Title: Bulged Stayed Firebox Sheets

Background:
The purpose of these rules/limits are to provide guidance to the locomotive owners/operators and the National Board Inspectors.

Proposed Action:
S1.4.2.8.1 Bulged Stayed Sheets

a) The maximum depth of the bulged section of the firebox sheet shall not exceed the firebox sheet thickness. The bulged section depth is defined as the protrusion of the firebox sheet beyond its original position. Where sheets are bulged more than ⅜” within one staybolt pitch, the thickness of the plate shall be verified. If the thickness is less than required the sheet shall be replaced. If the thickness of the sheet is adequate for the pressure, it shall be ensured that there is complete thread engagement between the staybolts and the sheet in the bulged area. If any deficiency is found in the thread engagement that impedes the holding power of the staybolt to a level below what is required for the operating pressure, the defective area shall be repaired or replaced.

b) If the maximum depth of the bulge exceeds the firebox sheet thickness, the bulged section of the firebox sheet shall be replaced. All staybolts within and/or contacting the bulged firebox sheet section shall be replaced. The adjacent sections of the firebox sheet shall be inspected to determine the cause of the bulge such as scale or mud accumulation prior to completing the repair.

c) If the bulged firebox sheet will remain in service, the conditions that caused the bulge shall be identified and corrected prior to placing the boiler back into operation.

d) If the bulged firebox sheet will remain in service the bulged sheet section and the sheet sections adjacent to the bulge shall be inspected for cracking and thinning (wastage) by use of NDE in order to confirm their suitability for service prior to placing the boiler back into operation.
I recommend we adopt the following rules and limits for the inspection of bulges in stayed firebox sheets. These would be placed in the Inspection Section (Part 2) of our NBIC Locomotive Code within the Stayed Firebox Sheet section.

1) The maximum depth of the bulged section of the firebox sheet shall not exceed the firebox sheet thickness. The bulged section depth is defined as the protrusion of the firebox sheet beyond its original position. Sheets bulged more than ¼” within one staybolt pitch, the thickness of the plate shall be verified. If the thickness is less than required the sheet shall be replaced. If the thickness of the sheet is adequate for the pressure, at least one staybolt per square foot of bulged area up to a maximum of three staybolts shall be removed and the condition of the threaded hole shall be evaluated. If any bolt hole is found to be deficient, at least three additional staybolts shall be removed as above and the holes evaluated and three more staybolts removed if one additional hole is found to be deficient and so on until three staybolts holes are found to be deficient, at which time the sheet shall be replaced.

2) If the maximum depth of the bulge exceeds the firebox sheet thickness, the bulged section of the firebox sheet shall be replaced. All staybolts within and/or contacting the bulged firebox sheet section shall be replaced. The adjacent sections of the firebox sheet shall be inspected to determine the cause of the bulge such as scale or mud accumulation prior to completing the repair.

3) If the bulged firebox sheet will remain in service, the conditions that caused the bulge shall be identified and corrected prior to placing the boiler back into operation.

4) If the bulged firebox sheet will remain in service the bulged sheet section and the sheet sections adjacent to the bulge shall be inspected for cracking and thinning (wastage) by use of NDE in order to confirm their suitability for service prior to placing the boiler back into operation.

Comments to Committee:

The purpose of these rules/limits are to provide guidance to the locomotive owners/operators and the National Board inspectors. I advocate using a ratio of the bulge depth to the firebox sheet thickness in order to provide a simple reference for the inspectors to use during their work. My initial method is to limit the bulge depth to the firebox sheet thickness as 1 :1 ratio. For a 3/8” thick side sheet this would allow a maximum allowable bulge depth of 3/8”.

We can increase the ratio to a higher value, such as 1.25 :1 or 1.5 :1 if our committee considers this necessary. For the 3/8” thick side sheet and the 1.25 :1 ratio the maximum allowable bulge depth would be 3/8” x 1.25 = 15/32” (.46875”).

