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AN ANALYSIS OF THREE APPROACHES TO THE HELICOPTER PRELIMINARY DESIGN PROBLEM

by

Allen C. Hansen

March 1984

Thesis Advisor: D. M. Layton

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An Analysis of
Three Approaches to the Helicopter Preliminary Design Problem

by

Allen C. Hansen
Lieutenant, United States Navy
B.A., University of Pennsylvania, 1976

Submitted in partial fulfillment of the
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Author: Allen C. Han

Approved by: Donald M Layton, Thesis Advisor

Donald M. Layton, Chairman, Department of Aeronautics

JM Dyer, Dean of Science and Engineering

ABSTRACT

Three methodologies from which to approach the problem of preliminary helicopter design are explored in this paper. The first is a sensitivity analysis of the basic helicopter performance equations. The purpose here is to ascertain where reasonable simplifications can be made that do not seriously degrade the accuracy of the results. The second is a graphical parametric design method, known as Carpet Plots. In this method a graphical solution is developed to meet the design criteria of the helicopter. In the third, an overview of Boeing Vertol's Helicopter Sizing and Performance Computer Program is given. The computer routines which enable a person to access HESCOMP on the Naval Postgraduate School main frame IBM system are also provided.

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I. INTRODUCTION

A. GENERAL

The helicopter design process, the subject of numerous articles and studies is an evolving discipline that borders on being an art. A successful design must balance the user's needs and desires against practical capabilities.

With the introduction of composite materials and new technologies, principally in rotor and engine performance, significant advances have been made in helicopter capabilities. In some instances, the performances of hybrid helicopter designs rivals that of a similarly sized conventional aircraft. For example, the YVX, a joint Boeing-Bell venture, will have the hover and low speed capabilities of a helicopter while being able to cruise at 300 knots.

Viable commercial and military helicopter designs are only thirty years old. The first major use of helicopters occurred during the Korean conflict. To put this in perspective, the first large scale use of conventional type aircraft was in World War I.

Helicopter design can proceed on a number of different levels, ranging from comprehensive computer design programs to preliminary analysis using simplifications of the basic performance equations. Each has its merit and place. Computer-aided design provides a great deal of data.

Generally, these programs integrate aircraft configuration sizing, performance and weight calculations in an iterative process. An example of a computer design program for helicopters is the Helicopter Sizing and Performance Computer Program [HESCOMP], orginally developed by Boeing-Vertol for NASA. This program is currently used as a wide number of institutions conducting studies in helicopter design.

On the opposite end of the spectrum would be sensitivity design studies using the performance equations. Surprisingly accurate simplications of these equations can be made. This provides the designer with an excellent method for doing first cut preliminary helicopter sizing at a low cost.

B. OBJECTIVE

This report is an investigation of several of the methods employed in the preliminary design of a helicopter. Conceptually, the report can be divided into three parts. In the first section, a sensitivity analysis of the basic performance equations is performed. The purpose here is to ascertain where reasonable simplications can be made that do not seriously degrade the accuracy of the result.

In the second section a graphical method of doing parametric design studies, known as Carpet Plots, is developed. This method allows the user to formulate a graphical solution matrix to meet the design criteria specified for the helicopter. Carpet Plots are particularly instructive since they give visual insight into the interplay of the various design parameters.

In the last section, an overview of HESCOMP is given. Programs are developed which enable a person to access HESCOMP on the Naval Postgraduate School Main Frame IBM system.

II. SENSITIVITY ANALYSES OF BASIC HELICOPTER EQUATIONS

A. DESCRIPTION OF PROBLEM

In preliminary helicopter design, there are a number of instances where a quick first cut analysis would be extremely helpful. This is especially true in determining the preliminary size of the helicopter required to meet the specifications.

Historically, there are a number of variables in the performance equations of helicopters which may be treated as constants. This may allow for significant simplifications and aid in the preliminary design process.

In this section, a sensitivity analysis of the performance equations is done. In a sensitivity analysis, each parameter [or variable] is varied in order to determine its effect on the equation. Variables which are shown to have little effect may be treated as constants and the equation simplified accordingly.

B. SOLIDITY

Solidity, σ , is the fraction of the disk area that is composed of blades. It is a function of b , the number of blades, of a constant cord, c , at a radius, R:

$$\sigma = \frac{bc}{\pi R} \tag{2.1}$$

C. DISK LOADING:

Disk loading is defined as the ratio of the weight to the total area of the rotor disk.

$$DL = \frac{WEIGHT}{AREA} = \frac{W}{A} = \frac{W}{\pi R^2} \; [lb/ft^2] \qquad (2.2)$$

D. POWER LOADING

Power loading is the ratio of weight to input power.

$$PL = \frac{W}{P_{in}} \; [lb/hp] \qquad (2.3)$$

In a hover, thrust equals weight; this allows us to rewrite the power loading for the hover condition as

$$PL = \frac{T}{P_{in}} = \frac{\text{ROTOR THRUST}}{\text{ROTOR HORSEPOWER}} \; [lb/hp] \qquad (2.4)$$

E. COEFFICIENT OF THRUST AND POWER

The coefficient of thrust, C_T , is a non-dimensional coefficient which facilitates computations and comparisons:

$$C_T = \frac{T}{A\rho V_T^2} = \frac{T}{\pi R^2 \rho (\Omega R)^2} \qquad (2.5)$$

Similarly, a coefficient of power, C_p , has been established as:

$$C_p = \frac{P}{A\rho V_T^3} = \frac{P}{\pi R^2 \rho (\Omega R)^3} \qquad (2.6)$$

No significant simplifications can be made to either of these coefficients. However, it should be observed that the coefficient of thrust is inversely proportional to the square of the rotor tip velocity, while the coefficient of power is inversely proportional to the cube.

Assuming all other factors being equal, increasing the rotor tip velocity from 600 fps to 700 fps [an increase of 16.7 percent] will have the following result on these coefficients.

$$C_T = \frac{T}{A\rho V_T^2}$$

$$= \frac{T}{A\rho (1.167)^2} \qquad (2.5)$$

$$= \frac{T}{A\rho (1.361)}$$

The coefficient of thrust is reduced by 26.9 percent. Similarly, for the coefficient of power:

$$C_P = \frac{P}{A\rho V_T^3}$$

$$= \frac{P}{A\rho(1.167)^3} \qquad (2.6)$$

$$= \frac{P}{A\rho(1.589)}$$

The coefficient of power is reduced by 37.1 percent.

F. HOVER POWER

The total power in a hover is made up of two terms, profile power, P_o , and induced power, P_i .

Utilizing black element theory the profile power required to hover can be expressed as:

$$P_o = \frac{1}{8}\, \sigma_r\, \bar{C}_{do}\, \rho\, A(\Omega R)^3 \qquad (2.7)$$

The induced power predicted by momentum theory is:

$$P_i = V_{in}\, T$$

$$= \frac{T^{3/2}}{\sqrt{2\pi\rho R^2}} \qquad (2.8)$$

The total power required to hover is:

$$P_T = P_i + P_o \qquad (2.9)$$

$$P_T = \frac{T^{3/2}}{\sqrt{2\pi\rho R^2}} + \frac{1}{8}\sigma_r C_{do}\,\rho\, A(\Omega R)^3 \qquad (2.10)$$

Donald M. Layton in Helicopter Performance, [Ref. 1], found that for the optimum hover power, the induced power is equal to twice the profile power. The analysis was performed in the following manner.

By assuming constant weight, density, solidity, and an average profile drag coefficient, as well as a fixed rotational velocity, equation (2.10) reduces to

$$P = \frac{C_1}{R} + C_2R^2 \qquad (2.11)$$

where C_1 and C_2 are constants.

As equation (2.12) shows, profile power increases as the square of the blade radius while the induced power decreases with increasing blade radius.

The optimum hover power with respect to rotor radius can be determined by taking the differential and setting it equal to zero.

$$\frac{dP}{dR} = 0 = -\frac{C_1}{R_2} + 2\,C_2R \qquad (2.12A)$$

or

$$\frac{C_1}{R} = 2\,C_2R^2 \qquad (2.12B)$$

which implies

$$P_i = 2\,P_o \qquad (2.12C)$$

G. HELICOPTER SIZING

A simplified relationship between the total power required, gross weight and rotor radius can be developed in the following manner.

The total power required to hover equation for the main rotor was developed in the preceding section and is repeated here for clarity.

$$P_T = P_i + P_o \qquad (2.9)$$

$$P_T = \frac{T^{3/2}}{\sqrt{2\pi\rho}} \cdot \frac{1}{R} + \frac{1}{8} \sigma_r \bar{C}_{do} \rho\pi V_{tip}{}^3 R^2 \qquad (2.10)$$

In a hover, thrust equals weight. Solving equation (2.11) for weight one obtains:

$$W^{3/2} = [P_T - \frac{1}{8} \sigma C_{do} \rho\pi V_T{}^3 R^2] \sqrt{\rho A} \qquad (2.13)$$

This equation may be further simplified if it is assumed that the density, average profile drag coefficient and tip velocity are constants; these are reasonable assumptions. Historically, the average profile drag coefficient of a helicopter has been approximately 0.01. The operating environment of today's helicopters, especially military, is below 5,000 feet agl. This allows for the use of the standard sea level value for density with little error. Primarily, due to tip mach effects, the upper limit on the rotor tip velocity is in the range of 700 fps.

The resulting equation with these assumptions incorporated into a constant, K , is:

$$W = [47.527\ P_T\ R - K_1\ bc]^{2/3} \qquad (2.13)$$

Equation (2.13) can be further reduced when the order of magnitude of the two terms is considered.

$$47.527\ P_T\ R >> K_1\ bc$$

Thus,

$$W \approx [47.527\ P_T\ R]^{2/3} \qquad (2.14)$$

To determine how accurate this simplification is, the equation is used to approximate the total weight of a number of helicopters for which the parameters are available. As Table 2.1 indicates, the weight approximation formula yields values within six percent of the actual total weight of these helicopters.

H. FIGURE OF MERIT

A figure of merit, FM , has been defined for the helicopter as the ratio of the ideal rotor induced power to the actual power required to hover, with non-uniform induced velocity, tip losses and profile drag power.

TABLE 2.1

HELICOPTER WEIGHT COMPARISON

HELICOPTER	TOTAL GROSS WEIGHT (1000 lbs)	CALCULATED GROSS WEIGHT (1000 lbs)	PERCENT OF ACTUAL GROSS WEIGHT
AH-64	14.66	14.69	101%
UH-1N	14.20	13.74	97%
H-3H	21.00	20.63	98%
S76	10.00	9.90	99%
UH-60A	20.25	19.33	95%
H-54B	42.00	42.00	100%
H-53D	42.00	41.00	98%
H-53E	73.50	69.00	84%

In a hover, the figure of merit may be written as:

$$FM = \frac{1}{\sqrt{2}} \cdot PL \cdot \frac{DL}{\sqrt{\rho}}$$

$$= \frac{CT^{1.5}}{\sqrt{2C_p}} \qquad (2.15)$$

The figure of merit is customarilty plotted against the quantity CT/σ . According to Zalesch [Ref. 2], CT/σ , is proportional to the average blade angle of attack and can be used as a measure of rotor efficiency. The curve in Figure 2.1 is based on data from Reference 2 for a typical tail rotor helicopter.

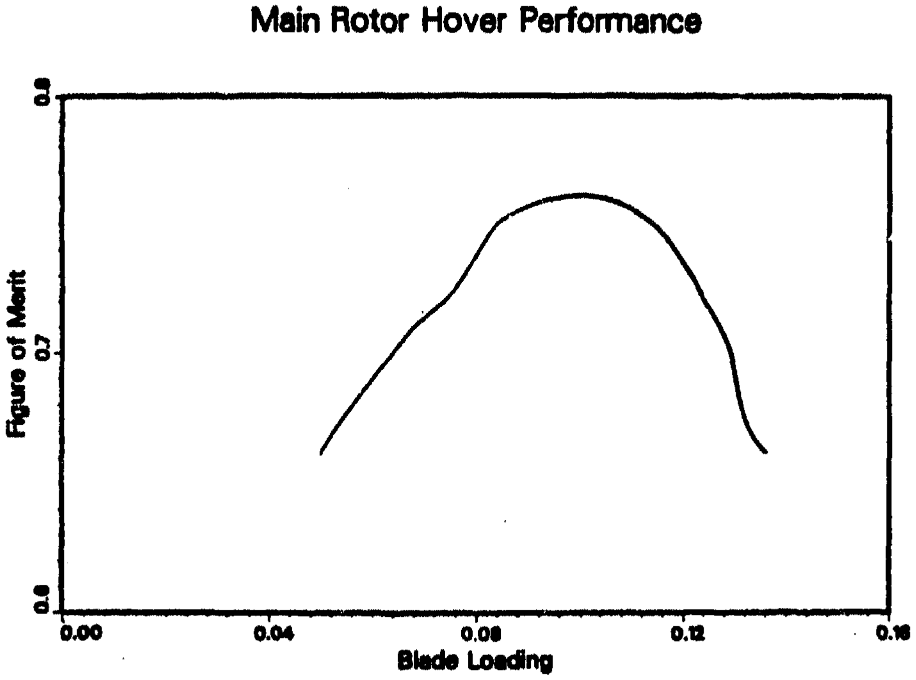


Figure 2.1. FM Versus Blade Loading CT/σ

Previous studies have shown that a figure of merit between 0.70 and 0.80 is considered average.[Ref. 3] If the induced power is between 70 and 80 percent of the total power, the figure of merit will be approximately 0.75.

With the figure of merit limited to values between 0.70 and 0.80, the following simplification can be made, assuming the hover condition of thrust equaling weight and standard sea level conditions:

$$FM = \frac{W^{3/2}}{67.214\ P_T R} \qquad (2.16)$$

For Navy helicopter design, the rotor radius has been limited by flight deck spotting constraints to less than 30 feet; the exception to this is the H-3, R = 31 feet and the H-53, R = 36 to 38 feet [depending on the model]. However, these two helicopters work almost exclusively from large air dedicated ships such as the LPH, LHA and CV.

If the small deck operating assumption is made, equation (2.16) can be further simplified to [assuming R = 28 feet]:

$$P = \frac{W^{3/2}}{1881.98\ FM} \qquad (2.17)$$

An FM of 0.80 will yield a P to W relationship of:

$$P_T = \frac{W^{3/2}}{1505.58} \qquad (2.18)$$

while an M of 0.70 yields a relationship

$$P = \frac{W^{3/2}}{1317.39} \qquad (2.19)$$

If equation (2.17) is solved utilizing the approximate weight relationship developed earlier of

$$W^{3/2} = 47.527\ P_T R \qquad (2.14)$$

a value for the figure of merit of 0.707 is obtained. This is within the historical range of values.

I. TAIL ROTOR SIZING

A historical analysis of typical helicopters [Ref. 3), shows the following empirical relationship for the tail rotor radius

$$R_T \simeq 1.3\ [\frac{GW}{1000}]^{1/2}\ [ft] \qquad (2.20)$$

when comparing the results of this equation with actual tail rotor radius data, it was found that if a multiplication factor of 1.2 is used vice 1.3 a better approximation is obtained. The results are tabulated in Table 2.2.

J. FORWARD FLIGHT POWER CONSIDERATIONS

The total power in forward flight consists of induced, profile and parasite power. If the helicopter is a single rotor vehicle, the tail rotor power should be taken into

TABLE 2.2

TAIL ROTOR SIZING

HELICOPTER	ACTUAL TAIL ROTOR RADIUS [FT]	APPROXIMATION [FT]	
		[2.20]	[2.21]
AH-64	4.6	4.98	4.59
UH-1N	4.3	4.90	4.52
SH-3H	5.3	5.95	5.5
S-76	4.0	4.11	3.79
UH-60A	5.5	5.85	5.4
CH-53D	8.0	8.42	7.78
CH-53E	10.0	11.15	10.29

account, as well as all mechanical losses [transmission, etc.] for accurate calculations. However, a reasonable approximation can be obtained by considering only the main rotor and increasing this power figure by several percent to account for these losses.

Figure 2.2 is a plot of the induced, profile, parasite and total power curves for typical tail rotor helicopter.

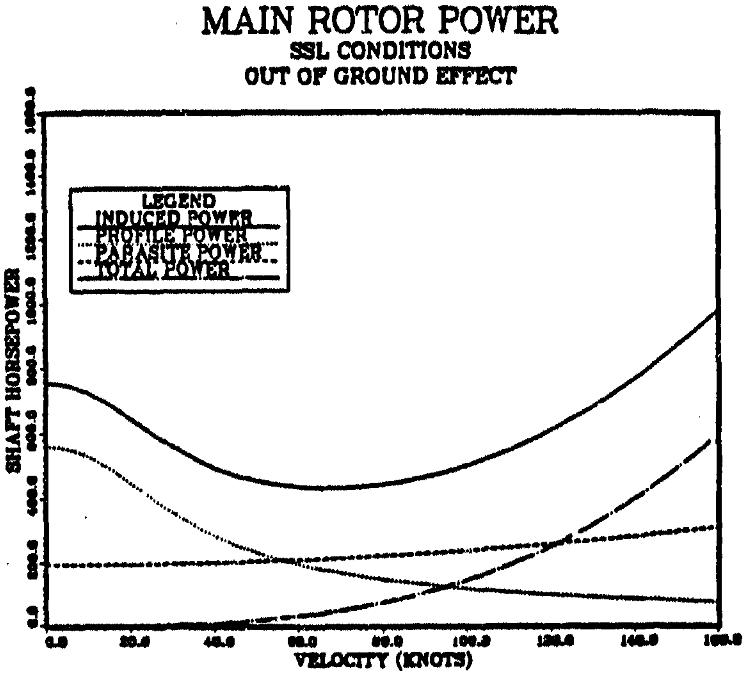


Figure 2.2. Power Required Versus Forward Velocity

The induced power drops off rapidly with increasing forward-velocity, whereas the parasite power increases rapidly.

Parasite power is the power required to overcome the drag forces created by the aircraft's geometry. These drag forces are due to pressure drag and skin friction.

Parasite drag is extremely sensitive to the helicopter's loading. It is generally a minimum for forward flight and increases for sideways flight. Helicopters are generally streamlined for forward flight and the flat plate area is a minimum in this direction. The equation for the parasite power is:

$$P_p = \frac{1}{2} \rho V_f^3 f_f \qquad (2.21)$$

The parasite power is a function of the cube of the forward velocity. As such, with the advent of high speed helicopters a great deal of consideration has been placed on streamlining the geometric shape in order to reduce this power requirement.

Blade element theory is commonly used to develop the profile power equation for forward flight. An excellent development of this equation is given in Reference 1.

The profile power equation in forward flight is:

$$P_{of} = \frac{1}{8} \sigma C_{do} \rho A V_T^3 [1 + 4.3 \mu^2] \qquad (2.22)$$

Equation (2.23) is a function primarily of the main rotor geometry. The variable with the most significance is the rotor tip velocity; increasing the tip velocity from 600 to 700 fps results in a 58.8 percent increase in profile power [assuming other factors are constant].

The induced power is a function of the induced velocity. In a hover, the total flow through the rotor system is induced. As the forward velocity increases, the mass flow rate through the rotor disc increases due to the forward translation of the helicopter. This reduces the induced velocity.

The equation for the induced power requirements at all forward velocities is:

$$P = T \cdot V_{it} \tag{2.23}$$

where

$$V_{it} = \left\{ - \frac{V_f^{\,2}/V^2}{2} + \sqrt{\left[V_f^{\,2}/2V^2\right]^2 + 1} \right\}^{1/2} . V \tag{2.23a}$$

At high forward velocities, the induced power required can be approximated as:

$$P_i = WV_{it} - \frac{W^2}{2\rho AV_f} \tag{2.24}$$

The total power for forward flight is the sum of the induced, profile and parasite powers.

$$P_T = P_i + P_o + P_p \tag{2.25}$$

$$P_T = T.V_{it} + \frac{1}{8}\sigma C_{do} \rho A V_T^3[1 + 4.3 \mu^2] + \frac{1}{2}\rho f_f V_f^3 \tag{2.25a}$$

At high forward velocities, equation (2.23) can be substituted into equation (2.25), resulting in:

$$P_T = \frac{W^2}{2\rho A V_f} + \frac{1}{8}\sigma C_{do} \rho A V_T^3[1 + 4.3 \frac{V_f}{\Omega R}] + \frac{1}{2}\rho f_f V_f^3 \tag{2.26}$$

If one makes the following assumptions:

$W = \text{const}$ $\quad C_{do} = \text{const}$

$\rho = \text{const}$ $\quad \sigma = \text{const}$

$VT = \text{const}$

Equation (2.26) reduces to

$$P_T = \frac{K_1}{R^2} + K^2 R^2 + P_p \tag{2.27}$$

The derivative of equation (2.27) with respect to radius is:

$$\frac{dP_T}{dR} = -\frac{2K_1}{R^3} + 2 K_2 R \tag{2.28}$$

Setting this equal to zero, one obtains:

$$-\frac{2K_1}{R^3} + 2\ K_2\ R = 0 \qquad (2.28a)$$

$$\frac{R}{2} * [-\frac{2K_1}{R^3} + 2\ K_2\ R] = 0 \qquad (2.28b)$$

$$\frac{K_1}{R^2} = K_2\ R^2 \qquad (2.28c)$$

$$P_i = P_o \qquad (2.28d)$$

This defines point of minimum total power required for VMAX range. This corroborates with the results obtained by Waldo Carmona [Ref. 4].

If the total power required is differentiated with respect to forward velocity and is set equal to zero, it can be seen that

$$P_i = 3\ P_o \qquad (2.29)$$

or

$$\frac{W^2}{2\rho AV_f} = \frac{3\rho fV_f{}^2}{2} \qquad (2.30)$$

Solving this equation for velocity results in:

$$V_f = \left[\left(\frac{W}{A} \; \frac{A}{3f_f}\right)^{1/2}\right]^{1/2} \quad \text{ft/sec} \qquad (2.31)$$

According to Carmona [Ref. 4], this corresponds to the best endurance velocity.

K. DENSITY EFFECTS ON TOTAL POWER

The effect of density on the total power required in forward flight is as follows:

The general operating altitudes of a helicopter are below 10,000 feet. The corresponding ICAO STANDARD ATMOSPHERE range for density is

$$\rho = 0.0023769 \; [\text{lb sec}^2/\text{ft}^4] \quad \text{SSL}$$

$$\rho = 0.0017553 \; [\text{lb sec}^2/\text{ft}^4] \quad \text{at 10,000 feet}$$

$\rho/\rho SSL$ varies from 1 to .7385.

The effect on the components of P_T are as follows:

Induced Power:

$$1/\rho/\rho SSL \Rightarrow 1 \text{ to } \frac{1}{.7385}$$

This translates to a 35 percent increase in the induced power.

Parasite and Profile Power:

Both parasite and profile powers are directly proportional to the density ratio. Therefore, as you go up in altitude both P_o and P_p are reduced.

III. CARPET PLOT DESIGN STUDY

A. DESCRIPTION OF PROBLEM

Preliminary helicopter design involves one with a wide range of choices. For any given payload and performance specifications, there a number of helicopter designs that satisfy the requirements. The problem in the preliminary design process is narrowing these possibilities and selecting the design which will provide the best helicopter for the mission.

Obviously, the operating environmental constraints help to define the basic configuration. These constraints are usually specified in the Request for Proposal [RFP], in the case of a military helicopter. For example, typical constraints placed on the design of a Navy helicopter are the size of the ship deck and hangar from which it will be operating, the requirement for a blade fold system, dual engine configuration and IFR capability.

Even with these design constraints, there is still a great deal of leeway. In order to insure that the best helicopter design is selected, an appropriate number of solutions satisfying the specifications should be investigated. Since each solution is generally characterized by a different combination of design parameters, the selection, according to Greenfield [Ref. 5], can best be made through a parametric study which allows for the optimization of many design parameters.

One method of parametric analysis used is Carpet Plots. This method is based on the simultaneous graphical solution of the weight and hover performance equations. To this solution set is added to the environmental constraints to the helicopters size. This effectively brackets the area of acceptable design solutions.

This method assumes that minimum gross weight is the criterion by which the best [or optimum] design parameters are selected.

B. ASSUMPTIONS

1. Airfoil used is a derivative of the NACA 0012 with the following mean approximate values from Reference 5.

a = slope of airfoil section lift curve, $dC_t/d\alpha$, per rad.

$a = 5.73$

δ = blade section drag coefficient

$\delta_0 = .009$

$\delta_2 = .3$

2. a) The tail rotor radius is assumed to be .16 times the main rotor radius [Ref. 5].

b) The distance between the rotors, or tail rotor moment arm, ℓ_{TR} is 1.19R [Ref. 5]. These ratios reflect the values of maximum rotor diameter and overall length specified as size limitations.

3. B = .97. Historical approximation [Ref. 7].

C. METHODOLOGY

In order to properly develop the weight and performance equations required for a carpet plot design study, the payload and performance specifications of the helicopter are needed. This data is used to tailor the equations for the design.

The equations will be developed here for a four-place light helicopter. The equation development procedure is applicable to other size helicopters; the development for a medium helicopter, 20,000 lb weight class, is to be found in Appendix B.

The following specification requirements which are similar to those in Reference 5 will apply to this design:

1. The rotor diameter should be less than 35.2 feet.
2. The overall length should be less than 41.4 feet.
3. The gross weight of the helicopter should not exceed 2,450 lbs.
4. The helicopter should be capable of hovering, out of ground effect at 6,000 feet with an ambient air temperature of 95°F.

5. The useful load at hover shall consist of, as a minimum, 200 lbs for the pilot, 400 lbs of payload and sufficient fuel to give the helicopter up to three hours endurance at sea level conditions.

