KING FAHD UNIVERSITY OF PETROLEUM & MINERALS

Aerospace Engineering Department

AE 499: Fundamentals of Helicopters

TERM PROJECT

Bell Helicopter model 407 Specifications

Total gross weight = 5250 lb.

Cruising speed is 120 knot = 203 ft/s

Fuel capacity = 127.8 US Gallon = 17.0844 ft^3

Maximum engine power output capacity = 674 hp. (P_{av})

Engine power at forward level flight =630 hp. (P_{level})

Distance between axes of rotation of the main and tail rotors = 23.05 ft.

Assumptions Made

Drag coefficient, C_{do} = 0.008.

Lift curve slope, a = 5.7.

Empirical correction factors, k = 1.15 and K = 4.7

Assume moment of inertia of helicopter is, I = 4000 lb-ft2

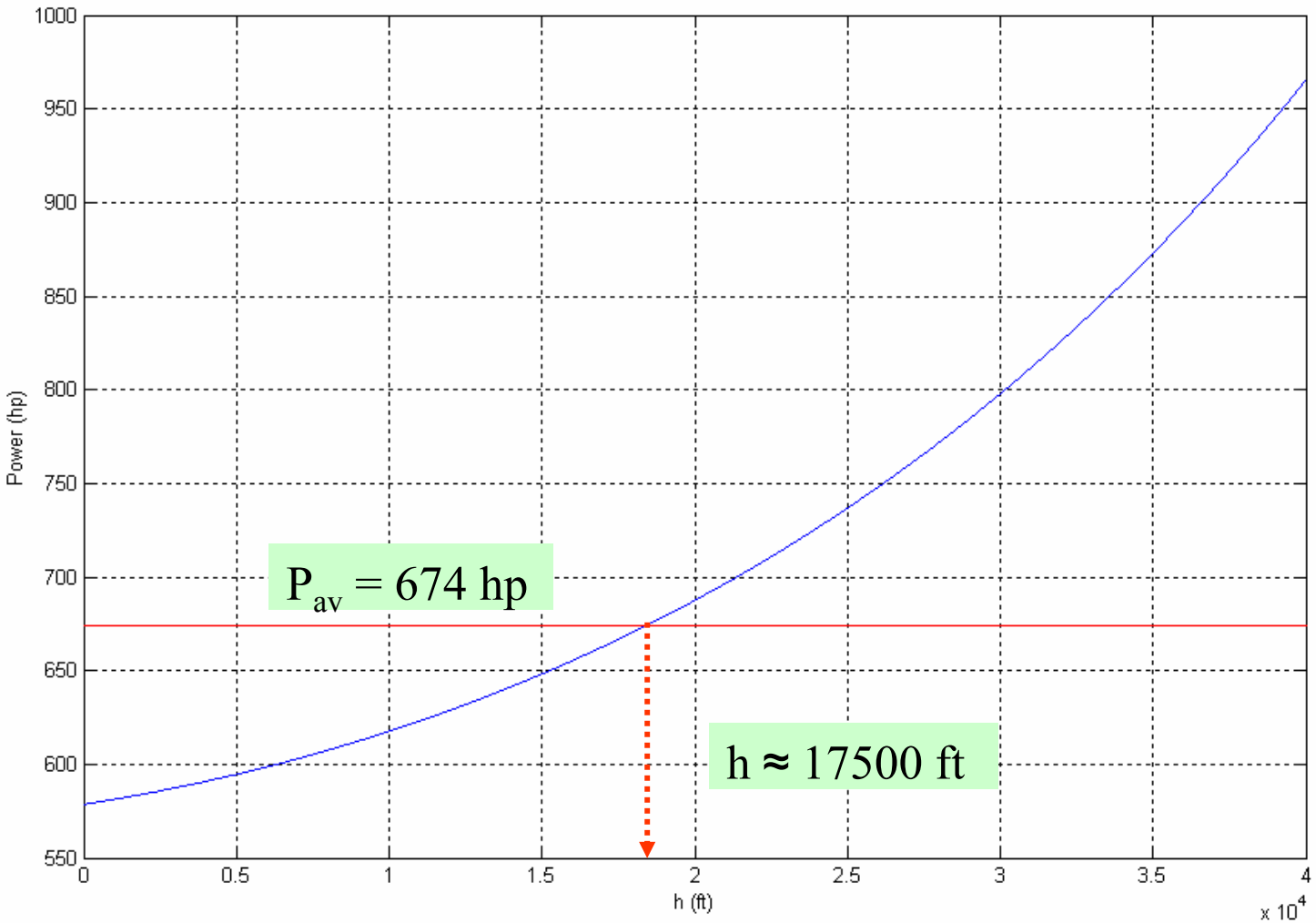
Fuel weight, W =870 lb

(assume fuel is Kerosene ρ = 50.9 lb/ft3)

