

SELF-PIERCE RIVETING SCHEDULE DEVELOPMENT ACCEPTANCE TEST FOR ALUMINUM UNCOATED AND COATED LOW CARBON STEEL SHEET

Application

This procedure defines the self-pierce riveting acceptance test for rivet schedule development for aluminum, uncoated and coated low carbon steel sheet. All such sheet material must pass minimum performance testing. Consult the appropriate Engineering Material Specification for material exceptions. Testing confirms that the correct rivet and die combination were used to satisfactorily join a given gauge of sheet metal together. Cross sections of the rivet joint must be evaluated to insure a robust rivet joint. After the correct tooling has been identified lap-shear and T-peel samples are built. Initial testing requires a sample size of 30 each for the strength tests. Samples are pulled on a tensile test machine.

Apparatus Required

Self-pierce riveting press

This test shall be conducted on an appropriate hydraulic or servo driven single point press-type SPR pedestal riveting system and, in general, complying with the Self-pierce Riveting Manufacturing requirements for size and type of machine required. It shall have preclamp and punch force capacities to meet the requirement of the range of material gauges to be tested.

Flushness Gauge

Digital Metric Dial Caliper – Mitutoyo Model #ID-C1012EB or equivalent.



Flushness Gauge (To calibrate the gauge place on a surface plate feet down and press the zero button)

Self-piercing Rivet

Ford standard design will be used for all tests. The rivet coating method and base material will be selected from Ford Manufacturing Standard, S900. Processing will follow Engineering Specification ES-5G1A-1B279-AA.

Date	Action	Revisions
2006 05 25	Activated	



Preparation of Material

The material for self-pierce riveting qualification shall be representative of production practices in the ordered thickness. The material shall be sheared in 25X100 mm pieces free from burrs and prepared from the material under test. Care shall be exercised so as not to remove any oils or die lubrication used for stamping, corrosion or shipping protection.

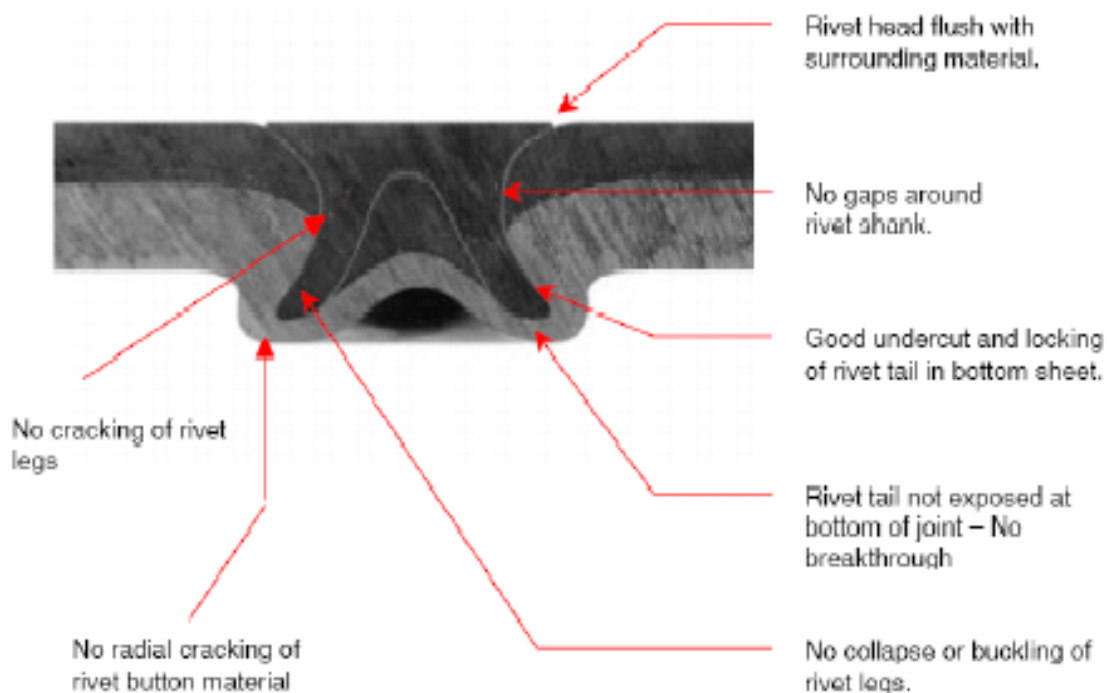
Coated Galvanized Sheet Material

Coating thickness on each side of panels must meet required manufacturer's specification for production intent.

