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WAATS - A COMPUTER PROGRAM FOR WEIGHTS ANALYSIS OF ADVANCED TRANSPORTATION SYSTEMS

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PREFACE

This report was prepared under Contract NAS 1-12008, Expansio and Extension of the ODIN/RLV Computer Program - Task 2, Evaluate and Improve the Existing ODIN Program Library. The contract was funded by the National Aeronautics and Space Administration, Langley Research Center, Space Systems Divisi Vehicle Analysis Branch.

The ODIN procedure is a programming concept which allows the of existing computer codes as part of a larger simulation. Communication of information among computer codes is accompli by means of a data base repository accessible and managed by ODIN executive computer code, DIALOG. The ODIN procedure and the executive program DIALOG were developed by Aerophysics Research Corporation and jointly sponsored by the National Aeronautics and Space Administration, Langley Research Center and the United States Air Force Flight Dynamics Laboratory.

The objective of this task was the elimination of unnecessary computer code and improvement in computational efficiency of the ODIN procedure. This was accomplished by development of a point design weights analysis computer program reported here

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WAATS - A COMPUTER PROGRAM FOR WEIGHTS

ANALYSIS OF ADVANCED TRANSPORTATION SYSTEMS.

by C. R. Glatt

AEROSPACE RESEARCH CORPORATION

1.0 SUMMARY

This document describes a method and computer program for the calculation and summation of system and subsystem weight elemen for advanced aerospace vehicle concepts. The method is based o the statistical analysis of historical weight data for the components of similar vehicle configurations. The correlations an correlating parameters for a variety of vehicles in the advance transportation class are presented. The user of the WAATS program has the option of accepting the vehicle correlation presen for modifying them on an individual component basis to suit veh concept under study.

The correlating parameters are described to the computer progra in terms of gross geometric characteristics and vehicle weight. Geometric characteristics include such items as wing area, aspe ratio, body length, etc. The vehicle is initially sized on the basis of an input gross weight (or landing weight). The progra accumulates system and subsystem weight elements resulting in the recalculation of the input vehicle weight. An iteration is performed to converge on a final estimated weight.

2.0 INTRODUCTION

The estimation of the mass properties of a vehicle is one of the most important considerations in the design process and y one of the most inexact engineering endeavors. While the cal lation of aerodynamic, propulsion and mission performance are based on widely recognized mathematical prediction techniques the estimation of weight must be based largely on historical The art of weight estimation has evolved through the years by the diligent collection and correlation of component weights previously built vehicles. New design weights are predicted the basis of the component weights of past designs. Little i mation is usually available on the other properties such as v area, center of gravity and inertia of the components. The W program may be described as a point design weight analysis of the above type.

2.1 BACKGROUND.

The impetus for development of WAATS was the need of a stand weight analysis program for use in the ODIN (Optimal Design Integration) system of references 1 and 2. WAATS is designed to work as an independent program or within the ODIN framewor as an element of an ODIN design analysis, WAATS accepts vehic characteristics f om the data base via its own input stream a generates elemental weights of the systems and subsystems.

Most good weights analysis are embodied in larger system synt such as VSAC, reference 1, SSSP, references 3 to 5 or ACSYNT, references 7 and 8. They combine weight analysis with sizing mission, propulsion, aerodynamics, etc. In the ODIN system, these technologies are frequently segregated into individual functions. For example, the aerodynamics may be estimated in a separate program such as TREND, references 9 or 10. Furthe the mission may be performed in a program such as ATOP, refer 11 to 13. Most technology modules generate data which ultima influence the weight of the vehicle. In the ODIN system, the data are placed in the design data base for use by other prog such as WAATS.

2.2 APPROACH.

The classical approach to weight estimation (i.e. the compone buildup technique) is used in program WAATS. Each component weight is based on the weight of the same component of simila vehicles that have actually been built or at least designed i great detail. The similarity law that gives the best correla for most systems has been shown to be the power law formula.

$$w_j = \sum A_i . X_i^{B_i}$$

where A_i is the empirical coefficient of the historical equati(

X_i is a predominant physical characteristic or combinati(thereof affecting the weight of the component

B_i is the empirical exponent of the historical weight equa

The component weight is obtained from the summation of all ph cal characteristic combinations, X_i which contribute to the w(of the component. The correlation parameters A_i and B_i are determined empirically from historical data on similar vehicl(systems or subsystems. WAATS is based on a preprogrammed set X_i. A_i and B_i are read into the program.

The weight of the vehicle is the cumulative total of all the weight components, w_j.

$$W = \sum w_j$$

w_j is the weight of the component above.

The program logic assumes the propellant weight and physical characteristics are known. It performs the weight estimation based on the above formulations with user supplied correlatio parameters, estimated gross weight and estimated landing weig An internal iteration loop cycles through the equations until convergence on gross weight is achieved. Appendix A presents listing of WAATS with the actual flow logic coded in the sub-routine MASSP.

2.3 CALCULATION OF WEIGHT COEFFICIENTS

Component weight estimation in this report is based on the po law formula:

$$W = A \cdot X^B$$

This equation form generates a straight line on log-log graph Consequently most historical data is correlated on this type paper. All available data is usually plotted against the cor tion parameter, X. A regression analysis produces a mean lin (s) through the data. The coefficients A and B are then dete The data in Section 3 presents the historical data, the trend from the regression analysis and the coefficients.

Frequently, however, the WAATS user desires to alter the tren line based on data for a vehicle more like to his study vehic This results a change in the coefficients. A method for determination of the adjusted coefficients is presented below.

If a new line is above or below the existing line, the A coefficient is simply scaled by the ratio of any two values lying on the two lines at the same value of the X correlation parameter:

$$\frac{A\ \text{new}}{A\ \text{old}} = \frac{W\ \text{new}\ @\ X}{W\ \text{old}\ @\ X}$$

The B exponent does not change since the "slope" or trend has nc changed. If the alteration of the "slope" or trend is indicatec the following procedure may be employed in the calculation of A and B.

Consider two correlation points, X_1 and X_2 and the correspondinc weight values W_1 and W_2 on the log-log graph paper. The value of B for a straight line through the two points is:

$$B = \frac{\log\ (W_2/W_1)}{\log\ (X_2/X_1)}$$

The logarithm may be any base. Suppose the two chosen points aı N cycles apart, the formula becomes:

$$B = \frac{\log\ (W_2/W_1)}{N},$$

if base 10 logarithm is employed in the numerator. The formula for natural logarithm is:

$$B \cong \frac{\ln\ (W_2/W_1)}{2.303\ N}$$

The A coefficient can be determined by substitution

$$A = \frac{W_i}{X_1^B} = \frac{W_2}{X_2^B}$$

Using the above equation, the WAATS user can establish any weigh trend line desired based on new or existing data within this report.

3.0 WAATS PROGRAM FORMULATION

Program WAATS computes approximate flight vehicle mass properti based on the statistics of past designs. This technique is bas on:

1. Correlation of past vehicle mass and volume properties against physically significant parameters.

2. Regression analysis of the correlations to provide an analytic model for flight vehicle mass properties.

The program operates at the subsystem and major component level The subsystem breakdown employed is:

1. Aerodynamic surfaces.
2. Body structure.
3. Induced environment protection.
4. Launch and recovery.
5. Main propulsion
6. Orientation controls and separation system.
7. Surface controls.
8. Power supply, conversion and distribution.
9. Avionics.
10. Crew systems.
11. Design reserve (contingency)
12 Personnel
13. Crew and life support systems and residuals.
14. Propellants.

Each subsystem is broken down into major components. For examp aerodynamic surfaces are broken down into four components:

1. Wings.
2. Vertical fin.
3. Horizontal stabilizer.
4. Fairings, shrouds and associated structure.

Each subsystem and subsystem component weight and estimating relationship used is presented in the following sections.

The WAATS computer program and the correlation data is present for most weight components in English Units. The following ta may be used or can be used to obtain International (SI) Units:

To Convert	To	Multiply By
Pounds	Kilograms	0.454
Feet	Meters	0.3048
Gallons	Liters	3.79

3.1 AERODYNAMIC SURFACES

The total weight of the aerodynamic surface group is given by

WSURF = WWING + WVERT + WHORZ + WFAIR

where WWING = wing weight
WVERT = vertical fin weight
WHORZ = horizontal tail weight
WFAIR = aerodynamic fairing weight

Expressions for each of these component weights are presented below.

3.1.1 Wing

The wing weight equation calculates an installed structural wing weight including control surfaces and carry through. The weight is calculated as a function of load and geometry.

```
WWING = AC(1) *(WTO*XLF*STSPAN*SWING/TROOT)**AC(78)*1.E-6
      + AC(2) *SWING + AC(3)
      + AC(117)*(WLAND*XLF*STSPAN*SWING/TROOT*1.E-9)
                                              **AC(118)
```

where WWING = total structural wing weight, lbs.
WTO = gross weight, lbs.
WLAND = landing weight, lb.
XLF = ultimate load factor
STSPAN= structural span (along .5 chord), ft.
SWING = gross wing area, $ft.^2$
TROOT = theoretical root thickness, ft.
AC(1) = wing weight coefficient
AC(78)= wing weight exponent
AC(2) = wing weight coefficient (f(gross area)), lbs/f
AC(3) = fixed wing weight, lbs.
AC(117) = wing weight coefficient F(WLAND)
AC(118) = wing weight exponent F(WLAND)

The data in Figures 3.1-1 and 3.1-2 represent wings that are basically constructed of aluminum and wings that are basically constructed of high temperature materials (steel and inconel), respectively. The latter data is also representative of supersonic wings with t/c values in the order of 3 to 3 1/2%. For variable sweep wing designs the various wing input terms should be based on the fully swept position. The AC(1) coefficient should then be increased by 15 to 20 per cent to account for the structural penalty for sweeping the wing forward. The user has an option of adding or removing a wing weight penalty on the basic wing calculation. An example would be to add a fixed weight per square foot for thermal

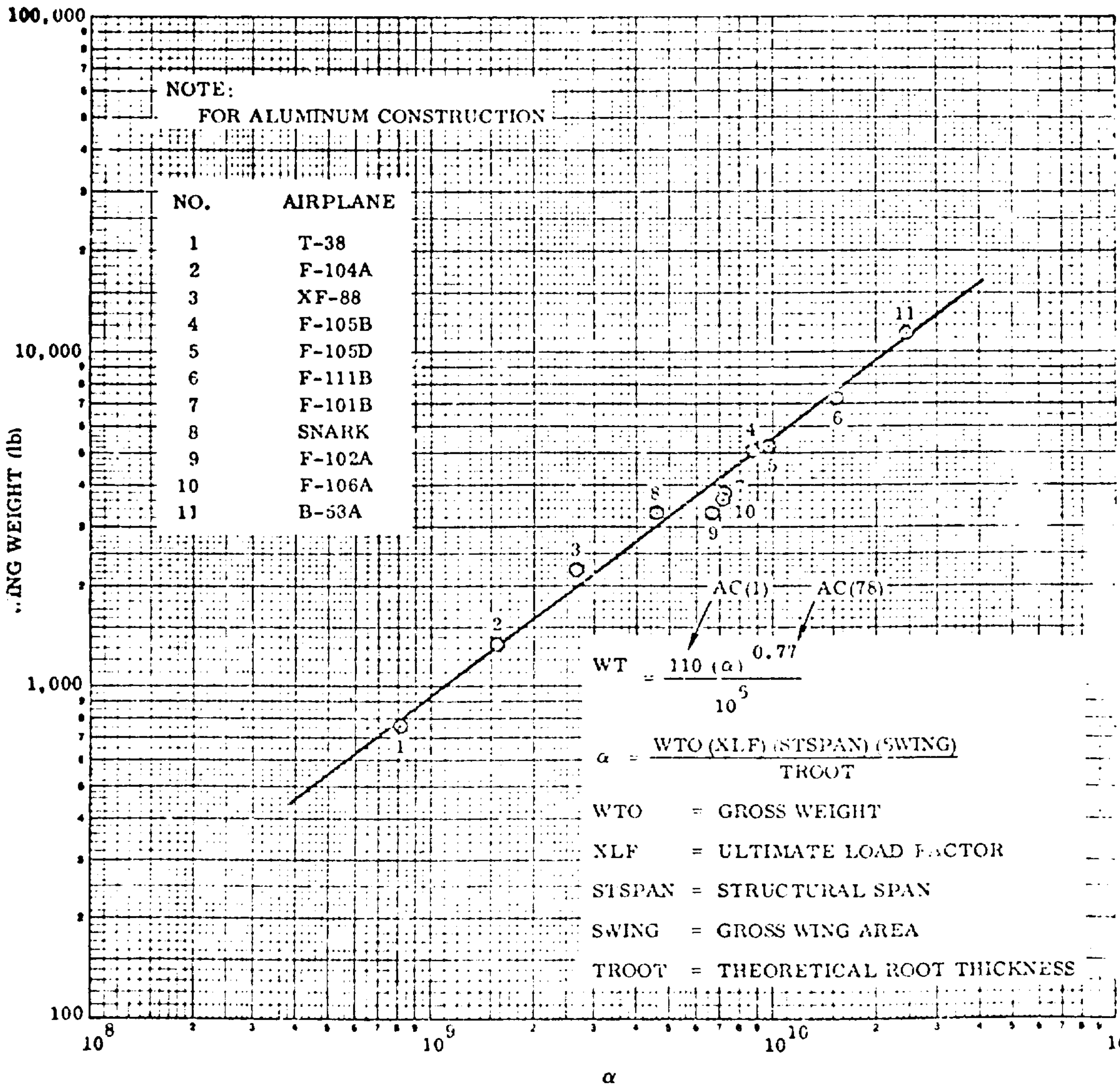


Figure 3.1-1 Wing weight for high speed aircraft - Aluminum construction

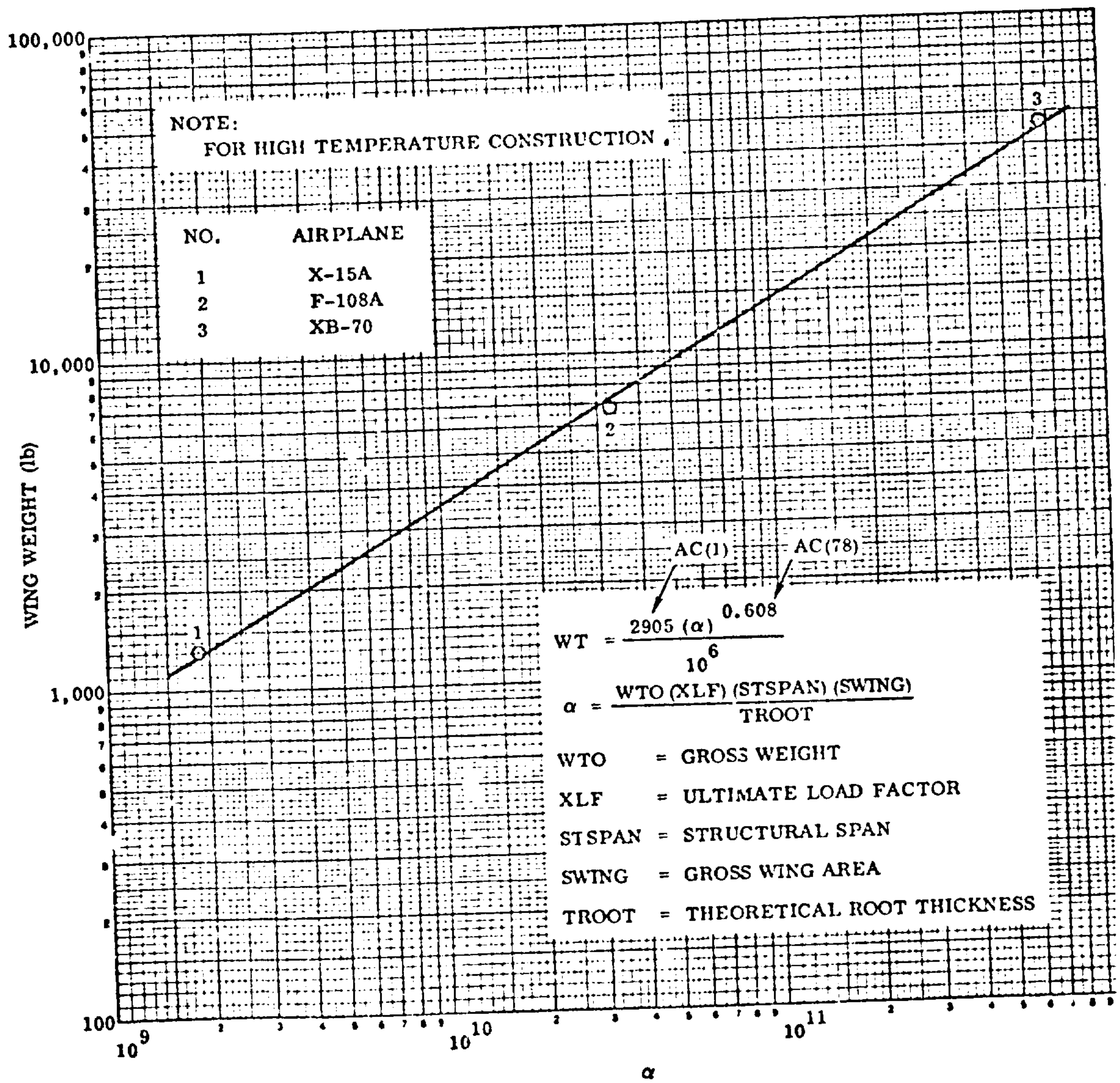


FIGURE 3.1-2 WING WEIGHT FOR HIGH SPEED AIRCRAFT HIGH TEMPERATURE CONSTRUCTION

protection system structure or high temperature resistant coatings. The coefficient AC(3) is to input a fixed weight to the wing calculation. AC(117) and AC(118) provide the user with the capability of weighing the wing on the basis of landing weight as is often done for reentry vehicles, Figure 3.1-3. The data are based on straight, swept and delta designs.

3.1.2 Vertical Fin

The vertical fin weight includes the weight of the control surface. The weight is calculated as a logarithmic function of surface area. The equation for vertical fin weight is:

WVERT = AC(4) * SVERT ** AC(89) + AC(5)

where
WVERT = total vertical fin weight, lbs
SVERT = vertical fin planform area, ft^2
AC(4) = vertical fin weight coefficient
AC(89)= vertical fin weight exponent (slope)
AC(5) = fixed vertical fin weight, lbs.

Correlation curves for vertical fin are shown in Figures 3.1-4 and 3.1-5.

The data of Figure 3.1-4 is based on Mach 2 type airplanes. They include aluminum, steel and inconel fin materials. It is assumed to be representative of the best type construction for the Mach 0.6 to 2.0 range. The data, as shown, does not include allowances for thermal protection system weight.

The data of Figure 3.1-5 are based on low to moderate speed straight and swept-wing aircraft.

3.1.3 Horizontal Stabilizer

The horizontal stabilizer weight includes the weight of the control surface. The weight is calculated as a function of weight/wing area, stabilizer planform area and dynamic pressure. The equation for horizontal stabilizer weight is

WHORZ = AC(6) * ((WTO/SWING) ** .6 * SHORZ ** 1.2 *QMAX
**.8) ** AC(90) + AC(7) + AC(119) * ((WLAND/SWING)
** .6 * SHORZ ** 1.2 * QMAX ** .8) ** AC(120)

where
WHORZ = total horizontal stabilizer weight, lbs.
WTO = gross weight, lbs.
WLAND = landing weight
SWING = gross wing area, ft^2
SHORZ = horizontal stabilizer planform area, ft^2
QMAX = maximum dynamic pressure, lbs/ft^2

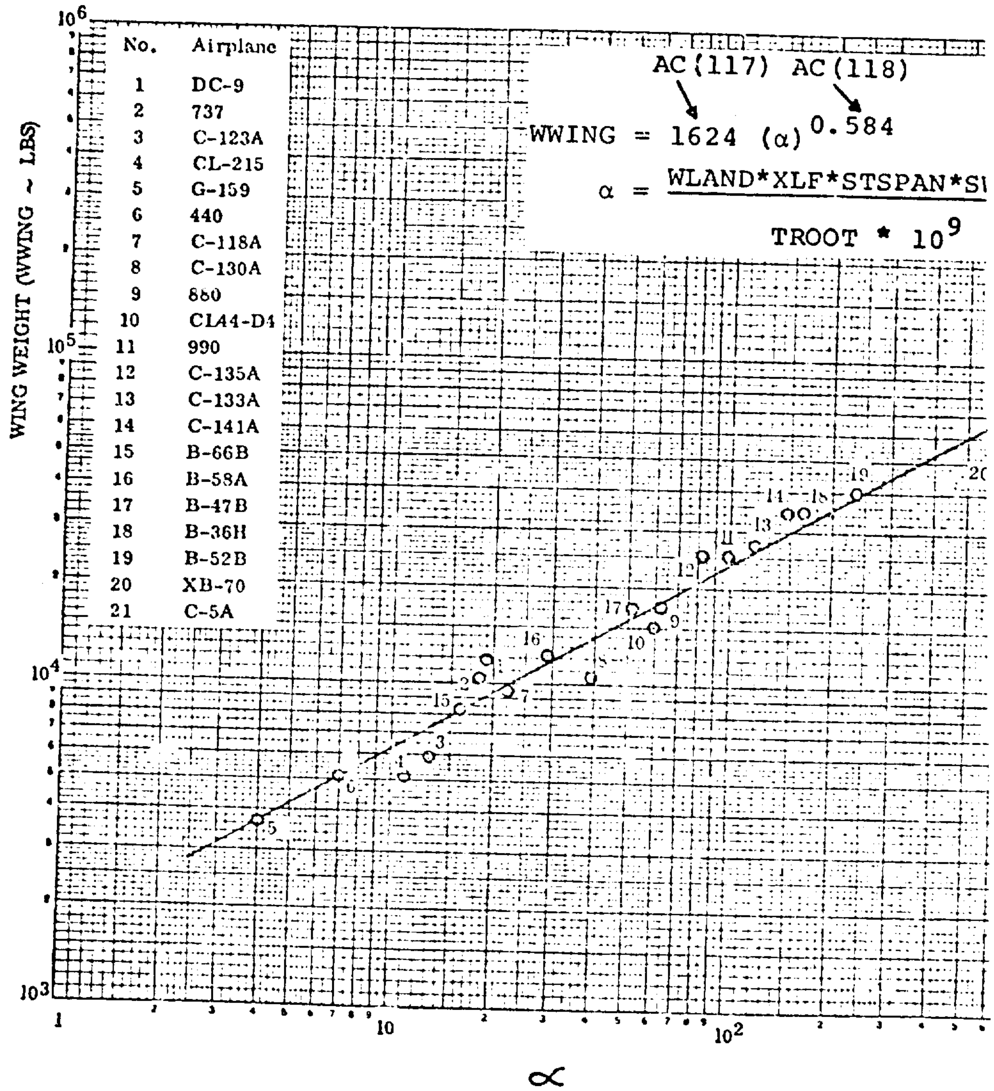


FIGURE 3.1-3 WING WEIGHT FOR LOW TO MODERATELY SWEPT WING AIRCRAFT

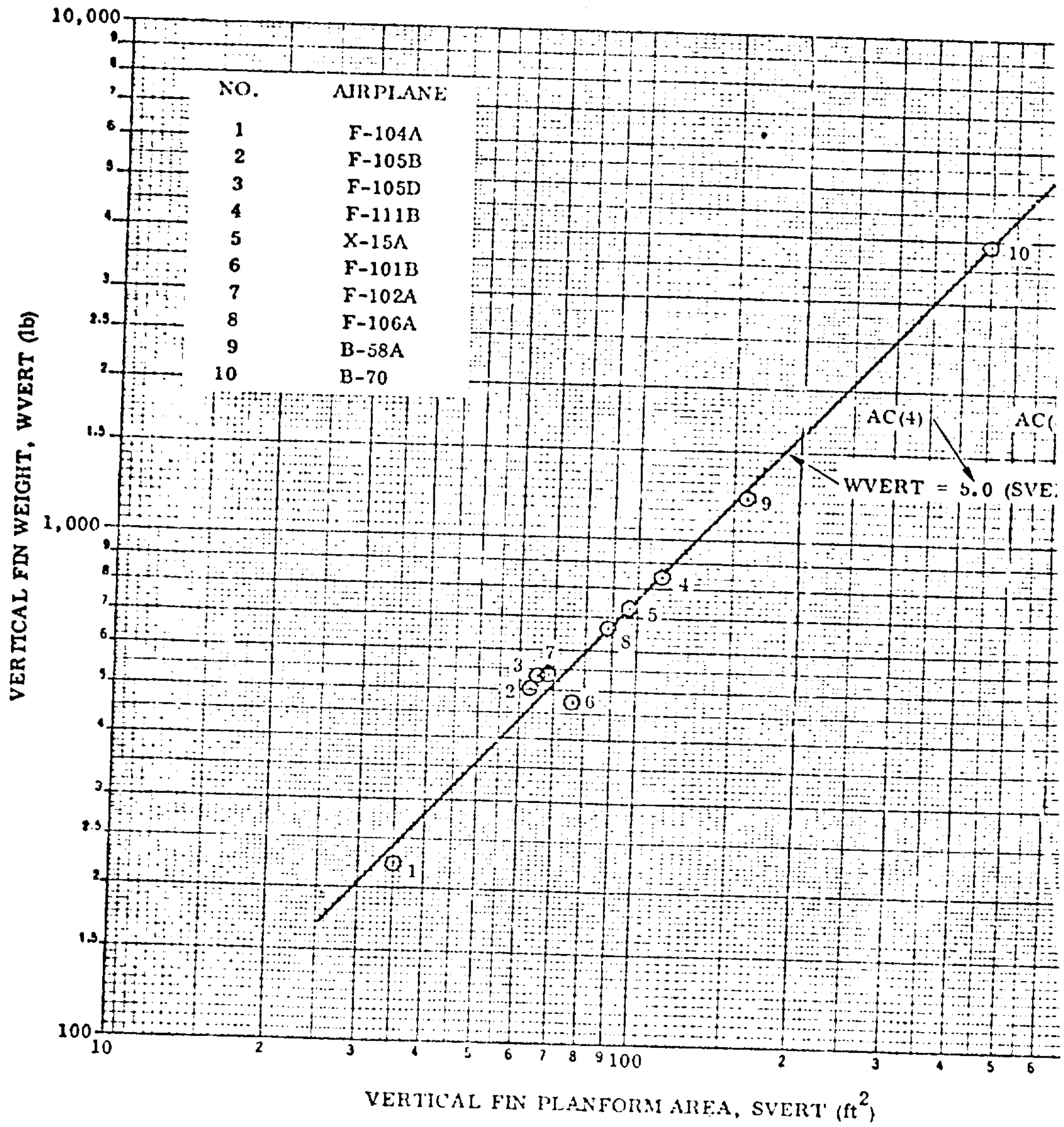


FIGURE 3.1-4 VERTICAL FIN WEIGHT FOR HIGH SPEED AIRCR

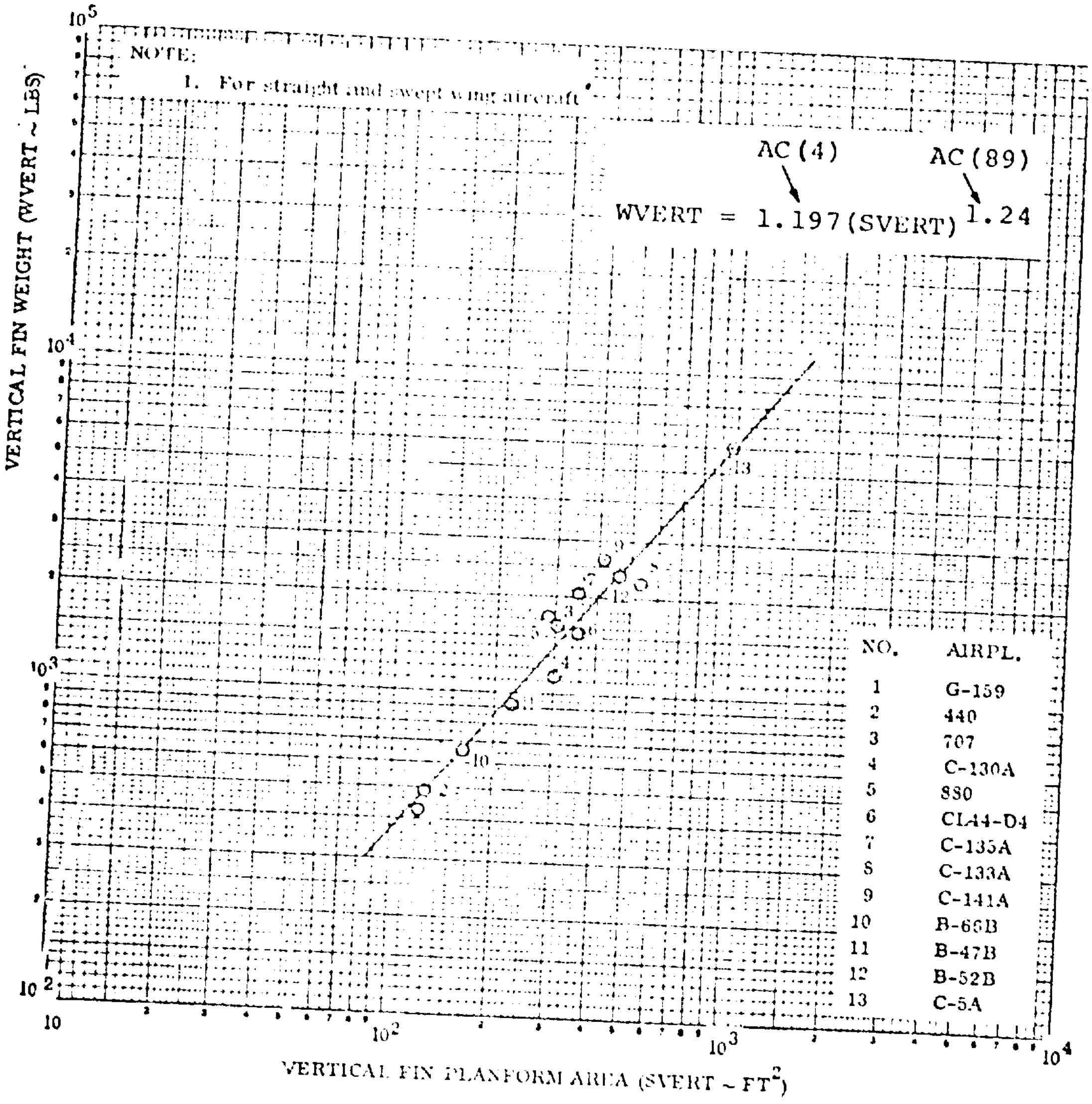


FIGURE 3.1-5 VERTICAL FIN WEIGHT FOR STRAIGHT AND SWEPT WING AIRCRAFT

AC(6) = horizontal stabilizer weight coefficient F(WTO)
AC(90) = horizontal stabilizer weight exponent F(WTO)
AC(7) = fixed horizontal stabilizer weight, lbs
AC(119) = horizontal stabilizer weight coefficient F(WLAND)
AC(120) = horizontal stabilizer weight exponent F(WLAND)

The horizontal stabilizer weight data is presented in figure 3.1-6 and 3.1-7. The data includes aluminum and inconel stabilizer materials. The data, as shown, does not include allowances for thermal protection system weight.

3.1.4 Fairings, Shrouds and Associated Structure

The type of aerodynamic structures included in this section are aerodynamic shrouds, equipment, dorsal, landing gear and canopy fairings. The canopy fairing is the structure aft of the canopy that is required to fair the canopy to the body. The weight of the canopy proper is included in body secondary structure. Wing to body fairings are included in the wing weights. Horizontal or vertical surface to body fairings are included in either the horizontal or vertical surface weight. Other types of fairing and shroud weight may be determined from their surface area and the operating environment and is given in the program as

WFAIR = AC(8) * SFAIR + AC(9)

where WFAIR = total weight of fairings or shrouds, lbs
SFAIR = total fairing or shroud surface area, ft^2
AC(8) = unit weight of fairing or shroud, lbs/ft^2
AC(9) = fixed weight of fairing or shroud, lbs

If the design loads and the fairing geometry is known, the weight in lbs/ft^2 (i.e., the coefficient AC(8) can be found by calculation. In most cases, however, empirical or statistical data has to be used. The coefficient AC(8) can be found by multiplying an empirical unit weight WF by a factor to account for dynamic pressure and temperature differences.

AC(8) = WF · KQ · KT

where WF = fairing weight factor, Table 3.1-1
KQ = fairing dynamic pressure coefficient, Figure 3.1-8
KT = fairing temperature coefficient, Figure 3.1-9

The factor KQ is shown plotted against dynamic pressure in Figure 3.1-8. This factor is 1.0 at a dynamic pressure of 400 lbs/ft^2. The factor KT is shown plotted versus temperature in Figure 3.1-9. The factor is 1.0 at a temperature of $400^{o}F$.