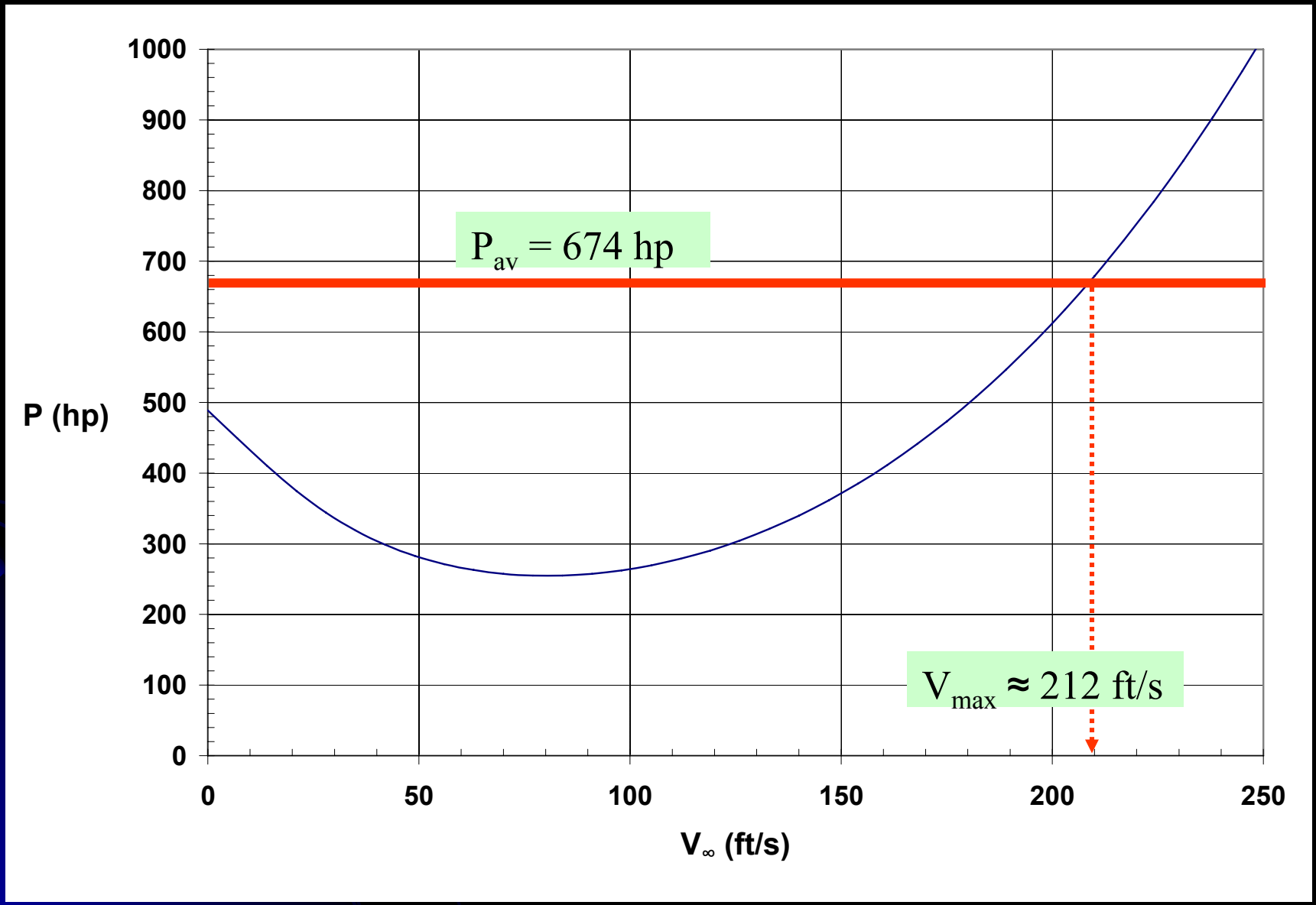
Transmission loss, 100 (1-630/701) =10 %