SPR C-frame Alignment

The C-frame alignment should be checked before test samples are built. A properly manufactured C-frame will produce a uniform, symmetrically shaped, round button. Alignment is checked by setting rivets in a coupon and evaluated by 2 cross sections taken inline and transverse through the rivet centerline.

Ideal Self-Pierce Rivet (SPR) Metallographic Cross-sections

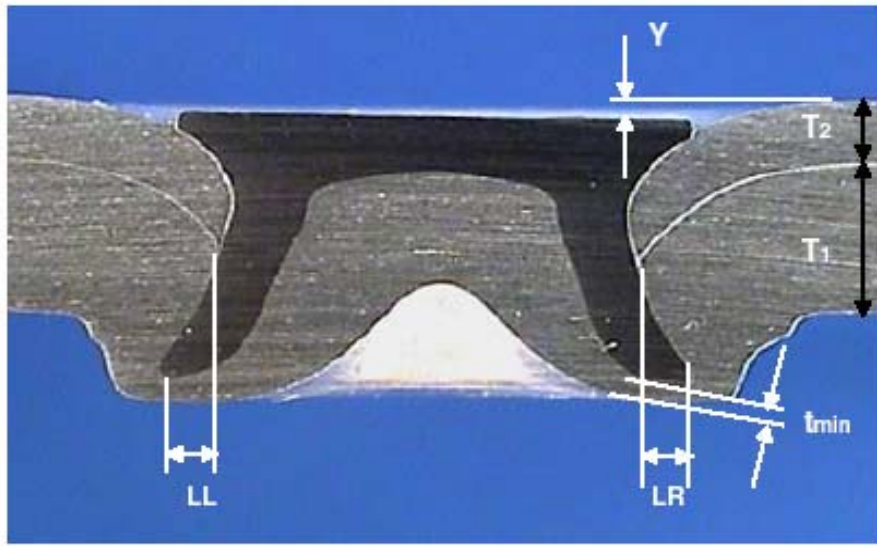


Note: Gaps around the rivet barrel, leg cracking or buckling and coining conditions may cause premature fatigue failure. When fastening dissimilar materials, rivet tail breakthrough and radial button cracking may cause corrosion failures.

Determining Acceptable Leg Flare

Metallographic Cross-section Evaluation

There are several significant joint characteristics and dimensions that must be assessed and measured by metallographic and optical microscopy techniques.



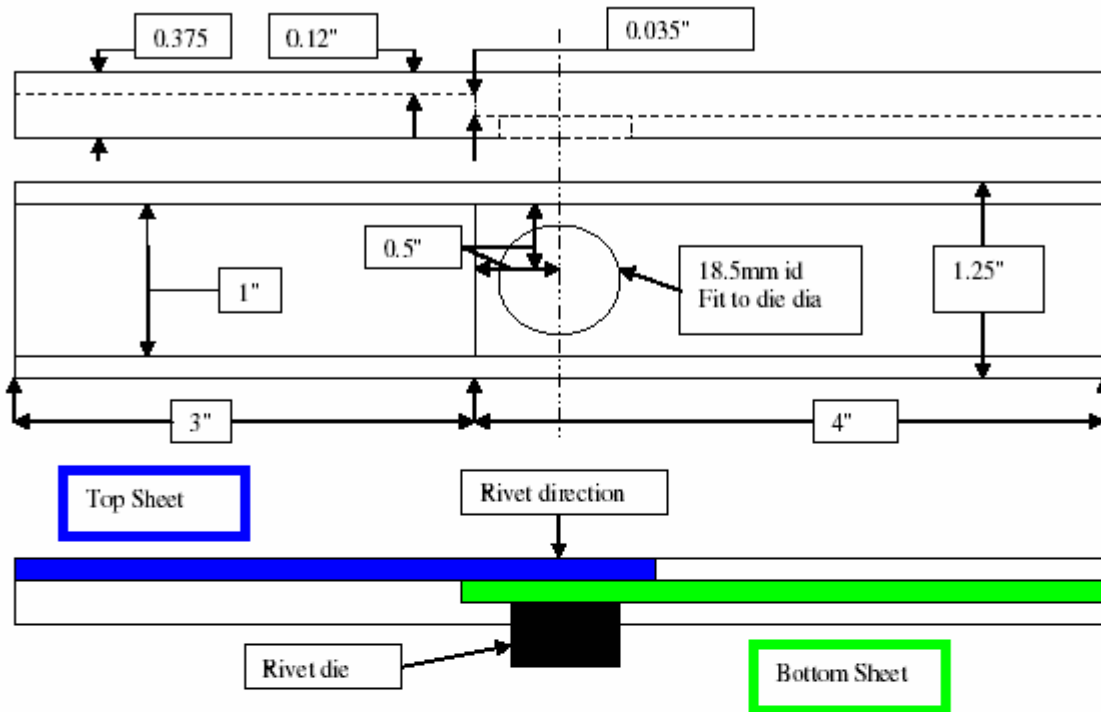
The following dimensions shall be checked during metallographic examination/optical microscopy:

