

APPENDIX C

Component Weight Estimates (Nicolai)

10. Component Weight Estimation from Nicolai

20.2.2 Conventional Metal Aircraft - Light Utility Aircraft:

The weight equations of Section 20.2.1 will predict unrealistic component weights for light utility aircraft such as those reported in Table E.4. The following equations, developed by Mr. Robert Anderson of the Air Force Flight Dynamics Laboratory (Reference 6) are recommended for the low to moderate performance (up to about 300 knots) light utility aircraft. The weight equations give the component weight in pounds.

1.0 Structure:

1.1 Wing or Canard:

$$Wt = 96.948 \left[\left(\frac{W_{TON}}{10^5} \right)^{.65} \left(\frac{A}{\cos \Delta_{1/4}} \right)^{.57} \left(\frac{S_W}{100} \right)^{.61} \left(\frac{1+\lambda}{2t/c} \right)^{.36} \right. \\ \left. \left(1 + \frac{V_e}{500} \right)^{.5} \right]^{.993} \quad (20-69)$$

where W_{TO} = take-off weight in lbs on wing or canard

N = ultimate load factor (1.5 times limit load factor) = 6.6

A = aspect ratio

$\Delta_{1/4}$ = wing quarter chord sweep

S_W = wing area in ft^2 (use S_C for canard)

λ = taper ratio

t/c = maximum thickness ratio = 0.12

V_e = equivalent max airspeed at SL in knots = 141 knots

1.2 Fuselage:

$$W_t = 200 \left[\left(\frac{W_{TO} N}{10^5} \right)^{.286} \left(\frac{L}{10} \right)^{.857} \left(\frac{W + D}{10} \right) \left(\frac{V_e}{100} \right)^{.338} \right]^{1.1} \quad (20-70)$$

where L = fuselage length in feet

W = fuselage max width in feet

D = fuselage max depth in feet

1.3 Horizontal Tail (do not apply to canard):

$$W_t = 127 \left[\left(\frac{W_{TO} N}{10^5} \right)^{.87} \left(\frac{S_H}{100} \right)^{1.2} \left(\frac{\ell_T}{10} \right)^{.483} \left(\frac{b_H}{t_{HR}} \right)^{.5} \right]^{.458} \quad (20-71)$$

where S_H = horizontal tail area in ft^2

ℓ_T = distance from wing 1/4 MAC to tail 1/4 MAC

b_H = horizontal tail span in feet

t_{HR} = horizontal tail max root thickness in inches

1.4 Vertical Tail:

$$W_t = 98.5 \left[\left(\frac{W_{TO} N}{10^5} \right)^{.87} \left(\frac{S_V}{100} \right)^{1.2} \left(\frac{b_V}{t_{VR}} \right)^{.5} \right]^{.458} \quad (20-72)$$

where S_V = vertical tail area in ft^2

b_V = vertical tail span in ft

t_{VR} = vertical tail max root thickness in inches

1.5 Landing Gear:

$$W_t = .054 (L_{LG})^{.501} (W_{Land} N_{Land})^{.684} \quad (20-73)$$

where L_{LG} = length of main landing gear strut in inches

W_{Land} = landing weight (if unknown, use W_{TO} - 60 percent fuel)

N_{Land} = ultimate load factor at W_{Land}

2.0 Propulsion:

2.1 Total Installed Propulsion Unit Weight Less Fuel System:

This includes mounting and air induction weight.

$$W_t = 2.575 (W_{ENG})^{.922} (N_E) \quad (20-74)$$

where W_{ENG} = bare engine weight

N_E = number of engines

2.2 Fuel System:

This includes fuel pumps, lines, and tanks.

$$W_{FS} = 2.49 \left[(F_G)^{.6} \left(\frac{1}{1 + Int} \right)^{.3} (N_T)^{.2} (N_E)^{.13} \right]^{1.21} \quad (20-75)$$

where F_G = total fuel in gallons

Int = percent of fuel tanks that are integral

N_T = number of separate fuel tanks

3.0 Surface Controls:

For powered surface control systems, use

$$W_t = 1.08 (W_{TO})^{.7} \quad (20-76)$$

For unpowered surface control systems, use

$$W_t = 1.066 (W_{TO})^{.626} \quad (20-77)$$

The weight prediction relationships are expressed in terms of the total weight of the fuel system and the electronics system - the primary users of electrical power on the aircraft.

$$W_t = 426 \left(\frac{W_{FS} + W_{TRON}}{1000} \right)^{.51} \quad (20-78)$$

where W_{FS} = fuel system weight in lfs, equation 20-75

W_{TRON} = weight of installed electronics in lbs, equation 20-81

6.0 Furnishings:

The weight expression for the crew seats is

$$W_t = 34.5 (N_{CR}) (q)^{.25} \quad (20-79)$$

where N_{CR} = number of crew

q = maximum dynamic pressure, psf

The weight of the passenger seats is determined from equation 20-54 and a weight allowance for miscellaneous furnishings from equation 20-62. If the aircraft is pressurized, an additional weight allowance should be considered using equation 20-60.

