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TENSILE AND BEARING CAPACITIES OF BOLTED CONNECTIONS

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PREFACE

Experimental studies were preformed to investigate the tensile capacity, bearing capacity and the interaction of tension and bearing capacities of flat sheet cold-formed steel bolted connections. The effect of bolt hole deformation on the bearing capacity of bolted connections, was also investigated. In the experimental investigation, single shear flat sheet connections were investigated for single bolt and multiple bolt configurations.

The intent of this investigation was to compare the current AISI and AISC Specifications for the nominal bearing and tensile capacities and to develop appropriate serviceability design criteria.

A review and evaluation of past research on the tensile and bearing capacity of bolted flat sheet connections was performed and is discussed.

The test results indicated that for connections failing in bearing, the AISI Specification correlated better with the test results than did the AISC Specification; for tension failure, both specifications correlated similarly to the test results. An analysis and discussion of the test results is included, as well as the development of a serviceability limit for nominal bearing capacity.

This report is based on a thesis presented to the Faculty of the Graduate School of

the University of Missouri-Rolla in partial fulfillment of the requirements for the degree of Master of Science.

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I. INTRODUCTION

A. GENERAL

In the United States, the design of cold-formed steel bolted connections is based on the AISI Specification for the Design of Cold-Formed Steel Structural Members[1]. Prior to the development of the design criteria, bolted connections were tested at the University of Michigan in the 1940's and then at Cornell University in the 1950's. Since 1960, additional connections have been tested at Cornell University, University of Missouri-Rolla, University of Wyoming and other institutions.

This previous research studied only bolted connections in flat sheets. The structural behavior of cold-formed steel tension members has not been fully studied, particularly for profile sections connected by mechanical fasteners. For some design cases, particularly for structural members, Sections C2 and E3.2 of the AISI Specification[1] for determining the tensile capacity of bolted connections may be inappropriate. This is especially true for connections containing connected parts other than flat sheets.

The current design provisions for the bearing capacity of bolted connections included in Section E3.3 of the AISI Specification[1] were based on the ultimate bearing capacities between the connected parts and the bolts. In order to reach the ultimate bearing capacities, it may be necessary to have large deformations around the bolt hole. Therefore, if the deformation around the hole is a critical design consideration, Section E3.3 may be found to be unconservative.

B. PURPOSE OF INVESTIGATION

The purpose of this investigation was to study the tensile capacity, bearing capacity, and the interaction of tensile and bearing capacities of connected flat sheets in bolted connections, and to develop the appropriate design recommendations.

C. SCOPE OF INVESTIGATION

The investigation consisted of a review of pertinent literature, an analysis of available test data, an experimental study of bolted connections using flat steel sheets, and an analysis of the experimental results.

A compilation of the available test data and analytical study of this data is contained herein. The analytical study consisted of a comparison between tested failure load and predicted failure load, where the predicted load was computed by each of the following:

(1) AISI Specification[1]

(2) AISC Specification[2]

(3) ECCS Recommendations[3]

(4) British Standard[4]

(5) Canadian Standard[5]

(6) Zadanfarrokh's Method[6]

The summary of pertinent literature is contained in Section II. The experimental phase of this investigation explored the bearing and tensile strength behavior of thin steel sheets

connected by bolts. Particular emphasis was placed on defining the influence of hole deformation on load capacity of a connection. The development of appropriate design recommendations and a summary of the research findings are presented in Section V.

II. LITERATURE REVIEW

A. GENERAL

For this phase of the investigation, relavant publications and research reports have been studied in detail. These publications and reports focus on the bearing and tensile capacities of cold-formed steel bolted connections. The purpose of the literature review was to study the previous experimental investigations on bearing and tensile capacities of cold-formed steel bolted connections, and to utilize the data from these studies to evaluate current design equations.

In the review of previous experimental studies, it was found that Winter[7,8] observed four general failure modes in cold-formed steel bolted connections:

TYPE I - Longitudinal shearing of the steel sheet along two practically parallel planes whose distance of separation equals the bolt diameter (Fig. 1a).

TYPE II - Bearing failure or "piling up" of material in front of the bolt (Fig. 1b).

TYPE III - Transverse tearing of the sheet in the net section (Fig. 1c).

TYPE IV - Shearing of the bolt (Fig. 1d).

A fifth failure mode was defined by Yu and Mosby [9] as:

TYPE V - Tearing of the sheet caused by the excessive bolt rotation and dishing of the sheet material (Fig. 1e)

Often a combination of these failure modes was observed.