Specific fuel onsumption, SFC = 0.4

Hover ceiling



Maximum forward speed at sea level



Speed For Maximum Endurance

$$E = W_f \left[\frac{1}{P \times SFC} \right]_{W_{GTOW}} - \frac{W_f}{2}$$

$$= 870 \left[\frac{1}{(588)(550) \times 2.064 \times 10^{-7}} \right] - \frac{870}{2}$$

$$= 12599 \text{ s}$$

$$= 3.5 \text{ hr}$$

Speed For Maximum Range

$$R = W_f \left[\frac{V_\infty}{P \times SFC} \right]_{W_{GTOW}} - \frac{W_f}{2}$$

$$= 870 \left[\frac{125}{(305)(550) \times 2.064 \times 10^{-7}} \right] - \frac{870}{2}$$

$$= 3140486.2 \text{ ft}$$

$$= 595 \text{ mile}$$

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$$= 3140486.2 \text{ ft}$$

$$= 595 \text{ mile}$$

Maximum rate of climb

$$\max(V_c) = \frac{P_{av} - \min(P_{level})}{T} = \frac{P_{av} - P_{\min}}{T \approx W} = \frac{(674 - 171) \times 550}{5250} = 52.7 \text{ ft/s}$$

Minimum descent rate

$$C_p = \frac{kC_w^2}{2\mu} + \frac{1}{2}\frac{f}{A}\mu^3 + \frac{\sigma C_{d_o}}{8}\left(1 + K\mu^2\right) + C_w\lambda_c = 0$$

$$\lambda_c = -\frac{kC_W}{2\mu} - \frac{1}{2C_W}\frac{f}{A}\mu^3 - \frac{\sigma C_{d_o}}{8C_W}\left(1 + K\mu^2\right)$$

$$\frac{d\lambda_c}{d\mu} = 0$$

$$V_D = \lambda_{c.\min} V_{Tm} = -31.68 \text{ ft/s}$$

Minimum descent angle

$$\frac{d\left(\lambda_c/\mu\right)}{d\mu}=0$$

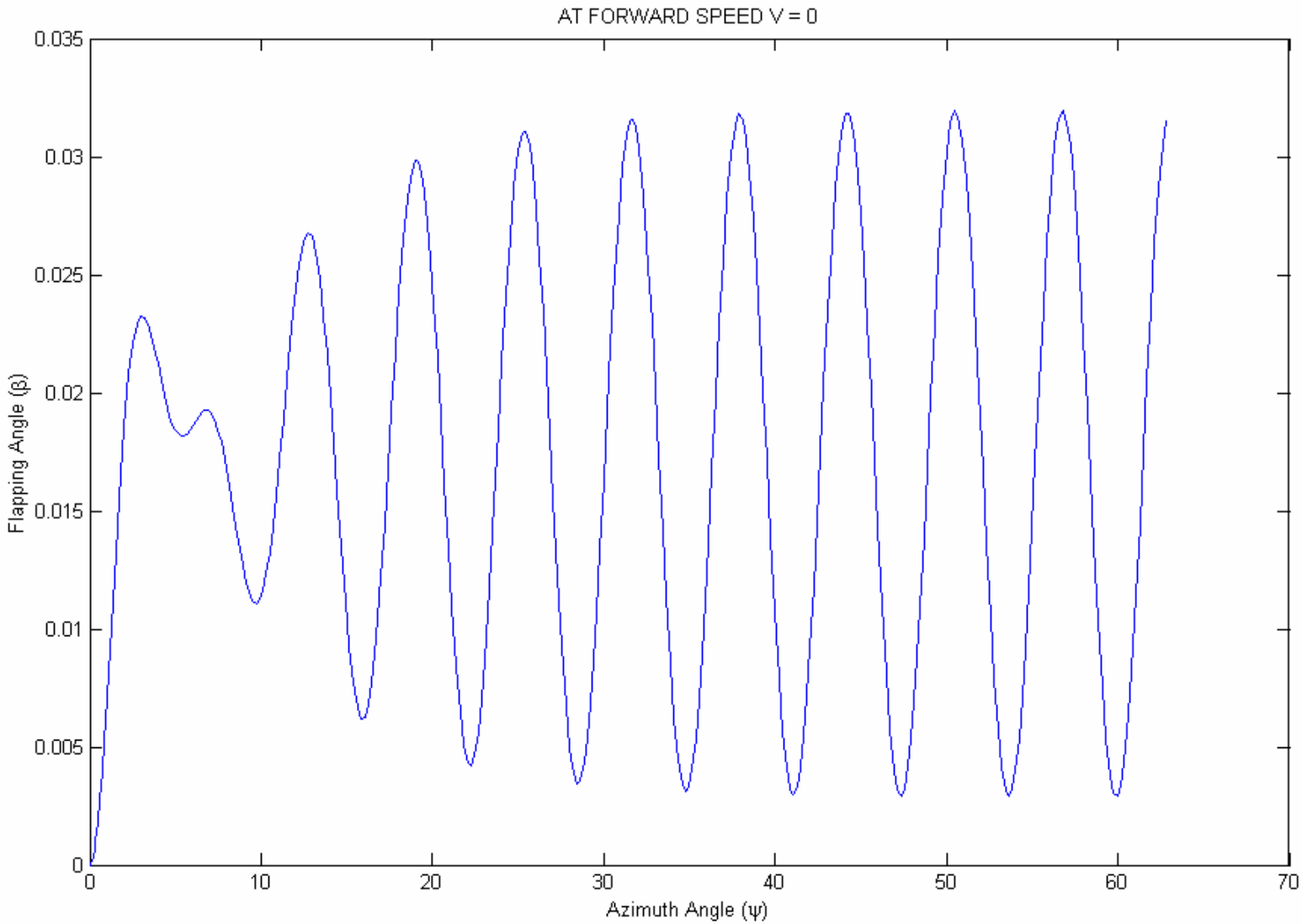
$$\alpha=\left|\frac{\lambda_c}{\mu}\right|=\left|-0.27952\right|=0.27952\ \text{rad}=16^0$$

