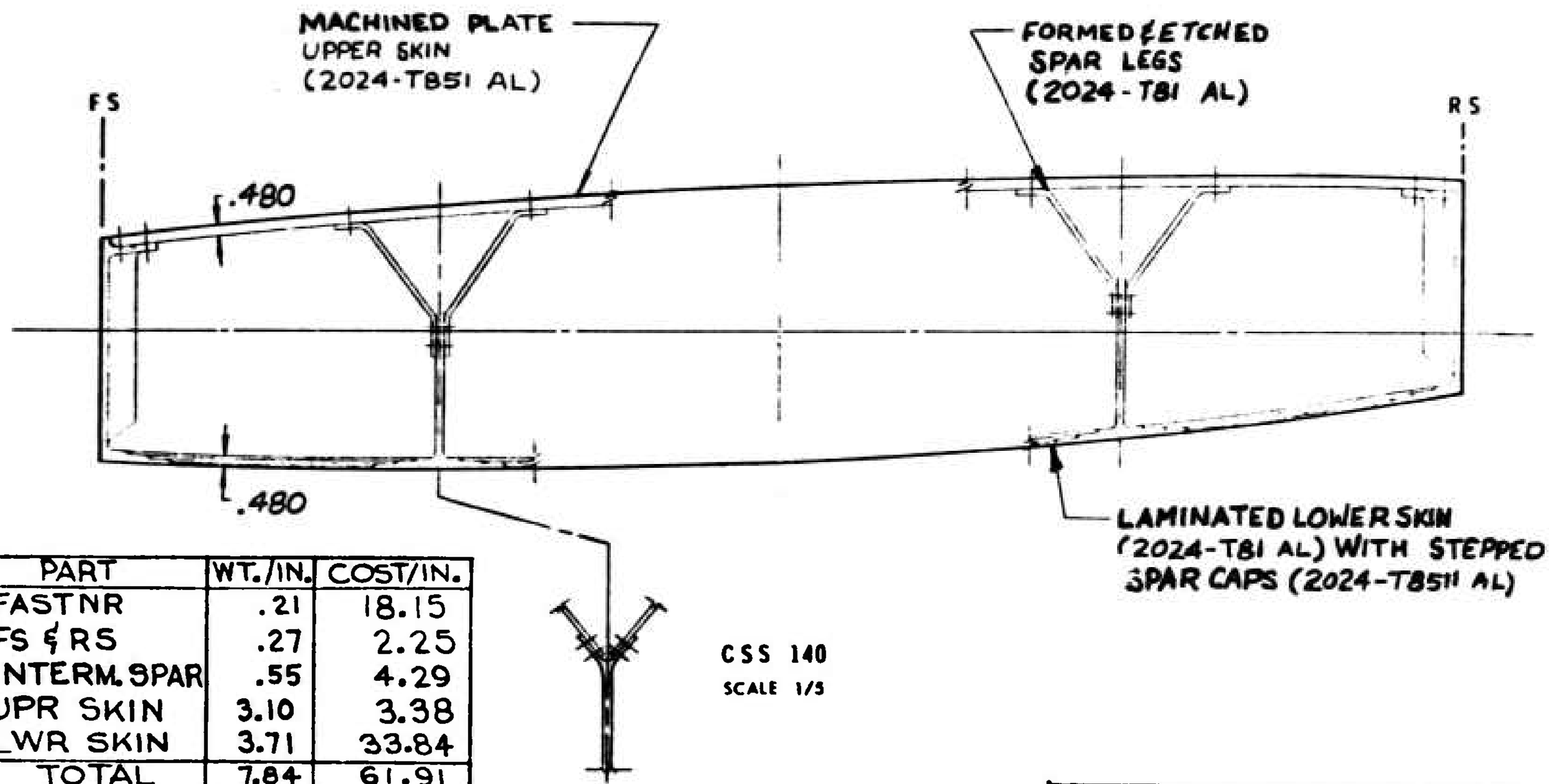


PART	WT./IN.	COST/IN.
FASTNER	.14	12.77
FS & RS	.29	2.42
INTERM. SPAR	.47	6.15
UPR SKIN	3.19	25.01
LWR SKIN	3.37	30.73
TOTAL	7.46	77.08

Figure 15 Honeycomb Spar & Upper Skin - 5 Spar

STRUCTURAL CONCEPT 633-011

TITLE ATW-4 WING-LAMINATED LWR SKIN; MACHINED PLATE UPR SKIN & CLOSURE SPARS; FORMED & ETCHED INTERM. SPARS; 5 SPAR CONFIG.; ALUMINUM



PART	WT./IN.	COST/IN.
FASTNR	.21	18.15
FS & RS	.27	2.25
INTERM. SPAR	.55	4.29
UPR SKIN	3.10	3.38
LWR SKIN	3.71	33.84
TOTAL	7.84	61.91

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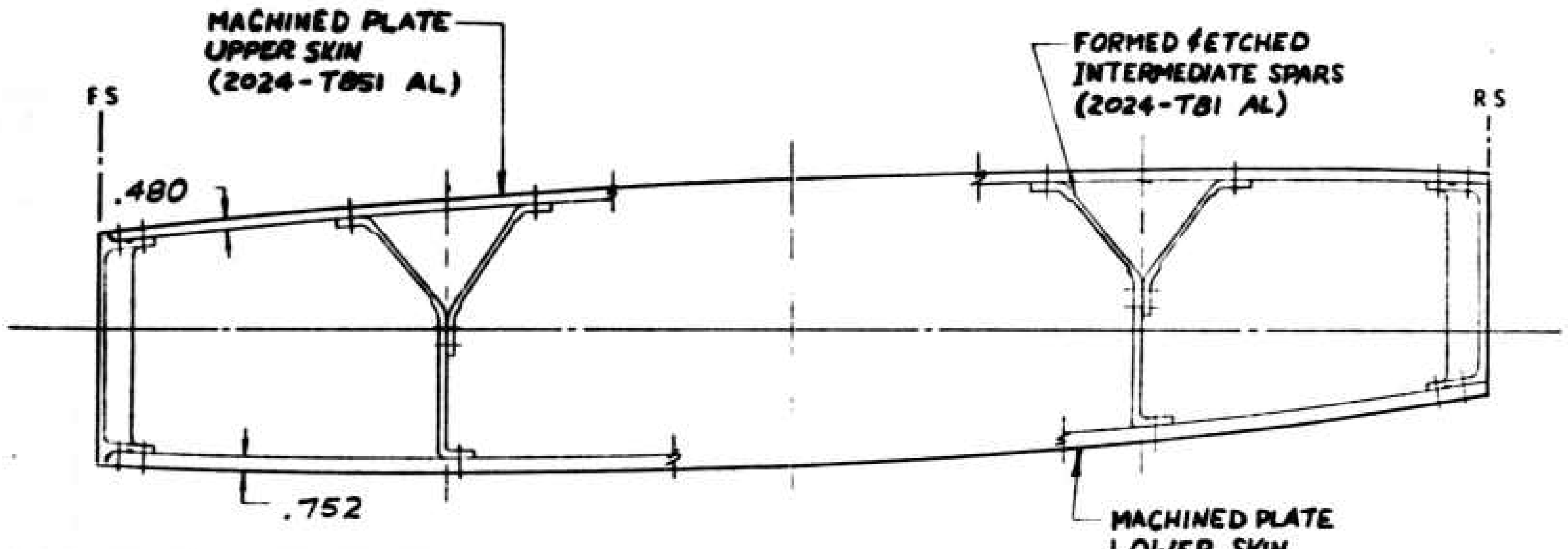
Figure 16 Formed & Etched Y-Spar

STRUCTURAL CONCEPT 633-012

TITLE ATW-4 WING - MACHINED UPR & LWR SKINS AND CLOSURE SPARS; FORMED & ETCHED INTERM. SPARS; 5 SPAR CONFIG.; ALUMINUM



PART	WT./IN.	COST/IN.
FASTNR	.45	200.84
FS & RS	.40	11.22
INTERM. SPAR	1.03	10.30
UPR SKIN	3.10	3.38
LWR SKIN	4.85	6.98
TOTAL	9.83	232.72

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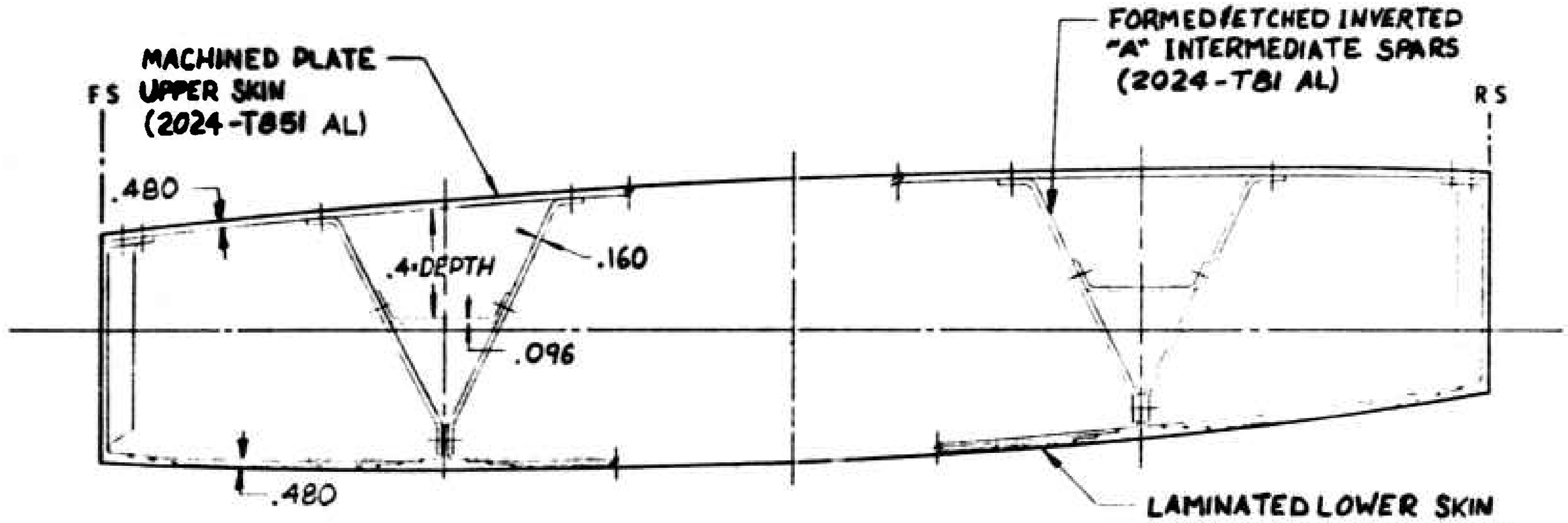
Figure 17 Formed & Etched 2 Piece Y-Spar

STRUCTURAL CONCEPT | 633-013

TITLE ATW-4 WING - LAMINATED LWR SKIN; MACHINED UPR SKIN & CLOSURE SPARS; FORMED & ETCHED INVERTED "A" INTERM. SPARS; 5 SPAR CONFIG.; ALUMINUM



PART	WT./IN.	COST/IN.
FASTNR	.19	18.33
FS & RS	.27	2.25
INTERM. SPAR	1.45	15.95
UPR SKIN	3.10	3.38
LWR SKIN	3.37	30.73
TOTAL	8.38	70.64

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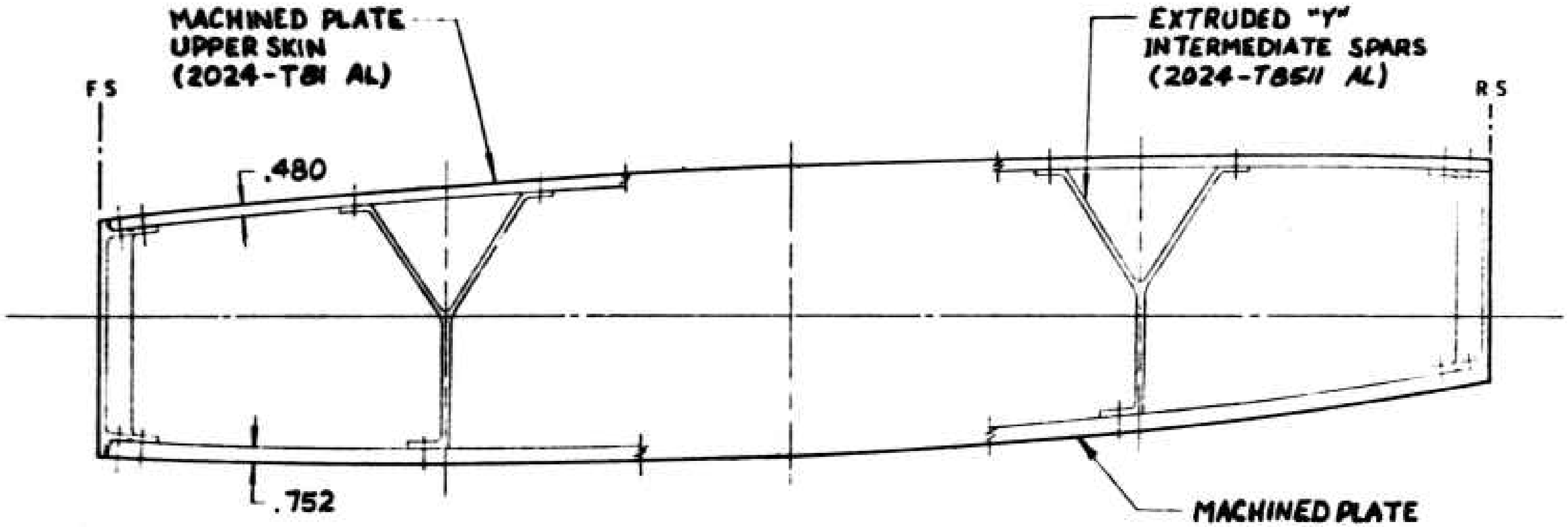
Figure 18 Inverted "A" Spar

STRUCTURAL CONCEPT | 633-014

TITLE ATW-4 WING - MACHINED SKINS & CLOSURE SPARS; EXTRUDED INTERM. SPARS; 5 SPAR CONFIG.; ALUMINUM



PART	WT./IN.	COST/IN.
FASTNR	.39	196.04
FS & RS	.40	11.22
INTERM. SPAR	1.12	3.00
UPR SKIN	3.10	3.38
LWR SKIN	4.85	6.98
TOTAL	9.86	220.62

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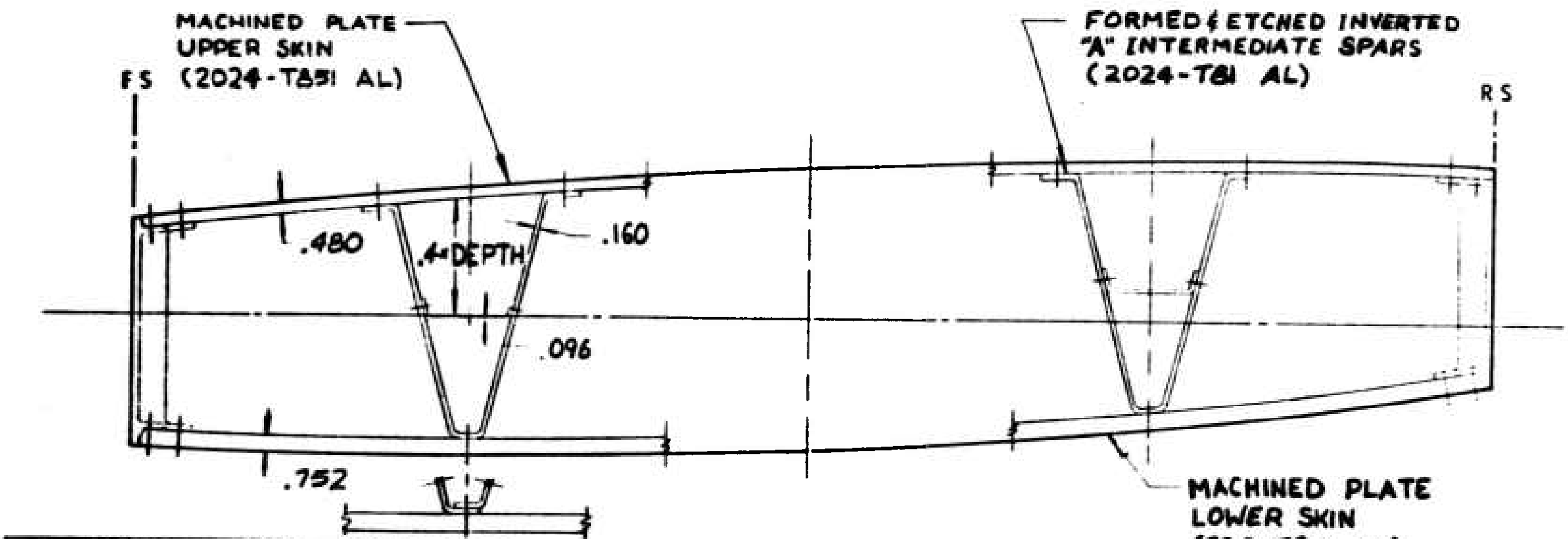
Figure 19 Extruded & Machined Y-Spar

STRUCTURAL CONCEPT	633-015
TITLE ATW-4 WING MACHINED UPR & LWR SKINS AND CLOSURE SPARS; FORMED & ETCHED INVERTED "A" INTERM. SPARS, 5 SPAR CONFIG. & ALUMINUM	



PART	WT/IN.	COST/IN.
FASTNR	.41	199.78
FS & RS	.40	11.22
INTERM.SPAR	1.45	15.23
UPR SKIN	3.10	3.38
LWR SKIN	4.85	6.98
TOTAL	10.21	236.59

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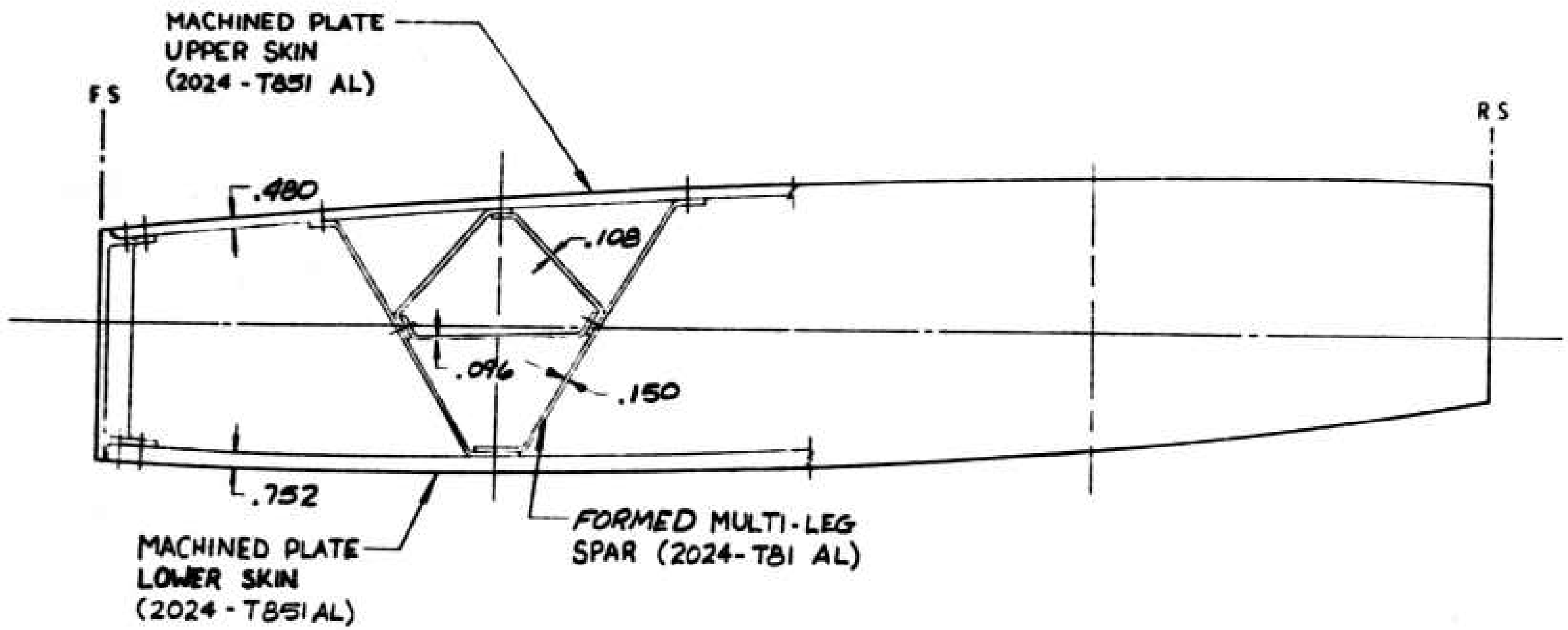
Figure 20 Inverted "A" Spar - Plate Skins

STRUCTURAL CONCEPT 633-016

TITLE ATW-4 MACHINED SKINS & CLOSURE SPARS ; FORMED MULTI-LEG INTERM. SPARS ; 4 SPAR CONFIG. ; ALUMINUM



PART	WT./IN.	COST/IN.
FASTNR	.29	116.69
FS & RS	.40	11.22
INTERM. SPAR	1.54	30.80
UPR. SKIN	3.10	3.38
LWR. SKIN	4.85	6.98
TOTAL	10.18	169.07

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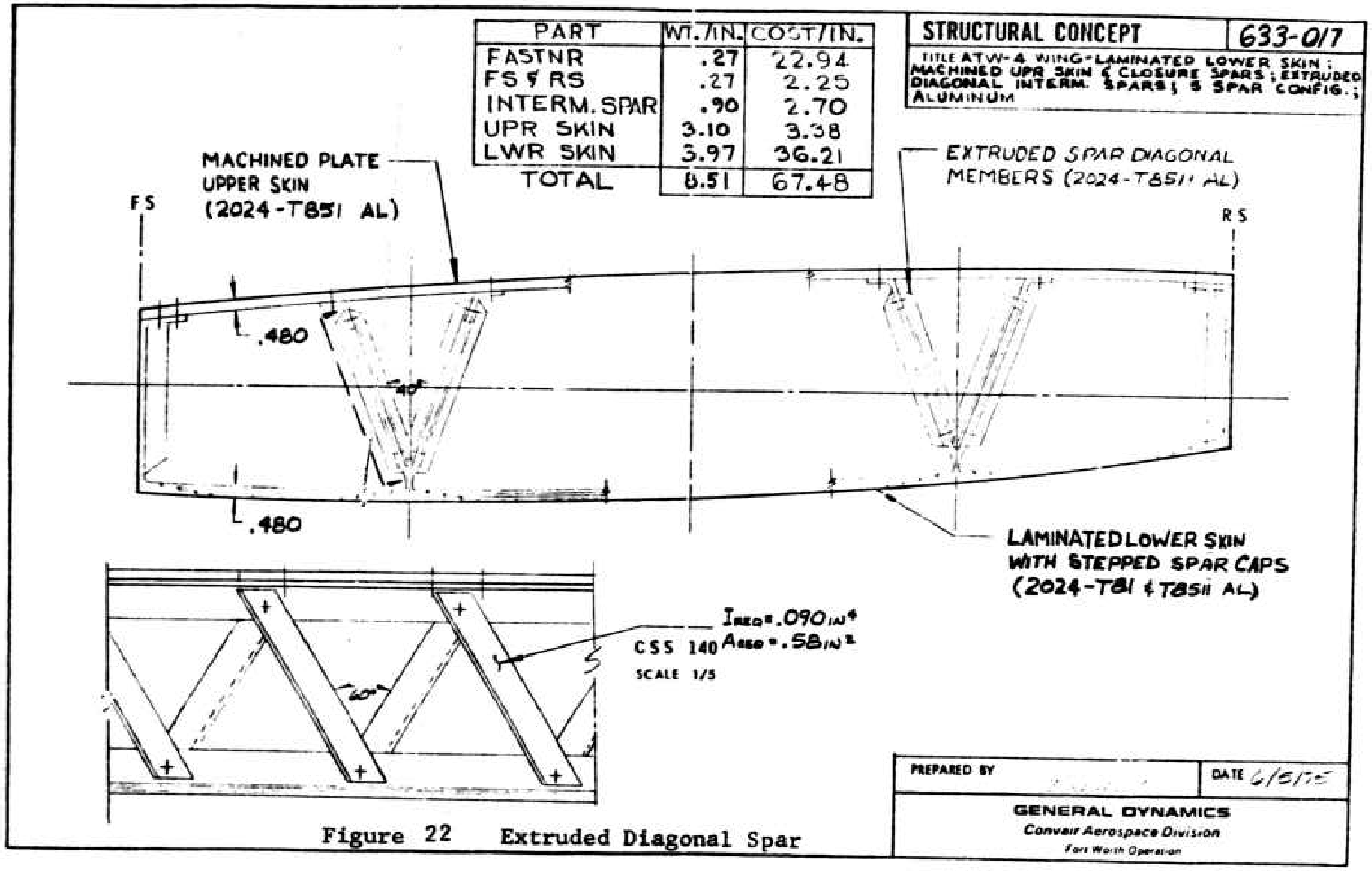
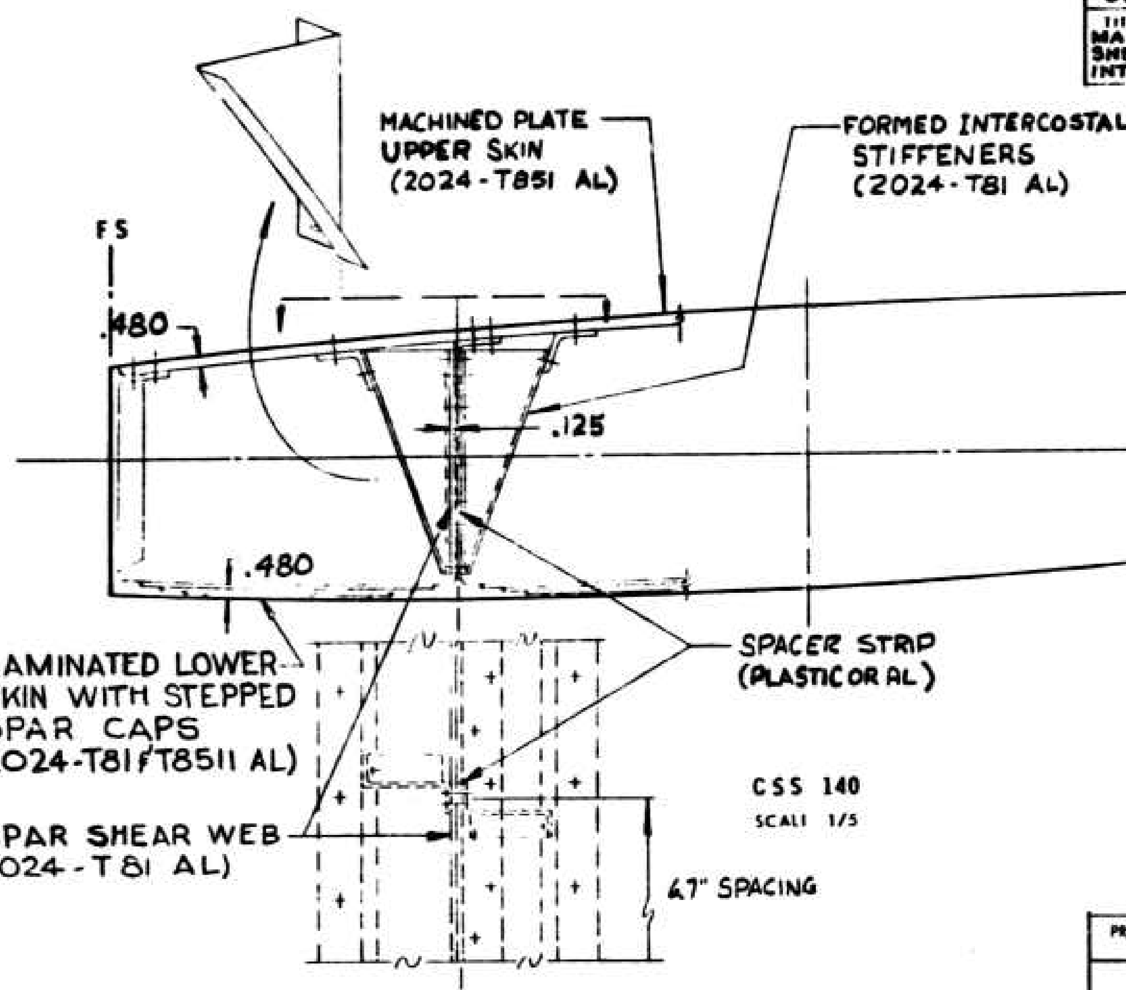
Figure 21 Multi-leg Spar



$I_{REQ} = .090\ in^4$, $A_{REQ} = .58\ in^2$

PART	WT./IN.	COST/IN.
FASTNR	.27	22.94
FS & RS	.27	2.25
INTERM. SPAR	.90	2.70
UPR SKIN	3.10	3.38
LWR SKIN	3.97	36.21
TOTAL	8.51	67.48

Figure 22 Extruded Diagonal Spar



STRUCTURAL CONCEPT 633-018

ATW-4 WING LAMINATED LWR SKIN; MACHINED UPR SKIN & CLOSURE SPARS; SHEET METAL INTERM. SPARS WITH FORMED INTERCOSTALS && SPAR CONFIG.; ALUMINUM

PART	WT./IN.	COST/IN.
FASTNR	.32	35.72
FS & RS	.27	2.25
INTERM. SPAR	.77	7.70
UPR SKIN	3.10	3.38
LWR SKIN	3.37	30.73
TOTAL	7.83	79.78

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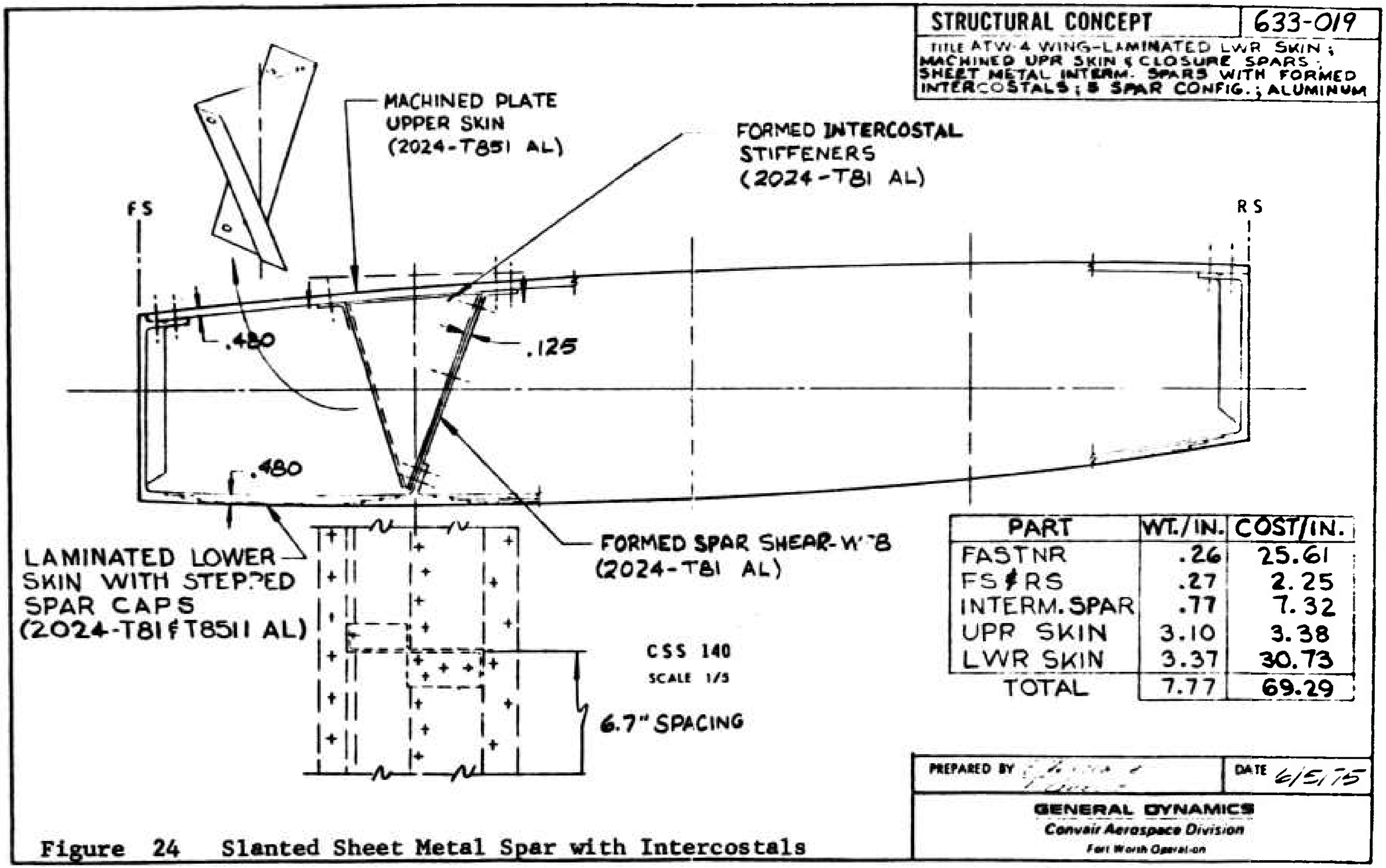
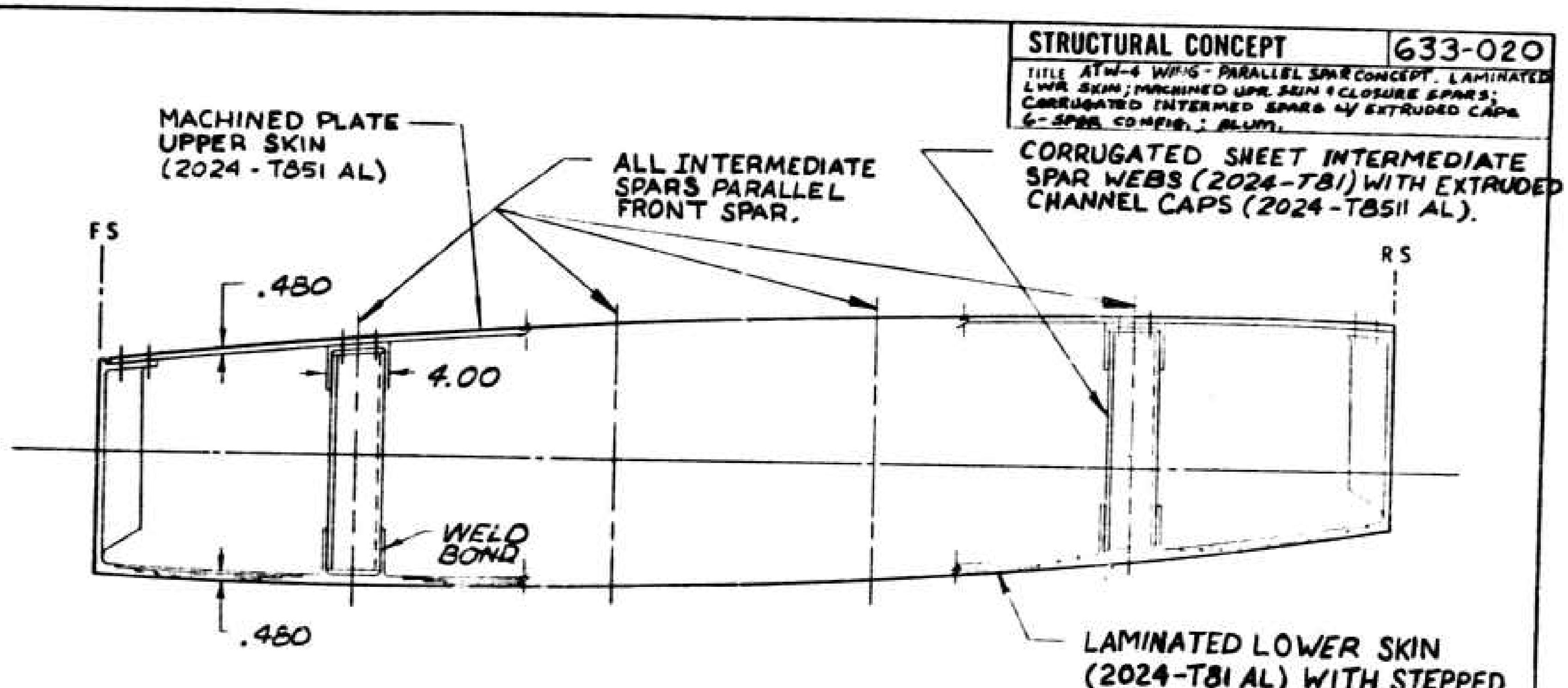
Figure 23 Sheet Metal Spar with Intercostals



PART	WT./IN.	COST/IN.
FASTNR	.26	25.61
FS & RS	.27	2.25
INTERM. SPAR	.77	7.32
UPR SKIN	3.10	3.38
LWR SKIN	3.37	30.73
TOTAL	7.77	69.29

Figure 24 Slanted Sheet Metal Spar with Intercostals



PART	WT./IN.	COST/IN.
FASTNRS.	.18	16.02
FS & RS	.27	2.25
INTERM. SPARS	.79	9.68
UPR. SKIN	3.10	3.38
LWR. SKIN	3.37	30.73
TOTAL	7.71	62.06

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Figure 25 Corrugated Spar

TABLE II WING BOX METALLIC CROSS SECTION CONCEPT SCORING & RANKING SUMMARY

CONCEPT	STRUCTURAL EFFICIENCY WEIGHT (.40)		STRUCTURAL EFFICIENCY COST (.60)		TOTAL SCORE (1.00)	RANKING
633-000	10.73	(.278)	233.46	(.147)	.425	20
633-001	10.46	(.285)	234.71	(.146)	.431	19
633-002	7.61	(.392)	81.25	(.421)	.813	14
633-003	7.63	(.391)	62.32	(.549)	.940	5
633-004	7.81	(.382)	63.25	(.541)	.923	9
633-005	7.71	(.387)	59.41	(.576)	.963	4
633-006	8.04	(.371)	57.43	(.596)	.967	2
633-007	7.62	(.392)	62.42	(.548)	.940	5
633-008	7.81	(.382)	57.01	(.600)	.982	1
633-009	7.85	(.380)	58.56	(.584)	.964	3
633-010	7.46	(.400)	77.08	(.444)	.844	12
633-011	7.84	(.381)	61.91	(.553)	.934	8
633-012	9.83	(.304)	232.72	(.147)	.451	18
633-013	8.38	(.356)	70.64	(.484)	.840	13
633-014	9.86	(.303)	220.62	(.155)	.458	17
633-015	10.21	(.292)	236.59	(.000)	.292	21
633-016	10.18	(.293)	169.07	(.202)	.495	16
633-017	8.51	(.351)	67.48	(.507)	.858	11
633-018	7.83	(.381)	79.78	(.429)	.810	15
633-019	7.77	(.384)	69.29	(.494)	.878	10
633-020	7.71	(.387)	62.06	(.551)	.938	7

3.2.1.2 Composite Concepts

The twelve composite cross-section concepts defined and evaluated incorporate a variety of concepts that improve producibility, are economical to manufacture and that reduce weight.

Skin concepts defined and studied are as follows:

- Planked, solid graphite epoxy layup
- Skins with and without fastener penetrations
- Graphite epoxy skins with and without buffer strips
- Lower skins with integral front and rear spar
- Intermediate lower spar caps embedded in the skin
- Graphite epoxy sandwich skins with nomex honey comb core
- Waffle pattern, Kevlar hat stiffened skins.

Alternate spar concepts considered were:

- Sandwich intermediate spars with nomex honey comb core
- Intermediate spars with embedded titanium lower caps
- Sine wave spar webs
- "Y" spars with and without solid nomex core in the webs
- "X" spar with trussed web
- A truss spar arrangement.

The concepts showing the most promise for low weight and cost and those selected for the composite analytical assemblies were as follows:

- Corrugated sine wave intermediate spars with embedded lower spar cap and buffered graphite epoxy skins
- Trussed spar arrangement with integral graphite epoxy skins

- "Y" spars with and without embedded lower caps and solid graphite epoxy skins without buffer strips

- Sandwich spars with lower titanium cap embedded in the lower skin. Both skins solid laminate graphite epoxy with buffer strips.

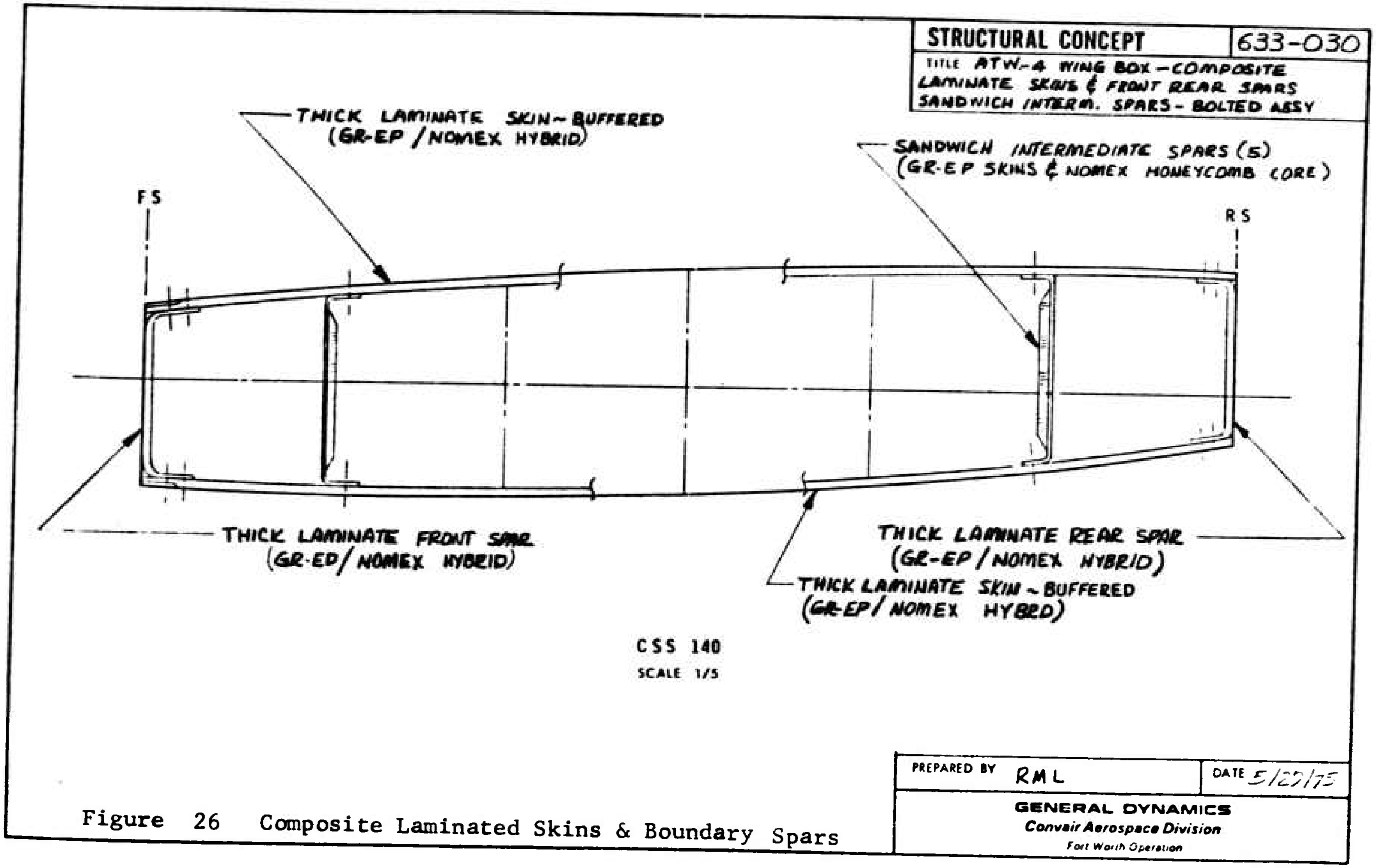

Figure 26 Composite Laminated Skins & Boundary Spars

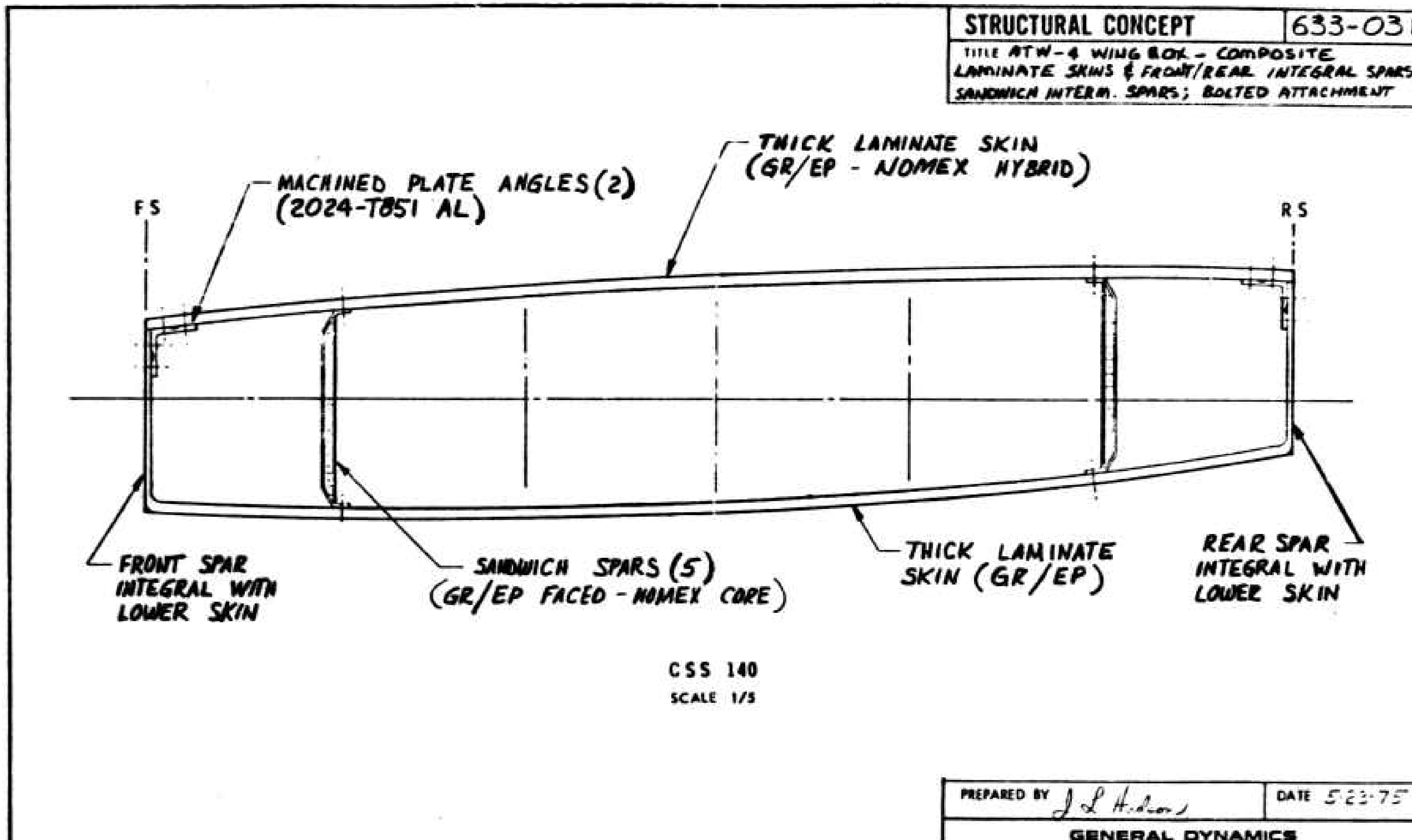

Figure 27 Composite Laminated Skins With Integral Boundary Spars

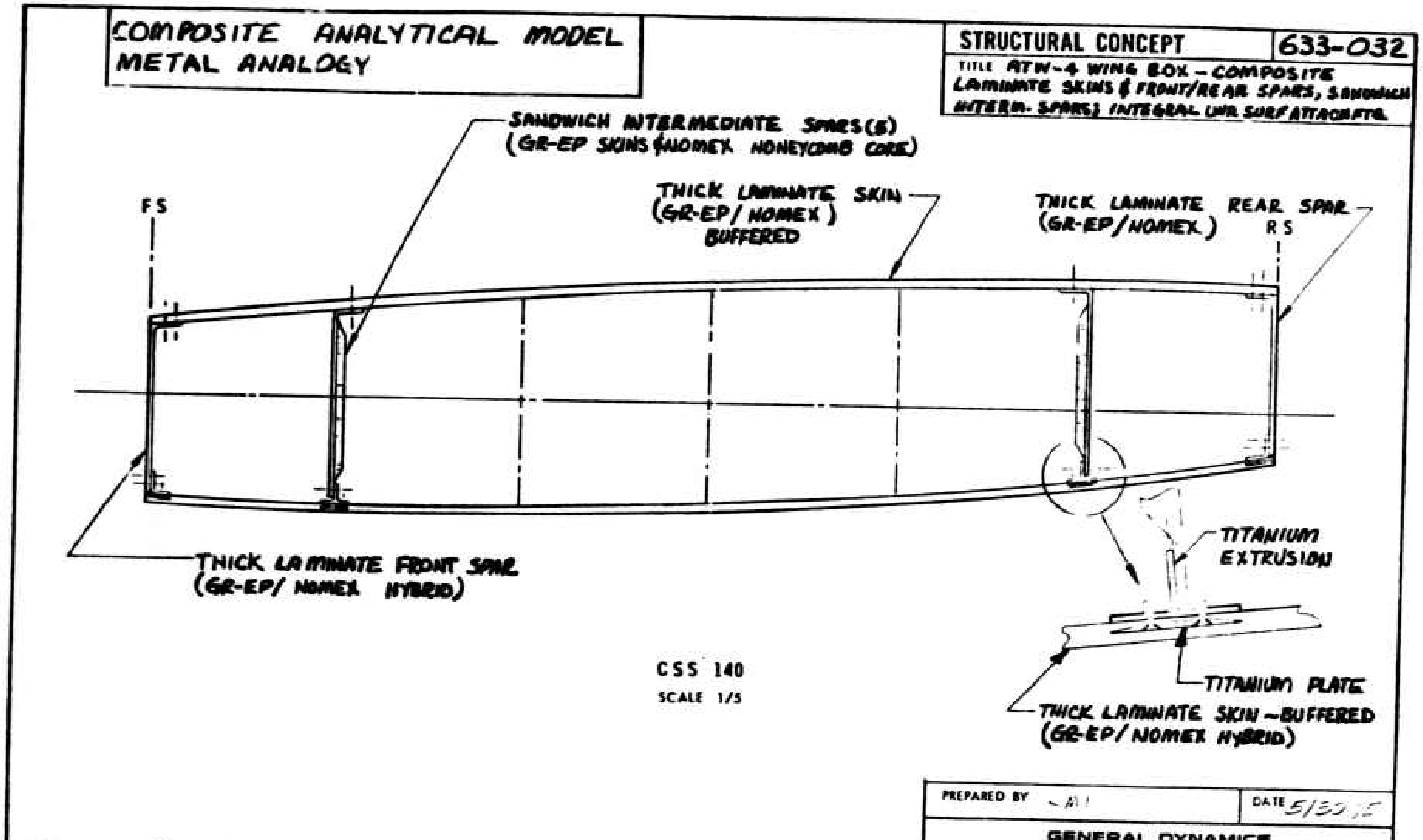

Figure 28 Composite Laminated Skins With Embedded Ti Plate

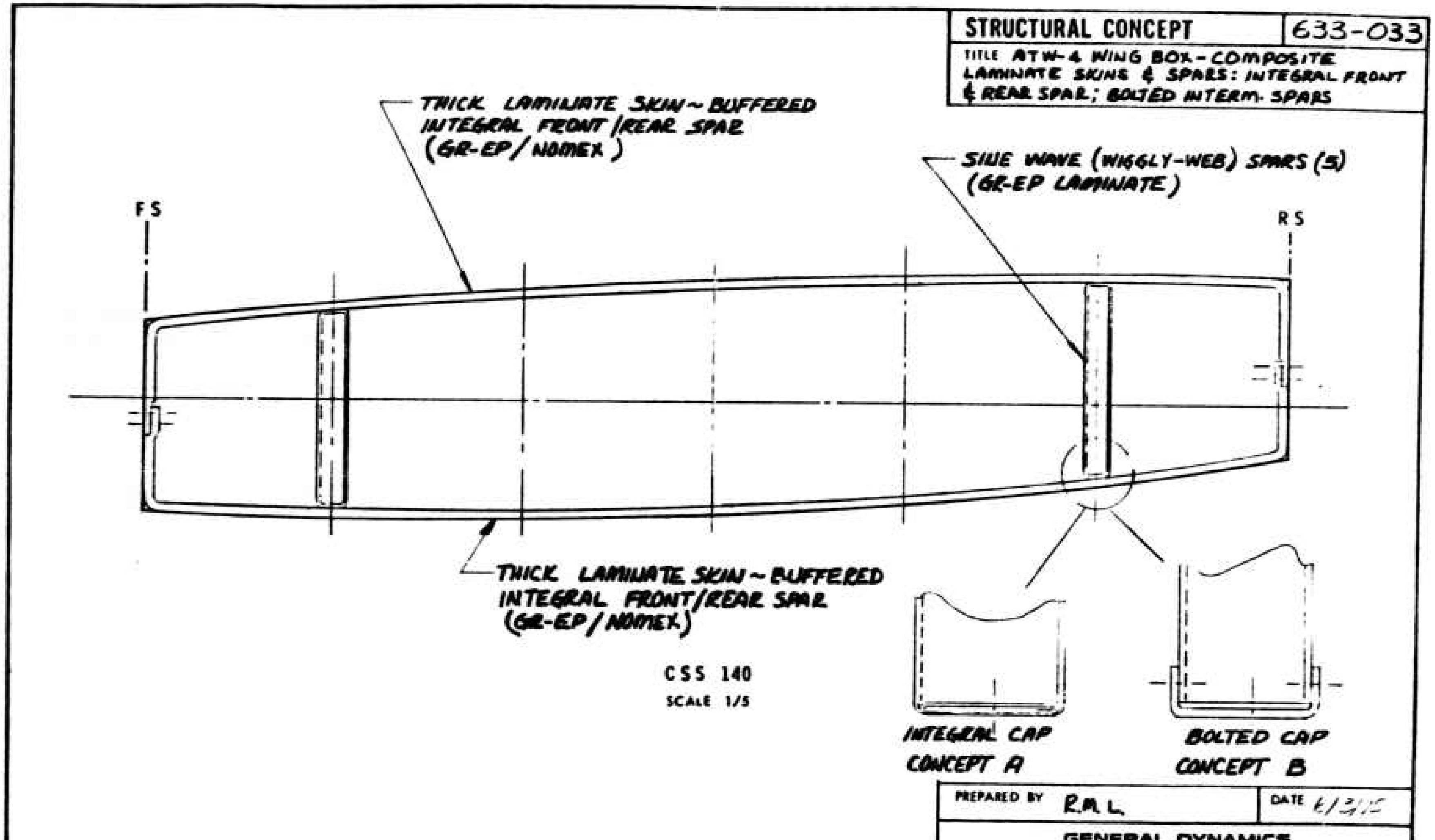

Figure 29 Composite Laminated Skins With Corrugated Skins

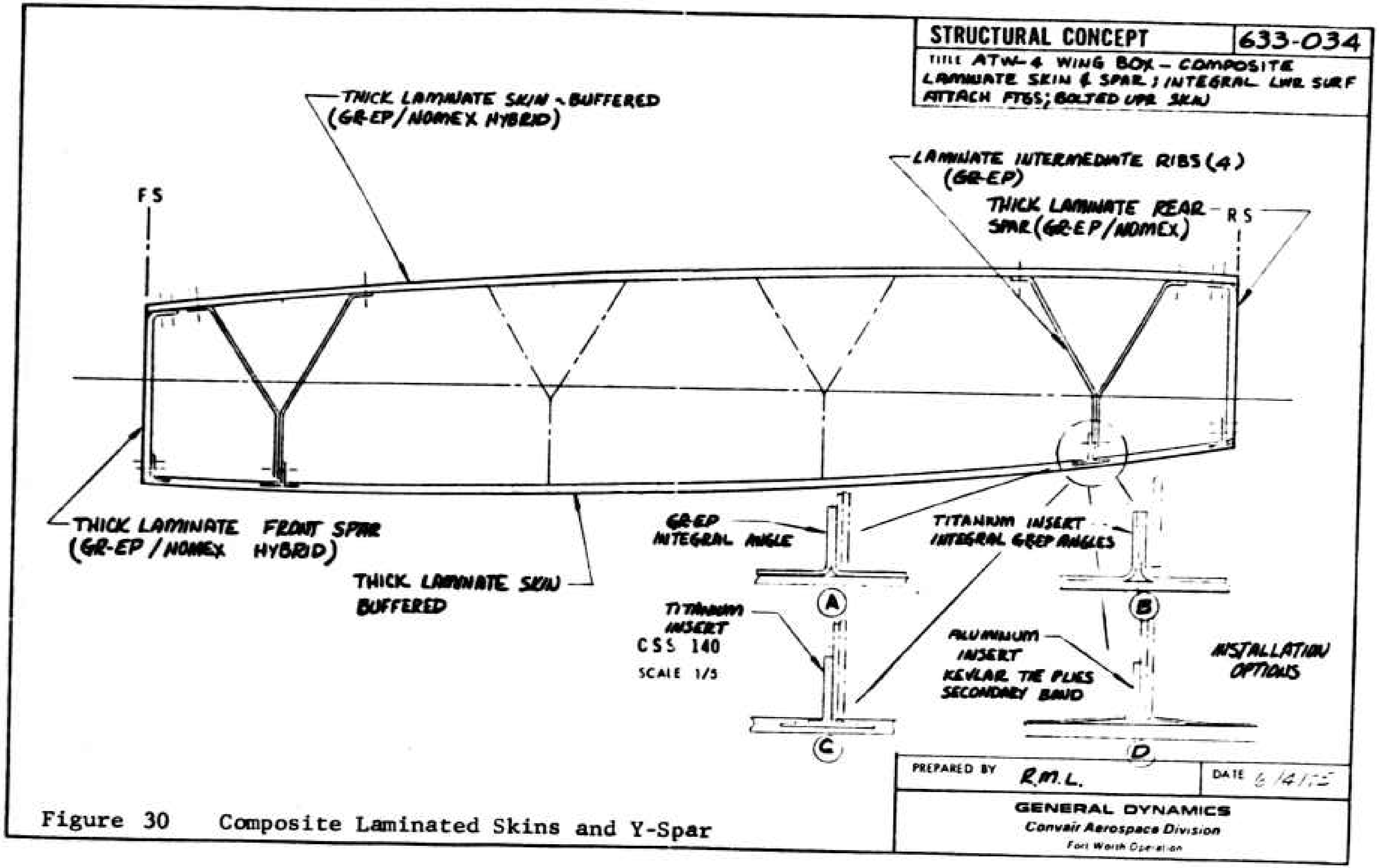

Figure 30 Composite Laminated Skins and Y-Spar

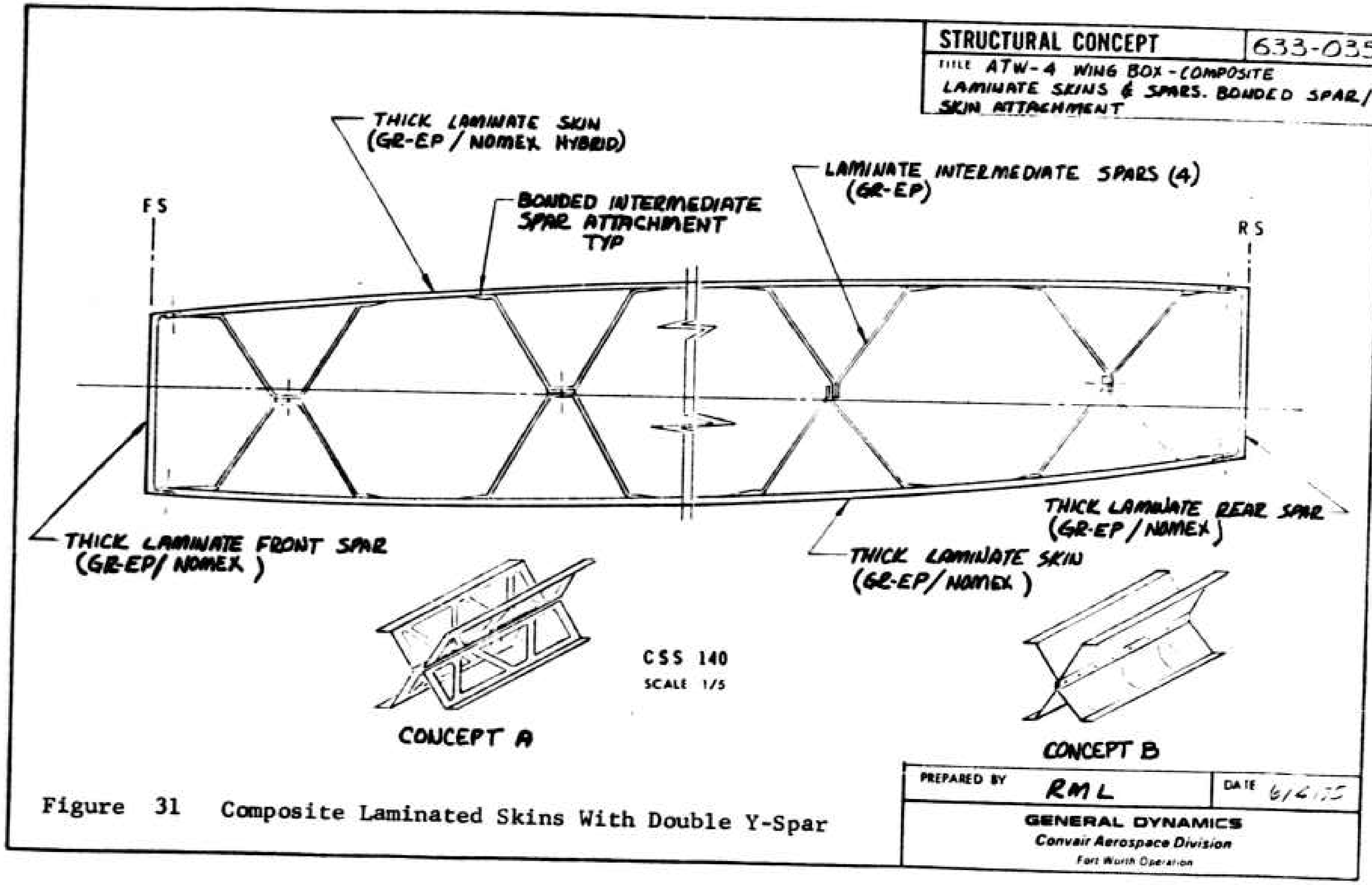

Figure 31 Composite Laminated Skins With Double Y-Spar

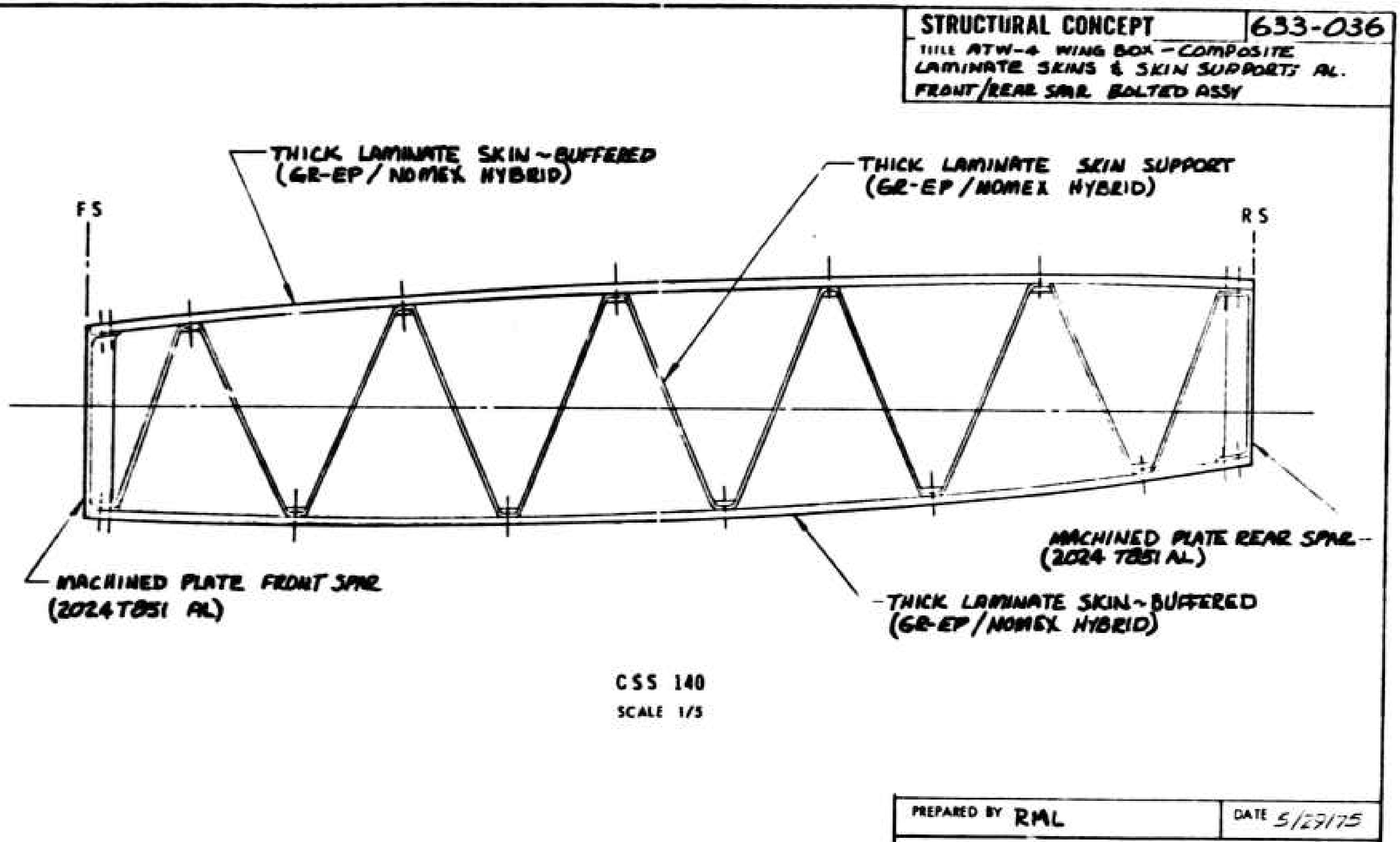

Figure 32 Composite Laminated Skins & Support Structure

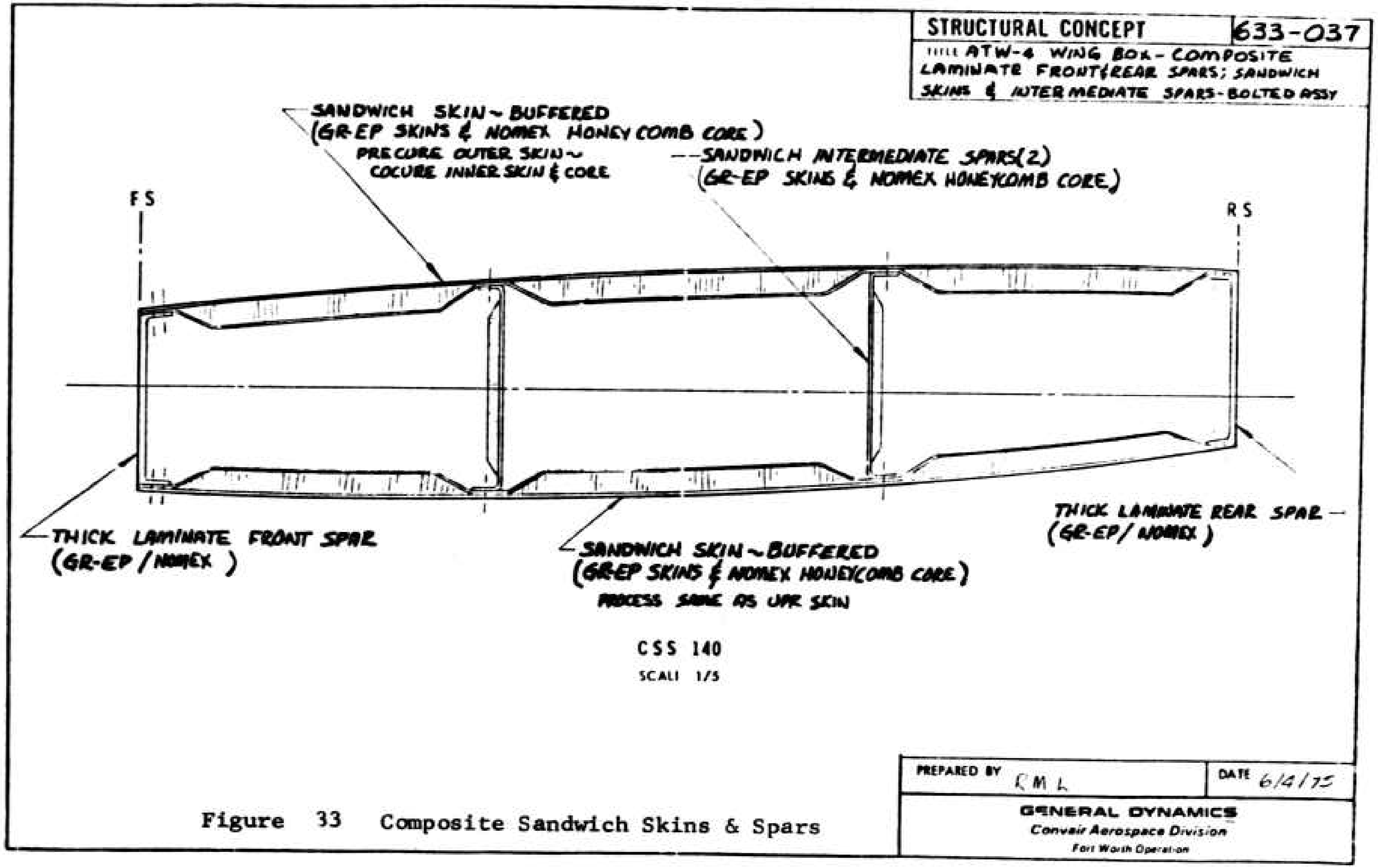

Figure 33 Composite Sandwich Skins & Spars

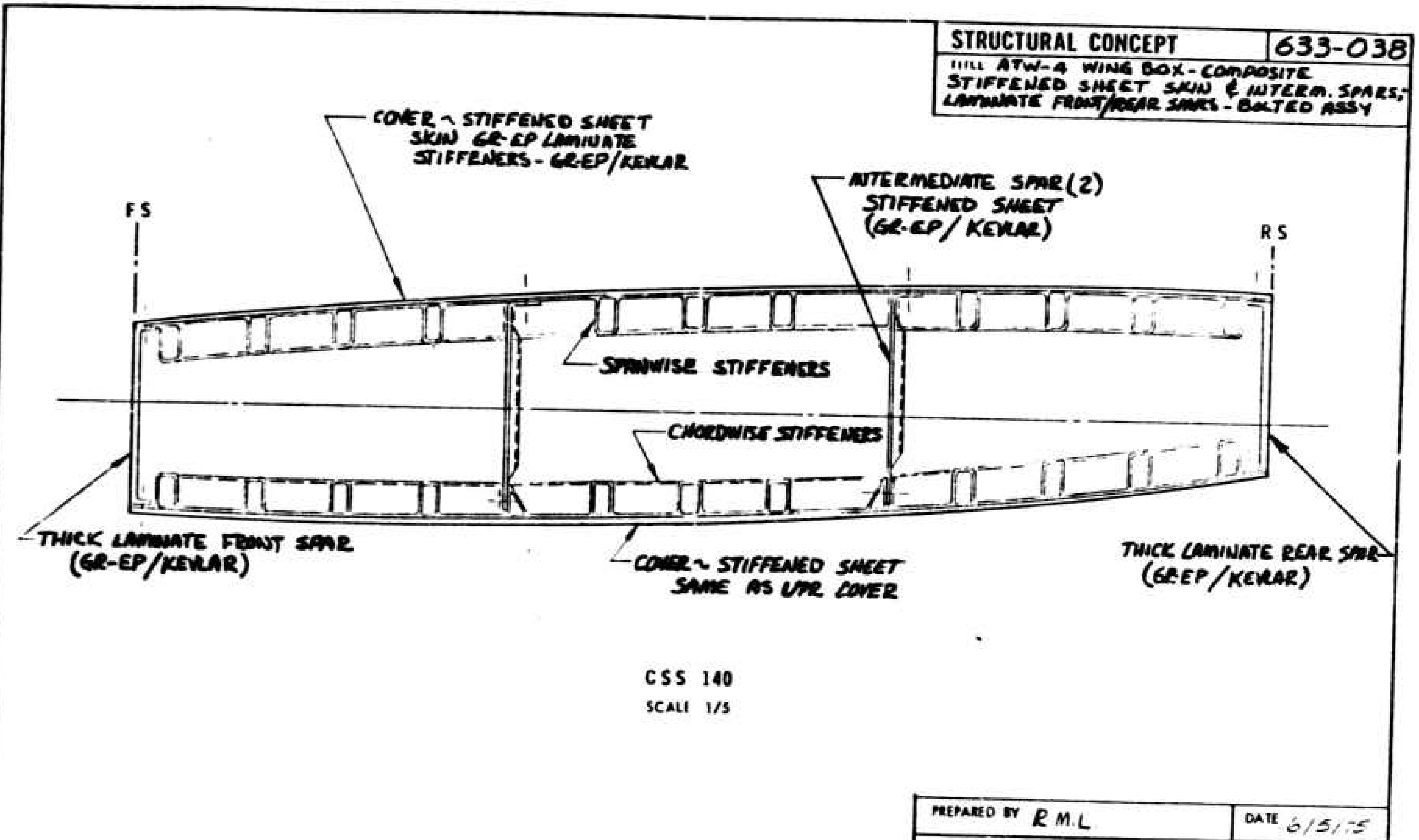

Figure 34 Composite Laminated Skins & Spars With Stiffeners

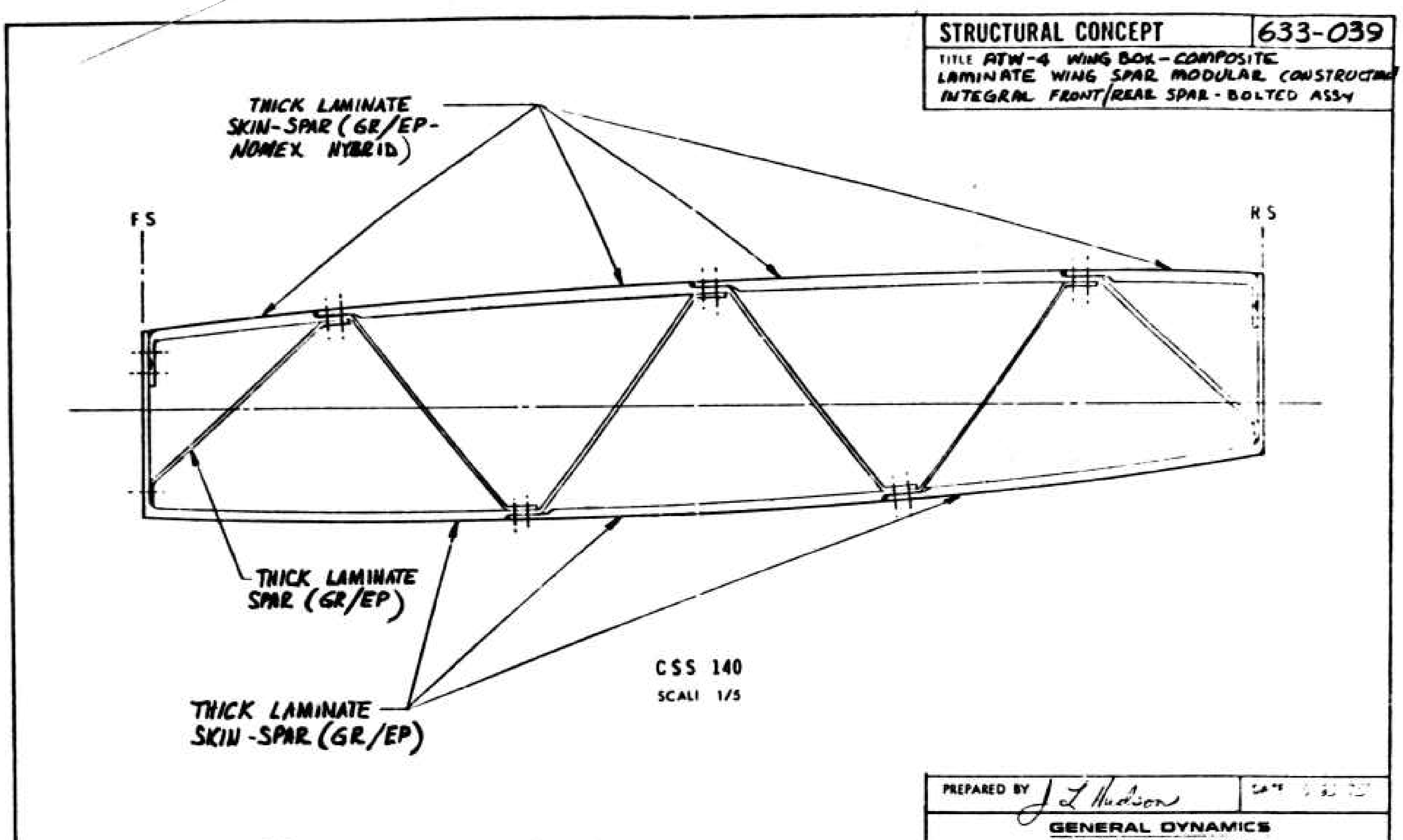

Figure 35 Modular Composite Structure

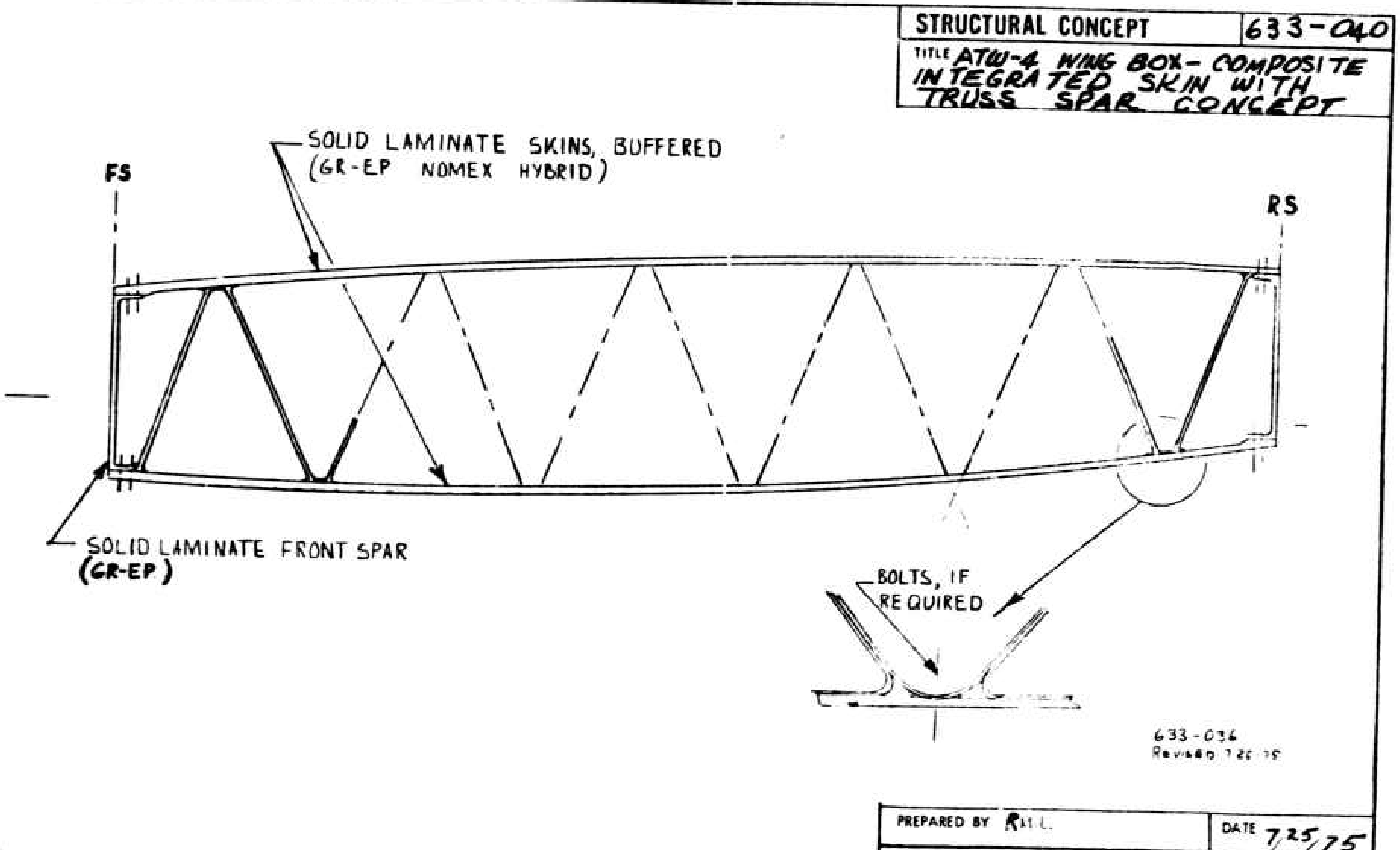

Figure 36 Composite Truss Spar

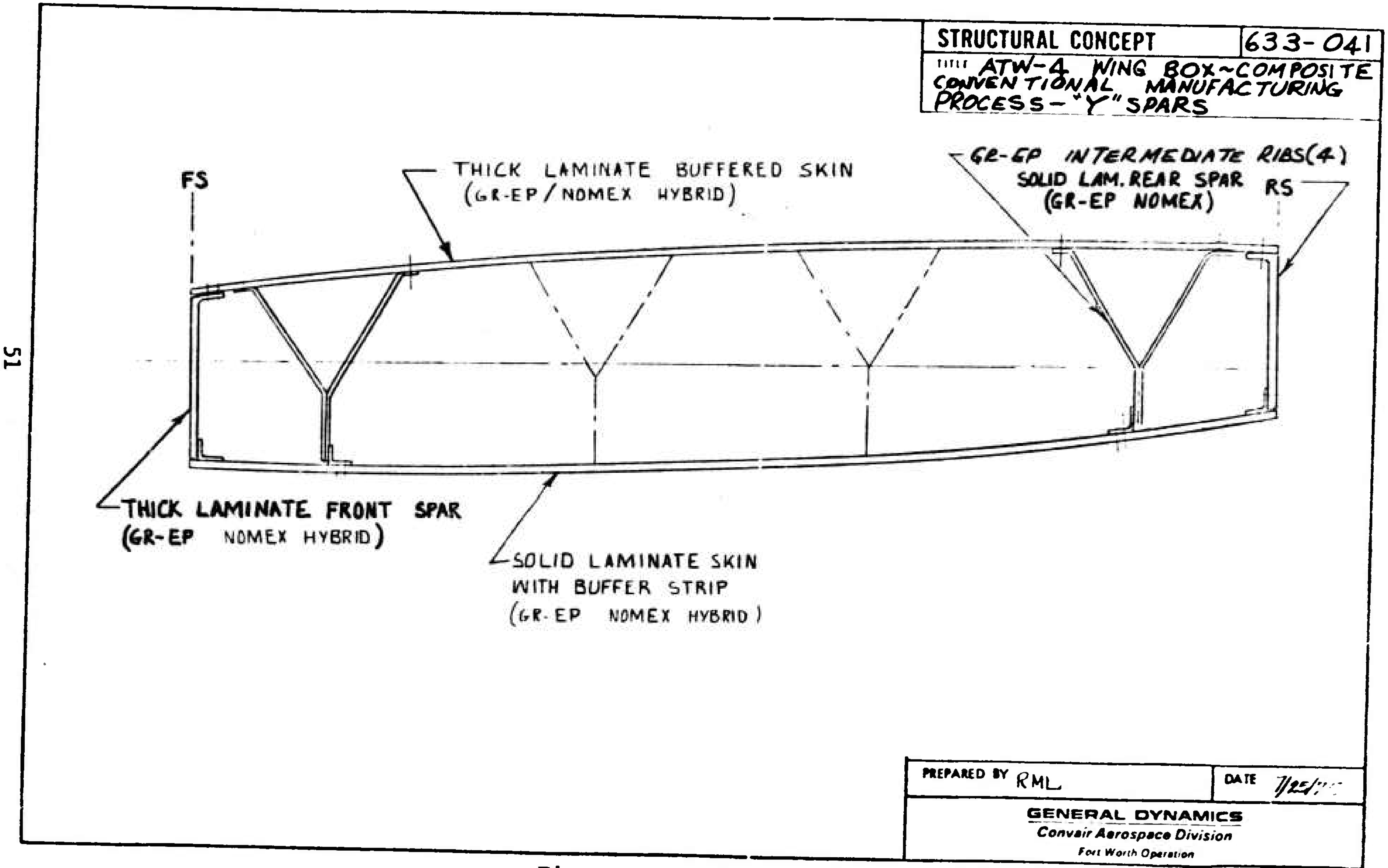

Figure 37 Composite Y-Spar

Table III WING BOX COMPOSITE CROSS SECTION CONCEPT SCORING AND RANKING SUMMARY

CONCEPT	STRUCTURAL EFFICIENCY		TOTAL SCORE (1.00)	RANKING
	WEIGHT (.40)	COST (.60)		
633-030	.348	.334	.882	7
633-031	.348	.541	.889	6
633-032	.348	.545	.893	5 *
633-033	.400	.600	1.000	1 *
633-034	.372	.578	.950	3 *
633-035	.385	.541	.889	6
633-036	.337	.542	.879	8
633-037	.400	.578	- FUEL VOL. LOSS UNACCEPTABLE -	
633-038	.337	.535	.872	9
633-039	.326	.533	.859	10
633-040	.337	.600	.937	4 *
633-041	.385	.578	.963	2 *

* THESE CONCEPTS INPUT INTO THE ANALYTICAL ASSEMBLY ITERATION

3.2.2 Analytical Assembly Iteration

Fourteen metallic wing box concepts, five composite wing box concepts, and a baseline wing box were defined on analytical assembly drawings. These design concepts are shown in Figure 38 thru 46 which correspond to drawing numbers 633RA000 thru 633RA008. Weight and cost for each significant detail is shown in the data block of each analytical assembly drawing.

Tables IV and V contain tabulated evaluation summaries of all design parameters specified in the AFFDL merit rating system for each analytical assembly concept studied. The costing ground rules are defined in Section VIII.

3.2.2.1 Metallic Analytical Assemblies

Of the fourteen promising metallic cross-section concepts that were carried into the analytical assembly iteration, the two concepts that emerged with the highest overall scores were 633RA003-801 (ranked first), 633RA001-1 (ranked second).

The 633RA003-801 analytical assembly concept is configured with laminated lower skins having no fastener penetrations and exposed, stepped spar caps; non-pocketed monolithic 2024-T851 aluminum plate upper skin; and intermediate spars having canted sheet aluminum webs stabilized by "V" shaped intercostals that support dual extruded upper spar caps. The front and rear spars are integrally machined members

The 633RA001-1 analytical assembly concept incorporates the same upper skin, lower skin, front spar and rear spar concepts as 633RA003-801. The difference between the two designs is in the intermediate spars. The 633RA001-1 design incorporates extruded "Y" spars.

3.2.2.2 Composite Analytical Assemblies

Of the five composite analytical assembly concepts studied, the number 1 ranking design is 633RA006-3. This design incorporates solid graphite epoxy laminate upper and lower skins without buffer strips and a "Y" intermediate spar concept with an embedded lower cap and 16 layers of nomex core material in the webs. This design is more cost effective than the other composite designs because it requires less composite material than the other and permits maximum utilization of the automatic tape laying machine for fabrication.

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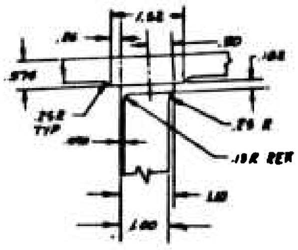
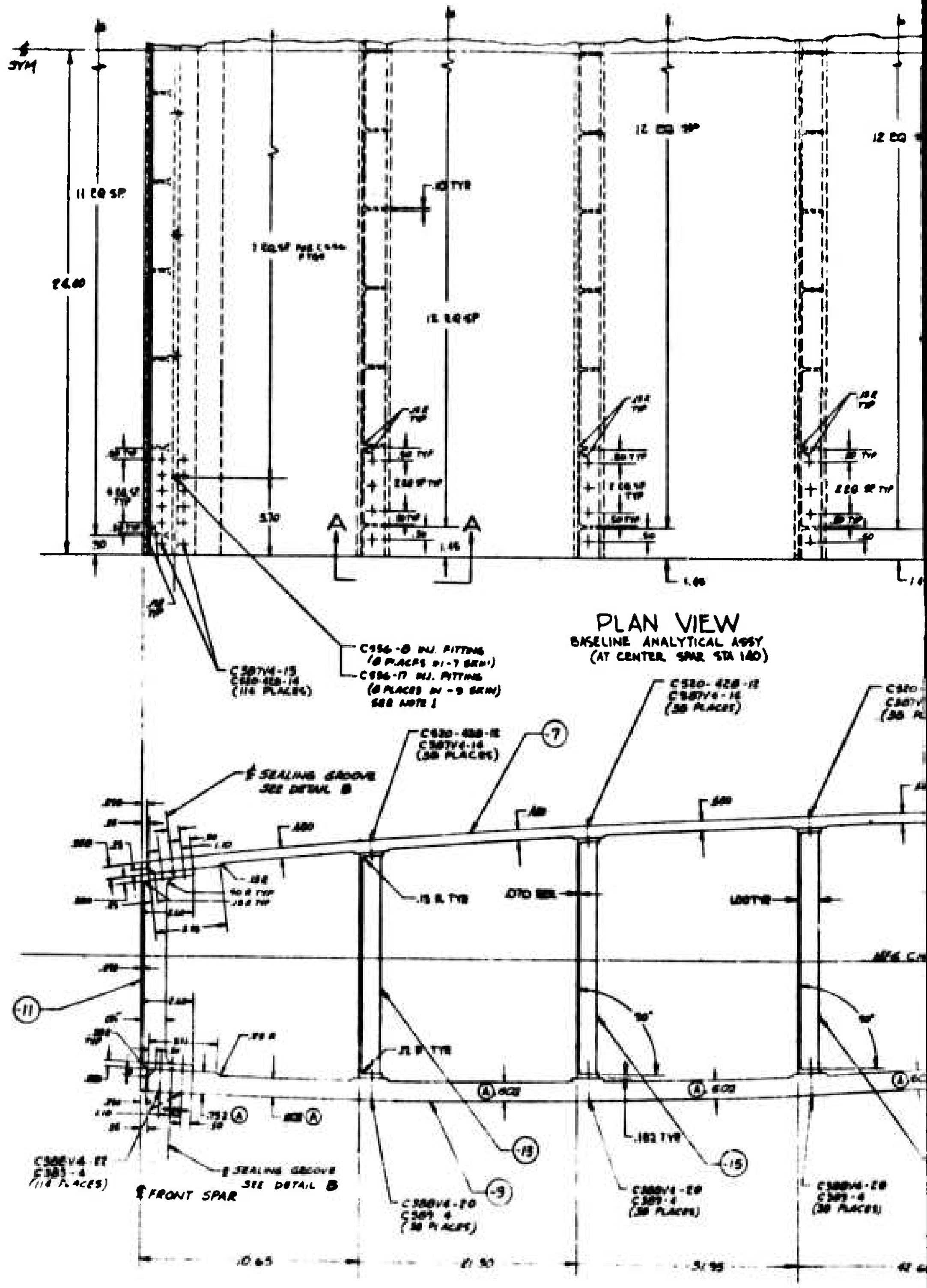
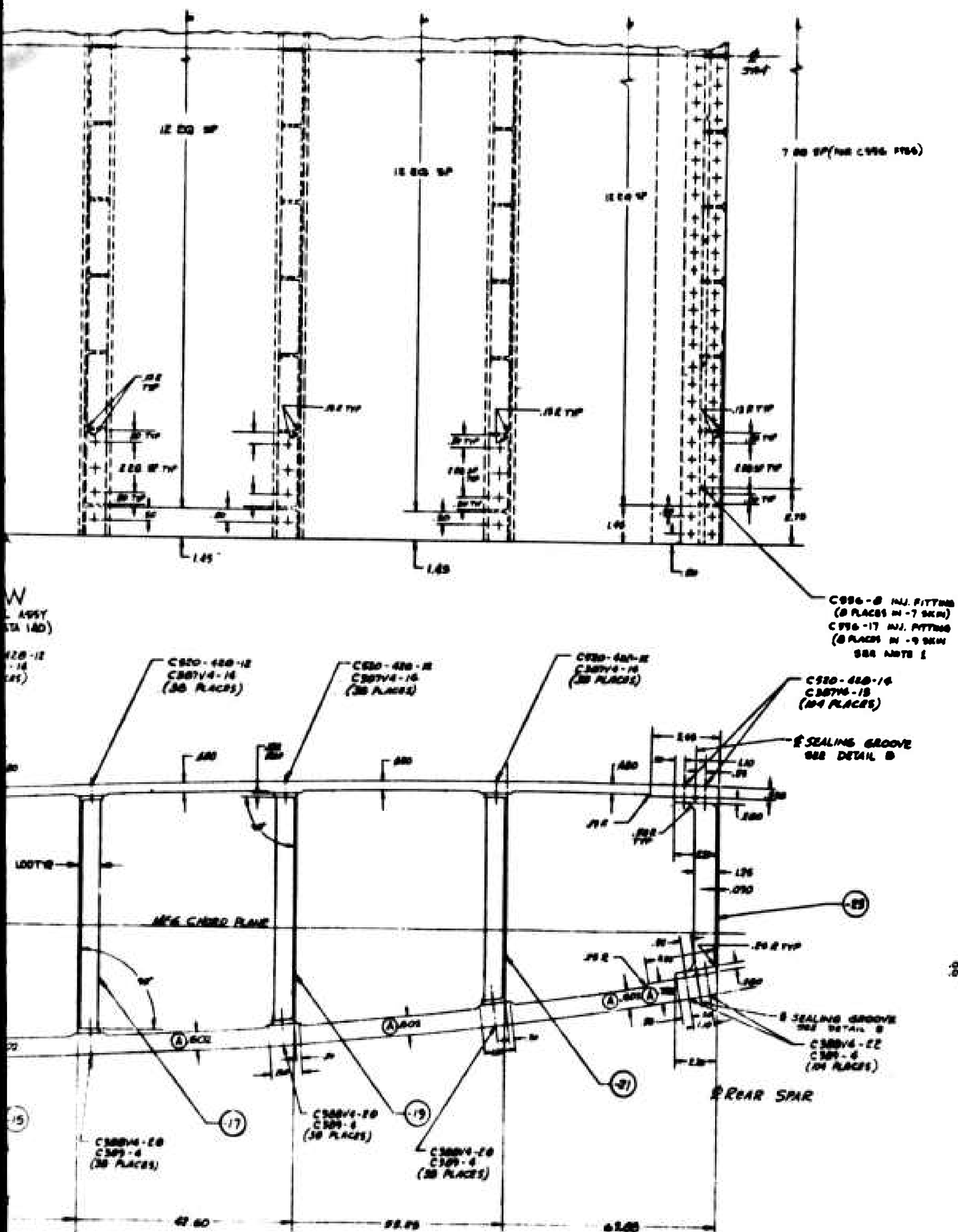


VIEW A-A
TYPICAL
(FULL SIZE)

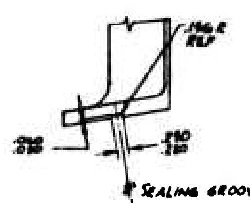


PLAN VIEW
BASELINE ANALYTICAL ASSY
(AT CENTER SPAR STA 140)

'2



DASH NO. ASSY	SUB ASSY	DETAIL	PART NAME	NO. REQD.	MATERIAL	SIZE
-3		-7	UPPER SKIN (SEE NOTE 3)	1	2024-T851	.750 X 54.0 X
		-9	LOWER SKIN (SEE NOTE 3)	1		.875 X 54.0 X
		-11	FRONT SPAR	1		2.75 X 11.1 X
		-13	FWD INTERM. SPAR	1		1.25 X 11.8 X
		-15	FWD CENTER SPAR	1		1.25 X 11.7 X
		-17	CENTER SPAR	1		1.25 X 11.9 X
		-19	REAR CENTER SPAR	1		1.25 X 11.6 X
		-21	REAR INTERM. SPAR	1		1.28 X 10.6 X
		-23	REAR SPAR	1	2024-T851	2.50 X 9.2 X
			SEALANT		FMS-1044 (SEE NOTE 2)	
			BOLT (C387V4-15)	208		
			BOLT (C387V4-14)	190		
			BOLT (C388V4-22)	208		
			BOLT (C388V4-20)	190		
			NUT (C389-4)	400		
			PRESS NUT (C520-428-12)	190		
			PRESS NUT (C520-428-16)	208		
			INJ. FTG (C596-8)			
			INJ. FTG (C596-17)			
			MATERIAL REMOVED FOR FASTENER HO…			
-1			ANALYTICAL ASSY		TOTA…	



DETAIL B

TYPICAL AT FRONT & REAR SPAR, UPPER & LOWER FLANGES (FULL SIZE)

3. -7 UPPER SKIN AND -9 LOWER SKIN SPAR LANDS TO BE MACHINED AND POCKETS TO BE CHEM ETCHED.
2. THE FAYING SURFACES AT THE UPPER S… AND ALL FASTENERS, SHALL BE SEALED PER FPS-1004.
1. INSTALL C596 INJECTION FITTINGS PER MO7G EQUALLY SPACED BETWEEN FASTENERS AS SHOWN AND CENTERED ON THE SEAL… GROOVE. PLUG WITH NAS 681-0649 SCRE…

NOTES:

Figure 38 Baseline Analy…

3

[illegible] NAME	NO. REQD	MATERIAL	RAW STOCK SIZE	RAW STOCK WEIGHT	FINISHED WT. DETAIL	FINISHED WT. ASSY	COST MAT'L	COST [illegible]	COST [illegible]	TOTAL COST
[illegible]ER SKIN ([illegible] NOTE 3)	1	2024-T851	.750 x 54.0 x 69.0	282.24	159.21		435.7	653.77	289	
[illegible]ER SKIN ([illegible] NOTE 3)	1		[illegible] 54.0 x 69.0	328.[illegible]	[illegible]		726.17	733.14		
[illegible]RONT SPAR	1		2.[illegible] 11.1 x 54.0	166.48	11.[illegible]		252.61	638.60		
[illegible] INTERM SPAR	1		1.25 x 11.8 x 54.0	74.99	[illegible]		115.77	393.88		
[illegible] CENTER SPAR	1		1.25 x 11.7 x 54.0	79.76	7.1[illegible]		123.14	397.29		
[illegible]TER SPAR	1		1.25 x 11.9 x 54.0	81.19	7.[illegible]		125.24	400.79		
[illegible] CENTER SPAR	1		1.25 x 11.6 x 54.0	79.00	7.18		121.95	389.19		
[illegible] INTERM SPAR	1		1.25 x 10.6 x 54.0	72.27	6.[illegible]		111.57	376.17		
[illegible]R SPAR	1	2024-T851	2.50 x 9.2 x 54.0	129.44	10.96		180.34	530.25		
[illegible]ALANT		FMS-1046 (SEE NOTE 2)		1.75	1.50					
[illegible] (C587V6-1[illegible])	208				1.996		2041.6[illegible]			
[illegible] (C587V4-14)	190				1.919					
[illegible] (C588V4-[illegible])	208				2.[illegible]					
[illegible] (C588V6-2[illegible])	190				.[illegible]					
[illegible] (C589-4)	400				1.[illegible]					
[illegible] NUT [illegible]520-420-12)	190				2.[illegible]					
[illegible] NUT [illegible]520-420-14)	208				2.475					
[illegible] (C596-8)					.[illegible]					
[illegible] (C596-17)					.171					
MATERIAL REMOVED FOR FASTENER HOLES					422.3[illegible] - 4.2[illegible]					
[illegible]TICAL ASSY			TOTAL WT. =		41[illegible]		4244	7777		$12,310.00
							ASSY	3259.3[illegible]		

[illegible]	[illegible]	DESCRIPTION	[illegible]	[illegible]
A		CHANGED LOWER SKIN THICKNESS FROM .912 TO .602 CHANGED LOWER SKIN SPAR LAND THICKNESS FROM 1.062 TO .752 REVISED ALL WEIGHTS IN L/M TO REFLECT LOWER SKIN AND LOWER SPAR LAND THICKNESS CHANGES	[illegible]	[illegible]

[illegible] UPPER SKIN AND -[illegible] LOWER SKIN SPAR [illegible]ANDS TO BE MACHINED AND POCKETS [illegible] BE CHEM-ETCHED.
[illegible]E FAYING SURFACES AT THE UPPER SKIN [illegible]D ALL FASTENERS SHALL BE SEALED [illegible]ER FPS-1064
[illegible]STALL C596 [illegible]ECTION FITTINGS PER [illegible] EQUALLY SPACED BETWEEN FASTENERS [illegible] SHOWN AND CENTERED ON THE SEALING [illegible]ROOVE. PLUG WITH [illegible] 081-0645 SCREWS

[illegible]TES:

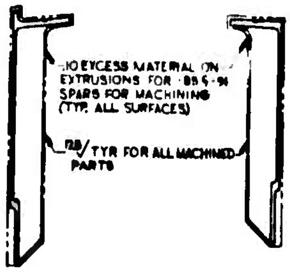
PRELIMINARY DESIGN DRAWING

ATW-4 BASELINE WING BOX MACHINED SKINS AND SPARS; ALUMINUM; ANALYTICAL ASSY.

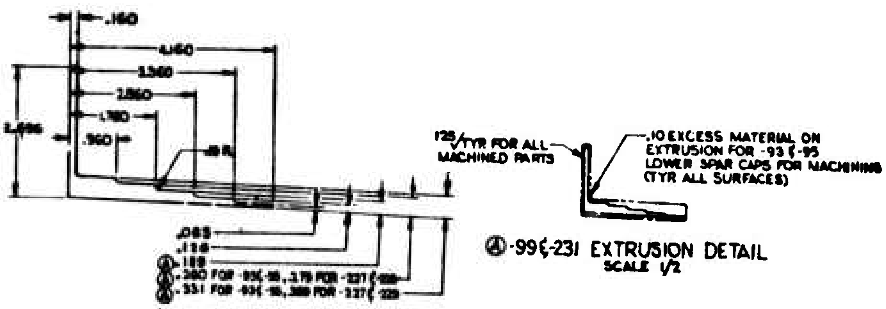
GENERAL DYNAMICS
Convair Aerospace Division

[illegible]-PA000A

[illegible]38 Baseline Analytical Assembly

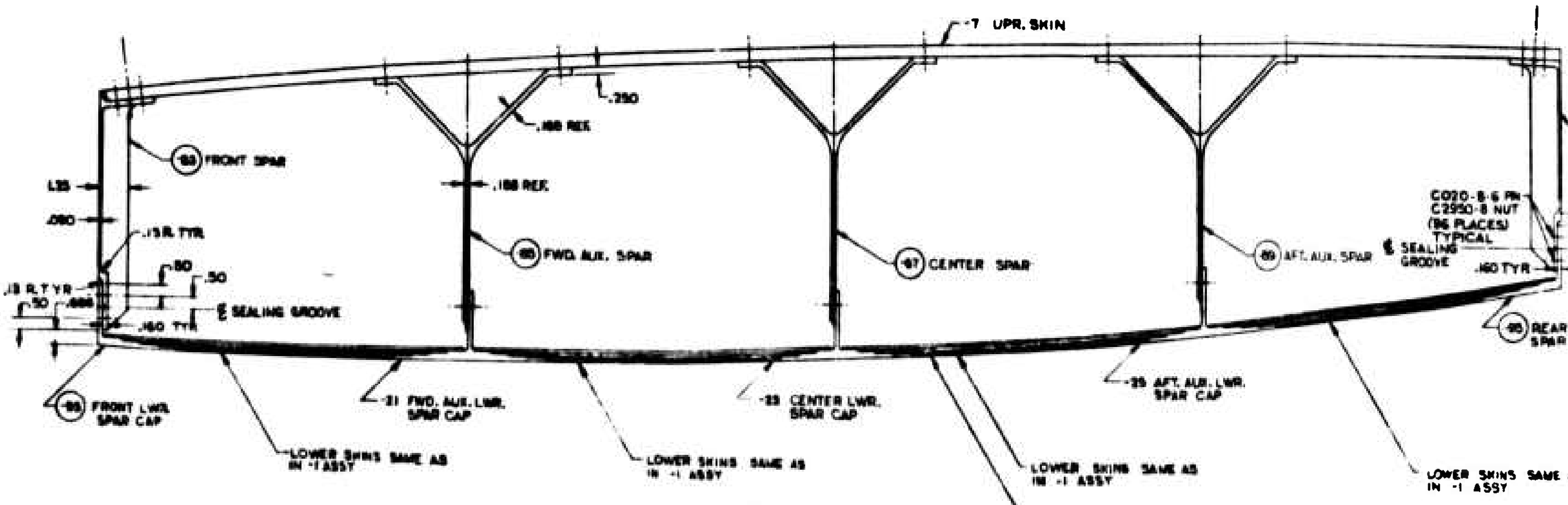


EXTRUSION DETAIL
-89 $ -91
SCALE 1/2



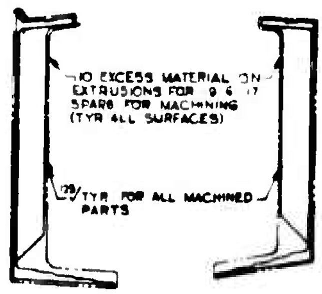
FRONT $ REAR SPAR
LWR. CAP DETAIL
Ⓐ -93,-95,-227, $ -229

Ⓐ -99 $ -231 EXTRUSION DETAIL
SCALE 1/2



VIEW A -3 ASSY
SCALE 1/2

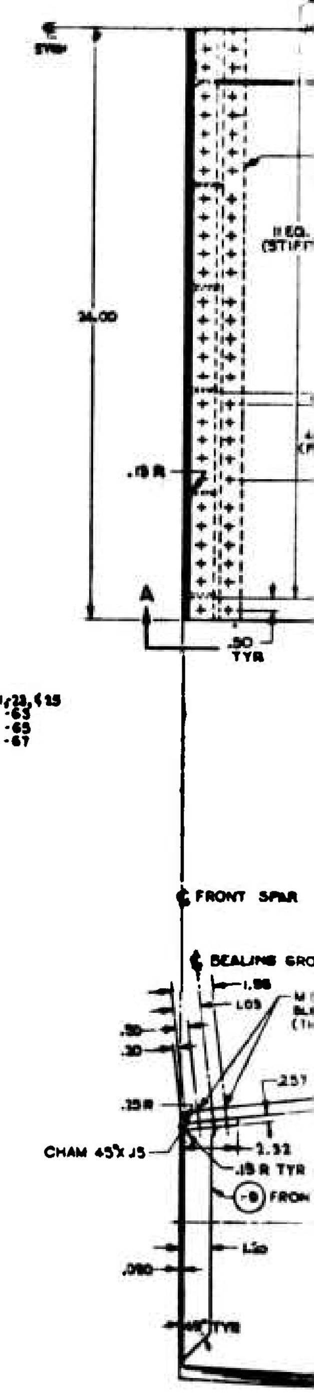
2

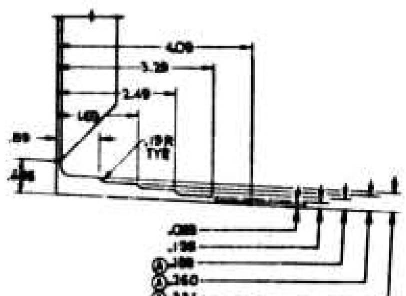


EXTRUSION DETAIL
-9 & -17
SCALE 1/2

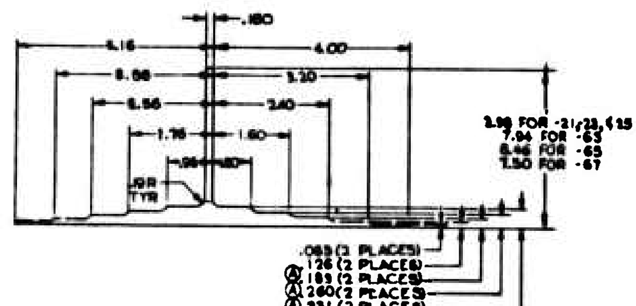
TABLE I
DETAILS OF LOWER SURFACE WING SKINS FOR -1, -9, & -[illegible] ASSY'S

DASH NO.	RAW STOCK SIZE	RAW STOCK WT.	MATERIAL	FINISHED STOCK SIZE	FINISHED WT. IN LBS.
-27	.063x7.9x50	2.51	2024-T81	.063x7.78x48	2.37
-28	.063x9.5x50	3.02	↓	.063x9.38x48	2.86
Ⓐ -31	.063x[illegible]x50	3.53	↓	.063x10.96x48	3.39
Ⓐ -33	.071x12.7x50	4.55	↓	.071x12.56x48	4.32
Ⓐ -35	.071x14.3x50	5.13	↓	.071x14.16x48	4.87
Ⓐ -37	.071x15.8x50	5.67	2024-T81	.071x15.58x48	5.34
-38	.063x7.8x50	2.48	2024-T81	.063x7.61x48	2.32
-41	.063x9.4x50	2.99	↓	.063x9.21x48	2.81
Ⓐ -43	.063x11.0x50	3.50	↓	.063x10.81x48	3.30
Ⓐ -45	.071x12.6x50	4.52	↓	.071x12.41x48	4.27
Ⓐ -47	.071x14.2x50	5.09	↓	.071x14.01x48	4.82
Ⓐ -49	.071x15.6x50	5.59	2024-T81	.071x15.43x48	5.31
-39	.063x7.8x50	2.48	2024-T81	.063x7.61x48	2.32
-41	.063x9.4x50	2.89	↓	.063x9.21x48	2.81
Ⓐ -43	.063x11.0x50	3.50	↓	.063x10.81x48	3.30
Ⓐ -45	.071x12.6x50	A.52	↓	.071x12.41x48	4.27
Ⓐ -47	.071x14.2x50	5.09	↓	.071x14.01x48	4.82
Ⓐ -40	.071x15.6x50	5.59	2024-T81	.071x15.43x48	5.31
-51	.063x7.6x50	2.42	2024-T81	.063x7.44x48	2.27
-53	.063x9.2x50	2.93	↓	.063x9.04x48	2.76
Ⓐ -55	.063x10.8x50	3.44	↓	.063x10.64x48	3.25
Ⓐ -57	.071x12.4x50	4.45	↓	.071x12.24x48	4.21
Ⓐ -58	.071x14.0x50	5.02	↓	.071x13.84x48	4.76
Ⓐ -61	.071x15.4x50	5.52	2024-T81	.071x15.26x48	5.25

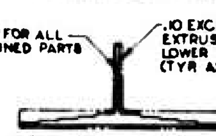




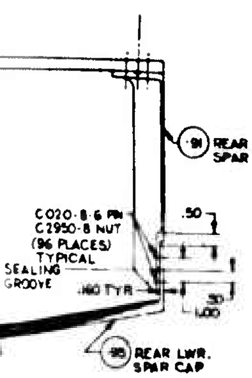
FRONT & REAR SPAR
LWR. CAP DETAIL
-9 & -17

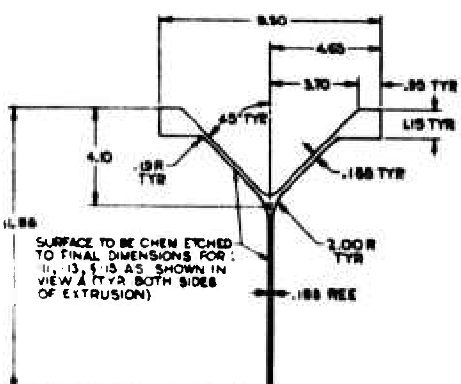


DETAIL -21, -23, -25, -63, -65, & -67
(FINISHED LENGTH IS 48.00)

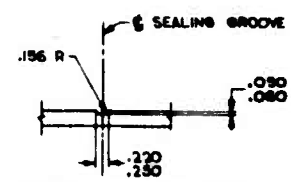


-71 & -77 EXTRUSION DETAIL
SCALE 1/2





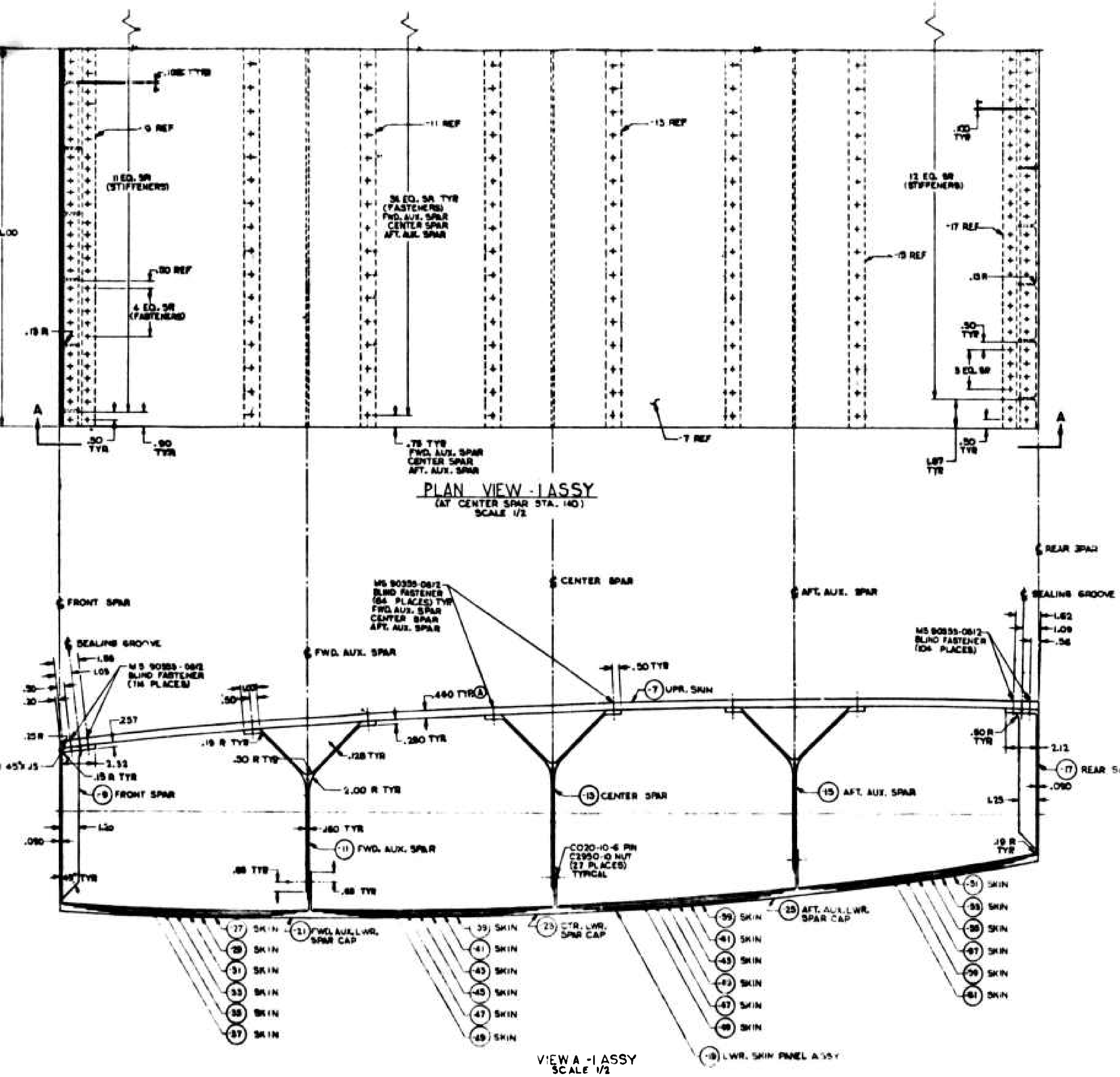
-75 EXTRUSION DETAIL
SCALE 1/2



FUEL SEALING GROOVE DETAIL
(TYP FOR -9 & -17)

LOWER SKINS SAME AS IN -1 ASSY

3



PLAN VIEW - I ASSY
(AT CENTER SPAR STA. 140)
SCALE 1/2

VIEW A - I ASSY
SCALE 1/2

REVISIONS				
SYM	ZONE	DESCRIPTION	DATE	APPROVED
A		CHANGED [illegible] THICKNESS FROM .409 TO [illegible] -409 ASSY'S CHANGED LOWER SKIN & LOWER SPAR CAP THICKNESS FROM .[illegible] TO .402 [illegible] THRU -[illegible] ASSY'S CHANGED LOWER SKIN & LOWER SPAR CAP THICKNESS FROM .486 TO .458 IN -[illegible]03 & -[illegible]05 ASSYS REVISED ALL WEIGHTS IN LM TO REFLECT SKIN THICKNESS CHANGES	[illegible]	[illegible]

LIST OF MATERIALS

ASSY	SUB ASSY	DETAIL	PART NAME	NO. REQD	MATERIAL	RAW STOCK SIZE	RAW STOCK WEIGHT	FINISHED WT DETAIL	FINISHED WT ASSY	COST MAT'L	COST [illegible]	COST [illegible]	TOTAL COST	
-1			ANALYTICAL ASSY	1					340.15	3395	4442	2544	10691	(A)
		-7	UPPER SKIN	1	2024-T851	.625X54X69	235.20	135.7[illegible]		379.36	3[illegible]			(A)
		-11	FWD. AUX. SPAR	1	MAKE FROM -75			14.85			4[illegible]			
		-75	SPAR EXTRU.	1	2024-T8511	EXTRU.X54(6.6 IN²)	36.00			148.47				
		-13	CENTER SPAR	1	MAKE FROM -75			15.33			3[illegible]			
		-75	SPAR EXTRU.	1	2024-T8511	EXTRU.X54(6.6 IN²)	36.00			148.47				
		-15	AFT. AUX. SPAR	1	MAKE FROM -75			14.[illegible]			3[illegible]			
		-75	SPAR EXTRU.	1	2024-T8511	EXTRU.X54(6.6 IN²)	36.00			148.47				
	-19		LWR. SKIN PANEL ASSY						1[illegible]		132.50			(A)
		-9	FRONT SPAR	1	2024-T8511	EXTRU.X54(17.[illegible] IN²)	84.35	1[illegible]		[illegible]	[illegible]			(A)
		-21	FWD. AUX. LWR. SPAR CAP	1	↕			10.0[illegible]			2[illegible]			(A)
		-77	SPAR EXTRU.	1		EXTRU.X54(5.4 IN²)	29.45			134.1[illegible]				(A)
		-23	CTR. LWR. SPAR CAP	1				10.0[illegible]			246.80			(A)
		-77	SPAR EXTRU.	1		EXTRU.X54(5.4 IN²)	29.45			134.1[illegible]				(A)
		-25	AFT. AUX. LWR. SPAR CAP	1				10.01			246.80			(A)
		-77	SPAR EXTRU.	1		EXTRU.X54(5.4 IN²)	29.45			134.1[illegible]				(A)
		-17	REAR SPAR	1	2024-T8511	EXTRU.X54(16.[illegible] IN²)	67.81	11.25		2[illegible]	2[illegible]			(A)
		-27 / -61	SKIN / SKIN	1 / 1	SEE TABLE I			[illegible]		201.93	179.49			(A)
		-79	ADHESIVE		FMS-1013, FORM IA (SEE NOTE 3)			[illegible]						
			BLIND FASTENER MS 90353-0812	410				6.[illegible]	}	1[illegible]				
			PIN (C020-10-6)	81				.34						
			NUT (C2950-10)	81				.41						
			SEALANT		FMS-1044 (SEE NOTE 1)		1.75	1.50						
										ASSY 2111				
					MATL REMOVED FOR FASTNR HOLES				2.69					(A)

ASSY	SUB ASSY	DETAIL	PART NAME	NO. REQD	MATERIAL	RAW STOCK SIZE	RAW STOCK WEIGHT	FINISHED WT DETAIL	FINISHED WT ASSY	COST MAT'L	COST [illegible]	COST [illegible]	TOTAL COST	
-3			ANALYTICAL ASSY	1					338.38	3612	4917	245	10774	(A)
		-7	UPPER SKIN	1	2024-T851	.625X54X69	235.20	135.78		379.35	382.05			(A)
		-83	FRONT SPAR	1	2024-T8511	EXTRU.X54(14.5 IN²)	79.21	9.63		261.00	3[illegible]			
		-85	FWD. AUX. SPAR	1	MAKE FROM -75			18.47			27[illegible]			
		-75	SPAR EXTRU.	1	2024-T8511	EXTRU.X54(6.6 IN²)	36.00			148.47				
		-87	CENTER SPAR	1	MAKE FROM -75			19.69			270.83			
		-75	SPAR EXTRU.	1	2024-T8511	EXTRU.X54(6.6 IN²)	36.00			148.47				
		-89	AFT. AUX. SPAR	1	MAKE FROM -75			18.67			265.71			
		-75	SPAR EXTRU.	1	2024-T8511	EXTRU.X54(6.6 IN²)	36.00			148.47				
		-91	REAR SPAR	1	2024-T8511	EXTRU.X54(13.3 IN²)	72.61	8.78		219.25	356.74			
	-87		LWR. SKIN PANEL ASSY	1					139.87		132.60			(A)
		-[illegible]	FRONT LWR. SPAR CAP	1	2024-T8511			5.15			184.89			(A)
		-[illegible]	SPAR EXTRU.	1	↕	EXTRU.X54(3.1 IN²)	16.91			107.78				(A)
		-21	FWD. AUX. LWR. SPAR CAP	1				10.01			246.80			(A)
		-77	SPAR EXTRU.	1		EXTRU.X54(5.4 IN²)	29.45			134.15				(A)
		-23	CTR. LWR. SPAR CAP	1				10.01			246.80			(A)
		-77	SPAR EXTRU.	1		EXTRU.X54(5.4 IN²)	29.45			134.15				(A)
		-25	AFT. AUX. LWR. SPAR CAP	1				10.01			246.80			(A)
		-77	SPAR EXTRU.	1		EXTRU.X54(5.4 IN²)	29.45			134.15				(A)
		-95	REAR LWR. SPAR CAP	1				5.15			184.89			(A)
		-99	SPAR EXTRU.	1	2024-T8511	EXTRU.X54(3.1 IN²)	16.91			107.78				(A)
		-27 / -61	SKIN / SKIN	1 / 1	SEE TABLE I			[illegible]		201.93	179.49			(A)
		-79	ADHESIVE		FMS 1013, FORM IA (SEE NOTE 3)			8.29						
			BLIND FASTENER MS 90353-0812	410				6.83	}					
			PIN (C020-10-6)	91				.34						
			NUT (C2950-10)	61				.41		1467				
			PIN (C020-8-6)	192				1.11						
			NUT (C2950-8)	192				.50						
			SEALANT		FMS-1044 (SEE NOTE 1)		1.75	1.50						
										ASSY	2555			
					MATL REMOVED FOR FASTNR HOLES				2.95					(A)

A

REAR SPAR

ALING GROOVE

-1.62
-1.09
-.56

2.12
(17) REAR SPAR
.090

3. USE FMS-1013 ADHESIVE FORM IA (RELIABOND 398) IN THE FOLLOWING AREAS:
   (1) BETWEEN ALL LOWER SURFACE SKINS & ADJACENT SPAR CAPS/SPARS IN THE -3, -91, -10, -69, -193, & -217 ASSY'S
   (2) BETWEEN ALL SKINS, SPAR LEGS, AUX. SPAR DOUBLERS, & DOUBLERS IN THE -159, -173, & -183 ASSYS
2. 125 √ FINISH REQD ON ALL MACHINED PARTS
1. THE FAYING SURFACES AT THE UPPER SURFACE OF THE FRONT AND REAR SPAR, THE UPPER SKIN, AND ALL FASTENERS SHALL BE SEALED PER FPS-1004

NOTES:

PRELIMINARY DESIGN DRAWING

ATW-4 WING - LAMINATED LWR. SKIN; MACHINED UPR. SKIN & CLOSURE SPARS; EXTRUDED & ETCHED INTERM. SPARS; ALUMINUM; ANALYTICAL ASSY

GENERAL DYNAMICS
Convair Aerospace Division

633-RA00'A

Figure 39 Extruded & Etched Y-Spar Analytical Assembly

LIST OF MATERIALS

ASSY (DASH NO.)	SUB ASSY (DASH NO.)	DETAIL (DASH NO.)	PART NAME	NO. REQD	MATERIAL	RAW STOCK SIZE	RAW STOCK WT	FINISHED WT DETAIL	FINISHED WT ASSY	COST MATL	COST FAB	COST TOOL	TOTAL COST
803			ANALYTICAL ASSY	1					158.00	2799	6672	306	$3777 (A)
		-7	UPPER SKIN	1	SEE -1 ASSY			35.79		373.35	3810.45		(A)
		-83	FRONT SPAR	1	SEE -1 ASSY			9.48		760.59	388.50		
		-91	REAR SPAR	1				8.76		229.25	356.15		
	-159		FWD. AUX. SPAR ASSY	1	SEE -803 ASSY				15.67	30.22	221		
	-173		CTR. AUX. SPAR ASSY	1	SEE -803 ASSY				15.72	31.02	221		
	-183		AFT. AUX. SPAR ASSY	1	SEE -803 ASSY				15.33	30.25	221		
	-217		LWR. SKIN PANEL ASSY	1					146.00		587.67		(A)
		-227	FRONT LWR. SPAR CAP	1	SEE -803 ASSY			6.9			184.85		(A)
		-231	SPAR EXTRU.	1						107.78			(A)
		-219	FWD. AUX. LWR. SPAR CAP	1	2024-T8511			6.09			157.45		(A)
		-225	SPAR EXTRU.	1		EXTRU. 1540 25 IN	6.82			35.83			(A)
		-221	CTR. AUX. LWR. SPAR CAP	1				6.09			157.45		(A)
		-225	SPAR EXTRU.	1		EXTRU. 1540 25 IN	6.8			35.83			(A)
		-223	AFT. AUX. LWR. SPAR CAP	1				6.09			157.45		(A)
		-225	SPAR EXTRU.	1	2024-T8511	EXTRU. 1540 25 IN	6.82			35.83			(A)
		-229	REAR LWR. SPAR CAP	1	SEE -803 ASSY			6.9			184.85		(A)
		-231	SPAR EXTRU.	1						107.78			(A)
		-51, -43, [illegible], -302, -333 THRU -349	SKIN / SKIN	SEE VIEW W -803 ASSY	FOR MATL TYPES & SIZES REFER TO RESPECTIVE DASH NUMBERS IN TABLE I & TABLES & TABLE III			107.51		1758.6	13463		(A)
		-79	ADHESIVE		FMS-1013 FORM 2A (SEE NOTE 3)			8.72					
			BLIND FASTENERS MS-90353-0812	410				6.88					
			PIN (C020-8-6)	192				3.33					
			NUT (C2950-8)	192				1.50		1326			
			PIN (C020-10-5)	81				.79					
			NUT (C2950-10)	81				.41					
			SEALANT		FMS-1044 (SEE NOTE 1)		1.75	1.50					
					MATL REMOVED FOR FASTNR HOLES				3.10				(A)
									ASSY	2752			

(A) TABLE III

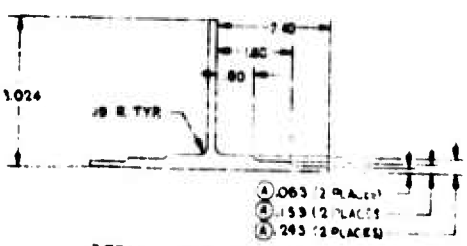
DETAILS OF LOWER SURFACE WING SKINS

DASH NO.	RAW STOCK SIZE	RAW STOCK WT.	MATERIAL	FINISHED STOCK SIZE	FINISHED WT. IN LBS.	NO. REQ'D
-233	.080 x 12.7 x 50	5.77	2024-T81	.080 x 10.56 x 48	5.48	1
-235	.080 x 14.5 x 50	6.50		[illegible]	[illegible]	1
-237	[illegible]	[illegible]		[illegible]	[illegible]	1
-239	[illegible]	[illegible]		[illegible]	[illegible]	1
-241	[illegible]	[illegible]		[illegible]	[illegible]	1
-243	[illegible]	[illegible]		[illegible]	[illegible]	1
-245	.080 x 12.4 x 50	5.64		[illegible]	[illegible]	1
-247	[illegible]	[illegible]		[illegible]	[illegible]	1
-249	.080 x 15.4 x 50	7.00	2024-T81	.080 x 15.36 x 48	6.66	1

LIST OF MATERIALS

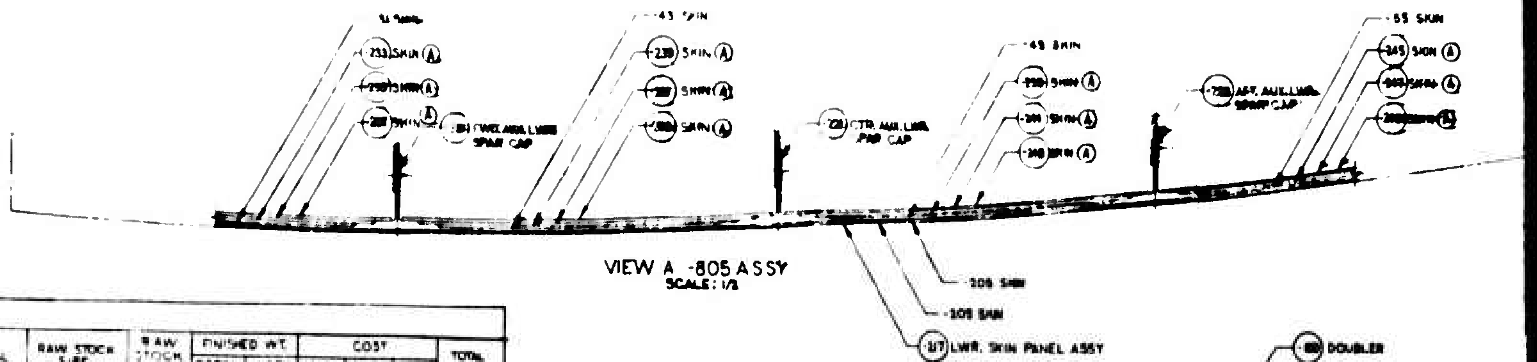
ASSY (DASH NO.)	SUB ASSY (DASH NO.)	DETAIL (DASH NO.)	PART NAME	NO. REQD	MA...
803			ANALYTICAL ASSY	1	
		-7	UPPER SKIN	1	SEE
		-83	FRONT SPAR	1	}
		-91	REAR SPAR	1	
	-159		FWD. AUX. SPAR ASSY	1	
		-161	FWD. AUX. SPAR LEG	1	202
		-163	FWD. AUX. SPAR DBLR.	1	
		-165	FWD. AUX. SPAR LEG	1	
		-167	FWD. AUX. SPAR DBLR.	1	
		-169	DOUBLER	2	
		-171	RADIUS BLOCK	2	2024
		-79	ADHESIVE		FMS
			PIN (C020-8-7)	27	
			NUT (C2950-8)	27	
	-173		CTR. AUX. SPAR ASSY	1	
		-175	CTR. AUX. SPAR LEG	1	202
		-177	CTR. AUX. SPAR DBLR.	1	
		-179	CTR. AUX. SPAR LEG	1	
		-181	CTR. AUX. SPAR DBLR.	1	
		-169	DOUBLER	2	
		-171	RADIUS BLOCK	2	202
		-79	ADHESIVE		FMS-10
			PIN (C020-8-7)	27	
			NUT (C2950-8)	27	
	-183		AFT. AUX. SPAR ASSY	1	
		-185	AFT. AUX. SPAR LEG	1	
		-187	AFT. AUX. SPAR DBLR.	1	
		-189	AFT. AUX. SPAR LEG	1	
		-191	AFT. AUX. SPAR DBLR.	1	
		-169	DOUBLER	2	
		-171	RADIUS BLOCK	2	
		-79	ADHESIVE		
			PIN (C020-8-7)	27	
			NUT (C2950-8)	27	
	-193		LWR. SKIN PANEL ASSY	1	
		-227	FRONT LWR. SPAR CAP	1	MAKE FR
		-231	SPAR EXTRU.	1	2024
		-195	FWD. AUX. LWR. SPAR CAP	1	2024
		-201	SPAR EXTRU.	1	
		-197	CTR. AUX. LWR. SPAR CAP	1	
		-201	SPAR EXTRU.	1	
		-199	AFT. AUX. LWR. SPAR CAP	1	
		-201	SPAR EXTRU.	1	2024
		-229	REAR LWR. SPAR CAP	1	MAKE FR
		-231	SPAR EXTRU.	1	2024
		-209 THRU -215	SKIN THRU SKIN	1	SEE TAB
		-79	ADHESIVE		FMS-1013
			BLIND FASTENERS MS 90353-0812	410	
			PIN (C020-8-6)	192	
			NUT (C2950-8)	192	
			PIN (C020-10-5)	81	
			NUT (C2950-10)	81	
			SEALANT		FMS-104
					MATL REM

-225 EXTRUSION DETAIL



DETAIL -219, -221 & -223 (FINISHED LENGTH IS 48.00)

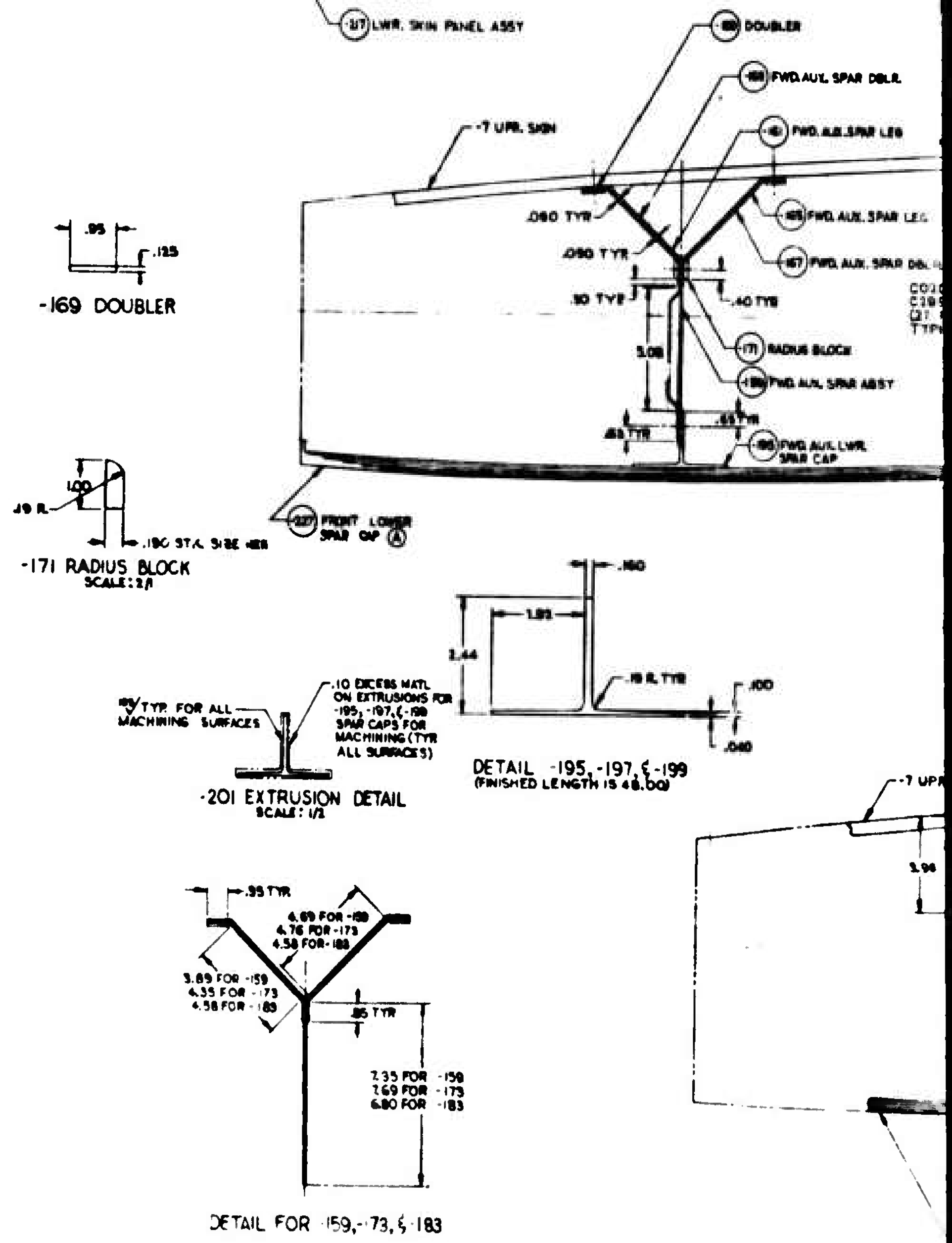
2



VIEW A -805 ASSY
SCALE: 1/2

...ERIALS

PART NAME	NO. REQD	MATERIAL	RAW STOCK SIZE	RAW STOCK WEIGHT	FINISHED WT. DETAIL	FINISHED WT. ASSY	COST MATL	COST FAB.	COST TOOL.	TOTAL COST	
...NALYTICAL ASSY	1					380.13	3168	6261	282	8974	(A)
...PPER SKIN	1	SEE -1 ASSY			130.78		379.86	18704			(A)
...RONT SPAR	1	SEE -3 ASSY			9.63		240.90	388.96			
...EAR SPAR	1				8.78		238.75	366.76			
...WD AUX SPAR ASSY	1					15.67		169.36			
...WD AUX SPAR LEG	1	2024-T81	.050X3.75X50	3.47	3.09		6.13	17.26			
...WD AUX SPAR DBLR	1		.080X6.90X50	2.79	2.29		4.55	6.30			
...WD AUX SPAR LEG	1		.050X4.48X50	3.65	3.36		6.43	6.30			
...WD AUX SPAR DBLR	1		.080X7.61X50	3.07	2.95		5.01	6.30			
...OUBLER	2		.160X1.25X50	2.03	1.15		3.36	4.01			
...ADIUS BLOCK	2	2024-T81	.190X1.50X50	2.88	1.92		4.78	11.49			
...HESIVE		FMS 1013 FORM IA (SEE NOTE 5)			.74						
...N (C020-8-7)	27				.19						
...UT (C2950-8)	27				.08						
...TR AUX SPAR ASSY	1					15.72		165.36			
...TR AUX SPAR LEG	1	2024-T81	.050X4.48X50	3.65	3.36		6.43	17.26			
...TR AUX SPAR DBLR	1		.080X7.27X50	2.94	2.43		4.79	6.30			
...TR AUX SPAR LEG	1		.050X4.87X50	3.75	3.36		6.60	6.30			
...TR AUX SPAR DBLR	1		.080X7.68X50	3.10	2.58		5.06	6.30			
...OUBLER	2		.160X1.25X50	2.03	1.15		3.35	4.01			
...ADIUS BLOCK	2	2024-T81	.190X1.50X50	2.88	1.92		4.78	11.49			
...HESIVE		FMS 1013 FORM IA (SEE NOTE 5)			.74						
...N (C020-8-7)	27				.19						
...T (C2950-8)	27				.08						
...T AUX SPAR ASSY	1					15.92		165.56			
...T AUX SPAR LEG	1		.050X3.78X50	3.48	3.10		6.12	17.26			
...T AUX SPAR DBLR	1		.080X7.31X50	3.01	2.53		4.24	6.30			
...T AUX SPAR LEG	1		.050X3.78X50	3.48	3.10		6.12	6.30			
...T AUX SPAR DBLR	1		.080X7.50X50	3.03	2.53		4.54	6.30			
...OUBLER	2		.160X1.25X50	2.03	1.15		3.36	4.01			
...ADIUS BLOCK	2		.190X1.50X50	2.88	1.92		4.78	11.49			
...HESIVE					.74						
...(C020-8-7)	27				.19						
...T (C2950-8)	27				.08						
...R. SKIN PANEL ASSY	1					167.92		844.9			(A)
...ONT LWR SPAR CAP	1	MAKE FROM -201			6.19			164.95			(A)
...AR EXTRU	1	2024-T8511	EXTRU 540.88 IN³	16.31			107.78				(A)
...CTR LWR SPAR CAP	1	2024-T8511			3.34			148.08			
...AR EXTRU	1		EXTRU 540.8 IN³	11.71			67.52				
...AUX LWR SPAR CAP	1				3.34			148.08			
...AR EXTRU	1		EXTRU 540.8 IN³	11.71			67.52				
...AUX LWR SPAR CAP	1				3.34			148.08			
...AR EXTRU	1	2024-T8511	EXTRU 540.15 IN³	11.71			67.52				
...R LWR SPAR CAP	1	MAKE FROM -201			6.19			164.95			(A)
...AR EXTRU	1	2024-T8511	EXTRU 540.88 IN³	16.31			107.78				(A)
...N / ... / ...N	/	SEE TABLE II			103.89		24145	44.82			(A)
...HESIVE		FMS 1013 FORM IA (SEE NOTE 5)			11.89						
...D FASTENERS ...0353-08Q	410				6.88	HDW	1536				
...C020-8-6)	192				3.33						
...(C2950-8)	192				1.50						
...(C020-10-5)	81				.79						
...(C2950-10)	81				.41						
...LANT		FMS 1044 (SEE NOTE 1)		.75	1.50						
		MATL REMOVED FOR FASTNR HOLES				3.10					(A)
							ASSY	2792			



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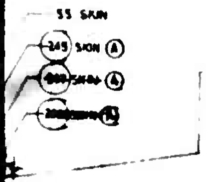
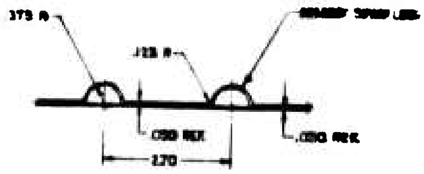
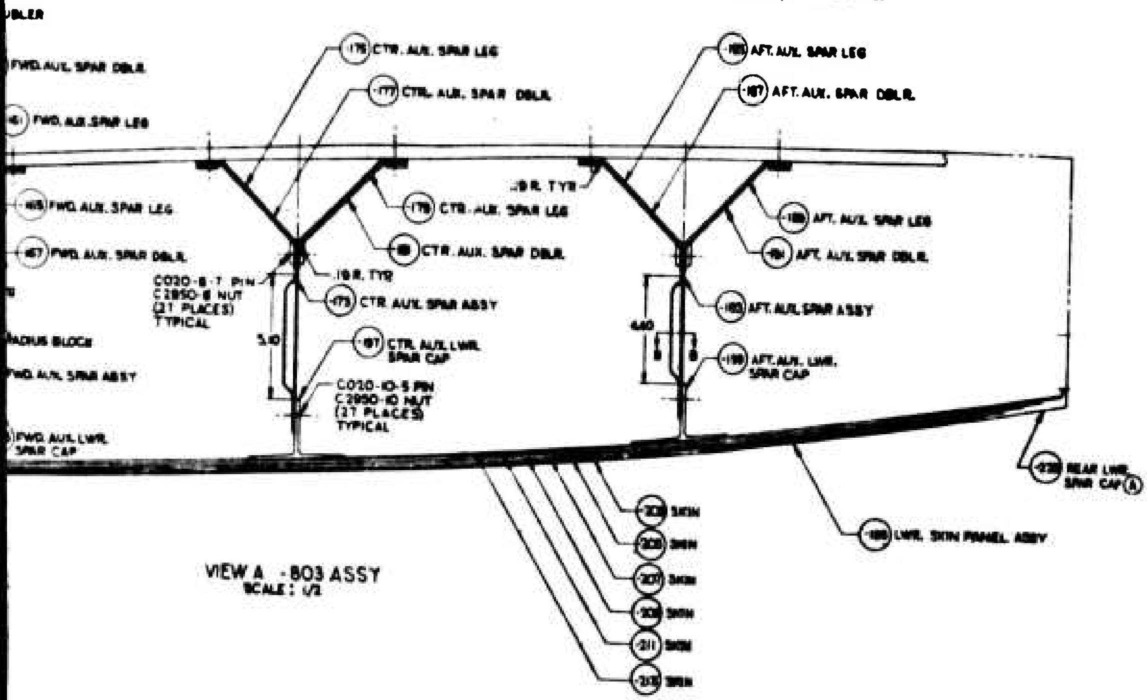
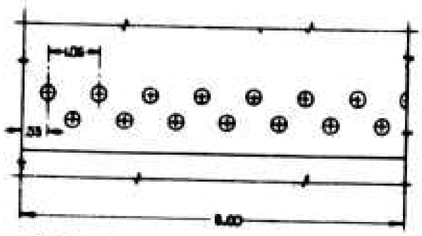




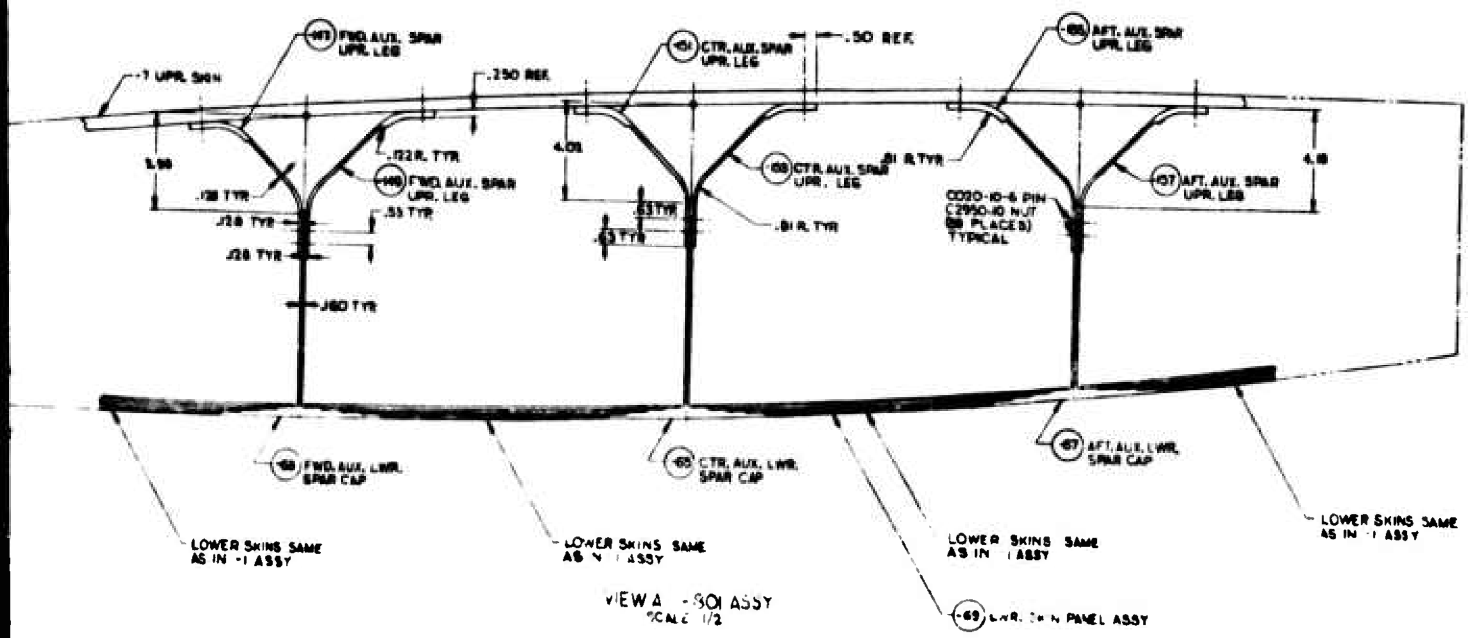
SECTION B-B
TYP OF -189, -187, & -185 SPAR ASSY



VIEW A -803 ASSY
SCALE: 1/2



INTERMEDIATE SPAR ATTACHMENTS FOR -801 ASSY

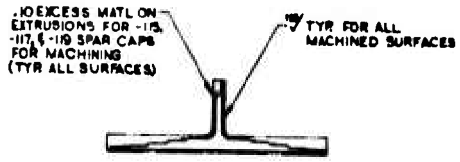


VIEW A -801 ASSY
SCALE 1/2

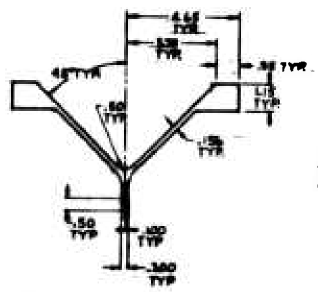
4

TABLE III DETAILS OF LOWER SURFACE WING SKINS FOR [illegible] ASSY							
	DASH NO.	QTY.	RAW STOCK SIZE	RAW STOCK WT.	MATERIAL	FINISHED STOCK SIZE	FINISHED WT.
Ⓐ	-103	2	.071x15.51x50	5.58	2024-T81	.071x15.29x48	5.28
Ⓐ	-105	2	.071x13.9x50	4.98		.071x13.69x48	4.71
Ⓐ	-107	2	.071x12.3x50	4.41		.071x12.09x48	4.16
Ⓐ	-109	2	.063x10.7x50	3.40		.063x10.49x48	3.30
	-111	2	.063x[illegible]x50	[illegible]		.063x8.89x48	[illegible]
	-113	2	.063x7.5x50	2.39	2024-T81	.063x7.29x48	[illegible]
	-121	2	.063x7.4x50	2.35	2024-T81	.063x7.28x48	[illegible]
	-123	2	.063x8.9x50	[illegible]		.063x8.88x48	2.71
Ⓐ	-125	2	.063x10.6x50	3.37		.063x10.48x48	3.20
Ⓐ	-127	2	.071x12.2x50	4.37		.071x12.08x48	4.[illegible]
Ⓐ	-129	2	.071x13.8x50	4.[illegible]		.071x13.68x48	4.71
Ⓐ	-131	2	.071x15.4x50	5.[illegible]	2024-T81	.071x15.28x48	5.26

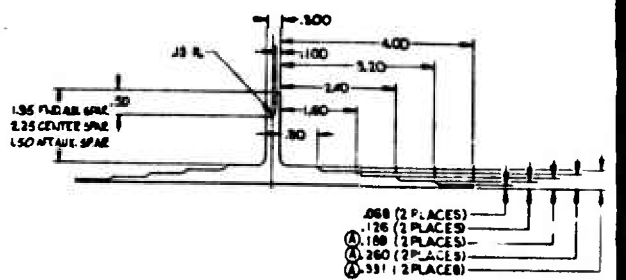
DETAILS OF LOWER SURFACE WING SKINS FOR -803 ASSY							
	-203	1	.063x55.90x50	17.78	2024-T81	.063x55.70x48	17.01
	-205	1	.063x57.50x50	18.29		.063x57.30x48	17.50
Ⓐ	-207	1	.063x59.10x50	18.80		.063x58.90x48	17.99
	-209	1	.090x60.70x50	27.59		.090x60.50x48	26.40
	-211	1	.090x62.30x50	28.32		.090x62.10x48	27.10
	-218	1	.090x63.50x50	28.86	2024-T81	.090x63.32x48	27.68



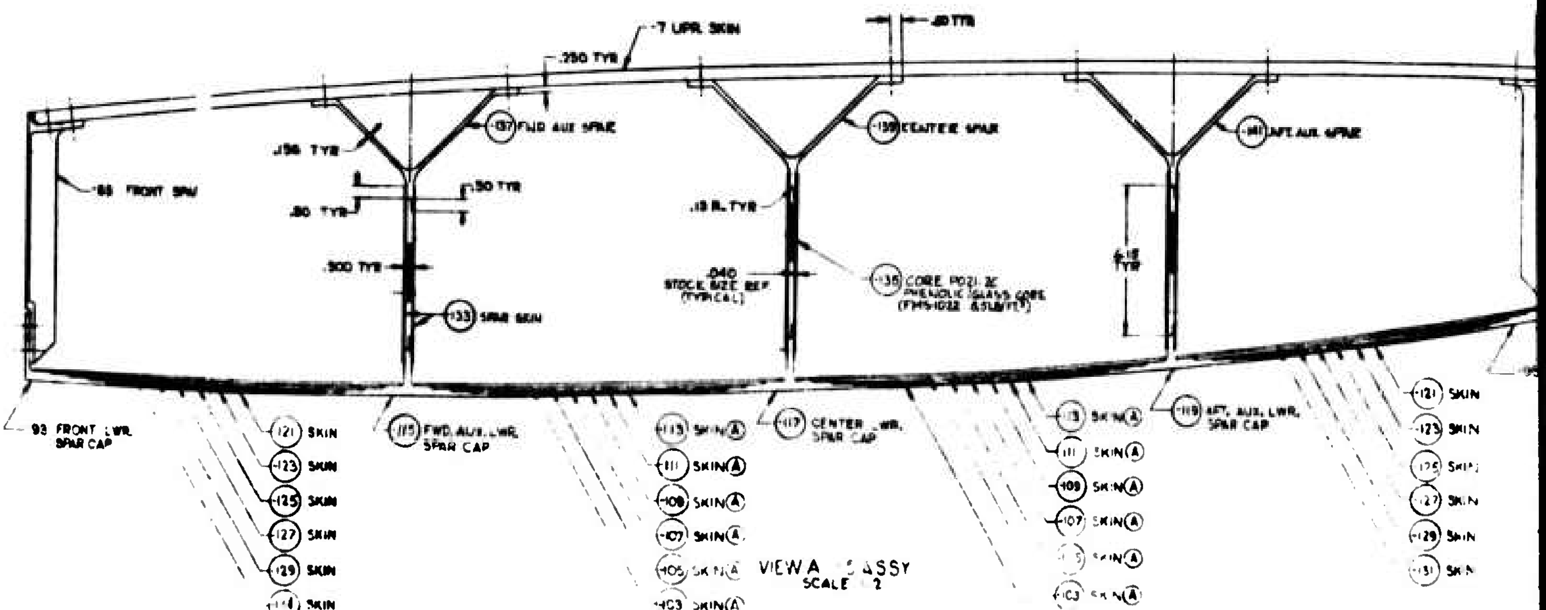
-145 EXTRUSION DETAIL
TYPICAL -115,117,119



