

Subject: 2010 Edition, Part 2, Supplement 2, S2.10.2 – Define Deteriorated Rivet Heads

File Number: NB11-1603

Prop. Page: 133

Proposal: Update text in S2.10.2 to include guidelines for decayed rivets.

Current Wording:

S2.10.2 RIVETS

When the diameter of the rivet holes in the longitudinal joints of a boiler is not known, the diameter of rivets, after driving, may be ascertained from the Table S2.10.2.

Proposed Wording:

S2.10.2 Rivets and Rivet Heads

When the diameter of the rivet holes in the longitudinal joint of a boiler is not known, the diameter of the rivets, after driving, may be ascertained from Table S2.10.2.

Thickness of Plate, inches (mm)	Diameter of Rivet after Driving, inches (mm)
1/4 (6)	11/16 (17)
9/32 (7)	11/16 (17)
5/16 (8)	3/4 (19)
11/32 (9)	3/4 (19)
3/8 (10)	13/16 (21)
13/32 (10)	13/16 (21)
7/16 (11)	15/16 (24)
15/32 (12)	15/16 (24)
1/2 (13)	15/16 (24)
9/16 (14)	1-1/16 (27)
5/8 (16)	1-1/16 (27)

Rivet Head Types

Finished rivet heads are shown in NBIC Part 3, Figure S2.13.13.4.

Note that a riveted seam may have more than one type of rivet to, for example, provide necessary clearance during operation, or for provision for equipment assembly and maintenance.

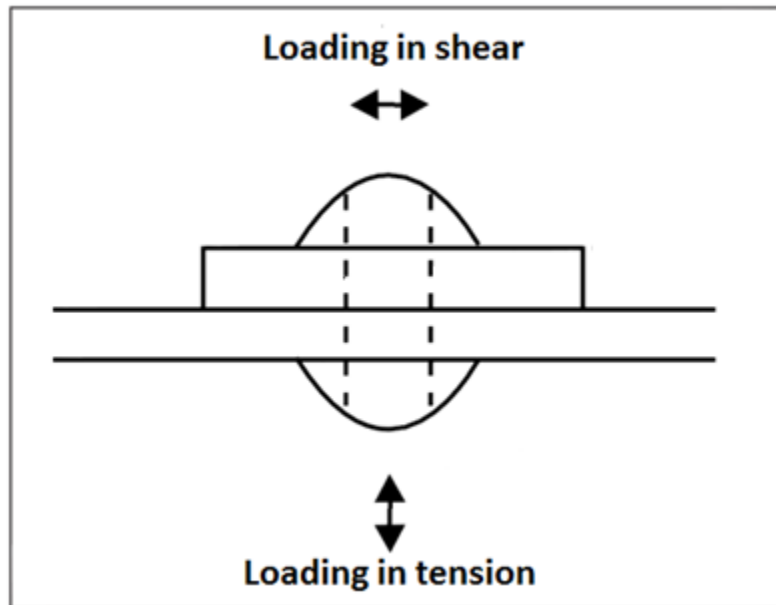
S2.10.2.1 Inspection of Corroded Rivets

A riveted seam or joint is very redundant by design. Therefore, the following guidelines apply when generalized corrosion is present and consistent on a group of adjacent rivets (typically 4 or more), and not to individual rivets. The inspector must consider the frequency and consistency of corroded rivet heads, and condition, location, and type of riveted joint (and how it may fail) in determining allowable corrosion.

- a. Visually identify all connections containing rivets which show signs of significant corrosion.
- b. Categorize each connection as the type which loads the rivets in one of three possible modes (pure shear, pure tension, or combined shear and tension). Refer to Figure S2.10.2.
- c. A leak around a rivet head may be indicative of a rivet which is loose, broken, or otherwise failing to provide adequate clamping force and will require further inspection.
 - i. A rivet shall be deemed loose if it can be felt to move after being struck on the side of the head in a direction approximately perpendicular to its shank with a 40oz. engineer's hammer.
 - ii. NBIC Part 3, S2.13.13 defines procedures to address a leak around a rivet head.
- d. Allowable corrosion:
 - i. For rivets in pure shear load, the amount of measured head deterioration shall not exceed 80% of its total head volume. Where rivets have countersunk heads, the head diameter must be equal or greater than 65% of the original head diameter. Severe head corrosion will require further evaluation of the condition and thickness of the plate at the joint.
 - ii. For rivets in pure tension, the amount of measured head deterioration shall not exceed 35% of its total head volume. Where rivets have countersunk heads, the head diameter must be equal or greater than 85% of original head diameter. Application of this value shall take into consideration the consistency and frequency of adjacent rivets showing excessive corrosion.