6. Maximum speed of at least 110 knots using Normal Rated Power, at sea level.

7. Total Power Required at 6,000 feet and 95°F shall be not more than 206.

D. HOVER EQUATIONS

1. The main rotor power required to hover out of ground effect is

Total Main Rotor Power [Hover] = Rotor Profile Power + Rotor Induced Power

$$P_T = \frac{1.13W}{550B\sqrt{2\rho_o}}\sqrt{\frac{DL}{\rho/\rho_o}} + \frac{6WV_T}{4400}\,\frac{\rho/\rho_o}{C_{LRo}}\left[\delta_0 + \delta_2\left[\frac{C_{LRo}}{\alpha\rho/\rho_o}\right]^2\right] \tag{3.1}$$

At an altitude of 6,000 feet and a temperature of 95° , ρ/ρ_o = .749395 . Therefore, equation (1) can be simplified to:

$$P_{T6000/95^\circ F} = .035479W[DL]^{1/2} + \frac{.91971}{C_{LRo}}[10]^{-5}(1 + 1.80779\,C_{LRo}{}^2)W\,V_T \tag{3.2}$$

The tail rotor thrust required to counterbalance the main rotor torque is:

$$T_{TR} = \frac{550\ P_T R}{\ell_{TR}\ V_T} = \frac{550\ P_T}{1.19 V_T} \qquad (3.3)$$

where ℓ_{TR} has been defined as 1.19R . With R_{TR} defined as .16R , the tail rotor disk loading can be written, using equation (3) as:

$$\begin{aligned} DL_{TR} &= \frac{T_{TR}}{A_{TR}} = \frac{550\ P_T}{1.19 V_T} \frac{1}{\pi(.16R)^2} \\ &= \frac{550\ P_T}{1.19(.0256) V_T} \frac{DL}{W} \end{aligned} \qquad (3.4)$$

Greenfield [Ref. 5], in his development, assumes that the tail rotor tip speed is equal to the main rotor tip speed and that $\delta_{TR} = .02$ and $\beta_{TR} = .90$. With these assumptions the equation for the tail rotor power required to hover can be written as:

$$\begin{aligned} P_{T_{TR_{Hover}}} &= 2055.7 \left[\frac{DL}{W\ \rho/\rho_o}\right]^{1/2} \left[\frac{P_{T_{Hover}}}{V_T}\right]^{3/2} \\ &+ \frac{.012605\ P_{T_{Hover}}}{C_{LRTR}} \end{aligned} \qquad (3.5)$$

The equation for the tail rotor mean blade lift coefficient can be written as

$$C_{LRTR} = \frac{P_T}{562.5(\rho/\rho_o)} \qquad (3.6)$$

if it is assumed that the tail rotor is designed to counterbalance a sea level main rotor torque equivalent to 90 percent of the installed power.

Substituting equation (3.6) into equation (3.5) one obtains the following expression for hover tail rotor power:

$$P_{T_{TR6000/950}} = 2374.7 \left[\frac{DL}{W} \right]^{1/2} \left[\frac{P_{T_H}}{V_T} \right]^{3/2} + 5.3134 \qquad (3.7)$$

It is assumed that the gear losses amount to 3 percent and that there is a 1 percent cooling power loss, the total brake horsepower required to hover becomes:

$$P_T = \frac{P_{Tm} + P_{TTR}}{96} \qquad (3.8)$$

Empirical studies have shown that the tail rotor power required to hover can be approximated by

$$P_{T_{AC}} \sim .8 \text{ [total horsepower to hover]}$$

This allows one to write the main rotor power required to hover as:

$$P_{Tm} = (.88)(P_{Tm}) \qquad (3.9)$$

Following Greenfield's [Ref. 5] development further, if equations (3.2) and (3.7) are substituted in equation (3.8), one obtains

$$
\begin{aligned}
P_{T_{H6000/95^\circ}} &= .036757\ W \sqrt{DL} \\
&\quad + \frac{.95803}{C_{LRo}} (10)^{-5} \left[1 + 1.80779\ C_{LRo}^{2}\right] W\ V_T \qquad (3.10) \\
&\quad + 2473.6 \sqrt{\frac{DL}{W}} \left[\frac{P_{Tm}}{V_T}\right]^{3/2} + 5.5348
\end{aligned}
$$

Utilizing the approximation for tail rotor power, equation (3.9), equation (3.10) can be solved for W (gross weight) as a function of variables V_T (tip speed), DL (rotor disk loading), C_{LRo} (rotor mean lift coefficient) and P_{T_H} (total power to hover).

$$
W = \frac{K_1 \left[1 - 411.51 \dfrac{DL^{3/4}}{V_T^{3/2}} \left(1 + K_2 \dfrac{V_T}{\sqrt{DL}}\right)^{1/2}\right] - K_3}{V_T + K_4 \sqrt{DL}} \qquad (3.11)
$$

where:

$$
K_1 = P_{T6000/90^\circ} \frac{(10)^5}{K_5} \qquad (3.11a)
$$

$$
K_2 = \frac{.00025929}{C_{LRo}} \left(1 + 1.80779\ C_{LRo}^{2}\right) \qquad (3.11b)
$$

$$K_3 = \frac{553480}{K_5} \qquad (3.11c)$$

$$K_4 = \frac{3695.7}{K_5} \qquad (3.11d)$$

$$K_5 = \frac{.95803}{C_{LRo}} (1 + 1.80779\ C_{LRo}{}^2) \qquad (3.11e)$$

Equation (3.11) has been programmed in Appendix B and solved for tip speeds from 600 to 700 cps and C_{LR} of .3 to .7.

Equation (3.11) is one of the two primary equations used to obtain the data required for a carpet plot design analysis. Generally, the variables V_T , DL, C_{LRo} and P_T , that are required for solution have specific ranges of values, depending on the weight class of the helicopter being designed. The graphical results of equation (3.11) for tip speeds of 600 to 700 fps and mean lift coefficients between .3 and .7 are illustrated in Figure 3.1.

Both the Fortran and Disspla programs, as well as a decision making flow chart are provided in Appendix C to aid in using this method for a design solution.

E. WEIGHT EQUATIONS

Weight equations need to be developed that realistically reflect the sizing class of the helicopter being designed. The evolution is greatly simplified if a specific engine

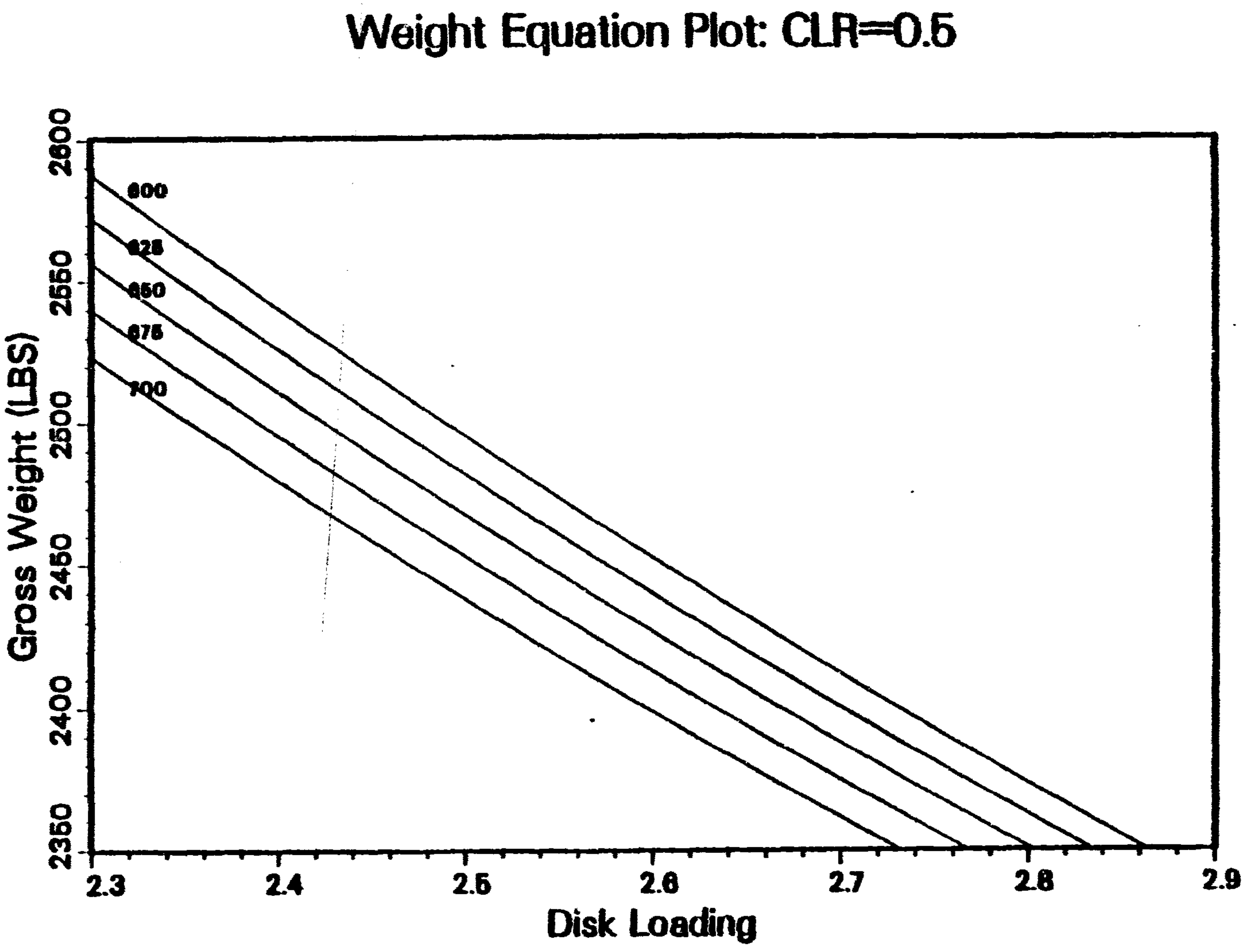


Figure 3.1. Weight Equation Plot: $C_{LR} = 0.5$

installation [# and horsepower] is assumed, since the weight of a number of components depend only on the installed power; this would include such terms as the engine controls and accessories. Another category would be those components whose weights depend on either the gross weight on two or more of the following in combination: rotor tip speed (V_T), rotor diameter (R), rotor solidity (σ).

The equations developed here are taken from the Hiller Aircraft Corporation Performance Data Report. [Ref. 5] In this report they assumed a specific engine installation, the Allison T-63 with a military power rating at sea level of 250 horsepower.

There is a possible problem of the validity of these weight relationships when applied to different helicopter design categories. However, assuming a specific engine determines a number of the component weights, and thus minimizes the inaccuracies. Using the weight estimation relationships developed in the Helicopter Design Manual [Ref. 2], the engine, control and accessory weight can be calculated and the weight formulas developed here applied to give a representative useful load and empty weight formula for preliminary design analysis. This is done in Appendix C, for a 20,000 pound class helicopter.

The following relations are used to reduce the component weight formulas for the specification helicopter:

$$W/DL = A = \pi R^2 \tag{3.12}$$

$$W/PL = MHP = 250 \tag{3.13}$$

(Military rating for Allison T-63 at sea level.) (PL = Power Loading.)

$$P = \sqrt{A}/V_T \tag{3.14}$$

Using these equations the component weight for the specified helicopter empty weight may be reduced to the following:

Engine, Controls and Accessories = 617.5 lbs.

Engine Section Group $.053[W/PL]^{1.07}$ = 19.5 lbs. (3.15)

Main Transmission $10.43\,\frac{W^{1.295}}{(PL\ V_T)^{.863}}$ = $1221\ p^{.803}$ (3.16)

Rotor Drive Shaft $5.56\,\frac{W^{1.05}}{(PL\ V_T)^{.7}(DL)^{.35}}$ = $266\ p^{.7}$ (3.17)

Tail Rotor $32.22\,\frac{W^{1.14}}{(PL\ V_T)^{1.7}}$ = $\frac{17449}{V_T^{1.14}}$ (3.18)

The engine, controls and accessories category includes such items as lubrication and oil cooling system, engines, communications, engine controls, engine accessories, instruments starting system, furnishing, flight controls, electrical system and stabilization. These are considered fixed weight items determined from specification of the engine and weight class of the helicopter.

Tail Rotor
Gear Box

$$3.7 \frac{W^{.75}}{(PL\ V_T^{\ .5}(DL)^{.25}} = 59.47 \sqrt{P} \tag{3.19}$$

Tail Rotor
Drive
Shaft

$$.124 \frac{W^{1.355}}{(PL\ V_T)^{.57}(DL)^{.785}} = 2.886\ P^{.57} \sqrt{A} \tag{3.20}$$

Body and.
Gear
Landing

$$= 1.91\ W^{.916} + .0294\ W^{.99}$$

Rotor
Blade
Teetering

$$35.15 \frac{W^{1.185}\sigma^{.33}}{V_T(DL)^{.185}} = 35.15 \frac{W}{V_T} A^{.185}\sigma^{.33} \tag{3.21}$$

Rotor Blade
Artic-
ulated

$$19.77 \frac{W^{1.205}\sigma^{.33}}{V_T(DL)^{.205}} = 19.77 \frac{W}{V_T} A^{.205}\sigma^{.33} \tag{3.22}$$

Rotor Hub
Teetering

$$.0088 \frac{W^{1.21}}{DL^{.21}} = .0088\ WA^{.21} \tag{3.23}$$

Rotor Hub
Artic-
ulated

$$.00975 \frac{W^{1.21}}{DL^{.21}} = 00975\ WA^{.21} \tag{3.24}$$

Fuel System .416 per gallon capacity $= .0615\ W_F$ (3.25)

where $W_F =$ fuel weight.

The individual component weights may now be combined into a single expression for the helicopter empty weight.

$$W_e = 617.5 + .0617W_F = 1221P^{.863} + 266P^{.7} + \frac{17449}{V_T^{1.14}} \qquad (3.26)$$

$$+ 58.47\sqrt{P} + 2.886P^{.57}\sqrt{A} + .191W^{.916} + .0294W^{.99}$$

+ appropriate rotor blade and hub weights.

As stated earlier, the design specifications called for a useful load consisting of a pilot (200 lbs), payload (400 lbs) and the required fuel weight (W_F). The fuel weight is calculated for the Allison T-63 in the following manner: endurance of three hours at 85 percent of normal rated powered for the T-63 is 180.2 HP and the specific fuel consumption at this power is .783 lbs fuel/BHP HR. Including an allowance for a three-minute warm-up at NRP and using a 5 percent correction factor on SFC, as specified in Reference 5, the fuel weight becomes:

$$W_F = 3(180.2)(.822) + \frac{3}{60}(212)(777) \qquad (3.27)$$

An allowance should also be made for oil plus trapped fuel. This is estimated at 20 lbs.

The total useful load is the sum of the useful load items.

$$W_u = 200 + 400 + 452.6 + 20 = 1072.6 \text{ lbs} \qquad (3.28)$$

A new variable, W_{BAR} , is defined as the sum of the emply weight plus useful load. It is the of equations (3.26) and (3.28).

$$W_{BAR} = 1717.9 + 1221P^{.863} = 266P^{.7} + \frac{17449}{V_T^{1.14}} + 58.47\sqrt{P}$$
$$+ 2.886P^{.57}\sqrt{A} + .191W^{.916} + .0294W^{.99} \qquad (3.29)$$
$$+ \text{ appropriate rotor blade and hub weights.}$$

Equation (3.11) together with equation (3.29) form the basis of a carpet plot design study. These equations are solved simultaneously for W_{BAR} . This solution is best illustrated graphically, as in Figure 3.2. The graph in Figure 3.2 was generated for a specific value of C_{LR} over a range of tip speeds [600 to 700].

F. GRAPHICAL ANALYSIS

Graphs similar to Figure 3.1 are generated for several value of C_{LR} , and are then cross plotted to form Figure 3.2.

The mean lift coefficient, C_{LR} , values are selected based on what is considered the historical average range of

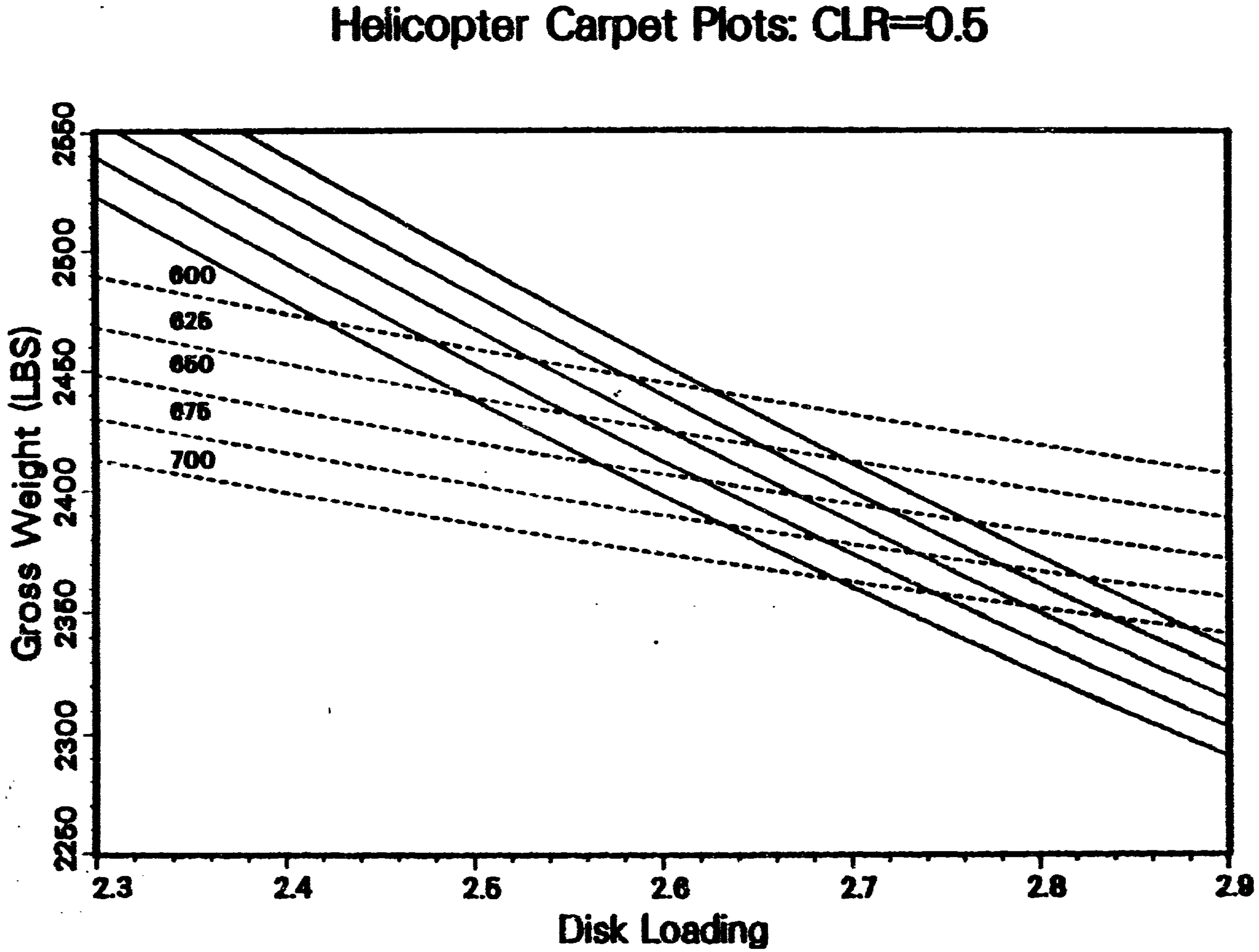


Figure 3.2. Helicopter Carpet Plots: $C_{LR} = 0.5$

values. Figure 3.3 is basic plot for a carpet plot design study. Programs are provided in Appendix D which will generate the required data sets and plots of Figures 3.2 and 3.3.

The solution field depicted in Figure 3.3 is too large to be of great analytic value and as such must be reduced. Three parameters, maximum gross weight, rotor diameter (both specified in the Design Specification) and the aspect ratio can be used to narrow the field of solutions.

1. Rotor Diameter Boundary

A net to exceed value for the rotor diameter is generally given in the design specifications. This limiting value is based on the operating environment of the helicopter. With R max specified, there is a linear relationship between the disk loading and the gross weight.

$$DL = \frac{W}{A} = \frac{W}{\pi R^2}$$

The resulting bracketing of the solution field by applying both the maximum gross weight and maximum rotor diameter limits to the carpet plot are shown in Figure 3.4.

2. Respect Ratio Boundary

It is evident that a further restriction is still necessary to completely define the region of acceptable

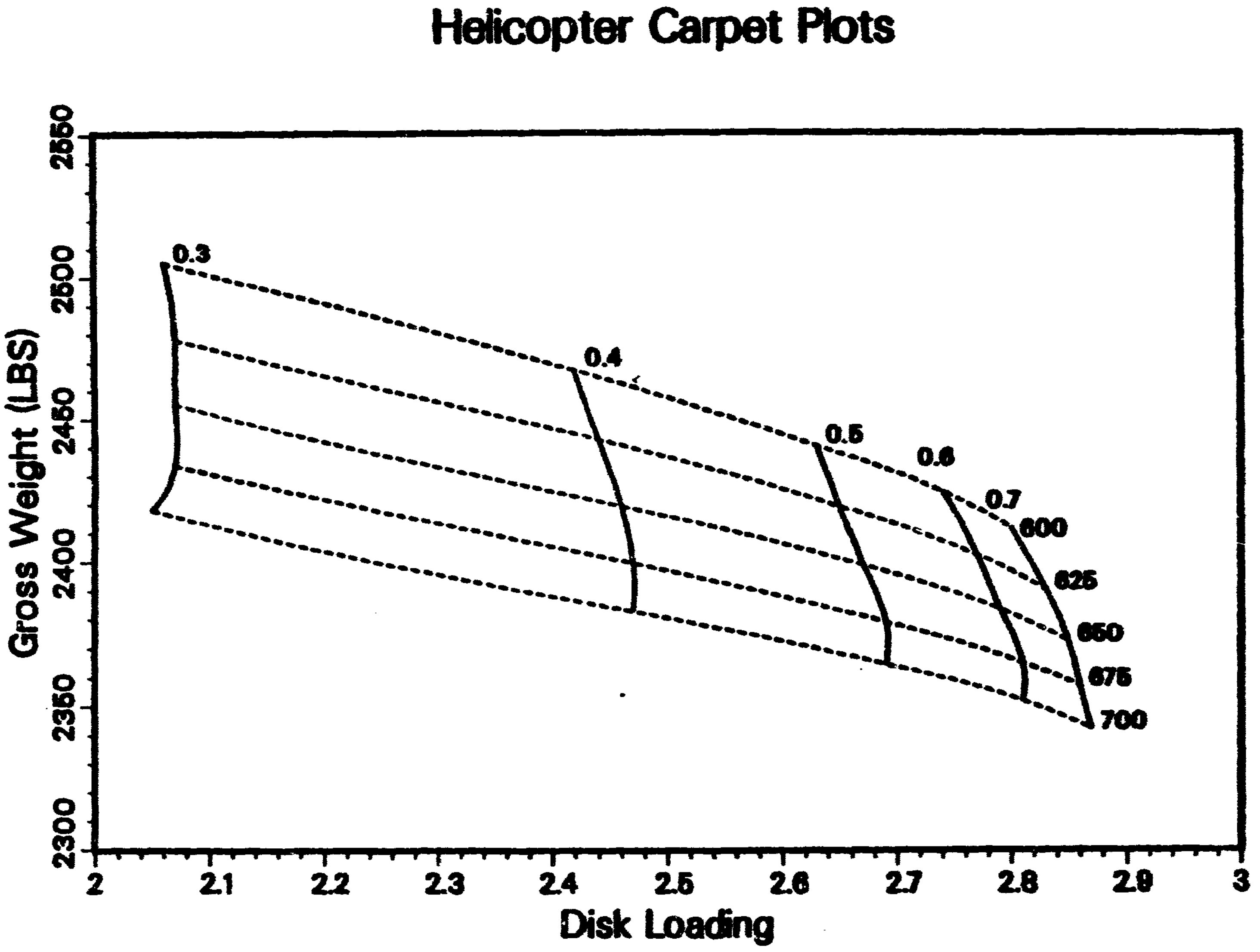
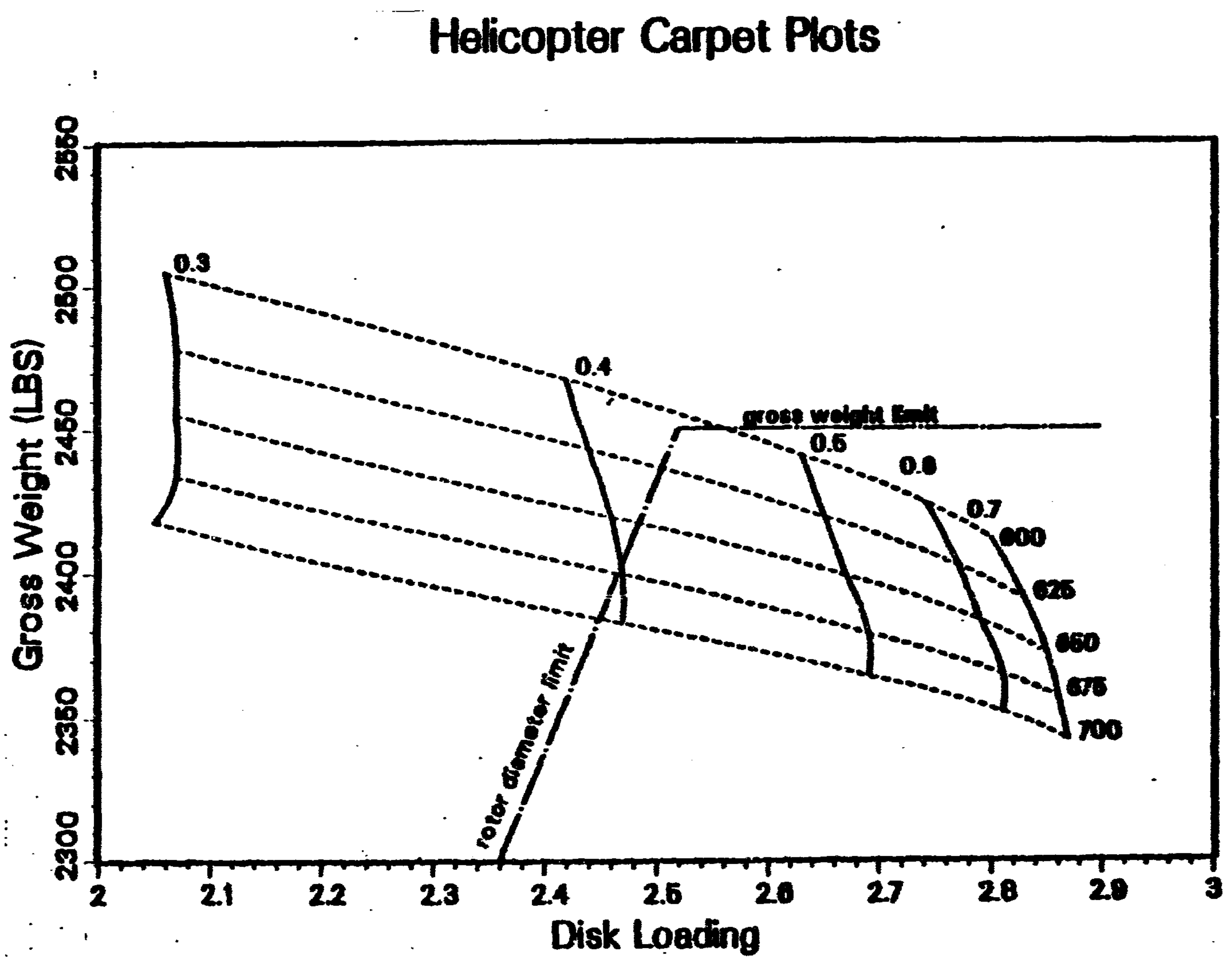


Figure 3.3. Helicopter Carpet Plots
Family of Solutions



Helicopter Carpet Plots

Figure 3.4. Helicopter Carpet Plots Rotor Diameter and Weight Limits

design solutions. Studies have indicated that a main rotor aspect ratio of 21,[1] is a representative upper limit. Thus

$$21 \geq \frac{R\langle mr\rangle}{C\langle mr\rangle} = \frac{b}{\pi\sigma} = \frac{b\ \rho_o\ C_{LR}\ V_T^2}{\sigma\pi\ DL}$$

or

$$DL \geq \frac{b\ \rho\ C_{LR}\ V_T^2}{126\pi}$$

For the case of a two bladed main rotor equation (3.30) reduces to:

$$DL \geq .000012\ C_{LR}\ V_T^2$$

The detemination of this boundary graphically is as follows:

The hover solution plot of Figure 3.2 is replotted[2] relative to the coordinates disk loading and design mean blade lift coefficient. The limiting curves for $DL = .000012\ C_{LR}\ V_T^2$ are then plotted. The intersection with the appropriate constant tip speed lines of the hover solution represent the aspect ratio boundary; Figure 3.5.

