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THE NATIONAL BOARD
OF BOILER AND PRESSURE VESSEL INSPECTORS

# NATIONAL BOARD INSPECTION CODE TASK GROUP LOCOMOTIVE BOILERS

# MINUTES

Meeting of June 1, 2023
Virtual Meeting using Microsoft Teams

*These minutes are subject to approval and are for committee use only. They are not to be duplicated or quoted for other than committee use.*

The National Board of Boiler & Pressure Vessel Inspectors
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1. **Call to Order**
   Chair Mr. G. Mark Ray called the meeting to order at 2:12 PM Eastern Time.

2. **Introduction of Members and Visitors**
   Each member and visitor introduced themselves with their name and occupation. See Attendance Record (**Attachment 1**).

3. **Check for a Quorum**
   With 10 out of 18 members present, a quorum was reached.

4. **Announcements**
   - Mr. Ray briefly discussed the option of attending (virtually or in person) the upcoming Historical Boilers Task Group (Historical) meeting on July 10, 2023, 8:00 AM Central Time.

   - Ms. Vance asked that everyone leave their microphones muted unless they would like to speak.

5. **Adoption of the Agenda**
   A motion was made to adopt the agenda as written. The motion was seconded and unanimously approved.

6. **Approval of the Minutes of the November 2022 Meeting**
   Mr. Ray briefly reviewed the minutes from the November 2022 meeting. A motion was made to approve the minutes. The motion was seconded and unanimously approved.

7. **Review of Rosters**

   a. **Membership Appointments**
      There were no membership appointments for this meeting.

   b. **Membership Reappointments**

      i. The following TG Locomotive memberships are set to expire in July 2023: Mr. David Conrad and Mr. Mark Jordan.

         Both gentlemen expressed their interest in continuing their membership for another term. They were then placed in a "Breakout Room" while the task group voted. A motion was made to recommend both members' reappointment. The motion was seconded and unanimously approved.

   c. **Officer Elections**
      There were no officer elections for this meeting.

8. **Interpretations**

   None

9. **Action Items**

**New Business:**

- Mr. David Griner lead a discussion regarding fillet welded staybolts.

  The task group held a lengthy discussion on the Fillet Welded Staybolt Inspection Procedure (See pages 7-8 of **Attachment 2**). They discussed which parts to potentially include or revise to include in the NBIC and parts that they would not incorporate. Mr. Griner, Mr. Moedinger, and possibly others will work on creating a proposal. Once a proposal is created, the task group will meet again to discuss.

**10. Discussion Items**

Mr. Ray reminded the task group that they are encouraged to attend the Historical meetings to see if there are items they should be involved in. NBIC registration (in person and remote) is currently open online at nbbi.org. They also discussed potentially inviting the members of Historical to attend a Locomotive meeting once a year.

**11. Future NBIC Meetings**

Mr. Ray reviewed the future NBIC meetings.

- July 10-13, 2023 – St. Louis, MO
- January 8-11, 2024 – Charlotte, NC
- TG Locomotive Meeting – TBD

**12. Adjournment**

Mr. Ray motioned to adjourn the meeting at 4:23 PM Eastern Time. The motion was seconded and unanimously approved.

Respectfully submitted,

Michelle Vance
TG Locomotive Boilers Secretary

**TG Locomotive Boilers Attendance: June 1, 2023**



| MEMBERS | Interest Category | Present | Not Present |
|---|---|---|---|
| G. Mark Ray | General Interest | x | |
| Charlie Cross | Users | | x |
| Erich Armpriester | | x | |
| Steven Butler | General Interest | x | |
| J. David Conrad | Users | x | |
| Dave Domitrovich | Users | | x |
| Wolf Fengler | | x | |
| Robert Franzen | General Interest | x | |
| Dave Griner | General Interest | x | |
| Matt Janssen | General Interest | | x |
| Mark Jordan | Jurisdictional Authorities | x | |
| Steve Lee | Users | | x |
| Kelly Lynch | | | x |
| Doyle McCormack | General Interest | | x |
| Linn Moedinger | Users | x | |
| Tim Sposato | | | x |
| Richard Stone | Manufacturers | x | |
| Brendan Ziegler | | | x |
| Michelle Vance | Secretary | x | |

| VISITORS | Company / Interest |
|---|---|
| Jonathan Ellis | NBBI |
| Max Casias | |

# FILLET WELDED STAYBOLT INSPECTION PROCEDURE

## PREMISE

In discussions with members of our Committee it has become apparent that we need an in-service inspection procedure for staybolts attached by fillet welds. The following notes are intended to provide a sound engineering basis for this work without reliance on practices or standards from sources where the engineering justification is unavailable or unknown.

