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PA-25 PAWNEE FRONT SPAR CAP FLANGE FATIGUE ANALYSIS
AIRW-D0027

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REV	DEVELOPED BY:	REVIEWED BY:	COMPLIANCE VERIFICATION BY:	APPROVED BY:
1	A.C. Smith 19 Oct 2025			

1. REFERENCES

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1.6 Structures Technical Memorandum 303 “A Review of Australian Investigations on Aeronautical Fatigue During the Period April 1977 to March 1979”, G.S. Jost April 1979

1.7 A Review of Australian Investigations on Aircraft Fatigue During the Period April 1973 to March 1975. Minutes of the Fourteenth Conference of the International Committee on Aeronautical Fatigue. Swiss Federal Aircraft Establishment, 1976

1.8 AIRW-D0026 “Pawnee Front Spar Stress Analysis”, Rev 1 6 Sep 2025

1.9 Excel Spreadsheet “Pawnee Shear and Bending Calculator 5_05 Piper.xlsx”

1.10 Excel Spreadsheet “Pawnee Shear and Bending Calculator 5_05 – Landing Piper.xlsx”

1.11 Excel Spreadsheet “Pawnee Shear and Bending Calculator 5 – Taxi Piper.xlsx”

1.12 Software AFGROW V5.04.05.25

1.13 Civil Air Regulations Part 3 – Airplane Airworthiness; Normal, Utility and Acrobatic Categories, 15 May 1956

1.14 MIL-C-5651D Cord, Elastic, Exerciser and Shock Absorber, For Aeronautical Use, 2 March 1977

1.15 SAE 870094 “Tensile and Strain-Controlled Fatigue Data for Certain Aluminium Alloys for Application in the Transportation Industry”, W.A Wong, R.J. Bucci, R.H. Stentz, J.B. Conway, February 1987

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1.17 Peterson’s Stress Concentration Factors, W.D. Pilkey 1997

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2. INTRODUCTION

2.1 The Piper PA-25 Pawnee was first designed in the early 1950's as an agricultural aircraft. Prior to this most agricultural aircraft were converted from existing civil or military designs. The type evolved over time with several versions of the Pawnee were made which increased engine power in later models, as well as strengthened wings. These models were referred to as Pawnee B, and Pawnee C. The last model, Pawnee D moved the fuel tank location from the fuselage to the wings outboard of the wing strut attachment.

2.2 The aircraft was popular with crop dusting / spraying operators in Australia in the 1960s and 1970s. The type was largely replaced in agricultural work in the 1980s by the larger and more powerful Air Tractor.

2.3 Pawnees became increasingly popular as glider towing aircraft at gliding clubs in the mid 1980's as they became available in the second-hand aircraft market. Without the agricultural equipment or weight of fertiliser / pesticide, the type has an excellent power to weight ratio which results in a very good climb rate whilst towing a glider. It is highly suitable for operations off unsealed airstrips and paddocks.

2.4 Piper ceased production of the Pawnee in 1981. On 15 April 1988, Piper Aircraft sold the design to Latino Americana de Aviación S.A (Laviasa) in Argentina. This resulted in Laviasa being the Type Certificate Holder and responsible for maintaining the ongoing airworthiness of the type.

2.5 Laviasa production aircraft, referred to as "Puelche", used Pawnee D wings, but without the wing tanks fitted. The fuel tank was in the forward fuselage as per the Pawnee B and C models. There were also minor changes to the wing spar design where a reinforcing strap attached to the spar under the wing strut attachment is fitted on the forward face of the spar web rather than the aft face of the spar web as per the Piper built aircraft. This change impacted airworthiness advice coming from Laviasa where inspections that could be performed on the Puelche aircraft could not be performed on the Piper built aircraft.

2.6 Some Pawnee B and C models were modified in New Zealand to have wing tanks similar to the Pawnee D. Four of these aircraft were imported to Australia and are used as glider tow planes.

2.7 Both CASA and CAA NZ permitted agricultural operation to exceed the originally approved Maximum Take Off Weight (MTOW). This was a blanket approval with no record kept of which aircraft operated at the increased MTOW.

2.8 The Airworthiness regulator of Argentina (ANAC) issued Airworthiness Directive 2024-05-01 (Reference 1.1) for the Piper PA-25 Pawnee. This Airworthiness Directive requires inspections for corrosion and cracking in the spars. This AD has ongoing inspections at every annual inspection or 100 hours. It is likely that this inspection interval is based on agricultural operations.

2.9 A criticism of Reference 1.1 is that the start of inspections is based on calendar time and years in service rather than flying hours accrued. It is likely that this inspection threshold is based on an assumed amount of agricultural operations per year.

2.10 The results are at Section 18 and the recommendations are at Section 20. The fatigue of Pawnees used as glider tow planes are significantly less than when it is used in the agricultural role. This reduction in fatigue justifies increased inspection start and reinspection interval hours.

3. AIM

3.1 This report investigates the estimated fatigue life of the screw holes in the front spar upper and lower cap flanges and considers agricultural and glider towing operations utilising a simplified fatigue model. This report also investigates suitable ongoing inspection intervals.

3.2 This report does not consider any other potential fatigue area in the spars.

4. SPAR STRESS

4.1 Reference 1.8 was created to calculate the shear and bending of the front and rear spars of PA-25 Pawnees using the C_L distribution used by Piper. It can consider aircraft with and without fuel tanks fitted to the wings.

4.2 Pawnees Without Wing Fuel Tanks: This shows the peak tension stresses typically occur at the lower spar cap at Wing Station 25 (measured from aircraft centreline) immediately outboard of the wing root fittings for low to moderate g loads.

4.3 Pawnees With Wing Fuel Tanks: This shows the peak tension stresses occur at the upper spar cap near Wing Station 80 (measured from aircraft centreline) roughly midspan between the wing root and strut attachment.

4.4 **LANDING:** Reference 1.10 is a variation of Reference 1.9. It has the landing flaps set to 57 degrees. It also assumes the aircraft is in the three point landing attitude.

> **Assumption: Reference 1.10 assumes the aircraft is in a three point landing attitude.** A component of the wing stress comes from the vector that the air loads are applied at. Another component of the wing stress comes from the vector that the inertial loads are applied at. Both stress components are sensitive to the angle at which they are applied. A landing that is "flown on" with a tail up attitude will have different stress compared to a landing that is "stalled on" with the tail wheel and the main wheels contacting the ground at the same time.

It calculates the aircraft to be at stall speed for the operating weight and g load of the aircraft. The calculation methodology is described in Section 8 of Reference 1.8.

4.5 **TAXIING:** Reference 1.11 is also a variation of Reference 1.9. It has the air loads removed and purely calculates the sheer and bending loads from the inertial g loads. The calculation methodology is described in Section 9 of Reference 1.8.

5. FUEL LEVELS

5.1 Aircraft fitted with fuel tanks in the fuselage were found to have a fatigue life that was not severely influenced by the fuel level. This is because the fuel was only a small component of the weight of the non-flying parts ie the net weight supported by the wings. However, aircraft fitted with wing tanks were found to have a fatigue life that was very influenced by the fuel level. This is because the amount of the fuel in the wings significantly affected the stress at the critical location. A large amount of fuel in the wings reduces the load on the strut. This in turn reduces the axial tension in the wing between the strut and the root. There is a trade off however, where the mass of fuel outboard of the strut increases the bending in the wing mid span between the root and the strut connection. This moves the critical point from near the root of the wing to the midspan between the root and the strut. At low fuel levels in the wing tanks, this affect is diminished and the stresses are nearly identical to those aircraft with fuel in the fuselage.

5.2 Despite the above differences, all aircraft fitted with wing tanks were considered to have three weight cases with 5/6, 1/2, and 1/6 fuel tank levels. Gliding operators of Pawnees were surveyed on the percentage of operations in each fuel bracket. The results are at Annex C. The gliding operations returned an average of:

Fuel Range	Average Fuel Level	Operating Percentage
Full to two thirds	5/6 fuel level	50%
Two thirds to one third	1/2 fuel level	45%
One third to empty	1/6 fuel level	5%

Table 5-1 Fuel Operating Brackets

5.3 A response was not received from agricultural operators. It is assumed that agricultural operators are similar to gliding operators and the same operating percentages were used.

Assumption: Agricultural operators are using similar fuel management practices to gliding operators. The percentage of the flight in each fuel bracket can have a significant impact on the fatigue life of the aircraft. Operating aircraft with a fuselage tanks at low fuel levels for a large percentage of the time will increase the predicted life. Operating aircraft with wing tanks at low fuel levels for a large percentage of the time will decrease the predicted life.

6. AGRICULTURAL LOAD SPECTRA –B AND C MODELS

6.1 Agricultural operations feature a large number of short flights with heavy payloads and often aggressive manoeuvring to realign the aircraft between delivery runs over the target area. The fatigue life of agricultural aircraft has been studied around the world, including Australia since the early 1960's. As a result, there are a number of load spectra to choose from.

6.2 Reference 1.2 is the internationally recognised standard for fatigue evaluation of light aircraft. This presents spectra which have been normalised for both g load and cruising speed.

6.3 For all agricultural operations, the aircraft is assumed to spend 50% of its time at take-off weight and 50% of its time without a payload in the hopper (2005 lb).

> **Assumption: Agricultural operations are assumed to spend 50% of flight time at take-off weight and 50% flight time without a payload in the hopper.** Several technical papers on agricultural aircraft fatigue stated that the ferry distance to and from the drop zone account for 75% to 85% of the flight time. The amount of time where the aircraft operates with partial payload is relatively small.

6.4 Reference 1.2 paragraph 2.7 b.(1) states that the speed for determining miles flown should not be less than 0.9 V_{NO}. Reference 1.3 gives a cruising speed of 95 kts at 2900 lb. Table 4.1 of Reference 1.5 shows a PA 25-235 conducting agricultural operations with a mean cruise speed of 95 kts. For lighter operations, the cruising speed is 108 kts which is max rough air speed.

6.5 Reference 1.13 does not specify a maximum weight for the pilot. A maximum pilot weight is not mentioned in Reference 1.3 or the aircraft flight manual. It is likely that the pilot weight is limited by the aft CG limit when operating without a payload and low fuel level (fuselage tank). A nominal pilot weight of 170 lb (77 kg) is mentioned in Reference 1.13 and the aircraft flight manual (weight and balance section). For the purposes of calculation it is conservative to use a heavier pilot weight and a weight of 242 lb (110 kg) is assumed.

> **Assumption: Pilot weight is assumed to be 242 lb (110 kg).** This is very conservative for the period from the 1960's to 1980's where pilot weights were assumed to be from 180 lb (81 kg) to 200 lb (91 kg). However, gliding operations involve a large number of pilots over the age of 55 years and many of these pilots have mature body shapes and higher average weights. 242 lb (110 kg) represents the maximum pilot weight specified in JAR-22 / CS-22 for sailplane design and is considered to be the maximum pilot weight for gliding operations.

6.6 As stated at Section 5, the aircraft were considered to have three weight cases with 5/6, 1/2, and 1/6 fuel tank levels. The aircraft was assumed to operate at each of these three as discussed at Section 5.

	Operating Weight (lbs)	Fuel Level	Cruise Speed	Gust Stall g Limit
Overweight	3166.4	5/6 (32.08 gal)	95 kts	+2.12 g / -0.92 g
	3089.3	1/2 (19.25 gal)	95 kts	+ 2.18 g / -0.96 g
	3012.2	1/6 (6.42 gal)	95 kts	+2.21 g / -0.99 g
MTOW	2861.4	5/6 (32.08 gal)	95 kts	+2.34 g / -1.03 g
	2784.3	1/2 (19.25 gal)	95 kts	+2.41 g / -1.05 g
	2707.2	1/6 (6.42 gal)	95 kts	+2.48 g / -1.09 g
Landing	1966.4	5/6 (32.08 gal)	108 kts	+ 4.37 g / - 1.90 g
	1889.3	1/2 (19.25 gal)	108 kts	+ 4.53 g / - 1.94 g
	1812.2	1/6 (6.42 gal)	108 kts	+ 4.71 g / - 1.94 g

Table 6-1 Operating Weight and Cruise Speed

6.7 **OVERWEIGHT – 3205 lb:** The design of the Pawnee allows up to 1200 lb (544 kg) payload in the hopper. However, a full payload, full fuel, and a heavy pilot results in the aircraft operating at 3205 lb (1454 kg). This represents a significant overload of the aircraft with the excess weight concentrated in the fuselage for Pawnee B/C models and with only a slight reduction in fuselage weight for the Pawnee D models with the fuel tanks in the wings.

6.8 Operating overweight would result in high wing bending stresses and is suspected of being a contributing factor in recent accidents overseas.

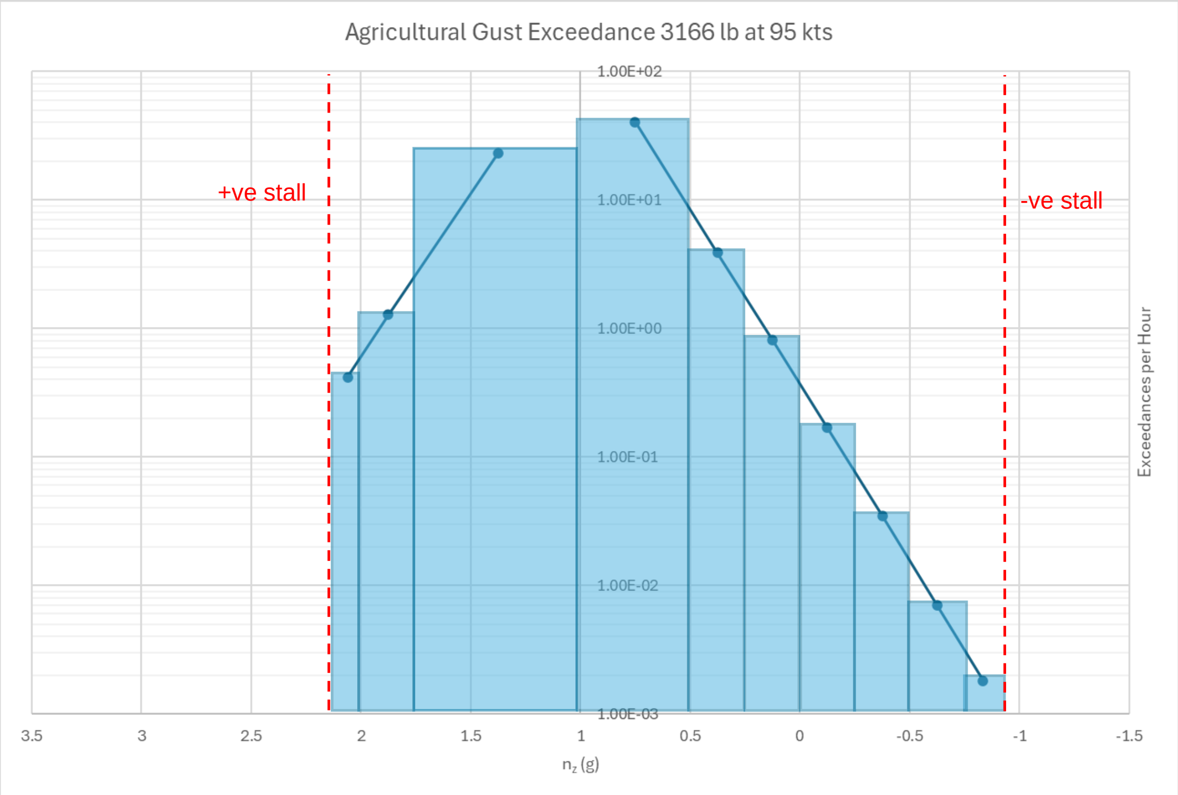

Figure 6-1 Agricultural Gust Exceedance for 3166 lb at 95 kts

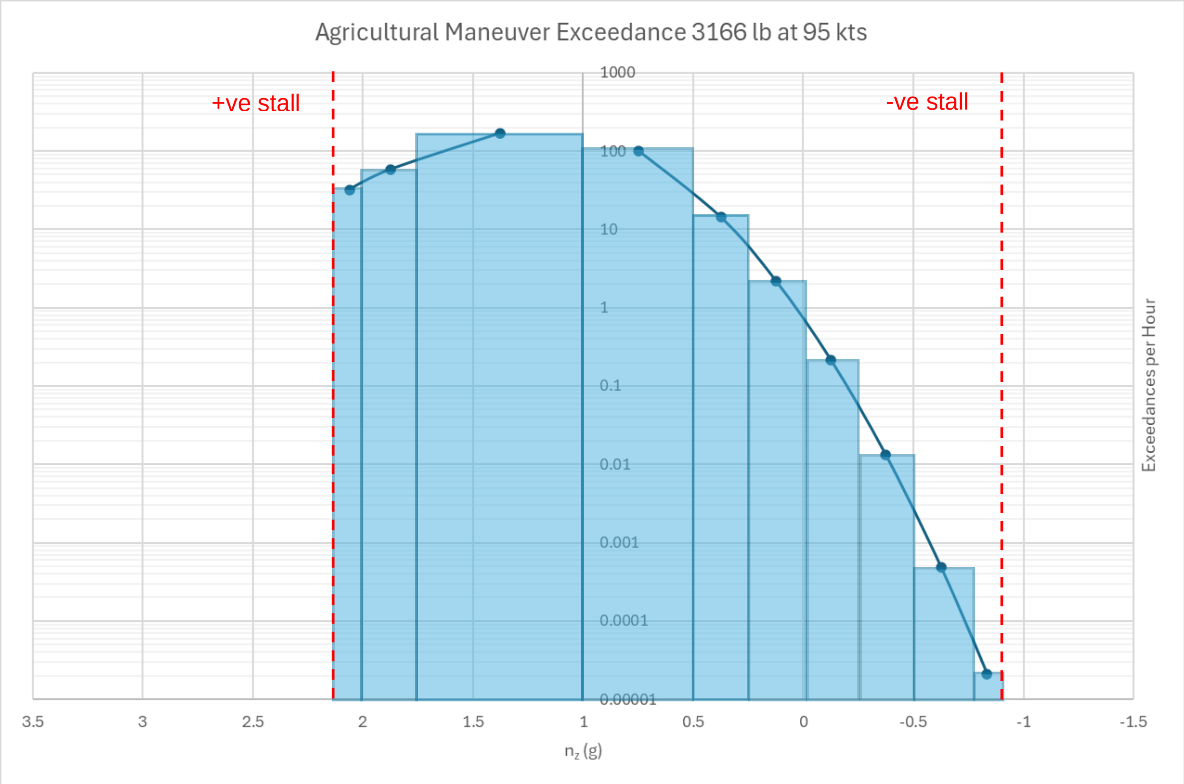

Figure 6-2 Agricultural Maneuver Exceedance for 3166 lb at 95 kts

Block Upper g limit	Block Mean g level	Gust Exceedance per hour	Maneuver Exceedance per hour	Total Exceedance	Occurrence per hour
2.12	2.06	0.4162	32.1111	32.5273	32.527
2.00	1.875	1.2734	57.6940	58.9673	26.4400
1.75	1.375	23.0208	167.9963	191.0170	132.0497
1.00					
1.00	0.75	40.5733	101.1171	141.6904	123.5698
0.50	0.375	3.8675	14.2532	18.1206	15.1060
0.25	0.125	0.8101	2.2045	3.0146	2.6308
0.00	-0.125	0.1689	0.2149	0.3838	0.3359
-0.25	-0.375	0.0348	0.0130	0.0479	0.0403
-0.50	-0.625	0.0071	0.0005	0.0075	0.0057
-0.75	-0.835	0.0018	0.0000	0.0018	0.0018
-0.92					

Table 6-2 Gust and Maneuver Exceedance for 3166 lb at 95 kts

	Block Mean g level	Max Spar Stress (ksi)	Min Spar Stress (ksi)	Occurrence per 1000 hr
1	2.055	14.711	7.777	33,093
2	1.875	13.623	7.777	25,874
3	1.375	10.427	7.777	132,050
4	0.75	7.777	5.894	123,570
5	0.375	7.777	2.901	15,106
6	0.125	7.777	0.800	2,631
7	-0.125	7.777	-1.379	336
8	-0.375	7.777	-3.632	40
9	-0.625	7.777	-6.144	6
10	-0.830	7.777	-8.473	2
Total				**332,707**

Table 6-3 AFGROW Gust and Maneuver Spectrum for 3166 lb at WS 25 without Wing Tanks per 1000 hrs

Figure 6-3 Agricultural Gust Exceedance for 3089 lb at 95 kts

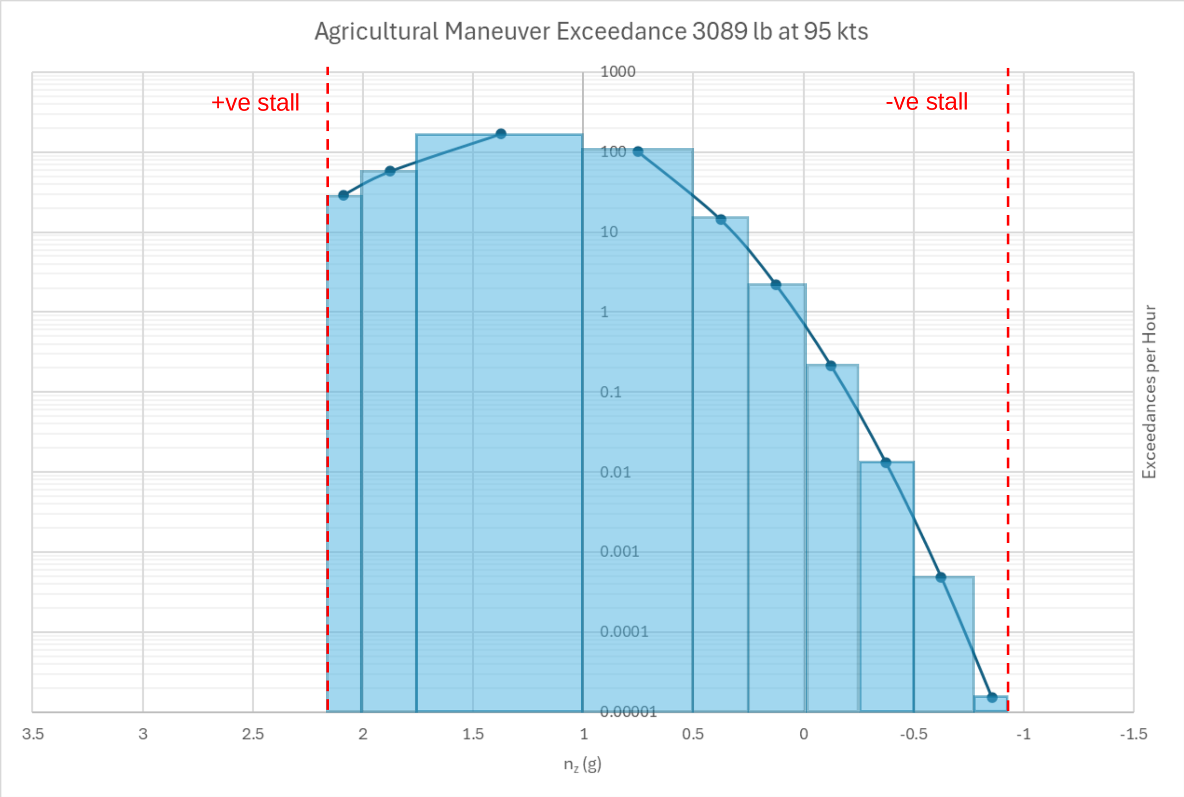

Figure 6-4 Agricultural Maneuver Exceedance for 3089 lb at 95 kts

Block Upper g limit	Block Mean g level	Gust Exceedance per hour	Maneuver Exceedance per hour	Total Exceedance	Occurrence per hour
2.18	2.09	0.3465	28.9432	29.2896	29.2896
2.00	1.875	1.2734	57.6940	58.9673	29.6777
1.75	1.375	23.0208	167.9963	191.0170	132.0497
1.00					
1.00	0.75	40.5733	101.1171	141.6904	123.5698
0.50	0.375	3.8675	14.2532	18.1206	15.1060
0.25	0.125	0.8101	2.2045	3.0146	2.6308
0.00	-0.125	0.1689	0.2149	0.3838	0.3359
-0.25	-0.375	0.0348	0.0130	0.0479	0.0403
-0.50	-0.625	0.0071	0.0005	0.0075	0.0059
-0.75	-0.855	0.0016	0.0000	0.0016	0.0016
-0.96					

Table 6-4 Gust and Maneuver Exceedance for 3089 lb at 95 kts

	Block Mean g level	Max Spar Stress (ksi)	Min Spar Stress (ksi)	Occurrence per 1000 hr
1	2.09	14.552	7.583	29,290
2	1.875	13.313	7.583	29,678
3	1.375	10.177	7.583	132,050
4	0.75	7.583	5.742	123,570
5	0.375	7.583	2.821	15,106
6	0.125	7.583	0.773	2,631
7	-0.125	7.583	-1.350	336
8	-0.375	7.583	-3.545	40
9	-0.625	7.583	-5.971	6
10	-0.855	7.583	-8.457	2
Total				**332,707**

Table 6-5 AFGROW Gust and Maneuver Spectrum for 3089 lb at WS 25 without Wing Tanks per 1000 hrs

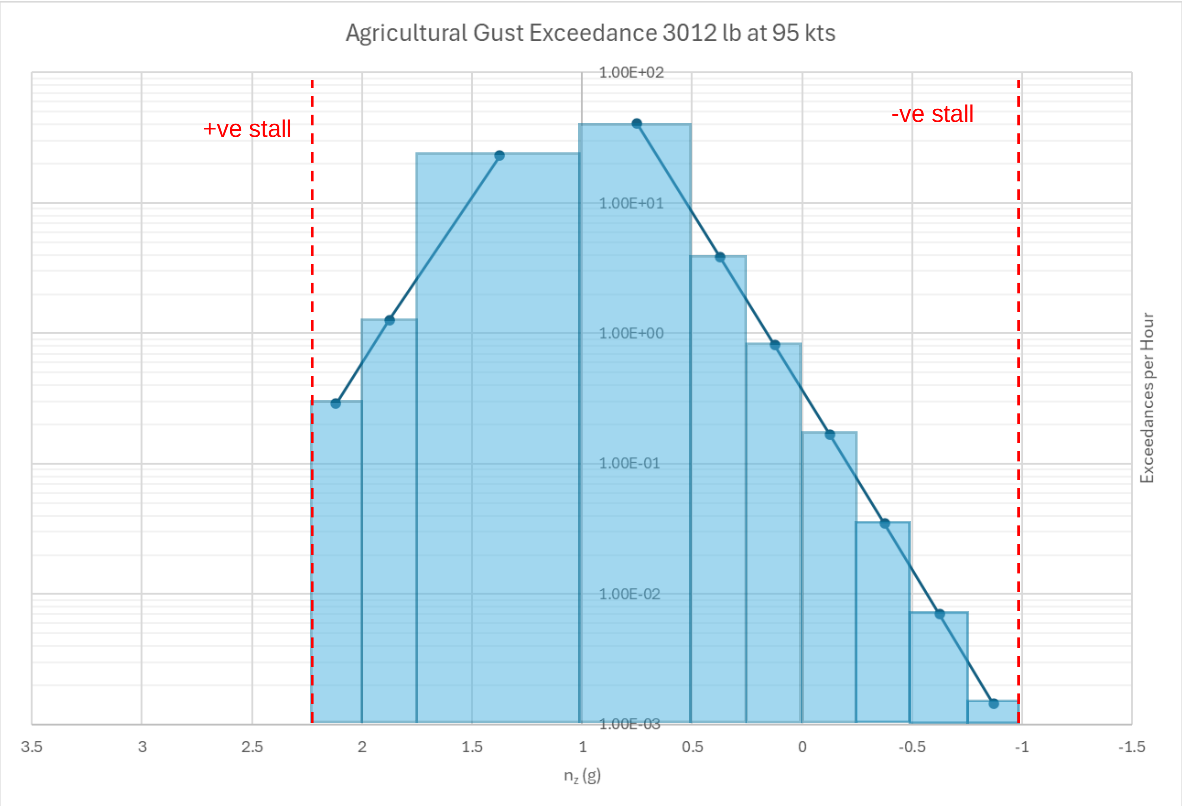

Figure 6-5 Agricultural Gust Exceedance for 3012 lb at 95 kts

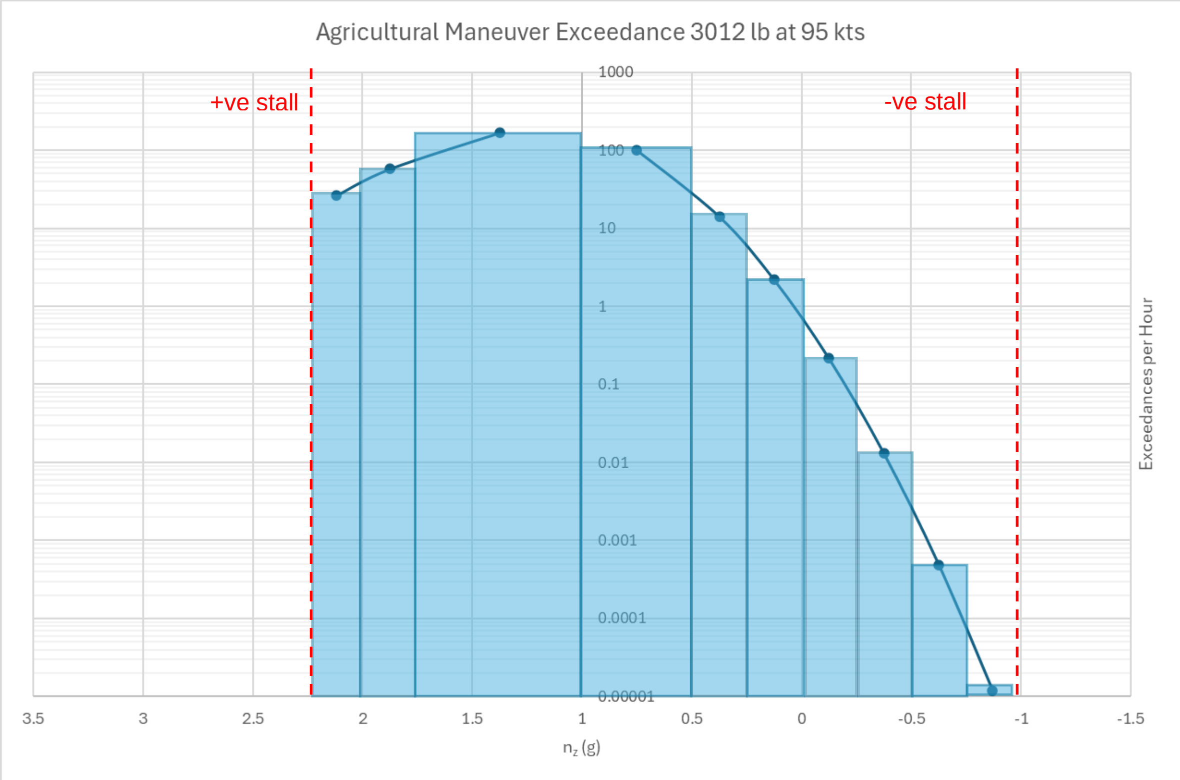

Figure 6-6 Agricultural Maneuver Exceedance for 3089 lb at 95 kts

Block Upper g limit	Block Mean g level	Gust Exceedance per hour	Maneuver Exceedance per hour	Total Exceedance	Occurrence per hour
2.24	2.12	0.2883	26.0255	26.3138	26.3138
2.00	1.875	1.2734	57.6940	58.9673	32.6535
1.75	1.375	23.0208	167.9963	191.0170	132.0497
1.00					
1.00	0.75	40.5733	101.1171	141.6904	123.5698
0.50	0.375	3.8675	14.2532	18.1206	15.1060
0.25	0.125	0.8101	2.2045	3.0146	2.6308
0.00	-0.125	0.1689	0.2149	0.3838	0.3359
-0.25	-0.375	0.0348	0.0130	0.0479	0.0403
-0.50	-0.625	0.0071	0.0005	0.0075	0.0061
-0.75	-0.87	0.0014	0.0000	0.0015	0.0015
-0.99					

Table 6-6 Gust and Maneuver Exceedance for 3012 lb at 95 kts

	Block Mean g level	Max Spar Stress (ksi)	Min Spar Stress (ksi)	Occurrence per 1000 hr
1	2.12	14.383	7.388	26,314
2	1.875	13.001	7.388	32,653
3	1.375	9.926	7.388	132,050
4	0.75	7.388	5.590	123,570
5	0.375	7.388	2.741	15,106
6	0.125	7.388	0.745	2,631
7	-0.125	7.388	-1.322	336
8	-0.375	7.388	-3.458	40
9	-0.625	7.388	-5.799	6
10	-0.87	7.388	-8.376	1
Total				**332,707**

Table 6-7 AFGROW Gust and Maneuver Spectrum for 3012 lb at WS 25 without Wing Tanks per 1000 hrs

6.9 **MAX TAKE OFF WEIGHT - 2900lb:** The design max take off weight is 2900 lb. With full fuel and a heavy pilot, this results in a payload of 895 lb in the hopper.

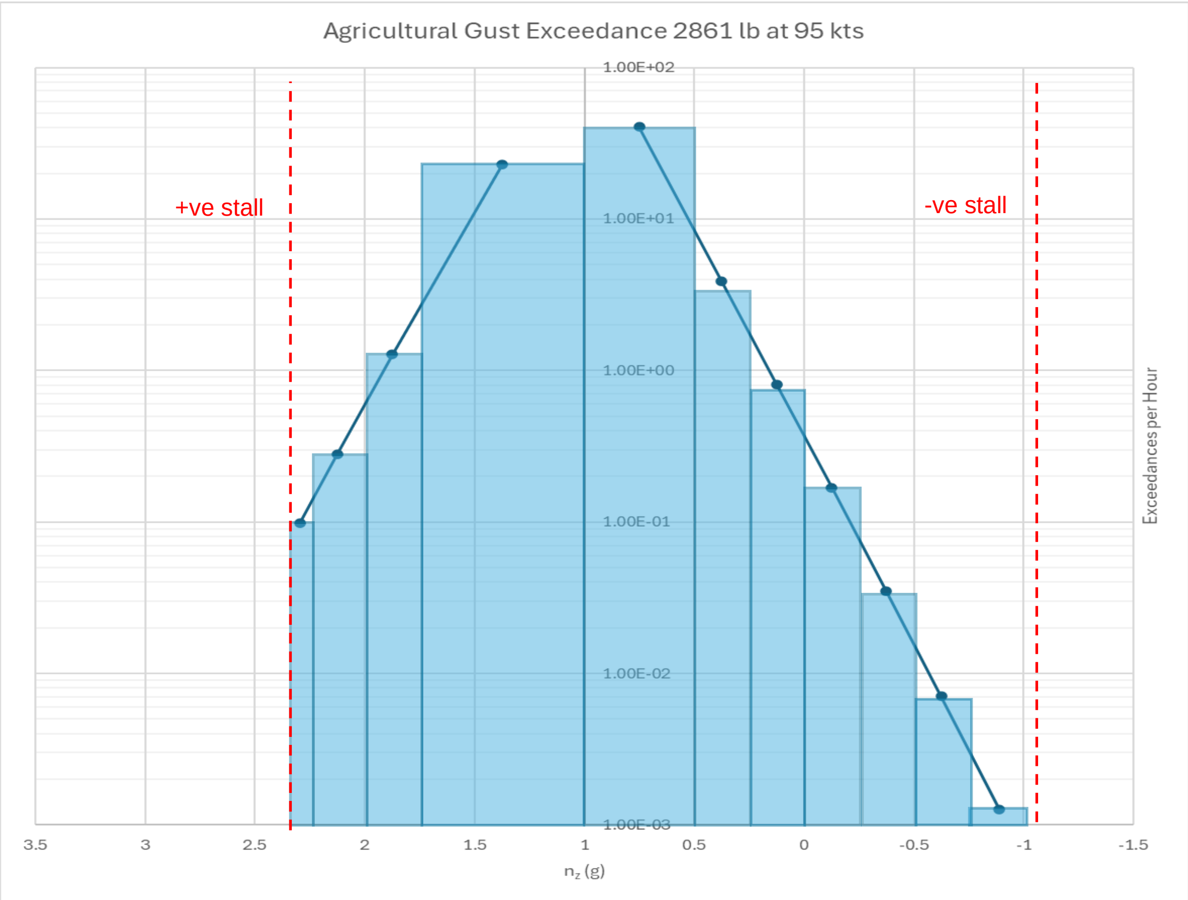

Figure 6-7 Agricultural Gust Exceedance for 2861 lb at 95 kts

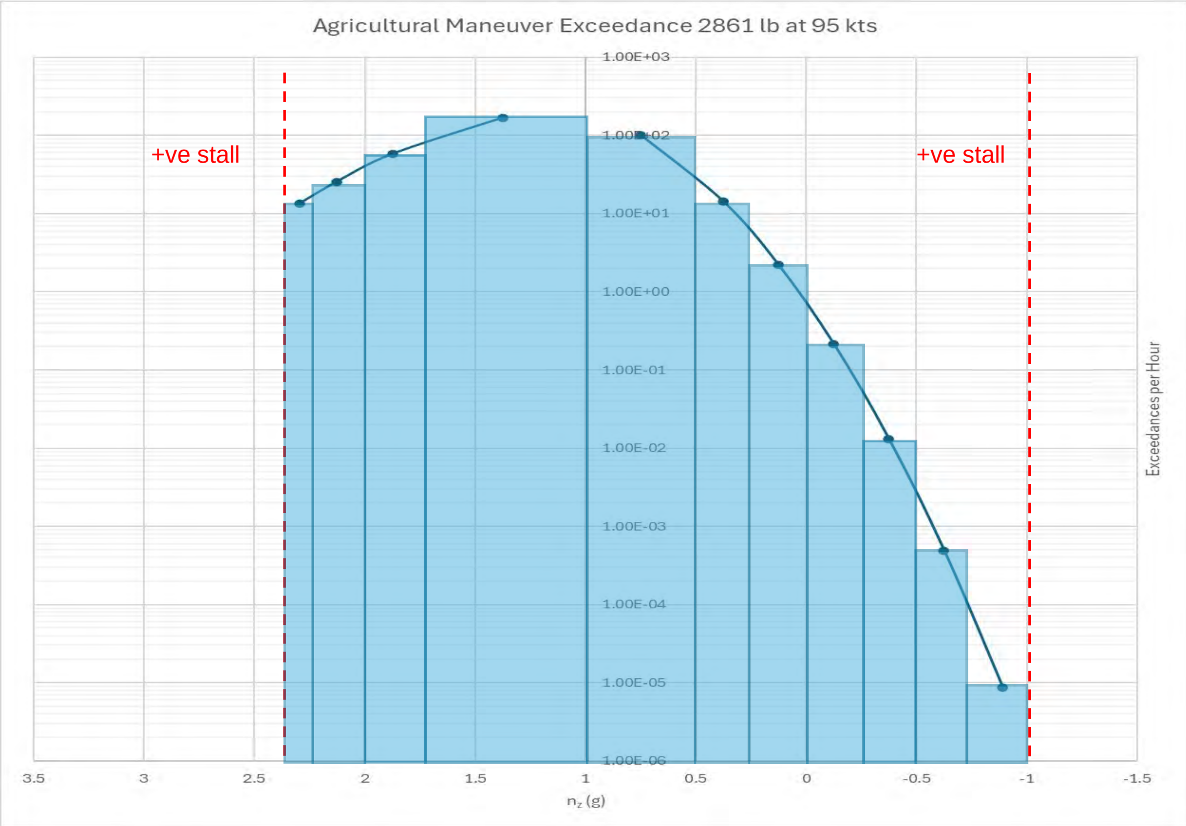

Figure 6-8 Agricultural Maneuver Exceedance for 2861 lb at 95 kts

Block Upper g limit	Block Mean g level	Gust Exceedance per hour	Maneuver Exceedance per hour	Total Exceedance per hour	Occurrence per hour
2.34	2.295	0.0977	13.6893	13.4703	13.4703
2.25	2.125	0.2796	25.6601	25.8424	12.3721
2.00	1.875	1.2734	57.8572	58.9673	33.1249
1.75	1.375	23.0208	166.5782	191.0170	132.0497
1.00					
1.00	0.75	40.5733	101.1171	141.6904	123.5698
0.50	0.375	3.8675	14.2532	18.1206	15.1060
0.25	0.125	0.8101	2.2045	3.0146	2.6308
0.00	-0.125	0.1689	0.2148	0.3837	0.3359
-0.25	-0.375	0.0348	0.0129	0.0477	0.0403
-0.50	-0.625	0.0071	0.0005	0.0075	0.0063
-0.75	-0.890	0.0013	8.7123E-06	0.0013	0.0013
-1.03					

Table 6-8 Gust and Maneuver Exceedance for 2861 lb at 95 kts

	Block Mean g level	Max Spar Stress (ksi)	Min Spar Stress (ksi)	Occurrence per 1000 hr
1	2.295	14.618	7.003	13,470
2	2.125	13.738	7.003	12,372
3	1.875	12.381	7.003	33,125
4	1.375	9.427	7.003	132,050
5	0.75	7.003	5.290	122,454
6	0.375	7.003	2.583	15,201
7	0.125	7.003	0.691	2,646
8	-0.125	7.003	-1.266	336
9	-0.375	7.003	-3.287	40
10	-0.625	7.003	-5.461	6
11	-0.89	7.003	-8.097	1
Total				**332,707**

Table 6-9 AFGROW Gust and Maneuver Spectrum for 2861 lb at WS 25 without Wing Tanks per 1000 Hours

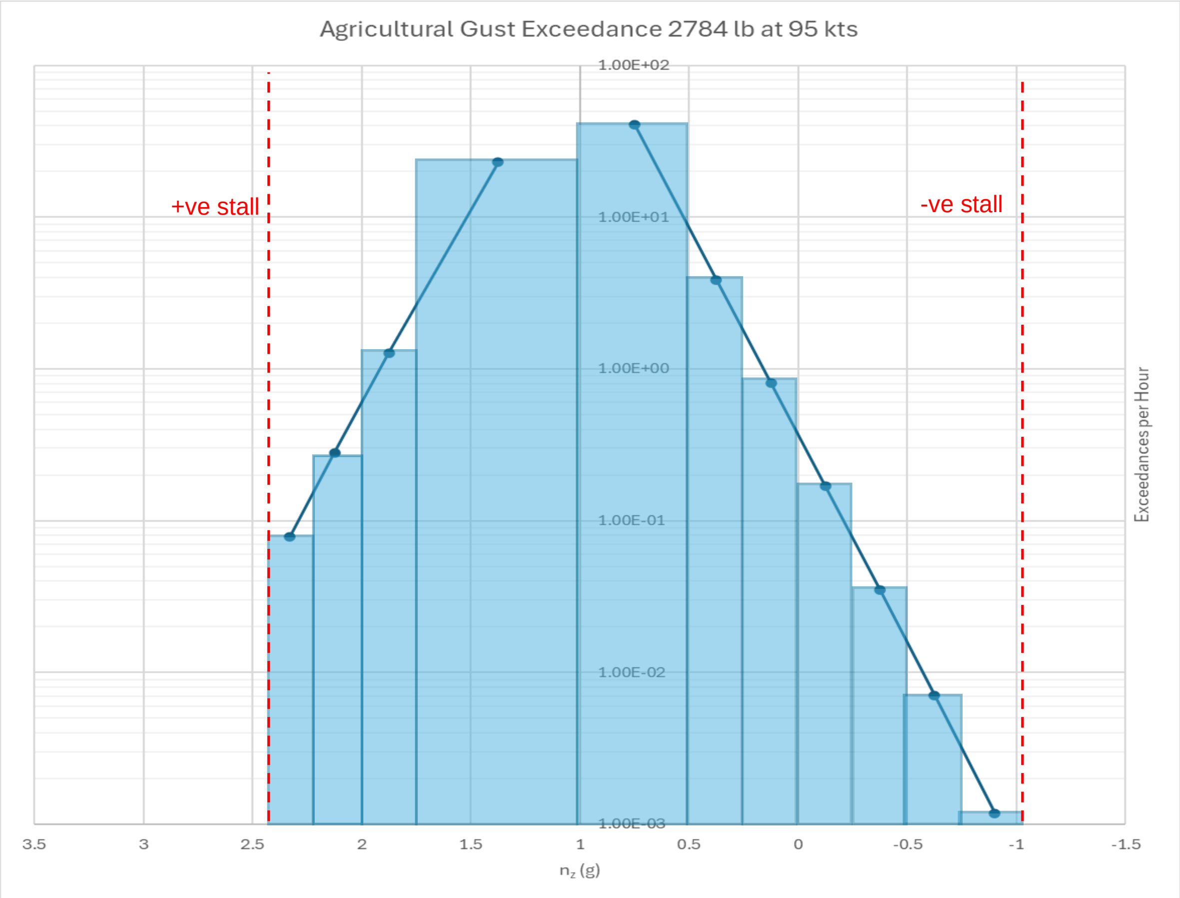

Figure 6-9 Agricultural Gust Exceedance for 2784 lb at 95 kts

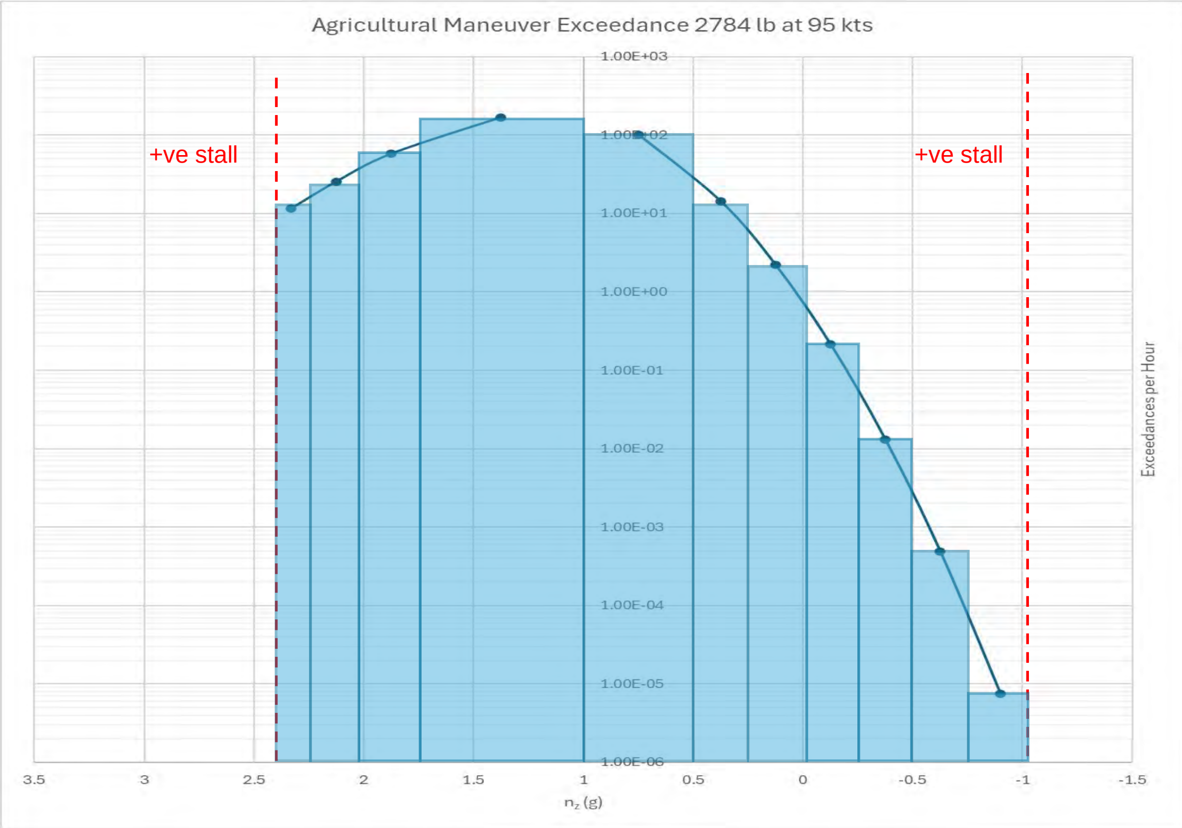

Figure 6-10 Agricultural Maneuver Exceedance for 2784 lb at 95 kts

Block Upper g limit	Block Mean g level	Gust Exceedance per hour	Maneuver Exceedance per hour	Total Exceedance per hour	Occurrence per hour
2.41	2.330	0.0785	11.5990	11.6776	11.6776
2.25	2.125	0.2796	25.5628	25.8424	16.1648
2.00	1.875	1.2734	57.6940	58.9673	33.1249
1.75	1.375	23.0208	167.9963	191.0170	132.0497
1.00					
1.00	0.75	40.5733	101.1171	141.6904	123.5698
0.50	0.375	3.8675	14.2532	18.1206	15.1060
0.25	0.125	0.8101	2.2045	3.0146	2.6308
0.00	-0.125	0.1689	0.2148	0.3838	0.3359
-0.25	-0.375	0.0348	0.0129	0.0479	0.0403
-0.50	-0.625	0.0071	0.0005	0.0075	0.0063
-0.75	-0.900	0.0012	7.4018E-06	0.0012	0.0012
-1.05					

Table 6-10 Gust and Maneuver Exceedance for 2784 lb at 95 kts

	Block Mean g level	Max Spar Stress (ksi)	Min Spar Stress (ksi)	Occurrence per 1000 hr

1	2.33	14.426	6.804	11,678
2	2.125	13.389	6.804	14,165
3	1.875	12.058	6.804	33,125
4	1.375	9.170	6.804	132,050
5	0.75	6.804	5.135	123,570
6	0.375	6.804	2.502	15,106
7	0.125	6.804	0.663	2,631
8	-0.125	6.804	-1.238	336
9	-0.375	6.804	-3.199	40
10	-0.625	6.804	-5.288	6
11	-0.90	6.804	-7.942	1
Total				**332,707**

Table 6-11 AFGROW Gust and Maneuver Spectrum for 2784 lb at WS 25 without Wing Tanks per 1000 Hours

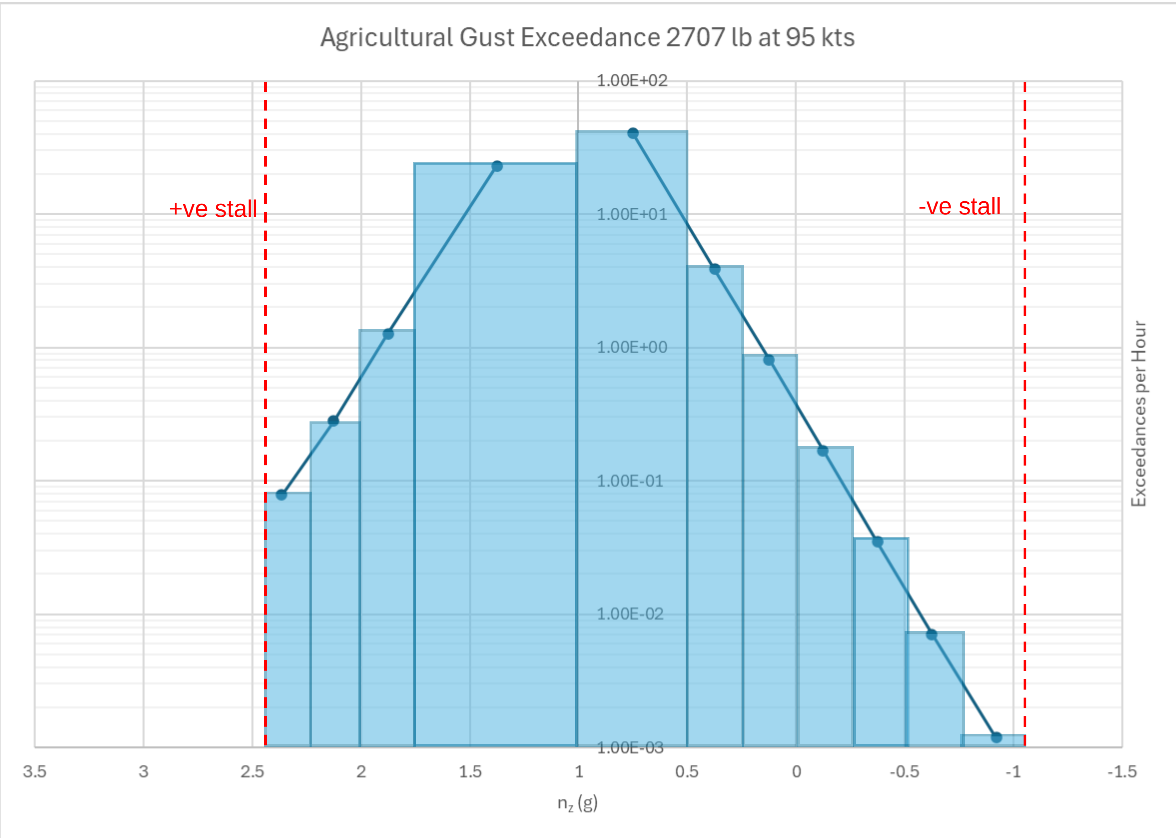

Figure 6-11 Agricultural Gust Exceedance for 2707 lb at 95 kts

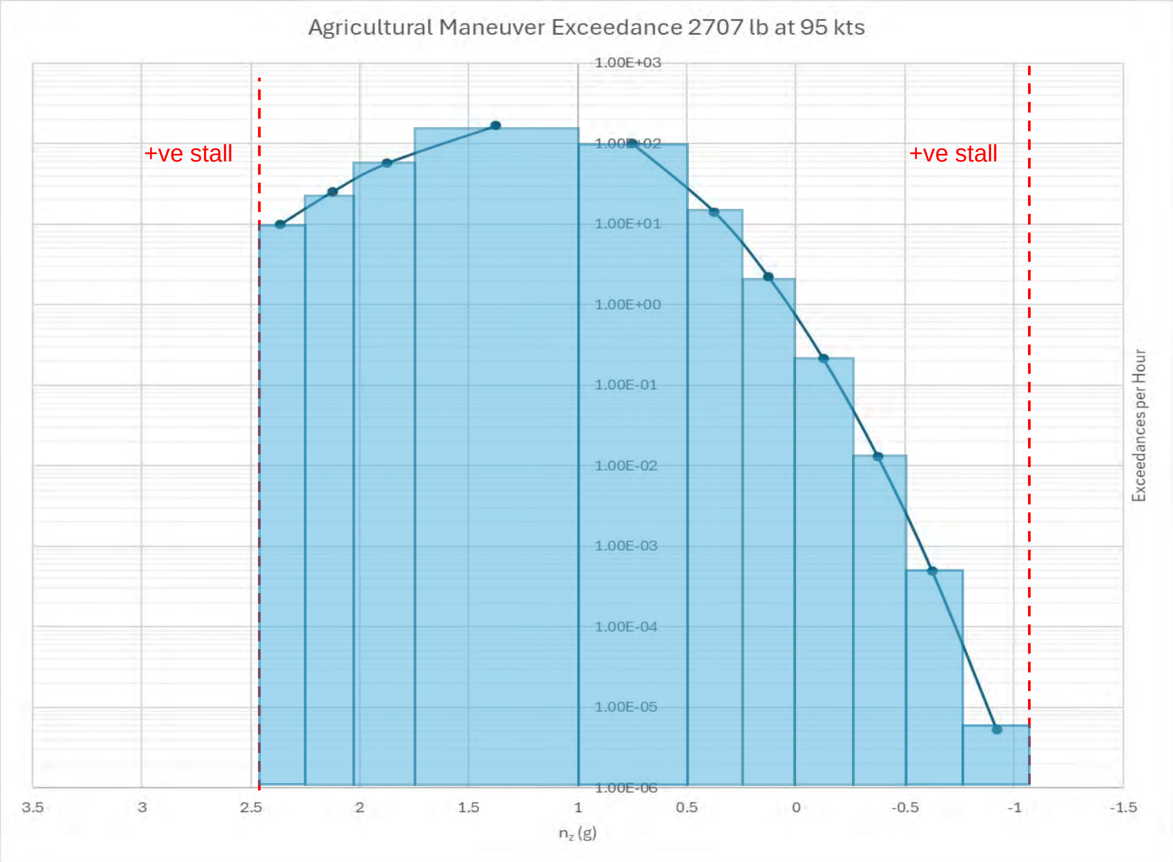

Figure 6-12 Agricultural Maneuver Exceedance for 2707 lb at 95 kts

Block Upper g limit	Block Mean g level	Gust Exceedance per hour	Maneuver Exceedance per hour	Total Exceedance per hour	Occurrence per hour
2.48	2.365	0.0631	10.0313	10.0944	10.0944
2.25	2.125	0.2796	25.5628	25.8424	15.7480
2.00	1.875	1.2734	57.6940	58.9673	33.1249
1.75	1.375	23.0208	167.9963	191.0170	132.0497
1.00					
1.00	0.75	40.5733	101.1171	141.6904	123.5698
0.50	0.375	3.8675	14.2532	18.1206	15.1060
0.25	0.125	0.8101	2.2045	3.0146	2.6308
0.00	-0.125	0.1689	0.2148	0.3838	0.3359
-0.25	-0.375	0.0348	0.0130	0.0479	0.0403
-0.50	-0.625	0.0071	0.0005	0.0075	0.0065
-0.75	-0.92	0.0010	5.3295E-06	0.0010	0.0010
-1.09					

Table 6-12 Gust and Maneuver Exceedance for 2707 lb at 95 kts

	Block Mean g level	Max Spar Stress (ksi)	Min Spar Stress (ksi)	Occurrence per 1000 hr
1	2.365	14.221	6.604	10,094
2	2.125	13.036	6.604	15,748
3	1.875	11.733	6.604	33,125
4	1.375	8.910	6.604	132,050
5	0.75	6.604	4.980	123,570
6	0.375	6.604	2.421	15,106
7	0.125	6.604	0.636	2,631
8	-0.125	6.604	-1.209	336
9	-0.375	6.604	-3.111	40
10	-0.625	6.604	-5.115	6
11	-0.92	6.604	-7.877	1
Total				**331,702**

Table 6-13 AFGROW Gust and Maneuver Spectrum for 2707 lb per 1000 Hours

6.10 **LANDING WEIGHT:** The calculated landing weight is 2005 lb using a nominal empty weight of 1531 lb, and a heavy pilot.