Flapping response

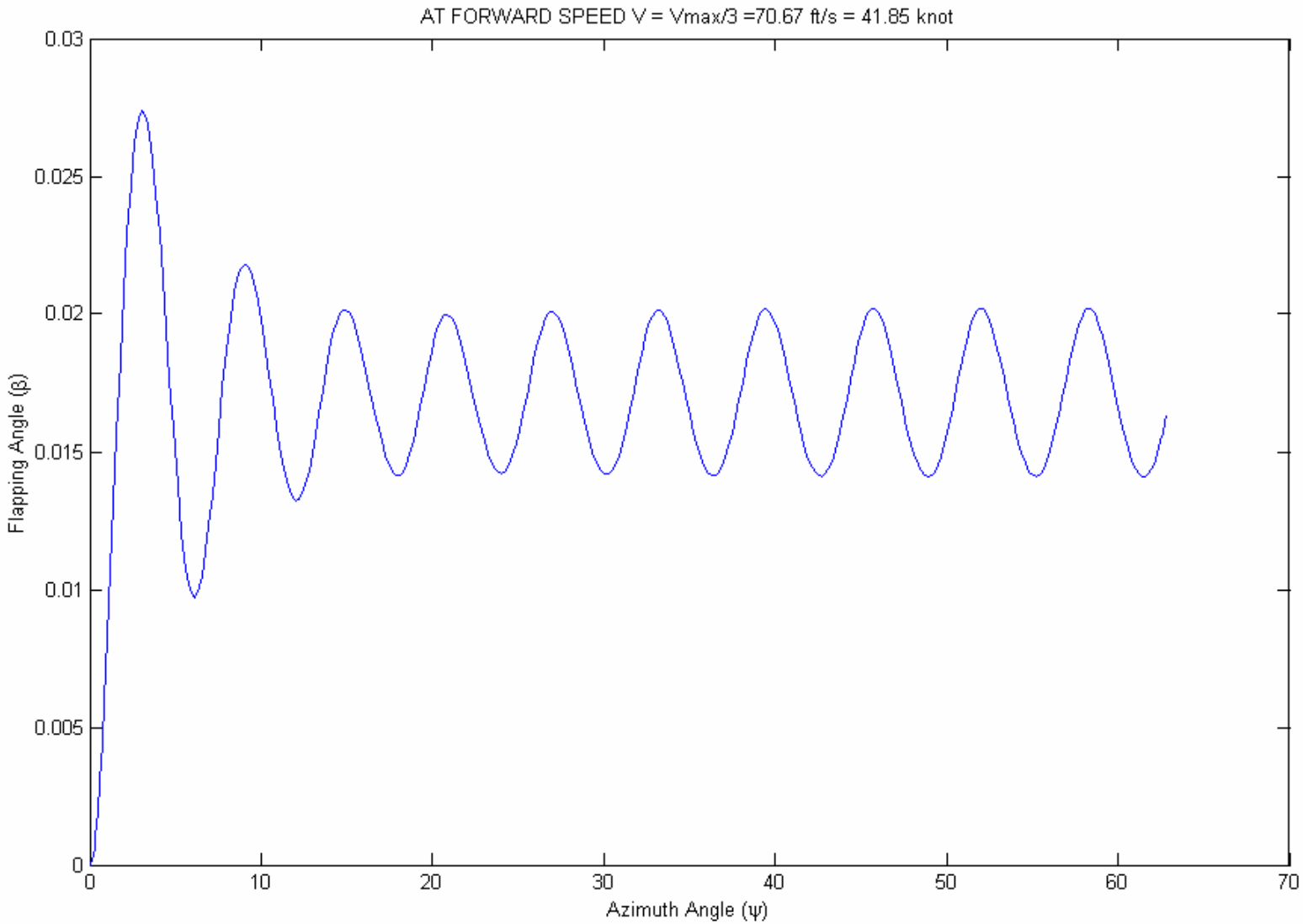
$$\overset{**}{\beta}+\gamma\left(1+\frac{4}{3}\mu\sin(\psi)\right)\overset{*}{\beta}+\left[1+\gamma\mu\cos(\psi)\left(\frac{1}{6}+\frac{\mu}{4}\sin(\psi)\right)\right]\quad \beta=\gamma\, f_h(\psi)$$

