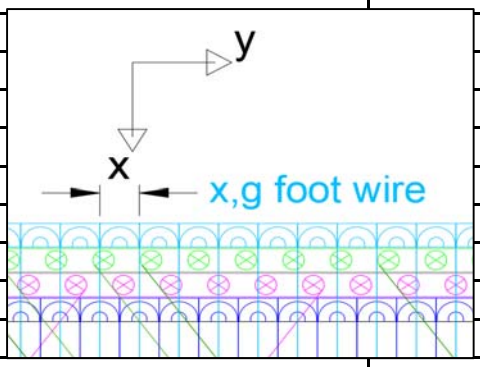
Summary of results of APA stack up analysis - board accuracy to 100 microns						
	sheet #	Worst case	RSS	Require-ment	Board accuracy contributes	Comments
Within a board stack						
Wire spacing						
Foot x and g	1a	0.09	0.09	0.5	no	
Foot u and v	1b	0.12	0.09	0.5	no	
Side	2	0.12	0.08	0.5	no	
head					*	
Plane to plane spacing						
Foot - new-tool	4a	0.56	0.29	0.5	yes	
Foot - baseline	4b	1.23	0.84	0.5	yes	
Side - u to v	5a	0.51	0.29	0.5	yes	
Side -v/x, u/g no bow	5b	1.02	0.28	0.5	yes	
Side -v/x, u/g w/bow	5c	1.52	0.57	0.5	yes	Very localized effect
Head	6	0.24	0.24	0.5	*	
Between boards						
Wire spacing						
Foot x and g	7a	1.06	0.50	0.5	no	
Foot u and v	7b	1.30	0.48	0.5	no	
Side	8	0.85	0.34	0.5	no	
head - x and g	9a	0.82	0.35	0.5	*	
head - u and v	9b	0.90	0.41	0.5	*	
Gap between boards						
Foot	10	0.86	0.36	0.4	yes	
Side	11	0.82	0.35	0.4	yes	
Head - straight	12a	0.82	0.35	0.4	yes	
Head - Angled	12b	0.90	0.41	0.4	yes	
Tooth strip to tooth strip						
Foot x and g	13	1.06	0.50	0.5	no	
Foot u and v	13	1.06	0.50	0.4	no	
Side	14	1.02	0.49	0.4	no	
Other locations to consider						
Wire spacing						
corner - foot to side boards						
side boards to combs						
corner - side to head						
Plane to plane spacing						
corner - foot to side boards						
side boards to combs						
corner - side to head						
*Wire location depends on solder pad locational accuracy rather than machining accuracy						

x and g wire spacing within a foot board

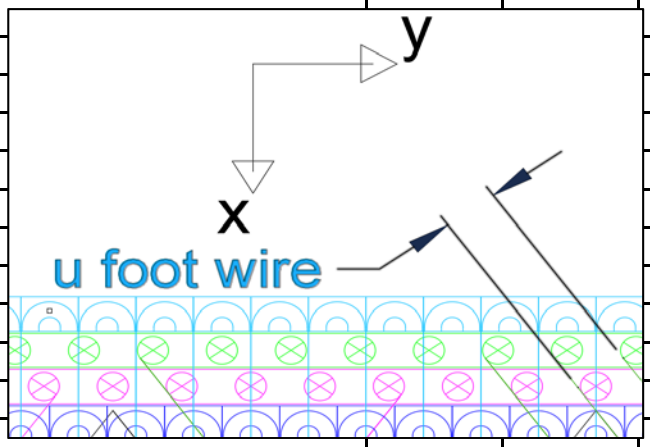
x and g wire spacing



Contributions to stack up in y

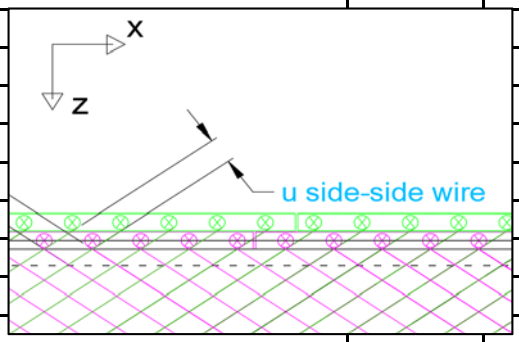
Description	DWG tolerance or spec	Effect on position	Stack-up Tolerance (+/-)	Effect on wire spacing (+/-)		
Tooth strip groove to groove	=+/-0.09	=t	0.090	0.053		
Tooth strip groove to groove	0.090					
Worst Case wire to wire	0.090					
RSS wire to wire	0.090					

u and v wire spacing within a foot board						
u wire spacing						
Contributions to stack up in y						
Description	DWG tolerance or spec	Effect on position	Stack-up Tolerance (+/-)	Effect on wire spacing (+/-)		
Tooth strip tooth to tooth	=+/-0.09	=t	0.090	0.073		
Total y cont for one board				0.073		
Contributions to stack up in x						
Tooth strip tooth to tooth	=+/-0.08	=t	0.080	0.047		
Total x cont for one board				0.047		
Total wire to wire				0.120		
RSS wire to wire				0.087		



