# RESEARCH COUNCIL ON STRUCTURAL CONNECTIONS (RCSC)
## MINUTES of SPECIFICATION COMMITTEE A.1

5 June 2014, 8:00AM (MDT), Estes Park, CO

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| **Members Present: (34)** | R. Baxter, P. Birkemoe, D. Bornstein, R. Brown, C. Curven, N. Deal, P. Dusicka, D. Ferrel, P. Fortney, K. Frank, B. Germuga, J. Greenslade, A. Harrold, T. Helwig, C. Hundley, L. Kruth, C. Larson, K. Lohr, C. Mayes, C. McGee, K. Menke, G. Mitchell, G. Rassati, T. Schlafly, G. Schroeder, R. Shanley, B. Shaw, V. Shneur, L. Shoemaker, J. Soma, W. Thornton, R. Tide, F. Vissat, J. Yura. |
| **Members Absent: (20)** | T. Anderson, A Astaneh-Asi, D. Bogaty, B. Cornelissen, D. Droddy, J. Fisher, J. Gialamas, R. Gibble, M. Gilmor, C. Kanapicki, P. Kasper, J. Kennedy, B. Lindley, N. McMillam. J. Mehta, H. Mitchell, J. Swanson, T. Tarpy, C. Wilson, A. Wong. |
| **Guests: (19)** | R. Babik, D. Barlow, S. Brahimi, G. Byrne, C. Carter, R. Connor, B. Dagher, C. Duncan, B. Duran, B. Goldsmith, P. Herbst, D. Kaufman, H. Mahmoud, C. McIntosh, J. McGormley, T. Murrey, J. Ocel, D. Sharp, T. Ude |

### AGENDA

**ITEM 1.0 <u>Chairman's Remarks:</u> (Harrold)**

- Specification Committee Chairman Harrold introduced host Curtis Mayes from LPR Construction.
- Specification Committee A.1 meeting will conclude around 12:00 Noon.
- Task Groups can meet after lunch; 12:30pm Field trip to LPR Construction
- Council Roster was circulated for verification and update of Email address, phone and fax numbers and any additional comments as required. Presently, there are fifty-four members on Specification Committee A.1. Guests were also asked to sign-in.
- Introduction of attendees.
- Discussions and voting shall be limited to Specification Committee A.1 members only.
- Discussions shall be limited only to agenda items listed.
- New specification to be issued by end of 2014; therefore ballot items need to be resolved by the end of this meeting.
- Harrold will be stepping down as chairman for Specification Committee A.1 and has accepted the chairmanship for the Research Council. Council is looking for Specification Committee A.1 chairman replacement.

**ITEM 2.0 <u>Approval of Minutes of the June 2013 Meeting:</u> (Harrold)**

- No additional comments, corrections and discussions took place. Therefore, Harrold ascertained that no comments are an approval of the minutes as written.

**ITEM 3.0 <u>Approval of Agenda:</u> (Harrold)**

- No additional agenda items were suggested; therefore Harrold concluded that the proposed agenda is approved as written.

**ITEM 4.0 Membership: (Harrold)**

- Roster was circulated for sign-in and updating of information.
- If guests are interested in joining Specification Committee A.1, they were asked to see Harrold during the break, after the meeting or send an email to Harrold.
- After the meeting, Bob Conner sent Harrold an email requesting Specification Committee A.1 membership.

**ITEM 5.0 Resolution of Ballot Results (Affirmative/Negative/Abstain): (Harrold)**

5.1 S12-047B Section 3.3 – Hole Definitions (Kruth): (2013-14 Ballot Item 2 Summary: 57/2/7 – Affirmative/Negative/Abstention). The ballot had two negatives (Miazga, H. Mitchell) both of which were changed to "Affirmative with comment" prior to the meeting based upon changes discussed between the TG and the voters. The committee reviewed the proposed editorial changes.

**ACTION ITEM 2014-01 (A.1) (S12-047B)**: The as-balloted item with proposed changes to the Specification were considered and accepted for inclusion into the 2014 Edition of the Specification.

5.2 S13-051 Section 9.2 – Snug-Tight Inspection (Carter): (2013-14 Ballot Item 3 Summary: 60/1/4 – Affirmative/Negative/Abstention). This ballot was the successor to ballot items S11-038 and S12-045 that were balloted on the 2012-13 ballot. The ballot had one negative (Curven). The negative voter provided no technical rationale for his negative other than he couldn't find the ballot language; Curven withdrew his negative at the meeting. Several affirmative votes with editorial comments were proposed and accepted. Connor and Sharp provided comments that were considered new business. Discussion followed (Frank, Shaw). Frank questioned the last sentence of Section 9.2.1, "A rotation that exceeds the required values, including tolerance, specified in Table 8.2 shall not be cause for rejection"; why have the tolerance?. Frank to propose new language as new business.

**ACTION ITEM 2014-02a (A.1) (S13-051)**: The as-balloted item with proposed changes to the Specification were considered and accepted for inclusion into the 2014 Edition of the Specification.

**ACTION ITEM 2014-02b (A.1):** Sharp requested new consideration of turn-of-nut rules for A325T bolts. S08-020 was a previous proposal that has languished in Spec Committee Task Group. This effort needs to be revived.

**ACTION ITEM 2014-02c (A.1):** Connor requested consideration for rules regarding requirements for "firm contact" when working with thick plates that will not easily close gaps through bolt tension alone.

**ACTION ITEM 2014-02d (A.1):** Frank to propose new language regarding the positive tolerance for future consideration.

5.3 S13-052 Section 6 – Use of Washers (Carter): (2013-14 Ballot Item 4 Summary: 62/0/4 - Affirmative/Negative/Abstention). The ballot had no negatives and passes with editorial corrections. Carter to forward Harrold additional commentary language; "With the 2011 revision of ASTM F436, special 5/16 in.-thick ASTM F436 washers are now called "extra thick"".

**ACTION ITEM 2014-03 (A.1) (S13-052)**: The as-balloted item with proposed changes to the Specification were considered and accepted for inclusion into the 2014 Edition of the Specification.

5.4 S12-040 Section 8.2.4 Commentary – DTI – Removal of Hardened Requirement (Brown) (2013-14 Ballot Item 1 Summary: 57/4/5 – Affirmative/Negative/Abstention). The ballot had four negatives (Birkemoe, Curven, Deal, and Lohr). Through an administrative error this item was sent to ballot rather than to the task group dealing with DTI issues. The Chair has determined that the negatives are to be considered persuasive and the ballot item will be returned to the task group for further evaluation.

**ACTION ITEM 2014-04 (A.1) (S12-040):** Task group to propose new language and submit to Chair for consideration. The change will need to be balloted. Task group is composed of Brown (chair), Curven, G. Mitchell, and Shaw.

**ITEM 6.0 <u>Discussions of Proposed Specification Changes:</u> (Harrold)**

- To make changes to the present specification, download from the RCSC web site a Proposed Change form, fill-out the proposed change, include rationale or justification for the change and add commentary as needed. The completed form needs to be submitted to the Chairman of the Executive Committee for consideration and assignment to the specification committee chair for creation of a task group or to become an agenda item at the next committee meeting. Proposed changes submitted after the Executive Committee meeting, typically in March, will not be acted on until the following year.

6.1 S14-053 Table 3.1 – Larger Standard Holes for Large Bolts (TG Chair - Carter): As discussed in the 2012 Specification Committee meeting, for high strength bolts greater than 1-1/4-inch in diameter, the upper limit bolt fabrication tolerance per ASME B18.2.6 exceeds the standard bolt hole diameter listed in RCSC Table 3.1, therefore field installation can be an issue. The tolerance issue is increased when galvanized bolts are introduced into painted/galvanized connections. Two options were suggested to resolve the problem: change hole size for high strength bolts greater than 1-1/4-inch in diameter; not the preferred option; or work with ASME B18.2.6 specification committee to revise upper bound tolerance to 0.062-inch (currently at 0.09-inch). Currently, ASME has the issue on the table for discussion, but has not changed the upper bound tolerance, therefore task group (Carter (chair), Shaw, G. Mitchell, Curven, Schlafly, Shneur) propose increasing bolt holes 1/8-inch larger than bolt sizes 1-inch in diameter and greater. Further discussion followed (Carter, Curven, Greenslade, Schroeder, Shaw, Shneur, Ferrel, Mayes, Baxter, Helwig, Deal, Frank). A 3mm larger hole diameter is permitted when using metric bolts in standard metric holes. If Table 3.1 is revised as proposed, Commentary language will also need to be changed. In reality, iron workers have two options to solve the tolerance issue, beat the bolts in or ream the holes. AISC is also looking into changing the bolt hole sizes for larger diameter bolts. This will also have an impact to AASHTO specifications; they meet in three weeks and Frank wants to provide AASHTO a heads-up as to the potential direction RCSC is heading. Any further comments are to be directed to the task group. Baxter, Deal & Ocel volunteered to be on the task group.

**ACTION ITEM 2014-05 (A.1) (S14-053):** The proposed change was sent back to the task group for further discussions. Carter to forward to Frank the proposed changes to Table 3.1.

6.2 S14-054 Section 5.4 – Limitation on $k_{sc}$ Equations (Murray): Executive Committee determined that the proposed Specification change to the two $k_{sc}$ equations were editorial in nature; where, $T_u/D_uT_bn_b \geq 0$ (LRFD) and $1.5T_a/D_uT_bn_b \geq 0$ (ASD).

**ACTION ITEM 2014-06 (A.1) (S14-054)**: The proposed editorial changes to the Specification were considered and accepted for inclusion into the 2014 Edition of the Specification.

6.3 S12-046 Glossary – Definition of Torque (TG Chair - Curven): The task group is composed of Curven (chair), Birkemoe, Brown, Mayes & Shneur. Task group proposes the following language to be added to the Glossary:

Bolt Tension: The axial force resulting from elongation of a bolt.
Torque: The moment (turning force) that tends to rotate a nut or bolt.
Further discussion followed (Kruth, Shneur, Ferrel, Mayes, Mahmound, Curven, Harrold, Deal, Mitchell, Fortney, Brahimi, Helwig). Concern arose regarding the misunderstanding by the engineers, inspectors and erectors that bolt elongation is not a bad thing. Suggest adding the word 'clamping' after the word axial.

**ACTION ITEM 2014-07 (A.1) (S12-046):** The proposed changes were considered and adopted for inclusion into the next revision of the specification. In order for the proposed changes to be included in the next revision to the Specification, the changes will need to be balloted.

6.4 S14-055 Section 2.4.2 Commentary – Lubricant Color (Tide): The proposed Commentary language was intended to promote a discussion within the industry so nut manufacturers can agree on a common lubricant color system to be used throughout the industry. Also, AASHTO mandates that lubricants on nuts be of a distinct visual color, whereas AISC and RCSC do not reference or address this subject. The last sentence of the proposed Commentary language should read "This green coloring infers over-tapped holes *after* the galvanizing operation". Further discussion followed (Tide, Harrold, Schroeder, Frank, Brahimi, Deal, Lohr). Executive Committee discussed this proposal in yesterday's meeting and decided not to pass it on to the Specification Committee. It was felt that ASTM should take the lead in establishing a standard. The nut manufacturers should come to an agreement on a common contrasting color system. End users should only be concerned with knowing that the nuts have been lubricated. Suggest that the reference to blue and green colors be removed from the proposed Commentary language and include the need for a contrasting color system.

**ACTION ITEM 2014-08 (A.1) (S14-055)**: Brahimi to forward this topic to Larson for ASTM Committee F16 consideration.

**ITEM 7.0 <u>Task Group (TG) Reports:</u>**

7.1 S13-039 Table 2.1 Commentary – Non-ASTM approved coatings (Schlafly): The Task Group is composed of Schlafly (chair), Auer-Collis, Babik, Gialamas, Kasper, Lohr, Mayes, G. Mitchell and Soma. Schlafly was asked to look into the approval for the usage of ASTM F1136 Zn/AL inorganic coatings on ASTM F1852 and F2280 TC-Bolt assemblies. The Zn/Al coatings were included in RCSC Table 2.1 (December 31, 2009) in anticipation of ASTM approval. Unfortunately, the proposal to ASTM was never moved to subcommittee for balloting the Zn/Al coating, therefore RCSC removed the usage on ASTM F1852 and F2280 bolt assemblies. The mission for the task group was to draft commentary language that discusses ramifications of using non-ASTM approved coatings on F1852 and F2280 TC-bolt assemblies. Schlafly to share first draft commentary language with his task group at lunch today.

Even though there have been thousands of TC-Bolts coated with Zn/Al and preforming well, if an end user wants to specify using this coating, Schlafly's research uncovered a list of items that need to be considered: coefficient of friction is different with this coating, therefore the torque required to shear off the spline is different, resulting in a modified pre-tension load; shear collar diameter needs to be altered. Nuts may need to be over-tapped. Grade of coating on the nut and bolt needs to be compatible. Testing – pre-installation verification testing required; proof load testing required?; rotational capacity not required for A490 & F2280 bolt assemblies, but maybe a testing protocol needs to be established. Corrosion - check if coating is acceptable when exposed to chemical, salt & concrete environments. Chrome in the coating may have an effect on the health of workers in a confined space environment.
Further discussion followed (Lohr, G. Mitchell, Larson, Brahimi, Frank, Birkemoe, Deal). TC-bolts are a calibrated assembly, therefore the bolt manufacturer needs to be responsible and in control of the entire finished product including coating, lubrication and testing. Many states are

requiring bolts in bridge construction to be galvanized, which eliminates A490 bolt usage. Stress corrosion experts, although not all aligned, are concerned that the Zn/Al coatings may have greater negative effects than the use of hot dipped galvanized coatings on A490 and F2280 bolts. Lohr passed out a 3 page draft write-up for specification committee and task group consideration. Since F2833 coating has been approved by ASTM and other such coatings are in various stages of approval, Table 2.1 is already considered outdated, regardless if F1136 coating is added to F1852 and F2280 TC-bolts; suggest leaving Table 2.1 as is and add Commentary language. Schlafly requested a straw vote to Revise Table 2.1, which involves the inclusion of ASTM F1136 Zn/Al inorganic coating to F1852 and F2280 TC-bolt assemblies and adding cautionary Commentary language. 4 negative votes recorded.

**ACTION ITEM 2014-09 (A.1) (S13-039)**: Task Group shall propose revisions, if required, to Table 2.1 and add Commentary language. Proposed changes are to be forwarded to the Executive Committee for review.

7.2 S13-049 Section 6.2.4 – Hardened Washers with DTI's (Brown): The task group is composed of Brown (chair), Curven, G. Mitchell, and Shaw. Brown was under the impression that the hardened washer with DTI's study was dropped from his task group last year, no further work has been done. During the 2013 Specification Committee meeting in Cincinnati OH, no discussion took place regarding the proposed Specification change (S12-040) requiring the removal of heat treatment in Section 8.2.4 Commentary per the latest ASTM F959. Brown wants to continue with the proposed change to the Specification (S12-040); see Section 5.4 above. The task group chair requested that this change proposal be dropped.

7.3 S13-050 Section 2.3 Commentary – Bolt Length Increments (H. Mitchell): The task group is composed of H. Mitchell (chair), Germuga, and Gialamas. H. Mitchell was not present to report progress. Harrold recommended that this topic be dropped until further information is available to discuss with the group.

7.4 Match-marking language for Turn-of-Nut (Kasper): The task group is composed of Kasper (chair), Mayes, G Mitchell, and Shaw. Kasper was not present to report progress. Shaw indicated that the task group has not had an opportunity to discuss, but does not want the topic dropped.

7.5 Snug Tight Definition – Turn of the Nut (Mayes): The task group is composed of Mayes (chair), Birkemoe, Jefferson, Kasper, Larson, McGormley, G. Mitchell, and Shneur. Mayes presented a video demonstration of a bolt installation per the Turn-of-Nut Pretensioning method starting with a snug-tightened condition per the present Specification definition '…tightened sufficiently to prevent the removal of the nuts without the use of a wrench". Following the Specification as written, resulted in the bolt reaching only 55% of the required minimum bolt pretension. Pre-installation verification would eliminate this from happening, but not all jobsites follow the rules. To resolve the issue immediately and not wait another 6 year specification revision cycle, Mayes proposes that the snug-tightened joint definition be revised to that of the 2004 Specification. Further discussion followed (G. Mitchell, Kruth, Schroeder, Shaw, Curven, Shneur, McGormley, Carter, Baxter, Lohr, Birkemoe). Over tensioning a bolt, 1/3 or 1/2 turn more, is usually not a problem unless the bolt breaks. For slip critical joints, the $D_u$ = 1.13 term is introduced to reflect the ratio of the mean installed bolt pretension to the specified minimum bolt pretension. Pre-installation verification is not always performed at a jobsite, therefore a snug-tightened condition as presently defined may not produce the proper pre-tensioning for the turn-of-nut installation method. Not to confuse the issue, the snug-tight definition applies to all pre-tensioning methods listed in Sections 8.2.1 through 8.2.4

In order to move this proposed change into the 2014 Specification edition, Harrold requested a straw vote to revise the definition of Snug-Tightened Joint in the Glossary to that shown in the 2004 Specification. McGormley cast the only negative vote, but would not hold-up the passage of the proposed change. All other members voted to accept the proposed change.
Mayes moved and Shaw seconded to ballot the proposed change.

**ACTION ITEM 2014-10 (A.1) (S07-013)**: The proposed changes to the Specification and Commentary were considered and accepted for inclusion into the 2014 Edition of the Specification. In order for the proposed changes to be included in the next revision to the Specification, the changes will need to be balloted.

7.6 Appendix A – Updates to testing protocol (Frank): The task group is composed of Frank (chair), Helwig, Ocel, and Yura. Task group will meet after lunch today. As some may be aware, there has been pressure on testing labs working with paint manufacturers to provide consistent testing results per the requirements of Appendix A. Discussion focused on ASTM considering updating and incorporating RCSC Specification Appendix A into an ASTM Standard and having Appendix A removed from RCSC's Specification. Further discussion followed (Frank, Brahimi, McGee, Schlafly). ASTM may be better prepared to provide more detail in re-writing the testing procedure. In order for RCSC to have input into the testing protocol, RCSC should have representation on associated ASTM Committee D01.46. Frank to update RCSC Specification Committee on the direction ASTM is planning to take.

**ITEM 8.0 Old Business: (Harrold)**

8.1 Thick Coatings (Birkemoe): No progress to report. This item will be removed from the agenda going forward.

8.2 Reduction in Shear Allowable for Long Joints (from Ballot S08-024) (Yura): Committee met last year, but minimum correspondence since. Yura has developed calculations that validate previous test results, which conclude that adding bolts to long joints does not increase the joint capacity. Controlling the stress level at the net section will determine the joint capacity. When completed, Yura will share his calculations with committee members.

8.3 Oversize Holes - Slip Critical? (Shear Connections) (Yura): Yura not reporting on this topic; to be removed from future agenda.

8.4 New Specification – XTB Bolts (Shaw): Internal draft was received by Executive Committee late yesterday, but was not given adequate time to be reviewed for discussion. One of the issues for discussion is whether the new specification is to be a stand-alone document or be incorporated into the existing RCSC Specification. Further discussion followed (Schlafly, Shaw, Harrold). AISC is meeting in the next few weeks to discuss XTB bolts and would like to know the direction RCSC is taking. Executive Committee would not have a disposition until after AISC meets. Because this new specification will need to be modified as new data is developed, Shaw would like to see the new specification be a stand-alone document.

**ACTION ITEM 2014-11 (A.1) (S14-060)**: Following the meetings, the initial proposal from Shaw was reviewed by the Executive Committee. The Executive Committee decided that it would be more appropriate if the XTB language was built into the existing Specification rather than writing a stand-alone document. This decision was returned to Shaw and a revised proposal will be required before any additional consideration will occur.

**ITEM 9.0 <u>New Business:</u> (Harrold)**

9.1 Specification Committee Organization (Harrold). To reduce the work load on the incumbent Specification Committee A.1 chair, Harrold suggests having several subcommittees responsible to specific sections of the current RCSC Specification. Proposed specification changes, task group reports and old/new business topics would be directed to the subcommittees for evaluation, discussion, disposition and reporting to Specification Committee A.1 at the annual meeting. Subcommittees would meet the day before the Specification Committee annual meeting to finalize their reports. Further discussion followed (Larsen, Harrold, Tide, Brahimi, Schlafly, Connor, McGormley, Shaw, Greenslade). The proposed Specification subcommittee structure has worked well for ASTM. Suggest having the subcommittees meet/teleconference several weeks/months prior to the annual meeting to discuss, disposition and report on their assigned tasks and use the day before the annual specification meeting to finalize their reports. Section 9.1 of the RCSC Articles of Association and Bylaws permits the Executive Committee to establish committees and subordinate groups. The majority of council members attend the specification committee meetings. Avoid duplicating reports from the subcommittee during the specification committee and main council meetings. First establish the chair for each subcommittee and the chair would solicit support staff for their respected subcommittees. If anyone is interested in becoming the chair for a subcommittee or is interested in becoming a member of a subcommittee they are asked to contact Harrold.

**ITEM 10.0 <u>Liaison Reports:</u>**

10.1 AISC (Carter): Next AISC specification meeting will be held June 24-27, 2014; balloting is currently underway. The August 1, 2014 RCSC Specification will be referenced in the next edition of the AISC Specification. There are still a few misalignments between the AISC Specification and the RCSC Specification.

10.2 S16 (Open): Greg Miazga was the S-16 liaison, but has since changed career paths and resigned from the Council. RCSC is looking for a Canadian candidate who will be the liaison between S-16 and RCSC.

10.3 ASTM F16 (Greenslade): Greenslade will issue his report during the main Council meeting.

**ITEM 11.0 <u>Date and time of next meeting:</u>**

To be coincident with the next annual meeting of the Research Council on Structural Connections

**ITEM 12.0 <u>Adjournment:</u>**

No motion was presented, Harrold declared the Specification Committee A.1 meeting adjourned; meeting disbanded at 11:49AM (MDT).

**ITEM 13.0 <u>Attachments:</u>**

13.1 Minutes of the June 2013 Meeting (Item 2.0)
13.2 Agenda (Item 3.0)
13.3 Resolution of Ballot Results (Item 5.0)

- S12-047B
- S13-051
- S13-052

- S12-040

13.4 Discussions of Proposed Specification Changes (Item 6.0)
- S14-053
- S14-054
- S12-046
- S14-055

13.5 Task Group (TG) Reports (Item 7.0)
- S13-039 Draft for Task Group Consideration (Lohr)
- Snug tight definition PowerPoint (Mayes)

13.6 Old Business (Item 8.0)
- XTB Bolts

13.7 New Business (Item 9.0)
- Specification Committee A.1 Organization (Harrold)

**RESEARCH COUNCIL ON STRUCTURAL CONNECTIONS (RCSC)**
**MINUTES of SPECIFICATION COMMITTEE A.1**
6 June 2013, 8:00AM, Cincinnati, OH

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| **Members Present: (37)** | T. Anderson, P. Birkemoe, D. Bogarty, D. Bornstein, R. Brown, C. Curven, D. Ferrell, P. Fortney, B. Germuga, J. Gialamas, J. Greenslade, A. Harrold, T. Helwig, C. Kanapicki, P. Kasper, L. Kruth, C. Larson, B. Lindley, K. Lohr, C. Mayes, C. McGee, K. Menke, G. Miazga, G. Mitchell, H. Mitchell, G. Rassati, T. Schlafly, G. Schroeder, R. Shaw, V. Shneur, L. Shoemaker, J. Swanson, W. Thornton, R. Tide, F. Vissat, A. Wong, J. Yura |
| **Members Absent: (15)** | A. Astaneh-Asi, R. Baxter, B. Cornelissen, N. Deal, D. Droddy, J. Fisher, K. Frank, R. Gibble, M. Gilmor, C. Hundley, J. Kennedy, N. McMillan, J. Mehta, T.Tarpy, C. Wilson |
| **Guest: (19)** | D. Auer-Collis, R. Babik, G. Byrne, R. Connor, C. Carter, G. DePhillis, P. Dusicka M. Eatherton, M. Friel, B. Goldsmith, P. Herbst, E. Jefferson, J. McGormley, J. Ocel, B. Porter, R. Shanley, J. Soma, T. Ude, W. Wloszek |

**AGENDA**

**ITEM 1.0 Chairman's Remarks: (Harrold)**

- Specification Committee Chairman Harrold introduced hosts Jim Swanson & Gian Rassati from the University of Cincinnati.
- Specification Committee A.1 meeting will conclude around 12:00 Noon.
- Task Groups can meet after lunch; 2:00pm testing of super-high-strength bolts at high bay lab; 4:00pm tour of the Cincinnati Museum Center (old train station).
- Council Roster was circulated for verification and update of Email address, phone and fax numbers and any additional comments as required. Presently, there are fifty-two members on Specification Committee A.1; guests were also asked to sign-in.
- Introduction of attendees.
- Discussions and voting shall be limited to Specification Committee A.1 members only.
- Discussions shall be limited only to agenda items listed.
- New specification to be issued by end of 2014; therefore ballot items need to be resolved by 2014 annual meeting.

**ITEM 2.0 Approval of Minutes of the June 2012 Meeting: (Harrold)**

Vissat noted that Item 5.4 was incorrectly written in the 2012 meeting minutes. The corrected editorial changes are as follows:

Pretension (verb). The act of tightening a fastener assembly such that the minimum specified tensile force exists. ~~to a specific level of tension or higher~~.

Pretension (noun). A level of minimum specified tensile force remaining ~~tension achieved~~ in a fastener assembly ~~through~~ after ~~its~~ installation, as required for pretensioned and slip-critical joints.

No additional comments, corrections and discussions took place; therefore Harrold concluded an approval of the minutes as noted.

**ITEM 3.0 <u>Approval of Agenda:</u> (Harrold)**

- Changes to agenda are as follows: Requested by Brown to add Item 6.4 to Discussion of Proposed Specification Changes section as related to ASTM F959 revision. Requested by Shaw to add Item 9.2 to New Business section regarding XTB bolts. Requested by Mayes to add Item 9.3 to New Business section regarding Snug Tight definition. Requested by Shaw to add Item 9.4 to New Business section regarding large holes and large bolts. No additional agenda items were suggested; therefore Harrold concluded that the proposed agenda, with noted changes incorporated, is approved as modifed.

**ITEM 4.0 <u>Membership:</u> (Harrold)**

- Roster was circulated for sign-in and updating of information.
- If guests are interested in joining Specification Committee A.1, they were asked to see Harrold during the break, after the meeting or send an email to Harrold.
- Geoff Kulak was approved by exec committee as a life member and has resigned from Specification Committee A.1.
- After the meeting, Rachel Shanley, Jim Soma and Peter Dusicka sent Harrold email requesting Specification Committee A.1 membership.

**ITEM 5.0 <u>Resolution of Ballot Results (Affirmative/Negative/Abstain):</u> (Harrold)**

5.1 S11-038 Sections 8.2, 8.2.1, and 8.2.3 - Pre-installation Verification Testing Language (Curven): (2012-13 Ballot Item 1 summary: 61/5/2 – Affirmative /Negative/Abstention). The ballot had 5 negatives (Ferrell, McGormley, G. Mitchell, H. Mitchell, and Tide). Addressing the first negative, Curven moved and Shaw seconded to find Ferrell's negative vote for the balloted proposed change to be non-persuasive. Discussion followed (Ferrell, McGormley, Carter, Harrold, Curven, Schroder, H. Mitchell, G. Mitchell, Yura). All five negative votes had similar comments; repeating the pre-installation verification in the definition of each installation method is not necessary. Incorrect references need to be corrected; considered editorial in nature.
Harrold requested a vote for the motion to find Ferrell's negative vote non-persuasive, with results as follows:

2 for the vote to be non-persuasive
19 against the vote to be non-persuasive
11 abstained

A task group was created to modify the language.

**ACTION ITEM 2013-01 (A.1) (S11-038)**: The as-balloted item with proposed changes to the Specification was considered and defeated for inclusion into the next revision of the Specification. A task group composed of Curven (chair), Carter, G. Mitchell, Shaw, and Ude will review and revise the "as presented" proposal language.

5.2 S12-039 Table 2.1 – Delete Zn/Al coating from F1852 and F2280 assemblies (Schlafly): (2012-13 Ballot Item 2 summary: 61/3/4 – Affirmative/Negative/Abstention). The ballot had three negatives (Kasper, Lohr, Mayes), all generally had similar issues; successful usage worldwide of Zn/Al coatings on TC bolts without ASTM language explicitly allowing the coating. Discussion followed (Harrold, Lohr, Larsen, Schafly, Curven, Kasper, Mayes, Greenslade, McGormley, Shaw). With several new coatings being introduced to the market, suggest referencing ASTM approved coatings list verses constantly updating RCSC Table 2.1. If the manufacture or user introduces a secondary process change (coating or lubrication) to the assembly, then the entire assembly needs to be tested and re-certified.
Tide moved and Shneur seconded to find all three negative votes for the balloted proposed change to be non-persuasive. Harrold requested a vote for the motion with the understanding that a Task Group would add Commentary language; result of the vote was as follows:

24 for the votes to be non-persuasive
5 against the votes to be non-persuasive
6 abstained

**ACTION ITEM 2013-02 (A.1) (S12-039)**: The as-balloted item with proposed changes to the Specification was considered and accepted for inclusion into the next revision of the Specification with the understanding that a Task Group will draft Commentary language that discusses ramifications of using non-ASTM approved coatings on ASTM F1852 & F2280 TC bolt assemblies. The Task Group is composed of Schlafly (chair), Auer-Collis, Babik , Gialamas, Kasper, Lohr, Mayes, G. Mitchell and Soma.

5.3 S12-042 Section 5.4 – Slip Critical Equations (Schlafly): (2012-13 Ballot Item 3 summary: 48/3/17 – Affirmative/Negative/Abstention). The ballot had eight affirmative votes with comments. Schlafly considered no actions/changes required from Baxton, Eatherton and Helwig comments. Changes as follows from Birkemoe, Chen, Connor, H. Mitchell and Schlafly were considered and accepted as editorial: in new Commentary language, include the words 'reliability index,' before the word 'beta,'; in Section 5.4, third paragraph, replace 'The available slip resistance for the limit state…'.with 'The *nominal* slip resistance *per bolt* for the limit state…'; remove Item (4) from Section 1.4; delete Commentary paragraph that begins with 'Because of the greater….'; change Commentary Item (2), second sentence 'should be' to '*are*'; change Commentary Item (3), first sentence 'can be' to '*is*'. The ballot had three negatives (Tide, Yura & Wong). Comments from Tide were editorial in nature; poor grammar and poor specification writing. Schlafly will include in the first sentence of Section 5.4 references to Sections 5.1, 5.2 and 5.3 for bearing-type connection limit states. With the understanding that editorial comments from Tide would be considered and accepted, Tide withdrew his negative vote. Yura suggested that in Section 5.4, reference to ASD and Canadian LSD be removed; Schlafly agreed with removing the Canadian reference, but not the LRFD & ASD duel system callout (LRFD (Φ) & ASD (Ω) is used throughout the Specification to align with AISC; see Ballot Item S11-033). Schlafly previously agreed with deleting Commentary paragraph that begins with 'Because of the greater…., change Commentary Item (2), second sentence 'should be' to 'are' and change Commentary Item (3), first sentence 'can be' to 'is'. Schlafly agreed to include at the end of the second to last sentence of the first paragraph in the Commentary '*for specimens tightened using the calibrated wrench method*' and remove from the first sentence of the seventh paragraph 'approximately in the single value of the slip probability factor $D_u$'. With the additions and deletions discussed and agreed upon, Yura withdrew his negative vote. Wong provided no explanation for the negative and per the bylaws of the Council that negative vote was ignored.

**ACTION ITEM 2013-3 (A.1) (S12-042)**: The as-balloted item with proposed changes to the Specification were considered and accepted for inclusion into the next revision of the Specification with the understanding that several editorial comments from affirmative and negative votes be included.

5.4 S12-043 Section 8.1 Commentary – TC bolts in Snug Tight joints (Schlafly): (2012-13 Ballot Item 4 summary: 66/1/1 – Affirmative/Negative/Abstention). Ballot language was written to eliminate economical or esthetical favoritism to either condition of having the splines of TC bolts twisted off or left in place. The ballot had five affirmative votes with comments. Schlafly considered no actions/changes required from Astaneh, Hay and Vissat comments. Chen comment not related to the ballot proposal, but considered new business if Chen desires to pursue. McGormley suggested that the word 'twisted-off" be replaced with the word 'removed'. A twisted-off condition would indicate that the bolt assembly was fully pre-tensioned. Discussion followed (McGormley, G. Mitchell, H. Mitchell, Mayes, Schroder, Ferrell, Kruth). Schlafly will consider the revised wording. The ballot had one negative (Frank). Further discussion followed (Yura, Shoemaker, Harrold, Fortney, Shneur, Larsen, Shaw, Ferrell). If so

required by the engineer that a snug tightened joint not have the splines removed, Commentary language should direct that required information be included on the Design Drawing or in the Specification. There is no maximum preload required for a snug tightened joint.
Schlafly moved and Ferrell seconded to find the negative vote for the balloted proposed change to be non-persuasive. Harrold requested a vote for the motion as follows:

33 for the vote to be non-persuasive
0 against the vote to be non-persuasive
3 abstained

**ACTION ITEM 2013-04 (A.1) (S12-043)**: The as-balloted item with proposed changes to the Specification was considered and accepted for inclusion into the next revision of the Specification.

5.5 S12-044 Section 5.1 – Fillers (Schlafly): (2012-13 Ballot Item 5 summary: 57/2/9 – Affirmative/Negative/Abstention). The ballot had eight affirmative votes with comments. Schlafly considered no actions/changes required from Birkemoe comment; changes from Chen, Ricles & Tide were considered and accepted as editorial; Conner comment to change *they* to *the connection* was accepted; Frank comment not related to the ballot proposal, but considered new business if Frank desires to pursue; Shaw comment that (4) be split into (4) and (5) was considered and accepted as editorial; Shoemaker comment regarding clarification to the number of tests using 24-bolt connections was considered and accepted as editorial.
The ballot had two negatives (Baxter, Dusicka). Further discussion followed (Schlafly, Yura, Shaw, Harrold). Baxter negative vote does not have data to support including alternate design fasteners (TC bolts) in (4). Schlafly moved and Shaw seconded to find Baxter's negative vote for the balloted proposed change to be non-persuasive. Harrold requested a vote for the motion as follows:

25 for the vote to be non-persuasive
0 against the vote to be non-persuasive
12 abstained

Dusicka negative vote basis needs further work with supporting data, therefore Schafly requested Dusicka to withdraw his negative vote and consider negative comment as New Business; Dusicka agreed to withdraw his negative vote.

**ACTION ITEM 2013-05 (A.1) (S12-044)**: The as-balloted item with proposed changes to the Specification was considered and accepted for inclusion into the next revision of the Specification with the understanding that several affirmative votes with comments would be included.

5.6 S12-045 Sections 8.2.3, 9.2.1, 9.2.2, 9.2.3 – Inspection Process (Curven): (2012-13 Ballot Item 6 summary: 52/10/6 – Affirmative/Negative/Abstention). The ballot had 10 negatives (Ferrell, Hay, Helwig, Lohr, Mayes, McGormley, G. Mitchell, H. Mitchell, Tide and Ude). Discussion followed (Curven, Harrold, Shaw). Since this ballot item is similar to Ballot Item 1 (S11-038), it was suggested that the 10 negative votes be found persuasive and the same Task Group for Ballot Item 1 also address Ballot Item 6.

**ACTION ITEM 2013-06 (A.1) (S12-045)**: The as-balloted item with proposed changes to the Specification was considered and defeated for inclusion into the next revision of the Specification. A task group composed of Curven (chair), Carter, G. Mitchell, Shaw, and Ude will review and revise the as presented proposal language.

5.7 S12-047 Section 3.3 – Hole Definitions (Kruth): (2012-13 Ballot Item 7 summary: 63/3/2 – Affirmative/Negative/Abstention). The ballot had three negatives (Curven, Frank, Helwig). Modifications (5/10/13) to the as-balloted items, shown as either double strikethrough or double underline, were made to satisfy Frank and Helwig negatives. These modifications in

essence find Frank and Helwig negative votes persuasive. Kurth moved and Shneur seconded to find Curven negative vote for the balloted proposed change to be non-persuasive.
Discussion followed (McGormley, Harrold, Kruth, Ferrell, Shneur, H. Mitchell, Fortney, Helwig). Since changes have been made to the as-balloted items, these changes will need to be re-balloted. The re-write to Section 3.3.3 Commentary needs to address end connection rotation effects on beam/girder members that are not laterally or torsionally restrained. The EOR needs to define not using short slotted holes; use permitted unless otherwise defined as not acceptable. The ballot item was returned to the task group for further discussion regarding the proposal.

**ACTION ITEM 2013-07 (A.1) (S12-047)**: The as-balloted item with proposed changes was considered and defeated for inclusion into the next revision of the specification. The original task group composed of Kurth (chair), Carter, Ferrell, Fortney, Gibble, and Shneur will review and revise the as presented proposal language.

**ITEM 6.0 <u>Discussions of Proposed Specification Changes:</u> (Harrold)**

- To make changes to the present specification, download from the RCSC web site a Proposed Change form, fill-out the proposed change, include rationale or justification for the change and add commentary as needed. The completed form needs to be submitted to the Chairman of the Executive Committee for consideration and assignment to the specification committee chair for creation of a task group or to become an agenda item at the next committee meeting. Proposed changes submitted after the Executive Committee meeting, typically in March, will not be acted on until the following year.

6.1 S12-048 Section 1.5 – ASTM Name (Harrold): ASTM, as referenced in the Specification, is now referred to as ASTM International without spelling out what the letters ASTM formerly meant. Executive Committee approved the change as editorial.

6.2 S13-049 Section 6.2.4 – Hardened Washers with DTI's (Brown): Section 6.2.4 is very specific regarding the use of ASTM F436 hardened washers in conjunction with ASTM F959 DTI's. Rowan University published testing results of curved protrusion DTI's without incorporating hardened washers, with acceptable pre-installation tensioning results. For bolt sizes 1-inch and less, ASTM F436 hardened washers have a flatness deviation tolerance of 0.010-inch and for bolt sizes greater than 1-inch, the flatness deviation tolerance is 0.015-inch. Recent field pre-installation verification testing results indicated unacceptable pre-tension results due to hardened washer installation orientation (concaved face). Further discussion followed (Brown, Harrold, Curven, Kasper, Schroeder, Shneur, G. Mitchell, Shaw). Remove language that addresses proprietary requirements as related to curved protrusions. Section 2.6.2 addresses Alternative Washer-Type Indicating Devices; suggest including a section that includes Alternative Fastener Installation Methods. Hole diameter tolerance for ASTM F436 hardened washers provides challenges in obtaining pre-installation tensioning results.
A task group composed of Brown (chair), Curven, G. Mitchell & Shaw shall propose new specification language which addresses the usage of ASTM F436 hardened washers with ASTM F959 DTI's and include the removal of heat treatment requirements in Section 8.2.4 Commentary per the latest ASTM F959.

**ACTION ITEM 2013-08 (A.1):** Task group to propose new language and submit to Harrold for consideration. In order for the proposed change to be included in the next revision to the Specification, the change will need to be balloted. Task group is composed of Brown (chair), Curven, G. Mitchell, and Shaw.

6.3 S13-050 Section 2.3 Commentary – Bolt Length Increments (H. Mitchell): Further discussion followed (Harrold, Friel, Miazga). No reference made in Commentary to support adjusting Table C-2.2 to the nearest ½-inch length increment for bolt lengths exceeding 5 or 6 inches. A task group composed of H. Mitchell (chair), Germuga & Gialamas will propose new language in Section 2.3 Commentary to define length increment value(s) based on input obtained from the various bolt manufacturers.

**ACTION ITEM 2013-09 (A.1):** Task group to propose new language and submit to Harrold for consideration. In order for the proposed change to be included in the next revision to the Specification, the change will need to be balloted. Task group is composed of H. Mitchell (chair), Germuga, and Gialamas.

6.4 S12-040 Section 8.2.4 Commentary – Removal of Hardened Requirement (Brown): Due to lack of time, no discussion took place. Subject will be addressed by Item 6.2 task group.

**ACTION ITEM 2013-10 (A.1):** Task group to propose new language and submit to Harrold for consideration. In order for the proposed change to be included in the next revision to the Specification, the change will need to be balloted. Task group is composed of Brown (chair), Curven, G. Mitchell, and Shaw.

**ITEM 7.0 <u>Task Group (TG) Reports:</u>**

7.1 Match-marking language for Turn-of-Nut (Kasper): Present language in the Specification does not require match-marking the nut and bolt position when pre-tensioning the assembly using the turn-of-nut method. In other parts of the world, match-marking is a requirement. Task group (Kasper (chair), Mayes, G Mitchell, Shaw) did not meet, but Kasper recommended continuing the task group. In addition to match-marking requirements, the task group will also consider introducing new tool technology that controls nut rotation.

**ACTION ITEM 2013-11 (A.1):** Task group to propose new language and submit to Harrold for consideration. In order for the proposed change to be included in the next revision to the Specification, the change will need to be balloted. Task group is composed of Kasper (chair), Mayes, G. Mitchell, and Shaw.

7.2 Glossary Definition of Torque (Curven): A task group composed of Curven (chair), Birkemoe, Brown, Mayes & Shneur is close to language agreement and ready to issue recommendation for balloting.

**ACTION ITEM 2013-12 (A.1):** Task group to propose new language and submit to Harrold for consideration. In order for the proposed change to be included in the next revision to the Specification, the change will need to be balloted. Task group is composed of Curven (chair), Birkemoe, Brown, Mayes, and Shneur.

**ITEM 8.0 <u>Old Business:</u> (Harrold)**

8.1 Failures due to tightening bolts from the head side (G. Mitchell): Delayed failures of ASTM A325 galvanized and A490 black bolts on bridge and power plant work when tightened from the head side. Limited testing has taken place, but not completed. Set-up similar to that of a compression slip test specimen: (3) ¾-inch Grade 50 steel plates, 7/8-inch diameter A325 bolts, hardened washer under the turned element, installed by turn-of-nut method. Checking torque values when bolt heads and nuts are turned with a load applied to the ¾-inch steel plates, which bears on the shank of the bolt. Further discussion followed (Schroder, Harrold, Brown, Larson). Consider lubricating the turned element (bolt head and or hardened washer). Second paragraph of Section 8.2 will need to be re-written to include lubrication requirements. Pre-installation verification testing will need to consider the as installed condition; with and without lubrication.

**ACTION ITEM 2013-13 (A.1)**: Research Committee chair, Todd Ude, to look for funding from RCSC, AISC, AASHTO and FHWA to support additional research on this issue.

8.2 Thick Coatings (Birkemoe): Due to lack of time, no discussion took place.

8.3 Shear Allowables (from Ballot S08-024) (Yura): Due to lack of time, no discussion took place.

8.4 Oversize Holes - Slip Critical? (Shear Connections) (Yura): Due to lack of time, no discussion took place.

**ITEM 9.0** **New Business:** **(Harrold)**

9.1 Appendix A creep tests at service load level (Yura): Due to lack of time, no discussion took place.

9.2 XTB (Shaw): Due to lack of time, no discussion took place.

9.3 Snug-Tight Definition: Mayes (LPR Construction) conducted a field study of nut rotations from snug-tight condition for turn-of-nut pre-tensioning and found pre-tension results not in line with specification requirements. A new Task Group composed of Mayes (chair), Larson, McGormley, Birkemoe, Kasper, G. Mitchell, Shneur, and Jefferson to re-study snug-tight definition as currently written in the Specification Glossary.

**ACTION ITEM 2013-14 (A.1):** Task group to propose new language and submit to Harrold for consideration. In order for the proposed change to be included in the next revision to the Specification, the change will need to be balloted. Task group is composed of Mayes (chair), Birkemoe, Jefferson, Kasper, Larson, McGormley, G. Mitchell, and Shneur.

9.4 Large Holes and Large Bolts: (Shaw): Due to lack of time, no discussion took place.

**ITEM 10.0** **Liaison Reports:**

10.1 AISC (Carter): Due to lack of time, no reports were presented.

10.2 S16 (Miazga): Due to lack of time, no reports were presented.

10.3 ASTM F16 (Greenslade): Due to lack of time, no reports were presented.

**ITEM 11.0** **Date and time of next meeting:**

To be coincident with the next annual meeting of the Research Council on Structural Connections

**ITEM 12.0** **Adjournment:**

No motion was presented, Harrold declared the Specification Committee A.1 meeting adjourned; meeting disbanded at 12:04PM.

**ITEM 13.0** **Attachments:**

13.1 Agenda (Item 3.0):

13.2 Resolution of Ballot Results (Item 5.0)

- S11-038
- S12-039

- S12-042
- S12-043
- S12-044
- S12-045
- S12-047

13.3 Discussions of Proposed Specification Changes (Item 6.0)

- S12-048
- S13-049
- S13-050

## RESEARCH COUNCIL ON STRUCTURAL CONNECTIONS

## SPECIFICATION COMMITTEE A.1 MEETING JUNE 5, 2014
## 8:00 AM - 12:00 PM

## AGENDA

0.1 ATTENDANCE

1.0 CHAIRMAN'S REMARKS

This meeting marks the close of the next edition of the specification. Items passed by the close of the meeting will be included.