## KNOWN INFORMATION

Materials :

In all instances under consideration, the staybolt material will be taken as having a tensile strength (TS) of 60,000 psi. It is recognized that there can be instances where this number is greater, however, this is taking the more conservative approach. It is also recognized that there may still be wrought iron bolt material available, but for this evaluation it will be considered prohibited.

Plate material will also be regarded as having a 60,000psi TS. Most of the older plates were 55,000psi TS (min.) and replacement plate will, typically be greater than 60,000psi. This figure is considered to be a reasonable compromise for the sake of simplicity regarding clarity during calculation. Actual values can be reviewed on a case by case basis.

Welding filler metal TS will be 60,000psi, using E6010 electrodes with the Shield Metal Arc Welding process (SMAW). Again, this can be accomplished with filler materials with higher tensile strengths, but is used here for providing the more conservative approach.

Welders will be qualified to ASME Section IX requirements for all positions, including the appropriate qualified Welding Procedure Specification (WPS).

Measurements:

Virtually all of the dimensional information relative to fillet welded staybolts has been derived from sources using the metric system. As such the following list will be of value.

1mm----------= .039 “
2mm----------= .078”
3mm----------= .117”
4mm----------= .156”
5mm----------= .195”
6mm----------= .234”
7mm----------= .273”
8mm----------= .312”
9mm----------= .351”
10mm----------= .390”

Existing Experience:

By conservative estimates, based on known construction documentation, there have been in excess of 8,000 locomotives built, each with at least 500 staybolts applied with a fillet weld attachment, for a total of 4 million installed bolts (in actuality 8 million welds).
Assuming that each engine operated 736 days, we would have 2.94 billion staybolt service days of experience with this type of application (5.88 billion weld service days). Our best information does not record a single firebox sheet failure resulting from the attachment method design being deficient

The German National Railway (Deutsche Bundesbahn) adopted this attachment method as their Standard Practice in 1959.
Ref. DV 946,Teilheft 1/Anlage 41,42 & 42, Ausgabe Jan.1959
These pages were distributed to the Committee on two (2) occasions. German practice to this day is conducted to these requirements, some 49 years of experience. Again, without a recorded sheet failure.

The Standard noted was the direct result of the scientific and engineering research conducted by Dr. Arnold Tross. His reports and documentation of testing both in the laboratory and on many locomotives in daily service are available in our archives and in part have been published “on-line”.

From their inception, flexible staybolt caps (type MKS) have been applied with a fillet weld. We have never questioned the validity of this attachment method, let alone, look to foreign practices for guidance on weld geometry, holding power, corrosion limits, or internal conditions related to corrosion.

Thermic siphon neck attachment weld geometry, weld size or stress values have not been addressed, but are commonly accepted without reservation or inspection criteria regarding erosion, etc. This weld functions in shear.

The ASME Code, Section I, PW-19.4.1, provides specific conditions regarding the use of fillet welds in securing diagonal stays to the boiler shell, again with the weld functioning in shear.

Included with this paper is an attachment showing the use of Finite Element Analysis for determining the allowable loads on fillet welds in applications such as those under discussion. This document confirms the values used to implement weld size criteria both for initial construction and for establishing minimum sizes for an inspection procedure.

## INSPECTION PROCEDURE DEVELOPMENT

Areas of Interest:

1. Determining the overall condition of the staybolt, internally and externally.
2. Determining if the staybolt is capable of performing its required function for a predetermined length of time.

It becomes apparent that overall condition will be predicated on corrosion, erosion, and service fatigue. These aspects are manifested in the form of dimensional change or cracking of any part of the structure.
[In this case the structure is defined as a completed installation of one staybolt, where there is the bolt (including the telltale hole), attaching welds and the plates making up both sides.]