u and v wire spacing within a side board

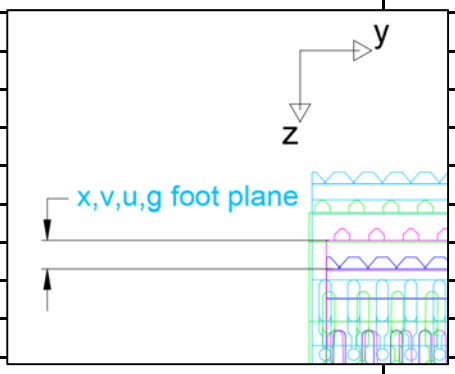
u wire spacing

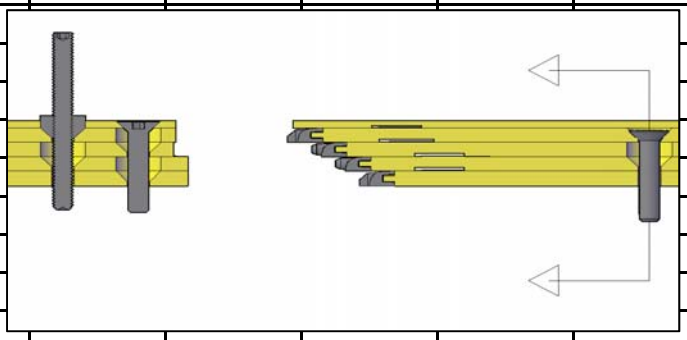


Contributions to stack up in x

Description	DWG tolerance or spec	Effect on position	Stack-up Tolerance (+/-)	Effect on wire spacing (+/-)		
Tooth strip tooth to tooth	=+/-0.09	=t	0.090	0.053		
Total y cont for one board				0.053		
Contributions to stack up in z						
Tooth strip tooth to tooth	=+/-0.08	=t	0.080	0.065		
Total x cont for one board				0.065		
Total wire to wire				0.117		
RSS wire to wire				0.084		

x,v,u,g foot board plane to plane spacing - with proposed tool

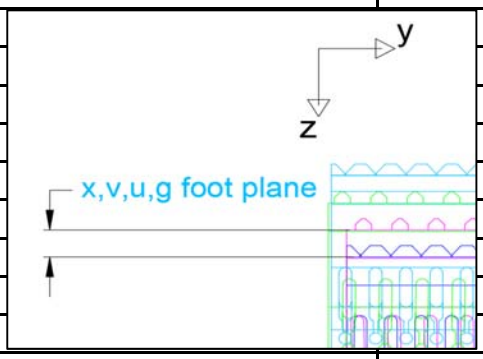


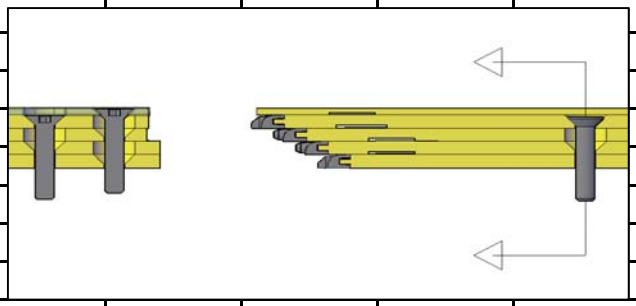


Contributions to stack up in z

Description	DWG tolerance or spec	Effect on position	Stack-up Tolerance (+/-)
Concentricity of tool	0.050	=t/2	0.025
Tool OD	=+/-0.025	=t/2	0.013
Min. clearance	0.000	=c/4	0.000
hole ID	=+/-0.100	=t/2	0.050
Location of "shoulder"	=+/-0.1	=t	0.100
Height of tooth strip	=+/-0.09	=t	0.090
Total for one board			0.278
Worst Case Plane to Plane			0.56
RSS Plane to Plane			0.292

x,v,u,g foot board plane to plane spacing





Contributions to stack up in z

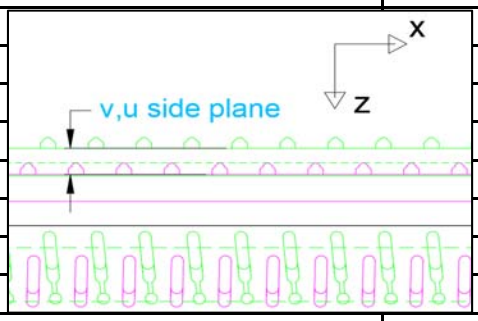
Description	DWG tolerance or spec	Effect on position	Stack-up Tolerance (+/-)
*Hole position in tube	0.250	=t/2	0.13
Tapped Hole pitch diameter	=+/-0.059	=t/2	0.03
Min screw radial clearance	0.022	=t/4	0.01
Screw pitch diameter	=+/-0.045	=t/2	0.02
**Concentricity screw head (3%)	0.240	=t	0.24
Location of "shoulder"	=+/-0.100	=t	0.10
Height of tooth strip	=+/-0.090	=t	0.09
Total for one board			0.61
Worst Case Plane to Plane			1.23
RSS Plane to Plane			0.836