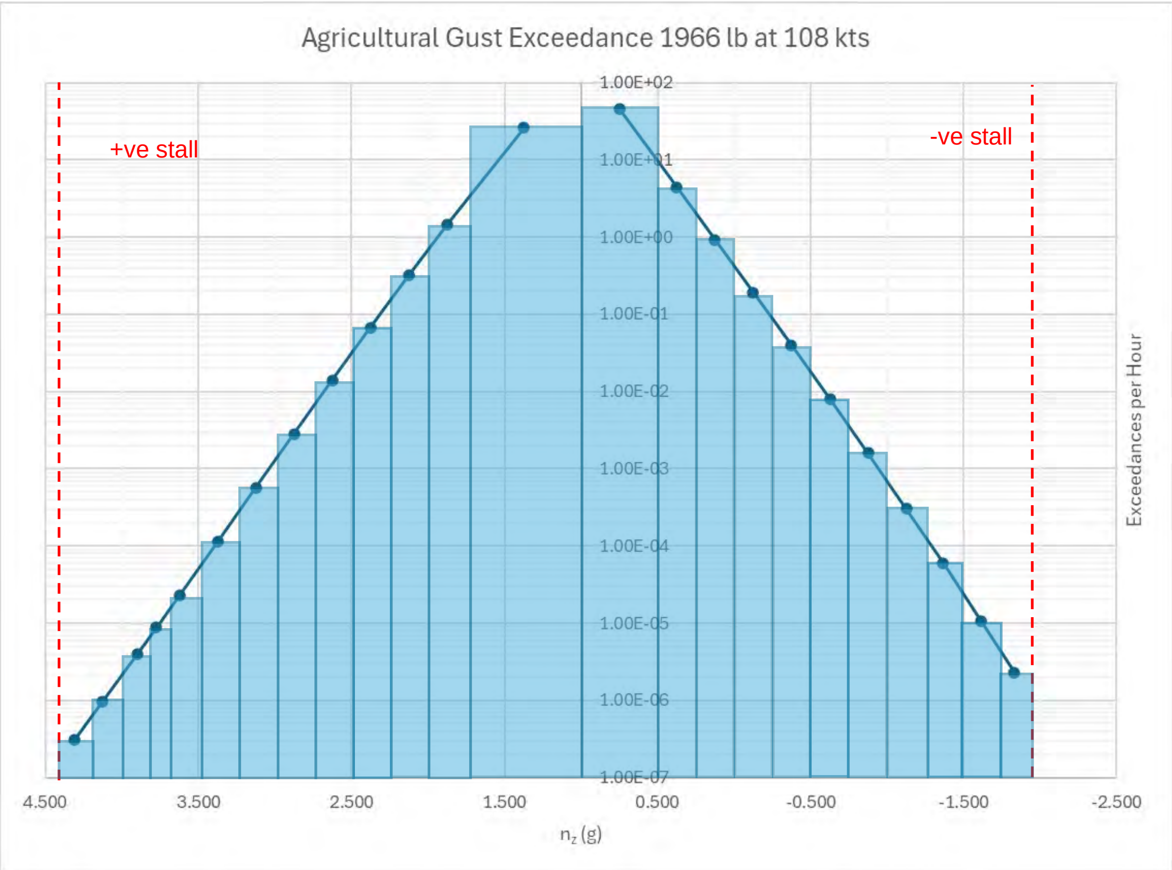

Figure 6-13 Agricultural Gust Exceedance for 1966 lb at 108 kts

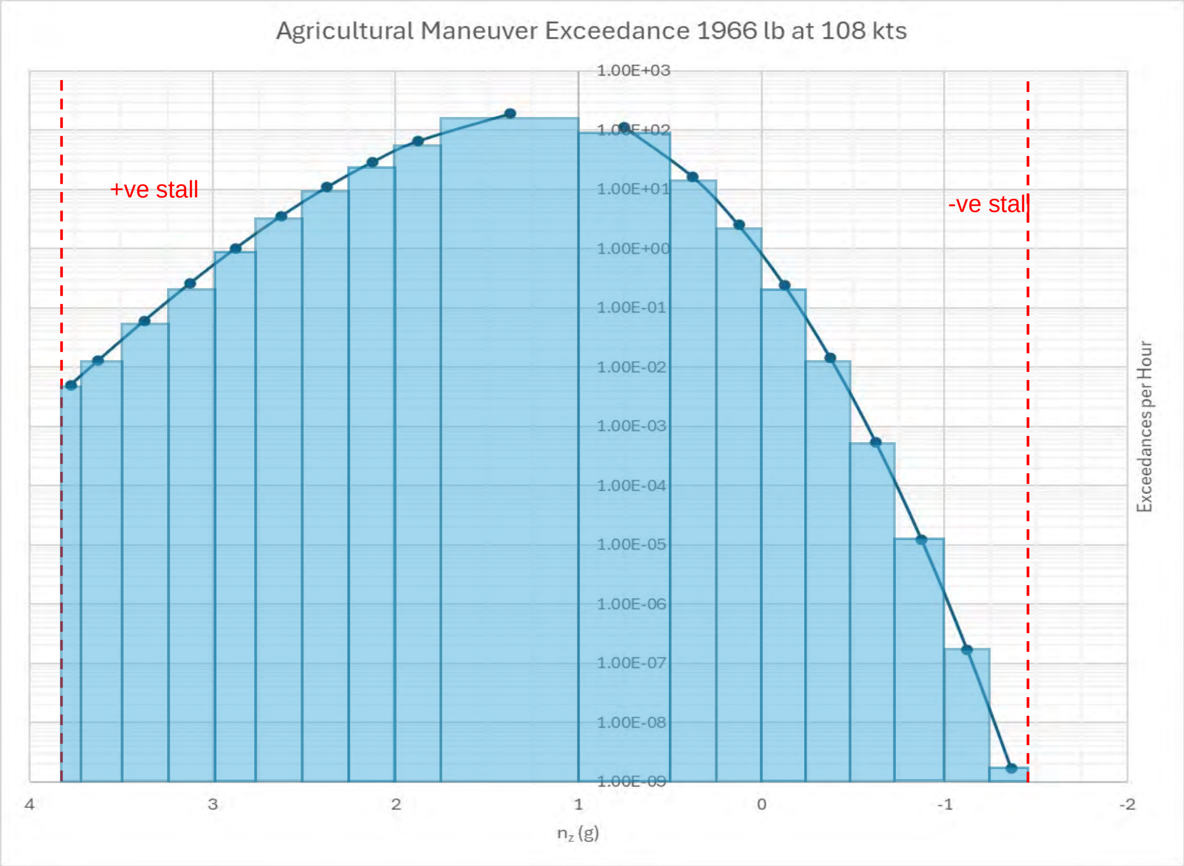

Figure 6-14 Agricultural Maneuver Exceedance for 1966 lb at 108 kts

Block Upper g limit	Block Mean g level	Gust Exceedance per hour	Maneuver Exceedance per hour	Total Exceedance per hour	Occurrence per hour
4.37	4.310	3.090E-07		3.090E-07	3.090E-07
4.25	4.125	9.671E-07		9.671E-07	6.581E-07
4.00	3.900	3.960E-06		3.960E-06	2.993E-06
3.80	3.775	8.739E-06	0.0050	0.0050	0.0050
3.75	3.625	2.273E-05	0.0130	0.0130	0.0080
3.50	3.375	0.0001	0.0602	0.0603	0.0473
3.25	3.125	0.0006	0.2589	0.2594	0.1991
3.00	2.875	0.0028	1.0144	1.0172	0.7578
2.75	2.625	0.0139	3.5577	3.5716	2.5544
2.50	2.375	0.0674	10.9658	11.0332	7.4616
2.25	2.125	0.3178	29.1715	29.4894	18.4562
2.00	1.875	1.4476	65.7745	67.2222	37.7328
1.75	1.375	26.1710	189.3731	215.5441	148.3219
1.00					
1.00	0.75	46.1255	113.8107	159.9361	139.2110

0.50	0.375	4.3967	16.3284	20.7251	17.2809
0.25	0.125	0.9209	2.5233	3.4442	3.0080
0.00	-0.125	0.1920	0.2442	0.4362	0.3820
-0.25	-0.375	0.0396	0.0147	0.0543	0.0457
-0.50	-0.625	0.0080	0.0005	0.0086	0.0070
-0.75	-0.875	0.0016	1.2325E-05	0.0016	0.0013
-1.00	-1.125	0.0003	1.6922E-07	0.0003	2.4377E-04
-1.25	-1.365	6.0008E-05	1.7092E-09	6.0010E-05	4.9391E-05
-1.48	-1.615	1.0619E-05		1.0619E-05	8.3182E-06
-1.75	-1.830	2.3007E-06		2.3007E-06	2.53007E-06
-1.91					

Table 6-14 Gust and Maneuver Exceedance for 1966 lb at 108 kts

	Block Mean g level	**Max Spar Stress (ksi)**	**Min Spar Stress (ksi)**	**Occurrence per 1000 hr**
	4.310	17.691	4.612	0.0003
	4.125	17.101	4.612	0.0006
	3.900	16.362	4.612	0.0030
1	3.775	15.941	4.612	5
2	3.625	15.426	4.612	8
3	3.375	14.544	4.612	47
4	3.125	13.631	4.612	199
5	2.875	12.686	4.612	758
6	2.625	11.709	4.612	2,554
7	2.375	10.701	4.612	7,462
8	2.125	9.662	4.612	18,456
9	1.875	8.592	4.612	37,733
10	1.375	6.362	4.612	148,322
11	0.75	4.612	3.410	139,211
12	0.375	4.612	1.554	17,281
13	0.125	4.612	0.284	3,008
14	-0.125	4.612	-1.013	382
15	-0.375	4.612	-2.335	46
16	-0.625	4.612	-3.683	7
17	-0.875	4.612	-5.054	1
	-1.125	4.612	-6.512	0.2438
	-1.365	4.612	-8.100	0.0494
	-1.615	4.612	-9.782	0.0083
	-1.830	4.612	-11.250	0.0023
Total				**378,236**

Table 6-15 AFGROW Gust and Maneuver Spectrum for 1996 lb at WS 25 without Wing Tanks per 1000 hrs

Note: Due to the low number of occurrences per 1000 hours, the extreme n_z levels were clipped. These occurrences were not included in the AFGROW spectrum.

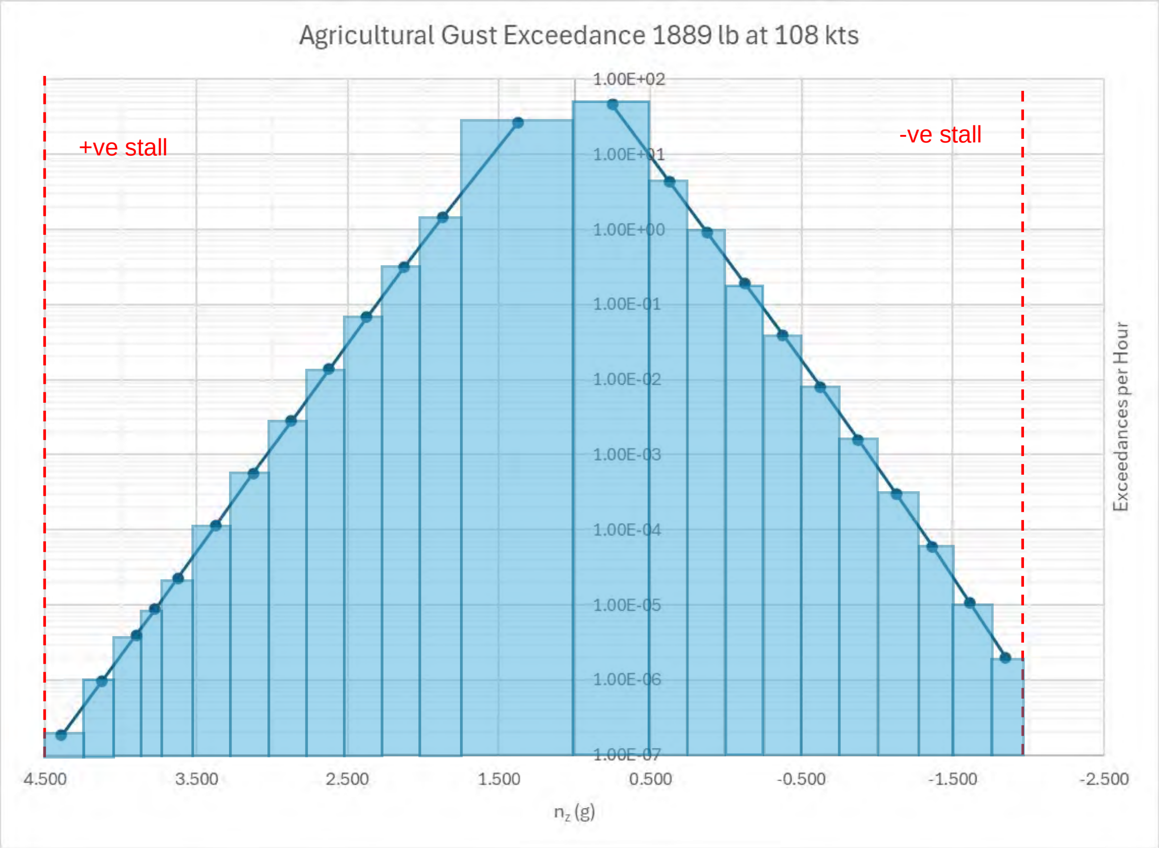

Figure 6-15 Agricultural Gust Exceedance for 1889 lb at 108 kts

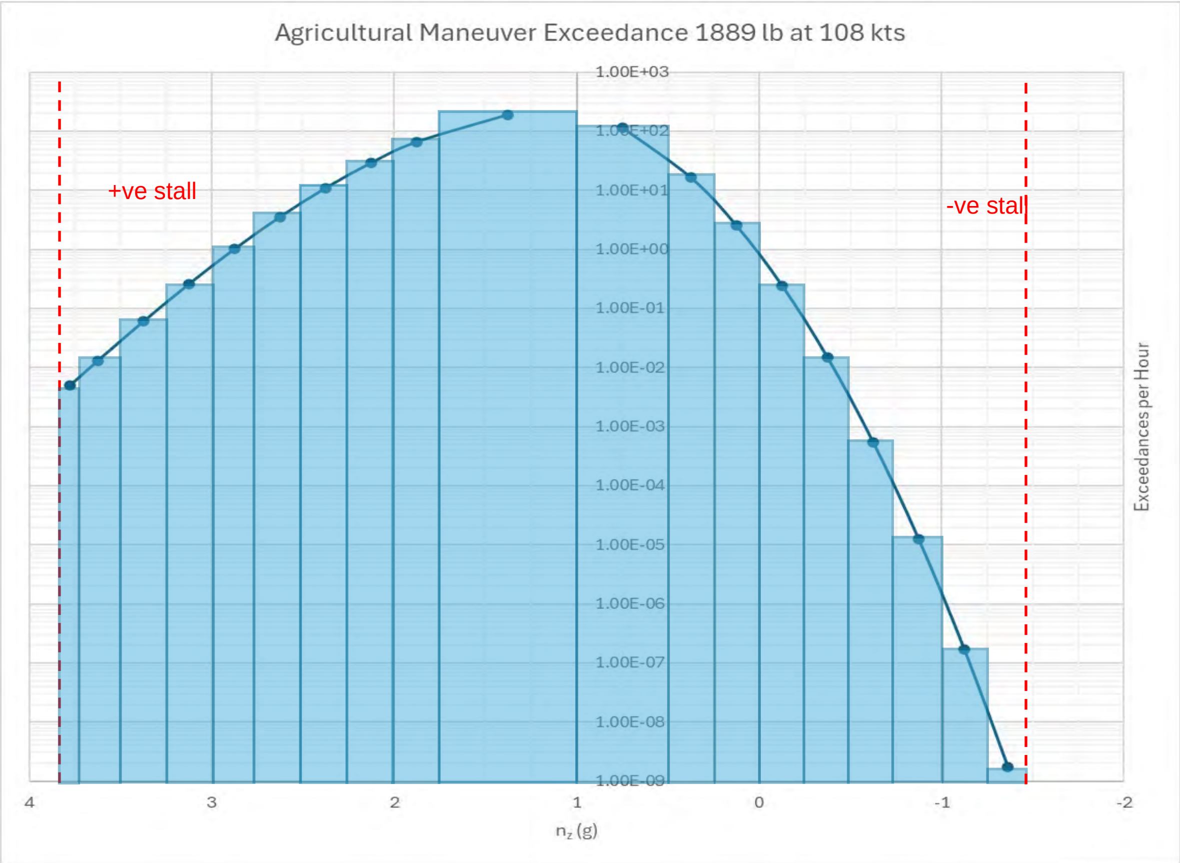

Figure 6-16 Agricultural Maneuver Exceedance for 1889 lb at 108 kts

Block Upper g limit	Block Mean g level	Gust Exceedance per hour	Maneuver Exceedance per hour	Total Exceedance per hour	Occurrence per hour
4.54	4.395	1.8410E-07		1.8410E-07	1.841E-07
4.25	4.125	9.671E-07		9.671E-07	7.830E-07
4.00	3.900	3.960E-06		3.960E-06	2.993E-06
3.80	3.775	8.739E-06	0.0050	0.0050	0.0050
3.75	3.625	2.273E-05	0.0130	0.0130	0.0080
3.50	3.375	0.0001	0.0602	0.0603	0.0473
3.25	3.125	0.0006	0.2589	0.2594	0.1991
3.00	2.875	0.0028	1.0144	1.0172	0.7578
2.75	2.625	0.0139	3.5577	3.5716	2.5544
2.50	2.375	0.0674	10.9658	11.0332	7.4616
2.25	2.125	0.3178	29.1715	29.4894	18.4562
2.00	1.875	1.4476	65.7745	67.2222	37.7328
1.75	1.375	26.1710	189.3731	215.5441	148.3219
1.00					
1.00	0.75	46.1255	113.8107	159.9361	139.2110
0.50	0.375	4.3967	16.3284	20.7251	17.2809
0.25	0.125	0.9209	2.5233	3.4442	3.0080
0.00	-0.125	0.1920	0.2442	0.4362	0.3820
-0.25	-0.375	0.0396	0.0147	0.0543	0.0457
-0.50	-0.625	0.0080	0.0005	0.0086	0.0070
-0.75	-0.875	0.0016	1.2325E-05	0.0016	0.0013
-1.00	-1.125	0.0003	1.6922E-07	0.0003	2.4377E-04
-1.25	-1.365	6.0008E-05	1.7092E-09	6.0010E-05	4.9391E-05
-1.48	-1.615	1.0619E-05		1.0619E-05	8.6273E-06
-1.75	-1.850	1.9915E-06		1.9915E-06	1.9915E-06
-1.95					

Table 6-16 Gust and Maneuver Exceedance for 1889 lb at 108 kts

Note: Due to the low number of occurrences per 1000 hours, the extreme n_z levels were clipped. These occurrences were not included in the AFGROW spectrum.

	Block Mean g level	Max Spar Stress (ksi)	Min Spar Stress (ksi)	Occurrence per 1000 hr
	4.395	17.255	4.396	0.0002
	4.125	16.425	4.396	0.0008
	3.900	15.709	4.396	0.0030
1	3.775	15.301	4.396	5
2	3.625	14.803	4.396	8
3	3.375	13.949	4.396	47
4	3.125	13.066	4.396	200
5	2.875	12.154	4.396	758
6	2.625	11.212	4.396	2,550
7	2.375	10.241	4.396	7,433
8	2.125	9.241	4.396	18,377
9	1.875	8.213	4.396	37,658
10	1.375	6.073	4.396	150,120
11	0.75	4.396	3.245	140,479
12	0.375	4.396	1.470	17,173
13	0.125	4.396	0.255	2,991
14	-0.125	4.396	-0.984	382
15	-0.375	4.396	-2.247	46
16	-0.625	4.396	-3.534	7
17	-0.875	4.396	-4.843	1
	-1.125	4.396	-6.193	0.2438
	-1.365	4.396	-7.709	0.0494
	-1.615	4.396	-9.313	0.0086
	-1.850	4.396	-10.845	0.0020
Total				**378,236**

Table 6-17 Gust and Maneuver Stresses for 1889 lb at WS 25 without Wing Tanks at 108 kts

Note: Due to the low number of occurrences per 1000 hours, the extreme n_z levels were clipped. These occurrences were not included in the AFGROW spectrum.

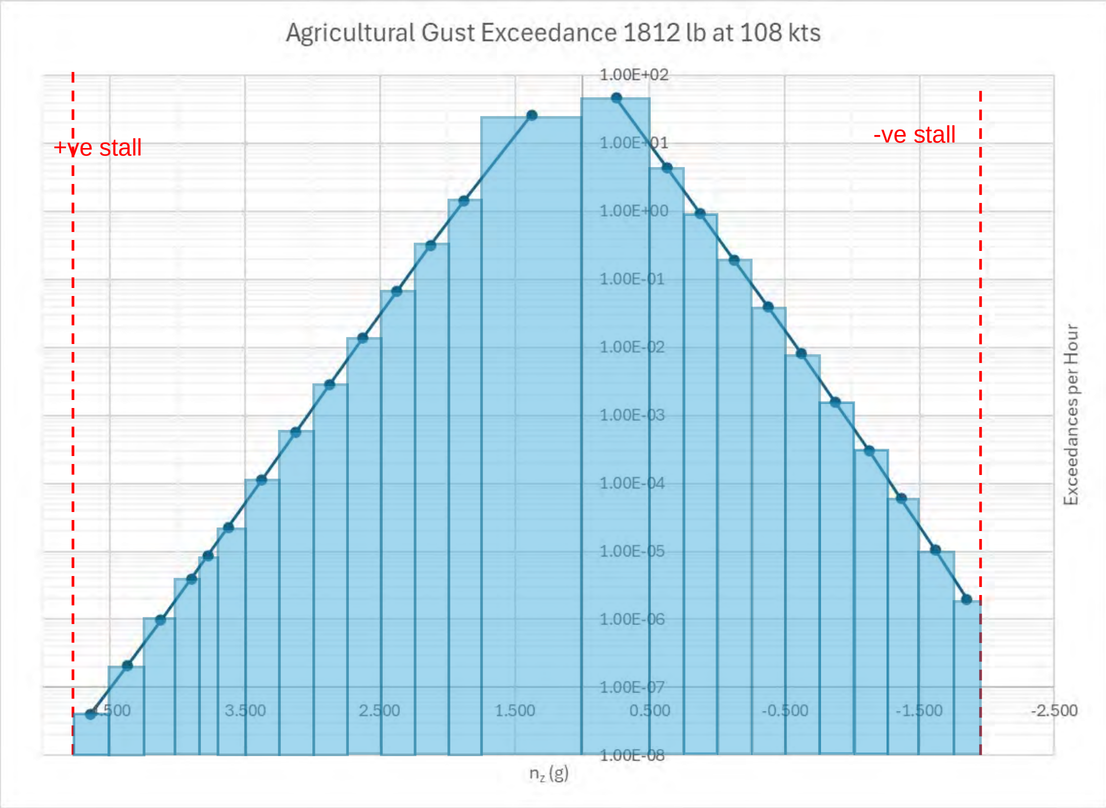

Figure 6-17 Agricultural Gust Exceedance for 1812 lb at 108 kts

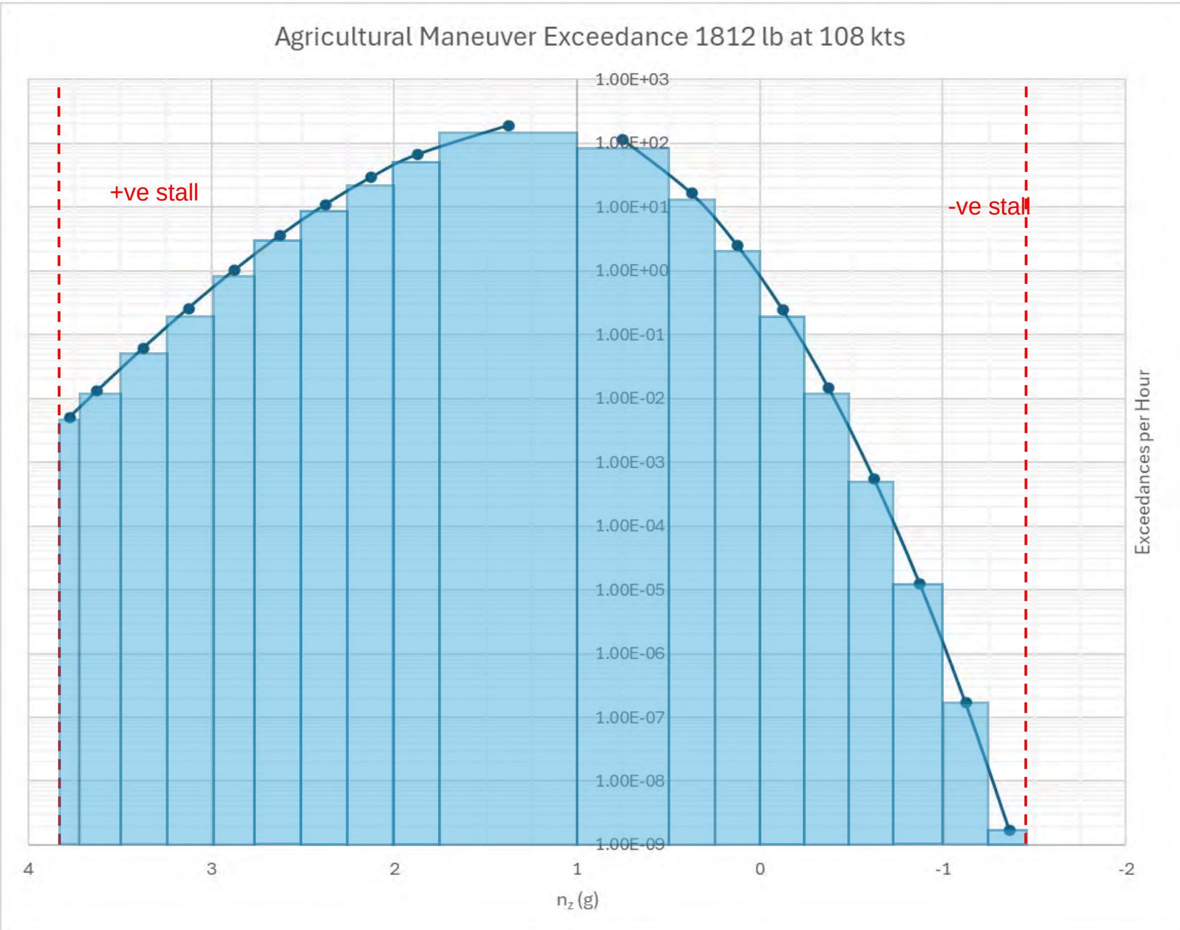

Figure 6-18 Agricultural Maneuver Exceedance for 1812 lb at 108 kts

Block Upper g limit	Block Mean g level	Gust Exceedance per hour	Maneuver Exceedance per hour	Total Exceedance per hour	Occurrence per hour
4.80	4.650	4.0062E-08		4.0062E-08	4.0062E-08
4.04	4.375	2.0787E-07		2.0787E-07	1.6780E-07
4.25	4.125	9.6707E-07		9.6707E-07	7.5920E-07
4.00	3.900	3.9599E-06		3.9599E-06	2.9929E-06
3.80	3.775	8.739E-06	0.0050	0.0050	0.0050
3.75	3.625	2.273E-05	0.0130	0.0130	0.0080
3.50	3.375	0.0001	0.0602	0.0603	0.0473
3.25	3.125	0.0006	0.2589	0.2594	0.1991
3.00	2.875	0.0028	1.0144	1.0172	0.7578
2.75	2.625	0.0139	3.5577	3.5716	2.5544
2.50	2.375	0.0674	10.9658	11.0332	7.4616
2.25	2.125	0.3178	29.1715	29.4894	18.4562
2.00	1.875	1.4476	65.7745	67.2222	37.7328
1.75	1.375	26.1710	189.3731	215.5441	148.3219
1.00					
1.00	0.75	46.1255	113.8107	159.9361	139.2110
0.50	0.375	4.3967	16.3284	20.7251	17.2809
0.25	0.125	0.9209	2.5233	3.4442	3.0080
0.00	-0.125	0.1920	0.2442	0.4362	0.3820
-0.25	-0.375	0.0396	0.0147	0.0543	0.0457
-0.50	-0.625	0.0080	0.0005	0.0086	0.0070
-0.75	-0.875	0.0016	1.2325E-05	0.0016	0.0013
-1.00	-1.125	0.0003	1.6922E-07	0.0003	2.4377E-04
-1.25	-1.365	6.0008E-05	1.7092E-09	6.0010E-05	4.9391E-05
-1.48	-1.615	1.0619E-05		1.0619E-05	8.6273E-06
-1.75	-1.850	1.9915E-06		1.9915E-06	1.9915E-06
-1.95					

Table 6-18 Gust and Maneuver Exceedance for 1812 lb at 108 kts

Note: Due to the low number of occurrences per 1000 hours, the extreme n_z levels were clipped. These occurrences were not included in the AFGROW spectrum.

	Block Mean g level	Max Spar Stress (ksi)	Min Spar Stress (ksi)	Occurrence per 1000 hr
	4.650	14.973	-0.149	0.0000
	4.375	13.844	-0.149	0.0002
	4.125	12.802	-0.149	0.0008
	3.900	11.858	-0.149	0.0030
1	3.775	11.331	-0.149	5
2	3.625	10.699	-0.149	8
3	3.375	9.645	-0.149	47
4	3.125	8.594	-0.149	200
5	2.875	7.545	-0.149	758
6	2.625	6.501	-0.149	2,550
7	2.375	5.462	-0.149	7,433
8	2.125	4.428	-0.149	18,377
9	1.875	3.400	-0.149	37,658
10	1.375	1.362	-0.149	150,120
11	0.75	-0.149	-1.147	140,479
12	0.375	-0.149	-2.630	17,173
13	0.125	-0.149	-3.607	2,991
14	-0.125	-0.149	-4.575	382
15	-0.375	-0.149	-5.533	46
16	-0.625	-0.149	-6.479	7
17	-0.875	-0.149	-7.416	1
	-1.125	-0.149	-8.342	0.2436
	-1.365	-0.149	-9.258	0.0494
	-1.615	-0.149	-10.246	0.0086
	-1.850	-0.149	-11.174	0.0020
Total				**378,236**

Table 6-19 Gust and Maneuver Stresses for 1812 lb at WS 25 without Wing Tanks at 108 kts

Note: Due to the low number of occurrences per 1000 hours, the extreme n_z levels were clipped. These occurrences were not included in the AFGROW spectrum.

6.11 **LANDING:** In all agricultural weight cases the aircraft is assumed to be landing at without a payload. Table 4.1 of Reference 1.5 gives the following for agricultural operations:

Assumption: All agricultural operations are assumed to be landing without a payload in the hopper. This assumption is reasonable as the intention of the flight is to apply all of the payload to the application area.

Aircraft	Hours	Landings	Landings / Hour
Fletcher FU24A/A4	1010	9064	8.97
Piper PA 25-235	440	3947	9.03

Table 6-20 Average Landing per Hour for Agricultural Operations

The combined average is 9 landings per hour. The data used in the development of Reference 1.2 had a total of 487 hours and 2252 flights for 5 agricultural aircraft, giving an average of 4.62 flights per hour. This highlights that there is considerable variation in agricultural operations in different countries. For the purpose of this analysis for Australian aircraft, it is more conservative to use 9 landings per hour.

Sink Rate (ft/sec)	Delta Nz (g)	Exceedance per landing	Exceedance per hour	Occurrence per hour
0.5	0.421	0.7300	6.5700	3.6000
1.5	1.264	0.3300	2.9700	2.2140
2.5	2.107	0.0840	0.7560	0.6660
3.5	2.950	0.0100	0.0900	0.0720
4.5	3.793	0.0020	0.0180	0.0132
5.5	4.635	0.0005	0.0048	0.0033
6.5	5.478	0.0002	0.0015	0.0015

Table 6-21 Landing Exceedance for 1966 lb

	Block Mean g level	Max Spar Stress (ksi)	Min Spar Stress (ksi)	Occurrence per 1000 hr
1	1.421	3.241	2.791	3,600
2	2.264	3.241	1.890	2,214
3	3.107	3.241	0.958	666
4	3.950	3.241	-0.118	72
5	4.793	3.241	-1.190	13
6	5.635	3.241	-2.263	3
7	6.478	3.241	-3.335	1
Total				**6,569**

Table 6-22 AFGROW Spectrum for Landing at 1996 lb at WS 25 without Wing Tanks per 1000 hrs

Note: There are 2400 occurrences for a sink rate of 0 ft sec. Because this does not produce a delta Nz, these have a constant stress and do not contribute to the fatigue cycle.

Sink Rate (ft/sec)	Delta Nz (g)	Exceedance per landing	Exceedance per hour	Occurrence per hour
0.5	0.430	0.7300	6.5700	3.6000
1.5	1.290	0.3300	2.9700	2.2140
2.5	2.150	0.0840	0.7560	0.6660
3.5	3.009	0.0100	0.0900	0.0720
4.5	3.869	0.0020	0.0180	0.0132
5.5	4.729	0.0005	0.0048	0.0033
6.5	5.589	0.0002	0.0015	0.0015

Table 6-23 Landing Exceedance for 1889 lb

	Block Mean g level	Max Spar Stress (ksi)	Min Spar Stress (ksi)	Occurrence per 1000 hr
1	1.430	3.076	2.617	3,600
2	2.290	3.076	1.698	2,214
3	3.150	3.076	0.715	666
4	4.009	3.076	-0.381	72
5	4.869	3.076	-1.476	13
6	5.729	3.076	-2.570	3
7	6.589	3.076	-3.664	1
Total				**6,569**

Table 6-24 AFGROW Spectrum for Landing at 1889 lb at WS 25 without Wing Tanks per 1000 hrs

Note: There are 2400 occurrences for a sink rate of 0 ft sec. Because this does not produce a delta Nz, these have a constant stress and do not contribute to the fatigue cycle.

Sink Rate (ft/sec)	Delta Nz (g)	Exceedance per landing	Exceedance per hour	Occurrence per hour
0.5	0.439	0.7300	6.5700	3.6000
1.5	1.317	0.3300	2.9700	2.2140
2.5	2.195	0.0840	0.7560	0.6660
3.5	3.073	0.0100	0.0900	0.0720
4.5	3.951	0.0020	0.0180	0.0132
5.5	4.829	0.0005	0.0048	0.0033
6.5	5.706	0.0002	0.0015	0.0015

Table 6-25 Landing Exceedance for 1812 lb

	Block Mean g level	Max Spar Stress (ksi)	Min Spar Stress (ksi)	Occurrence per 1000 hr
1	1.439	2.911	2.442	3,600
2	2.317	2.911	1.504	2,214
3	3.195	2.911	0.468	666
4	4.073	2.911	-0.650	72
5	4.951	2.911	-1.768	13
6	5.829	2.911	-2.885	3
7	6.706	2.911	-4.002	1
Total				**6,569**

Table 6-26 AFGROW Spectrum for Landing at 1812 lb at WS 25 without Wing Tanks per 1000 hrs

Note: There are 2400 occurrences for a sink rate of 0 ft sec. As this does not produce a delta Nz, these have a constant stress and do not contribute to the fatigue cycle.

6.12 **TAXIING:** Taxiing is independent of the payload weight. It is also independent of the fuel weight if the aircraft does not have wing tanks. Taxiing also assuming a worst case average of 9 landings per hour:

Block Upper delta n_z limit	Block Mean delta n_z level	Aircraft N_z	Exceedance per landing	Exceedance per hour	Occurrence per hour
0.6	0.55	1.55	0.0445	0.4004	0.4004
0.5	0.45	1.45	0.0936	0.8426	0.4422
0.4	0.35	1.35	0.2140	1.9259	1.0833
0.3	0.15	1.15	1.8715	16.8438	14.918
0					
-0.3	-0.15	0.85	1.8715	16.8438	14.918
-0.4	-.35	0.65	0.2140	1.9259	1.0833
-0.5	-.45	0.55	0.0936	0.8426	0.4422
-0.6	-.55	0.45	0.0445	0.4004	0.4004

Table 6-27 Taxiing Exceedance

	Aircraft N_z	Max Spar Stress (ksi)	Min Spar Stress (ksi)	Occurrence per 1000 hr
1	1.55	-1.086	-1.684	400
2	1.45	-1.086	-1.575	442
3	1.35	-1.086	-1.467	1,083
4	1.15	-1.086	-1.249	14,918
5	0.85	-0.923	-1.086	14,918
6	0.65	-0.706	-1.086	1,083
7	0.55	-0.597	-1.086	442
8	0.45	-0.489	-1.086	400
Total				**33,686**

Table 6-28 AFGROW Spectrum for Taxiing at WS 25 without Wing Tanks

6.13 Taxiing applies compression in the critical areas for Pawnees without fuel tanks in the wings. This will contribute to fatigue by itself, but it may contribute to the ground – air – ground cycle.

6.14 **GROUND-AIR-GROUND CYCLE:** Ground air ground cycles were determined by fitting curves to the stress versus exceedance charts for the particular operating weight. These curves were then used to estimate the occurance for a particular stress per flight. The ground air ground cycles for agricultural use assumes the aircraft spent 50 % of the flight at the take off weight and 50% of the time at the landing weight as per paragraph 6.6.

6.15 **OVERWEIGHT – 3205 lb:** The ground-air-ground spectra for overweight operations are at Table 6-30, Table 6-32. And Table 6-34 below:

	3166 lb		1996 lb		1996 lb		
Stress	**Gust**	**Maneuver**	**Gust**	**Maneuver**	**Landing**	**Taxi**	**Total**
17.000	0.0018	0.3597	0.0000	0.0000			0.3615
16.000	0.0056	0.7699	0.0000	0.0002			0.7758
15.637	0.0085	0.9912	0.0000	0.0005			1.0002
15.000	0.0170	1.4981	0.0000	0.0015			1.5166
14.000	0.0484	2.6498	0.0000	0.0081			2.7064
-1.000	0.0121	0.0178	0.0107	0.0137	0.0026	5.1172	5.1740
-1.250	0.0101	0.0134	0.0079	0.0082	0.0018	1.8579	1.8993
-1.307	0.0097	0.0125	0.0074	0.0073	0.0016	0.9642	1.0027
-1.500	0.0085	0.0100	0.0058	0.0049	0.0012	0.1640	0.1944
-1.750	0.0071	0.0075	0.0043	0.0029	0.0009	0.0286	0.0513

Table 6-29 Ground-Air-Ground Stress for Overweight Agricultural Operation at WS 25 with 5/6 Capacity Fuel (32.08 Gal) without Wing Tanks

Note: the aircraft is limited to 15.054 ksi as a maximum stress by the stall curve of the aircraft at 3166 lb at 95 kts. To get the total exceedance for the maximum positive stress to 1.00, the aircraft would need to be operating at a higher speed (~97kts) such that a higher stress can be achieved within the flight envelope.

	Max Spar Stress (ksi)	**Min Spar Stress (ksi)**	**Occurrence per 1000 hr**
1	15.637	-1.307	9,000
Total			**9,000**

Table 6-30 AFGROW Spectrum for Overweight Agricultural Operation at 3166 lb at WS 25 without Wing Tanks

	3089 lb		1889 lb		1889 lb		
Stress	**Gust**	**Maneuver**	**Gust**	**Maneuver**	**Landing**	**Taxi**	**Total**
17.000	0.0011	0.2631	0.0000	0.0000			0.2643
16.000	0.0037	0.5920	0.0000	0.0002			0.5960
15.291	0.0085	0.9909	0.0000	0.0009			1.0003
15.000	0.0118	1.2066	0.0000	0.0015			1.2199
14.000	0.0348	2.2278	0.0000	0.0081			2.2707
-1.000	0.0119	0.0174	0.0107	0.0137	0.0040	5.1172	5.1749
-1.250	0.0099	0.0130	0.0079	0.0082	0.0027	1.8579	1.8996
-1.307	0.0095	0.0121	0.0074	0.0073	0.0025	0.9642	1.0030
-1.500	0.0083	0.0096	0.0058	0.0049	0.0019	0.1640	0.1944
-1.750	0.0069	0.0071	0.0043	0.0029	0.0013	0.0286	0.0512

Table 6-31 Ground-Air-Ground Stress for Overweight Agricultural Operation at WS 25 with 1/2 Capacity Fuel (19.25 Gal) without Wing Tanks

Note: the aircraft is limited to 15.162 ksi as a maximum stress by the stall curve of the aircraft at 3089 lb at 95 kts. To get the total exceedance for the maximum positive stress to 1.00, the aircraft would need to be operating at a higher speed (~97kts) such that a higher stress can be achieved within the flight envelope.

	Max Spar Stress (ksi)	Min Spar Stress (ksi)	Occurrence per 1000 hr
1	15.291	-1.307	9,000
Total			**9,000**

Table 6-32 AFGROW Spectrum for Overweight Agricultural Operation at 3089 lb at WS 25 without Wing Tanks

	3012 lb		1812 lb		1812 lb		
Stress	**Gust**	**Maneuver**	**Gust**	**Maneuver**	**Landing**	**Taxi**	**Total**
16.000	0.0024	0.4437	0.0000	0.0002			0.4464
15.000	0.0079	0.9507	0.0000	0.0015			0.9602
14.943	0.0085	0.9899	0.0000	0.0017			1.0001
14.000	0.0244	1.8382	0.0000	0.0081			1.8708
12.000	0.1932	5.0499	0.0005	0.1381			5.3817
-1.000	0.0117	0.0170	0.0107	0.0137	0.0063	5.1172	5.1767
-1.250	0.0097	0.0125	0.0079	0.0082	0.0042	1.8579	1.9005
-1.307	0.0093	0.0117	0.0074	0.0073	0.0039	0.9642	1.0038
-1.500	0.0081	0.0092	0.0058	0.0049	0.0029	0.1640	0.1948
-2.000	0.0056	0.0049	0.0032	0.0016	0.0014	0.0044	0.0211

Table 6-33 Ground-Air-Ground Stress for Overweight Agricultural Operation at WS 25 with 1/6 Capacity Fuel (6.4 Gal) without Wing Tanks

	Max Spar Stress (ksi)	Min Spar Stress (ksi)	Occurrence per 1000 hr
1	14.943	-1.307	9,000
Total			**9,000**

Table 6-34 AFGROW Spectrum for Overweight Agricultural Operation at 3012 lb at WS 25 without Wing Tanks

6.16 **Maximum Takeoff Weight – 2920 lb:** The ground-air-ground spectra for overweight operations are at Table 6-36, Table 6-38, and Table 6-40below:

	2861 lb		1966 lb		1966 lb		
Stress	**Gust**	**Maneuver**	**Gust**	**Maneuver**	**Landing**	**Taxi**	**Total**
16.000	0.0009	0.2194	0.0000	0.0002			0.2205
15.000	0.0034	0.5440	0.0000	0.0015			0.5490
14.250	0.0085	0.9860	0.0000	0.0055			1.0000
14.000	0.0114	1.1832	0.0000	0.0081			1.2028
13.000	0.0360	2.2716	0.0001	0.0364			2.3441
-1.000	0.0114	0.0161	0.0107	0.0137	0.0026	5.1172	5.1717
-1.250	0.0093	0.0117	0.0079	0.0082	0.0018	1.8579	1.8968
-1.307	0.0089	0.0109	0.0074	0.0073	0.0016	0.9642	1.0003
-1.500	0.0077	0.0084	0.0058	0.0049	0.0012	0.1640	0.1920
-2.000	0.0052	0.0043	0.0032	0.0016	0.0007	0.0044	0.0194

Table 6-35 Ground-Air-Ground Stress for MTOW Agricultural Operation at WS 25 with 5/6 Capacity Fuel (32.08 Gal) without Wing Tanks

	Max Spar Stress (ksi)	Min Spar Stress (ksi)	Occurrence per 1000 hr
1	14.25	-1.307	9,000
Total			**9,000**

Table 6-36 AFGROW Spectrum for MTOW Agricultural Operation at 2861 lb at WS 25 without Wing Tanks

	2784 lb		1889 lb		1889 lb		
Stress	**Gust**	**Maneuver**	**Gust**	**Maneuver**	**Landing**	**Taxi**	**Total**
14.500	0.0040	0.6057	0.0000	0.0013			0.6109
14.000	0.0074	0.9067	0.0000	0.0031			0.9172
13.888	0.0085	0.9880	0.0000	0.0037			1.0003
13.500	0.0136	1.3135	0.0000	0.0072			1.3343
13.000	0.0245	1.8427	0.0000	0.0160			1.8833
-1.000	0.0112	0.0157	0.0103	0.0130	0.0040	5.1172	5.1714
-1.250	0.0091	0.0112	0.0075	0.0076	0.0027	1.8579	1.8961
-1.307	0.0087	0.0104	0.0070	0.0067	0.0025	0.9642	0.9995
-1.500	0.0074	0.0080	0.0055	0.0044	0.0019	0.1640	0.1911
-1.750	0.0061	0.0057	0.0040	0.0025	0.0013	0.0286	0.0482

Table 6-37 Ground-Air-Ground Stress for MTOW Agricultural Operation at WS 25 with 1/2 Capacity Fuel (19.25 Gal) without Wing Tanks

	Max Spar Stress (ksi)	Min Spar Stress (ksi)	Occurrence per 1000 hr
1	13.888	-1.307	9,000
Total			**9,000**

Table 6-38 AFGROW Spectrum for MTOW Agricultural Operation at 2784 lb at WS 25 without Wing Tanks

	2707 lb		1812 lb		1812 lb		
Stress	**Gust**	**Maneuver**	**Gust**	**Maneuver**	**Landing**	**Taxi**	**Total**
15.000	0.0012	0.2709	0.0000	0.0001			0.2723
14.000	0.0047	0.6735	0.0000	0.0010			0.6792
13.524	0.0085	0.9889	0.0000	0.0024			0.9999
13.000	0.0162	1.4567	0.0000	0.0062			1.4791
12.500	0.0294	2.0380	0.0000	0.0143			2.0818
-1.000	0.0110	0.0152	0.0100	0.0123	0.0063	5.1172	5.1720
-1.250	0.0089	0.0108	0.0071	0.0070	0.0042	1.8579	1.8959
-1.307	0.0085	0.0099	0.0066	0.0061	0.0039	0.9642	0.9992
-1.500	0.0072	0.0076	0.0051	0.0039	0.0029	0.1640	0.1906
-2.000	0.0047	0.0037	0.0026	0.0011	0.0014	0.0044	0.0180

Table 6-39 Ground-Air-Ground Stress for MTOW Agricultural Operation at WS 25 with 1 with 1/6 Capacity Fuel (6.4 Gal) without Wing Tanks

	Max Spar Stress (ksi)	Min Spar Stress (ksi)	Occurrence per 1000 hr
1	13.524	-1.307	9,000
Total			**9,000**

Table 6-40 AFGROW Spectrum for MTOW Agricultural Operation at 2707 lb at WS 25 without Wing Tanks

7. AGRICULTURAL LOAD SPECTRA – D MODELS

7.1 Similar to Section 6, Pawnee D aircraft fitted with wing tanks were considered to have three weight cases with 5/6, 1/2, and 1/6 fuel tank levels. The aircraft was assumed to operate at each of these three weight cases as per Section 5. Similar to Section 6, all agricultural operations are assumed to spend 50% of flight time at take-off weight and 50% flight time without a payload in the hopper. The exceedances were identical, but the wing stresses were different.

7.2 **OVERWEIGHT – 3205 lb:** The gust and maneuvre exceedance are identical to those at Section 6.7. However, because the fuel is in the wings outboard of the strut attachment, the wing stresses vary greater with fuel load and the critical location moves to WS 80. WS 25 becomes more critical at very low fuel loads and the fatigue life becomes sensitive to the assumption of how long the aircraft operates at each fuel load.

	Block Mean g level	Max Spar Stress (ksi)	Min Spar Stress (ksi)	Occurrence per 1000 hr
1	2.06	12.998	4.542	32,527
2	1.875	11.538	4.542	26,440
3	1.375	7.529	4.542	132,050
4	0.75	4.542	2.576	123,570
5	0.375	4.542	-0.329	15,106
6	0.125	4.542	-2.229	2,631
7	-0.125	4.542	-4.094	336
8	-0.375	4.542	-5.918	40
9	-0.625	4.542	-7.735	6
10	-0.835	4.542	-9.326	2
Total				**332,707**

Table 7-1 AFGROW Gust and Maneuver Stresses for 3166 lb at WS 80 with Wing Tanks per 1000 hrs

	Block Mean g level	Max Spar Stress (ksi)	Min Spar Stress (ksi)	Occurrence per 1000 hr
1	2.09	12.520	4.204	29,290
2	1.875	10.893	4.204	29,678
3	1.375	7.057	4.204	132,050
4	0.75	4.204	2.325	123,570
5	0.375	4.204	-0.452	15,106
6	0.125	4.204	-2.270	2,631
7	-0.125	4.204	-4.054	336
8	-0.375	4.204	-5.800	40
9	-0.625	4.204	-7.543	6
10	-0.855	4.204	-9.216	2
Total				**332,707**

Table 7-2 AFGROW Gust and Maneuver Spectrum for 3089 lb at WS 80 with Wing Tanks per 1000 hrs

	Block Mean g level	Max Spar Stress (ksi)	Min Spar Stress (ksi)	Occurrence per 1000 hr
1	2.12	12.082	3.894	26,314
2	1.875	10.302	3.894	32,653
3	1.375	6.626	3.894	132,050
4	0.75	3.894	2.095	123,570
5	0.375	3.894	-0.565	15,106
6	0.125	3.894	-2.307	2,631
7	-0.125	3.894	-4.018	336
8	-0.375	3.894	-5.693	40
9	-0.625	3.894	-7.368	6
10	-0.87	3.894	-9.083	1
Total				**332,707**

Table 7-3 AFGROW Gust and Maneuver Spectrum for 3012 lb at WS 80 with Wing Tanks per 1000 hrs

7.3 **MAX TAKE OFF WEIGHT - 2900lb:** The design max take off weight is 2900 lb. With full fuel and a heavy pilot results in a payload of 895 lb. The critical location is WS 80. WS 25 becomes more critical at lower fuel loads and the fatigue life becomes sensitive to the assumption of how long the aircraft operates at each fuel load.

