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WEAPON SYSTEM COSTING METHODOLOGY FOR
AIRCRAFT AIRFRAMES AND BASIC STRUCTURES.
VOLUME III. COST DATA BASE

R. E. Kenyon

General Dynamics

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Air Force Flight Dynamics Laboratory

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**WEAPON SYSTEM COSTING METHODOLOGY
FOR AIRCRAFT AIRFRAMES AND
BASIC STRUCTURES**

VOLUME III + COST DATA BASE

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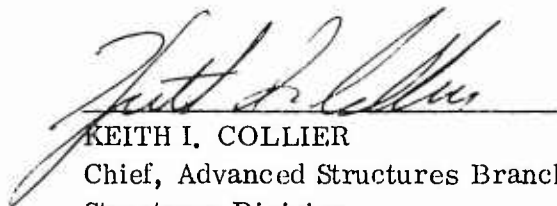
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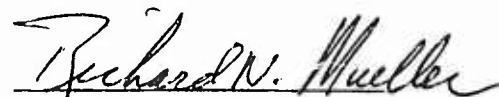
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This report covers work conducted from July, 1972 to November, 1973 and was submitted by the author in December 1973, under General Dynamics Report CASD-AFS-73-001 as an Interim Technical Report. The principal author and project leader on this program is Mr. R. E. Kenyon of Convair Aerospace.

This report has been reviewed and is approved for publication.



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ABSTRACT

This volume presents the cost data used as the basis for developing the trade cost estimating technique for aerodynamic surfaces. Other data that has become available in the course of the study is also presented. Raw data and organized data are presented. An ultimate objective of the study with respect to the cost data base is to present back-up data for each individual CER, including both trade study and system costing relationships.

The cost trend data that is included was produced under an amendment to the contract. Its intent was to provide a data base for cost estimate evaluation.

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SECTION I

INTRODUCTION

This volume presents the cost data used in the formulation of cost estimating relationships for the aerodynamic surfaces trade study cost estimating module, and the cost trend data that was prepared as an add-on task to the basic contract. An overlap exists between trade study and system cost data in the area of commonly used cost estimating relationships, i. e., the data supporting development of nonrecurring cost estimating relationships. Such data is included under trade study cost data (Section 2.3) since it was first used for this purpose.

Trade study cost data is described in terms of the effort directed towards its collection and in terms of its subsequent organization. Minimum data consists of at least one data point suitable for use as an analog. Cost data is organized to support the CER structure.

System cost data will ultimately be included and will cover subsystem level data and airframe level data. Airframe level data is to be used in the verification of the estimating method inasmuch as this is a more commonly available level of cost.

Cost trend data is supplementary data prepared as an add-on task. It reflects an effort to show general cost trends. To a degree it also serves as background to the estimating procedures.

In addition to the above data and as a matter of convenience, work sheets showing the back-up data for the derivation of complexity factors for design options used in the estimating procedure as outlined in Volume IV are included in this data volume as Appendix A. Inclusion of this data provides a basis for interpolation between complexity factors for perceived variations in construction methods.

SECTION II
TRADE STUDY COST DATA

2.1 SUBASSEMBLY LEVEL COST DATA COLLECTION

Major aircraft structural components were analyzed at a subassembly level in order to develop detailed cost data that could be related to the CER structure for manufacturing first unit cost in order to provide the cost data base for calibrating general CERs, or as a minimum to provide a relevant set of cost estimating analogs. The cost data and its development are discussed by major component in the following.

2.1.1 HORIZONTAL STABILIZER. Data shown for the horizontal stabilizer is that developed for the feasibility study under Air Force Contract F33615-70-C-1340. The data and the steps in its development are discussed below by individual aircraft.

C-5A Horizontal Stabilizer

An initial analysis of the C-5A Horizontal Stabilizer first unit cost was completed. The results of this analysis are shown in Table 1. These data were derived from an analysis of actual costs together with planned standard hours to apportion costs to the breakdown indicated. This breakdown was inadequate, however, because it did not correspond to the CER format. Using these data as a starting point, a further breakout to the desired format was accomplished. This required an analysis and sorting of weight records, and a resorting of planning and detailed drawings to conform to the weight breakdown that is the basis for the CER structure. This resorting served also to reconcile C-141 and C-5 breakdowns, which had not agreed since each one was in accordance with its own assembly sequence. The CER weight breakdown format was adhered to in preference to the assembly sequence so that the CER structure matched the output of the structural synthesis program. Weight records exist for each of these parts.

Actual costs were allocated to this same level of detail, and then totaled according to the CER and weight breakdown format. The resulting revised data is shown in Table 2.

C-141A Horizontal Stabilizer

The C-141A Horizontal Stabilizer underwent the same initial and revised analyses as the C-5A. Table 3 shows the initial data and the resulting revised data is shown in Table 4.

Table 1. C-5A Horizontal Stabilizer Actual Hours and Material Costs

Component	Factory Hours (Shipset No. 1)		Total	Subcontract	Total	Inspection (15.23 % of Factory)	Tool Mfg. Hours (Non-Recur)	Material (\$) (Shipset No. 1)
	Fabrication	Assembly						
Center Bullet Fairing	850	621	1471	-	-	224	24,547	438.00
Front Beam	181	184	365	-	-	56	6410	2570.00
Rear Beam	1537	545	2082	-	-	317	28,200	5061.00
Ribs	1490	464	1954	-	-	298	16,441	3315.00
Upper Skin	446	2511	2957	1871	4828	450	12,667	17,920.00
Lower Skin	378	2713	3091	3258	6349	471	9530	11,844.00
Trailing Edge	1847	1926	3773	-	-	575	28,090	2764.00
Fixed Tips	446	615	1055	-	-	161	8135	434.00
Lox Assembly	675	6993	7668	-	-	1168	27,313	526.00
Structure Mate	2621	2716	5337	-	-	313	30,410	1,142.00
Subtotal	10,465	19,298	29,763	5129	-	4533	191,773	-
Forward Bullet	-	-	1092	-	-	258	25,270	783.00
Aft Bullet	-	-	2028	-	-	309	26,100	835.00
Inboard Elevators	-	-	3955	-	-	602	23,020	3440.00
Outboard Elevators	-	-	2613	-	-	398	14,108	3864.00
Leading Edges	-	-	759	-	-	116	6144	269.00
Removable Tips	-	-	346	-	-	53	4283	105.00
Systems Installation	-	-	1235	-	-	189	8359	1879.00
Primary Assembly	1640	2450	4090	-	-	623	12,263	2960.00
Totals	-	-	46,471	-	-	7080	311,380	-

Table 3. C-141 Horizontal Stabilizer Actual Hours and Material Costs

Component	Factory Hours (Shipset No. 1)		Subcontract	Total	Inspection (22.3% of Factory)	Tool Mfg. Hours (Non-Recur)	Material (\$) (Shipset No. 1)
	Fabrication	Assembly					
Center Tie Box	3418	1238	-	4656	1038	22,486	12,950.00
Front Spar	655	96	-	751	167	7371	4736.00
Rear Spar	410	78	-	483	109	4291	1116.00
Ribs	722	190	-	912	203	-	2511.00
Upper Skin Panel	342	360	130	702	157	9260	3130.00
Lower Skin Panel	184	299	125	483	108	7583	2258.00
Trailing Edge and Other	818	312	-	1130	252	2922	-
Structure Assembly	481	3925	-	4409	983	19,835	2539.00
Subtotal	7033	6498	255	13,531	3017	73,748	-
Forward Bullet	-	-	24	1477	320	10,101	1824.00
Aft Bullet	-	-	-	1865	410	10,805	1927.00
Elevators	-	-	397	6384	1421	27,540	8264.00
Leading Edges	-	-	404	2855	637	7032	2594.00
Tips	-	-	-	226	50	1843	28.00
Primary Assembly	1096	1162	-	2258	504	17,694	2347.00
Total	-	-	825	28,596	6377	154,823	-

A(X) Horizontal Stabilizer

Cost estimates used in competitive bidding on the Air Force A(X) program were analyzed to develop a data breakdown at a relevant level. The results of this analysis are presented in Table 5.

VF(X) Horizontal Stabilizer

The Navy VF(X) proposal cost estimates were analyzed in a manner similar to that for the A(X). These data are presented in Table 6.

F-111A Horizontal Stabilizer

The standard F-111A horizontal stabilizer was fabricated by Grumman Aircraft Corporation. The data presented in Tables 7 and 8 were obtained from Grumman for this study. The first shows basic manufacturing labor and material data, and the second gives related tooling and inspection data. These data were further analyzed to arrive at projected first unit costs for the comparison in the demonstration estimates. The first 26 units shown include 23 RDT&E ship sets, and three sets of test articles. A unit includes left and right stabilizers. The RDT&E phase was divided into six lots. Tooling is based on a production capability of 16 units per month although actual production was only from four to eight per month.

F-111B Experimental Boron Epoxy Horizontal Stabilizer

Material and structural cost data for the F-111B experimental boron epoxy horizontal stabilizer are presented in Tables 9 and 10.

Note on Boron Epoxy Tape for F-111B Horizontal Stabilizer: 75,900 lineal feet of NARMCO 5505 preimpregnated boron tape was order to manufacture five shipsets of F-111B horizontal stabilizers. The boron epoxy material weighed 1100 pounds. The following procedure was used to establish a cost per pound value for the boron epoxy material actually used in each shipset.

The boron material cost of \$325,446 was divided by 1100 pounds to obtain a \$296 per pound cost for raw material. Scrappage and loss percentage, assuming the 1100 pounds were all used, was calculated as follows:

$$163.3 \text{ lb/ss} \times 5 = 815 \text{ lb for 5 ss}$$

$$1100 \text{ lb} - 815 \text{ lb} = 285 \text{ lb scrapped or rejected}$$

$$\frac{285}{815} = 35\% \text{ loss percentage}$$

Table 7. F-111 Horizontal Stabilizer -- RDT&E Actual Manufacturing Hours

	<u>Center Section</u>	<u>Leading Edge</u>	<u>Trailing Edge</u>	<u>Tip</u>	<u>Final Assembly</u>	<u>Total</u>
Lot I (5 Units) Avg.						
Detail	8,135	1,482	1,315	52	1,053	12,037
Assembly	1,280	268	249	-	1,166	2,963
Total						<u>15,000</u>
Lot II (4 Units) Avg.						
Detail	5,740	467	467	37	408	7,119
Assembly	623	161	123	-	804	<u>1,711</u>
Total						8,830
Lot III (2 Units) Avg.						
Detail	4,918	534	515	37	461	6,465
Assembly	601	137	132	-	864	<u>1,734</u>
Total						8,199
Lot IV (4 Units) Avg.						
Detail	4,103	520	443	53	488	5,607
Assembly	556	126	119	-	740	<u>1,541</u>
Total						7,148
Lot V (3 Units) Avg.						
Details	3,666	485	345	220	400	5,116
Assembly	456	107	102	247	625	<u>1,537</u>
Total						6,653
Lot VI (8 Units) Avg.						
Details	2,933	431	325	276	319	4,324
Assembly	502	117	107	303	550	<u>1,580</u>
Total						5,904
Material (26 Units) Avg.	\$26,091	\$4,051	\$3,975	\$1,243	\$2,536	\$37,896

Applied to the raw material cost this gives: $\$296/\text{lb} \times 1.35 = \$400/\text{lb}$. This cost is assumed to cover all boron epoxy material lost, whatever the cost.

Table 8. F-111 Horizontal Stabilizer -- Inspection and Tooling Hours

Mfg to Inspection ratio: (Hrs)	Lot I 12.3%
	Lot II 13.2%
	Lot III 12.0%
	Lot IV 12.3%
	Lot V 12.1%
	Lot VI 10.8%
	Average 12.08%
Nonrecurring Tooling:	240,155 hrs
	\$2,054,697
Nonrecurring Tooling Material:	\$231,356
Sustaining Tooling:	17,328 hours

Table 9. F-111A Boron Horizontal Stabilizer Structural Cost Data

Data Source Nomenclature	Manufacturing Hours First Unit (hr/lb)
Steel Pivot Fitting	12.0
Titanium Assemblies	47.0
Boron Substructure	44.4
Bag Core	9.0
Box Assembly	14.7
Assembly only - Tip, Leading and Trailing Edges	22.8
Boron Skins	16.0
Total Manufacturing Hours (with Pivot Fitting)	29.0

Table 10. F-111B Experimental Boron Epoxy Horizontal Stabilizer Material Cost Analysis

Assembly No.	Nomenclature	Assembly Weight (lb)	Weight Boron Epoxy (lb)	Raw Material and Purchase Parts Cost (\$)	Boron Epoxy Cost (\$)	Total Cost (\$)
FW 6730614	Trailing Edge	23.5	7.3	278.00	2917.00	3195.00
FW 6730615	Leading Edge	23.9	7.2	101.00	2877.00	2978.00
FW 6730634	Stabilizer Installation	41.1	-	327.00	-	927.00
FW 6730635	Box Assembly	301.3	115.3	5300.00	46,074.00	51,374.00
FW 6730637	Plate	39.8	-	2890.00	-	2890.00
FW 6730638	Pivot Fitting	232.4	-	410.00	-	410.00
FW 6730639	Root Rib (Forward and Aft)	36.1	-	2543.00	-	2543.00
FW 6730640	Front Spar	16.4	1.7	163.00	679.00	842.00
FW 6730641	Closure Forward Root Rib	25.6	17.9	22.00	7153.00	7175.00
FW 6730642	Closure Aft Root Rib	8.0	2.2	7.00	879.00	886.00
FW 6730643	Tip Box Closure	7.6	1.4	6.00	559.00	565.00
FW 6730644	Tip Cap Assembly	27.0	7.3	288.00	2917.00	3205.00
FW 6730645	Retainer	0.8	-	16.00	-	16.00
FW 6730646	Spar and Rib Forward Canted	18.5	-	627.00	-	627.00
FW 6730647	Rib Aft Canted	11.5	-	394.00	-	394.00
FW 6730648	Rear Spar	6.6	1.0	47.00	400.00	447.00
	TOTAL	<u>820.1</u>	<u>163.3</u>	<u>14,019.00</u>	<u>64,455.00</u>	<u>78,474.00</u>

2.1.2 WING. Data shown for the wing has been used in conjunction with previously developed horizontal stabilizer data in the development of the aerodynamic surfaces module. The data and the steps in its development are discussed below by individual aircraft.

A(X) Wing

Manufacturing direct labor hours for the Convair proposed A(X) aircraft have been detailed as shown in Table 11. Aircraft subsystem hours under Wing Primary Assembly represent assembly, installation, detail fabrication and bench assembly for those elements and parts of the aircraft subsystems that are assembled into the wing, i. e., fuel system, flight controls, environmental control, hydraulics/pneumatics, electrical, etc. A manufacturing WBS includes this portion of the assembly task as part of the wing whereas an engineering WBS includes it as part of the respective subsystem. Under an engineering oriented WBS, a wing contains structural task only. The breakdown of this data permits consideration either way. Material costs are shown in Table 12.

Advanced Structure Fighter Wing Box

A cost estimate was submitted to the Fort Worth operation for the Upper and Lower Adhesive Bonded Honeycomb Panel Wing Box structural design concept (GD Convair Drawing No. 610RW 004 "A"). A summary of the data submitted is presented herewith. The estimate is based on the AFFDL cost estimating method for aerodynamic surfaces, including CERs, for adhesive bonding that will be incorporated in the method:

	<u>Recurring</u>	<u>First Unit</u>
Manufacturing Labor:		
Detail Fabrication		9,935 hrs
Subassembly		2,525 hrs
Box Assembly		6,590 hrs
Material:		
Structural	\$13,136	
Assembly	3,360	
Quality Control:		4,000 hrs

The above estimate does not include pylon fittings, pivot fitting, or any allowance for rework. The following summary shows the extension of cost to the 506th unit, and includes rework.

Table 11. A(X) Prototype Estimate - Wing Manufacturing Labor Hours.

	Detail Fab	Bench Sub Assy	Floor Assy	Major Assy	Wing Primary	Wing Final	Total
<u>Wing Box</u>		-		7,735	-	-	7,735
Ribs	1,821	-	925	-	-	-	2,746
Spars	2,729	-	2,660	-	-	-	5,389
Skins & Stringers	632	-	784	-	-	-	1,416
Fuel Tight Corners	554	-	-	-	-	-	554
Other	<u>1,193</u>	<u>169</u>	<u>-</u>	<u>-</u>	<u>-</u>	<u>-</u>	<u>1,362</u>
Sub Total	6,929	169	4,369	7,735	-	-	19,202
<u>Secondary Structure</u>							
Leading Edge	2,369	2,160	-	-	-	-	4,529
Trailing Edge	118	89	-	-	-	-	207
Ailerons	1,827	-	996	-	-	-	2,823
Tips	277	-	-	-	-	-	277
Spoilers	1,586	-	2,148	-	-	-	3,734
Flaps	2,707	-	2,675	-	-	-	5,382
Eng. Supt. Fittgs.	641	15	-	-	-	-	476
Access Doors	572	1,143	-	-	-	-	1,715
Other	<u>2,689</u>	<u>104</u>	<u>1,920</u>	<u>-</u>	<u>-</u>	<u>-</u>	<u>4,713</u>
Sub Total	12,606	3,511	7,739	-	-	-	23,856
<u>Wing Primary Assy</u>							
* Fuel System	2,941	656	-	-	3,571	-	7,168
* Flight Controls	3,614	1,058	-	-	2,051	-	6,723
* Envir. Control	264	119	-	-	314	-	697
* Hyd/Pneu	1,325	199	-	-	1,278	-	2,802
* Electrical	277	-	-	-	4,216	-	4,493
Other	<u>-</u>	<u>-</u>	<u>-</u>	<u>-</u>	<u>792</u>	<u>-</u>	<u>792</u>
Sub Total	8,421	2,032	-	-	12,222	-	22,675
<u>Wing Final Assy</u>							
Leading Edge	-	-	-	-	-	2,895	2,895
Trailing Edge	-	-	-	-	-	89	89
Flaps	-	-	-	-	-	1,150	1,150
Spoilers	-	-	-	-	-	297	297
Wing Tips	-	-	-	-	-	163	163
Access Door	-	-	-	-	-	620	620
Aileron	-	-	-	-	-	183	183
Other	<u>-</u>	<u>-</u>	<u>-</u>	<u>-</u>	<u>-</u>	<u>586</u>	<u>586</u>
Subtotal	-	-	-	-	-	5,983	5,983
TOTAL	27,956	5,712	12,108	7,735	12,222	5,983	71,716

Table 12. A(X) Prototype Estimate - Wing Material Cost.

Component Description	S/S Mat'l Cost Sub Total	MUV Rate Applic. %	MUV Cost (S/S)	S/S Total Mat'l Cost (By Component)	
<u>Wing Box</u>					
Ribs	\$ 2,393	20	\$ 479	\$ 2,872	
Spars	2,665	20	533	3,198	
Covers/Stringers	3,782	20	756	4,538	
Fuel Tight Corners	12	20	2	14	
Other	646	20	129	775	
Struct Box Assy	459	14	64	523	
Sub Total	\$ 9,957		\$1,963	\$11,920	\$11,920
<u>Secondary Structure</u>					
Leading Edge	\$ 791	20	\$ 158	\$ 949	
Trailing Edge	230	20	46	276	
Ailerons	1,251	20	250	1,501	
Wing Tips	46	20	9	55	
Spollers	324	20	65	389	
Flaps	545	20	109	654	
Engine Suppt Figs	540	20	108	648	
Access Doors	232	20	46	278	
Other	4,929	20	987	5,915	
Sub Total	\$ 8,888		\$1,777	\$10,665	\$10,665
<u>Wing Primary Assy</u>					
Wing Assy	\$ 1,102	14	\$ 154	\$ 1,256	
Fuel Syst	19,208	Various	877	20,085	
Flight Controls	20,286	"	619	20,905	
Environ Controls	2,048	"	48	2,096	
Hydraulic Syst	5,903	"	199	6,102	
Elect Syst	2,850	"	467	3,317	
Sub Total	\$51,397		\$2,364	\$53,761	\$53,761
<u>Wing Final Assy</u>					
Wing Mate	\$ 275	14	\$ 39	\$ 314	\$ 314
Wing Ship Set Material Grand Total =					\$76,660

	<u>First Unit</u>	<u>506th Unit</u>
Manufacturing Detail Fabrication	9,935 hrs	745 hrs
Manufacturing Assembly	9,115 hrs	1,375 hrs
Quality Control	4,000 hrs	445 hrs
Rework at 12%		<u>310 hrs</u>
Labor		2,875 hrs
Material	\$16,500	\$10,400

Progress Curve Application:

73% Learning Factor $(0.0592) + 0.0158 = 0.075$ for mfg. detail fabrication

81% Learning Factor for mfg. assembly

21% of manufacturing labor hours for quality control

95% learning factor for material

The Manufacturing and Quality Control labor total of 2,875 hours compares to 2,907 hours obtained by the Fort Worth operation by grass roots estimating techniques; the \$10,400 material estimate compares to a figure of \$11,284.

F-111 Wing

Cost data is presented for the F-111 wing box based on an analysis performed under Contract F33615-72-C-2149, Advanced Air Superiority Fighter Wing Structures Program. Wing box data is based on the F-111F design. A separate analysis was performed for secondary structure.

Figures were extrapolated from costs gathered during the production of a specific aircraft: aircraft No. 506. Using these data as a point baseline, learning curves and recorded data were used to establish a baseline for costs. Unit costs for the 1st, 2nd, 50th, 150th, 200th, 506th, and 800th unit are presented. These costs were generated for a production rate of 20 aircraft per month. The point cost for Unit 506 was determined for the actual production rate and is provided for reference. Component costs for skins, ribs, spars, etc., were established for the point aircraft only.

The cost information is based on expenses incurred in the fabrication, assembly, and outside procurement activities for the production of an F-111F wing during manufacturing Lot Number 20. This lot consisted of 22 F-111F aircraft numbered 37 through 58 and represents Aircraft 495 through 516 in the overall F-111 production program. Only the basic wing box is included in the first set of numbers; the leading edge, trailing edge, tip, and pivot fitting follow. Pylon attach points are included, but the components required to rotate them are not included. Electrical and fuel equipment is not

included. All assembly operations associated with the basic wing box are included in the cost. These include fuel sealing and internal corrosion protection systems required to ensure the integrity of the integral fuel tank. Painting of the external surface is not included since that operation is performed after installation to the aircraft. The point cost generated for F-111 number 506 has been used to establish a stable baseline for comparison. Since the production rate greatly affects the overall cost of a structure, the baseline cost was evaluated to determine the effect of an alternate 20 aircraft per month production rate. Labor rates and material costs in effect during production of the point aircraft were used to cost the baseline, and to generate the baseline cost curve. This curve shows costs for 1, 2, 50, 150, 200, 506, and 800 aircraft all based on rates and charges used for the point aircraft.

A breakdown of costs by general components is provided in Table 13. Included in the individual component cost is all recurring direct charges for material, fabrication, hardware, finishing, installation into the basic wing box, and sealing operations. These figures are based on the point aircraft at the average production rate actually experienced during the F-111 program.

Costs for production quantities are shown in detail in Table 14. The point aircraft costs for both actual production rate and for 20 aircraft per month are shown in Table 14 to permit cross referencing to Table 13.

Overhead costs plus General and Administrative charges are shown in Table 14 for information. Table 14 is from Reference 1.

Available secondary structure cost data is summarized in Table 15. Figures are per wing, i. e., 1/2 ship set.

A-5A Wing (Including Empennage)

Available cost data for the A-5A wing and tail structure is shown in Table 16.

T-2A Wing (Including Empennage)

Available cost data for the T-2A wing and tail structure is shown in Table 17.

2.1.3 VERTICAL STABILIZER. Resources have not been invested in a systematic study of detailed vertical stabilizer costs since it was considered to be similar to the horizontal stabilizer. Readily available data was accumulated and is shown.

C-5A Vertical Stabilizer Material Cost

Table 18 gives average ship-set material cost for Lot 3 by manufacturing item number. Costs shown exclude manufacturing usage variance and allocation for bulk materials. Lot 3 comprises units 14 thru 31.

Table 13. F-111 Wing Box Component Cost Breakdown, 506th Unit

<u>Component/Activity</u>	<u>Cost</u>
1. Upper Skin	\$ 1,903.89
2. Lower Skin	3,011.75
3. Spars	19,803.13
4. Ribs	2,825.07
5. Pylons	9,023.75
6. Miscellaneous	6,072.41
7. Mfg. Direct Charges	<u>116.00</u>
8. Subtotal (1-7)	<u>\$42,756.00</u>
9. Engineering	1,400.00
10. Tooling Maintenance	554.00
11. Other Direct Charges	<u>35.00</u>
12. Subtotal (9-11)	<u>\$ 2,029.00</u>
13. Overhead	23,665.00
14. General & Administrative	<u>5,475.00</u>
15. Subtotal (13 & 14)	<u>\$29,140.00</u>
Total Cost	\$73,925

C-141 Vertical Stabilizer

Table 19 gives the unit labor hours for the first five production units broken down by major structural item and by category of manufacturing cost. Additional detailed data is available organized in a standard manufacturing breakdown.

2.1.4 FUSELAGE. Detailed analyses of fuselage cost for a section of the DC-10 fuselage and for the Convair proposed A(X) are currently in progress. The B-58 aircraft cost study provided under NASA was reviewed for detailed cost data, however, it was found that the subsystem level was the lowest level to which costs were broken down. This data appears in Sections 2.3 and 3.2 as appropriate. The following data is available for the A-5A and T-2A aircraft.

A-5A Fuselage

Available data is summarized in Table 20.

Table 14. F-111 Wing Box Cost Data
 (Data is Per Wing 1/2 Ship; Set - Based on 20 A/C Per Month Except as Noted)

	Unit No. 1		Unit No. 2		Unit No. 50		Unit No. 150		Unit No. 200		Unit No. 505 (Actual Rate)		Unit No. 505 (20 A/C Per Mo.)		Unit No. 800	
	Hours	Cost	Hours	Cost	Hours	Cost	Hours	Cost	Hours	Cost	Hours	Cost	Hours	Cost	Hours	Cost
A. DIRECT LABOR																
1. Engineering	416	3128	341	2564	136	1023	99	745	91	684	70	527	70	527	60	459
2. Product Assurance	15	114	12	91	5	38	4	30	3	25	2.5	19	2.5	19	2	15
3. Configuration Management	9	54	7	42	3	18	2	12	2	12	1.5	9	1.5	9	1	6
4. Total Eng. Pool	440	3296	360	2697	144	1079	105	787	96	719	74	555	74	555	63	480
5. Tool Maintenance (Eng.)	832	4834	682	3962	272	1550	198	1150	183	1063	140	810	140	810	123	714
6. Tool Maintenance (Mfg.)	725	3756	595	3652	237	1228	173	895	159	824	122	630	122	630	107	554
7. Total Tool Maintenance	1557	8590	1277	7614	509	2808	371	2046	342	1887	262	1440	262	1440	230	1268
8. Factory	29657	140062	22303	105270	4816	22731	2917	13769	2560	12093	2309	10896	1684	7946	1371	6471
9. Quality Assurance	628	3391	4704	25543	1916	5517	616	3344	540	2932	486	2644	355	1927	289	1570
10. Total Manufacturing Pool	37487	182625	28284	137857	6341	31066	3904	19159	3442	16902	3067	14980	2301	11313	1890	9509
TOTAL DIRECT LABOR		185919		140554		32135		19336		17621		15536		11864		9781
B. OTHER DIRECT CHARGES																
1. Engineering		164		135		54		29		36		28		28		24
2. Product Assurance		8		7		3		2		2		2		2		1
3. Tooling		29		24		10		7		6		5		5		4
4. Manufacturing		687		563		224		164		151		116		116		101
TOTAL DIRECT CHARGES		889		729		291		212		195		151		151		130
C. PROCUREMENT/SUBCENT.																
1. Purchased Parts		15467		14694		11579		10675		10450		9757		9757		9431
2. Raw Material		18641		17709		13955		12866		12595		11758		11758		11367
3. Production Aid		544		446		178		130		119		88		88		80
4. Outside Production		11886		11292		8898		8204		8031		7497		7497		7248
TOTAL PROCUREMENT/SUBCENT.		46538		44141		34610		31875		31195		29100		29100		28126
TOTAL FAHICATION COSTS		233116		185424		67026		52033		49011		44786		41119		38915
D. OVL/HEAD-DIVISION																
1. Engineering	440	3155	360	2581	144	1032	105	753	96	683	74	530	74	530	63	452
2. Manufacturing	37487	260634	28284	196573	6341	44070	3904	27133	3442	23922	3057	21243	2301	15982	1890	13135
3. Material		1070		2459		2250		2072		2027		1891		1891		1828
TOTAL DIVISION OVERHEAD		166714		202023		47352		29558		26637		23665		18403		13433
E. GENERAL & ADMIN.		4003		30996		9143		6560		6052		5476		4762		4277
TOTAL COST		540065		418443		123531		88551		81700		73925		64283		57737

Table 15. F-111 Wing Secondary Structure Cost Breakdown

Item	Machine & Assembly Labor (hr)	Installation Labor (hr)	Material	Outside Procurement
Inboard and Outboard Spoiler Assemblies	141	16	\$ 302	\$ 482
Airflow Deflectors	173	16	191	-
Trailing Edge Assembly	825	480	12,277	7,235
Leading Edge Assembly	876	176	4,202	3,949

Table 16. A-5A Aerodynamic Surfaces Cost Data (50 A/C Program)

Item	Weight (lb)	Hours/Lb (First Unit)
Grand Total Body, Wing & Tail Structure	14,079	23.8
Total Wing Structure	5,167	13.6
Spoilers & Deflectors	314	18.4
Flaps	534	10.9
Outer & Intermediate Panel		
Trailing & Leading Edges	4,319	13.7
Total Tail Structure	1,731	16.1
Horizontal Stabilizer	1,165	11.7
Vertical Stabilizer	566	24.3

Table 17. T-2A Aerodynamic Surfaces Cost Data
(200 A/C Program)

Item	Weight (lb)	Hours/Lb (First Unit)
Total Body, Wing, and Tail Structure	2,661	20.1
Total Wing Group Structure	1,161	17.1
Wing Structure (Incl. Tips)	879	19.0
Flaps	127	11.5
Ailerons	87	7.5
Main Gear Doors (wing)	68	11.2
Total Tail Group Structure	285	19.3
Stabilizer	162	13.8
Elevators	85	19.6
Rudders	38	44.0

Table 18. Total Unit Average Material Cost -- C-5A Vertical
Stabilizer Box Structure

CV Mfg. Item No.	Convair Mfg. Item Description	Lot III S/S Avg. Cost By Mfg. Item
15	Structural Assembly Task	\$ 1,855.93
16	Ladder Assembly	60.40
18	Pivot Fitting Assembly	6,303.70
21	Rear Beam Assembly	2,097.64
22	Front Auxiliary Beam Assembly	703.88
23	Rib Assemblies	1,521.48
24	Front Beam Assembly	1,854.66
25	Auxiliary Beam Assembly	222.25
26	Skin Panel Assembly, L. H.	20,040.39
260	Skin Panel Assembly, R. H.	17,752.83
S/S Average Cost Excl. MUV & Alloc.		\$ 52,413.16

Table 19. C-141 Vertical Stabilizers Manufacturing Labor

Item	Cost Category	Unit Hours Per Ship				
		#1	#2	#3	#4	#5
Vertical Stabilizer Assembly	Fabrication	4768	4768	4767	4767	4767
	Sub Assembly	1453	1453	1453	1453	1452
	Major	7535	4870	5105	4575	3978
	Assist	539	539	539	539	538
	Total	14295	11630	11864	11334	10735
5 Unit Total = 59858						
Rudder	Fabrication	380	380	379	379	379
	Sub Assembly	360	360	360	360	359
	Major	818	671	620	606	528
	Assist	36	36	35	35	35
	Total	1594	1447	1394	1380	1301
5 Unit Total = 7116						
Vertical Stabilizer Leading Edge	Fabrication	77	77	77	77	76
	Sub Assembly	4	4	4	3	3
	Major	225	92	152	66	93
	Assist	9	9	9	9	8
	Total	315	182	242	155	180
5 Unit Total = 1074						
Summary						
Vertical Stabilizer Components	Fabrication	5225	5225	5223	5223	5222
	Sub Assembly	1817	1817	1817	1816	1814
	Major	8578	5633	5877	5247	4599
	Assist	584	584	583	583	581
	Total	16204	13259	13500	12869	12216
5 Unit Total = 68048						
Static Article						
Fabrication	13551					
Sub Assembly	2414					
Major Assembly	12482					
Assist	<u>531</u>					
Total	28978					
Fatigue Article						
Fabrication	13528					
Sub Assembly	3454					
Major Assembly	9806					
Assist	<u>531</u>					
Total	27319					

Table 20. A5A Fuselage Cost Data (50 A/C Program)

Item	Weight (lb)	Hours/Lb (First Unit)
Grand Total Body, Wing & Tail Structure	14,079	23.8
Total Body Structure	7,181	33.3
Total Forward Fuselage Structure	1,086	42.7
Forward Fuselage Structure	418	90.9
Windshield	88	16.2
Canopy	423	12.0
Auxiliary Landing Gear Door	35	9.8
Door, Inflight Refueling Probe	7	103.0
Radome	75	7.5
Equipment Bay Access Door	40	4.3
Total Intermediate Fuselage Structure	2,521	40.0
Intermediate Structure	2,359	39.4
Main Landing Gear Door	162	14.5
Total Aft Fuselage Structure	3,574	27.4
Aft Fuselage Structure	3,038	27.8
Engine Access Doors	536	19.4

T-2A Fuselage

Available data is summarized in Table 21.

Table 21. T-2A Fuselage Cost Data (200 A/C Program)

Item	Weight (lb)	Hours/Lb (First Unit)
Total Body, Wing, and Tail Structure	2,661	20.1
Total Body Structure	1,215	23.6
Total Forward Fuselage Structure	658	24.9
Forward Fuselage Structure	325	34.1
Windshield	47	6.5
Canopy Structure	151	16.4
Nose Gear Door	14	27.1
Forward Engine Access Doors	63	19.0
Baggage Compartment Door	22	20.0
Equipment Bay Access Door	36	19.8
Total Intermediate Fuselage Structure	320	23.3
Intermediate Fuselage Structure	249	23.7
Aft Engine Access Door	71	18.7
Total Aft Fuselage Structure	237	19.0
Aft Fuselage Structure	188	20.3
Speed Brake	49	14.2

2.2 SUBASSEMBLY LEVEL COST DATA ORGANIZATION

Detailed level cost data has been organized according to the manufacturing first unit CER structure to support the derivation of estimating coefficients.

2.2.1 MANUFACTURING LABOR. A series of 39 charts, Figures 1 thru 39 inclusive, show the plots of available data for first unit detail fabrication and subassembly labor hours for aerodynamic surfaces. These charts will be augmented as additional data is processed. The use of this data in the derivation of cost estimating coefficients is explained in Volume I. Similar charts for fuselage components will be developed during the next phase of the study.

Rib Detail Fabrication

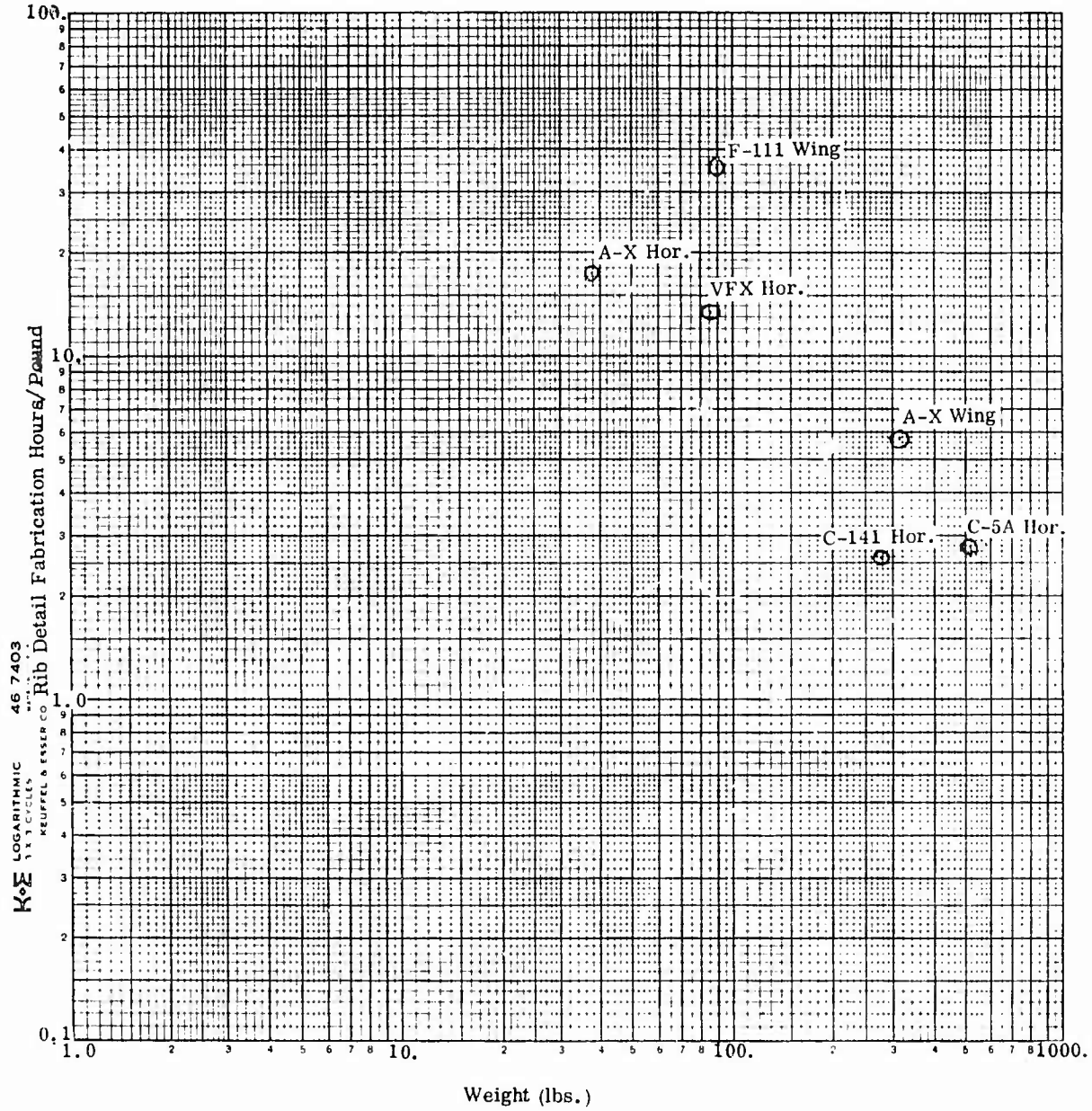


Figure 1. Rib Detail Fabrication, Hrs/Lb and Weights.

Rib Subassembly

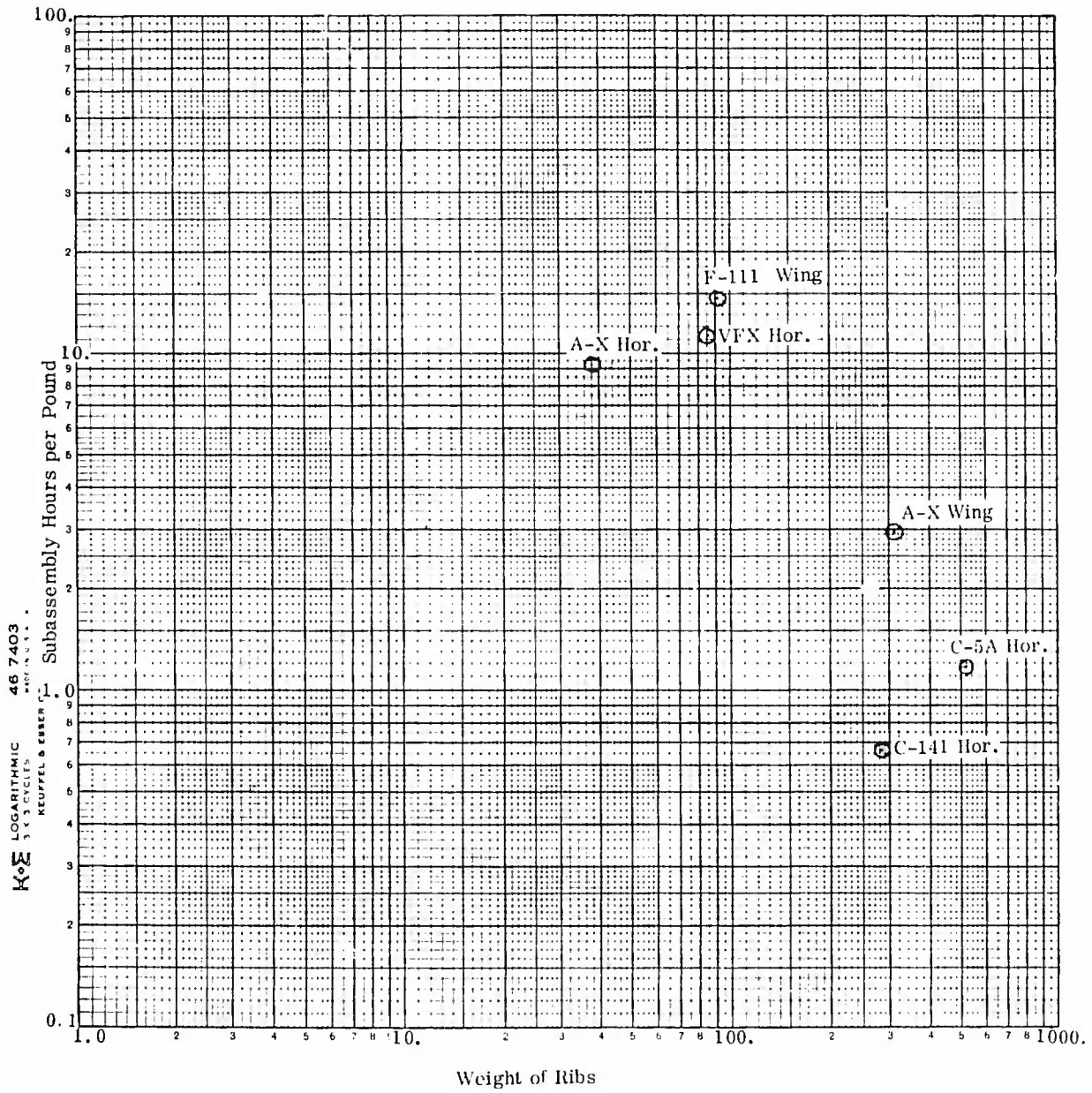


Figure 2. Rib Subassembly, Hrs/Lb and Weights.

Spar Detail Fabrication

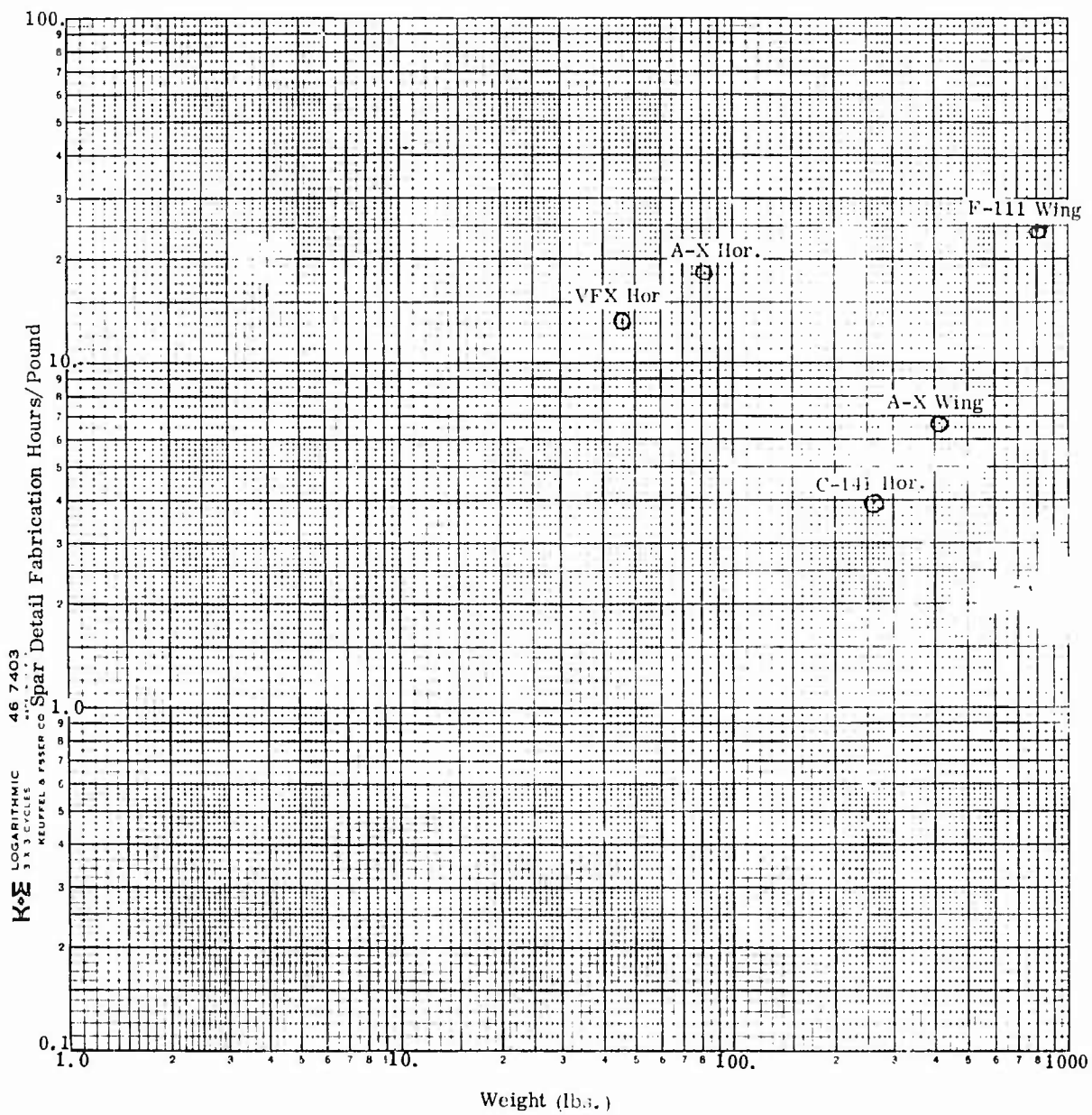


Figure 3. Spar Detail Fabrication, Hrs/Lb and Weights.

Spar Subassembly

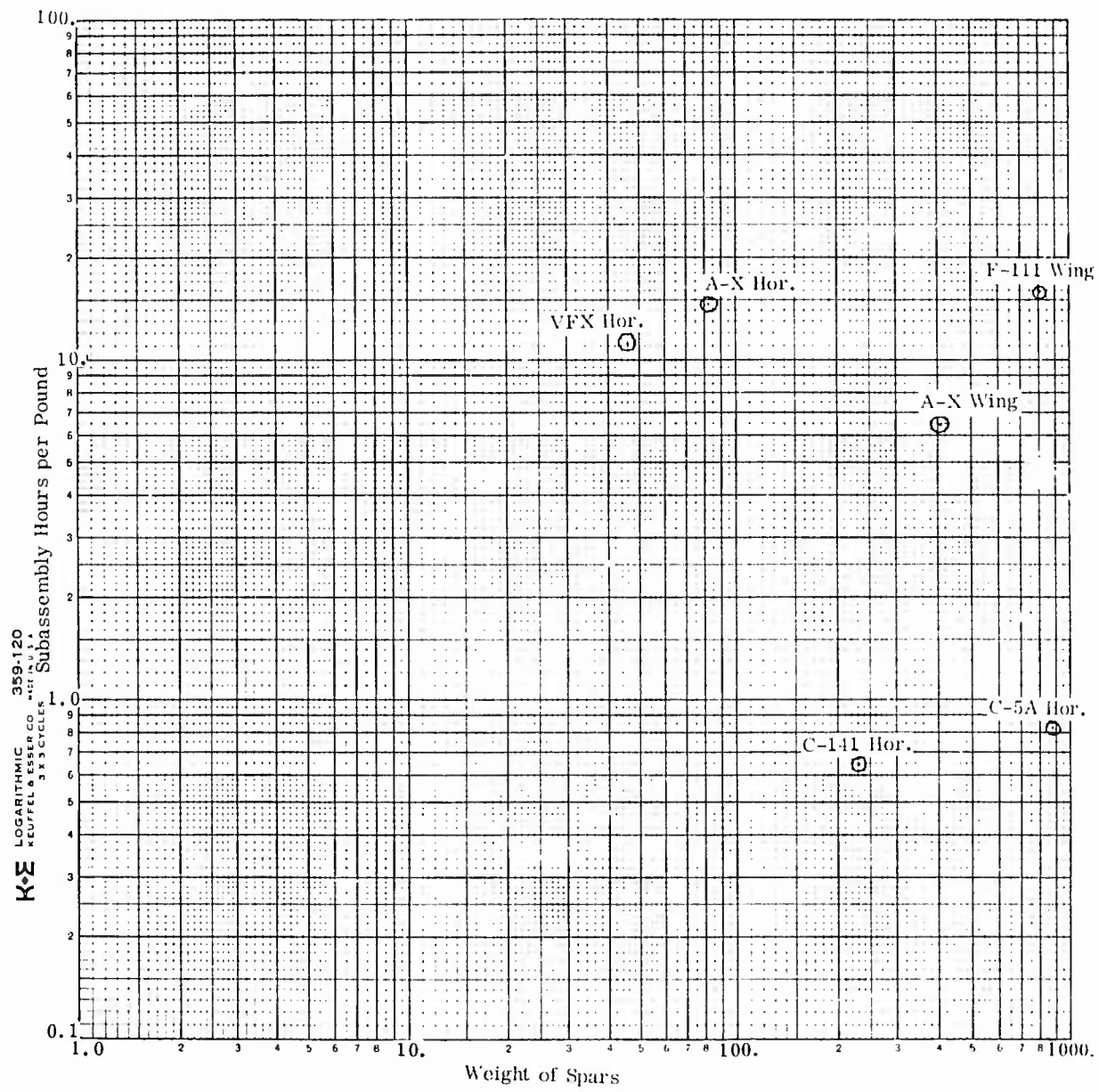


Figure 4. Spar Subassembly, Hrs/lb and Weights.

