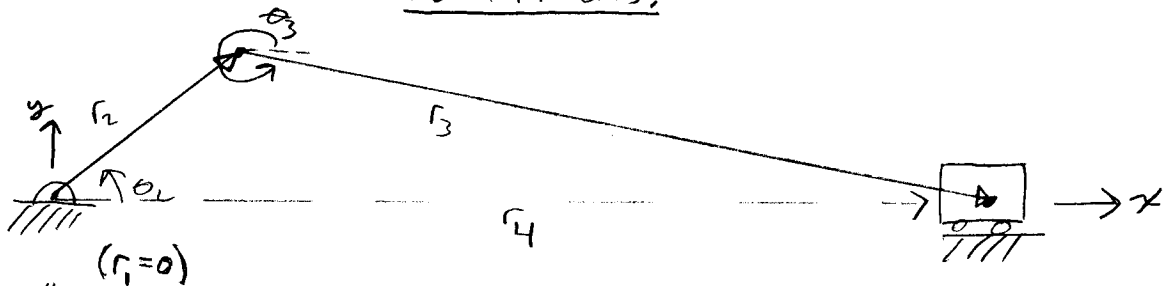


Assume:

- Assume 3900 RPM for engine and 120" MAP
- 13" dia. prop x 117.5" pitch
- Prop shaft speed = 12,000 RPM
- Fuel \approx 6 lb/gal
- Air @ STP $\therefore \rho = 0.075 \text{ lb}_m/\text{ft}^3$
- 3800 HP
- Blower serv: 6,390:1 ; Gearbox 3:1

Piston Parameters:



$r_2 = 3''$

$r_3 = 10''$

$\dot{\theta}_2 = 3900 \frac{\text{rev}}{\text{min}} \times \frac{2\pi}{\text{rev}} \times \frac{1 \text{ min}}{60 \text{ s}} = \underline{\underline{408 \text{ rad/sec}}}$

$\ddot{\theta}_2 = 0$

Vector-loop Sol'n:

from Hull's Text, Purdue Univ. Mech. Engr

eq. 7 ps 1.17 $\rightarrow r_4 = r_2 \cos \theta_2 \pm \sqrt{r_2^2 \cos^2 \theta_2 - r_1^2 - r_2^2 + r_3^2 - 2r_1 r_2 \sin \theta_2}$] Pos (1)

eq. 11 ps 1.17 $\rightarrow \sin \theta_3 = (-r_2 \sin \theta_2 - r_1) / r_3$] (2)

eq. 5 ps 1.17 $\rightarrow (-r_3 \sin \theta_3) \dot{\theta}_3 - \dot{r}_4 = r_2 \dot{\theta}_2 \sin \theta_2$] vel (3)

eq. 6 ps 1.17 $\rightarrow (r_3 \cos \theta_3) \dot{\theta}_3 = -r_2 \dot{\theta}_2 \cos \theta_2$] (4)



$$\text{eq. 9 ps 1.20} \rightarrow (-r_3 \sin \theta_3) \ddot{\theta}_3 - \dot{r}_4 = r_2 \ddot{\theta}_2 \sin \theta_2 + r_2 \dot{\theta}_2^2 \cos \theta_2 + r_3 \dot{\theta}_3^2 \cos \theta_3 \quad (5)$$

$$\text{eq 10 ps 1.20} \rightarrow (r_3 \cos \theta_3) \ddot{\theta}_3 = -r_2 \ddot{\theta}_2 \cos \theta_2 + r_2 \dot{\theta}_2^2 \sin \theta_2 + r_3 \dot{\theta}_3^2 \sin \theta_3 \quad (6)$$

∴ from (1), (2)

$$r_4 = r_2 \cos \theta_2 + \sqrt{r_2^2 \cos^2 \theta_2 - r_1^2 - r_2^2 + r_3^2 - 2r_1 r_2 \sin \theta_2} \quad (7)$$

$$\theta_3 = \sin^{-1} \left(-\frac{(r_2 \sin \theta_2 - r_1)}{r_3} \right) \quad (8)$$

from (4):

$$\dot{\theta}_3 = \frac{-r_2 \dot{\theta}_2 \cos \theta_2}{r_3 \cos \theta_3} \quad (9)$$

from (5):

$$\dot{r}_4 = -r_3 \sin \theta_3 - r_2 \dot{\theta}_2 \sin \theta_2 \quad (10)$$

from (6)

$$\ddot{\theta}_3 = \frac{-r_2 \ddot{\theta}_2 \cos \theta_2 + r_2 \dot{\theta}_2^2 \sin \theta_2 + r_3 \dot{\theta}_3^2 \sin \theta_3}{r_3 \cos \theta_3} \quad (11)$$

from (5)

$$\ddot{r}_4 = -\left[r_3 \ddot{\theta}_3 \sin \theta_3 + r_2 \ddot{\theta}_2 \sin \theta_2 + r_2 \dot{\theta}_2^2 \cos \theta_2 + r_3 \dot{\theta}_3^2 \cos \theta_3 \right] \quad (12)$$

eq 7-12 → Matlab for sol'n

Max velocity = 70 MPH

max accel ≈ 1500 g @ 0°
900 g @ 180°

Avg. velocity = 44 MPH

Revolutions:

$$3900 \frac{\text{rev}}{\text{min}} \times \frac{1 \text{ min}}{60 \text{ sec}} = \boxed{65 \text{ rev}}$$