t min (mm)	Remaining Material Thickness – The thinnest part of the plastically deformed material on the die side.
LL (mm)	This value is the distance between the rivet leg tip and the tangential point of the rivet leg side to the lower material in the joint. This gives the Left Hand locking value.
LR (mm)	This value is the distance between the rivet leg tip and the tangential point of the rivet leg side to the lower material in the joint. This gives the Right Hand locking value.
Y (mm) – Flushness	This is a measure of flushness. With a countersunk rivet, ideally, the surface on the head should be flush with the top sheet of material. With a headed rivet the underside of the head should be flush up against the top sheet of material.
T1 (mm)	Material thickness bottom sheet
T2 (mm)	Material thickness top sheet

Note: The cross section of a rivet joint should be free of any voids around the outside of the barrel and or under the rivet head. Voids inside the barrel under the rivet head are acceptable when joining HSLA materials. Button cap thickness (tmin) is determined in the destructive testing phase. If the cap remains attached to the parent sheet material and does not crack around the base of the rivet tail it is considered acceptable.

Sample preparation

Samples must be assembled in a test fixture, which provides a 25mm overlap of the 25X100 mm test samples to eliminate testing errors. The fixture ensures that the rivet is installed in the center of the 25mm overlap consistently.



Lap-shear Coupon Assembly Fixture





Sample Lap-shear Data

Sample #	Head Height	Peak Load (lbf)	Energy (in-lbf)	Failure Mode
1	+0.00 mm	792.1	206.8	Tearing of bottom material
2	+0.01 mm	772.1	197.6	Tearing of bottom material
3	+0.01 mm	790.7	248.5	Tearing of bottom material
4	+0.00 mm	789.3	248.3	Tearing of bottom material
5	-0.01 mm	800.9	230.8	Tearing of bottom material
6	+0.02 mm	794.4	211.2	Tearing of bottom material
7	+0.00 mm	789.0	215.2	Tearing of bottom material
8	+0.00 mm	762.2	204.1	Tearing of bottom material
9	+0.00 mm	768.6	226.5	Tearing of bottom material
10	+0.00 mm	772.3	229.5	Tearing of bottom material
11	-0.01 mm	772.0	206.8	Tearing of bottom material
12	-0.01 mm	793.1	220.4	Tearing of bottom material
13	+0.00 mm	807.5	256.7	Tearing of bottom material
14	+0.00 mm	800.2	230.4	Tearing of bottom material
15	+0.00 mm	790.6	211.0	Tearing of bottom material
16	+0.00 mm	775.6	243.6	Tearing of bottom material
17	+0.02 mm	768.6	250.7	Tearing of bottom material
18	+0.01 mm	801.2	214.8	Tearing of bottom material
19	+0.01 mm	779.1	212.5	Tearing of bottom material
20	+0.01 mm	799.0	212.8	Tearing of bottom material
21	+0.00 mm	798.0	207.7	Tearing of bottom material
22	+0.00 mm	792.2	211.2	Tearing of bottom material
23	+0.00 mm	761.7	200.7	Tearing of bottom material
24	+0.00 mm	740.3	186.7	Tearing of bottom material
25	+0.00 mm	761.9	207.5	Tearing of bottom material
26	+0.00 mm	781.0	204.9	Tearing of bottom material
27	+0.01 mm	766.2	223.9	Tearing of bottom material
28	+0.00 mm	769.4	200.5	Tearing of bottom material
29	+0.01 mm	769.2	191.0	Tearing of bottom material
30	+0.00 mm	776.5	194.2	Tearing of bottom material
	Mean	781.2	216.9	
	Std. Dev.	15.78	18.52	
	Low	740.3	186.7	
	High	807.5	256.7	