Cover Detail Fabrication

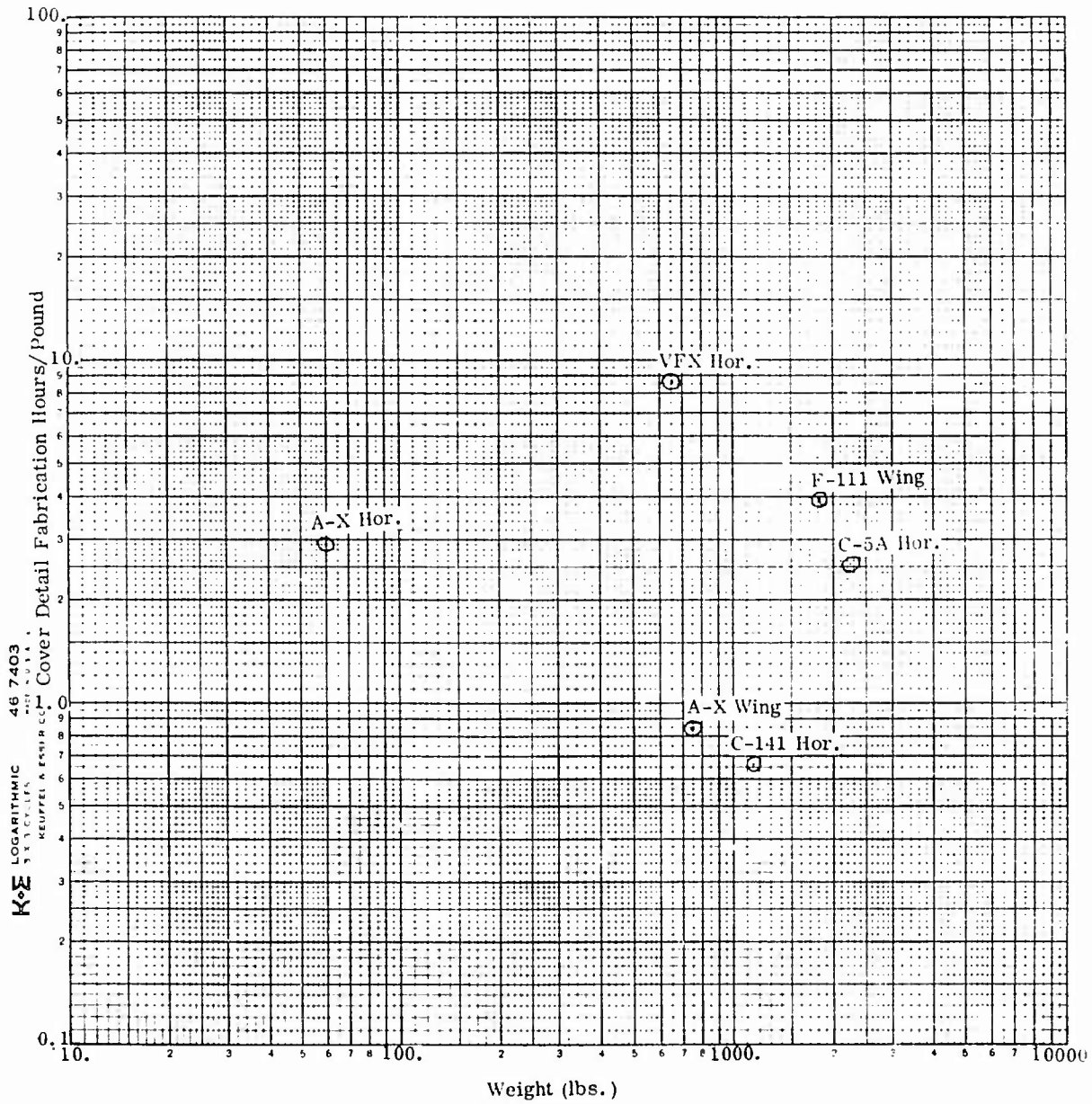


Figure 5. Cover Detail Fabrication, Hrs/Lb and Weights.

Cover Subassembly

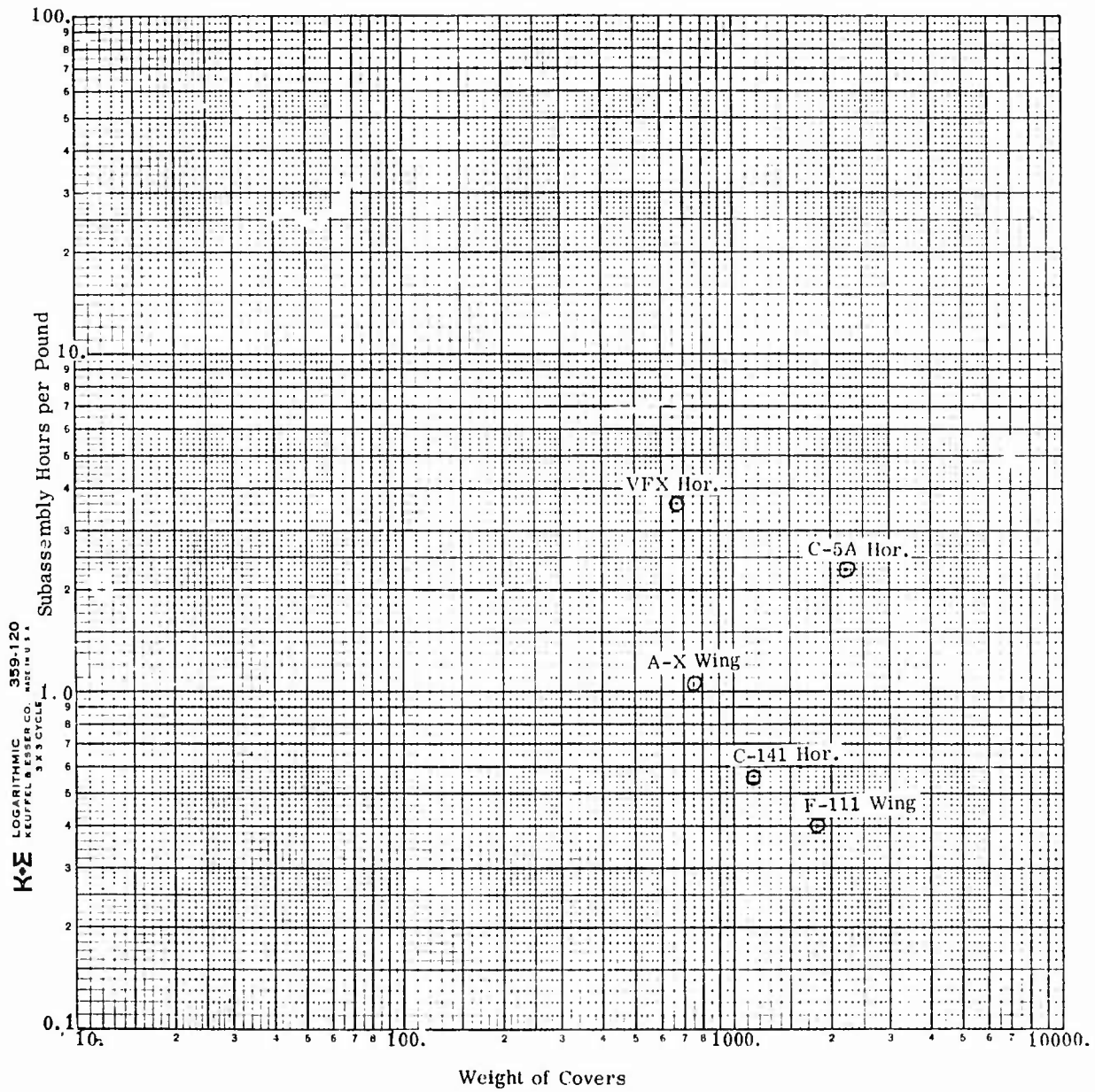


Figure 6. Cover Subassembly, Hrs/Lb and Weights.

Leading Edge Detail Fabrication

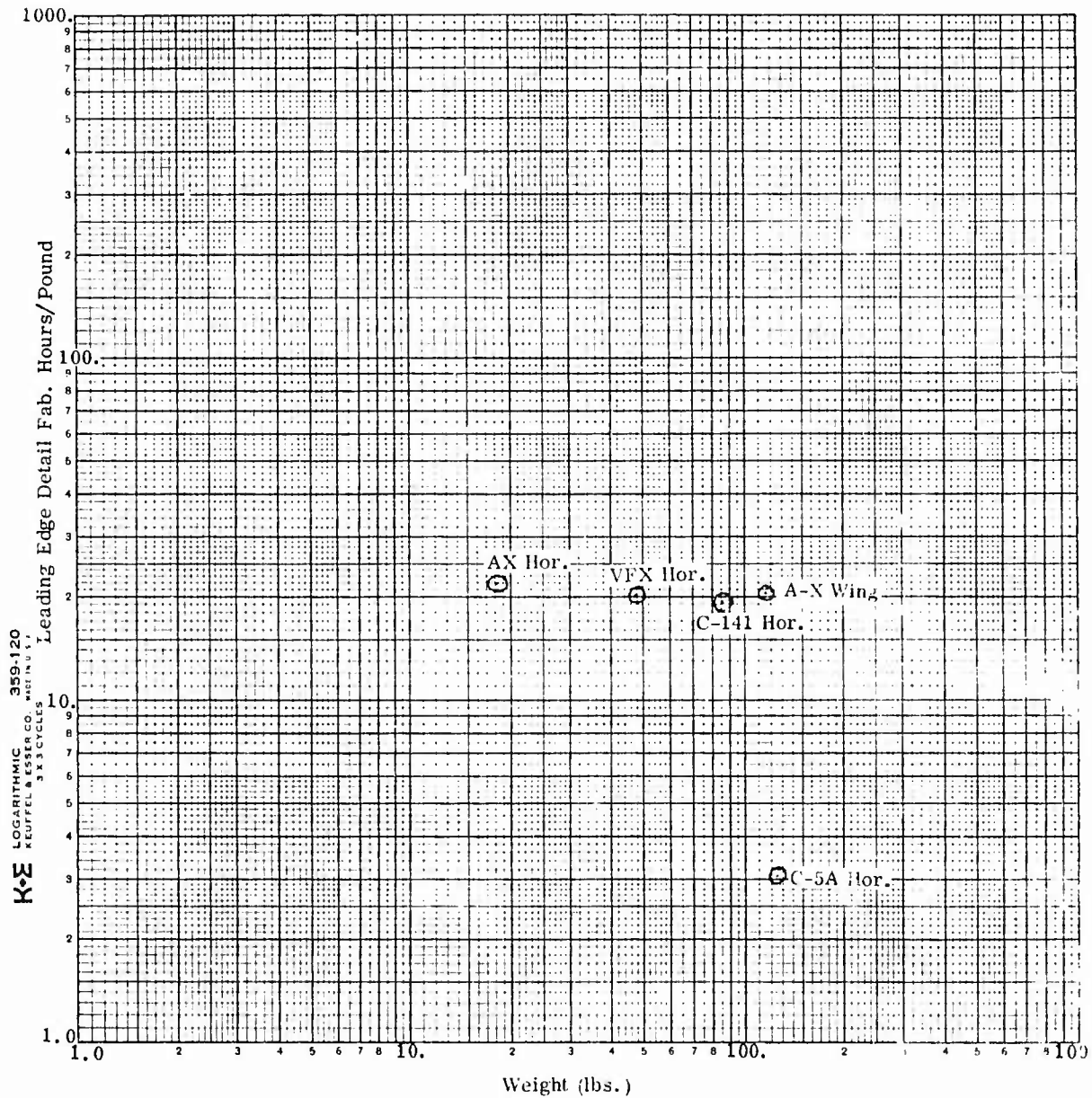


Figure 7. Leading Edge Detail Fabrication, Hrs/Lb and Weights

Leading Edge Subassembly

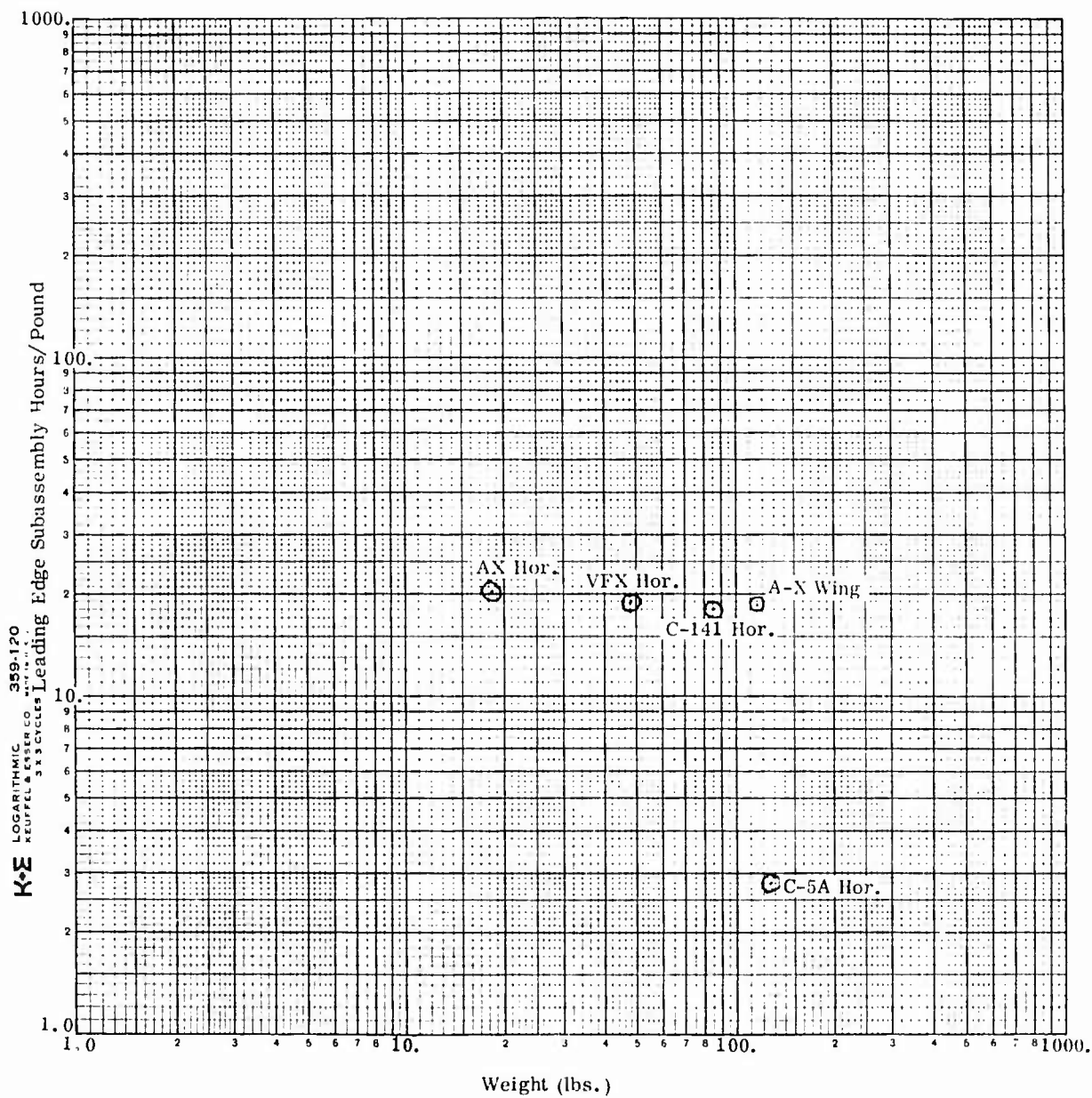


Figure 8. Leading Edge Subassembly, Hrs./Lb and Weights.

Trailing Edge Detail Fabrication

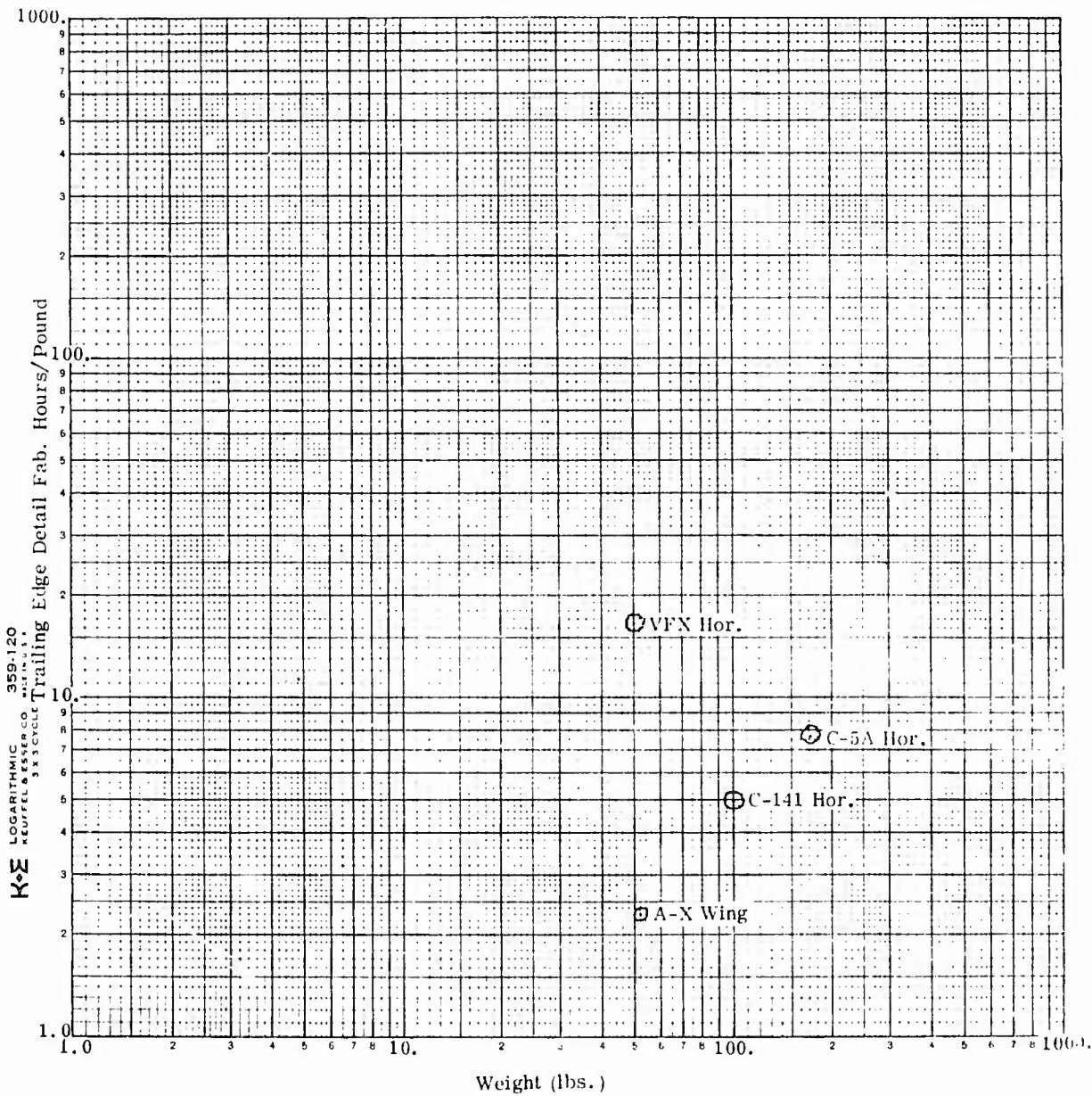


Figure 9. Trailing Edge Detail Fabrication, Hrs/lb and Weight.

Trailing Edge Subassembly

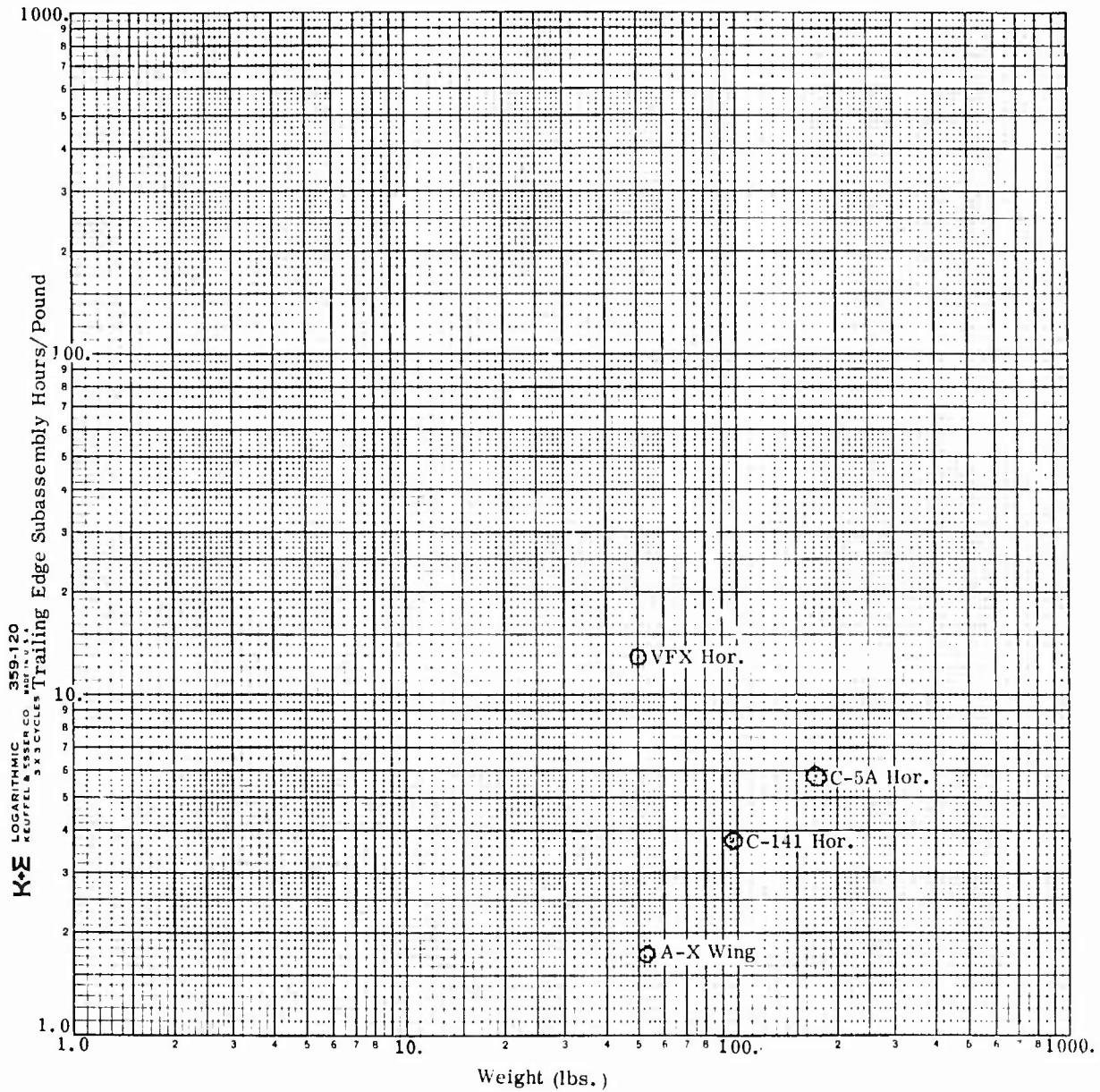


Figure 10. Trailing Edge Subassembly, Hrs/Lb and Weights.

Ailerons Detail Fabrication

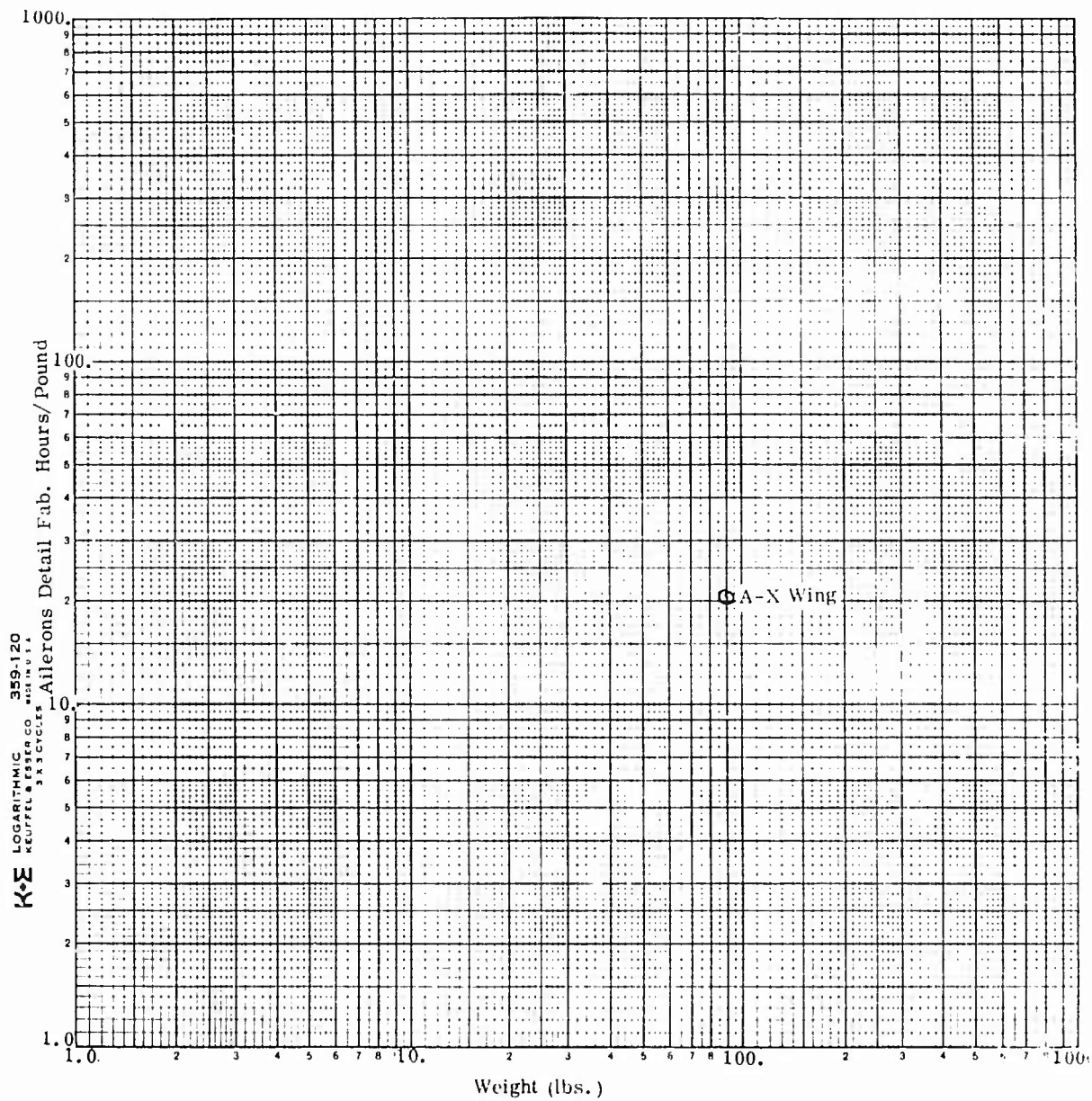


Figure 11. Ailerons Detail Fabrication, Hrs/Lb and Weights.

Ailerons Subassembly

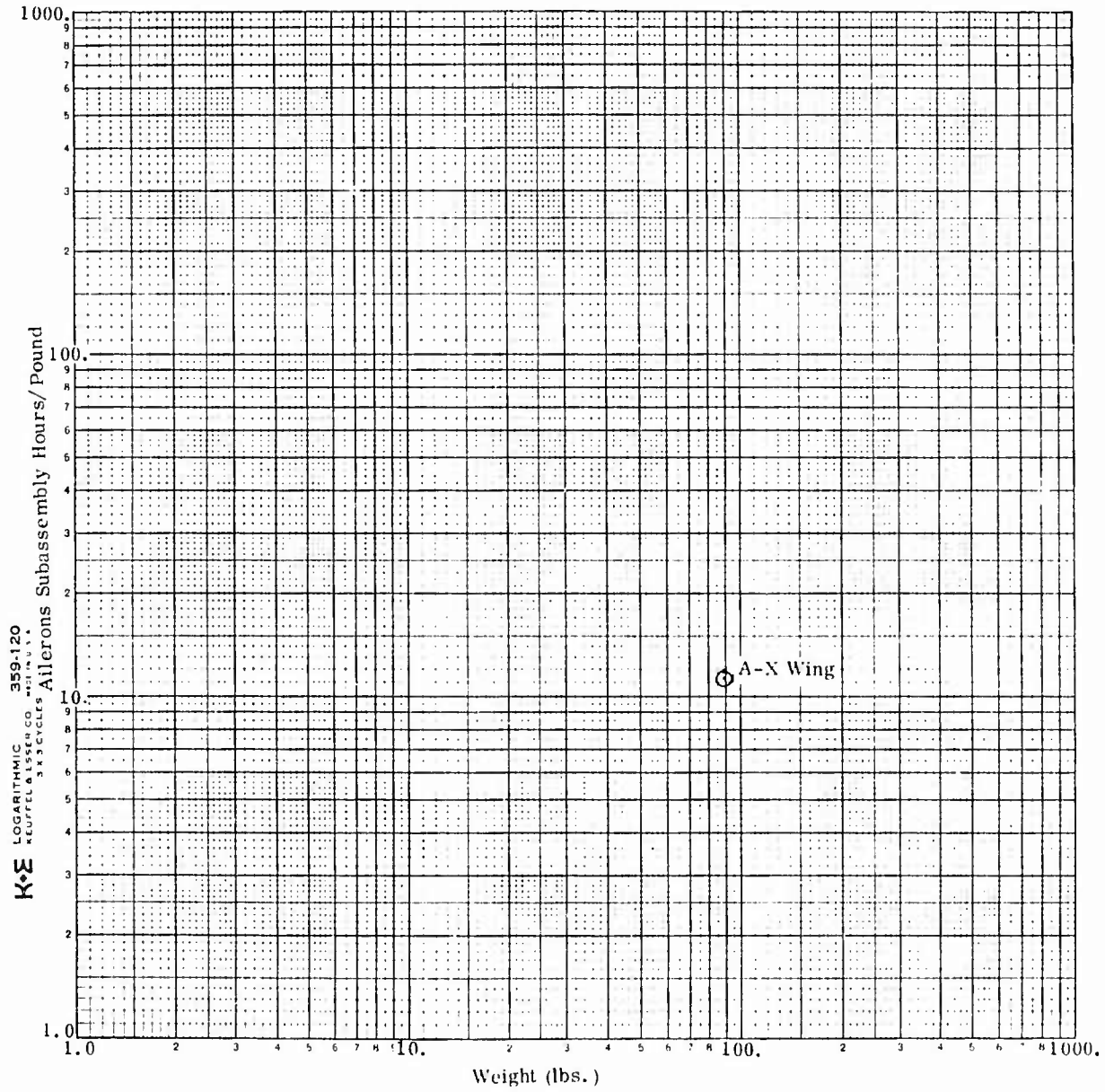


Figure 12. Ailerons Subassembly, Hrs/Lb and Weights.

Fairings Detail Fabrication

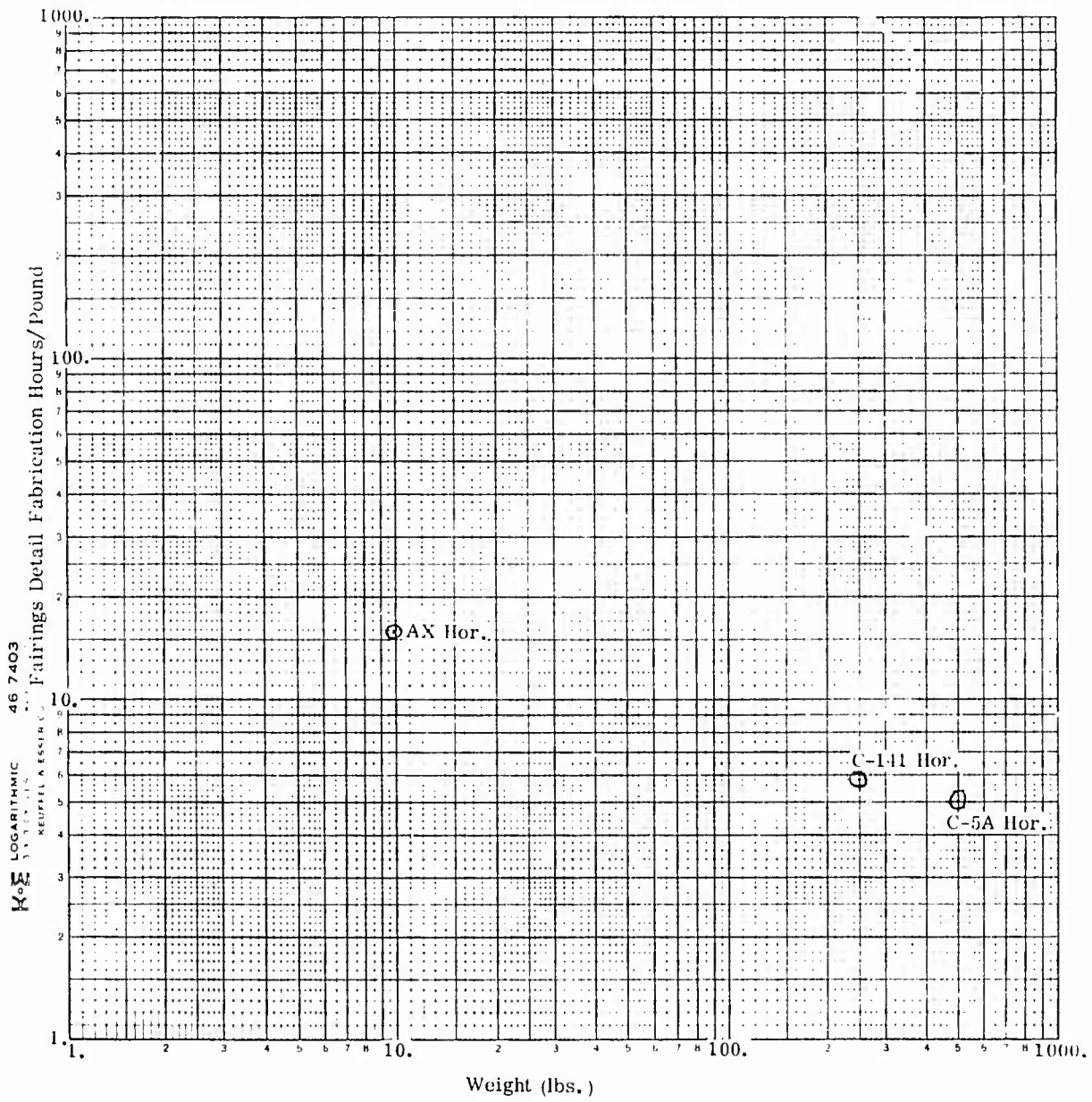


Figure 13. Fairings Detail Fabrication, Hrs/Lb and Weights.

Fairing Subassembly

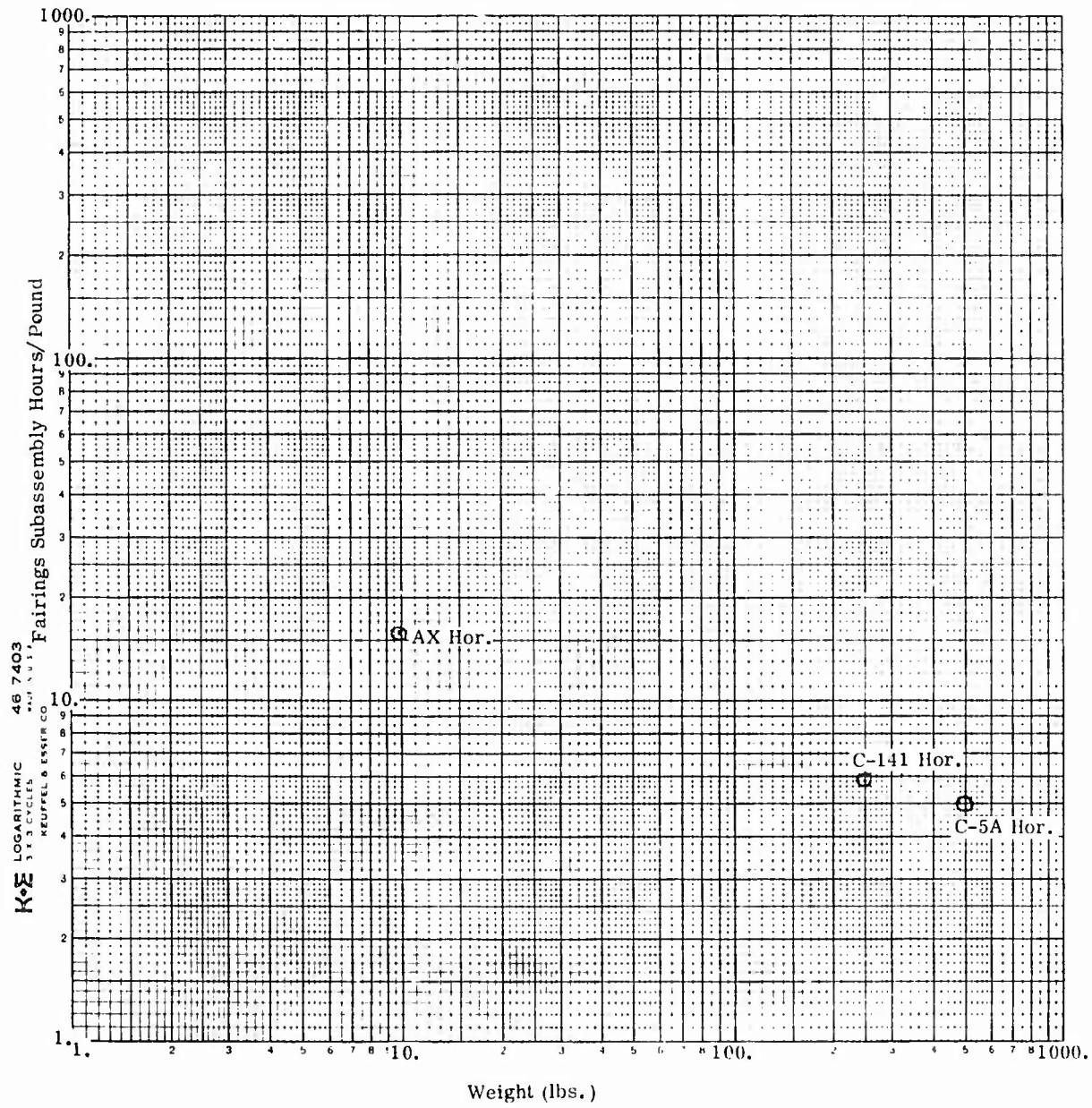


Figure 14. Fairings Subassembly, Hrs/Lb and Weights.

Tips Detail Fabrication

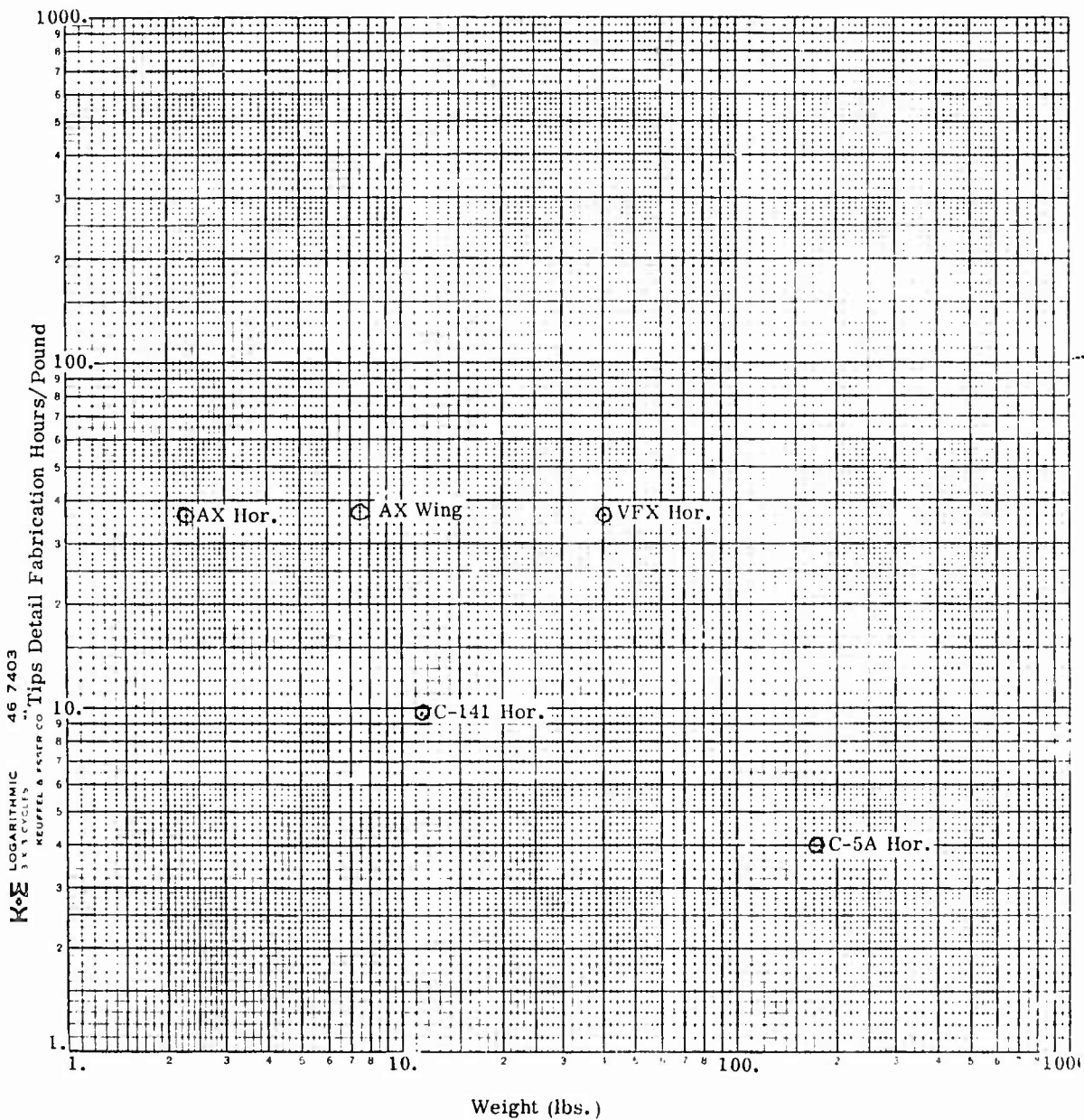


Figure 15. Tips Detail Fabrication, Hrs/Lb and Weights.

Tips Subassembly

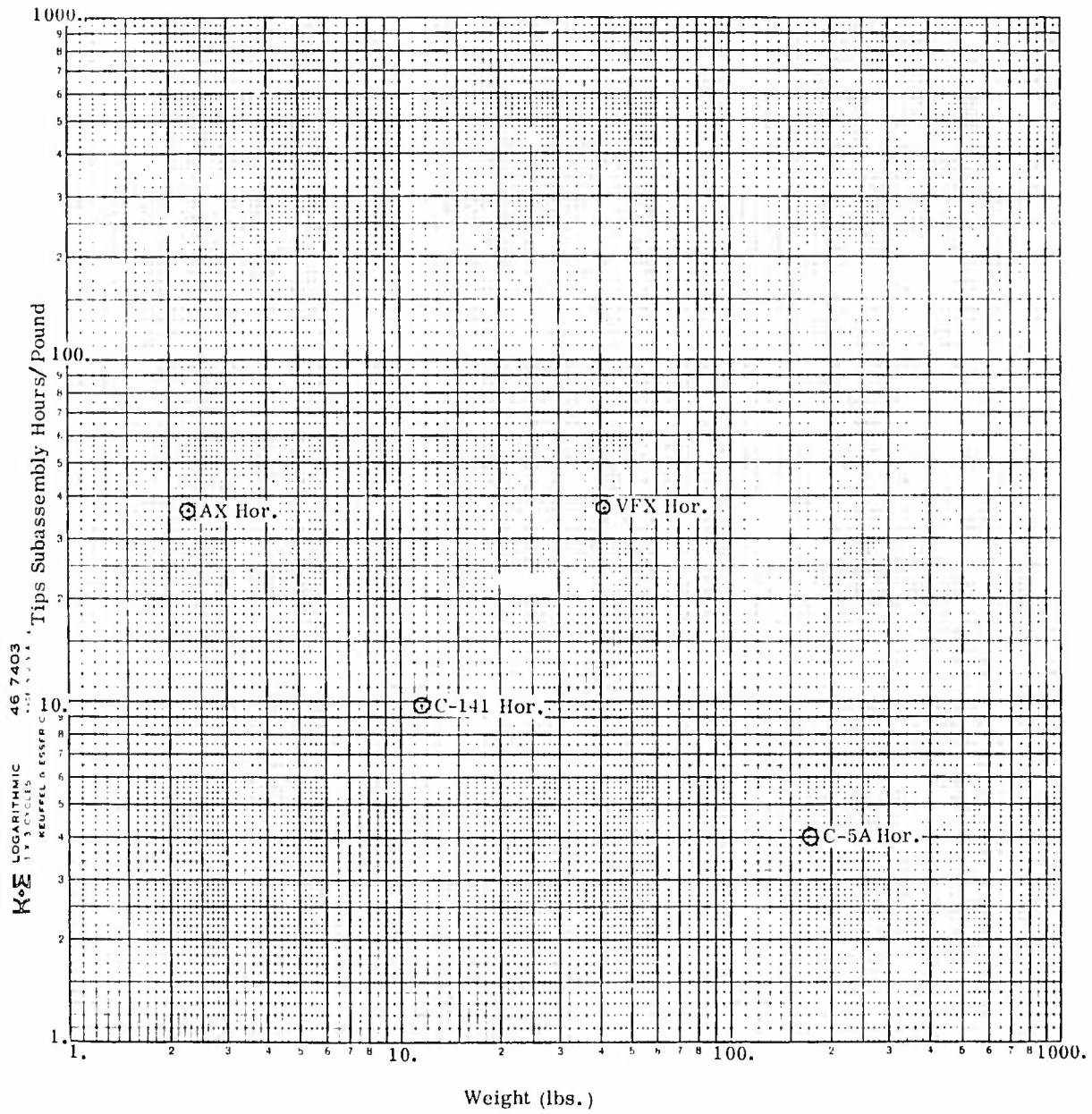


Figure 16. Tips Subassembly, Hrs/Lb and Weights.

Spoilers Detail Fabrication

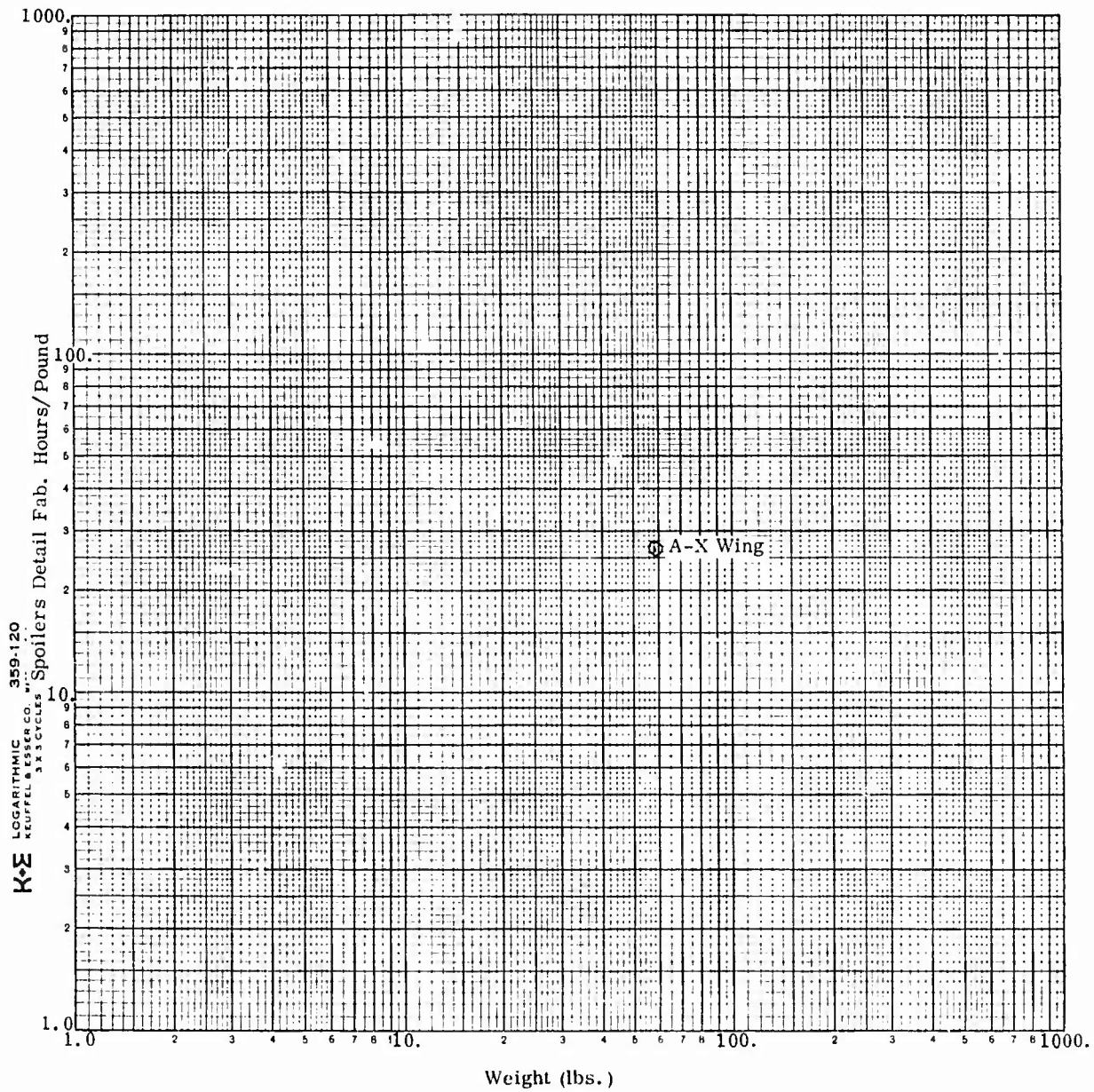


Figure 17. Spoilers Detail Fabrication, Hrs/Lb and Weights.

Spoilers Subassembly

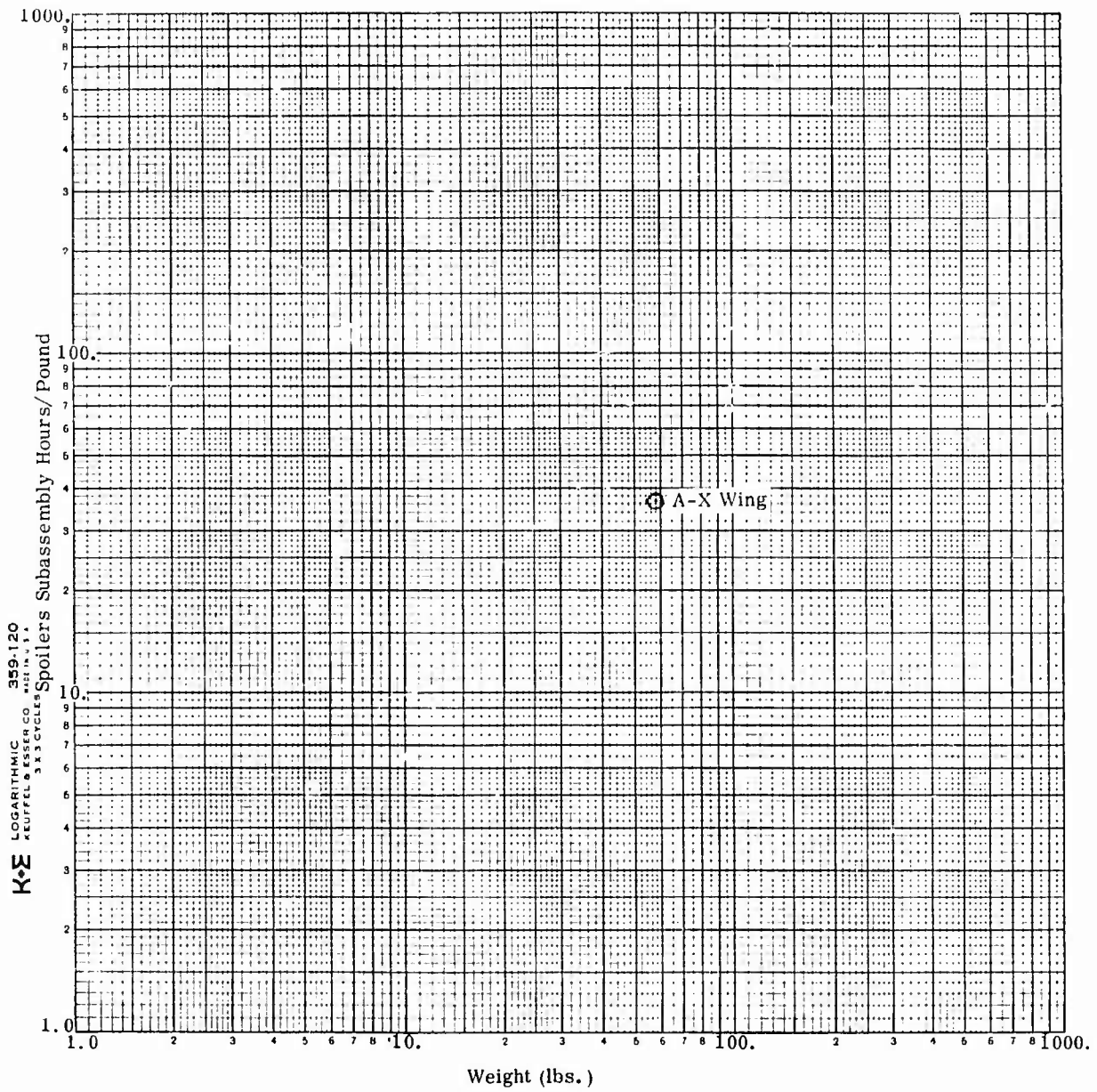


Figure 18. Spoilers Subassembly, Hrs/Lb and Weights.