-143 EXTRUSION DETAIL
TYPICAL -137,139,141

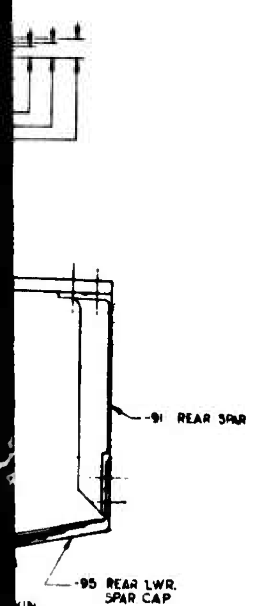


DETAIL -115,-117, & -119
(FINISHED LENGTH IS 48.00)



VIEW A [illegible] ASSY
SCALE [illegible] 2

5



LIST OF MATERIALS

ASSY	SUB ASSY	DETAIL	PART NAME	NO. REQD	MATERIAL	RAW STOCK SIZE	RAW WT	FINISHED WT DETAIL	FINISHED WT ASSY	COST MAT'L	COST FAB	COST TOOL	TOTAL COST	
-5			ANALYTICAL ASSY	1					347.98	3589	7067	336	109929	Ⓐ
		-7	UPPER SKIN	1	SEE -1 ASSY			135.78		379.35	387.04			Ⓐ
		-83	FRONT SPAR	1	SEE -3 ASSY			9.83		260.09	388.36			
		-91	REAR SPAR	1				8.78		218.25	356.75			
			LWR. SKIN, PANEL ASSY											
	-101		INTERMEDIATE SPAR ASSY	1					188.44		1538.			Ⓐ
		-35	FRONT LWR SPAR CAP	1	SEE -3 ASSY			3.15			184.85			Ⓐ
		-99	SPAR EXTRU.	1						107.78				Ⓐ
		-15	FWD AUX SPAR CAP	1	2024-T8511			9.84			271.48			Ⓐ
		-145	SPAR EXTRU.	1		EXTRU.	31.52			138.71				Ⓐ
		-117	CENTER SPAR CAP	1				10.10			271.49			Ⓐ
		-145	SPAR EXTRU	1		EXTRU.	31.52			138.71				Ⓐ
		-19	AFT AUX SPAR CAP	1				9.18			271.49			Ⓐ
		-145	SPAR EXTRU	1	2024 T8511	EXTRU.	31.52			138.71				Ⓐ
		-95	REAR LWR SPAR CAP	1	SEE -3 ASSY			8.18			184.85			Ⓐ
		-99	SPAR EXTRU.	1						107.78				Ⓐ
		-105 / -119	SKIN / SKIN	2	SEE TABLE II			64.58		95.76				Ⓐ
		-121 / -151	SKIN / SKIN	2	SEE TABLE II			44.93		84.94	179.50			Ⓐ
		-133	SPAR SKINS	6	2024-T81	.040 x .050	1.50/FT	1.40/FT		16.12	44.87			
		-135	CORE	3	SEE 135 DETAIL	10.15 x 2.75 x 54		.41/FT		69.71	16.03			
		-157	FWD AUX SPAR	1	MAKE FROM -143			10.64			218.71			
		-143	SPAR EXTRU		2024-T8511	EXTRU.	30.00			123.56				
		-159	CENTER SPAR	1	MAKE FROM -143			13.53			203.81			
		-143	SPAR EXTRU		2024-T8511	EXTRU.	30.00			123.56				
		-161	AFT AUX SPAR	1	MAKE FROM -143			15.70			203.11			
		-143	SPAR EXTRU		2024-T8511	EXTRU.	30.00			123.56				
		-79	ADHESIVE		FMS-1013 IA (SEE NOTE 3)			10.51			-			
			BLIND FASTENER MS90353-0812	410				4.88						
			PIN (C020-8-6)	192				1.11		1441				
			NUT (C2950-8)	192				.80						
			SEALANT		FMS-1044 (SEE NOTE 1)		1.75	1.50						
			MAT'L REMOVED FOR FASTENER HOLES						2.71					Ⓐ
										ASSY	2346			

ASSY	SUB ASSY	DETAIL	PART NAME	NO. REQD	MATERIAL	RAW STOCK SIZE	RAW WT	FINISHED WT DETAIL	FINISHED WT ASSY	COST MAT'L	COST FAB	COST TOOL	TOTAL COST	
-801			ANALYTICAL ASSY	1					349.05	3503	6966	192	106608	Ⓐ
		-7	UPPER SKIN	1	SEE -1 ASSY			135.78		379.35	387.04			Ⓐ
		-83	FRONT SPAR	1	SEE -3 ASSY			9.83		260.09	388.36			
		-147	FWD AUX. SPAR UPR LEG	1	2024-T81	.250 x 7.04 x 50	8.89	4.54						
		-149	FWD AUX. SPAR UPR LEG	1		.250 x 8.02 x 50	10.13	5.15						
		-151	CTR AUX. SPAR UPR LEG	1		.250 x 7.37 x 50	9.30	4.75		87.65	134.64			
		-153	CTR AUX. SPAR UPR LEG	1		.250 x 7.89 x 50	9.96	5.07						
		-155	AFT AUX. SPAR UPR LEG	1		.250 x 8.02 x 50	10.13	5.15						
		-157	AFT AUX. SPAR UPR LEG	1	2024-T81	.250 x 7.94 x 50	10.03	5.10						
		-91	REAR SPAR	1	SEE -5 ASSY			8.78		233.25	356.75			
	-69		LWR. SKIN PANEL ASSY	1					180.00		112.53			Ⓐ
		-93	FRONT LWR. SPAR CAP	1	SEE -3 ASSY			5.13			184.85			Ⓐ
		-99	SPAR EXTRU.	1						107.78				Ⓐ
		-63	FWD AUX. LWR. SPAR CAP	1	2024-T8511			13.37			285.15			Ⓐ
		-71	SPAR EXTRU.	1		EXTRU.	40.36			176.12				Ⓐ
		-65	CTR. AUX. LWR. SPAR CAP	1				13.77			255.15			Ⓐ
		-71	SPAR EXTRU.	1		EXTRU.	41.45			180.40				Ⓐ
		-67	AFT. AUX. LWR. SPAR CAP	1				13.02			255.18			Ⓐ
		-71	SPAR EXTRU.	1	2024-T8511	EXTRU.	39.81			172.58				Ⓐ
		-95	REAR LWR. SPAR CAP	1	SEE -3 ASSY			5.15			184.85			Ⓐ
		-99	SPAR EXTRU.	1						107.78				Ⓐ
		-17 / -61	SKIN / SKIN	1	SEE TABLE I			91.29		195.31	179.50			Ⓐ
		-79	ADHESIVE		FMS-1013 IA (SEE NOTE 3)			8.25						Ⓐ
			BLIND FASTENER MS 90353-0812	410				6.88						
			PIN (C020-10-7)	267				1.00						
			NUT (C2950-10)	267				.45		1596				
			PIN (C020-8-6)	192				3.83						
			NUT (C2950-8)	192				1.50						
			SEALANT		FMS-1044 (SEE NOTE 1)		1.75	1.50						
					MAT'L REMOVED FOR FASTNR HOLES				3.56					Ⓐ
										ASSY	3238			

PRELIMINARY DESIGN DRAWING
ATA W/ WING ELEM. ... LWR. SKIN, MACHINED ... CLOSURE ... BARS, EXTRUDED ... SPARS, ALUM ... ANALYTICAL ASSY
GENERAL DYNAMICS ... -2400 A
Convair Aerospace Division

Figure 39 Extruded & Etched Y-Spar Analytical Assembly (Continued)

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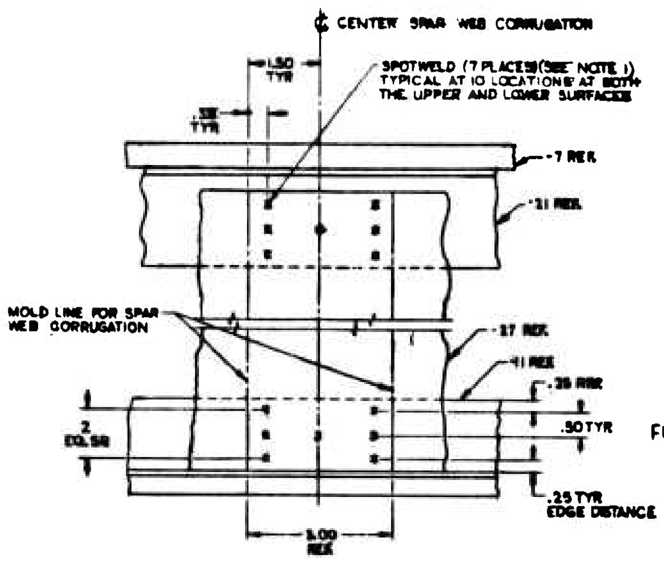
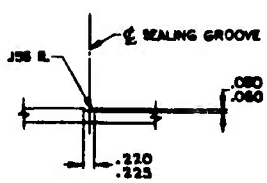


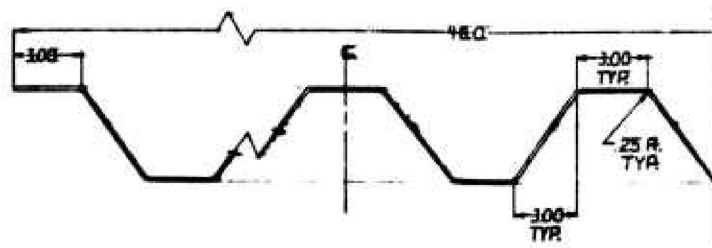
SECTION B-B

SPOTWELD PATTERN SHOWN IS TYPICAL AT THE FWD. AUX. AND AFT. AUX. SPARS

FULL SIZE



FUEL SEALING GROOVE DETAIL
TYP. FOR -9 & -17
FULL SIZE

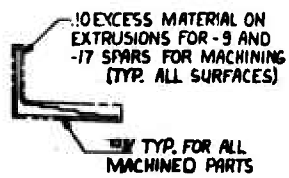


HEIGHT OF CORRUGATED WEBS*
-25, h=11
-27, h=11.4
-29, h=10.6

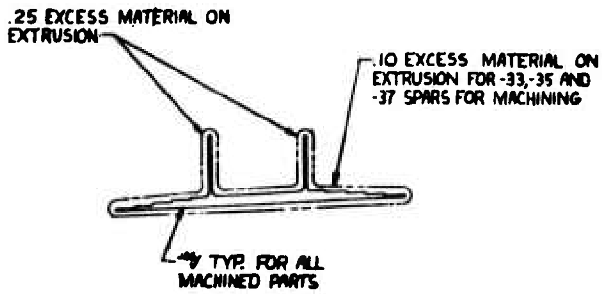
*REFER TO END VIEW -1 ASSY

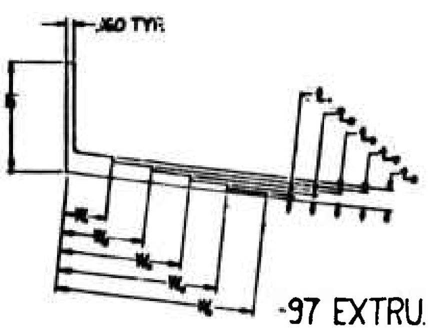
DETAIL OF -25, -27, -29 CORRUGATED WEB

DIMENSION (IN INCHES)	FWD. AUX. SPAR (-33)	CENT. SPAR (-35)	AFT. AUX. SPAR (-37)
h	2.89	2.89	2.89
t_1	.063	.063	.063
t_2	.126	.126	.126
Ⓐ t_3	.189	.188	.188
Ⓐ t_4	.260	.260	.260
Ⓐ t_5	.331	.331	.331
t_6	.063	.063	.063
t_7	.126	.126	.126
Ⓐ t_8	.189	.188	.188
Ⓐ t_9	.260	.260	.260
Ⓐ t_{10}	.331	.331	.331
W_1	2.8	2.8	2.8
W_2	3.6	3.6	3.6
W_3	4.4	4.4	4.4
W_4	5.2	5.2	5.2
W_5	2.8	2.8	2.8
W_6	3.6	3.6	3.6
W_7	4.4	4.4	4.4
W_8	5.2	5.2	5.2
W_9 (REF.)	12.0	12.0	12.0

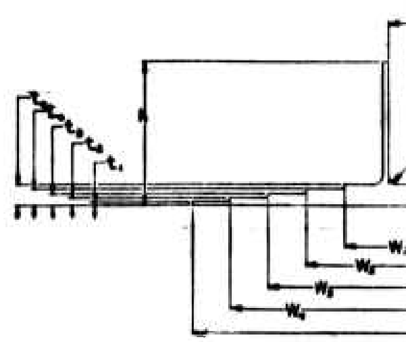


DIMENSION (IN INCHES)	FWD. SPAR (-9)	AFT SPAR. (-17)
h	2.4	2.4
t_1	.063	.063
t_2	.126	.126
Ⓐ t_3	.188	.188
Ⓐ t_4	.260	.260
Ⓐ t_5	.331	.331
W_1	.96	.96
W_2	1.76	1.76
W_3	2.56	2.56
W_4	3.36	3.36
W_5	4.16	4.16



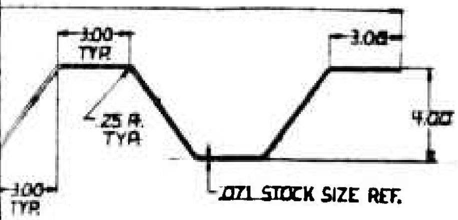


-97 EXTRU. DETAIL OF -31 AND -39 SPAR CAPS
FULL SIZE



-95 EXTRU. DETAIL

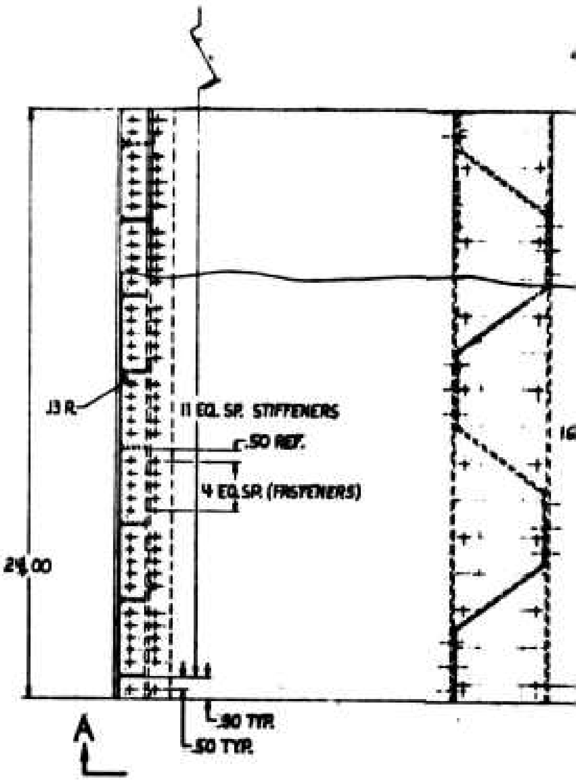
2



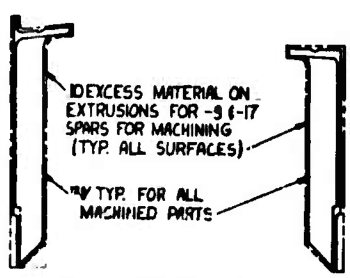
D WEBS *

SSY
CORRUGATED WEBS

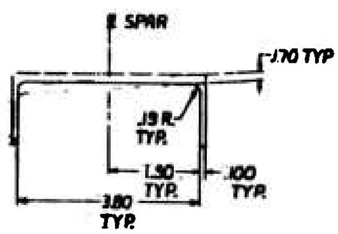
TABLE I DETAIL OF LOWER SURFACE WING SKIN						
	DASH NO.	RAW STOCK SIZE	RAW STOCK WT.	MATERIAL	FINISHED STOCK SIZE	FINISHED WT. IN LBS.
	-43	.063 X 5.6 X 50	1.78	2024-T81	.063 X 5.43 X 48	1.68
	-45	.063 X 7.3 X 50	2.29	↕	.063 X 7.03 X 48	2.16
Ⓐ	-47	.063 X 8.8 X 50	2.80	↕	.063 X 8.68 X 48	2.68
Ⓐ	-49	.071 X 10.4 X 50	3.78	↕	.071 X 10.23 X 48	3.59
Ⓐ	-51	.071 X 12.0 X 50	4.30	↕	.071 X 11.88 X 48	4.07
Ⓐ	-53	.071 X 13.6 X 50	4.88	2024-T81	.071 X 13.43 X 48	4.63
	-55	.063 X 3.8 X 50	1.21	2024-T81	.063 X 3.55 X 48	1.09
	-57	.063 X 5.4 X 50	1.72	↕	.063 X 5.13 X 48	1.58
Ⓐ	-58	.063 X 7.0 X 50	2.23	↕	.063 X 6.75 X 48	2.07
Ⓐ	-61	.071 X 8.6 X 50	3.08	↕	.071 X 8.33 X 48	2.88
Ⓐ	-63	.071 X 10.2 X 50	3.68	↕	.071 X 9.93 X 48	3.44
Ⓐ	-65	.071 X 11.8 X 50	4.23	2024-T81	.071 X 11.60 X 48	3.99
	-56	.063 X 3.8 X 50	1.21	2024-T81	.063 X 3.53 X 48	1.09
	-57	.063 X 5.4 X 50	1.72	↕	.063 X 5.13 X 48	1.58
Ⓐ	-59	.063 X 7.0 X 50	2.23	↕	.063 X 6.79 X 48	2.07
Ⓐ	-61	.071 X 8.6 X 50	3.08	↕	.071 X 8.39 X 48	2.88
Ⓐ	-68	.071 X 10.2 X 50	3.66	↕	.071 X 9.98 X 48	3.44
Ⓐ	-65	.071 X 11.8 X 50	4.23	2024-T81	.071 X 11.50 X 48	3.99
	-43	.063 X 5.6 X 50	1.78	2024-T81	.063 X 5.43 X 48	1.68
	-45	.063 X 7.2 X 50	2.29	↕	.063 X 7.03 X 48	2.16
Ⓐ	-47	.063 X 8.8 X 50	2.80	↕	.063 X 8.6 X 48	2.63
Ⓐ	-49	.071 X 10.4 X 50	3.73	↕	.071 X 10.23 X 48	3.52
Ⓐ	-51	.071 X 12.0 X 50	4.30	↕	.071 X 11.83 X 48	4.07
Ⓐ	-53	.071 X 12.6 X 50	4.88	2024-T81	.071 X 13.48 X 48	4.63



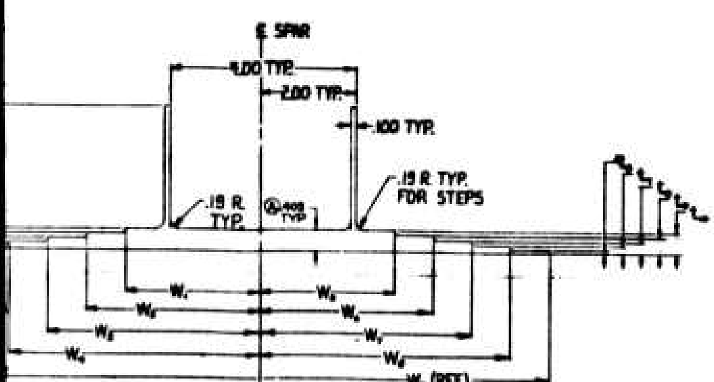
AUX. SPAR (-37)
2.88
.068
.126
.189
.260
.331
.063
.126
.189
.260
.581
2.8
3.6
4.4
5.2
2.8
3.6
4.4
5.2
12.0



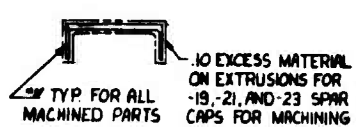
EXTRUSION DETAIL
-9 & -17

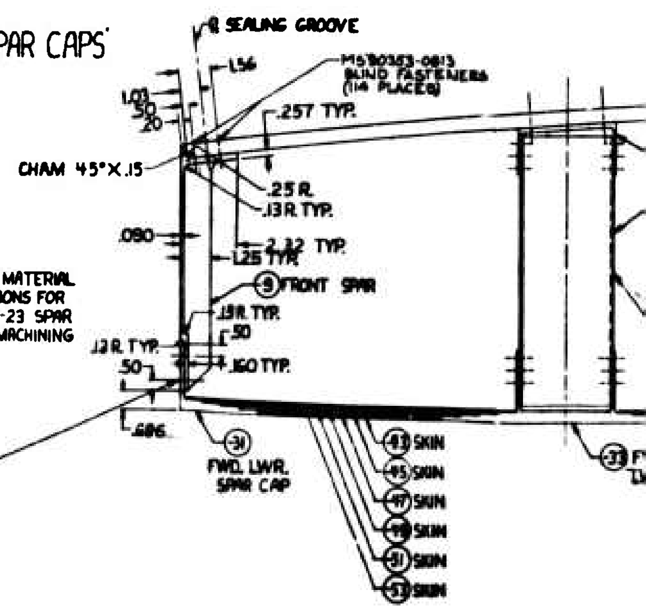


-91 EXTRU. DETAIL OF -19, 21 AND -23 SPAR CAPS
(-23 ROTATED 180°)
FULL SIZE



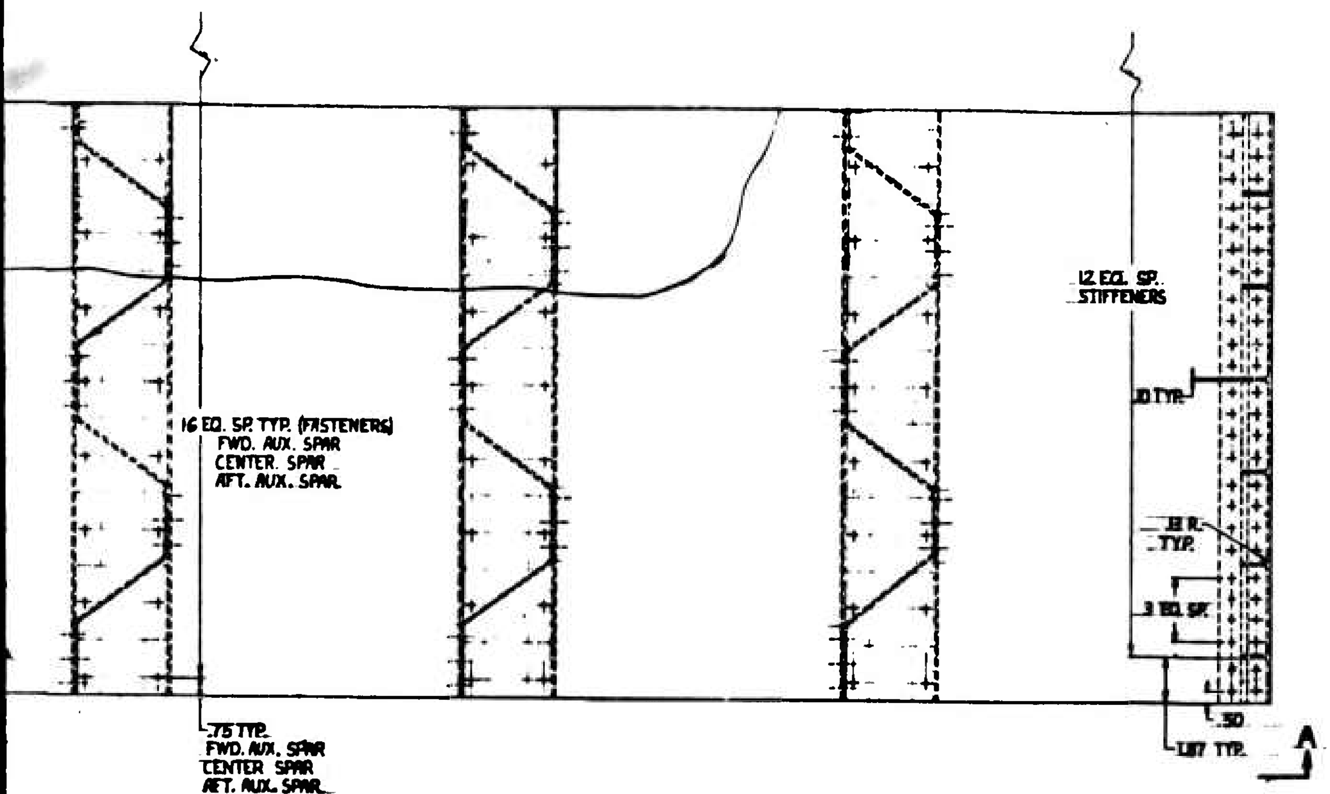
TRU. DETAIL OF -33, -35 AND -37 SPAR CAPS
FULL SIZE



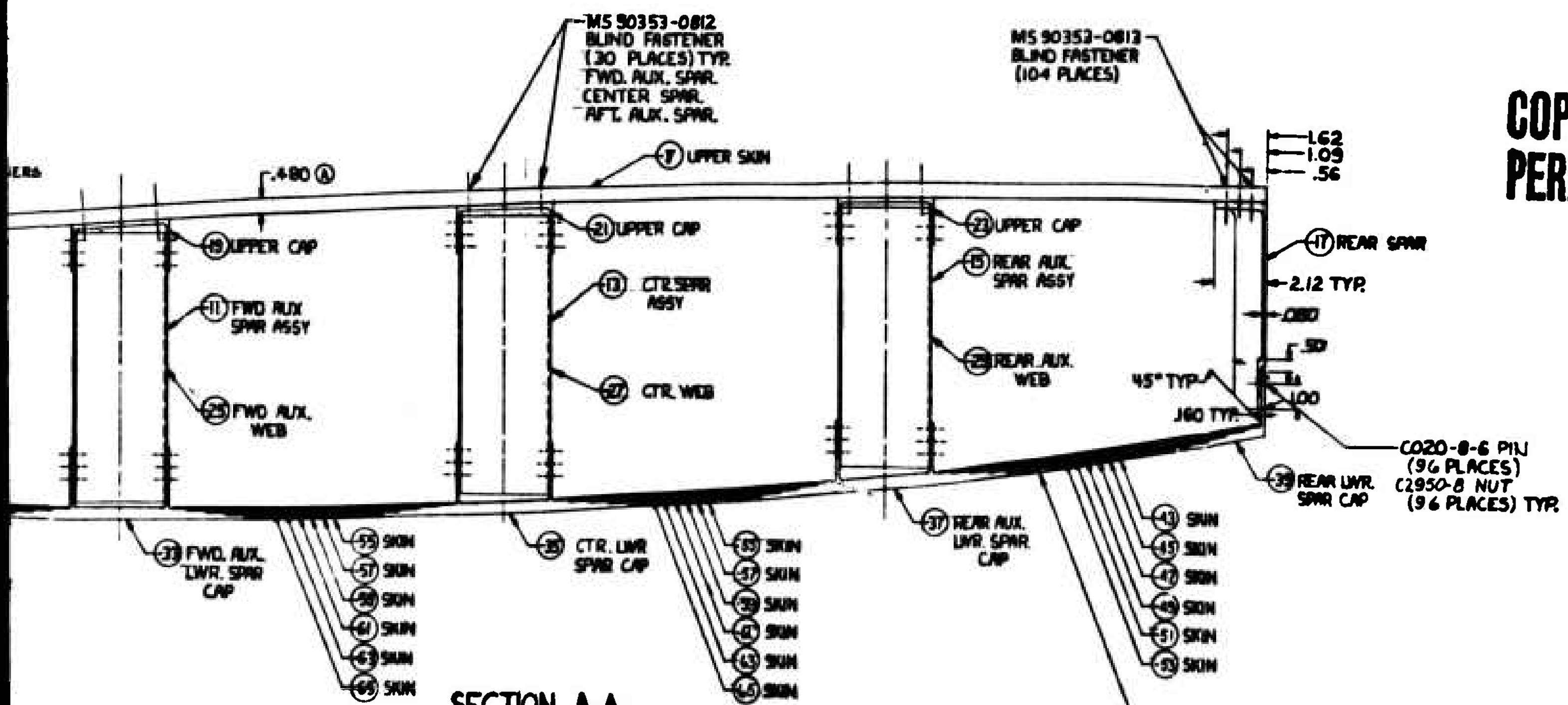


C020-8-6 PIN
(96 PLACES)
C2950 -8 NUT
(96 PLACES) TYP.

3



ASSY	SUB ASSY	DETAIL		PART NAME
LIST OF MATERIALS				
-1				ANALYTICAL ASSY
		-7		UPPER SKIN
		-9		FRONT SPAR
		-17		REAR SPAR
	-11			FWD. AUX. SPAR ASSY
		-19		UPPER CAP
			-91	CAP EXTRUSION
		-25		FWD. AUX. WEB
				ADHESIVE
	-13			CENTER SPAR ASSY
		-21		UPPER CAP
			-91	CAP EXTRUSION
		-27		CENTER WEB
				ADHESIVE
	-15			AFT. AUX. SPAR ASSY
		-23		UPPER CAP
			-91	CAP EXTRUSION
		-29		AFT. AUX. WEB
				ADHESIVE
	-41			LOWER SKIN PANEL ASSY
		-31		FRONT LWR SPAR CAP
			-87	FRONT SPAR EXTRU.
		-33		FWD. AUX. LWR. SPAR CAP
			-85	FWD. AUX. CAP EXTRU.
		-35		CTR. LWR. SPAR CAP
			-85	CTR. CAP EXTRU.
		-37		AFT AUX LWR SPAR CAP
			-85	AFT. AUX. CAP EXTRU
		-39		REAR LWR. SPAR CAP
			-87	REAR SPAR CAP EXTRU
		-43 / -65		SKIN / SKIN
		-93		ADHESIVE
				BLIND FASTENER MS90353-0812
				BLIND FASTENER MS90353-0813
				PIN (C020-8-6)
				NUT (C2950-8)
				SEALANT



SECTION A-A

-1 ASSY

COPY AVAILAB
PERMIT FULLY

4

ERIALS

PART NAME	NO. REQ'D	MATERIAL	RAW STOCK SIZE	RAW STOCK WEIGHT	FINISHED WT DETAIL	FINISHED WT ASSY	COST MAT'L	COST FAB	COST TOOL	TOTAL COST	
ANALYTICAL ASSY						351.83	3033	6801	212	9546	A
UPPER SKIN	1	2024-T851	[illegible]	18.20	140.13		3751	248.81			A
FRONT SPAR	1	2024-T8511	EXTRUSION	17.96	[illegible]		[illegible]	[illegible]			
REAR SPAR	1	2024-T8511	EXTRUSION	78.27	[illegible]		[illegible]	[illegible]			
FWD AUX. SPAR ASSY	1					11.34					
UPPER CAP	1	MAKE FROM -31			3.80			[illegible]			
CAP EXTRUSION	1	2024-T8511	EXTRUSION	13.05			75.46	✓			
FWD AUX WEB	1	2024-T81	SHEET	5.36	3.46		2.04	85.47			
ADHESIVE					.07						
CENTER SPAR ASSY	1					11.40					
UPPER CAP	1	MAKE FROM -31			3.81			[illegible]			
CAP EXTRUSION	1	2024-T8511	EXTRUSION	13.08			75.43	✓			
CENTER WEB	1	2024-T8	SHEET	5.36	[illegible]		2.44	85.47			
ADHESIVE					.07						
AFT AUX SPAR ASSY	1					11.03					
UPPER CAP	1	MAKE FROM -31			3.80			[illegible]			
CAP EXTRUSION	1	2024-T8511	EXTRUSION	13.09			75.48	✓			
AFT AUX WEB	1	2024-T81	SHEET	[illegible]	[illegible]		[illegible]	[illegible]			
ADHESIVE					.06						
LOWER SKIN PANEL ASSY	1					145.20		335.54			A
FRONT LWR SPAR CAP	1	MAKE FROM -37			5.19			165			A
FRONT SPAR EXTRU	1	2024-T8511	EXTRUSION	17.03			107.78	✓			A
FWD AUX LWR SPAR CAP	1	MAKE FROM -35			30.19			250.07			A
FWD AUX CAP EXTRU	1	2024-T8511	EXTRUSION	43.96			190.06	✓			A
CTR LWR SPAR CAP	1	MAKE FROM -35			30.30			[illegible]			A
CTR CAP EXTRU	1	2024-T8511	EXTRUSION	43.96			190.06	✓			A
AFT AUX LWR SPAR CAP	1	MAKE FROM -35			30.33			248.37			A
AFT AUX CAP EXTRU	1	2024-T8511	EXTRUSION	43.96			190.06	✓			A
REAR LWR SPAR CAP	1	MAKE FROM -37			5.15			165			A
REAR SPAR CAP EXTRU	1	2024-T8511	EXTRUSION	17.03			107.78	✓			A
SKIN / SKIN	/	SEE TABLE I			[illegible]		136.15	[illegible]			A
ADHESIVE		FMS-1013, FORM I A (SEE NOTE 3)			6.81						
BLIND FASTENER MS20353-0818	30				1.31	}	872				
BLIND FASTENER MS20353-0818	218				3.86						
PIN [illegible]	[illegible]				1.11						
NUT [illegible]	[illegible]				.50						
SEALANT		FMS-1044 (SEE NOTE 1)		1.75	[illegible]						
		MAT'L REMOVED FOR FASTENER HOLES			2.15		8557	[illegible]			A

SYM	ZONE	REVISION DESCRIPTION	DATE	APPROVED
A		CHANGED -7 THICKNESS FROM .380 TO .340. CHANGED LOWER SKIN THICKNESS FROM .488 TO .402. REVISED ALL WEIGHTS IN L/M TO REFLECT -7 UPPER SKIN THICKNESS CHANGE & LOWER SKIN THICKNESS CHANGE, INCLUDING LWR-SKIN-CAPS.		[illegible]

AVAILABLE TO DDC DOES NOT
T FULLY LEGIBLE PRODUCTION

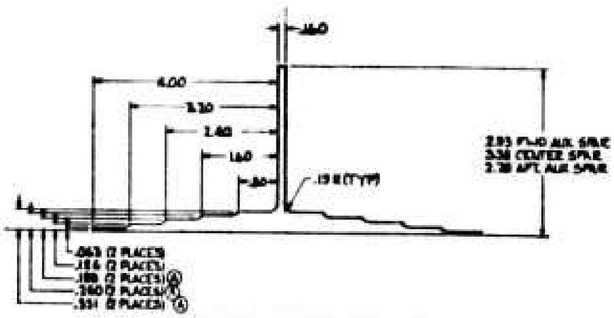
NOTES:

1. THE FAYING SURFACES AT THE UPPER SURFACE OF THE FRONT AND REAR SPAR, THE UPPER SKIN, AND ALL FASTENER SHALL BE SEALED PER FPS-1004.
2. [illegible] FINISH REQ'D ON ALL MACHINED PARTS.
3. USE FMS-1013 ADHESIVE FORM I A (RELIABOND 398) IN THE FOLLOWING AREAS:
   (1) BETWEEN ALL LOWER SURFACE SKINS AND ADJACENT LWR. SPAR CAPS/ SPARS IN THE -41 ASSY
   (2) BETWEEN ALL INTERM. SPAR WEBS & ADJACENT UPR. SPAR CAPS IN THE -11, -13, & -15 ASSYS

PRELIMINARY DESIGN DRAWING
ATW -4 WING - LAMINATED LWR. SKIN; MACHINED UPR SKIN & CLOSURE SPARS; CORRUGATED INTERM. SPARS WITH EXTRUDED CAPS (ALUMINUM); ANALYTICAL ASSY.
GENERAL DYNAMICS
Convair Aerospace Division
633-RA002 A

Figure 40 Corrugated Spar Analytical Assembly

FRONT/REAR LOWER SPAR CAP
TYP -85, -87
SCALE 1/1



DETAIL LOWER SPAR CAP
TYP -89, -91, -93
SCALE 2/1

TABLE I

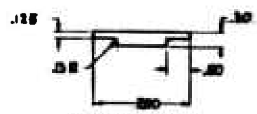
DETAILS OF UPPER SURFACE SANDWICH CORE AND DETAILS OF INTERMEDIATE SPAR CORE

DASH NO.	NO. REQ'D.	RAW STOCK SIZE	RAW STOCK WT.	MATERIAL	FINISHED STOCK SIZE	FINISHED WT. IN LBS.
-31	1	.500×32×54	1.68	5005-1/3 AL CORE FMS-1070A 8.1 LB/FT.³	.300×31.3×48	.88
-33	1	.500×49×54	1.89		.300×45.37×48	1.01
-35	1	.500×49.7×54	1.89		.300×49.7×48	1.01
-37	1	.500×13.29×54	1.63		.500×13.29×48	.30
-45	3	.500×7.48×54	.98/FT	5021-1C PHENOLIC/GLASS CORE FMS-1051 8.0 LB/FT³	.300×7.4×48	.82/FT

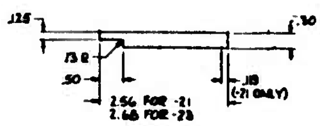
TABLE II

DETAILS OF LOWER SURFACE WING SKINS

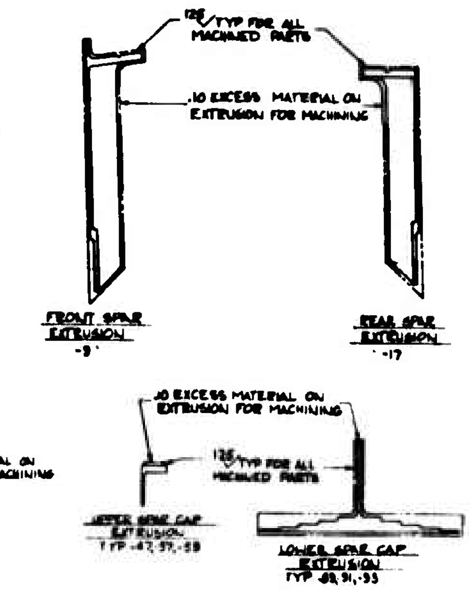
DASH NO.	NO. REQ'D.	RAW STOCK SIZE	RAW STOCK WT.	MATERIAL	FINISHED STOCK SIZE	FINISHED WT. IN LBS.
-61	1	.071×54×50	5.83	2024-T81	.071×52.27×48	5.34
-63	1	.071×58×50	4.95		.071×46.67×48	4.71
-65	1	.071×122×50	4.37		[illegible]	4.13
-67	1	[illegible]	3.37		[illegible]	3.30
-69	1	[illegible]	1.50		[illegible]	[illegible]
-71	1	[illegible]	1.40		[illegible]	[illegible]
-73	3	.071×15×50	1.59/FT		[illegible]	[illegible]/FT
-75	3	.071×40×50	5.03/FT		[illegible]	[illegible]/FT
-77	3	[illegible]	4.44/FT		[illegible]	[illegible]/FT
-79	3	[illegible]	1.84/FT		[illegible]	[illegible]/FT
-81	3	[illegible]	1.93/FT		[illegible]	[illegible]/FT
-83	3	.063×74×50	2.35/FT	2024-T81	.063×7.45×48	2.25/FT



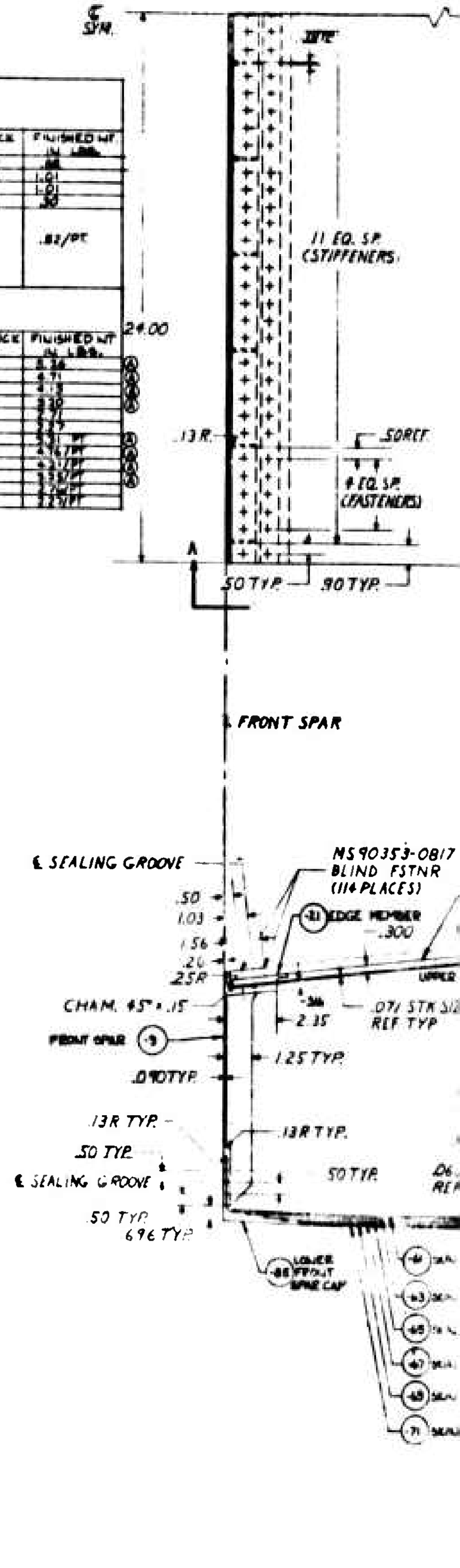
DETAIL SLUG
TYP -25, 27, -29
SCALE 1/1



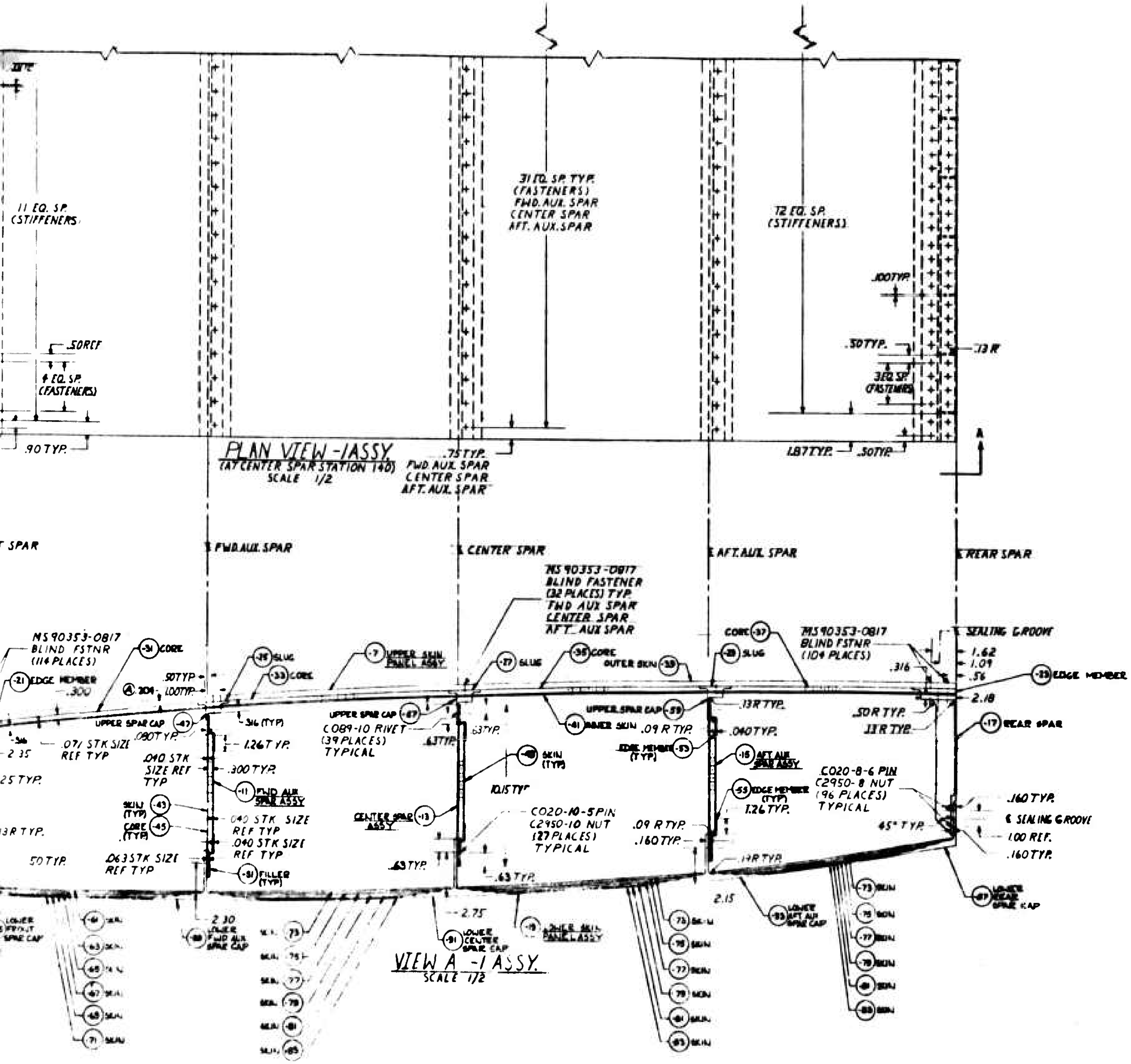
DETAIL EDGE MEMBER
TYP -21, -23
SCALE 1/1



EXTRUSION DETAILS



2


11 EQ. SP. (STIFFENERS)
.50 REF
4 EQ. SP. (FASTENERS)
.90 TYP.
31 EQ. SP. TYP. (FASTENERS) FWD. AUX. SPAR CENTER SPAR AFT. AUX. SPAR
12 EQ. SP. (STIFFENERS)
.100 TYP.
.50 TYP.
.13 R
3 EQ. SP. (FASTENERS)
PLAN VIEW -1 ASSY (AT CENTER SPAR STATION 140) SCALE 1/2
.75 TYP. FWD. AUX. SPAR CENTER SPAR AFT. AUX. SPAR
1.87 TYP.
.50 TYP.
A
FWD. AUX. SPAR
CENTER SPAR
AFT. AUX. SPAR
REAR SPAR
MS 90353-0817 BLIND FASTENER (32 PLACES) TYP. FWD AUX SPAR CENTER SPAR AFT AUX SPAR
MS 90353-0817 BLIND FSTNR (114 PLACES)
MS 90353-0817 BLIND FSTNR (104 PLACES)
-31 CORE
-21 EDGE MEMBER
-25 SLUG
-33 CORE
-7 UPPER SKIN PANEL ASSY
-27 SLUG
-35 CORE
OUTER SKIN -39
CORE -37
-29 SLUG
SEALING GROOVE
1.62
1.09
.56
.316
-23 EDGE MEMBER
2.18
-17 REAR SPAR
UPPER SPAR CAP -47
UPPER SPAR CAP -87
UPPER SPAR CAP -59
-41 INNER SKIN
.071 STK SIZE REF TYP
.080 TYP.
.316 (TYP)
1.26 TYP.
C089-10 RIVET (39 PLACES) TYPICAL
.63 TYP.
.13 R TYP.
.50 R TYP.
.13 R TYP.
.09 R TYP.
.040 TYP.
EDGE MEMBER -53 (TYP)
-15 AFT AUX SPAR ASSY
.040 STK SIZE REF TYP
.300 TYP.
-11 FWD AUX SPAR ASSY
SKIN -49 (TYP)
.015 TYP
C020-8-6 PIN C2950-8 NUT (96 PLACES) TYPICAL
-55 EDGE MEMBER (TYP)
1.26 TYP.
.160 TYP.
SEALING GROOVE
1.00 REF.
.160 TYP.
45° TYP.
SKIN -43 (TYP)
CORE -45 (TYP)
.040 STK SIZE REF TYP
.040 STK SIZE REF TYP
.063 STK SIZE REF TYP
-81 FILLER (TYP)
CENTER SPAR -13 ASSY
C020-10-5 PIN C2950-10 NUT (27 PLACES) TYPICAL
.09 R TYP.
.160 TYP.
.13 R TYP.
.63 TYP.
.63 TYP.
2.15
-93 LOWER AFT AUX SPAR CAP
-97 LOWER REAR SPAR CAP
2.30
-89 LOWER FWD AUX SPAR CAP
2.75
-91 LOWER CENTER SPAR CAP
-19 LOWER SKIN PANEL ASSY
LOWER FRONT SPAR CAP
-61 SKIN
-63 SKIN
-65 SKIN
-67 SKIN
-69 SKIN
-71 SKIN
SKIN 73
SKIN 75
SKIN 77
SKIN 79
SKIN 81
SKIN 85
-73 SKIN
-75 SKIN
-77 SKIN
-79 SKIN
-81 SKIN
-83 SKIN
VIEW A -1 ASSY. SCALE 1/2

3

REV	ZONE	DESCRIPTION		APPROVED
A		CHANGED UPPER OUTER SKIN THICKNESS FROM .375 TO .204 IN -1 ASSY CHANGED LOWER SKIN THICKNESS FROM .486 TO .402 IN -1, -3, & -801 ASSY'S CHANGED UPPER SKIN THICKNESS FROM .499 TO .480 IN -3 ASSY CHANGED UPPER SKIN THICKNESS FROM .499 TO .524 IN -5 ASSY CHANGED LOWER SKIN THICKNESS FROM .486 TO .459 ASSY -5 ASSY CHANGED UPPER SKIN THICKNESS FROM .499 TO .440 IN -801 ASSY REVISED ALL WEIGHTS IN L/M TO REFLECT CHANGES IN UPPER & LOWER SKIN THICKNESSES IN -1, -3, -5, & -801 ASSY'S	[illegible]	E.G.Q.

DASH NO. ASSY	SUB ASSY	DETAIL	PART NAME	NO. REQD	MATERIAL	RAW STOCK SIZE	RAW STOCK WEIGHT	FINISHED WT DETAIL	FINISHED WT ASSY	COST MATL.	COST FAB.	COST TOOL.	TOTAL COST	
-1			ANALYTICAL ASSY	1					297.38	4956	7058	263	12277	Ⓐ
	-7		UPPER SKIN PANEL ASSY	1					121.48		12554			Ⓐ
		-31	EDGE MEMBER	1	2024-T851	.375×[illegible]×54	4.34	2.75		30.46	86.16			
		[illegible]	EDGE MEMBER	1	2024-T851	.375×[illegible]	4.34	2.50			86.16			
		[illegible]	SLUG	1	2024-T851	.375×[illegible]×54	6.4	2.10			112.16			
		[illegible]	SLUG	1	2024-T851	.375×10×54	6.4	2.0			112.16			
		[illegible]	SLUG	1	2024-T851	.375×10×54	6.4	2.10			112.16			
		[illegible]	CORE	1	SEE TABLE I			.69			2.42			
		-53	CORE	1				1.01		11.58	2.34			
		-55	CORE	1				1.0			5.34			
		-57	CORE	1	SEE TABLE I			.90			5.34			
		-39	OUTER SKIN	1	2024-T851	.375×54×69	141.15	63.98		225.36	5.34			Ⓐ
		-41	INNER SKIN	1	2024-T81	.071×54×69	26.71	22.37		44.89	5.34			Ⓐ
			ADHESIVE		FMS-1013 FORM IA (SEE NOTE 3)			4.34						
		-9	FRONT SPAR	1	2024-T851	EXTRU [illegible]	35.45	10.03		[illegible]	[illegible]			
		-17	REAR SPAR	1	2024-T8511	EXTRU [illegible]	72.10	9.34		[illegible]	[illegible]			
	-11		FWD AUX SPAR ASSY	1					8.47		12365			
		-43	SKIN	1	2024-T81	.040×18.1×80	3.04	1.88		3.66	[illegible]			
		-45	CORE	1	SEE TABLE			.67		76.20	5.34			
		-47	UPPER SPAR CAP	1	2024-T8511	EXTRU [illegible]	7.84	7.08		28.38	41.37			
		-49	SKIN	1	2024-T81	.040×74×50	1.54	1.44		2.75	5.34			
		-51	FILLER	1	2024-T81	.063×8×50	.45	.38		.76	4.34			
		-53	UPPER EDGE MEMBER	1	2024-T81	.040×5×50	.65	.57		1.12	8.01			
		-55	LOWER EDGE MEMBER		2024-T81		.63	.56		1.12	8.01			
			ADHESIVE		FMS-1013 FORM IA (SEE NOTE 3)			.20						
			RIVET [illegible]	39				.23						
	-13		CENTER SPAR ASSY	1	SAME AS -11 SUB ASSY EXCEPT REPLACE -47CAP WITH -57CAP				8.47	98.26	182.32			
	-15		AFT AUX SPAR ASSY	1	SAME AS -11 SUB ASSY EXCEPT REPLACE -47CAP WITH -58CAP				8.47	107.26	152.32			
	-19		LOWER SKIN PANEL ASSY	1					198.87		2646			Ⓐ
		-61 / -83	SKIN / SKIN		SEE TABLE II			89.96		181.69	181.43			Ⓐ
		-84	FRONT LOWER SPAR CAP	1	2024-T8511	EXTRU [illegible]	17.02	5.45		97.56	176.29			Ⓐ
		-87	REAR LOWER SPAR CAP	1	2024-T8511	EXTRU [illegible]	17.03	5.45		107.56	176.29			Ⓐ
		-88	LOWER FWD AUX SPAR CAP	1	2024-T8511	EXTRU [illegible]	31.09	9.58		136.99	145.74			Ⓐ
		-89	LOWER CENTER SPAR CAP	1	2024-T8511	EXTRU [illegible]	31.09	9.75		136.99	145.74			Ⓐ
		-90	LOWER AFT AUX SPAR CAP	1	2024-T8511	EXTRU [illegible]	31.09	9.42		136.99	245.74			Ⓐ
			ADHESIVE		FMS-1013 FORM IA (SEE NOTE 3)			8.75						
			SEALANT		FMS-1044 (SEE NOTE 1)		1.75	1.30						
			[illegible]	192				1.11						
			[illegible]	192				.40	HDW	1176				
			[illegible]	81				.78						
			[illegible]	81				.41						
			BLIND FASTENER MS 90353-0817	344				4.40						
			MAT'L REMOVED FOR FASTENERS					3.46						

COPY AVAILABLE TO DDC DOES NOT PERMIT FULLY LEGIBLE PRODUCTION

3 USE FMS-1013 ADHESIVE FORM IA (RELIABOND 398) IN THE FOLLOWING AREAS:
1) BETWEEN ALL LWR SURFACE SKINS AND ADJACENT SPAR CAPS IN THE -19 ASSY
2) BETWEEN ALL EDGE MEMBERS, CORE AND SKINS IN THE -11, -13 & -15 ASSY
3) BETWEEN ALL EDGE MEMBERS, SLUGS, CORE, OUTER SKIN & INNER SKIN IN THE -7 ASSY

2 $\sqrt{}$ FINISH REQ'D. ON ALL MACHINED PARTS

1 THE FAYING SURFACE AT THE UPPER SURFACE OF THE FRONT AND REAR SPAR, THE UPPER SKIN, AND ALL FASTENERS SHALL BE SEALED PER FPS-1004

PRELIMINARY DESIGN DRAWING

[illegible] LAMINATED [illegible] SKIN, SANDWICH PANEL INTERMEDIATE SPARS, SANDWICH PANEL UPR SKIN ALUMINUM, ANALYTICAL ASSY

GENERAL DYNAMICS
Convair Aerospace Division

633-RA 003A

Figure 41 Sandwich Spar & Upper Skin Analytical Assembly

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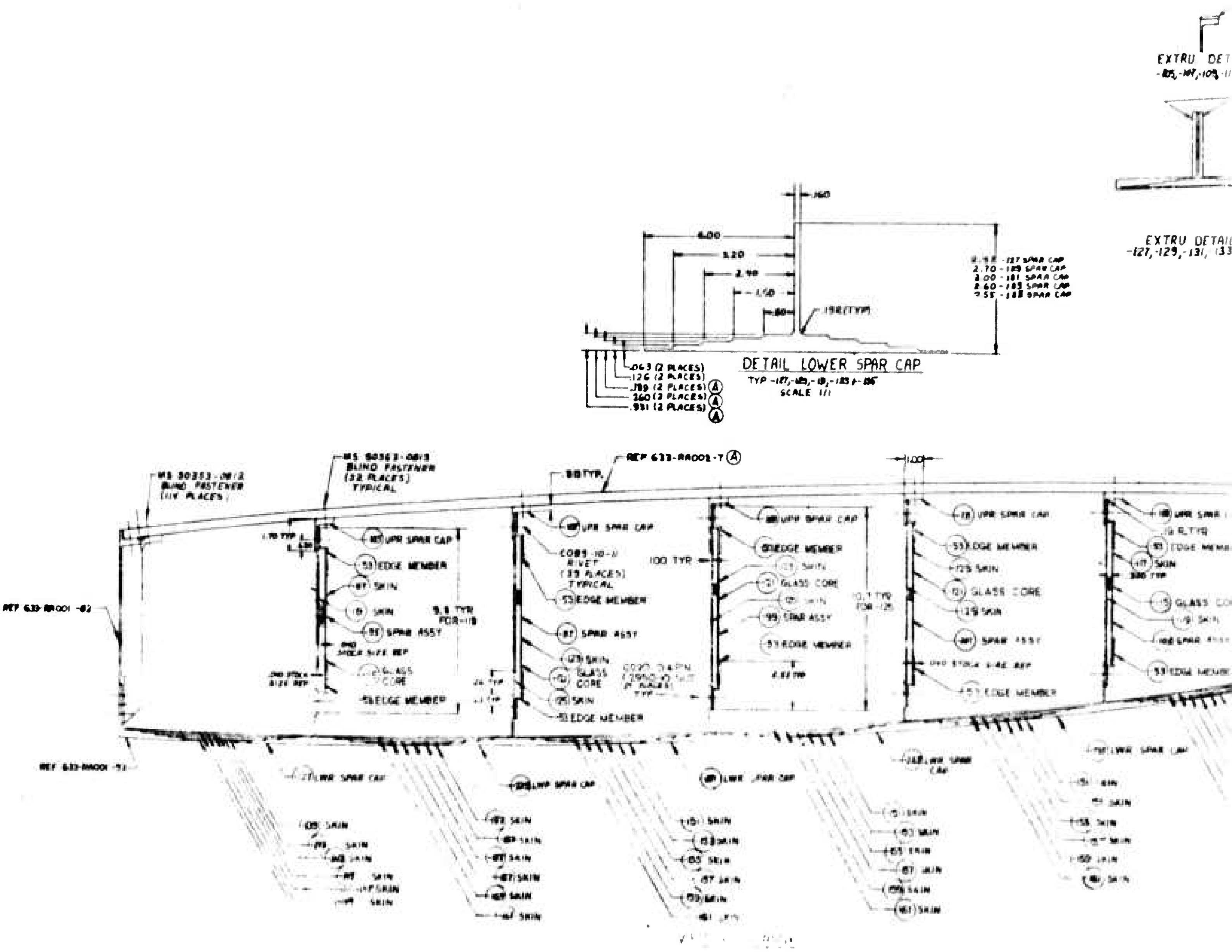
TABLE II

DETAILS OF LOWER SURFACE WING SKINS

DASH NO.	NO. REQD	SAW STOCK SIZE	STOCK WT	MATERIAL	[illegible]
-139	1	.063x2 x50	.67	2024-T81	[illegible]
-141	1	.063x3.7x50	1.18		[illegible]
(A) -143	1	.070x6.3x50	1.65		[illegible]
(A) -145	1	.071x6.9x50	2.47		[illegible]
(A) -147	1	.071x8.[illegible]x50	3.05		[illegible]
(A) -149	1	.071x10.[illegible]x50	3.6[illegible]		[illegible]
-61	4	.063x2.25x60	.72		[illegible]
-163	4	.063x3.95x60	1.23		[illegible]
(A) -165	4	.063x5.[illegible]x60	1.75		[illegible]
(A) -167	4	.071x[illegible]x50	2.3[illegible]		[illegible]
(A) -169	4	.071x[illegible]x60	[illegible]		[illegible]
(A) -1[illegible]	4	.071x10.[illegible]x50	2.88		[illegible]
-163	1	.063x2x[illegible]	.67		[illegible]
-164	1	.063x3.[illegible]x50	1.15		[illegible]
(A) -167	1	.063x5.2x50	1.65		[illegible]
(A) -169	1	.071x6.8x50	2.44		[illegible]
(A) -171	1	.071x8.[illegible]x50	3.01		[illegible]
(A) -173	1	.070x10x60	3.59	2024-T81	[illegible]



Fig

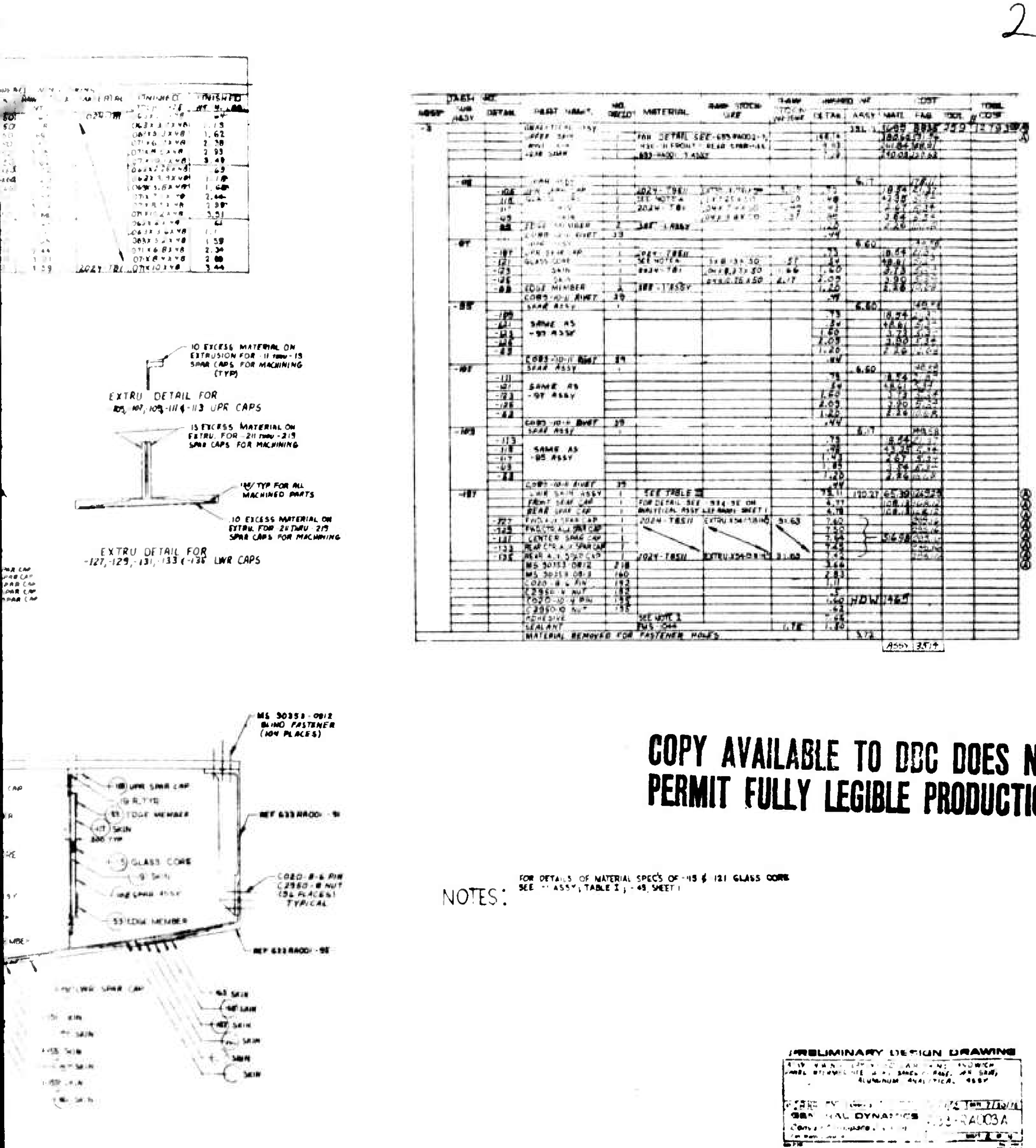


Figure 41 Sandwich Spar & Upper Skin Analytical Assembly (Continued)

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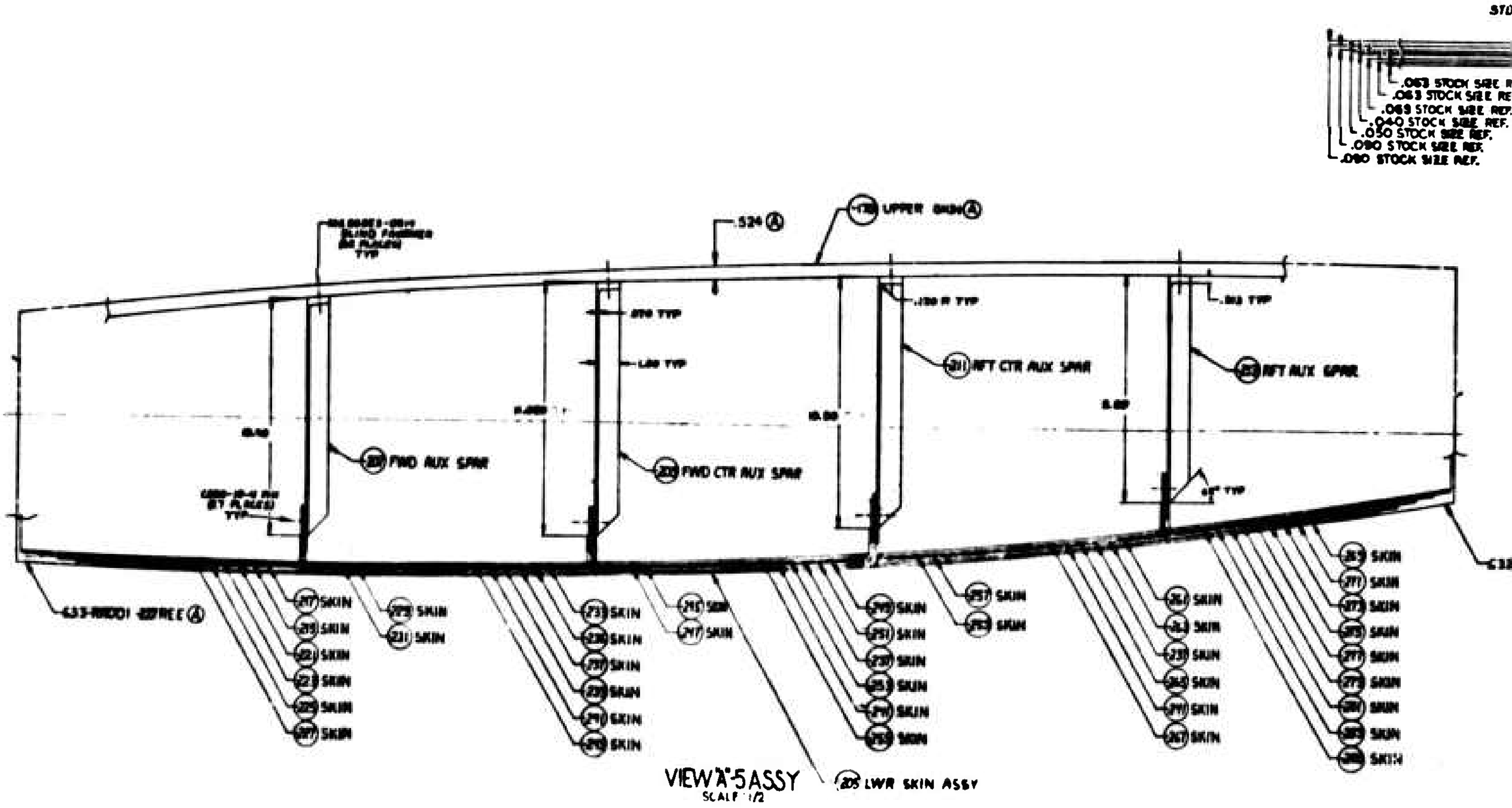

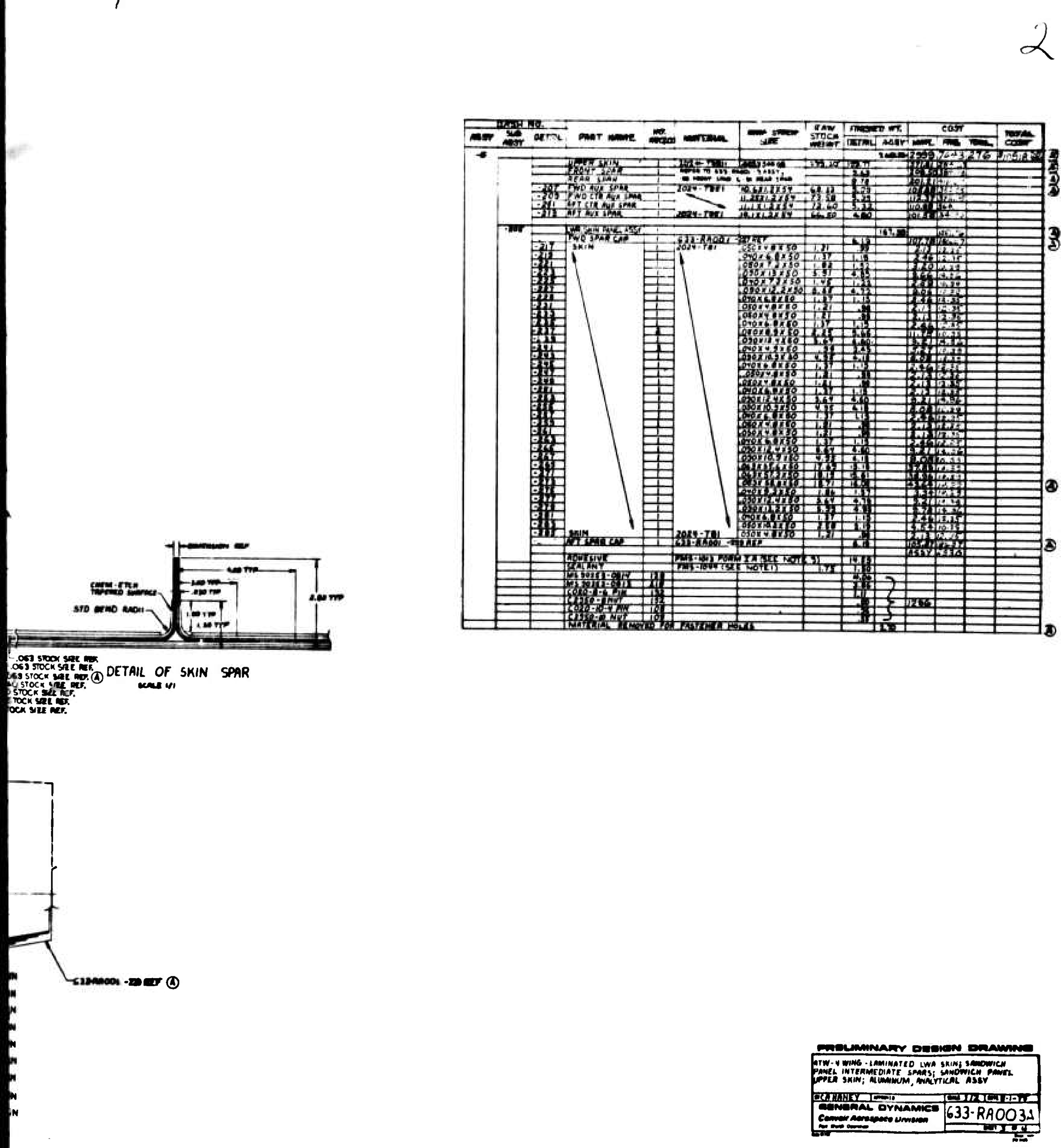

Figure 41 Sandwich Spar & Upper Skin Analytical Assembly (Continued)

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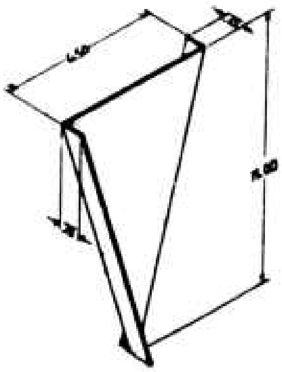
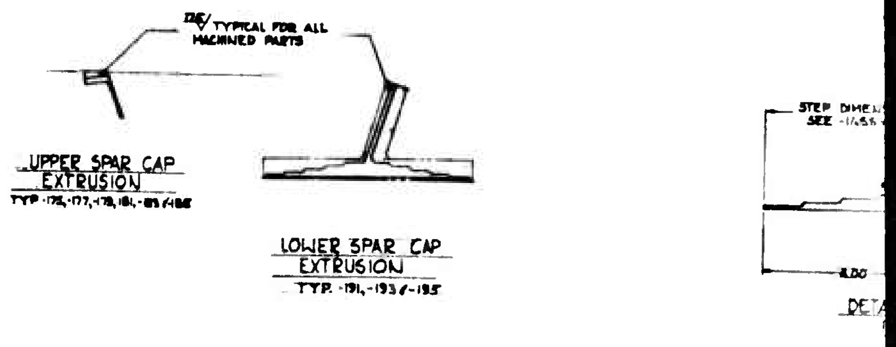
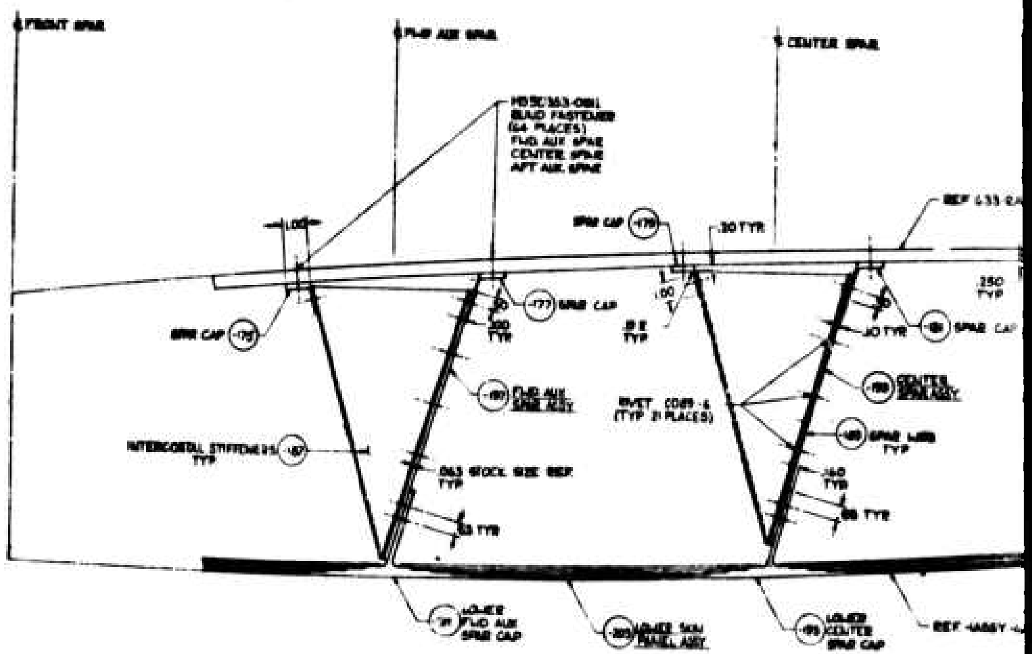
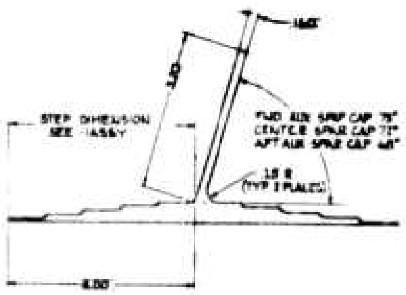


-187 INTERCOSTAL STIFFENERS DETAIL





VIEW A-801 ASSY



DETAIL LOWER SPAR CAP
TYP -191, -193 & 195
SCALE A

ASSY	SUB ASSY	DETAIL	PART NAME	NO REQ'D	MATERIAL	RAW STOCK SIZE	RAW STOCK WEIGHT	FINISHED WT DETAIL	FINISHED WT ASSY	COST MAT'L	COST FAB	COST TOOL	TOTAL COST	
-601			ANALYTICAL ASSY						350.[illegible]	1520.[illegible]	[illegible]	228	[illegible]	(A)
			UPPER SKIN	1	2024-T81	[illegible]	238.10	30.71		[illegible]	[illegible]			(A)
			FRONT SPAR	1	REF 633-RA001	-83 & -91		3.63		[illegible]	[illegible]			
			REAR SPAR	1				3.74		[illegible]	[illegible]			
	-197		FWD AUX SPAR ASSY						11.[illegible]					
		-175	UPPER SPAR CAP	1	2024-T851	EXTRUSION [illegible]	2.45	1.72		17.15	21.37			
		-177	UPPER SPAR CAP	1	2024-T851	EXTRUSION [illegible]	2.45	1.[illegible]		17.12	21.37			
		-187	INTERCOSTAL STIFFENERS	7	2024-T81	.063×8×11.3	.58	.55/PT		3.92	106.84			
		-189	SPAR WEB	1	2024-T81	.125×17×50	2.39	4.37		11.88	5.34			
			C020-8-6 PIN	7				.04						
			C020-8-5 PIN	29				.[illegible]						
			C020-8-3 PIN	7				.03						
			C2950-8 NUT	43				.11						
			C089-6 RIVET	21				.04						
	-199		CTR SPAR ASSY						11.23					
		-179	UPPER SPAR CAP	1	2024-T851	EXTRUSION [illegible]	2.45	1.72		17.15	21.37			
		-181	UPPER SPAR CAP	1	2024-T851	EXTRUSION [illegible]	2.45	1.[illegible]		17.15	21.37			
		-187	INTERCOSTAL STIFFENERS	7	2024-T81	.063×8×11.3	.58	.55/PT		3.92	106.84			
		-185	SPAR WEB	1	2024-T81	.125×[illegible]×50	[illegible]	4.37		11.88	5.34			
			C020-8-6 PIN	7				.04						
			C020-8-5 PIN	29				.12						
			C020-8-3 PIN	7				.03						
			C2950-8 NUT	43				.11						
			C089-6 RIVET	21				.04						
	-201		AFT AUX SPAR ASSY						11.[illegible]					
		-83	UPPER SPAR CAP	1	2024-T851	EXTRUSION [illegible]	2.45	1.72		17.15	21.37			
		-85	UPPER SPAR CAP	1	2024-T851	EXTRUSION [illegible]	2.45	1.76		17.12	21.37			
		-87	INTERCOSTAL STIFFENERS	7	2024-T81	.063×8×11.3	.58	.55/PT		3.92	106.64			
		-189	SPAR WEB	1	2024-T81	.125×11.7×50	7.18	4.37		11.88	5.34			
			C020-8-6 PIN	7				.04						
			C020-8-4 PIN	29				.12						
			C020-8-3 PIN	7				.03						
			C2950-8 NUT	43				.11						
			C089-6 RIVET	21				.04						
	-103		LOWER SKIN PANEL ASSY						156.59		1488.80			(A)
		-61 thru -83	SKIN thru SKIN		SEE -1ASSY TABLE II -61 SKIN THRU -83 SKIN			60.60		131.65	129.21			(A)
		-85	FRONT LOWER SPAR CAP	1	SEE -1ASSY			5.49		121.24	76.29			(A)
		-87	REAR LOWER SPAR CAP	1	SEE -1ASSY			5.49		121.24	76.29			(A)
		-191	LOWER FWD AUX SPAR CAP	1	2024-T851	EXTRUSION [illegible]	18.56	8.34		126.03	245.74			(A)
		-193	LOWER CENTER SPAR CAP	1	2024-T851	EXTRUSION [illegible]	18.56	8.34		126.08	245.74			(A)
		-195	LOWER AFT AUX SPAR CAP	1	2024-T851	EXTRUSION [illegible]	18.56	8.36		126.03	245.74			(A)
			ADHESIVE		FM-1000 FORM [illegible] NOTE [illegible]			7.63						
			MS 90353-8-1 BLIND FASTENER	410				6.90	HWD	1678				
			C020-10-6 PIN	47				.49						
			C020-10-5 PIN	218				2.8[illegible]						
			C2950-10 NUT	267				1.54						
			C020-8-6 PIN	191				1.11						
			C2950-8 NUT	192	SEE -1ASSY			.48						
			SEALANT					1.50						
			MAT'L REMOVED FOR FASTENERS						-3.31					

ASSY 2826.25

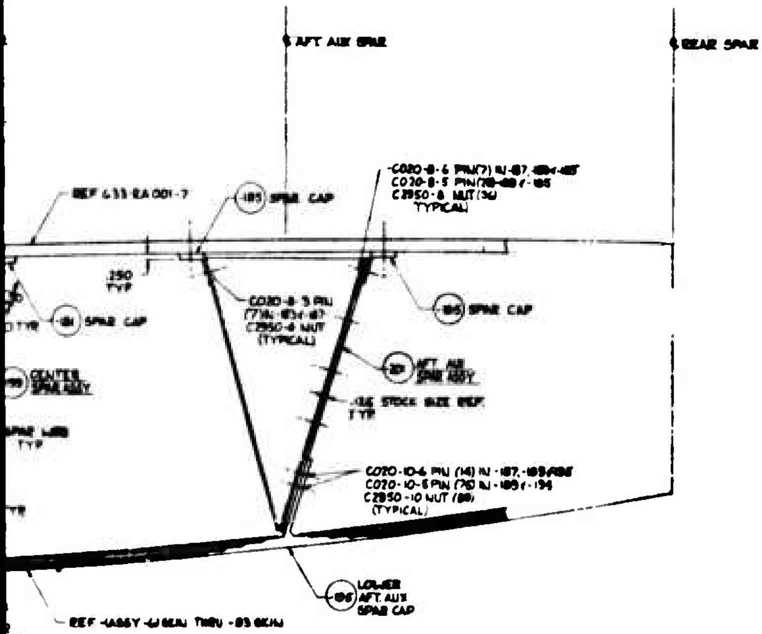


Figure 41 Sandwich Spar & Upper Skin An

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DISTRIBUTION STATEMENT A

APPROVED FOR PUBLIC RELEASE; DISTRIBUTION UNLIMITED.

COST			TOTAL COST	
MAT'L	FAB	TOOL		
3520	[illegible]	226	[illegible]	Ⓐ
[illegible]	[illegible]			Ⓐ
[illegible]	[illegible]			
[illegible]	[illegible]			
17.15	21.37			
17.15	21.37			
3.92	106.84			
11.88	5.34			
17.15	21.37			
17.15	21.37			
3.92	106.84			
11.88	5.34			
17.15	21.37			
17.16	21.37			
3.92	106.64			
11.88	5.34			
	1089.80			Ⓐ
131.69	120.21			Ⓐ
121.24	176.29			Ⓐ
21.24	176.29			Ⓐ
126.03	245.74			Ⓐ
126.03	245.74			Ⓐ
126.03	245.74			Ⓐ
678				
ASSY	2832.25			

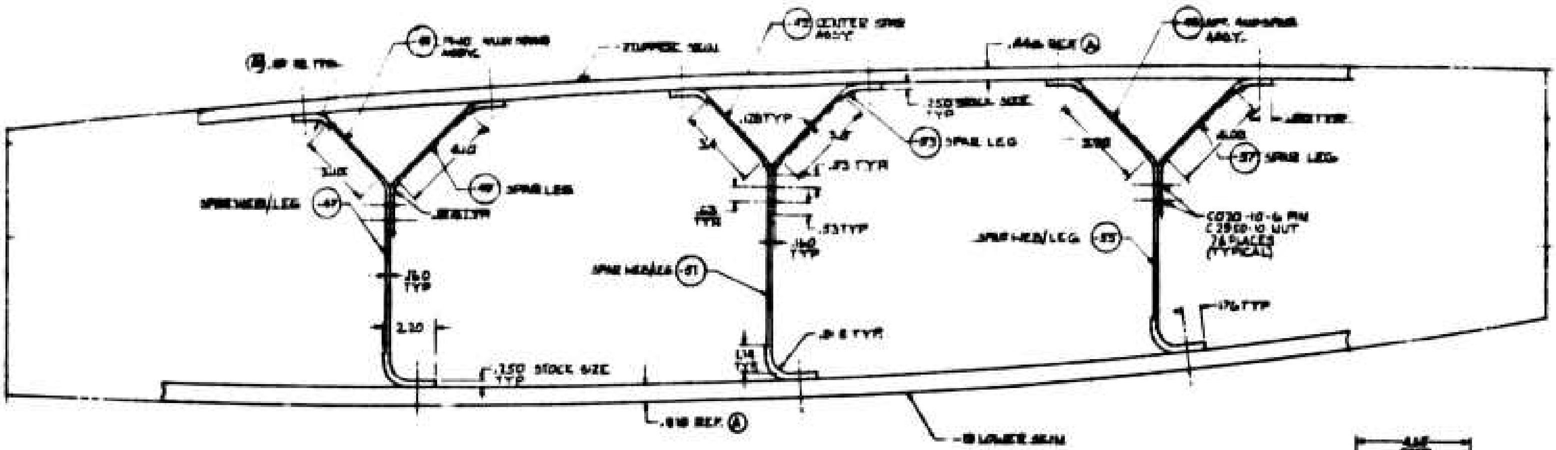
PRELIMINARY DESIGN DRAWING

ATW A..NG LAMINATED ..E SKIN; SANDWICH PANEL INTERMEDIATE SPARS, SANDWICH PANEL UPR SKIN; ALUM ...., ANALYTICAL ASSY

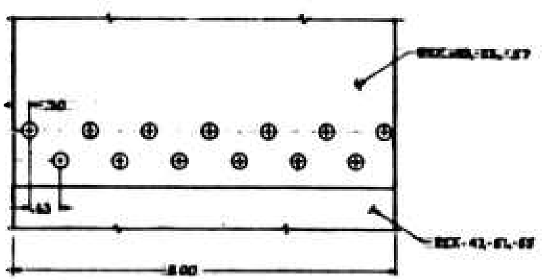
GENERAL DYNAMICS
Convair Aerospace Division

633-RA003A

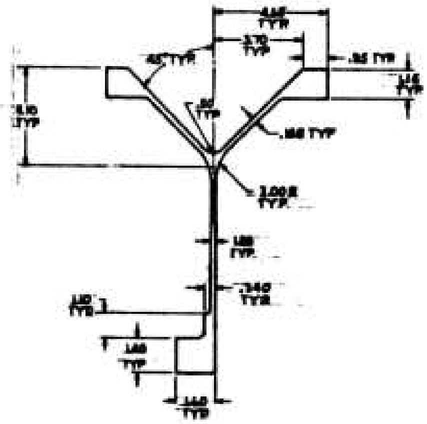
& Upper Skin Analytical Assembly (Continued)



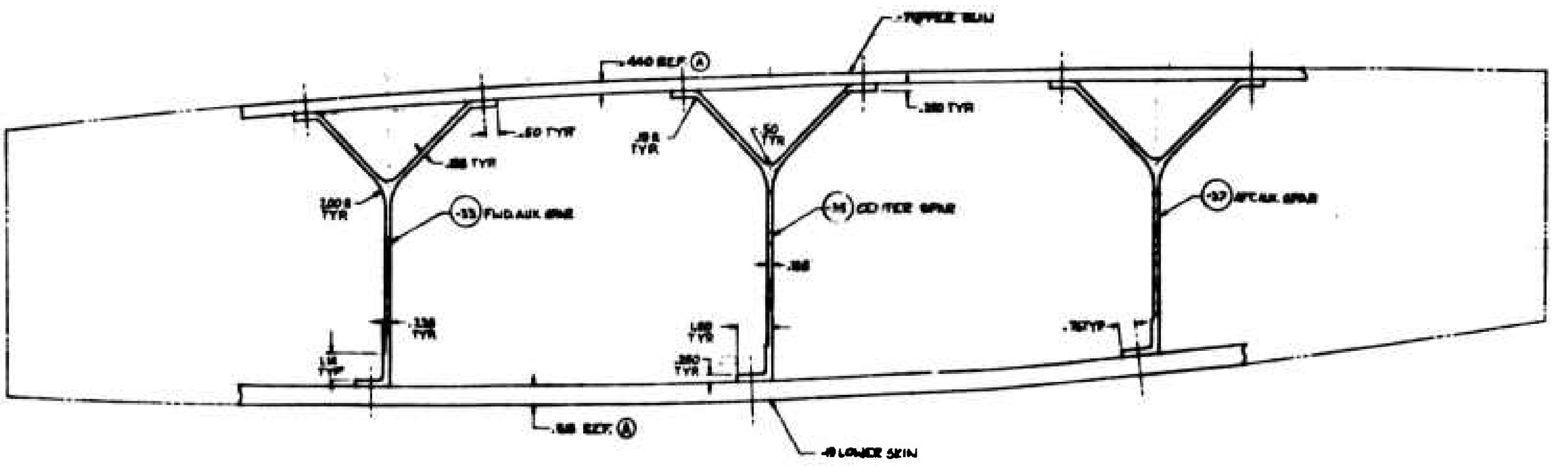
VIEW A-5 ASSY



INTERMEDIATE SPAR ATTACHMENT
TYP -41, -43, -45
SCALE: 4

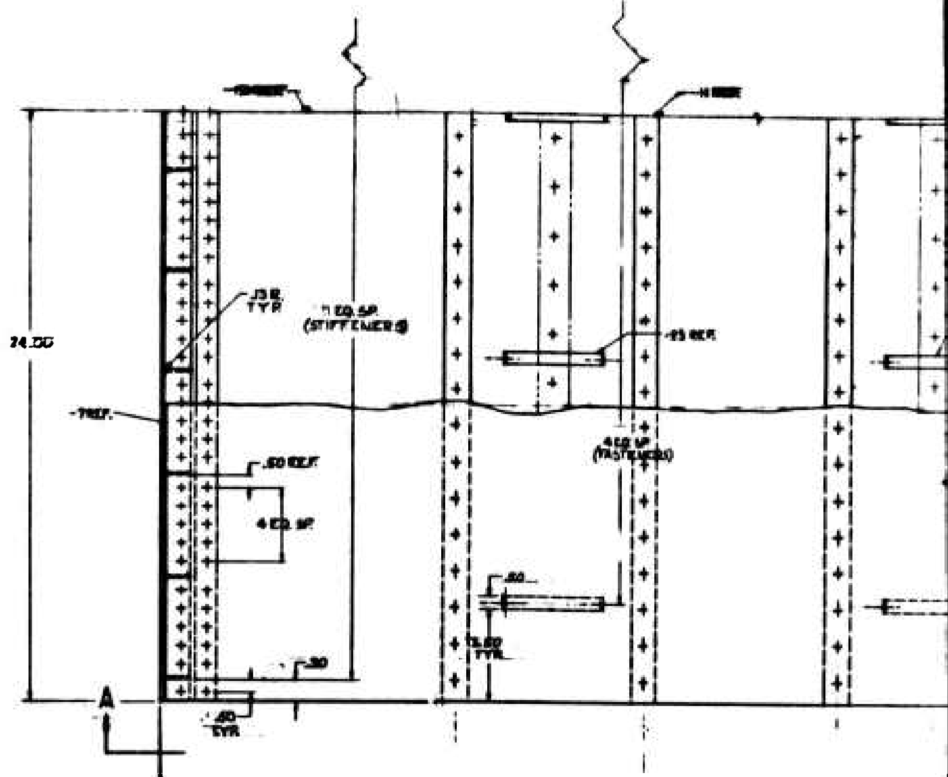


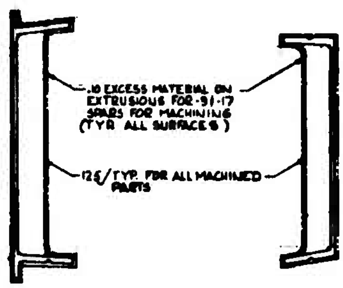
-33 EXTRUSION DETAIL
TYP -33, -35, -37



VIEW A-3 ASSY

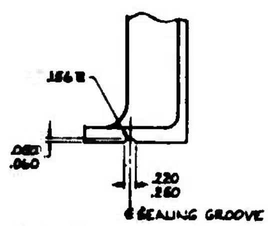
2





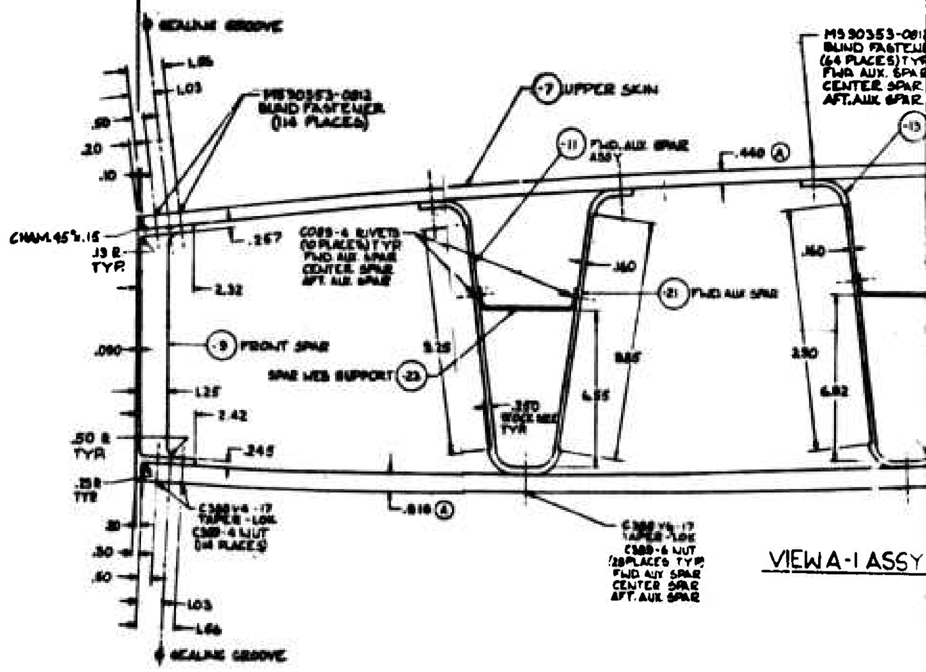
EXTRUSION DETAILS

-91-17



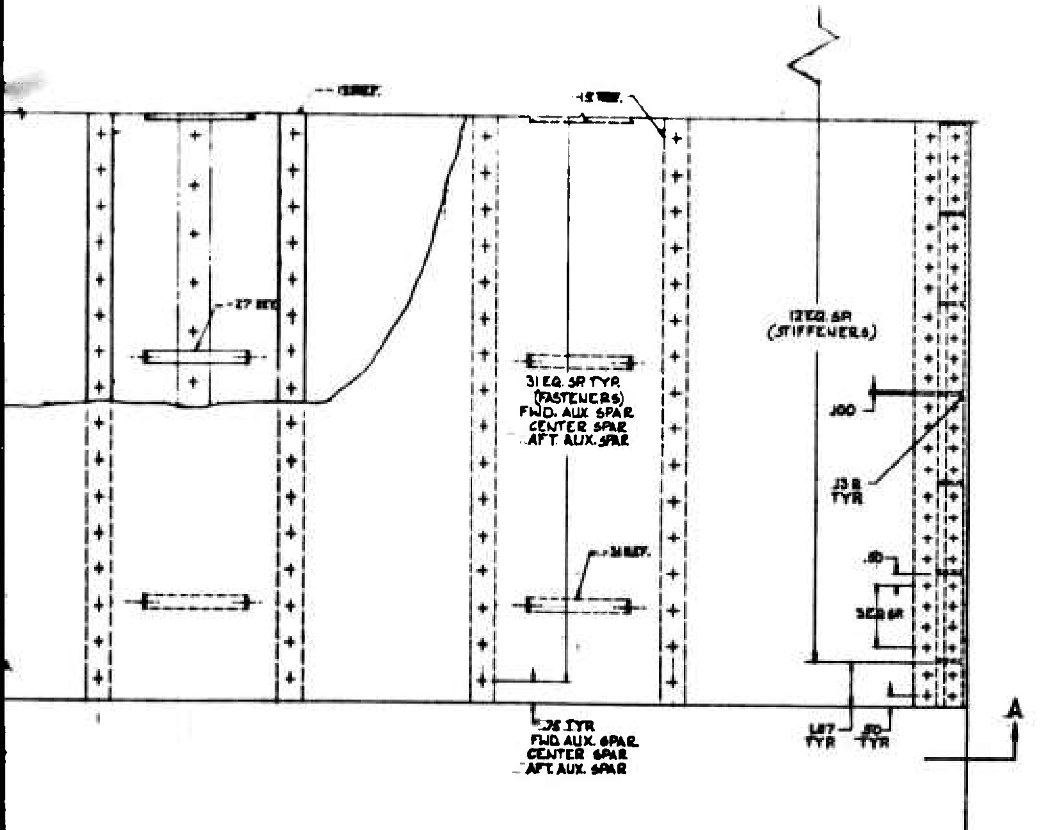
FUEL SEALING GROOVE

TYPICAL AT FRONT AND REAR SPAR UPPER AND LOWER FLANGES SCALE: ½

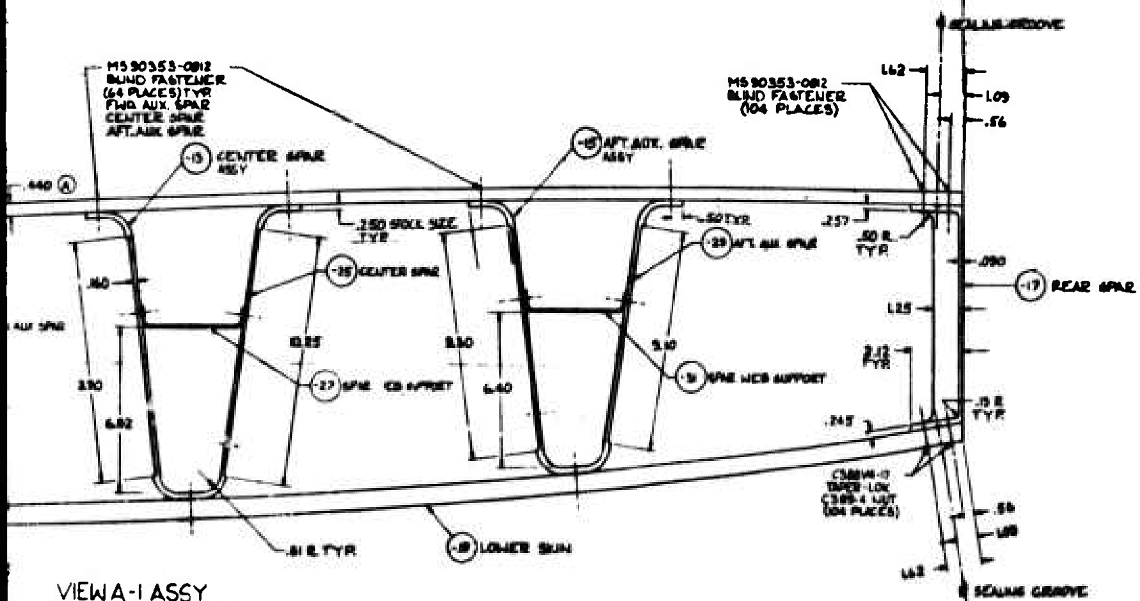


VIEW A-1 ASSY

3



PLAN VIEW-1 ASSY.



VIEW A-1 ASSY

ASSY	SUB ASSY.	DETL.	PART NAME	NO. REQ'D	MATERIAL	RAW STOCK SIZE
-1			ANALYTICAL ASSY.	1		
		-7	UPPER SKIN	1	2024-T851	.25×54×69
		-9	FRONT SPAR	1	2024-T8511	EXTRU.[illegible]
	-11		FWD. AUX SPAR ASSY	1		
		-21	FWD. AUX SPAR	1	2024 T81	.250×29.4×50
		-23	SPAR WEB SUPPORT	5	2024-T81	[illegible]
			C089-4 RIVETS	10		
	-13		CENTER SPAR ASSY	1		
		-25	CENTER SPAR	1	2024-T81	.250×30.4×50
		-27	SPAR WEB SUPPORT	5	2024-T81	.100×50×6.8
			C089-4 RIVETS	10		
	-15		AFT. AUX. SPAR ASSY.	1		
		-29	AFT AUX. SPAR	1	2024-T81	.250×28.7×50
		-31	SPAR WEB SUPPORT	5	2024 T81	.100×50×6.8
			C089-4 RIVETS	10		
		-17	REAR SPAR	1	2024-T8511	EXTRU.[illegible]
		-19	LOWER SKIN	1	2024-T851	.750×54×69
			BLIND FASTENER MS90353-0812	410		
			TAPER-LOK C388V6-17	84		
			TAPER-LOK C388V4-17	218		
			C389-6 NUT	84		
			C389-4 NUT	218		
			SEALANT		FMS-1044 (SEE NOTE 1)	
			MAT'L REMOVED FOR FASTENERS			
-3			ANALYTICAL ASSY	1		
		-7	UPPER SKIN	1	SEE -1 ASSY	
		-9	FRONT SPAR	1	SEE -1 ASSY	
		-33	FWD AUX. SPAR	1	MAKE FROM -39	
		-39	SPAR EXTRU.	1	2024-T8511	EXTRU.(54.93 IN²)
		-35	CENTER SPAR	1	MAKE FROM -39	
		-39	SPAR EXTRU.	1	2024-T8511	EXTRU.(54.93 IN²)
		-37	AFT. AUX SPAR	1	MAKE FROM -39	
		-39	SPAR EXTRU.	1	2024-T8511	EXTRU.(54.93 IN²)
		-17	REAR SPAR	1	SEE -1 ASSY	
		-19	LOWER SKIN	1	SEE -1 ASSY	
			FASTNR'S & MISC. HARDWARE	—	SEE -1 ASSY	
			MAT'L REMOVED FOR FASTENERS			
-5			ANALYTICAL ASSY	1		
		-7	UPPER SKIN		SEE -1 ASSY	
		-9	FRONT SPAR		SEE -1 ASSY	
	-41		FWD AUX SPAR ASSY.	1		
		-47	SPAR WEB/LEG	1	2024-T81	.250×16.70×50
		-49	SPAR LEG	1	2024-T81	.250×10.20×50
			C020-10-6 PIN	76		
			C2950-10 NUT	76		
	-43		CENTER SPAR ASSY.	1		
		-51	SPAR WEB/LEG	1	2024-T81	.250×20.70×50
		-53	SPAR LEG	1	2024-T81	.250×9.87×50
			C020-10-6 PIN	76		
			C2950-10 NUT	76		
	-45		AFT AUX. SPAR ASSY.	1		
		-55	SPAR WEB/LEG	1	2024-T81	.250×16.[illegible]×50
		-57	SPAR LEG	1	2024-T81	.250×10.02×50
			C020-10-6 PIN	76		
			C2950-10 NUT	76		
		-17	REAR SPAR	1	SEE -1 ASSY	
		-19	LOWER SKIN	1	SEE -1 ASSY	
			FASTNRS & MISC. HARDWARE	—	SEE -1 ASSY	
			MAT'L REMOVED FOR FASTENERS			

Figure 42

4

REQD	MATERIAL	RAW STOCK SIZE	RAW STOCK WEIGHT	WEIGHT DETAIL	WEIGHT ASSY.	COST MAT'L	COST FAB.	COST TOOL	TOTAL COST	
1					482.64	3770	4048	173	7991	A
1	2024-T851	.625×[illegible]×68	135.20	35.78		319.35	186.97			Ⓐ
1	2024-T8511	EXTRUSION [illegible] IN²	85.00	10.72		490.13	302.65			
1					28.49					
1	2024-T81	.250×29.4×50	37.13	25.30		54.04	52.42			Ⓐ
5	2024-T81	.100×50×6.8	.04/FT	.03/FT		.28	14.87			
10				.01						
1					26.27					
1	2024-T81	.250×30.4×50	38.38	26.11		55.90	53.42			Ⓐ
5	2024-T81	.100×50×6.8	.04/FT	.03/FT		.28	14.87			
10				.01						
1					24.91					
1	2024-T81	.250×28.7×50	36.26	24.75		52.80	53.42			Ⓐ
5	2024 T81	.100×50×6.8	.04/FT	.03/FT		.28	14.87			
10				.01						
1	2024-T8511	EXTRUSION [illegible] IN²	76.44	9.09		440.85	381.96			
1	2024-T851	.750×54×69	282.24	188.80		508.84	216.30			Ⓐ
410				6.90						
84				2.40						
218				2.62		1787.96				
84				.90						
218				.70						
	FMS-1044 (SEE NOTE 1)		1.76	1.50		ASSY	266.6			
FOR FASTENERS					4.14					Ⓐ
1					412.11	4564	4594	150	9308	Ⓐ
1	SEE -1 ASSY			135.78		379.35	186.97			Ⓐ
1				10.72		490.13	301.04			
1	MAKE FROM -39			18.44		319.10	300.87			
1	2024-T8511	EXTRU. [illegible] IN²	55.34							
1	MAKE FROM -39			19.26		319.10	300.87			
1	2024-T8511	EXTRU. [illegible] IN²	55.34							
1	MAKE FROM -39			18.44		319.10	300.87			
1	2024-T8511	EXTRU. [illegible] IN²	65.34							
1	SEE -1 ASSY			9.09		440.85	381.37			
1				188.50		508.34	216.30			Ⓐ
—				16.02		1787.96				
FOR FASTENERS					4.14	ASSY	255.9			Ⓐ
1					419.48	4198	4277	207	8682	Ⓐ
	SEE -1 ASSY			135.78		379.35	186.97			Ⓐ
				10.72		490.13	301.04			
1					20.18					
1	2024-T81	.250×16.70×50	21.11	12.63		30.71	42.74			Ⓐ
1	2024-T81	.250×10.20×50	12.88	6.37		18.75	32.05			Ⓐ
76				.79						
76				.39						
1					21.75					
1	2024-T81	.250×20.70×50	26.16	13.76		30.06	42.74			Ⓐ
1	2024-T81	.250×9.87×50	12.47	6.83		16.49	32.05			Ⓐ
76				.79						
76				.39						
1					20.78					
1	2024-T81	.250×16.94×50	21.41	13.29		31.17	42.74			Ⓐ
1	2024-T81	.250×10.02×50	12.65	6.31		18.42	32.05			Ⓐ
76				.79						
76				.39						
1	SEE -1 ASSY			9.09		440.85	381.57			
1				188.50		508.34	216.30			Ⓐ
—				16.02	HDW	2234				
FOR FASTENERS					4.14	ASSY	287.16			Ⓐ

REV		DESCRIPTION		
A		CHANGED -7 THICKNESS FROM .490 TO .443 REVISED ALL WEIGHTS IN L/M TO REFLECT -7 THICKNESS CHANGE. CHANGED -21, -25, 29, -47, -49, -51, -53, -55, & -57 RAW STOCK LENGTH IN L/M FROM 48.00 TO 50.00 CHANGED LOWER SKIN THICKNESS FROM .777 TO .615 REVISED ALL WEIGHTS IN L/M TO REFLECT LOWER SKIN THICKNESS CHANGE		

3. -21, -25, -29 OF -1 ASSY AND -47, -49, -51, -53, -55 AND -57 OF -5 ASSY TO BE FORMED & CHEM-ETCHED

2. 125/ FINISH REQ'D. ON ALL MACHINED PARTS.

1. THE FAYING SURFACES AT THE UPPER SURFACE OF THE FRONT/REAR SPAR, THE UPPER SKIN AND ALL FASTENERS SHALL BE SEALED PER FPS-1004

NOTE:

PRELIMINARY DESIGN DRAWING

[illegible] WING MACHINED [illegible] AND CLOSURE SPARS; FORMED/ETCHED INVERTED "A" INTERM. SPARS; ALUMINUM ANALYTICAL ASSY.

GENERAL DYNAMICS
Convair Aerospace Division

633-[illegible]-[illegible]4A

Figure 42 Inverted "A" Spar Analytical Assembly

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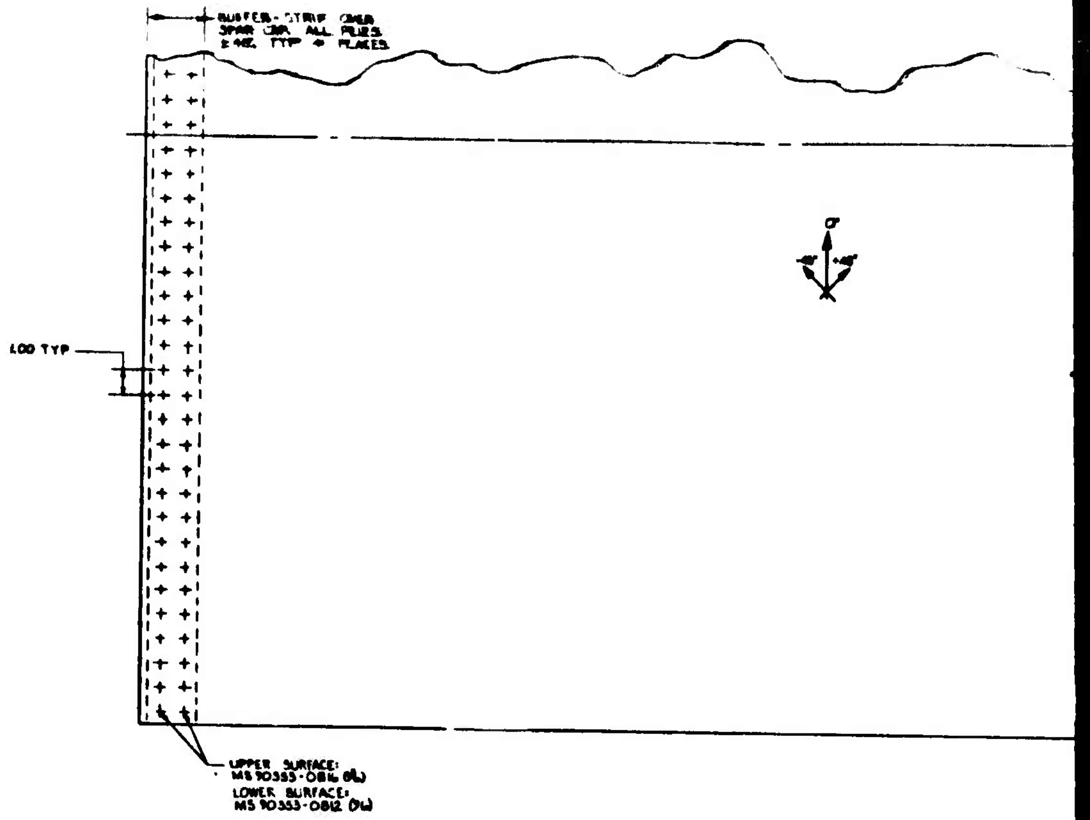
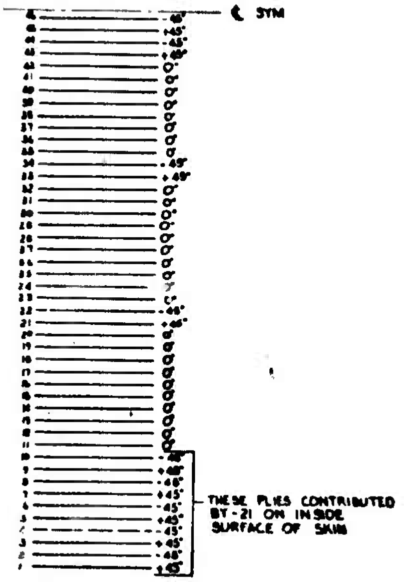
Table IV ATW METALLIC WING BOX ANALYTICAL ASSY EVALUATION SUMMARY

CONFIG. NO.	DESCRIPTION	STRUCT. EFFIC COST 1975 $ (.24)	STRUCT. EFFIC WEIGHT LBS. (.16)	TECHNOLOGY IMPROV CONCEPT (.05)	TECHNOLOGY IMPROV MATL (.02)	TECHNOLOGY IMPROV MFG (.03)	DAMAGE TOL. SAFE CRACK (.08)	DAMAGE TOL. FAIL SAFE (.12)	-ABILITIES INSPECT- (.06)	-ABILITIES MFG- (.06)	-ABILITIES MAIN-TAIN- (.06)	-ABILITIES REPAIR- (.06)	-ABILITIES DUR- (.06)	TOTAL SCORE	RANK
633-RA000-1	BASELINE WING BOX-MACHINED SKINS & SPARS; 7 SPAR CONFIG; ALUMINUM	12,310 .156	418.09 .114	.000	.000	.000	.075	.000	.060	.060	.060	.060	.060	.645	9
633-RA001-1	LAMINATED LWR SKIN; MACHINED UPR. SKIN & CLOS SPAR. EXTR & ETCHED INTERM "Y" SPARS, 5 SPAR CONFIG; ALUMINUM	10,091 .190	340.75 .140	.042	.000	.030	.080	.120	.045	.052	.057	.059	.024	.839	2
633-RA001-3	LAM. LWR SKIN; MACH UPR SKIN & CLOS SPAR; EXTR INTER "Y" SPAR; 5 SPAR CONFIG; ALUMINUM	10,774 .178	359.38 .132	.040	.000	.027	.080	.120	.045	.052	.057	.059	.024	.814	3
633-RA001-5	LAM. LWR SKIN; MACH. UPR SKIN & CLOS. SPARS; SAND WEB INTERM "Y" SPAR WITH EXTRU. CAPS; 5 SPAR CONFIG; ALUMINUM	10,992 .174	347.88 .137	.046	.000	.029	.080	.120	.045	.046	.057	.059	.020	.813	4
633-RA001-801	LAM. LWR SKIN; MACH. UPR SKIN & CLOS. SPARS; FORMED & ETCHED INTERM "Y" SPAR, 5 SPAR CONFIG; ALUMINUM	10,660 .180	345.05 .138	.044	.000	.027	.080	.120	.045	.044	.057	.059	.020	.814	3
633-RA001-803	LAM. LWR SKIN; MACH. UPR SKIN & CLOS. SPARS; FORMED/BEADED INTERM "Y" SPARS; 5 SPARS; ALUMINUM	9,741 .197	380.13 .125	.046	.000	.029	.078	.000	.030	.040	.057	.059	.015	.676	12
633-RA001-805	LAM LWR SKIN/EMBEDDED SPAR CAPS; MACH UPR SKIN AND CLOS SPARS: FORMED/BEADED INTERM "Y" SPARS, 5 SPARS, AL	9,777 .196	359.09 .133	.046	.000	.029	.078	.000	.030	.040	.057	.059	.015	.683	8
633-RA002-1	LAM LWR SKIN; MACH. UPR SKIN & CLOS SPARS; CORR. INTERM. SPARS WITH EXTR CAPS; 5 SPAR CONFIG. AL	9,546 .201	351.83 .135	.034	.000	.027	.080	.120	.045	.052	.057	.059	.024	.834	3

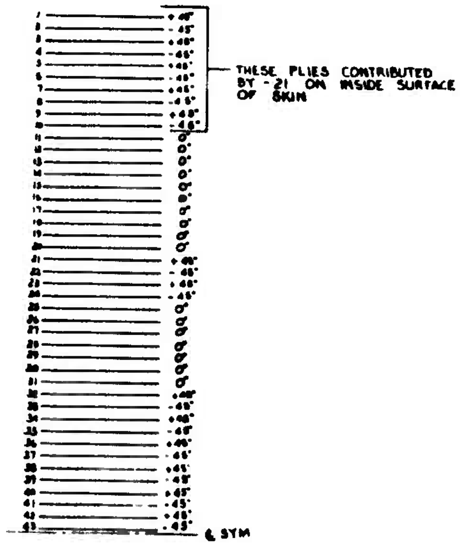
Table IV ATW METALLIC WING BOX ANALYTICAL ASSY EVALUATION SUMMARY (CONTINUED)

CONFIG. NO.	DESCRIPTION	STRUCT. EFFIC.		TECHNOLOGY IMPROV.			DAMAGE TOL.		-ABILITIES					TOTAL SCORE	RANK
		COST 1975 $ (.24)	WEIGHT LBS. (.16)	CONCEPT (.05)	MATL (.02)	MFG. (.03)	SAFE CRACK (.08)	FAIL SAFE (.12)	INSPECT- (.06)	MFG.- (.06)	MAIN-TAIN- (.06)	REPAIR- (.06)	DUR- (.06)		
633-RA003-1	LAM LWR SKIN; SAND PNL UPR SKIN & INTERM SPARS; MACH CLOS SPARS; 5 SPAR CONFIG; AL	12,277 .156	297.58 .16	.028	.000	.016	.080	.120	.043	.044	.057	.059	.025	.788	5
633-RA003-3	LAM LWR SKIN; MACH UPR SKIN & CLOS SPARS; SAND PANEL INTERM. SPARS; 7 SPAR CONFIG; ALUMINUM	12,793 .150	331.13 .144	.028	.000	.014	.080	.120	.045	.050	.057	.059	.029	.776	6
633-RA003-5	LAM LWR SKIN; MACH UPR SKIN & SPARS; 6 SPARS, LAM. LWR SPAR CAPS	10,918 .176	369.91 .129	.024	.000	.014	.078	.000	.030	.050	.057	.059	.024	.641	10
633-RA003-801	LAM. LWR. SKIN; MACH SKIN & CLOS SPARS; SHEET METAL INTERM CANTED SPARS W/FORMED INTERCOSTALS 5 SPAR CONFIG; AL	10,733 .179	330.04 .144	.050	.000	.030	.080	.120	.045	.052	.057	.059	.027	.843	1
633-RA004-1	MACH UPR & LWR SKINS & CLOS. SPARS; FORMED & ETCHED INVERTED "A" INTERM SPARS, 5 SPARS AL, BOLTED LWR SKIN	7,991 .24	432.61 .000	.030	.000	.014	.075	.000	.060	.056	.059	.059	.029	.622	11
633-RA004-3	MACH SKINS & CLOSURE SPARS; EXTRUDED INTER "Y" SPAR; 5 SPAR CONFIG.; ALUMINUM BOLTED LWR SKIN	9,308 .206	412.11 .116	.026	.000	.014	.075	.000	.060	.059	.059	.059	.029	.703	7
633-RA004-5	MACH UPR & LWR SKINS & CLOSURE SPARS; FORMED & ETCHED INTERM "Y" SPARS, 5 SPARS BOLTED LWR SKIN	8,682 .221	418.68 .000	.024	.000	.014	.075	.000	.060	.052	.059	.059	.024	.588	13





DETAIL A



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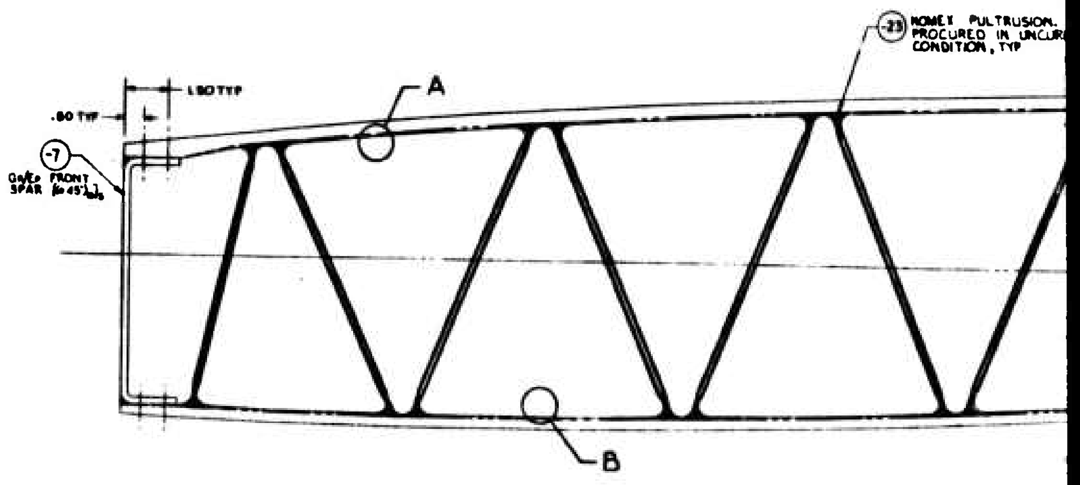
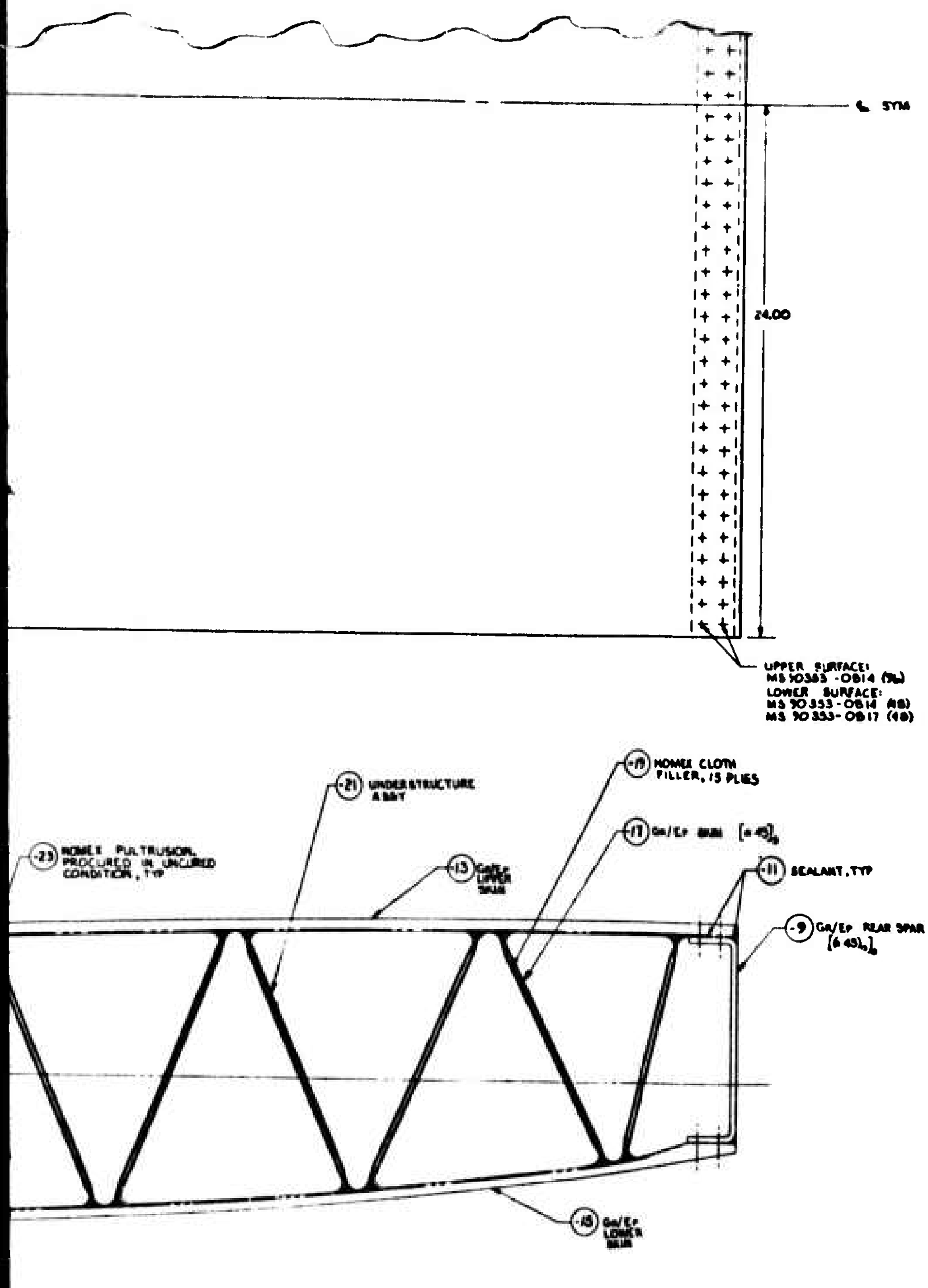


-1 ASSY

2



℄ SYM
24.00
UPPER SURFACE:
MS 90353 -OB14
LOWER SURFACE:
MS 90353-OB14
MS 90353-OB17
-19 NOMEX CLOTH FILLER, 15 PLIES
-21 UNDERSTRUCTURE ASSY
-17 Gr/Ep SKIN
-23 NOMEX PULTRUSION, PROCURED IN UNCURED CONDITION, TYP
-13 Gr/Ep UPPER SKIN
-11 SEALANT, TYP
-9 Gr/Ep REAR SPAR
-15 Gr/Ep LOWER SKIN

DASH NO. ASSY	SUB ASSY	DETAIL	PART NAME	NO. REQ'D	MATERIAL	RAW STOCK SIZE	RAW STOCK WEIGHT	FINISHED WT DETAIL	FINISHED WT ASSY	COST MAT'L	COST FAB.	COST TOOL.	TOTAL COST
		-7	FRONT SPAR	1	[illegible] GR/EP TAPE	[illegible] FT TAPE	16.5 #	13.9 #		1782.53	[illegible]	291	
		-9	REAR SPAR	1	6" GR/EP TAPE	1032 FT TAPE	16.5 #	14.2 #		1677.60	[illegible]		
		-11	SEALANT	AR	FMS 1044	AR	6.5 #	5.0 #					
		-13	UPPER SKIN	1	3" GR/EP TAPE	6010 FT TAPE	[illegible]	45.7 #		[illegible]	[illegible]		
		-15	LOWER SKIN	1	6" GR/EP TAPE	7398 FT TAPE	103.2 #	77.5 #		[illegible]	[illegible]		
		-17	SKIN		3" GR/EP TAPE	3455 FT TAPE	79.1 #	57.9 #		8637.29	114.74		
		-19	FILLER		[illegible]	[illegible]	58.9 #	42.8 #		114.75	265.72		
	-21		UNDER STRUCTURE	1					99.8 #				
		-23	FILLER	22				3.3 #		280.34	46.43		
		[illegible]	RIVET	96				1.8 #					
		[illegible]	RIVET	96				1.4 #		1245			
		[illegible]	RIVET	144				2.6 #					
		[illegible]	RIVET	48				.9 #					
-1									3000 #	37762	5227	291	43280
										ASSY	8261		

PRELIMINARY DESIGN DRAWING

ATW-4 WING TRUSS SPAR
GR/EP CO CURED CONSTRUCTION
ANALYTICAL ASSY OF

GENERAL DYNAMICS
Convair Aerospace Division

633RA005

Figure 43 Composite Truss Spar Analytical Assembly

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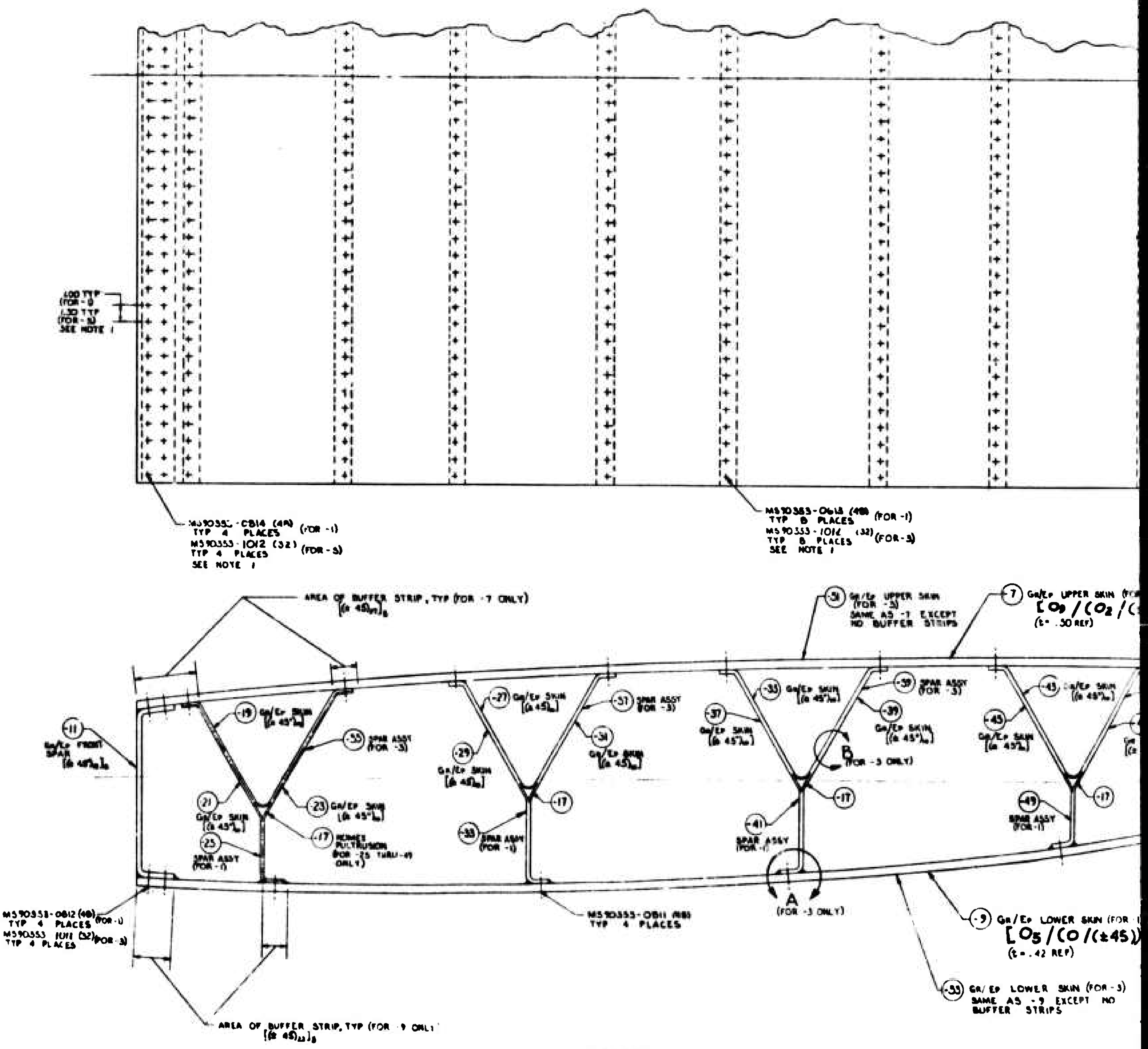
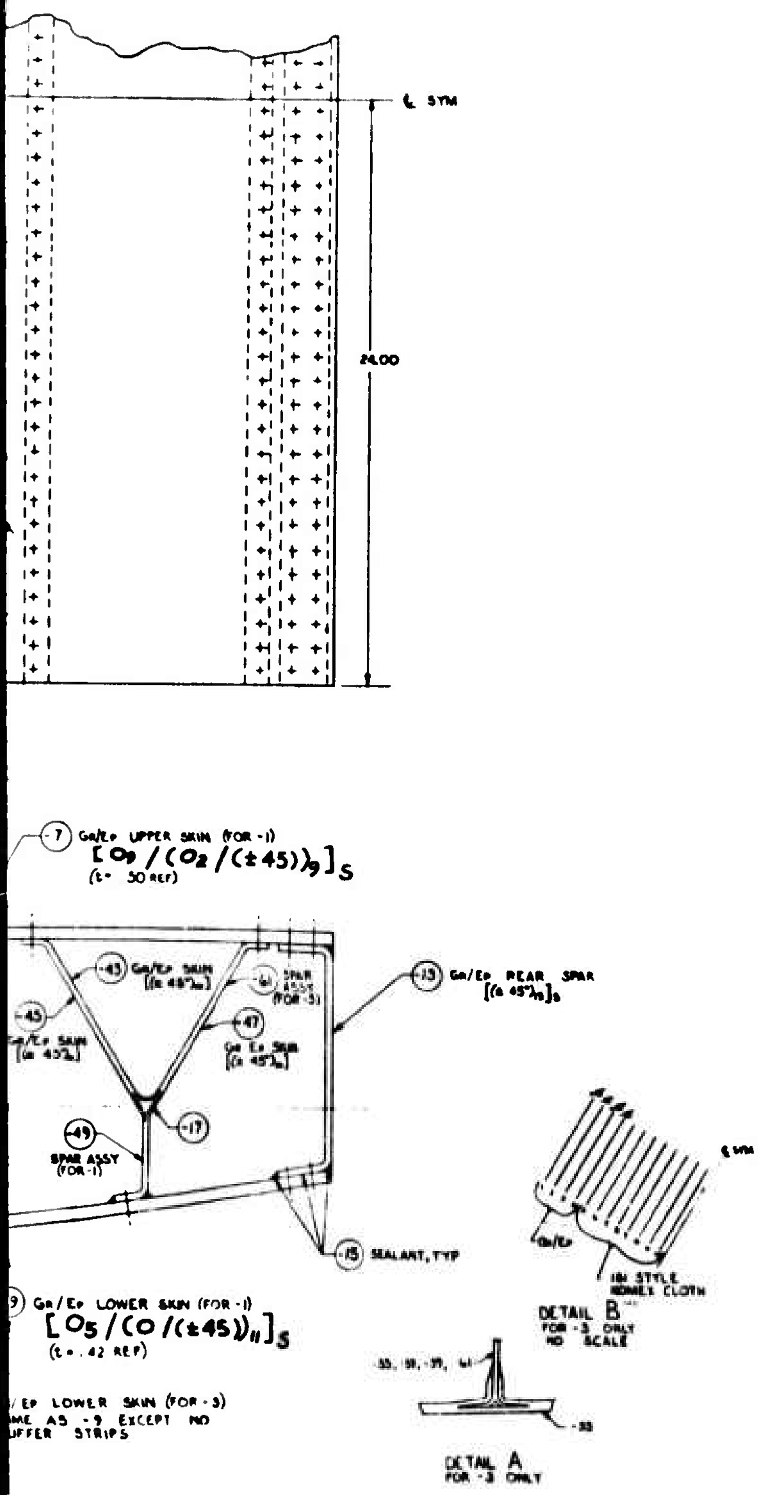


-1 ASSY
3 ASSY

2



DASH NO. ASSY	DASH NO. SUB ASSY	DASH NO. DETAIL	PART NAME	NO. REQ'D	MATERIAL	RAW STOCK SIZE	RAW STOCK WEIGHT	FINISHED WEIGHT DETAIL	FINISHED WEIGHT AS[SY]
		-7	UPPER SKIN	1	Gr/Ep TAPE	3524 FT. 3" TAPE	123.6 •	93.0 •	
		-9	LOWER SKIN	1	Gr/Ep TAPE	7076 FT. 3" TAPE	102.6 •	75.9 •	
		-11	FRONT SPAR	1	Gr/Ep TAPE	1120 FT. 3" TAPE	16.2 •	11.7 •	
		-13	REAR SPAR	1	Gr/Ep TAPE	1043 FT. 3" TAPE	15.1 •	10.9 •	
		-15	SEALANT	AR	FMS-1044	AR	1.75•	1.50•	
		-17	FILLER	1	NOMEX	.20 in² x 50 in	.5 •	.5 •	
		-19	SKIN	1	Gr/Ep TAPE	520 FT. 3" TAPE	7.6 •	5.5 •	
		-21	SKIN	1	Gr/Ep TAPE	411 FT. 3" TAPE	5.9 •	4.5 •	
		-23	SKIN	1	Gr/Ep TAPE	411 FT. 3" TAPE	5.9 •	4.5 •	
	-25		SPAR ASSY	1					14.
		-17	FILLER	1	NOMEX	.20 in² x 50 in	.5 •	.5 •	
		-27	SKIN	1	Gr/Ep TAPE	498 FT. 3" TAPE	7.2 •	5.2 •	
		-29	SKIN	1	Gr/Ep TAPE	447 FT. 3" TAPE	6.5 •	4.7 •	
		-31	SKIN	1	Gr/Ep TAPE	447 FT. 3" TAPE	6.5 •	4.7 •	
	-33		SPAR ASSY	1					13.
		-17	FILLER	1	NOMEX	.20 in² x 50 in	.5 •	.5 •	
		-35	SKIN	1	Gr/Ep TAPE	498 FT. 3" TAPE	7.2 •	5.2 •	
		-37	SKIN	1	Gr/Ep TAPE	440 FT. 3" TAPE	6.4 •	4.6 •	
		-39	SKIN	1	Gr/Ep TAPE	440 FT. 3" TAPE	6.4 •	4.6 •	
	-41		SPAR ASSY	1					14.
		-17	FILLER	1	NOMEX	.20 in² x 50 in	.5 •	.5 •	
		-43	SKIN	1	Gr/Ep TAPE	513 FT. 3" TAPE	7.4 •	5.4 •	
		-45	SKIN	1	Gr/Ep TAPE	411 FT. 3" TAPE	5.9 •	4.3 •	
		-47	SKIN	1	Gr/Ep TAPE	411 FT. 3" TAPE	5.9 •	4.3 •	
	-49		SPAR ASSY	1					14.
		[illegible]	RIVET	192				3.1 •	
		[illegible]	RIVET	384				3.3 •	
		[illegible]	RIVET	192				2.8 •	
		[illegible]	RIVET	192				2.7 •	
-1			ANALYTICAL ASSY						258

		-11	FRONT SPAR	1	Gr/Ep TAPE	1120 FT. 3" TAPE	16.2 •	11.7 •	
		-13	REAR SPAR	1	Gr/Ep TAPE	1043 FT. 3" TAPE	15.1 •	10.9 •	
		-15	SEALANT	AR	FMS-1044	AR	1.50•	1.25•	
		-51	UPPER SKIN	1	Gr/Ep TAPE	8626 FT. 3" TAPE	123.6 •	90.0 •	
		-53	LOWER SKIN	1	Gr/Ep TAPE	7076 FT. 3" TAPE	102.6 •	78.9 •	
	-55		SPAR ASSY	1	Gr/Ep TAPE NOMEX CLOTH	317 FT. 3" TAPE 159 FT²	4.6 • 12.6 •	3.31 • 9.75 •	13.0
	-57		SPAR ASSY	1	Gr/Ep TAPE NOMEX CLOTH	314 FT. 3" TAPE 157 FT²	4.5 • 12.4 •	3.28 • 9.66 •	12.9
	-59		SPAR ASSY	1	Gr/Ep TAPE NOMEX CLOTH	323 FT. 3" TAPE 160 FT²	4.6 • 12.7 •	3.34 • 9.84 •	13.1
	-61		SPAR ASSY	1	Gr/Ep TAPE NOMEX CLOTH	311 FT. 3" TAPE 156 FT²	4.5 • 12.4 •	3.23 • 9.57 •	12.8
		[illegible]	RIVET	136				3.40	
		[illegible]	RIVET	272				6.8	
		[illegible]	RIVET	136				2.9	
-3									252

Figure 44

W STOCK SIZE	RAW STOCK WEIGHT	FINISHED WT. DETAIL	FINISHED WT. ASSY	COST MATL	COST FAB.	COST TOOL.	TOTAL COST
FT 3" TAPE	123.6 •	[illegible] •		13345	664.03		
FT 3 TAPE	102.6 •	73.9 •		11078	593.51		
FT 3 TAPE	[illegible] •	[illegible] •		1763	182.17		
3 FT 3" TAPE	15.1 •	[illegible] •		1632	182.17		
AR	1.75 •	1.50 •					
50 in	.5 •	.5 •		14	1.47		
FT 3" TAPE	7.6 •	5.5 •		826	[illegible]		
FT 3" TAPE	5.9 •	4.3 •		643	139.50		
FT 3" TAPE	5.9 •	4.3 •		643	99.50		
			14.6 •		5.88		
50 in	.5 •	.5 •		14	1.47		
FT 3" TAPE	7.2 •	5.2 •		779	99.50		
FT 3" TAPE	6.5 •	4.7 •		690	99.50		
FT 3" TAPE	6.5 •	4.7 •		690	99.50		
			15.1 •		5.88		
50 in	.5 •	.5 •		14	1.47		
FT 3" TAPE	7.2 •	5.2 •		779	99.50		
FT 3" TAPE	6.4 •	4.6 •		688	99.50		
FT 3" TAPE	6.4 •	4.6 •		688	99.50		
			14.9 •		5.88		
50 in	.5 •	.5 •		14	1.47		
FT 3" TAPE	7.4 •	5.4 •		803	99.50		
FT 3" TAPE	5.9 •	4.3 •		643	99.50		
FT 3" TAPE	5.9 •	4.3 •		643	99.50		
			14.5 •		5.88		
		3.1 •					
		3.3 •		3112			
		2.8 •					
		2.7 •					
			258 •	39507	5652	149	453[illegible]
				ASSY	2796		

FT 3" TAPE	16.2 •	11.7 •		1753	182.17		
FT 3" TAPE	15.1 •	10.9 •		1632	182.17		
AR	1.50 •	1.25 •					
FT 3" TAPE	123.6 •	89.0 •		12345	664.03		
FT 3" TAPE	102.6 •	73.9 •		11078	593.51		
FT 3" TAPE	4.6 •	3.31 •					
FT²	12.6 •	9.75 •					
			13.06 •	784	235.04		
FT 3" TAPE	4.5 •	3.28 •					
FT²	12.4 •	9.66 •					
			12.94 •	776	235.04		
FT 3" TAPE	4.6 •	3.34 •					
FT²	12.7 •	9.84 •					
			13.18 •	791	235.04		
FT 3" TAPE	4.5 •	3.25 •					
FT²	12.4 •	9.57 •					
			12.82 •	770	235.04		
		3.40					
		2.8		1763			
		2.9					
			252.6	32680	4573	149	57812[illegible]
				ASSY	2411		

NOTES:
1. FASTENER PATTERNS SHOWN ARE FOR -1, -3 FASTENER REQTS. ARE SPECIFIED IN CAL[illegible] AND IN L.M.