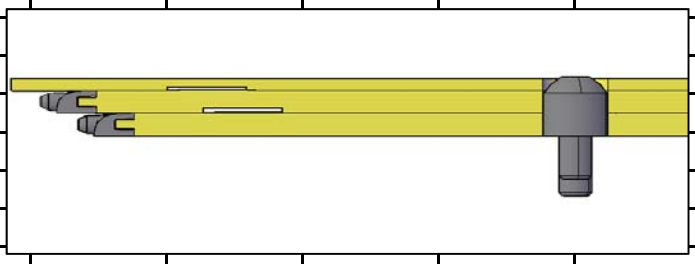
*Verified with TradeTech (frame vendor) via email

**Screw thread standards for Federal services, 1944.

"heads … shall be concentric within … 3% of axis of body"

v,u side board plane to plane spacing - does not include x to v or u to g

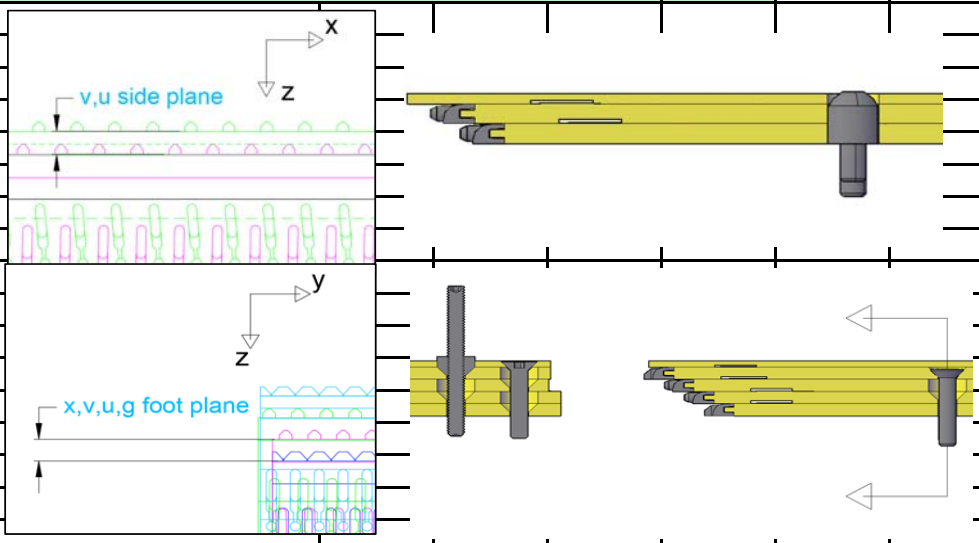




Contributions to stack up in z

Description	DWG tolerance or spec	Effect on position	Stack-up Tolerance (+/-)
Pin OD	=+/-0.025	=t/2	0.013
Min clearance	0.000	=c/4	0.000
Hole ID	=+/-0.100	=t/2	0.050
Location of "shoulder"	=+/-0.100	=t	0.100
Height of tooth strip	=+/-0.090	=t	0.090
Total for one board			0.253
Worst Case Plane to Plane			0.505
RSS Plane to Plane			0.288

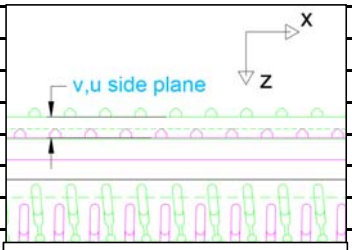
v to x and u to g plane to plane spacing - this is a local effect

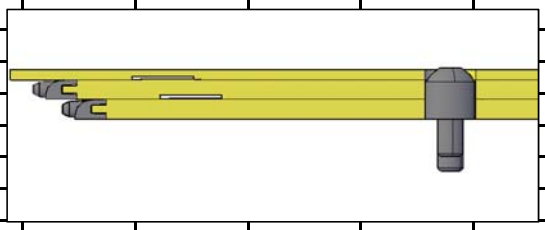


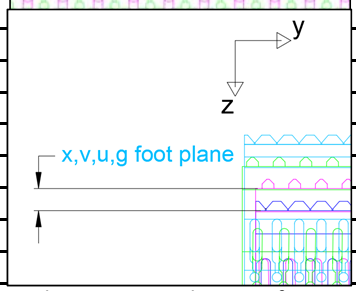
Contributions to stack up in z from u or v board						
Description	DWG tolerance or spec	Effect on position	Stack-up Tolerance (+/-)			
*Hole position in tube	0.250	=t/2	0.125			
Tapped Hole pitch diameter	=+/-0.059	=t/2	0.030			
Min screw radial clearance	0.022	=t/4	0.006			
Screw pitch diameter	=+/-0.045	=t/2	0.023			
Screw major diameter tolerance	=+/-0.070	=t/2	0.035			
Sleeve ID tolerance	=+/-.025	=t/2	0.013			
Min screw radial clearance	0.020	=t/4	0.005			
sleeve concentricity	0.025	=t/2	0.013			
Pin OD	=+/-0.025	=t/2	0.013			
Min clearance	0.000	=c/4	0.000			
Hole ID	=+/-0.100	=t/2	0.050			
Location of "shoulder"	=+/-0.100	=t	0.100			
Height of tooth strip	=+/-0.090	=t	0.090			
Total for one board			0.500			
Contributions to stack up in z from x or g foot board						
*Hole position in tube	0.250	=t/2	0.125			
Tapped Hole pitch diameter tol.	=+/-0.059	=t/2	0.030			
Min screw radial clearance	0.022	=t/4	0.006			
Screw pitch diameter tol	=+/-0.045	=t/2	0.023			
Tapped Hole pitch diameter tol.	=+/-0.059	=t/2	0.030			
Min screw radial clearance	0.022	=t/4	0.006			
Screw pitch diameter tol	=+/-0.045	=t/2	0.023			
Concentricity of tool	0.050	=t/2	0.025			
Tool OD	=+/-0.025	=t/2	0.013			
Min. clearance	0.000	=c/4	0.000			
hole ID	=+/-0.100	=t/2	0.050			
Location of "shoulder"	=+/-0.1	=t	0.100			
Height of tooth strip	=+/-0.09	=t	0.090			
Total for one board			0.518			
Worst case for plane to plane for both boards			1.018			
RSS Plane to Plane			0.281			
*Verified with TradeTech (frame vendor) via email						