	Block Mean g level	Max Spar Stress (ksi)	Min Spar Stress (ksi)	Occurrence per 1000 hr
1	2.295	13.065	3.761	13,470
2	2.125	11.860	3.761	12,372
3	1.875	10.058	3.761	33,125
4	1.375	6.442	3.761	132,050
5	0.75	3.761	1.996	123,570
6	0.375	3.761	-0.614	15,106
7	0.125	3.761	-2.323	2,631
8	-0.125	3.761	-4.002	336
9	-0.375	3.761	-5.647	40
10	-0.625	3.761	-7.258	6
11	-0.89	3.761	-9.064	1
Total				**331,702**

Table 7-4 AFGROW Gust and Maneuver Spectrum for 2861 lb at WS 80 with Wing Tanks per 1000 Hours

	Block Mean g level	Max Spar Stress (ksi)	Min Spar Stress (ksi)	Occurrence per 1000 hr
1	2.33	12.514	3.422	11,678
2	2.125	11.126	3.422	14,165
3	1.875	9.409	3.422	33,125
4	1.375	5.970	3.422	132,050
5	0.75	3.422	1.743	123,570
6	0.375	3.422	-0.738	15,106
7	0.125	3.422	-2.364	2,631
8	-0.125	3.422	-3.962	336
9	-0.375	3.422	-5.528	40
10	-0.625	3.422	-7.065	6
11	-0.90	3.422	-8.855	1
Total				**331,702**

Table 7-5 AFGROW Gust and Maneuver Spectrum for 2784 lb at WS 80 with Wing Tanks per 1000 Hours

	Block Mean g level	Max Spar Stress (ksi)	Min Spar Stress (ksi)	Occurrence per 1000 hr
1	2.365	12.007	3.112	10,094
2	2.125	10.453	3.112	15,748
3	1.875	8.814	3.112	33,125
4	1.375	5.538	3.112	132,050
5	0.75	3.112	1.513	123,570
6	0.375	3.112	-0.851	15,106
7	0.125	3.112	-2.401	2,631
8	-0.125	3.112	-3.925	336
9	-0.375	3.112	-5.420	40
10	-0.625	3.112	-6.888	6
11	-0.92	3.112	-8.728	1
Total				**331,702**

Table 7-6 AFGROW Gust and Maneuver Spectrum for 2707 lb with Wing Tanks per 1000 Hours

7.4 **OPERATIONS AT LANDING WEIGHT:** The calculated landing weight uses a nominal empty weight of 1531 lb, the fuel load, and a heavy pilot.

	Block Mean g level	Max Spar Stress (ksi)	Min Spar Stress (ksi)	Occurrence per 1000 hr
	4.310	16.454	0.497	0.0003
	4.125	15.572	0.497	0.0007
	3.900	14.485	0.497	0.0030
1	3.775	13.877	0.497	5
2	3.625	13.144	0.497	8
3	3.375	11.920	0.497	47
4	3.125	10.695	0.497	200
5	2.875	9.473	0.497	758
6	2.625	8.254	0.497	2,550
7	2.375	7.041	0.497	7,433
8	2.125	5.835	0.497	18,377
9	1.875	4.636	0.497	37,658
10	1.375	2.259	0.497	150,120
11	0.75	0.497	-0.666	140,479
12	0.375	0.497	-2.392	17,173
13	0.125	0.497	-3.529	2,991

14	-0.125	0.497	-4.653	382
15	-0.375	0.497	-5.765	46
16	-0.625	0.497	-6.863	7
17	-0.875	0.497	-7.949	1
	-1.125	0.497	-9.021	0.2438
	-1.365	0.497	-10.075	0.0494
	-1.615	0.497	-11.210	0.0083
	-1.830	0.497	-12.186	0.0023
Total				**378,236**

Table 7-7 Gust and Maneuver Stresses for 1966 lb at WS 80 with wing tanks at 108 kts

Note: Due to the low number of occurrences per 1000 hours, the extreme n_z levels were clipped. These occurrences were not included in the AFGROW spectrum.

	Block Mean g level	Max Spar Stress (ksi)	Min Spar Stress (ksi)	Occurrence per 1000 hr
	4.395	15.333	0.160	0.0002
	4.125	14.131	0.160	0.0008
	3.900	13.117	0.160	0.0030
1	3.775	12.551	0.160	5
2	3.625	11.870	0.160	8
3	3.375	10.734	0.160	47
4	3.125	9.599	0.160	200
5	2.875	8.467	0.160	758
6	2.625	7.339	0.160	2,550
7	2.375	6.217	0.160	7,433
8	2.125	5.101	0.160	18,377
9	1.875	3.991	0.160	37,658
10	1.375	1.791	0.160	150,120
11	0.75	0.160	-0.917	140,479
12	0.375	0.160	-2.516	17,173
13	0.125	0.160	-3.570	2,991
14	-0.125	0.160	-4.612	382
15	-0.375	0.160	-5.644	46
16	-0.625	0.160	-6.663	7
17	-0.875	0.160	-7.670	1
	-1.125	0.160	-8.666	0.2438

	-1.365	0.160	-9.648	0.0494
	-1.615	0.160	-10.706	0.0086
	-1.850	0.160	-11.700	0.0020
Total				**378,236**

Table 7-8 Gust and Maneuver Stresses for 1889 lb at WS 80 with wing tanks at 108 kts

Note: Due to the low number of occurrences per 1000 hours, the extreme n_z levels were clipped. These occurrences were not included in the AFGROW spectrum.

	Block Mean g level	**Max Spar Stress (ksi)**	**Min Spar Stress (ksi)**	**Occurrence per 1000 hr**
	4.650	14.973	-0.149	0.0000
	4.375	13.844	-0.149	0.0002
	4.125	12.802	-0.149	0.0008
	3.900	11.858	-0.149	0.0030
1	3.775	11.331	-0.149	5
2	3.625	10.699	-0.149	8
3	3.375	9.645	-0.149	47
4	3.125	8.594	-0.149	200
5	2.875	7.545	-0.149	758
6	2.625	6.501	-0.149	2,550
7	2.375	5.462	-0.149	7,433
8	2.125	4.428	-0.149	18,377
9	1.875	3.400	-0.149	37,658
10	1.375	1.362	-0.149	150,120
11	0.75	-0.149	-1.147	140,479
12	0.375	-0.149	-2.630	17,173
13	0.125	-0.149	-3.607	2,991
14	-0.125	-0.149	-4.575	382
15	-0.375	-0.149	-5.533	46
16	-0.625	-0.149	-6.479	7
17	-0.875	-0.149	-7.416	1
	-1.125	-0.149	-8.342	0.2436
	-1.365	-0.149	-9.258	0.0494
	-1.615	-0.149	-10.246	0.0086
	-1.850	-0.149	-11.174	0.0020
Total				**378,236**

Table 7-9 Gust and Maneuver Stresses for 1812 lb with wing tanks at 108 kts

Note: Due to the low number of occurrences per 1000 hours, the extreme n_z levels were clipped. These occurrences were not included in the AFGROW spectrum.

7.5 **LANDING:** The landing exceedance are the same as shown in Table 6-21, Table 6-23, and Table 6-25 The difference is predominantly in the wing stress due to the different fuel tank levels.

	Block Mean g level	Max Spar Stress (ksi)	Min Spar Stress (ksi)	Occurrence per 1000 hr
1	0.421	3.395	2.962	3,600
2	1.264	3.395	2.096	2,214
3	2.107	3.395	1.230	666
4	2.950	3.395	0.248	72
5	3.793	3.395	-0.783	13
6	4.635	3.395	-1.813	3
7	5.478	3.395	-2.843	1
Total				**6,569**

Table 7-10 AFGROW Spectrum for Landing at 1966 lb at WS 80 with Wing Tanks per 1000 hrs

	Block Mean g level	Max Spar Stress (ksi)	Min Spar Stress (ksi)	Occurrence per 1000 hr
1	0.421	3.226	2.784	3,600
2	1.264	3.226	1.901	2,214
3	2.107	3.226	1.017	666
4	2.950	3.226	-0.020	72
5	3.793	3.226	-1.071	13
6	4.635	3.226	-2.122	3
7	5.478	3.226	-3.173	1
Total				**6,569**

Table 7-11 AFGROW Spectrum for Landing at 1889 lb at WS 80 with Wing Tanks per 1000 hrs

	Block Mean g level	Max Spar Stress (ksi)	Min Spar Stress (ksi)	Occurrence per 1000 hr
1	0.421	3.056	2.605	3,600
2	1.264	3.056	1.703	2,214
3	2.107	3.056	0.784	666
4	2.950	3.056	-0.292	72
5	3.793	3.056	-1.365	13
6	4.635	3.056	-2.438	3
7	5.478	3.056	-3.511	1
Total				**6,569**

Table 7-12 AFGROW Spectrum for Landing at 1812 lb at WS 80 with Wing Tanks per 1000 hrs

7.6 **TAXIING:** The taxiing exceedances are the same as Table 6-27. However, the wing stress at the critical location will change with the different fuel tank levels.

	Aircraft N_z	Max Spar Stress (ksi)	Min Spar Stress (ksi)	Occurrence per 1000 hr
1	1.55	-0.674	-1.045	400
2	1.45	-0.674	-0.977	442
3	1.35	-0.674	-0.910	1,083
4	1.15	-0.674	-0.775	14,918
5	0.85	-0.573	-0.674	14,918
6	0.65	-0.438	-0.674	1,083
7	0.55	-0.371	-0.674	442
8	0.45	-0.303	-0.674	400
Total				**33,686**

Table 7-13 AFGROW Spectrum for Taxiing at 1996 lb at WS 80 with Wing Tanks

	Aircraft N_z	Max Spar Stress (ksi)	Min Spar Stress (ksi)	Occurrence per 1000 hr
1	1.55	-0.782	-1.212	400
2	1.45	-0.782	-1.134	442
3	1.35	-0.782	-1.056	1,083
4	1.15	-0.782	-0.899	14,918
5	0.85	-0.665	-0.782	14,918
6	0.65	-0.508	-0.782	1,083
7	0.55	-0.430	-0.782	442
8	0.45	-0.352	-0.782	400
Total				**33,686**

Table 7-14 AFGROW Spectrum for Taxiing at 1889 lb at WS 80 with wing tanks

	Aircraft N_z	Max Spar Stress (ksi)	Min Spar Stress (ksi)	Occurrence per 1000 hr
1	1.55	-0.861	-1.335	400
2	1.45	-0.861	-1.249	442
3	1.35	-0.861	-1.163	1,083
4	1.15	-0.861	-0.990	14,918
5	0.85	-0.732	-0.861	14,918
6	0.65	-0.560	-0.861	1,083
7	0.55	-0.474	-0.861	442
8	0.45	-0.387	-0.861	400
Total				**33,686**

Table 7-15 AFGROW Spectrum for Taxiing at 1812 lb at WS 80 with wing tanks

7.7 Taxiing applies compression in the critical areas for Pawnees with fuel tanks in the wings. This will not contribute to fatigue by itself, but it may contribute to the ground – air – ground cycle.

7.8 **GROUND-AIR-GROUND CYCLE:** Ground air ground cycles were determined by fitting curves to the stress versus exceedance charts for the particular operating weight. These curves were then used to estimate the exceedance for a particular stress. The ground air ground cycles for agricultural use assumes the aircraft spent 50 % of it's flight at the take off weight and 50% of it's time at the landing weight as per paragraph 6.6. The GAG cycle stresses are predicted to occur at least once per flight.

	3166 lb		1996 lb		1996 lb	1996 lb	
Stress (ksi)	Gust	Maneuver	Gust	Maneuver	Landing	Taxi	Total
15.000	0.0047	0.6735	0.0000	0.0001			0.6783
14.500	0.0071	0.8751	0.0000	0.0001			0.8822
14.253	0.0086	0.9913	0.0000	0.0002			1.0001
14.000	0.0105	1.1230	0.0000	0.0002			1.1337
13.500	0.0156	1.4235	0.0000	0.0005			1.4396
-2.000	0.0543	0.1575	0.4246	1.6055	0.0000		2.2419
-2.500	0.0356	0.0893	0.2150	0.8089	0.0000		1.1488
-2.598	0.0328	0.0795	0.1880	0.6990	0.0000		0.9994
-3.000	0.0233	0.0489	0.1082	0.3691			0.5495
-4.000	0.0099	0.0132	0.0269	0.0570			0.1069

Table 7-16 Ground-Air-Ground Stress for MTOW Agricultural Operation at WS 80 with Wing Tanks at 5/6 Capacity (32.08 Gal)

Note: the aircraft is limited to 13.732 ksi as a maximum stress by the stall curve of the aircraft at 3166 lb at 95 kts. To get the total exceedance for the maximum positive stress to 1.00, the aircraft would need to be operating at a higher speed such that a higher stress can be achieved.

	Max Spar Stress (ksi)	Min Spar Stress (ksi)	Occurrence per 1000 hr
1	14.253	-2.598	9,000
Total			**9,000**

Table 7-17 AFGROW Spectrum for MTOW Agricultural Operation with Wing Tanks at 5/6 Capacity (32.08 Gal)

	3089 lb		1889 lb		1889 lb	1889 lb	
Stress (ksi)	**Gust**	**Maneuver**	**Gust**	**Maneuver**	**Landing**	**Taxi**	**Total**
15.000	0.0024	0.4286	0.0000	0.0000			0.4310
14.000	0.0057	0.7598	0.0000	0.0000			0.7655
13.501	0.0086	0.9911	0.0000	0.0001			0.9998
13.000	0.0130	1.2771	0.0000	0.0001			1.2902
12.500	0.0196	1.6230	0.0000	0.0003			1.6429
-2.000	0.0569	0.1669	0.5313	1.9754			2.7305
-2.500	0.0367	0.0924	0.2554	0.9727			1.3572
-2.702	0.0307	0.0720	0.1896	0.7070			0.9993
-3.000	0.0236	0.0493	0.1219	0.4266			0.6214
-4.000	0.0097	0.0125	0.0271	0.0579			0.1072

Table 7-18 Ground-Air-Ground Stress for MTOW Agricultural Operation with Wing Tanks at 1/2 Capacity (19.25 Gal)

Note: the aircraft is limited to 13.342 ksi as a maximum stress by the stall curve of the aircraft at 3089 lb at 95 kts. To get the total exceedance for the maximum positive stress to 1.00, the aircraft would need to be operating at a higher speed such that a higher stress can be achieved.

	Max Spar Stress (ksi)	Min Spar Stress (ksi)	Occurrence per 1000 hr
1	13.501	-2.702	9,000
Total			**9,000**

Table 7-19 AFGROW Spectrum for MTOW Agricultural Operation at WS 80 with Wing Tanks at 1/2 Capacity (19.25 Gal)

	3012 lb		1812 lb		1812 lb	1812 lb	
Stress (ksi)	**Gust**	**Maneuver**	**Gust**	**Maneuver**	**Landing**	**Taxi**	**Total**
13.500	0.0047	0.6735	0.0000	0.0000			0.6782
13.000	0.0073	0.8934	0.0000	0.0000			0.9007
12.809	0.0086	0.9914	0.0000	0.0000			1.0001
10.000	0.0905	3.6026	0.0000	0.0020			3.6951
7.500	0.6562	7.7647	0.0002	0.0598			8.4809
-2.000	0.0594	0.1768	0.6738	2.4325	0.0000	0.0000	3.3426
-2.500	0.0376	0.0957	0.3066	1.1753	0.0000		1.6152
-2.797	0.0286	0.0652	0.1913	0.7157	0.0000		1.0008
-3.000	0.0237	0.0497	0.1383	0.4961			0.7078
-4.000	0.0094	0.0118	0.0274	0.0589			0.1076

Table 7-20 Ground-Air-Ground Stress for Overweight Agricultural Operation at WS 80 with Wing Tanks at 1/6 Capacity (6.4 Gal)

	Max Spar Stress (ksi)	Min Spar Stress (ksi)	Occurrence per 1000 hr
1	12.809	-2.797	9,000
Total			**9,000**

Table 7-21 AFGROW Spectrum for MTOW Agricultural Operation at WS 80 with Wing Tanks at 1/6 Capacity (6.4 Gal)

8. AGRICULTURAL LOAD SPECTRA – TWO SEAT MODEL WITHOUT WING TANKS

8.1 Several Pawnees have been rebuilt in Australia with a bench seat and dual controls. These were originally used for agricultural pilot training but are now used for glider towing pilot conversion and currency training. The cockpit weight is limited by the aft CG limit. They are frequently fitted with ballast at the firewall to bring the CG forward which further increases the empty weight. The empty weight is increased to 1831.7 lb (831 kg) with pilot weight of 396.9 lb (180 kg).

Figure 8-1 VH-PPC Showing Side by Side Pilot Seating During Glider Towing Operations

8.2 There is one Pawnee with wing tanks operating in Australia that has been modified to have two seats, VH-TUG. As of August 2025, this aircraft failed the inspection requirements of Reference 1.1 and is being fitted with new spars. This aircraft does not need consideration of previous hours as an agricultural aircraft.

8.3 The maximum operating weight with 1200 lb payload is 3660 lb (1659.9 kg) with two pilots on board. Operating at MTOW of 2900 lb remains unchanged from Section 6.10. The landing weight in both the overload and MTOW operation becomes 2460 lb (1115.6 kg).

	Operating Weight (lbs)	Fuel Level	Cruise Speed	Gust Stall g Limit
Overweight	3621.4	5/6 (32.08 gal)	95 kts	+1.97 g / -0.87 g
	3544.3	1/2 (19.25 gal)	95 kts	+ 2.01 g / -0.89 g
	3467.2	1/6 (6.42 gal)	95 kts	+2.05 g / -0.91 g
MTOW	2861.4	5/6 (32.08 gal)	95 kts	+2.34 g / -1.03 g
	2784.3	1/2 (19.25 gal)	95 kts	+2.41 g / -1.05 g
	2707.2	1/6 (6.42 gal)	95 kts	+2.48 g / -1.09 g
Landing	2421.4	5/6 (32.08 gal)	108 kts	+ 3.93 g / - 1.69 g
	2344.3	1/2 (19.25 gal)	108 kts	+ 4.02 g / - 1.76 g
	2267.2	1/6 (6.42 gal)	108 kts	+ 4.16 g / - 1.83 g

Table 8-1 Two Seat Agricultural Operation Weights

8.4 **OVERWEIGHT – 3660 lb:** Operating the Pawnee with two pilots on board and a full hopper represents a significant overload of the aircraft. These aircraft were converted during after already accruing hours in agricultural operations.

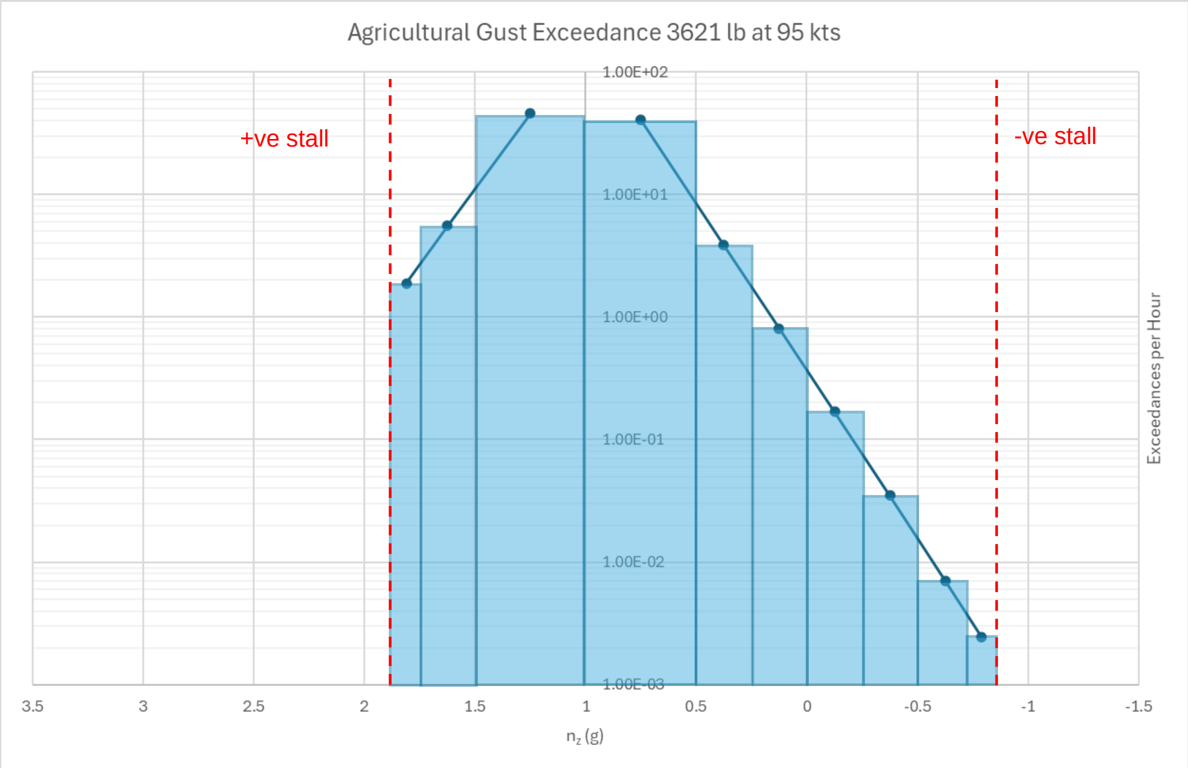

Figure 8-2 Agricultural Two Seat Gust Exceedance for 3621 lb at 95 kts

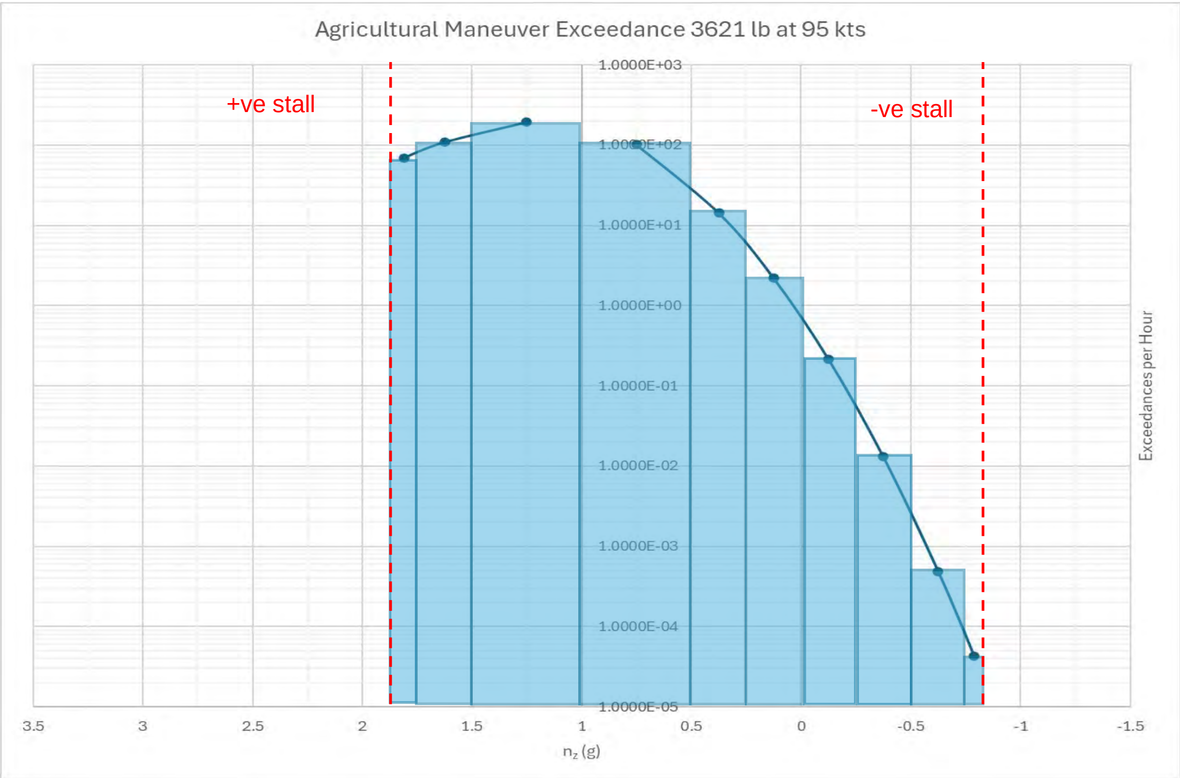

Figure 8-3 Agricultural Two Seat Maneuver Exceedance for 3621 lb at 95 kts

Block Upper g limit	Block Mean g level	Gust Exceedance per hour	Maneuver Exceedance per hour	Total Exceedance	Occurrence per hour
1.87	1.810	1.8759	69.2622	71.1381	71.1381
1.75	1.625	5.5548	108.6898	114.2445	43.1064
1.50	1.250	45.8558	192.8795	238.7353	124.4907
1.00					
1.00	0.75	40.5733	101.1171	141.6904	123.5698
0.50	0.375	3.8675	14.2532	18.1206	15.1060
0.25	0.125	0.8101	2.2045	3.0146	2.6308
0.00	-0.125	0.1689	0.2149	0.3838	0.3359
-0.25	-0.375	0.0348	0.0130	0.0479	0.0403
-0.50	-0.625	0.0071	0.0005	0.0075	0.0051
-0.75	-0.790	0.0024	0.0000	0.0025	0.0025
-0.83					

Table 8-2 Gust and Maneuver Exceedance for 3621 lb at 95 kts

	Block Mean g level	Max Spar Stress (ksi)	Min Spar Stress (ksi)	Occurrence per 1000 hr
1	1.860	14.954	8.901	71,138
2	1.625	13.683	8.901	43,106
3	1.250	10.906	8.901	124,491
4	0.75	8.901	6.774	123,570
5	0.375	8.901	3.368	15,106
6	0.125	8.901	0.962	2,631
7	-0.125	8.901	-1.545	336
8	-0.375	8.901	-4.145	40
9	-0.625	8.901	-7.158	5
10	-0.775	8.901	-9.271	2
Total				**380,426**

Table 8-3 AFGROW Gust and Maneuver Spectrum for 3621 lb at WS 25 without Wing Tanks per 1000 hrs

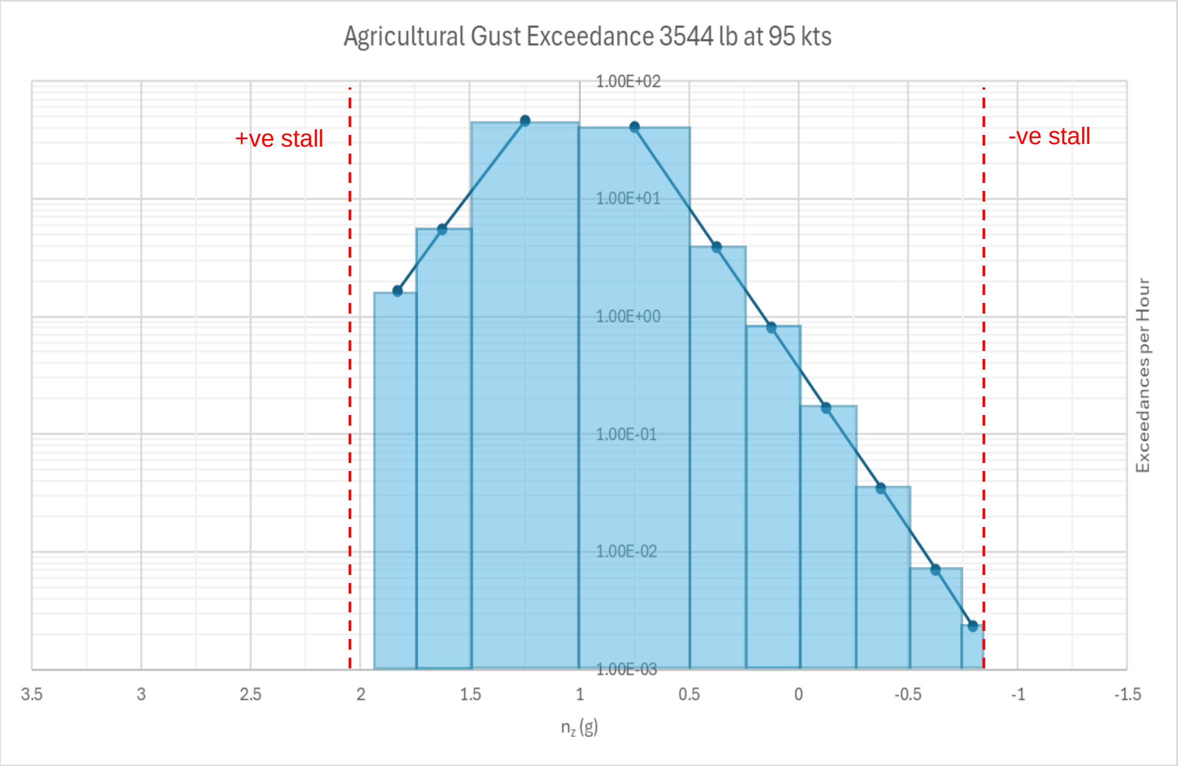

Figure 8-4 Agricultural Two Seat Gust Exceedance for 3544 lb at 95 kts

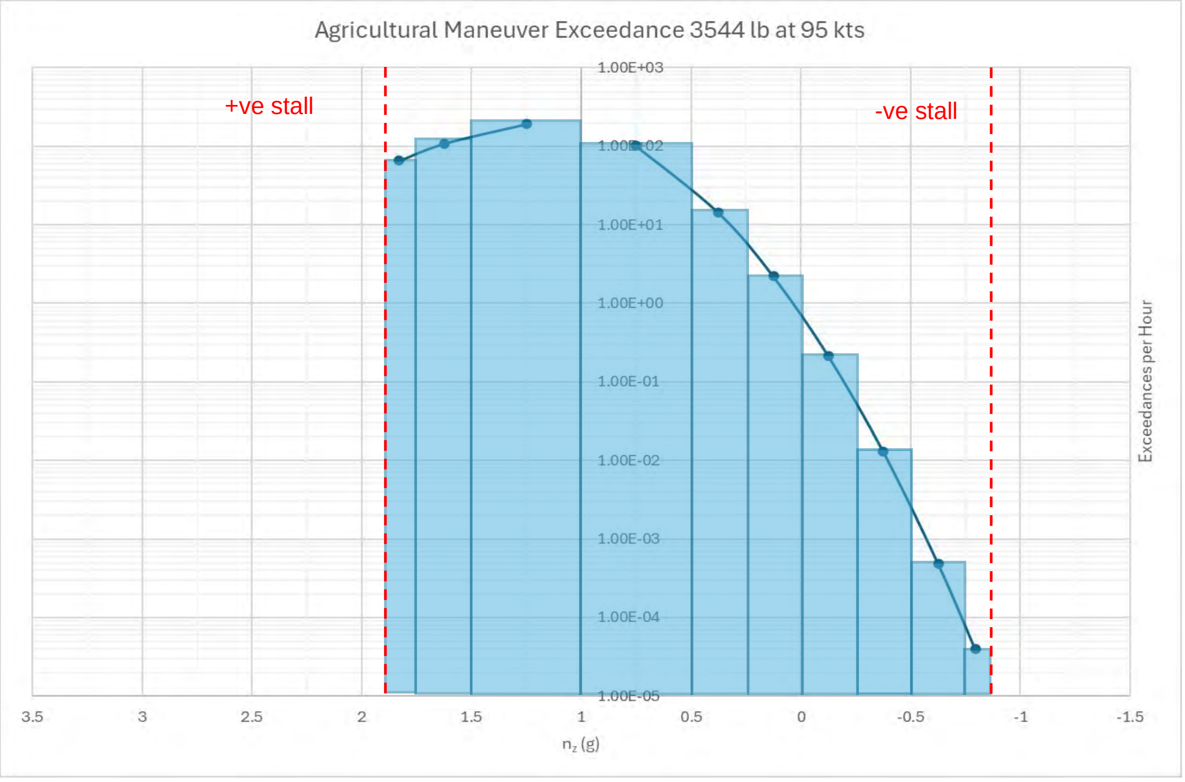

Figure 8-5 Agricultural Two Seat Maneuver Exceedance for 3544 lb at 95 kts

Block Upper g limit	Block Mean g level	Gust Exceedance per hour	Maneuver Exceedance per hour	Total Exceedance	Occurrence per hour
1.91	1.830	1.6657	65.5615	67.2271	67.2271
1.75	1.625	5.5548	108.6898	114.2445	47.0174
1.50	1.250	45.8558	192.8795	238.7353	124.4907
1.00					
1.00	0.75	40.5733	101.1171	141.6904	123.5698
0.50	0.375	3.8675	14.2532	18.1206	15.1060
0.25	0.125	0.8101	2.2045	3.0146	2.6308
0.00	-0.125	0.1689	0.2149	0.3838	0.3359
-0.25	-0.375	0.0348	0.0130	0.0479	0.0403
-0.50	-0.625	0.0071	0.0005	0.0075	0.0052
-0.75	-0.795	0.0023	0.0000	0.0024	0.0024
-0.84					

Table 8-4 Gust and Maneuver Exceedance for 3544 lb at 95 kts

	Block Mean g level	Max Spar Stress (ksi)	Min Spar Stress (ksi)	Occurrence per 1000 hr
1	1.830	14.800	8.713	67,227
2	1.625	13.416	8.713	47,017
3	1.250	10.683	8.713	124,491
4	0.75	8.713	6.626	123,570
5	0.375	8.713	3.289	15,106
6	0.125	8.713	0.934	2,631
7	-0.125	8.713	-1.517	336
8	-0.375	8.713	-4.058	40
9	-0.625	8.713	-6.986	5
10	-0.795	8.713	-9.114	2
Total				**380,426**

Table 8-5 AFGROW Gust and Maneuver Spectrum for 3544 lb at WS 25 without Wing Tanks per 1000 hrs

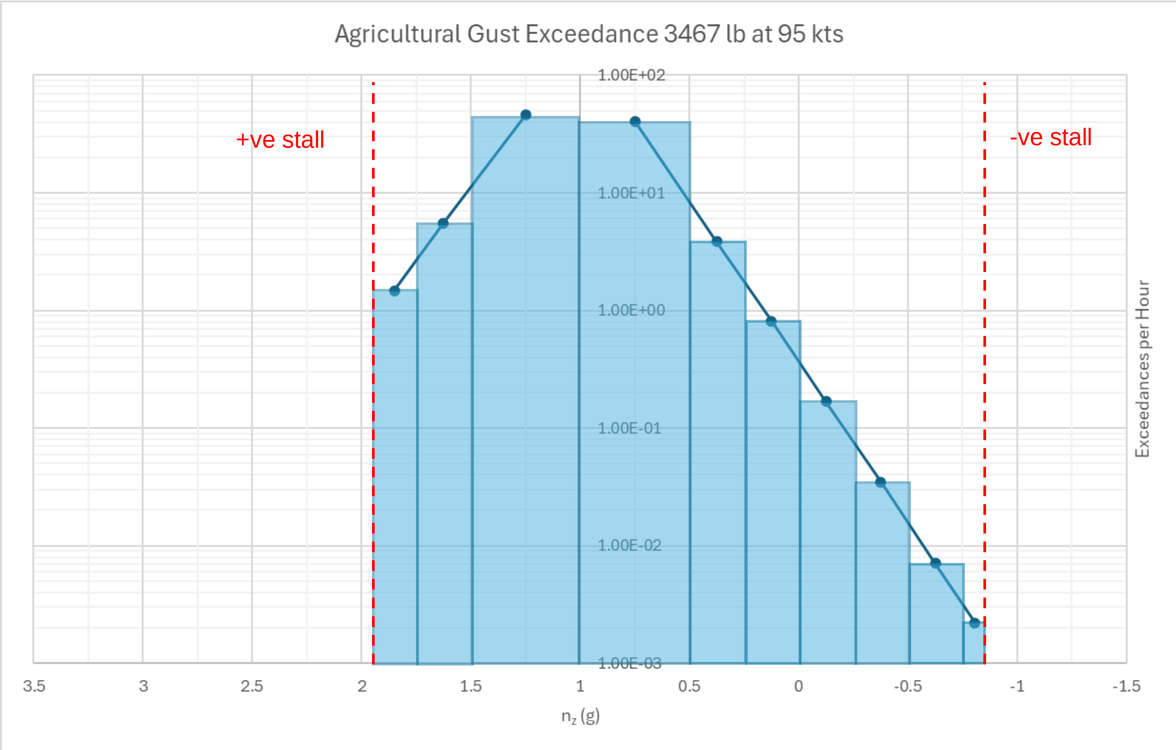

Figure 8-6 Agricultural Two Seat Gust Exceedance for 3467 lb at 95 kts

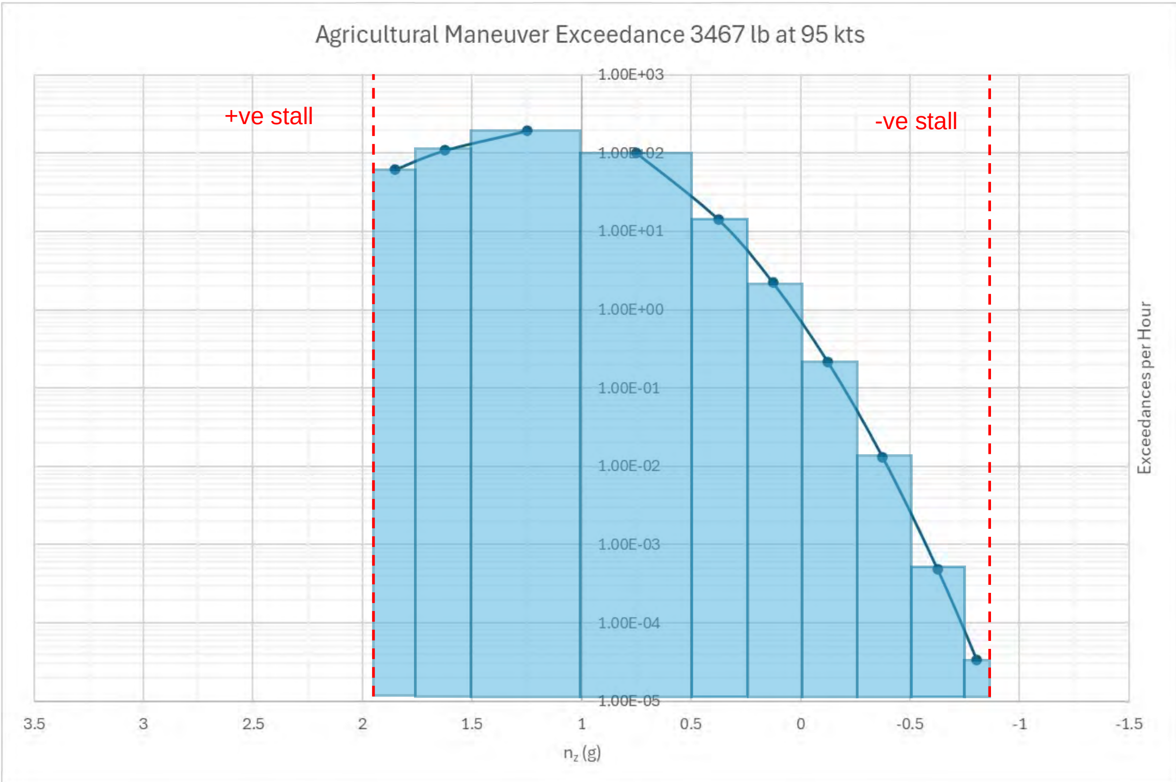

Figure 8-7 Agricultural Two Seat Maneuver Exceedance for 3467 lb at 95 kts

Block Upper g limit	Block Mean g level	Gust Exceedance per hour	Maneuver Exceedance per hour	Total Exceedance	Occurrence per hour
1.95	1.850	1.4785	61.9856	63.4641	63.4641
1.75	1.625	5.5548	108.6898	114.2445	50.7805
1.50	1.250	45.8558	192.8795	238.7353	124.4907
1.00					
1.00	0.75	40.5733	101.1171	141.6904	123.5698
0.50	0.375	3.8675	14.2532	18.1206	15.1060
0.25	0.125	0.8101	2.2045	3.0146	2.6308
0.00	-0.125	0.1689	0.2149	0.3838	0.3359
-0.25	-0.375	0.0348	0.0130	0.0479	0.0403
-0.50	-0.625	0.0071	0.0005	0.0075	0.0053
-0.75	-0.805	0.0022	0.0000	0.0022	0.0022
-0.86					

Table 8-6 Gust and Maneuver Exceedance for 3467 lb at 95 kts

	Block Mean g level	Max Spar Stress (ksi)	Min Spar Stress (ksi)	Occurrence per 1000 hr
1	1.850	14.640	8.524	63,464
2	1.625	13.147	8.524	50,780
3	1.250	10.459	8.524	124,491
4	0.75	8.524	6.478	123,570
5	0.375	8.524	3.210	15,106
6	0.125	8.524	0.907	2,631
7	-0.125	8.524	-1.489	336
8	-0.375	8.524	-3.972	40
9	-0.625	8.524	-6.815	5
10	-0.805	8.524	-9.016	2
Total				**380,426**

Table 8-7 AFGROW Gust and Maneuver Spectrum for 3467 lb at WS 25 without Wing Tanks per 1000 hrs

8.5 **TWO SEAT OPERATIONS AT LANDING WEIGHT:** The calculated landing weight uses a nominal empty weight of 1831.7 lb (831 kg), the fuel load, and two pilots 396.9 lb (180 kg).

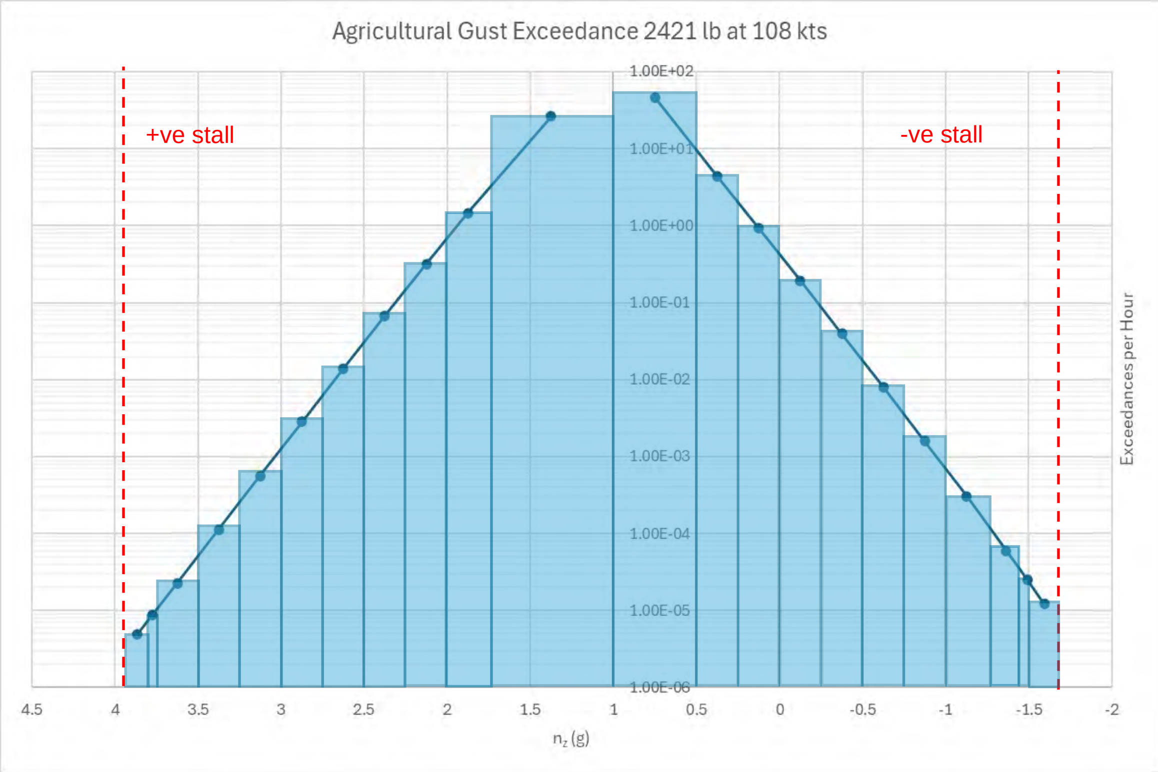

Figure 8-8 Agricultural Two Seat Gust Exceedance for 2421 lb at 108 kts

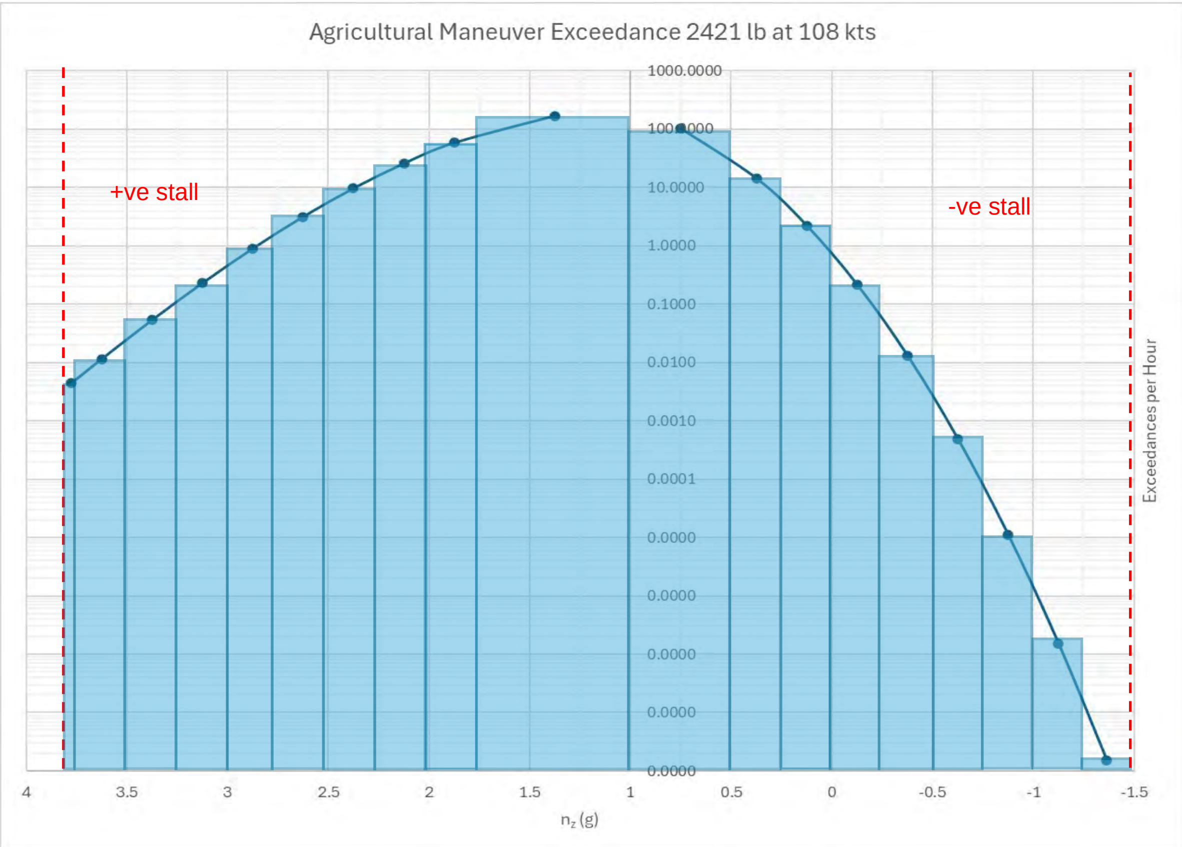

Figure 8-9 Agricultural Two Seat Maneuver Exceedance for 2421 lb at 108 kts

Block Upper g limit	Block Mean g level	Gust Exceedance per hour	Maneuver Exceedance per hour	Total Exceedance per hour	Occurrence per hour
3.93	3.865	0.0000	0.0000	0.0000	0.0000
3.80	3.775	0.0000	0.0044	0.0044	0.0044
3.75	3.525	0.0000	0.0114	0.0114	0.0070
3.50	3.375	0.0001	0.0531	0.0532	0.0418
3.25	3.125	0.0006	0.2283	0.2289	0.1757
3.00	2.875	0.0028	0.8935	0.8963	0.6674
2.75	2.625	0.0139	3.1269	3.1408	2.2445
2.50	2.375	0.0674	9.6185	9.6859	6.5451
2.25	2.125	0.3178	25.5628	25.8807	16.1948
2.00	1.875	1.4476	57.6940	59.1416	33.2609
1.75	1.375	26.1710	167.9963	194.1672	135.0257
1.00					
1.00	0.75	40.5733	101.1171	141.6904	123.5698
0.50	0.375	3.8675	14.2532	18.1206	15.1060
0.25	0.125	0.8101	2.2045	3.0146	2.6308
0.00	-0.125	0.1689	0.2149	0.3838	0.3359
-0.25	-0.375	0.0348	0.0130	0.0479	0.0403
-0.50	-0.625	0.0071	0.0005	0.0075	0.0061
-0.75	-0.875	0.0014	0.0000	0.0014	0.0011
-1.00	-1.125	0.0003	0.0000	0.0003	0.0002
-1.25	-1.365	0.0001	0.0000	0.0001	0.0000
-1.48	-1.49	2.5392E-05	0.0000	2.5392E-05	0.0000
-1.50	-1.595	1.2218E-05	0.0000	1.2218E-05	0.0000
-1.69					

Table 8-8 Gust and Maneuver Exceedance for 2421 lb at 108 kts

	Block Mean g level	Max Spar Stress (ksi)	Min Spar Stress (ksi)	Occurrence per 1000 hr
	3.865	19.861	5.868	0
1	3.775	19.516	5.868	4
2	3.625	18.932	5.868	7
3	3.375	17.897	5.868	42
4	3.125	16.822	5.868	176
5	2.875	15.703	5.868	667
6	2.625	14.539	5.868	2,244
7	2.375	13.330	5.868	6,545
8	2.125	12.074	5.868	16,195
9	1.875	10.773	5.868	33,261
10	1.375	8.035	5.868	135,026
11	0.75	5.868	4.370	128,593
12	0.375	5.868	2.048	15,524
13	0.125	5.868	0.451	2,719
14	-0.125	5.868	-1.183	354
15	-0.375	5.868	-2.855	44
16	-0.625	5.868	-4.561	7
17	-0.875	5.868	-6.329	1
	-1.125	5.868	-8.393	0.2438
	-1.365	5.868	-10.413	0.0346
	-1.490	5.868	-11.478	0.0132
	-1.595	5.868	-12.379	0.0122
Total				**341,410**

Table 8-9 Gust and Maneuver Stresses for 2421 lb at WS 25 without wing tanks at 108 kts

Note: Due to the low number of occurrences per 1000 hours, the extreme n_z levels were clipped. These occurrences were not included in the AFGROW spectrum.