---

[1] For a helicopter rotor, the aspect ratio is defined as the radius divided by the chord.

[2] For clarity lines of constant gross weight are omitted.

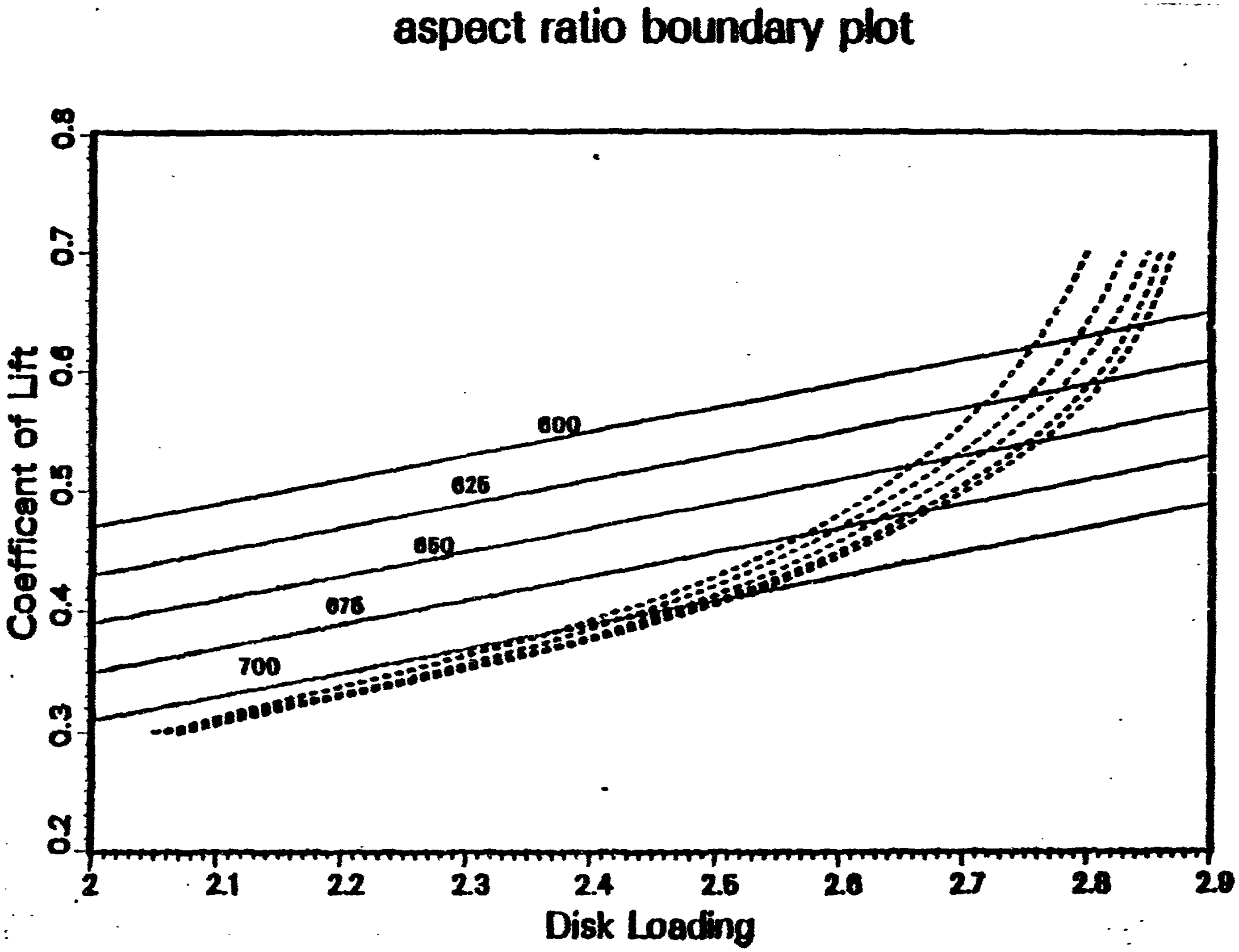


Figure 3.5. Aspect Ratio Boundary Plot

These intersection points are then cross plotted onto Figure 3.4. Figure 3.6 represents a graphical plot of the solution set satisfying the performance and structural design criteria of a small observation helicopter as specified in this study.

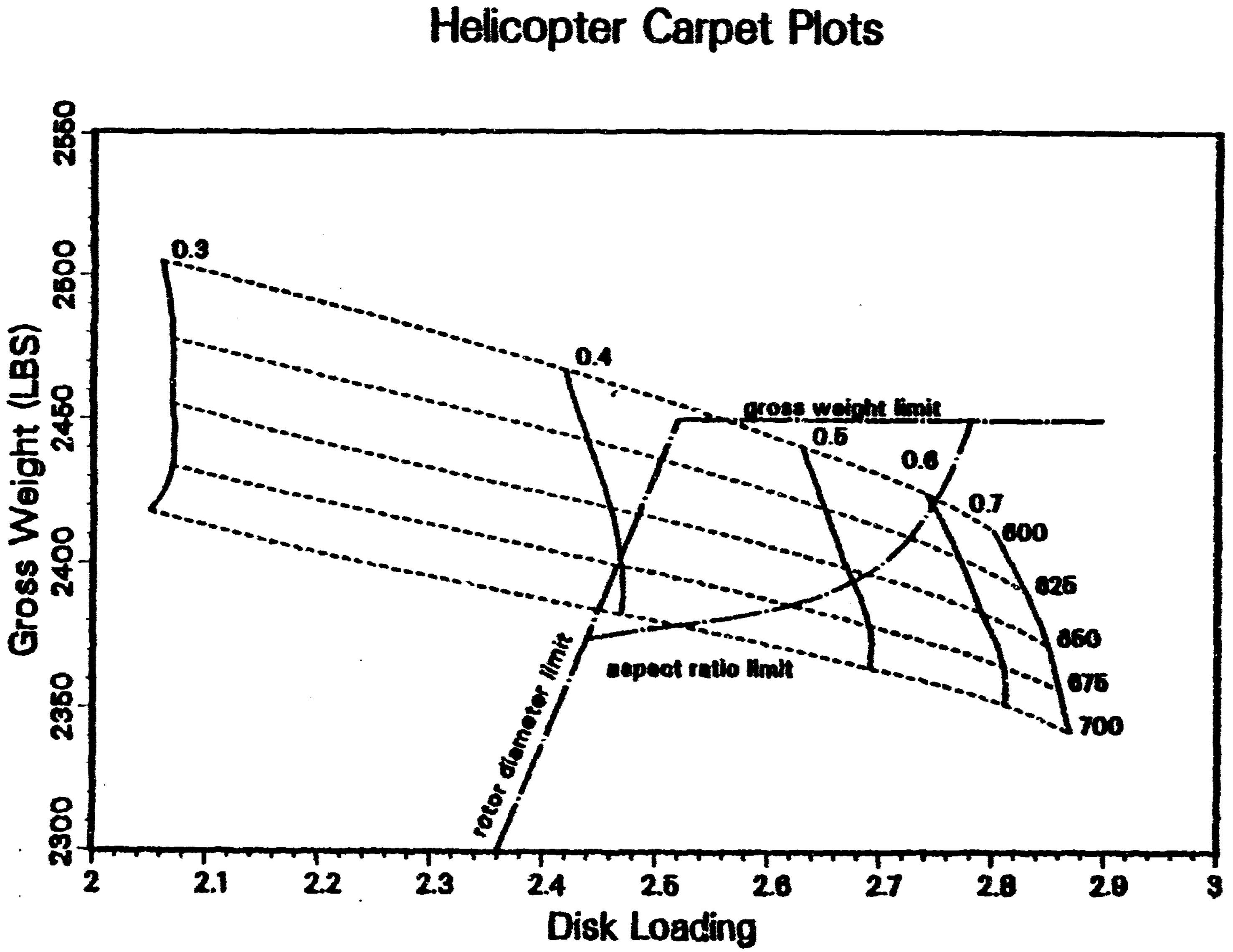


Figure 3.6. Helicopter Carpet Plots
Final Solution

IV. HESCOMP

A. DESCRIPTION OF PROGRAM

HESCOMP is a helicopter sizing and performance computer program developed by the Boeing Vertol Company. The program was originally formulated to provide for rapid configuration design studies.

A number of programming options are available to the user of HESCOMP. When the type and mission profile of the helicopter are known, HESCOMP may be used to size the aircraft. Alternately, it may be used for mission profile calculations when the sizing details [gross weight, payload, engine size, etc.] are specified. A combination of these two options is also available; the program may be used to first size a helicopter for a primary mission and then calculate the off-design performance for other missions. Finally, HESCOMP may be used solely for obtaining helicopter weight.

Sensitivity studies involving both design and performance tradeoffs can easily be done with HESCOMP. Incremental multiplicative and additive factors can be imbedded in the input data.

The various helicopter configurations that may be studied using HESCOMP are detailed in Table 4.1.

TABLE 4.1

HELICOPTER CONFIGURATIONS WHICH MAY BE STUDIED USING HESCOMP

HELICOPTER CONFIGURATIONS WHICH MAY BE STUDIED USING HESCOMP.

Helicopter Type (Both Single & Tandem Rotor) / Additional Lift/Propulsion System Components Which Must be Added to "Pure" Conf.	Wing	Propeller for Auxiliary Propulsion	Auxiliary Independent Engines	Type of Auxiliary Independdnt Engines		
				T/Shaft	T/Fan	T/Jet
Pure Helicopter						
Winged Helicopter	X					
Compound Helicopter						
(1) Coupled (prim. engines drive auxiliary propulsion system)	X	X				
(2) Auxiliary independent propulsion system						
(a) T/Shaft engine	X	X	X	X		
(b) T/Fan engine	X		X		X	
(c) T/Jet engine	X		X			X
Auxiliary Propulsion Helicopter						
(1) Coupled (prim. engines drive auxiliary propulsion system)		X				
(2) Auxiliary independent propulsion system						
(a) T/Shaft engine		X	X	X		
(b) T/Fan engine			X		X	
(c) T/Jet engine			X			X
oaxial Rotor Helicopter						
(1) Coupled (prim. engines drive auxiliary propulsion system)		X				
(2) Auxiliary independent propulsion system						
(a) T/Shaft engine		X	X	X		
(b) T/Fan engine			X		X	
(c) T/Jet engine			X			X

B. PROGRAM MODIFICATIONS AND IMPLEMENTATION

The computer program received from Boeing Vertol required some modification and reformating in order to run properly on the Naval Postgraduate School IBM system. These alterations did not, however, alter the program output or usability.

HESCOMP, as received from Boeing Vertol, was 17821 lines long and set-up as a sequential data set to be assemble on a 'G compiler'. The Batch processing system at the Naval Postgraduate School accepts only programs set to run on 'H compiler'. Normally, the differences between these two compilers are minor and programs that run on one will run on the other. However, this was not the case with HESCOMP.

In order to facilitate the program debugging process, HESCOMP was reformatted as a partitioned data set. What this effectively did was to break the program down into eight members of approximately 2000 lines. The program breakdown is illustrated in Table 4.2.

Each of these were compiled individually and then error codes analyzed. The member data set was then modified as required to properly compile.

Once all the members of the partitioned data set compiled properly, HESCOMP was again formated as a sequential data set and run utilizing input data for which there was a known output. This insured that the modifications made to the original program had not altered the logic, ie., gave faulty results.

The control language program to access HESCOMB on the Batch processing system and a sample input and out data set are shown in Appendix D. These are also available on the Aero disk for copying and use.

TABLE 4.2

PARTITIONED DATA SET

MEMBER NAME	LINE NUMBER	SIZE	FIRST ROUTINE
S1	1 - 1681	1681	AERO
S2	1682 - 4132	2451	CLIMB
S3	4133 - 6531	2399	XIBIV
S4	6532 - 8974	2443	POWAVL
S5	8975 - 10870	1896	PRINT 1
S6	10871 - 13042	2172	ROT POW
S7	13043 - 15383	2341	CRUS 3
S8	15384 - 17821	2448	TAXI

C. PROGRAM FLOW

The program is conceptually outlined in Figure 4.1, [Ref. 7]. The program flow is monitored by a general loop, which controls a series of peripheral programs. There are

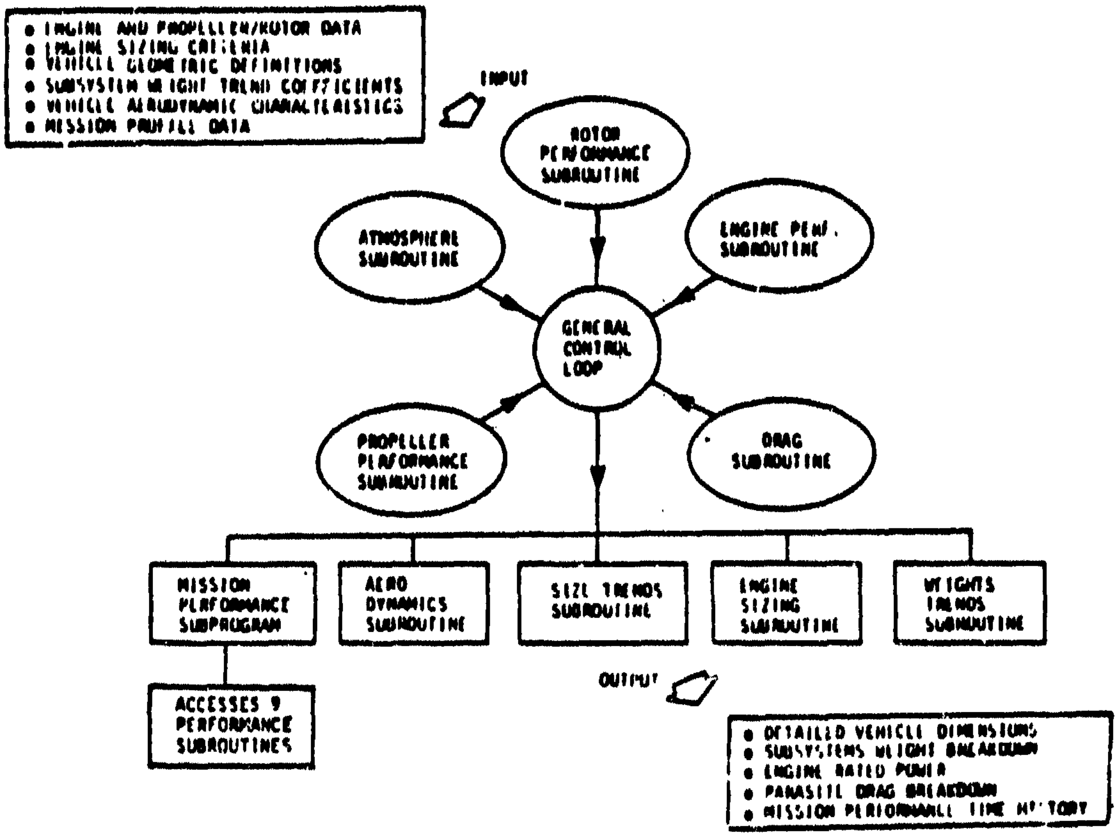


Figure 4.1. HESCOMP Program Flow

a total of 44 subroutines. Detailed program descriptions cam be found in Section 4 of the HESCOMP User's Manual.

D. PROGRAM INPUT

Program input can be loosely group into ten categories: general information, aircraft descriptive information, mission profile information, rotor tip speed schedule, incremental rotor performance, auxiliary propulsion input schedule, engine cycle information, rotor performance information, propeller performance information, and supplementary input information.

The actual amount of input data requires varies greatly with the program options selected. An example of a data set formatted to run on the IBM system is shown in Appendix E. A more detailed explantion is available in Section 5 of the HESCOMP User's Manual.

E. PROGRAM OUTPUT

An example of the program output is included in Appendix E. The printout consists of general data, input data, sizing data [program output] and mission performance data [for the size helicopter]. Detailed descriptions of these and diagnostic error statements are described in Section 6 of Reference 6.

V. CONCLUSIONS AND RECOMMENDATIONS

Three approaches to analyzing a preliminary helicopter design were explored in the course of this paper. It was found that a number of the performance equations could be greatly simplified with little degradation in the final results. A sensitivity analysis brought further insight into the inter-play of the parameters and how changes in them tended to effect the helicopter performance equations.

Carpet Plots provided the most interesting method of analysis. Development of a graphical solution matrix using this method provides a usual interpretation of what is occurring when key parameters are varied.

Two cases were explored; a light observation helicopter in the 3,000 pound weight class and a heavier utility helicopter in the 20,000 pound weight class. The Carpet Plot method provided reasonable solutions in both cases. In doing the analysis for the utility helicopter, the initial weight estimation equation had to be adjusted upward by approximately 2,000 pounds for the equations to intersect properly. This is not considered a limitation to this method of analysis, however, it does point up an area for further investigation. It may be possible to develop more accurate weighing factors for this equation when dealing with higher gross weight helicopters.

HESCOMP provides a plethora of information to the user. However, the price is the amount of inputed data required for even a simplified analysis. At a preliminary design level of analysis, the other methods explored provide a quicker first-cut look at the potential design.

APPENDIX A: NOMENCLATURE

TERM	DEFINITION	UNITS
a	Slope of Airfoil Section Lift Curve	Radians
A	Rotor Disk Area	ft^2
AR	Aspect Ratio	Dimensionless
A_{TR}	Tail Rotor Disk Area	ft^2
b	Number of Rotor Baldes	Dimensionless
B	Tip Loss Factor	Dimensionless
C	Main Rotor Cord	ft
C_{do}	Profile Drag Coefficient at Zero Lift	Dimensionless
C_{LRo}	Design Mean Blade Lift Coefficient at Sea Level	Dimensionless
C_T	Coefficient of Thrust	Dimensionless
C_p	Coefficient of Power	Dimensionless
δ	Blade Section Drag Coefficient	Dimensionless
DL	Disk Loading	lb/ft^2
FM	Figure of Merit	Dimensionless
HP	Horsepower	
L_{TR}	Tail Rotor Moment Arm	ft
ρ	Air Density	$lb\ sec^2/ft^4$
μ	Advance Ratio	Dimensionless
R	Rotor Radius	ft

TERM	DEFINITION	UNITS
P_T	Total Power	HP
P_{TM}	Main Rotor Total Power	HP
P_{TTR}	Tail Rotor Total Power	Hp
P_o	Profile Power	HP
P_i	Induced Power	HP
P_p	Parasite Power	HP
PL	Power Loading	LB/HP
R	Rotor Radius	ft
T	Thrust	HP
V_I	Induced Velocity	ft/sec
V_F	Forward Velocity	ft/sec
V	Aircraft Forward Speed	ft/sec
V_T	Rotor Tip Speed	ft/sec
W	Aircraft Gross Weight	lbs
W_c	Empty Weight	lbs
W_F	Fuel Weight	lbs
W_u	Useful Load	lbs
W_{BAR}	Empty Weight Plust Useful Load	lbs
σ	Solidity	Dimensionless

APPENDIX B: CARPET PLOT FORMULATION FOR 20,000 LB. CLASS HELICOPTER

B1 SPECIFICATIONS:

Maximum Gross Weight: 20,000 pounds
Maximum Rotor Diameter: 30 feet

B2 PRELIMINARY ENGINE SIZING:

B2.1 Utilize equation (2.14) to determine engine horsepower category.

$$W = [4.753P_TR]^{2/3}$$

$$20{,}000 = [47.53P_T\ 30]^{2/3}$$

$$P_T = 1983 \text{ HP}$$

B2.2 Use the engine selection parameters tables B.1 to determine the number and type of power plant [table taken from Reference 3].

B2.2a Type and number selected: 2 type C.

B2.2b Specifications:

Dry Weight Per Engine: 423 pounds

Shaft Horsepower at Standard Sea Level:

Military	1561 HP
Normal	1318 HP

B3 WEIGHT EQUATION FORMULATION

B3.1 To obtain the engine control and accessory weight use items 7, 9, 10, 11, 12 and 13 of the weight estimation relationships developed in Reference 3 for a utility helicopter: #7: 609 lbs; #9: 129 lbs; #10: 76 lbs; #11: 410 lbs; #12: 439 lbs; and #13: 302 lbs.

TABLE B.1

ENGINE SELECTION PARAMETERS

The following turboshat power plant data are presented for one engine.

Engines:		A	B	C	D*	E	F
Dry Weight (lbs)		158	288	423	709	580	750
SHP (ssl)	Military	420	708	1561	1800	2500	3400
	Normal	370	639	1318	1530	2200	3000
	Cruise	278	494	1989	1148	1650	2250
SFC (ssl)	Military	.650	.573	.460	.595	.615	.543
	Normal	.651	.573	.470	.606	.622	.562
	Cruise	.709	.599	.510	.661	.678	.610
Initial Costs		$93K	$100K	$580K	$360K	$640K	$700K
Operating Cost per hour/engine		$8	$16	$20	$35	$40	$60
Preventative Maint per hour/engine		$25	$50	$100	$125	$160	$220
MTBMA (hrs)		3.5	3.0	2.0	3.0	4.0	3.5
MDT (hrs)		0.7	0.6	0.5	1.3	2.0	2.6
MTBF (hrs)		185	210	205	285	280	320
MTBR (hrs)		600	750	800	800	1000	750

B3.2 Simplifications

$$\frac{W}{DL} - A = \pi R^2 \quad , \quad \frac{W}{\ell pm} = MHP = 31{,}00 \;;\quad P = \sqrt{\frac{A}{V_T}}$$

B3.3 Engine Group

$$.053(5100)^{1.07} = 272 \text{ lbs}$$

B3.4 Main Transmission

$$10.43 \frac{W^{1.295}}{(\ell pm\ V_t)^{.863} \left[\frac{W}{A}\right]^{.432}} = 10.43 \frac{W^{.863}\ A^{+.432}}{(\ell pm)^{.863} V_T^{\ .863}}$$

$$= (10.43)(3100)^{.863} P^{.863}$$

$$= 10{,}748 P^{.863}$$

B3.5 Rotor Drive Shaft

$$5.56 \frac{W^{1.05}}{(\ell pm\ V_T)^{.7} \left[\frac{W}{A}\right]^{.35}} = 5.56(3100)^{.7} P^{.7}$$

$$= 1545 P^{.7}$$

B3.6 Tail Rotor

$$32.22 \frac{W^{1.14}}{(\ell pm\ V_T)^{1.14}} = \frac{307{,}600}{V_T^{\ 1.14}}$$

B3.7 Tail Rotor Gear Box

$$3.7 \frac{W^{.75}}{(\ell pm\ V_T)^{.5} \left[\frac{W}{A}\right]^{.25}} = (3.7)(3100)^{.5} P^{.5}$$

$$= 206P^{.5}$$

B3.8 Tail Rotor Drive Shaft

$$.124 \frac{W^{1.355}}{(\ell pm)^{.57} \frac{W^{.785}}{A^{.785}}} = (.124)(3100)^{.57} P^{.57} \sqrt{A}$$

$$= 12.12P^{.57} \sqrt{A}$$

B3.9 Landing Gear

$$= .191W^{.916} + .0294W^{.99}$$

B3.10 Rotor Blades Articulated

$$19.77 \frac{W^{1.206}}{V_T} \frac{\sigma^{.33}}{DL^{.205}}$$

$$= 19.77 \frac{W}{V_T} A^{.205} \sigma^{.33}$$

B3.11 Rotor Hub Articulated

$$.00975 \frac{W^{1.21}}{DL^{.21}} = .00975WA^{.21}$$

B3.12 Fuel System $.0615\ W_F$

Calculation of fuel weight three hours at cruise SHP

1513 lbs + 10%

1664 lbs

B3.13 Total Equation

$$WB = 12{,}987,^{*} + 107948P^{.863} + 1545P^{.7}$$

$$+ \frac{307600}{V_T^{1.14}} + 206P^{.5} + 12.12P^{.57}\sqrt{A}$$

$$+ .191W^{.916} + .0294W^{.99}$$

$$+ 19.77\,\frac{W}{V_T}\,A^{.205}S^{.33} + .00975WA^{.21}$$

B4 HOVER EQUATION

Following the formulation in Section of Chapter 3, the weight equation based on the design mean lift coefficient and power required is:

$$W = \frac{K_2\left[1 - 411.51\,\frac{DL^{3/4}}{V_T^{3/2}}\left(1 + K_3\,\frac{V_T}{\sqrt{DL}}\right)^{1/2}\right] - K_4}{V_T + K_5\sqrt{DL}}$$

---

[*] This number was increased from 8987 to 12987 to bring the curves together. This reflects a 4000 lb useful load.

where:

$$K_1 = \frac{.9583}{C_{LRo}} (1 + 1.8078\ C_{LRo}{}^2)$$

$$K_2 = P_{T6000/950}\ \frac{(10^5)}{K_1}$$

$$K_3 = \frac{0.00025929}{C_{LR_o}} \quad (1 + 1.8078 C_{LRo}{}^2)$$

$$K_4 = \frac{553480.0}{K_1}$$

$$K_5 = \frac{3695.7}{K_1}$$

B.5 GRAPHICAL RESULTS

Figure B.1 is an example of equation (3.13) plotted against equation (B.4) for a specific design mean lift coefficient.