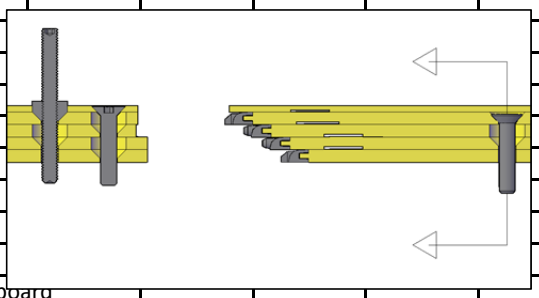
v to x and u to g plane to plane spacing Including frame bow- very local effect

Bow tolerance is 11mm which translates to 0.5mm over one cell.





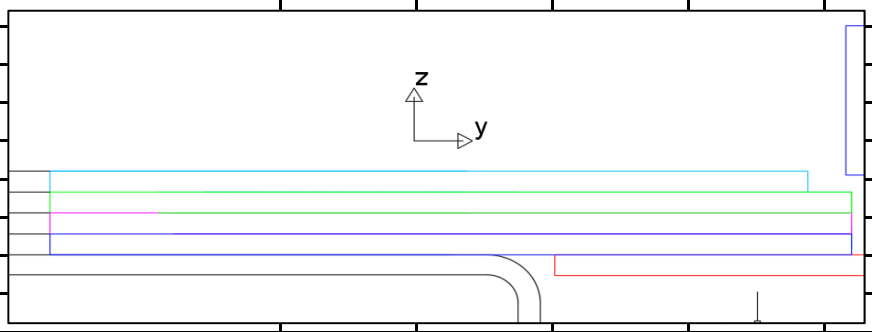




Contributions to stack up in z from u or v board

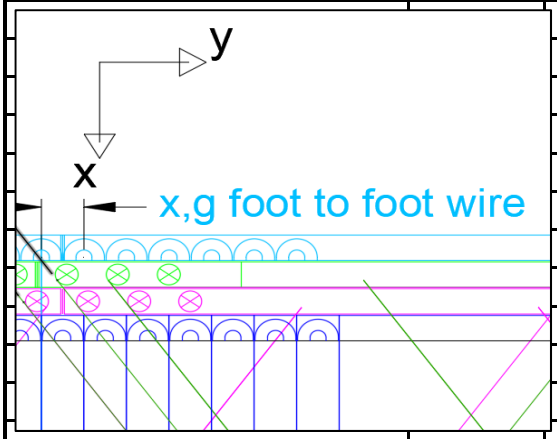
Description	DWG tolerance or spec	Effect on position	Stack-up Tolerance (+/-)
Bow in frame limit for one cell	+/-0.5	=t	0.5
*Hole position in tube	0.250	=t/2	0.13
Tapped Hole pitch diameter	=+/-0.059	=t/2	0.03
Min screw radial clearance	0.022	=t/4	0.01
Screw pitch diameter	=+/-0.045	=t/2	0.02
Screw major diameter tolerance	=+/-0.070	=t/2	0.035
Sleeve ID tolerance	=+/-.025	=t/2	0.013
Min screw radial clearance	0.020	=t/4	0.005
sleeve concentricity	0.025	=t/2	0.013
Pin OD	=+/-0.025	=t/2	0.013
Min clearance	0.000	=c/4	0.000
Hole ID	=+/-0.100	=t/2	0.050
Location of "shoulder"	=+/-0.100	=t	0.100
Height of tooth strip	=+/-0.090	=t	0.090
Total for one board			1.000
Contributions to stack up in z from x or g foot board			
*Hole position in tube	0.250	=t/2	0.13
Tapped Hole pitch diameter tol.	=+/-0.059	=t/2	0.03
Min screw radial clearance	0.022	=t/4	0.01
Screw pitch diameter tol	=+/-0.045	=t/2	0.02
Tapped Hole pitch diameter tol.	=+/-0.059	=t/2	0.03
Min screw radial clearance	0.022	=t/4	0.01
Screw pitch diameter tol	=+/-0.045	=t/2	0.02
Concentricity of tool	0.050	=t/2	0.025
Tool OD	=+/-0.025	=t/2	0.013
Min. clearance	0.000	=c/4	0.000
hole ID	=+/-0.100	=t/2	0.050
Location of "shoulder"	=+/-0.1	=t	0.100
Height of tooth strip	=+/-0.09	=t	0.090
Total for one board			0.518
Worst case for plane to plane for both boards			1.518
RSS Plane to Plane			0.574
*Verified with TradeTech (frame vendor) via email			