2.0 APPROVAL OF MINUTES OF JUNE 2013 MEETING

3.0 APPROVAL OF AGENDA

4.0 MEMBERSHIP
- 4.1 Review and Update Membership List

5.0 RESOLUTION OF BALLOT RESULTS (Affirmative/Negative/Abstain)

| | | | |
|---|---|---|---|
| 5.1 | S12-047B | Section 3.3 - Hole Definitions (57/2*/7) (Negatives changed to Affirm w/comment) | (Kurth) |
| 5.2 | S13-051 | Section 9.2 – Snug Tight Inspection (60/1/4) | (Carter) |
| 5.3 | S13-052 | Section 6 – Use of Washers (62/0/4) | (Carter) |
| 5.4 | S12-040 | Section 8.2.4 Commentary – DTI – Removal of Hardened Requirement (57/4/5) | (Brown) |

6.0 DISCUSSION OF PROPOSED SPECIFICATION CHANGES

| | | | |
|---|---|---|---|
| 6.1 | S14-053 | Table 3.1 – Larger Standard Holes for Large Bolts (TG Report) | (Carter) |
| 6.2 | S14-054 | Section 5.4 – Limitation on $k_{sc}$ Equations | (Murray) |
| 6.3 | S12-046 | Glossary Definition of Torque (TG Report) | (Curven) |
| 6.4 | S14-055 | Section 2.4.2 Commentary – Lubricant Color | (Tide) |

7.0 TASK GROUP REPORTS

| | | | |
|---|---|---|---|
| 7.1 | S13-039 | Table 2.1 Commentary – Non-ASTM approved coatings | (Schlafy) |
| 7.2 | S13-049 | Section 6.2.4 – Hardened Washers with DTI's | (Brown) |
| 7.3 | S13-050 | Section 2.3 Commentary – Bolt Length Increments | (H. Mitchell) |
| 7.4 | Match-marking language for Turn of the Nut | | (Kasper) |
| 7.5 | Snug Tight Definition – Turn of the Nut | | (Mayes) |
| 7.6 | Appendix A – Updates to testing protocol | | (Frank) |

8.0 OLD BUSINESS

| | | |
|---|---|---|
| 8.1 | Thick Coatings | (Birkemoe) |
| 8.2 | Shear Allowables (from Ballot S08-024) | (Yura) |
| 8.3 | Oversize Holes - Slip Critical? (Shear Connections) | (Yura) |
| 8.4 | New Specification – XTB bolts | (Shaw) |

9.0 NEW BUSINESS

| | | |
|---|---|---|
| 9.1 | Specification Committee Organization | (Harrold) |

10.0 LIAISON REPORTS

| | | |
|---|---|---|
| 10.1 | AISC | (Carter/Schlafly) |
| 10.2 | S16 | |
| 10.3 | ASTM F16 | (Greenslade) |

11.0 NEXT MEETING

12.0 ADJOURNMENT

# RCSC Proposed Change: S12-047B

**Name:** Lawrence F. Kruth
**E-mail:** lkruth@douglassteel.com
**Phone:** 517-999-4113
**Fax:** 517-322-0050

**Ballot History:**

2012-13 Ballot Item # 7 (S12-047)
63 Affirmative
3 Negative (Curven, Frank, Helwig)
2 Abstain

2013-14 Ballot Item # 2
57 Affirmative
2 Negative (Miazga, Heath Mitchell) Both changed to Affirmative w/Comments
7 Abstain

**Proposed Change:**

***{This proposal is in response to persuasive negatives on Proposal S11-035. The proposed language modifies the current 2009 Specification language without regard to the previous proposal S11-035 which has been terminated.}***

***The current ballot proposal S12-047B replaces the proposed language in S12-047. The original balloted proposal and a listing of all negatives and comments follow the current proposal listing. (Scroll down to the words "S12-047 (Original balloted proposal – 2012-13 Ballot Item #7)" for historical information.)***

**2/24/14 Proposal as modified and agreed upon by the Task Group in response to voter comments on the 2013-14 Ballot item. All negative voters have agreed to the changes and changed their votes to "affirmative w/ comments".**
**Changes made as a result of ballot comments are shown as double strikethrough for deletions from the balloted language and double underline for additions to the balloted language.**

## 1.4. Drawing Information

The *Engineer of Record* shall specify the following information in the contract documents:

(1) The ASTM designation and type (Section 2) of bolt to be used;
(2) The *joint* type (Section 4);
(3) The required class of slip resistance if *slip-critical joints* are specified (Section 4); and,

------------------------------------For Committee Use Below-----------------------------------------------

Date Received: 6/8/12 Exec Com Meeting: _______ Forwarded: Yes ☐ /No ☐

Committee Assignment: Executive -A. ☐ Editorial -B. ☐ Nominating -C. ☐

Specifications -A.1 X Research -A.2 ☐ Membership & Funding -A.3 ☐ Education -A.4 ☐
Committee Chair: Harrold Task Group #: ___________ T.G. Chair: Kurth
Date Sent to Main Committee: _______________Final Disposition: ______________________

(4) Whether slip is checked at the factored-load level or the service-load level, if *slip-critical joints* are specified (Section 5).

**Commentary:**
A summary of the information that the *Engineer of Record* is required to provide in the contract documents is provided in this Section. The parenthetical reference after each listed item indicates the location of the actual requirement in this Specification. In addition, the approval of the *Engineer of Record* is required in this Specification in the following cases:

(1) For the reuse of non-galvanized ASTM A325 bolts (Section 2.3.3);
(2) For the use of alternative washer-type indicating devices that differ from those that meet the requirements of ASTM F959, including the corresponding installation and inspection requirements that are provided by the *manufacturer* (Section 2.6.2);
(3) For the use of alternative-design fasteners, including the corresponding installation and inspection requirements that are provided by the *manufacturer* (Section 2.8);
(4) For the use of faying-surface coatings in *slip-critical joints* that provide a *mean slip coefficient* determined per Appendix A, but differing from Class A or Class B (Section 3.2.2(b));
(5) For the use of thermal cutting ~~in the production~~ of bolt holes produced free hand or for use in cyclically loaded joints (Section 3.3);
(6) For the use of oversized (Section 3.3.2), short-slotted (Section 3.3.3) or long slotted holes (Section 3.3.4) in lieu of standard holes;
(7) For the use of a value of $D_u$ other than 1.13 (Section 5.4.1); and,
(8) For the use of a value of $D$ other than 0.80 (Section 5.4.2).

## 3.3. Bolt Holes

The nominal dimensions of standard, oversized, short-slotted and long-slotted holes for *high-strength bolts* shall be equal to or less than those shown in Table 3.1. Holes larger than those shown in Table 3.1 are permitted when specified or approved by the *Engineer of Record*. ~~Where thermally cut holes are permitted, the surface roughness profile of the hole shall not exceed 1,000 microinches as defined in ASME B46.1. Occasional gouges not more than 1/16 in. in depth are permitted.~~ When complete connection design is not shown in the structural design drawings, the ~~The~~ *Engineer of Record* shall be notified of the type and dimensions of holes to be used. ~~Oversize~~ Oversized holes, short slots not perpendicular to the applied load and long slots in any direction shall be subject to approval by the *Engineer of Record*. Any restrictions on the use of hole types permitted in sections 3.3.1, 3.3.2, 3.3.3 and 3.3.4 ~~3.3.3~~ other than those ~~listed~~ permitted shall be specified in the design documents.

Thermally cut holes produced by mechanically guided means are permitted in statically loaded *joints*. The surface roughness profile of the hole shall not exceed 1,000 microinches as defined in ASME B46.1. Occasional gouges not more than 1/16 in. in depth are permitted. Thermally cut holes produced free hand shall be permitted in statically loaded *joints* if approved by the *Engineer of Record*. For cyclically loaded *joints*, thermally cut holes shall be permitted if approved by the *Engineer of Record*.

**Commentary:**

The footnotes in Table 3.1 provide for slight variations in the dimensions of bolt holes from the nominal dimensions. When the dimensions of bolt holes are such that they exceed these permitted variations, the bolt hole must be treated as the next larger type.

Slots longer than standard long slots may be required to accommodate construction tolerances or expansion *joints*. Larger oversized holes may be necessary to accommodate construction tolerances or misalignments. In the latter two cases, the Specification provides no guidance for further reduction of *design strengths* or allowable loads. Engineering design considerations should include, as a minimum, the effects of edge distance, net section, reduction in clamping force in *slip-critical joints*, washer requirements, bearing capacity, and hole deformation.

~~Short slots are used to account for minor adjustments in main members such as web thickness differences and member length. This practice is prevalent enough that this specification recognizes it and permits it unless it is specifically prohibited on design documents. This specification requires the *Engineer of Record* to be notified of the hole types and dimensions by showing this information on shop detail drawings as opposed to obtaining prior approval of the *Engineer of Record*.~~

For thermally cut holes produced free hand, it is usually necessary to grind the hole surface after thermal cutting in order to achieve a maximum surface roughness profile of 1,000 microinches.

Slotted holes in statically loaded *joints* are often produced by punching or drilling the hole ends and thermally cutting the sides of the slots by mechanically guided means. The sides of such slots should be ground smooth, particularly at the junctures of the thermal cuts to the hole ends.

For cyclically loaded *joints*, test results have indicated that when no major slip occurs in the *joint*, fretting fatigue failure usually occurs in the gross section prior to fatigue failure in the net section (Kulak et al., 1987, pp. 116, 117). Conversely, when slip occurs in the *joints* of cyclically loaded *connections*, failure usually occurs in the net section and the edge of a bolt hole becomes the point of crack initiation (Kulak et al., 1987, pp. 118). Therefore, for cyclically loaded *joints* designed as slip critical, the method used to produce bolt holes (either thermal cutting or drilling) should not influence the ultimate failure load, as failure usually occurs in the gross section when no major slip occurs.

3.3.1. Standard Holes: ~~In the absence of approval by the *Engineer of Record* for the use of other hole types, standard~~ Standard holes ~~shall~~ are permitted to be used in all plies of bolted *joints*.

### Table 3.1. Nominal Bolt Hole Dimensions

| Nominal Bolt Diameter, $d_b$, in. | Nominal Bolt Hole Dimensions [a,b], in. | | | |
|---|---|---|---|---|
| | Standard (diameter) | Oversized (diameter) | Short-slotted (width × length) | Long-slotted (width × length) |
| **½** | 9/16 | 5/8 | 9/16 × 11/16 | 9/16 × 1 1/4 |
| **5/8** | 11/16 | 13/16 | 11/16 × 7/8 | 11/16 × 1 9/16 |
| **¾** | 13/16 | 15/16 | 13/16 × 1 | 13/16 × 1 7/8 |
| **7/8** | 15/16 | 1 1/16 | 15/16 × 1 1/8 | 15/16 × 2 3/16 |
| **1** | 1 1/16 | 1 ¼ | 1 1/16 × 1 5/16 | 1 1/16 × 2 ½ |
| **≥1 1/16** | $d_b$ + 1/16 | $d_b$ + 5/16 | ($d_b$ + 1/16) × ($d_b$ + 3/8) | ($d_b$ + 1/16) × (2.5$d_b$) |

[a] The upper tolerance on the tabulated nominal dimensions shall not exceed 1/32 in. Exception: In the width of slotted holes, gouges not more than 1/16 in. deep are permitted.

[b] The slightly conical hole that naturally results from punching operations with properly matched punches and dies is acceptable.

**Commentary:**
The use of bolt holes 1/16 in. larger than the bolt installed in them has been permitted since the first publication of this Specification. Allen and Fisher (1968) showed that larger holes could be permitted for *high-strength bolts* without adversely affecting the bolt shear or member bearing strength. However, the slip resistance can be reduced by the failure to achieve adequate pretension initially or by the relaxation of the bolt pretension as the highly compressed material yields at the edge of the hole or slot. ~~The provisions for oversized and slotted holes in this Specification are based upon these findings and the additional concern for the consequences of a slip of significant magnitude if it should occur in the direction of the slot. Because an increase in hole size generally reduces the net area of a connected part, the use of oversized holes or of slotted holes is subject to approval by the *Engineer of Record*.~~

3.3.2. Oversized Holes: When approved by the *Engineer of Record*, oversized holes are permitted in any or all plies of *slip-critical joints* as defined in Section 4.3.

**Commentary:**
~~See the Commentary to Section 3.3.1.~~The provisions for oversized holes in this Specification are based upon the findings of Allen and Fisher (1968) and the additional concern for the consequences of a slip of significant magnitude ~~if it should~~ that can occur ~~in~~ as permitted by the oversized hole.

3.3.3. Short-Slotted Holes: ~~When approved by the *Engineer of Record*, s~~Short-slotted holes are permitted in any ~~or all plies~~one ply at each faying surface of *snug-tightened joints* as defined in Section 4.1, ~~and~~ *pretensioned joints* as defined in Section 4.2 and *slip critical joints* as defined in Section 4.3, provided the applied load is approximately perpendicular (between 80 and 100 degrees) to the axis of the slot. When complete connection design is not shown in the structural design drawings, the *Engineer of Record* shall be notified when short-slotted holes are used in this manner. When approved by the *Engineer of Record*, short-slotted holes are permitted in ~~any~~ more than one or all plies of *snug-tightened joints* as defined in Section 4.1, and *pretensioned joints* as defined in Section 4.2 provided the applied load is approximately perpendicular (between 80 and 100 degrees) to the axis of the slot and in any or all plies of *slip-critical joints* as defined in Section 4.3 without regard for the direction of the applied load.

**Commentary:**
~~See the Commentary to Section 3.3.1.~~ For beam end connections, the ~~The~~ use of short-slotted holes approximately perpendicular to the applied load in conjunction with snug tight bolts can provide the shear capacity and may allow the beam to rotate ~~which matches~~ consistent with the design assumptions. Deformation of connections can be a concern where the beam is not laterally or torsionally restrained by floor, roof or other framing.

Short slots are used to account for minor adjustments in main members such as web thickness differences and member length. This practice is prevalent enough that this specification recognizes it and permits it unless it is specifically prohibited by the *Engineer of Record* in the design documents. This specification requires the *Engineer of Record* to be notified of the hole types and dimensions by showing this information on shop detail drawings or by obtaining prior approval of the *Engineer of Record*.

The provision of limiting the use of short slotted holes to one ply with snug tight bolts is to avoid the use of short slotted holes in opposing plies of a faying surface. The use of short slotted holes with snug tight bolts in connections with multiple plies that do not share a faying surface is ~~are~~ still permitted. An example that would be permitted with multiple plies includes beam end connections on opposing sides of a column web.

3.3.4. Long-Slotted Holes: When approved by the *Engineer of Record*, long-slotted holes are permitted in only one ply at any individual *faying surface* of *snug-tightened joints* as defined in Section 4.1, and *pretensioned joints* as defined in Section 4.2, provided the applied load is approximately perpendicular (between 80 and 100 degrees) to the axis of the slot. When approved by the *Engineer of Record*, long-slotted holes are permitted in one ply only at any individual *faying surface* of *slip-critical joints* as defined in Section 4.3 without regard for the direction of the applied load. Fully inserted finger shims between the *faying* *surfaces* of load-transmitting elements of bolted *joints* are not considered a long-slotted element of a *joint*; nor are they considered to be a ply at any individual *faying surface*. However, finger shims must have the same faying surface as the rest of the plies.

**Commentary:**
See the Commentary to Section 3.3.1.

Finger shims are devices that are often used to permit the alignment and plumbing of structures. When these devices are fully and properly inserted, they do not have the same effect on bolt pretension relaxation or the *connection* performance, as do long-slotted holes in an outer ply. When fully inserted, the shim provides support around approximately 75 percent of the perimeter of the bolt in contrast to the greatly reduced area that exists with a bolt that is centered in a long slot. Furthermore, finger shims are always enclosed on both sides by the connected material, which should be effective in bridging the space between the fingers.

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**Rationale or Justification for Change (attach additional pages as needed):**
The change in item 5 of the commentary to Section 1.4 was required to get it to agree with the current (2009) wording of second paragraph of Section 3.3 permitting the use of mechanically guided thermally cut holes in statically loaded joints.

This ballot language is the result of a task group consensus formed following the 2013 RCSC Specification Committee meeting in order to resolve the negative votes on the previous version.

The requirements for the responsibility in specifying hole types in the RCSC Specification are in conflict with the AISC and CSC Specification. By making this change, the RCSC Specification is more in compliance with the AISC and CSC Specification.

The need to use perpendicular short slots is a constructability issue as opposed to a design issue. Due to the varying web thicknesses of beams, the outstanding legs of clip angle connections are required to have short slots in them to meet the fabricator's need to standardize connection clip angles. Short slots are also required by erectors to account for variations in plumbness in the structure due to mis-located anchor rods, sweep in columns and other erection tolerances. These issues are rarely understood or accounted for by the engineer of record.

The statement, "In the absence of the approval of the Engineer of Record for the use of other hole types, standard holes shall be used…" has caused engineers to believe that there is something wrong with the use of any other type of hole rather than a standard hole. In order to be conservative, engineers have required that standard holes be used no matter what the fabricator's or erector's reasons might be.

Section 3.3 requires that the Engineer of Record be notified of the type and dimensions of holes that will be used on the project. This was added to relieve concerns that a fabricator can use any type or dimension of hole without discretion. This gives the engineer of record the ability to prohibit any type of hole, including short slots, if in the engineer of record's opinion the type of hole selected by the fabricator would be detrimental to the member or structure.

The most recent revision is due to the affirmative and negative ballot responses.

**6/28/13 Proposal as agreed upon by the Task Group (Ballot Item S12-047B)**
**(Fortney, Carter, Kurth, Ferrell, Shneur, Gibble)**

## 1.4. Drawing Information

The *Engineer of Record* shall specify the following information in the contract documents:

(5) The ASTM designation and type (Section 2) of bolt to be used;
(6) The *joint* type (Section 4);
(7) The required class of slip resistance if *slip-critical joints* are specified (Section 4); and,
(8) Whether slip is checked at the factored-load level or the service-load level, if *slip-critical joints* are specified (Section 5).

**Commentary:**
A summary of the information that the *Engineer of Record* is required to provide in the contract documents is provided in this Section. The parenthetical reference after each listed item indicates the location of the actual requirement in this Specification. In addition, the approval of the *Engineer of Record* is required in this Specification in the following cases:

(9) For the reuse of non-galvanized ASTM A325 bolts (Section 2.3.3);
(10) For the use of alternative washer-type indicating devices that differ from those that meet the requirements of ASTM F959, including the corresponding installation and inspection requirements that are provided by the *manufacturer* (Section 2.6.2);
(11) For the use of alternative-design fasteners, including the corresponding installation and inspection requirements that are provided by the *manufacturer* (Section 2.8);
(12) For the use of faying-surface coatings in *slip-critical joints* that provide a *mean slip coefficient* determined per Appendix A, but differing from Class A or Class B (Section 3.2.2(b));
(13) For the use of thermal cutting ~~in the production~~ of bolt holes produced free hand or for use in cyclically loaded joints (Section 3.3);
(14) For the use of oversized (Section 3.3.2), short-slotted (Section 3.3.3) or long slotted holes (Section 3.3.4) in lieu of standard holes;
(15) For the use of a value of $D_u$ other than 1.13 (Section 5.4.1); and,
(16) For the use of a value of $D$ other than 0.80 (Section 5.4.2).

## 3.3. Bolt Holes

The nominal dimensions of standard, oversized, short-slotted and long-slotted holes for *high-strength bolts* shall be equal to or less than those shown in Table 3.1. Holes larger than those shown in Table 3.1 are permitted when specified or approved by the *Engineer of Record.* Where thermally cut holes are permitted, the surface roughness profile of the hole shall not exceed 1,000 microinches as defined in ASME B46.1. Occasional gouges not more than 1/16 in. in depth are permitted. The *Engineer of Record* shall be notified of the type and dimensions of holes to be used. Oversize holes, short slots not perpendicular to the applied load and long slots in any direction shall be subject to approval by the *Engineer of Record*. Any restrictions on the use of hole types permitted in sections 3.3.1, 3.3.2 and 3.3.3 other than those listed shall be specified.

Thermally cut holes produced by mechanically guided means are permitted in statically loaded *joints*. Thermally cut holes produced free hand shall be permitted in statically loaded *joints* if approved by the *Engineer of Record*. For cyclically loaded *joints*, thermally cut holes shall be permitted if approved by the *Engineer of Record*.

**Commentary:**
The footnotes in Table 3.1 provide for slight variations in the dimensions of bolt holes from the nominal dimensions. When the dimensions of bolt holes are such that they exceed these permitted variations, the bolt hole must be treated as the next larger type.

Slots longer than standard long slots may be required to accommodate construction tolerances or expansion *joints*. Larger oversized holes may be necessary to accommodate construction tolerances or misalignments. In the latter two cases, the Specification provides no guidance for further reduction of *design strengths* or allowable loads. Engineering design considerations should include, as a minimum, the effects of edge distance, net section, reduction in clamping force in *slip-critical joints*, washer requirements, bearing capacity, and hole deformation.

Short slots are used to account for minor adjustments in main members such as web thickness differences and member length. This practice is prevalent enough that this specification recognizes it and permits it unless it is specifically prohibited on design documents. This specification requires the *Engineer of Record* to be notified of the hole types and dimensions by showing this information on shop detail drawings as opposed to obtaining prior approval of the *Engineer of Record*.

For thermally cut holes produced free hand, it is usually necessary to grind the hole surface after thermal cutting in order to achieve a maximum surface roughness profile of 1,000 microinches.

Slotted holes in statically loaded *joints* are often produced by punching or drilling the hole ends and thermally cutting the sides of the slots by mechanically guided means. The sides of such slots should be ground smooth, particularly at the junctures of the thermal cuts to the hole ends.

For cyclically loaded *joints*, test results have indicated that when no major slip occurs in the *joint*, fretting fatigue failure usually occurs in the gross section prior to fatigue failure in the net section (Kulak et al., 1987, pp. 116, 117). Conversely, when slip occurs in the *joints* of cyclically loaded *connections*, failure usually occurs in the net section and the edge of a bolt hole becomes the point of crack initiation (Kulak et al., 1987, pp. 118). Therefore, for cyclically loaded *joints* designed as slip critical, the method used to produce bolt holes (either thermal cutting or drilling) should not influence the ultimate failure load, as failure usually occurs in the gross section when no major slip occurs.

3.3.1. Standard Holes: ~~In the absence of approval by the *Engineer of Record* for the use of other hole types, standard~~ Standard holes ~~shall~~ are permitted to be used in all plies of bolted *joints*.

**Table 3.1. Nominal Bolt Hole Dimensions**

| Nominal Bolt Diameter, $d_b$, in. | Nominal Bolt Hole Dimensions [a,b], in. | | | |
|---|---|---|---|---|
| | Standard (diameter) | Oversized (diameter) | Short-slotted (width × length) | Long-slotted (width × length) |
| ½ | 9/16 | 5/8 | 9/16 × 11/16 | 9/16 × 1 1/4 |
| 5/8 | 11/16 | 13/16 | 11/16 × 7/8 | 11/16 × 1 9/16 |
| ¾ | 13/16 | 15/16 | 13/16 × 1 | 13/16 × 1 7/8 |
| 7/8 | 15/16 | 1 1/16 | 15/16 × 1 1/8 | 15/16 × 2 3/16 |
| 1 | 1 1/16 | 1 ¼ | 1 1/16 × 1 5/16 | 1 1/16 × 2 ½ |
| ≥1 1/16 | $d_b$ + 1/16 | $d_b$ + 5/16 | ($d_b$ + 1/16) × ($d_b$ + 3/8) | ($d_b$ + 1/16) × (2.5$d_b$) |

[a] The upper tolerance on the tabulated nominal dimensions shall not exceed 1/32 in. Exception: In the width of slotted holes, gouges not more than 1/16 in. deep are permitted.

[b] The slightly conical hole that naturally results from punching operations with properly matched punches and dies is acceptable.

**Commentary:**

The use of bolt holes 1/16 in. larger than the bolt installed in them has been permitted since the first publication of this Specification. Allen and Fisher (1968) showed that larger holes could be permitted for *high-strength bolts* without adversely affecting the bolt shear or member bearing strength. However, the slip resistance can be reduced by the failure to achieve adequate pretension initially or by the relaxation of the bolt pretension as the highly compressed material yields at the edge of the hole or slot. ~~The provisions for oversized and slotted holes in this Specification are based upon these findings and the additional concern for the consequences of a slip of significant magnitude if it should occur in the direction of the slot. Because an increase in hole size generally reduces the net area of a connected part, the use of oversized holes or of slotted holes is subject to approval by the *Engineer of Record*.~~

3.3.2. Oversized Holes: When approved by the *Engineer of Record*, oversized holes are permitted in any or all plies of *slip-critical joints* as defined in Section 4.3.

**Commentary:**
~~See the Commentary to Section 3.3.1.~~The provisions for oversized holes in this Specification are based upon the findings of Allen and Fisher (1968) and the additional concern for the consequences of a slip of significant magnitude if it should occur in the oversized hole.

3.3.3. Short-Slotted Holes: ~~When approved by the *Engineer of Record*, s~~Short-slotted holes are permitted in any ~~or all plies~~one ply at each faying surface of *snug-tightened joints* as defined in Section 4.1, ~~and~~ *pretensioned joints* as defined in Section 4.2 and *slip critical joints* as defined in Section 4.3, provided the applied load is approximately perpendicular (between 80 and 100 degrees) to the axis of the slot. When approved by the *Engineer of Record*, short-slotted holes are permitted in ~~any~~ more than one or all plies of *snug-tightened joints* as defined in Section 4.1, and *pretensioned joints* as defined in Section 4.2 provided the applied load is approximately perpendicular (between 80 and 100 degrees) to the axis of the slot and in any or all plies of *slip-critical joints* as defined in Section 4.3 without regard for the direction of the applied load.

**Commentary:**
~~See the Commentary to Section 3.3.1.~~ The use of short-slotted holes approximately perpendicular to the applied load in conjunction with snug tight bolts can provide the shear capacity and may allow the beam to rotate which matches the design assumptions. Deformation of connections can be a concern where the beam is not laterally or torsionally restrained by floor, roof or other framing.

The provision of limiting the use of short slotted holes to one ply with snug tight bolts is to avoid the use of short slotted holes in opposing plies of a faying surface. The use of short slotted holes with snug tight bolts in connections with multiple plies that do not share a faying surface are still permitted. An example that would be permitted with multiple plies includes beam end connections on opposing sides of a column web.

3.3.4. Long-Slotted Holes: When approved by the *Engineer of Record*, long-slotted holes are permitted in only one ply at any individual *faying surface* of *snug-tightened joints* as defined in Section 4.1, and *pretensioned joints* as defined in Section 4.2, provided the applied load is approximately perpendicular (between 80 and 100 degrees) to the axis of the slot. When approved by the *Engineer of Record*, long-slotted holes are permitted in one ply only at any individual *faying surface* of *slip-critical joints* as defined in Section 4.3 without regard for the direction of the applied load. Fully inserted finger shims between the *faying surfaces* of load-transmitting elements of bolted *joints* are not considered a long-slotted element of a *joint*; nor are they considered to be a ply at any individual *faying surface*. However, finger shims must have the same faying surface as the rest of the plies.

**Commentary:**

See the Commentary to Section 3.3.1.

Finger shims are devices that are often used to permit the alignment and plumbing of structures. When these devices are fully and properly inserted, they do not have the same effect on bolt pretension relaxation or the *connection* performance, as do long-slotted holes in an outer ply. When fully inserted, the shim provides support around approximately 75 percent of the perimeter of the bolt in contrast to the greatly reduced area that exists with a bolt that is centered in a long slot. Furthermore, finger shims are always enclosed on both sides by the connected material, which should be effective in bridging the space between the fingers.

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**Rationale or Justification for Change (attach additional pages as needed):**

The change in item 5 of the commentary to Section 1.4 was required to get it to agree with the current (2009) wording of second paragraph of Section 3.3 permitting the use of mechanically guided thermally cut holes in statically loaded joints.

This ballot language is the result of a task group consensus formed following the 2013 RCSC Specification Committee meeting in order to resolve the negative votes on the previous version.

The requirements for the responsibility in specifying hole types in the RCSC Specification are in conflict with the AISC and CSC Specification. By making this change, the RCSC Specification is more in compliance with the AISC and CSC Specification.

The need to use perpendicular short slots is a constructability issue as opposed to a design issue. Due to the varying web thicknesses of beams, the outstanding legs of clip angle connections are required to have short slots in them to meet the fabricator's need to standardize connection clip angles. Short slots are also required by erectors to account for variations in plumbness in the structure due to mis-located anchor rods, sweep in columns and other erection tolerances. These issues are rarely understood or accounted for by the engineer of record.

The statement, "In the absence of the approval of the Engineer of Record for the use of other hole types, standard holes shall be used…" has caused engineers to believe that there is something wrong with the use of any other type of hole rather than a standard hole. In order to be conservative, engineers have required that standard holes be used no matter what the fabricator's or erector's reasons might be.

Section 3.3 requires that the Engineer of Record be notified of the type and dimensions of holes that will be used on the project. This was added to relieve concerns that a fabricator can use any type or dimension of hole without discretion. This gives the engineer of record the ability to prohibit any type of hole, including short slots, if in the engineer of record's opinion the type of hole selected by the fabricator would be detrimental to the member or structure.

## Ballot Actions and Information:

2013-14 Ballot Item # 2

57 Affirmative

2 Negative (Miazga, Heath Mitchell)

7 Abstain

**Affirmatives with Comments:**

**Peter Birkemoe:**

Editorial only: Commentary 3.3.2 end of sentence after magnitude ….that can occur as permitted by the oversized hole. Commentary 3.3.3 last paragraph … change "are" to "is"

**Garret Byrne:**

Table 3.1 has formatting issues with the dimensions. There is a similar typo in the first line of the commentary of 3.3.1 (/1/6).

**Helen Chen:**

Recommend delete "in any direction". Also the last sentence, would it sounds better "Any restrictions on the use of hole types in sections 3.3.1, 3.3.2, and 3.3.3 other than those permitted shall be specified"? Commentary below Table 3.1, is "/1/16 in…" means "with 1/16 in…"? The commentary below 3.3.2, "…and the additional concern for the consequences of a slip of significant magnitude if should occur in the oversided hole." What does this mean here with respect to the Spec above?

**Rod Gibble:**

There appears to be a typo in Section 3.3. The last sentence of the first paragraph should read "…sections 3.3.2, 3.3.3, and 3.3.4…"

**Allen J. Harrold:**

1) Table 3.1 and the bolt size reference at the start of the commentary section both read incorrectly due to font type anomalies. Neither item has a change proposed with this ballot so there should be no issue.

2) With the addition of the new sentence in the first paragraph of section 3.3, the previous sentence which starts "Where thermally cut holes are permitted.." feels out of place. It would seem to fit better in the second paragraph of section 3.3. At a minimum it should be the last sentence of the first paragraph rather than in the middle of the paragraph. Any adjustments would be editorially in nature.

**Jonathan C. McGormley:**

My acceptance is based on the language as modified not limiting the Engineer from using short slots or oversize holes as he/she sees best for the condition, e.g. in 3.3.3 the EOR can use a pretension bolt in a short slot parallel to load if that works for them.

**Gene Mitchell:**

3.3.3 drop "any and" to agree with other sections.

**Tom Schlafly:**

Correct fractions due to fonts. Ex. - Commentary 3.3.1.

**Rachel Shanley:**

Section 3.3 (and throughout) is inconsistent in the use of "oversize" and "oversized." I am not sure which is correct. Additionally, Table 3.1 is messed up because of the fractions, but I assume you know of this. This is the case with fractions throughout.

**James A. Swanson:**

Table 3.1 seems to have extraneous numbers.

**Raymond Tide:**
Ballot Item No. 2. Currently it shows /1/6 in. when it should be 1/16 in. Then in Commentary Sect. 3.3.1 it refers to CSC when it should be CSA.

**Floyd Vissat:**
Table 3.1 & Section 3.3.1 Commentary, first sentence needs editorial corrections; numeric format conversion.

**Joseph Yura:**
The Commentary material in Section 3.3.1, Standard Holes, after the first sentence should be moved to Section 3.3.2, Oversize holes. Also, there are many typo fractions in Table 3.1 and the Commentary.

**Negatives with Comments:**
**Greg Miazga:**
There are many good(!) suggestions in this ballot - some are new items not previously addressed in the ballots leading up to this proposed ballot. Alternate wording and suggestions I have are as follows:

1. Sentences added to Section 3.3: I find the first added sentence too all-encompassing as it implies that a summary of all hole types used need to be communicated to the EOR – this would include standard holes and this is unnecessary? The Specification has not previously used or defined the word “notified” or “notify” previously so this is open to interpretation. I would omit the addition of this sentence. I think the comments to oversize holes, short slots and long slots belong in their respective Sections (3.3.2, 3.3.3 and 3.3.4) – this avoids the first paragraph in 3.3 from becoming a ‘catch-all’ of miscellaneous requirements. I also find the 3rd sentence vague as presented: “... shall be specified”. I think it may be meant that “the EOR shall specify restrictions... in the design documents” - and I would use the word limitations rather than restrictions. I’m also adding the words “in the design documents” because the fabricator needs to know this before starting shop drawings (and possibly connection design) – to hopefully avoid major fights with the EOR during the production and review of shop drawings. As an aside, I would move the sentences related to thermal cutting to the 2nd paragraph under 3.3, as this is all about thermal cutting. So maybe the first two paragraphs under 3.3 could look like:

   **The nominal dimensions of standard, oversized, short-slotted and long-slotted holes for high-strength bolts shall be equal to or less than those shown in Table 3.1. Holes larger than those shown in Table 3.1 are permitted when specified or approved by the Engineer of Record. Any limitations on the use of the hole types permitted in Sections 3.3.1, 3.3.2, and 3.3.3, other than those listed, shall be specified by the Engineer of Record in the design documents.**
   **Thermally cut holes produced by mechanically guided means are permitted in statically loaded joints, and the surface profile of the hole shall not exceed 1,000 microinches as defined in ASME B46.1. Occasional gouges not more than 1/16” in depth are permitted. Thermally cut holes produced free hand shall be permitted in statically loaded joints if approved by the Engineer of Record. For cyclically loaded joints, thermally cut holes shall be permitted if approved by the Engineer of Record.**

2. Commentary to 3.3: to the second sentence I would add "...**specifically prohibited by the Engineer of Record in the design documents**". I would omit the last added sentence – I don't think the shop drawing review process constitutes proper "notification" per my previous comments.

3. Section 3.3.1: I understand the need to change the sentence under 3.3.1, but I find the proposed change to be too self-evident. i.e. "you can use standard holes everywhere...". Maybe we could say "**Standard holes are to be used in all plies of bolted joints, unless the Engineer of Record has specified or approved the use of other holes types, when such approval is required in Sections 3.3.2, 3.3.3 and 3.3.4."** I know we usually would use the word "shall" but maybe we could use "are to" instead to soften it a bit? Also, this suggestion covers the situation in 3.3.3 where EOR approval is not required for some short slots, and possibly other future relaxations of EOR approval in these sections.

4. Commentary to 3.3.3: To the first sentence I would add the words "For beam end connections" and "consistent" as follows: **For beam end connections, the use of short-slotted holes approximately perpendicular to the applied load in conjunction with snug tight bolts can provide the shear capacity and may allow the beam to rotate consistent with the design assumptions.**

## Heath Mitchell:

See **2013-14 Ballot Attachment B_Heath Mitchell** for comments.

**S12-047 (Original balloted proposal – 2012-13 Ballot Item #7)**

## 1.4. Drawing Information

The *Engineer of Record* shall specify the following information in the contract documents:

(1) The ASTM designation and type (Section 2) of bolt to be used;

(2) The *joint* type (Section 4);

(3) The required class of slip resistance if *slip-critical joints* are specified (Section 4); and,

(4) Whether slip is checked at the factored-load level or the service-load level, if *slip-critical joints* are specified (Section 5).

**Commentary:**

A summary of the information that the *Engineer of Record* is required to provide in the contract documents is provided in this Section. The parenthetical reference after each listed item indicates the location of the actual requirement in this Specification. In addition, the approval of the *Engineer of Record* is required in this Specification in the following cases:

(1) For the reuse of non-galvanized ASTM A325 bolts (Section 2.3.3);

(2) For the use of alternative washer-type indicating devices that differ from those that meet the requirements of ASTM F959, including the corresponding installation and inspection requirements that are provided by the *manufacturer* (Section 2.6.2);

(3) For the use of alternative-design fasteners, including the corresponding installation and inspection requirements that are provided by the *manufacturer* (Section 2.8);

(4) For the use of faying-surface coatings in *slip-critical joints* that provide a *mean slip coefficient* determined per Appendix A, but differing from Class A or Class B (Section 3.2.2(b));

(5) For the use of thermal cutting in the production of bolt holes (Section 3.3);

(6) For the use of oversized (Section 3.3.2), short-slotted (Section 3.3.3) or long slotted holes (Section 3.3.4) in lieu of standard holes;

(7) For the use of a value of $D_u$ other than 1.13 (Section 5.4.1); and,

(8) For the use of a value of $D$ other than 0.80 (Section 5.4.2).

## 3.3. Bolt Holes

The nominal dimensions of standard, oversized, short-slotted and long-slotted holes for *high-strength bolts* shall be equal to or less than those shown in Table 3.1. Holes larger than those shown in Table 3.1 are permitted when specified or approved by the *Engineer of Record*. Where thermally cut holes are permitted, the surface roughness profile of the hole shall not exceed 1,000 microinches as defined in ASME B46.1. Occasional gouges not more than z in. in depth are permitted.

Thermally cut holes produced by mechanically guided means are permitted in statically loaded *joints*. Thermally cut holes produced free hand shall be permitted in statically loaded *joints* if approved by the *Engineer of Record*. For cyclically loaded *joints*, thermally cut holes shall be permitted if approved by the *Engineer of Record*.

**Commentary:**
The footnotes in Table 3.1 provide for slight variations in the dimensions of bolt holes from the nominal dimensions. When the dimensions of bolt holes are such that they exceed these permitted variations, the bolt hole must be treated as the next larger type.

Slots longer than standard long slots may be required to accommodate construction tolerances or expansion *joints*. Larger oversized holes may be necessary to accommodate construction tolerances or misalignments. In the latter two cases, the Specification provides no guidance for further reduction of *design strengths* or allowable loads. Engineering design considerations should include, as a minimum, the effects of edge distance, net section, reduction in clamping force in *slip-critical joints*, washer requirements, bearing capacity, and hole deformation.

For thermally cut holes produced free hand, it is usually necessary to grind the hole surface after thermal cutting in order to achieve a maximum surface roughness profile of 1,000 microinches.

Slotted holes in statically loaded *joints* are often produced by punching or drilling the hole ends and thermally cutting the sides of the slots by mechanically guided means. The sides of such slots should be ground smooth, particularly at the junctures of the thermal cuts to the hole ends.

For cyclically loaded *joints*, test results have indicated that when no major slip occurs in the *joint*, fretting fatigue failure usually occurs in the gross section prior to fatigue failure in the net section (Kulak et al., 1987, pp. 116, 117). Conversely, when slip occurs in the *joints* of cyclically loaded *connections*, failure usually occurs in the net section and the edge of a bolt hole becomes the point of crack initiation (Kulak et al., 1987, pp. 118). Therefore, for cyclically loaded *joints* designed as slip critical, the method used to produce bolt holes (either thermal cutting or drilling) should not influence the ultimate failure load, as failure usually occurs in the gross section when no major slip occurs.

3.3.1. Standard Holes: ~~In the absence of approval by the *Engineer of Record* for the use of other hole types, standard~~ Standard holes ~~shall~~ are permitted to be used in all plies of *snug-tightened joints* as defined in Section 4.1, *pretensioned* joints as defined in Section 4.2 and slip critical joints as defined in Section 4.3. ~~bolted *joints*.~~

**Table 3.1. Nominal Bolt Hole Dimensions**

| Nominal | Nominal Bolt Hole Dimensions [a,b], in. |
|---|---|

| Bolt Diameter, $d_b$, in. | Standard (diameter) | Oversized (diameter) | Short-slotted (width × length) | Long-slotted (width × length) |
|---|---|---|---|---|
| **½** | 9/16 | 5/8 | 9/16 × 11/16 | 9/16 × 1 1/4 |
| **5/8** | 11/16 | 13/16 | 11/16 × 7/8 | 11/16 × 1 9/16 |
| **¾** | 13/16 | 15/16 | 13/16 × 1 | 13/16 × 1 7/8 |
| **7/8** | 15/16 | 1 1/16 | 15/16 × 1 1/8 | 15/16 × 2 3/16 |
| **1** | 1 1/16 | 1 ¼ | 1 1/16 × 1 5/16 | 1 1/16 × 2 ½ |
| **≥1 1/16** | $d_b$ + 1/16 | $d_b$ + 5/16 | ($d_b$ + 1/16) × ($d_b$ + 3/8) | ($d_b$ + 1/16) × (2.5$d_b$) |

[a] The upper tolerance on the tabulated nominal dimensions shall not exceed 1/32 in. Exception: In the width of slotted holes, gouges not more than 1/16 in. deep are permitted.

[b] The slightly conical hole that naturally results from punching operations with properly matched punches and dies is acceptable.

**Commentary:**
The use of bolt holes 1/16 in. larger than the bolt installed in them has been permitted since the first publication of this Specification. Allen and Fisher (1968) showed that larger holes could be permitted for *high-strength bolts* without adversely affecting the bolt shear or member bearing strength. However, the slip resistance can be reduced by the failure to achieve adequate pretension initially or by the relaxation of the bolt pretension as the highly compressed material yields at the edge of the hole or slot. The provisions for oversized and slotted holes in this Specification are based upon these findings and the additional concern for the consequences of a slip of significant magnitude if it should occur in the direction of the slot. Because an increase in hole size generally reduces the net area of a connected part, the use of oversized holes or of slotted holes is subject to approval by the *Engineer of Record*.

3.3.2. Oversized Holes: When approved by the *Engineer of Record*, oversized holes are permitted in any or all plies of *slip-critical joints* as defined in Section 4.3.

**Commentary:**
See the Commentary to Section 3.3.1.

3.3.3. Short-Slotted Holes: ~~When approved by the *Engineer of Record*, s~~Short-slotted holes are permitted in any or all plies of *snug-tightened joints* as defined in Section 4.1, ~~and~~ *pretensioned joints* as defined in Section 4.2 and slip critical joints as defined in Section 4.3, provided the applied load is approximately perpendicular (between 80 and 100 degrees) to the axis of the slot. When approved by the *Engineer of Record*, short-slotted holes are permitted in any or all plies of *slip-critical joints* as defined in Section 4.3 without regard for the direction of the applied load.

**Commentary:**
See the Commentary to Section 3.3.1.

3.3.4. Long-Slotted Holes: When approved by the *Engineer of Record*, long-slotted holes are permitted in only one ply at any individual *faying surface* of *snug-tightened joints* as defined in Section 4.1, and *pretensioned joints* as defined in Section 4.2, provided the applied load is approximately perpendicular (between 80 and 100 degrees) to the axis of the slot. When approved by the *Engineer of Record*, long-slotted holes are permitted in one ply only at any individual *faying surface* of *slip-critical joints* as defined in Section 4.3 without regard for the direction of the applied load. Fully inserted finger shims between the *faying surfaces* of load-transmitting elements of bolted *joints* are not considered a long-slotted element of a *joint*; nor are they considered to be a ply at any individual *faying surface*. However, finger shims must have the same faying surface as the rest of the plies.

**Commentary:**
See the Commentary to Section 3.3.1.

Finger shims are devices that are often used to permit the alignment and plumbing of structures. When these devices are fully and properly inserted, they do not have the same effect on bolt pretension relaxation or the *connection* performance, as do long-slotted holes in an outer ply. When fully inserted, the shim provides support around approximately 75 percent of the perimeter of the bolt in contrast to the greatly reduced area that exists with a bolt that is centered in a long slot. Furthermore, finger shims are always enclosed on both sides by the connected material, which should be effective in bridging the space between the fingers.

**Rationale or Justification for Change (attach additional pages as needed):**
This ballot language is the result of a task group consensus formed following the 2012 RCSC Specification Committee meeting.

The requirements for the responsibility in specifying hole types in the RCSC Specification are in conflict with the AISC and CSC Specification. By making this change, the RCSC Specification is more in compliance with the AISC and CSC Specification.

The need to use perpendicular short slots is a constructability issue as opposed to a design issue. Due to the varying web thicknesses of beams, the outstanding legs of clip angle connections are required to have short slots in them to meet the fabricator's need to standardize connection clip angles. Short slots are also required by erectors to account for variations in plumbness in the structure due to mis-located anchor rods, sweep in columns and other erection tolerances. These issues are rarely understood or accounted for by the engineer of record.

The statement, "In the absence of the approval of the Engineer of Record for the use of other hole types, standard holes shall be used…" has caused engineers to believe that there is something wrong with the use of any other type of hole rather than a standard hole. In order to be conservative, engineers have required that standard holes be used no matter what the fabricator's or erector's reasons might be.

**Ballot Actions and Information:**

2012-13 Ballot Item # 7

63 Affirmative

3 Negative (Curven, Frank, Helwig)

2 Abstain

## Affirmative with Comments:

**Abolhassan Astaneh:**
This is an excellent change.

**Peter Birkemoe:**
It would be an easier read if presented as a list of three items “Standard holes are permitted to be used in all plies of: 1 Snug-tightened joints as defined in Section 4.1; 2 Pre-tensioned joints…..” note that these Ballot Comments are restricted to text input and if the italics shown used in the recommended changes are adopted they should be used in a parallel manner in the series whether a list is used or not.

**Allen Harrold:**
Table 3.1 has a variety of bogus entries due to format conversions, however there were no proposed changes to the table in actuality. Editorial corrections will be made to insure that the table reads correctly in the final version.

**Joe Yura:**
Although it is not part of this ballot, item 1.4 (4) needs to be removed because of the changes recommended in Ballot #3

## Negative with Comments:

**Chris Curven:**
Current wording is concise in its requirements. It allows short-slotted allows but keeps the EOR in the decision making process. Proposed changes makes it easy for fabricators to misinterpret the specification. For 3.3.1, new wording, in particular “permitted” implies that hole type is an option without contacting EOR. For 3.3.3, the first sentence makes short-slotted hole permissible without contacting EOR. Current wording clearly states that the EOR must approve hole type, not limiting them. The RCSC need not follow AISC’s lead. They are two different groups. AISC can choose not to adopt the RCSC specification.

**Karl Frank:**
I firmly believe that short slotted holes should not be used unless the EOR approves their use. I would think the commentary could be expanded to point out in simple shear connections of gravity loaded beams, short slotted holes in conjunction with snug tight bolts can provide the shear capacity and allow the beam to rotate which matches the design assumptions.

**Todd Helwig:**
I don’t have a problem with getting rid of the first sentence of Section 3.3.1; however I don’t agree with the changes to the change on the paragraph in section 3.3.3. While the use of slotted holes can make erection easier, I think the EOR needs to be consulted in many applications where the use of the slot can affect the behavior of the structural member. The end connections are very important to the stability of the member and the use of slotted holes can result in relatively large twists/lateral movements that can affect the behavior of the member. There are cases where member stability could be affected if a short slotted hole is used with a snug tight bolt.

**5/10/13 Proposal with changes to satisfy the Frank and Helwig negatives:**

***{Modifications are shown as either double strikeout or double underscore to distinguish the proposed changes from the balloted changes. Changes exist in the Commentary to Sections 3.3.1, 3.3.2, and 3.3.3}***

## 1.4. Drawing Information

The *Engineer of Record* shall specify the following information in the contract documents:

(1) The ASTM designation and type (Section 2) of bolt to be used;
(2) The *joint* type (Section 4);
(3) The required class of slip resistance if *slip-critical joints* are specified (Section 4); and,
(4) Whether slip is checked at the factored-load level or the service-load level, if *slip-critical joints* are specified (Section 5).

**Commentary:**
A summary of the information that the *Engineer of Record* is required to provide in the contract documents is provided in this Section. The parenthetical reference after each listed item indicates the location of the actual requirement in this Specification. In addition, the approval of the *Engineer of Record* is required in this Specification in the following cases:

(1) For the reuse of non-galvanized ASTM A325 bolts (Section 2.3.3);
(2) For the use of alternative washer-type indicating devices that differ from those that meet the requirements of ASTM F959, including the corresponding installation and inspection requirements that are provided by the *manufacturer* (Section 2.6.2);
(3) For the use of alternative-design fasteners, including the corresponding installation and inspection requirements that are provided by the *manufacturer* (Section 2.8);
(4) For the use of faying-surface coatings in *slip-critical joints* that provide a *mean slip coefficient* determined per Appendix A, but differing from Class A or Class B (Section 3.2.2(b));
(5) For the use of thermal cutting in the production of bolt holes (Section 3.3);
(6) For the use of oversized (Section 3.3.2), short-slotted (Section 3.3.3) or long slotted holes (Section 3.3.4) in lieu of standard holes;
(7) For the use of a value of $D_u$ other than 1.13 (Section 5.4.1); and,
(8) For the use of a value of $D$ other than 0.80 (Section 5.4.2).