Figure B.2 illustrates the family of curves obtained when the design mean lift coefficient is varied from 0.3 to 0.7 .

In Figure B.3 the solution matrix depicted in Figure B.2 is narrowed by the constraints placed on the gross weight, rotor diameter and aspect ratio.

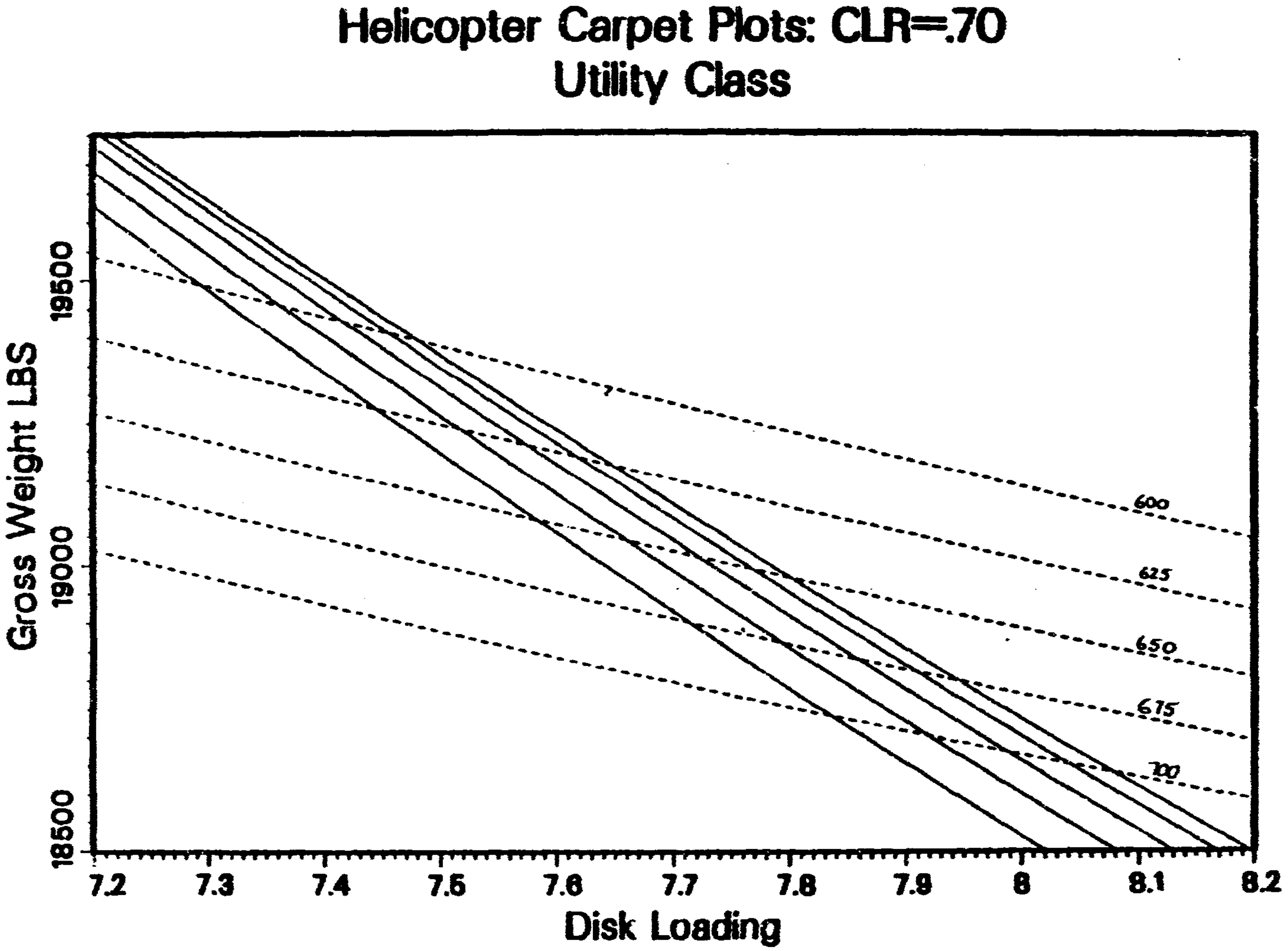


Figure B1. Helicopter Carpet Plots: C_{LR} = .70
Utility Class

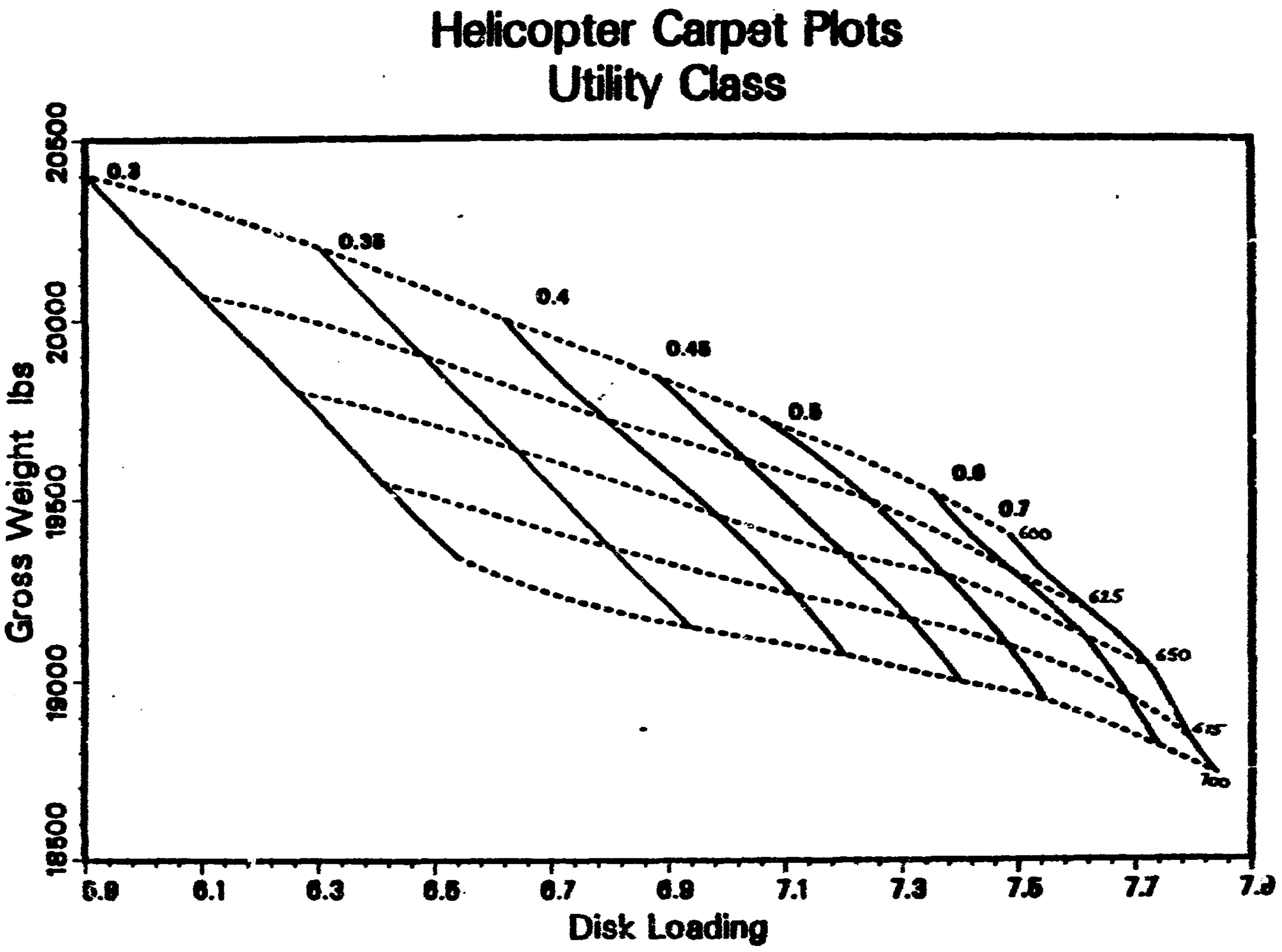


Figure B2. Helicopter Carpet Plots
Utility Class

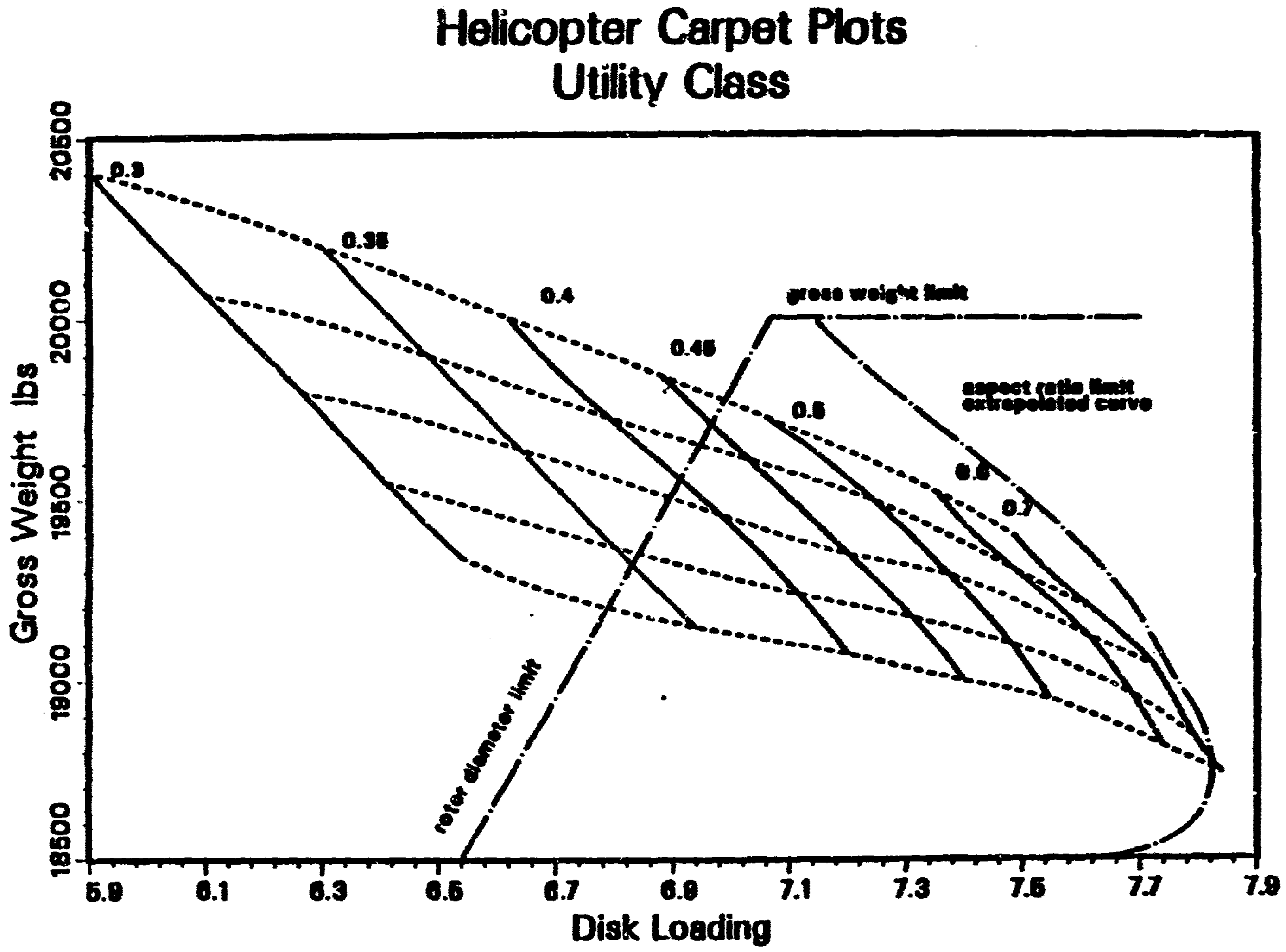
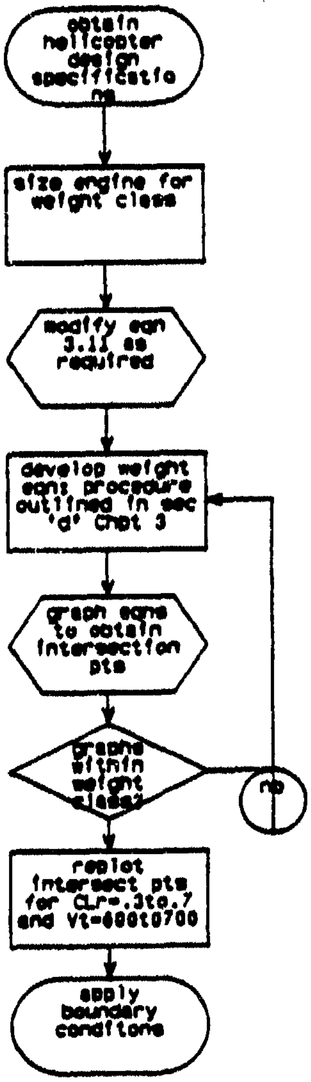


Figure B3. Helicopter Carpet Plots
Utility Class

APPENDIX C. CARPET PLOT METHODOLOGY FLOW CHART AND EXAMPLE PROGRAMS:

This section contains a flow chart to help organize a carpet analysis and example IBM computer programs to produce the data sets and disspla graphs.