- iii. For connections subjected to combined shear and tension loads, the amount of measured head deterioration shall not exceed 60% of its total head volume. Where rivets have countersunk heads, the head diameter must be equal or greater than 75% of original head diameter. Application of this value shall take into consideration the consistency and frequency of adjacent rivets showing excessive corrosion.

Figure S2.10.2



The condition of the plate surrounding the rivets including general wastage, pitting, and the condition of the caulking edge, must be considered.

Explanation

Supplement 1 (Locomotives) has a guideline for deteriorated rivet head acceptance/rejection [5]. Supplement 2 (Historical Boilers) does not have such a guideline. This report itemizes concerns and errors in Supplement 1 guidelines, and proposes a new Supplement 2 guideline.

Supplement 1 Errors & Omissions

- 1.) No guidelines for rivets in shear.
- 2.) S1.4.2.1.L wording is unclear / self-contradictory. The first sentence discusses wastage, and the 2nd sentence discusses remaining height at shank diameter, both using 0.25D.

Discussion

[1, 9] state “U.S. Navy rules require the repair or replacement of rivets when head thickness has been reduced by 25% for 40.8lb [1-inch thick] plate and smaller and by 20% in plate over this weight.”

[8] is heavily referenced, and states that current practice is to replace all rivets in connections subject to tensile or tensile-shear loading that have heads corroded to the point of losing 50% or more of their projection beyond the shank. An original copy of this publication could not be sourced, but this wording is consistent among all papers referencing this work.

[2] performs FEA on a 7/8” button head rivet, and recommends that the measured amount of head deterioration shall not exceed 35% of its total head volume.

Caveats:

- [2] assumes A502 grade rivets, other reports do not appear to specify the grade of rivet. Historical boilers are using A-31 grade rivets.
- All referenced work assumes no change to the load of the rivets. NBIC is unique where the standard will degrade MAWP based on boiler condition, thus changing the load imposed on the rivet. However, FEA in [2] shows a rather sharp increase in stress when deterioration surpasses 35%. This increase is far greater than the reduction due to change in MAWP. The paper reports that measurements have shown rivet clamping force approaches yield load of the rivet.
- Where mentioned, only button head rivet designs are discussed in reference materials.

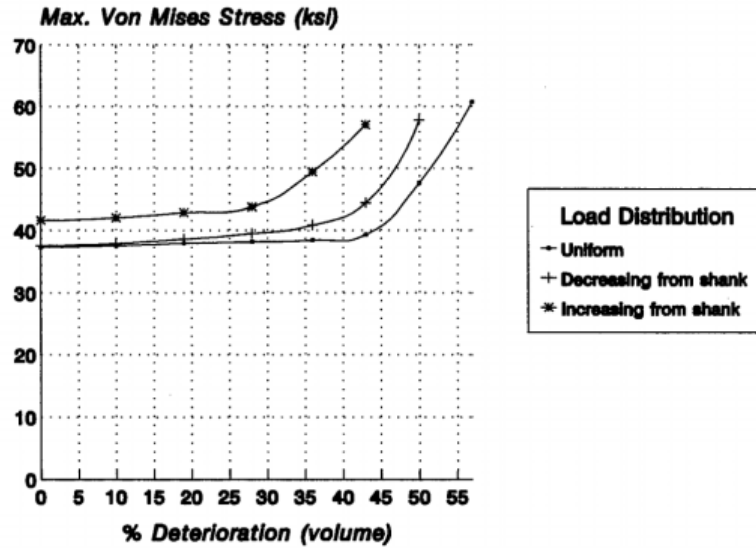


Figure 12 - Max. Stress Vs. Loss of Head Volume (Uniform Model)