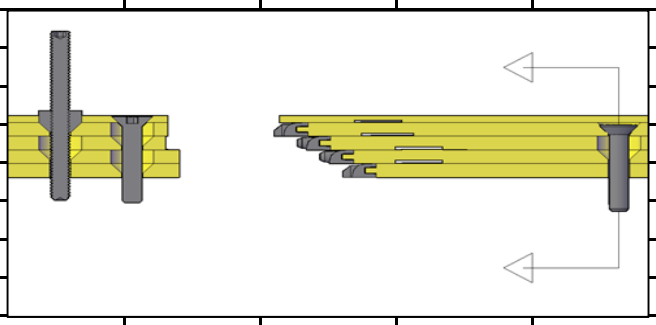
Plane spacing between head boards						
v wire spacing						
Contributions to stack up in z						
Description	DWG tolerance or spec	Effect on position	Stack-up Tolerance (+/-)			
z board thickness	0.240	=t	0.240			
Worst case plane to plane			0.240			
RSS Plane to Plane			0.240			



Wire spacing for x and g teeth across the gap on foot boards

x and g wire spacing





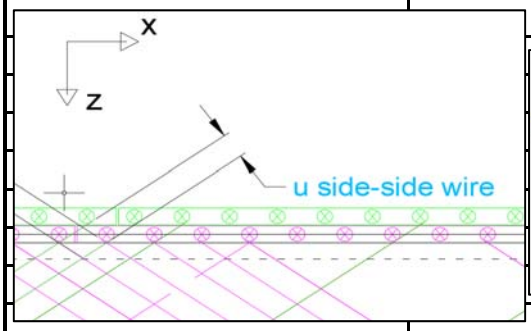
Contributions to stack up in y

Description	DWG tolerance or spec	Effect on position	Stack-up Tolerance (+/-)
*Hole position in tube	0.250	=t/2	0.125
Tapped Hole pitch diameter tol.	=+/-0.059	=t/2	0.030
Min screw radial clearance	0.022	=t/4	0.006
Screw pitch diameter tol	=+/-0.045	=t/2	0.023
Tapped Hole pitch diameter tol.	=+/-0.059	=t/2	0.030
Min screw radial clearance	0.022	=t/4	0.006
Screw pitch diameter tol	=+/-0.045	=t/2	0.023
Concentricity of tool	0.050	=t/2	0.025
Tool OD	=+/-0.025	=t/2	0.013
Min. clearance	0.000	=c/4	0.000
hole ID	=+/-0.100	=t/2	0.050
Location of tooth	=+/-0.2	=t	0.200
Total for one board			0.528
Worst case for tooth to tooth across gap			1.055
RSS Plane to Plane			0.497

*Verified with TradeTech (frame vendor) via email

Wire spacing between u and v teeth across the gap on foot boards						
v wire spacing						

Wire spacing between u teeth across the gap on side boards



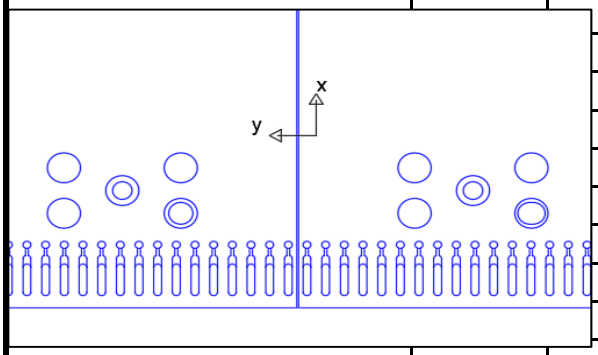
Contributions to stack up in z from u or v board

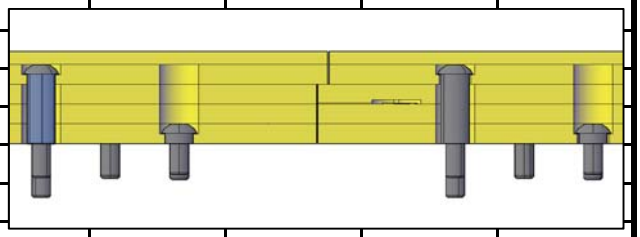
Description	DWG tolerance or spec	Effect on position	Stack-up Tolerance (+/-)	Effect on wire spacing
v board thickness	0.150	=t	0.150	0.122
Strip datum to pin	0.080	=t	0.080	0.065
Total x cont for one board				0.187