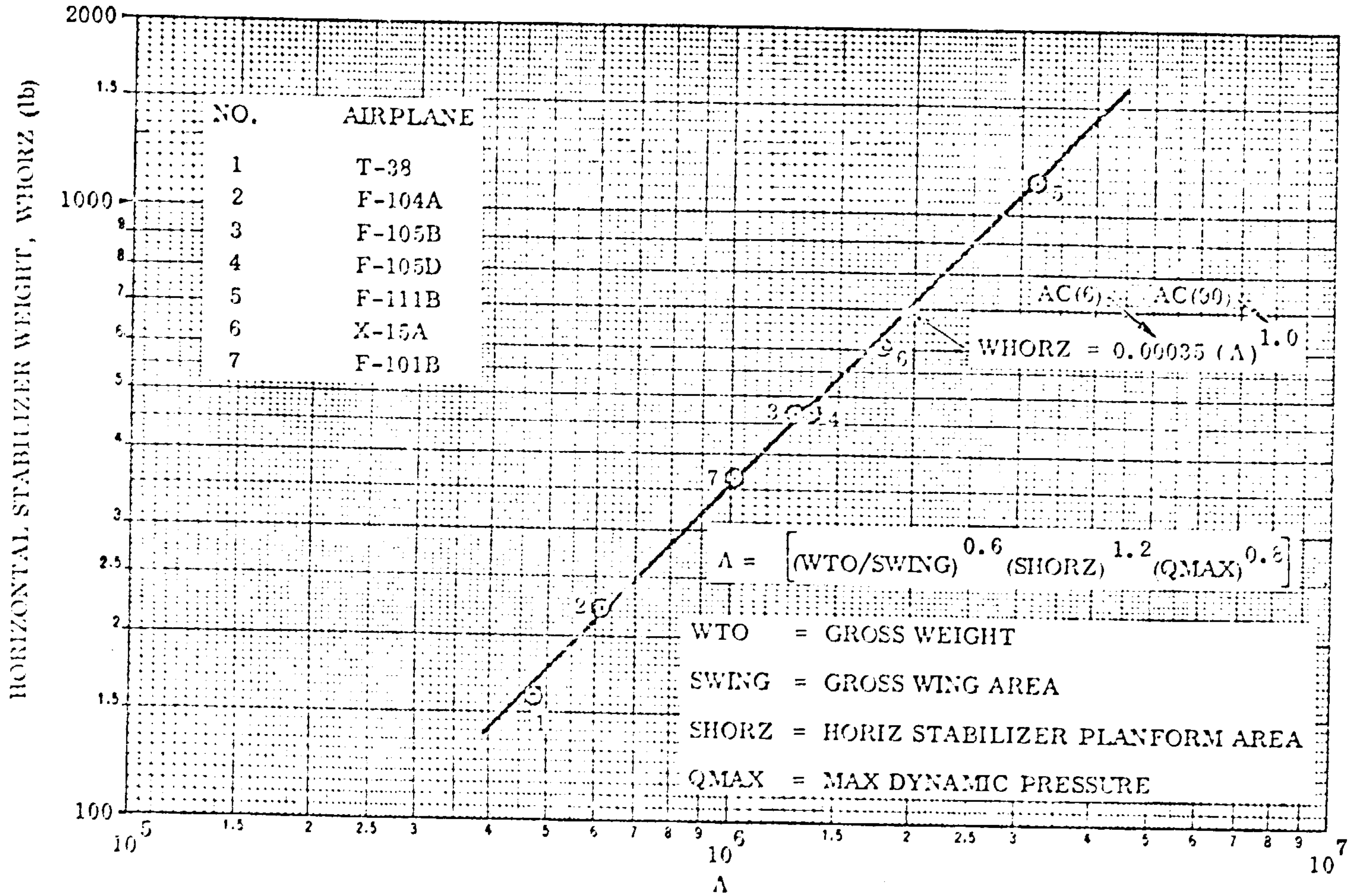


FIGURE 3.1-6 HORIZONTAL STABILIZER WEIGHT FOR HIGH SPEED AIRCRAFT

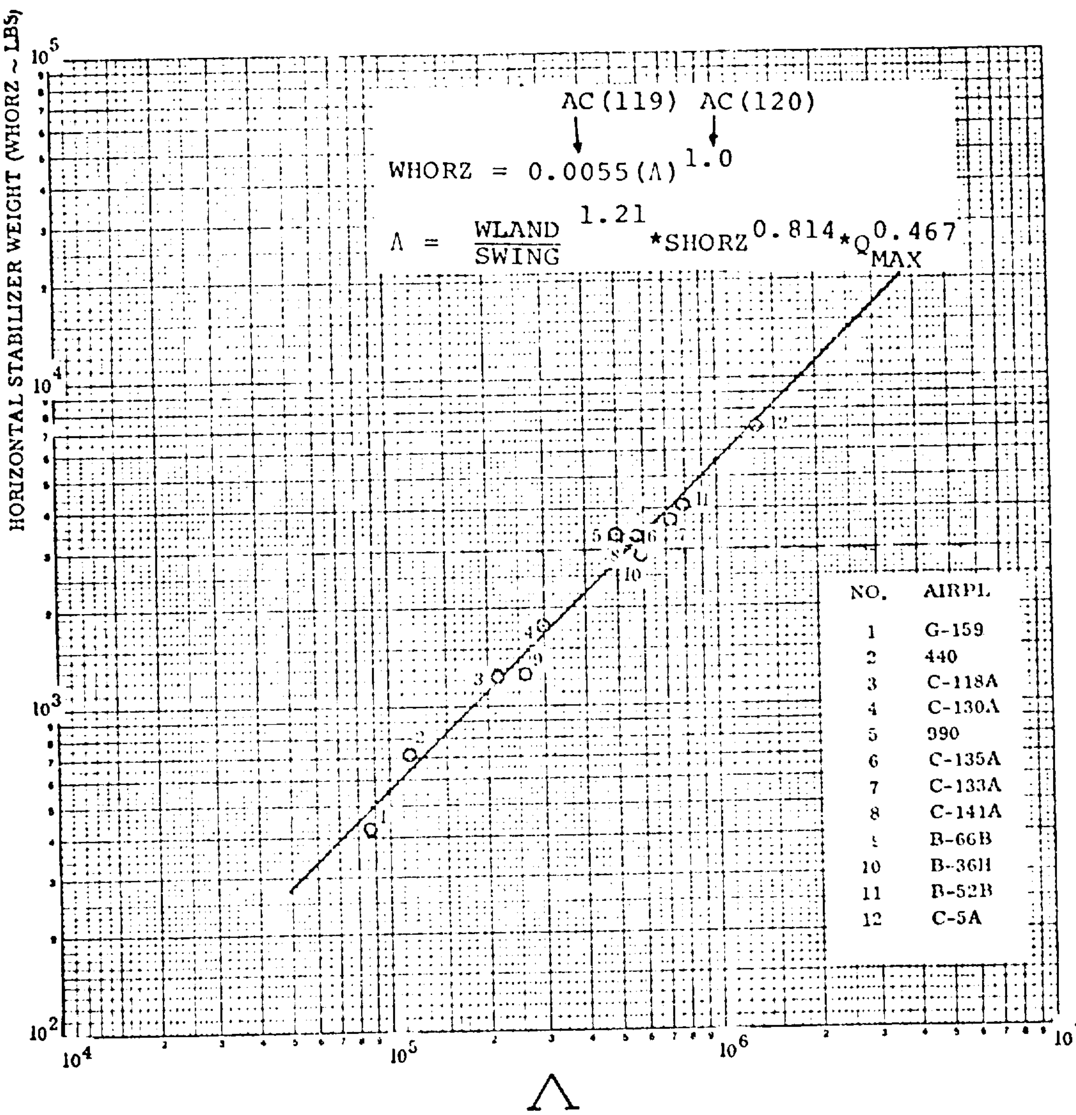


FIGURE 3.1-7 HORIZONTAL STABILIZER WEIGHT FOR LOW SPEED AIRCRAFT

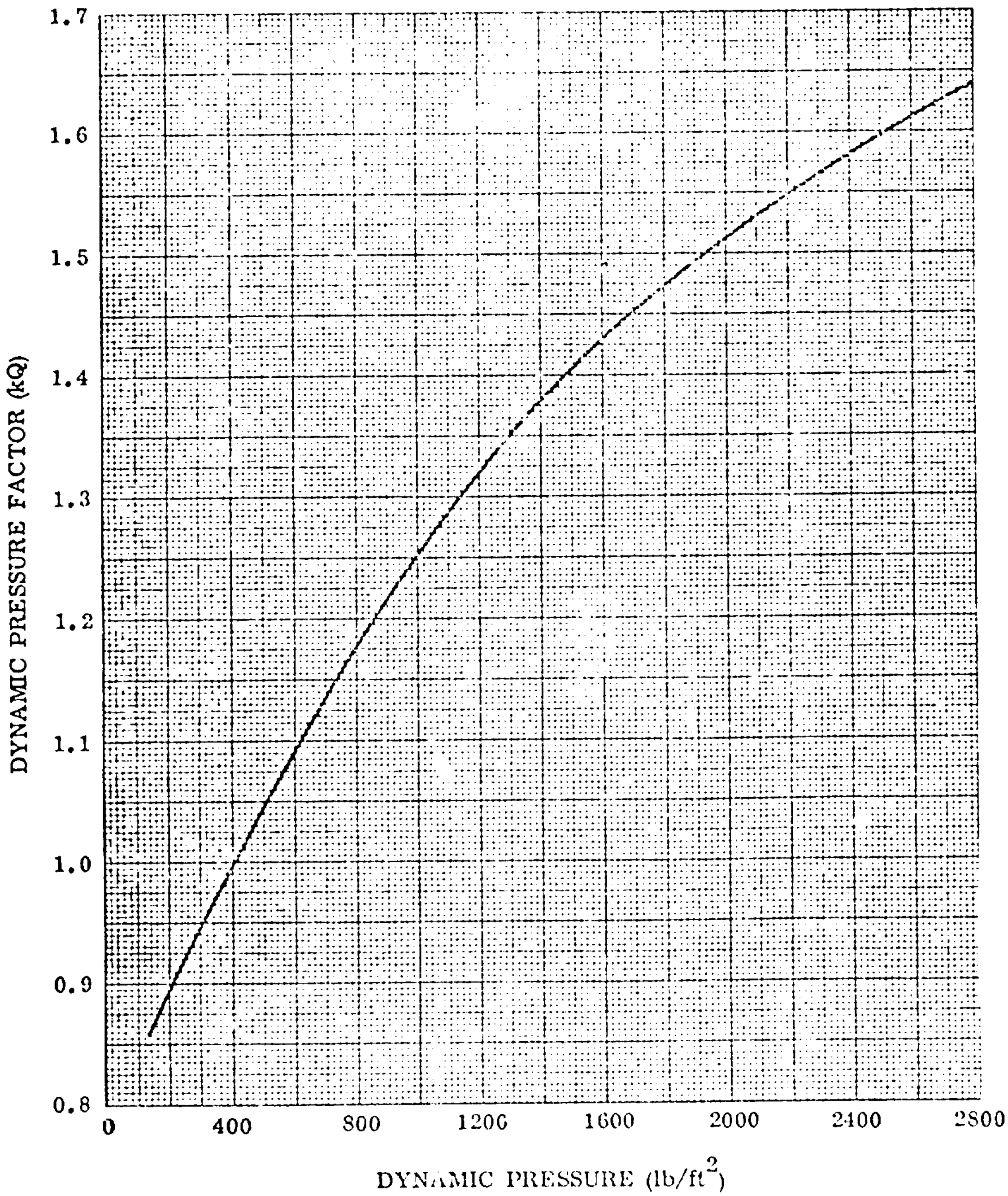


FIGURE 3.1-8 FAIRING DYNAMIC PRESSURE COEFFICIENT

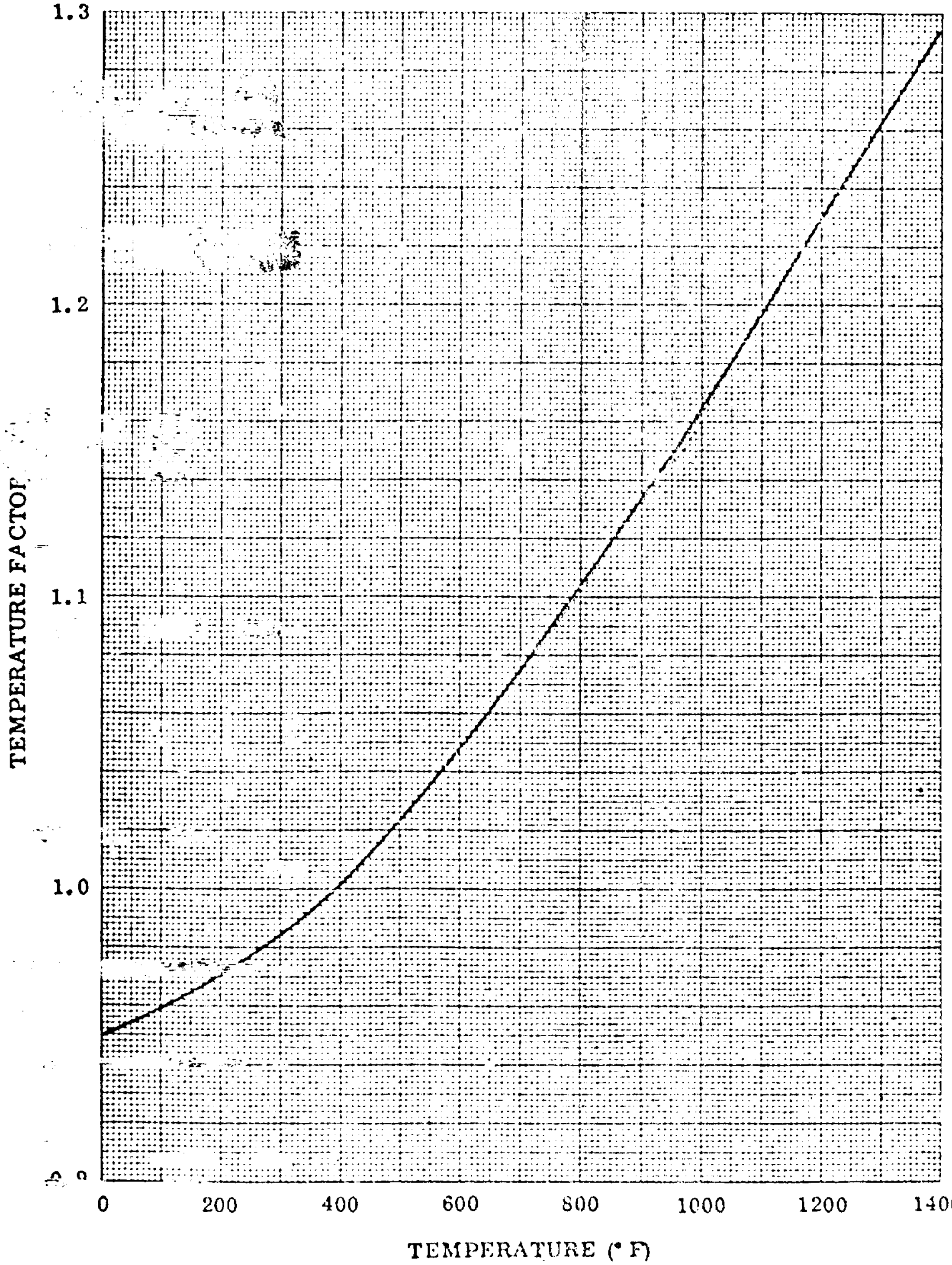


FIGURE 3.1-9 FAIRING TEMPERATURE COEFFICIENT

The unit weight of typical fairings WF is shown in Table 3.1-1. These unit weights have been normalized to a Q o 400 lbs/ft^2 and 400^{o}F. In addition, this table shows a recommended AC(8) input for different types of fairings at a Q of 1000 lbs/ft^2 and a temperature of 800^{o}F.

The coefficient AC(9) is used for those portions of the fairings that have weight not dependent on fairing sizin or it may be used either as a contingency or for a fixed input weight for the fairings.

Table 3.1-1 Typical Fairing Weights

Fairing Type	WF at Q = 400 lbs/ft^2 and T = 400^{o}F	AC(8) at Q = 1000 lbs/ft and T = 800^{o}F
Aerodynamic Shroud	4.80	6.6
Canopy Fairing	4.00	5.5
Equipment Fairing	1.50	2.06
Dorsal Fairing	2.00	2.75
Cable Fairing	1.50	2.06
Landing Gear Fairing	2.00	2.75

3.2 BODY STRUCTURE

The total weight of the aircraft body group is given by

WBODY = WBASIC + WSECST + WTHRST + WINFUT + WINOXT

where WBASIC = basic body weight
WSECST = secondary structure weight
WTHRST = thrust structure weight
WINFUT = installed fuel tank weight
WINOXT = installed oxydizer tank weight

Expressions for each component weight are given below. The weight of booster as well as aircraft type body structures can be estimated.

3.2.1 Basic Body Structure

The vehicle body weight equation is based upon correlating the actual weight of existing hardware with significant load, geometry and environmental parameters. For vehicles of an advanced nature, modifying factors based upon design studies of cruise vehicles are applied to the basic data to account for the expected advances in technology and more severe environment. Equations derived from existing data includes non-optimum factors which are difficult to justify by analytical procedures. These non-optimum factors are important weight items, as shown by the weight growth of many vehicles between the initial concept and the finished hardware.

The equation used for basic body weight is

```
WBASIC = AC(14) * SBODY + AC(15)*((ELBODY*XLF/HBODY)
         **.15 * QMAX ** .16 * SBODY **1.05) ** AC(81)
         + AC(16)
```

where WBASIC = total weight of basic body, lbs
SBODY = total body wetted area, ft^2
XLF = ultimate load factor
ELBODY = body length, ft
QMAX = maximum dynamic pressure, lbs/ft^2
HBODY = body height, ft
AC(14) = basic body unit weight, lbs/ft^2
AC(15) = basic body weight coefficient (intercept)
AC(81) - basic body weight coefficient (slope)
AC(16) = fixed basic body weight, lbs

The primary function of the first part of the basic body equation, AC(14) * SBODY allows a weight penalty based upon a constant unit weight of structural area without involving the parameters used in the second part of the overall equation. The second part of the equation obtains the basic body weight using design and geometry parameters. The basic body weight data is shown in Figure 3.2-1. Since the data is for aluminum structure, operating at temperatures of 250°F, a modifying factor must be used with AC(15) for other materials and temperatures. The modifying factor (MF) is obtained from Figure 3.2-2. The AC(15) obtained from Figure 3.2-1 is multiplied by the modifying factor (MF) to obtain the input for aluminum, titanium or Rene' 41 at elevated temperatures.

$$AC(15)_{actual} = AC(15)\ \text{Fig. 3.2-2} \times MF$$

3.2.2 Body Secondary Structure

Secondary structure includes windshields, canopy, landing gear doors, flight opening doors and speed brakes. If a weight estimate based upon analysis is available, it should be used in lieu of the following data.

The equation for calculating secondary structure is

WSECST = AC(17) * SBODY + AC(18)

where WSECST = weight of body secondary structure, lbs
SBODY = total body wetted area, ft^2
AC(17) = secondary structure unit weight, lbs/ft^2
AC(18) = fixed secondary structure weight, lbs

The body secondary weight coefficient AC(17) varies from 0.58 to 1.38. If specific design detail is not available, an average value of 0.98 may be used for the AC(17) coefficient However, if any design detail is available, the coefficient should be tailored using the data shown in Table 3.2-1 as a guideline.

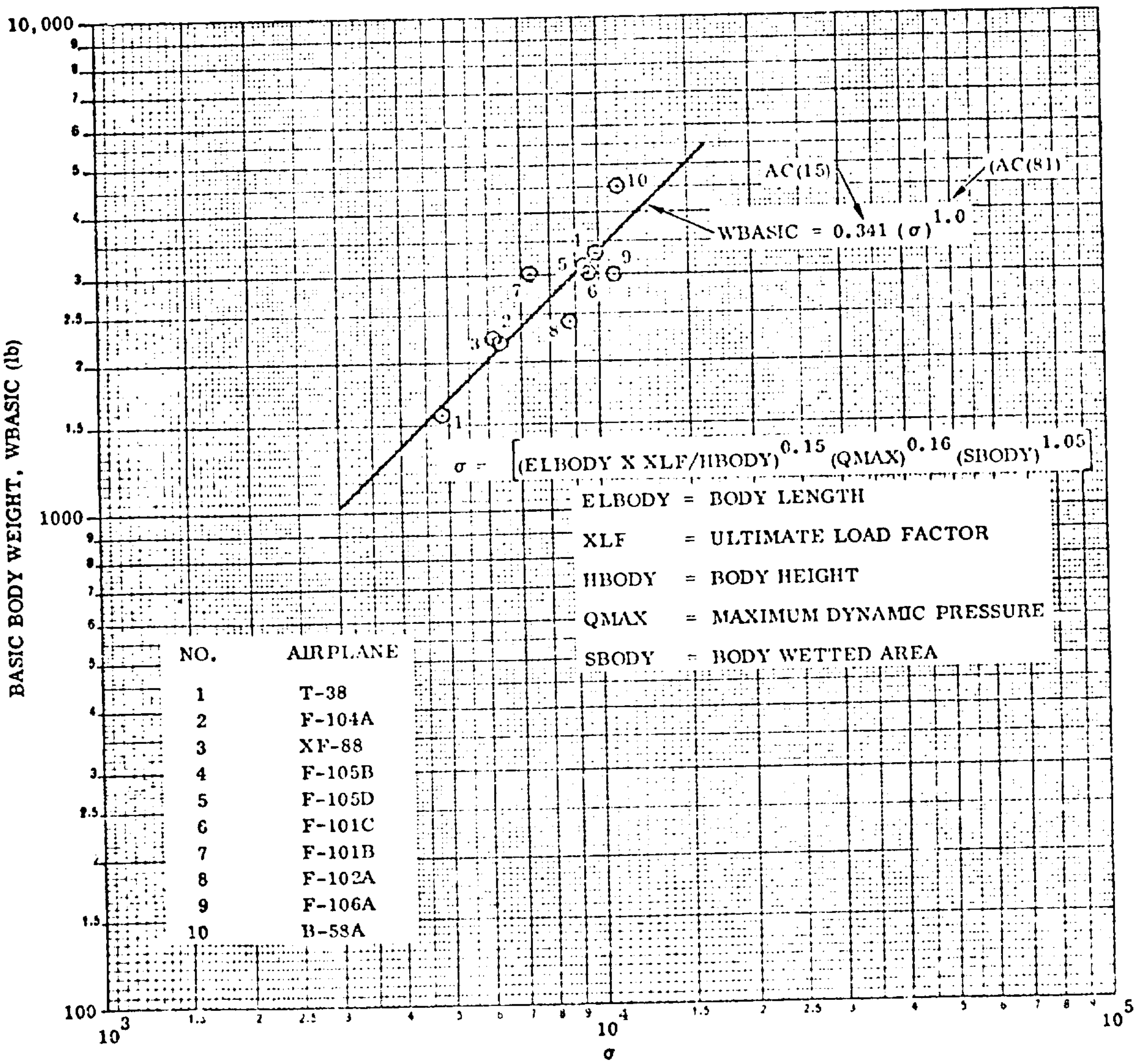


FIGURE 3.2-1 BASIC BODY WEIGHT FOR HIGH SPEED AIRCRAFT

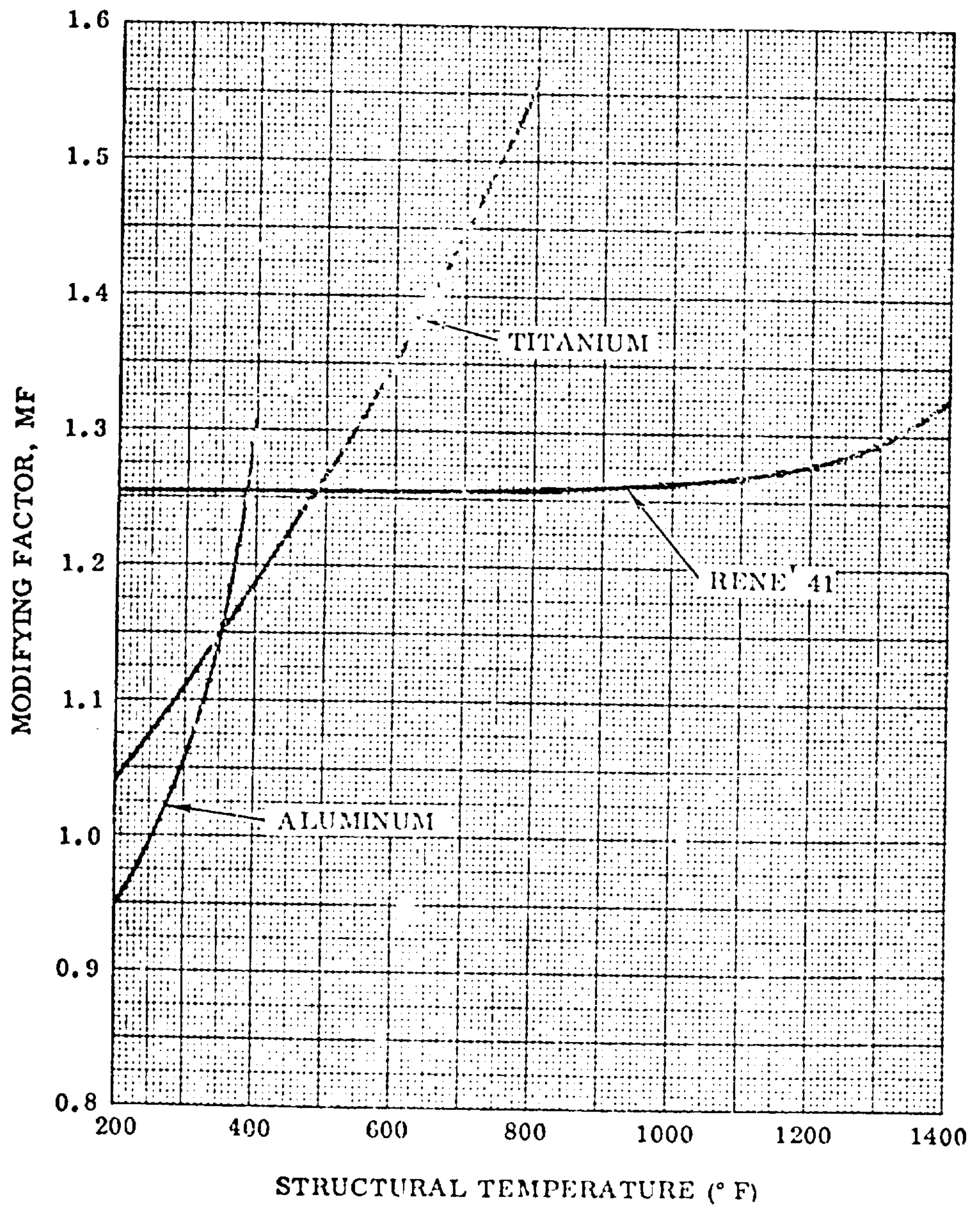


FIGURE 3.2-2 MODIFYING FACTOR FOR BASIC BODY WEIGHT COEFFICIENT

Table 3.2-1 Guidelines for Estimating AC(17)

No.	Airplane	Nose Gear Door	Windshield and Canopy	Main Gear Doors	Flight Opening Doors	Speed Brakes	Total Secondary Structure	Body Wetted Area	AC(17)
1	T-33	20	266	42	0	53	451	533	0.90
2	F-104A	21	168	197	0	37	403	669	0.60
3	XF-88	32	174	177	0	31	414	715	0.58
4	F-105B	41	293	40	384	402	1190	1030	1.23
5	F-105D	35	278	169	480	402	1364	991	1.35
6	F-101C	27	251	136	407	174	995	1036	0.96
7	F-101B	25	376	127	272	250	953	827	1.15
8	F-102A	30	302	166	536	35	1059	901	1.07
9	F-106A	70	662	171	632	72	1607	1222	1.32
10	B-58A	53	486	235	0	0	806	1573	0.59

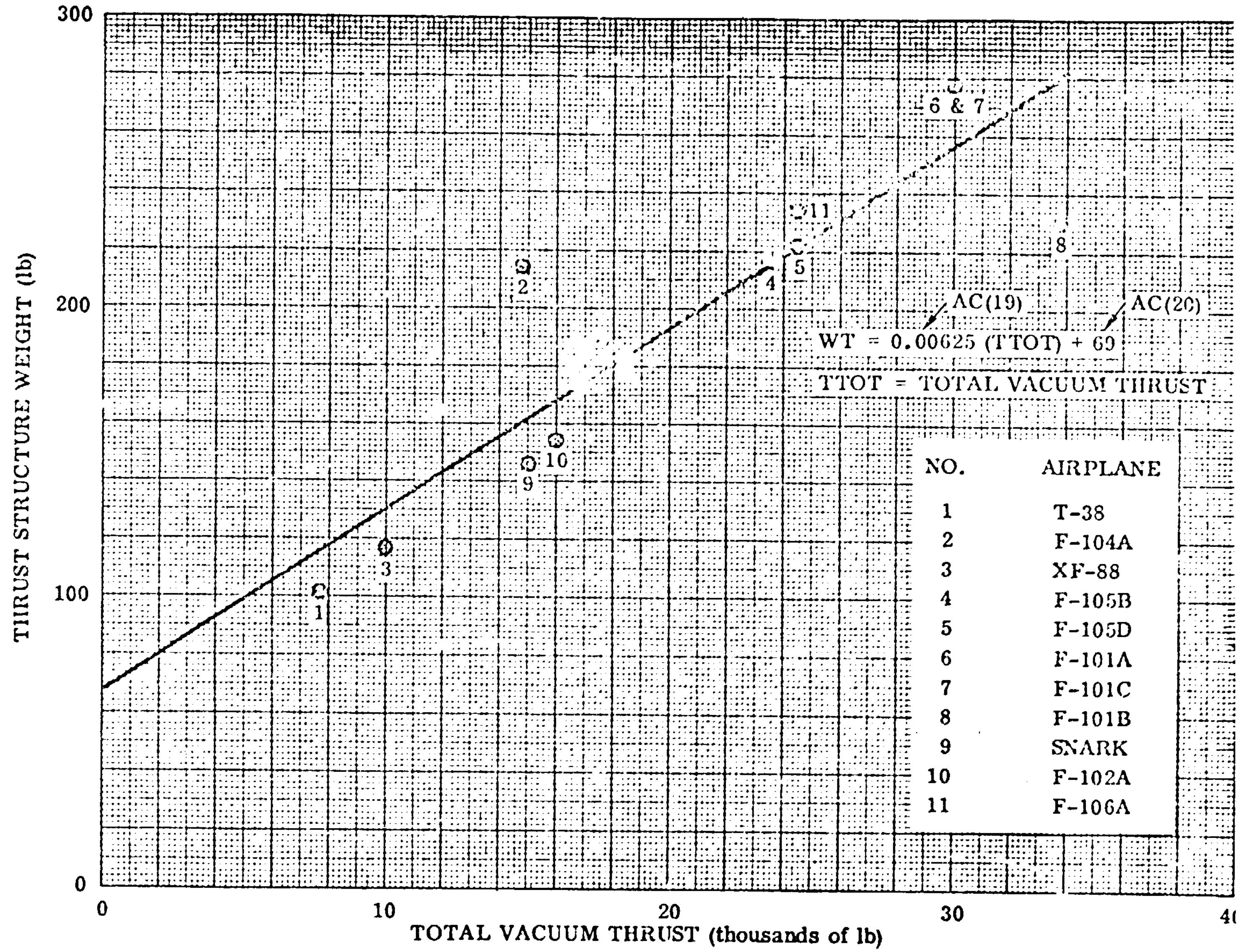
3.2.3 Thrust Structure

The thrust structure weights are a function of the total vacuum thrust of the engines. The equation used for thrust structure weight is

WTHRUST = AC(19) * TTOT + AC(20)

where
- WTHRUST = weight of thrust structure, lbs
- TTOT = total stage vacuum thrust, lbs
- AC(19) = thrust structure weight coefficient
- AC(20) = f ·ed thrust structure weight, lbs

The aircraft thrust structures are required to mount airbreathing engines and rocket engines. The airbreathing thrust structure weight coefficients AC(19) and AC(20) are obtained from Figure 3.2-3. The input for rocket engine thrust structure weight is obtained from Figure 3.2-4. The rocket engine thrust structure assumed for this data is a cone or barrel structure attached to a bulkhead.



THRUST STRUCTURE WEIGHT (lb)
300
200
100
0
0
10
20
30
40
TOTAL VACUUM THRUST (thousands of lb)
1
2
3
4
5
6 & 7
8
9
10
11
AC(19)
AC(20)
WT = 0.00625 (TTOT) + 69
TTOT = TOTAL VACUUM THRUST
NO. AIRPLANE
1 T-38
2 F-104A
3 XF-88
4 F-105B
5 F-105D
6 F-101A
7 F-101C
8 F-101B
9 SNARK
10 F-102A
11 F-106A

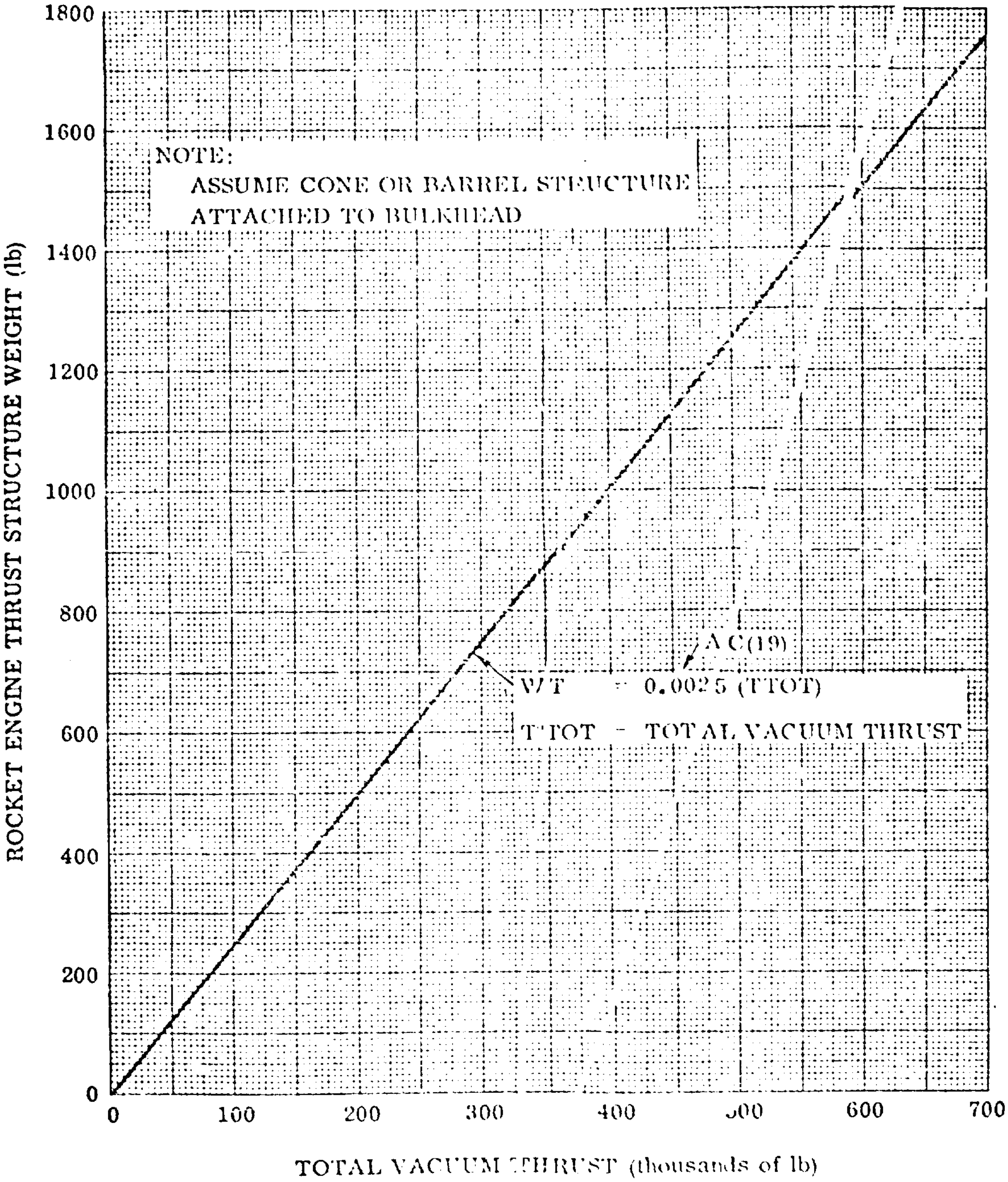


FIGURE 3.2-4 THRUST STRUCTURE WEIGHT FOR ROCKET ENGINES

3.2.4 Integral Fuel Tanks

The integral fuel tanks are sized as a function of total tank volume, including ullage and residual volume. The input coefficients are based on historical data from the Saturn family of LO_2/LH_2 vehicles. The equation for integral fuel tank weight is

WINFUT = AC(130) * VFUTK + AC(131)

where
- WINFUT = weight of integral fuel tank, lbs
- VFUTL = total volume of fuel tank, ft^3
- AC(130) = integral fuel tank weight coefficient, lbs/ft^3
- AC(131) = fixed integral fuel tank weight, lbs

The integral fuel tank weight coefficients AC(130) and AC(131) are obtained from Figure 3.2-5. When a non-Saturn type tank configuration is utilized, the coefficient AC(130) should be multiplied by a configuration factor.

3.2.5 Integral Oxidizer Tanks

The integral oxidizer tanks are sized as a function of total tank volume, including ullage and residual volume. The input coefficients are based on historical data from the Saturn family of LO_2/LH_2 vehicles. The equation for integral oxidizer tank weight is

WINOXT = AC(132) * VOXTK + AC(133)

where
- WINOXT = weight of integral oxidizer tank, lbs
- VOXTK = total volume of oxidizer tank, ft^3
- AC(132) = integral oxidizer tank weight coefficient, lbs/ft^3
- AC(133) = fixed integral oxidizer tank weight, lbs

The integral oxidizer tank weight coefficients AC(132) and AC(133) are obtained from Figure 3.2-6. When a non-Saturn type tank configuration is utilized, the coefficient AC(132) should be multiplied by a configuration factor.