PRELIMINARY DESIGN DRAWING
ATW-4 WING- GR/EP SKINS WITH BUFFER STRIPS, GR/EP "Y" SPARS, ANALYTICAL ASSY OF
GENERAL DYNAMICS
Convair Aerospace Division
633RA006

Figure 44 Composite Y-Spar Analytical Assembly

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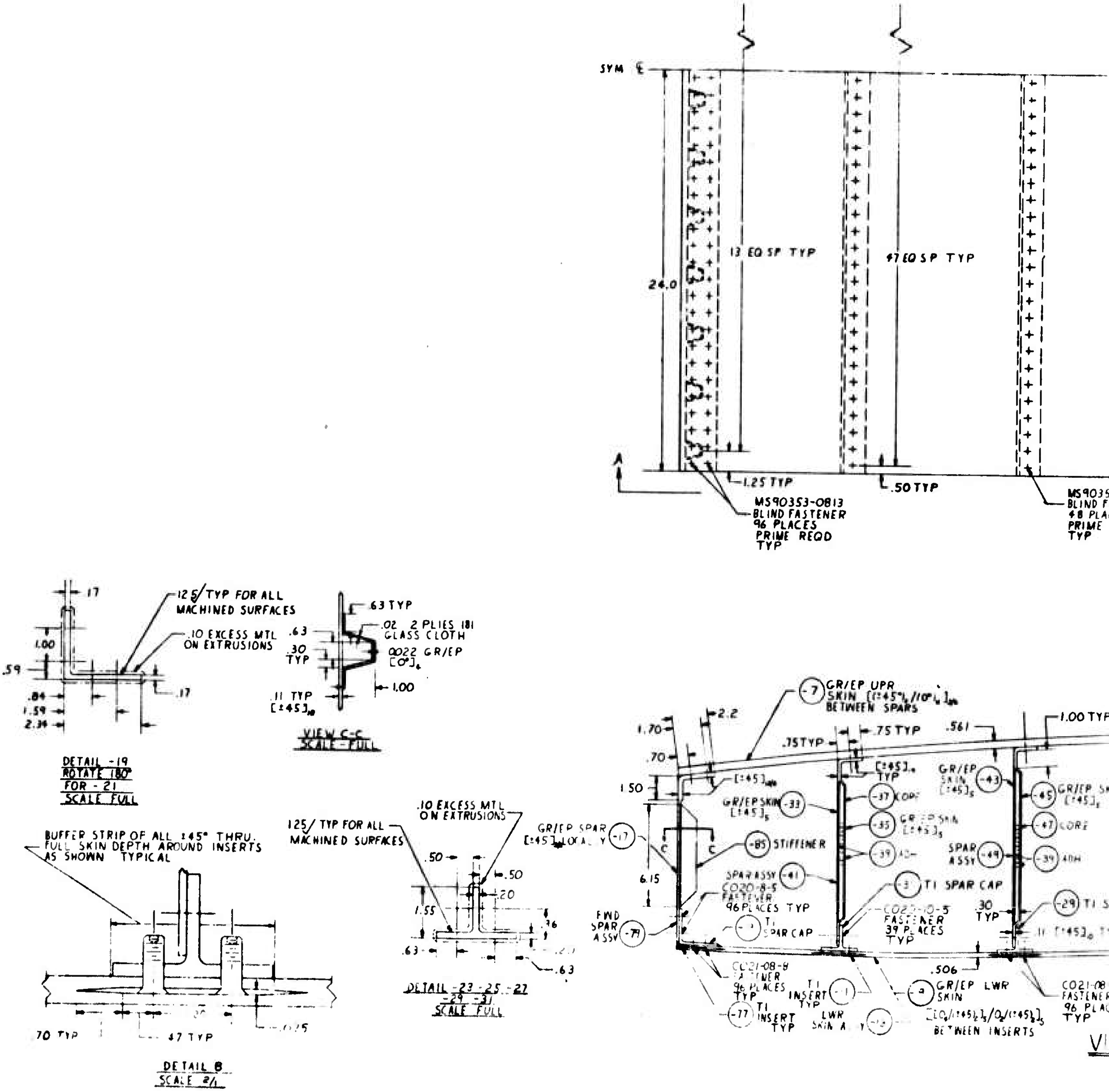

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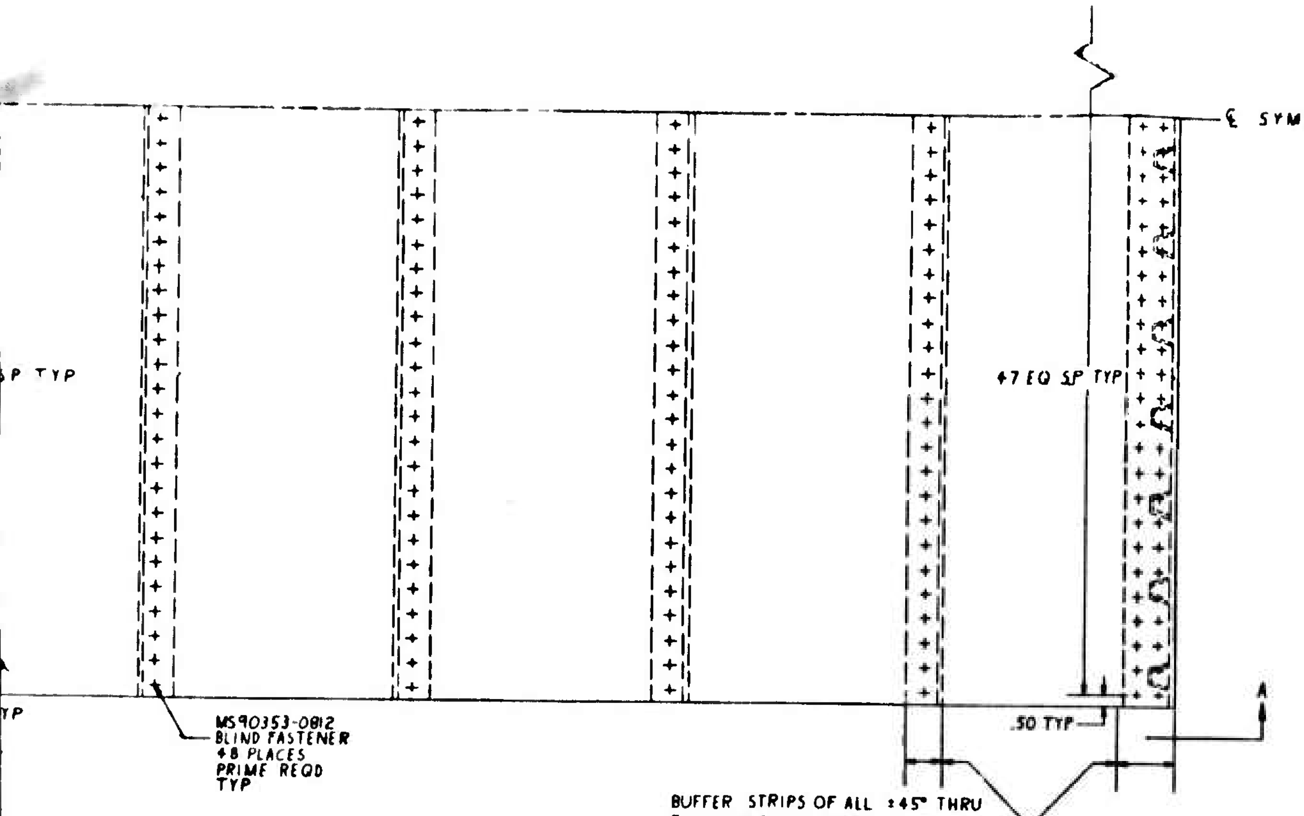
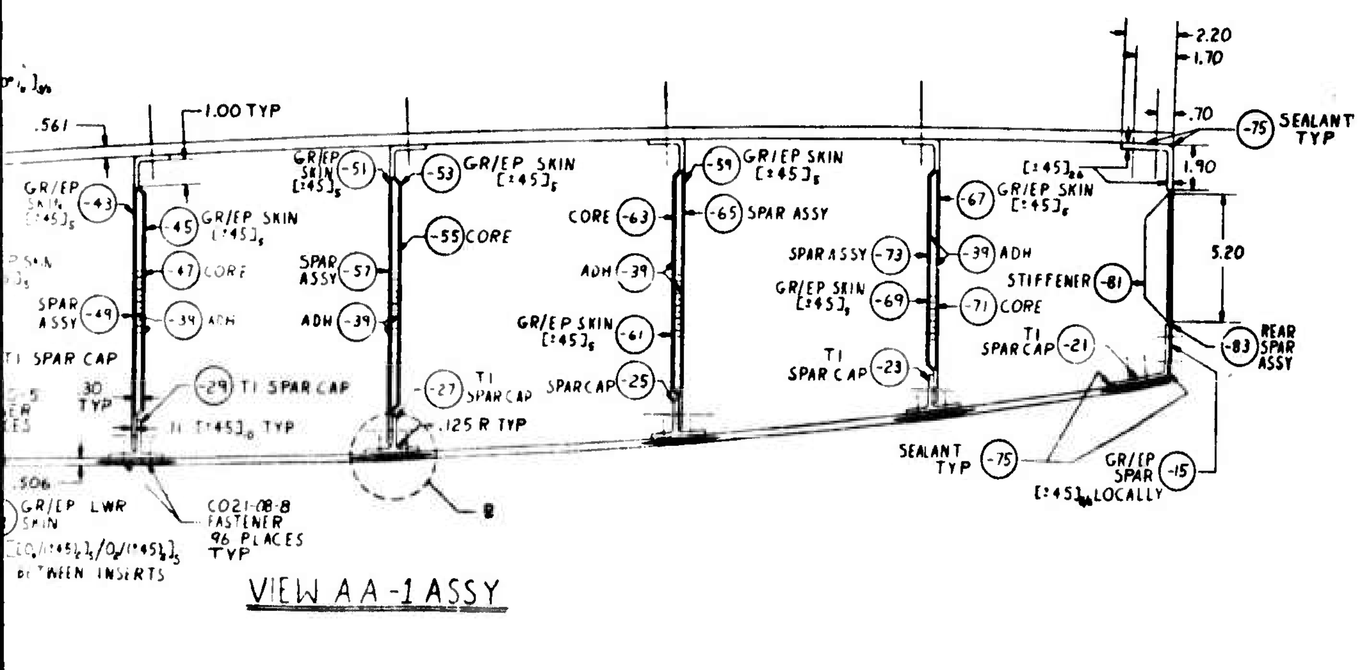


PLAN VIEW -1 ASSY



VIEW AA -1 ASSY

ASSY	ASSY	DETAIL	PART NAME	NO REQD
-1			WING BOX	1
		-7	UPPER SKIN	
		MS90353-0813	FASTENER	492
		C020-8-5	FASTENER	192
		C2950-8	NUT	192
		C020-10-5	FASTENER	195
		C2950-10	NUT	195
		-75	SEALANT	AS REQD
	-13		LWR SKIN ASSY	1
		-9	LWR SKIN	1
		-77	INSERT	2
		-11	INSERT	5
		-19	SPAR CAP	1
		-21	SPAR CAP	1
		-23	SPAR CAP	1
		-25	SPAR CAP	1
		-27	SPAR CAP	1
		-29	SPAR CAP	1
		-31	SPAR CAP	1
		C021-8-8	FASTENER	672
		C2950-8	NUT	672
	-41		FWD AUX SPAR	1
		-33	OUTER SKIN	1
		-35	INNER SKIN	1
		-37	CORE	1
		-39	ADH	AS REQD
	-49		FWD AUX SPAR	1
		-43	OUTER SKIN	1
		-45	INNER SKIN	1
		-47	CORE	1
		-39	ADH	AS REQD
	-57		CENTER SPAR	1
		-51	OUTER SKIN	1
		-53	INNER SKIN	1
		-55	CORE	1
		-39	ADH	AS REQD
	-65		REAR AUX SPAR	1
		-59	OUTER SKIN	1
		-61	INNER SKIN	1
		-63	CORE	1
		-39	ADH	AS REQD
	-73		REAR AUX SPAR	1
		-67	OUTER SKIN	1
		-69	INNER SKIN	1
		-71	CORE	1
		-39	ADH	AS REQD
	-79		FWD SPAR ASSY	1
		-17	FWD SPAR	1
		-85	STIFFENER	14
	-83		REAR SPAR ASSY	1
		-15	REAR SPAR	1
		-81	STIFFENER	14

Figure 45 Composite Sandwich Spa

3

ASSY	SUB ASSY	DETAIL	PART NAME	NO. REQ'D	MATERIAL	RAW STOCK SIZE	RAW STOCK WEIGHT	FINISHED WT DETAIL	FINISHED WT ASSY	COST MAT.	COST LABOR		TOOL COST
-1			[illegible]	1					[illegible]	36838	11043212		1809314
		-7	[illegible]		3"GR/EP TAPE	[illegible]	[illegible]	[illegible]		1107014	66939		
		[illegible]	FASTENER	458				[illegible]					
		[illegible]	FASTENER	192				[illegible]					
		[illegible]	NUT	192				[illegible]		2016			
		[illegible]	FASTENER	145				.86					
		[illegible]	NUT	145				1.02					
		-75	SEALANT	AS REQD	FMS-1044		1.75	1.50					
	-13		LWR SKIN ASSY	1					141.55		145.37		
		-9	LWR SKIN	1	3"GR/EP TAPE	8168 OFT	118.4	85.35		17165.5	775.34		
		-77	INSERT	2	6-4 TI STRIP	[illegible]	[illegible]	[illegible]		117.65	78.51		
		-11	INSERT	5	6-4 TI STRIP	[illegible]	2.88/...	[illegible]		346.15	[illegible]		
		-19	SPAR CAP	1	6-4 TI EXTRU	EXTRU×501(.75 in²)	14.0/FT	5.41/...		[illegible]	11.35		
		-21	SPAR CAP	1	6-4 TI EXTRU	EXTRU×501(.75 in²)	14.0/FT	5.41/...		265.25	11.35		
		-23	SPAR CAP	1	6-4 TI EXTRU	EXTRU×501(.66 in²)	12.5/FT	5.41/...		226.53	11.35		
		-25	SPAR CAP	1	6-4 TI EXTRU	EXTRU×501(.66 in²)	12.5/FT	5.41/...		226.53	11.35		
		-27	SPAR CAP	1	6-4 TI EXTRU	EXTRU×501(.66 in²)	12.5/FT	5.41/...		226.53	11.35		
		-29	SPAR CAP	1	6-4 TI EXTRU	EXTRU×501(.66 in²)	12.5/FT	5.41/...		226.53	11.35		
		-31	SPAR CAP	1	6-4 TI EXTRU	EXTRU×501(.66 in²)	12.5/FT	5.41/...		226.53	11.35		
		[illegible]-8-8	FASTENER	672				9.66					
		[illegible]2950-8	NUT	672				1.29					
	-41		FWD AUX SPAR	1					5.28		217.42		
		-33	OUTER SKIN	1	3"GR/EP TAPE	211.5 FT	3.1	2.21		361.02	76.59		
		-35	INNER SKIN	1	3"GR/EP TAPE	219.2 FT	3.2	2.29		361.07	76.35		
		-37	CORE	1	52"#/FT NOMEX	30×10×50	.45	.35		5.73	117.53		
		-39	ADH	AS REQD	FMS-1013-1A		.55	.43					
	-49		FWD AUX SPAR	1					5.64		217.42		
		-43	OUTER SKIN	1	3"GR/EP TAPE	224.9 FT	3.3	2.35		362	76.33		
		-45	INNER SKIN	1	3"GR/EP TAPE	232.6 FT	3.4	2.43		366.04	76.57		
		-47	CORE	1	52"#/FT NOMEX	30×11×50	.50	.38		6.29	117.53		
		-39	ADH	AS REQD	FMS-1013-1A		.58	.48					
	-57		CENTER SPAR	1					5.71		217.42		
		-51	OUTER SKIN	1	3"GR/EP TAPE	227.8 FT	3.3	2.38		370.53	76.39		
		-53	INNER SKIN	1	3"GR/EP TAPE	233.5 FT	3.4	2.44		366.46	76.35		
		-55	CORE	1	52"#/FT NOMEX	30×11×50	.50	.40		6.29	117.53		
		-39	ADH	AS REQD	FMS-1013-1A		.60	.49					
	-65		REAR AUX SPAR	1					5.57		217.42		
		-59	OUTER SKIN	1	3"GR/EP TAPE	221.1 FT	3.2	2.31		346.80	76.33		
		-61	INNER SKIN	1	3"GR/EP TAPE	229.7 FT	3.3	2.40		360.50	76.30		
		-63	CORE	1	52"#/FT NOMEX	30×10×50	.45	.38		5.73	117.53		
		-39	ADH	AS REQD	FMS-1013-1A		.58	.48					
	-73		REAR AUX SPAR	1					5.17		217.42		
		-67	OUTER SKIN	1	3"GR/EP TAPE	206.7 FT	3.0	2.16		323.43	76.39		
		-69	INNER SKIN	1	3"GR/EP TAPE	215.3 FT	3.1	2.25		336.97	76.35		
		-71	CORE	1	52"#/FT NOMEX	30×9×50	.41	.34		5.15	117.53		
		-39	ADH	AS REQD	FMS-1013-1A		.52	.42					
	-79		FWD SPAR ASSY	1					5.73				
		-17	FWD SPAR	1	3"GR/EP TAPE	502.4 FT	7.3	5.25		785.31	325.24		
		-85	STIFFENER	14	[illegible] CLOTH	[illegible] in²	.04/...	.03		7.22	88.76		
					3"GR/EP TAPE	.31 FT	.005/...	.004					
	-83		REAR SPAR ASSY	1					5.72				
		-15	REAR SPAR	1	3"GR/EP TAPE	503.4 FT	7.3	5.26		787.08	325.24		
		-81	STIFFENER	14	[illegible] CLOTH	[illegible] in²	.04/...	.03		5.48	88.76		
					3"GR/EP TAPE	25 FT	.004/...	.003					
										41557	3630		

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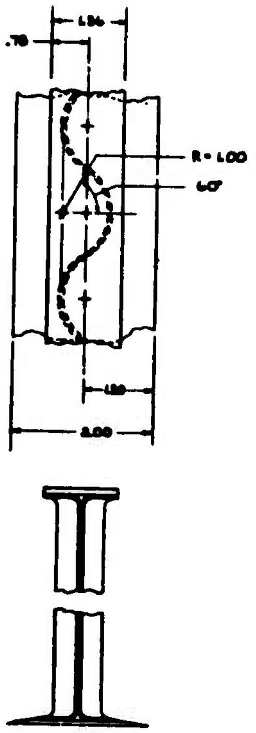
PRELIMINARY DESIGN DRAWING

ATW-4 WING - BURIED TI INSERT IN LOWER SKIN, SANDWICH SPARS, ANALYTICAL ASSY OF

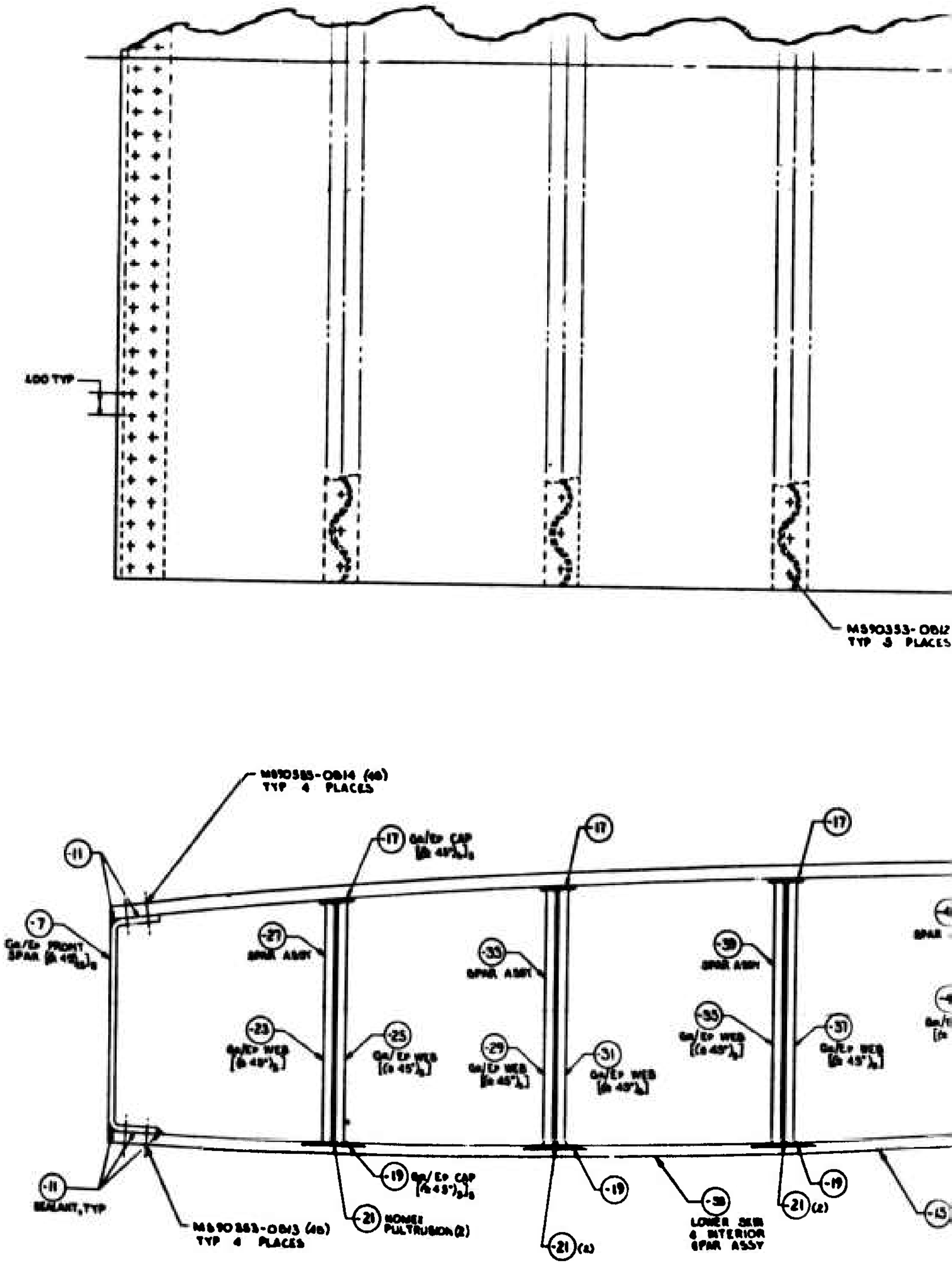
GENERAL DYNAMICS
Convair Aerospace Division

633RA007

[illegible]posite Sandwich Spar with Buried Ti Plate

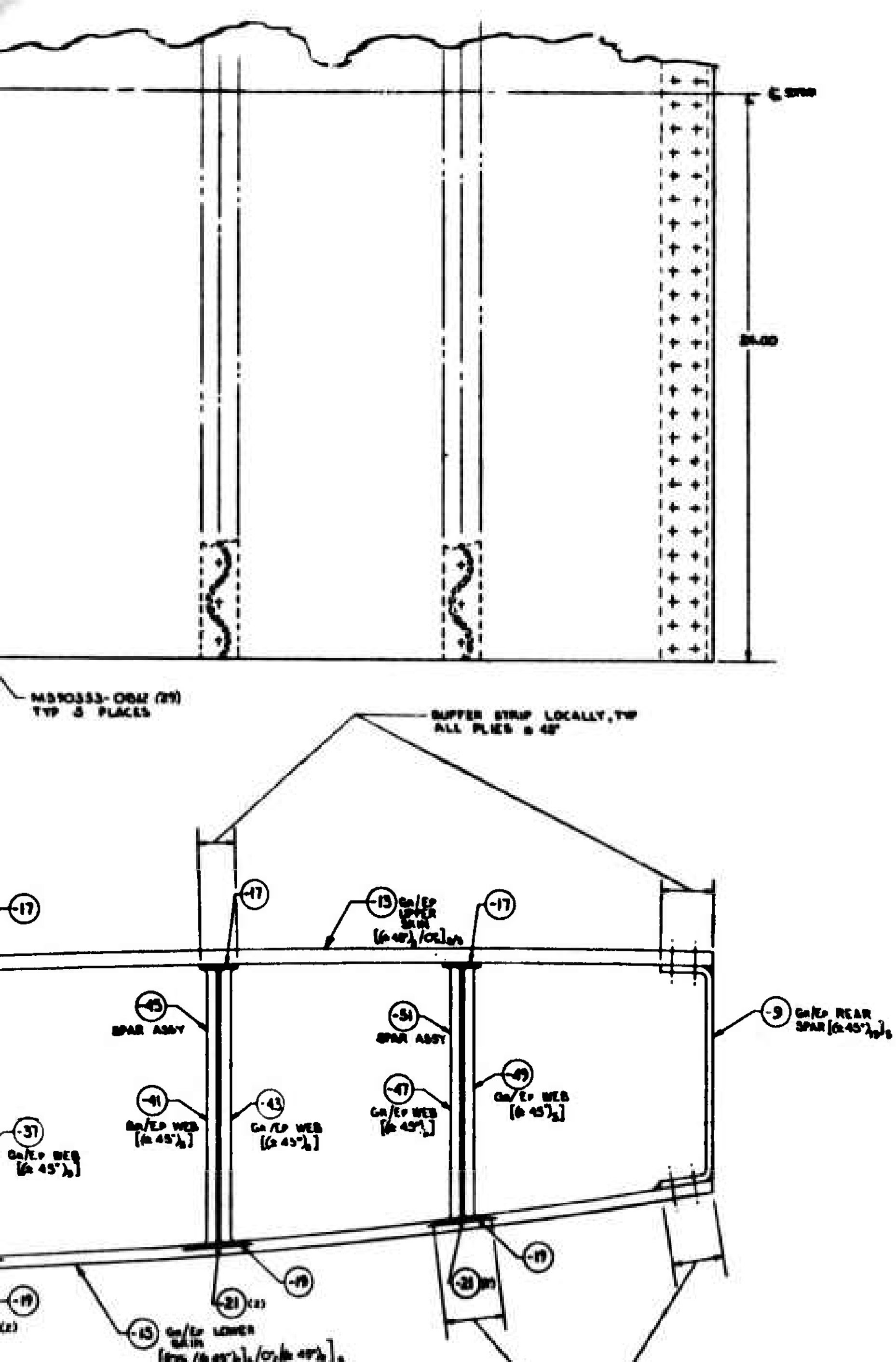


DETAIL -27, -33, -39, -45, & -51 SPAR ASSYS
SCALE ~ 1/1



-1 ASSY

2



DASH NO.						
ASSY	SUB ASSY	DETAIL	PART NAME	NO. REQ'D	MATERIAL	[illegible]
		-7	FRONT SPAR	1	3" Gr/Ep TAPE	11
		-9	REAR SPAR	1	3" Gr/Ep TAPE	10
		-11	SEALANT	AR	FMS 1044	
		-13	UPPER SKIN	1	3" Gr/Ep TAPE	95
		-15	LOWER SKIN	1	3" Gr/Ep TAPE	8
		-17	CAP	1	3" Gr/Ep TAPE	5
		-19	CAP	1	3" Gr/Ep TAPE	[illegible]
		-21	FILLER	2	[illegible]	[illegible]
		-23	WEB	1	3" Gr/Ep TAPE	2
		-25	WEB	1	3" Gr/Ep TAPE	2
	-27		SPAR ASSY	1		
		-17	CAP	1	3" Gr/Ep TAPE	5
		-19	CAP	1	3" Gr/Ep TAPE	5
		-21	FILLER	2	[illegible]	.0
		-29	WEB	1	3" Gr/Ep TAPE	25
		-31	WEB	1	3" Gr/Ep TAPE	2
	-33		SPAR ASSY	1		
		-17	CAP	1	3" Gr/Ep TAPE	5
		-19	CAP	1	3" Gr/Ep TAPE	5
		-21	FILLER	2	[illegible]	.
		-35	WEB	1	3" Gr/Ep TAPE	2
		-37	WEB	1	3" Gr/Ep TAPE	2
	-39		SPAR ASSY	1		
		-17	CAP	1	3" Gr/Ep TAPE	5
		-19	CAP	1	3" Gr/Ep TAPE	5
		-21	FILLER	2	[illegible]	.0
		-41	WEB	1	3" Gr/Ep TAPE	2
		-43	WEB	1	3" Gr/Ep TAPE	2
	-45		SPAR ASSY	1		
		-17	CAP	1	3" Gr/Ep TAPE	5
		-19	CAP	1	3" Gr/Ep TAPE	5
		-21	FILLER	2	[illegible]	[illegible]
		-47	WEB	1	3" Gr/Ep TAPE	2
		-49	WEB	1	3" Gr/Ep TAPE	2
	-51		SPAR ASSY	1		
-53			[illegible] SPAR ASSY	1		
		[illegible]	RIVET	145		
		[illegible]	RIVET	192		
		[illegible]	RIVET	192		
-1			ANALYTICAL ASSEMBLY			

Figure 46 Compos

3

L	PART NAME	NO. REQ'D	MATERIAL	RAW STOCK SIZE	RAW STOCK WEIGHT	FINISHED WT. DETAIL	FINISHED WT. ASSY	COST MATL.	COST FAB.	COST TOOL.	TOTAL COST
	FRONT SPAR	1	3" GR/EP TAPE	1113 FT TAPE	[illegible]	11.6		179.96	182.17		
	REAR SPAR	1	3" GR/EP TAPE	1059 FT TAPE	[illegible]	11.1		169.45	182.17		
	SEALANT	AR	FMS 1044	AR	[illegible]	1.50					
	UPPER SKIN	1	3" GR/EP TAPE	9566 FT TAPE	[illegible]	100.0		[illegible]	[illegible]		
	LOWER SKIN	1	3" GR/EP TAPE	8628 FT TAPE	150	90.2		[illegible]	[illegible]		
	CAP	1	3" GR/EP TAPE	55 FT. TAPE	.80	.57		86.07	82.27		
	CAP	1	3" GR/EP TAPE	53 FT. TAPE	.76	.55		82.36	82.27		
	FILLER	2	[illegible]	.03 m² x 48 m	.10	.07		6.59	5.88		
	WEB	1	3" GR/EP TAPE	220 FT. TAPE	3.20	2.30		344.32	111.65		
	WEB	1	3" GR/EP TAPE	220 FT. TAPE	3.20	2.30		344.32	111.65		
	SPAR ASSY	1					5.79		17.63		
	CAP	1	3" GR/EP TAPE	55 FT. TAPE	.80	.57		86.07	82.27		
	CAP	1	3" GR/EP TAPE	53 FT. TAPE	.76	.55		82.96	82.27		
	FILLER	2	[illegible]	.03 m² x 48 m	.10	.07		6.59	5.88		
	WEB	1	3" GR/EP TAPE	232 FT. TAPE	3.40	2.40		363.1	111.65		
	WEB	1	3" GR/EP TAPE	232 FT. TAPE	3.40	2.40		363.1	111.66		
	SPAR ASSY	1					5.99		17.63		
	CAP	1	3" GR/EP TAPE	55 FT. TAPE	.80	.57		86.07	82.27		
	CAP	1	3" GR/EP TAPE	53 FT. TAPE	.76	.55		82.96	82.27		
	FILLER	2	[illegible]	.03 m² x 48 m	.10	.07		6.59	5.88		
	WEB	1	3" GR/EP TAPE	236 FT. TAPE	3.40	2.50		369.36	111.65		
	WEB	1	3" GR/EP TAPE	236 FT. TAPE	3.40	2.50		369.36	111.65		
	SPAR ASSY	1					6.19		17.63		
	CAP	1	3" GR/EP TAPE	55 FT. TAPE	.80	.57		86.07	82.27		
	CAP	1	3" GR/EP TAPE	53 FT. TAPE	.76	.55		82.36	82.27		
	FILLER	2	[illegible]	.03 m²	.10	.07		6.59	5.88		
	WEB	1	3" GR/EP TAPE	231 FT. TAPE	3.40	2.40		361.54	111.66		
	WEB	1	3" GR/EP TAPE	231 FT. TAPE	3.40	2.40		361.54	111.65		
	SPAR ASSY	1					5.99		17.63		
	CAP	1	3" GR/EP TAPE	55 FT. TAPE	.80	.57		86.07	82.27		
	CAP	1	3" GR/EP TAPE	53 FT. TAPE	.76	.55		82.96	82.27		
	FILLER	2	[illegible]	.03 m²	.10	.07		6.59	5.88		
	WEB	1	3" GR/EP TAPE	213 FT. TAPE	3.10	2.20		333.51	111.65		
	WEB	1	3" GR/EP TAPE	213 FT. TAPE	3.10	2.20		333.51	111.65		
	SPAR ASSY	1					5.59		17.63		
	[illegible] SPAR ASSY	1					[illegible]				
	RIVET	145				2.9	}				
	RIVET	192				2.9	}	1716			
	RIVET	192				2.1	}				
	ANALYTICAL ASSEMBLY						252	38011	5706	202	43721
								ASSY	1661		

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PRELIMINARY DESIGN DRAWING

ATW-4 WING- CORRUGATED INTERIOR SPARS INTEGRAL WITH LOWER SKIN, ANALYTICAL ASSY OF

GENERAL DYNAMICS
Convair Aerospace Division

633RA008

Figure 46 Composite Corrugated Spar Analytical Assembly

Table V ATW COMPOSITE WING BOX ANALYTICAL ASSY EVALUATION SUMMARY

CONFIG. NO.	DESCRIPTION	STRUCT EFFIC.		TECHNOLOGY IMPROV.			DAMAGE TOL.		-ABILITIES					TOTAL SCORE	RANK
		COST* 1975 $ (.24)	WEIGHT LBS (.16)	CONCEPT (.05)	MATL (.02)	MFG (.03)	SAFE CRACK (.08)	FAIL SAFE (.12)	INSPECT- (.06)	MFG (.06)	MAIN-TAIN- (.06)	REPAIR (.06)	DUR- (.06)		
633-RA005-1	TRUSS SPAR, GRAPHITE/EPOXY CO-CURED CONSTRUCTION	43,280 .210	300.70 .134	.025	.02	.03	.080	.000	.030	.045	.050	.040	.060	.724	5
633-RA006-1	GRAPHITE/EPOXY SKINS WITH BUFFER STRIPS; GRAPHITE/EPOXY "Y" SPARS	45,308 .200	258.0 .156	.025	.02	.025	.080	.000	.060	.055	.060	.06	.045	.786	3
633-RA006-3	GRAPHITE/EPOXY SKINS NO BUFFER STRIPS; "Y" SPAR WITH "NOMEX" CORE EMBEDDED LOWER CAPS	37,812 .240	252.60 .160	.050	.02	.03	.080	.000	.060	.060	.060	.06	.060	.880	1
633-RA007-1	BURIED Ti INSERT IN GR/EP LWR SKIN; SANDWICH SPARS	48,093 .189	294.22 .137	.025	.02	.025	.080	.000	.060	.040	.060	.06	.050	.746	4
633-RA003-1	GR/EP - CORRUGATED INTERIOR SPARS INTEGRAL WITH LOWER SKIN	42,721 .208	252.00 .160	.050	.02	.03	.080	.000	.060	.055	.060	.06	.060	.843	2

* ALL COSTS REVISED TO LATEST LEARNING CURVE AND RANKED WITH RESPECT TO COMPOSITE CONCEPTS ONLY.

3.2.3 Preliminary Design Concepts

The baseline concept, two advanced metallic concepts, and one advanced composite design was defined as complete wing designs from pivot to tip on preliminary design drawings. The main features of these 4 designs are described briefly below.

3.2.3.1 Baseline Configuration

The baseline concept, 633RW000 illustrated by Figure 47 embodies the same fabrication, material and joining concepts as the FB-111 wing box. However, the supercritical airfoil geometry and is larger, 725.7 sq. ft. versus 550.0 sq. ft. for the FB-111 wing. The closure and intermediate spars are machined from 2024-T851 Al plate. The upper and lower skins are machine pocketed, then chemically milled from 2024-T851 plate. The pivot fitting is a weldment of D6ac steel machined forgings and machined plate. The lower skin is joined to the spars and pivot fitting with Taper-Loc fasteners. The upper plate is joined to the spars and bulkheads by means straight shank, close tolerance fasteners.

3.2.3.2 Laminated Lower Skin "Y"-Spar Configuration

The 633RW001-1 wing box concept is illustrated by Figure 48. This wing box concept incorporate an adhesive bonded laminated 2024-T81 lower skin without fastener penetrations, extruded aluminum "Y" intermediate spars, exposed lower spar caps, and a constant tapered non-pocketed not-etched upper skin. The upper skin is attached with blind rivets in lieu of close tolerance bolts and Davis Pressnuts. The front and rear spars are machined from 2024-T851 plate. The pivot for the -1 assembly is a closed torque box to the pivot pin spool that encloses the pivot pin. The lower skin is continued inboard of the pivot to form one of three load pathes of a fail-safe lower pivot lug.

3.2.3.3 Laminated Skin Slanted Spar Configuration

The 633RW002-1 and -3 concepts are identical except in the area of the pivot. The 633RW002-1 pivot concept is the same as the 633RW001-1 pivot concept. The 633RW002 wing box outboard of the pivot is illustrated by Figure 49. This design has a laminated adhesive bonded 2024-T81 aluminum lower skin with embedded lower spar caps. The intermediate spars are configured of a slanted sheet aluminum web stabilized by "V" shaped sheet aluminum intercostals. Each spar has two extruded aluminum upper caps. The front and rear spars are machined of 2024-T851 aluminum plate. The upper skin is a non-pocketed non-etched constant tapered 2024-T851 aluminum plate.

The 633RW002-3 pivot concept is similar to the -1 pivot con-concept except -1 is open in the area of the pivot lugs and transfers wing shear loads to the pivot spool by means of two vertical shear lugs. The lower pivot lug incorporates the same fail safe feature as the 633RW001-1 lower lug design.

3.2.3.4 Composite Wing Configuration

The 633RW003-1 and -3 designs are graphite epoxy wing box concepts. The -1 and -3 designs differ only in the pivot area. The lower skin is a solid layup design without buffer strips. The intermediate spars are of a "Y" shaped configuration with lower cap embedded in the lower skin. The lower cap design is a unique configuration that incorporates a prefabricated, embedded longitudinal member that provides transverse or chordwise bending continuity, longitudinal axial load continuity plus a shear load path in the lower skin at its intersection with the vertical web of the intermediate spars. The intermediate spars have a core of nomex laminate with graphite epoxy outer plys. The front and rear spars and the upper skin are solid graphite epoxy laminate with no buffer strips. The upper skin is attached with blind rivets. The -1 pivot concept is open in the pivot area with double shear fittings between the inboard pivot bulkhead and the spool that encapsulates the pivot pin. The -3 pivot concept is a closed torque box design. Both -1 and -3 designs are configured with the upper and lower skins forming a major load carrying layer of the pivot lugs. The metal in the pivot lug members is titanium. The 633RW003-1 and -3 designs are shown in Figure 50.

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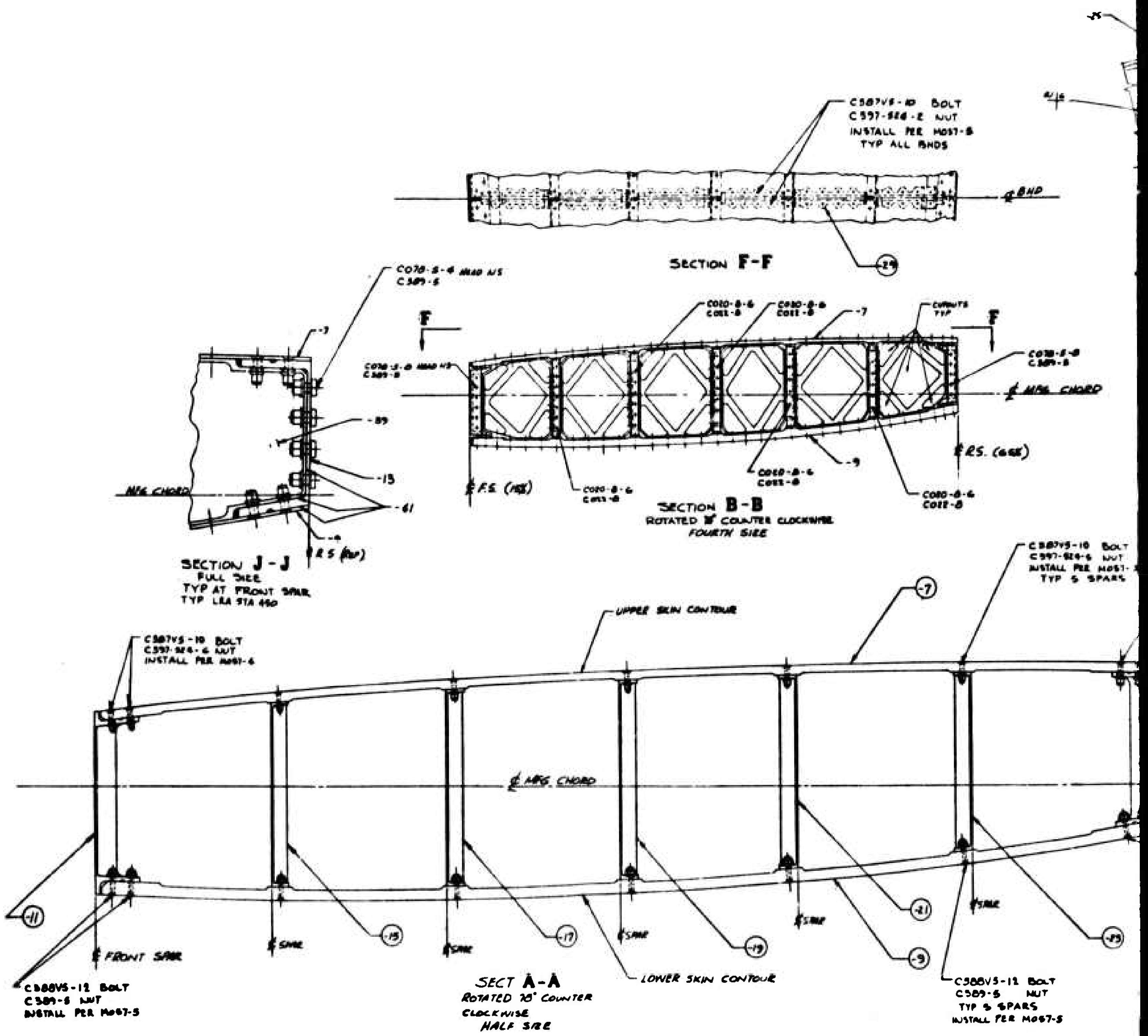

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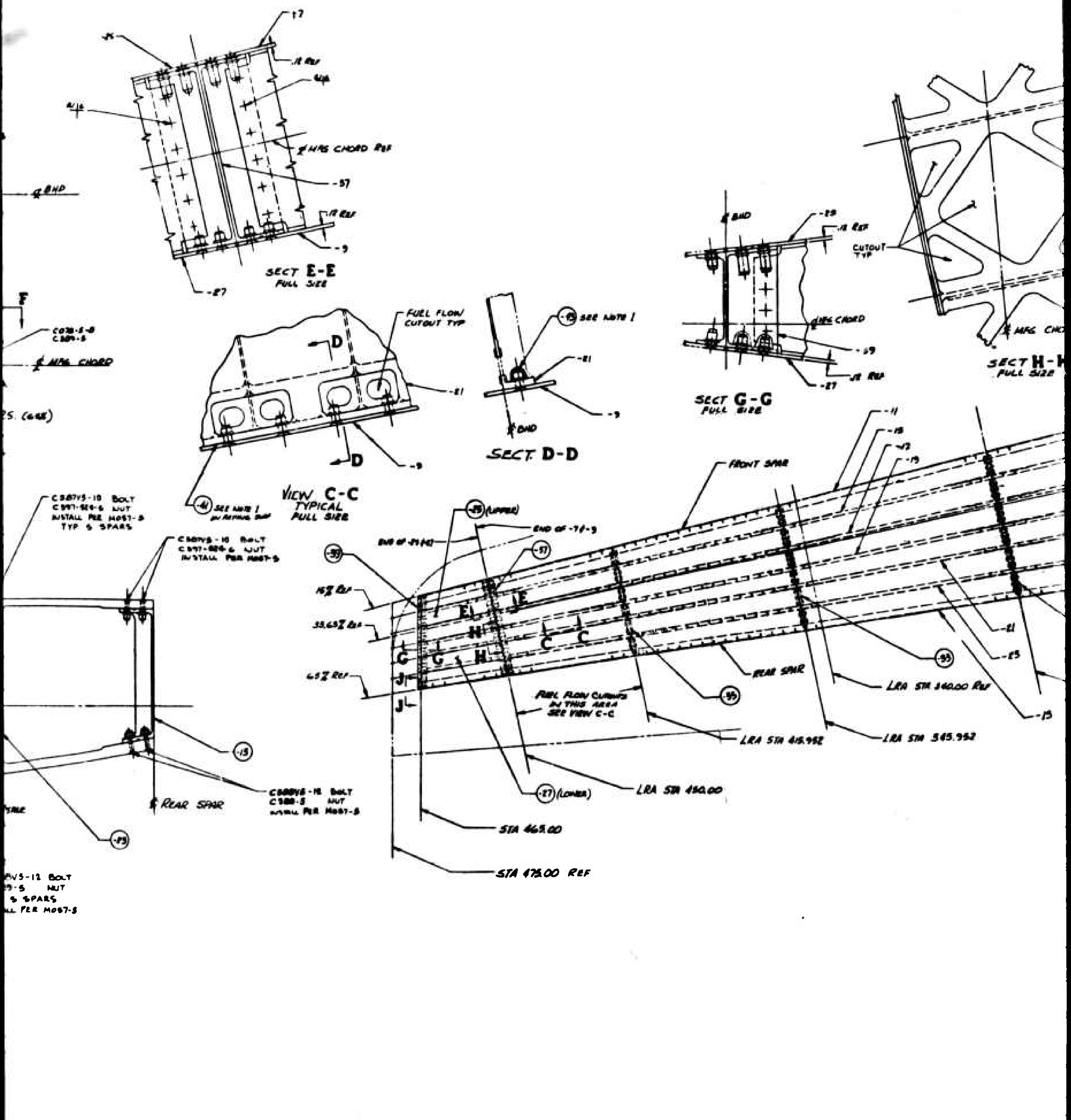
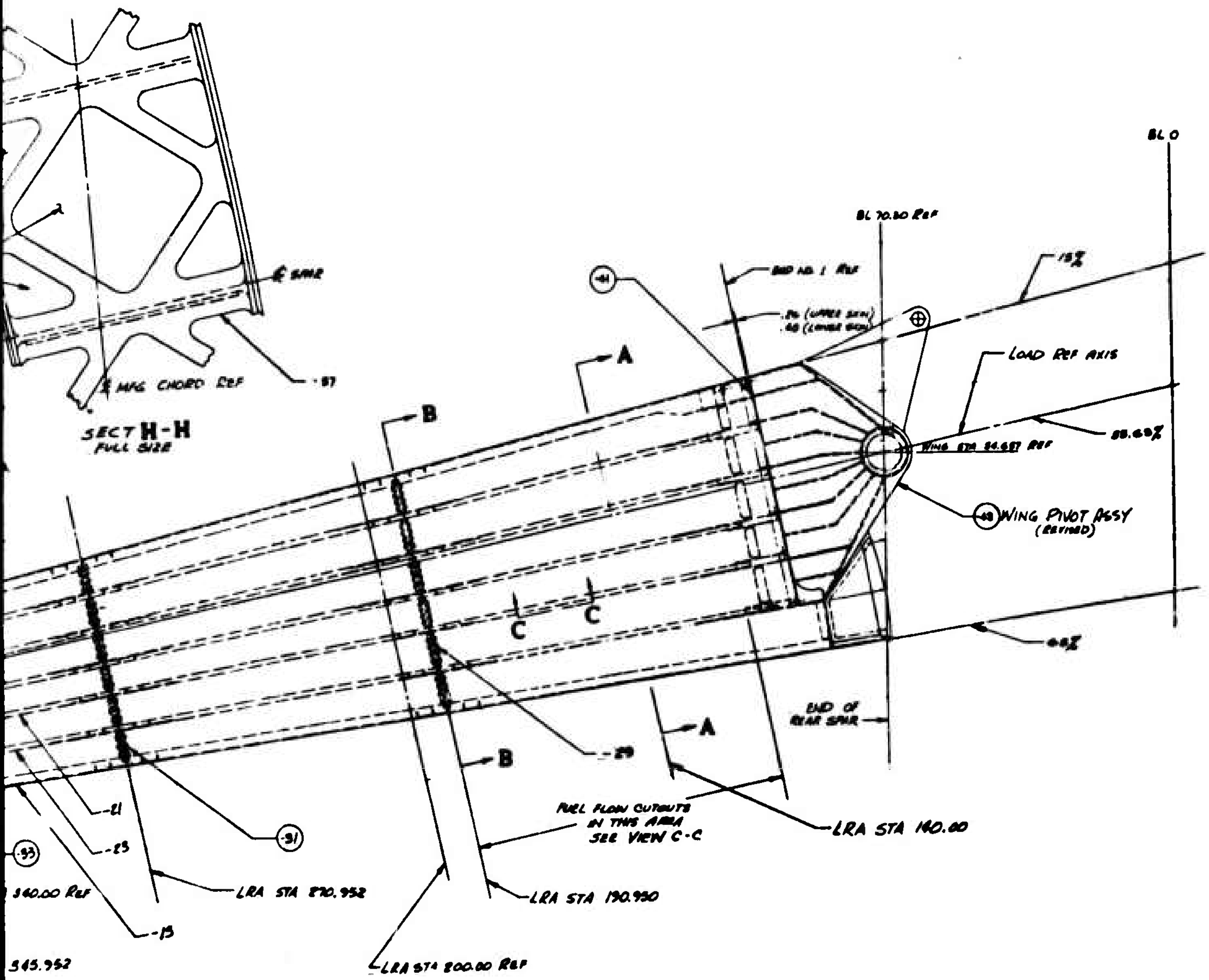


SECT E-E
FULL SIZE
SECT G-G
FULL SIZE
SECT H-H
FULL SIZE
SECT. D-D
VIEW C-C
TYPICAL
FULL SIZE
FUEL FLOW CUTOUT TYP
CUTOUT TYP
FRONT SPAR
REAR SPAR
FUEL FLOW CUTOUTS IN THIS AREA SEE VIEW C-C
LRA STA 415.952
LRA STA 345.952
LRA STA 340.00 REF
LRA STA 450.00
STA 465.00
STA 475.00 REF
END OF -71-3
SEE NOTE 1
MFG CHORD
MFG CHORD REF
REAR SPAR

3



DASH	
ASSY	SUB ASSY
-29	
-31	
-33	
-35	
-43	
-47	
-49	
-1	

✻3. -29 TH

2. -43 WIN

1. ALL SEAL
SHALL

NOTES:

DASH NO. ASSY	SUB ASSY	DETAIL	PART NAME	NO. REQD	MATERIAL	RAW STOCK SIZE	RAW STOCK WEIGHT	FINISHED WT. DETAIL	FINISHED WT. ASSY	COST MAT'L	COST FAB.	COST TOOL.	TOOL COST
		-7	UPPER SKIN	1	2024-T851	1.50 X 77 X 368	4,282.9#	614.52#					
		-9	LOWER SKIN	1	2024-T851	1.75 X 77 X 368	5,008.4#	793.00#					
		-11	FRONT SPAR	1									
		-13	REAR SPAR	1	2024-T851	—	2,339.5#	323.39#					
		-15	SPAR	1									
		-17	SPAR	1									
		-19	SPAR	1									
		-21	SPAR	1									
		-23	SPAR	1									
		-25	SKIN (OUTBD UPPER END)	1	2024-T851	—	67.17#	25.66#					
		-27	SKIN (OUTBD LOWER END)	1									
-29			BULKHEAD	[illegible]									
-31			BULKHEAD	[illegible]	2024-T851	—	1,148.00#		116.80#				
-33			BULKHEAD	[illegible]									
-35			BULKHEAD	[illegible]									
		-37	BULKHEAD	1									
		-39	BULKHEAD	1									
		-41	BULKHEAD	1									
-43			WING PIVOT ASSY	1	[illegible] AC STEEL		1,234.00#		737.70#				
	-45		MISC MACHINED FITTINGS & PARTS		2024-T851	—	348.00#	70.98#					
-47			GENERAL SEALANT	—	FMS-1044		8.84#		5.98#				
-49			FILLET SEALANT	—									
			STRAIGHT SHANK BOLT (C367V5-10)	1,530				21.42#					
			SHEAR FASTENER (C078-5-8)	60				1.40#					
			(C020-8-4)	242				1.40#					
			TAPER LOK (C388V8-12)	1,530				28.01#					
			PRESSNUT (C380-524-4)	1,530				14.30#					
			NUT (C022-8)	242				.30#					
			(C398-5)	1,530				10.97#					
			TOTAL FASTENER WT.					78.4#					
-1			WING BOX ASSY						2751.0				

3. -29 THRU -35 EACH MADE UP OF 6 PIECES.

2. -43 WING PIVOT FITTING SAME CONCEPT AS F-111.

1. ALL SEALING MATERIALS & METHODS OF APPLICATION SHALL BE AS SPECIFIED IN FPS-1004.

NOTES:

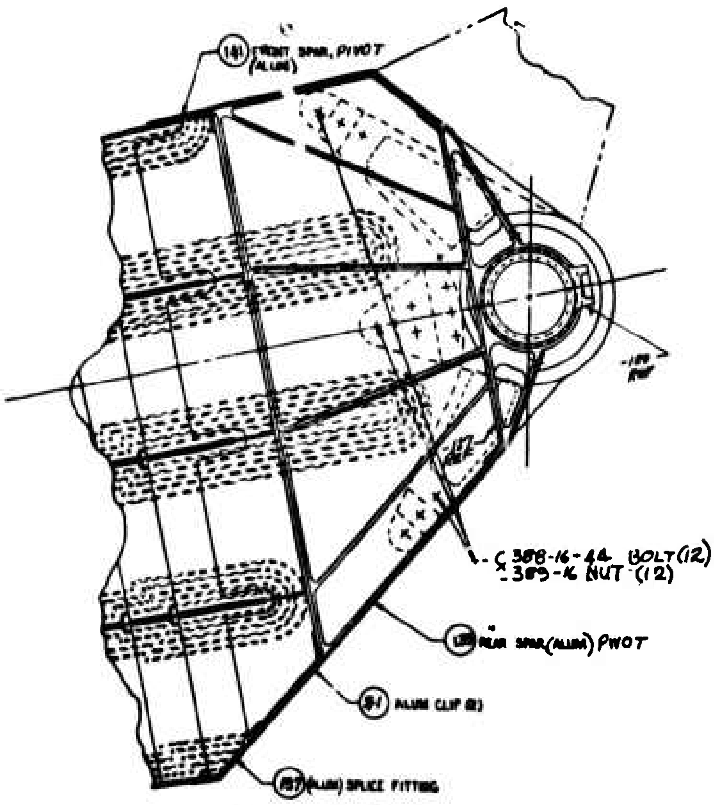
PRELIMINARY DESIGN DRAWING

WING BOX - ATW - 4
BASELINE

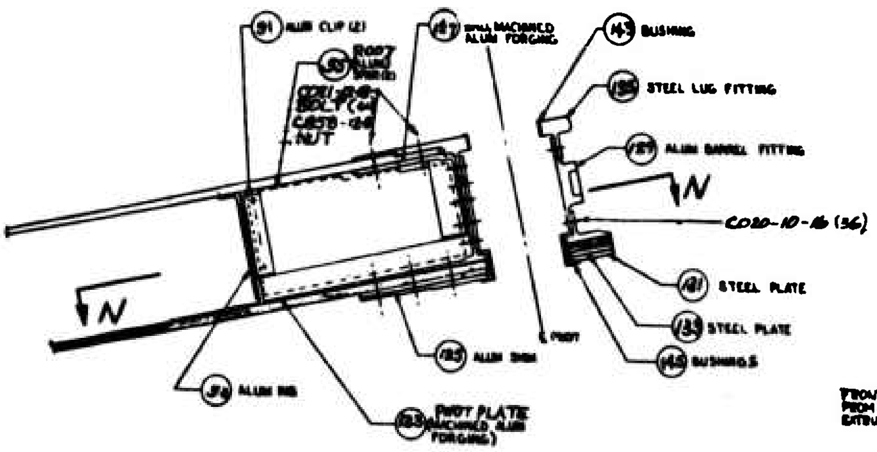
GENERAL DYNAMICS
Convair Aerospace Division

653RW000

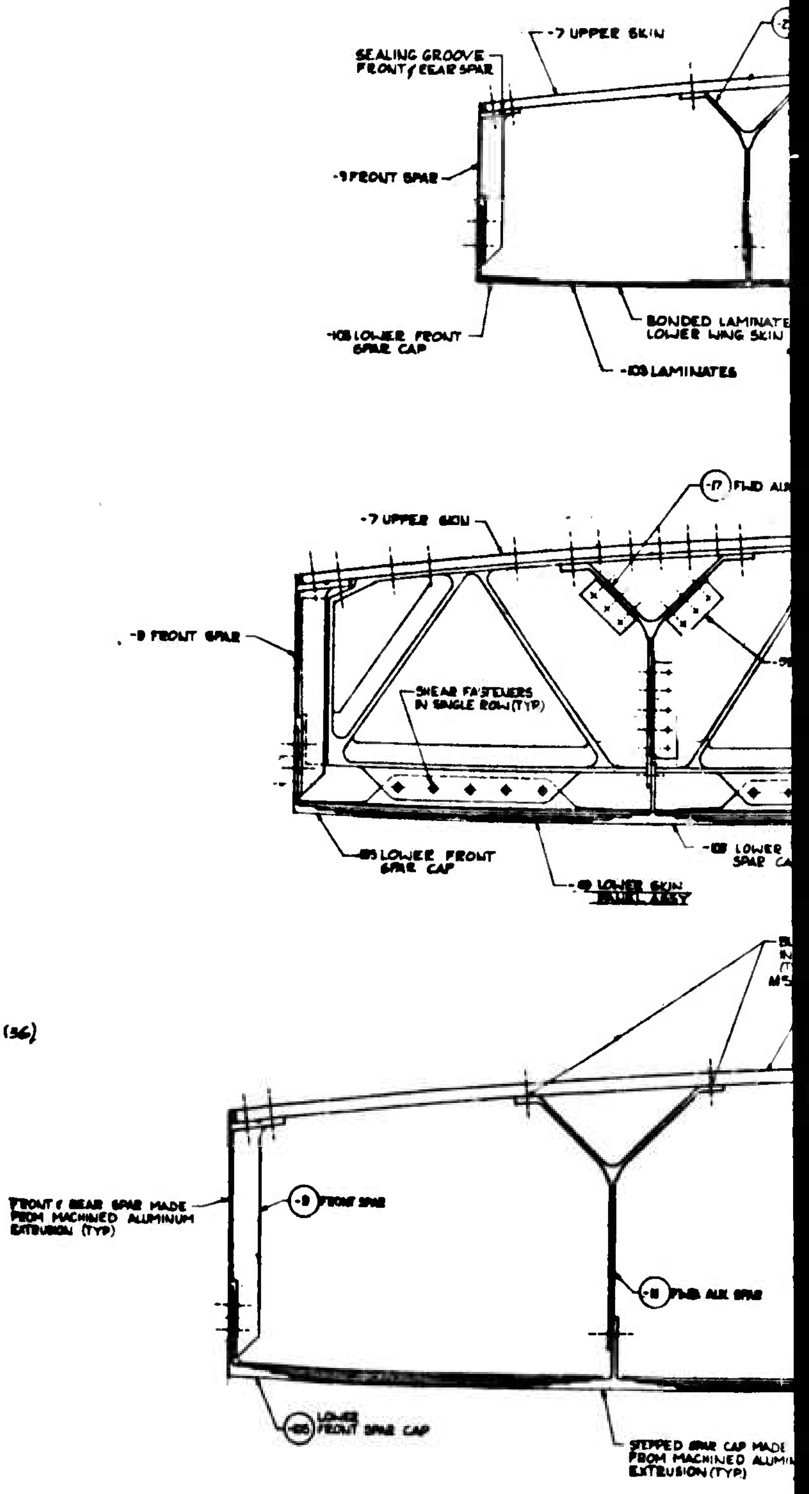
Figure 47 Baseline Preliminary Design



SECTION N-N
(1/5 SIZE)



SECTION M-M
(1/5 SIZE)



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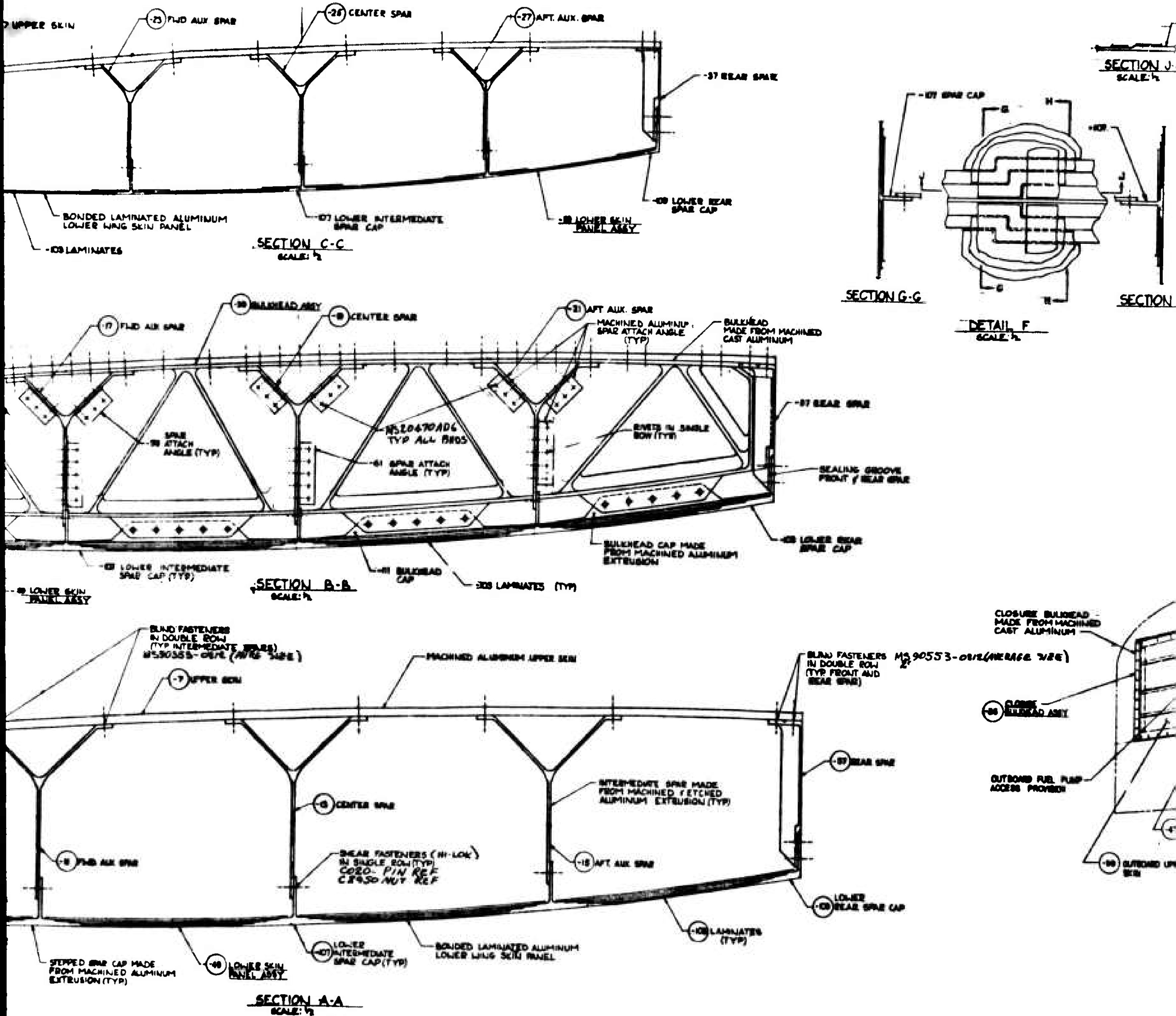
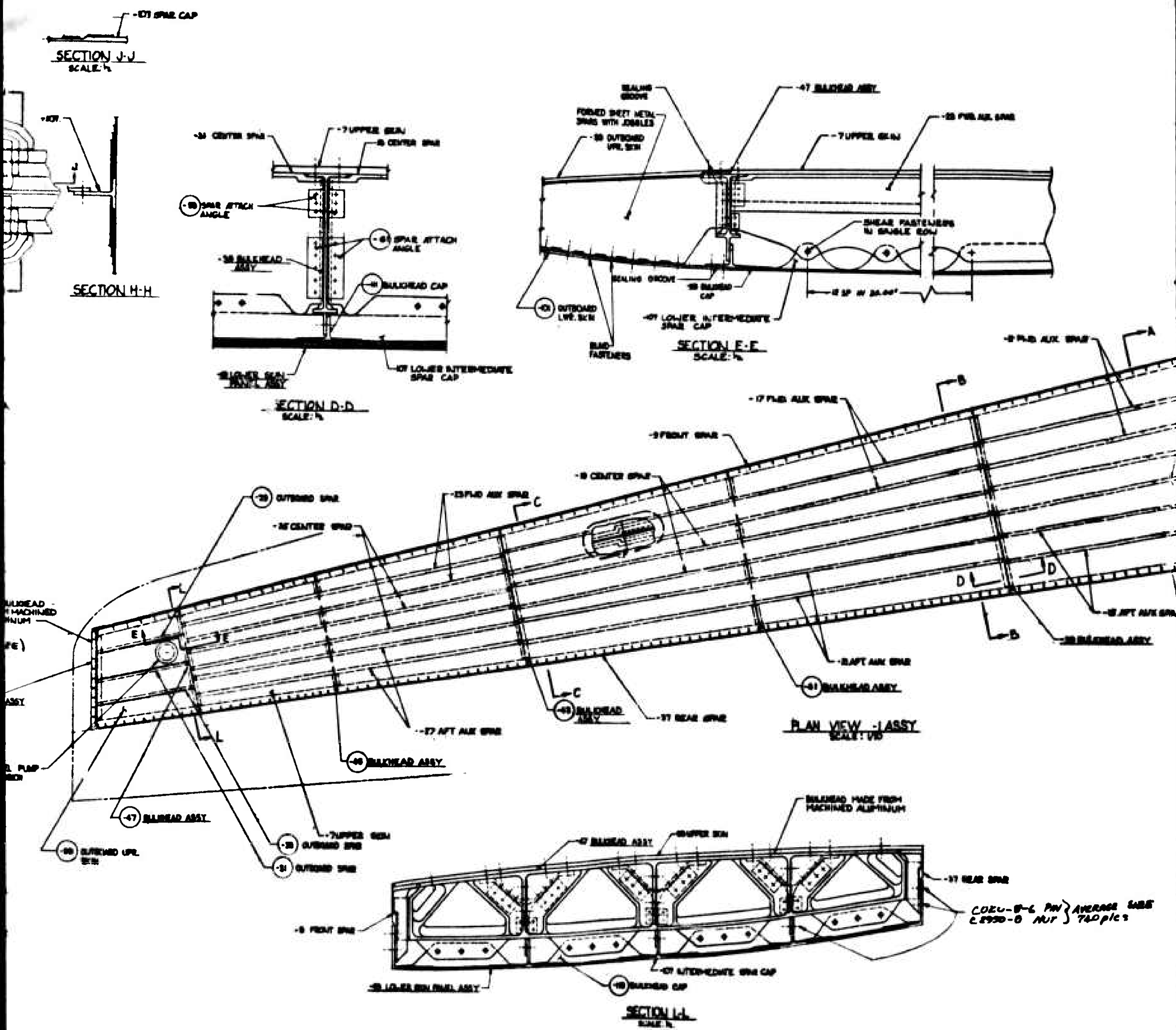
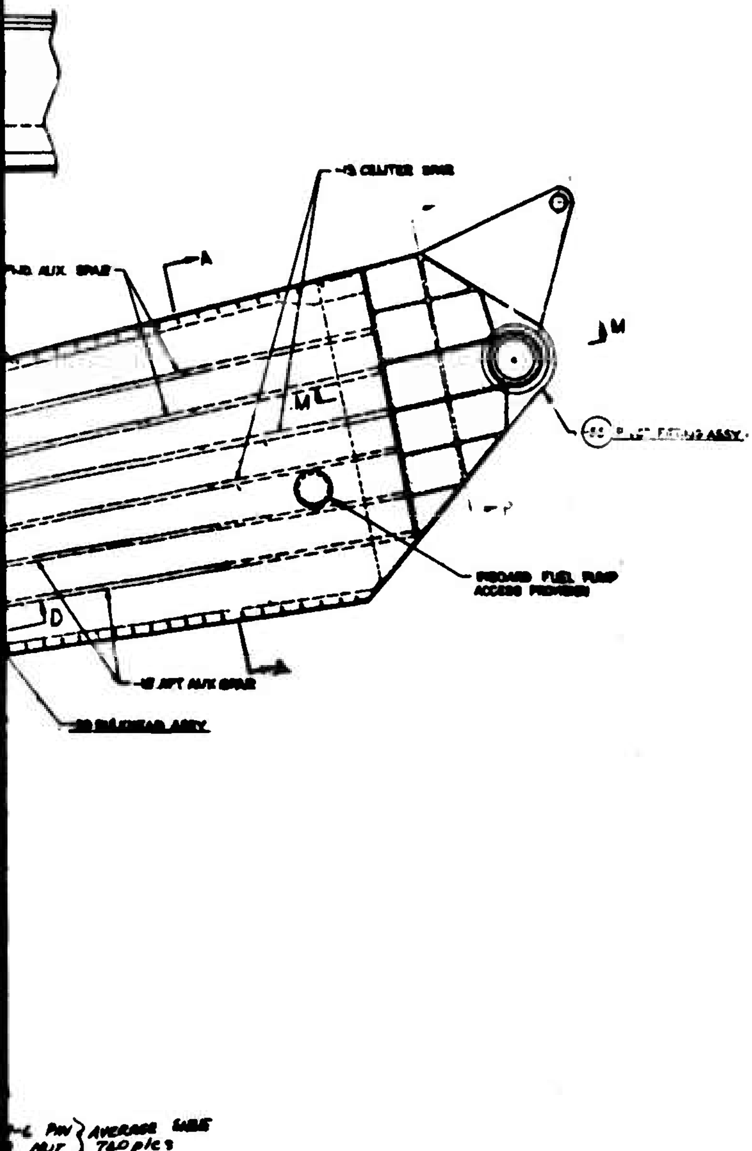

UPPER SKIN
-25 FWD AUX SPAR
-26 CENTER SPAR
-27 AFT. AUX. SPAR
-37 REAR SPAR
-109 LOWER REAR SPAR CAP
BONDED LAMINATED ALUMINUM LOWER WING SKIN PANEL
-107 LOWER INTERMEDIATE SPAR CAP
LOWER SKIN PANEL ASSY
-108 LAMINATES
SECTION C-C
SCALE: ½
SECTION J
SCALE: ½
-107 SPAR CAP
SECTION G-G
DETAIL F
SCALE: ½
SECTION
BULKHEAD ASSY
-17 FWD AUX SPAR
CENTER SPAR
-21 AFT AUX. SPAR
MACHINED ALUMINUM SPAR ATTACH ANGLE (TYP)
BULKHEAD MADE FROM MACHINED CAST ALUMINUM
-37 REAR SPAR
SPAR ATTACH ANGLE (TYP)
MS20470AD6 TYP ALL BHDS
RIVETS IN SINGLE ROW (TYP)
-61 SPAR ATTACH ANGLE (TYP)
SEALING GROOVE FRONT & REAR SPAR
BULKHEAD CAP MADE FROM MACHINED ALUMINUM EXTRUSION
LOWER REAR SPAR CAP
LOWER INTERMEDIATE SPAR CAP (TYP)
BULKHEAD CAP
-108 LAMINATES (TYP)
LOWER SKIN PANEL ASSY
SECTION B-B
SCALE: ½
CLOSURE BULKHEAD - MADE FROM MACHINED CAST ALUMINUM
BLIND FASTENERS IN DOUBLE ROW (TYP INTERMEDIATE SPARS)
MACHINED ALUMINUM UPPER SKIN
-7 UPPER SKIN
BLIND FASTENERS IN DOUBLE ROW (TYP FRONT AND REAR SPAR)
MS90553-0812(AVERAGE SIZE)
CLOSURE BULKHEAD ASSY
-37 REAR SPAR
OUTBOARD FUEL PUMP ACCESS PROVISION
INTERMEDIATE SPAR MADE FROM MACHINED & ETCHED ALUMINUM EXTRUSION (TYP)
CENTER SPAR
FWD AUX SPAR
SHEAR FASTENERS (HI-LOK) IN SINGLE ROW (TYP)
G020 PIN REF
C2450 NUT REF
-15 AFT AUX SPAR
LOWER REAR SPAR CAP
OUTBOARD UPPER SKIN
-108 LAMINATES (TYP)
STEPPED SPAR CAP MADE FROM MACHINED ALUMINUM EXTRUSION (TYP)
LOWER SKIN PANEL ASSY
-107 LOWER INTERMEDIATE SPAR CAP (TYP)
BONDED LAMINATED ALUMINUM LOWER WING SKIN PANEL
SECTION A-A
SCALE: ½

3


SECTION J-J
SECTION H-H
SPAR ATTACH ANGLE
BULKHEAD CAP
SECTION D-D
SEALING GROOVE
FORMED SHEET METAL SPARS WITH JOGGLES
7 UPPER SKIN
SHEAR FASTENERS IN SINGLE ROW
SECTION E-E
PLAN VIEW -1 ASSY
BULKHEAD ASSY
OUTBOARD SPAR
OUTBOARD UPR. SKIN
7 UPPER SKIN
27 REAR SPAR
BULKHEAD MADE FROM MACHINED ALUMINUM
9 FRONT SPAR
SECTION L-L

4



CENTER SPAR
AUX SPAR
A
M
FITTING ASSY
FUEL PUMP
ACCESS PROVISION
D
AFT AUX SPAR
BULKHEAD ASSY
PIN
NUT
AVERAGE
760 plcs

5

LIST OF MATERIALS

ASSY	DASH NO. SUB ASSY	DETAIL	PART NAME	NO. REQ'D	DESCRIPTION	MATERIAL	RAW STOCK SIZE	RAW STOCK WEIGHT	FINISHED WT. IN LBS.	COST $
			WING BOX ASSY	1					2341.0	
		-7	UPPER SKIN	1	MACHINE FROM PLATE	2024-T851	[illegible]	1986.8	[illegible]	
		-9	FRONT SPAR	1	MACHINED EXTRU	2024-T8511	—	612.0	[illegible]	
		-11	[illegible]	1	CHEM ETCH MACHINED EXTRU	2024-T8511	—	3550	235.9	
		-13	CENTER SPAR	1			—			
		-15	AFT AUX SPAR	1			—			
		-17	FWD AUX SPAR	1			—			
		-19	CENTER SPAR	1			—			
		-21	AFT AUX SPAR	1			—			
		-23	FWD AUX SPAR	1			—			
		-25	CENTER SPAR	1			—			
		-27	AFT AUX SPAR	1	CHEM ETCH MACHINED EXTR	2024-T8511	—			
		-29, -31, -33	OUTBOARD SPAR		FORMED SHEET METAL	2024-T81	[illegible]	5.4	4.2	
		-35	CLOSURE		MACHINED FROM CAST ALUMINUM		—	4.6	3.7	
			BULKHEAD (TIP)							
		-37	REAR SPAR	1	MACHINED EXTRU	2024-T8511	—	[illegible]	[illegible]	
		-51	CLIPS	4	MACH FROM EXTR	2024-T3511	—	1.6	[illegible]	
		-53	RIB	1	MACH FROM EXTR	2024-T3511	—	15.0	[illegible]	
		-55	ROOT SPARS	1	MACH FROM EXTR	2024-T3511	—	5.3	[illegible]	
		—	BOLTS	40		[illegible]	—		[illegible]	
		—	NUT	40		[illegible]	—		[illegible]	
		—	RIVETS	300		[illegible]	—	—	[illegible]	

LIST OF [illegible]

ASSY	DASH NO. SUB ASSY	DETAIL	PART NAME	NO. REQ'D	DESCRIPTION	MATERIAL	RAW STOCK SIZE	RAW STOCK WEIGHT	FINISHED WT. IN LBS.	COST $
	-39		BULKHEAD ASSY							
		-57	BULKHEAD	1	MACH FROM PLATE	2024-T851	[illegible]	186.	[illegible]	
		-59	SPAR ATTACH ANGLE	12	CUT FROM EXTR	2024-T3511	—			
		-61	SPAR ATTACH ANGLE	6	CUT FROM EXTR	2024-T3511	—	1.5	[illegible]	
	-41		BULKHEAD ASSY							
		-63	BULKHEAD	1	MACH FROM PLATE					
		-65	BULKHEAD	1		2024-T851	[illegible]	138.	[illegible]	
		-67	BULKHEAD	1						
		-69	BULKHEAD	1						
		-71	SPAR ATTACH ANGLE	12	CUT FROM EXTR	2024-T3511	[illegible]	1.4	[illegible]	
		-73	SPAR ATTACH ANGLE	6	CUT FROM EXTR	2024-T3511	[illegible]			
	-43		BULKHEAD ASSY							
		-75	BULKHEAD	1	MACH FROM PLATE	2024-T851	[illegible]	110.	[illegible]	
		-77	SPAR ATTACH ANGLE	12	CUT FROM EXTR	2024-T3511	—	1.2	[illegible]	
		-79	SPAR ATTACH ANGLE	6	CUT FROM EXTR	2024-T3511	—			
	-45		BULKHEAD ASSY							
		-81	BULKHEAD	1	MACH FROM PLATE	2024-T851	[illegible]	75.0	[illegible]	
		-83	BULKHEAD	1						
		-85	BULKHEAD	1						
		-87	BULKHEAD	1						
		-89	SPAR ATTACH ANGLE	12	CUT FROM EXTR	2024-T3511	—	1.0	.8	
		-91	SPAR ATTACH ANGLE	6	CUT FROM EXTR	2024-T3511	—			
	-47		BULKHEAD ASSY							
		-93	BULKHEAD	1	MACHINE FROM PLATE	2024-T851		61.0	4.1	
		-95	SPAR ATTACH ANGLE	12	CUT FROM EXTR	2024-T3511				
		-97	SPAR ATTACH ANGLE	6	CUT FROM EXTR	2024-T3511		.5	.4	
		-99	OUTBD UPR SKIN	1	STRETCH & ETCH	2024-T81	[illegible]	[illegible]	[illegible]	
		-101	OUTBD LWR SKIN	1	STRETCH & ETCH	2024-T81	[illegible]	[illegible]	[illegible]	
	-49		LWR SKIN PANEL ASSY							
		-103	LAMINATES		PROFILE, CHEM ETCH & CONST. TAPER IN 20% OF THE TOTAL AREA OF ALL LAMINATES & ROLL FORM CONTOUR		[illegible]	4800.0	333.2	
		-123	PIVOT PLATE	1	MACHINED FORGING	2024-T851	[illegible]	1580	65.7	
		-105	LOWER FRONT SPAR CAP	1	MACHINED ALUMINUM EXTRUSION	2024-T8511	—	94.0	57.7	
		-107	LOWER INTERMEDIATE SPAR CAP	3			—	660.0	178.1	
		-109	LOWER REAR SPAR CAP	1	MACHINED ALUMINUM EXTRUSION	2024-T8511	[illegible]	91.3	55.9	
		-111	BULKHEAD CAP	1	MACHINED ALUMINUM EXTRUSION	2024-T8511	TEE	2.3	2.1	
		-113		4				2.0	1.7	
		-115		1				1.5	1.4	
		-117		4				1.4	1.2	
		-119	BULKHEAD CAP	1	MACHINED ALUMINUM EXTRUSION	2024-T8511		1.3	1.1	
		-121	ADHESIVE		SEE NOTE	FMS-1013 FORM 1A	496. FT²	55.7	55.1	
	-125		SHIM (PIVOT FTG)	1	MACH FROM PLATE	2024-T851	[illegible]	10.2	5.1	
	-127		BHD	1	MACHINED FORGING	2024-T851	10 x 4.5 x 7.5	50.0	36.0	
	-129		BARREL FTG	1	MACHINED FORGING	2024-T851	15.0 DIA x 11.3	141.0	13.6	
	-131		PLATE (ALIGN)	1	MACH FROM PLATE	10NI STL	.75 x 20 x 30	80.0	36.0	
	-133		PLATE (STIFFENER)	1	MACH FROM PLATE	10NI STL	[illegible]	212.0	50.0	
	-135		PIVOT LUG, UPR	1	MACHD FORGING	10NI STL	[illegible]	439.	166.0	
	-137		SPLICE FTG	1	MACH'D EXTR.	2024-T8511	.5 in² x 15	.6	.3	
	-139		REAR SPAR, PIVOT	1	MACH'D EXTR.	2024-T8511	2.0 in² x 44	113.0	11.3	
	-141		FRT SPAR, PIVOT	1	MACH'D EXTR.	2024-T8511	2.0 in² x 27	91.0	9.1	
	-143		BUSHING	1	MACH'D FORGING	10NI STL	3.00 DIA x 2	10.5	3.5	
	-145		BUSHINGS	2	MACH'D FORGING	10NI STL	9.00 DIA x 2	65.6	16.4	
	-147		WING ACT ARM	1	MACH'D FORGING	10NI STL	[illegible] x 28	96.0	24.0	
	-149		MISC. FTG'S	—	MACH FROM PLATE	2024-T851	3" PLATE	386.6	31.0	
	-151		POLYURETHANE TANK COATING		—	POLYURETHANE		—	17.0	
	-153		SEALANT & FINISHES		—	—			8.2	
	—		TAPER-LOC BOLT	12		C388-12-44			[illegible]	
	—		NUTS	12		C389-12-8			[illegible]	
	—		BLIND RIV.	2520		MS90353-08[illegible]			48.[illegible]	
	—		(HI LOC) PIN	740	(AVERAGE SIZE)	C[illegible]-8-6	PIN		4.[illegible]	
	—		HI LOC NUT	740		C2930-8	NUT		1.9[illegible]	

(TOT) 2341.0

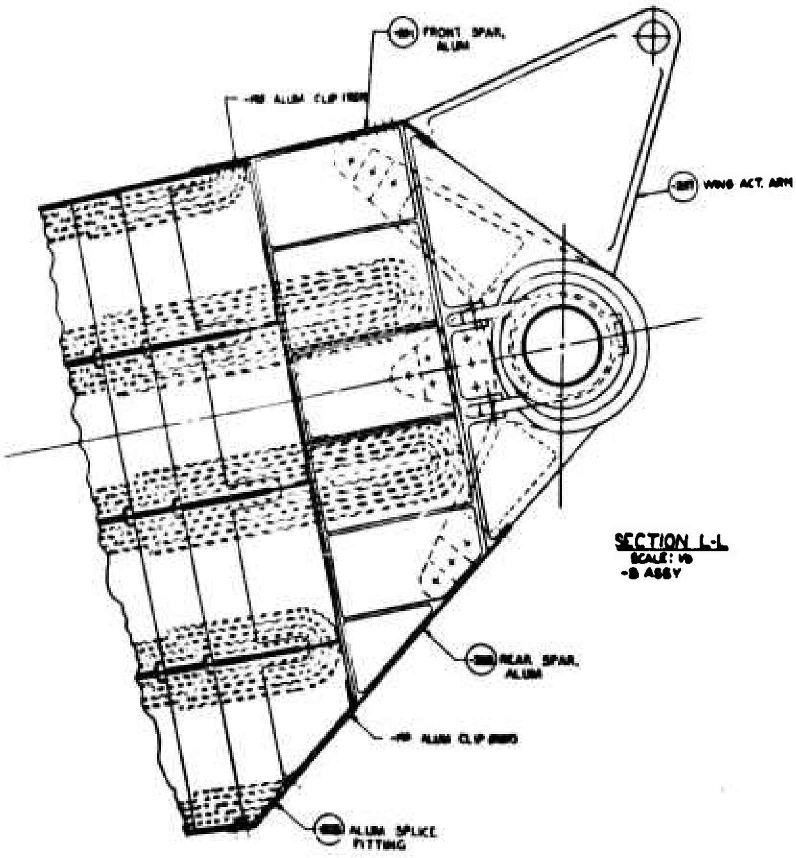
PRELIMINARY DESIGN DRAWING

RW-4 WING BOX LAMINATED LOWER SKIN WITH "Y" SPARS

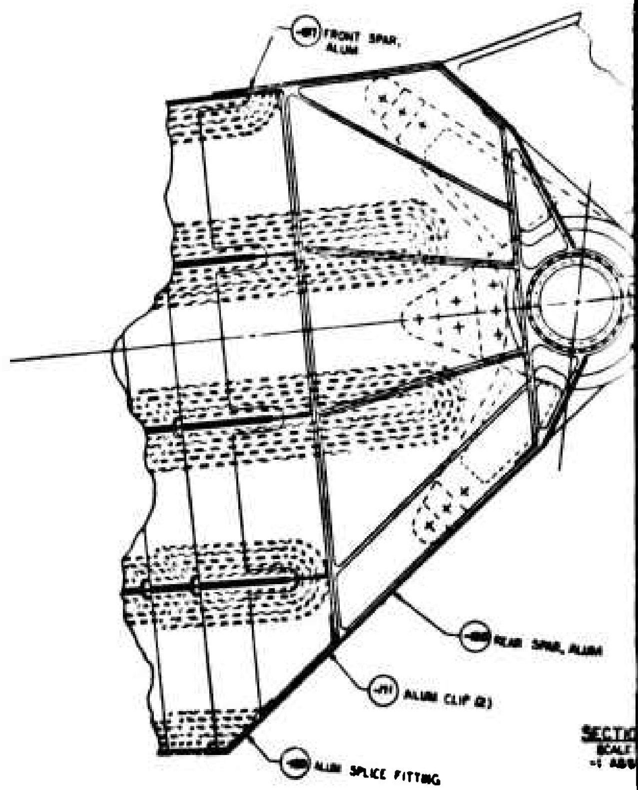
GENERAL DYNAMICS
Convair Aerospace Division
Fort Worth Operation

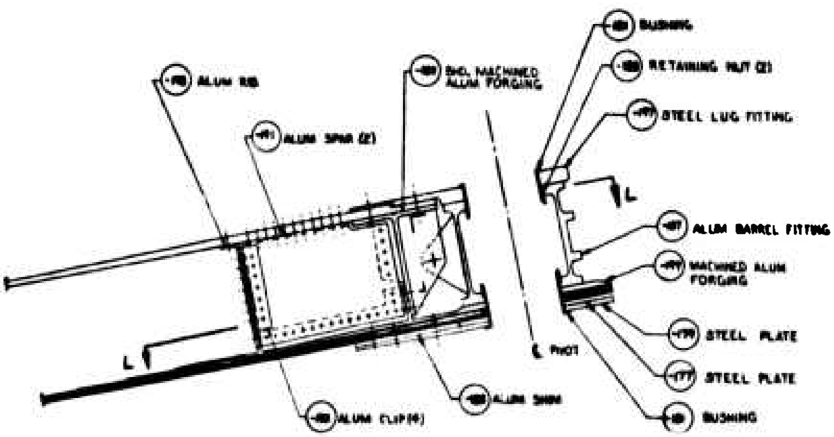
633-RW001

Figure 48 Y-Spar Preliminary Design

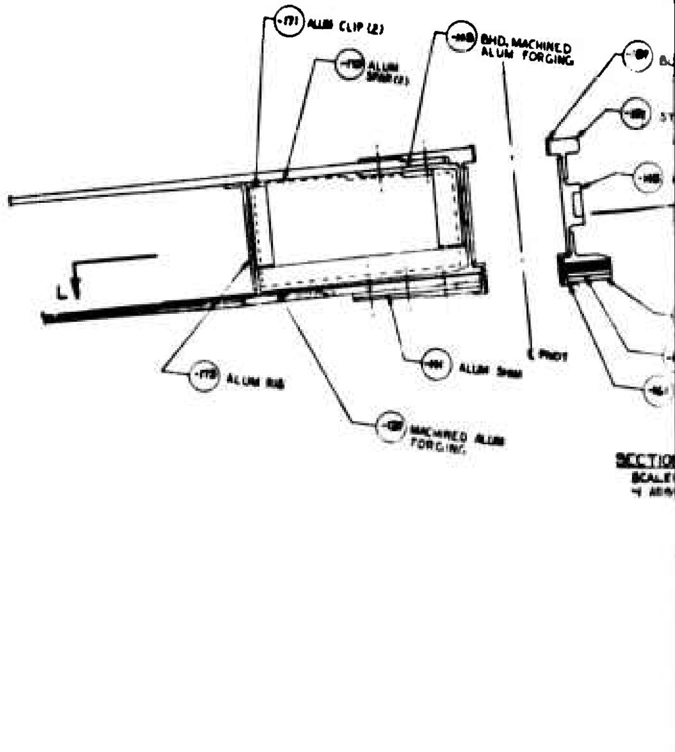


SECTION L-L
SCALE: 1/8
-3 ASSY





SECTION K-K
SCALE: 1/8
-3 ASSY



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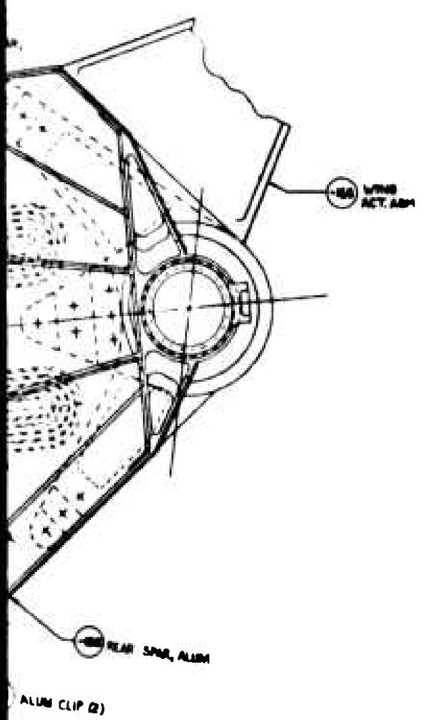
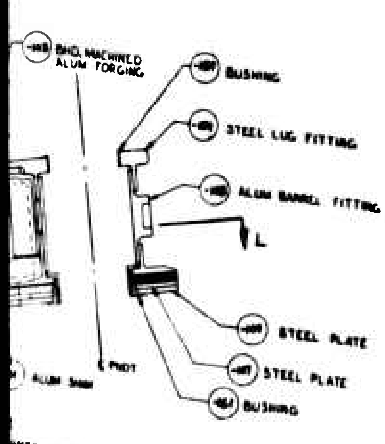
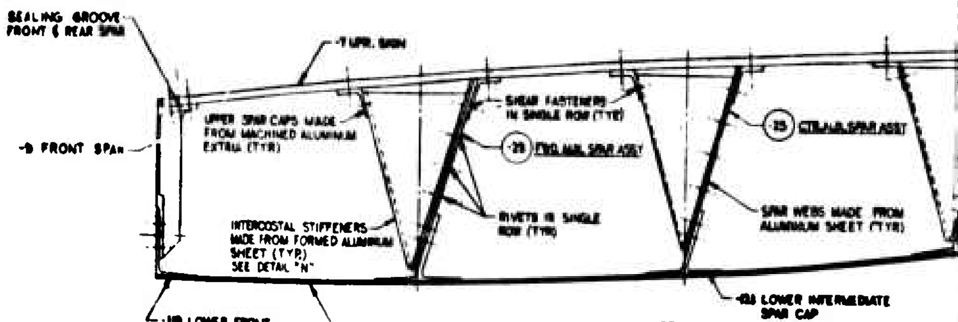


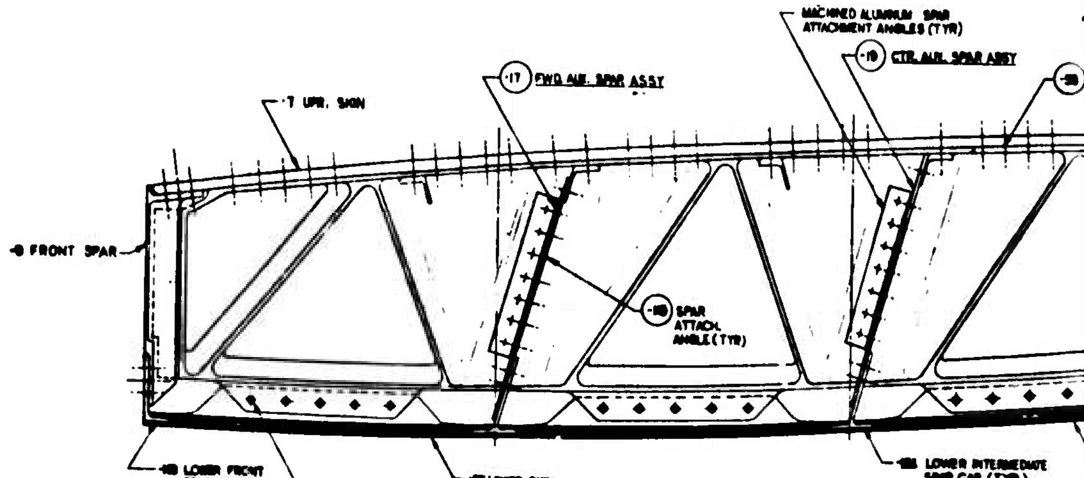
SECTION L-L
SCALE: 4/0
-1 ASSY



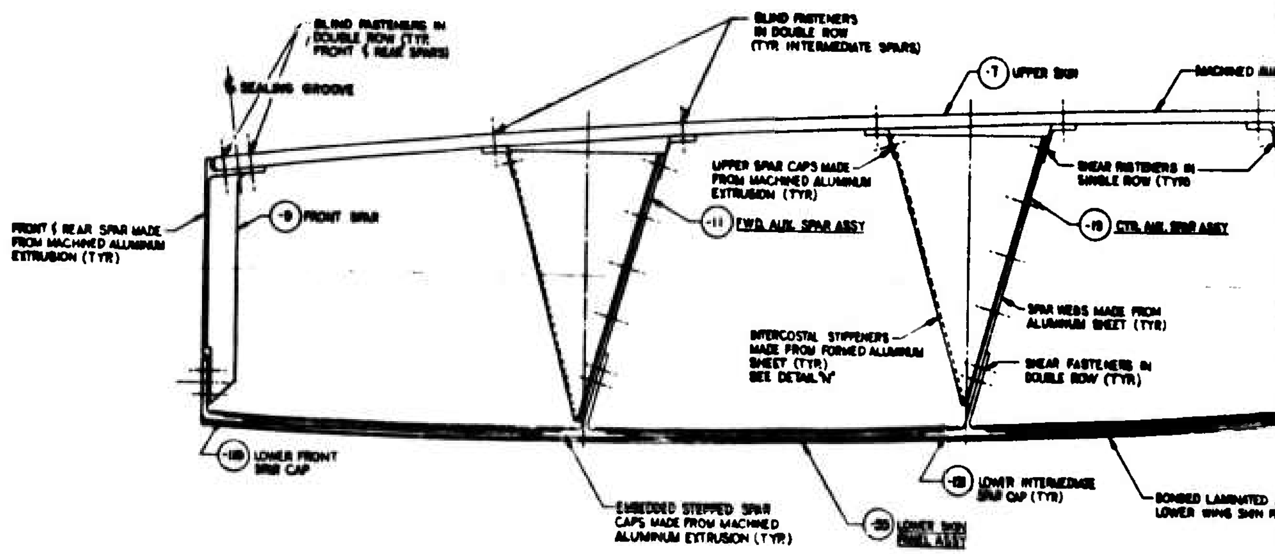
SECTION K-K
SCALE: 1/0
-1 ASSY



SECTION C-C
SCALE: 1/2

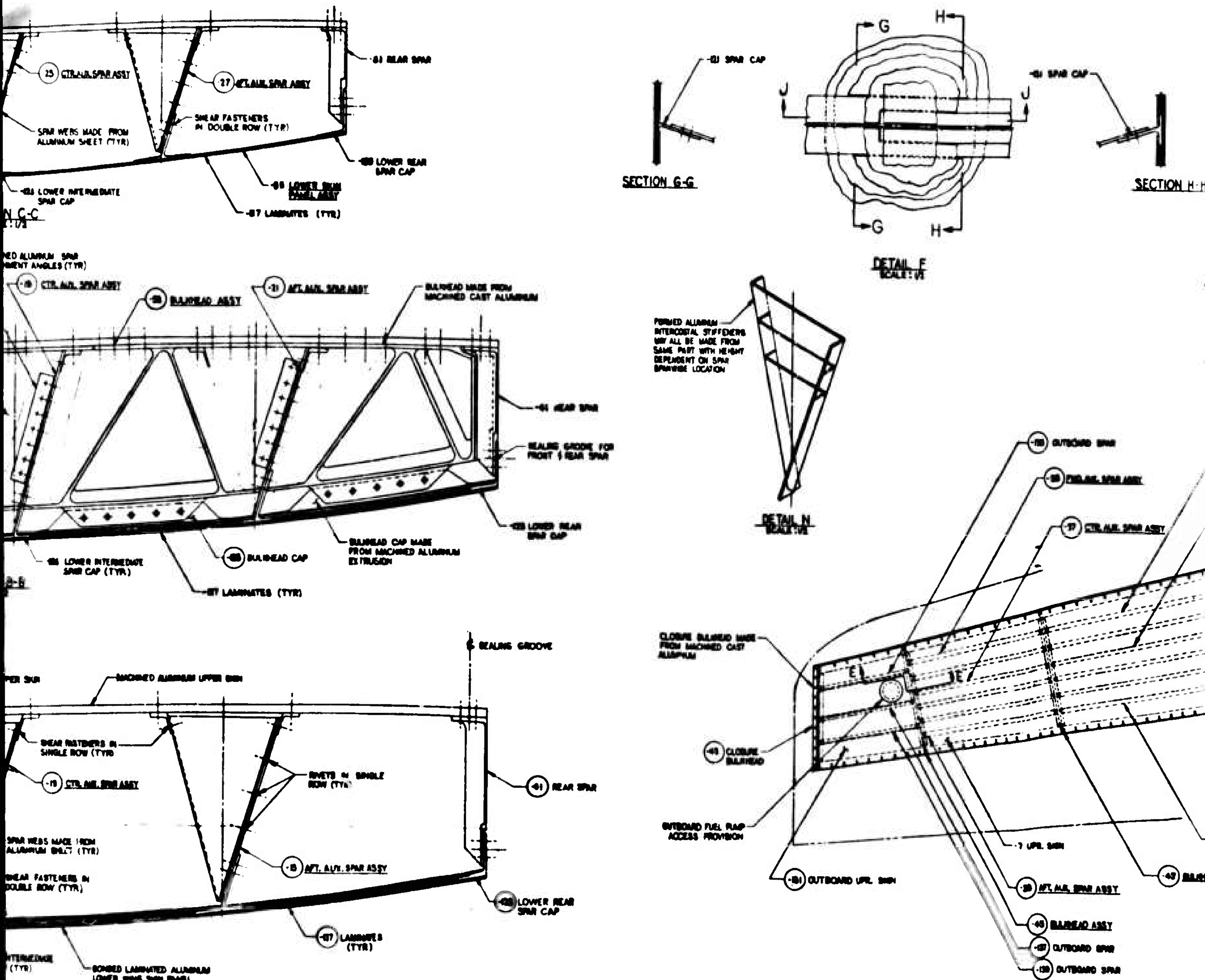


SECTION B-B
SCALE: 1/2



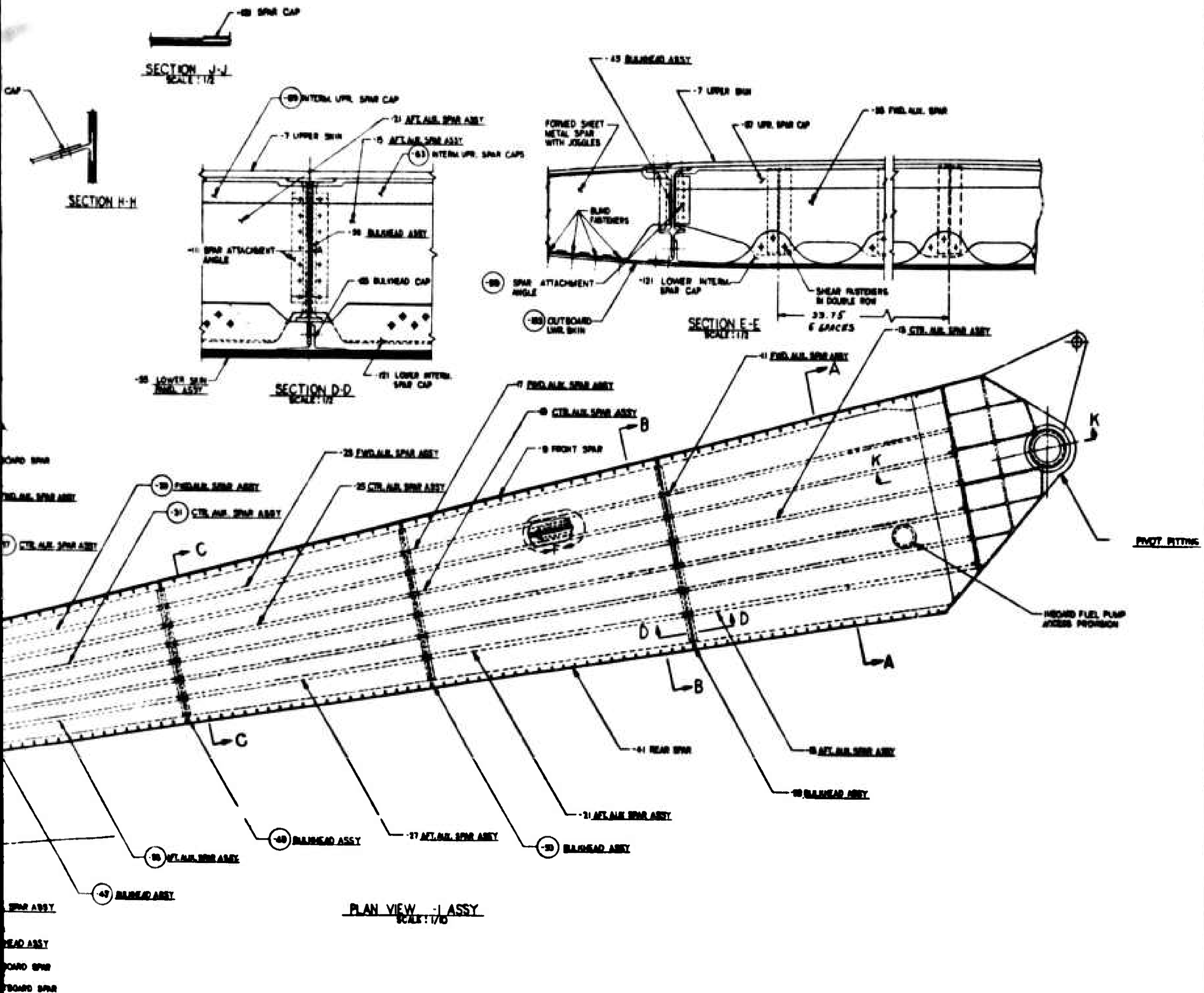
SECTION A-A
SCALE: 1/2

3

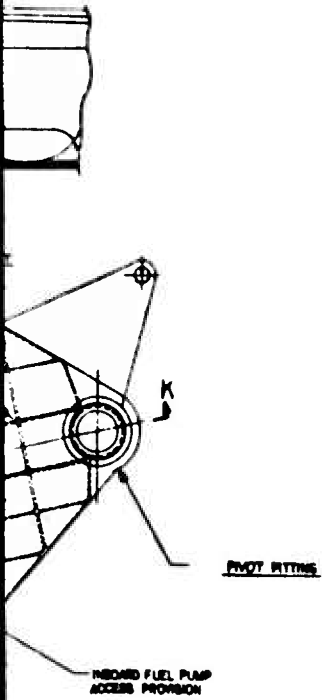


REAR SPAR
CTR AUX SPAR ASSY
AFT AUX SPAR ASSY
SPAR WEBS MADE FROM ALUMINUM SHEET (TYP)
SHEAR FASTENERS IN DOUBLE ROW (TYP)
LOWER REAR SPAR CAP
LOWER INTERMEDIATE SPAR CAP
LOWER SKIN PANEL ASSY
LAMINATES (TYP)
SPAR CAP
SECTION G-G
SECTION H-H
DETAIL F
BULKHEAD ASSY
BULKHEAD MADE FROM MACHINED CAST ALUMINUM
SEALING GROOVE FOR FRONT & REAR SPAR
BULKHEAD CAP
BULKHEAD CAP MADE FROM MACHINED ALUMINUM EXTRUSION
LOWER INTERMEDIATE SPAR CAP (TYP)
FORMED ALUMINUM INTERCOSTAL STIFFENERS MAY ALL BE MADE FROM SAME PART WITH HEIGHT DEPENDENT ON SPAR SPANWISE LOCATION
DETAIL N
OUTBOARD SPAR
CTR AUX SPAR ASSY
SEALING GROOVE
MACHINED ALUMINUM UPPER SKIN
SHEAR FASTENERS IN SINGLE ROW (TYP)
RIVETS IN SINGLE ROW (TYP)
REAR SPAR
SPAR WEBS MADE FROM ALUMINUM SHEET (TYP)
SHEAR FASTENERS IN DOUBLE ROW (TYP)
AFT. AUX. SPAR ASSY
LOWER REAR SPAR CAP
LAMINATES (TYP)
BONDED LAMINATED ALUMINUM LOWER WING SKIN PANEL
CLOSURE BULKHEAD MADE FROM MACHINED CAST ALUMINUM
CLOSURE BULKHEAD
OUTBOARD FUEL PUMP ACCESS PROVISION
OUTBOARD UPR. SKIN
UPR. SKIN
AFT. AUX. SPAR ASSY
BULKHEAD ASSY
OUTBOARD SPAR

4



SPAR CAP
SECTION J-J
SCALE : 1/2
SECTION H-H
INTERM. UPR. SPAR CAP
-21 AFT AUX. SPAR ASSY
-7 UPPER SKIN
-15 AFT AUX. SPAR ASSY
INTERM. UPR. SPAR CAPS
BULKHEAD ASSY
SPAR ATTACHMENT ANGLE
BULKHEAD CAP
LOWER SKIN PANEL ASSY
-121 LOWER INTERM. SPAR CAP
SECTION D-D
SCALE : 1/2
-43 BULKHEAD ASSY
-7 UPPER SKIN
FORMED SHEET METAL SPAR WITH JOGGLES
UPR. SPAR CAP
FWD. AUX. SPAR
BLIND FASTENERS
SPAR ATTACHMENT ANGLE
-121 LOWER INTERM. SPAR CAP
SHEAR FASTENERS IN DOUBLE ROW
OUTBOARD LWR. SKIN
33.75
6 SPACES
SECTION E-E
SCALE : 1/2
-13 CTR. AUX. SPAR ASSY
-11 FWD. AUX. SPAR ASSY
-17 FWD. AUX. SPAR ASSY
CTR. AUX. SPAR ASSY
-9 FRONT SPAR
-23 FWD. AUX. SPAR ASSY
-25 CTR. AUX. SPAR ASSY
FWD. AUX. SPAR ASSY
CTR. AUX. SPAR ASSY
PIVOT FITTING
INBOARD FUEL PUMP ACCESS PROVISION
-41 REAR SPAR
AFT. AUX. SPAR ASSY
BULKHEAD ASSY
-21 AFT. AUX. SPAR ASSY
-27 AFT. AUX. SPAR ASSY
BULKHEAD ASSY
AFT. AUX. SPAR ASSY
BULKHEAD ASSY
PLAN VIEW -1 ASSY
SCALE : 1/10



LIST OF MATERIALS

ASST	SUB ASSY	DETAIL	PART NAME	NO REQ'D	DESCRIPTION	MATERIAL	RAW STOCK SIZE	RAW STOCK WEIGHT	FINISHED WT. IN LBS.	COST $
-1	-11,13,15		INTERM. SPAR ASSY'S	1 EACH					71.76	
		-63	INTERM. UPR. SPAR CAPS	2 EACH	AL EXTR	2024 T8511	0.32 in² × 90.0	17.28	17.28	
		-65	INTERCOSTAL STIFFENERS	12 EA.	FORMED AL	2024-T81	8.5 × 1.5 × 0.080	33.13	15.41	
		-67	SPAR WEB	1 EACH	AL SHEET	2024 T81	12.0 × 90.0 × .125	40.80	38.91	
			RIVET	390	C089-5-6				0.26	
	-17,19,21		INTERM SPAR ASSY'S	1 EACH					43.61	
		-69	INTERM. UPR SPAR CAPS	2 EACH	AL EXTR	2024-T8511	0.32 in² × 80.0	15.36	15.36	
		-71	INTERCOSTAL STIFFENERS	11 EA	FORMED AL	2024-T81	8.5 × 11.3 × 0.080	33.91	10.73	
		-73	SPAR WEB	1 EACH	AL SHEET	2024 T81	10.8 × 80.0 × 0.100	23.20	23.28	
			RIVET	320	C089-5-6				0.24	
	-23,25,27		INTERM. SPAR ASSY'S	1 EACH					37.56	
		-75	INTERM UPR SPAR CAPS	2 EACH	AL EXTR	2024 T8511	0.32 in² × 75.0	14.40	14.40	
		-77	INTERCOSTAL STIFFENERS	10 EA	FORMED AL	2024-T81	8.5 × 11.8 × 0.080	23.46	8.18	
		-79	SPAR WEB	1 EACH	AL SHEET	2024-T81	9.0 × 75.0 × 0.080	16.20	14.58	
			RIVET	300	C089-5-6				0.22	
	-29,31,33		INTERM SPAR ASSY'S	1 EACH					24.23	
		-81	INTERM UPR SPAR CAPS	2 EACH	AL EXTR	2024-T8511	0.32 in² × 60.0	11.32	11.32	
		-83	INTERCOSTAL STIFFENERS	9 EA	FORMED AL	2024-T81	8.5 × 11.5 × 0.080	18.77	4.58	
		-85	SPAR WEB	1 EACH	AL SHEET	2024-T81	8.0 × 60.0 × 0.063	9.07	7.96	
			RIVET	250	C089-5-8				0.17	
	-35,37,39		INTERM. SPAR ASSY'S	1 EACH					16.80	
		-87	INTERM. UPR. SPAR CAPS	2 EACH	AL EXTR	2024-T8511	0.32 in² × 46.0	8.64	8.64	
		-89	INTERCOSTAL STIFFENERS	6 EA	FORMED AL.	2024-T81	8.5 × 11.3 × 0.080	14.08	2.70	
		-91	SPAR WEB	1 EACH	AL SHEET	2024-T81	8.3 × 45.0 × 0.063	8.83	8.10	
			RIVET	210	C089-5-8				0.16	
		-43	CLOSURE BULKHEAD	1	ALUM. CASTING	A356-T6	43.5 in³	4.33	3.69	
	-45		BULKHEAD ASSY	1					3.57	
		-97	BULKHEAD	1	MACH ALUM.	2024-T851	8.5 × 35.0 × 2.75	62.56	3.46	
		-99	SPAR ATTACH. ANGLE	3	FORMED AL ANGLES	2024-T81	2.0 × .063 × 3.0	0.11	0.11	
	-47		BULKHEAD ASST	1					4.80	
		-101	BULKHEAD	1	MACH. ALUM.	2024-T851	7.8 × 40.0 × 2.75	82.50	4.49	
		-103	SPAR ATTACH. ANGLE	6	FORMED AL. ANGLES	2024-T81	2.0 × .063 × 4.1	0.31	0.31	
	-49		BULKHEAD ASSY	1					6.50	
		-105	BULKHEAD	1	MACH. ALUM.	2024-T851	9.0 × 45.0 × 2.75	111.38	6.14	
		-107	SPAR ATTACH. ANGLE	6	FORMED AL ANGLES	2024-T81	2.0 × .063 × 4.8	0.36	0.36	
	-51		BULKHEAD ASSY	1					8.83	
		-109	BULKHEAD	1	MACH. ALUM.	2024-T851	10.5 × 52.0 × 2.75	150.18	8.43	
		-111	SPAR ATTACH. ANGLE	6	FORMED AL ANGLES	2024-T81	3.0 × .063 × 5.7	0.43	0.40	
	-53		BULKHEAD ASSY	1					11.76	
		-113	BULKHEAD	1	MACH. ALUM.	2024-T851	12.0 × 60.0 × 2.75	198.00	11.25	
		-115	SPAR ATTACH. ANGLE	9	FORMED AL. ANGLES	2024-T81	2.0 × .063 × 6.3	0.81	0.81	
	-55		LOWER SKIN PANEL ASSY	1					884.77	
		-117	LAMINATES	AS REQD	PROFILE, CHEM. ETCH A CONSTANT TAPER IN 20% OF THE TOTAL AREA OF ALL LAMINATES, & ROLL FORM CONTOUR PRIOR TO BONDING	2024-T81	.063 × 70 × 413 .063 × 70 × 413 .063 × 70 × 310 .071 × 70 × 310 .071 × 70 × 335 .071 × 70 × 155	874.48	585.21	
		-119	LWR. FRONT SPAR CAP	1	AL. EXTR.	2024-T8511	1.0 in² × 350.0	35.0	23.45	
		-121	LWR. INTERM. SPAR CAP	3	AL. EXTR.	2024 T8511	2.0 in² × 950.0	210.0	117.92	
		-123	LWR. REAR SPAR CAP	1	AL. EXTR.	2024 T8511	1.0 in² × 350.0	38.0	23.45	
		-125	BULKHEAD CAP	5	ALUM. EXTR.	2024-T8511	0.37 in² × 46.0 AVG	20.0	9.43	
		-127	ADHESIVE			FMS 1013	52.49 yd²	42.0	38.0	
		-129	PIVOT PLATE	1	MACH FORGING	2024-T851	48 × 58 × 4	188.0	65.7	
		-141	SHIM (PIVOT FTG)	1	MACH PLATE	2024-T851	12 × 14 × 0.60	10.2	8.1	
		-143	BULKHEAD	1	MACH. FORGING	2024-T851	10 × 10 × 45	90.0	36.0	
		-145	BARREL FTG	1	MACH FORGING	2024-T851	15 DIA × 11.3	141.0	15.8	
		-147	PLATE (ALMOND)	1	MACH PLATE	10 Ni STEEL	30 × 20 × 0.75	80.0	38.0	
		-149	PLATE (BOOMERANG)	1	MACH PLATE	10 Ni STEEL	85 × 95 × 0.75	212.0	80.0	
		-151	PIVOT LUG, UPR	1	MACH FORGING	10 Ni STEEL	22 × 45 × 15	495.0	166.0	
		-153	SPLICE FTG	1	MACH EXTR.	2024-T8511	0.5 in² × 18	0.6	0.3	
		-155	REAR SPAR, PIVOT	1	MACH EXTR	2024-T8511	2.0 in² × 44	13.0	11.3	
		-157	FRONT SPAR, PIVOT	1	MACH EXTR	2024-T8511	2.0 in² × 27	10.0	9.1	
		-159	BUSHING	1	MACH. FORGING	10 Ni STEEL	9.0 DIA × 2	10.8	3.9	
		-161	BUSHING	2	MACH FORGING	10 Ni STEEL	9.0 DIA × 3	85.8	16.4	
		-163	WING ACT ARM	1	MACH FORGING	10 Ni STEEL	26 × 26	96.0	24.0	
		[illegible]	MISC FITTINGS		MACH PLATE	2024-T851			38.1	
		[illegible]	TANK COATING			POLYURETHANE			17.0	
		[illegible]	SEALANT & FINISH						8.2	
			BOLT	12	C380-13-44				3.04	
			NUT	12	C289-13				0.48	
			RIVET, BLIND	2320	MS 90353-082				42.9	
			PIN	740	CC2C × 6 [illegible]				4.2	
-1			NUT	740	C2950 [illegible]				1.92	

6

STOCK SIZE	RAW STOCK WEIGHT	FINISHED WT. IN LBS.	COST $
		71.76	
·900	17.26	17.26	
·0.080	58.18	15.41	
·125	40.80	38.81	
		0.26	
		42.81	
·80.0	15.38	15.38	
5·0.080	25.81	10.73	
·0.100	25.20	25.26	
		0.24	
		27.56	
·72.0	14.40	14.40	
5·0.080	28.48	8.16	
73.0·0.080	16.20	14.58	
		0.22	
		24.23	
·60.0	11.82	11.82	
5·0.080	16.77	4.38	
·0.063	9.07	7.96	
		0.19	
		16.80	
·45.0	8.84	8.64	
5·0.080	14.08	2.70	
45.0·0.080	8.88	8.10	
		0.16	
	4.23	3.69	
		3.57	
35.0·2.75	62.56	3.46	
63·3.0	0.11	0.11	
		9.80	
0.0·2.75	82.50	4.49	
063·4.1	0.81	0.31	
		6.50	
0·2.75	111.38	6.14	
63·4.8	0.36	0.36	
		8.85	
20·2.75	150.15	8.42	
63·5.7	0.43	0.48	
		11.76	
0·2.75	198.00	11.25	
63·6.8	0.91	0.81	
		884.77	
0·412 0·412 0·370 0·310 0·235 0·95	874.45	865.79	
·350.0	38.0	23.45	
350.0	210.0	117.62	
·350.0	38.0	23.45	
·46.0	20.0	9.42	
	42.0	36.0	
·4	156.0	65.7	
	10.2	8.1	
·45	90.0	36.0	
·3	141.0	13.8	
·0.75	80.0	36.0	
·0.75	212.0	80.0	
·19	498.0	166.0	
·5	0.6	0.2	
·44	12.0	11.2	
·27	10.0	9.1	
·2	10.5	3.6	
·3	85.6	16.4	
	96.0	24.0	
		38.1	
		170	
		8.2	
		3.04	
		0.46	
		42.9	
		4.2	
		1.92	

LIST OF MATERIALS

ASSY	SUB ASSY	DETAIL	PART NAME	NO. REQ'D	DESCRIPTION	MATERIAL	RAW STOCK SIZE	RAW STOCK WEIGHT	FINISHED WT. IN LBS	COST $
-1 CONT.			RIVET	300	MS20426AD6				0.2	
		-7	UPPER SKIN	1	MACHINE FROM PLATE	2024-T851	575·4·2·(TAPER)	1968.0	636.0	
		-9	FRONT SPAR	1	MACHINE FROM EXTRU.	2024-T8511	8.120 in²·	812.0	67.30	
		-41	REAR SPAR	1	MACHINE FROM EXTRU.	2024-T8511	860·°	860	64.20	
		-131	OUTBD. UPR. SKIN	1	STRETCH FORM & ETCH	2024-T81	0.150·36·40	22.0	12.88	
		-133	OUTBD. LWR. SKIN	1	STRETCH FORM & ETCH	2024-T81	0.180·36·40	22.0	12.88	
		-135	OUTBD. SPAR	1	FORMED AL.	2024-T81	.080·7·96	1.80	1.40	
		-137	OUTBD. SPAR	1	FORMED AL.	2024-T81	.080·7·96	1.80	1.40	
		-139	OUTBD. SPAR	1	FORMED AL.	2024-T81	.080·7·96	1.80	1.40	
		-171	CLIPS	4	MACH. EXTR.	2024-T8511	9.0·3.0·0.18	1.6	1.4	
		-173	RIB	1	MACH. EXTR.	2024-T8511	1.8 in²·56	12.0	9.8	
		-175	BOOT SPARS	2	MACH. EXTR.	2024-T8511	1.8 in²·16	9.8	7.8	
			BOLT	40	C081-12-18				13.76	
			NUT, BLIND	40	C050-1216-8				7.42	
-1			WING BOX ASSY	1					2481.0	

NOTE: -3 ASSY SAME AS -1 EXCEPT FOR SUBSTITUTIONS & ADDITIONS AS SHOWN IN -3 ASSY L.M. BELOW.

ASSY	REPLACES -1	-3 DETAIL	PART NAME	NO. REQ'D	DESCRIPTION	MATERIAL	RAW STOCK SIZE	RAW STOCK WEIGHT	FIN. WEIGHT	COST $
-3	-167	-177	PLATE (ALMOND)	1	MACH. PLATE	10 Ni STEEL	30·20·0.75	127.4	[illegible]	
	-169	-179	PLATE (BOOMERANG)	1	MACH. PLATE	10 Ni STEEL	50·[illegible]·1.0	272.4	[illegible]	
	-157, -161	-181	BUSHING	2	MACH. FORGING	10 Ni STEEL	[illegible]·4.0	20.0	7.0	
		-183	RETAINING NUT	2	MACH. FORGING	10 Ni STEEL	9.40·3.0	12.0	4.3	
	-141	-185	SHIM	1	MACH. PLATE	2024-T851	12·14·0.60	16.1	8.1	
	-145	-187	BARREL FITTING	1	MACH. FORGING	2024-T851	18 DIA·11.8	161.0	48.6	
	-143	-189	BULKHEAD	1	MACH. FORGING	2024-T851	10·10·48	[illegible]	48.7	
	-175	-191	INTERIOR SPAR	2	MACH. EXTR.	2024-T8511	[illegible] in²·16.0	[illegible]	[illegible]	
	-171	-193	CLIP	4	FORMED AL.	2024-T81	9.0·3.0·0.180	1.6	1.3	
	-173	-195	RIB	1	MACH. EXTR.	2024-T8511	1.8 in²·56	12.0	[illegible]	
	-151	-197	LUG FITTING	1	MACH. FORGING	10 Ni STEEL	22·46·1.8	800.0	[illegible]	
	-129	-199	PIVOT PLATE	1	MACH. FORGING	2029-T851	48·80·4	800.0	[illegible]	
	-187	-201	FRONT SPAR	1	MACH. EXTR.	2024-T8511	2.0 in²·27	5.4	5.2	
	[illegible]	-203	REAR SPAR	1	MACH. EXTR.	2024-T8511	2.0 in²·44	8.6	8.4	
	[illegible]	-205	SPLICE FTG.	1	MACH. EXTR.	2024-T8511	0.5 in²·15	0.7	0.5	
	[illegible]	-207	WING ACT. ARM	1	MACH. FORGING	10 Ni STEEL	36·28	96.0	24.0	
		✓	BOLT	6	C081-10-36				0.67	
		✓	NUT	2	C080-10				0.09	
-3			ALT. WING BOX ASSY						[illegible]	

PRELIMINARY DESIGN DRAWING

ATW-4 WING BOX - LAMINATED ALUMINUM LOWER SKIN, CANTED SPARS

GENERAL DYNAMICS
Convair Aerospace Division

633-RW002

Figure 49 Slanted Spar Preliminary Design

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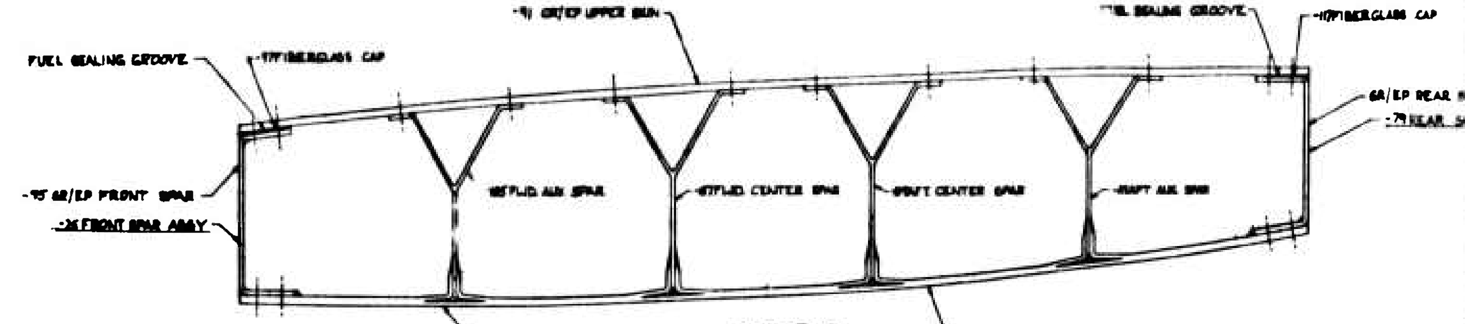
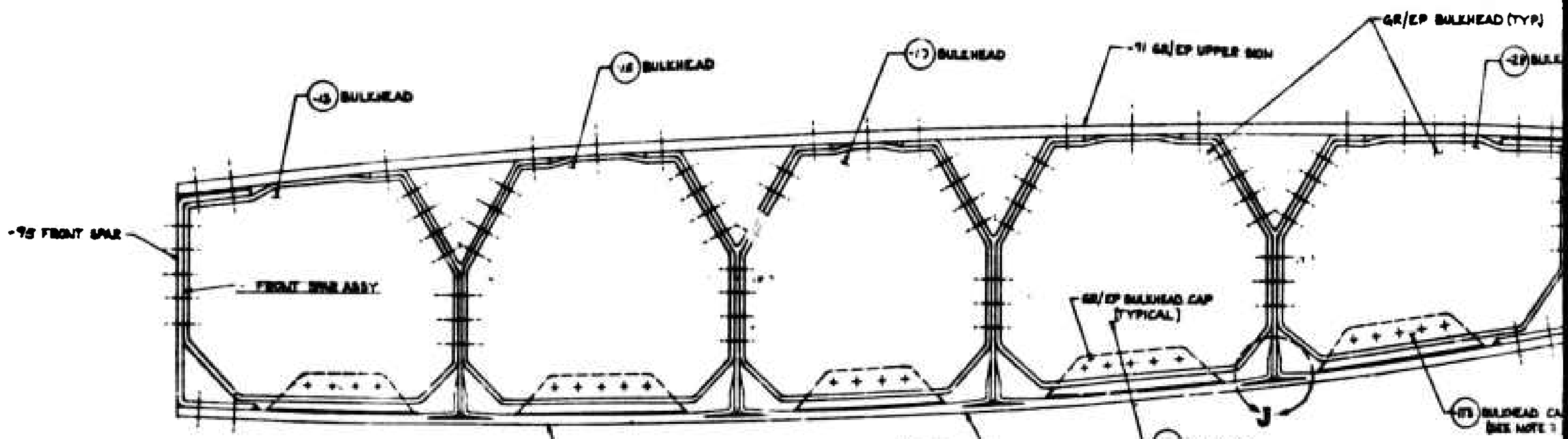


SECT. C-C



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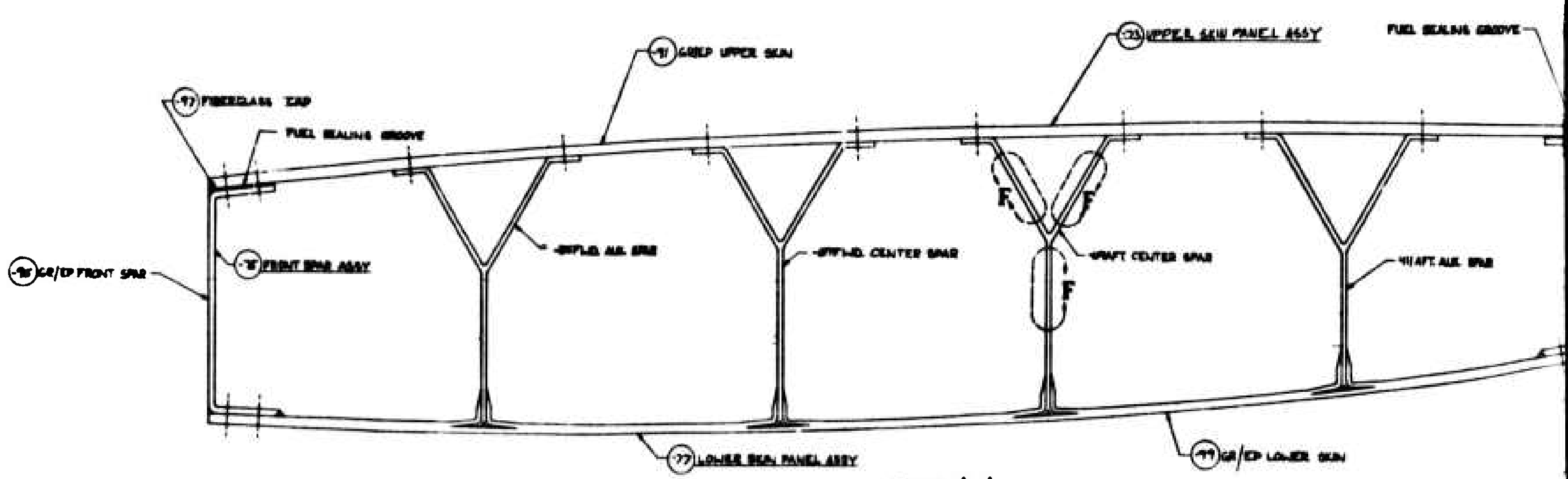
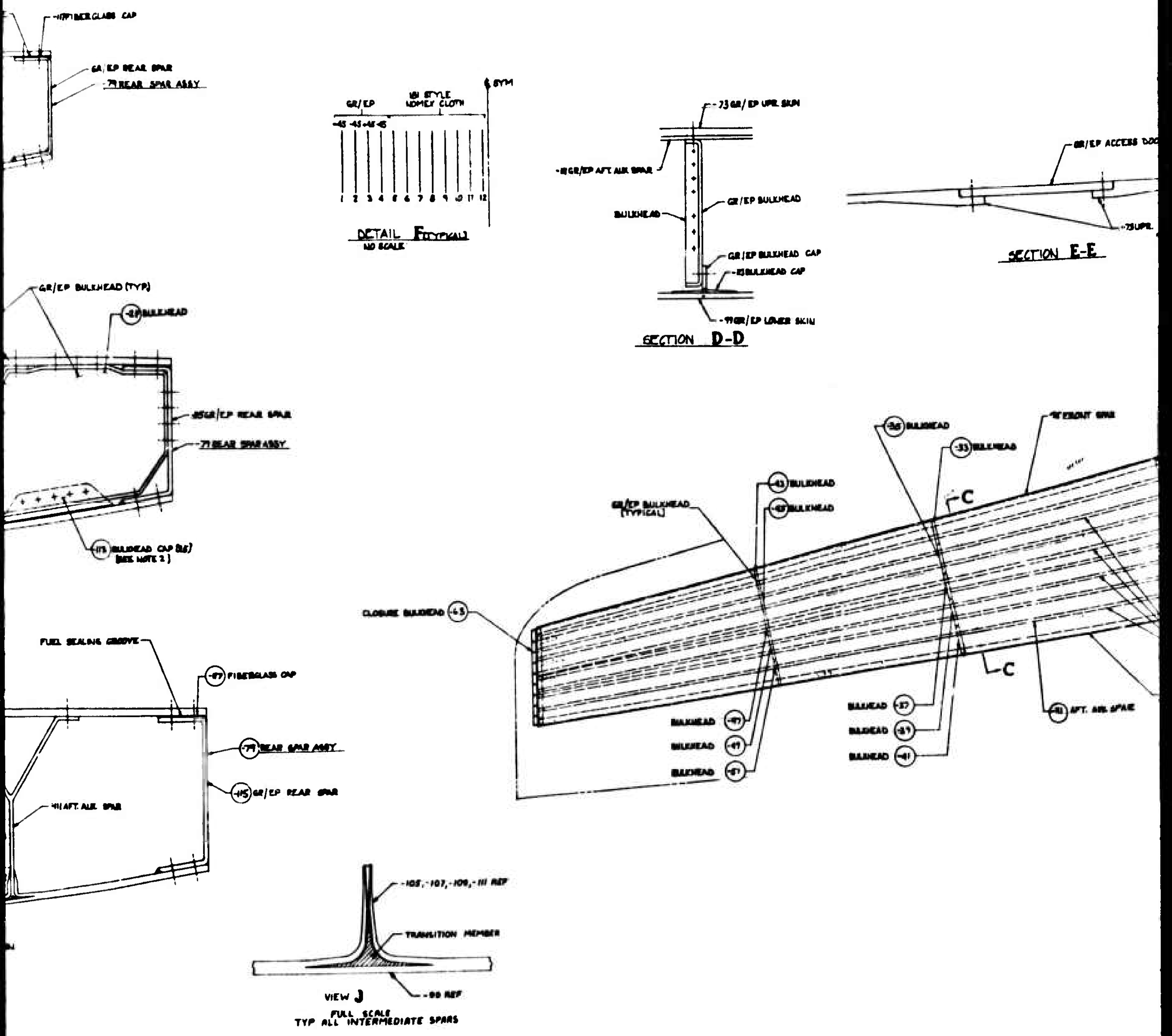


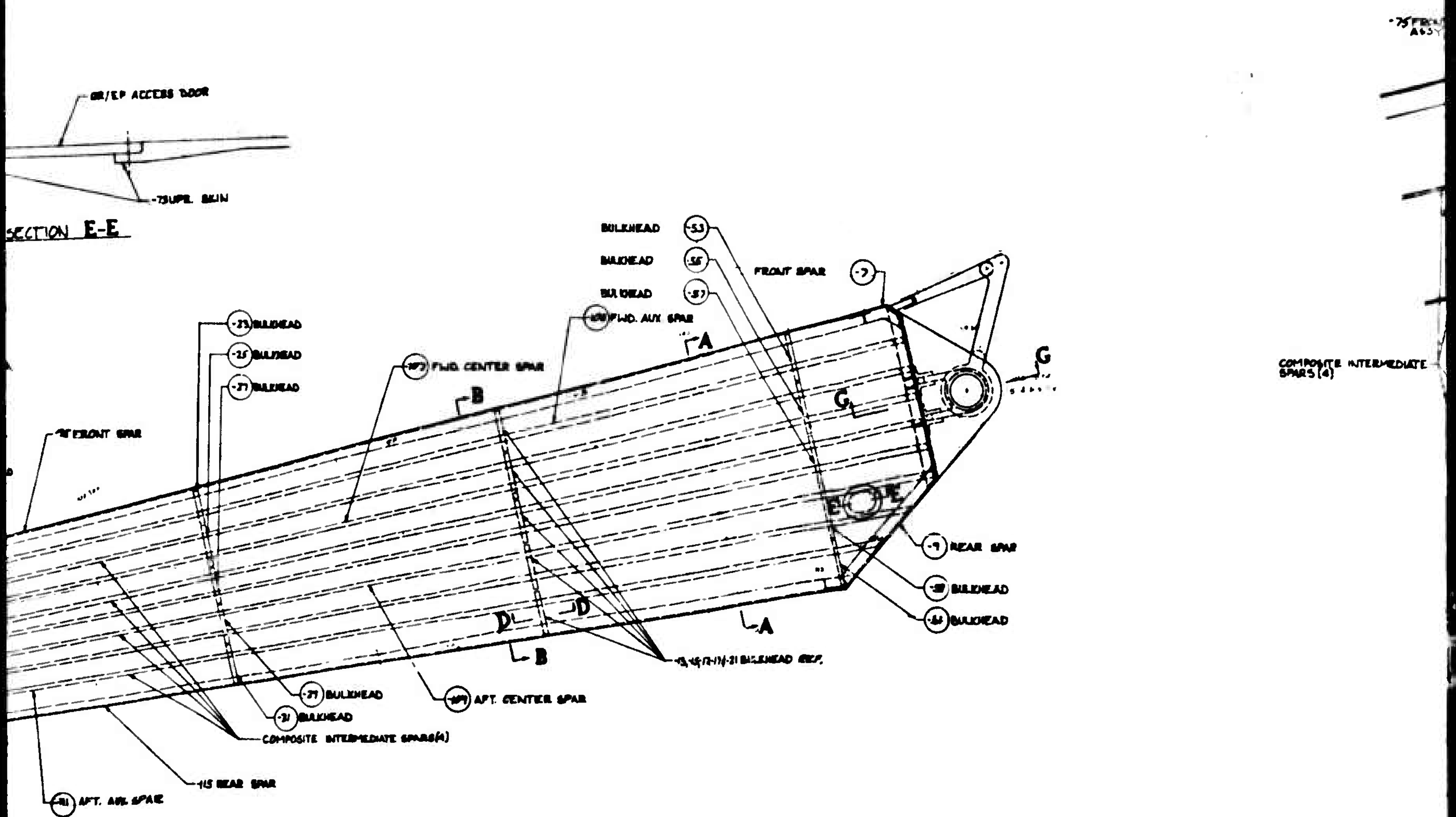
SECT. A-A

2



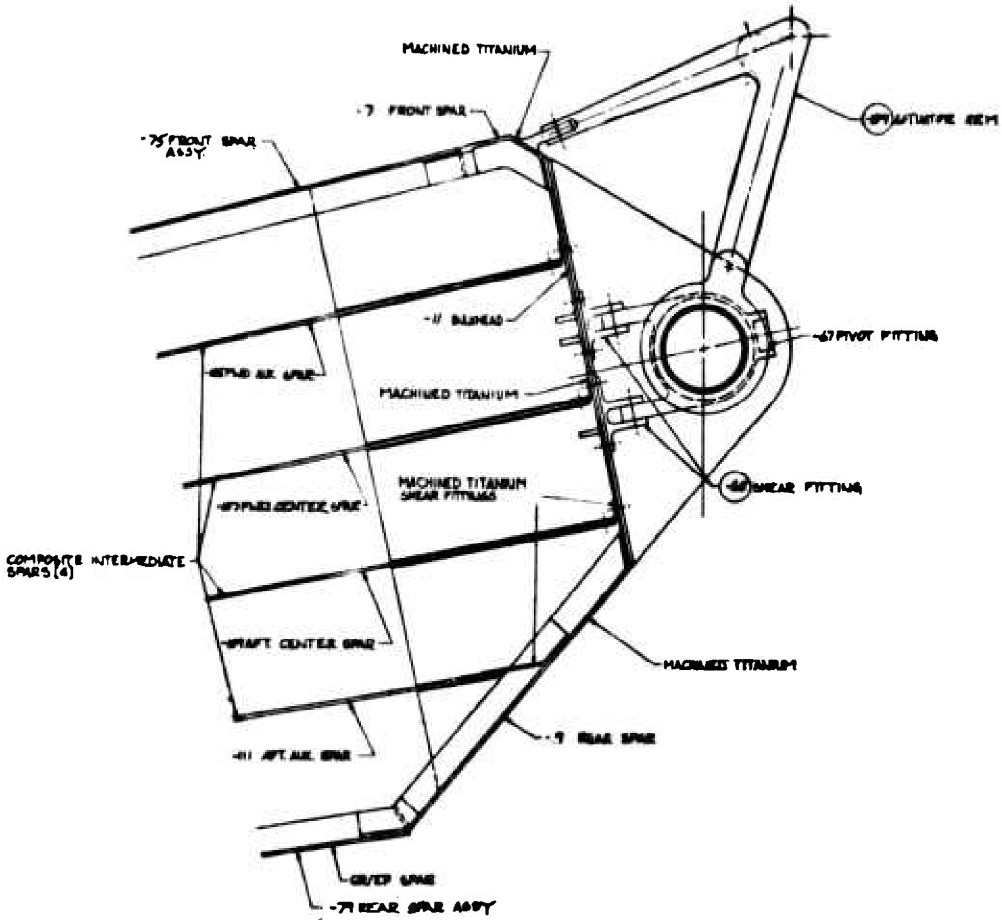
-117 FIBERGLASS CAP
GR/EP REAR SPAR
-79 REAR SPAR ASSY
GR/EP
181 STYLE NOMEX CLOTH
℄ SYM
1 2 3 4 5 6 7 8 9 10 11 12
DETAIL F (TYPICAL)
NO SCALE
-73 GR/EP UPR SKIN
GR/EP AFT AUX SPAR
BULKHEAD
GR/EP BULKHEAD
GR/EP BULKHEAD CAP
-15 BULKHEAD CAP
GR/EP LOWER SKIN
SECTION D-D
GR/EP ACCESS DOOR
-73 UPR.
SECTION E-E
GR/EP BULKHEAD (TYP)
BULKHEAD
GR/EP REAR SPAR
-79 REAR SPAR ASSY
BULKHEAD CAP
(SEE NOTE 2)
BULKHEAD
BULKHEAD
FRONT SPAR
BULKHEAD
BULKHEAD
GR/EP BULKHEAD (TYPICAL)
C
CLOSURE BULKHEAD (-65)
FUEL SEALING GROOVE
FIBERGLASS CAP
(-79) REAR SPAR ASSY
(-115) GR/EP REAR SPAR
AFT AUX SPAR
BULKHEAD (-37)
BULKHEAD
BULKHEAD (-41)
AFT. AUX SPAR
BULKHEAD
BULKHEAD
BULKHEAD
-105, -107, -109, -111 REF
TRANSITION MEMBER
VIEW J
FULL SCALE
TYP ALL INTERMEDIATE SPARS

3

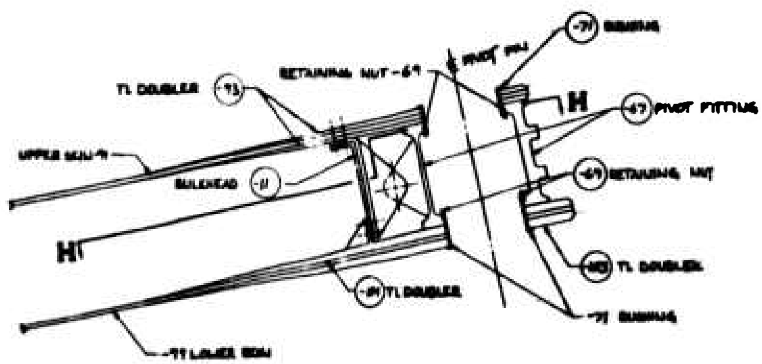


ACCESS DOOR
-73UPR. SKIN
SECTION E-E
BULKHEAD
BULKHEAD
BULKHEAD
FRONT SPAR
FWD. AUX SPAR
FWD. CENTER SPAR
BULKHEAD
BULKHEAD
BULKHEAD
FRONT SPAR
A
B
G
G
E
E
REAR SPAR
BULKHEAD
BULKHEAD
A
D
D
B
BULKHEAD REF.
BULKHEAD
BULKHEAD
APT. CENTER SPAR
COMPOSITE INTERMEDIATE SPARS(4)
-115 REAR SPAR
APT. AUX SPAR
COMPOSITE INTERMEDIATE SPARS (4)

4



VIEW H-H



SECT. G-G

ASSY	DASH NO SUB ASSY	DETAIL	PART NAME
-7			GR/EP WING BOX
		-7	FRONT SPAR (PIVOT)
		-9	REAR SPAR (PIVOT)
		-11	CLOSURE BHD. (PIVOT)
		-13	BULKHEAD
		-61	BULKHEAD
		-63	CLOSURE AND
		-65	SHEAR FITTING
		-67	PIVOT FITTING
		-69	RETAINING NUT
		-71	BUSHING
	-73		UPPER SKIN PANEL ASSY
		-91	UPPER SKIN
		-93	TI DOUBLER
	-75		FRONT SPAR ASSY
		-95	FRONT SPAR
		-97	CAP
	-77		LOWER SKIN PANEL ASSY
		-99	LOWER SKIN
		-101	TI DOUBLER
		-103	TI DOUBLER
		-105	FWD AUX SPAR
		-107	FWD CENTER SPAR
		-109	AFT CENTER SPAR
		-111	AFT AUX SPAR
		-113	BULKHEAD CAP
	-79		REAR SPAR ASSY
		-115	REAR SPAR
		-117	CAP
		-81	ADHESIVE
		-83	SEALANT
		-85	MISC. HARDWARE
			FASTENERS
			BLIND FASTENERS
			M6 2140-0809 (AVG. FASTENER)
			SHEAR FASTENER C030-10-6 (AVG. FASTENER)
			C2950-10 (NUT) (AVG. NUT)
			C081-10 (BOLT)
			C080-10 (NUT)
		-87	FLUID BARRIER
		-89	ACTUATOR ARM
-5			GR/EP WING BOX

5

ASSY	DASH NO SUB ASSY	DETAIL	PART NAME	NO REQ'D	DESCRIPTION	MATERIAL	RAW STK. SIZE	RAW STK. WT	FINISHED WT. IN LBS	COST $
-1			GR/EP WING BOX						2247.[illegible]	
		-7	FRONT SPAR (PIVOT)	1	MACHINED TI	TI 6AL-4V BETA ANNEALED COND	904 IN³	144.77	14.76	
		-9	REAR SPAR (PIVOT)	1	MACHINED TI.	TI 6AL-4V BETA ANNEALED COND	1430 IN³	228.80	38.40	
		-11	CLOSURE BHD. (PIVOT)	1	MACHINED TI	TI 6AL 4V BETA ANNEALED COND	1674.75 IN³	262.96	26.18	
		-13 thru -61	BULKHEAD thru BULKHEAD	25	GR/EP BHD SEG.	T300-5208 GR/EP 3" PRE PREG TAPE	27,788 FT OF 3" TAPE	59.39	28.40	
		-63	CLOSURE BHD	1	AL CASTING	A356-T6	43.3 in³	4.33	3.69	
		-65	SHEAR FITTING	2	MACHINED TI	TI 6AL-4V BETA			30.[illegible]	
		-67	PIVOT FITTING	1	MACHINED TI	ANNEALED COND	9.50 IN DIA RING	408.84?	84.45?	
		-69	RETAINING NUT	2	MACHINED FORG.	17-4PH	[illegible] IN DIA RING	8.00	3.20	
		-71	BUSHING	2	MACHINED FORG.	17-4PH	65.74 IN³/PT	32.80	14.40	
	-73		UPPER SKIN PANEL ASSY	1					[illegible]	
		-91	UPPER SKIN	1	GR/EP WING SKIN	T300-5208 GR/EP 3" PRE-PREG TAPE	46,070. FT OF 3" TAPE	662.60	481.40	
		-93	TI DOUBLER	2	MACHINED TI	TI 6AL-4V BETA ANNEALED COND			257.00	
	-75		FRONT SPAR ASSY							
		-95	FRONT SPAR		GR/EP FRONT SPAR	T300-5208 GR/EP 3" PRE-PREG TAPE	[illegible] FT OF 3" TAPE	83.0[illegible]	59.86	
		-97	CAP	1	FIBERGLASS CAP	FMS-1023 CLASS I			4.25	
	-77		LOWER SKIN PANEL ASSY							
		-99	LOWER SKIN	1	GR/EP WING SKIN	T300-5208 GR/EP 3" PRE PREG TAPE	42,931. FT OF 3" TAPE	622.2	448.60	
		-101	TI DOUBLER	1	MACHINED TI	TI 6AL-4V BETA	[illegible] IN³	[illegible]	[illegible]	
		-103	TI DOUBLER	1	MACHINED TI	ANNEALED COND	[illegible] IN³	376	[illegible]	
		-105	FWD AUX SPAR	1	GR/EP INTMED Y SPAR W/ NOMEX CLOTH CORE	T300-5208 GR/EP 3" PRE-PREG TAPE	600[illegible] FT OF 3" TAPE	87	([illegible])	
		-107	FWD CENTER SPAR	1						
		-109	AFT CENTER SPAR	1						
		-111	AFT AUX SPAR	1		NOMEX CLOTH	[illegible] FT³	[illegible]	([illegible])	
		-113	BULKHEAD CAP	25	GR/EP BHD CAP	T300-5208 GR/EP 3" PRE-PREG TAPE	[illegible] FT OF 3" TAPE	[illegible]	[illegible]	
	-79		REAR SPAR ASSY							
		-115	REAR SPAR	1	GR/EP REAR SPAR	T300-5208 GR/EP 3" PRE-PREG TAPE	5,0[illegible] FT OF 3" TAPE	72.70	51.42	
		-117	CAP	1	FIBERGLASS CAP	FMS-1023 CLASS I			4.00	
		-81	ADHESIVE			FMS-[illegible]		5.30	4.25	
		-83	SEALANT						4.90	
		-85	MISC HARDWARE						56.00	
			FASTENERS							
			RIVET C089-10	103					.82	
			BLIND FASTENERS (M62140-0809 AVG FASTENER)	4200					58.80	
			SHEAR FASTENER C020-10-6 (AVG FASTENER)	252					2.62	
			C2950-10 (NUT) (AVG NUT)	252					1.44	
			[illegible] (BOLT)	2					.47	
			[illegible] (NUT)	2					.08	
		-87	[illegible] BARRIER						48.00	
		-89	ACTUATOR ARM		MACHINED FORG.	10NI. STEEL		96	28.00	
-3			GR/EP WING BOX ASSY		SEE NOTE 1				2,006.00	

NOTE:

1. -3 WING BOX ASSY SAME AS -1 ASSY EXCEPT PIVOT FITTING IN -3 ASSY IS A CLOSED TORQUE BOX DESIGN SIMILAR TO PIVOT FITTING ON 633-RW001.
2. -113 BULKHEAD LOWER CAPS WILL BE CUT FROM 96" LONG PREFABRICATED CONSTANT SECTION MEMBERS.

PRELIMINARY DESIGN DRAWING

ATW-4 GRAPHITE EPOXY COMPOSITE WING BOX "Y" SPARS/EMBEDDED LWR. CAPS

GENERAL DYNAMICS
Convair Aerospace Division

633-RW003

Figure 50 Composite Y-Spar Preliminary Design

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TABLE VI ATW WING BOX PRELIMINARY DESIGN EVALUATION SUMMARY
(1975 DOLLARS)

DRAWING NUMBER	DESCRIPTION	STRUCT. EFFIC. COST* 1975 $ (.24)	STRUCT. EFFIC. WEIGHT* LBS. (.16)	TECHNOLOGY IMPROVE. CONCEPT (.05)	TECHNOLOGY IMPROVE. MATL. (.02)	TECHNOLOGY IMPROVE. MFG. (.03)	DAMAGE TOL. SAFE CRACK (.08)	DAMAGE TOL. FAIL SAFE (.12)	ABILITIES INSPECT- (.06)	ABILITIES MFG- (.06)	ABILITIES MAINT- (.06)	ABILITIES REPAIR- (.06)	ABILITIES DURA- (.06)	TOTAL SCORE (1.0)	RANK
633RW000	BASELINE - ATW-4 MACHINED AL., BOLTED STRUCT.	200K .209	2759.0 .116	.000	.000	.000	.078	.000	.060	.05	.058	.055	.055	.681	4
633RW001	AL. LAM. LWR. SKIN "Y" SPARS, EXPOSED LWR CAPS - CLSD PIVOT LUG AREA	174K .240	2341.0 .137	.042	.01	.024	.080	.120	.055	.052	.057	.055	.055	.927	1
633RW002 -1	AL. LAM. LWR. SKIN, SLANT SPARS, EMBEDDED LWR CAPS - CLSD PIVOT LUG AREA	178K .235	2421.0 .133	.042	.01	.024	.080	.000	.045	.052	.058	.055	.050	.784	2
633RW002 -3	AL. LAM. LWR. SKIN, SLANT SPARS, EMBEDDED LWR CAPS, OPEN PIVOT LUG AREA	185K .227	2608.0 .123	.042	.01	.028	.080	.000	.050	.055	.058	.059	.050	.782	3
633RW003 -1	GRAPHITE/EPOXY - "Y" SPAR, OPEN PIVOT LUG AREA	325K .000	2247.8 .143	.050	.02	.03	.080	.000	.06	.06	.06	.06	.060	.623	5
633RW003 -3	GRAPHITE/EPOXY - "Y" SPARS - CLOSED PIVOT LUG AREA	315K .000	2006.0 .160	.050	.02	.028	.080	.000	.05	.052	.058	.055	.060	.613	6

* COSTS AND WEIGHTS SHOWN ARE FOR ONE SIDE AND INCLUDE THE WING BOX STRUCTURE FROM THE TIP BHD TO AND INCLUDING THE PIVOT FITTING

TABLE VII ATW WING BOX PRELIMINARY DESIGN EVALUATION SUMMARY
(1980 DOLLARS)

DRAWING NUMBER	DESCRIPTION	STRUCT. EFFIC.		TECHNOLOGY IMPROVE.			DAMAGE TOL.		ABILITIES					TOTAL SCORE (1.0)	RANK
		COST* 1980 $ (.24)	WEIGHT* LBS. (.16)	CONCEPT (.05)	MATL. (.02)	MFG. (.03)	SAFE CRACK (.08)	FAIL SAFE (.12)	INSPECT- (.06)	MFG- (.06)	MAINT- (.06)	REPAIR- (.06)	DURA- (.06)		
633RW000	BASELINE - ATW-4 MACHINED AL., BOLTED STRUCT.	252K .211	2759.0 .116	.000	.000	.000	.078	.000	.060	.05	.058	.055	.055	.683	4
633RW001	AL. LAM. LWR. SKIN "Y" SPARS, EXPOSED LWR CAPS - CLSD PIVOT LUG AREA	221K .240	2341.0 .137	.042	.01	.024	.080	.120	.055	.052	.057	.055	.055	.927	1
633RW002 -1	AL. LAM. LWR. SKIN, SLANT SPARS, EMBEDDED LWR CAPS - CLSD PIVOT LUG AREA	225K .235	2421.0 .133	.042	.01	.024	.080	.000	.045	.052	.058	.055	.050	.784	2
633RW002 -3	AL. LAM. LWR. SKIN, SLANT SPARS, EMBEDDED LWR CAPS, OPEN PIVOT LUG AREA	234K .227	2608.0 .123	.042	.01	.028	.080	.000	.050	.055	.058	.059	.050	.782	3
633RW003 -1	GRAPHITE/EPOXY - "Y" SPAR, OPEN PIVOT LUG AREA	341K .000	2247.8 .143	.050	.02	.03	.080	.000	.06	.06	.06	.06	.060	.623	5
633RW003 -3	GRAPHITE/EPOXY - "Y" SPARS - CLOSED PIVOT LUG AREA	325K .000	2006.0 .160	.050	.02	.028	.080	.000	.05	.052	.058	.055	.060	.613	6

* COSTS AND WEIGHTS SHOWN ARE FOR ONE SIDE AND INCLUDE THE WING BOX STRUCTURE FROM THE TIP BHD TO AND INCLUDING THE PIVOT FITTING

SECTION IV

STRESS ANALYSIS

A large number of structural concepts was considered for application to the ATW-4 wing box. The majority of these had been considered in depth during Contracts F33615-72-C-2149 and F33615-74-C-3026. During those contracts the concepts were evaluated using a merit rating system which was acceptable to the AFFDL. It enabled refinement of very large numbers of ideas into a manageable few which are outstanding for minimizing weight and cost while meeting the strength and durability requirements of MIL-A-83444, MIL-A-8866, and MIL-STD-1530.

4.1 BASELINE STRENGTH CONSIDERATIONS

The current, ATW-4, baseline is similar in aspect ratio and root attachment to the baselines for the two previous contracts. For this reason, it has been possible to select directly the more promising arrangements and evaluate them for compliance with the current merit rating system.

The baseline for this study is a wing with supercritical airfoil. Its aspect ratio is similar to the F-111 wing but has a greater span. The baseline then is a wing that resembled an existing wing but one which had to be defined for this program (see Figure 51). Construction of the baseline was chosen to be the same as the F-111 except that two additional spars were required to accommodate the increased chord while maintaining skin stress levels similar to those on the F-111. The baseline meets the requirements of MIL-A-83444, MIL-A-8866, and MIL-STD-1530.

4.2 DESIGN LOADS

Preliminary external loadings were used to make an initial sizing of the baseline wing box for purposes of obtaining inertia data, calculating preliminary stiffness data and constructing a finite element model. These data were utilized for the preparation of the "Design Loads Data for the Variable Camber Supercritical Wing Program," FZM-12-6466 (see Appendix A).

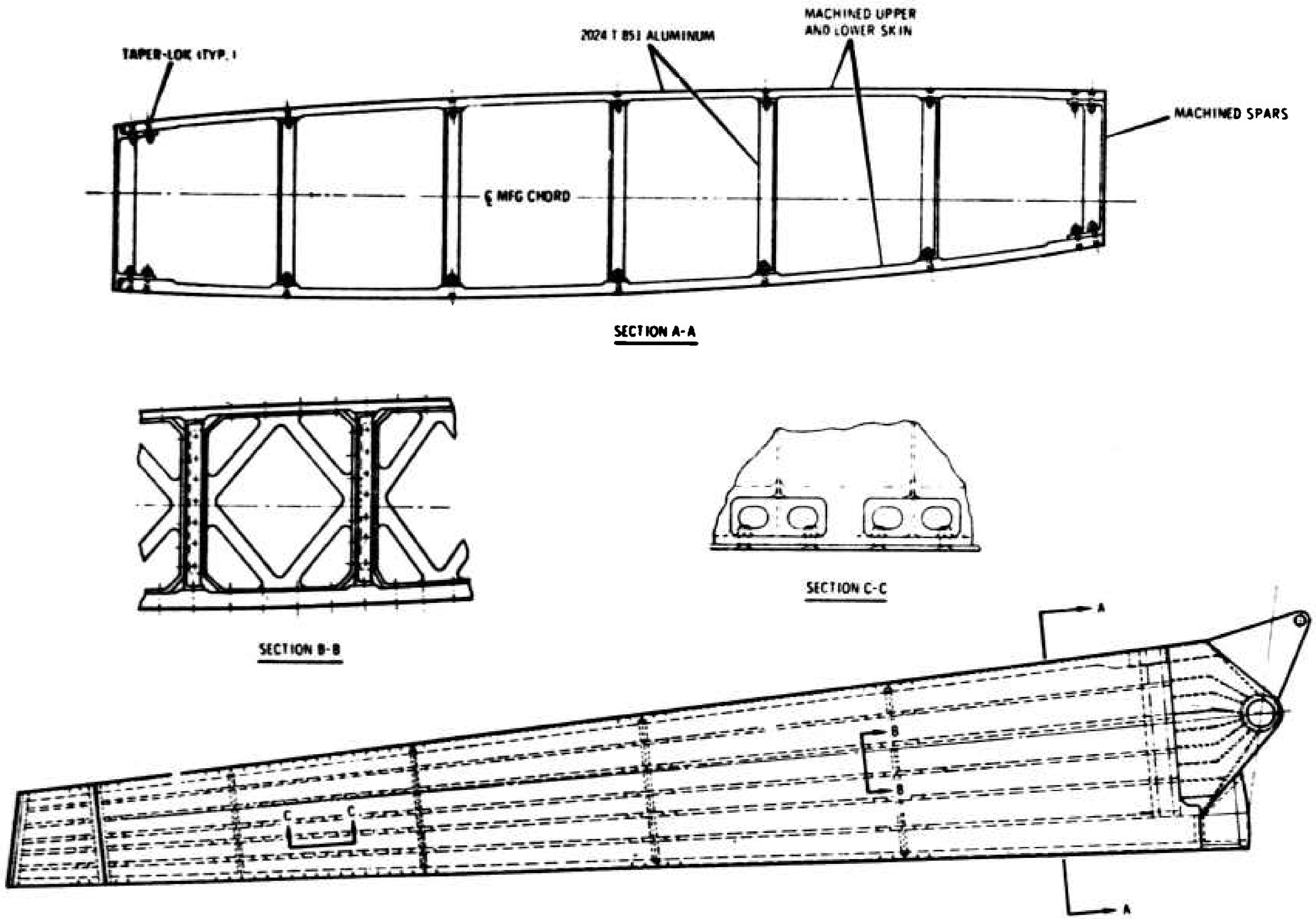


Figure 51 ATW-4 Wing Box Baseline

External loads from FZM-12-6466 were then applied to the finite element model to obtain internal loads for sizing Analytical Assemblies and Preliminary Designs of full span wing boxes. Samples of these internal loads are illustrated in Figure 52 thru Figure 54.

Fuel pressure loadings were computed using the roll rates of the F-111 with the load factors of this study and 6.0 psi constant system pressure. The resulting pressures are shown in Figure 55.

4.3 STRESS ANALYSIS AT THE ANALYTICAL ASSEMBLY LEVEL

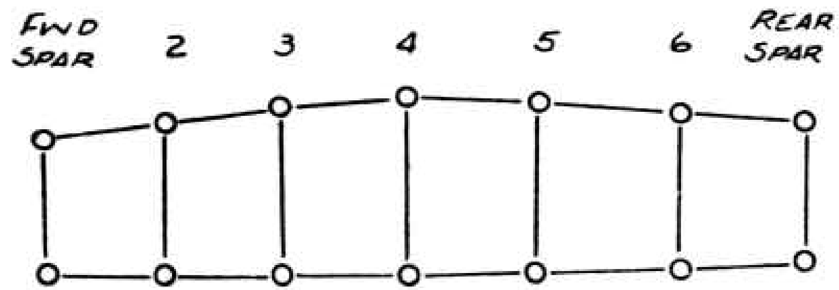
The first evaluations for this program were made at the level of "Analytical Assemblies", as first used in Contract F33615-72-C-2149: These being 48.0 inch span length boxes of full wing-box chord and of constant cross section, sized in complete detail.

All sizing was made using internal loads data obtained from the baseline finite element model and fatigue and damage tolerance designs allowables shown in Figures 56 thru 64. These design allowables were converted to equivalent static ultimate design stresses by multiplying them by the ratio of the maximum static ultimate root bending moment to the maximum root moment in the cyclic loading spectrum, but limited by the static tension strength of the material. These data are summarized in Table VIII for the Analytical Assemblies at span station 140.

Analytical Assemblies at span station 140 were given "Fail Safe" and "Safe Crack" ratings which are illustrated in Tables IX and X. The rating procedures are the same as those used during Contracts F33615-72-C-2149 and F33615-74-C-3026: Fail safe scores were given to concepts which are capable of resisting at least 115% of limit load with one major load path, such as a spar cap, failed; and the concepts with more elements at a spar cap were given higher scores. Safe crack scores were awarded proportionally to the safety factor between fracture design allowable stress and maximum static design tension stress.

The graphite epoxy Analytical Assemblies were rated with the maximum score of eight percent for Safe Crack.