Contributions to stack up in x from u or v board

*Hole position in tube	0.250	=t/2	0.13	0.073
Tapped Hole pitch diameter	=+/-0.059	=t/2	0.03	0.017
Min screw radial clearance	0.022	=t/4	0.01	0.003
Screw pitch diameter	=+/-0.045	=t/2	0.02	0.013
Screw major diameter tolerance	=+/-0.070	=t/2	0.035	0.020
Sleeve ID tolerance	=+/-.025	=t/2	0.013	0.007
Min screw radial clearance	0.020	=t/4	0.005	0.003
sleeve concentricity	0.025	=t/2	0.013	0.007
Pin OD	=+/-0.025	=t/2	0.013	0.007
Min clearance	0.000	=c/4	0.000	0.000
Hole ID	=+/-0.100	=t/2	0.050	0.029
Location of "edge"	=+/-0.100	=t	0.100	0.058
Total for one board				0.239
Total for two boards				0.853
RSS board to board				0.345

Solder pad spacing between x and g solder pads across the gap on head boards

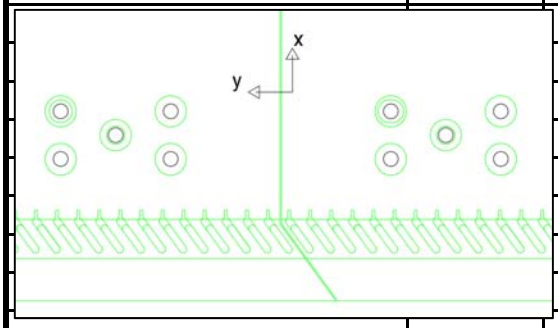


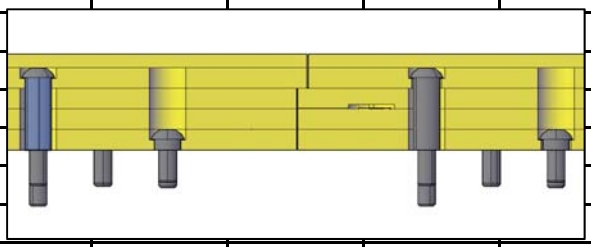


Contributions to stack up in y from g board

Description	DWG tolerance or spec	Effect on position	Stack-up Tolerance (+/-)
*Hole position in tube	0.250	=t/2	0.13
Tapped Hole pitch diameter	=+/-0.059	=t/2	0.03
Min screw radial clearance	0.022	=t/4	0.01
Screw pitch diameter	=+/-0.045	=t/2	0.02
Screw major diameter tolerance	=+/-0.070	=t/2	0.035
Sleeve ID tolerance	=+/-.025	=t/2	0.013
Min screw radial clearance	0.020	=t/4	0.005
sleeve concentricity	0.025	=t/2	0.013
Pin OD	=+/-0.025	=t/2	0.013
Min clearance	0.000	=c/4	0.000
Hole ID	=+/-0.100	=t/2	0.050
Location of "solder pad"	=+/-0.100	=t	0.100
Total for one board			0.410
Total for two boards			0.820
RSS board to board			0.354

Solder pad spacing between u and v solder pads across the gap on head boards

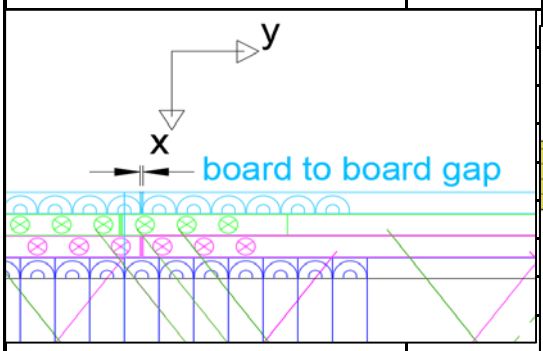


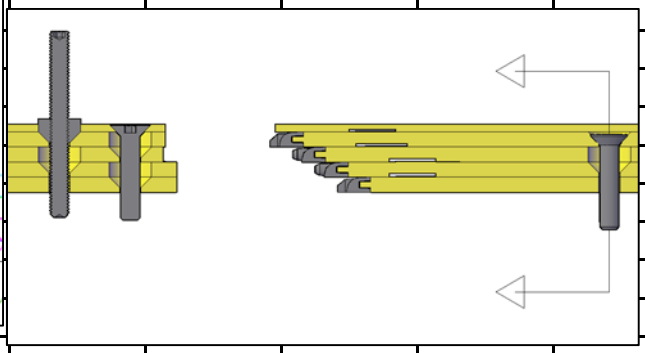


Contributions to stack up to perpendicular distance between solder pads

Description	DWG tolerance or spec	Effect on position	Stack-up Tolerance (+/-)
*Hole position in tube	0.250	=t/2	0.13
Tapped Hole pitch diameter	=+/-0.059	=t/2	0.03
Min screw radial clearance	0.022	=t/4	0.01
Screw pitch diameter	=+/-0.045	=t/2	0.02
Screw major diameter tolerance	=+/-0.070	=t/2	0.035
Sleeve ID tolerance	=+/-.025	=t/2	0.013
Min screw radial clearance	0.020	=t/4	0.005
sleeve concentricity	0.025	=t/2	0.013
Pin OD	=+/-0.025	=t/2	0.013
Min clearance	0.000	=c/4	0.000
Hole ID	=+/-0.100	=t/2	0.050
Location of "pad"	=+/-0.141	=t	0.141
Total for one board			0.451
Total for two boards			0.902
			0.406