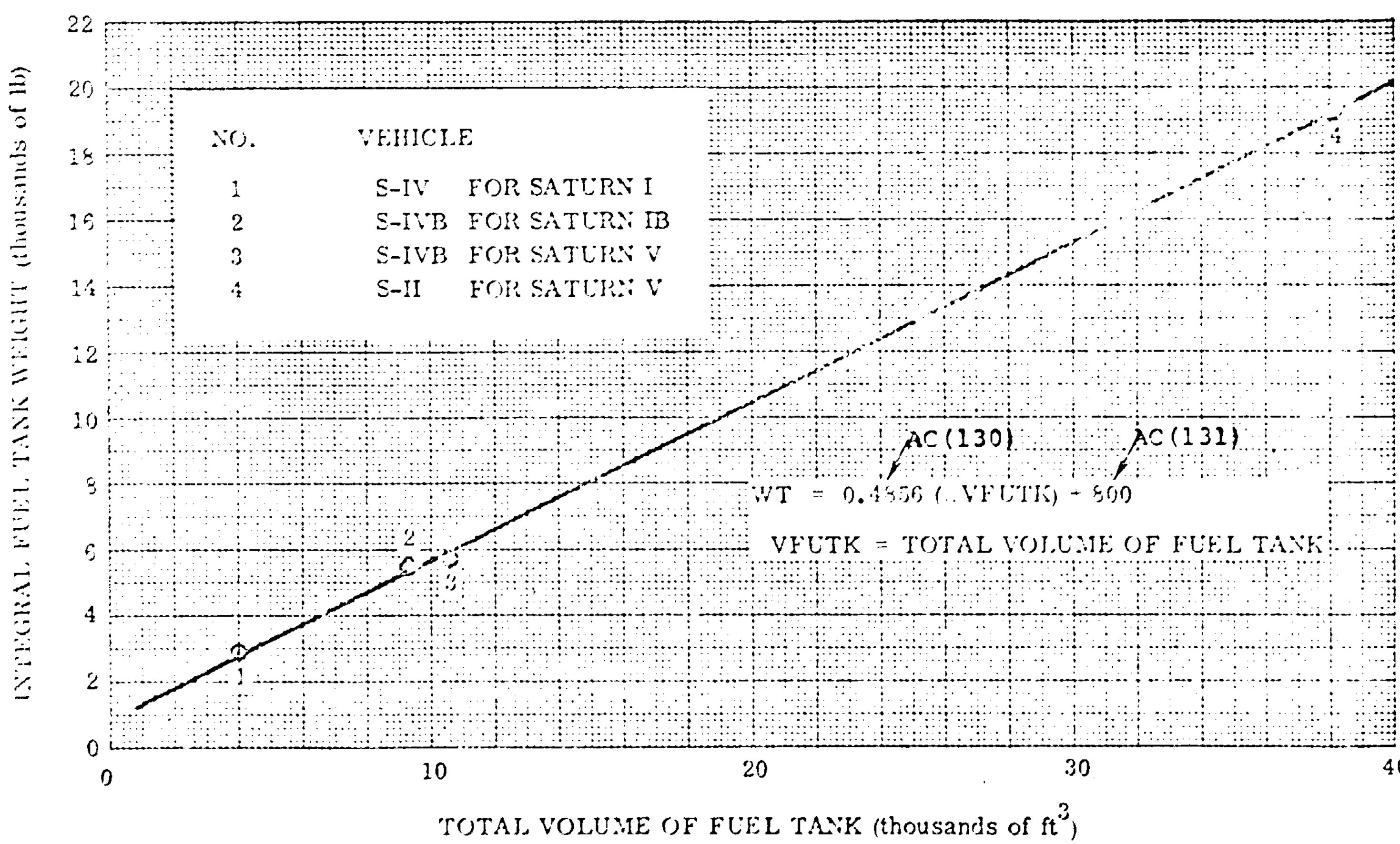


FIGURE 3.2-5 INTEGRAL FUEL TANK VOLUME

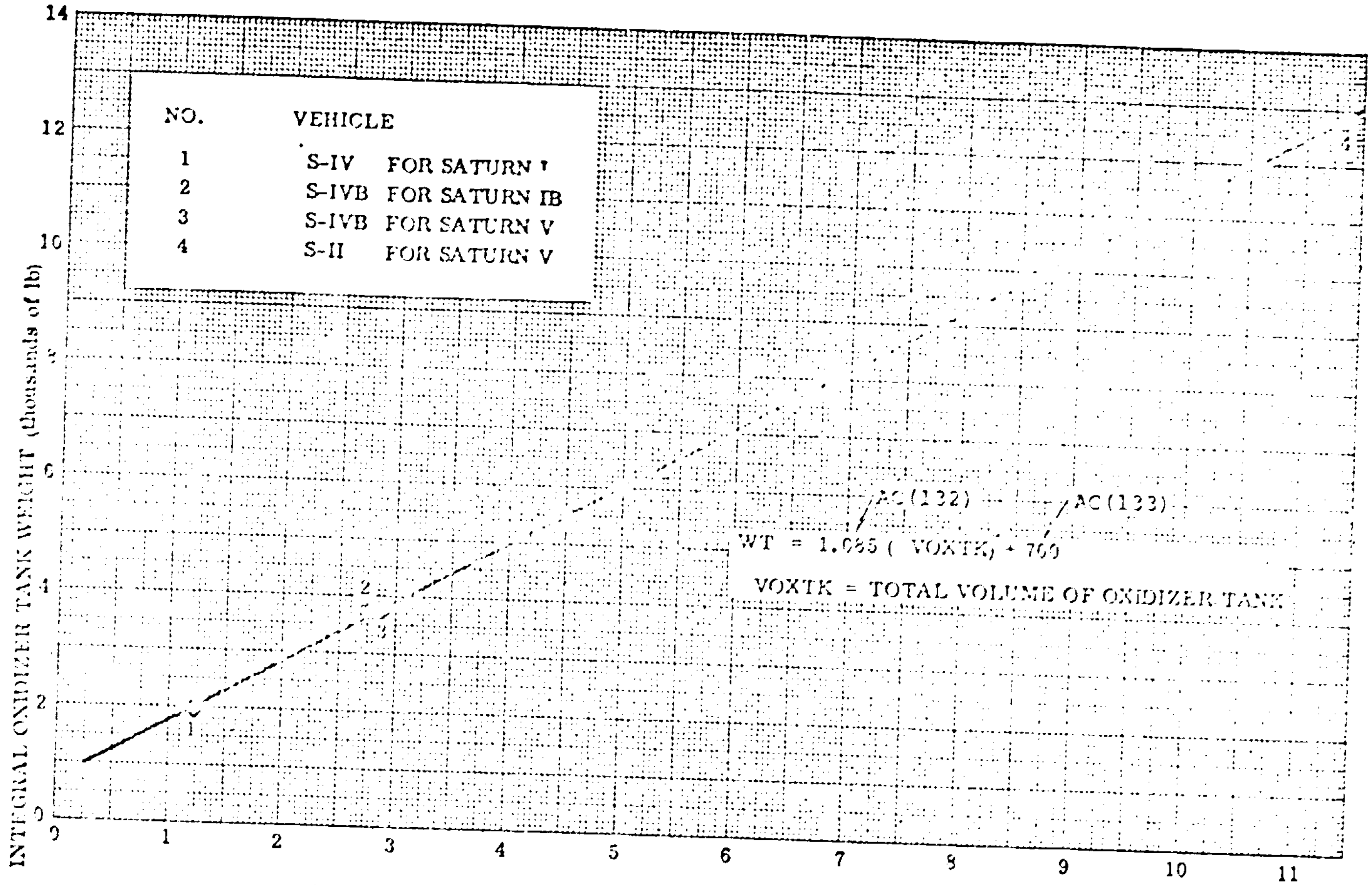


FIGURE 3.2-6 INTEGRAL OXIDIZER TANK WEIGHT

3.3 INDUCED ENVIRONMENTAL PROTECTION

The total weight of the aircraft induced environmental protection group is given by

WTPS = WINSUL + WCOVER

where WINSUL = insulation weight
WCOVER = cover plate weight

The inputs for a specific design concept are normally obtained by a thermal analysis. This method should be used when specific design conditions are known, as it yields the most accurate results accounting for all the features of a particular design. When detailed knowledge of a design is not available, generalized data is given based upon the results of prior design studies. The data presented is simplified for use in generalized aircraft weight/sizing. The results do not replace a detailed thermal analysis.

A radiative protection system to hold structural temperatures within acceptable limits is the type of vehicle thermal protection system considered for this study. This system utilizes radiative cover panels with or without insulation.

3.3.1 Insulation

When insulation is used, it assumes that the structural temperature is held to approximately 200°F. The insulation must then be protected from the flight conditions by radiative cover panels. The equation for the insulation weight is

WINSUL = AC(21) * STPS + AC(76)

where WINSUL = total weight of TPS insulation, lbs
STPS = total TPS surface area, ft^2
AC(21) = insulation unit weight, lbs/ft^2
AC(76) = fixed insulation weight, lbs

The coefficient AC(21) is an insulation unit weight that may be obtained as a function of surface temperature from Figure 3.3-1. The user must estimate the surface temperature that will be encountered in order to input the coefficient AC(21). The data shown in Figure 3.3-1 is based on microquartz insulation for a 1.0 hour time duration. The three curves represent allowable heating rates of 100, 400, and 700 Btu/ft^2 with the structural temperature being held to approximately 200°F. The area of the aircraft which is to be covered by insulation is specified in the input data as discussed in Section 4. Figure 3.3-2 presents data for estimating C(21) based on 30-minute time duration.

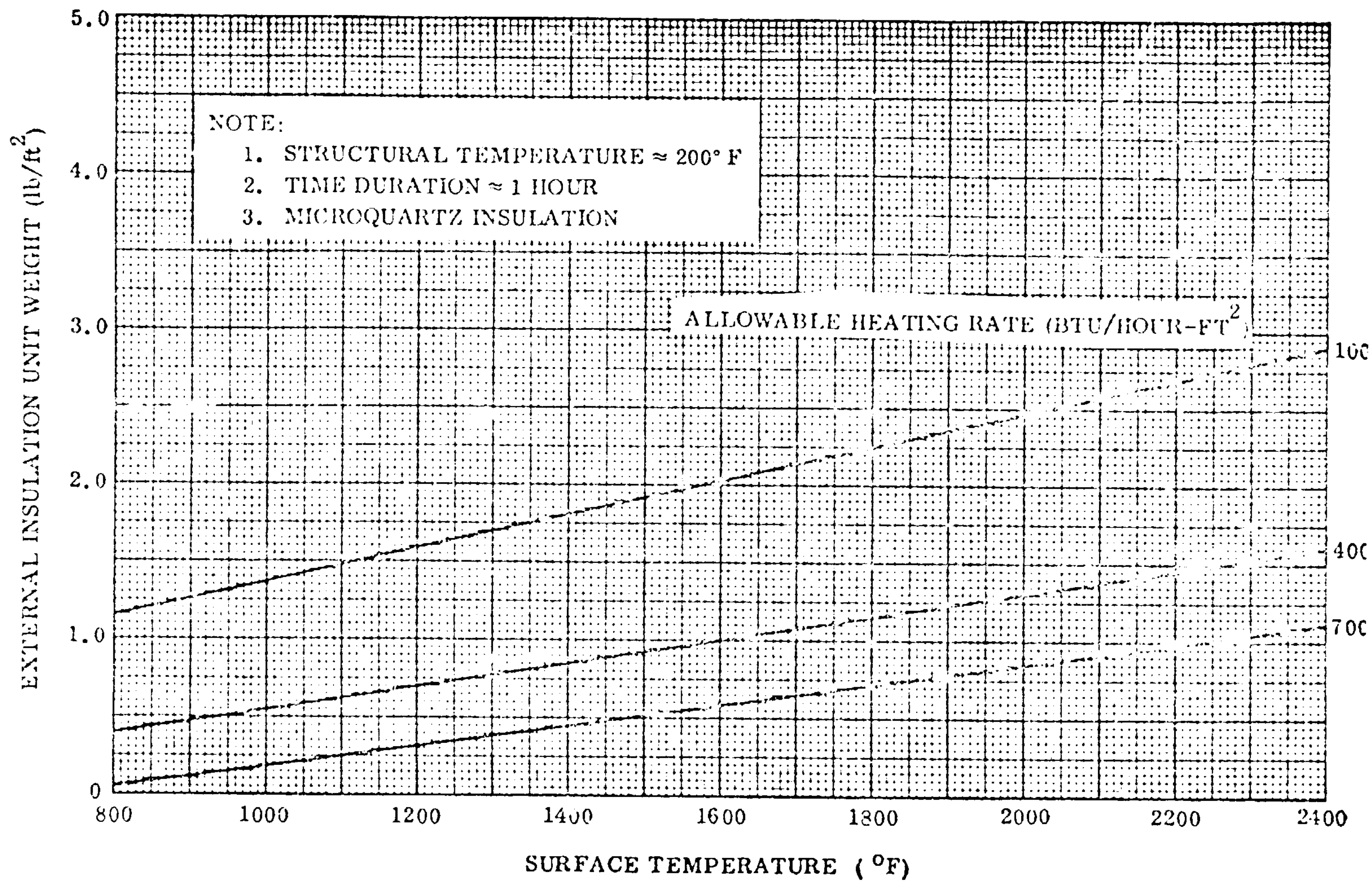


FIGURE 3.3-1 EXTERNAL INSULATION UNIT WEIGHTS FOR ONE-HOUR DURATION

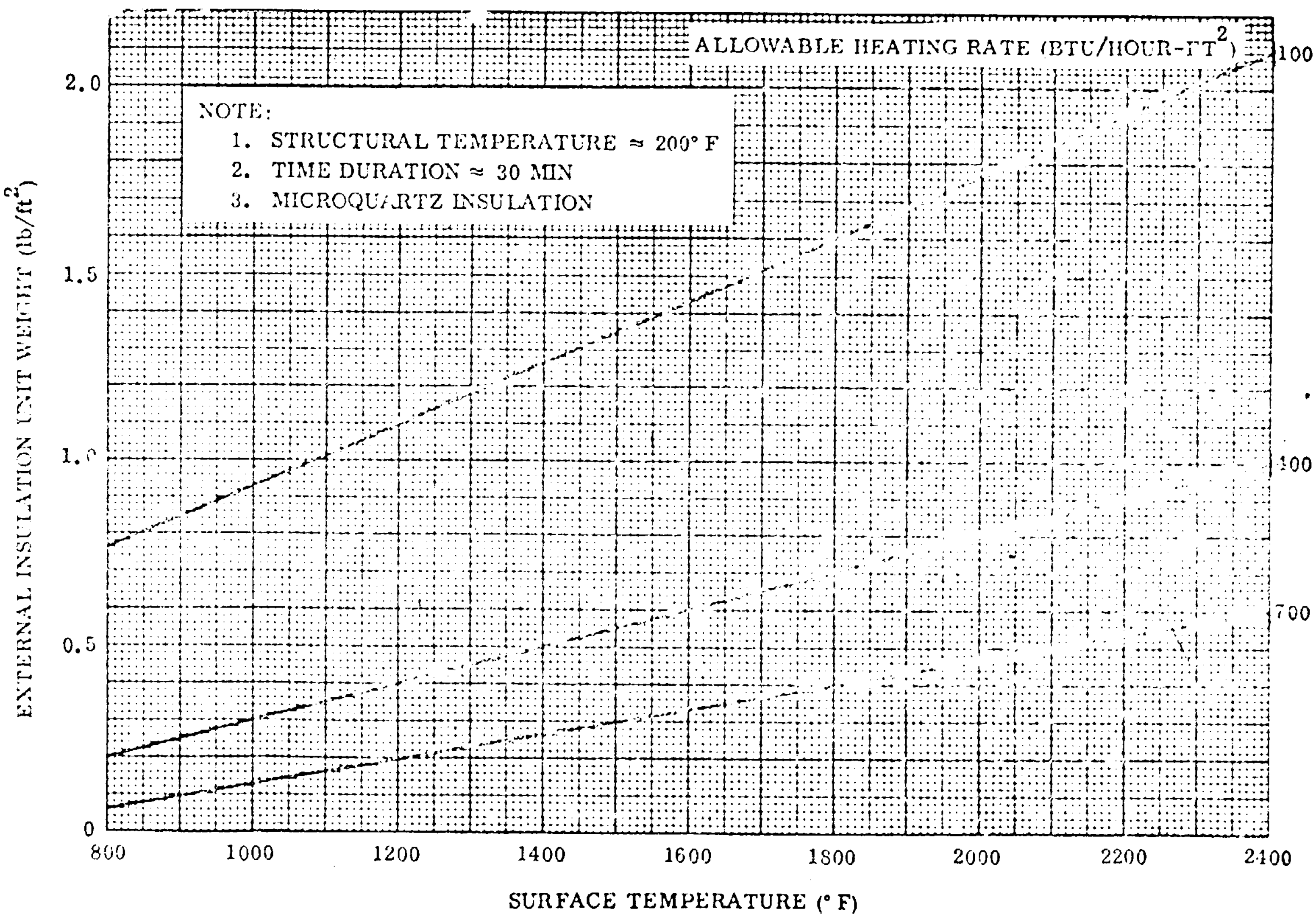


FIGURE 3.3-2 EXTERNAL INSULATION UNIT WEIGHT FOR 30-MINUTE DURATION

The coefficient AC(76) is a fixed input weight to the insulation calculation. A typical example of the use of this coefficient would be to add a fixed insulation weight for localized hot spots.

3.3.2 Cover Panels

When the design concept utilizes insulation panels to hold the structural temperature within acceptable limits, the insulation must be protected from flight conditions. This protection is provided by cover panels. The equation for the cover panel weight is

WCOVER = AC(22) *STPS + AC(77)

where WCOVER = total weight of TPS cover panels, lbs
STPS = total TPS surface area, ft^2
AC(22) = cover panel unit weight, lbs/ft^2
AC(77) = fixed cover panel weight, lbs

Cover panels used in recent studies have varied greatly in design features and materials. The generalized equation used in this program must be input from point design data if a specific design is to be properly represented. A range of input values are included to provide the user with a weight that will be representative of the cover panel designs used in recent studies.

The coefficient will vary from AC(22) = 0.8 to 1.5 if insulation is used in conjunction with the cover panels. If insulation panels are not utilized, the input will vary from AC(22) = 1.25 to 2.0. The lower values are representative of efficient attachment capability and the higher value requiring deep frame or standoff's for attachment. The values shown are average unit weights to be used with the total body wetted area.

3.4 LAUNCH AND RECOVERY

The total weight of the launch and recovery gear is given by

WGEAR = WLANCH + WLG

where WLANCH = launch system weight (if any)
WLG = landing gear weight

Expressions for these component weights are given below.

3.4.1 Launch Gear

The launch gear equation is used for the support structure and devices associated with aircraft that are used to attach to a hover ship. This includes struts, pads, sequencing devices, controls, etc. The equation for launch gear is

WLANCH = AC(23) *WTO + AC(24)

where WLANCH = total weight of launch gear, lbs
WTO = gross weight, lbs
AC(23) = launch gear weight coefficient
AC(24) = fixed launch gear weight, lbs

The weight coefficient AC(23) is a proportion of the computed gross weight. A typical value for preliminary design purposes, would be AC(23) = 0.0025.

3.4.2 Landing Gear

The landing gear equation has been developed from data correlation of existing aircraft. This data included the nose gear, main gear and controls. The equation for calculating landing gear (including controls is

WLG = AC(25) *WTO **AC(101) + AC(26) * WLAND ** AC(121)
+ AC(27)

where WLG = total weight of landing gear and controls, lbs
WTO = gross weight, lbs
WLAND = maximum landing weight, lbs
AC(25) = landing gear weight coefficient (intercept f(WTO)
AC(101) = landing gear weight exponent (slope f(WTO)
AC(26) = landing gear weight coefficient (f(WLAND))
AC(27) = fixed landing gear weight, lbs
AC(121) = landing gear weight exponent (f(WLAND))

The landing gear weight coefficients for take-off design gears are shown in Figure 3.4-1. These coefficients should be used when the landing gear is to be scaled as a function

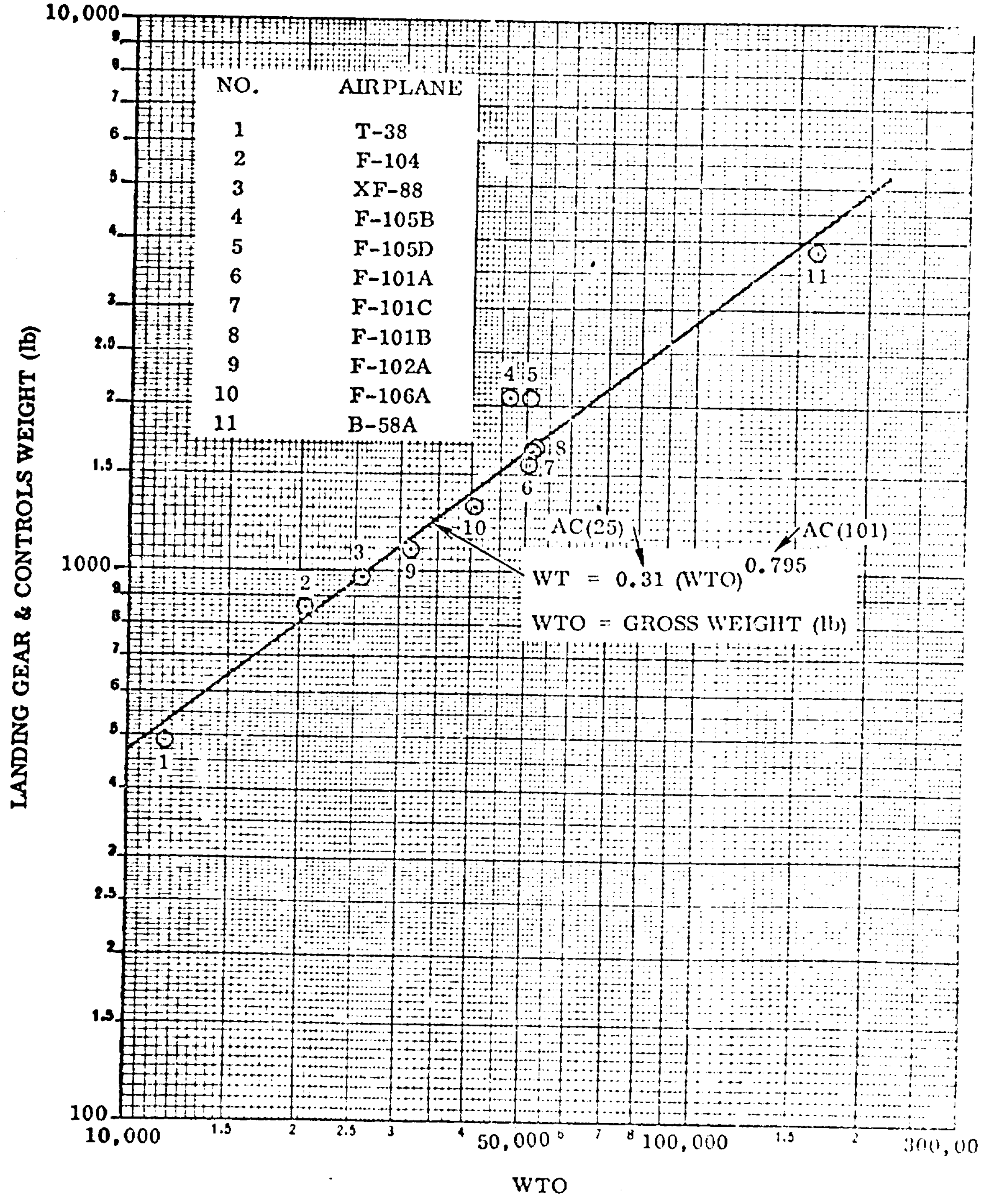


FIGURE 3.4-1 LANDING GEAR AND CONTROLS WEIGHT FOR TAKEOFF DESIGNED GEARS

of gross weight. When the coefficients AC(25) and AC(101) are used, the coefficients AC(26) and AC(121) should be zero.

The weights coefficient AC(26) and AC(121) are used for vehicles whose gear is used only for landing. Gear weight will then vary with the landing weight instead of gross weight. Figure 3.4-2 may be used for estimating these coefficients.

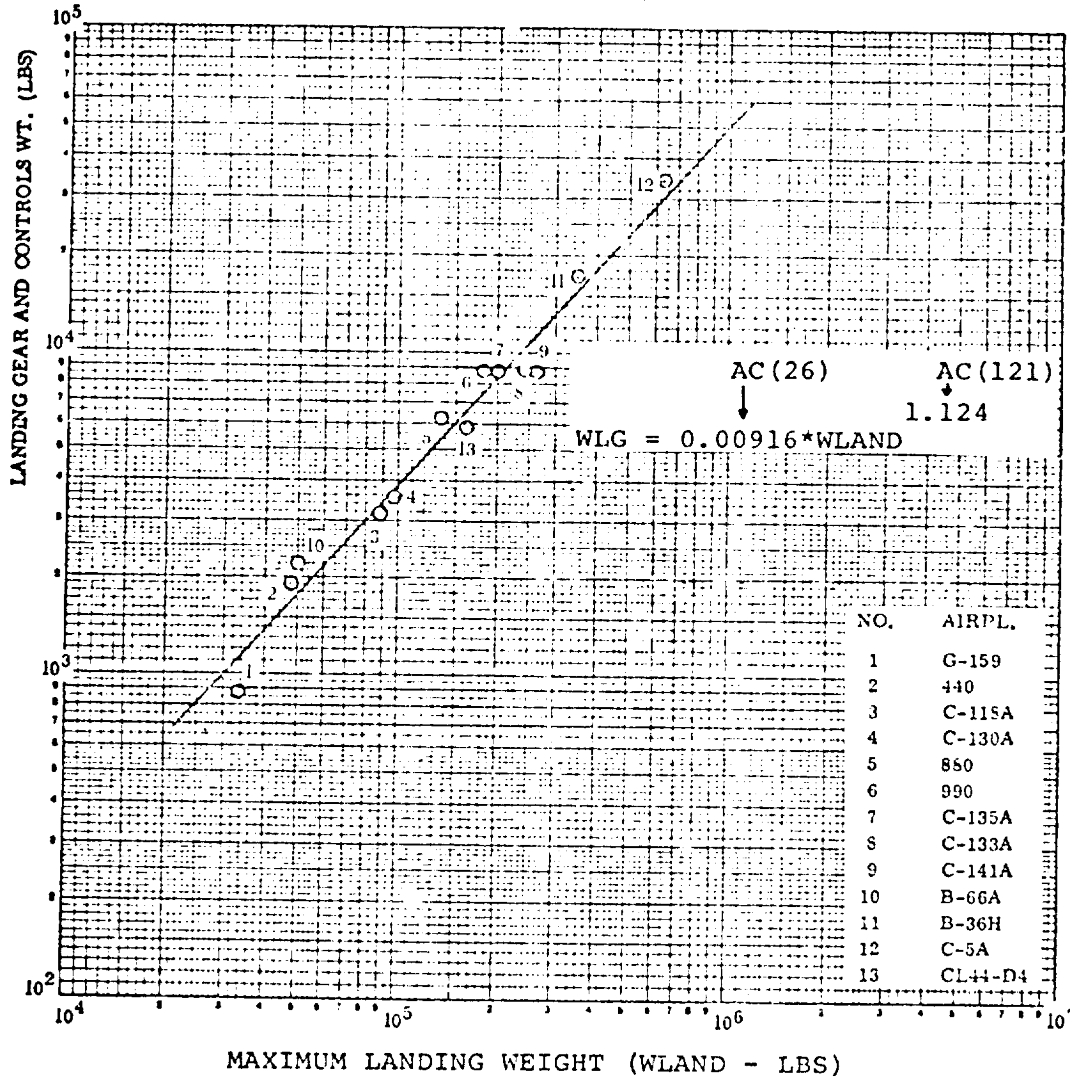


FIGURE 3.4-2 LANDING GROSS WEIGHT FOR LANDING DESIGNED GEARS

3.5 MAIN PROPULSION

The total weight of the aircraft main propulsion group is given by

```
WPROPU = WABENG + WRENGS + WFUNCT + WOXCNT + WINSFT
       + WINSOT + WFUSYS + WOXSYS + WPRSYS + WINLET
```

where

WABSEG	= airbreathing engine weight including engine mounts
WRENGS	= rocket engine weight, including engine mounts
WFUNCT	= fuel tank weight
WOXCNT	= oxidizer tank weight, rocket engines only
WINSFT	= fuel tank insulation weight
WINSOT	= oxidizer tank weight. rocket engines only
WYUSYS	= weight of storable propellant fuel system, less tanks
WOXSYS	= crogenic propellant oxidizer system weight
WPRSYS	= propellant pressurization system weight
WINLET	= inlet system weight

Expressions for each component weight are presented below.

3.5.1 Main Propulsion Engines

The main engines are used to propel the vehicle. This includes either airbreathing or rocket propulsion systems. The airbreathing engines considered in this study are the turboramjet and ramjet.

3.5.1.1 Turboramjet

The turboramjet data is for the GE 12/JZ8 engine. The equation for turboramjet follows.

```
WABENG = (AC(32) * e ** (AC(33) * WA) * ((PT2-PHIGH)/
         (PLOW-PHIGH) + AC(34) * e ** (AC(35) * WA)
         * ((PT2-PLOW)/(PHIGH-PLOW)) * ENGINS + AC(91)
         * ENGINS + WENGMT
```

where

WABENG	= total weight of airbreathing engines, lbs
WA	= calculated turboramjet engine air flow rate, lbs/sec
PT2	= calculated turboramjet engine inlet pressure, psi
PHIGH	= turboramjet engine inlet pressure (upper design curve, psi
PLOW	= turboramjet engine inlet pressure (lower design curve, psi
ENGINS	= total number of engines per stage
WENGMT	= weight of engine mounts, lbs (Section 3.5.2)

AC(32) = turboramjet engine weight coefficient (lower design point)
AC(33) = turboramjet engine weight coefficient (lower design point)
AC(34) = turboramjet engine weight coefficient (upper design point)
AC(35) = turboramjet engine weight coefficient (upper design point)
AC(91) = fixed turboramjet engine weight, lbs

The weight coefficients, AC(32), AC(33), AC(34) and AC(35) are used to scale the turboramjet engine weight as a function of engine air flow rate and pressure. The input values for these coefficients may be obtained from Figure 3.5-1. The data presented is for two design conditions of the GE 14/JZ8 engine. The data in the lower curve represents an engine for Mach 4.5 with a pressure of 46 psia at a cruise altitude of 90,000 feet. The data in the upper curve represents an engine for Mach 4.5 with a pressure of 176 psia at a cruise altitude of 61,600 feet. The ratio of calculated pressure (PT2) to the pressure for the upper curve (PHIGH = 176 psia) and the pressure for the lower curve (PLOW = 46 psia) allows a scaling capability around the two design conditions.

3.5.1.2 Ramjet

The ramjet engine is sized as a function of thrust. The equation for ramjet engine weight is

WABENG = AC(82) * TTOT + AC(83) + WENGMT

where WABENG = total weight of airbreathing engines, lbs
TTOT = total stage vacuum thrust, lbs (THRUST * ENGINS * ACTR)
AC(82) = ramjet engine weight coefficient
AC(83) = fixed ramjet engine weight, lbs
WENGMT = weight of engine mounts, lbs; see Section 3.5.2

The input value of AC(82) = 0.01 is representative of a low volume ramjet engine with a thrust to calculated weight ratio equal to 100:1. Figure 3.5-2 shows ramjet engine weight versus thrust for an AC(82) value of 0.01.

3.5.1.3 Rocket

The rocket engine data is based on the LR-129 LO_2/LH_2 engine. The weight is scaled as a function of total stage vacuum thrust and area ratio. The equation for rocket engine weight is

WRENGS = AC(28) *TTOT + AC(29) * TTOT * ARATIO ** AC(30) + AC(31) * ENGINS + WENGMT

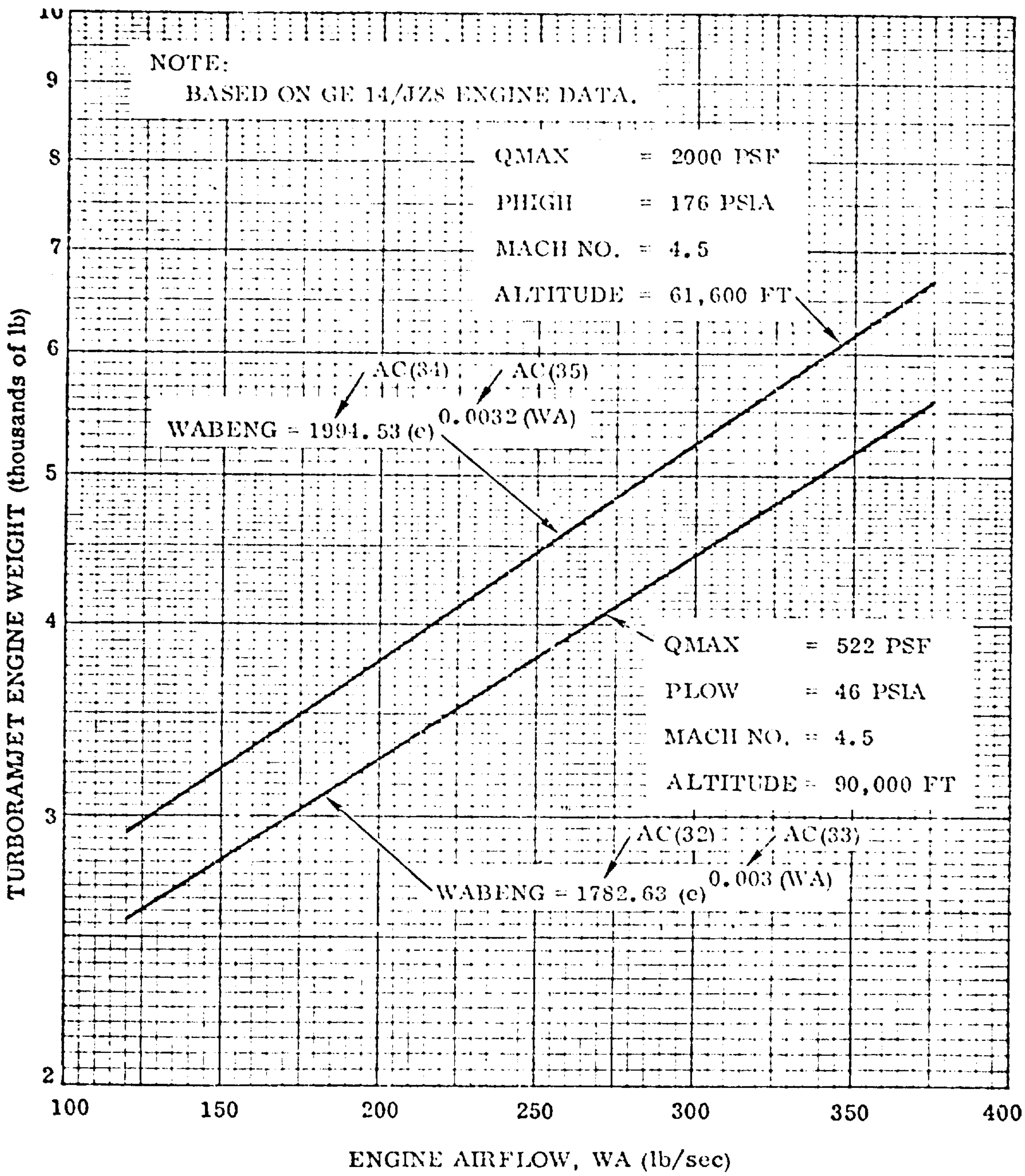


FIGURE 3.5-1 TURBOJET ENGINE WEIGHTS

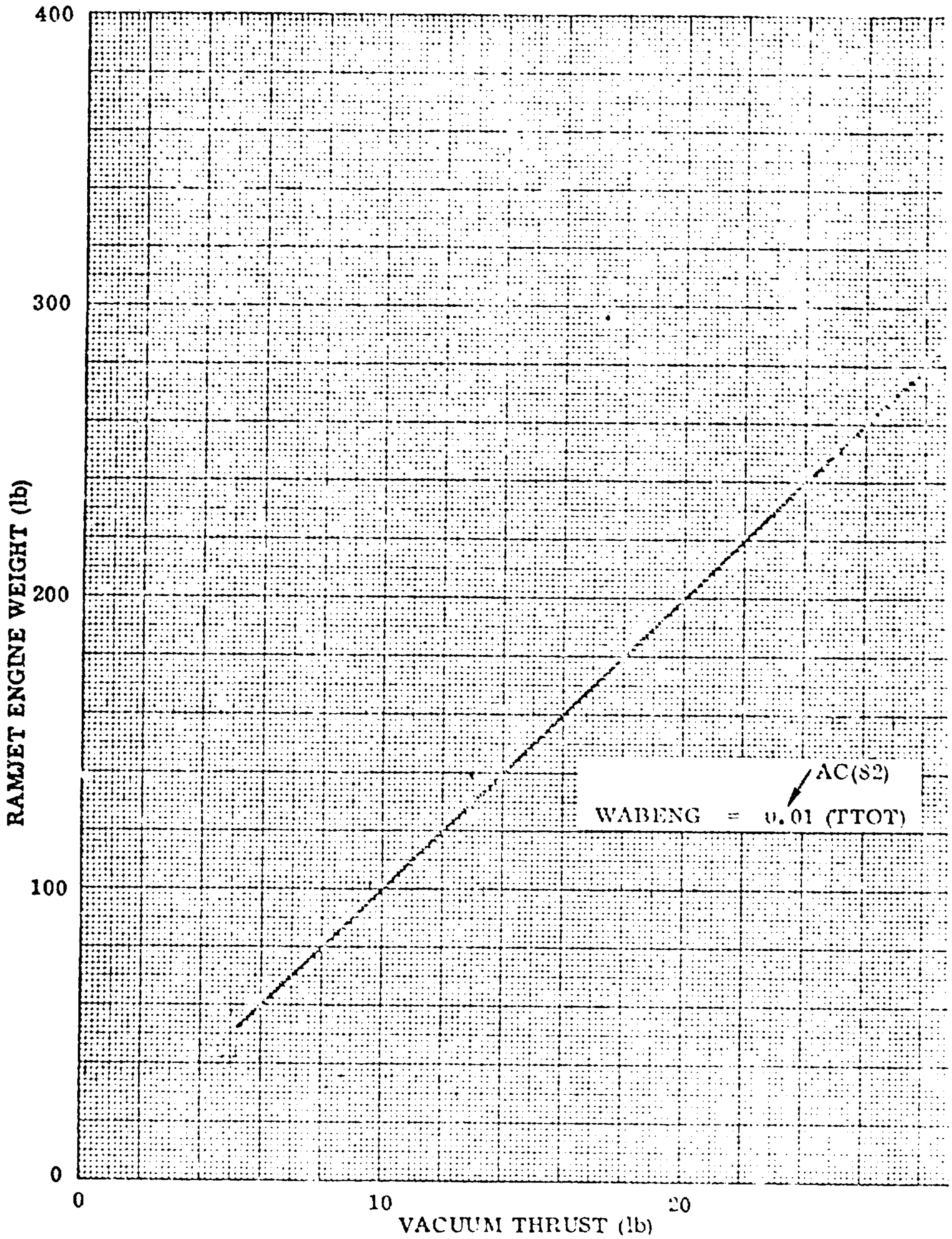


FIGURE 3.5-2 RAMJET ENGINE WEIGHT

where WRENGS = total weight of rocket engine installation, lbs
TTOT = total stage vacuum thrust, lbs (THRUST * ENGINS * ACTR)
ARATIO = rocket engine area ratio
ENGINS = total number of engines per stage
WENGMT = weight of engine mounts, lbs; see Section 3.5.2
AC(28) = rocket engine weight coefficient (f(Thrust))
AC(29) = rocket engine weight coefficient (f(Thrust and area ratio))
AC(30) = rocket engine area ratio exponent
AC(31) = fixed rocket engine weight, lbs

The weight coefficients AC(28), AC(29) and AC(30) are obtained from Figure 3.5-3. The engine data presented does not include allowances for PVC ducts or gimbal system. The gimbal system weight equation is not included. The assumption has been made that PVC ducts are not required on the type vehicles used for this study.

3.5.2 Engine Mounts

The weight equation for engine mounts if

WENGMT = AC(102) * TTOT + AC(103)

where WENGMT = weight of engine mounts, lbs
TTOT = total stage vacuum thrust, lbs (THRUST * ENGINS * ACTR)
AC(102) = engine mount weight coefficient
AC(103) = fixed engine mount weight, lbs

The expression AC(102) * TTOT is the penalty for engine mounts attached to the engine. The engine mounting penalty associated with the body is included in basic body structure. A typical value used in design studies is AC(102) = 0.004 for airbreathing engine installations and AC(102) = 0.0001 for rocket engines.