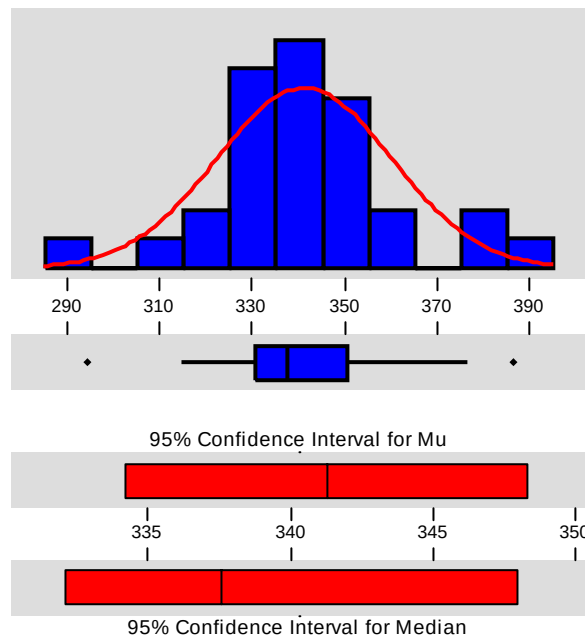


Sample T-Peel Data

Sample #	Head Height	Peak Load (lbf)	Energy (in-lbf)	Failure Mode
31	-0.02 mm	330.9	140.3	Tail pull-out
32	+0.00 mm	386.2	166.9	Tail pull-out
33	-0.01 mm	352.6	145.6	Tail pull-out
34	+0.00 mm	353.5	146.0	Tail pull-out
35	+0.00 mm	349.9	151.2	Tail pull-out
36	+0.02 mm	337.9	143.9	Tail pull-out
37	-0.01 mm	376.4	161.4	Tail pull-out
38	+0.00 mm	336.6	148.0	Tail pull-out
39	-0.01 mm	349.2	145.2	Tail pull-out
40	+0.00 mm	333.6	145.6	Tail pull-out
41	+0.00 mm	294.3	121.4	Tail pull-out
42	+0.00 mm	342.9	146.6	Tail pull-out
43	+0.00 mm	345.8	149.5	Tail pull-out
44	+0.00 mm	329.7	137.7	Tail pull-out
45	-0.01 mm	321.9	138.1	Tail pull-out
46	-0.02 mm	375.4	149.3	Tail pull-out
47	-0.01 mm	335.4	141.0	Tail pull-out
48	+0.00 mm	326.4	140.8	Tail pull-out
49	+0.00 mm	331.6	143.6	Tail pull-out
50	-0.01 mm	363.2	146.4	Tail pull-out
51	+0.00 mm	314.3	142.1	Tail pull-out
52	-0.01 mm	324.1	142.2	Tail pull-out
53	+0.00 mm	336.3	148.3	Tail pull-out
54	+0.00 mm	358.9	156.0	Tail pull-out
55	+0.00 mm	326.7	139.1	Tail pull-out
56	-0.01 mm	331.6	143.6	Tail pull-out
57	-0.01 mm	348.6	148.0	Tail pull-out
58	-0.02 mm	343.5	147.5	Tail pull-out
59	-0.01 mm	343.7	147.1	Tail pull-out
60	-0.02 mm	337.2	146.4	Tail pull-out
	Mean	341.3	145.6	
	Std. Dev.	18.89	7.776	
	Low	294.3	121.4	
	High	386.2	166.9	

**Rivet Schedule Analysis**

The underlying assumption of the statistical tests used in this procedure requires the data to be at least approximately normally distributed. Data should be analyzed for normality, stability and capability. If data is not found to be normal a transformation is required. To check for normality of data using Minitab 13, load data into the worksheet and pick, Stat > Basic Statistics > Display Descriptive Statistics, then select output data from list. Then pick graphs and check the Graphical Summary box, then pick OK, OK to generate the graph below.