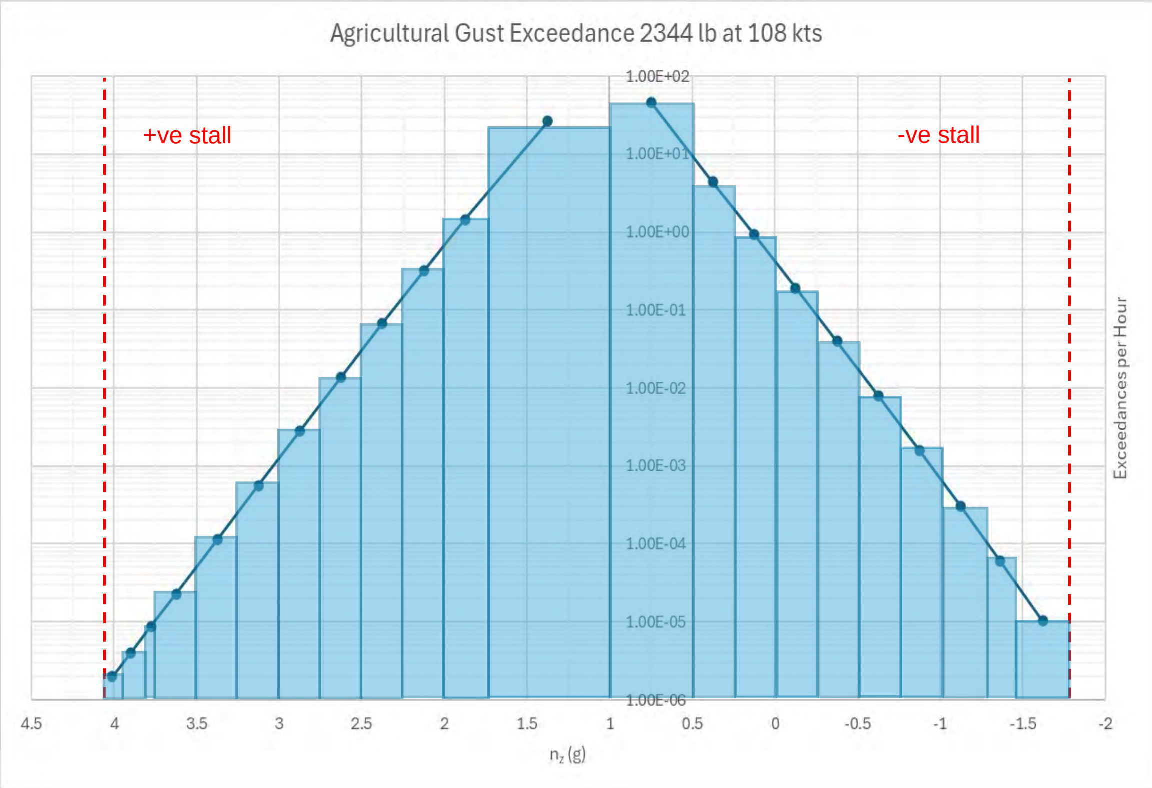

Figure 8-10 Agricultural Two Seat Gust Exceedance for 2344 lb at 108 kts

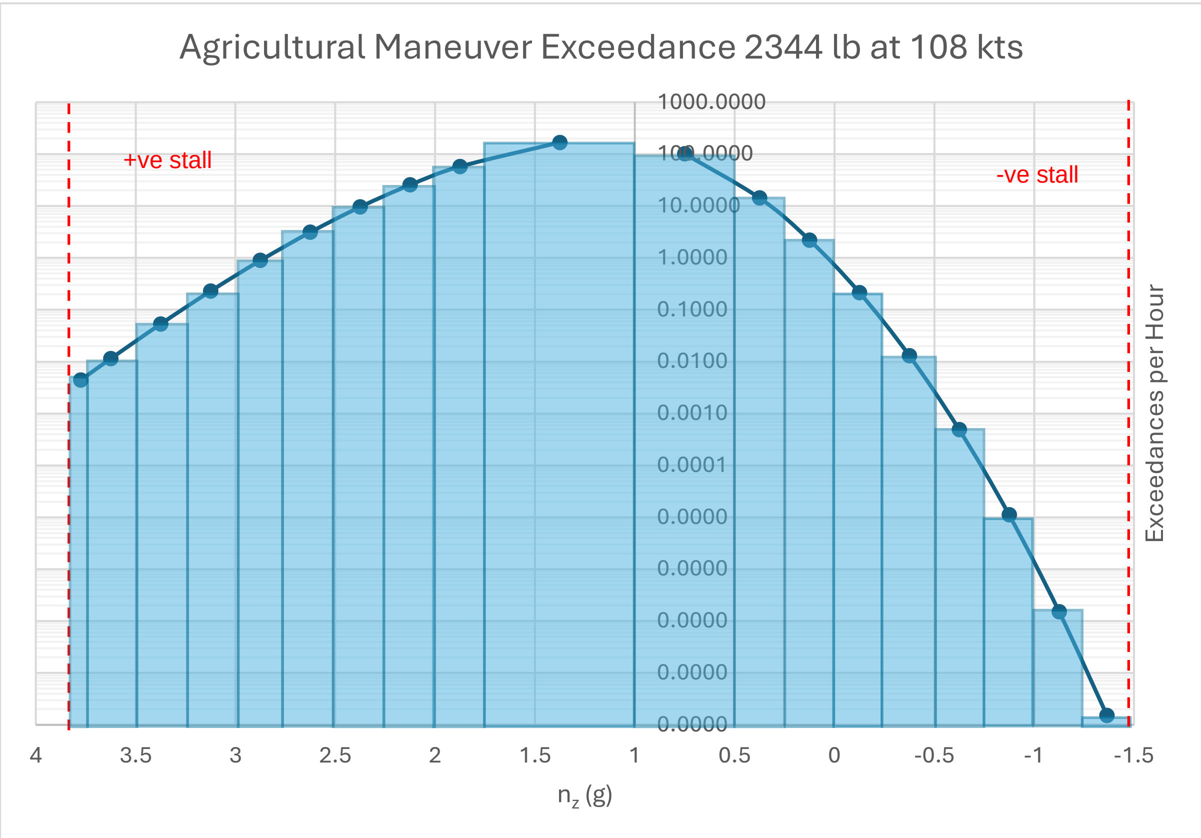

Figure 8-11 Agricultural Two Seat Maneuver Exceedance for 2344 lb at 108 kts

Block Upper g limit	Block Mean g level	Gust Exceedance per hour	Maneuver Exceedance per hour	Total Exceedance per hour	Occurrence per hour
4.02	4.010	0.0000	0.0000	0.0000	0.0000
4.00	3.900	0.0000	0.0000	0.0000	0.0000
3.80	3.775	0.0000	0.0044	0.0044	0.0044
3.75	3.525	0.0000	0.0114	0.0114	0.0070
3.50	3.375	0.0001	0.0531	0.0532	0.0418
3.25	3.125	0.0006	0.2283	0.2289	0.1757
3.00	2.875	0.0028	0.8935	0.8963	0.6674
2.75	2.625	0.0139	3.1269	3.1408	2.2445
2.50	2.375	0.0674	9.6185	9.6859	6.5451
2.25	2.125	0.3178	25.5628	25.8807	16.1948
2.00	1.875	1.4476	57.6940	59.1416	33.2609
1.75	1.375	26.1710	167.9963	194.1672	135.0257
1.00					
1.00	0.75	46.1255	101.1171	147.2425	128.5927
0.50	0.375	4.3967	14.2532	18.6499	15.5244
0.25	0.125	0.9209	2.2045	3.1255	2.7186
0.00	-0.125	0.1920	0.2149	0.4069	0.3543
-0.25	-0.375	0.0396	0.0130	0.0526	0.0441
-0.50	-0.625	0.0080	0.0005	0.0085	0.0069
-0.75	-0.875	0.0016	0.0000	0.0016	0.0013
-1.00	-1.125	0.0003	0.0000	0.0003	0.0002
-1.25	-1.365	0.0001	0.0000	0.0001	0.0000
-1.48	-1.620	1.0252E-05	0.0000	1.0252E-05	0.0000
-1.76					

Table 8-10 Gust and Maneuver Exceedance for 2344 lb at 108 kts

	Block Mean g level	Max Spar Stress (ksi)	Min Spar Stress (ksi)	Occurrence per 1000 hr
	4.010	19.812	5.657	**0**
	3.900	19.409	5.657	0
1	3.775	18.944	5.657	4
2	3.625	18.358	5.657	7
3	3.375	17.348	5.657	42
4	3.125	16.298	5.657	176
5	2.875	15.207	5.657	667
6	2.625	14.073	5.657	2,244
7	2.375	12.895	5.657	6,545
8	2.125	11.674	5.657	16,195
9	1.875	10.410	5.657	33,261
10	1.375	7.756	5.657	135,026
11	0.75	5.657	4.209	128,593
12	0.375	5.657	1.965	15,524
13	0.125	5.657	0.423	2,719
14	-0.125	5.657	-1.155	354
15	-0.375	5.657	-2.767	44
16	-0.625	5.657	-4.413	7
17	-0.875	5.657	-6.090	1
	-1.125	5.657	-8.075	0.2438
	-1.365	5.657	-10.021	0.0498
	-1.620	5.657	-12.124	0.0103
Total				**341,410**

Table 8-11 Gust and Maneuver Stresses for 2344 lb at WS 25 without wing tanks at 108 kts

Note: Due to the low number of occurrences per 1000 hours, the extreme n_z levels were clipped. These occurrences were not included in the AFGROW spectrum.

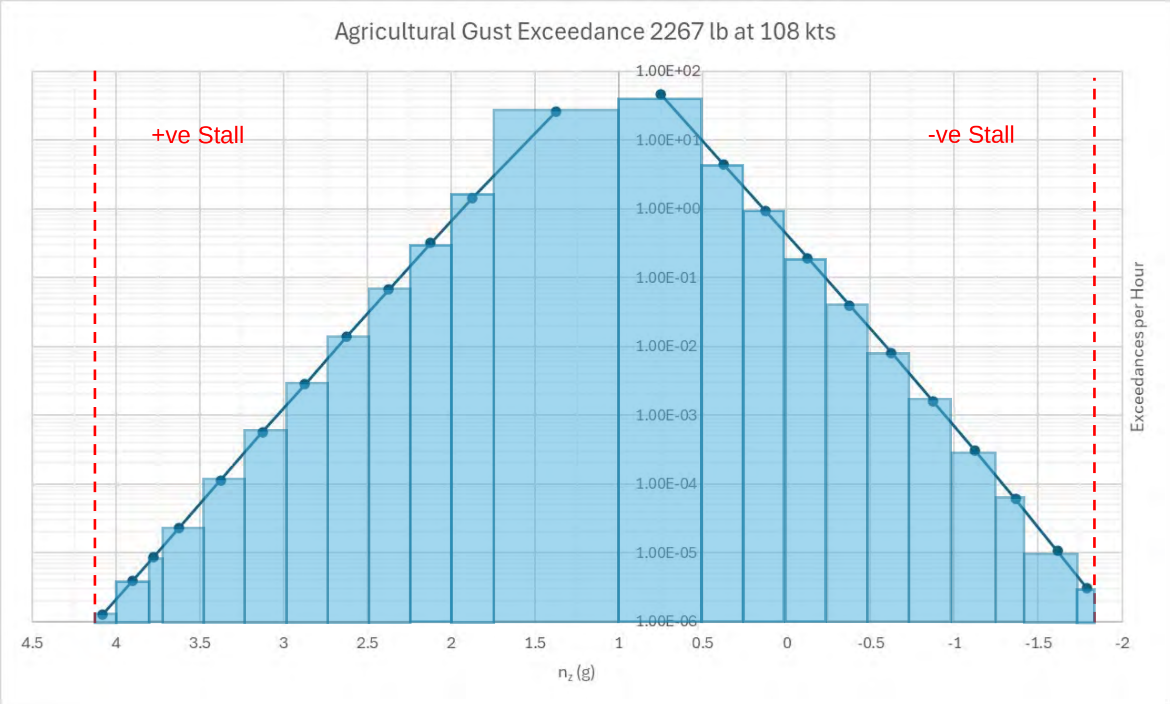

Figure 8-12 Agricultural Two Seat Gust Exceedance for 2267 lb at 108 kts

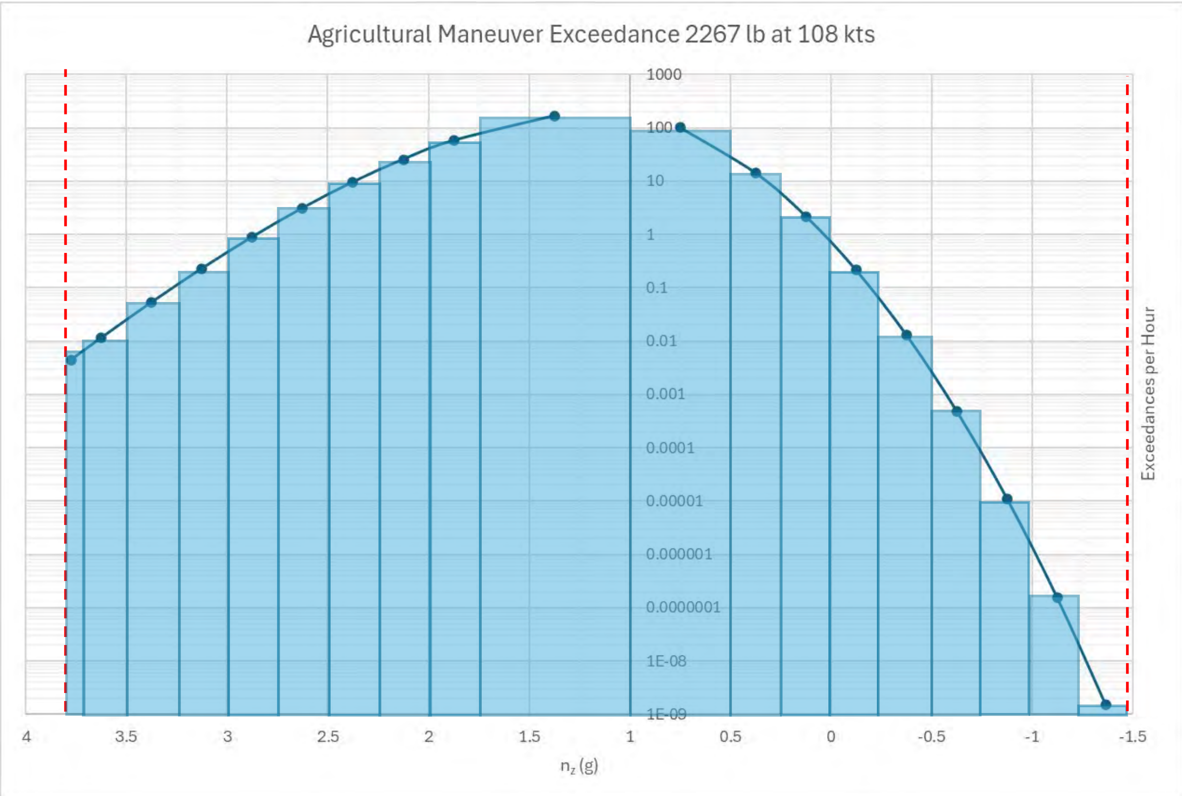

Figure 8-13 Agricultural Two Seat Maneuver Exceedance for 2267 lb at 108 kts

Block Upper g limit	Block Mean g level	Gust Exceedance per hour	Maneuver Exceedance per hour	Total Exceedance per hour	Occurrence per hour
4.16	4.08	0.0000	0.0000	0.0000	0.0000
4.00	3.900	0.0000	0.0000	0.0000	0.0000
3.80	3.775	0.0000	0.0044	0.0044	0.0044
3.75	3.525	0.0000	0.0114	0.0114	0.0070
3.50	3.375	0.0001	0.0531	0.0532	0.0418
3.25	3.125	0.0006	0.2283	0.2289	0.1757
3.00	2.875	0.0028	0.8935	0.8963	0.6674
2.75	2.625	0.0139	3.1269	3.1408	2.2445
2.50	2.375	0.0674	9.6185	9.6859	6.5451
2.25	2.125	0.3178	25.5628	25.8807	16.1948
2.00	1.875	1.4476	57.6940	59.1416	33.2609
1.75	1.375	26.1710	167.9963	194.1672	135.0257
1.00					
1.00	0.75	46.1255	101.1171	147.2425	128.5927
0.50	0.375	4.3967	14.2532	18.6499	15.5244
0.25	0.125	0.9209	2.2045	3.1255	2.7186
0.00	-0.125	0.1920	0.2149	0.4069	0.3543
-0.25	-0.375	0.0396	0.0130	0.0526	0.0441
-0.50	-0.625	0.0080	0.0005	0.0085	0.0069
-0.75	-0.875	0.0016	0.0000	0.0016	0.0013
-1.00	-1.125	0.0003	0.0000	0.0003	0.0002
-1.25	-1.365	0.0001	0.0000	0.0001	0.0000
-1.48	-1.615	0.0000	0.0000	0.0000	0.0000
-1.75	-1.790	0.0000	0.0000	0.0000	0.0000
-1.83					

Table 8-12 Gust and Maneuver Exceedance for 2267 lb at 108 kts

	Block Mean g level	Max Spar Stress (ksi)	Min Spar Stress (ksi)	Occurrence per 1000 hr
	4.080	19.455	5.446	0
	3.900	18.816	5.446	0
1	3.775	18.350	5.446	4
2	3.625	17.776	5.446	7
3	3.375	16.791	5.446	42
4	3.125	15.767	5.446	176
5	2.875	14.704	5.446	667
6	2.625	13.600	5.446	2,244
7	2.375	12.456	5.446	6,545
8	2.125	11.270	5.446	16,195
9	1.875	10.045	5.446	33,261
10	1.375	7.474	5.446	55,863
11	0.75	5.446	4.047	128,593
12	0.375	5.446	1.882	15,524
13	0.125	5.446	0.395	2,719
14	-0.125	5.446	-1.126	354
15	-0.375	5.446	-2.679	44
16	-0.625	5.446	-4.264	7
17	-0.875	5.446	-5.879	1
	-1.125	5.446	-7.756	0
	-1.365	5.446	-9.629	0
	-1.620	5.446	-11.613	0
Total				**392,253**

Table 8-13 Gust and Maneuver Stresses for 2267 lb at WS 25 without wing tanks at 108 kts

Note: Due to the low number of occurrences per 1000 hours, the extreme n_z levels were clipped. These occurrences were not included in the AFGROW spectrum.

8.6 **LANDING:** The landing exceedance are similar as shown in Table 6-21, Table 6-23, and Table 6-25 The difference is the n_z resulting from the increased landing weight.

Sink Rate (ft/sec)	Delta Nz (g)	Exceedance per landing	Exceedance per hour	Occurrence per hour
0.5	0.380	0.7300	6.5700	3.6000
1.5	1.139	0.3300	2.9700	2.2140
2.5	1.899	0.0840	0.7560	0.6660
3.5	2.658	0.0100	0.0900	0.0720
4.5	3.418	0.0020	0.0180	0.0132
5.5	4.177	0.0005	0.0048	0.0033
6.5	4.937	0.0002	0.0015	0.0015

Table 8-14 Landing Exceedance for 2421 lb

	Block Mean g level	Max Spar Stress (ksi)	Min Spar Stress (ksi)	Occurrence per 1000 hr
1	1.380	4.208	3.802	3600
2	2.139	4.208	2.991	2214
3	2.899	4.208	2.179	666
4	3.658	4.208	1.359	72
5	4.418	4.208	0.388	13
6	5.177	4.208	-0.579	3
7	5.937	4.208	-1.545	1
Total				**6569**

Table 8-15 AFGROW Spectrum for Two Seat Landing at 2421 lb without Wing Tanks per 1000 hrs

Sink Rate (ft/sec)	Delta Nz (g)	Exceedance per landing	Exceedance per hour	Occurrence per hour
0.5	0.386	0.7300	6.5700	3.6000
1.5	1.158	0.3300	2.9700	2.2140
2.5	1.930	0.0840	0.7560	0.6660
3.5	2.702	0.0100	0.0900	0.0720
4.5	3.473	0.0020	0.0180	0.0132
5.5	4.245	0.0005	0.0048	0.0033
6.5	5.017	0.0002	0.0015	0.0015

Table 8-16 Landing Exceedance for 2344 lb

	Block Mean g level	Max Spar Stress (ksi)	Min Spar Stress (ksi)	Occurrence per 1000 hr
1	1.386	4.045	3.633	3600
2	2.158	4.045	2.808	2214
3	2.930	4.045	1.983	666
4	3.702	4.045	1.117	72
5	4.473	4.045	0.131	13
6	5.245	4.045	-0.851	3
7	6.017	4.045	-1.833	1
Total				**6569**

Table 8-17 AFGROW Spectrum for Two Seat Landing at 2344 lb without Wing Tanks per 1000 hrs

Sink Rate (ft/sec)	Delta Nz (g)	Exceedance per landing	Exceedance per hour	Occurrence per hour
0.5	0.392	0.7300	6.5700	3.6000
1.5	1.177	0.3300	2.9700	2.2140
2.5	1.962	0.0840	0.7560	0.6660
3.5	2.747	0.0100	0.0900	0.0720
4.5	3.532	0.0020	0.0180	0.0132
5.5	4.317	0.0005	0.0048	0.0033
6.5	5.102	0.0002	0.0015	0.0015

Table 8-18 Landing Exceedance for 2267 lb

	Block Mean g level	Max Spar Stress (ksi)	Min Spar Stress (ksi)	Occurrence per 1000 hr
1	1.392	3.882	3.462	3600
2	2.177	3.882	2.624	2214
3	2.962	3.882	1.785	666
4	3.747	3.882	0.872	72
5	4.532	3.882	-0.129	13
6	5.317	3.882	-1.128	3
7	6.102	3.882	-2.127	1
Total				**6569**

Table 8-19 AFGROW Spectrum for Two Seat Landing at 2344 lb without Wing Tanks per 1000 hrs

Note: There are 2400 occurrences for a sink rate of 0 ft sec. Because this does not produce a delta Nz, these have a constant stress and do not contribute to the fatigue cycle.

8.7 **TAXIING:** Taxiing is independent of the payload weight, and is unchanged from Table 6-27and Table 6-28. Taxiing applies compression in the critical areas for both Pawnees with and without fuel tanks in the wings. Neither will contribute to fatigue by itself, but it may contribute to the ground – air – ground cycle.

8.8 **GROUND-AIR-GROUND CYCLE:** Ground air ground cycles were determined by fitting curves to the stress versus exceedance charts for the particular operating weight. These curves were then used to estimate the exceedance for a particular stress. The ground air ground cycles for agricultural use assumes the aircraft spent 50 % of it's flight at the take off weight and 50% of it's time at the landing weight as per paragraph 6.6.

	3621 lb		2421 lb		2421 lb		
Stress	**Gust**	**Maneuver**	**Gust**	**Maneuver**	**Landing**	**Taxi**	**Total**
19.000	0.0020	0.4178	0.0000	0.0000			0.4198
18.000	0.0057	0.8084	0.0000	0.0000			0.8141
17.665	0.0080	0.9921	0.0000	0.0000			1.0002
17.000	0.0155	1.4540	0.0000	0.0002			1.4697
16.000	0.0403	2.4308	0.0000	0.0009			2.4721
-1.000	0.0129	0.0198	0.0114	0.9600	0.0003	5.1172	6.1217
-1.250	0.0111	0.0155	0.0091	0.7099	0.0002	1.8579	2.6037
-1.400	0.0101	0.0133	0.0079	0.5874	0.0002	0.3811	1.0000
-1.500	0.0095	0.0121	0.0072	0.5159	0.0002	0.1640	0.7088
-1.750	0.0082	0.0094	0.0057	0.3684	0.0001	0.0286	0.4204

Table 8-20 Ground-Air-Ground Stresses for Overweight Agricultural Two Seat Operation at 3621 lb at WS 25 without Wing Tanks

Note: the aircraft is limited to 15.353 ksi as a maximum stress by the stall curve. To get the total exceedance for the maximum positive stress to 1.00, the aircraft would need to be operating at a higher speed such that a higher stress can be achieved.

	Max Spar Stress (ksi)	Min Spar Stress (ksi)	Occurrence per 1000 hr
1	17.665	-1.400	9,000
Total			**9,000**

Table 8-21 AFGROW Spectrum for Overweight Agricultural Two Seat Operation at 3621 lb without Wing Tanks

	3544 lb		2344 lb		2344 lb		
Stress	**Gust**	**Maneuver**	**Gust**	**Maneuver**	**Landing**	**Taxi**	**Total**
19.000	0.0014	0.3244	0.0000	0.0000			0.3258
18.000	0.0040	0.6510	0.0000	0.0000			0.6551
17.336	0.0080	0.9917	0.0000	0.0001			0.9998
17.000	0.0113	1.2115	0.0000	0.0002			1.2230
16.000	0.0303	2.0907	0.0000	0.0009			2.1220
-1.000	0.0128	0.0195	0.0114	0.9600	0.0004	5.1172	6.1213
-1.250	0.0109	0.0151	0.0091	0.7099	0.0003	1.8579	2.6033
-1.400	0.0099	0.0130	0.0079	0.5874	0.0003	0.3811	0.9996
-1.500	0.0093	0.0117	0.0072	0.5159	0.0003	0.1640	0.7084
-1.750	0.0080	0.0091	0.0057	0.3684	0.0002	0.0286	0.4200

Table 8-22 Ground-Air-Ground Stresses for Overweight Agricultural Two Seat Operation at 3544 lb at WS 25 without Wing Tanks

Note: the aircraft is limited to 15.321 ksi as a maximum stress by the stall curve of the aircraft at 3544 lb at 95 kts. To get the total exceedance for the maximum positive stress to 1.00, the aircraft would need to be operating at a higher speed such that a higher stress can be achieved.

	Max Spar Stress (ksi)	Min Spar Stress (ksi)	Occurrence per 1000 hr
1	17.336	-1.400	9,000
Total			**9,000**

Table 8-23 AFGROW Spectrum for Overweight Agricultural Two Seat Operation at 3621 lb without Wing Tanks

	3467 lb		2267 lb		2267 lb		
Stress	**Gust**	**Maneuver**	**Gust**	**Maneuver**	**Landing**	**Taxi**	**Total**
19.000	0.0009	0.2470	0.0000	0.0000			0.2479
18.000	0.0028	0.5152	0.0000	0.0000			0.5180
17.004	0.0081	0.9916	0.0000	0.0002			0.9999
17.000	0.0081	0.9941	0.0000	0.0002			1.0024
16.000	0.0224	1.7744	0.0000	0.0009			1.7977
-1.000	0.0127	0.0191	0.0114	0.9600	0.0006	5.1172	6.1210
-1.250	0.0108	0.0148	0.0091	0.7099	0.0004	1.8579	2.6029
-1.399	0.0098	0.0127	0.0079	0.5882	0.0004	0.3846	1.0035
-1.500	0.0092	0.0114	0.0072	0.5159	0.0003	0.1640	0.7080
-2.000	0.0067	0.0067	0.0045	0.2585	0.0002	0.0044	0.2811

Table 8-24 Ground-Air-Ground Stresses for Overweight Agricultural Two Seat Operation at 3467 lb at WS 25 without Wing Tanks

Note: the aircraft is limited to 15.276 ksi as a maximum stress by the stall curve of the aircraft at 3467 lb at 95 kts. To get the total exceedance for the maximum positive stress to 1.00, the aircraft would need to be operating at a higher speed such that a higher stress can be achieved.

	Max Spar Stress (ksi)	Min Spar Stress (ksi)	Occurrence per 1000 hr
1	17.004	-1.400	9,000
Total			**9,000**

Table 8-25 AFGROW Spectrum for Overweight Agricultural Two Seat Operation at 3467 lb without Wing Tanks

	2861 lb		2421 lb		2421 lb		
Stress	**Gust**	**Maneuver**	**Gust**	**Maneuver**	**Landing**	**Taxi**	**Total**
16.000	0.0009	0.2194	0.0000	0.0106			0.2309
15.000	0.0034	0.5440	0.0001	0.0439			0.5914
14.378	0.0073	0.8954	0.0004	0.0973			1.0003
14.000	0.0114	1.1832	0.0006	0.1527			1.3480
13.000	0.0360	2.2716	0.0029	0.4483			2.7587
-1.000	0.0114	0.0161	0.0114	0.0134	0.0003	5.1172	5.1698
-1.250	0.0093	0.0117	0.0091	0.0091	0.0002	1.8579	1.8973
-1.307	0.0089	0.0109	0.0086	0.0083	0.0002	0.9642	1.0011
-1.500	0.0077	0.0084	0.0072	0.0061	0.0002	0.1640	0.1935
-2.000	0.0052	0.0043	0.0045	0.0027	0.0001	0.0044	0.0212

Table 8-26 Ground-Air-Ground Stress for MTOW Agricultural Two Seat Operation at 2861 lb at WS 25 without Wing Tanks

	Max Spar Stress (ksi)	Min Spar Stress (ksi)	Occurrence per 1000 hr
1	14.378	-1.307	9,000
Total			**9,000**

Table 8-27 AFGROW Spectrum for MTOW Agricultural Two Seat Operation at 2861 lb without Wing Tanks

	2784 lb		2344 lb		2344 lb		
Stress	**Gust**	**Maneuver**	**Gust**	**Maneuver**	**Landing**	**Taxi**	**Total**
14.500	0.0040	0.6057	0.0001	0.0474			0.6572
14.000	0.0074	0.9067	0.0003	0.0913			1.0058
14.007	0.0074	0.9018	0.0003	0.0905			1.0000
13.500	0.0136	1.3135	0.0007	0.1678			1.4957
13.000	0.0245	1.8427	0.0016	0.2950			2.1638
-1.000	0.0112	0.0157	0.0112	0.0129	0.0004	5.1172	5.1685
-1.250	0.0091	0.0112	0.0088	0.0086	0.0003	1.8579	1.8959
-1.307	0.0087	0.0104	0.0083	0.0078	0.0003	0.9642	0.9997
-1.500	0.0074	0.0080	0.0069	0.0057	0.0003	0.1640	0.1922
-1.750	0.0061	0.0057	0.0054	0.0038	0.0002	0.0286	0.0498

Table 8-28 Ground-Air-Ground Stress for MTOW Agricultural Two Seat Operation at 2784 lb at WS 25 without Wing Tanks

	Max Spar Stress (ksi)	Min Spar Stress (ksi)	Occurrence per 1000 hr
1	14.007	-1.307	9,000
Total			**9,000**

Table 8-29 AFGROW Spectrum for MTOW Agricultural Two Seat Operation at 2861 lb without Wing Tanks

	2707 lb		2267 lb		2267 lb		
Stress	**Gust**	**Maneuver**	**Gust**	**Maneuver**	**Landing**	**Taxi**	**Total**
15.000	0.0012	0.2709	0.0000	0.0115			0.2837
14.000	0.0047	0.6735	0.0002	0.0507			0.7290
13.632	0.0074	0.9089	0.0003	0.0832			0.9998
13.000	0.0162	1.4567	0.0008	0.1830			1.6568
12.500	0.0294	2.0380	0.0019	0.3235			2.3928
-1.000	0.0110	0.0152	0.0108	0.0123	0.0006	5.1172	5.1671
-1.250	0.0089	0.0108	0.0084	0.0081	0.0004	1.8579	1.8945
-1.307	0.0085	0.0099	0.0079	0.0074	0.0004	0.9642	0.9983
-1.500	0.0072	0.0076	0.0066	0.0053	0.0003	0.1640	0.1909
-2.000	0.0047	0.0037	0.0040	0.0022	0.0002	0.0044	0.0192

Table 8-30 Ground-Air-Ground Stress for MTOW Agricultural Two Seat Operation at 2707 lb at WS 25 without Wing Tanks

	Max Spar Stress (ksi)	Min Spar Stress (ksi)	Occurrence per 1000 hr
1	13.632	-1.307	9,000
Total			**9,000**

Table 8-31 AFGROW Spectrum for MTOW Agricultural Two Seat Operation at 2707 lb without Wing Tanks

9. GLIDER TOWING LOAD SPECTRA

9.1 The fatigue life of glider tow planes has not been a significant concern of operators or regulators. The aircraft is operated without the heavy payload and without aggressive manoeuvring. Many of the aircraft types utilised for glider towing operations do not have published fatigue lives or ongoing fatigue inspections. As a result, suitable load spectra is very limited.

9.2 Reference 1.4 details studies performed on the fatigue of gliders in Australia, notably the L-13 Blanik which was a popular two seat training glider of aluminium construction. Figure 3 in Reference 1.1 shows flight load spectra for the L-13 Blanik, but also includes a spectra for the Piper PA-18-150 Super Cub being used as a glider tow plane. This document cites Reference 1.5 as the source data.

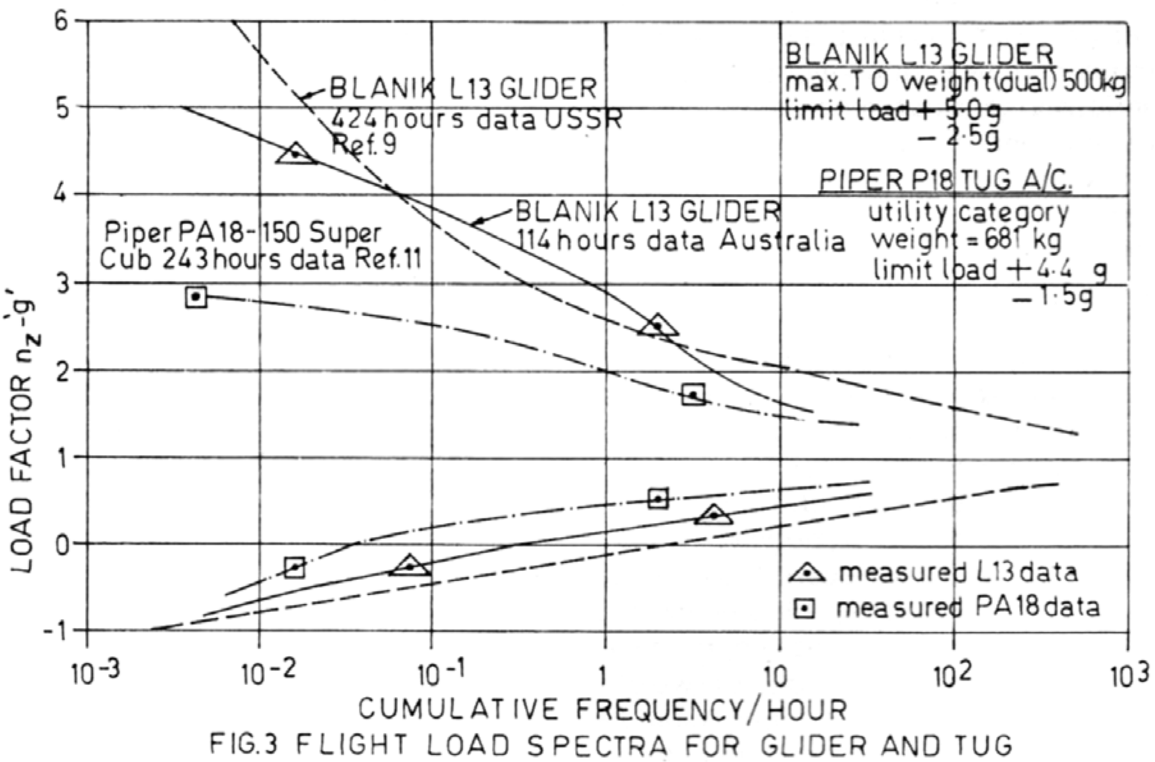

Figure 9-1 Figure 3 from Reference 1.2

9.3 Reference 1.3 shows similar data at Figure 9.2 and cites Reference 1.7 as the source data. This shows a greater number of hours of data for the Piper PA-18-150 Super Cub than above, but also includes data for a PA-25-180 Pawnee.

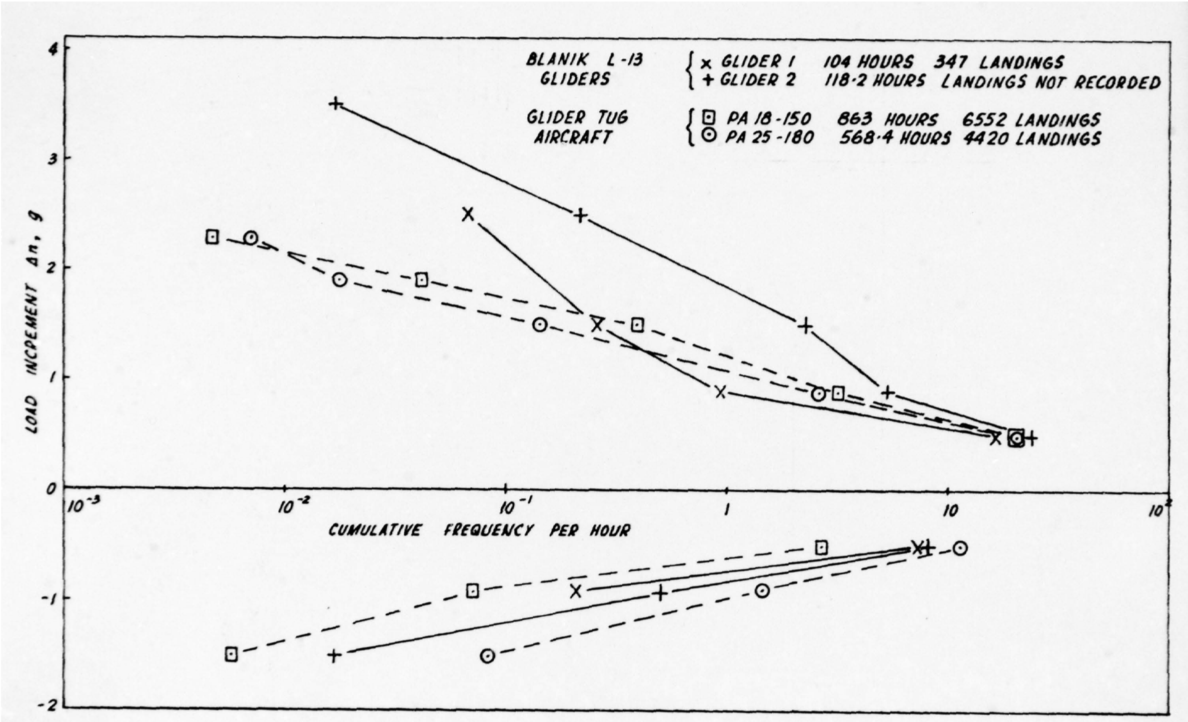

FIG. 9.2 FLIGHT LOADS SPECTRA

Figure 9-2 Figure 9.2 from Reference 1.6

9.4 Reference 1.5 provides generic flight loads spectra for both agricultural operations and glider towing. For consistency of comparison this report uses the spectra provided at Figure 4.1. The spectra for glider towing operations closely matches that shown in References 1.1 and 1.6 respectively.

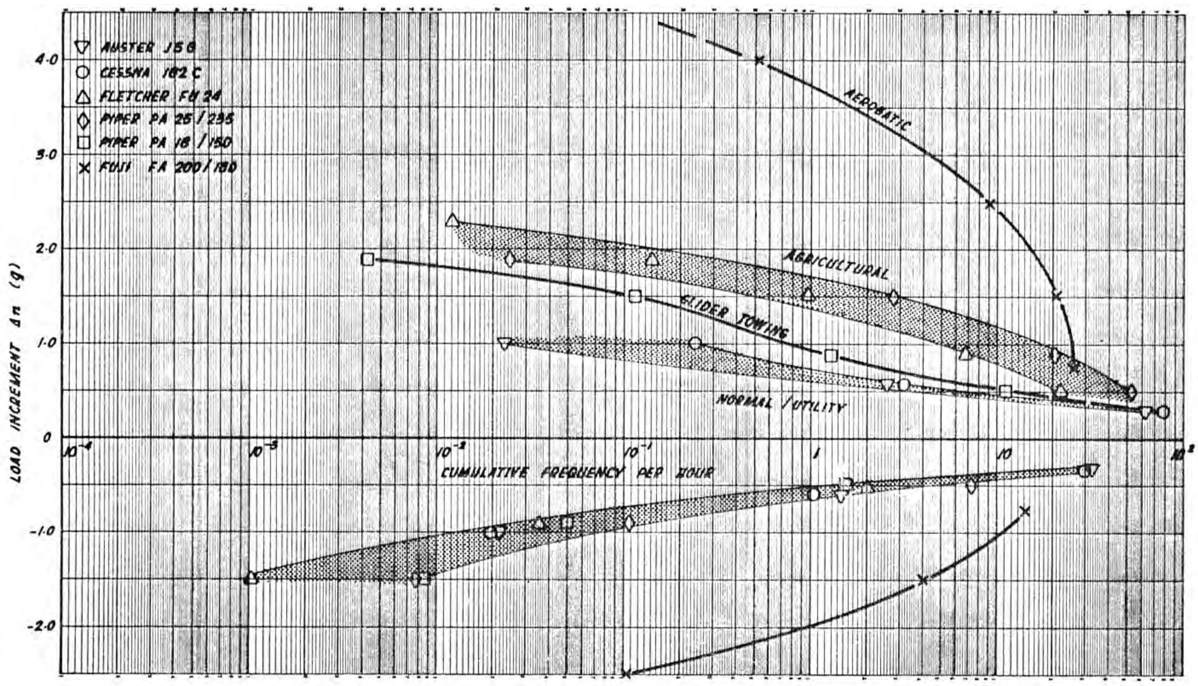

FIG. 4.1 FLIGHT LOADS SPECTRA - SINGLE ENGINE AIRCRAFT

Figure 9-3 Figure 4.1 of Reference 1.5

9.5 The original fatigue spectrum data sheets from References 1.5 and 1.6 were found by CASA AEB. This data consisted of:

Aircraft	Rego	Hours	Landings	Landings / Hour
PA 18-150	VH-RTM	963	7552	7.84
PA 25-180	VH-FSJ	568.4	4390	7.72
Combined		**1531.4**	**11942**	**7.80**

Table 9-1 Average Landing per Hour for Glider Towing Operations

Note: VH-FSJ is a PA 25-150 modified with a 180 hp engine.

9.6 These data sheets were entered into an Excel spreadsheet. The load factor was centred on 1 g to represent straight and level flight in smooth conditions. A comparison was made to a combined Single Engine – Personal maneuver and gust spectra from Reference 1.2. The Single Engine – Personal spectra is dominated by the gust spectra. The PA 25-180 Pawnee and PA 18-150 Super Cub averaged (together) 7.8 flights per hour. Typical glider towing operations will lack a lot of straight and level cruise flying per hour that a ‘single engine personal use’ aircraft would perform per hour. Consequently, a glider tow plane will manoeuvre more per hour as a result. The ‘single engine personal use’ manoeuvre spectrum multiplied by a factor of 3 and combined with the gust spectrum gives the following:

Figure 9-4 Flight Loads Spectra for Glider Towing Operations Compared to AC23-13A Single Engine Personal Use with 3 x Maneuver per hour

9.7 The AC23-13A Single Engine – Personal spectra will be used for glider towing with the maneuver spectrum exceedances per hour multiplied by 3.

9.8 Reference 1.2 paragraph 2.7 b.(1) states that the speed for determining miles flown should not be less than 0.9 V_{NO}. Reference 1.3 gives a cruising speed of 95 kts at 2900 lb. For lighter operations, the cruising speed is assumed to be 108 kts which is max rough air speed. However, typical glider towing operations with the PA 25 climb at 70 kts and descend at 95 to 100 kts. The speed used in the spectra to determine miles flown is 0.90 x 108 = 97 kts.

9.9 A survey of PA 25 Pawnees operating as glider towplanes showed that the average empty weight is 1562 lbs. This is heavier than the 1531 lbs from Reference 1.3. In Europe and the UK, Pawnees used for glider towing operate with a 1000 kg (2205 lb) MTOW limitation. This weight would include repairs, fitment of other engines and options like retractable towing cable systems. For consistency with international operations, the empty weight is increased from 1531 lb (694 kg) to 1731 lb (785 kg).

9.10 Several Pawnees have been rebuilt in Australia with a wider cockpit, a bench seat and dual controls. These were originally used for agricultural pilot training but are now used for glider towing pilot conversion and currency training. The cockpit weight is limited by the aft CG limit. They are frequently fitted with ballast at the firewall to bring the CG forward which further increases the empty weight. The empty weight is increased to 1831.7 lb (831 kg) with pilot weight of 396.9 lb (180 kg). The maximum operating weight is 2460 lb (1115.6 kg).

Seats	Operating Weight	Speed	Gust Stall g Limit
Single Seat	2205 lb	97 kts	+ 3.3 g / - 1.46 g
Two Seat	2460 lb	97 kts	+ 2.83 g / -1.25 g

Table 9-2 Glider Towing Maximum Weights

9.11 The taxi spectra at Reference 1.2 are from Table VIII of MIL-A-8866B and this probably represents the best data available at the time. However, this most likely includes extended taxiing from the hangar to the runway threshold and from the runway to the hangar again. A very large proportion of glider towing flights will involve a short taxi from the landing roll out back to the runway threshold to launch the next sailplane. In some operations, there is sufficient runway such that the landing roll out coincides with the launch point of the sailplane given extremely short taxi duration per flight. The use of the taxi spectra at Reference 1.2 is therefore extremely conservative for glider towing operations.

10. GLIDER TOWING LOAD SPECTRA – B AND C MODELS

10.1 Glider towing operations feature a large number of short flights, similar to agricultural operations, but without the heavy payload. The aircraft with a fuselage fuel tank is assumed to be operating with fuel loads as per Section 5.

10.2 Normally the towplane and glider would take off and climb at around 70 knots, typical of the PA-25 Pawnee speed for best rate of climb. After the sailplane has released, the towplane will descend at a speed between 95 to 100 kts. Because of these difference in speeds and the difference between climb rate and descent rate, the climb phase is approximately 60% of the flight.

10.3 Using the spectra from Section 9 above and the same procedure used in Section 6 produces the following:

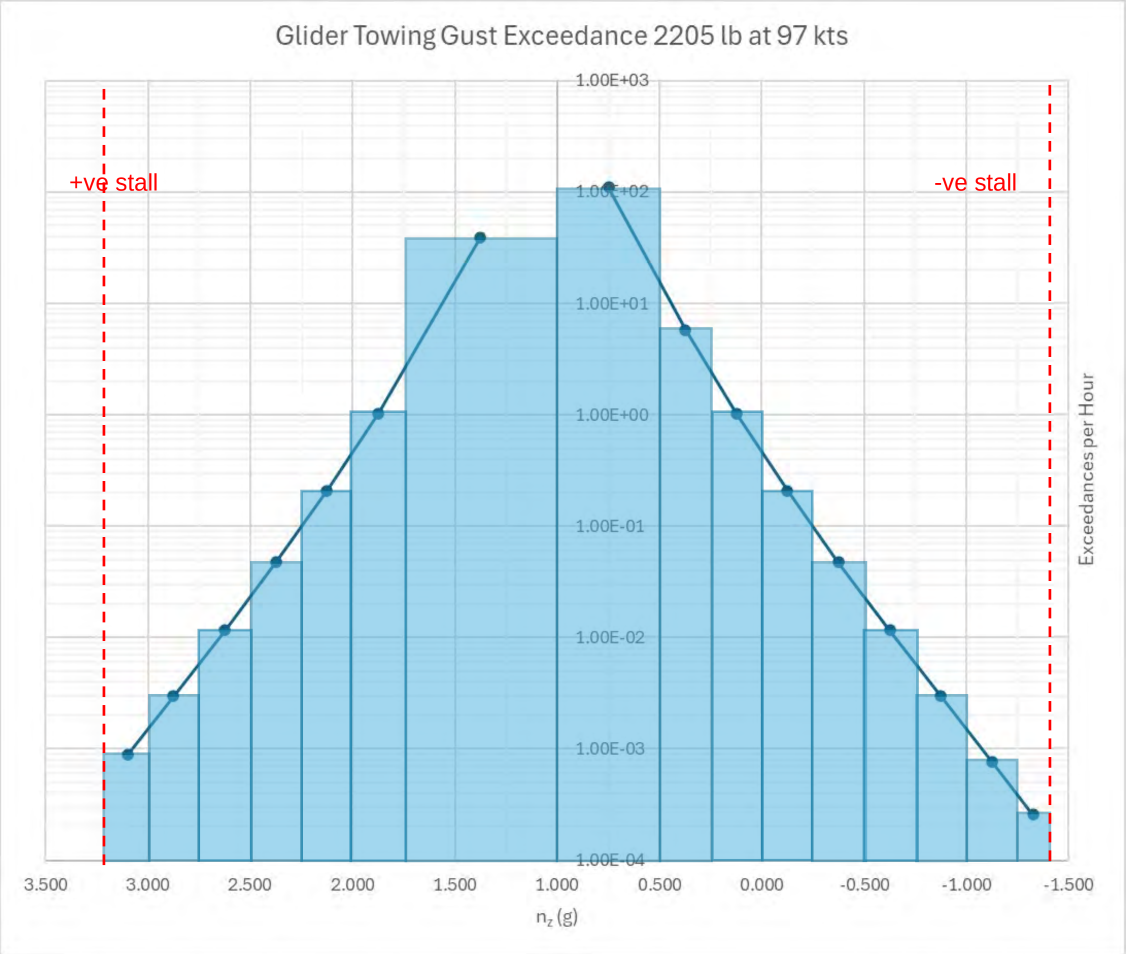

Figure 10-1 Gust Exceedances for Single Seat Glider Towing at 97 kts

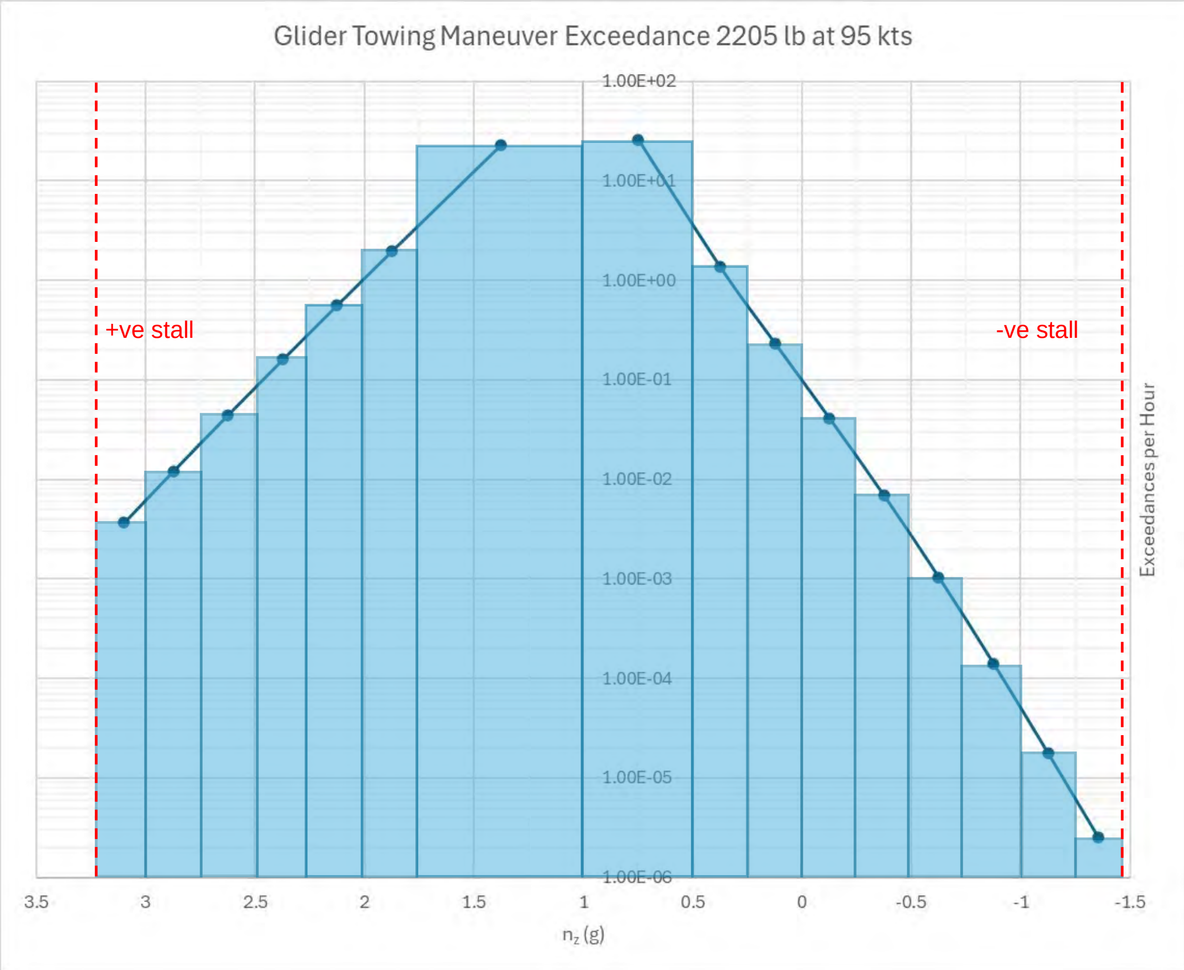

Figure 10-2 Maneuver Exceedances for Single Seat Glider Towing at 2205 lb at 97 kts

Block Upper g limit	Block Mean g level	Gust Exceedance per hour	Maneuver Exceedance per hour	Total Exceedance per hour	Occurrence per hour
3.20	3.100	0.0009	0.0037	0.0045	0.0045
3.00	2.875	0.0030	0.0121	0.0151	0.0105
2.75	2.625	0.0116	0.0444	0.0560	0.0410
2.50	2.375	0.0473	0.1597	0.2071	0.1510
2.25	2.125	0.2083	0.5641	0.7725	0.5654
2.00	1.875	1.0239	1.9629	2.9868	2.2143
1.75	1.375	39.2446	23.0317	62.2763	59.2895
1.00					
1.00	0.75	110.1529	26.0267	136.1796	129.0103
0.50	0.375	5.8038	1.3655	7.1693	5.9120
0.25	0.125	1.0237	0.2337	1.2573	1.0080
0.00	-0.125	0.2083	0.0411	0.2493	0.1952
-0.25	-0.375	0.0473	0.0069	0.0541	0.0415
-0.50	-0.625	0.0116	0.0010	0.0126	0.0095

-0.75					
	-0.875	0.0030	1.4147E-04	0.0031	0.0023
-1.00					
	-1.125	0.0008	1.7649E-05	0.0008	0.0005
-1.25					
	-1.325	2.5591E-04	3.2466E-06	2.5915E-04	2.5915E-04
-1.40					

Table 10-1 Gust and Maneuver Exceedance for Single Seat Glider Towing at 97 kts

	Block Mean g level	Max Spar Stress (ksi)	Min Spar Stress (ksi)	Occurrence per 1000 hr
1	3.100	14.612	5.279	5
2	2.875	13.769	5.279	11
3	2.625	12.791	5.279	41
4	2.375	11.766	5.279	151
5	2.125	10.694	5.279	565
6	1.875	9.573	5.279	2,214
7	1.375	4.000	5.279	59,290
8	0.75	5.279	3.950	129,010
9	0.375	5.279	1.875	5,912
10	0.125	5.279	0.441	1,008
11	-0.125	5.279	-1.034	195
12	-0.375	5.279	-2.547	42
13	-0.625	5.279	-4.096	10
14	-0.875	5.279	-5.806	2
15	-1.125	5.279	-7.695	1
16	-1.325	5.279	-9.235	0
Total				**198,456**

Table 10-2 AFGROW Gust and Maneuver Spectrum for Single Seat Glider Towing at WS 25 without Wing Tanks per 1000 hrs

10.4 From Table 9-1, the PA 25-180 Pawnee and PA 18-150 Super Cub averaged 7.8 flights per hour:

Sink Rate (ft/sec)	Delta Nz (g)	Exceedance per landing	Exceedance per hour	Occurrence per hour
0.5	0.398	0.7300	5.6940	3.1200
1.5	1.194	0.3300	2.5740	1.9188
2.5	1.990	0.0840	0.6552	0.5772
3.5	2.786	0.0100	0.0780	0.0624
4.5	3.581	0.0020	0.0156	0.0115
5.5	4.377	0.0005	0.0041	0.0028

6.5	5.173	0.0002	0.0013	0.0013

Table 10-3 Landing Exceedance for 2205 lb

	Block Mean g level	Max Spar Stress (ksi)	Min Spar Stress (ksi)	Occurrence per 1000 hr
1	1.398	3.750	3.325	3,120
2	2.194	3.750	2.474	1,919
3	2.990	3.750	1.623	577
4	3.786	3.750	0.672	62
5	4.581	3.750	-0.343	11
6	5.377	3.750	-1.355	3
7	6.173	3.750	-2.368	1
Total				**5,694**

Table 10-4 AFGROW Landing Spectrum for Single Seat Glider Towing without Wing Tanks per 1000 hrs

10.5 Taxiing using an average of 7.8 landings per hour and the single engine taxi spectra:

Block Upper g limit	Block Mean g level	Exceedance per landing	Exceedance per hour	Occurrence per hour
1.5	1.45	0.0193	0.1504	0.1504
1.4	1.35	0.5226	4.0766	3.9262
1.3	1.25	9.7172	75.7940	71.7173
1.2	1.15	92.2108	719.2441	643.4501
1.1	1.05	332.2880	2591.8461	1872.6020
1				
0.9	0.95	332.2880	2591.8461	1872.6020
0.8	0.85	92.2108	719.2441	643.4501
0.7	0.75	9.7172	75.7940	71.7173
0.6	0.65	0.5226	4.0766	3.9262
0.5	0.55	0.0193	0.1504	0.1504

Table 10-5 Taxiing Exceedance for Single Seat Glider Towing

	Block Mean g level	Max Spar Stress (ksi)	Min Spar Stress (ksi)	Occurrence per 1000 hr
1	1.45	-1.086	-1.575	150
2	1.35	-1.086	-1.467	3,926
3	1.25	-1.086	-1.358	71,717
4	1.15	-1.086	-1.249	643,450
5	1.05	-1.086	-1.141	1,872,602
6	0.95	-1.032	-1.086	1,872,602
7	0.85	-0.923	-1.086	643,450
8	0.75	-0.815	-1.086	71,717
9	0.65	-0.706	-1.086	3,926

10	0.55	-0.598	-1.086	150
Total				**5,183,692**

Table 10-6 AFGROW Taxiing Spectrum for Single Seat Glider Towing at WS 25 without Wing Tanks per 1000 hrs

10.6 Ground air ground cycles were determined by fitting curves to the stress vs exceedance charts for the operating weight. These curves were then used to estimate the exceedance for a particular stress.