obtain helicopter design specifications
size engine for weight class
modify eqn 3.11 as required
develop weight eqns procedure outlined in sec 'd' Chpt 3
graph eqns to obtain intersection pts
graphs within weight class?
no
replot intersect pts for CLr=.3to.7 and Vt=600to700
apply boundary conditons

```
C************************************************************************
C************************************************************************
C**********        GRAPHICAL HELICOPTER DESIGN PROGRAM         **********
C*********               CARPET PLOT NUMBER 1                   *********
C*********                  BY AL HANSEN                        *********
C*********                                                      *********
C*********     THIS PROGRAM IS DESIGNED TO PROVIDE A WEIGHT VS.  *********
C*********      DISK LOADING GRAPH AT SEVERAL DIFFERENT ROTOR   *********
C*********       TIP VELOCITIES FOR A SPECIFIED DESIGN MEAN     *********
C*********                LIFT COEFFICENT.                      *********
C**********              OBSERVATION CLASS                     **********
C************************************************************************
C************************************************************************
C****                                                               *****
C**                         NOMENCLATURE                              ***
C*                                                                     **
C*      VARIABLES:                                                     **
C*                                                                     **
C*      CLR       DESIGN MEAN LIFT COEFFICENT                          **
C*      VT        TIP VELOCITY                                         **
C*      DL        DISK LOADING
C*      W         WEIGHT AS CALCULATED FROM POWER EQUATION             **
C*      WB        USEFUL LOAD PLUS EMPTY WEIGHT                        **
C*      PA        POWER AVAILABLE IN HORSEPOWER                        **
C*                                                                     **
C****                                                               *****
C************************************************************************
      REAL CLR,DL(150),W1(150),W2(150),W3(150),W4(150),W5(150),
     1WB1(150),WB2(150),WB3(150),WB4(150),WB5(150)
C
      INTEGER I
C
C
C---- DEFINE FILES ------------------------------------------------------
C
      CALL FRTCMS ('FILEDEF ','3        ','DISK    ','CRPT35',
     1             'DATA    ','A        ')
C
C
      CALL FRTCMS ('FILEDEF ','4        ','DISK    ','CRPT45',
     1             'DATA    ','A        ')
C---- READ DATA FROM FILE: CRPTX DATA A --------------------------------
C
      DO 10 I=1,99
C     CRPT1 DATA A
      READ (3,70) DL(I),W1(I),WB1(I),W2(I),WB2(I)
C     CRPT2 DATA A
      READ (4,71) W3(I),WB3(I),W4(I),WB4(I),W5(I),WB5(I)
10    CONTINUE
C
C---- CALL DISSPLA ROUTINES FOR PLOT -----------------------------------
C
      CALL TEK618
      CALL MEDEUP
      CALL RESET (3HALL)
      CALL HWSCAL ('SCREEN')
      CALL PAGE (12.0, 9.5)
      CALL GRACE (0.0)
      CALL PHYSOR (1.0,1.2)
      CALL AREA2D (10.0,6.5)
      CALL FRAME
      CALL SWISSL
      CALL BASALF ('L/CSTD')
      CALL MIXALF ('STAND')
      CALL INTAXS
      CALL YTICKS (5)
      CALL XTICKS (5)
      CALL SHDCHR (.90,1,.015,1)
      CALL HEIGHT (.16)
      CALL XNAME ('(D)ISK (L)OADING$',100)
      CALL YNAME ('(G)ROSS (W)EIGHT ((LBS))$',100)
      CALL HEIGHT (.290)
      CALL HEADIN ('(H)ELICOPTER (C)ARPET (P)LOTS: (CLR=0.5)$',
     1             100,1.0,1)
C     CALL MESSAG ('(H)ELICOPTER (C)ARPET (P)LOTS: (CLR=0.5)$',
C    1             100,3.25,7.55)
```

```
      CALL HEIGHT (.20)
      CALL GRAF (2.3,.1,2.9,2250.,50.,2550.,
      IYGRID=5
      CALL THKCRV (.018)
      CALL LEGLIN
      CALL CURVE (DL,W1,95,0)
      CALL CURVE (DL,W2,95,0)
      CALL CURVE (DL,W3,95,0)
      CALL CURVE (DL,W4,95,0)
      CALL CURVE (DL,W5,95,0)
      CALL DASH
      CALL CURVE (DL,WE1,95,0)
      CALL CURVE (DL,WE2,95,0)
      CALL CURVE (DL,WE3,95,0)
      CALL CURVE (DL,WE4,95,0)
      CALL CURVE (DL,WE5,95,0)
      CALL THKCRV (.030)
C     CALL BLREC (4.2,4.65,1.6,1.35,1)
C     CALL GRID (1,IYGRID)
C     CALL BLOFF (1)
      MAXLIN=LINEST(IPAK1,300,20)
      CALL HEIGHT (.12)
      CALL LINESP (2.0)
      CALL LINES ('(W)EIGHTS',IPAK1,1)
C     CALL LINES ('(I)NDUCED$',IPAK1,2)
C     CALL LINES ('(F)ECFILES',IPAK1,3)
C     CALL LINES ('(P)ARASITES',IPAK1,4)
C     CALL MYLEGN ('(P)OWER (C)URVES',16)
C     CALL LEGEND (IPAK1,4,4.43,4.8)
      CALL DONEPL
      STOP
C     FORMAT STATEMENTS
 70   FORMAT (5(2X,F10.3))
 71   FORMAT (6(2X,F10.3))
      END
```

```
C*******************************************************************
C*******************************************************************
C***********        GRAPHICAL HELICOPTER DESIGN PROGRAM     **********
C*********               FAMILY OF SOLUTIONS                *********
C*********               CARPET PLOT NUMBER 2               *********
C*********                  BY AL HANSEN                    *********
C*********                                                  *********
C*********     THIS PROGRAM IS DESIGNED TO ILLUSTRATE THE FAMILY *****
C*********       OF SOLUTIONS FOR HOVER AND USEFUL LOAD     *********
C*********      REQUIREMENTS OF A TEETERING ROTOR SYSTEM    *********
C*********         WITHOUT ANY BOUNDARY CONDITIONS          ********
C*********               OBSERVATION CLASS                  *********
C***********                                               **********
C*******************************************************************
C*******************************************************************
C****                                                          *****
C**                          NOMENCLATURE                        ***
C*                                                                **
C*      VARIABLES:                                                **
C*                                                                **
C*      CLB      DESIGN MEAN LIFT COEFFICENT                      **
C*      VT       TIP VELOCITY                                     **
C*      DL       DISK LOADING
C*      W        WEIGHT AS CALCULATED FROM POWER EQUATION         **
C*      WB       USEFUL LOAD PLUS EMPTY WEIGHT                    **
C*      PA       POWER AVAILABLE IN HORSEPOWER                    **
C*                                                                **
C****                                                          *****
C*      DL3 EQUALS THE DISK LOADING FOR CLR=.3
C*      DL4 EQUALS THE DISK LOADING FOR CLR=.4
C*      DL5 EQUALS THE DISK LOADING FOR CLR=.5
C*      DL6 EQUALS THE DISK LOADING FOR CLR=.6
C*      DL7 EQUALS THE DISK LOADING FOR CLR=.7
C*      W3 EQUALS THE WEIGHT FOR CLR=.3
C*      W4 EQUALS THE WEIGHT FOR CLR=.4
C*      W5 EQUALS THE WEIGHT FOR CLR=.5
C*      W6 EQUALS THE WEIGHT FOR CLR=.6
C*      W7 EQUALS THE WEIGHT FOR CLR=.7
C*      WVT1 EQUALS WEIGHTS AT VT=600
C*      WVT2 EQUALS WEIGHTS AT VT=625
C*      WVT3 EQUALS WEIGHTS AT VT=650
C*      WVT4 EQUALS WEIGHTS AT VT=675
C*      WVT5 EQUALS WEIGHTS AT VT=700
C*      DVT1 EQUALS THE CORRESPONDING DISK LOADING AT VT=600
C*      DVT2 EQUALS THE CORRESPONDING DISK LOADING AT VT=625
C*      DVT3 EQUALS THE CORRESPONDING DISK LOADING AT VT=650
C*      DVT4 EQUALS THE CORRESPONDING DISK LOADING AT VT=675
C*      DVT5 EQUALS THE CORRESPONDING DISK LOADING AT VT=700
C*******************************************************************
        REAL*4 DL3(5),DL4(5),DL5(5),DL6(5),DL7(5),W3(5),W4(5),
     *W5(5),W6(5),W7(5),WVT1(5),WVT2(5),WVT3(5),WVT4(5),
     *WVT5(5),DVT1(5),DVT2(5),DVT3(5),DVT4(5),DVT5(5)
C
C---- DEFINE DATA ----------------------------------------------------
        DATA DL3/2.06,2.07,2.07,2.07,2.05/
        DATA W3/2505.,2478.2,2455.46,2433.85,2418.25/
        DATA DL4/2.42,2.44,2.46,2.47,2.47/
        DATA W4/2467.17,2442.95,2419.62,2399.72,2382.99/
        DATA DL5/2.63,2.65,2.67,2.69,2.69/
        DATA W5/2440.72,2419.51,2399.00,2379.13,2364.65/
        DATA DL6/2.74,2.77,2.79,2.81,2.81/
        DATA W6/2424.68,2402.48,2383.58,2365.10,2352./
        DATA DL7/2.80,2.83,2.85,2.86,2.87/
        DATA W7/2411.92,2390.72,2372.50,2357.35,2342.25/
        DATA WVT1/2505.,2467.17,2440.72,2424.67,2411.92/
        DATA WVT2/2478.2,2442.95,2419.51,2402.53,2390.72/
        DATA WVT3/2455.46,2419.62,2395.,2383.58,2372.5/
        DATA WVT4/2433.85,2399.72,2379.13,2365.1,2357.35/
        DATA WVT5/2418.25,2382.99,2364.65,2352.,2342.25/
        DATA DVT1/2.06,2.42,2.63,2.74,2.80/
        DATA DVT2/2.07,2.44,2.65,2.77,2.83/
        DATA DVT3/2.07,2.46,2.67,2.79,2.85/
        DATA DVT4/2.07,2.47,2.69,2.81,2.86/
        DATA DVT5/2.05,2.47,2.69,2.81,2.87/
C
C
```

```
C---- CALL DISSPLA ROUTINES FOR PLOT ----------------------------------
C
      CALL TEK618
      CALL HRDHUP
      CALL RESET (3HALL)
      CALL HWSCAL ('SCREEN')
      CALL PAGE (12.0, 9.5)
      CALL GRACE (0.0)
      CALL PHYSOR (1.0,1.2)
      CALL AREA2D (10.0,6.5)
      CALL FRAME
      CALL SWISSL
      CALL BASALF ('L/CSTD')
      CALL MIXALF ('STAND')
      CALL INTAXS
      CALL YTICKS (5)
      CALL XTICKS (5)
      CALL SHDCHR (.90,1,.015,1)
      CALL HEIGHT (.16)
      CALL XNAME ('(D)ISK (L)OADING$',100)
      CALL YNAME ('(G)ROSS (W)EIGHT ((LBS))$',100)
      CALL HEIGHT (.290)
      CALL HEADIN ('(H)ELICOPTER (C)ARPET (P)LOTS$',
     1             100,1.0,1)
      CALL HEIGHT (.20)
      CALL GRAF (2.0,.1,3.0,2300.,50.,2550.)
      IYGRID=5
      CALL THKCRV (.018)
      CALL PARA3
      CALL LEGLIN
      CALL CURVE (DL3,W3,5,0)
      CALL CURVE (DL4,W4,5,0)
      CALL CURVE (DL5,W5,5,0)
      CALL CURVE (DL6,W6,5,0)
      CALL CURVE (DL7,W7,5,0)
      CALL DASH
      CALL CURVE (DVT1,WVT1,5,0)
      CALL CURVE (DVT2,WVT2,5,0)
      CALL CURVE (DVT3,WVT3,5,0)
      CALL CURVE (DVT4,WVT4,5,0)
      CALL CURVE (DVT5,WVT5,5,0)
      CALL THKCRV (.030)
C     CALL BLREC (4.2,4.65,1.6,1.35,1)
C     CALL GRID (1,IYGRID)
C     CALL BLOFF (1)
C     MAXLIN=LINEST(IPAK1,300,20)
C     CALL HEIGHT (.12)
C     CALL LINESP (2.0)
C     CALL LINES ('(W)EIGHTS$',IPAK1,1)
C     CALL LINES ('(I)NDUCED$',IPAK1,2)
C     CALL LINES ('(P)ROFILES$',IPAK1,3)
C     CALL LINES ('(P)ARASITES$',IPAK1,4)
C     CALL MYLEGN ('(P)OWER (C)URVES',16)
C     CALL LEGEND (IPAK1,4,4.43,4.8)
      CALL DONEPL
      STOP
C     FORMAT STATEMENTS
C70   FORMAT (5(2X,F10.3))
C71   FORMAT (6(2X,F10.3))
      END
```

```
C*****************************************************************
C*****************************************************************
C**********       GRAPHICAL HELICOPTER DESIGN PROGRAM     **********
C*********            ASPECT RATIO BOUNDARY                ********
C********        LOCI OF HOVER AND USEFUL-LOAD SOLUTIONS   ********
C********               CARPET PLOT NUMBER 3               ********
C********                  BY AL HANSEN                    ********
C********                                                  ********
C********    THIS PROGRAM IS DESIGNED TO GRAPHICALLY DETERMINE ********
C********       THE ASPECT RATIO BOUNDARY REQUIREMENTS FOR ********
C********      A ROTOR SYSTEM USING PREVIOUSLY GENERATED DATA ********
C**********                                              **********
C*****************************************************************
C*****************************************************************
C****                                                        *****
C**                          NOMENCLATURE                      ***
C*                                                              **
C*     VARIABLES:                                               **
C*                                                              **
C*     CLR      DESIGN MEAN LIFT COEFFICENT                     **
C*     VT       TIP VELOCITY                                    **
C*     DL       DISK LOADING
C*     AR       ASPECT RATIO. HISTORICALLLY ASSUMED TO BE LESS THAN 21  **
C*                                                              **
C****                                                        *****
C*     DVT1 EQUALS THE CORRESPONDING DISK LOADING AT VT=600
C*     DVT2 EQUALS THE CORRESPONDING DISK LOADING AT VT=625
C*     DVT3 EQUALS THE CORRESPONDING DISK LOADING AT VT=650
C*     DVT4 EQUALS THE CORRESPONDING DISK LOADING AT VT=675
C*     DVT5 EQUALS THE CORRESPONDING DISK LOADING AT VT=700
C*     C600 EQUALS THE LIFT COEF AT VT=600
C*     C625 EQUALS THE LIFT COEF AT VT=625
C*     C650 EQUALS THE LIFT COEF AT VT=650
C*     C675 EQUALS THE LIFT COEF AT VT=675
C*     C700 EQUALS THE LIFT COEF AT VT=700
C*****************************************************************
       REAL*4 CLR(5),DL(10),C600(10),C625(10),C650(10),
     *C675(10),C700(10),
     *DVT1(5),DVT2(5),DVT3(5),DVT4(5),DVT5(5)
C
C---- DEFINE DATA ------------------------------------------------
       DATA DVT1/2.06,2.42,2.63,2.74,2.80/
       DATA DVT2/2.07,2.44,2.65,2.77,2.83/
       DATA DVT3/2.07,2.46,2.67,2.79,2.85/
       DATA DVT4/2.07,2.47,2.69,2.81,2.86/
       DATA DVT5/2.05,2.48,2.70,2.82,2.87/
       DATA CLR/.3,.4,.5,.6,.7/
       DATA DL/2.,2.1,2.2,2.3,2.4,2.5,2.6,2.7,2.8,2.9/
       DATA C600/.47,.49,.51,.53,.55,.57,.59,.61,.63,.65/
       DATA C625/.43,.45,.47,.49,.51,.53,.55,.57,.59,.61/
       DATA C650/.39,.41,.43,.45,.47,.49,.51,.53,.55,.57/
       DATA C675/.35,.37,.39,.41,.43,.45,.47,.49,.51,.53/
       DATA C700/.31,.33,.35,.37,.39,.41,.43,.45,.47,.49/
C
C
C---- CALL DISSPLA ROUTINES FOR PLOT -----------------------------
C
       CALL TEK618
       CALL MEDBUF
       CALL RESET (3HALL)
       CALL HWSCAL ('SCREEN')
       CALL PAGE (12.0, 9.5)
       CALL GRACE (0.0)
       CALL PHYSOR (1.0,1.2)
       CALL AREA2D (10.0,6.5)
       CALL FRAME
       CALL SWISSL
       CALL BASALF ('L/CSTD')
       CALL MIXALF ('STAND')
       CALL INTAXS
       CALL SHDCHR (.90,1,.015,1)
       CALL HEIGHT (.16)
       CALL XNAME ('(D)ISK (L)OADING$',100)
       CALL YNAME ('(C)OEFFICENT OF (L)IFT$',100)
       CALL HEIGHT (.290)
       CALL MESSAG ('(H)ELICOPTER (C)ARPET (P)LOTS$',
```

```
1                 100.3.25,7.55)
      CALL HEIGHT (.20)
      CALL GRAF (2.0,.1,2.9,.2,.05,.8)
      IYGRID=5
      CALL THKCRV (.018)
      CALL PARA3
      CALL LEGLIN
      CALL CURVE (DI,C600,10,0)
      CALL CURVE (DI,C625,10,0)
      CALL CURVE (DI,C650,10,0)
      CALL CURVE (DI,C675,10,0)
      CALL CURVE (DI,C700,10,0)
      CALL DASH
      CALL CURVE (DVT1,CLR,5,0)
      CALL CURVE (DVT2,CLR,5,0)
      CALL CURVE (DVT3,CLR,5,0)
      CALL CURVE (DVT4,CLR,5,0)
      CALL CURVE (DVT5,CLR,5,0)
      CALL THKCRV (.030)
      CALL DONEPL
      STOP
      END
```

```
C**********************************************************************
C**********************************************************************
C**********      GRAPHICAL HELICOPTER DESIGN PROGRAM         **********
C********              FAMILY OF SOLUTIONS                    ********
C********              CARPET PLOT NUMBER 4                   ********
C********                  BY AL HANSEN                       ********
C********                                                     ********
C********    THIS PROGRAM IS DESIGNED TO ILLUSTRATE THE FAMILY ********
C********      OF SOLUTIONS FOR HOVER AND USEFUL LOAD         ********
C********      REQUIREMENTS OF A TEETERING ROTOR SYSTEM       ********
C********      WITH ROTOR DIAMETER AND MAX GROSS BOUNDRIES.   ********
C********            OBSERVATION CLASS HELICOPTER             ********
C**********                                                  **********
C**********************************************************************
C**********************************************************************
C****                                                             *****
C**                          NOMENCLATURE                           ***
C*                                                                   **
C*      VARIABLES:                                                   **
C*                                                                   **
C*      CLR       DESIGN MEAN LIFT COEFFICENT                        **
C*      VT        TIP VELOCITY                                       **
C*      DL        DISK LOADING
C*      W         WEIGHT AS CALCULATED FROM POWER EQUATION           **
C*      WB        USEFUL LOAD PLUS EMPTY WEIGHT                      **
C*      PA        POWER AVAILABLE IN HORSEPOWER                      **
C*                                                                   **
C****                                                             *****
C*      DL3 EQUALS THE DISK LOADING FOR CLR=.3
C*      DL4 EQUALS THE DISK LOADING FOR CLR=.4
C*      DL5 EQUALS THE DISK LOADING FOR CLR=.5
C*      DL6 EQUALS THE DISK LOADING FOR CLR=.6
C*      DL7 EQUALS THE DISK LOADING FOR CLR=.7
C*      W3 EQUALS THE WEIGHT FOR CLR=.3
C*      W4 EQUALS THE WEIGHT FOR CLR=.4
C*      W5 EQUALS THE WEIGHT FOR CLR=.5
C*      W6 EQUALS THE WEIGHT FOR CLR=.6
C*      W7 EQUALS THE WEIGHT FOR CLR=.7
C*      WVT1 EQUALS WEIGHTS AT VT=600
C*      WVT2 EQUALS WEIGHTS AT VT=625
C*      WVT3 EQUALS WEIGHTS AT VT=650
C*      WVT4 EQUALS WEIGHTS AT VT=675
C*      WVT5 EQUALS WEIGHTS AT VT=700
C*      DVT1 EQUALS THE CORRESPONDING DISK LOADING AT VT=600
C*      DVT2 EQUALS THE CORRESPONDING DISK LOADING AT VT=625
C*      DVT3 EQUALS THE CORRESPONDING DISK LOADING AT VT=650
C*      DVT4 EQUALS THE CORRESPONDING DISK LOADING AT VT=675
C*      DVT5 EQUALS THE CORRESPONDING DISK LOADING AT VT=700
C*      RDB ROTOR DISK BOUNDARY
C*      WBG MAX GROSS WEIGHT BOUNDARY
C**********************************************************************
        REAL*4  DL3(5),DL4(5),DL5(5),DL6(5),DL7(5),W3(5),W4(5),RDB(2),
     *W5(5),W6(5),W7(5),WVT1(5),WVT2(5),WVT3(5),WVT4(5),WMG(2),
     *WVT5(5),DVT1(5),DVT2(5),DVT3(5),DVT4(5),DVT5(5),D1(2),D2(2)
C
C---- DEFINE DATA -----------------------------------------------------
        DATA DL3/2.06,2.07,2.07,2.07,2.05/
        DATA W3/2505.,2478.2,2455.46,2433.85,2418.25/
        DATA DL4/2.42,2.44,2.46,2.47,2.47/
        DATA W4/2467.17,2442.95,2419.62,2399.72,2382.99/
        DATA DL5/2.63,2.65,2.67,2.69,2.69/
        DATA W5/2440.72,2419.51,2399.00,2379.13,2364.65/
        DATA DL6/2.74,2.77,2.79,2.81,2.81/
        DATA W6/2424.67,2402.48,2383.58,2365.10,2352./
        DATA DL7/2.80,2.83,2.85,2.86,2.87/
        DATA W7/2411.92,2390.72,2372.50,2357.35,2342.25/
        DATA WVT1/2505.,2467.17,2440.72,2424.67,2411.92/
        DATA WVT2/2478.2,2442.95,2419.51,2402.53,2390.72/
        DATA WVT3/2455.46,2419.62,2399.,2383.58,2372.5/
        DATA WVT4/2433.85,2399.72,2379.13,2365.1,2357.35/
        DATA WVT5/2418.25,2382.99,2364.65,2352.,2342.25/
        DATA DVT1/2.06,2.42,2.63,2.74,2.80/
        DATA DVT2/2.07,2.44,2.65,2.77,2.83/
        DATA DVT3/2.07,2.46,2.67,2.79,2.85/
        DATA DVT4/2.07,2.47,2.69,2.81,2.86/
        DATA DVT5/2.05,2.47,2.69,2.81,2.87/
```

```
      DATA D1/2.52,2.9/
      DATA WMG/2450.,2450./
      DATA D2/2.36,2.52/
      DATA RDB/2300.,2450./
C
C
C---- CALL DISSPLA ROUTINES FOR PLOT -----------------------------------
C
      CALL TEK618
      CALL MEDBUF
      CALL RESET (3HALL)
      CALL HWSCAL ('SCREEN')
      CALL PAGE (12.0, 9.5)
      CALL GRACE (0.0)
      CALL PHYSOR (1.0,1.2)
      CALL AREA2D (10.,6.5)
      CALL FRAME
      CALL SWISSL
      CALL BASALF ('L/CSTD')
      CALL MIXALF ('STAND')
      CALL INTAXS
      CALL YTICKS (5)
      CALL XTICKS (5)
      CALL SHDCHR (.90,1,.015,1)
      CALL HEIGHT (.16)
      CALL XNAME ('(D)ISK (L)OADING$',100)
      CALL YNAME ('(G)ROSS (W)EIGHT ((LBS))$',100)
      CALL HEIGHT (.290)
      CALL HEADIN ('(H)ELICOPTER (C)ARPET (P)LOTS$',
     1            100,1.0,1)
      CALL HEIGHT (.20)
      CALL GRAF (2.0,.1,3.0,2300.,50.,2550.)
      IYGRID=5
      CALL THKCRV (.018)
      CALL PARA3
      CALL LEGLIN
      CALL CURVE (DL3,W3,5,0)
      CALL CURVE (DL4,W4,5,0)
      CALL CURVE (DL5,W5,5,0)
      CALL CURVE (DL6,W6,5,0)
      CALL CURVE (DL7,W7,5,0)
      CALL DASH
      CALL CURVE (DVT1,WVT1,5,0)
      CALL CURVE (DVT2,WVT2,5,0)
      CALL CURVE (DVT3,WVT3,5,0)
      CALL CURVE (DVT4,WVT4,5,0)
      CALL CURVE (DVT5,WVT5,5,0)
      CALL THKCRV (.030)
      CALL CHNDOT
      CALL CURVE (D1,WMG,2,0)
      CALL CURVE (D2,RDB,2,0)
      CALL DONEPL
      STOP
      END
```

```
C***********************************************************************
C***********************************************************************
C***********       GRAPHICAL HELICOPTER DESIGN PROGRAM        ***********
C*********              FAMILY OF SOLUTIONS                    *********
C*********              CARPET PLOT NUMBER 5                   *********
C*********                 BY AL HANSEN                        *********
C*********                                                     *********
C*********     THIS PROGRAM IS DESIGNED TO ILLUSTRATE THE FAMILY *********
C*********       OF SOLUTIONS FOR HOVER AND USEFUL LOAD        *********
C*********       REQUIREMENTS OF A TEETERING ROTOR SYSTEM      *********
C*********       WITH ROTOR DIAMETER, MAX GROSS WEIGHT AND     *********
C*********              ASPECT RATIO BOUNDARIES.               *********
C*********             OBSERVATION CLASS HELICOPTER            *********
C***********                                                 ***********
C***********************************************************************
C***********************************************************************
C*****                                                             *****
C**                            NOMENCLATURE                          ***
C*                                                                    **
C*    VARIABLES:                                                      **
C*                                                                    **
C*    CLR      DESIGN MEAN LIFT COEFFICENT                            **
C*    VT       TIP VELOCITY                                           **
C*    DL       DISK LOADING
C*    W        WEIGHT AS CALCULATED FROM POWER EQUATION               **
C*    WE       USEFUL LOAD PLUS EMPTY WEIGHT                          **
C*    PA       POWER AVAILABLE IN HORSEPOWER                          **
C*                                                                    **
C****                                                              *****
C*    DL3 EQUALS THE DISK LOADING FOR CLR=.3
C*    DL4 EQUALS THE DISK LOADING FOR CLR=.4
C*    DL5 EQUALS THE DISK LOADING FOR CLR=.5
C*    DL6 EQUALS THE DISK LOADING FOR CLR=.6
C*    DL7 EQUALS THE DISK LOADING FOR CLR=.7
C*    W3 EQUALS THE WEIGHT FOR CLR=.3
C*    W4 EQUALS THE WEIGHT FOR CLR=.4
C*    W5 EQUALS THE WEIGHT FOR CLR=.5
C*    W6 EQUALS THE WEIGHT FOR CLR=.6
C*    W7 EQUALS THE WEIGHT FOR CLR=.7
C*    WVT1 EQUALS WEIGHTS AT VT=600
C*    WVT2 EQUALS WEIGHTS AT VT=625
C*    WVT3 EQUALS WEIGHTS AT VT=650
C*    WVT4 EQUALS WEIGHTS AT VT=675
C*    WVT5 EQUALS WEIGHTS AT VT=700
C*    DVT1 EQUALS THE CORRESPONDING DISK LOADING AT VT=600
C*    DVT2 EQUALS THE CORRESPONDING DISK LOADING AT VT=625
C*    DVT3 EQUALS THE CORRESPONDING DISK LOADING AT VT=650
C*    DVT4 EQUALS THE CORRESPONDING DISK LOADING AT VT=675
C*    DVT5 EQUALS THE CORRESPONDING DISK LOADING AT VT=700
C*    RDB ROTOR DISK BOUNDARY
C*    WMG MAX GROSS WEIGHT BOUNDARY
C*    AR WEIGHTS FOR THE ASPECT RATIO BOUNDARY
C*    D3 DISK LOADING CORRESPONDING TO THE ASPECT RATIO WEIGHTS
C***********************************************************************
      REAL*4 DL3(5),DL4(5),DL5(5),DL6(5),DL7(5),W3(5),W4(5),RDB(2),
     *W5(5),W6(5),W7(5),WVT1(5),WVT2(5),WVT3(5),WVT4(5),WMG(2),
     *WVT5(5),DVT1(5),DVT2(5),DVT3(5),DVT4(5),DVT5(5),D1(2),D2(2),
     *D3(5),AR(5)
C
C---- DEFINE DATA -------------------------------------------------------
      DATA DL3/2.06,2.07,2.07,2.07,2.05/
      DATA W3/2505.,2476.2,2455.46,2433.85,2418.25/
      DATA DL4/2.42,2.44,2.46,2.47,2.47/
      DATA W4/2467.17,2442.95,2419.62,2399.72,2382.99/
      DATA DL5/2.63,2.65,2.67,2.69,2.69/
      DATA W5/2440.72,2419.51,2399.00,2379.13,2364.65/
      DATA DL6/2.74,2.77,2.79,2.81,2.81/
      DATA W6/2424.66,2402.48,2383.58,2365.10,2352./
      DATA DL7/2.80,2.83,2.85,2.86,2.87/
      DATA W7/2411.52,2390.72,2372.50,2357.35,2342.25/
      DATA WVT1/2505.,2467.17,2440.72,2424.67,2411.92/
      DATA WVT2/2478.2,2442.95,2419.51,2402.53,2390.72/
      DATA WVT3/2455.46,2419.62,2399.,2383.58,2372.5/
      DATA WVT4/2433.85,2399.72,2379.13,2365.1,2357.35/
      DATA WVT5/2418.25,2382.99,2364.65,2352.,2342.25/
      DATA DVT1/2.06,2.42,2.63,2.74,2.80/
```

```
      DATA DVT2/2.07,2.44,2.65,2.77,2.83/
      DATA DVT3/2.07,2.46,2.67,2.79,2.85/
      DATA DVT4/2.07,2.47,2.69,2.81,2.88/
      DATA DVT5/2.05,2.47,2.69,2.81,2.87/
      DATA D1/2.52,2.9/
      DATA WMG/2450.,2450./
      DATA D2/2.36,2.82/
      DATA RDB/2300.,2450./
      DATA AR/2374.461,2390.,2405.,2420.,2450./
      DATA D3/2.44,2.65,2.715,2.745,2.78/
C
C
C---- CALL DISSPLA ROUTINES FOR PLOT ----------------------------------
C
      CALL TEK618
      CALL HZCEDF
      CALL RESET (3HALL)
      CALL HWSCAL ('SCREEN')
      CALL PAGE (12.0, 9.5)
      CALL GRACE (0.0)
      CALL PHYSOR (1.0,1.2)
      CALL AREA2D (10.,6.5)
      CALL FRAME
      CALL SWISSL
      CALL BASALF ('L/CSTD')
      CALL MIXALF ('STAND')
      CALL INTAXS
      CALL YTICKS (5)
      CALL XTICKS (5)
      CALL SHDCHR (.90,1,.015,1)
      CALL HEIGHT (.16)
      CALL XNAME ('(D)ISK (L)OADING$',100)
      CALL YNAME ('(G)ROSS (W)EIGHT ((LBS))$',100)
      CALL HEIGHT (.290)
      CALL HEADIN ('(H)ELICOPTER (C)ARPET (P)ILOTS$',
     1             100,1.0,1)
      CALL HEIGHT (.20)
      CALL GRAF (2.0,.1,3.0,2300.,50.,2550.)
      IYGRID=5
      CALL THKCRV (.018)
      CALL PARA3
      CALL LEGLIN
      CALL CURVE (DI3,W3,5,0)
      CALL CURVE (DI4,W4,5,0)
      CALL CURVE (DI5,W5,5,0)
      CALL CURVE (DI6,W6,5,0)
      CALL CURVE (DI7,W7,5,0)
      CALL DASH
      CALL CURVE (DVT1,WVT1,5,0)
      CALL CURVE (DVT2,WVT2,5,0)
      CALL CURVE (DVT3,WVT3,5,0)
      CALL CURVE (DVT4,WVT4,5,0)
      CALL CURVE (DVT5,WVT5,5,0)
      CALL THKCRV (.030)
      CALL CHNDOT
      CALL CURVE (D1,WMG,2,0)
      CALL CURVE (D2,RDB,2,0)
      CALL CURVE (D3,AR,5,0)
      CALL DONEPL
      STOP
      END
```

```
C  THIS PROGRAM IS DESIGN TO GENERATE THE DATA FOR THE GRAPHICAL
C  SOLUTION OF THE WEIGHT AND THE USEFUL LOAD EQUATION.  THIS IS THE
C  FIRST STEP IN A CARPET PLOT HELICOPTER DESIGN PARAMETRIC OPTIMIZATION
C
C     ASSUMPTIONS:
C                1> ENGINESPECIFIED
C VARIABLE OPTIONS
C
      REAL*4 CLR,PA,DL,K1,K2,K3,K4,K5,R,S,A,P,W(10),WE(10)
      INTEGER VT,D,I,CL
C
C-----------------------------------------------------------------------
      CALL FRTCMS ('FILEDEF ','02      ','DISK    ','CRPT1',
     >'DATA    ','A       ')
C-----------------------------------------------------------------------
C-----------------------------------------------------------------------
      CALL FRTCMS ('FILEDEF ','03      ','DISK    ','CRPT2',
     >'DATA    ','A       ')
C-----------------------------------------------------------------------
C
C
C     CLR= DESIGN MEAN LIFT COEFFICIENT
      DO 90 CL=3,7
      CLR=CL*(0.1)
      WRITE(2,10)CLR
C     PA= POWER AVAILABLE HP
      PA=206
C     DL= DISK LOADING
C     VT= TIP VELOCITY FT/SEC
C
C     CONSTANTS BASED ON CLR
C
      K1=(0.9583)/CLR*(1+1.8078*CLR**2)
      K2=PA*10**5/K1
      K3=(0.0025929)/CLR*(1+1.8078*CLR**2)
      K4=553480.0/K1
      K5=3695.7/K1
      DO 100  D=200,300
       DL=D*(0.01)
       I=0
         DO 110  VT=600,700,25
C
C          ARRAY INCREMENTER
           I=I+1
C          WEIGHT EQUATION
C
      W(I)=(K2*(1-(411.51*DL**.75)/(VT**1.5)*(1+K3*VT/DL**.5)**.5)-K4)
     1/(VT+K5*DL**.5)
C
C     CALCULATION OF WE DATA
C
      A=W(I)/DL
      R=(A/3.14)**.5
      P=A**.5/VT
      S=(6.*DL)/(0.0023679*CLR*VT**2)
C
C     ASSUMING A TEETERING SYSTEM
C
      WE(I)=1717.9+1221.*P**.863+266.*P**.7+17449./VT**1.14
     1+2.886*A**.5*P**.87+.191*W(I)**.916+.0294*W(I)**.99
     2+35.15*(W(I)/VT)*(A**.185)*S**.33+.0088*W(I)*A**.21
C          WRITE (5,20) VT
C          WRITE(5,30)R
 110     CONTINUE
           WRITE (2,31)DL,W(1),WE(1),W(2),WE(2)
           WRITE (3,31) DL,W(3),WE(3),W(4),WE(4),W(5),WE(5)
 100  CONTINUE
  90  CONTINUE
C     FORMAT STATEMENTS
 10   FORMAT ('1','CLR=',1F10.4///)
 31   FORMAT (6(2X,F10.3))
      STOP
      END
```

```
C*************************************************************
C*************************************************************
C   THIS PROGRAM IS DESIGN TO OBTAIN THE GROSS WEIGHT FROM THE       *
C   ASPECT RATIO GRAPH INTERSECTION POINT DATA. IN ORDER TO GRAPH    *
C   THE ASPECT RATIO BOUNDARY ON THE MAIN CARPET PLOT A              *
C   CORRESPONDING WEIGHT MUST BE OBTAINED. THIS PROGRAM UTILIZES     *
C   THE WEIGHT ESTIMATION FORMULATION FROM THE CARPET PROGRAM.       *
C*************************************************************
C*************************************************************
C   ASSUMPTIONS:                                                     *
C                    1> ENGINESPECIFIED                              *
C*************************************************************
C*************************************************************
C VARIABLE OPTIONS
      REAL*4  VT(5),DL(5),CLR(5),W(5)
      DATA CLR/.625,.575,.535,.460,.42/
      DATA VT/600.,625.,650.,675.,700./
      DATA DL/2.75,2.75,2.72,2.67,2.53/
C-----------------------------------------------------------------
      CALL FRTCMS ('FILEDEF ','03      ','DISK    ','CRPTAR',
     >'DATA    ','A       ')
C-----------------------------------------------------------------
C
      DO 90 L=1,5
      WRITE(3,10)CLR(L)
      WRITE(3,20)VT(L)
      WRITE(3,30)DL(L)
C     PA= POWER AVAILABLE HP
      PA=206
C     DL= DISK LOADING
C     VT= TIP VELOCITY FT/SEC
C
C     CONSTANTS BASED ON CLR
C
      K1=(0.9583)/CLR(L)*(1+1.8078*CLR(L)**2)
      K2=PA*10**5/K1
      K3=(0.00025929)/CLR(L)*(1+1.8078*CLR(L)**2)
      K4=553480.0/K1
      K5=3695.7/K1
C         WEIGHT EQUATION
C
      W(L)=(K2*(1-(411.51*DL(L)**.75)/(VT(L)**1.5)*
     1(1+K3*VT(L)/DL(L)**.5)**.5)-K4)/(VT(L)+K5*(DL(L)**.5))
      WRITE (3,31)W(L)
 90   CONTINUE
C     FORMAT STATEMENTS
 10   FORMAT ('1','CLR=',1F10.4///)
 20   FORMAT (2X,'VT=',1F10.4///)
 30   FORMAT (2X,'DL=',1F10.4///)
 31   FORMAT (2X,F10.3)
      STOP
      END
```