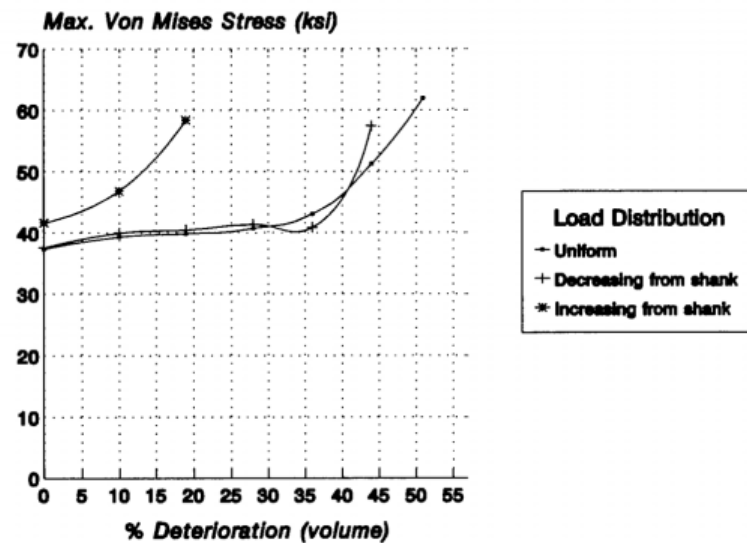
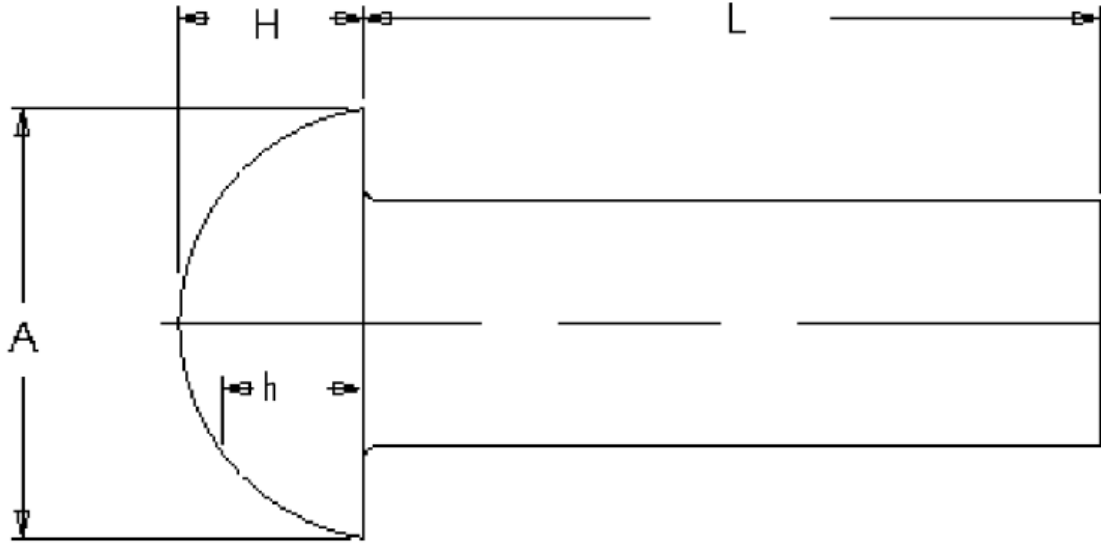


Figure 13 - Max. Stress Vs. Loss of Head Volume (Non-Uniform Model)

New Button Head Rivet Dimensions

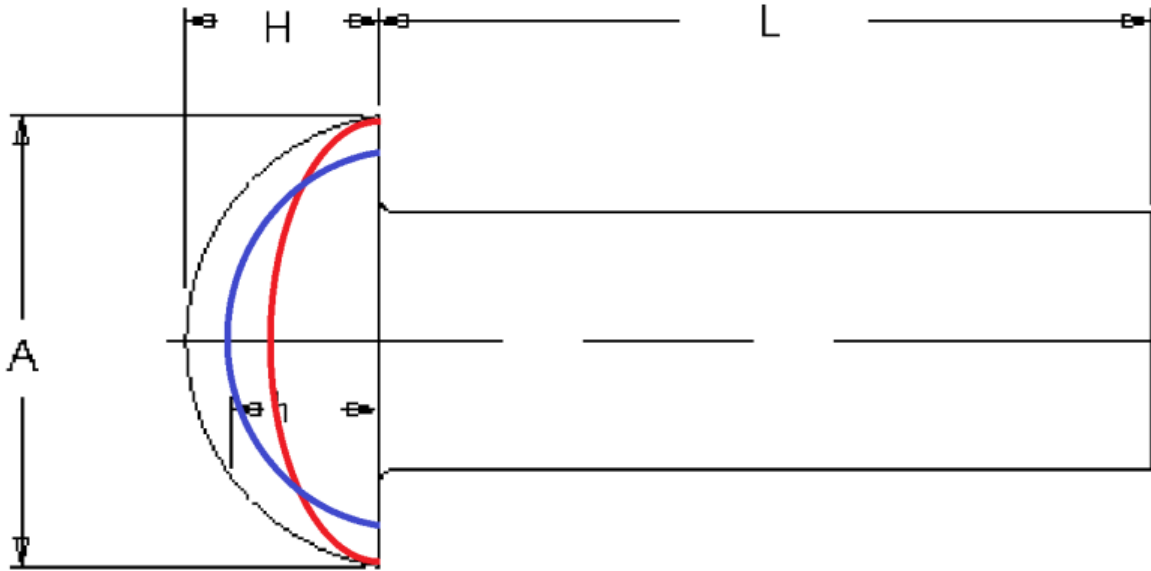
Values are taken from [6]. Calculated values below are based on equations from [7].