Values:

Each valve \rightarrow avg. over revolution $\therefore \frac{65}{2} \approx \boxed{33 \text{ openings}}$

All valves: $32.5 \times 8 = \boxed{1560 \text{ openings}}$

Sparkplugs

$$\text{Every other rev.} \therefore \frac{65}{2} \times 24 = \boxed{780 \times}$$

↑
plugs

- or -

Each plug fires $\boxed{33 \text{ times}}$

Piston Travel

$$65 \text{ rev} \times \frac{(6 \times 2) \text{ in}}{\text{rev}} = 780 \text{ in} \times \frac{1 \text{ ft}}{12 \text{ in}} = \boxed{65 \text{ ft}}$$

Direction reversals/rev = 2 $\therefore \Delta \text{ dir} \rightarrow \boxed{130 \text{ times}}$ (over 6")

Acceleration about $\frac{1}{2} 1000 \text{ g's}$

Power Pulses

$\frac{1}{2}$ Cylinders fire on each revolution

$$\therefore 12 \text{ cyl. of } 65 \text{ rev} \rightarrow 6 \times 65 = \boxed{390 \text{ Pulses}}$$

Blower Tip Speed:

$$3900 \text{ RPM} \times 6.39 = 24,921 \frac{\text{rev}}{\text{min}}$$

$$\text{Circ} = \pi D = \pi (12") = 37.7 \frac{\text{m}}{\text{sec}} = \pi \frac{\text{ft}}{\text{sec}} \text{ for } 1^{\text{st}} \text{ Stage}$$



$$V_t = \omega r$$

$$\omega = \text{RPM} \rightarrow \frac{\text{rev}}{\text{sec}} : 24921 \frac{\text{rev}}{\text{min}} \times \frac{2\pi}{60} = 830.7\pi \frac{\text{rev}}{\text{sec}}$$

$$V_t = \underbrace{(830.7\pi)}_{\frac{\text{in}}{\text{sec}}} \left(\frac{12}{2}\right) \cdot \frac{1}{12} = \underline{1305 \frac{\text{ft}}{\text{sec}}} = 890 \text{ MPH} \approx$$

$$C = 761 \text{ MPH @ STP} \Rightarrow M = \frac{V}{C} = \frac{890}{761} = \boxed{1.17 M}$$

Blower revs / Tip travel

$$24921 \frac{\text{rev}}{\text{min}} \times \frac{1 \text{ min}}{60 \text{ s}} = \boxed{415 \text{ rev}}$$

$$C_{\text{rev}} = \pi \text{ ft/rev} \therefore 415\pi \frac{\text{ft}}{\text{rev}} = \boxed{1304 \text{ ft} \approx 4 \frac{1}{3} \text{ football fields}}$$

Air Flow

$$120 \text{ "Hg} = \boxed{4 \times \text{atmosphere}}$$

$$23,500 \frac{\text{lb}}{\text{hr}} \times \frac{1 \text{ hr}}{3600 \text{ s}} \times \frac{1 \text{ ft}^3}{0.07516} = \boxed{86 \text{ ft}^3}$$

Average human inhalation $\approx 0.5 \text{ L} = 0.02 \text{ ft}^3 \therefore \Rightarrow 4870 \text{ human breaths}$

Average human $\approx 20 \text{ breaths/minute} \Rightarrow 244 \text{ minutes} \approx \underline{4 \text{ hrs}}$

\therefore In 1 sec, Merlin breathes as much air as a human in 4 hrs

$$23,500 \frac{\text{lb}}{\text{hr}} \times \frac{1 \text{ hr}}{3600 \text{ s}} = \boxed{6.516 \text{ Air}}$$

Fuel flow:

$$\text{Assume } f/A = 0.085 \Rightarrow 6.5 \frac{\text{lb}}{\text{hr}} \times 0.085 = \boxed{0.555 \text{ lb Fuel}}$$

$$\text{@ } 6 \frac{\text{lb}}{\text{gal}} \Rightarrow \boxed{0.09 \text{ gal}} \text{ or } \boxed{11.5 \text{ fl oz}} \text{ or } 0.35 \text{ Air} \approx \boxed{1 \text{ can of pop}}$$

$$\text{Assume } 125,000 \frac{\text{BTU}}{\text{gal}} \times 0.09 \text{ gal} = 11,250 \text{ BTU} = 3.3 \text{ kW-hr}$$

\Rightarrow

Assume Avg US household uses ~ 9000 kW-hr / yr

$$\Rightarrow 1.03 \text{ kW-hr / hr}$$

In 1 sec Merlin uses same energy (in kind) to run an average US house for 3 hrs!