Stress	Gust	Maneuver	Landing	Taxi	Total
10.000	0.0615	0.1367			0.1982
9.000	0.2614	0.4019			0.6634
8.666	0.4300	0.5705			1.0005
8.000	1.1913	1.1323			2.3236
7.000	5.9629	3.0865			9.0494
-0.500	0.0399	0.0082	0.0015	0.0009	0.0505
-1.000	0.0235	0.0045	0.0008	256.0323	256.0610
-1.445	0.0149	0.0026	0.0005	0.9743	0.9923
-1.500	0.0141	0.0024	0.0004	0.1951	0.2121
-2.000	0.0086	0.0013	0.0003	0.0000	0.0103

Table 10-7 Ground-Air-Ground Spectrum for Single Seat Glider Towing without Wing Tanks

	Max Spar Stress (ksi)	Min Spar Stress (ksi)	Occurrence per 1000 hr
1	8.666	-1.445	7,800
Total			**7,800**

Table 10-8 AFGROW Spectrum for Single Seat Glider Towing without Wing Tanks

11. GLIDER TOWING LOAD SPECTRA – D MODEL

11.1 Similar to Section 7, Pawnee D aircraft fitted with wing tanks are considered to have three weight cases with 5/6, ½, and 1/6 fuel tank levels. The aircraft are assumed to operate at each of these weight cases as per Section 5. Similar to Section 10 the aircraft is assumed to be operating at a constant weight with maximum fuel each flight.

11.2 The fatigue life was found to be driven by the Ground Air Ground cycle and the WS 25 location was found to be the most critical despite the highest stresses being found at WS 80 during high g maneuvers and gusts. This is because the stresses at WS 25 were higher than WS 80 for the milder maneuvers and gusts which are more frequent.

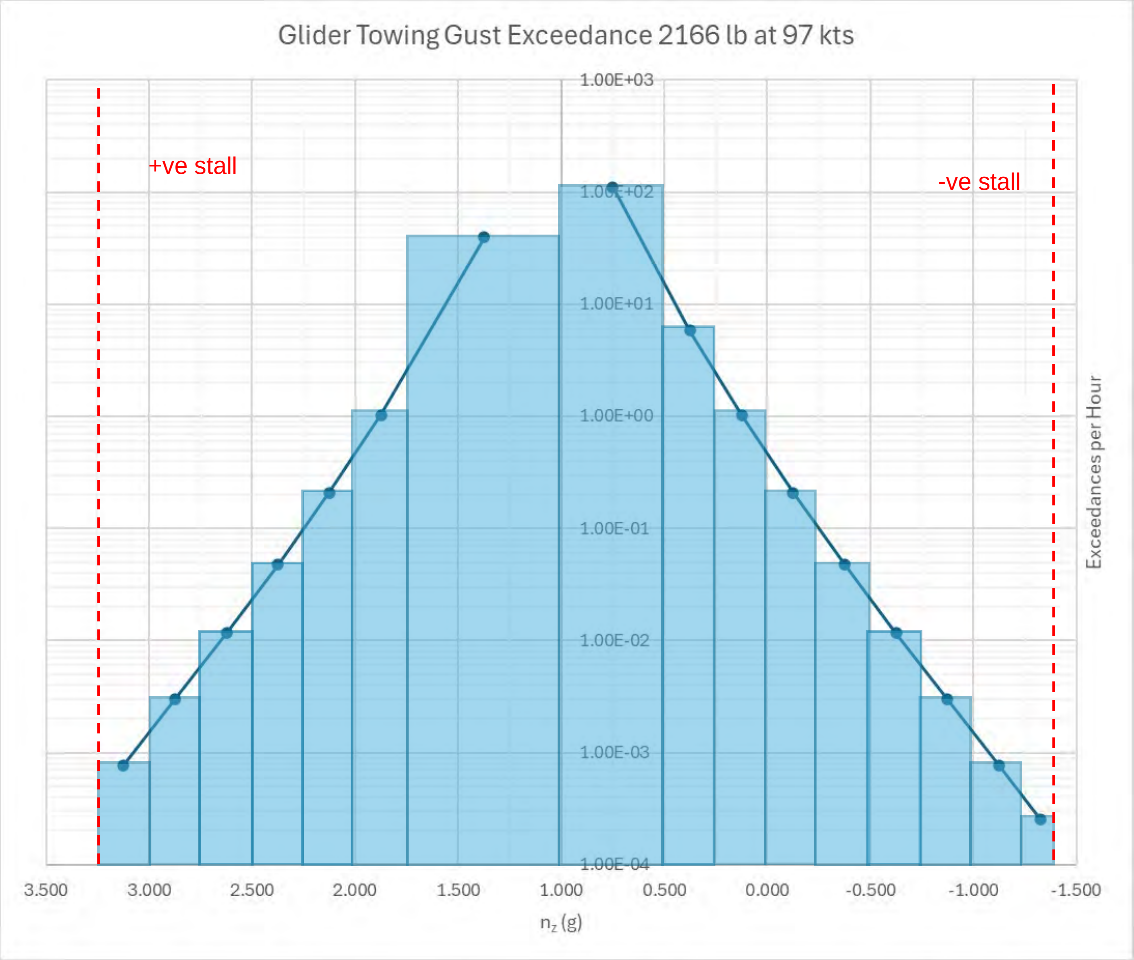

Figure 11-1 Gust Exceedances for Single Seat Glider Towing with Wing Tanks at 2166 lb and 97 kts

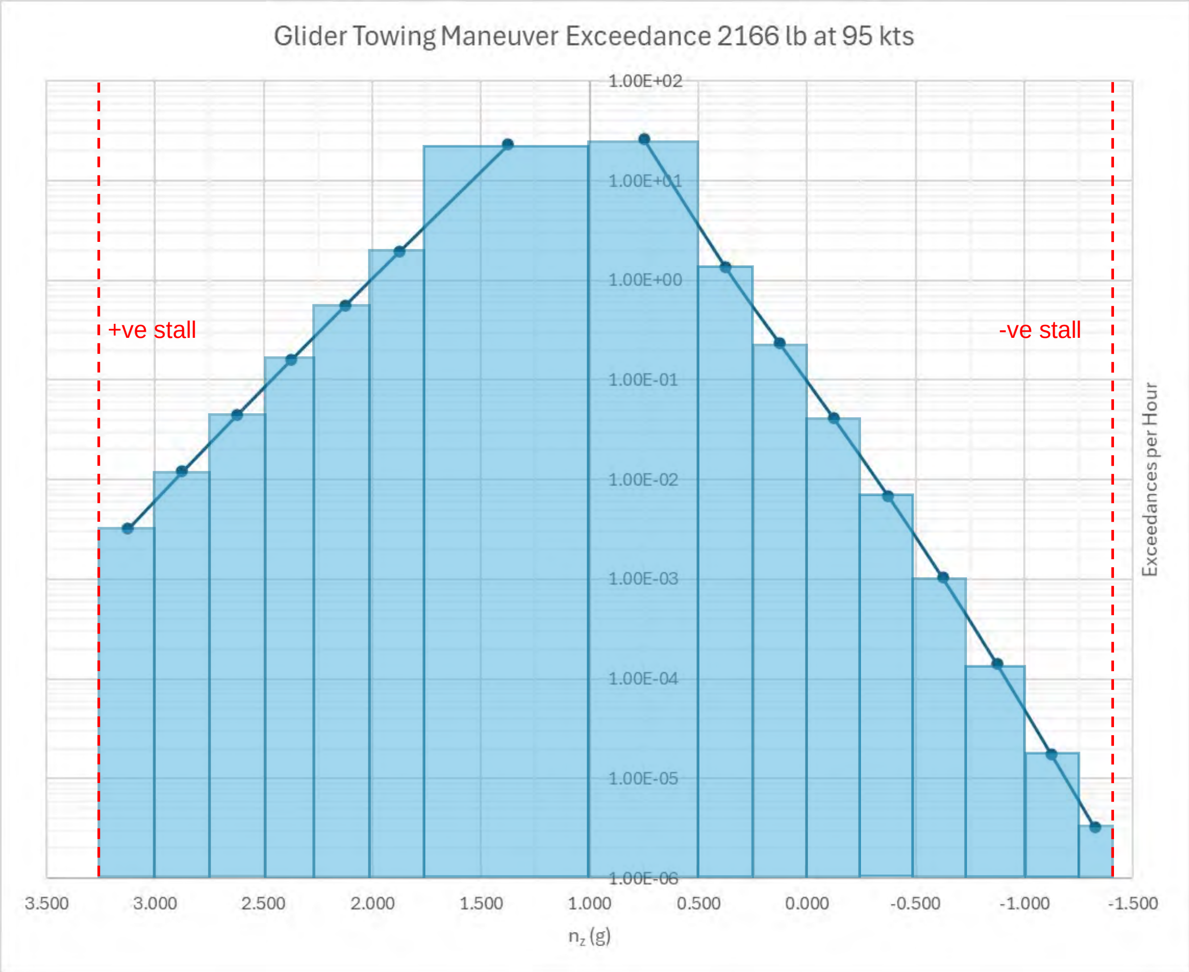

Figure 11-2 Maneuver Exceedances for Single Seat Glider Towing at 2166 lb at 97 kts

Block Upper g limit	Block Mean g level	Gust Exceedance per hour	Maneuver Exceedance per hour	Total Exceedance per hour	Occurrence per hour
3.25	3.125	0.0008	0.0032	0.0040	0.0040
3.00	2.875	0.0030	0.0121	0.0151	0.0111
2.75	2.625	0.0116	0.0444	0.0560	0.0410
2.50	2.375	0.0473	0.1597	0.2071	0.1510
2.25	2.125	0.2083	0.5641	0.7725	0.5654
2.00	1.875	1.0239	1.9629	2.9868	2.2143
1.75	1.375	39.2446	23.0317	62.2763	59.2895
1.00					
1.00	0.75	110.1529	26.0267	136.1796	129.0103
0.50	0.375	5.8038	1.3655	7.1693	5.9120
0.25	0.125	1.0237	0.2337	1.2573	1.0080
0.00	-0.125	0.2083	0.0411	0.2493	0.1952
-0.25	-0.375	0.0473	0.0069	0.0541	0.0415
-0.50	-0.625	0.0116	0.0010	0.0126	0.0095

-0.75	-0.875	0.0030	1.4147E-04	0.0031	0.0023
-1.00	-1.125	0.0008	1.7649E-05	0.0008	0.0005
-1.25	-1.325	2.5591E-04	3.2466E-06	2.5915E-04	2.5915E-04
-1.40					

Table 11-1 Gust and Maneuver Exceedance for Single Seat Glider Towing with Wing Tanks at 2166 lb at 97 kts

	Block Mean g level	Max Spar Stress (ksi)	Min Spar Stress (ksi)	Occurrence per 1000 hr
1	3.125	10.914	10.914	4
2	2.875	10.296	10.296	11
3	2.625	9.632	9.632	41
4	2.375	8.918	8.918	151
5	2.125	8.154	8.154	565
6	1.875	7.339	7.339	2,214
7	1.375	5.555	5.555	59,290
8	0.75	4.086	3.045	129,010
9	0.375	4.086	1.394	5,912
10	0.125	4.086	0.235	1,008
11	-0.125	4.086	-0.969	195
12	-0.375	4.086	-2.218	42
13	-0.625	4.086	-3.510	10
14	-0.875	4.086	-4.868	2
15	-1.125	4.086	-6.490	1
16	-1.325	4.086	-7.824	0
Total				**198,456**

Table 11-2 AFGROW Gust and Maneuver Spectrum for Single Seat Glider Towing at WS 25 with wing tanks at 2166 lb per 1000 hrs

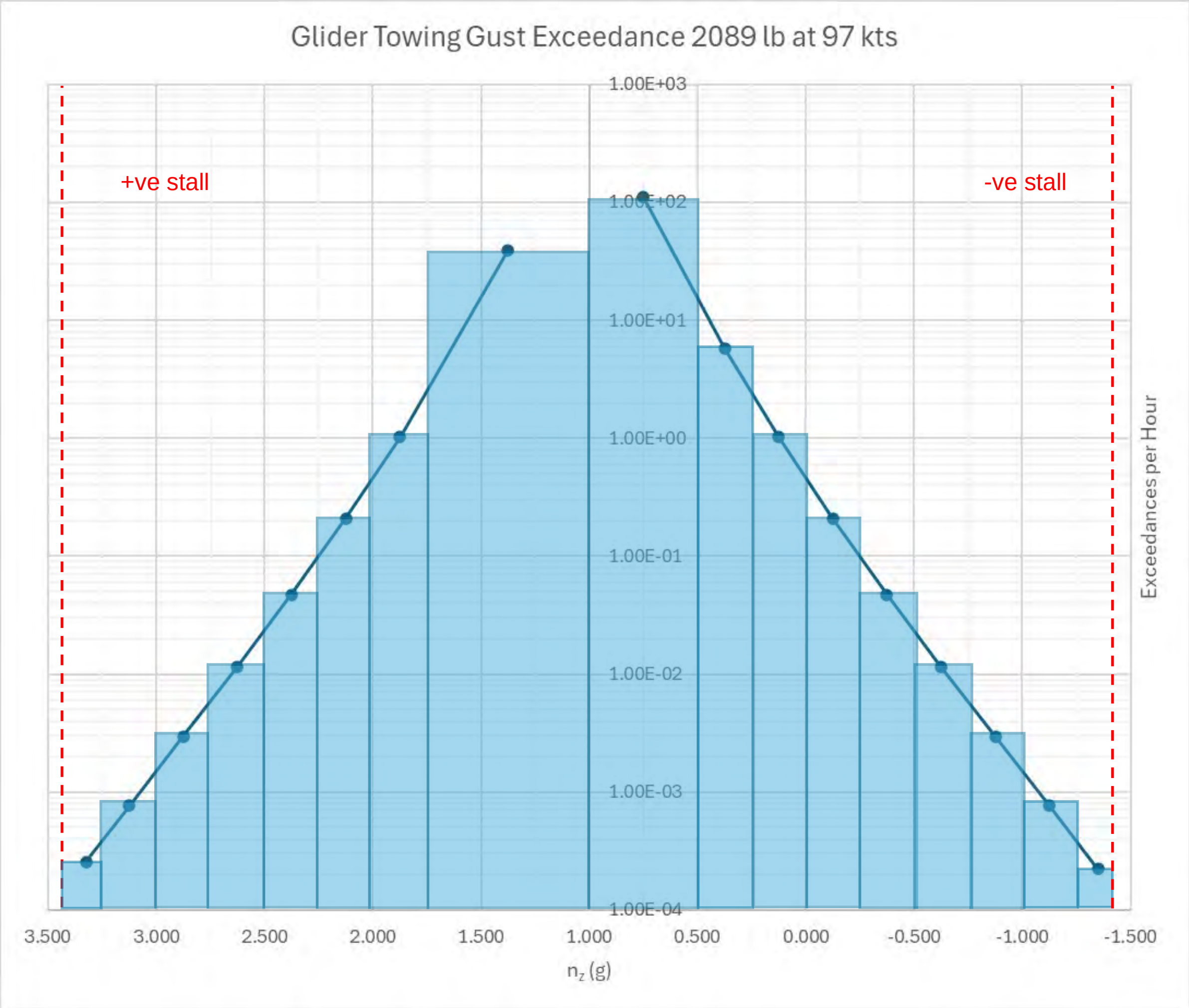

Figure 11-3 Gust Exceedances for Single Seat Glider Towing with Wing Tanks at 2089 lb and 97 kts

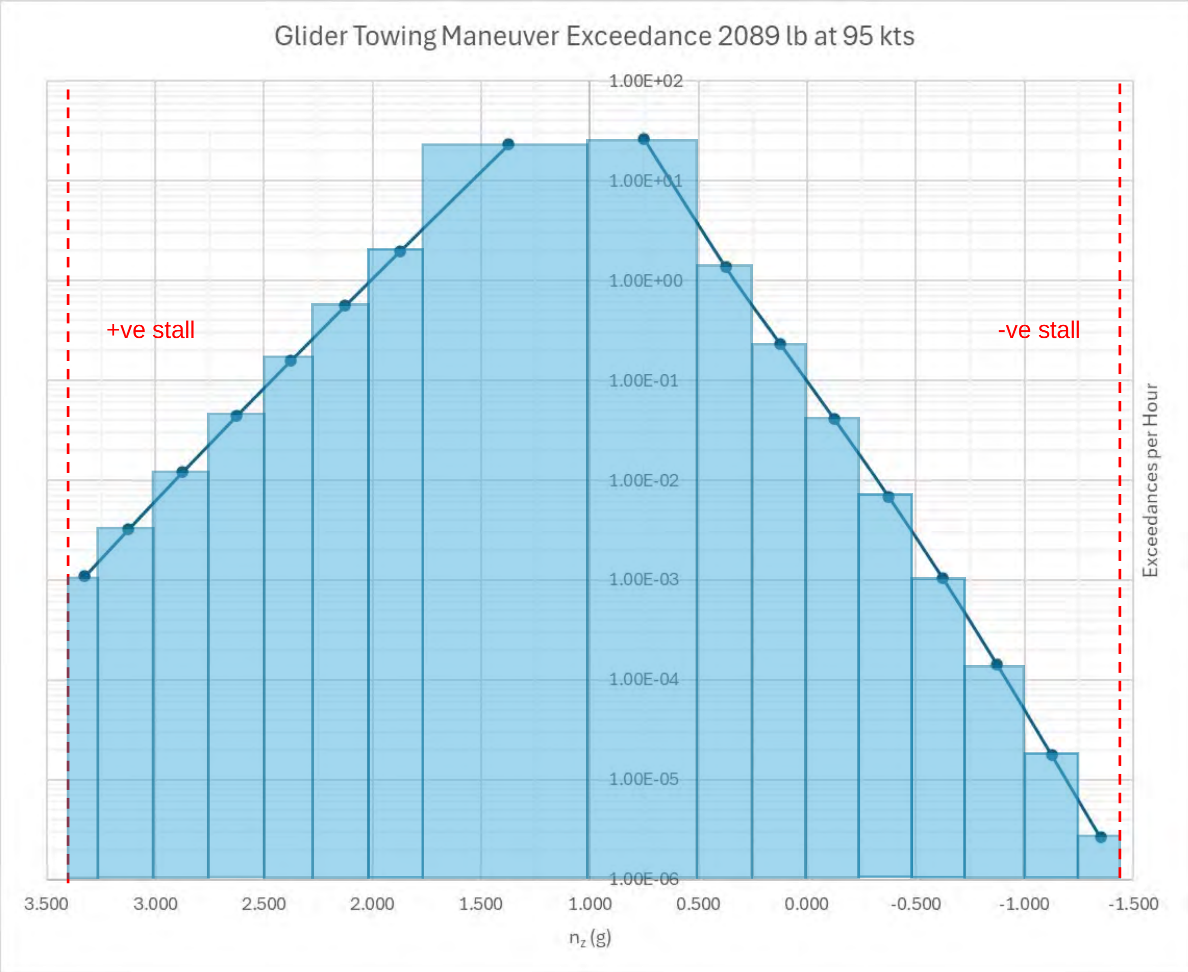

Figure 11-4 Maneuver Exceedances for Single Seat Glider Towing at 2089 lb at 97 kts

Block Upper g limit	Block Mean g level	Gust Exceedance per hour	Maneuver Exceedance per hour	Total Exceedance per hour	Occurrence per hour
3.40	3.325	0.0003	0.0011	0.0013	0.0013
3.25	3.125	0.0008	0.0032	0.0040	0.0026
3.00	2.875	0.0030	0.0121	0.0151	0.0111
2.75	2.625	0.0116	0.0444	0.0560	0.0410
2.50	2.375	0.0473	0.1597	0.2071	0.1510
2.25	2.125	0.2083	0.5641	0.7725	0.5654
2.00	1.875	1.0239	1.9629	2.9868	2.2143
1.75	1.375	39.2446	23.0317	62.2763	59.2895
1.00					
1.00	0.75	110.1529	26.0267	136.1796	129.0103
0.50	0.375	5.8038	1.3655	7.1693	5.9120
0.25	0.125	1.0237	0.2337	1.2573	1.0080
0.00	-0.125	0.2083	0.0411	0.2493	0.1952

-0.25	-0.375	0.0473	0.0069	0.0541	0.0415
-0.50	-0.625	0.0116	0.0010	0.0126	0.0095
-0.75	-0.875	0.0030	1.4147E-04	0.0031	0.0023
-1.00	-1.125	0.0008	1.7649E-05	0.0008	0.0005
-1.25	-1.35	2.2268E-04	2.6284E-06	2.2531E-04	2.2531E-04
-1.45					

Table 11-3 Gust and Maneuver Exceedance for Single Seat Glider Towing with Wing Tanks at 2089 lb at 97 kts

	Block Mean g level	Max Spar Stress (ksi)	Min Spar Stress (ksi)	Occurrence per 1000 hr
1	3.325	12.310	4.269	1
2	3.125	11.768	4.269	3
3	2.875	11.054	4.269	11
4	2.625	10.297	4.269	41
5	2.375	9.495	4.269	151
6	2.125	8.648	4.269	565
7	1.875	7.754	4.269	2,214
8	1.375	5.830	4.269	59,290
9	0.75	4.269	3.174	129,010
10	0.375	4.269	1.452	5,912
11	0.125	4.269	0.253	1,008
12	-0.125	4.269	-0.986	195
13	-0.375	4.269	-2.264	42
14	-0.625	4.269	-3.580	10
15	-0.875	4.269	-4.957	2
16	-1.125	4.269	-6.589	1
17	-1.325	4.269	-8.094	0
Total				**198,455**

Table 11-4 AFGROW Gust and Maneuver Spectrum for Single Seat Glider Towing at WS 25 with wing tanks at 2089 lb per 1000 hrs

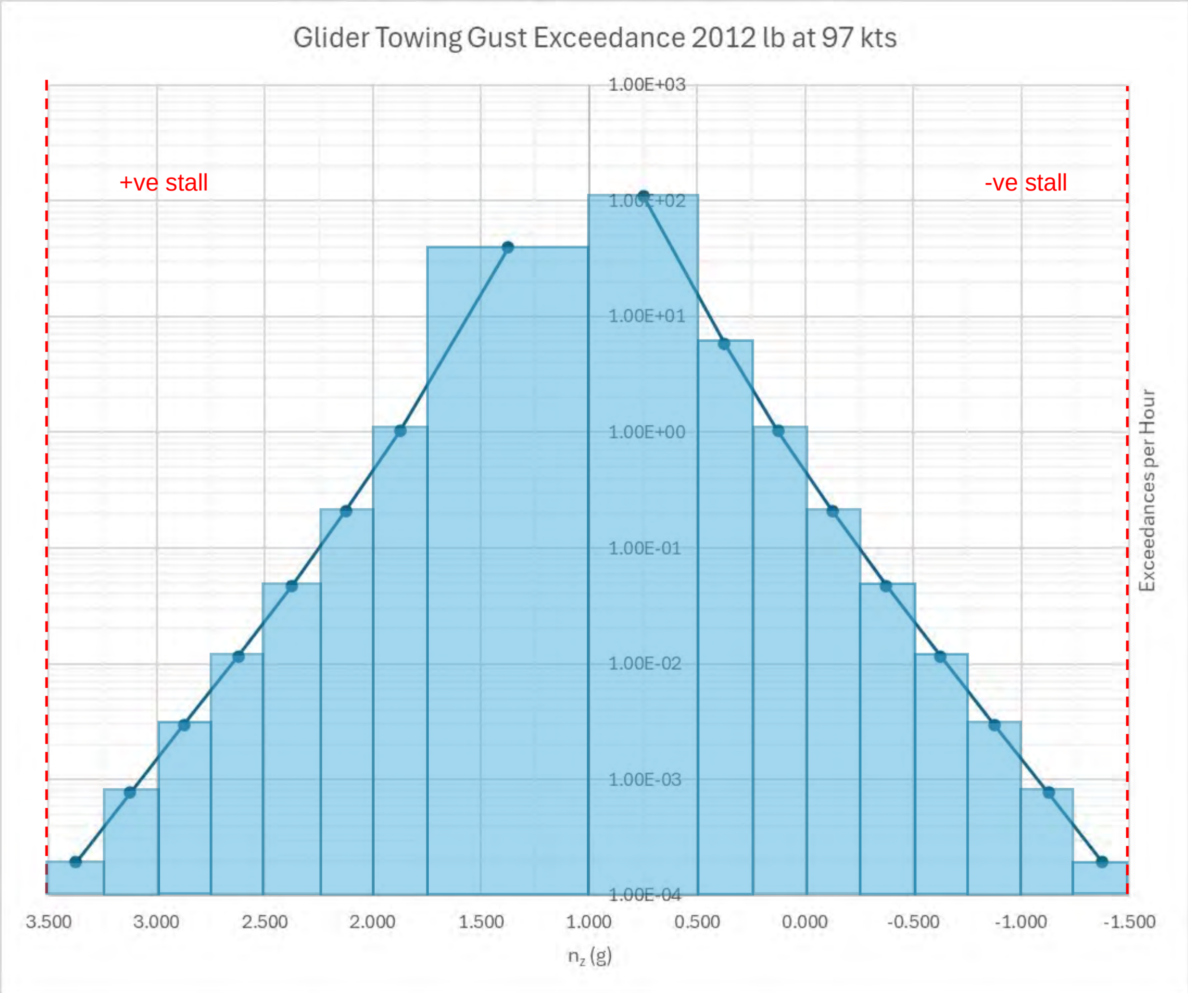

Figure 11-5 Gust Exceedances for Single Seat Glider Towing with Wing Tanks at 2012 lb and 97 kts

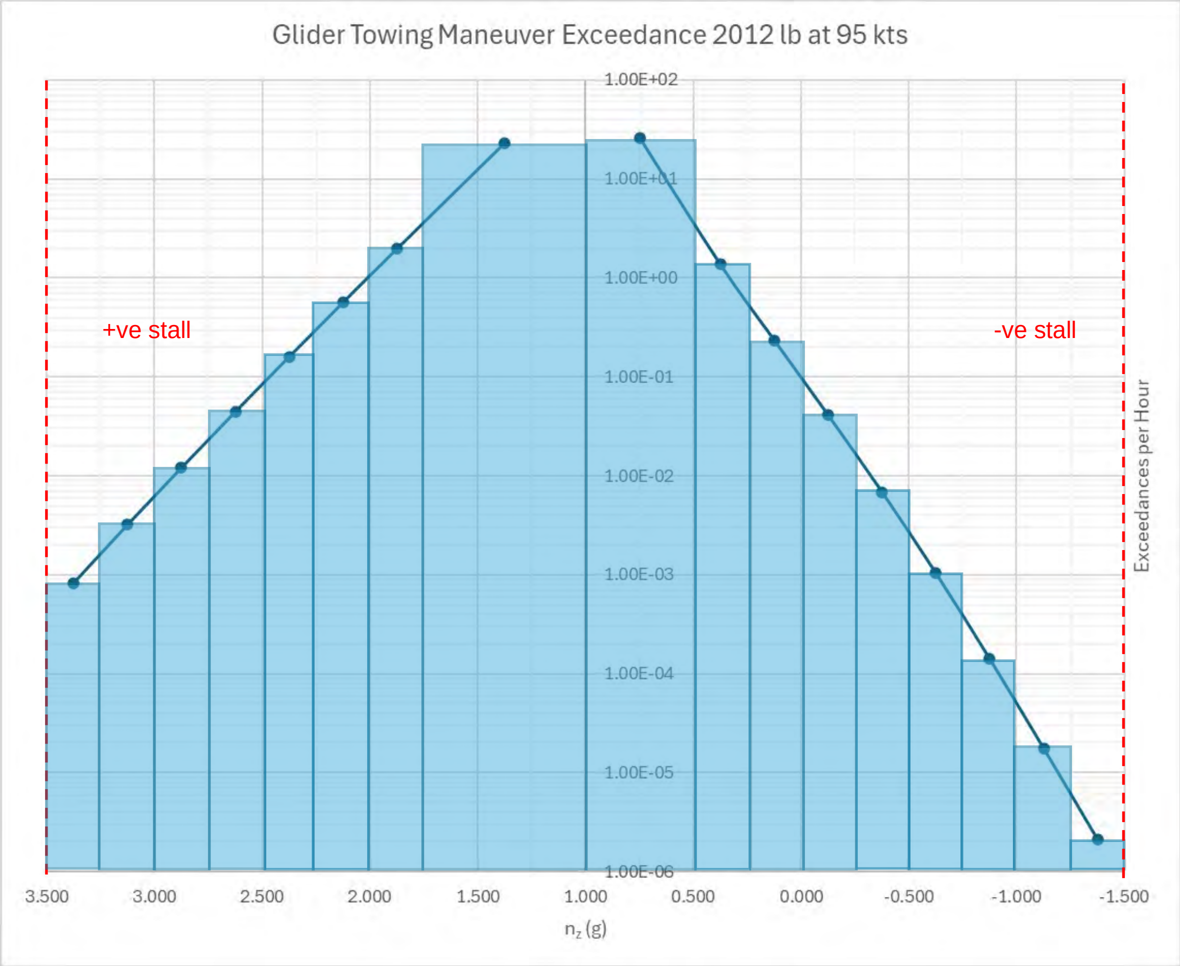

Figure 11-6 Maneuver Exceedances for Single Seat Glider Towing at 2012 lb at 97 kts

Block Upper g limit	Block Mean g level	Gust Exceedance per hour	Maneuver Exceedance per hour	Total Exceedance per hour	Occurrence per hour
3.50	3.375	0.0002	0.0008	0.0010	0.0010
3.25	3.125	0.0008	0.0032	0.0040	0.0030
3.00	2.875	0.0030	0.0121	0.0151	0.0111
2.75	2.625	0.0116	0.0444	0.0560	0.0410
2.50	2.375	0.0473	0.1597	0.2071	0.1510
2.25	2.125	0.2083	0.5641	0.7725	0.5654
2.00	1.875	1.0239	1.9629	2.9868	2.2143
1.75	1.375	39.2446	23.0317	62.2763	59.2895
1.00					
1.00	0.75	110.1529	26.0267	136.1796	129.0103
0.50	0.375	5.8038	1.3655	7.1693	5.9120
0.25	0.125	1.0237	0.2337	1.2573	1.0080
0.00	-0.125	0.2083	0.0411	0.2493	0.1952
-0.25	-0.375	0.0473	0.0069	0.0541	0.0415

-0.50	-0.625	0.0116	0.0010	0.0126	0.0095
-0.75	-0.875	0.0030	1.4147E-04	0.0031	0.0023
-1.00	-1.125	0.0008	1.7649E-05	0.0008	0.0005
-1.25	-1.365	1.9366E-04	2.1288E-06	2.3160E-04	1.9579E-04
-1.48					

Table 11-5 Gust and Maneuver Exceedance for Single Seat Glider Towing with Wing Tanks at 2012 lb at 97 kts

	Block Mean g level	Max Spar Stress (ksi)	Min Spar Stress (ksi)	Occurrence per 1000 hr
1	3.375	13.363	4.445	1
2	3.125	12.593	4.445	3
3	2.875	11.786	4.445	11
4	2.625	10.939	4.445	41
5	2.375	10.052	4.445	151
6	2.125	9.123	4.445	565
7	1.875	8.154	4.445	2,214
8	1.375	6.094	4.445	59,290
9	0.75	4.445	3.298	129,010
10	0.375	4.445	1.509	5,912
11	0.125	4.445	0.271	1,008
12	-0.125	4.445	-1.002	195
13	-0.375	4.445	-2.309	42
14	-0.625	4.445	-3.648	10
15	-0.875	4.445	-5.043	2
16	-1.125	4.445	-6.684	1
17	-1.375	4.445	-8.295	0
Total				**198,455**

Table 11-6 AFGROW Gust and Maneuver Spectrum for Single Seat Glider Towing with Wing Tanks at 2012 lb at WS 25 per 1000 hrs

11.3 From Table 9-1, the PA 25-180 Pawnee and PA 18-150 Super Cub averaged 7.8 flights per hour:

Sink Rate (ft/sec)	Delta Nz (g)	Exceedance per landing	Exceedance per hour	Occurrence per hour
0.5	0.402	0.7300	5.6940	3.1200
1.5	1.205	0.3300	2.5740	1.9188
2.5	2.008	0.0840	0.6552	0.5772
3.5	2.811	0.0100	0.0780	0.0624
4.5	3.614	0.0020	0.0156	0.0115
5.5	4.417	0.0005	0.0041	0.0028
6.5	5.220	0.0002	0.0013	0.0013

Table 11-7 Landing Exceedance for 2166 lb

	Block Mean g level	Max Spar Stress (ksi)	Min Spar Stress (ksi)	Occurrence per 1000 hr
1	1.401	3.833	3.421	3,120
2	2.204	3.833	2.595	1,919
3	3.007	3.833	1.770	577
4	3.810	3.833	0.924	62
5	4.613	3.833	-0.062	11
6	5.416	3.833	-1.043	3
7	6.219	3.833	-2.024	1
Total				**5,694**

Table 11-8 AFGROW Landing Spectrum for Single Seat Glider Towing at 2166 lb at WS 25 with Wing Tanks per 1000 hrs

Sink Rate (ft/sec)	Delta Nz (g)	Exceedance per landing	Exceedance per hour	Occurrence per hour
0.5	0.409	0.7300	5.6940	3.1200
1.5	1.227	0.3300	2.5740	1.9188
2.5	2.044	0.0840	0.6552	0.5772
3.5	2.862	0.0100	0.0780	0.0624
4.5	3.680	0.0020	0.0156	0.0115
5.5	4.497	0.0005	0.0041	0.0028
6.5	5.315	0.0002	0.0013	0.0013

Table 11-9 Landing Exceedance for 2089 lb

	Block Mean g level	Max Spar Stress (ksi)	Min Spar Stress (ksi)	Occurrence per 1000 hr
1	1.409	3.665	3.244	3,120
2	2.227	3.665	2.404	1,919
3	3.044	3.665	1.564	577
4	3.862	3.665	0.667	62
5	4.680	3.665	-0.336	11
6	5.497	3.665	-1.335	3
7	6.315	3.665	-2.334	1
Total				**5,694**

Table 11-10 AFGROW Landing Spectrum for Single Seat Glider Towing at 2089 lb with Wing Tanks per 1000 hrs

Sink Rate (ft/sec)	Delta Nz (g)	Exceedance per landing	Exceedance per hour	Occurrence per hour
0.5	0.417	0.7300	5.6940	3.1200
1.5	1.250	0.3300	2.5740	1.9188
2.5	2.083	0.0840	0.6552	0.5772
3.5	2.916	0.0100	0.0780	0.0624
4.5	3.749	0.0020	0.0156	0.0115
5.5	4.582	0.0005	0.0041	0.0028
6.5	5.415	0.0002	0.0013	0.0013

Table 11-11 Landing Exceedance for 2012 lb

	Block Mean g level	Max Spar Stress (ksi)	Min Spar Stress (ksi)	Occurrence per 1000 hr
1	1.417	3.496	3.068	3,120
2	2.250	3.496	2.211	1,919
3	3.083	3.496	1.355	577
4	3.916	3.496	0.406	62
5	4.749	3.496	-0.615	11
6	5.582	3.496	-1.633	3
7	6.415	3.496	-2.651	1
Total				**5,694**

Table 11-12 AFGROW Landing Spectrum for Single Seat Glider Towing at 2012 lb at WS 25 with Wing Tanks per 1000 hrs

11.4 Taxiing using an average of 7.8 landings per hour and the single engine taxi spectra:

Block Upper g limit	Block Mean g level	Exceedance per landing	Exceedance per hour	Occurrence per hour
1.5	1.45	0.0193	0.1504	0.1504
1.4	1.35	0.5226	4.0766	3.9262
1.3	1.25	9.7172	75.7940	71.7173
1.2	1.15	92.2108	719.2441	643.4501
1.1	1.05	332.2880	2591.8461	1872.6020
1				
0.9	0.95	332.2880	2591.8461	1872.6020
0.8	0.85	92.2108	719.2441	643.4501
0.7	0.75	9.7172	75.7940	71.7173
0.6	0.65	0.5226	4.0766	3.9262
0.5	0.55	0.0193	0.1504	0.1504

Table 11-13 Taxiing Exceedance for Single Seat Glider Towing

	Block Mean g level	Max Spar Stress (ksi)	Min Spar Stress (ksi)	Occurrence per 1000 hr
1	1.45	-2.218	-3.216	150
2	1.35	-2.218	-2.994	3,926
3	1.25	-2.218	-2.772	71,717
4	1.15	-2.218	-2.551	643,450
5	1.05	-2.218	-2.329	1,872,602
6	0.95	-2.107	-2.218	1,872,602
7	0.85	-1.885	-2.218	643,450
8	0.75	-1.663	-2.218	71,717
9	0.65	-1.442	-2.218	3,926
10	0.55	-1.220	-2.218	150
Total				**5,183,692**

Table 11-14 AFGROW Taxiing Spectrum for Single Seat Glider Towing at 2166 lb at WS 25 with Wing Tanks per 1000 hrs

	Block Mean g level	Max Spar Stress (ksi)	Min Spar Stress (ksi)	Occurrence per 1000 hr
1	1.45	-1.755	-2.544	150
2	1.35	-1.755	-2.369	3,926
3	1.25	-1.755	-2.193	71,717
4	1.15	-1.755	-2.018	643,450
5	1.05	-1.755	-1.842	1,872,602
6	0.95	-1.667	-1.755	1,872,602
7	0.85	-1.491	-1.755	643,450
8	0.75	-1.316	-1.755	71,717
9	0.65	-1.140	-1.755	3,926
10	0.55	-0.965	-1.755	150

Total				**5,183,692**

Table 11-15 AFGROW Taxiing Spectrum for Single Seat Glider Towing at 2089 lb at WS 25 with Wing Tanks per 1000 hrs

	Block Mean g level	Max Spar Stress (ksi)	Min Spar Stress (ksi)	Occurrence per 1000 hr
1	1.45	-1.301	-1.886	150
2	1.35	-1.301	-1.756	3,926
3	1.25	-1.301	-1.626	71,717
4	1.15	-1.301	-1.496	643,450
5	1.05	-1.301	-1.366	1,872,602
6	0.95	-1.236	-1.301	1,872,602
7	0.85	-1.106	-1.301	643,450
8	0.75	-0.976	-1.301	71,717
9	0.65	-0.846	-1.301	3,926
10	0.55	-0.715	-1.301	150
Total				**5,183,692**

Table 11-16 AFGROW Taxiing Spectrum for Single Seat Glider Towing with Wing Tanks at 2012 lb per 1000 hrs

11.5 Ground air ground cycles were determined by fitting curves to the stress vs exceedance charts for the operating weight. These curves were then used to estimate the exceedance for a particular stress.

Stress	Gust	Maneuver	Landing	Taxi	Total
7.500	0.0951	0.1976			0.2927
7.000	0.2535	0.4092			0.6627
6.750	0.4170	0.5828			0.9998
6.500	0.6906	0.8252			1.5157
6.000	1.9408	1.6308			3.5717
-2.000	0.0075	0.0011	0.0002	205.8711	205.8799
-2.500	0.0043	0.0005	0.0001	135.9118	135.9167
-2.948	0.0026	0.0003	0.0000	0.9995	1.0025
-3.000	0.0025	0.0003		0.4804	0.4832
-3.500	0.0015	0.0001		0.0003	0.0019

Table 11-17 Ground-Air-Ground Spectrum for Single Seat Glider Towing at 2166 lb at WS 25 with Wing Tanks

	Max Spar Stress (ksi)	Min Spar Stress (ksi)	Occurrence per 1000 hr
1	6.750	-2.948	7,800
Total			**7,800**

Table 11-18 AFGROW Spectrum for Single Seat Glider Towing with Wing Tanks at 2166 lb

Stress	Gust	Maneuver	Landing	Taxi	Total
8.000	0.0838	0.1795			0.2633
7.500	0.2053	0.3519			0.5572
7.114	0.4164	0.5839			1.0002
7.000	0.5147	0.6766			1.1913
6.500	1.3299	1.2803			2.6102
-2.000	0.0079	0.0012	0.0003	110.2713	110.2806
-2.250	0.0060	0.0008	0.0002	4.0048	4.0118
-2.332	0.0054	0.0007	0.0002	1.0032	1.0096
-2.500	0.0045	0.0006		0.0451	0.0502
-2.750	0.0035	0.0004		0.0004	0.0042

Table 11-19 Ground-Air-Ground Spectrum for Single Seat Glider Towing with Wing Tanks at 2089 lb at WS 25

	Max Spar Stress (ksi)	Min Spar Stress (ksi)	Occurrence per 1000 hr
1	7.114	-2.332	7,800
Total			**7,800**

Table 11-20 AFGROW Spectrum for Single Seat Glider Towing with Wing Tanks at 2089 lb

Stress	Gust	Maneuver	Landing	Taxi	Total
8.000	0.1681	0.3157			0.4838
7.500	0.3930	0.5864			0.9794
7.485	0.4033	0.5972			1.0005
7.000	0.9444	1.0636			2.0080
6.500	2.3445	1.8807			4.2252
-1.250	0.0195	0.0035	0.0008	355.8825	355.9063
-1.500	0.0146	0.0025	0.0006	87.1626	87.1802
-1.730	0.0112	0.0018	0.0004	0.9790	0.9925
-1.750	0.0109	0.0017	0.0004	0.6068	0.6199
-2.000	0.0083	0.0012	0.0003	0.0010	0.0108

Table 11-21 Ground-Air-Ground Spectrum for Single Seat Glider Towing with Wing Tanks at 2012 lb at WS 25

	Max Spar Stress (ksi)	Min Spar Stress (ksi)	Occurrence per 1000 hr
1	7.485	-1.730	7,800
Total			**7,800**

Table 11-22 AFGROW Spectrum for Single Seat Glider Towing with Wing Tanks at 2012 lb

12. GLIDER TOWING LOAD SPECTRA – TWO SEAT MODEL WITHOUT WING TANKS

12.1 This is similar to Section 10 with the exception that the aircraft is operating at 2460 lbs (1116 kg) instead of 2205 lbs (1000 kg).

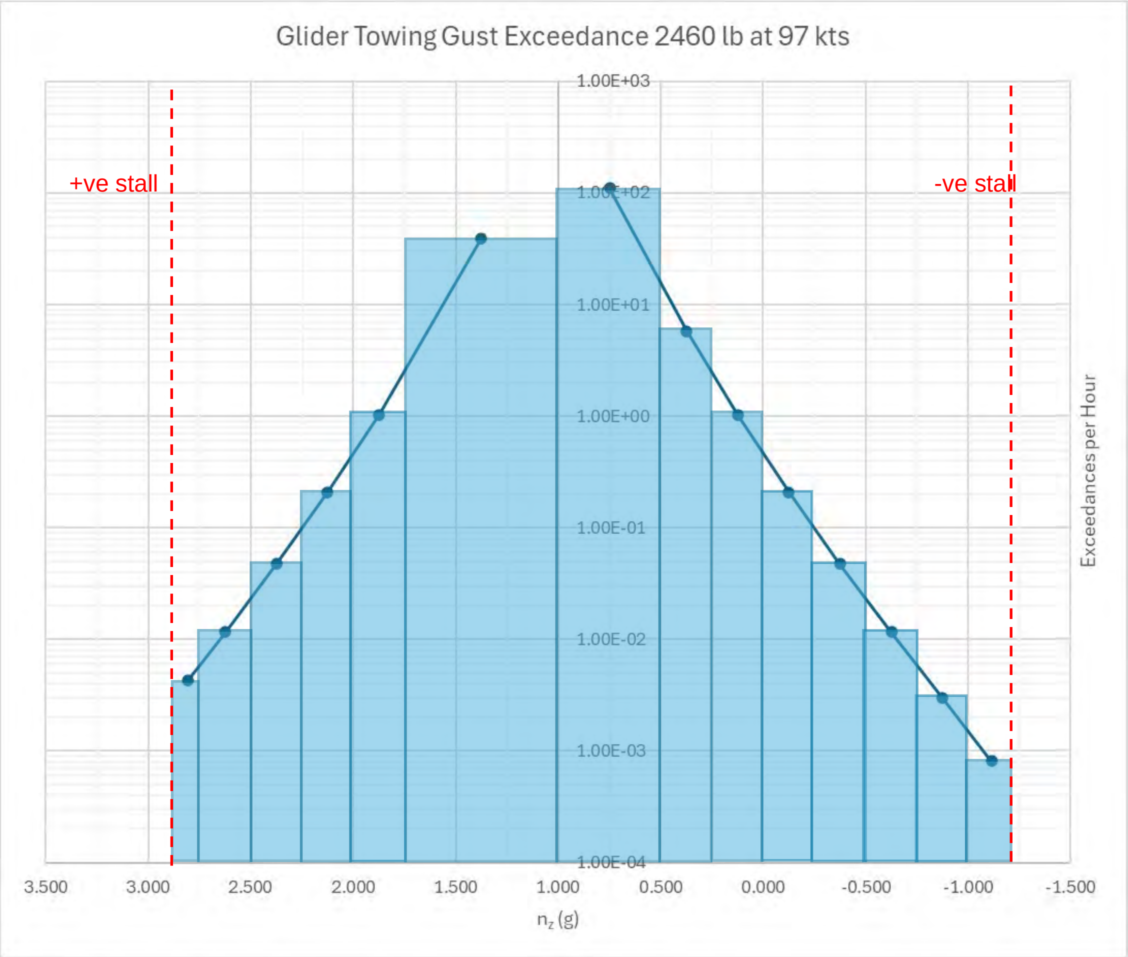

Figure 12-1 Gust Exceedances for Dual Seat Glider Towing at 97 kts

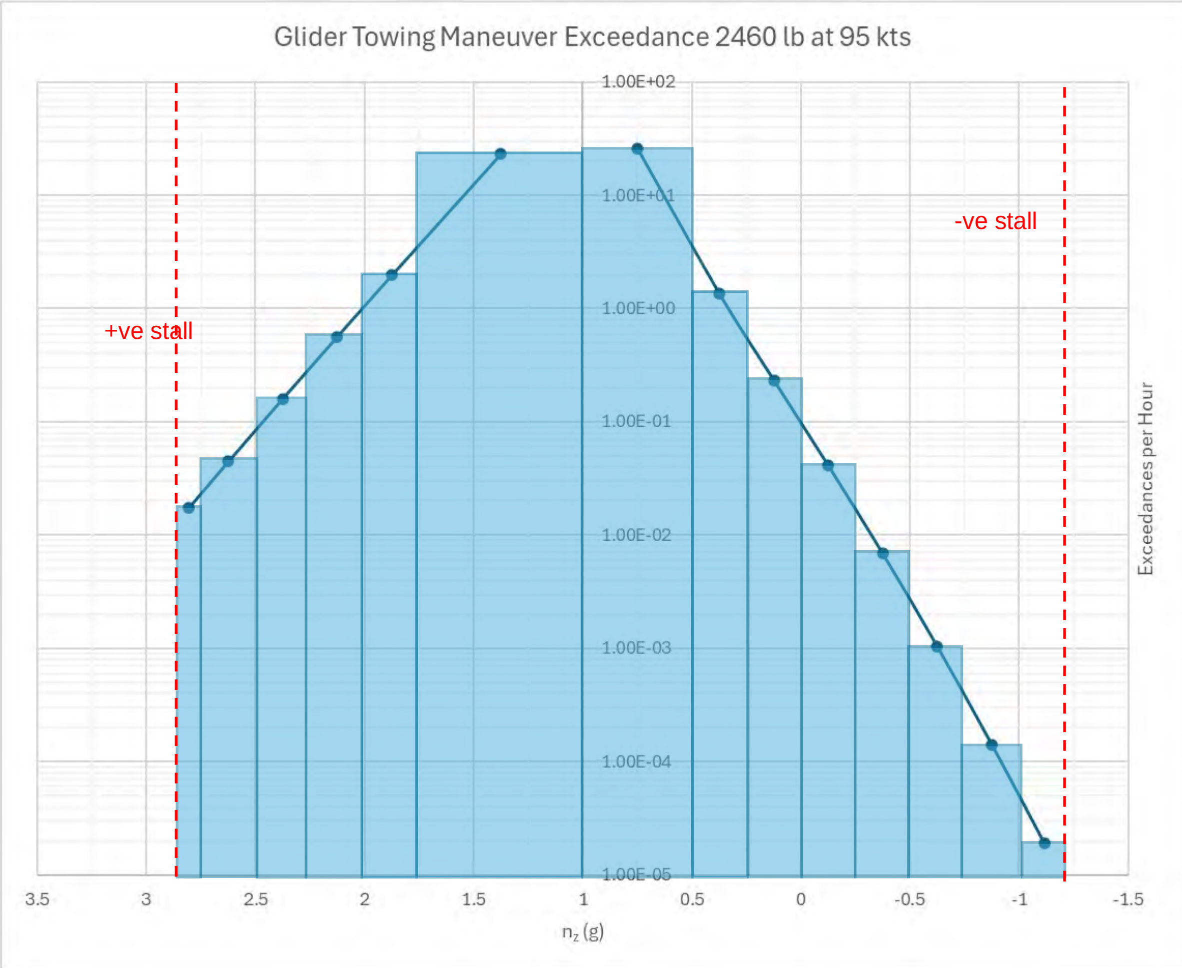

Figure 12-2 Maneuver Exceedances for Dual Seat Glider Towing at 2460 lb at 97 kts

Block Upper g limit	Block Mean g level	Gust Exceedance per hour	Maneuver Exceedance per hour	Total Exceedance per hour	Occurrence per hour
2.86					
2.75	2.805	0.0043	0.0174	0.0218	0.0218
2.50	2.625	0.0116	0.0444	0.0560	0.0342
2.25	2.375	0.0473	0.1597	0.2071	0.1510
2.00	2.125	0.2083	0.5641	0.7725	0.5654
1.75	1.875	1.0239	1.9629	2.9868	2.2143
1.00	1.375	39.2446	23.0317	62.2763	59.2895
1.00					
0.50	0.75	110.1529	26.0267	136.1796	129.0103
0.25	0.375	5.8038	1.3655	7.1693	5.9120
0.00	0.125	1.0237	0.2337	1.2573	1.0080
-0.25	-0.125	0.2083	0.0411	0.2493	0.1952
-0.50	-0.375	0.0473	0.0069	0.0541	0.0415
-0.75	-0.625	0.0116	0.0010	0.0126	0.0095
	-0.875	0.0030	1.4147E-04	0.0031	0.0023

-1.00	-1.115	0.0008	1.9203E-05	0.0008	0.0008
-1.23					

Table 12-1 Gust and Maneuver Exceedance for Dual Seat Glider Towing at 2460 lb at 97 kts

	Block Mean g level	Max Spar Stress (ksi)	Min Spar Stress (ksi)	Occurrence per 1000 hr
1	2.805	15.006	5.962	22
2	2.625	14.237	5.962	34
3	2.375	13.122	5.962	151
4	2.125	11.951	5.962	565
5	1.875	10.722	5.962	2,214
6	1.375	8.088	5.962	59,290
7	0.75	5.962	4.476	129,010
8	0.375	5.962	2.149	5,912
9	0.125	5.962	0.534	1,008
10	-0.125	5.962	-1.129	195
11	-0.375	5.962	-2.839	42
12	-0.625	5.962	-4.592	10
13	-0.875	5.962	-6.624	2
14	-1.115	5.962	-8.678	1
Total				**198,456**

Table 12-2 AFGROW Gust and Maneuver Spectrum for Single Seat Glider Towing without Wing Tanks per 1000 hrs

12.2 From Table 9-1, the PA 25-180 Pawnee and PA 18-150 Super Cub averaged 7.8 flights per hour:

Sink Rate (ft/sec)	Delta Nz (g)	Exceedance per landing	Exceedance per hour	Occurrence per hour
0.5	0.377	0.7300	5.6940	3.1200
1.5	1.130	0.3300	2.5740	1.9188
2.5	1.884	0.0840	0.6552	0.5772
3.5	2.637	0.0100	0.0780	0.0624
4.5	3.391	0.0020	0.0156	0.0115
5.5	4.144	0.0005	0.0041	0.0028
6.5	4.898	0.0002	0.0013	0.0013

Table 12-3 Landing Exceedance for 2205 lb

	Block Mean g level	Max Spar Stress (ksi)	Min Spar Stress (ksi)	Occurrence per 1000 hr
1	1.377	4.290	4.290	3,120
2	2.130	4.290	3.887	1,919
3	2.884	4.290	3.082	577
4	3.637	4.290	2.276	62
5	4.391	4.290	1.471	11
6	5.144	4.290	0.516	3
7	5.898	4.290	-0.444	1
Total				**5,694**

Table 12-4 AFGROW Landing Spectrum for Dual Seat Glider Towing without Wing Tanks per 1000 hrs

12.3 Taxiing using an average of 7.8 landings per hour and the single engine taxi spectra: Taxi is same as single seat glider towing operations.

12.4 Ground air ground cycles were determined by fitting curves to the stress vs exceedance charts for the operating weight. These curves were then used to estimate the exceedance for a particular stress.