			Condition No. 1	2	3	4
SPAR CAP LOADS		FWD	-13	-11	-12	-12
	UPPER (KIPS)	2	- 9	- 8	- 9	- 9
		3	- 9	- 8	- 9	- 9
		4	- 9	- 8	- 9	- 9
		5	- 8	- 7	- 8	- 8
		6	- 7	- 6	- 7	- 8
		REAR	- 9	- 8	- 9	-10
	LOWER (KIPS)	FWD	6	5	6	6
		2	5	4	5	5
		3	5	4	5	5
		4	5	4	5	5
		5	5	4	5	5
		6	4	3	4	4
		REAR	4	4	4	4
SPAR WEB	(KIPS/IN)	-FWD	1.7	2.0	0.6	0
		2	1.3	1.3	0.8	0.6
		3	1.3	1.1	1.0	0.9
		4	1.1	0.8	1.0	1.0
		5	1.0	0.5	1.0	1.1
		6	0.8	0.2	1.0	1.3
		REAR	1.0	0	1.6	2.2
UPPER SKIN	(KIPS/IN)	1-2	-21	-19	-20	-21
		2-3	-22	-20	-21	-22
		3-4	-22	-19	-21	-22
		4-5	-21	-18	-21	-21
		5-6	-19	-17	-19	-19
		6-7	-17	-15	-17	-17
LOWER SKIN	(KIPS/IN)	1-2	20	18	20	20
		2-3	22	20	22	22
		3-4	23	21	23	23
		4-5	22	20	22	23
		5-6	20	18	20	21
		6-7	16	14	16	16

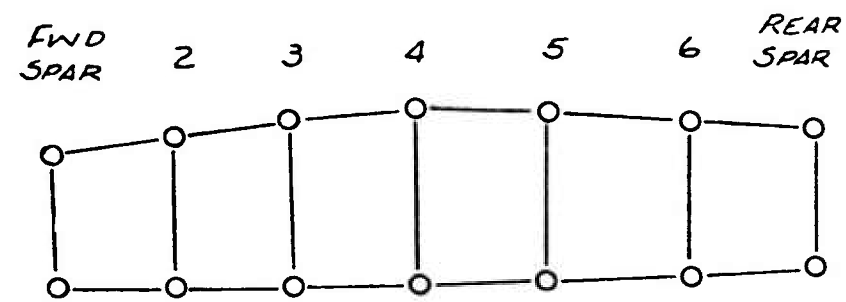


LOADS FROM MATH MODEL:

206323-H 18 July 75

Figure 52 Math Model - Internal Loads @ S. S. 140

			Condition 1	Condition 2	Condition 3	Condition 4
SPAR CAP LDS (KIPS)		FWD	-5	-6	-5	-6
	UPPER	2	-3	-4	-4	-4
	UPPER	3	-3	-4	-4	-4
	UPPER	4	-3	-4	-4	-4
	UPPER	5	-3	-4	-3	-4
	UPPER	6	-3	-3	-3	-4
	UPPER	REAR	-4	-4	-4	-5
	LOWER	FWD	2	2	2	2
	LOWER	2	2	2	2	2
	LOWER	3	2	2	2	2
	LOWER	4	2	3	2	3
	LOWER	5	2	3	2	3
	LOWER	6	2	2	2	3
	LOWER	REAR	3	3	3	3
SPAR WEB (KIPS/IN)		FWD	0.3	0.9	0.1	0
		2	0.3	0.5	0.2	0.3
		3	0.4	0.5	0.3	0.4
		4	0.4	0.4	0.4	0.5
		5	0.5	0.4	0.5	0.7
		6	0.5	0.3	0.6	0.9
		REAR	0.8	0.3	1.0	1.7
UPPER SKIN (KIPS/IN)		1-2	-4	-5	-5	-6
		2-3	-4	-5	-5	-6
		3-4	-4	-5	-5	-6
		4-5	-4	-5	-5	-6
		5-6	-4	-5	-4	-5
		6-7	-4	-4	-4	-5
LOWER SKIN (KIPS/IN)		1-2	3	4	4	4
		2-3	4	5	5	5
		3-4	5	6	5	6
		4-5	5	6	5	6
		5-6	5	6	5	6
		6-7	4	5	5	5



LOADS FROM MATH MODEL:

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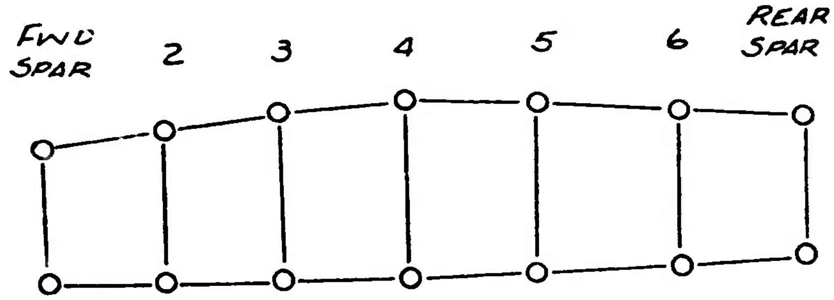
Figure 53 Math Model - Internal Loads @ S.S. 350

		CONDITION NO. 1	2	3	4
SPAR CAP LDS (KIPS) UPPER	- FWD	- 2	- 2	- 2	- 2
	2	- 1	- 1	- 1	- 1
	3	- 1	- 1	- 1	- 1
	4	- 1	- 1	- 1	- 1
	5	- 1	- 1	- 1	0
	6	0	0	0	0
	REAR	0	0	0	0
LOWER	FWD	0	0	0	0
	2	0	0	0	0
	3	0	0	0	0
	4	1	1	1	1
	5	1	1	1	1
	6	1	1	1	1
	REAR	1	1	1	1
SPAR WEB (KIPS/IN)	- FWD	0	0.3	0	0.1
	2	0.1	0.2	0	0
	3	0.1	0.2	0.1	0.1
	4	0.2	0.1	0.1	0.1
	5	0.2	0.1	0.1	0.2
	6	0.2	0.1	0.2	0.3
	REAR	0.3	0	0.3	0.4
UPPER SKIN (KIPS/IN)	1-2	- 1.0	- 1.0	- 1.1	- 1.1
	2-3	- 0.9	- 0.8	- 1.0	- 0.9
	3-4	- 0.8	- 0.8	- 0.8	- 0.8
	4-5	- 0.6	- 0.6	- 0.7	- 0.6
	5-6	- 0.5	- 0.5	- 0.5	- 0.4
	6-7	- 0.3	- 0.3	- 0.4	- 0.2
LOWER SKIN (KIPS/IN)	1-2	.3	.2	.3	.3
	2-3	.5	.5	.6	.5
	3-4	.8	.7	.8	.7
	4-5	.9	.9	.9	.8
	5-6	1.0	1.0	1.0	.8
	6-7	1.0	1.0	1.0	.9



LOADS FROM MATH MODEL:

206323-H 18 July 75

Figure 54 Math Model - Internal Loads @ S.S. 450

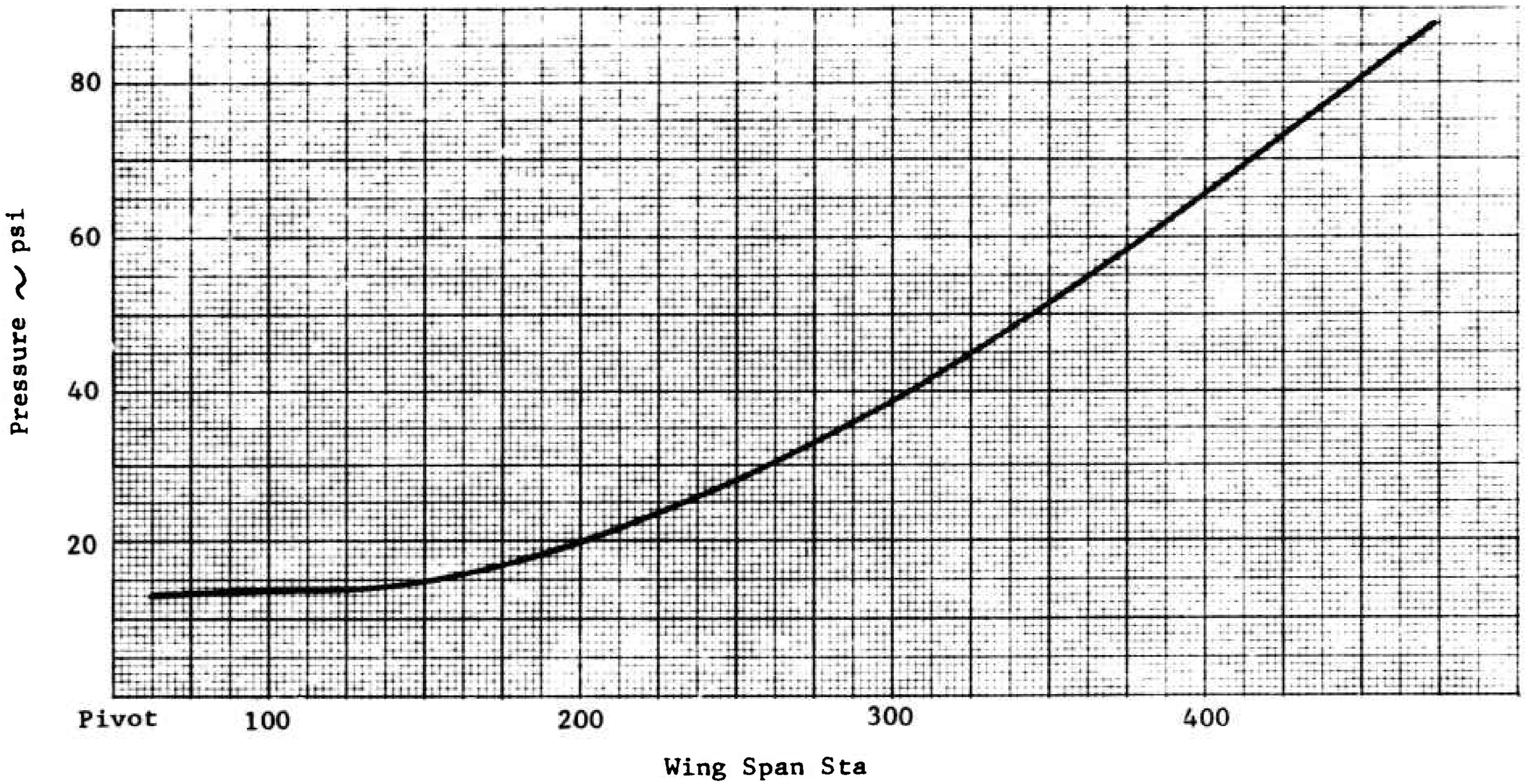


Figure 55 Ultimate Wing Fuel Pressures Due to 150°/Sec Roll Rate Plus 5.5 psi System Pressure (Wing Forward)

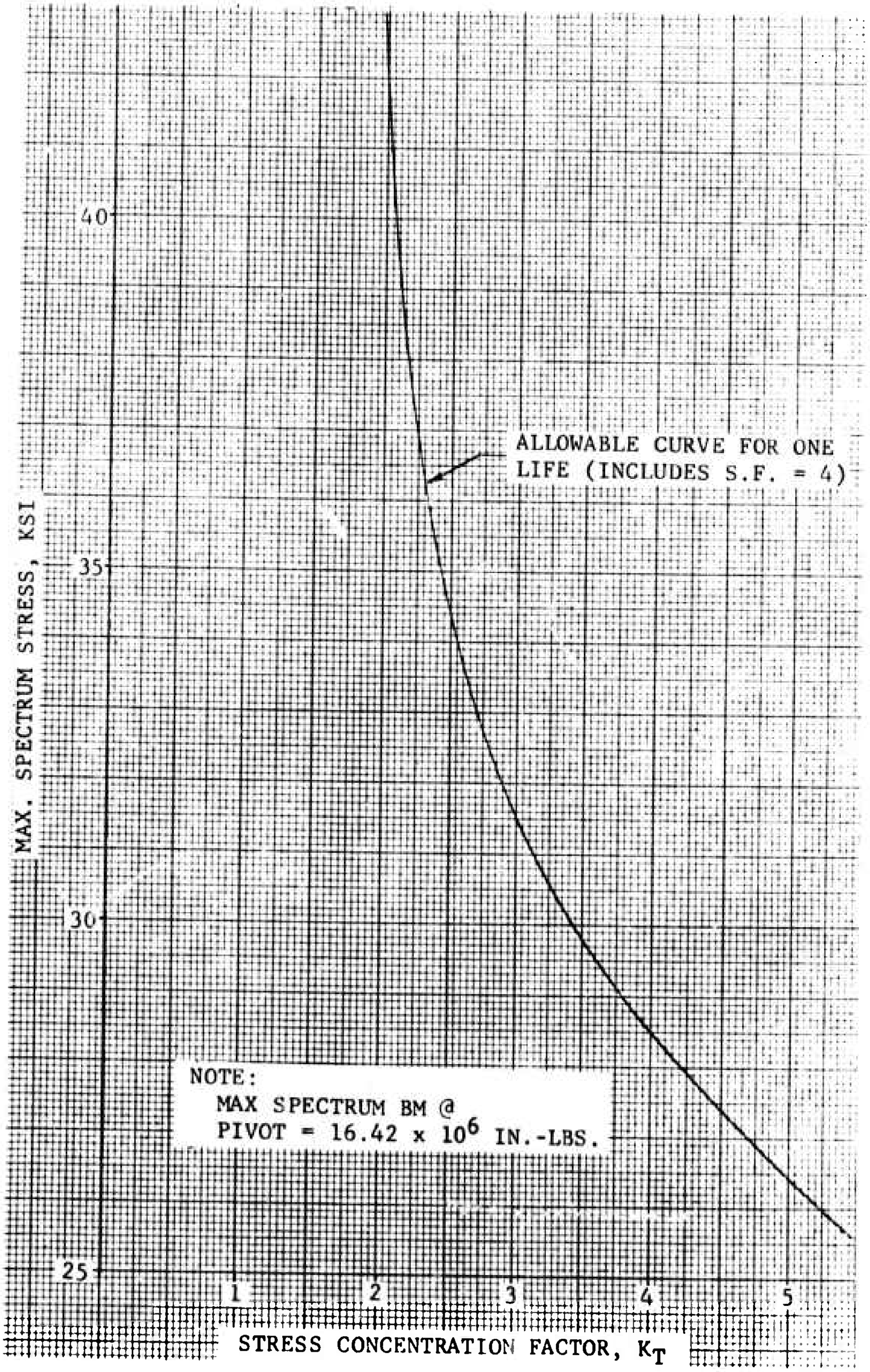
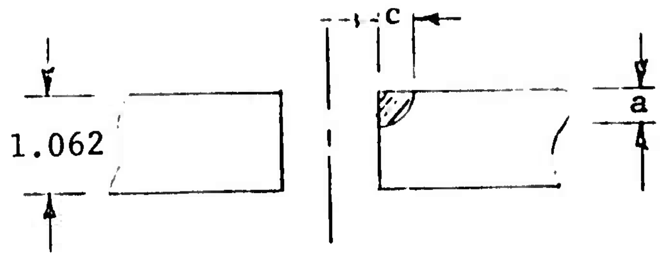


FIGURE 56 Fatigue Design Allowable Curve - Wing Box Lower Surface (2024-T851 Aluminum)



a/2c = 0.5

NOTE: MAX. SPECTRUM BM @ PIVOT = 16.42 X 10^6 IN.-LBS.

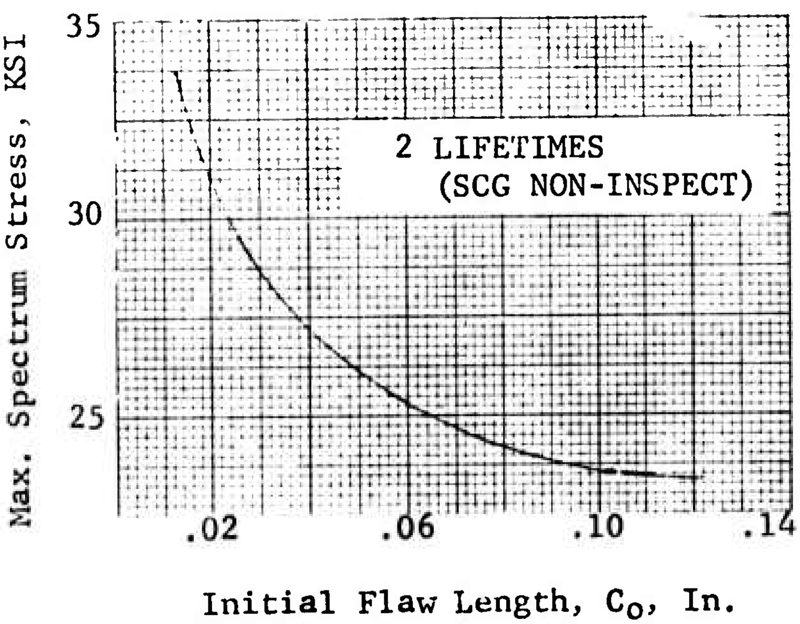


FIGURE 57 Fracture Design Allowable Curve - Wing Box Lower Surface (2024-T851 Aluminum Corner Flaw)

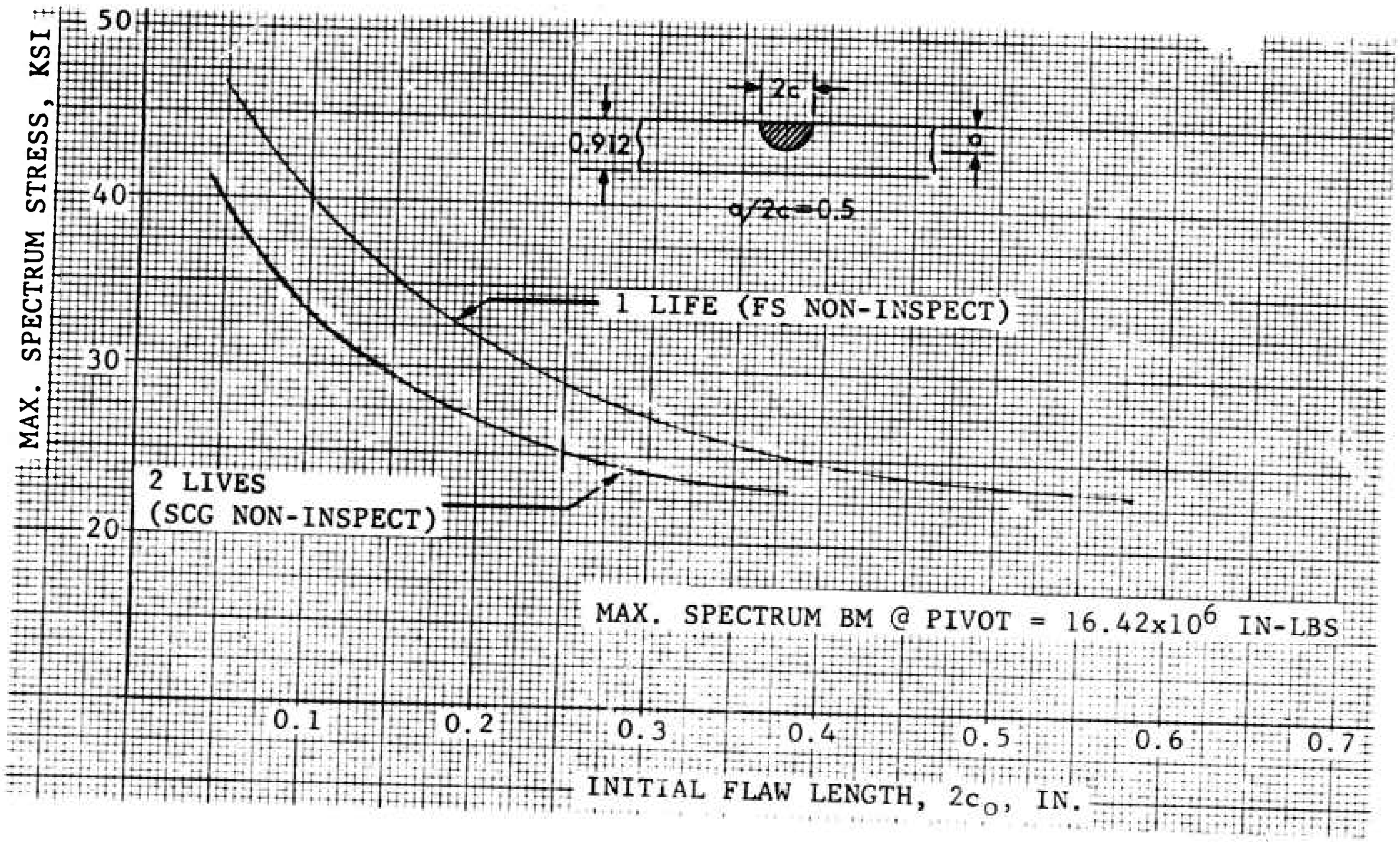


FIGURE 58 Fracture Design Allowable Curve - Wing Box Lwr Surface (2024-T851 Aluminum Surface Flaw)

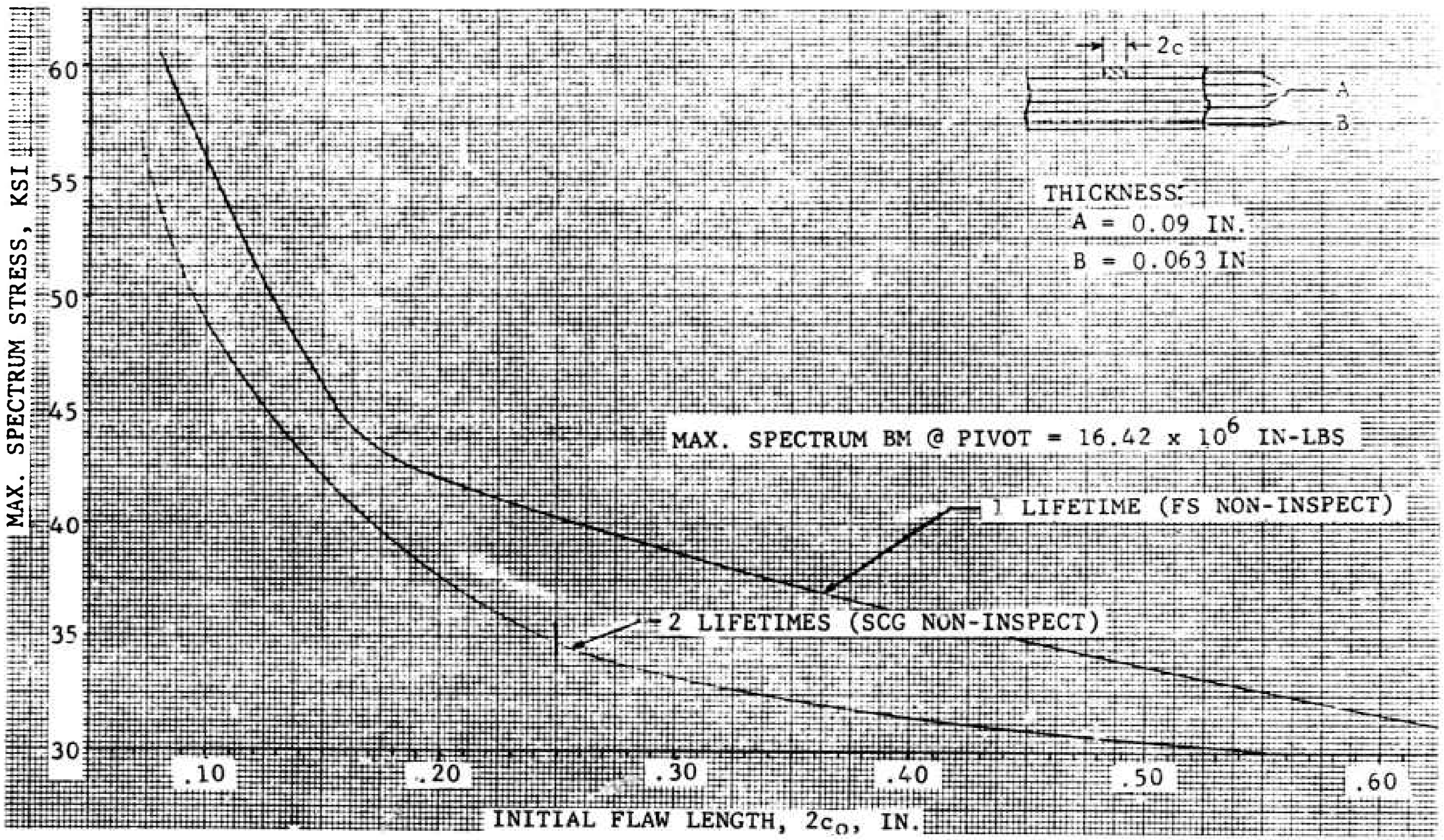


FIGURE 59 Fracture Design Allowable Curve - Wing Box Lwr Surface (Laminated 2024-T81 Aluminum Surface Flaw)

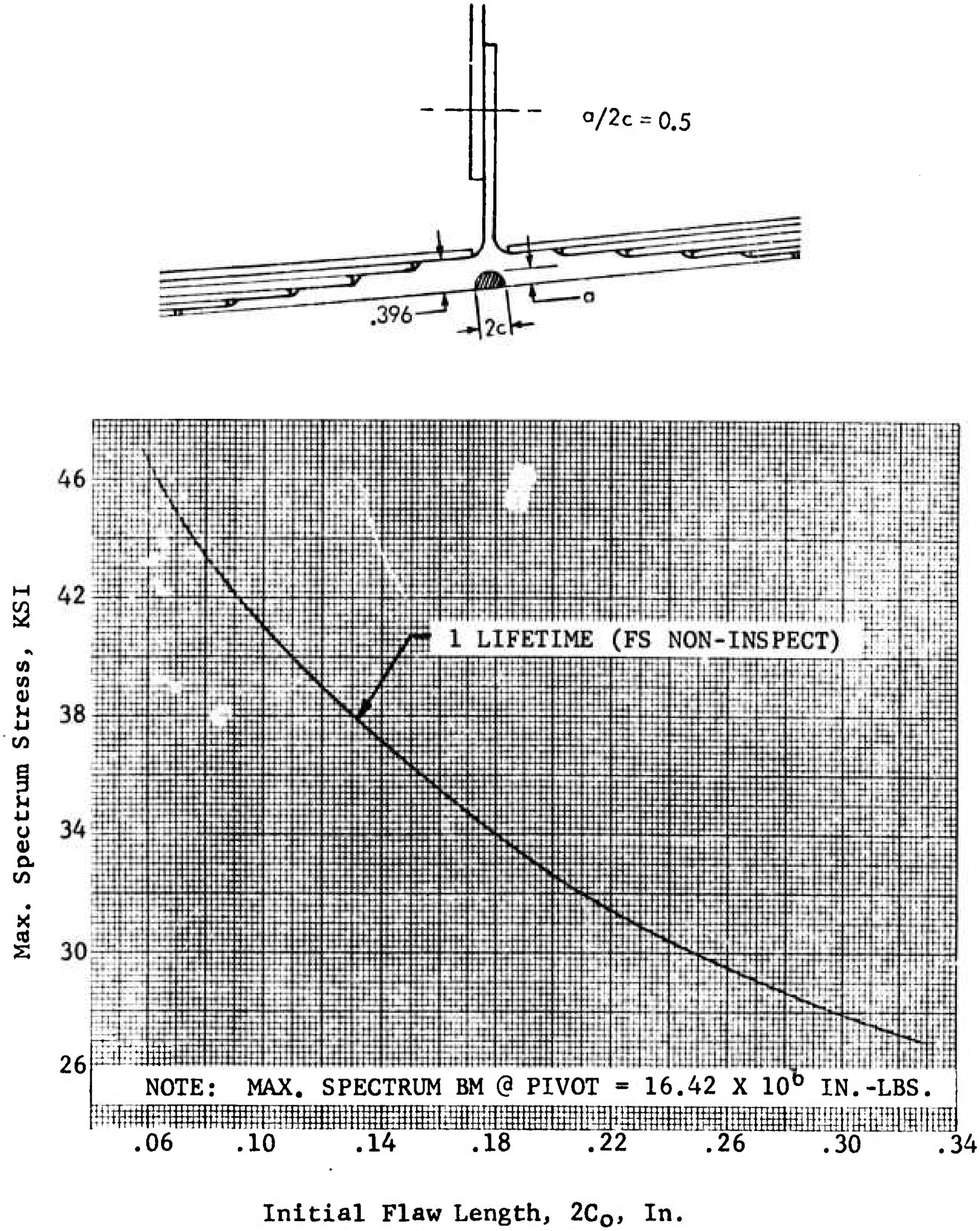
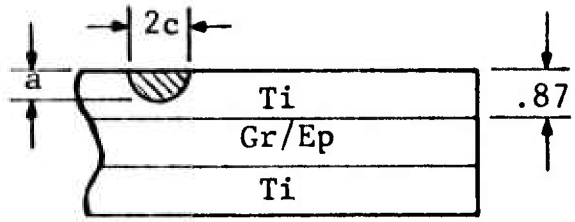


FIGURE 60 Fracture Design Allowable Curve - Wing Box Lwr Spar Cap (2024-T8511 Aluminum Surface Flaw)

a/2c = 0.5



NOTE: Max Spectrum BM @ Pivot = 16.42×10^6 In-Lbs

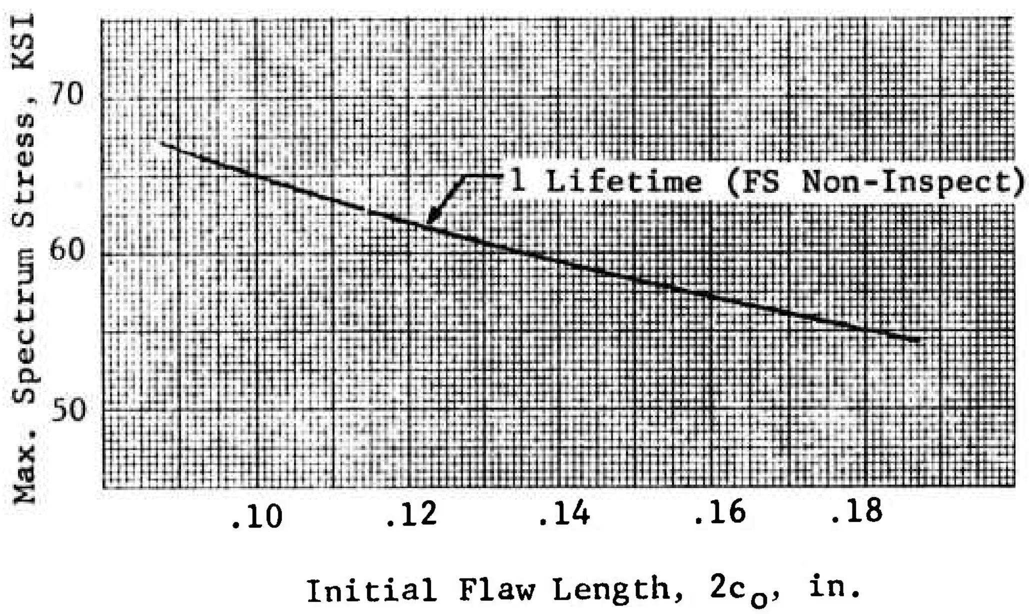
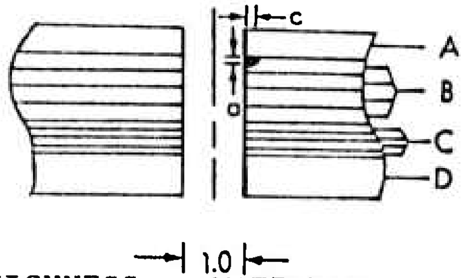


FIGURE 61 Fracture Design Allowable Curve - Wing Pivot Fitting (Ti-6AL-4V Surface Flaw)

TAPER-LOK BOLT HOLE
$a/2c = 0.5$



THICKNESS	MATERIAL
A=0.2 IN	2024-T8511 AL
B=0.09 IN	2024-T81 AL
C=0.063 IN	2024-T81 AL
D=0.31 IN	10 NICKEL STEEL

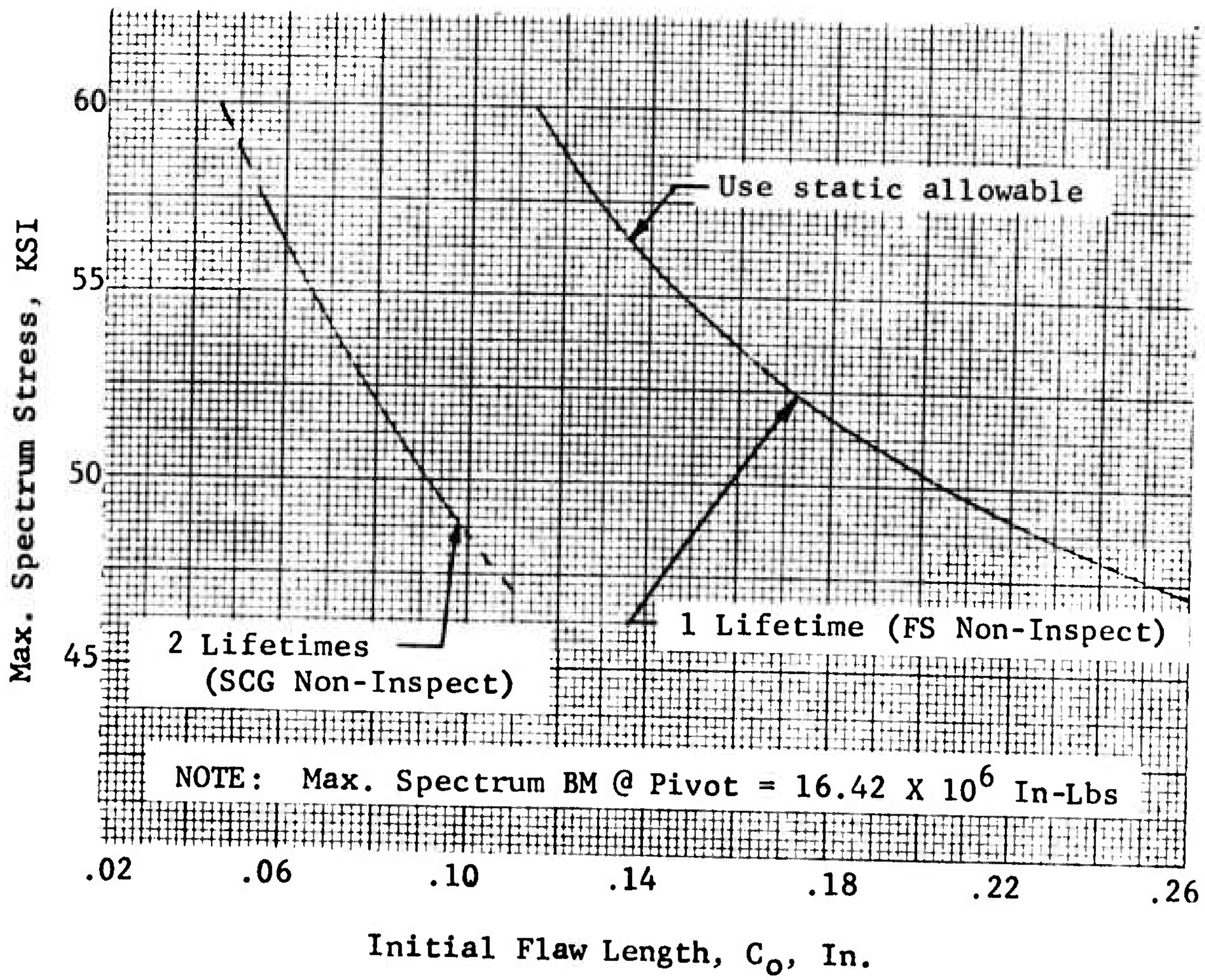


FIGURE 62 Fracture Design Allowable Curve - Wing Pivot Fitting (Laminated 2024-T81 Aluminum Corner Flaw)

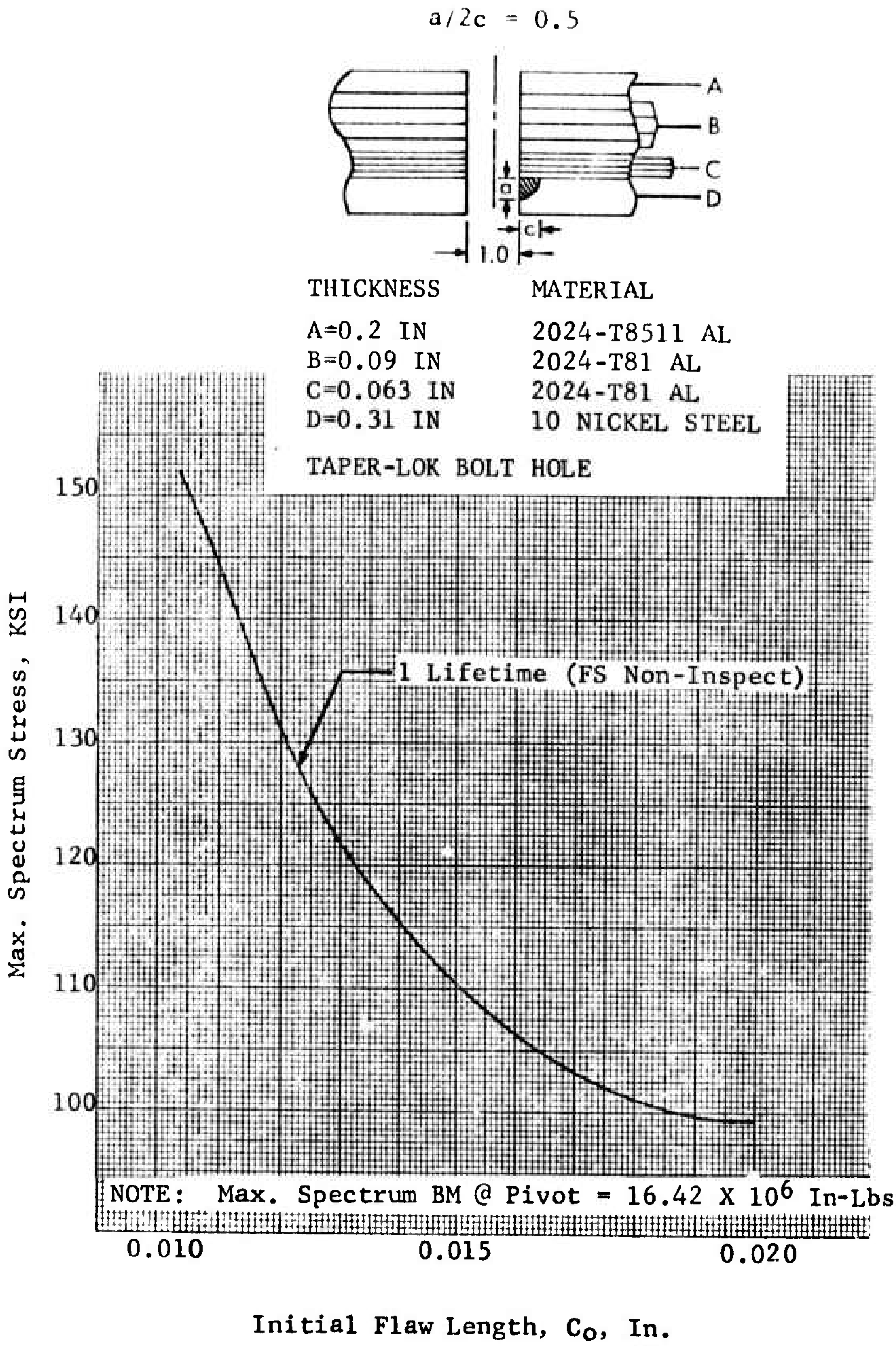


Figure 63 Fracture Design Allowable Curve - Wing Pivot Fitting (10 Nickel Steel Corner Flaw)

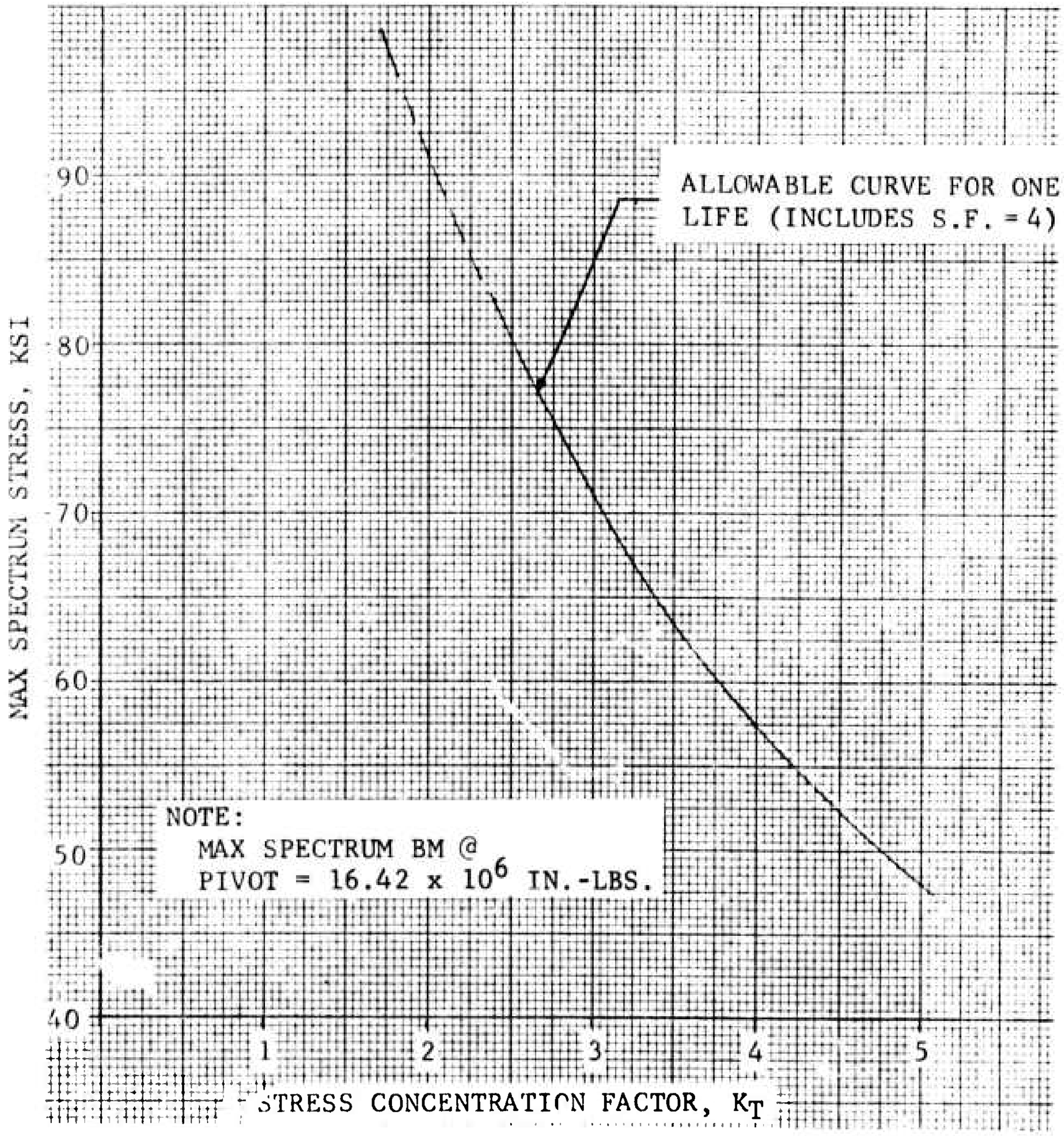


FIGURE 64 Fatigue Design Allowable Curve - Wing Box Lower Surface (6AL-4V Beta Annealed Titanium)

TABLE VIII
"ANALYTICAL ASSEMBLY" DESIGN STRESS DATA

	Lower Skin					Upper Skin			
	Material	Class	Max K_T	$S_{Fatigue}$*	$S_{Dmg\ Tol.}$*	Material	Type	$S_{Crit.}$	Comments
633RA-000-1	2024-T851	Safe Life	3.4	48600 psi	41500 psi	2024-T851	Plate	53500 psi	Baseline
633RA-001-1	2024-T81	Fail Safe	2.0	68360	66900	2024-T851	Plate	59500	Planked & Laminated Lwr Skin/ Exposed Caps/Extruded "Y" Intr Spars (3)
633RA-001-3,-5	2024-T81	Fail Safe	2.0	68360	66900	2024-T851	Plate	59500	Planked & Laminated Lwr Skin/ Exposed Caps/Sandwich "Y" Intr Spars (3)
633RA-001-801	2024-T81	Fail Safe	2.0	68360	66900	2024-T851	Plate	59500	Planked & Laminated Lwr Skin/ Exposed Caps/Sheet "Y" Intr Spars (3)
633RA-001-803	2024-T81	Safe Life	2.0	68360	57840	2024-T851	Plate	59500	Laminated Lwr Skin/Covered Caps/ Beaded "Y" Intr Spars (3)
633RA-001-805	2024-T81	Safe Life	2.0	68360	57840	2024-T851	Plate	59500	Laminated Lwr Skin/Covered Caps/ Extruded "Y" Intr Spars (3)
633RA-002-1	2024-T81	Fail Safe	2.0	68360	66900	2024-T851	Plate	53700	Planked & Laminated Lwr Skin/ Exposed Caps/Corrugated Intr Spars (3)
633RA-003-1	2024-T81	Fail Safe	2.0	68360	66900	2024-T851	Sandwich	62000	Planked & Laminated Lwr Skin/ Exposed Caps/5 Intr Sandwich Spars
633RA-003-3	2024-T81	Fail Safe	2.0	68360	66900	2024-T851	Plate	53500	Planked & Laminated Lwr Skin/ Exposed Caps/7 Intr Sandwich Spars
633RA-003-5	2024-T81	Safe Life	2.0	68360	57840	2024-T851	Plate	48400	Laminated Lwr Skin/Covered Caps/ 6 Intr Laminated Spars
633RA-003-801	2024-T81	Fail Safe	2.0	68360	66900	2024-T851	Plate	59500	Planked & Laminated Lwr Skin/ Exposed Caps/Canted Intr Spars (3)
633RA-003-801A	2024-T81	Safe Life	2.0	68360	57840	2024-T851	Plate	59500	Laminated Lwr Skin/Covered Caps/ Canted Intr Spars (3)
633RA-004-1	2024-T851	Safe Life	4.5**	45040	41500	2024-T851	Plate	59500	Plate Skins/Inverted "A" Spars
633RA-004-3	2024-T851	Safe Life	4.5**	45040	41500	2024-T851	Plate	59500	Plate Skins/Extruded "Y" Spars
633RA-004-5	2024-T851	Safe Life	4.5**	45040	41500	2024-T851	Plate	59500	Plate Skins/Sheet "Y" Spars

** With straight shank fasteners

* Equivalent static ultimate stress $= \frac{18.3(10^6)}{16.4(10^6)}$ (1.5)(Max allowable cyclic stress)

TABLE IX ANALYTICAL ASSEMBLY "SAFE CRACK" RATING

	$S_{cg}\frac{18.3(10^6)(1.5)^*}{16.4(10^6)}$ = Safe Crack, Ult	fx	fs	S_{max}	$\frac{S_{Safe\ Crack}}{S_{max}}$ = R	Score: $\frac{.08R}{R_{max}}$
633RA000-1	41500	37459	5863	38355	1.082	.075
633RA001-1	66900	56930	8911	58292	1.148	.080
633RA001-3	66900	56930	8911	58292	1.148	.080
633RA001-5	66900	56930	8911	58292	1.148	.080
633RA001-801	66900	56930	8911	58292	1.148	.080
633RA001-803	57840	50218	7860	51419	1.125	.078
633RA001-805	57840	50218	7860	51419	1.125	.078
633RA002-1	66900	56930	8911	58292	1.148	.080
633RA003-1	66900	56930	8911	58292	1.148	.080
633RA003-3	66900	56930	8911	58292	1.148	.080
633RA003-5	51840	50218	7860	51419	1.125	.078
633RA003-801	66900	56930	8911	58292	1.148	.080
633RA004-1	41500	37459	5863	38355	1.082	.075
633RA004-3	41500	37459	5863	38355	1.082	.075
633RA004-5	41500	37459	5863	38355	1.082	.075
633RA005-1						.080
633RA006-1						.080
633RA007-1						.080
633RA008-1						.080

* Maximum allowable spectrum stress for stable crack growth, times ratio of limit root bending to max. spectrum bending; all times 1.5 for equivalent ultimate

TABLE X
ANALYTICAL ASSEMBLY "FAIL SAFE" RATING

	Minimum Number of Elements in Fail Safe Path	Score
633RA000-1	0	0
633RA001-1	7	.12
633RA001-3	7	.12
633RA001-5	7	.12
633RA001-801	7	.12
633RA001-803	0	0
633RA001-805	0	0
633RA002-1	7	.12
633RA003-1	7	.12
633RA003-3	7	.12
633RA003-5	0	0
633RA003-801	7	.12
633RA004-1	0	0
633RA004-3	0	0
633RA004-5	0	0
633RA005-1	0	0
633RA006-1	0	0
633RA007-1	0	0
633RA008-1	0	0

4.4 STRESS ANALYSIS OF FULL SPAN WING BOXES

The full span wing box preliminary designs (see Figures 65 thru 67) have been analyzed in two portions each with an arbitrary line of demarcation at span station 100, for the metal designs; and at span station 107 for the composite design. The demarcation line permits examination of features associated with splicing, or attaching the wing to the fuselage. It also permits evaluation of the various wing box concepts without the accommodations required for attachment to the fuselage.

Sizing of the structural members was done using internal loads from the finite element model of the baseline, fatigue and damage tolerance design allowable stresses and fuel pressures as described for the Analytical Assembly phase.

Finite element models of the Preliminary Design wings were made to demonstrate the member stress levels, to examine the deformations of the boxes and to obtain the modes of vibration for the various designs, including the baseline, updated for fatigue and damage tolerance allowables. Figures 68 and 69 illustrate the stress distributions.

4.5 PIVOT FITTING STRESS ANALYSIS

The desirability of a fail-safe multi-loadpath wing pivot fitting, for possible weight and cost reduction, prompted evaluation of a three path fitting: One path in the continuous laminated aluminum skin and two additional paths through steel plates. This concept was modeled mathematically and is illustrated in Figures 70 thru 72. Figures 73 and 74 show the pivot fitting arrangements for preliminary design drawings 633RW001 and 633RW002.

A three path fitting was also used with the graphite-epoxy wing, as shown in Preliminary Design drawing 633RW003, and illustrated by Figure 75. In this case two Titanium tapered plates supplement the continuous composite skin.

Two concepts were evaluated for reacting wing torque at the attachment to the fuselage. The first concept as illustrated by Figures 72 and 73 maintains a closed torque box up to the center of the pivot lugs. A second concept terminates the wing torque

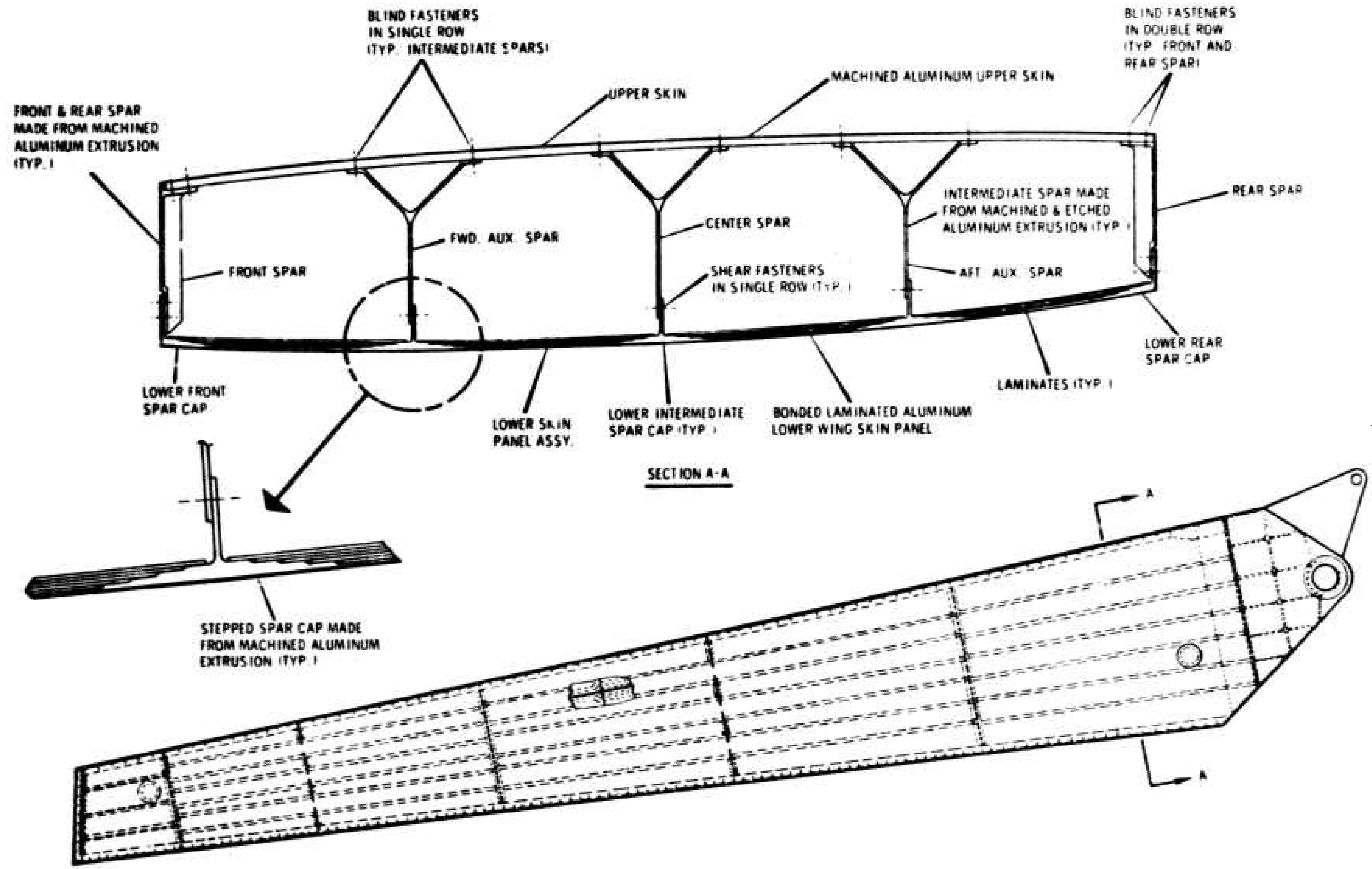


Figure 65 ATW-4 Wing Box Laminated Aluminum Lower Skin With "Y" Spars

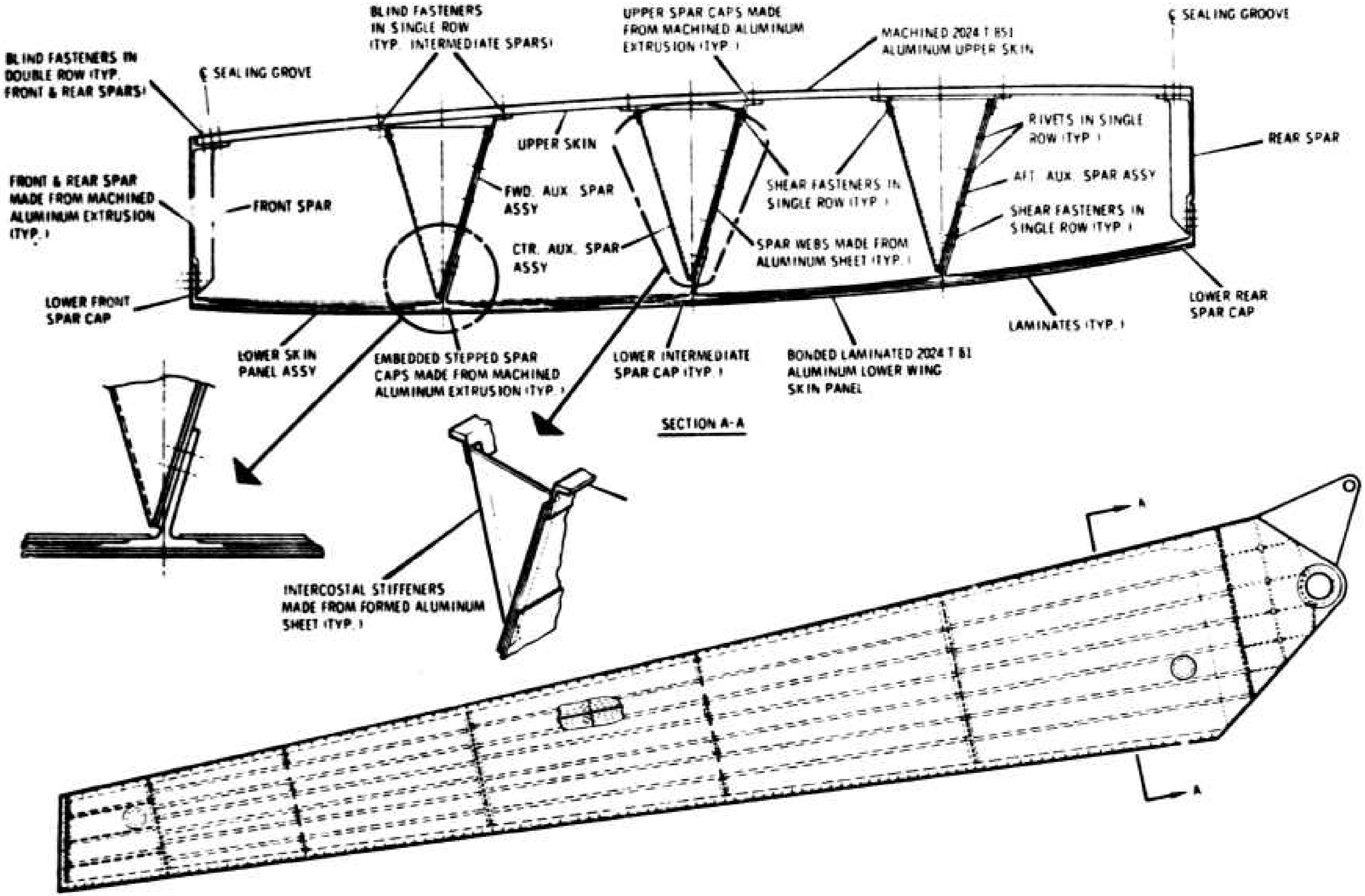


Figure 66 ATW-4 Wing Box Laminated Aluminum Lower Skin, Canted Spars

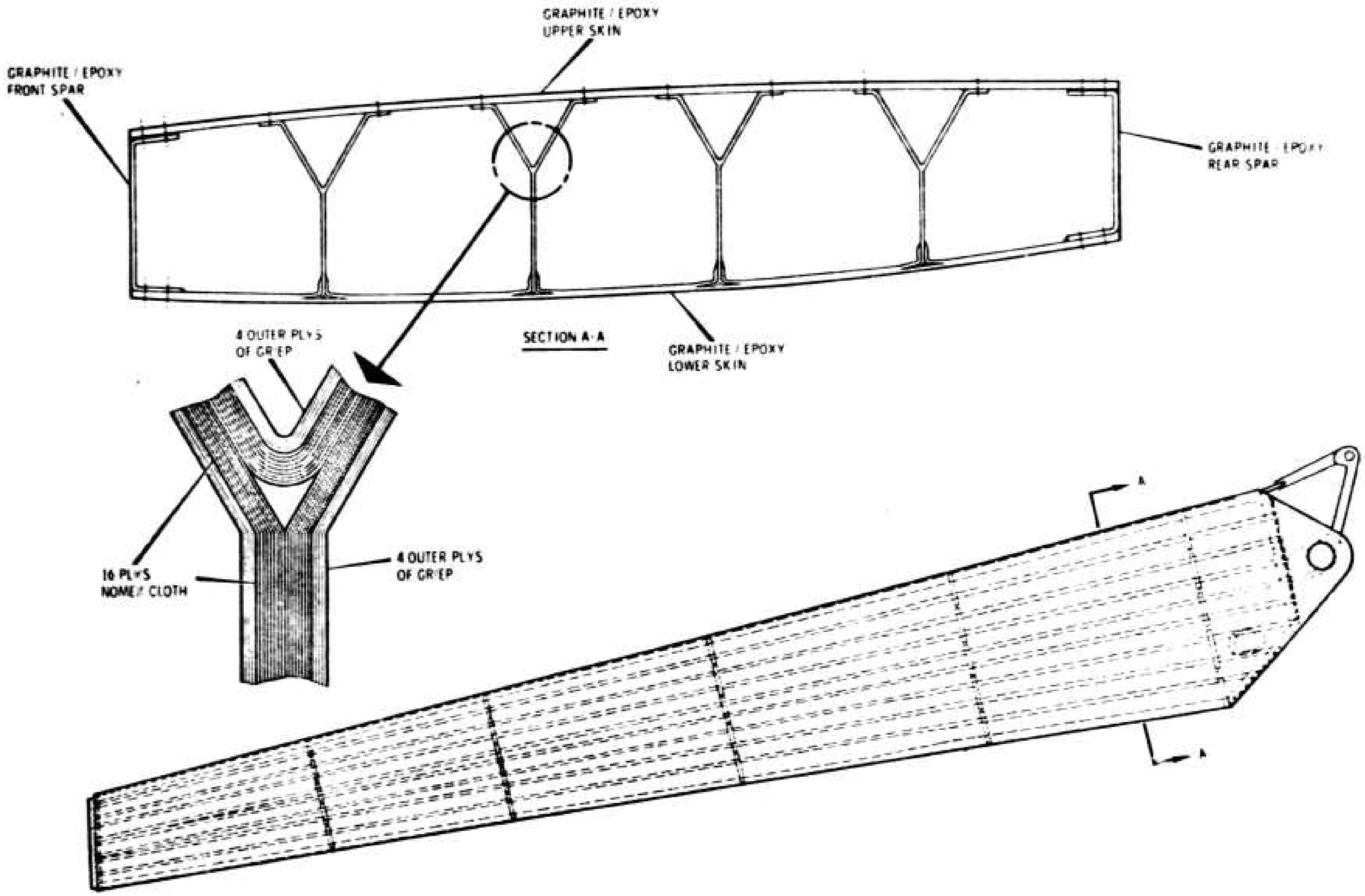
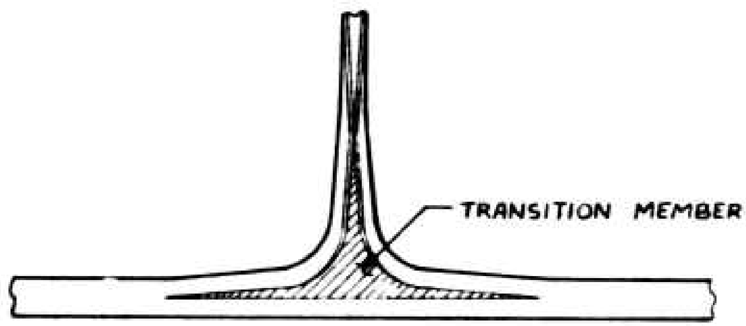


Figure 67 ATW-4 Graphite Epoxy Composite Wing Box "Y" Spars/Embedded (Sheet 1 of 2)

633RW003 LOWER SPAR CAP DETAIL



TYP ALL INTERMEDIATE SPARS

Figure 67 ATW-4 Graphite Epoxy Composite Wing Box "Y" Spars/Embedded Lwr. Caps (Sheet 2 of 2)

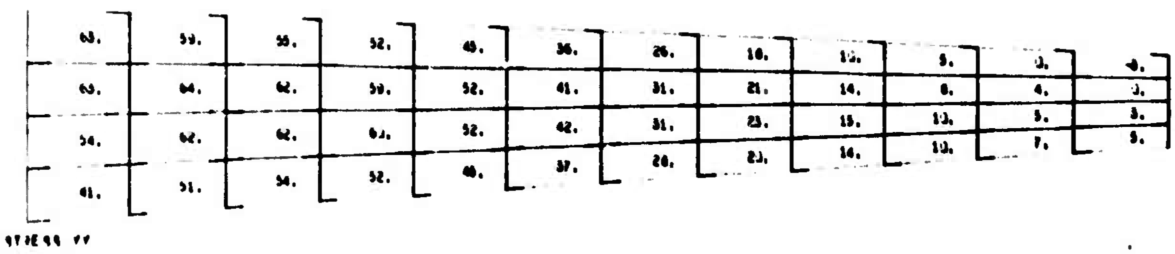


Figure 68 Lower Surface of Metal Y Box Finite Element Model with Condition 1 (KSI, Ultimate)

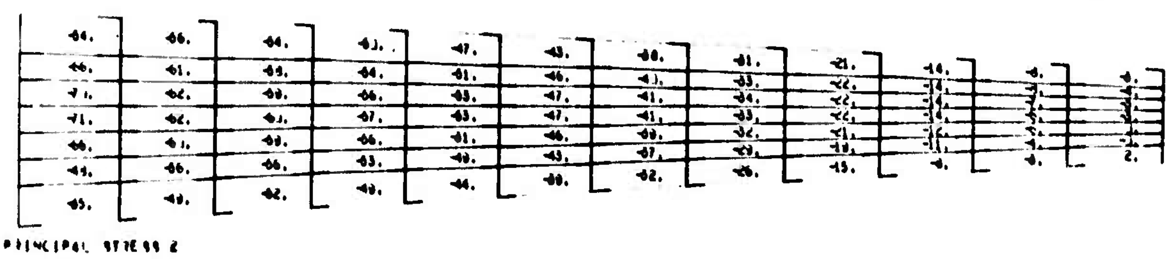


Figure 69 Upper Surface of Metal Y Box Finite Element Model with Condition 4 (KSI, Ultimate)

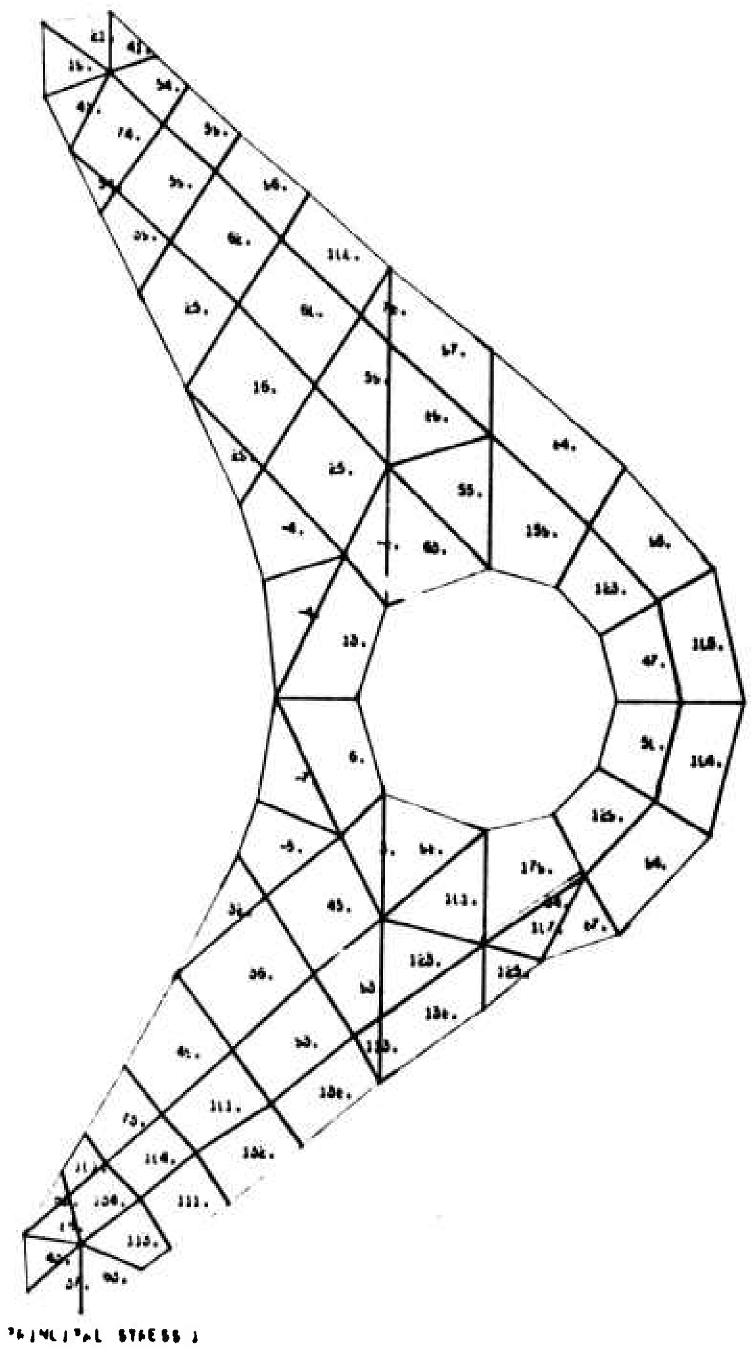


Figure 70 Failsafe Pivot Inner Steel Element

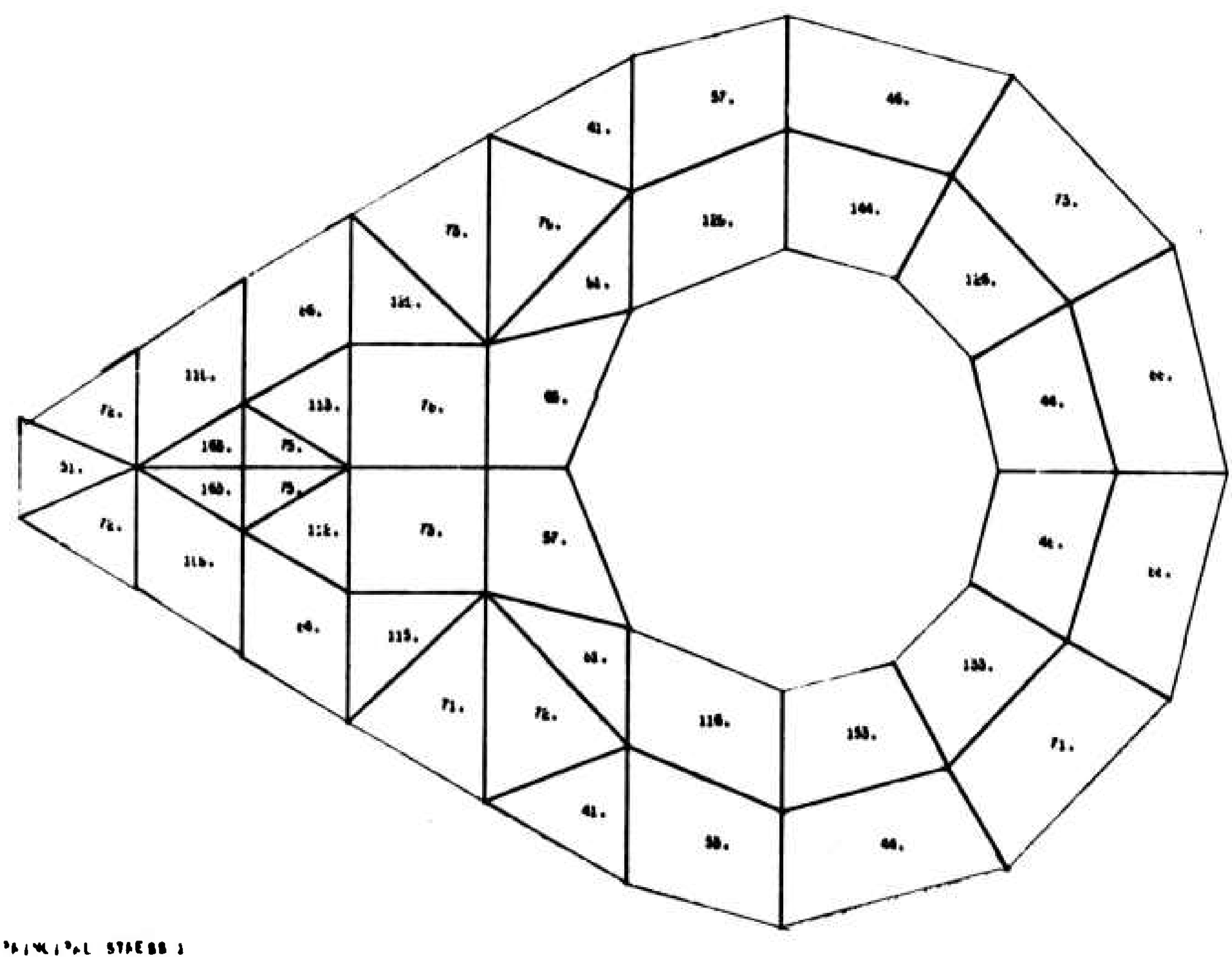


Figure 71   Failsafe Pivot Outer Steel Element

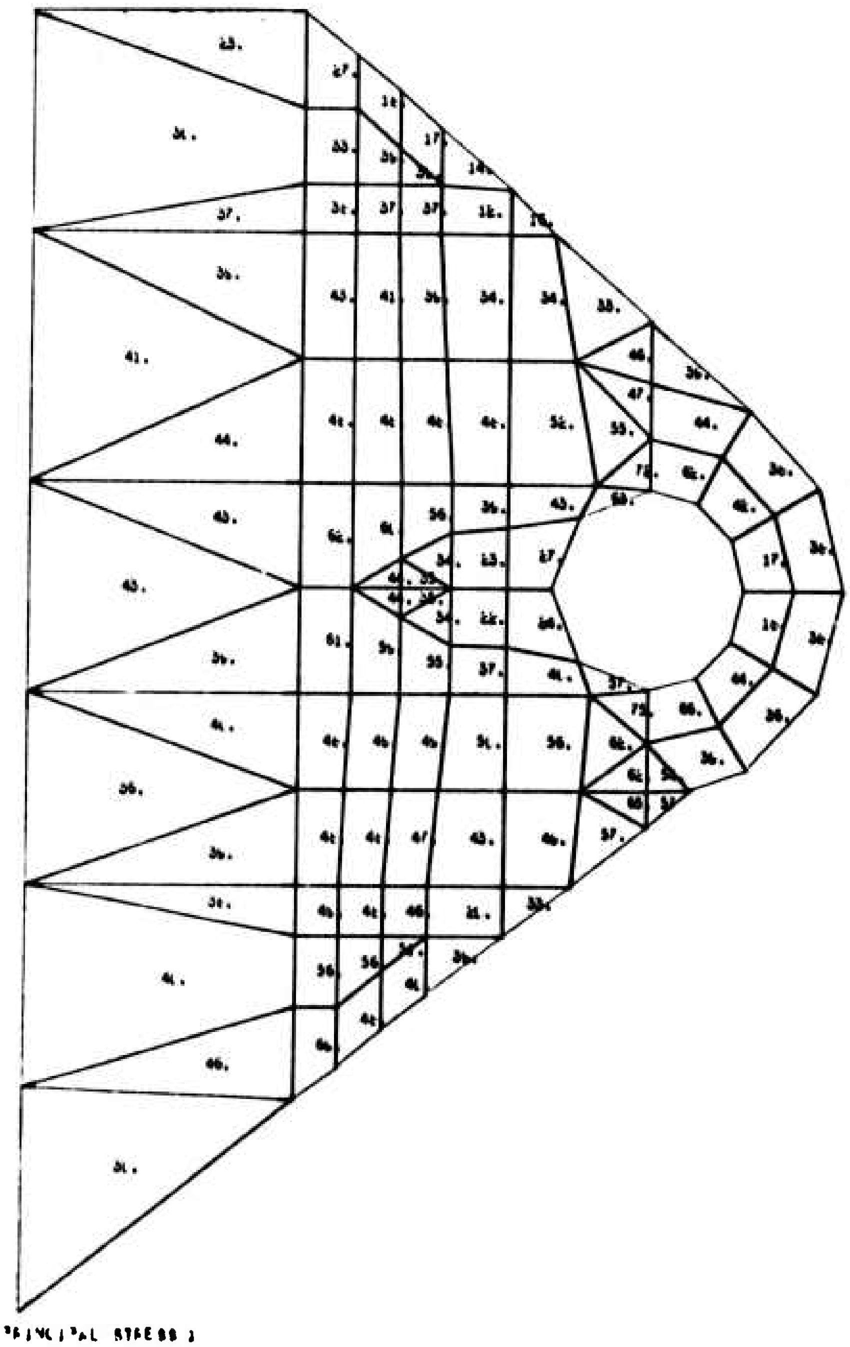


Figure 72 Failsafe Pivot Aluminum Element

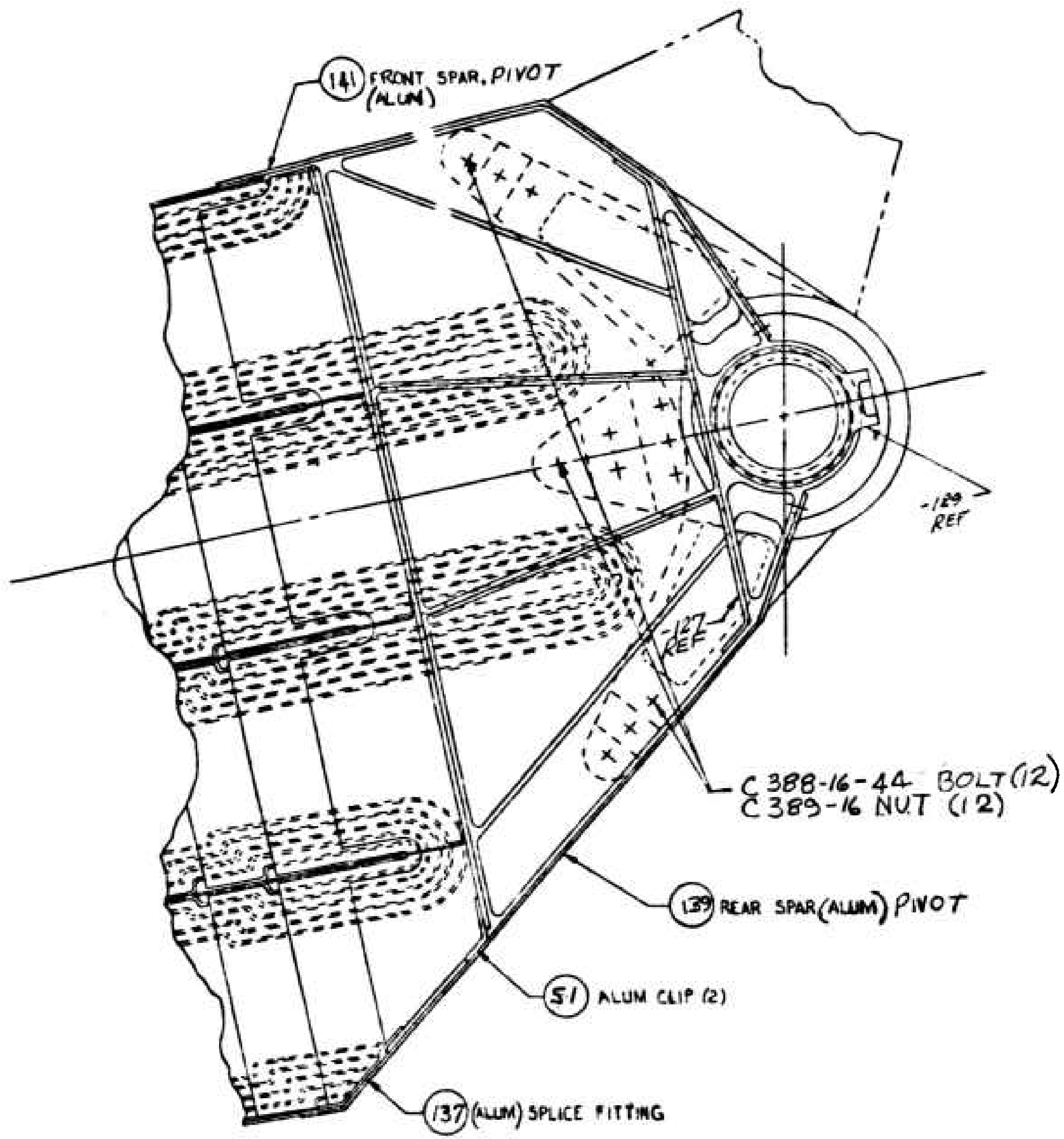


Figure 73 633RW001 Pivot Fitting (Sheet 1 of 2)

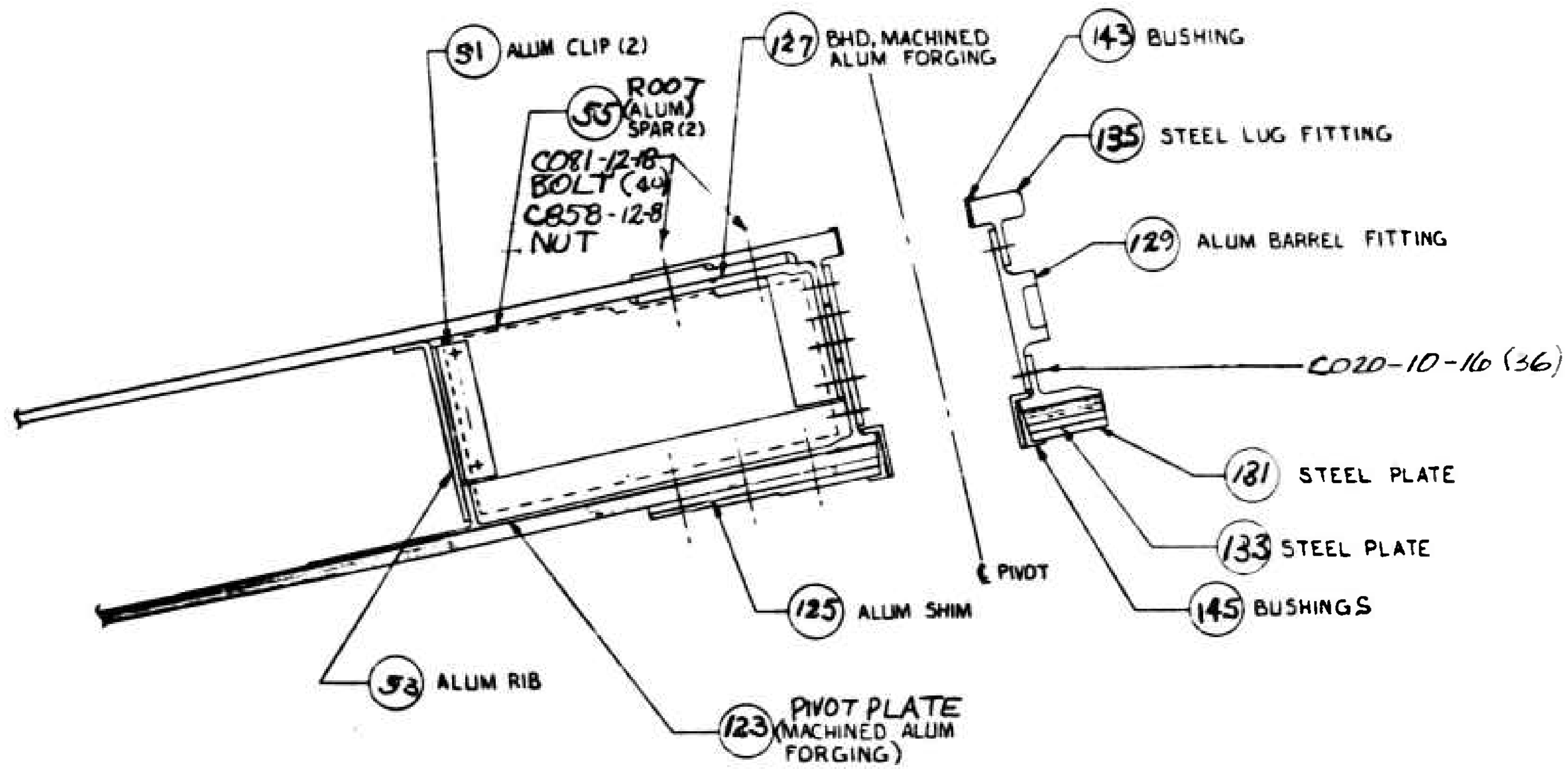


Figure 73 633RW001 Pivot Fitting (Sheet 2 of 2)

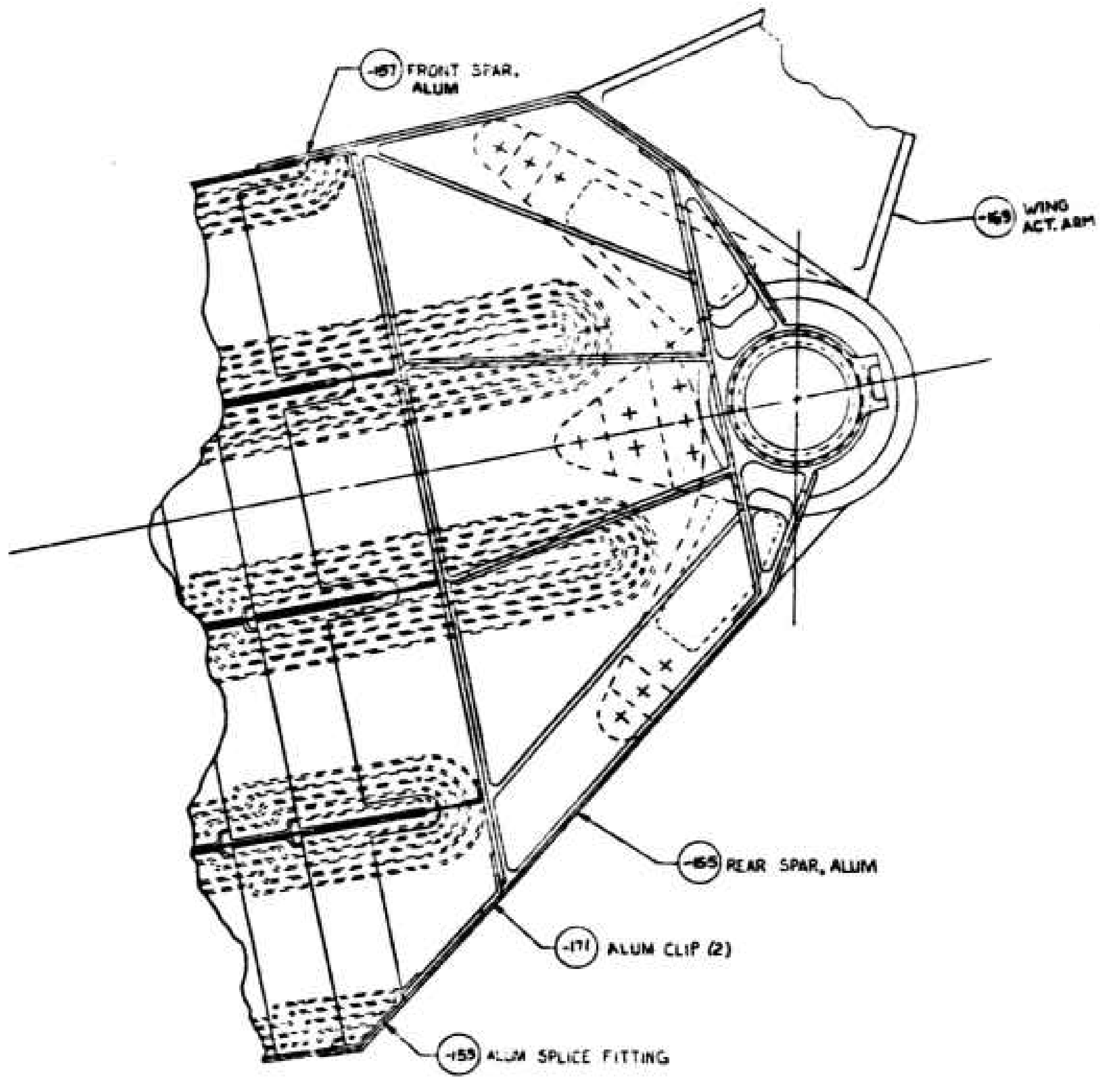


Figure 74 633RW002-1 Pivot Fitting (Sheet 1 of 2)

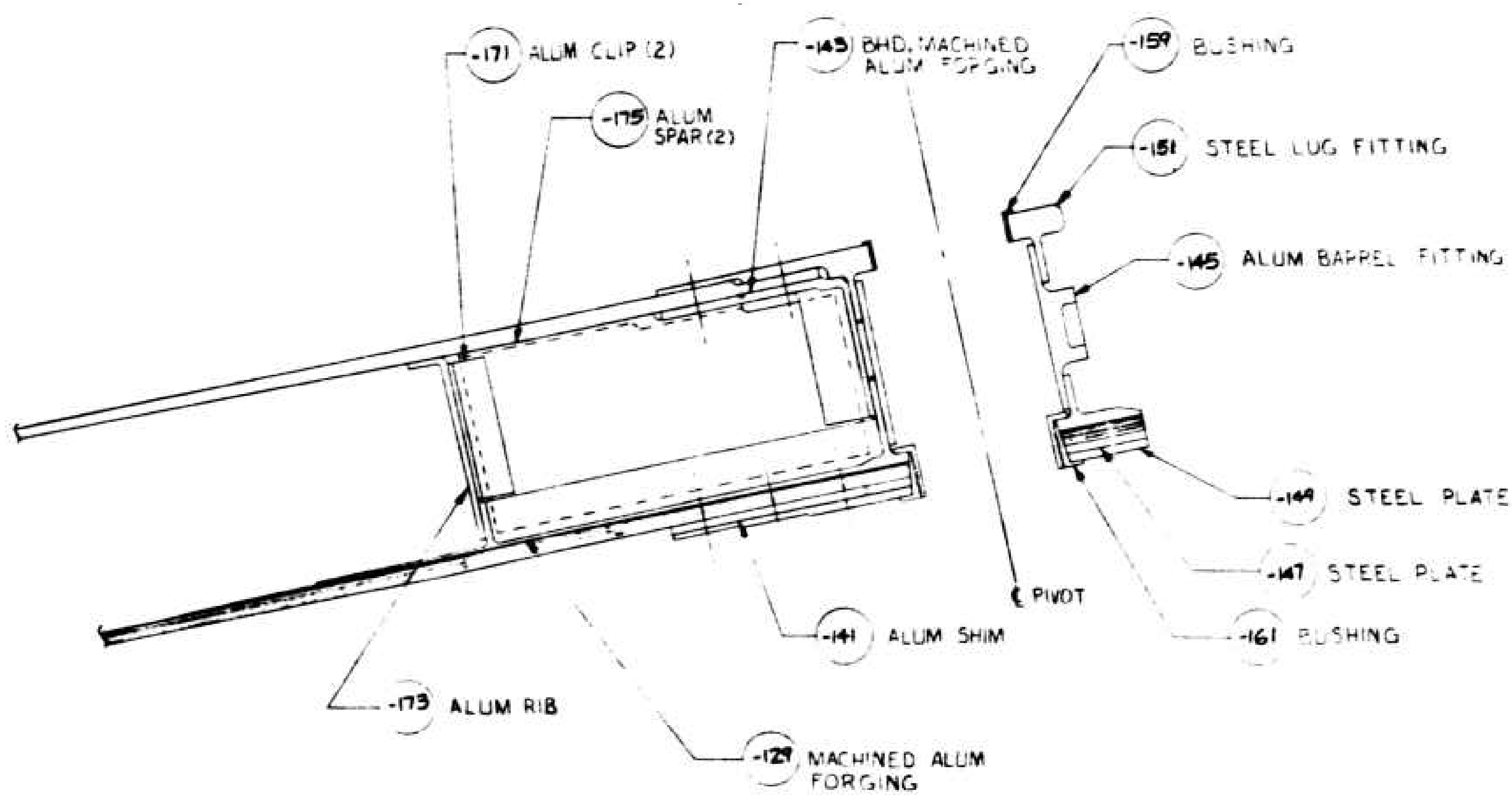


Figure 74 633RW002-1 Pivot Fitting (Sheet 2 of 2)

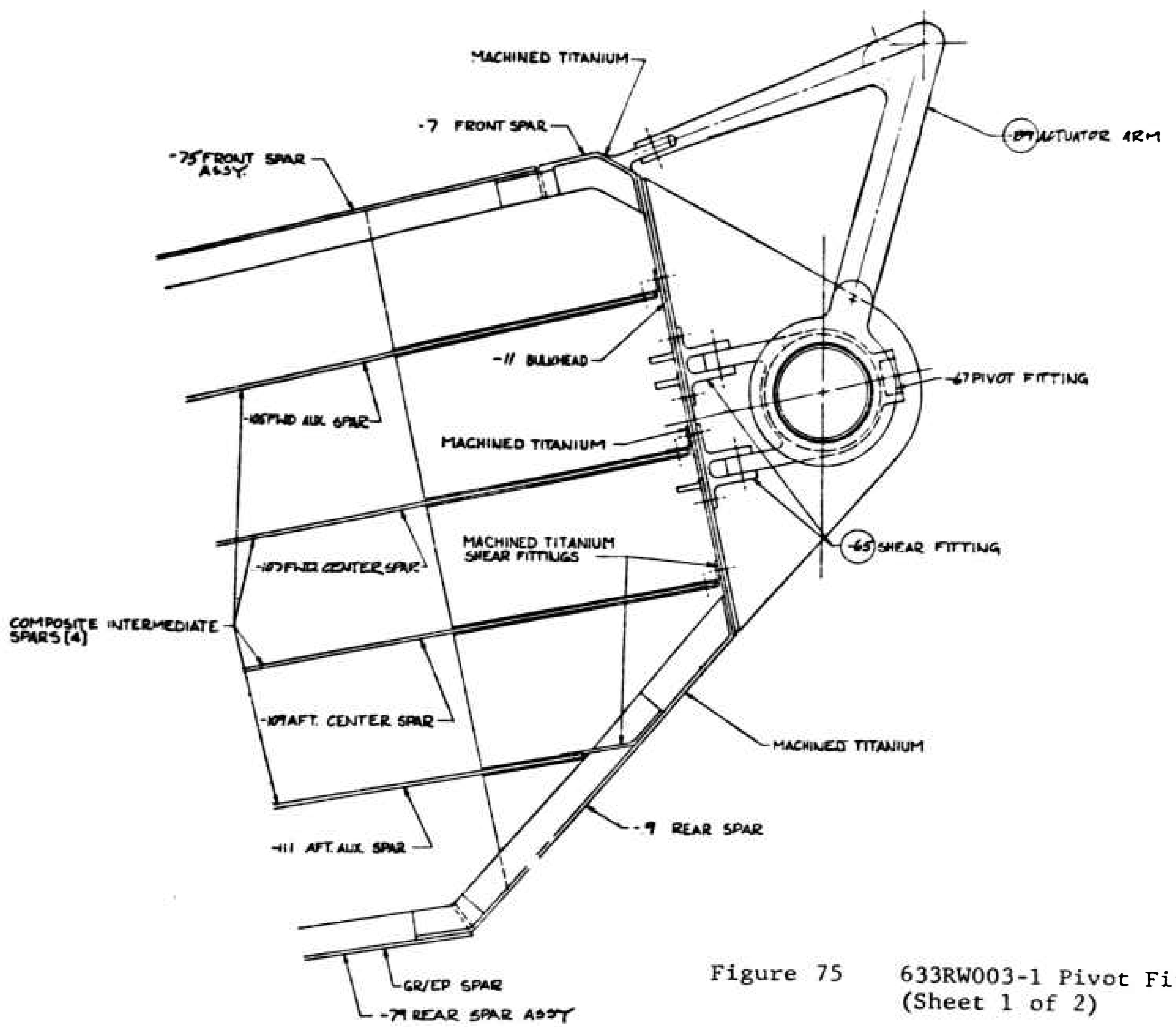


Figure 75 633RW003-1 Pivot Fitting (Sheet 1 of 2)

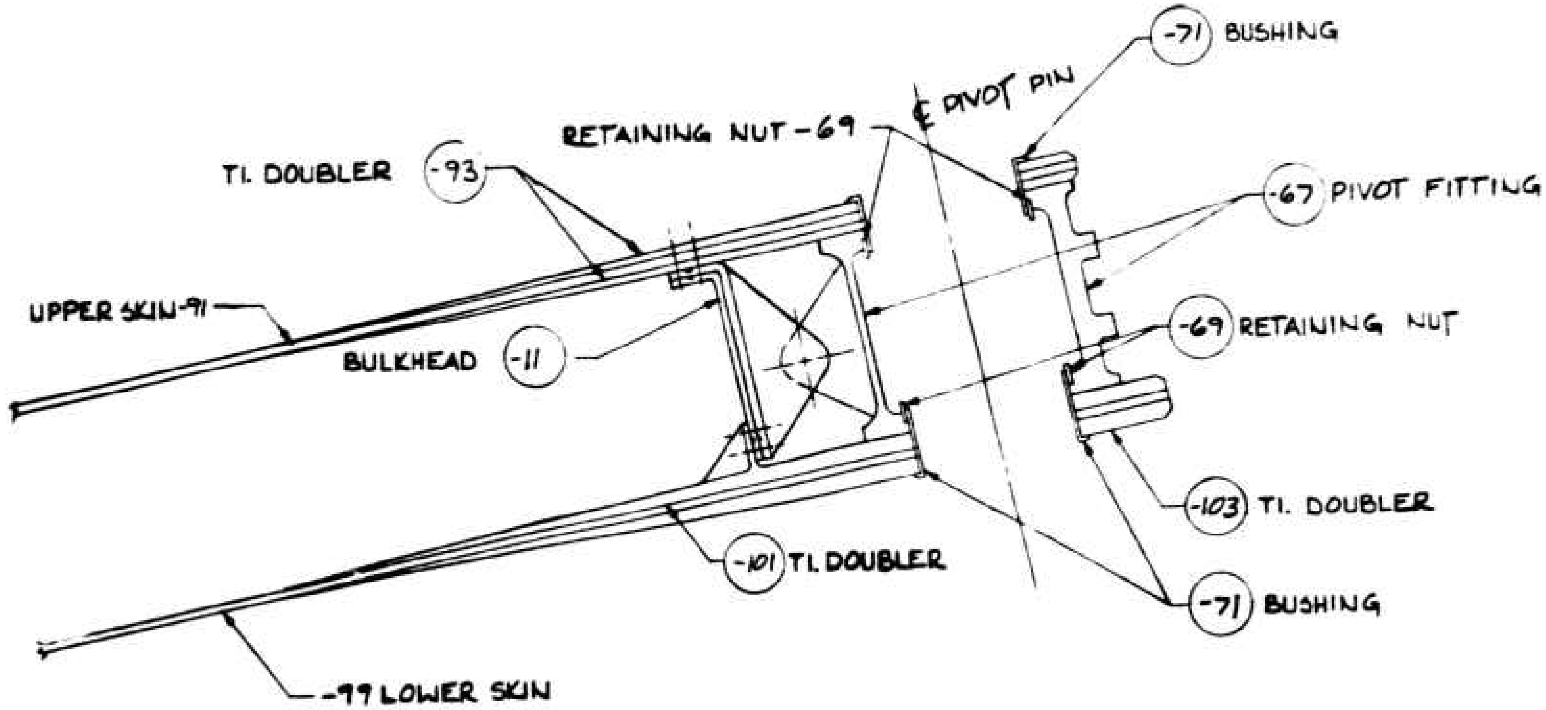


Figure 75 633RW003-1 Pivot Fitting (Sheet 2 of 2)

box outboard of the pivot as illustrated in Figure 76. This second concept permits improved accessibility to the area of the lugs, but it produces additional bending in the upper and lower skins in the vicinity of the pivot fitting.

The weights of these lugs are shown in combination with wing boxes in Table XI. One of these combinations, the composite wing box and the continuous torque box metallic pivot fittings, has not been explored fully. This combination represents a goal which should be achievable, but whose details are not essential to the study at this stage.

4.6 FLUTTER ANALYSIS

Flutter checks were made of the baseline wing box, the graphite-epoxy wing box and the Y-spar advanced metallic wing box. Results of these checks are summarized in Table XII and they indicate satisfactory flutter characteristics on the basis of having more than twenty percent speed margin above .90M at sea level with the wings swept fully forward.

The normal modes of vibration were obtained for each design by means of the program (UGO) used for mathematically modelling each design; and with the final mass distribution of the wing box and concentrated masses representing the leading and trailing edge.

Flutter speed solutions were obtained using procedure AA8 which uses the normal modes expressed as generalized mass coordinates and aerodynamic force coordinates computed using the Kernel function method.

The Kernel function relates pressure at specific points on the airfoil as functions of "downwash". The "downwash" is a function of the model deflections and is also related to the free stream flow normal to the chord plane.

Integration of these data over the airfoil forms a pressure distribution, or aerodynamic force coordinates, for each deflection mode, for use in the solution procedure, and each solution yields a value of frequency and the damping required to maintain neutral stability.

Plots of damping versus velocity provide the means to predict a critical velocity or flutter speed with respect to the minimum damping criteria. These plots are illustrated in Figures 77 through 79.

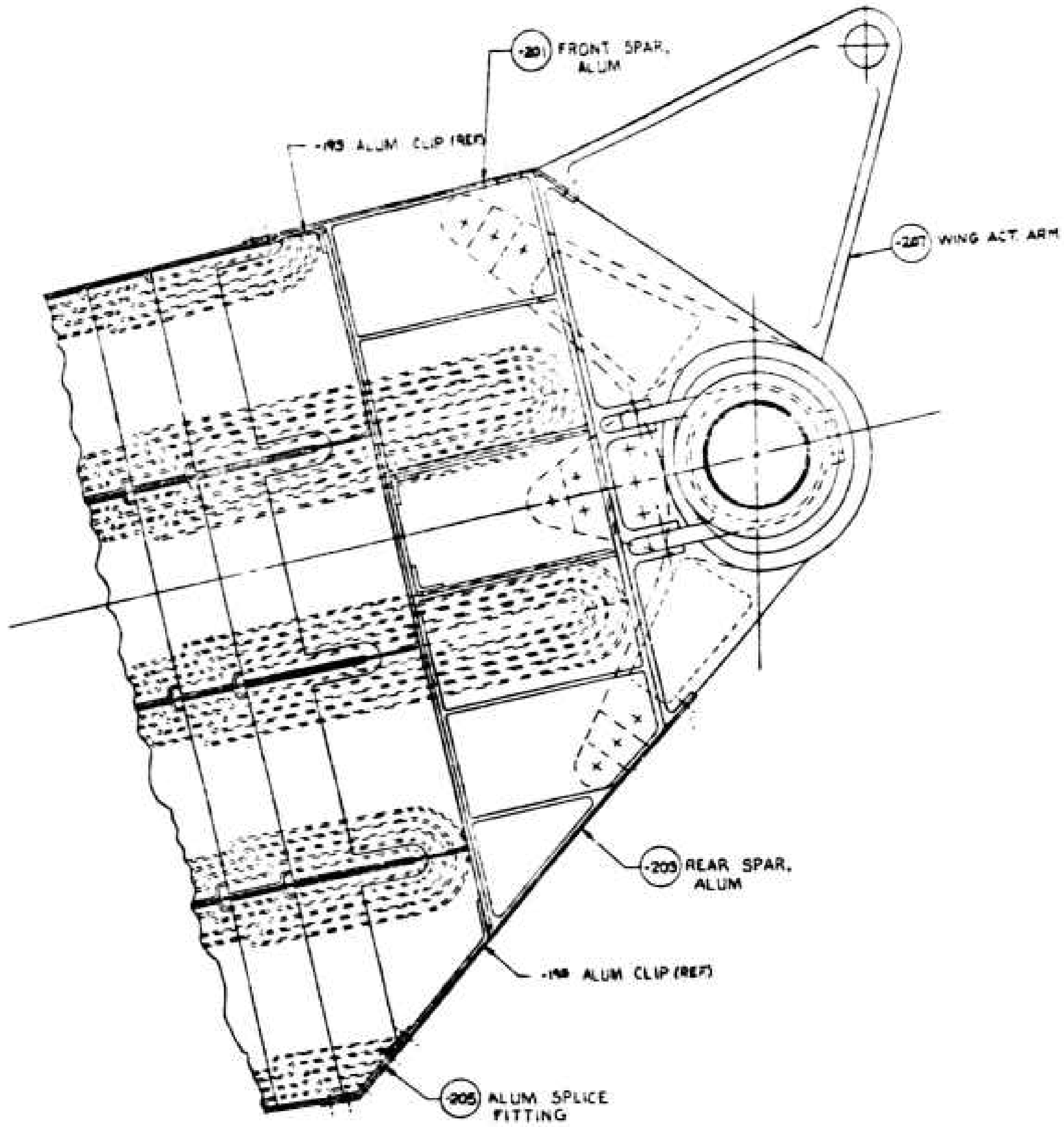


Figure 76 633RW002-3 Pivot Fitting (Sheet 1 of 2)

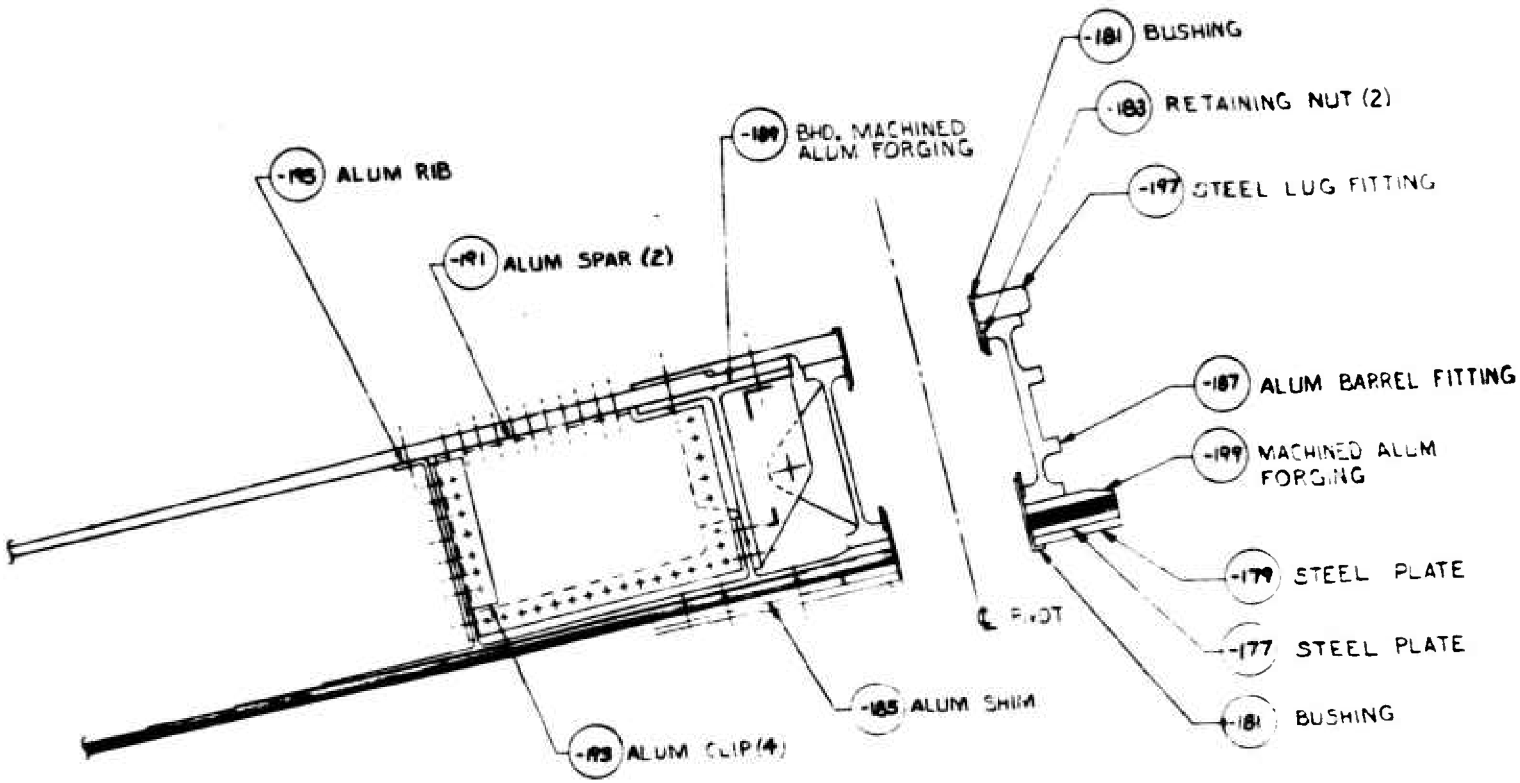


Figure 76 633RW002-3 Pivot Fitting (Sheet 2 of 2)

TABLE XI

WING WEIGHT COMPARISON (LBS. PER SIDE)

	Box Outbd. of Root	Root	Recurring & Non-Opt Weight	Total Wing Box
Baseline	1489	740	530	2759
GR/E (A)	1045	825	378*	2248
GR/E (B)	1045	583	378*	2006
3Y Mtl (TACT Ftg.)	1228	770	530	2528
3Y Mtl (Box Ftg.)	1228	583	530	2341
3V Mtl (TACT Ftg.)	1298	770	530	2598
3V Mtl (Box Ftg.)	1298	583	530	2411

* Includes 48 lbs. for fuel barrier material

TABLE XII

RESULTS OF FLUTTER CHECKS

Configuration	Flutter Speed (S.L. Density, KTS)	Flutter Frequency (HZ)
Baseline Wing Box	915	11.5
Graphite-Epoxy Wing Box	965	13.3
Adv. Metallic (Y-Spar) Wing Box	880	9.4

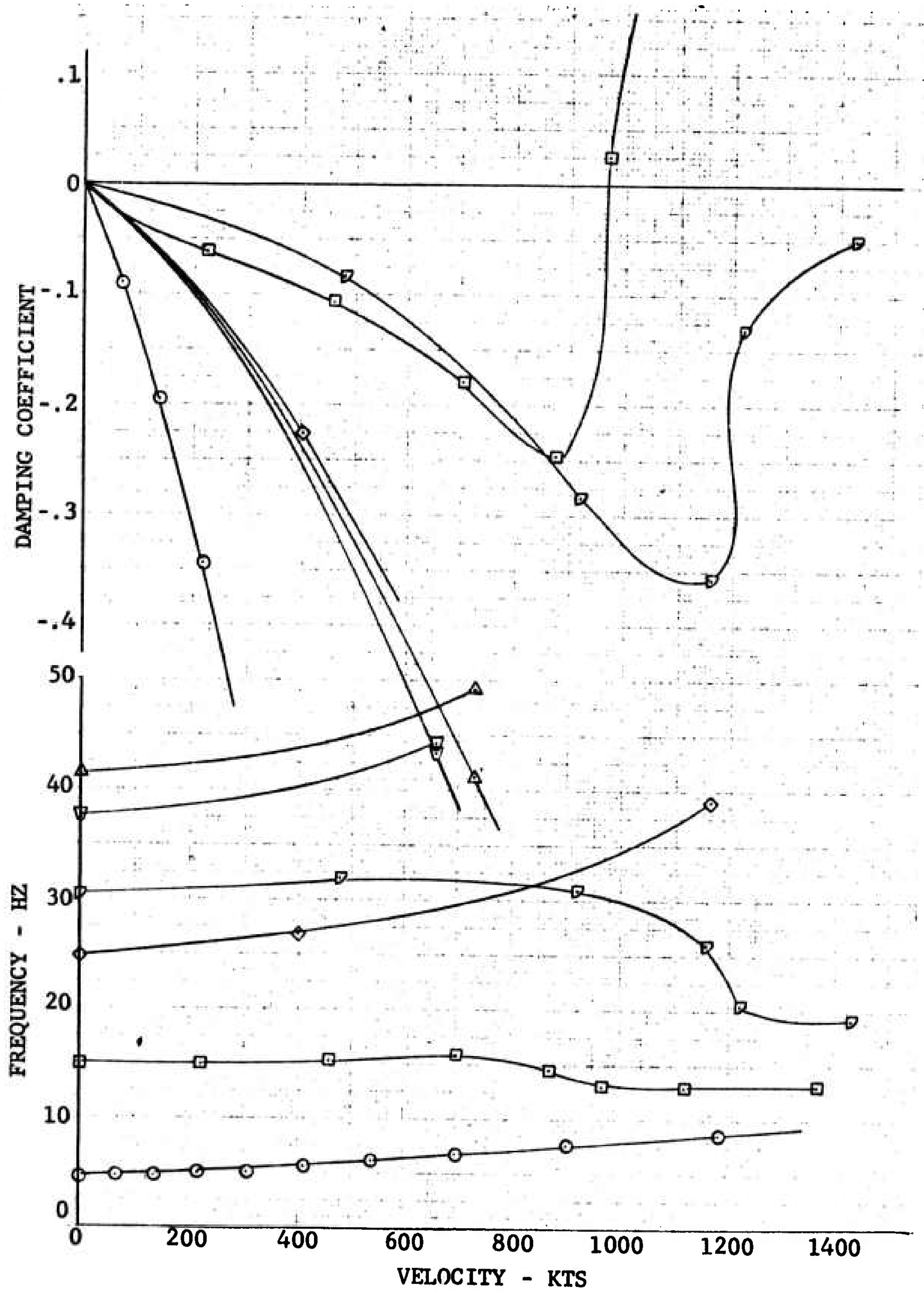


Figure 77 ATW-4 Composite Wing Mach No. 0.9 Seal Level

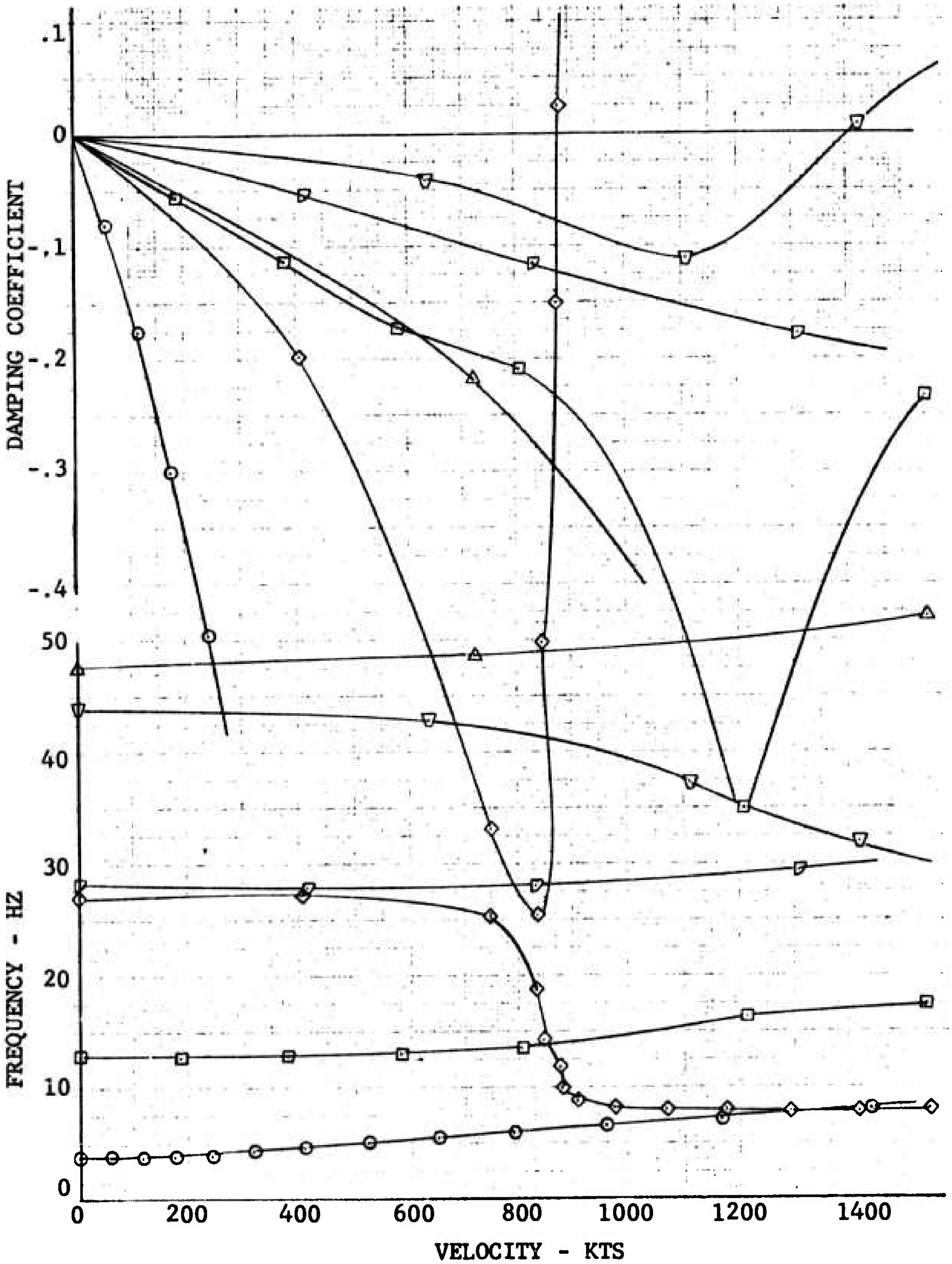


Figure 78 ATW-4 Advanced Metallic Wing Mach No. 0.9 Sea Level

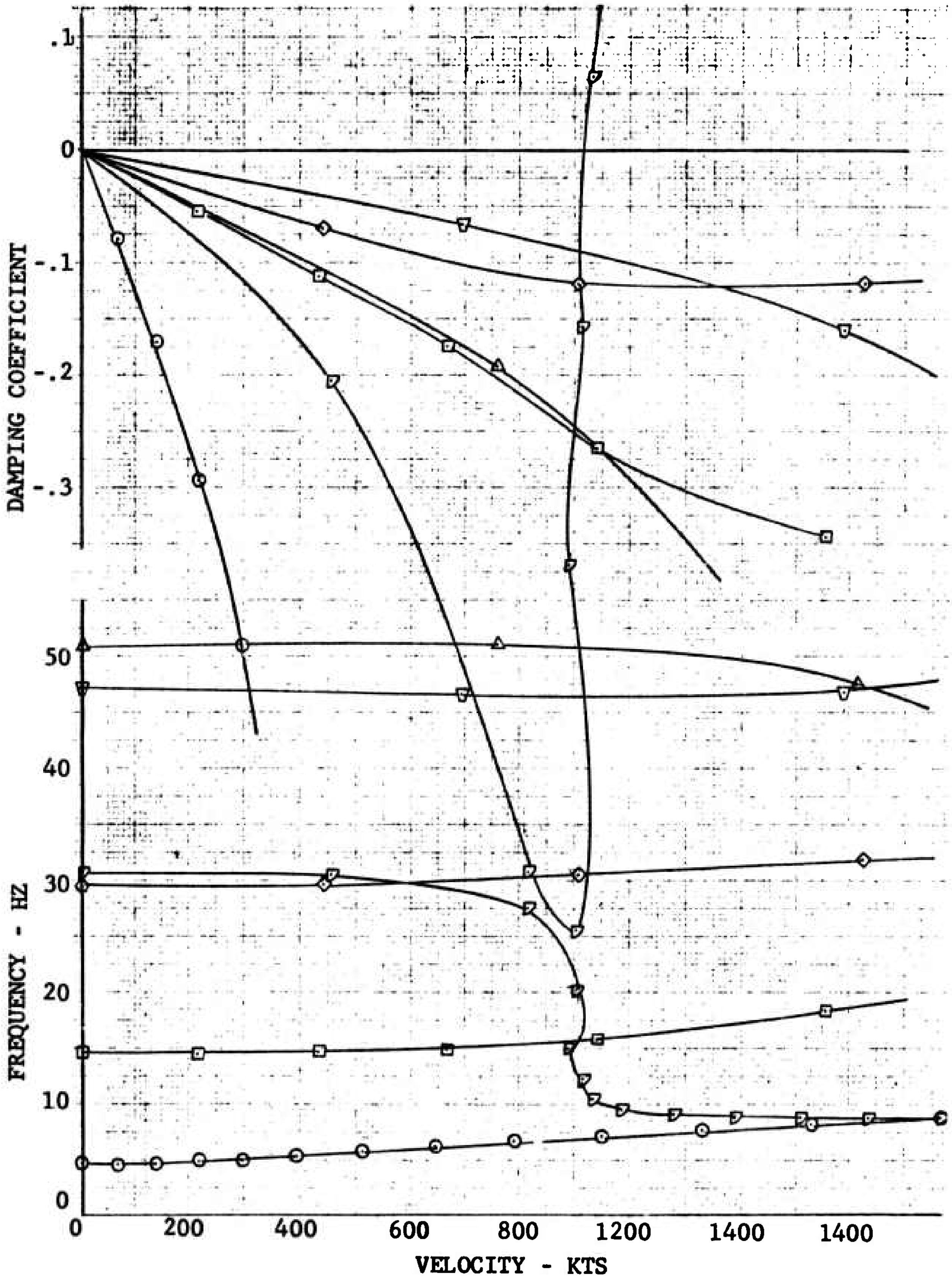


Figure 79 ATW-4 Baseline Wing Mach No. 0.9 Sea Level

4.7 "FAIL SAFE" AND "SAFE CRACK" SCORES FOR FULL SPAN WINGS

"Fail Safe" and "Safe Crack" scoring of the preliminary designs was made using the same procedure that was used for the "Analytical Assemblies" and the results are shown in Tables XIII and XIV.

TABLE XIII

PRELIMINARY DESIGN "FAIL SAFE" RATING

	MINIMUM NUMBER OF ELEMENTS IN FAILSAFE PATH	SCORE
633RW000	0	0
633RW001	4	.120
633RW002-1	0	0
633RW002-3	0	0
633RW003-1	0	0
633RW003-3	0	0

TABLE XIV

PRELIMINARY DESIGN "SAFE CRACK" RATING

	$S_{cg} \frac{18.3(10^6)\ 1.5*}{16.4(10^6)} = \sigma_{Safe\ Crack}$ (Ult)	σ_{Max}	$\frac{\sigma_{Safe\ Crack}}{\sigma_{Max}} = R$	Score = $(.08)\frac{R}{R_{Max}}$	Rank
633RW000	41500	41576	.998	.078	2
633RW001	66900	65232	1.026	.080	1
633RW002-1	57840	56398	1.026	.080	1
633RW002-3	57840	56398	1.026	.080	1
633RW003-1	-	75844	-	.080**	1
633RW003-3	-	75844	-	.080**	1

** Based on the assumption that the advanced composite design is as good as the best.

* Maximum allowable spectrum stress for stable crack growth, times ratio of limit root bending to max spectrum bending; times 1.5 for equivalent ultimate.

SECTION V

FATIGUE ANALYSIS OF ADVANCED TRANSONIC WING (ATW-4)

Fatigue analyses have been performed to demonstrate analytical compliance of the three preliminary wing designs with the baseline fatigue requirements. The following discussions provide a summary of fatigue analysis procedures and results.

5.1 FATIGUE CRITERIA & PROCEDURES

The fatigue life requirements used for this contract are identical to those of the baseline and are summarized below:

1. The structural service life shall be 1280 flights.
2. The fatigue design life shall be the structural service life times a scatter factor of 4.
3. The AFFDL furnished General Dynamics with an analytical fatigue loads spectrum of B-1 wing pivot bending moments. This B-1 wing pivot bending moment spectrum was adjusted to yield wing pivot bending moments compatible with the ATW-4 wing geometry and configurations as discussed in paragraph 4.0 of FZM-12-6466. The analytical fatigue loads spectrum for the ATW-4 wing box is shown in Table XV and Figure 80. The analytical design sections were selected at a wing chord plane perpendicular to the load reference axis (LRA) as shown in Figure 80. Hence, the wing pivot bending moment spectrum was adjusted by the appropriate factors for each mission segment to yield the wing bending moment spectrum 68" outboard of the wing pivot for the fatigue analyses. These factors are presented in Table XV under the column heading $BM_p/BM(68")$.

The fatigue loads spectrum in Table XV was range pair cyclic counted using computerized procedures developed for the AMAVS program (Contract No. F33615-73-C-3001). The wing pivot bending moment was used for all analyses.

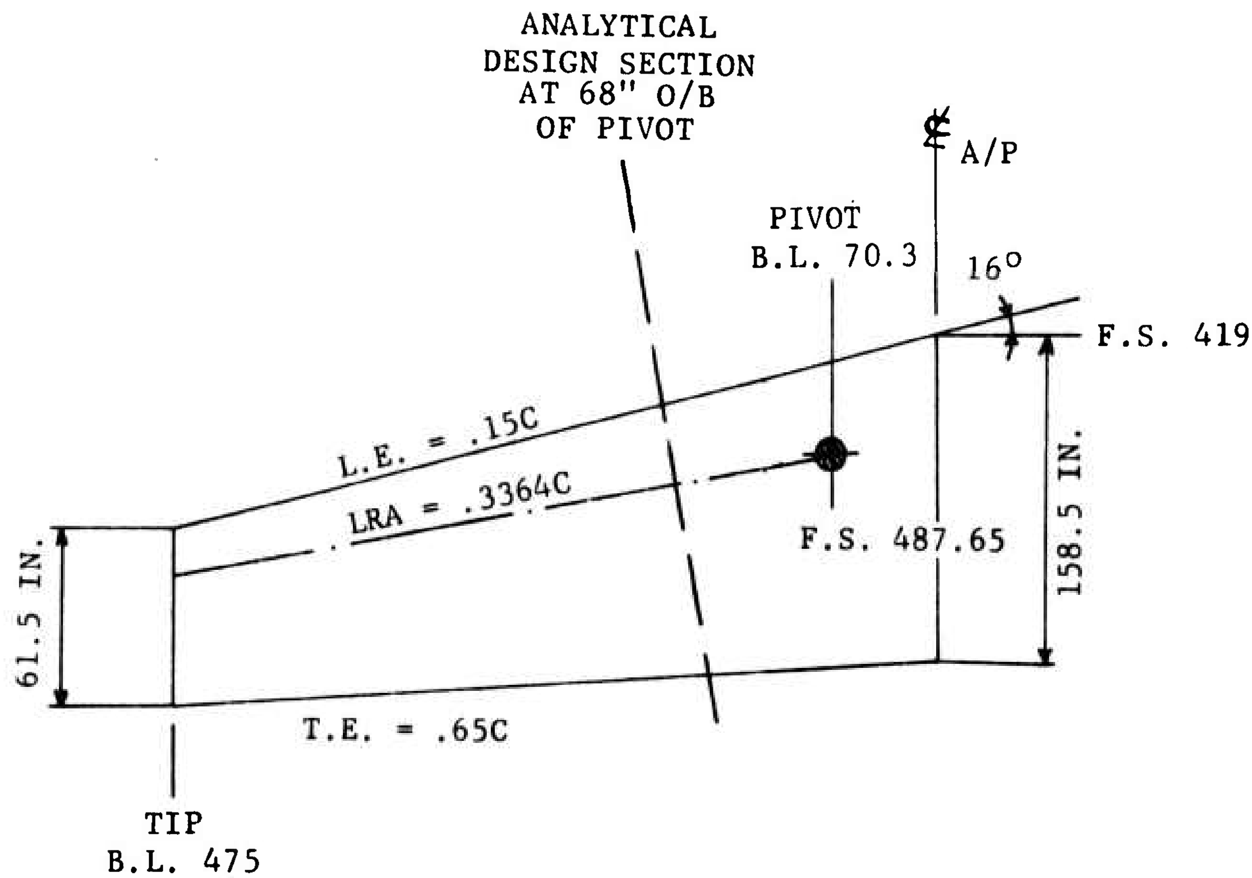
The safe-life concept was used as the primary means of satisfying the fatigue life requirements. The fatigue analyses were generally done according to the following procedure:

1. Fatigue control points were selected.
2. Control point unit stresses (stress per unit of load) were established.
3. Fatigue test (S-N) data were selected for each control point for the appropriate material and stress concentration (K_T).
4. A fatigue stress spectrum was established for each control point by combining the repeated loads and occurrences with the unit stress data.

TABLE XV ANALYTICAL WING PIVOT BENDING MOMENT SPECTRUM FLIGHT-BY-FLIGHT COMPOSITE MISSION

LOAD STEP	MISSION SEGMT.	$\frac{BM_P}{BM(68")}$	$BM_P \times 10^6$ in.-lb. Limit Ld	T_{AW}(°F)	WING SWEEP ANGLE		% OF CONDITION MAX.	% OF CONDITION MIN.	PIVOT $BM_P \times 10^6$ MAX	PIVOT $BM_P \times 10^6$ MIN.	CYCLES/ MISSION
1	GROUND	1.6	-2.9624	58.69	16°		11.5	60.8	-.341	-1.8	1
2	POST TAKE-OFF	1.5	17.93	70.13	16°	M	85.1	51.5	16.62	10.06	0.01
3							76.6	51.5	14.96	10.06	0.1
4							59.3	51.5	11.58	10.06	2
5							51.5	41.4	10.06	8.08	2
6						G	60.5	56.8	11.8	11.09	2
7							60.9	36.2	11.89	7.07	1
8							50.5	44.5	9.86	8.69	29
9	CLIMB CRUISE & REFUEL	1.5	18.3	38.97	16°	M	56.0	37.0	10.25	6.77	1
10							64.5	56.0	11.8	10.25	22
11							56.0	50.5	10.25	9.24	22
12							69.0	46.5	12.63	8.51	1
13							46.5	31.0	8.51	5.67	1
14							54.0	46.5	9.88	8.51	58
15							46.5	42.5	8.51	7.78	58
16	FLY-UP	1.5	16.106	126.15	65°		68.5	25.5	11.03	4.11	1
17							46.7	26.5	7.52	4.27	1
18	TERRAIN FOLLOWING	1.5	16.106	126.15	65°	G	64.7	48.2	10.42	7.76	0.1
19							55.1	28.0	8.87	4.51	1
20							45.1	34.5	7.26	5.56	7
21							48.6	8.1	7.83	1.3	1
22							32.1	18.1	5.17	2.92	132
23							28.6	-4.4	4.61	-.71	1
24							19.6	8.4	3.16	1.35	13[illegible]
25						M	65.4	3.7	10.53	.596	1
26							49.5	6.8	7.97	1.1	9
27							32.1	14	5.17	2.255	95
28	PRELANDING	1.5	17.828	70.13	16°	M	92.1	51.7	16.42	9.22	0.01
29							82.9	-13.8	14.78	-2.46	0.1
30							71.3	51.7	12.71	9.22	1
31	GROUND	1.6	-2.9624	58.69	16°		11.5	60.8	-.341	-1.8	1
32	TAKE-OFF	1.5	17.93	70.13	16°		73.2	49.4	13.12	8.86	1
33	CLIMB	1.5	18.3	38.97	16°		80.5	56.0	14.73	10.25	1
34	PRELANDING	1.5	17.[illegible]	70.13	16°	M	51.7	34.5	9.22	6.15	1
35							59.9	51.7	10.68	9.22	19
36							51.7	46.1	9.22	8.22	19
37						G	76.8	47.9	13.69	8.54	1
38							65.7	56.2	11.71	10.02	4
39							67.0	33.6	11.94	5.99	1
40							60.6	39.9	10.8	7.11	9
41							57.4	43.1	10.23	7.68	48
42							53.0	46.1	9.45	8.22	294
43	GROUND	1.6	-2.9624	58.69	16°		11.5	60.8	-.341	-1.8	8
44							15.4	56.2	-.456	-1.665	154

NOTES: (1) THIS COMPOSITE MISSION TABLE CONTAINS 1143.32 CYCLES PER MISSION & 1,463,449.6 CYCLES PER LIFE.
(2) LEGEND: M = MANEUVER LOAD G = GUST LOAD BM_P = BENDING MOMENT AT WING PIVOT
(3) THE WING BENDING MOMENT IS IN THE LOAD REFERENCE AXIS SYSTEM. (+) BM IS WING TIP UP. SEE FIGURE 6-1.
(4) BM (68") = WING BM 68" O/B OF WING PIVOT.



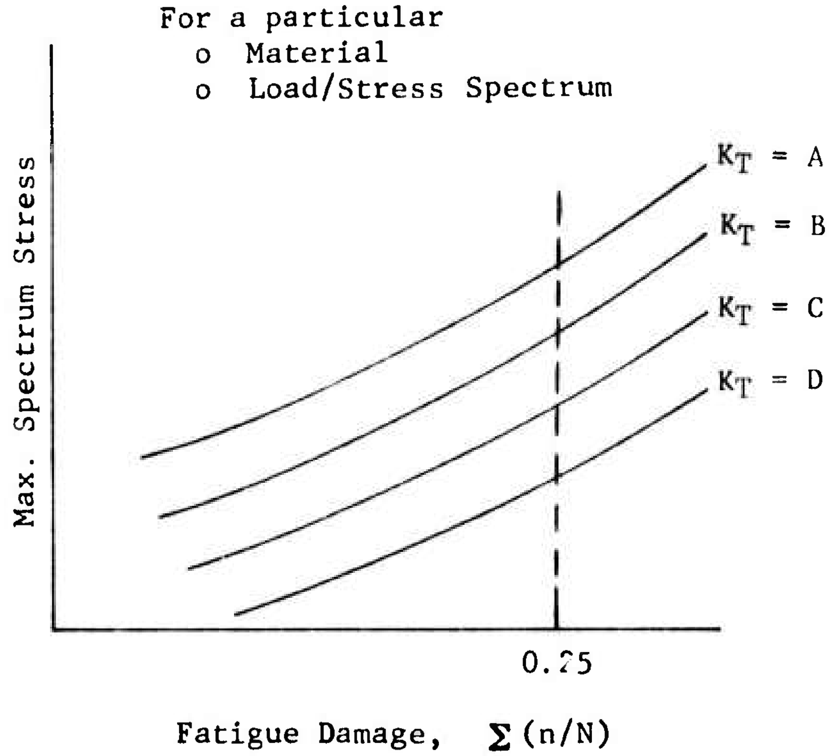
Notes:

1. LRA = Load Reference Axis
2. Wing Bending Moment is in the Load Reference Axis System.

FIGURE 80 Baseline Wing Geometry

5. The fatigue damage calculations were made for the stress spectrum of (4) using the S-N data selected in (3) and using Miner's cumulative damage rule which is $\Sigma(n/N)=1.0$ at failure.

Flexibility and rapid determination of fatigue damage was accomplished for this program by expanding the above procedure on a parametric basis as shown schematically in the figure below.



The approach in the above figure was used to compile a library of fatigue data which reflected the applicable material and stress level. The data in the above figure was then cross plotted at $\Sigma(n/N)=0.25$ to produce fatigue damage data as shown schematically in Figure 81. The fatigue damage for an intermediate K_T value can be readily determined from Figure 81.

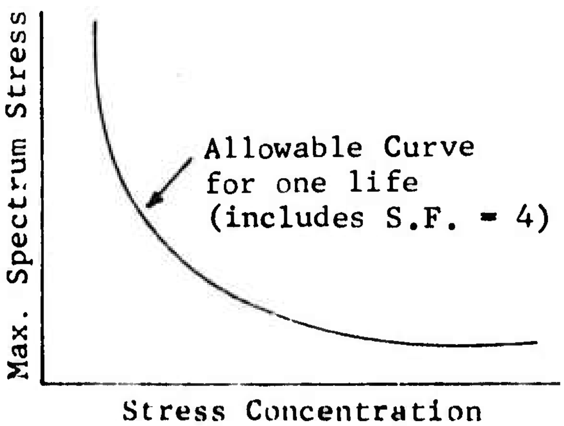


Figure 81 Fatigue Damage Data Schematic

Fatigue S-N data curves were adjusted to account for the reduction in fatigue strength due to elevated temperatures which occur in certain usage segments. The operating temperatures were not available for the various mission segments in the fatigue spectrum. Therefore, an arbitrary 5 per cent reduction in all fatigue S-N data was assumed to apply to all the control points.

The fatigue design allowable curves introduced in this section essentially indicate the interacting relationships between stress, stress concentration factor (K_T), and fatigue life for the baseline fatigue loads spectrum. These curves were developed considering each of the materials utilized in the design of the wing lower surface. The fatigue allowable curves are presented in Appendix (B).

5.2 PRELIMINARY DESIGN FATIGUE ANALYSIS

Fatigue design allowable stresses were determined for each fatigue control point in the three preliminary wing box designs and in the baseline wing box. These allowable stresses are the maximum allowable spectrum stress based on the calculated K_T of each control point and are summarized in Table XVI. As previously stated, Miner's Rule was used in the fatigue analyses for developing the fatigue design allowable curves. Each of the designs were sized to meet or exceed the fatigue requirements summarized in paragraph 5.1. For the slow crack growth structure the final allowable design stress was generally based on the damage tolerance requirements of Section VI whereas the final allowable design stress for the multiple load path-fail safe structure was generally based on the fatigue requirements.

Figures 82 through 87 show the general location of the selected control points. Table XVI indicates the K_T used for design and the net section max allowable spectrum stress at each control point. The max spectrum wing pivot bending moment is 16.42×10^6 in.-lbs. The max design limit wing pivot bending moment is 18.3×10^6 in.-lbs.

The selected control points are located in the wing lower surface of each design because the lower surface has primarily tension loads. The upper surface is primarily loaded in compression or some small tension loads; consequently, the upper surface has been statically designed primarily for compression buckling requirements.

The selection of control points was based on a review of the stresses and a review of the final preliminary design drawings to to locate areas of known or potential stress concentrations. Control point locations other than those documented in this section would probably require evaluation during a detail design effort.

TABLE XVI

FATIGUE ANALYSIS
PRELIMINARY WING DESIGNS

* Wing Configuration and Fatigue Control Points	K_T	Max. Allowable Spectrum Stress, KSI
633-RW000 Baseline Wing Box, Machined Skins & Spars, Plate		
1. Wing Box Lwr Skin Taper-Lok Bolt Hole - Aluminum	3.2	30.7
2. Wing Lower Skin to Pivot Fitting Splice - Aluminum	3.2	30.7
3. Wing Pivot Fitting Lower Lug - D6ac	4.5	99.4
633-RW001 Laminated Lwr Skin, Extruded "Y" & Machined Spars		
4. Spar Web to Cap Attach Bolt Hole - Aluminum	3.5	29.9
633-RW001 and 633-RW002 Wing Pivot Attachment		
5. Laminated Wing Pivot Attach Lower Lug - 10 Ni (HY 180)	5.0	131
6. Laminated Wing Pivot Attach Lower Lug - Aluminum	4.5	27.4
7. Laminated Wing Pivot Taper-Lok Hole - Aluminum	3.7	29.2
8. Laminated Wing Pivot Taper-Lok Hole - 10 Ni (HY 180)	4.8	150
633-RW002 Laminated Lwr Skin, Canted Spars		
9. Spar Web to Cap Attach Bolt Hole - Aluminum	3.5	29.9
633-RW003 Adhesive Bonded Gr/Ep and Titanium Composite Wing Pivot Attachment		
10. Wing Pivot Attachment Lwr Surf Skin Bolt Hole - Titanium	2.4	82

* The fatigue damage is ≤ 1.0 for a scatter factor of 4.0.

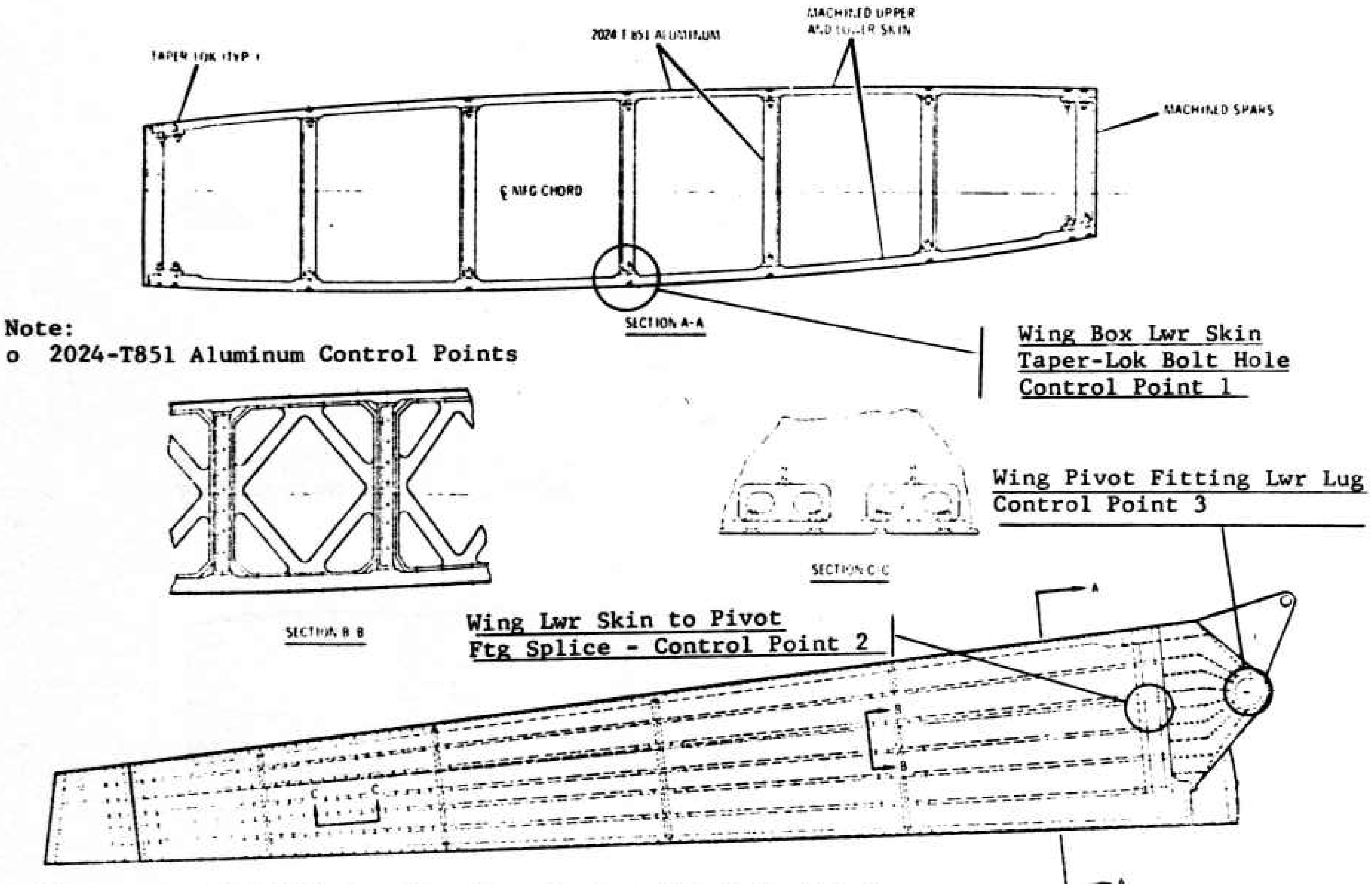


Figure 82 633-RW000 Baseline Wing Control Points 1, 2 & 3

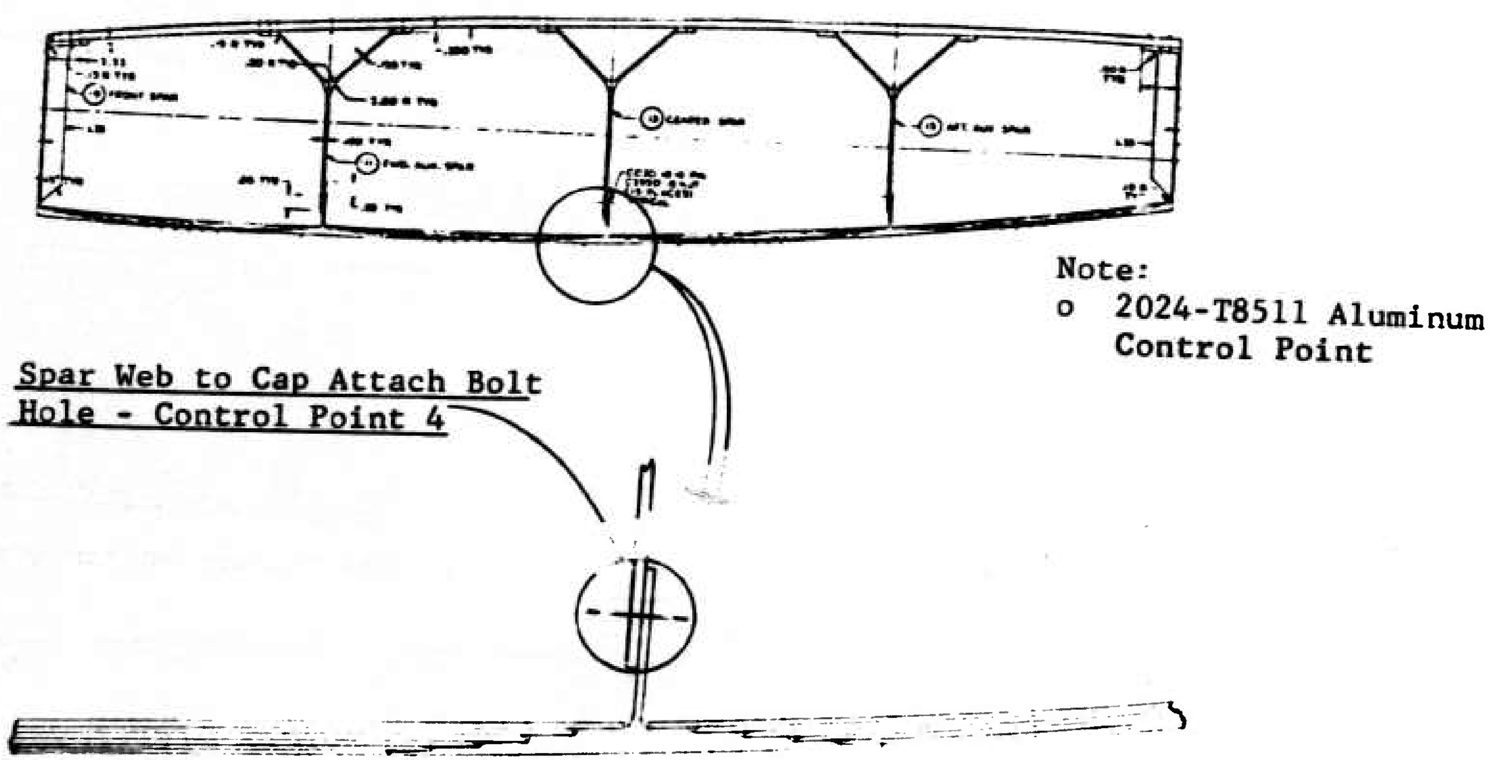
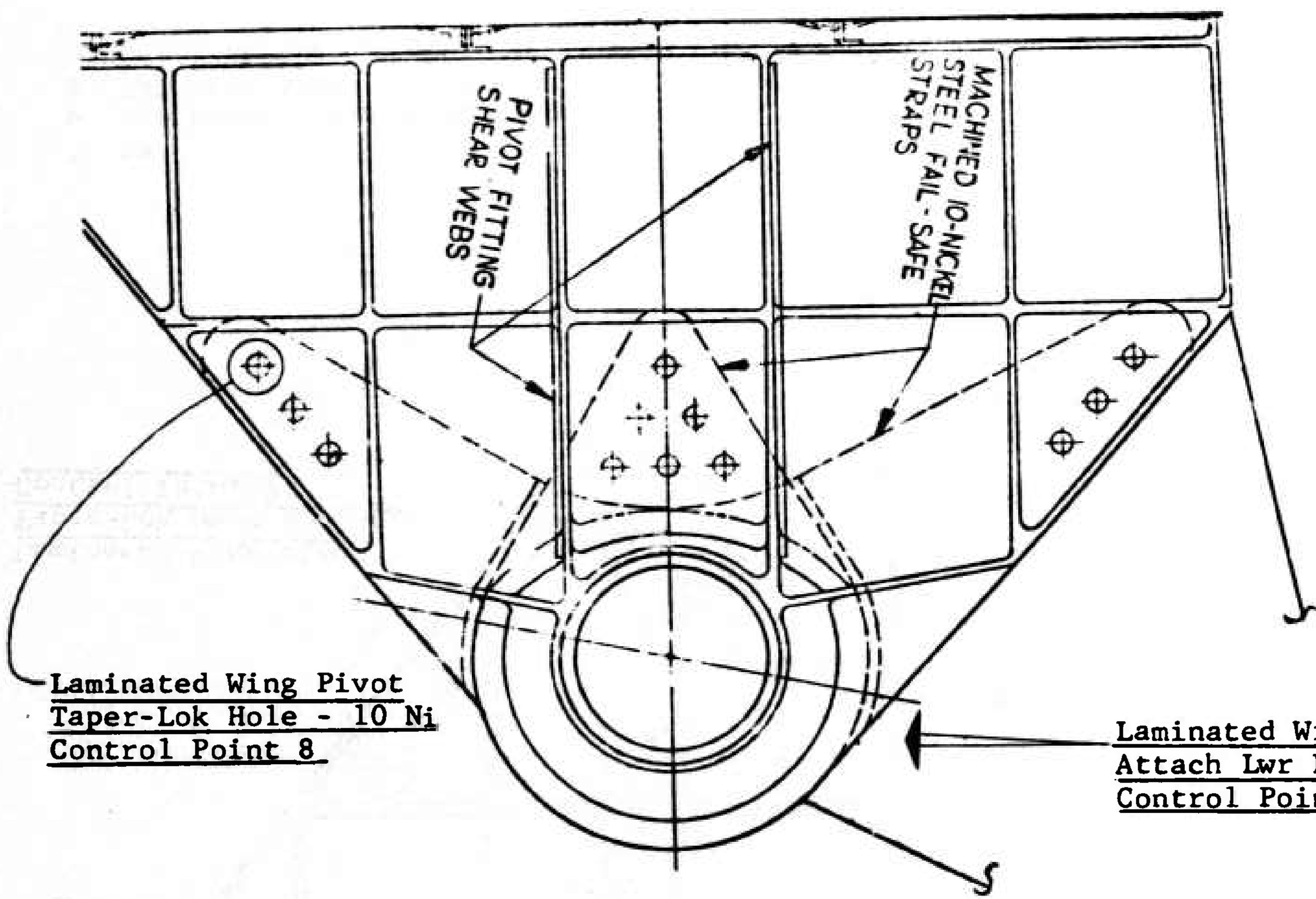
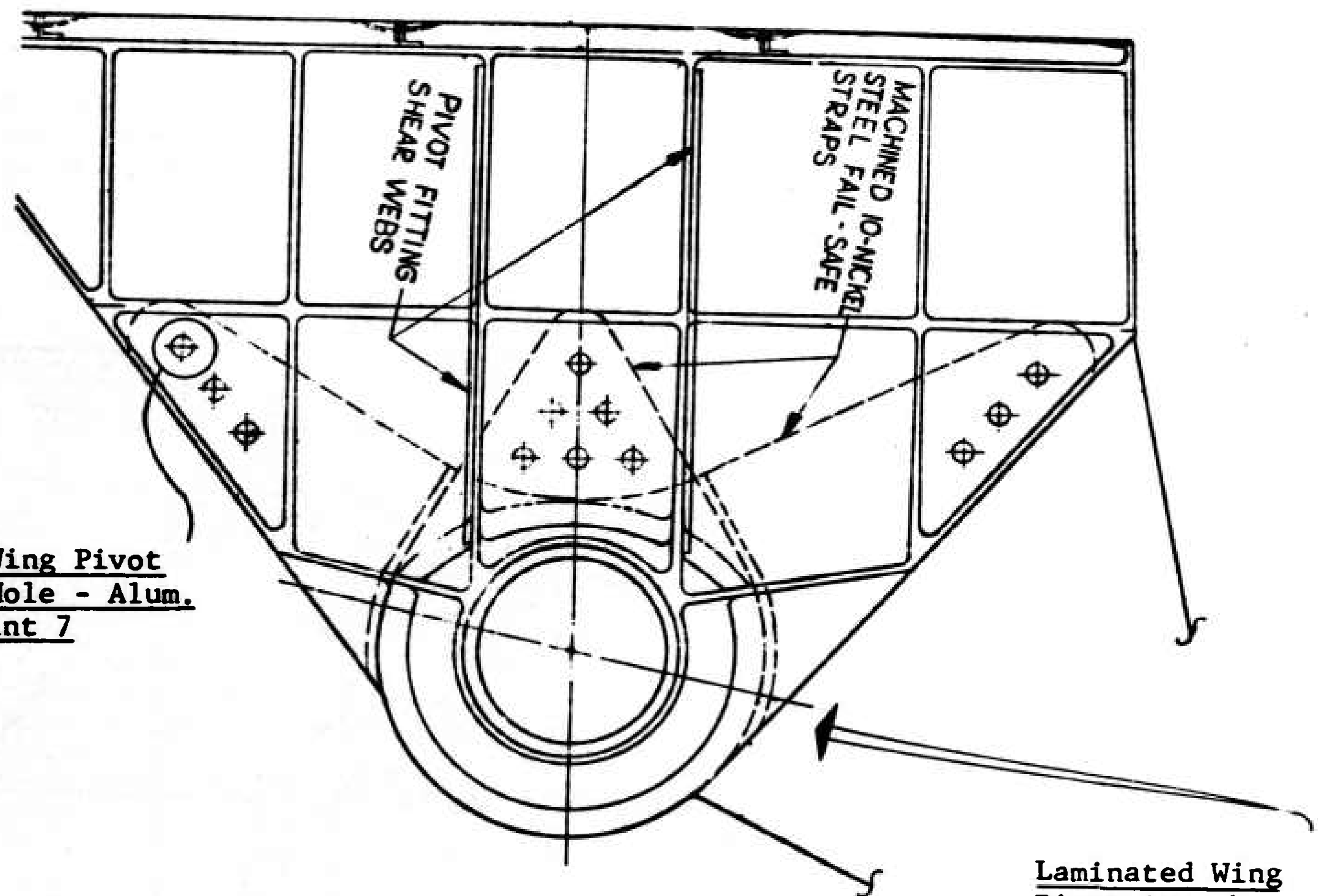


Figure 83 633RW001 Preliminary Wing Box Design - Control Point 4



Notes:
- o Wing pivot strap
- o 10 Nickel Steel Control Points
- o One inch taper-lok hole

Figure 84 633-RW001 and 633-RW002 Wing Pivot Attachment - Control Points 5 & 8



Notes:
- o Laminated lower wing skin
- o 2024-T81 Aluminum Control Points
- o One inch taper-lok hole

Figure 85 633-RW001 and 633-RW002 Wing Pivot Attachment - Control Points 6 & 7

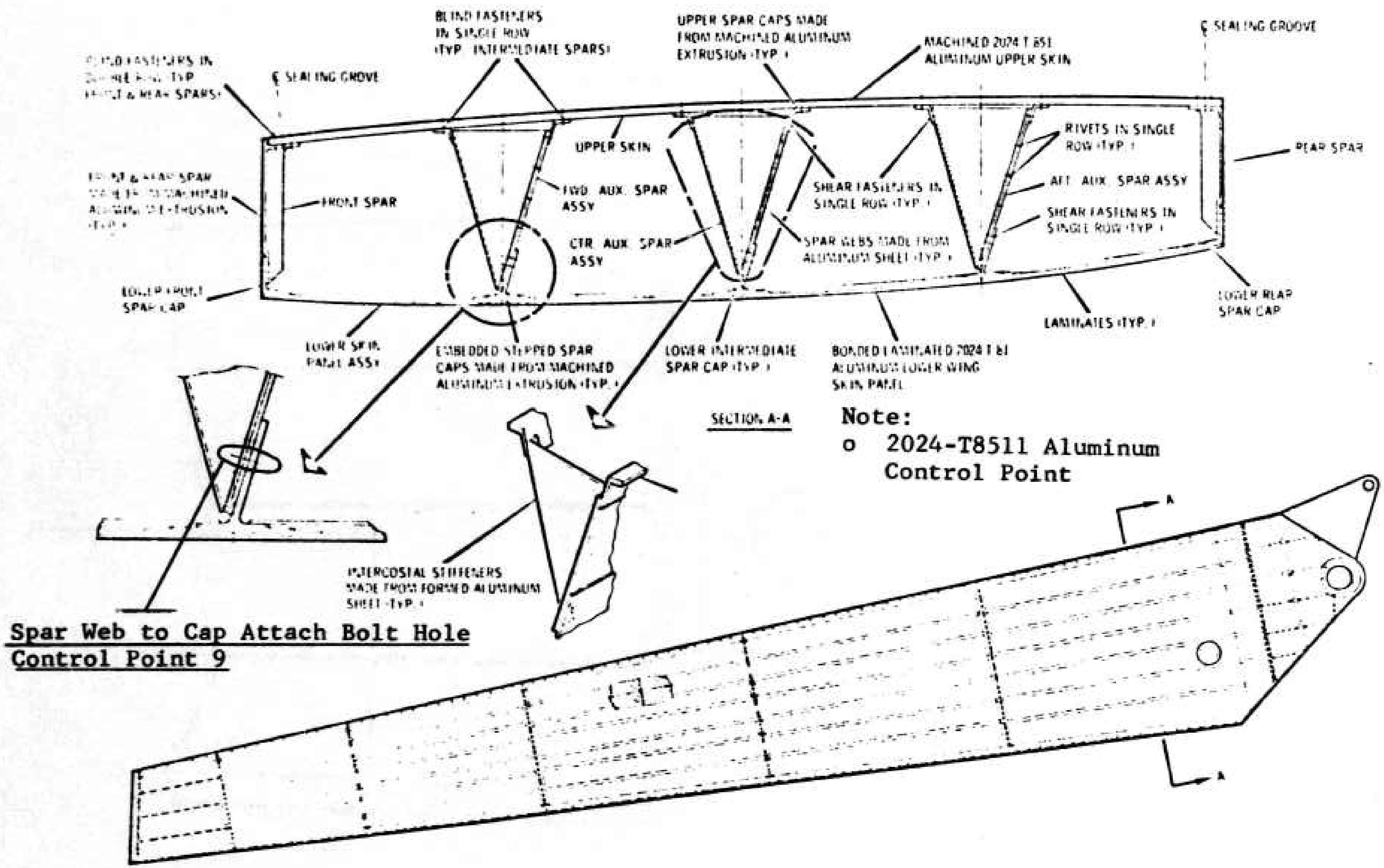


Figure 86 633-RW002 Preliminary Wing Box Design Control Point 9

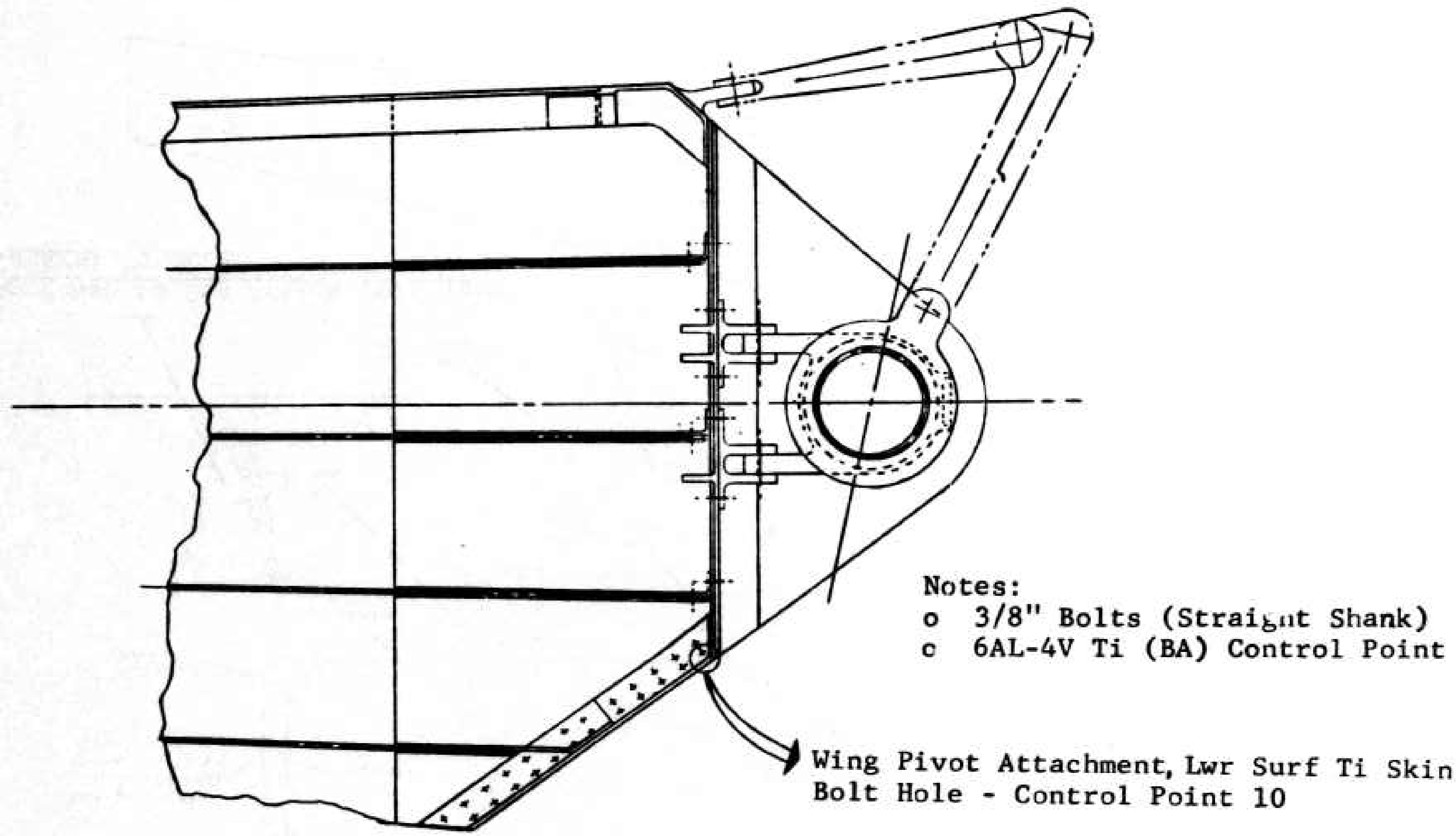


Figure 87 633RW003 Wing Pivot Attachment Control Point 10

Stress concentrations (K_T) were determined using the guidelines discussed in paragraph 5.2.2. The best way to evaluate stress concentration effects is by spectrum testing of components or full scale hardware. This type of test establishes a fatigue quality parameter, K_f, which reflects fretting, residual stress, fabrication, installation quality, etc. that may increase the theoretical stress concentration based on the structural geometry at the control point. In lieu of tests results, the K_T's assigned for this preliminary wing design program are thought to be conservative but within the bounds of good engineering judgement.