7.0 Air Conditioning and Anti-Icing (omit):

If the aircraft has air conditioning and anti-icing, the following expression can be used to estimate the weight of this equipment:

$$W_t = .265 (W_{TO})^{.52} (N_{CR} + N_{PASS})^{.68} (W_{TRON})^{.17} (M_E)^{.08} \quad (20-80)$$

where N_{PASS} = number of passengers

N_{CR} = number of crew

W_{TRON} = weight of installed electronics in lbs, see equation 20-81

M_E = equivalent max Mach number at sea level

8.0 Electronics (Avionics):

The total installed weight of the avionics equipment is

$$W_{\text{TRON}} = 2.117 (W_{\text{AU}})^{.933}$$

(20-81)

where W_{AU} = bare avionics equipment weight (uninstalled) = 15 lbs

APPENDIX D

Component Weight Estimates (Cessna)

12. CESSNA - WEIGHT ESTIMATE OF AIRCRAFT MAJOR COMPONENTS

Limits: Conventional Single Engine and Conventional Light Twins to 5000 lbs

I. Fuselage

Use 11% of the proposed aircraft gross weight

II. Wing

A. Cantilever (includes fuselage carry thru for spars, attachment hardware and fairing strips)

$$W_W = 69 (B \times 10^{-6})^{.69}$$

$$\text{where } B = \frac{W n' S (1.9 A/R - 4)}{1 + .11 t_{cr}}$$

w = design gross weight

n' = design load factor (5.7 for normal category)

S = wing area (ft²)

A/R = aspect ratio

t_{cr} = thickness of root chord (at C_L) in %

B. Strut Braced Wings (conventional riveted design, includes fuselage carry thru structure for spars, struts, strut fairings, and attachment hardware)

$$W_W = .95 S \left(\frac{n' W}{1000 C_m} \right)^{.5}$$

C_m = mean geom. chord

$$W_W = 1.05 S \left(\frac{n' W}{1000 C_m} \right)^{.5}$$

(for wings with bonded construction; strut attached in integral fuel tank area)

III. Vertical Tail

$$W_{VT} = 1.28 S_{VT}$$

where S_{VT} = vertical tail area in ft²
(includes rudder, fin & dorsal)

IV. Horizontal Tail

$$W_{HT} = 1.2 \left(\frac{W}{3000} \right)^{.25} S_{HT}$$

where S_{HT} = horizontal tail area in ft²
(includes area thru fuselage)

Weight Estimate of Aircraft Major Components

V. Landing Gear Installation

A. Main Gears (includes fairings, brakes, wheels, & fittings)

1. Tri Gear (retractable) (no fairings) (or fixed oleo)

$$W_{mG} = .019W + 38$$

2. Tri Gear (fixed)

$$W_{mG} = .019W + 50$$

3. Tailwheel Airplane

$$W_{mG} = .019W + 79 \text{ (spring gear)}$$

B. Nose Gear or Tail Gear

$$W_{nG} = .006W + 19$$

$$W_{tG} = .006W$$

C. Retraction System (includes actuators, lines, pumps, selectors, valves, and fluid)

$$W_{rctr} = .019W + 11$$

VI. Powerplant Installation

Obtain basic dry weight from manufacturers engine spec (W_{es})

W_p = installation weight

= 1.16 W_{es} (for fixed pitch prop engines)

= 1.26 W_{es} (for controllable prop engines)

= 1.47 W_{es} (for controllable prop engines with turbo charging)

VII. Nacelle (including engine mount)

W_n (Single Engine Aircraft) = .175 x max. cont. horsepower

W_n (Multi-Engine Aircraft) = .275 x max. cont. horsepower

W_n (Jet) = .046 x thrust (lbs)

Weight Estimate of Aircraft Major Components

VIII. Control System (includes flight and engine controls)

Use 40 lbs for light single engine, fixed prop aircraft

Use 50 lbs for standard single engine, controllable prop aircraft

or $30 + .005 W$

Use 75 lbs for light twin engine, controllable prop aircraft

IX. Equipment

Use 70 lbs (max) for single engine aircraft

or $35 + .01 W$

or $43 + .069 W$

Use 100 lbs for multi-engine aircraft

X. Furnishings (includes seats, upholstery, restraint system and ventilation)

Use 40 lbs per occupant

or $80 + 30 \times (\text{no. of occupants other than pilot \& copilot})$

XI. Oil

Lubricating 7.5 lbs/gal or 1.875 lbs/qt

Hydraulic 7.0 lbs/gal or 1.75 lbs/qt

XII. Fuel

6.0 lbs/gal

XIII. Occupants

170 lbs each

XIV. Optional Equipment

Estimated from previous production configuration

XV. Paint

Singles .0172 WA + 1.5 (stripe)

Twins .034 WA + 3.0 (stripe)