3.5.3 Fuel and Oxidizer Tanks

The type of fuel and oxidizer tank construction include non self-sealing (bladder), self-sealing and integral. The configuration concepts that utilize airbreathing engines with JP-4 and JP-5 type fuel may use any one of the three type fuel tank constructions discussed. However, when air-breathing engines are used with liquid hydrogen fuel the tanks are assumed to be an integral design based on the X-15 concept. The configuration concepts that utilize a rocket engine installation are assumed to have an integral tank design for both fuel and oxidizer that is based on the X-15 design concept.

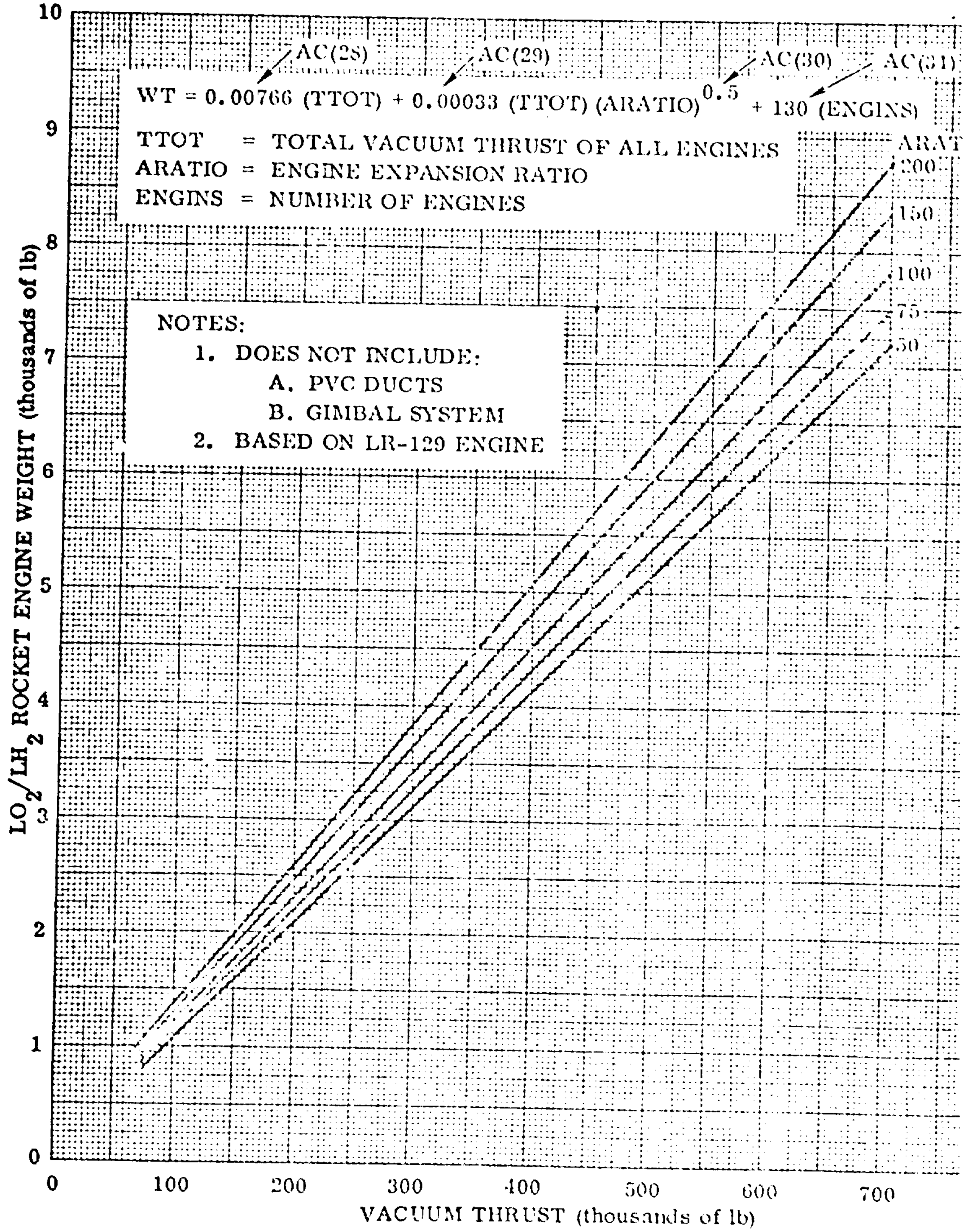


FIGURE 3.5-3 ROCKET ENGINE WEIGHT

3.5.3.1 JP-4 and JP-5 Type Fuel

The non self-sealing and self-sealing fuel tank weights for JP-4 and JP-5 type fuel are derived by the equation

WFUNCT = AC(36) * (GAL/TANKS) ** .6 * TANKS + AC(37)

where WFUNCT = total weight of fuel tank, lbs
GAS = total gallons of fuel
TANKS = number of fuselage fuel tanks
AC(36) = fuel tank weight coefficient (=0, for integral tanks)
AC(37) = fixed fuel tank weight, lbs (=0, **for** integral tanks)

The weight coefficient AC(36) is obtained from Figure 3.5-4. The weight for these tanks include supports and backing boards. Existing airplanes that utilize integral fuel tank are the F-102, F-106 and F-111. The F-4 and A-7 also utilize this concept in the wings but not in the fuselage.

3.5.3.2 Liquid Hydrogen Fuel and Rockets

The aircraft stages that use either airbreathing engines with liquid hydrogen fuel or rocket engines are assumed to have propellant tanks that are integral and based on the X-15 design concept. The equation for fuel tank weight is

WFUNCT = AC(36) * VFUTK + AC(37)

where WFUNCT = total weight of fuel tank, lbs
VFUTK = total volume of fuel tank, ft^3
AC(36) = fuel tank weight coefficient, lbs/ft^3
AC(37) = fixed fuel tank weight, lbs

The weight coefficient AC(36) is obtained from Figure 3.5-5. The equation for oxidizer tank weight is

WOXCNT = AC(38) * VOXTK + AC(39)

where WOXCNT = total weight of oxidizer tank, lbs
VOXTK = total volume of oxidizer tank, ft^3
AC(38) = oxidizer tank weight coefficient, lbs/ft^3 (=0, for airbreather)
AC(39) = fixed oxidizer tank weight, lbs (=0, for airbreather)

The weight coefficient AC(38) is obtained from Figure 3.5-5.

3.5.4 Fuel Tank Insulation

This section presents the data to obtain a weight penalty associated with protection required to prevent excessive boil-off from cryogenic propellant tanks. The insulation penalty is in terms of lbs/ft^2 of tank area.

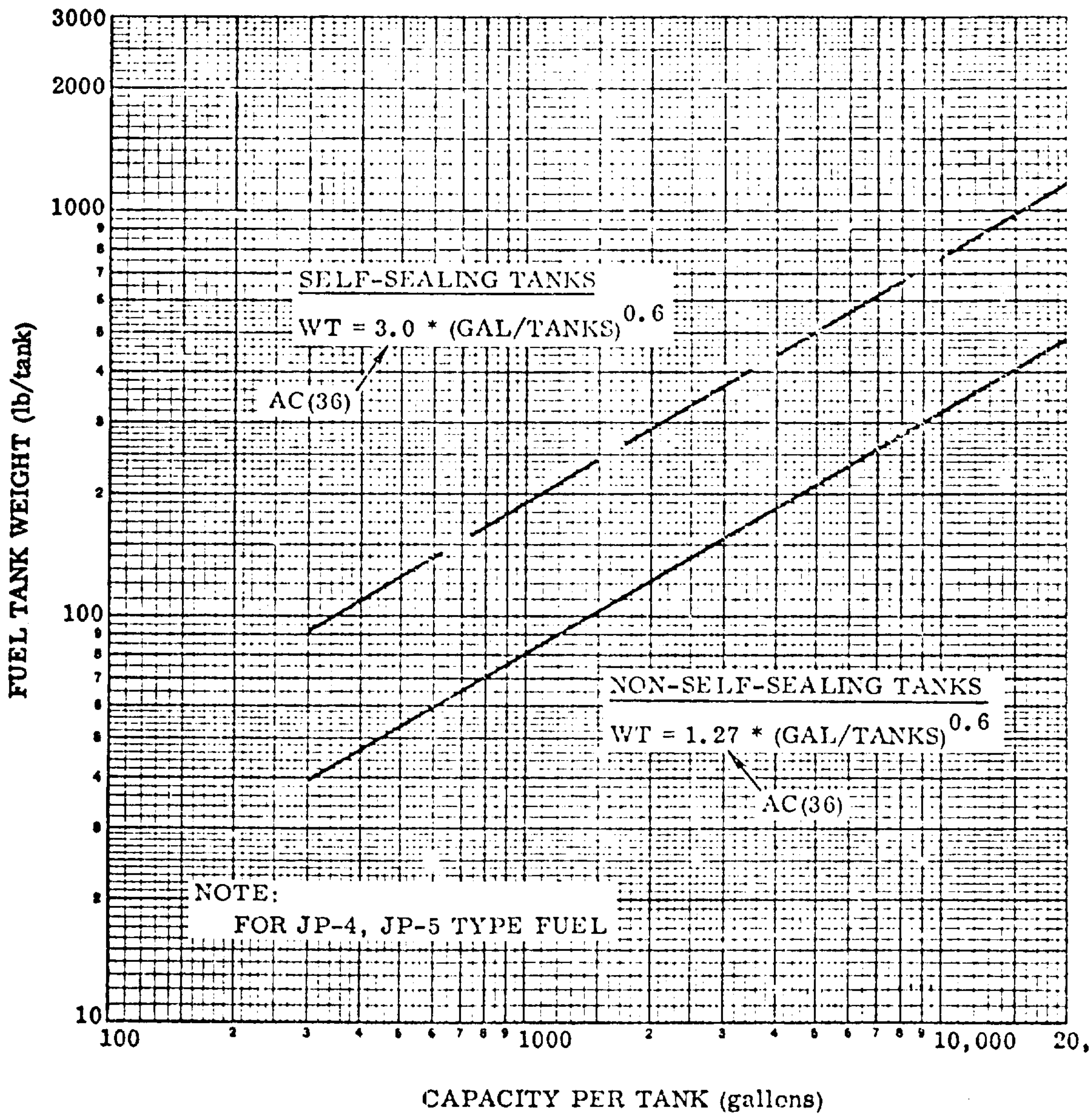


FIGURE 3.5-4 NON-STRUCTURAL FUEL TANK CONTAINER

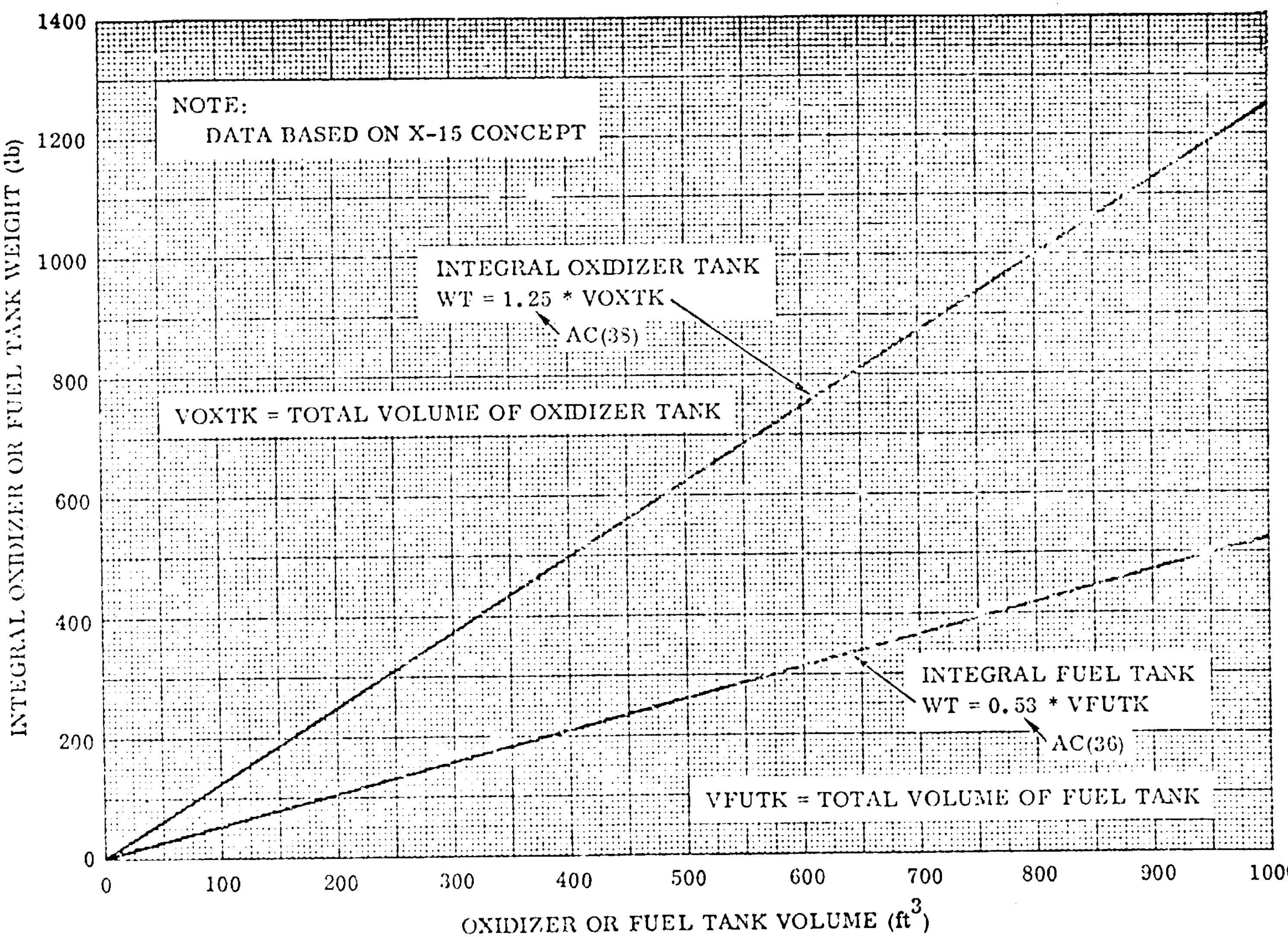


FIGURE 3.5-5 INTEGRAL FUEL AND OXIDIZER TANK WEIGHT FOR X-15 CONCEPT

The equation for fuel tank insulation weight is

WINSFT = AC(40) * SFUTK + AC(41)

where WINSFT = total weight of fuel tank insulation, lbs
SFUTK = total fuel tank wetted area, ft^2
AC(40) = fuel tank insulation unit weight, lbs/ft^2
AC(41) = fixed fuel tank insulation weight, lbs

The weight coefficient AC(40) is obtained from Figure 3.5-6. The fuel tank insulation unit weight is a function of radiating temperature. A typical radiating temperature of 500°F may be assumed for preliminary runs if other data is not available for making a specific selction.

The AC(40) value obtained from Figure 3.5-6 is for a total flight duration time of 5000 seconds. When other flight times are anticipated, the AC(40) value should be modified by multiplying it by the time correction factor (T_{CORR}) obtained from Figure 3.5-7.

3.5.5 Oxidizer Tank Insulation

No requirement for the insulation of the main oxidizer tanks has been necessary in past design studies because storage times have been relatively low. However, an equation and input data is provided for cases where oxidizer tank insulation is required. The equation for oxidizer tank insulation weight is

WINSOT = AC(42) * SOXTK + AC(43)

where WINSOT = total weight of oxidizer tank insulation, lbs
SOXTK = total oxidizer tank wetted area, ft^2
AC(42) = oxidizer tank insulation unit weight, lbs/ft^2
AC(43) = fixed oxidizer tank insulation weight, lbs

The weight coefficient AC(42) is obtained from Figures 3.5-6 and 3.5-7. The selection criteria used to obtain AC(42) is the same as that used for AC(40).

3.5.6 Storable Propellant Fuel System

The weight of the storable propellant fuel system is given by the following equation

WFUSYS = WBPUMP + WDIST1 + WDIST2 + WFCONT + WRSFUL + WDRANS + WSEAL

where WBPUMP = boost and transfer pump weight
WDIST1 = weight of fuel lines, supports, fittings, etc., from reservoir tank to engines
WDIST2 = weight of fuel lines, supports, fittings, etc., between tanks

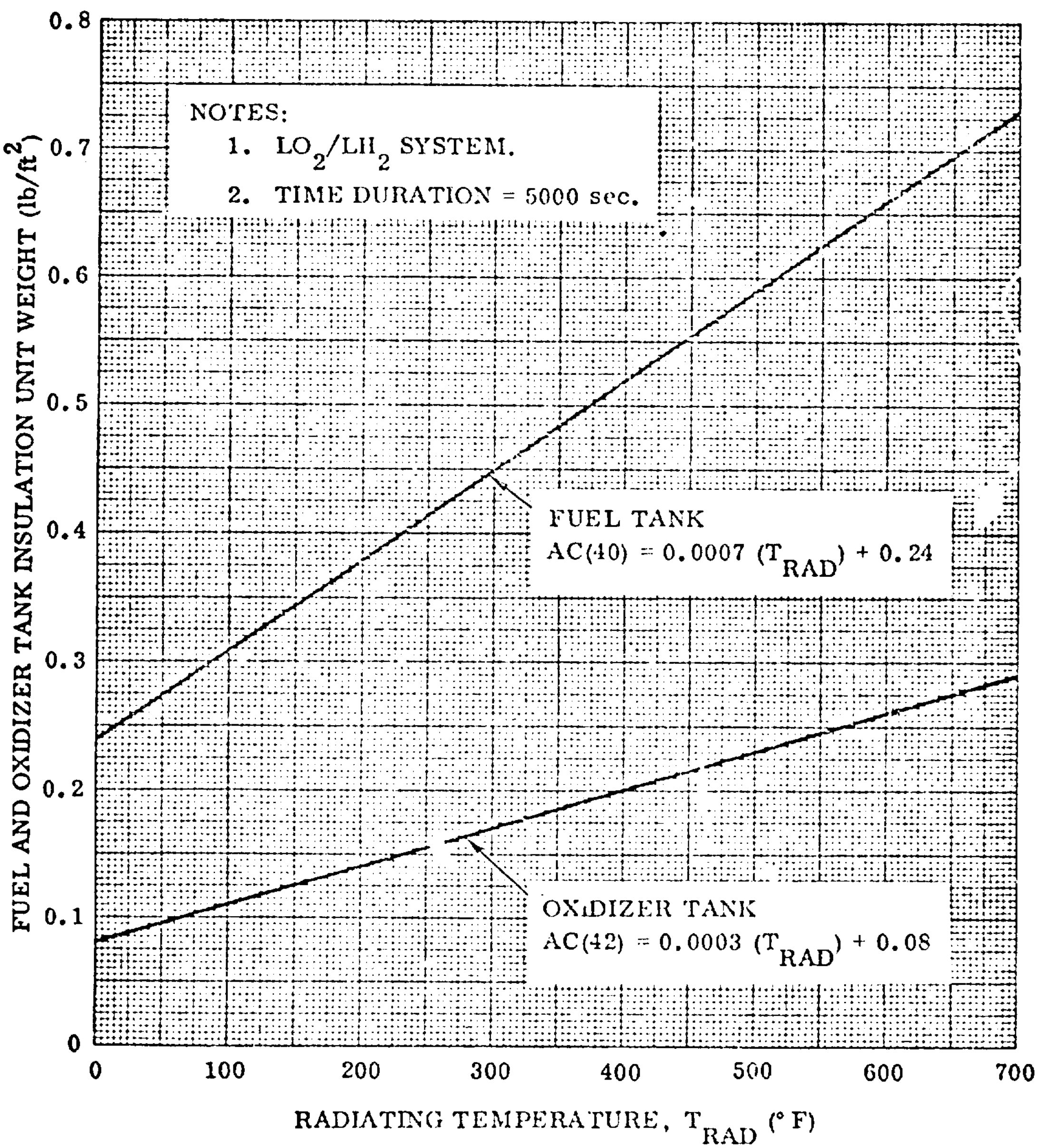


FIGURE 3.5-6 FUEL AND OXIDIZER INSULATION WEIGHT

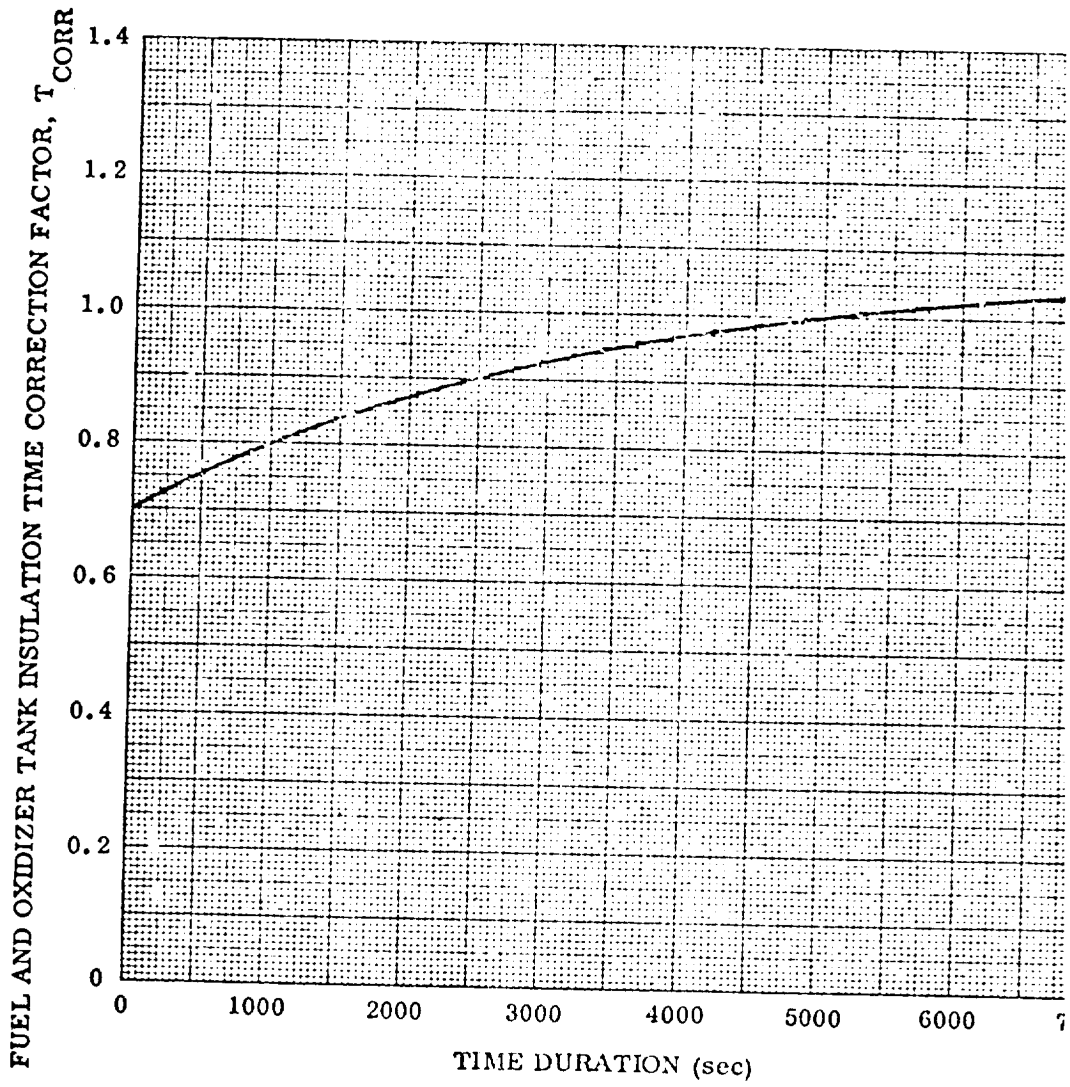


FIGURE 3.5-7 FUEL AND OXIDIZER TANK INSULATION TIME CORRECTION FACTOR

WFCONT = fuel system control weight
WREFUL = tank refueling system weight
WDRANS = dump and drain system weight
WSEAL = sealing weight

Expressions for each component weight are provided below.

3.5.6.1 Boost and Transfer Pumps

The weight of the boost and transfer pumps is a function of the engine thrust and the number of engines. The equation for boost and transfer pumps is

$$WBPUMP = \frac{TTOT}{1000} * (1.75 + 0.266 * ENGINS)$$

where
WBPUMP = total weight of boost and transfer pumps, lbs
TTOT = total stage vacuum thrust, lbs (THRUST * ENGINS * ACTR)
ENGINS = total number of engines per stage

3.5.6.2 Fuel Distribution, Reservoir to Engine

The fuel distribution system, Part 1, is the total of all fuel lines, supports, fittings, etc., to provide fuel flow from a reservoir tank to the engines. The equation for the fuel distribution Part 1 weight is

WDISTI = ENGINS * AC(104) * (TTOT/ENGINS) ** .5

where
WDITSI = total weight of fuel distribution system Part 1, lbs
ENGINS = total number of engines per stage
TTOT = total stage vacuum thrust, lbs (THRUST * ENGINS * ACTR)
AC(104) = weight coefficient for fuel distribution system Part 1

The weight coefficient AC(104) is used to differentiate between a non-afterburning and afterburning engine. The value of AC(104) is obtained from Figure 3.5-8.

3.5.6.3 Fuel Distribution, Inter-Tank

The fuel distribution system, Part II, is the total of all fuel lines, fittings, supports, etc., to provide flow between various tanks within the system. The equation for the fuel distribution system Part II weight is

WDIST2 = 0.255 * GAL ** .7 * TANKS ** .25

where
WDIST2 = total weight of fuel distribution system Part II, lbs
GAL = total gallons of fuel
TANKS = number of fuselage fuel tanks

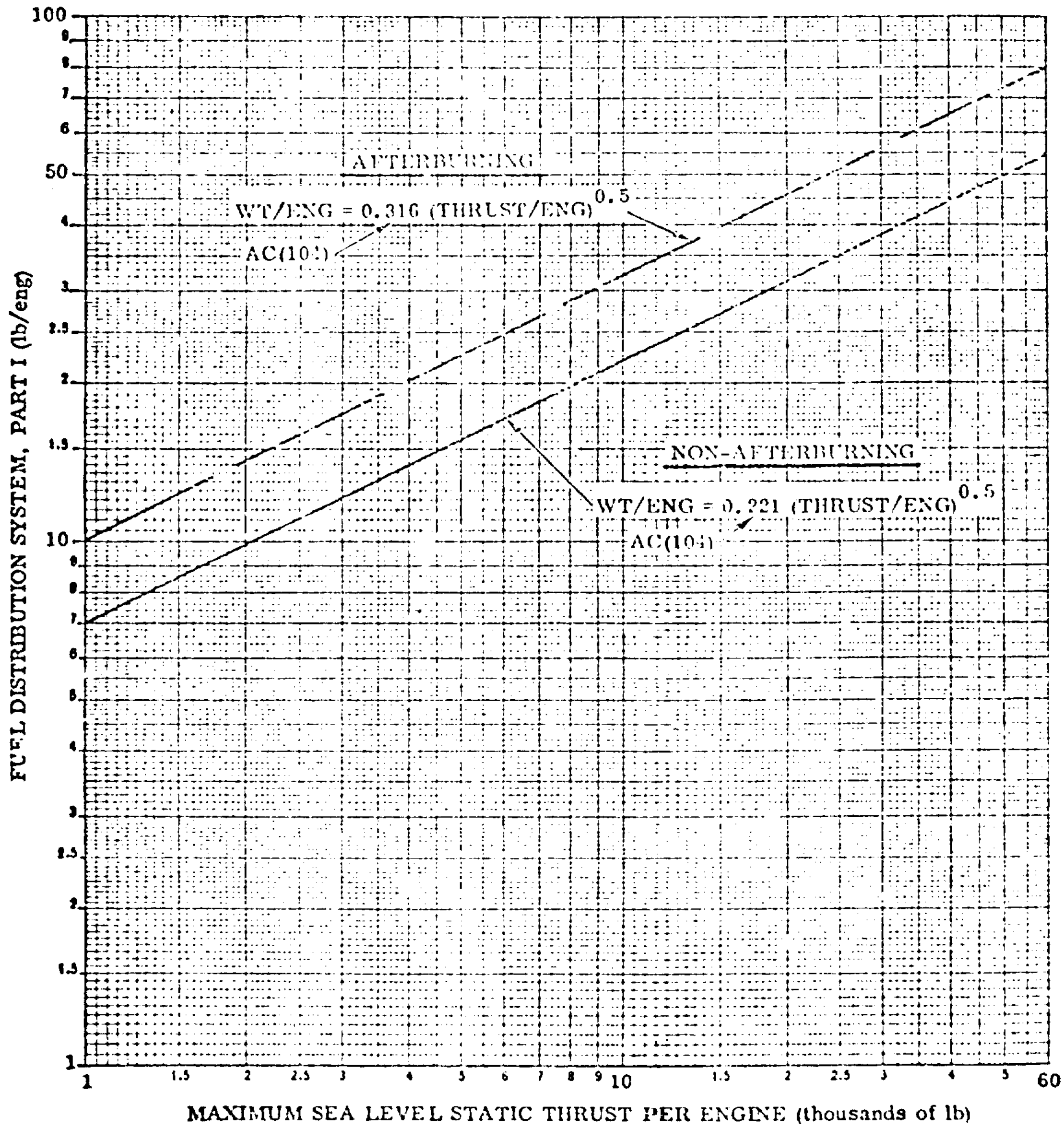


FIGURE 3.5-8 FUEL DISTRIBUTION SYSTEM, PART I

3.5.6.4 Fuel System Controls

The fuel system controls is the total of all valves and valve operating equipment such as wiring, relays, cables, etc. The equation for the fuel system controls weight is

WFCONT = 0.169 * TANKS * GAL ** .5

where WFCONT = total weight of fuel system controls, lbs
TANKS = number of fuselage fuel tanks
GAL = total gallons of fuel

3.5.6.5 Refueling System

The fuel tank refueling system includes the ducts and valves necessary to fill the fuel tanks. The equation for fuel tank refueling system weight is

WREFUL = TANKS * (3.0 + 0.45 * GAL ** .333)

where WREFUL = total weight of fuel tank refueling system, lbs
TANKS = number of fuselage fuel tanks
GAL = total gallons of fuel

3.5.6.6 Dump and Drain System

The fuel tank dump and drain system is the total valves and plumbing necessary to dump and drain the fuel system. The equation for fuel tank dump and drain system weight is

WDRANS = 0.159 * GAL ** .65

where WDRANS = total weight of fuel tank dump and drain system, lbs
GAL = total gallons of fuel

3.5.6.7 Sealing

The fuel tank bay sealing is the total weight of sealing compound and structure required to provide a fuel tight compartment. This sealing is used with a bladder tank to prevent fuel leakage and it is used to seal off a structural compartment to provide an integral tank concept. The equation for fuel tank bay sealing weight is

WSEAL = 0.045 * TANKS & (GAL/TANKS) ** .75

where WSEAL = total fuel tank bay sealing weight, lbs
TANKS = number of fuselage fuel tanks
GAL = total gallons of fuel

3.5.7 Cryogenic Propellant Fuel System

The equation for cryogenic propellant fuel system weight is used for airbreathing engines that utilize liquid hydrogen fuel and with rocket engine installations. This system weight includes the pumps, lines, valves, supports, etc. associated with the cryogenic fuel system. It is divided into the components that are thrust dependent and the components that are primarily length dependent. The equation for the cryogenic fuel system weight is

WFUSYS = AC(44) * TTOT + AC(45) * ELBODY + AC(46)

where
- WFUSYS = total weight of fuel system, lbs
- TTOT = total stage vacuum thrust, lbs
- ELBODY = body length, ft
- AC(44) = cryogenic fuel system weight coefficient (f(Thrust))
- AC(45) = cryogenic fuel system weight coefficient (f(Length)), lbs/ft
- AC(46) = fixed cryogenic fuel system weight, lbs

The thrust dependent weight coefficient AC(44) is obtained from the upper curve in Figure 3.5-9 and the length dependent weight coefficient AC(45) is obtained from the lower curve.

3.5.8 Cryogenic Propellant Oxidizer System

The equation for cryogenic propellant oxidizer system weight is used with rocket engine installations. This system weight includes the pumps, lines, valvues, supports, etc. associated with the cryogenic oxidizer system. It is divided into the components that are thrust dependent and the components that are primarily length dependent. The equation for the cryogenic oxidizer system weight is

WOXSYS = AC(47) * TTOT + AC(48) * ELBODY + AC(49)

where
- WOXSYS = total weight of oxidizer system, lbs
- TTOT = total stage vacuum thrust, lbs (THRUST * ENGINS * ACTR)
- ELBODY = body length, ft
- AC(47) = cryogenic oxidizer system weight coefficient (f(thrust))
- AC(48) = cryogenic oxidizer system weight coefficient (f(length)), lbs/ft
- AC(49) = fixed cryogenic oxidizer system weight, lbs

The thrust dependent weight coefficient AC(47) is obtained from the upper curve in Figure 3.5-10 and the length dependent weight coefficient AC(48) is obtained from the lower curve. When an airbreathing engine installation is used with liquid hydrogen fuel the coefficients AC(47), AC(48) and AC(49) must be set to zero.