5.2.1 Fatigue S-N Data

Notched fatigue S-N data was available for 2024-T851 and for 10 Ni Steel, but no S-N data was available for 2024-T81/-T8511. The following table shows a summary of the S-N data used in the four ATW-4 wing box designs:

TABLE XVII S-N DATA SUMMARY

Material	S-N Data Used for Analysis
2024-T851 2024-T81 2024-T8511	2024-T851 Aluminum, 2" Pl, Long. Grain, K_T=2, 3, 4, and 5 available from F-111 fatigue programs.
10 Ni Steel (HY 180)	10 Nickel Steel, 0.5" Pl, Longitudinal Grain, K_T=1.0, 2.4 and 5 available from AMAVS program.
6AL-4V Ti (Beta Annealed)	6AL-4V Titanium (Beta Annealed), 0.59" Pl, Longitudinal Grain, K_T=1.0, 2.4, and 5.0 available from AMAVS program.

5.2.2 Stress Concentration Factors

The prime objectives of this program have been cost and weight reduction. The 2024-T81 sheet material is cost effective. The laminated structure allows a considerable weight reduction. Except for the wing pivot fitting, generally the laminates were bonded thus eliminating the need for bolts thru the lower surface of the wing box. Consequently, there are no stress concentrations for bolt holes in most of the lower wing surface. However, in the baseline wing box structure of F-111 construction, bolts were used to attach the wing skins to the spars and to the wing pivot fitting. These bolts caused stress concentrations resulting in lowering the allowable fatigue stress. Also, the wing lower surface fuel pump cutout was eliminated thus removing another area of stress concentration. Both bolted and laminated types of construction were used and evaluated during this preliminary design program.

Stress concentration factors for bolted load transfer joints were calculated using a procedure taken from Metal Fatigue by Sines and Waisman. This procedure accounts for the ΔK_T resulting from loaded fasteners as shown in Figure 88.

Using Sines and Waisman's technique, a K_T of 2.9 was calculated with the following formula for the stress concentration at a taper-lok in the baseline wing box lower surface skin.

$$K_T = K'_T + .75 \left(\frac{f_{br}}{f_{ten}}\right)$$

$$K_T = 1.9 + .75 \left(\frac{40}{30}\right)$$

$$K_T = 2.9$$

The K'_T = 1.9 is based on F-111 fatigue developmental tests for an unloaded taper-lok bolt. However for the baseline wing box lower surface skin, a K_T of 3.2 was used based on a F-111 fatigue test failure.

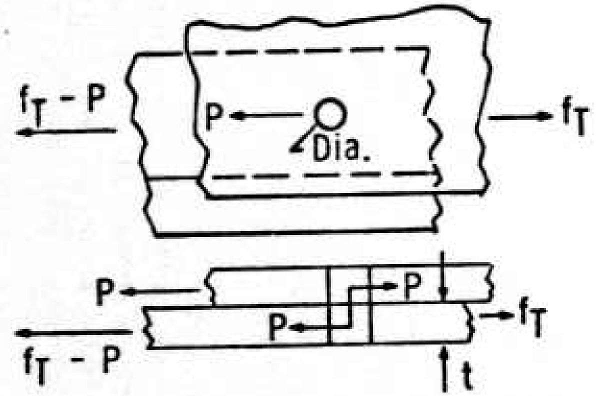
A K_T of 3.2 was also used for the stress concentration at a taper-lok hole in the splice of the wing box lower surface to the wing pivot fitting lower surface. This K_T was chosen because a K_T of 3.2 was calculated from the F-111 fatigue test failure at a taper-lok hole in a splice at this same area of the wing and with similar geometry.

A K_T of 4.5 was used for the wing pivot fitting lower lug based on a 3/8 scale spectrum loaded fatigue test specimen of similar geometry evaluated during the F-111 fatigue development test program.

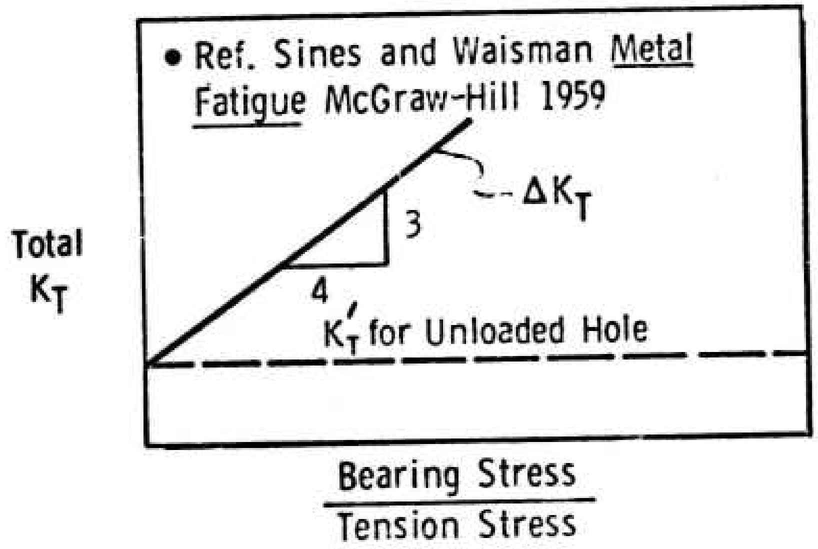
For the splicing of the lower spar cap to the center spar web of the laminated structure, a K_T of 3.5 was used. This was calculated by using the Sines and Waisman's technique and by using Stress Concentration Design Factors by R. E. Peterson.

Wing designs other than the baseline and the Graphite-Epoxy (Gr/Ep) composite designs use taper-lok bolts in the wing pivot attachment. These taper-lok bolts cause local stress concentrations at the holes. The Sines and Waisman's technical and Stress Concentration Design Factors by R. E. Peterson were used to determine

• SINGLE SHEAR BOLT LOADS



f_T = Plate Stress
P = Bolt Load



• TOTAL $K_T = K_T'$ FOR UNLOADED HOLE + ΔK_T FOR LOADED HOLE EFFECT

$$\text{WHERE } \Delta K_T = .75 \left(\frac{\text{Bearing Stress}}{\text{Net Tension Stress}} \right) = .75 \left(\frac{\text{Bolt Load/Bolt Dia. x Plate Thickness}}{f_T\text{, Net Section}} \right)$$

- K_T' Unloaded Holes
  - Interference Fit Fasteners - K_f = 1.9 (BASED ON F-111 FATIGUE DEVELOPMENT TESTS)
  - Non-Interference Fit Fasteners - K_T = 3.0 (OPEN HOLE)

Figure 88 Loaded Fastener Stress Concentration Factor

the stress concentration at these bolt holes in the laminated structure. A K_T of 3.7 was calculated for a hole in the aluminum portion of the structure. A K_T of 4.8 was calculated for a hole in the steel portion of the structure.

The Gr/Ep composite wing design used two plies of 6AL-4V Ti in the wing pivot attachment. The two plies of titanium are bolted and adhesively bonded to the Gr/Ep composite. These straight shank bolts cause local stress concentrations at the bolt holes. A stress concentration factor of 2.4 in the titanium was determined by using the Sines and Waisman technique with Stress Concentration Design Factors by R. E. Peterson. The bearing stress in the titanium was determined to be relatively low resulting in a small K_T. Thus the K_T of 2.4 was determined. Consequently, taper-lok bolts were deemed not necessary to reduce the stress concentration.

Generally the Gr/Ep composite is not fatigue and fracture critical when good engineering design is practiced; therefore, no fatigue and fracture allowables were developed for this material for the preliminary wing design.

SECTION VI

DAMAGE TOLERANCE OF ADVANCED TRANSONIC WING (ATW-4)

Fracture mechanics was utilized throughout this program as the primary technology in providing damage tolerant design. Fracture analyses were performed for the purposes of (1) developing fracture design allowable data and (2) verifying that the final selected designs meet the specified damage tolerance criteria. The detail damage tolerance requirements utilized for this program are specified in MIL-A-83444.

6.1 DAMAGE TOLERANCE CRITERIA

Damage tolerance requirements are specified in MIL-A-83444 for slow crack growth structure (monolithic structure) and two types of fail safe structure. In this program the structure was classified as slow crack growth or multiple load path-fail safe structure. These requirements basically specify initial flaw sizes, residual strength loads, and flaw growth limits. A non-inspectable category was chosen as the basis for sizing the wing box structure. One design service life is 1280 flights.

6.2 DAMAGE TOLERANCE EVALUATION

Fracture design allowable curves were initially prepared for surface flaws and bolt hole flaws in the materials considered for design to aid in the sizing of structural parts. The emphasis was on those readily available materials which would be most cost effective and which possess relatively good fracture properties.

Preliminary analyses were prepared for the wing box lower surface parts which appear to be fracture critical. For example, fracture critical parts are those whose failure would cause loss of the aircraft or severe operating penalties. Analyses were also prepared for points in the wing pivot attachment area for both the baseline structure and a viable alternate for the baseline wing pivot attachment area. This analysis reflects the preliminary part thicknesses, fastener sizes, and stress levels. Maximum principle stresses were calculated for areas of biaxial loading.

The cyclic loads spectra used for crack propagation analyses was identical to that used in the fatigue analyses. This spectrum is shown in Table XV. Flaw growth was calculated in 10 flight block increments. Loads experienced once per 10 flights or once per 100 flights were applied in the proper sequence.

6.2.1 Fracture Design Allowables

Fracture design allowable curves are included in Appendix (C) and were developed for each material and flaw type as shown schematically in Figure 89. The following four steps are a detailed explanation of the analytical technique used to develop the fracture design allowable stress.

1. For an anticipated flaw type and thickness, crack growth analyses were performed to establish a series of crack growth curves representing a range of stress levels.

2. From step 1 the maximum initial flaw size was determined which would permit one interval of growth (one or two lifetimes) as a function of maximum stress in the spectrum. The interval of growth selected was a function of the specified period of unrepaired service usage for the applicable degree of inspectability. The specified period of unrepaired service usage for the noninspectable multiple load path-fail safe structure is one design lifetime. The specified period of unrepaired service usage for the noninspectable slow crack growth structure is two design service lives.

3. The allowable spectrum stress was plotted as a function of initial flaw size.

4. The allowable spectrum stress level was determined from step 3 in accordance with the initial flaw size and period of unrepaired service usage requirements specified in MIL-A-83444.

Procedures and assumptions used in the fracture analysis effort are discussed in paragraphs 6.2.2 through 6.2.4. The basic fracture data utilized for analysis are discussed in paragraph 6.2.6.

6.2.2 Flaw Growth Model

The basic flaw growth model used for fracture analysis is described as follows:

$$a_n = a_o + \sum_{n=1}^{N} (C_p) \qquad (da/dN) = f(\Delta K) \qquad \text{where}$$

a_n = Crack length after "n" load applications

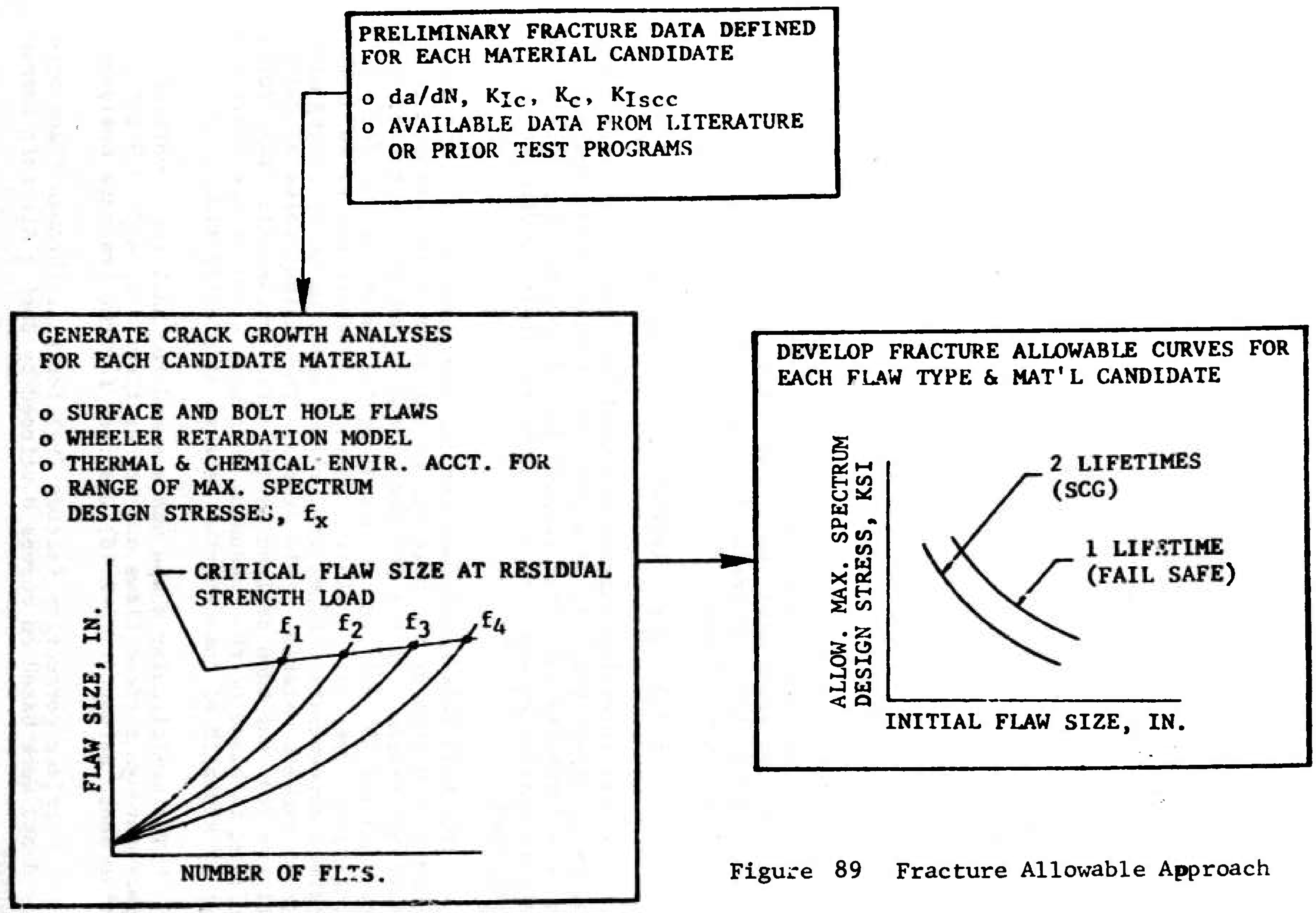


Figure 89 Fracture Allowable Approach

a_o = Initial crack length

C_p = Spectrum interaction parameter that reflects retardation of flaw growth

da/dN = Rate of crack growth

ΔK - Range of stress intensity during a load cycle

The spectrum retardation parameter, C_p, is the basis for the Wheeler model developed for use during the F-111 Recovery Program. The Wheeler model is intended to account for spectrum interaction through empirical correlation to establish a retardation exponent "m". The value of "m" is varied repetitively until the analysis produces a crack growth curve which forms a lower "m" bound of spectrum environmental test results.

The value of "m" used for this program was zero because determining "m" was not within the scope of this task. Also, an "m" value of zero eliminates the C_p parameter from the calculated flaw growth which yields conservative crack growth rates (shorter time to critical crack length).

6.2.3 Stress Intensity and Flaw Growth

Stress intensity expressions used for fracture analyses are shown in Figure 6-2. These expressions include equations for stress intensity and crack lengths for various types of flaws. The secant correction was used to account for finite width when required.

The bolt hole models account for geometric stress concentration at the edge of the hole but do not account for effects of the fastener system. In the GKT model, the stress concentration (K_T) assumed for the hole was identical to that used for the fatigue analysis. However, provision was made to handle the cases where stress concentration times the maximum spectrum or operating stress (MOS) exceeds material yield stress. The maximum value of GKT (see Figure 90) was then defined as the ratio ($\sigma ys/\sigma max$). This definition is based on the reasoning that peak stresses are limited to yield strength of the material because of plastic flow.

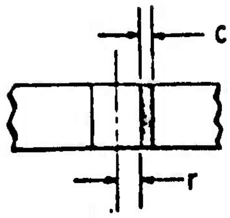
The semicircular shape was assumed for analyses involving part-through surface flaws and corner flaws. An a/2c=0.5 and a flaw shape parameter (Q=2.46) was used for the fracture analyses.

Backface correction factors (M_K) for part-through flaws were used and were based on curves developed by Boeing Aircraft Corporation.

- **BOLT HOLES (Bowie Model)**

$$K = \sigma\sqrt{\pi c}\ F(c/r)$$

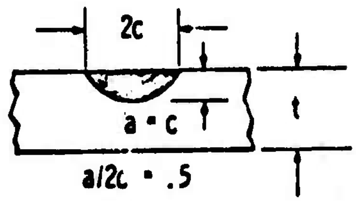
$$c = \frac{K^2}{\pi\sigma^2 [F(c/r)]^2}$$



- **SURFACE FLAW (Part through)**

$$K = M_K \frac{1.1\sigma\sqrt{\pi a}}{\sqrt{\phi^2 - .212(\sigma/\sigma_y)^2}}$$

$$a = \frac{K^2[\phi^2 - .212(\sigma/\sigma_y)^2]}{1.21\pi\sigma^2 M_K^2}$$



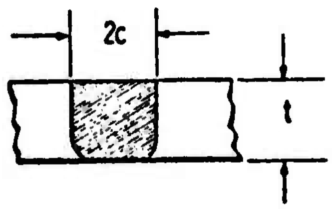
- **SURFACE FLAW (through the Thickness)**

$$K = \sigma\sqrt{w \tan\left(\frac{\pi a}{w} + \frac{K^2}{2w\sigma_y^2}\right)}$$

DERIVED (FOR w ≥ 6")

$$2c = \frac{1}{\pi}\left(2.0 - \frac{\sigma^2}{\sigma_y^2}\right)\left(\frac{K}{\sigma}\right)^2 \quad \text{Plane Stress}$$

$$2c = \frac{1}{\pi}\left(2.0 - \frac{\sigma^2}{3\sigma_y^2}\right)\left(\frac{K}{\sigma}\right)^2 \quad \text{Plane Strain}$$



- **SEMICIRCULAR CORNER CRACK**

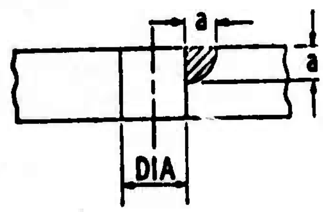
$$K = \frac{1.2\sigma\sqrt{\pi a}}{\phi}(GKT)$$

$$a = \frac{K^2\phi^2}{1.44\pi\sigma^2 (GKT)^2}$$

$$GKT = G_{min} + (G_{max} - G_{min})\,Exp\left[Ln(.01)\frac{a}{DIA}\right]$$

$$G_{min} = 1.0\ ,\quad G_{max} = K_T$$

For $K_T \times \sigma_{max} \geq \sigma_{ys}$, $G_{max} = \sigma_{ys}/\sigma_{max}$ By Definition



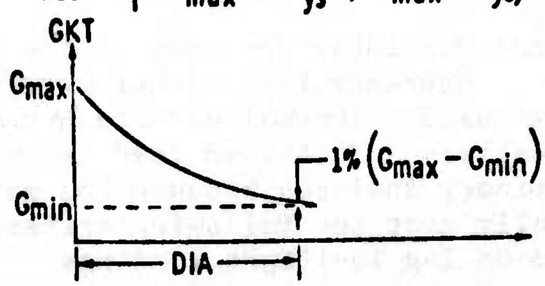


Figure 90 Stress Intensity Expressions

Flaw growth calculations were made using a General Dynamics developed IBM 370 computer program identified as TR9. This program produces results almost identical to those produced by the AFFDL-TR-70-107 CRACKS program. TR9 was used because it involves somewhat less computer run time for a typical analysis.

6.2.4 Initial Flaw Sizes

The initial flaw sizes and types are given specifically in MIL-A-83444. For this preliminary design analysis, the degree of inspectability was assumed to be In-Service Non-inspectable Structure. The following is a brief summary of the initial flaw sizes and types for noninspectable structure:

1. Slow crack growth (monolithic) structure

   (a) The initial crack length, $2c_o$, for a surface flaw is assumed to be 0.25 inches in length.

   (b) The initial crack length, c_o, a cracked hole is assumed to be 0.05 inches in length.

2. Multiple load path-fail safe structure

   (a) The initial crack length, $2c_o$, for a surface flaw is assumed to be 0.10 inches in length.

   (b) The initial crack length, c_o, for a cracked hole is assumed to be 0.02 inches in length.

6.2.5 Material Fracture Data

The basic fracture data required for a comprehensive fracture analysis should include the following data for each material utilized:

1. Fracture Toughness - K_{IC}, K_C, K_{ISCC}

2. Crack Growth Data - da/dN, da/dt

Crack growth data was not available for some of the desired thicknesses and environments. Consequently, either conservative or representative da/dN data was used. Thermal effects on crack growth were neglected for the analyses. Sustained load crack growth was neglected for the preliminary analyses because the metallic materials selected will usually meet the following criteria when sustained stresses are based on 1-g in-flight loadings.

$$\frac{\text{Max. 1-g Sustained Tensile Stress}}{\text{Max. Operating Tensile Stress}} < \frac{K_{ISCC}}{K_{IC}}$$

However, additional data must be developed before ascertaining the importance of sustained load crack growth on the Graphite-Epoxy (Gr/Ep) composite materials.

The following is a summary of the fracture toughness data assumed for the preliminary design analyses:

Material	K_{IC}, ksi $(in.)^{1/2}$	K_C, ksi $(in.)^{1/2}$
2024-T851 Alum.	22.2	35.4
2024-T81 Alum.	60	60 for 1 ply 170 for 4 ply
2024-T8511 Alum.	22.2	35.4
10 Nickel Steel	160	160
6AL-4V Titanium (Beta Annealed)	80	193

The toughness values shown in this summary represent values in the L-T direction. All values are typical of the raw stock sizes for the forms specified for the more critical parts evaluated such as the wing box lower surface.

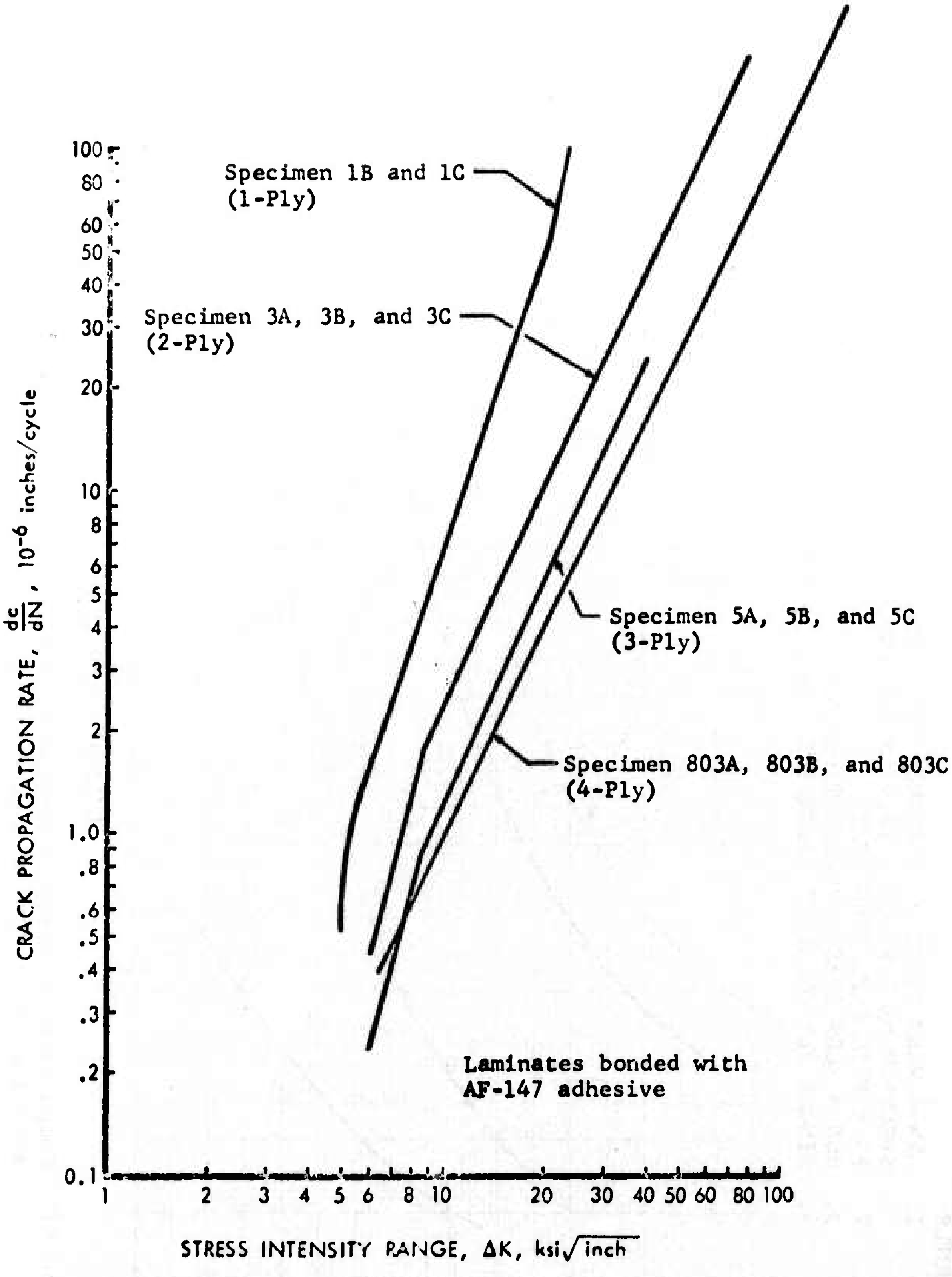
Flaw propagation data (da/dN) used for the analyses is summarized in Table XVIII. When flaw growth data was not available for the desired material thickness, the growth data from a thicker part of the same type material was used for a conservative analysis. In Research Report ERR-FW-1584, flaw growth data is available from small test specimens of 4 ply bonded laminates made from 2024-T81 aluminum. Where applicable the decrease in flaw growth rate due to the bond lines in laminated panels was used to greatly increase the allowable fracture stress. Figure 91 shows a plot comparing flaw growth data for 1, 2, 3, and 4 ply bonded laminates of 2024-T81 aluminum. Figure 92 compares the fracture design allowables stress for sheet, plate, and 4 ply bonded laminates made from 2024 aluminum. Figure 93 compares the structural life of 2024 aluminum sheet, plate, and 4 ply bonded laminates.

TABLE XVIII

PRELIMINARY DESIGN ANALYSIS
FLAW GROWTH DATA SUMMARY

Material	(dc/dN) or (da/dN) Data Assumed
2024-T851 Aluminum Plate	AFML-TR-66-291 CNT Data, R = 0.33, 310 cpm, RT Air, Foreman Eq.
2024-T81 Aluminum Laminated Sheet	ERR-FW-1584 Data, Center Cracked Outer Ply, 4 Ply Laminate, Adhesive Bonded, R = 0.1, RT Air, Paris Eq.
2024-T8511 Aluminum Extrusion	AFML-TR-66-291 CNT Data, R = 0.33, 310 cpm, RT Air, Foreman Eq.
10 Nickel Steel	AFFDL-TR-74-17 CT Data, R = 0.1, 60 cpm, STW, Foreman Eq.
6AL-4V Titanium (Beta Annealed)	AFFDL Damage Tolerant Design Handbook MCIC-HB-01, CT Data, R = 0.5, 70F, STW, 6 cpm, L-T Direction, Foreman Eq.

CNT - Center-notch tensile specimen
RT - Room temperature
CT - Compact specimen
STW - Sump tank water



Fatigue Crack Propagation of 1-Ply, 2-Ply, 3-Ply, and 4-Ply Laminates of Adhesive Bonded 2024-T81 Aluminum, .100 Inch Sheet, R = 0.1, Dry Air, L-T Direction

Figure 91

NOTES:

1. ATW-4 WING PIVOT BM SPECTRUM FOR WING LOWER SURFACE. MAXIMUM WING SPECTRUM BM @ PIVOT = 16.42×10^6 IN-LBS.
2. FS = FAIL SAFE STRUCTURE.
3. SCG = SLOW CRACK GROWTH STRUCTURE.
4. SINGLE PLY OR SHEET THICKNESS = 0.090; PLEATE THICKNESS = 0.912.

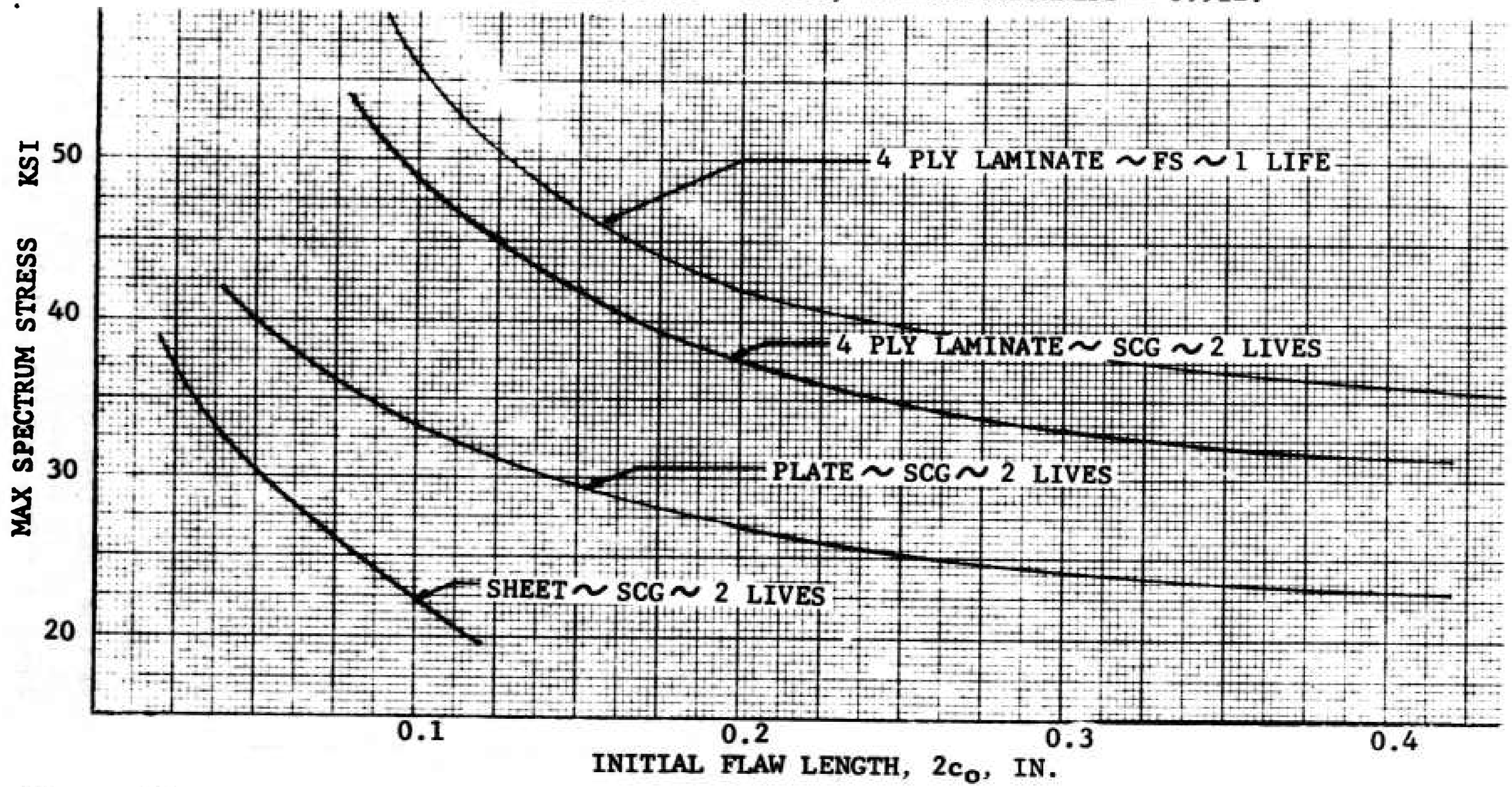


Figure 92 Comparison of Fracture Design Allowables Sheet vs. Plate vs. Laminate Noninspectable Structure 2024 Aluminum Surface Flaw

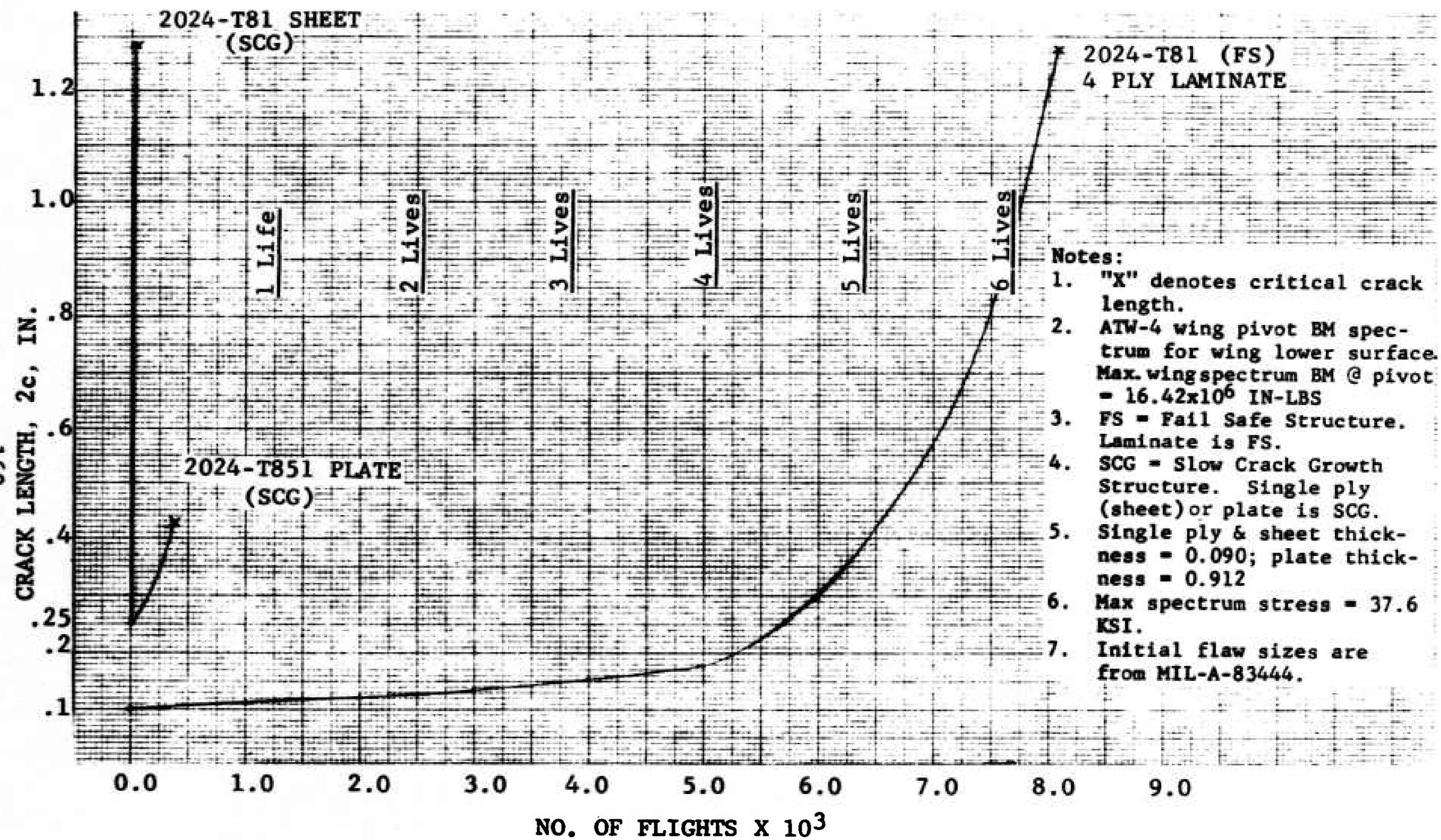


Figure 93 Comparison of Structural Life Sheet vs. Plate vs.Laminate Noninspectable Structure 2024 Aluminum Surface Flaw

6.2.6 Residual Strength Load Determination

The residual strength load requirement specified in MIL-A-83444 for noninspectable structure is denoted as P_{LT}, which is the maximum one time load occurring in 20 lifetimes as determined from average load exceedance data.

Wing pivot bending moment cumulative exceedance plots were constructed from the fatigue loads spectra data shown in Table XV and documented in FZM-12-6466. The exceedance plot was increased by a factor of 20 to develop exceedances for 20 lifetimes as specified in MIL-A-83444 for non-inspectable structure. The two points on the plot for the two largest wing pivot bending moments were used to make a straight line extrapolation of the plot to the one time occurrence level. This exceedance plot is shown in Figure 6-6. Using the extrapolated data for the 20 lifetime occurrences, the residual strength load requirement, P_{LT}, is 23.5 X 10^6 in.-lbs. of wing pivot net bending moment. The design limit wing pivot net bending moment is 18.3 X 10^6 in.-lbs. MIL-A-83444 states that if P_{LT} is greater than the design limit load for one lifetime, then the residual strength load need not be greater than 1.2 times the maximum operating load for one design lifetime. Therefore, P_{LT} for these fracture analyses was determined to be 1.2 (16.4 X 10^6) = 19.68 X 10^6 in.-lbs. of wing net bending moment instead of the 23.5 X 10^6 in.-lbs. determined from the exceedance plot.

6.2.7 Preliminary Wing Design Analysis

Preliminary fracture analyses sufficient to evaluate the baseline wing box, two metallic wing boxes, and one composite wing box are presented in this section. All four wing boxes were designed to conform to the MIL-A-83444 damage tolerance requirements for in-service non-inspectable structure. Even though some of the structure is inspectable, all the analyses were accomplished as if the structure was In-Service Non-inspectable Structure. For each of the analyses the fracture allowable stress for the maximum spectrum bending moment was developed to conform to the residual strength requirement specified in MIL-A-83444. The four wing box designs are the baseline box and the final three configurations selected according to their ranking in the preceding task. Generally the analyses are of the wing box lower surface.

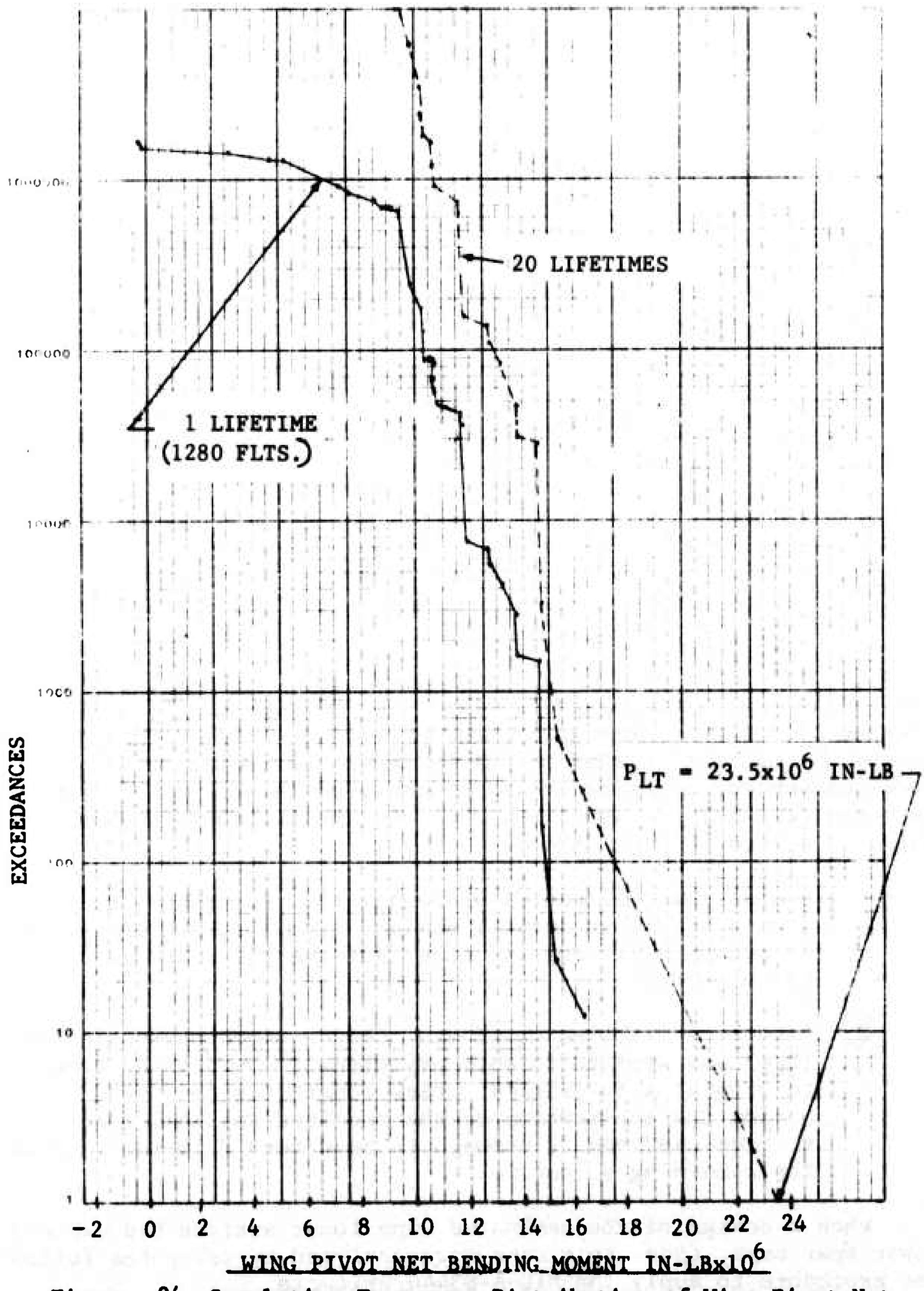


Figure 94 Cumulative Frequency Distribution of Wing Pivot Net Bending Moment

6.2.7.1 Baseline Wing Box (633-RW000)

The baseline wing box, 633-RW000, shown in Figures 95 and 96 was classified as monolithic structure because the whole lower surface skin is one piece construction in the chordwise direction. Failure of the wing lower surface skin would cause loss of the aircraft. Consequently, this lower skin was required to sustain two design service lives without the specified initial flaw sizes attaining critical crack size. Corner flaws and surface flaws were both analyzed for the lower surface of the baseline wing box.

6.2.7.2 Wing Box with Laminated Skin and Exposed Spar Cap (633-RW001)

The ATW-4 wing box design with the laminated lower surface skin and with the exposed lower spar caps as shown in Figure 97 and 98 was classified as multiple load path-fail safe structure. Crack arrest capability was provided in this design by ending each ply at the adjacent spar; hence, a chordwise crack in a ply would not propagate into or past the adjacent ply or spar during the specified inspection interval because of the inability of the crack to propagate through the bonding material. For a similar reason, a crack in the spar cap would propagate until reaching the bond line and the stop.

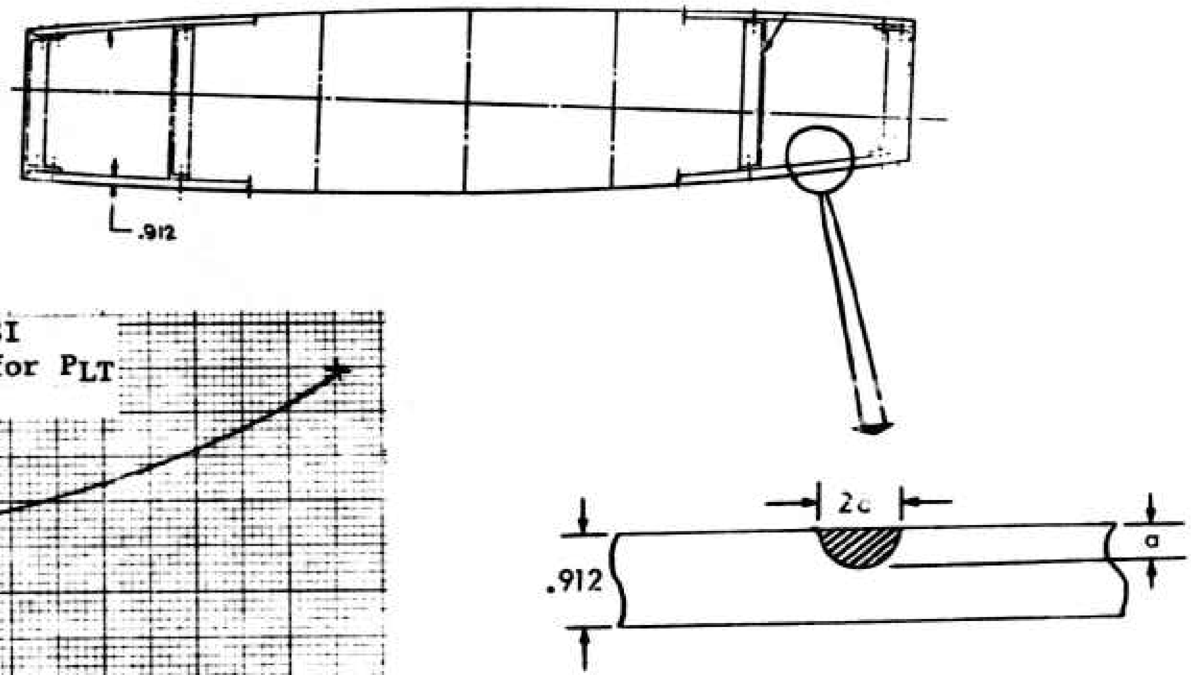
When a design of the laminated wing lower surface had exposed lower spar caps, the laminated lower wing surface panels were treated as multiple load path structures, i.e., each ply was considered a load path within the laminated panel, and each ply was made independent by using bonding techniques rather than fasteners. Then the critical ply was sized according to the following criteria which is stated in MIL-A-83444.

1. A crack was allowed to propagate for one design lifetime from a specified initial surface flaw. During the crack propagation for one lifetime, all the plies are assumed to be bonded.

2. After one lifetime of growth, the required residual load (P_{LT}) was applied to this ply without causing the crack to propagate to critical crack length for this ply. During the application of the required residual load, this cracked ply is assumed to have been delaminated from the remaining structure.

When a design of the laminated wing lower surface had exposed lower spar caps, these spar caps were analyzed by using the following procedure to apply the MIL-A-83444 criteria.

Notes:
- o Lower wing skin
- o Surface flaw
- o Slow crack growth structure
- o 2024-T851 Aluminum
- o Non-inspectable structure
- o a/2c=0.5



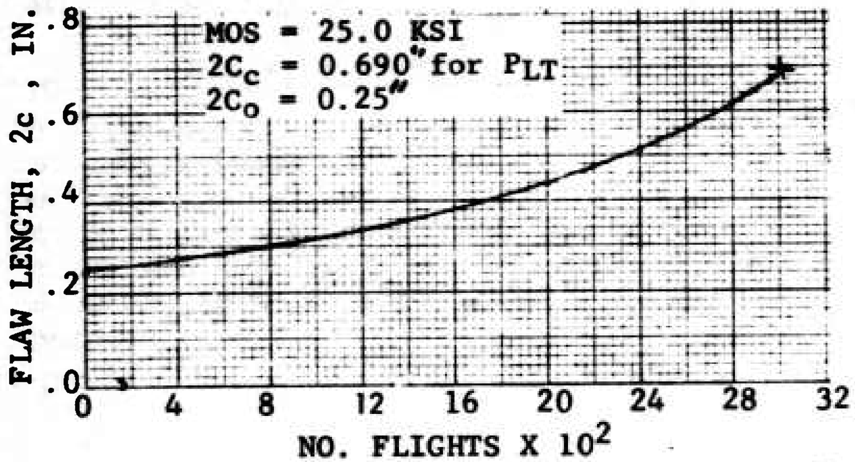
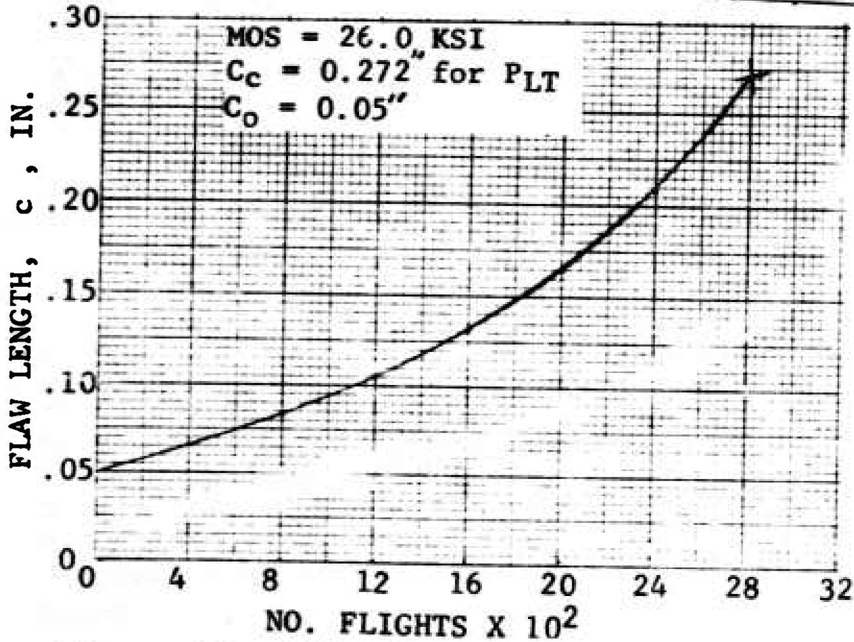


Figure 95 633-RW000 Baseline Wing Box Preliminary Fracture Analysis - Control Point A

Notes:
- o Monolithic lwr wing skin
- o Corner flaw in taper lok hole
- o Slow crack growth structure
- o 2024-T851 Aluminum
- o Non-inspectable structure
- o a/2c=0.5



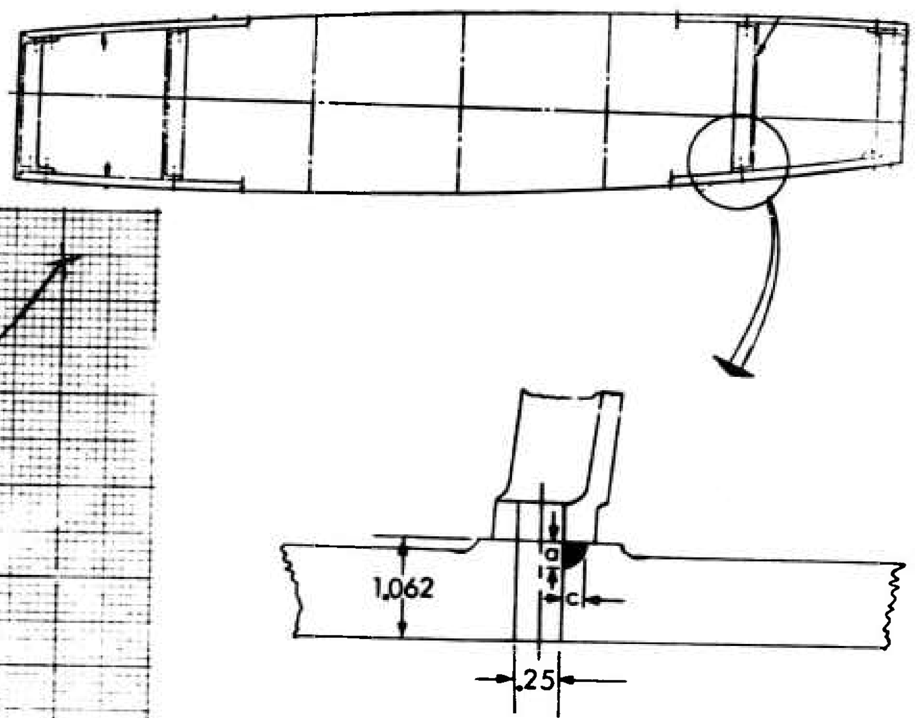


Figure 96 633-RW000 Baseline Wing Box Preliminary Fracture Analysis - Control Point B

Notes:
- o Laminated lower wing skin
- o Surface flaw in one ply
- o Multiple load path-fail safe structure
- o 2024-T81 Aluminum
- o Non-inspectable
- o a/2c=0.5

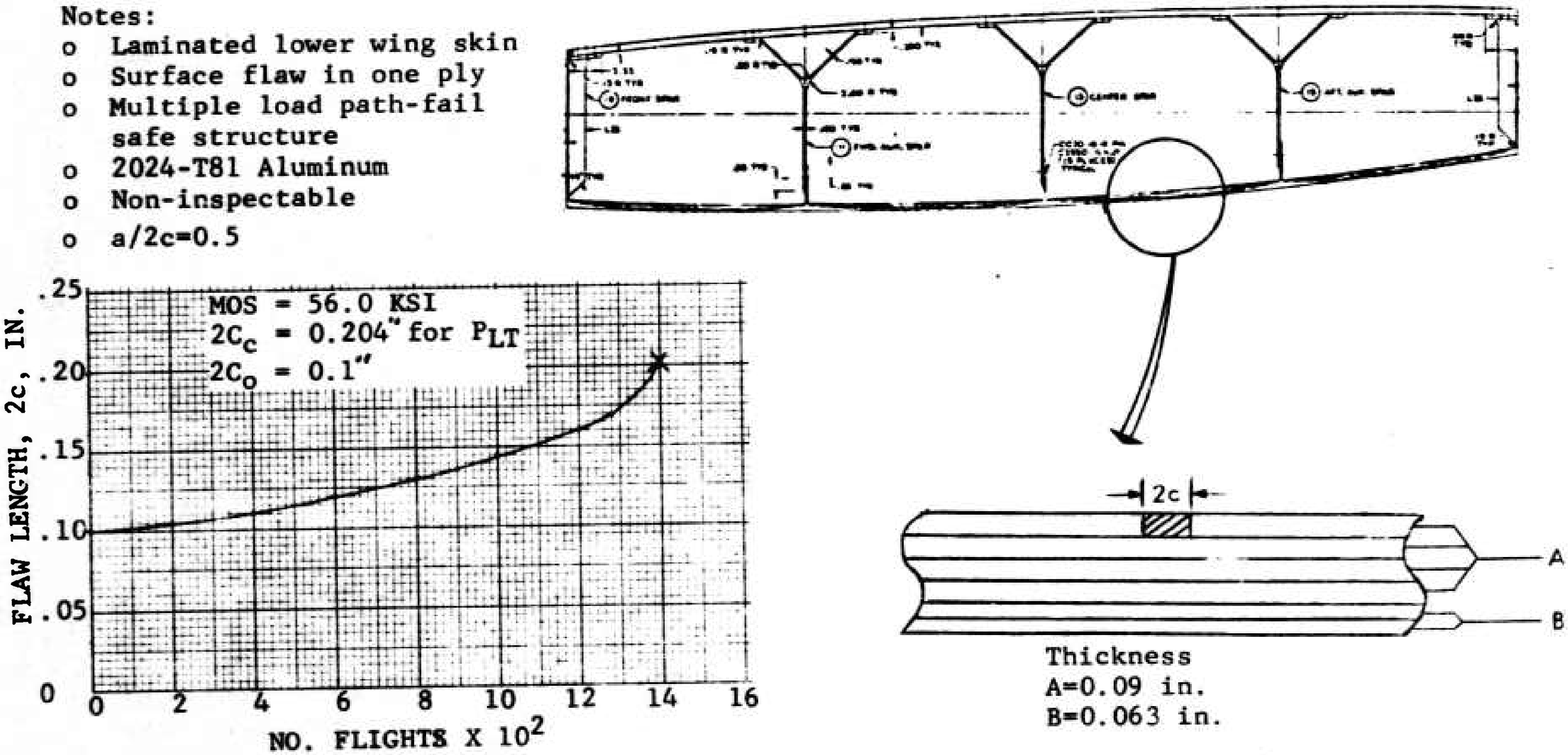


Figure 97 633-RW001 Wing Box Preliminary Fracture Analysis Control Point C

Notes:

- o Lower spar cap
- o Surface flaw
- o Multiple load path - fail safe structure
- o 2024-T8511 Aluminum
- o Non-inspectable structure
- o $a/2c=0.5$

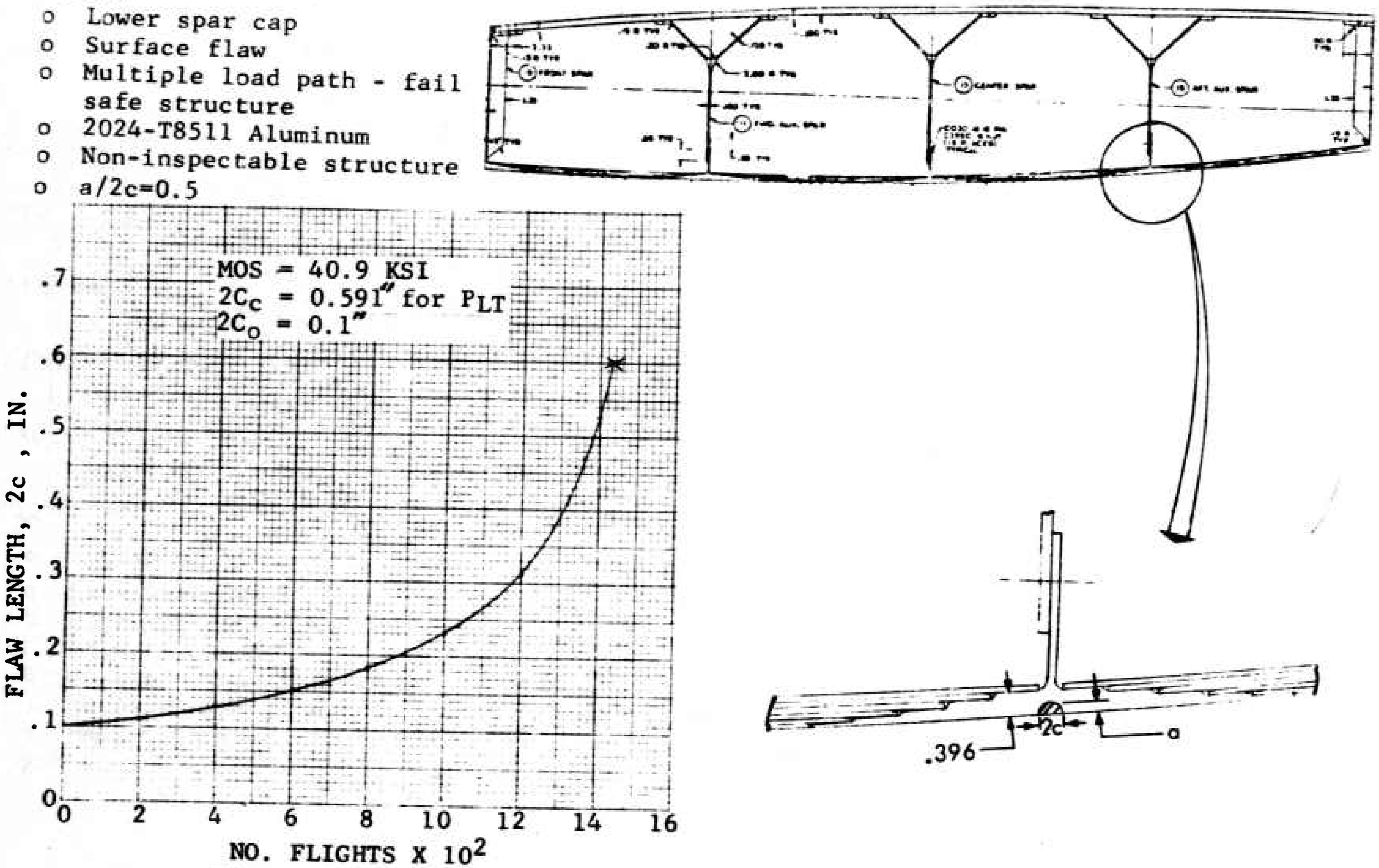


Figure 98 633-RW001 Wing Box Preliminary Fracture Analysis Control Point D

1. Crack propagation data for this type of spar cap was unavailable because of the stepped forward and aft flange of the cap and because of the laminated effect at the forward and aft edges of the cap flange. As shown in Figure 91, the laminated structure (bonded plies) has a slower crack growth rate than the monolithic structure (single ply). The crack growth rate for this exposed spar cap is thought to be between the rate for the laminated plies and the rate for plate material. Therefore, crack propagation data for the plate material was used as a conservative crack propagation rate for this spar cap.

2. Because the spar cap could fail without loss of the aircraft, the spar cap was treated as multiple load path-fail safe structure.

3. Therefore, a specified initial surface flaw was allowed to propagate for one lifetime while assuming the cap was not bonded to the plies.

4. After one lifetime of growth, the required residual load (P_{LT}) was applied to the spar cap without causing the crack to propagate to critical crack length. During the application of the required residual load, this cracked cap was assumed to have been delaminated from the remaining structure.

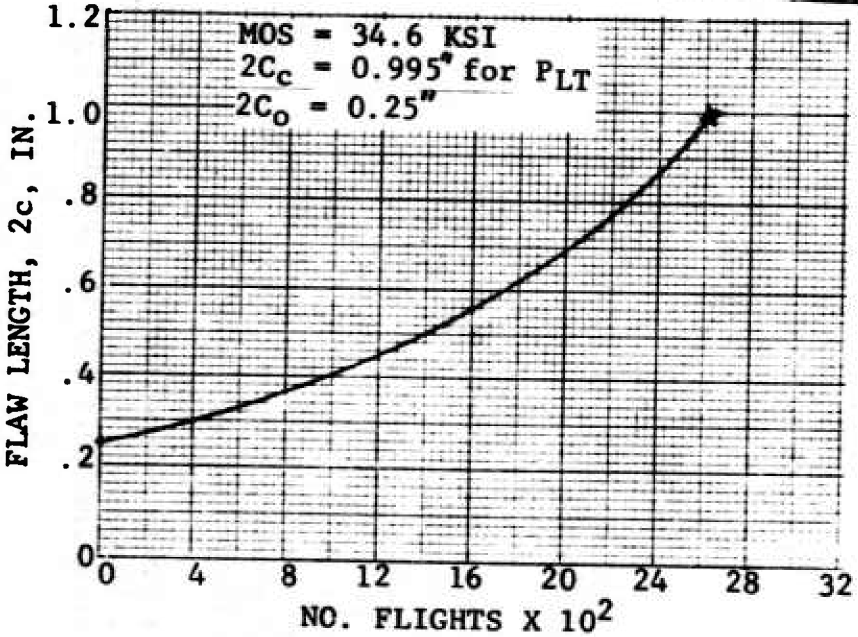
6.2.7.3 Wing Box with Laminated Skin and Imbedded Spar Cap (633-RW002)

Another ATW-4 wing box design has a laminated lower surface skin with imbedded lower spar caps as shown in Figure 99 and 100. The exterior ply of the lower wing surface is continuous from the front spar to the rear spar. Some of the interior plies terminate at the spar caps. Because loss of the exterior ply would result in loss of the aircraft, the exterior ply of this wing box design was treated as slow crack growth structure. This exterior ply was sized according to the MIL-A-83444 criteria by using the following procedure:

1. A crack was allowed to grow for two design lifetimes from a specified initial through-the-thickness flaw while assuming this ply was bonded to the remaining structure.

Notes:

- o Laminated lower wing skin
- o Surface flaw in one ply
- o Slow crack growth structure
- o 2024-T81 Aluminum
- o Non-inspectable structure
- o a/2c=0.5



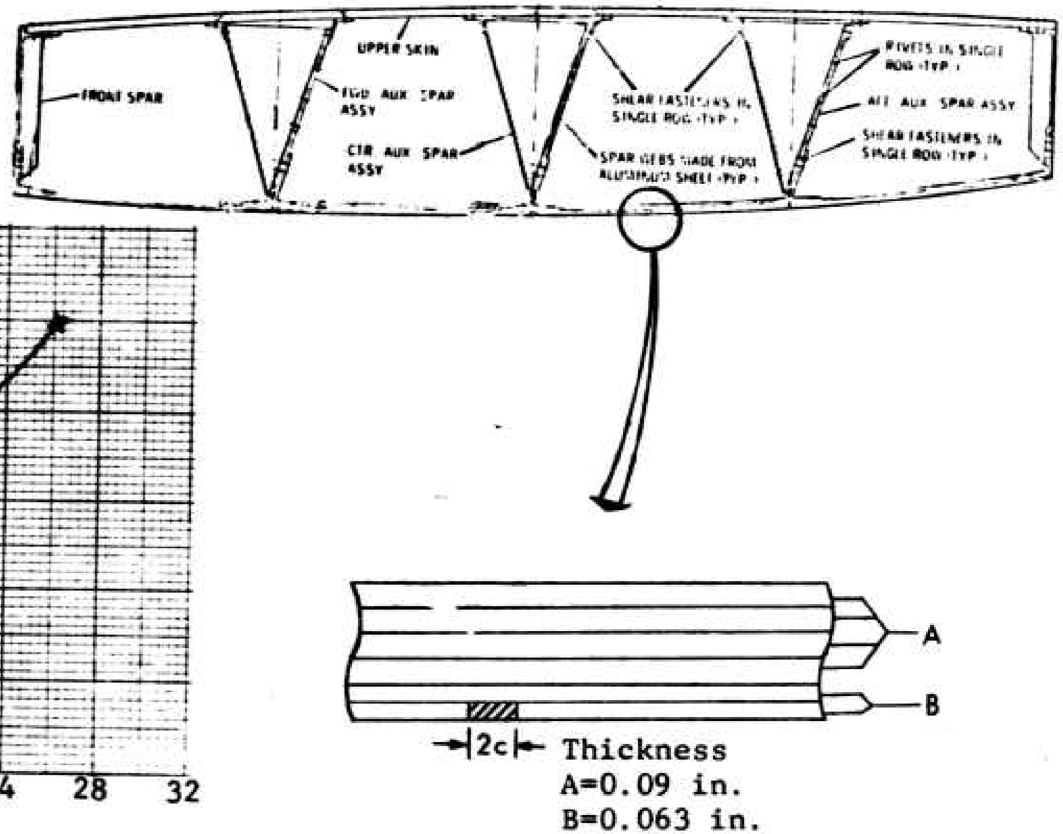
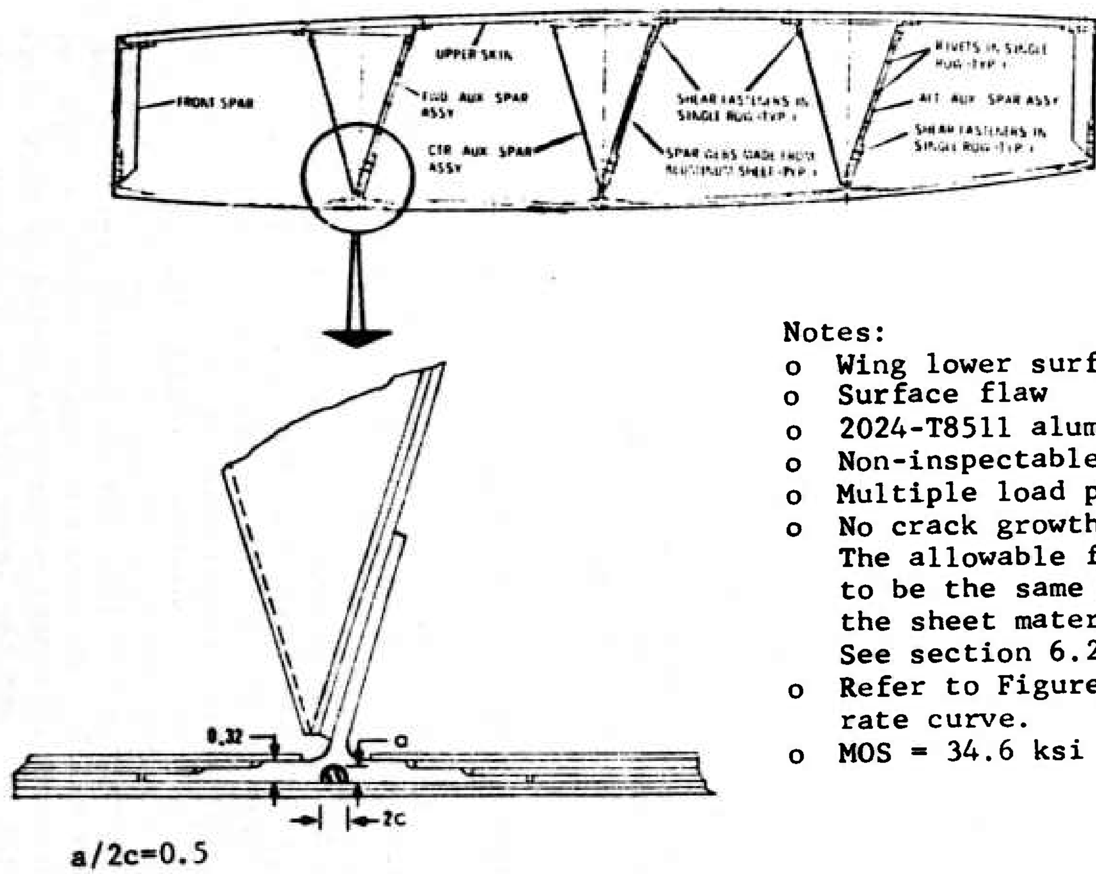


Figure 99 633-RW002 Wing Box Preliminary Fracture Analysis Control Point E



Notes:
- o Wing lower surface spar cap
- o Surface flaw
- o 2024-T8511 aluminum control point
- o Non-inspectable structure
- o Multiple load path-fail safe structure
- o No crack growth analysis was made.
  The allowable fracture stress was assumed to be the same as the allowable stress in the sheet material bonded to the spar cap. See section 6.2.7.3 for the rationalization.
- o Refer to Figure 6-11 for assumed crack growth rate curve.
- o MOS = 34.6 ksi

Figure 100 633-RW002 Wing Box Preliminary Fracture Analysis Control Point F

2. After two lifetimes of growth, the required residual load (P_{LT}) was applied to the cracked ply without causing the crack to propagate to critical crack length. During the application of this residual load, this cracked ply was assumed to have been delaminated from the remaining structure.

For the wing box design having a laminated lower surface skin with imbedded lower spar caps as shown in Figures 99 and 100, no fracture analysis of the imbedded spar cap was made because no crack growth data was available. However, a fracture allowable stress was determined using the following rationalization:

1. No crack growth data was available for a stepped fore and aft flange of a spar cap.

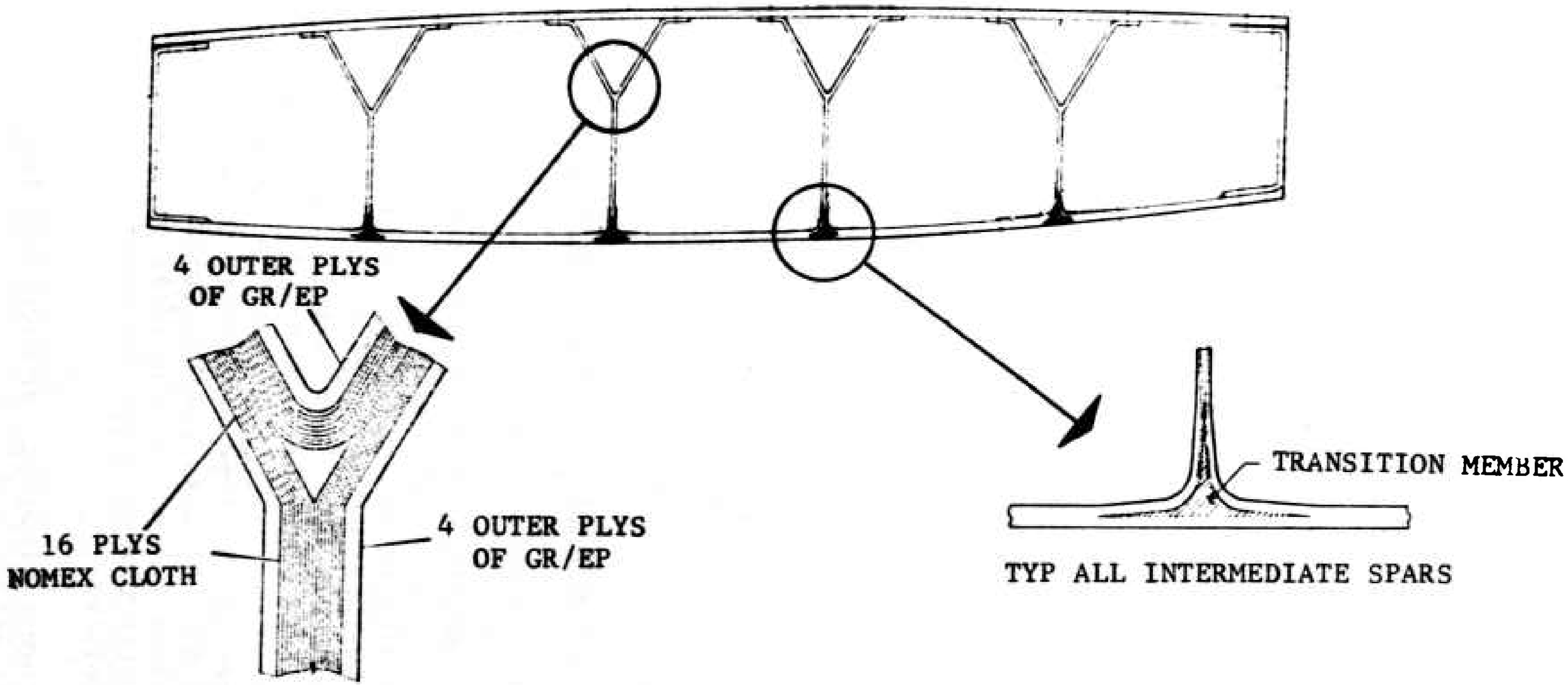
2. No crack growth data was available for a spar cap bonded to or in a laminate.

3. However, the crack growth rate in an imbedded cap is thought to be between the crack growth rate for the exposed spar cap and the laminated skin panel.

4. The imbedded cap and adjacent plies of skin must strain at the same rate to remain bonded. Hence, the allowable operating stress is the same in the cap as in the adjacent plies of skin. Consequently the fracture allowable stress for the cap was assumed to be the same as the fracture allowable stress for the exterior ply of the skin panel.

6.2.7.4 <u>Graphite-Epoxy (Gr/Ep) Composite Wing Box (633-RW003)</u>

The ATW-4 Graphite-Epoxy composite wing box design, 633-RW003, as shown in Figure 101 has Gr/Ep skins and imbedded Gr/Ep "Y" spars. The upper wing surface skin is bolted to the spars. The lower wing surface skin is bonded to the precured intermediate spars and bolted to the front and rear spars. Ordinarily the bolts are in Nomex buffer strips, which have only ± 45° plies, thus reducing the stress concentrations at the bolt hole and prolonging the fatigue life. However, a small amount of test data developed during a current program has indicated the Nomex buffer strips are unnecessary for this design because the bolt bearing stresses are so small. To save cost these buffer strips were omitted. This composite design was classified as slow crack growth structure because the lower skin is one piece construction having no spanwise buffer strips or splices. An assumption has been made that the graphite epoxy wing box will be



Notes:
- o Gr/Ep Composite Spars & Skins
- o "Y" Spars with Imbedded Lower Caps
- o Slow Crack Growth Structure
- o Non-inspectable Structure
- o No crack growth analysis was made. The fracture allowable stress was assumed to be the same as the static allowable stress because dry Gr/Ep composite structure is generally not fracture critical when good engineering design is practiced. See Section 6.2.7.4 for a discussion.

Figure 101 633-RW003 Wing Box Design

prevented from absorbing moisture, fuel, and etc. by painting all the wing surfaces, installing a fuel bladder inside the wing box, and etc. Thus the Gr/Ep would be kept dry. Generally a Gr/Ep composite exposed to a high humidity or fuel and to an elevated temperature greater than 200°F loses much of its strength for shear and compression loads but retains most of its strength for tension loads. Usually shear loads and compression loads do not cause fatigue or fracture problems. Dry Gr/Ep composite material is very resistant to fatigue and fracture. The static design allowable stress was used for the fatigue and fracture design allowable stress for three reasons: (1) the Gr/Ep composite would be kept dry, (2) shear and compression stresses generally do not cause fatigue or fracture problems, and (3) dry Gr/Ep composite structure is generally not fatigue or fracture critical. Thus no fracture analysis has been made for the preliminary design of the Gr/Ep composite wing box. A detailed fracture analysis will be accomplished for this Gr/Ep composite wing box if this design is selected for the final ATW-4 wing.

6.2.7.5 Baseline Wing Pivot Fitting

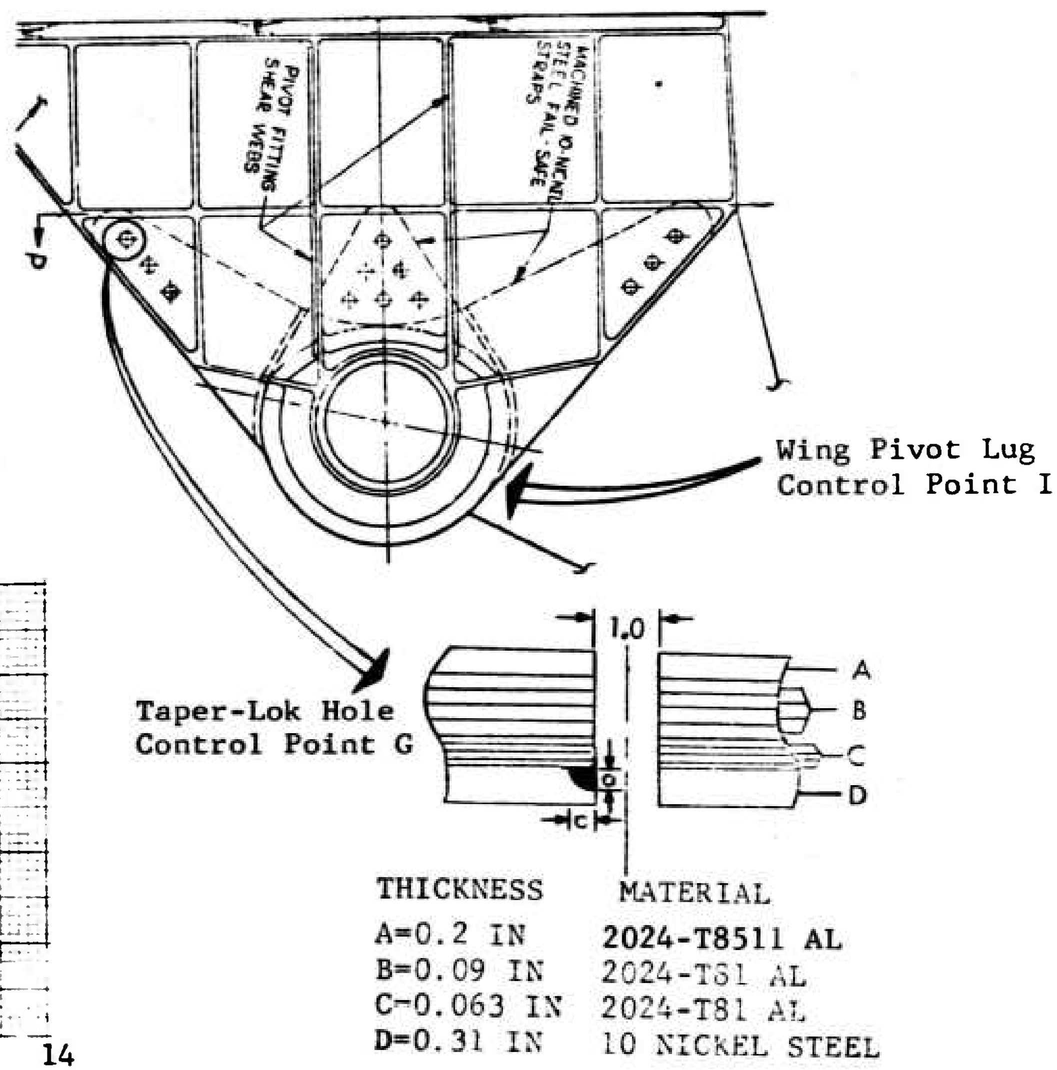
The baseline wing design has a wing pivot fitting with similar geometry, similar construction, and the same kind of material as the F-111 design. The lower surface of the wing pivot fitting is classified as slow crack growth structure. An assumption was made to use the same fracture allowable stresses for the baseline wing pivot fitting as was used for the F-111 wing pivot fitting.

6.2.7.6 Metallic Wing Pivot Attachment (633-RW001 and 633-RW002)

The ATW-4 metallic wing designs have a wing pivot attachment classified as multiple load path-fail safe structure. The wing pivot attachment consists of laminated 2024 aluminum plies bolted to two 10 Ni steel plates by using 1" taper-lok bolts as shown in Figures 102 and 103. This wing pivot attachment is fail safe because the laminated aluminum plies or one of the steel plates can fail without loss of the aircraft. Three control points were chosen for fracture analysis. As shown in Figure 102, one control point is located at the 1" taper-lok bolt hole in the end of the 10 Nickel steel plate that has a shape similar to a boomerang. A second control point is located at this same taper-lok bolt hole but in one of the aluminum plies instead of the stell plate as shown in Figure 103. The procedure used for analyzing both of these control points is as follows:

1. Assume an initial corner flaw, c_o, of 0.02 inch long per MIL-A-83444 criteria.

Notes:
- o Wing pivot strap
- o Corner flaw in taper-lok hole
- o Corner flaw in wing pivot lug
- o Multiple load path-fail safe structure
- o 10 Nickel Steel Control Point
- o One inch taper-lok hole
- o Non-inspectable structure
- o a/2c=0.5



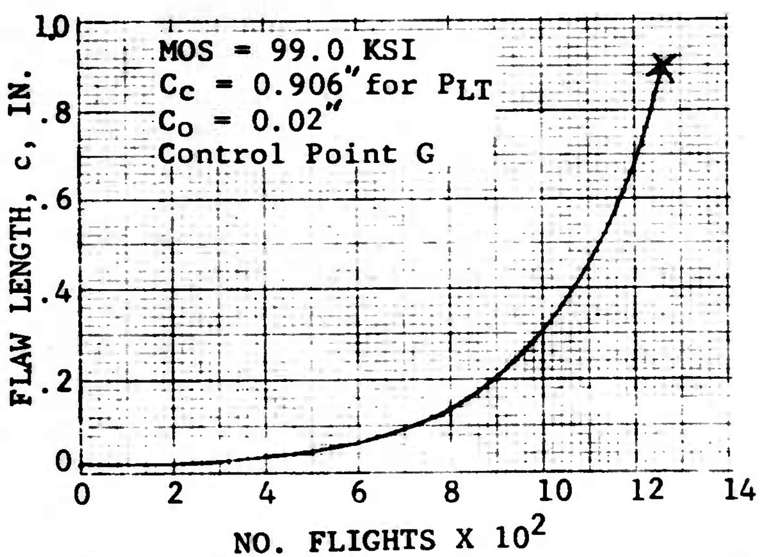
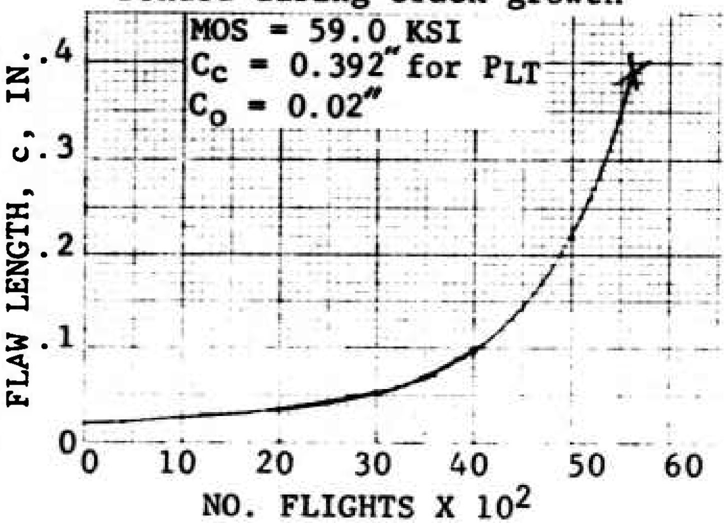
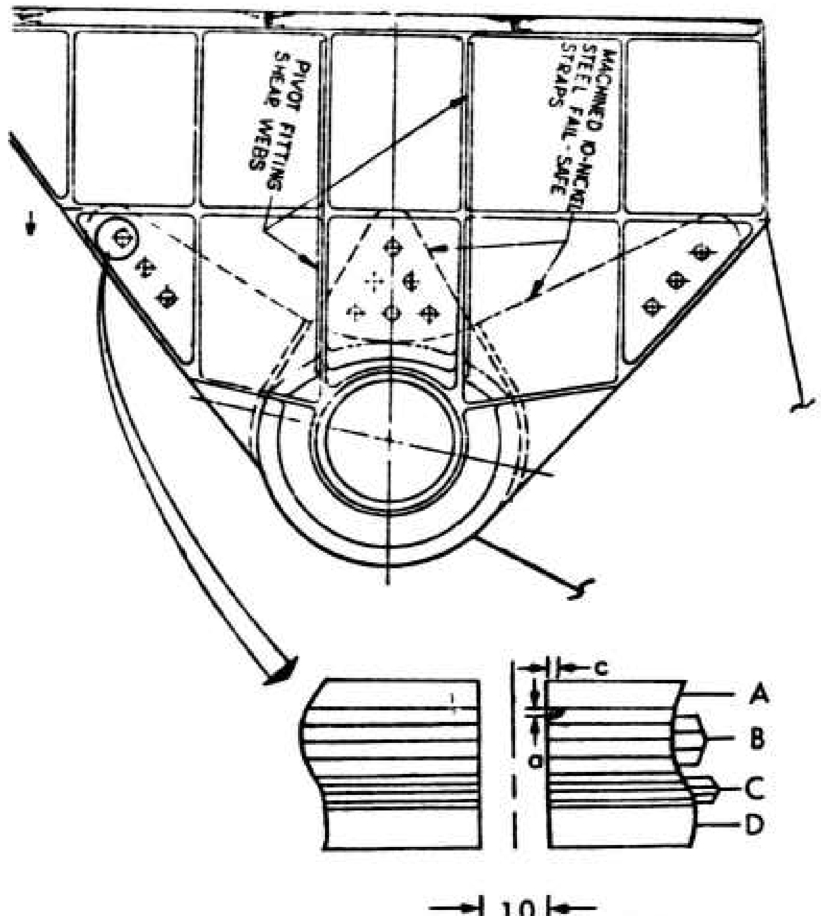


Figure 102 633-RW001 and 633-RW002 Wing Pivot Attachment - Control Points G and I

Notes:
- o Laminated lower wing skin
- o Corner flaw in taper-lok hole
- o Multiple load path-fail safe structure
- o 2024-T81 Aluminum Control Point
- o One inch taper-lok hole
- o Non-inspectable structure
- o a/2c=0.5
- o Assumed material "A" was not bonded during crack growth





THICKNESS	MATERIAL
A=0.2 IN	2024-T8511 AL
B=0.09 IN	2024-T81 AL
C=0.063 IN	2024-T81 AL
D=0.31 IN	10 NICKEL STEEL

Figure 103 633-RW001 and 633-RW002 Wing Pivot Attachment - Control Point H

2. This initial flaw was allowed to propagate for one design service life.

3. The aluminum laminate was sized such that the crack in the cracked ply would not grow to critical crack length when the MIL-A-83444 required residual load was applied after one design service life. When the residual load was applied, the aluminum ply was assumed not to have been attached to the remaining structure.

   The 10 Nickel steel plate was sized such that the crack in the plate would not propagate to critical crack length when the MIL-A-83444 required residual load was applied.

The third control point is located in the 10 nickel steel portion of the ATW-4 wing pivot attachment lug as shown in Figure 102. For this preliminary fracture analysis, the allowable stress for the wing pivot lug was assumed to be the same value as was used in the 1" taper-lok bolt hole control point in the 10 Nickel steel plate as discussed in the first paragraph of this section. A detailed fracture analysis will be accomplished for this 10 Nickel steel wing pivot attachment lug if this design is selected for the final ATW-4 wing.

6.2.7.7 <u>Graphite-Epoxy (Gr/Ep) Composite Wing Pivot Attachment (633-RW003)</u>

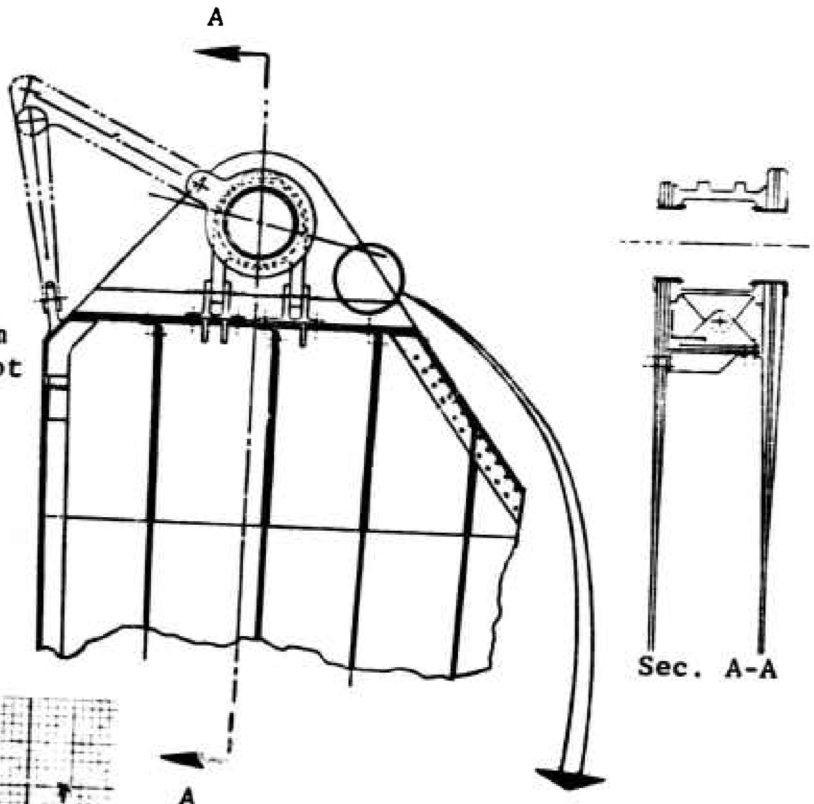
The ATW-4 Gr/Ep composite wing design has a wing pivot attachment that is different from the metallic wing designs. The lower surface of the wing pivot attachment of the Gr/Ep composite wing has Gr/Ep composite sandwiched between two plies of 6AL-4V Titanium (Beta Annealed) as shown in Figure 104. The outboard portion of the titanium is both bolted and adhesively bonded whereas the area near the wing pivot pin is only adhesively bonded. This fracture analysis concerns the area of bonded titanium plate without bolts. This structure is classified as multiple load path-fail safe structure because one ply of 6AL-4V Ti or the Gr/Ep composite could fail without loss of the aircraft. A fracture analysis of the titanium plate was performed using the following procedure:

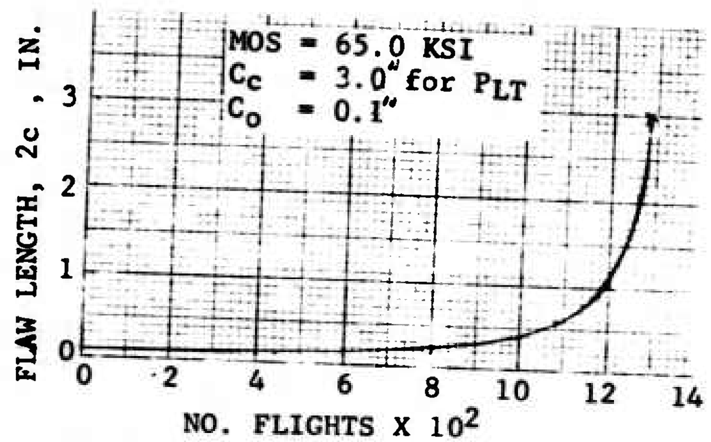
1. Assumed bonding effects were negligible.

2. Assume an initial surface flaw, $2c_o$, of 0.10 inch long per MIL-A-83444 criteria.

Notes:

- o Adhesive bonded Gr/Ep and Titanium
- o Surface flaw in Titanium Wing Pivot Attachment Lwr. Skin
- o Multiple load path-fail safe structure
- o Ti 6AL-4V (BA) Control Point
- o Non-inspectable structure
- o a/2c = 0.5





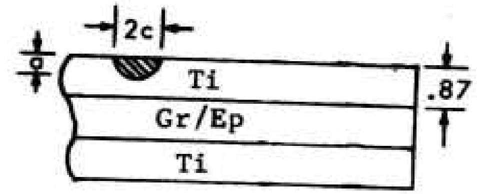


Figure 104 633-RW003 Wing Pivot Attachment Control Point J

3. This initial flaw was allowed to propagate for one design service life.

4. The cracked interior titanium ply was sized such that the crack would not grow to critical crack length when the MIL-A-83444 required residual load was applied after one design service life.

6.3 DISCUSSION

Figures 95 through 104 show the flaw growth analyses for each assumed failure mode. These failure modes are part-through, through the thickness, and bolt hole flaws as shown on the figures. Maximum operating stress (MOS) are indicated and correspond to the maximum spectrum wing pivot bending moment of 16.42 X 10^6 in.-lbs.

Table XIX presents a summary of the fracture design allowable stresses for the control points in the baseline wing design and the preliminary ATW-4 wing designs.

Appendix C contains the preliminary fracture design allowables data for the baseline and the other wing designs. This data is presented for surface flaws and corner flaws in each of the designs. This data consists of plots of initial flaw length versus the maximum spectrum or operating stress for one or two design lifetimes. The fracture allowable design stress is determined by entering the allowable curve at the initial flaw size specified in MIL-A-83444 and then reading the maximum spectrum stress for the appropriate number of lifetimes. This data is presented for selected control points of surface flaws and corner flaws.

6.4 CONCLUSION

The fracture allowable design stresses are much larger for the bonded laminated structure than for the monolithic structure. As was stated before, all the fracture analyses were done in accordance with the MIL-A-83444 damage tolerance criteria for In-Service Non-Inspectable Structure. The crack growth is much slower for a 4-ply lamination of 2024-T81 sheet material than for a single ply of the same material. A comparison of the flaw growth data for 1, 2, 3, and 4 ply bonded laminates of 2024-T81 aluminum is shown in Figure 91. Where applicable, the decrease in flaw growth rate due to the bond lines in laminated panels was used to greatly increase the fracture allowable stress values. A comparison of fracture design allowable stresses for 2024 aluminum sheet, plate, and bonded laminate is shown in Figure 92. For an assumed initial flaw size in Figure 91, the max. fracture

TABLE XIX

FRACTURE ANALYSIS RESULTS FOR PRELIMINARY WING DESIGNS

CONTROL POINT	WING CONFIGURATION & FLAW DESCRIPTION	TYPE STRUCT.	*MAX. OPERATING TENSILE STRESS ksi
	633-RW000 -- Baseline Wing Box, Machined Spars & Skins		
A	Part-through surface flaw in the wing lwr skin	SCG	25.0
B	Corner flaw in lwr skin taper-lok hole at intermediate spar	SCG	26.0
	633-RW001 -- Laminated Lwr Skin, Extruded "Y" & Machined Spars		
C	Through the thickness surface flaw in singly ply	FS	56.0
D	Part-through surface flaw in lwr spar cap	FS	40.9
	633-RW002 -- Laminated Lwr Skin, Canted Spars		
E	Through the thickness surface flaw in exterior ply	SCG	34.6
F	Part-through surface flaw in lwr spar cap	FS	34.6
	633-RW001 and 633-RW002 -- Wing Pivot Attachment, Laiminated Lwr Skin		
G	Corner flaw in lwr skin taper-lok hole - 10 Nickel Steel	FS	99.0
H	Corner flaw in lwr skin taper-lok hole - 2024 Aluminum	FS	59.0
I	Corner flaw in wing pivot attachment lug - 10 Nickel Steel	FS	99.0
	633-RW003 -- Adhesive Bonded Gr/Ep & Titanium Composite Wing Pivot Attachment		
J	Surface flaw in titanium wing pivot attachment lwr skin	FS	65.0

*Fatigue Allowable

allowable operating stress is much larger for the 4-ply bonded laminate than for the plate or sheet material. To further illustrate the advantages of bonded laminates for increasing fracture resistance, a comparison of structural life of 2024 aluminum sheet, plate, and 4-ply bonded laminate is shown in Figure 93. For an assumed max. operating stress, the sheet and plate material show less than ½ design service life whereas the 4-ply bonded laminate shows greater than 6 design service lives. Consequently, the bonded laminate designs were controlled by the fatigue requirements whereas the monolithic structure design was controlled by the fracture requirements.

The Gr/Ep composite material is fatigue and fracture resistant when kept in dry air; therefore, provisions should be incorporated in design to prevent moisture absorption during the composite material service life. However, more data is needed to determine the importance of environmental effects on the Gr/Ep composite.

SECTION VII

SPAR LOCATION SENSITIVITY STUDIES

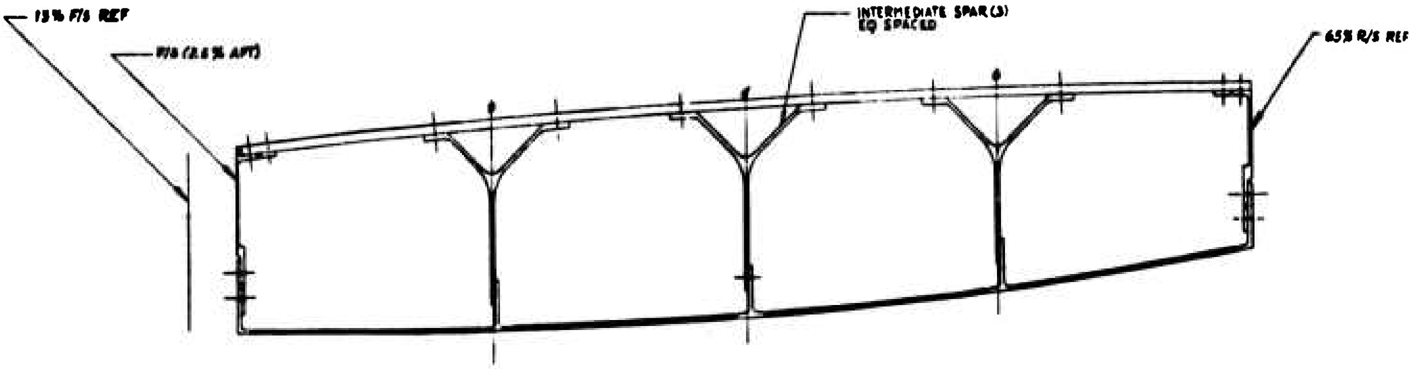
Front and rear spar location sensitivity studies were performed. The Front Spar was relocated from .150C to .175C and .200C, while holding the Rear Spar at .650C; and the Rear Spar was relocated from .650C to .700C and .750C, while holding the Front Spar at .150C. Figures 105 thru 108 show these spar location changes.

The studies were performed on the laminated lower skin box concept with three extruded "Y" internal spars, using the existing finite element model with the necessary spar relocation and the material thicknesses unchanged.

Stresses for the relocated spar case were used to adjust thicknesses to restore the stresses to their original values and the sum of the effects of thickness change is shown in Table XX for each relocation case. Table XX also shows the fuel volume changes associated with the spar location changes.

It has been determined that changing spar locations would not re-rank the three preliminary designs. The most significant effect of changing the spars is the change in fuel volume. Moving the rear spar to .75C will add 1386 pounds of fuel per aircraft.

It is interesting to note that moving the rear spar aft increases fuel volume but also increases the box weight. The weight increase is due to the fact that aft of .65C the added skin material has a reduced centroidal distance and also to the fact that the outboard portion of the wing skins is sized by fuel pressure. Extra chord width outboard, then, does not reduce skin stresses at all.



SECTION B-B
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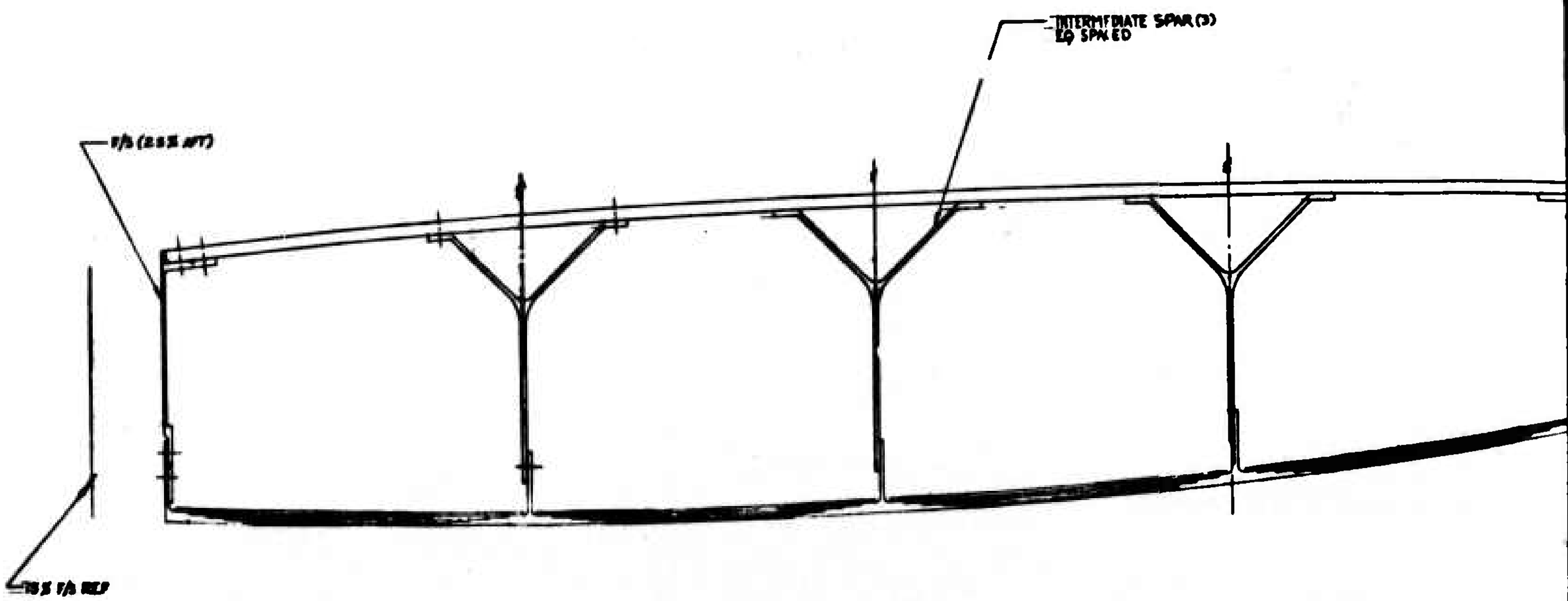
SS 340.00 REF



SECTION A-A
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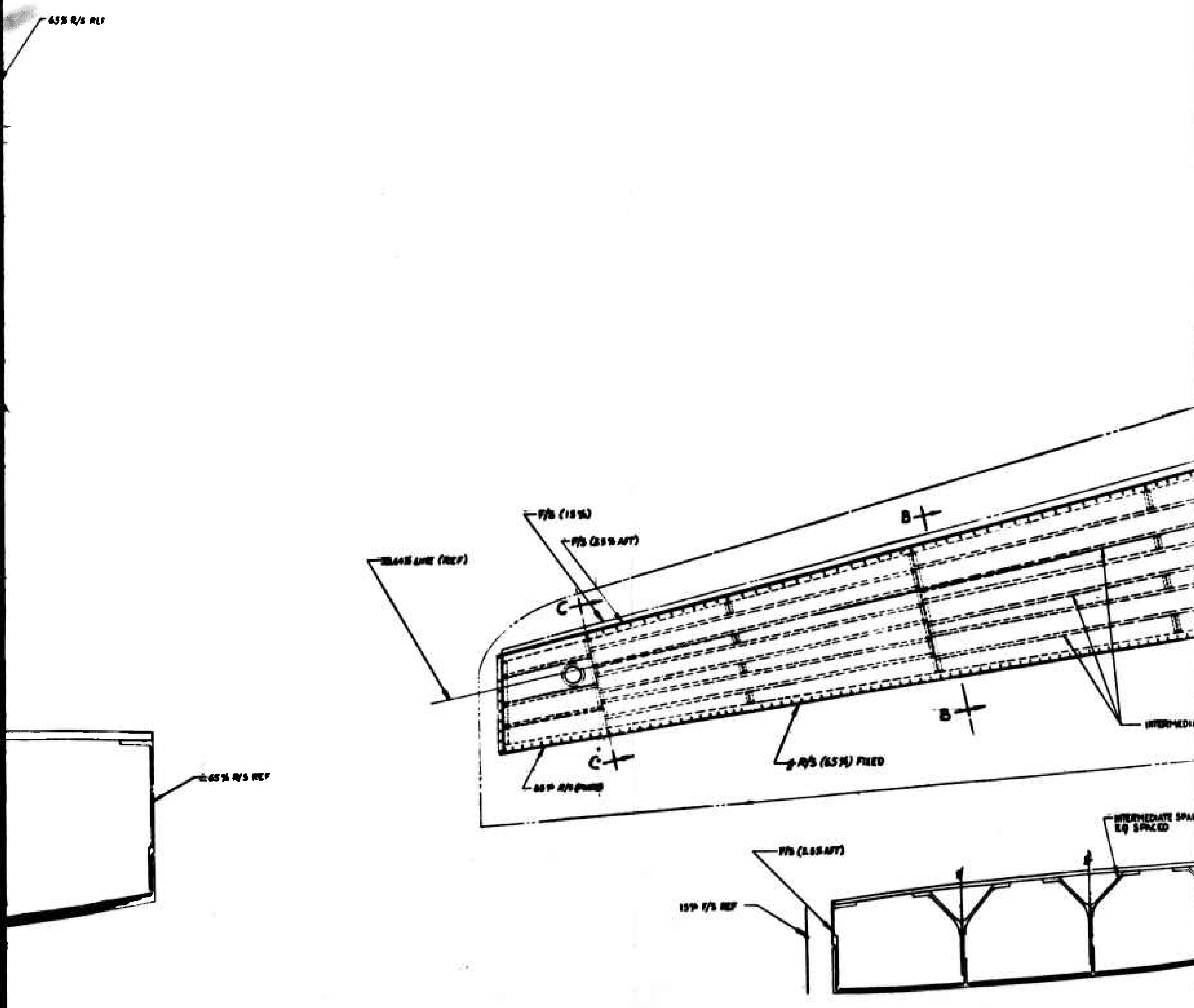
SS 140.00 REF

2


65% R/S REF
F/S (15%)
B
C
R/S (65%) FIXED
65% R/S REF
INTERMEDIATE SPAR
EQ SPACED
15% F/S REF
SECTION C-C

3

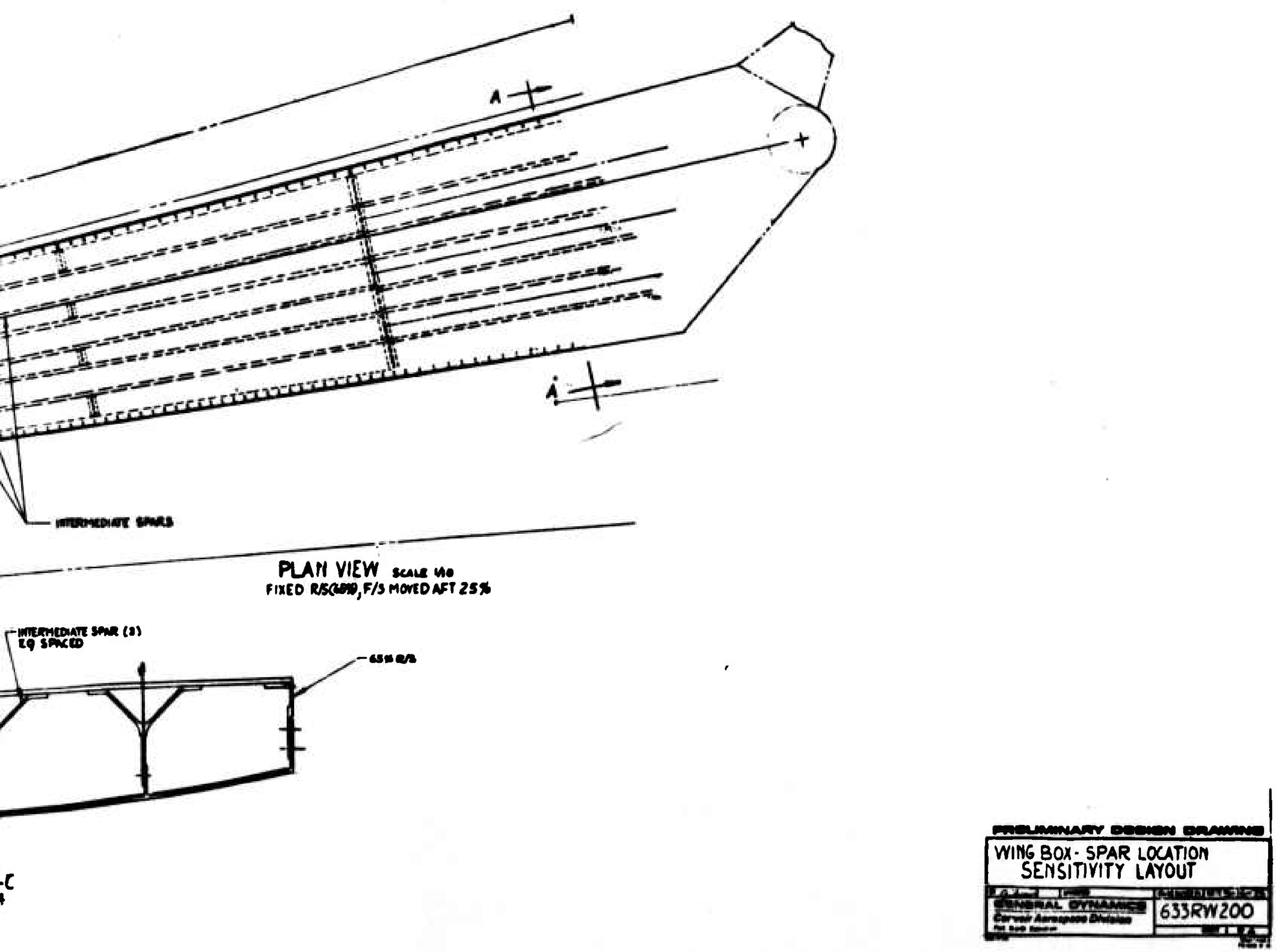
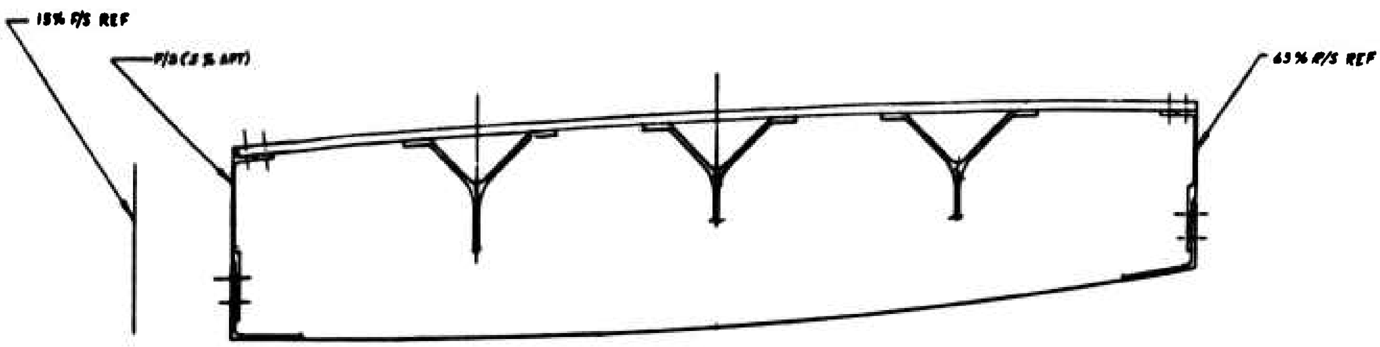


FIGURE 105 FRONT SPAR MOVED AFT. 2.5 %



SECTION E-E
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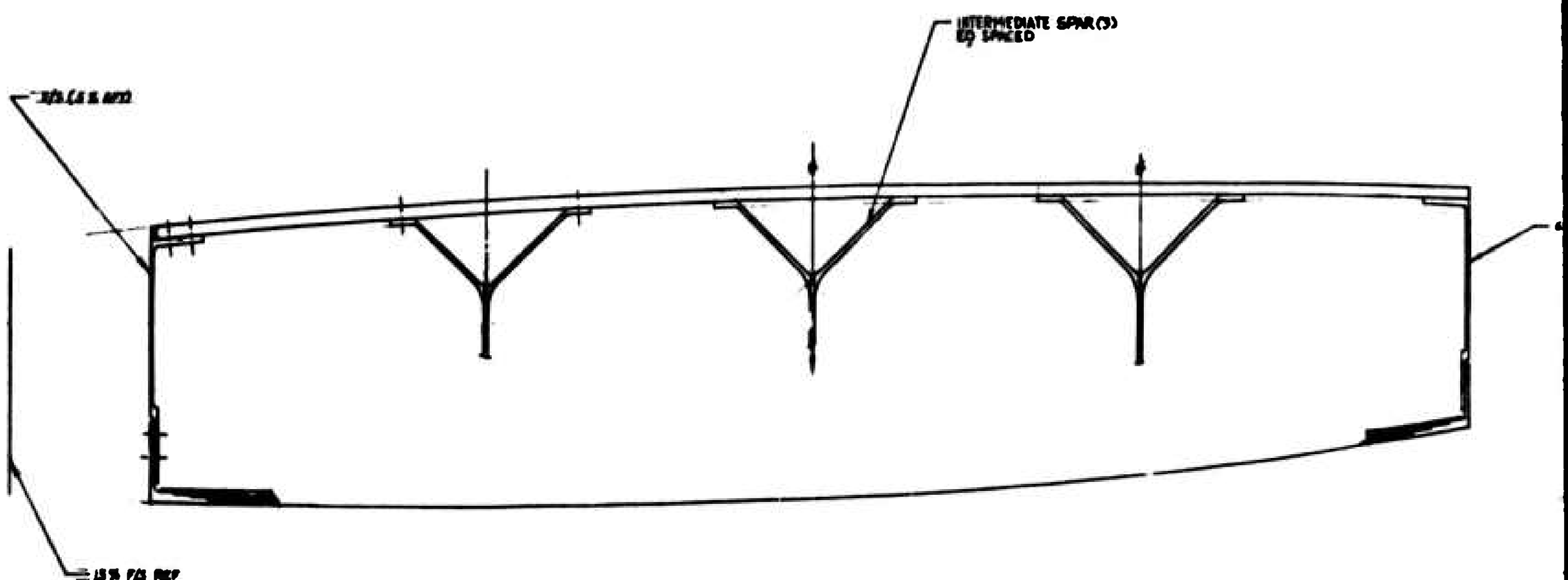

SECTION D-D
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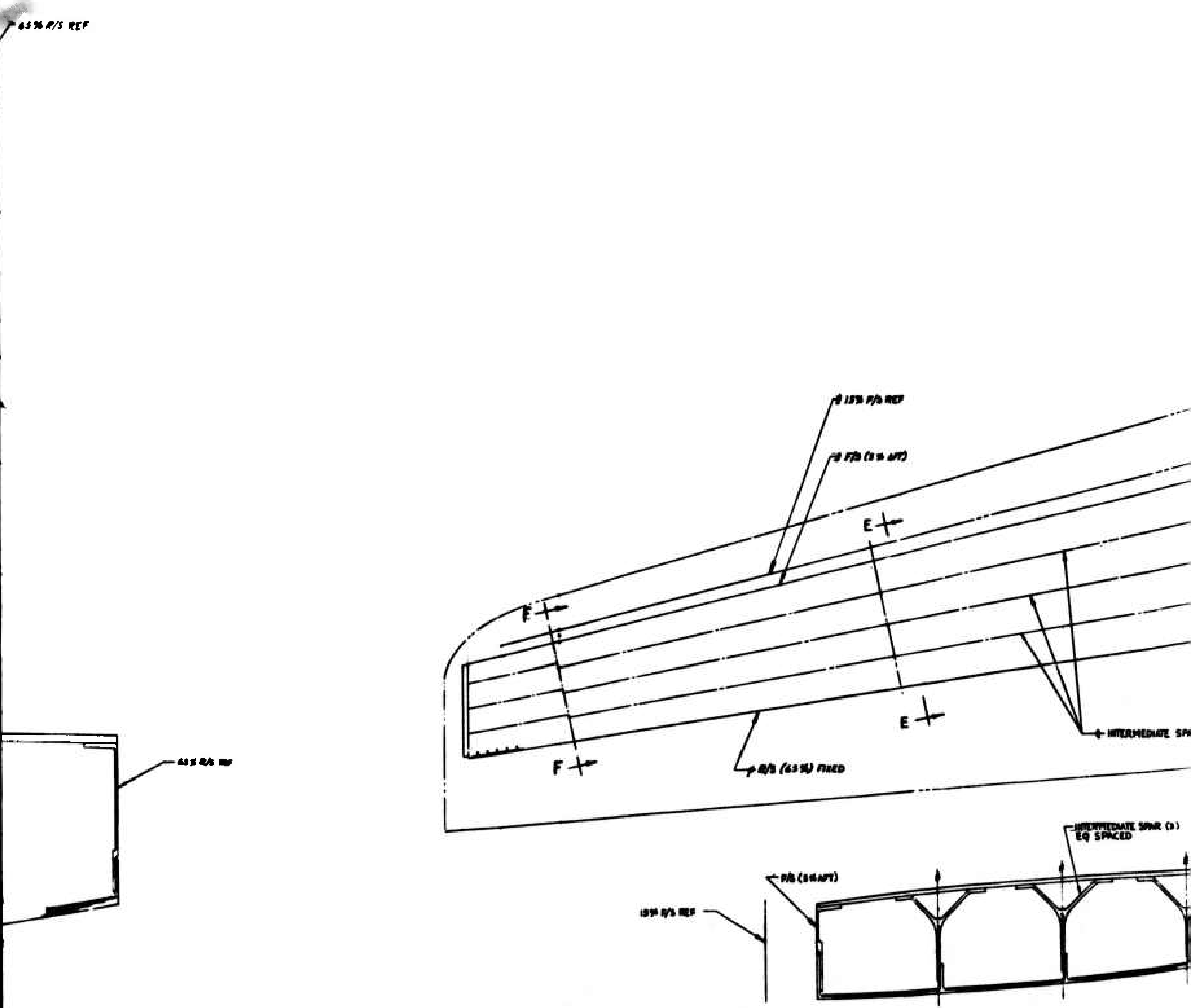
2



SECTION F-F
SCALE 1/2
BS 450.00
SAME AS C-C EXCEPT AS SHOWN

3

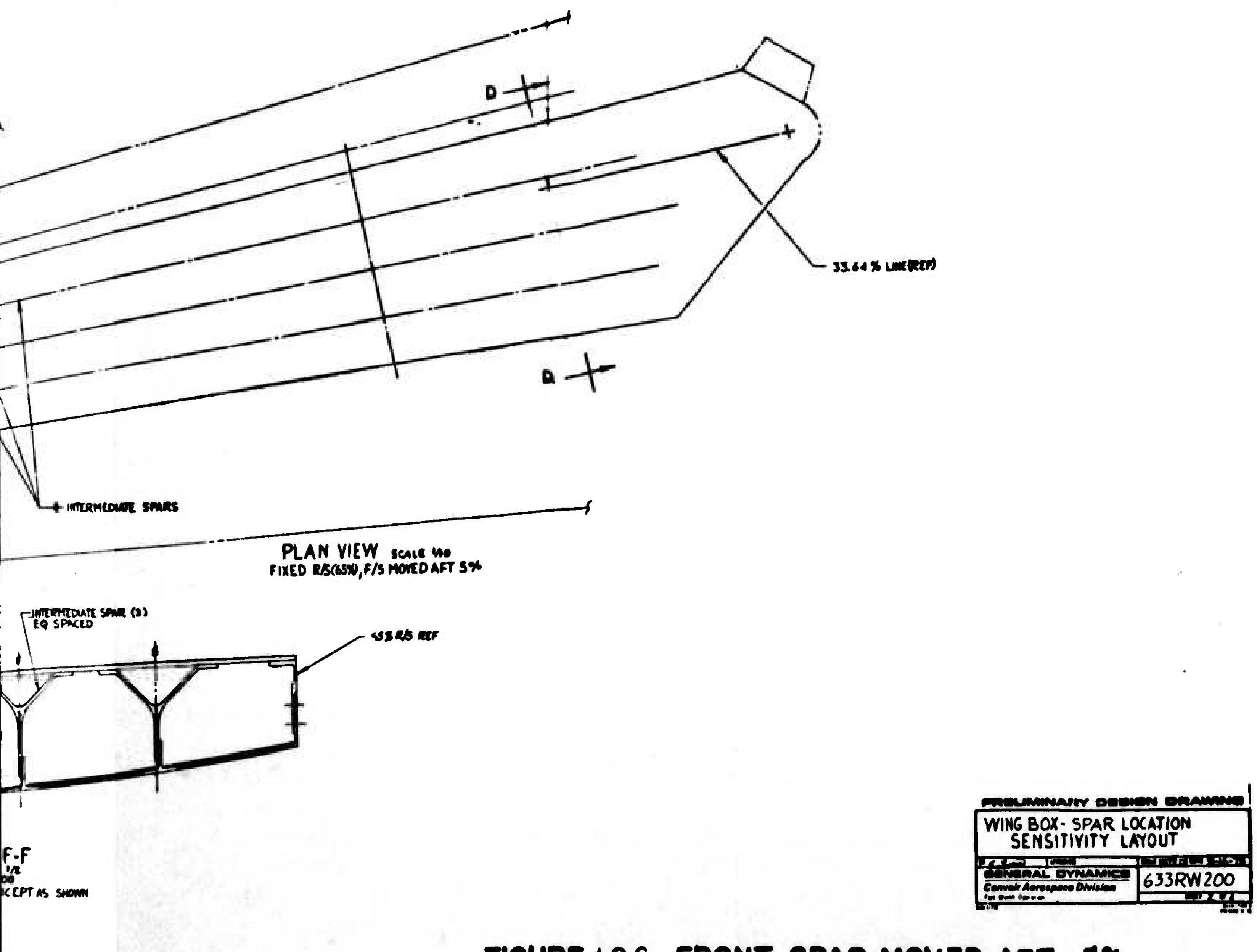


FIGURE 106 FRONT SPAR MOVED AFT. 5%

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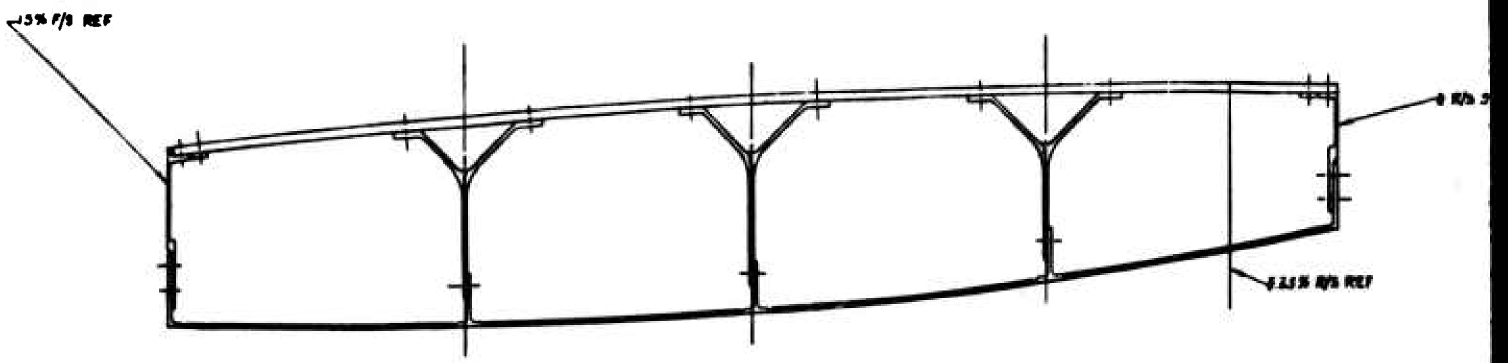

SECTION H-H
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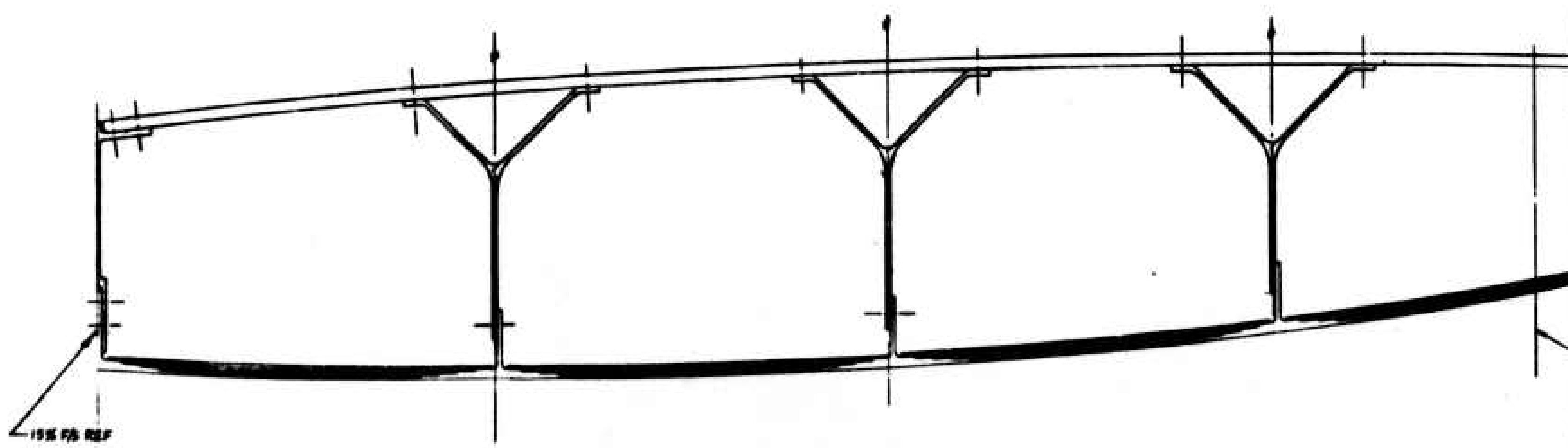
SS 340.00



SECTION G-G
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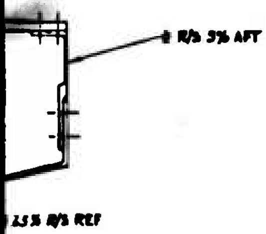
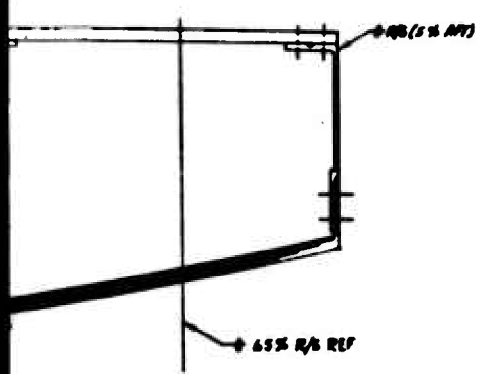
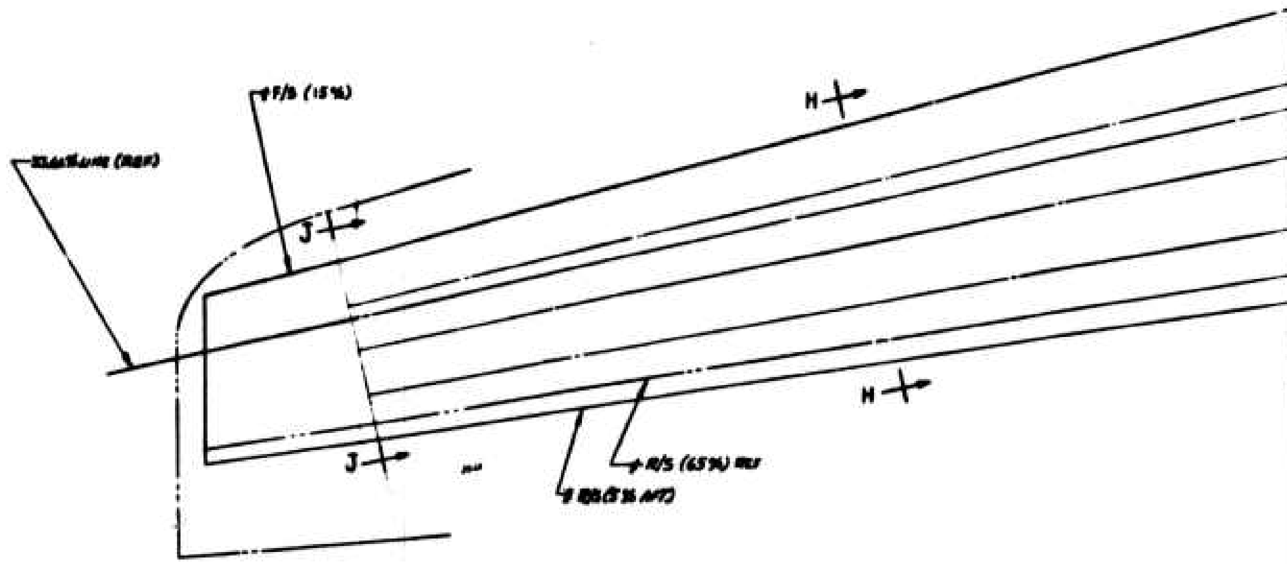
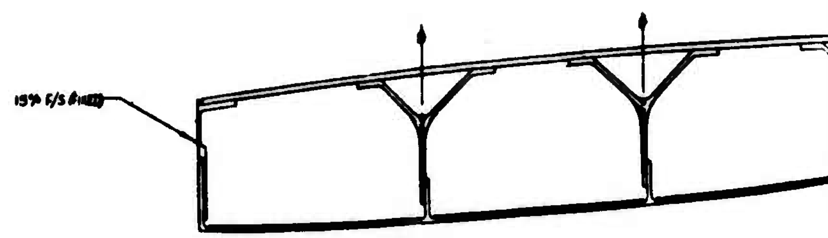
SS 140.00

2









SECTION J-J
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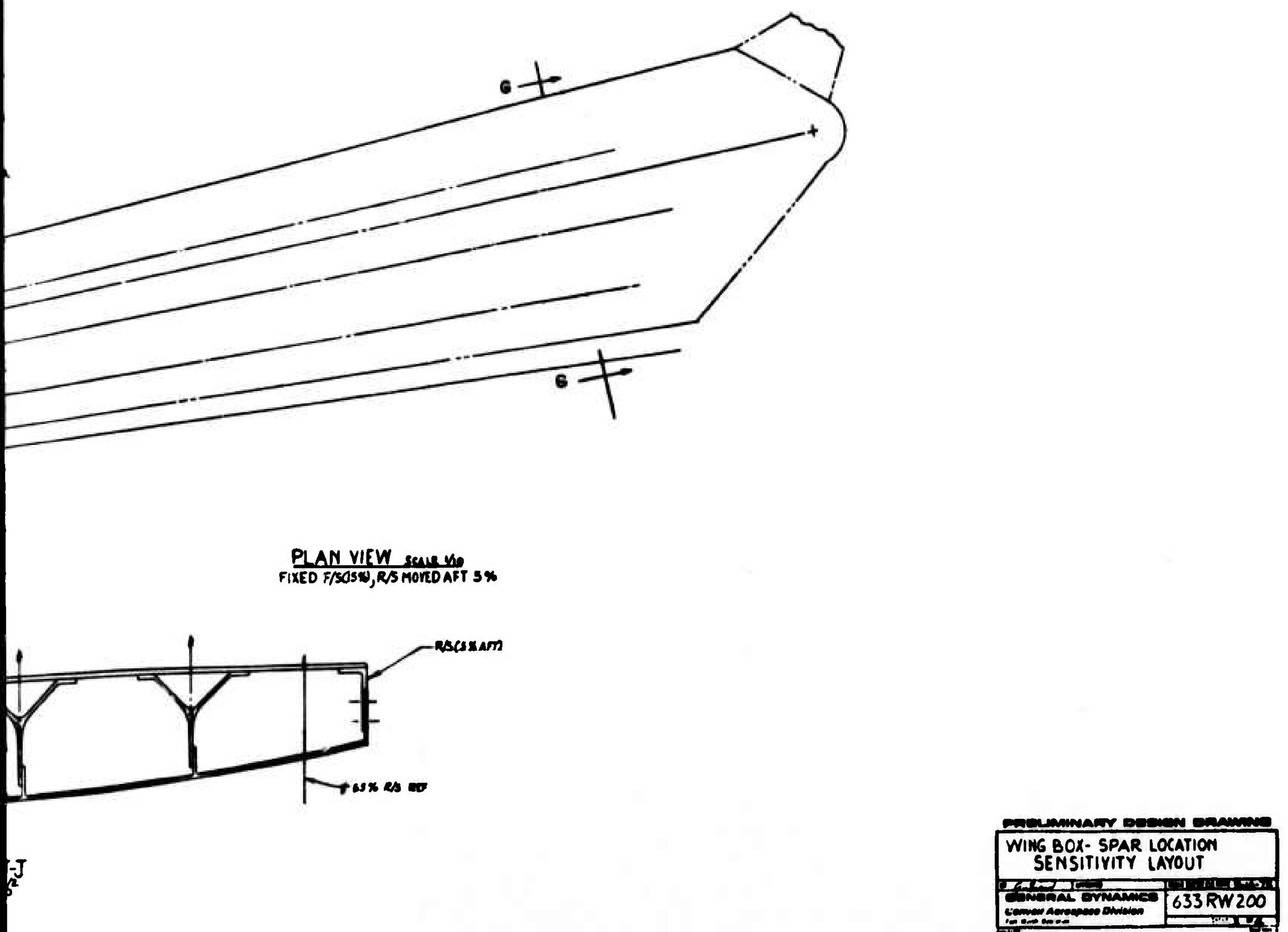
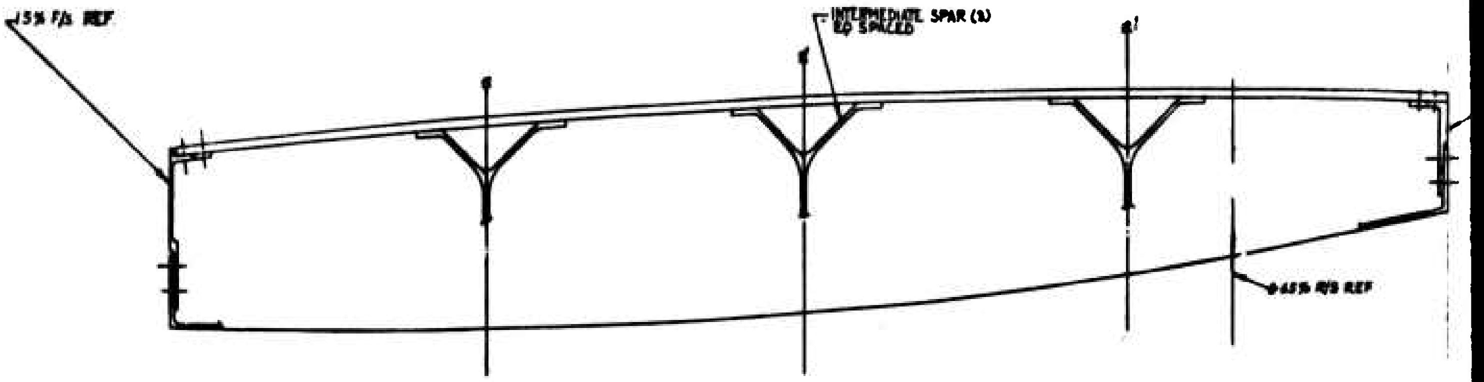
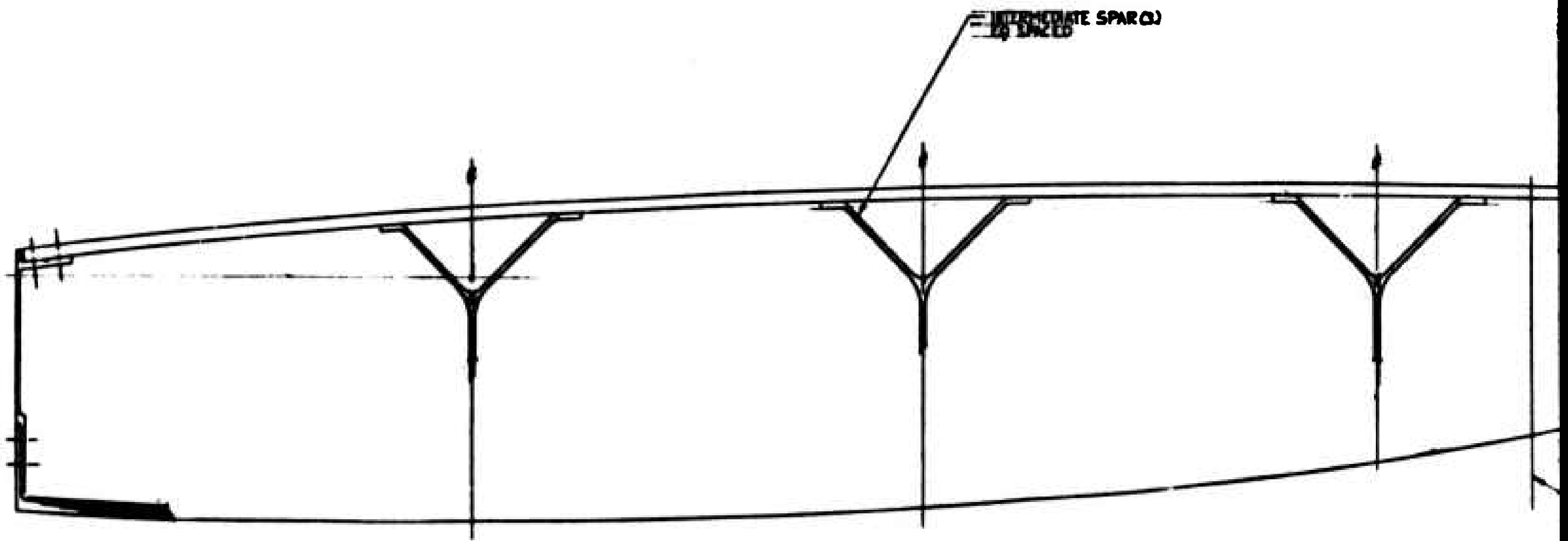


FIGURE 107 REAR SPAR MOVED AFT 5%

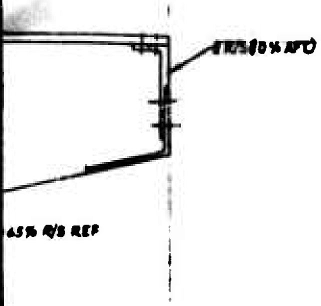


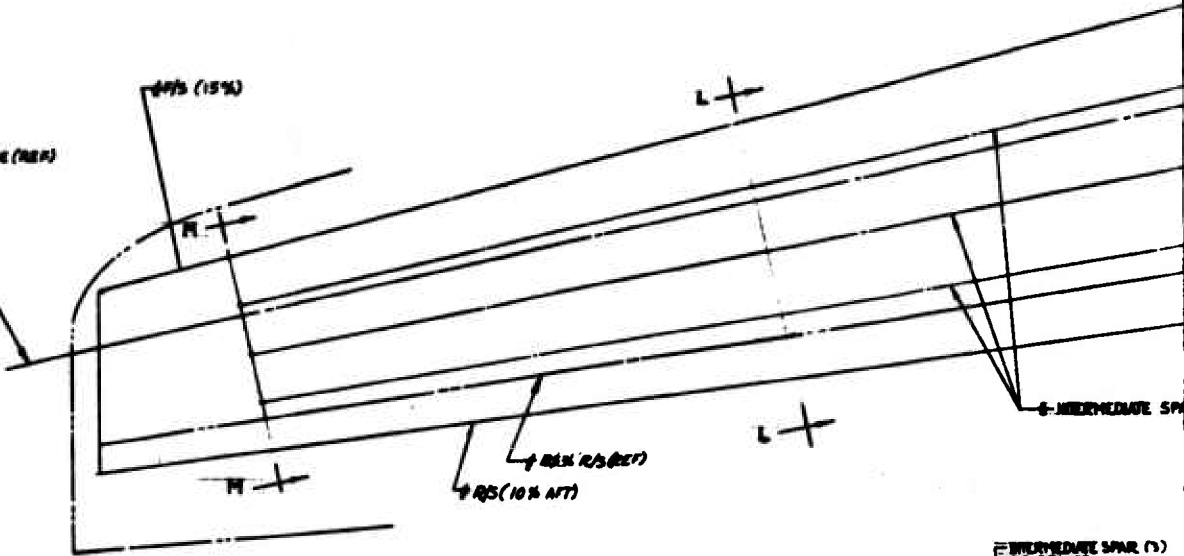
SECTION L-L
SCALE 1/2
BS 340.00
SAME AS H-H EXCEPT AS SHOWN

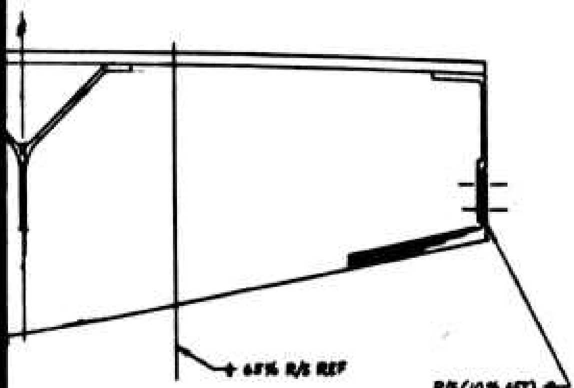


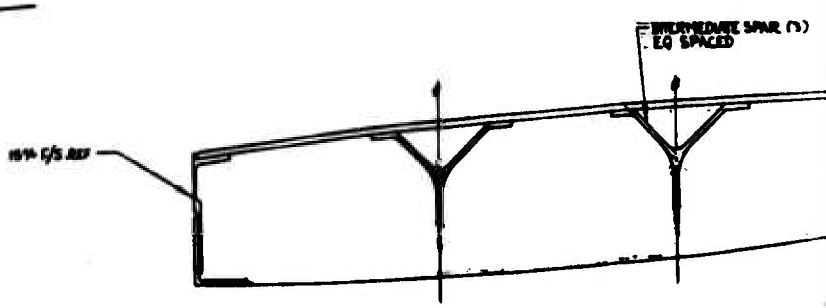
SECTION K-K
SCALE 1/2
BS 140.00
SAME AS G-G EXCEPT AS SHOWN

2









SECTION M-M
SCALE 1/2
SAME AS JJ EXCEPT AS SHOWN

3

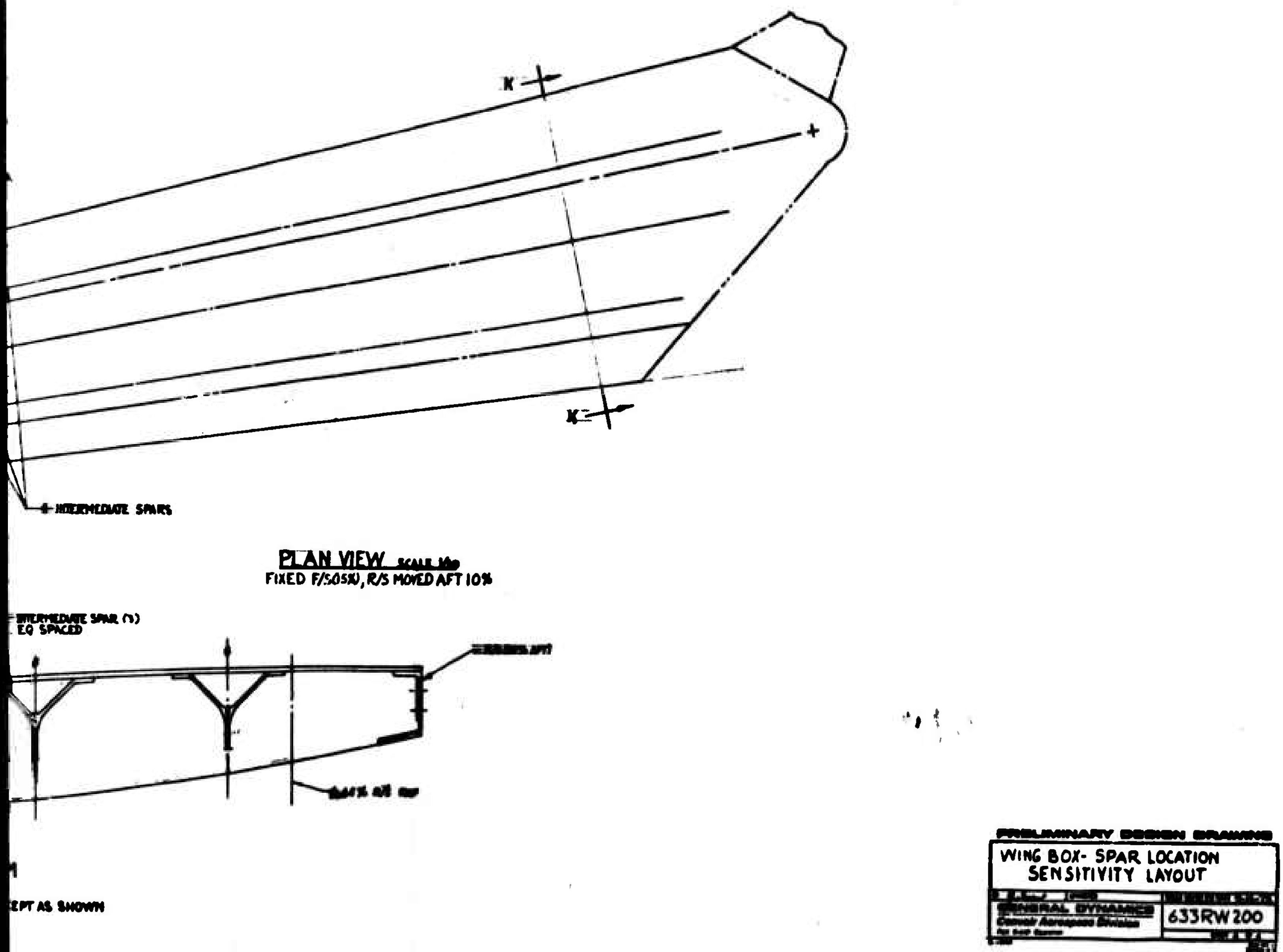


FIGURE 108 REAR SPAR MOVED AFT 10%

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TABLE XX

FRONT AND REAR SPAR RELOCATION SENSITIVITY**

	WING BOX WEIGHT CHANGE (Lbs/Side)	TIP DEFLECTION* (in.)	TIP TWIST* (Deg.)	VOLUME CHANGE (in^3/side)
F. S. To .175C	-30.7	59.68	+3.17	-11022
F. S. To .200C	-48.7	61.13	+3.18	-18952
R. S. To .700C	+46.5	55.58	+2.63	+12306
R. S. To .750C	+116.8	54.51	+2.30	+24633
F. S. At .15C, R. S. At .65C	Reference	57.39	+2.93	Reference

** EFFECT ON WING BOX ONLY

* USING CONDITION 4 FOR REFERENCE. TIP UP AND L.E. DOWN ARE POSITIVE, BOTH ULTIMATE

SECTION VIII

VALUE ENGINEERING

Throughout this program Value Engineering in consonance with grass roots estimating personnel have provided accurate cost data, evaluation and trade study inputs to design personnel for each concept, at each phase of the program, identifiable by element within the concept. This information was used to identify areas requiring additional design and trade study effort as shown in Figure 109.

8.1 COSTING GROUNDRULES

Costing groundrules were as follows:

- o Estimates to be made for recurring acquisition costs
- o Production rate of four ship sets (8 units) per month
- o Average cummulative costs for 200 ship sets in 1975 dollars for the analytical assembly concepts
- o For the preliminary design concepts compute 1975 and 1980 average cummulative costs for 1, 4, 40, 100 and 200 ship sets
- o Use General Dynamics rates and cost structure.