Gap between foot boards						

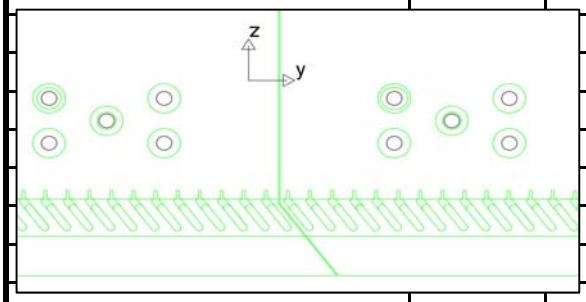


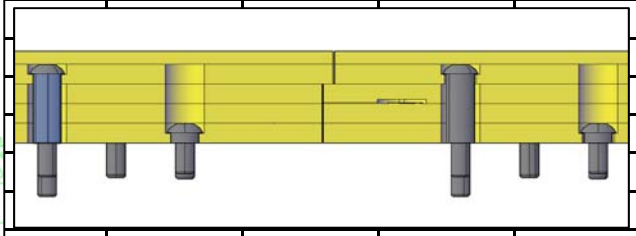


Contributions to stack up in y						
Description	DWG tolerance or spec	Effect on position	Stack-up Tolerance (+/-)			
*Hole position in tube	0.250	=t/2	0.125			
Tapped Hole pitch diameter tol.	=+/-0.059	=t/2	0.030			
Min screw radial clearance	0.022	=t/4	0.006			
Screw pitch diameter tol	=+/-0.045	=t/2	0.023			
Tapped Hole pitch diameter tol.	=+/-0.059	=t/2	0.030			
Min screw radial clearance	0.022	=t/4	0.006			
Screw pitch diameter tol	=+/-0.045	=t/2	0.023			
Concentricity of tool	0.050	=t/2	0.025			
Tool OD	=+/-0.025	=t/2	0.013			
Min. clearance	0.000	=c/4	0.000			
hole ID	=+/-0.100	=t/2	0.050			
Location of board edge	=+/-0.100	=t	0.100			
Total for one board			0.428			
Worst case for tooth to tooth across gap			0.855			
RSS Plane to Plane			0.356			
*Verified with TradeTech (frame vendor) via email						

Gap between side boards						

Gap between u and v head boards

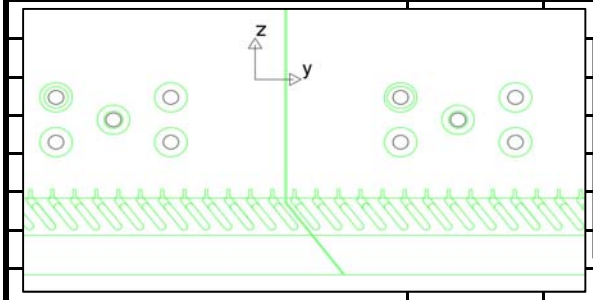


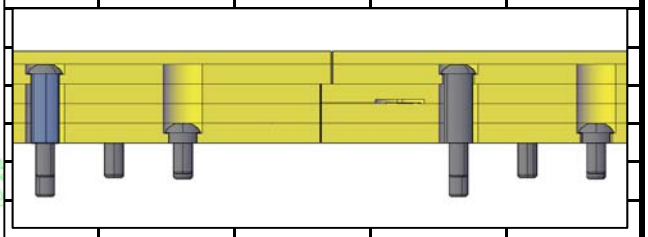


Contributions to stack up in y from v board

Description	DWG tolerance or spec	Effect on position	Stack-up Tolerance (+/-)
*Hole position in tube	0.250	=t/2	0.125
Tapped Hole pitch diameter	=+/-0.059	=t/2	0.030
Min screw radial clearance	0.022	=t/4	0.006
Screw pitch diameter	=+/-0.045	=t/2	0.023
Screw major diameter tolerance	=+/-0.070	=t/2	0.035
Sleeve ID tolerance	=+/-.025	=t/2	0.013
Min screw radial clearance	0.020	=t/4	0.005
sleeve concentricity	0.025	=t/2	0.013
Pin OD	=+/-0.025	=t/2	0.013
Min clearance	0.000	=c/4	0.000
Hole ID	=+/-0.100	=t/2	0.050
Location of "straight" edge	=+/-0.100	=t	0.100
Total for one board			0.410
Total for two boards			0.820
RSS board to board			0.354