## 3.3. Bolt Holes

The nominal dimensions of standard, oversized, short-slotted and long-slotted holes for *high-strength bolts* shall be equal to or less than those shown in Table 3.1. Holes larger than those shown in Table 3.1 are permitted when specified or approved by the *Engineer of Record*. Where thermally cut holes are permitted, the surface roughness profile of the hole shall not exceed 1,000 microinches as defined in ASME B46.1. Occasional gouges not more than z in. in depth are permitted.

Thermally cut holes produced by mechanically guided means are permitted in statically loaded *joints*. Thermally cut holes produced free hand shall be permitted in statically loaded *joints* if approved by the *Engineer of Record*. For cyclically loaded *joints*, thermally cut holes shall be permitted if approved by the *Engineer of Record*.

**Commentary:**
The footnotes in Table 3.1 provide for slight variations in the dimensions of bolt holes from the nominal dimensions. When the dimensions of bolt holes are such that they exceed these permitted variations, the bolt hole must be treated as the next larger type.

Slots longer than standard long slots may be required to accommodate construction tolerances or expansion *joints*. Larger oversized holes may be necessary to accommodate construction tolerances or misalignments. In the latter two cases, the Specification provides no guidance for further reduction of *design strengths* or allowable loads. Engineering design considerations should include, as a minimum, the effects of edge distance, net section, reduction in clamping force in *slip-critical joints*, washer requirements, bearing capacity, and hole deformation.

For thermally cut holes produced free hand, it is usually necessary to grind the hole surface after thermal cutting in order to achieve a maximum surface roughness profile of 1,000 microinches.

Slotted holes in statically loaded *joints* are often produced by punching or drilling the hole ends and thermally cutting the sides of the slots by mechanically guided means. The sides of such slots should be ground smooth, particularly at the junctures of the thermal cuts to the hole ends.

For cyclically loaded *joints*, test results have indicated that when no major slip occurs in the *joint*, fretting fatigue failure usually occurs in the gross section prior to fatigue failure in the net section (Kulak et al., 1987, pp. 116, 117). Conversely, when slip occurs in the *joints* of cyclically loaded *connections*, failure usually occurs in the net section and the edge of a bolt hole becomes the point of crack initiation (Kulak et al., 1987, pp. 118). Therefore, for cyclically loaded *joints* designed as slip critical, the method used to produce bolt holes (either thermal cutting or drilling) should not influence the ultimate failure load, as failure usually occurs in the gross section when no major slip occurs.

3.3.1. Standard Holes: ~~In the absence of approval by the *Engineer of Record* for the use of other hole types, standard~~ Standard holes ~~shall~~ are permitted to be used in all plies of *snug-tightened joints* as defined in Section 4.1, *pretensioned* joints as defined in Section 4.2 and slip critical joints as defined in Section 4.3. ~~bolted *joints*.~~

**Table 3.1. Nominal Bolt Hole Dimensions**

| Nominal | Nominal Bolt Hole Dimensions [a,b], in. |
|---|---|

| Bolt Diameter, $d_b$, in. | Standard (diameter) | Oversized (diameter) | Short-slotted (width × length) | Long-slotted (width × length) |
|---|---|---|---|---|
| ½ | 9/16 | 5/8 | 9/16 × 11/16 | 9/16 × 1 1/4 |
| 5/8 | 11/16 | 13/16 | 11/16 × 7/8 | 11/16 × 1 9/16 |
| ¾ | 13/16 | 15/16 | 13/16 × 1 | 13/16 × 1 7/8 |
| 7/8 | 15/16 | 1 1/16 | 15/16 × 1 1/8 | 15/16 × 2 3/16 |
| 1 | 1 1/16 | 1 ¼ | 1 1/16 × 1 5/16 | 1 1/16 × 2 ½ |
| ≥1 1/16 | $d_b$ + 1/16 | $d_b$ + 5/16 | ($d_b$ + 1/16) × ($d_b$ + 3/8) | ($d_b$ + 1/16) × (2.5$d_b$) |

[a] The upper tolerance on the tabulated nominal dimensions shall not exceed 1/32 in. Exception: In the width of slotted holes, gouges not more than 1/16 in. deep are permitted.

[b] The slightly conical hole that naturally results from punching operations with properly matched punches and dies is acceptable.

**Commentary:**
The use of bolt holes 1/16 in. larger than the bolt installed in them has been permitted since the first publication of this Specification. Allen and Fisher (1968) showed that larger holes could be permitted for *high-strength bolts* without adversely affecting the bolt shear or member bearing strength. However, the slip resistance can be reduced by the failure to achieve adequate pretension initially or by the relaxation of the bolt pretension as the highly compressed material yields at the edge of the hole or slot. ~~The provisions for oversized and slotted holes in this Specification are based upon these findings and the additional concern for the consequences of a slip of significant magnitude if it should occur in the direction of the slot. Because an increase in hole size generally reduces the net area of a connected part, the use of oversized holes or of slotted holes is subject to approval by the *Engineer of Record*.~~

3.3.2. Oversized Holes: When approved by the *Engineer of Record*, oversized holes are permitted in any or all plies of *slip-critical joints* as defined in Section 4.3.

**Commentary:**
See the Commentary to Section 3.3.1. The provisions for oversized holes in this Specification are based upon these findings and the additional concern for the consequences of a slip of significant magnitude if it should occur in the oversized hole. Because an increase in hole size generally reduces the net area of a connected part, the use of oversized holes is subject to approval by the *Engineer of Record.*

3.3.3. Short-Slotted Holes: ~~When approved by the *Engineer of Record*, s~~Short-slotted holes are permitted in any or all plies of *snug-tightened joints* as defined in Section 4.1, ~~and~~ *pretensioned joints* as defined in Section 4.2 and slip critical joints as defined in Section 4.3, provided the applied load is approximately perpendicular (between 80 and 100 degrees) to the axis of the slot. When approved by the *Engineer of Record*, short-slotted holes are permitted in any or all plies of *slip-critical joints* as defined in Section 4.3 without regard for the direction of the applied load.

**Commentary:**
See the Commentary to Section 3.3.1. The use of short-slotted holes approximately perpendicular to the applied load in conjunction with snug tight bolts can provide the shear capacity and may allow the beam to rotate which matches the design assumptions. End connections are very important to the stability of the member. The use of short-slotted holes may result in twists and or lateral movement that may affect the behavior of the member. In cases where the use of short-slotted holes affects the behavior of the structural member, the *Engineer of Record* should be consulted.

The provisions for short-slotted holes in a direction that is other than perpendicular to the applied loading are based upon these findings and the additional concern for the consequences of a slip of significant magnitude if it should occur in the short-slotted hole. Because an increase in hole size generally reduces the net area of a connected part, the use of slotted holes other than perpendicular to the applied loading is subject to approval by the *Engineer of Record.*

3.3.4. Long-Slotted Holes: When approved by the *Engineer of Record*, long-slotted holes are permitted in only one ply at any individual *faying surface* of *snug-tightened joints* as defined in Section 4.1, and *pretensioned joints* as defined in Section 4.2, provided the applied load is approximately perpendicular (between 80 and 100 degrees) to the axis of the slot. When approved by the *Engineer of Record*, long-slotted holes are permitted in one ply only at any individual *faying surface* of *slip-critical joints* as defined in Section 4.3 without regard for the direction of the applied load. Fully inserted finger shims between the *faying surfaces* of load-transmitting elements of bolted *joints* are not considered a long-slotted element of a *joint*; nor are they considered to be a ply at any individual *faying surface*. However, finger shims must have the same faying surface as the rest of the plies.

**Commentary:**
See the Commentary to Section 3.3.1.

Finger shims are devices that are often used to permit the alignment and plumbing of structures. When these devices are fully and properly inserted, they do not have the same effect on bolt pretension relaxation or the *connection* performance, as do long-slotted holes in an outer ply. When fully inserted, the shim provides support around approximately 75 percent of the perimeter of the bolt in contrast to the greatly reduced area that exists with a bolt that is centered in a long slot. Furthermore, finger shims are always enclosed on both sides by the connected material, which should be effective in bridging the space between the fingers.

Specification. In addition, the approval of the *Engineer of Record* is required in this Specification in the following cases:

(1) For the reuse of non-galvanized ASTM A325 bolts (Section 2.3.3);
(2) For the use of alternative washer-type indicating devices that differ from those that meet the requirements of ASTM F959, including the corresponding installation and inspection requirements that are provided by the *manufacturer* (Section 2.6.2);
(3) For the use of alternative-design fasteners, including the corresponding installation and inspection requirements that are provided by the *manufacturer* (Section 2.8);
(4) For the use of faying-surface coatings in *slip-critical joints* that provide a *mean slip coefficient* determined per Appendix A, but differing from Class A or Class B (Section 3.2.2(b));
(5) For the use of thermal cutting ~~in the production~~ of bolt holes produced free hand or for use in cyclically loaded joints (Section 3.3);
(6) For the use of oversized (Section 3.3.2), short-slotted (Section 3.3.3) or long slotted holes (Section 3.3.4) in lieu of standard holes;
(7) For the use of a value of $D_u$ other than 1.13 (Section 5.4.1); and,
(8) For the use of a value of $D$ other than 0.80 (Section 5.4.2).

## 3.3. Bolt Holes

The nominal dimensions of standard, oversized, short-slotted and long-slotted holes for *high-strength bolts* shall be equal to or less than those shown in Table 3.1. Holes larger than those shown in Table 3.1 are permitted when specified or approved by the *Engineer of Record*. Where thermally cut holes are permitted, the surface roughness profile of the hole shall not exceed 1,000 microinches as defined in ASME [illegible]1. Occasional gouges not more than 1⁄16 in. in depth are permitted~~. The *Engineer of Record* shall be notified of the type and dimensions of holes to be used. Oversize holes, short slots not perpendicular to the applied load and long slots in any direction shall be subject to approval by the *Engineer of Record*. Any restrictions on the use of hole types permitted in sections 3.3.1, 3.3.2 and 3.3.3 other than those listed shall be specified.~~

Thermally cut holes produced by mechanically guided means are permitted in statically loaded *joints*. Thermally cut holes produced free hand shall be permitted in statically loaded *joints* if approved by the *Engineer of Record*. For cyclically loaded *joints*, thermally cut holes shall be permitted if approved by the *Engineer of Record*.

**Commentary:**
The footnotes in Table 3.1 provide for slight variations in the dimensions of bolt holes from the nominal dimensions. When the dimensions of bolt holes are such

# Summary of Comments on Microsoft Word - 2013-2014 RCSC Ballot Response Form

## Page: 3

Number: 1 Author: mitchell Subject: Highlight Date: 10/17/2013 2:16:02 PM -05'00'

Number: 2 Author: mitchell Subject: Highlight Date: 10/17/2013 2:16:05 PM -05'00'

Number: 3 Author: mitchell Subject: Sticky Note Date: 10/17/2013 2:18:24 PM -05'00'

1. This only applies to delegated connection design. As written this is not clear. See highlighted sentence above that does make this distinction albeit indirectly. We need to be consistent.
2. As i understand it, this only applies to the use of short-slotted holes loaded perpendicular. I suggest that this staement is more appropriately located in Section 3.3.3.

Number: 4 Author: mitchell Subject: Cross-Out Date: 10/17/2013 2:13:49 PM -05'00'

Number: 5 Author: mitchell Subject: Sticky Note Date: 10/17/2013 2:20:13 PM -05'00'

This is redundant. These requirements are already specified in Section 3.3.2, 3.3.3, and 3.3.4.

Number: 6 Author: mitchell Subject: Cross-Out Date: 10/17/2013 2:19:04 PM -05'00'

Number: 7 Author: mitchell Subject: Cross-Out Date: 10/17/2013 2:20:32 PM -05'00'

Number: 8 Author: mitchell Subject: Sticky Note Date: 10/17/2013 2:24:16 PM -05'00'

The general concept stated is that the contract documents need to specify any requirements that are in addition to or in exception to those found in this Specification. Perhaps we want to consider such a statement in the Scope as is done in the AISC Code, however i don't think we want to start down the road of noting this in each section.

that they exceed these permitted variations, the bolt hole must be treated as the next larger type.

Slots longer than standard long slots may be required to accommodate construction tolerances or expansion *joints*. Larger oversized holes may be necessary to accommodate construction tolerances or misalignments. In the latter two cases, the Specification provides no guidance for further reduction of *design strengths* or allowable loads. Engineering design considerations should include, as a minimum, the effects of edge distance, net section, reduction in clamping force in *slip-critical joints*, washer requirements, bearing capacity, and hole deformation.

~~Short slots are used to account for minor adjustments in main members such as web thickness differences and member length. This practice is prevalent enough that this specification recognizes it and permits it unless it is specifically prohibited on design documents. This specification requires the *Engineer of Record* to be notified of the hole types and dimensions by showing this information on shop detail drawings as opposed to obtaining prior approval of the *Engineer of Record*.~~

For thermally cut holes produced free hand, it is usually necessary to grind the hole surface after thermal cutting in order to achieve a maximum surface roughness profile of 1,000 microinches.

Slotted holes in statically loaded *joints* are often produced by punching or drilling the hole ends and thermally cutting the sides of the slots by mechanically guided means. The sides of such slots should be ground smooth, particularly at the junctures of the thermal cuts to the hole ends.

For cyclically loaded *joints*, test results have indicated that when no major slip occurs in the *joint*, fretting fatigue failure usually occurs in the gross section prior to fatigue failure in the net section (Kulak et al., 1987, pp. 116, 117). Conversely, when slip occurs in the *joints* of cyclically loaded *connections*, failure usually occurs in the net section and the edge of a bolt hole becomes the point of crack initiation (Kulak et al., 1987, pp. 118). Therefore, for cyclically loaded *joints* designed as slip critical, the method used to produce bolt holes (either thermal cutting or drilling) should not influence the ultimate failure load, as failure usually occurs in the gross section when no major slip occurs.

3.3.1. Standard Holes: ~~In the absence of approval by the *Engineer of Record* for the use of other hole types, standard~~ Standard holes ~~shall~~ are permitted to be used in all plies of bolted *joints*.

**Table 3.1. Nominal Bolt Hole Dimensions**

| Nominal Bolt Diameter, $d_b$, in. | Nominal Bolt Hole Dimensions [a,b], in. | | | |
|---|---|---|---|---|
| | Standard (diameter) | Oversized (diameter) | Short-slotted (width × length) | Long-slotted (width × length) |
| □ | ⅑/⅙ | ⅕/⅛ | ⅑/⅙ × /⅙ | ⅑/⅙ × 1 1/¼ |
| ⅕/⅛ | /⅙ | ⅓/⅙ | /⅙ × ⅐/⅛ | /⅙ × 1 ⅑/⅙ |

# Page: 4

Number: 1 Author: mitchell Subject: Cross-Out Date: 10/17/2013 2:30:30 PM -05'00'

Number: 2 Author: mitchell Subject: Sticky Note Date: 10/17/2013 2:31:05 PM -05'00'
This is more appropriately located in 3.3.3, not here in this general section.

| | | | | |
|---|---|---|---|---|
| □ | ⅓/⅙ | ⅕/⅙ | ⅓/⅙ × 1 | ⅓/⅙ × 1 ⅐/⅛ |
| **⅐/⅛** | ⅕/⅙ | 1 /⅙ | ⅕/⅙ × 1 /⅛ | ⅕/⅙ × 2 ⅓/⅙ |
| **1** | 1 /⅙ | 1 □ | 1 /⅙ × 1 ⅕/⅙ | 1 /⅙ × 2 □ |
| **≥1 /⅙** | $d_b$ + /⅙ | $d_b$ + ⅕/⅙ | ($d_b$ + /⅙) × ($d_b$ + ⅓/⅛) | ($d_b$ + /⅙) × (2.5$d_b$) |

[a] The upper tolerance on the tabulated nominal dimensions shall not exceed /⅓½ in. Exception: In the width of slotted holes, gouges not more than /⅙ in. deep are permitted.

[b] The slightly conical hole that naturally results from punching operations with properly matched punches and dies is acceptable.

**Commentary:**

The use of bolt holes /⅙ in. larger than the bolt installed in them has been permitted since the first publication of this Specification. Allen and Fisher (1968) showed that larger holes could be permitted for *high-strength bolts* without adversely affecting the bolt shear or member bearing strength. However, the slip resistance can be reduced by the failure to achieve adequate pretension initially or by the relaxation of the bolt pretension as the highly compressed material yields at the edge of the hole or slot. ~~The provisions for oversized and slotted holes in this Specification are based upon these findings and the additional concern for the consequences of a slip of significant magnitude if it should occur in the direction of the slot. Because an increase in hole size generally reduces the net area of a connected part, the use of oversized holes or of slotted holes is subject to approval by the *Engineer of Record*.~~

3.3.2. Oversized Holes: When approved by the *Engineer of Record*, oversized holes are permitted in any or all plies of *slip-critical joints* as defined in Section 4.3.

**Commentary:**

~~See the Commentary to Section 3.3.1.~~The provisions for oversized holes in this Specification are based upon the findings of Allen and Fisher (1968) and the additional concern for the consequences of a slip of significant magnitude if it should occur in the oversized hole.

3.3.3. Short-Slotted Holes: ~~When approved by the *Engineer of Record*, s~~Short-slotted holes are permitted in ~~any or all plies~~~~one ply at each faying surface~~ [1] *snug-tightened joints* as defined in Section 4.1, ~~and~~ *pretensioned joints* as defined in Section 4.2 and *slip critical joints* as defined in Section 4.3, provided the applied load is [2]imately perpendicular (between 80 and 100 degrees) to the axis of the slot. When approved by the *Engineer of Record*, short-slotted holes are permitted in ~~any~~ more than one or all plies of *snug-tightened joints* as defined in Section 4.1, and *pretensioned joints* as defined in Section 4.2 provided the applied load is approximately perpendicular (between 80 and 100 degrees) to the axis of the slot and in any or all plies of *slip-critical joints* as defined in Section 4.3 without regard for the direction of the applied load.

**Commentary:**

# Page: 5

Number: 1 Author: mitchell Subject: Replacement Text Date: 10/17/2013 2:28:05 PM -05'00'

replace with "only one ply at any individual *faying surface*" to be consistent with similar language in 3.3.4.

Number: 2 Author: mitchell Subject: Sticky Note Date: 10/17/2013 4:30:05 PM -05'00'

Insert "When complete connection design is not shown in the structural design drawings, the Engineer of Record shall be notified when short-slotted holes are used in this manner." or something similar. The intent is that the EoR need not notify themselves if they are the connection designer, but they need to be notified otherwise.

~~See the Commentary to Section 3.3.1.~~ The use of short-slotted holes approximately perpendicular to the applied load in connection with snug tight bolts can provide the shear capacity and may allow the beam to rotate which matches the design assumptions. Deformation of connections can be a concern where the beam is not laterally or torsionally restrained by floor, roof or other framing.

The provision of limiting the use of short slotted holes to one ply with snug tight bolts is to avoid the use of short slotted holes in opposing plies of a faying surface. The use of short slotted holes with snug tight bolts in connections with multiple plies that do not share a faying surface ~~are~~ ll permitted. An example that would be permitted with multiple plies includes beam end connections on opposing sides of a column web.

3.3.4. Long-Slotted Holes: When approved by the *Engineer of Record*, long-slotted holes are permitted in only one ply at any individual *faying surface* of *snug-tightened joints* as defined in Section 4.1, and *pretensioned joints* as defined in Section 4.2, provided the applied load is approximately perpendicular (between 80 and 100 degrees) to the axis of the slot. When approved by the *Engineer of Record*, long-slotted holes are permitted in one ply only at any individual *faying surface* of *slip-critical joints* as defined in Section 4.3 without regard for the direction of the applied load. Fully inserted finger shims between the *faying surfaces* of load-transmitting elements of bolted *joints* are not considered a long-slotted element of a *joint*; nor are they considered to be a ply at any individual *faying surface*. However, finger shims must have the same faying surface as the rest of the plies.

**Commentary:**
See the Commentary to Section 3.3.1.

Finger shims are devices that are often used to permit the alignment and plumbing of structures. When these devices are fully and properly inserted, they do not have the same effect on bolt pretension relaxation or the *connection* performance, as do long-slotted holes in an outer ply. When fully inserted, the shim provides support around approximately 75 percent of the perimeter of the bolt in contrast to the greatly reduced area that exists with a bolt that is centered in a long slot. Furthermore, finger shims are always enclosed on both sides by the connected material, which should be effective in bridging the space between the fingers.

**Formatted:** Indent: First line: 0.5"

**Rationale or Justification for Change (attach additional pages as needed):**
The change in item 5 of the commentary to Section 1.4 was required to get it to agree with the current (2009) wording of second paragraph of Section 3.3 permitting the use of mechanically guided thermally cut holes in statically loaded joints.

# Page: 6

Number: 1 Author: mitchell Subject: Sticky Note Date: 10/17/2013 2:37:16 PM -05'00'

I think i understand what this paragraph is trying to convey. However, I don't think this will be clear to the average user. And... it's not clear enough to me that i can suggest alternate language.

Number: 2 Author: mitchell Subject: Sticky Note Date: 10/17/2013 2:33:50 PM -05'00'

Move proposed commentary from 3.3 here - "Short slots are used to account for minor adjustments in main members
such as web thickness differences and member length. This practice is prevalent enough that this specification recognizes it and permits it unless it is specifically prohibited on design documents. This specification requires the *Engineer of Record* to be notified of the hole types and dimensions by showing this information on shop detail drawings as opposed to obtaining prior approval of the *Engineer of Record*."

Number: 3 Author: mitchell Subject: Replacement Text Date: 10/17/2013 2:33:16 PM -05'00'

"is"

# RCSC Proposed Change:  S13-051

**Name:** Charlie Carter **E-mail:** carter@aisc.org
**Phone:** 312-670-5414 **Fax:**

**Ballot History:**

2012-13 Ballot Item # 1 (S11-038)
61 Affirmative,
5 Negative (Ferrell, McGormley, G. Mitchell, H. Mitchell, Tide)
2 Abstain

2012-13 Ballot Item # 6 (S12-045)
52 Affirmative
10 Negative (Ferrell, Hay, Helwig, Lohr, Mayes, McGormley, G. Mitchell, H. Mitchell, Tide, Ude)
6 Abstain

2013-4 Ballot Item # 3 (S13-051)
60 Affirmative
1 Negative (Curven)
4 Abstain

**Proposed Changes:**

***{The current ballot proposal S13-051 replaces the proposed language of S11-038 and S12-045. The original balloted proposals with listings of all negatives and comments follow the current proposal listing. (Scroll down to the words "S11-038 (Original balloted proposal – 2012-13 Ballot Item #1)" and "S12-045 (Original balloted proposal – 2012-13 Ballot Item #6)" for historical information.)***

**6/28/13 Proposal as agreed upon by the Task Group (Ballot Item S13-051)**
**(Curven, G. Mitchell, Shaw, Carter, Ude)**

***{Note: There are no proposed modifications from the 2009 Edition language for Section 8.2.3 unlike proposal S12-045.}***

**9.2. Pretensioned Joints**

For *pretensioned joints*, the following inspection shall be performed in addition to that required in Section 9.1:

(1) When the turn-of-nut pretensioning method is used for installation, the inspection shall be in accordance with Section 9.2.1;
(2) When the calibrated wrench pretensioning method is used for installation, the inspection shall be in accordance with Section 9.2.2;

------------------------------------For Committee Use Below-----------------------------------------------

Date Received: 5/31/12 Exec Com Meeting: 6/6/12 Forwarded: Yes X /No ☐

Committee Assignment: Executive -A. ☐ Editorial -B. ☐ Nominating -C. ☐

Specifications -A.1 X Research -A.2 ☐ Membership & Funding -A.3 ☐ Education -A.4 ☐

Committee Chair: Harrold Task Group #: ___________ T.G. Chair: ________________

Date Sent to Main Committee: _______________Final Disposition: ______________________

(3) When the twist-off-type tension-control bolt pretensioning method is used for installation, the inspection shall be in accordance with Section 9.2.3;
(4) When the direct-tension-indicator pretensioning method is used for installation, the inspection shall be in accordance with Section 9.2.4; and,
(5) When alternative-design fasteners that meet the requirements of Section 2.8 or alternative washer-type indicating devices that meet the requirements of Section 2.6.2 are used, the inspection shall be in accordance with inspection instructions provided by the *manufacturer* and approved by the *Engineer of Record*.

**Commentary:**
When *joints* are designated as pretensioned, they are not subject to the same faying-surface-treatment inspection requirements as is specified for *slip-critical joints* in Section 9.3.

9.2.1. Turn-of-Nut Pretensioning: The *inspector* shall observe the pre-installation verification testing required in Section ~~8.2.1.~~ 8.2. Subsequently, it shall be ensured by *routine observation* that the bolting crew properly rotates the turned element relative to the unturned element by the amount specified in Table 8.2. Alternatively, when *fastener assemblies* are match-marked after the initial fit-up of the *joint* but prior to pretensioning, visual inspection after pretensioning is permitted in lieu of routine observation. No further evidence of conformity is required. A pretension that is greater than the value specified in Table 8.1 shall not be cause for rejection. A rotation that exceeds the required values, including tolerance, specified in Table 8.2 shall not be cause for rejection.

Comment [AJH1]: S06-002B Already approved for inclusion in 2014 Edition.

**Commentary:**
Match-marking of the assembly during installation as discussed in the Commentary to Section 8.2.1 improves the ability to inspect bolts that have been pretensioned with the turn-of-nut pretensioning method. The sides of nuts and bolt heads that have been impacted sufficiently to induce the Table 8.1 minimum pretension will appear slightly peened.

The turn-of-nut pretensioning method, when properly applied and verified during the construction, provides more reliable installed pretensions than after-the-fact *inspection* testing. Therefore, proper inspection of the method is for the inspector to observe the required pre-installation verification testing of the *fastener assemblies* and the method to be used, followed by monitoring of the work in progress to ensure that the method is routinely and properly applied, or visual inspection of match-marked assemblies.

Some problems with the turn-of-nut pretensioning method have been encountered with hot-dip galvanized bolts. In some cases, the problems have been attributed to an especially effective lubricant applied by the *manufacturer* to ensure that bolts and nuts from stock will meet the ASTM Specification requirements for minimum turns testing of galvanized fasteners. Job-site testing in the *tension calibrator* demonstrated that the lubricant reduced the coefficient of friction between the bolt and nut to the degree that “the full effort of an ironworker using an ordinary spud wrench" to snug-tighten the *joint* actually induced the full required pretension. Also, because the nuts could be removed with an ordinary spud wrench, they were erroneously judged by the *inspector* to be improperly pretensioned. Excessively lubricated *high-strength bolts* may require significantly less torque to induce the specified pretension. The required pre-installation verification will reveal this potential problem.

Conversely, the absence of lubrication or lack of proper over-tapping can cause seizing of the nut and bolt threads, which will result in a twist failure of the bolt at less than the specified pretension. For such situations, the use of a *tension calibrator* to check the bolt assemblies to be installed will be helpful in establishing the need for lubrication.

9.2.2. Calibrated Wrench Pretensioning: The *inspector* shall observe the pre-installation verification testing required in Sections 8.2 and 8.2.2. Subsequently, it shall be ensured by *routine observation* that the bolting crew properly applies the calibrated wrench to the turned element. No further evidence of conformity is required. A pretension that is greater than the value specified in Table 8.1 shall not be cause for rejection.

**Commentary:**
For proper inspection of the method, it is necessary for the *inspector* to observe the required pre-installation verification testing of the *fastener assemblies* and the method to be used, followed by monitoring of the work in progress to ensure that the method is routinely and properly applied within the limits on time between removal from *protected storage* and final pretensioning.

9.2.3. Twist-Off-Type Tension-Control Bolt Pretensioning: The *inspector* shall observe the pre-installation verification testing required in Section ~~8.2.3.~~ 8.2. Subsequently, it shall be ensured by *routine observation* that the splined ends are properly severed during installation by the bolting crew. No further evidence of conformity is required. A pretension that is greater than the value specified in Table 8.1 shall not be cause for rejection.

**Commentary:**
The sheared-off splined end of an installed twist-off-type tension-control bolt assembly merely signifies that at some time the bolt was subjected to a torque that was adequate to cause the shearing. If in fact all fasteners are individually pretensioned in a single continuous operation without first properly snug-tightening all fasteners, they may give a misleading indication that the bolts have been properly pretensioned. Therefore, it is necessary that the *inspector* observe the required pre-installation verification testing of the *fastener assemblies*, and the ability to apply partial tension prior to twist-off is demonstrated. This is followed by monitoring of the work in progress to ensure that the method is routinely and properly applied within the limits on time between removal from *protected storage* and final twist-off of the splined end.

9.2.4. Direct-Tension-Indicator Pretensioning: The *inspector* shall observe the pre-installation verification testing required in Sections 8.2 and 8.2.4. Subsequently, but prior to pretensioning, it shall be ensured by *routine observation* that the appropriate feeler gage is accepted in at least half of the spaces between the protrusions of the direct tension indicator and that the protrusions are properly oriented away from the work. If the appropriate feeler gage is accepted in fewer than half of the spaces, the direct tension indicator shall be removed and replaced. After pretensioning, it shall be ensured by *routine observation* that the appropriate feeler gage is refused entry into at least half of the spaces between the protrusions. No further evidence of conformity is required. A pretension that is greater than that specified in Table 8.1 shall not be cause for rejection.

**Commentary:**
When the *joint* is initially snug tightened, the direct tension indicator arch-like protrusions will generally compress partially. Whenever the snug-tightening operation causes one-half or more of the gaps between these arch-like protrusions to close to 0.015 in. or less (0.005 in. or less for coated direct tension indicators), the direct tension indicator should be replaced. Only after this initial operation should the bolts be pretensioned in a systematic manner. If the bolts are installed and pretensioned in a single continuous operation, direct tension indicators may give the *inspector* a misleading indication that the bolts have been properly pretensioned. Therefore, it is necessary that the *inspector* observe the required pre-installation verification testing of the *fastener assemblies* with the direct-tension indicators properly located and the method to be used. Following this operation, the *inspector* should monitor the work in progress to ensure that the method is routinely and properly applied.

**Rationale or Justification for Change:**

**Explanation:**

Preinstallation verification is described in Section 7 and associated requirements for its use are stated in Section 8. There are general requirements in Section 8.2 that apply to all four methods of pretensioning and two of the methods have additional requirements specific to the method: calibrated wrench in Section 8.2.2 and direct tension indicators in Section 8.2.4. Section 9 covers inspection and references Section 8 for preinstallation verification requirements.

We have a problem in the current RCSC Specification with the way in which Section 9 refers to the requirements in Section 8. Each of Sections 9.2.1, 9.2.2, 9.2.3, and 9.2.4 refer to the requirements as they are stated in Section 8.2.1, 8.2.2, 8.2.3, and 8.2.4, respectively. However, this misses the general requirements in Section 8.2 for all methods. It also is confusing because Sections 8.2.1 and 8.2.3 do not have any preinstallation verification requirements beyond those in Section 8.2. The correct referencing scheme would be as follows:

Section 9.2.1 (turn-of-nut): refer to Section 8.2 only
Section 9.2.2 (calibrated wrench): refer to Section 8.2 and 8.2.2
Section 9.2.3 (twist-off-type tension-control bolt assemblies): refer to Section 8.2 only
Section 9.2.4 (direct-tension-indicators): refer to Section 8.2 and 8.2.4

**Previous work:**

A proposal was made and balloted to move and repeat the general requirements from Section 8.2 in each of Sections 8.2.1, 8.2.2, 8.2.3, and 8.2.4. This approach was rejected by the Specification Committee because of the repetition.

**Solution:**
We can go the opposite direction and simply modify the referencing of Section 8 requirements in Sections 9.2.1, 9.2.2, 9.2.3, and 9.2.4. Accordingly, the proposed changes are shown in redline and strikeout format above:

## Ballot Actions and Information:

2013-4 Ballot Item # 3 (S13-051)

60 Affirmative

1 Negative (Curven)

4 Abstain

## Affirmatives with Comments:

**Peter Birkemoe:**
Editorial only: 9.2.1 Commentary last paragraph …replace “lack of propera’ with “improper”

**Helen Chen:**
Section 9.2.1, add “the” before “cause”

**Robert J. Connor:**
This could be challenging to enforce in some cases where thick plates are very difficult to bring into “firm” contact, especially when slightly distorted by welding. We might want to compare our wording to what is in AWS tolerances for example or at least add commentary regarding plate distortion from welding and how it may or may not affect connections.

**David Sharp:**
Comment for new business only. We should add some clarity about the applicability of T-O-N method with respect to ASTM A325T fully threaded bolts.

## Negatives with Comments:

**Chris Curven:**
As I do not see the ballot item attached.

**S11-038 (Original balloted proposal – 2012-13 Ballot Item #1)**

**8.2. Pretensioned Joints and Slip-Critical Joints**

One of the pretensioning methods in Sections 8.2.1 through 8.2.4 shall be used, except when alternative-design fasteners that meet the requirements of Section 2.8 or alternative washer-type indicating devices that meet the requirements of Section 2.6.2 are used, in which case, installation instructions provided by the *manufacturer* and approved by the *Engineer of Record* shall be followed.

*{Table 8.1 "Minimum Bolt Pretension, Pretensioned and Slip-Critical Joints" is unchanged and will not be reproduced here.}*

When it is impractical to turn the nut, pretensioning by turning the bolt head is permitted while rotation of the nut is prevented, provided that the washer requirements in Section 6.2 are met. A pretension that is equal to or greater than the value in Table 8.1 shall be provided. The pre-installation verification procedures specified in Section 7 shall be performed as indicated in Sections 8.2.1 through 8.2.4, using *fastener assemblies* that are representative of the condition of those that will be pretensioned in the work.

The required p~~P~~re-installation testing shall be performed for each fastener assembly lot prior to the use of that assembly lot in the work. The testing shall be done at the start of the work. For calibrated wrench pretensioning, this testing shall be performed daily for the calibration of the installation wrench.

**Commentary:**

*{There are no proposed changes to the commentary for this subsection.}*

8.2.1. Turn-of-Nut Pretensioning: The pre-installation verification procedures specified in Section 7 shall demonstrate that the required rotation from snug-tight shall reach at least the minimum required tension in Table 7.1. All bolts shall be installed in accordance with the requirements in Section 8.1, with washers positioned as required in Section 6.2. Subsequently, the nut or head rotation specified in Table 8.2 shall be applied to all *fastener assemblies* in the *joint*, progressing systematically from the most rigid part of the *joint* in a manner that will minimize relaxation of previously pretensioned bolts. The part not turned by the wrench shall be prevented from rotating during this operation. Upon completion of the application of the required nut rotation for pretensioning, it is not permitted to turn the nut in the loosening direction except for the purpose of complete removal of the individual fastener assembly. Such fastener assemblies shall not be reused except as permitted in Section 2.3.3.

*{Table 8.2 "Nut Rotation from Snug-Tight Condition for Turn-of-Nut Pretensioning" is unchanged and will not be reproduced here.}*

**Commentary:**

*{There are no proposed changes to the commentary for this subsection.}*

8.2.2. Calibrated Wrench Pretensioning:

*{There are no proposed changes to this subsection.}*

8.2.3. Twist-Off-Type Tension-Control Bolt Pretensioning: Twist-off-type tension-control bolt assemblies that meet the requirements of ASTM F1852 or F2280 shall be used. The pre-installation verification procedures specified in Section 7 shall demonstrate that, when the splined end is severed off with the required tool, the bolt tension shall be at least equal to that required in Table 7.1.

All *fastener assemblies* shall be installed in accordance with the requirements in Section 8.1 without severing the splined end and with washers positioned as required in Section 6.2. If a splined end is severed during this operation, the *fastener assembly* shall be removed and replaced. Subsequently, all bolts in the *joint* shall be pretensioned with the twist-off-type tension-control bolt installation wrench, progressing systematically from the most rigid part of the *joint* in a manner that will minimize relaxation of previously pretensioned bolts.

**Commentary:**
*{There are no proposed changes to the commentary for this subsection.}*

8.2.4. Direct-Tension-Indicator Pretensioning:
*{There are no proposed changes to this subsection.}*

**Rationale or Justification for Change (attach additional pages as needed):**

Sections 9.2.1 and 9.2.3 make a reference to the pre-installation verification testing in Sections 8.2.1 and 8.2.3 respectively. There is currently no language in Sections 8.2.1 and 8.2.3 that refer to the pre-installation testing.

This proposal corrects that omission and makes all four subsections of Section 8.2 refer to Chapter 7 pre-installation requirements in an equivalent manner.

**Ballot Actions and Information:**

2012-13 Ballot Item # 1

61 Affirmative,

5 Negative (Ferrell, McGormley, G. Mitchell, H. Mitchell, Tide)

2 Abstain

## Affirmative with Comments:

**Peter Birkemoe:**

Commentary in Section 7 suggests that the hydraulic calibrator is softer than solid steel and the readings of turns to achieve a given load will be higher. Without specific recommendations on how to account for this when verifying T.O.N., it would be assumed that the verification is "that the assembly can reach the required pretension by turning." Similarly, for bolts too short to fit in a calibrator it is permitted to verify T.O.N. by tightening an assembly in solid steel by turning the nut. Since the force in the bolt can not be verified, it would be assumed here that the verification is "the survival by the assembly of the applied turn." The "clarification" in this Ballot puts more focus on the parallel requirement for Verification of T.0.N. and I would suggest some clarification of this aspect of the associated commentary. Also, in 8.2 the first amended paragraph would be improved by adding "and configuration" after "condition." If the bolt head is turned, that is the way the assembly performance should be verified.

**Robert Hay:**

Language provided helps to clarify preinstallation requirements.

**Bob Shaw:**

Editorial only – in 8.2.1 third line, change "reach" to "provide"

**Joe Yura:**

For turn-of-nut method, the last sentence in the Commentary of Section 7.1 states that short bolts do not need verification of the bolt tension in Table 7.1 so perhaps the following should be added to Section 8.2.1: "… in Table 7.1, except for short bolts where the required turns must be verified."

## Negative with Comments:

**Doug Ferrell:**

In my opinion the requirement of pre-Installation verification is adequately stated in the wording of 8.2. Repeating this requirement in the definition of each installation method is not necessary. Also the additional performance requirements of each method is not necessary.

**Jonathan McGormley:**

As it stands today, the current text indirectly achieves its purpose via Section 8.2. The proposed text could be eliminated by changing the references to 8.2.1 and 8.2.3 in Sections 9.2.1 and 9.2.3, respectively, to Section 8.2 which currently, without modification, requires pre-installation verification. Similar modifications should be made to 9.2.2 and 9.2.4. Less text is better, in my opinion.

**Eugene Mitchell:**
Section 7 doesn't detail any installation procedures. This can be handled once in 8.2 with a statement like: "Regardless of the installation method, the pre-installation verification shall demonstrate that the bolt assemblies tested reach an installed tension that is equal to or greater than the minimum required tension in Table 7.1." The current wording in 8.2.4 can be removed and nothing needs to be added to 8.2.2 & 8.2.3.

**Heath Mitchell:**
I'm not convinced that there is any confusion resulting from the spec as-is in this case, but for the sake of consistency these changes are likely warranted. I think the implementation can use a little more work to be consistent in style and terminology across all installation methods. See attached revisions and comments (See Attachment A).

**S12-045 (Original balloted proposal – 2012-13 Ballot Item #6)**

8.2.3. Twist-Off-Type Tension-Control Bolt Pretensioning: Twist-off-type tension-control bolt assemblies that meet the requirements of ASTM F1852 or F2280 shall be used.

All *fastener assemblies* shall be installed in accordance with the requirements in Section 8.1 without severing the splined end and with washers positioned as required in Section 6.2. If a splined end is severed during this operation, the *fastener assembly* shall be removed and replaced. Subsequently, all bolts in the *joint* shall be ~~pretensioned~~ tightened with the twist-off-type tension-control bolt installation wrench until the splined-end shears off, progressing systematically from the most rigid part of the *joint* in a manner that will minimize relaxation of previously pretensioned bolts.

**Commentary:**
ASTM F1852 and F2280 twist-off-type tension-control bolt assemblies have a splined end that extends beyond the threaded portion of the bolt. During installation, this splined end is gripped by a specially designed wrench chuck and provides a means for turning the nut relative to the bolt. This product is, in fact, based upon a torque-controlled installation method to which the *fastener assembly* variables affecting torque that were discussed in the Commentary to Section 8.2.2 apply, except for wrench calibration, because torque is controlled within the *fastener assembly*.

Twist-off-type tension-control bolt assemblies must be used in the as-delivered, clean, lubricated condition as specified in Section 2. Adherence to the requirements in this Specification, especially those for storage, cleanliness and verification, is necessary for their proper use.

9.2.1. Turn-of-Nut Pretensioning: The *inspector* shall observe the pre-installation verification testing required in Section 8.2.1. Subsequently, but prior to pretensioning and optional match-marking, it shall be ensured by *routine observation* that the plies have been brought into *firm contact*. Subsequently, it shall be ensured by *routine observation* that the bolting crew properly rotates the turned element relative to the unturned element by the amount specified in Table 8.2. Alternatively, when *fastener assemblies* are match-marked after the initial fit-up of the *joint* but prior to pretensioning, visual inspection after pretensioning is permitted in lieu of routine observation. No further evidence of conformity is required. A pretension that is greater than the value specified in Table 8.1 shall not be cause for rejection.

**Commentary:**
Match-marking of the assembly during installation as discussed in the Commentary to Section 8.2.1 improves the ability to inspect bolts that have been pretensioned with the turn-of-nut pretensioning method. The sides of nuts and bolt heads that have been impacted sufficiently to induce the Table 8.1 minimum pretension will appear slightly peened.

The turn-of-nut pretensioning method, when properly applied and verified during the construction, provides more reliable installed pretensions than after-the-fact *inspection* testing. Therefore, proper inspection of the method is for the inspector to observe the required pre-installation verification testing of the *fastener assemblies* and the method to be used, followed by monitoring of the work in progress to ensure that the method is routinely and properly applied, or visual inspection of match-marked assemblies.

Some problems with the turn-of-nut pretensioning method have been encountered with hot-dip galvanized bolts. In some cases, the problems have been attributed to an especially effective lubricant applied by the *manufacturer* to ensure that bolts and nuts from stock will meet the ASTM Specification requirements for minimum turns testing of galvanized fasteners. Job-site testing in the *tension calibrator* demonstrated that the lubricant reduced the coefficient of friction between the bolt and nut to the degree that “the full effort of an ironworker using an ordinary spud wrench” to snug-tighten the *joint* actually induced the full required pretension. Also, because the nuts could be removed with an ordinary spud wrench, they were erroneously judged by the *inspector* to be improperly pretensioned. Excessively lubricated *high-strength bolts* may require significantly less torque to induce the specified pretension. The required pre-installation verification will reveal this potential problem.

Conversely, the absence of lubrication or lack of proper over-tapping can cause seizing of the nut and bolt threads, which will result in a twist failure of the bolt at less than the specified pretension. For such situations, the use of a *tension calibrator* to check the bolt assemblies to be installed will be helpful in establishing the need for lubrication.

9.2.2. Calibrated Wrench Pretensioning: The *inspector* shall observe the daily pre-installation verification testing required in Section 8.2.2. Subsequently, but prior to pretensioning, it shall be ensured by *routine observation* that the plies have been brought into *firm contact*. Subsequently, it shall be ensured by *routine observation* that the bolting crew properly applies the calibrated wrench to the turned element. No further evidence of conformity is required. A pretension that is greater than the value specified in Table 8.1 shall not be cause for rejection.

**Commentary:**
For proper inspection of the method, it is necessary for the *inspector* to observe the required pre-installation verification testing of the *fastener assemblies* and the method to be used, followed by monitoring of the work in progress to ensure that the method is routinely and properly applied within the limits on time between removal from *protected storage* and final pretensioning.

9.2.3. Twist-Off-Type Tension-Control Bolt Pretensioning: The *inspector* shall observe the pre-installation verification testing required in Section 8.2.3. Subsequently, but prior to pretensioning, it shall be ensured by *routine observation* that the plies have been brought into *firm contact* without the splined ends being severed. If the splined end is severed, the bolt must be removed and replaced. Subsequently, it shall be ensured by *routine observation* that the splined ends are properly severed during installation by the bolting crew. No further evidence of conformity is required. A pretension that is greater than the value specified in Table 8.1 shall not be cause for rejection.

**Commentary:**
The sheared-off splined end of an installed twist-off-type tension-control bolt assembly merely signifies that at some time the bolt was subjected to a torque that was adequate to cause the shearing. If in fact all fasteners are individually pretensioned in a single continuous operation without first properly snug-tightening all fasteners, they may give a misleading indication that the bolts have been properly pretensioned. Therefore, it is necessary that the *inspector* observe the required pre-installation verification testing of the *fastener assemblies*, and the ability to apply partial tension prior to twist-off is demonstrated. This is followed by monitoring of the work in progress to ensure that the method is routinely and properly applied within the limits on time between removal from *protected storage* and final twist-off of the splined end.

**Rationale or Justification for Change (attach additional pages as needed):**

8.2.3 does not actually state when the installer is to stop tightening or when the bolt is deemed tight. It states what type of installation tool to be used, but not what the installer is looking for.
For example, 8.2.1. states to rotate the head or nut as specified in table 8.2., 8.2.2. states to apply the installation torque determined by the pre-installation verification, and 8.2.4. has the installer making sure the achieved gap is less than the job inspection gap.

Also, Section 9.2.4. is the only installation method that has the inspector verify that snugging of the bolts and plies have taken place before the chosen pretensioning method takes place. 9.2.1., 9.2.2.,and 9.2.3. would obviously like to have inspection of the snug condition, but it is not listed.
For example, 9.2.4. …All bolts shall be installed in accordance with the requirements in Section 8.1, with washers positioned as required in Section 6.2. The installer shall verify that the direct-tension-indicator protrusions have not been compressed to a gap that is less

than the job inspection gap during this operation, and if this has occurred, the direct tension indicator shall be removed and replaced….

**Ballot Actions and Information:**

2012-13 Ballot Item # 6

52 Affirmative

10 Negative (Ferrell, Hay, Helwig, Lohr, Mayes, McGormley, G. Mitchell, H. Mitchell, Tide, Ude)

6 Abstain

## Affirmative with Comments:

**Peter Birkemoe:**
Re: 9.2.3 The second "subsequently" if changed to "afterward" would improve the distinction of the two requirements. The note of indication of "impacting" in the Commentary to 8.2, Par 1 should be amended unless "only impact wrenches" can be employed to perform the prescribed turns; if that remains, electric geared reaction wrenches and the hydraulic wrenches that are used on larger fastener assemblies are implicitly disallowed.

**Helen Chen:**
See Attachment H.

**Chris Curven:**
"snug tightened" needs to be hyphenated.

**Bob Shaw:**
Editorial only – suggest 8.2.3 9th line use "twists off" instead of "shears off"

**Joe Yura:**
Editorial suggestions – remove the word "subsequently in all the sections. There is one "subsequently" followed by another "subsequently". The word is just not necessary.