The costs developed included recurring costs such as:

- o Manufacturing
- o Product Assurance
- o Configuration Control
- o Materials
- o Overhead
- o Tool Engineering Maintenance
- o Tool Manufacturing Maintenance
- o Quality Assurance
- o General & Administrative
- o Tool Material Maintenance

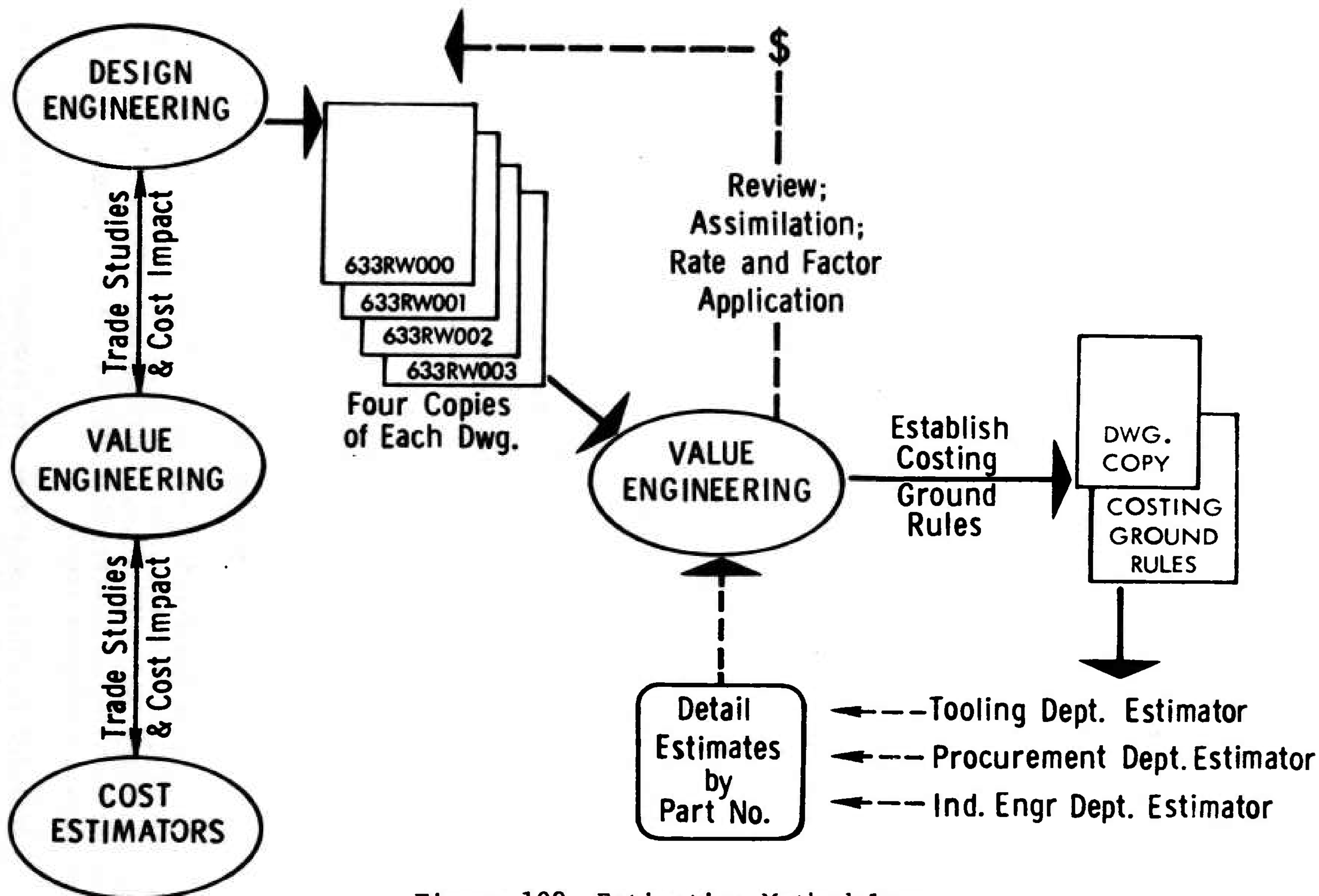


Figure 109 Estimating Methodology

The estimates did not include non-recurring costs such as:

- o Engineering Design & Development Costs
- o Basic and Augmentation Tooling
- o Production Aid Tooling
- o Flight Testing

8.2 MATERIAL COSTS

Material costs were projected to a cummulative average for 200 ship sets from a list of material (LM) on the released full size component and analytical assembly drawings. Start and finish weights and dimensions were provided for costing purposes.

Procurement department estimating personnel estimated each line item in detail using recent purchase orders, vendor published catalogues or direct vendor quotes. Material form, dimensional requirement and "extras" such as heat treat, cut to length, etc., were considered in the estimates.

Historical material factors were added to the basic estimate to reflect hidden costs such as attrition, freight in and material overhead. Costs for quantities of one through 40 were adjusted to reflect a 95% learning curve. Because materials are usually purchased in yearly lots, only one half of the value for the 95 percent cost curve was used to project average unit costs for 100 and 200 unit quantities.

The material cost data was made available to the designers through a series of master costing drawings which were left open in the design area for review, evaluation, and comparison.

8.3 MANUFACTURING COSTS

Industrial Engineering personnel, utilizing labor standards and applicable realization factors considered the material form, material type, and approximately 82% average learning curves to project cummulative average 200 ship set manufacturing costs for the various configurations.

Included in those estimates are provisions for historically hidden costs such as processing, allocations, rework and shop liaison.

An additional factor was applied to these direct labor hours to arrive at a projected cost for quality assurance.

This data was then made available to the designers through the same series of master costing drawings as was described in section 8.2 under material costs.

8.4 TOOLING COSTS

Projected recurring costs include provisions for various "maintenance type" tooling costs such as tool manufacturing, tool engineering, tool materials, and tooling QA charges. These costs were derived through use of empirical ratios applied to detail estimates for non-recurring tool manufacturing and tool augmentation costs.

These detail estimates include the basic tools which would be necessary to fabricate the full size components in addition to the augmentation tools necessary to arrive at a four ship set per month production rate.

8.5 COMPARISON OF ANALYTICAL ASSEMBLY COSTS BETWEEN BASELINE AND ADVANCED CONCEPTS

Table XXI is a tabulation of cummulative average costs for 200 units of each advanced analytical assembly concept and the baseline in 1975 dollars.

8.6 COMPARISON OF COSTS BETWEEN BASELINE AND ADVANCED CONCEPTS FOR PRELIMINARY DESIGN CONCEPTS

Table XXII is a tabulation of cummulative average costs of 1, 4, 40, 100, and 200 unit wing boxes for advanced concepts and the ATW-4 baseline shown in 1975 and 1980 dollars. Illustration of these designs are shown in Figures 110 through 113.

TABLE XXI SUMMARY ANALYTICAL ASSY COST
WING BOX

(1975 DOLLARS)

ASSY NO	MATL $	MFG $	TOOLING $	TOTAL
633RA000-1	4244	7777	289	12310
633RA001-1	3395	6442	254	10091
633RA001-3	3612	6917	245	10774
633RA001-5	3589	7067	336	10992
633RA001-801	3503	6965	192	10660
633RA001-803	3168	6291	282	9741
633RA001-805	2799	6672	306	9777
633RA002-1	3033	6301	212	9546
633RA003-1	4956	7058	263	12277
633RA003-3	3699	8835	259	12793
633RA003-5	2999	7643	276	10918
633RA003-801	3520	6985	228	10733
633RA004-1	3770	4048	173	7991
633RA004-3	4564	4594	150	9308
633RA004-5	4198	4277	207	8682
633RA005-1	37762	5227	291	43280
633RA006-1	39507	5652	149	45308
633RA006-3	32690	4973	149	37812
633RA007-1	36838	11043	212	48093
633RA008-1	38011	5508	202	43721

Average for 200 Units

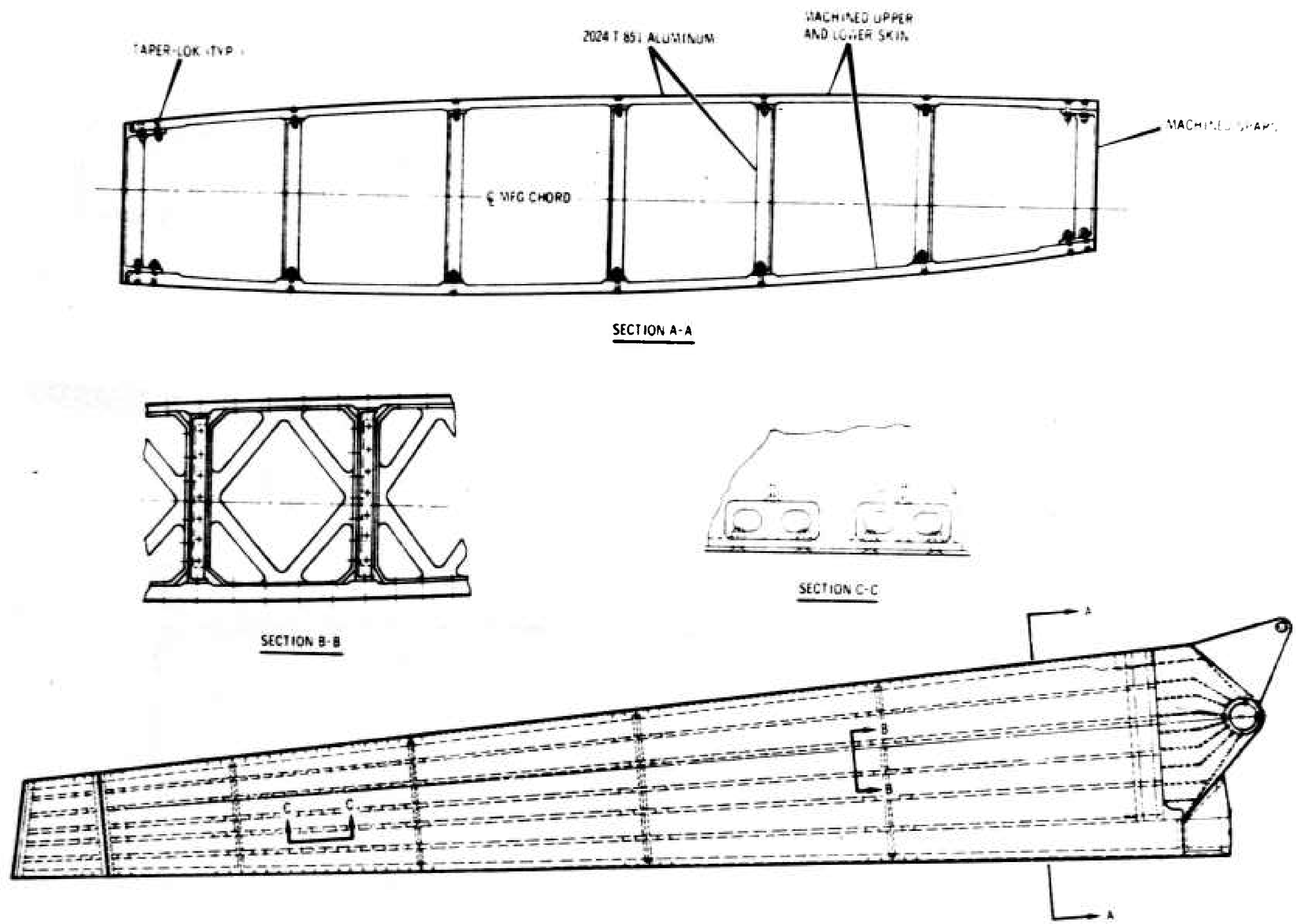


Figure 110 ATW-4 Wing Box Baseline

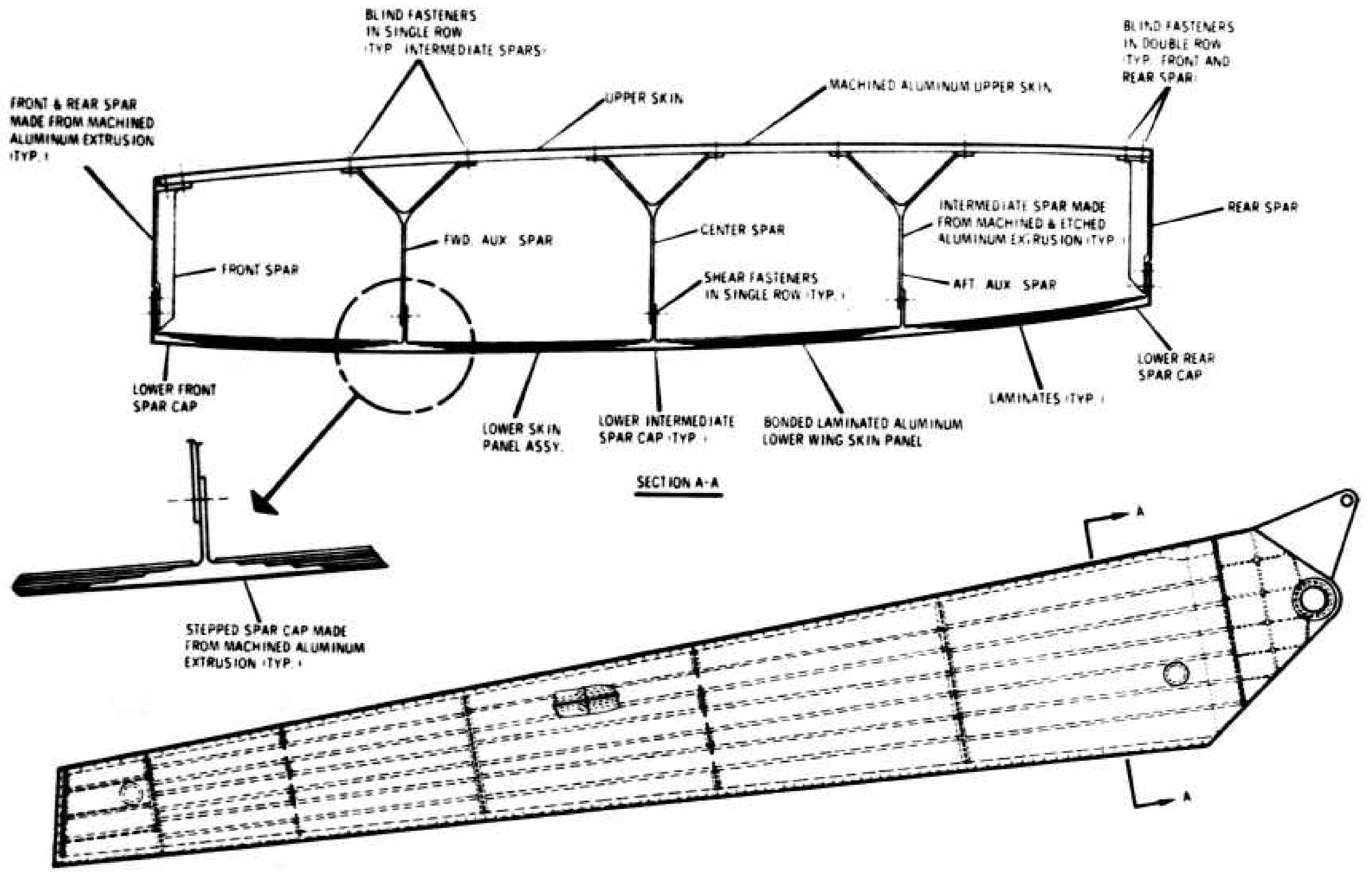


Figure 111 ATW-4 Wing Box-Laminated Aluminum Lower Skin With "Y" Spars

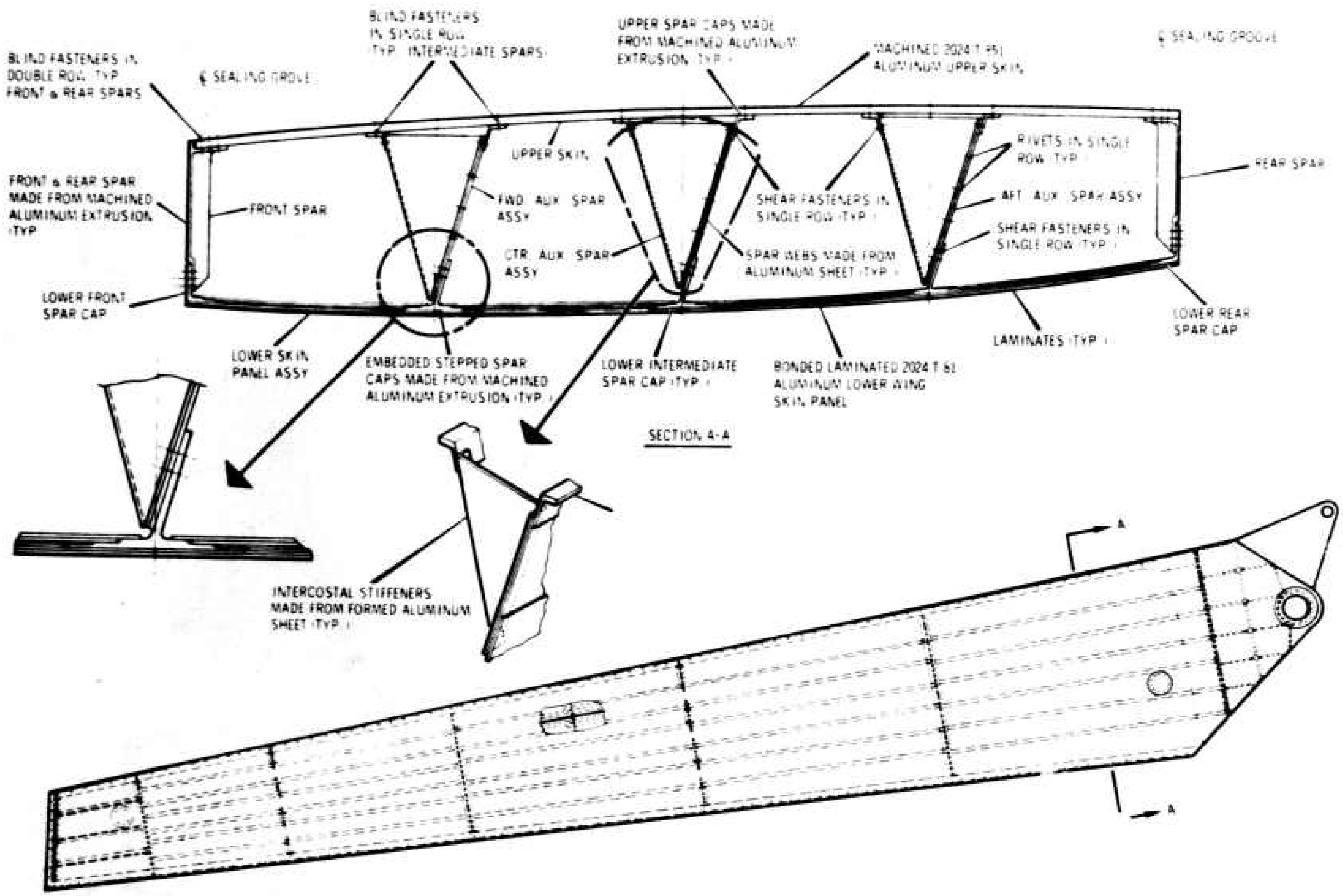


Figure 112 ATW-4 Wing Box-Laminated Aluminum Lower Skin, Canted Spars

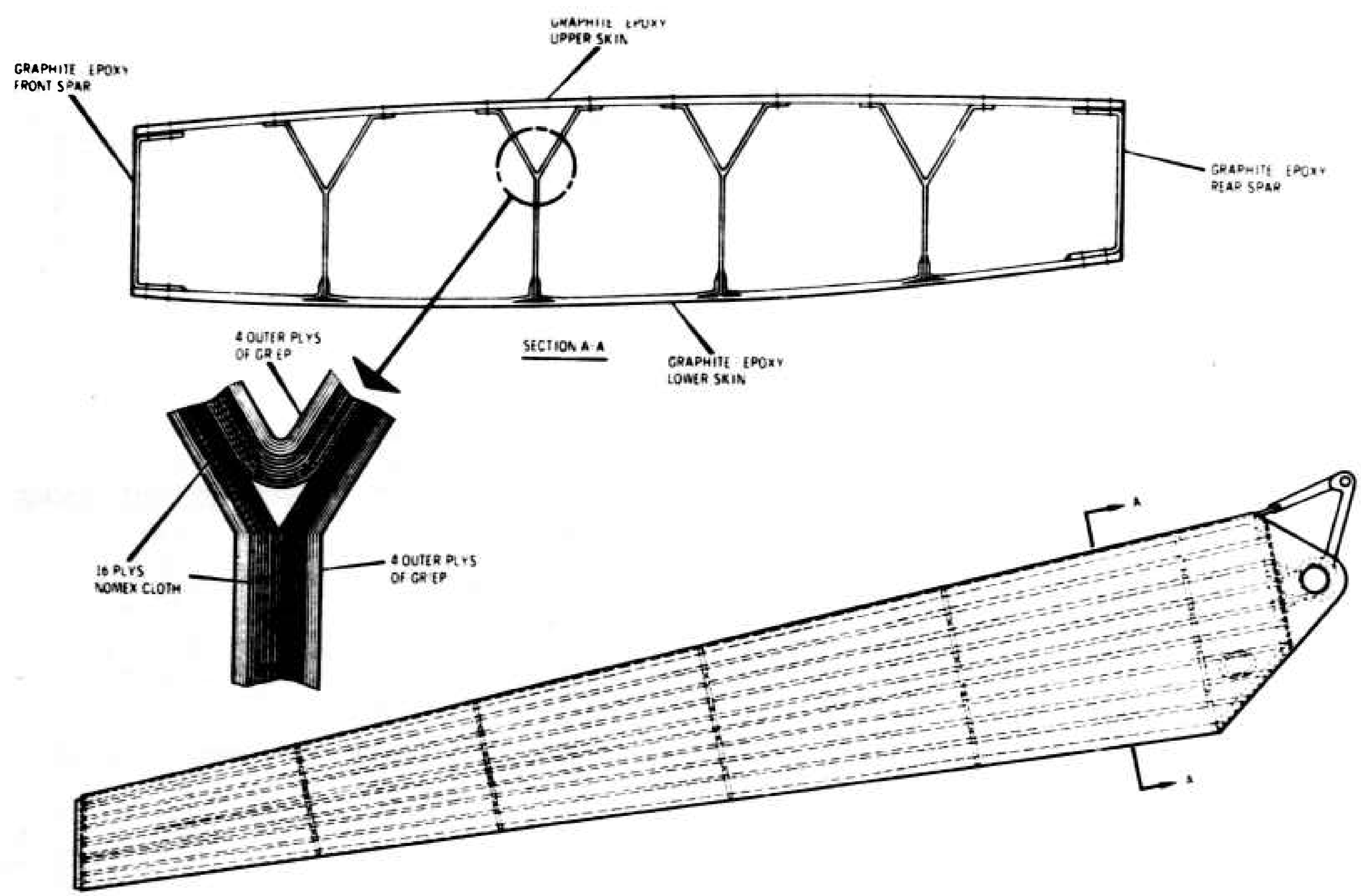


Figure 113 ATW-4 Graphite Epoxy Conposite Wing Box "Y" Spars/Embedded Lwr. Caps

Table XXII Wing Box Cost Analysis Supercritical Wing Preliminary Design Study

Configuration	Lot Size	Average Unit Values (000)					
		1975 Dollars			1980 Dollars		
		Cost	Earnings	Price	Cost	Earnings	Price
Baseline Design Drawing No. 633RW00-1	1	578	59	637	728	73	801
	4	465	47	512	585	59	644
	40	287	29	316	362	36	398
	100	234	23	257	294	30	324
	200	200	20	220	252	25	277
Supercritical Design Drawing No. 633RW001-1	1	496	50	546	626	63	689
	4	398	40	438	503	50	553
	40	248	25	273	314	31	345
	100	203	20	223	257	26	283
	200	174	18	192	221	22	243
Supercritical Design Drawing No. 633RW002-1	1	519	52	571	654	65	719
	4	416	41	457	524	52	576
	40	256	26	282	324	32	356
	100	208	21	229	264	26	290
	200	178	18	196	225	23	248
Supercritical Design Drawing No. 633RW002-3	1	542	54	596	682	68	750
	4	434	44	478	547	55	602
	40	267	27	294	336	34	370
	100	216	22	238	274	27	301
	200	185	18	203	234	23	257
Supercritical Design Drawing No. 633RW003-1	1	651	65	716	727	73	800
	4	554	55	609	610	61	671
	40	398	40	438	427	43	470
	100	355	35	390	375	37	412
	200	326	33	359	341	34	375
Supercritical Design Drawing No. 633RW003-3	1	621	62	683	689	69	758
	4	528	53	581	578	58	636
	40	383	38	421	406	41	447
	100	342	34	376	357	36	393
	200	315	32	347	325	33	358

SECTION IX

MANUFACTURING

The method of manufacturing of the wing boxes developed in this study was determined at both the analytical assembly level and at the preliminary design phase. This included a listing of all tools required to manufacture the analytical assemblies and the preliminary design boxes as well as an estimate of the non-recurring cost of these tools. This estimate was necessary in order to determine the recurring cost to maintain these tools in the production lots required by the contract as well as define the manufacturing plan for use by industrial engineering to develop the manufacturing costs.

9.1 ANALYTICAL ASSEMBLY STUDY

Each of the analytical assemblies was evaluated to determine the manufacturing processes that were required and the tools necessary for fabrication. Added to this was the additional tools required to meet the production rate requirements. From this information the tool manufacturing hours were estimated. Table XXIII summarizes a typical tooling summary for 633RA003-801 analytical assembly. The total non-recurring tooling mfg. hours were then determined for each analytical assembly, including tool engineering hours and tool material costs. From this information the total recurring costs were determined. A summary of these costs are shown in Table XXIV.

9.2 PRELIMINARY DESIGN STUDY

The preliminary wing box designs were analyzed to determine the manufacturing processes and tools that would be required for the fabrication of a complete wing box. In addition, the extra tools required to meet the production rate requirements were also considered. Total tooling recurring costs were determined and manufacturing plans were outlined for each preliminary wing box design in order to develop the manufacturing costs and to assist in the evaluation of each of the wing box configurations. The manufacturing plan for the baseline design, the top ranked design, and the composite wing design are being discussed in this section.

TABLE XXIII 633RA003-801 TOOL SUMMARY

TASK ITEM	TOOL CODE	UNIT HOURS	ADD FOR RATE NO. TOOLS	ADD FOR RATE TOTAL HOURS	REMARKS
-7 SKIN	FLTP		1	6	SAW (EXCESS)
	CKTP		1	12	BRAKE FORM
	RTEX		1	40	ROUT TO SIZE
-83 F. SPAR	PDTA	80	2	160	MILL COMPLETE
-91 R. SPAR	MLFX	80	2	160	
-175, -177 UP.AUX.SPAR CAP -179, -181 UP.AUX.SPAR CAP -183, -185 UP.AUX.SPAR CAP	MLFX	80	6	480	MILL COMPLETE
-191 LWR.AUX.SPAR CAP	PDTA	60	3	180	MILL COMPLETE
-193 LWR.AUX.SPAR CAP	MLFX	80	3	240	
-195 LWR.AUX.SPAR CAP					
-187 INTERCOSTAL	FLTP	6	1	6	SHEAR TO SIZE
	TOTP	6	1	6	BRAKE ONE FLG
	HPFM	18	2	36	FINISH FORM
-189 SPAR WEB	SCS			-	SHEAR TO SIZE
SKINS (-1 ASSY)	CKTP	8	6	48	SHEAR FOR 4 SKINS
	FLTP	6	12	72	ROLL CONTOUR SHEAR TO SIZE
-203 LWR SKIN ASSY	PRFX		1	120	PREFIT DETAILS
	VFBX		1	80	BOND PROCEDURE
	BNFM		1	240	SAME AS 633RA001
-801 ASSY	ASFX		1	240	LOCATE DETAILS, DRILL, INSTALL FASTENERS
				2126	TOTAL ESTIMATED TOOL MFG. HRS.

TABLE XXIV TOOLING SUMMARY FOR ANALYTICAL ASSEMBLIES

ITEM	NON RECURRING						RECURRING					
	TOOL	MFG.	TOOL	ENG.	TOOL	MAT'L	TOOL	MFG.	TOOL	ENG.	TOOL	MAT'L
633RA000-1		2904		1540		$6534		1567		1830		$3526
633RA001-1		2382		1262		5360		1286		1500		2894
633RA001-3		2286		1212		5144		1235		1440		2778
633RA001-5		3104		1645		6984		1676		1956		4401
633RA001-801		1768		937		3978		955		1114		2507
633RA001-803		2622		1390		5900		1416		1652		3186
633RA001-805		2860		1516		6435		1545		1802		3476
633RA002-1		1976		1046		4446		1066		1244		2400
633RA003-1		2454		1301		5522		1325		1546		2981
633RA003-3		2410		1278		5423		1302		1518		2930
633RA003-5		2576		1366		5796		1392		1624		3132
633RA003-801		2126		1127		4784		1148		1340		2583
633RA004-1		1612		854		3627		871		1016		1960
633RA004-3		1414		750		3182		764		871		1719
633RA004-5		1930		1023		4343		1042		1216		2345
633RA005-1		2660		1410		8000		1436		1676		4308
633RA006-1		1360		720		6714		735		857		2205
633RA007-1		2058		1029		4630		1112		1297		2502
633RA008-1		1884		1000		4240		1018		1187		2291

9.2.1 Preliminary Manufacturing Plan for Baseline 633-RW000

The manufacturing process for the baseline design is defined in Table XXV and schematically shown in Figure 114. The methods of fabrication are discussed below:

9.2.1.1 Upper and Lower Skin Fabrication

The upper skin and lower skin are sculptured plate made from 2024-T851 aluminum alloy.

Basic tapers will be machined on a numerical control skin mill. Contour will be formed on a 1000 ton numerical control brake. The skin will then be etched and routed to finish dimensions.

9.2.1.2 Spar Fabrication

The wing spars are all integrally machined structure made from 2024-T8511 aluminum alloy extrusions.

9.2.1.3 Bulkhead and Rib Fabrication

The bulkheads and ribs are all integrally machined structure made from 2024-T851 aluminum alloy.

9.2.1.4 Pivot Fitting Fabrication

The pivot fitting is a welded assembly containing a mechanically attached shear web (Fig. 115).

The welded assembly consists of an upper plate, a lower plate, shear ring, and shear webs machined from D6Ac forgings and plate.

The mechanically attached shear web is machined from 6Al-4V titanium plate.

9.2.1.5 Final Assembly of Wing Box

A major assembly and drill fixture commonly known as a "wing buck" will be required to perform final assembly operations of the box.

TABLE XXV BASELINE 633-RW000 WING BOX MANUFACTURING ANALYSIS

DESCRIPTION	QTY	MATERIAL		FAB. METHOD
		TYPE	SIZE	
-7 & -9 UPR & LWR SKINS	2	2024-T851	1.50 & 1.75 X 77 X 368	PURCHASE ROUGH SIZE, MILL TAPER, ETCH LANDS, ROUT PERIPHERY
-11 & -13 FRONT & REAR SPARS	2	2024-T8511	2.75 X 12 X 380	EXTRU. - N/C MILL TO SIZE
-15, -17, -19, -21, -23 AUX. SPARS	5	2024-T8511	1.25 X 12 X 350	EXTRU. - N/C MILL TO SIZE
-25 & -27 UPPER & LOWER OUT-BOARD SKINS	2	2024-T851	.125 X 32 X 36	SHEAR OVERSIZE, ROLL CONTOUR, ROUT TO SIZE
-29, -31, -33, -35 BULKHEADS	24	2024-T851	3.0 X 6.5 X 6 TO 3.0 X 12 X 11	PURCHASE OR SAW ROUGH SIZE, N/C MILL COMPLETE
-37 & -39 BULKHEADS	2	2024-T851	3.0 X 7 X 28	PURCHASE OR SAW ROUGH SIZE, N/C MILL COMPLETE
- OUTBOARD AUX. SPARS	5	2024-T8511	1.25 X 6 X 28	EXTRU. - N/C MILL TO SIZE
- PIVOT ASSEMBLY				SEE FIGURE 9-2
- 1 ASSEMBLY				oPOSITION LWR.SKIN, ATTACH PIVOT FITTING oINSTALL AUX.SPARS, BULKHDS,FRT.& REAR SPARS oINSTALL PLUMBING & MISC. EQUIPMENT oINSTALL UPPER SKIN oINSTALL OUTBD SPARS, MISC.HARDWARE, & SKINS

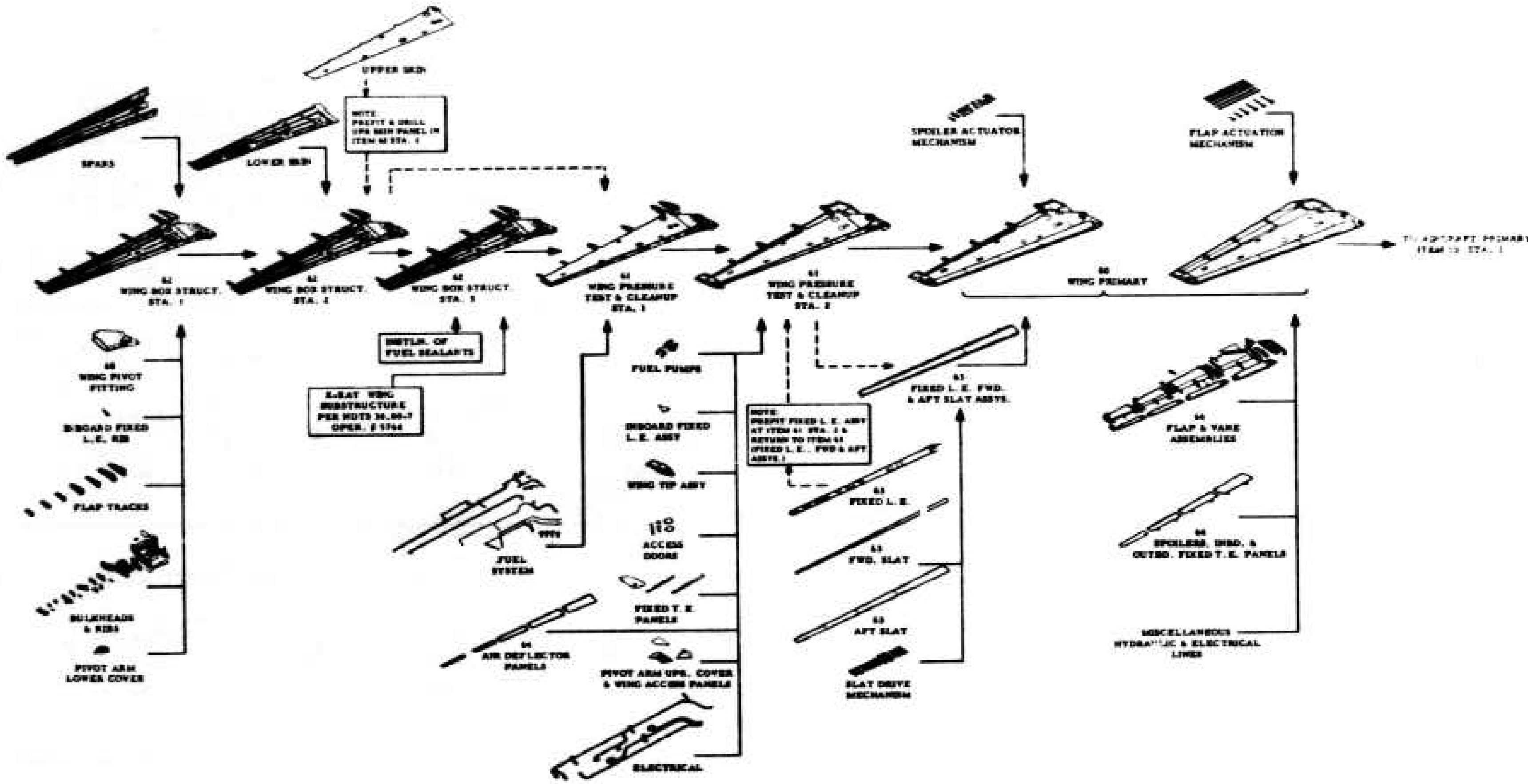


Figure 114 Baseline 633-RW000 Manufacturing Sequence

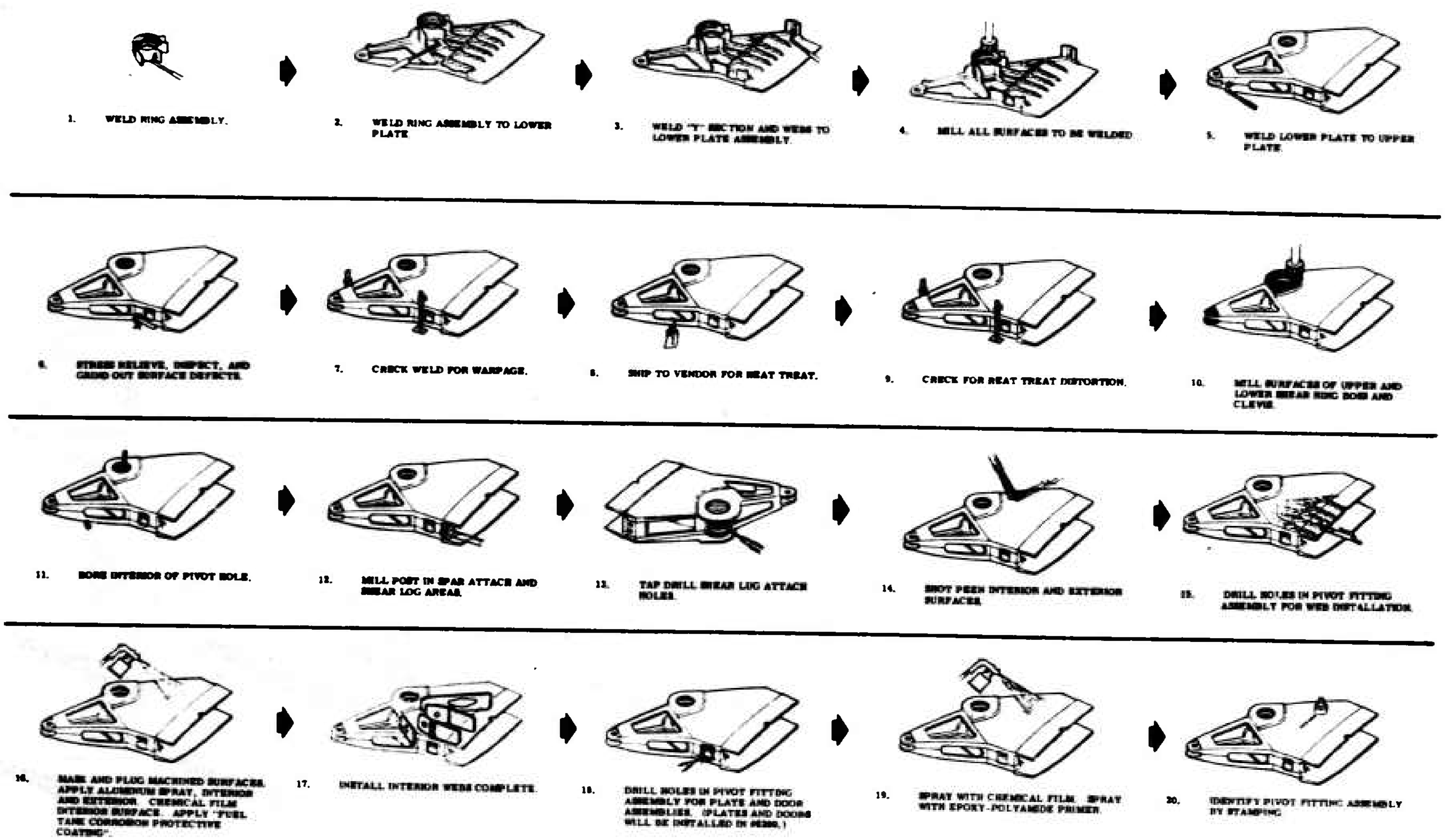


Figure 115 Baseline 633-RW000 Pivot Fitting Manufacturing Sequence

The fixture will first be used to receive and locate the pivot fitting assembly, bulkheads, and spars.

The fixture will then be used to provide a method for positioning, holding, and locating hole drilling tooling for drilling holes common to the upper skin, understructure, and lower skin.

Upon completion of the hole drilling operations on the lower skin, all faying surfaces formed by the front and rear spars will have fuel sealing applications and all understructure will be permanently attached to the lower skin with taper-lok bolts. Following the hole drilling operations on the upper skin, the skin is removed and self-locking nuts are installed in the upper attach surfaces of the understructure. All faying surfaces formed by the front and rear spars will then have fuel sealing applications and all understructure will be permanently attached to the upper skin with bolts.

9.2.2 Preliminary Manufacturing Plan for 633-RW001

The manufacturing approach for the number one ranked design is discussed below. The process is defined in Table XXVI and is also shown schematically in Figures 116 through 126.

9.2.2.1 Front and Rear Spar Fabrication

The front and rear spars are one-piece, integrally machined structure made from a 2024-T8511 aluminum alloy extrusion. Numerically controlled milling machines are used to pocket and contour the spar (Fig. 116).

9.2.2.2 Intermediate Spar Fabrication

The intermediate spars are one-piece, machined and chem-etched structure made from a 2024-T8511 aluminum alloy extrusion.

The upper caps (flanges) are contour machined to the inner surface of the upper skin and machine tapered. The spar web is routed to the proper depth profile. The spar web and diagonal legs are then chem-etched to finish dimensions.

The manufacturing steps are shown in Figure 117.

TABLE XXVI 633-RW001 WING BOX ANALYSIS
(Page 1 of 4)

DESCRIPTION	QTY	MATERIAL		FAB. METHOD
		TYPE	SIZE	
-7 UPPER SKIN	1	2024-T851	1.0 X 77 X 360	PURCHASE ROUGH SIZE, MILL TAPER, BRAKE FORM CONTOUR, ROUT PERIPHERY
-9 & -37 FRONT & REAR SPAR	2	2024-T8511	2.50 X 11 X 370	ROUGH EXTRUSION - N/C MILL COMPLETE
-11, -13, -15, -17, -19, -21, -23, -25, -27 AUX. SPARS	9	2024-T8511	Y EXTRU. LENGTH RANGE: 72 TO 128	ETCH LEGS TO THICKNESS, MILL "Y" BOSSES, ROUT LEG & FUEL CUTOUTS
-29, -31, -33 OUTBOARD SPARS	3	2024-T81	12 X 26	SHEAR TO SIZE, HYDROPRESS FORM, HEAT TREAT, STRAIGHTEN
-35 CLOSURE BULKHEAD	1		CASTING	N/C MILL UPPER & LOWER SURFACES
<u>-39 ASSY</u>				
-57 BULKHEAD	1	2024-T851	3.0 X 12 X 60	SAW ROUGH SIZE, N/C MILL COMPLETE
-59 & -61 ATTACH ANGLE	18	2024-T8511	2 & 4 IN. LENGTH	EXTRU. - SAW TO LENGTH
<u>-41 ASSY</u>				
-63, -65, -67, -69 BULKHEADS	4	2024-T851	3.0 X 11 X 15	SAW ROUGH SIZE, MILL COMPLETE
-71 & -73 ATTACH ANGLE	18	2024-T8511	2 & 4 IN. LENGTH	EXTRU. - SAW TO LENGTH

TABLE XXVI 633-RW001 WING BOX ANALYSIS
(Page 2 of 4)

DESCRIPTION	QTY	MATERIAL		FAB. METHOD
		TYPE	SIZE	
-43 ASSY				
-75 BULKHEAD	1	2024-T851	3.0 X 10 X 46	SAW ROUGH SIZE, N/C MILL COMPLETE
-77 & -79 ATTACH ANGLE	18	2024-T8511	2 - 4 IN. LENGTH	EXTRU. - SAW TO LENGTH
-45 ASSY				
-81, -83, -85, -87 BULKHEAD	4	2024-T851	3.0 X 10 X 14	SAW ROUGH SIZE, MILL COMPLETE
-89 & -91 ATTACH ANGLES	18	2024-T8511	1.5 - 3	SAW TO LENGTH
-47 ASSY				
-93 BULKHEAD	1	2024-T851	3.0 X 7 X 35	SAW ROUGH SIZE, N/C MILL COMPLETE
-95 & -97 ATTACH ANGLE	18	2024-T8511	1.5 - 3	SAW TO LENGTH
-99 & -101 OUTBOARD UPPER & LOWER SKINS	2	2024-T851	32 X 36	SHEAR OVERSIZE, ROLL CONTOUR, ROUT TO SIZE
-49 ASSY				
-103 LAMINATES	32	2024-T851	APPROX. LENGTH RANGE: 40 - 380	SHEAR TO LENGTH WITH WIDTH FOR SEVERAL PARTS. ROLL FORM, TAPER ETCH, ROUGH SAW TO SEPARATE PARTS, ROUT TO SIZE

TABLE XXVI 633-RW001 WING BOX ANALYSIS
(Page 3 of 4)

DESCRIPTION	QTY	MATERIAL		FAB. METHOD
		TYPE	SIZE	
-105, -107, -109 LOWER SPAR CAPS	5	2024-T8511	EXTRUSIONS - 380	N/C MILL TO SIZE - ROUT FUEL CUTOUTS
-111, -113, -115, -117, -119 BULKHEAD CAPS	5	2024-T8511	EXTRUSIONS - 30 TO 60	N/C MILL TO SIZE - ROUT FUEL CUTOUTS
<u>ASSEMBLY -49</u> NOTE: PRIOR TO BONDING, TRAPPED AIR MUST BE REMOVED FROM LAMINATES BY APPLYING VACUUM TO ASSEMBLY AND OUTER SURFACE OF BLANKET WITH SLIGHTLY HIGHER PRESSURE ON OUTER SIDE. MODIFICATION OF AUTO-CLAVE OR A SPECIAL TOOL FOR THIS PURPOSE WILL BE REQUIRED.				PREFIT SPAR & AUX. SPAR CAPS, SKINS, AND BULKHEAD CAPS. CLEAN FOR BONDING, APPLY ADHESIVE AND ASSEMBLE DETAILS, POSITION ASSY IN BONDING FIXTURE AND INSTALL VACUUM BLANKET. (SEE NOTE) BOND IN AUTOCLAVE. CLEAN TO REMOVE EXCESS ADHESIVE
-53 (?) PIVOT FITTING ASSY. UPPER STEEL FORGING LWR ALUM FORGING RING SPLICE BULKHEAD FAIL SAFE STRAPS SPAR ATTACH ANGLES STEEL BUSHINGS				

TABLE XXVI 633-RW001 WING BOX ANALYSIS
(Page 4 of 4)

DESCRIPTION	QTY	MATERIAL		FAB. METHOD
		TYPE	SIZE	
<u>-1 ASSEMBLY</u>				o PREFIT LWR. ALUM. FORGING TO -49 SKIN ASSY. CLEAN AND BOND TO SKIN IN AUTOCLAVE o INSTALL PIVOT DETAILS o INSTALL SPARS, BULKHEADS, PLUMBING, MISC. EQUIPMENT AND UPPER SKIN o INSTALL OUTBD. SPARS, CLOSURE BULKHEAD, MISC. HARDWARE, AND SKINS o SIZE PIVOT BUSHINGS

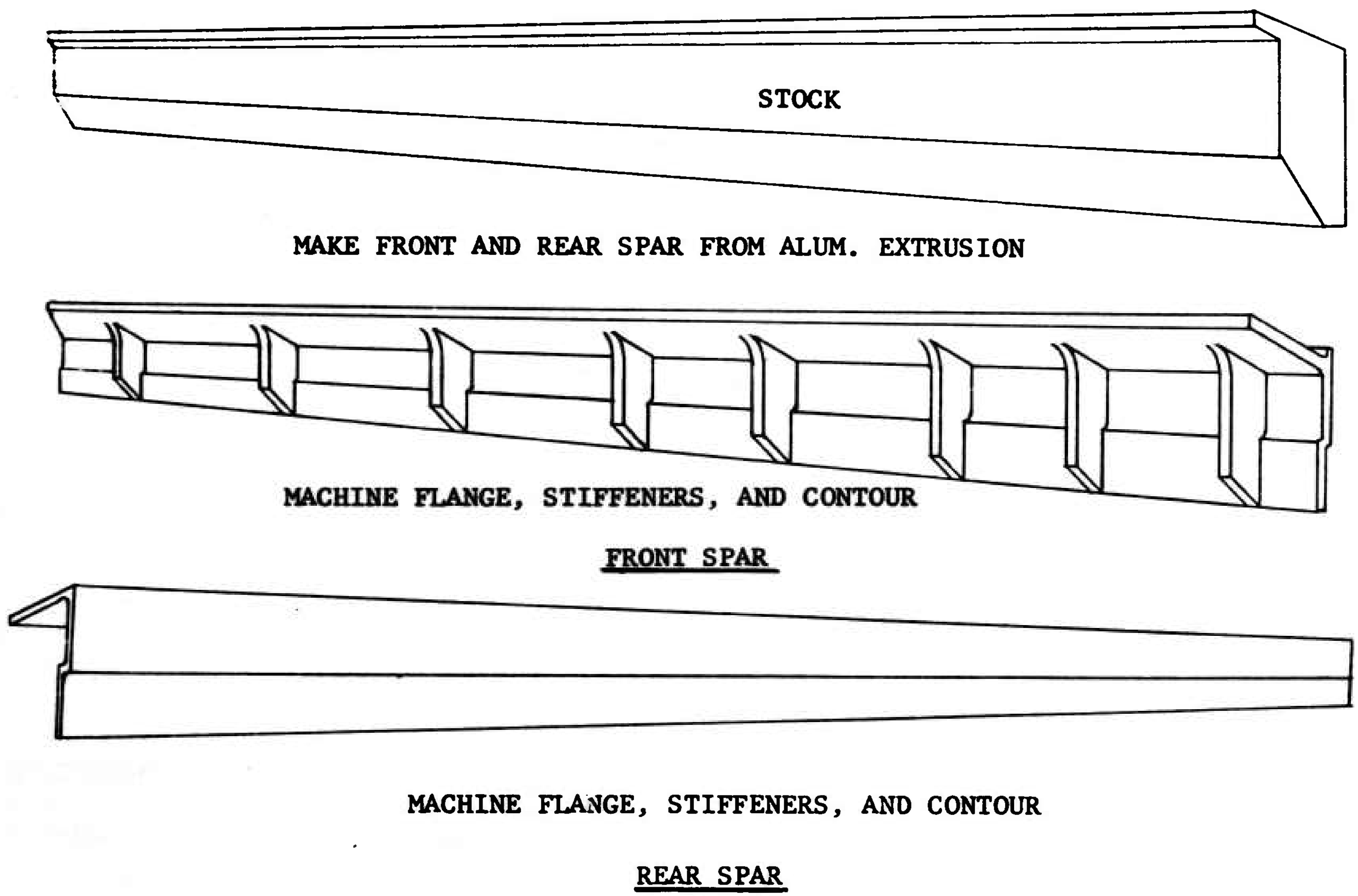


Figure 116 Basic Manufacturing Front and Rear Spars

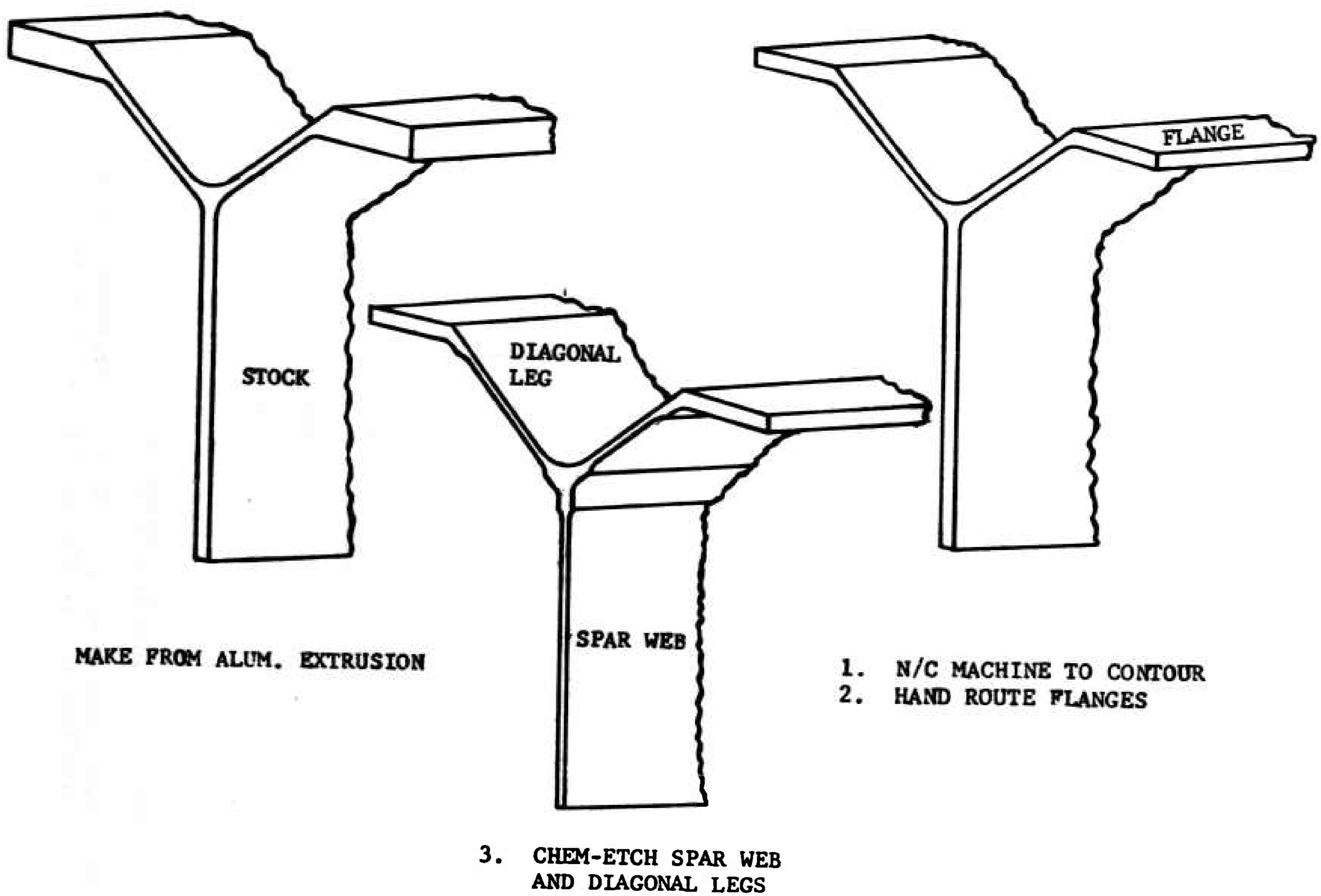


Figure 117 Basic Manufacturing Intermediate Spars

9.2.2.3 Lower Skin Laminates

The laminates will be formed from 2024-T81 aluminum alloy sheet stock, ranging from .063 to .071 inch thickness.

Laminates are to be sheared, rolled to contour, taper etched, routed, and deburred in preparation for bonding operation (Fig. 118).

9.2.2.4 Lower Spar Cap Fabrication

The lower spar caps are tapered and stepped "Tee" type structure machined from 2024-T8511 aluminum alloy extrusions.

The lower caps are contour machined to the outer contour of the lower wing surface. Numerical control machining techniques will be used to generate maximum effective metal removal and ultimate dimensional control.

The manufacturing steps are shown in Figure 119.

9.2.2.5 Upper Skin Fabrication

The upper skin is a one-piece tapered plate containing the entire upper surface contour and machined from 2024-T851 aluminum alloy.

Basic tapers on the inside skin will be machined on a numerical control skin mill. Contour will be formed on 1000 ton numerical control brake. The skin will then be routed to finish dimensions (Fig. 120).

9.2.2.6 Fabrication of Bulkheads and Ribs

Major bulkheads and ribs may be fabricated by machining from plate or by machining from castings. Production quantity and rate will determine the most economical method. Figure 121 depicts the two methods.

9.2.2.7 Lower Pivot Plate Fabrication

The lower pivot plate is a one-piece integrally machined structure made from a 2024-T851 aluminum alloy forging.

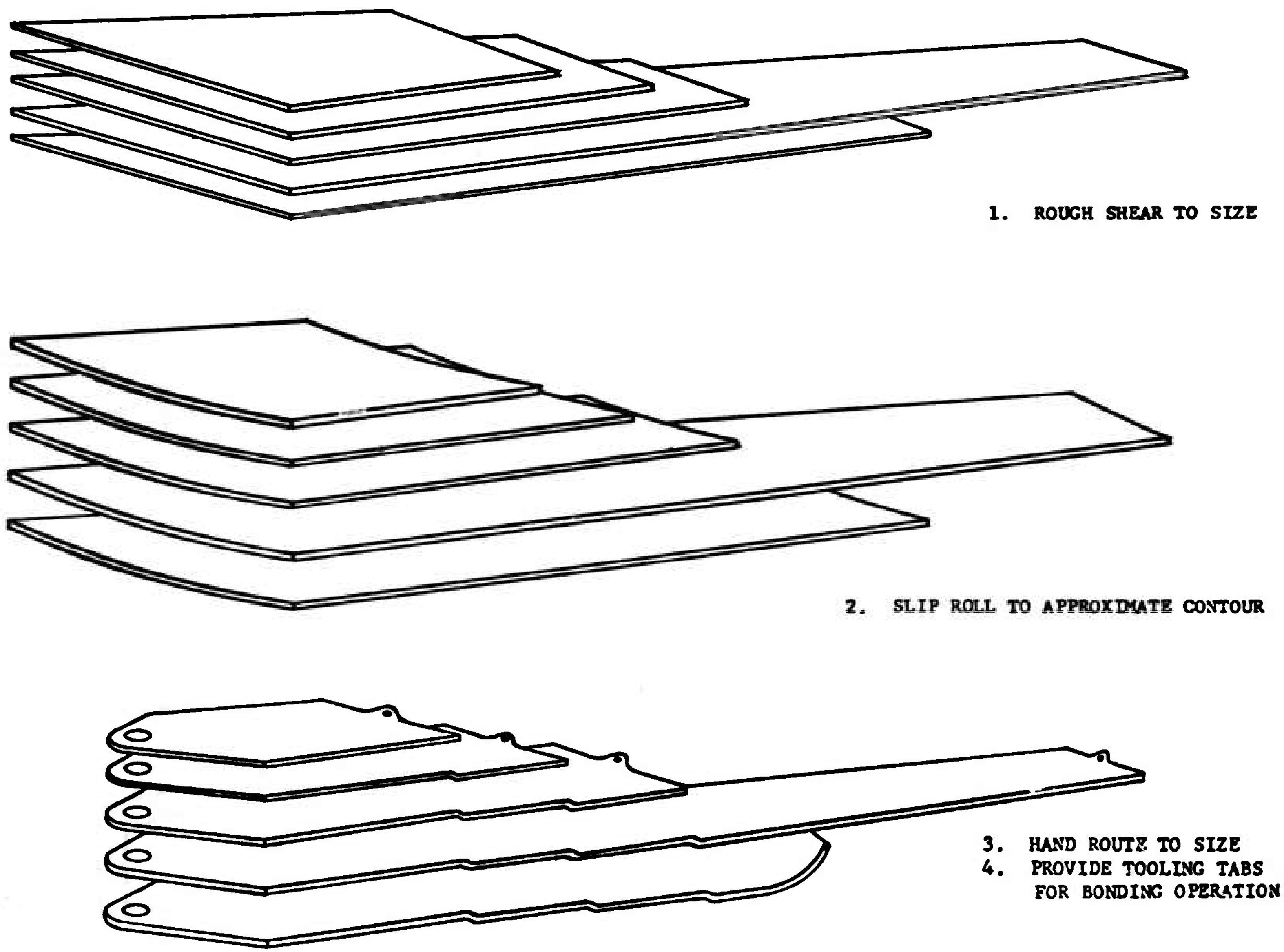
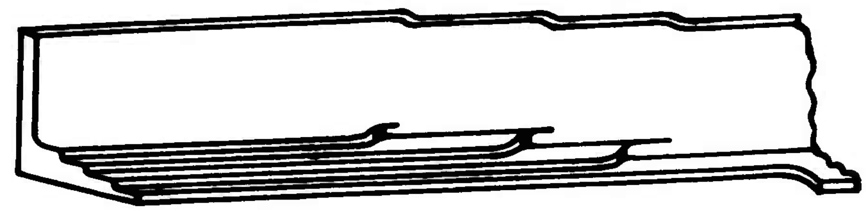


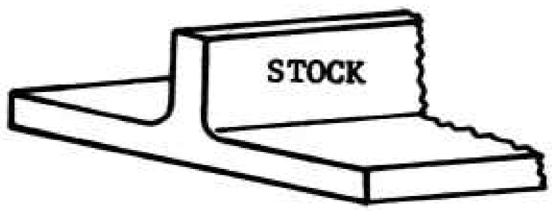
Figure 118 Basic Manufacturing Lower Skin Laminates

MAKE FROM ALUM. EXTRUSION

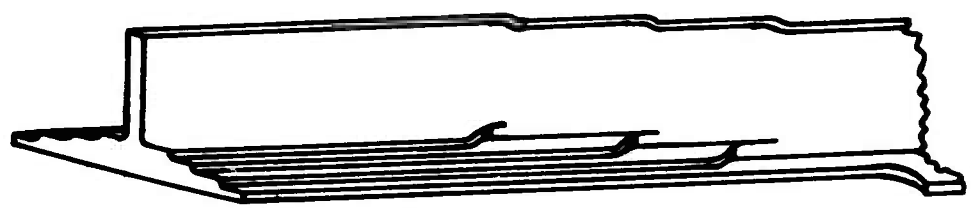


1. MACHINE STEPS & CONTOUR
2. HAND ROUTE FLANGES

FRONT & REAR
LWR SPAR CAPS



MAKE FROM ALUM. EXTRUSION



1. MACHINE STEPS & CONTOUR
2. HAND ROUTE FLANGES

INTERMEDIATE
LWR SPAR CAPS

Figure 119 Basic Manufacturing Lower Spar Caps

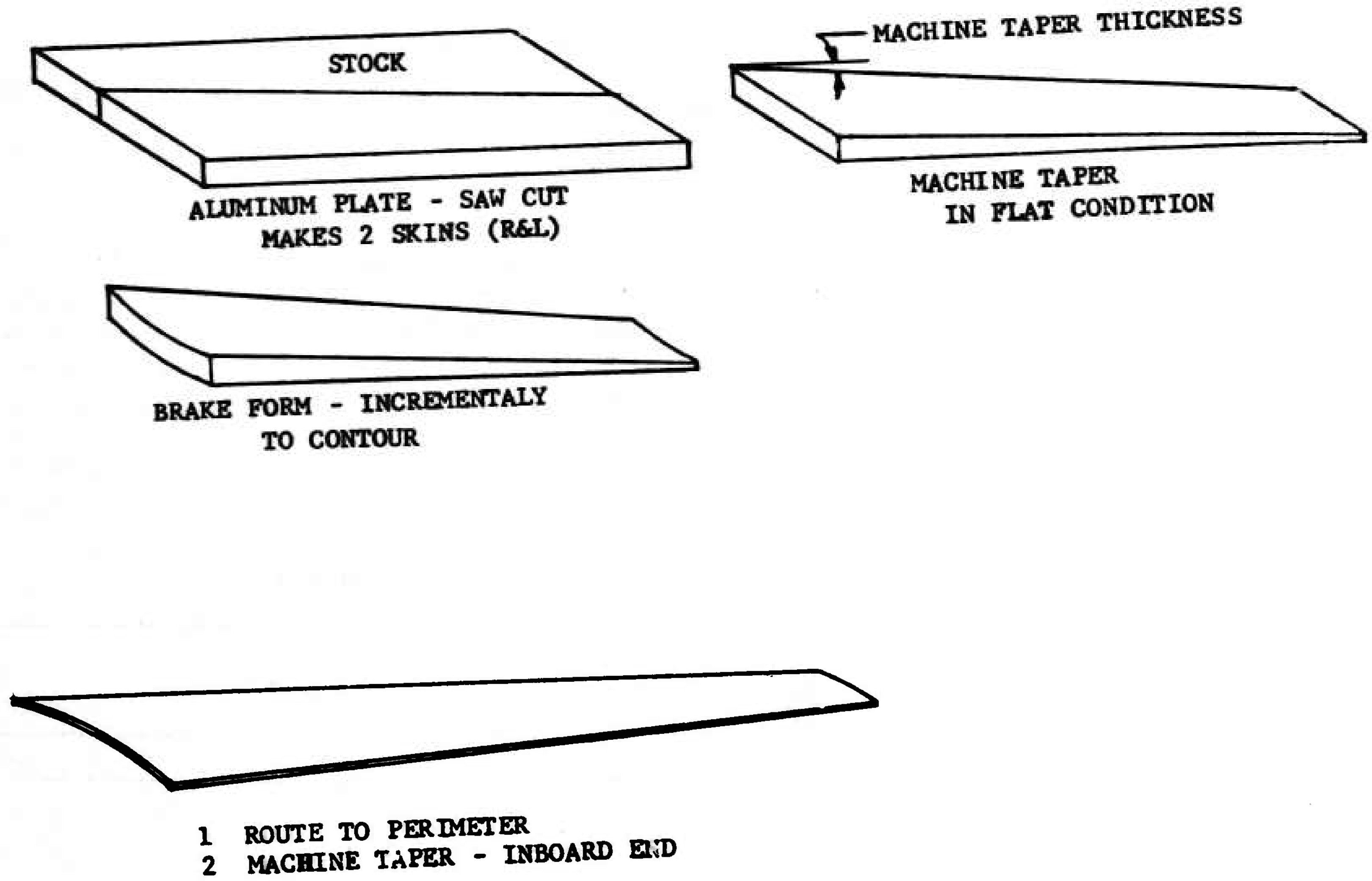


Figure 120 Basic Manufacturing Upper Skin

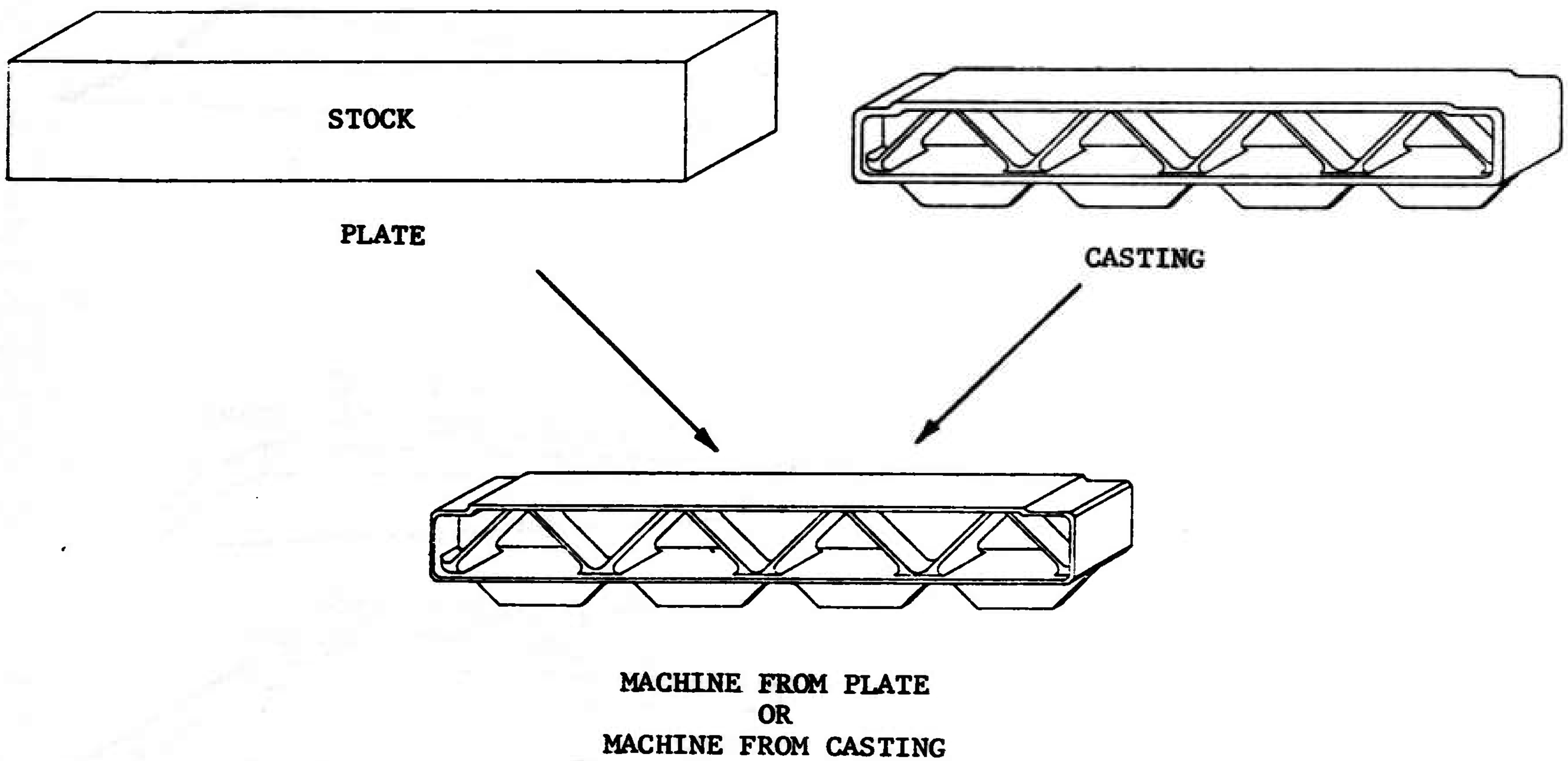


Figure 121 Basic Manufacturing Bulkheads and Ribs

The outer surface of the pivot plate is contour machined to the inner surface of the inboard lower skin laminates. The inner surface of the pivot plate is machined to finish dimensions.

The manufacturing steps are shown in Figure 122.

9.2.2.8 Pivot Fitting Fabrication

The pivot fitting consists of an upper pivot plate, shear ring, root spars, failsafe straps, and steel bushings.

The upper pivot plate is a one-piece integrally machined structure made from a HY-180 steel forging. The outer surface of the pivot plate is contour machined to the outer contour of the upper wing surface.

The shear ring is a one-piece integrally machined structure made from a 2024-T851 aluminum alloy forging.

The root spars are integrally machined structure made from a 2024-T8511 aluminum alloy extrusion.

The failsafe straps and bushings are machined structure made from HY-180 steel plate and forgings respectively.

9.2.2.9 Assembly of Lower Surface

This assembly consists of the aluminum skin sheets laminated and joined to the lower spar caps which were step machined in detail to provide overlap of each individual skin laminate with the spar cap flange. This total assembly is bonded in one bond cycle (Fig. 123).

9.2.2.10 Assembly of Lower Surface and Lower Pivot Plate

This assembly consists of the laminated lower skin panel (skin sheets/spar caps) joined to the lower pivot plate (Fig. 124). This assembly is bonded as a secondary operation to the bonding operation described in paragraph 9.2.2.9.

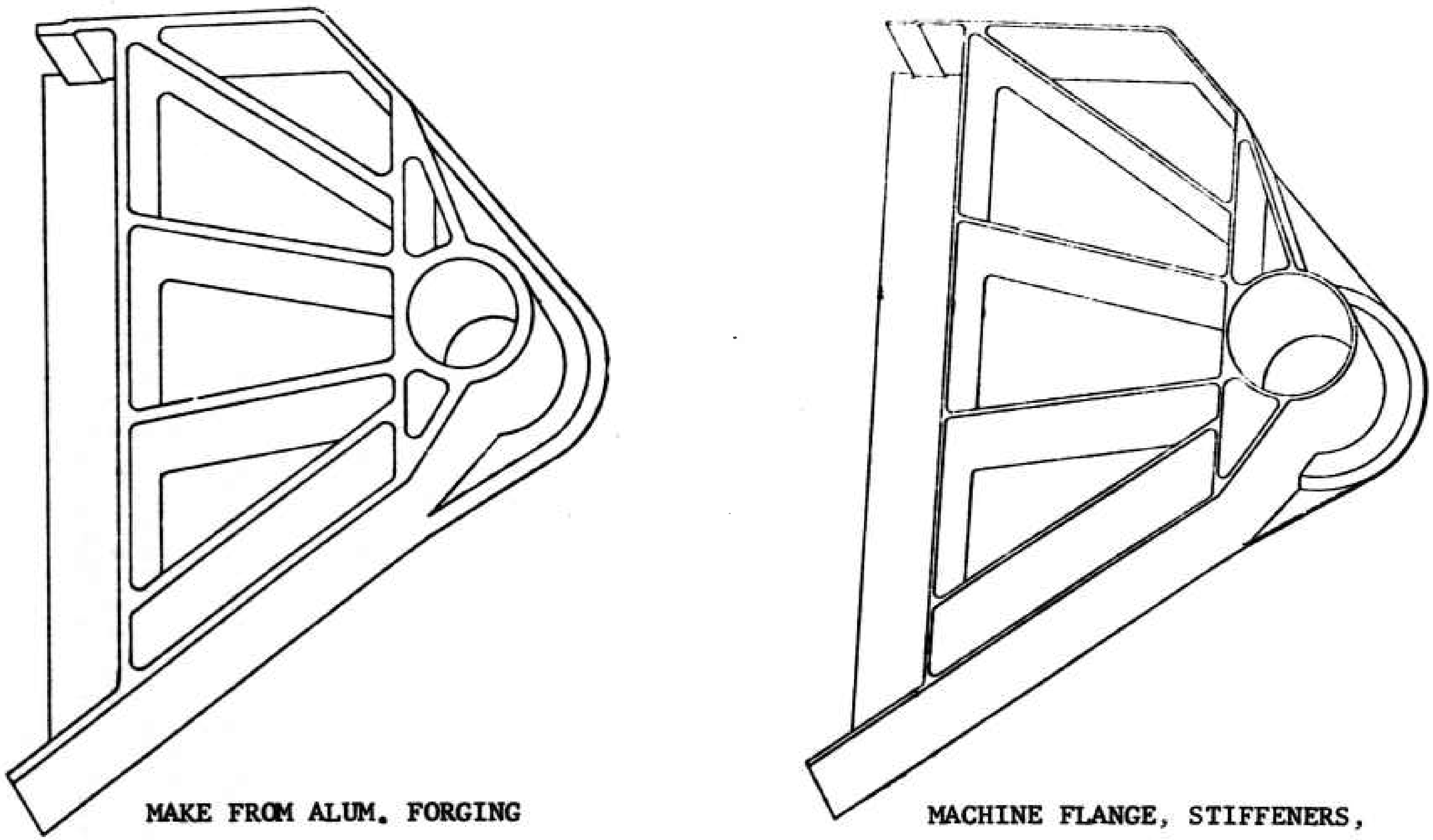
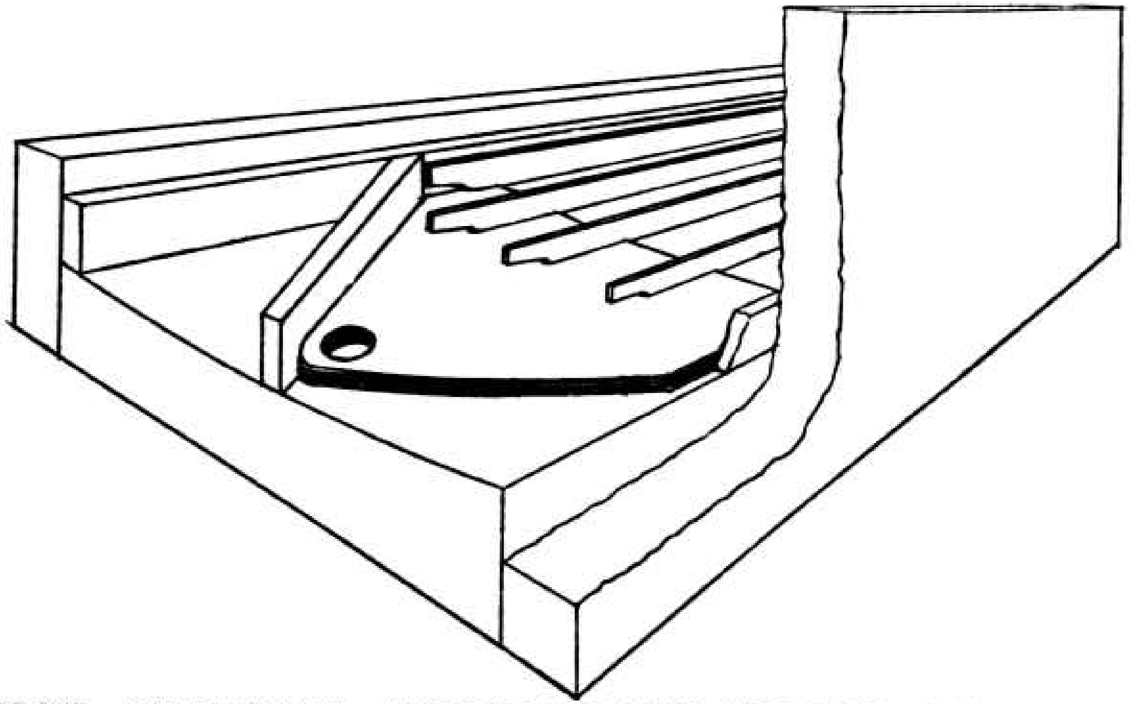
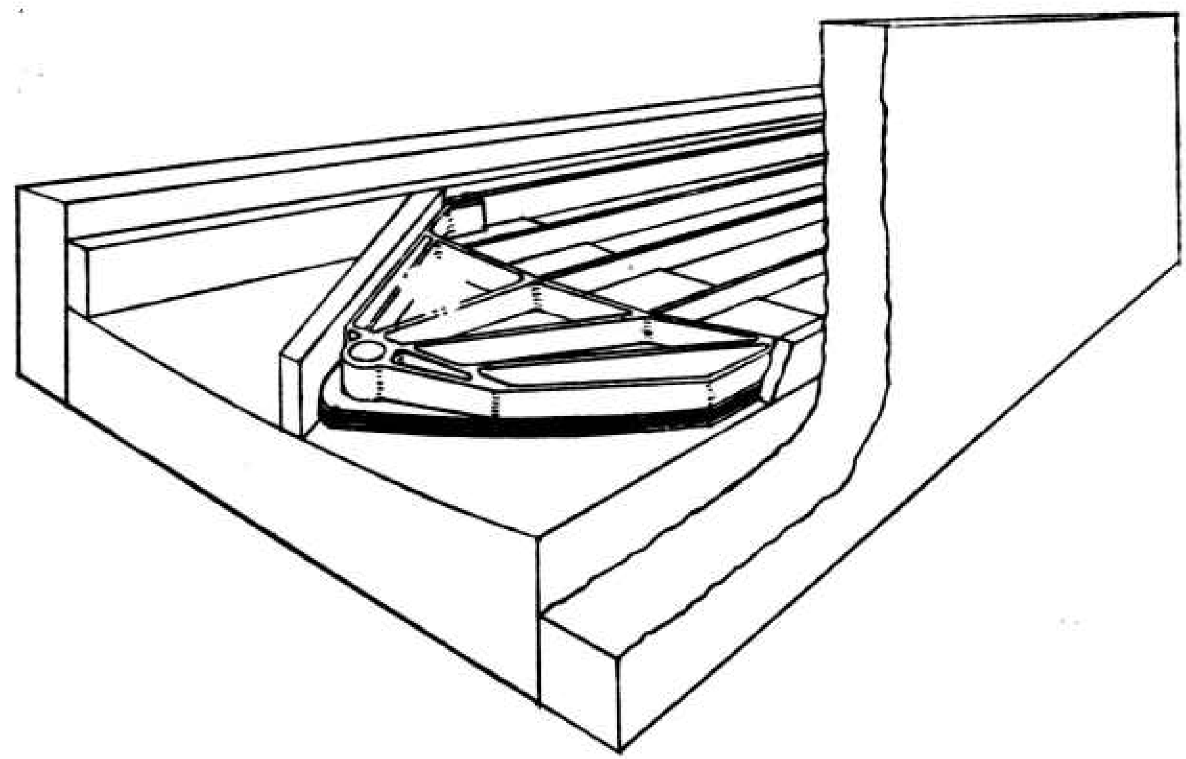


Figure 122 Basic Manufacturing Lower Pivot Plate



1. LOCATE FRONT, INTERMEDIATE, AND REAR LWR SPAR CAPS FROM LOCATORS ON FIXTURE
2. LOCATE LAMINATES FROM TOOLING HOLES AT ENDS OF DETAILS
3. APPLY ADHESIVE BONDING TAPE
4. ADHESIVE BOND AND CURE LAMINATED LOWER SKIN PANEL

Figure 123 Secondary Manufacturing Lower Surface Laminated Skin Panel Adhesive Bonded Assembly



1. LOCATE LOWER SKIN PANEL AND PIVOT PLATE FROM LOCATORS ON FIXTURE
2. APPLY ADHESIVE BONDING TAPE
3. ADHESIVE BOND AND CURE LAMINATED LOWER SKIN PANEL & PIVOT PLATE

Figure 124 Secondary Manufacturing Lower Skin Panel & Lower Pivot Plate Adhesive Bonded Assembly

9.2.2.11 Final Assembly of Wing Box

A major assembly and drill fixture commonly known as a "wing buck" will be required to perform final assembly operations of the box.

The fixture will first be used to receive and locate the basic lower skin panel assembly, pivot fitting, bulkheads, and spars. The fixture will then be used to provide a method of positioning, holding, and locating hole drilling tooling for drilling holes common to the upper skin, understructure, and lower skin.

Upon completion of the hole drilling operations on the lower skin and understructure all faying surfaces formed by the front and rear spars will have fuel sealing applications and all understructure will be permanently attached to the lower skin with bolts (Fig. 125). Following the hole drilling operation on the upper skin all faying surfaces formed by the upper skin will have fuel sealing applications and all understructure will be permanently attached to the upper skin with blind fasteners (Fig. 126).

9.2.3 Preliminary Manufacturing Plan for 633-RW003

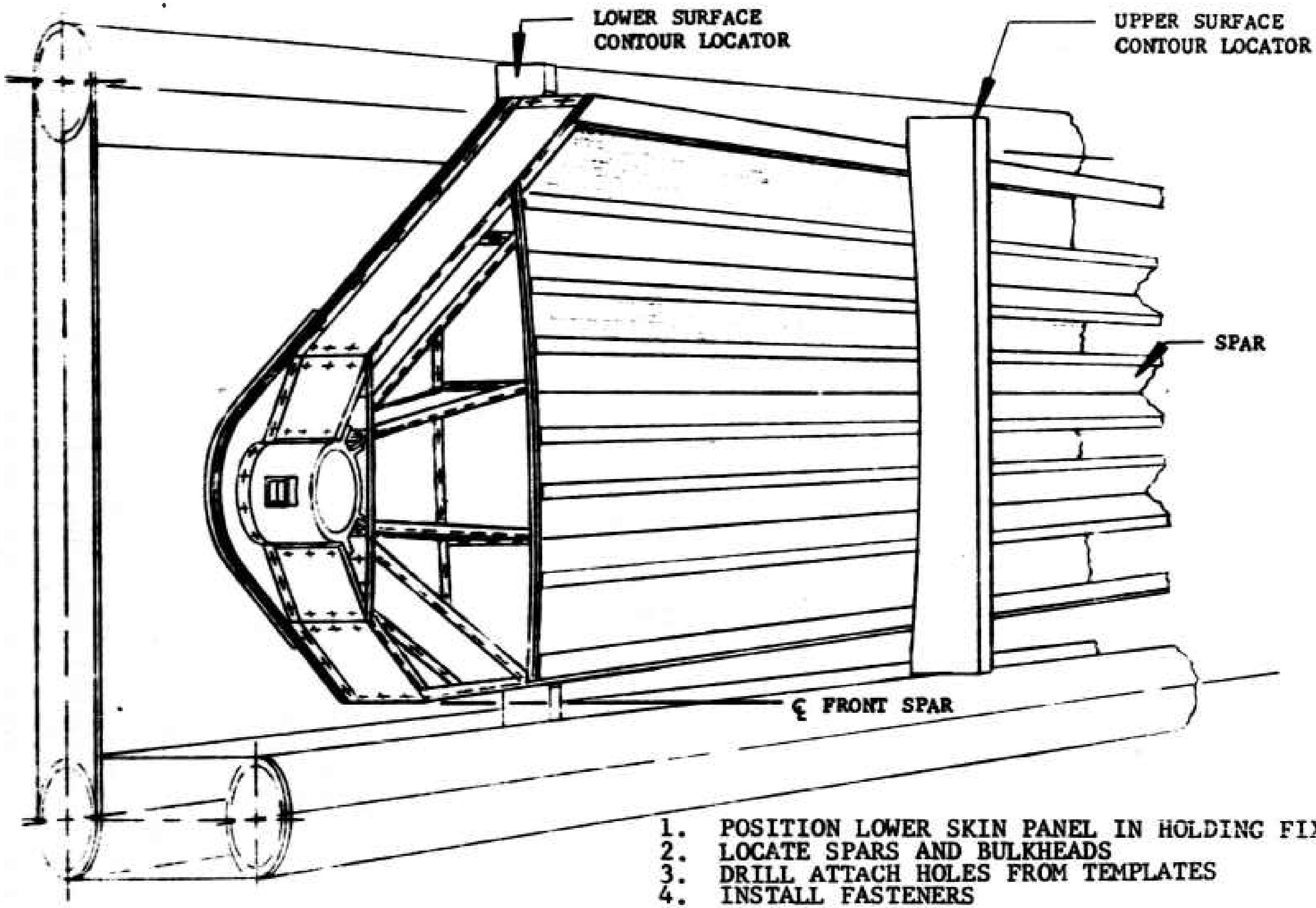
The manufacturing approach for the composite wing design is discussed below. The processes are shown schematically in Figures 127 through 131.

9.2.3.1 Front and Rear Spar Fabrication

The front and rear spars are made of graphite/epoxy material with fiberglass material for the upper cap sealing grooves. The spars are manufactured by draping machine-layed, "dinked-out" pieces into a hard female tool and cured with a male rubber punch in place. In this manner, skin/spar cap faying surface geometry can be well maintained (Fig. 127).

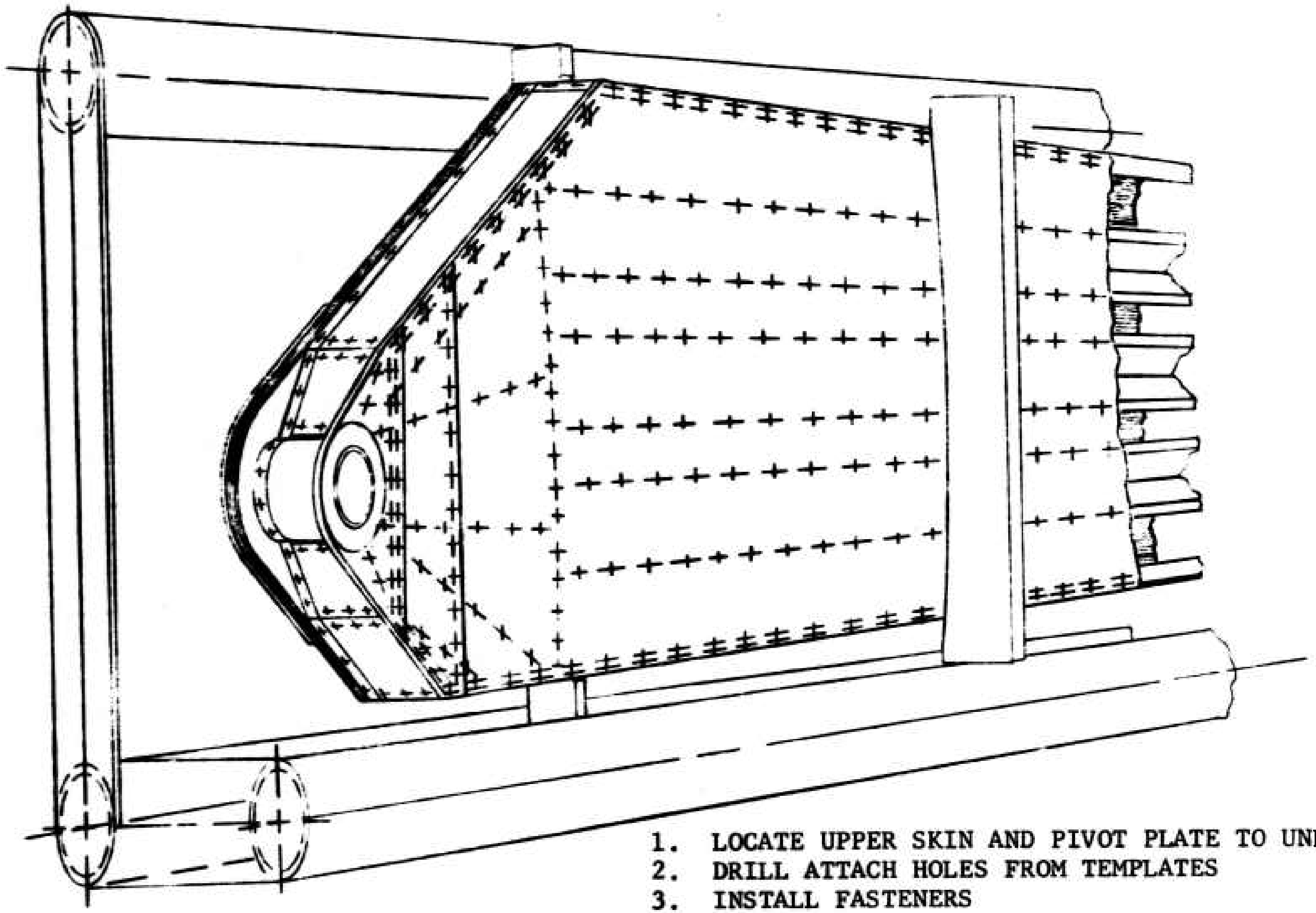
9.2.3.2 Intermediate Spar Fabrication

The intermediate spars are made of graphite/epoxy material and nomex cloth material with chopped fiberglass/epoxy pre-cast material for the lower skin transition members. The spars are machine-layed, "dinked-out", and draped over the tool and cured (Fig. 128).



1. POSITION LOWER SKIN PANEL IN HOLDING FIXTURE
2. LOCATE SPARS AND BULKHEADS
3. DRILL ATTACH HOLES FROM TEMPLATES
4. INSTALL FASTENERS

Figure 125 Secondary Manufacturing Lower Skin Panel and Understructure Assembly



1. LOCATE UPPER SKIN AND PIVOT PLATE TO UNDERSTRUCTURE
2. DRILL ATTACH HOLES FROM TEMPLATES
3. INSTALL FASTENERS

Figure 126 Secondary Manufacturing Final Assembly Upper Skin and Understructure

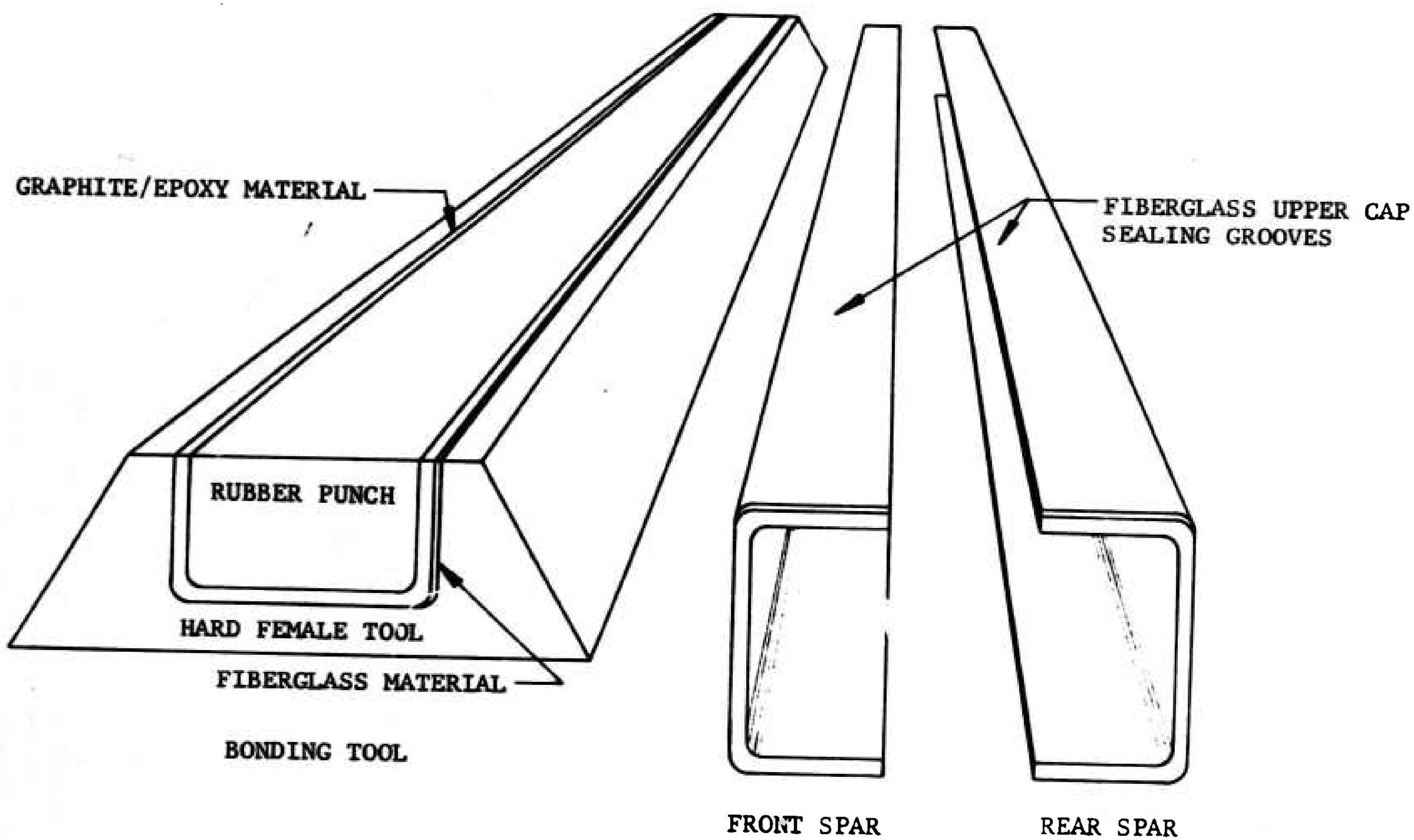


Figure 127 Basic Manufacturing Front and Rear Spars

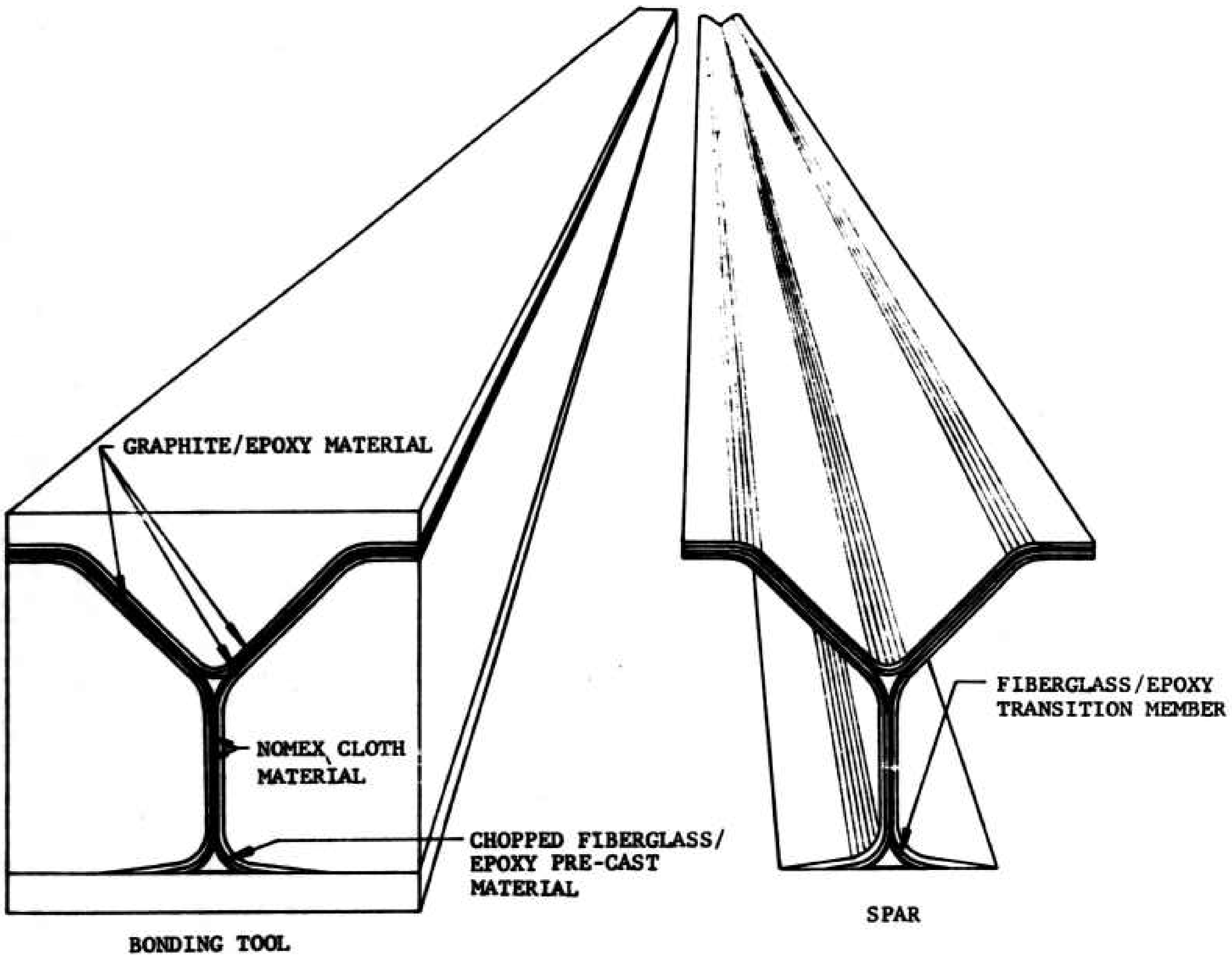


Figure 128 Basic Manufacturing Intermediate Spars

9.2.3.3 Fabrication of Bulkheads

The bulkheads are made of graphite/epoxy material. The bulkheads are made by draping machine-layed, "dinked-out" pieces into a hard female tool and cured with a male rubber punch in place to maintain outer surface contour.

9.2.3.4 Fabrication of Closure Bulkhead

The closure bulkhead is a one-piece, machined casting made from A356-T6 aluminum casting alloy.

9.2.3.5 Pivot Fitting Fabrication

The pivot fitting consists of upper and lower skin transition doublers, a shear fitting, root spars, and steel bushings.

The upper and lower skin transition doublers are machined structure made from 6Al-4V Beta annealed titanium. The outer surfaces of the doublers are contour machined.

The shear fitting is a one-piece integrally machined structure made from 6Al-4V Beta annealed titanium.

The root spars are integrally machined structure made from 6Al-4V Beta annealed titanium.

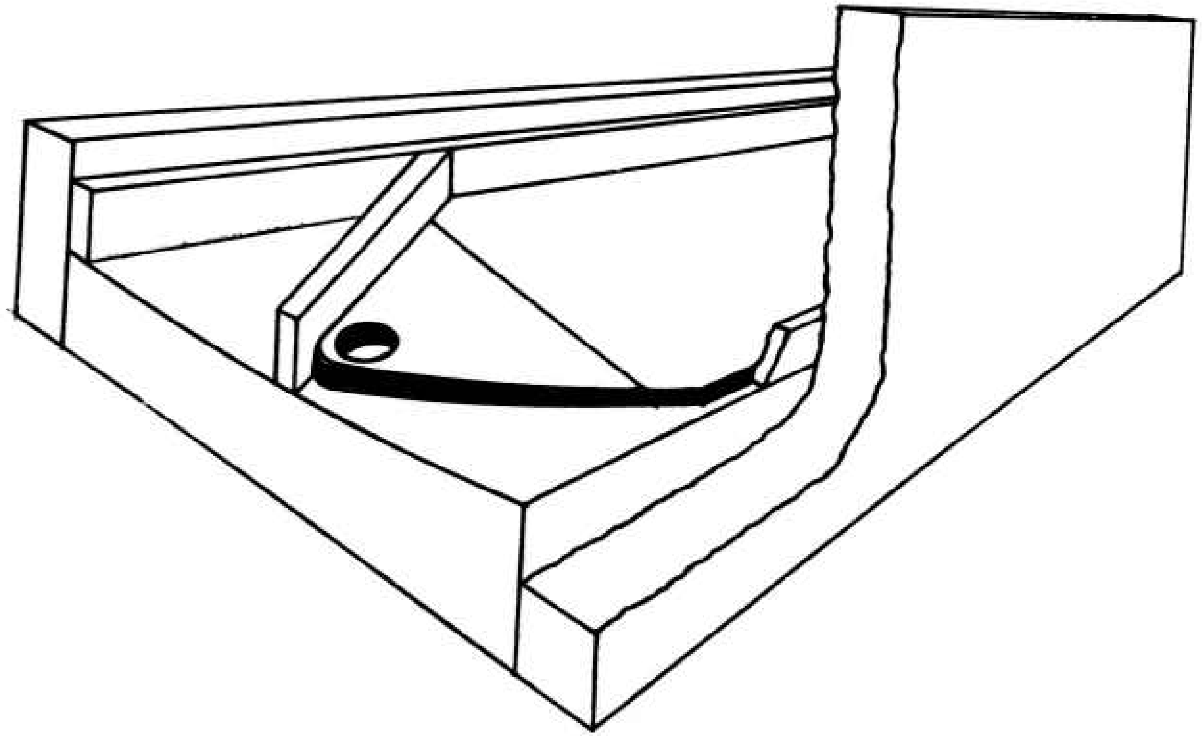
The bushings are machined structure made from 17-4PH steel forgings.

9.2.3.6 Assembly of Upper Skin

The upper skin is a bonded assembly consisting of a graphite/epoxy skin and machined titanium transition doublers (Pivot Area). The graphite/epoxy skin material is layed-up (machine-layup) and co-cured with the transition doublers (Fig. 129). It is assumed that the machine-layup of the graphite/epoxy material requires no pre-bleeding.

9.2.3.7 Assembly of Lower Skin and Intermediate Spars

The lower skin is a bonded assembly consisting of a graphite/epoxy skin, the intermediate spars, and machined titanium transition doublers (Pivot Area). The skins' graphite/epoxy outer plies



1. LOCATE TRANSITION DOUBLERS AND GRAPHITE/EPOXY SKIN MATERIAL ON FIXTURE
2. CURE SKIN PANEL

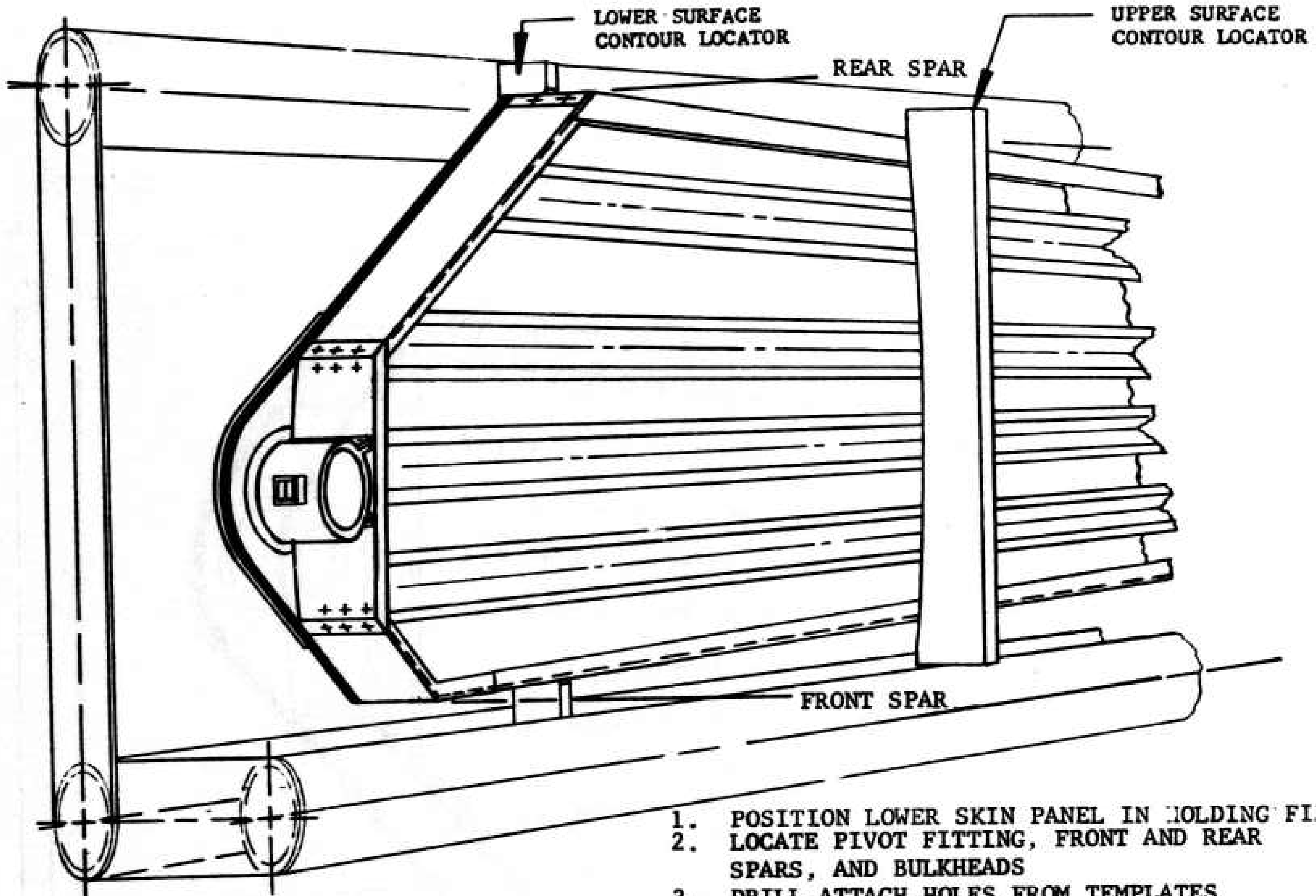
Figure 129 Secondary Manufacturing Upper Skin Bonded Assembly are first layed-up (machine-layup) and draped and the intermediate spars located. The skins' inner plies are then layed-up and draped and the entire lower skin assembly is co-cured. It is assumed that the machine-layup of the graphite/epoxy material requires no pre-bleeding; i.e., the graphite/epoxy tape is "net material".

9.2.3.8 Final Assembly of Wing Box

A major assembly and drill fixture commonly known as a "wing buck" will be required to perform final assembly operations of the box.

The fixture will first be used to receive and locate the basic lower skin panel assembly and understructure (pivot fitting, bulkheads, and front and rear spars). The fixture will then be used to provide a method of positioning, holding, and locating hole drilling tooling for drilling holes common to the upper skin, understructure, and lower skin assembly.

Upon completion of the hole drilling operations on the lower skin and understructure all faying surfaces formed by the front and rear spars will have fuel sealing applications and all understructure will be permanently attached to the lower skin with bolts (Fig. 130). Following the hole drilling operation on the upper skin all faying surfaces formed by the upper skin will have fuel sealing applications and all understructure will be permanentl attached to the upper skin with blind fasteners (Fig. 131).



1. POSITION LOWER SKIN PANEL IN HOLDING FIXTURE
2. LOCATE PIVOT FITTING, FRONT AND REAR SPARS, AND BULKHEADS
3. DRILL ATTACH HOLES FROM TEMPLATES
4. INSTALL FASTENERS

Figure 130 Secondary Manufacturing Lower Skin Panel and Understructure Assembly

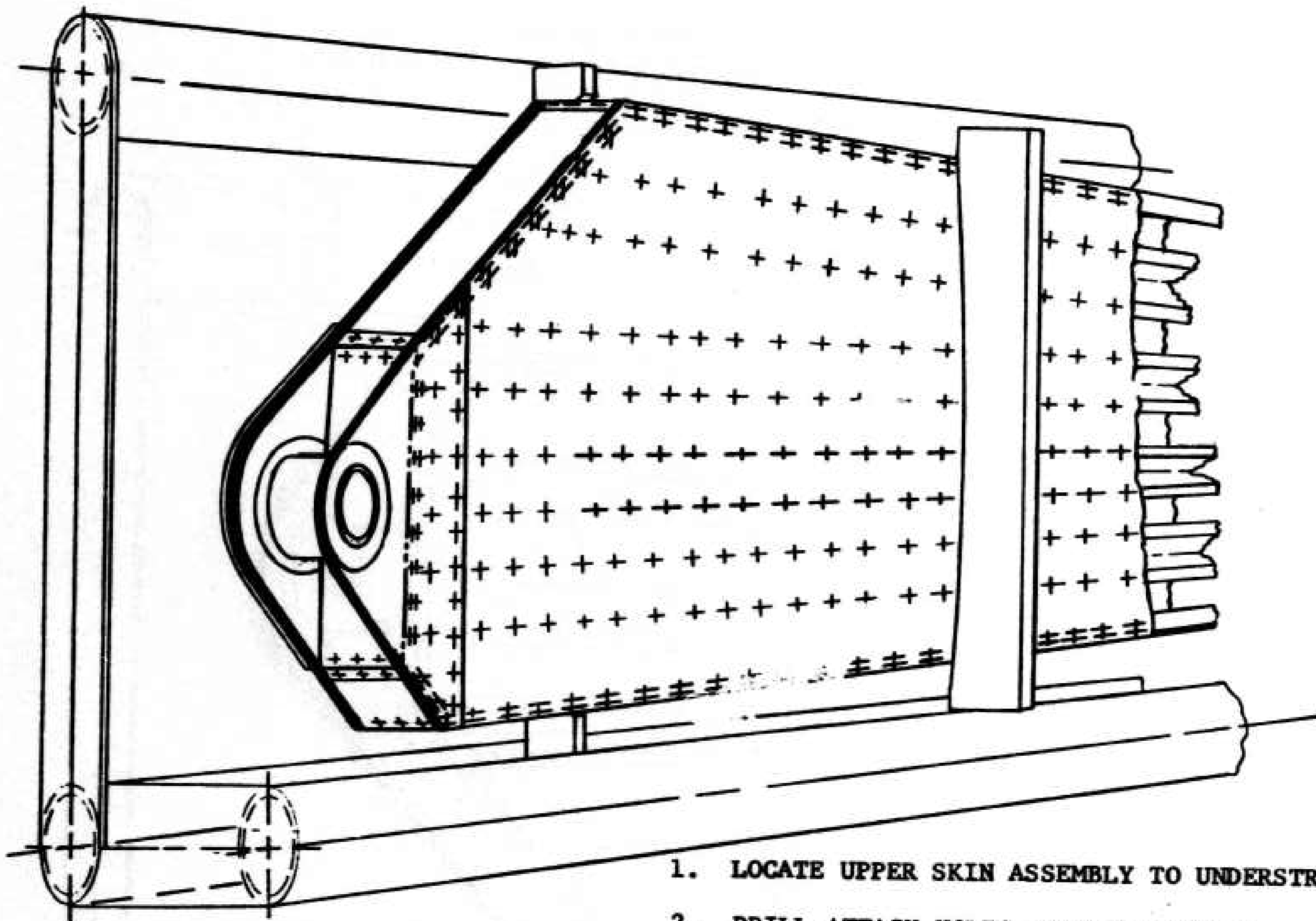


Figure 131 Secondary Manufacturing Final Assembly Upper Skin and Understructure

SECTION X

CONCLUSIONS

The overall goal of the program was to establish the applicability and payoffs, in terms of acquisition cost and weight, of innovative structural concepts to a variable camber supercritical wing box configuration. The program has met this goal by developing preliminary designs that provide cost savings up to 12.3% and weight savings up to 27%.

10.1 COST EVALUATIONS

Preliminary design configurations were developed and analyzed that produce the following results:

633RW001	12.3% savings	
633RW002	10.7% savings	
633RW003	29% increase for Vendor A 13.9% increase for Vendor B 4.4% increase for $20/Lb	See paragraph 10.1.2 & Table XXVIII

The two metallic configurations produce a cost savings while the composite configuration gives a cost increase. Detailed examination of the items that make up the cost for the composite box as compared to the baseline is shown in Table XXVII. It is evident from this table that the total cost for the composite design is dominated by the material cost.

10.1.1 Factors That Influence Costs

The costs shown in Table XXVII above were derived by the Fort Worth Plant Industrial Engineering, Tooling, Material, and Division Estimating Departments. The costs used in this section are those defined by the groundrules listed in Section VIII and excludes profit. The numbers for 1980 year dollars reflect the professional opinions of the estimating personnel in these departments with regard to the effect that certain economic factors will have on wing box prices in 1980 year dollars. The economic factors considered to be most significant in increasing costs are: in-house labor rates, vendor labor rates, transportation, energy cost changes, and general economic inflation. Significant decreasing costs at the Fort Worth Plant are: diminishing overhead and administrative costs, learning, technology advancement and production quantity increases. It should be noted however, that all of the designs costed were estimated by applying the same procedure to each design.

TABLE XXVII COST BREAKDOWN
(200 Unit Average in 1980 Dollars)

CONFIGURATION	MATERIAL	TOOLING	FABRICATION	TOTAL
633RW000-1	42903	13413	195838	252154
633RW001-1	42932	13622	164737	221291
633RW002-1	36044	13584	175736	225364
633RW002-3	35257	13584	184777	233618
633RW003-1	188875	14203	137708	340786
633RW003-3	183072	14800	127976	325848

General Dynamics recognizes that other assumptions could have been made in predicting the 1980 prices, particularly in the area of composite materials.

10.1.2 Composite Material Costs

The cost of the composite material was based upon $.95 per foot for 3 inch tape in 1975 dollars ($66.50/lb). The projection for 1980 used a basic tape cost of $.55 per foot in 1975 dollars (38.50/lb). Currently, there are other sources of material that are not qualified to our specification but that may meet our requirements in the future. One of these materials, (designated as Vendor "B" in Table XXVIII) is quoted at about 3/4 the cost in 1980 of our qualified material. Another popular figure being quoted by many for the 1980 cost is $20 per pound. In light of these variations in predictions the cost of the 633RW003-3 configuration using these various estimates is shown in Table XXVIII.

10.1.3 Other Costs

A breakdown of the total material costs for each of the preliminary designs is shown in Table XXIX. It is evident from this table that the increased cost of the 633RW003 design is not entirely due to the composites. Part of the cost increase can be attributed to the titanium pivot fitting that was used to be able to get the 27% weight savings. A bolted steel fitting would have yielded a better cost picture, however, the weight savings would not have been outstanding. It would have been desirable to have conducted a study of a steel bolted configuration in order to have established the boundaries of the designs for maximum weight savings and the minimum cost composite designs.

A comparison of the fabrication hours for each of the preliminary designs is shown in Table XXX. This table shows that there is a reduction in factory manhours for the composite design over the metallic designs.

10.2 WEIGHT EVALUATIONS

The preliminary design configurations all saved weight over the baseline as follows:

633RW001	15%
633RW002	12%
633RW003	27%

TABLE XXVIII COMPOSITE MATERIAL PRICE VARIATION ANALYSIS

(AVERAGE COST FOR 200 UNITS IN 1980 DOLLARS)

COST ITEM	633RW003-3			BASELINE 633RW000
	VENDOR A	VENDOR B	$20/#	
MATERIAL	183K	145K	121K	43K
MFG	128K	128K	128K	196K
TOOLING	14K	14K	14K	13K
TOTAL	325K	287K	263K	252K

TABLE XXIX MATERIAL COST BREAKDOWN

MATERIAL	633RW000 BASELINE			633RW001 ADV. MET.			633RW002-1 ADV. MET.			633RW002-3 ADV. MET.			633RW003-1 COMPOSITE			633RW003-3 COMPOSITE		
	*BUY WT. (LBS.)	FLY WT. (LBS.)	**MATL. COST	BUY WT. (LBS.)	FLY WT. (LBS.)	MATL. COST	BUY WT. (LBS.)	FLY WT. (LBS.)	MATL. COST	BUY WT. (LBS.)	FLY WT. (LBS.)	MATL. COST	BUY WT. (LBS.)	FLY WT. (LBS.)	MATL. COST	BUY WT. (LBS.)	FLY WT. (LBS.)	MATL. COST
STEEL	1530	738	1893	1174	296	8857	1174	296	8857	1010	351	7624	172	42	1154	172	42	1154
ALUMINUM	16350	1942	26306	7936	1913	24248	6830	1990	17059	6962	2121	17477	5	4	364	412	72	1564
TITANIUM													3003	769	38328	2328	459	31262
FIBERGLASS & NOMEX													238	141	5702	238	141	5702
GR/EP													1893	1134	129401	1893	1134	129401
HARDWARE		73	13731		74	8838		75	9142		76	9170		65	12895		65	12895
MISC***		6			58			60			60			93			93	
TOOLING MATL			973			989			986			986			1031			1074
TOTALS PER SIDE		2759	42903		2341	42932		2421	36044		2608	35257		2248	188875		2006	183072

* BUY WT. IS: RAW STOCK WT. PLUS ATTRITION

** MATERIAL COSTS ARE AVERAGE COST PER UNIT OF 200 UNITS IN 1980 DOLLARS

*** COST INCLUDED IN FACTOR FOR ALL ALLOCATED MATERIALS

TABLE XXX MANUFACTURING COMPARISONS
(Unit Average for 200 Units)

CONFIGURATION	MFG. (HOURS)	QA (HOURS)	TOTAL (HOURS)
633RW000	7041	1084	8125
633RW001	5924	912	6836
633RW002-1	6319	973	7292
633RW002-3	6644	1023	7667
633RW003-1	4901	808	5709
633RW003-3	4554	751	5305

One significant item became apparent during the program. The 633RW003 composite wing box indicated a potential of approximately 40% savings in the analytical assembly phase. When trying to splice this wing into the existing wing pivot fitting, much of the weight savings was going to dissappear. The importance of tailoring the attachment for the structural concept was clear; therefore, a new pivot fitting was designed and evaluated for cost and weight savings.

A second important item is that while the composite concepts do not rank above the baseline by using the merit rating system it does offer an attractive weight savings on a dollar per pound savings basis. Table XXXI shows the potential for the various composite materials.

10.3 FINAL EVALUATION SUMMARY

As part of the groundrules of the program all designs were evaluated by the merit rating system. The design that provides the best balance of all the priorities established by this system is to be considered the best design. The concept chosen using this criteria is the 633RW001. This configuration has a bonded laminated aluminum lower skin, etched aluminum "Y" intermediate spars, machined aluminum front & rear spars, straight tapered aluminum upper skin, and a 10 Ni fail safe wing pivot fitting. It is our recommendation at this point that we proceed into a "proof of concept" test program as outlined in Appendix D.

TABLE XXXI COST PER POUND OF WEIGHT SAVINGS

(AVERAGE COST FOR 200 UNITS IN 1980 DOLLARS)

MATERIAL COST	COST PER POUND SAVINGS VS BASELINE	COST PER POUND SAVINGS VS 633RW001
VENDOR A	$96.95	$310.45
VENDOR B	$46.48	$197.01
$20/#	$14.61	$125.37

APPENDIX A

DESIGN LOADS DATA

FOR THE

VARIABLE CAMBER SUPERCRITICAL

WING PROGRAM

Abstract

Preliminary design loads data are presented for conceptual design of a supercritical wing with leading and trailing edge variable camber devices. The baseline wing is Advanced Transonic Wing ATW-4, integrated into a study configuration of the FB-111 airplane for a strategic mission. The preliminary design conditions are presented with criteria used to establish condition parameters. A brief discussion of basic data and analysis procedures is included. Static design loads distributions and related data are presented for design of the wing box and leading and trailing edge variable camber devices. The final section presents a fatigue loads spectrum of wing bending moment and the data for developing fatigue loads spectra for the variable camber devices.

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APPENDIX A

DESIGN LOADS DATA

A.1 BASELINE WING GEOMETRY

The baseline wing used for this data package is Advanced Transonic Wing ATW-4 as configured for a strategic mission aerodynamic and performance evaluation in Reference 1. The leading and trailing edge variable camber surface hinge lines were taken along the reference wing 15 and 65 percent chord lines respectively. A load reference axis was taken along the reference wing 33.64 percent chord line passing through the wing pivot center. The reference wing geometry is shown in the Figure A.1

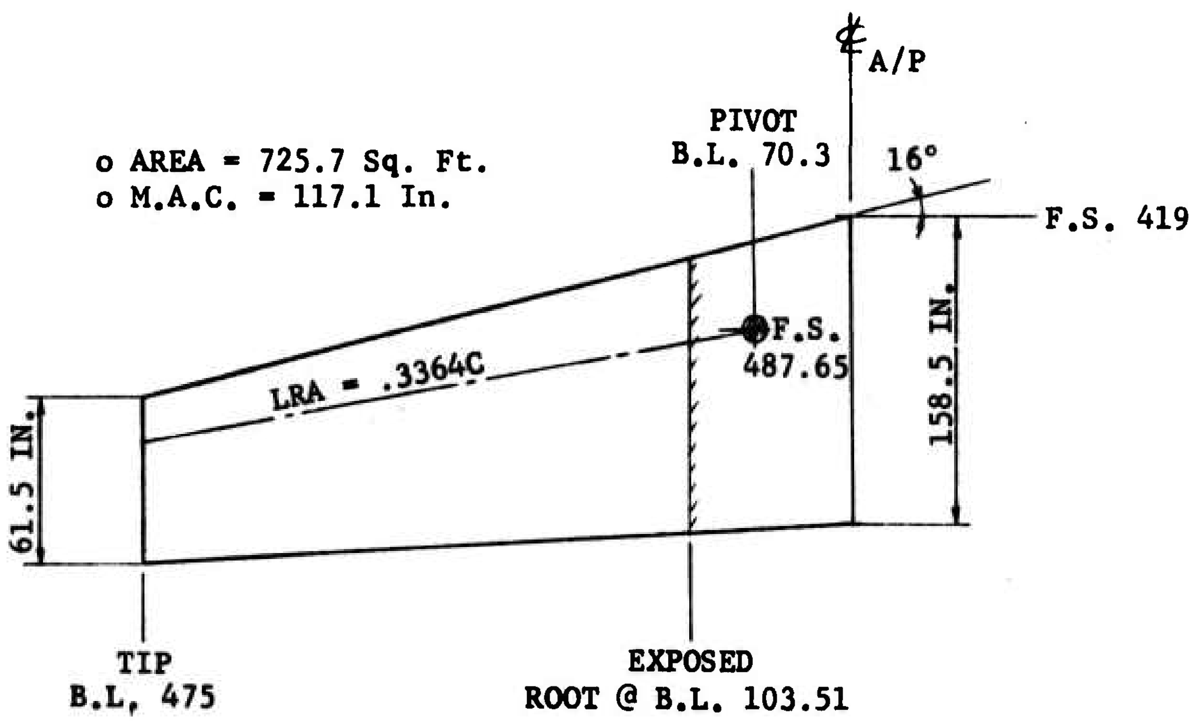


Figure A.1 Wing Geometry

A.2 PRELIMINARY DESIGN CONDITIONS

Conditions for which preliminary design loads data have been developed are presented in Table A-I. These conditions are thought to be representative of likely high load conditions suitable for preliminary design of the wing structural box and/or variable camber surfaces. Their selection was based, to a great extent, on past supercritical wing preliminary design studies at GD/FW.

Table A-I - Preliminary Design Conditions

Condition Number Description	1 Take-off	1A Take-off	2 Dash	3 Refuel (Sym.Man.)	4 Refuel (Roll Control)
Wing Sweep, Deg.	16	16	65	16	16
Mach No.	.35	.51	.85	.80	.80
Altitude, Ft.	SL	SL	SL	20,000	20,000
Gross Weight, Lbs.	128,500	128,500	110,400	110,400	110,400
Center of Gravity, %$\bar{c}$	-	-	36.4	25.14	25.14
Angle of Attack, Deg.[(c)]	-	-	10.78	6.68	4.8
Load Factor, g's	2.0	(Fig. 12)	3.0	2.6	1.9
L.E. Deflection, Deg.[(a)]	20.0	20.0	12.5	4.0	10.0
T.E. Deflection, Deg.[(a)]	15.0	7.5	-3.1	3.5	3.5$\pm$5.0[(b)]

(a) Plus sign is for surfaces deflected downward.

(b) Linear variation 0° at root to $\pm$ 5° at tip.

(c) Measured with respect to the manufacturing chord plane which has a 1 deg. positive inclination to the waterline reference at the wing pivot.

A.3 CRITERIA

A.3.1 Maneuver Load Factor

The general approach was to establish limit maneuver load factor for each condition based either on wing carry-through box allowable load limits or on a desired maneuver capability goal. The carry-through box allowable load limits for the F-111A series airplanes were used. The following symmetric maneuver capability goals were established:

(a) Take-off and Landing Conditions; $n_z = 2.0g$

(b) All Other Conditions; $n_z = 3.0g$

Asymmetric maneuver load factor goals are equal to 1.0g + 2/3 (n_z symmetric - 1.0).

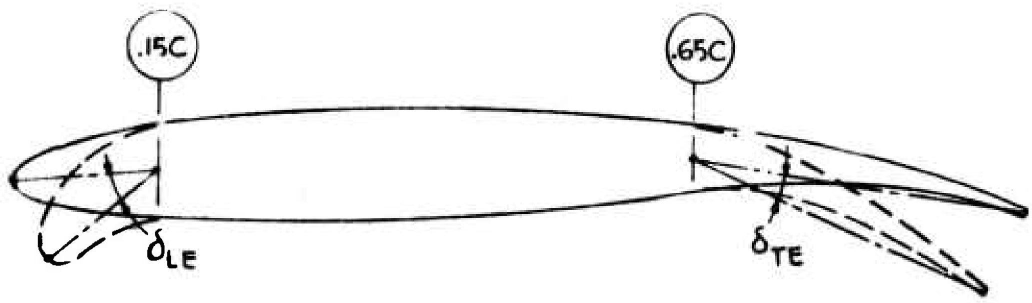
As shown on Table A-I the maneuver load factor goals were achieved for conditions 1 and 2, while the load factors for conditions 3 and 4 are somewhat less than the goals (3.0g for condition 3 and 2.33 g for condition 4). The analysis resulting in lower maneuver load factors is conservative having been based on linear aerodynamic theory and, very likely, conservative trailing edge camber settings.

A.3.2 Airplane Weight and Balance

Airplane gross weight and center of gravity values are based on a GD/FW procedure R5C weight study for the FB-111F with the ATW-4 wing, dated 5-30-75. The fuel burn sequence used assumes that wing fuel is used first. Wing net loads for gross weights with and without wing fuel were checked for relative criticalness to establish design maneuver load factor levels. As a result, the gross weight used for conditions 2, 3, and 4 on Table A-I is for wing tanks empty of fuel (produces the lowest allowable maneuver load factor). Full wing tanks was assumed for the take-off condition. The design gross weight for this condition is set somewhat greater than the maximum from procedure R5C in order to develop net wing pivot loads at 2.0 g's load factor which are equal to the carry-through box allowable load limits. The design center-of-gravity was set at 1.5 percent M.A.C. forward of the actual location.

A.3.3 Variable Camber Settings

The leading and trailing edge variable camber surface deflection angles used for developing airload distributions are preliminary estimates of 1.0g trim flight camber settings for optimum performance. These 1.0g trim camber settings were also assumed to be held constant during maneuvering flight conditions. Leading and trailing edge deflections are measured as illustrated below.



DEFLECTIONS WITH RESPECT TO THE BASIC SECTION

Endpoints and vertices of the chordal angle reference lines are located on the mean camber line(s). The chordal angles specified are for the wing in the reference position (i.e., 16 degrees leading edge sweep angle).

The trailing edge trim camber setting used for Conditions 3 and 4 is most likely conservative for structural loads. A constant deflection angle of 3.5 degrees was assumed along the span for these conditions. A more likely deflection schedule would have a linearly varying angle along the span, i.e., 3.5 degrees at the inboard end to 0.0 degrees at the outboard end.

A.3.4 Thermal Criteria

Static strength properties of external structure shall be established taking into consideration the effects of 56 total hours exposure at 2.0 Mach number at 35,000 feet altitude.

A 4 PROCEDURES AND BASIC DATA

Analyses required to evaluate the relative criticalness of the complete operational loads environment were beyond the intended scope of this program. Therefore, the critical structural design loads conditions for the ATW-4 wing box and variable camber devices were postulated based on past supercritical wing design studies (B-1/W11 wing and F-111/TACT wing), and preliminary usage criteria for the variable camber system. The conditions selected are summarized in Table A-I. Preliminary design loads were not developed for supersonic flight conditions based on the following considerations:

1. The B-1/W-11 wing box supersonic condition was considerably less critical than subsonic flight conditions.

2. Lifting surface leading edge airloads for supersonic flight conditions are typically of smaller magnitude than loads for subsonic/transonic conditions.

3. Expected use of the variable camber system for trim control, while configured to aft wing sweep positions, results in relatively low net differential pressure load normal to the trailing edge variable camber surface.

Wing local pressure distributions are strongly influenced by variable camber settings (deflection angles), and thereby, unique load distributions are produced at any given flight condition. Geometric simularity (supercritical wing planform and flap settings) of the low speed high lift configurations enabled the development of preliminary design loads data for the ATW-4 wing conditions 1 and 1A by scaling load distributions which were available from the B-1/W-11 wing design study program. Equations used for scaling airloads accounted for effects of differences in wing area, span, wing loading, exposed wing root location, pivot location, etc. The flight conditions for the ATW-4 configuration conditions 1 and 1A were established at a higher Mach number and dynamic pressure than used for the corresponding B-1/W11 conditions due to a slightly higher wing loading. Using this approach, airplane trim angles of attack were not predicted to develop the ATW-4 wing data; therefore, values are not given for angle of attack in Table A-I for conditions 1 and 1A.

Variable camber settings cause the load distributions for conditions 2, 3 and 4 to be unique for the ATW-4 wing; therefore, the required data for these conditions were developed using theoretical prediction techniques. Rigid airframe pressure distributions and airplane force data (lift and pitching moment) were predicted using the finite element theory and procedures presented in Reference 2. In addition to basic camber and angle of attack data, pressure distributions and force data were also predicted for leading and trailing edge variable camber deflections. These rigid aerodynamic data were corrected for static aeroelasticity, based on preliminary estimates of wing box structural stiffness (EI and GJ distributions), using the procedure described in Reference 3. The resulting flexible aerodynamic data were used to determine trim airplane angle of attack and to build up wing airload distributions.

Spanwise load distribution data are presented with respect to the load reference axis (LRA) as shown in Figure 1. This implies local strip loads are on chords oriented perpendicular to the LRA. The wing basic aerodynamic distribution data (local pressure, c_ℓ and c_m) were predicted for streamwise chords. As an expediency in developing design load distributions for the conditions having 16 degrees wing sweep (conditions 3 and 4), it was assumed that local streamwise aero data at given span stations could be applied to chords oriented perpendicular to the LRA at that station. This assumption is invalid for higher wing sweep conditions. Therefore, for condition 2, streamwise pressures were interpolated onto the exposed wing panel (i.e., outboard of B.L. 103.51) chords oriented perpendicular to the LRA. This accounts for the truncated appearance of the chordwise pressure distributions inboard of .4738 ETA for condition 2.

A.5 DESIGN LOADS DATA

Preliminary design loads data for the wing box and variable camber surfaces are presented on the figures which follow. All loads data are design limit values. Data presented are summarized below:

Figure Number	Data
A.2	Loads Reference Axis and Sign Convention
A.3 and A.4	Wing Unit Inertia Distributions
A.5 thru A.14	Loads Data for Condition 1
A.15	Loads Data for Condition 1A
A.16 thru A.27	Loads Data for Condition 2
A.28 thru A.43	Loads Data for Condition 3
A.44 thru A.58	Loads Data for Condition 4

Loads data for Conditions 1, 2, 3 and 4 consist of:

(1) Wing spanwise shear, bending moment and torsion distributions.

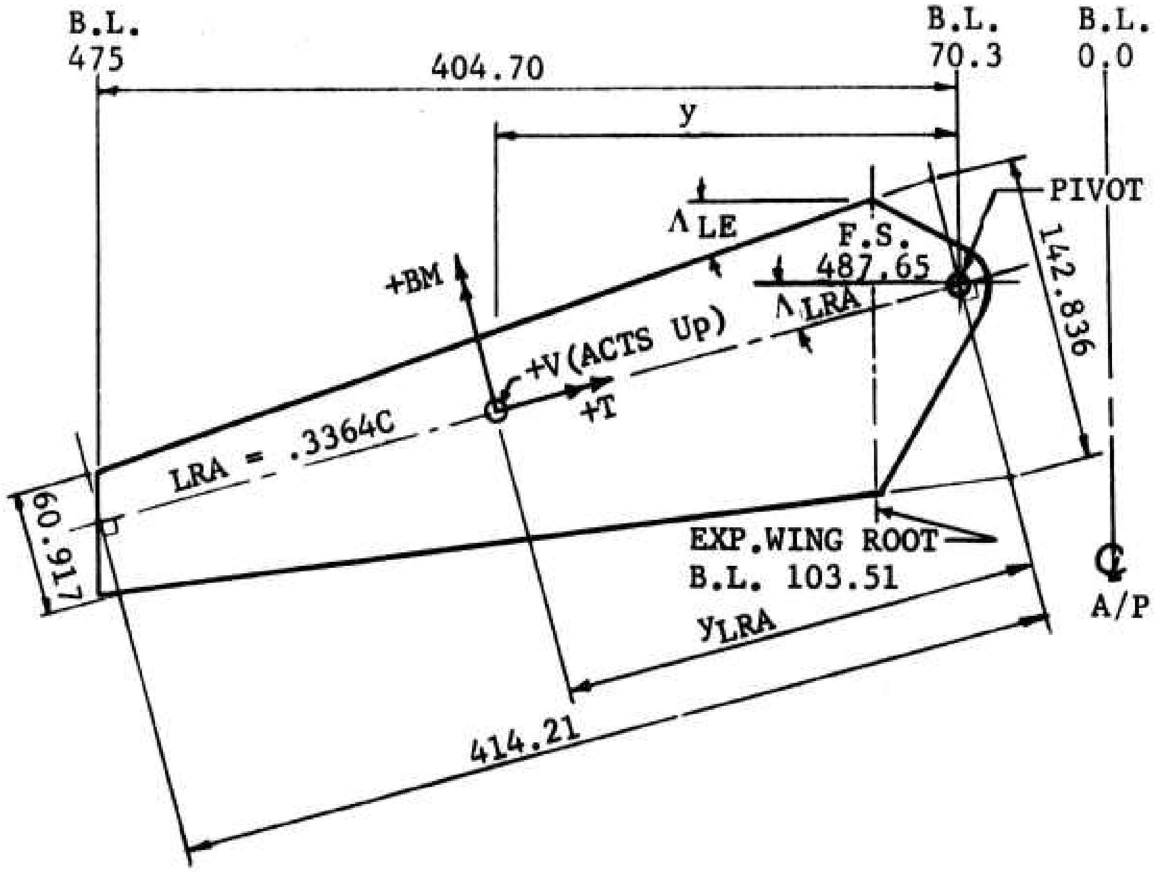
(2) Leading and trailing edge camber surface loads.

(3) Chordwise pressure distributions.

(4) Non-dimensional aerodynamic wing span load distributions for panel local lift force and torsion.

Loads data for condition 1A (see Figure A-12) consist of one distribution each for the leading edge and trailing edge variable camber surfaces. Comparable conditions are included in the B-1/W-11 data package. This condition was not critical for W-11 wing box design, therefore, the associated ATW-4 wing box spanwise load data were not developed for this design loads package.

Some of the structural loads data presented are obviously not critical for determining structural static strength. For example, the trailing edge flap load for condition 2 is quite low compared with other conditions. In this case, the flap is used to augment airplane trim (i.e., the surface is deflected up from the basic position) and thereby produces a tendency to washout the usually dominant local pressures from basic camber, as evidenced by the net chordwise pressure distributions. The flap load for this condition is included in this report for use in development of variable camber surface fatigue loads spectra.



NOTES:

(1) RIGHT HAND RULE FOR MOMENT VECTORS

(2) LRA = LOAD REFERENCE AXIS

(3) Λ_{LRA} = 12.301° WHEN Λ_{LE} = 16°

(4) $\eta_{LRA} = y_{LRA}/414.21$

(5) LOCAL CHORD ⊥ TO LRA: $C = 142.836 - 81.919\,\eta_{LRA}$

(6) AVG CHORD ⊥ TO LRA: C_{AVG} = 101.876 IN.

(7) $S/_2 = \dfrac{(LRA) \times C_{AVG}}{144} = 293.042 \text{ FT}^2$

Figure A.2 Sign Convention and Reference Axis for Wing Loads - ATW-4 Wing

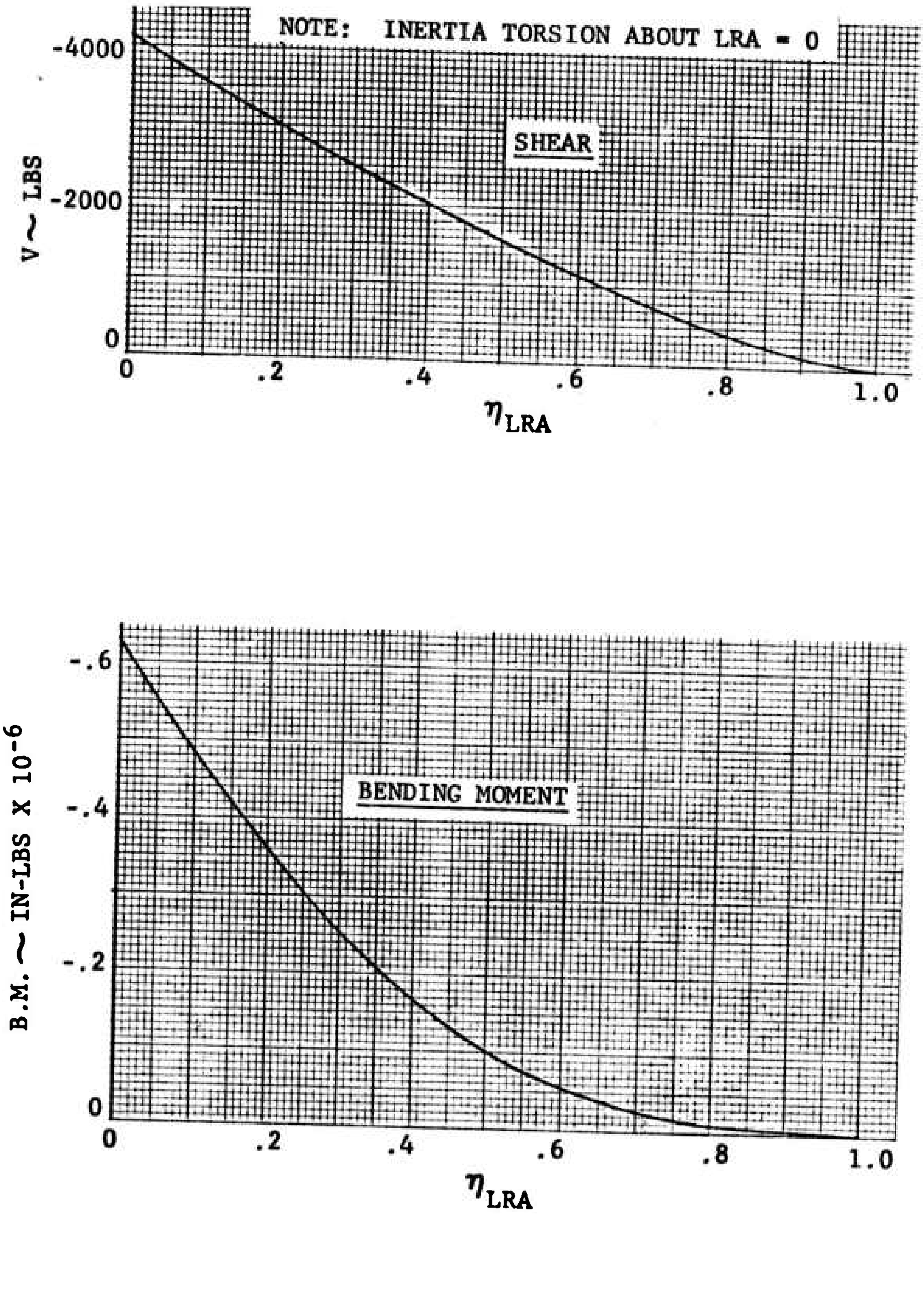


Figure A.3 ATW-4 Wing Structure Inertia Shear and Bending Moment Distributions ($N_Z = 1.0g$)

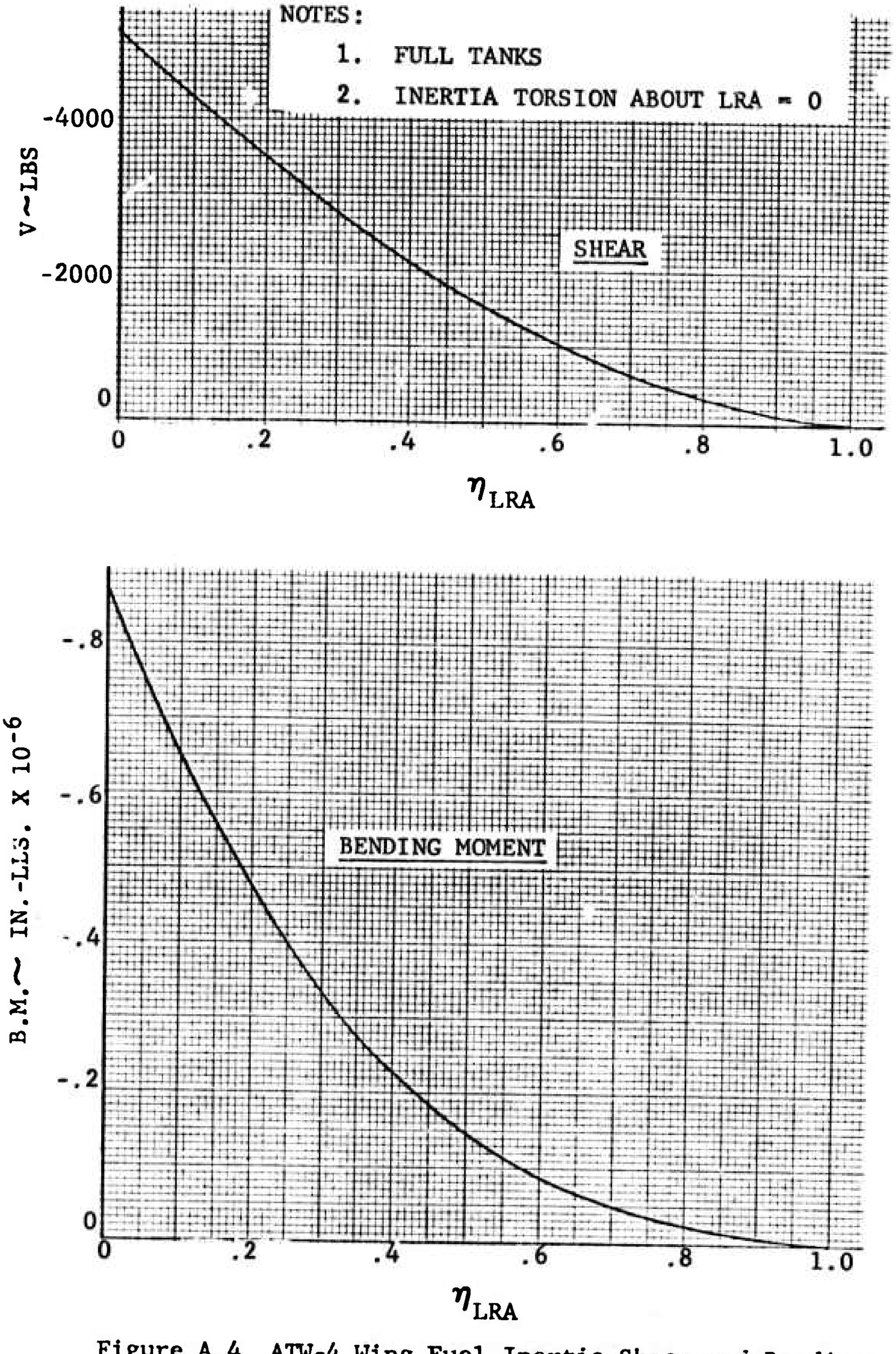


Figure A.4 ATW-4 Wing Fuel Inertia Shear and Bending Moment Distributions (N_Z = 1.0g)

A.5.1 Condition 1 - Take-Off with Full Flaps

Figures A.5 through A.14 define preliminary design loads for condition 1, take-off with full flaps.