Stress	Gust	Maneuver	Landing	Taxi	Total
11.000	0.0790	0.1656			0.2446
10.000	0.2968	0.4391			0.7360
9.726	0.4302	0.5696			0.9998
9.000	1.1743	1.1201			2.2944
8.000	4.9662	2.7682			7.7344
-0.500	0.0408	0.0084	0.0005	0.0009	0.0506
-1.000	0.0255	0.0049	0.0003	256.0323	256.0630
-1.445	0.0170	0.0031	0.0002	0.9743	0.9945
-1.500	0.0162	0.0029	0.0002	0.1951	0.2143
-2.000	0.0104	0.0017	0.0001	0.0000	0.0122

Table 12-5 Ground-Air-Ground Spectrum for Dual Seat Glider Towing without Wing Tanks

	Max Spar Stress (ksi)	Min Spar Stress (ksi)	Occurrence per 1000 hr
1	9.726	-1.445	7,800
Total			**7,800**

Table 12-6 AFGROW Spectrum for Dual Seat Glider Towing without Wing Tanks

13. GLIDER TOWING LOAD SPECTRA – TWO SEAT MODEL WITH WING TANKS

13.1 There is one Pawnee with wing tanks operating in Australia that has been modified to have two seats, VH-TUG. As of August 2025, this aircraft failed the inspection requirements of Reference 1.1 and is being fitted with new spars. This aircraft does not need consideration of previous hours as an agricultural aircraft.

13.2 As stated at Section 5, Pawnee aircraft fitted with wing tanks were considered to have three weight cases with 5/6, 1/2, and 1/6 fuel tank levels. The aircraft was assumed to operate at each of these three weight cases as per Section 5. Similar to Section 12, this aircraft is assumed to have a MTOW of 2460 lb.

	Operating Weight	Fuel Level	Cruise Speed	Gust Stall g Limit
Glider Towing – Two Seats	2421.4	5/6 (32.08 gal)	97 kts	+2.12 g / -0.92 g
	2344.3	1/2 (19.25 gal)	97 kts	+ 2.18 g / -0.96 g
	2267.2	1/6 (6.42 gal)	97 kts	+2.21 g / -0.99 g

Table 13-1 Operating Weight and Cruise Speed

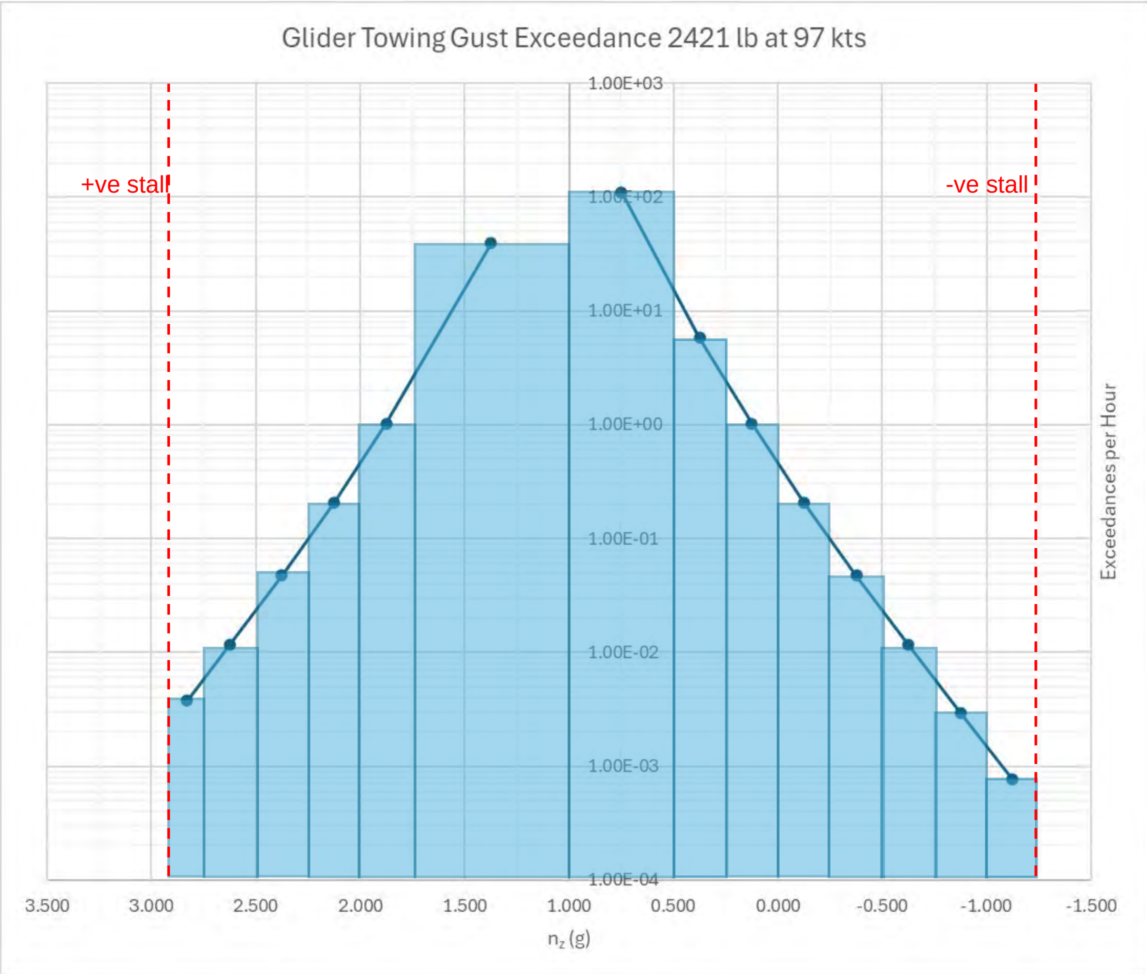

Figure 13-1 Gust Exceedances for Dual Seat Glider Towing with Wing Tanks at 2421 lb at 97 kts

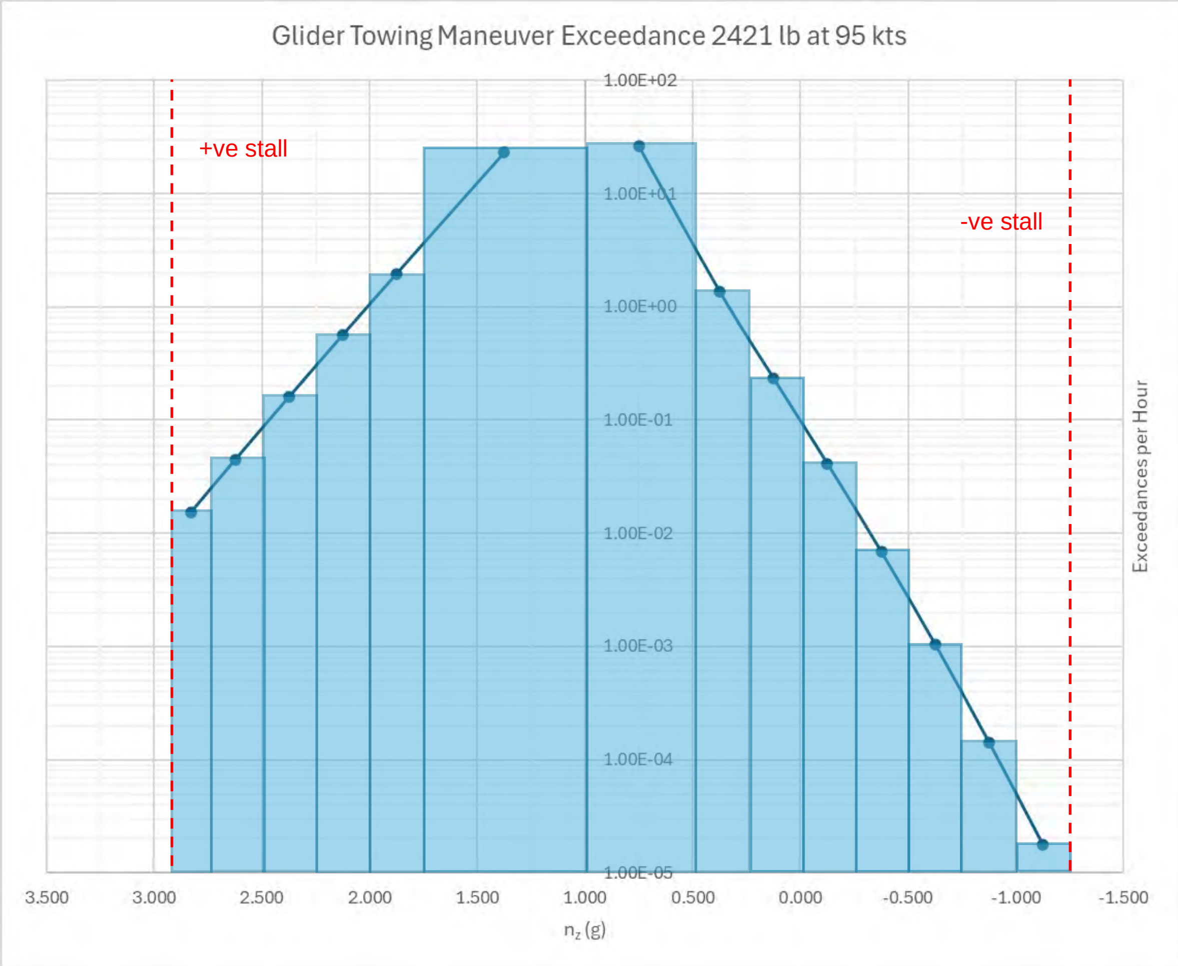

Figure 13-2 Maneuver Exceedances for Dual Seat Glider Towing with Wing Tanks at 2421 lb at 97 kts

Block Upper g limit	Block Mean g level	Gust Exceedance per hour	Maneuver Exceedance per hour	Total Exceedance per hour	Occurrence per hour
2.91	2.83	0.0038	0.0153	0.011	0.0191
2.75	2.625	0.0116	0.0444	0.0560	0.0369
2.50	2.375	0.0473	0.1597	0.2071	0.1510
2.25	2.125	0.2083	0.5641	0.7725	0.5654
2.00	1.875	1.0239	1.9629	2.9868	2.2143
1.75	1.375	39.2446	23.0317	62.2763	59.2895
1.00					
1.00	0.75	110.1529	26.0267	136.1796	129.0103
0.50	0.375	5.8038	1.3655	7.1693	5.9120
0.25	0.125	1.0237	0.2337	1.2573	1.0080
0.00	-0.125	0.2083	0.0411	0.2493	0.1952
-0.25	-0.375	0.0473	0.0069	0.0541	0.0415
-0.50	-0.625	0.0116	0.0010	0.0126	0.0095

-0.75	-0.875	0.0030	1.4147E-04	0.0031	0.0023
-1.00	-1.125	0.0008	1.7649E-05	0.0008	0.0008
-1.25					

Table 13-2 Gust and Maneuver Exceedance for Dual Seat Glider Towing at 2421 lb at 97 kts

	Block Mean g level	Max Spar Stress (ksi)	Min Spar Stress (ksi)	Occurrence per 1000 hr
1	2.830	11.648	4.756	22
2	2.625	11.036	4.756	34
3	2.375	10.237	4.756	151
4	2.125	9.379	4.756	565
5	1.875	8.459	4.756	2,214
6	1.375	6.435	4.756	59,290
7	0.75	4.756	3.563	129,010
8	0.375	4.756	1.663	5,912
9	0.125	4.756	0.327	1,008
10	-0.125	4.756	-1.064	195
11	-0.375	4.756	-2.507	42
12	-0.625	4.756	-4.001	10
13	-0.875	4.756	-5.685	2
14	-1.125	4.756	-7.560	1
Total				**198,456**

Table 13-3 AFGROW Gust and Maneuver Spectrum for Dual Seat Glider Towing with Wing Tanks at 2421 lb at WS 25 per 1000 hrs

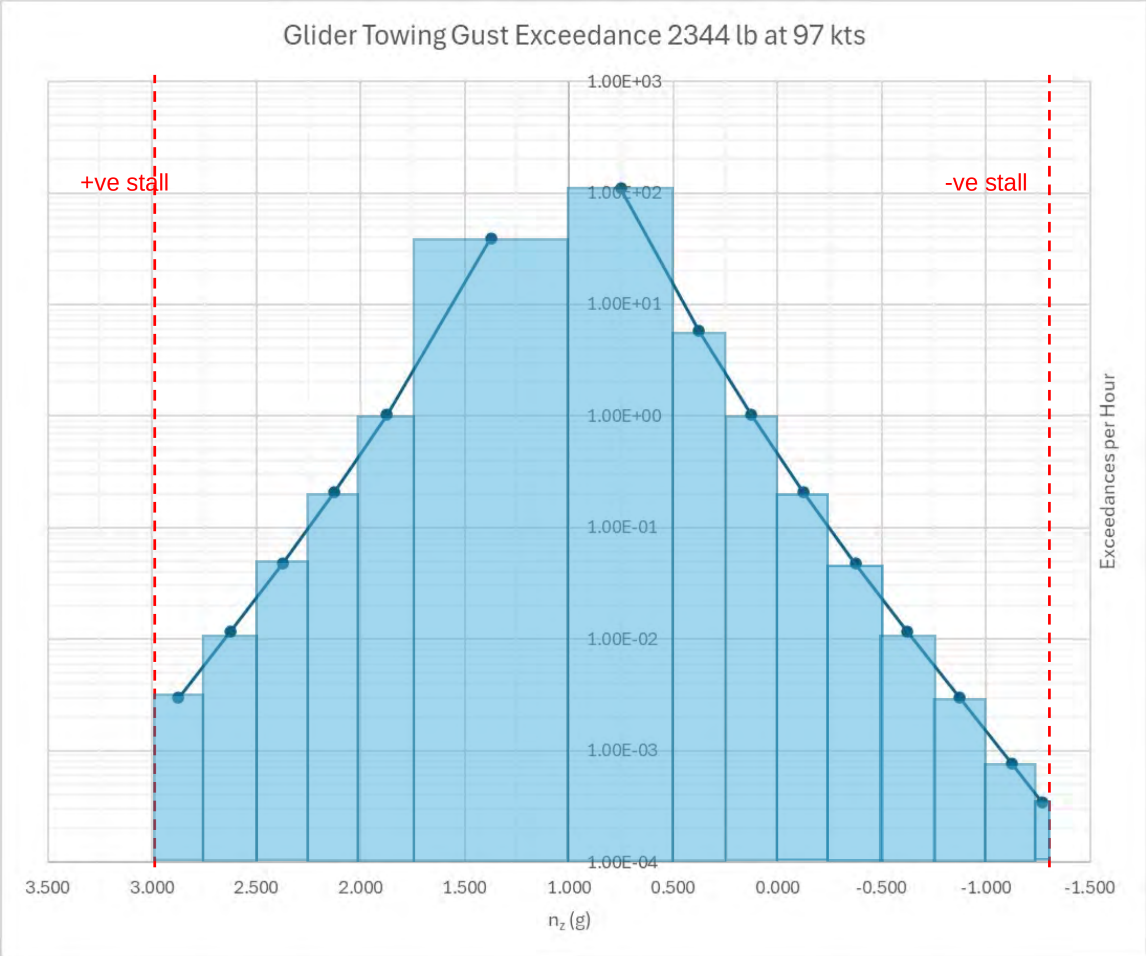

Figure 13-3 Gust Exceedances for Dual Seat Glider Towing with wing tanks at 2344 lb at 97 kts

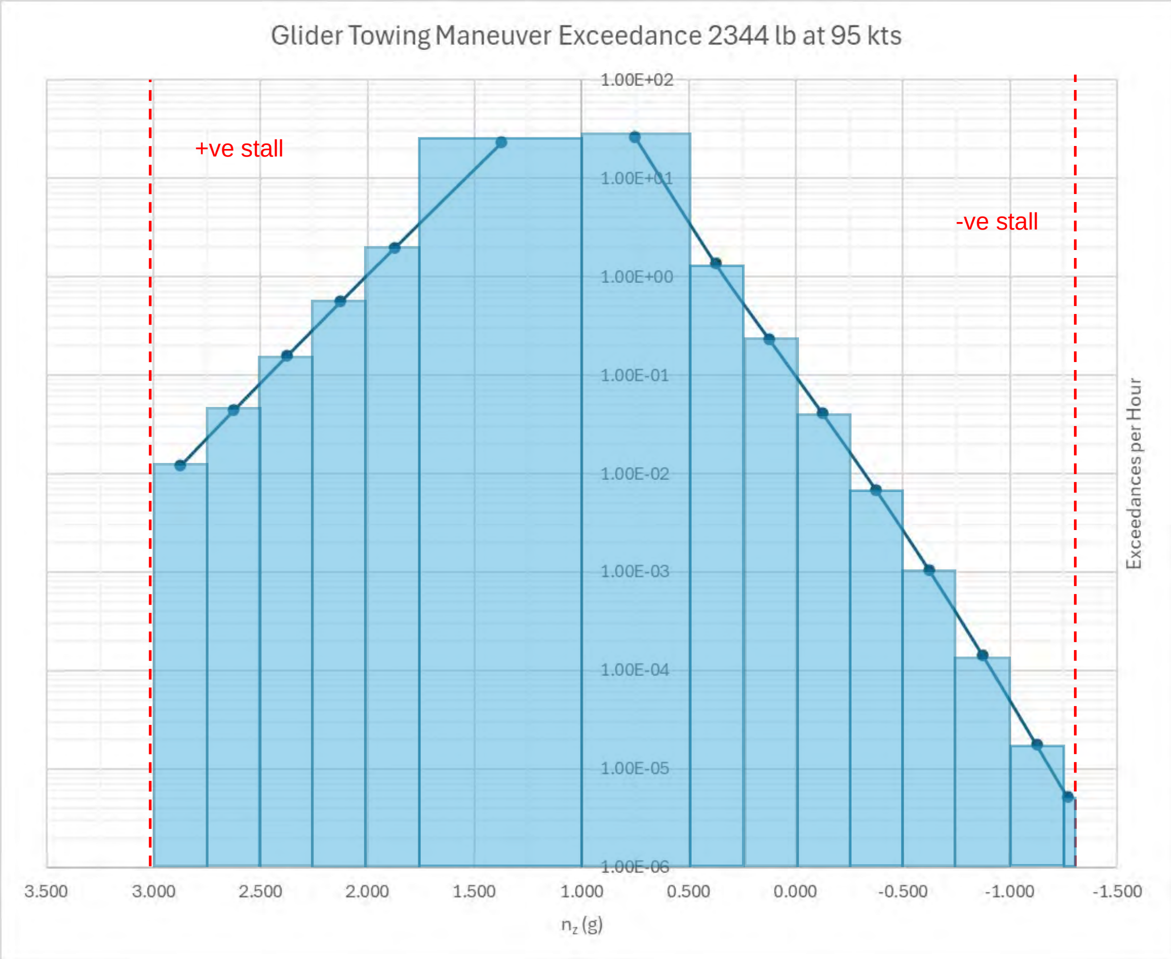

Figure 13-4 Maneuver Exceedances for Dual Seat Glider Towing at 2344 lb at 97 kts

Block Upper g limit	Block Mean g level	Gust Exceedance per hour	Maneuver Exceedance per hour	Total Exceedance per hour	Occurrence per hour
3.00	2.875	0.0030	0.0121	0.0151	0.0151
2.75	2.625	0.0116	0.0444	0.0560	0.0410
2.50	2.375	0.0473	0.1597	0.2071	0.1510
2.25	2.125	0.2083	0.5641	0.7725	0.5654
2.00	1.875	1.0239	1.9629	2.9868	2.2143
1.75	1.375	39.2446	23.0317	62.2763	59.2895
1.00					
1.00	0.75	110.1529	26.0267	136.1796	129.0103
0.50	0.375	5.8038	1.3655	7.1693	5.9120
0.25	0.125	1.0237	0.2337	1.2573	1.0080
0.00	-0.125	0.2083	0.0411	0.2493	0.1952
-0.25	-0.375	0.0473	0.0069	0.0541	0.0415
-0.50	-0.625	0.0116	0.0010	0.0126	0.0095
-0.75	-0.875	0.0030	1.4147E-04	0.0031	0.0023

-1.00	-1.125	0.0008	1.7649E-05	0.0008	0.0004
-1.25	-1.270	3.4692E-04	5.1719E-06	3.5209E-04	3.5209E-04
-1.29					

Table 13-4 Gust and Maneuver Exceedance for Dual Seat Glider Towing at 2344 lb at 97 kts

	Block Mean g level	Max Spar Stress (ksi)	Min Spar Stress (ksi)	Occurrence per 1000 hr
1	2.875	12.573	4.946	15
2	2.625	11.734	4.946	41
3	2.375	10.843	4.946	151
4	2.125	9.896	4.946	565
5	1.875	8.894	4.946	2,214
6	1.375	6.721	4.946	59,290
7	0.75	4.946	3.696	129,010
8	0.375	4.946	1.723	5,912
9	0.125	4.946	0.345	1,008
10	-0.125	4.946	-1.081	195
11	-0.375	4.946	-2.554	42
12	-0.625	4.946	-4.071	10
13	-0.875	4.946	-5.771	2
14	-1.125	4.946	-7.654	0
15	-1.270	4.946	-8.770	0
Total				**198,456**

Table 13-5 AFGROW Gust and Maneuver Spectrum for Dual Seat Glider Towing with Wing Tanks at 2344 lb at WS 25 per 1000 hrs

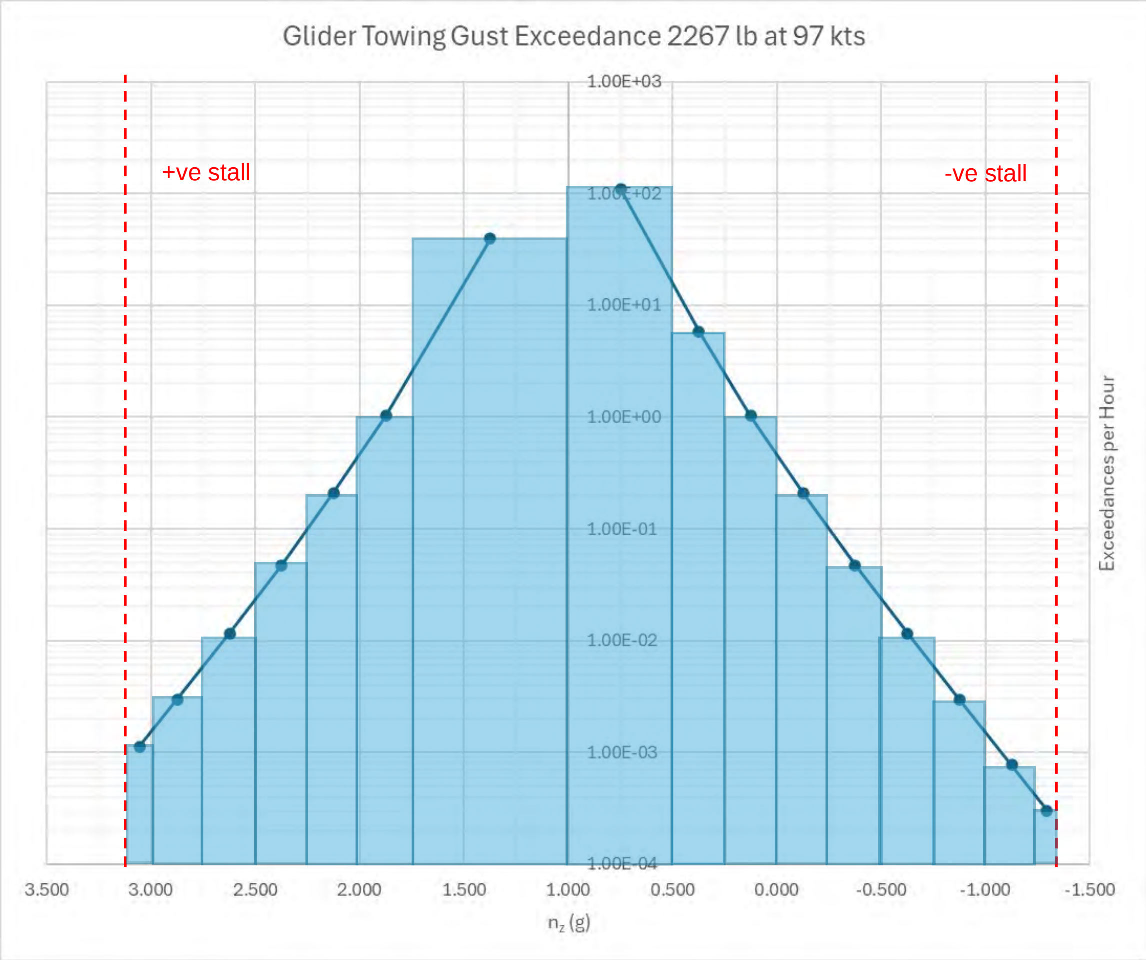

Figure 13-5 Gust Exceedances for Dual Seat Glider Towing with wing tanks at 2267 lb at 97 kts

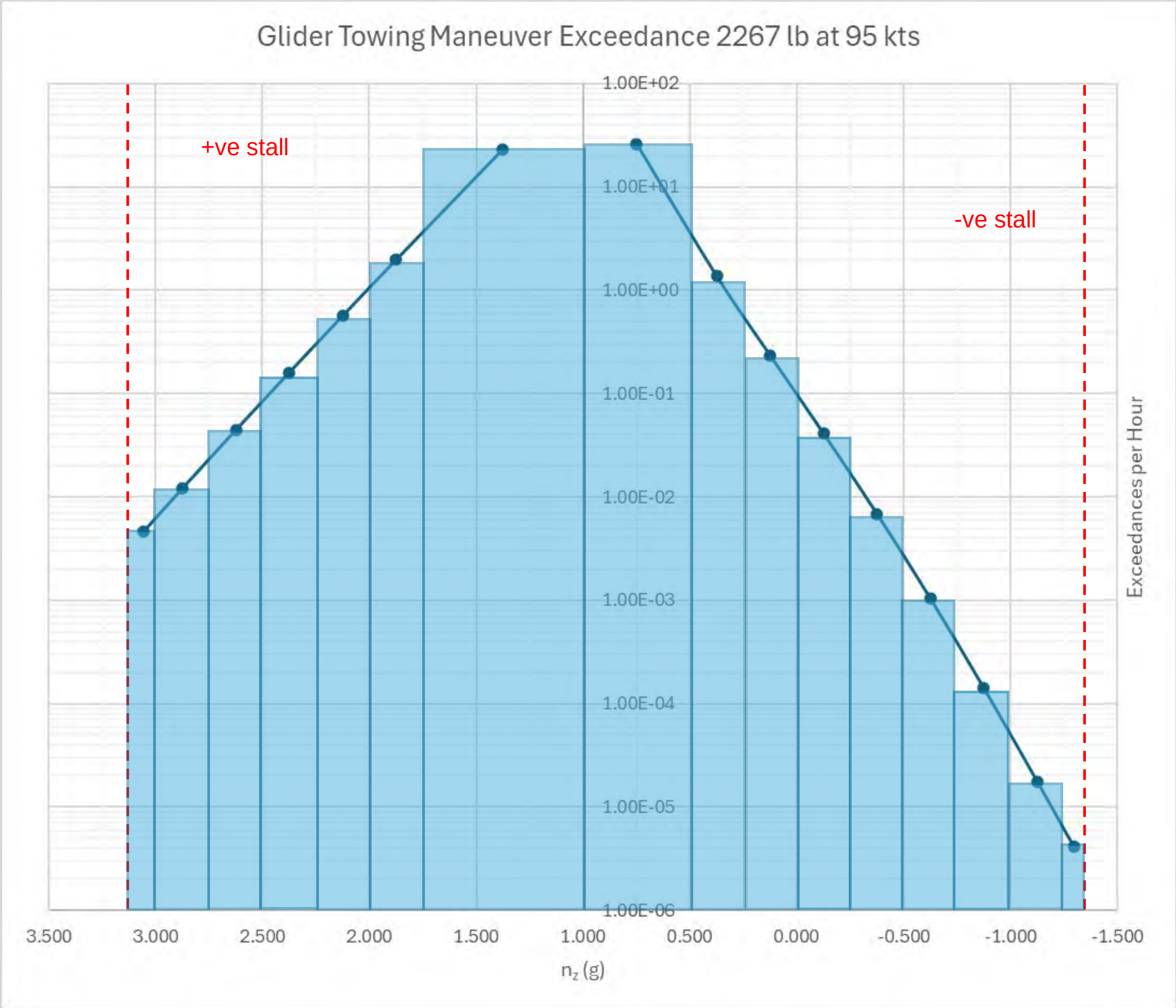

Figure 13-6 Maneuver Exceedances for Dual Seat Glider Towing at 2267 lb at 97 kts

Block Upper g limit	Block Mean g level	Gust Exceedance per hour	Maneuver Exceedance per hour	Total Exceedance per hour	Occurrence per hour
3.11	3.055	0.0011	0.0047	0.0058	0.0058
3.00	2.875	0.0030	0.0121	0.0151	0.0093
2.75	2.625	0.0116	0.0444	0.0560	0.0410
2.50	2.375	0.0473	0.1597	0.2071	0.1510
2.25	2.125	0.2083	0.5641	0.7725	0.5654
2.00	1.875	1.0239	1.9629	2.9868	2.2143
1.75	1.375	39.2446	23.0317	62.2763	59.2895
1.00					
1.00	0.75	110.1529	26.0267	136.1796	129.0103
0.50	0.375	5.8038	1.3655	7.1693	5.9120
0.25	0.125	1.0237	0.2337	1.2573	1.0080
0.00	-0.125	0.2083	0.0411	0.2493	0.1952
-0.25	-0.375	0.0473	0.0069	0.0541	0.0415

-0.50	-0.625	0.0116	0.0010	0.0126	0.0095
-0.75	-0.875	0.0030	1.4147E-04	0.0031	0.0023
-1.00	-1.125	0.0008	1.7649E-05	0.0008	0.0004
-1.25	-1.295	3.0219E-04	4.1849E-06	3.0638E-04	3.0638E-04
-1.34					

Table 13-6 Gust and Maneuver Exceedance for Dual Seat Glider Towing at 2267 lb at 97 kts

	Block Mean g level	Max Spar Stress (ksi)	Min Spar Stress (ksi)	Occurrence per 1000 hr
1	3.055	13.986	5.128	6
2	2.875	13.343	5.128	9
3	2.625	12.409	5.128	41
4	2.375	11.427	5.128	151
5	2.125	10.395	5.128	565
6	1.875	9.313	5.128	2,214
7	1.375	6.995	5.128	59,290
8	0.75	5.128	3.824	129,010
9	0.375	5.128	1.781	5,912
10	0.125	5.128	0.363	1,008
11	-0.125	5.128	-1.097	195
12	-0.375	5.128	-2.598	42
13	-0.625	5.128	-4.138	10
14	-0.875	5.128	-5.853	2
15	-1.125	5.128	-7.744	0
16	-1.295	5.128	-9.055	0
Total				**198,456**

Table 13-7 AFGROW Gust and Maneuver Spectrum for Dual Seat Glider Towing with Wing Tanks at 2267 lb per 1000 hrs

13.3 **LANDING:** From Table 9-1, the PA 25-180 Pawnee and PA 18-150 Super Cub averaged 7.8 flights per hour:

Sink Rate (ft/sec)	Delta Nz (g)	Exceedance per landing	Exceedance per hour	Occurrence per hour
0.5	0.380	0.7300	5.6940	3.1200
1.5	1.139	0.3300	2.5740	1.9188
2.5	1.899	0.0840	0.6552	0.5772
3.5	2.658	0.0100	0.0780	0.0624
4.5	3.418	0.0020	0.0156	0.0115
5.5	4.178	0.0005	0.0041	0.0028
6.5	4.937	0.0002	0.0013	0.0013

Table 13-8 Landing Exceedance for 2421 lb

	Block Mean g level	Max Spar Stress (ksi)	Min Spar Stress (ksi)	Occurrence per 1000 hr
1	1.380	4.388	3.997	3,120
2	2.139	4.388	3.217	1,919
3	2.899	4.388	2.436	577
4	3.658	4.388	1.655	62
5	4.418	4.388	0.817	11
6	5.178	4.388	-0.115	3
7	5.937	4.388	-1.043	1
Total				**5,694**

Table 13-9 AFGROW Landing Spectrum for Dual Seat Glider Towing with Wing Tanks at 2421 lb per 1000 hrs

Sink Rate (ft/sec)	Delta Nz (g)	Exceedance per landing	Exceedance per hour	Occurrence per hour
0.5	0.386	0.7300	5.6940	3.1200
1.5	1.158	0.3300	2.5740	1.9188
2.5	1.930	0.0840	0.6552	0.5772
3.5	2.702	0.0100	0.0780	0.0624
4.5	3.473	0.0020	0.0156	0.0115
5.5	4.245	0.0005	0.0041	0.0028
6.5	5.017	0.0002	0.0013	0.0013

Table 13-10 Landing Exceedance for 2344 lb

	Block Mean g level	Max Spar Stress (ksi)	Min Spar Stress (ksi)	Occurrence per 1000 hr
1	1.386	4.221	3.824	3,120
2	2.158	4.221	3.030	1,919
3	2.930	4.221	2.237	577
4	3.702	4.221	1.444	62
5	4.473	4.221	0.556	11
6	5.245	4.221	-0.390	3
7	6.017	4.221	-1.333	1
Total				**5,694**

Table 13-11 AFGROW Landing Spectrum for Dual Seat Glider Towing with Wing Tanks at 2344 lb per 1000 hrs

Sink Rate (ft/sec)	Delta Nz (g)	Exceedance per landing	Exceedance per hour	Occurrence per hour
0.5	0.392	0.7300	5.6940	3.1200
1.5	1.177	0.3300	2.5740	1.9188
2.5	1.962	0.0840	0.6552	0.5772
3.5	2.747	0.0100	0.0780	0.0624
4.5	3.532	0.0020	0.0156	0.0115
5.5	4.317	0.0005	0.0041	0.0028
6.5	5.102	0.0002	0.0013	0.0013

Table 13-12 Landing Exceedance for 2267 lb

	Block Mean g level	Max Spar Stress (ksi)	Min Spar Stress (ksi)	Occurrence per 1000 hr
1	1.392	4.053	3.649	3,120
2	2.177	4.053	2.843	1,919
3	2.962	4.053	2.036	577
4	3.747	4.053	1.229	62
5	4.532	4.053	0.291	11
6	5.317	4.053	-0.670	3
7	6.102	4.053	-1.629	1
Total				**5,694**

Table 13-13 AFGROW Landing Spectrum for Dual Seat Glider Towing with Wing Tanks at 2267 lb per 1000 hrs

13.4 Taxiing using an average of 7.8 landings per hour and the single engine taxi spectra: Taxi is same as single seat aerotow operations with wing tanks.

13.5 Ground air ground cycles were determined by fitting curves to the stress vs exceedance charts for the operating weight. These curves were then used to estimate the exceedance for a particular stress.

Stress	Gust	Maneuver	Landing	Taxi	Total
8.500	0.1221	0.2384			0.3605
8.000	0.2921	0.4522			0.7444
7.797	0.4179	0.5825			1.0004
7.500	0.7089	0.8386			1.5476
7.000	1.7541	1.5268			3.2809
-2.000	0.0098	0.0015	0.0000	205.8711	205.8825
-2.500	0.0060	0.0008	0.0000	135.9118	135.9186
-2.948	0.0039	0.0005	0.0000	0.9995	1.0039
-3.000	0.0037	0.0005		0.4804	0.4846
-3.500	0.0024	0.0002		0.0003	0.0029

Table 13-14 Ground-Air-Ground Spectrum for Dual Seat Glider Towing with Wing Tanks at 2421 lb at WS 25 per 1000 hrs

	Max Spar Stress (ksi)	Min Spar Stress (ksi)	Occurrence per 1000 hr
1	7.797	-2.948	7,800
Total			**7,800**

Table 13-15 AFGROW Spectrum for Dual Seat Glider Towing with Wing Tanks at 2421 lb per 1000 hrs

Stress	Gust	Maneuver	Landing	Taxi	Total
9.000	0.1105	0.2213			0.3318
8.500	0.2472	0.4012			0.6484
8.179	0.4176	0.5826			1.0002
8.000	0.5611	0.7153			1.2764
7.500	1.2981	1.2565			2.5546
-2.000	0.0101	0.0017	0.0001	110.2713	110.2832
-2.250	0.0079	0.0012	0.0000	4.0048	4.0141
-2.333	0.0073	0.0011	0.0000	0.9858	0.9943
-2.500	0.0062	0.0009		0.0451	0.0523
-2.750	0.0049	0.0007		0.0004	0.0060

Table 13-16 Ground-Air-Ground Spectrum for Dual Seat Glider Towing with Wing Tanks at 2344 lb per 1000 hrs

	Max Spar Stress (ksi)	Min Spar Stress (ksi)	Occurrence per 1000 hr
1	8.179	-2.333	7,800
Total			**7,800**

Table 13-17 AFGROW Spectrum for Dual Seat Glider Towing with Wing Tanks at 2344 lb per 1000 hrs

Stress	Gust	Maneuver	Landing	Taxi	Total
9.500	0.0990	0.2037			0.3027
9.000	0.2089	0.3555			0.5644
8.546	0.4169	0.5828			0.9997
8.500	0.4475	0.6124			1.0599
8.000	0.9770	1.0429			2.0199
-1.250	0.0223	0.0041	0.0003	355.8825	355.9092
-1.500	0.0173	0.0030	0.0002	87.1626	87.1832
-1.730	0.0137	0.0023	0.0002	0.9790	0.9952
-1.750	0.0135	0.0022	0.0002	0.6068	0.6227
-2.000	0.0105	0.0017	0.0001	0.0010	0.0133

Table 13-18 Ground-Air-Ground Spectrum for Dual Seat Glider Towing with Wing Tanks at 2267 lb at WS 25 per 1000 hrs

	Max Spar Stress (ksi)	Min Spar Stress (ksi)	Occurrence per 1000 hr
1	8.546	-1.730	7,800
Total			**7,800**

Table 13-19 AFGROW Spectrum for Dual Seat Glider Towing with Wing Tanks at 2267 lb per 1000 hrs

14. FATIGUE MODEL

14.1 Both the front and rear spars consist of a single 6061-T6 extrusion. Both the upper and lower caps have flanges turned inwards with the free ends of the flanges having bulbs. The spar cross sections were measured on the wing of a damaged Pawnee.

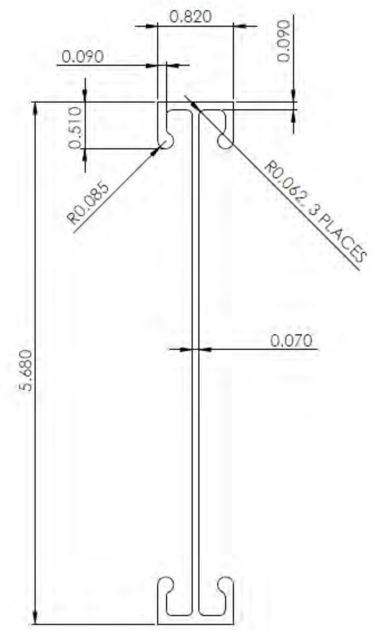

Figure 14-1 Front Spar Cross Section

14.2 The spar cap and flanges were modelled in Reference 1.12 as a flat plate of 0.090 in thickness. The width of the plate was determined by flattening the flange bulbs into an equivalent area of plate with 0.090 in thickness. The width of the bulb equivalent plate is:

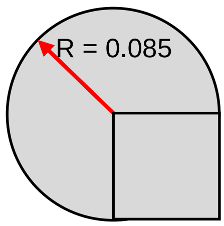

Figure 14-2 Area of Flange Bulb

Bulb Area = $0.75 \times \pi \times 0.085^2 + 0.085^2 = 0.02425 \text{ in}^2$

Equivalent Width = 0.02425 / 0.090 = 0.2694 in

This equivalent flat plate ignores any effect of the spar web on crack growth. In reality, any crack growing across the cap would be retarded by the spar web until the crack started growing up the spar web as well. This would increase the fatigue life in light load cases.

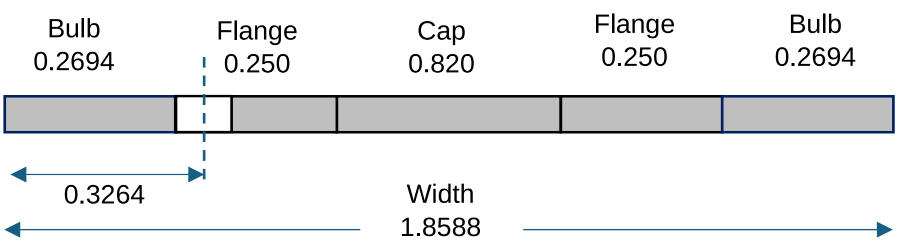

Figure 14-3 Spar Cap Equivalent Flat Plate

14.3 The nominal screw hole diameter as drilled is 0.098 in. However, the screws are thread forming with a shank diameter of 0.106 in and a thread diameter of 0.114 in. A hole representing the maximum diameter of the screw thread was added to the centre of one flange to represent a nominal design of the spar. The hole is positioned at the inner edge of the bulb as this represents the highest stress concentration around the hole.

> **Assumption: The thread does not impact the stress concentration of the hole.** No published information is readily available on the increase in stress concentration for a thread forming screw. Using an oversize hole based on the thread diameter compensates by increasing the stress concentration factor of having a larger hole near the edge.
>
> **Assumption: The screws do not have any cold working benefit.** The screws plasticly deform the spar cap around the circumference of the hole. The material beyond the plasticly deformed circumference is in elastic tension which applies a residual compressive stress on the plasticly deformed circumference. This compressive stress will suppress crack initiation and early crack growth. However, once the crack has grown through the plasticly deformed circumference and enters the material in elastic tension, the crack growth will accelerate. No published information is readily available on the cold working benefit for a thread forming screw

14.4 The equivalent plate is loaded in pure cyclic tension in AFGROW. At high g loads, approximately 46% of the caps stress is from axial tension. The inner most tip of the bulb is 82% of the distance from the neutral axis of the outer edge of the cap. The innermost tip of the bulb is at ~91% of the stress of the outer edge of the cap. Therefore, the bulb and flange can be readily modelled as if the entire equivalent flat plat is under pure tension as the stress field along the flange is relatively uniform.

14.5 The maximum edge stress has been used rather than the mean stress at the centreline of the hole. A through crack is assumed rather than a corner crack.

> **Assumption: The maximum edge stress has been used.** This is very conservative. The stress at the hole centreline for a hole closest to the bulb is typically ~ 5% less that the peak stress in the cap. This stress reduction decreases to ~2.5% for a hole closest to the cap. Use of maximum edge stress will decrease the inspection threshold and the inspection interval by a small amount.

> **Assumption: The crack starts as a through crack.** It is most likely that the crack would originate from a corner at the edge of the hole. However, with the unknown impact of the thread on the stress concentration, it is more conservative to use a through crack. A corner crack takes more cycles to grow until it becomes a through crack. Assuming a through crack will reduce the inspection threshold by having faster crack growth from initiation to a 0.050" crack.

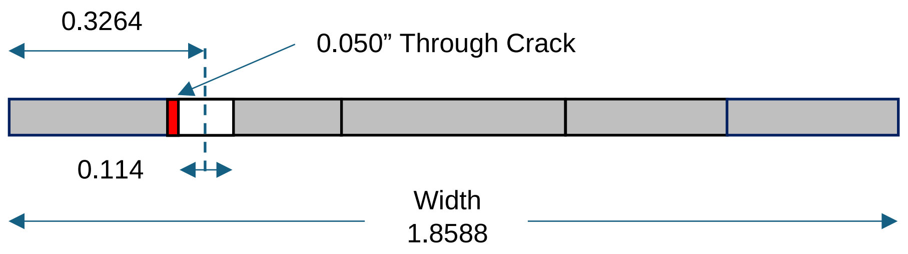

Figure 14-4 Fatigue Model for Initial Crack at Screw Hole at Inner Edge of Bulb

14.6 An initial 0.050” crack was added to side of the hole closest to the edge as shown above in Figure 14-4. This crack is allowed to grow to the outer edge of the bulb. A second crack is then assumed to start immediately on the spar web side of the hole and allowed to grow.

Assumption: The first crack to grow is on the bulb side where the stress concentration is at it’s highest.

Assumption: The second crack is assumed to start immediately on the spar web side of the hole once the first crack has reached the edge of the bulb. The initiation phase and growth to 0.050” for the second crack is assumed to occur during the growth of the first crack.

The first crack is modelled as a slot in AFGROW as shown below:

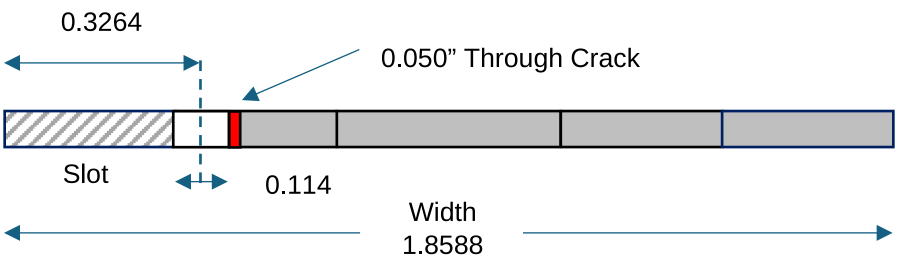

Figure 14-5 Fatigue Model for Second Crack at Screw Hole at Inner Edge of Bulb

Assumption: The second crack starts as a through crack. It is most likely that the crack would originate from a corner at the edge of the hole. However, with the unknown impact of the thread on the stress concentration, it is more conservative to use a through crack. A corner crack takes more cycles to grow until it becomes a through crack. Assuming a through crack will reduce the inspection interval slightly by having the second crack grow faster.

14.7 In AFGROW the screw hole is modelled as a “filled” unloaded hole. There are no open holes in the spar flanges in the original design. The screws support the leading edge skins and apply a load at 90 degrees to the axial and bending stresses in the spar. The loads from the leading edge skin have been assessed as negligible compared to the axial and bending stresses in the spar.

Assumption: All holes are “filled” unloaded holes. The screw holes are used to attach either the ribs or the leading edge skins. Poor workmanship during replacement of the leading edge skins has resulted in additional holes in the flange. These additional holes may have close proximity to the bulb outer edge or other holes. Some additional holes may contain the stub of a broken fastener, some may be empty / unfilled. Reference 1.1 does not allow any additional holes. This report only considers the holes allowed by Reference 1.1.

CASA may approve aircraft to continue operating with additional holes in the spar via AMOC providing it can be demonstrated that the additional holes do not compromise the strength or the fatigue life of the spar.

15. CRITICAL CRACK LENGTH

15.1 The critical crack length is defined as the crack length that would allow failure by exceeding K_{IC} within the flight envelope. The maximum stress for each case was run in Reference 1.12 to determine the crack length at failure. The results are at Table 15-1 below

Weight	Design Critical Condition	Location	Max Stress (ksi)	Crack towards bulb edge	Crack towards web	Total Crack Length (Including Hole Diameter)
3660 lb (two seat)	3.8g at 150 kts	WS 25	32.636	0.2406	-	0.3546
3205 lb	3.8g at 150 kts	WS 25	28.808	0.2694 (Failed)	0.1030	0.4864
3205 lb with wing tanks	3.8g at 127 kts	WS 80	24.928	0.2694 (Failed)	0.2485	0.6319
2900 lb	3.8g at 121 kts	WS 25	26.130	0.2694 (Failed)	0.1899	0.5733
2900 lb with wing tanks	3.8g at 121 kts	WS 80	22.516	0.2694 (Failed)	0.3714	0.7548
2460 lb	3.8g at 150 kts	WS 25	22.106	0.2694 (Failed)	0.4032	0.7866
2460 lb with wing tanks	26.2 ft/sec gust at 116 kts	WS 80	20.623	0.2694 (Failed)	0.5009	0.8843
2205 lb	27.1 ft/sec gust at 114 kts	WS 25	20.757	0.2694 (Failed)	0.4918	0.8752
2205 lb with wing tanks	27.1 ft/sec gust at 114 kts	WS 80	19.846	0.2694 (Failed)	0.5521	0.9355

Table 15-1 Critical Crack Lengths

Note: The very high stresses when operating the two seat modified Pawnees at full fuel and full hopper allow failure of the spar cap once the crack has severed the ligament between the screw hole and the bulb edge..

15.2 The relationship between maximum stress and critical crack length is shown below in Figure 15-1. At lower maximum stresses the critical crack length gets very close to the distance from the inner edge of the hole to the spar web (0.546 in). Because of the proximity the β factor is likely to be very different from the flat plate assumption.

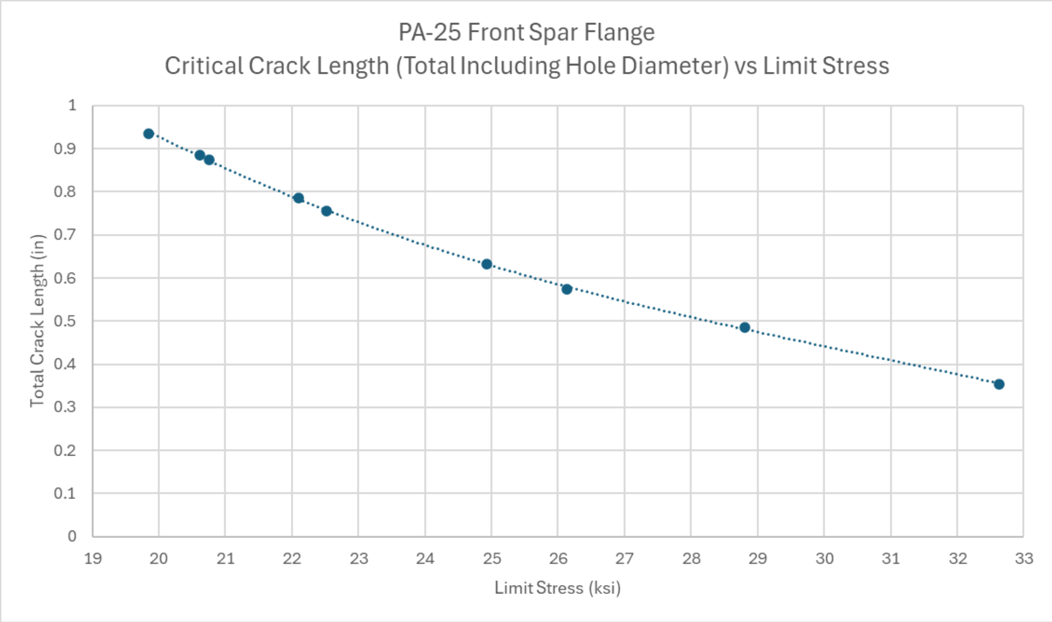

Figure 15-1 Critical Crack Length Versus Limit Stress

16. MATERIAL FATIGUE INITIATION

16.1 Each spectrum was run in Reference 1.12 with the crack initiation model on and the crack growth limited to 0.050". Whilst Reference 1.12 has material data for 6061-T6 to enable crack growth rate modelling, it does not have data for initiation. The initiation data for 6061-T6 Extrusion from Reference 1.15 was manually entered as shown in Table 16-1 below.

Coefficient	**Value**
Cyclic Strength Coefficient K'	53.95
Cyclic Strain Hardening exponent n'	0.024
Fatigue Strength Coefficient SIGF'	86.01
Fatigue Strength Exponent b	-0.093
Fatigue Ductility Coefficient EPSF	5.39
Fatigue Ductility Exponent c	-1.10

Table 16-1 Initiation Data for 6061-T6 Aluminium Extrusion

16.2 The fatigue initiation is heavily influenced by the stress concentration factor K_t. The stress concentration factor for a hole near the edge of a finite plate is given in Chart 4.3 of Reference 1.17. Given the following:

H = 1.8588"

e = 1.5328"

a = 0.057"

C_1 = 2.9956

C_2 = 0.2080

C_3 = 0.7381

C_4 = 5.1825

K_t = 3.082

16.3 A hole filled with a fastener will have a better fatigue performance than an open hole. Figure 7.7.29 of Reference1.19 gives hole filling factors for various fastener types. Threaded bolts have a range from 0.75 to 0.90. Whilst the screws in the spar flanges are initially an interference fit, a value of 0.90 is used as it the screws may loosen over time, particularly if they have been removed and refitted, and it is more conservative. The K_t for fatigue is therefore:

K_t = 3.082 x 0.90 = 2.774

16.4 The fatigue initiation is also heavily influenced by the Fatigue Notch Constant, a. The Fatigue Notch Constant defines the fatigue stress concentration for initiation using the following equation:

$$K_f = 1.0 + \frac{K_t - 1}{1 - \frac{a}{r}}$$

16.5 Reference 1.17 gives a nominal value of a = 0.02 for aluminium alloy but gives an approximate relationship for steels between F_{TU} and a. The a = 0.02 is assumed to be for annealed aluminium alloys. Reference 1.18 gives experimental a values for 2024-T3 and 7075-T6. These are shown in Table 16-2 and Figure 16-1 below:

Material	F_{TU} (ksi)	A (in)	Comment
2024-O	27	0.02	Assumed
2024-T3	68	0.008	Reference 1.18
7075-T6	84	0.003	Reference 1.18

Table 16-2 Fatigue Notch Constants

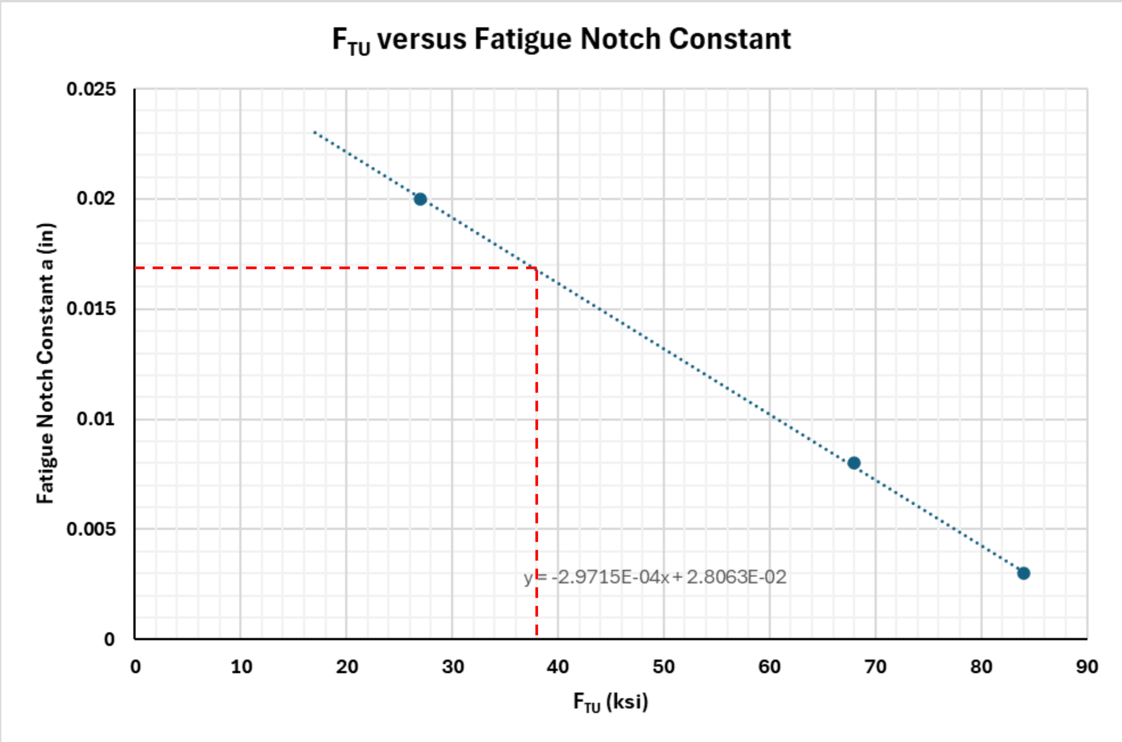

Figure 16-1 Fatigue Notch Constant for 6061-T6 and 6061-0

16.6 Figure 16-1 shows a linear relationship between F_{TU} and Fatigue Notch Constant. 6061-T6 Extrusion has an F_{TU} of 38 ksi which has an estimated Fatigue Notch Constant, a =0.017. This is conservative as a lower fatigue notch constant results in less cycles to initiate a crack. The default value for fatigue notch constant in AFGROW is 0.02 for aluminium alloys.