## Negative with Comments:

**Doug Ferrell:**
Commentary of 8.2 adequately explains the requirements of snug-tight and all plies in firm contact before pretensioning. Perhaps this paragraph of commentary should be moved to within the main text of 8.2. This is a necessary requirement of all installation methods, except perhaps DTI.

**Robert Hay:**
The proposed additional language regarding the inspection of the snug tight condition would be redundant since 9.1 clearly requires the inspection prior to pretensioning. The modification to 8.2.3 is subtle and I have no objection to that.

**Todd Helwig:**
While you can tell around the edge that the plies have been brought into contact, how do you tell in the middle of the plate that the plies have been brought into contact? I'm don't think this is something that can be reliably checked.

**Ken Lohr:**
I feel we need to look at the wording proposed and that if changes are needed that they be applied to all methods of installation.

**Curtis Mayes:**
This ballot item does not change the spec which is already clear. All Pretensioning methods already require snug tightening section 9.1. This proposal adds redundancy to the spec. We need less redundancy. I might vote for only modifying section 9.2.3 with, “If the splined end is severed, the bolt must be removed and replaced.”

**Jonathan McGormley:**
Section 9.1 already requires that the inspector verify that the plies are in firm contact. Section 9.2 which includes all of the tightening methods requires conformance with Section 9.1; therefore, adding repeated language to the tightening methods is verbose. With respect to the langue in Section 9.2.4, it is needed in order to form the basis (start point) for determining whether the pretension method has worked.

**Eugene Mitchell:**
Instead of adding the statement to all the other installation methods, delete from the DTI specification.

**Heath Mitchell:**
Voted negative with no comment.

**Ray Tide:**
Although a slightly different topic, if the above changes are forthcoming then these changes recommended by Chris would require additional changes. One editorial item is raised by Chris in the second paragraph of Section 8.2.3, fifth line where he has changed “pretensioned” to “tightened”. However, throughout the total RCSC Spec we use “pretensioned”. I do NOT agree with this proposed change.

**Todd Ude:**
As I read 9.2 and 9.3, they both flow back to require the 9.1 inspection and verification of the snug tight condition (plies in firm contact) prior to final tensioning, regardless of method? This makes additions to 9.2.1 and 9.2.2 unnecessary? I take no exception and would vote affirmative to the changes proposed for 8.2.3 and 9.2.3.

## Abstain with Comments:

**Matthew Eatherton:**
I’m abstaining on this ballot item because I’m not confident about whether the change is appropriate or not. I’m unsure if specifying daily inspections in 9.2.2. is necessary or too onerous. Also, it’s unclear to me why the snug tight condition would need to be inspected for the calibrated wrench method or the twist-off bolt method.

# RCSC Proposed Change: S13-052

**Name:** Charlie Carter **E-mail:** carter@aisc.org
**Phone:** 312/670-5414 **Fax:** 312/670-5402

**Ballot History:**

2013-14 Ballot Item #4 (S13-052)
62 Affirmative
0 Negative
4 Abstain

**Proposed Change:**

## SECTION 6. USE OF WASHERS

### 6.1. Snug-Tightened Joints

Washers are not required in snug-tightened joints, except as required in Sections 6.1.1 and 6.1.2.

6.1.1. Sloping Surfaces: When the outer face of the *joint* has a slope that is greater than 1:20 with respect to a plane that is normal to the bolt axis, an ASTM F436 beveled washer shall be used to compensate for the lack of parallelism.

6.1.2. Slotted Hole: When a slotted hole occurs in an outer ply, an ASTM F436 washer or 5/16 in. thick common plate washer shall be used as required to completely cover the hole.

### 6.2. Pretensioned Joints and Slip-Critical Joints

Washers are not required in *pretensioned joints* and *slip-critical joints*, except as required in Sections 6.1.1, 6.1.2, 6.2.1, 6.2.2, 6.2.3, 6.2.4 and 6.2.5.

6.2.1. Specified Minimum Yield Strength of Connected Material Less Than 40 ksi: When ASTM A490 or F2280 bolts are pretensioned in connected material of specified minimum yield strength less than 40 ksi, ASTM F436 washers shall be used under both the bolt head and nut, except that a washer is not needed under the head of an ASTM F2280 round head twist-off bolt.

6.2.2. Calibrated Wrench Pretensioning: When the calibrated wrench pretensioning method is used, an ASTM F436 washer shall be used under the turned element.

------------------------------------For Committee Use Below-----------------------------------------------

Date Received: ______ Exec Com Meeting: _______ Forwarded: Yes ☐ /No ☐

Committee Assignment: Executive -A. ☐ Editorial -B. ☐ Nominating -C. ☐

Specifications -A.1 ☐ Research -A.2 ☐ Membership & Funding -A.3 ☐ Education -A.4 ☐
Committee Chair: ____________ Task Group #: ___________ T.G. Chair: ________________
Date Sent to Main Committee: _______________Final Disposition: ______________________

6.2.3. Twist-Off-Type Tension-Control Bolt Pretensioning: When the twist-off-type tension-control bolt pretensioning method is used, an ASTM F436 washer shall be used under the nut as part of the *fastener assembly*.

6.2.4. Direct-Tension-Indicator Pretensioning: When the direct-tension-indicator pretensioning method is used, an ASTM F436 washer shall be used as follows:

(1) When the nut is turned and the direct tension indicator is located under the bolt head, an ASTM F436 washer shall be used under the nut;
(2) When the nut is turned and the direct tension indicator is located under the nut, an ASTM F436 washer shall be used between the nut and the direct tension indicator;
(3) When the bolt head is turned and the direct tension indicator is located under the nut, an ASTM F436 washer shall be used under the bolt head; and,

### Table 6.1. Washer Requirements for Pretensioned and Slip-Critical Bolted *Joints* with Oversized and Slotted Holes in the Outer Ply

<table>
<tr><th rowspan="2">ASTM Designation</th><th rowspan="2">Nominal Bolt Diameter, $d_b$, in.</th><th colspan="3">Hole Type in Outer Ply</th></tr>
<tr><th>Oversized</th><th>Short-Slotted</th><th>Long-Slotted</th></tr>
<tr><td>A325 or F1852</td><td>1/2 – 1 1/2</td><td colspan="2" rowspan="2">ASTM F436 [a]</td><td rowspan="2">5/16 in. thick plate washer or continuous bar [b,c]</td></tr>
<tr><td rowspan="2">A490 or F2280</td><td>≤ 1</td></tr>
<tr><td>> 1</td><td colspan="2">ASTM F436 extra thick~~with 5/16 in. thickness~~ [a,b,d]</td><td>ASTM F436 washer with either a 3/8 in. thick plate washer or continuous bar [b,c]</td></tr>
<tr><td colspan="5">[a] This requirement shall not apply to heads of round head tension-control bolt assemblies that meet the requirements in Section 2.7 and provide a bearing circle diameter that meets the requirements of ASTM F1852 or F2280.<br>[b] See ASTM F436 Section 1.2.2.4. Multiple washers with a combined thickness of 5/16 in. or larger do not satisfy this requirement.<br>[c] The plate washer or bar shall be of structural-grade steel material, but need not be hardened.<br>[d] Alternatively, a 3/8 in. thick plate washer and an ordinary thickness F436 washer may be used. The plate washer need not be hardened.</td></tr>
</table>

(4) When the bolt head is turned and the direct tension indicator is located under the bolt head, an ASTM F436 washer shall be used between the bolt head and the direct tension indicator.

6.2.5. Oversized or Slotted Hole: When an oversized or slotted hole occurs in an outer ply, the washer requirements shall be as given in Table 6.1. The washer used shall be of sufficient size to completely cover the hole.

**Commentary:**

It is important that shop drawings and *connection* details clearly reflect the number and disposition of washers when they are required, especially the thick hardened washers or plate washers that are required for some slotted hole applications. The total thickness of washers in the *grip* affects the length of bolt that must be supplied and used.

The primary function of washers is to provide a hardened non-galling surface under the turned element, particularly for torque-based pretensioning methods such as the calibrated wrench pretensioning method and twist-off-type tension-control bolt pretensioning method. Circular flat washers that meet the requirements of ASTM F436 provide both a hardened non-galling surface and an increase in bearing area that is approximately 50 percent larger than that provided by a heavy-hex bolt head or nut. However, tests have shown that washers of the standard E in. thickness have a minor influence on the pressure distribution of the induced bolt pretension. Furthermore, they showed that a larger thickness is required when ASTM A490 bolts are used with material that has a minimum specified yield strength that is less than 40 ksi. This is necessary to mitigate the effects of local yielding of the material in the vicinity of the contact area of the head and nut. The requirement for standard thickness hardened washers, when such washers are specified, is waived for alternative design fasteners that incorporate a bearing surface under the head of the same diameter as the hardened washer.

Extra thick ASTM F436 washers~~Heat-treated washers not less than 5/16 in. thick~~ are required to cover oversized and short-slotted holes in external plies, when ASTM A490 or F2280 bolts of diameter larger than 1 in. are used, except as permitted by Table 6.1 footnotes a and d. This was found necessary to distribute the high clamping pressure so as to prevent collapse of the hole perimeter and enable the development of the desired clamping force. Preliminary investigation has shown that a similar but less severe deformation occurs when oversized or slotted holes are in the interior plies. The reduction in clamping force may be offset by "keying," which tends to increase the resistance to slip. These effects are accentuated in *joints* of thin plies. When long-slotted holes occur in an outer ply, ⅜ in. thick plate washers or continuous bars and one ASTM F436 washer are required in Table 6.1. This requirement can be satisfied with material of any structural grade. Alternatively, either of the following options can be used:

(1) The use of material with $F_y$ greater than 40 ksi will eliminate the need to also provide ASTM F436 washers in accordance with the requirements in Section 6.2.1 for ASTM A490 or F2280 bolts of any diameter; or,
(2) Material with $F_y$ equal to or less than 40 ksi can be used with ASTM F436 washers in accordance with the requirements in Section 6.2.1.

This specification previously required a washer under bolt heads with a bearing area smaller than that provided by an ASTM F436 washer. Tests indicate that the pretension achieved with a bolt having the minimum ASTM F1852 or F2280 bearing circle diameter is the same as that of a bolt with the larger bearing circle diameter equal to the size of an ASTM F436 washer, provided that the hole size meets the RCSC Specification limitations (Schnupp, 2003).

**Rationale or Justification for Change (attach additional pages as needed):**

This change is proposed to coordinate with a revision made in ASTM F436. ASTM F436 Section 1.2.4 now recognizes an "extra thick" product that meets the special 5/16-in. thickness we have required for A490 strength level with oversized and short-slotted holes in our Specification. Now that it is in ASTM F436, we do not need the special requirements and can simply use the requirements in ASTM F436. This proposed change provides for that.

## Ballot Actions and Information:

2013-14 Ballot Item #4 (S13-052)

62 Affirmative

0 Negative

4 Abstain

## Affirmative with Comments:

**Peter Birkemoe:**

Extra thick may well be covered in F436 (revised) but usage in RCSC should say something about what "extra thickness" means dimensionally. Extra thickness implies that it is something that is thicker that ordinary and should be a unique thickness just as "ordinary" is defined dimensionally. One should be able to identify an extra thick washer in the field without a micrometer. The substitution of multiple washers of "ordinary thickness" should be obviously not in compliance. Visually identifying a washer twice as thick as an "ordinary" washer should be easy and a commentary on identification should cover it.

**Rod Gibble:**

Since the words "extra thick" mean something very specific, I would prefer to see the reference to ASTM F436 Section 1.2.2.4 in the table rather than the footnote to avoid the possibility of people taking the words to simply mean "thicker than a normal washer." As currently proposed, one would not know that F436 recognizes an "extra thick" variant of the product.

**Allen J. Harrold:**

The ASTM reference in the rationale should be to Section 1.2.2.4. The reference is correct in the Note b of Table 6.1. The minimum nominal bolt diameter for A325 bolts in the table is bogus due to font inconsistencies. There is no change proposed for that reference so the value may be corrected editorially during publishing of the Specification.

**Greg Miazga:**

"Extra thick" doesn't sound like a technical term, but it appears to be by the newest revision to ASTM F436, so I agree we should use it per this ballot proposal. However, maybe in the commentary there should be something that elaborates on the ASTM definition of "extra thick" for those who do not have access to the ASTM F436 publication (i.e. the minimum thickness of "extra thickness" is..)

# RCSC Proposed Change:  S12-040

**Name:** Rich Brown  **E-mail:** Rich.Brown@TurnaSure.com
**Phone:** 215-750-1300  **Fax:** 215-750-6300

**Ballot History:**

2013-14 Ballot Item # 1
57 Affirmative
4 Negative (Birkemoe, Curven, Deal, Lohr)
5 Abstain

**Proposed Change:**

8.2.4. Direct-Tension-Indicator Pretensioning: Direct tension indicators that meet the requirements of ASTM F959 shall be used. The pre-installation verification procedures specified in Section 7 shall demonstrate that, when the pretension in the bolt reaches that required in Table 7.1, the gap is not less than the job inspection gap in accordance with ASTM F959.

All bolts shall be installed in accordance with the requirements in Section 8.1, with washers positioned as required in Section 6.2. The installer shall verify that the direct-tension-indicator protrusions have not been compressed to a gap that is less than the job inspection gap during this operation, and if this has occurred, the direct tension indicator shall be removed and replaced. Subsequently, all bolts in the *joint* shall be pretensioned, progressing systematically from the most rigid part of the *joint* in a manner that will minimize relaxation of previously pretensioned bolts. The installer shall verify that the direct tension indicator protrusions have been compressed to a gap that is less than the job inspection gap.

**Commentary:**
ASTM F959 direct tension indicators are recognized in this Specification as a bolt-tension-indicating device. Direct tension indicators are ~~hardened,~~ washer-shaped devices incorporating small arch-like protrusions on the bearing surface that are designed to deform in a controlled manner when subjected to compressive load.

During installation, care must be taken to ensure that the direct-tension-indicator arches are oriented to bear against the hardened bearing surface of the bolt head or nut, or against a hardened flat washer if used under turned element, whether that turned element is the nut or the bolt. Proper use and orientation is illustrated in Figure C-8.1.

-----------------------------------For Committee Use Below---------------------------------------------

Date Received: 07/01/13 Exec Com Meeting: Carter 7/1/13 Forwarded: Yes X /No ☐

Committee Assignment: Executive -A. ☐ Editorial -B. ☐ Nominating -C. ☐

Specifications -A.1 X Research -A.2 ☐ Membership & Funding -A.3 ☐ Education -A.4 ☐
Committee Chair: Harrold Task Group #: ___________ T.G. Chair: ________________
Date Sent to Main Committee: _______________Final Disposition: ______________________

In some cases, more than a single cycle of systematic partial pretensioning may be required to deform the direct-tension-indicator protrusions to the gap that is specified by the *manufacturer*. If the gaps fail to close or when the washer *lot* is changed, another verification procedure using the *tension calibrator* must be performed.

Provided the connected plies are in *firm contact*, partial compression of the direct tension indicator protrusions is commonly taken as an indication that the snug-tight condition has been achieved.

**Rationale or Justification for Change (attach additional pages as needed):**

ASTM F959-13 and F959M-13 have revised section 5.3 to clarifying the language as follows:

5.3 *Heat Treatment:*
5.3.1 The heat treatment of DTIs is optional at the manufacturer's discretion, provided the DTIs meet all of the mechanical and performance requirements.
5.3.2 If heat treatment is performed, the process shall be through-hardening by heating to a temperature above the upper transformation temperature, quenching in a liquid medium, and tempering by heating to a suitable temperature.

The abstract on the ASTM web site for both these standards have also been revised as follows:

## ASTM F959

### Abstract

This specification covers the requirements for four types (Types 325, 325-3, 490, and 490-3) of compressible-washer-type direct tension indicators, in nominal diameter sizes ½ through 1 ½ in., capable of indicating the achievement of a specified minimum bolt tension in a structural bolt and are intended for installation under either a bolt head or a hardened washer. Steel materials used in the manufacture of direct tension indicators shall be designed, processed, and protectively coated as specified. The direct tension indicators shall conform to required chemical composition, compression load, and dimensional values.

The writer believes that the ASTM has now made it very clear that Direct Tension Indicators need not be "Hardened" and the use of this word in the commentary should be removed.

## Ballot Actions and Information

2013-14 Ballot Item # 1

57 Affirmative

4 Negative (Birkemoe, Curven, Deal, Lohr)

5 Abstain

## Affirmative with Comments:

**Helen Chen:**

A not related comment: should it read "…required to deform the direct-tension-indicator protrusions to REDUCE the gap…"

## Negative with Comments:

**Peter Birkemoe:**

The RCSC Specification accepts ASTM Specs for material, dimensional and manufacturing requirements; it further provides additional information on installation usage and design requirements using fastener assemblies. A change in the manufacturing requirements for DTI's in ASTM F959 was evidently supported by demonstration testing of bolt assemblies using a nonhardened version of a DTI. If RCSC agrees that this report truly demonstrates that the usage of this version as part of a fastener assembly produces the same results as a hardened version then the RCSC should clearly indicate that by citing the reference in the Commentary. Further in the Commentary, to avoid confusion and emphasize that the removal of the hardness requirement is only an exception in ASTM 959 and not in anyway applied to F436 requirements.

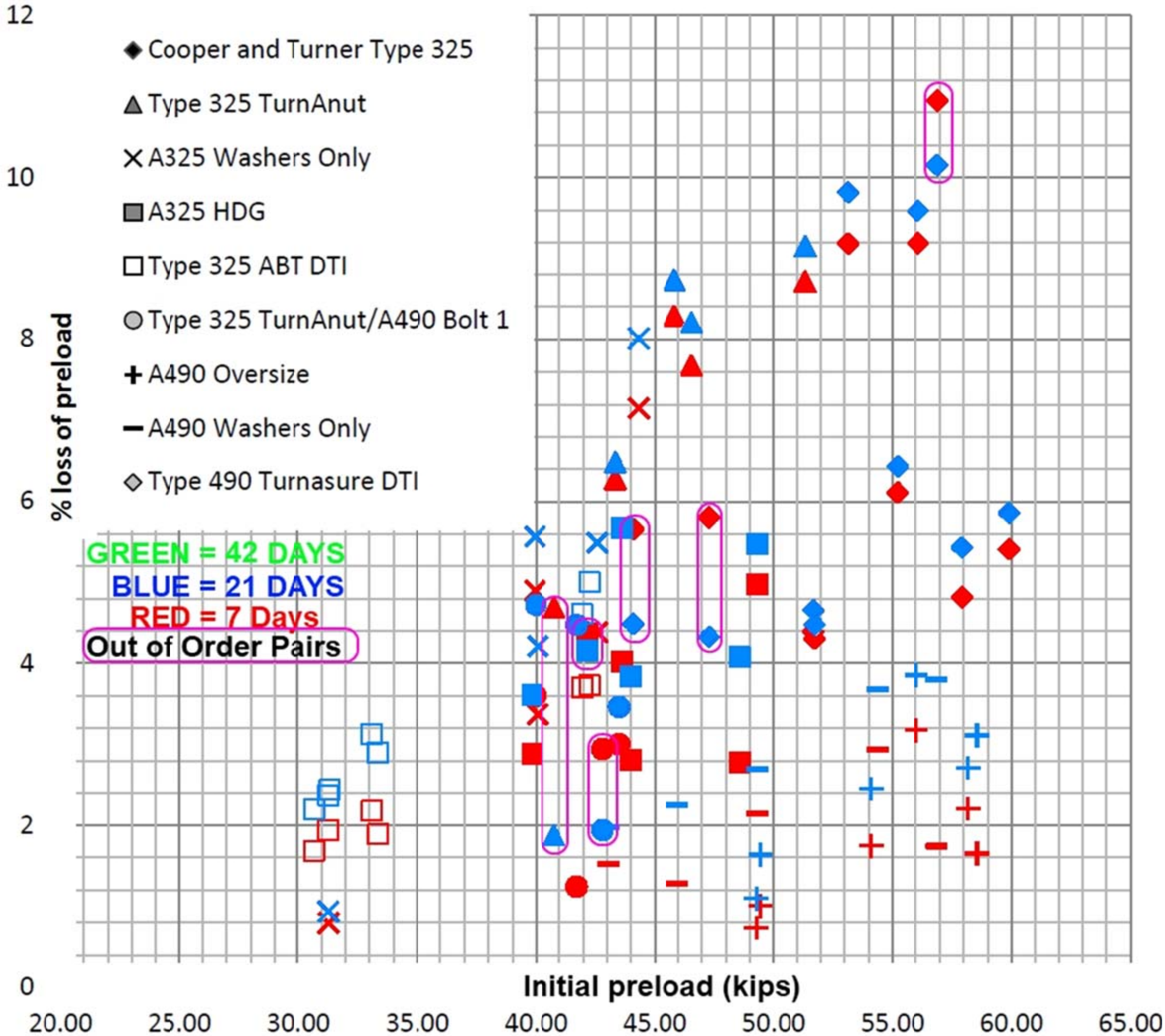
**Chris Curven:**

ASTM allows this type of DTI for manufacturing, but does not make a determination regarding appropriateness of items to be installed in structural steel connections. It is within the RCSC's scope to determine the suitability for such devices (see RCSC bylaws section 1.2). RCSC should make its own determination regarding suitability of DTIs that have not been Q&T before altering the specification per the ballot item. To date, the only research that has been offered in support of change to the current RCSC spec (Study of Long-Term Relaxation of Structural Assemblies with Direct Tension Indicators by Rowan University, 2011) is flawed since test assemblies were not measured at the conclusion of the study to reduce error and confirm methodology, the device used was operating out of its ±5% inspection range, and the data indicates that most bolts (60%) actually tightened during the course of the study, counter to all accepted research to date. Also, the study did not include any live loads or multi-ply connections and it was admitted that the temperature fluctuated by 10F during the course of the study. Since measuring bolt length & tension are highly susceptible to temp changes, 10F is not an insignificant swing. **See 2013-14 Ballot Attachment A_Chris Curven**.

**Nick Deal:**

Once the DTI is installed and demonstrates it can indicate proper compression loads even though it is not hardened, it becomes an unhardened ply in the bolted assembly. I have maintained that we need to look at F436 and F959 washers in an assembly the same way both hardened or neither hardened. Restating my concern: The fact that DTI'S can be manufactured to achieve their compression indications without hardening becomes a secondary issue to me rather, I'm concerned about an unhardened ply in the bolting assembly.

**Ken Lohr:**
I have not yet seen the ASTM review but it is my understanding there is some questionable data about tensions increasing after installation. If this is the case we might want to look closer.



Cooper and Turner Type 325
Type 325 TurnAnut
A325 Washers Only
A325 HDG
Type 325 ABT DTI
Type 325 TurnAnut/A490 Bolt 1
A490 Oversize
A490 Washers Only
Type 490 Turnasure DTI
GREEN = 42 DAYS
BLUE = 21 DAYS
RED = 7 Days
Out of Order Pairs
% loss of preload
Initial preload (kips)
0
2
4
6
8
10
12
20.00
25.00
30.00
35.00
40.00
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55.00
60.00
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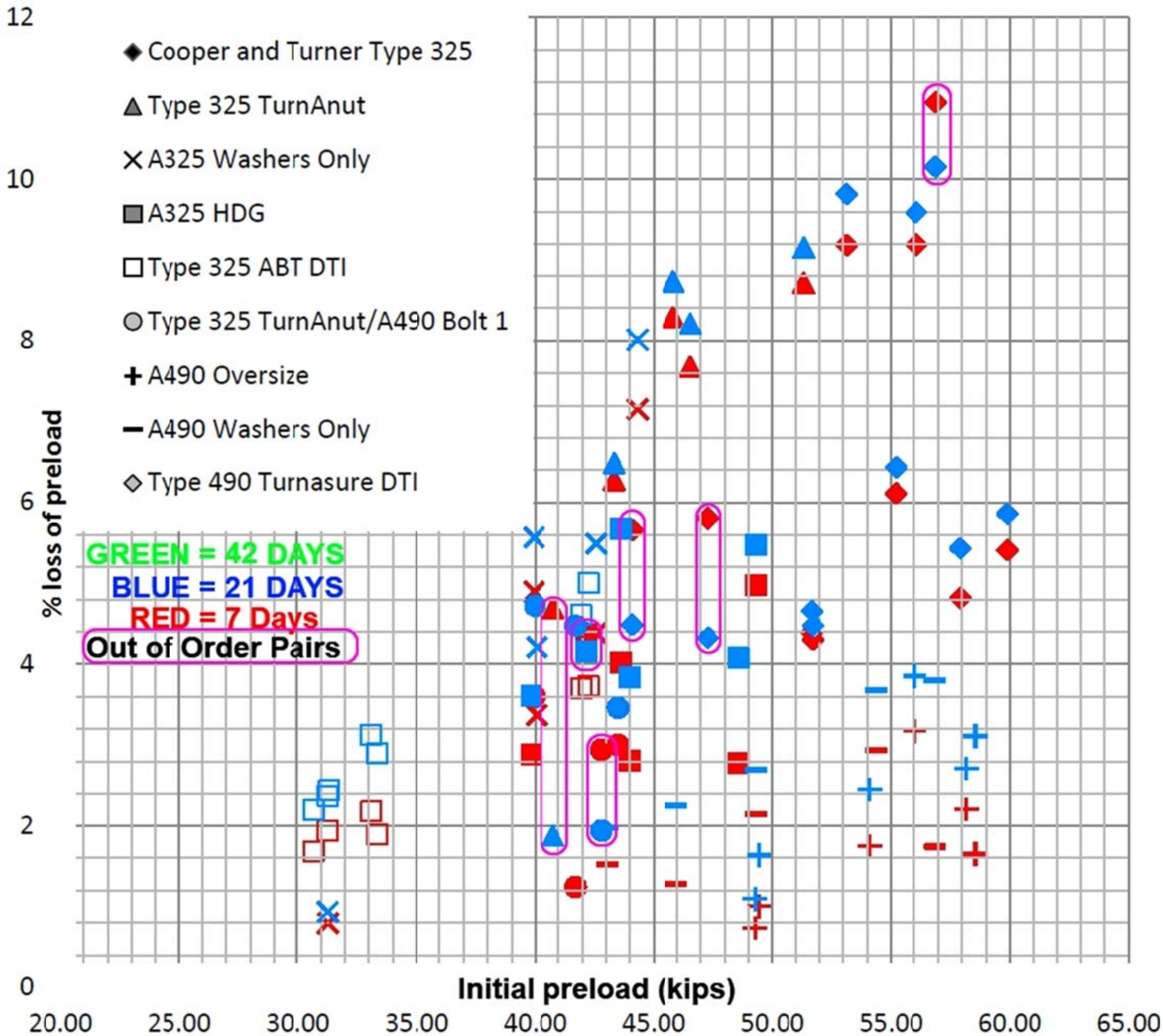
Cooper and Turner Type 325
Type 325 TurnAnut
A325 Washers Only
A325 HDG
Type 325 ABT DTI
Type 325 TurnAnut/A490 Bolt 1
A490 Oversize
A490 Washers Only
Type 490 Turnasure DTI
GREEN = 42 DAYS
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Out of Order Pairs
% loss of preload
Initial preload (kips)
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4
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60.00
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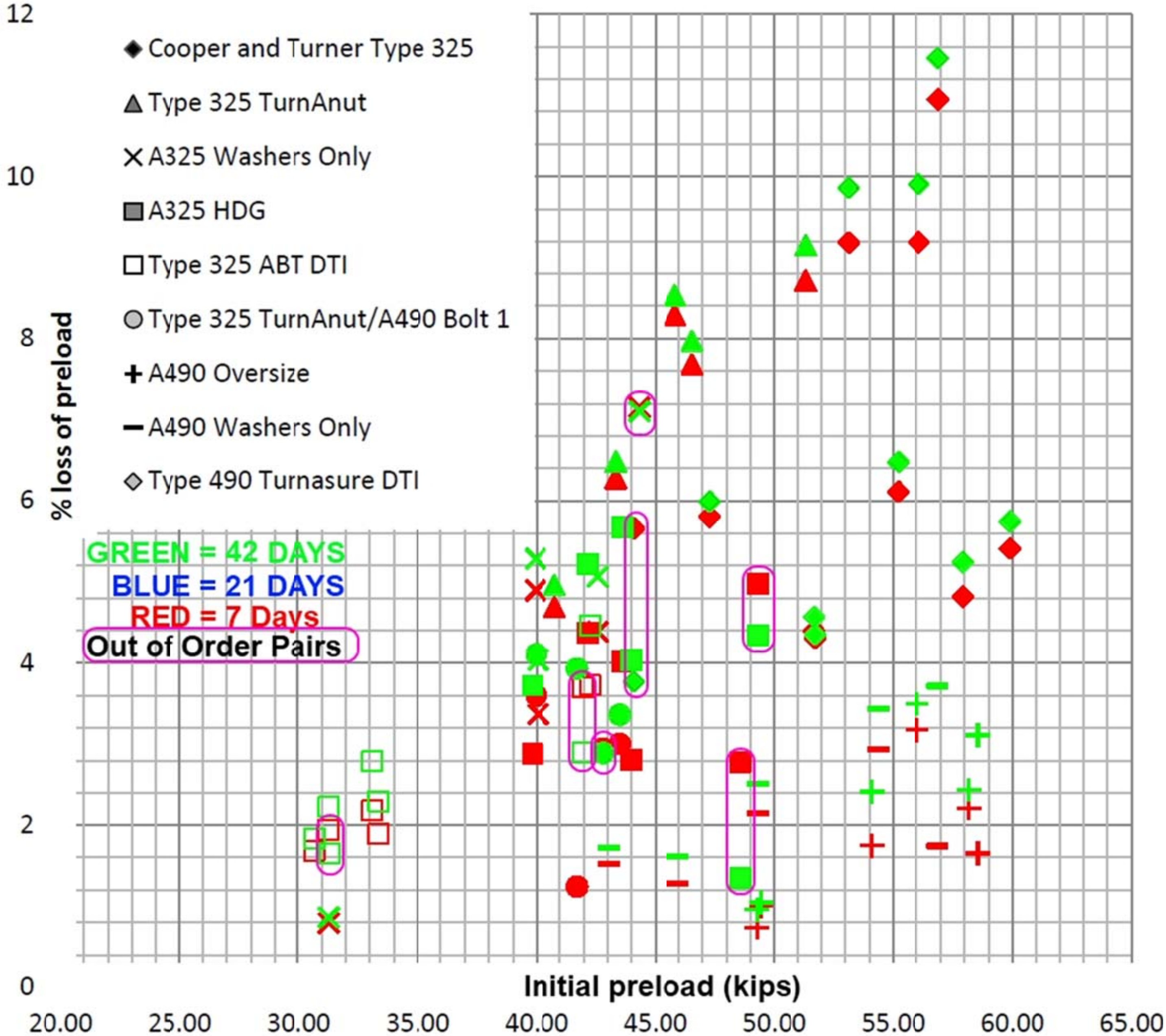

Cooper and Turner Type 325
Type 325 TurnAnut
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20.00
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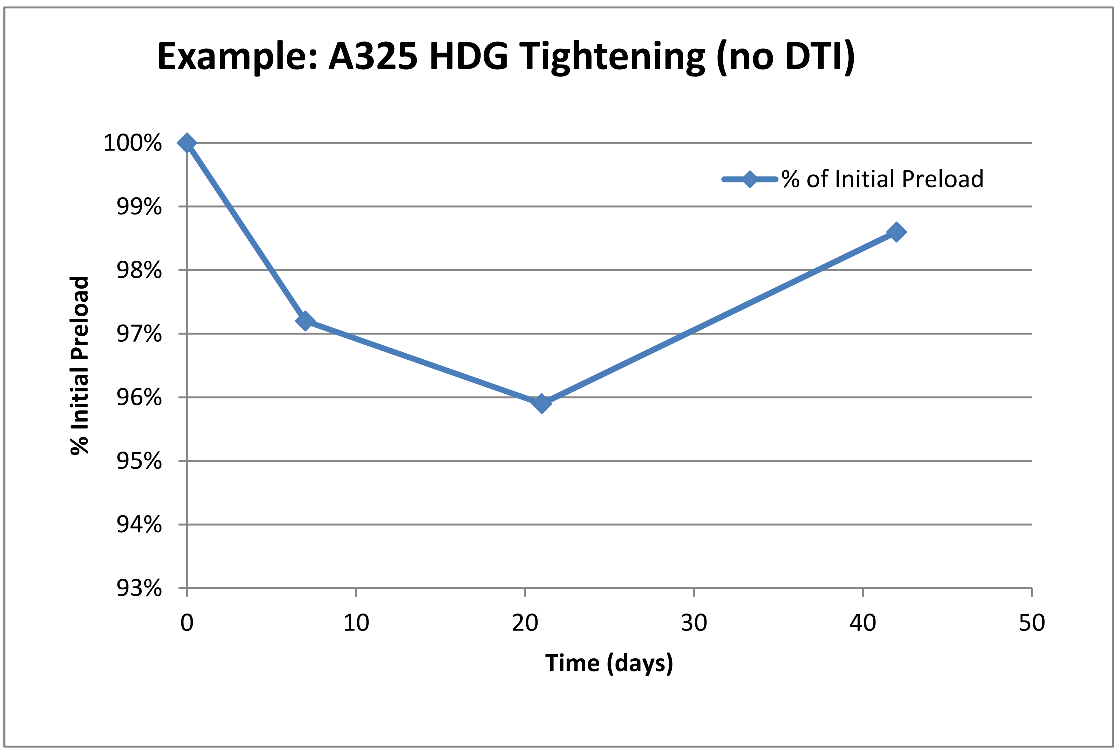
Ballot item S12-040 should be rejected since the evidence submitted (Study of Long-Term Relaxation of Structural Assemblies with Direct Tension Indicators by Rowan University, 2011) was not conducted with the proper equipment or methodology.

1. **Equipment:** All results were obtained with a measuring device (Loadmaster 3600DXP) that does not have adequate resolution (±5% accuracy) to discern meaningful differences within the scope of the study. (see spec sheet generated by mfg.)
2. **Methodology:** The reference lengths required per ASTM E1685 were not obtained. Sections 7.5, and 7.7 require all tensioned fasteners to be measured after the conclusion of the study to compare the final length to the initial reference length. This step was not performed. Also, it has been admitted that the ambient temperature varied by 10F during the course of the study. Since temperature directly affects tension measurements, this fluctuation should be cause for concern about the validity of the data. (See attached email statement as written by Rich Brown.)

Item number one, equipment, is most evident by figures 7, 8, and 9 of the report indicating installed bolts tighten, rather than relax, over time, counter to all accepted research to date.

Using the information from the study, the graph below depicts a Hot Dipped Galvanized assembly consisting of a nut bolt and washer only, tightening between 21 and 42 days. This contradicts what is stated in the **Guide to Design Criteria for Bolted and Riveted Joints** by Geoffrey Kulak, et al. As the Guide, states; relaxation for plain coated assemblies would be about 6% and galvanized assemblies will relax more (page 62).




This phenomenon (tightening not relaxing) occurs in 60% of the assemblies inspected during the study.

# Appendix A. Details of ultrasonic system

Tel: 610 272 2600
Fax: 610 272 5223
www.LoadCT.com
3630 Horizon Drive
King of Prussia, PA 19406

## LoadMaster® 3600DXP

**Description:**

The LoadMaster® 3600 is an i-Bolt® load measurement system for inspecting bolt load or measuring and controlling load during assembly. The unit comes with a 1-year warranty and software upgrades, includes an i-Probe®, integrated calibration bolt and temperature probe.

The LoadMaster® 3600DXP is supplied with a LoadMaster® DataManager® laptop PC. This portable unit can be hot-sync'd with the PC for bi-directional data transfer. PC software provides full data display and analysis of inspection data and assembly tightening curves. With USB, Bluetooth connectivity setup and pre-installed LoadMaster® DataManager® software, the DataManager® laptop PC comes ready-to-go out of the box.

**Technical Specifications:**

**LoadMaster®:**

| | |
|---|---|
| Load Accuracy | |
| Assembly Mode: | ±3% (3σ) typical |
| Inspection Mode: | ±5% (3σ) typical |
| Dimensions: | 185mm x 150mm x 50mm |
| Weight: | 1.6kg |
| Power Supply: | Li-On Battery – 10 hrs continuous use<br>External supply (5V) |
| Connectivity: | USB 2.0<br>Bluetooth<br>Wireless LAN 802.11 b/g<br>3G |

**DataManager® PC:**

| | |
|---|---|
| Laptop PC | Lenovo Thinkpad X120E (AMD E-350, 1.6GHz, 4GB Memory, 320GB Hard Disk, Bluetooth 3.0) |
| Operating System: | Windows XP |
| Software: | Office 2007, LoadMaster® DataManager® Connectivity and Analysis Software (pre-installed and configured) |

**Item Code:** LM3600 DXP

**From:** Rich Brown [mailto:rich.brown@turnasure.com]
**Sent:** Wednesday, October 17, 2012 9:46 AM
**To:** mikeh@appliedbolting.com
**Cc:** 'Joe Greenslade'; david.mccrindle@primus.ca; salim.brahimi@ibeca.ca; 'Rodgers, Jen'
**Subject:** Revision to F959 Negative Vote

Mike,

I am preparing for the upcoming meeting and thought it best to reach out to you regarding your negative votes.  Would you consider withdrawing your negatives for the following reasons; …

1. One other comment I would make is that bolts don't "tighten" in applications but their loads do increase and decrease significantly during working cycles, most noticeably from differential thermal expansion, elastic interaction and rocking effects.  Even under controlled lab conditions, you can expect some effect from these factors.  The measurement temperature did vary by 10F over the test period. …

So again, I would kindly ask you to consider withdrawing your negative votes for the reasons stated above.  Please contact me should you have any questions.  I look forward to hearing from you.

Regards,
*Rich*

*Rich Brown*
*VP Quality & Engineering*
*TurnaSure LLC*
*(O) 215-750-1300*
*(C) 215-431-7028*

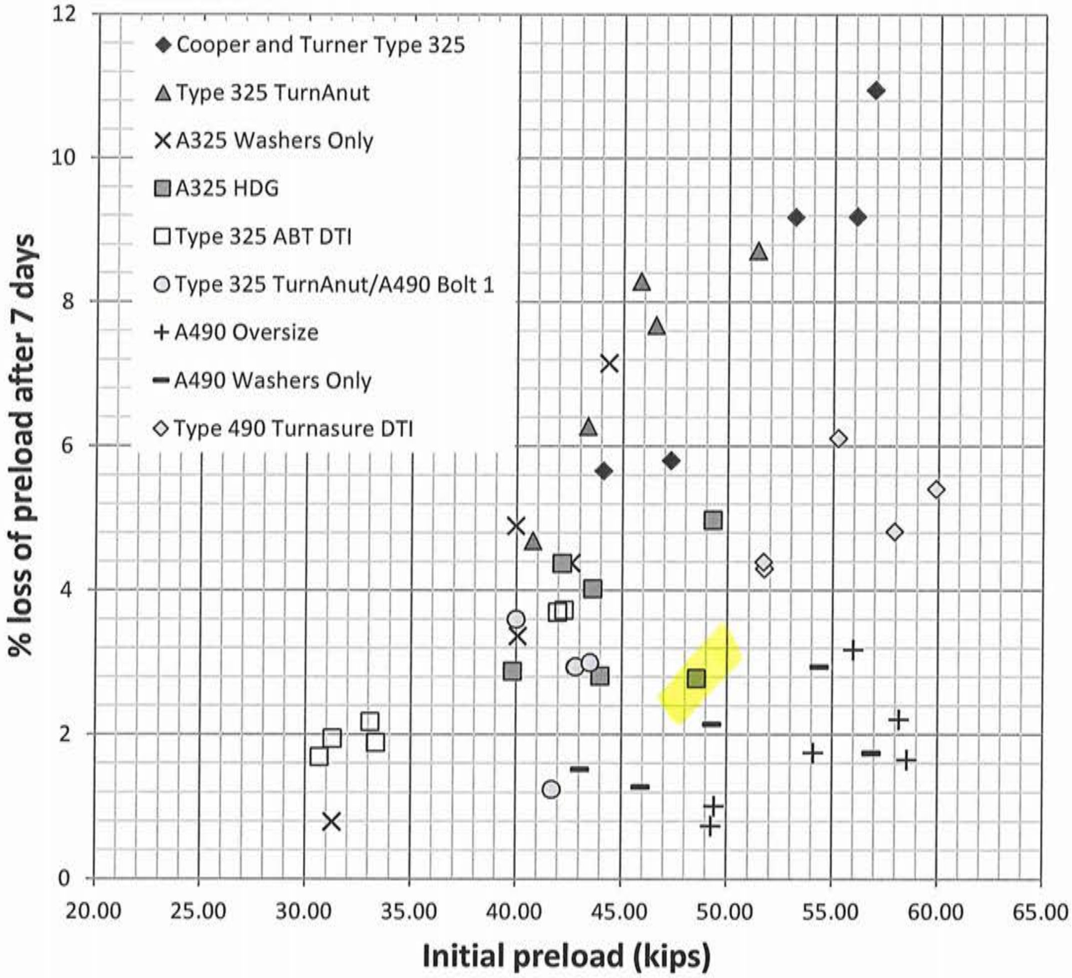



Figure 7. Percent loss of bolt tension relative to initial tension at 7 days.

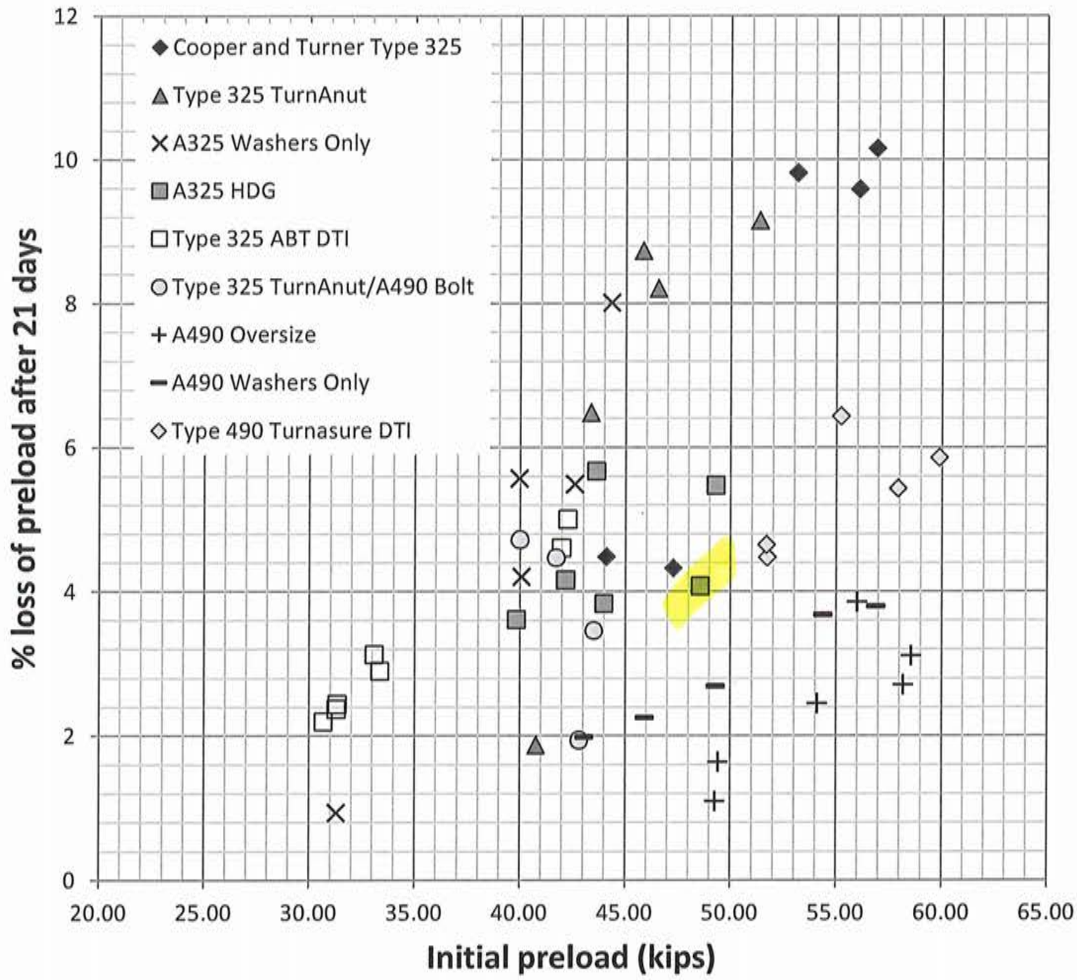



Figure 8. Percent loss of bolt tension relative to initial tension at 21 days.

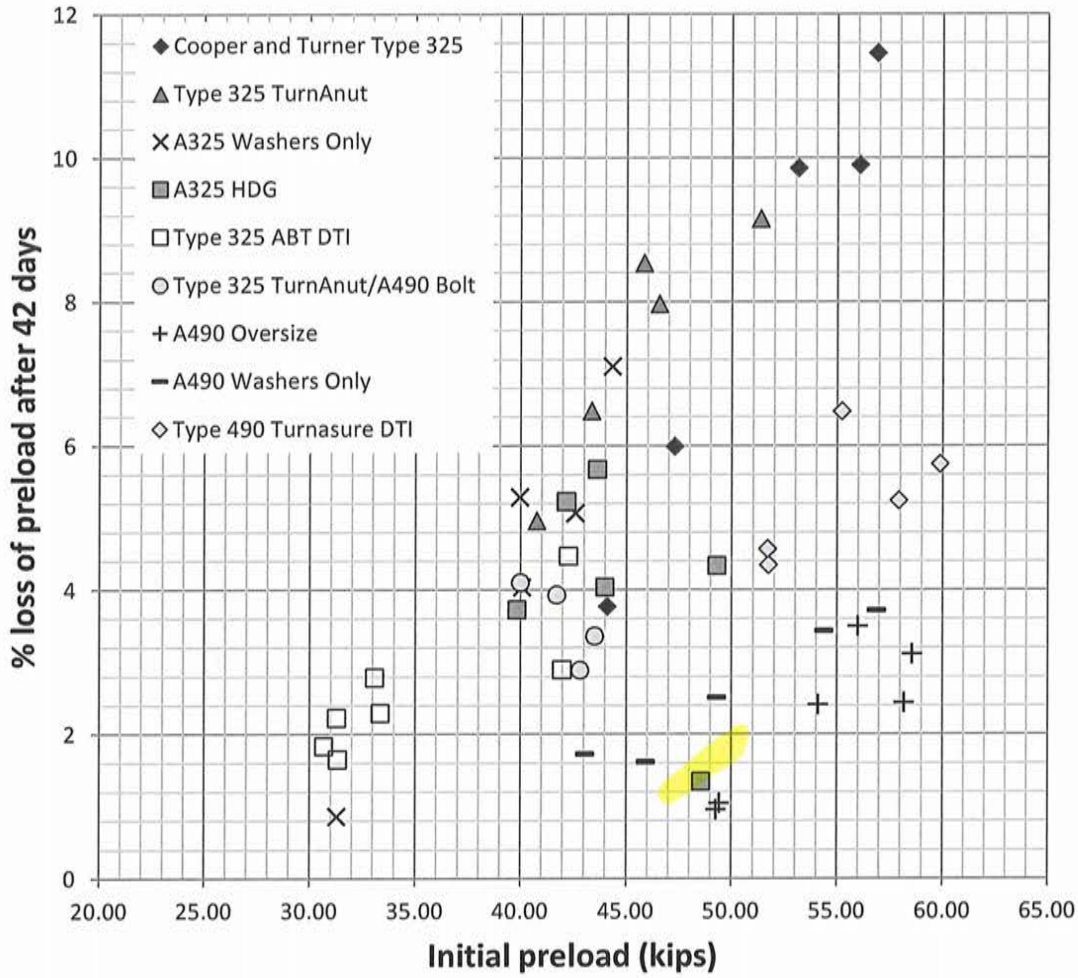



Figure 9. Percent loss of bolt tension relative to initial tension at 42 days.

