



## **NATIONAL TRANSPORTATION SAFETY BOARD**

Office of Aviation Safety  
Washington, D.C. 20594

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# **STRUCTURES**

## **Group Chairman's Rudder Loads Study**

**ANC20LA059**

**Appendix B – Rudder Loads  
(2 pages)**

Failed Rudder Information					
Rudder	Area (in <sup>2</sup> )	Area ft <sup>2</sup>	Centroid X (in)	Centroid Y (in)	y (in)
A	313.4100	2.1765	9.0625	0.4375	8.5000
B	305.7500	2.1233	8.8750	0.3125	8.1875
C	298.1900	2.0708	8.6875	0.1250	7.8750

Aircraft Data							
	W (lb)	S (ft <sup>2</sup> )	b (ft)	c (in)	Rudder deflect	n	W/S
PA-12 (normal)	1750	179.96	35.5	60	20	3.8	9.724383196
PA-12 (utility)	1500	179.96	35.5	60	20	4.4	8.335185597
PA-12S (normal)	1838	179.96	35.5	60	20	3.8	10.21338075
PA-18 (normal)	1750	178.5	35.21	60	25	3.8	9.803921569
PA-18 (utility)	1500	178.5	35.21	60	25	4.4	8.403361345
PA-18S (normal)	1760	178.5	35.21	60	25	3.8	9.859943978

Material Information					
Material	Ftu (ksi)	Fty (ksi)	Se-50 (ksi)	Se-35 (ksi)	Se-60 (ksi)
1025	55	36	27.5	19.25	33
4130	90	70	45	31.5	54

Rudder Tube Info	
do (in)	0.875
di (in)	0.805
I (in <sup>4</sup> )	0.008160544

Figure 3-3(b) data pulled from chart (Kwbar in psf)				
W/S	Curve A	Curve B	Curve C	Curve 25
~8.4	19.5	17.0	13.5	18.3
~9.8	22.5	19.5	15.5	17.5
~10.2	23.5	20.5	16.0	22.0

CAR 3.219(a) Calculations								
PA-12 (normal)			PA-18 (normal)					
wbar (psf)	w (lb)	Sigma (ksi)	wbar (psf)	w (lb)	Sigma (ksi)			
Rudder A	16.8409091	36.65354	16.70297203	Rudder A	15.11363636	32.8942	14.9898467	
Rudder B	16.8409091	35.75769	15.69566633	Rudder B	15.11363636	32.090238	14.0858544	
Rudder C	16.8409091	34.87355	14.72331542	Rudder C	15.11363636	31.296772	13.21323179	
PA-12 (utility)			PA-18 (utility)					
wbar (psf)	w (lb)	Sigma (ksi)	wbar (psf)	w (lb)	Sigma (ksi)			
Rudder A	17	36.99979	16.86075989	Rudder A	18.25	39.720365	18.10052165	
Rudder B	17	36.09549	15.84393848	Rudder B	18.25	38.749566	17.00893395	
Rudder C	17	35.20299	14.86240207	Rudder C	18.25	37.791441	15.95522576	
PA-12S (normal)			PA-18S (normal)					
wbar (psf)	w (lb)	Sigma (ksi)	wbar (psf)	w (lb)	Sigma (ksi)			
Rudder A	17.7045455	38.53321	17.5595347	Rudder A	15.11363636	32.8942	14.9898467	
Rudder B	17.7045455	37.59142	16.50057229	Rudder B	15.11363636	32.090238	14.0858544	
Rudder C	17.7045455	36.66193	15.47835724	Rudder C	15.11363636	31.296772	13.21323179	

CAR 3.219(b) Calculations								
PA-12 (normal)			PA-18 (normal)					
wbar (psf)	w (lb)	Sigma (ksi)	wbar (psf)	w (lb)	Sigma (ksi)			
Rudder A	13.3863636	29.13486	13.27672136	Rudder A	13.38636364	29.134863	13.27672136	
Rudder B	13.3863636	28.42278	12.95222729	Rudder B	13.38636364	28.422783	12.47604246	
Rudder C	13.3863636	27.72	12.63196944	Rudder C	13.38636364	27.719998	11.70314816	
PA-12 (utility)			PA-18 (utility)					
wbar (psf)	w (lb)	Sigma (ksi)	wbar (psf)	w (lb)	Sigma (ksi)			
Rudder A	13.5	29.38219	13.38942697	Rudder A	13.5	29.382188	13.38942697	
Rudder B	13.5	28.66406	12.58195114	Rudder B	13.5	28.664063	12.58195114	
Rudder C	13.5	27.95531	11.80249576	Rudder C	13.5	27.955313	11.80249576	
PA-12S (normal)			PA-18S (normal)					
wbar (psf)	w (lb)	Sigma (ksi)	wbar (psf)	w (lb)	Sigma (ksi)			
Rudder A	13.8181818	30.0747	13.70500269	Rudder A	13.38636364	29.134863	13.27672136	
Rudder B	13.8181818	29.33965	12.87849545	Rudder B	13.38636364	28.422783	12.47604246	
Rudder C	13.8181818	28.61419	12.08066907	Rudder C	13.38636364	27.719998	11.70314816	