I developed these rules/limits by equating the bulged section of the stayed firebox sheet as a uniformly loaded simply supported beam. The loading of which is created by the boiler pressure acting on the firebox sheet cross-section and the beam length is the pitch (distance) between the staybolts.

The bulge occurs when the firebox sheet, as it becomes over-heated, exceeds its allowable temperature and suffers a reduction of tensile strength as a result. This tensile strength reduction allows the boiler pressure to form the bulge by forcing the overheated section of the firebox sheet into the firebox interior.

As the bulge forms on the overheated firebox sheet, the physical deformation, strain, and deflection of the
bulge first causes the firebox sheet to become thinner, then to work harden as a result. This work hardening process often allows the firebox sheet to recover its strength sufficiently to prevent the bulge from rupturing, but the bulge remains in position and becomes a permanent part of the firebox sheet.

For reference bulges and overheating of our stayed fire locomotive boilers can be caused by poor heat transfer through the sheet as a result of mud and scale; poor water chemistry; over-firing (more of a problem with oil burners than coal burners); oil burner misalignment that causes the flame to impinge directly on the firebox sheet; defective fire pan brick work; and poor operating practice such as firing with low water or firing up the boiler when the water level is too low to cover all of the sheet surfaces.

A mechanical cause of firebox sheet bulges occurs when multiple broken staybolts cause the now insufficiently supported section of the firebox sheet to be forced by the boiler pressure into the firebox interior. The same process by which the physical deformation, strain, and deflection of the bulge cause the firebox sheet to become thinner, then to work harden occurs. This work hardening process often allows the firebox sheet to recover its strength sufficiently to prevent the bulge from rupturing, but the bulge remains in position and becomes a permanent part of the firebox sheet.
Proposal:

Introduce a new section to provide guidance for bulged stayed surfaces to address requests for guidance from various jurisdictions. Proposed wording is as follows:

**S2.10.4.2 BULGING**

Stayed surfaces shall be examined, and any deformations shall be measured and recorded. Deformations may be caused from freezing, localized overheating, broken staybolts, or extended use (cyclic activity). Deformations may be described as bulging, bagging, or pillow/mattress-effects. The bulged section depth is defined as the protrusion of the sheet beyond its original position.

a) Changes in deformations between inspections shall be noted and shall require additional evaluation to determine fitness for service.

b) The probable cause of the deformation shall be determined and, where possible, resolved. For example, overheating due to scale build-up requires removal of scale.

c) The amount of the bulging shall be measured:
   i. If the depth of the bulge does not exceed 50% of plate thickness, then no further activity is required.
   ii. If the depth of the bulge is between 50% and 100% plate thickness, and thread engagement is not affected, then additional NDE is required.
      ▪ Note: If ultrasonic thickness testing (S2.6.2.c) is performed, then it is performed on a tight (1-inch) grid to determine any thinning throughout the deformation. Any generalized thinning (S2.6.2.b) shall be used in the calculation of MAWP.
   iii. If the depth of the bulge exceeds the thickness of the plate, then repair is required.

d) The location of the deformations shall be examined. If the point of tangency of the curve in a bulge is within ‘t’ of the edge of the staybolt head, then determination of thread engagement shall be made. (‘t’ is defined in S2.10.6, and is the thickness of the plate.) Removal of one or more staybolts may be required to make this determination. Refer to Figure S2.10.4.2.d.
   i. Cracks, deformations, and/or missing portions of the threaded staybolt head may indicate a deformation of the plate at the staybolt.
e) The following guidelines apply where repair is required.

i. Plate may only be repaired using a flush patch, in accordance with Supplement 2 of Part 3.

ii. Where a deformation is to be repaired, all portions of that deformity shall be repaired. For example, for contiguous bulging where only some bulges exceed allowable deformation, the entire bulged area shall be repaired. Unrelated bulges separated by non-deformed plate shall be independently evaluated.