$$f_h(\psi)=\frac{1}{240}[30\theta_0+24\theta_{tw}-40\lambda+40\theta_{1s}\mu+30\theta_0\mu^2+20\theta_{tw}\mu^2+15\theta_{1c}(2+\mu^2)\cos\psi-$$
$$10\mu(4\theta_{1s}+3\theta_0\mu+2\theta_{tw}\mu)\cos 2\psi-15\theta_{1c}\mu^2\cos 3\psi+30\theta_{1s}\sin\psi+80\theta_0\mu\sin\psi$$
$$60\theta_{tw}\mu\sin\psi-60\lambda\mu\sin\psi+45\theta_{1s}\mu^2\sin\psi+40\theta_{1c}\mu\sin 2\psi-15\theta_{1s}\mu^2\sin 3\psi]$$

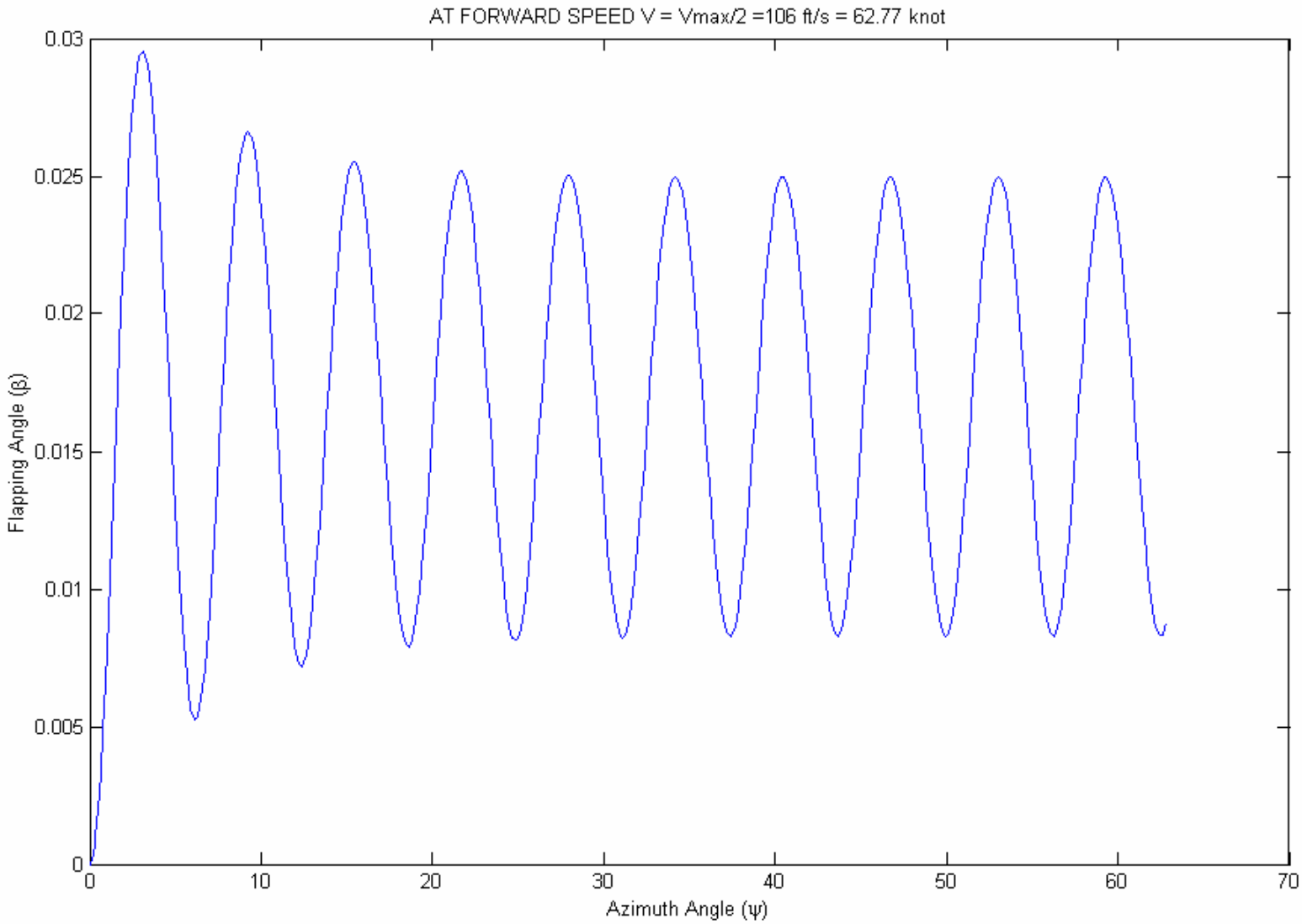
$V_\infty = 0$ ft/s


AT FORWARD SPEED V = 0
Flapping Angle (β)
Azimuth Angle (ψ)
0.035
0.03
0.025
0.02
0.015
0.01
0.005
0
0
10
20
30
40
50
60
70

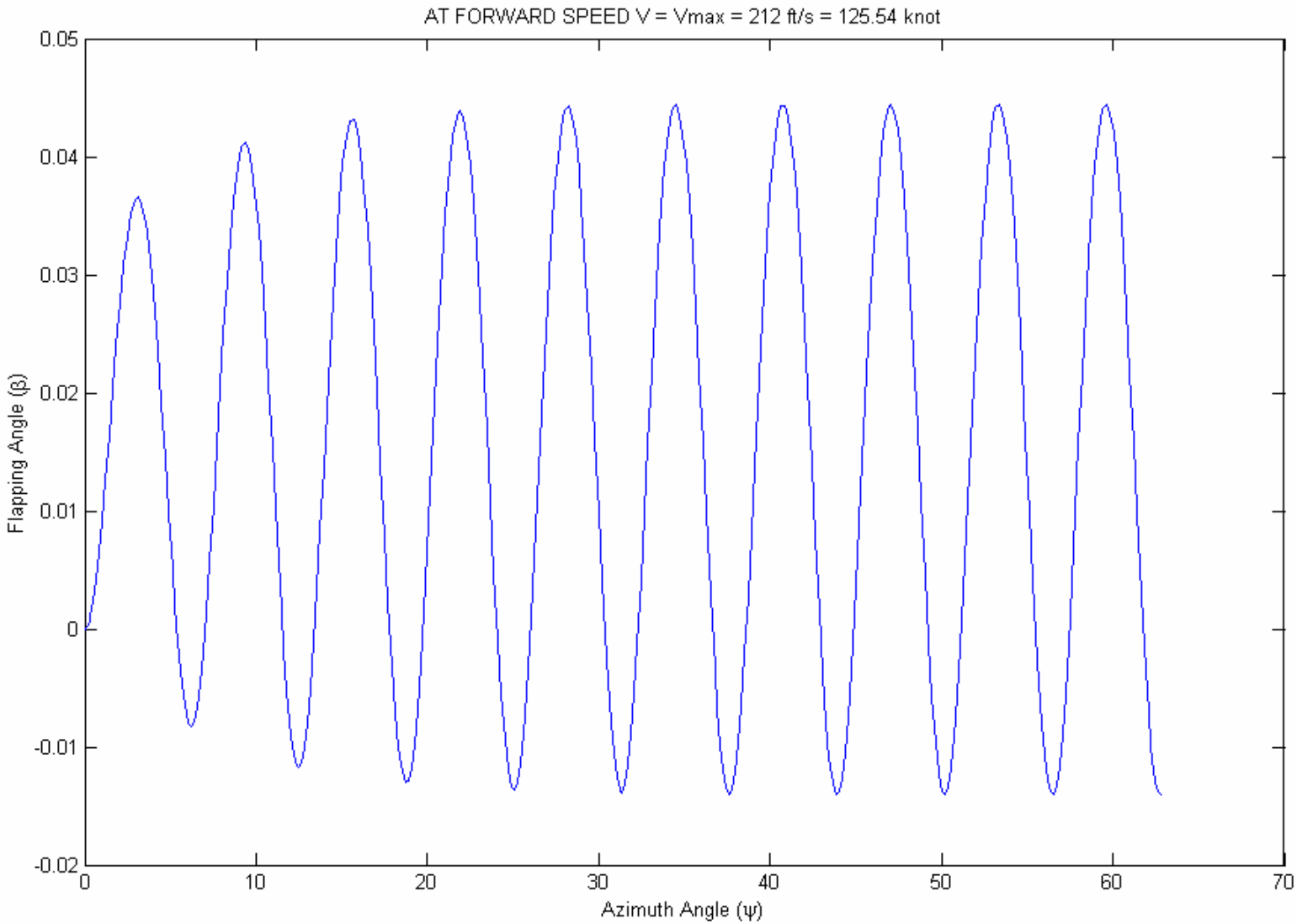
$$V_\infty = \frac{V_{\max}}{3} = \frac{212}{3} = 70.67 \text{ ft/s} = 41.85 \text{ knot}$$