17. CRACK GROWTH

17.1 The fatigue life has three phases: Initiation of the first crack to 0.050" length, growth of the first crack from 0.050" till it severs the bulb, and growth of the second crack until it reaches the critical crack length. The initiation phase is used to determine the period when inspections should start. The growth of the first and second crack is added together and used to determine the inspection interval.

17.2 The exception is for the two seat conversions operating overweight. The initiation of the first crack to 0.050" length to determine the period when inspections should start. This is followed by the growth of the first crack to critical length to determine the inspection interval.

17.3 OVERWEIGHT AGRICULTURAL WITHOUT WING TANKS: Agricultural Pawnees are assumed to spend 50% of their flying time with full hopper at 1200 lb and 50% of their time flying with the hopper empty. The hours to initiate is given by:

$$Initiation\ Hours_{Agricultural} = 1000 \times \left(\frac{0.50 \times \text{Cycles}_{Spectrum}}{Initiation\ _{Weight}} + \frac{0.50 \times \text{Cycles}_{Spectrum}}{\text{Initiation}_{2005}} + \frac{\text{Cycles}_{Spectrum}}{\text{Initiation}_{Landing}} + \frac{\text{Cycles}_{Spectrum}}{\text{Initiation}_{Taxi}} + \frac{\text{Cycles}_{Spectrum}}{Initiation_{GAG}}\right)^{-1}$$

The crack growth hours is similar and given by:

$$Crack\ Growth_{Agricultural} = 1000 \times \left(\frac{0.50 \times \text{Cycles}_{Spectrum}}{Crack\ Growth\ _{Weight}} + \frac{0.50 \times \text{Cycles}_{Spectrum}}{Crack\ Growth_{2005}} + \frac{\text{Cycles}_{Spectrum}}{Crack\ Growth_{Landing}} + \frac{\text{Cycles}_{Spectrum}}{Crack\ Growth_{Taxi}} + \frac{\text{Cycles}_{Spectrum}}{Crack\ Growth_{GAG}}\right)^{-1}$$

The overall hours assumes that the aircraft spend a percentage of their time operating in each fuel block as per Section 5. The aircraft in Australia perform a large number of flights per hour. The payload is assumed to be the same for each fuel block. The overall hours is given by:

$$Hours_{Agricultural} = \left(\frac{0.50}{Hours\ _{32.1\ gal}} + \frac{0.45}{Hours\ _{19.25\ gal}} + \frac{0.05}{Hours\ _{6.4\ gal}}\right)^{-1}$$

Case	Cycles per 1000 hrs	Cycles to Initiate 32.1 gal fuel	Cycles to Initiate 19.25 gal fuel	Cycles to Initiate 6.4 gal fuel	
3205 lb Agricultural	332,707	2.07608E+08	1.57334E+08	1.91421E+08	
2005 lb Agricultural	375,480	>2.0E+09	>2.0E+09	>2.0E+09	
Landing	6,569	>2.0e+09	>2.0e+09	>2.0e+09	
Taxi	33,686	>2.0e+09	>2.0e+09	>2.0e+09	
3205 lb Agricultural GAG	9,000	135,414	166,976	207,138	
Hours		14,866.8	18,195.9	22,564.0	16,507.4

Table 17-1 Hours to Initiate 0.050" Crack for Agricultural Pawnees without Wing Tanks at 3205 lb

Case	Cycles per 1000 hrs	Cycles for First Crack 32.1 gal fuel	Cycles for First Crack 19.25 gal fuel	Cycles for First Crack 6.4 gal fuel	
3205 lb Agricultural	332,707	1.17326E+06	1.25735E+06	1.35796E+06	
2005 lb Agricultural	375,480	5.15797E+06	6.2537E+06	7.69708E+06	
Landing	6,569	No Growth	No Growth	No Growth	
Taxi	33,686	No growth	No growth	No growth	
3205 lb Agricultural GAG	9,000	32,301	34,731	37,394	
Hours		2,189	2,372	2,580	**2,286**

Table 17-2 Hours to Grow First Crack for Agricultural Pawnees without Wing Tanks at 3205 lb

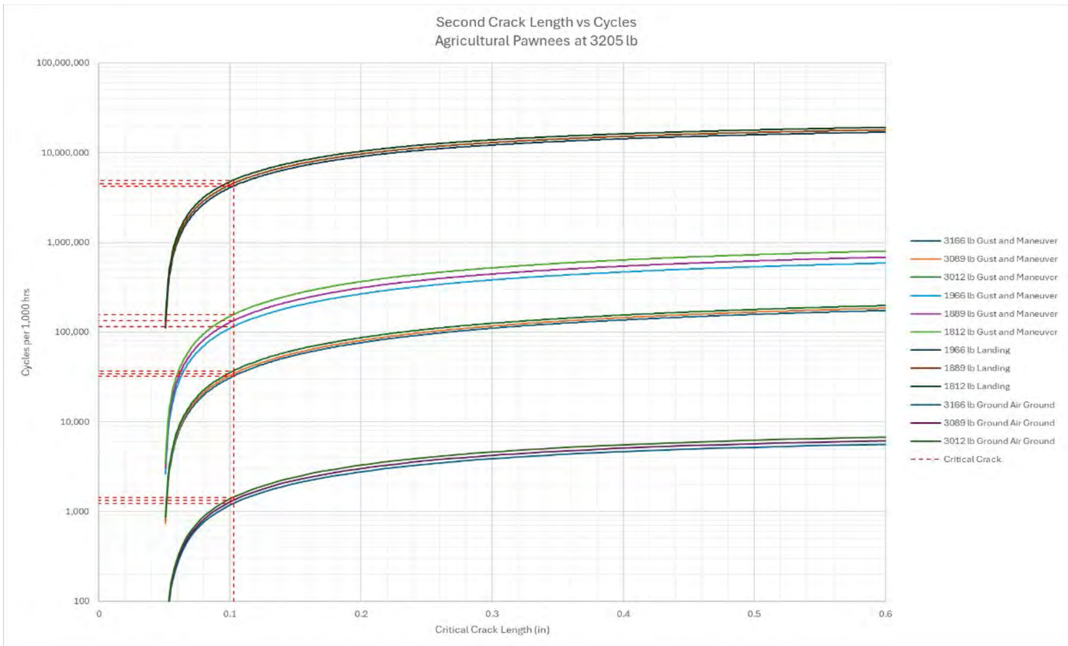

Figure 17-1 Second Crack Growth to C_{Crit} of 0.1030" for Agricultural Pawnees without Wing Tanks at 3205 lb

Case	Cycles per 1000 hrs	Cycles for 2nd Crack 32.1 gal fuel	Cycles for 2nd Crack 19.25 gal fuel	Cycles for 2nd Crack 6.4 gal fuel	
3205 lb Agricultural	332,707	32,362	34,278	36,956	
2005 lb Agricultural	375,480	114,792	133,671	156,745	
Landing	6,569	4.23068E+06	4.53867E+06	4.91085E+06	
Taxi	33,686	No growth	No growth	No growth	
3205 lb Agricultural GAG	9,000	1,231	1,333	1,442	
Hours		71	76	83	**74**

Table 17-3 Hours to Grow Second Crack for Agricultural Pawnees without Wing Tanks at 3205 lb

17.4 OVERWEIGHT AGRICULTURAL WITH WING TANKS: The wing tanks significantly alter the wing stress depending on the amount of fuel on board. The payload is assumed to be the same for each fuel block.

Case	**Cycles per 1000 hrs**	**Cycles to Initiate 32.1 gal fuel**	**Cycles to Initiate 19.25 gal fuel**	**Cycles to Initiate 6.4 gal fuel**	
Wing tanks – 1200 lb Payload	332,707	1.15756E+08	1.94249E+08	2.18763E+08	
Wing tanks – empty payload	375,480	>2.0e+09	>2.0e+09	>2.0e+09	
Wing Tanks – Landing	6,569	>2.0e+09	>2.0e+09	>2.0e+09	
Wing Tanks - Taxi	33,686	>2.0e+09	>2.0e+09	>2.0e+09	
Wing tanks GAG	9,000	216,454	367,518	622,733	
Hours		23,247.0	39,455.5	65,733.9	**29,696.4**

Table 17-4 Hours to Initiate Cracking for Agricultural Pawnees with Wing Tanks at 3205 lb

Case	**Cycles per 1000 hrs**	**Cycles for First Crack 32.1 gal fuel**	**Cycles for First Crack 19.25 gal fuel**	**Cycles for First Crack 6.4 gal fuel**	
Wing tanks – 1200 lb Payload	332,707	1.06737E+06	1.25765E+06	1.50073E+06	
Wing tanks – empty payload	375,480	1.16682E+07	1.91514E+07	3.4229E+07	
Wing Tanks – Landing	6,569	No growth	No growth	No growth	
Wing Tanks - Taxi	33,686	No growth	No growth	No growth	
Wing tanks GAG	9,000	39,453	46,513	54,961	
Hours		2,499	2,980	3,570	**2,739**

Table 17-5 Hours to Grow First Crack for Agricultural Pawnees with Wing Tanks at 3205 lb

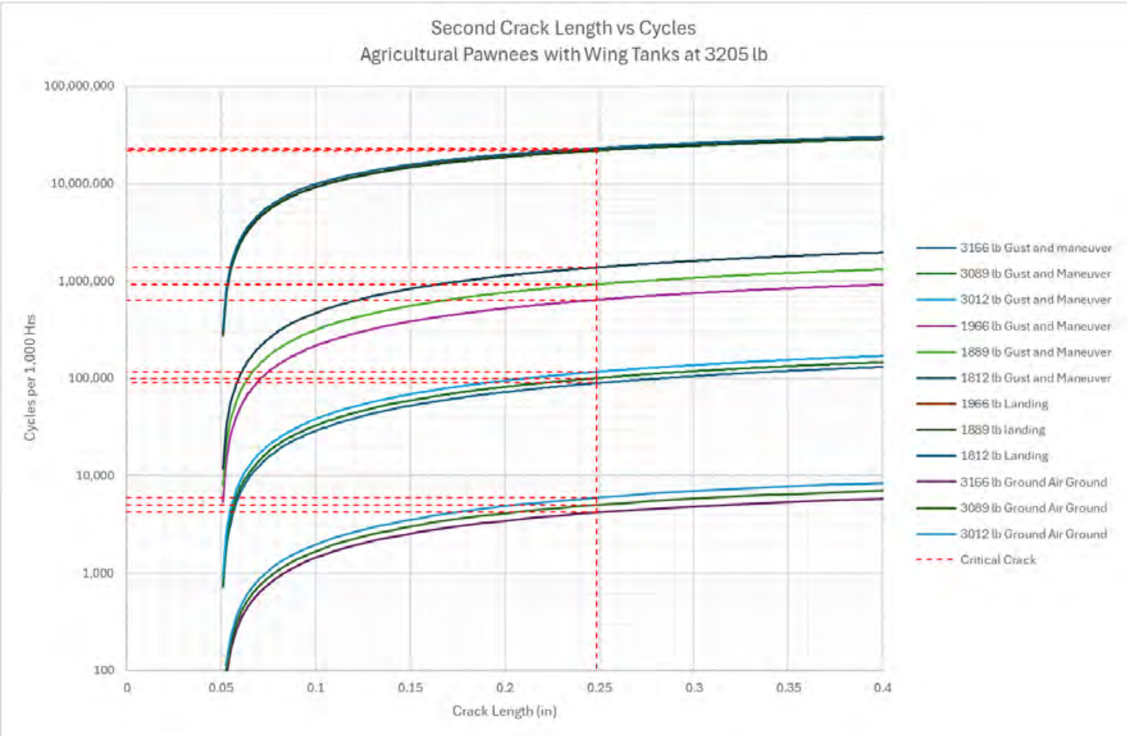

Figure 17-2 Second Crack Growth to C_{Crit} of 0.2485" for Agricultural Pawnees at 3205 lb with Wing Tanks

Case	Cycles per 1000 hrs	Cycles for Second Crack 32.1 gal fuel	Cycles for Second Crack 19.25 gal fuel	Cycles for Second Crack 6.4 gal fuel	
Wing tanks – 1200 lb Payload	332,707	88,972	100,313	116,098	
Wing tanks – empty payload	375,480	637,805	920,561	1,372,153	
Wing Tanks – Landing	6,569	2.20117E+07	2.17363E+07	2.30511E+07	
Wing Tanks - Taxi	33,686	No growth	No growth	No growth	
Wing tanks GAG	9,000	4,170	5,005	5,939	
Hours		231	273	324	**252**

Table 17-6 Hours to Grow Second Crack for Agricultural Pawnees with Wing Tanks at 3205 lb

17.5 MTOW AGRICULTURAL WITHOUT WING TANKS: The 2005 lb gust and maneuver, landing, and taxi second crack growth curves are identical to those at Figure 17-1 for aircraft without wing tanks and Figure 17-2 for aircraft with wing tanks with the exception that the critical crack length is increased.

Case	Cycles per 1000 hrs	Cycles to Initiate 32.1 gal fuel	Cycles to Initiate 19.25 gal fuel	Cycles to Initiate 6.4 gal fuel	
2900 lb Agricultural	332,707	2.47617E+08	2.09121E+08	2.48764E+08	
2005 lb Agricultural	375,480	>2.0E+09	>2.0E+09	>2.0E+09	
Landing	6,569	>2.0e+09	>2.0e+09	>2.0e+09	
Taxi	33,686	>2.0e+09	>2.0e+09	>2.0e+09	
2900 lb Agricultural GAG	9,000	329,500	427,161	558,030	
Hours		34,894.6	44,130.0	57,255.4	**39,371.2**

Table 17-7 Hours to Initiate Cracking for Agricultural Pawnees without Wing Tanks at 2900 lb

Case	Cycles per 1000 hrs	Cycles for First Crack 32.1 gal fuel	Cycles for First Crack 19.25 gal fuel	Cycles for First Crack 6.4 gal fuel	
2900 lb Agricultural	332,707	1.46421E+06	1.57851E+06	1.70708E+07	
2005 lb Agricultural	375,480	5.15797E+06	6.2537E+06	7.69708E+06	
Landing	6,569	No Growth	No Growth	No Growth	
Taxi	33,686	No growth	No growth	No growth	
2900 lb Agricultural GAG	9,000	43,618	47,462	51,869	
Hours		2,806	3,076	4,815	**2,986**

Table 17-8 Hours to Grow First Crack for Agricultural Pawnees without Wing Tanks at 2900 lb

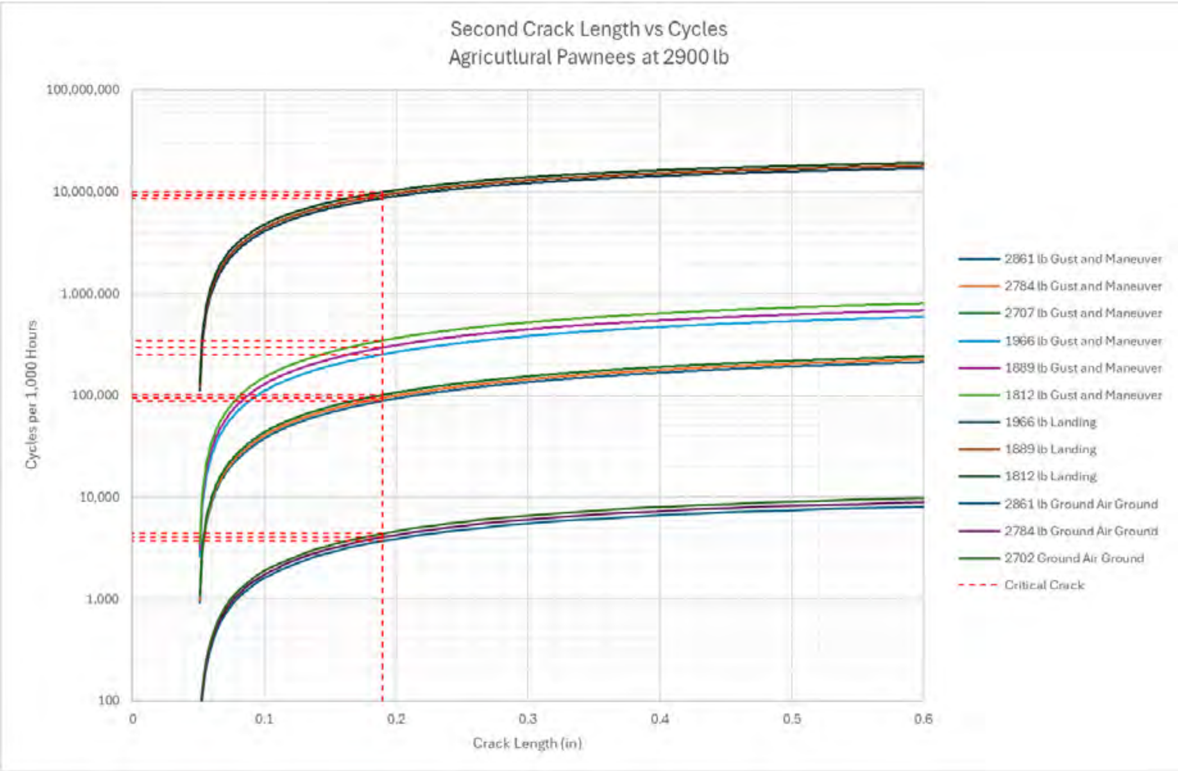

Figure 17-3 Second Crack Growth to C_{Crit} of 0.1899" for Agricultural Pawnees at 2900 lb

Case	Cycles per 1000 hrs	Cycles for Second Crack 32.1 gal fuel	Cycles for Second Crack 19.25 gal fuel	Cycles for Second Crack 6.4 gal fuel	
2900 lb Agricultural	332,707	88,577	94,552	101,239	
2005 lb Agricultural	375,480	253,688	295,755	347,124	
Landing	6,569	8.67150E+06	9.25565E+06	9.94315E+06	
Taxi	33,686	No growth	No growth	No growth	
2900 lb Agricultural GAG	9,000	3,708	4,042	4,403	
Hours		198	216	236	**207**

Table 17-9 Hours to Grow Second Crack for Agricultural Pawnees without Wing Tanks at 2900 lb

17.6 MTOW AGRICULTURAL WITH WING TANKS: The 2005 lb gust and maneuver, landing, and taxi second crack growth curves are identical to those at Figure 17-2 for aircraft with wing tanks with the exception that the critical crack length is increased.

Case	Cycles per 1000 hrs	Cycles to Initiate 32.1 gal fuel	Cycles to Initiate 19.25 gal fuel	Cycles to Initiate 6.4 gal fuel	
Wing tanks – 895 lb Payload	332,707	1.60802E+08	2.09020E+08	3.91990E+08	
Wing tanks – empty payload	375,480	>2.0e+09	>2.0e+09	>2.0e+09	
Wing Tanks – Landing	6,569	>2.0e+09	>2.0e+09	>2.0e+09	
Wing Tanks - Taxi	33,686	>2.0e+09	>2.0e+09	>2.0e+09	
Wing tanks GAG	9,000	770,164	1.19543E+06	2.27750E+06	
Hours		72,701	109,644	208,313	**89,113**

Table 17-10 Hours to Initiate Cracking for Agricultural Pawnees with Wing Tanks at 2900 lb

Case	Cycles per 1000 hrs	Cycles for First Crack 32.1 gal fuel	Cycles for First Crack 19.25 gal fuel	Cycles for First Crack 6.4 gal fuel	
Wing tanks – 895 lb Payload	332,707	1.37391E+06	1.70297E+06	2.11021E+06	
Wing tanks – empty payload	375,480	1.16682E+07	1.91514E+07	3.4229E+07	
Wing Tanks – Landing	6,569	No growth	No growth	No growth	
Wing Tanks - Taxi	33,686	No growth	No growth	No growth	
Wing tanks GAG	9,000	58,790	71,523	86,580	
Hours		3,445	4,285	5,311	**3,853**

Table 17-11 Hours to Grow First Crack for Agricultural Pawnees with Wing Tanks at 2900 lb

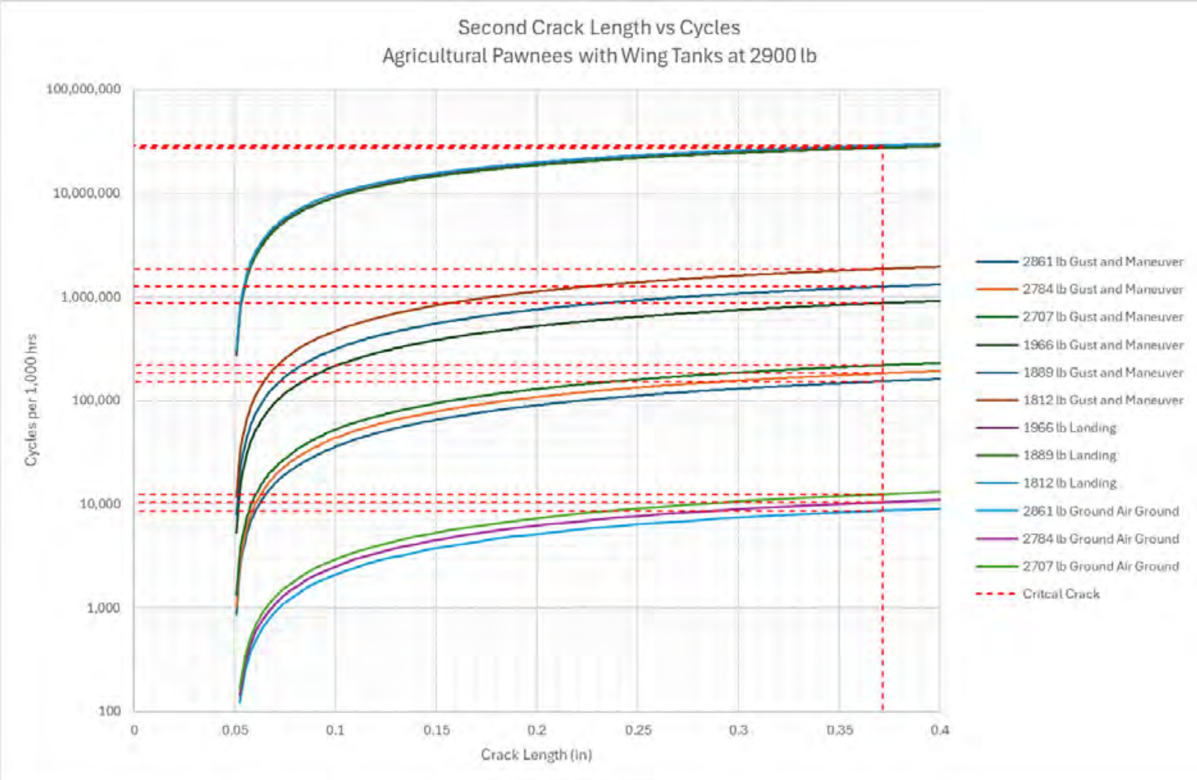

Figure 17-4 Second Crack Growth to C_{Crit} of 0.3714" for Agricultural Pawnees at 2900 lb with Wing Tanks

Case	Cycles per 1000 hrs	Cycles for Second Crack 32.1 gal fuel	Cycles for Second Crack 19.25 gal fuel	Cycles for Second Crack 6.4 gal fuel	Cycles for Second Crack
Wing tanks – 895 lb Payload	332,707	152,851	182,898	218,688	
Wing tanks – empty payload	375,480	871,542	1.25208E+06	1.86399E+06	
Wing Tanks – Landing	6,569	2.78735E+07	2.73719E+07	2.88991E+07	
Wing Tanks - Taxi	33,686	No growth	No growth	No growth	
Wing tanks GAG	9,000	8,617	10,474	12,481	
Hours		425	521	631	**472**

Table 17-12 Hours to Grow Second Crack for Agricultural Pawnees with Wing Tanks at 2900 lb

17.7 OVERWEIGHT TWO SEAT AGRICULTURAL WITHOUT WING TANKS:

Case	Cycles per 1000 hrs	Cycles to Initiate 32.1 gal fuel	Cycles to Initiate 19.25 gal fuel	Cycles to Initiate 6.4 gal fuel	
3660 lb Agricultural	380,425	1.91016E+08	2.28374E+08	2.72236E+08	
2460 lb Agricultural	341,409	2.33709E+08	2.88369E+08	4.35168E+08	
2460 lb Landing	6,570	>2.0e+09	>2.0e+09	>2.0e+09	
Taxi	33,686	>2.0e+09	>2.0e+09	>2.0e+09	
3660 lb Agricultural GAG	9,000	48,056	56,013	64,975	
Hours		5,243	6,115	7,107	**5,682**

Table 17-13 Hours to Initiate Cracking for Agricultural Two Seat Pawnees without Wing Tanks at 3660 lb

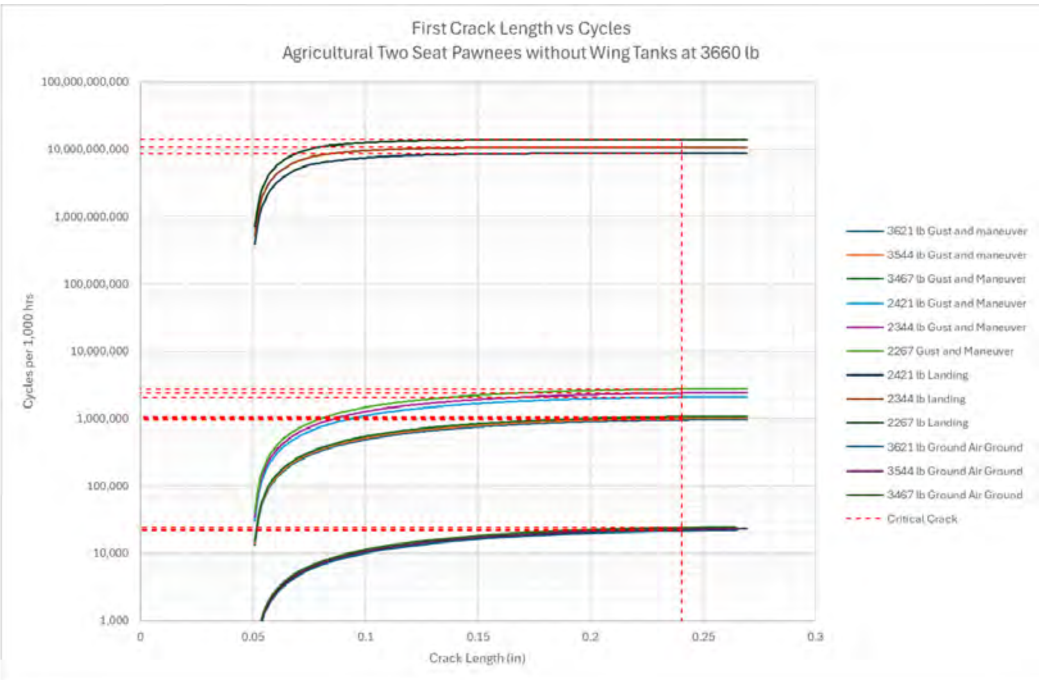

Figure 17-5 First Crack Growth to C_{Crit} of 0.2406" for Agricultural Two Seat Pawnees at 3660 lb

Case	Cycles per 1000 hrs	Cycles for 1st Crack 32.1 gal fuel	Cycles for 1st Crack 19.25 gal fuel	Cycles for 1st Crack 6.4 gal fuel	
3660 lb Agricultural	380,425	963,273	1,011,380	1,066,843	
2460 lb Agricultural	341,409	2.09622E+06	2.39703E+08	2.76227E+06	
Landing	6,570	8.67627E+09	1.08666E+10	1.40072E+10	
Taxi	33,686	No Growth	No Growth	No Growth	
3660 lb Agricultural GAG	9,000	21,528	22,835	24,240	
Hours		1,025	1,296	1,174	**1,139**

Table 17-14 Hours to Grow Second Crack for Glider Towing Pawnees without Wing Tanks at 2205 lb

17.8 MTOW TWO SEAT AGRICULTURAL WITHOUT WING TANKS:

Case	Cycles per 1000 hrs	Cycles to Initiate 32.1 gal fuel	Cycles to Initiate 19.25 gal fuel	Cycles to Initiate 6.4 gal fuel	
2900 lb Agricultural	332,707	2.47617E+08	2.09121E+08	2.48764E+08	
2460 lb Agricultural	341,409	2.33709E+08	2.88369E+08	4.35168E+08	
2460 lb Landing	6,570	>2.0e+09	>2.0e+09	>2.0e+09	
Taxi	33,686	>2.0e+09	>2.0e+09	>2.0e+09	
2900 lb / 2460 lb Agricultural GAG	9,000	302,693	391,852	514,032	
Hours		30,733.7	38,845.9	50,940.8	**34,680.6**

Table 17-15 Hours to Initiate Cracking for Agricultural Two Seat Pawnees without Wing Tanks at 2900 lb

Case	Cycles per 1000 hrs	Cycles for First Crack 32.1 gal fuel	Cycles for First Crack 19.25 gal fuel	Cycles for First Crack 6.4 gal fuel	
2900 lb Agricultural	332,707	1.46421E+06	1.57851E+06	1.70708E+07	
2460 lb Agricultural	375,480	2.11992E+06	2.42251E+06	2.79115E+06	
2460 lb Landing	6,569	8.67751E+09	1.08678E+10	1.40086E+10	
Taxi	33,686	No growth	No growth	No growth	
2900 lb / 2460 lb Agricultural GAG	9,000	42,425	46,193	50,497	
Hours		1,978	2,173	4,131	**2,118**

Table 17-16 Hours to Grow First Crack for Agricultural Two Seat Pawnees without Wing Tanks at 2900 lb

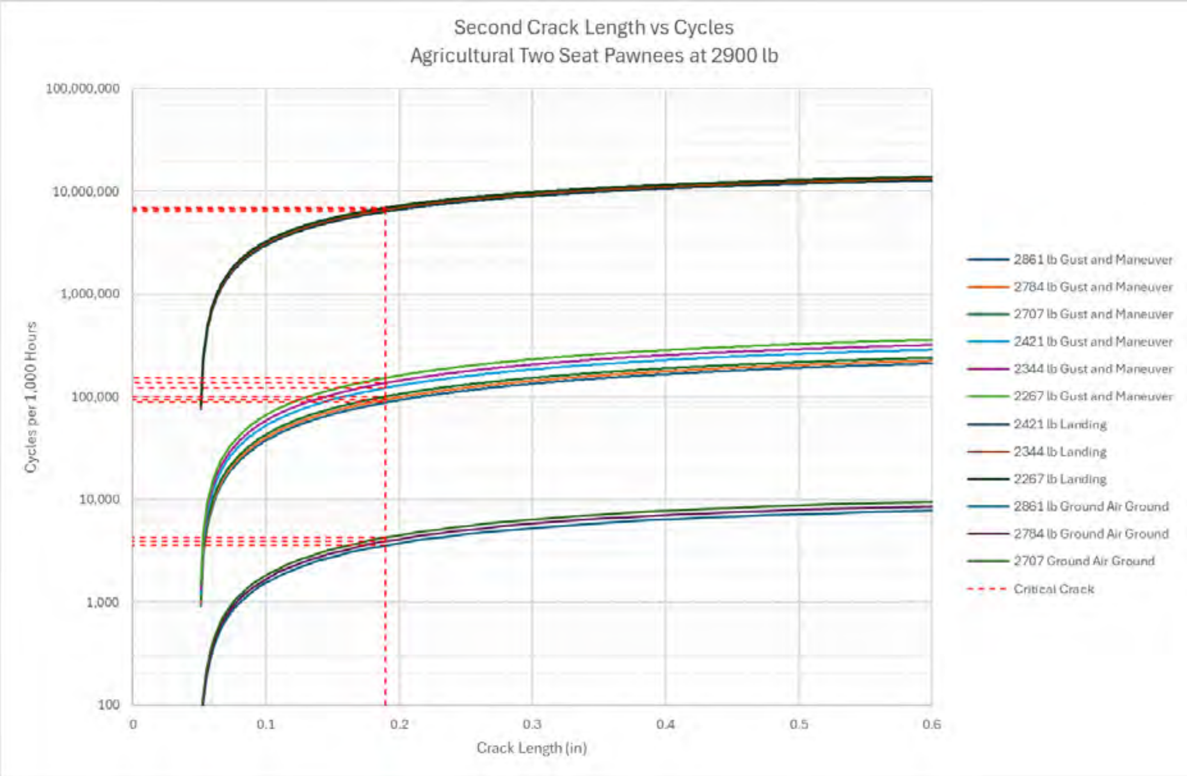

Figure 17-6 Second Crack Growth to C_{Crit} of 0.1899" for Agricultural Two Seat Pawnees at 2900 lb without Wing Tanks

Case	Cycles per 1000 hrs	Cycles for Second Crack 32.1 gal fuel	Cycles for Second Crack 19.25 gal fuel	Cycles for Second Crack 6.4 gal fuel	
2900 lb Agricultural	332,707	88,577	94,552	101,239	
2460 lb Agricultural	375,480	122,826	137,022	153,998	
Landing	6,569	6.39670E+06	6.679,84E+06	6.99490E+06	
Taxi	33,686	No growth	No growth	No growth	
2900 lb / 2460 lb Agricultural GAG	9,000	3,596	3,929	4,293	
Hours		173	188	206	**181**

Table 17-17 Hours to Grow Second Crack for Agricultural Two Seat Pawnees without Wing Tanks at 2900 lb

17.9 SINGLE SEAT GLIDER TOWING WITHOUT WING TANKS:

Case	Cycles per 1000 hrs	Cycles to Initiate 32.1 gal fuel	Cycles to Initiate 19.25 gal fuel	Cycles to Initiate 6.4 gal fuel	
2205 lb Glider Towing	198,456	>2.0e+09	>2.0e+09	>2.0e+09	
2205 lb Landing	5,694	>2.0e+09	>2.0e+09	>2.0e+09	
Taxi	5.18382E+06	>2.0e+09	>2.0e+09	>2.0e+09	
2205 lb Glider Towing GAG	7,800	4.88136E+07	7.90654E+07	9.78767E+07	
Hours		6.25815E+06	1.01366E+07	1.25483E+07	**7.79581E+06**

Table 17-18 Hours to Initiate Cracking for Glider Towing Pawnees without Wing Tanks at 2205 lb

Case	Cycles per 1000 hrs	Cycles for First Crack 32.1 gal fuel	Cycles for First Crack 19.25 gal fuel	Cycles for First Crack 6.4 gal fuel	
2205 lb Glider Towing	198,456	4.70363E+07	5.79185E+07	7.19406E+07	
2205 lb Landing	5,694	No growth	No growth	No growth	
Taxi	5.18382E+06	No growth	No growth	No growth	
2205 lb Glider Towing GAG	7,800	236,280	277,616	324,195	
Hours		26,859	31,723	37,288	**29,289**

Table 17-19 Hours to Grow First Crack for Glider Towing Pawnees without Wing Tanks at 2205 lb

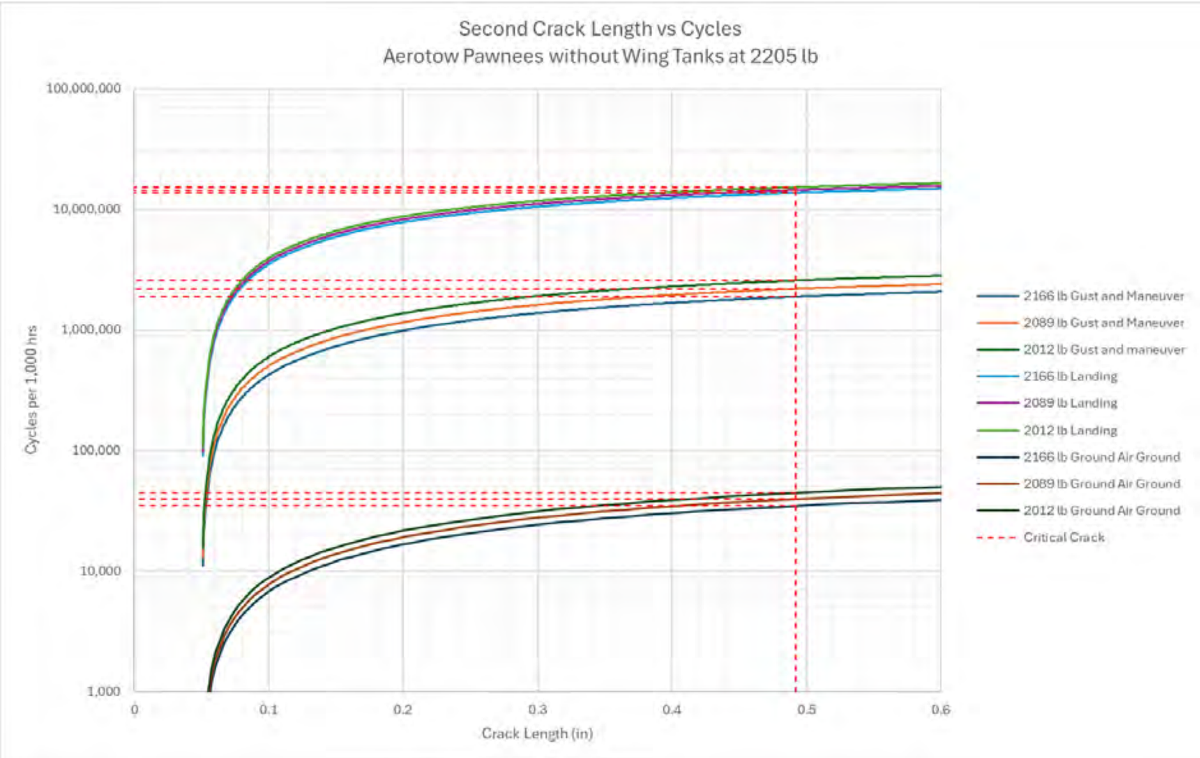

Figure 17-7 Second Crack Growth to C_{Crit} of 0.4918" for Glider Towing Pawnees at 2205 lb

Case	Cycles per 1000 hrs	Cycles for 2nd Crack 32.1 gal fuel	Cycles for 2nd Crack 19.25 gal fuel	Cycles for 2nd Crack 6.4 gal fuel	
2205 lb Glider Towing	198,456	1.88410E+06	2.19050E+06	2.57309E+06	
2205 lb Landing	5,694	1.37049E+07	1.44464E+07	1.52379E+07	
Taxi	5.18382E+06	No growth	No growth	No growth	
2205 lb Glider Towing GAG	7,800	34,778	39,652	44,609	
Hours		3,033	3,480	3,968	**260**

Table 17-20 Hours to Grow Second Crack for Glider Towing Pawnees without Wing Tanks at 2205 lb

17.10 SINGLE SEAT GLIDER TOWING WITH WING TANKS:

Case	Cycles per 1000 hrs	Cycles to Initiate 32.1 gal fuel	Cycles to Initiate 19.25 gal fuel	Cycles to Initiate 6.4 gal fuel	
2205 lb Glider Towing	198,456	>2.0e+09	>2.0e+09	>2.0e+09	
2205 lb Landing	5,694	>2.0e+09	>2.0e+09	>2.0e+09	
Wing Tanks - Taxi	5.18382E+06	>2.0e+09	>2.0e+09	>2.0e+09	
2205 lb Glider Towing Wing Tanks GAG	7,800	2.05468E+08	1.72122E+08	1.50283E+08	
Hours		2.63421E+07	2.20669E+07	1.92671E+07	**2.38273E+07**

Table 17-21 Hours to Initiate Cracking for Glider Towing Pawnees with Wing Tanks at 2205 lb

Case	Cycles per 1000 hrs	Cycles for First Crack 32.1 gal fuel	Cycles for First Crack 19.25 gal fuel	Cycles for First Crack 6.4 gal fuel	
2205 lb Glider Towing	198,456	1.995761E+08	1.38404E+09	1.0027E+08	
2205 lb Landing	5,694	No growth	No growth	No growth	
Wing Tanks - Taxi	5.18382E+06	No growth	No growth	No growth	
2205 lb Glider Towing Wing Tanks GAG	7,800	529,894	427,277	383,700	
Hours		63,636	54,352	44,828	**57,964**

Table 17-22 Hours to Grow First Crack for Glider Towing Pawnees with Wing Tanks at 2205 lb

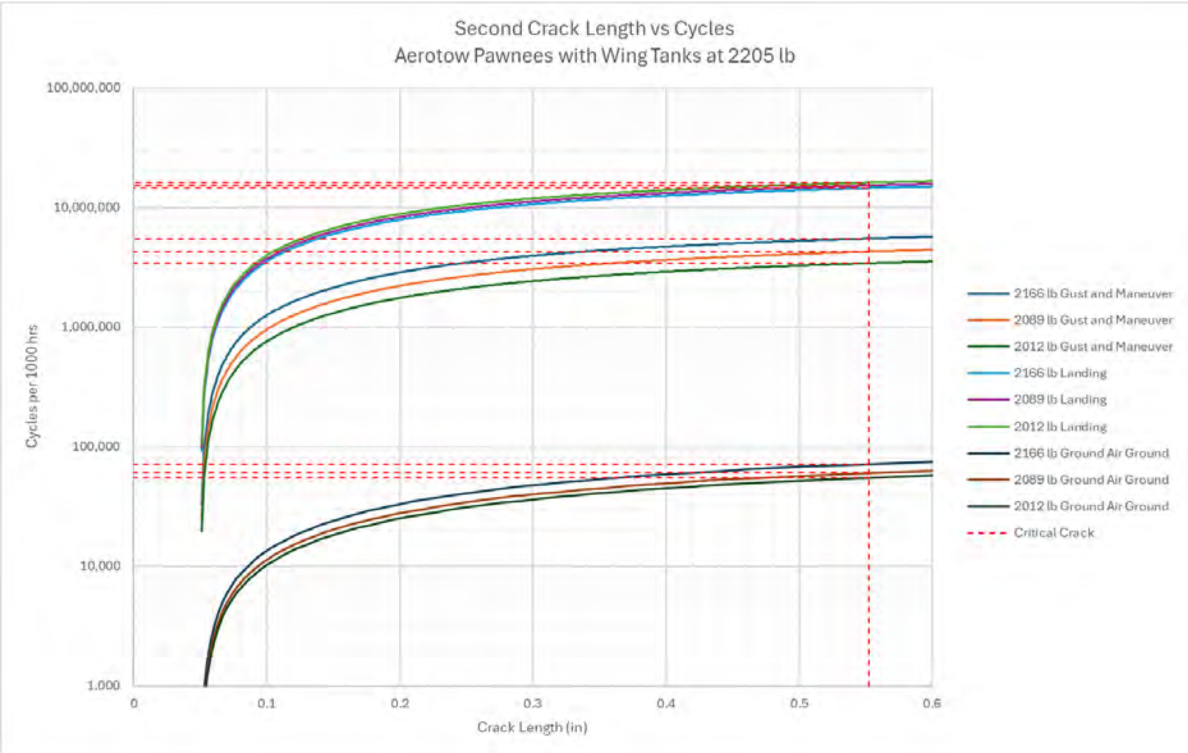

Figure 17-8 Second Crack Growth to C_{Crit} of 0.5521” for Glider Towing Pawnees at 2205 lb with Wing Tanks

Case	Cycles per 1000 hrs	Cycles for 2nd Crack 32.1 gal fuel	Cycles for 2nd Crack 19.25 gal fuel	Cycles for 2nd Crack 6.4 gal fuel	
2205 lb Glider Towing	198,456	5.50286E+06	4.27918E+06	3.42423E+06	
2205 lb Landing	5,694	1.45525E+07	1.52952E+07	1.61541E+07	
Wing Tanks - Taxi	5.18382E+06	No growth	No growth	No growth	
2205 lb Glider Towing Wing Tanks GAG	7,800	71,475	60,267	54,925	
Hours		6,869	5,676	4,992	**6,169**

Table 17-23 Hours to Grow Second Crack for Glider Towing Pawnees with Wing Tanks at 2205 lb

17.11 TWO SEAT GLIDER TOWING WITHOUT WING TANKS:

Case	Cycles per 1000 hrs	Cycles to Initiate 32.1 gal fuel	Cycles to Initiate 19.25 gal fuel	Cycles to Initiate 6.4 gal fuel	
2460 lb Glider Towing	198,456	>2.0e+09	>2.0e+09	>2.0e+09	
2460 lb Landing	5,694	>2.0e+09	>2.0e+09	>2.0e+09	
Taxi	5.18382E+06	>2.0e+09	>2.0e+09	>2.0e+09	
2460 lb Glider Towing GAG	7,800	1.46979E+07	2.10698E+07	3.07600E+07	
Hours		1.88435E+06	2.70126E+06	3.94359E+06	**2.24915E+06**

Table 17-24 Hours to Initiate Cracking for Glider Towing Pawnees without Wing Tanks at 2460 lb

Case	Cycles per 1000 hrs	Cycles for First Crack 32.1 gal fuel	Cycles for First Crack 19.25 gal fuel	Cycles for First Crack 6.4 gal fuel	
2460 lb Glider Towing	198,456	2.47876E+07	2.98615E+07	3.61079E+07	
2460 lb Landing	5,694	7.73405E+09	9.64691E+09	1.23838E+10	
Taxi	5.18382E+06	No growth	No growth	No growth	
2460 lb Glider Towing GAG	7,800	158,012	178,654	204,252	
Hours		17,430	19,878	22,891	**18,689**

Table 17-25 Hours to Grow First Crack for Glider Towing Pawnees without Wing Tanks at 2460 lb

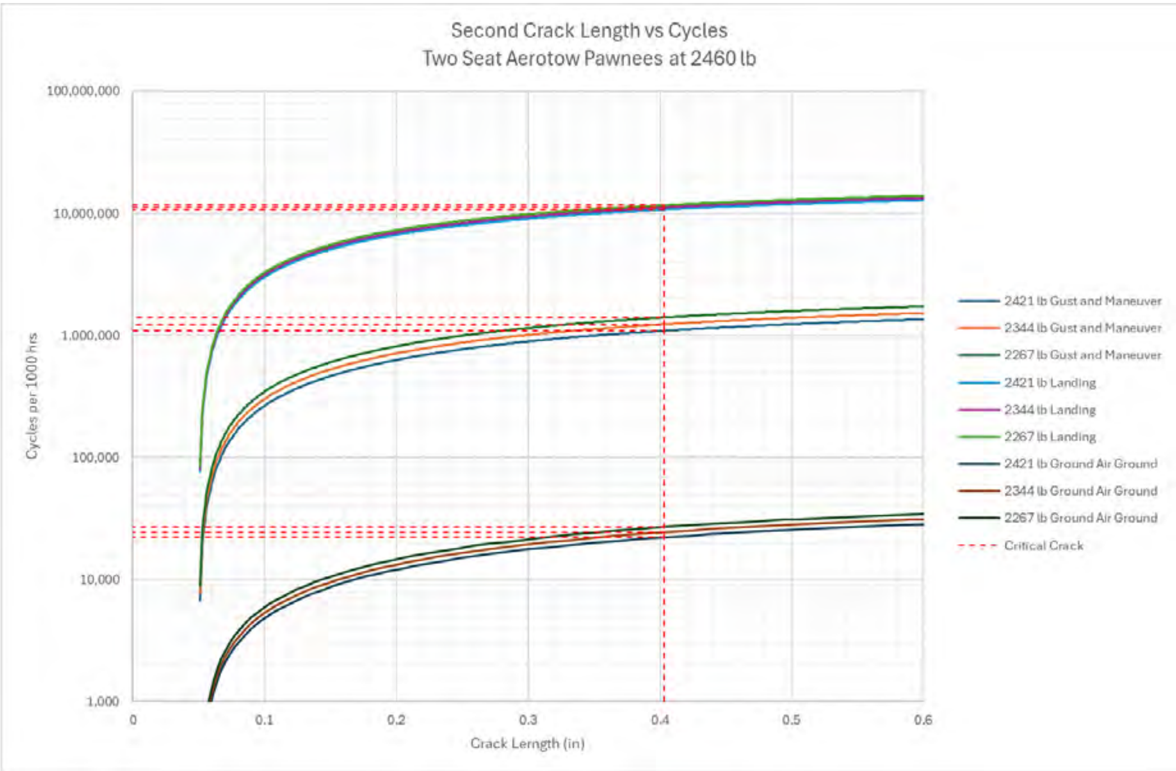

Figure 17-9 Second Crack Growth to C_{Crit} of 0.4032" for Two Seat Glider Towing Pawnees at 2460 lb

Case	Cycles per 1000 hrs	Cycles for 2nd Crack 32.1 gal fuel	Cycles for 2nd Crack 19.25 gal fuel	Cycles for 2nd Crack 6.4 gal fuel	
2460 lb Glider Towing	198,456	1.09178E+06	1.233514E+06	1.40409E+06	
2460 lb Landing	5,694	1.07492E+07	1.11967E+07	1.16947E+07	
Taxi	5.18382E+06	No growth	No growth	No growth	
2460 lb Glider Towing GAG	7,800	22,206	24,419	26,980	
Hours		1,874	2,079	2,320	**1,981**

Table 17-26 Hours to Grow Second Crack for Glider Towing Pawnees without Wing Tanks at 2460 lb

17.12 TWO SEAT GLIDER TOWING WITH WING TANKS:

Case	Cycles per 1000 hrs	Cycles to Initiate 32.1 gal fuel	Cycles to Initiate 19.25 gal fuel	Cycles to Initiate 6.4 gal fuel	
2460 lb Glider Towing	198,456	>2.0e+09	>2.0e+09	>2.0e+09	
2460 lb Landing	5,694	>2.0e+09	>2.0e+09	>2.0e+09	
Wing Tanks - Taxi	5.18382E+06	>2.0e+09	>2.0e+09	>2.0e+09	
2460 lb Glider Towing Wing Tanks GAG	7,800	5.28544E+07	4.70069E+07	4.50351E+07	
Hours		6.77621E+06	6.02653E+06	5.77373E+06	**6.36467E+06**

Table 17-27 Hours to Initiate Cracking for Two Seat Glider Towing Pawnees with Wing Tanks at 2421 lb

Case	Cycles per 1000 hrs	Cycles for First Crack 32.1 gal fuel	Cycles for First Crack 19.25 gal fuel	Cycles for First Crack 6.4 gal fuel	
2460 lb Glider Towing	198,456	9.0254E+07	6.5623E+07	4.92173E+07	
2460 lb Landing	5,694	8.04716E+09	No growth	No growth	
Wing Tanks - Taxi	5.18382E+06	No growth	No growth	No growth	
2460 lb Glider Towing Wing Tanks GAG	7,800	297,908	251,794	236,866	
Hours		35,233	29,410	27,054	**31,908**

Table 17-28 Hours to Grow First Crack for Two Seat Glider Towing Pawnees with Wing Tanks at 2421 lb

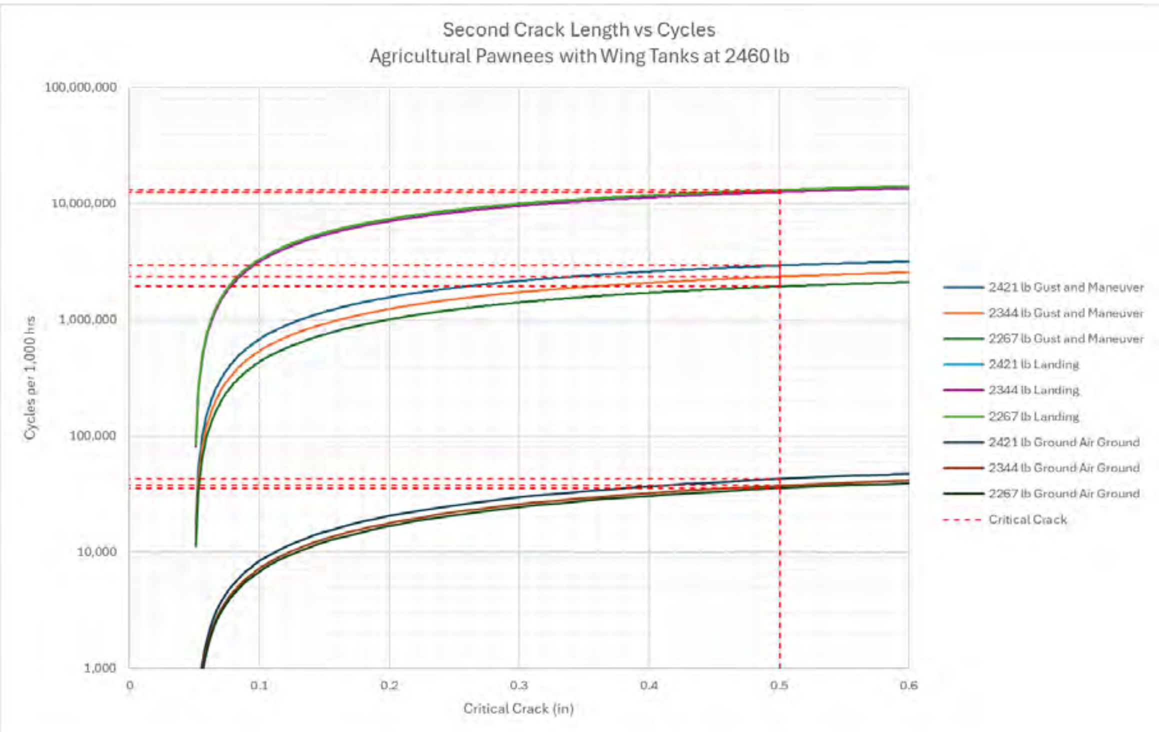

Figure 17-10 Second Crack Growth to C_{Crit} of 0.5009" for Glider Towing **Pawnees at 2460 lb with Wing Tanks**

Case	Cycles per 1000 hrs	Cycles for 2nd Crack 32.1 gal fuel	Cycles for 2nd Crack 19.25 gal fuel	Cycles for 2nd Crack 6.4 gal fuel	
2460 lb Glider Towing	198,456	2.93221E+06	2.35708E+06	1.93931E+06	
2460 lb Landing	5,694	1.26489E+07	1.25866E+07	1.317328E+07	
Wing Tanks - Taxi	5.18382E+06	No growth	No growth	No growth	
2460 lb Glider Towing Wing Tanks GAG	7,800	42,655	37,356	35,400	
Hours		3,984	3,408	3,095	**3,653**

Table 17-29 Hours to Grow Second Crack for Two Seat Glider Towing Pawnees with Wing Tanks at 2460 lb

18. INSPECTION THRESHOLD AND INTERVALS

18.1 Calculated inspection threshold requires a significant knock down factor of 5 to account for the variability in fatigue calculations.

$$Threshold = (\frac{1}{5})(Hours_{Initiation})$$

18.2 The inspection interval is a similar calculation. Reference 1.2 requires at least two inspections prior to the crack reaching the critical crack length. Dividing the crack growth period by a factor of 3.1 gives an interval where there are four inspections (inspection once the threshold is reached plus three additional inspections) prior to reaching the predicted critical crack length.

$$Interval_{Agricultural} = (\frac{1}{5 \times 3.1})(Hours_{First\ Crack} + Hours_{Second\ Crack})$$

18.3 Agricultural Pawnees:

	Inspection Threshold	Inspection Interval
Pawnee without wing tanks operating up to 2900 lb	7,874 Hrs	206 Hrs
Pawnee with wing tanks operating up to 2900 lb	17,822 Hrs	279 Hrs
Pawnee without wing tanks operating over MTOW	3,301 Hrs	152 Hrs
Pawnee with wing tanks operating over MTOW	5,939 Hrs	193 Hrs
Two Seat Pawnee without wing tanks operating up to 2900 lb	6,936 Hrs	148 Hrs
Two Seat Pawnee without wing tanks operating over MTOW	1,136 Hrs	73 Hrs

Table 18-1: Agricultural Pawnee Inspection Threshold and Interval

18.4 Glider towing Pawnees:

	Inspection Threshold	Inspection Interval
Pawnee without wing tanks operating up to 2205 lb	1,559,162 Hrs	2,100 Hrs
Pawnee with wing tanks operating up to 2205 lb	4,765,457 Hrs	4,137 Hrs
Two Seat Pawnee without wing tanks up to 2460 lb	449,830 Hrs	1,333 Hrs
Two Seat Pawnee with wing tanks up to 2460 lb	1,272,933 Hrs	2,294 Hrs

Table 18-2 Glider Towing Pawnee Inspection Threshold and Interval

NOTE: The inspection threshold for glider towing Pawnees assumes that no agricultural flying has been conducted previously. This would apply to aircraft that have new spars fitted and have only performed glider towing operations since.