Flaps Detail Fabrication

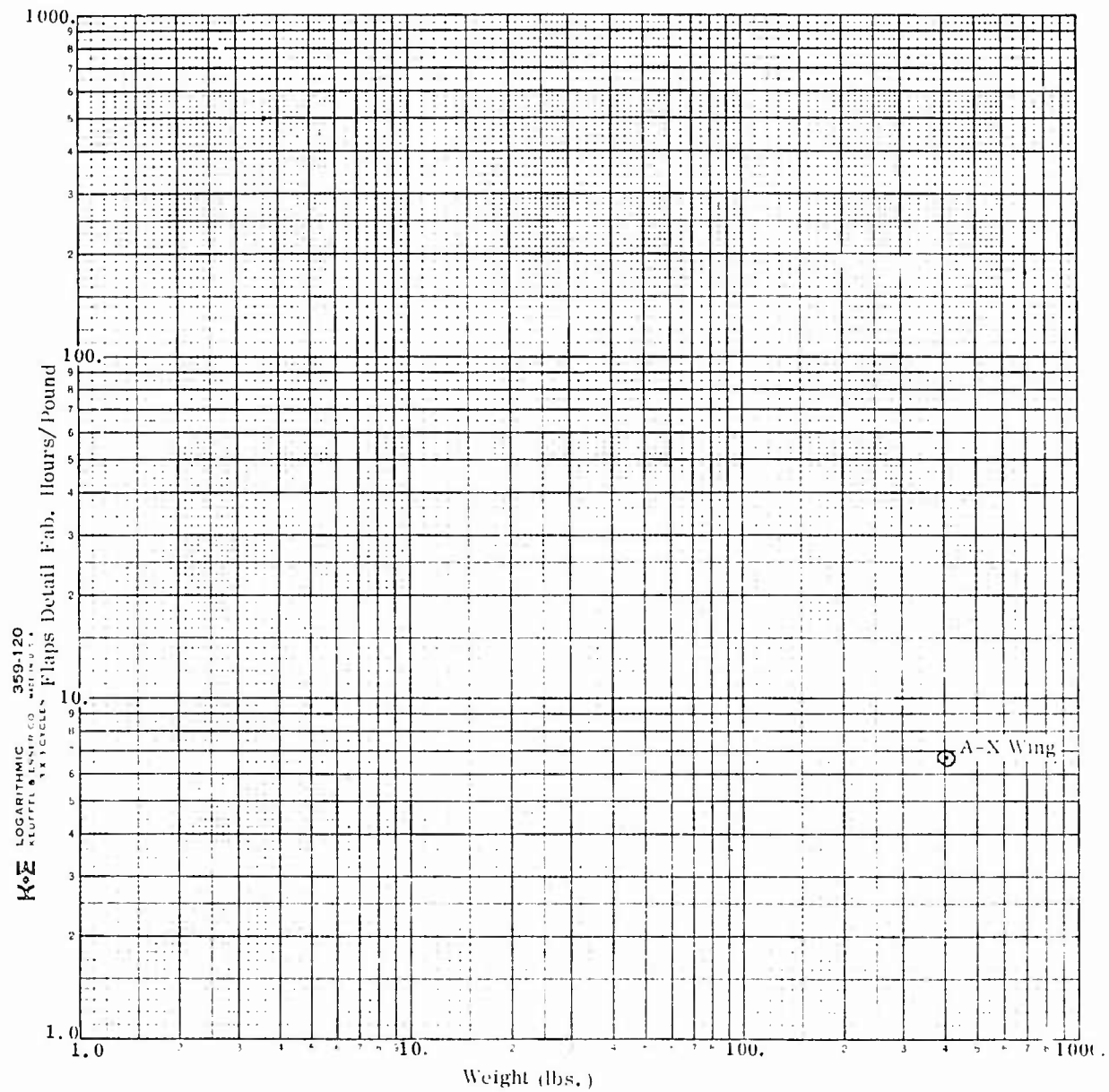


Figure 19. Flaps Detail Fabrication, Hrs/Lb and Weights.

Flaps Subassembly

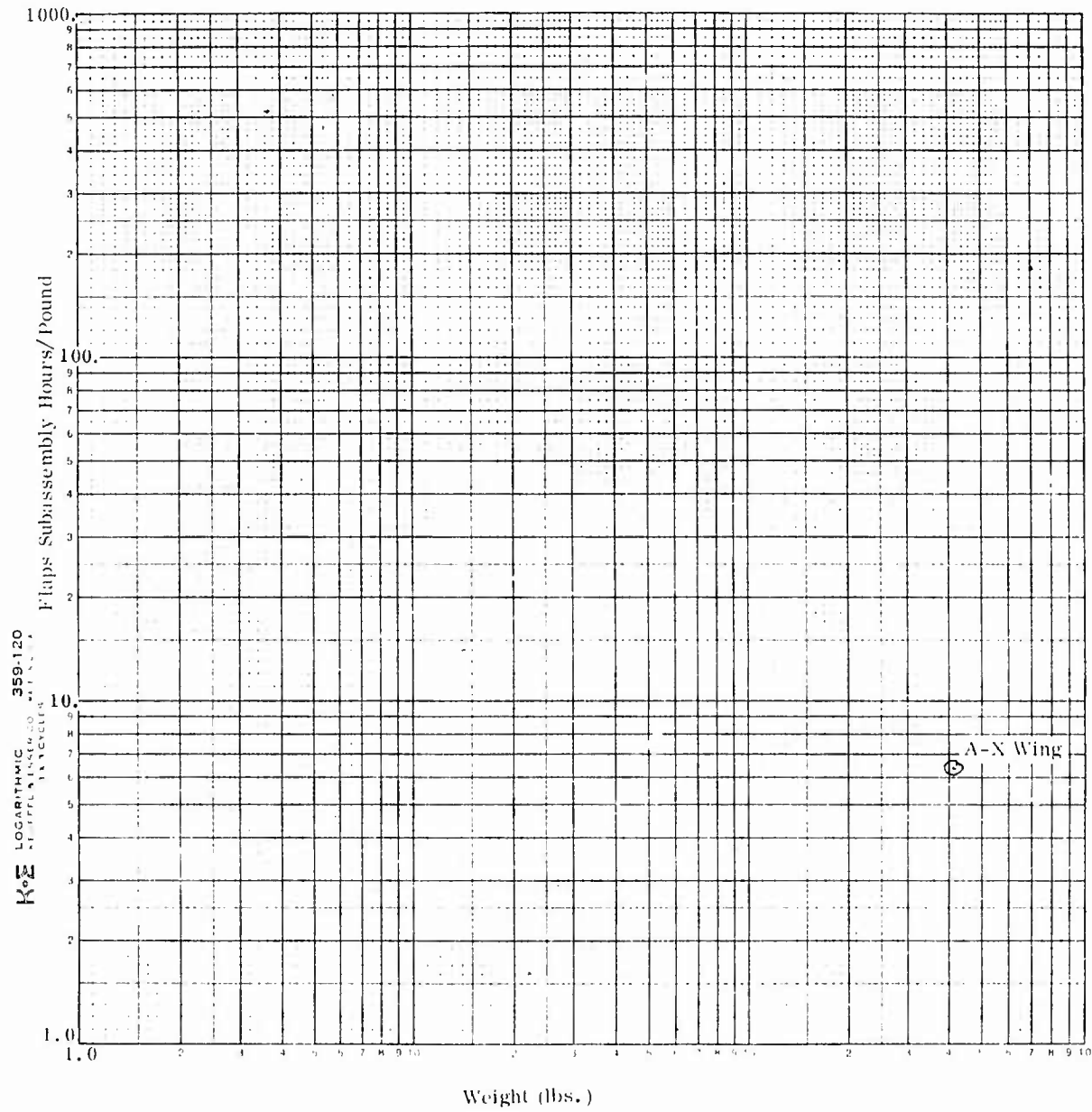


Figure 20. Flaps Subassembly, Hrs/Lb and Weights.

Attachment Structure Detail Fab.

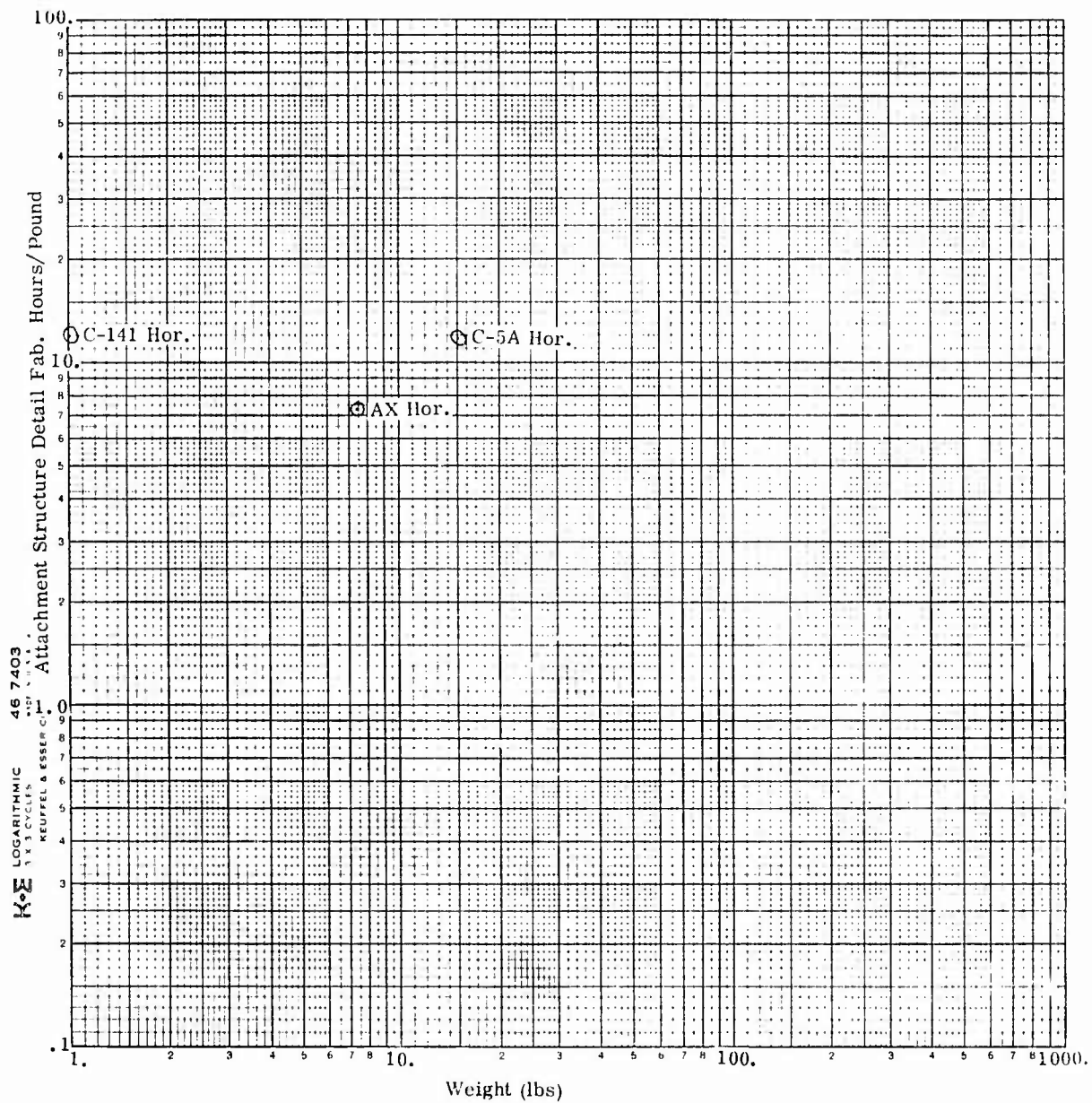


Figure 21. Attachment Structure Detail Fabrication, Hrs/Lb and Weights.

Attachment Structure Subassembly

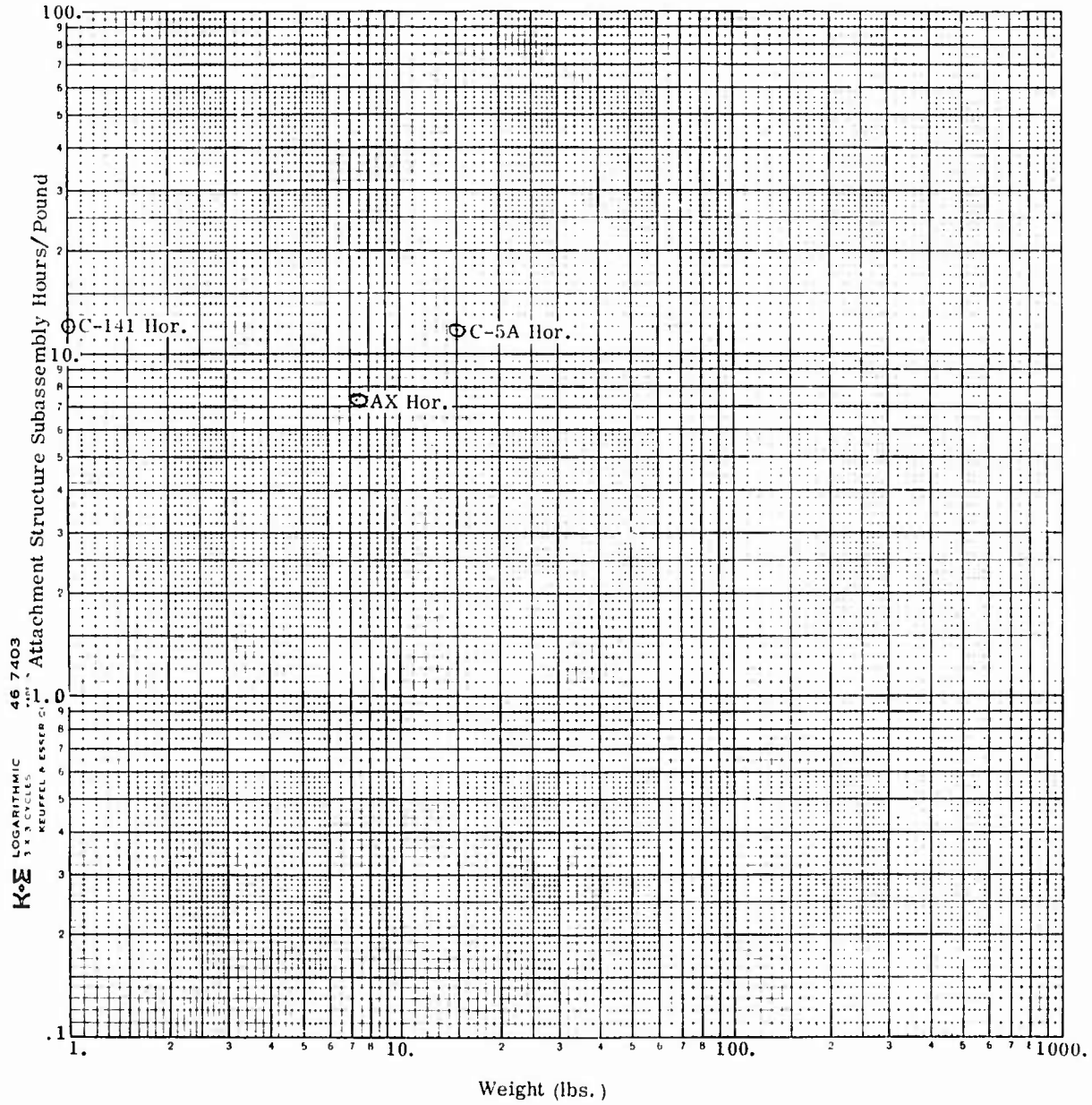


Figure 22. Attachment Structure Subassembly, Hrs/Lb and Weights.

Access Doors Detail Fabrication

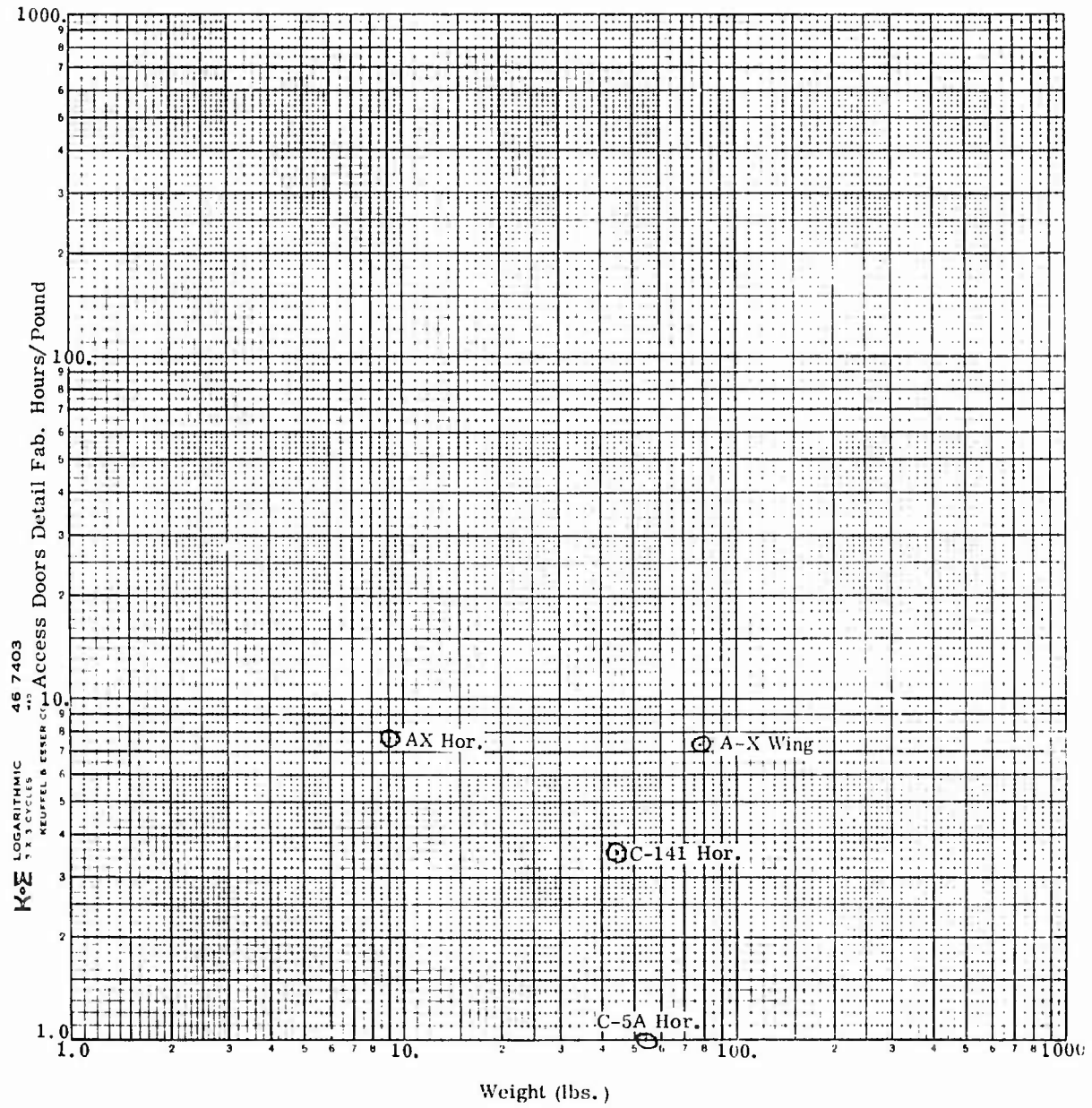


Figure 23. Access Doors Detail Fabrication, Hrs/Lb and Weights.

Access Doors Subassembly

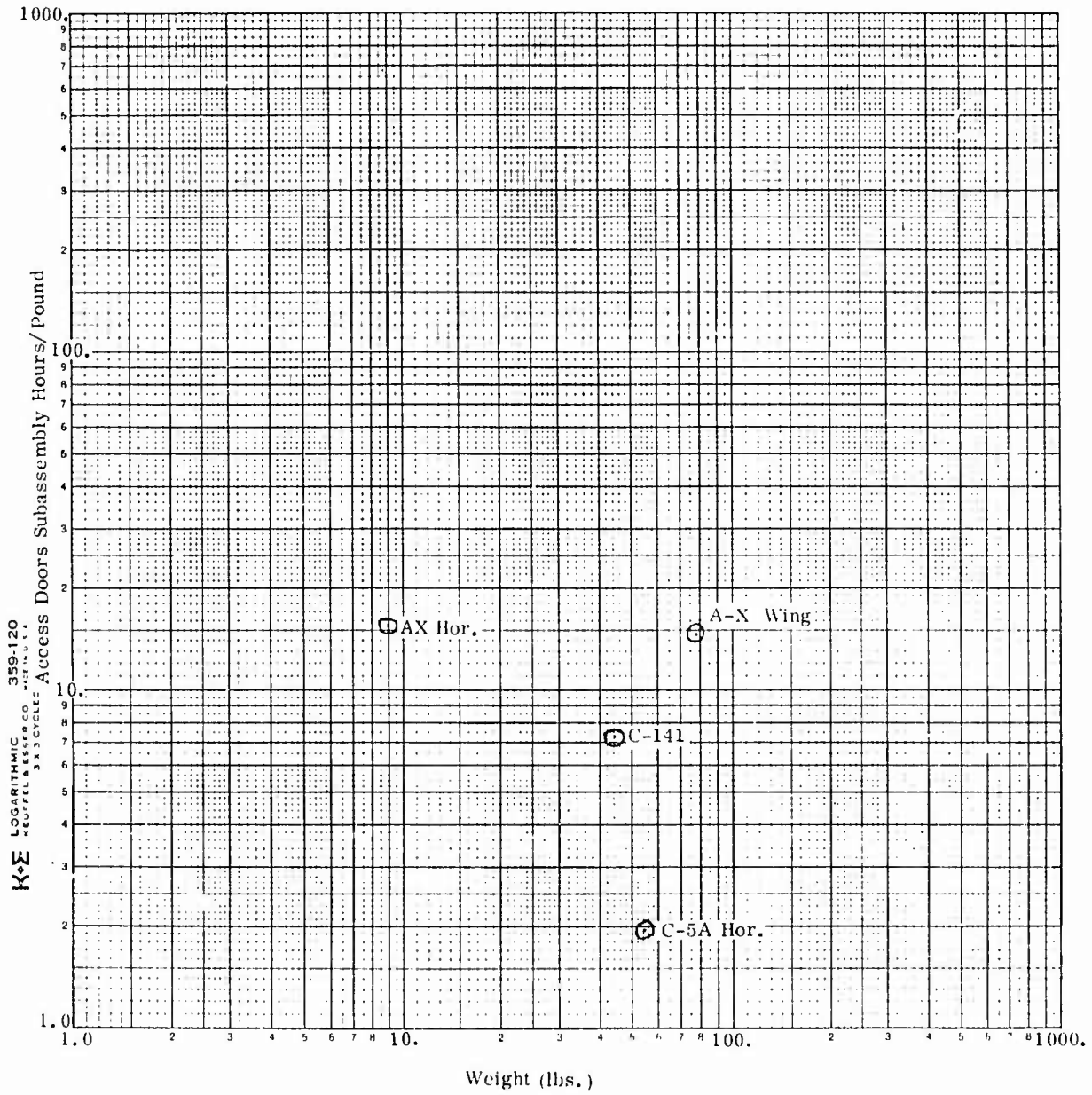


Figure 24. Access Doors Subassembly, Hrs/Lb and Weights.

Hinges, Brackets and Seals Detail Fab.

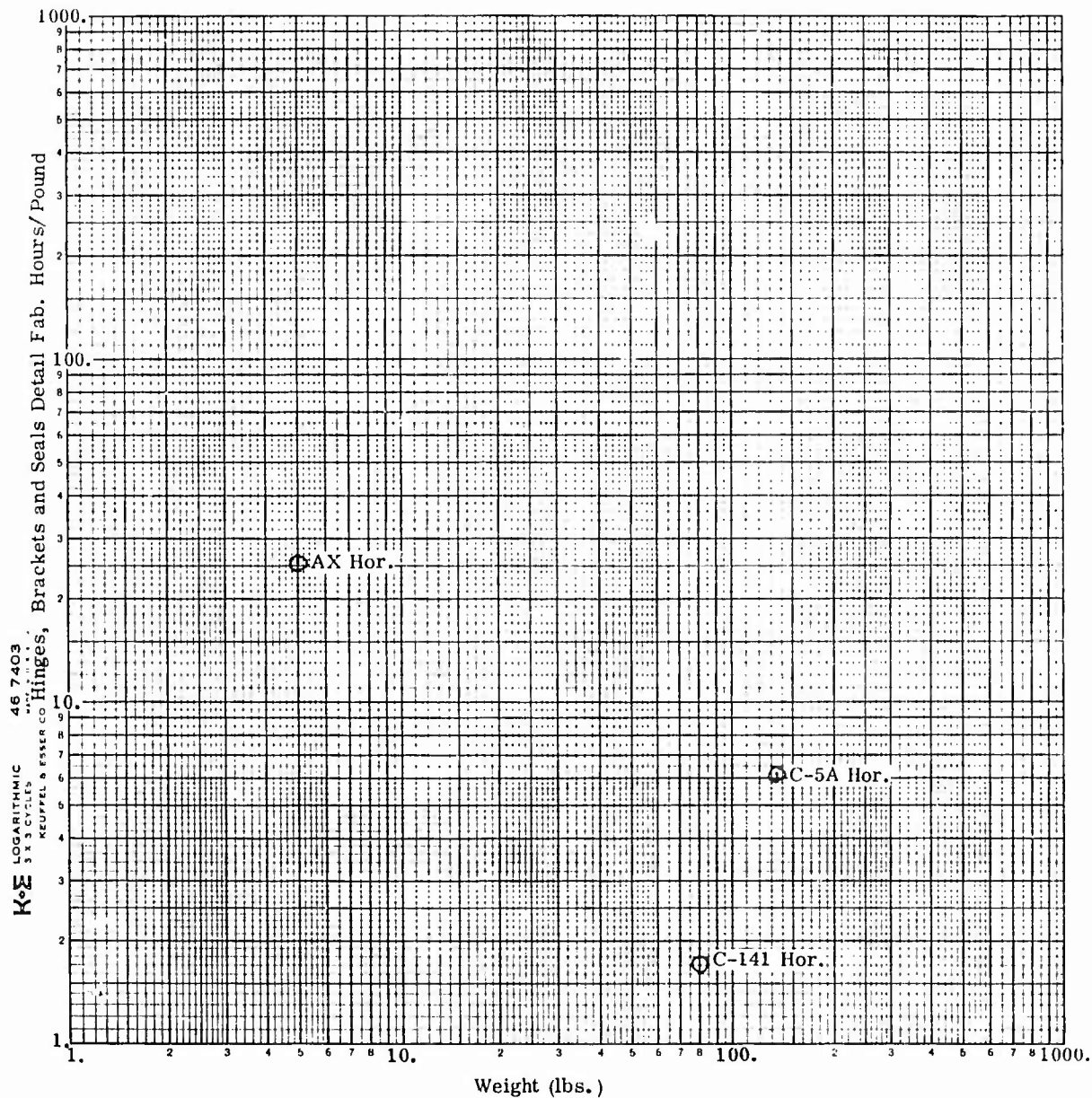


Figure 25. Hinges, Brackets and Seals Detail Fabrication, Hrs/Lb and Weights.

Hinges, Brackets and Seals Subassembly

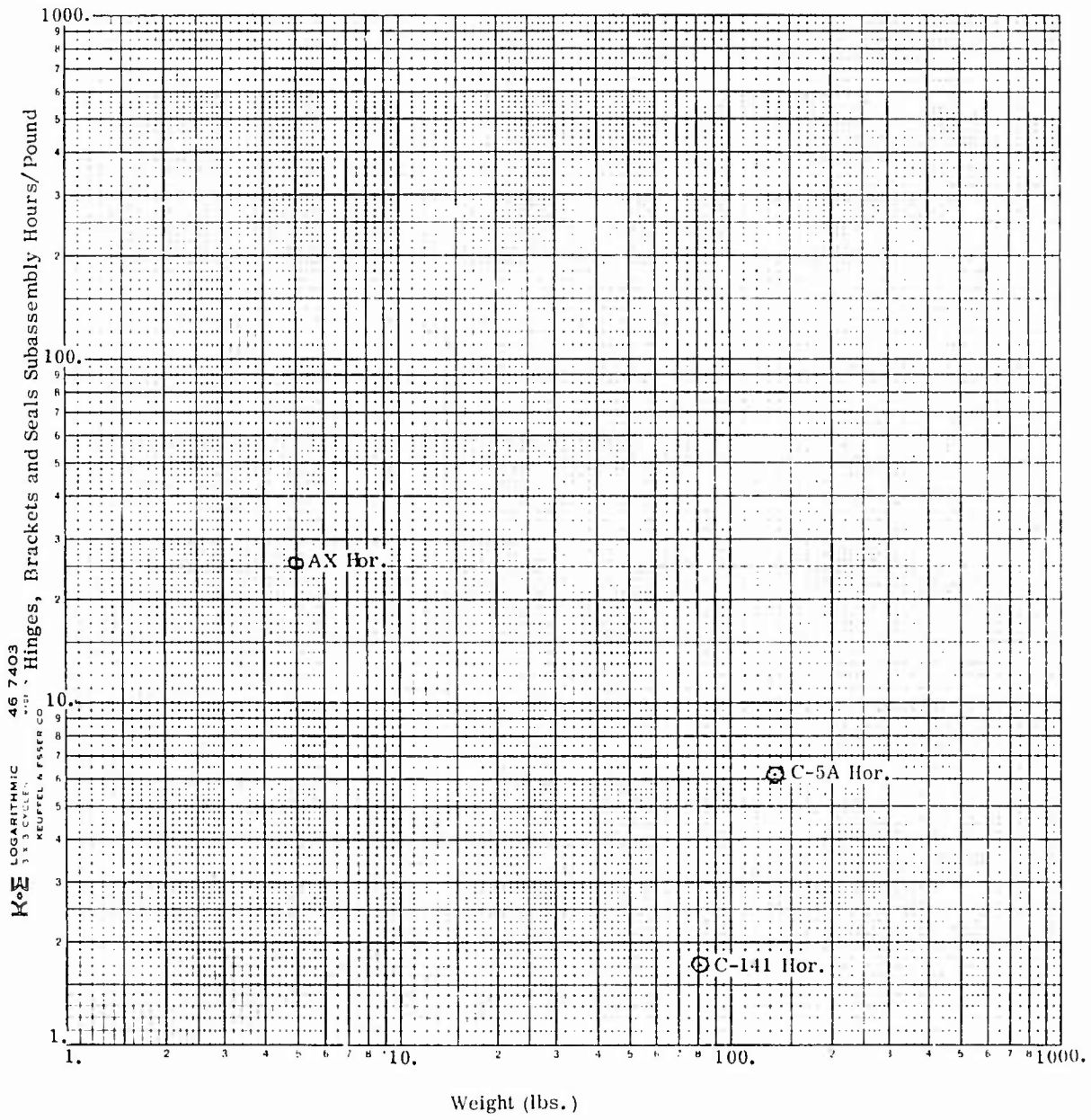


Figure 26. Hinges, Brackets and Seals Subassembly,
Hrs/Lb and Weights.

Pivots and Folds Detail Fabrication

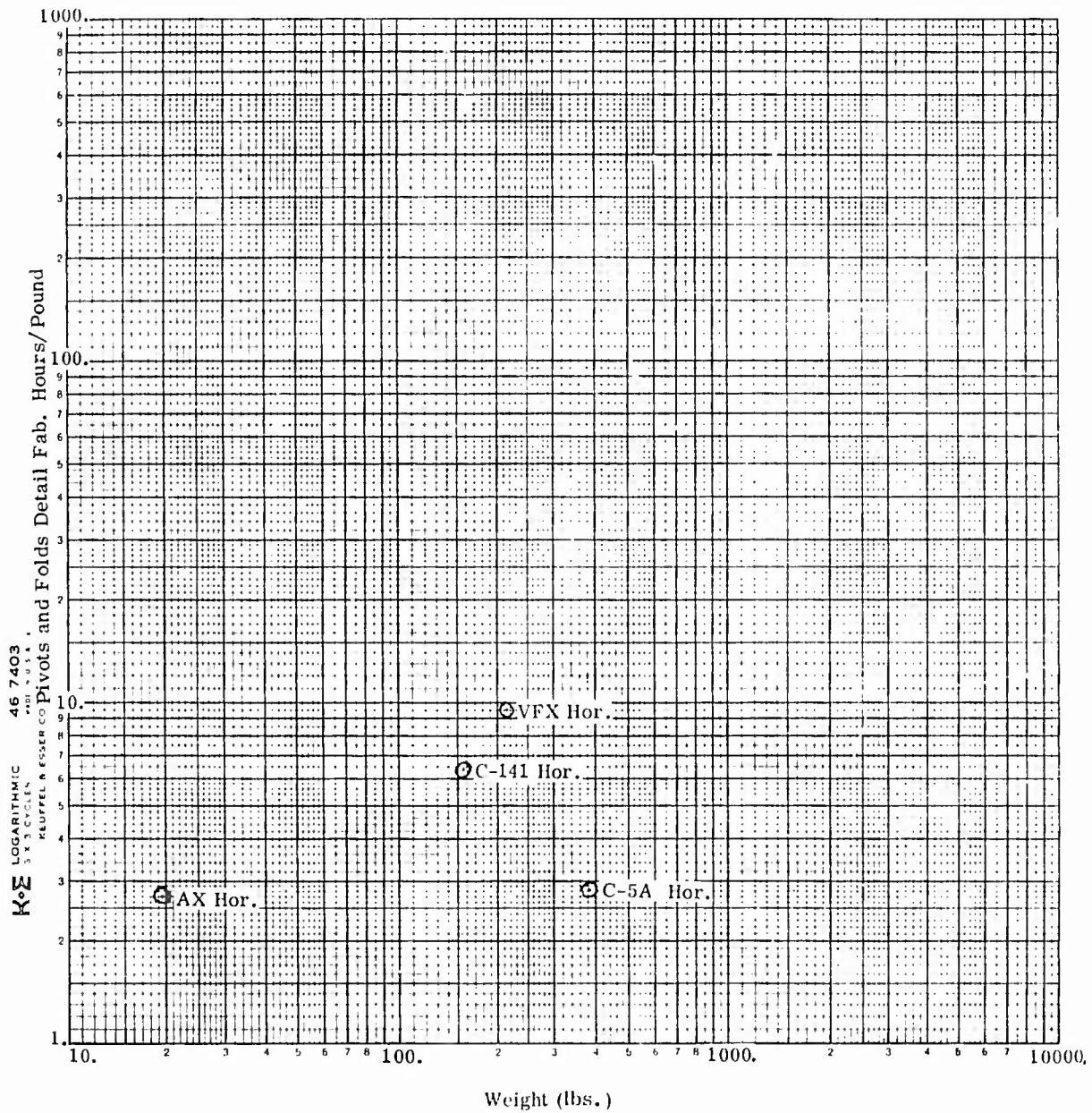


Figure 27. Pivots and Folds Detail Fabrication, Hrs/Lb and Weights.

Pivots and Folds Subassembly

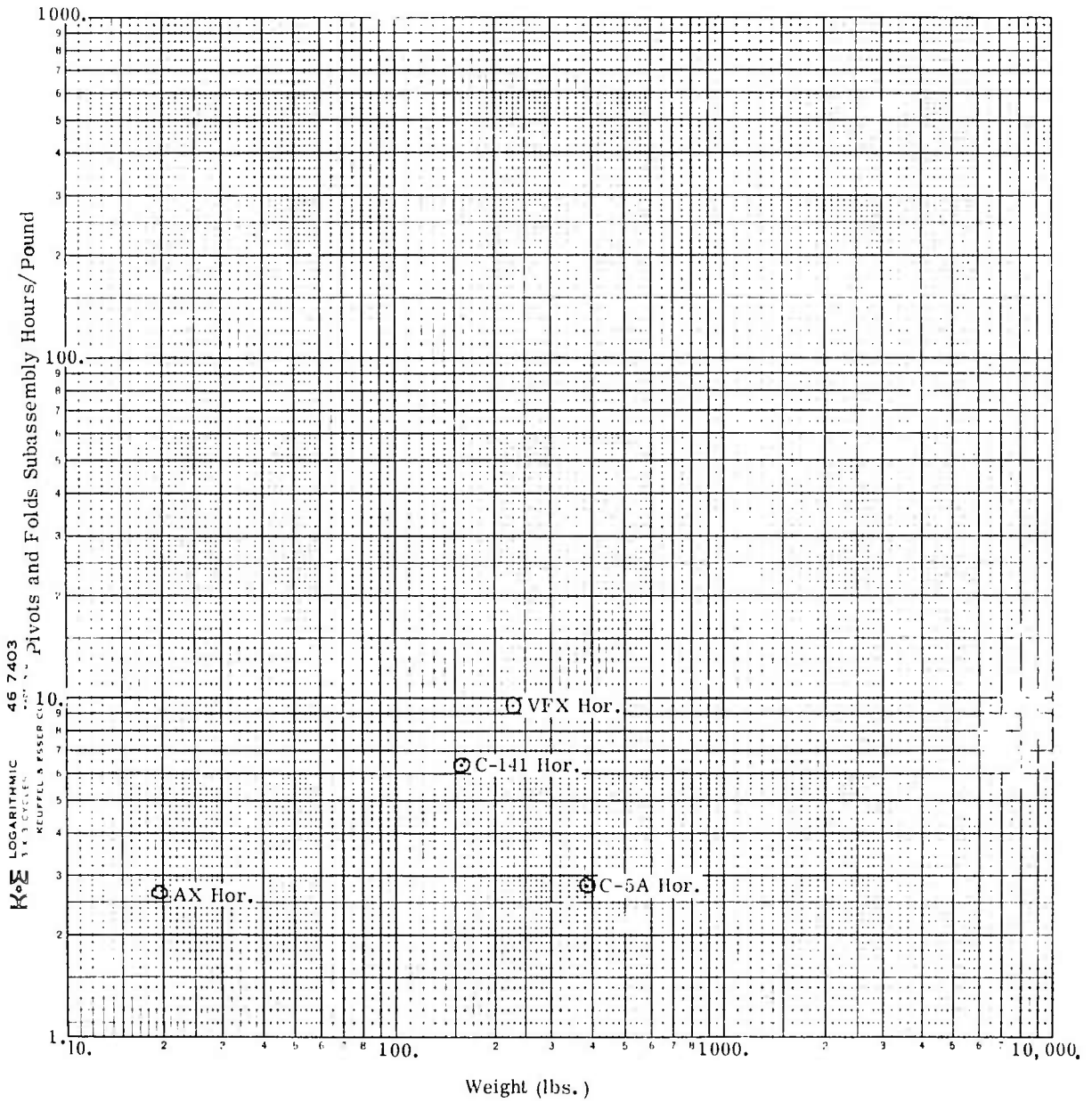


Figure 28. Pivots and Folds Detail Fabrication, Hrs/Lb and Weights.

Center Section Detail Fabrication

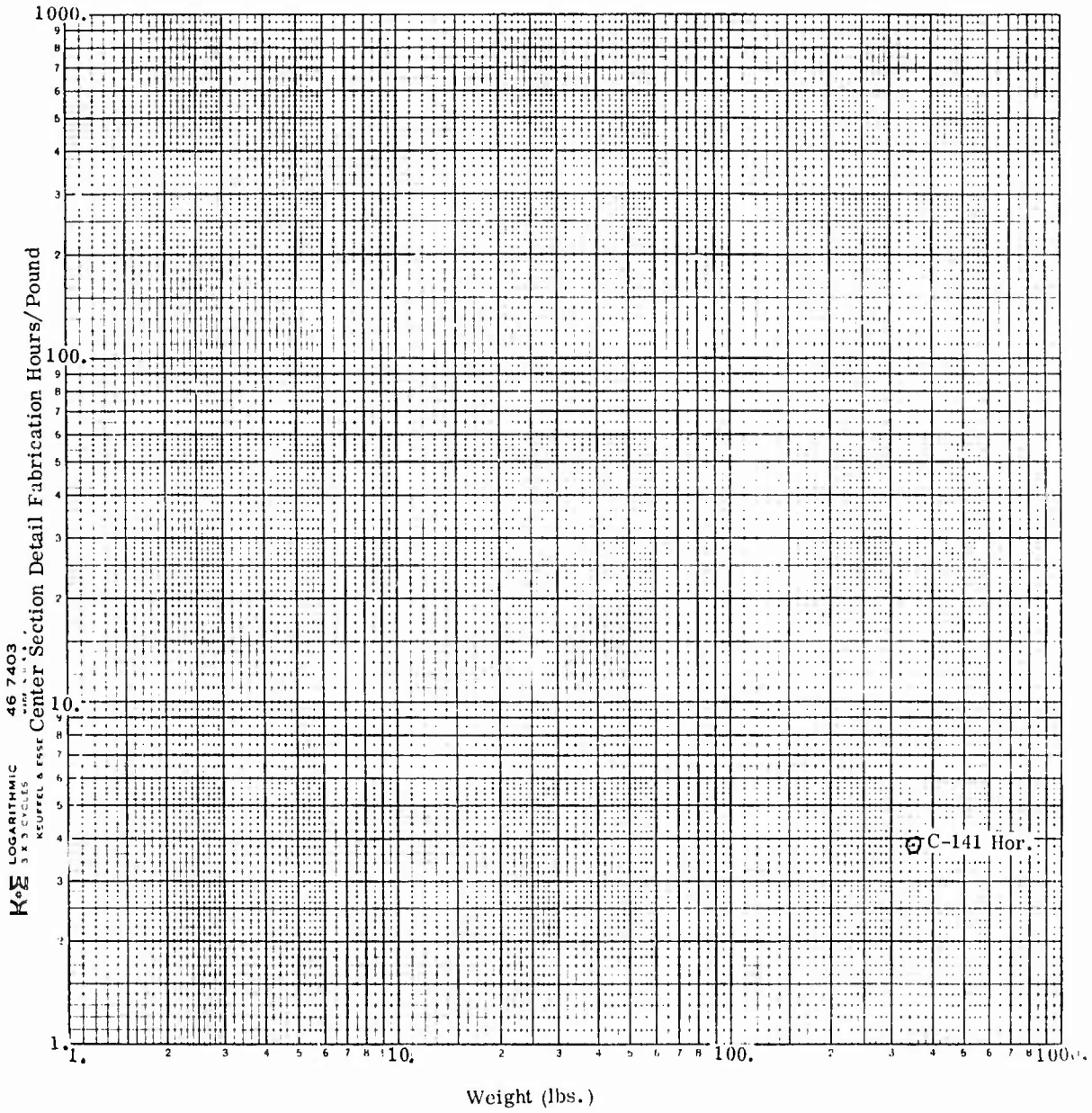


Figure 29. Center Section Detail Fabrication, Hrs/Lb and Weights.

Center Section Subassembly

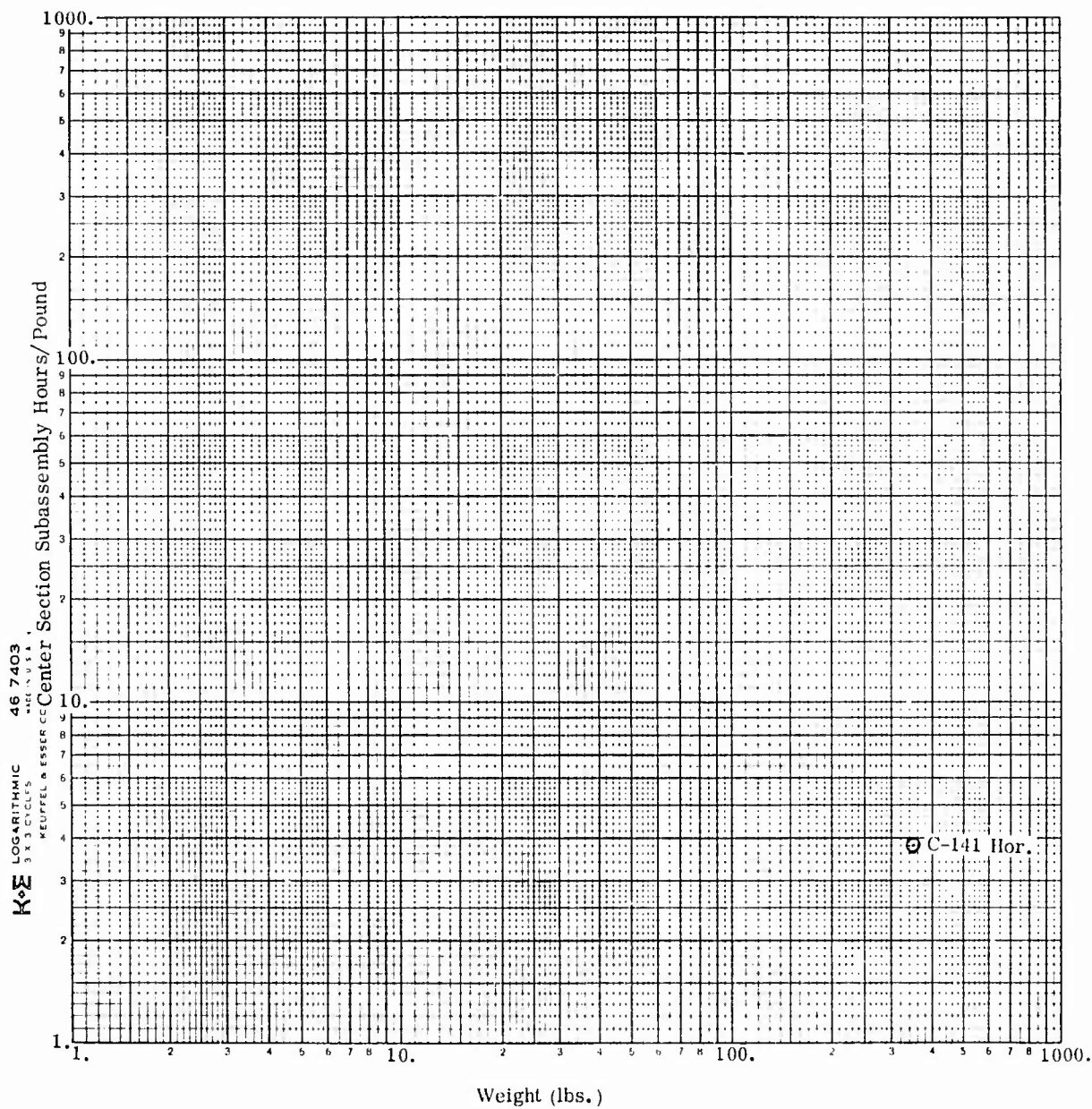


Figure 30. Center Section Subassembly, Hrs/Lb and Weights.

Other Detail Fabrication

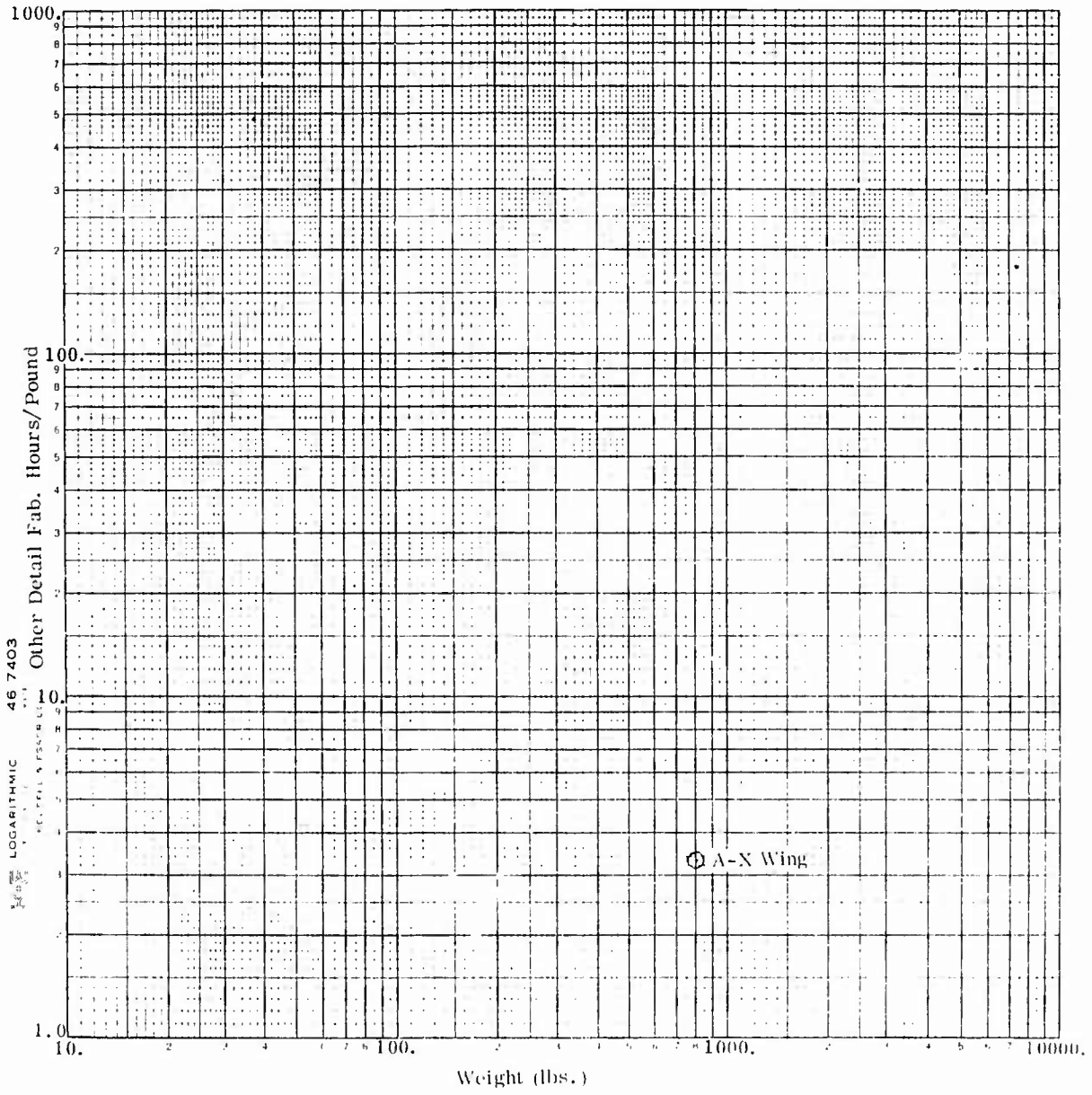


Figure 31. Other Detail Fabrication, Hrs/Lb and Weights.