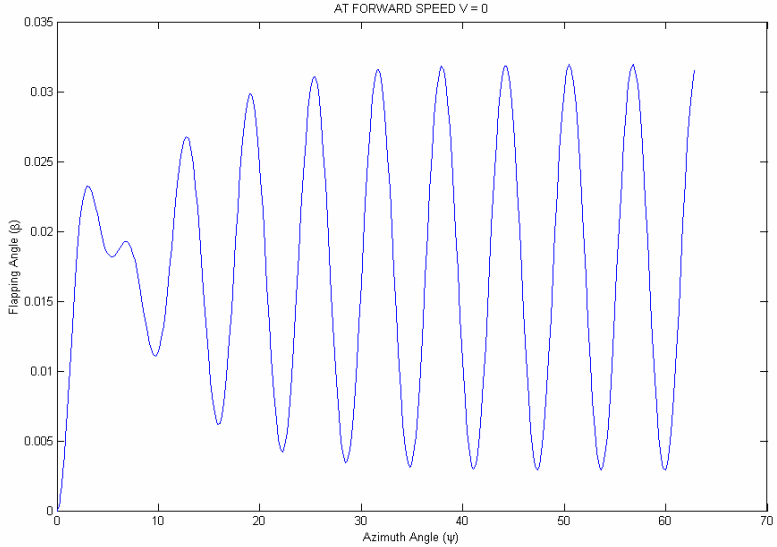


$$V_\infty = \frac{V_{max}}{2} = \frac{212}{2} = 106 \text{ ft/s} = 62.77 \text{ knot}$$