*Comparison of A325 washer only vs. Type 325 Quenched and Tempered DTI vs. Type 325 Cold-worked and Annealed DTI*

A comparison of the tension measured in the bolt assemblies at 7 days relative to that measured at 20 minutes is provided in Figure 10 for the A325 assemblies installed using simulated field methods. Data from assemblies not considered in the comparison have been removed for clarity in the figure. The Plate 3 data for the ABT DTI are also included to provide data from that assembly type at a higher initial load. Note that those two assemblies from Plate 3 were installed on a Grade 50 rather than a Grade 36 plate. Also note that a small load increase was reported for one of the ABT DTIs resulting in a negative

I have voted negative to S12-040 which proposes the removal of thru-hardening from the Commentary Section of 8.2.4. I am concerned that the report provided is not comprehensive or well executed and it would be negligent of the group to change the specification with this report as support. I also have concern that this topic was not given due process by the committee and it was rushed to ballot without the task group assigned ever meeting about it.

A couple of points I would like to make about the supplied report and discuss with the group:

- The conditions of the test were too loose and have consequently introduced errors into the findings. You can see where bolts have tightened over time. Evidence of poor research process is present within the report by the authors own comments:
  - "There are both positive and negative fluctuations on the measured loads".
  - "The change in ordering simply reflects the scatter of the data from variations in lab conditions".
- No hardened DTI's were included within the report yet the intent of this assertion is that the non-hardened DTI's perform the same as hardened DTI's. How are we to evaluate the results when the baseline of the comparison is missing?
- I can see a clear difference on Figure 5 where there is at least double the magnitude of creep with the un-hardened DTIs compared to F436 Hardened washers.
- Figure 4 clearly shows un-hardened DTI's falling below RCSC minimum pre-tension by the end of the test where they were initially tensioned above the minimum. This is counter to the written words by the author and leaves me with disbelief about the report.
- The most significant time period for creep has been neglected by the report. All prior work has identified creep being exponential with time where the most significant creep happens within seconds to minutes after tightening. We have only been presented with one or two readings before 10 hours!

I hope you will find my negative persuasive and maintain the requirement that DTIs be hardened until further research can be conducted and the process owing to this change is upheld.

Please contact me with any questions or concerns.

Regards,

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Field Bolting Training Videos

http://www.appliedbolting.com/video-dtis-and-squirter-dtis-for-engineers.html

# Time-Dependent Behavior of Structural Bolt Assemblies with TurnaSure Direct Tension Indicators and Assemblies with Only Washers

A Report Prepared for TurnaSure, LLC

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July 2012

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**Problem Statement:** Direct Tension Indicators (DTIs) are one-way mechanical load cells used in the pretensioning of mechanical fasteners. DTIs have been used in structural and other applications since their inception in England in 1962. Direct Tension Indicators have been produced to numerous worldwide product standards, including BS 7644 Part 1, ASTM F959, ASTM F959M, ASTM F2437, and EN-14399-9.

In this report the creep/relaxation load losses of structural bolt assemblies that include the current TurnaSure, LLC DTIs are compared to load losses of structural bolt assemblies that do not include any DTI's. In all cases, the assemblies are evaluated using criteria derived from the 13th edition of the *Manual of Steel Construction*, published by the American Institute of Steel Construction (AISC, 2005) and AASHTO bridge requirements (U.S. Department of Transportation (1991)).

**Scope:** In this study, time-dependent loss of initial pretension in 7/8 inch ASTM A325 and A490 bolted assemblies were investigated. The tests compared the behavior of assemblies with Type 325 TurnaSure DTIs attached to a nut to assemblies with washers only and compared assemblies with Type 490 DTIs to assemblies with washers only. Loads in the bolted assemblies were monitored for 1000 hours (42 days) using an ultrasonic technique meeting the recommendations of *ASTM E1685 – Standard Practice for Measuring the Change in Length of Fasteners Using the Ultrasonic Pulse-Echo Technique* . The results presented in this report are a subset of results from a larger study that also included DTIs that are no longer manufactured, galvanized assemblies, assemblies using a competitor's DTI, and assemblies with oversized holes.

**Experimental Program:**

*Test Matrix*

The bolted assembly configurations that are considered in this report are described in Figure 1. In this figure, the curved arrow denoted the element that was turned during tensioning. All bolts were 7/8 inch nominal diameter with coarse (UNC) threads. All bolt assemblies were installed through a 1.5 inch thick plate, and used 3 inch long bolts. The grip length corresponds to an effective length of approximately 2.15 inch, which meets the recommendation of a ratio of effective length to bolt diameter of at least 2:1 found in *ASTM E1685 – Standard Practice for Measuring the Change in Length of Fasteners Using the Ultrasonic Pulse-Echo Technique*. The test matrix described in this report is summarized in Table 1. The tensioning methods used were intended to produce a range of pretension loads, as would be expected in field installations.

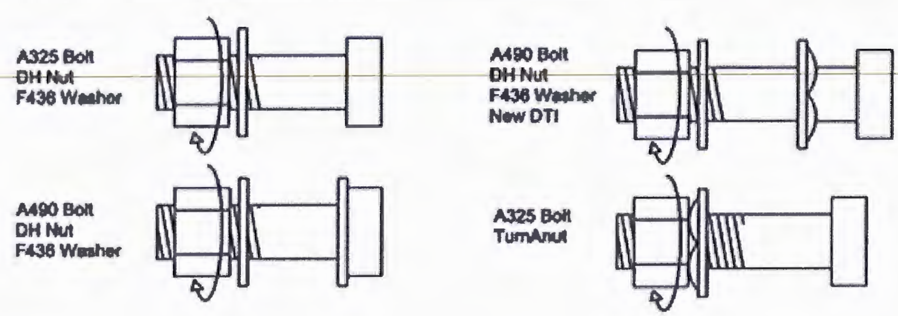



Figure 1. Bolt assembly configurations used in the test procedure.

Table 1. Test Matrix

| Bolt Hole diam. (inches) | Test Plate Grade | Structural Bolt Grade (ASTM) | Washer Spec. (ASTM) | Heavy Hex Nut Grade (ASTM A563) | Num. of Samples | DTI Type and Grade (ASTM F959) |
|---|---|---|---|---|---|---|
| 15/16 | ASTM A36 | A325 | - | Plain DH | 5 | Type 325 |
| 15/16 | ASTM A36 | A490 | F436 | Plain DH | 5 | Type 490 |
| 15/16 | ASTM A36 | A325 | F436 | Plain DH | 5 | None |
| 15/16 | ASTM A36 | A490 | F436 | Plain DH | 5 | None |

*Pre-installation verification of the Assemblies*

A pre-installation verification procedure was employed for each combination of the structural bolt assemblies used. All bolts, nuts, washers, etc. for the pre-installation testing were in the as-received condition. The purpose of the pre-installation verification was to verify the suitability of the assemblies for pretensioning and to confirm the procedure to be used during tightening during the creep/relaxation tests.

For the TurnaSure products, three samples of each assembly were randomly selected. Each bolt assembly was tensioned with a hand wrench with a handle extension on a bolt tension calibrator to the required minimum bolt pretension indicated in Table 7.1 of *Specification for Structural Joints Using High-Strength Bolts* (41 kips for A325 and 51 kips for A490) and the number of gaps open to a 0.005 inch feeler gage was recorded. Then each was tensioned incrementally until there was refusal of a 0.005 inch feeler gage in at least half of the gaps. The 0.005 inch feeler gage rather than 0.015 inch was selected as compatible with AASHTO bridge requirements (U.S. Department of Transportation (1991)) and because it should result in somewhat higher loads on the bolt assemblies. Results of pre-installation verification are provided in Table 2.

Table 2. Results of pre-installation verification for bolt assemblies using TurnaSure DTIs.

| **Assembly Type** | **Assembly Number** | **Minimum Pretension Load (kips)** | **Gaps Open at Min. Pretension** | **Load at 50% Refusal (kips)** | **Gaps Open at 50% Refusal** |
|---|---|---|---|---|---|
| Type 325 TurnaSure DTI attached to nut | 1 | 41 | 5 of 5 | 46 | 2 of 5 |
| | 2 | 41 | 5 of 5 | 47 | 2 of 5 |
| | 3 | 41 | 5 of 5 | 47 | 2 of 5 |
| Type 490 TurnaSure DTI | 1 | 51 | 6 of 6 | 56 | 3 of 6 |
| | 2 | 51 | 6 of 6 | 56 | 3 of 6 |
| | 3 | 51 | 6 of 6 | 57 | 3 of 6 |

For the A325 and A490 assemblies without DTIs, increasing torque was applied with a 1000 ft-lb torque wrench until a tension of 41 kips and 51 kips respectively was obtained at which point the torque was recorded. The bolt tension was measured on a bolt tension calibrator. The resulting torque measurements are shown in Table 3.

Table 3. Results of pre-installation verification for assemblies without DTI.

| Assembly Type | Assembly Number | Load (kips) | Torque (ft-lbs) |
|---|---|---|---|
| A325 Assembly (no DTI) | 1 | 41 | 665 |
| | 2 | 41 | 530 |
| | 3 | 41 | 710 |
| | average | 41 | 635 |
| A490 Assembly (no DTI) | 1 | 51 | 700 |
| | 2 | 51 | 750 |
| | 3 | 51 | 800 |
| | average | 51 | 750 |

*Timing of Measurements*

Initial tensioning of the bolt assemblies was performed on August 1st, 2011. Initial tension was measured using an ultrasonic method at approximately 20 minutes into the test, and within 25 minutes after tensioning. The measurements were taken at approximately 20 minutes to simulate field practices in which all bolts on an assembly are snug tightened and then fully tightened followed by verification of required tension with the feeler gage. Ultrasonic measurements were performed by Load Control Technologies in King of Prussia, PA and observed by the authors. Additional measurements were made over a period of 42 days.

**Results**

*Initial Tension in the Bolt Assemblies*

The bolted assemblies were tensioned in a manner intended to reproduce the scatter in initial tension that could be expected in field applications. Adequate tensioning of the bolted assemblies employing DTIs were determined based on measurement of the gaps in the DTIs. All bolted assemblies were first tightened to snug-tight with a hand wrench, and then further tensioned using an impact wrench. Tension was increased until at least half of the DTI gaps refused a 0.005 inch feeler gage. The number of gaps closed when tensioning was stopped is provided in Table 4 for each assembly. In some cases, multiple gaps closed nearly simultaneously, resulting in more than half of the gaps being closed at the end of tensioning.

The results from the pre-installation verification were used to establish the initial tension of the assemblies that did not have DTIs. The A325 and A490 assemblies without DTIs were first tightened to snug with a hand wrench and then further tensioned with a 1000 ft-lb torque wrench to the average torque measured in the pre-installation verification (635 ft-lb for A325 and 750 ft-lb for A490, as per Table 3). The resulting bolt tension measured 20 minutes after initial tensioning for each assembly is shown in Figure 2.

All assemblies employing DTIs reached the minimum pretension of 39 kips for A325 assemblies or 49 kips for A490 assemblies, as specified in RCSC *Specification* (2009) Table 8.1. Because the average torques measured at the specified tensile load during the pre-installation verification were used for tensioning the assemblies with washers only, approximately half reached the minimum initial pretension for these tests. The spread in the initial tension for the A325 assemblies were similar with the highest spread occurring with the assemblies without DTIs. The spread in initial tension ranged from 10.6 kips for the Type 325 and 13.0 kips for the washer-only assemblies. For the A490 groups, the initial tensioning load for DTI assemblies had a spread of 7.2 kips and the initial tensioning loads for washer-only assemblies had a spread of 13.8 kips.

Table 4. Results of feeler gage testing following tensioning.

| Assembly Type | Assembly Number | Gaps Closed |
|---|---|---|
| Type 325 TurnaSure DTI attached to nut | 1 | 3 of 5 |
| | 2 | 3 of 5 |
| | 3 | 3 of 5 |
| | 4 | 3 of 5 |
| | 5 | 3 of 5 |
| Type 490 TurnaSure DTI | 1 | 3 of 6 |
| | 2 | 3 of 6 |
| | 3 | 4 of 6 |
| | 4 | 3 of 6 |
| | 5 | 4 of 6 |

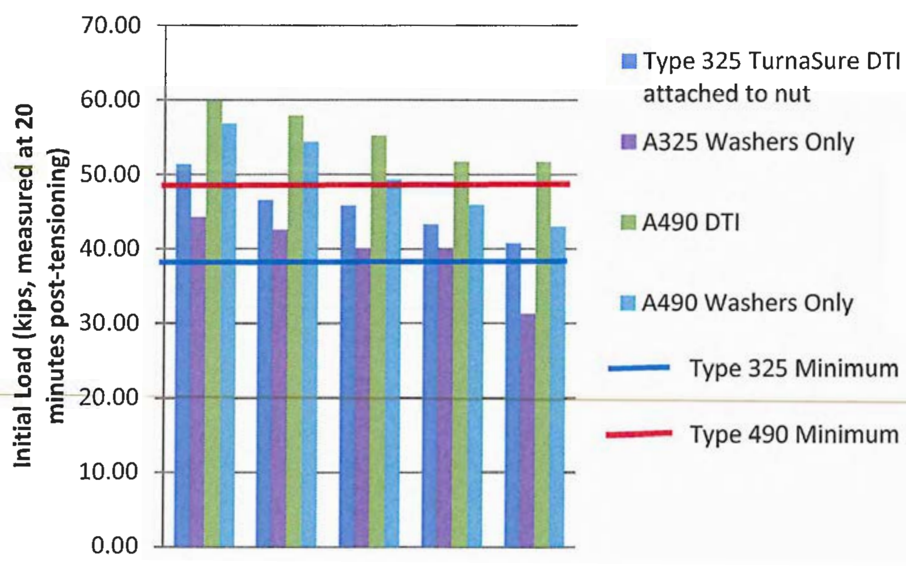



Figure 2. Tension (measured at 20 minutes) in the bolts tightened to replicate field installation methods and techniques (feeler gage for DTIs and measured torque for washers only).

*Time-dependent loss of pretension*

The time history of measured bolt tension is plotted in Figure 3 for assemblies with washers and Figure 4 for assemblies with DTIs. The majority of the losses occur in the first 24 hours after loading and the bolts are essentially stable after 7 days. Very little change occurs beyond the first week and there are both positive and negative fluctuations in the measured loads beyond that point. It appears that future studies could be terminated at 7 days (168 hours) to improve the efficiency of data collection.

Despite any time-dependent losses and the varied initial loads observed in the assemblies with DTIs that were tensioned using field methods, all maintained a tension greater than the RCSC specified minimum through 1000 hours of testing within the range of load fluctuation observed beyond the seven day measurements.

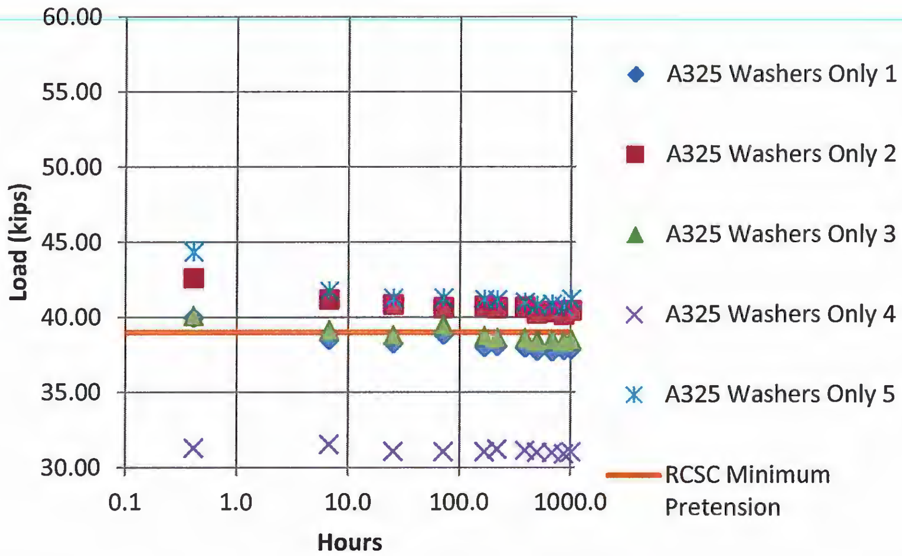
Figure 5 shows the percentage loss in tension as a function of the initial tension for each type of assembly after 42 days. The loads measured at approximately 20 minutes are used as the reference loads. While the values have some variation as a function of time, the general trends are similar at all times.

*Comparison of A325 washer only vs. Type 325 Cold-worked and Annealed DTI*

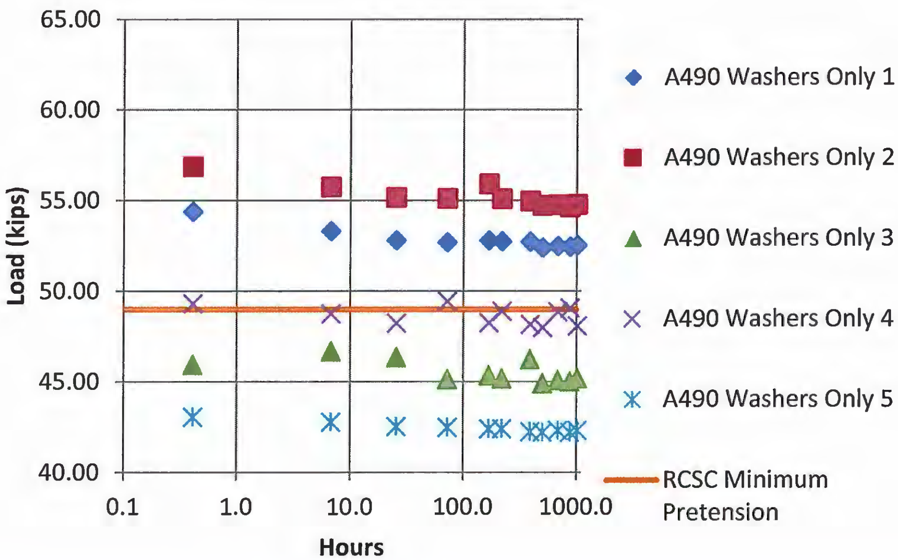
The measurements shown in Figure 5 shows that there is no significant difference in the behavior of the various assemblies. Rather, the data suggest the percentage loss of tension is primarily dependent on the level of initial load. The relative positioning of the trend lines through the data sets rearranges somewhat over time. For example, at 7 days, there are slightly higher losses for the Type 325 assemblies relative to the A325 washer only assemblies whereas at 21 days this order reverses with slightly higher losses for the washer only assemblies. These differences are not considered significant and the change in ordering simply reflects the scatter of the data from variations in lab conditions once the assemblies have stabilized. The magnitudes of the losses observed in all A325 assemblies are less than the range of initial loads obtained when a procedure used to replicate field installation methods was used to develop the pretension load.

*Behavior of A490 Assemblies*

Somewhat larger loss of initial load was found in the Type 490 DTI assemblies than in the assemblies with only washers installed in standard holes. These losses in the DTI assemblies were not considered to be of a magnitude to raise long-term performance concern, as the losses on all of the A490 assemblies (both in terms of fraction of initial load and absolute magnitude) were smaller than those found with A325 bolts. Furthermore, the losses did not result in loads below the specified minimum pretension, as previously discussed. Similar to the trend found with A325 assemblies, the magnitude of total loss is less than the range of initial loads.

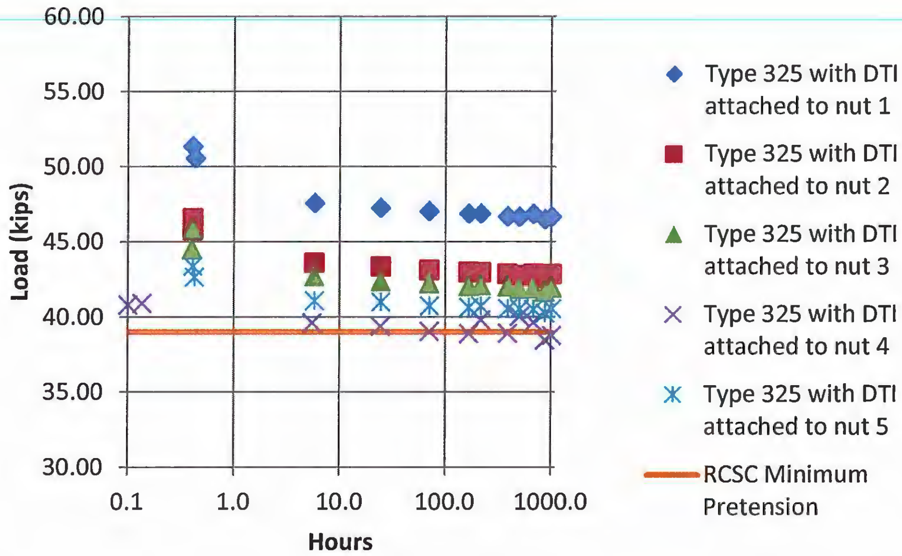



a)

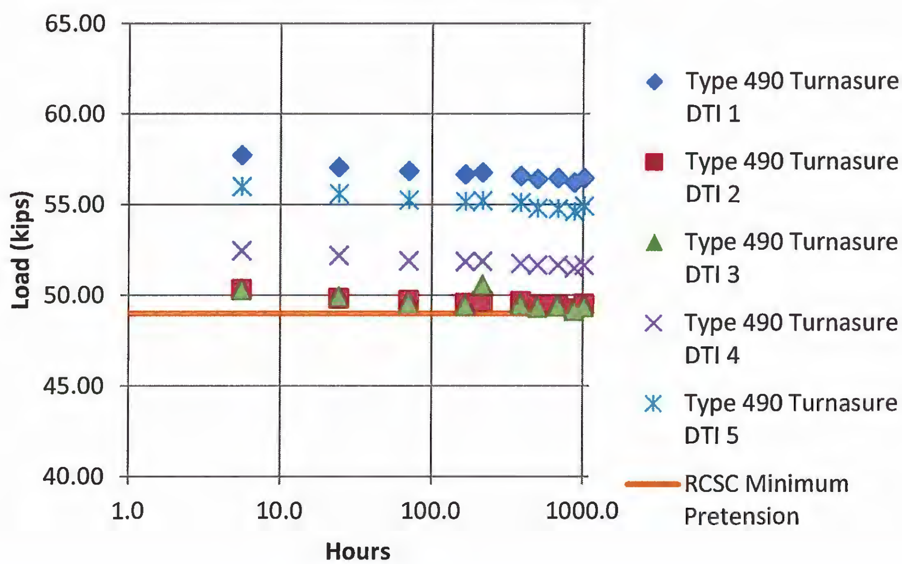



b)

Figure 3. Time history of measured bolt tension for assemblies with only washers a) A325 washer only and b) A490 washers only (tensioned with measured torque).




a)




b)

Figure 4. Time history of measured bolt tension for assemblies with DTIs a) Type 325, b) Type 490 (tensioned with feeler gage).

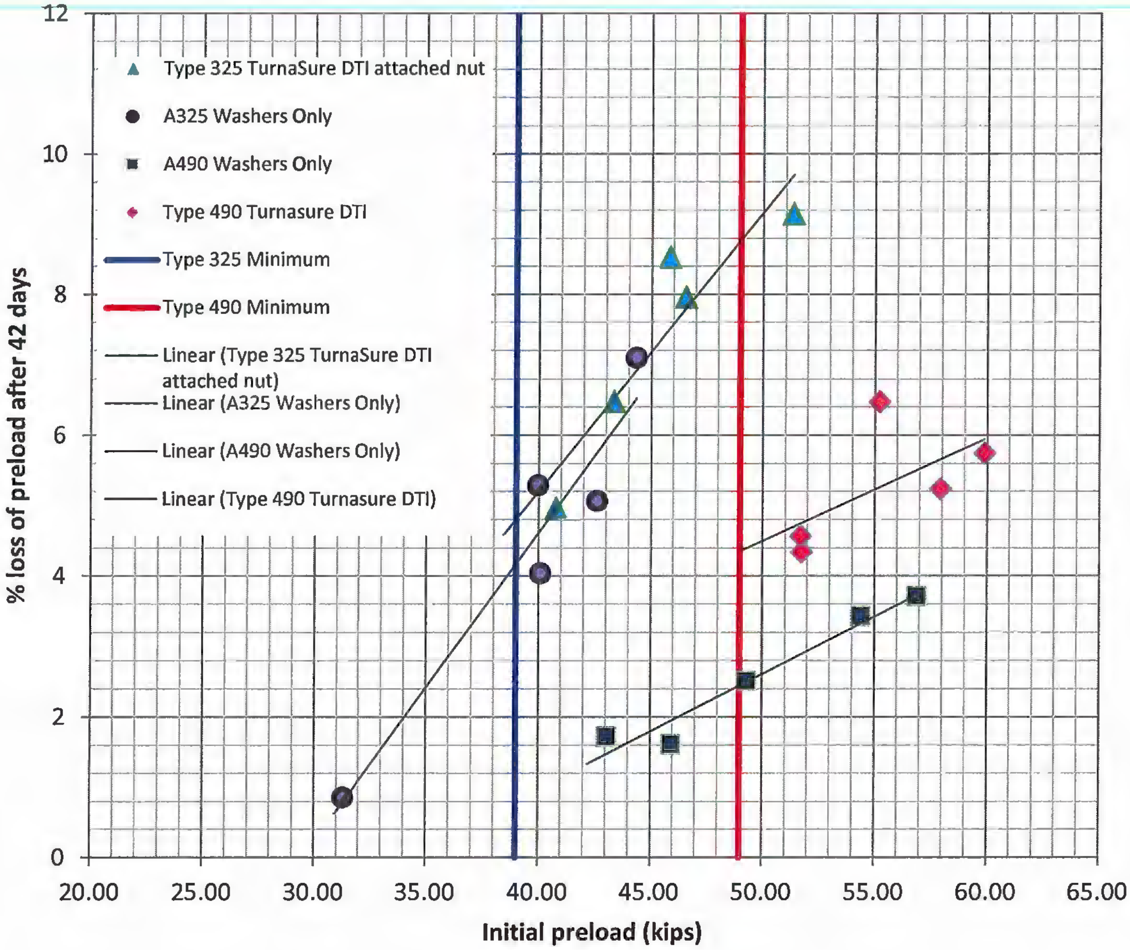



Figure 5. Percent loss of bolt tension relative to initial tension at 42 days.

**Conclusions**

- The loss of pretension in all bolted assemblies studied occurred primarily in the first 24 hours and bolt tensions were stable within 7 days. Time-dependent losses of tension did not result in assemblies with DTIs falling below the minimum required tension after 1000 hours of monitoring when initial tension requirements were satisfied. The total loss of tension in any assembly was less than the range of tension achieved within any assembly group tensioned using field methods.

- For bolted assemblies tested with A325 bolts, initial tension was found to be the most important predictor of creep/relaxation losses. This suggests that most of the losses occur in the bolt and/or nut, rather than the DTI or washer.

- For all bolted assemblies tested with 490 bolts, there is some effect of the DTI on the creep/relaxation losses. However, overall losses were smaller compared to assemblies with A325 bolts, suggesting that creep/relaxation might not be as significant on bolted assemblies with A490 bolts compared to A325 bolts.

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AISC (2005). *Manual of Steel Construction, 13th Edition,* American Institute of Steel Construction, Chicago, IL.

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ASTM (1989). ASTM F959-89: Standard Specification for Compressible-Washer-Type Direct Tension Indicators for Use with Structural Fasteners, ASTM International, West Conshohocken, PA.

ASTM (2009). ASTM F959-09: Standard Specification for Compressible-Washer-Type Direct Tension Indicators for Use with Structural Fasteners, ASTM International, West Conshohocken, PA.

ASTM (2006). ASTM F2437 – 06: Standard Specification for Carbon and Alloy Steel Compressible-Washer-Type Direct Tension Indicators for Use with Cap Screws, Bolts, Anchors, and Studs, ASTM International, West Conshohocken, PA.

BS 7644-1:1993 Direct tension indicators — Part 1: Specification for compressible washers

CEN EN 14399-9: High-strength structural bolting assemblies for preloading - Part 9: System HR or HV - Direct tension indicators for bolt and nut assemblies.

Research Council on Structural Connections (2009). *Specification for Structural Joints using High-Strength Bolts*, Chicago, Illinois, December 31, 2009.

U. S. Department of Transportation (1991). *High Strength Bolts for Bridges, Report Number FHWA-SA-91-031*, Appendix A6 - Procedure For Verification And Installation Of High Strength Bolts With Direct Tension Indicators (Dtis),

# Study of Long-Term Relaxation of Structural Bolt Assemblies with Direct Tension Indicators

Report Prepared for TurnaSure, LLC

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October 28, 2011

**Executive Summary:** Results from a series of tests intended to study creep/relaxation losses of bolted assemblies are presented. The test matrix included assemblies with various direct tension indicators, some through-hardened and some not, as well as assemblies without direct tension indicators. Seven-eighths inch diameter bolts of grade A490, A325 and A325 hot dipped galvanized were evaluated. Load losses were monitored for 42 days (1000 hours) but load levels stabilized by 7 days. For assemblies with A325 bolts, creep/relaxation losses were mainly dependent on initial tension load, and not affected by DTI or washer configuration. This suggests that losses result mainly from deformation in the bolt and nut, not the DTI or washer. Assemblies with A325 hot dipped galvanized bolts resulted in less creep/relaxation losses than observed for assemblies with A325 bolts, although no galvanized DTI's were included in the test matrix. Assemblies with A490 bolts exhibited some effects of DTI/washer configuration on creep/relaxation losses. However, for comparable loads, the magnitude of losses in all configurations with A490 bolts were less than those observed in configurations with A325 bolts. Creep/relaxation below minimum pretension levels was not found to be problem for any bolted assembly that was initially tensioned to specified levels.

**Problem Statement:** Direct Tension Indicators (DTIs) are one-way mechanical load cells used in the pretensioning of mechanical fasteners. DTIs have been used in structural and other applications since their inception in England in 1962. Direct Tension Indicators have been produced to numerous worldwide product standards, including BS 7644 Part 1, ASTM F959, ASTM F959M, ASTM F2437, and EN-14399-9.

Since the invention of DTIs nearly 50 years ago, numerous changes in materials, processes, and design have been made to refine and improve upon the original. A number of these improvements have been patented or otherwise protected through intellectual property rights. Direct Tension Indicators produced today are highly evolved versions of the originals.

*ASTM Standard F959-09: Specification For Compressible-Washer-Type Direct Tension Indicators For Use With Structural Fasteners*, is perhaps the most commonly used consensus standard for the manufacture and supply of DTIs worldwide. ASTM F959 does not presently, nor has it in any earlier form, include requirements for product hardness. Prior to 1989, ASTM F959 required that DTIs be through-hardened and tempered during manufacture to attain necessary mechanical properties (i.e. compression load).

Presently ASTM F959-09 includes the following statement in clause 5.3

> *"The process used for heat treatment of DTIs shall be through-hardening by heating to a temperature above the upper transformation temperature, quenching in a liquid medium, and then retempering by reheating to a suitable temperature to attain desired mechanical/performance properties."*

The *ASTM Standard Specification for Carbon and Alloy Steel Compressible-Washer-Type Direct Tension Indicators for Use with Cap Screws, Bolts, Anchors, and Studs, F2437-06*, has a similar statement with the exception that through-hardening is specified as the heat treatment "if required". On one hand, the phrase "to attain desired mechanical/performance properties" in ASTM F959 could be interpreted as having a similar meaning to the phrase "if required" in F2437. On the other hand, some might argue for an interpretation that through-hardening and re-tempering are required in all cases.

The direct tension indicators (DTIs) currently manufactured by TurnaSure, LLC of Langhorne, PA and its licensees are not always through-hardened and tempered. Rather, TurnaSure's DTIs may be cold-worked and annealed, as this manufacturing process has reportedly been found by TurnaSure, LLC to improve the mechanical properties and performance characteristics of the indicators. However, a question has been raised as to whether creep and/or relaxation losses of load could be attributed to pretensioned structural bolt assemblies when DTIs which have not been through-hardened and tempered are used.

The purpose of this study is to compare the creep/relaxation load losses of structural bolt assemblies that include the current TurnaSure, LLC DTIs to load losses of structural bolt assemblies which included through-hardened and tempered DTIs, as well as structural bolt assemblies that do not include any DTI's, or structural bolt assemblies which incorporate proprietary load-indicating washer devices. In all cases, the assemblies will be evaluated using criteria derived from the 13th edition of the *Manual of Steel Construction*, published by the American Institute of Steel Construction (AISC, 2005) and AASHTO bridge requirements (U.S. Department of Transportation (1991)).

**Scope:** In this study, time-dependent loss of initial pretension in 7/8 inch ASTM A325 and A490 bolted assemblies were investigated. Test configurations included: older style DTIs that were through hardened by a quench and tempering process as specified in ASTM F959-89 (or before) and manufactured by Cooper & Turner; current type TurnaSure DTIs; DTIs manufactured by Applied Bolting Technologies (ABT); assemblies with only hardened washers; assemblies with galvanized bolts, nuts and washers; and assemblies with oversized holes. Loads in the bolted assemblies were monitored for 1000 hours (42 days) using an ultrasonic technique meeting the recommendations of *ASTM E1685 – Standard Practice for Measuring the Change in Length of Fasteners Using the Ultrasonic Pulse-Echo Technique* .

**Historic Bolt Relaxation Trends:** Relaxation tests on bolted assemblies performed by Chesson and Munse; by Allan and Fisher; by Munse; and by Tajima are summarized by Kulak, Fisher, and Struik (2001). It was reported that immediately upon completion of the tensioning there were losses of 2% to 11% and that the average loss was 5% of the maximum registered bolt tension. Kulak, et al., note that losses of 5% to 10% were reported by Allan and Fisher for grip lengths of 3 to 6 inches. It was speculated that the losses were caused by elastic recovery taking place when the wrench is removed; by creep and yielding at the root of the threads; as well as by plastic flow in the steel plates under the bolt head and nut. In the Chesson and Munse (1965) study the grip length was 1-1/2 inches. It was reported that after 21 days, losses of 4% of the tension measured after 1 minute were reported, with 90% of the loss occurring in the first 24 hours. Kulak et al. also state that results similar to those of Chesson and Munse and those of Allan and Fisher were reported by Tajima. Kulak, et al., state that Munse reported losses with galvanized assemblies to be up to twice those of plain assemblies. A more recent study by Nah, et al. (2010) found loss of initial clamping force ranging from 6.2% to 8.0% over a period of 744 hours for M20 tension control or hexagonal bolts with varying faying surface properties. Higher losses of nearly 25% were reported in the case of assemblies with red lead paint treatment.

**Experimental Program:**

*Test Matrix*

The bolted assembly configurations that are considered in this report are described in Figure 1. In this figure, the curved arrow denoted the element that was turned during tensioning. All bolts were 7/8 inch nominal diameter with coarse (UNC) threads. All bolt assemblies were installed through a 1.5 inch thick plate, and used 3 inch long bolts. The grip length corresponds to an effective length of approximately 2.15 inch, which meets the recommendation of a ratio of effective length to bolt diameter of at least 2:1 found in *ASTM E1685 – Standard Practice for Measuring the Change in Length of Fasteners Using the Ultrasonic Pulse-Echo Technique*. Three test plates were used in the testing. Test Plates 1 and 2 were ASTM A36 steel and contained three rows of five holes with a center-to-center hole spacing (vertically and horizontally) of 3 inches. Test Plate 3 was of ASTM A572 GR50 steel and had three rows of six holes with a center-to-center holes spacing (vertically and horizontally) of 3 inches. All holes in plates 1 and 2 were 15/16 inch diameter, standard for 7/8 inch diameter bolts. The top two rows of Plate 3 were also 15/16 inch diameter, while oversized 1-1/16 inch diameter holes were used for the bottom row. The test matrix described in this report is summarized in Table 1. The tensioning methods used on Test Plates 1 and 2 were intended to produce a range of pretension loads, as would be expected in field installations. The Test Plate 3 was used to test galvanized assemblies and assemblies with oversized holes. It was also a means to address trends that were revealed in the initial two test plates. The additional TurnAnut assemblies on Test Plate 3 were used to further look at the influence of bolt grade and the additional ABT assemblies were used to include samples initially tensioned to greater than the minimum pretension. An image of a TurnAnut type 325 DTI being pretensioned on Test Plate 1 is shown in Figure 2.

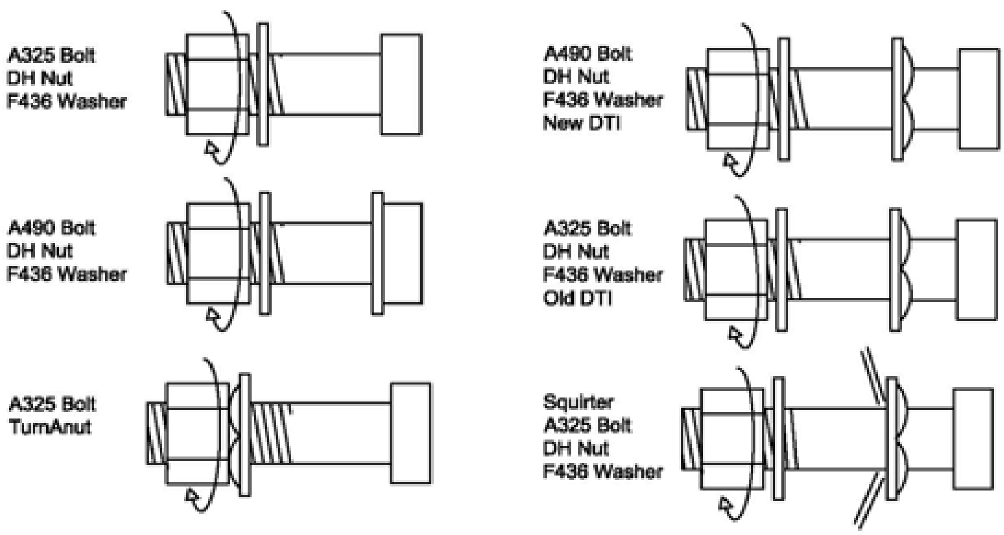



Figure 1. Bolt assembly configurations used in the test procedure.

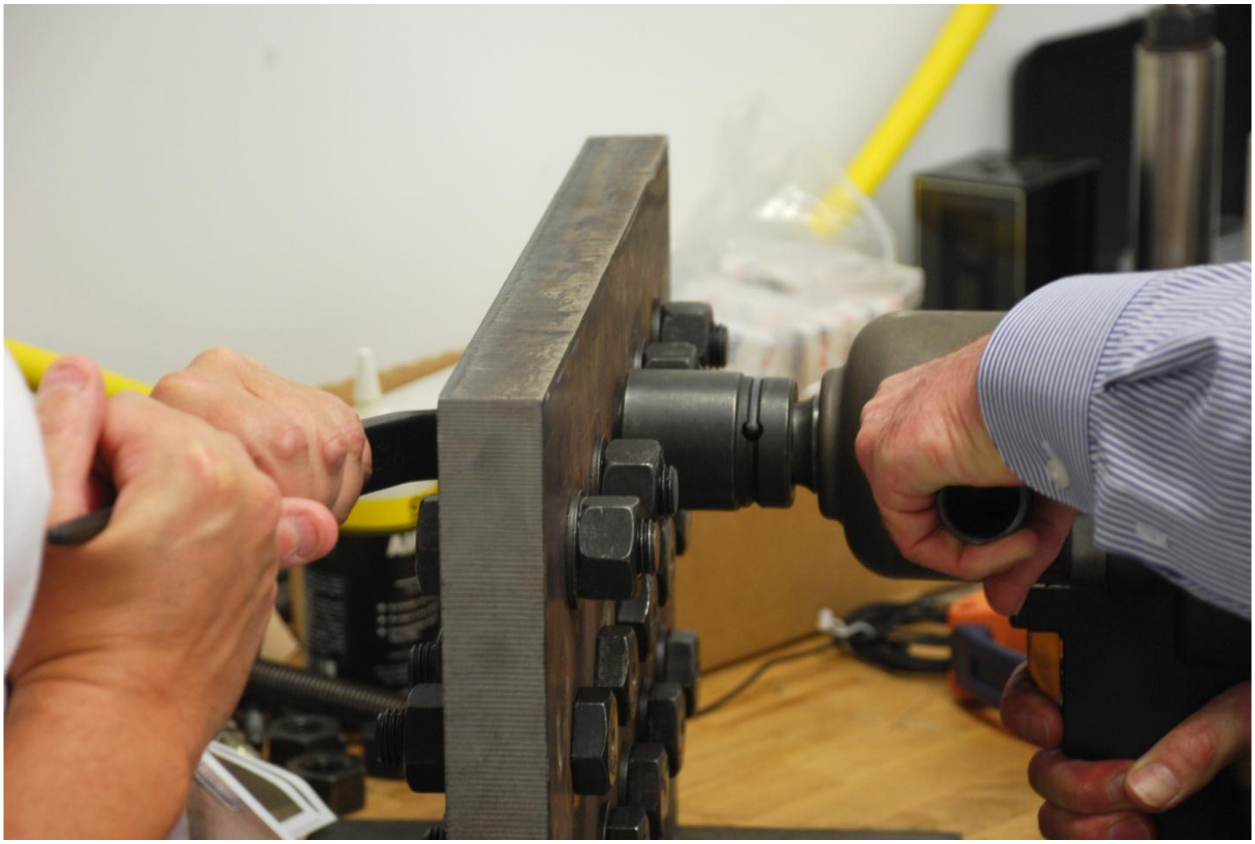


Figure 2.  TurnAnut type 325 DTI being pretensioned.

Table 1. Test Matrix

| Bolt Hole diam. (inches) | Test Plate No. | Test Plate Grade | Structural Bolt Grade (ASTM) | Washer Spec. (ASTM) | Heavy Hex Nut Grade (ASTM A563) | Num. of Samples | DTI Type and Grade (ASTM F959) |
|---|---|---|---|---|---|---|---|
| 15/16 | 1 | ASTM A36 | A325 | - | Plain DH | 5 | TurnAnut Type 325 |
| 15/16 | 1 | ASTM A36 | A490 | F436 | Plain DH | 5 | TurnaSure Type 490 |
| 15/16 | 1 | ASTM A36 | A325 | F436 | Plain DH | 5 | Older through hardened Cooper & Turner Type 325 |
| 15/16 | 2 | ASTM A36 | A325 | F436 | Plain DH | 5 | Applied Bolting Type 325 |
| 15/16 | 2 | ASTM A36 | A325 | F436 | Plain DH | 5 | None |
| 15/16 | 2 | ASTM A36 | A490 | F436 | Plain DH | 5 | None |
| 15/16 | 3 | ASTM A572 GR50 | A325 | F436 | Plain DH | 2 | Applied Bolting Type 325 |
| 15/16 | 3 | ASTM A572 GR50 | A490 | F436 | Plain DH | 4 | TurnAnut Type 325 |
| 15/16 | 3 | ASTM A572 GR50 | A325 Hot Dipped Galvanized | Rockwell C26 HDG | HDG DH | 6 | None |
| 1-1/16 | 3 | ASTM A572 GR50 | A490 | F436 | Plain DH | 6 | None |

*Pre-installation verification of the Assemblies*

A pre-installation verification procedure was employed for each combination of the structural bolt assemblies used on Test Plates 1 and 2. All bolts, nuts, washers, etc. for the pre-installation testing were in the as-received condition. The purpose of the pre-installation verification was to verify the suitability of the assemblies for pretensioning and to confirm the procedure to be used during tightening during the creep/relaxation tests.

For the TurnaSure products (Plate 1), three samples of each assembly were randomly selected. Each bolt assembly was tensioned with a hand wrench with a handle extension on a bolt tension calibrator to the required minimum bolt pretension indicated in Table 7.1 of *Specification for Structural Joints Using High-Strength Bolts* (41 kips for A325 and 51 kips for A490) and the number of gaps open to a 0.005 inch feeler gage was recorded. Then each was tensioned incrementally until there was refusal of a 0.005 inch feeler gage in at least half of the gaps. The 0.005 inch feeler gage rather than 0.015 inch was selected as compatible with AASHTO bridge requirements (U.S. Department of Transportation (1991)) and because it should result in somewhat higher loads on the bolt assemblies. Results of pre-installation verification are provided in Table 2.

Table 2. Results of pre-installation verification for bolt assemblies using TurnaSure DTIs.

| **Assembly Type** | **Assembly Number** | **Minimum Pretension Load (kips)** | **Gaps Open at Min. Pretension** | **Load at 50% Refusal (kips)** | **Gaps Open at 50% Refusal** |
|---|---|---|---|---|---|
| Type 325 TurnAnut | 1 | 41 | 5 of 5 | 46 | 2 of 5 |
| | 2 | 41 | 5 of 5 | 47 | 2 of 5 |
| | 3 | 41 | 5 of 5 | 47 | 2 of 5 |
| Type 490 TurnaSure DTI | 1 | 51 | 6 of 6 | 56 | 3 of 6 |
| | 2 | 51 | 6 of 6 | 56 | 3 of 6 |
| | 3 | 51 | 6 of 6 | 57 | 3 of 6 |
| Older Type 325 Cooper & Turner DTI | 1 | 41 | 5 of 5 | 46 | 2 of 5 |
| | 2 | 41 | 5 of 5 | 43.5 | 2 of 5 |
| | 3 | 41 | 3 of 5 | 45 | 2 of 5 |

For the three Applied Bolting Technologies squirter Type 325 assemblies, increasing torque was applied with a wrench until a tension of 41 kips was obtained. The bolt tension was measured on a bolt tension calibrator and the volume of squirt was observed and photo-documented for reference for later tightening of test assemblies on Test Plate 1.

For the A325 and A490 assemblies without DTIs used on Test Plate 2, increasing torque was applied with a 1000 ft-lb torque wrench until a tension of 41 kips and 51 kips respectively was obtained at which point the torque was recorded. The bolt tension was measured on a bolt tension calibrator. The resulting torque measurements are shown in Table 3.