APPENDIX D. PROGRAMS TO ACCESS HESCOMP

This section contains the control language programs needed to access HESCOMP on the IBM main-frame computer.

```
C****************************************************************
C****************************************************************
C******                                                    *******
C**  NOTE!!!! THE PROGRAM INPUT CARDS (DATA LINES) DO NOT HAVE TO ***
C**     BE IN NUMERICAL ORDER. ERASE THESE COMMENT LINES IF RUNNING ***
C**    PROGRAM                                                  ***
C******                                                    *******
C****************************************************************
C****************************************************************
//HESCOMP1 JOB (2399,5555),'AL HANSEN',CLASS=B
//*MAIN ORG=RPGVM1.2399F,LINES=(10)
//    EXEC HESCOMP
//SYSIN DD *
77777
    SAMPLE CASE NO. 1   RUN 1            1/26/84
120150.         0.            0.           2.           0.
120610.
122310.965
130151.761      0.159         0.           0.032        950.
130651100.      1856.         2000.        2000.        8.
13115870.       1200.         1400.        1600.        1800.
131652000.      2200.         2600.        5.           0.
132140.2        0.4           0.6          0.8
132650.         0.            0.           0.           0.
13325.163       .1676         .1613        .2041        .236
13385.335       .3444         .3725        .4194        .4851
13445.544       .5592         .6049        .6511        .7877
13505.770       .7916         .8562        .964         1.115
135651.0        1.028         1.112        1.252        1.448
136251.2        1.2336        1.3344       1.5024       1.7376
136851.55       1.5934        1.7236       1.9406       2.2444
137458.         870.          1200.        1400.        1600.
137951800.      2000.         2200.        2600.        5.
138450.         0.2           0.4          0.6          0.8
13905.065       .0651         .0653        .067         .071
13965.115       .116          .118         .128         .15
14025.180       .181          .15          .208         .227
14085.26        .261          .273         .295         .325
14145.342       .347          .362         .389         .425
14205.425       .435          .451         .486         .517
14265.5         .511          .53          .56          .61
14325.626       .631          .66          .718         .78
143863.         870.          1600.        2600.
144743.         0.            0.4          0.8
145430.26       0.271         0.29
146030.82       0.84          0.90
146631.09       1.116         1.165
150258.         870.          1200.        1400.        1600.
150751800.      2000.         2200.        2600.        5.
151250.         0.2           0.4          0.6          0.8
151850.26       0.265         0.271        0.28         0.29
152450.52       0.527         0.54         0.56         0.59
153050.68       0.69          0.705        0.73         0.76
153650.82       0.824         0.84         0.868        0.90
154250.92       0.93          0.95         0.98         1.02
154851.0        1.002         1.02         1.05         1.09
155451.052      1.055         1.07         1.10         1.131
156051.09       1.10          1.118        1.135        1.165
66666
120150.         0.            0.           2.           0.
120610.
122320.965      0.
130151.761      0.159         0.           0.032        950.
130651100.      1856.         2000.        2000.        8.
13115870.       1200.         1400.        1600.        1800.
131652000.      2200.         2600.        5.           0.
132140.2        0.4           0.6          0.8
132650.         0.            0.           0.           0.
13325.163       .1676         .1613        .2041        .236
13385.335       .3444         .3725        .4194        .4851
13445.544       .5592         .6049        .6811        .7877
13505.770       .7916         .8562        .964         1.115
135651.0        1.028         1.112        1.252        1.448
136251.2        1.2336        1.3344       1.5024       1.7376
136851.55       1.5934        1.7236       1.9406       2.2444
137458.         870.          1200.        1400.        1600.
```

```
024622.         1.105
024851.         900.       10.        .075       .97
025310.
02542.82        .80
02572140.       3.
026114.0
026240.         0.2        0.4        0.8
02724.85        .83        .80        .78
031241130.      .555       .75        1.0
032310.0
032711.02
032821.464COCOCE 066.28
033017.0
033150.0        0.2        0.4        0.6        0.8
033621.0        1.4
03355.006       .0062      .007       .008       .0095
03442.012       .020
260232200.      450.       20C0.
26053100.       0.         0.
260E50.         0.         0.         0.         0.
2613525.        25.        25.        0.         0.
2618430.        .18        25.        0.
26225125.       2.C8       .04        .8         0.
262751.         0.         2.C6       2.0        24.1
263251.0        .75        1.0        .75        0.
263754.         2.2        61.        .286       1.15
264514.2        14.2       1.C        1.0        250.
264753.         250.       250.       1.         .11
26522.17        .17
265451.0        1.0        1.0        1.0        1.0
265551.0        1.0        1.C        1.0        1.0
266451.0        1.0        1.0        1.0        1.0
266951.0        1.0        1.C        1.0        1.0
034753.0        3.0        0.0        0.5        1.0
035430.0        0.5        1.C
036131.0        1.0        1.0
036831.0        1.0        1.0
037531.C        1.0        1.0
040110.
041111.0333
042110.
043111.0
044111.105
046121.0        1.0
048120.         0.
05012C.         0.
051120.         0.
052121.06       1.06
05312.02        .02
054121.105      1.105
05512.1         2
057121.         1.
059120.         0.
06012.3         .4
061120.         0.
C6212500.       500.
063122.         2.
064125000.      3C00.
065121.105      1.105
066126.         6.
067121.105      1.105
068121.         1.
069120.         0.
070121.         1.
072132.         4.         4.
C7311170.
074130.         0.         0.
07513.5         .5         .5
076130.         0.         0.
0771315.        15.        15.
078132.         2.         2.
0791360.        150.       100.
080131.105      1.105      1.1C5
C81130.         0.         0.
082131.105      1.105      1.1C5
083130.         0.         0.
```

```
137551800.      -2000.     2200.      2600.      5.
138450.         0.2        0.4        0.6        0.8
13905.065       .0651      .0653      .067       .071
13965.115       .116       .118       .128       .14
14025.180       .181       .19        .208       .227
14085.26        .261       .273       .295       .325
14145.342       .347       .362       .389       .425
14205.425       .435       .451       .486       .517
14265.5         .511       .53        .56        .61
14325.626       .631       .66        .718       .78
143043.         870.       1600.      2600.
144743.         0.         0.4        0.8
145430.26       0.271      0.29
146030.62       0.84       0.96
146631.09       1.118      1.165
150258.         870.       1200.      1400.      1600.
150751800.      2000.      2200.      2600.      5.
151250.         0.2        0.4        0.6        0.8
151850.26       0.265      0.271      0.23       0.29
152450.52       0.527      0.54       0.56       0.59
153050.66       0.69       0.705      0.73       0.76
153650.82       0.824      0.84       0.868      0.90
154250.92       0.93       0.95       0.98       1.02
154851.0        1.002      1.02       1.05       1.09
155451.052      1.055      1.07       1.10       1.131
156051.09       1.10       1.118      1.135      1.165
66666
160123.0        -9.0
16035.0074918   -.028      .262       .276       2.45
16081.865
16055.0079059   2.82       .09        1.17       .00124
16102.758       .743
1616510.        0.         .004       .007       .009
16215.010       .011       .0115      .012       .0155
16265.022       1.018      1.065      1.154      1.233
163151.279      1.314      1.327      1.337      1.364
163611.357
000151.         1.         2.         0.         1.
000654.         4.         1.         1.         3.
001151.         2.         0.         1.         1.
001642.         2.         2.         0.
002252.         25000.     0.         0.         0.
002750.         .33        220.       220.       3.5
003251.0        0.0        1.05       1.0        2.0
003754.0        3.0        4.0        9.0        2.0
004258.0        6.0        3.0        4.0        60.
004711000.
010310.5
01055.20        .12        0.         .5         1.0
01105.2         .8         4.0        1.15       .12
01152.0162      .5
012050.0        0.0        7.0        6.5        1.3
012551.6        12.        0.         .55        5.
01302.3         1.1
01365.45        .15        .8         .85        .5
01415180.       .035       2.0        .078       0.1
01465.035       2.0        .078       0.         0.
01511.1
01525.4         .2         .5         .4         3.
017133.         1.         11.
017654.         -9.        .25        .075       .1
01815725.       .12        1.06       165.       3000.
0186543.2       .110       1.75       1.35       1.0
019131.53       0.         .85
020355.         -4.        .3         .075       690.
02085.17        .30        .75        1.00       .72
021331.00       1.0        1.05
021610.
021711.761
021932.0        2.0        1.0
02235.97        100.       1.0        1.0        4000.
022851.06       50.3       1.165      0.0        .95
023350.0        2.0        3000.      170.       43.2
023641.105      .75        .30        0.
024211.761
024511.0
```

```
08413.55            .60             .70
085130.             0.              0.
103120.             0.
10412.4             .4
105120.             0.
10612.05            .05
107121.105          1.105
10812.5             .25
109121.105          1.105
110120.0            0.0
11111.35
112120.0            0.0
113120.0            0.0
11611-1000.
11711.01
118111000.
119111.0
88888
59999
/*
//
```