ADI Flow

$$1500 \frac{\text{lb}}{\text{hr}}$$

$$\times \frac{1 \text{ gpm}}{450 \text{ lb/hr}} = 3.3 \text{ gpm} \times \frac{1 \text{ hr}}{60 \text{ min}} = 0.056 \frac{\text{gal}}{\text{sec}} \Rightarrow \boxed{7.1 \text{ Fl oz}}$$

$$\times \frac{1 \text{ hr}}{3600 \text{ sec}} \Rightarrow \boxed{0.42 \text{ lb}}$$

Nitrous flow

~~Assume 0.2 N/A ratio for NACA~~

~~$$\therefore 6.5 \frac{\text{lb}}{\text{sec}} \times 0.2 = 1.3 \text{ lb NO}_2$$~~

$$1200 \frac{\text{lb}}{\text{hr}} \times \frac{1 \text{ hr}}{3600} = 0.33 \text{ lb}$$

Total fluids:

- Assume NO₂ to be in fluid form @ time of injection

$$\text{Fuel} = 0.56$$

$$\text{ADI} = 0.42$$

$$\text{NO}_2 = 1.30$$

$$\boxed{2.28 \text{ lb/sec fluids}}$$

$$\text{- excluding NO}_2 \rightarrow 0.95 \text{ lb/sec} \Rightarrow \underline{\underline{1 \text{ lb fluid/sec}}}$$

Oil Consumption

$$0.010 \frac{\text{lb}}{\text{hphr}} \times 3300 \text{ hp} \times \frac{1 \text{ hr}}{3600 \text{ sec}} = \frac{0.009 \text{ lb}}{\text{sec}} \times \frac{1 \text{ gal}}{7.4} \Rightarrow \underline{\underline{0.159 \text{ fl oz}}}$$

Work:

$$3300 \text{ hp} \Rightarrow 1.815 \times 10^6 \frac{\text{ft} \cdot \text{lb}}{\text{sec}}$$

$$\text{VV bag} \approx 1800 \text{ lb} \Rightarrow 1008 \text{ ft} \text{ cm lift} \quad \text{E.T} = 1000'$$

\therefore Lift VV bag to top of Eiffel Tower in 1 sec. (≈ 75 stories)

Prop Rev:

$$\text{Engine} = 65 \frac{\text{rev}}{\text{sec}} \times \frac{3}{1} = \boxed{195 \frac{\text{rev}}{\text{sec}}}$$

Prop Tip Speed

$$V_t = \omega r$$

$$= \left(195 \frac{\text{rev}}{\text{sec}} \times \frac{2\pi}{1 \text{ rev}} \right) 6.5 \text{ m} = 7964 \frac{\text{m}}{\text{sec}} \Rightarrow \boxed{664 \frac{\text{ft}}{\text{sec}} \text{ - or - } 453 \text{ MPH}}$$

Prop Tip Dist

$$C = \pi D = 13\pi$$

$$\text{Dist. Rev} \times C \rightarrow 195 \frac{\text{rev}}{\text{sec}} \times 13\pi'' = \boxed{7964 \text{ in} \Rightarrow 664 \text{ ft} \Rightarrow 2.2 \text{ Football Fields}}$$

Blade Cycle

Each blade enters and leaves the water 1/rev

\therefore each blade \rightarrow 195 entries/exits or a total 390 for 2 blades

↳ minus 2 blades
pool

Boat Dist travel:

Assum. zero-slip pitch = 17.5"

$$195 \text{ rev} \times 17.5 \text{"/rev} = 3413 \text{ m} \rightarrow 284 \text{ ft} = 95 \text{ yds}$$

$$= 0.05 \text{ mi} \approx 2.2\% \text{ of race course}$$

90 sec (Scaled from 1 sec)

5850 vcu

2970 each vcu sec

140,400 all vcu sec

70,200 total Sp-K phy (sec)

2970 each phy sec

70,200 in \Rightarrow 5850 ft \rightarrow 19.5 football fields

11,700 direction changes w/ 1000s acceleration

35,100 power pulses

890 mph = 1.17 M blower tip speed

37,350 rev. for blower

117,338 m = 9978 ft = 33 football fields blower tip travel

4x atmospheric

7740 cu ft air = 585 pounds

= 18,600 minute ft. hr \rightarrow 13 days

50 lb fuel = 8.3 gal

= 304 kw. hr \Rightarrow 11 days for Ag. vs baseline

5 gal ADI = 38 lb

30 lb NO_2

585 + 50 + 38 + 30 = 703 lb Propane in 90 sec

14.3 Fl oz oil \approx 1.1/4 cups of pop

$1.815 \times 10^6 \times 90 = 163 \times 10^6 \text{ ft-lb}$

\Rightarrow 73 UW by 10 top of 2.5 pc shale build
 \Rightarrow 100 ft to top of ME M. km by

Assoc. - 3 mi lap
- Full M. / Full power all day
- 120°
- 2900 RPM
- 2300 HP

17,550 p.p.r.

6641 ft/mi = 453 MPH HP speed

716,754' = 59,729' = 200 football fields

17,550 Cycles/blade - or - 35,100 total blade Cycles

307,125" = 25,594' = 4.8 mi

- or -

Know what 3 mi

∴ 10.8" actual pitch (36% slip)