Other Subassembly

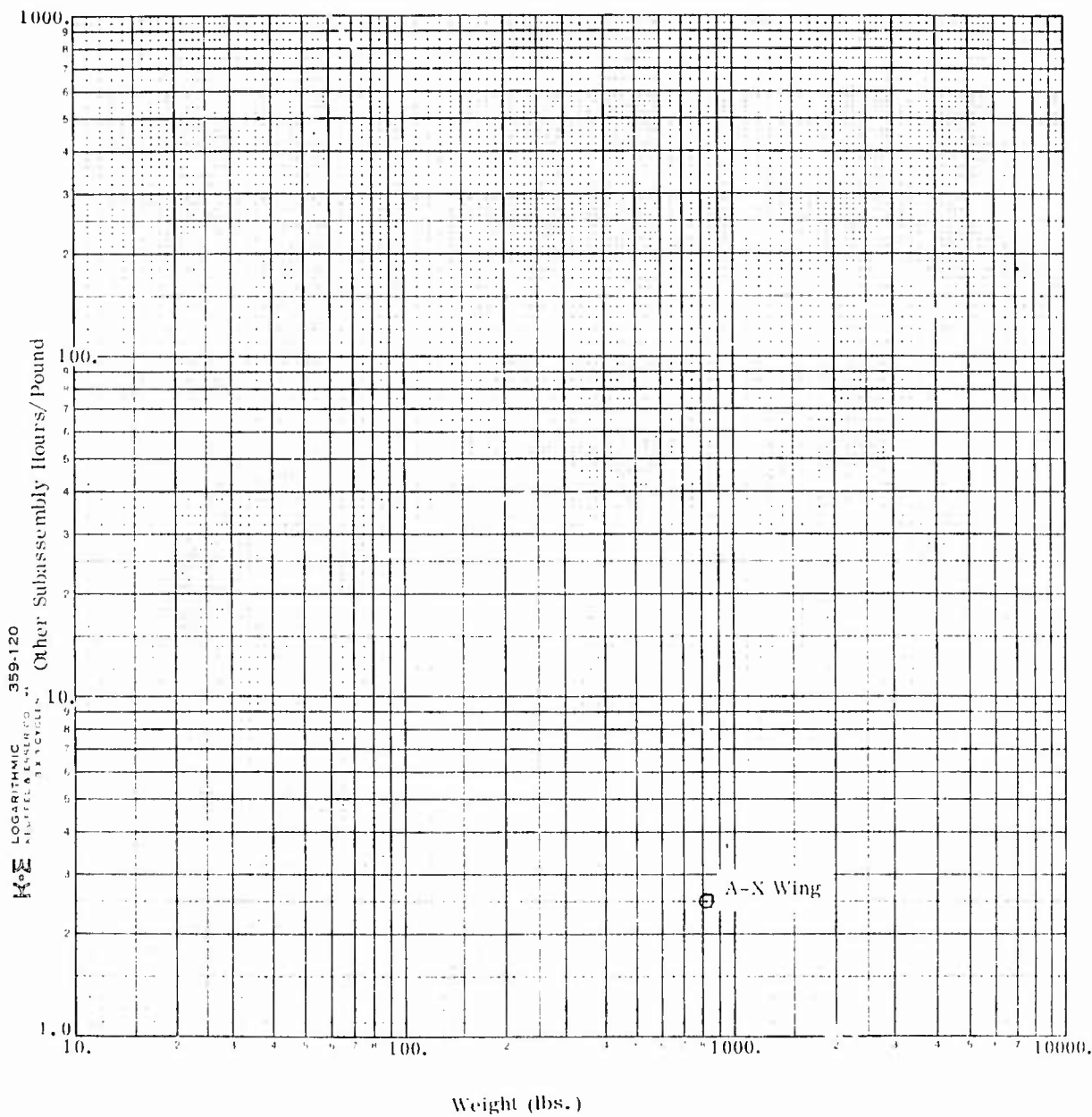


Figure 32. Other Subassembly, Hrs/Lb and Weights.

Elevators Detail Fabrication

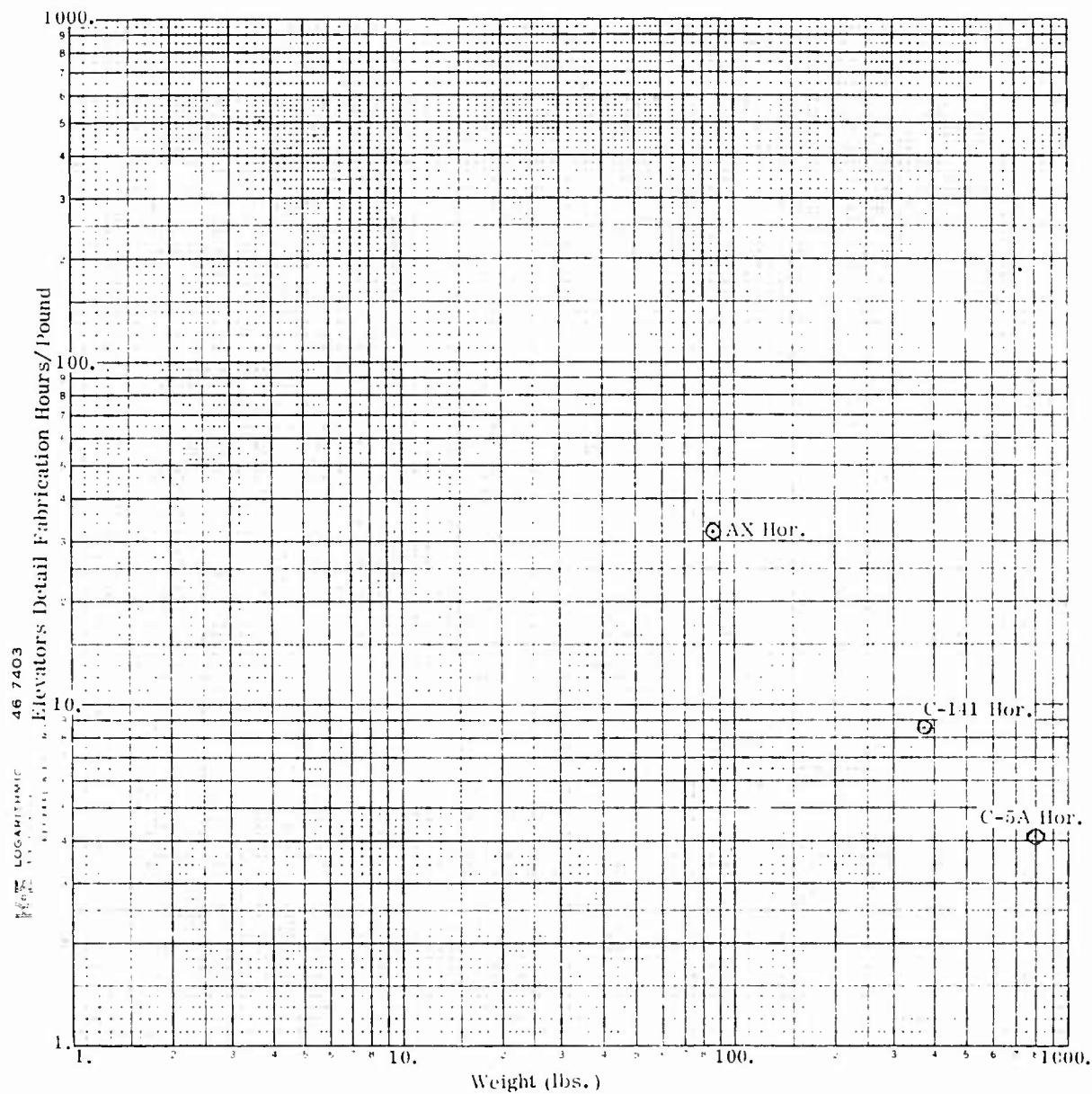


Figure 33. Elevators Detail Fabrication, Hrs/Lb and Weights.

Elevators Subassembly

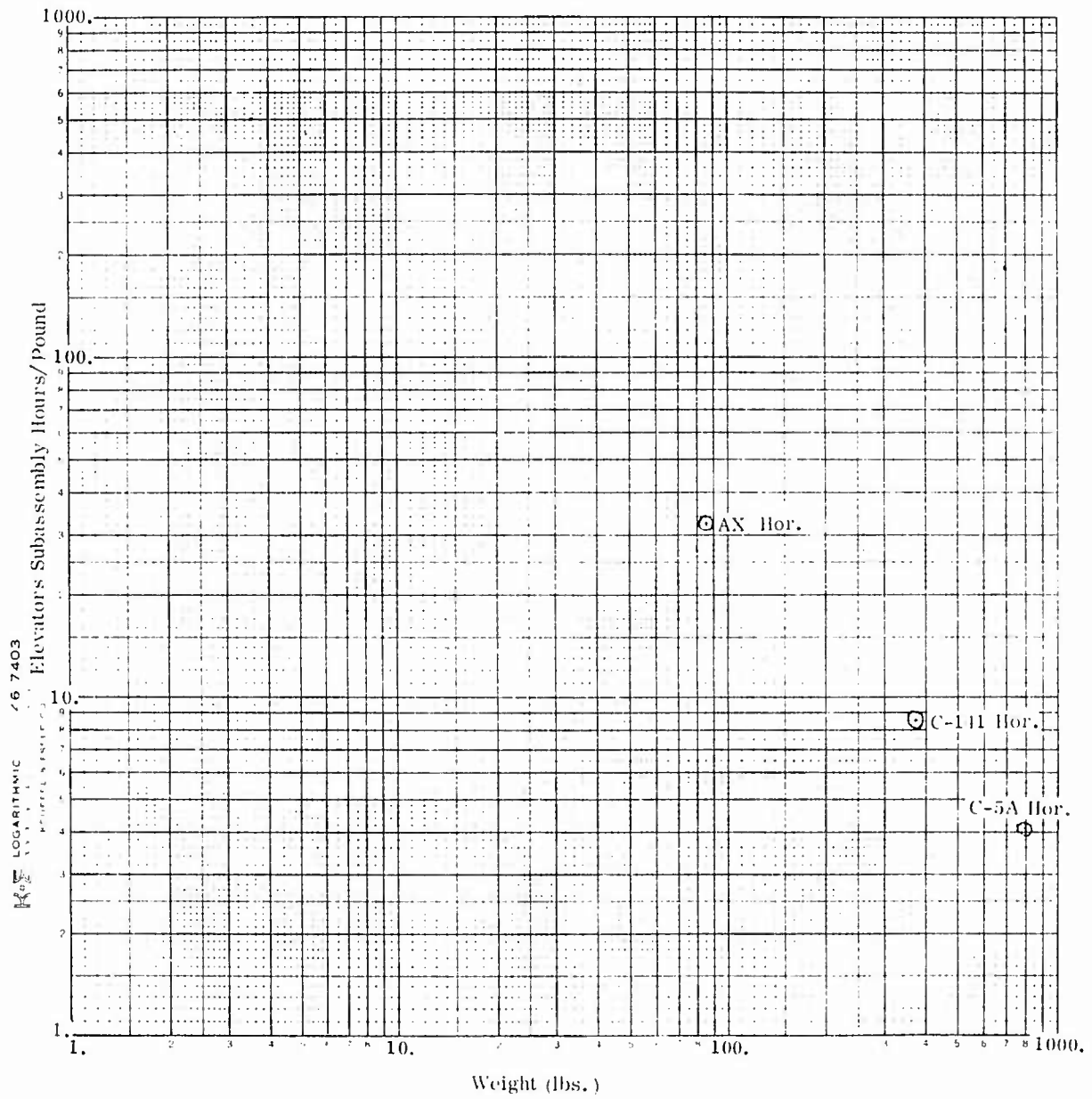


Figure 34. Elevators Subassembly, Hrs/Lb and Weights.

Balance Weights Detail Fabrication

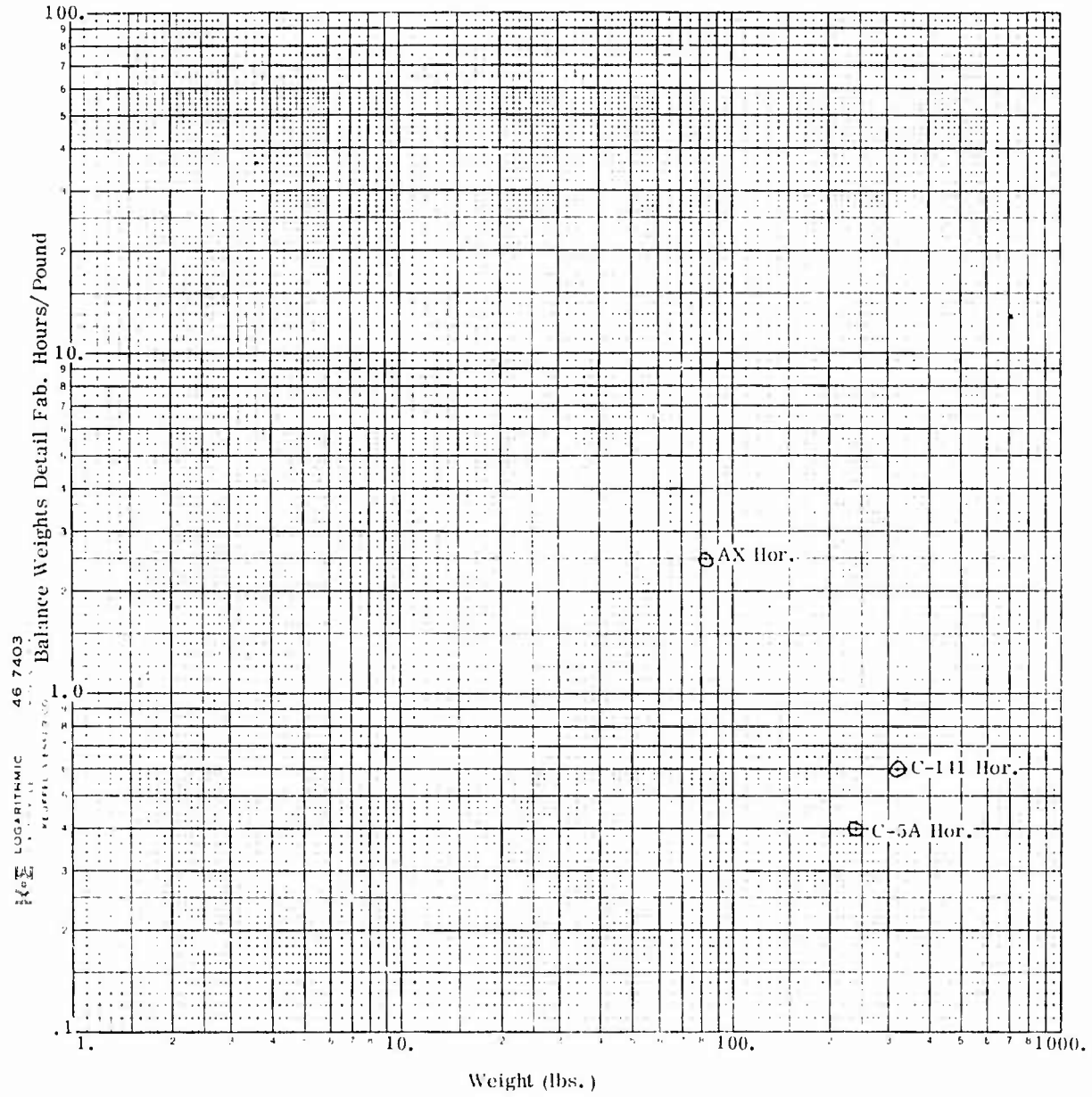


Figure 35. Balance Weights Detail Fabrication, Hrs/Lb and Weights.

Balance Weights Subassembly

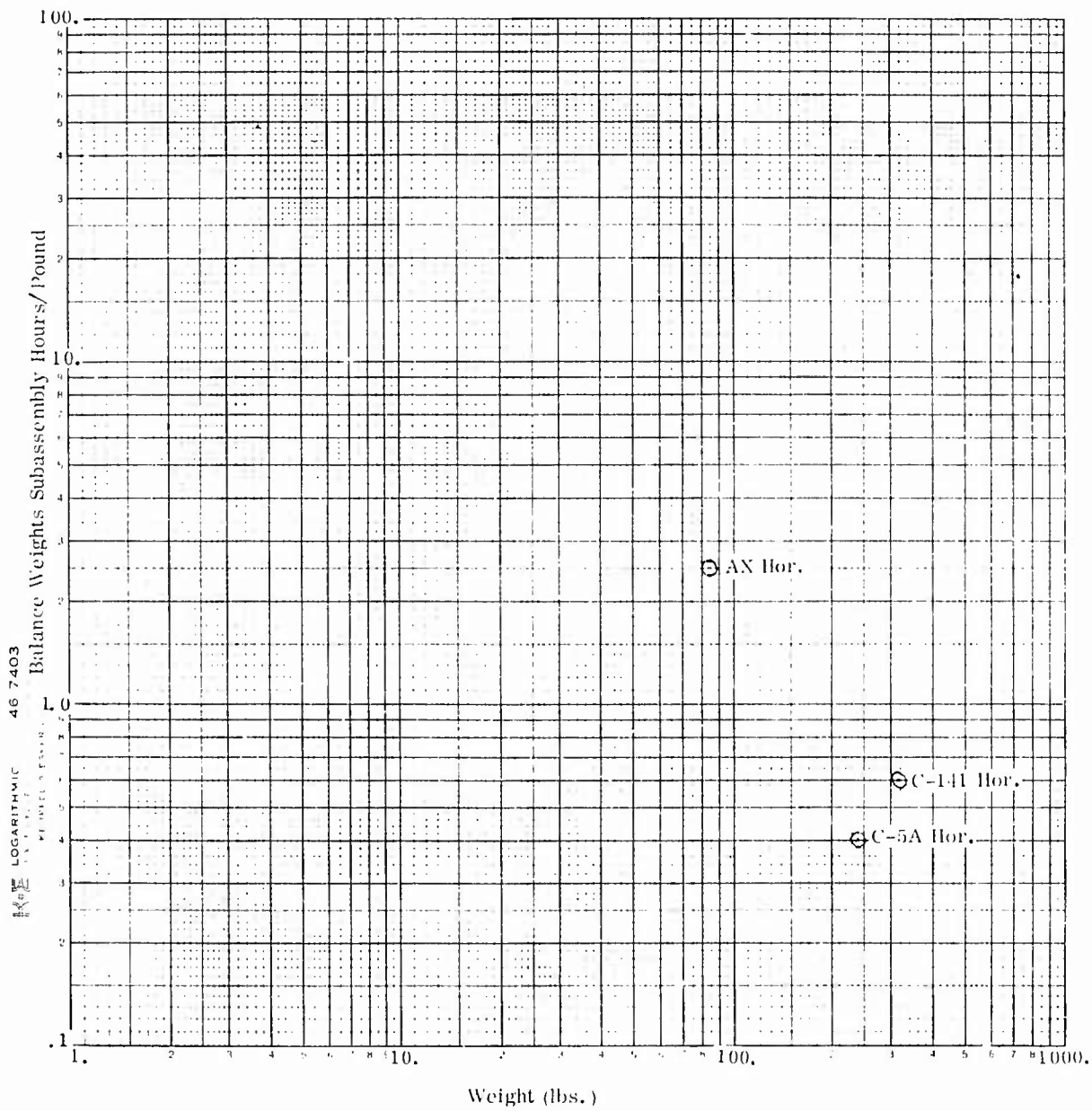


Figure 36. Balance Weights Detail Fabrication, Hrs/Lb and Weights

Primary Box Assembly

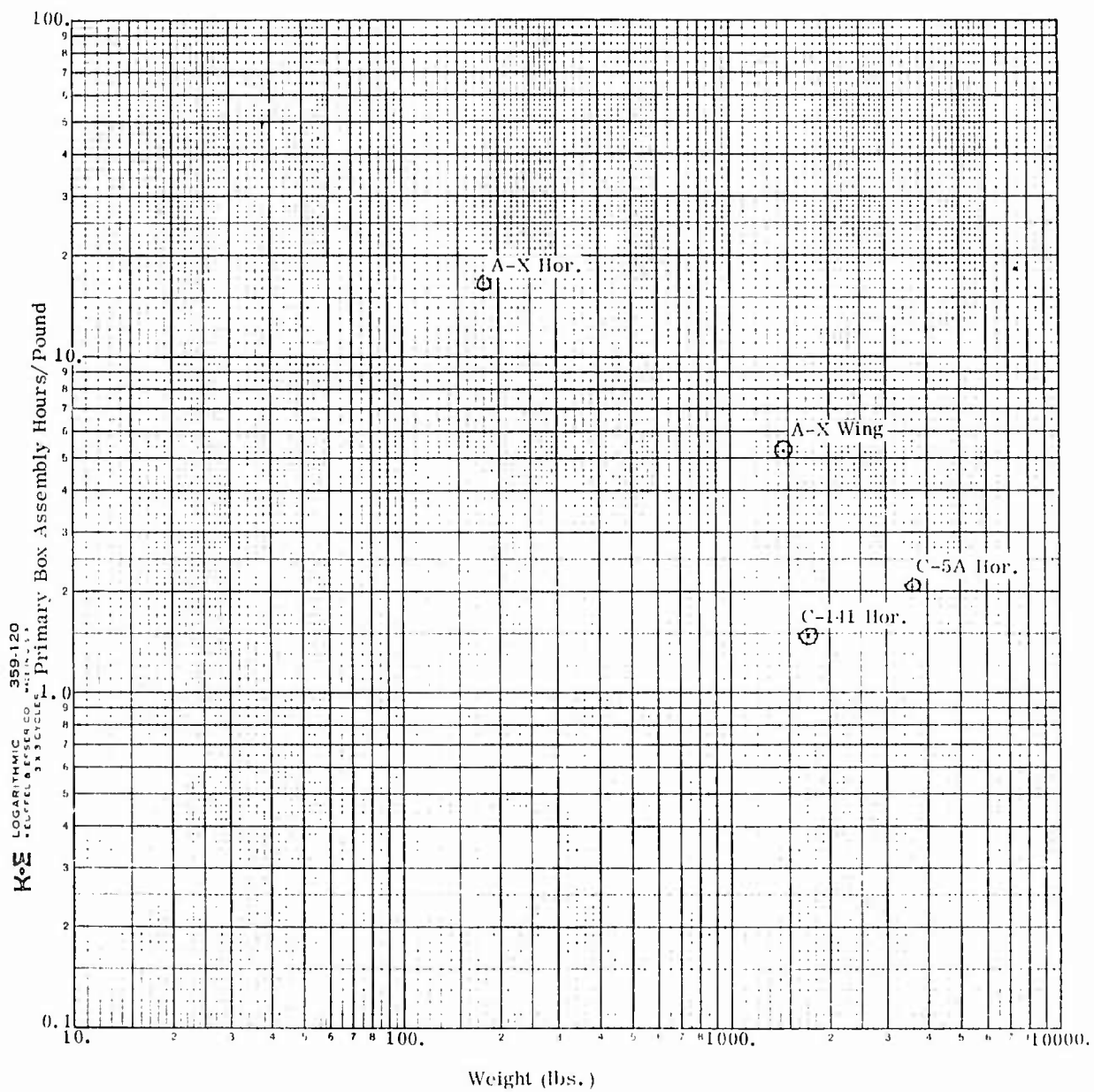


Figure 37. Primary Box Assembly, Hrs/Lb and Weights.

Final Assembly

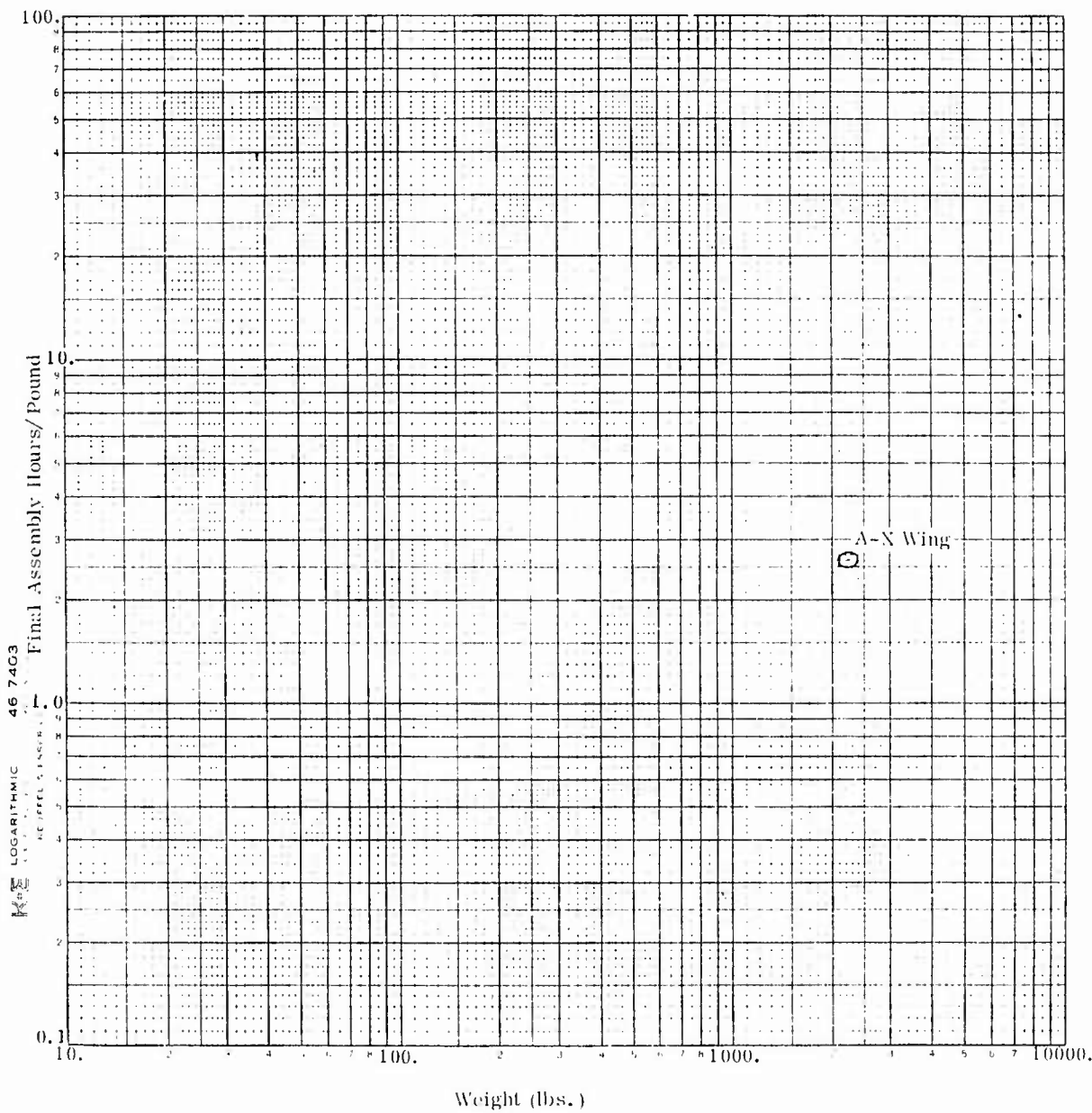


Figure 38. Final Assembly, Hrs/Lb and Weights.

Tips Detail Fabrication

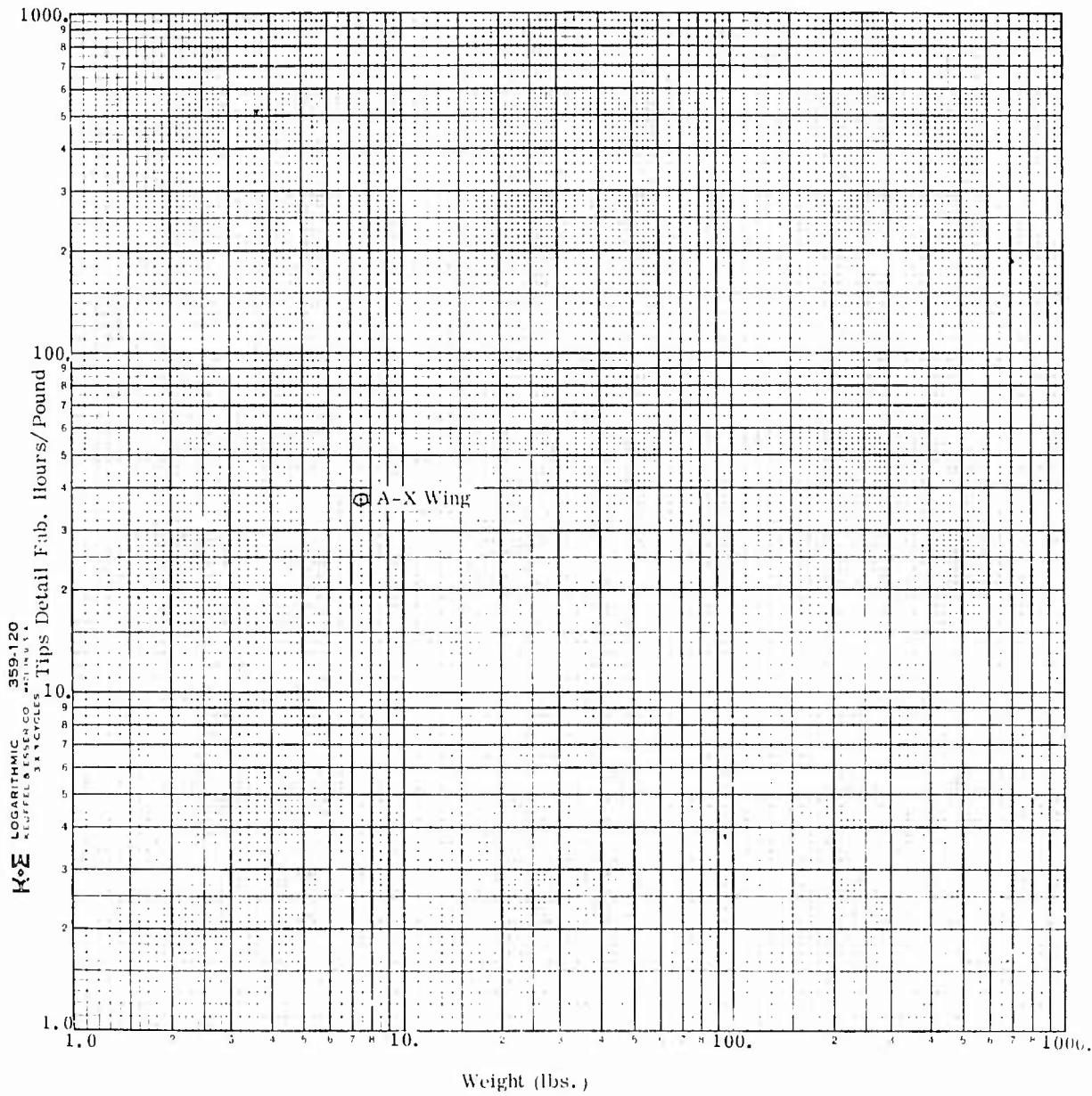


Figure 39. Tips Detail Fabrication, Hrs/Lb and Weights.

2.2.2 MATERIAL COST DATA. The material cost data organization is that developed for the horizontal stabilizer feasibility study. Basic data is shown in Figure 40 for ribs, spars, and covers. Sheet stock cost for sheet design covers is taken as the reference cost, which is shown by the solid line. Differences between mill prices and the costs indicated reflect adjustment for actual scrappage from cut-off, machining, drilling, etc., as well as the cost of shipping, receiving inspection, inventory storage, and a portion of material control and handling costs. The estimating equations use adjusted raw material cost and a scrappage factor as the estimating variables. Scrappage factors were independently developed. These are shown in Table 22. These factors were applied to the original data (Figure 40) to arrive at a normalized set of values, as shown in Figure 41. A curve fit of normalized aluminum and titanium values gives the two curves shown in Figure 41. (Also shown in Figure 40.) Extrapolating these lines back to the one-pound intercept provides the basis for the adjusted raw material cost used for estimating purposes. These values are summarized in Table 23.

Figure 42 shows data for secondary box structure and other structure material cost. This includes fairings, leading edges, training edges, elevators, balance weights, tips, hinges, brackets, seals, access doors and frames, actuator attachment structure, pivots and folds, and center sections.

The material cost per assembly hour factors used in various material cost estimating equations are based on Figure 43 for basic box assembly hours and Figure 44 for component final assembly hours. These values are summarized in Table 23.

Fastener type material cost factors are given in Table 23. These were developed based on consideration of the C-5 fastener type material cost factors noted in Figures 43 and 44 modified by manufacturing experience.

2.3 SUBSYSTEM LEVEL COST DATA

Subsystem level cost data is used in both the trade study and system costing methods: in the area of nonrecurring costs, where common CERs are used; as data showing actual costs of basic structure major components to be used to calibrate the results of the detailed estimating process; and in the system cost estimating technique development in the derivation of cost estimating relationships. It should be noted that subsystem level data has been shown throughout this volume in the form of aggregations of the detailed data. This data is not being repeated. The data shown in this section is that used in the derivation of subsystem level trade study CERs.

2.3.1 ENGINEERING DIRECT LABOR DATA. Data used in the development of the cost estimating relationship for nonrecurring engineering direct labor hours is given in Table 24. Data is also included for the fuselage since this component is expected to be handled by the same CER form.

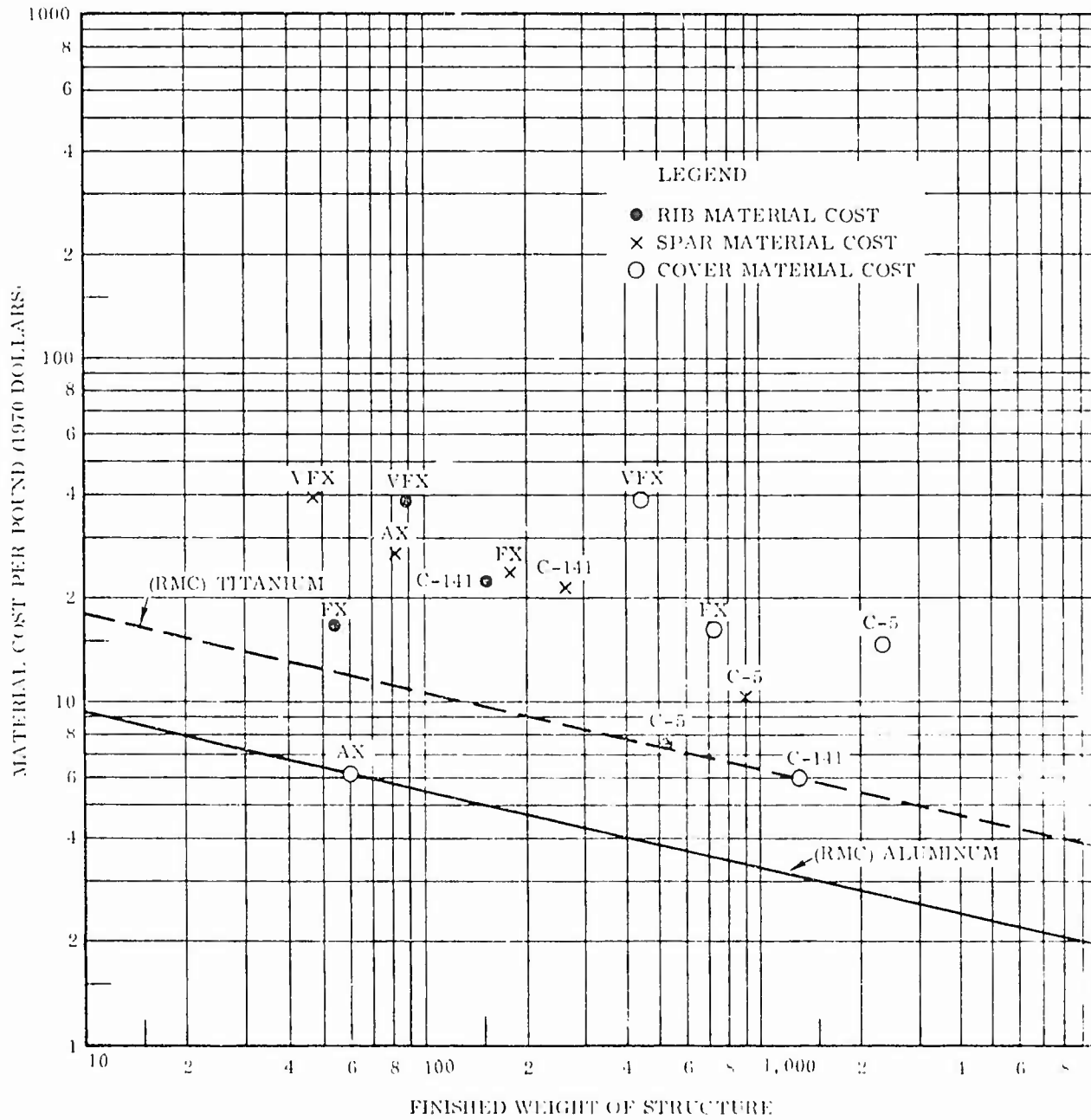


Figure 40. Rib, Spar, and Cover Cost per Pound Versus Structure Weight

Table 22. Material Cost Processing and Scrapage Factors for Ribs, Spars, and Covers

STRUCTURE TYPE	MATERIAL TYPE	BUILT-UP WEB STIFFENER	BUILT-UP TRUSS	SHEET WEB	CORRUGATED WEB	INTEGRAL WEB STIFFENER	INTEGRAL TRUSS		
RIBS (SF 1)	ALUMINUM TITANIUM STEEL	2.0	2.0	2.0	2.0	5.3	5.3		
		3.5	3.5	3.5	3.5	5.3	5.3		
SPARS (SF 2)	ALUMINUM TITANIUM STEEL	3.0	3.0	3.0	3.0	5.3	5.3		
		3.0	3.0	3.0	3.0	5.3	5.3		
COVERS (SF 3)	ALUMINUM TITANIUM STEEL	BUILT-UP SKIN STRUCTURE	INTEGRAL SKIN STRINGER	MACHINED PLATE	SHEET				
						2.0	5.3	4.5	1.0
						3.5	5.3	4.5	1.0
						1.0			

Table 23. Material Cost Input Values

STRUCTURAL MATERIAL COMPONENT				
	ALUMINUM	STEEL	TITANIUM	ALUMINUM AND STEEL
RIB SPAR AND COVER BASIC MATERIAL (RMC)	18.0	22.0	28.0	
SECONDARY AND OTHER STRUCTURE BASIC MATERIAL (COM)	40.0	55.0	70.0	50.0 (Use When Aluminum Secondary Structure Includes a Steel Pivot)
ASSEMBLY MATERIAL COMPONENT				
	(AMF)			
(AMF ₁) BASIC BOX -- --	MATERIAL DOLLARS PER ASSEMBLY HOUR = 0.34			
(AMF ₂) STRUCTURAL BOX -- --	MATERIAL DOLLARS PER ASSEMBLY HOUR = 0.68			
(AMF ₃) FINAL ASSEMBLY -- --	MATERIAL DOLLARS PER ASSEMBLY HOUR = 0.68			
	SUBSONIC ALUMINUM AIRCRAFT	SUPERSONIC ALUMINUM AIRCRAFT	STEEL & COMPOSITE AIRCRAFT	TITANIUM FASTENERS
ASSEMBLY FASTENER TYPE MATERIAL COST FACTOR FM ₁	1.0	1.5	1.5	2.6
FM ₂ AND FM ₃	1.0	2.0	2.0	4.5
WHERE G = 0.77				

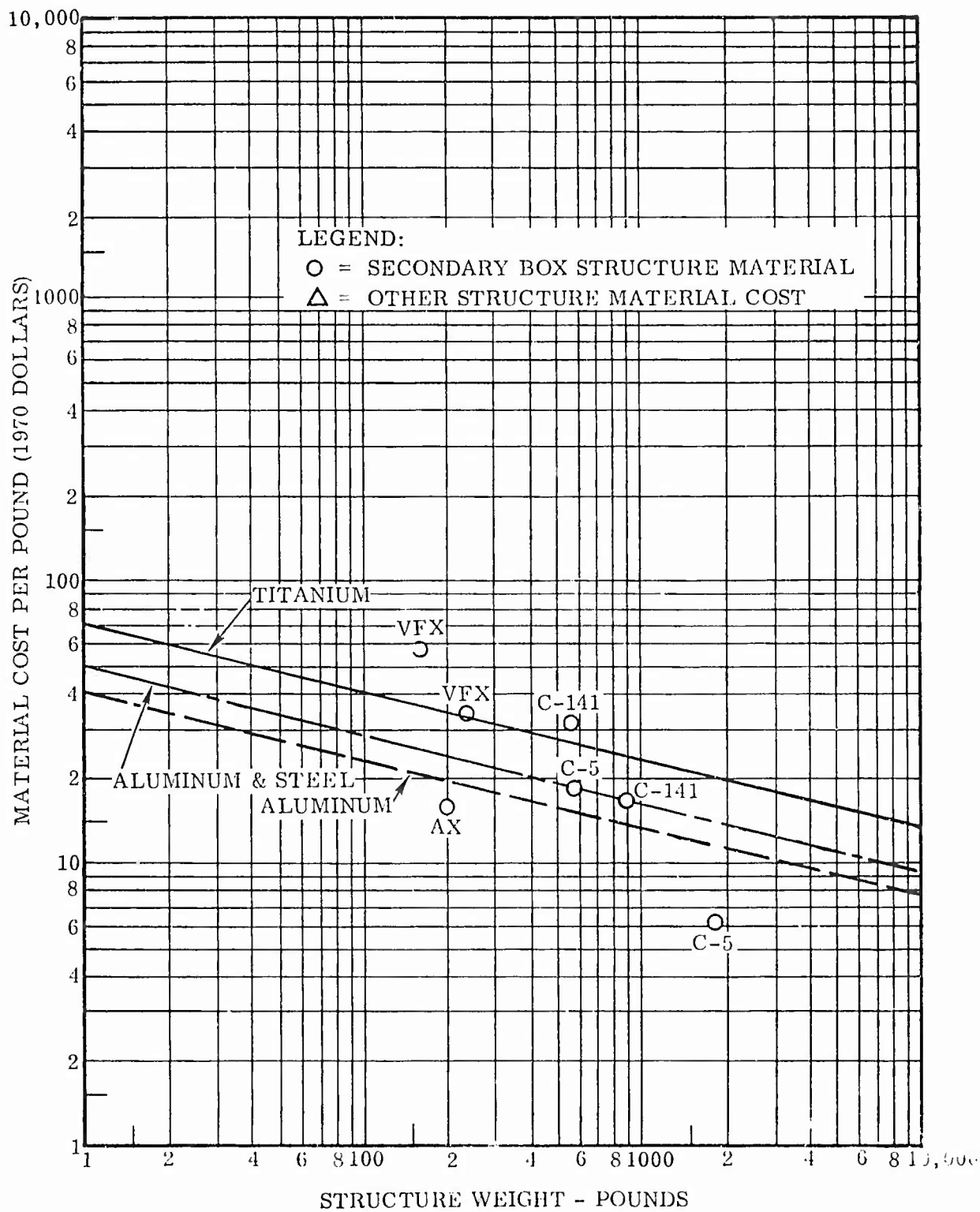


Figure 42. Secondary Box and Other Structure Cost Versus Structure Weight

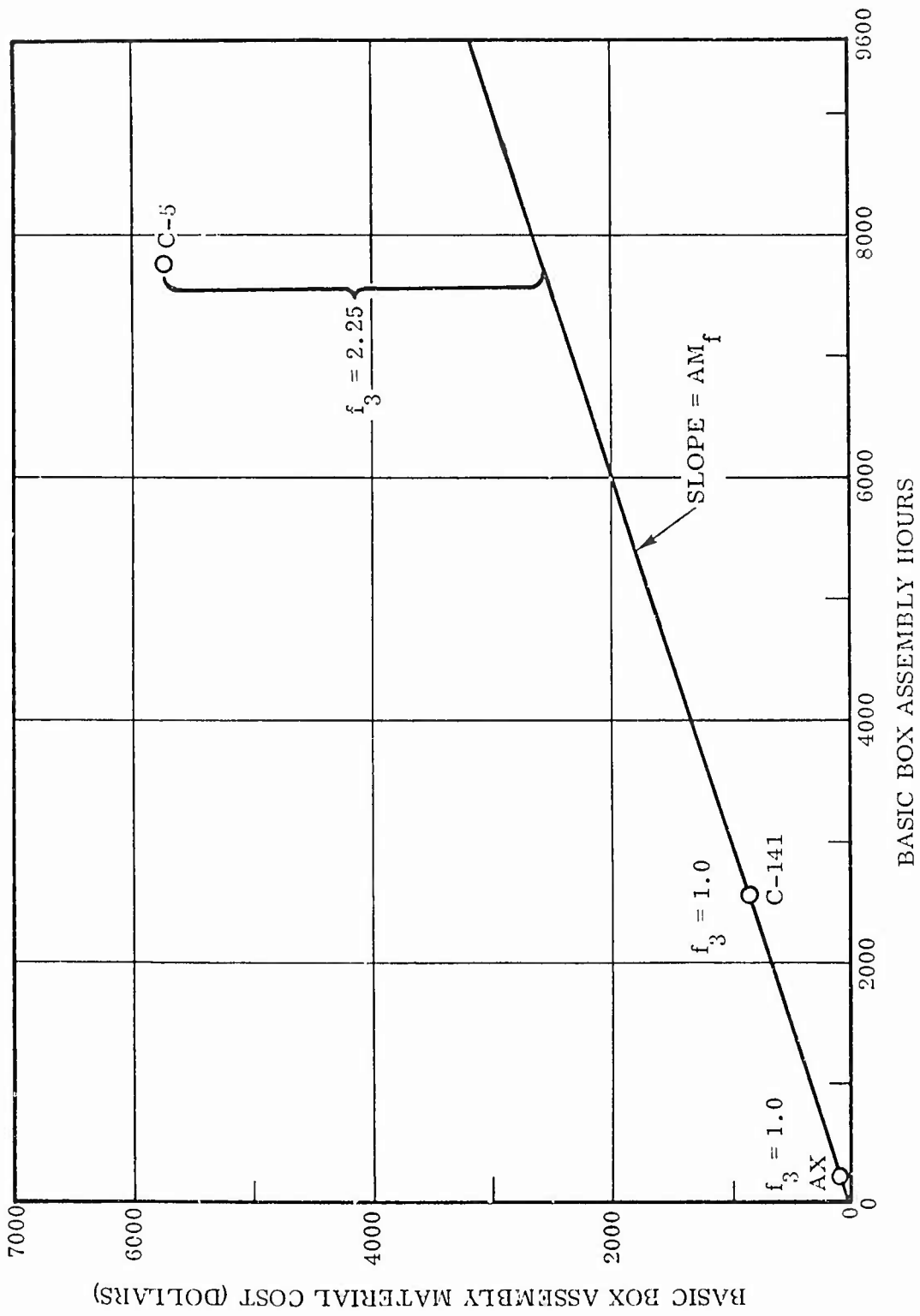


Figure 43. Basic Box Assembly Material Cost Versus Basic Box Assembly Hours

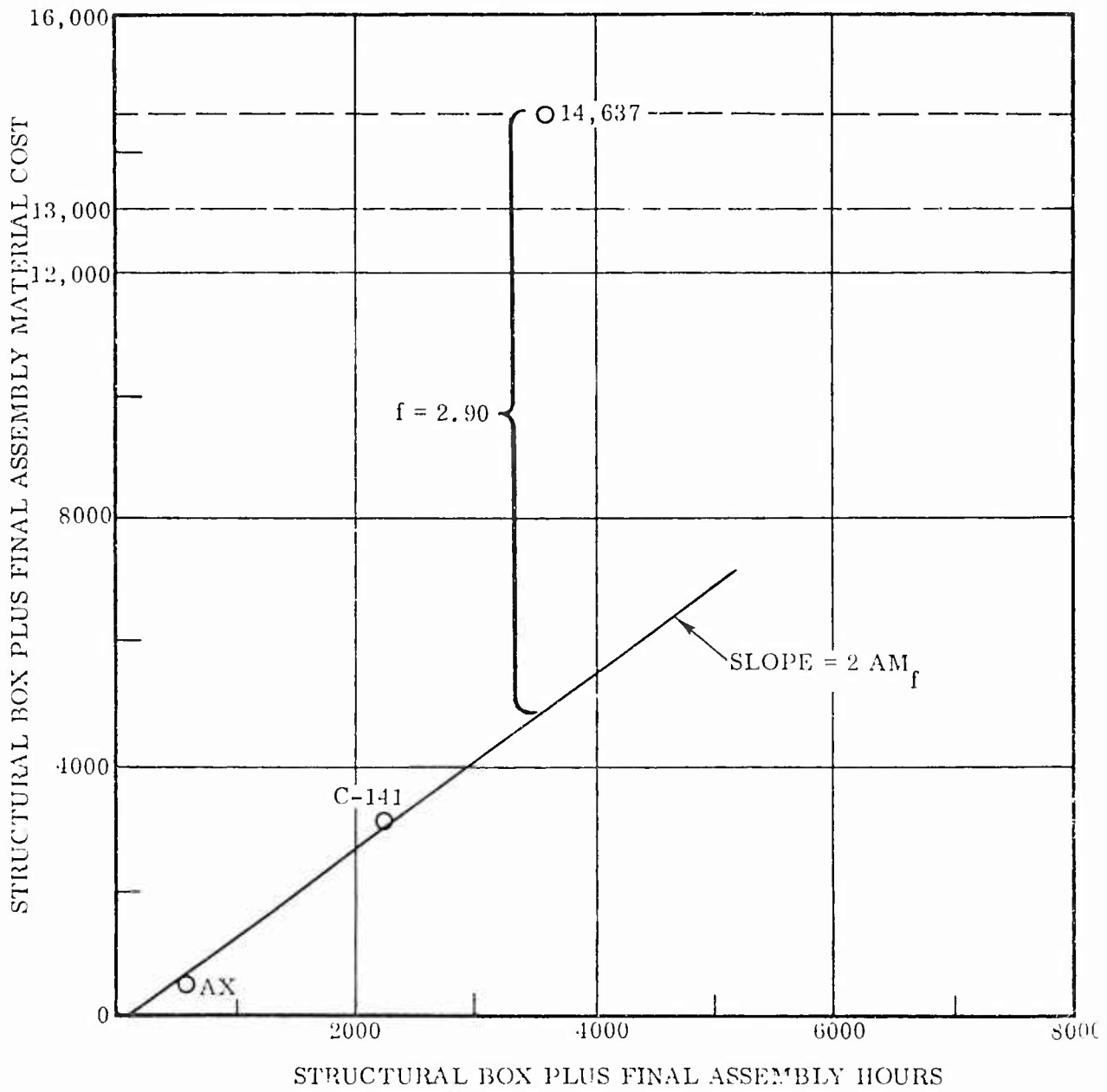


Figure 44. Material Cost Versus Structural Box Plus Final Assembly Hours

Table 24. Engineering Director Labor Hours Data.

	Wing			Empennage			Fuselage		
	Original Design	First Flight	Total Hours	Original Design	First Flight	Total Hours	Original Design	First Flight	Total Hours
Model 240 Commercial Transport	40,330	43,919	66,719	10,223	11,133	-	40,358	43,979	-
Model 340 Commercial Transport	32,806	35,464	75,064	7,927	9,657	-	26,335	30,309	-
XF2Y-1*	12,873	13,041	36,112	6,940	6,958	-	18,082	18,625	-
XFY-1*	30,053	32,705	87,905	6,934	8,363	-	18,798	24,871	-
F-102	47,494	60,998	151,698	12,945	14,133	-	81,715	107,505	-
R3Y	120,616	132,707	372,707	39,885	45,129	-	55,779	73,434	-
Model 48 (Charger)*	15,697	21,598	28,098	12,987	17,889	-	18,055	24,870	-
F-106A	91,052	53,115	206,615	22,640	23,717	-	227,993	234,778	-
Model 880 Commercial Transport	222,441	225,713	420,713	165,686	167,439	-	238,591	245,314	-
Model 110*	39,250	45,412	66,612	11,813	13,668	-	35,437	41,001	-
XB-46*	79,547	82,968	123,968	21,978	22,923	-	39,506	41,205	-
XC-99*	104,031	120,676	188,376	14,593	16,913	-	93,417	108,270	-
XP5Y-1*	47,900	63,226	142,026	11,600	14,831	-	38,600	43,191	-
B-58	-	-	1,093,000	-	-	169,000	-	419,600	550,000
C-5A	-	-	-	352,861	437,259	-	-	-	-
C-141	-	-	-	176,753	237,514	-	-	-	-
F-111 Wing Carry Through	-	75,702	106,687	-	-	-	-	-	-

*Prototype or Experimental Programs

2.3.2 TOOLING DIRECT LABOR DATA. Applicable tool manufacturing direct labor hours data are shown in Table 25.

2.3.3 MANUFACTURING COST DATA. Data is presented in the form of either first unit cost or first unit cost per pound. This data is in addition to previously detailed data.