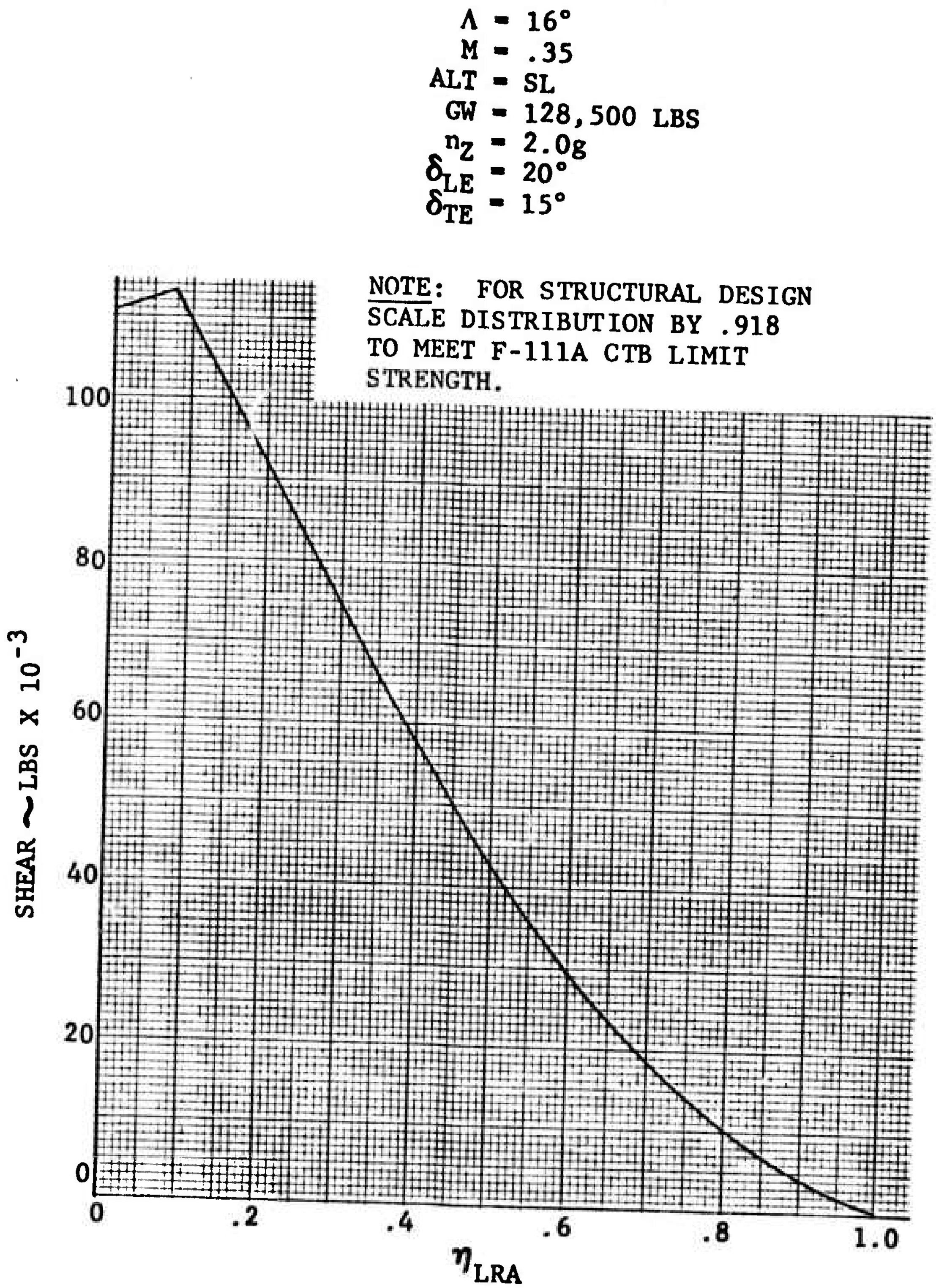


Figure A.5 ATW-4 Wing Shear Distribution - Condition 1

$\Lambda = 16°$
$M = .35$
ALT = SL
GW = 128,500 LBS
$n_Z = 2.0g$
$\delta_{LE} = 20°$
$\delta_{TE} = 15°$

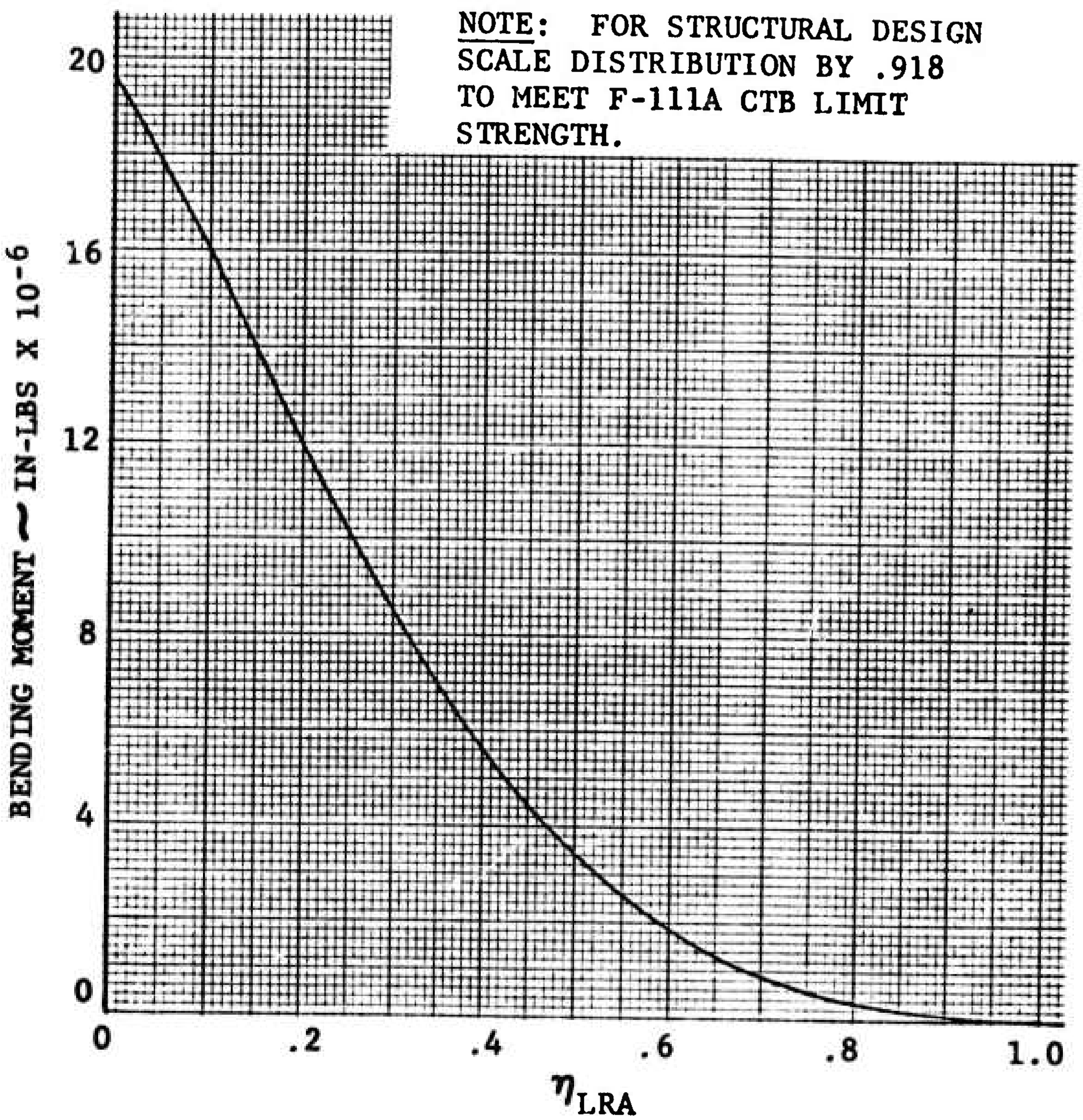


Figure A.6 ATW-4 Wing Bending Moment Distribution - Condition 1

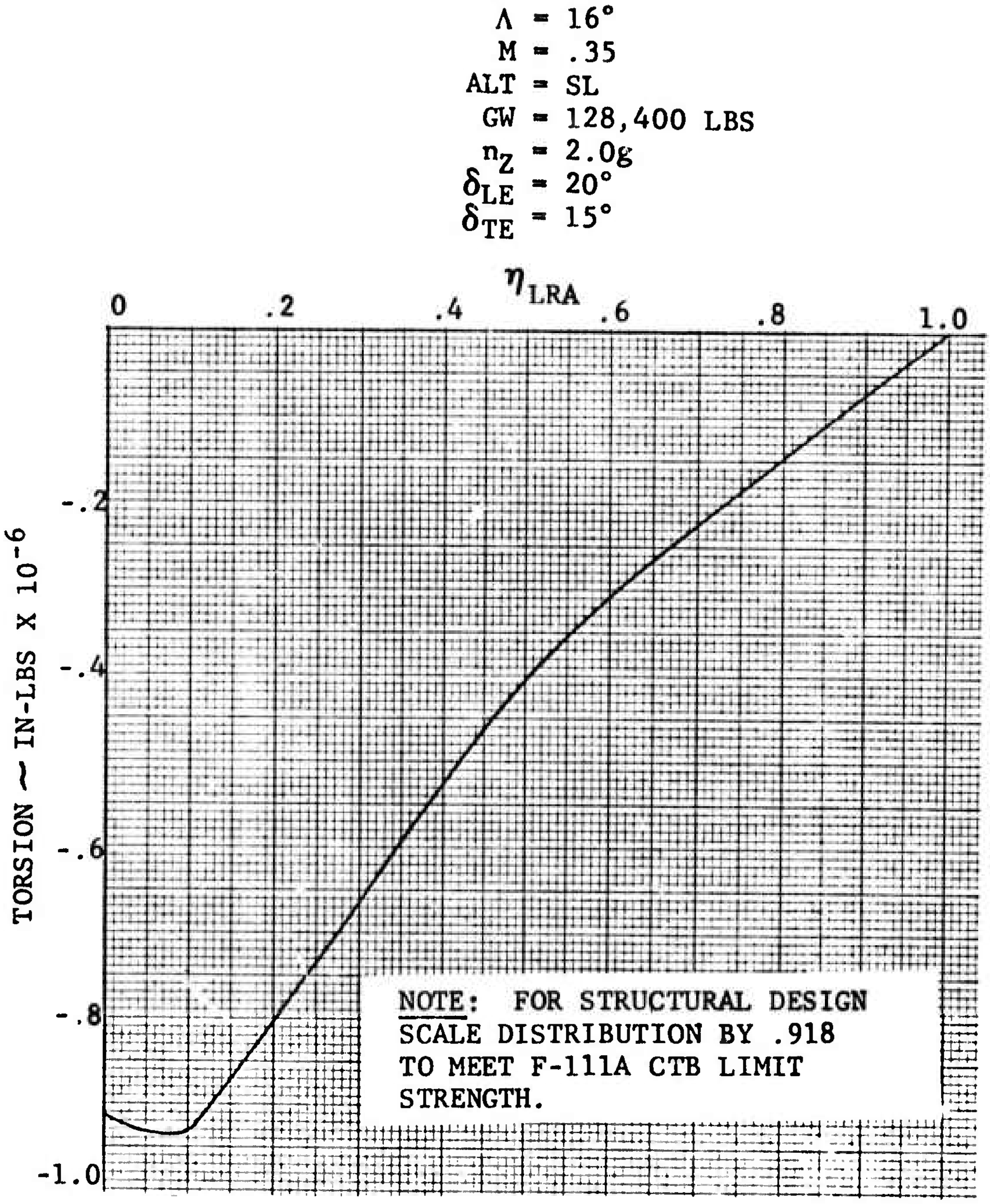


Figure A.7 ATW-4 Wing Torsion Distribution - Condition 1

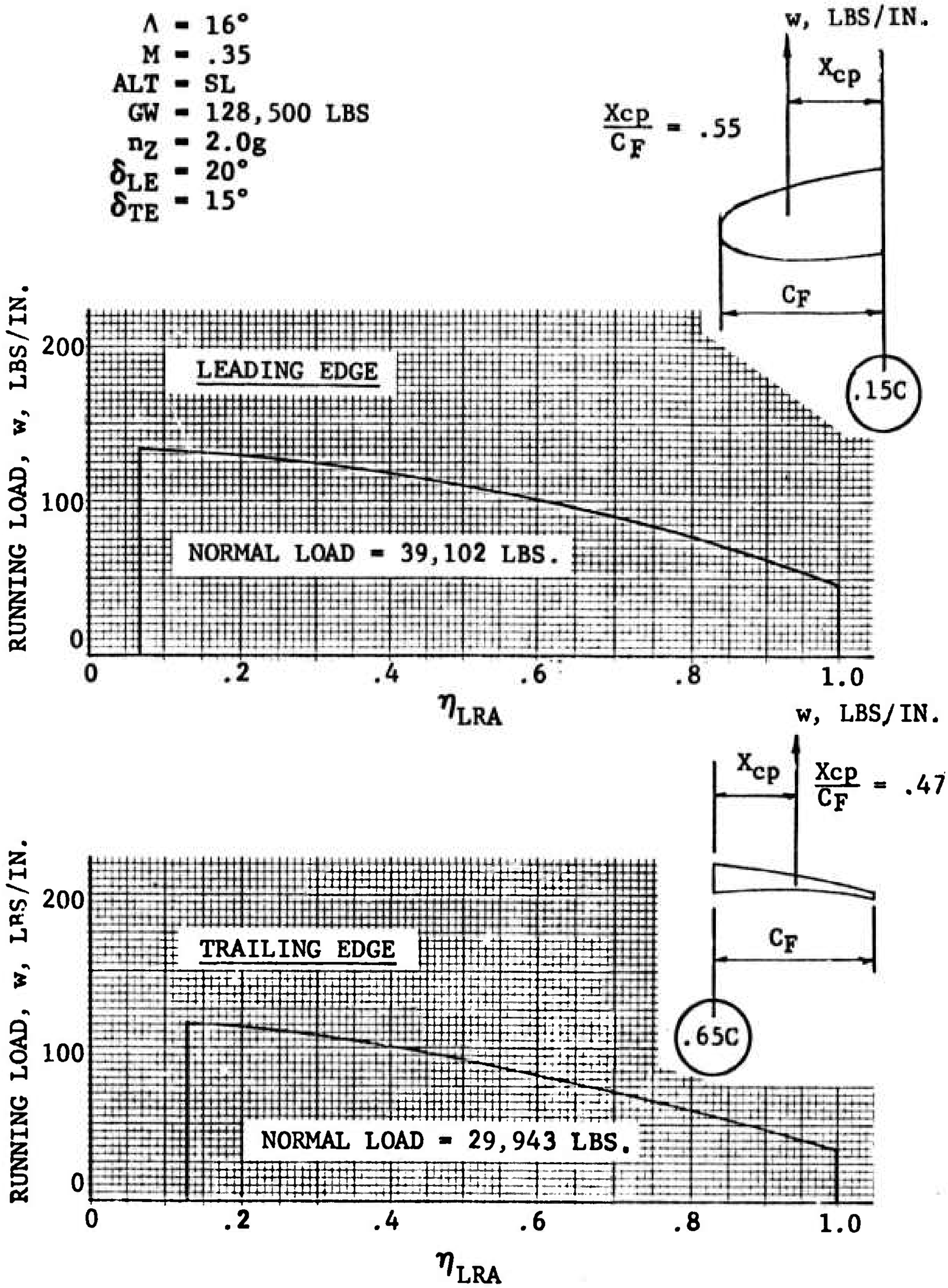
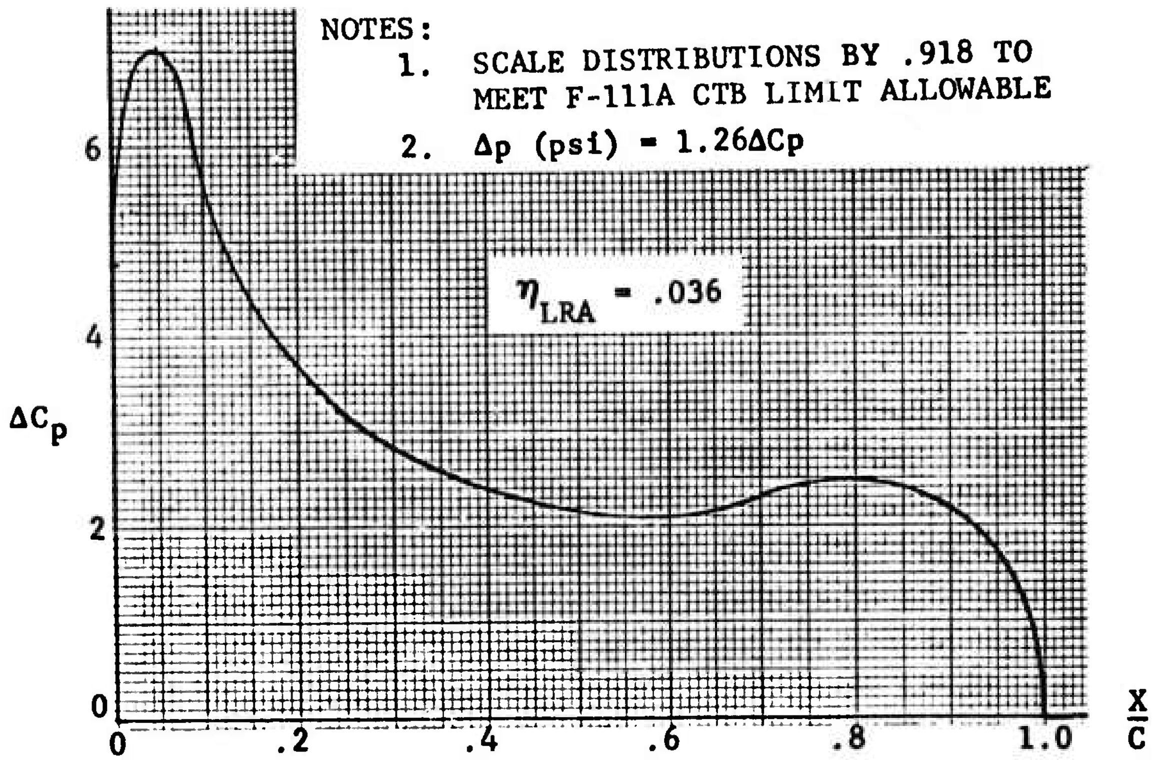


Figure A.8 ATW-4 Wing Leading and Trailing Edge Flap Running Loads - Condition 1



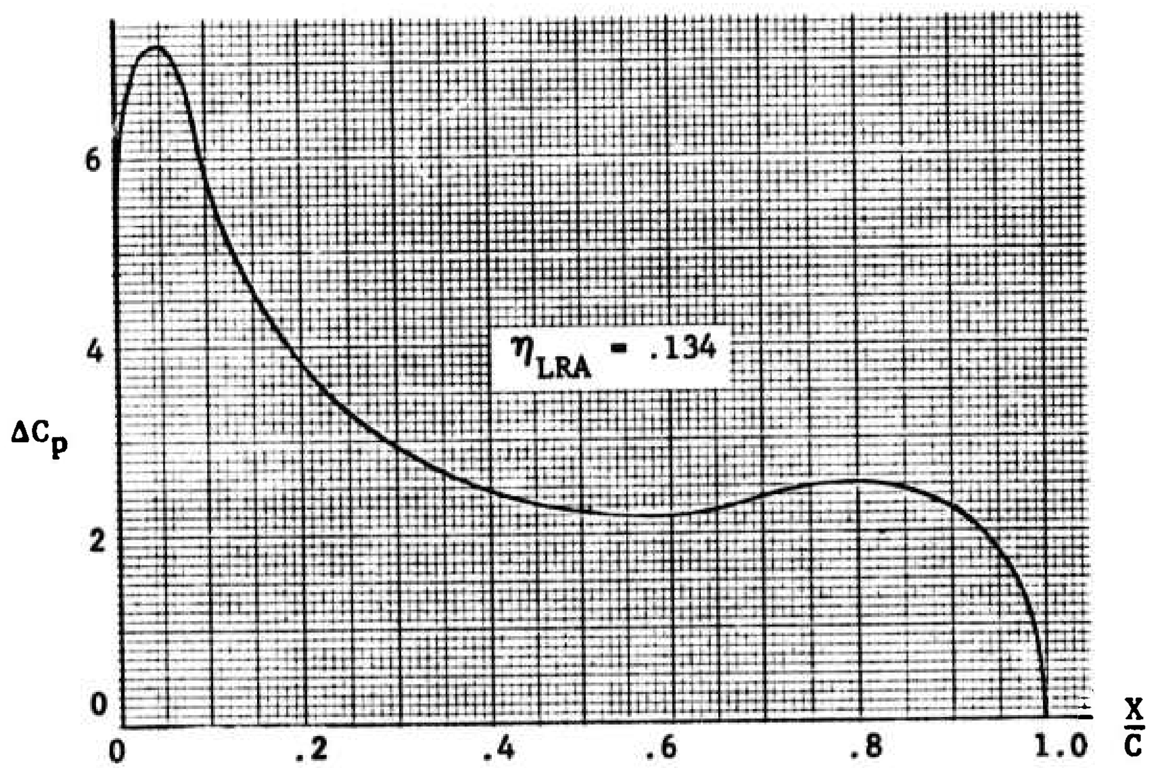


Figure A.9 ATW-4 Wing Chordwise Pressure Distributions for .251 and .369 ETA_{LRA} - Condition 1

NOTES:

1. SCALE DISTRIBUTIONS BY .918 TO MEET F-111A CTB LIMIT ALLOWABLE
2. Δp (psi) = $1.26 \Delta C_p$

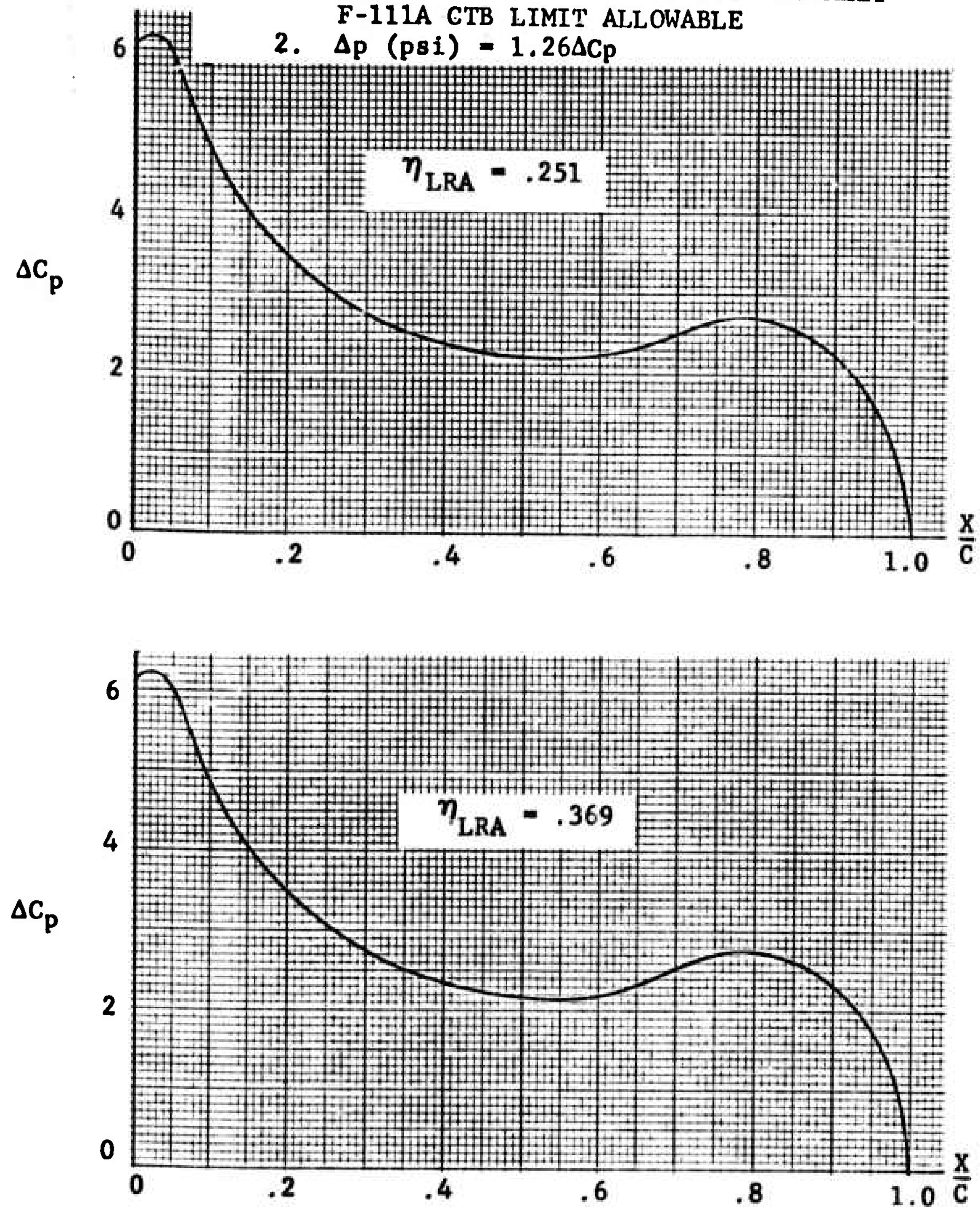
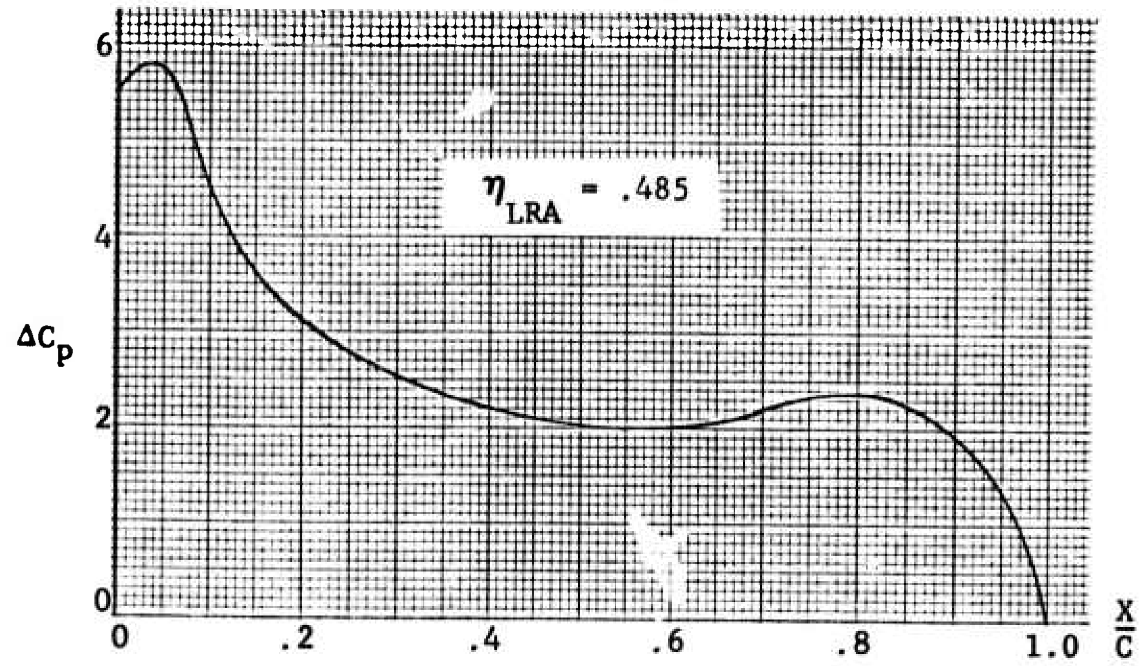


Figure A.10 ATW-4 Wing Chordwise Pressure Distributions for .251 and .369 ETA_{LRA} - Condition 1

NOTES:

1. SCALE DISTRIBUTIONS BY .917 TO MEET F-111A CTB LIMIT ALLOWABLE
2. Δp (PSI) = 1.26ΔCp



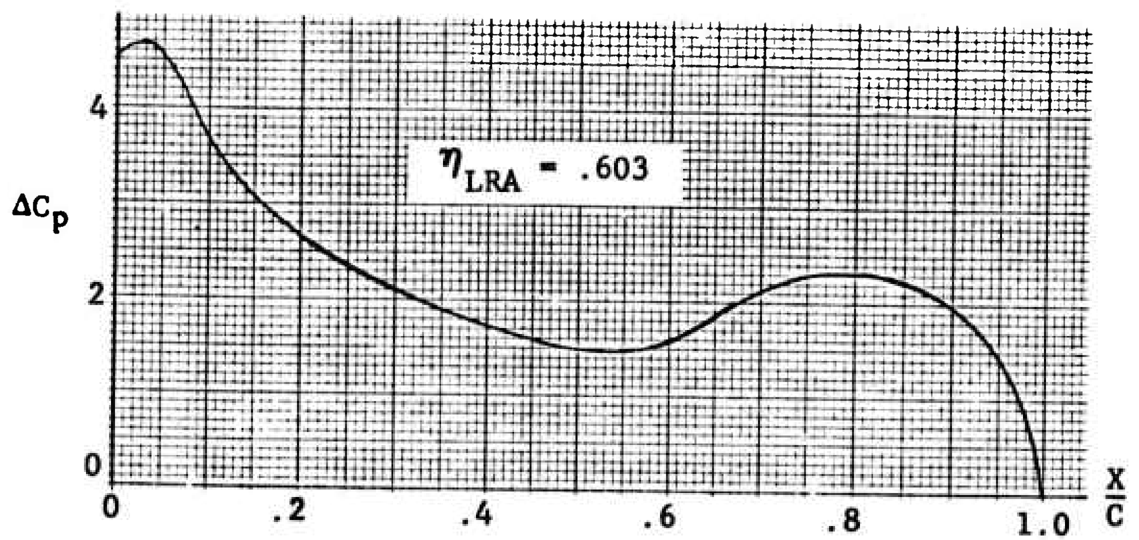
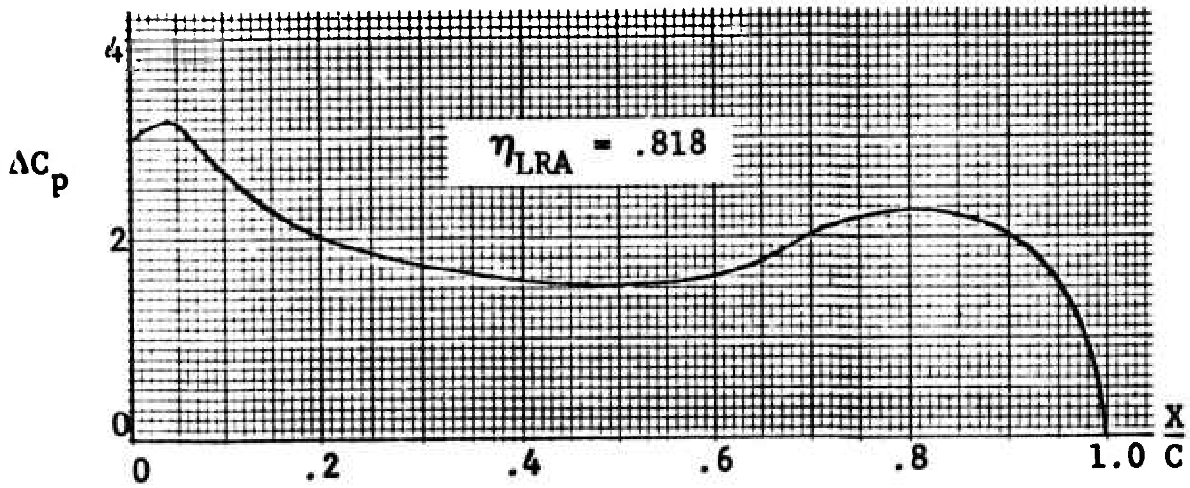


Figure A.11 ATW-4 Wing Chordwise Pressure Distributions for .485 and .603 ETA_{LRA} - Condition 1

NOTES:
1. SCALE DISTRIBUTIONS BY .918 TO MEET F-111A CTB LIMIT ALLOWABLE
2. Δp (psi) = 1.26ΔCp



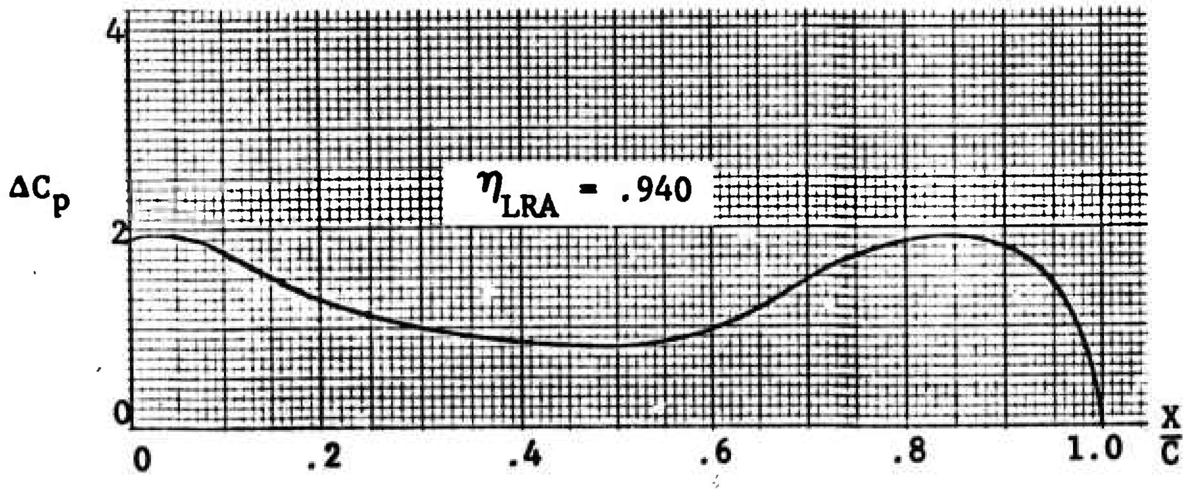


Figure A.12 ATW-4 Wing Chordwise Pressure Distributions for .818 and .940 ETA_{LRA} - Condition 1

NOTES:

1. LOCAL LIFT ON CHORDS ⊥ TO LRA
2. SEE FIGURE A.1 FOR CHORD GEOMETRY AND DIMENSIONAL DATA
3. SCALE ORDINATES BY .918 TO MEET F-111A CTB LIMIT STRENGTH

$\Lambda = 16°$
$M = .35$
ALT = SL
GW = 128,500 LBS
$n_Z = 2.0g$
$\delta_{LE} = 20°$
$\delta_{TE} = 15°$

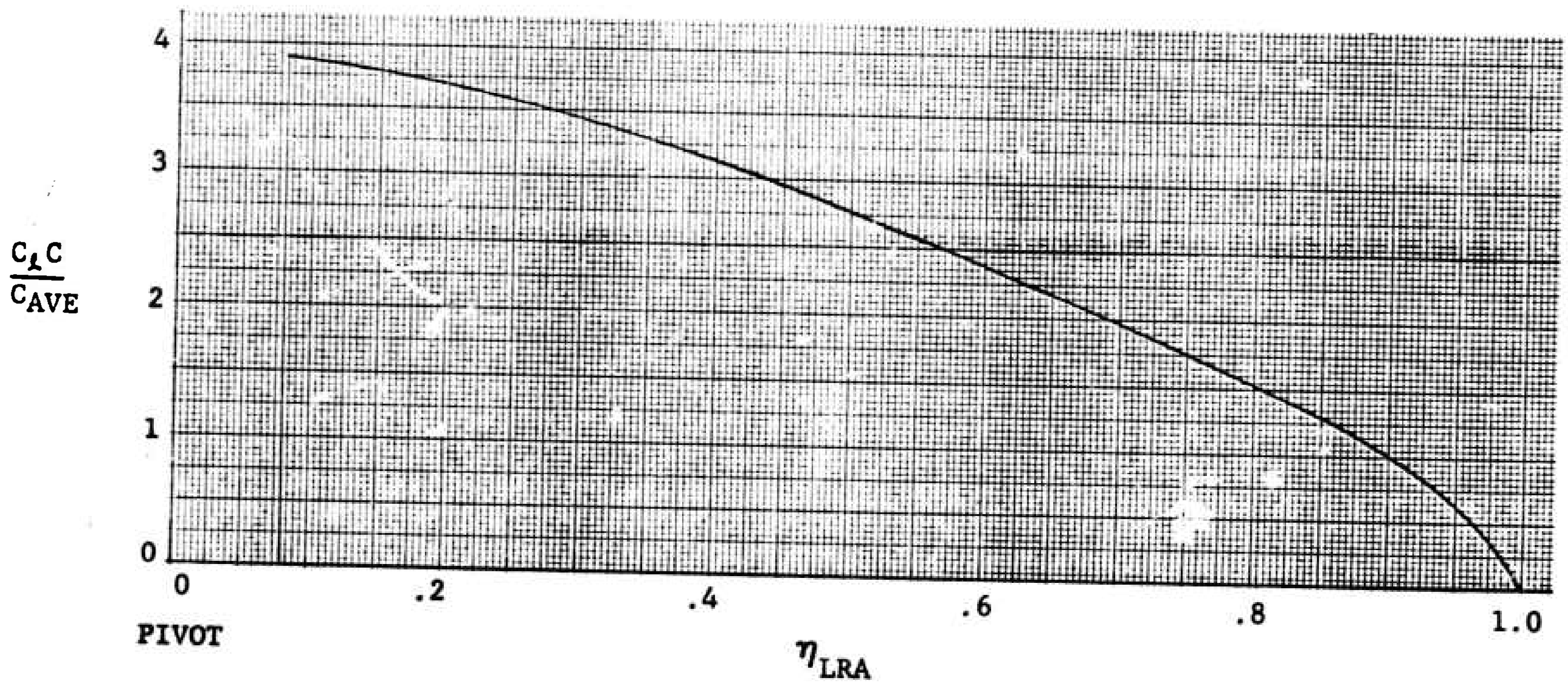


Figure A.13 ATW-4 Wing Local Lift Spanwise Distribution - Condition 1

NOTES:

1. LOCAL TORSION ON CHORDS ⊥ TO LRA
2. SEE FIGURE A-1 FOR CHORD GEOMETRY AND DIMENSIONAL DATA
3. MOM. REF. IS LRA
4. $\overline{C}$ = 117.1 IN. (THEORETICAL REF. WING MAC)
5. SCALE ORDINATES BY .918 TO MEET F-111A CTB LIMIT STRENGTH

Λ = 16°
M = .35
ALT = SL
GW = 128,500 LBS
n_Z = 2.0g
δ_{LE} = 20°
δ_{TE} = 15°

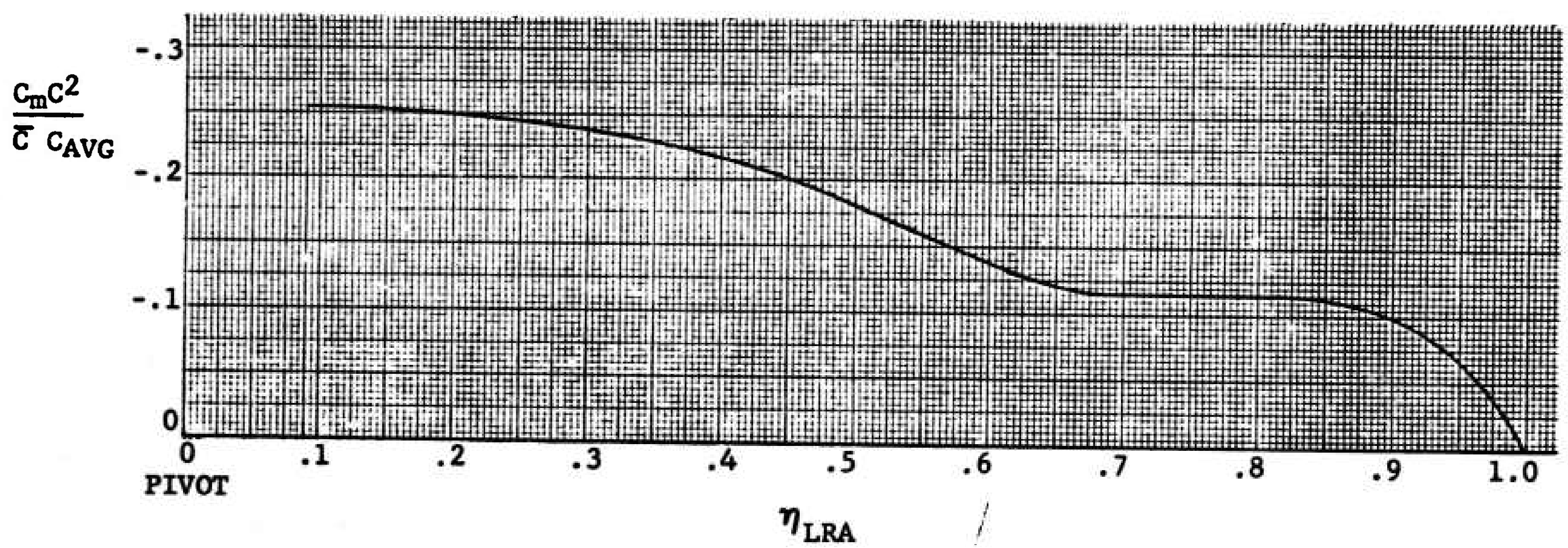


Figure A-14 ATW-4 Wing Local Torsion Spanwise Distribution - Condition 1

A.5.2 Condition 1A - Take-Off with Half Flaps

Figure A.15 shows the wing leading and trailing edge running loads for the take-off condition with half flaps. This condition is not critical; therefore, the chordwise pressure distributions were not plotted.

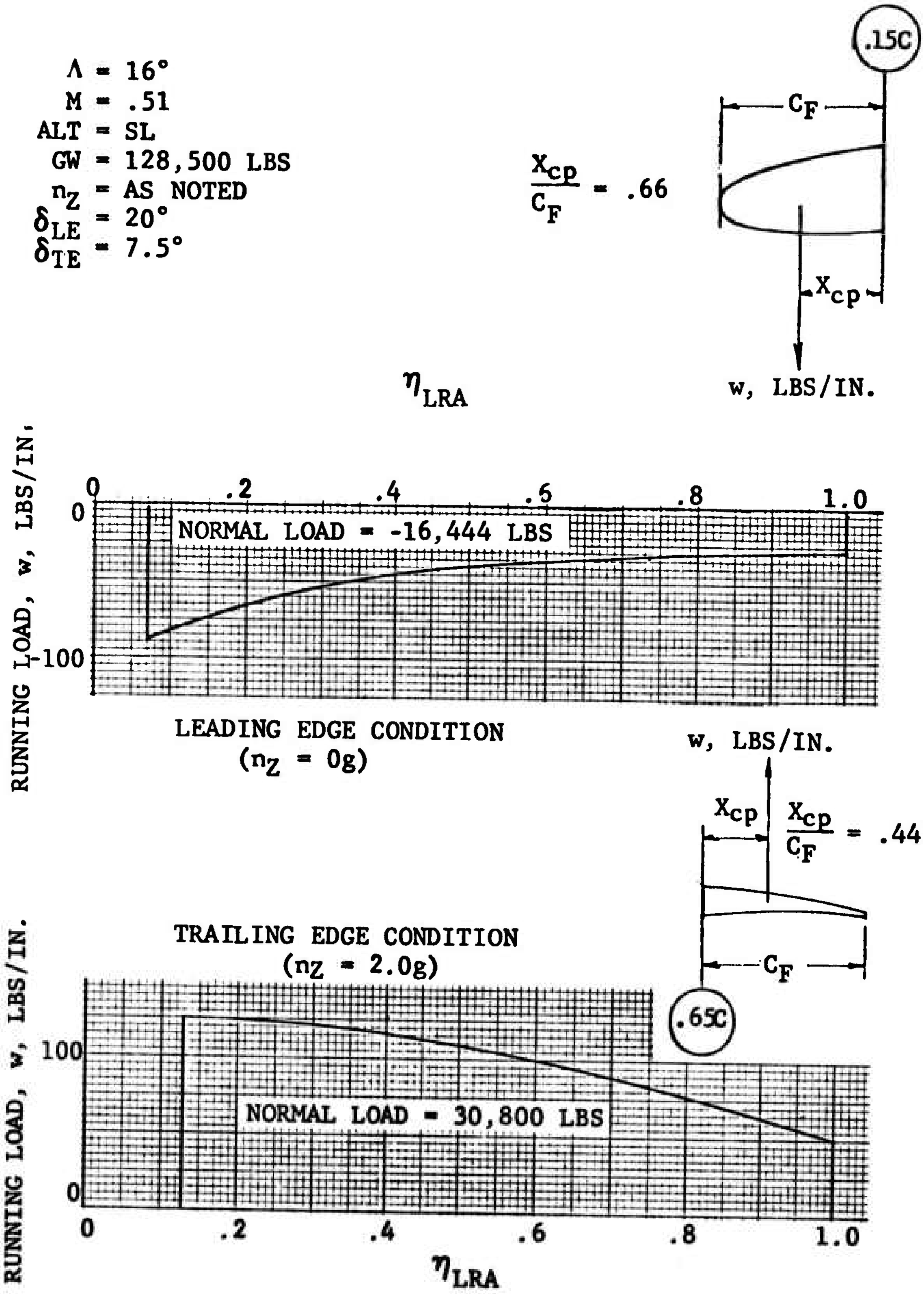


Figure A.15 ATW-4 Wing Leading and Trailing Edge Flap Running Loads - Condition 1A

A.5.3 Condition 2 - Dash

Figure A.16 through A.27 define preliminary design loads for condition 2, the sea level dash condition.

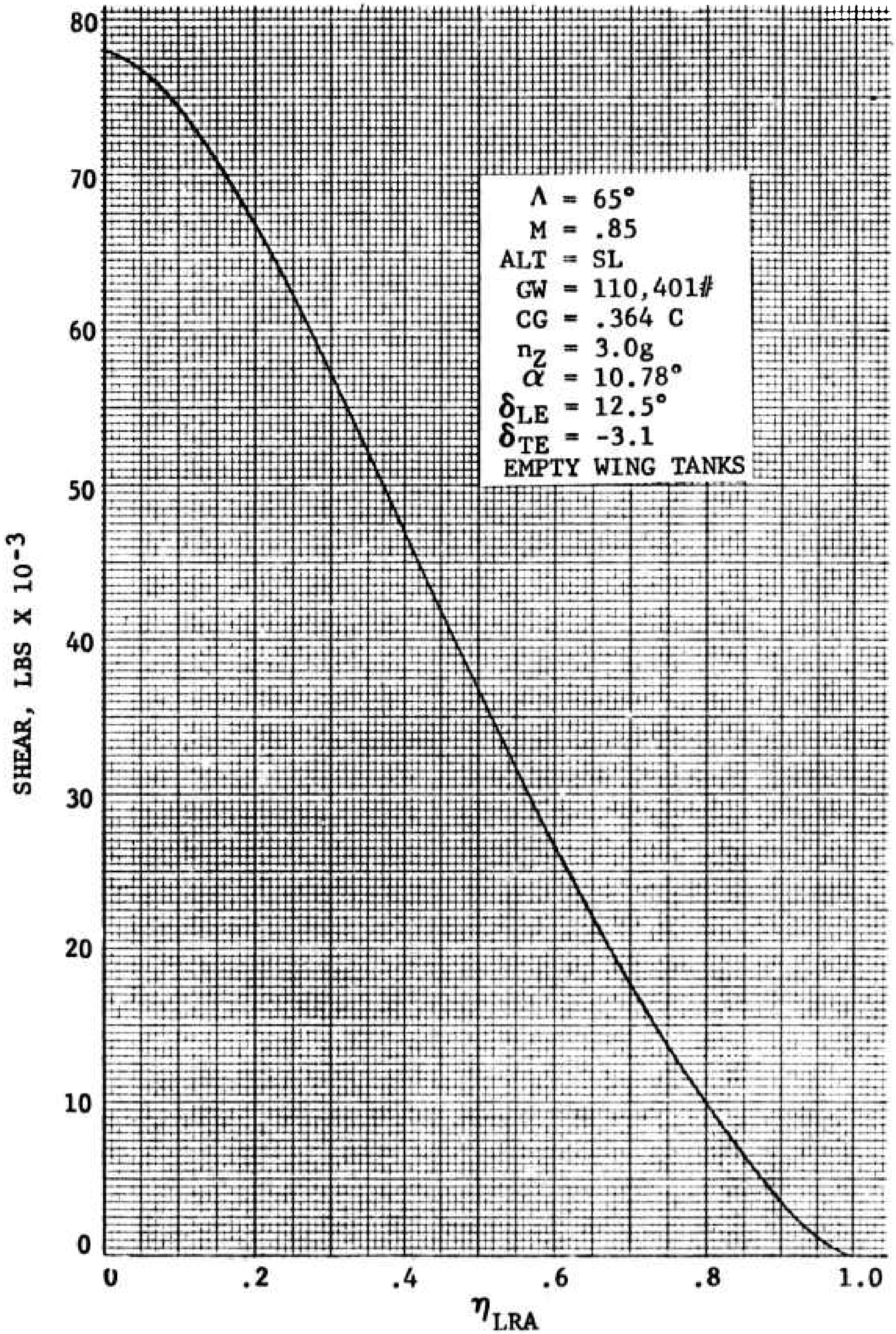


Figure A.16 ATW-4 Wing Shear Distribution - Condition 2

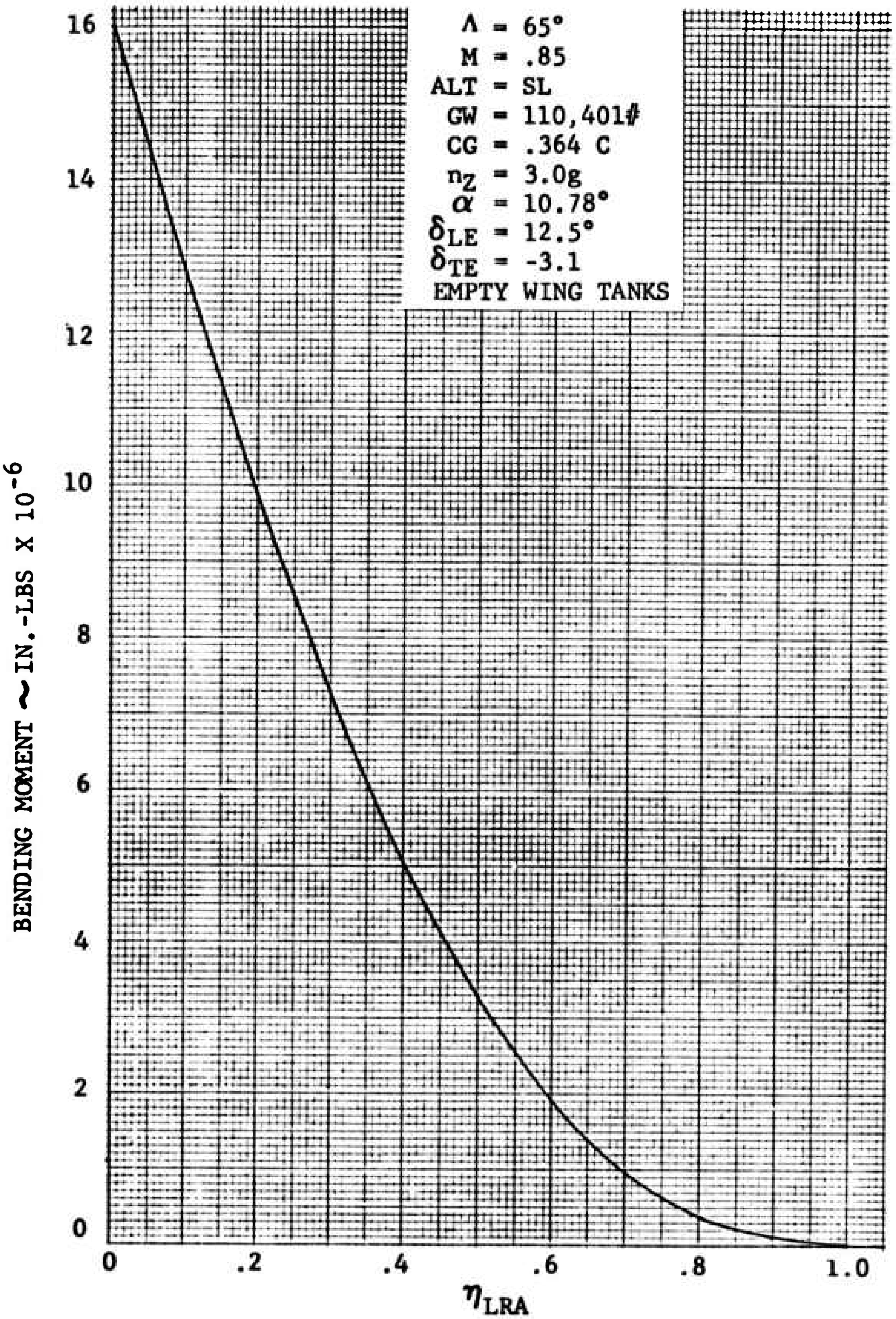


Figure A.17 ATW-4 Wing Bending Moment Distribution - Condition 2

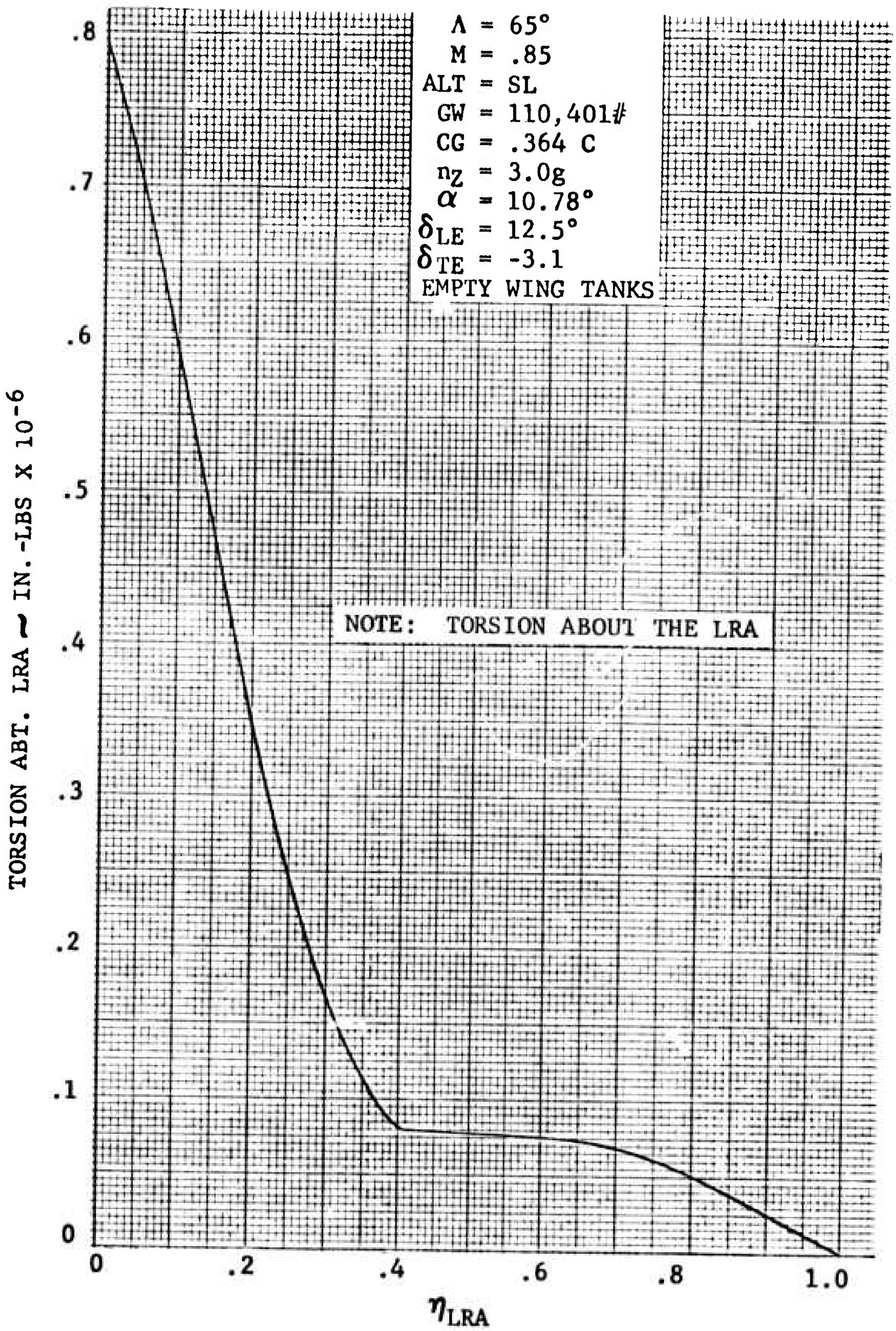


Figure A.18 ATW-4 Wing Torsion Distribution - Condition 2

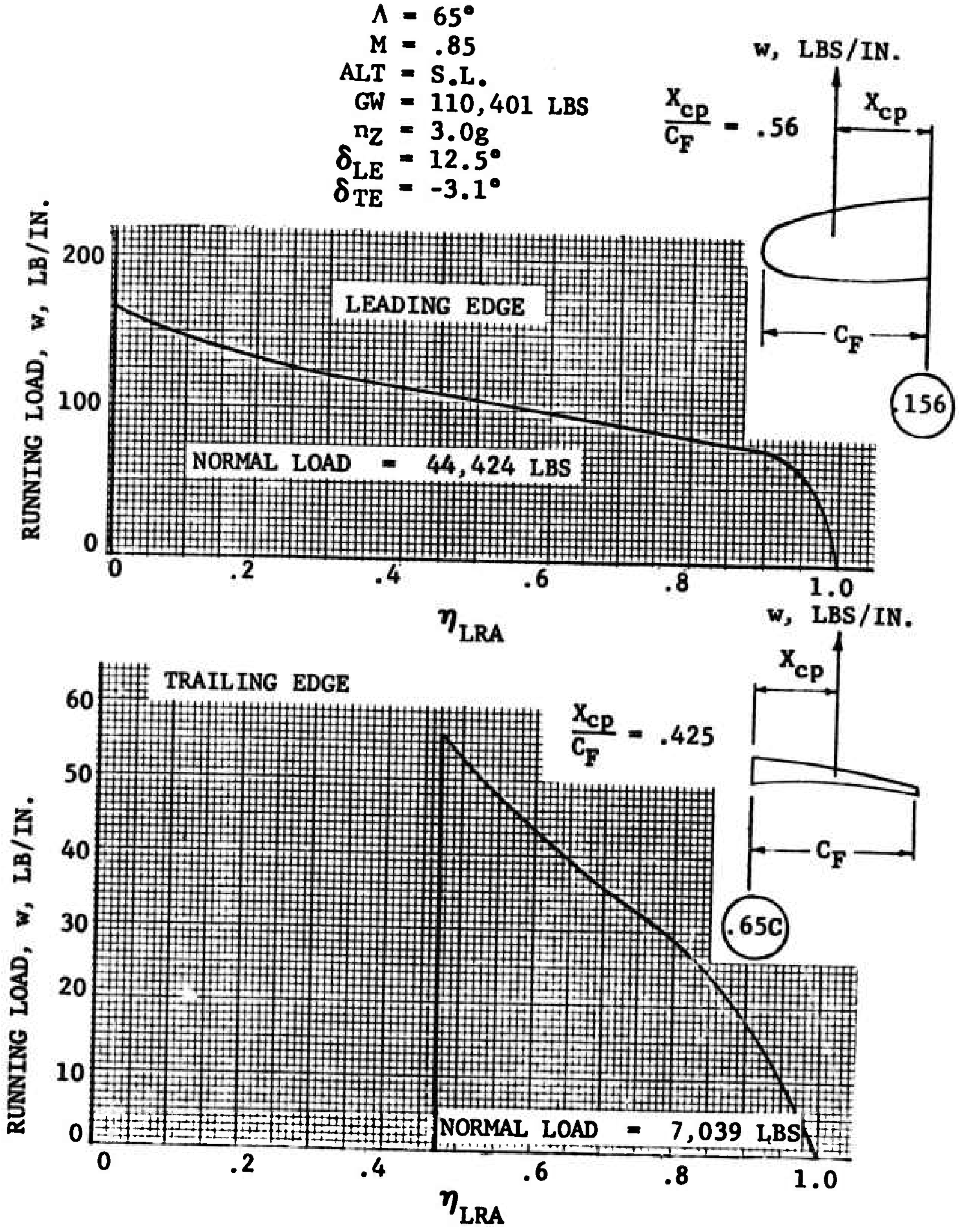


Figure A.19 ATW-4 Wing Leading and Trailing Edge Flap Running Loads - Condition 2

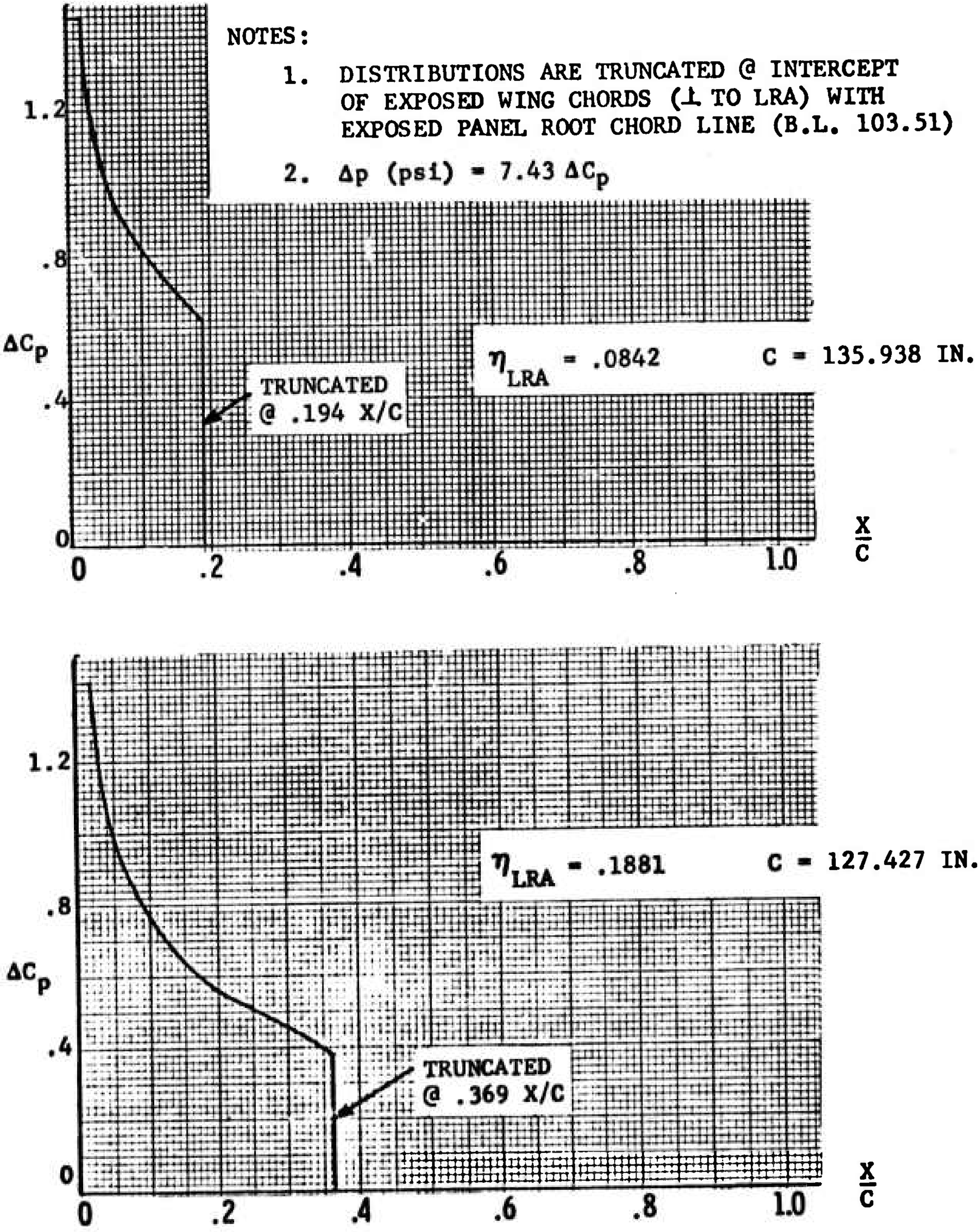


Figure A.20 ATW-4 Wing Chordwise Pressure Distributions for .0842 and .1881 ETA_{LRA} - Condition 2

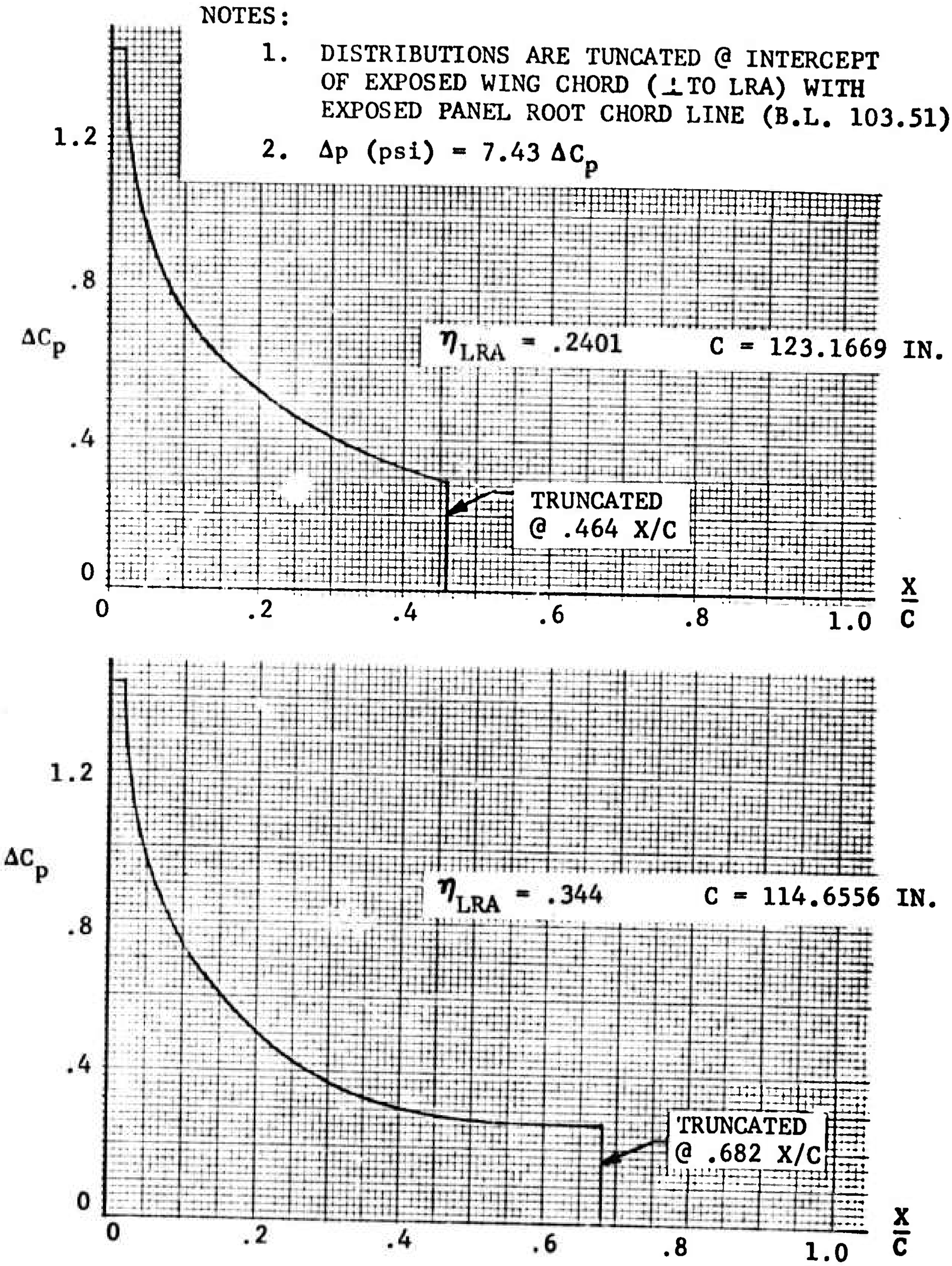
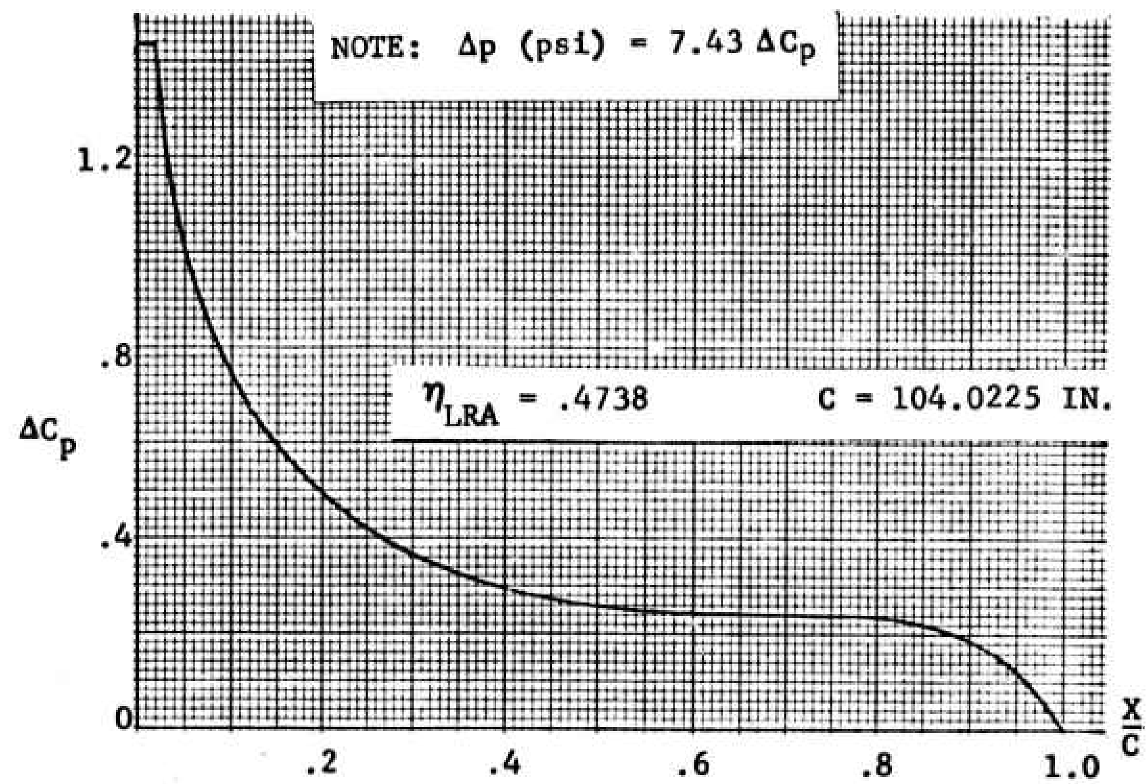


Figure A.21 ATW-4 Wing Chordwise Pressure Distributions for .2401 and .344 ETA_{LRA} - Condition 2



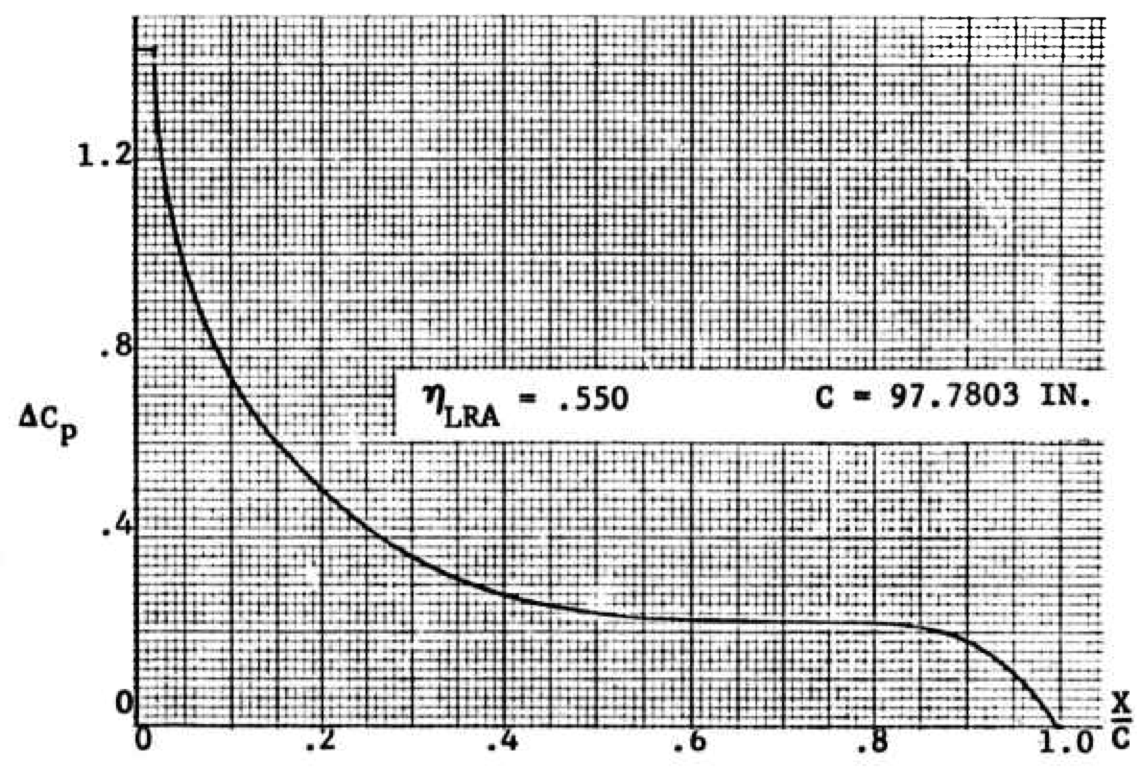


Figure A.22 ATW-4 Wing Chordwise Pressure Distributions for .4738 and .550 ETA_{LRA} - Condition 2

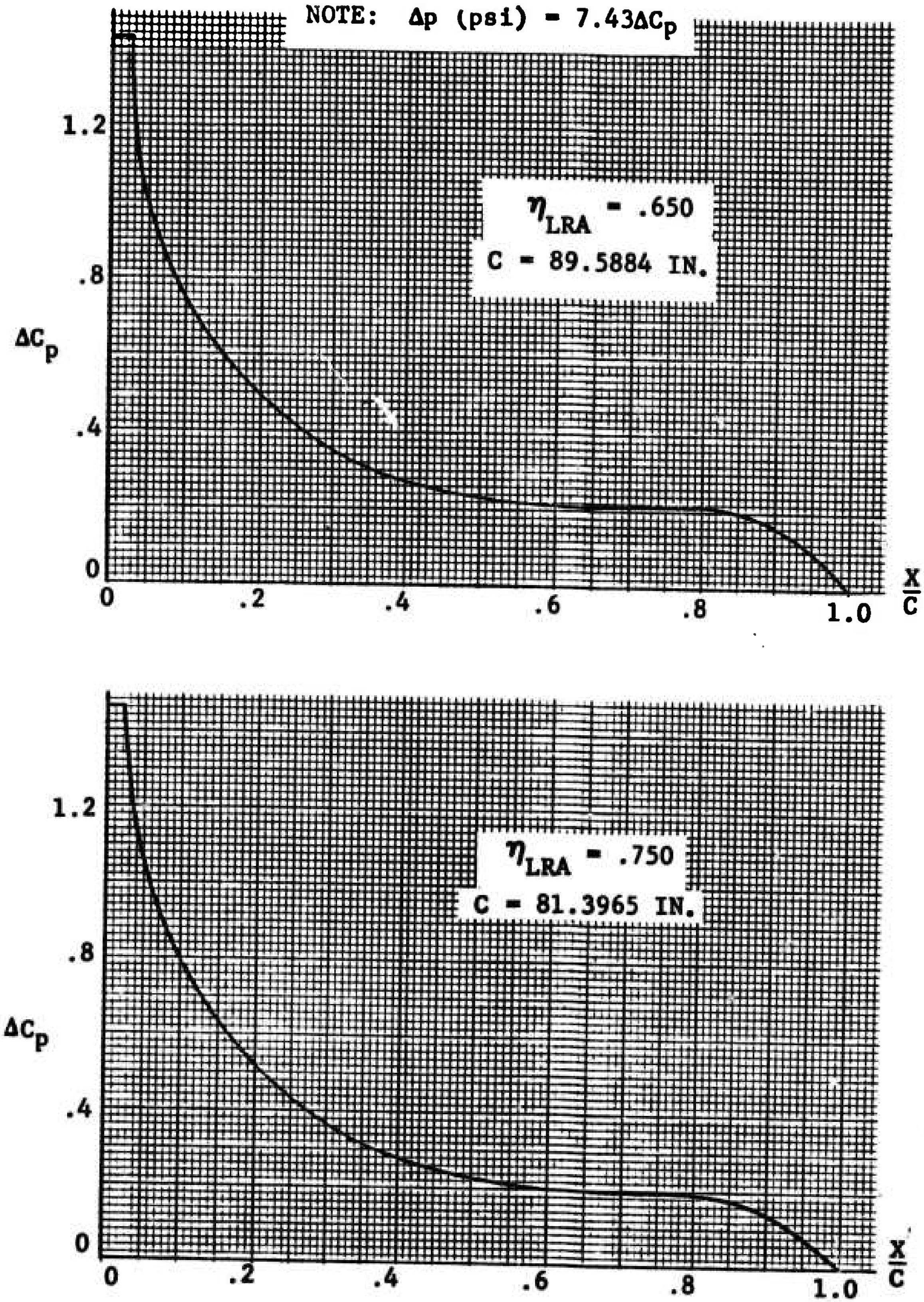


Figure A-23 ATW-4 Wing Chordwise Pressure Distributions for .650 and .750 ETA_{LRA} - Condition 2

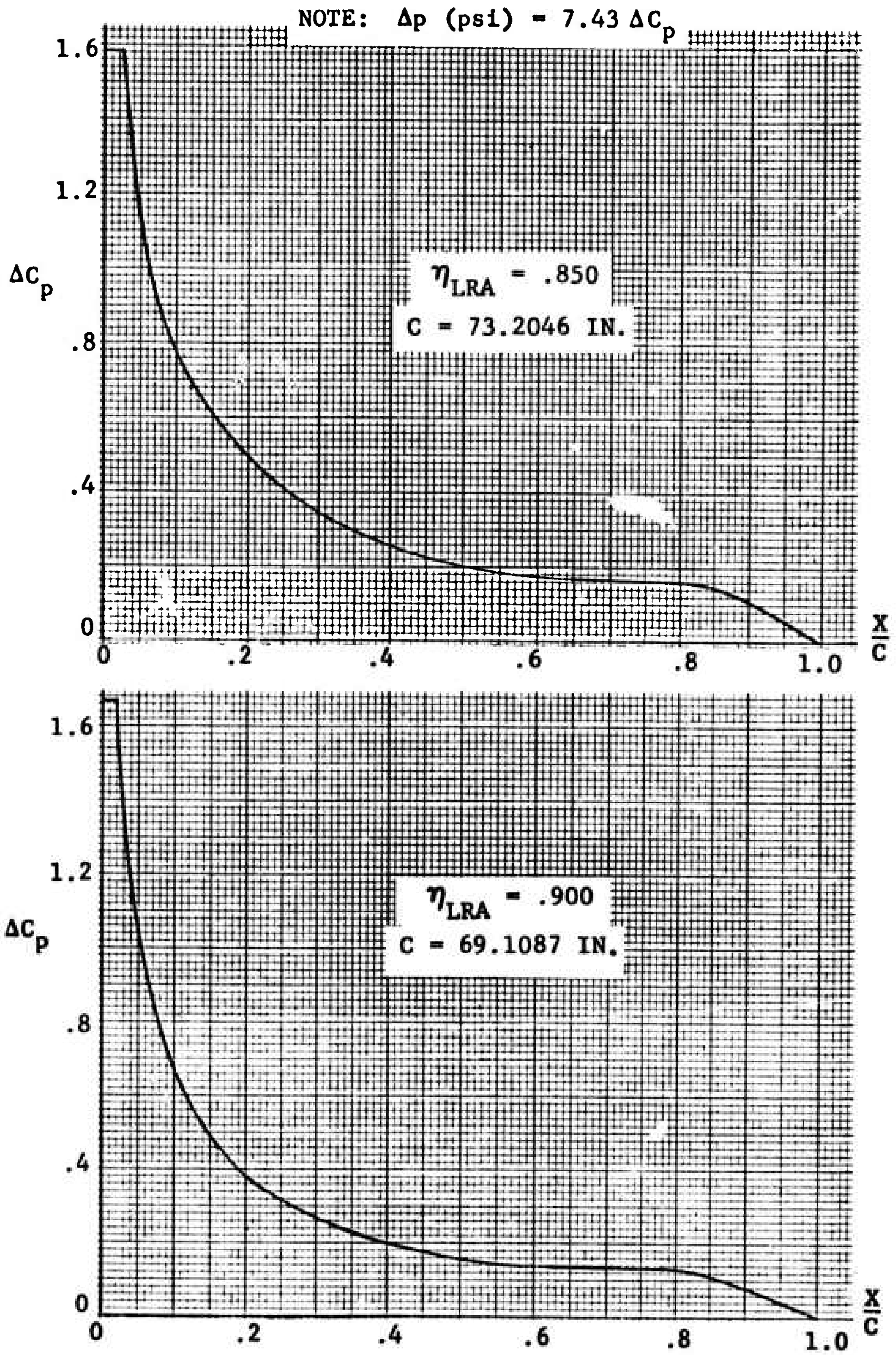


Figure A.24 ATW-4 Wing Chordwise Pressure Distributions for .850 and .900 ETA_{LRA} - Condition 2

NOTE: Δp (psi) = 7.43 ΔC_p

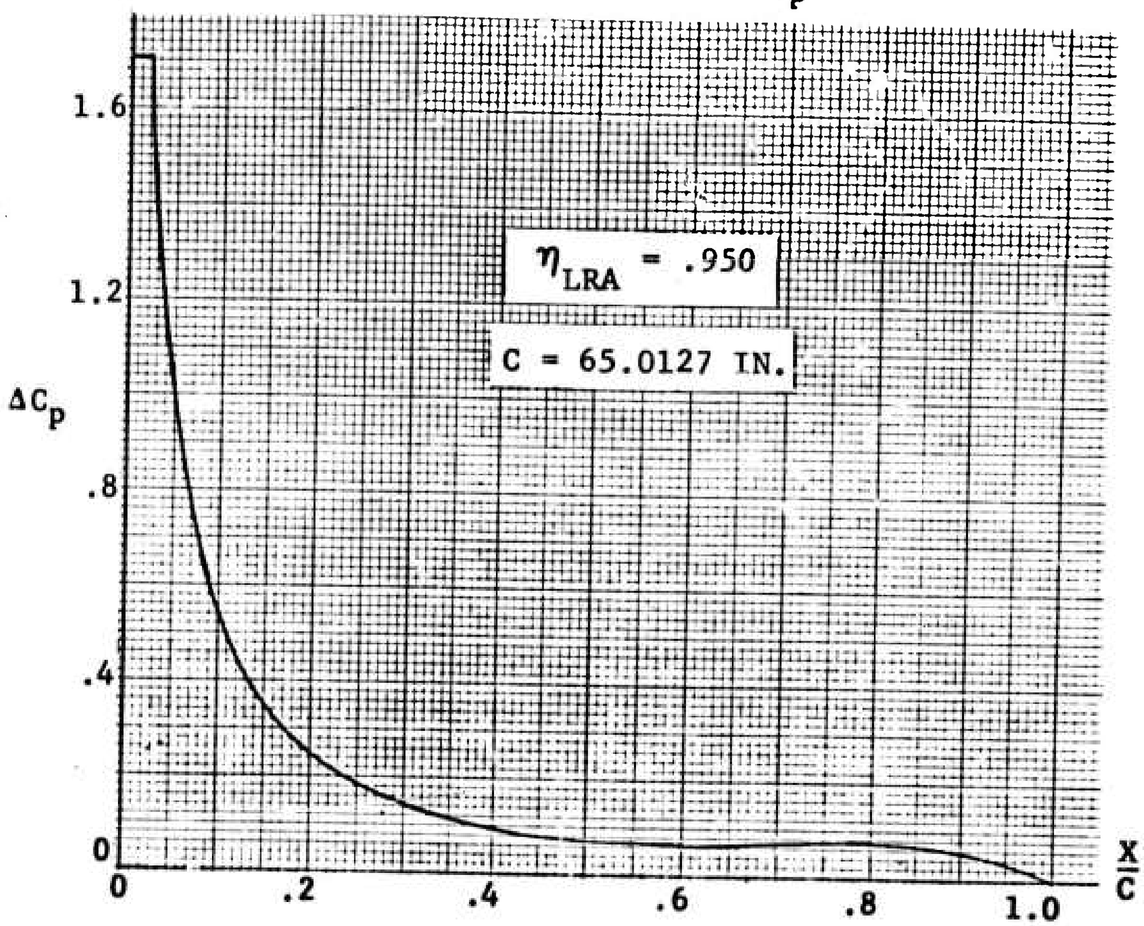


Figure A.25 ATW-4 Wing Chordwise Pressure Distribution for .950 ETA_{LRA} - Condition 2

NOTE:

1. LOCAL LIFT ON CHORDS ⊥ TO THE LRA
2. SEE FIGURE A-1 FOR CHORD GEOMETRY AND DIMENSIONAL DATA

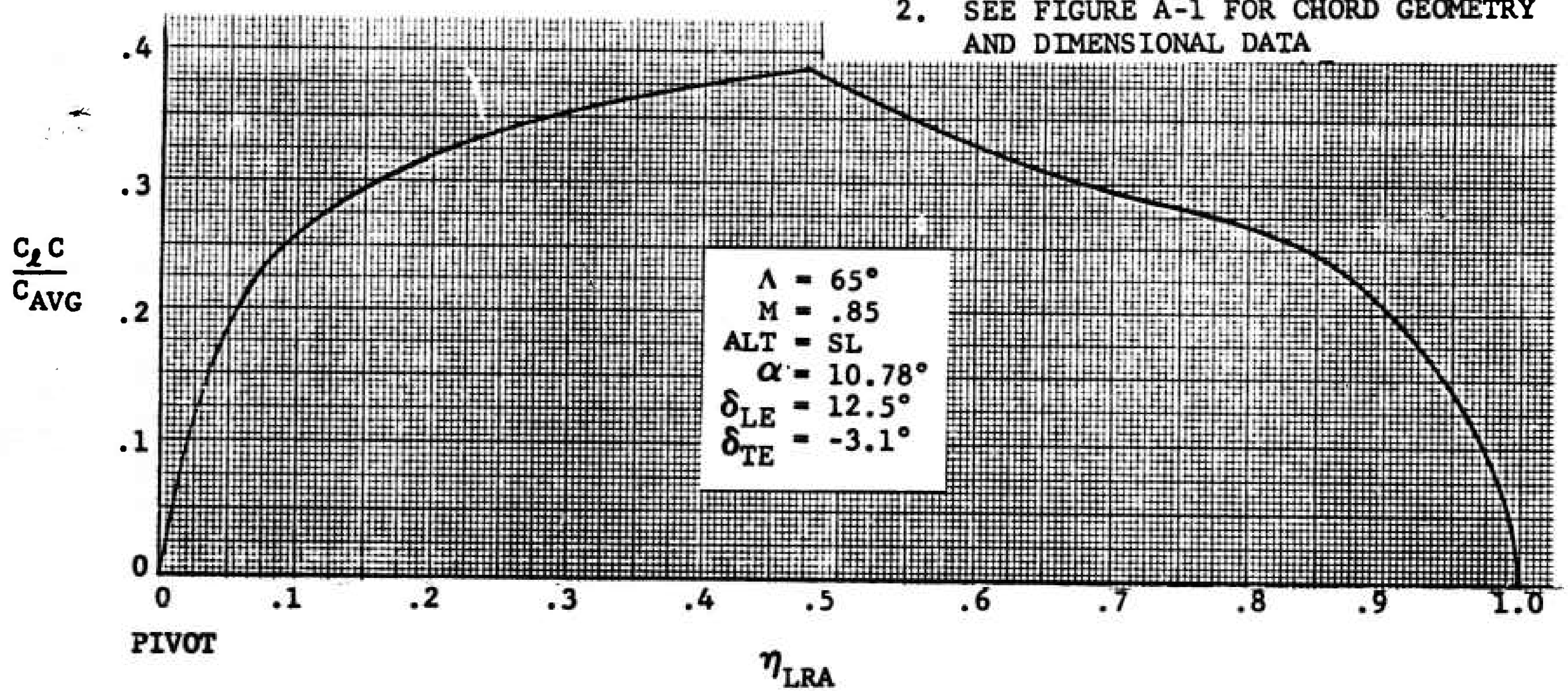


Figure A-26 ATW-4 Wing Local Lift Spanwise Distribution - Condition 2

NOTES:

1. LOCAL TORSION ON CHORDS ⊥ TO LRA
2. SEE FIGURE A-1 FOR CHORD GEOMETRY AND DIMENSIONAL DATA
3. MOMENT REFERENCE IS LRA
4. $\bar{C}$ = 117.1 IN. (THEORETICAL REF. WING MAC)

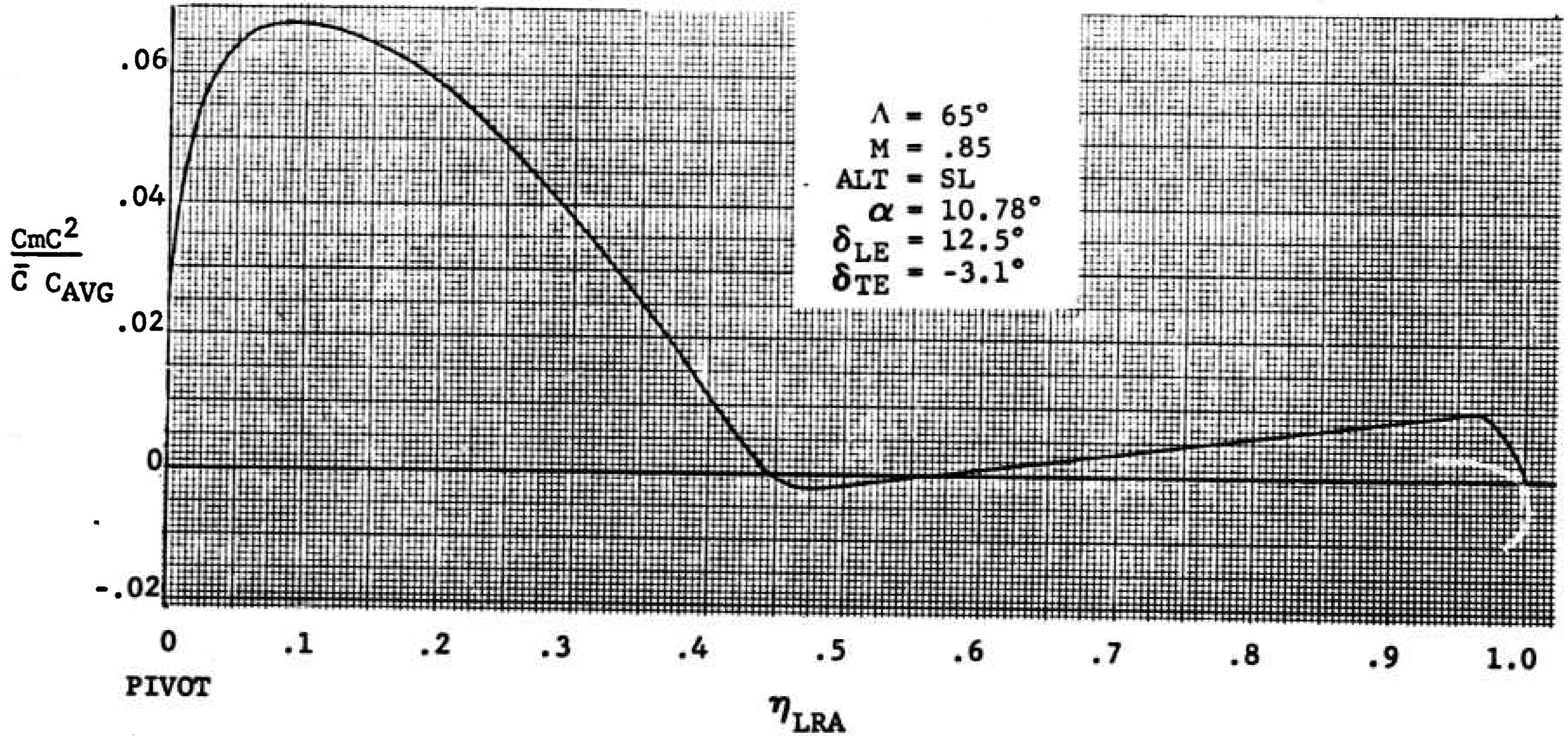


Figure A.27 ATW-4 Wing Local Torsion Spanwise Distribution - Condition 2

A.5.4 Condition 3 - Refuel with Symmetrical Maneuver

Figures A.28 through A.43 define the preliminary design loads for the refuel mission segment with symmetrical maneuver loads applied.

Λ = 16°
M = .80
ALT = 20,000 FT.
GW = 110,400 LBS
n_Z = 2.58g

δ_{LE} = 4°
δ_{TE} = 3.5°
WING TANK EMPTY

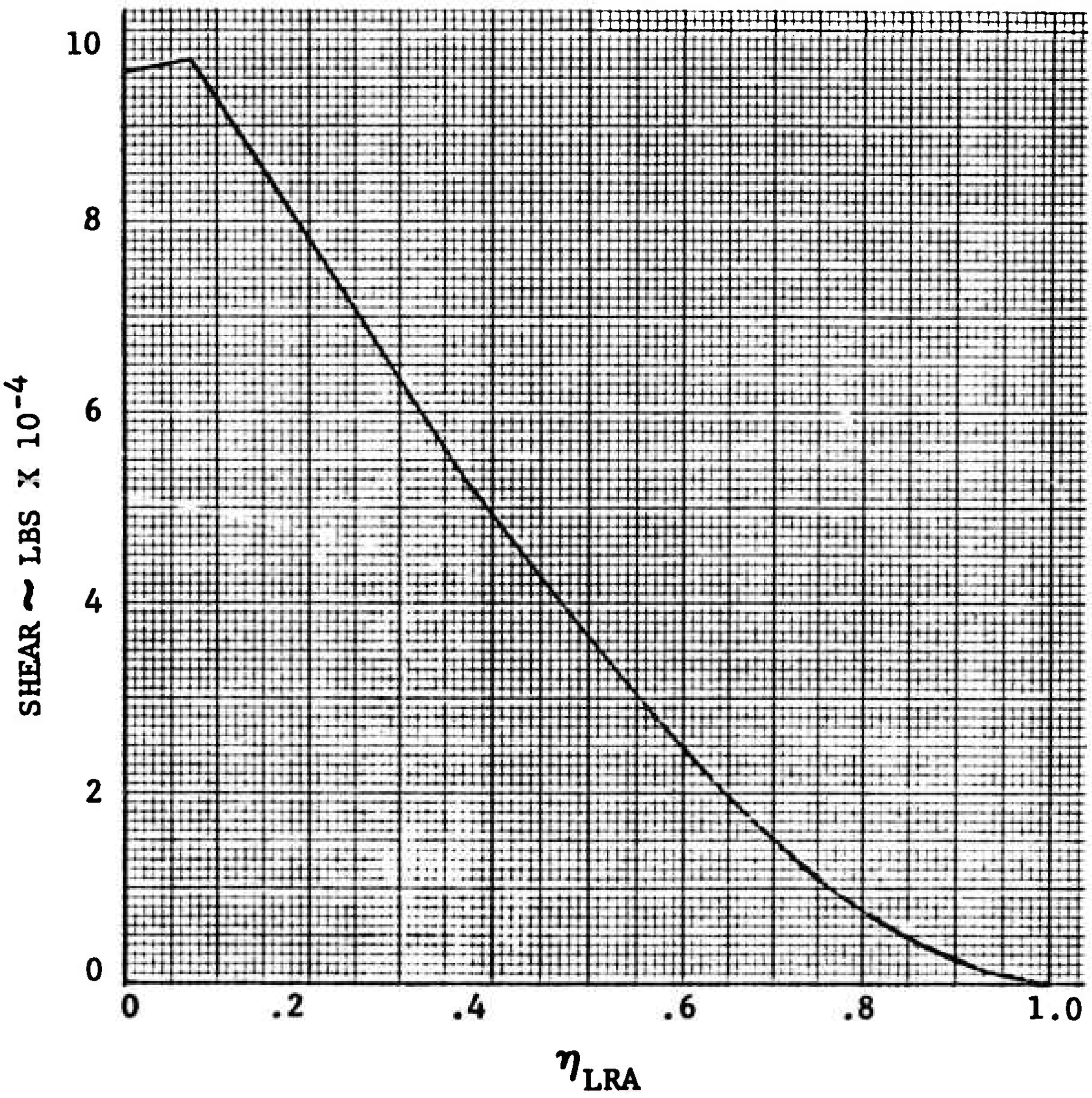


Figure A.28 ATW-4 Wing Shear Distribution - Condition 3

Λ = 16°
M = .80
ALT = 20,000 FT
GW = 110,400 LBS
n_Z = 2.58g

δ_{LE} = 4°
δ_{TE} = 3.5°
WING TANKS EMPTY

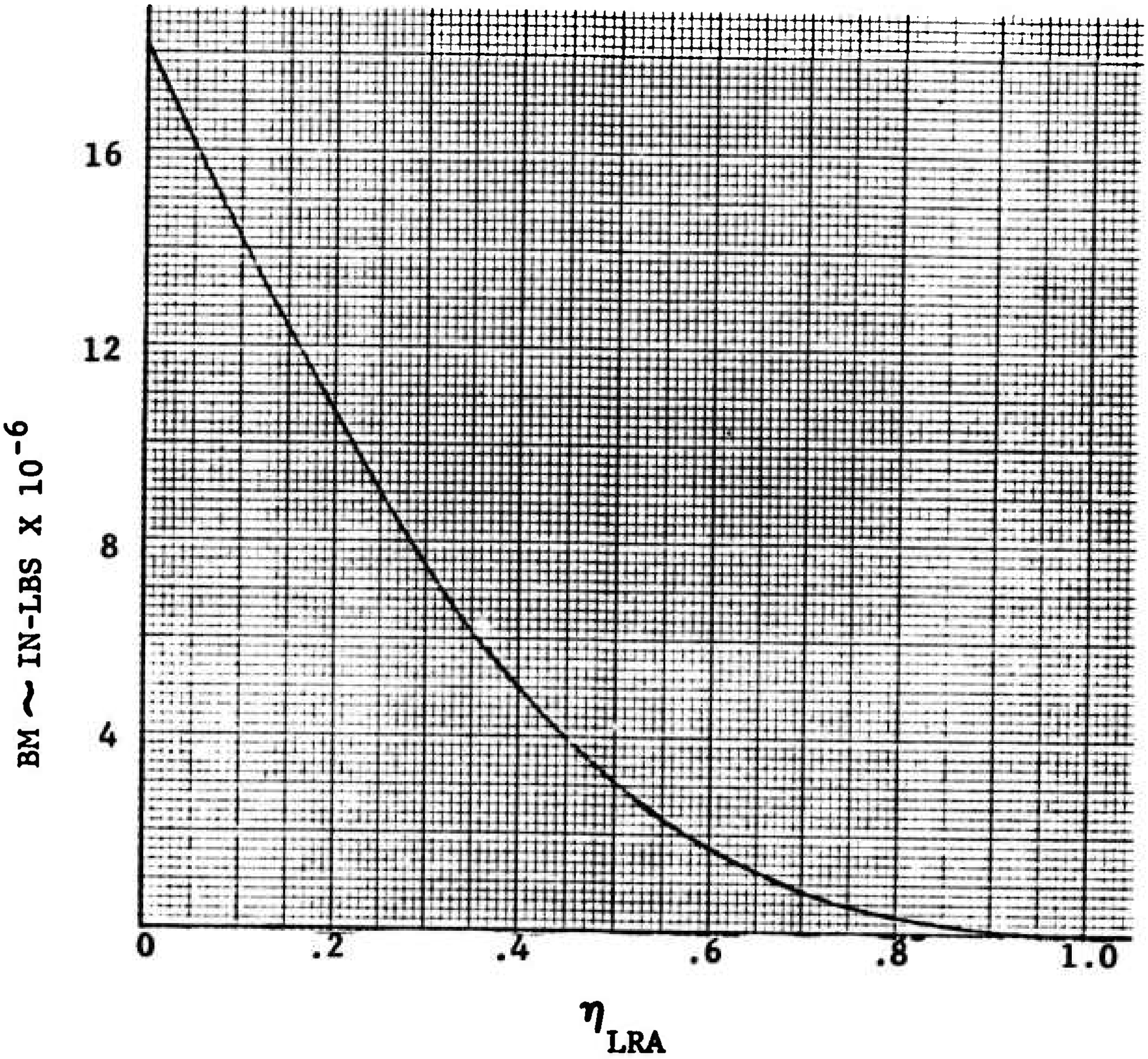


Figure A.29 ATW-4 Wing Bending Moment Distribution - Condition 3

Λ = 16°
M = .80
ALT = 20,000 FT.
GW = 110,400 LBS
n_Z = 2.58g

δ_{LE} = 4°
δ_{TE} = 3.5°
WING TANKS EMPTY

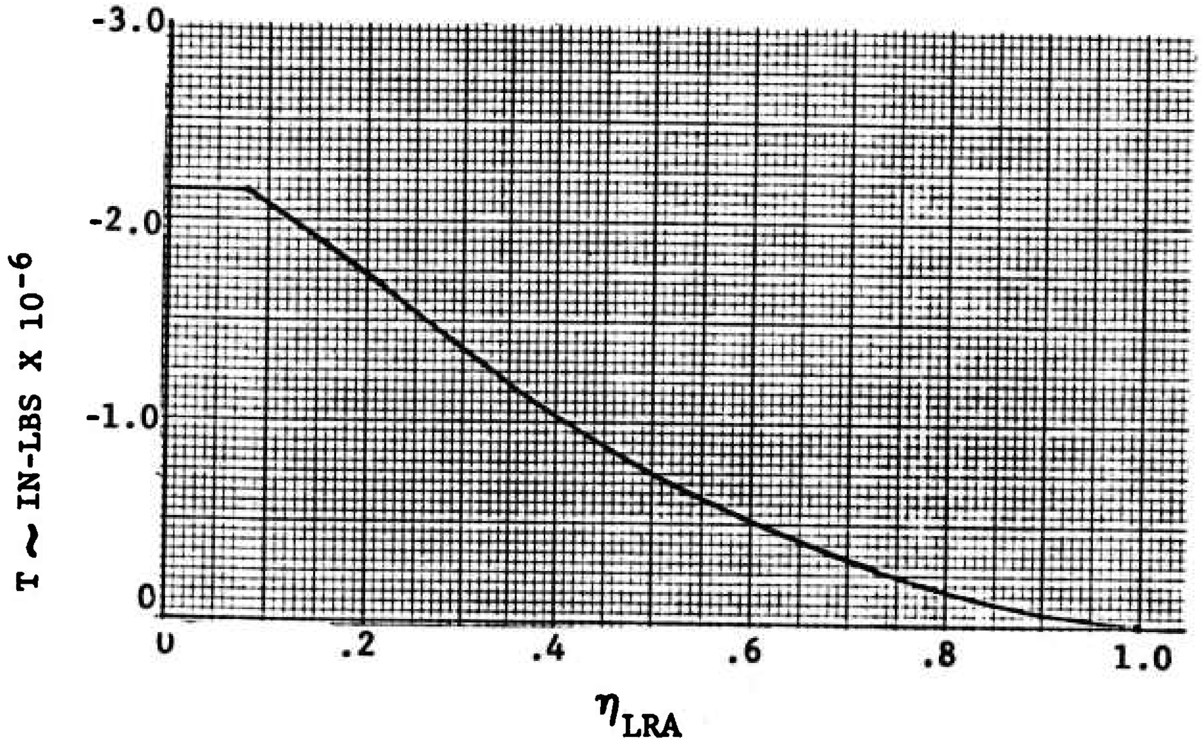


Figure A.30 ATW-4 Wing Torsion Distribution - Condition 3

NOTES:

1. X_{cp} DISTANCE FWD. OF .15C FOR L.E. FLAP C.P.
2. X_{cp} DISTANCE AFT OF .65C FOR T.E. FLAP C.P.
3. C_F IS LOCAL FLAP CHORD

Λ = 16°
M = .80
ALT = 20,000 FT.
GW = 110,400 LBS.
n_Z = 2.6g
δ_{LE} = 4°
δ_{TE} = 3.5°

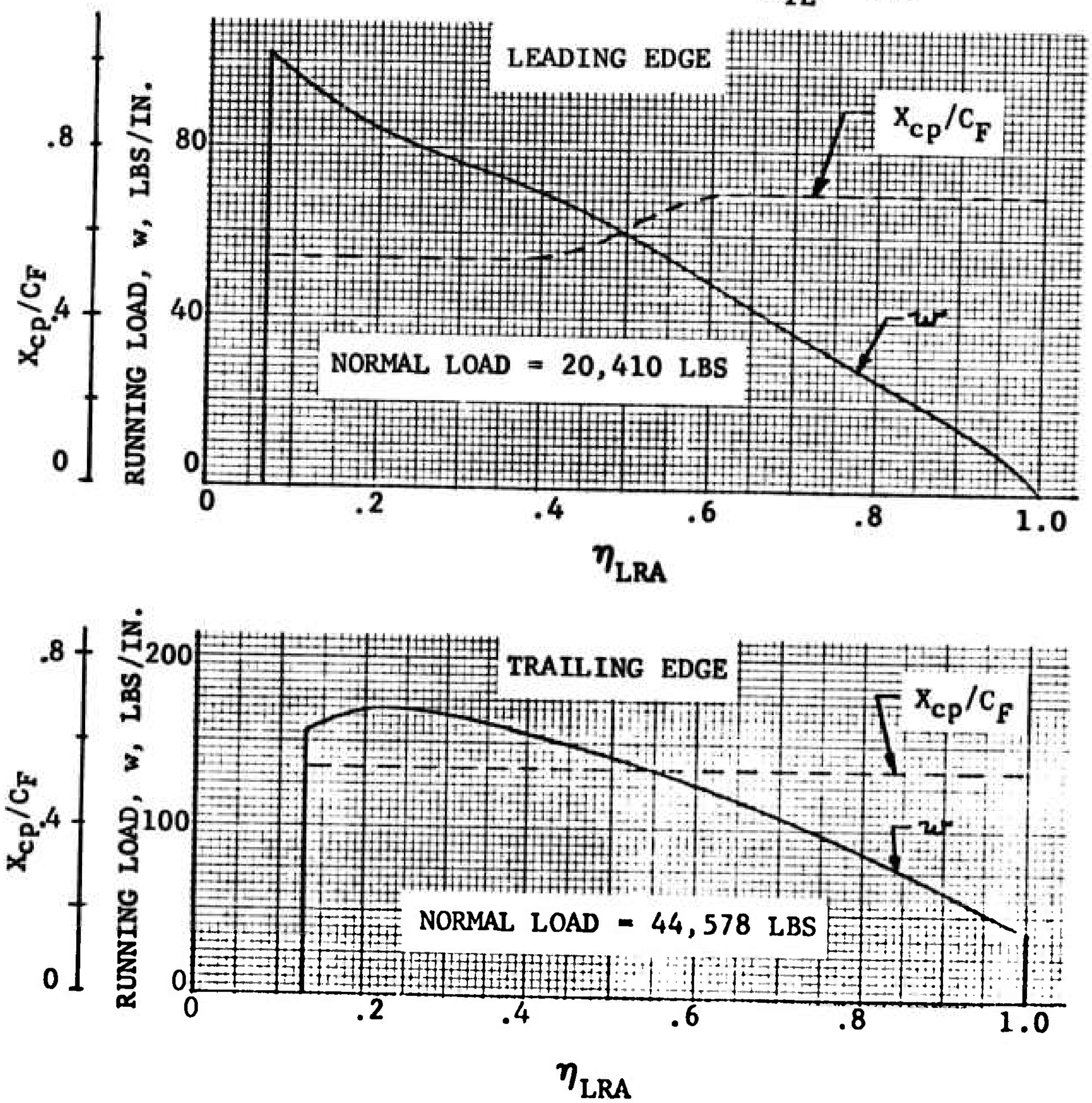


Figure A.31 ATW-4 Wing Leading and Trailing Edge Flap Running Loads - Condition 3

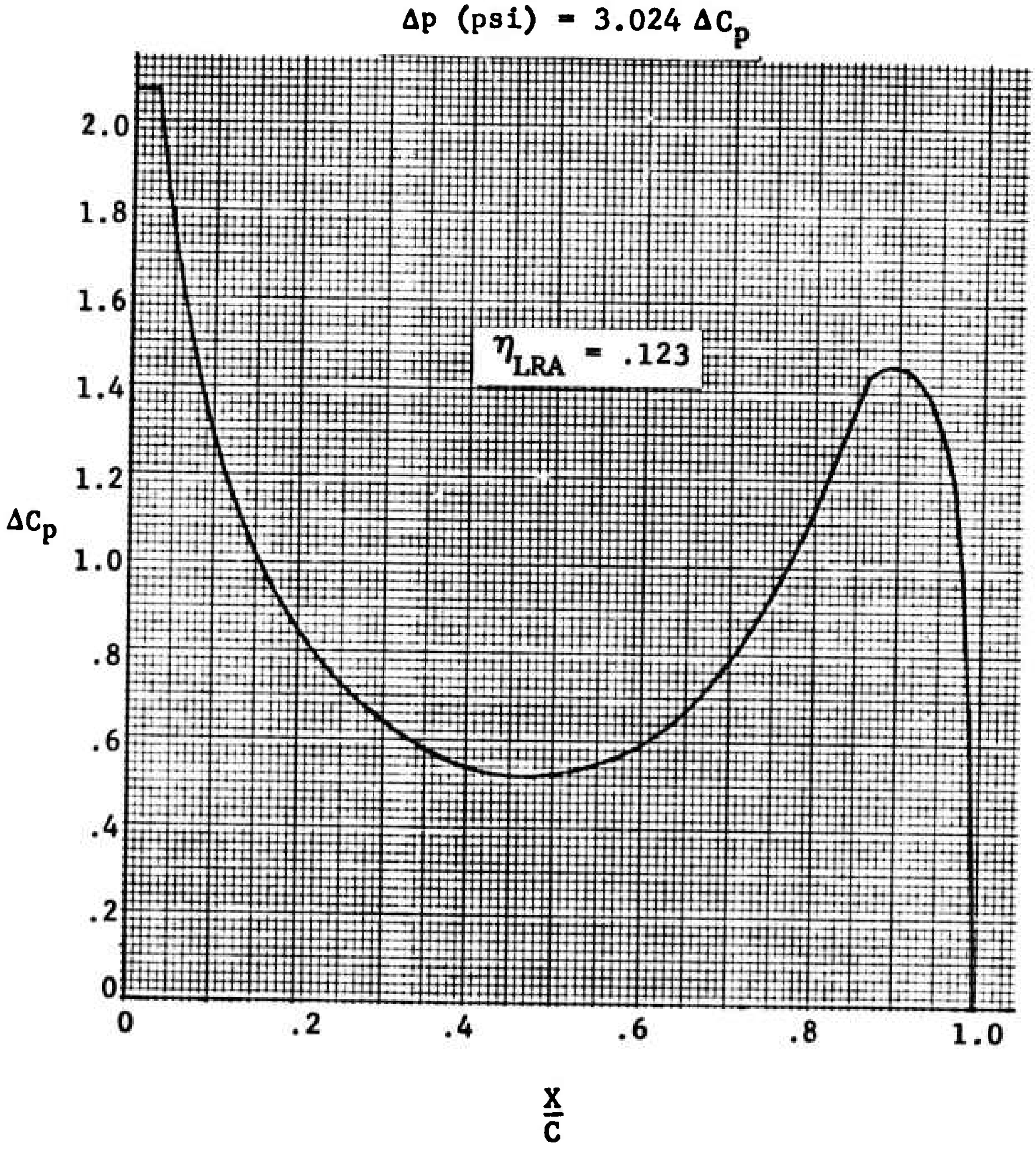


Figure A.32 ATW-4 Wing Chordwise Pressure Distribution for .123 ETA_{LRA} - Condition 3

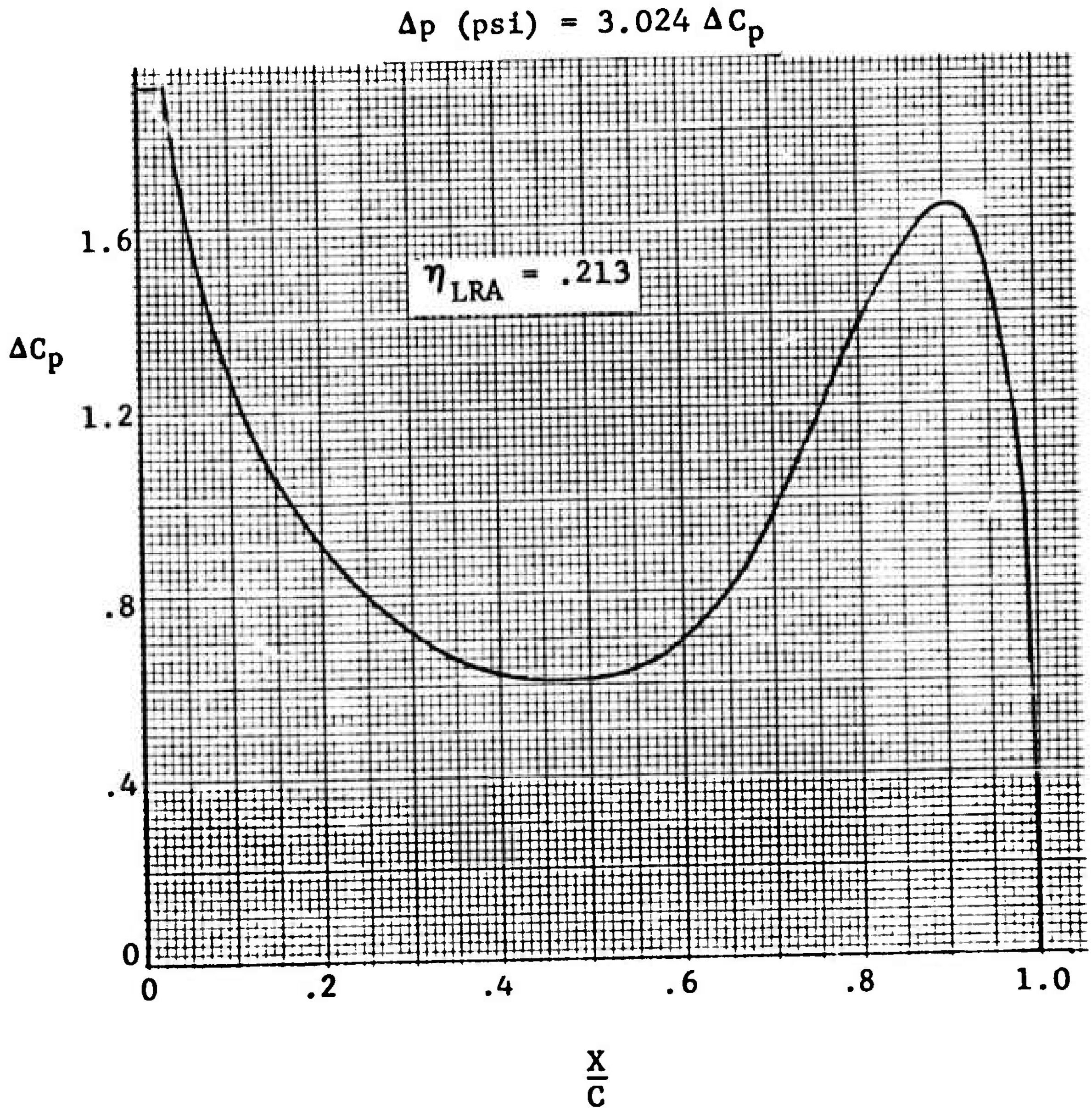


Figure A.33 ATW-4 Wing Chordwise Pressure Distribution for .213 ETA_{LRA} - Condition 3

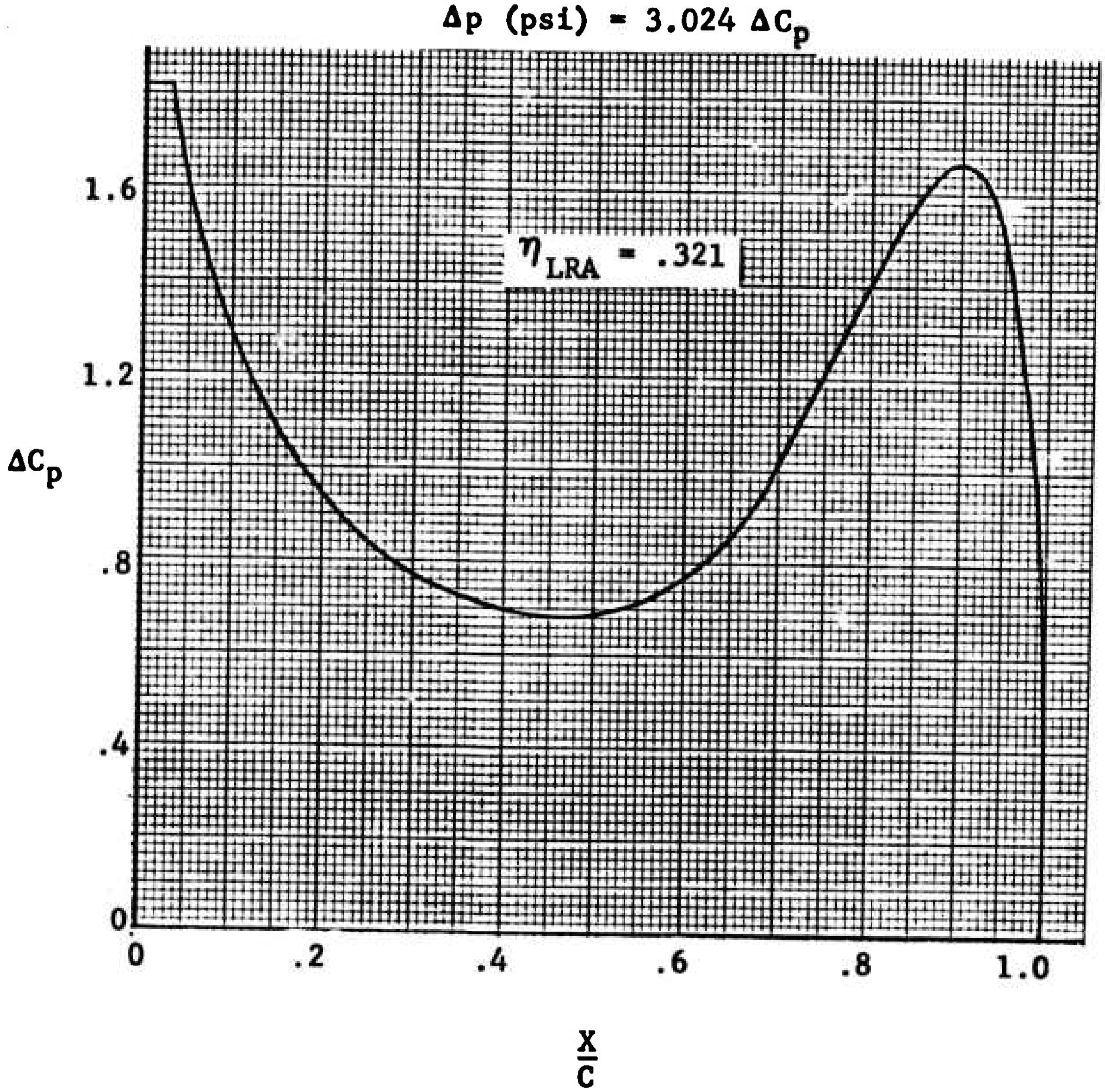


Figure A.34 ATW-4 Wing Chordwise Pressure Distribution for .321 ETA_{LRA} - Condition 3

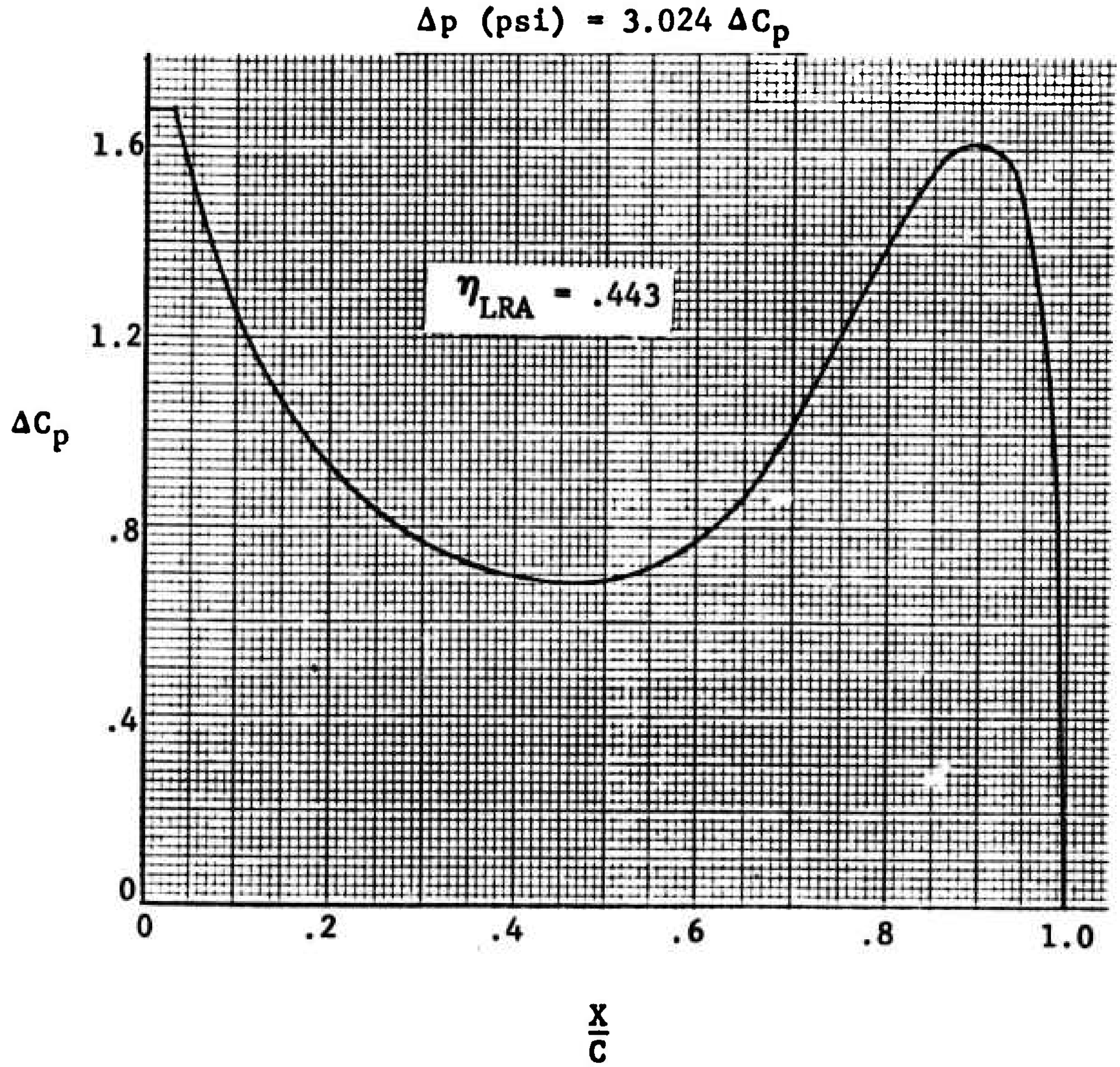


Figure A.35 ATW-4 Wing Chordwise Pressure Distribution for .443 ETA_{LRA} - Condition 3

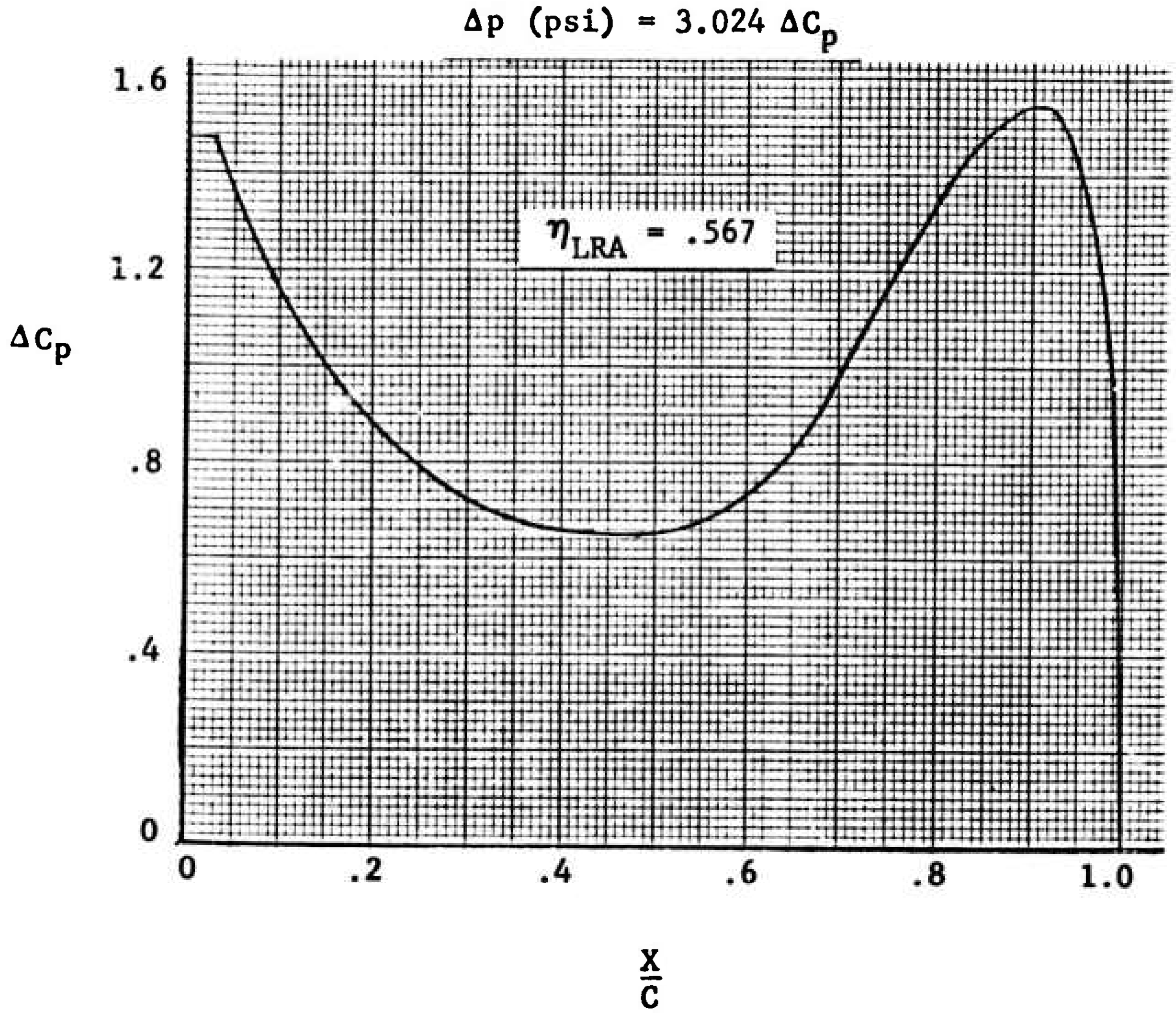


Figure A.36 ATW-4 Wing Chordwise Pressure Distribution for .567 ETA_{LRA} - Condition 3

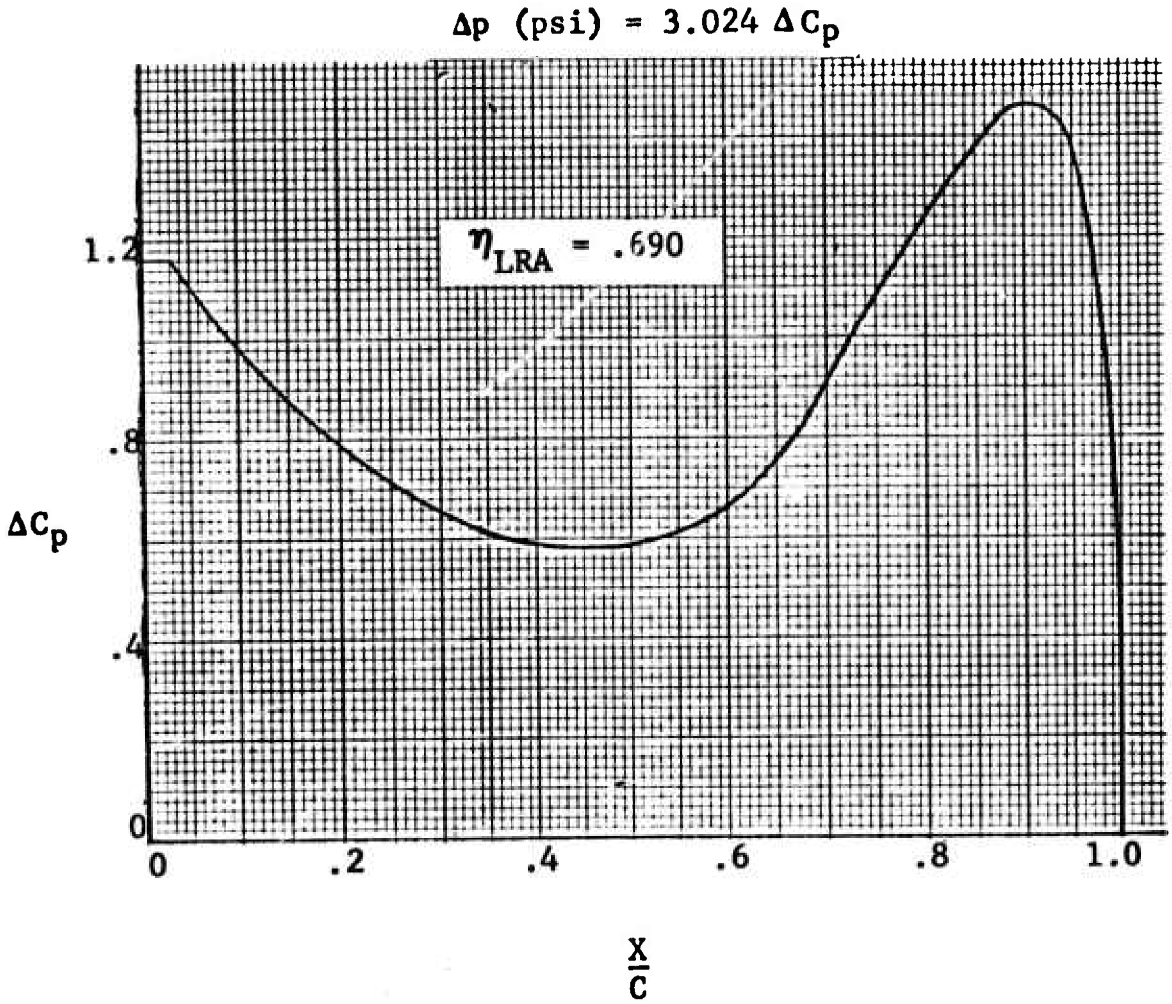


Figure A.37 ATW-4 Wing Chordwise Pressure Distribution for .690 ETA_{LRA} - Condition 3

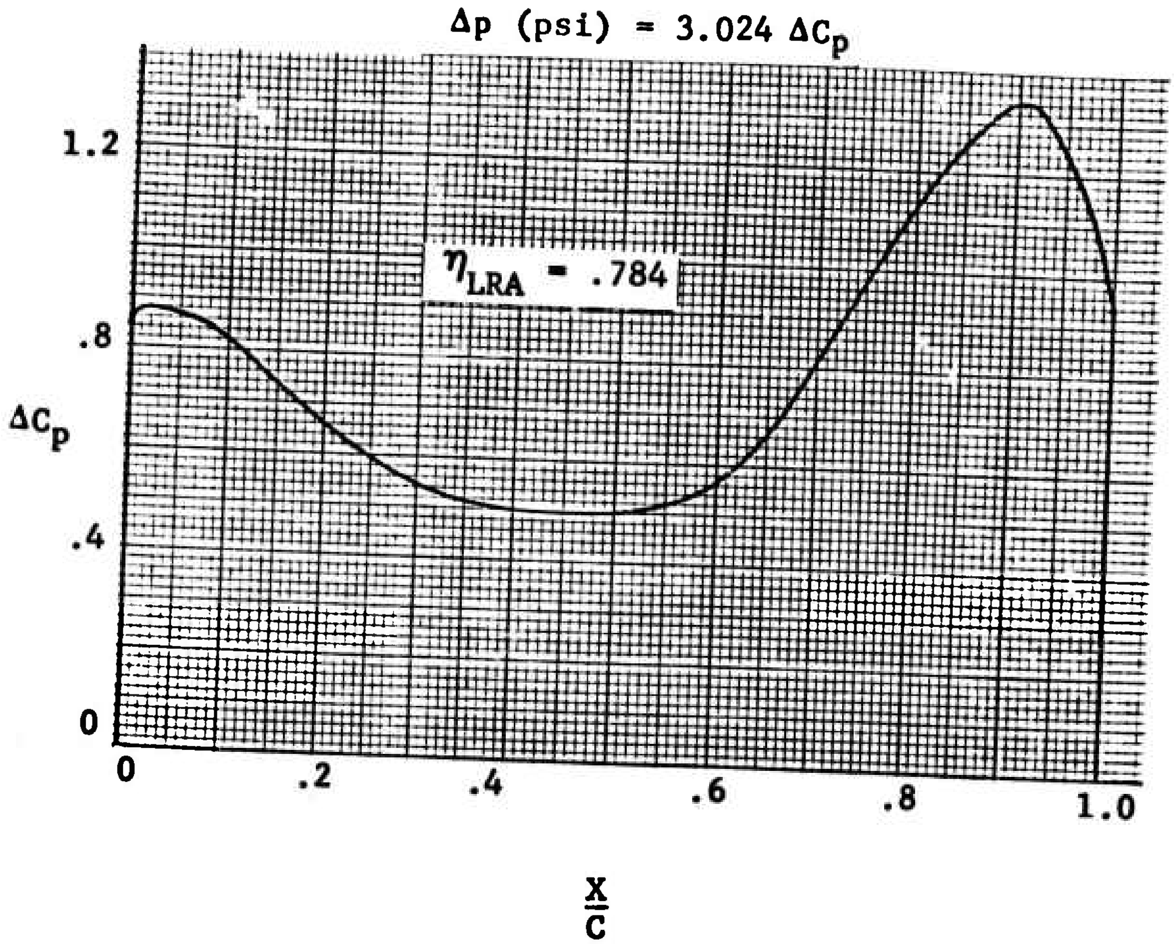


Figure A.38 ATW-4 Wing Chordwise Pressure Distribution for .784 ETA_{LRA} - Condition 3

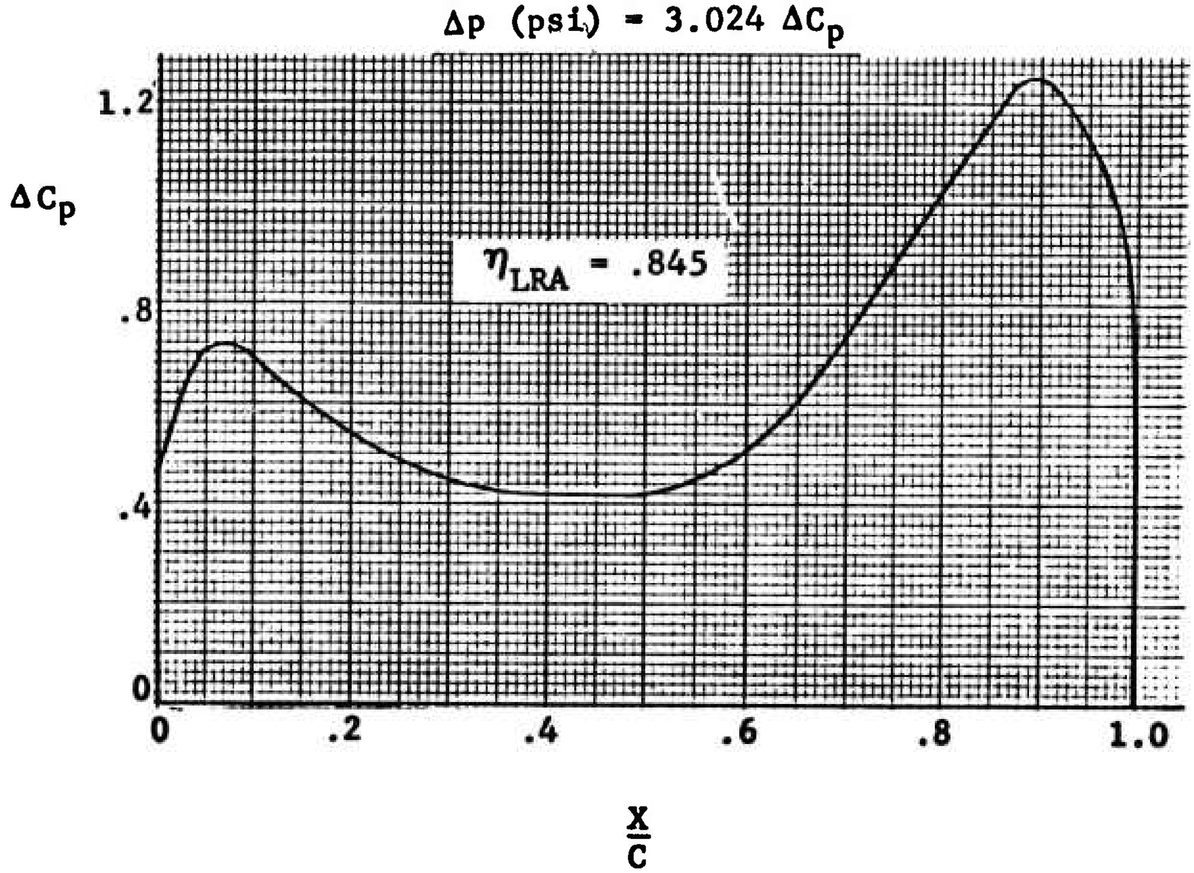


Figure A.39 ATW-4 Wing Chordwise Pressure Distribution for .845 ETA_{LRA} - Condition 3

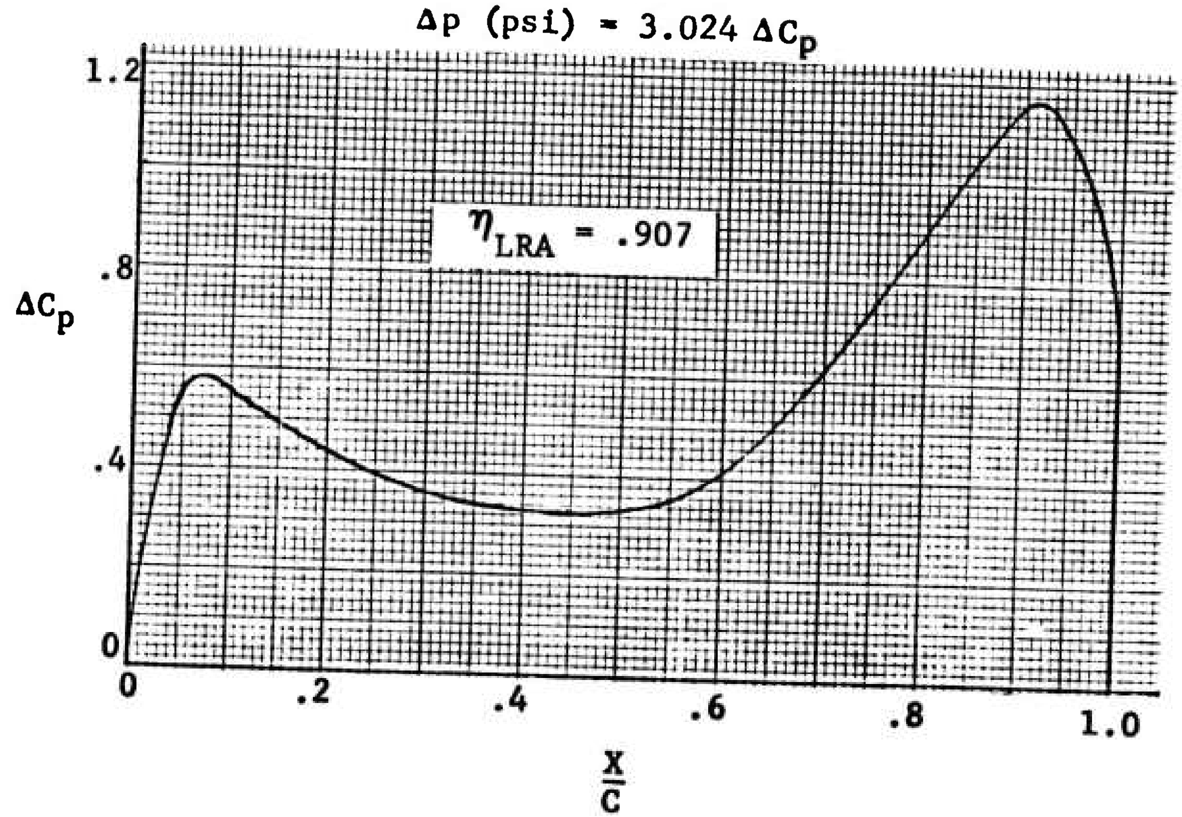


Figure A.40 ATW-4 Wing Chordwise Pressure Distributions for .907 ETA_{LRA} - Condition 3

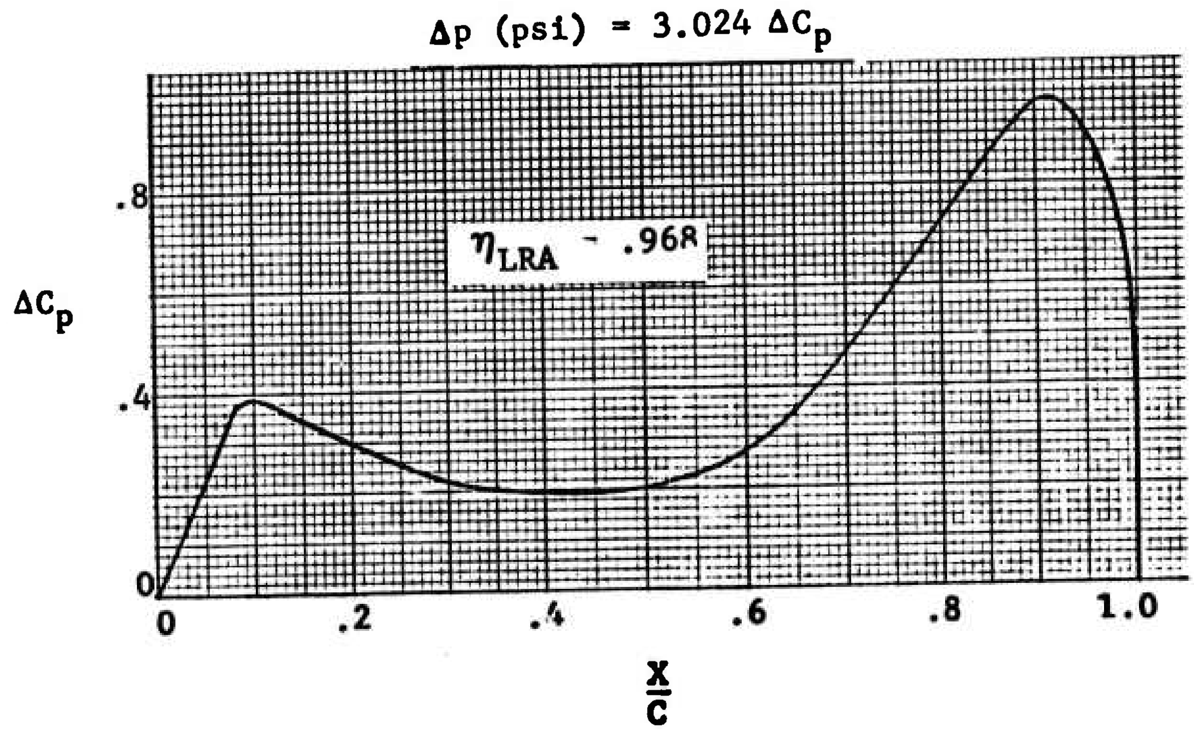


Figure A.41 ATW-4 Wing Chordwise Pressure Distribution for .968 ETA_{LRA} - Condition 3

NOTES:

1. LOCAL LIFT ON CHORDS ⊥ TO LRA
2. SEE FIGURE A-1 FOR CHORD GEOMETRY AND DIMENSIONAL DATA

Λ = 16°
M = .80
ALT = 20,000 FT
GW = 110,400 LBS
α = 6.68°
δ_{LE} = 4.0°
δ_{TE} = 3.5°

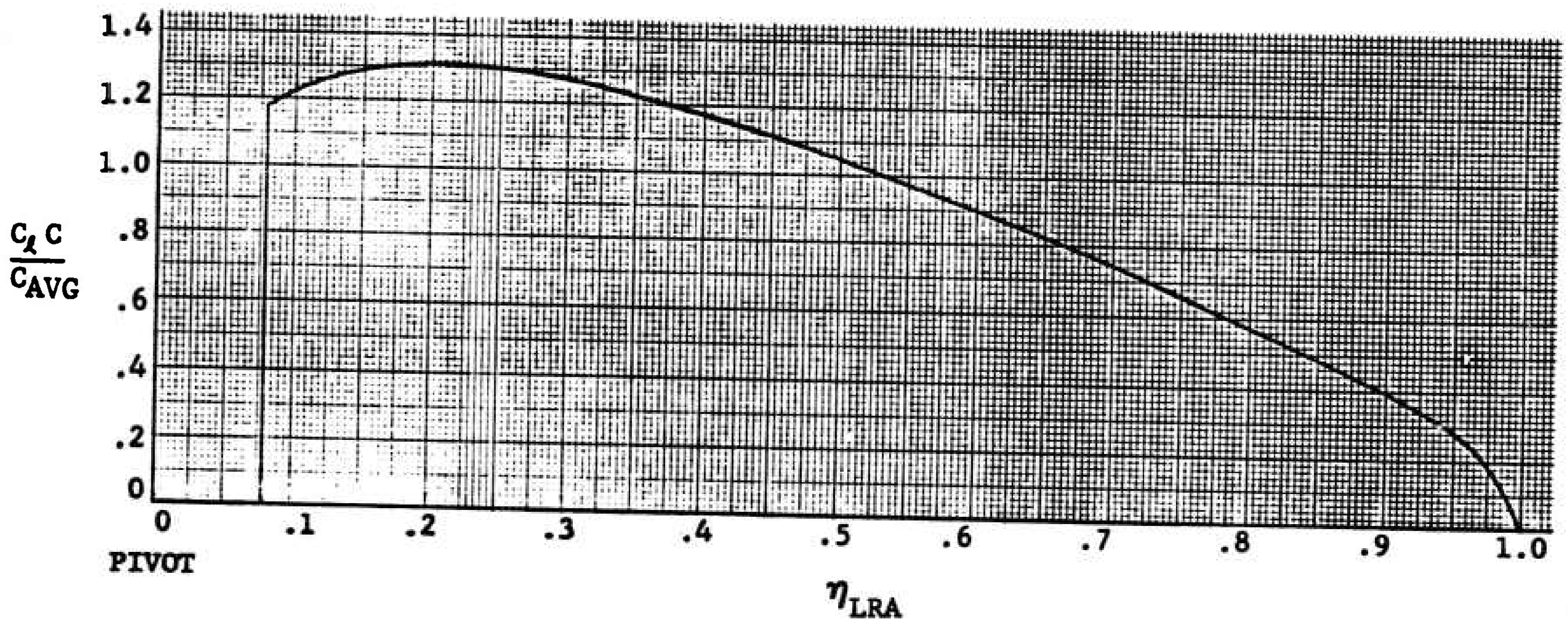


Figure A.42 ATW-4 Wing Local Lift Spanwise Distribution - Condition 3

NOTES:

1. LOCAL TORSION ON CHORDS ⊥ TO LRA
2. SEE FIGURE A-1 FOR CHORD GEOMETRY AND DIMENSIONAL DATA
3. MOM. REF. IS LRA
4. $\bar{C}$ = 117.1 IN. (THEORETICAL REF. WING MAC)

Λ = 16°
M = .80
ALT = 20,000 FT
GW = 110,400 LBS
α = 6.68°
δ_{LE} = 4.0°
δ_{TE} = 3.5°

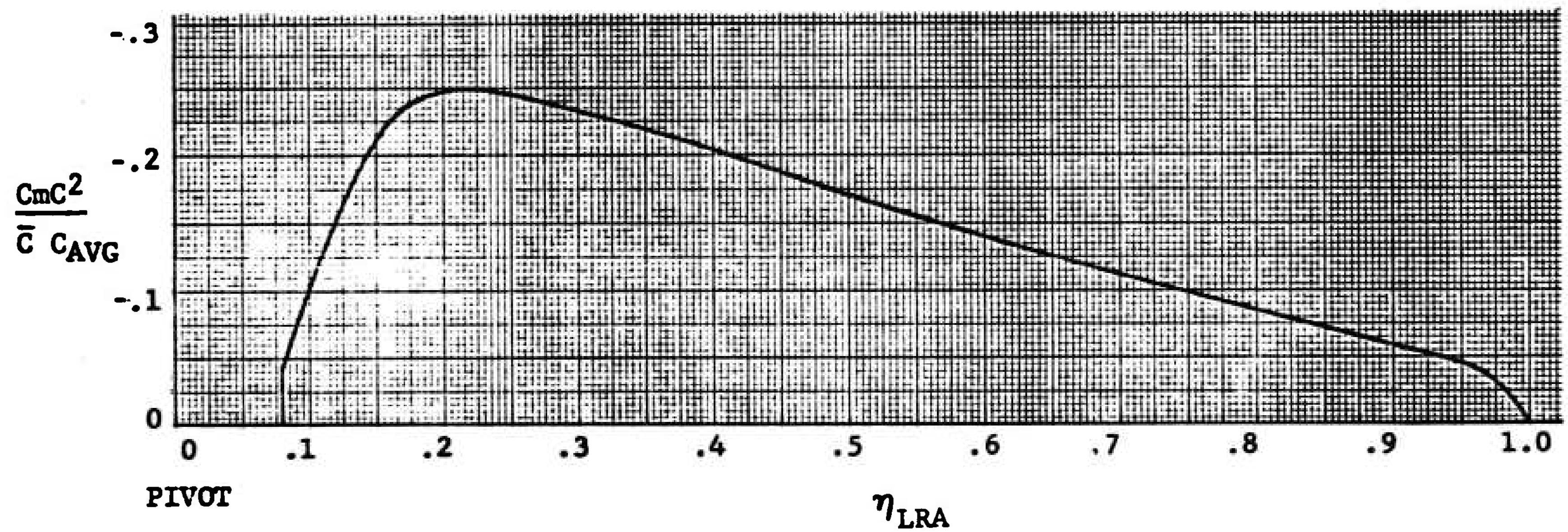


Figure A.43 ATW-4 Wing Local Torsion Spanwise Distribution - Condition 3

A.5.5 Condition 4 - Refuel with Roll Maneuver

Figures A.44 through A.58 define the preliminary design loads for the refuel mission segment with roll maneuver loads applied.

Λ = 16°
M = .80
ALT = 20,000 FT
GW = 110,400 LBS (EMPTY WING TANKS)
n_Z = 1.92g
δ_{LE} = 10°
δ_{TE} = 3.5° @ I/B END TO 8.5° @ O/B END

NOTE: EFFECTS OF ROLL DAMPING AND ROLL ACCELERATION ARE NEGLECTED.

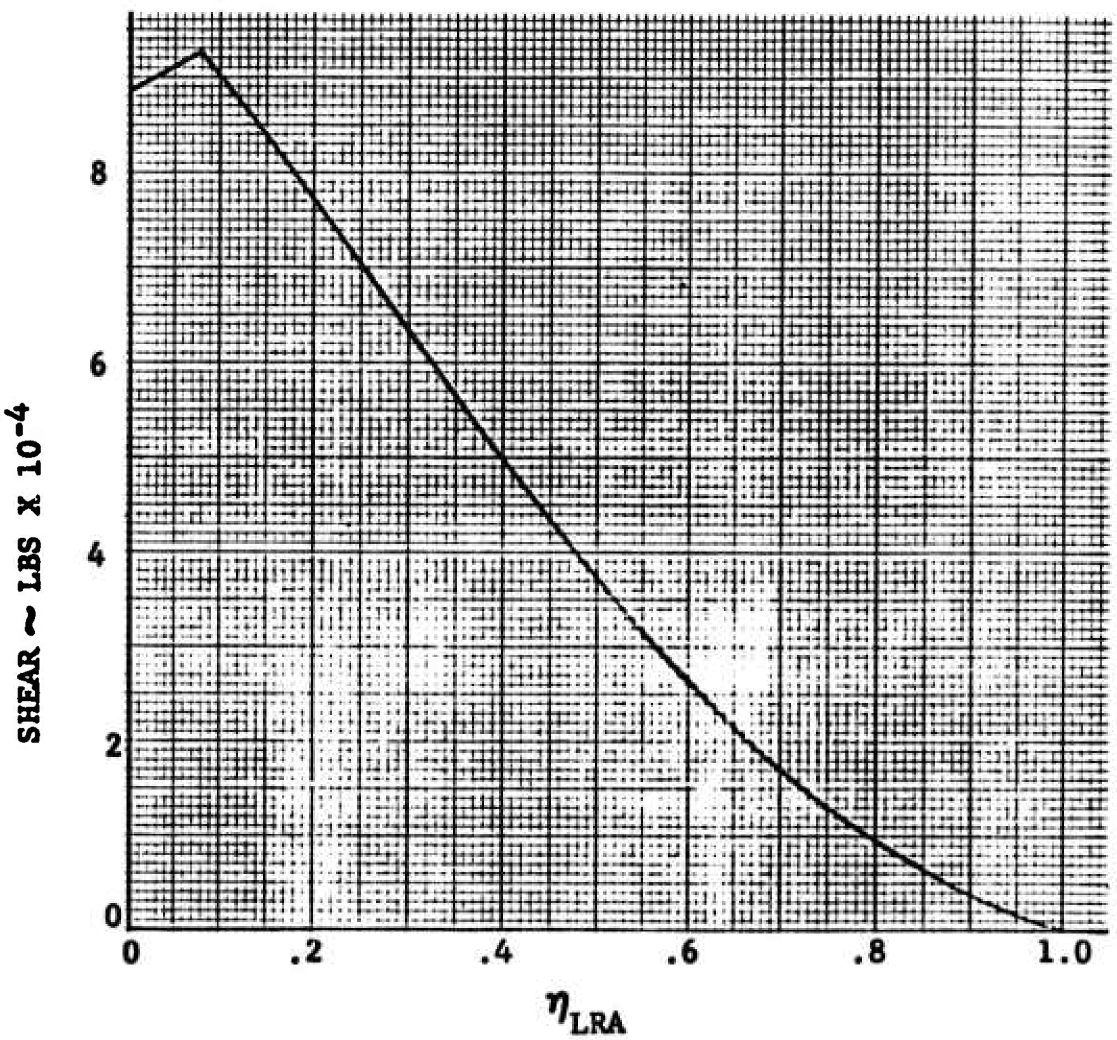


Figure A.44 ATW-4 Wing Shear Distribution - Condition 4

Λ = 16°
M = .80
ALT = 20,000 FT
GW = 110,400 LBS (EMPTY WING TANKS)
n_Z = 1.92g
δ_{LE} = 10°
δ_{TE} = 3.5° @ I/B END TO 8.5° @ O/B END

NOTE: EFFECTS OF ROLL DAMPING AND ROLL ACCELERATION ARE NEGLECTED.