18.5 In can be concluded that the combination of reduced operating weight and a significantly more benign operating profile (fatigue spectrum) results in a major increase in expected fatigue life for the front spar of the PA-25 Pawnee for glider towing operations compared to that of agricultural operations.

18.6 **TOWPLANES WITH AGRICULTURAL HOURS:** The majority of Pawnees used in glider towing will have front spars that have accumulated agricultural hours. The inspection threshold can be calculated using the following:

$$Threshold_{New} = Hrs_{Ag} + (1 - \frac{Hrs_{Ag}}{Threshold_{Ag}}) \times Threshold_{Tow}$$

As an example: A Pawnee without wing tanks that has always been operated within the maximum take off limit with 6,300 hrs is converted to glider towing. The new inspection threshold is:

$$Threshold_{New} = 6{,}300 + \left(1 - \frac{6{,}300}{7{,}874}\right) \times 1{,}559{,}162 = 317{,}974\ Hrs$$

18.7 **TWO SEAT PAWNEES USED AS TOWPLANES:** Two seat Pawnees used in glider towing are primarily operated with only one occupant. It is estimated that two seat operations (eg pilot conversion to glider towing and currency checks) are only 5% of the operating time. Operators have the option of either performing the inspections as if the aircraft was always operated with two occupants or track the number of pilots in the logbook and calculate the threshold where hours with two occupants is worth 3.5 hours of single seat operations and calculate the inspection interval where hours with two occupants is worth 1.6 hours of single seat operations.

19. INSPECTION AREAS

19.1 The fatigue is driven by the Ground – Air – Ground cycle stresses for both agricultural and glider towing. The fatigue critical areas are those with high tension levels combined with a negative stress. Figure 19-1 to Figure 19-4 below show the stress range for the upper and lower spar caps respectively using the agricultural ground – air – ground cycle at 2900 lb as an example. The inspection areas for glider towing Pawnees are identical with the only difference being the stress magnitudes and therefore the inspection intervals.

19.2 The areas to be inspected are on both the forward and aft sides of the spar flanges. The forward faces of the spar flanges have the screws securing the ribs whilst the aft faces of the spar have the crews securing the ribs and the screws securing the leading edge skins.

19.3 Inspection of the forwards faces will require removal of the leading edge skins to facilitate the inspection of the screw holes securing the ribs. This may not be economical for the agricultural aircraft where the inspection interval is comparatively short.

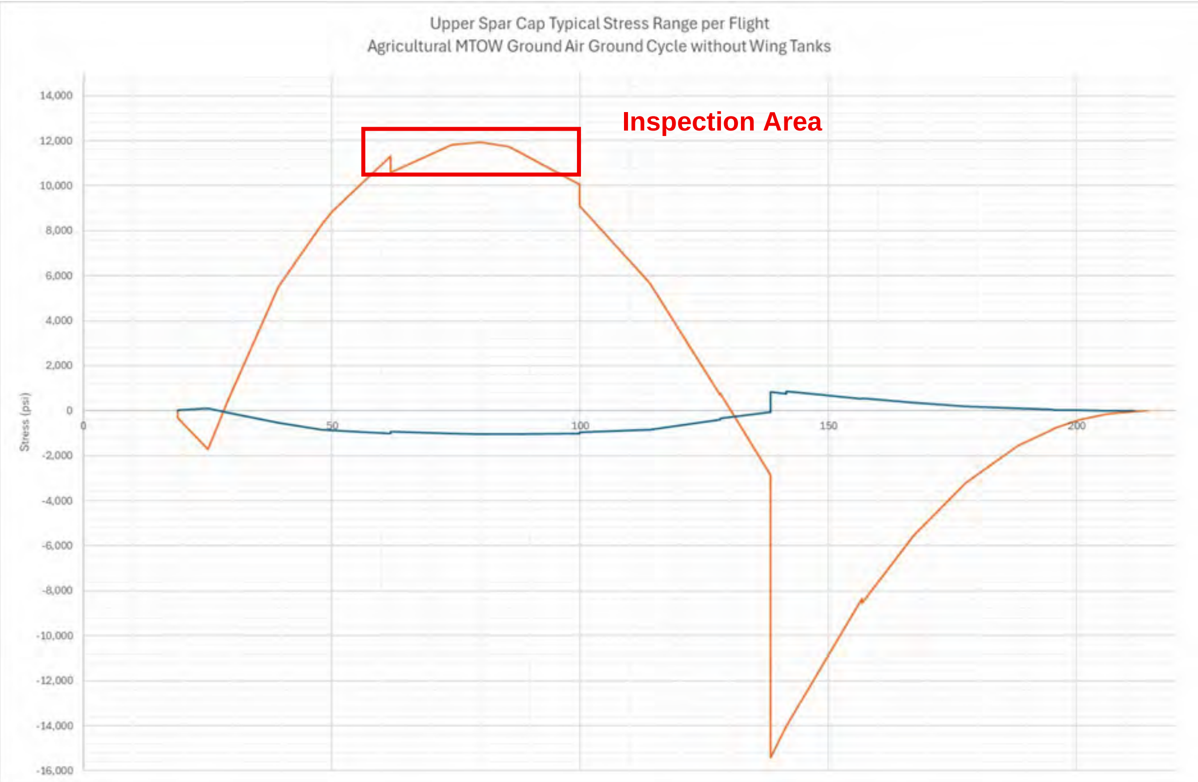

Figure 19-1 Upper Spar Cap Stress Range for Agricultural GAG Cycle without Wing Tanks

Figure 19-2 Lower Spar Cap Stress Range for Agricultural GAG Cycle without Wing Tanks

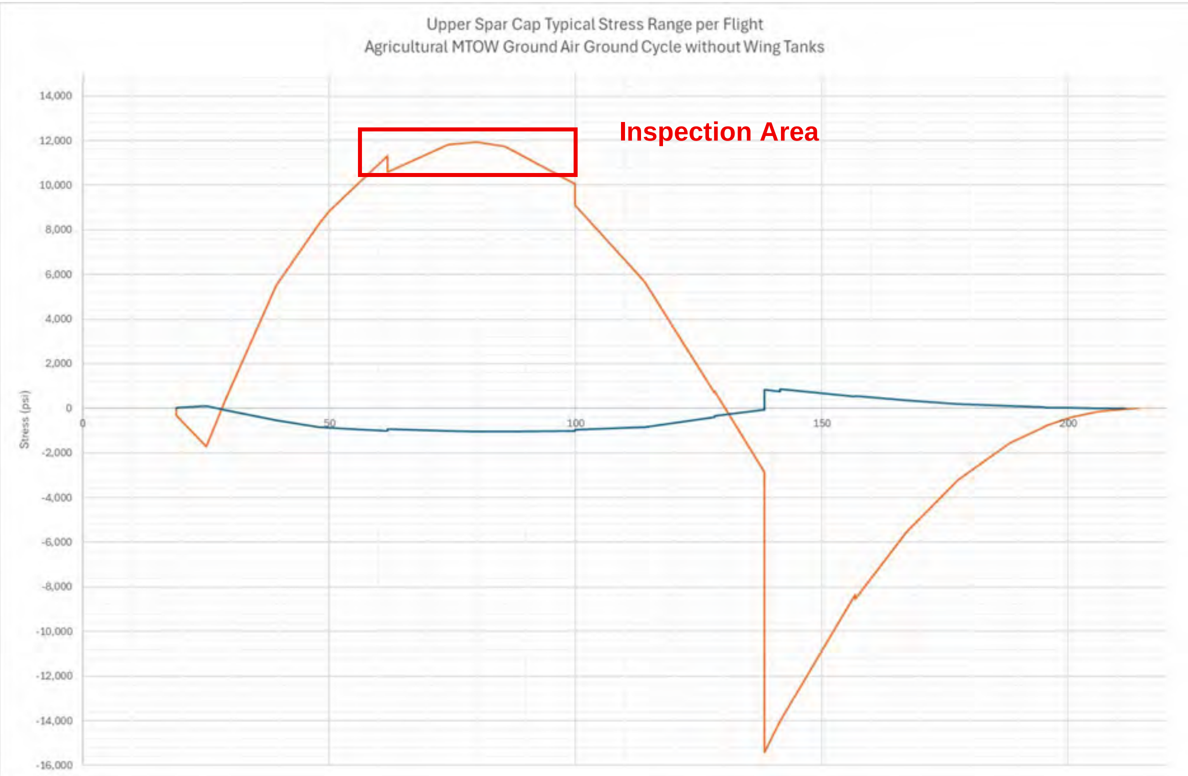

Figure 19-3 Upper Spar Cap Stress Range for Agricultural GAG Cycle with Wing Tanks

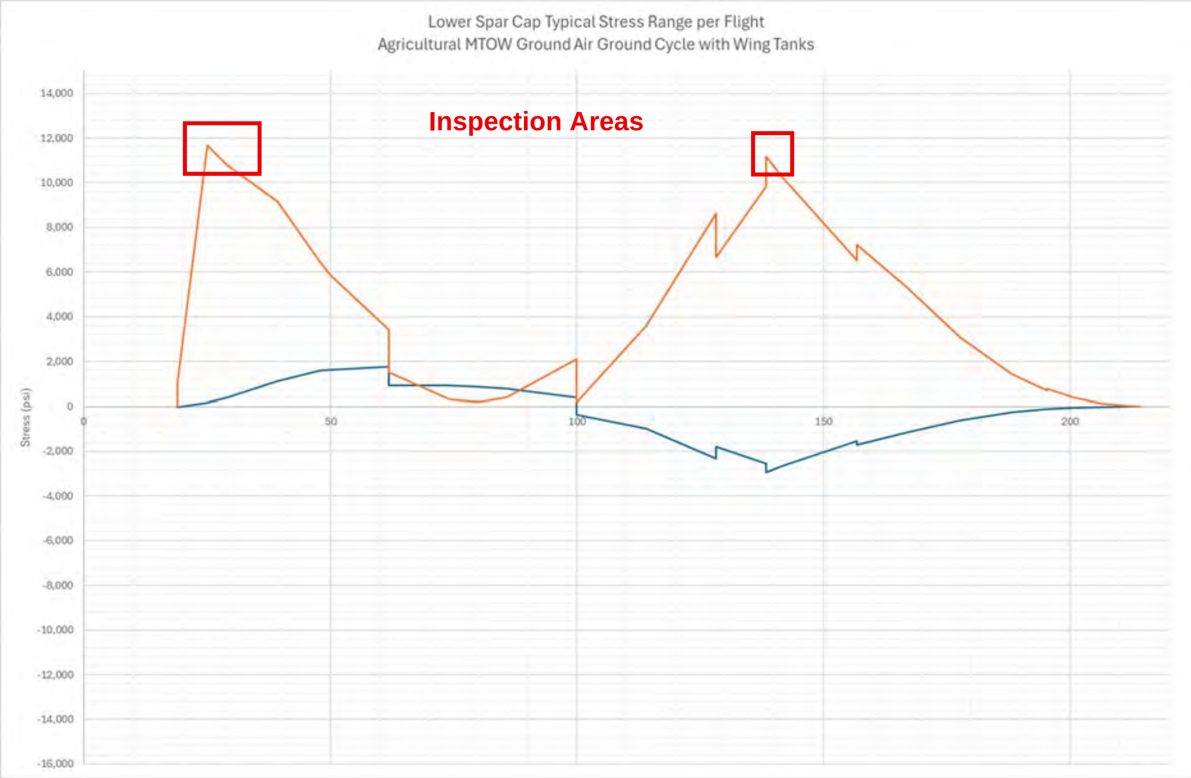

Figure 19-4 Lower Spar Cap Stress Range for Agricultural GAG Cycle with Wing Tanks

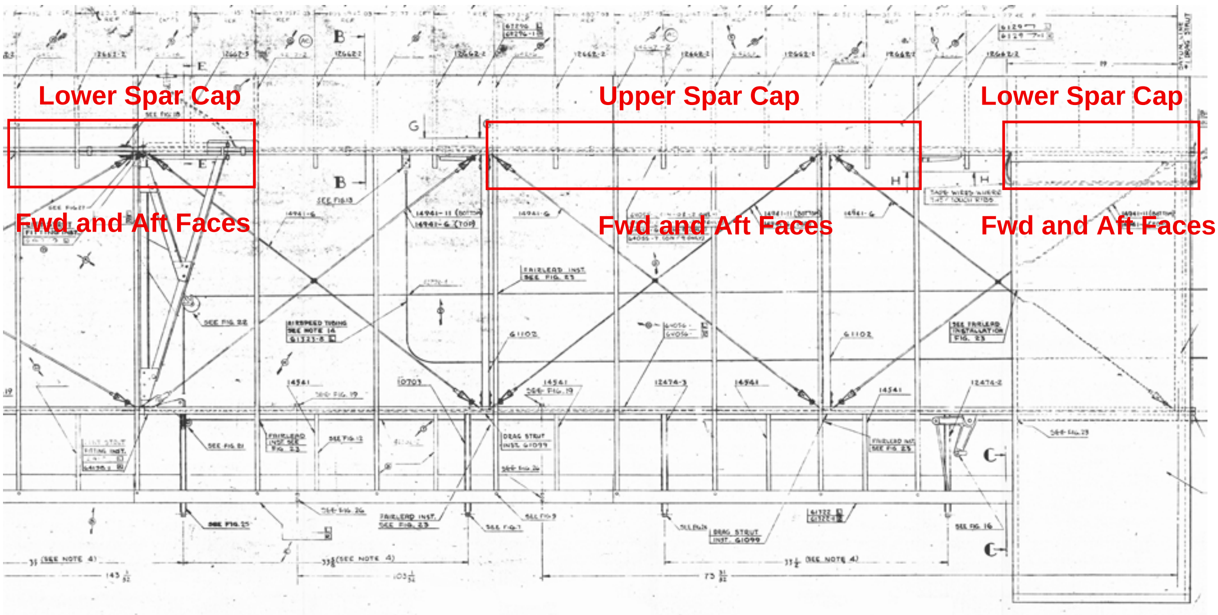

Figure 19-5 Pawnee Wing Inspection Areas

20. RECOMMENDATIONS

20.1 There are significant increases in fatigue life for PA-25 Pawnee front spars operating purely as glider tow planes. This is due the more benign operating profiles resulting in reduced stresses in the spars.

20.2 Reinspection intervals from Reference 1.1 can be markedly increased for Pawnees operating as glider towplanes but will require a placarded reduction in maximum take-off weight for glider tow planes as a mitigation strategy.

20.3 Inspection intervals for two seat modified Pawnees can be carried out earlier as per Table 18-2 or by tracking the hours where both seats are occupied and calculating an interval where the two seat hours are the equivalent of 1.6 single occupant operation hours.

20.4 The minimum edge distance allowed by the ‘A’ end of Gauge LA-96001-1 allows the shank of the screw to penetrate the bulb of the flange edge as shown below in Figure 20-1. The offset at the “A” end should be increased from 0.06” +0.01 / -0.00” to 0.13” +0.01 / -0.00”.

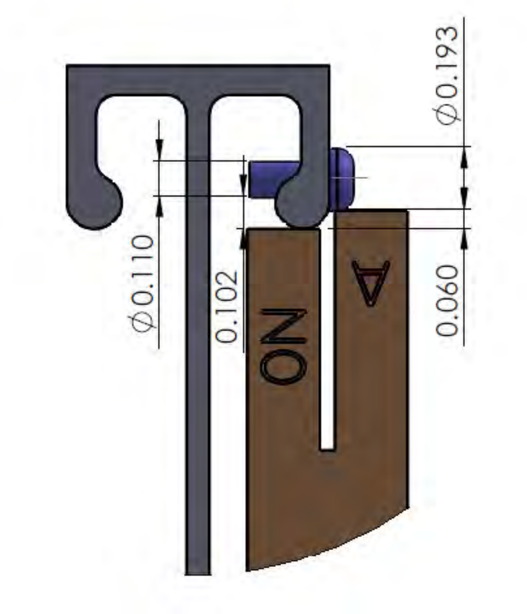

Figure 20-1 Minimum Allowable Edge Distance Allowed by Gauge LA-96001-1

20.5 For this analysis to be valid, all holes in the spar flanges must be filled with a screw. Only #4 size screws are considered, any other fastener types or oversize screws need separate analysis. A national regulator may approve aircraft to continue operating with additional holes in the spar via AMOC providing it can be demonstrated that the additional holes do not compromise the strength or the fatigue life of the spar.

20.6 This analysis does not consider fatigue inspection of potentially high fatigue areas such as:

a. Wing root fittings,

b. Strut attachment fittings, or

c. Reinforcing strap at the strut attachment.

These should be considered in any future fatigue analysis.

20.7 This analysis does not consider whether the fatigue inspection of the lower spar cap under the strut connection is required for tow planes with wing tanks. This can be considered in any future analysis.

ANNEX A GUST SPECTRA

The spectra presented in Reference 1.2 are nondimensionalised. To aid creation of occurrence block data, the gust spectra from Reference 1.2 had a polynomial curve fitted using the following process:

The log of exceedance per nautical mile was calculated and plotted.

A polynomial curve was fitted to the log (exceedance)

The curve fit of the spectra becomes $10^{(Ax^3+Bx^2+C^x+D)}$

Agricultural Gust: Table A1-11

Acceleration Fraction a_n / a_{nLLF}	Exceedance per Nautical Mile	Log (Exceedance)	Curve Fit
0.10	3.7771E-01	-0.4228	3.7939E-01
0.15	1.6154E-01	-0.7917	1.6740E-01
0.20	7.2232E-02	-1.1413	7.2413E-02
0.25	3.2027E-02	-1.4945	3.0761E-02
0.30	1.3486E-02	-1.8701	1.2854E-02
0.35	5.3651E-03	-2.2704	5.2920E-03
0.40	2.1319E-03	-2.6712	2.1503E-03
0.45	8.4762E-04	-3.0718	8.6370E-04
0.50	3.3652E-04	-3.4730	3.4352E-04
0.55	1.3320E-04	-3.8755	1.3552E-04
0.60	5.2259E-05	-4.2818	5.3110E-05
0.65	2.0430E-05	-4.6897	2.0713E-05
0.70	7.9428E-06	-5.1000	8.0522E-06
0.75	3.1294E-06	-5.5045	3.1254E-06
0.80	1.2381E-06	-5.9072	1.2132E-06
0.85	4.8659E-07	-6.3128	4.7173E-07
0.90	1.8960E-07	-6.7222	1.8406E-07
0.95	7.2897E-08	-7.1373	7.2177E-08
1.00	2.7294E-08	-7.5639	2.8494E-08
-0.10	3.1192E-01	-0.5060	3.1490E-01
-0.15	1.3164E-01	-0.8806	1.2680E-01
-0.20	5.1616E-02	-1.2872	5.1017E-02
-0.25	2.1531E-02	-1.6669	2.0490E-02
-0.30	8.1650E-03	-2.0880	8.2070E-03
-0.350	3.2107E-03	-2.4934	3.2749E-03
-0.4	1.2679E-03	-2.8969	1.3006E-03
-0.450	5.0163E-04	-3.2996	5.1360E-04
-0.50	1.9834E-04	-3.7026	2.0146E-04
-0.55	7.7862E-05	-4.1087	7.8419E-05
-0.60	3.0225E-05	-4.5196	3.0261E-05
-0.65	1.1596E-05	-4.9357	1.1565E-05
-0.70	4.3969E-06	-5.3569	4.3731E-06
-0.75	1.6473E-06	-5.7832	1.6345E-06

-0.80	6.0968E-07	-6.2149	6.0325E-07
-0.85	2.2266E-07	-6.6524	2.1964E-07
-0.9	8.0021E-08	-7.0968	7.8809E-08
-0.95	2.8075E-08	-7.5517	2.7841E-08
-1	9.3802E-09	-8.0278	9.6738E-09

Table A-0-1 Gust Exceedance Curve Fit for Agricultural Aircraft

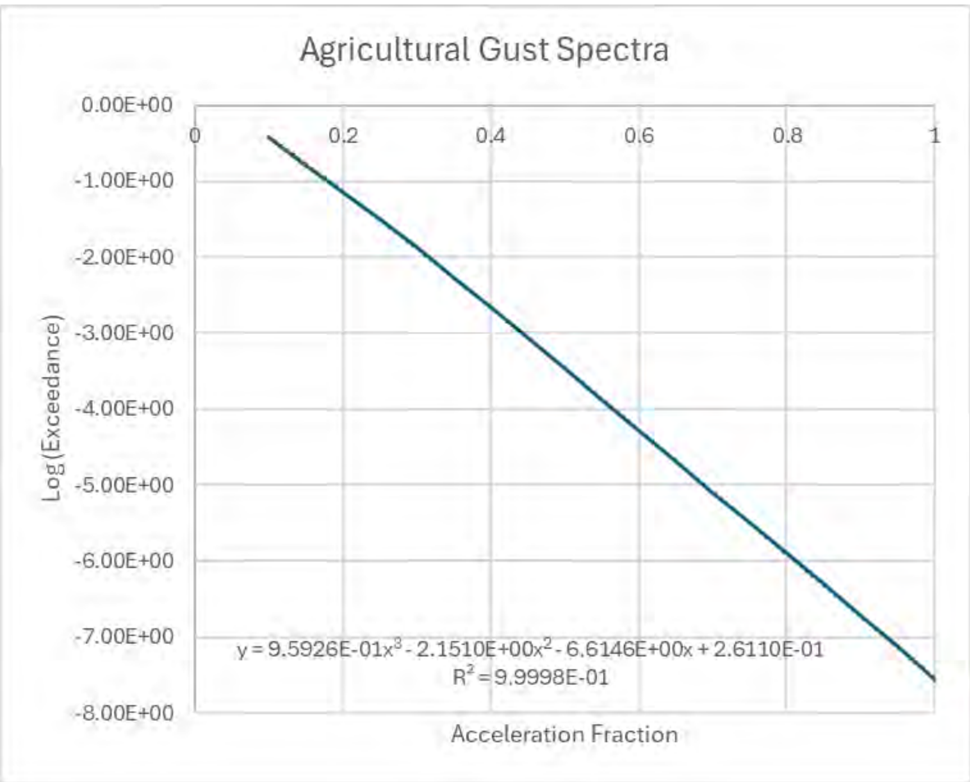

Figure A-0-1 Positive Gust Exceedance Curve Fit for Agricultural Aircraft

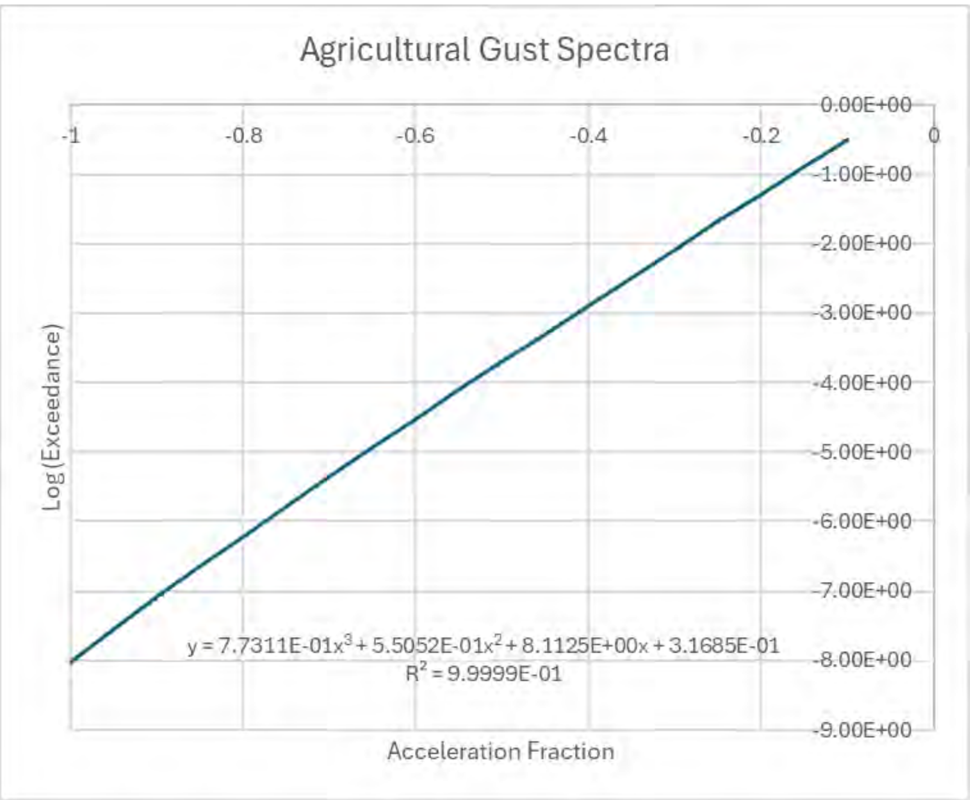

Figure A-0-2 Negative Gust Exceedance Curve Fit for Agricultural Aircraft

Glider Towing Gust: Glider towing aircraft use the Single Engine – Unpressurised data from Table A1-1:

Acceleration Fraction a_n / a_{nLLF}	Exceedance per Nautical Mile	Log (Exceedance)	Curve Fit
0.10	7.99E-01	-9.74E-02	7.8477E-01
0.15	2.40E-01	-6.20E-01	2.3967E-01
0.20	8.27E-02	-1.08E+00	7.8454E-02
0.25	2.60E-02	-1.59E+00	2.7340E-02
0.30	9.43E-03	-2.03E+00	1.0075E-02
0.35	3.74E-03	-2.43E+00	3.8995E-03
0.40	1.57E-03	-2.81E+00	1.5746E-03
0.45	6.77E-04	-3.17E+00	6.5881E-04
0.50	2.97E-04	-3.53E+00	2.8371E-04
0.55	1.31E-04	-3.88E+00	1.2490E-04
0.60	5.79E-05	-4.24E+00	5.5836E-05
0.65	2.56E-05	-4.59E+00	2.5175E-05
0.70	1.13E-05	-4.95E+00	1.1371E-05
0.75	4.97E-06	-5.30E+00	5.1107E-06
0.80	2.19E-06	-5.66E+00	2.2702E-06
0.85	9.58E-07	-6.02E+00	9.8998E-07
0.90	4.16E-07	-6.38E+00	4.2094E-07
0.95	1.76E-07	-6.75E+00	1.7335E-07
1.00	7.06E-08	-7.15E+00	6.8675E-08

-0.10	7.99E-01	-9.74E-02	7.8477E-01
-0.15	2.40E-01	-6.20E-01	2.3967E-01
-0.20	8.27E-02	-1.08E+00	7.8454E-02
-0.25	2.60E-02	-1.59E+00	2.7340E-02
-0.30	9.43E-03	-2.03E+00	1.0075E-02
-0.350	3.74E-03	-2.43E+00	3.8995E-03
-0.4	1.57E-03	-2.81E+00	1.5746E-03
-0.450	6.77E-04	-3.17E+00	6.5881E-04
-0.50	2.97E-04	-3.53E+00	2.8371E-04
-0.55	1.31E-04	-3.88E+00	1.2490E-04
-0.60	5.79E-05	-4.24E+00	5.5836E-05
-0.65	2.56E-05	-4.59E+00	2.5175E-05
-0.70	1.13E-05	-4.95E+00	1.1371E-05
-0.75	4.97E-06	-5.30E+00	5.1107E-06
-0.80	2.19E-06	-5.66E+00	2.2702E-06
-0.85	9.58E-07	-6.02E+00	9.8998E-07
-0.9	4.16E-07	-6.38E+00	4.2094E-07
-0.95	1.76E-07	-6.75E+00	1.7335E-07
-1	7.06E-08	-7.15E+00	6.8675E-08

Table A-0-2 Gust Exceedance Curve Fit for Single Engine - Unpressurised Aircraft

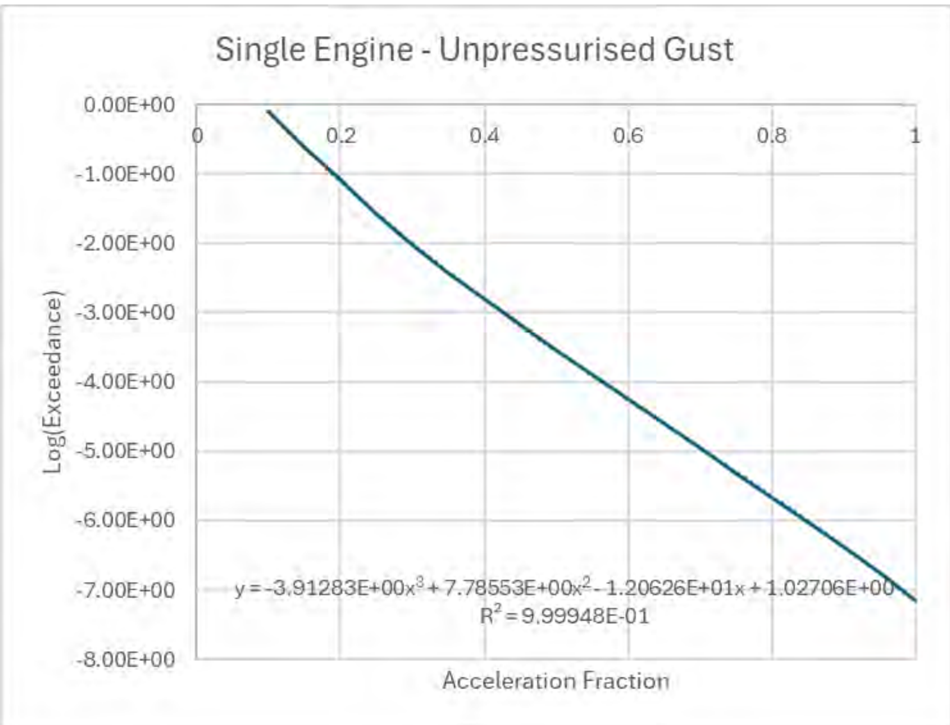

Figure A-0-3 Positive Gust Exceedance Curve Fit for Single Engine - Unpressurised Aircraft

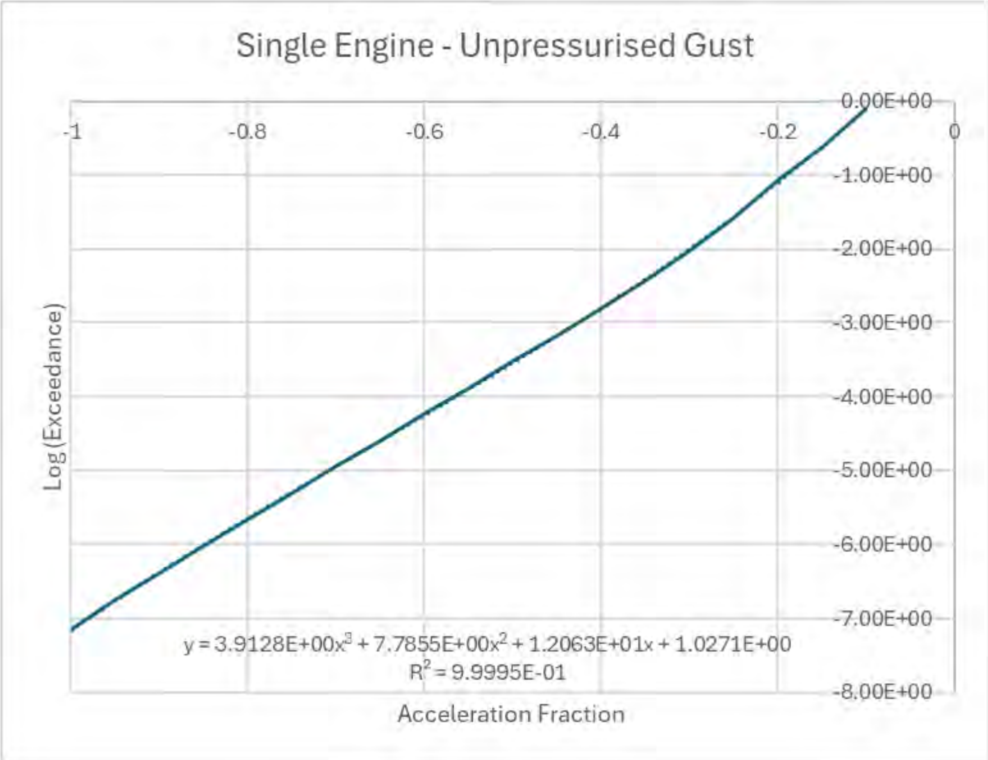

Figure A-0-4 Negative Gust Exceedance Curve Fit for Single Engine - Unpressurised Aircraft

ANNEX B MANEUVER SPECTRA

The spectra presented in Reference 1.2 are nondimensionalised. Similar to the gust data, the maneuver spectra had a polynomial curve fitted. The curve fit of the spectra becomes $10^{(Ax^3+Bx^2+C^x+D)}$

Agricultural Gust: Table A1-12

The tabulated maneuver spectra had discrepancies at -0.70, -.080, and -0.90 respectively. These appeared to be typographical errors. These were corrected to better fit the curve at Figure A1:12:

Acceleration Fraction	Original Exceedance per Nautical Mile	Corrected Exceedance per Nautical Mile
-0.70	9.6277E-07	9.96277E-07
-0.80	9.2187E-08	1.92187E-08
-0.90	1.1152E-09	2.11152E-09

Acceleration Fraction a_n / a_{nLLF}	**Exceedance per Nautical Mile**	**Log (Exceedance)**	**Curve Fit**
0.10	1.9568E+00	0.2915	1.9740E+00
0.15	1.6240E+00	0.2106	1.6604E+00
0.20	1.3082E+00	0.1167	1.3068E+00
0.25	9.9799E-01	-0.0009	9.6523E-01
0.30	6.8833E-01	-0.1622	6.7113E-01
0.35	4.4498E-01	-0.3517	4.4061E-01
0.40	2.7344E-01	-0.5631	2.7395E-01
0.45	1.6171E-01	-0.7913	1.6181E-01
0.50	8.9738E-02	-1.0470	9.1058E-02
0.55	4.8039E-02	-1.3184	4.8974E-02
0.60	2.4806E-02	-1.6054	2.5249E-02
0.65	1.2339E-02	-1.9087	1.2517E-02
0.70	5.8900E-03	-2.2299	5.9839E-03
0.75	2.7619E-03	-2.5588	2.7674E-03
0.80	1.2609E-03	-2.8993	1.2418E-03
0.85	5.5656E-04	-3.2545	5.4228E-04
0.90	2.3850E-04	-3.6225	2.3117E-04
0.95	9.8932E-05	-4.0047	9.6488E-05
1.00	3.7596E-05	-4.4249	3.9552E-05
-0.10	1.0697E+00	0.0293	1.0727E+00
-0.15	5.9480E-01	-0.2256	6.2734E-01
-0.20	3.1318E-01	-0.5042	3.2936E-01
-0.25	1.6199E-01	-0.7905	1.5502E-01
-0.30	7.1184E-02	-1.1476	6.5318E-02
-0.35	2.7168E-02	-1.5660	2.4603E-02
-0.40	8.7856E-03	-2.0562	8.2731E-03
-0.45	2.4335E-03	-2.6138	2.4799E-03

-0.50	6.2862E-04	-3.2016	6.6172E-04
-0.55	1.4284E-04	-3.8452	1.5696E-04
-0.60	2.9688E-05	-4.5274	3.3049E-05
-0.65	5.4276E-06	-5.2654	6.1683E-06
-0.70	9.9628E-07	-6.0016	1.0191E-06
-0.75	1.6630E-07	-6.7791	1.4882E-07
-0.80	1.9219E-08	-7.7163	1.9184E-08
-0.85	2.4159E-09	-8.6169	2.1797E-09
-0.9	2.1152E-10	-9.6747	2.1800E-10
-0.95	1.7920E-11	-10.7467	1.9163E-11
-1	1.44E-12	-11.8420	1.4785E-12

Table B-0-1 Gust Maneuver Exceedance Curve Fit for Agricultural Aircraft

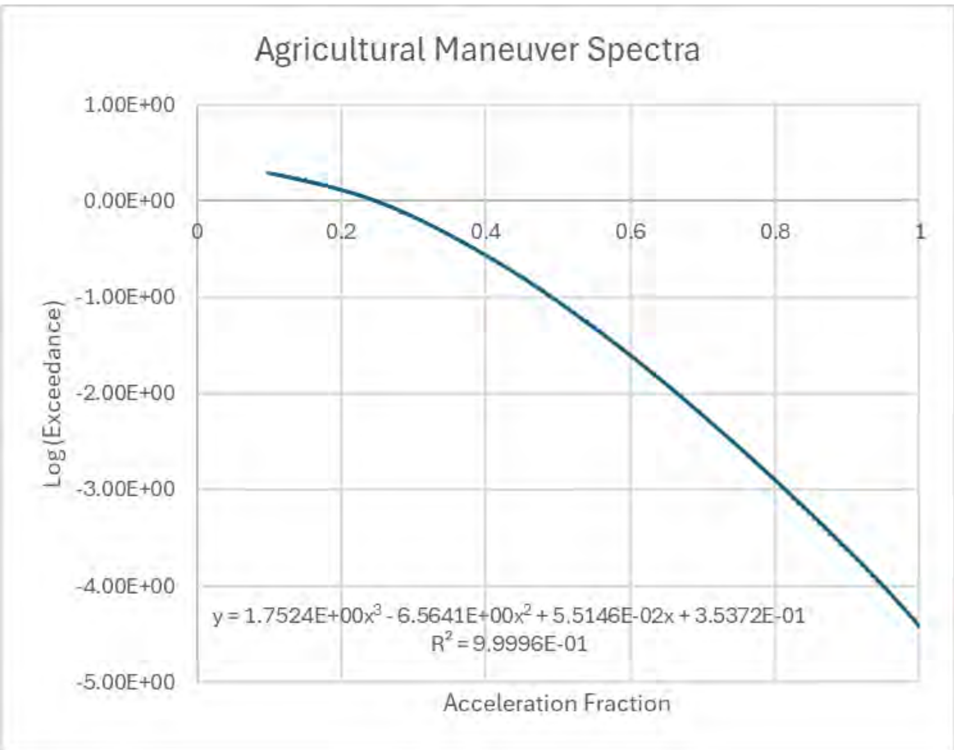

Figure B-0-1 Positive Maneuver Exceedance Curve Fit for Agricultural Aircraft

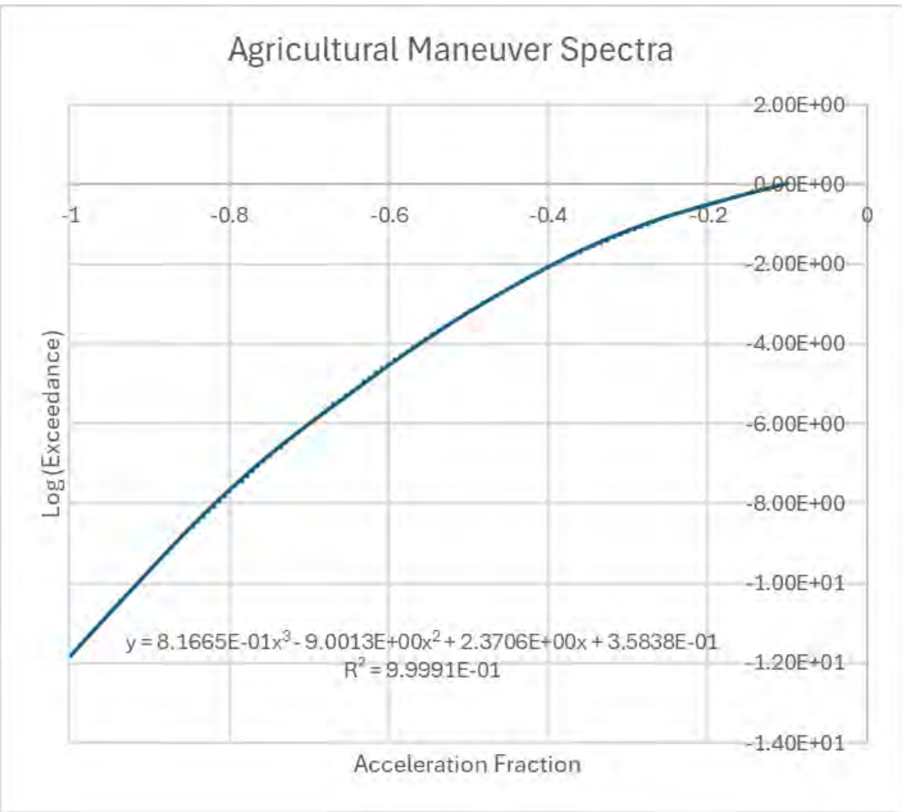

Figure B-0-2 Negative Maneuver Exceedance Curve Fit for Agricultural Aircraft

<u>Glider Towing Maneuver:</u> Glider towing aircraft use the Single Engine – Personal Use data from Table A1-3:

Acceleration Fraction a_n / a_{nLLF}	**Exceedance per Nautical Mile**	**Log (Exceedance)**	**Curve Fit**
0.10	1.28156E-01	-8.92E-01	1.2598E-01
0.15	6.27614E-02	-1.20E+00	6.3490E-02
0.20	3.09500E-02	-1.51E+00	3.1942E-02
0.25	1.58120E-02	-1.80E+00	1.6032E-02
0.30	8.12433E-03	-2.09E+00	8.0239E-03
0.35	4.12127E-03	-2.38E+00	4.0018E-03
0.40	2.04241E-03	-2.69E+00	1.9878E-03
0.45	9.97803E-04	-3.00E+00	9.8283E-04
0.50	4.83819E-04	-3.32E+00	4.8341E-04
0.55	2.33291E-04	-3.63E+00	2.3640E-04
0.60	1.12320E-04	-3.95E+00	1.1487E-04
0.65	5.40555E-05	-4.27E+00	5.5429E-05
0.70	2.59889E-05	-4.59E+00	2.6547E-05
0.75	1.24766E-05	-4.90E+00	1.2611E-05
0.80	5.97051E-06	-5.22E+00	5.9394E-06
0.85	2.83754E-06	-5.55E+00	2.7714E-06
0.90	1.32888E-06	-5.88E+00	1.2805E-06
0.95	6.02384E-07	-6.22E+00	5.8553E-07
1.00	2.52545E-07	-6.60E+00	2.6481E-07

-0.10	9.71117E-02	-1.01E+00	9.1009E-02
-0.15	3.13880E-02	-1.50E+00	3.2206E-02
-0.20	1.09533E-02	-1.96E+00	1.2208E-02
-0.25	4.71523E-03	-2.33E+00	4.8659E-03
-0.30	2.07230E-03	-2.68E+00	2.0060E-03
-0.350	8.91311E-04	-3.05E+00	8.4303E-04
-0.4	3.75403E-04	-3.43E+00	3.5664E-04
-0.450	1.55129E-04	-3.81E+00	1.5028E-04
-0.50	6.29010E-05	-4.20E+00	6.2531E-05
-0.55	2.50877E-05	-4.60E+00	2.5526E-05
-0.60	9.84679E-06	-5.01E+00	1.0175E-05
-0.65	3.80374E-06	-5.42E+00	3.9500E-06
-0.70	1.44615E-06	-5.84E+00	1.4924E-06
-0.75	5.41094E-07	-6.27E+00	5.4950E-07
-0.80	1.99191E-07	-6.70E+00	1.9782E-07
-0.85	7.20825E-08	-7.14E+00	7.0002E-08
-0.9	2.55778E-08	-7.59E+00	2.4525E-08
-0.95	8.83264E-09	-8.05E+00	8.5864E-09
-1	2.89847E-09	-8.54E+00	3.0379E-09

Table B-0-2 Gust Maneuver Exceedance Curve Fit for Single Engine – Personal Use Aircraft

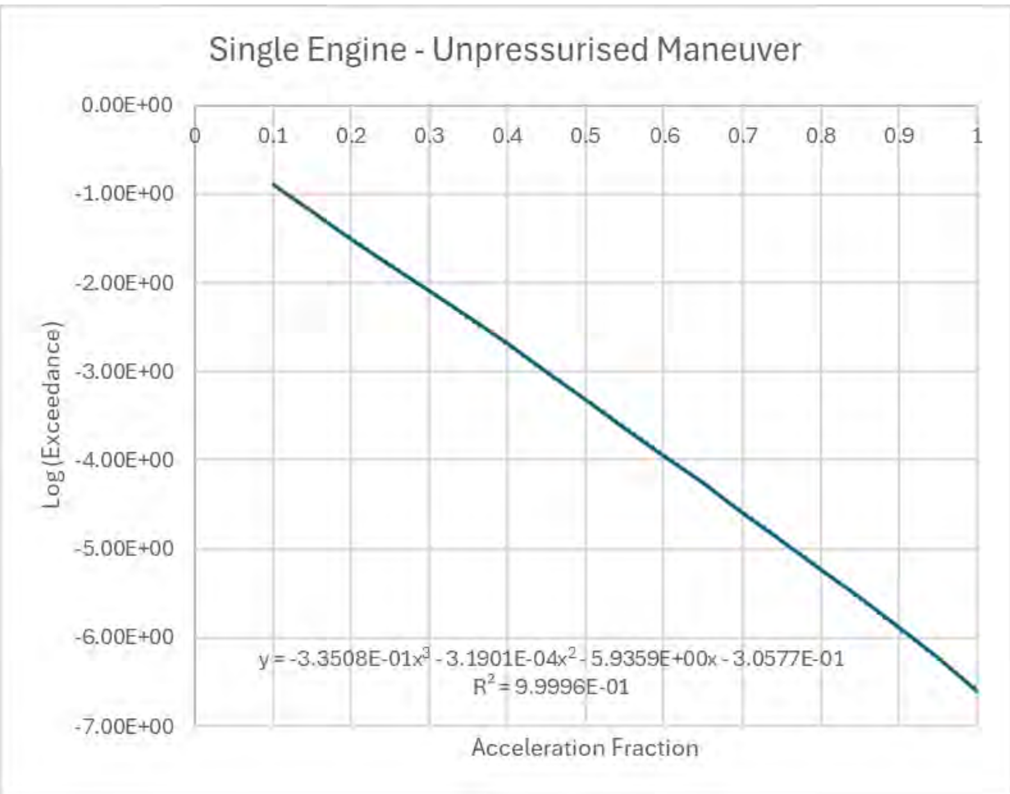

Figure B-0-3 Positive Maneuver Exceedance Curve Fit for Single Engine – Personal Use Aircraft

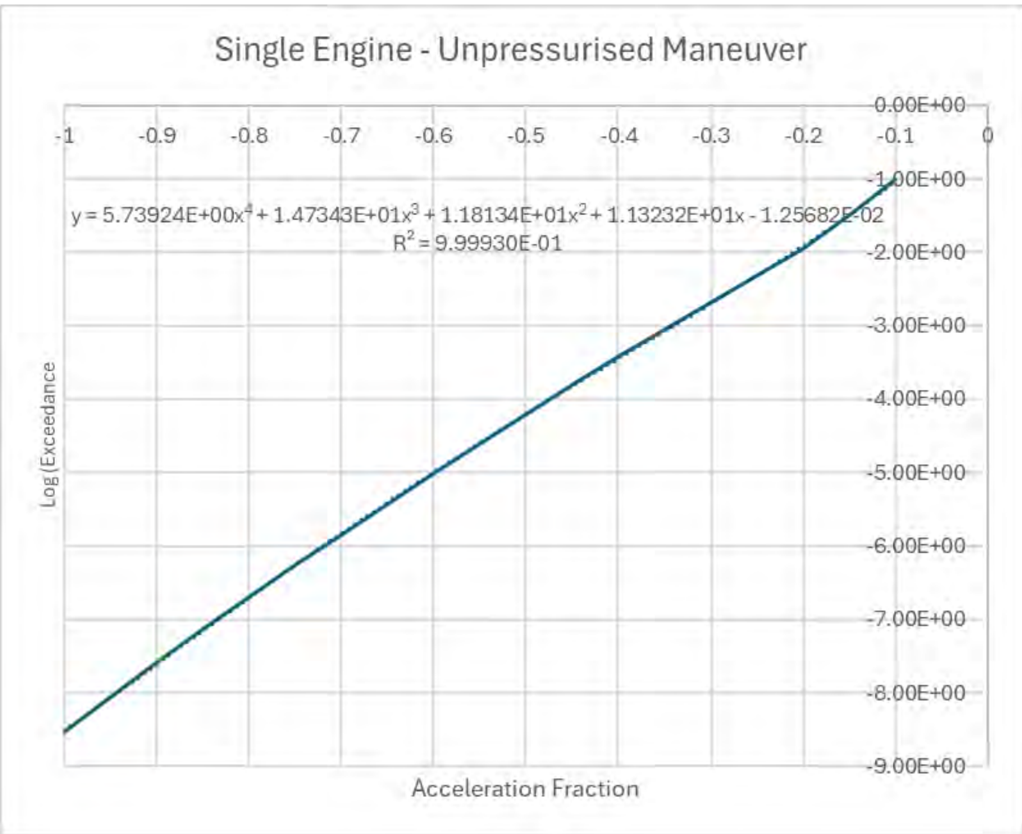

Figure B-0-4 Negative Maneuver Exceedance Curve Fit for Single Engine – Personal Use Aircraft

ANNEX C FUEL USAGE

A survey of gliding operators of Pawnees was carried out where operators were asked to estimate how much time they operated at the following weight brackets: full to two thirds, two thirds to one third, one third to empty. There were 12 responses representing 22 Pawnees (out of a total of 45 Pawnees). The majority of operators were starting with full fuel and then operating to a prescribed limit of tacho time (varied between operator) before refueling. This resulted in minimal (on average) operations into the below 1/3 fuel bracket.

Registration	Full to 2/3	2/3 to 1/3	Below 1/3
TOJ	60%	30%	10%
ALA	60%	30%	10%
SWR	45%	45%	10%
MLR	45%	45%	10%
CPU	50%	50%	0%
FBI	50%	50%	0%
SMS	50%	50%	0%
ALD	55%	40%	5%
BXP	55%	40%	5%
MCF	55%	40%	5%
IGR	20%	70%	10%
KLZ	46%	52%	2%
ORL	46%	52%	2%
CSN	60%	40%	0%
PIT	75%	34%	1%
BOT	75%	34%	1%
BCK	50%	40%	10%
TNC	50%	40%	10%
TUG	52%	45%	3%
FOO	45%	45%	10%
TNA	45%	45%	10%
WGC	55%	40%	5%
Average	**50%**	**45%**	**5%**