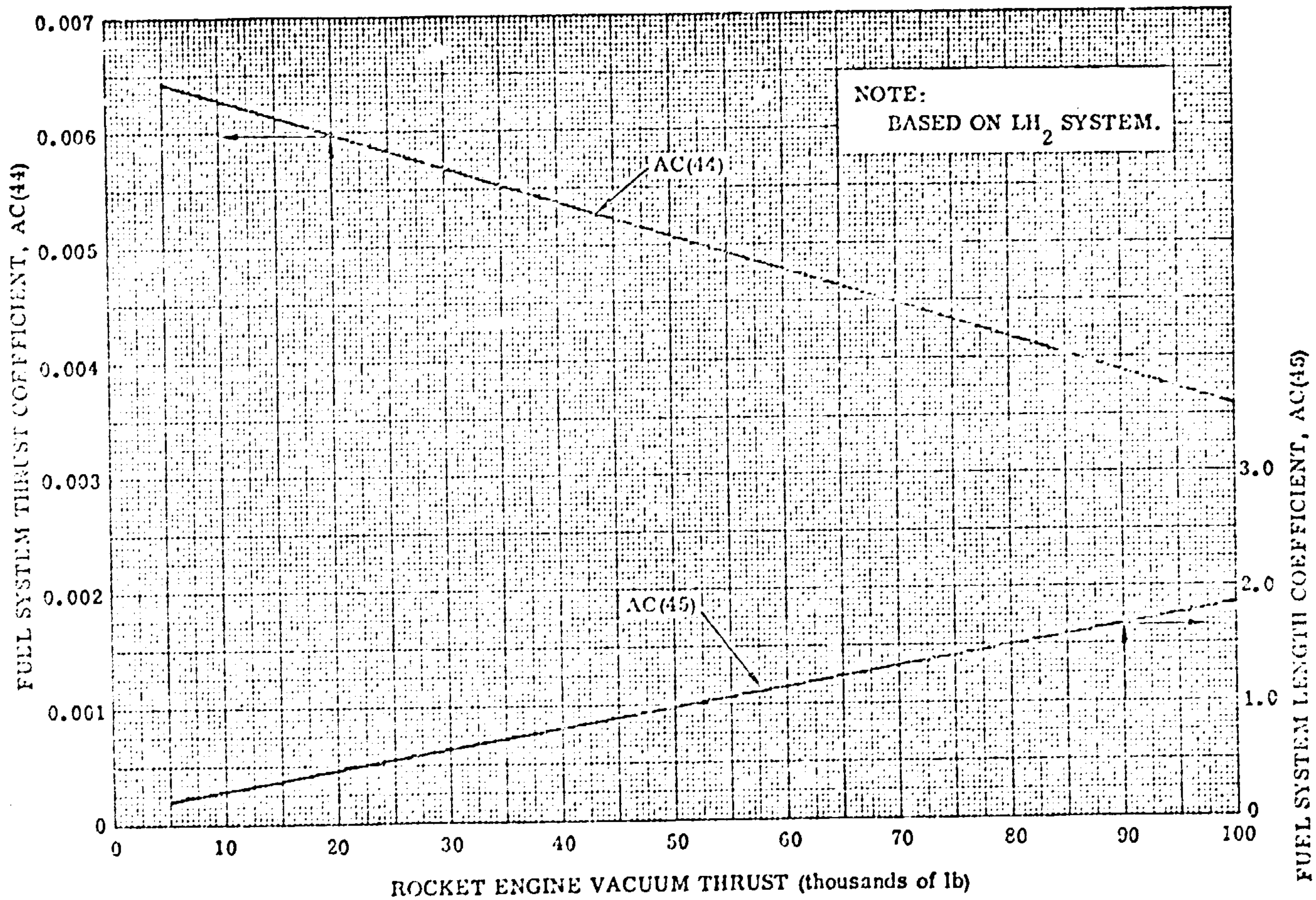


FIGURE 3.5-9 FULL SYSTEM THRUST AND LENGTH COEFFICIENTS

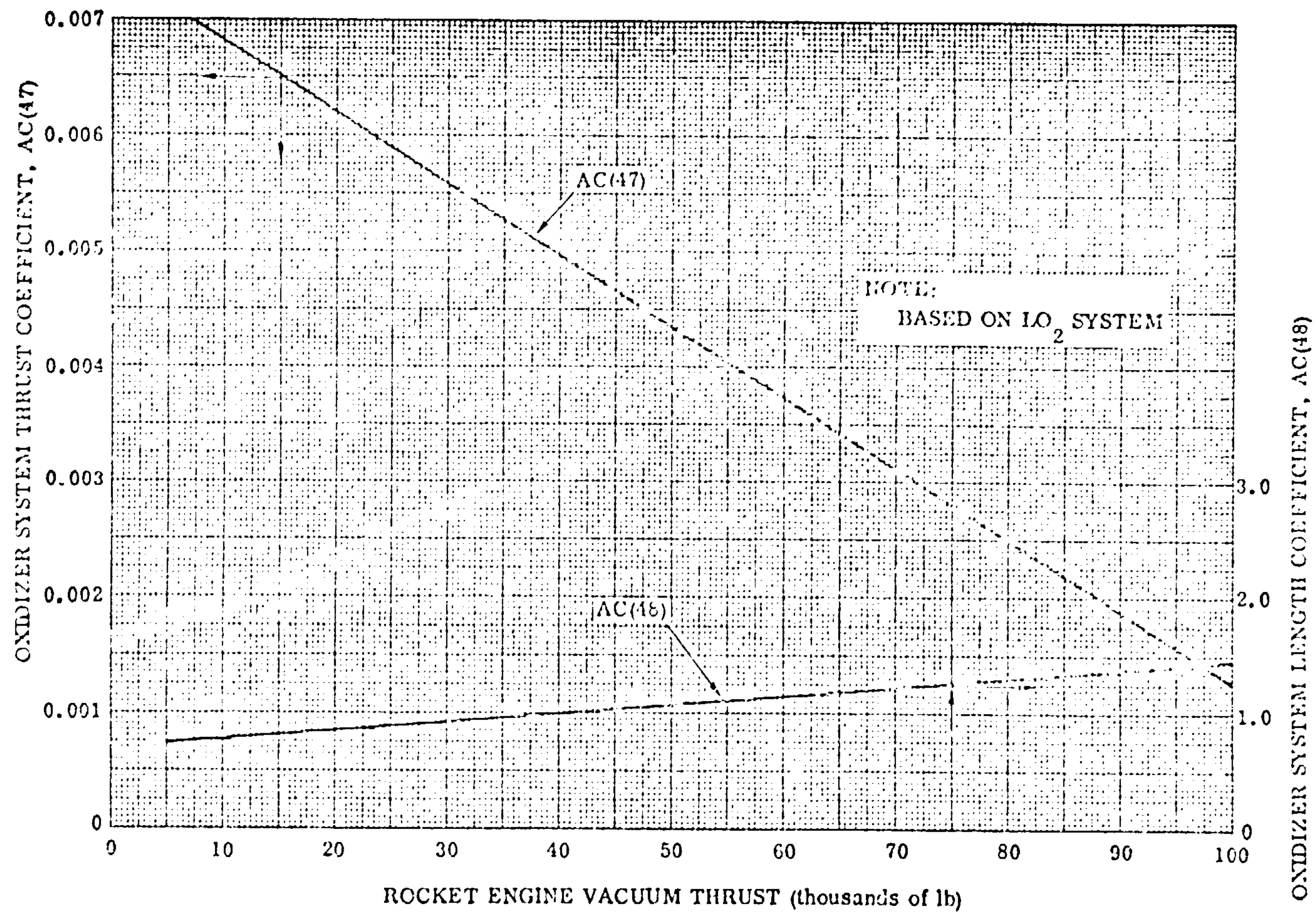


FIGURE 3.5-10 OXIDIZER SYSTEM THRUST AND LENGTH COEFFICIENT

3.5.9 Storable Propellant Pressurization System

The pressurization system for storable propellants includes the bottles, valves, plumbing and supports. This system is used on the aircraft stage with airbreathing engines. The equation for storable propellant pressurization system weight is

WPRSYS = 0.0009 * TTOT * TANKS

where WPRSYS = weight of pressurization system, lbs
TTOT = total stage vacuum thrust, lbs
TANKS = number of fuselage fuel tanks

3.5.10 Cryogenic Propellant Pressurization System

The cryogenic propellant pressurization system is based on the X-15 concept. The system weight includes the storage bottles, stored gas and system components. The weight equation inputs are based on the fuel and oxidizer tank volumes. The equation for cryogenic propellant pressurization system weight is

WPRSYS = AC(50) * VFUTK + AC(51) * VOXTK + AC(52)

where WPRSYS = weight of pressurization system, lbs
VFUTK = total volume of fuel tank, ft^3
VOXTK = total volume of oxidizer tank, ft^3
AC(50) = fuel tank pressure system weight coefficient, lbs/ft^3
AC(51) = oxidizer tank pressure system weight coefficient, lbs/ft^3
AC(52) = fixed pressurization system weight, lbs

The coefficients AC(50) and AC(51) are fuel and oxidizer dependent, respectively, for the pressurization system weights. The input value for these coefficients are obtained from Figure 3.5-11. When an airbreathing engine is used with liquid hydrogen fuel, the coefficient AC(51) must be set to zero.

3.5.11 Inlet System

The weight of the inlet system is given by

WINLET = WIDUCT + WVRAMP + WSPIKE

where WIDUCT = internal duct weight
WVRAMP = ramp and ramp control weight
WSPIKE = spike weight

Expressions for each component weight are given below.

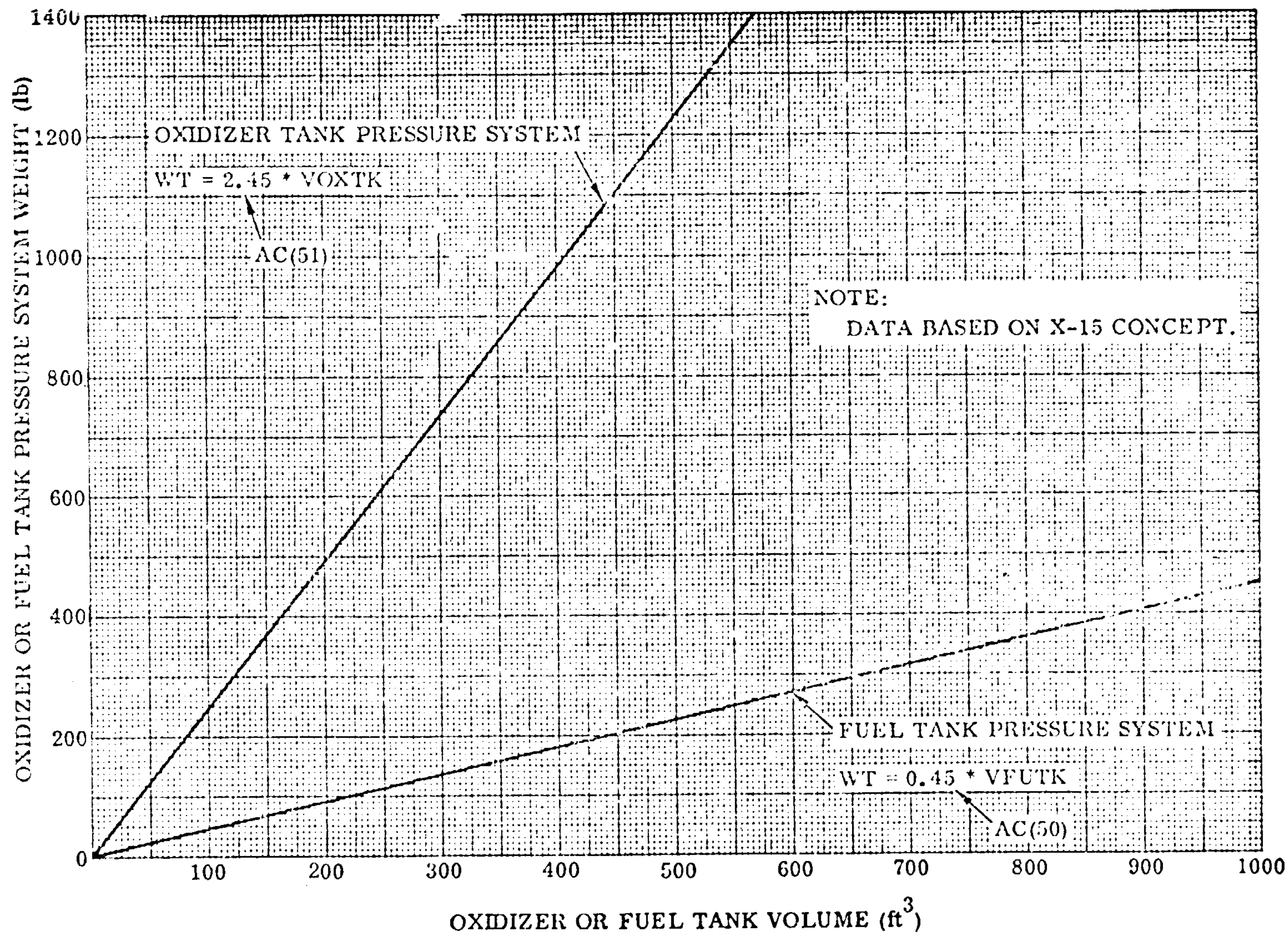


FIGURE 3.5-11 OXIDIZER AND FUEL PRESSURIZATION SYSTEM WEIGHT

3.5.11.1 Internal Duct

The equation for inlet internal duct weight is

WIDUCT = AC(53) * ((ELNLET*XINLET) ** .5 *(AICAPT/

XINLET) ** .3334 * PT2 **.6667 * GEOFCT * FCTMOK)

** AC(54) + AC(105)

where WIDUCT = weight of inlet internal duct, lbs
ELNLET = length of duct (lip to engine fact), ft
XINLET = number of inlets
AICAPT = total inlet capture area, ft^2
PT2 = calculated engine inlet pressure, psia
GEOFCT = geometrical out of round factor
1.0 for round or one flat side
1.33 for two or more flat sides
FCTMOK = Mach number factor
1.0 for Mach $\leq$ 1.4
1.5 for Mach $\geq$ 1.4
AC(53) = inlet internal duct weight coefficient (intercept)
AC(54) = inlet internal duct weight coefficient (slope)
AC(105) = fixed internal duct weights, lbs

The inlet internal duct weight coefficients AC(53) and AC(54) are available from Figure 3.5-12.

3.5.11.2 Ramp

The weight for variable ramps, actuators and controls is dependent on temperature as the design Mach number increases. The equation for the temperature correction factor follows.

$$TMPFCT = \begin{cases} 1.0 & \text{Mach number} < 3.0 \\ 0.203 * DM + 0.4, & \text{Mach number} \geq 3.0 \end{cases}$$

where TMPFCT = temperature correction factor
DM = design Mach number

The design Mach number of 3.0 gives a temperature correction factor of 1.0 and should be considered as a minimum input.

The equation for variable ramps, actuators and controls is

WVRAMP = AC(106) * (ELRAMP * XINLET * (AICAPT/XINLET)

** .5 * TMPFCT) ** AC(107) + AC(108)

where WVRAMP = weight of inlet variable ramps, actuators and controls, lbs
ELRAMP = total length of ramp, ft
XINLET = number of inlets
AICAPT = total inlet capture area, ft^2

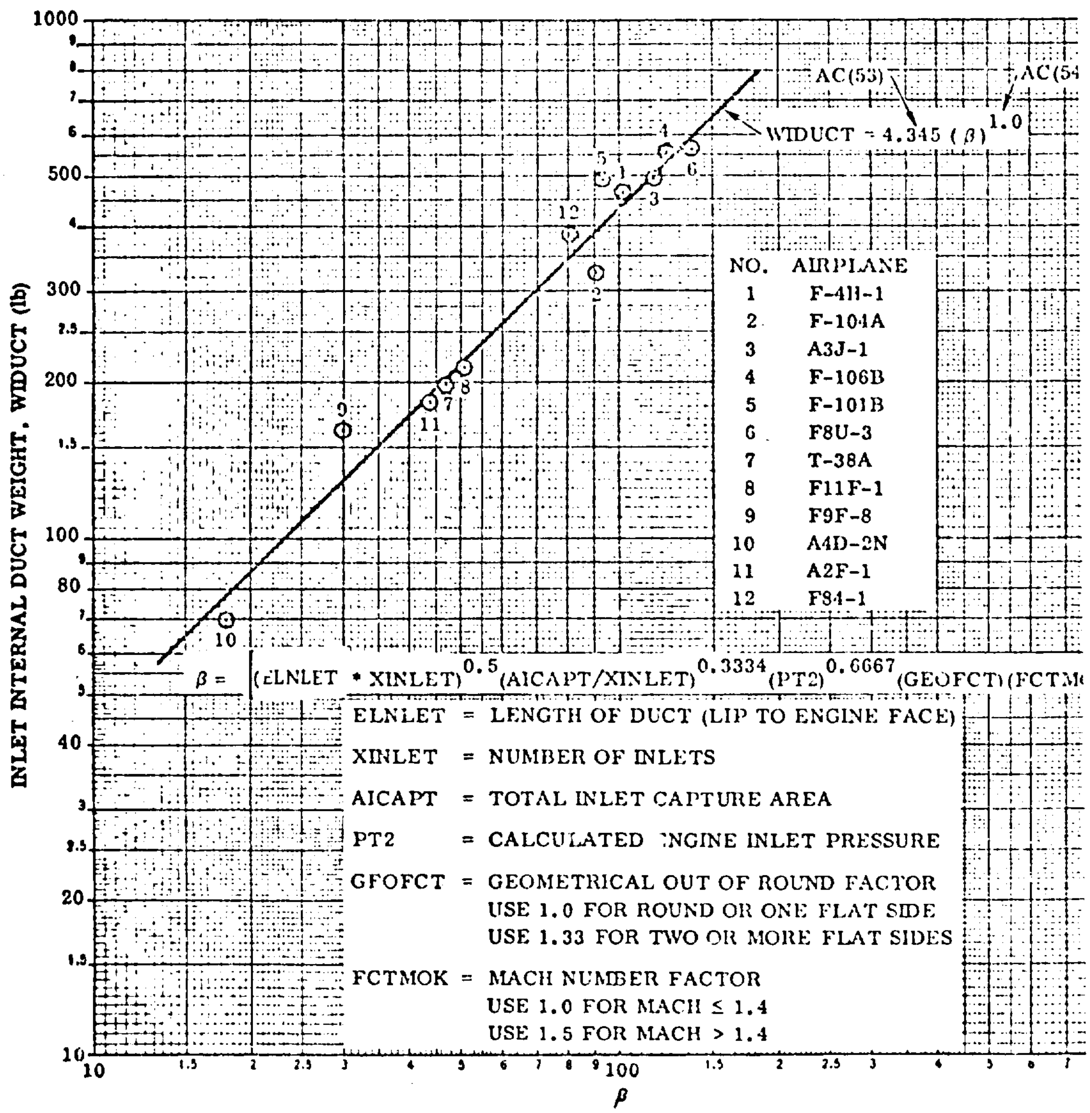


FIGURE 3.5-12 INLET INTERNAL DUCT WEIGHT

TMPFCT = temperature correction factor
AC(106) = variable ramps, actuators and controls weight coefficient (intercept)
AC(107) = variable ramps, actuators and controls weight coefficient (slope)
AC(108) = fixed weight for variable ramps, actuators and controls, lbs

The variable ramps, actuators and controls weight coefficients, AC(106) and AC(107) are given in Figure 3.5-13.

3.5.11.3 Spike

The weight of the spike is a fixed input which depends on the type of spike used. The equation for total spike weight is

WSPIKE = AC(109) * XINLET

where WSPIKE = total weight of spikes, lbs
XINLET = number of inlets
AC(109)= spike weight coefficient, lbs

The weight coefficient AC(109) is obtained from Table 3.5-1

TYPE OF SPIKE	AC(109)
1/2 ROUND - FIXED	35
FULL ROUND - TRANSLATING	70
FULL TRANSLATING AND EXPANDING	200

TABLE 3.5-1. TYPICAL SPIKE WEIGHTS

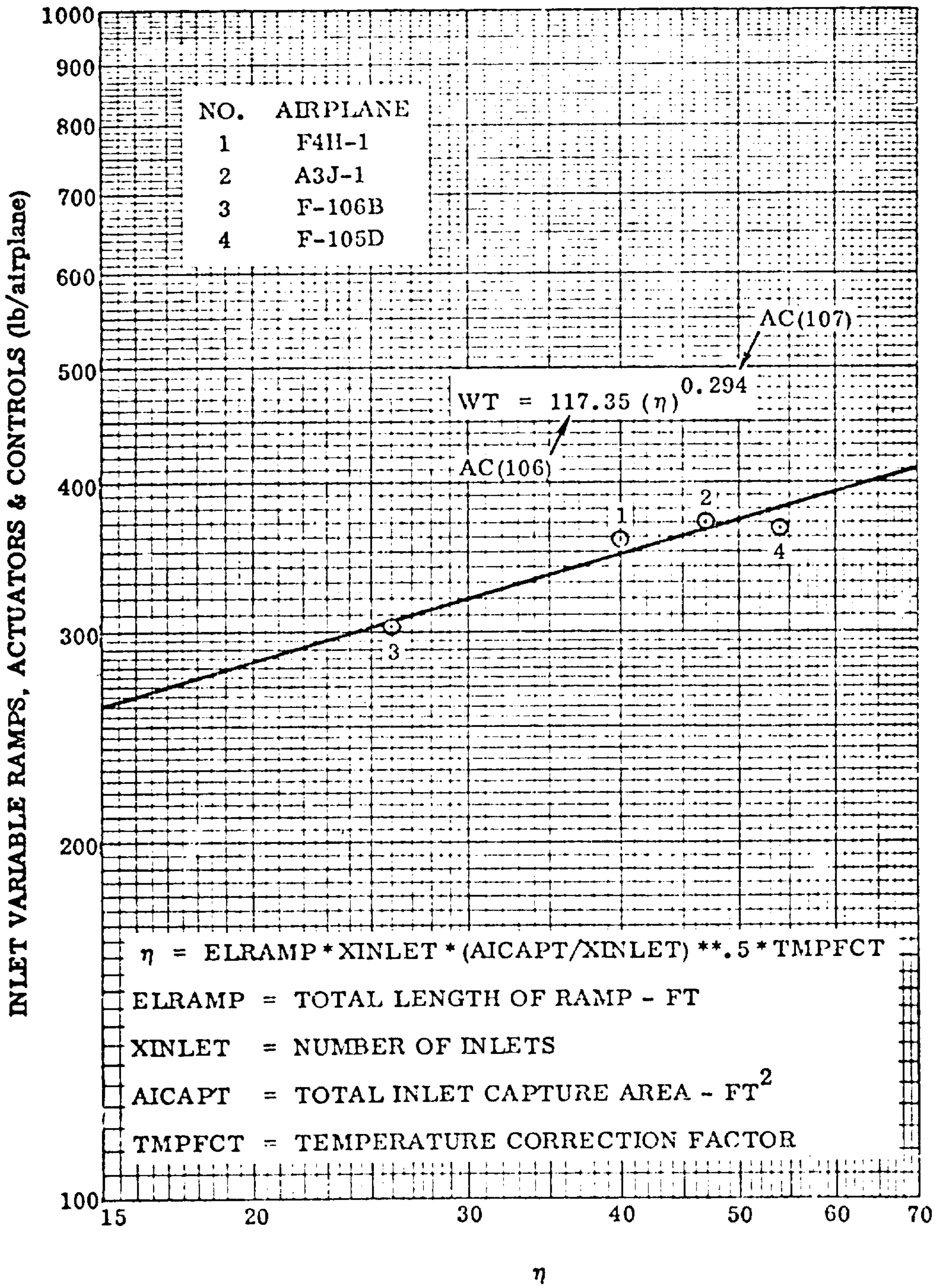


FIGURE 3.5-13 INLET VARIABLE RAMP WEIGHT

3.6 ORIENTATION CONTROLS AND SEPARATION

The total weight of the aircraft orientation controls and separation group is given by

WORNT = WGIMBL + WACS + WACSTK + WAERO + WSEP

where WGIMBL = gimbal system weight
WACS = attitude control system weight
WACSTK = attitude control system tank weight
WAERO = aerodynamic control system weight
WSEP = separation system weight

Expressions for each component weight are given below.

3.6.1 Gimbal System

The gimbal (thrust-vector-control) actuation system is utilized on the aircraft configuration when a rocket engine is used for main impulse. The data in Figures 3.6-1 and 3.6-2 is for an electrical system consisting of a silver-zinc primary battery, a d.c. electric motor and a gear train, two magnetic partical clutches and ball-screw actuators. Reference 1 also discussed a pneumatic actuation system. Both systems were competitive from a weight standpoint with a slight advantage for electrical systems for the longer operating times (≈1200 seconds) and for all torque levels greater than 1000 lb-in.

Delivered Torque	6,000 to 3,000,000 lb-in
Nozzle Deflection	2 to 20 degrees
Nozzle Deflection Rate	5 to 25 degrees/second
Operating Time	50 to 1200 seconds
Thermal Environment	-420 to 4400 °F
Acceleration	2.5 to 15g

TABLE 3.6-1 GIMBAL SYSTEM PARAMETERS

The system weight is expressed in parametric form as a function of delivered torque, maximum deflection rate of nozzle and operating time. The range of significant operational requirements and conditions for the data presented are given in Table 3.6-1. The system assumes pitch and yaw control for single engine and pitch, yaw and roll control for multiple engines. The equation for delivered torque is

TDEL = 750 * (TTOT/ENGINS/PCHAM) ** 1.25

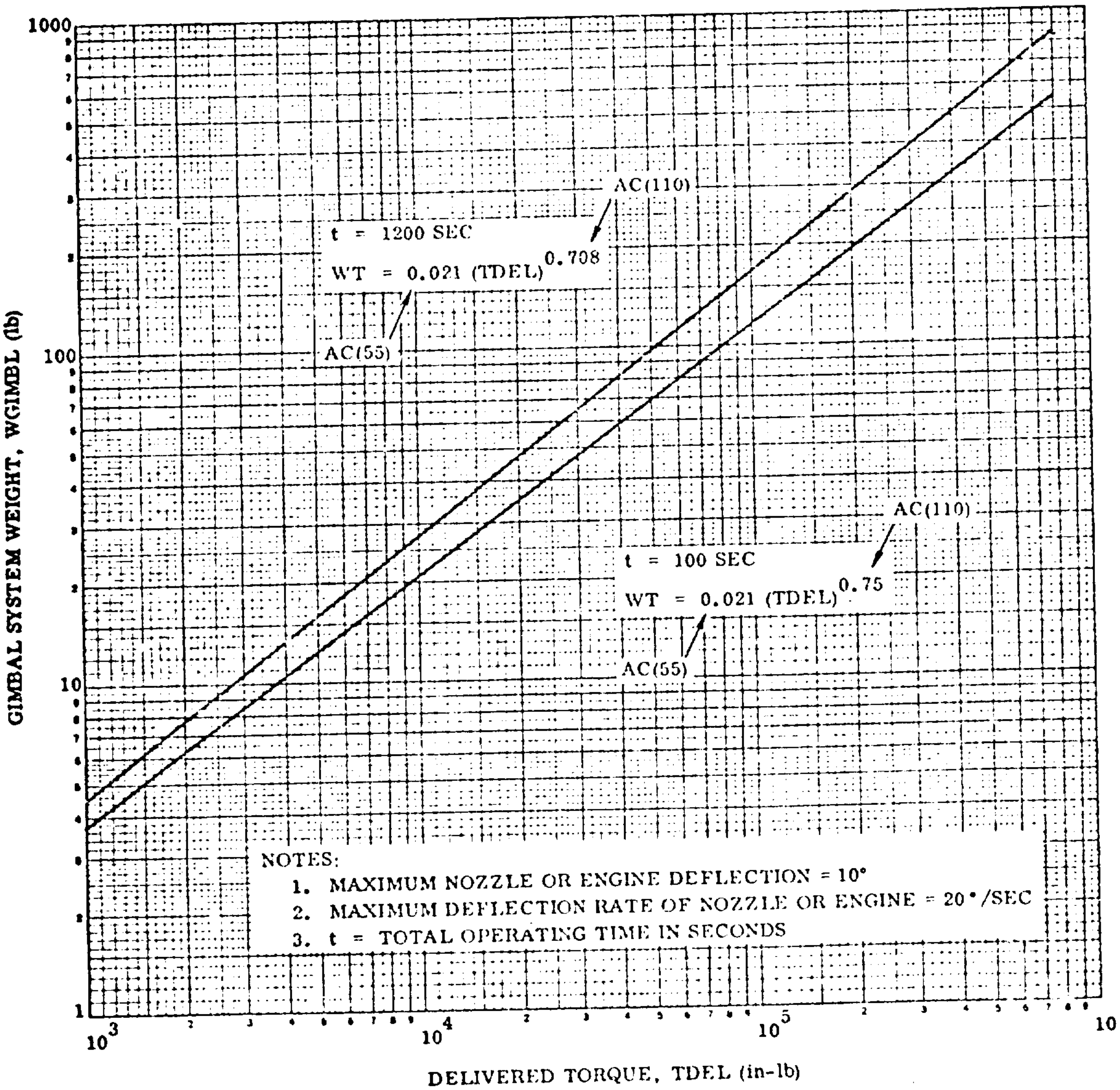


FIGURE 3.6-1 GIMBAL SYSTEM WEIGHT - 20°/SEC DEFLECTION RATE

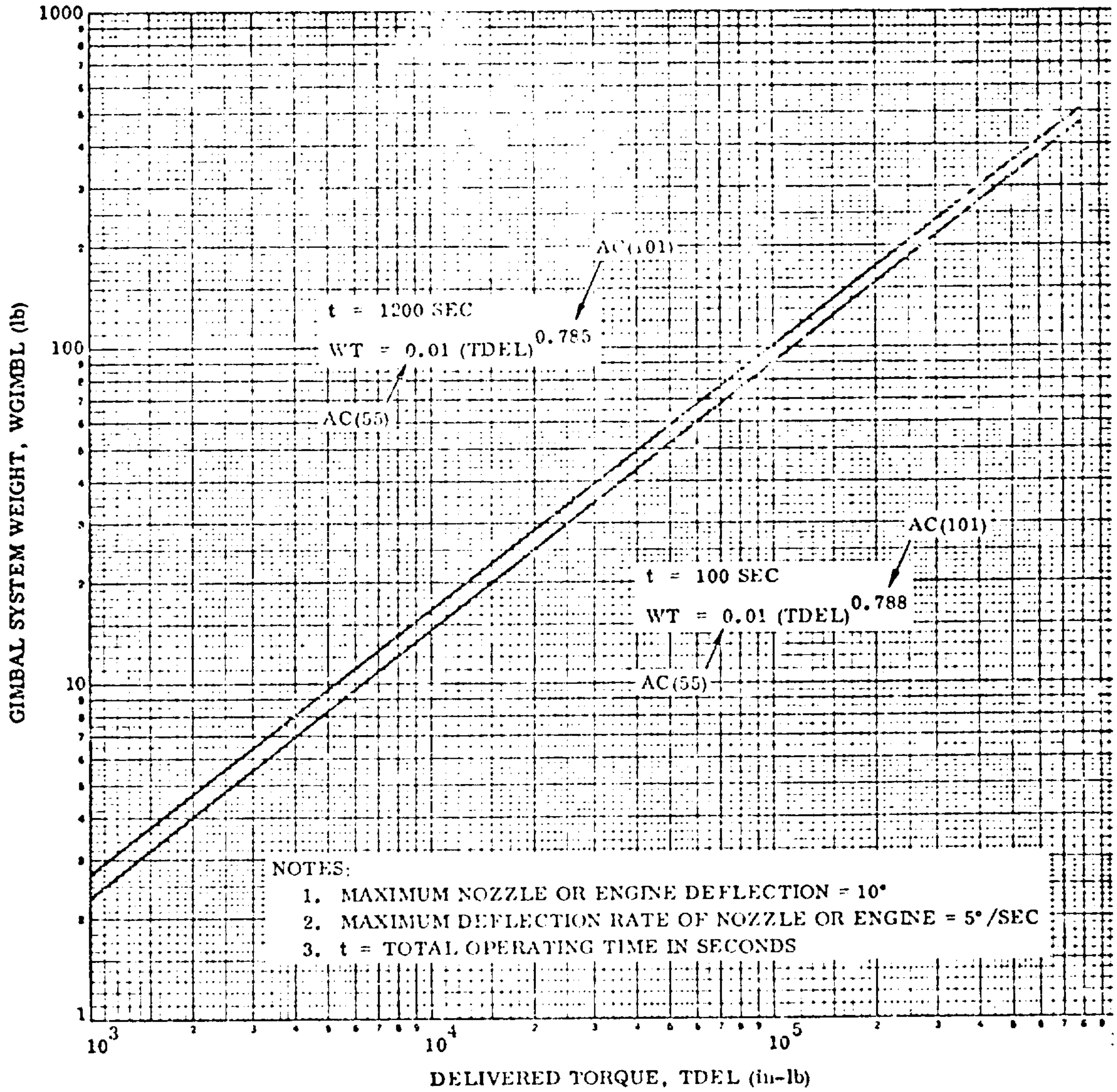


FIGURE 3.6-2 GIMBAL SYSTEM WEIGHT - 5°/SEC DEFLECTION RATE

where TDEL = gimbal system delivered torque, lb-in
TTOT = total stage vacuum thrust, lbs (THRUST * ENGINS * ACTR)
ENGINS=total number of engines per stage
PCHAM= rocket engine chamber pressure, psia

The delivered torque calculation assumes a maximum nozzle deflection of 10 degrees. The calculated delivered torque is then used in the gimbal system weight equation which is

WGIMBL = AC(55) * TDEL ** AC(110) + AC(56)

where WGIMBL = weight of engine gimbal system, lbs
TDEL = gimbal system delivered torque, lb-in
AC(55) = gimbal system weight coefficient (intercept)
AC(110)= gimbal system weight coefficient (slope)
AC(56) = fixed gimbal system weight, lbs

The weight coefficients AC(55) and AC(110) are obtained from Figures 3.6-1 and 3.6-2. The data in Figure 3.6-1 represents a gimbal system with a maximum nozzle deflection rate of 20 degrees per second and Figure 3.6-2 is for five degrees per second. Both figures are for maximum deflections of 10 degrees and operating times of 100 and 1200 seconds. When the airplane configuration utilizes airbreathing engines for main impulse, a gimbal system is not required. Directional control will be accomplished through the use of aerodynamic surfaces.

3.6.2 Spatial Attitude Control System

This subsystem includes the weight of the attitude control system which includes engines, valves, pressurant and residual propellants. It does not include the propellants and their associated tankage.

The system includes 4-pitch, 4-yaw and 4-roll engines with each of the pitch and yaw engines having identical thrust levels, the thrust of the roll engines being half that of a pitch or yaw engine. All the engines are radiation cooled with a pitch and yaw thrust range from 30 to 100 lbs. The equation for attitude control system weight is

WACS=AC(57)*WTO**AC(58)+AC(59)+AC(114)*WENTRY**AC(125)

where WACS = weight of attitude control system, lbs
WTO = gross weight, lbs
AC(57),AC(114)=ACS weight intercept.
AC(58),AC(115)=ACS weight slope
AC(59)= fixed ACS system weight, lbs

The weight coefficients AC(57) and AC(58) represents the intercept and slope, respectively, for the data shown in Figure 3.6-3. The curves in Figure 3.6-3 represent three

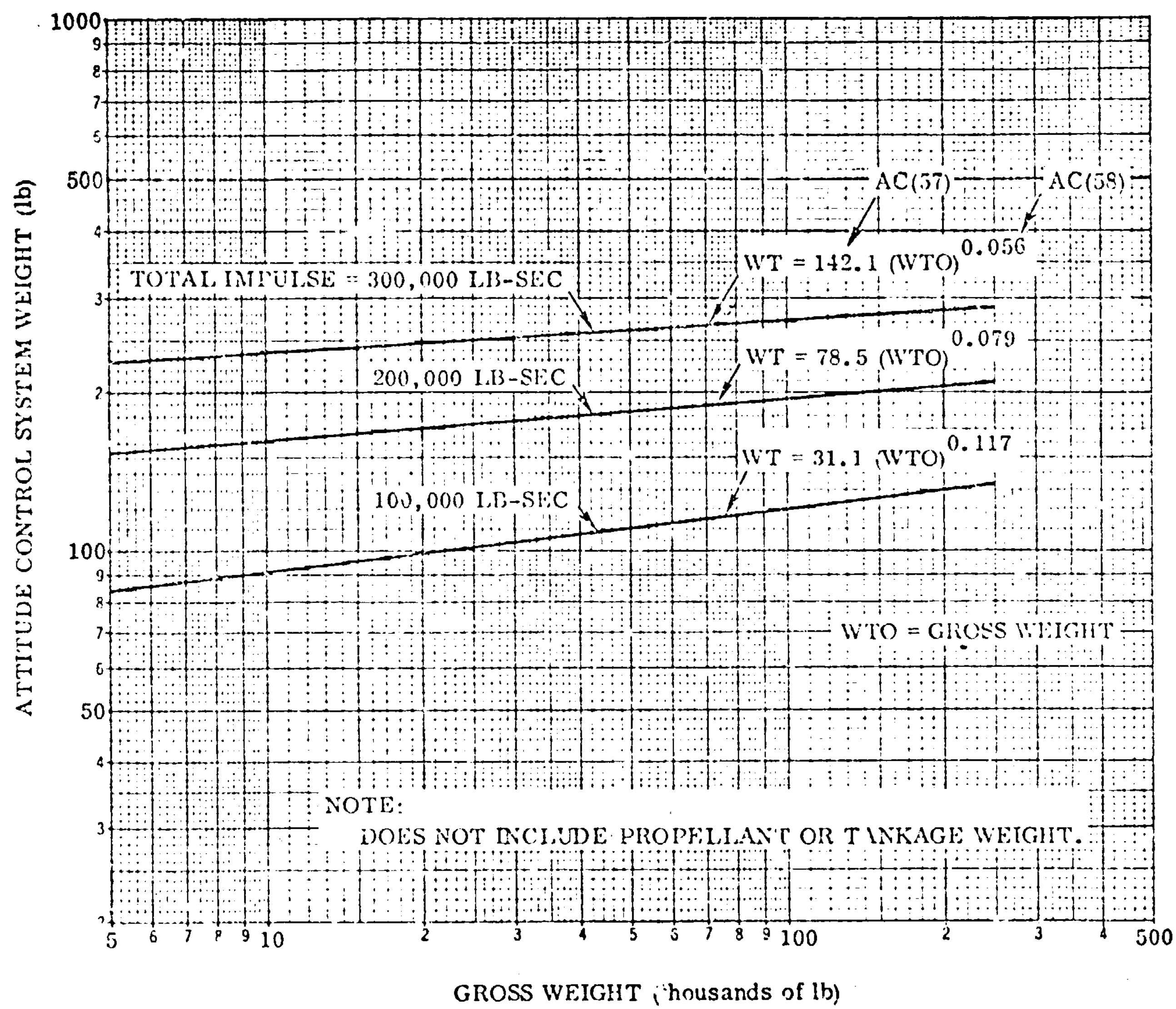


FIGURE 3.6-3 ATTITUDE CONTROL SYSTEM WEIGHT

different size systems with total impulse ranges of 100,000; 200,000 and 300,000 lb/sec. When design data is not available to base a total impulse estimate on, the user may input AC(57) and AC(58) on the 200,000 lb-sec., curve. The X-15 had 235,000 lb-sec as a comparative bases.

3.6.3 Attitude Control System Tankage

The attitude control system tankage weight includes the bladders, insulation, mounting, etc., but does not include the propellants. The tankage system assumes storable monopropellants, helium pressurization and titanium tank material. The equation for attitude control system tankage weight is

WACSTK = AC(64) * (WACSFU + WACSOX) + AC(65)

where
- WACSTK = weight of attitude control system tankage, lbs
- WACSFU = weight of ACS fuel, lbs
- WACSOX = weight of ACS oxidizer, lbs
- AC(65) = fixed ACS tank weight, lbs
- AC(64) = ACS tank weight coefficient

The weight coefficient AC(64) is a ratio of tankage weight to propellant weight. A typical predesign value for AC(64) is 0.10.

3.6.4 Aerodynamic Controls

The weight of this subsystem includes the total weight of the aerodynamic control system. It includes all control levers, push-pull rods, cables and actuators from the control station up to but not including the aerodynamic surfaces. It will also include the autopilot if it is not integral with the navigation system. This weight does not include the hydraulic/pneumatic system weight. The aerodynamic controls data for straight and swept wing aircraft has been separated from the delta wing aircraft data. The basic equation for aerodynamic controls system weight is

WAERO=AC(60)*WTO**.667*(ELBODY+GSPAN)**.25)**AC(111)+AC(61)
+AC(122)*(WENTRY**.667*(ELBODY+GSPAN)**.25)**AC(123)

where
- WAERO = weight of aerodynamic controls, lbs
- WTO = gross weight, lbs (WTOIN)
- ELBODY = body length, ft
- GSPAN = geometric wing span, ft
- AC(60),AC(122) = aerodynamic control system weight coefficient (intercept)
- AC(111),AC(123)= aerodynamic control system weight coefficient (slope)
- AC(61) = fixed aerodynamic control system weight, lbs

The weight coefficients AC(60) and AC(111) are obtained from Figure 3.6-4.