B-58 Cost Data

Results of the B-58 Aircraft Cost Study performed for NASA by the Fort Worth Division under Contract NAS9-12101 were reviewed. The cost data contained therein is at the subsystem level of detail. These data will be useful to this study in two ways: (a) as a set of data points showing actual costs of basic structure major components that can be used to calibrate the results of the detailed estimating process, and (b) in the system cost estimating technique development as data for use in developing cost estimating relationships. The data is summarized in Table 26.

Table 25. Tooling Cost Comparisons

Program	AMPR Wt.	Diss. Parts	Tot. Parts	Tls/Part	Tot. Tools	Av. Hr./ Tl.	Tool Mfg. Hrs.	T.E. %
A	19,838	16,785		1.51	25,400	29.6	751,734	16.3
B	21,673	22,000		1.51	33,200	31.0	1,029,820	
C	65,700	51,000		1.77	90,181	50.2	4,526,110	
D	87,150				66,154	45.0	2,986,930	24.9
E	12,074	13,815		2.62	36,191	58.0	2,099,772	23.6
F	15,037	18,166		2.31	42,060	55.7	2,341,320	
G	32,830	35,866		1.44	51,751	40.6	2,100,000	
H	6,087	4,871	10,170	1.30	6,315	38.4	242,363	32.7
I	11,839	6,077	9,916	1.72	10,439	41.4	432,059	33.8
J	42,390	24,020		1.69	40,506	43.8	1,772,730	40.0 40.0
K	28,600	28,800	52,000	1.70	48,960	40.0	1,958,400	40.0 40.0
L	18,263	10,709		1.36	14,569	31.8	559,440	33.0
M	52,548	22,741		2.34	53,000	71.0	3,775,000	
N	25,365	24,300		1.7	42,200	77.0	3,250,000	40.0
O	33,166	11,367	33,185	2.13	24,174	55.0	1,314,467	36.0
P	15,500						2,165,600	

Table 26. B-58 Subsystems First Unit Cost

Airframe and Related Subsystems:

Structure		\$ 8.54M
Landing Gear	\$0.78M	
Nacelles	1.95M	
Fuselage	2.17M	
Wing	3.36M	
Tail	0.28M	
Propulsion		0.06M
Flight Control		1.39M
Electrical Power		0.50M
Hydraulics		0.13M
Escape Capsule		0.18M
Environmental Control		0.36M
Vehicle Installation, Assembly and Checkout		<u>1.70M</u>
		\$12.86M

Avionics Subsystems

Bomb/Nav.	\$9.17	
M&T C ont.	0.40	
Passive Defense	1.08	
Data	2.66	
Active Defense	<u>0.53</u>	<u>13.84</u>
		\$26.70M

SECTION III

COST TREND DATA

A variety of cost trend charts have been prepared under a cost trend data amendment to contract number F33615-72-C-2083. Charts presenting costs (inflated to 1973 dollars) as a function of physical/design parameters and other cost trends have been prepared. A specific cost terminology has been used for all charts, as defined below.

Program cost includes the R&D cost plus procurement cost for the specified number of aircraft. If a 100-aircraft program number is mentioned, for example, this always means the entire cost for the first 100 or other specified number produced. Aircraft cost includes all of the recurring cost of aircraft produced, including cost of engines, avionics, armament, recurring tooling support, recurring engineering support, and all other recurring production costs. Airframe cost again refers to recurring aircraft production costs including recurring engineering and tooling but omitting engines, armament, and avionics.

Structure cost means cost of structure only. This has been achieved in some cases by adjusting "cost center data" to remove costs incurred at the cost center for installing portions of electrical, hydraulic instrumentation, flight control and other nonstructural subsystems. Adjustment percentages used were based upon F4H and B-58 cost breakdowns available.

Charts are presented in the following subcategories and in the order listed.

- a. Parametric Cost Trend Charts
- b. Economic Factors Cost Trend Charts
- c. Aircraft Program Cost Charts
- d. Structure Subassembly Cost Charts

Inflation adjustments have been taken from Cost Research Report Number 110A, dated May 1973, prepared by the comptroller's office at Aeronautical Systems Division of Wright-Patterson Air Force Base, Ohio. Data have been obtained from reports available to General Dynamics Convair. In some cases it was necessary to make calculations, by using cost-quantity curves for example, to produce comparable data values. Occasionally, other adjustments such as estimating for and adding in a missing cost such as production material cost was necessary. These adjustments and interpretations have been made on a best efforts basis.

It is quite probable that with additional resources some additional data could be developed. The areas of effort would include additional library search and possibly more analysis of available information. Additional data points would be expected to reinforce the general trends already shown by the charts.

Most desirable are additional data on structural costs relating to the major structure subassemblies. These data are needed to more accurately calibrate and evaluate the cost prediction technique which is the primary contractual effort. In this area no additional data are available without extensive development.

Parametric Cost Trend Charts

Two sets of cost - aircraft and airframe, have been plotted against AMPR weight, design gross weight, speed, range, density, wing loading, design Q, and wetted surface area. Costs are plotted in terms of 1973 dollars per AMPR pound which normalizes the direct effect of weight/size on total aircraft or airframe cost.

AMPR weight is defined in the Aeronautical Manufacturers' Planning Report as "the empty weight of the planes less (1) wheels, brakes, tires and tubes; (2) engines; (3) starter; (4) cooling fluid; (5) rubber or nylon fuel cells; (6) instruments; (7) batteries and electrical power supply and conversion equipment; (8) electronic equipment; (9) turret mechanism and power operated gun mounts; (10) remote fire mechanism and sighting and scanning equipment; (11) airconditioning units and fluid; (12) auxiliary power plant; and (13) trapped fuel and oil." This weight concept may be referred to in current sources as "DCPR" weight, after the new Defense Contractors' Planning Report.

In different words the aircraft cost for purposes of the cost trend charts includes manufacturing labor, recurring quality control manufacturing materials, recurring engineering and tooling as well as installed propulsion, avionics, armament or other special systems. The airframe cost includes all the above excepting installed propulsion, avionics, or armament systems. Costs for all the cost versus parameter charts are cumulative average values for the first 100 aircraft produced in 1973 dollars. Comments regarding the individual charts follows:

Figure 45. There is a separation of aircraft cost as a function of speed seen in the chart. The faster aircraft show higher cost. Also, a downward slope with increasing weight is seen for aircraft with the same general speed range. Data points are more scattered for the aircraft points than for the airframe points because of variations in amount and complexity of installed equipment.

Figure 46. The same separation by speed range and same downward cost trend with increasing weight is seen as before. The dashed trend lines indicate these effects.

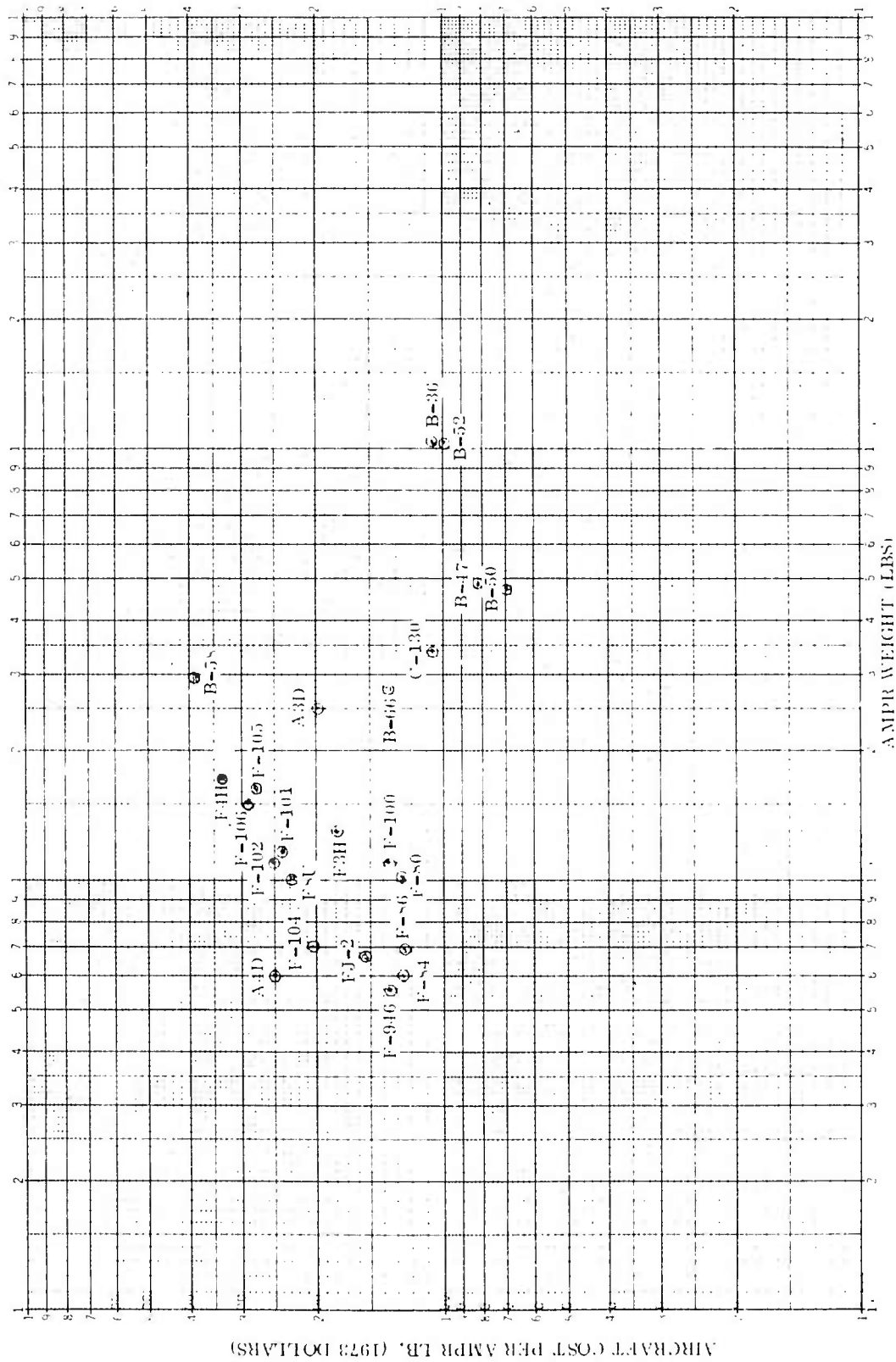


Figure 45. Aircraft Cost per lb. versus AMPR Wt. (Costs are 100th Unit Cum. Avg.).

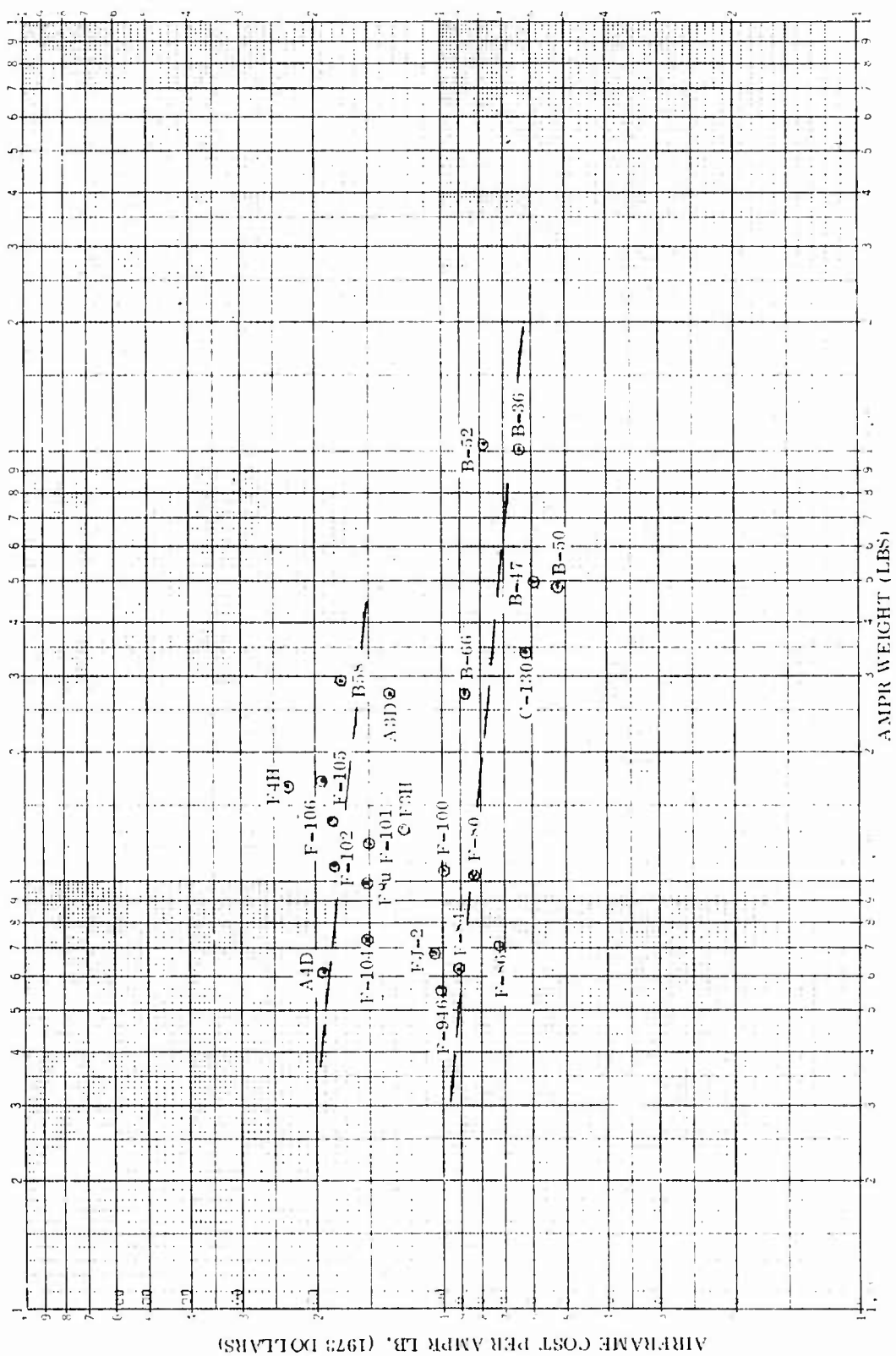


Figure 46. Airframe Cost/lb. versus AMPR Wt. (Cum. Ave. at 100 Units).

Figures 47 and 48. The same general remarks as for Figures 45 and 46 apply to the cost versus gross weight presentations. Gross weight is the maximum allowable takeoff weight. The dashed trend lines are again drawn in Figure 48.

Figures 49 and 50. These examine costs as a function of maximum speed in knots at best altitude. A definite upward cost trend with increasing speed is seen.

Figures 51 and 52. These show costs as a function of maximum operating range. Although a definite trend can be seen for the subsonic aircraft, range does not appear as a good cost-related parameter for the higher performance aircraft.

Figures 53 and 54. The figures show an increasing cost trend as density increases. Density here is defined as AMPR weight divided by airframe volume.

Figures 55 and 56. These charts of cost versus wing loading do not show any obvious trends. Wing loading is defined as maximum gross weight divided by wing area.

Figures 57 and 58. These charts show costs as a function of aerodynamic pressure, or "design Q," in terms of pounds per square foot. The charts show an increasing cost with increasing Q. The slope of the trend breaks sharply upward as pressures rise above 1000 pounds per square foot.

Figure 59. The points available for plotting show a decreasing cost per pound trend with increasing wetted surface area. It should be noted that a cluster of fighters make up one end of the trend line while relatively slow bombers and a cargo carrier make up the other end. The larger, fast aircraft such as B-58, B-1, B-70 and SST would be expected to fall well above the trend line indicated here. Also note that surface area is a size parameter which is related to weight, therefore, similarity to cost compared to weight can be expected.

Figure 60. The same downward cost trend with increasing wetted surface area is seen. Scatter of data points about the trend is less using "airframe" cost.

Figure 61. This figure shows whole airframe costs as a function of wetted surface area while airframe cost is calculated by multiplying the cost per pound times the AMPR weight. No trend improvement over that of Figure 60 is seen. An increasing cost with size trend is noted. The C-130 being a slower, boxy type aircraft stands off the trend line on the low side. This is probably typical of cargo type aircraft.

While costs do exhibit trends with various single parameters, improved fits to predicted versus actual cost line have been obtained by others using multiple correlation statistical analysis techniques which consider more than one parameter simultaneously. Parametric cost predictions at the whole airframe or aircraft level usually use equations based upon this type of analysis. Computer processing is required. Reference 1

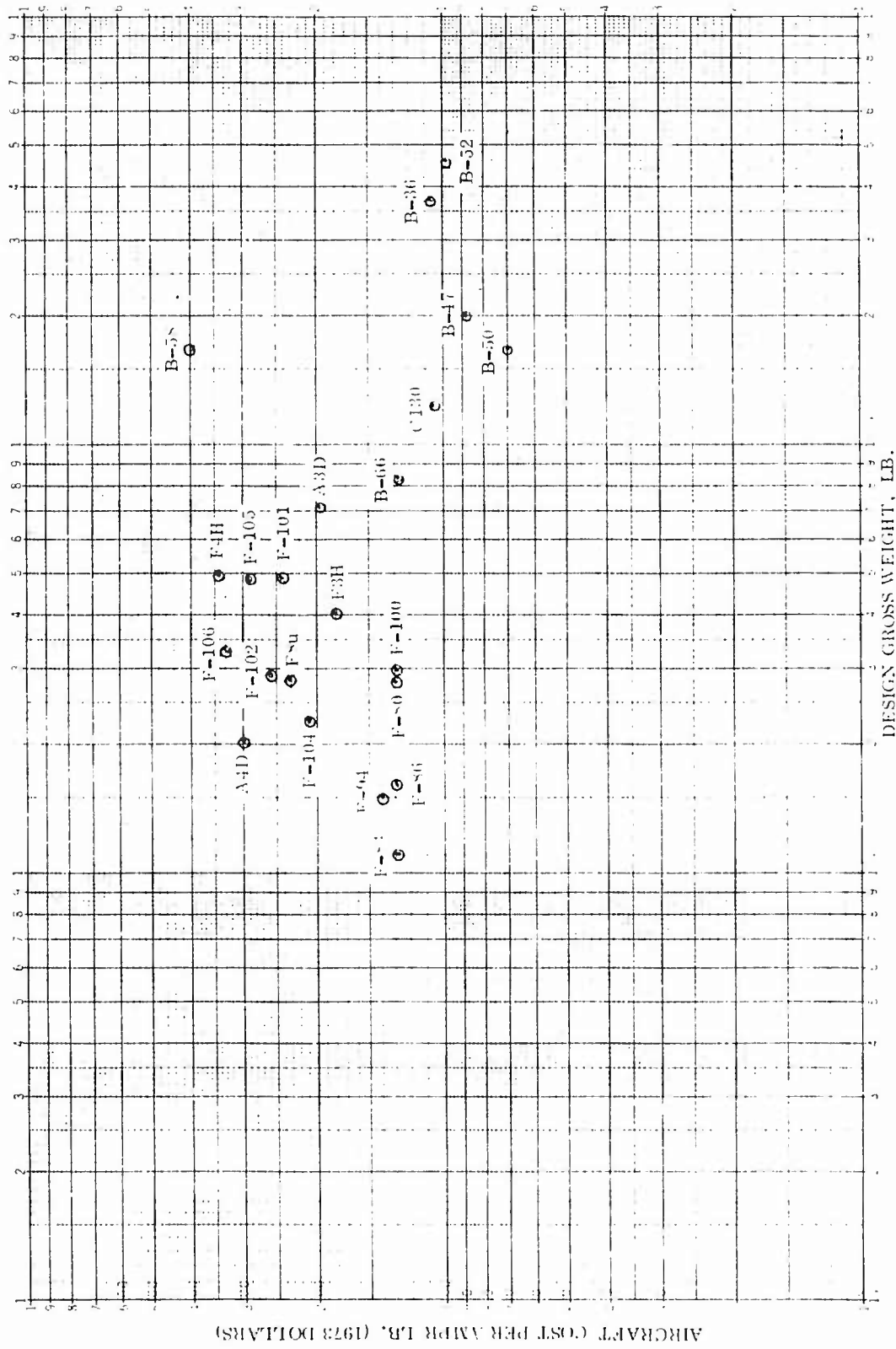


Figure 47. Aircraft Cost/lb. versus Design Gross Wt. (Costs are 100th Unit Cum. Avg.).

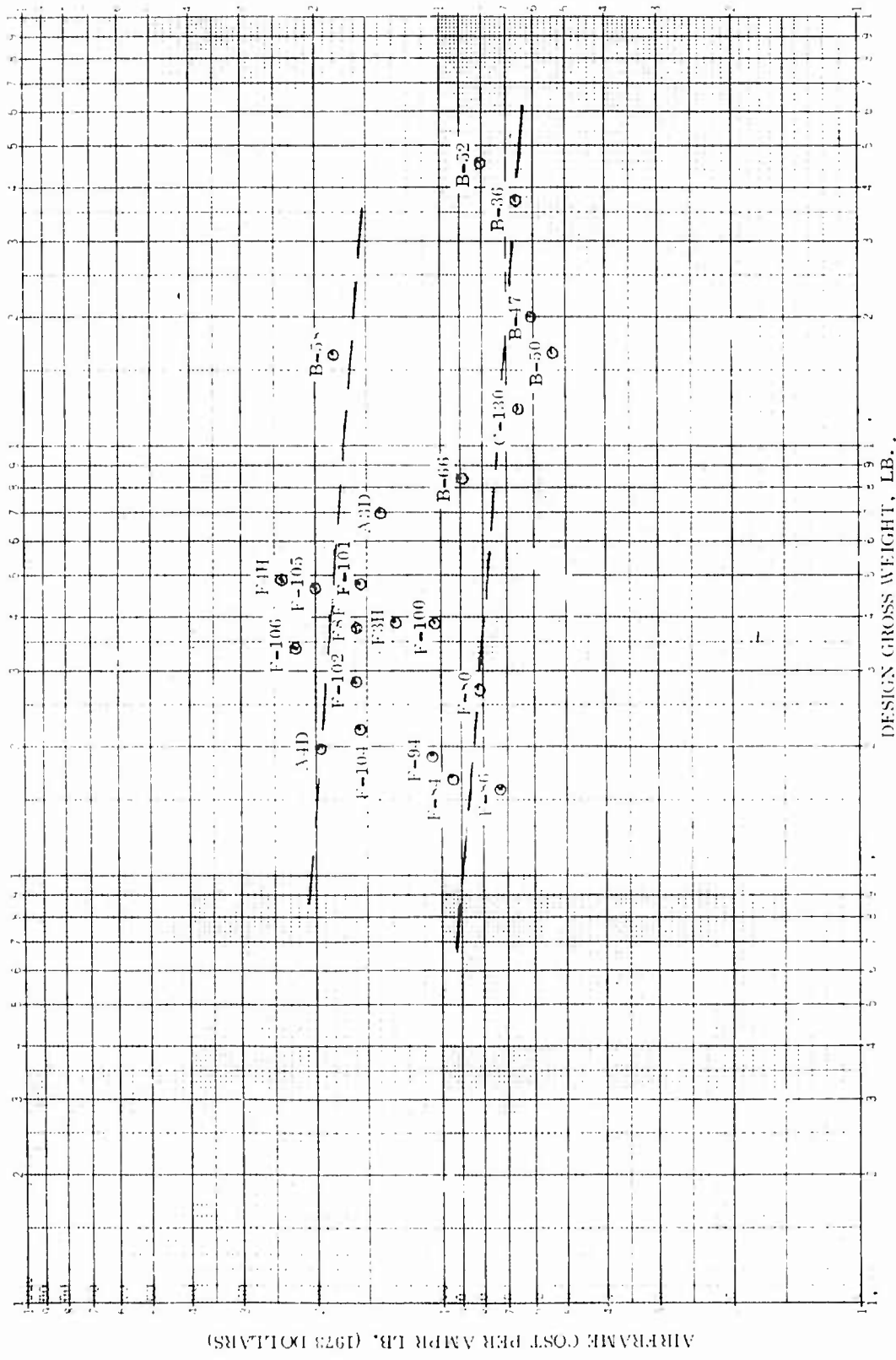


Figure 48. Airframe Cost/lb. versus Design Gross Wt. (Costs are 100th Unit Cum. Avg.).

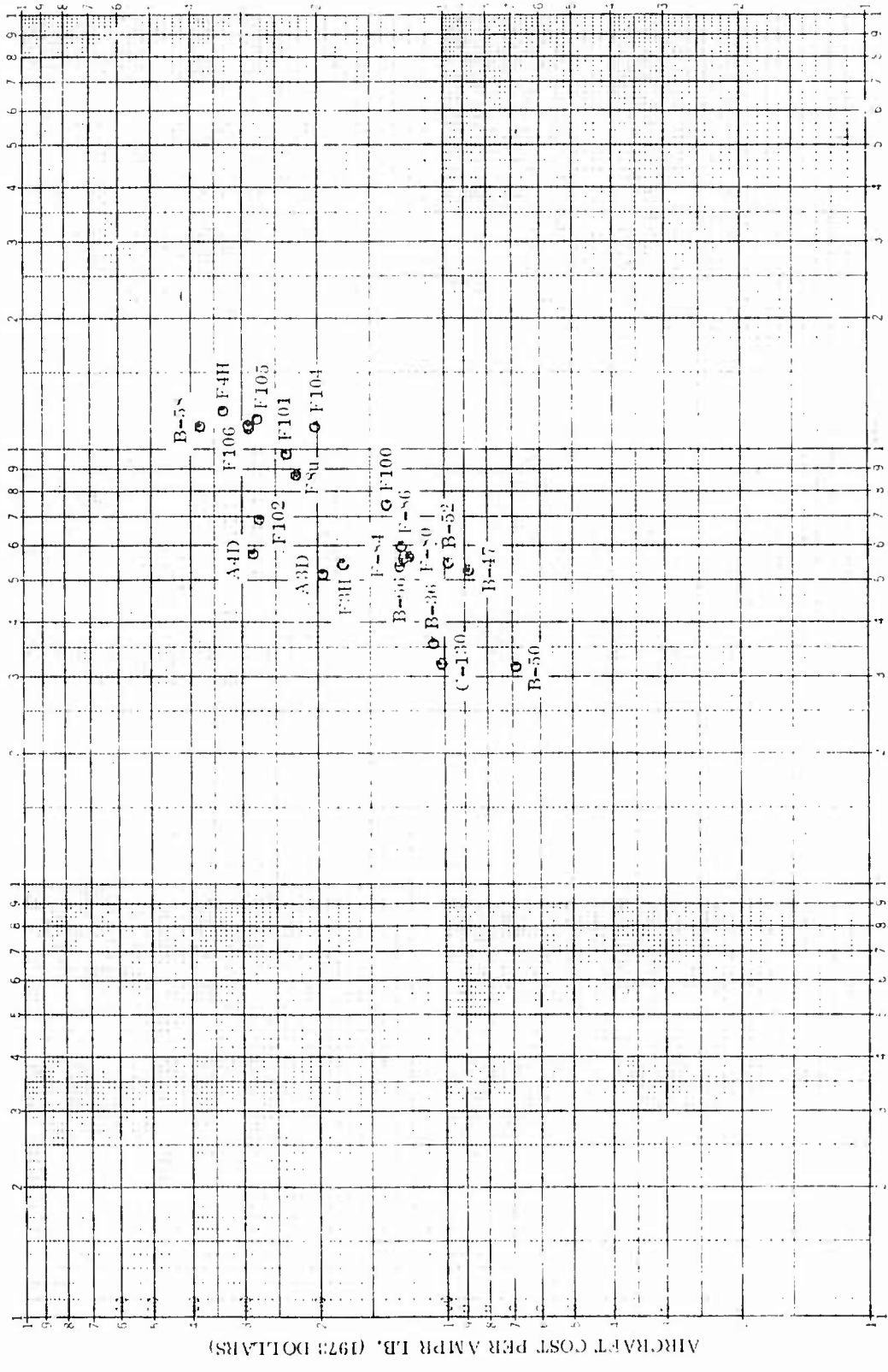


Figure 49. Aircraft Cost/lb. versus Speed (Costs are 100th Unit Cum. Avg.)

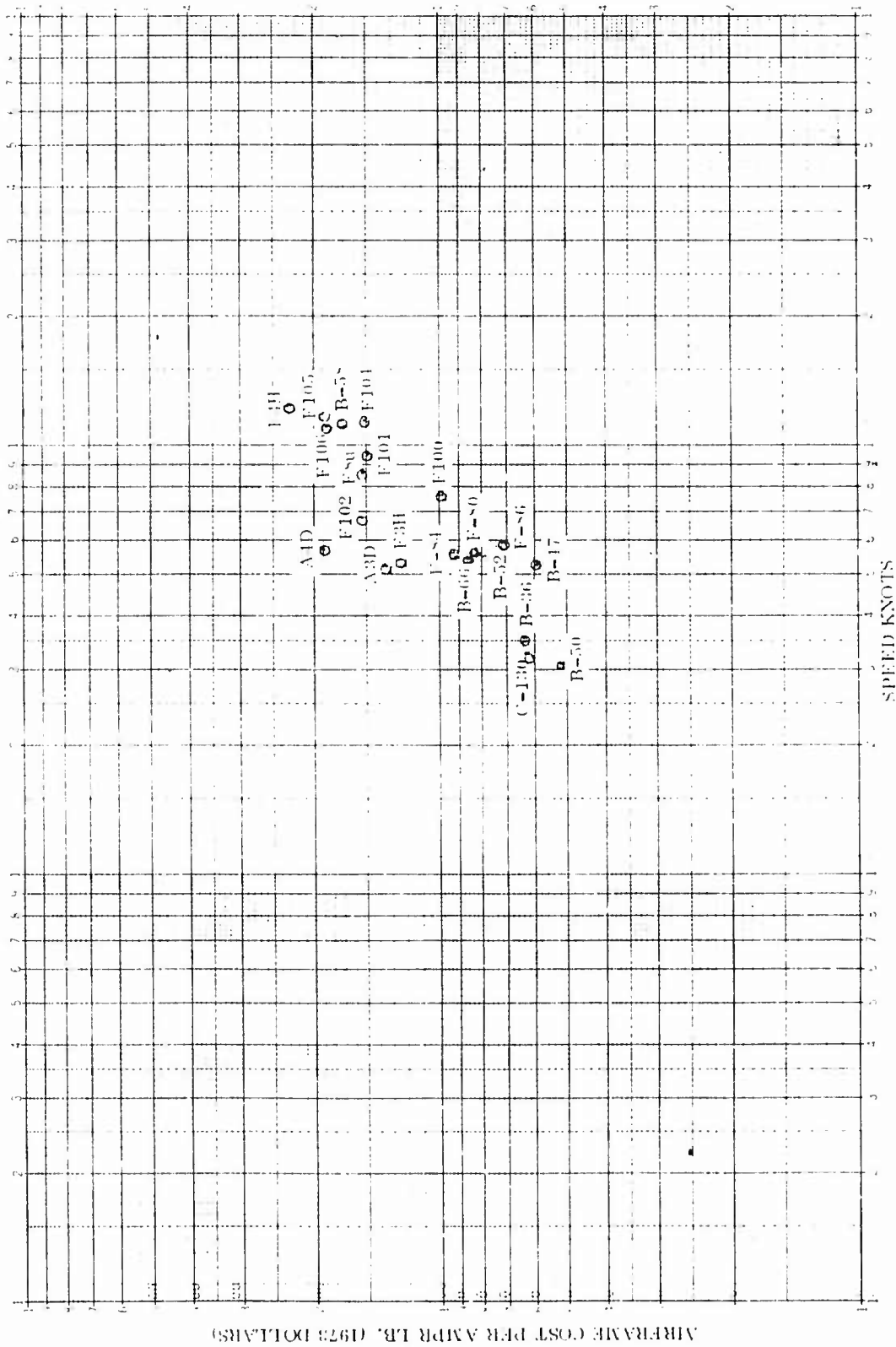


Figure 50. Airframe cost/lb. versus Speed (Costs are 100th Unit Cum. Avg.).

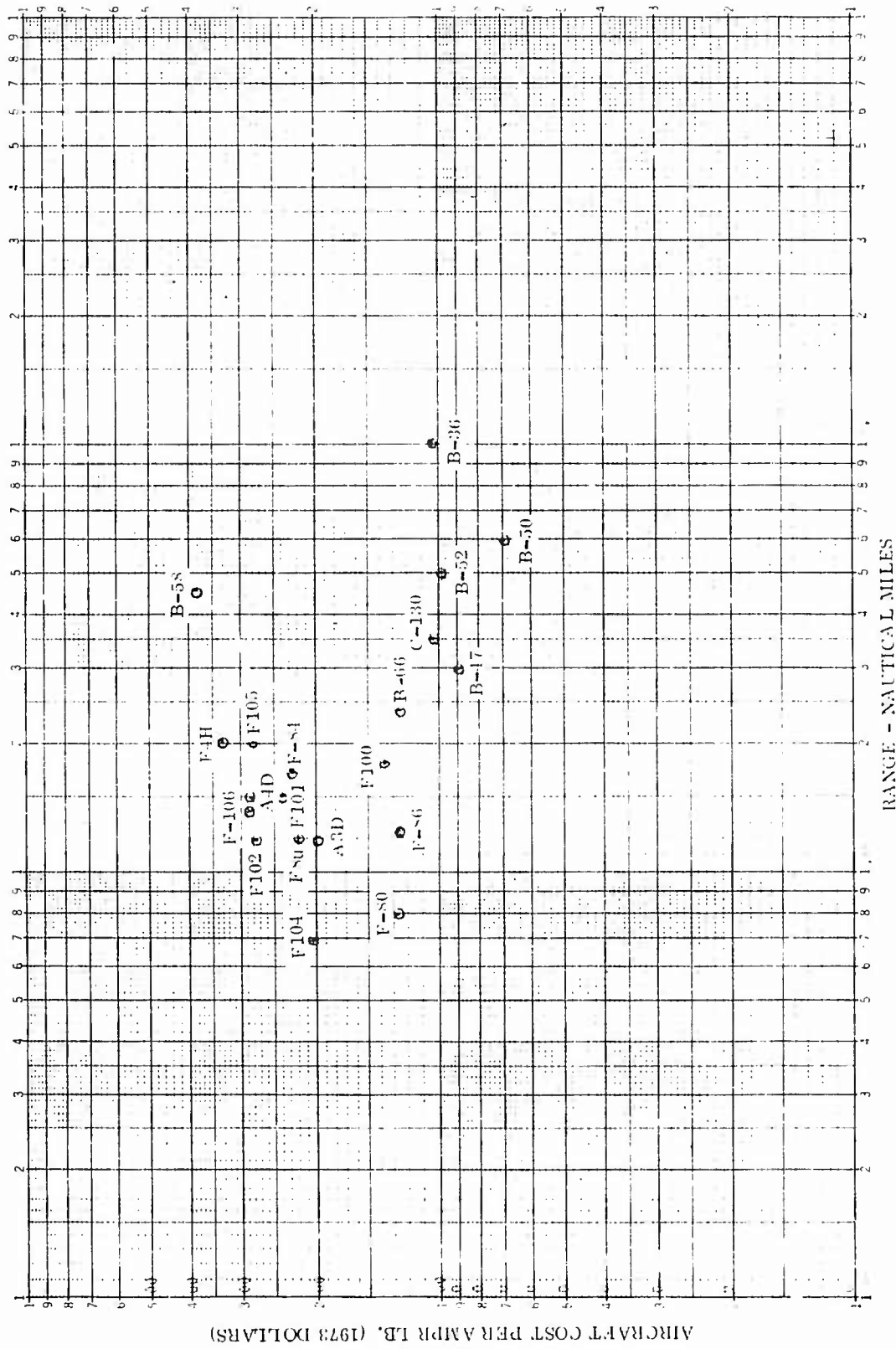


Figure 51 Aircraft Cost/lb. versus Range (Costs are 100th Unit Cum. Avg.).

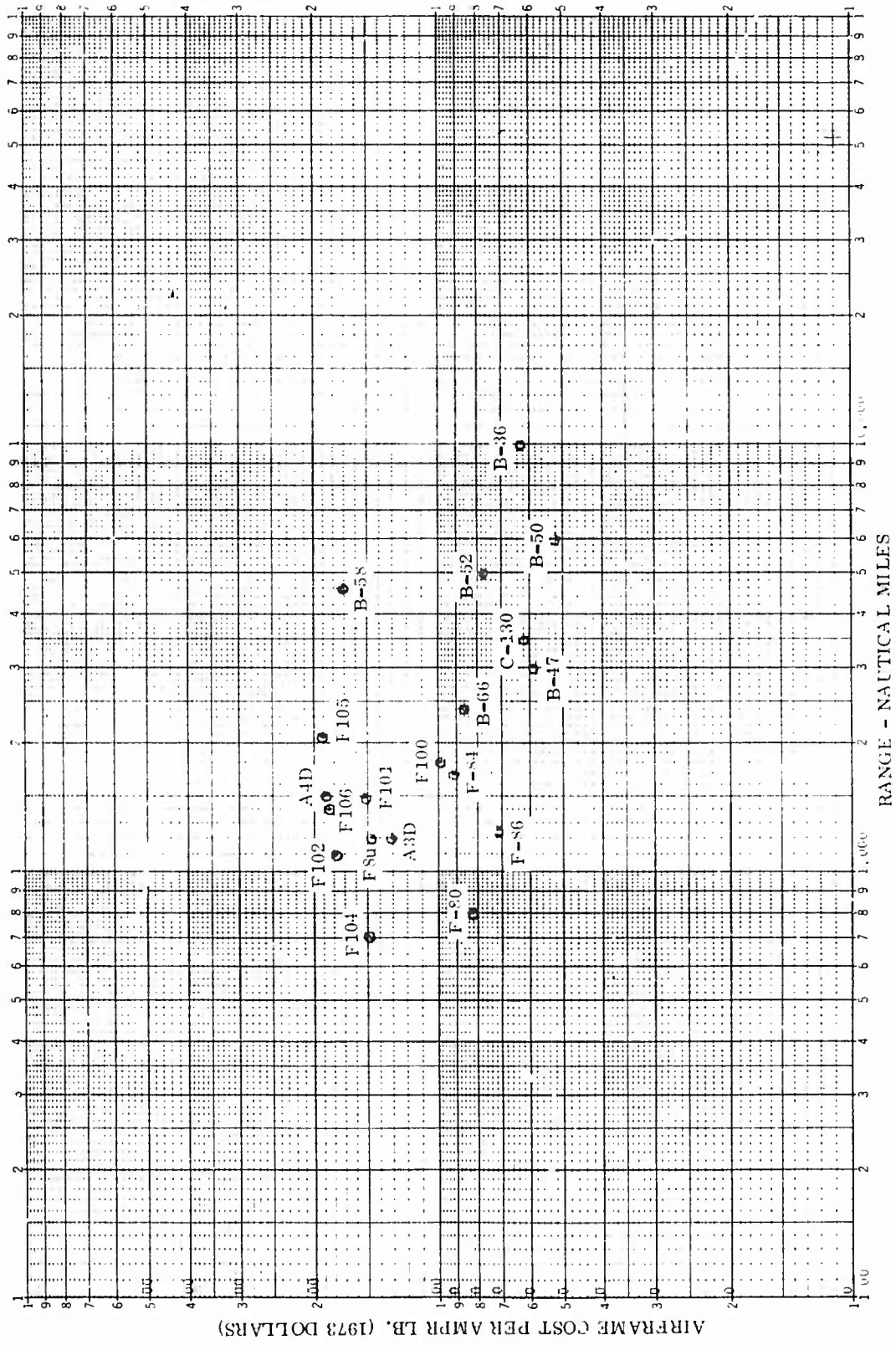


Figure 52. Airframe Cost/lb. versus Range (Costs are 100th Unit Cum. Avg.).

K&E LOGARITHMIC 46 7203
2 X 2 CYCLES
KEUFFEL & ESSER CO.

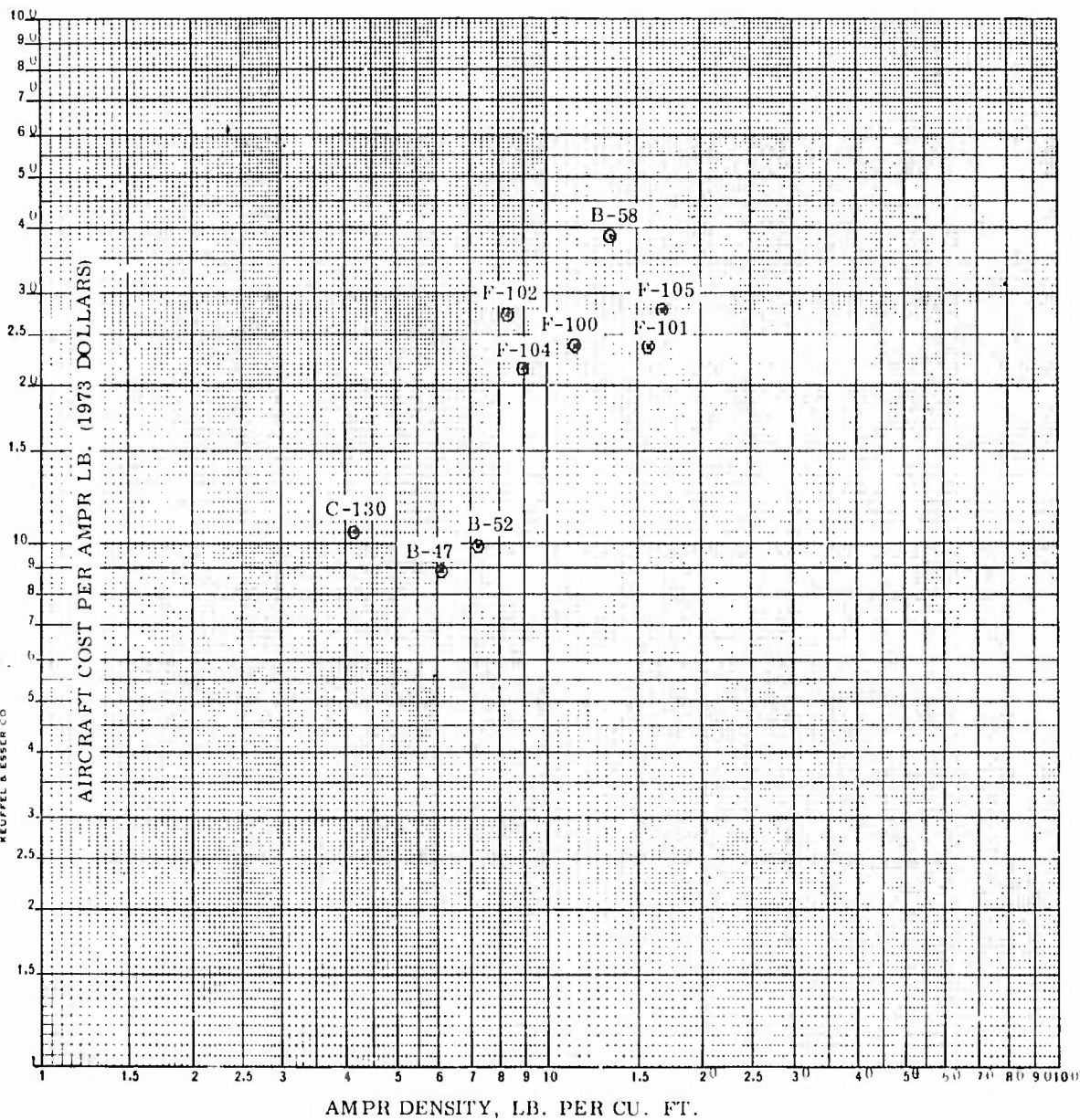


Figure 53. Aircraft Cost/lb. versus Density (Costs are 100th Unit Cum. Avg.).

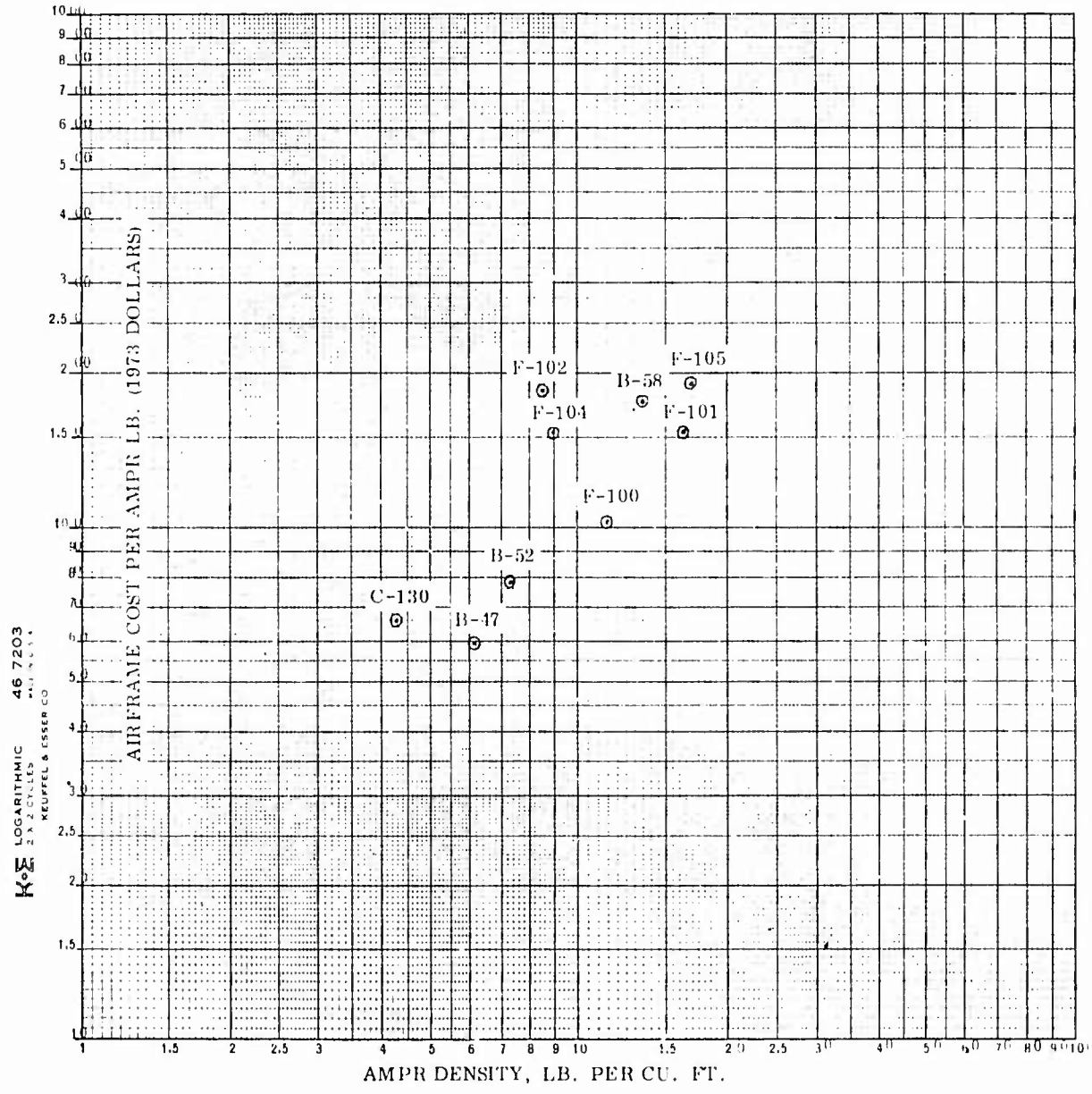


Figure 54. Airframe Cost/lb. versus Density (Costs are 100th Unit Cum. Avg.).

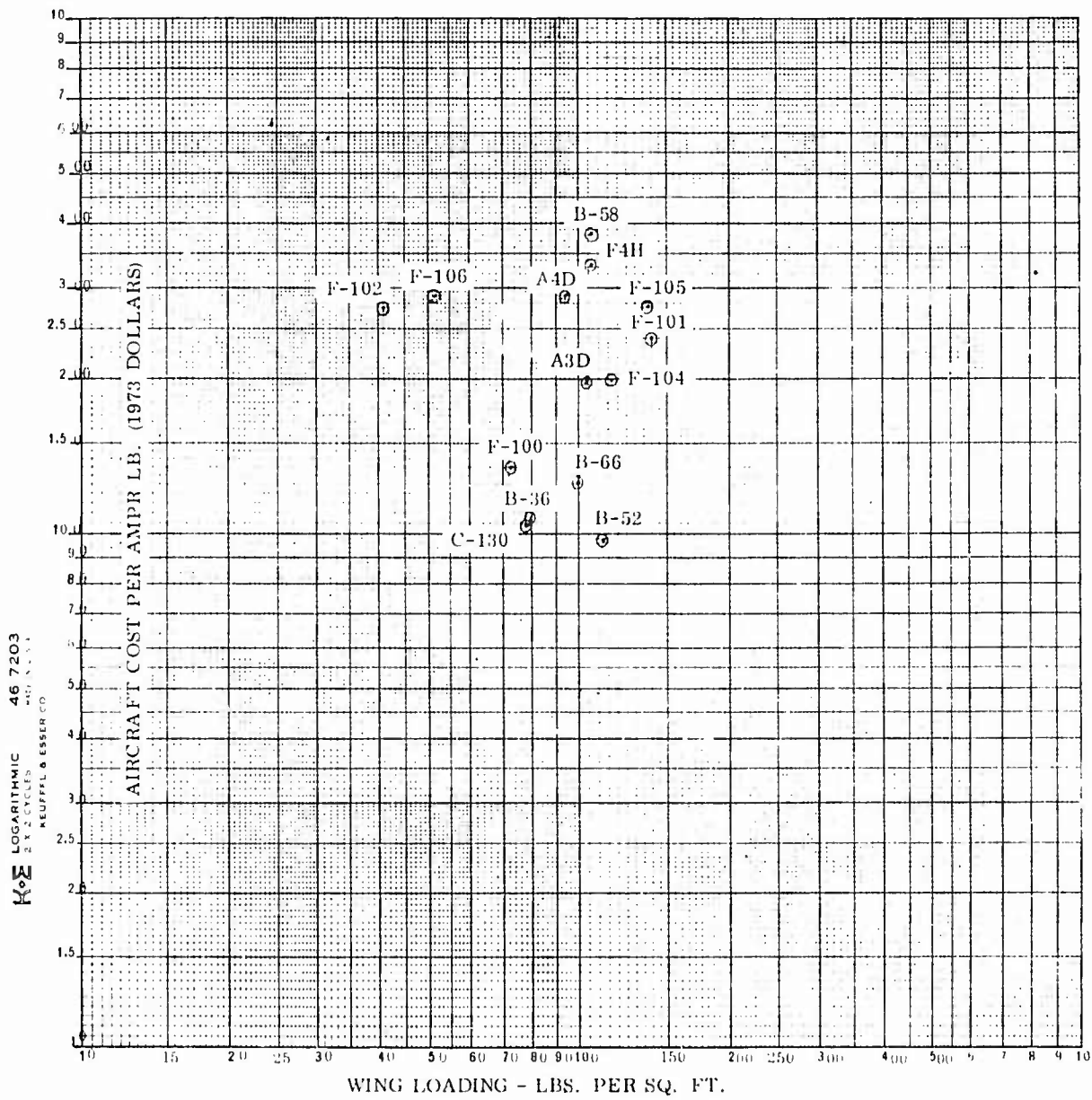


Figure 55. Aircraft Cost per lb. versus Wing Loading
(Costs are 100th Unit Cum. Avg.).