Table 3. Results of pre-installation verification for assemblies without DTI.

| Assembly Type | Assembly Number | Load (kips) | Torque (ft-lbs) |
|---|---|---|---|
| A325 Assembly (no DTI) | 1 | 41 | 665 |
| | 2 | 41 | 530 |
| | 3 | 41 | 710 |
| | average | 41 | 635 |
| A490 Assembly (no DTI) | 1 | 51 | 700 |
| | 2 | 51 | 750 |
| | 3 | 51 | 800 |
| | average | 51 | 750 |

*Timing of Measurements*

Initial tensioning of the bolt assemblies on Test Plates 1 and 2 was performed on August 1$^{st}$, 2011. Initial tension was measured using an ultrasonic method at approximately 20 minutes into the test, and within 25 minutes after tensioning. The measurements were taken at approximately 20 minutes to simulate field practices in which all bolts on an assembly are snug tightened and then fully tightened followed by verification of required tension with the feeler gage. An image of the ultrasonic testing being performed is shown in figure 3.

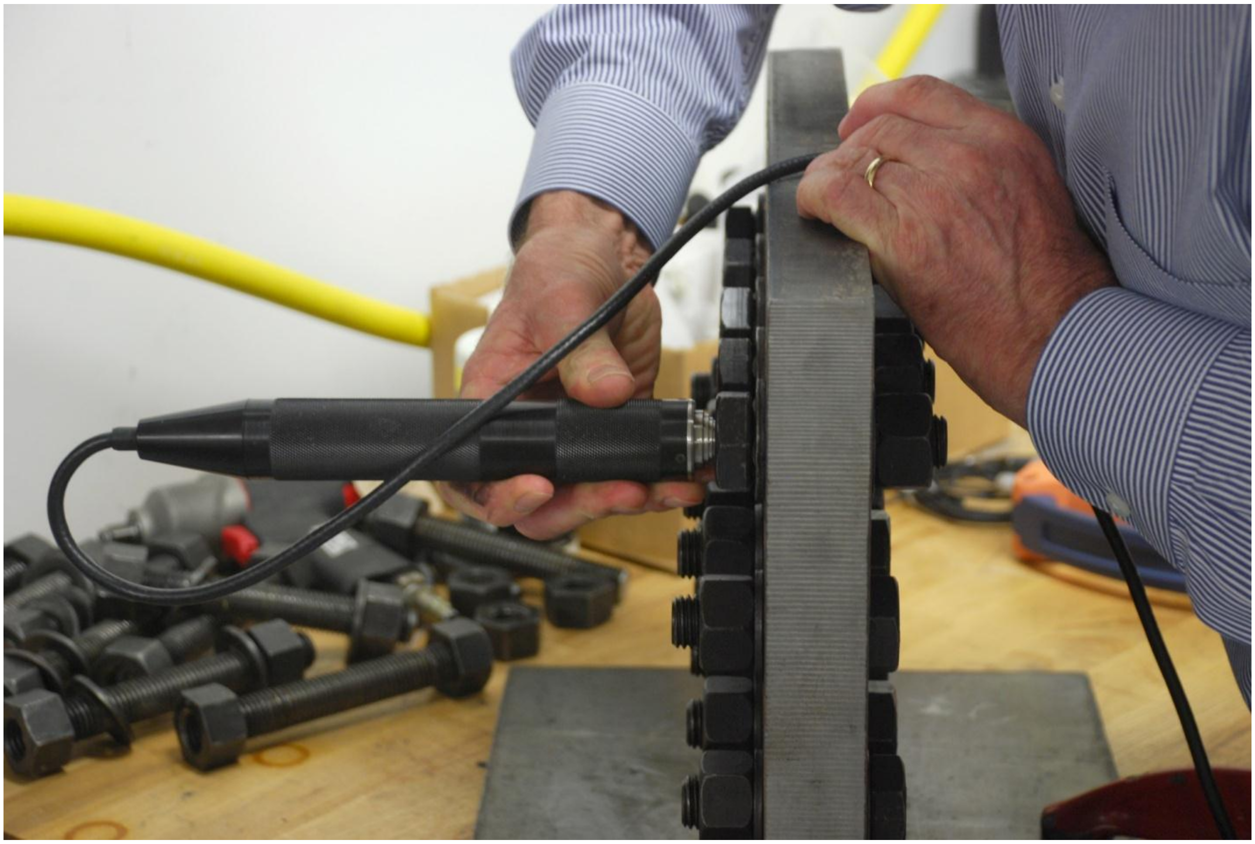


Figure 3. Ultrasonic testing being performed on bolted assemblies.

Refer to Appendix A for details and specifications regarding this system which meets the requirements of ASTM E1685. Additional measurements were taken at

- 5-6 hours after initial tensioning
- 1 day
- 3 days
- 7 days
- 9 days
- 16 days
- 21 days
- 28 days
- 36 days
- 42 days (approximately 1000 hours) after initial tensioning

Bolt assemblies on Test Plate 3 were initially tensioned on August 24, 2011. Initial tension was measured using an ultrasonic method at approximately 20 minutes, and within 25 minutes of tensioning. Measurements were repeated on a schedule similar to that used for the first two test plates.

- 5-6 hours after initial tensioning
- 1 day
- 3 days
- 7 days
- 9 days
- 16 days
- 21 days
- 28 days
- 37 days
- 42 days (approximately 1000 hours) after initial tensioning

**Results**

*Initial Tension in the Bolt Assemblies*

The bolted assemblies on Plates 1 and 2 were tensioned in a manner intended to reproduce the scatter in initial tension that could be expected in field applications. Adequate tensioning of the bolted assemblies on Plate 1 were determined based on measurement of the gaps in the DTIs. All bolted assemblies on Plate 1 were first tightened to snug-tight with a hand wrench, and then further tensioned using an impact wrench. Tension was increased until at least half of the DTI gaps refused a 0.005 inch feeler gage. The number of gaps closed when tensioning was stopped is provided in Table 4 for each assembly. In some cases, multiple gaps closed nearly simultaneously, resulting in more than half of the gaps being closed at the end of tensioning.

The results from the pre-installation verification were used to establish the initial tension of the assemblies on Test Plate 2. The A325 and A490 assemblies without DTIs were first tightened to snug with a hand wrench and then further tensioned with a 1000 ft-lb torque wrench to the average torque measured in the pre-installation verification (635 ft-lb for A325 and 750 ft-lb for A490, as per Table 3). The Applied Bolting Technologies assemblies were tensioned until the same amount of silicone was extruded as was observed in the pre-installation verification. The resulting bolt tension measured 20 minutes after initial tensioning for each assembly on Plates 1 and 2 is shown in Figure 4.

The assemblies on Test Plate 3 were initially tensioned approximately three weeks after Test Plates 1 and 2. The assemblies on Test Plate 3 were loaded to a specific target tension using an impact wrench controlled by ultrasonic feedback measurements. The wrench was programmed to stop when the specified tension was reached in the assembly. For the Type 325 TurnAnut assemblies with A490 bolts, the target loads were 45 kips for all four assemblies. The same load was used for the two ABT bolted assemblies. For the A325 HDG assemblies the target initial loads were 41 kips, 45 kips, and 50 kips (two assemblies each). For the A490 assemblies in oversized holes the target initial loads were 51 kips, 56 kips, and 60 kips (two assemblies each). The specified tensions were chosen to allow specific comparisons between sets of data, based on preliminary results from plate one and two. The targets for initial tension were achieved within plus/minus 0.5 kips for each assembly.

All assemblies employing DTIs reached the minimum pretension of 39 kips for A325 assemblies or 49 kips for A490 assemblies, as specified in RCSC *Specification* (2009) Table 8.1 with the exception of the ABT assemblies. The currently published installation instructions for the ABT product recommend tightening to 10% to 15% above the minimum pretension, rather than the 5% used in this study, when developing the visual standard for volume of extrusion. Because the average torques measured at the specified tensile load during the pre-installation verification were used for tensioning the assemblies with washers only, approximately half reached the minimum initial pretension for these tests. The spread in the initial tension for the A325 assemblies on Plates 1 and 2 were similar with the highest spread occurring with the assemblies without DTIs. The spread in initial tension ranged from 10.6 kips for the TurnAnut, 12.8 kips for the old style Turner & Cooper DTI, and 13.0 kips for the washer-only assemblies. For the A490 groups, the initial tensioning loads for DTI assemblies had a spread of 7.2 kip and the initial tensioning loads for washer-only assemblies had a spread of 13.8 kips.

Table 4. Results of feeler gage testing following tensioning.

| Assembly Type | Assembly Number | Gaps Closed |
|---|---|---|
| Type 325 TurnAnut | 1 | 3 of 5 |
| | 2 | 3 of 5 |
| | 3 | 3 of 5 |
| | 4 | 3 of 5 |
| | 5 | 3 of 5 |
| Type 490 TurnaSure DTI | 1 | 3 of 6 |
| | 2 | 3 of 6 |
| | 3 | 4 of 6 |
| | 4 | 3 of 6 |
| | 5 | 4 of 6 |
| Older Type 325 Turner & Cooper DTI | 1 | 5 of 5 |
| | 2 | 3 of 5 |
| | 3 | 4 of 5 |
| | 4 | 3 of 5 |
| | 5 | 3 of 5 |

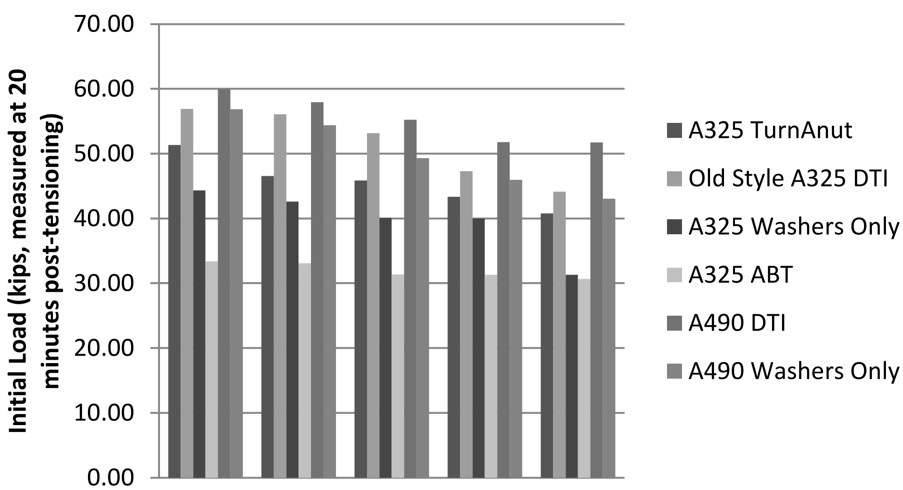


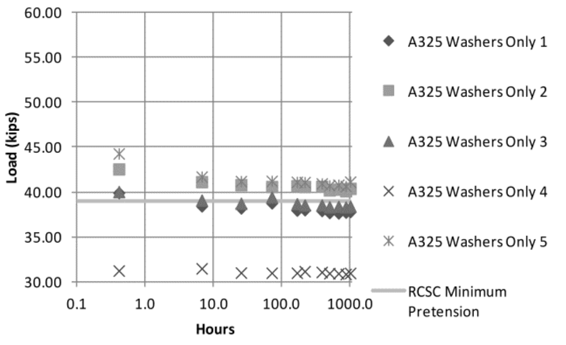

Figure 4. Tension (measured at 20 minutes) in the bolts tightened to replicate field installation methods and techniques (for each category of assembly the results are arranged from highest to lowest tension value and the figure does not reflect the order of tensioning).

*Time-dependent loss of pretension*

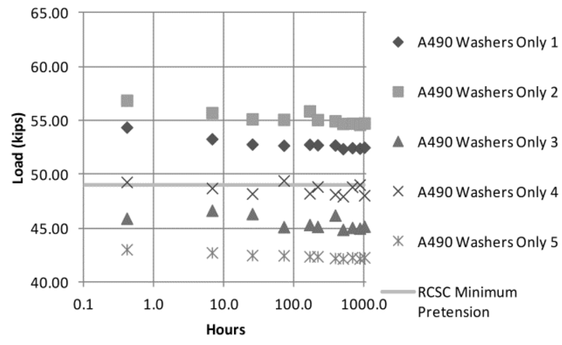
The time history of measured bolt tension is plotted in Figure 5 for assemblies with washers and Figure 6 for assemblies with DTIs. The majority of the losses occur in the first 24 hours after loading and the bolts are essentially stable after 7 days. Very little change occurs beyond the first week and there are both positive and negative fluctuations in the measured loads beyond that point. It appears that future studies could be terminated at 7 days (168 hours) to improve the efficiency of data collection.

Despite any time-dependent losses and the varied initial loads observed in the assemblies with DTIs that were tensioned using field methods, all maintained a tension greater than the RCSC specified minimum through 1000 hours of testing within the range of load fluctuation observed beyond the seven day measurements. The Type 325 ABT assemblies that were tightened to sufficient initial pretension (Figure 6(b), samples 6 and 7) also maintained tension greater than the minimum specified.

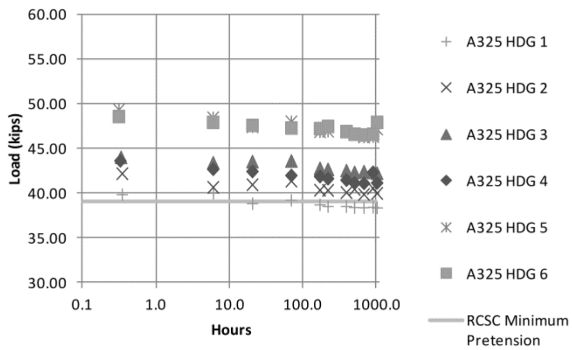
Figures 7 through 9 show the percentage loss in tension as a function of the initial tension for each type of assembly after 7, 21, and 42 days. In all cases, the loads measured at approximately 20 minutes are used as the reference loads. While the values have some variation as a function of time, the general trends are similar at all times.



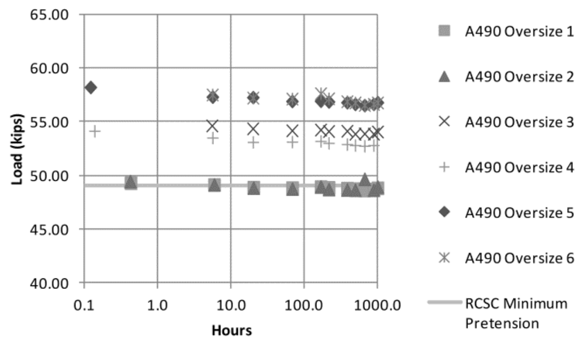

a)




b)




c)




d)

Figure 5. Time history of measured bolt tension for assemblies with only washers a) A325 washer only, b) A490 washers only, c) A325 hot dipped galvanized, d) A490 w/ oversized holes.

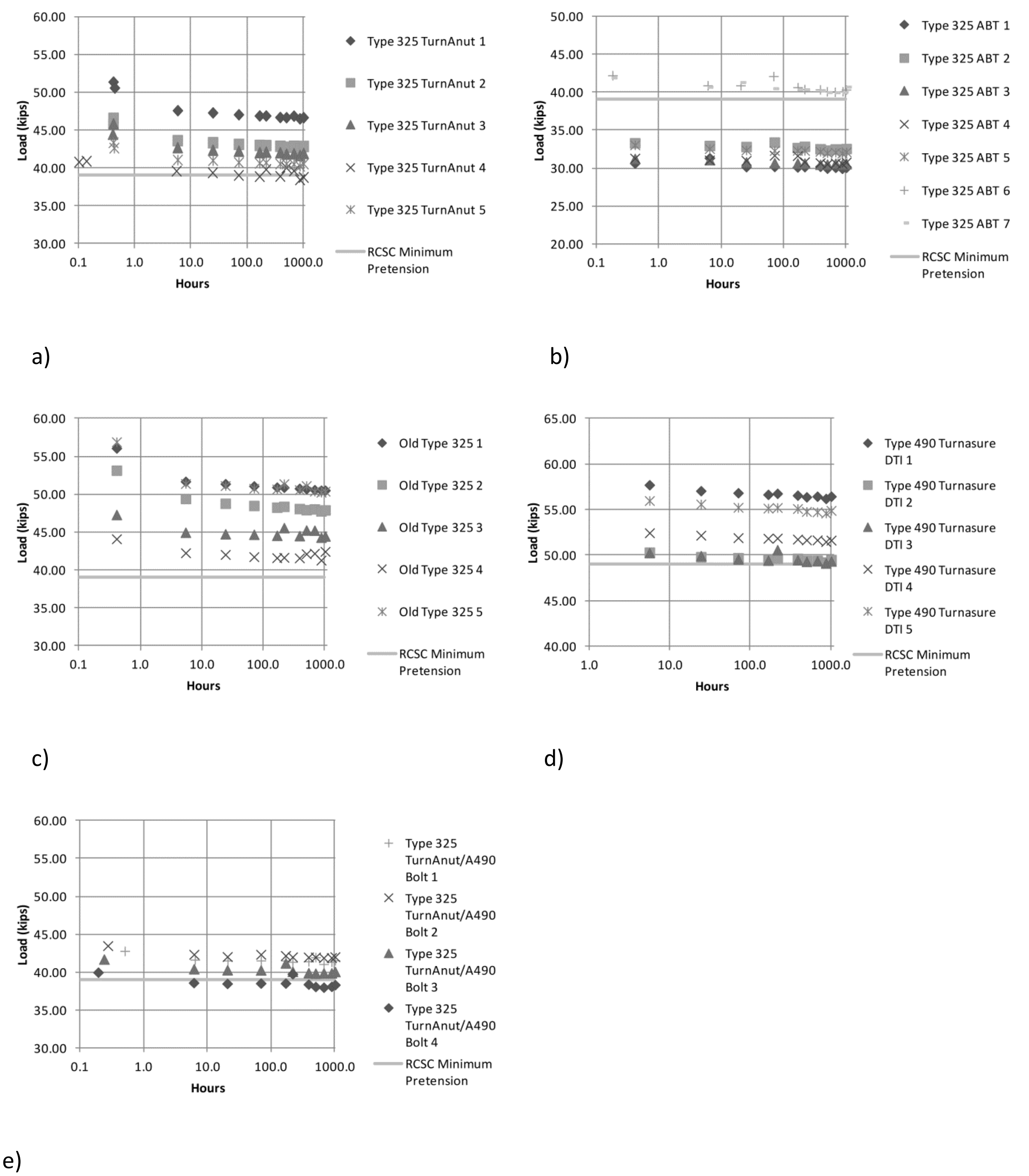



Figure 6. Time history of measured bolt tension for assemblies with DTIs a) Type 325 TurnAnut, b) Type 325 ABT, c) Type 325 Cooper & Turner, d) Type 490 TurnaSure, and e) Type 325 TurnAnut installed with A490 bolt.

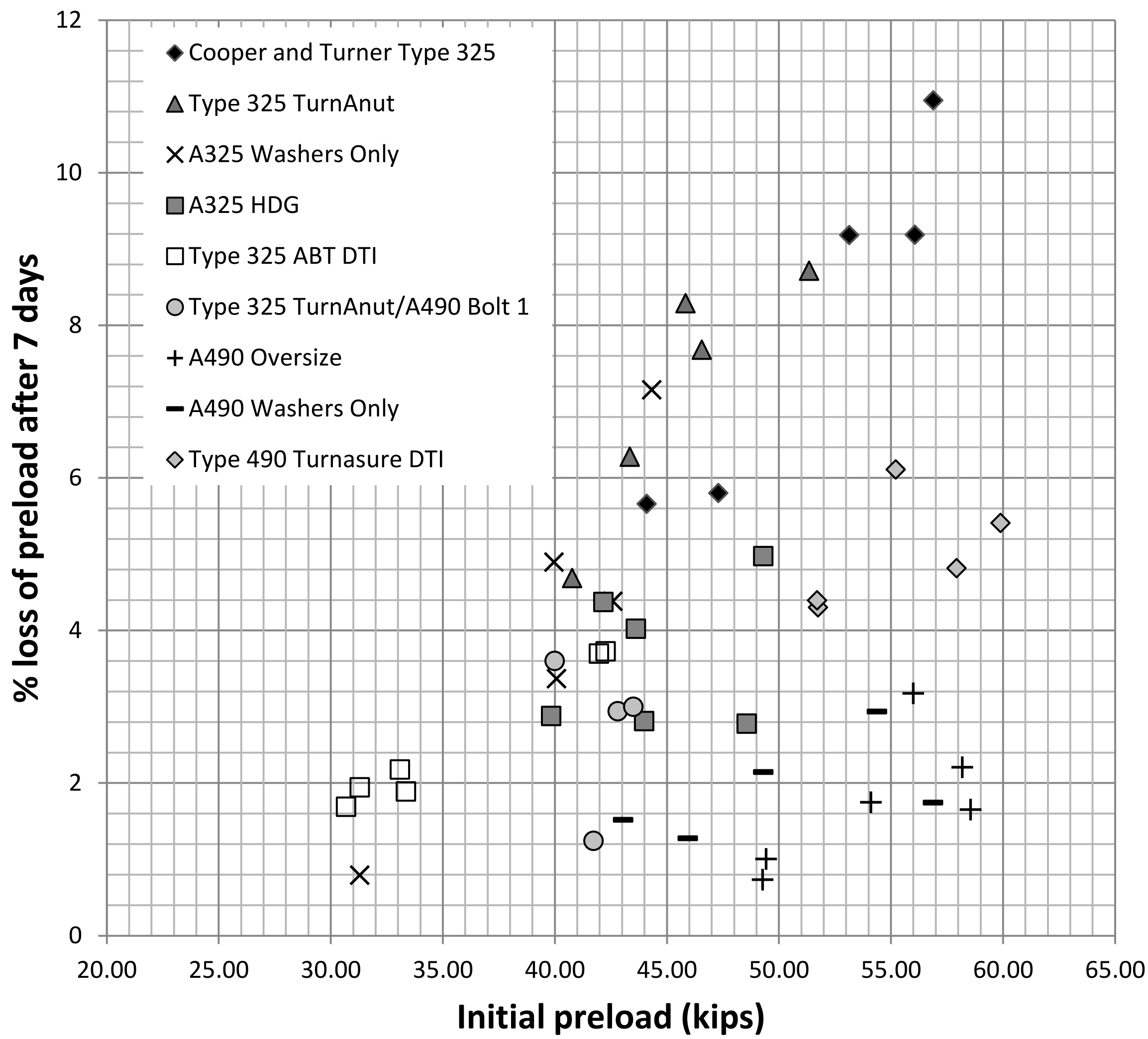



Figure 7. Percent loss of bolt tension relative to initial tension at 7 days.

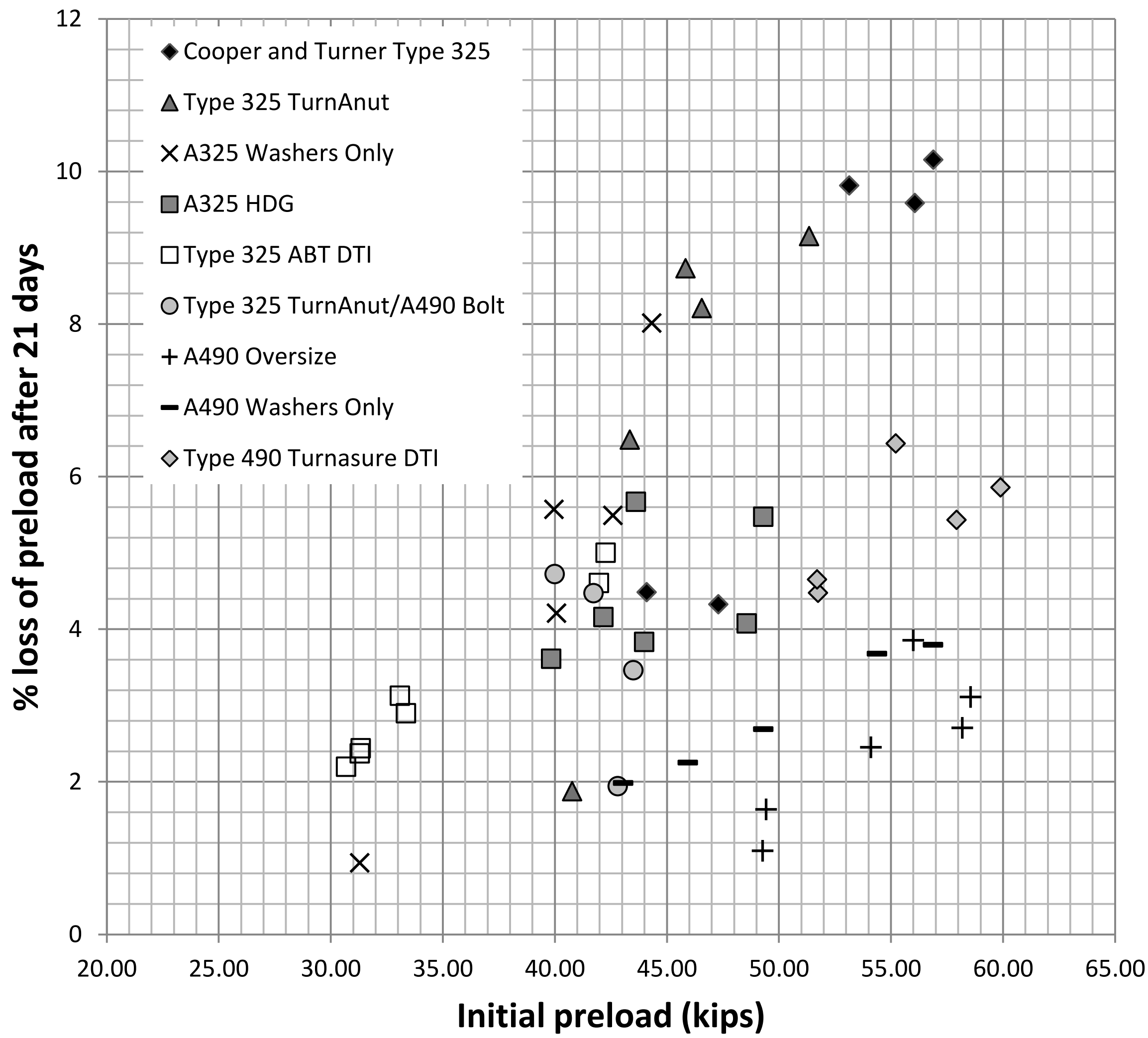



Figure 8. Percent loss of bolt tension relative to initial tension at 21 days.

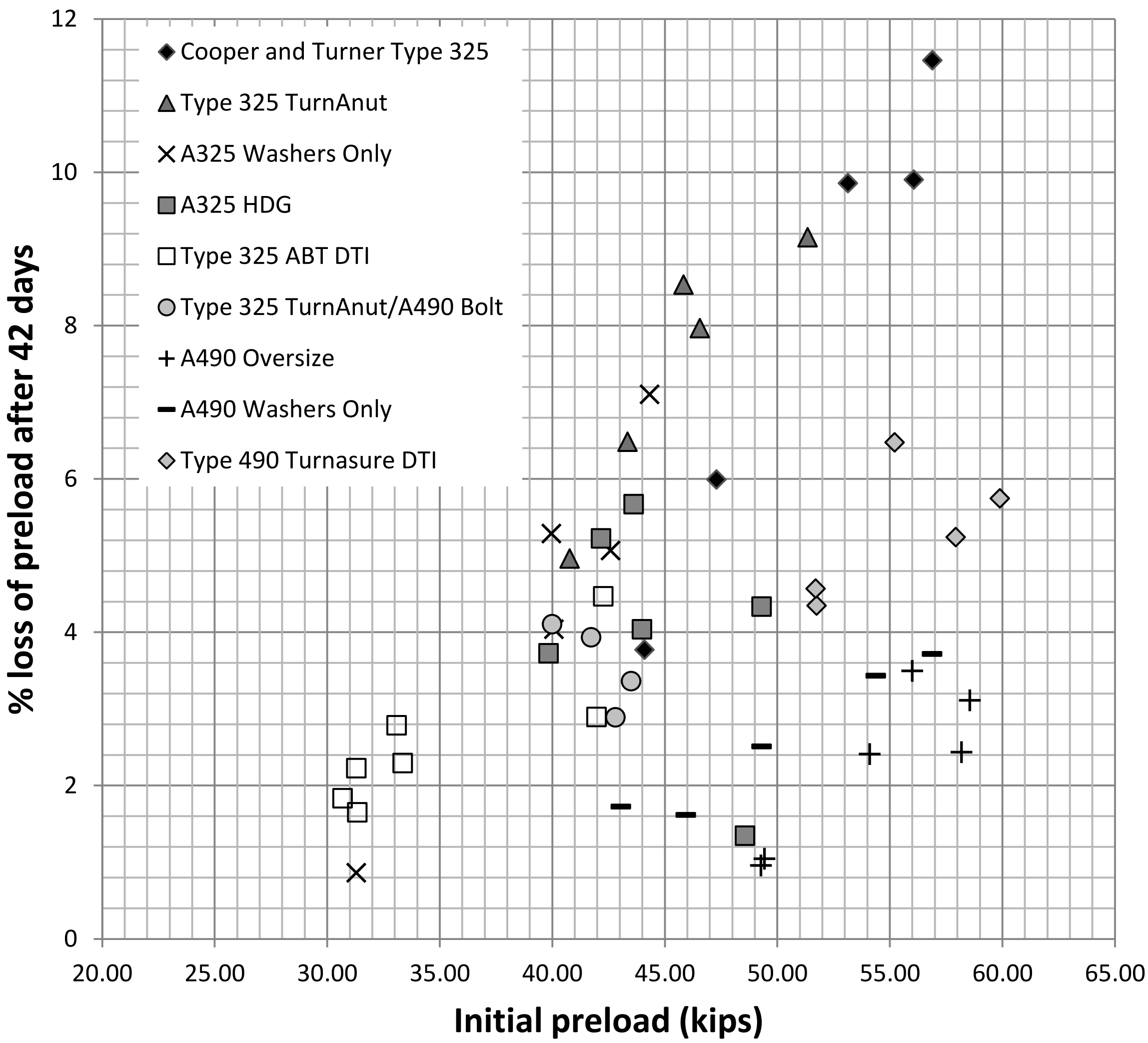



Figure 9. Percent loss of bolt tension relative to initial tension at 42 days.

*Comparison of A325 washer only vs. Type 325 Quenched and Tempered DTI vs. Type 325 Cold-worked and Annealed DTI*

A comparison of the tension measured in the bolt assemblies at 7 days relative to that measured at 20 minutes is provided in Figure 10 for the A325 assemblies installed using simulated field methods. Data from assemblies not considered in the comparison have been removed for clarity in the figure. The Plate 3 data for the ABT DTI are also included to provide data from that assembly type at a higher initial load. Note that those two assemblies from Plate 3 were installed on a Grade 50 rather than a Grade 36 plate. Also note that a small load increase was reported for one of the ABT DTIs resulting in a negative calculated percent loss, hence the data point does not appear on the figure although that point is considered in the trend line. The measurements show that there is no significant difference in the behavior of the various assemblies. Rather, the data suggest the percentage loss of tension is primarily dependent on the level of initial load. The relative positioning of the trend lines through the data sets rearranges somewhat over time. For example, at 7 days, as shown in the figure below, there are slightly higher losses for the Type 325 TurnAnut assemblies relative to the A325 washer only assemblies whereas at 21 days. This order reverses with slightly higher losses for the washer only assemblies. These differences are not considered significant and the change in ordering simply reflects the scatter of the data from variations in lab conditions once the assemblies have stabilized. The magnitudes of the losses observed in all A325 assemblies are less than the range of initial loads obtained when a procedure used to replicate field installation methods was used to develop the pretension load (Plates 1 and 2).

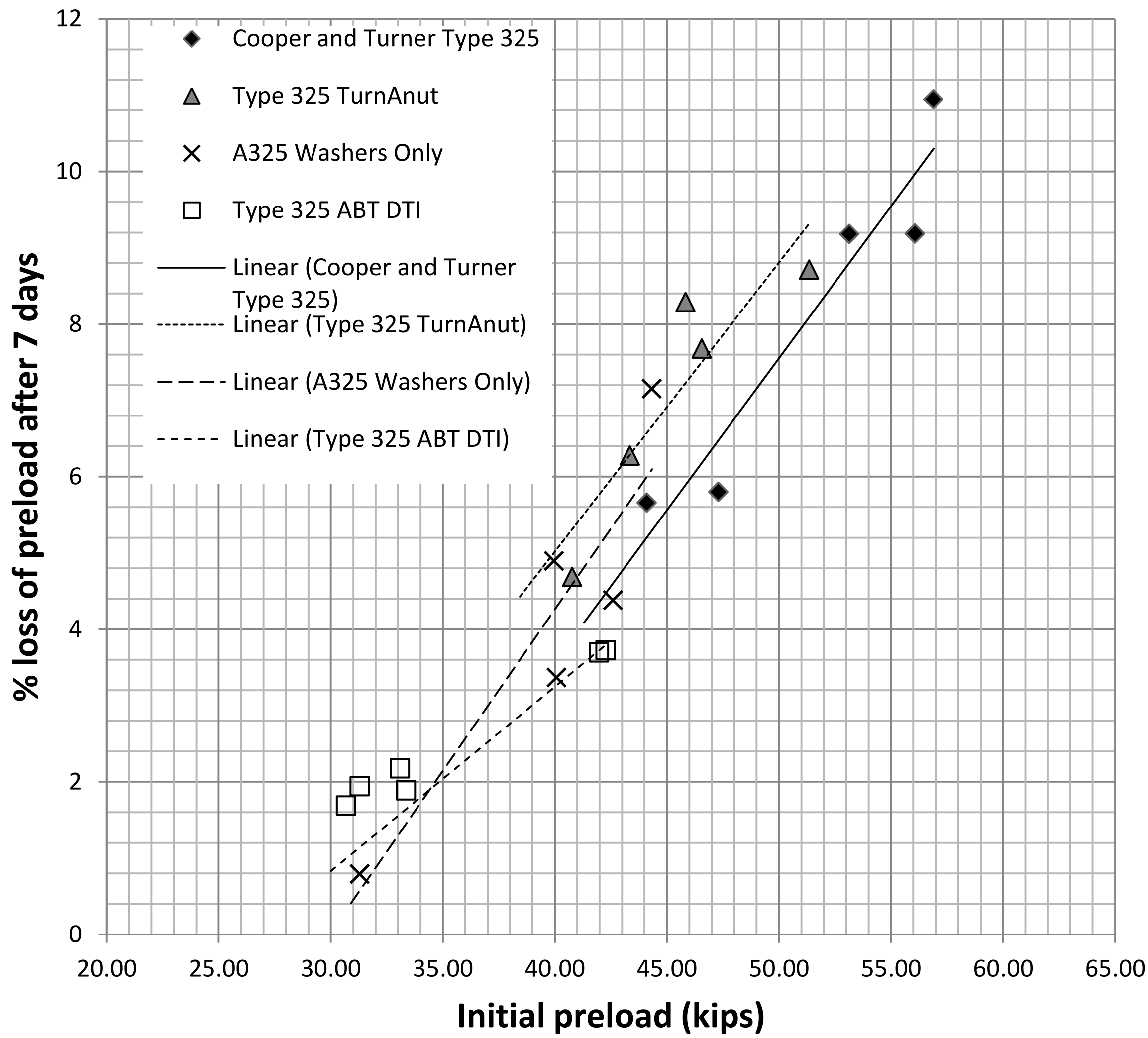



Figure 10. Percent loss of bolt tension relative to initial tension at 7 days, A325 assemblies.

*Behavior of A490 Assemblies*

The data measured at 7 days for A490 assemblies are presented in Figure 11. Somewhat larger loss of initial load was found in the Type 490 DTI assemblies than in the assemblies with only washers installed in standard and oversized holes. These losses in the DTI assemblies were not considered to be of a magnitude to raise long-term performance concern, as the losses on all of the A490 assemblies (both in terms of fraction of initial load and absolute magnitude) were smaller than those found with A325 bolts. Furthermore, the losses did not result in loads below the specified minimum pretension, as previously discussed. Similar to the trend found with A325 assemblies, the magnitude of total loss is less than the range of initial loads.

The measurements from A490 assemblies also provide a measure of the importance of the size of the bolt hole and grade of the plate material within the range considered in this study. Comparison of the two A490 assemblies that did not incorporate DTIs: those with oversized holes on a GR50 plate and those with standard holes on a GR36 plate, indicates these two variables are of relatively small importance because the observed loss in tension is very similar and close to zero for both cases over a comparable range of loads. Because multiple variables are considered simultaneously in this analysis further investigation is warranted.

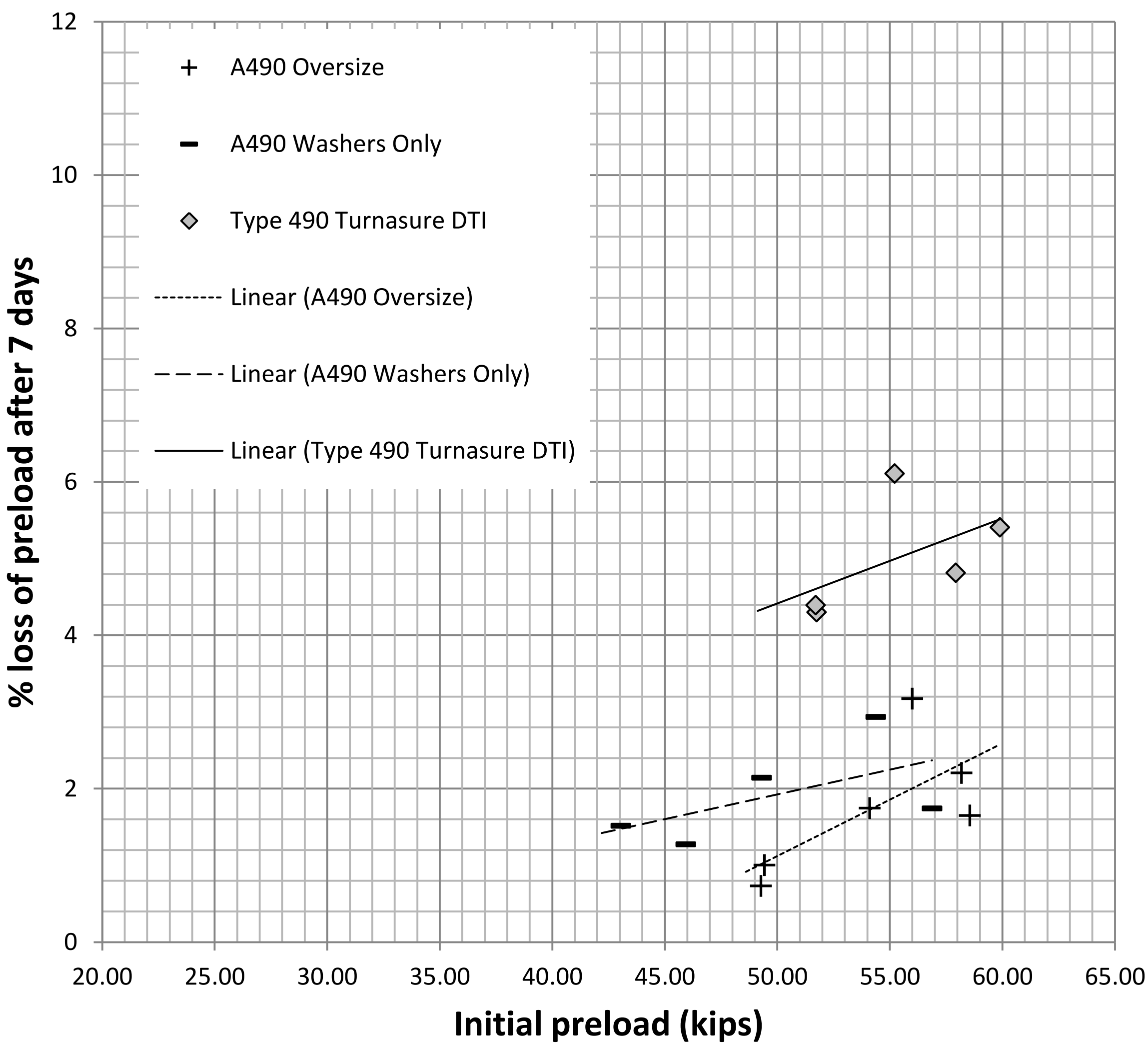



Figure 11. Percent loss of bolt tension relative to initial tension at 7 days, A490 assemblies.

*Influence of Bolt Grade on Loss of Load*

The findings presented above suggest that the bolt and bolt material are far more important factors in the loss of initial load than the presence of a DTI or the manufacturing process used to produce the DTI. To further evaluate this, four Type 325 TurnAnut assemblies were installed on Plate 3 with A490 bolts. These assemblies were loaded to 45 kips and provide a direct comparison between cold-worked and annealed DTIs on A325 and A490 bolts at similar loads. In this comparison identical DTIs and nuts are used, leaving the bolt as the only variable. A comparison of the percentage loss of bolt tension after seven days is shown in Figure 12. The losses are referenced to 20 minute readings to allow a direct comparison between the data sets. This comparison makes it clear the bolt material is the important factor in time-dependent loss of load. For a comparable tension, the losses in an assembly with the A490 bolt are smaller than those in an assembly with an A325 bolt. If the DTI were a significant contributor to the time-dependent losses in bolt assemblies, then the losses between these two groups of assemblies would be similar regardless of the bolt material.

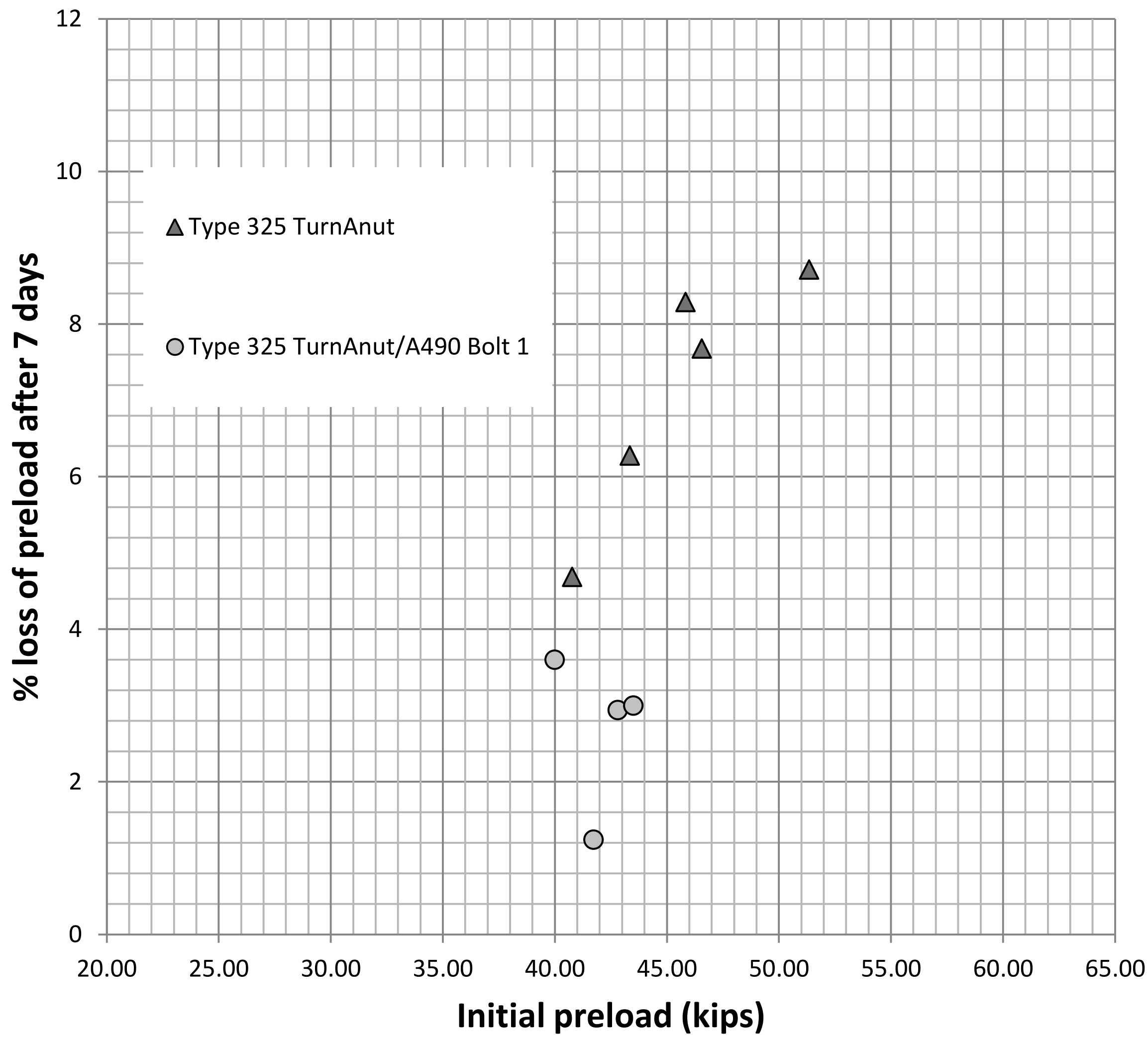



Figure 12. Comparison of percent loss of bolt tension relative to initial tension at 7 days, Type 325 TurnAnut assemblies using A325 and A490 bolts.

*Results from Galvanized A325 Assemblies*

The time-dependent losses measured in the A325 hot-dipped galvanized assemblies were unexpectedly small, when compared to trends reported in Kulac, et al. (2001). These losses were previously shown in Figure 5 (c). The comparison of bolt load at 7 days relative to the 20 minute load reading is provided in Figure 13. There is the possibility that with the original research cited by Kulac, et al., the bolted assemblies used had conventional galvanizing which normally has a layer of very soft pure Zinc on the surface (Hardness ≈ 50 HV). Galvanized assemblies in more recent years have tended to have Zn-Fe alloy layers at the surface; these have much higher surface hardness of about 150 HV; which would reduce the possibility of relaxation. Even with mechanical galvanizing where particles of pure Zinc are used, the coating process would work harden the Zinc resulting in higher levels of surface hardness than conventional galvanizing (personal communication, Roger Reed, Chairman CEN TC 185 WG 6 Structural Fasteners, October 21, 2011).