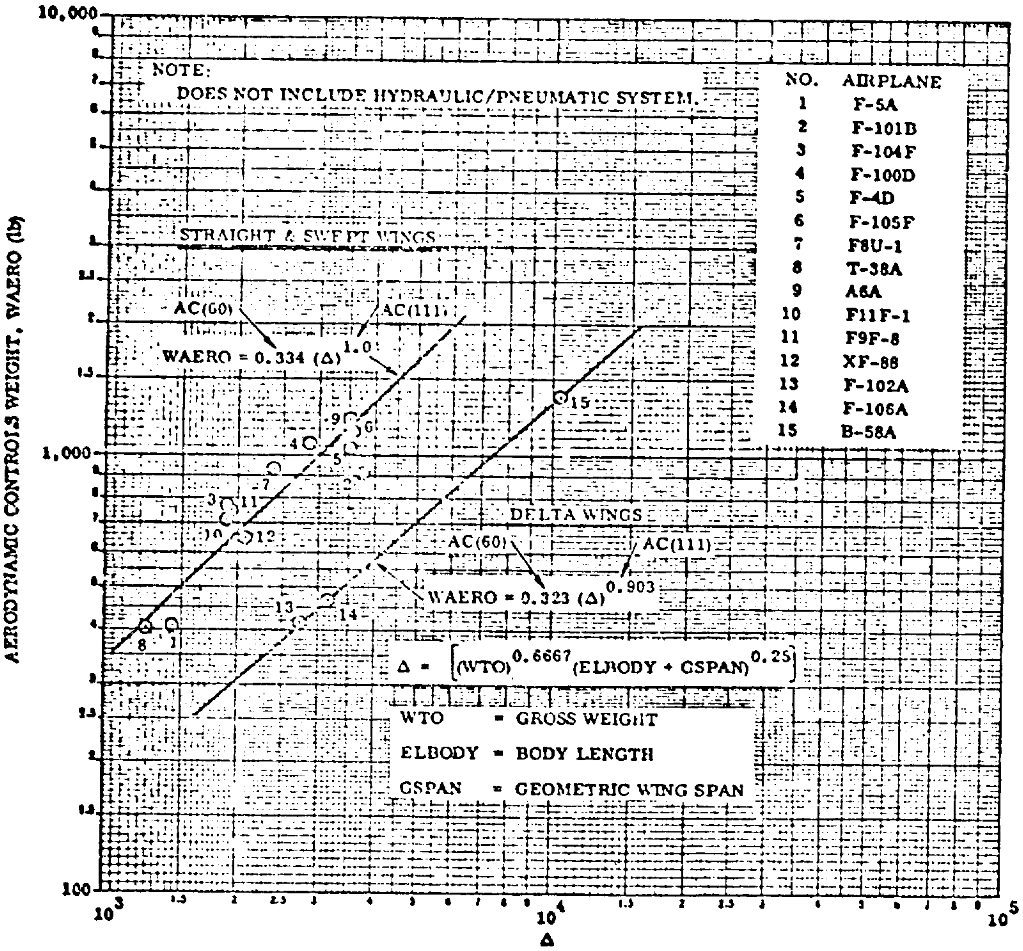


FIGURE 3.6-4 AERODYNAMIC CONTROLS WEIGHT

3.6.5 Separation System

The separation system weight includes the system and attachments on the airplane for separating the two stages from each other. The equation for the separation system weight is

WSEP = AC(62) * WTO + AC(63)

where WSEP = weight of separation system, lbs
WTO = gross weight, lbs (WTOIN)
AC(62)= separation system weight coefficient
AC(63)= fixed separation system weight, lbs

The coefficient AC(62) is a constant that will scale the separation system weight as a function of gross weight. If design data is not available, and it is assumed that the major loads are reacted by the booster, a preliminary design value of AC(62) = 0.003 may be used.

3.7 POWER SUPPLY, CONVERSION AND DISTRIBUTION

The total weight of the aircraft power supply, conversion and distribution group is given by

```
WPWRSY = WELECT + WHYPNU
```

where WELECT = electrical system weight
WHYPNU = hydraulic/pneumatic system weight

Expressions for each component weight are given below.

3.7.1 Electrical System

This subsystem includes the weight for the items required to generate, convert and distribute electrical power required to operate the various vehicle subsystems. Subsystems requiring electrical power are mainly electronics equipment, life support, environmental control equipment, lights, heaters and blower motors. The electrical load varies with flight conditions and flight phase depending upon the demands of each subsystem. The electrical system data presented provides a preliminary weight representative of high speed fighter aircraft.

Major components represented in the system weight are batteries and AC generators, transformer rectifier units, control equipment and power distribution system. The equation for electrical system weight is

```
WELECT=AC(66)*(SQRT(WTO)*ELBODY**.25)**AC(112)+AC(67)
    +AC(126)*(SQRT(WENTRY)*ELBODY**.25)**AC(127)
```

where WELECT = weight of electrical system, lbs
WTO = gross weight, lbs (WTOIN)
ELBODY = body length, ft.
AC(66),AC(126) = electrical system weight coefficient (intercept)
AC(112),AC(127)= electrical system weight coefficient
AC(67) = fixed electrical system weight, lbs (slope)

The weight coefficients AC(66) and AC(112) are obtained from Figure 3.7-1.

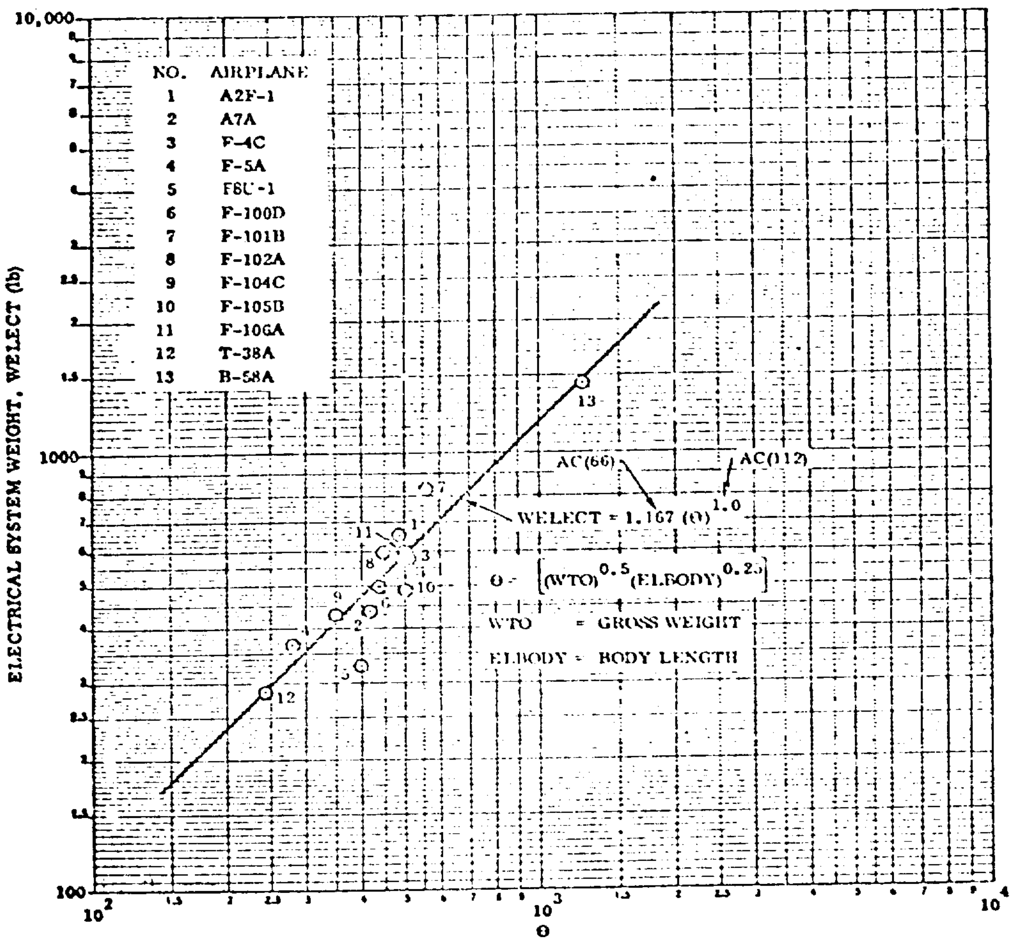


FIGURE 3.7-1 ELECTR... SYSTEM WEIGHT

3.7.2 Hydraulic/Pneumatic System

The hydraulic/pneumatic system is comprised of the system components to produce fluid or pneumatic pressure, control equipment, storage vessels, hydraulic fluid and a distribution system up to but not including the various functional branches actuators, etc. The equation for hydraulic/pneumatic system weight is

```
WHYPNU = AC(68) * ((SWING+SHORZ+SVERT) * QMAX/1000)
         ** 0.334 + (ELBODY + STSPAN) ** 0.5 * TYTAIL)
         ** AC(113) + AC(69) + AC(128) *WTO + AC(129)
         * WENTRY
```

where

WHYPNU	=	weight of hydraulic/pneumatic system, lbs
SWING	=	gross wing area, ft^2
SHORZ	=	horizontal stabilizer planform area, ft^2
SVERT	=	vertical fin planform area, ft^2
QMAX	=	maximum dynamic pressure, lbs/ft^2
ELBODY	=	body length, ft
STSPAN	=	structural span (along .5 chord, ft^2
TYTAIL	=	type tail coefficient 1.0 for conventional tail 1.25 for delta planform 1.5 for all moving horizontal and/or vertical
WTO	=	gross takeoff weight (WTOIN)
WENTRY	=	entry weight (calculated)
AC(68)	=	hydraulic/pneumatic system weight coefficient (intercept)
AC(113)	=	hydraulic/pneumatic system weight coefficient (slope)
AC(69)	=	fixed hydraulic/pneumatic system weight, lbs
AC(128)	=	hydraulic/pneumatic system weight coefficient (F(WTO))
AC(129)	=	hydraulic/pneumatic system weight coefficient ((F(WENTRY))

The weight coefficients AC(68) and AC(113) are obtained from Figure 3.7-2.

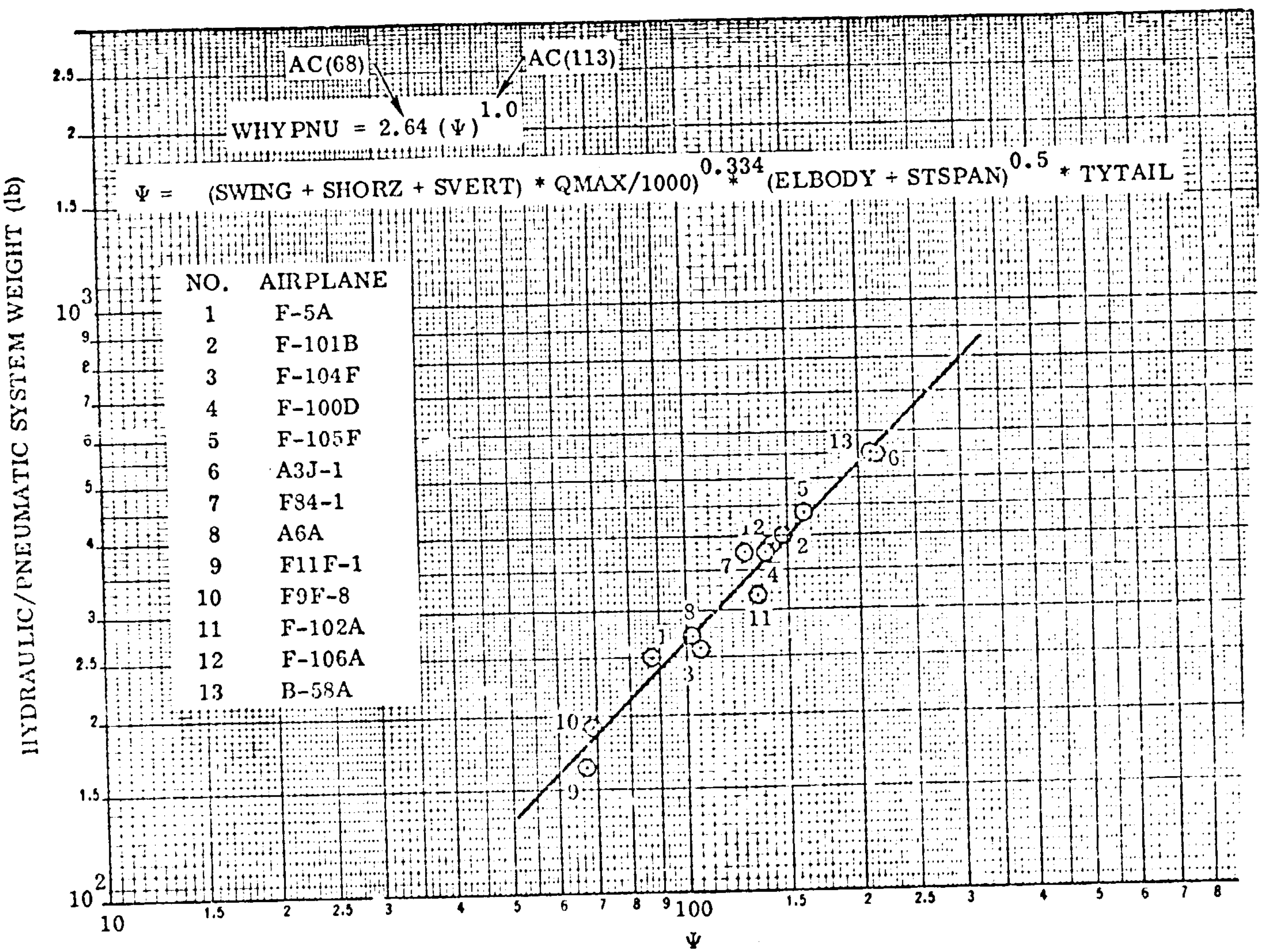


FIGURE 3.7-2 HYDRAULIC/PNEUMATIC SYSTEM WEIGHT

3.8 AVIONICS

The avionic system includes the guidance and navigation system, the instrumentation and the communications system.

The guidance and navigation system includes those items necessary to insure that the vehicle position and its trajectory is known at all times. This system also generates commands for the flight control system for changing or correcting the vehicle heading.

The instrumentation system provides for a weight allocation assigned to the basic instruments normally required for sensing and readout of the normal flight parameters needed for monitoring a flight program. In addition to this basic system there are many possible mission oriented instrumentation functions that may be required. Weight allocation for the instrumentation system is normally part of a design study for a particular vehicle design and mission requirement.

The communication system weight allocation is for all equipment necessary to provide for the communication between vehicle and air or ground stations including communication within the vehicle itself.

The equation for avionic system weight is

WAVONC = AC(70) * WTO ** AC(114) + AC(71)

where
- WAVONC = weight of avionics system, lbs
- WTO = gross weight, lbs
- AC(70) = avionic system weight coefficient (intercept)
- AC(114) = avionic system weight coefficient (slope)
- AC(71) = fixed avionic system weight, lbs

The weight coefficients AC(70) and AC(114) are obtained from Figure 3.8-1. This data represents systems of advanced capability with significant fire control capability (F-111 and B-58 type).

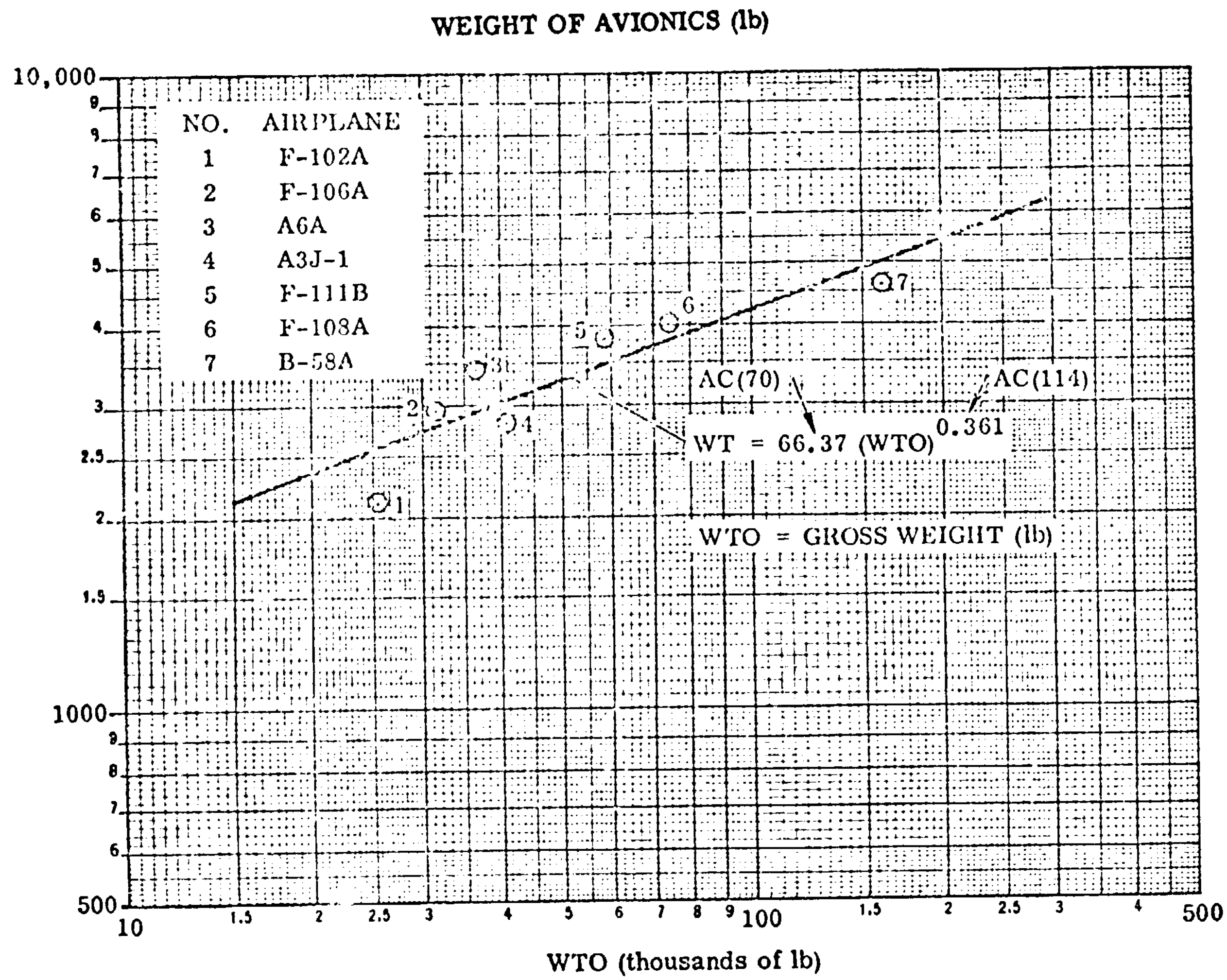


FIGURE 3.8-1 AVIONICS SYSTEM WEIGHT

3.9 AIRCRAFT CREW SYSTEMS

The crew provisions include the equipment and personnel environment control system, crew compartment insulation, personnel accommodations, fixed life support equipment, emergency equipment, crew station controls and panels.

The equipment environmental control system is used to maintain the correct operating conditions for vehicle system equipment. The function of the personnel environmental control system is to provide an acceptable environmental condition for the crew. This includes temperature, atmosphere and pressurization equipment and supports. The compartment insulation is required for controlling environment in conjunction with the overall active environmental system. The accommodations for personnel includes seats, supports, restraints, shock absorbers, ejection mechanisms, etc. The fixed life support system includes food containers, waste management, hygiene equipment, etc. The fixed emergency equipment includes a built-in fire extinguishing system, life rafts, etc. The crew station control and panels is for installation of crew station flight controls, instrument panels, control pedestals and stands.

The crew provisions are a combined function of gross weight, crew size and fixed weights. Therefore, the weight penalty may be represented by one equation and the various inputs collected and summed from Table 3.9-1. The equation for crew provisions weight is

$$WCPROV = AC(74) * WTO + AC(80) * CREW + AC(75)$$

where WCPROV = weight of crew provisions, lbs
WTO = gross weight, lbs (WTOIN)
CREW = number of crew members
AC(74) = equipment ECS weight coefficient
AC(80) = crew provisions weight coefficient
AC(75) = fixed crew provisions weight, lbs

SYSTEM DESCRIPTION	AC(74)	AC(50)	AC(75)
Equipment Environmental Control	0.0005	-	100
Personnel Environmental Control	-	10	250
Compartment Insulation	-	50	-
Accommodations for Personnel			
B-70 Type Encapsulated Seat	-	570	-
X-15 Ejection Seat	-	300	-
Gemini Ejection Seat	-	220	-
Lightweight Ejection Seat	-	100	-
Conventional Crew Seat	-	50-120	-
Fixed Life Support	-	10	-
Fixed Emergency Equipment	-	50	-
Crew Station Controls and Panels	-	40	50

TABLE 3.9-1. TYPICAL CREW PROVISION INPUTS

3.10 DRY WEIGHT

The dry weight consists of all the previous components as estimated but does not include design reserve or contingency. The equation used is

WDRY = WSURF + WBODY + WTPS + WGEAR + WPROPU + WORNT
+ WPWRSY + WAVONC + WCPROV

where
WSURF = Aerodynamic surface weight (3.1)
WBODY = body structure weight (3.2)
WTPS = induced environmental protection (3.3)
WGEAR = launch and recovery gear weight (3.4)
WPROPU= propulsion system weight (3.5)
WORNT = orientation system weight (3.6)
WPWRSY= power supply weight (3.7)
WAVONC= avionics system weight (3.8)
WCPROV= crew provisions weight (3.9)

3.11 DESIGN RESERVE (CONTINGENCY)

The input for contingency and growth permits a proportion of dry weight and/or a fixed weight to be set aside for growth allowance, design unknowns, etc.

This value for dry weight is then used in the equation for contingency and growth which is

WCONT = AC(98) * WDRY + AC(99)

where
- WCONT = weight of contingency and growth, lbs
- WDRY = stage dry weight, lbs
- AC(98) = contingency and growth coefficient
- AC(99) = fixed contingency and growth weight, lbs

3.12 EMPTY WEIGHT

The empty weight of the aircraft is the estimated dry weight plus the design contingency.

WEMPTY = WDRY + WCONT

where
- WEMPTY = empty weight
- WDRY = dry weight (3.10)
- WCONT = design contingency (3.11)

3.13 PAYLOAD

This is the payload or cargo component. It is a fixed input to the program.

WPAYLD = payload or cargo (input)

3.14 CREW AND CREW LIFE SUPPORT

This section includes the crew, gear and accessories as well as the crew life support. The crew, gear and accessories include crew, constant wear and protection garments, pressure suits, head gear, belt packs, personal parachutes, portable hygienic equipment, maps, manuals, log books, portable fire extinguishers, maintenance tools, etc. The crew life support includes food, water, portable containers, medical equipment, survival kits, etc. The equation for crew and crew life support weight is

WCREW = AC(72) * CREW + AC(73)

where WCREW = weight of crew, gear, and crew life support, lbs.
CREW = number of crew numbers
AC(72)= crew weight coefficient
AC(73)= fixed crew weight, lbs

Typical values for the crew dependent weight is shown in Table 3.14-1. The input coefficient AC(73) is used for fixed crew life support weight. A typical input for AC(73) is shown in Table 3.14-1. This coefficient may also be used to input a fixed weight for crew and crew life support. When AC(73) is used for this purpose the coefficient AC(72) may be set to zero.

DESCRIPTION	AC(72)	AC(73)
Crew, Gear and Accessories	220-[illegible]	---
Crew Life Support	2-5	25-50

TABLE 3.14-1. TYPICAL INPUTS FOR CREW AND CREW LIFE SUPPORT

3.15 RESIDUAL PROPELLANTS

The residual propellant includes the trapped fuel and oxidizer.

WRESID = WFTRAP + WOTRAP

where WRESID = residual propellant weight
WFTRAP = trapped fuel weight
WOTRAP = trapped oxidizer weight

3.15.1 Trapped Fuel

The equation for trapped fuel weight is

WFTRAP = AC(92) * WFUEL + AC(93)

where WFTRAP = weight of fuel trapped in tank and lines, lbs
WFUEL = weight of main impulse plus reserve fuel, lbs (calculated)
AC(92) = trapped fuel weight coefficient
AC(93) = fixed trapped fuel weight, lbs

A typical input value for AC(92) will vary from 0.005 to 0.03.

3.15.2 Trapped Oxidizer

The equation for trapped oxidizer weight is

WOTRAP = AC(94) * WOXID + AC(95)

where WOTRAP = weight of oxidizer trapped in tank and lines, lbs
WOXID = weight of main impulse plus reserve oxidizer, lbs
AC(94) = trapped oxidizer weight coefficient
AC(95) = fixed trapped oxidizer weight, lbs

A typical input value for AC(94) will vary from 0.005 to 0.03.

3.16 LANDING WEIGHT

The landing weight is calculated as

WLAND = WEMPTY + WPAYLD + WCREW + WREID + WACSRE

where WEMPTY = empty weight (3.12)
WPAYLD = payload (3.13)
WCREW = crew and crew life support (3.14)
WRESID = main propellant residuals (3.15)
WACSRE = attitude control system propellant residuals (3.16.1)

3.16.1 Attitude Control System Residuals

The attitude control system residuals are assumed to be a fraction of the total attitude control propellant.

WACSRE = AC(115) * WACSP

WHERE WACSRE = attitude control system propellant residuals
WACSP = attitude control system propellant (3.17)
AC(115)= ACS propellant coefficient

3.17 ATTITUDE CONTROL SYSTEM (ACS) PROPELLANTS

The attitude control system is based on a monopropellant system. The equations for ACS fuel and oxidizer weight are

WACSFU - AC(96) * WENTRY + AC(97)

WACSOX = WACSFU * OFACS

WACSP = WACSFU + WACSOX

where WACSP = ACS propellant
WACSFU = ACS fuel
WACSOX = ACS oxidizer
OFACS = mixture rating
WENTRY = entry weight
AC(96) = entry weight coefficient
AC(97) = fixed ACS fuel weight

3.18 ENTRY WEIGHT

The entry weight is defined as the landing weight plus the attitudes control propellant

WENTRY = WLAND + WACSP

where WLAND = landing weight (3.16)
WACSP = ACS propellant (3.17)

3.19 MAIN PROPELLANTS

The main propellant is input to the program (WPMAIN).

The main impulse propellant components are

WFUELM = WPMAIN/(1. + OF)

WOXIDM = WFUELM * OF

where WFUELM = weight of main impulse fuel, lbs
WPMAIN = weight of main impulse propellant, lbs.
OF = main oxidizer to fuel mixture ratio by weight
WOXIDM = weight of main impulse oxidizer, lbs

3.20 RESERVE PROPELLANT

Total reserves are the sum of reserve fuel and reserve oxidizer

WPRESV = WFRESV + WORESV

The equation for reserve fuel weight is

WFRESV = AC(84) * WFUELM + AC(85)

where WFRESV = weight of fuel reserve, lbs
WFUELM = weight of main impulse fuel, lbs
AC(84) = reserve fuel weight coefficient
AC(85) = fixed reserve fuel weight, lbs

The equation for reserve oxidizer weight is

WORESV = AC(86) * WOXIDM + AC(87)

where WORESV = weight of oxidizer reserve, lbs
WOXIDM = weight of main impulse oxidizer, lbs
AC(86) = reserve oxidizer weight coefficient
AC(87) = fixed reserve oxidizer weight, lbs

A typical input value for AC(84) and AC(86) will vary from 0.01 to 0.20.

3.21 INFLIGHT LOSSES

The inflight losses are a function of the main propellant

WPLOSS = AC(116) * WPMAIN

where WPMAIN = main impulse propellant
AC(116) = propellant coefficient

3.22 TAKEOFF GROSS WEIGHT

The takeoff gross weight is calculated in the following manner

$$WTO = WENTRY + WPMAIN + WPRESV + WPLOSS$$

where WTO = takeoff gross weight
WENTRY= entry weight (3.18)
WPMAIN= main impulse propellant (3.19)
WPRESV= reserve propellant (3.20)
WPLOSS= inflight propellant losses (3.21)

4.0 USER INSTRUCTIONS

This section provides instructions for using the WAATS program. It includes deck setup and a description of input and output. WAATS can be used in a stand alone manner or within the ODIN system. In the stand alone mode the user provides all weight coefficients and exponents, geometric data, areas, volumes and propellant requirements. The program computes the component weights in an iterative manner to satisfy the propellant requirement. When used within the ODIN system, the geometric characteristics as well as weight coefficients may be computed in other programs and passed to WAATS through the ODIN design data base.

4.1 DECK SETUP

The program is stored on data cell and can be retrieved and executed in the following manner.

```
JOB, ---
USER, ---
FETCH, A3983, SPRA02*, BINARY.
BNFILE.
7-8-9
 $INWAP
    (namelist data)
 $
7-8-9
6-7-8-9
```

The wedge number * is subject to change. The current number may be obtained from the ODIN data base manager.
The namelist data includes the weight coefficients and the geometric characteristics described in Section 4.2.

WAATS may also be used in the ODIN system. Any input may come from the data base and all component weights and summations are available to the data base. The deck setup for WAATS within an ODIN simulation is

```
'EXECUTE WAATS'
 $INWAP
   (namelist data)
 $
7-8-9
```

The use of WAATS within the ODIN system assures the use of the most current production version of the program.

4.2 PROGRAM INPUT

WAATS uses namelist input. Namelist is a standard FORTRAN feature. The rules are described in any good FORTRAN manual. The single namelist name for this program is:

```
$INWAP      (starting in column 2)
```

Each input variable or array has a name and value(s).

```
    name = value,
  or
    name = value, value,
  or
    name (I) = value, value,
```

The namelist is terminated with a $ (dollar) in column 2 or greater.

Table 4.2-1 defines the input variables and the computed values. The user need specify only these variables which require values different than shown in Table 4.2-1 .

Every input variable is not necessarily required for all vehicles. For example, a vehicle not having a turbo ramjet engine does not require input values for PHIGH and PLOW.

A good procedure to follow in setting up a WAATS input deck is:

1. Read through Section 3 to determine which component weights are going to be considered. The equations for each component are specified in detail. In most cases, the input requirements are given along with the equation. The one exception is TTOT, total thrust, which is computed from input variables as follows:

   TTOT = ENGINES * THRUST * ACTR

2. Specify the weight coefficients for the component weight equations selected. See Section 2.3 for using coefficients other than those presented in Section 3.

   AC(I) = XXX,

3. Note which input variables are required for the selected weight components. The equations are given in Section 3.

W A A T S   I N P U T   D E F I N A T I O N

INPUT NAME	COMPILED VALUE	DEFINATION
ACTR	1.	THRUST SCALING FACTOR
AICAPT	0.	TOTAL CAPTURE AREA OF INLETS (SQ FT)
ARATIO	80.	ROCKET ENGINE AREA RATIO (AIRCRAFT)
CREW	2.	NUMBER OF CREW MEMBERS
DH	60000	DESIGN ALTITUDE ,FT
DM	4.5	DESIGN MACH NUMBER
ELBODY	350.	BODY REFERENCE LENGTH, FT.
ELNLET	0.	TOTAL INLET LENGTH, FT.
ELRAMP	0.	TOTAL LENGTH OF RAMP,FT
ENGINS	22.	NUMBER OF ENGINES
FCTMOR	1.	MACH NUMBER FACTOR
GEOFCT	1.	GEOMETRICAL OUT OF ROUND FACTOR
GSPAN	141.	GEOMETRIC WING SPAN ,FT
GO	32.174	SEA LEVEL GRAVITY, FPSS
HBODY	20.	MAXIMUM BODY HEIGHT, FT.
ICRY	2	PROPELLANT TYPE INDICATOR,
		ICRY = 1 NON - CRYOGENIC
		ICRY = 2 CRYOGENIC
IENG	1	= 1 FOR ROCKET ENGINES
		= 2 FOR TURBORAMJET ENGINES
		= = 3 FOR AIRBREATHING, NON-TURBORAMJET ENGI
ISHAPE	2	SHAPE FLAG
		= 1 FOR BOOSTER-TYPE (NO WINGS OR TAIL)
		= 2 FOR AIRCRAFT
		= 3 FOR LIFTING BODY
		= 4 FOR LIFTING BODY + WING
OF	6.	OXIDIZER TO FUEL MIXTURE RATIO BY WEIGHT
OFACS	0.	ACS OXIDIZER TO FUEL MIXTURE RATIO BY WEIGHT
PCHAM	1000.	ROCKET ENGINE CHAMBER PRESSURE
PHIGH	176.	TURBORAMJET ENGINE INLET PRESSURE (UPPER DESIGN CURVE)
PLOW	46.	TURBORAMJET ENGINE INLET PRESSURE (LOWER DESIGN CURVE)
QMAX	2500.	MAXIMUM DYNAMIC PRESSURE, LB/SFT
RE	20.92 E6	EARTH RADIUS, FT
SBODY	32800.	TOTAL BODY WETTED AREA, SQ.FT.
SFAIR	0.	TOTAL FAIRING OR ELEVON SURFACE PLANFORM
SFUTK	0.	FUEL TANK WETTED AREA, SQ. FT.
SHORZ	1.	TOTAL HORIZONTAL SURFACE PLANFORM AREA, SQ.
SOXTK	0.	OXIDIZER TANK WETTED AREA, SQ. FT.
STPS	42300.	TPS AREA, SFT

TABLE 4.2-1 WAATS INPUT DEFINITION

STSPAN	93.71	WING STRUCTURAL SPAN PER AIRPLANE (ALONG 50 PERCENT CHORD), FT
SVERT	1380.	TOTAL VERTICAL SURFACE PLANFORM AREA, SQ.FT.
SWING	11579.	THEORETICAL WING AREA PER AIRPLANE, SQ.FT.
TANKS	2.	NUMBER OF FUSELAGE FUEL TANKS
THRUST	470000.	THRUST OF ONE ENGINE
TROOT	11.46	WING THICKNESS AT THEORETICAL ROOT
TYTAIL	1.25	TYPE TAIL COEFFICIENT
VFUTK	145200.	VOLUME OF FUEL TANK, CU. FT.
VOXTK	53100.	VOLUME OF OXIDIZER TANK, CU. FT.
WLANDI	3.0 E6	LANDING WEIGHT, LB (ESTIMATE)
WPAYLD	40000.	WEIGHT OF PAYLOAD, LB.
WPMAIN	4.4 E6	WEIGHT OF MAIN IMPULSE PROPELLANT, LB
WTOIN	7.5 E6	TOTAL WEIGHT AT TAKE-OFF, LB (ESTIMATE)
XINLET	0.	NUMBER OF INLETS
ALF	3.75	WING ULTIMATE LOAD FACTOR
WAREF	122.7	REFERENCE ENGINE AIR FLOW (LB/SEC)

WEIGHT TARES, COEFFICIENTS, AND EXPONENTS

AC(1)	0.	WING WEIGHT COEFFICIENT
AC(2)	0.	UNIT WING WEIGHT
AC(3)	0.	FIXED WING WEIGHT
AC(4)	0.	UNIT VERTICAL WEIGHT
AC(5)	0.	FIXED VERTICAL WEIGHT
AC(6)	0.	UNIT HORIZONTAL WEIGHT
AC(7)	0.	FIXED HORIZONTAL WEIGHT
AC(8)	0.	UNIT FAIRING OR ELEVON WEIGHT
AC(9)	0.	FIXED FAIRING OR VERTICAL WEIGHT
AC(10)	0.	NOT USED
AC(11)	0.	NOT USED
AC(12)	0.	NOT USED
AC(13)	0.	NOT USED
AC(14)	0.	UNIT BODY WEIGHT COEFFICIENT (F(SBODY))
AC(15)	0.	UNIT BODY WEIGHT COEFFICIENT (F(SBODY))
AC(16)	0.	FIXED BODY WEIGHT
AC(17)	0.	UNIT SECONDARY STRUCTURE WEIGHT
AC(18)	0.	FIXED SECONDARY STRUCTURE WEIGHT
AC(19)	0.	THRUST STRUCTURE WEIGHT COEFFICIENT
AC(20)	0.	FIXED THRUST STRUCTURE WEIGHT
AC(21)	0.	UNIT INSULATION WEIGHT
AC(22)	0.	UNIT COVER PANEL WEIGHT
AC(23)	0.	LAUNCH GEAR WEIGHT COEFFICIENT
AC(24)	0.	FIXED LAUNCH GEAR WEIGHT
AC(25)	0.	LANDING GEAR WEIGHT COEFFICIENT (F(WTO))

TABLE 4.2-1 WAATS INPUT DEFINITION (Cont'd)