APPENDIX E: HESCOMP INPUT AND OUTPUT EXAMPLES

This section contains samples of the IBM computer input and output.

```
                              H E S C O M P
     HELICOPTER SIZING & PERFORMANCE COMPUTER PROGRAM     E-

     THE FOLLOWING IS A CARD BY CARD REPRODUCTION OF THE INPUTS THIS CASE

LOC.  CORRESPONDS TO LOCATION NUMBER GIVEN ON INPUT SHEET
NUM   STANDS FOR THE NUMBER OF SEQUENTIAL INPUT VALUES STARTINGC.  (MAX. =5)
VAL   EQUALS VALUE FOR VARIABLE CORRESPONDING TO LOC.
VAL1        VALUE              CORRESPONDING TO LOC.+0001
VAL2        VALUE              CORRESPONDING TO LOC.+0002
      ETC.

LOC.       NUM        VAL              VAL1              VA       VAL3             VAL4

     NOTE : IN USING AUXILIARY ENGINES ; AUXILIARY ENGINE CYCLLOCATIONS CAN BE CREATED
     BY PLACING A 66666 CARD IN FRONT AND BEHIND A STANDARD ENIE

1201        5        .0               .0                .0       2.0000           .0
1206        1        .0
1223        1        .90500
1301        5        1.7610           .15900            .0       .32000E-01       950.00
1306        5        1100.0           1856.0            200      2030.0           8.0000
1311        5        870.00           1230.0            140      1600.0           1800.0
1316        5        2000.0           2230.0            260      5.0000           .0
1321        4        .20000           .40000            .80      .80000
1326        5        .0               .0                .0       .0               .0
1332        5        .18300           .16760            .18      .20410           .23600
1338        5        .35500           .34440            .37      .41940           .48510
1344        5        .54400           .55920            .60      .68110           .78770
1350        5        .77000           .79160            .85      .96400           1.1150
1356        5        1.0000           1.0280            1.1      1.2520           1.4480
1362        5        1.2000           1.2336            1.3      1.5024           1.7376
1368        5        1.5500           1.5934            1.7      1.9406           2.2444
1374        5        8.0000           870.00            120      1400.0           1600.0
1379        5        1800.0           2000.0            220      2600.0           5.0000
1384        5        .0               .20000            .40      .60000           .80000
1390        5        .65000E-01       .65100E-01        .65      .67000E-01       .71000E-01
1396        5        .11500           .11600            .11      .12800           .14000
1402        5        .18000           .18100            .19      .20800           .22700
1408        5        .26000           .26100            .27      .29500           .32500
1414        5        .34200           .34700            .36      .38900           .42500
1420        5        .42500           .43500            .45      .48600           .51700
1426        5        .50000           .51100            .53      .56000           .61000
1432        5        .62600           .63100            .66      .71800           .78000
1438        4        3.0000           870.00            160      2600.0
1447        4        3.0000           .0                .40      .80000
1454        3        .26000           .27100            .29
1460        3        .82000           .84000            .90
1466        3        1.0500           1.1180            1.1
1502        5        8.0000           870.00            120      1430.0           1600.0
1507        5        1800.0           2000.0            220      2600.0           5.0000
1512        5        .0               .20000            .40      .60000           .60000
1518        5        .26000           .26500            .27      .28000           .29000
1524        5        .52000           .52700            .54      .56000           .59000
1530        5        .66000           .69000            .70      .73000           .76000
1536        5        .82000           .82400            .84      .86800           .90000
1542        5        .92000           .93000            .95      .93000           1.0200
1548        5        1.0000           1.0020            1.0      1.0500           1.0900
1554        5        1.0520           1.0550            1.0      1.1000           1.1310
1560        5        1.0500           1.1000            1.1      1.1350           1.1650
2201        5        .0               .0                .0       2.0000           .0
2206        1        .0
```

```
2223   2   .90500        .0
2301   5   1.7610        .15900         .0     .32000E-01    950.00
2306   2   1100.0        1856.0         200    2030.0        8.0000
2311   5   870.00        1230.0         140    1600.0        1800.0
2316   5   2000.0        2230.0         260    5.0000        .0
2321   4   .20000        .40000         .60    .80000
2326   2   .0            .0             .0     .0            .0
2332   5   .16300        .16760         .18    .20410        .23600
2338   5   .33500        .34440         .37    .41940        .48510
2344   2   .54400        .55920         .60    .68110        .78770
2350   2   .77000        .79160         .85    .96400        1.1150
2356   5   1.0000        1.0280         1.1    1.2520        1.4480
2362   5   1.2000        1.2336         1.3    1.5024        1.7376
2368   5   1.5500        1.5934         1.7    1.9406        2.2444
2374   2   8.0000        873.00         120    1400.0        1600.0
2379   5   1800.0        2030.0         220    2600.0        5.0000
2384   5   .0            .23000         .40    .60000        .80000
2390   5   .65000E-01    .65100E-01     .65    .67000E-01    .71000E-01
2396   2   .11500        .11600         .11    .12800        .14000
2402   5   .18000        .18100         .19    .20800        .22700
2408   2   .26000        .26100         .27    .29500        .32500
2414   5   .34200        .34700         .36    .38900        .42500
2420   2   .42500        .43500         .45    .48600        .51700
2426   5   .50000        .51100         .53    .56000        .61000
2432   5   .62000        .63100         .66    .71800        .78000
2438   4   3.0000        873.00         160    2600.0
2447   4   3.0000        .0             .40    .80000
2454   3   .26000        .27100         .29
2460   3   .82000        .84000         .90
2466   3   1.0500        1.1180         1.1
2502   5   8.0000        873.00         120    1400.0        1600.0
2507   5   1800.0        2030.0         220    2600.0        5.0000
2512   5   .0            .23000         .40    .60000        .80000
2518   2   .28000        .26500         .27    .28000        .29000
2524   5   .52000        .52700         .54    .56000        .59000
2530   2   .68000        .69000         .70    .73000        .76000
2536   5   .82000        .82400         .84    .86800        .90000
2542   5   .92000        .93000         .95    .98000        1.0230
2548   5   1.0000        1.0020         1.0    1.0500        1.0900
2554   5   1.0520        1.0550         1.0    1.1000        1.1310
2560   2   1.0900        1.1000         1.1    1.1350        1.1650
1601   5   3.0000        -9.3000
1603   1   .74518E-02    -.28000E-01    .26    .27600        2.4500
1608   1   .86530
1609   5   .75059E-02    2.8200         .90    1.1700        .12400E-02
1614   2   .75600        .78300
1616   5   10.000        .0             .40    .73000E-02    .90000E-02
1621   2   .10000E-01    .11000E-01     .11    .12000E-01    .15500E-01
1626   2   .22000E-01    1.3180         1.0    1.1540        1.2330
1631   5   1.2790        1.3140         1.3    1.3370        1.3640
1636   1   1.3570
   1   5   1.0000        1.0000         2.0    .0            1.0000
   6   5   4.0000        4.0000         1.0    1.0000        3.0000
  11   5   1.0000        2.0000         .0     1.0000        1.0000
  16   4   2.0000        2.0000         2.0    .0
  22   5   2.0000        25000.         .0     .0            .0
  27   5   .0            .33000         220    220.00        3.5000
  32   2   1.0000        .0             1.0    1.0000        2.0000
  37   5   4.0000        3.0000         4.0    9.0000        2.0000
  42   5   8.0000        6.0000         3.0    4.0000        60.000
  47   1   100.00
 103   1   .50000
 105   5   .20000        .12000         .0     .50000        1.0000
 110   5   .20000        .83000         4.0    1.1500        .12000
```

```
 115    2    .16200E-01    .50000
 120    5    .0            .0            7.0    6.5000       1.3000
 125    5    1.0000        12.000        .0     .55000       5.0000
 130    2    .30000        1.1000
 136    5    .45000        .15000        .80    .85000       .50000
 141    5    180.00        .35000E-01    2.0    .73000E-01   .10000
 146    5    .35000E-01    2.0000        .78    .0           .0
 151    1    .10000
 152    5    .40000        .20000        .50    .40000       3.0000
 171    3    3.0000        1.3000        11.
 176    5    4.0000        -9.0000       .25    .75000E-01   .10000
 181    5    725.00        .12000        1.0    165.00       3000.0
 186    5    43.200        .11000        1.7    1.3500       1.0000
 191    3    1.5300        .0            .65
 203    5    5.0000        -4.0000       .30    .75000E-01   690.00
 208    5    .17000        .30000        .75    1.0000       .72000
 213    3    1.0000        1.0000        1.0
 216    1    .0
 217    1    1.7610
 219    3    2.0000        2.0000        1.0
 223    5    .97000        100.00        1.0    1.0000       4000.0
 228    5    1.0000        50.300        1.1    .0           .95000
 231    5    .0            2.0000        300    170.00       43.200
 238    4    1.1050        .75000        .30    .0
 242    1    1.7610
 245    1    1.0000
 246    2    2.0000        1.1050
 248    5    1.0000        900.00        10.    .75000E-01   .97000
 253    1    .0
 254    2    .82000        .30000
 257    2    140.00        3.0000
 261    1    4.0000
 262    4    .0            .20000        .40    .80000
 272    4    .85000        .83000        .80    .78000
 316    4    1130.0        .55500        .75    1.0000
 323    1    .0
 327    1    1.0200
 328    2    .14640E+07    6.2800
 330    1    7.0000
 331    5    .0            .20000        .40    .60000       .80000
 336    2    1.0000        1.4000
 339    5    .60000E-02    .62000E-02    .70    .80000E-02   .95000E-02
 344    2    .12000E-01    .20000E-01
2602    3    2200.0        450.00        200
2605    3    100.00 .      .0            .0
2608    5    .0            .0            .0     .0           .0
2613    5    25.000        25.000        25.    .0           .0
2618    4    30.000        .18000        25.    .0
2622    5    125.00        2.0800        .40    .80000       .0
2627    5    1.0000        .0            2.0    2.0000       24.100
2632    5    1.0000        .75000        1.0    .75000       .0
2637    5    44.000        2.2000        61.    .28600       1.1500
2642    5    14.200        14.200        1.0    1.0000       250.00
2647    5    3.0000        250.00        250    1.0000       .11000
2652    2    .17000        .17000
2654    5    1.0000        1.0000        1.0    1.0000       1.0000
2659    5    1.0000        1.0000        1.0    1.0000       1.0000
2664    5    1.0000        1.0000        1.0    1.0000       1.0000
2665    5    1.0000        1.0000        1.0    1.0000       1.0000
 347    5    3.0000        3.0000        .0     .50000       1.0000
 354    3    .0            .50000        1.0
 361    3    1.0000        1.0000        1.0
 368    3    1.0000        1.0000        1.0
```

```
 375     3     1.0000        1.0000        1.0
 401     1     .0
 411     1     .33300E-01
 421     1     .0
 431     1     1.0000
 441     1     1.1050
 461     2     1.0000        1.0000
 481     2     .0            .0
 501     2     .0            .0
 511     2     .0            .0
 521     2     1.0600        1.0600
 531     2     .20000E-01    .20000E-01
 541     2     1.1050        1.1050
 551     2     .10000        .20000
 571     2     1.0000        1.0000
 591     2     .0            .0
 601     2     .30000        .40000
 611     2     .0            .0
 621     2     500.00        500.00
 631     2     2.0000        2.0000
 641     2     5000.0        3000.0
 651     2     1.1050        1.1050
 661     2     4.0000        6.0000
 671     2     1.1050        1.1050
 681     2     1.0000        1.0000
 691     2     .0            .0
 701     2     1.0000        1.0000
 721     3     2.0000        4.0000        4.0
 731     1     170.00
 741     1     .0            .0            .0
 751     3     .50000        .50000        .50
 761     3     .0            .0            .0
 771     3     15.000        15.000        15.
 781     3     2.0000        2.0000        2.0
 791     3     60.000        150.00        300
 801     3     1.1050        1.1050        1.1
 811     3     .0            .0            .0
 821     3     1.1050        1.1050        1.1
 831     3     .0            .0            .0
 841     3     .55000        .60000        .70
 851     3     .0            .0            .0
1031     2     .0            .0
1041     2     .40000        .40000
1051     2     .0            .0
1061     2     .50000E-01    .50000E-01
1071     2     1.1050        1.1050
1081     2     .50000        .25000
1091     2     1.1050        1.1050
1101     2     .0            .0
1111     1     .35000
1121     2     .0            .0
1131     2     .0            .0
1161     1    -1000.0
1171     1     .10000E-01
1181     1     1000.0
1191     1     1.0000
WG = 0.250000E+05  WFA = 0.0           WFR = 0.0
WG = 0.250000E+05  WFA = 0.738579E+04  WFR = 0.512283E+04
WG = 0.217672E+05  WFA = 0.580161E+04  WFR = 0.453304E+04
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                              H E S C O M P
          HELICOPTER SIZING & PERFORMANCE COMPUTER PROGRAM     E-

    SINGLE ROTOR
              COMPOUND HELICOPTER
                                 AUX. INDEPENDENT T/SHAFT CRUISION

S I Z E   D A T A   THIS RUN CONVERGED IN  3 ITERATIONS
                              GROSS WEIGHT =  17043.  LB

        FUSELAGE

          LB              LENGTH(BODY+TAILBOOM)                    50.1 FT.
          LC              LENGTH(CABIN)                            12.0 FT.
          LB              LENGTH(BODY)                             27.5 FT.
          LTB             LENGTH(TAILBOOM)                         22.6 FT.
          XM              FWD. ROTOR LOCATION                      15.1 FT.
          WF              WIDTH                                     6.5 FT.
          SF              WETTED AREA                             737.5 SQ. FT.

        WING

          AR              ASPECT RATIO                              4.51
          SW              AREA                                    113.3 SQ. FT.
          BW              SPAN                                     22.6 FT.
          CBARW           MEAN CHORD                                5.0 FT.
          LAMBDA C/4      QUARTER CHORD SWEEP                       0.0 DEG.
          LAMBDA          TAPER RATIO                             0.500
          (T/C)R          ROOT THICKNESS/CHORD                    0.200
          (T/C)T          TIP THICKNESS/CHORD                     0.120
          WG/SW           WING LOADING                            155.7 LBS/SQ. FT.
          GRW             ROTOR/WING GAP                            3.6 FT.
          CF/C            FLAP CHORD/MEAN CHORD RATIO             1.000

        HOR. TAIL

          ARHT            ASPECT RATIO                            4.000
          SHT             AREA                                     35.5 SQ. FT.
          BHT             SPAN                                     11.9 FT.
          CBARHT          MEAN CHORD                                3.0 FT.
          LAMBDA H        TAPER RATIO                             0.500
          (T/C)HT         THICKNESS/CHORD                         0.120
          LTH             HOR. TAIL ARM                            26.0 FT.

        VERT. TAIL

          ARVT            ASPECT RATIO                            1.523
          SVT             AREA                                     21.2 SQ. FT.
          BVT             SPAN                                      5.7 FT.
          CBARVT          MEAN CHORD                                3.7 FT.
          LAMBDA VT       TAPER RATIO                             0.450
          ZTR             TAIL ROTOR(VERT.) LOCATION                4.6 FT.
          ZETAVT          TAIL ROTOR/VERT. TAIL OVERLAP RATIO     0.800
          (T/C)VT         THICKNESS/CHORD                         0.150
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                                    H E S C O M P
         HELICOPTER SIZING & PERFORMANCE COMPUTER PROGRAM     E-

   SINGLE ROTOR
           COMPOUND HELICOPTER
                                 AUX. INDEPENDENT T/SHAFT CRUISION

S I Z E   D A T A   THIS RUN CONVERGED IN  3 ITERATIONS

                                 GROSS WEIGHT =  17643.  LB

       FUSELAGE

          LF             LENGTH(BODY+TAILBOOM)                      50.1 FT.
          LC             LENGTH(CABIN)                              12.0 FT.
          LB             LENGTH(BODY)                               27.5 FT.
          LTB            LENGTH(TAILBOOM)                           22.6 FT.
          XH             FWD. HINGE LOCATION                        15.1 FT.
          WF             WIDTH                                       6.5 FT.
          SF             WETTED AREA                   .           717.5 SQ. FT.

       WING

          AR             ASPECT RATIO                                4.51
          SW             AREA                                      113.3 SQ. FT.
          BW             SPAN                                       22.6 FT.
          CBARW          MEAN CHORD                                  5.0 FT.
          LAMBDA C/4     QUARTER CHORD SWEEP                         0.0 DEG.
          LAMBDA         TAPER RATIO                               0.500
          (T/C)R         ROOT THICKNESS/CHORD                      0.200
          (T/C)T         TIP THICKNESS/CHORD                       0.120
          WG/SW          WING LOADING                              155.7 LBS/SQ. FT.
          GRW            ROTOR/WING GAP                              8.6 FT.
          CF/C           FLAP CHORD/MEAN CHORD RATIO               1.000

       HOR. TAIL

          ARHT           ASPECT RATIO                              4.000
          SHT            AREA                                       35.5 SQ. FT.
          BHT            SPAN                                       11.9 FT.
          CBARHT         MEAN CHORD                                  3.0 FT.
          LAMBDA H       TAPER RATIO                               0.500
          (T/C)HT        THICKNESS/CHORD                           0.120
          LTH            EQV. TAIL ARM                              26.0 FT.

       VERT. TAIL

          ARVT           ASPECT RATIO                              1.523
          SVT            AREA                                       21.2 SQ. FT.
          BVT            SPAN                                        5.7 FT.
          CBARVT         MEAN CHORD                                  3.7 FT.
          LAMBDA VT      TAPER RATIO                               0.450
          ZTR            TAIL ROTOR(VERT.) LOCATION                  4.6 FT.
          ZETAVT         TAIL ROTOR/VERT. TAIL OVERLAP RATIO       0.800
           (T/C)VT       THICKNESS/CHORD                           0.150
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MAIN ROTOR PYLON

    AR             ASPECT RATIO                                 0.500
    SWP            WETTED AREA                                   39.1 SQ. FT.
    FAPF           FRONTAL AREA                                   6.2 SQ. FT.
    HPY            HEIGHT                                         3.0 FT.
    CBARPF         MEAN CHORD                                     6.0 FT.
    LAMBDA PP      TAPER RATIO                                  0.400
    (T/C)R         ROOT THICKNESS/CHORD                         0.400
    (T/C)T         TIP THICKNESS/CHORD                          0.200

PRIMARY ENGINE NACELLE

    LN             LENGTH                                         5.8 FT.
    DN             MEAN DIAMETER                                   2. FT.
    SN             WETTED AREA(TOTAL FOR ALL ENGINES)            60.8 SQ. FT.

AUXILIARY INDEPENDENT ENGINE NACELLE

    LNI            LENGTH                                         4.5 FT.
    DNI            MEAN DIAMETER                                   1. FT.
    SNI            WETTED AREA(TOTAL FOR ALL ENGINES)             19. SQ. FT.

AUXILIARY INDEPENDENT ENGINE NACELLE STRUT

    SSTR           WETTED AREA(TOTAL)                              0. SQ. FT.
    BNS            SPAN                                           3.1 FT.
    CNS            MEAN CHORD                                     2.8 FT.

PROPELLER(AUXILIARY PROPULSION)

    DAP            DIAMETER                                      10.0 FT.
    AF             ACTIVITY FACTOR PER BLADE                    140.0
    SIGAP          SOLIDITY                                     0.171
    NPA            NO. OF PROPELLERS                               1.
    NO. BLADES     NO. OF BLADES/PROP                              3.
    VTIP           TIP SPEED                                     900. FT./SEC

MAIN ROTOR

    DMR            DIAMETER                                      45.2 FT.
    SIGMR          SOLIDITY                                     0.128
    WG/A           DISC LOADING                                  11.0 LB/SQ. FT.
    CT/SIGMA       THRUST COEFF./SOLIDITY                       0.110
    NR             NO. OF ROTORS                                   1.
    NO. BLADES     NO. OF BLADES/ROTOR                             4.
    THETA          BLADE TWIST                                 -9.000 DEG.
    XC             BLADE CUTOUT/RADIUS RATIO                    0.250
    VTIP           TIP SPEED                                     725. FT./SEC.

TAIL ROTOR

    DTR            DIAMETER                                      10.8 FT.
    SIGTR          SOLIDITY                                     0.237
    (T/A)NET       NET DISC LOADING                              17.6 LB./SQ. FT.
    CT/SIGMA       THRUST COEFF./SOLIDITY                       0.170
    NO. BLADES     NO. OF BLADES/ROTOR                             5.
    THETA          BLADE TWIST                                 -4.000 DEG.
    XCTR           BLADE CUTOUT/RADIUS RATIO                    0.100
    G              MAIN/TAIL ROTOR GAP                            1.0 FT.
    VTIP           TIP SPEED                                     690. FT./SEC.
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                                              H E S C O M P
              HELICOPTER SIZING & PERFORMANCE COMPUTER PROGRAM     E-


W E I G H T S   D A T A     IN LBS

         MLF               MANEUVER LOAD FACTOR
         GLF               GUST LOAD FACTOR
         ULF               ULTIMATE LOAD FACTOR

      PROPULSION GROUP
            WMRG           TOTAL MAIN ROTOR GROUP                   .
         K12 WMRB              MAIN ROTOR BLADE (PER ROTOR)     1023.
         K13 WMRH              MAIN ROTOR HUB (PER ROTOR)        511.
             WBF               BLADE FOLDING(PER ROTOR)          230.
         K15 WAR           AUXILIARY PROPULSION ROTOR GROUP         .
             WDS           DRIVE SYSTEM                             .
         K16 WMDS              MAIN ROTOR DRIVE SYSTEM          1359.
         K20 WTRDS             TAIL ROTOR DRIVE SYSTEM           118.
         K17 WADS              AUXILIARY PROPULSION DRIVE SYSTEM 205.
         K18 WPE           PRIMARY ENGINES                          .
         K19 WEA           AUXILARY ENGINES                         .
             WPEI          PRIMARY ENGINE INSTALLATION              .
             WAEI          AUXILIARY ENGINE INSTALLATION            .
             WFS           FUEL SYSTEM                              .
         DELTA WP          PROPULSION GROUP WEIGHT INCREMENT        .
               WP     TOTAL PROPULSION GROUP WEIGHT                          5091.

      STRUCTURES GROUP
         K8  WW            WING
             WTG           TAIL GROUP                               .
         K9  WHT               HOR. TAIL                            .  71.
         K14 WTR               TAIL ROTOR                         123.
         K6  WB            FUSELAGE                                 .
         K7  WLG           LANDING GEAR                             .
             WNG               NOSE GEAR                          141.
             WMG               MAIN GEAR                          565.
             WTES          TOTAL ENGINE SECTION                     .
             WPES              PRIMARY ENGINE SECTION             145.
             WAES              AUXILIARY ENGINE SECTION            51.
         DELTA WST         STRUCTURE WEIGHT INCREMENT               .
               WST    TOTAL STRUCTURE WEIGHT                                 3272.

      FLIGHT CONTROLS GROUP
             WPFC          PRIMARY FLIGHT CONTROLS                  .
             WCC               COCKPIT CONTROLS                    81.
         K1  WRC               MAIN ROTOR CONTROLS                356.
         K2  WSC               MAIN ROTOR SYSTEMS CONTROLS        248.
         K3  WFW               FIXED WING CONTROLS                  0.
             WTM               TILT MECHANISM                       0.
             WSAS              SAS                                 30.
             WAFC          AUXILIARY FLIGHT CONTROLS                .
         K4  WRCA              AUX. PROPULSION ROTOR CONTROLS      24.
         K5  WSCA              AUX. PROPULSION ROTOR SYS. CONTRO   32.
             WMC               MISCELLANEOUS CONTROLS               0.
         DELTA WFC         CONTROL WEIGHT INCREMENT                 .
               WFC    TOTAL CONTROL WEIGHT                                    870.
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WFE           WEIGHT OF FIXED EQUIPMENT                  2200.
WE            WEIGHT EMPTY                              11433.
WFUL          FIXED USEFUL LOAD                           450.
OWE           OPERATING WEIGHT EMPTY                    11883.
WPL           PAYLOAD                                    2000.
(WF)A         FUEL                                       3760.
WG            GROSS WEIGHT                              17643.
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A E R O D Y N A M I C S   D A T A
        FE                   TOTAL EFFECTIVE FLATPLATE AREA                 SQFT
        SWET                 TOTAL WETTED AREA                              SQFT
        CFAVG                MEAN SKIN FRICTION COEFF.
      D R A G   B R E A K D O W N           IN  SQFT
        FEW                  WING FE                                 .729
        FEF                  FUSELAGE FE                             .233
        FEFP                 FORWARD(MAIN) ROTOR PYLON FE            .0
        FEAP                 AFT ROTOR PYLON FE                      .0
        FEMRH                MAIN ROTOR HUB(S) FE                    .0
        FETRH                TAIL ROTOR HUB FE                       .0
        FEVT                 VERTICAL TAIL FE                        .0
        FEHT                 HORIZONTAL TAIL FE                      .0
        FEN                  PRIMARY ENGINE NACELLE FE               .0
        FEAI                 AUX. INDEPENDENT CRUISE ENG. NAC. FE    .0
        FEAS                 AUX. INDEPENDENT CRUISE ENG. STRUT FE   .0
        DELTA FE             INCREMENTAL FE                          .0
A E R O D Y N A M I C   C O E F F .
        A5                                                           79
        A6                                                           64
        A7                                                           20
        A8                                                           13
        A9                                                           48
        E          WING LIFT EFFICIENCY FACTOR                     C.
        EVT        VERTICAL TAIL LIFT EFFICIENCY FACTOR            0.
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R O T O R   D A T A

        ROTOR CYCLE NO.     3.0000

        MAIN ROTOR SOLIDITY SIZED BY MANUEVER CONDITIONS
        H =      3000.0 FT. , TEMP =        91.5 DEG. , V =      KT.
        100.0 PERCENT HOVER RPM
        ROTOR MANUEVER G'S =  1.350 , CT/SIGMA = 0.110

        TAIL ROTOR SIZED AT        1.050 TIMES THE SOLIDITY
        REQUIRED TO SATISFY HOVERING TURN REQUIREMENTS AT :
                         H                                 =      4000
                         TEMP                              =      95.0F.
                         CTG/CTNET                         =       1.2
                         YAW RATE                          =       0.7EC.
                         YAW ACCELERATION                  =       0.3EC2
                         TAIL ROTOR POLAR
                         MOM. OF INERTIA(PER BLADE) =       4.1FT2
                         HELICOPTER YAW
                         MOM. OF INERTIA                   =    36385FT2
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P R O P U L S I O N   D A T A
          PRIMARY PROPULSION CYCLE NO.     1.761
                 TURBOSHAFT ENGINE

                  2.  ENGINES

              BHP*E            MAX. STANDARD S.L. STATIC H.P.              H.P.

              ENGINE SIZED FOR TAKEOFF AT T/W =1.06
               95.0 PERCENT MILITARY POWER SETTING,
              H = 4000. FT, TEMPERATURE = 95.04 DEG.F.,
               0.0   ENGINES INOPERATIVE, AND    0.0  FT/MIN VERTI OF CLIMB.

          AUX. INDEPENDENT PROPULSION CYCLE NO.     1.761
                 TURBOSHAFT ENGINE

                  1.  ENGINES

              BHP*PI            MAX. STANDARD S.L. STATIC H.P.     .       H.P.

              ENGINE SIZED FOR CRUISE AT VC = 170. KNOTS,
               NORMAL  POWER SETTING,
              HC =  3000. FT, TEMPERATURE =  91.50 DEG.F.,
              AND  0.0   ENGINES INOPERATIVE.

                 MAIN AND TAIL ROTOR DRIVE SYSTEM RATING              H.P.

                 MAIN ROTOR DRIVE SYSTEM RATING          2914.

          XMSN SIZED AT 100. PERCENT OF MAIN ROTOR HOVER POWER REQ
          AT H = 4000. FT, TEMP = 95.04 DEG.F., 100.0 PERCENT HOVE
                 TAIL ROTOR DRIVE SYSTEM RATING           436.

          XMSN SIZED AT 100. PERCENT OF TAIL ROTOR HOVER POWER REQ
          AT H = 4000. FT, TEMP = 95.04 DEG.F., 100.0 PERCENT HOVE

                 AUXILIARY INDEPENDENT PROPULSION DRIVE SYSTEM RA        871.     H.P.

          XMSN SIZED AT 100. PERCENT OF AUX. PROPULSION CRUISE POWER  AT VC =170. KT,
          HC =  3000. FT, TEMP= 91.50 DEG.F.
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                                        H E S C O M P
                 HELICOPTER SIZING & PERFORMANCE COMPUTER PROGRAM

            MISSION PERFORMANCE DATA

      TAXI  FOR  0.033  HRS. AT GROUND IDLE ENGINE RATING
                                                                PRIM.    PRIM.   TOTAL      AUX.     AUX.    AUX.    AUX. ENG.   TEMP.
                         FUEL                  PRESS.           TURB.    ENG.    FUEL       TURB.    ENG.    ENG.    FUEL FLOW   DEG.
  TIME       RANGE       USED       WEIGHT     ALT.      TAS    TEMP.    CODE    FLOW       TEMP.    CODE    PERF    (LBS/HR)    (F)
  (HRS)      (N.M.)      (LBS)      (LBS.)     (FT)      (KTS)  (R)              (LBS/HR)   (R)

  0.0          0.0         0.0      17643.       0.        0.0   950.0    T        438.     550.0     T       0.0       95.       59.0
  0.033        0.0        14.6      17628.       0.        0.0   950.0    T        438.     550.0     T       0.0       95.       59.0

      TAKEOFF, HOVER, OR LAND AT  T/W = 1.060 FOR  0.100 HRS.
                                                                PRIM.    PRIM.   TOTAL      THRUST
                         FUEL                  PRES.            TURB.    ENG.    FUEL         TO
  TIME       RANGE       USED       WEIGHT     ALT.      TAS    TEMP.    CODE    FLOW       WEIGHT    FM      BHP      CT       CT/SIGMA
  (HRS)      (N.M.)      (LBS)      (LBS.)     (FT)      (KTS)  (R)              (LBS/HR)

  M.ROTOR    M.ROTOR     T.ROTOR    T.ROTOR    VRC    PRIM.ENG   AUX.ENG    ROTOR   TEMP
   VTIP       RHP         VTIP       RHP       RHP    FUEL FLOW  FUEL FLOW  CODE    DEG.      DELDCM    FMI     CPPRO    CPIND     CDC
                          (FPS)                       (LBS/HR)   (LBS/HR)           (F)

  0.033        0.0        14.6      17628.       0.        0.0   1685.7    P       1527.     1.060    0.705     2889.   0.0093    0.073
  725.0      2387.       690.0        318.       0.     1432.      95.     A        59.0     0.0      0.705  0.00011   0.0079    0.0068

  0.053        0.0        45.1      17598.       0.        0.0   1684.2    P       1524.     1.060    0.705     2881.   0.0093    0.073
  725.0      2380.       690.0        317.       0.     1429.      95.     A        59.0     0.0      0.705  0.00011   0.0079    0.0068

  0.073        0.0        75.6      17567.       0.        0.0   1682.8    P       1521.     1.060    0.705     2872.   0.0093    0.073
  725.0      2373.       690.0        316.       0.     1427.      95.     A        59.0     0.0      0.705  0.00011   0.0079    0.0068

  0.093        0.0       106.0      17537.       0.        0.0   1681.3    P       1519.     1.060    0.705     2864.   0.0093    0.072
  725.0      2367.       690.0        314.       0.     1424.      95.     A        59.0     0.0      0.705  0.00011   0.0079    0.0068

  0.113        0.0       136.4      17507.       0.        0.0   1679.9    P       1516.     1.060    0.705     2856.   0.0093    0.072
  725.0      2360.       690.0        313.       0.     1421.      95.     A        59.0     0.0      0.705  0.00011   0.0078    0.0068

  0.133        0.0       166.7      17476.       0.        0.0   1678.5    P       1513.     1.060    0.705     2848.   0.0092    0.072
  725.0      2353.       690.0        312.       0.     1418.      95.     A        59.0     0.0      0.705  0.00011   0.0078    0.0068

  0.133        0.0       166.7      17476.       0.        0.0   1678.5    P       1513.     1.060    0.705     2848.   0.0092    0.072
  725.0      2353.       690.0        312.       0.     1418.      95.     A        59.0     0.0      0.705  0.00011   0.0078    0.0068
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   CRUISE AT   170.0  KNOTS TAS, LIMITED BY  NORMAL   ENGINE RATING
                                                       PRIM.    PRIM.                    CT PRIME
 TIME      RANGE     FUEL      WEIGHT     PRES.      TAS      TURB.    ENG.     EAS      MU      OVER     ALPHA     SPEC.       BHP
 (HRS)     (N.M.)    USED      (LBS.)     ALT.       (KTS)    TEMP.    CODE     (KTS)            SIGMA    D/L       RANGE
                     (LBS)                (FT)                (R)                                         (DEG)     (NAMP)

M.ROTOR   M.ROTOR   T.ROTOR   T.ROTOR    PROF     PRIM.ENG    BHP      ETAP   AUX. ENG.  AUX.     AUX.     AUX.                  AUX.
 VTIP      RHP       VTIP      RHP       VTIP     FUEL FLOW   AUX      PROP   FUEL FLOW  TURB.    ENG.     ENG.                ENG. BHP