Descriptive Statistics**Variable: UTS T-peel (lbf)****Anderson-Darling Normality Test**

A-Squared: 0.453
P-Value: 0.253

Mean 341.277
StDev 18.888
Variance 356.745
Skewness 0.258607
Kurtosis 1.03055
N 30

Minimum 294.300
1st Quartile 330.600
Median 337.550
3rd Quartile 350.575
Maximum 386.200

95% Confidence Interval for Mu
334.224 348.329

95% Confidence Interval for Sigma
15.042 25.391

95% Confidence Interval for Median
332.057 347.960

Descriptive Statistics: UTS T-peel (lbf)

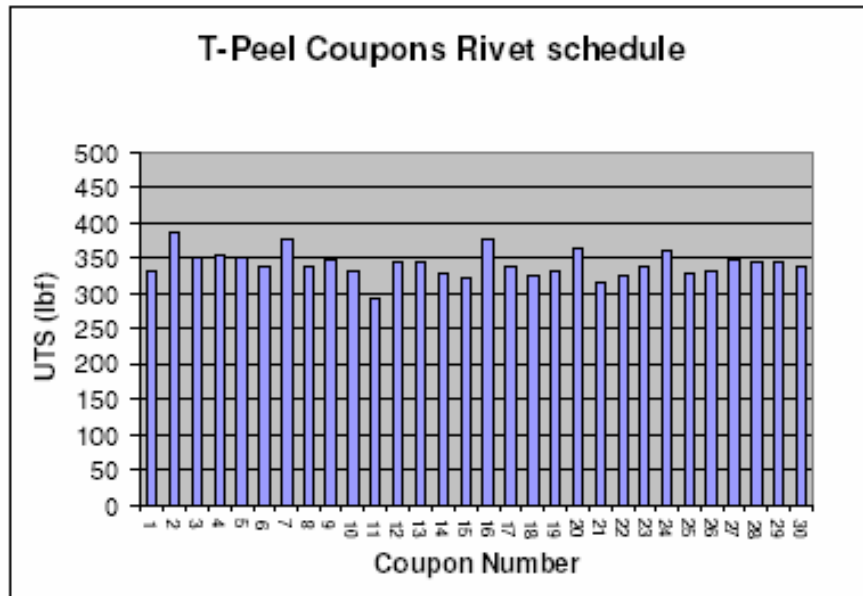
Variable	N	Mean	Median	TrMean	StDev	SE Mean
UTS T-pe	30	341.28	337.55	341.04	18.89	3.45
Variable	Minimum	Maximum	Q1	Q3		
UTS T-pe	294.30	386.20	330.60	350.58		

The P-value in the graph table above is the number to look at to evaluate the normality of the data. If the P-value is greater than 0.05 it is sufficient evidence to continue with standard statistical testing. If the StDev number is small as compared to the mean it is a good indicator of the stability and repeatability of the rivet schedule.

Note: T-Peel data is analyzed first because it is more sensitive to variations and will first indicate any instability in the rivet schedule

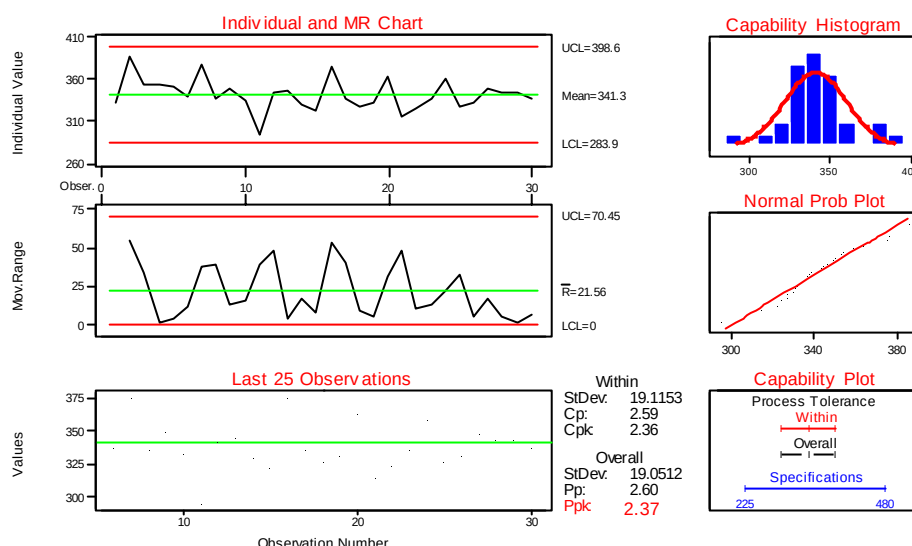
Rivet Schedule Analysis (Stability of process)