AC(26)	0.	LANDING GEAR WEIGHT COEFFICIENT (F(WLAND))
AC(27)	0.	FIXED LANDING GEAR WEIGHT
AC(28)	0.	ROCKET ENGINE WEIGHT COEFFICIENT (W/T)
AC(29)	0.	ROCKET ENGINE WEIGHT COEFFICIENT
AC(30)	0.	NOZZLE EXPONENT
AC(31)	0.	FIXED ROCKET ENGINE WEIGHT
AC(32)	0.	TURBORAMJET ENGINE WEIGHT COEFFICIENT (LOWER DESIGN POINT)
AC(33)	0.	TURBORAMJET ENGINE WEIGHT COEFFICIENT (LOWER DESIGN POINT)
AC(34)	0.	TURBORAMJET ENGINE WEIGHT COEFFICIENT (UPPER DESIGN POINT)
AC(35)	0.	TURBORAMJET ENGINE WEIGHT COEFFICIENT (UPPER DESIGN POINT)
AC(36)	0.	FUEL TANK WEIGHT COEFFICIENT (NON-STRUCTURAL)
AC(37)	0.	FIXED FUEL TANK WEIGHT (NON-STRUCTURAL)
AC(38)	0.	OXIDIZER TANK WEIGHT COEFFICIENT (NON-STRUCTURAL
AC(39)	0.	FIXED OXIDIZER TANK WEIGHT (NON-STRUCTURAL)
AC(40)	0.	UNIT FUEL TANK INSULATION WEIGHT
AC(41)	0.	FIXED FUEL TANK INSULATION WEIGHT
AC(42)	0.	UNIT OXIDIZER TANK INSULATION WEIGHT
AC(43)	0.	FIXED OXIDIZER TANK INSULATION WEIGHT
AC(44)	0.	FUEL SYSTEM WEIGHT COEFFICIENT (F(THRUST))
AC(45)	0.	FUEL SYSTEM WEIGHT COEFFICIENT (F(WP))
AC(46)	0.	FIXED FUEL SYSTEM WEIGHT
AC(47)	0.	OXIDIZER SYSTEM WEIGHT COEFFICIENT (F(THRUST))
AC(48)	0.	OXIDIZER SYSTEM WEIGHT COEFFICIENT (F(WP))
AC(49)	0.	FIXED OXIDIZER SYSTEM WEIGHT
AC(50)	0.	FUEL TANK PRESSURE SYSTEM WEIGHT COEFFICIENT
AC(51)	0.	OXIDIZER TANK PRESSURE SYSTEM WT. COEFFICIENT
AC(52)	0.	FIXED PRESSURE SYSTEM WEIGHT
AC(53)	0.	INLET WEIGHT COEFFICIENT
AC(54)	0.	FIXED INLET WEIGHT
AC(55)	0.	GIMBAL SYSTEM WEIGHT COEFFICIENT
AC(56)	0.	FIXED GIMBAL SYSTEM WEIGHT
AC(57)	0.	ACS SYSTEM WEIGHT COEFFICIENT
AC(58)	0.	ACS SYSTEM WEIGHT EXPONENT
AC(59)	0.	FIXED ACS SYSTEM WEIGHT
AC(60)	0.	AERODYNAMIC CONTROL SYSTEM WEIGHT COEFFICIENT
AC(61)	0.	FIXED AERODYNAMIC CONTROL SYSTEM WEIGHT
AC(62)	0.	SEPARATION SYSTEM WEIGHT COEFFICIENT
AC(63)	0.	FIXED SEPARATION SYSTEM WEIGHT
AC(64)	0.	ACS TANK WEIGHT COEFFICIENT
AC(65)	0.	FIXED ACS TANK WEIGHT
AC(66)	0.	ELECTRICAL SYSTEM WEIGHT COEFFICIENT
AC(67)	0.	FIXED ELECTRICAL SYSTEM WEIGHT

TABLE 4.2-1 WAATS INPUT DEFINITION (Cont'd)

AC(68)	0.	HYDRAULIC SYSTEM WEIGHT COEFFICIENT
AC(69)	0.	FIXED HYDRAULIC SYSTEM WEIGHT
AC(70)	0.	AVIONIC SYSTEM WEIGHT COEFFICIENT
AC(71)	0.	FIXED AVIONIC SYSTEM WEIGHT
AC(72)	0.	CREW WEIGHT COEFFICIENT
AC(73)	0.	FIXED CREW WEIGHT
AC(74)	0.	CREW PROVISIONS WEIGHT COEFFICIENT
AC(75)	0.	FIXED CREW PROVISIONS WEIGHT
AC(76)	0.	FIXED VEHICLE INSULATION WEIGHT
AC(77)	0.	FIXED VEHICLE COVER PANEL WEIGHT
AC(78)	0.	WING WEIGHT COEFFICIENT
AC(79)	0.	UNUSED
AC(80)	0.	CREW PROVISION WEIGHT COEFFICIENT
AC(81)	0.	BASIC BODY WEIGHT COEFFICIENT
AC(82)	0.	RAMJET ENGINE WEIGHT COEFFICIENT
AC(83)	0.	FIXED RAMJET ENGINE WEIGHT
AC(84)	0.	RESERVE FUEL WEIGHT COEFFICIENT
AC(85)	0.	FIXED RESERVE FUEL WEIGHT
AC(86)	0.	RESERVE OXIDIZER WEIGHT COEFFICIENT
AC(87)	0.	FIXED RESERVE OXIDIZER WEIGHT
AC(88)	0.	UNUSED
AC(89)	0.	VERTICAL FIN WEIGHT COEFFICIENT
AC(90)	0.	HORIZONTAL STABILIZER WEIGHT COEFFICIENT
AC(91)	0.	FIXED TURBORAMJET ENGINE WEIGHT
AC(92)	0.	TRAPPED FUEL WEIGHT COEFFICIENT
AC(93)	0.	FIXED TRAPPED FUEL WEIGHT
AC(94)	0.	TRAPPED OXIDIZER WEIGHT COEFFICIENT
AC(95)	0.	FIXED TRAPPED OXIDIZER WEIGHT
AC(96)	0.	ACS FUEL WEIGHT COEFFICIENT
AC(97)	0.	FIXED ACS FUEL WEIGHT
AC(98)	0.	CONTINGENCY WEIGHT COEFFICIENT
AC(99)	0.	FIXED CONTINGENCY WEIGHT
AC(100)	0.	NOT USED
AC(101)	0.	LANDING GEAR WEIGHT COEFFICIENT F(WTO)
AC(102)	0.	ENGINE MOUNT WEIGHT COEFFICIENT
AC(103)	0.	FIXED ENGINE MOUNT WEIGHT
AC(104)	0.	WT COEF FOR FUEL DISTRIBUTION SYSTEM
AC(105)	0.	FIXED INTERNAL DUCT WEIGHT
AC(106)	0.	WT COEF FOR VARIABLE RAMPS, ACTUATORS + CONTROL
AC(107)	0.	WT COEF FOR VARIABLE RAMPS, ACTUATORS + CONTROL
AC(108)	0.	FIXED WT OF VARIABLE RAMPS, ACTUATORS + CONTROL
AC(109)	0.	SPIKE WEIGHT COEFFICIENT
AC(110)	0.	GIMBAL SYSTEM WEIGHT COEFFICIENT
AC(111)	0.	AERODYNAMIC CONTROL SYSTEM WEIGHT COEFFICIENT
AC(112)	0.	ELECTRICAL SYSTEM WEIGHT COEFFICIENT
AC(113)	0.	HYDRAULIC/PNEUMATIC SYSTEM WEIGHT COEFFICIENT

TABLE 4.2-1 WAATS INPUT DEFINITION (Cont'd)

AC(114)	0.	AVIONIC SYSTEM WEIGHT COEFFICIENT	
AC(115)	0.	ACPS RESERVES COEFF.	F(WACSP)
AC(116)	0.	INFLIGHT LOSS COEFF.	F(WPMAIN)
AC(117)	0.	WING WEIGHT COEFFICIENT	F(WLAND,XLF,STSPAN,SWING,TROOT)
AC(118)	0.	WING WEIGHT EXPONENT	F(WLAND,XLF,STSPAN,SWING,TROOT)
AC(119)	0.	HORIZONTAL STAB. COEFF.	F(WLAND,SWING,SHORZ,QMAX)
AC(120)	0.	HORIZONTAL STAB. EXP	F(WLAND,SWING,SHORZ,QMAX)
AC(121)	0.	LANDING GEAR EXP.	F(WLAND)
AC(122)	0.	AERO CONTROLS COEFF.	F(WENTRY,ELBODY,GSPAN)
AC(123)	0.	AERO CONTROLS EXP	F(WENTRY,ELBODY,GSPAN)
AC(124)	0.	ATTITUDE CONT. COEFF.	F(WENTRY)
AC(125)	0.	ATTITUDE CONT.EXP	F(WENTRY)
AC(126)	0.	ELECTRICAL SYS COEFF.	F(WENTRY,ELBODY)
AC(127)	0.	ELECTRICAL SYS EXP.	F(WENTRY,ELBODY)
AC(128)	0.	HYDRAULIC POWER COEFF.	F(WTU)
AC(129)	0.	HYDRAULIC POWER COEFF.	F(WENTRY)
AC(130)	0.	INTEGRAL FUEL TANK COEFF	F(VFUTK)
AC(131)	0.	INTEGRAL FUEL TANK FIXED	WEIGHT
AC(132)	0.	INTEG. OXIDIZER TK CCEFF	F(VOXTK)
AC(133)	0.	INTEG. OXIDIZER TK FIXED	WEIGHT
AC(134)	0.	ACS FUEL COEFFICIENT	F(WENTRY)

TABLE 4.2-1 WAATS INPUT DEFINITION (Cont'd)

4. Set up the input deck according to Section 4.1.

If the ODIN procedure is used the data setup is exactly as described above except the input data may be replaced with ODIN data base names.

```
name = 'ODIN name',
```

or

```
name (I) = 'ODIN name',
```

An example might be the case where the thermal protection system unit weight was computed by another program and stored in the data base as TPSUW. Further the wetted area for thermal protection may have been computed in a second program and stored in the data base as AWTPS. In this example the input to WAATS for induced environmental protection, Section 3.3 would be

```
STPS = 'AWTPS',
AC(21) = 'TPSUW',
```

In a similar example where the weight of the TPS is entirely evaluated elsewhere and stored as WTPS, the WAATS input would be

```
AC(22) = 'WTPS', (see Section 3.3)
```

This permits weight components computed elsewhere to be summed in WAATS.

4.3 PROGRAM OUTPUT

The program has several forms of output. An example namelist input is printed as shown in Table 4.3-1. The non-zero weight coefficients are printed as exemplified in Table 4.3-2. Some pertinent design data is printed as shown in Table 4.3-3. A output weight statement is exemplified in Table 4.3-4. Finally, the ODIN output list of all the component weights is available on a file called NMLIST. This file is used by the ODIN system to communicate information to the data base. The ODIN names and descriptions are presented in Figure 4.3-5.

```
$INWAP
THRUST  =  0.47E+06,
ISHAPE  =  2,
CREW    =  0.2E+01,
ACTR    =  0.1E+01,
IENG    =  1,
PCHAM   =  0.1E+04,
DM      =  0.45E+01,
DH      =  0.6E+05,
WAREF   =  0.1227E+03,
PHIGH   =  0.176E+03,
PLOW    =  0.46E+02,
TANKS   =  0.2E+01,
XINLET  =  0.0,
WPMAIN  =  0.44E+07,
OF      =  0.6E+01,
WTOIN   =  0.7E+07,
OFACS   =  0.0,
XLF     =  0.375E+01,
STSPAN  =  0.9371E+02,
SWING   =  0.11579E+05,
TROOT   =  0.1146E+02,
SVERT   =  0.138E+04,
SHORZ   =  0.1E+01,
QMAX    =  0.25E+04,
```

TABLE 4.3-1 NAMELIST INPUT PRINTOUT

SFAIR	=	0.0,
ARATIO	=	0.8E+02,
VFUTK	=	0.1432E+06,
VOXTK	=	0.531E+05,
SFUTK	=	0.0,
SOXTK	=	0.0,
ELBODY	=	0.35E+03,
ELRAMP	=	0.0,
AICAPT	=	0.0,
ELNLET	=	0.0,
FCTMOK	=	0.1E+01,
GEOFCT	=	0.1E+01,
GSPAN	=	0.141E+03,
TYTAIL	=	0.125E+01,
STPS	=	0.423E+05,
SBODY	=	0.328E+05,
WPAYLD	=	0.4E+05,
HBODY	=	0.2E+02,
ENGINS	=	0.22E+02,
GO	=	0.32174049E+02,
RE	=	0.20920024E+08,
ICRY	=	2,
WLANDI	=	0.9E+06,

TABLE 4.3-1 NAMELIST INPUT PRINTOUT (Cont'd)

NON-ZERO WEIGHT COEFFICIENTS

```
AC(  4) =   4.2000000
AC( 14) =   1.2378000
AC( 19) =  4.00000000E-03
AC( 21) =   2.3000000
AC( 26) =  9.16000000E-03
AC( 28) =  7.60000000E-03
AC( 29) =  3.30000000E-04
AC( 30) =   .50000000
AC( 31) =   700.00000
AC( 44) =  2.20000000E-03
AC( 45) =   .50000000
AC( 47) =  4.30000000E-03
AC( 48) =   .50000000
AC( 71) =   6600.0000
AC( 73) =   1330.0000
AC( 75) =   2675.0000
AC( 84) =  4.00000000E-03
AC( 85) =   .50000000
AC( 86) =  4.00000000E-03
AC( 89) =   1.1000000
AC( 92) =  7.50000000E-03
AC( 94) =  7.50000000E-03
AC( 98) =   .12000000
AC(102) =  1.00000000E-04
AC(115) =  1.50000000E-02
AC(116) =  4.00000000E-03
AC(117) =   2400.0000
AC(118) =   .58400000
AC(121) =   1.1240000
AC(122) =   .33400000
AC(123) =   1.0000000
AC(124) =  1.37500000E-02
AC(125) =   1.0000000
AC(126) =   .10950000
AC(127) =   1.4425000
AC(129) =  1.14000000E-02
AC(130) =   .63700000
AC(132) =   .53400000
AC(134) =  5.00000000E-02
```

TABLE 4.3-2 NONZERO WEIGHT COEFFICIENTS

D E S I G N   D A T A

WETTED AREAS	
GROSS BODY	32800.00
FUEL TANKS	0.00
OXIDIZER TANKS	0.00
PLAN AREAS	
WING	11579.00
VERTICAL SURFACES	1380.00
HORIZONTAL SURFACES	1.00
FAIRING OR ELEVON	0.00
TPS SURFACE AREA	42300.00
DIMENSIONAL DATA	
WING GEOMETRIC SPAN	141.00
WING STRUCTURAL SPAN	93.71
WING THICKNESS AT THEORETICAL ROOT	11.46
TOTAL INLET CAPTURE AREA	0.00
TOTAL INLET LENGTH	0.00
BODY LENGTH	350.00
BODY HEIGHT	20.00

TABLE 4.3-3 DESIGN DATA

AERODYNAMIC SURFACES		78483
WING	66540	
VERTICAL SURFACES	11943	
HORIZONTAL SURFACES	0	
FAIRINGS	0	
BODY STRUCTURE		201534
BASIC BODY STRUCTURE	40600	
SECONDARY STRUCTURE	0	
THRUST STRUCTURE	41360	
INTEGRAL FUEL TANKS	91218	
INTEGRAL OXYDIZER TANKS	28355	
INDUCED ENVIRONMENTAL PROTECTION		97290
VEHICLE INSULATION	97290	
COVER PANELS	0	
LAUNCH AND RECOVERY		41341
LAUNCH GEAR	0	
LANDING GEAR	41341	
PROPULSION		193098
ROCKET ENGINES	125538	
AIRBREATHING ENGINES	0	
NON-STRUCTURAL FUEL CONTAINER	0	
NON-STRUCTURAL OXIDIZER CONTAINER	0	
FUEL TANK INSULATION	0	
OXIDIZER TANK INSULATION	0	
FUEL SYSTEM	22923	
OXIDIZER SYSTEM	44637	
PRESSURIZATION SYSTEM	0	
INLETS	0	

TABLE 4.3-4 WEIGHTS STATEMENT

ORIENTATION CONTROL SYSTEM		26457
ENGINE GIMBAL SYSTEM	0	
ATTITUDE CONTROL SYSTEM	12055	
AERODYNAMIC CONTROLS	14402	
SEPARATION SYSTEM	0	
ATTITUDE CONTROL SYSTEM TANKAGE	0	
POWER SUPPLY		27499
ELECTRICAL SYSTEM	17505	
HYDRAULIC/PNEUMATIC SYSTEM	9995	
AVIONICS SYSTEM		6630
CREW PROVISIONS		2675
VEHICLE DRY WEIGHT		674976
DESIGN RESERVE (CONTINGENCY)		80997
EMPTY WEIGHT		755973
PAYLOAD		40000
CREW		1330
RESIDUAL PROPELLANT		33132
TRAPPED FUEL	4733	
TRAPPED OXIDIZER	28399	
LANDING WEIGHT		831093
ACS PROPELLANT		43836
FUEL	43836	
OXIDIZER	0	
ENTRY WEIGHT		874928
MAIN PROPELLANTS		4400000
FUEL	628571	
OXIDIZER	3771429	
RESERVE PROPELLANT		17600
FUEL	2515	
OXIDIZER	15086	
INFLIGHT LOSSES		17600
GROSS WEIGHT		5310129

TABLE 4.3-4 WEIGHTS STATEMENT (Cont'd)

```
                    O D I N   O U T P U T   D E F I N A T I O N
C
WWING      0.          TOTAL WING WEIGHT, LB
WSURF      0.          TOTAL AERODYNAMIC SURFACE WEIGHT, LB
WVERT      0.          VERTICAL STABILIZER WEIGHT, LB
WHORZ      0.          HORIZONTAL STABILIZER WEIGHT, LB
WFAIR      0.          TOTAL AERODYNAMIC FAIRING WEIGHT, LB
WBODY      0.          TOTAL BODY WEIGHT, LB
WBASIC     0.          BASIC BODY STRUCTURAL WEIGHT, LB
WSECST     0.          BODY SECONDARY STRUCTURE WEIGHT, LB
WTHRST     0.          BODY THRUST STRUCTURE, LB
WTPS       0.          INDUCED ENVIRONMENTAL PRODECTION SYSTEM WEIGHT,LB
WINSUL     0.          EPS INSULATION WEIGHT, LB
WCOVER     0.          EPS COVER WEIGHT, LB
WGEAR      0.          LAUNCH AND RECOVERY GEAR WEIGHT, LB
WLANCH     0.          LAUNCH GEAR WEIGHT (F(WTO)), LB
WLG        0.          LANDING GEAR WEIGHT (F(WLAND)), LB
WPROPU     0.          TOTAL PROPULSION SYSTEM WEIGHT, LB
WRENGS     0.          ROCKET ENGINE WEIGHT, LB
WABENG     0.          AIRBREATHING ENGINE WEIGHT, LB
WFUNCT     0.          NON-STRUCTURAL FUEL CONTAINER,WEIGHT, LB
WOXCNT     0.          NON-STRUCTURAL OXIDIZER CONTAINER WEIGHT, LB
WINSFT     0.          FUEL TANK INSULATION WEIGHT, LBS
WINSOT     0.          OXIDIZER TANK INSULATION WEIGHT LB
WFUSYS     0.          FUEL SYSTEM WEIGHT, LB
WOXSYS     0.          OXIDIZER SYSTEM WEIGHT, LB
WPRSYS     0.          PRESSURIZATION SYSTEM WEIGHT, LB
WINLET     0.          INLET WEIGHT, LB
WORNT      0.          ORIENTATION CONTROL SYSTEM WEIGHT,LB
WGIMBL     0.          ENGINE GIMBAL SYSTEM WEIGHT, LB
WACS       0           ATTITUDE CONTROL SYSTEM WEIGHT, LB
WAERO      0.          AERODYNAMIC CONTROLS WEIGHT,LB
WSEP       0.          SEPERATION SYSTEM WEIGHT, LB
WACSTK     0.          ATTITUDE CONTROL SYSTEM TANKAGE WEIGHT, LB
WPWRSY     0.          POWER SUPPLY WEIGHT, LB
WELECT     0.          ELECTRICAL SYSTEM WEIGHT, LB
WHYPNU     0.          HYDRAULIC/PNEUMATIC SYSTEM WEIGHT, LB
WAVONC     0.          AVIONICS SYSTEM WEIGHT, LB
WCPROV     0.          CREW PROVISIONS WEIGHT, LB
WDRY       0.          VEHICLE DRY WEIGHT, LB
WCONT      0.          DESIGN RESERVE (CONTINGENCY) WEIGHT, LB
WCREW      0.          CREW WEIGHT, LB
WPAYLD     0.          PAYLOAD WEIGHT, LB
WRESID     0.          RESIDUAL PROPELLANT WEIGHT, LB
WFTRAP     0.          TRAPPED FUEL WEIGHT, LB
WOTRAP     0.          TRAPPED OXIDIZER WEIGHT, LB
```

TABLE 4.3-5 ODIN OUTPUT INFORMATION

WACSP	0.	ACS PROPELLANT WEIGHT, LB
WACSFU	0.	ACS FUEL WEIGHT, LB
WACSOX	0.	ACS OXIDIZER WEIGHT, LB
WPRESV	0.	RESERVE PROPELLANT, LB
WFRESV	0.	RESERVE FUEL WEIGHT, LB
WORESV	0.	RESERVE OXIDIZER WEIGHT, LB
WPMAIN	0.	MAIN PROPELLANT WEIGHT, LB
WFUELM	0.	MAIN FUEL WEIGHT, LB
WOXIDM	0.	MAIN OXIDIZER WEIGHT, LB
WTO	0.	CALCULATED TAKE-OFF WEIGHT, LB
WINFUT	0.	INTEGRAL FUEL TANK WEIGHT, LB
WINOXT	0.	INTEGRAL OXIDIZER TANK WEIGHT, LB
WENGMT	0.	ENGINE MOUNT WEIGHT, LB
WPPUMP	0.	FUEL PUMP WEIGHT, LB
WDIST1	0.	FUEL DISTRIBUTION, RESERVOIR TO ENGINE, LB
WSPIKE	0.	INLET SPIKE WEIGHT, LB
WFUEL	0.	MAIN PLUS RESERVE FUEL, LB
WOXID	0.	MAIN PLUS RESERVE OXIDIZER, LB
WFUTOT	0.	TOTAL FUEL (INCL. WFTRAP), LB
WOXTOT	0.	TOTAL OXIDIZER (INCL. WOTRAP),LB
WP	0.	TOTAL PROPELLANT (INCL WPRESV AND WRESID), LB
WDIST2	0.	FUEL DISTRIBUTION, INTERTANK, LB
WFCONT	0.	FUEL SYSTEM CONTROLS WEIGHT, LB
WREFUL	0.	REFUELING SYSTEM WEIGHT, LB
WDRANS	0.	DUMP AND DRAIN SYSTEM WEIGHT, LB
WACSRE	0.	ATTITUDE CONTROL SYSTEM PROPELLANT RESERVES, L
WPLOSS	0.	INFLIGHT PROPELLANT LOSSES, LB
WENTRY	0.	REENTRY WEIGHT, LB
WSEAL	0.	SEALING WEIGHT, LB
WIDUCT	0.	INTERNAL DUCT WEIGHT, LB
WVRAMP	0.	INLET VARIABLE RAMP WEIGHT, LB
WEMPTY	0.	EMPTY WEIGHT, LB
WOPMTY	0.	OPERATING WEIGHT EMPTY, LB
WLAND	0.	LANDING WEIGHT, LB

TABLE 4.3-5 ODIN OUTPUT INFORMATION (Cont'd)