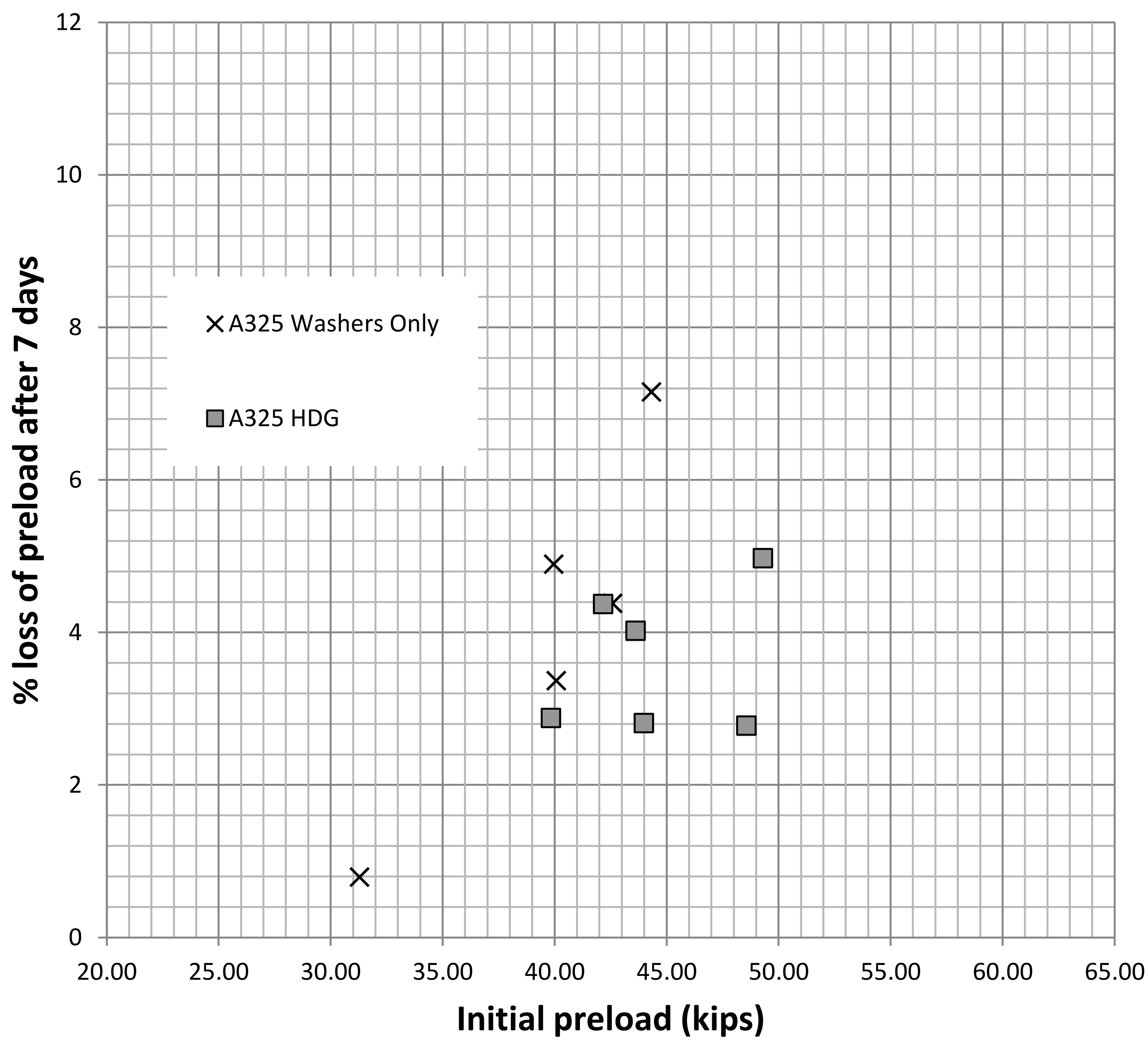



Figure 13. Comparison of percent loss of bolt tension relative to initial tension at 7 days, A325 Hot-dipped Galvanized Assemblies.

**Conclusions**

- The loss of pretension in all bolted assemblies studied occurred primarily in the first 24 hours and bolt tensions were stable within 7 days. Time-dependent losses of tension did not result in assemblies with DTIs falling below the minimum required tension after 1000 hours of monitoring when initial tension requirements were satisfied. The total loss of tension in any assembly was less than the range of tension achieved within any assembly group tensioned using field methods.

- For all bolted assemblies tested with A325 bolts, initial tension was found to be the most important predictor of creep/relaxation losses. This suggests that most of the losses occur in the bolt and/or nut, rather than the DTI or washer. Consequently there is no difference in behavior attributed to heat treatment or lack of heat treatment for Type 325 DTIs.

- For all bolted assemblies tested with 490 bolts, there is some effect of the DTI on the creep/relaxation losses. However, overall losses were smaller compared to assemblies with A325 bolts, suggesting that creep/relaxation might not be as significant on bolted assemblies with A490 bolts compared to A325 bolts.

- The assemblies with A325 hot-dipped galvanized materials exhibited less creep/relaxation losses than the bolted assemblies with A325 plain material. This observed trend is counter to the trend presented in the literature and may reflect changes to the galvanizing processes. No configurations were evaluated with hot-dipped galvanized DTI's.

## References

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ASTM (2006). ASTM E1685-00: Standard Practice for Measuring the Change in Length of Fasteners Using the Ultrasonic Pulse-Echo Technique, ASTM International, West Conshohocken, PA.

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ASTM (2009). ASTM F959-09: Standard Specification for Compressible-Washer-Type Direct Tension Indicators for Use with Structural Fasteners, ASTM International, West Conshohocken, PA.

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BS 7644-1:1993 Direct tension indicators — Part 1: Specification for compressible washers

CEN EN 14399-9: High-strength structural bolting assemblies for preloading - Part 9: System HR or HV - Direct tension indicators for bolt and nut assemblies.

Chesson, Jr., E., and Munse, W. H. (1965). *Studies of the Behavior of High-Strength Bolts and Bolted Joints,* Engineering Experiment Bulletin 469, University of Illinois, Urbana.

Nah, Hwan-Seon, Heon-Ju Lee, Kang-Seok Kim, Jin-Ho Kim, and Woo-Bum Kim (2010). Evaluating Relaxation of High-strength Bolts by Parameters on Slip Faying Surfaces of Bolted Connections, *International Journal of Steel Structures*, 10(3), 295-303, 2010.

Kulak, Geoffrey L.; Fisher, John W.; and Struik, John H. (2001). *Guide to Design Criteria for Bolted and Riveted Joints, 2nd Edition*, American Institute of Steel Construction, Chicago, IL, pp 61-62 and pp 180.

Research Council on Structural Connections (2009). *Specification for Structural Joints using High-Strength Bolts*, Chicago, Illinois, December 31, 2009.

U. S. Department of Transportation (1991). *High Strength Bolts for Bridges, Report Number FHWA-SA-91-031*, Appendix A6 - Procedure For Verification And Installation Of High Strength Bolts With Direct Tension Indicators (Dtis),

# Appendix A. Details of ultrasonic system

LOAD CONTROL TECHNOLOGIES
an Innovation Plus LLC Company

Tel: 610 272 2600
Fax: 610 272 5223
www.LoadCT.com
3630 Horizon Drive
King of Prussia, PA 19406

## LoadMaster® 3600DXP

**Description:**

The LoadMaster® 3600 is an i-Bolt® load measurement system for inspecting bolt load or measuring and controlling load during assembly. The unit comes with a 1-year warranty and software upgrades, includes an i-Probe®, integrated calibration bolt and temperature probe.

The LoadMaster® 3600DXP is supplied with a LoadMaster® DataManager® laptop PC. This portable unit can be hot-sync'd with the PC for bi-directional data transfer. PC software provides full data display and analysis of inspection data and assembly tightening curves. With USB, Bluetooth connectivity setup and pre-installed LoadMaster® DataManager® software, the DataManager® laptop PC comes ready-to-go out of the box.

**Technical Specifications:**

**LoadMaster®:**

| | |
|---|---|
| Load Accuracy | |
| Assembly Mode: | ±3% (3σ) typical |
| Inspection Mode: | ±5% (3σ) typical |
| Dimensions: | 185mm x 150mm x 50mm |
| Weight: | 1.6kg |
| Power Supply: | Li-On Battery – 10 hrs continuous use<br>External supply (5V) |
| Connectivity: | USB 2.0<br>Bluetooth<br>Wireless LAN 802.11 b/g<br>3G |

**DataManager® PC:**

| | |
|---|---|
| Laptop PC | Lenovo Thinkpad X120E (AMD E-350, 1.6GHz, 4GB Memory, 320GB Hard Disk, Bluetooth 3.0) |
| Operating System: | Windows XP |
| Software: | Office 2007, LoadMaster® DataManager® Connectivity and Analysis Software (pre-installed and configured) |

**Item Code:** LM3600 DXP

## Appendix B – Material Certifications

# Turn A Nut™ DTI

## Direct Tension Indicating Assembly

**Testing Performed For:**
TurnaSure LLC
340 E. Maple Avenue
Suite 206
Langhorne, PA 19047

TurnaSure LLC

**Testing Performed By:**
Alpha Stamping Company
33375 Glendale Avenue
Livonia, MI 48150

Alpha

### TurnAnut Lot Details

| | | | |
|---|---|---|---|
| **TurnaSure Part # :** | 7/8 TURNANUT | **I D - Lot Number:** | 7/8TNA-8A |
| **Alpha Part # :** | TNA-0003 | **Alpha Lot Number:** | 0-223-1 |
| **Heat # :** | B26782 | **Finish:** | Plain |

### TurnAnut DTI Testing

| TEST GAP | ZERO AT | MIN (kips) | MAX (kips) |
|---|---|---|---|
| 0.020 | 39.0 | 41.0 | 47.0 |

**DTI Test Results**

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| **1** | 45.5 | **8** | 46.2 | **15** | 45.5 | **22** | 45.4 |
| **2** | 45.4 | **9** | 45.7 | **16** | 45.2 | **23** | 46.0 |
| **3** | 45.5 | **10** | 45.9 | **17** | 45.9 | **24** | 45.6 |
| **4** | 46.2 | **11** | 45.6 | **18** | 45.6 | **25** | 44.6 |
| **5** | 45.9 | **12** | 45.3 | **19** | 45.7 | **26** | 45.1 |
| **6** | 45.5 | **13** | 46.2 | **20** | 45.8 | **27** | 44.4 |
| **7** | 46.0 | **14** | 45.6 | **21** | 45.7 | **28** | 45.6 |
| | Test Date: | 8/11/2010 | | | | **29** | 45.2 |

**Mean = 45.58** **Std Dev = 0.42**

**Testing Equipment Used:** Digital Omega Pressure Monitor Cert 60021576
**Last Calibration Date:** 10/24/2008
**Next Due Date:** 10/24/2011

### Skidmore TurnAnut Assembly Testing

| Acceptance Criteria |
|---|
| Zero 0.005" Feeler Gage Refusals at 41,000 pound load. |

number of feeler gage entries

**1)** 5
**2)** 5 Test Date ☑ PASS
**3)** 5 1/5/2011

**Testing Equipment Used:** Skidmore-Wilhelm Load cell unit Cert # 60023782
**Last Calibration Date:** 10/7/2010
**Next Due Date:** 10/7/2011

Certification By: Rob Kennedy Date: 1/5/2011

Signature: RtSh

Federal Screw Works

TRAVERSE CITY DIVISION
2270 TRAVERSEFIELD DRIVE, TRAVERSE CITY, MI 49686 PHONE (231) 922-9500

CORPORATE OFFICES:
20229 NINE MILE ROAD
ST. CLAIR SHORES, MI 48080
PHONE (586) 443-4200
FAX (586) 443-4210

# TEST REPORT

Test Report Serial Number: TVC00101 Test Report Date: 12-16-10

Customer Name: Alpha Stamping
32711 Glendale Ave.
Livonia, Mi. 48150-1611

Customer Part Number: TNA-0003 7/8-10 TurnANut Assembly

Applies to the following FSW Container Number: 30 piece Samples picked up on 12-9-10

Customer P.O. #P007147

This report contains the following certifications:

A. Chemical Analysis

B. Mechanical Properties Test Results

C. Physical Properties Test Results

D. Washer TNA-0003-PP Lot # 01741 8A 932
*(Washer Certification Provided by Alpha Stamping)*

Report Assembled by:

Jeffrey J Halstead

Jeffrey J. Halstead
Quality Engineer

Republic ENGINEERED PRODUCTS 3049 LAKESHORE-GATE 6 PHONE: 330-438-5694 BUFFALO, NY 14219 FAX: 330-438-5695

CERTIFICATE OF TESTS REPUBLIC ENGINEERED PRODUCTS September 7, 2010 PAGE 1 OF 2

| | | | |
|---|---|---|---|
| PURCHASE ORD: | 86970 | PURCHASE ORDER DATE: | 7/13/2010 |
| PART NUMBER: | 1035-1-11/32-GR | ACCOUNT NUMBER: | 5604-1727-01 |
| ORDER NUMBER: | 1455465 - 01 | SCHEDULE: | 8918-71 |
| HEAT: | 5095618 | REVISION: | 1 |

===== CHARGE ADDRESS ===== SHIP TO =====

FEDERAL SCREW WORKS
20229 E 9 MILE RD
ST CLAIR SHORES, MI 480801775

FEDERAL SCREW WORKS
DAVE BAILEY
C/O KREHER WIRE PROCESSING
34822 GODDARD RD
ROMULUS, MI 48174

----- MATERIAL DESCRIPTION -----

HOT ROLLED STEEL COILS CARBON FEDERAL SCREW WORKS SPEC 35 AKFG III REVISION DTD 03/30/99 EXC PARA 4,5, 6 & 11 AISI-1035 AK COLD WORKING QUALITY PPAP SUB RESTRICTED CHEMISTRY RESTRICTED MAX INCIDENTAL ELEMENTS

SIZE: RDS 1.3437 DIAM X COIL
RDS 34.1300MM DIAM X COIL

----- LADLE CHEMISTRY % -----

| C | MN | P | S | SI | CU | NI | CR |
|---|---|---|---|---|---|---|---|
| 0.34 | 0.75 | 0.008 | 0.007 | 0.08 | 0.07 | 0.06 | 0.08 |
| V | MO | SN | AL | CB | N | | |
| 0.003 | 0.03 | 0.005 | 0.038 | 0.000 | 0.0058 | | |

----- CALCULATED TESTS -----

REDUCTION RATIO 25.4 TO 1

AUSTENITIC GRAIN SIZE 5 OR FINER BASED ON A TOTAL ALUMINUM CONTENT EQUAL TO OR GREATER THAN .020% PER ASTM A29.

----- SEMI - FINISHED RESULTS -----

----- FINISHED SIZE RESULTS -----

DECARBURIZATION TEST SAE J419/ASTM EI077/JIS G0558
ETCHANT = NITAL MAGNIFICATION = 100X

| | COMPLETE INCHES | TOTAL DEPTH INCHES |
|---|---|---|
| PCE 01 | 0 | 0.011 |

----- NOTES -----

REPUBLIC ENGINEERED PRODUCTS HEREBY CERTIFY THAT THE MATERIAL LISTED HEREIN HAS BEEN INSPECTED AND TESTED IN ACCORDANCE WITH THE METHODS PRESCRIBED IN THE GOVERNING SPECIFICATIONS AND BASED UPON THE RESULTS OF SUCH INSPECTION AND TESTING HAS BEEN APPROVED FOR CONFORMANCE TO THE SPECIFICATIONS.

CERTIFICATE OF TESTS SHALL NOT BE REPRODUCED EXCEPT IN FULL.

ALL TESTING HAS BEEN PERFORMED USING THE CURRENT REVISION OF THE TESTING SPECIFICATIONS.

RECORDING OF FALSE, FICTITIOUS OR FRAUDULENT STATEMENTS OR ENTRIES ON THIS DOCUMENT MAY BE PUNISHED AS A FELONY UNDER FED STATUES TITLE 18 CHAPTER 47.

THE MATERIAL WAS NOT EXPOSED TO MERCURY OR ANY METAL ALLOY THAT IS LIQUID AT AMBIENT TEMPERATURE DURING PROCESSING OR WHILE IN OUR POSSESSION.

NO WELD OR WELD REPAIR WAS PERFORMED ON THIS MATERIAL.

N. J. HUETTICH BY HILDA BEGUE
VICE PRESIDENT, BUSINESS DEVELOPMENT & TECH SRVCES

Neil J. Huettich

Republic ENGINEERED PRODUCTS 3049 LAKESHORE-GATE 6 PHONE: 330-438-5694 BUFFALO, NY 14219 FAX: 330-438-5695

CERTIFICATE OF TESTS REPUBLIC ENGINEERED PRODUCTS September 7, 2010
PAGE 2 OF 2

PURCHASE ORD: 86970
PART NUMBER: 1035-1-11/32-GR
ORDER NUMBER: 1455465 - 01
HEAT: 5095618

PURCHASE ORDER DATE: 7/13/2010
ACCOUNT NUMBER: 5604-1727-01
SCHEDULE: 8918-71
REVISION: 1

THE RESULTS REPORTED RELATE ONLY TO THE ITEMS TESTED

---------- SOURCE INFORMATION ----------

MELT SOURCE: CANTON FLEX CASTER MELT COUNTRY: U.S.A HOT ROLL SOURCE: LACKAWANNA 13in, U.S.A
MELT METHOD: EF BILLET RED. RATIO: 25.4

---------- END OF DATA ---------- CC ---------- END OF DATA ----------

---------- SOURCE INFORMATION (CONTINUED) ----------

WITH SHIPMENT 1 COPY PRINTED AT SHIPPING AREA
FAX SHIP TO 1 COPY ATTENTION DAVE BAILEY 17349415740
FILE 1 COPY

N. J. HUETTICH BY HILDA BEGUE
VICE PRESIDENT, BUSINESS DEVELOPMENT & TECH SRVCES

Neil J. Huettich

# RTI LABORATORIES

## - Report of Analytical Services -

**Submitter:**
Federal Screw Works
2270 Traversefield Dr
Traverse City, Michigan 49686

**Report Date:** 11/5/2010
**Phone:**(231) 922-9500
**FAX:**(231) 922-1811

**Attn:** Jeffrey J. Halstead

**P.O. Number:** 802095

**RTI Lab#:** 1011148-001A
**Client Sample ID:** Grade: 1035 Dir. Longitudinal
**HT #:** RE5095618
**Sample Type:** 1.218" Dia. x 8.0" Test Pc
**Sample Receipt Date:** 11/4/2010

Sample tested in accordance with the current revision of ASTM A370-09a$^{\varepsilon 1}$, E8/E8M-09

Analyst: **JS**

Date of Analysis: 11/5/2010

| Test | Result | Units | Low Limit | High Limit |
|---|---|---|---|---|
| Original Diameter | .504 | In | | |
| Tensile Strength | 64.1 | ksi | | |
| Yield Strength (0.2% offset) | 29.8 | ksi | | |
| Elongation (in 2.0 in) | 35.0 | % | | |
| Reduction of Area | 67.8 | % | | |

**Notes:**

G.Fonarev

**Approved By** **Gregory Fonarev**
**Materials Engineer**





33080 INDUSTRIAL RD LIVONIA, MI 48150 (734) 422-8000 FAX (734) 422-5342
E-mail: information@rtilab.com Website: rtilab.com

# Thompson Dayton Steel Service

27840 Groesbeck Hwy. - Roseville, MI 48066
Phone: (586) 775-6804 - Fax: (586) 775-1444

Customer: Alpha Stamping
33375 Glendale
Livonia, MI 48150

Date: 9/24/2009

## CERTIFICATE OF TEST

| Item No. | Customer Order No. | TSC Order No. | Grade | Size | Weight | Part Number |
|---|---|---|---|---|---|---|
| 1 | P006530 | 13412R | 1050 | 6.300x.148/.152 | 5,334 | HC6310 |
| 2 | P006529 | 13413R | 1050 | 2.165x.148/.152 | 9,074 | HC2160 |

6,30 x ,148/,152
HC6310
395187-29
2@ 5334

2,165 x ,148/,152
HC2160
395188-29
10 @ 9074

| Item No. | Heat No. | C. | Mn. | Ph. | S. | Si. | Al. | Rockwell | Coils | Weight |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | B26782 | .53 | .77 | .010 | .001 | .17 | .037 | | | |
| 2 | B26782 | .53 | .77 | .010 | .001 | .17 | .037 | | | |

RECEIVED
SEP 2 2009

**It is certified that the above is a true statement of the test data contained in the records of this company.**

**Quality Control**

2546
2788

4334
4740

**WORTHINGTON**
STEEL
A Worthington Industries Company

1127 Dearborn Drive
Columbus OH, 43085

# CERTIFICATE OF CHEMICAL ANALYSES AND TESTS

| | |
|---|---|
| **Certificate Number** 1318794 | **Revision No.** 0 |
| **Customer Order No.** 1807 | **Date** 2010-06-24 |
| **Sales Order No.** 1188324 1.1 | **Mill Order No.** |
| **B/L No.** WSC0356114 | **Weight** 3590 lbs |
| **Alloy / Grade** 1045/1050 | **Part No.** CAT #14R |
| **Specification No.** ASTM F959-07 | |
| **Description** Cold Rolled Strip Annealed 1045/1050 0.1580 in X 6.4000 in X COIL | |

Turnasure LLC
Rotation Engineering and Manufacturing
8800 Xylon Ave N
Minneapolis, MN 554451811
US

Melted and Mfg. in USA

**Heat Number** 10379020

**Chemical Analysis**

| | |
|---|---|
| C | .530 ✓ |
| MN | .760 ✓ |
| P | .010 ✓ |
| S | .001 ✓ |
| SI | .180 ✓ |

| **Heat Number** | **Coil No.** |
|---|---|
| 10379020 | 2077094 |

**Mechanical Analysis**

| | |
|---|---|
| RBW Hardness | 96.0 |
| RBW Hardness | 91.6 |

THE CHEMICAL DATA REQUIRED ABOVE CONFORM TO AISI SPECIFICATIONS.
THE MECHANICAL PROPERTIES REPORTED ABOVE WERE DETERMINED USING RECOMMENDED ASTM PRACTICES.

Bill Kelly

OK Rich 6-24-10

**Bill Kelly** Quality Manager

06/24/2010 03:36:26 PM

LABORATORY TESTING INC.

2331 Topaz Drive, Hatfield, PA 19440
TEL: 800-219-9095 • FAX: 800-219-9096

*Certified Test Report*

TLL001-10-10-33917-1

Accredited Nadcap
Materials Testing Laboratory
Nondestructive Testing

**TESTING PERFORMED FOR**
**DTI MANUFACTURER:**
TurnaSure LLC
340 East Maple Avenue, Suite 305
Langhorne, PA 19047

**REPORT ISSUED TO:**
TurnaSure LLC
340 East Maple Avenue, Suite 305
Langhorne, PA 19047

**CERTIFICATION DATE**
10/14/2010

**SHIP VIA**
E-MAIL AND MAIL

**DESCRIPTION**

**Product Tested:** Direct Tension Indicators
**Nominal Size:** 7/8"
**Finish:** Plain
**Date Received:** 10/13/2010
**Standard:** ASTM F959
**Type:** 490
**Heat Number:** 10379020
**Date Tested:** 10/14/2010

**REQUIREMENTS: Minimum - 49 KIPS / Maximum - 59 KIPS**
**COMPRESSION TEST RESULTS**
**LOT NUMBER 784B35**

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| (1) | 56.4 | (9) | 56.4 | | | | | |
| (2) | 56.3 | (10) | 55.4 | | | | | |
| (3) | 54.9 | (11) | 54.7 | | | | | |
| (4) | 55.6 | (12) | 56.1 | | | | | |
| (5) | 56.5 | (13) | 55.5 | | | | | |
| (6) | 54.9 | (14) | 56.5 | | | | | |
| (7) | 55.3 | (15) | 55.7 | | | | | |
| (8) | 55.5 | | | | | | | |
| | | | | | | | | |
| MEAN COMPRESSION LOAD: | | | 55.71 | KIPS / STANDARD DEVIATION: | | | 0.62 | KIPS |

Compression Load Tests were performed on (15) pieces of the submitted Test Specimens and (15) pieces were found to be in conformance with the compression load requirements of ASTM F-959. The compression test results above were generated on a Digital Compression Load Analyzer Test System which is calibrated annually on test equipment directly traceable to the National Institute of Standards and Technology. All compression load tests are performed in accordance with test method ASTM F-606 at a test gap of 0.015" with results reported to the nearest 100 lbs.

DTI's MANUFACTURED IN THE USA FROM STEEL MELTED AND MANUFACTURED IN THE USA.
Laboratory Testing Inc. is accredited by A2LA for Compression Testing of Washers, Certificate Number 117.02

The services performed above were done in accordance with LTI's Quality System Program Manual Revision 18 dated 7/27/07 and ISO/IEC 17025. These results relate only to the items tested and this report shall not be reproduced, except in full, without the written approval of Laboratory Testing, Inc. L.T.I. is accredited by PRI to ISO17025 and by Nadcap for NDT and Materials Testing for the test methods and specific services as listed in the Scopes of Accreditation available at www.labtesting.com and www.eAuditNet.com. The results reported on this test report represent the actual attributes of the material tested and indicate full compliance with all applicable specification and contract requirements.

**MERCURY CONTAMINATION:** During the testing and inspection, the product did not come in direct contact with mercury or any of its compounds nor with any mercury containing devices employing a single boundary of containment.

**NOTE:** The recording of false, fictitious or fraudulent statements or entries on this document may be punishable as a felony under Federal Statutes.

Sherri L. Scheifele
QA Specialist
Sherri L. Scheifele
Authorized Signature (ES)

Page 1 of 1

NUCOR FASTENER

A Division of Nucor Corporation
Post Office Box 6100 · Saint Joe, Indiana 46785 · Telephone 219/337-1600

CUSTOMER NUMBER 712 DATE SHIPPED 12/12/97
CUSTOMER NAME E & A PRODUCTS
CUSTOMER P.O. # 16161 NUCOR ORDER # 248156
CUSTOMER PART # DATE TESTED 8/18/97
****************CERTIFIED MATERIAL TEST REPORT**************** MANUFACTURER ID: n

| PART NO. | QUANTITY | LOT NO. | DESCRIPTION | | |
|---|---|---|---|---|---|
| 161440 | 900 | 82414C | 7/8-9 X 3 | A325 HVY HX | STRUC SCREW PLAIN |

--CHEMISYRY MATERIAL GRADE -1037ML
**CHEMISTRY COMPOSITION (WT% HEAT ANALYSIS) BY MATERIAL SUPPLIER

| MATERIAL NUMBER | HEAT NUMBER | C | MN | P | S | SI |
|---|---|---|---|---|---|---|
| RM011857 | NU 156209 | .38 | 1.13 | .007 | .025 | .28 |

--MECHANICAL PROPERTIES IN ACCORDANCE WITH ASTM A325-93

| SURFACE HARDNESS (R30N) | CORE HARDNESS (RC) | PROOF LOAD 39300 LBS | TENSILE STRENGTH 10 DEG-WEDGE (LBS) | STRESS (PSI) |
|---|---|---|---|---|
| N/A | 28.2 | PASS | 64478 | 139563 |
| N/A | 27.9 | PASS | 65633 | 142063 |
| N/A | 28.0 | PASS | 64799 | 140258 |
| N/A | 27.9 | PASS | 64229 | 139024 |
| N/A | 28.3 | PASS | 65210 | 141147 |
| N/A | 28.1 | PASS | 64774 | 140203 |
| N/A | 28.6 | PASS | 64579 | 139781 |
| N/A | 27.7 | PASS | 64263 | 139054 |
| AVERAGE VALUES FROM 8 TESTS | 28.1 | PRODUCTION LOT SIZE 37553 PCS | 64743 | 140137 |

--VISUAL INSPECTION IN ACCORDANCE WITH ASTM A325 440 PCS. SAMPLED LOT PASSED
HEAT TREATMENT - AUSTENITIZED, OIL QUENCHED & TEMPERED (MIN 800 DEG F)

THE NUCOR FASTENER TESTING LABORATORY HAS BEEN ACCREDITED BY THE AMERICAN ASSOCIATION FOR LABORATORY ACCREDITATION IN THE FIELD OF MECHANICAL TESTING. ALL TESTS ARE IN ACCORDANCE WITH THE LATEST REVISIONS OF THE METHODS PRESCRIBED IN THE APPLICABLE SAE AND ASTM SPECIFICATIONS. THE SAMPLES TESTED CONFORM TO ANSI B18.2.1-1992 DIMENSIONAL SPECIFICATIONS ALONG WITH THE SPECIFICATIONS AS DESCRIBED/LISTED ABOVE AND WERE MANUFACTURED FREE OF MERCURY CONTAMINATION
THE STEEL WAS MELTED AND MANUFACTURED IN THE U.S.A. AND THE PRODUCT WAS MANUFACTURED AND TESTED IN THE U.S.A.
WE CERTIFY THAT THIS DATA IS A TRUE REPRESENTATION OF INFORMATION PROVIDED BY THE MATERIAL SUPPLIER AND OUR TESTING LABORATORY. THIS CERTIFIED MATERIAL TEST REPORT RELATES ONLY TO THE ITEMS LISTED ON THIS DOCUMENT AND MAY NOT BE REPRODUCED EXCEPT IN FULL.

NUCOR FASTENER
A DIVISION OF NUCOR CORPORATION

John R. Harden

JOHN R. HARDEN
QUALITY CONTROL SUPERVISOR

A2LA ACCREDITED

STATE OF INDIANA
COUNTY OF DEKALB

Crystal D. Gillespie
NOTARY PUBLIC, CRYSTAL D. GILLESPIE

1-19-99
DATE OF EXPIRATION

07/11/97 10:01:22 402-644-0329-> 219 337 5314 NUCOR STEEL-NE Page 000

Attention: CRYSTAL GILLESPIE
B/L-0063289 P.O.-42812

11857

DATE 7/10/97

# NUCOR CORPORATION

HEAT NUMBER 156209

For Chemical Testing
Lab Code: 101371
Expires: 10-30-1998

NUCOR STEEL DIVISION
POST OFFICE BOX 309 NORFOLK, NEBRASKA 68701 PHONE (402) 644-0200

## CHEMICAL ANALYSIS

| SPEC | HEAT NUMBER | C | Mn | Si | S | P | Cu |
|---|---|---|---|---|---|---|---|
| 1037ML | 156209 | .38 | 1.13 | .28 | .025 | .007 | .07 |
| | Cr | Ni | Mo | Al | V | Nb | Sn |
| | .05 | .02 | .01 | .003 | .001 | .001 | .017 |

## PHYSICAL PROPERTIES

| SIZE | | SHAPE | YIELD PSI | TENSILE PSI | % ELONGATION IN 8" | % RA |
|---|---|---|---|---|---|---|
| 57/64 | | Rounds | 68,865 | 102,415 | 15 | |
| Strand Cast | | | | | | |

All Manufacturing processes, including melting, have been performed in the U.S.A. Mercury, in any form, has not been used in the production or testing of this material. Welding or weld repair was not performed on this material. This material conforms to the specifications described on this document. This report relates only to the material listed on this document and may not be reproduced except in full, without written approval of Nucor Corporation.

## ADDITIONAL CHEMICAL ANALYSIS

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| B | | | | | | | |
| .0002 | | | | | | | |

Reduction Ratio 70:1

NUCOR FASTENERS
P. O. BOX 6100
ST JOE, IN 46785

JIM HILL DIVISION METALLURGIST

This product is NAFTA certified under paragraph "B" of the NAFTA rules of origin.

# NUCOR

LOT NO.
163317D

Saint Joe, Indiana 46785
Telephone 260/337-1600

## FASTENER DIVISION

CUSTOMER NO/NAME
712 E & A PRODUCTS
NUCOR ORDER # 472646
TEST REPORT SERIAL# FB206067
CUST PART #
TEST REPORT ISSUE DATE 3/06/03
DATE SHIPPED 8/06/03
CUSTOMER P.O. # 37469
NAME OF LAB SAMPLER: JACK M. MILLER, LAB TECHNICIAN


****************CERTIFIED MATERIAL TEST REPORT****************

| NUCOR PART NO | QUANTITY | LOT NO. | DESCRIPTION |
|---|---|---|---|
| 165440 | 300 | 163317D | 7/8-9 X 3 A490 HVY HX STRUC SCREW PLAIN |

MANUFACTURE DATE 2/07/03

--CHEMISTRY
MATERIAL GRADE -4135MLV
**CHEMISTRY COMPOSITION (WT% HEAT ANALYSIS) BY MATERIAL SUPPLIER

| MATERIAL NUMBER | HEAT NUMBER | | C | MN | P | S | SI | CR | MO | V |
|---|---|---|---|---|---|---|---|---|---|---|
| RM019987 | NU 718659 | | .34 | .92 | .013 | .020 | .23 | .98 | .17 | .020 |
| | | MIN | .30 | | | | | | | |
| | | MAX | .48 | | .040 | .040 | | | | |

NUCOR STEEL - NEBRASKA
A2LA NO: 780.01 EXP: 2004-11-30
FOR CHEMICAL TESTING

--MECHANICAL PROPERTIES IN ACCORDANCE WITH ASTM A490-02

| SURFACE HARDNESS (R30N) | CORE HARDNESS (RC) | PROOF LOAD 55450 LBS | TENSILE STRENGTH 10 DEG-WEDGE (LBS) | STRESS (PSI) |
|---|---|---|---|---|
| N/A | 35.1 | PASS | 74910 | 162143 |
| N/A | 35.5 | PASS | 75322 | 163035 |
| N/A | 34.8 | PASS | 74452 | 161152 |
| N/A | 36.2 | | | |
| AVERAGE VALUES FROM TESTS | 35.4 | PRODUCTION LOT SIZE 5400 PCS | 74895 | 162110 |

--WET MAGNETIC PARTICLE INSPECTION IN ACCORDANCE WITH ASTM A490 200 PCS. SAMPLED LOT PASSED

--MICROHARDNESS TEST RESULT IN ACCORDANCE WITH SAE J121(HKN)
POSITION 1. 388 2. 399 3. 387
CARBURIZATION/DECARBURIZATION TEST IN ACCORDANCE WITH A490 - LOT PASSED
HEAT TREATMENT - AUSTENITIZED, OIL QUENCHED & TEMPERED (MIN 800 DEG F)

--DIMENSIONS PER ASME B18.2.6-1996

| CHARACTERISTIC | #SAMPLES TESTED | MINIMUM | MAXIMUM |
|---|---|---|---|
| Width Across Corners | 8 | 1.6160 | 1.6200 |
| Grip Length | 8 | 1.3870 | 1.4240 |
| Head Height | 8 | 0.5460 | 0.5560 |
| Threads | 8 | PASS | PASS |

ALL TESTS ARE IN ACCORDANCE WITH THE LATEST REVISIONS OF THE METHODS PRESCRIBED IN THE APPLICABLE SAE AND ASTM SPECIFICATIONS. THE SAMPLES TESTED CONFORM TO THE SPECIFICATIONS AS DESCRIBED/LISTED ABOVE AND WERE MANUFACTURED FREE OF MERCURY CONTAMINATION.
THE STEEL WAS MELTED AND MANUFACTURED IN THE U.S.A. AND THE PRODUCT WAS MANUFACTURED AND TESTED IN THE U.S.A.
WE CERTIFY THAT THIS DATA IS A TRUE REPRESENTATION OF INFORMATION PROVIDED BY THE MATERIAL SUPPLIER AND OUR TESTING LABORATORY. THIS CERTIFIED MATERIAL TEST REPORT RELATES ONLY TO THE ITEMS LISTED ON THIS DOCUMENT AND MAY NOT BE REPRODUCED EXCEPT IN FULL.

ACCREDITED

MECHANICAL FASTENER
CERTIFICATE NO. A2LA 139-01
EXPIRATION DATE 12/31/03

NUCOR FASTENER
A DIVISION OF NUCOR CORPORATION
Morton Schaffer
MORTON SCHAFFER
QUALITY ASSURANCE SUPERVISOR

Page 1 of 1

STATE OF INDIANA
COUNTY OF DEKALB

NOTARY PUBLIC, CRYSTAL D. GILLESPIE

DATE OF EXPIRATION

19987

ATTN: CRYSTAL GILLESPIE BL#-0155322 P.O.-70094

Date: 8/07/02

# Nucor Corporation

Heat Number: 718659

Nucor Steel Division
Post Office Box 309 Norfolk, Nebraska 68702 Phone (402) 644-0200
Mill Certification

ISO 9002 Registered by

Chemical Testing
Certificate: 0780-01Chemical Analysis
Expires: 11/30/02

ACCREDITED

SRI Quality System Registrar

Test conform to ASTM A29, ASTM E415 and ASTM E1019-resulphurized grades
Spec: 4135MLV Size: 57/64 Rounds
.8906

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| C | .34 | P | .013 | Mo | .17 | Sn | .011 |
| Mn | .92 | Cu | .15 | Al | .001 | B | .0002 |
| Si | .23 | Cr | .98 | V | .02 | | |
| S | .020 | Ni | .06 | Nb | .001 | | |

Physical Properties

| | Imperial | | | Metric | | |
|---|---|---|---|---|---|---|
| Yield | ------ | ------ | psi | ------ | ------ | MPA |
| Tensile | 139,015 | | psi | 958 | | MPA |
| % Elongation | 5 | | % in 8" | 5 | | % in 203.3 mm |

Strand Cast

Reduction Ratio: 70:1

Chemistry Verification Checks

Part # 8014 RM # 19987

| | Checked By | Date |
|---|---|---|
| Receiving OK: | 081 | 8-27-02 |
| Certifications OK: | 375 | 9-16-02 |

NUCOR FASTENERS
P. O. BOX 6100
ST JOE, IN 46785

Jim Hill Division Metallurgist

All Manufacturing processes, including melting have been performed in the U.S.A. Mercury, in any form, has not been used in the production or testing of this material. Welding or weld repair was not performed on this material. This material conforms to the specifications described on this document and may not be reproduced except in full, without written approval of Nucor Corporation. This product is NAFTA certified under Paragraph "B" of the NAFTA rules of origin.
Form 10F002 HT3000R

# INSPECTION CERTIFICATE

UNYTITE, INC.
One Unytite Drive
Peru, Illinois 61354
815-224-2221 — FAX# 815-224-3434

| Customer | Specification | Size | Lot No. | Date |
|---|---|---|---|---|
| | ASTM A-563 GRADE DH HEAVY HEX NUT | 7/8- 9 UNC | SD431 | Oct.28,'10 |

Mechanical properties tested in accordance to ASTM F606/F606M, ASTM A370, ASTM E18

## Chemical Composition (%)

| Mill Maker | Material Size | Heat No. | Spec. | C | Si | Mn | P | S | Cu | Ni | Cr | Mo | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| GERDAU AMER | CARBON | | | 0.20 0.55 | - | MIN. 0.60 | MAX. 0.040 | MAX. 0.050 | - | - | - | - | - |
| ISTEEL (NC) | STEEL | M659670 | | 0.44 | 0.20 | 0.68 | 0.019 | 0.023 | 0.22 | 0.06 | 0.17 | 0.02 | - |

## Mechanical Property Inspection

| Item | Proof Load | Cone stripping | Hardness | After Heat Treatment Hardness | Absorbed Energy | Heat Treatment |
|---|---|---|---|---|---|---|
| Spec. | 80,850 lbf | - kN·kgf·lbf | 24-38 HrC | HrB·HB | J·kgfm·ftlbf | T:MIN.800 °F |
| Results | n: 5 | n: - | 28.5 28.3 28.7 29.6 29.5 | 5 Piece Average After Heat Treament | - | Q:FORGING Q (W.Q.) T:1220 F/45M. (W.C.) |
| | Results: GOOD | Results: - | 28.9 | Hardness Treatment After 24 Hr.X °F°C | at °F°C | Q: Quenching T: Tempering ST: Solution Treatment |

| | |
|---|---|
| Shape & Dimension Inspection | ANSI B18.2.2 GOOD |
| Thread Precision Inspection | ANSI B1.1 CLASS 2B GOOD |
| Appearance Inspection | ~~GOOD~~ |

Remarks:

PRODUCTION QUNTITY
54,734

"DH U"

OFFICIAL SEAL
JEAN MARGHERIO
NOTARY PUBLIC - STATE OF ILLINOIS
MY COMMISSION EXPIRES:10/18/13

10-29-10

Material used for the nut was melted and manufactured in the USA. The nut was manufactured in the USA to the above specification.

Chief of Quality Assurance Section

We hereby certify that the material described has been manufactured and inspected satisfactorily with the requirement of the above specification.

**GERDAU AMERISTEEL**

ST PAUL STEEL MILL
1678 RED ROCK ROAD
ST PAUL MN 55119 USA

## Chemical and Physical Test Report

MADE IN UNITED STATES

SHAPE + SIZE: R1 1/4SBQ
GRADE: C1045M23F
SPECIFICATION: A576-90b (2006) A29/A29M-05
SALES ORDER
CUST P.O. NUMBER

| HEAT I.D. | C | Mn | P | S | Si | Cu | Ni | Cr | Mo | V | Nb | N | Sn | Al | Ti | Cx | Zn | Ca |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| M659670 | .44 | .68 | .019 | .023 | .20 | .22 | .08 | .17 | .021 | .024 | .000 | .0077 | .007 | .001 | .00100 | .00180 | .00100 | .007 |

Mechanical Test: Red R 30.78 Idl Diam 1.4 Corrosion Index: 5.1
Cleanliness Test
Grain Test: Grain Size Units Fine (5-8) Macro Etch:S-2,R-2,C-2
Customer Requirements SOURCE: GA-STP CASTING: STRAND CAST

This material, including the billets, was melted and manufactured in the United States of America

Bhaskar Yalamanchili
Quality Director
Gerdau Ameristeel

THE ABOVE FIGURES ARE CERTIFIED EXTRACTS FROM THE ORIGINAL CHEMICAL AND PHYSICAL TEST RECORDS AS CONTAINED IN THE PERMANENT RECORDS OF COMPANY.

Metallurgical Services Manager
ST PAUL STEEL MILL

Seller warrants that all material furnished shall comply with specifications subject to standard published manufacturing variations. NO OTHER WARRANTIES, EXPRESSED OR IMPLIED, ARE MADE BY THE SELLER, AND SPECIFICALLY EXCLUDED ARE WARRANTIES OF MERCHANTABILITY AND FITNESS FOR A PARTICULAR PURPOSE. In no event shall seller be liable for indirect, consequential or punitive damages arising out of or related to the materials furnished by seller. Any claim for damages for materials that do not conform to specifications must be made from buyer to seller immediately after delivery of same in order to allow the seller the opportunity to inspect the material in question.

TSI EST. 1991 TECHNICAL STAMPING

# TECHNICAL STAMPING, INC.

50600 E. RUSSELL SCHMIDT BLVD.
CHESTERFIELD TWP., MI 48051
PH(586)948-3285 / FX(586)948-3286

## MATERIAL CERTIFICATION

| CUSTOMER NAME | | CUSTOMER ORDER NUMBER | DATE |
|---|---|---|---|
| E&A Products | | 11024 | 08/24/10 |
| PART NUMBER | CUSTOMER LOT NO. | LOT NUMBER | QUANTITY |
| 7/8" F436 | F436014PLDOM | 0610-884 | 3,125 |

| STEEL GRADE | HEAT | C | MN | P | S | SI | AL | REVISION |
|---|---|---|---|---|---|---|---|---|
| SAE 1050 | 202991 | .52 | .63 | .008 | .002 | .223 | .033 | ASTM F-436-09 |

| SPECIFICATION | | ACTUAL | GAUGE |
|---|---|---|---|
| O.D - | 1.718 - 1.782 | 1.760 - 1.763 | CALIPER |
| I.D - | .938 - .970 | .959 - .962 | CALIPER, PIN GAUGE |
| THICKNESS- | .136 - .177 | 0.138 | MICROMETER |
| FLAT- | Max .010 | .004 | CALIPER |
| HEAT TREAT - | 38 - 45 HRC | 42 - 44 | |
| PLATING- | | N / A | |
| OTHER | | N / A | |
| | | | |

WE HEARBY [illegible] PRODUCT WAS PRODUCED UNDER A ISO-9001:2000 QUALITY ASSURANCE SYSTEM. ISO-9001:2000 CERTIFICATION NUMBER-1265 - DATE OF REGIS. JAN. 5, 2003 ALL MATERIA[illegible] MA[illegible] AND MELTED IN THE U.S.A. THIS PRODUCT WAS MANUFACTURED IN CHESTERFIELD, MICHIGAN, U.S.A. THIS PRODUCT CONFORMS TO ALL REQUIREMENTS FOR WASHERS AS PROD[illegible]ED ACCORDING TO A.S.T.M. F-436-09. THE ABOVE TEST RESULTS APPLY ONLY TO THE ITEMS TESTED. THIS TEST REPORT MUST NOT BE REPRODUCED EXCEPT IN FULL WITHOUT PRIOR WRITTEN APPROVAL.

Brittany Ritchie
AUTHORIZED SIGNATURE

CERTIFIED ISO 9001:2000

QR-9008 Rev. 2 11/25/01

01/07/2010 17:06 7634933214 EA PRODUCTS PAGE 11/12

4257

# INDUSTRIAL STEEL TREATING COMPANY, INC

613 Carroll Street Jackson, MI 49202
P.O. Box 98 Jackson MI, 49204
Voice: 517-787-6312 Fax: 517-787-6441

## HEAT TREAT CERTIFICATION

Customer:
TECHNICAL STAMPING, INC.
Attn: SHANNON
50600 E. RUSSELL SCHMIDT
CHESTERFIELD, MI 48051

Certification Date:
06/21/2010

ISO/TS 16949:2002 IST Registered

Page: 1 of 1

## Order Details

| | | | |
|---|---|---|---|
| Part Number | F0078 | Blue Print Rev. | 1279 |
| Packing Slip: | 4871 | Material Type: | 1030 -1050 |
| Purchase Order | | Quantity: | 105,612 |
| IST Order Number: | 66690-1 | Net Weight: | 7,076.0 |
| Lot Number: | 0610-884 | Part Desc: | WASHER |
| Heat Number: | | Comments: | 5 TUBS #501,505,600,503, 420 |

| SPECIFICATIONS | RESULTS |
|---|---|
| HRC 38 - 45 | HRC 42 - 44 |

Approval: Tom Levy

Tom Levy - Quality Assurance Supervisor

Contact
Tom Levy - Quality Assurance Supervisor
Voice: 517-780-9043 Fax: 517-787-6441
E-Mail: tolevy@indstl.com



09/08/2011 14:32 12157506300 TURNASURE PAGE 11/12

21

NUCOR
SHEET MILL GROUP

Nucor Steel-Crawfordsville
4537 South Nucor Road
Crawfordsville, IN 47933-0907

# METALLURGICAL TESTING CERTIFICATION

4873798

Certificate Number: 343457
Date Issued: 02/25/2010
Page: 1 of 1

Order Number: 202737 - 0001
Order Dimensions: 0.1800 in X 48.0000 in
HOT ROLLED BAND,C1050,MILL

SAE J403 1050

Customer Name: SOUND STEEL, INC.
Customer Address: 23680 RESEARCH DRIVE
FARMINGTON HILLS MI 48335

Cust PO Number: 004974

Coil Number 1467851.000

Rockwell B: TAIL 90

Part Number
.180 x 48.00

CHEMICAL ANALYSIS

| Heat | Slab | C | Mn | P | S | Si | Cu | Sn | Ni | Cr | Mo | Al | N | V | Nb | Ti | B | Sb |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 202991 | 01 | 0.52 | 0.630 | 0.008 | 0.002 | 0.223 | 0.118 | 0.007 | 0.048 | 0.054 | 0.018 | 0.033 | 0.008 | 0.004 | 0.001 | 0.004 | <0.0005 | 0.002 |

WE HEREBY CERTIFY THE ABOVE IS CORRECT AS CONTAINED IN THE RECORDS OF THE CORPORATION
MELTED AND ROLLED IN THE USA

QF-0261 09/18/2007

NUCOR QUALITY ASSURANCE

Eric E. Gallo

# RCSC Proposed Change: S14-xxx

**Name:** Charlie Carter, TG Chair **E-mail:** carter@aisc.org
**Phone:** 312-670-5414 **Fax:** 312-896-9022

**Ballot Actions:**

**Proposed Change:**
***{Primary change is in Table 3.1. The entire Section 3.3 with subsections is provided for clarity. Ballot S12-047B also involves these sections, but the modifications proposed in that ballot and the changes shown in this proposal do not conflict.}***

**3.3. Bolt Holes**

The nominal dimensions of standard, oversized, short-slotted and long-slotted holes for *high-strength bolts* shall be equal to or less than those shown in Table 3.1. Holes larger than those shown in Table 3.1 are permitted when specified or approved by the *Engineer of Record*. Where thermally cut holes are permitted, the surface roughness profile of the hole shall not exceed 1,000 microinches as defined in ASME B46.1. Occasional gouges not more than z in. in depth are permitted.