Next check to see if the data collected are representative of a stable, in control process and therefore predictable. Plotting bar charts with Excel of the T-peel and Lap-shear strength data will give you an indication of the variability of the rivet schedule. If low UTS outliers are prevalent in the T-peel data bar chart, additional work may be required to meet strength requirements. Final strength numbers to be used for evaluation are equal to the mean – 3 StDev.



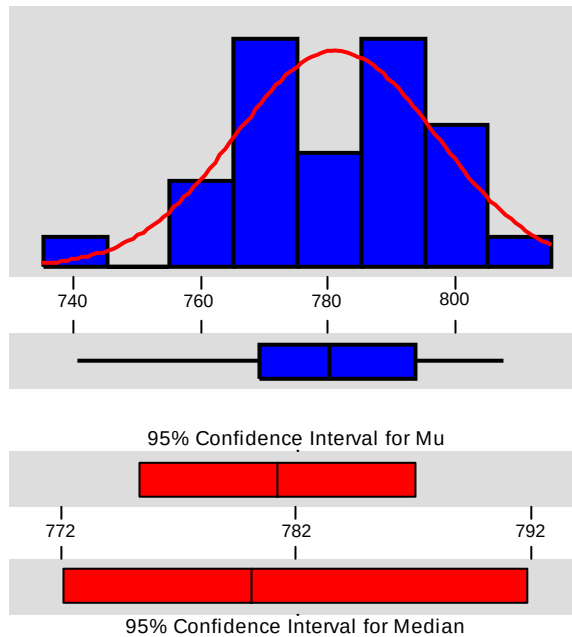
Additional evaluation for normality and stability of the data can be obtained by using I-MR Charts and Descriptive Statistics Graphs found in Minitab 13. To generate the graph below, load data into worksheet then, pick Stat > Quality tools > Capability six-pack (normal), Select UTS(lbf) for the response variable (Y) and group size 1, pick tests and check box Perform all eight tests, click Ok, then input upper and lower specification, click Ok.

T-Peel Capability Analysis



**Rivet Schedule Analysis**

Validity of testing requires that data be normal. To check normality of data using Minitab 13, load data into the worksheet and pick, Stat > Basic Statistics > Display Descriptive Statistics, then select output data from list. Then pick graphs and check the Graphical summary box, then pick Ok, OK to generate the graph below.

Descriptive Statistics

Variable: UTS (lbf)
Lap-Shear Study

Anderson-Darling Normality Test

A-Squared: 0.593
P-Value: 0.113

Mean 781.163
StDev 15.776
Variance 248.876
Skewness -4.0E-01
Kurtosis -2.1E-01
N 30

Minimum 740.300
1st Quartile 769.050
Median 780.050
3rd Quartile 793.425
Maximum 807.500

95% Confidence Interval for Mu
775.273 787.054

95% Confidence Interval for Sigma
12.564 21.208

95% Confidence Interval for Median
772.023 791.780

Descriptive Statistics: Peak Load (lbf)

Variable	N	Mean	Median	TrMean	StDev	SE Mean
Peak Load	30	781.16	780.05	781.70	15.78	2.88
Variable	Minimum	Maximum	Q1	Q3		
Peak Load	740.30	807.50	769.05	793.43		

The P-value in the graph table above is the number to look at to evaluate the normality of the data. If the P-value is greater than 0.05 it is sufficient evidence to continue with standard statistical testing. If the StDev number is small as compared to the mean it is a good indicator of the stability and repeatability of the rivet schedule.