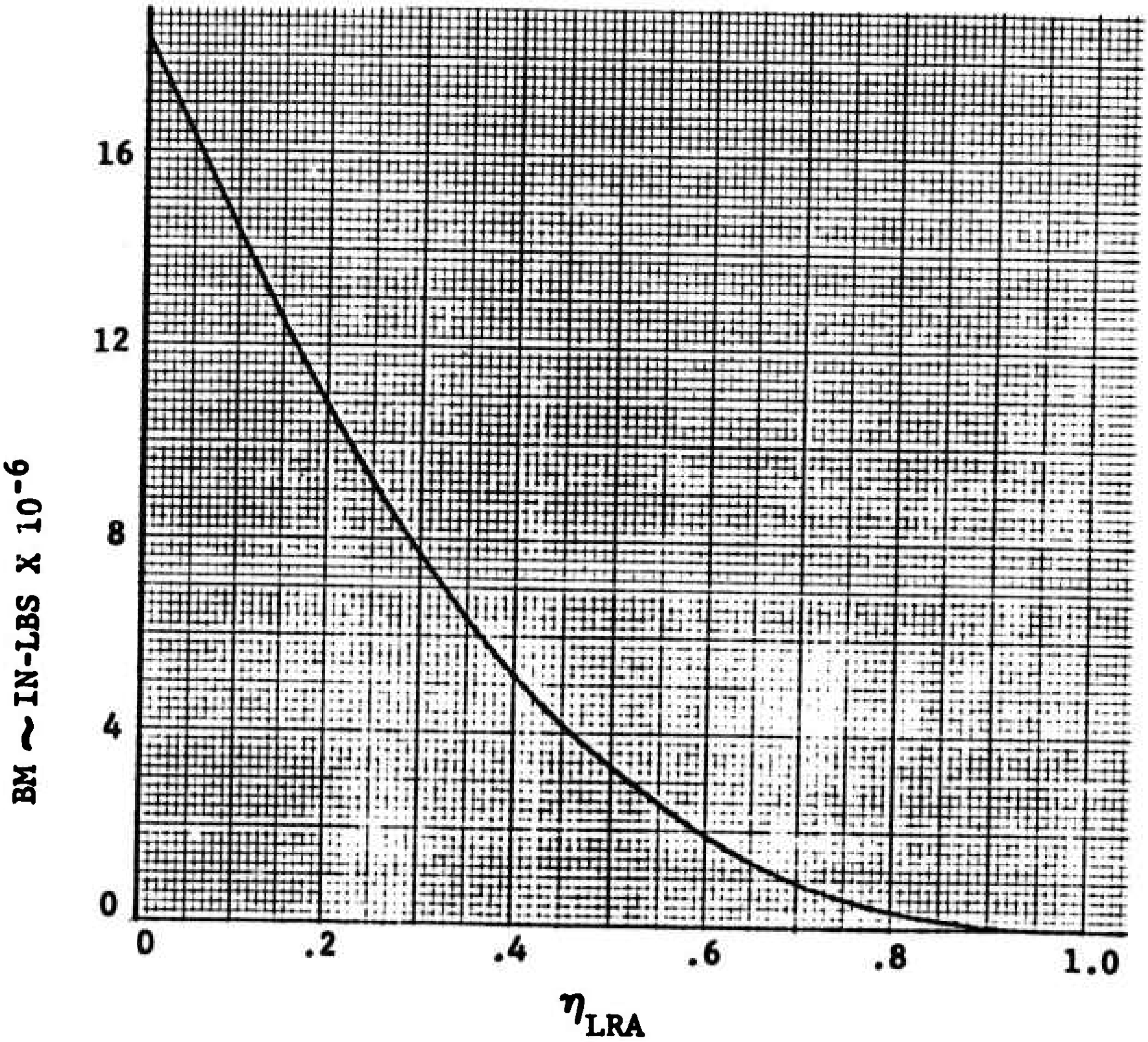


Figure A.45 ATW-4 Wing Bending Moment Distribution - Condition 4

Λ = 16°
M = .80
ALT = 20,000 FT
GW = 110,400 LBS (EMPTY WING TANKS)
n_Z = 1.92g
δ_{LE} = 10°
δ_{TE} = 3.5° @ I/B END TO 8.5° @ O/B END

NOTE: EFFECTS OF ROLL DAMPING AND ROLL ACCELERATION ARE NEGLECTED

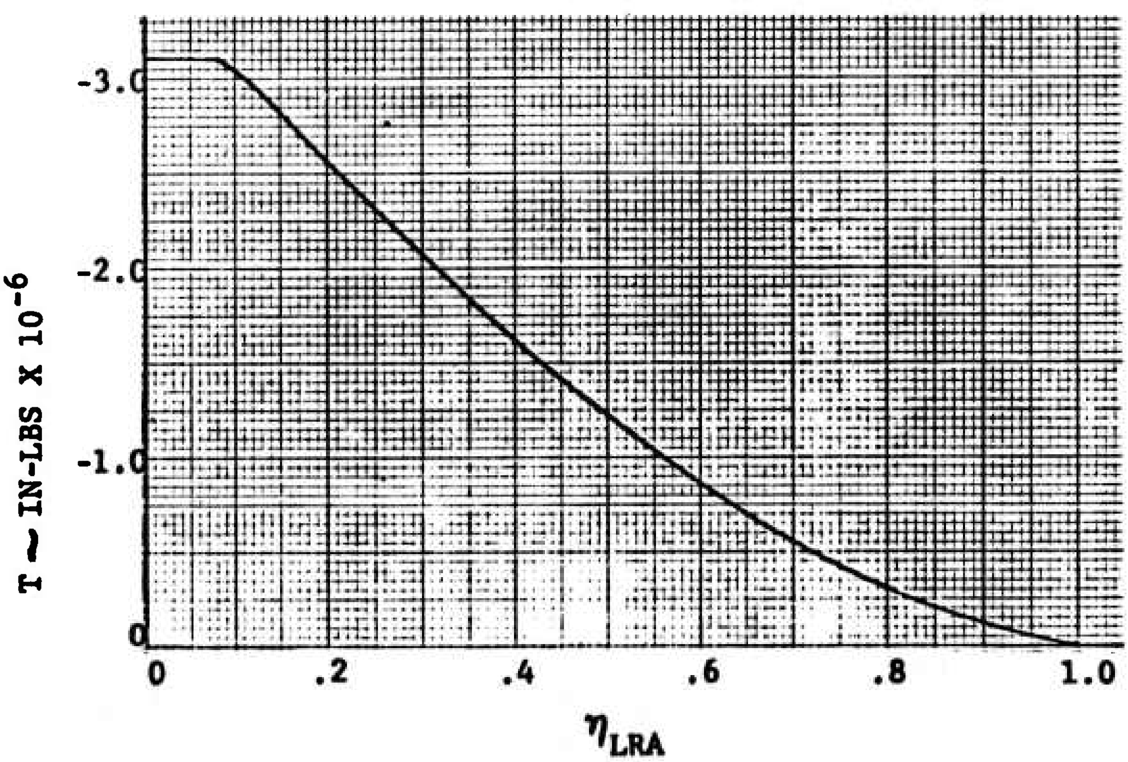


Figure A.46 ATW-4 Wing Torsion Distribution - Condition 4

Λ = 16°
M = .80
ALT = 20,000 FT.
GW = 110,400 LBS
n_Z = 1.9g's
δ_{LE} = 10°
δ_{TE} = 3.0° @ I/B END TO 8.5° @ O/B END

NOTES:

1. X_{cp} MEAS. FWD OF .15C @ L.E. FLAP
2. X_{cp} MEAS. AFT OF .65C @ T.E. FLAP
3. C_F = LOCAL FLAP CHORD

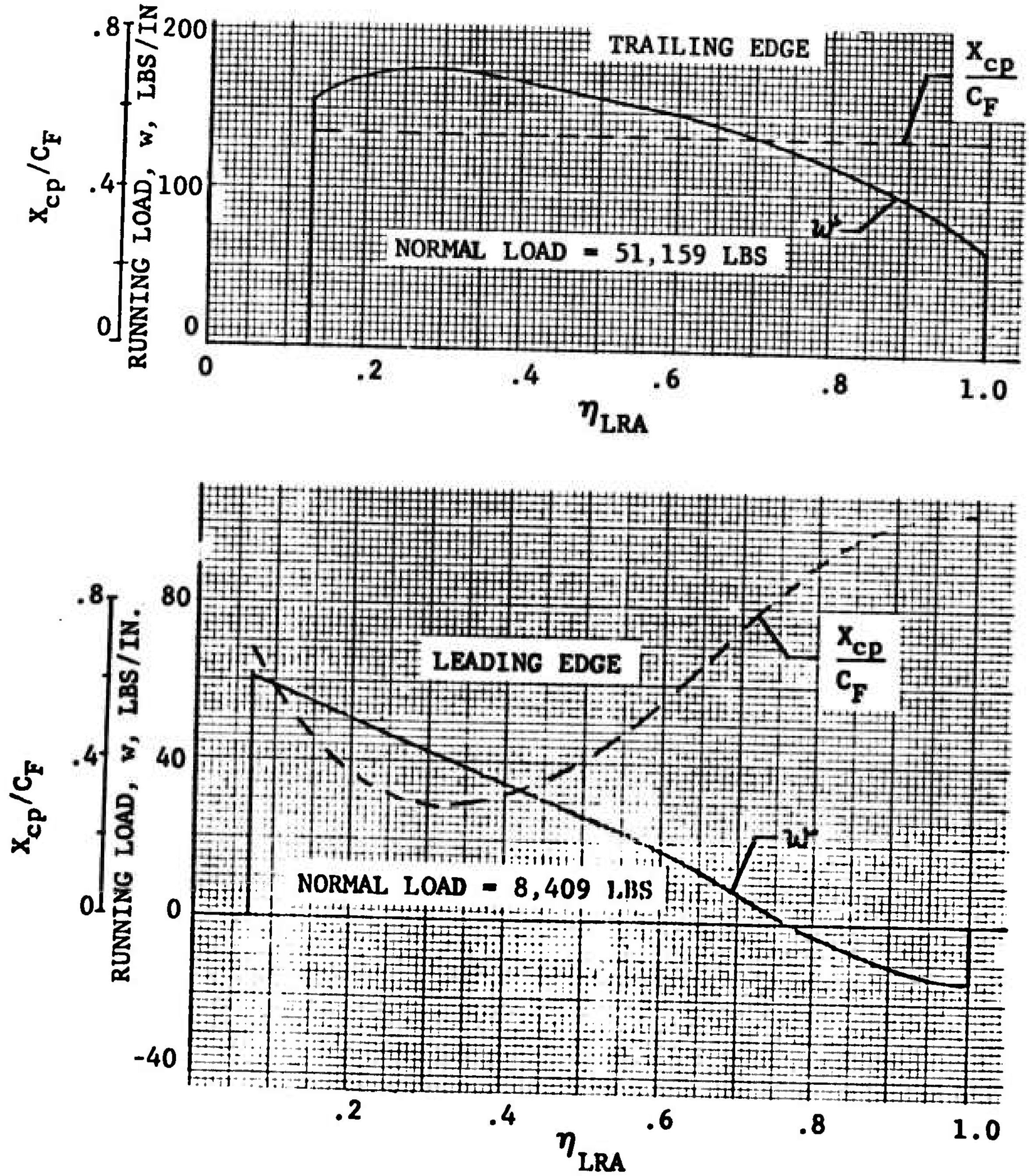


Figure A.47 ATW-4 Wing Leading and Trailing Edge Flap Running Loads - Condition 4

Δp (psi) = $3.024\, \Delta C_p$

$\eta_{LRA} = .123$

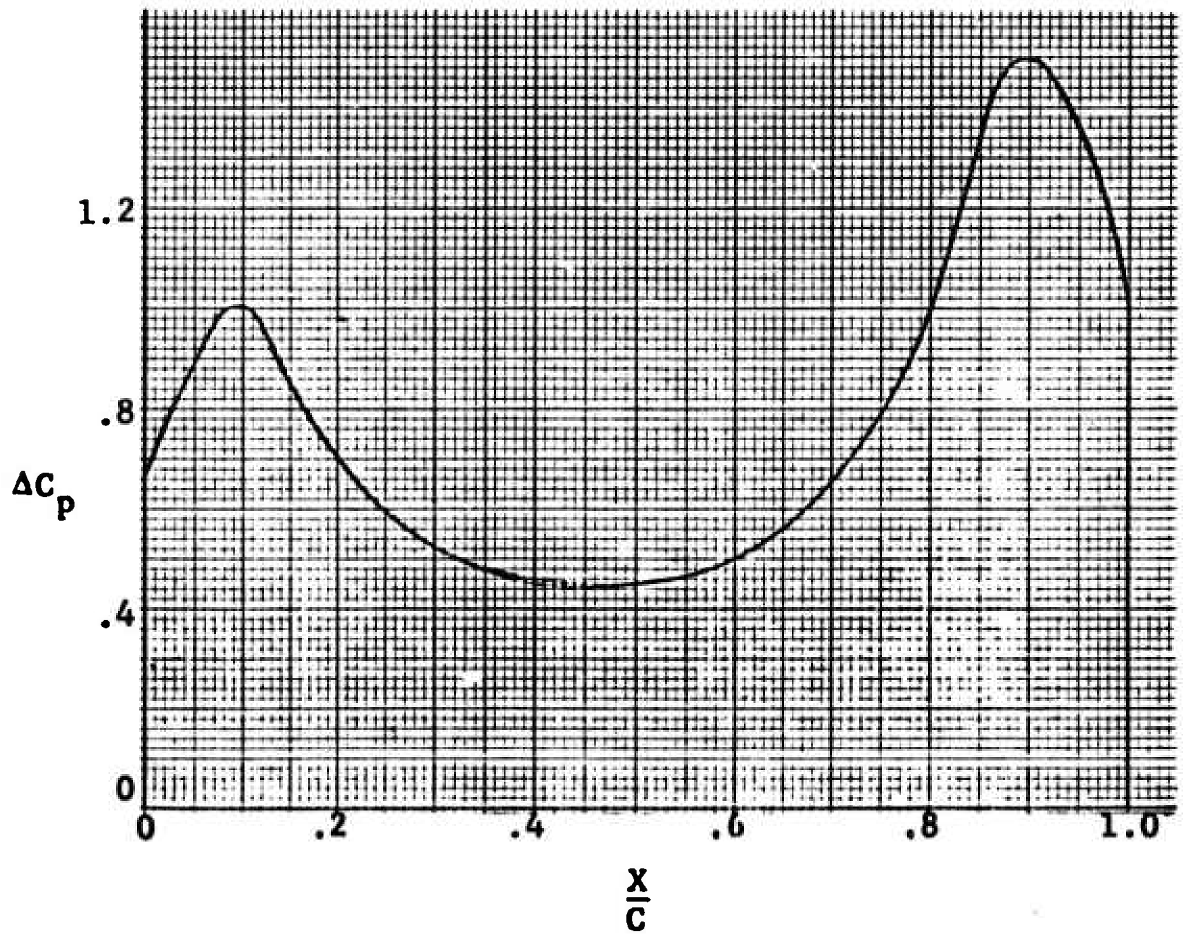


Figure A.48 ATW-4 Wing Chordwise Pressure Distribution for .123 ETA_{LRA} - Condition 4

Δp (psi) = 3.024 ΔC_p

η_{LRA} = .213

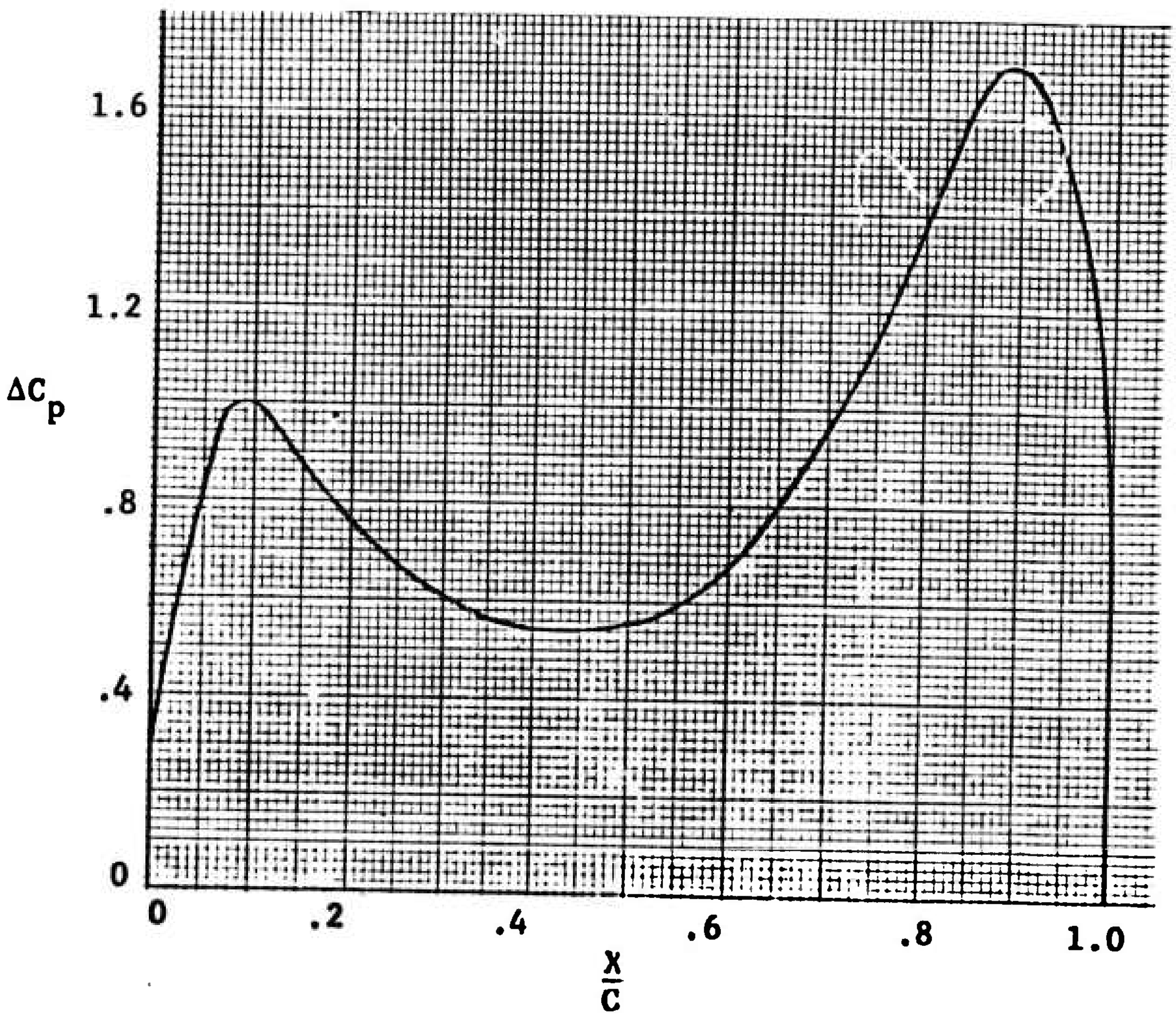


Figure A.49 ATW-4 Wing Chordwise Pressure Distribution for .213 ETA_{LRA} - Condition 4

Δp (psi) = 3.024 ΔC_p

η_{LRA} = .321

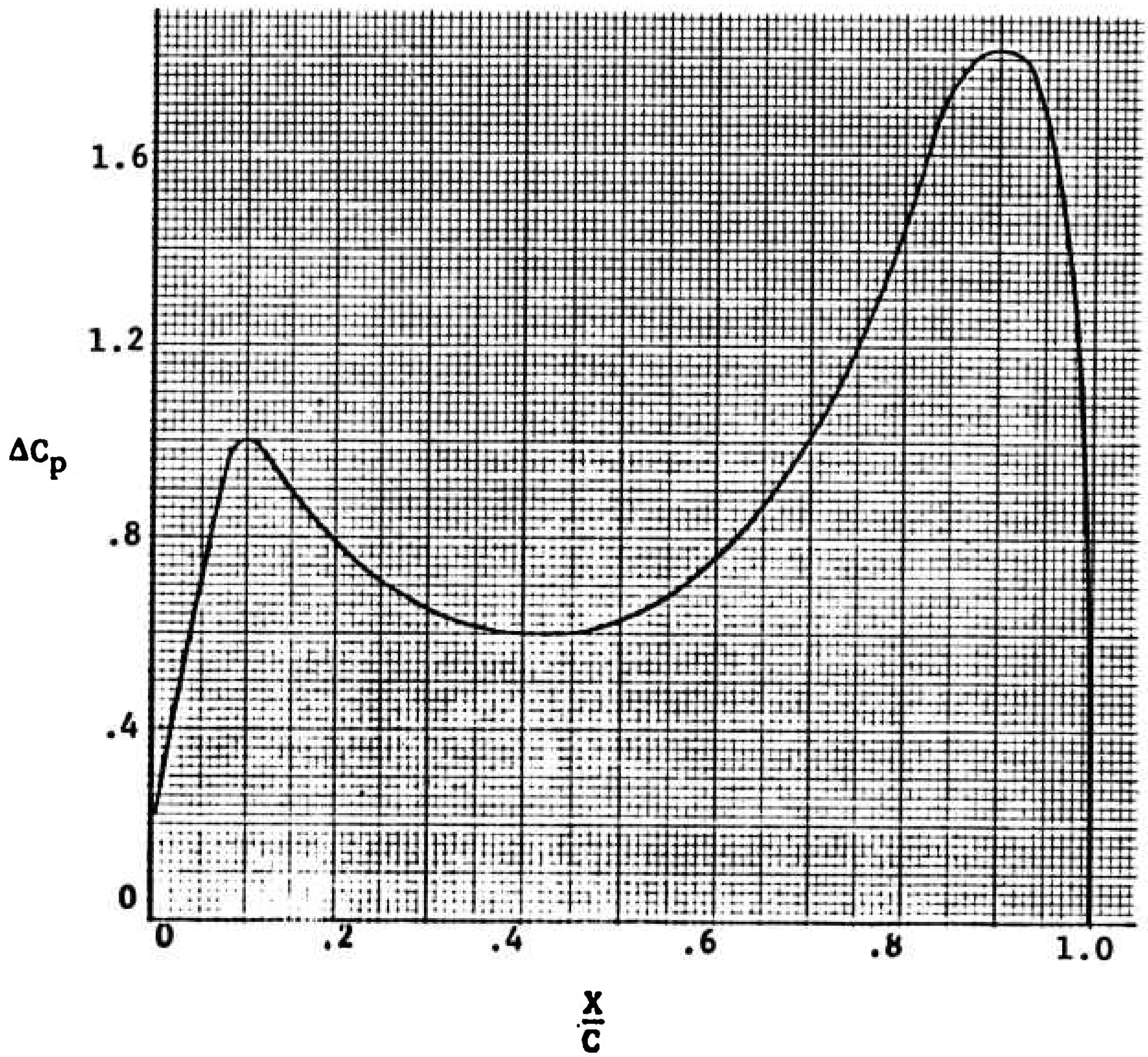


Figure A.50 ATW-4 Wing Chordwise Pressure Distribution for .321 ETA_{LRA} - Condition 4

$\Delta p \text{ (psi)} = 3.024\, \Delta C_p$

$\eta_{LRA} = .443$

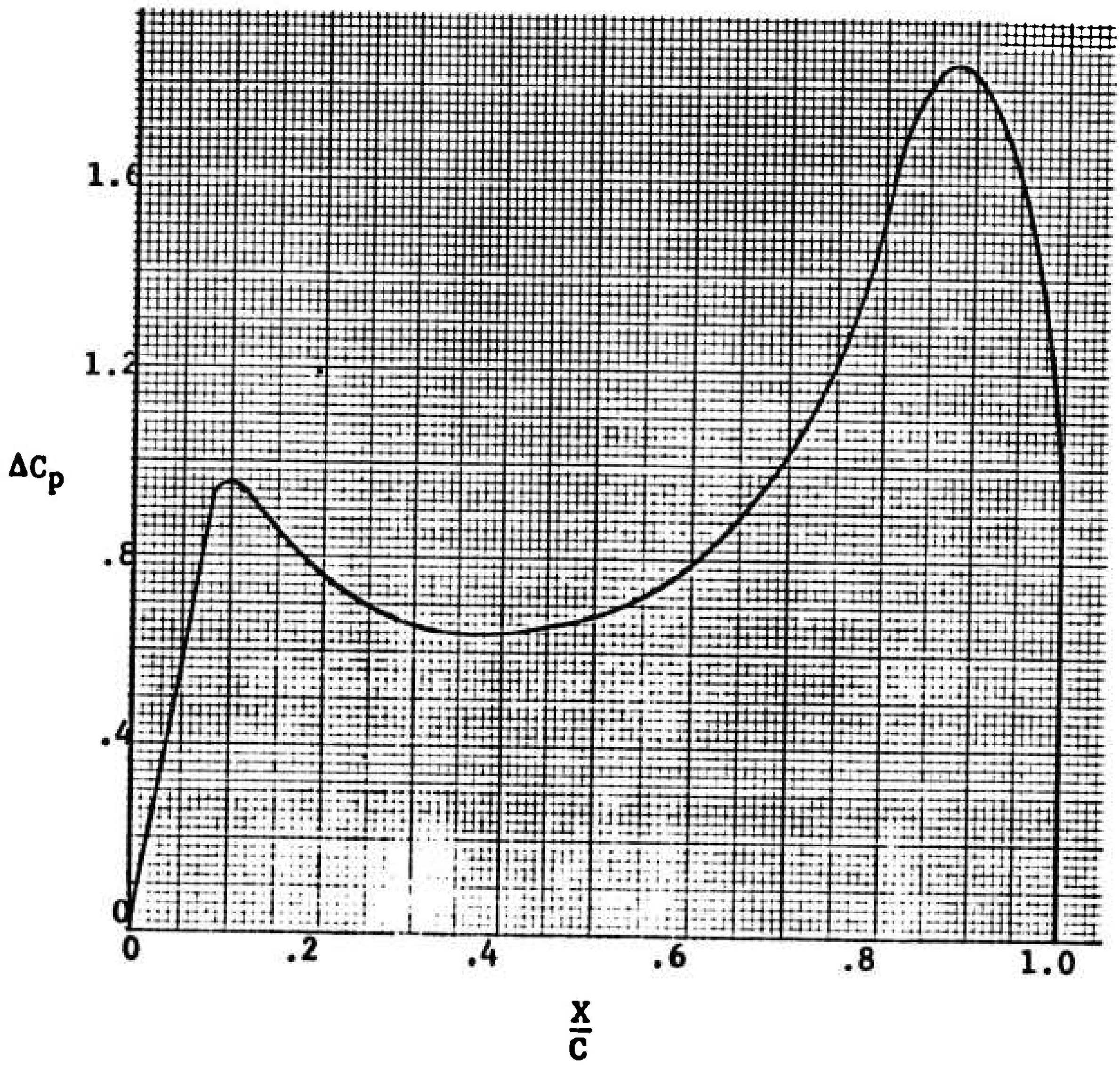


Figure A.51 ATW-4 Wing Chordwise Pressure Distribution for .443 ETA_{LRA} - Condition 4

Δp (psi) = 3.024 ΔC_p

η_{LRA} = .567

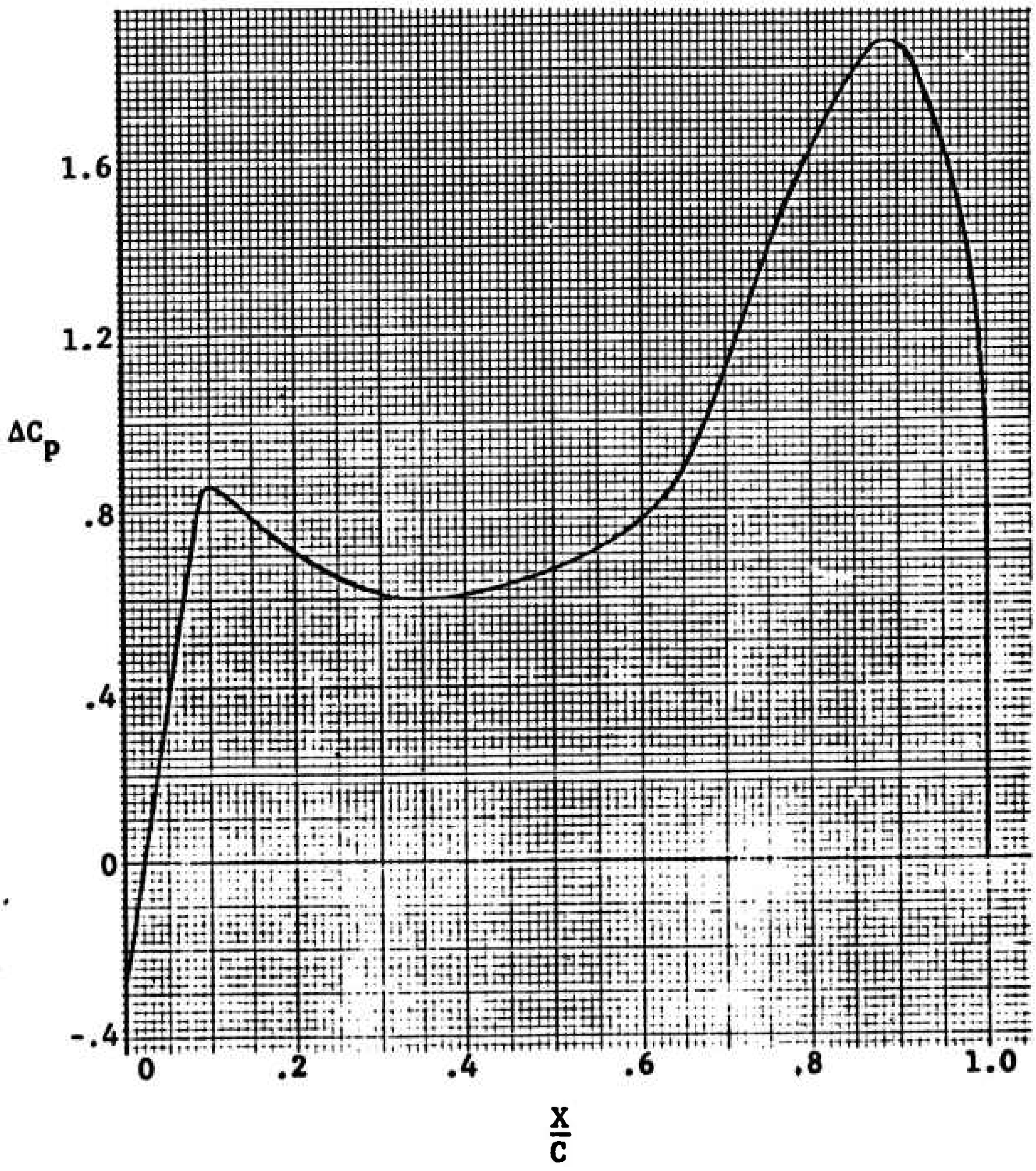


Figure A.52 ATW-4 Wing Chordwise Pressure Distribution for .567 ETA_{LRA} - Condition 4

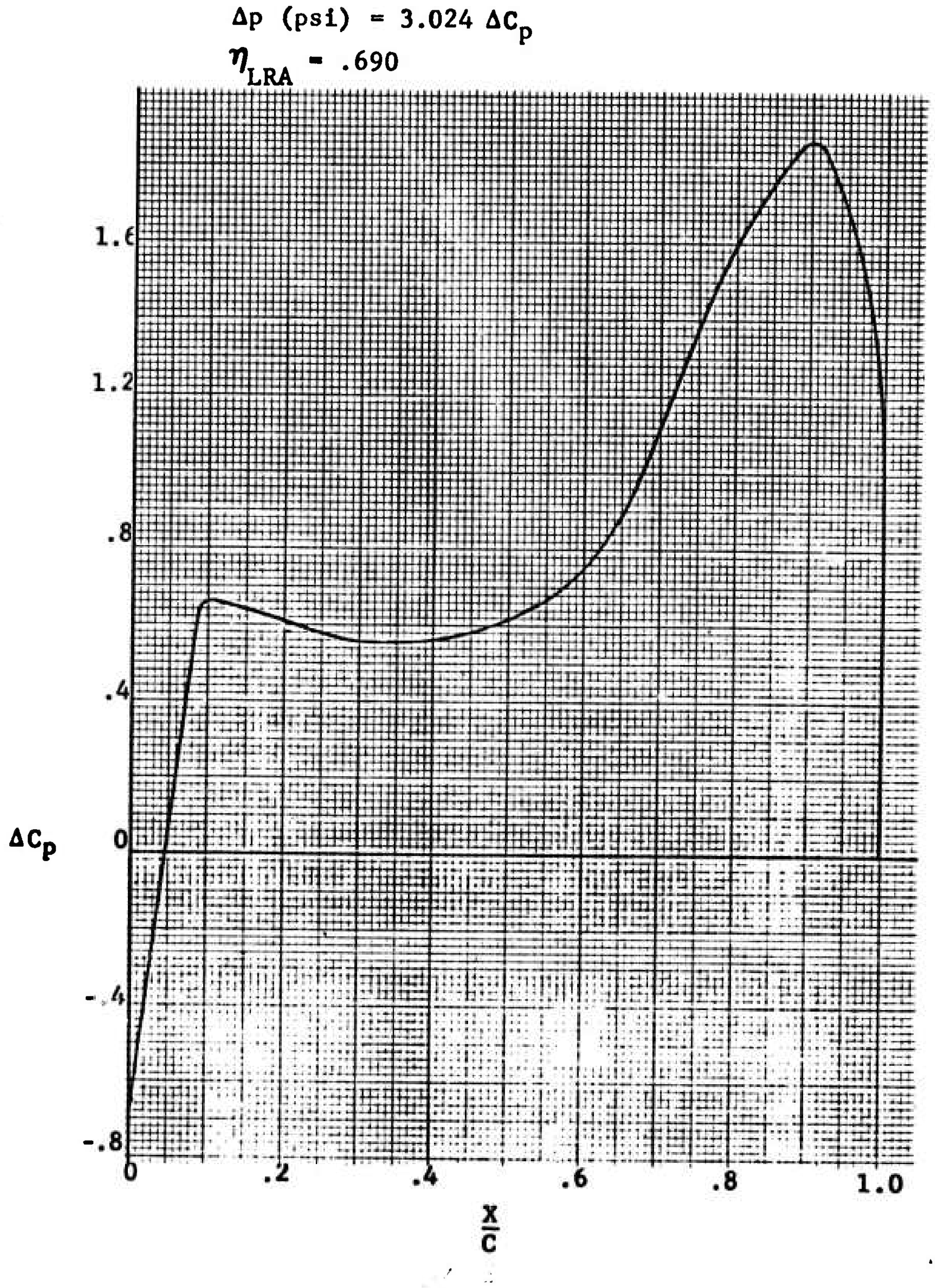


Figure A.53 ATW-4 Wing Chordwise Pressure Distribution for .690 ETA_{LRA} - Condition 4

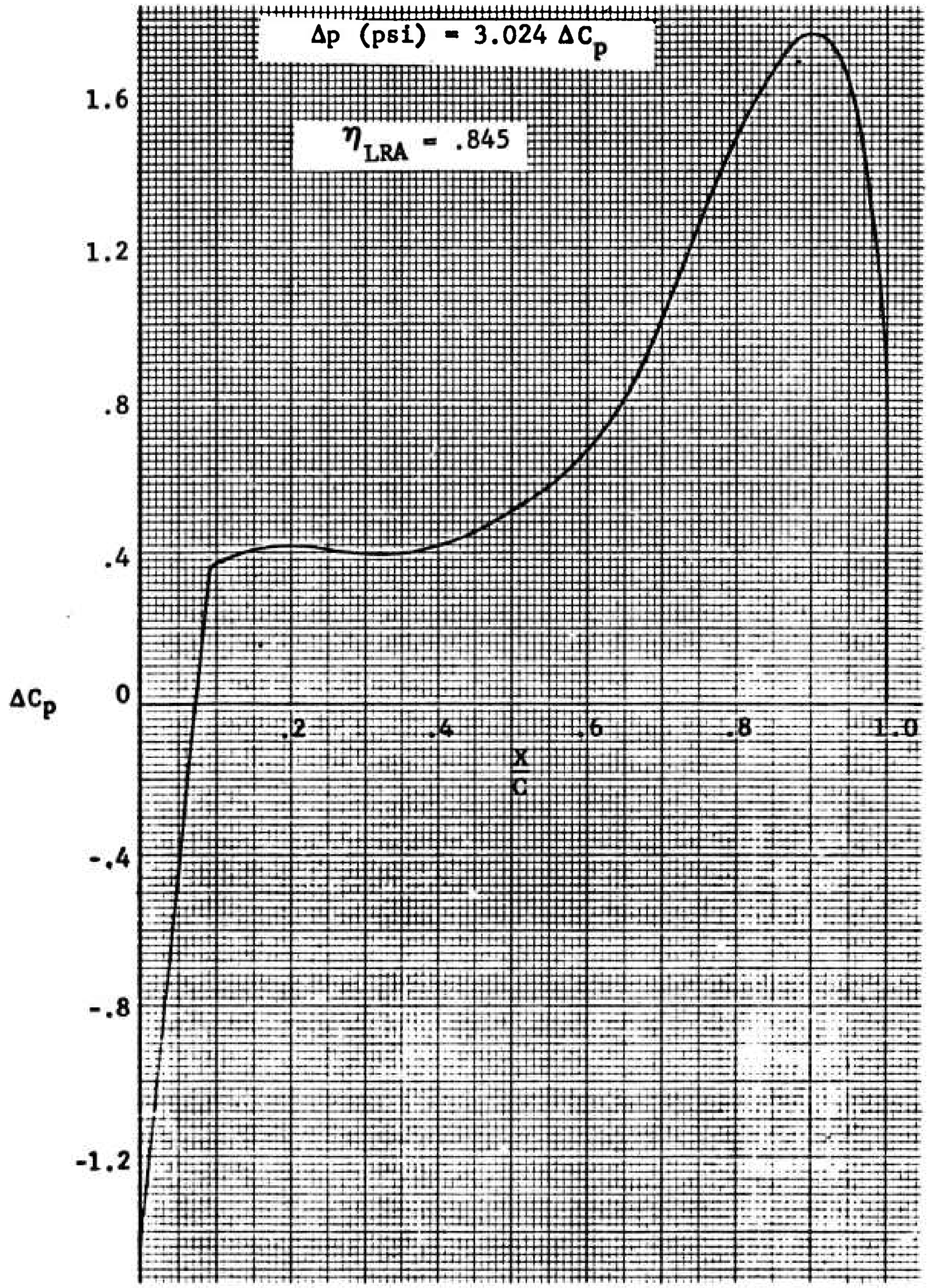


Figure A.54 ATW-4 Wing Chordwise Pressure Distribution for .845 ETA_{LRA} - Condition 4

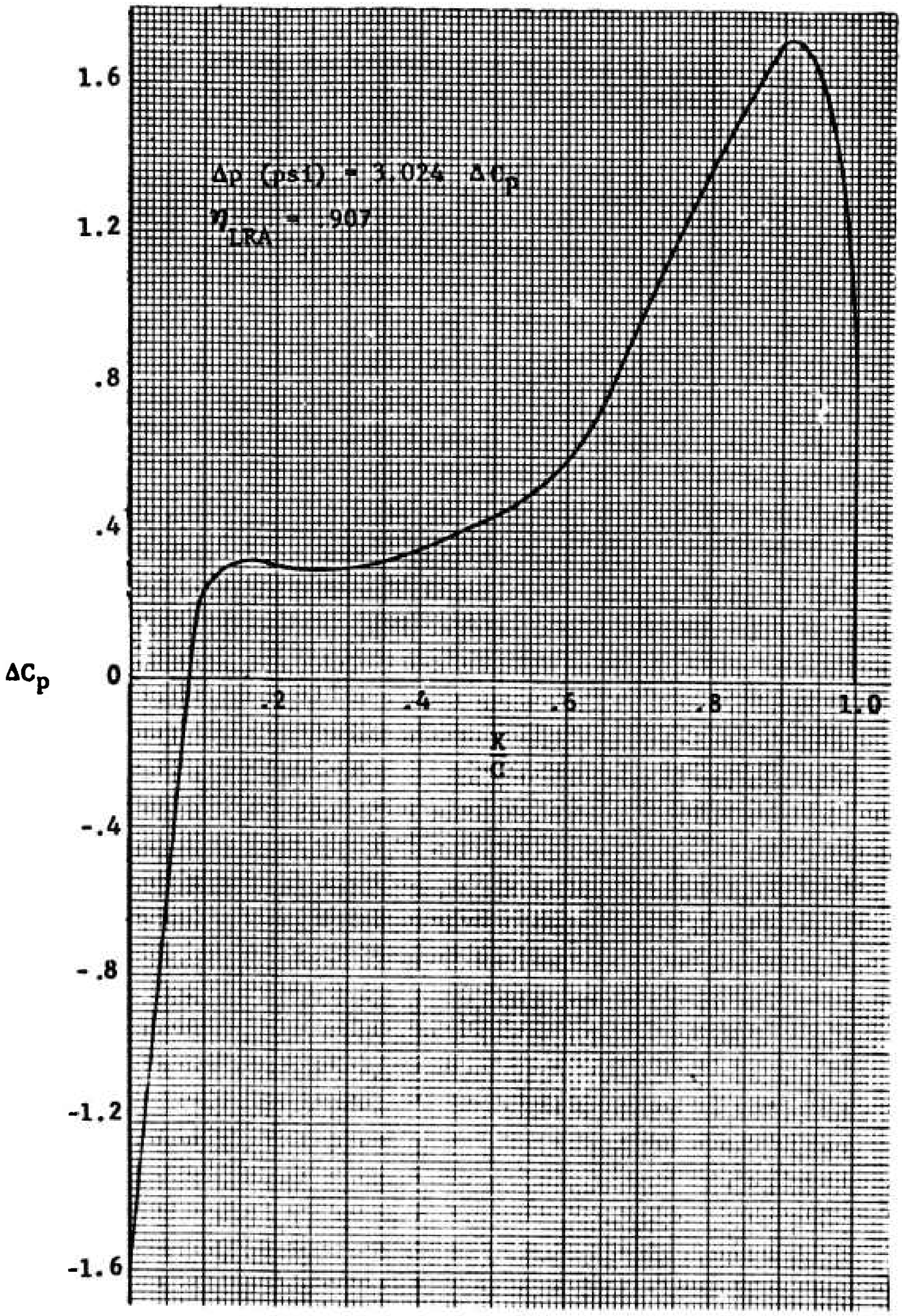


Figure A.55 ATW-4 Wing Chordwise Pressure Distribution for .907 ETA_{LRA} - Condition 4

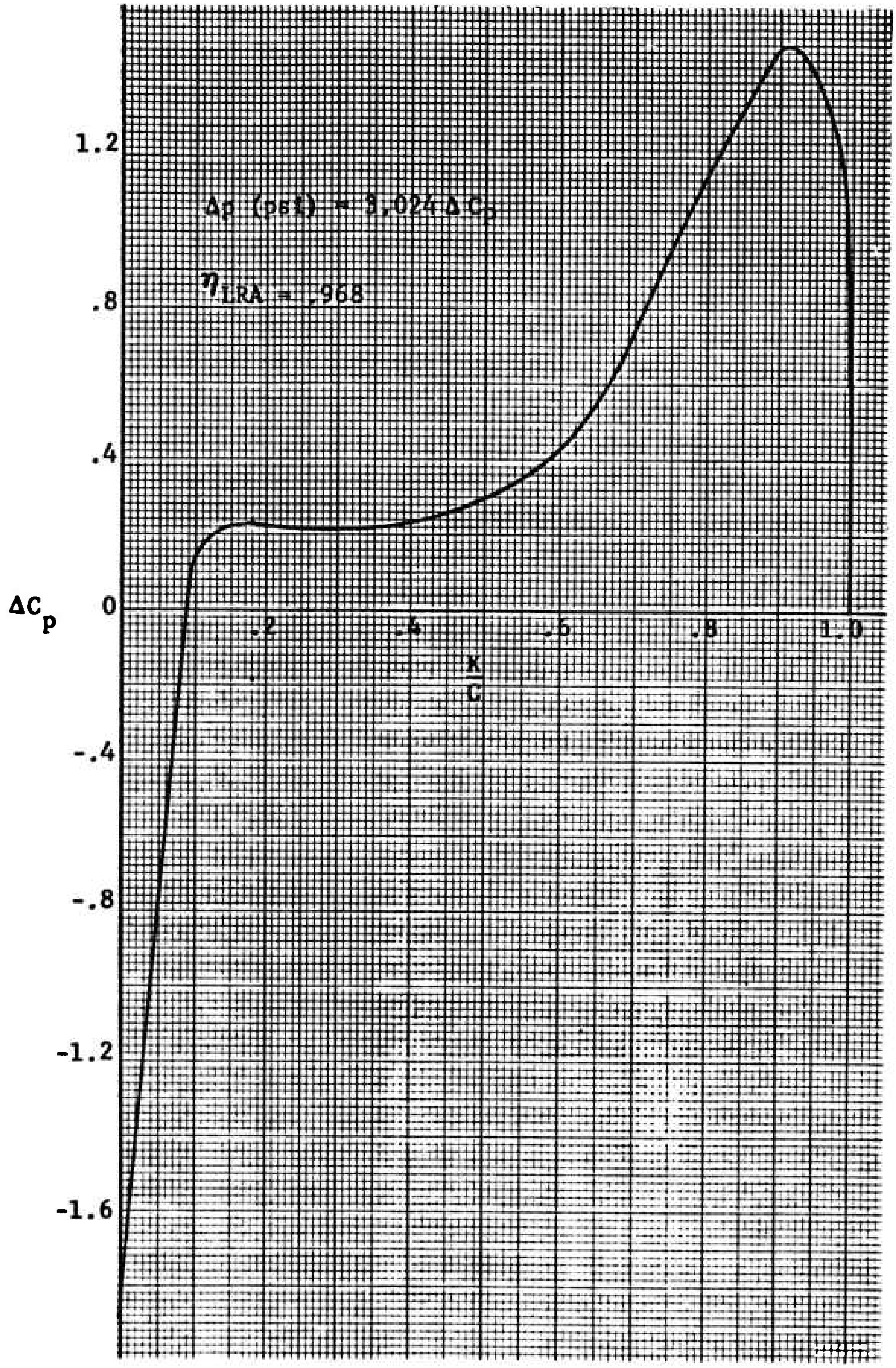


Figure A.56 ATW-4 Wing Chordwise Pressure Distribution for .968 ETA_{LRA} - Condition 4

NOTES:

1. LOCAL LIFT ON CHORDS ⊥ TO LRA
2. SEE FIGURE A-1 FOR CHORD GEOMETRY AND DIMENSIONAL DATA

Λ = 16°
M = .80
ALT = 20,000 FT
GW = 110,400 LBS
α = 4.8°
δ_{LE} = 10°
δ_{TE} = 3.5° @ I/B END TO 8.5° @ O/B END

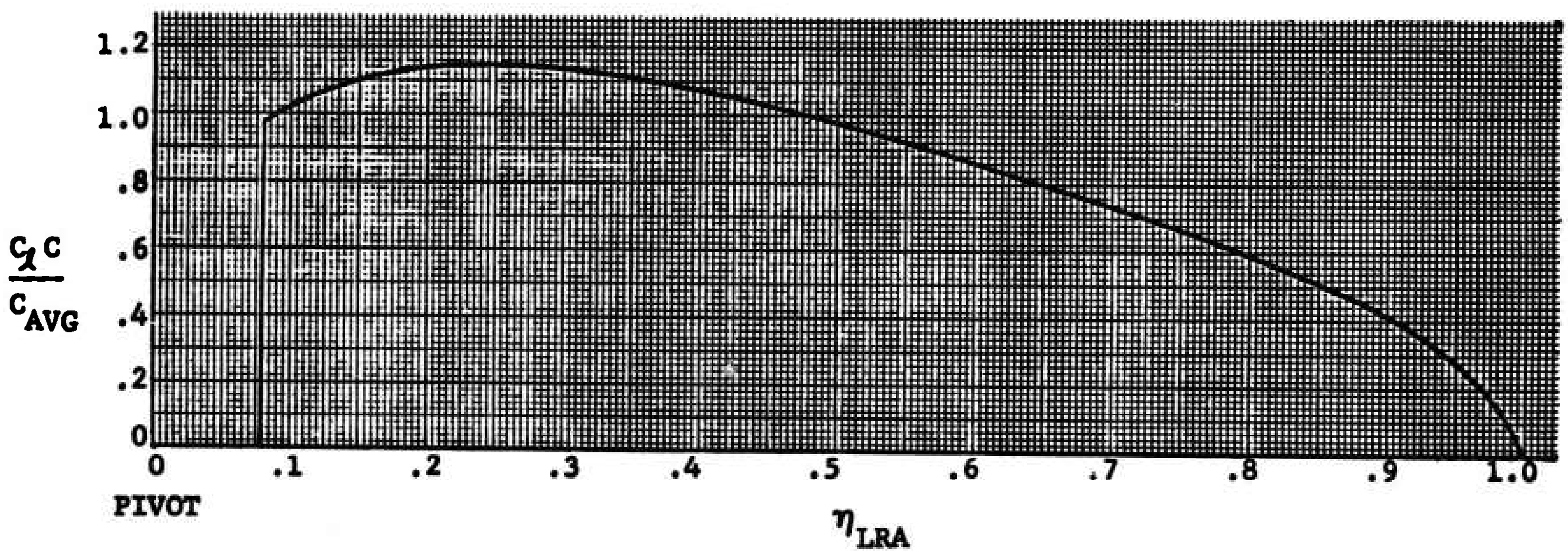


Figure A.57 ATW-4 Wing Local Lift Spanwise Distribution - Condition 4

NOTES:

1. LOCAL TORSION ON CHORDS ⊥ TO LRA
2. SEE FIGURE A-1 FOR CHORD GEOMETRY AND DIMENSIONAL DATA
3. MOM. REF. IS LRA
4. $\bar{C}$ = 117.1 IN. (THEORETICAL REF. WING MAC)

Λ = 16°
M = .80
ALT = 20,000 FT
GW = 110,400 LBS
α = 4.8°
δ_{LE} = 10°
δ_{TE} = 3.5° @ I/B END TO 8.5° @ O/B END

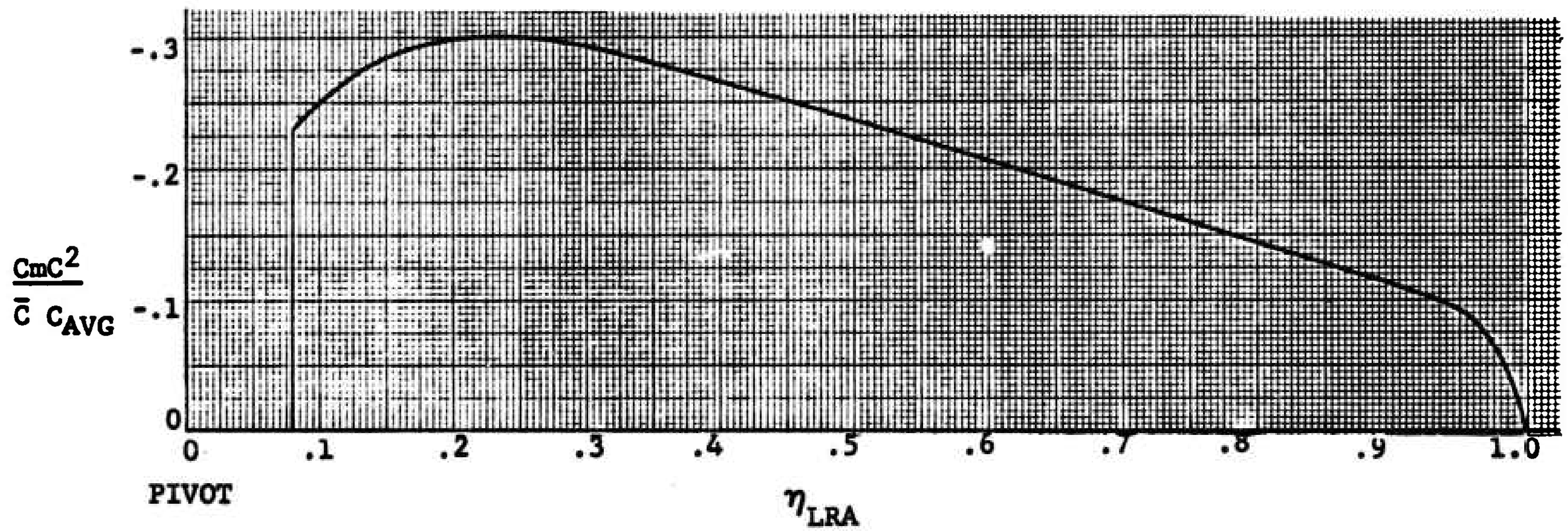


Figure A.58 ATW-4 Wing Local Torsion Spanwise Distribution - Condition 4

A.6.0 FATIGUE LOADS SPECTRA

A.6.1 Wing Box

The spectrum of wing bending moment is presented in Table A-II (2 pages). This spectrum is based on the B-1 flight-by-flight composite mission analytic wing bending moment spectrum. ATW-4 wing bending moments are used in lieu of B-1 wing values. Also, the percent of condition max/min values for load steps 9 through 15 and 33 were adjusted upward. This was done because the magnitude of the ATW-4 wing 1.0g bending moment, expressed in terms of percent design limit bending moment of baseline condition 3, is higher than the corresponding percentage ratio for the B-1 wing. Therefore, the upward adjustment of cyclic peaks provides a more reasonable distribution of the bending moment spectrum with respect to the 1.0g bending moment. The column headed "BM_p/BM(68")" is the ratio of wing net bending moment at the pivot to the bending moment at the conceptual design section located 68 inches outboard of the pivot along the load reference axis (LRA). The ATW-4 wing design data were utilized as listed below:

Mission Segment	ATW-4 Wing Data
Ground ------------------	Unit Inertia (Full Tanks), 2.0g's
Post Takeoff ------------	Condition 1 (91.8%)
Climb, Cruise, Refuel ---	Condition 3 (With Condition 4)
Fly-Up ------------------	Condition 2
Terrain-Following -------	Condition 2
Prelanding --------------	Condition 1 (91.8%)
Ground ------------------	Unit Inertia (Full Tanks), 2.0g's
Takeoff -----------------	Condition 1
Climb -------------------	Condition 3 (With Condition 4)
Prelanding --------------	Condition 1 (91.8%)
Ground ------------------	Unit Inertia (Full Tanks), 2.0g's

Condition 4 loads are for a roll maneuver at the same flight condition as symmetric maneuver condition 3. The wing bending moment in the vicinity of the pivot is essentially the same for both conditions since the carry-through-box allowable limit is developed in each case (compare Figures A-26 and A-41). However, the bending moment on the outer portion of the wing panel is slightly higher for condition 4, therefore, the loading for this condition should be included in the spectrum for fatigue evaluations on the outer portion of the wing panel. For this purpose it is assumed that 50% of the maneuver occurrences (designated "M" on Table A-II) are symmetric and 50% are roll maneuvers.

A.6.2 Variable Camber Devices

Cyclic loads spectra for the leading and trailing edge variable camber devices are assumed to be comprised of:

1. Maneuver and gust occurrences as shown for the composite mission spectrum on Table A-III (3 pages).

2. Load cycles related to different trim settings in changing from one mission segment to the next while progressing through the composite mission on Table A-III.

The flap loads spectra data in Table A-III are based on the wing bending moment spectra data in Table A-II. In addition to maneuver and gust load cycles per mission, the percent of condition (wing bending moment) max/min values shown on Table A-II have been retained on Table A-III. These wing bending moment data were used to estimate the delta N_Z spectra max/min values on Table A-III. The leading and trailing edge flap unit loads data for developing loads spectra are referenced on Table A-III by figure numbers associated with given mission segments. Finally, the load steps on Table A-II have been resequenced on Table A-III to accommodate roll maneuvers and additional load cycles from changing trim settings between mission segments. The latter spectra are presented in supplementary Table A-IIIA, and integrated into the total spectrum according to load step numbers. Three cycles per mission are assumed for each load step on Table A-IV.

The unit loads data referenced on Table A-III are presented in Figures A.59 through A.62 for four baseline conditions. These conditions correspond with preliminary design condition 1 through 4 presented on Table A-I with the exception of values for load factor and angle of attack. For each of these conditions, leading and trailing edge flap spanwise running loads and center-of-pressure distribution data are presented for the following cases:

1. $N_z = 1.0g$

2. $\Delta N_z = 1.0g$

Leading and trailing edge flap loads for maneuver and gust loads spectra are developed using the following equations for running load and center of pressure distributions:

$$w_p = w_{1.0g} + \frac{\Delta w}{g} (N_z - 1.0)$$

$$w_p \left(\frac{X_{CP}}{C_F}\right)_p = w_{1.0g} \left(\frac{X_{CP}}{C_F}\right)_{1.0g} + \frac{\Delta w}{g} (N_z - 1) \left(\frac{X_{CP}}{C_F}\right)_{\Delta N_z = 1}$$

where

1) Values for w and X_{CP}/C_F appearing on the right hand side of the equations are read from Figures A.59 through A.66 at given ETA stations.

2) $(N_z - 1.0) = \Delta N_z$ values given for load steps on Table A-III.

3) Subscript p is attached to cyclic peak load distribution.

For the "Climb/Cruise/Refuel" mission segment it is assumed that 50% of the maneuver occurrences are symmetric maneuvers (baseline condition 3) and 50% are roll maneuvers (baseline condition 4).

The leading and trailing edge flap load distributions related to trim change cycles correspond with the 1.0g distributions referenced by figure number on Table A-IV.

TABLE A-II

ATW-4 WING BENDING MOMENT SPECTRUM AT WING PIVOT

LOAD STEP	MISSION SEGMENT	$\frac{BM_D}{BM(68")}$	BM X 10^6 in – lb LIMITS	T_{AW}(°F)	WING ANGLE		% OF CONDITION MAX	% OF CONDITION MIN	BM X 10^{-6} MAX	BM X 10^{-6} MIN	CYCLES/ MISSION
1	GROUND	1.6	-2.9624	58.69	16°		11.5	60.8	-.341	-1.8	1
2	POST TAKE-OFF	1.5	17.93	70.13	16°	M	85.1	51.5	16.62	10.06	.01
3						M	76.6	51.5	14.96	10.06	.1
4						M	59.3	51.5	11.58	10.06	2
5						M	51.5	41.4	10.06	8.08	2
6						G	60.5	56.8	11.8	11.09	2
7						G	60.9	36.2	11.89	7.07	1
8						G	50.5	44.5	9.86	8.69	29
9	CLIMB, CRUISE & REFUEL	1.5	18.3	38.97	16°	M	56.0	37.0	10.25	6.77	1
10						M	64.5	56.0	11.8	10.25	22
11						M	56.0	50.5	10.25	9.24	22
12						M	69.0	46.5	12.63	8.51	1
13						M	46.5	31.0	8.51	5.67	1
14						M	54.0	46.5	9.88	8.51	58
15						M	46.5	42.5	8.51	7.78	58
16	FLY-UP	1.5	16.106	126.15	65°		68.5	25.5	11.03	4.11	1
17							46.7	26.5	7.52	4.27	1
18	TERRAIN FOLLOWING	1.5	16.106	126.15	65°	G	64.7	48.2	10.42	7.76	.1
19						G	55.1	28.0	8.87	4.51	1
20						G	45.1	34.5	7.26	5.56	7
21						G	48.6	8.1	7.83	1.3	1
22						G	32.1	18.1	5.17	2.92	132
23						G	28.6	-4.4	4.61	-.71	1
24						G	19.6	8.4	3.16	1.35	132
25						M	65.4	3.7	10.53	.596	1
26						M	49.5	6.8	7.97	1.1	9
27						M	32.1	14	5.17	2.255	95
28	PRELANDING	1.5	17.828	70.13	16°	M	92.1	51.7	16.42	9.22	.01
29						M	82.9	-13.8	14.78	-2.46	.1
30						M	71.3	51.7	12.71	9.22	1
31	GROUND	1.6	-2.9624	58.69	16°		11.5	60.8	-3.41	-1.8	1
32	TAKE-OFF	1.5	19.527	70.13	16°		73.2	49.4	14.29	9.65	1

TABLE A-II (CONTINUED)

LOAD STEP	MISSION SEGMENT	$\frac{BM_P}{BM(68")}$	BM X 10^6 in-lb LIMITS	T_{AW}(°F)	WING ANGLE	% OF CONDITION MAX	% OF CONDITION MIN	BM X 10^{-6} MAX	BM X 10^{-6} MIN	CYCLES/ MISSION
33	CLIMB	1.5	18.3	38.97	16°	80.5	56.0	14.73	10.25	1
34						51.7	34.5	9.22	6.15	1
35						M 59.9	51.7	10.68	9.22	19
36						51.7	46.1	9.22	8.22	19
37	PRELANDING	1.5	17.828	70.13	16°	76.8	47.9	13.69	8.54	1
38						65.7	56.2	11.71	10.02	4
39						G 67.0	33.6	11.94	5.99	1
40						60.6	39.9	10.8	7.11	9
41						57.4	43.1	10.23	7.68	48
42						53.0	46.1	9.45	8.22	294
43	GROUND	1.6	-2.9629	58.69	16°	11.5	60.8	-.341	-1.8	8
44						15.4	56.2	-.456	-1.665	154

NOTES:

(1) THIS COMPOSITE MISSION TABLE CONTAINS 1143.32 CYCLES PER MISSION AND 1,463,449.6 CYCLES PER LIFE.

(2) LEGEND: M - MANEUVER LOAD
G - GUST LOAD

(3) BENDING MOMENT IS IN THE LOAD REFERENCE AXIS SYSTEM.

TABLE A-III

ATW-4 WING VARIABLE CAMBER SYSTEM MANEUVER/GUST LOAD N_Z SPECTRUM

LOAD STEP	MISSION SEGMENT	REF. FIG. NO.	WING ANGLE		% OF CONDITION MAX	% OF CONDITION MIN	ΔN_Z MAX	ΔN_Z MIN	CYCLES/ MISSION
1	GROUND	—	16°		11.5	60.8	—	—	—
3	POST TAKE-OFF	A.59 & A.60	16°	M	85.1	51.5	.74	.16	.01
4		A.59 & A.60		M	76.6	51.5	.60	.16	.1
5		A.59 & A.60		M	59.3	51.5	.29	.16	2
6		A.59 & A.60		M	51.5	41.4	.16	-.02	2
7		A.59 & A.60		G	60.5	56.8	.31	.25	2
8		A.59 & A.60		G	60.9	36.2	.32	-.11	1
9		A.59 & A.60		G	50.5	44.5	.14	.03	29
11	CLIMB, CRUISE & REFUEL	A.63 & A.64	16°	M	56.0	37.0	.144	-.48	1
12		A.63 & A.64		M	64.5	56.0	.43	.144	11
13		A.65 & A.66		M	64.5	56.0	-.23	-.50	11
14		A.63 & A.64		M	56.0	50.5	.144	-.038	11
15		A.65 & A.66		M	56.0	50.5	-.50	-.68	11
16		A.63 & A.64		M	69.0	46.5	.586	-.168	1
17		A.63 & A.64		M	46.5	31.0	-.168	-.688	1
18		A.63 & A.64		M	54.0	46.5	.092	-.168	29
19		A.65 & A.66		M	54.0	46.5	-.56	-.81	29
20		A.63 & A.64		M	46.5	42.5	.168	-.298	29
21		A.65 & A.66		M	46.5	42.5	-.81	-.94	29
23	FLY-UP	A.61 & A.62	65°		68.5	25.5	1.07	-.205	1
24		A.61 & A.62			46.7	26.5	.425	-.175	1

TABLE A-III (CONTINUED)

LOAD STEP	MISSION SEGMENT	REF. FIG. NO.	WING ANGLE	% OF CONDITION MAX	% OF CONDITION MIN	ΔN_Z MAX	ΔN_Z MIN	CYCLES/ MISSION
25	TERRAIN FOLLOWING	A.61 & A.62	65°	64.7	48.2	.98	.47	.1
26		A.61 & A.62		55.1	28.0	.68	-.13	1
27		A.61 & A.62		G 45.1	34.5	.38	.065	7
28		A.61 & A.62		48.6	8.1	.47	-.715	1
29		A.61 & A.62		32.1	18.1	0	-.415	132
30		A.61 & A.62		28.6	-4.4	-.115	-1.09	1
31		A.61 & A.62		19.6	8.4	-.40	-.715	132
32		A.61 & A.62		M 65.4	3.7	.98	-.85	1
33		A.61 & A.62		49.5	6.8	.5	-.76	9
34		A.61 & A.62		32.1	14	0	-.55	95
36	PRE-LANDING	A.59 & A.60	16°	92.1	51.7	.865	.16	.01
37		A.59 & A.60		M 82.9	-13.8	.71	-.99	.1
38		A.59 & A.60		71.3	51.7	.5	.16	1
40	GROUND		16°	11.5	60.8	—	—	—
42	TAKE-OFF	A.59 & A.60	16°	73.2	49.4	.54	.12	1
44	CLIMB	A.63 & A.64	16°	80.5	56.0	.807	-.233	1
46	PRE-LANDING	A.59 & A.60	16°	51.7	34.5	.16	-.14	1
47		A.59 & A.60		M 59.9	51.7	.31	.16	19
48		A.59 & A.60		51.7	46.1	.16	.06	19
49		A.59 & A.60		76.8	47.9	.60	.09	1
50		A.59 & A.60		65.7	56.2	.41	.245	4
51		A.59 & A.60		G 67.0	33.6	.43	-.16	1
52		A.59 & A.60		60.6	39.9	.32	-.05	9
53		A.59 & A.60		57.4	43.1	.26	0	48
54		A.59 & A.60		53.0	46.1	.18	.06	294

TABLE A-III (CONTINUED)

LOAD STEP	MISSION SEGMENT	REF. FIG. NO.	WING ANGLE	% OF CONDITION		ΔN_Z MAX	ΔN_Z MIN	CYCLES/ MISSION
				MAX	MIN			
56	GROUND	—	16°	11.5	60.8	—	—	—
57		—		15.4	56.2	—	—	—

LEGEND: M - MANEUVER LOAD
G - GUST LOAD

NOTES:

(1) REFERENCE FIGURES NOTED FOR L.E. AND T.E. FLAPS UNIT LOADS DATA

(2) $N_Z = 1.0 + \Delta N_Z$

TABLE A-IV

ATW-4 WING VARIABLE CAMBER SYSTEM LOADS SPECTRA FROM TRIM CHANGES

LOAD STEP	WING ANGLE MAX/MIN	REF. FIG. NO. MAX	REF. FIG. NO. MIN	LOAD (LBS) MAX	LOAD (LBS) MIN	CYCLES/ MISSION
(LEADING EDGE FLAP)						
2	16°/16°	A.59	—	5,685	0	3
10	16°/16°	A.59	A.63	5,685	-3071	3
22	65°/16°	A.61	A.63	11,865	-3071	3
35	65°/16°	A.61	A.59	11,865	5,685	3
39	16°/16°	A.59	—	5,685	0	3
41	16°/16°	A.59	—	5,685	0	3
43	16°/16°	A.59	A.63	5,685	-3071	3
45	16°/16°	A.59	A.63	5,685	-3071	3
55	16°/16°	A.59	—	5,685	0	3
(TRAILING EDGE FLAP)						
2	16°/16°	A.59	—	20,734	0	3
10	16°/16°	A.59	A.63	39,926	20,734	3
22	65°/16°	A.61	A.63	39,226	3,737	3
35	65°/16°	A.61	A.59	20,734	3,737	3
39	16°/16°	A.59	—	20,734	0	3
41	16°/16°	A.59	—	20,734	0	3
43	16°/16°	A.59	A.63	39,226	20,734	3
45	16°/16°	A.59	A.63	39,226	20,734	3
55	16°/16°	A.59	—	20,734	0	3

NOTES: (1) REFERENCE FIGURES NOTED FOR L.E. AND T.E. FLAPS LOADS DISTRIBUTIONS

(2) INTEGRATE SPECTRA FROM THIS TABLE WITH TABLE III MANEUVER AND GUST LOADS SPECTRA ACCORDING TO LOAD STEP SEQUENCE NUMBER

NOTES:

1. $+X_{cp}$ MEAS FWD OF .15C @ L.E. FLAP
2. $+X_{cp}$ MEAS AFT OF .65C @ T.T. FLAP
3. C_F IS FLAP LOCAL CHORD

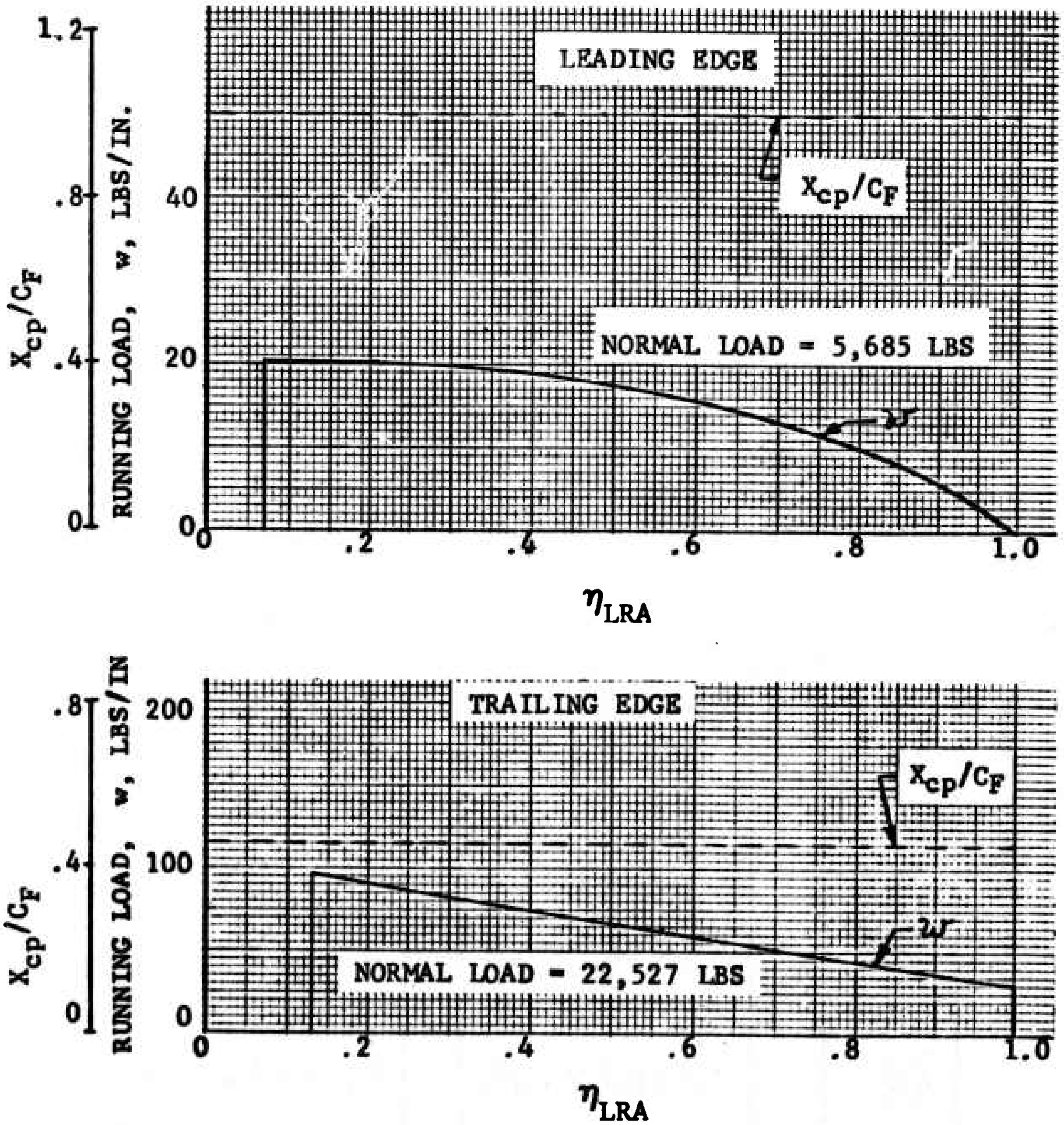
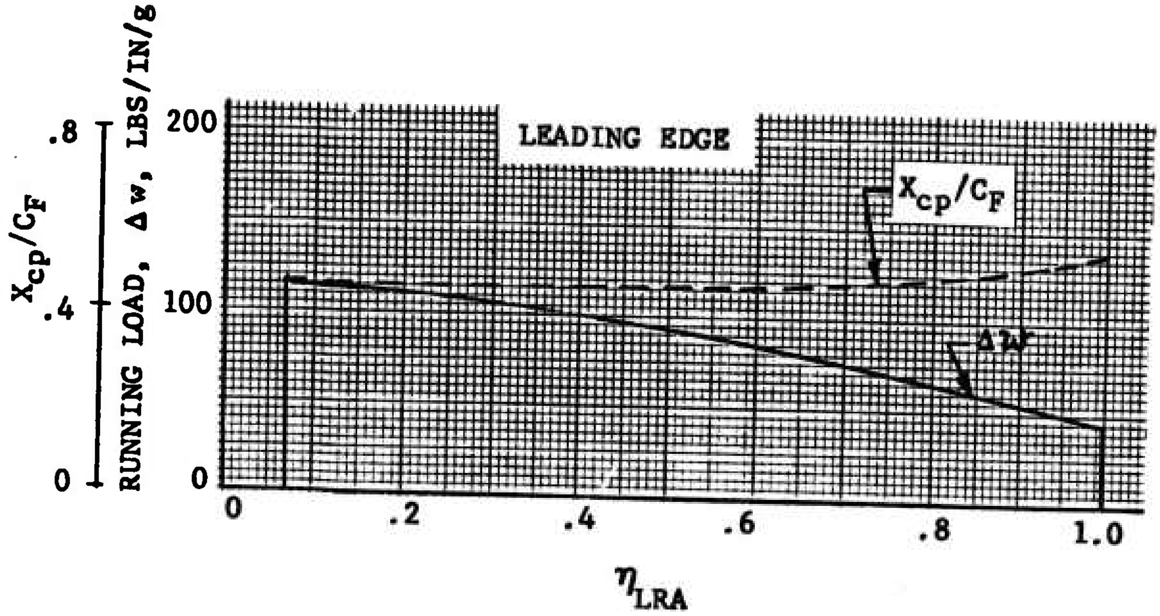


Figure A.59 ATW-4 Wing Leading and Trailing Edge Flap Loads for N_Z = 1.0g - Condition 1

NOTES:

1. X_{cp} MEAS. FWD. OF .15C @ L.E. FLAP
2. X_{cp} MEAS. AFT OF .65C @ T.E. FLAP
3. C_F IS FLAP LOCAL CHORD



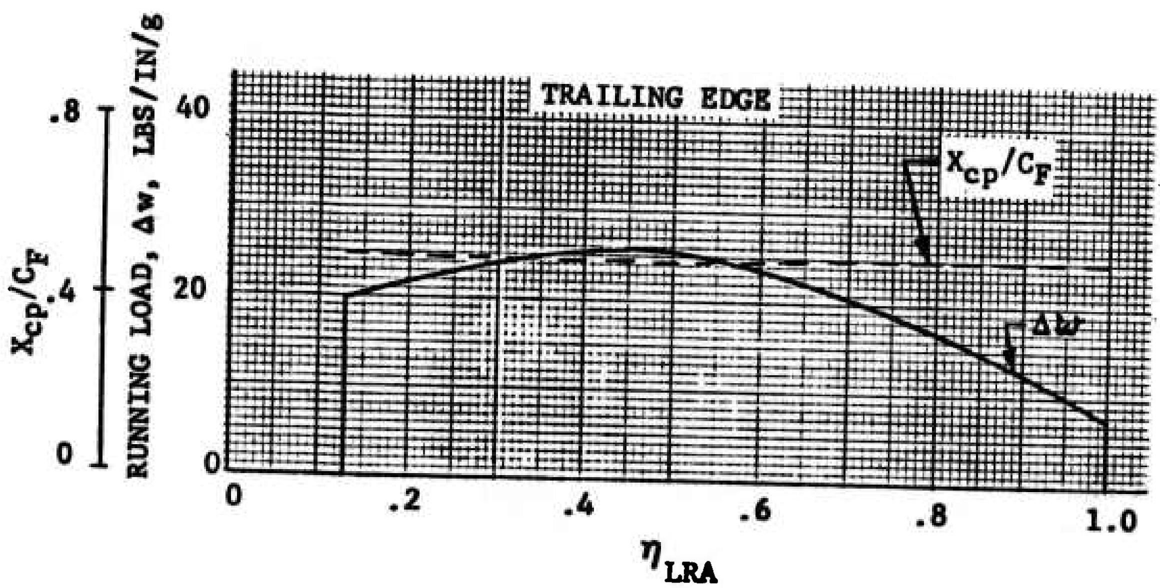


Figure A.60 ATW-4 Wing Leading and Trailing Edge Flap Loads for $\Delta N_Z = 1.0g$ - Condition 1

NOTES:

1. X_{cp} MEAS. FWD. OF .15C @ L.E. FLAP
2. X_{cp} MEAS. AFT OF .65C @ T.E. FLAP
3. C_F = FLAP LOCAL CHORD

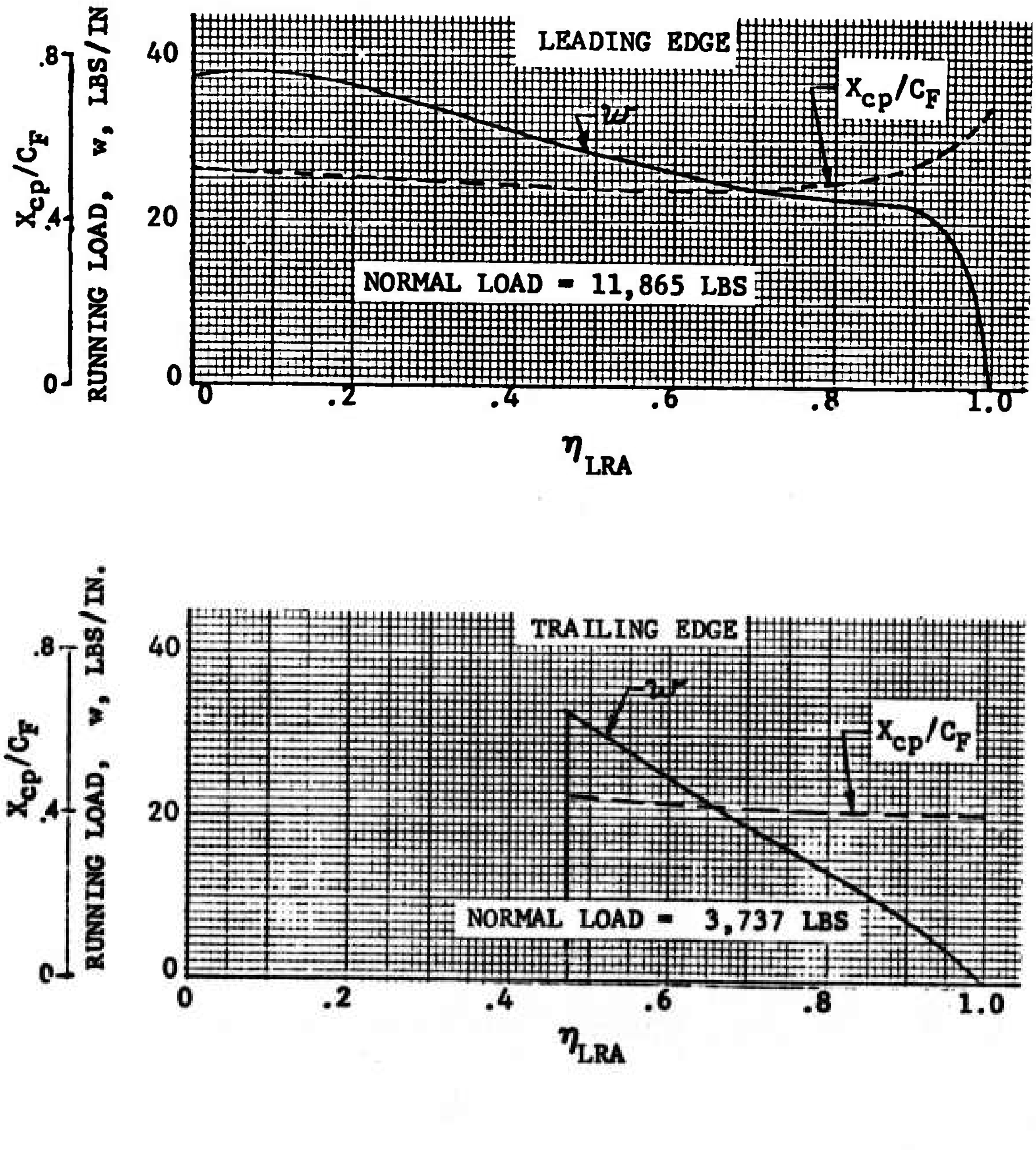


Figure A.61 ATW-4 Wing Leading Edge and Trailing Edge Flap Loads for N_Z - 1.0g - Condition 2

NOTES:

1. X_{cp} MEAS. FWD. OF .15C @ L.E. FLAP
2. X_{cp} MEAS. AFT OF .65C @ T.E. FLAP
3. C_F - FLAP LOCAL CHORD

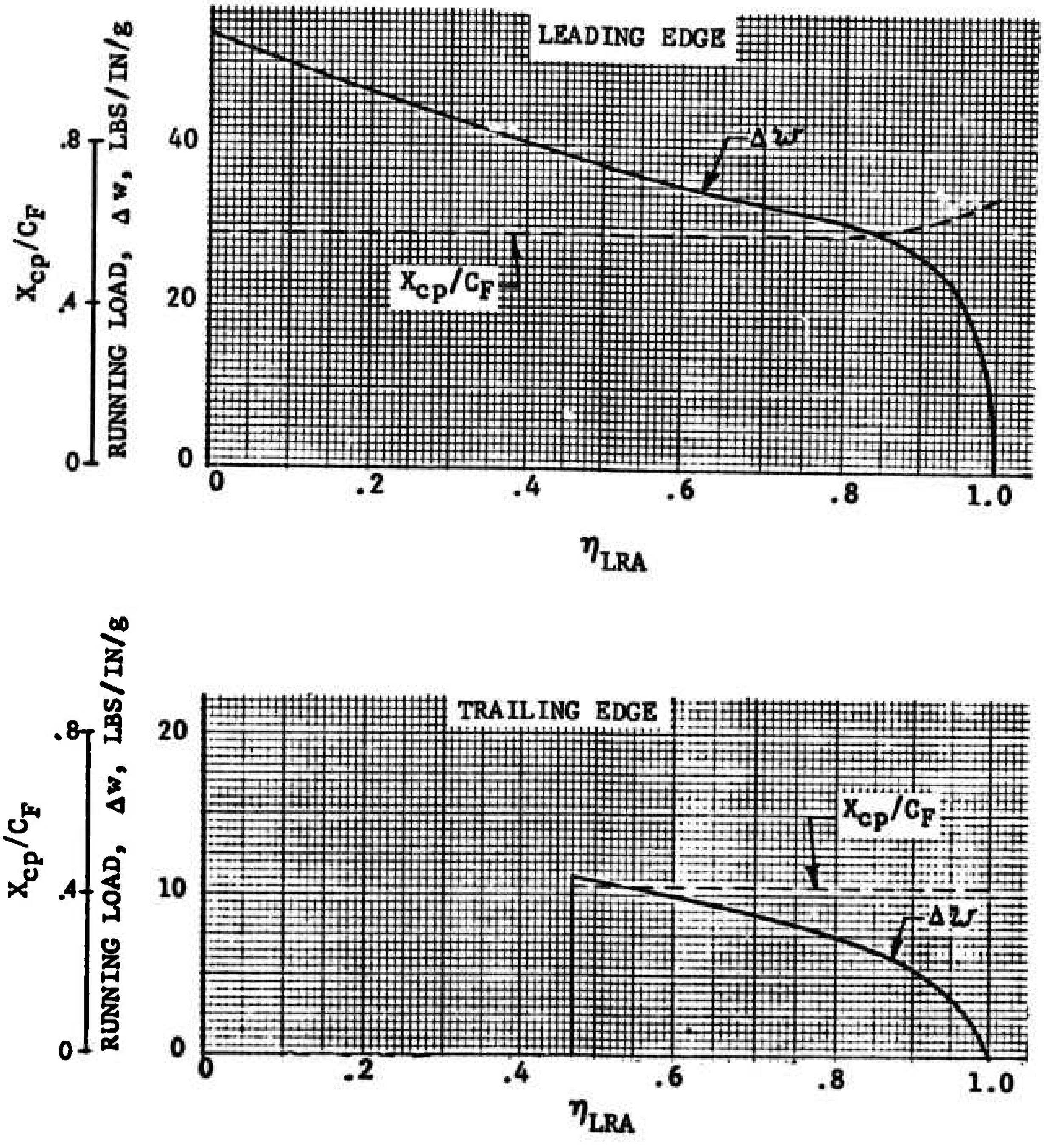


Figure A.62 ATW-4 Wing Leading and Trailing Edge Flap Loads for $\Delta N_Z = 1.0g$ - Condition 2

NOTES:
1. $+X_{cp}$ MEAS. FWD. OF .15C @ L.E. FLAP
2. $+X_{cp}$ MEAS. AFT OF .65C @ T.E. FLAP
3. C_F IS FLAP LOCAL CHORD

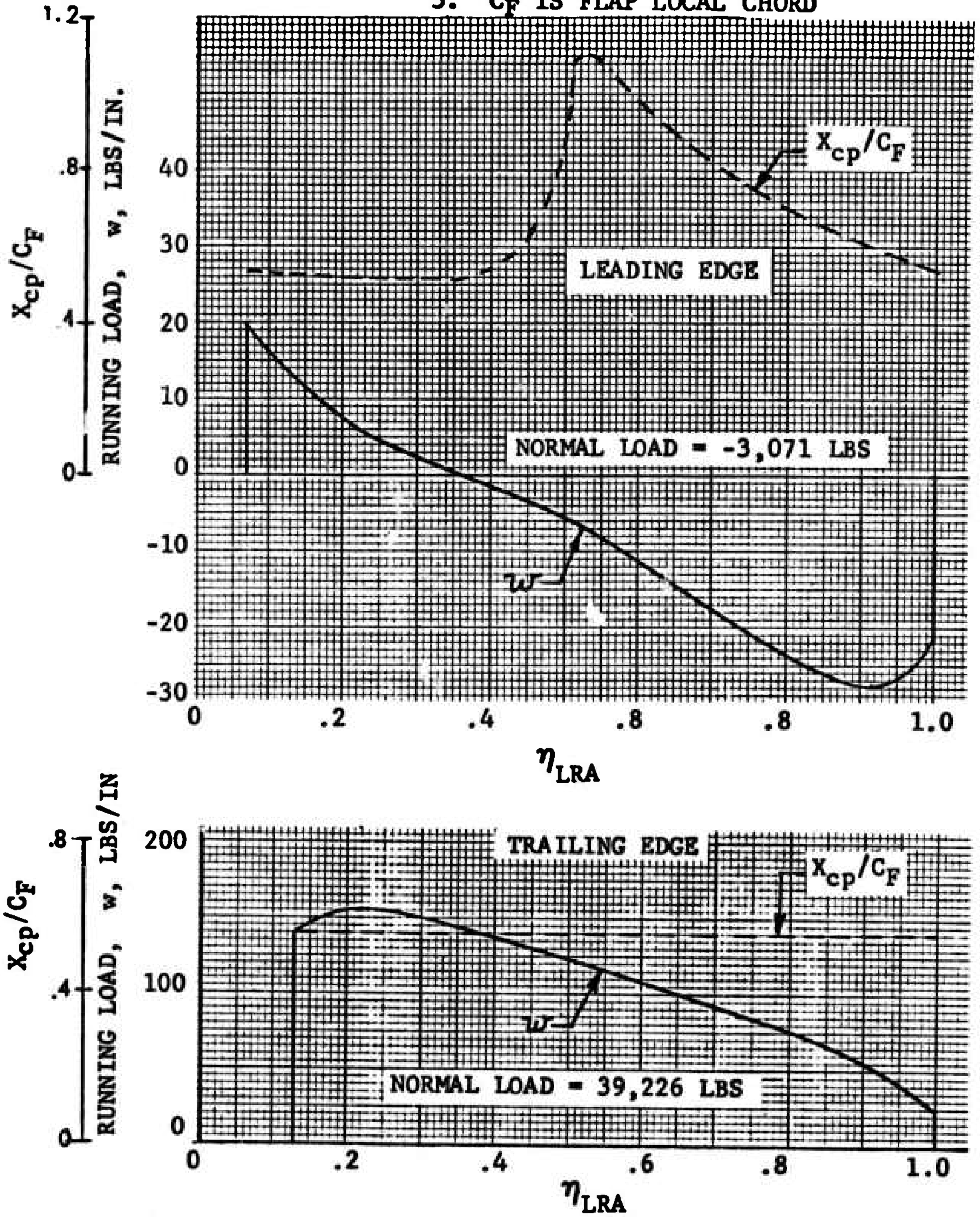


Figure A.63 ATW-4 Wing Leading and Trailing Edge Flap Loads for $N_Z = 1.0g$ - Condition 3

NOTES:

1. X_{cp} MEAS. FWD. OF .15C @ L.E. FLAP
2. X_{cp} MEAS. AFT OF .65C @ T.E. FLAP
3. C_F IS FLAP LOCAL CHORD

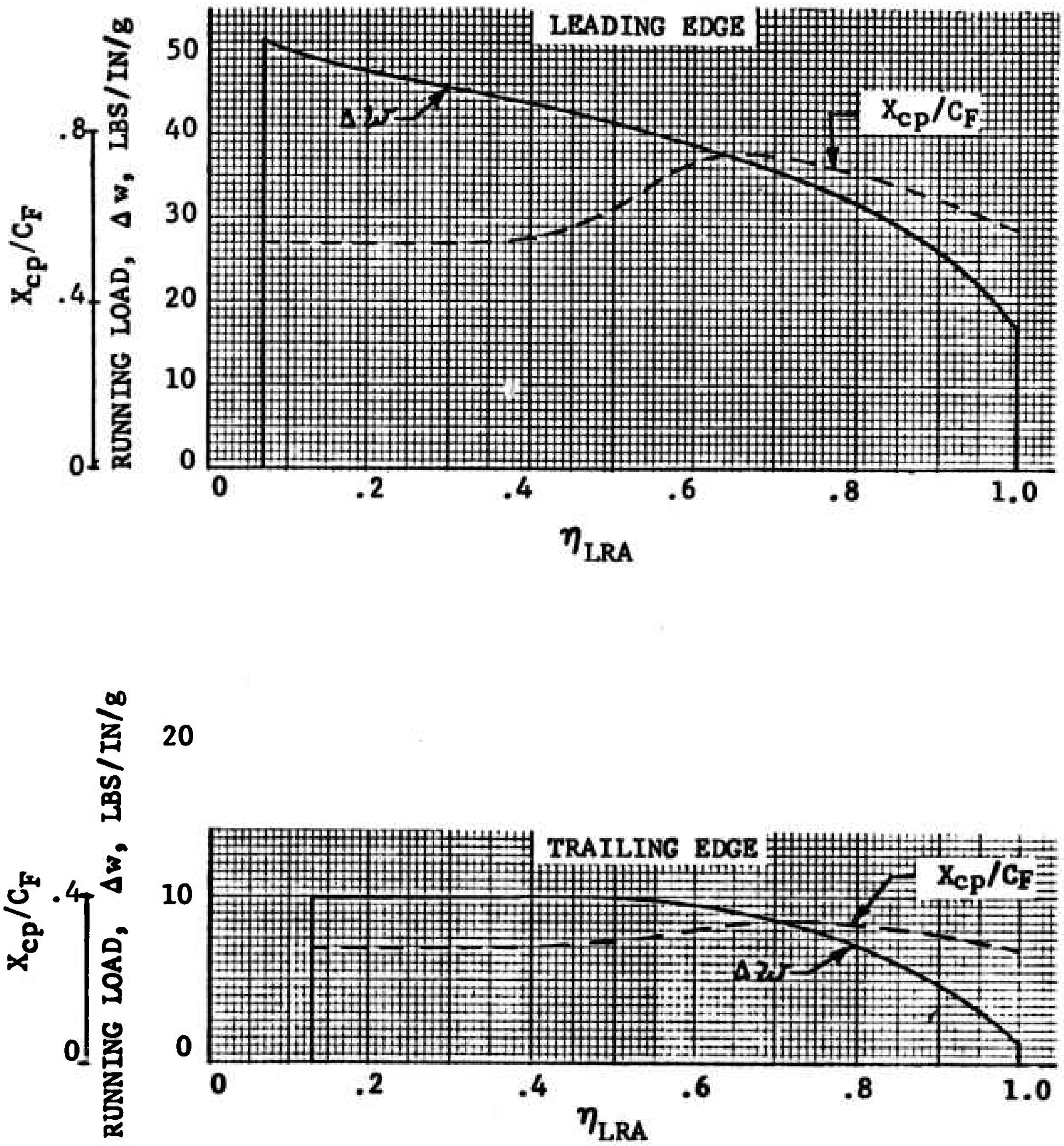


Figure A.64 ATW-4 Wing Leading and Trailing Edge Flap Loads for ΔN_Z = 1.0g - Condition 3

NOTES:

1. $+X_{cp}$ MEAS. FWD. OF .15C @ L.E. FLAP AND AFT OF .65C @ T.E. FLAP
2. C_F IS FLAP LOCAL CHORD

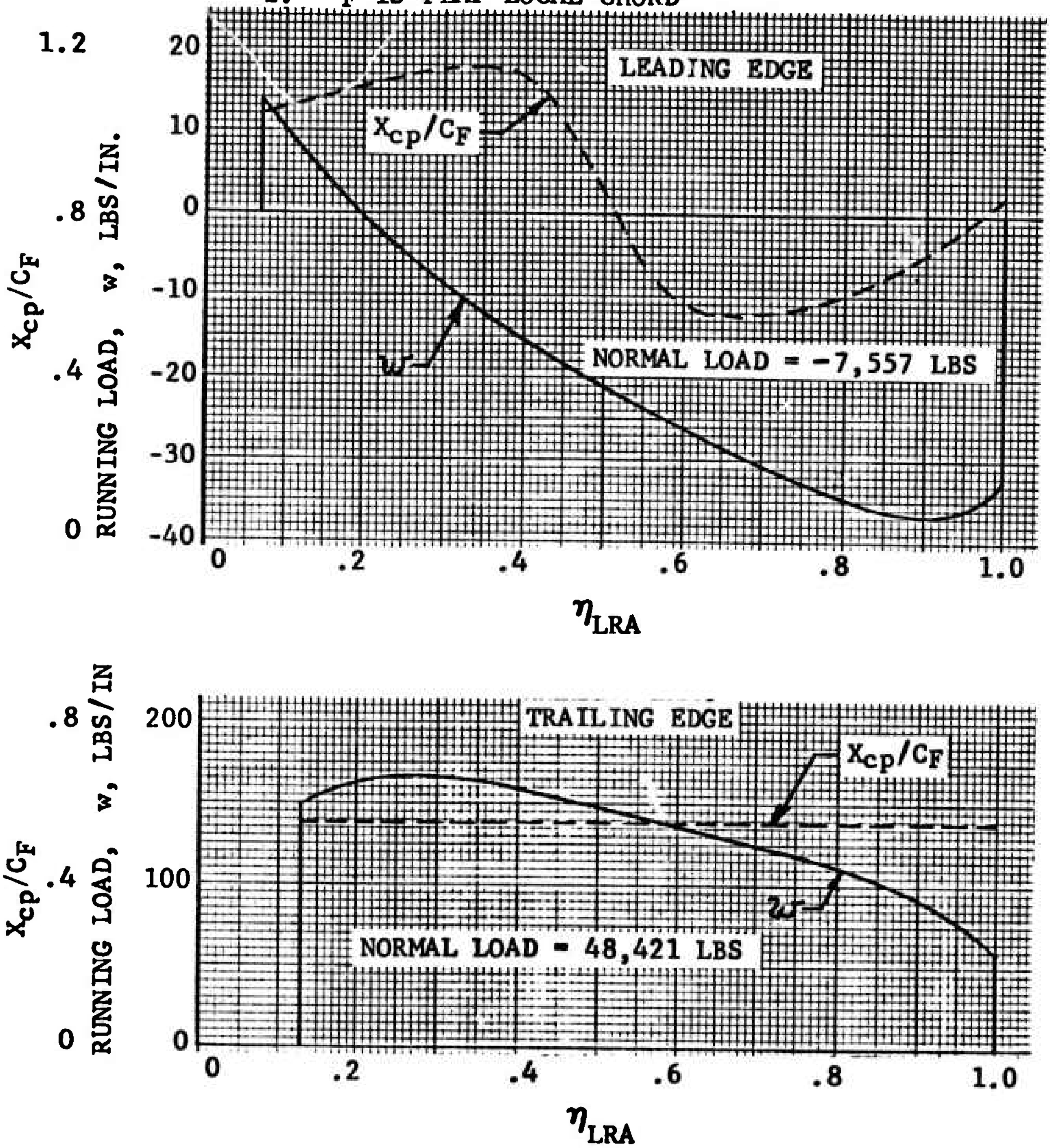


Figure A.65 ATW-4 Wing Leading and Trailing Edge Flap Loads for N_Z = 1.0g - Condition 4

NOTES:

1. X_{cp} MEAS. FWD. OF .15C @ L.E. FLAP
2. X_{cp} MEAS. AFT OF .65C @ T.E. FLAP
3. C_F IS FLAP LOCAL CHORD

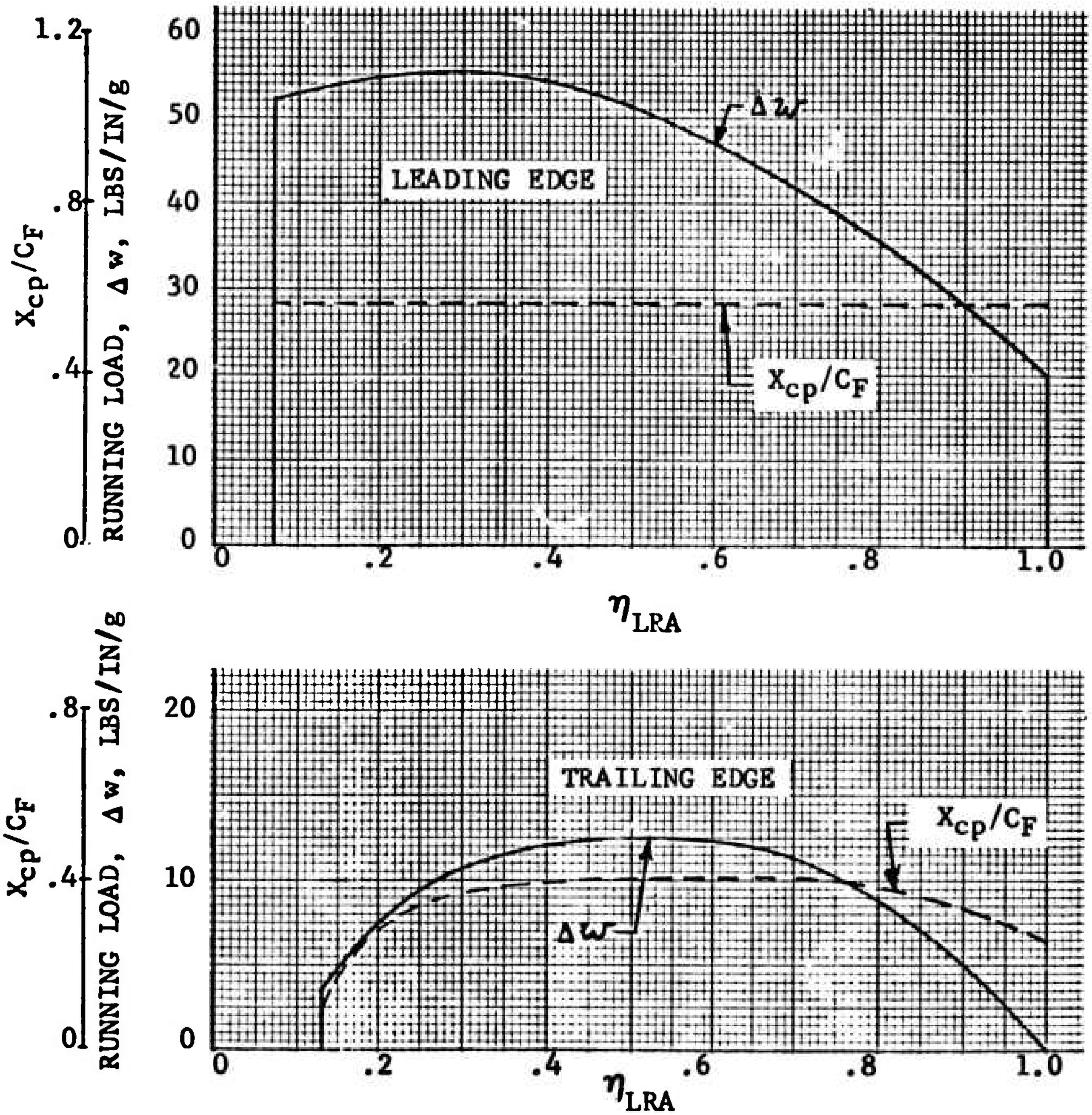


Figure A.66 ATW-4 Wing Leading and Trailing Edge Flap Loads for $\Delta N_Z = 1.0g$ - Condition 4

APPENDIX B

FATIGUE DESIGN ALLOWABLE CURVES

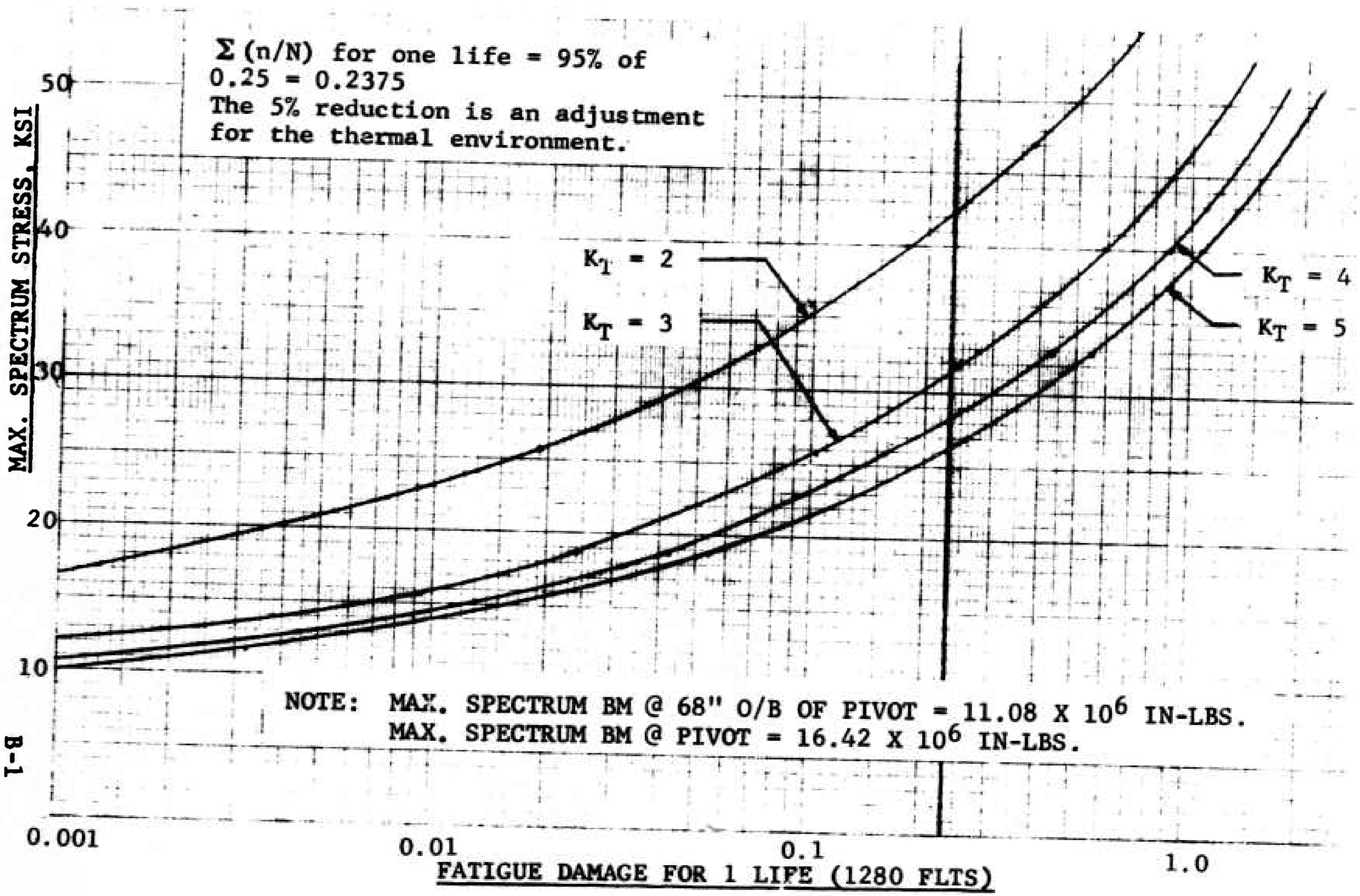


Figure B.1 ATW-4 Wing Box Lower Surface Fatigue Design Allowable Curves (2024-T851 Aluminum)

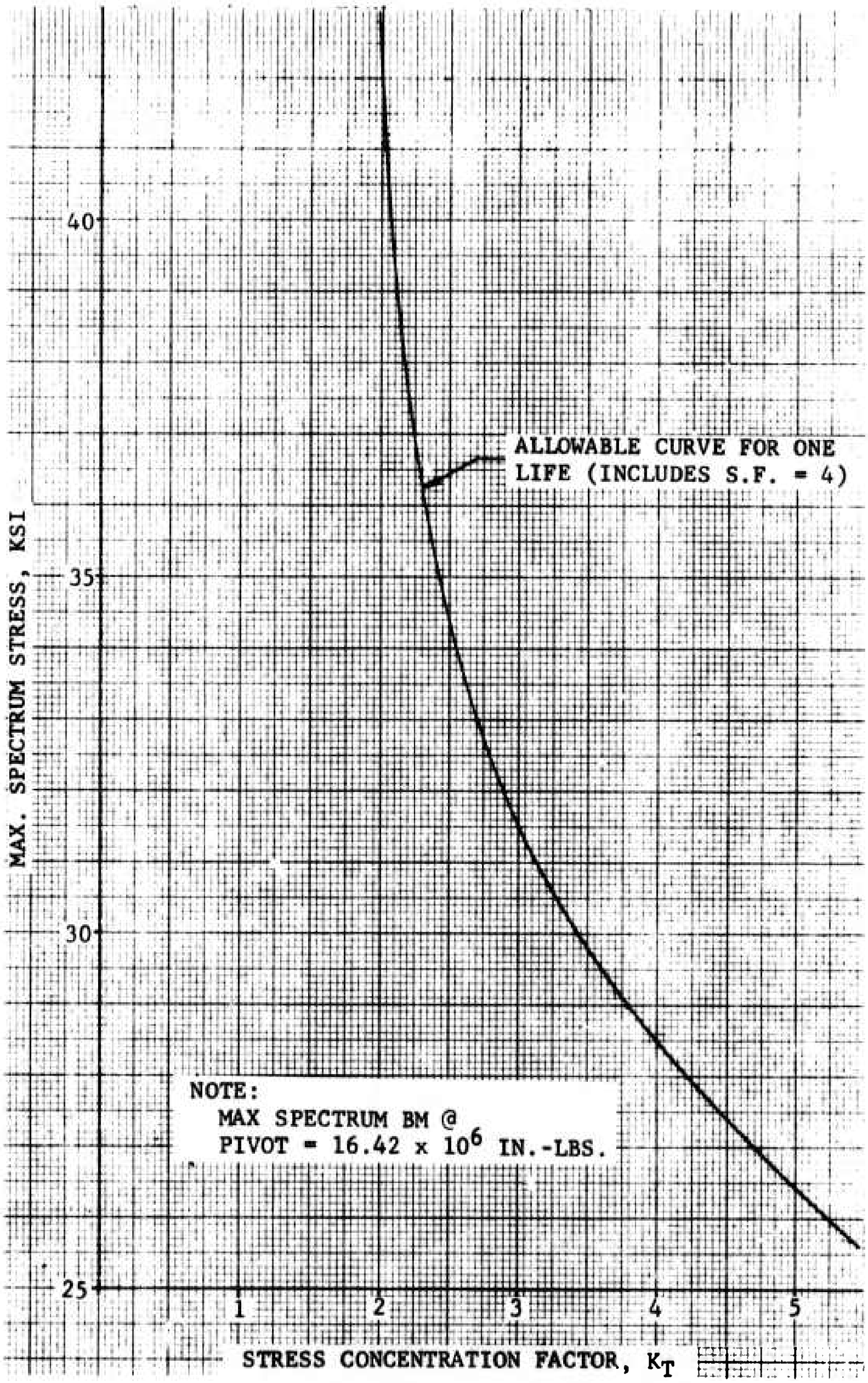


Figure B.2 Fatigue Design Allowable Curve - Wing Box Lower Surface (2024-T851 Aluminum)

NOTE: MAX. SPECTRUM BM @ 68" O/B OF PIVOT = 11.08 X 10^6 IN-LBS.
MAX. SPECTRUM BM @ PIVOT = 16.42 X 10^6 IN-LBS.

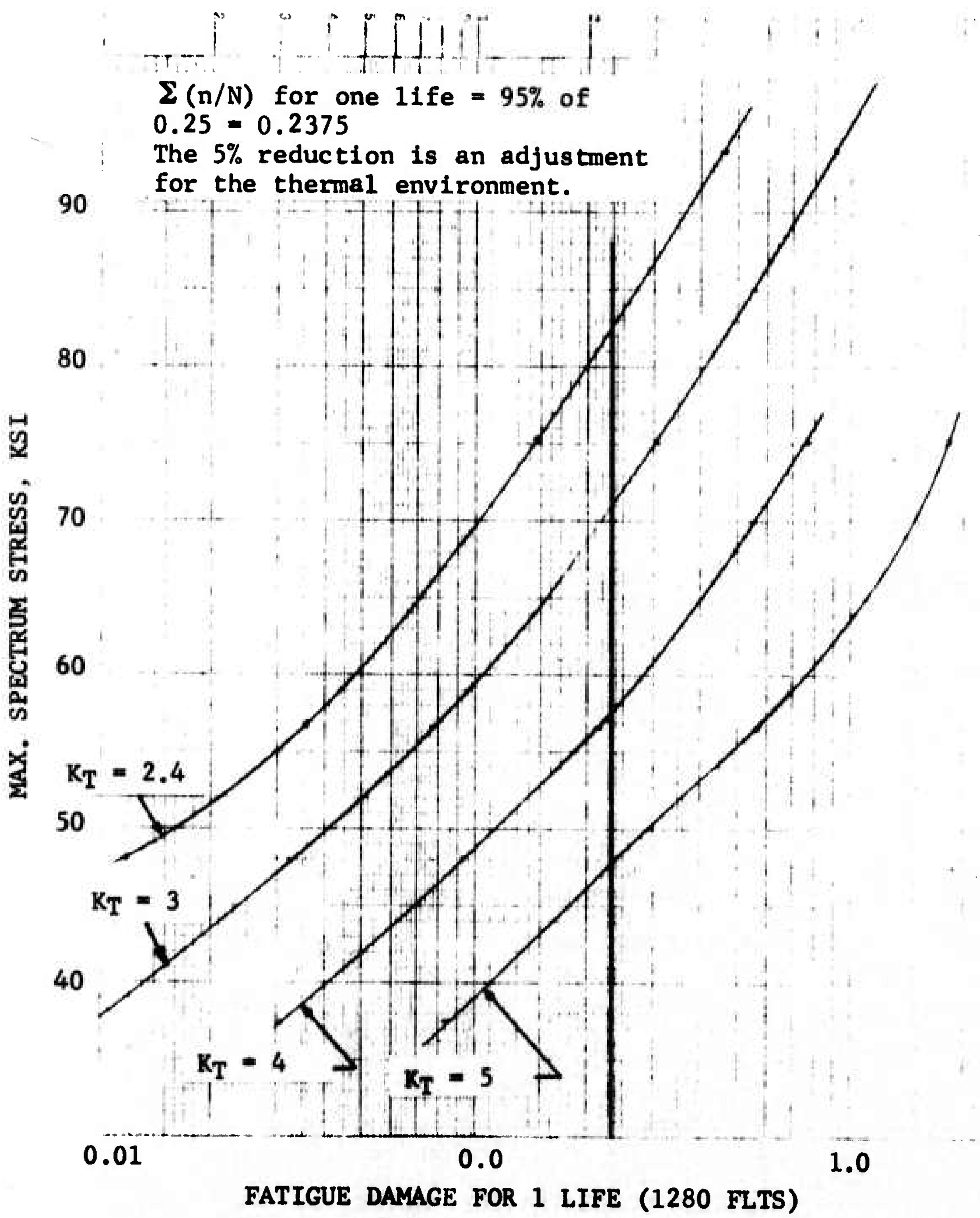


Figure B.3 ATW-4 Wing Box Lower Surface Fatigue Design Allowable Curves (6AL-4V Beta Annealed Titanium)

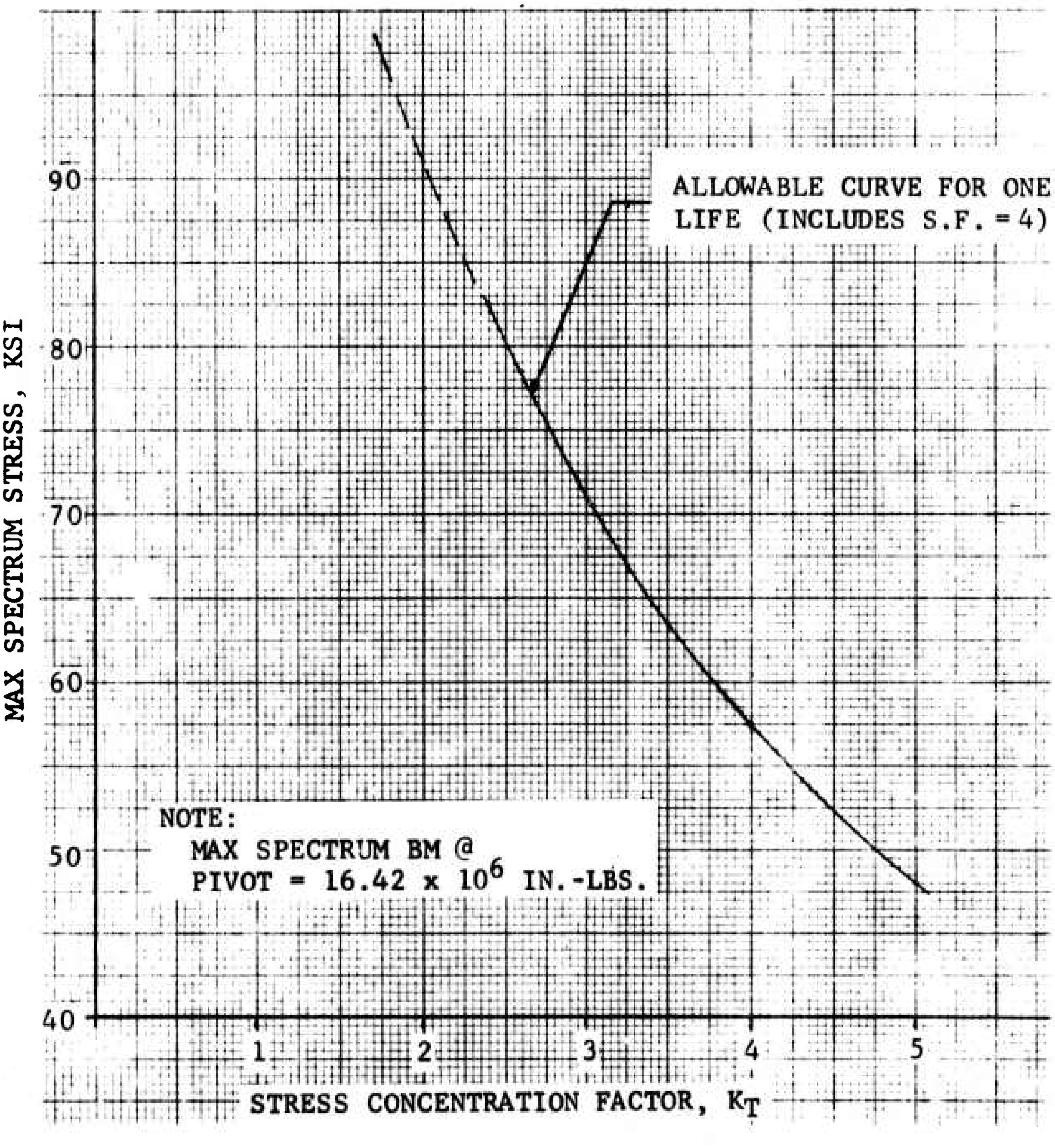


Figure B.4 Fatigue Design Allowable Curve - Wing Box Lower Surface (6AL-4V Beta Annealed Titanium)

APPENDIX C

FRACTURE DESIGN ALLOWABLE CURVES

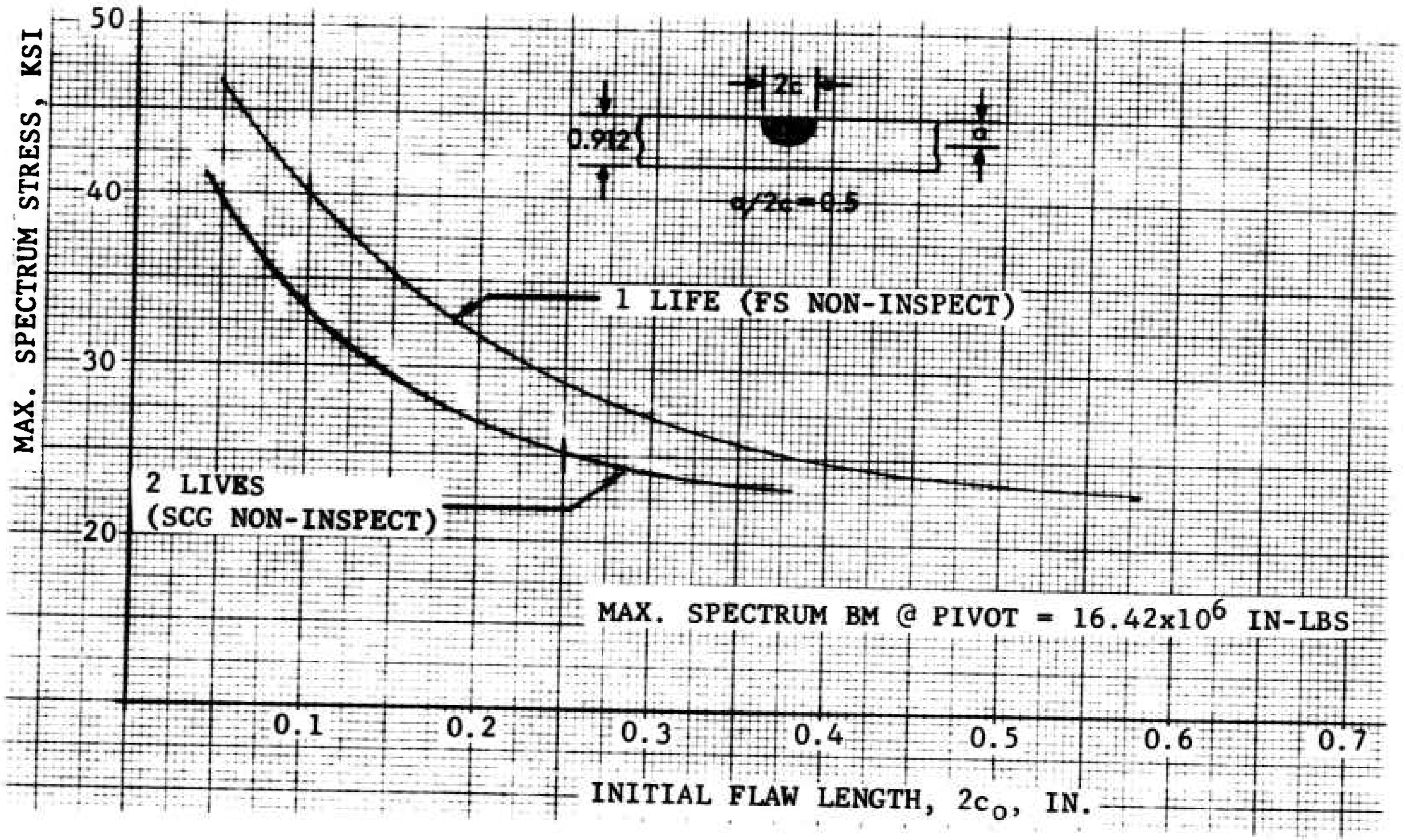
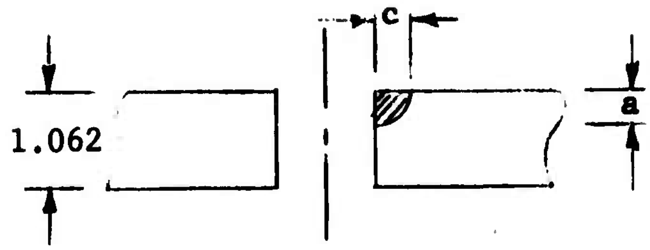


Figure C.1 Fracture Design Allowable Curve - Wing Box Lwr Surface (2024-T851 Aluminum Surface Flaw)



a/2c = 0.5

NOTE: MAX. SPECTRUM BM @ PIVOT = 16.42×10^6 IN.-LBS.

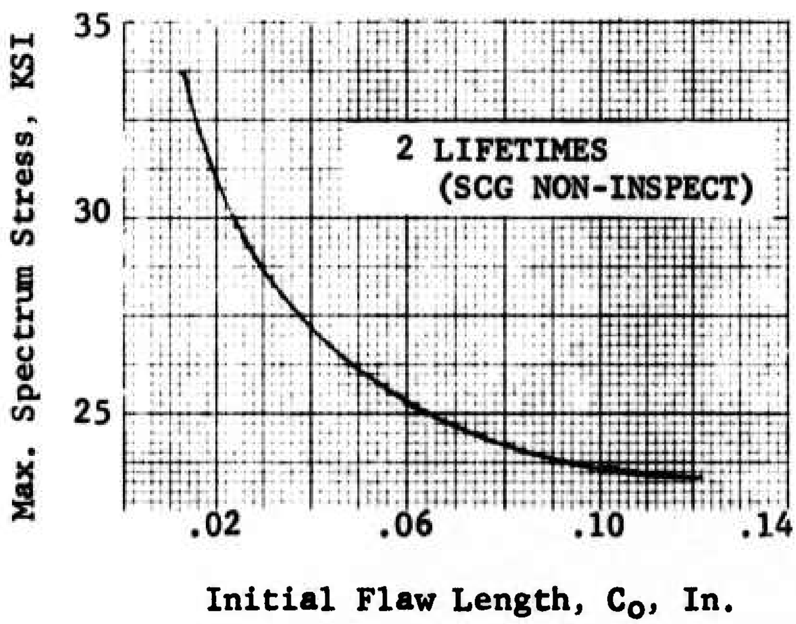


Figure C.2 Fracture Design Allowable Curve - Wing Box Lower Surface (2024-T851 Aluminum Corner Flaw)

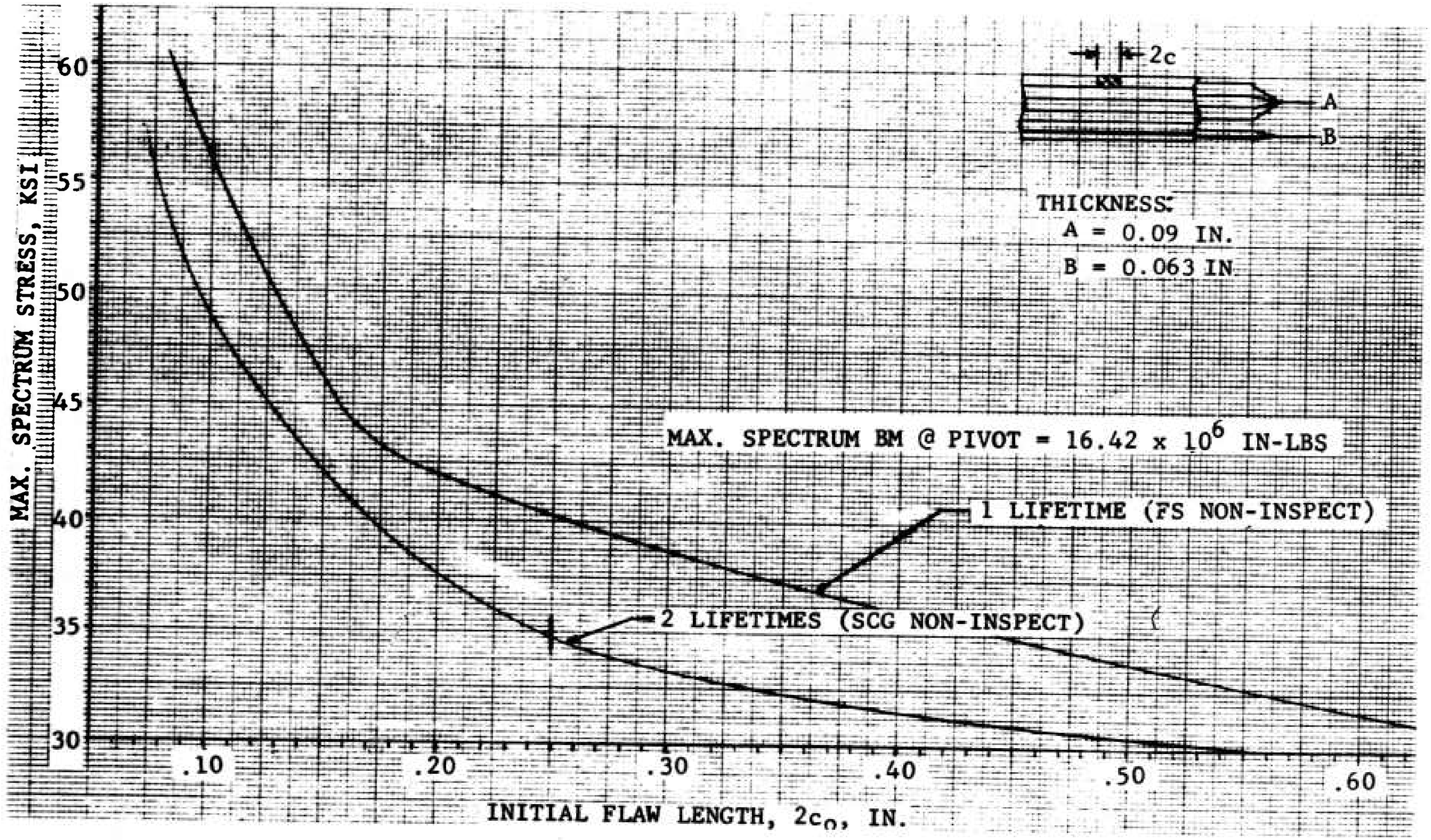
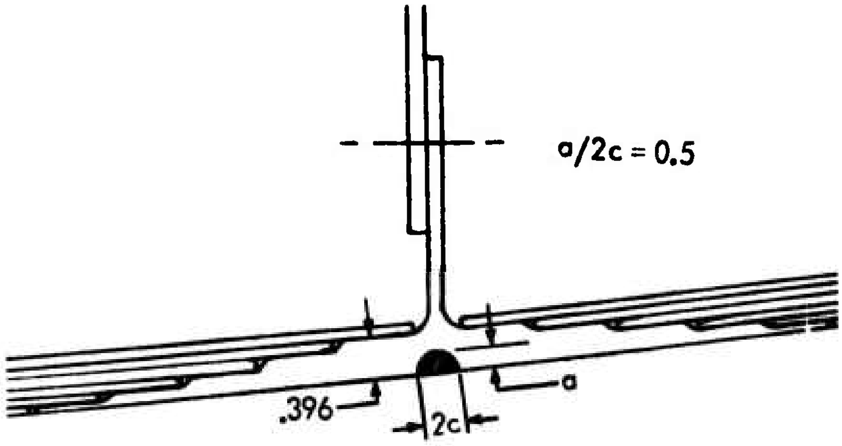


Figure C.3 Fracture Design Allowable Curve - Wing Box Lwr Surface (Laminated 2024-T81 Aluminum Surface Flaw)



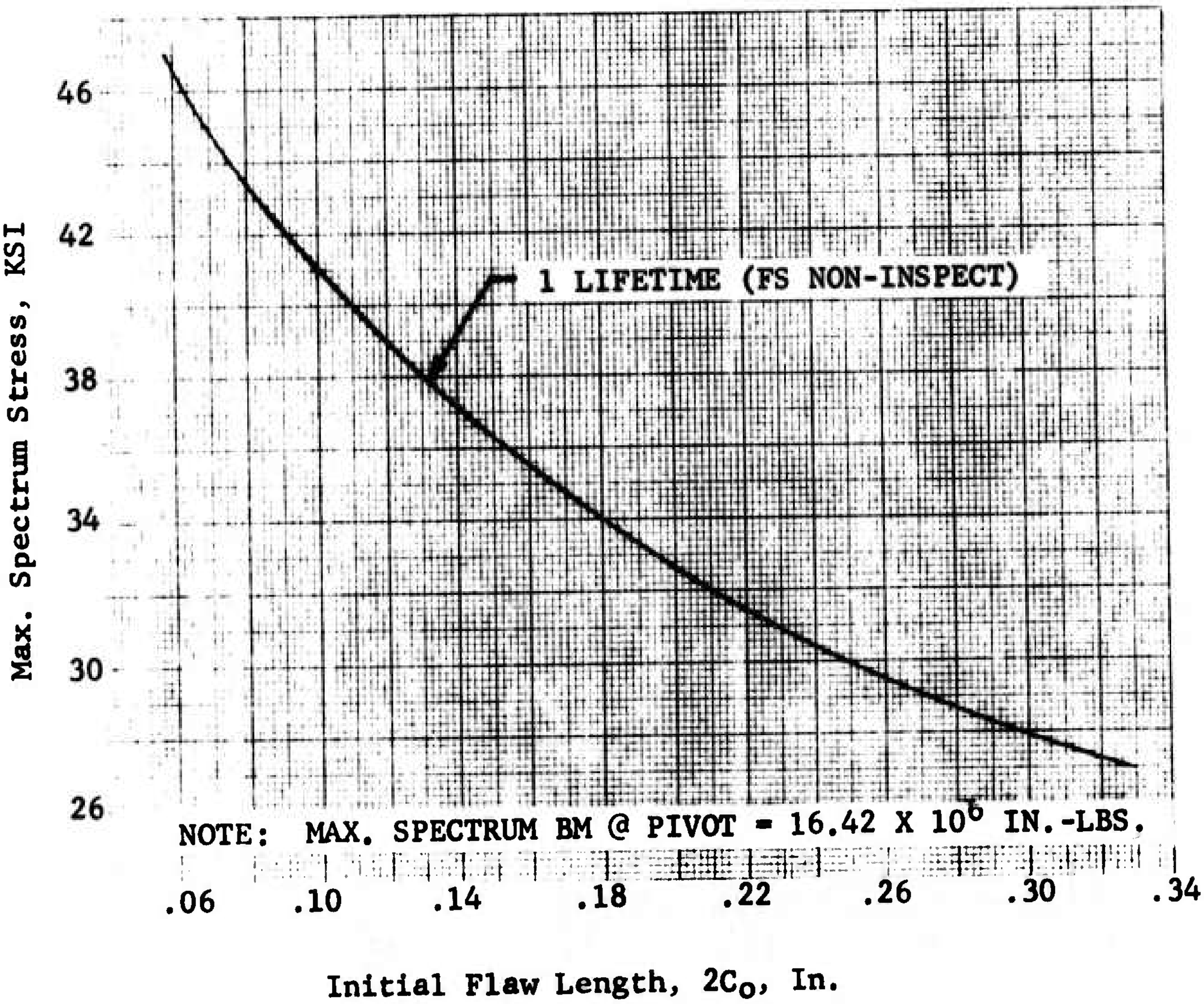
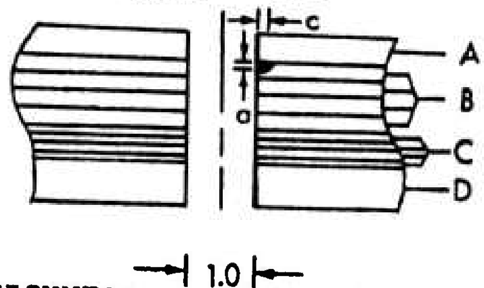


Figure C.4 Fracture Design Allowable Curve - Wing Box Lwr Spar Cap (2024-T8511 Aluminum Surface Flaw)

TAPER-LOK BOLT HOLE
a/2c = 0.5



THICKNESS	MATERIAL
A=0.2 IN	2024-T8511 AL
B=0.09 IN	2024-T81 AL
C=0.063 IN	2024-T81 AL
D=0.31 IN	10 NICKEL STEEL

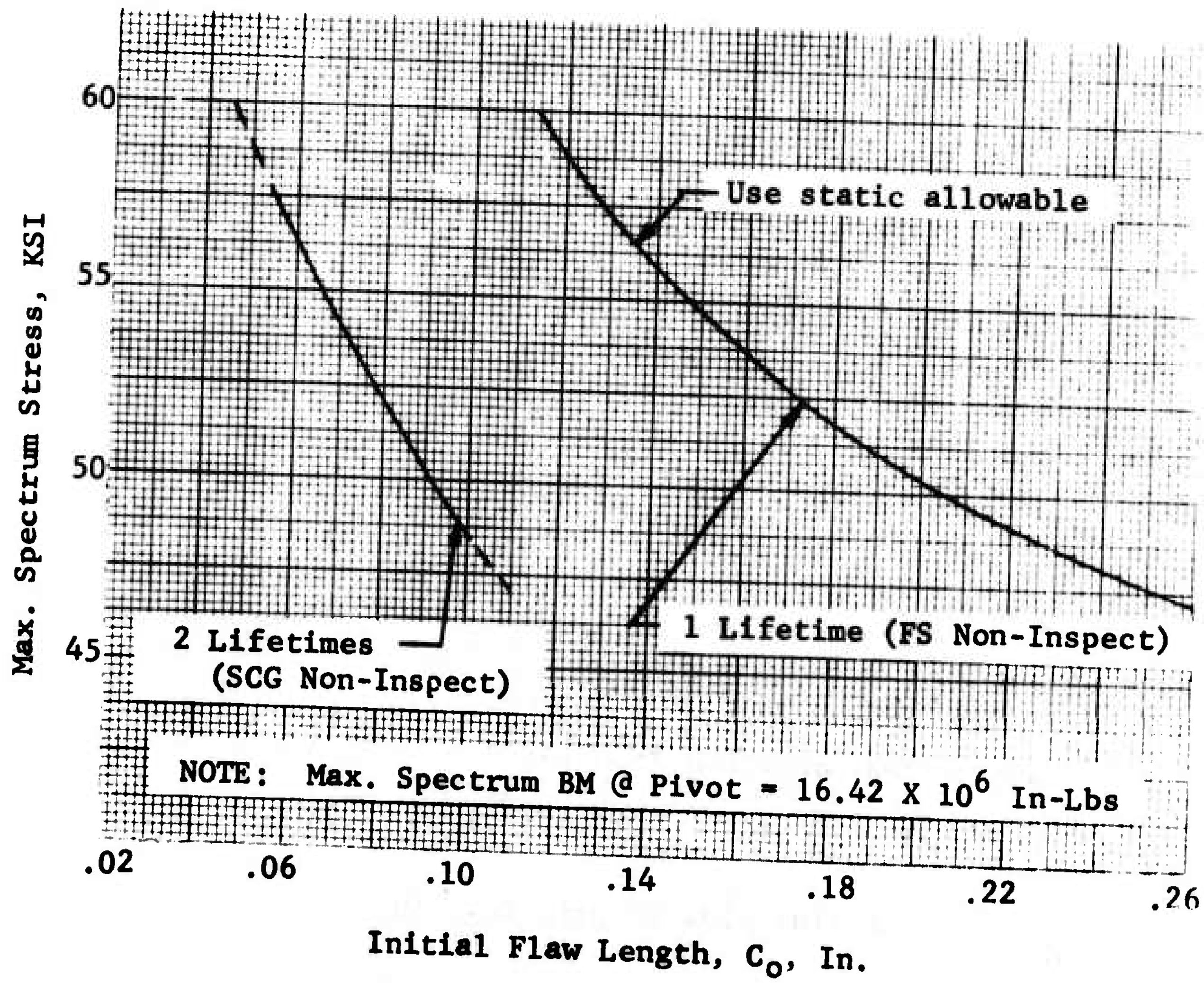


Figure C.5 **Fracture Design Allowable Curve - Wing Pivot Fitting (Laminated 2024-T81 Aluminum Corner Flaw)**

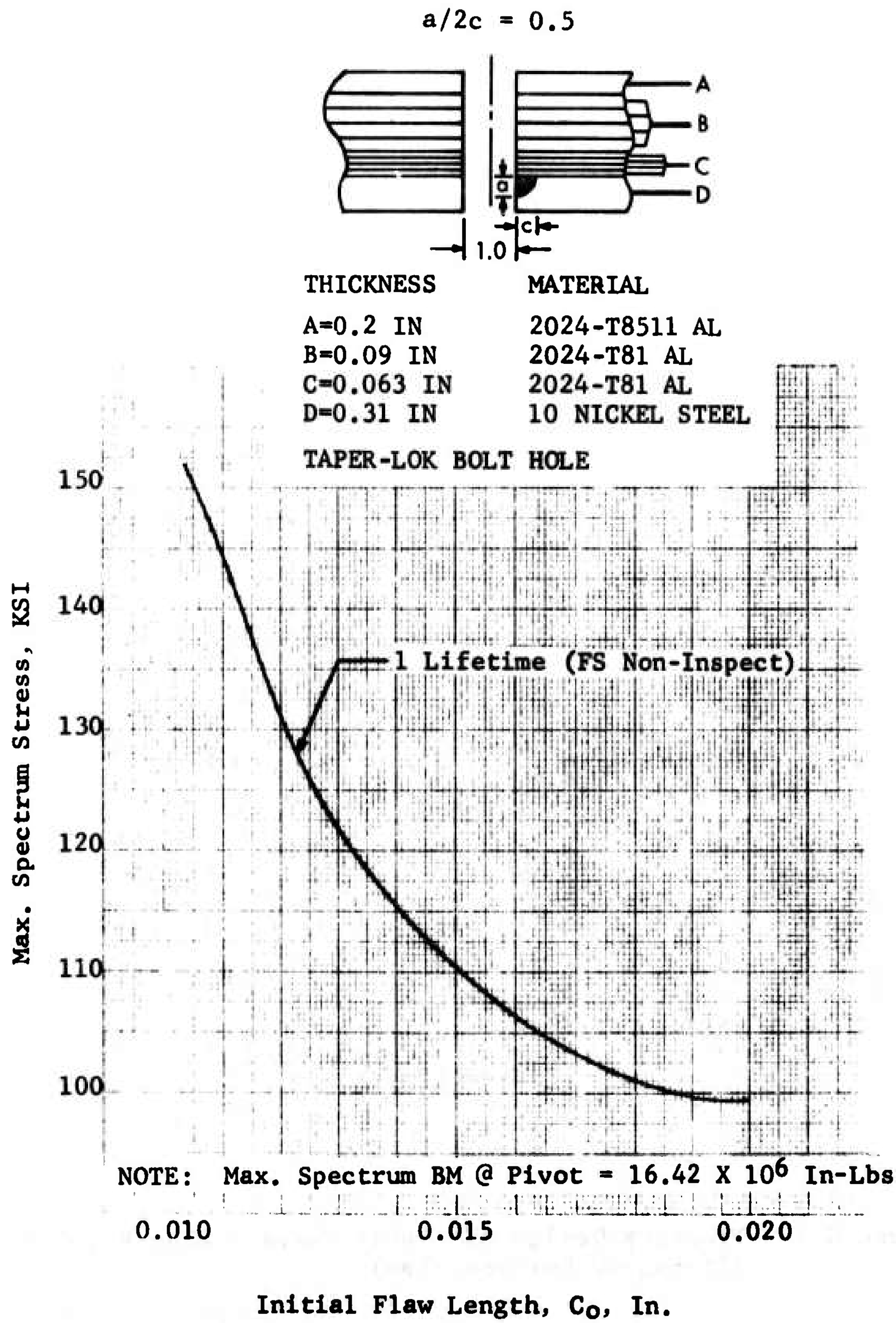
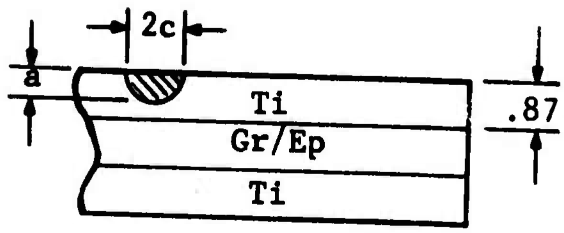


Figure C.6 Fracture Design Allowable Curve - Wing Pivot Fitting (10 Nickel Steel Corner Flaw) a/2c = 0.5



NOTE: Max Spectrum BM @ Pivot = 16.42×10^6 In-Lbs

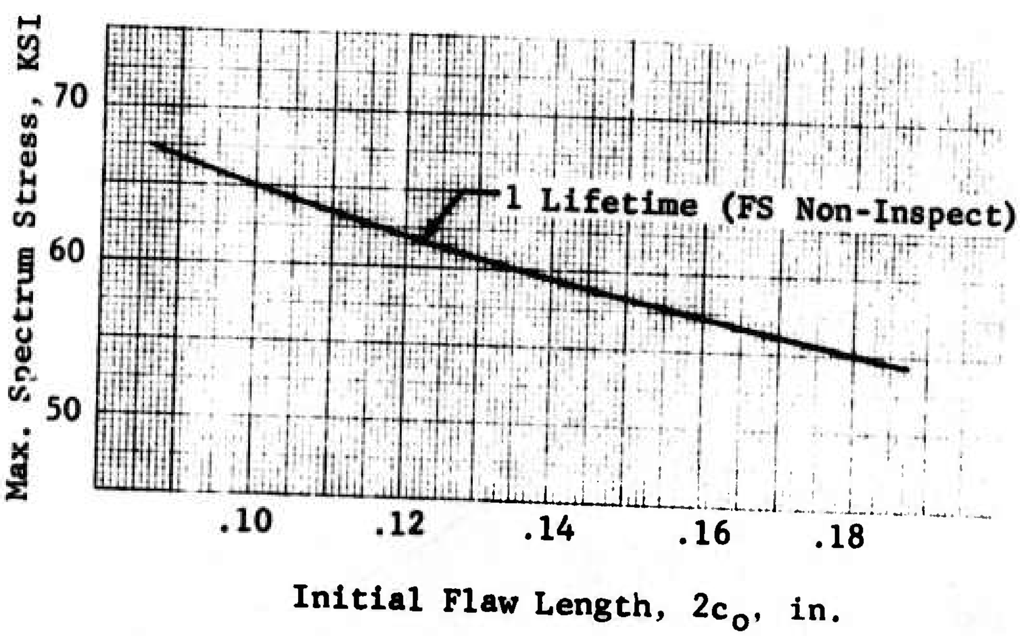


Figure C.7 Fracture Design Allowable Curve - Wing Pivot Fitting (Ti-6AL-4V Surface Flaw)

APPENDIX D

FOLLOW-ON PROGRAM

APPENDIX D

FOLLOW-ON PROGRAM

The logical steps that are needed to fully develop the supercritical wing for use on a future vehicle, such as the ATF, would include the following:

- o Kinematic model that demonstrates the mechanical feasibility of Variable Camber High Lift System
- o Supercritical Wing Structural Component Test Program
- o Full Scale Wing Structural Test Adv. Dev. Program
- o Flight Test Adv. Dev. Program

The first two of the above tasks are described with a statement of work in this section.

D.1 STATEMENT OF WORK FOR DESIGN AND CONSTRUCTION OF VARIABLE CAMBER SYSTEM KINEMATIC MODEL

D.1.1 Introduction

The task defined herein encompasses the design definition and fabrication of one (1) constant section kinematic model that duplicates a production design concept of a leading and trailing edge variable camber system. The task will span a 5 month period. The kinematic model will be used as an instrument to:

- o Promote interest in the variable camber wing concept.
- o Build confidence in leading and trailing edge variable camber devices, particularly in the area of flexible skins and variable camber driving mechanisms.

- o Improve understanding of selected variable camber devices and provide insight into the principles of operation of these devices.

- o Demonstrate the aerodynamic shapes and smoothness obtainable with variable camber devices.

The variable camber devices will be supported structurally by a simulated wing box which will be supported on an attractive pedestal.

D.1.2 Engineering Task

D.1.2.1 Design

The design task will require the preparation of the following drawings:

D.1.2.1.1 Leading Edge

(a) Layout

(b) Actuation Arm

(c) Roller

(d) Leading Edge

(e) Upper Skin

(f) Lower Skin

(g) Front Spar

(h) Machined Details

(i) Leading Edge Variable Camber Assembly drawing.

D.1.2.1.2 Trailing Edge

(a) Layout

(b) Upper Skin

(c) Lower Skin

(d) Skin Beam Details

(e) Skin Details, Trailing Edge

(f) Channel Link Details

(g) Actuator Beam Details

(h) Socket Fitting Details

(i) Sleeve Fitting Details

(j) Coupling Details

(k) Swivel

(l) Beam Pivot Block Details

(m) Pin and Bolt Details

(n) Link Details

(o) Fork, Trailing Edge Actuation

(p) Slide Members, Trailing Edge

(q) Bushing Details

(r) Pivot Fitting Details

D.1.2.1.3 Electrical Drive & Control

An electrical drive and control drawing will be prepared with a circuit diagram included.

D.1.2.1.4 Pedestal & Simulated Wing Box

A drawing of the pedestal & simulated wing box will be prepared.

D.1.2.2 Stress Analysis

A stress analysis shall be conducted to verify that part sizing and material selection for the model is compatible with airplane criteria required under contract F33615-75-C-3018.

D.1.2.3 Engineering Support

Engineering support shall be provided throughout fabrication of the model.

D.1.3 Tooling Task

An overall manufacturing plan shall be made to assure that the tooling and manufacturing task is executed in an efficient manner. Parts planning shall also be accomplished. Parts planning shall make maximum use of drawing references in order to minimize the parts planning task.

Minimum cost tooling shall be provided for the composite, glass fiber, and molded rubber parts. No assembly tools will be required.

D.1.4 Fabrication Task

One (1) leading edge assembly, one (1) trailing edge assembly, and one (1) simulated wing box member shall be fabricated as shown on Figure D.1. The wing model components will be joined with mechanical fasteners to form a wing cross-section member.

The 38 inch long constant cross-section model will be mounted on a wooden pedestal as shown in Figure D.1.

Two 110V, 60 cps, 1/4 HP A.C. reversible motors will be installed in the pedestal and one mechanically linked to the leading edge drive shaft and one to the trailing edge drive shaft. Four protective limit switches will be provided, two on each of

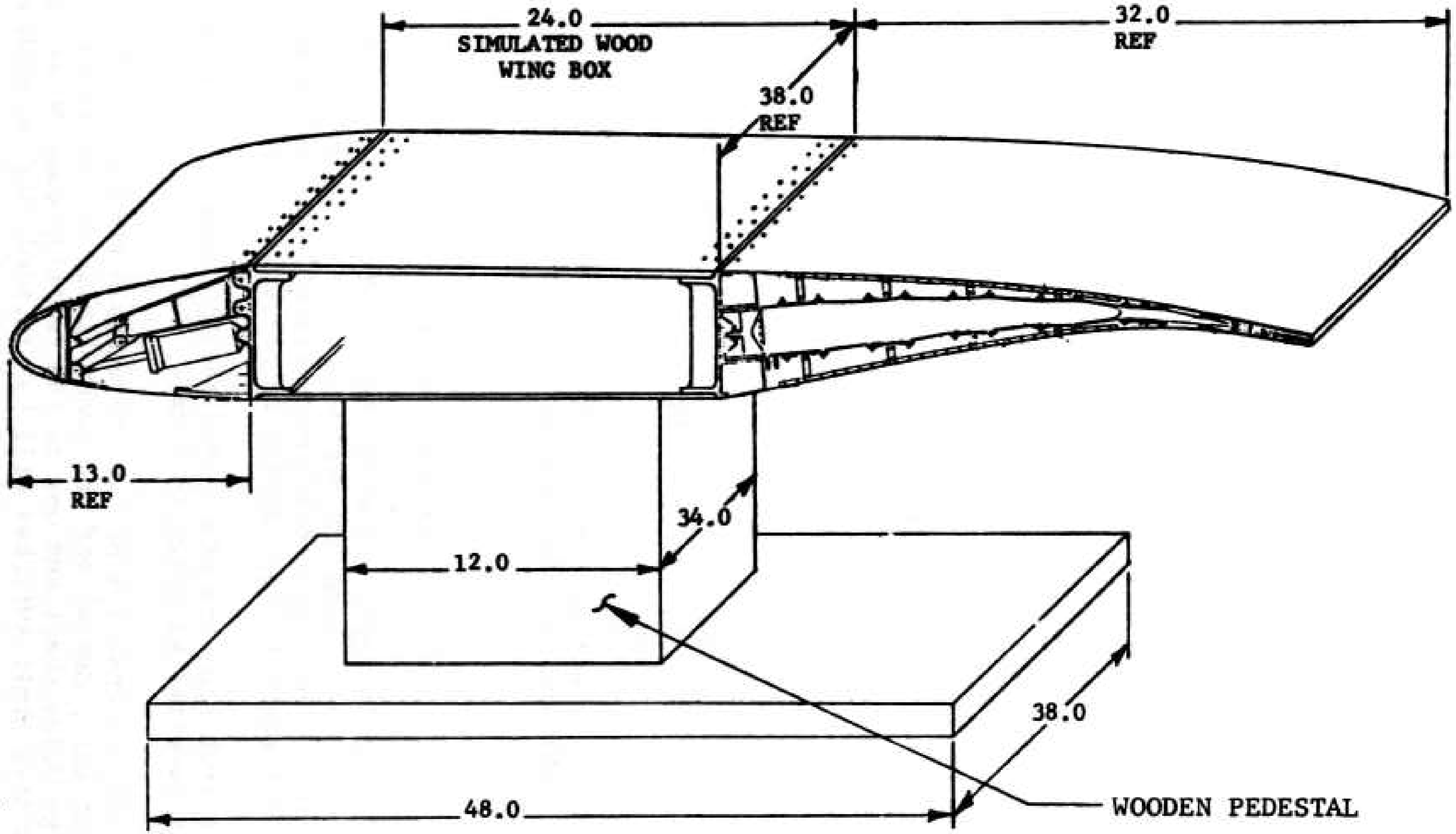


Figure D.1 Variable Camber System Kinematic Model the leading edge device and two on each of the trailing edge device. Two control switches in separate circuits will be provided so that the leading edge and trailing edge can be operated separately.

D.1.5 Inspection

Inspection will be limited to material receiving inspection only. Final disposition of rejected material will be determined by engineering design personnel.

D.2 STATEMENT OF WORK FOR ADVANCED TRANSONIC WING DEVELOPMENT PROGRAM

D.2.1 Objective

The objective of this program is to evaluate the feasibility of integrating the advanced technologies of the Variable Camber Program and the Supercritical Wing Box Program on to a full scale advanced technology test wing. The overall approach used to accomplish this objective will be to conduct a test program to demonstrate the feasibility of the leading and trailing concepts developed during the Variable Camber Program and the wing box concept developed during the Supercritical Wing Box Program.

D.2.2 Scope

This program will consist of designing, fabricating, and testing a supercritical wing section which incorporates the top ranked leading and trailing edge concepts developed during the Variable Camber Program and the top ranked wing box structural concept developed during the Supercritical Wing Box Program. The task will span a 12 month period.

D.2.3 Program Tasks

The following paragraphs define the basic tasks that are a part of this program

D. 2.3.1 Develop a test component integrating the selected leading and trailing edge variable camber concept and the selected supercritical wing box concept. This test component will be approximately 72 inches in length and of constant size airfoil shape (ATW-4 airfoil configuration at C.S.S. 140).

D. 2.3.1.1 Develop detail design drawings of the test component (leading and trailing edge structure, mechanical drive systems and linkages, wing box structure, and load introduction fittings) such that actual hardware can be fabricated and assembled.

D. 2.3.1.2 Perform stress analysis to size test component.

D. 2.3.1.3 Perform fatigue analysis to size test component in accordance with MIL-A-008866A.

D. 2.3.1.4 Perform damage tolerance analysis to size test component in accordance with MIL-A-83444.

D. 2.3.1.5 Compute detailed weight calculations for test component.

D. 2.3.1.6 Compute budgetary cost estimate for test component.

D. 2.3.1.7 Determine the methods of fabrication and quality assurance provisions necessary for the manufacture of the test component. Develop a manufacturing plan for the test component and fabricate all tooling and fixtures required.

D. 2.3.2 Fabricate test component.

D. 2.3.2.1 Fabricate one test component for the leading and trailing edge and wing box design.

D.2.3.2.2 Conduct (NDI) inspection procedures required during fabrication of test component using current state-of-the-art equipment with the necessary refinements for adapting to the specific component.

D.2.3.2.3 Monitor all costs relevant to the fabrication of the test component. Compare these actual costs with those estimated in paragraph D.2.3.1.6.

D.2.3.2.4 Determine actual weights of test component and compare with those estimated in paragraph D.2.3.1.5.

D.2.3.2.5 Develop test plan for static and fatigue testing (wing bending and variable camber deflection) the test component. Include loads, instrumentation, inspection requirements, fatigue spectrum, and safety provisions necessary for testing.

D.2.3.2.6 Fabricate the test fixtures required for conducting the static and fatigue tests.

D.2.3.3 Conduct testing of the component in accordance with test plan prepared in paragraph D.2.3.2.5 and summarized in Table D-I. The loads that will be shown in the test plan will simulate those measured on the baseline aircraft. The instrumentation required by the test plan will be adequate to control inputs and measure load distribution and response to the applied loads.

D.2.3.3.1 Conduct strain survey of test component at limit load to determine stress distribution.

D.2.3.3.2 Conduct fatigue test of component to four lives. During fatigue loading (wing bending loads) perform cyclic operations (deflections) of variable camber systems.

TABLE D-I TEST PLAN SUMMARY

TEST	SPECIMEN	INSTRUMENTATION** AND INSPECTION	LOADING	LOADING CONTROL
Strain Survey	See Figure D.2	Inspect after loading to limit load	1 condition - Max bending @ Limit Load. See Figure D-2	Manually Controlled
Fatigue*	See Figure D.2	Inspect after each lifetime	4 lives @ 142,060 cycles per lifetime of wing bending. 4 lives @ 2,560 cycles per lifetime of variable camber deflection. See Figure D-2	Programmed
Static	See Figure D.2	Inspect after failure	1 condition - Max bending to failure. See Figure D-2	Manually Controlled

* Fatigue spectrum based on B-1 Exceedence Spectrum with ATW-4 Supercritical Airfoil Configuration Loads.

** Assume 8 Rosettes and 4 Axial strain gages on box beam component. Assume 6 Rosettes and 6 Axial strain gages on leading edge system and on trailing edge system.

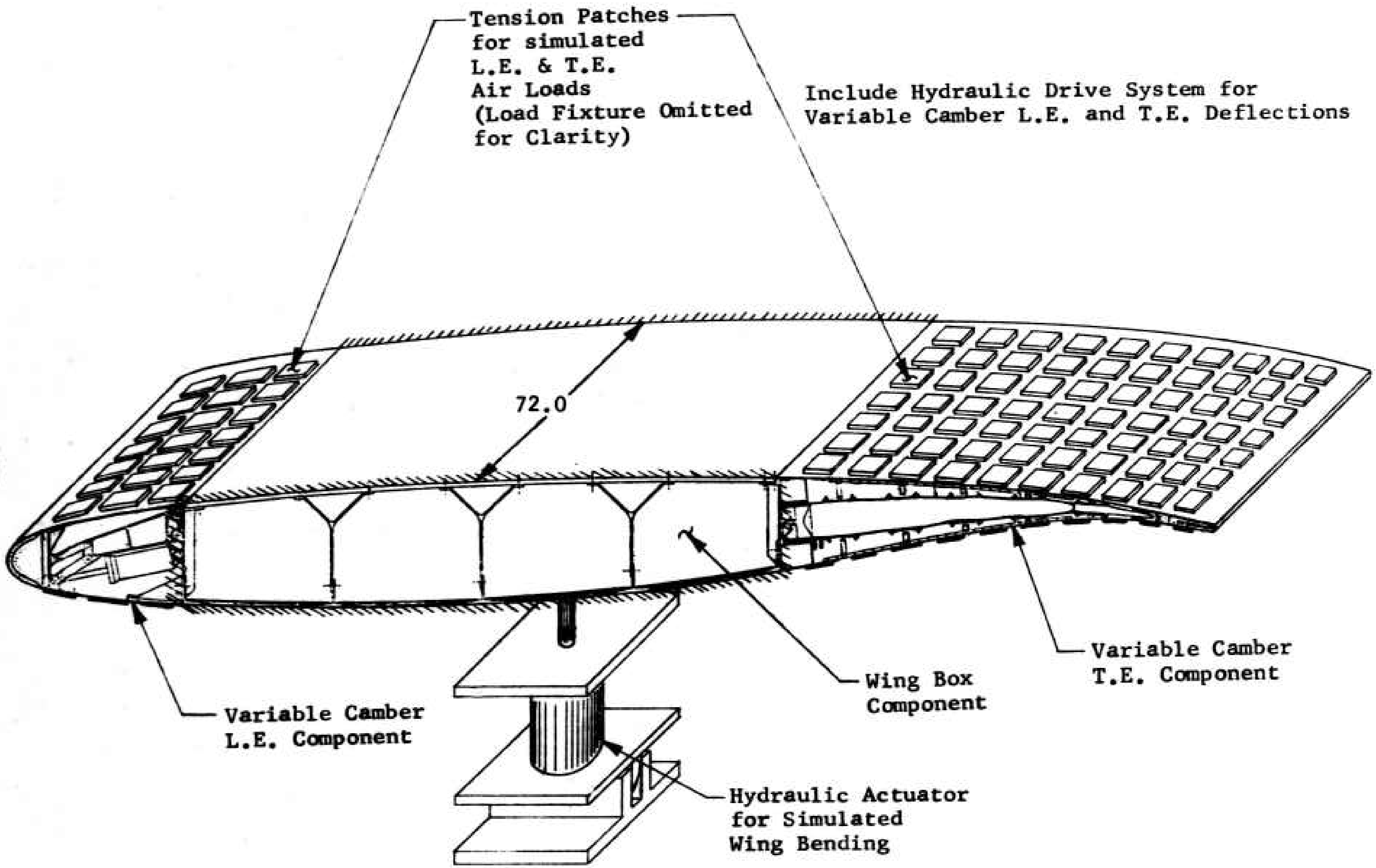


Figure D.2 Static and Fatigue Test "Set-Up" for Advanced Transonic Wing Test Component

D.2.3.3.3 Conduct static test of component to failure after completion of fatigue testing.

D.2.3.3.4 Conduct nondestructive evaluation prior to testing to detect and monitor any failure.

D.2.3.3.5 Reduce recorded results, analyze, and evaluate. Compare with analytical predictions calculated previously.

D.2.3.4 Evaluate reliability and efficiency of the leading and trailing edge systems and wing box configuration.

D.2.3.5 Evaluate operational durability of the variable camber systems.

D.2.3.6 Evaluate internal loads and stress distributions in the leading and trailing edge systems and wing box structure.

References

1. FZP-1718 "A Proposal for an Advanced Technology Wing (ATW) Configuration Design and Analysis Program".

2. ERR-FW-867, Vol. I "A Computer Program for the Aerodynamic Analysis and Design of Wing-Body-Tail Combinations at Subsonic and Supersonic Speeds", by F. A. Woodward and D. S. Hague.

3. MRL-163 "The Effects of Static Aeroelasticity in the Design of Advanced Air Vehicles", by E. E. Cwach and J. J. Hosek.

☆ U. S. GOVERNMENT PRINTING OFFICE: 1976 — 657-630/586

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