Gap between angled surface of u and v head boards

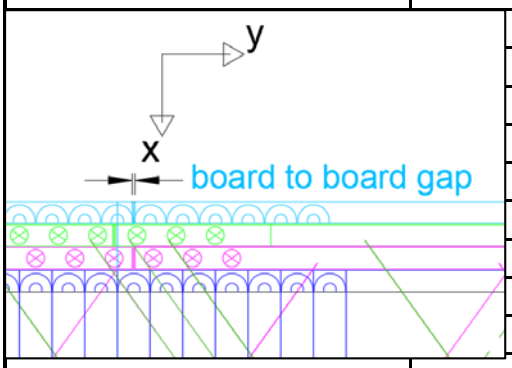


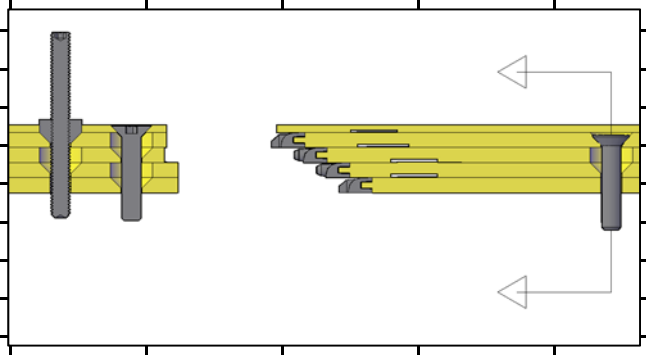


Contributions to stack up perpendicular to angled gap

Description	DWG tolerance or spec	Effect on position	Stack-up Tolerance (+/-)
*Hole position in tube	0.250	=t/2	0.13
Tapped Hole pitch diameter	=+/-0.059	=t/2	0.03
Min screw radial clearance	0.022	=t/4	0.01
Screw pitch diameter	=+/-0.045	=t/2	0.02
Screw major diameter tolerance	=+/-0.070	=t/2	0.035
Sleeve ID tolerance	=+/-.025	=t/2	0.013
Min screw radial clearance	0.020	=t/4	0.005
sleeve concentricity	0.025	=t/2	0.013
Pin OD	=+/-0.025	=t/2	0.013
Min clearance	0.000	=c/4	0.000
Hole ID	=+/-0.100	=t/2	0.050
Location of "angled" edge	=+/-0.141	=t	0.141
Total for one board			0.451
			0.902
			0.406

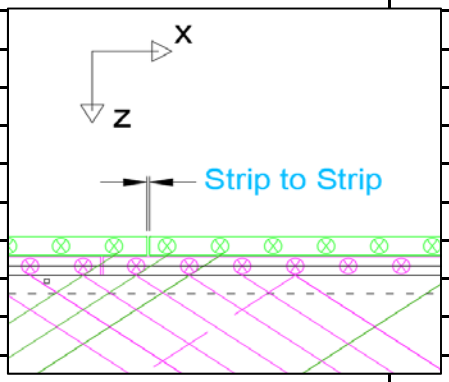
Gap between foot tooth strips						

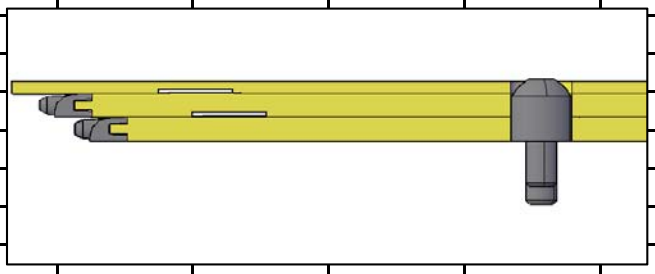




Contributions to stack up in y						
Description	DWG tolerance or spec	Effect on position	Stack-up Tolerance (+/-)			
*Hole position in tube	0.250	=t/2	0.125			
Tapped Hole pitch diameter tol.	=+/-0.059	=t/2	0.030			
Min screw radial clearance	0.022	=t/4	0.006			
Screw pitch diameter tol	=+/-0.045	=t/2	0.023			
Tapped Hole pitch diameter tol.	=+/-0.059	=t/2	0.030			
Min screw radial clearance	0.022	=t/4	0.006			
Screw pitch diameter tol	=+/-0.045	=t/2	0.023			
Concentricity of tool	0.050	=t/2	0.025			
Tool OD	=+/-0.025	=t/2	0.013			
Min. clearance	0.000	=c/4	0.000			
hole ID	=+/-0.100	=t/2	0.050			
Location of tooth edge	=+/-0.200	=t	0.200			
Total for one board			0.528			
Worst case for tooth to tooth across gap			1.055			
RSS Plane to Plane			0.497	Nominal gap is 0.5		
*Verified with TradeTech (frame vendor) via email						

Gap between side tooth strips





Contributions to stack up in x

Description	DWG tolerance or spec	Effect on position	Stack-up Tolerance (+/-)
*Hole position in tube	0.250	=t/2	0.13
Tapped Hole pitch diameter	=+/-0.059	=t/2	0.03
Min screw radial clearance	0.022	=t/4	0.01
Screw pitch diameter	=+/-0.045	=t/2	0.02
Screw major diameter tolerance	=+/-0.070	=t/2	0.035
Sleeve ID tolerance	=+/-.025	=t/2	0.013
Min screw radial clearance	0.020	=t/4	0.005
sleeve concentricity	0.025	=t/2	0.013
Pin OD	=+/-0.025	=t/2	0.013
Min clearance	0.000	=c/4	0.000
Hole ID	=+/-0.100	=t/2	0.050
Location of "edge"	=+/-0.200	=t	0.200
Total for one strip			0.510
Total for two strip			1.020
RSS strip to strip			0.495