 (FPS)               (FPS)               (FPS)    (LBS/HR)                    (LBS/HR)   TEMP.    CODE     PERF                OR THRUST

CPPRO     CPINC     CPPAR     CPAUD      CDO      DELCDS     DELCDM    CXR       J       CP       CT       CLM       CDM         MN


0.133        0.0     166.7     17476.       0.      170.0    1604.6       P    170.0    0.396    0.046    -5.0     .10066       2545.
725.0       2216.    650.0       156.     ----      1239.     ----    0.821    400.   1679.4      P      0.620                   1119.
0.000478 0.000049 0.000265  0.000042  0.01735   0.00012   0.00933 0.000517   ----     ----     ----    0.500      0.007       0.682

0.222       15.00    315.7     17327.       0.      170.0    1602.8       P    170.0    0.396    0.046    -5.0     .10091       2534.
725.0       2206.    650.0       155.     ----      1235.     ----    0.821    400.   1679.0      P      0.619                   1119.
0.000476 0.000048 0.000265  0.000042  0.01727   0.00010   0.00527 0.000517   ----     ----     ----    0.500      0.007       0.680

0.310       30.00    464.4     17179.       0.      170.0    1600.9       P    170.0    0.396    0.045    -5.1     .10116       2523.
725.0       2195.    650.0       155.     ----      1281.     ----    0.821    400.   1678.5      P      0.618                   1119.
0.000474 0.000047 0.000265  0.000041  0.01720   0.00009   0.00521 0.000516   ----     ----     ----    0.500      0.007       0.677

0.398       45.00    612.7     17030.       0.      170.0    1599.1       P    170.0    0.396    0.045    -5.1     .10140       2512.
725.0       2185.    650.0       154.     ----      1277.     ----    0.821    399.   1678.0      P      0.618                   1119.
0.000472 0.000046 0.000268  0.000041  0.01713   0.00008   0.00515 0.000516   ----     ----     ----    0.500      0.007       0.674

0.486       60.00    760.6     16882.       0.      170.0    1597.3       P    170.0    0.396    0.044    -5.2     .10164       2501.
725.0       2175.    650.0       154.     ----      1273.     ----    0.821    399.   1677.6      P      0.617                   1119.
0.000471 0.000044 0.000268  0.000040  0.01707   0.00008   0.00509 0.000515   ----     ----     ----    0.500      0.007       0.671
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CRUISE AT SPEED FOR 99 PER CENT BEST RANGE WITH HEADWIND OF   0.0

                                                                      PRIM.     PRIM.                       CT PRIME
TIME      RANGE     FUEL      WEIGHT    PRES.                         TURB.     ENG.                         OVER     ALPHA      SPEC.
(HRS)     (N.M.)    USED      (LBS.)    ALT.       TAS                TEMP.     CODE      EAS        MU       SIGMA     C/L        RANGE        BHP
                    (LBS)               (FT)       (KTS)              (R)                 (KTS)                         (DEG)      (NM/P)

M.ROTOR   M.ROTOR   T.ROTOR   T.ROTOR   PROP      PRIM.ENG            BHP       ETAP      AUX. ENG.  AUX.     AUX.      AUX.                     AUX.
 VTIP      RHP       VTIP      RHP      VTIP      FUEL FLOW           AUX       FRCP      FUEL FLOW  TURB.    ENG.      ENG.                  ENG. BHP
 (FPS)               (FPS)              (FPS)     (LBS/HR)                                (LBS/HR)   TEMP.    CODE      PERF                  OR THRUST

CPFRC     CPINC     CPPIR     CPAUD     CDO       DELCDS              DELCDM    CXR       J          CP       CT        CLW        CDP          RN


0.597         67.95     845.5    16797.   5000.      149.1    1517.6        P     138.4    0.347    0.059      -2.8      .11667       1877.
725.0         1616.     650.0      108.   ----        994.    ----      0.826      285.   1538.1      P        0.471                   549.
0.000412 0.000092  0.000153 0.000054 0.01654    0.00021   0.00843  0.000371    ----     ----      ----       0.500      0.007        0.781

0.648         82.95     974.1    16669.   5000.      149.1    1515.6        P     138.4    0.347    0.059      -2.8      .11700       1867.
725.0         1606.     650.0      107.   ----        991.    ----      0.826      285.   1537.7      P        0.471                   548.
0.000410 0.000090  0.000152 0.000054 0.01647    0.00019   0.00837  0.000370    ----     ----      ----       0.500      0.007        0.779

0.748         97.95    1102.3    16541.   5000.      149.1    1513.6        P     138.4    0.347    0.058      -2.9      .11734       1856.
725.0         1597.     650.0      107.   ----        987.    ----      0.826      284.   1537.3      P        0.470                   547.
0.000408 0.000088  0.000152 0.000053 0.01640    0.00018   0.00832  0.000370    ----     ----      ----       0.500      0.007        0.778

0.899        112.95    1230.2    16413.   5000.      149.1    1511.6        P     138.4    0.347    0.058      -2.9      .11766       1846.
725.0         1587.     650.0      107.   ----        984.    ----      0.826      284.   1536.8      P        0.470                   547.
0.000406 0.000086  0.000152 0.000053 0.01633    0.00017   0.00826  0.000370    ----     ----      ----       0.500      0.007        0.776

0.989        127.95    1357.6    16285.   5000.      149.1    1509.7        P     138.4    0.347    0.057      -2.9      .11799       1836.
725.0         1578.     650.0      106.   ----        981.    ----      0.826      284.   1536.4      P        0.469                   546.
0.000405 0.000084  0.000152 0.000052 0.01626    0.00015   0.00821  0.000369    ----     ----      ----       0.500      0.007        0.774

1.090        142.95    1484.8    16156.   5000.      149.1    1507.7        P     138.4    0.347    0.056      -2.9      .11832       1826.
725.0         1569.     650.0      106.   ----        977.    ----      0.826      284.   1536.0      P        0.469                   546.
0.000403 0.000083  0.000152 0.000052 0.01620    0.00014   0.00815  0.000369    ----     ----      ----       0.500      0.007        0.772

1.137        150.00    1544.4    16095.   5000.      149.1    1506.8        P     138.4    0.347    0.056      -2.9      .11847       1822.
725.0         1565.     650.0      106.   ----        976.    ----      0.826      284.   1535.7      P        0.468                   545.
0.000402 0.000082  0.000152 0.000051 0.01616    0.00014   0.00813  0.000368    ----     ----      ----       0.500      0.007        0.772
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        CLIMB  TO  5000.  FT. WITH   MAXIMUM R/C  AT  NORMAL   ENGINE RAT
         ** TAS(AND EAS) IS THE HORIZONTAL COMPONENT OF THE FLIGHT PATH

                                                        PRIM.    PRIM.                            CT PRIME
                               FUEL               PRES.         TURB.    ENG.                        OVER    ALPHA
 TIME      RANGE               USED     WEIGHT    ALT.    TAS   TEMP.    CODE     EAS      MU      SIGMA    D/L    GAMMA    SHP      R/C
 (HRS)     (N.M.)              (LBS)    (LBS.)    (FT)   (KTS)  (R)               (KTS)                     (DEG)  (DEG)            (FPM)

 M.ROTOR   M.ROTOR   T.ROTOR   T.ROTOR   PROP   PRIM.ENG    SHP      ETAP   AX. ENG.   AUX.     AUX.     AUX.             AUX.
  VTIP      SHP       VTIP      SHP      VTIP   FUEL FLOW   AUX      PROP   FUEL FLOW  TURB.    ENG.     ENG.          ENG. SHP
 (FPS)               (FPS)              (FPS)   (LBS/HR)                    (LBS/HR)   TEMP.    CODE     PERF         (% INSTL.)

 CPPRO     CPINC     CPPAR     CPMUD     CDO     DELCDS     DELCDM    CXR      J        CP       CT       CLW     CDW     HN


 0.488       60.00     760.6     16882.        0.     76.4    1856.0      1      76.4    0.180    0.062     -2.4    7.3    1949.  1012.
 725.0       1111.     650.0        54.     -----     896.     -----   0.820      0.   1856.0       1     0.835                 0.
 0.000152 0.000200 0.000061 0.000011 0.00830  0.00000  0.00047 0.000332  -----    -----    -----     0.300  0.007    0.959

 0.494       60.64     768.5     16875.      500.     76.4    1856.0      1      75.7    0.180    0.064     -2.3    7.1    1926.   976.
 725.0       1123.     650.0        64.     -----     885.     -----   0.820      0.   1856.0       1     0.837                 0.
 0.000153 0.000206 0.000061 0.000011 0.00834  0.00000  0.00051 0.000333  -----    -----    -----     0.300  0.007    0.960

 0.503       61.30     775.6     16868.     1000.     76.4    1856.0      1      75.3    0.180    0.065     -2.3    6.8    1907.   939.
 725.0       1125.     650.0        63.     -----     874.     -----   0.820      0.   1856.0       1     0.838                 0.
 0.000154 0.000213 0.000061 0.000011 0.00838  0.00000  0.00055 0.000334  -----    -----    -----     0.300  0.007    0.960

 0.512       61.99     783.3     16860.     1500.     77.4    1856.0      1      75.7    0.182    0.066     -2.3    6.5    1887.   902.
 725.0       1129.     650.0        63.     -----     864.     -----   0.820      0.   1856.0       1     0.840                 0.
 0.000156 0.000216 0.000063 0.000012 0.00845  0.00000  0.00062 0.000342  -----    -----    -----     0.300  0.007    0.960

 0.521       62.71     791.3     16852.     2000.     77.4    1856.0      1      75.2    0.183    0.067     -2.3    6.2    1866.   864.
 725.0       1132.     650.0        63.     -----     853.     -----   0.820      0.   1856.0       1     0.841                 0.
 0.000157 0.000223 0.000064 0.000012 0.00850  0.00001  0.00067 0.000343  -----    -----    -----     0.300  0.007    0.960

 0.531       63.47     799.5     16844.     2500.     77.4    1856.0      1      74.6    0.183    0.068     -2.3    5.9    1846.   825.
 725.0       1135.     650.0        62.     -----     842.     -----   0.820      0.   1856.0       1     0.843                 0.
 0.000157 0.000230 0.000064 0.000012 0.00855  0.00001  0.00071 0.000344  -----    -----    -----     0.300  0.007    0.961

 0.541       64.26     808.0     16835.     3000.     78.4    1856.0      1      75.0    0.185    0.069     -2.3    5.6    1825.   786.
 725.0       1140.     650.0        62.     -----     832.     -----   0.820      0.   1856.0       1     0.844                 0.
 0.000160 0.000233 0.000066 0.000012 0.00864  0.00001  0.00080 0.000352  -----    -----    -----     0.300  0.007    0.960

 0.551       65.11     816.8     16826.     3500.     78.4    1856.0      1      74.5    0.185    0.070     -2.3    5.3    1804.   747.
 725.0       1144.     650.0        62.     -----     821.     -----   0.820      0.   1856.0       1     0.846                 0.
 0.000161 0.000240 0.000066 0.000012 0.00870  0.00001  0.00086 0.000353  -----    -----    -----     0.300  0.007    0.961

 0.563       65.59     826.5     16817.     4000.     79.4    1856.0      1      74.8    0.187    0.071     -2.3    5.0    1784.   707.
 725.0       1149.     650.0        62.     -----     811.     -----   0.820      0.   1856.0       1     0.847                 0.
 0.000163 0.000244 0.000069 0.000012 0.00881  0.00002  0.00096 0.000361  -----    -----    -----     0.300  0.007    0.961

 0.574       66.94     835.5     16807.     4500.     79.4    1856.0      1      74.3    0.187    0.072     -2.3    4.7    1763.   666.
 725.0       1153.     650.0        61.     -----     801.     -----   0.820      0.   1856.0       1     0.849                 0.
 0.000165 0.000252 0.000065 0.000012 0.00887  0.00002  0.00102 0.000362  -----    -----    -----     0.300  0.007    0.961

 0.587       67.55     845.5     16797.     5000.     79.4    1856.0      1      73.7    0.187    0.073     -2.2    4.4    1743.   626.
 725.0       1156.     650.0        61.     -----     790.     -----   0.820      0.   1856.0       1     0.850                 0.
 0.000166 0.000260 0.000065 0.000014 0.00854  0.00003  0.00109 0.000364  -----    -----    -----     0.300  0.007    0.962
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TRANSFER ALTITUDE TO    1000. FT.

                             FUEL                        PRES.
  TIME       RANGE           USED        WEIGHT          ALT.
  (HRS)      (N.M.)          (LBS)       (LBS.)          (FT)
  1.137        150.00        1544.4       16099.          5000.
  1.137        150.00        1544.4       16099.          1000.

TAKEOFF, HOVER, OR LAND AT  T/W = 1.060 FOR  0.200 HRS.

                                                                PRIM.     PRIM.   TOTAL     THRUST
                         FUEL                  PRES.            TURB.     ENG.    FUEL        TO
TIME       RANGE         USED       WEIGHT     ALT.      TAS    TEMP.     CODE    FLOW      WEIGHT     FM       SHP       CT       CT/SIGMA
(HRS)      (N.M.)        (LBS)      (LBS.)     (FT)     (KTS)   (R)               (LBS/HR)

M.ROTOR    M.ROTOR       T.ROTOR    T.ROTOR    VRC      PRIM.ENG   AUX.ENG   ACTIV   TEMP
 VTIP       RHP          VTIP        RHP       RHP      FUEL FLOW  FUEL FLOW  CODE   DEG.      DELDCP     FMI      CPPRC     CTINW      CDC
                         (FPS)                          (LBS/HR)  (LBS/HR)          (F)

1.137       150.00       1544.4      16099.    1000.       0.0     1633.1      P     1390.      1.060     0.709     2564.    0.0088     0.068
725.0        2101.        690.0       270.        0.     1298.        92.      A       55.4     0.0       0.709   0.00011    0.0071     0.0068

1.157       150.00       1572.1      16071.    1000.       0.0     1631.9      P     1387.      1.060     0.709     2538.    0.0088     0.068
725.0        2095.        690.0       269.        0.     1295.        92.      A       55.4     0.0       0.709   0.00011    0.0071     0.0068

1.177       150.00       1599.9      16043.    1000.       0.0     1630.6      F     1385.      1.060     0.709     2531.    0.0087     0.068
725.0        2090.        690.0       268.        0.     1293.        92.      A       55.4     0.0       0.709   0.00011    0.0071     0.0068

1.197       150.00       1627.6      16015.    1000.       0.0     1629.4      P     1383.      1.060     0.709     2524.    0.0087     0.068
725.0        2084.        690.0       267.        0.     1291.        92.      A       55.4     0.0       0.709   0.00011    0.0070     0.0068

1.217       150.00       1655.3      15988.    1000.       0.0     1628.2      P     1380.      1.060     0.709     2517.    0.0087     0.068
725.0        2079.        690.0       266.        0.     1288.        92.      A       55.4     0.0       0.709   0.00011    0.0070     0.0068

1.237       150.00       1682.5      15960.    1000.       0.0     1627.0      F     1378.      1.060     0.709     2511.    0.0087     0.068
725.0        2073.        690.0       265.        0.     1286.        92.      A       55.4     0.0       0.709   0.00011    0.0070     0.0068

1.257       150.00       1710.4      15933.    1000.       0.0     1625.8      F     1376.      1.060     0.709     2504.    0.0087     0.068
725.0        2067.        690.0       264.        0.     1284.        92.      A       55.4     0.0       0.709   0.00011    0.0070     0.0068

1.277       150.00       1737.5      15905.    1000.       0.0     1624.6      P     1374.      1.060     0.709     2497.    0.0087     0.068
725.0        2062.        690.0       263.        0.     1282.        92.      A       55.4     0.0       0.709   0.00011    0.0070     0.0069

1.297       150.00       1765.4      15878.    1000.       0.0     1623.4      P     1371.      1.060     0.709     2490.    0.0086     0.068
725.0        2056.        690.0       262.        0.     1279.        92.      A       55.4     0.0       0.709   0.00011    0.0069     0.0068

1.317       150.00       1792.6      15850.    1000.       0.0     1622.2      F     1369.      1.060     0.709     2484.    0.0086     0.067
725.0        2051.        690.0       261.        0.     1277.        92.      A       55.4     0.0       0.709   0.00011    0.0069     0.0068

1.337       150.00       1820.2      15823.    1000.       0.0     1621.0      F     1367.      1.060     0.709     2477.    0.0086     0.067
725.0        2045.        690.0       260.        0.     1275.        92.      A       55.4     0.0       0.709   0.00011    0.0069     0.0068

1.337       150.00       1820.2      15823.    1000.       0.0     1621.0      P     1367.      1.060     0.709     2477.    0.0086     0.067
725.0        2045.        690.0       260.        0.     1275.        92.      A       55.4     0.0       0.709   0.00011    0.0069     0.0068
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CHANGE PAYLOAD,  REMOVE    1000.  LB.

                          FUEL                    PRES.
 TIME        RANGE        USED        WEIGHT      ALT.
 (HRS)       (N.M.)       (LBS)       (LBS.)      (FT)
 1.337        150.00      1820.2       15823.     1000.
 1.347        150.00      1820.2       14823.     1000.
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        LOITER  FOR  0.500 HRS.

                                                                      PRIM.     PRIM.                         CT PRIME
                                FUEL                PRES.             TURB.     ENG.                            OVER     ALPHA     TOTAL
  TIME      RANGE               USED      WEIGHT    ALT.      TAS     TEMP.     CODE      EAS       MU         SIGMA     D/L       FUEL FLOW       BHP
  (HRS)     (N.M.)              (LBS)     (LBS.)    (FT)      (KTS)   (R)                 (KTS)                          (DEG)     (LBS/HR)

                                                                                                    AUX.       AUX.      AUX.                      AUX.
  M.ROTOR   M.ROTOR             T.ROTOR   T.ROTOR   PROP    PRIM.ENG   BHP      ETAP    AUX. ENG.   TURB.      ENG.      ENG.                  ENG. BHP
   VTIP      RHP                 VTIP      RHP      VTIP   FUEL FLOW   AUX      PROP    FUEL FLOW   TEMP.      CODE      PERF                  OR THRUST
  (FPS)                         (FPS)               (FPS)   (LBS/HR)                    (LBS/HR)

  CPFRC     CPIND     CPFAR     CPAUD     CDO       DELCDS    DELCOM    CXR       J         CP         CT        CLM       CDW           RN


  1.347       150.00    1820.2    14823.    1000.      75.6   1375.0       P      74.5     0.176      0.056      -1.5      967.          1093.
  725.0          906.    650.0       57.    ----      813.   ----     0.835     155.    1207.7        P        0.044                     55.
  0.000150  0.000162  0.000033  0.000009  0.00822   0.0      0.00039  0.000183  ----     ----       ----       0.400     0.007         0.942

  1.397       150.00    1868.6    14774.    1000.      75.6   1374.4       P      74.5     0.176      0.056      -1.5      966.          1090.
  725.0          903.    650.0       57.    ----      812.   ----     0.835     155.    1207.6        P        0.044                     55.
  0.000150  0.000160  0.000033  0.000009  0.00822   0.0      0.00038  0.000183  ----     ----       ----       0.400     0.007         0.942

  1.447       150.00    1916.5    14726.    1000.      75.6   1373.8       P      74.5     0.176      0.056      -1.5      965.          1087.
  725.0          900.    650.0       57.    ----      811.   ----     0.835     155.    1207.6        P        0.043                     55.
  0.000150  0.000159  0.000033  0.000009  0.00822   0.0      0.00038  0.000183  ----     ----       ----       0.400     0.007         0.942

  1.497       150.00    1965.2    14678.    1000.      75.6   1373.2       P      74.5     0.176      0.056      -1.5      964.          1083.
  725.0          897.    650.0       57.    ----      810.   ----     0.835     155.    1207.6        P        0.043                     55.
  0.000150  0.000158  0.000033  0.000009  0.00822   0.0      0.00038  0.000183  ----     ----       ----       0.400     0.007         0.942

  1.547       150.00    2013.4    14630.    1000.      75.6   1372.6       P      74.5     0.176      0.055      -1.5      963.          1080.
  725.0          894.    650.0       57.    ----      809.   ----     0.835     155.    1207.5        P        0.043                     55.
  0.000150  0.000157  0.000033  0.000009  0.00821   0.0      0.00038  0.000183  ----     ----       ----       0.400     0.007         0.942

  1.597       150.00    2061.6    14581.    1000.      75.6   1372.0       P      74.5     0.176      0.055      -1.5      962.          1077.
  725.0          891.    650.0       57.    ----      808.   ----     0.835     155.    1207.5        P        0.043                     55.
  0.000150  0.000156  0.000033  0.000009  0.00821   0.0      0.00038  0.000183  ----     ----       ----       0.400     0.007         0.941

  1.647       150.00    2109.7    14533.    1000.      75.6   1371.4       P      74.5     0.176      0.055      -1.5      961.          1074.
  725.0          888.    650.0       57.    ----      807.   ----     0.835     155.    1207.4        P        0.043                     55.
  0.000150  0.000155  0.000032  0.000009  0.00821   0.0      0.00037  0.000182  ----     ----       ----       0.400     0.007         0.941

  1.697       150.00    2157.7    14485.    1000.      75.6   1370.8       P      74.5     0.176      0.055      -1.5      960.          1070.
  725.0          885.    650.0       56.    ----      806.   ----     0.835     155.    1207.4        P        0.043                     54.
  0.000150  0.000154  0.000032  0.000009  0.00821   0.0      0.00037  0.000182  ----     ----       ----       0.400     0.007         0.941

  1.747       150.00    2205.7    14437.    1000.      74.6   1370.5       P      73.5     0.174      0.055      -1.5      959.          1068.
  725.0          883.    650.0       56.    ----      805.   ----     0.835     154.    1206.2        P        0.042                     53.
  0.000149  0.000155  0.000031  0.000009  0.00818   0.0      0.00035  0.000179  ----     ----       ----       0.400     0.007         0.942

  1.797       150.00    2253.7    14389.    1000.      74.6   1369.9       P      73.5     0.174      0.055      -1.5      958.          1065.
  725.0          879.    650.0       56.    ----      804.   ----     0.835     154.    1206.2        P        0.042                     53.
  0.000149  0.000154  0.000031  0.000009  0.00818   0.0      0.00035  0.000178  ----     ----       ----       0.400     0.007         0.942

  1.847       150.00    2301.6    14341.    1000.      74.6   1369.3       P      73.5     0.174      0.054      -1.5      957.          1061.
  725.0          876.    650.0       56.    ----      803.   ----     0.835     154.    1206.2        P        0.042                     53.
  0.000149  0.000153  0.000031  0.000009  0.00818   0.0      0.00034  0.000178  ----     ----       ----       0.400     0.007         0.942
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     CLIMB  TO  3000.  FT. WITH   MAXIMUM R/C  AT  NORMAL   ENGINE RAT
       ** TAS(AND EAS) IS THE HORIZONTAL COMPONENT OF THE FLIGHT PATH

                                                          PRIM.   .PRIM.                   CT PRIME
                         FUEL                 PRES.       TURB.    ENG.                     OVER    ALPHA
TIME      RANGE          USED      WEIGHT     ALT.    TAS    TEMP.    CODE     EAS     MU     SIGMA     D/L     GAMMA    BHP     R/C
(HRS)     (N.M.)         (LBS)     (LBS.)     (FT)    (KTS)  (R)               (KTS)                    (DEG)   (DEG)            (FPM)

                                                                                       AUX.    AUX.     AUX.          AUX.
M.ROTOR   M.ROTOR   T.ROTOR   T.ROTOR   PROF   PRIM.ENG    BHP      ETAP   UX. ENG.   TURB.   ENG.     ENG.        ENG. BHP
 VTIP      RHP       VTIP      RHP      VTIP   FUEL FLOW   AUX      PROP   UEL FLOW   TEMP.   CODE     PERF        OR THRUST
(FPS)               (FPS)              (FPS)  (LBS/HR)                    (LBS/HR)

CPPRO     CPIND     CPPAR     CPHUB     CDO    DELCDS      DELCDM   CXR      J       CP      CT       CLW     CDW    RA


1.847       150.00    2301.6     14341.   1000.       71.5   1856.0       T      70.5   0.165   0.055    -2.6    11.3    1905. 1469.
725.0         943.     650.0        56.   ----       874.   ----      0.820      0.   1856.0    T       0.838                0.
0.000147 0.000159 0.000054  0.000006 0.00813   0.0       0.00030 0.000317  ----   ----    ----     0.400   0.007   0.943

1.853       150.41    2306.6     14336.   1500.       71.5   1856.0       T      69.9   0.165   0.055    -2.6    11.0    1884. 1429.
725.0         943.     650.0        57.   ----       863.   ----      0.820      0.   1856.0    T       0.840                0.
0.000147 0.000164 0.000054  0.000006 0.00815   0.0       0.00033 0.000318  ----   ----    ----     0.400   0.007   0.946

1.859       150.83    2311.6     14331.   2000.       72.5   1856.0       T      70.4   0.171   0.056    -2.6    10.6    1864. 1389.
725.0         945.     650.0        57.   ----       852.   ----      0.820      0.   1856.0    T       0.841                0.
0.000149 0.000166 0.000056  0.000005 0.00820   0.0       0.00038 0.000326  ----   ----    ----     0.400   0.007   0.945

1.865       151.28    2316.7     14326.   2500.       72.5   1856.0       T      69.9   0.171   0.057    -2.6    10.3    1843. 1349.
725.0         946.     650.0        57.   ----       842.   ----      0.820      0.   1856.0    T       0.843                0.
0.000149 0.000171 0.000057  0.000005 0.00823   0.0       0.00041 0.000327  ----   ----    ----     0.400   0.007   0.946

1.871       151.73    2321.9     14321.   3000.       72.5   1856.0       T      69.4   0.171   0.058    -2.5    10.0    1823. 1308.
725.0         947.     650.0        56.   ----       831.   ----      0.820      0.   1856.0    T       0.844                0.
0.000150 0.000177 0.000057  0.000005 0.00826   0.0       0.00044 0.000328  ----   ----    ----     0.400   0.007   0.947
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     CRUISE AT SPEED FOR 99 PER CENT BEST RANGE WITH HEADWIND OF    0.0

                                                             PRIM.    PRIM.                      CT PRIME
                       FUEL                 PRES.            TURB.    ENG.                          OVER     ALPHA
TIME      RANGE        USED      WEIGHT     ALT.     IAS     TEMP.    CODE     EAS       MU         SIGMA     D/L       SPEC.       BHP
(HRS)     (N.M.)       (LBS)     (LBS.)     (FT)     (KTS)   (R)               (KTS)                          (DEG)     RANGE
                                                                                                                      (NMPP)

                                                                                        AUX.      AUX.      AUX.                   AUX.
M.ROTOR   M.ROTOR    T.ROTOR   T.ROTOR    PROF    PRIM.ENG    BHP     ETAP     AX. ENG.  TURB.     ENG.      ENG.                ENG. BHP
 VTIP      RHP        VTIP      RHP       VTIP    FUEL FLOW   AUX     PROP     FUEL FLOW TEMP.     CODE      PERF                OR THRUST
(FPS)                 (FPS)               (FPS)   (LBS/HR)                     (LBS/HR)

CPPRO     CPINC      CPFAR     CPNUD      CDO      DELCOS    DELCDM    CXR       J        CP        CT        CLW       CDW         RN


1.871         151.73    2321.5     14321.   3000.     150.1   1460.1      P     143.6    0.345     0.044     -2.8     .11817      1613.
725.0          1367.     650.0      100.    ----       937.   ----     0.826    335.    1609.1      P        0.547                  672.
0.000361 0.000050  0.000114   0.000041 0.01443  0.00001  0.00652 0.000273   ----     ----      ----      0.500     0.007       0.723

1.971         166.73    2448.5     14194.   3000.     150.1   1458.7      P     143.6    0.345     0.044     -2.8     .11842      1605.
725.0          1360.     650.0      100.    ----       934.   ----     0.826    334.    1608.7      P        0.547                  672.
0.000360 0.000049  0.000114   0.000040 0.01438  0.00001  0.00647 0.000273   ----     ----      ----      0.500     0.007       0.721

2.071         181.73    2575.5     14067.   3000.     150.1   1457.3      P     143.6    0.345     0.043     -2.8     .11867      1597.
725.0          1353.     650.0      100.    ----       932.   ----     0.826    334.    1608.2      P        0.546                  671.
0.000359 0.000048  0.000113   0.000040 0.01434  0.00001  0.00643 0.000273   ----     ----      ----      0.500     0.007       0.718

2.171         196.73    2701.5     13941.   3000.     150.1   1455.9      P     143.6    0.345     0.042     -2.9     .11892      1590.
725.0          1346.     650.0       99.    ----       929.   ----     0.826    334.    1607.7      P        0.546                  670.
0.000357 0.000047  0.000113   0.000039 0.01429  0.00000  0.00639 0.000272   ----     ----      ----      0.500     0.007       0.716

2.271         211.73    2828.1     13815.   3000.     150.1   1454.6      P     143.6    0.345     0.042     -2.9     .11917      1582.
725.0          1339.     650.0       99.    ----       927.   ----     0.826    334.    1607.2      P        0.545                  670.
0.000356 0.000045  0.000113   0.000039 0.01425  0.00000  0.00634 0.000272   ----     ----      ----      0.500     0.007       0.713

2.371         226.73    2953.5     13689.   3000.     150.1   1453.2      P     143.6    0.345     0.041     -2.9     .11941      1575.
725.0          1332.     650.0       99.    ----       925.   ----     0.826    333.    1606.8      P        0.544                  669.
0.000355 0.000044  0.000113   0.000038 0.01420  0.00000  0.00630 0.000272   ----     ----      ----      0.500     0.007       0.711

2.471         241.73    3079.6     13563.   3000.     150.1   1451.9      P     143.6    0.345     0.041     -3.0     .11966      1568.
725.0          1325.     650.0       99.    ----       922.   ----     0.826    333.    1606.3      P        0.544                  668.
0.000354 0.000043  0.000113   0.000038 0.01416  0.00000  0.00626 0.000271   ----     ----      ----      0.500     0.007       0.708

2.571         256.73    3204.5     13438.   3000.     150.1   1450.6      P     143.6    0.349     0.040     -3.0     .11990      1561.
725.0          1318.     650.0       99.    ----       920.   ----     0.826    333.    1605.8      P        0.543                  667.
0.000353 0.000042  0.000113   0.000037 0.01412  0.00000  0.00622 0.000271   ----     ----      ----      0.500     0.007       0.705

2.670         271.73    3330.0     13313.   3000.     150.1   1449.3      P     143.6    0.349     0.040     -3.0     .12015      1553.
725.0          1312.     650.0       98.    ----       918.   ----     0.826    333.    1605.3      P        0.543                  667.
0.000352 0.000041  0.000113   0.000037 0.01408  0.00000  0.00617 0.000271   ----     ----      ----      0.500     0.007       0.703

2.770         286.73    3454.5     13188.   3000.     150.1   1448.0      P     143.6    0.349     0.039     -3.1     .12038      1546.
725.0          1305.     650.0       98.    ----       916.   ----     0.826    332.    1604.9      P        0.542                  666.
0.000351 0.000040  0.000113   0.000036 0.01403  0.00000  0.00613 0.000271   ----     ----      ----      0.500     0.007       0.700

2.859         300.00    3565.1     13078.   3000.     150.1   1446.9      P     143.6    0.345     0.039     -3.1     .12060      1540.
725.0          1259.     650.0       98.    ----       914.   ----     0.826    332.    1604.5      P        0.542                  665.
0.000350 0.000039  0.000112   0.000036 0.01400  0.00000  0.00610 0.000270   ----     ----      ----      0.500     0.007       0.697
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      LOITER  FOR  0.250 HRS. FOR RESERVE FUEL

                                                              PRIM.     PRIM.                    CT PRIME
                         FUEL                  PRES.          TURB.     ENG.                      OVER     ALPHA      TOTAL
 TIME      RANGE         USED      WEIGHT      ALT.      IAS    TEMP.     CODE      EAS     MU      SIGMA      D/L     FUEL FLOW     BHP
 (HRS)     (N.M.)        (LBS)     (LBS.)      (FT)     (KTS)   (R)                 (KTS)                    (DEG)    (LBS/HR)

                                                                                          AUX.    AUX.      AUX.
 M.ROTOR   M.ROTOR     T.ROTOR    T.ROTOR    PROP   PRIM.ENG     BHP      ETAP    UX. ENG.  TURB.   ENG.      ENG.                   AUX.
  VTIP      RHP         VTIP       RHP       VTIP   FUEL FLOW    AUX      PRCP    UEL FLOW  TEMP.   CODE      PEHF               ENG. BHP
 (FPS)                 (FPS)                 (FPS)  (LBS/HR)                      (LBS/HR)                                      OR THRUST

 CPFRO     CPIND       CPPAR      CPNUD      CDO     DELCDS      DELCDM    CXR       J       CP      CT        CLM       CDM       RN


 2.859       300.00     3565.1     13078.    3000.       73.1    1361.3      P      69.9    0.170   0.053     -2.2       835.      1022.
 725.0         841.      650.0        53.    ----        758.    ----     0.835     78.    852.1     P       0.0                    0.
 0.000148 0.000146 0.000045   0.000008 0.00820   0.0       0.00037 0.000264  ----    ----    ----     0.400      0.007     0.943

 2.909       300.00     3606.5     13036.    3000.       73.1    1360.9      P      69.9    0.170   0.052     -2.3       835.      1019.
 725.0         839.      650.0        53.    ----        757.    ----     0.835     78.    852.1     P       0.0                    0.
 0.000148 0.000145 0.000045   0.000008 0.00820   0.0       0.00037 0.000264  ----    ----    ----     0.400      0.007     0.942

 2.959       300.00     3648.6     12994.    3000.       73.1    1360.3      P      69.9    0.170   0.052     -2.3       834.      1017.
 725.0         836.      650.0        53.    ----        756.    ----     0.835     78.    852.1     P       0.0                    0.
 0.000148 0.000144 0.000045   0.000008 0.00820   0.0       0.00036 0.000263  ----    ----    ----     0.400      0.007     0.942

 3.009       300.00     3690.3     12953.    3000.       73.1    1359.7      P      69.9    0.170   0.052     -2.3       833.      1014.
 725.0         833.      650.0        53.    ----        755.    ----     0.835     78.    852.1     P       0.0                    0.
 0.000149 0.000143 0.000045   0.000008 0.00820   0.0       0.00036 0.000263  ----    ----    ----     0.400      0.007     0.942

 3.059       300.00     3731.5     12911.    3000.       73.1    1359.2      P      69.9    0.170   0.052     -2.3       832.      1011.
 725.0         831.      650.0        53.    ----        755.    ----     0.835     78.    852.1     P       0.0                    0.
 0.000148 0.000142 0.000045   0.000008 0.00820   0.0       0.00036 0.000263  ----    ----    ----     0.400      0.007     0.942

 3.109       300.00     3773.5     12869.    3000.       72.1    1358.6      P      69.0    0.168   0.052     -2.2       831.      1008.
 725.0         828.      650.0        53.    ----        754.    ----     0.835     78.    852.1     P       0.0                    0.
 0.000147 0.000144 0.000044   0.000007 0.00817   0.0       0.00034 0.000258  ----    ----    ----     0.400      0.007     0.943

                   MISSION FUEL REQUIRED =  3565.08
                   RESERVE FUEL REQUIRED =   208.46
                   TOTAL   FUEL REQUIRED =  3773.53

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