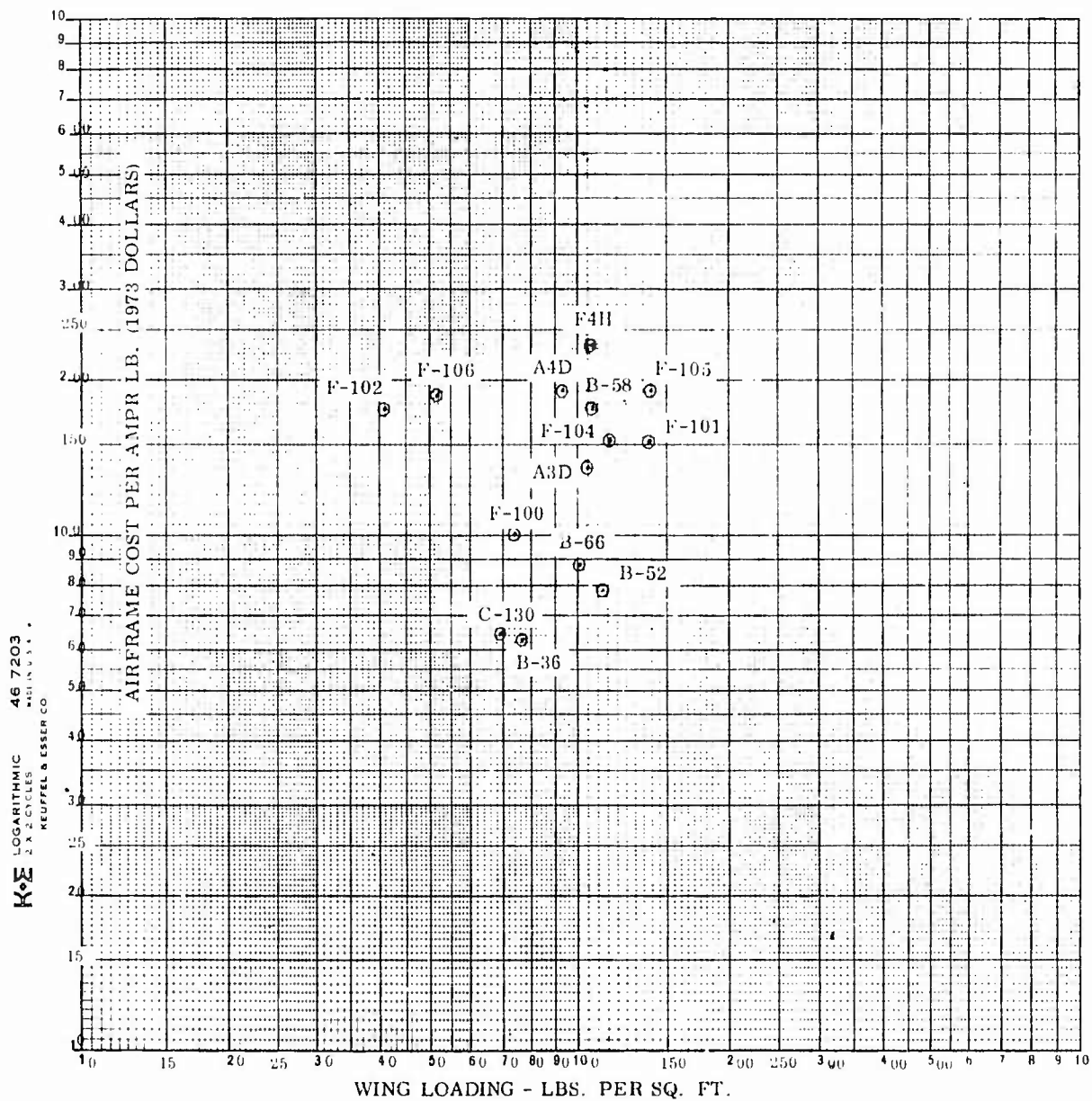


Figure 56. Airframe Cost per lb. versus Wing Loading
(Costs are 100th Unit Cum. Avg.).

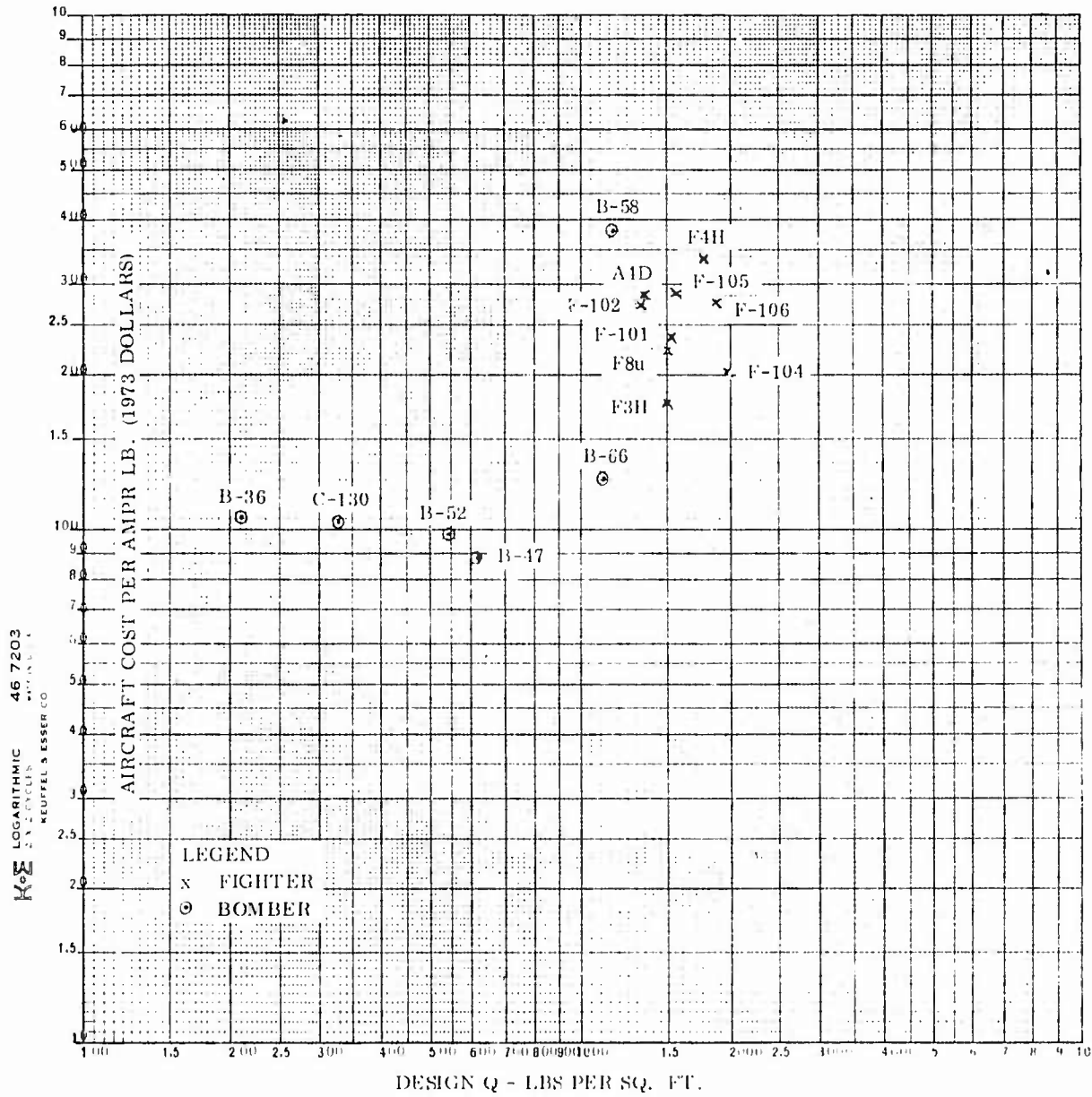


Figure 57. Aircraft Cost/lb. versus Design Q
 (Costs are 100th Unit Cum. Avg.).

K-Σ LOGARITHMIC 46 7203
 KEUFFEL & ESSER CO.

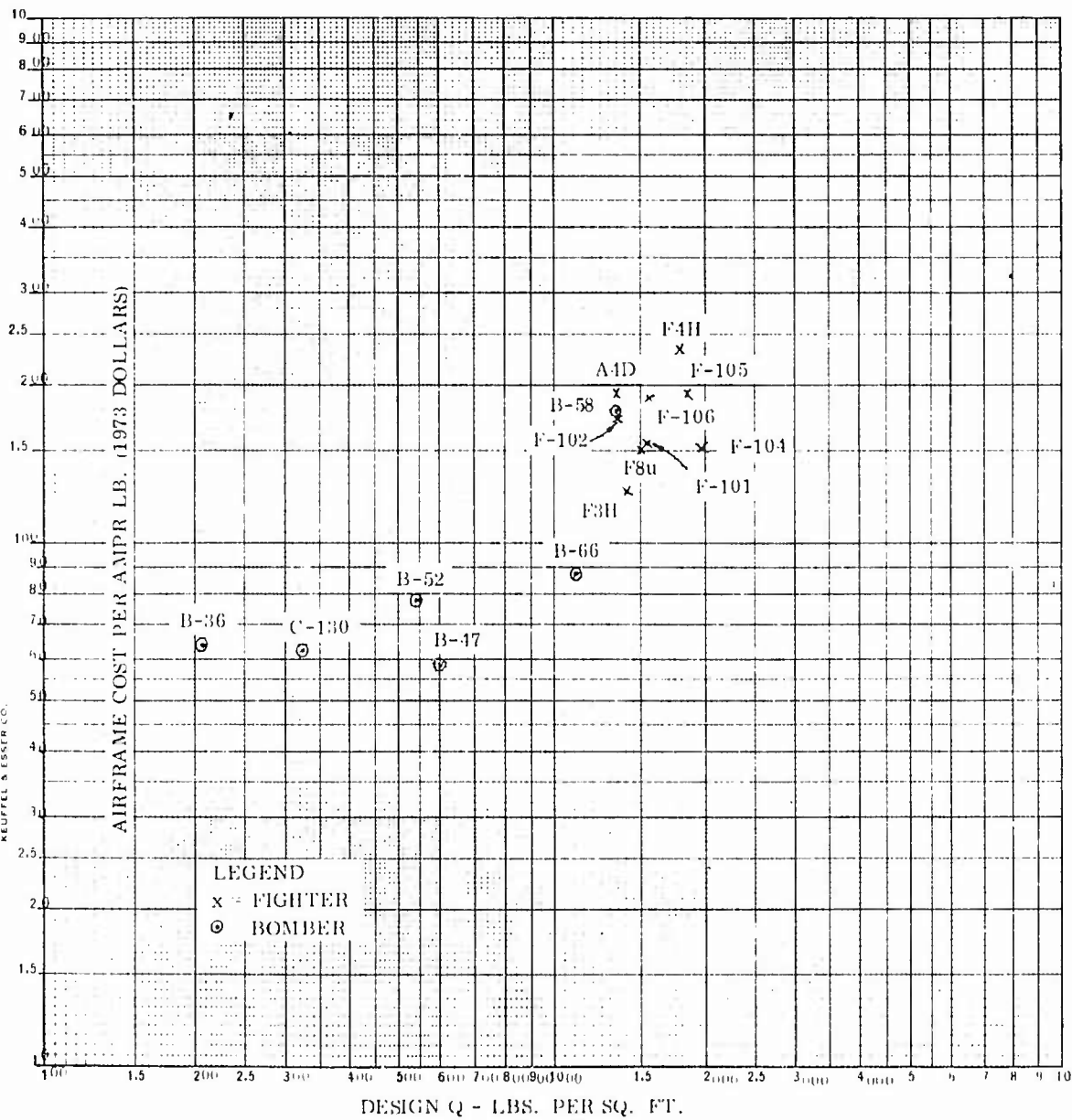


Figure 58. Airframe Cost/lb. versus Design Q
 (Costs are 100th Unit Cum. Avg.).

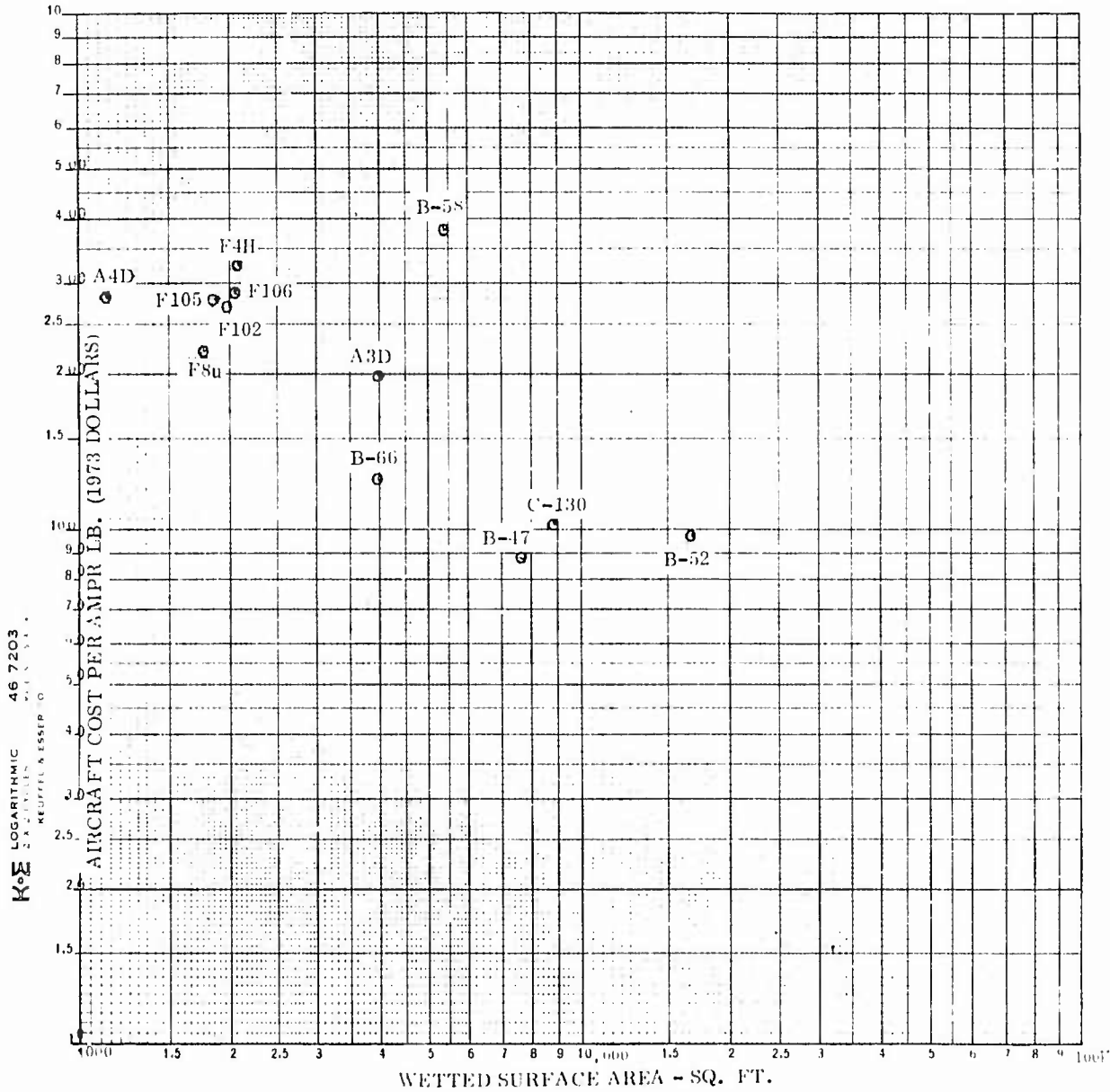


Figure 59. Aircraft Cost/lb. versus Wetted Surface Area
(Costs are 100th Unit Cum. Avg.).

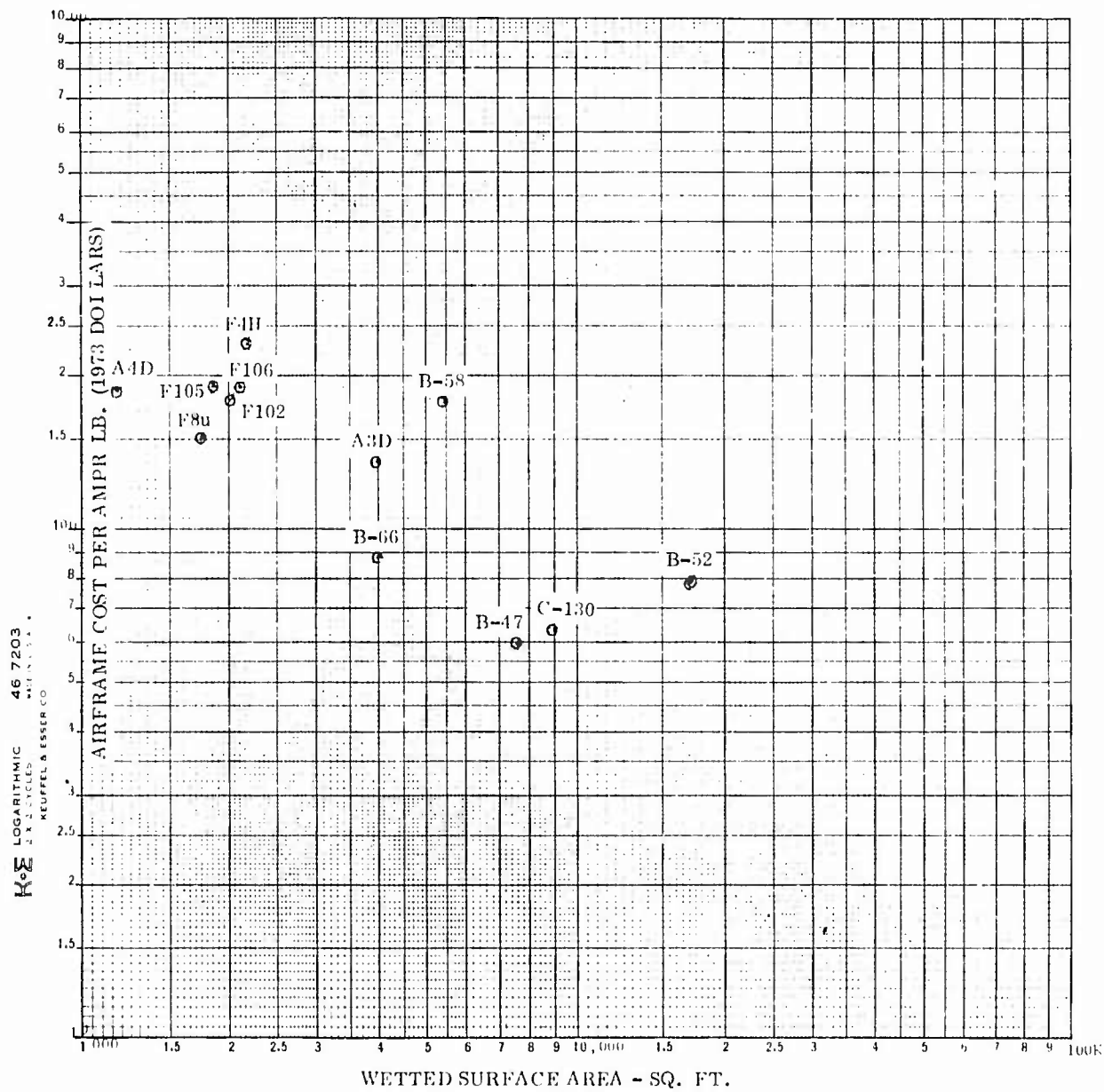


Figure 60. Airframe Cost/lb. versus Wetted Surface Area
 (Costs are 100th Unit Cum. Avg.)

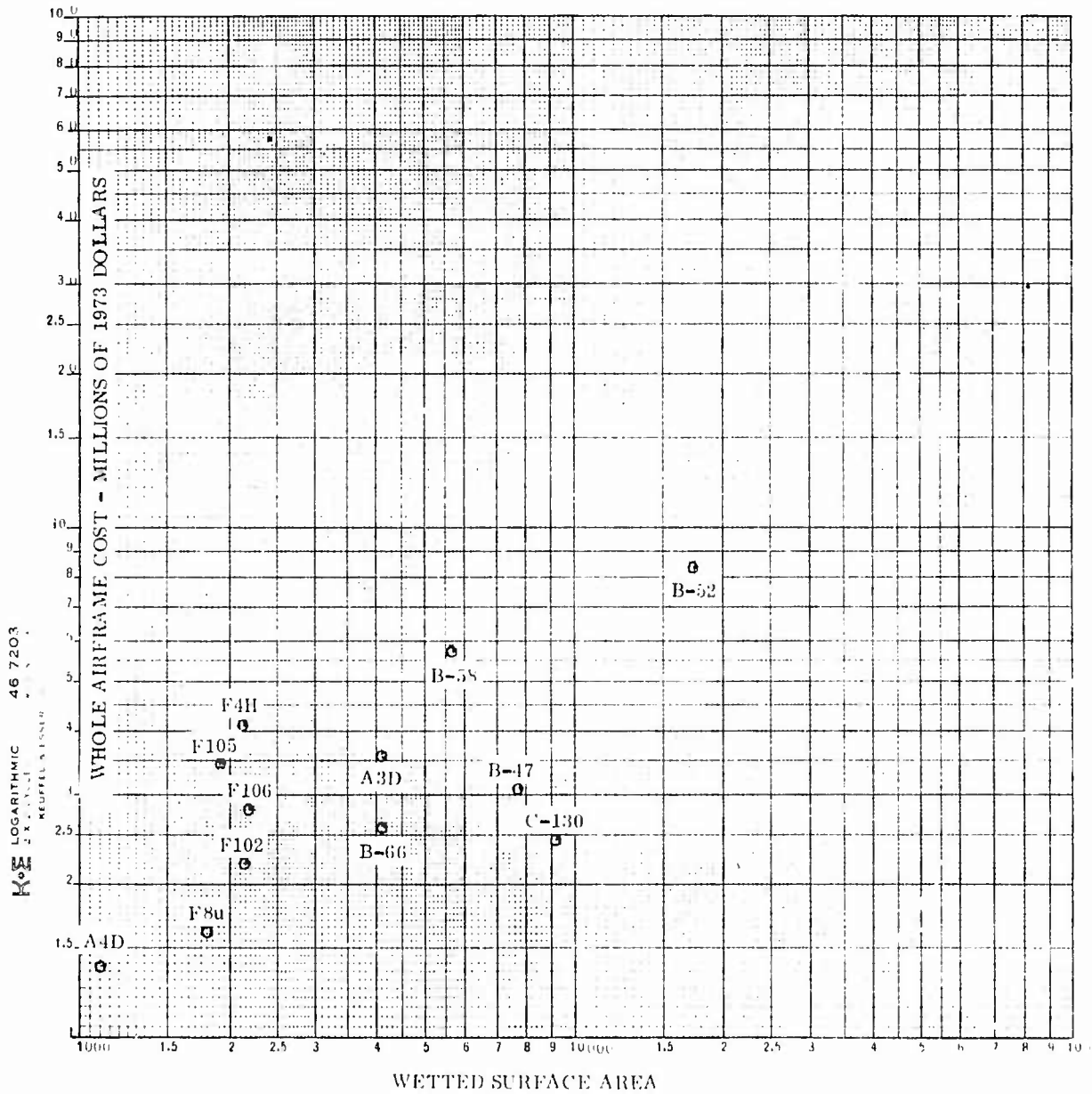


Figure 61. Whole Airframe Cost versus Wetted Surface Area
 (Costs are 100th Unit Cum. Avg.).

describes a set of equations based upon multiple correlation of AMPR weight and speed which is widely used. Over the years, considerable resources have been spent in pursuit of similar techniques. So far, no one has achieved really outstanding results, probably because all aircraft and aircraft manufacturers have some unique design attributes or structural features which are not account for by these relatively simple procedures.

Economic Cost Trend Charts

This section is made up of a series of charts showing several economic trends. The first chart, Figure 62, shows the generally increasing cost per pound of newer aircraft. The costs shown are not inflated, therefore, the upward cost trend since the late 1930's includes not only inflation factors but improvements in general flight performance and greater avionic system capability as well. Weights data for several of the older aircraft were furnished by Col. Clark, Ret., of the San Diego Aerospace Museum. Cost per pound for the Spad and the SE-5 came out relatively high because of the very low AMPR weight of these aircraft.

Figure 63 examines RDT&E costs as a function of the aircraft design gross weight. The RDT&E costs include the full aircraft development program including avionics, armament and any other special system development but excludes engine development. The available data points show good correlation between RDT&E and design gross weight although the faster aircraft and/or those with complex systems appear on the high side of the trend.

Figure 64 shows the same RDT&E costs plotted against speed. There is a definite upward cost trend with speed but with more scatter. The X-15 aircraft stands out on this chart. This aircraft was more of a prototype/research bed than a true aircraft. As is well known, it was launched at 50,000 from under the wing of a "mother" ship. Only minimum aircraft subsystems were aboard, landing was on skids for example.

Figure 65 describes costs to carry freight under both military and commercial operations. Costs of the military aircraft cargo aircraft are influenced by several factors which can occur. These are:

- a. Follow-on from a commercial program with lower R&D/modification costs and price advantages due to prior production.
- b. Large production orders which yield lower average procurement cost and lower pro-rated R&D cost per aircraft.
- c. Special design requirements such as short field and/or rough field specifications which may add to cost and may reduce ton mile capability.

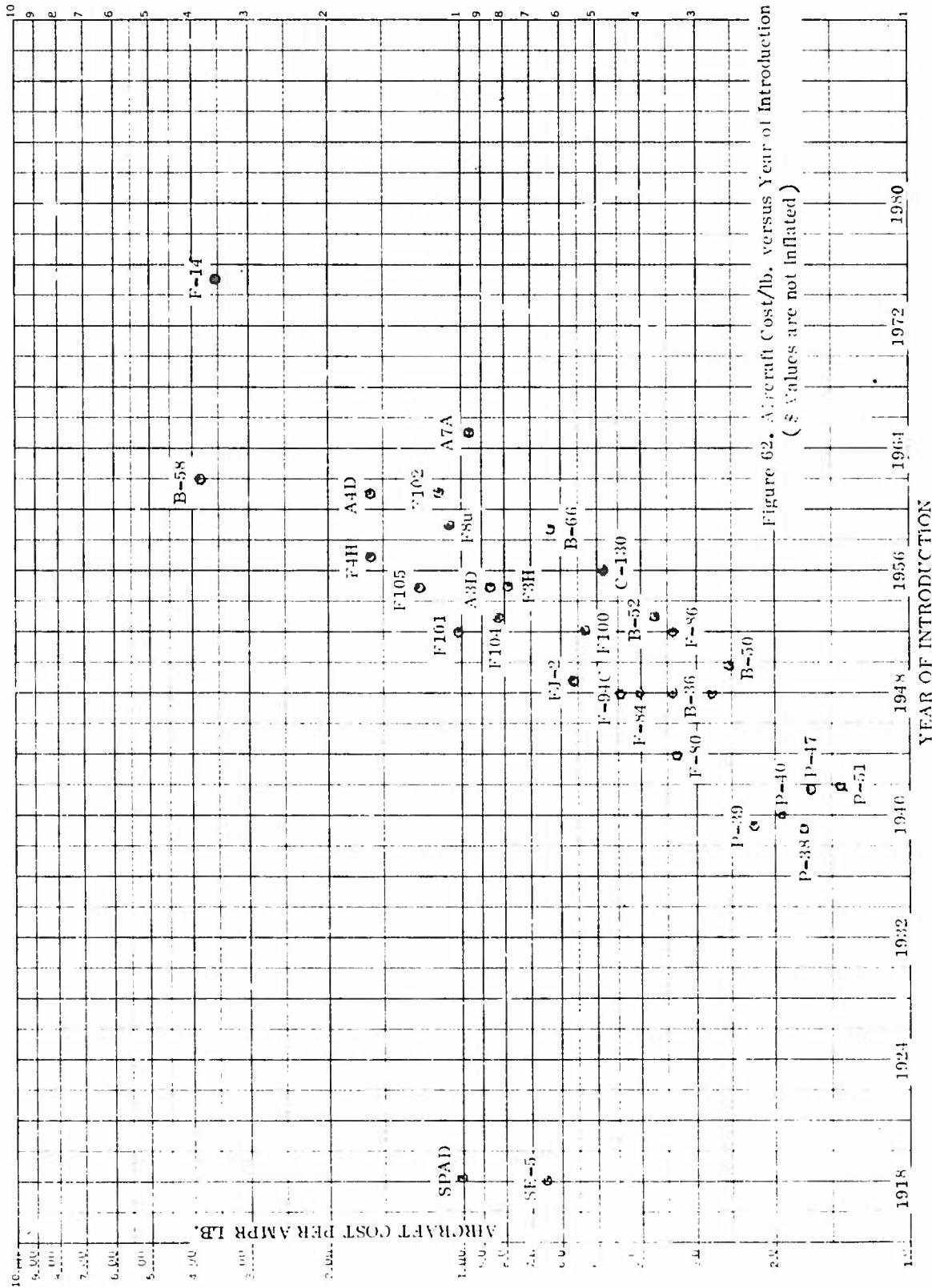


Figure 62. Aircraft Cost/lb. versus Year of Introduction (\$ Values are not Inflated)

Figure 62. Aircraft Cost /lb. versus Year of Introduction (\$ Values are not Inflated).

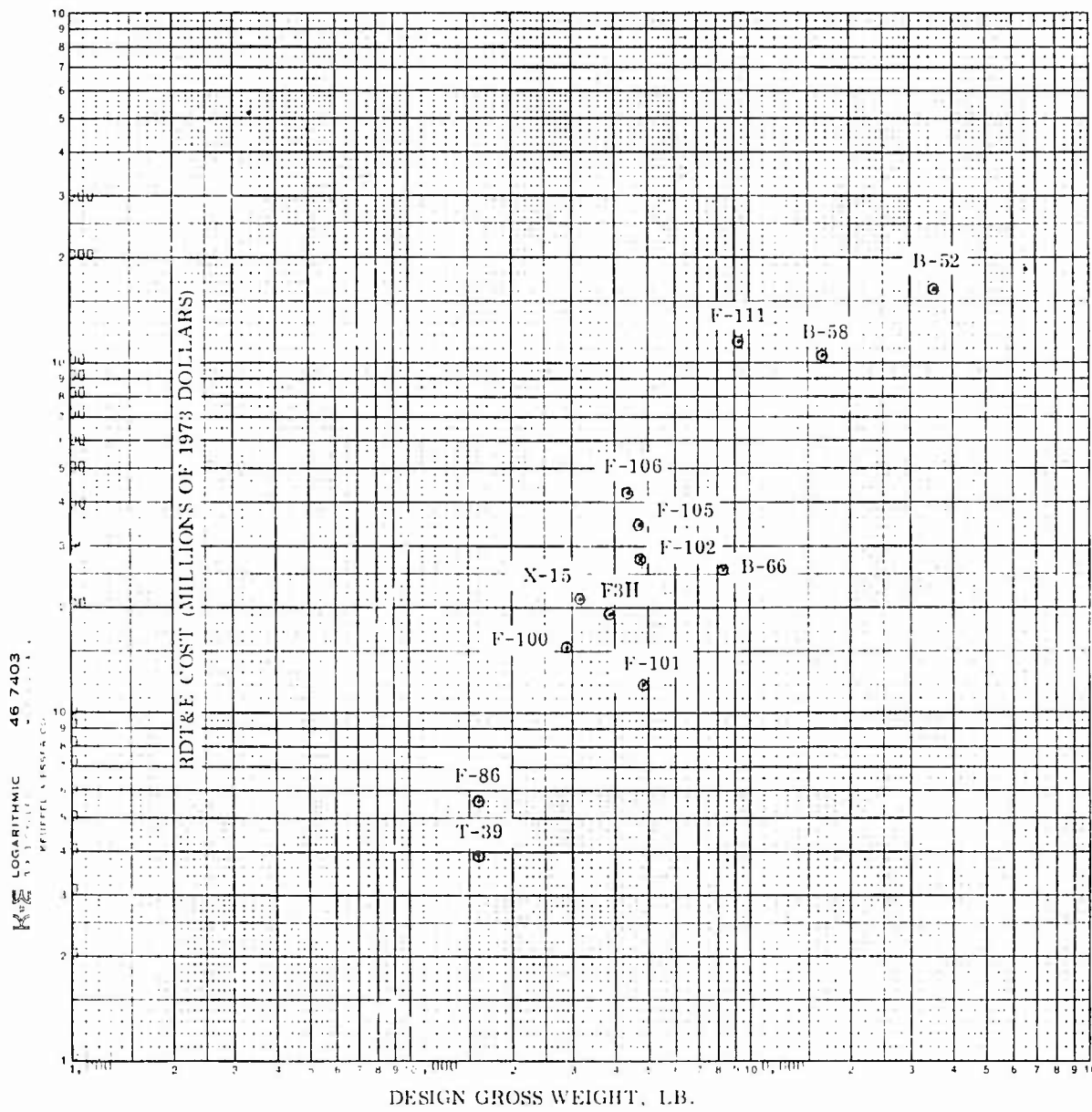


Figure 63. RDT&E Costs versus Design Gross Weight
(Costs include avionics but not engine development).

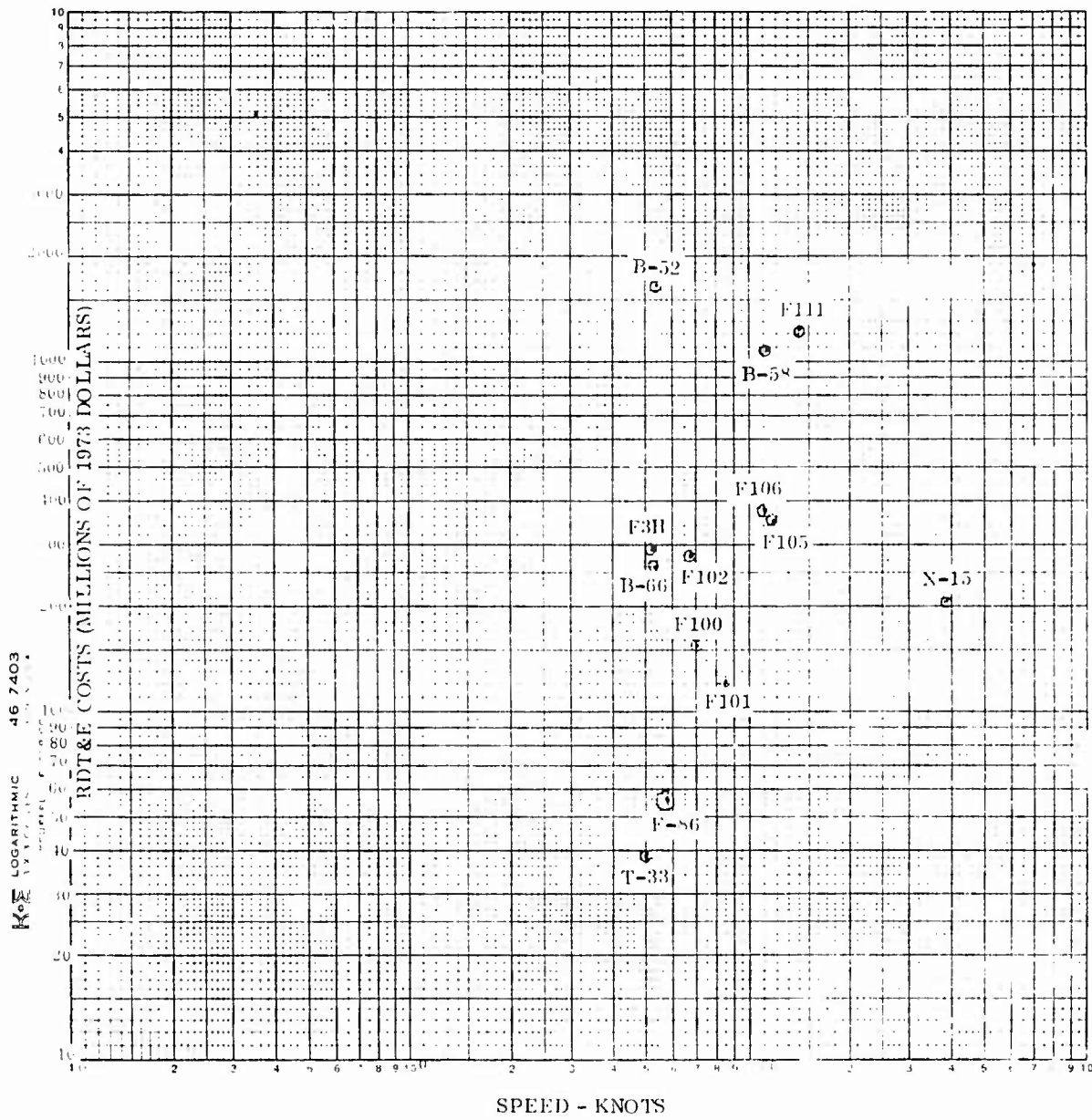


Figure 64. RDT&E Costs versus Speed
 (Costs include avionics but not engine development)

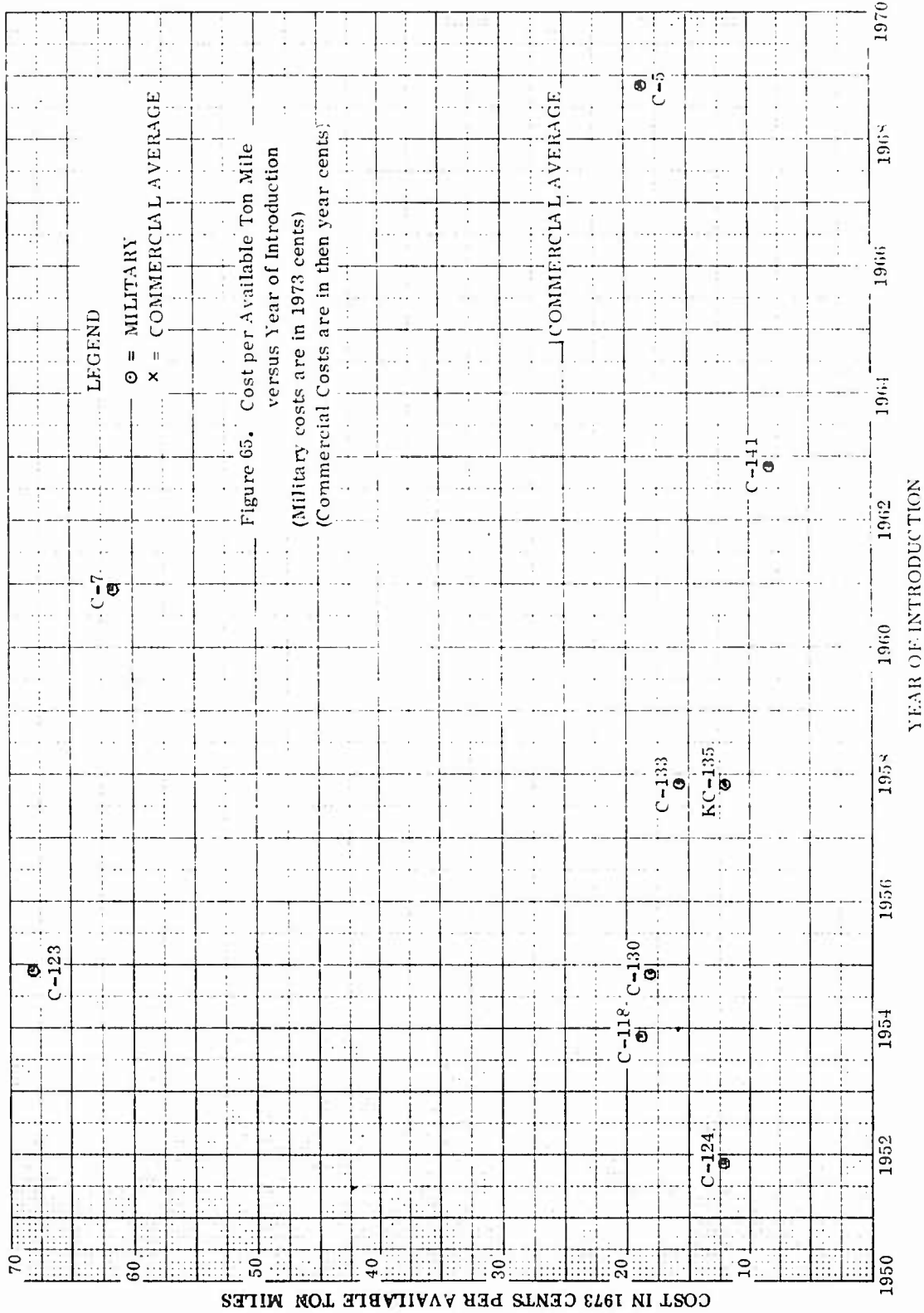


Figure 65. Cost per Available Ton Mile versus Year of Introduction (Military costs are in 1973 cents) (Commercial Costs are in then year cents).

Costs per ton mile are influenced by the additional consideration of aircraft speed, payload capacity, hours of utilization. There seem to be a slight downward military ton mile cost trend with time.

Commercial costs shown are average values from 12 airlines. The commercial costs are not directly comparable to the military costs because the commercial includes costs for ground cargo handling as well as costs for all other supporting personnel, whereas, the military costs are only those directly attributable to aircraft procurement including RDT&E, plus direct flying and aircraft maintenance costs. The C-5 is assumed limited to 10,000 hours of useful life because of structural fatigue experience. The ton mile cost would improve by more than a factor of 2 if useful life could be increased to the 36,000 hours expected for the C-141.

Figure 66 shows the same cost values as plotted previously against year of introduction now plotted against payload capacity. The previous comments regarding cost per ton mile continue to apply. As was logically expected, there is a downward cost trend with increasing payload capacity but with considerable scatter attributable to the factors previously discussed.

Aircraft Program Cost Charts

Charts have been prepared describing the F-102, F-106, and the B-58 programs. All costs have been inflated to 1973 dollar values. These charts show graphically the relation between monies expended for RDT&E compared to production hardware expenditures for various quantities of aircraft.

Figure 67 shows the cost distribution for a 100-aircraft F-102 program excluding engine and avionics considerations as noted. Figure 68 shows the 300-aircraft F-102 program on the same basis. Figure 69 shows the 500-aircraft F-102 program. In this case production costs of engines and avionics are included as separate "pie" sections. Figures 70 and 71 show similar cost breakdowns as have been described for the F-102 program.

The foregoing charts show what everybody already knows, and that is, average pro-rated RDT&E cost per aircraft goes down the more of that aircraft produced. So, there are two areas for cost per aircraft improvement with larger orders: The usual cost-quantity effect and the lower pro-rata RDT&E.

Figure 72 shows a 100-aircraft B-58 program. This aircraft was characterized by a very unusual number of on-board special systems. There was additional ground handling and special checkout equipment also. All of these systems together made the B-58 an elaborate and relatively expensive aircraft.

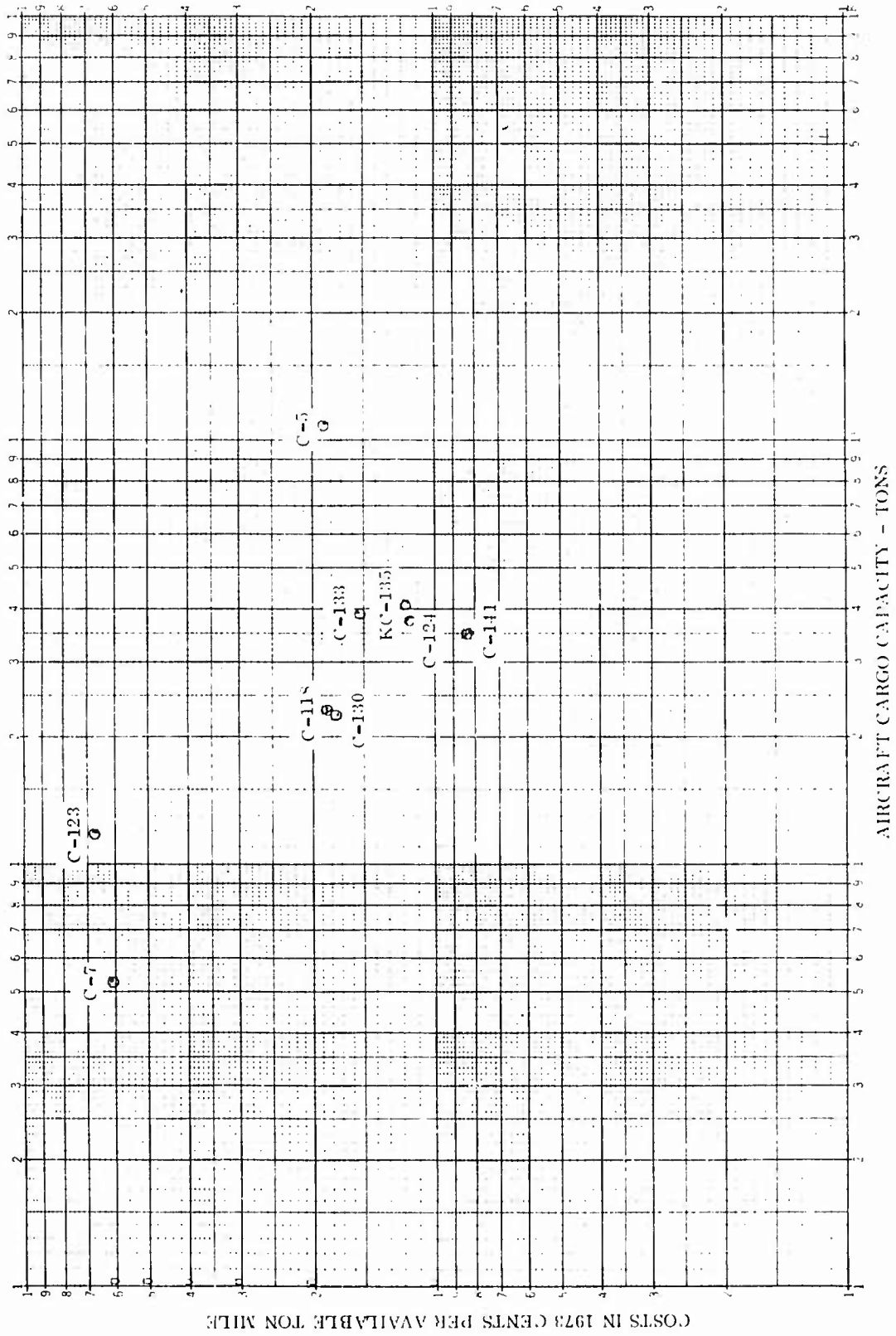
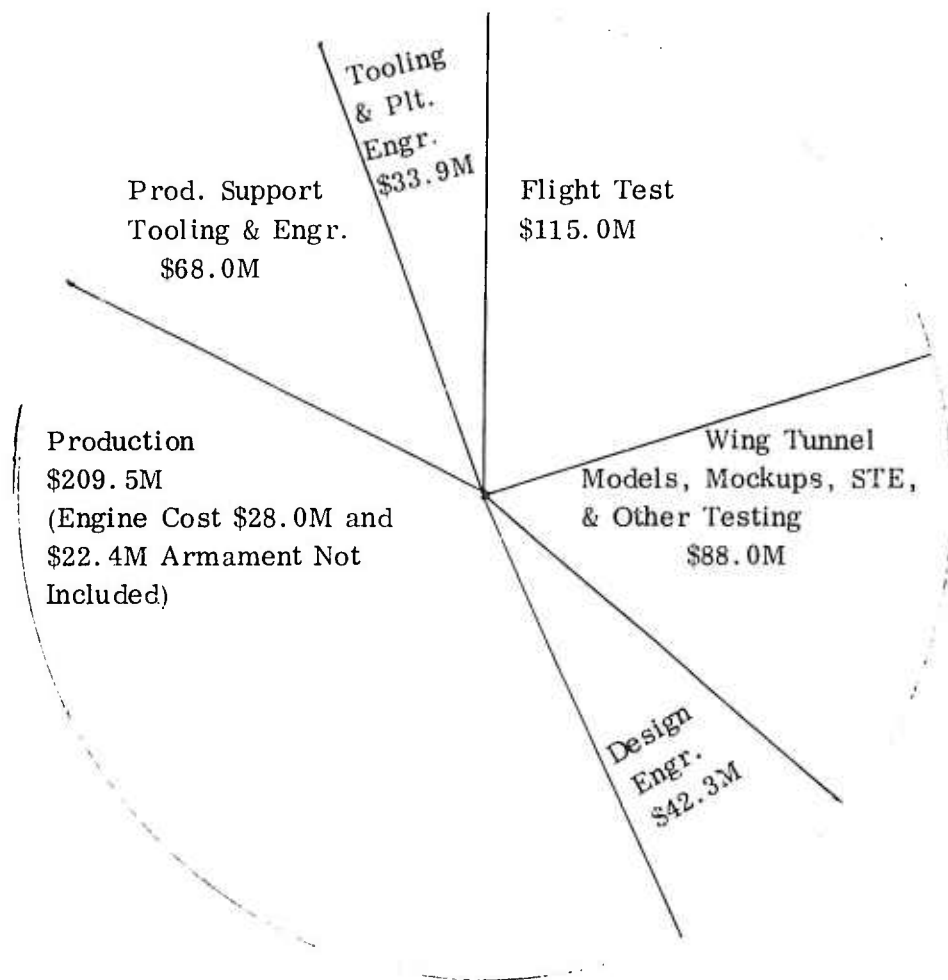


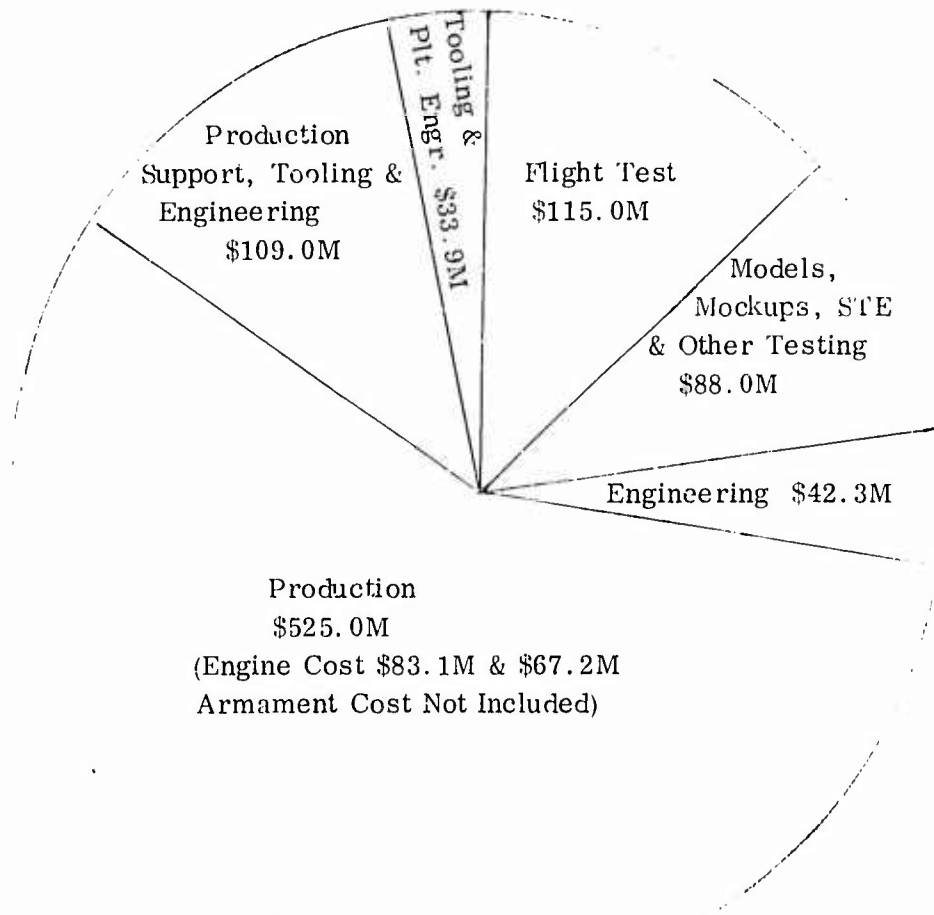
Figure 66. Cost per Available Ton Mile versus Aircraft Payload (In 1973 cents).