Determination of the ability of the staybolt to perform its required function is the verification that dimensional change or cracking has not infringed upon established minimums.

NOTE OF CLARIFICATION

ASME has established what the initial dimensional requirements should be, however, a good set of inspection criteria can be developed based on experience and good engineering practice. This approach would have been conducted when setting out the construction dimensions, in that minimums would have to be determined, hence this is a valid aspect of setting out the entire practice regarding fillet welded attachment of staybolts.

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It must be recognized that the safe function of a fillet welded staybolt is predicated on the proper cross sectional area of the bolt and the dimension of the attaching weld and plate condition. As such, the measurement of the bolt body beyond the sheet is not a satisfactory determination of the functionality of the attachment weld. Rather it is the dimension of the existing attachment weld.

DETERMINATION OF THE MINIMUM WELD DIMENSION

It is quite clear that the most important dimension of a fillet welded staybolt will be the weld leg size. Any inspection procedure will require a minimum number for this dimension. An accurate engineering assessment of this question can begin by examining the notes of a Registered Professional Engineer who evaluated it as follows:

LOAD ON STAYBOLT---------- 4,141 LBS
BOLT DIAMETER---------- 22mm = 0.866”
WELD LEG DIMENSION---------- 6mm = 0.236”

THROAT OF WELD = .707 x 0.236 = 0.167”

EFFECTIVE WELD AREA IN SHEAR:

BOLT CIRCUMFERENCE x WELD THROAT
= 0.866 x 3.141 x 0.167 = .454 sq. in.

SHEAR STRESS IN WELD:

LOAD / AREA OF WELD IN SHEAR
4141 / 0.454 = 9106 psi

E6010 ELECTRODES USED WITH THE SMAW PROCESS HAVE A MINIMUM TENSILE STRENGTH OF 60,000 psi

ALLOWABLE SHEAR STRESS OF THE WELD METAL IS DETERMINED BY:

0.3 x TENSILE STRENGTH
0.3 x 60,000 = 18,000 psi Allowable Shear stress

THE APPLIED LOAD WELD SHEAR STRESS IS 9106 psi, WHICH IS LESS THAN 18,000 psi. THE WELD IS THEN SATISFACTORY FOR THE APPLIED LOAD

This particular example reflects roughly a 4" x 4" pitch with an MAWP of 250 psi. using a weld just shy of ¼" leg height.

The method used by the AWS to establish fillet weld shear stress values:

AWS: Allowable Load = .707 x Leg size x .3 x Tensile Strength

Tensile Strength x .3 is the common method in this determination, however, other values are currently being used allowing higher allowable loads (Ref. attached FEA paper). It is felt the".3" value is acceptable for this application.

The following charts have been generated using this method of determining allowable loads on fillet welds.

LEG HEIGHT AND ALLOWABLE LOADS

| Diam. | C.S.A. | Circum. | 1/8" 1590# per linear in. | 3/16" 2390# per linear in. | 1/4" 3180# per linear in. | 5/16" 3980# per linear in. | 3/8" 4770# per linear in. |
|---|---|---|---|---|---|---|---|
| 3/4" | 0.442 | 2.356" | 3746.0# | 5630.8# | 7492.1# | 9376.9# | 11238.1# |
| 13/16" | 0.518 | 2.553" | 4059.3# | 6101.7# | 8118.5# | 10160.9# | 12177.8# |
| 7/8" | 0.601 | 2.749" | 4370.9# | 6570.1# | 8741.8# | 10941.0# | 13112.7# |
| 15/16" | 0.690 | 2.945" | 4682.6# | 7038.6# | 9365.1# | 11721.1# | 14047.7# |
| 1" | 0.785 | 3.141" | 4994.2# | 7506.9# | 9988.4# | 12501.2# | 14982.6# |
| 1 1/16" | 0.886 | 3.336" | 5304.2# | 7973.0# | 10608.5# | 13277.3# | 15912.7# |
| 1 1/8" | 0.994 | 3.534" | 5619.1# | 8446.3# | 11238.1# | 14065.3# | 16875.2# |