Shank Diameter	A Head Diameter	H Head Height	h Height at Shank Circumference (new)	Head Volume
0.500	0.875	0.375	0.298	0.140
0.625	1.094	0.469	0.372	0.274
0.750	1.312	0.562	0.446	0.473
0.875	1.531	0.656	0.521	0.752
1.000	1.750	0.750	0.595	1.123
1.125	1.969	0.844	0.670	1.600
1.250	2.188	0.938	0.745	2.200
1.375	2.406	1.031	0.818	2.918
1.500	2.625	1.125	0.893	3.790
1.625	2.844	1.219	0.968	4.820
1.750	3.062	1.312	1.041	6.013

Deteriorated Button Head Rivet Dimensions

We will consider two types of generalized deterioration. All red values will represent even deterioration at the crown of the head, where the base of the rivet head remains intact. All blue values represent equal deterioration around the rivet head.



NBIC S1.4.2.1: minimum $h = 0.25 * \text{shank diameter}$

Assuming even deterioration at the rivet head crown, but no deterioration at the edge of the rivet head (red line), **60%** of rivet head material is removed before the rivet must be replaced.

Assuming even deterioration (blue line) throughout the rivet head, **52.5%** of material is removed before the rivet must be replaced.

US Navy [1, 9]: minimum $H = 0.75 * \text{original } H$

Assuming even deterioration at the rivet head crown, but no deterioration at the edge of the rivet head (red line), **31.5%** of rivet head material is removed before the rivet must be replaced.

Assuming even deterioration throughout the rivet head, **55%** of material is removed before the rivet must be replaced.

[8] is calculated in the same manner, except **$H = 0.5 * \text{original } H$** . Assuming even deterioration at the rivet head crown, but no deterioration at the edge of the rivet head (red line), **57.5%** of rivet head material is removed before the rivet must be replaced. However, assuming even deterioration throughout the rivet head, deterioration enters the rivet shank so these values are not considered. Given this result, [8] will not be further considered until a copy is attained to determine how to interpret its guidelines.

US Army [2]: minimum head volume = $0.65 * \text{original head volume}$

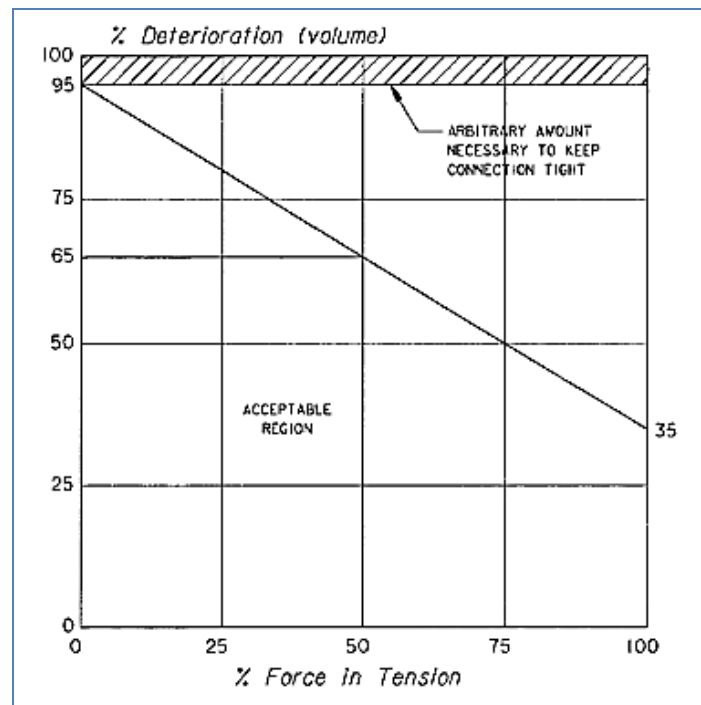
Assuming even deterioration at the rivet head crown, but no deterioration at the edge of the rivet head (red line), to obtain 35% removal of head volume, 'h' must only reduce by **20%** of its original height. Using NBIC S1.4.2.1 metrics, 'h' must be **40%** or greater than shank diameter.