Total 1973 Dollars = \$576.7M

Note: Avionics and Engines Are Not Included in Either RDT&E Or Production

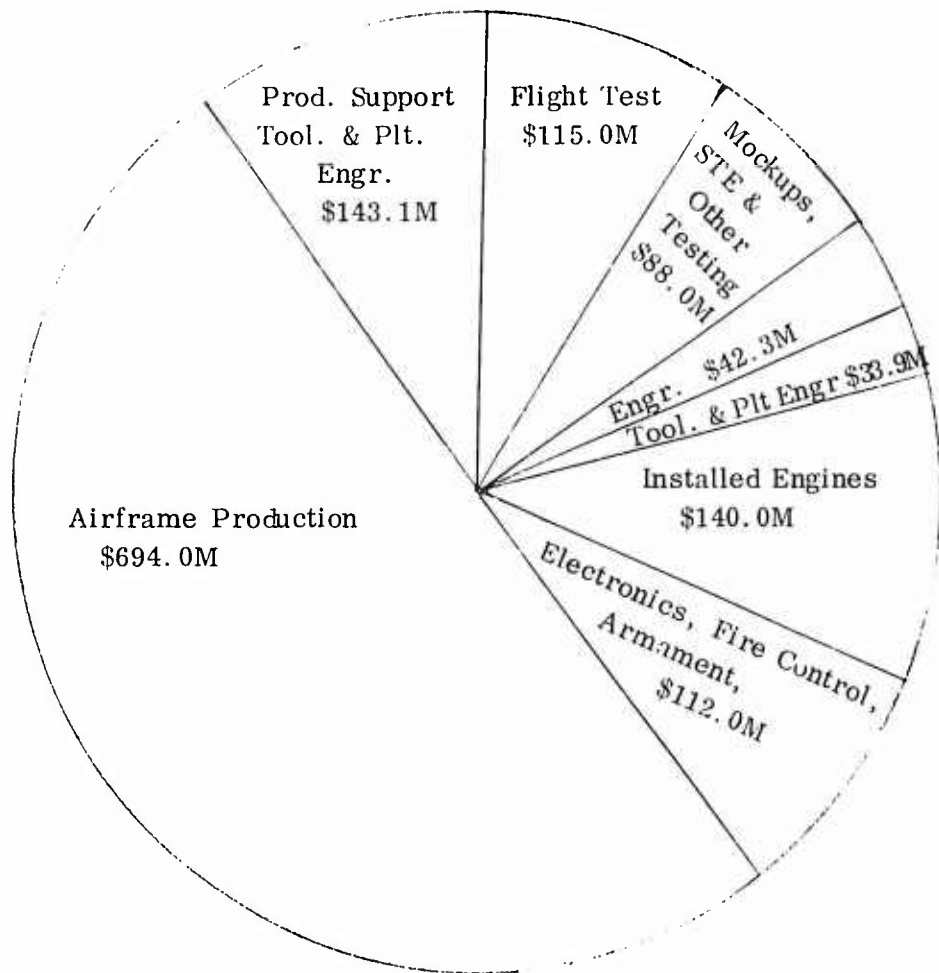
Figure 67. F-102 One Hundred Aircraft Program.



Total 1973 Dollars = \$913.2M

Note: Avionics and Engines Are Not Included In Either RDT&E Or Production

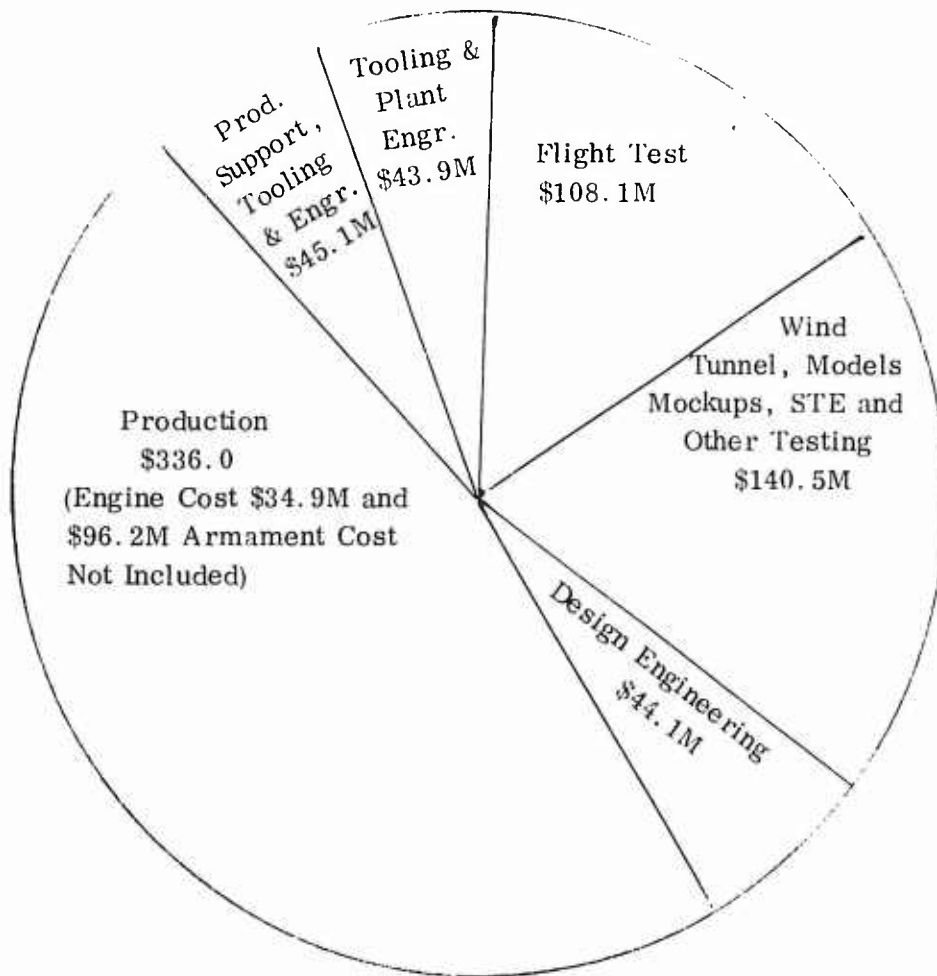
Figure 68. F-102 Three Hundred Aircraft Program.



Total 1973 Dollars = \$1367.9M

Note: Avionics and Engine Costs Have Been Added For Production Only

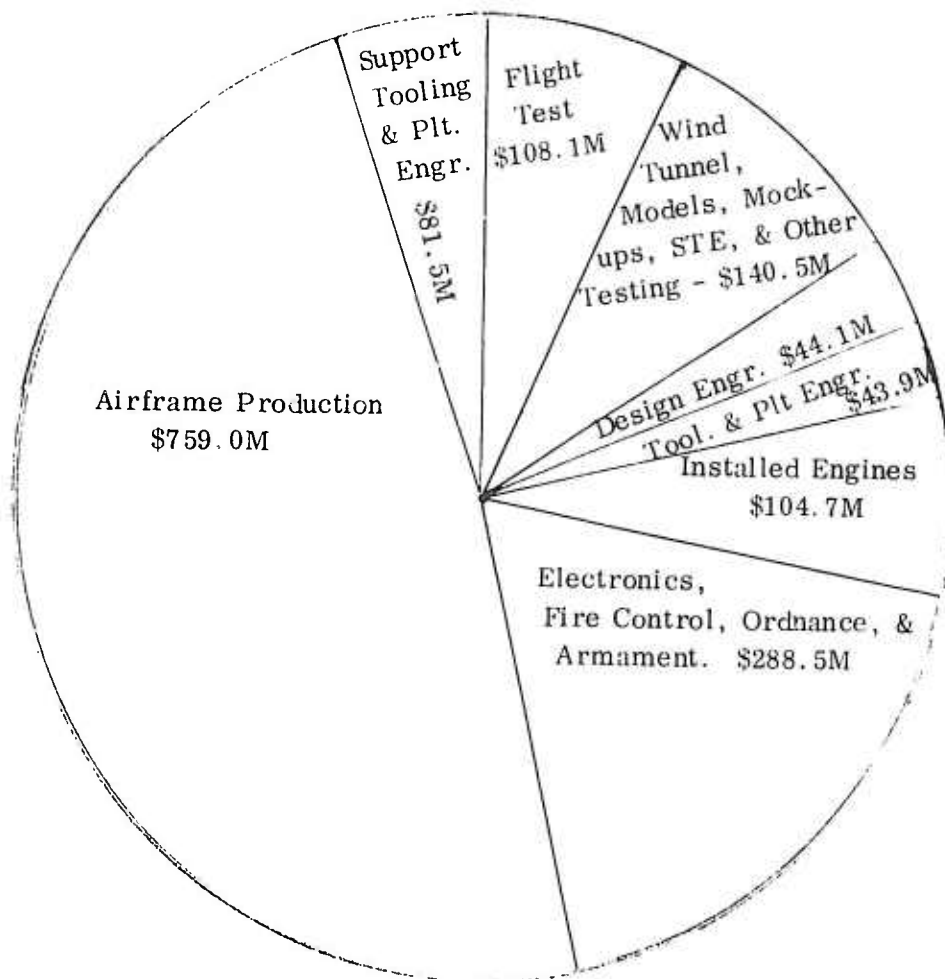
Figure 69. F-102 Five Hundred Aircraft Program.



Total 1973 Dollars = \$717.7M

Note: Avionics and Engines are Not Included in Either RDT&E Or Production

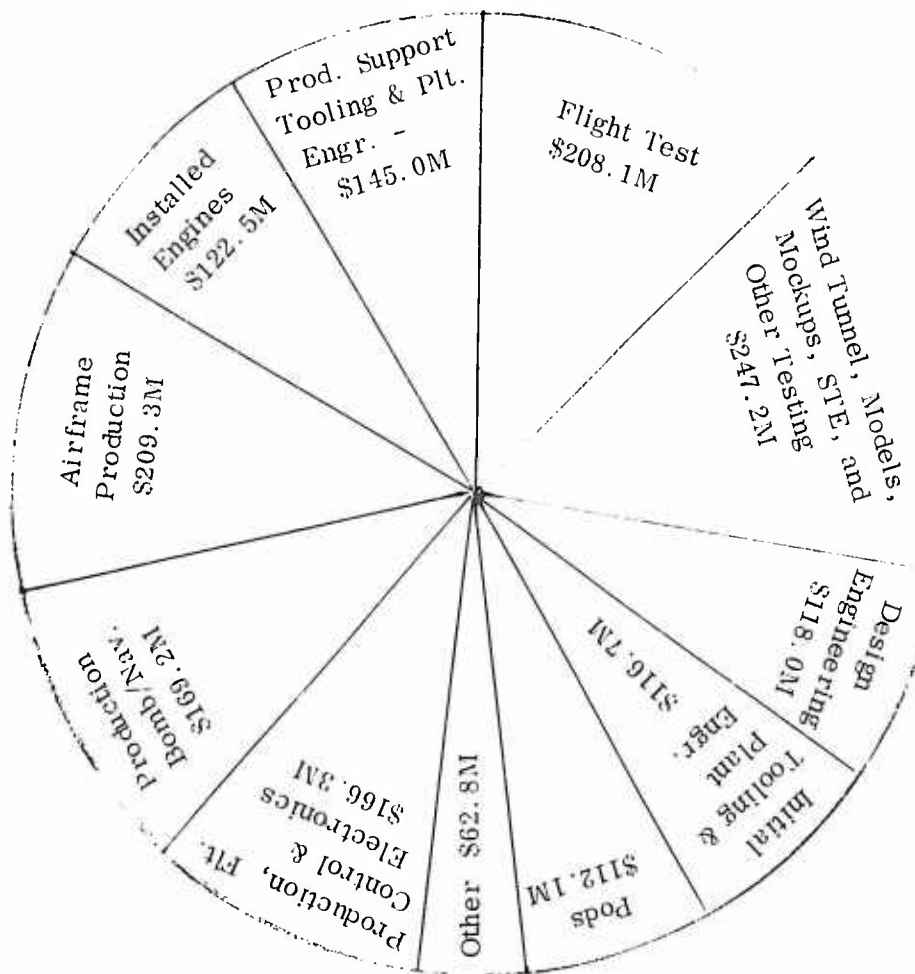
Figure 70. F-106 One Hundred Aircraft Program.



Total 1973 Dollars = \$1570.3M

Note: Avionics and Engine Costs Have Been Added For Production Only

Figure 71. F-106 Three Hundred Aircraft Program.



Total 1973 Dollars = \$1677.7M

Notes - None of the Following Program Costs Are Included Above.

Modifications	\$174.0M
Spares	\$123.4M
AGE	\$161.3M
Personnel Subsystems	\$ 69.4M
Other	\$137.7M

- Airframe Production Includes \$91.1M for Assembly & checkout

Figure 72. B-58 One Hundred Aircraft Programs.

Structure Subassembly Cost Charts

The following collection of charts examines costs of structure in terms of labor hours per pound against structure weight. Four categories of structures are examined: wing, fuselage, vertical stabilizer, and horizontal stabilizer. Hours are defined as recurring manufacturing labor including recurring quality control hours. Effort was made to adjust for outside contract tasks which would normally be a part of the manufacturing task. Recurring tooling or engineering hours are not included.

An important adjustment was required on some of the data points for fuselage and wing. This adjustment process was necessary because aircraft manufacturers usually do not manufacture structure only, but also "build in" parts of other aircraft subsystems at the same time. Subsystems parts of which may be assembled during structure buildup include electrical, hydraulic, instrumentation, flight control, fuel, and others. The procedure for adjustment consisted first in reading any description accompanying the data very carefully to determine if such an adjustment has already been made. If not, then a reduction of 32.5 percent was made in the fuselage manufacturing hours and a 24.5 percent reduction was made in the wing hours. No adjustment of horizontal or vertical stabilizer structure was made. These adjustment percentages are based upon study of available detailed cost breakdown data and are considered as approximate values for military aircraft. Additional data are needed in this area to perhaps improve this adjustment procedure.

The structure subassembly manufacturing labor cost charts are arranged to show first shipset unit cost first followed by a chart showing the cumulative average cost for 50 shipsets and also a chart for the cumulative average cost for 100 shipsets. Also in each series is a chart of first unit shipset hours plotted as a function of the aircraft best speed at best altitude.

Fuselage Structure

Figure 73 shows the first of the series of fuselage structure manufacturing labor cost charts. The fuselage structure is assumed complete, including doors, access openings, and all other included structure items. This chart shows first unit hours. Probably a trend line for subsonic aircraft could be drawn using the T2A, CL-41, DC-10 and C-141 points. The higher performance aircraft fuselage structure hours fall well above this line.

Figures 74 and 75 show data for a cumulative average production of 50 and 100 shipsets respectively. Cost relations/trends are similar in both Figures 74 and 75 to those of Figure 73.

Figure 76 shows the first unit labor hours per pound plotted against aircraft speed. An upward trend with speed is seen.

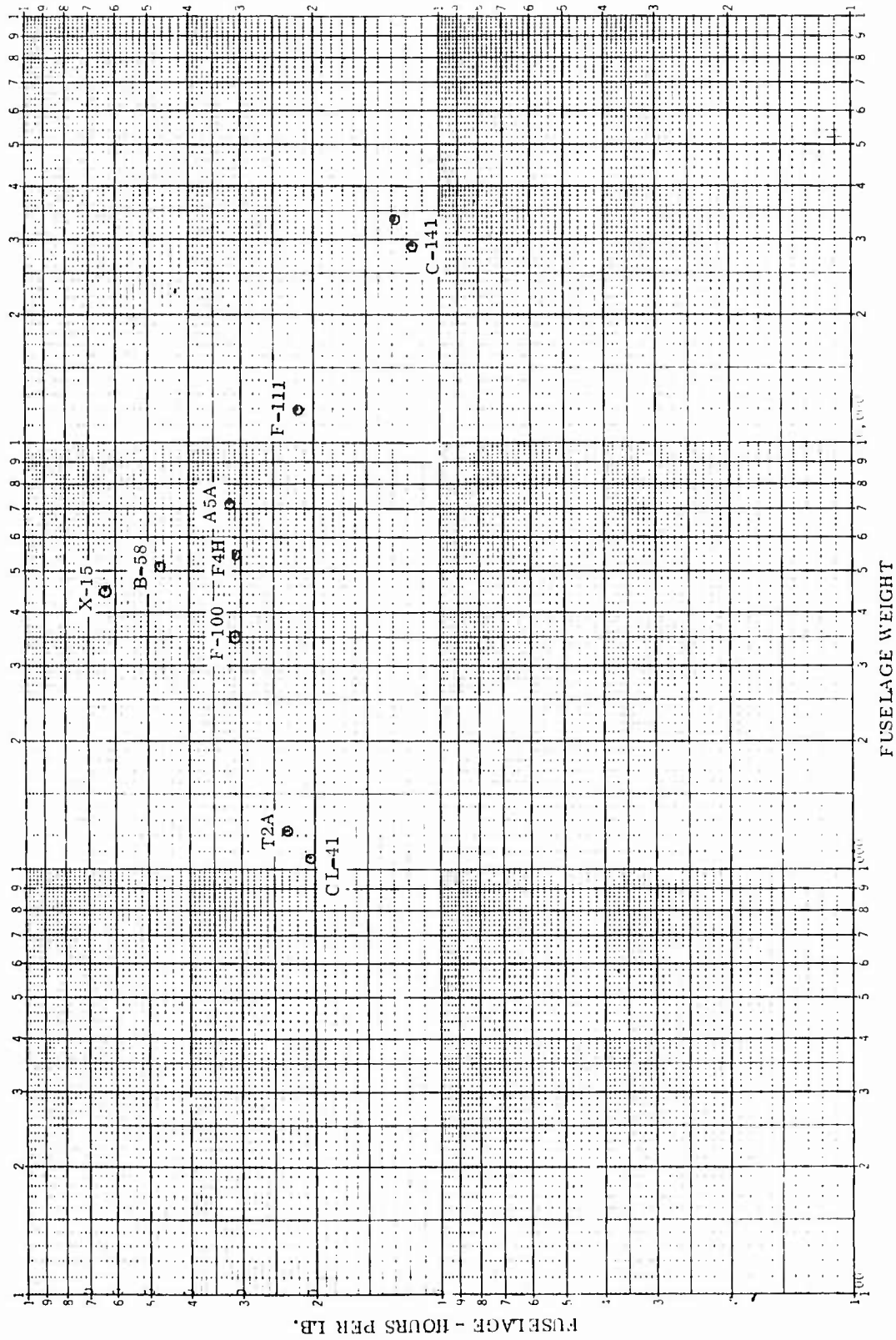


Figure 73. Fuselage Structure Hours per lb. versus Fuselage Weight (First Shipset).

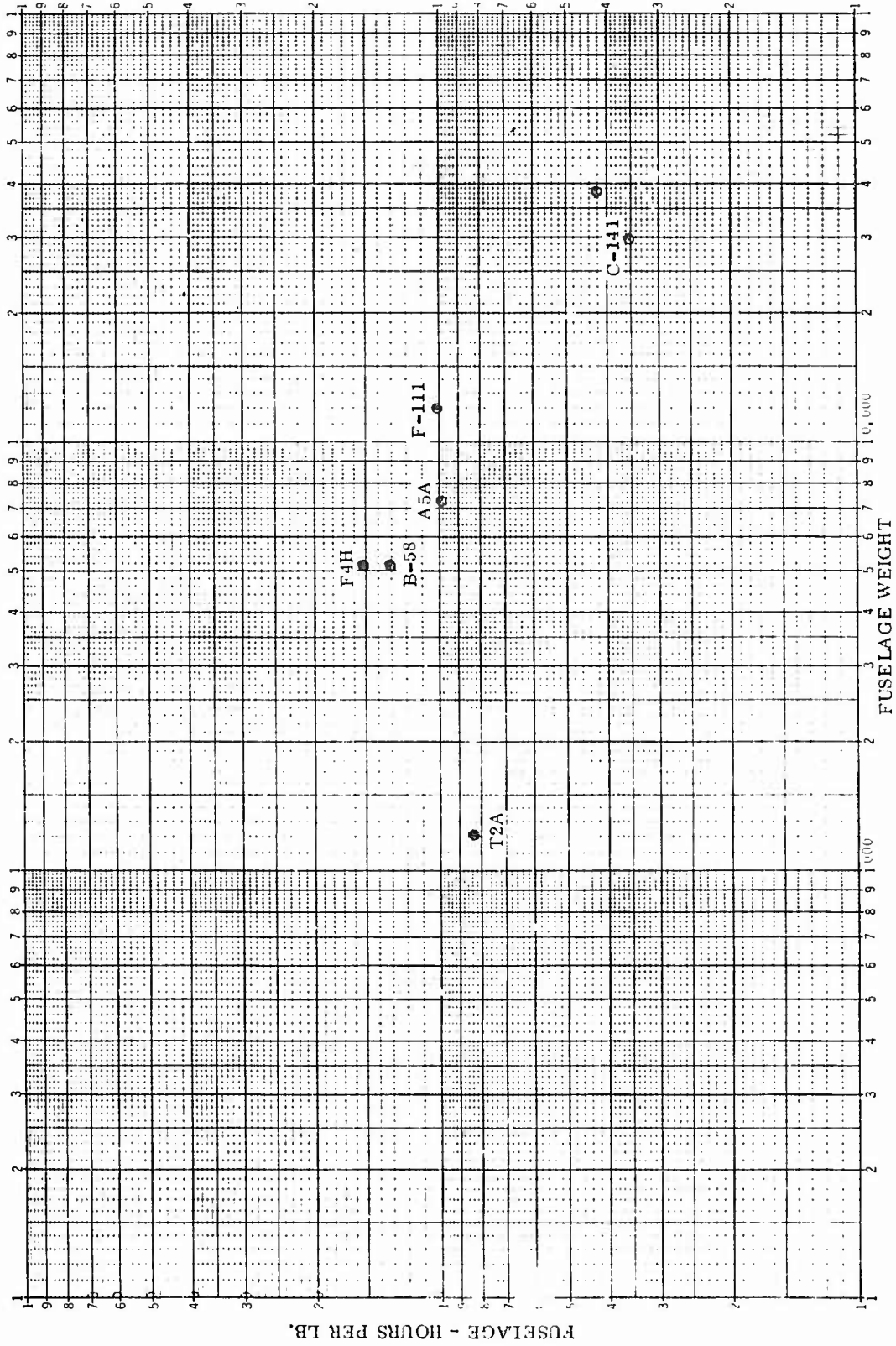


Figure 74. Fuselage Structure Hours per lb. versus Fuselage Weight (Cum. Avg. for the 50th Shipset).

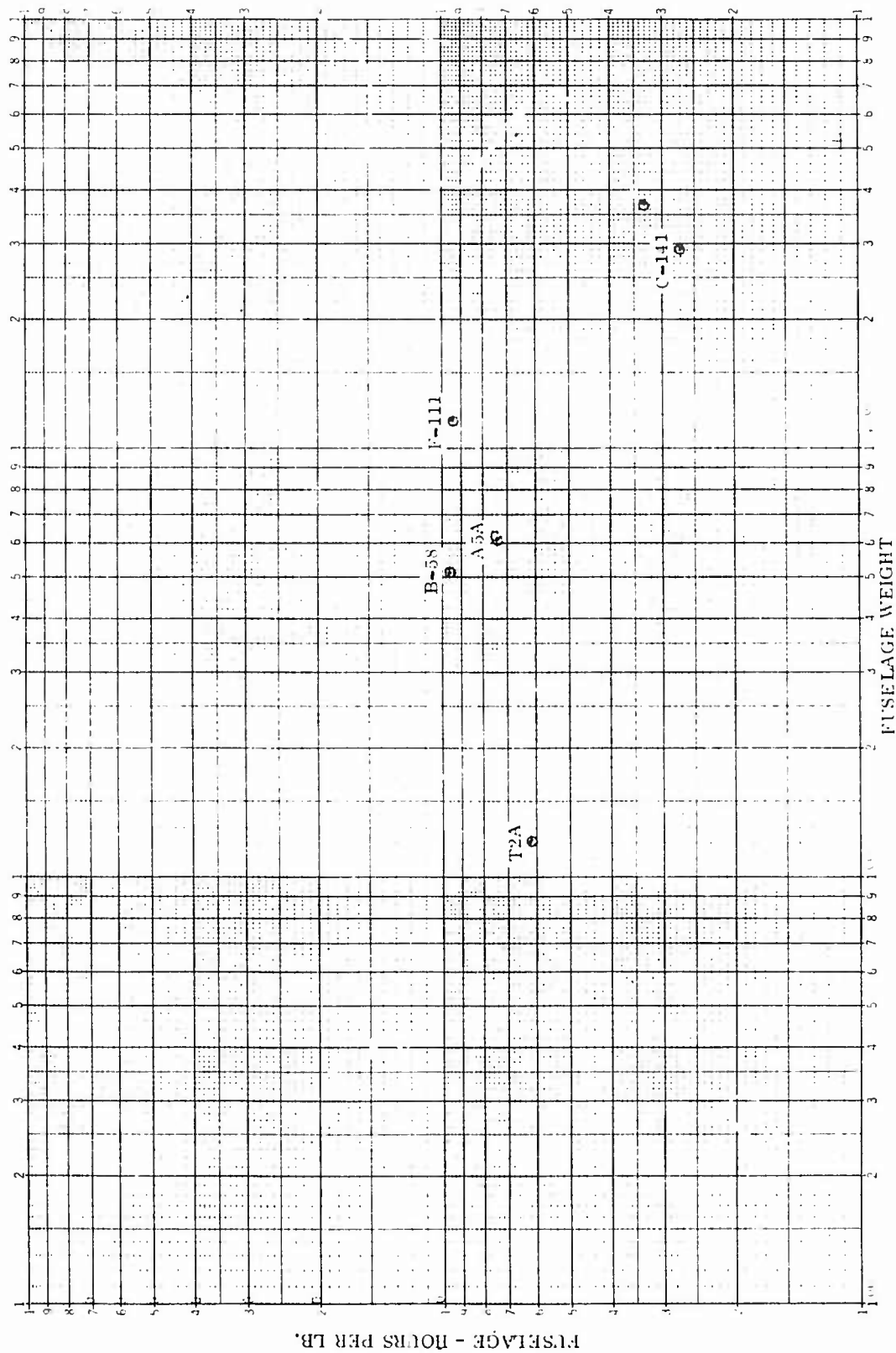


Figure 75. Fuselage Structure Hours per lb. versus Fuselage Weight (Cum. Avg. for the 100th Shipset).

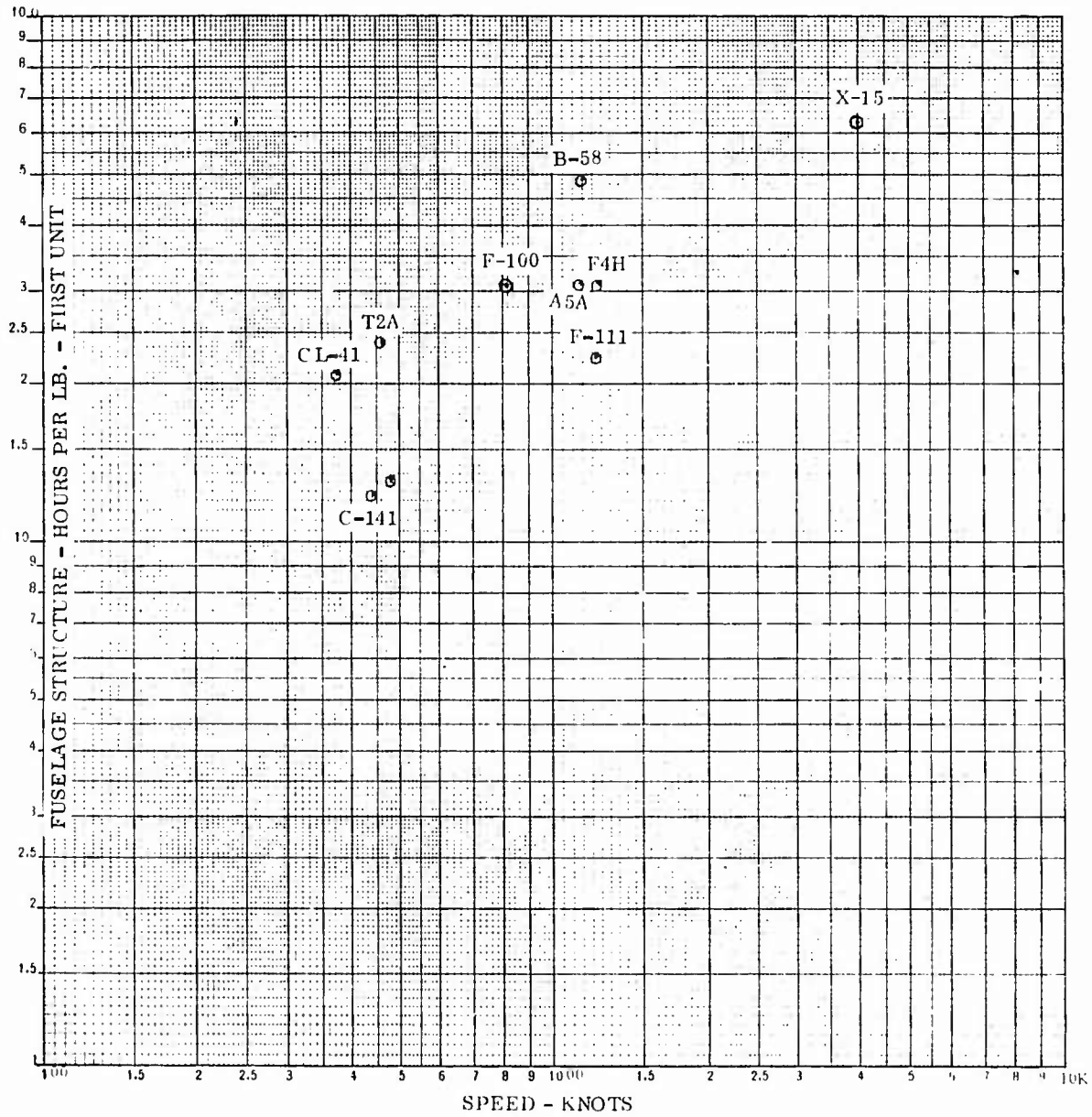


Figure 76. Fuselage Structure Hours/Lb. Versus Speed.

Wing Structure. Wing structure includes both wings and includes flaps, tips, roll control surfaces or elevons, etc. Not included are fuel tanks or fuel system elements, landing gear or other subsystem controls or hardware. Figures 77 through 80 show the same sequence of charts as was shown for fuselages. In the case of wings, the spread of costs between wings for low and high speed aircraft in terms of cost per pound versus weight seems narrower, i. e., less scatter. The same general downward slope with weight is seen although the slope may be somewhat less than for fuselages.

Horizontal Stabilizer Structure. Horizontal stabilizer structure includes all structural elements including control surfaces and ballast weight. Inclusion of the ballast weight tends to lower the apparent cost per pound since little labor is spent on the weights. In Figure 81, the first unit costs follow a rather good trend line. The abbreviation owp stands for outer wing panel. Figures 82 and 83 show more scatter developing as different learning curve slopes come into effect. Figure 84 does not show any definite cost trends with speed.

Vertical Stabilizer Structure. Vertical stabilizer structure is intended to include all structural elements including the rudder. However, in the case of the B-52 and the F-111, the rudders are not included in either the hours or the weight. Including the rudder probably would not effect hours per pound greatly, but would shift weights somewhat to the right on the chart. Figures 85 through 88 show available data for vertical stabilizer structure on the same basis as the previous figures. Cost trends compare with those seen for the horizontal stabilizer.

Summary of Structure Subassembly Costs

Costs for structure subassemblies were found to follow understandable trends. No outstandingly low costs per pound were found. On some aircraft the actual cost of structure is rather low compared to the total program cost. For example, in the 116-aircraft B-58 program, disregarding the structural cost aspects of the flight test and pod programs, the cost for basic aircraft structure itself, including RDT&E, was only 14.5 percent of the total program cost.

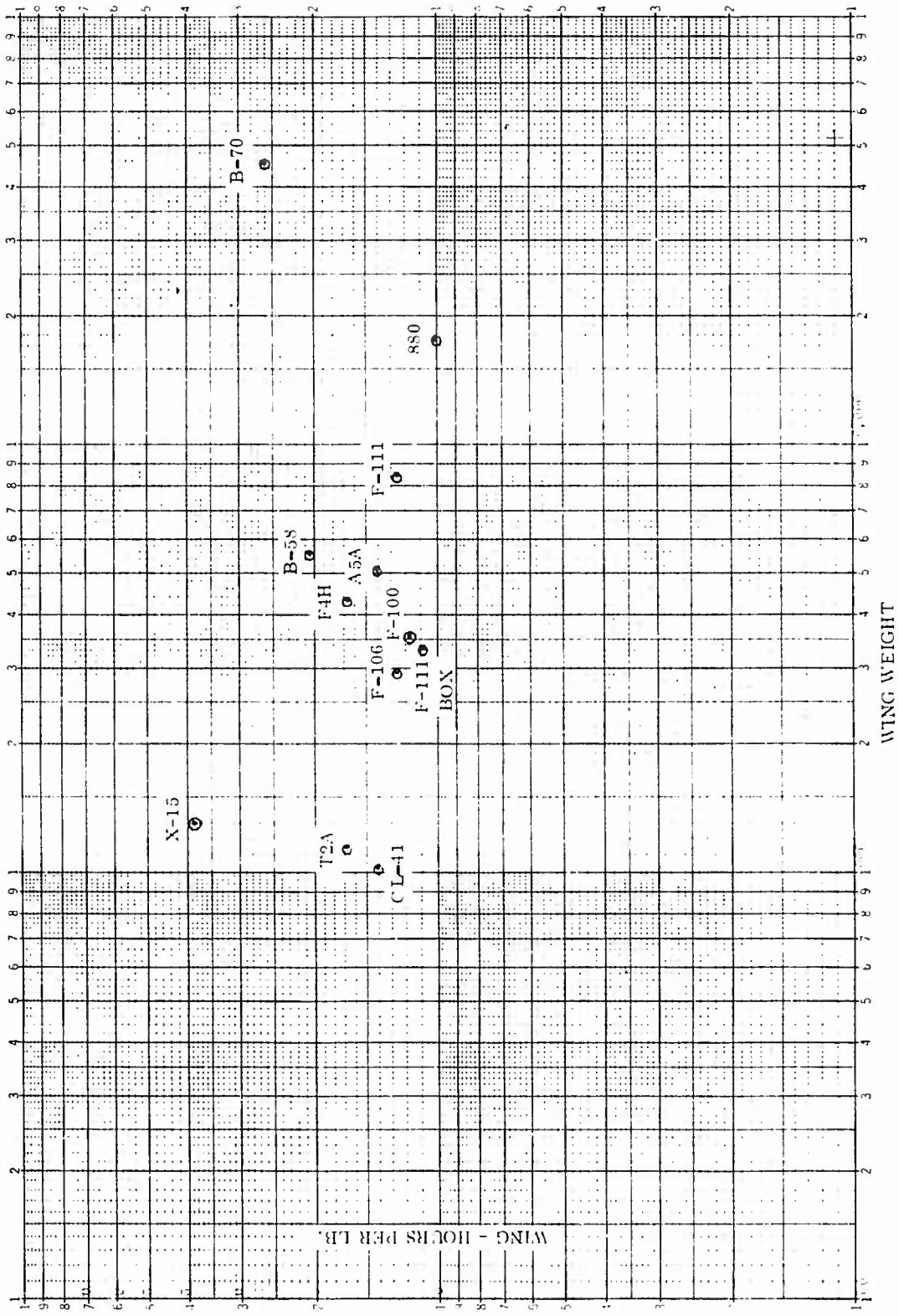


Figure 77. Wing Structure Hours per Lb. versus Wing Weight (First Shipset).

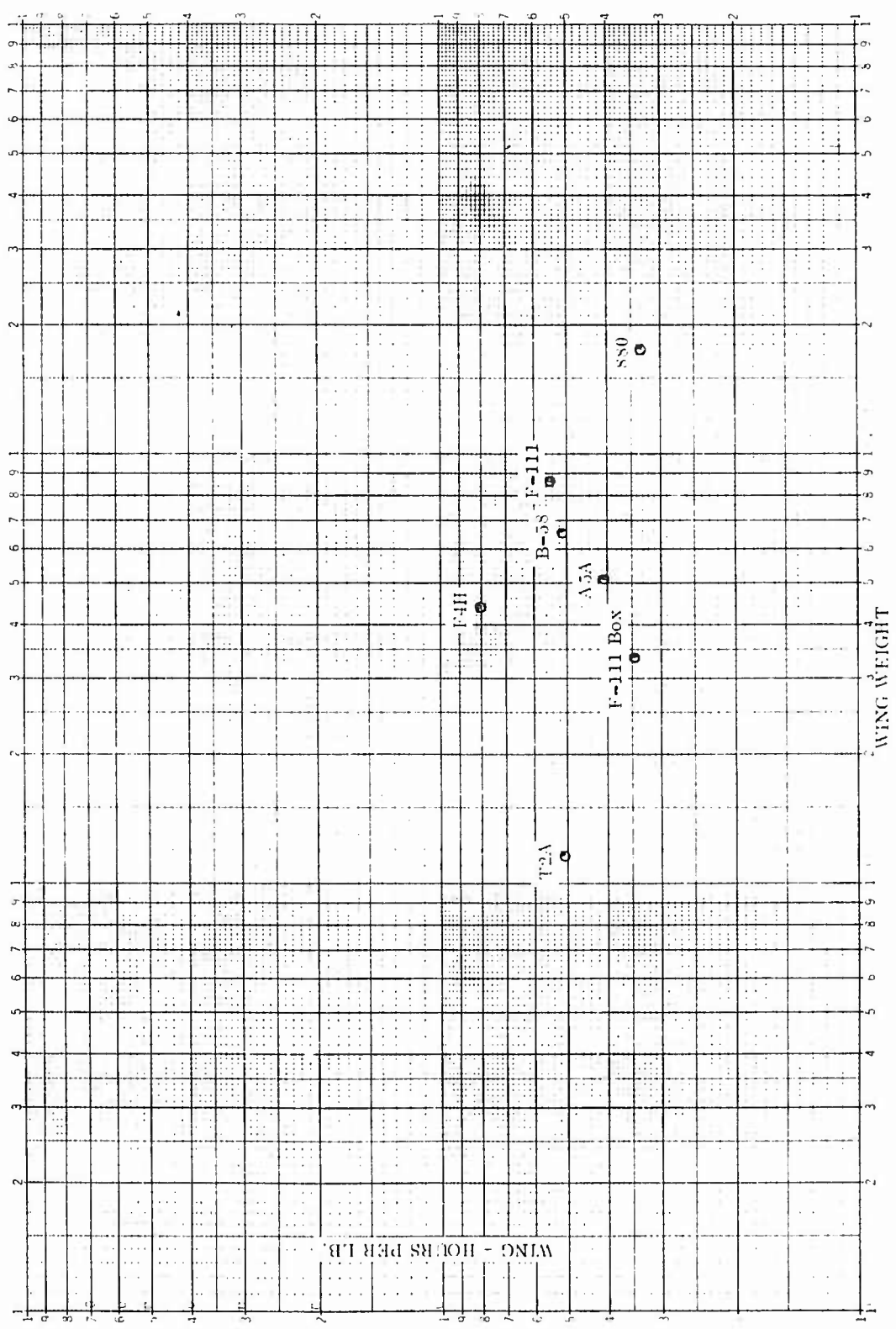


Figure 78. Wing Structure Hours per lb. versus Wing Weight (Cum. Avg. for the 50th Shipset).

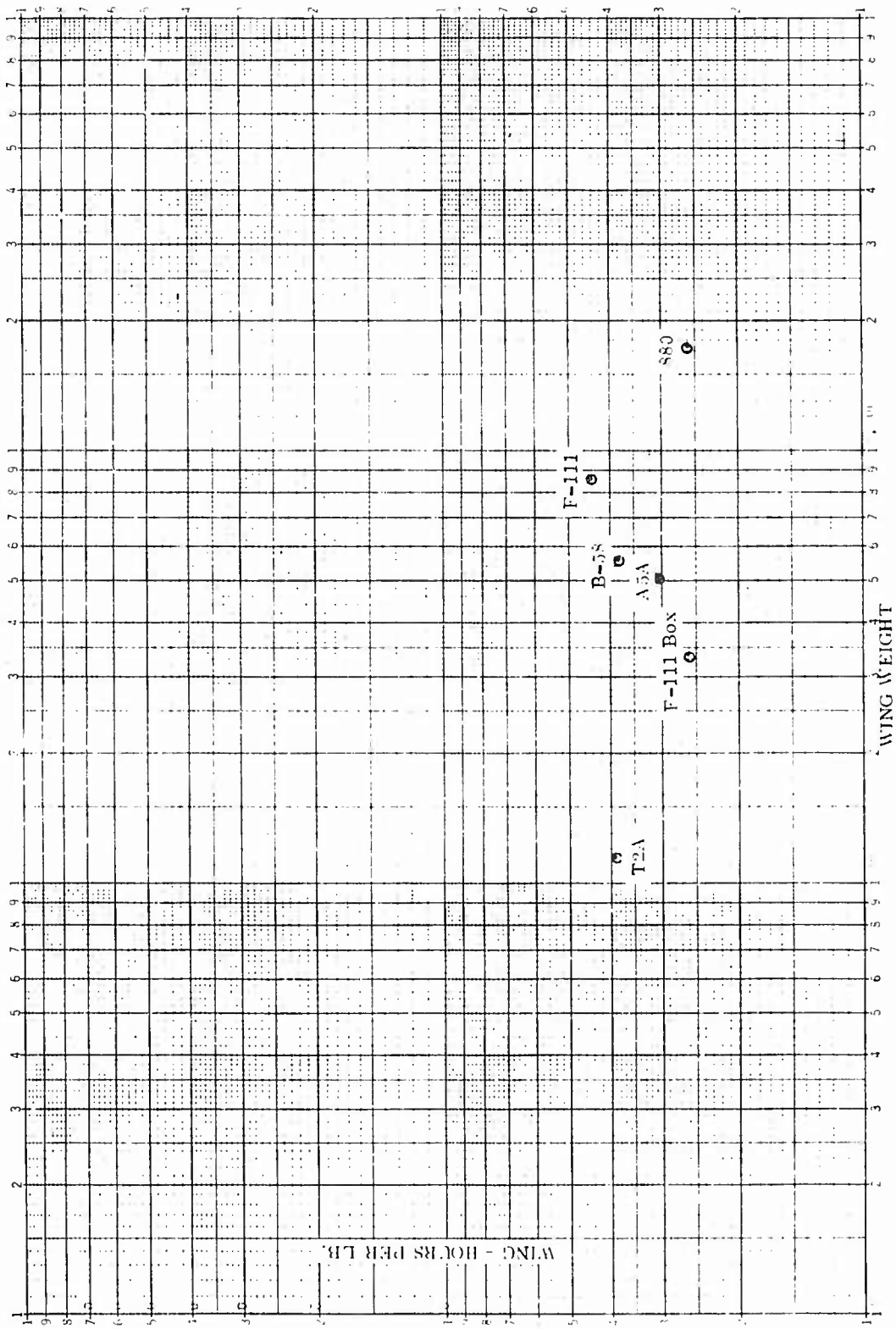


Figure 79. Wing Structure Hours per lb. versus Wing Weight (Cum. Avg. for 100th Unit).

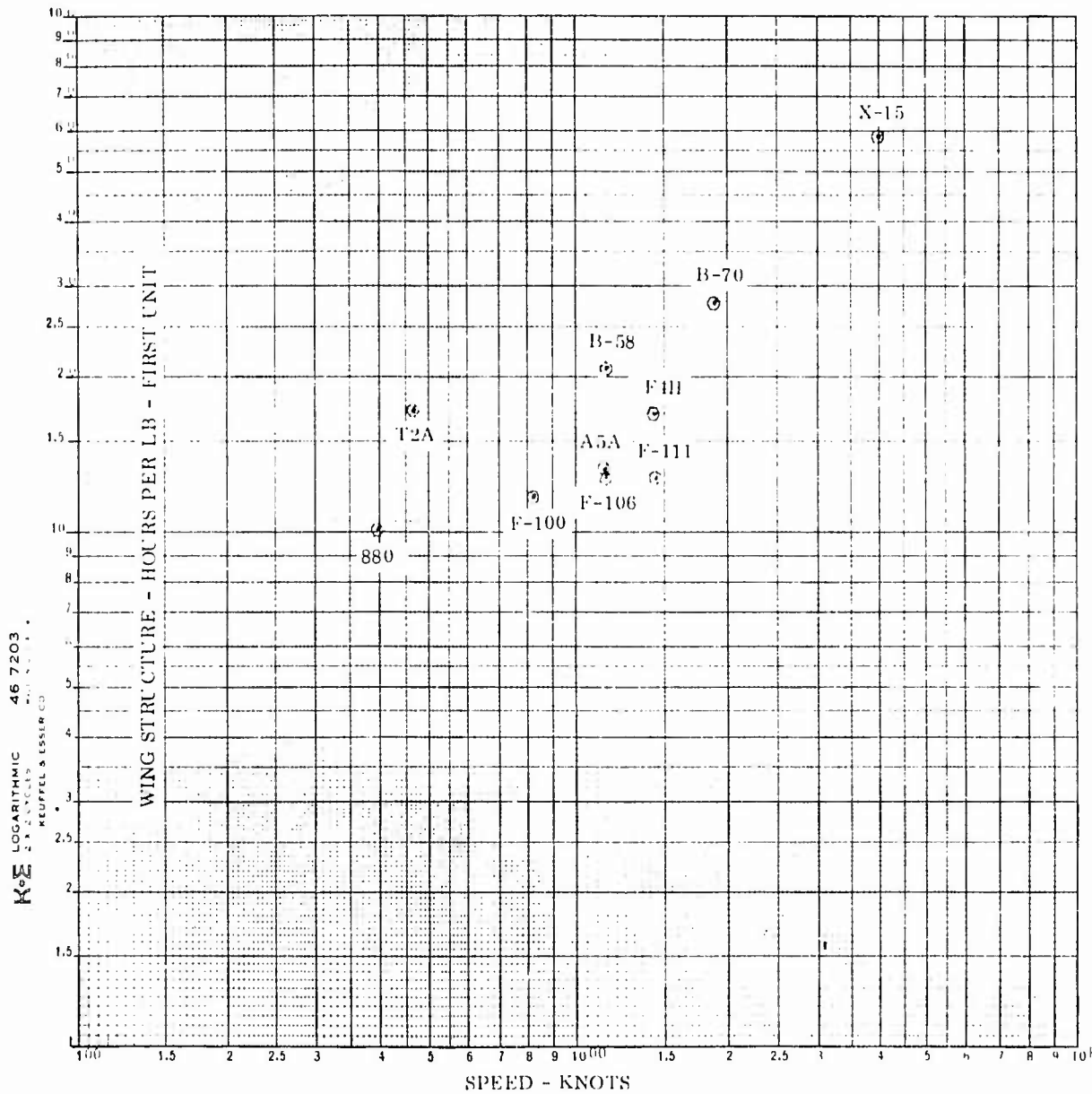


Figure 80. Wing Structure Hours per lb. versus Speed.

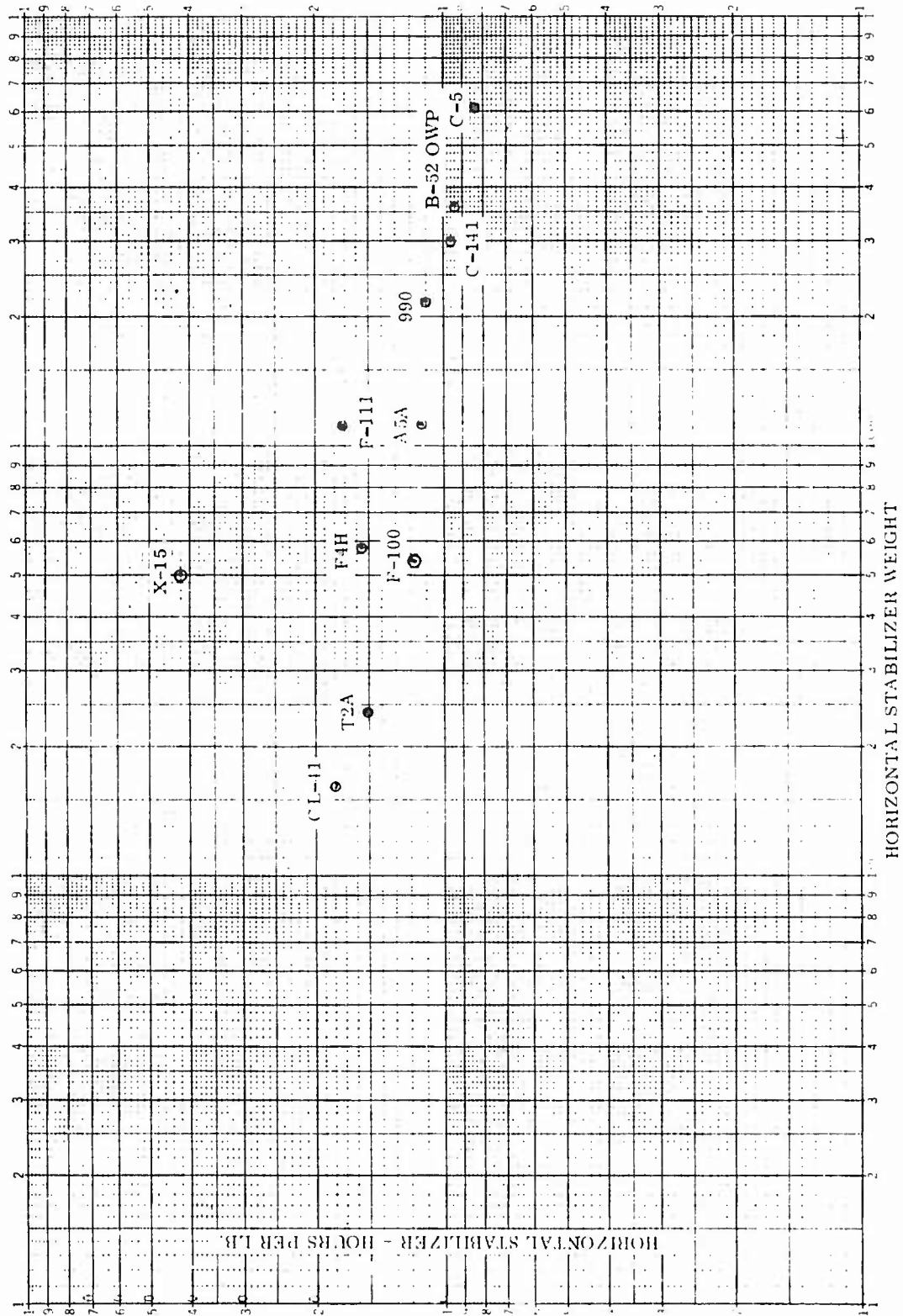


Figure 81. Horizontal Stabilizer Structure Hours per lb. versus Horizontal Stabilizer Wt. (First Unit).