Thermally cut holes produced by mechanically guided means are permitted in statically loaded *joints*. Thermally cut holes produced free hand shall be permitted in statically loaded *joints* if approved by the *Engineer of Record*. For cyclically loaded *joints*, thermally cut holes shall be permitted if approved by the *Engineer of Record*.

**Commentary:**
The footnotes in Table 3.1 provide for slight variations in the dimensions of bolt holes from the nominal dimensions. When the dimensions of bolt holes are such that they exceed these permitted variations, the bolt hole must be treated as the next larger type.

Slots longer than standard long slots may be required to accommodate construction tolerances or expansion *joints*. Larger oversized holes may be necessary to accommodate construction tolerances or misalignments. In the latter two cases, the Specification provides no guidance for further reduction of *design strengths* or allowable loads. Engineering design considerations should include, as a minimum, the effects of edge distance, net section, reduction in clamping force in *slip-critical joints*, washer requirements, bearing capacity, and hole deformation.

------------------------------------For Committee Use Below----------------------------------------------

Date Received: ______ Exec Com Meeting: _______ Forwarded: Yes ☐ /No ☐

Committee Assignment: Executive -A. ☐ Editorial -B. ☐ Nominating -C. ☐

Specifications -A.1 ☐ Research -A.2 ☐ Membership & Funding -A.3 ☐ Education -A.4 ☐
Committee Chair: ____________ Task Group #: ___________ T.G. Chair: ________________
Date Sent to Main Committee: _______________Final Disposition: ______________________

For thermally cut holes produced free hand, it is usually necessary to grind the hole surface after thermal cutting in order to achieve a maximum surface roughness profile of 1,000 microinches.

Slotted holes in statically loaded *joints* are often produced by punching or drilling the hole ends and thermally cutting the sides of the slots by mechanically guided means. The sides of such slots should be ground smooth, particularly at the junctures of the thermal cuts to the hole ends.

For cyclically loaded *joints*, test results have indicated that when no major slip occurs in the *joint*, fretting fatigue failure usually occurs in the gross section prior to fatigue failure in the net section (Kulak et al., 1987, pp. 116, 117). Conversely, when slip occurs in the *joints* of cyclically loaded *connections*, failure usually occurs in the net section and the edge of a bolt hole becomes the point of crack initiation (Kulak et al., 1987, pp. 118). Therefore, for cyclically loaded *joints* designed as slip critical, the method used to produce bolt holes (either thermal cutting or drilling) should not influence the ultimate failure load, as failure usually occurs in the gross section when no major slip occurs.

3.3.1. Standard Holes: In the absence of approval by the *Engineer of Record* for the use of other hole types, standard holes shall be used in all plies of bolted *joints*.

## Table 3.1. Nominal Bolt Hole Dimensions

| Nominal Bolt Diameter, $d_b$, in. | Nominal Bolt Hole Dimensions [a,b], in. | | | |
|---|---|---|---|---|
| | **Standard (diameter)** | **Oversized (diameter)** | **Short-slotted (width × length)** | **Long-slotted (width × length)** |
| **½** | 9/16 | 5/8 | 9/16 x 11/16 | 9/16 x 1 ¼ |
| **5/8** | 11/16 | 13/16 | 11/16 x 7/8 | 11/16 x 1 9/16 |
| **¾** | 13/16 | 15/16 | 13/16 x 1 | 13/16 x 1 7/8 |
| **7/8** | 15/16 | 1 1/16 | 15/16 x 1 1/8 | 15/16  2 3/16 |
| **1** | ~~1 1/16~~ 1 1/8 | 1 ¼ | ~~1 1/16 x 1 5/16~~ 1 1/8 x 1 5/16 | ~~1 1/16 x 2 ½~~ 1 1/8 x 2 ½ |
| **≥1 1/8** | ~~$d_b$ + 1/16~~ $d_b$ + 1/8 | $d_b$ + 5/16 | ~~($d_b$ + 1/16) × ($d_b$ + 3/8)~~ ($d_b$ + 1/8) × ($d_b$ + 3/8) | ~~(db + 1/16) × (2.5db)~~ ($d_b$ + 1/8) × (2.5$d_b$) |

[a] The upper tolerance on the tabulated nominal dimensions shall not exceed 1/32 in. Exception: In the width of slotted holes, gouges not more than 1/16 in. deep are permitted.

[b] The slightly conical hole that naturally results from punching operations with properly matched punches and dies is acceptable.

**Commentary:**
The use of bolt holes 1/16 in. larger than the bolt installed in them has been permitted since the first publication of this Specification. Allen and Fisher (1968) showed that larger holes could be permitted for *high-strength bolts* without adversely affecting the bolt shear or member bearing strength. However, the slip resistance can be reduced by the failure to achieve adequate pretension initially or by the relaxation of the bolt pretension as the highly compressed material yields at the edge of the hole or slot. The provisions for oversized and slotted holes in this Specification are based upon these findings and the additional concern for the consequences of a slip of significant magnitude if it should occur in the direction of the slot. Because an increase in hole size generally reduces the net area of a connected part, the use of oversized holes or of slotted holes is subject to approval by the *Engineer of Record*.

3.3.2. Oversized Holes: When approved by the *Engineer of Record*, oversized holes are permitted in any or all plies of *slip-critical joints* as defined in Section 4.3.

**Commentary:**
See the Commentary to Section 3.3.1.

3.3.3. Short-Slotted Holes: When approved by the *Engineer of Record*, short-slotted holes are permitted in any or all plies of *snug-tightened joints* as defined in Section 4.1, and *pretensioned joints* as defined in Section 4.2, provided the applied load is approximately perpendicular (between 80 and 100 degrees) to the axis of the slot. When approved by the *Engineer of Record*, short-slotted holes are permitted in any or all plies of *slip-critical joints* as defined in Section 4.3 without regard for the direction of the applied load.

**Commentary:**
See the Commentary to Section 3.3.1.

3.3.4. Long-Slotted Holes: When approved by the *Engineer of Record*, long-slotted holes are permitted in only one ply at any individual *faying surface* of *snug-tightened joints* as defined in Section 4.1, and *pretensioned joints* as defined in Section 4.2, provided the applied load is approximately perpendicular (between 80 and 100 degrees) to the axis of the slot. When approved by the *Engineer of Record*, long-slotted holes are permitted in one ply only at any individual *faying surface* of *slip-critical joints* as defined in Section 4.3 without regard for the direction of the applied load. Fully inserted finger shims between the *faying surfaces* of load-transmitting elements of bolted *joints* are not considered a long-slotted element of a *joint*; nor are they considered to be a ply at any individual *faying surface*. However, finger shims must have the same faying surface as the rest of the plies.

**Commentary:**
See the Commentary to Section 3.3.1.

Finger shims are devices that are often used to permit the alignment and plumbing of structures. When these devices are fully and properly inserted, they do not have the same effect on bolt pretension relaxation or the *connection* performance, as do long-slotted holes in an outer ply. When fully inserted, the shim provides support around approximately 75 percent of the perimeter of the bolt in contrast to the greatly reduced area that exists with a bolt that is centered in a long slot. Furthermore, finger shims are always enclosed on both sides by the connected material, which should be effective in bridging the space between the fingers.

**Rationale or Justification for Change (attach additional pages as needed):**

# RCSC Proposed Change:  S14-054

**Name:** Tom Murray
**E-mail:** thmurray@vt.edu
**Phone:** 540-731-3330
**Fax:** n/a

**Ballot Actions:**

**Proposed Change:**
Revise Equations 5.7a and 5.7b to add a lower bound to the equation.  The result of each equation must be positive.  There are no modifications to the commentary language.

***{The base language for this change is the revision to Section 5.4 that was approved with ballot S12-042.  The entire section has been included here so that everyone can see the context in which the latest change is located.}***

## 5.4. Design Slip Resistance

Slip-critical connections shall be designed to prevent slip and for the limit states of bearing-type connections.  When slip-critical bolts pass through fillers, all *faying surfaces* subject to slip shall be prepared to achieve design slip resistance.

At US LRFD or Canadian LSD load levels the design slip resistance is $\phi R_n$ and at ASD load levels the allowable slip resistance is $R_n/\Omega$ where $R_n$,, $\phi$ and $\Omega$ are defined below.

The available slip resistance for the limit state of slip shall be determined as follows:

$$R_n = \mu D_u h_f T_b n_s k_{sc} \qquad \text{(Equation 5.6)}$$

For standard size and short-slotted holes perpendicular to the direction of the load
$\phi = 1.00$ (LRFD, LSD) $\quad \Omega = 1.50$ (ASD)

For oversized and short-slotted holes parallel to the direction of the load
$\phi = 0.85$ (LRFD, LSD) $\quad \Omega = 1.76$ (ASD)

For long-slotted holes
$\phi = 0.70$ (LRFD, LSD) $\quad \Omega = 2.14$ (ASD)

where
$\mu$ = mean slip coefficient for Class A or B surfaces, as applicable, and determined as follows, or as established by tests:

-----------------------------------For Committee Use Below---------------------------------------------
Date Received: ______ Exec Com Meeting: _______ Forwarded: Yes ☐ /No ☐

Committee Assignment: Executive -A. ☐ Editorial -B. ☐ Nominating -C. ☐

Specifications -A.1 ☐ Research -A.2 ☐ Membership & Funding -A.3 ☐ Education -A.4 ☐
Committee Chair: ____________ Task Group #: ___________ T.G. Chair: ________________
Date Sent to Main Committee: _______________Final Disposition: ______________________

(1) For Class A surfaces (unpainted clean mill scale steel surfaces or surfaces with Class A coatings on blast-cleaned steel or hot-dipped galvanized and roughened surfaces)

$\mu = 0.30$

(2) For Class B surfaces (unpainted blast-cleaned steel surfaces or surfaces with Class B coatings on blast-cleaned steel)

$\mu = 0.50$

$D_u$ = 1.13; a multiplier that reflects the ratio of the mean installed bolt pretension to the specified minimum bolt pretension; the use of other values may be approved by the engineer of record.

$T_b$ = minimum fastener tension given in Table 8.1, kips

$h_f$ = factor for fillers, determined as follows:

(1) Where there are no fillers or bolts have been added to distribute loads in the filler

$h_f = 1.0$

(2) Where bolts have not been added to distribute the load in the filler:

(i) For one filler between connected parts

$h_f = 1.0$

(ii) For two or more fillers between connected parts

$h_f = 0.85$

$n_s$ = number of slip planes required to permit the connection to slip

$$k_{sc} = 1 - \frac{T_u}{D_u T_b n_b} \geq 0 \qquad \text{(LRFD, LSD)} \qquad \text{(Equation 5.7a)}$$

$$= 1 - \frac{1.5 T_a}{D_u T_b n_b} \geq 0 \qquad \text{(ASD)} \qquad \text{(Equation 5.7b)}$$

where

$T_a$ = required tension force using *ASD load combinations*, kips
$T_u$ = required tension force using US *LRFD or Canadian LSD load combinations*, kips
$n_b$ = number of bolts carrying the applied tension

**Commentary:**

The *nominal strength* $R_n$ represents the mean resistance, which is a function of the *mean slip coefficient* μ and the specified minimum bolt pretension (clamping force) $T_m$. The 1.13 multiplier in Equation 5.6 accounts for the statistical relationship between calculated slip resistance and historical measured test results. In the absence of other field test data, this value is used for all methods.

For most applications, the assumption that the slip resistance at each fastener is equal and additive with that at the other fasteners is based on the fact that all locations must develop the slip force before a total *joint* slip can occur at that plane. Similarly, the forces developed at various slip planes do not necessarily develop simultaneously, but one can assume that the full slip resistances must be mobilized at each plane before full *joint* slip can occur.

The nominal resistance in 5.4 results in a reliability consistent with the reliability of structural member design. The engineer should not need to design to a higher reliability in normal structural applications. The following comments reflect the collective thinking of the Council and are provided as guidance and an indication of the intent of the Specification (see also the Commentary to Sections 4.2 and 4.3):

(1) If *joints* with standard holes have only one or two bolts in the direction of the applied load, a small slip may occur. In this case, *joints* subject to vibration should be proportioned to resist slip;

(2) In built-up compression members, such as double-angle struts in trusses, a small relative slip between the elements especially at the end *connections* can increase the effective length of the combined cross-section to that of the individual components and significantly reduce the compressive strength of the strut. Therefore, the *connection* between the elements at the ends of built-up members should be checked to prevent slip, whether or not a *slip-critical joint* is required for serviceability. As given by Sherman and Yura (1998), the required slip resistance is $0.008P_uLQ/I$, where $P_u$ is the axial compressive force in the built-up member, kips, $L$ is the total length of the built-up member, in., $Q$ is the first moment of area of one component about the axis of buckling of the built-up member, in.$^3$, and $I$ is the moment of inertia of the built-up member about the axis of buckling, in.$^4$;

(3) In *joints* with long-slotted holes that are parallel to the direction of the applied load, the *joint* can be designed to prevent slip, however, the effect of the factored loads acting on the deformed structure (deformed by the maximum amount of slip in the long slots at all locations) must be included in the structural analysis; and,

(4) In *joints* subject to fatigue, design should be based upon service-load criteria and the design slip resistance of the governing cyclic design specification because fatigue is a function of the service load performance rather than that of the factored load.

Extensive data developed through research sponsored by the Council and others during the past twenty years has been statistically analyzed to provide improved information on slip probability of *joints* in which the bolts have been pretensioned to the requirements of Table 8.1. Two variables, the *mean slip coefficient* of the *faying surfaces* and the bolt pretension, were found to affect the slip resistance of *joints*. Field studies (Kulak and Birkemoe, 1993) of installed bolts in various structural applications indicate that the Table 8.1 pretensions have been achieved as anticipated in the laboratory research.

An examination of the slip-coefficient data for a wide range of surface conditions indicates that the data are distributed normally and the standard deviation is essentially the same for each surface condition class. This means that different reduction factors should be applied to classes of surfaces with different *mean slip coefficients*—the smaller the mean value of the coefficient of friction, the smaller (more severe) the appropriate reduction factor—to provide equivalent reliability of slip resistance.

The bolt clamping force data indicate that bolt pretensions are distributed normally for each pretensioning method. However, the data also indicate that the mean value of the bolt pretension is different for each method. If the calibrated wrench method is used to pretension ASTM A325 bolts, the mean value of bolt pretension is about 1.13 times the specified minimum pretension in Table 8.1. If the turn-of-nut pretensioning method is used, the mean pretension is about 1.35 times the specified minimum pretension for ASTM A325 bolts and about 1.26 for ASTM A490 bolts.

The combined effects of the variability of the *mean slip coefficient* and bolt pretension have been accounted for approximately in the single value of the slip probability factor $D_u$ in the equation for nominal slip resistance. This implies that slip will not occur with a beta of at least 2.6 regardless of the method of pretensioning.

The calibrated wrench installation method targets a specific bolt pretension, which is 5 percent greater than the specified minimum value given in Table 8.1. Thus, regardless of the actual strength of production bolts, this target value is unique for a given fastener grade. On the other hand, the turn-of-nut installation method imposes an elongation on the fastener. Consequently, the inherent strength of the bolts being installed will be reflected in the resulting pretension because this elongation will bring the fastener to its proportional limit under combined torsion and tension. As a result of these differences, the mean value and nature of the frequency distribution of pretensions for the two installation methods differ. Turn-of-nut installations result in higher mean levels of pretension than do calibrated wrench installations. Twist-off type tension control bolt and direct tension indicator pretensions are similar to those of calibrated wrench. These differences were taken into account when the design criteria for *slip-critical joints* were developed.

In any of the foregoing installation methods, it can be expected that a portion of the bolt assembly (the threaded portion of the bolt within the *grip* length and/or the engaged threads of the nut and bolt) will reach the inelastic region of behavior. This permanent distortion has no undesirable effect on the subsequent performance of the bolt.

Because of the greater likelihood that significant deformation can occur in *joints* with oversized or slotted holes, lower values of design slip resistance are provided for *joints* with these hole types through a modification of the resistance factor $\phi$. For the case of long-slotted holes, even though the slip load is the same for loading transverse or parallel to the axis of the slot, the value for loading parallel to the axis has been further reduced, based upon judgment, in recognition of the greater consequences of slip.

Although the design philosophy for *slip-critical joints* presumes that they do not slip into bearing when subject to loads in the service range, it is mandatory that *slip-*

*critical joints* also meet the requirements of Sections 5.1, 5.2 and 5.3. Thus, they must meet the strength requirements to resist the factored loads as *shear/bearing joints*.

Section 3.2.2(b) permits the *Engineer of Record* to authorize the use of *faying surfaces* with a *mean slip coefficient* μ that is less than 0.50 (Class B) and other than 0.30 (Class A). This authorization requires that the *mean slip coefficient* μ must be determined in accordance with Appendix A.

Prior to the 1994 edition of this Specification, μ for galvanized surfaces was taken as 0.40. This value was reduced to 0.35 in the 1994 edition for better agreement with the available research (Kulak et al., 1987; pp. 78-82) and to 0.30 in the 2014 edition to be consistent with slip coefficients cited previously.

**Rationale or Justification for Change (attach additional pages as needed):**

$k_{sc}$ as defined above can be less than 0.0 which is not correct.

Table 1.
ASTM A325 Maximum $k_{sc}$ Values

| Bolt, $d_b$ (in) | $T_u = \phi r_n$ (kips) | $T_m$ (kips) | $k_{sc}$ $D_u$=1.13 | $k_{sc}$ $D_u$=1.0 |
|---|---|---|---|---|
| 0.625 | 20.7 | 19 | 0.964 | -0.089 |
| 0.75 | 29.8 | 28 | 0.942 | -0.064 |
| 0.875 | 40.6 | 39 | 0.921 | -0.041 |
| 1 | 53.0 | 51 | 0.920 | -0.039 |
| 1.125 | 67.1 | 56 | -0.060 | -0.198 |
| 1.25 | 82.8 | 71 | -0.032 | -0.166 |
| 1.375 | 100 | 85 | -0.041 | -0.176 |
| 1.5 | 119 | 103 | -0.022 | -0.155 |

Table 2
ASTM A490 Maximum $k_{sc}$ Values

| Bolt, $d_b$ (in) | $T_u = \phi r_n$ (kips) | $T_m$ (kips) | $k_{sc}$ $D_u$=1.13 | $k_{sc}$ $D_u$=1.0 |
|---|---|---|---|---|
| 0.625 | 26 | 24 | 0.957 | -0.083 |
| 0.75 | 37.4 | 35 | 0.946 | -0.069 |
| 0.875 | 51 | 49 | 0.921 | -0.041 |
| 1 | 66.6 | 64 | 0.921 | -0.041 |
| 1.125 | 84.2 | 80 | 0.931 | -0.053 |
| 1.25 | 104 | 102 | 0.902 | -0.020 |
| 1.375 | 126 | 121 | 0.922 | -0.041 |
| 1.5 | 150 | 148 | 0.897 | -0.014 |

# RCSC Proposed Change:  S12-046

**Name:** Chris Curven    **E-mail:** _chrisc@appliedbolting.com
**Phone:** 802-460-3100    **Fax:**

**Ballot History:**

**Proposed Change:**
***{The original proposal was sent to a task group at the 2012 Specification meeting. The task group members are Chris Curven (chair), Victor Shneur, Curtis Mayes, Rich Brown and Pete Birkemoe. The following is the proposal that has come back from the task group.}***

**Glossary**
*{All existing terms in Glossary remain unchanged.}*
*Bolt Tension*. The axial force resulting from elongation of a bolt.

Torque. The moment (turning force) that tends to rotate a nut or bolt.

***{Original proposal in 2012}***
**Glossary**
*{All existing terms in Glossary remain unchanged.}*
*Torque* (noun). **1.** The moment of a force; the measure of a force's tendency to produce torsion and rotation about an axis, equal to the vector product of the radius vector from the axis of rotation to the point of application of the force and the force vector.
**2.** A turning or twisting force.
*(Both copied from The Free Dictionary by Farlex)*
3. A rotational moment; it is a measure of how much twisting is applied to a fastener.
*(Copied from boltscience.com)*

*Torque* (verb). to impart a twisting force. *(copied from The Free Dictionary by Farlex)*

*Tension*. A bolt resistance to elongation that provides a clamping in a bolted connection.

**Rationale or Justification for Change:**

Torque and tension are the two basic terms used in structural bolting with the term torque being used predominantly. However, in the field and in offices, their definitions and physical differences are not understood. The users of this specification would be well served if we provide them with a definition.

-----------------------------------For Committee Use Below--------------------------------------------

Date Received: 5/31/12 Exec Com Meeting: 6/6/12 Forwarded: Yes ☐ /No ☐

Committee Assignment: Executive -A. ☐ Editorial -B. ☐ Nominating -C. ☐

Specifications -A.1 ☐ Research -A.2 ☐ Membership & Funding -A.3 ☐ Education -A.4 ☐
Committee Chair: ____________ Task Group #: ___________ T.G. Chair: ________________
Date Sent to Main Committee: _______________Final Disposition: ______________________

I am not committed to any of the definitions I have offered, but merely would like to use them as a starting point so we CAN include them in the glossary of the specification.

# RCSC Proposed Change:  S14-055

**Name:** Ray Tide **E-mail:** rtide@wje.com
**Phone:** 847-272-7400 **Fax:** 847-291-4813

**Ballot Actions:**

**Proposed Change:**

2.4.2. Geometry: Heavy-hex nut dimensions shall meet the requirements of ANSI/ASME B18.2.6.

**Commentary:**
Heavy-hex nuts are required by ASTM Specifications to be distinctively marked. Certain markings are mandatory. In addition to the mandatory markings, the *manufacturer* may apply additional distinguishing markings. The mandatory markings and sample optional markings are illustrated in Figure C-2.1.

Hot-dip galvanizing affects the stripping strength of the bolt-nut assembly because, to accommodate the relatively thick zinc coatings of non-uniform thickness on bolt threads, it is usual practice to hot-dip galvanize the blank nut and then to tap the nut over-size. This results in a reduction of thread engagement with a consequent reduction of the stripping strength. Only the stronger hardened nuts have adequate strength to meet ASTM thread strength requirements after over-tapping. Therefore, as specified in ASTM A325, only ASTM A563 grade DH are suitable for use as galvanized nuts. This requirement should not be overlooked if non-galvanized nuts are purchased and then sent to a local galvanizer for hot-dip galvanizing. Because the mechanical galvanizing process results in a more uniformly distributed and smooth zinc coating, nuts may be tapped over-size before galvanizing by an amount that is less than that required for the hot-dip process before galvanizing.

To distinguish between hot-dipped galvanized and mechanical galvanized nuts, producers often coat the nuts with different colored lubricants.  A blue coating indicates mechanical galvanized and a green coating indicates hot-dipped galvanizing.  This green coloring infers over-tapped holes prior to the galvanizing operation.

Despite the thin-film of the Zn/Al Inorganic Coating, tapping the nuts over-size may be necessary. Similar to mechanical galvanizing, the process results in a comparatively uniform and evenly distributed coating.

In earlier editions, this Specification permitted the use of ASTM A194 grade 2H nuts in the same finish as that permitted for ASTM A563 nuts in the

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Date Received: ______ Exec Com Meeting: _______ Forwarded: Yes ☐ /No ☐

Committee Assignment: Executive -A. ☐ Editorial -B. ☐ Nominating -C. ☐

Specifications -A.1 ☐ Research -A.2 ☐ Membership & Funding -A.3 ☐ Education -A.4 ☐
Committee Chair: ____________ Task Group #: ___________ T.G. Chair: ________________
Date Sent to Main Committee: _______________Final Disposition: ______________________

following cases: with ASTM A325 Type 1 plain, Type 1 galvanized and Type 3 plain bolts and with ASTM A490 Type 1 plain bolts. Reference to ASTM A194 grade 2H nuts has been removed following the removal of similar reference within the ASTM A325 and A490 Specifications. However, it should be noted that ASTM A194 grade 2H nuts remain acceptable in these applications as indicated by footnote in Table 2.1, should they be available.

ASTM A563 nuts are manufactured to dimensions as specified in ANSI/ASME B18.2.6. The basic dimensions, as defined in Figure C-2.2, are shown in Table C-2.1

**Rationale or Justification for Change (attach additional pages as needed):**

This is a question (inquiry) that has come up several times in the last year or so.  A commentary change in Section 2.4.2 would address the issue.

*Draft for Task Group's Consideration*
*Submitted by K Lohr* REC'D 6/5/14

## A Request for RCSC to re-consider vote on item 5.2 S12-039 Table 2.1 and Commentary

At the 2013 RCSC meeting, a vote was held on item 5.2 S12-039 Table 2.1 – Delete Zn/Al coating from F1852 and F2280 assemblies (Schlafly): (2012-13 Ballot Item 2 summary: 61/3/4 Affirmative/Negative/Abstention). A short discussion was held and the negative voters agreed to remove the negative votes provided they could form a task group to address this issue further in a commentary.

## Task Group's Recommendation (Rational)

The task group has determined that the RCSC should retain Zn/Al coating on F1852 and F2280 bolts in Table 2.1 and associated commentary, because:

- ASTM and RCSC recognize the equivalency of <u>ASTM A490 and A325, with F1852, and F2280 bolts</u>
- Conclusive evidence has determined the coating is safe for ASTM A490, A325, F1852, and F2280 bolts
- Based on this evidence, the ASTM specification allows for this coating on A490s and A325s (not including an explicit mention in the F1852 and F2280 fasteners as well was a simple omission, not a deliberate exclusion)
- In both practice and specifications, these bolts have been considered practical equivalents for decades
- Any concerns about proper fabrication (i.e. the significantly different coefficient of friction generated by the Zn/Al coating in comparison with normal lubricated assemblies, resulting in bolts that have not been properly tensioned) is spurious, as faulty product would be addressed, and any compromised bolts excluded in advance, by the required pre-installation testing.

## Supporting evidence

### Accepted Equivalency

ASTM A325 / A490 & F1852 / F2280 are treated the same throughout the RCSC specification. All require pre-installation verification testing to be conducted prior to use.

Throughout the RCSC Specification, A 325/ F1852 & A490/ F2280 are addressed as equivalents. The same holds true for ASTM: materials, chemistry, hardness, tensile strength, testing etc. are exactly the same. The only difference is that the TC bolts are sold as a set consisting of a bolt, lubricated nut and washer assemblies.

To further support that these bolts are accepted equivalents, it is important to note that for 25 years A325 TC bolts were produce and used under the ASTM A325 Specification until the F1852 was developed; A490 TC bolts were produced for 33 years under the ASTM A490 specification prior to the introduction of the F2280 specification.

ASTM A490 States in Section 4
4.3 *Protective Coatings:*
4.3.1 When a protective coating is required and specified, the bolts shall be coated with Zinc/Aluminum

Corrosion Protective Coatings in accordance with Specification F1136, Grade 3 or Specification F2833, Grade 1. These coatings have been qualified based on the findings of an investigation founded on IFI 144. 6

### Accepted Use of Coatings

These coatings have been qualified based on the findings of an investigation founded on IFI 144

**Section 2.3.3 Commentary (2009 RCSC) states in the fourth** *paragraph*

An extensive investigation conducted in accordance with IFI-144 was completed in 2006 and presented to the ASTM F16 Committee on Fasteners (F16 Research Report RR: F16-1001). The investigation demonstrated that Zn/Al Inorganic Coating, when applied per ASTM F1136 Grade 3 to ASTM A490 bolts, does not cause delayed cracking by internal hydrogen embrittlement, nor does it accelerate environmental hydrogen embrittlement by cathodic hydrogen absorption. It was determined that this is an acceptable finish to be used on Type 1 ASTM A325 and A490 bolts and F1852 and F2280 twist-off-type tension-control bolt assemblies.

Based on the above, in 2009 RCSC adopted the use of this coating on both grades ASTM A490, A325, F1852, and F2280 bolts, based on ASTM information that the coating would be published in the upcoming ASTM specification. Unfortunately, due to an oversight, when ASTM published the new specification, the coating was only listed under A325 & A490, not explicitly extended to F1852 and F2280 (although their inclusion is implicit, given their equivalency). Conversations with a number of ASTM Members indicated the exclusion was a simple oversight.

Commentary under Section 1.1 Scope, states: That ASTM A490, A325, F1852, and F2280 are equivalent.
**Commentary:**
This Specification deals principally with two strength grades of *high-strength bolts*, ASTM A325 and A490, and with their design, installation and inspection in structural steel *joints*. Equivalent fasteners, however, such as ASTM F1852 (equivalent to ASTM A325) and F2280 (equivalent to ASTM A490) twist-off type Tension control bolt assemblies, are also covered.

### Pre-Installation Testing Requirement protects against improper fabrication

On the RCSC Proposed Change: *S12-039* there was a concern raised *regarding the proper fabrication of the assembly parts given the significantly different coefficient of friction generated by the Zn/Al coating in comparison with normal lubricated assemblies. This difference could result in bolts that have not been properly tensioned.*

However, under the RCSC Specification, both the Hex and the TC are required to pass the Pre-Installation verification testing prior to use in the work. Neither can be used if they fail this testing, based on this we feel this concern is unfounded and inconsequential in practical terms.

There are also sufficient safeguards listed in ASTM that require the manufacturer to conduct and report testing to assure the fastener sets meet the specification. The RCSC requires additional safeguards to ensure fasteners must pass the pre-installation verification testing prior to use on a project.

### Common Use

Since the RCSC 2009 publication, millions of *Zn/Al coated* ASTM A490, A325, F1852, and F2280 bolts have been supplied to projects in the US, Canada and throughout South America, on power plants, chemical plants, industrial, paper mill and mining construction. Many projects are currently ongoing, with more starting up. Many of these projects are long term and have been under construction for a number of years, with projected construction times of up to 6 to 8 additional years.

There have been countless successful installations using Zn/Al Inorganic Coatings; withholding the coating specification out of a theoretical concern (that, in fact, the current required testing would prevent) would unnecessarily penalize suppliers of fasteners that can be properly tensioned, as well as all parties involved on current ongoing projects.

## Conclusion

Based on the above the Zn/Al Inorganic Coating should be explicitly included on F1852 / F2280 fasteners in ASTM RCSC. There is no practical difference between these fasteners and their non-TC equivalents, and current testing requirements safeguard against improper fabrication.

## Implementation

Ballot ASTM to include the coating verbiage for Zn/Al Inorganic Coating on F1852 / F2280 fasteners and for RCSC to retain the wording in our commentary as well as make applicable additions to Table 2.

2009 Modified RCSC Snug Tightened Joint Definition

vs…

Turn-of-Nut Method

# Task Committee “New” 2009 Snug tight definition vs.. turn of nut rotation values

Members

| | |
|---|---|
| Curtis Mayes (chair) | Peter Birkemoe |
| Paul Jefferson | Peter Kasper |
| Chad Larson | Jon McGormley |
| Victor Shneur | Gene Mitchell |

Chronology:

Dec 31, 2009, Revised RCSC Bolt Spec Published with new Snug Tight Definition

July, 2012 – LPR Training Program discovers mismatch of 2009 Snug tight rules vs. Turn of Nut Rotation Table 8.2

June 6, 2013 RCSC assigns Task Group

June 5, 2014. Today. Our first real opportunity to correct our error.

December 31, 2014 Mismatch solved,
or we risk 6 more years of the potential of failing connections due to this oversight.

These rotations were developed using an initial snug tightness similar to RCSC 2004 snug tight definition

**Table 8.2. Nut Rotation from Snug-Tight Condition for Turn-of-Nut Pretensioning [a,b]**

| Bolt Length [c] | Disposition of Outer Faces of Bolted Parts | | |
|---|---|---|---|
| | Both faces normal to bolt axis | One face normal to bolt axis, other sloped not more than 1:20 [d] | Both faces sloped not more than 1:20 from normal to bolt axis [d] |
| Not more than $4d_b$ | ⅓ turn | ½ turn | ⅔ turn |
| More than $4d_b$ but not more than $8d_b$ | ½ turn | ⅔ turn | ⅚ turn |
| More than $8d_b$ but not more than $12d_b$ | ⅔ turn | ⅚ turn | 1 turn |

Commitment to Safety and Quality

LPR

CONSTRUCTION

# Snug Tightened Joint Definition:

A joint in which the bolts have been installed in accordance with Section 8.1. Snug tight is the condition that exists when all of the plies in a connection have been pulled into firm contact by the bolts in the joint and all of the bolts in the joint have been tightened sufficiently to prevent the removal of the nuts without the use of a wrench.

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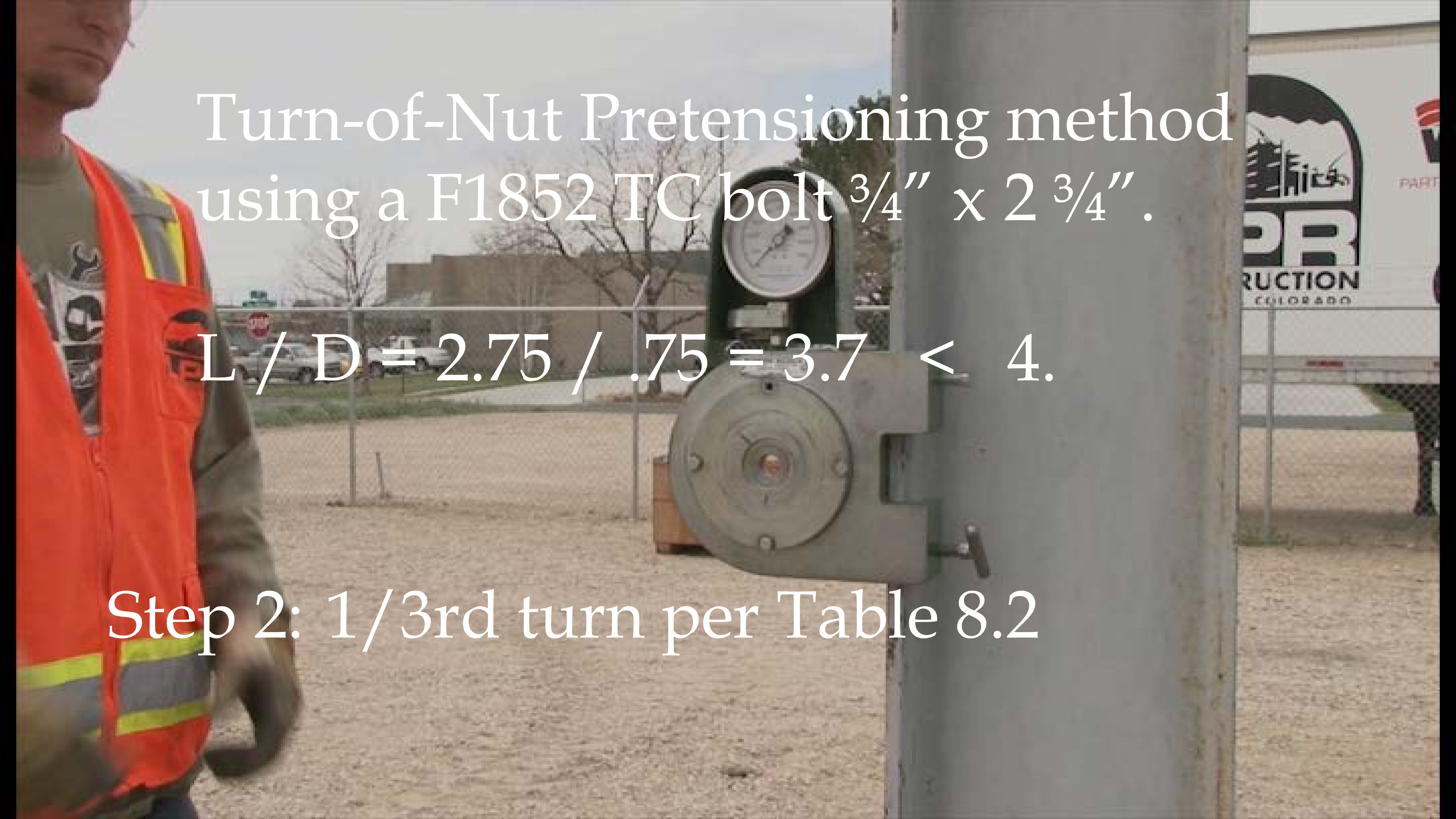
RCSC 2009

Turn-of-Nut Pretensioning method using a F1852 TC bolt ¾″ x 2 ¾″.

$L / D = 2.75 / .75 = 3.7 < 4$.

Step 1: Snug tighten just beyond finger tight



Turn-of-Nut Pretensioning method using a F1852 TC bolt ¾″ x 2 ¾″.

$L / D = 2.75 / .75 = 3.7 < 4.$

Step 2: 1/3rd turn per Table 8.2


COLORADO

Following the most recent 2009 RCSC rules, the resulting fastener tension for this example is 16 kips, which is only…

Following the most recent 2009 RCSC rules, the resulting fastener tension for this example is 16 kips, which is only… 55% of the minimum specified Skidmore pretension of 29 kips.

Can we allow this mismatch to exist for another 6 years?

Granted preinstallation verification exists as a stop gap measure, but what if preinstallation verification does not happen? Many think Turn of Nut is infallible, but RCSC accidently  made it very fallible in 2009.

# Task Committee Proposed Solution:

It must be simple for us to move forward and act now.

**Revert Snug Tight Definition to 2004 Definition.**

"The snug-tightened condition is the tightness that is attained with a few impacts of an impact wrench or the full effort of an ironworker using an ordinary spud wrench to bring the connected plies into firm contact." (2004)

**From:** Carter, Charlie [mailto:carter@aisc.org]
**Sent:** Friday, December 06, 2013 9:51 AM
**To:** Harrold, Allen J.
**Subject:** Fwd: Slip Coeff Testing

Al,

Please see the message from Karl below. Shall we accept his offer?

By the way, I'm still herding votes to make the ballot valid. It is unbelievable the number of people who can't seem to be bothered to vote even on a simple ballot.

Charlie

---------- Forwarded message ----------
From: **Karl Frank** <karl.frank@hirschfeld.com>
Date: Thu, Dec 5, 2013 at 4:40 PM
Subject: Slip Coeff Testing
To: "Carter, Charlie" <carter@aisc.org>
Cc: "Justin.Ocel@dot.gov" <Justin.Ocel@dot.gov>, "Helwig, Todd A" <thelwig@mail.utexas.edu>, "yura@mail.utexas.edu" <yura@mail.utexas.edu>, Bill McEleney <mceleney@aisc.org>

Charlie,

As you may be aware, there are two research programs underway to address issues with measurement of the slip coefficient and the ability of commercial coatings to attain the specified/ expected values. One project sponsored by FHWA is concerned with organic zinc rich paints. There have been problems with the organic coatings meeting a slip coefficient of 0.50. This work is part of Justin Ocel's research program and consists of a round robin testing program that includes the FHWA lab, KTA and CCC&L. This program includes paints from at least 3 suppliers. In addition, Todd and Joe have a program looking at the performance of galvanized coatings slip performance. These programs may result in new specified slip coefficient values for design. One issue that needs to be addressed is if we lower the value for organic zinc rich paint must we also lower the value for inorganic zinc rich or should they have different values. Presently, blasted and all zinc rich paints have the same value of 0.50. The British specification uses 0.40 for the paints. NSBA has fund Mike Grubb to look the effect of lowering the slip coefficient for the coating in bridge design. He found the shear/bearing strength controls the connections and lowering the coefficient to 0.45 or even 0.40 will not affect bridge design.

As part of this work, we have uncovered some areas were the testing specification that requires updating:

1. Defining the load to be used in the creep test that is independent of the design specification, should be the same load for bridges and buildings.

2. Tightening up what clamping force should be used to calculate the slip test load.

3. Lowering the post slip load to something less the mean slip load.

4. Minor edits to handle removal of paint on the edges of the slip specimens.

I suggest that a task group within RCSC be formed to address these issues. I would be happy to chair the task force if you wish. I would suggest that Justin, Todd, Joe and I be on the task group. You might want to consider someone from testing labs KTA and CCC&L: and maybe some paint manufacturers.

Let me know how you want to proceed on this topic.


Karl H. Frank

Chief Engineer

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HIRSCHFELD INDUSTRIES BRIDGE


**From:** Bob Shaw - SSTC [mailto:rshaw@steelstructures.com]
**Sent:** Wednesday, May 28, 2014 4:05 PM
**To:** 'Carter, Charlie'; Harrold, Allen J.
**Cc:** schlafly@aisc.org; Larry Muir
**Subject:** XTB (200 ksi tensile strength) bolts - standards status

At Tom's request, here's a status report:

At ASTM, we are very close to having a standard for the twist-off type tension control bolt. We have to add language on dephosphating, something at the manufacturing stage prior to heat treatment, that was agreed upon in F16.02 meeting earlier this month. It will be balloted this summer, and assuming nothing happens on the three sentences anticipated, we will have a complete standard in place for these bolts this Fall. The other 33 pages of the standard has now been approved, and is no longer subject to balloting.

For the heavy hex type, we will be submitting this for ASTM F16.02 ballot later this month. It replicates all we have on the twist-off, with the exception of changing the head dimensions, adding a chamfered washer for placement under the head, removing the twist-off type assembly test, and providing the Appendix for pre-installation verification testing, pretensioning, and inspection using turn-of-nut. I anticipate this to go a bit smother that the twist-off, as many of the issues like thread profile have been resolved.

As for RCSC, after Cincinnati's presentation at the Annual meeting, it was discussed that I would prepare a separate RCSC Spec for these bolts, rather than try to merge it into the existing Spec. This was for both timing and technical reasons. This work is underway, and I should have something for you to look at just before Estes Park. It is on the agenda to overview this work in the last moments of the Spec Committee meeting. It will include twist-off, turn-of-nut, and calibrated wrench, but DTIs will have to wait until we have samples made and tested with the bolts. Cincinnati's final report has been slow in coming, as has Virginia Tech's, so the final touches will not be in place until October. Most of what is needed is the written conclusions of what I've been told the results are (and I've looked at hundreds of individual test results), but I have also asked for a more thorough review of data to provide proper tolerances for turn-of-nut. I'd hope that we can go through both a Fall and a Spring written ballot of the new RCSC Spec, and have it ready for final approval at the 2015 meeting.

As for AISC, I'm obviously trying to get things in place for adoption into 360-16, and have provided a draft to Tom and Larry of what would be added to 360 (Chapters A and J) for inclusion of these bolts. I am working on Commentary. Final Commentary will have to follow final reports from UC and VT. I also have to create some design examples. Since we have already done some comparison studies on real project heavy connections, we've been down that path already. All the design rules remain the same, we just have a fastener Group C to use for strengths and pretensions.

Should we run into a hornet's nest at RCSC, I think we can rely upon the ASTM Appendices that address what RCSC would provide for installation and inspection.  That's why it is there – until we have RCSC in place. I'll get you a copy of the latest ASTM.

By the way, everything will be predicated on using what has been termed Grade 2 fastener assemblies (or bolt assemblies). These use the XTB thread profiles that have been used in Japan and have been subjected to the testing here in the US. The UNJ thread profiles added to the standard at the ASTM meeting in November (that we discussed at AISC in November) that have not yet been manufactured by anyone and remain untested, have a different stress area and hence different pretensions, and have a higher stress concentration at the root, are not included in the RCSC or AISC materials. I'm sure RCSC would not support an untested fastener, and AISC would feel the same. Grade 1 assemblies (so termed because they are of a lower strength for tensile load and pretension) will be excluded. If someone decides to make some and have them tested, then we can consider that for the next round.

Obviously, I am an optimist, but working hard to satisfy everyone's concerns and keep everything on track. Any questions?

Thanks for listening,

Bob

## RCSC SPECIFICATION COMMITTEE ORGANIZATION

To ease the workload of the next Specification Committee Chairman I have done some thinking in relation to the formation of some standing task groups under the Specification Committee umbrella. Chad Larson has implemented a similar approach at the ASTM F16.02 subcommittee. The approach is to have the majority of committee business initially handled by appropriate smaller groups. Ideally each group would have somewhere in the range of 10-15 active members with a reasonable distribution of users, general interest, producers, etc.. This should allow the Specification Committee to complete their business in a more timely fashion while also giving proposals more in-depth evaluation at the early stages of the process.

The ad-hoc task groups that spring up to address specific issues could still function under the auspices of the more formal task groups much in the fashion they do today.

My initial breakdown of standing task groups would look something like this. Some sections of the Specification lend themselves to easy grouping while others are a bit more variable in terms of their best locations.

Task Group A.1.1 General Requirements and Components (Sections 1 and 2)

Task Group A.1.2 Joint Types and Non-Hardware Components (Sections 3, 4, and 6)

Task Group A.1.3 Design (Section 5 and Appendix A)

Task Group A.1.4 Installation (Section 7, 8, and 9)

Task Group A.1.5 XTB Specification

Glossary and symbol items would be based on the section where the term or symbol is first referenced.

None of this is cast in stone at the present time, and the group may find that none of this is logical at all.

Looking at the current agenda and adding each existing agenda item to the appropriate task group could look something like this.

Task Group A.1.1

| | | |
|---|---|---|
| | Item 6.3 | S12-046 – Glossary definition of Torque |
| | Item 6.4 | S14-055 – Lubricant Color |
| | Item 7.1 | S13-039 – Non-ASTM approved coatings |
| | Item 7.3 | S13-050 – Bolt Length Increments |
| | Item 8.1 | Thick Coatings |

Task Group A.1.2

| | | |
|---|---|---|
| | Item 5.1 | S12-047B – Hole Definitions |
| | Item 5.3 | S13-052 – Use of Washers |
| | Item 6.1 | S14-053 – Larger Standard Holes for Large Bolts |
| | Item 7.2 | S13-049 – Hardened Washers with DTI's |
| | Item 8.3 | Oversize Holes – Slip Critical? (Shear Connections) |

Task Group A.1.3

| | | |
|---|---|---|
| | Item 6.2 | S14-054 – Limitation on $k_{sc}$ Equations |
| | Item 7.6 | Appendix A – Updates to testing protocol |
| | Item 8.2 | Shear Allowables |

Task Group A.1.4

| | | |
|---|---|---|
| | Item 5.2 | S13-051 – Snug Tight Inspection |
| | Item 5.4 | S12-040 – Removal of DTI "hardened" requirement (This could also fall under TG A.1.1 if it were deemed the allowance should be under Section 2.6 rather than the current section 8.2.4) |
| | Item 7.4 | Match-marking language for Turn of the Nut |
| | Item 7.5 | Snug Tight Definition – Turn of the Nut |

Task Group A.1.5

| | | |
|---|---|---|
| | Item 8.4 | XTB Specification |