Assuming even deterioration throughout the rivet head, to obtain **35%** removal of head volume, 'h' must only reduce by **17.5%** of its original height. Using NBIC S1.4.2.1 metrics, 'h' must be **46%** or greater than shank diameter.

Discussion

The FEA results [2] assumed even corrosion around the entire rivet head. These conclusions (35% volume removal) are similar to the rule-of-thumb U.S. Navy guidelines [1, 9] (31.5%) when corrosion is maximum at the crown of the rivet head. Given this consistency, this draft targets a maximum 35% volume removal threshold for rivets in pure tension.

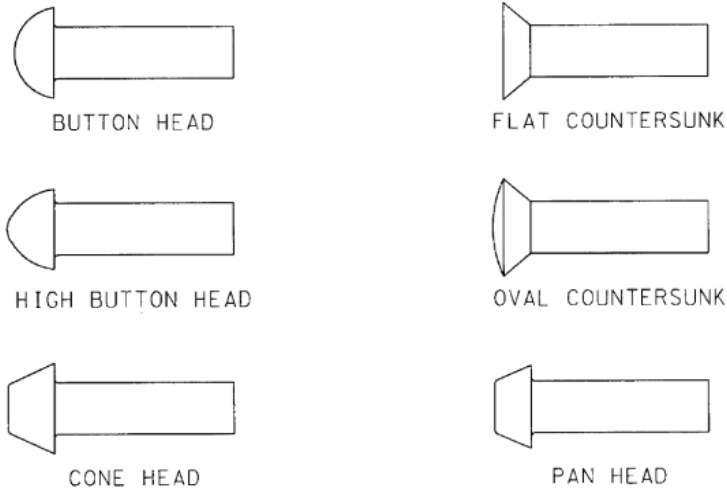
[2] also suggested that for rivets in pure shear, rivets do not need to be replaced as long as the corrosion has not extended into the shank and that the rivet is not loose. Furthermore, the ratio of total head volume removed may linearly scale from 35% (for 100% tension) to 95% (for 100% shear). Refer to below figure from [2].



However, in practicality, one must expect the plate to deteriorate with the rivet head. For example, when a flat countersunk rivet head is 20% of its original volume, the adjoining plate is 33% of its original thickness. So, in practice, it is reasonable to expect a repair that replaces both plate and rivets when severe rivet head decay is present.

Regardless of the type of corrosion, NBIC S1.4.2.1 allows more corrosion than all other approaches for rivets in pure tension. Research and references to peer reviewed documents for NBIC S1.4.2.1 is unknown so cannot be considered. However, due to the difficulties in determining the ratio of shear/tension load on a specific rivet, this draft

adopts the rule to apply equal 50/50% shear/tension. Given the above text, allowable head corrosion for rivets in combined shear/tension is 60%; consistent with NBIC S1.4.2.1.



We assume equal allowable wastage regardless of rivet head type because all known construction codes assume equal allowable loading regardless of rivet head type.

References

- [1] "Atlantic Area Best Practices: Rivet Inspection Guidance", U.S. Department of Transportation, United States Coast Guard, 2000.
- [2] "Rivet Replacement Analysis", Erich Edward Reichle, U.S. Army Corps of Engineers, 1999.
- [3] "Inspection, Evaluation, and Repair of Hydraulic Steel Structures", U.S. Army Corps of Engineers, 2001.
- [4] "Guidelines for Assessing Condition of Riveted Spillway Gates", REMR Technical Note CS-ES-1.12, 1994
- [5] NBIC Supplement 1, Part 2, 2010.
- [6] ASME B18.1.2: American National Standard Large Rivets
- [7] http://en.wikipedia.org/wiki/Spherical_cap
- [8] "Rivet Replacement Criteria", Fazio, A.E., and R.N. Fazio, Second Bridge Engineering Conference. Washington, D.D. Transportation Research Board. Vol 1, TRR-950
- [9] "Procedures For Hull Inspection and Repair on Vessels Built of Riveted Construction", U.S. Department of Transportation, United States Coast Guard, 2001.