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APPENDIX A - WAATS PROGRAM LISTING

```
      PROGRAM A3983 (INPUT=1001, OUTPUT=1001, NMLIST=1001,
     *                 TAPE5=INPUT, TAPE6=OUTPUT, TAPE78=NMLIST)
      COMMON /COMON/ C(100)
      COMMON /WTS/ W(100)
      COMMON /ACOEFF/ AC(150)
C
C     WEIGHTS ANALYSIS FOR ADVANCED TRANSPORTATION SYSTEM
C
      CALL BLKDAT1
      CALL NPUT
      CALL MASS
      CALL PRINTA
      CALL EXIT
C
      END
      SUBROUTINE ATMOS(IMV)
C
C                  1962 ATMOSPHERE
C
C
C        ALTITUDE MUST BE LESS THAN 299500 FT.
C
C     ************* START COMMON ********************************
      COMMON / COMON / C(1)
      EQUIVALENCE (C( 53), GO      )
      EQUIVALENCE (C( 54), RE      )
      EQUIVALENCE (C( 51), CMT     )
      EQUIVALENCE (C( 52), CHT     )
      COMMON/ATMOUT/TALT,PALT,DTDH,  QO,G,RHO,THETA,RTHETA,DELTA
     1 ,RENO,AMU
C     *************  END  COMMON ********************************
C
      DATA AK /.3048 /
      DATA CHT1, V1, CMT1 /  3*-1. /
      DATA C1 /  .08389492331   /
C                   C1   = 28.9664 * 144./(1545.31 * GO)
C
C        ALM = MOLECULAR SCALE TEMPERATURE GEOPOTENTIAL GRADIENT
C        BH = GEOPOTENTIAL ALTITUDE
C        P = PRESSURE (METRIC UNITS)
C        PB = PRESSURE (METRIC UNITS) AT BASE OF LAYER
C        PSL = SEA LEVEL PRESSURE (METRIC)
C        TMB = TEMPERATURE AT BASE OF LAYER
C        TMPB = TEMPERATURE (METRIC UNITS)
C        TSL = SEA LEVEL TEMPERATURE (METRIC UNITS)
C
C                  INPUTS TO THIS SUBROUTINE
C        CMT = MACH NUMBER
C        CHT = ALTITUDE, FEET
C                  OUTPUTS FROM THIS SUBROUTINE
```

```
C          DELTA = PRESSURE RATIO
C          DTDH =
C          GO = ACCELERATION DUE TO GRAVITY
C          PALT = PRESSURE (ENGLISH UNITS)
C          QD = DYNAMIC PRESSURE
C          RHO = DENSITY
C          RTHETA = SQUARE ROOT OF TEMPERATURE RATIO
C          TALT = TEMPERATURE (ENGLISH UNITS)
C          THETA = TEMPERATURE RATIO
C          V = VELOCITY
C
C ***** IMV=1  V KNOWN, DETERMINE MACH IN ATMOS
C ***** IMV=2  MACH KNOWN, DETERMINE V IN ATMOS
C
      IF(CHT-CHT1)60,20,60
   20 GO TO (30,40),IMV
   30 IF(V-V1)60,310,60
   40 IF(CMT-CMT1)60,310,60
   60 CONTINUE
      V1 = V
      CMT1 = CMT
      CHT1 = CHT
      JSWA = 1
      G = GO * (RE   /(RE   +CHT))**2
      HK = AK * CHT
      BH = REMTR*HK/(REMTR+HK)
      IF(BH+3000.)300,300,90
   90 IF(BH-11000.) 200,100,100
  100 IF(BH-20000.)210,110,110
  110 IF(BH-32000.)220,120,120
  120 IF(BH-47000.)225,130,130
  130 IF(BH-52000.)230,140,140
  140 IF(BH-61000.)240,150,150
  150 IF(BH-79000.)245,250,250
  200 HB = 0.
      ALM = -.0065
      PB = 760.
      TMB = 288.15
      GO TO 260
  210 HB = 11000.
      ALM = 0.
      PB = 169.79
      TMB = 216.65
      JSWA = 2
      GO TO 260
  220 HB = 20000.
      ALM = .001
      PB = 41.0669
      TMB = 216.65
      GO TO 260
  225 HB = 32000.
```

```
      ALM = .0028
      PB = 6.51064
      TMB = 228.65
      GO TO 260
  230 HB = 47000.
      ALM = 0.
      JSWA = 2
      PB = .831859
      TMB = 270.65
      GO TO 260
  240 HB = 52000.
      ALM = -.002
      PB = .44254
      TMB = 270.65
      GO TO 260
  245 HB = 61000.
      ALM = -.004
      PB = .136585
      TMB = 252.65
      GO TO 260
  250 HB = 79000.
      ALM = 0.
      JSWA = 2
      PB = .0077834
      TMB = 180.65
  260 PSL = 760.
      TSL = 288.15
      TMPB = TMB + ALM * (BH-HB)
      GO TO (270,280),JSWA
  270 EX  = .034163195/ALM
      P = PB * (TMB/TMPB)**EX
      GO TO 290
  280 EX  = (-.034163195 * (BH-HB) ) / TMB
      P = PB*EXP(EX)
  290 DELTA = P/PSL
      THETA = TMPB/TSL
      RTHETA = SQRT(THETA)
      TMPA = ALM* ((REMTR**2*AK) / (REMTR+HK)**2)
      DTDH = TMPA/(2.*TMPB)
      GO TO (291,292),IMV
  291 CMT = V/(1116.89 * RTHETA)
      GO TO 293
  292 V = 1116.89*    RTHETA *CMT
  293 CONTINUE
      QD = 1481.*DELTA*CMT**2
      PALT = P*.0193385
      TALT = TMPB * 1.8
      RHO = C1*PALT/TALT
      AMU = 1.456E-06 * TMPB * SQRT(TMPB)/(TMPB + 110.4) * 7.2330137
      RENO = RHO * V / AMU
      GO TO 310
```

```
  300 IERR = 1
      PRINT 1000,CHT
  310 RETURN
C
 1000 FORMAT (13H0015 ALTITUDE,E15.7,17HFT.,  IS NEGATIVE )
      END
      SUBROUTINE  BLKDAT1
C
C
C     ************* START COMMON *********************************
      COMMON /WTS/ W(1)
      COMMON /ACOEF/ AC (150)
      COMMON /COMON/ C(1)
      EQUIVALENCE (C(   1), NR      )
      EQUIVALENCE (C(   2), THRUST  )
      EQUIVALENCE (C(   3), ISHAPE  )
      EQUIVALENCE (C(   4), CREW    )
      EQUIVALENCE (C(   5), NW      )
      EQUIVALENCE (C(   6), ACTR    )
      EQUIVALENCE (C(   7), IENG    )
      EQUIVALENCE (C(   8), PCHAM   )
      EQUIVALENCE (C(   9), DM      )
      EQUIVALENCE (C(  10), DH      )
      EQUIVALENCE (C(  11), WAREF   )
      EQUIVALENCE (C(  13), C23     )
      EQUIVALENCE (C(  14), PHIGH   )
      EQUIVALENCE (C(  15), PLOW    )
      EQUIVALENCE (C(  16), TANKS   )
      EQUIVALENCE (C(  17), XINLET  )
      EQUIVALENCE (C(  18), WPMAIN  )
      EQUIVALENCE (C(  19), OF      )
      EQUIVALENCE (C(  20), WTOIN   )
      EQUIVALENCE (C(  21), OFACS   )
      EQUIVALENCE (C(  22), XLF     )
      EQUIVALENCE (C(  23), STSPAN  )
      EQUIVALENCE (C(  24), SWING   )
      EQUIVALENCE (C(  25), TROOT   )
      EQUIVALENCE (C(  26), SVERT   )
      EQUIVALENCE (C(  27), SHORZ   )
      EQUIVALENCE (C(  28), QMAX    )
      EQUIVALENCE (C(  29), SFAIR   )
      EQUIVALENCE (C(  30), ARATIO  )
      EQUIVALENCE (C(  31), VFUTK   )
      EQUIVALENCE (C(  32), VOXTK   )
      EQUIVALENCE (C(  33), SFUTK   )
      EQUIVALENCE (C(  34), SOXTK   )
      EQUIVALENCE (C(  35), FLBODY  )
      EQUIVALENCE (C(  36), ELRAMP  )
      EQUIVALENCE (C(  37), AICAPT  )
      EQUIVALENCE (C(  38), ELNLET  )
      EQUIVALENCE (C(  39), C13     )
```

```
      EQUIVALENCE (C( 40), FCTMOK )
      EQUIVALENCE (C( 41), GEOFCT )
      EQUIVALENCE (C( 42), GSPAN  )
      EQUIVALENCE (C( 43), TYTAIL )
      EQUIVALENCE (C( 44), STPS   )
      EQUIVALENCE (C( 45), SBODY  )
      EQUIVALENCE (C( 46), WPAYLD )
      EQUIVALENCE (C( 47), HBODY  )
      EQUIVALENCE (C( 49), ENGINS )
      EQUIVALENCE (C( 53), GO     )
      EQUIVALENCE (C( 54), RE     )
      EQUIVALENCE (C( 55), ICRY   )
      EQUIVALENCE (C( 56), NODIN  )
      EQUIVALENCE (C( 57), WLANDI )
C     *************  END  COMMON ****************************************
C
C                   DATA STATEMENTS
C
      DATA PI,RTOD,FPNM,GO/3.14159265,  57.29578,  6076.1033, 32.174049/
      DATA C13, C23 / .333333333 , .666666667 /
      DATA RAD / .01745329 /
      DATA RE / 20920024. /
      DATA PHIGH, PLOW /   176.,    46.   /
      DATA TANKS, GEOFCT, FCTMOK, FLRAMP, DM, PCHAM, TYTAIL, IFNG/
     1  1., 1.,  1.,  0.,  4.5,  1000.,  1.25, 2    /
      DATA WAREF, DH  /   122.7,   60000.   /
      DATA      CREW, WPMAIN, OF, OFACS, XLF, TROOT, ARATIO /
     1           1.,  0.,  0.,  2.,  4.,  1.5,  0.    /
      DATA HBODY, FLBODY, VOXTK, SOXTK, VFUTK, SFUTK /  6*0. /
      DATA GSPAN, STSPAN / 0., 0. /
      DATA AICAPT, ELNLET, XINLET /   0.,   0.,   0. /
      DATA ISHAPE / 1 /
      ACTR = 1.
      ENGINS = 1.
      ICRY = 2
      ITHRST = 3
      NODIN = 78
      NR = 5
      NW = 6
      PT2 = 3000.
      QMAX = 1500.
      SBODY = 0.
      SFAIR = 0.
      SHORZ = 0.
      STPS = 0.
      SVERT = 0.
      SWING = 500.
      TANKS = 1.
      THRUST = 0.
      WLANDI = 0.
      WPAYLD = 0.
```

```
      WTOIN = 0.
      DO 110 I=1,150
      AC(I)=0.
  110 CONTINUE
      DO 130 I=1,100
      W(I) = 0.
  130 CONTINUE
      RETURN
      END
      SUBROUTINE MASS
C
C                AIRPLANE MASS PROPERTIES SUBROUTINE
C
C     ************* START COMMON **********************************
      COMMON /ACOEF/ AC (150)
      COMMON /COMON/ C(1)
      EQUIVALENCE (C(  2), THRUST )
      EQUIVALENCE (C(  3), ISHAPE )
      EQUIVALENCE (C(  4), CREW   )
      EQUIVALENCE (C(  5), NW     )
      EQUIVALENCE (C(  6), ACTR   )
      EQUIVALENCE (C(  7), IENG   )
      EQUIVALENCE (C(  8), PCHAM  )
      EQUIVALENCE (C(  9), DM     )
      EQUIVALENCE (C( 10), DH     )
      EQUIVALENCE (C( 11), WAREF  )
      EQUIVALENCE (C( 13), C23    )
      EQUIVALENCE (C( 14), PHIGH  )
      EQUIVALENCE (C( 15), PLOW   )
      EQUIVALENCE (C( 16), TANKS  )
      EQUIVALENCE (C( 17), XINLET )
      EQUIVALENCE (C( 18), WPMAIN )
      EQUIVALENCE (C( 19), OF     )
      EQUIVALENCE (C( 20), WTOIN  )
      EQUIVALENCE (C( 21), OFACS  )
      EQUIVALENCE (C( 22), XLF    )
      EQUIVALENCE (C( 23), STSPAN )
      EQUIVALENCE (C( 24), SWING  )
      EQUIVALENCE (C( 25), TROOT  )
      EQUIVALENCE (C( 26), SVERT  )
      EQUIVALENCE (C( 27), SHORZ  )
      EQUIVALENCE (C( 28), QMAX   )
      EQUIVALENCE (C( 29), SFAIR  )
      EQUIVALENCE (C( 30), ARATIO )
      EQUIVALENCE (C( 31), VFUTK  )
      EQUIVALENCE (C( 32), VOXTK  )
      EQUIVALENCE (C( 33), SFUTK  )
      EQUIVALENCE (C( 34), SOXTK  )
      EQUIVALENCE (C( 35), ELBODY )
      EQUIVALENCE (C( 36), ELRAMP )
      EQUIVALENCE (C( 37), AICAPT )
```

```
      EQUIVALENCE (C( 38), ELNLET )
      EQUIVALENCE (C( 39), C13    )
      EQUIVALENCE (C( 40), FCTMOK )
      EQUIVALENCE (C( 41), GEOFCT )
      EQUIVALENCE (C( 42), GSPAN  )
      EQUIVALENCE (C( 43), TYTAIL )
      EQUIVALENCE (C( 44), STPS   )
      EQUIVALENCE (C( 45), SBODY  )
      EQUIVALENCE (C( 46), WPAYLD )
      EQUIVALENCE (C( 47), HBODY  )
      EQUIVALENCE (C( 48), TTOT   )
      EQUIVALENCE (C( 49), ENGINS )
      EQUIVALENCE (C( 50), PT2    )
      EQUIVALENCE (C( 51), CMT    )
      EQUIVALENCE (C( 52), CHT    )
      EQUIVALENCE (C( 55), ICRY   )
      EQUIVALENCE (C( 57), WLANDI )
      COMMON /WTS/ W(1)
      EQUIVALENCE (W(  1), WCREW  )
      EQUIVALENCE (W(  2), WABENG )
      EQUIVALENCE (W(  3), WGIMBL )
      EQUIVALENCE (W(  4), WOXCNT )
      EQUIVALENCE (W(  5), WINSFT )
      EQUIVALENCE (W(  6), WINSOT )
      EQUIVALENCE (W(  7), WPENGS )
      EQUIVALENCE (W(  8), WINLET )
      EQUIVALENCE (W(  9), WOXSYS )
      EQUIVALENCE (W( 10), WTHRST )
      EQUIVALENCE (W( 11), WENGMT )
      EQUIVALENCE (W( 12), WBPUMP )
      EQUIVALENCE (W( 13), WDIST1 )
      EQUIVALENCE (W( 14), WSPIKE )
      EQUIVALENCE (W( 15), WFUELM )
      EQUIVALENCE (W( 16), WOXIDM )
      EQUIVALENCE (W( 17), WFRESV )
      EQUIVALENCE (W( 18), WORESV )
      EQUIVALENCE (W( 19), WPRESV )
      EQUIVALENCE (W( 20), WFUEL  )
      EQUIVALENCE (W( 21), WOXID  )
      EQUIVALENCE (W( 22), WFTRAP )
      EQUIVALENCE (W( 23), WOTRAP )
      EQUIVALENCE (W( 24), WFUTOT )
      EQUIVALENCE (W( 25), WOXTOT )
      EQUIVALENCE (W( 26), WP     )
      EQUIVALENCE (W( 27), WRESID )
      EQUIVALENCE (W( 28), WACSFU )
      EQUIVALENCE (W( 29), WACSOX )
      EQUIVALENCE (W( 30), WACSP  )
      EQUIVALENCE (W( 31), WWING  )
      EQUIVALENCE (W( 32), WVERT  )
      EQUIVALENCE (W( 33), WHORZ  )
```

```
      EQUIVALENCE (W( 34), WFAIR  )
      EQUIVALENCE (W( 35), WFUNCT )
      EQUIVALENCE (W( 36), WBASIC )
      EQUIVALENCE (W( 37), WSFCST )
      EQUIVALENCE (W( 38), WBODY  )
      EQUIVALENCE (W( 39), WFUSYS )
      EQUIVALENCE (W( 40), WSURF  )
      EQUIVALENCE (W( 41), WPRSYS )
      EQUIVALENCE (W( 42), WDIST2 )
      EQUIVALENCE (W( 43), WFCONT )
      EQUIVALENCE (W( 44), WREFUL )
      EQUIVALENCE (W( 45), WDRANS )
      EQUIVALENCE (W( 46), WSEAL  )
      EQUIVALENCE (W( 47), WINSUL )
      EQUIVALENCE (W( 48), WIDUCT )
      EQUIVALENCE (W( 49), WVRAMP )
      EQUIVALENCE (W( 50), WPROPU )
      EQUIVALENCE (W( 51), WAERO  )
      EQUIVALENCE (W( 52), WORNT  )
      EQUIVALENCE (W( 53), WSEP   )
      EQUIVALENCE (W( 54), WACS   )
      EQUIVALENCE (W( 55), WACSTK )
      EQUIVALENCE (W( 56), WELECT )
      EQUIVALENCE (W( 57), WHYPNU )
      EQUIVALENCE (W( 58), WPWRSY )
      EQUIVALENCE (W( 59), WAVONC )
      EQUIVALENCE (W( 60), WCPROV )
      EQUIVALENCE (W( 61), WDRY   )
      EQUIVALENCE (W( 62), WCONT  )
      EQUIVALENCE (W( 63), WEMPTY )
      EQUIVALENCE (W( 64), WOPMTY )
      EQUIVALENCE (W( 65), WZROFU )
      EQUIVALENCE (W( 66), WLAND  )
      EQUIVALENCE (W( 67), WCOVER )
      EQUIVALENCE (W( 68), WTPS   )
      EQUIVALENCE (W( 69), WLANCH )
      EQUIVALENCE (W( 70), WLG    )
      EQUIVALENCE (W( 71), WGEAR  )
      EQUIVALENCE (W( 72), WTO    )
      EQUIVALENCE (W( 73), WACSRE )
      EQUIVALENCE (W( 74), WPLOSS )
      EQUIVALENCE (W( 75), WENTRY )
      EQUIVALENCE (W( 76), WINFUT )
      EQUIVALENCE (W( 77), WINOXT )
      COMMON/ATMOUT/TALT,PALT,DTDH,  QO,G,RHO,THETA,RTHETA,DELTA
     1 ,RENO,AMU
C
C     *************  END  COMMON *********************************
C
      WTO = WTOIN
      WLAND = WLANDI
```

```
      WENTRY=WLAND
C                    IH = 1 FOR NON-CRYOGENIC,  2 FOR CRYOGENIC
      IH = ICRY
      L = 1
      TTOT = THRUST * ENGINS * ACTR
      ISHAPX = ISHAPE
      WCREW = AC(72)*CREW + AC(73)
      WABENG = 0.
      WGIMBL = 0.
      WOXCNT = 0.
      WINSFT = 0.
      WINSOT = 0.
      WRENGS = 0.
      WINLET=0.
      WOXSYS = 0.
      WTHRST = AC(19) * TTOT   +AC(20)
      WENGMT = AC(102) *TTOT + AC(103)
      GO TO (10,20,30),IENG
C
C       ROCKET ENGINE
C
   10 TDEL = 750. * (TTOT/ENGINS/PCHAM)**1.25
      WGIMBL = AC(55) * TDEL ** AC(110) + AC(54)
      GO TO 40
C
C       TURBORAMJET ENGINE
C
   20 GO TO (22,28),L
   22 L = 2
      CMT = DM
      CHT = DH
      CALL ATMOS(2)
      X = 1. + .2*CMT**2
      PTO = PALT * X**3 * SQRT(X)
      PR = 1.
      IF(CMT-1.)27,27,23
   23 IF(CMT-5.)24,24,26
   24 PR = 1. - .075 * (CMT-1.)**1.35
      GO TO 27
   26 PR = 800./(CMT**4 + 935.)
   27 PT2 = PR * PTO
   28 WA = WAREF * ACTR
      WABENG = (AC(32) * EXP(AC(33)*WA) * ((PT2-PHIGH)/(PLOW-PHIG
     1  + AC(34) * EXP(AC(35)*WA) * ((PT2-PLOW)/(PHIGH-PLOW)))
     2 *ENGINS + AC(91) * ENGINS + WENGMT
      GO TO 32
C
C       AIRBREATHING ENGINE
C
   30 WABENG = AC(82) * TTOT + AC(83)   + WENGMT
   32 IF(IH.EQ.2) GO TO 40
```

```
      WBPUMP = TTOT * (1.75 + .266 * ENGINS) * .001
      WPRSYS = .0009 * TTOT * TANKS
      WDIST1 = ENGINS * AC(104) * SQRT(TTOT/ENGINS)
      TMPFCT = .203 * DM + .4
      WSPIKE = AC(109) * XINLET
C
C        CALCULATE PROPELLANT WEIGHTS
C
   40 WFUELM = WPMAIN/(1.+OF)
      WOXIDM = WFUELM * OF
      WFRESV = AC(84)*WFUELM + AC(85)
      WORESV = AC(86)* WOXIDM + AC(87)
      WPRESV = WFRESV + WORESV
      WFUEL =  WFUELM + WFRESV
      WOXID =  WOXIDM + WORESV
      WFTRAP = AC(92) * WFUEL + AC(93)
      WOTRAP = AC(94) * WOXID + AC(95)
      WFUTOT = WFUEL + WFTRAP
      WOXTOT = WOXID + WOTRAP
      WP = WFUTOT + WOXTOT
C
C        WRESID = TOTAL WEIGHT OF RESIDUALS
C
      WRESID = WFTRAP + WOTRAP
C
      WRITE (NW,1001)
 1001 FORMAT (1H1, 14HMASS ITERATION / )
C
C        ITERATE ON TAKE-OFF WEIGHT
C
   50 CONTINUE
C
      WACSFU = AC(96) * WTO + AC(97)
     1        + AC(1.4) * WENTRY
      WACSOX = WACSFU * OFACS
      WACSP = WACSOX + WACSFU
C       ACPS RESERVES
      WACSRE =AC(115) * WACSP
C
C       INFLIGHT LOSSES
      WPLOSS =AC(116) * WPMAIN
      GO TO (160,110,100,110),ISHAPX
C
C        LIFTING BODY
C
  100 WWING = 0.
      WVERT = 0.
      WHORZ = 0.
      GO TO 160
C
C        WINGED CRAFT
```

```
C
  110 WWING = AC(1)*(WTO*XLF    * STSPAN * SWING / TROOT )**AC(78)*1
     1 + AC(2) * SWING + AC(3)
     2  + AC(117) * (WLAND*XLF*STSPAN*SWING/TROOT*1.E-9)**AC(118)
  130 WVERT = AC(4)*(    SVERT)**AC(89) + AC(5)
      WHORZ = AC(6) *((WTO/SWING)**.6*SHORZ**1.2*QMAX**.8)**AC(90)
     1  + AC(7)
     2 + AC(119) * ((WLAND/SWING)**0.6*SHORZ**1.2*QMAX**0.8)**AC(12
  160 WFAIR = AC(8) * SFAIR + AC(9)
C
C         WSURF = TOTAL WEIGHT OF AERODYNAMIC SURFACES
C
      WSURF = WWING + WVERT + WHORZ + WFAIR
C
      WBASIC = AC(14) * SBODY + AC(15) * ((ELBODY*XLF/HBODY)**.15
     1 *QMAX**.16*SBODY**1.05)**AC(81) + AC(16)
      WSECST = AC(17) * SBODY + AC(18)
      WINFUT = AC(130) * VFUTK + AC(131)
      WINOXT = AC(132) * VOXTK + AC(133)
C
C         BODY
C
      WBODY = WBASIC + WSECST + WTHRST + WINFUT + WINOXT
C
      WINSUL = AC(21) * STPS + AC(76)
      WCOVER = AC(22)* STPS + AC( 77)
C
C         WTPS = TOTAL WEIGHT OF THERMAL PROTECTION SYSTEM
C
      WTPS = WINSUL + WCOVER
      WLANCH = AC(23) * WTO + AC(24)
      WLG = AC(25) * WTO**AC(101) + AC(26) * WLAND**AC(121) + AC(27
C
C         WGEAR = TOTAL WEIGHT OF LAUNCH AND RECOVERY SYSTEM
C
      WGEAR = WLANCH + WLG
      GO TO (250,190),IH
  190 GO TO (200,250,250),IENG
C
C        ROCKET ENGINE
C
  200 WRENGS = AC(28) * TTOT    + AC(29) * TTOT    * ARATIO**AC(30) +
     1 AC(31) * ENGINS + WENGMT
  210 WFUNCT = AC(36) * VFUTK + AC(37)
      WOXCNT = AC(38) * VOXTK + AC(39)
      WINSFT = AC(40) * SFUTK + AC(41)
      WINSOT = AC(42) * SOXTK + AC(43)
      WFUSYS = AC(44) * TTOT    + AC(45)*ELBODY + AC(46)
      WOXSYS = AC(47) * TTOT    + AC(48) * ELBODY + AC(49)
      WPRSYS = AC(50) * VFUTK   + AC(51) * VOXTK + AC(52)
      GO TO 300
```

```
C
C        AIRBREATHING ENGINE
C
  250 GAL = 7.481 * VFUTK
      WFUNCT = AC(36) * (GAL/TANKS)**.6 * TANKS + AC(37)
      WDIST2 = .255*GAL**.7 * TANKS**.25
      WFCONT = .169 * TANKS * SQRT(GAL)
      WREFUL = TANKS*(3. + .45 * GAL**C13)
      WDRANS = .159 * GAL**.65
      WSEAL = .045 * TANKS * (GAL/TANKS)**.75
      WFUSYS = WBPUMP + WDIST1 + WDIST2 + WFCONT + WREFUL + WDRANS
     1 WSEAL
C
      WID =            XINLET * SQRT(AICAPT/XINLET)
      WIDUCT = AC(53) * (SQRT(ELNLET*XINLET)*(AICAPT/XINLET)**C13
     1 *PT2**C23*GEOFCT*FCTMOK)**AC(54) + AC(105)
      WVRAMP = AC(106) * (ELRAMP*WID*TMPFCT)**AC(107) + AC(108)
      WINLET = WIDUCT + WVRAMP + WSPIKE
C
  300 CONTINUE
C         WPROPU = TOTAL WEIGHT OF MAIN PROPULSION
C
      WPROPU = WRENGS + WABENG +           WFUNCT + WOXCNT + WINSFT
     1 WINSOT + WFUSYS + WOXSYS + WPRSYS + WINLET
  400 WTOX = WTO
      WAERO = AC(60) * (WTO**C23*(ELBODY+GSPAN)**.25)**AC(111) +AC
     1  + AC(122) * (WENTRY**C23*(ELBODY+GSPAN)**0.25)**AC(123)
      WSEP = AC(62) * WTO + AC(63)
      WACS = AC(57)*WTO**AC(58) + AC(59)
     1  + AC(124) * WENTRY**AC(125)
      WACSTK = AC(64) * WACSP + AC(65)
C
C         WORNT = TOTAL WEIGHT OF ORIENTATION CONTROL SYSTEM
C
      WORNT = WGIMBL + WACS + WAERO + WSEP + WACSTK
      WELECT = AC(66) * (SQRT(WTO)*ELBODY**.25)**AC(112)+AC(67)
     1  + AC(126) * (SQRT(WENTRY)*ELBODY**0.25)**AC(127)
      WHYPNU= AC(68) * ((SWING+SHORZ+SVERT)*.0010*QMAX)**.3340 *
     1 (SQRT(ELBODY + STSPAN) * TYTAIL)**AC(113) + AC(69)
     2  + AC(128) * WTO + AC(129)*WENTRY
C
C         WPWRSY = TOTAL WEIGHT OF POWER SUPPLY
C
      WPWRSY = WELECT + WHYPNU
      WAVONC = AC(70) * WTO**AC(114) + AC(71)
      WCPROV = AC(74)*WTO + AC(80) * CREW + AC(75)
      WDRY = WSURF + WBODY + WTPS + WGEAR + WPROPU + WORNT + WPWRS
     1 + WAVONC + WCPROV
      WCONT = AC(98) * WDRY + AC(99)
      WEMPTY = WDRY + WCONT
      WOPMTY = WEMPTY + WRESID + WCREW + WACSP
```

```
      WZROFU = WOPMTY + WPAYLD
      WLAND = WEMPTY + WPAYLD + WCREW + WRESID + WACSRE
      WENTRY = WLAND + WACSP
      WTO = WENTRY + WPMAIN + WPRESV + WPLOSS
      WRITE (NW,1005) WTO,  WENTRY, WLAND, WDRY
 1005 FORMAT(10X,7H WTO = F10.2, 10H WENTRY = F10.2,
     1            9H WLAND = F10.2, 8H WDRY = F10.2)
      IF(ABS((WTOX-WTO)/WTO ) .LE. .001 ) GO TO 915
      GO TO 50
C
  915 CONTINUE
C
  999 CONTINUE
      RETURN
      END
      SUBROUTINE NPUT
C
      COMMON /ACOFF/ AC (150)
      COMMON /COMON/ C(1)
      EQUIVALENCE (C(   1), NR      )
      EQUIVALENCE (C(   2), THRUST  )
      EQUIVALENCE (C(   3), ISHAPE  )
      EQUIVALENCE (C(   4), CREW    )
      EQUIVALENCE (C(   5), NW      )
      EQUIVALENCE (C(   6), ACTR    )
      EQUIVALENCE (C(   7), IENG    )
      EQUIVALENCE (C(   8), PCHAM   )
      EQUIVALENCE (C(   9), DM      )
      EQUIVALENCE (C(  10), DH      )
      EQUIVALENCE (C(  11), WAREF   )
      EQUIVALENCE (C(  14), PHIGH   )
      EQUIVALENCE (C(  15), PLOW    )
      EQUIVALENCE (C(  16), TANKS   )
      EQUIVALENCE (C(  17), XINLET  )
      EQUIVALENCE (C(  18), WPMAIN  )
      EQUIVALENCE (C(  19), OF      )
      EQUIVALENCE (C(  20), WTOIN   )
      EQUIVALENCE (C(  21), OFACS   )
      EQUIVALENCE (C(  22), XLF     )
      EQUIVALENCE (C(  23), STSPAN  )
      EQUIVALENCE (C(  24), SWING   )
      EQUIVALENCE (C(  25), TROOT   )
      EQUIVALENCE (C(  26), SVERT   )
      EQUIVALENCE (C(  27), SHORZ   )
      EQUIVALENCE (C(  28), QMAX    )
      EQUIVALENCE (C(  29), SFAIR   )
      EQUIVALENCE (C(  30), ARATIO  )
      EQUIVALENCE (C(  31), VFUTK   )
      EQUIVALENCE (C(  32), VOXTK   )
      EQUIVALENCE (C(  33), SFUTK   )
      EQUIVALENCE (C(  34), SOXTK   )
```

```
      EQUIVALENCE (C( 35), ELBODY )
      EQUIVALENCE (C( 36), ELRAMP )
      EQUIVALENCE (C( 37), AICAPT )
      EQUIVALENCE (C( 38), ELNLET )
      EQUIVALENCE (C( 40), FCTMOK )
      EQUIVALENCE (C( 41), GEOFCT )
      EQUIVALENCE (C( 42), GSPAN  )
      EQUIVALENCE (C( 43), TYTAIL )
      EQUIVALENCE (C( 44), STPS   )
      EQUIVALENCE (C( 45), SBODY  )
      EQUIVALENCE (C( 46), WPAYLD )
      EQUIVALENCE (C( 47), HBODY  )
      EQUIVALENCE (C( 49), ENGINS )
      EQUIVALENCE (C( 53), GO     )
      EQUIVALENCE (C( 54), RE     )
      EQUIVALENCE (C( 55), ICRY   )
      EQUIVALENCE (C( 57), WLANDI )
C
      NAMELIST /INWAP/ THRUST, ISHAPE, CREW  , ACTR  , IENG  , PCH/
     *       , DM    , DH    , WAREF , PHIGH , PLOW  , TANKS , XINI
     *       , WPMAIN, OF    , WTOIN , OFACS , XLF   , STSPAN, SWIN
     *       , TROOT , SVERT , SHORZ , QMAX  , SFAIR , ARATIO, VFU'
     *       , VOXTK , SFUTK , SOXTK , ELBODY, ELRAMP, AICAPT, ELNI
     *       , FCTMOK, GEOFCT, GSPAN , TYTAIL, STPS  , SBODY , WPA'
     *       , HBODY , ENGINS, GO    , RE    , ICRY  , WLANDI, AC
C
      READ (NR,INWAP)
      WRITE (NW, INWAP)
      WRITE (NW, 1000)
 1000 FORMAT (1H1,  5X, 30H NON-ZERO WEIGHT COEFFICIENTS //)
      DO 100 I = 1, 150
      IF ( AC(I) . EQ . 0. ) GO TO 100
      WRITE (NW, 1001) I, AC(I)
 1001 FORMAT (1H , 10X, 3HAC( I3, 4H) =  G15.8)
  100 CONTINUE
C
C         PRINT DESIGN DATA
C
      WRITE (NW,1360)
 1360 FORMAT (1H1, 5X, 23H D E S I G N   D A T A // 13H WETTED ARE
      WRITE (NW,1365) SBODY
      WRITE (NW,1370) SFUTK
      WRITE (NW,1375) SOXTK
      WRITE (NW,1380)
      WRITE (NW,1385) SWING
      WRITE (NW,1400) SVERT
      WRITE (NW,1405) SHORZ
      WRITE (NW,1410) SFAIR
      WRITE (NW,1460) STPS
      WRITE (NW,1455)
 1455 FORMAT (17HODIMENSIONAL  DATA )
```

```
      WRITE (NW,1450) GSPAN
      WRITE (NW,1490) STSPAN
      WRITE (NW,1500) TROOT
      WRITE (NW,1585) AICAPT
      WRITE (NW,1590) ELNLET
      WRITE (NW,1475) ELBODY
      WRITE (NW,1480) HBODY
C
 1365 FORMAT (5X,10HGROSS BODY,27X,F9.2)
 1370 FORMAT (5X,10HFUEL TANKS,27X,F9.2)
 1375 FORMAT (5X,14HOXIDIZER TANKS,23X,F9.2)
 1380 FORMAT (11HOPLAN AREAS)
 1385 FORMAT (5X,4HWING,33X,F9.2)
 1400 FORMAT(5X,17HVERTICAL SURFACES,20X,F9.2)
 1405 FORMAT (5X,19HHORIZONTAL SURFACES,18X,F9.2)
 1410 FORMAT (5X,17HFAIRING OR ELEVON,20X,F9.2)
 1460 FORMAT (5X,16HTPS SURFACE AREA,21X,F9.2)
 1450 FORMAT (5X,19HWING GEOMETRIC SPAN,18X,F9.2)
 1490 FORMAT (5X,20HWING STRUCTURAL SPAN,17X,F9.2)
 1500 FORMAT (5X,34HWING THICKNESS AT THEORETICAL ROOT,3X,F9.2)
 1585 FORMAT (5X,24HTOTAL INLET CAPTURE AREA,13X,F9.2)
 1590 FORMAT (5X,18HTOTAL INLET LENGTH,19X,F9.2)
 1475 FORMAT (5X,11HBODY LENGTH,26X,F9.2)
 1480 FORMAT (5X,11HBODY HEIGHT,26X,F9.2)
C
      RETURN
      END
      SUBROUTINE PRINTA
C         AIRCRAFT WEIGHTS AND VOLUME  PRINT ROUTINE
C
C     ************* START COMMON ********************************
C
      COMMON /COMON/ C(1)
      EQUIVALENCE (C(  5), NW     )
      EQUIVALENCE (C( 18), WPMAIN )
      EQUIVALENCE (C( 46), WPAYLD )
      EQUIVALENCE (C( 56), NODIN  )
      COMMON /WTS/ W(1)
      EQUIVALENCE (W(  1), WCREW  )
      EQUIVALENCE (W(  2), WABENG )
      EQUIVALENCE (W(  3), WGIMBL )
      EQUIVALENCE (W(  4), WOXCNT )
      EQUIVALENCE (W(  5), WINSFT )
      EQUIVALENCE (W(  6), WINSOT )
      EQUIVALENCE (W(  7), WPENGS )
      EQUIVALENCE (W(  8), WINLET )
      EQUIVALENCE (W(  9), WOXSYS )
      EQUIVALENCE (W( 10), WTHRST )
      EQUIVALENCE (W( 11), WENGMT )
      EQUIVALENCE (W( 12), WBPUMP )
      EQUIVALENCE (W( 13), WDISTL )
```

```
      EQUIVALENCE (W( 14), WSPIKE )
      EQUIVALENCE (W( 15), WFUELM )
      EQUIVALENCE (W( 16), WOXIDM )
      EQUIVALENCE (W( 17), WFRESV )
      EQUIVALENCE (W( 18), WORESV )
      EQUIVALENCE (W( 19), WPRESV )
      EQUIVALENCE (W( 20), WFUEL  )
      EQUIVALENCE (W( 21), WOXID  )
      EQUIVALENCE (W( 22), WFTRAP )
      EQUIVALENCE (W( 23), WOTRAP )
      EQUIVALENCE (W( 24), WFUTOT )
      EQUIVALENCE (W( 25), WOXTOT )
      EQUIVALENCE (W( 26), WP     )
      EQUIVALENCE (W( 27), WRESID )
      EQUIVALENCE (W( 28), WACSFU )
      EQUIVALENCE (W( 29), WACSOX )
      EQUIVALENCE (W( 30), WACSP  )
      EQUIVALENCE (W( 31), WWING  )
      EQUIVALENCE (W( 32), WVERT  )
      EQUIVALENCE (W( 33), WHORZ  )
      EQUIVALENCE (W( 34), WFAIR  )
      EQUIVALENCE (W( 35), WFUNCT )
      EQUIVALENCE (W( 36), WBASIC )
      EQUIVALENCE (W( 37), WSFCST )
      EQUIVALENCE (W( 38), WBODY  )
      EQUIVALENCE (W( 39), WFUSYS )
      EQUIVALENCE (W( 40), WSURF  )
      EQUIVALENCE (W( 41), WPRSYS )
      EQUIVALENCE (W( 42), WDIST2 )
      EQUIVALENCE (W( 43), WFCONT )
      EQUIVALENCE (W( 44), WREFUL )
      EQUIVALENCE (W( 45), WDRANS )
      EQUIVALENCE (W( 46), WSEAL  )
      EQUIVALENCE (W( 47), WINSUL )
      EQUIVALENCE (W( 48), WIDUCT )
      EQUIVALENCE (W( 49), WVRAMP )
      EQUIVALENCE (W( 50), WPROPU )
      EQUIVALENCE (W( 51), WAERO  )
      EQUIVALENCE (W( 52), WORNT  )
      EQUIVALENCE (W( 53), WSEP   )
      EQUIVALENCE (W( 54), WACS   )
      EQUIVALENCE (W( 55), WACSTK )
      EQUIVALENCE (W( 56), WELECT )
      EQUIVALENCE (W( 57), WHYPNU )
      EQUIVALENCE (W( 58), WPWRSY )
      EQUIVALENCE (W( 59), WAVONC )
      EQUIVALENCE (W( 60), WCPROV )
      EQUIVALENCE (W( 61), WDRY   )
      EQUIVALENCE (W( 62), WCONT  )
      EQUIVALENCE (W( 63), WEMPTY )
      EQUIVALENCE (W( 64), WOPMTY )
```

```
      EQUIVALENCE (W( 65), WZROFU )
      EQUIVALENCE (W( 66), WLAND  )
      EQUIVALENCE (W( 67), WCOVER )
      EQUIVALENCE (W( 68), WTPS   )
      EQUIVALENCE (W( 69), WLANCH )
      EQUIVALENCE (W( 70), WLG    )
      EQUIVALENCE (W( 71), WGEAR  )
      EQUIVALENCE (W( 72), WTO    )
      EQUIVALENCE (W( 73), WACSRE )
      EQUIVALENCE (W( 74), WPLOSS )
      EQUIVALENCE (W( 75), WENTRY )
      EQUIVALENCE (W( 76), WINFUT )
      EQUIVALENCE (W( 77), WINOXT )
C
C
C     *************  END  COMMON *************************************
      NAMELIST /VSACPA/ WSURF, WWING, WVERT, WHORZ, WFAIR, WBODY, WI
     * ,WSECST, WTHRST, WTPS, WINSUL, WCOVER, WGEAR, WLANCH, WLG, WI
     * ,WRENGS, WABENG, WFUNCT, WOXCNT, WINSFT, WINSOT, WFUSYS, WOX
     * ,WPRSYS, WINLET, WORNT, WGIMBL,WACS, WAERO, WSEP, WACSTK, WP
     * ,WELECT, WHYPNU, WAVONC, WCPROV, WDRY, WCONT, WCREW, WPAYLD
     * ,WRESID, WFTRAP, WOTRAP, WACSP, WACSFU, WACSOX, WZRFU, WPRES
     * ,WFRESV, WORESV, WPMAIN, WFUELM, WOXIDM, WTO   , WINFUT, WIN
     * ,WENGMT, WBPUMP, WDIST1, WSPIKE, WFUEL , WOXID , WFUTOT, WOX
     * ,WP    , WDIST2, WFCONT, WRFFUL, WDRANS, WACSRF, WPLOSS, WEN
     * ,WSEAL , WIDUCT, WVRAMP, WEMPTY, WOPMTY, WLAND
C
C                               ODIN DATA BASE OUTPUT
      WRITE (NODIN,VSACPA)
C
C         PRINT WEIGHTS
C
      WRITE (NW,1000)
 1000 FORMAT (1H1, 5X, 35H W E I G H T    S T A T E M E N T  , 35X,
     1       22H ODIN NAME AND FORMULA ///  )
C
      WRITE (NW,1005) WSURF, WWING, WVERT, WHORZ, WFAIR
 1005 FORMAT (21H AERODYNAMIC SURFACES, 41X, F9.0, 5X,
     1       40H WSURF = WWING + WVERT + WHORZ + WFAIR  //
     2         5X, 4HWING, 44X, F9.0, 14X,
     3       53H WWING = AC(1) * (WTO*XLF*STSPAN*SWING/TROOT)**AC(78)
     4        82X, 32H * 1.E6 + AC(2) * SWING + AC(3) /
     *        82X, 43H + AC(117) * (WLAND*XLF*STSPAN*SWING/TROOT  /
     *        82X, 18H * 1.E-9)**AC(118)  //
     5         5X,17HVERTICAL SURFACES, 31X,F9.0, 14X,
     6       40H WVERT = AC(4) * (SVERT)**AC(89) + AC(5) //
     7         5X, 19HHORIZONTAL SURFACES, 29X,F9.0, 14X,
     8       47H WHORZ = AC(6) * ((WTO/SWING)**0.6 * SHORZ**1.2 /
     9        82X, 29H * QMAX**0.8)**AC(90) + AC(7) /
     *        82X, 42H + AC(119) * ((WLAND/SWING)**.6*SHORZ**1.2  /
     *        82X, 21H * QMAX**.8)**AC(120)  //
```

```
     *          5X,  8HFAIRINGS, 40X, F9.0, 14X,
     1         30H WFAIR = AC(8) * SFAIR + AC(9) //)
C
       WRITE (NW,1030) WBODY, WBASIC, WSECST, WTHRST, WINFUT, WINOXT
 1030 FORMAT (15H BODY STRUCTURE, 47X, F9.0, 5X,
     1         51H WBODY = WBASIC + WSECST + WTHRST + WINFUT + WINOXT
     2          5X, 20HBASIC BODY STRUCTURE, 28X, F9.0, 14X,
     3         29H WBASIC = AC(14)*SBODY+AC(16) /
     4          82X,  43H + AC(15)*((FLBODY*XLF/HBODY**.15*QMAX**.16 /
     5          82X,  23H * SBODY**1.05)**AC(81) //
     6          5X, 19HSECONDARY STRUCTURE, 29X, F9.0, 14X,
     7         31H WSECST = AC(17)*SBODY + AC(18) //
     8          5X, 16HTHRUST STRUCTURE, 32X, F9.0, 14X,
     9         30H WTHRST = AC(19)*TTOT + AC(20) //
     *          5X, 19HINTEGRAL FUEL TANKS, 29X, F9.0, 14X,
     1         33H WINFUT = AC(130)*VFUTK + AC(131) //
     2          5X, 23HINTEGRAL OXYDIZER TANKS, 25X, F9.0, 14X,
     3         33H WINOXT = AC(132)*VOXTK + AC(133) //)
C
       WRITE (NW,1060) WTPS
       WRITE (NW,1065) WINSUL
       WRITE (NW,1070) WCOVER
       WRITE (NW,1075) WGEAR
       WRITE (NW,1080) WLANCH
       WRITE (NW,1085) WLG
       WRITE (NW,1090) WPROPU
       WRITE (NW,1095) WRENGS
       WRITE (NW,1100) WABENG
       WRITE (NW,1110) WFUNCT
       WRITE (NW,1115) WOXCNT
       WRITE (NW,1120) WINSFT
       WRITE (NW,1125) WINSOT
       WRITE (NW,1130) WFUSYS
       WRITE (NW,1135) WOXSYS
       WRITE (NW,1140) WPRSYS
       WRITE (NW,1145) WINI
       WRITE (NW,1150) WORN
       WRITE (NW,1155) WGIMBL
       WRITE (NW,1160) WACS
       WRITE (NW,1165) WAERO
       WRITE (NW,1170) WSEP
       WRITE (NW,1175) WACSTK
       WRITE (NW,1185) WPWRSY
       WRITE (NW,1190) WELECT
       WRITE (NW,1195) WHYPNU
       WRITE (NW,1200) WAVONC
       WRITE (NW,1205) WCPROV
C
       WRITE (NW,1210) WDRY
 1210 FORMAT (19H VEHICLE DRY WEIGHT, 43X, F9.0, 5X,
     1         53H WDRY = WSURF + WBODY + WTPS + WGEAR + WPROPU + WORN
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     2        82X, 27H + WPWRSY + WAVONC + WCPROV // )
C
      WRITE (NW,1215) WCONT
 1215 FORMAT (29H0DESIGN RESERVE (CONTINGENCY),33X,F9.0)
C
      WRITE (NW,1320) WEMPTY
 1320 FORMAT (13H EMPTY WEIGHT, 49X, F9.0, 5X,
     1        22H WEMPTY = WDRY + WCONT //)
C
      WRITE (NW,1225) WPAYLD
      WRITE (NW,1220) WCREW
      WRITE (NW,1230) WRESID
      WRITE (NW,1235) WFTRAP
      WRITE (NW,1240) WOTRAP
C
      WRITE (NW,1300) WLAND
 1300 FORMAT (15H LANDING WEIGHT, 47X, F9.0, 5X,
     1        50H WLAND = WEMPTY + WPAYLD + WCREW + WRESID + WACSRE
C
      WRITE (NW,1575)  WACSP
      WRITE (NW,1285) WACSFU
      WRITE (NW,1290) WACSOX
 1575 FORMAT (15H0ACS PROPELLANT,47X,F9.0)
 1285 FORMAT (5X, 4HFUEL,44X,F9.0)
 1290 FORMAT (5X, 8HOXIDIZER,40X,F9.0)
C
      WRITE (NW,1310) WENTRY
 1310 FORMAT (13H ENTRY WEIGHT, 49X, F9.0, 5X,
     1        24H WENTRY = WLAND + WACSP //)
C
      WRITE (NW,1280) WPMAIN
      WRITE (NW,1285) WFUELM
      WRITE (NW,1290) WOXIDM
C
      WRITE (NW,1580) WPRESV
      WRITE (NW,1285) WFRESV
      WRITE (NW,1290) WORESV
 1580 FORMAT (19H0RESERVE PROPELLANT,43X,F9.0)
C
      WRITE (NW,1330) WPLOSS
 1330 FORMAT (18H INFLIGHT LOSSES  , 44X, F9.0, 5X,
     1        27H WPLOSS = AC(116) * WPMAIN  // )
C
      WRITE (NW,1295) WTO
 1295 FORMAT (13H GROSS WEIGHT, 49X, F9.0, 5X,
     1        40H WTO = WENTRY + WPMAIN + WPRESV + WPLOSS //)
C
 1060 FORMAT (33H0INDUCED ENVIRONMENTAL PROTECTION,29X,F9.0)
 1065 FORMAT (5X,18HVEHICLE INSULATION,30X,F9.0)
 1070 FORMAT (5X,12HCOVER PANELS,36X,F9.0)
 1075 FORMAT (20H0LAUNCH AND RECOVERY,42X,F9.0)
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1080 FORMAT (5X,11HLAUNCH GEAR,37X,F9.0)
1085 FORMAT (5X,12HLANDING GEAR,36X,F9.0)
1090 FORMAT (11HOPROPULSION,51X,F9.0)
1095 FORMAT (5X,14HROCKET ENGINES,34X,F9.0)
1100 FORMAT (5X,20HAIRBREATHING ENGINES,28X,F9.0)
1110 FORMAT (5X,29HNON-STRUCTURAL FUEL CONTAINER,19X,F9.0)
1115 FORMAT (5X,33HNON-STRUCTURAL OXIDIZER CONTAINER,15X,F9.0)
1120 FORMAT (5X,20HFUEL TANK INSULATION,28X,F9.0)
1125 FORMAT (5X,24HOXIDIZER TANK INSULATION,24X,F9.0)
1130 FORMAT (5X,11HFUEL SYSTEM,37X,F9.0)
1135 FORMAT (5X,15HOXIDIZER SYSTEM,33X,F9.0)
1140 FORMAT (5X,21HPRESSURIZATION SYSTEM,27X,F9.0)
1145 FORMAT (5X, 6HINLETS,42X,F9.0)
1150 FORMAT(27HOORIENTATION CONTROL SYSTEM,35X,F9.0)
1155 FORMAT (5X,20HENGINE GIMBAL SYSTEM,28X,F9.0)
1160 FORMAT (5X,23HATTITUDE CONTROL SYSTEM,25X,F9.0)
1165 FORMAT (5X,20HAERODYNAMIC CONTROLS,28X,F9.0)
1170 FORMAT (5X,17HSEPARATION SYSTEM,31X,F9.0)
1175 FORMAT (5X,31HATTITUDE CONTROL SYSTEM TANKAGE,17X,F9.0)
1185 FORMAT (13HOPOWER SUPPLY,49X,F9.0)
1190 FORMAT (5X,17HELECTRICAL SYSTEM,31X,F9.0)
1195 FORMAT (5X,26HHYDRAULIC/PNEUMATIC SYSTEM,22X,F9.0)
1200 FORMAT (16HOAVIONICS SYSTEM,46X,F9.0)
1205 FORMAT (16HOCREW PROVISIONS,46X,F9.0)
1220 FORMAT ( 5HOCREW,57X,F9.0)
1225 FORMAT ( 8HOPAYLOAD,54X,F9.0)
1230 FORMAT (20HORESIDUAL PROPELLANT,42X,F9.0)
1235 FORMAT (5X,12HTRAPPED FUEL,36X,F9.0)
1240 FORMAT (5X,16HTRAPPED OXIDIZER,32X,F9.0)
1280 FORMAT (17HOMAIN PROPELLANTS,45X,F9.0)
C
 900 RETURN
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