PITCH, PRESSURE AND RESULTING LOADS *

| PITCH INCHES | AREA SQUARE INCHES | 150psi PRESSURE | 200psi PRESSURE | 250psi PRESSURE | 300psi PRESSURE |
|---|---|---|---|---|---|
| 3.5" x 3.5" | 12.75 | 1837.5# | 2450.0# | 3062.5# | 3675.0# |
| 3.5" x 3.75" | 13.13 | 1968.8# | 2626.0# | 3282.5# | 3939.0# |
| 3.75" x3.75" | 14.06 | 2109.3# | 2812.0# | 3515.0# | 4218.0# |
| 4.0" x 4.0" | 16.0 | 2400.0# | 3200.0# | 4000.0# | 4800.0# |
| 4.0" x4.5" | 18.0 | 2700.0# | 3600.0# | 4500.0# | 5400.0# |
| 4.5" x 4.5" | 20.25 | 3037.5# | 4050.0# | 5062.5# | 6075.0# |
| | | | | | |

*Pitch areas are developed WITHOUT deducting the area of the staybolt. (More conservative condition)

Reviewing the charts, it becomes apparent that the minimum leg size should be limited to 3/16". It must be understood that the weld load values are NOT the same as the staybolt stress values which are developed on a

different basis. The weld stress values are incorporated in the allowable load per linear inch.

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## THE FILLET WELDED STAYBOLT INSPECTION PROCEDURE

### PREFACE

The inspection of this type of installation should be conducted the same as for other forms of attachment, i.e. hammer testing, and visual inspection (VT). It is incumbent on the Owner/Operator to assure that the individual conducting the inspection has had the proper training and experience. As such, that person must have the capability to make acceptable visual examinations of all conditions found on a given boiler related to its safe operation.

A Visual Inspection of the fillet weld of a staybolt should be within the abilities of the inspector. Under that assumption if they find visual evidence of any reduction in weld condition or size, further means of evaluation will be brought into play.

Minimum weld size will be taken as a 3/16” equal leg fillet weld.

Under these considerations we can build a procedure as follows:

### INSPECTION PROCEDURE

1. The firebox shall be entered every 31 service days, Annual and 1472 service day inspection.
2. All staybolts shall be hammer tested under at least 50% of the Maximum Allowable Working Pressure (MAWP), or the boiler completely empty of water.
3. Staybolts leaking from the telltale hole shall be replaced before the boiler is returned to service.
4. Staybolts showing evidence of cracking in the area of, or adjacent to the weld shall be replaced or have the indication removed and repaired.

5. Where Visual Inspection (VT) indicates evidence of erosion or corrosion which reduces the installed size of the attaching fillet weld, the complete weld will be examined with a gauge set to indicate a weld size equivalent to a 3/16" equal leg fillet weld.
6. Any weld where more than one quarter (1/4) of its circumference is less than the 3/16" equal leg dimension will be restored to its original installed dimension. The weld to be restored will be ground to bright metal and Visually Inspected for indications prior to welding.
7. Indications will be evaluated to the indication acceptance criteria provided in the ASME Code, Section I (PW51).
8. Any unacceptable indication shall be removed prior to restoring the weld to the installed size.
9. Completed welds shall be Visually Inspected for unacceptable indications. Where repairs are required, the weld may be repaired once, if unacceptable on final inspection the entire staybolt shall be removed and replaced according to the initial installation criteria.
10. All welding will be conducted by welders qualified to the ASME Code, Section IX, for all positions (6G), or to the position to be welded.
11. When any repair or restoration has been conducted to attachment welds, the boiler shall be hydrostatically tested to 95% of the MAWP.
12. Where the inspector determines service corrosion conditions to be uncontrolled a random selection of staybolts (not less than ten (10)) shall be removed from the boiler and examined for evidence of wastage in the area where the staybolt interfaces with the wrapper and firebox plate.
13. Where this examination shows deterioration of the body of a staybolt to exceed more than 20% of the original diameter, a complete evaluation of the firebox and staybolts will be conducted.
14. A foot note will be attached to all records, documenting inspections of fillet welded staybolts, noting conditions found along with the signature of the inspector conducting the examination.