CAR 3.219(c) Calculations								
PA-12 (normal)			PA-18 (normal)					
wbar (psf)	w (lb)	Sigma (ksi)	wbar (psf)	w (lb)	Sigma (ksi)			
Rudder A	19.4318182	42.29254	19.27266004	Rudder A	19.43181818	42.292543	19.27266004	
Rudder B	19.4318182	41.25888	18.11038422	Rudder B	19.43181818	41.258878	18.11038422	
Rudder C	19.4318182	40.23871	16.98844087	Rudder C	19.43181818	40.238707	16.98844087	
PA-12 (utility)			PA-18 (utility)					
wbar (psf)	w (lb)	Sigma (ksi)	wbar (psf)	w (lb)	Sigma (ksi)			
Rudder A	19.5	42.44094	19.34028341	Rudder A	19.5	42.440938	19.34028341	
Rudder B	19.5	41.40365	18.17392943	Rudder B	19.5	41.403646	18.17392943	
Rudder C	19.5	40.3799	17.04804944	Rudder C	19.5	40.379896	17.04804944	
PA-12S (normal)			PA-18S (normal)					
wbar (psf)	w (lb)	Sigma (ksi)	wbar (psf)	w (lb)	Sigma (ksi)			
Rudder A	20.2954545	44.17221	20.12922271	Rudder A	19.43181818	42.292543	19.27266004	
Rudder B	20.2954545	43.09261	18.91529019	Rudder B	19.43181818	41.258878	18.11038422	
Rudder C	20.2954545	42.02709	17.74348269	Rudder C	19.43181818	40.238707	16.98844087	

Car 3.220 Calculations											
U	30	fps									
V	110	mph	PA-12, PA-12S, PA-18S								
v	121	mph	PA-18								
m	2.51	per radian									
PA-12 (normal)			PA-18 (normal)								
W/Sv (psf)	K	wbar (psf)	w (lb)	Sigma (ksi)	W/Sv (psf)	K	wbar (psf)	w (lb)	Sigma (ksi)		
Rudder A	804.058581	1.300198	18.72963352	40.76426696	18.576227	Rudder A	804.05858	1.300197908	20.60259687	44.84069	20.43384936
Rudder B	824.20278	1.300746	18.73752725	39.78471498	17.463308	Rudder B	824.20278	1.300745885	20.61127998	43.76319	19.20963835
Rudder C	845.098763	1.30129	18.74536656	38.87122815	16.388304	Rudder C	845.09876	1.301290084	20.61990321	42.69895	18.02713484
PA-12 (utility)			PA-18 (utility)								
W/Sv (psf)	K	wbar (psf)	w (lb)	Sigma (ksi)	W/Sv (psf)	K	wbar (psf)	w (lb)	Sigma (ksi)		
Rudder A	689.19307	1.296545	18.67701724	40.64974981	18.524041	Rudder A	689.19307	1.296545323	20.54471896	44.71472	20.3764455
Rudder B	706.459526	1.29716	18.68587843	39.67505091	17.415171	Rudder B	706.45953	1.297160461	20.55446628	43.64256	19.15668819
Rudder C	724.370368	1.297771	18.69467854	38.71226523	16.34399	Rudder C	724.37037	1.297771358	20.56414639	42.58349	17.97838894
PA-12S (normal)			PA-18S (normal)								
W/Sv (psf)	K	wbar (psf)	w (lb)	Sigma (ksi)	W/Sv (psf)	K	wbar (psf)	w (lb)	Sigma (ksi)		
Rudder A	844.491242	1.301275	18.74514344	40.79802364	18.59161	Rudder A	808.6532	1.300324996	18.73146425	40.76825	18.57804242
Rudder B	865.648406	1.301803	18.75275198	39.81704111	17.477497	Rudder B	828.91251	1.300870637	18.73932432	39.78853	17.46498245
Rudder C	887.595157	1.302327	18.76038087	38.84816849	16.401367	Rudder C	849.9279	1.301412515	18.74713019	38.82088	16.38994628

Limit Bending Stress in Rudder Post for Maneuvering and Gust					
	Rudder	CAR 3.219(a) (ksi)	CAR3.219(b) (ksi)	CAR 3.219(c) (ksi)	CAR 3.220 (ksi)
PA-12 (normal)	A	16.7	13.3	19.3	18.6
	B	15.7	13.0	18.1	17.5
	C	14.7	12.6	17.0	16.4
PA-12 (utility)	A	16.9	13.4	19.3	18.5
	B	15.8	12.6	18.2	17.4
	C	14.9	11.8	17.0	16.3
PA-12S (normal)	A	17.6	13.7	20.1	18.6
	B	16.5	12.9	18.9	17.5
	C	15.5	12.1	17.7	16.4
PA-18 (normal)	A	15.0	13.3	19.3	20.4
	B	14.1	12.5	18.1	19.2
	C	13.2	11.7	17.0	18.0
PA-18 (utility)	A	18.1	13.4	19.3	20.4
	B	17.0	12.6	18.2	19.2
	C	16.0	11.8	17.0	18.0
PA-18S (normal)	A	15.0	13.3	19.3	18.6
	B	14.1	12.5	18.1	17.5
	C	13.2	11.7	17.0	16.4