$$V_{\infty} = V_{\max} = 212 \text{ ft/s} = 125.54 \text{ knot}$$

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0.035
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0.025
0.02
0.015
0.01
0.005
0
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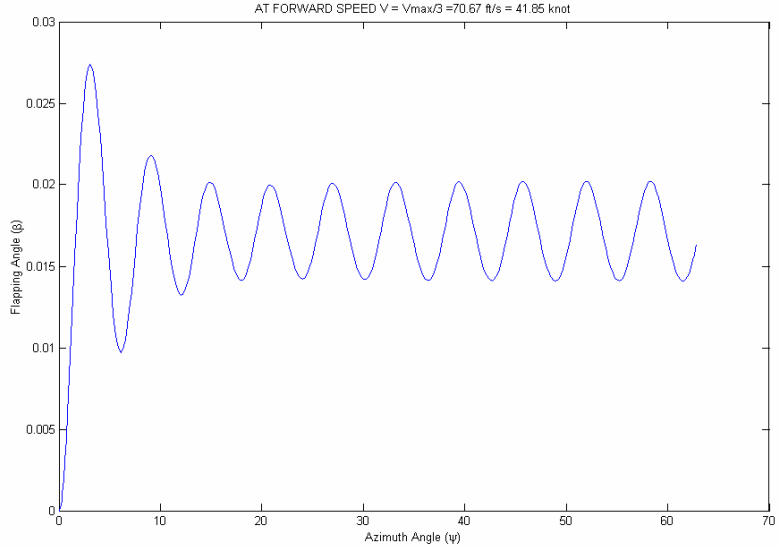
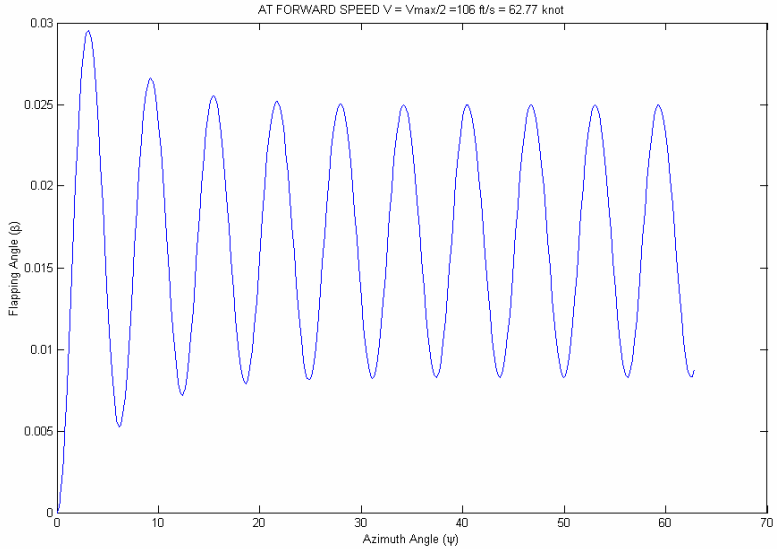
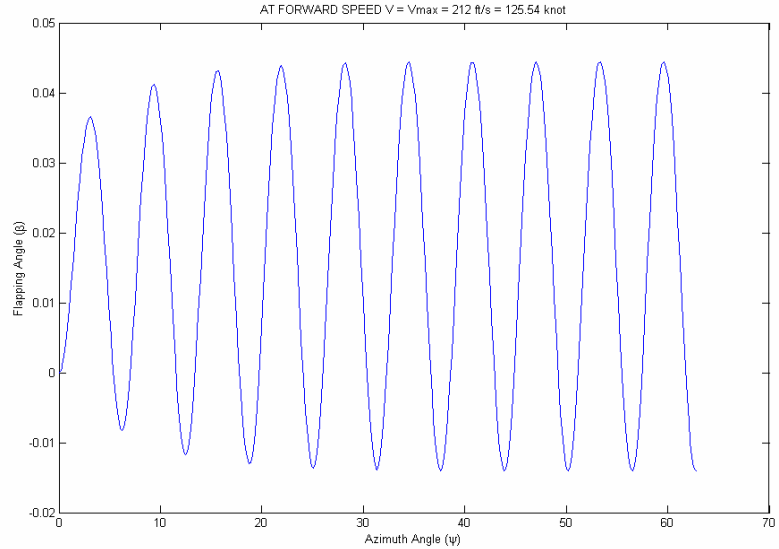
70


AT FORWARD SPEED V = Vmax/3 =70.67 ft/s = 41.85 knot
Flapping Angle (β)
Azimuth Angle (ψ)
0.03
0.025
0.02
0.015
0.01
0.005
0
0
10
20
30
40
50
60
70


AT FORWARD SPEED V = Vmax/2 =106 ft/s = 62.77 knot
Flapping Angle (β)
Azimuth Angle (ψ)
0.03
0.025
0.02
0.015
0.01
0.005
0
0
10
20
30
40
50
60
70


AT FORWARD SPEED V = Vmax = 212 ft/s = 125.54 knot
Flapping Angle (β)
Azimuth Angle (ψ)
0.05
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0.03
0.02
0.01
0
-0.01
-0.02
0
10
20
30
40
50
60
70

Comparison

	Calculated results	Actual results	% Error
Hover ceiling	17,500 ft	16,050 ft	9 %
Maximum forward speed	212 ft/s	132 knot = 223 ft/s	5 %
Velocity of maximum endurance	95 ft/s	Not given	
Velocity of maximum range	125 ft/s	Not given	
Maximum endurance	3.5 hr	3.7 hr	5.4 %
Maximum range	595 mile	Not given	
Range at V_∞ = 121 knot = 204 ft/s	460 mile	326 nm = 377 mile	22 %
Maximum rate of climb	52.7 ft/s	Not given	
Minimum descent rate	-31.67 ft/s	Not given	
Minimum descent angle	16^o	Not given	