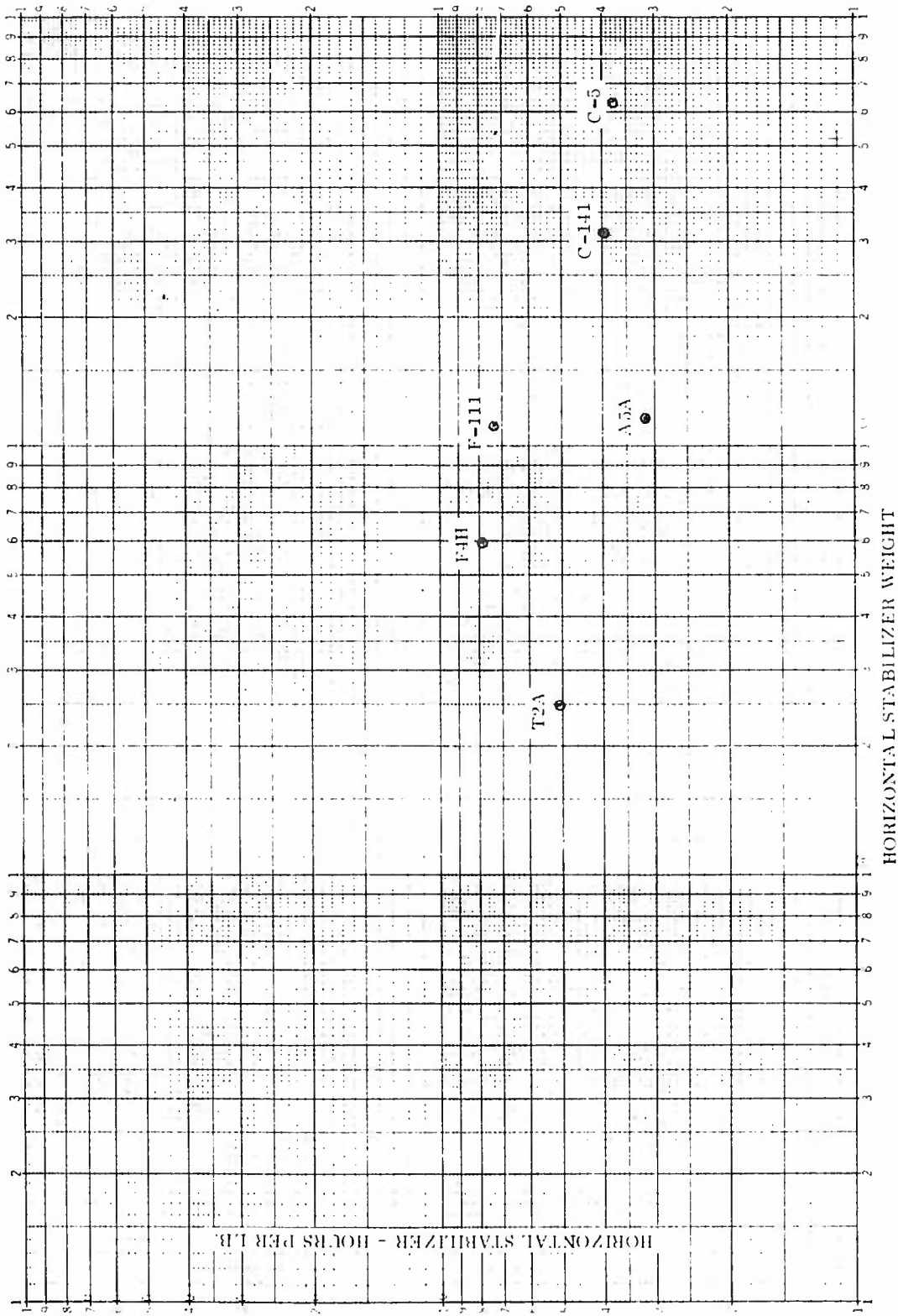


Figure 82. Horizontal Stabilizer Structure Hours per lb. versus Horizontal Stabilizer Wt. (Cum. Avg. 50th Unit).

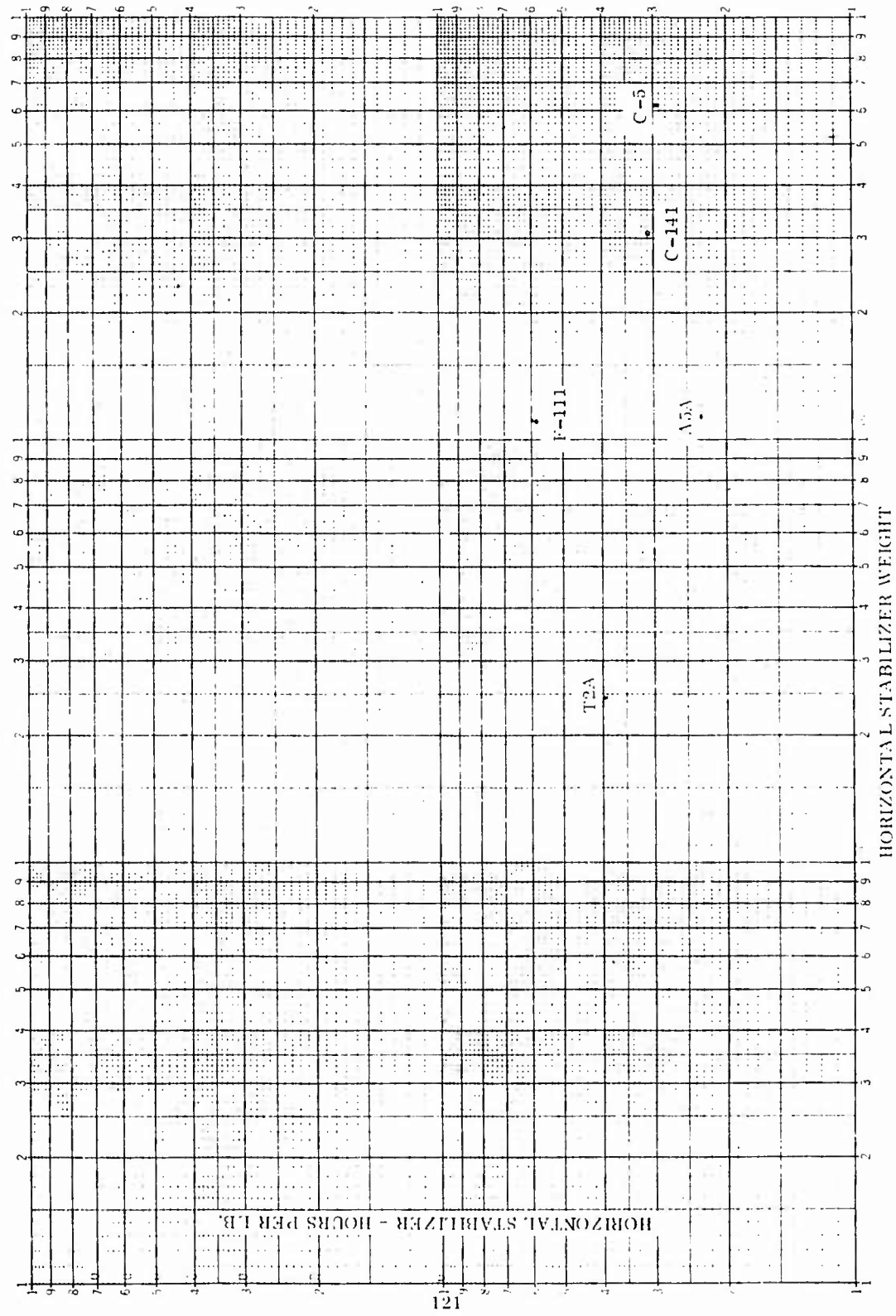


Figure 83. Horizontal Stabilizer Structure Hours per lb. versus Horizontal Stabilizer Wt. (Cum. Avg. 100th Unit).

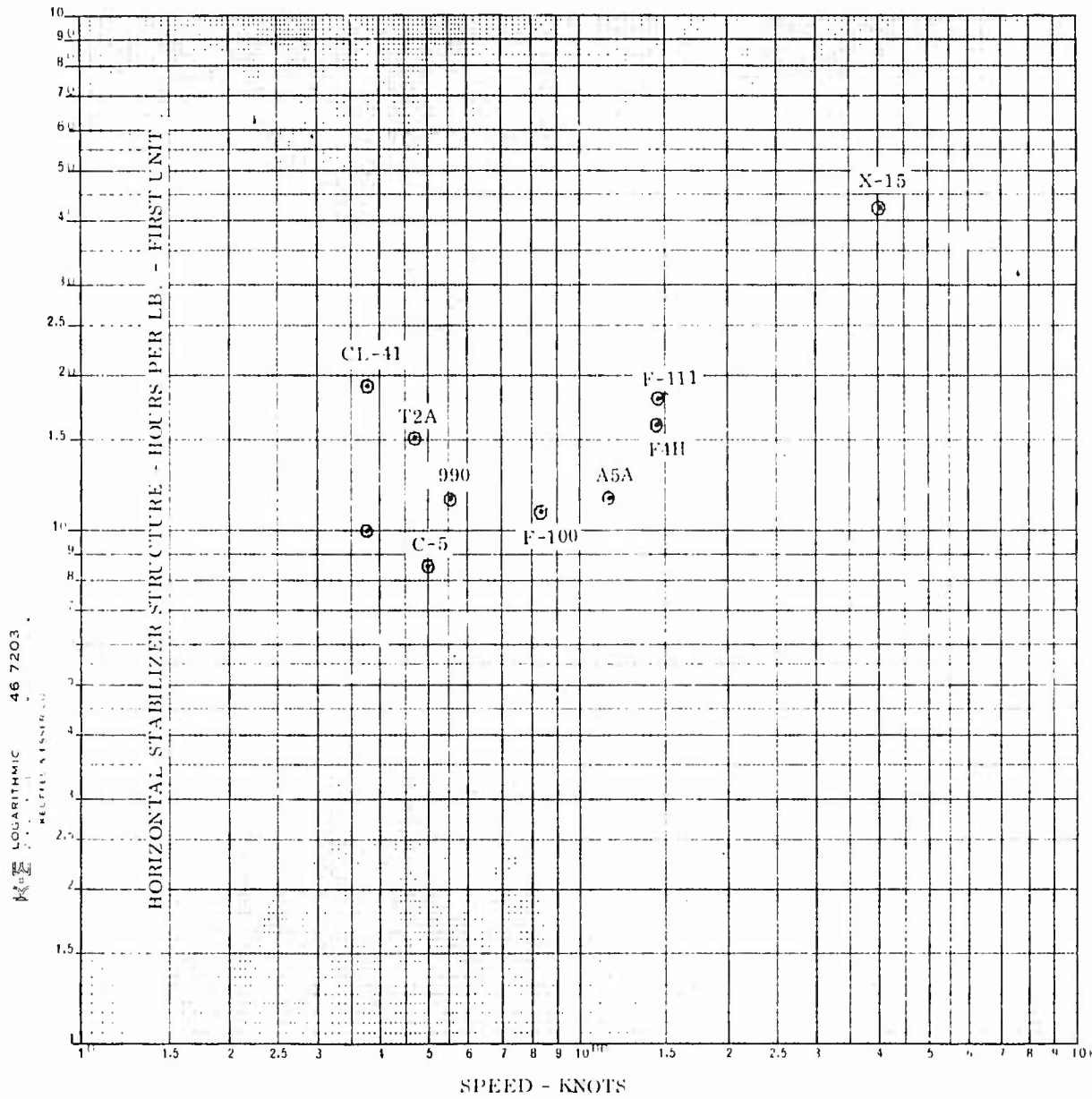


Figure 84. Horizontal Stabilizer Structure Hours per lb. versus Speed.

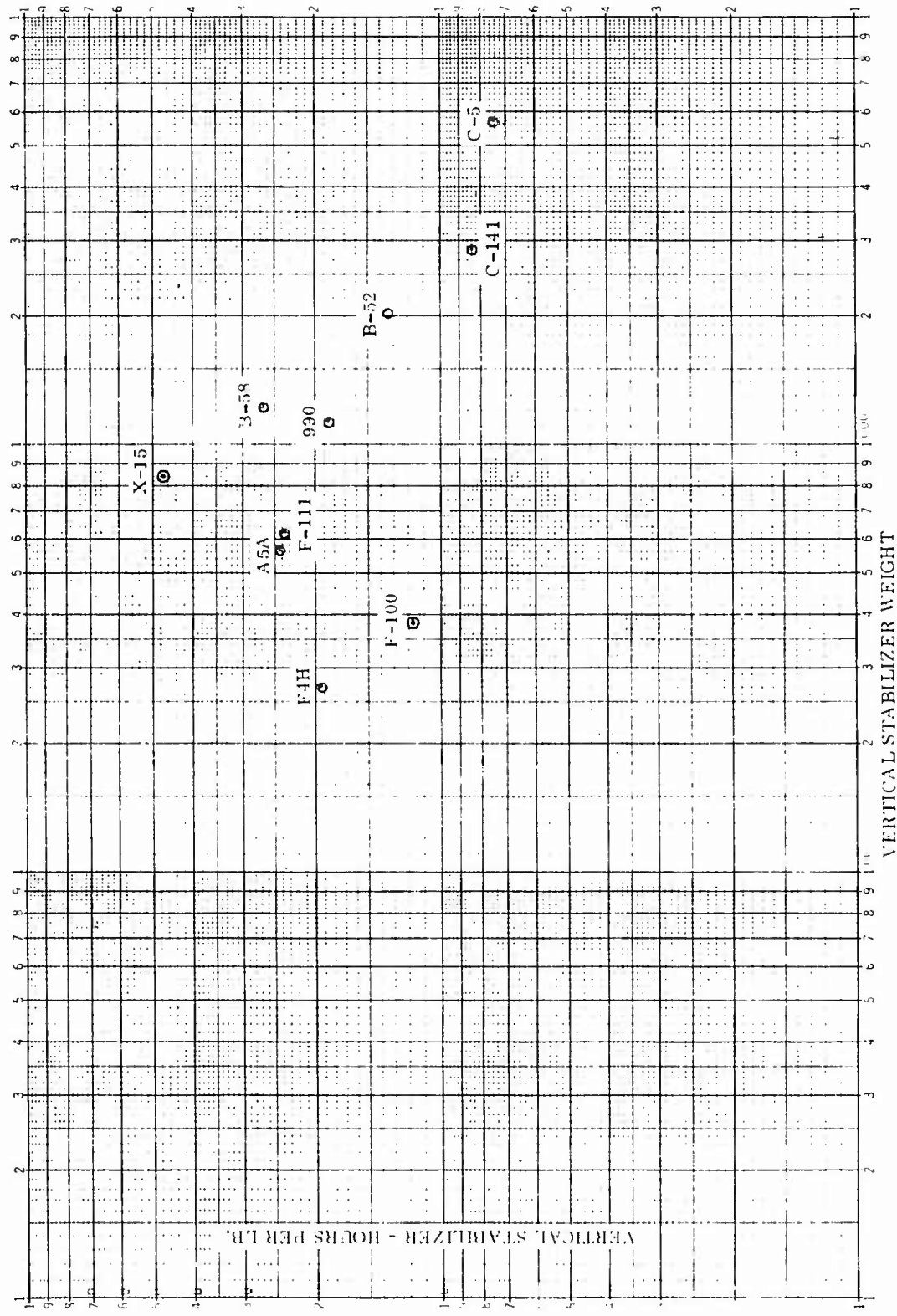


Figure 85. Vertical Stabilizer Structure Hours per lb. versus Vertical Stabilizer Wt. (First Unit)

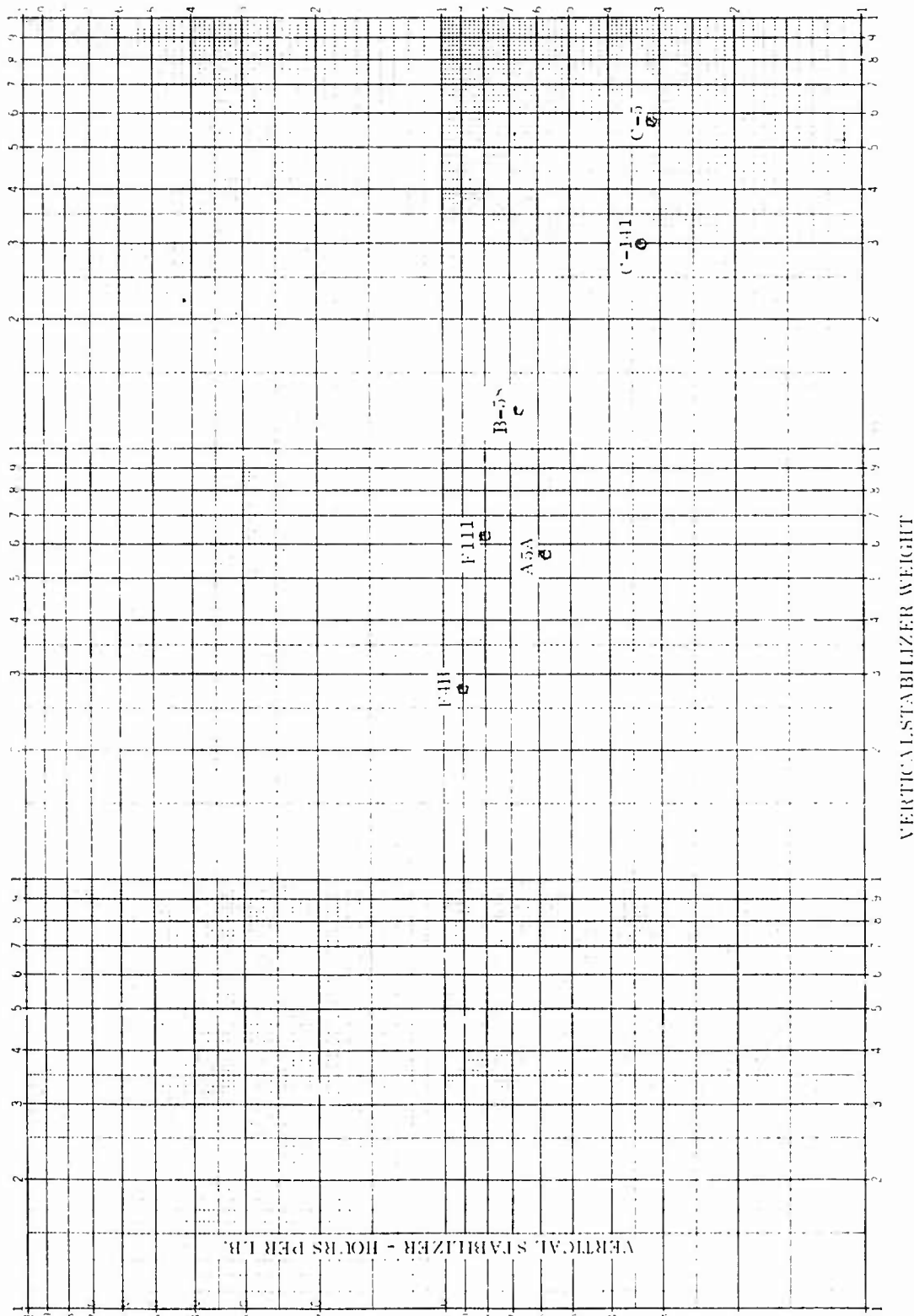


Figure 86. Vertical Stabilizer Structure Hours per lb. versus Vertical Stabilizer Weight (Cum. Avg. 50th Unit).

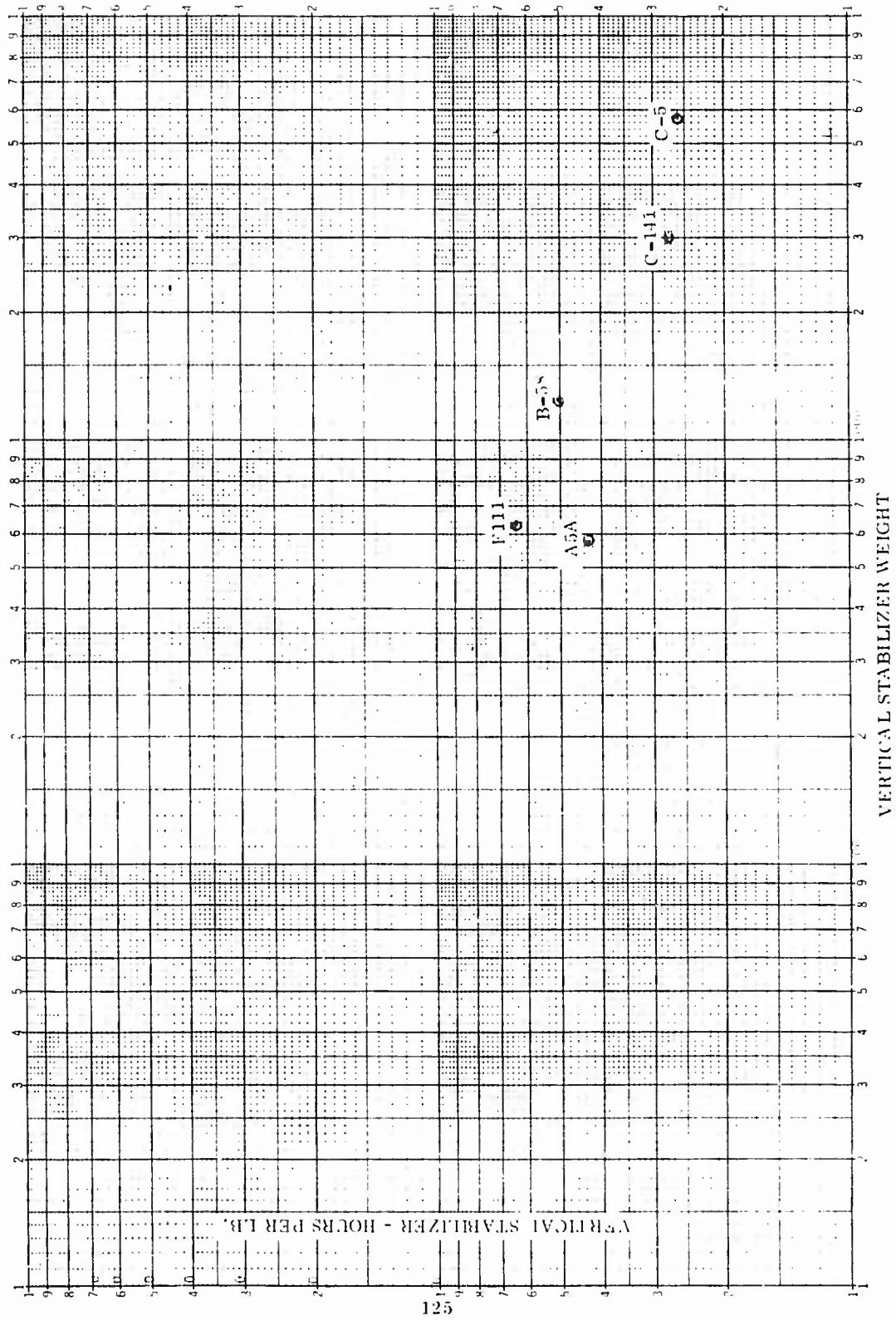


Figure 87. Vertical Stabilizer Structure Hours per lb. versus Vertical Stabilizer Weight (Cum. Avg. 100th Unit).

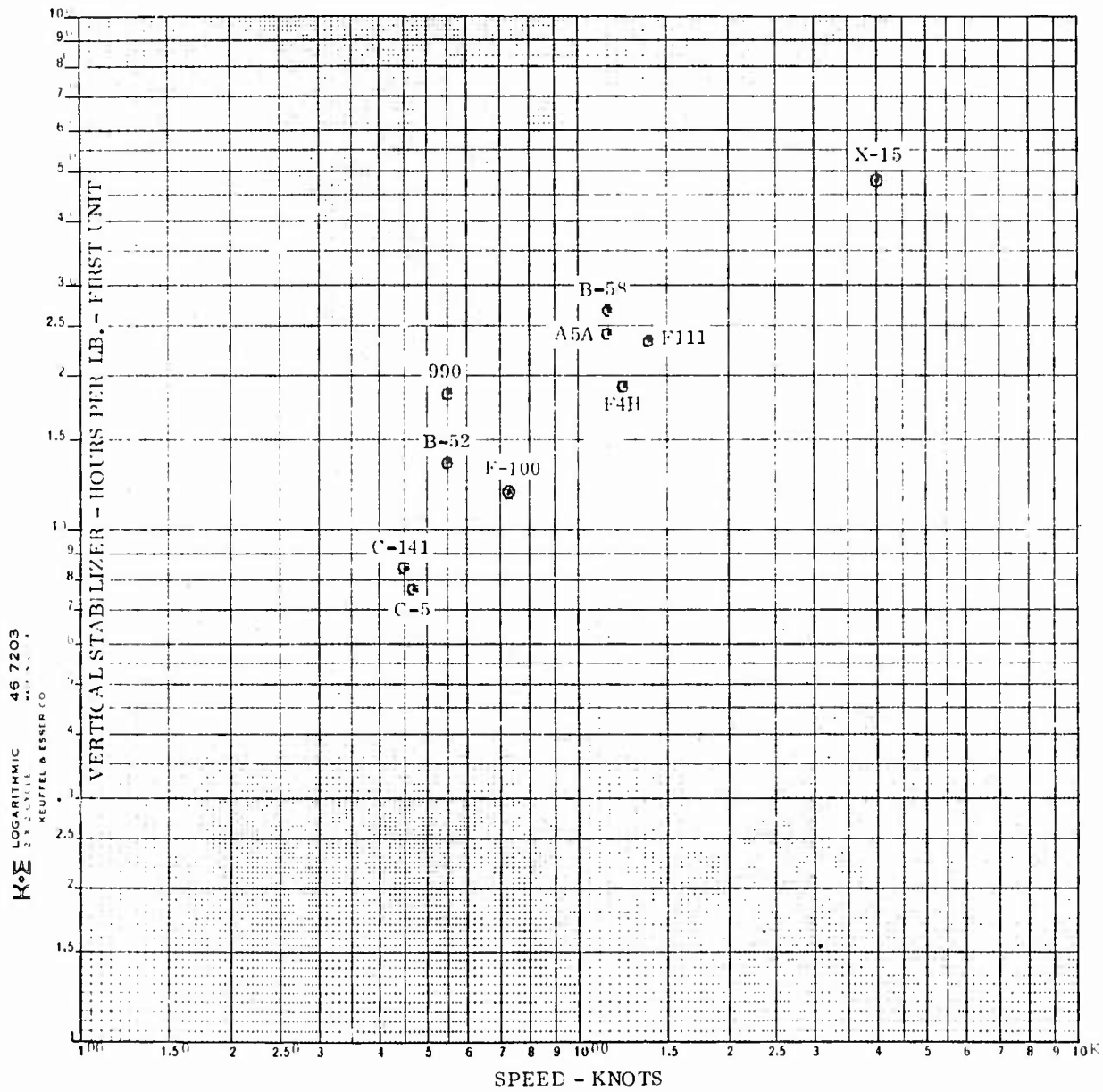


Figure 88. Vertical Stabilizer Structure Hours per lb. versus Speed (1st Unit).

APPENDIX A

SUPPLEMENTAL COMPLEXITY FACTOR DATA

This appendix consists of a series of seventeen worksheets that provide back-up data for the derivation of complexity factors used in the estimating procedure as outlined in Volume IV. The derivation of complexity factors is described in Volume I, pp. 51-58.

APPROVALS		DATE	LEGEND		TOOLING		STATION SUMMARY		PROJECT		
			TOOLING		TOOLING		1ST	2ND	3RD	TOTL	DEPT.
			TOOLING		TOOLING		9.8				STATION
			TOOLING		TOOLING		33				MOVE CYCLE
			TOOLING		TOOLING						ASST. FOR
			TOOLING		TOOLING						% REAL
OPERATION NO.	TITLE	ZONE	STD	ACT	CREW	PERSONNEL					
1	Rib size 48" x 12" x 2"					F-600/12/12/5					
	Detail bolts are tails (2), web (1), stiffeners (2) and 1) in webs (1).					1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16					
	Fabrication of ribs (2)										
	Set-up saw			.5							
	Saw extension to length (2)			.3							
	Burr edges			.5							
	Set-up router			.3							
	Route stringer flange			.3							
	Burr			.5							
	Set-up rolls			.5							
	Roll form to contour			.3							
	Process to spec. (alodine)			4.0							
	Prime surfaces			.5							
	Identify and inspect			.5							
	Fabrication of web (1)										
	Set-up shear			.5							
	Shear part to width & length (12" x 48")			.3							
	Burr			.3							
	Set-up router			.5							
	Route web to shape			.5							
	Burr			.3							
	Process to spec. (alodine)			4.0							
	Prime surfaces			.5							
	Identify and inspect			.5							
	Fabrication of stiffeners (2)										
	Set-up saw			.5							
	Saw extension (2)			.3							
	Burr			.3							
	Set-up rolls			.5							
	Roll form to contour			.5							
	Process to spec. (alodine)			4.0							
	Prime surfaces			.5							
	Identify and inspect			.5							
	Fabrication of stiffeners (3)										
	Set-up saw			.5							
	Saw extension (3)			.3							
	Burr			.3							
	Process to spec. (alodine)			4.0							
	Prime surfaces			.5							
	Identify and inspect			.5							
	Total Detail Fab.			28.3							

PREPARED BY

APPROVALS _____ DATE _____

PROJECT _____ DEPT. _____ STATION _____

SHIFT _____ 1ST _____ 2ND _____ 3RD _____ TOTL _____

STANDARD HOURS _____ ACT. HRS. _____

MOVE CYCLE _____ ASST. FOR _____ % REAL _____

PERSONNEL _____

STATION SEQUENCE & LOAD CHART

LEGEND

IN WORK	T	TOOLING	
COMPLETED	P	PLANNING	
S	SHORTAGES	Q	SEQUENCE
E	ENGINEERING	O	OTHER

NOTES

OPERATION NO.	TITLE	ZONE	STD	ACT	CREW
	BUILT UP WEB STIFFENER RTB ASSEMBLY PAGE 2 of 2				
	Assembly operations Load in car in ORFX			.5	
	Clamp (R)			.3	
	Drill 40 1/16 dia. holes in 1/8 material			1.2	
	Clamp (10)			.3	
	Jack rivet			.5	
	Remove from DMFX			.2	
	Wet complete (7)			1.0	
	Identify and inspect			.5	
	Forward to next assembly				
	Total Subassembly			4.5	

1-60-14 H9 V24.5
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16

PREPARED BY _____

APPROVALS _____ DATE _____

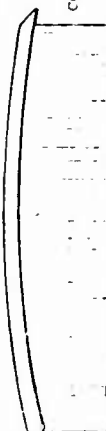
PROJECT _____ DEPT. _____ STATION _____ MOVE CYCLE _____

STATION SUMMARY
 1ST 2ND 3RD TOTL
 6.7
 21

STANDARD HOURS _____ ACT HOURS _____ MAINTENANCE _____

NOTES _____

CORRUGATED WEB 3



OPERATION NO.	TITLE	ZONE	STD	ACT	CREW	PERSONNEL
1	Rib is a welded headed structure					
2	Detail parts are: Caps - 2" x 48" x .185" (2)					
3	and a corrugated web (1)					
4	Fabrication of web					
5	Set-up shear					
6	Shear material 0.12" x 48" dim.					
7	Set up footer					
8	Route edges in contour					
9	Surf					
10	Set up brake					
11	Step brake form corrugations					
12	Process per spec. (clean steel for welding)					
13	XXXXXXXXXX wrap and stack					
14	Identify and inspect					
15	Fabrication of caps (2)					
16	Set-up shear					
17	Shear material 0.12" x 48" x .185"					
18	Surf					
19	Process to spec (clean and rich for welding)					
20	XXXXXXXXXX wrap and stack					
21	Identify and inspect					
22	XXXXXXXXXX					
23	Load caps and web in MEX					
24	Clamp (4)					
25	Jack weld B plates					
26	Certify weld schedule					
27	Weld web to rails					
28	Inspect (non-destructive), X-ray or equal					
29	Process per spec. (aloids)					
30	Prime surface					
31	Identify and inspect					
32	Total Detail Fab.		11.7			
33	Total Subtotal		9.3			

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APPROVALS		STATION SUMMARY		PROJECT		PERSONNEL
INTEGRAL WEB STIFFENER		1ST	2ND	3RD	TOTL	
OPERATION NO.	TITLE	ZONE	STD	ACT	CREW	
010	4" x 12" x 12" Flange					
020	Profile Mill					
030	Profile Mill					
040	Profile Mill					
050	Profile Mill					
060	Profile Mill					
070	Profile Mill					
080	Profile Mill					
090	Profile Mill					
100	Profile Mill					
110	Profile Mill					
120	Profile Mill					
130	Profile Mill					
140	Profile Mill					
150	Profile Mill					
160	Profile Mill					
170	Profile Mill					
180	Profile Mill					
190	Profile Mill					
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1940	Profile Mill					
1950	Profile Mill					
1960	Profile Mill					
1970	Profile Mill					
1980	Profile Mill					
1990	Profile Mill					
2000	Profile Mill					

APPROVALS _____ DATE _____

STATION SEQUENCE & LOAD CHART

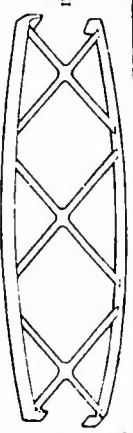
NOTES: BASED ON PROJECTIONS QUANTITIES, THE PART LEND TOWARD 7/0 MACHINING IN LIEU OF STANDARD TRACER PROFILING

INTEGRAL THICKNESS **5**

STATION SUMMARY

SHIFT	1ST	2ND	3RD	TOTL
STD. HRS.	3.8			
ACT. HRS.	15.6			
MANPOWER				

PROJECT _____ DEPT. _____ STATION _____ MOVE CYCLE _____ ASST. FOR _____ % REAL _____



OPERATION NO.	TITLE	ZONE	STD	ACT	CREW	PERSONNEL
45	45' Long x 12' W x 18' 2" Ranges					
000	Set p. saw			.5		
010	Roll Saw Length and Width			.3		
020	Allow Access on Ends for TIG					
030	Mill (2) Surfaces to Size			.7		
040	Profile Mill Perimeter			.5		
050	Profile Mill Picker (1) Side			1.5		
060	Profile Mill Picker (1) Side			1.5		
070	Profile Mill Web (trous)			2.0		
080	Profile Mill Web (trous)			.7		
090	In Mill Cutout (1) End			.7		
100	Rebar			.2		
110	dent flag			.5		
115	HW			.5		
120	cut			.5		
125	Penetrant Insp			1.0		
130	Assemble			4.0		
140	dent flag			.3		
	Total Detail Fab			15.6		

PREPARED BY _____

STATION SEQUENCE & LOAD CHART

APPROVALS _____ DATE _____

LEGEND

OUT-OF-TRUSSES 6

PROJECT _____ DEPT. _____

STATION _____

MODE CYCLE _____

ASST FOR _____

% REAL _____

STATION SUMMARY

SHIFT	1ST	2ND	3RD	TOTL
STR. HRS.				
ACT HRS.	7.2			23.5
MANHRS				

OPERATION NO.	TITLE	ZONE	STD	ACT	CREW	PERSONNEL
1	Sub 13 riveted cross assembly					
2	Detail ends of cap rails (1) and extruded					
3	cap rails (2)					
4	cap rails (1)					
5	Setup shear					
6	Shear material to dim. 7" x 48" x 1/8"					
7	Setup roller					
8	Roll sheaves					
9	Burr					
10	Process per spec (alodine)					
11	Identify and inspect					
12	Process (1)					
13	Setup sub					
14	Set extrusion to length					
15	Roll					
16	Process to spec. (alodine)					
17	Grind surfaces					
18	Identify and inspect					
19	Plan installation					
20	Setup shear					
21	Shear material to size 3" x 2" x 1/8"					
22	Process to spec. (alodine)					
23	Grind surfaces					
24	Identify and inspect					
25	Assembly of rib					
26	Load rails, clips and trans numbers in ASF					
27	Clamp in					
28	Drill 5/16 holes in .385 material					
29	Clamp on					
30	Final 5/16 rivets					
31	Inspect					
32	Forward to next assembly					
	<i>Total Detail Fat</i>		19.5			
	<i>Substructure</i>		4.0			

PREPARED BY _____

APPROVALS _____ DATE _____

PROJECT: _____
 DEPT.: _____
 STATION: _____
 MOVE CYCLE: _____
 ASST. FOR: _____
 % REAL: _____

STATION SUBBILITY

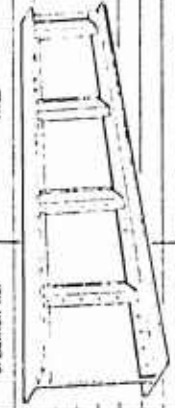
SHIFT	1ST	2ND	3RD	TOTL.
STD. HRS.	4.6			
ACT. HRS.	23.5			
MANPR.	as noted			

STATION SEQUENCE & LOAD CHART

LEGEND

IN WORK	T	TOOLING
COMPLETED	P	PLANNING
SHORTAGES	Q	SEQUENCE
ENGINEERING	C	OTHER

NOTES _____

OPERATION NO.	TITLE	ZONE	STD	ACT	CREW	FLOW HOURS	PERSONNEL
						1 2 3 4 5 6 7 8 9 0	
							
	Detail parts ref: 1. web, 2. rails (2)						
	Fabrication of stiffeners (4)						
	Setup shear						
	Shear part to template						
	buff edges						
	move to process line						
	process part to spec. (alodine)						
	apply prime coat to both sides						
	identify and inspect						
	move to stock						
	Fabrication of rails (2)						
	Setup saw						
	cut extrusion to length						
	buff						
	move to process line						
	process part to spec. (alodine)						
	apply prime coat to a part						
	identify and inspect						
	move to stock						
	Fabrication of stiffeners (4)						
	Setup saw						
	cut extrusion to size						
	buff						
	move to process line						
	process part to spec. (alodine)						
	apply prime coat to parts						
	identify and inspect						
	move to stock						
	Assemble assembly						
	Load detail parts in DEX (7)						
	close in place (4)						
	Drill 1/4" dia. holes in rails						
	lock rivets (10) places						
	remove from fixture and complete riveting (24)						
	inspect and identify						
	Total Detail Fab.						
	Total Subassembly						

STATION SEQUENCE & LOAD CHART

APPROVALS _____ DATE _____

LEGEND

IN WORK	T	TOOLING
COMPLETED	P	PLANNING
SHORTAGES	Q	SEQUENCE
ENGINEERING	O	OTHER

STATION SUMMARY

SHIFT	1ST	2ND	3RD	TOTL
STD HRS.	5.1			
ACT HRS.	16.8			

PROJECT: _____ DEPT.: _____ STATION: _____
 NOTE CYCLE: _____ ASST FOR: _____ % REAL: _____

OPERATION NO. _____ **TITLE** **ZONE** **STD** **ACT** **CREW** **NOTES**

2

2 1/2" x 4" x 10" TRUSS

DESCRIPTION	ZONE	STD	ACT	CREW	NOTES
Detail parts are rails (2), stiffeners (6)					
Fabrication of rails			.5	1	
set-up a saw			.3	1	
saw extrusion to length (2)			.3	1	
buff edges					
move to processing			4.0	1	
process parts to spec. (alodine)			.5	1	
prime parts			.5	1	
Identify and inspect			.5	1	
Fabrication of stiffeners (6)					
set-up5	1	
saw extrusion to length			.5	1	
buff edges			.5	1	
move to processing			4.0	1	
process parts to spec. (alodine)			1.0	1	
prime parts			.5	1	
Identify and inspect			.5	1	
assembly of detail parts					
load 1st parts in DUFF			.5	1	
Clamp 1st plates			.7	1	
Drill 27 3/16 holes in parts 1/4" thick			.5	2	
back-pipe 171 plates			1.0	2	
remove from fixture and complete riveting			.5	1	
Identify and inspect					
Move to next assembly					
Total Detail Fab			13.1		
Total Subassembly			3.7		

APPROVALS _____ DATE _____

STATION SEQUENCE & LOAD CHART

PROJECT _____
 DEPT. _____
 STATION _____
 MOVE CYCLE _____
 ASST. FOR _____
 % REAL _____

STATION SUMMARY				
SHIFT	1ST	2ND	3RD	TOTL
STD. HRS.				
ACT. HRS.				
MANPOWER				

NOTES
 6.8 STD
 18.9

LEGEND	
IN WORK	WORKING
COMPLETED	PLANNING
SCHEDULED	SEQUENCE
ENGINEERING	OTHER

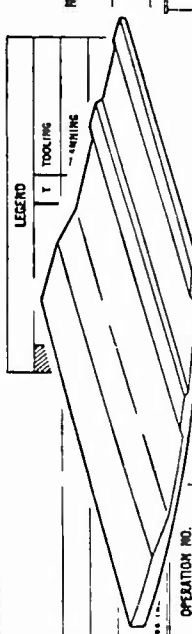
OPERATION NO.	TITLE	ZONE	STD	ACT	CREW	PERSONNEL
001	3. 11' x 10' Length and Width	5		5		
002	4. 11' x 10' Length and Width	5		7		
003	5. 11' x 10' Length and Width	5		1.0		
004	6. 11' x 10' Length and Width	5		1.7		
005	7. 11' x 10' Length and Width	5		1.9		
006	8. 11' x 10' Length and Width	5		2.1		
007	9. 11' x 10' Length and Width	5		2.3		
008	10. 11' x 10' Length and Width	5		2.5		
009	11. 11' x 10' Length and Width	5		2.7		
010	12. 11' x 10' Length and Width	5		2.9		
011	13. 11' x 10' Length and Width	5		3.1		
012	14. 11' x 10' Length and Width	5		3.3		
013	15. 11' x 10' Length and Width	5		3.5		
014	16. 11' x 10' Length and Width	5		3.7		
015	17. 11' x 10' Length and Width	5		3.9		
016	18. 11' x 10' Length and Width	5		4.1		
017	19. 11' x 10' Length and Width	5		4.3		
018	20. 11' x 10' Length and Width	5		4.5		
019	21. 11' x 10' Length and Width	5		4.7		
020	22. 11' x 10' Length and Width	5		4.9		
021	23. 11' x 10' Length and Width	5		5.1		
022	24. 11' x 10' Length and Width	5		5.3		
023	25. 11' x 10' Length and Width	5		5.5		
024	26. 11' x 10' Length and Width	5		5.7		
025	27. 11' x 10' Length and Width	5		5.9		
026	28. 11' x 10' Length and Width	5		6.1		
027	29. 11' x 10' Length and Width	5		6.3		
028	30. 11' x 10' Length and Width	5		6.5		
029	31. 11' x 10' Length and Width	5		6.7		
030	32. 11' x 10' Length and Width	5		6.9		
031	33. 11' x 10' Length and Width	5		7.1		
032	34. 11' x 10' Length and Width	5		7.3		
033	35. 11' x 10' Length and Width	5		7.5		
034	36. 11' x 10' Length and Width	5		7.7		
035	37. 11' x 10' Length and Width	5		7.9		
036	38. 11' x 10' Length and Width	5		8.1		
037	39. 11' x 10' Length and Width	5		8.3		
038	40. 11' x 10' Length and Width	5		8.5		
039	41. 11' x 10' Length and Width	5		8.7		
040	42. 11' x 10' Length and Width	5		8.9		
041	43. 11' x 10' Length and Width	5		9.1		
042	44. 11' x 10' Length and Width	5		9.3		
043	45. 11' x 10' Length and Width	5		9.5		
044	46. 11' x 10' Length and Width	5		9.7		
045	47. 11' x 10' Length and Width	5		9.9		
046	48. 11' x 10' Length and Width	5		10.1		
047	49. 11' x 10' Length and Width	5		10.3		
048	50. 11' x 10' Length and Width	5		10.5		
049	51. 11' x 10' Length and Width	5		10.7		
050	52. 11' x 10' Length and Width	5		10.9		
051	53. 11' x 10' Length and Width	5		11.1		
052	54. 11' x 10' Length and Width	5		11.3		
053	55. 11' x 10' Length and Width	5		11.5		
054	56. 11' x 10' Length and Width	5		11.7		
055	57. 11' x 10' Length and Width	5		11.9		
056	58. 11' x 10' Length and Width	5		12.1		
057	59. 11' x 10' Length and Width	5		12.3		
058	60. 11' x 10' Length and Width	5		12.5		
059	61. 11' x 10' Length and Width	5		12.7		
060	62. 11' x 10' Length and Width	5		12.9		
061	63. 11' x 10' Length and Width	5		13.1		
062	64. 11' x 10' Length and Width	5		13.3		
063	65. 11' x 10' Length and Width	5		13.5		
064	66. 11' x 10' Length and Width	5		13.7		
065	67. 11' x 10' Length and Width	5		13.9		
066	68. 11' x 10' Length and Width	5		14.1		
067	69. 11' x 10' Length and Width	5		14.3		
068	70. 11' x 10' Length and Width	5		14.5		
069	71. 11' x 10' Length and Width	5		14.7		
070	72. 11' x 10' Length and Width	5		14.9		
071	73. 11' x 10' Length and Width	5		15.1		
072	74. 11' x 10' Length and Width	5		15.3		
073	75. 11' x 10' Length and Width	5		15.5		
074	76. 11' x 10' Length and Width	5		15.7		
075	77. 11' x 10' Length and Width	5		15.9		
076	78. 11' x 10' Length and Width	5		16.1		
077	79. 11' x 10' Length and Width	5		16.3		
078	80. 11' x 10' Length and Width	5		16.5		
079	81. 11' x 10' Length and Width	5		16.7		
080	82. 11' x 10' Length and Width	5		16.9		
081	83. 11' x 10' Length and Width	5		17.1		
082	84. 11' x 10' Length and Width	5		17.3		
083	85. 11' x 10' Length and Width	5		17.5		
084	86. 11' x 10' Length and Width	5		17.7		
085	87. 11' x 10' Length and Width	5		17.9		
086	88. 11' x 10' Length and Width	5		18.1		
087	89. 11' x 10' Length and Width	5		18.3		
088	90. 11' x 10' Length and Width	5		18.5		
089	91. 11' x 10' Length and Width	5		18.7		
090	92. 11' x 10' Length and Width	5		18.9		



5
 5
 5

PREPARED BY _____

APPROVALS		DATE	STATION SEQUENCE & LOAD CHART				PROJECT	DEPT.	STATION	MOVE CYCLE	ASST. FOR	% REAL																					
			<p>NOTES: THIS PART IS ADAPTABLE TO S/C MACHINING IF PRODUCTION QUANTITIES WARRANT</p>				<p>STATION SUMMARY</p> <table border="1"> <tr> <td>SHIFT</td> <td>1ST</td> <td>2ND</td> <td>3RD</td> <td>TOTL</td> </tr> <tr> <td>STD. HRS.</td> <td>6.8</td> <td></td> <td></td> <td></td> </tr> <tr> <td>ACT. HRS.</td> <td>23.7</td> <td></td> <td></td> <td></td> </tr> <tr> <td>MANHRS.</td> <td></td> <td></td> <td></td> <td></td> </tr> </table>	SHIFT	1ST	2ND	3RD	TOTL	STD. HRS.	6.8				ACT. HRS.	23.7				MANHRS.										
SHIFT	1ST	2ND	3RD	TOTL																													
STD. HRS.	6.8																																
ACT. HRS.	23.7																																
MANHRS.																																	
OPERATION NO.	DESCRIPTION	QTY	UNIT	MANHRS	LOAD	REMARKS	PERSONNEL																										
0-10	1.0	1.0																															
0-20	1.0	1.0																															
0-30	1.1	1.1																															
0-40	2.3	2.3																															
0-50	1.9	1.9																															
0-60	1.7	1.7																															
0-70	1.7	1.7																															
0-80	4.0	4.0																															
0-90	5	5																															
1-00	3	3																															
1-10	1.0	1.0																															
1-20	1.7	1.7																															
1-30	1.0	1.0																															
1-40	1.0	1.0																															
1-50	1.0	1.0																															
1-60	4.0	4.0																															
1-70	3	3																															
1-80	23.7	23.7																															
<p>On 7/2 Mills this Type of Part Average 8 Manhours per h. P. Depending on the number of Risers. Use Panels with 2 Risers 1.5, 3 Mill/Qu. H.</p>																																	
<p>PREPARED BY</p>																																	

APPROVALS _____ DATE _____		STATION SEQUENCE & LOAD CHART NOTES _____	PROJECT _____ DEPT. _____ STATION _____ MOVE CYCLE _____ ASST. FOR _____ % REAL _____	<table border="1" style="width:100%; border-collapse: collapse;"> <tr> <th colspan="4">STATION SUMMARY</th> </tr> <tr> <td>SHIFT</td> <td>1ST</td> <td>2ND</td> <td>3RD</td> </tr> <tr> <td>STD. HRS.</td> <td>5.7</td> <td></td> <td></td> </tr> <tr> <td>ACT. HRS.</td> <td>20.9</td> <td></td> <td></td> </tr> <tr> <td>MANPOWER</td> <td></td> <td></td> <td></td> </tr> </table>	STATION SUMMARY				SHIFT	1ST	2ND	3RD	STD. HRS.	5.7			ACT. HRS.	20.9			MANPOWER				PERSONNEL _____ PREPARED BY _____
STATION SUMMARY																									
SHIFT	1ST	2ND	3RD																						
STD. HRS.	5.7																								
ACT. HRS.	20.9																								
MANPOWER																									
MACHINED PLATE 3																									
OPERATION NO.		CREW																							
010	Roll saw to length and width	1.0																							
020	Mill ends to size	1.0																							
030	Mill sides to size	1.0																							
040	Mill surfaces to size	2.8																							
050	Mill excess 2" Plus	1.7																							
060	Mill angle 45° Plus to level both surfaces	2.3																							
070	Grind 1 end	2.5																							
080	Grind 2nd end	2.3																							
090	Grind	1.0																							
100	Grind surface	1.5																							
105	PAW	.5																							
110	Grind	1.0																							
115	Grind rest of end	1.0																							
120	Assemble	4.0																							
130	dent (RS)	.3																							
	Total Mach. Lab.	20.9																							

APPROVALS	DATE	STATION SEQUENCE & LOAD CHART					PROJECT	DEPT.	STATION	MOVE CYCLE	ASST. FOR	% REAL																											
<div style="display: flex; justify-content: space-between;"> <div style="width: 45%;"> <p>LEGEND</p> <table border="1" style="width:100%; border-collapse: collapse;"> <tr> <td style="width: 20%;">IN WORK</td> <td style="width: 20%;">TOOLING</td> </tr> <tr> <td>COMPLETED</td> <td>PLANNING</td> </tr> <tr> <td>SHORTAGES</td> <td>SEQUENCE</td> </tr> <tr> <td>ENGINEERING</td> <td>OTHER</td> </tr> </table> </div> <div style="width: 45%;"> <p>STATION SUMMARY</p> <table border="1" style="width:100%; border-collapse: collapse;"> <tr> <td>SHIFT</td> <td>1ST</td> <td>2ND</td> <td>3RD</td> <td>TOTL</td> </tr> <tr> <td>STD. HRS.</td> <td colspan="4" style="text-align:center;">1.4</td> </tr> <tr> <td>ACT. HRS.</td> <td colspan="4" style="text-align:center;">6.5</td> </tr> <tr> <td>MANPWR.</td> <td colspan="4"></td> </tr> </table> </div> </div>		IN WORK	TOOLING	COMPLETED	PLANNING	SHORTAGES	SEQUENCE	ENGINEERING	OTHER	SHIFT	1ST	2ND	3RD	TOTL	STD. HRS.	1.4				ACT. HRS.	6.5				MANPWR.					NOTES		PERSONNEL		PREPARED BY					
IN WORK	TOOLING																																						
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ACT. HRS.	6.5																																						
MANPWR.																																							
OPERATION NO.	TITLE	ZONE	STD	ACT	CREW	<i>1.4.4.1.0.2.4</i>																																	
	SHEET 4																																						
	Part is a skin panel 48" x 78" x .185 material																																						
	Lubrication of panel																																						
	Set-up shear			.5																																			
	Shear material to size			.5																																			
	Burr edges			3																																			
	Process to spec. (inoline)			4.0																																			
	Prime surfaces			.7																																			
	Identify and inspect.			.5																																			
	Move to next assembly																																						
	<i>Total Detail Fab.</i>			<i>6.5</i>																																			

REFERENCES

1. "Advanced Air Superiority Fighter Wing Structures, Baseline Definition Cost Description," FZM 5990, Contract No. F33615-72-C-2149, 28 July 1972.