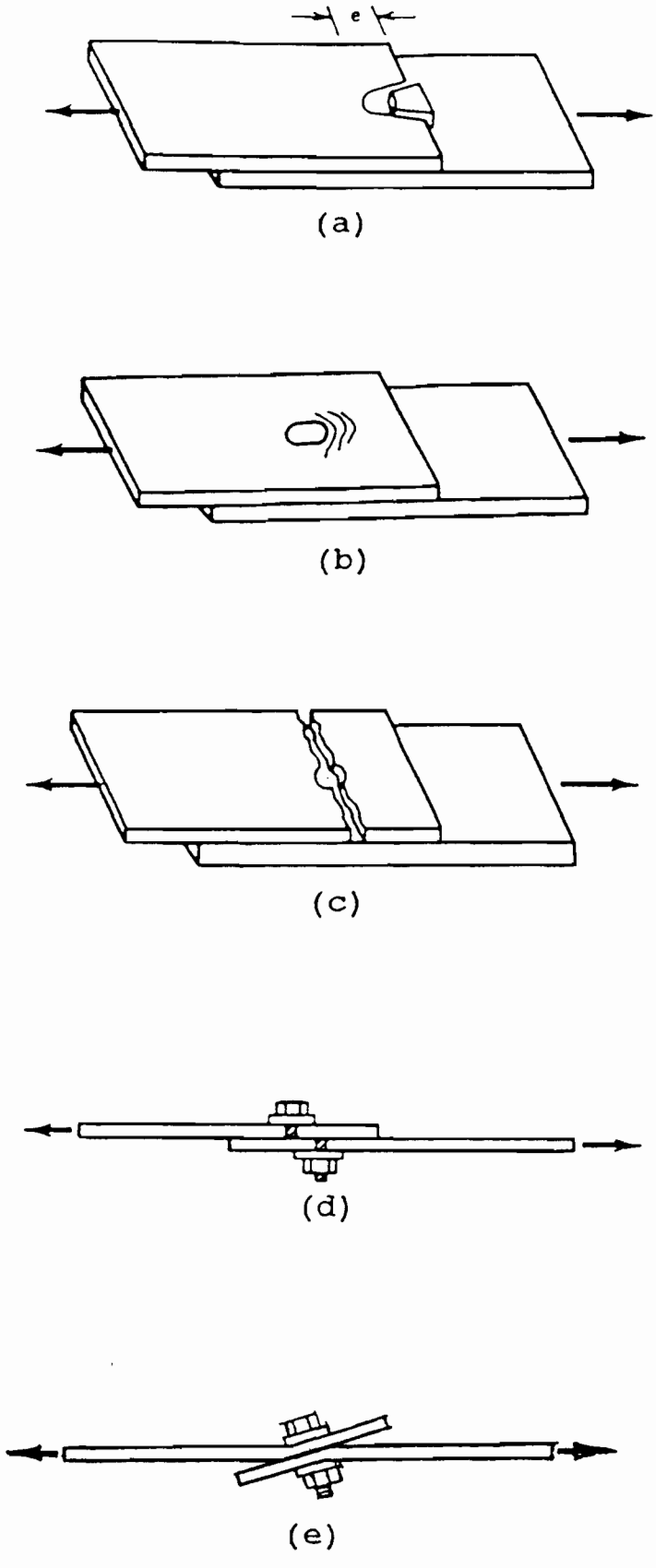


Figure 1. Failure Types Of Bolted Connections[10].

During the review of previous experimental studies due consideration was given to the following parameters which may affect the tensile and bearing capacities of bolted connections:

a) Bolt diameter, d

b) Edge distance, e (Fig. 2)

c) Bolt spacing parallel to the direction of stress, e1 (Fig. 2)

d) Bolt spacing normal to the direction of stress, s (Fig. 2). For a single bolt, s is the full width of the connected sheet.

e) Thickness of connected sheet, t

f) Yield stress, F_y

g) Tensile strength, F_u

h) e/d, d/t, d/s and F_u/F_y ratios

i) Number of bolts

j) Use of washers

k) Single or double shear connections

B. BEARING CAPACITY STUDIES

From tests performed at Cornell University[11, 12, 13, 14], Winter [7,8] concluded that a type of failure by bearing will control the load carrying capacity of a bolted connection when the edge distance of a bolt is relatively large. Tests results indicated that when the e/d ratio is equal to or greater than 3.5, the ultimate bearing stress can conservatively be determined by:

$$\sigma_b = 4.9F_y \qquad \text{(Eq. 1)}$$

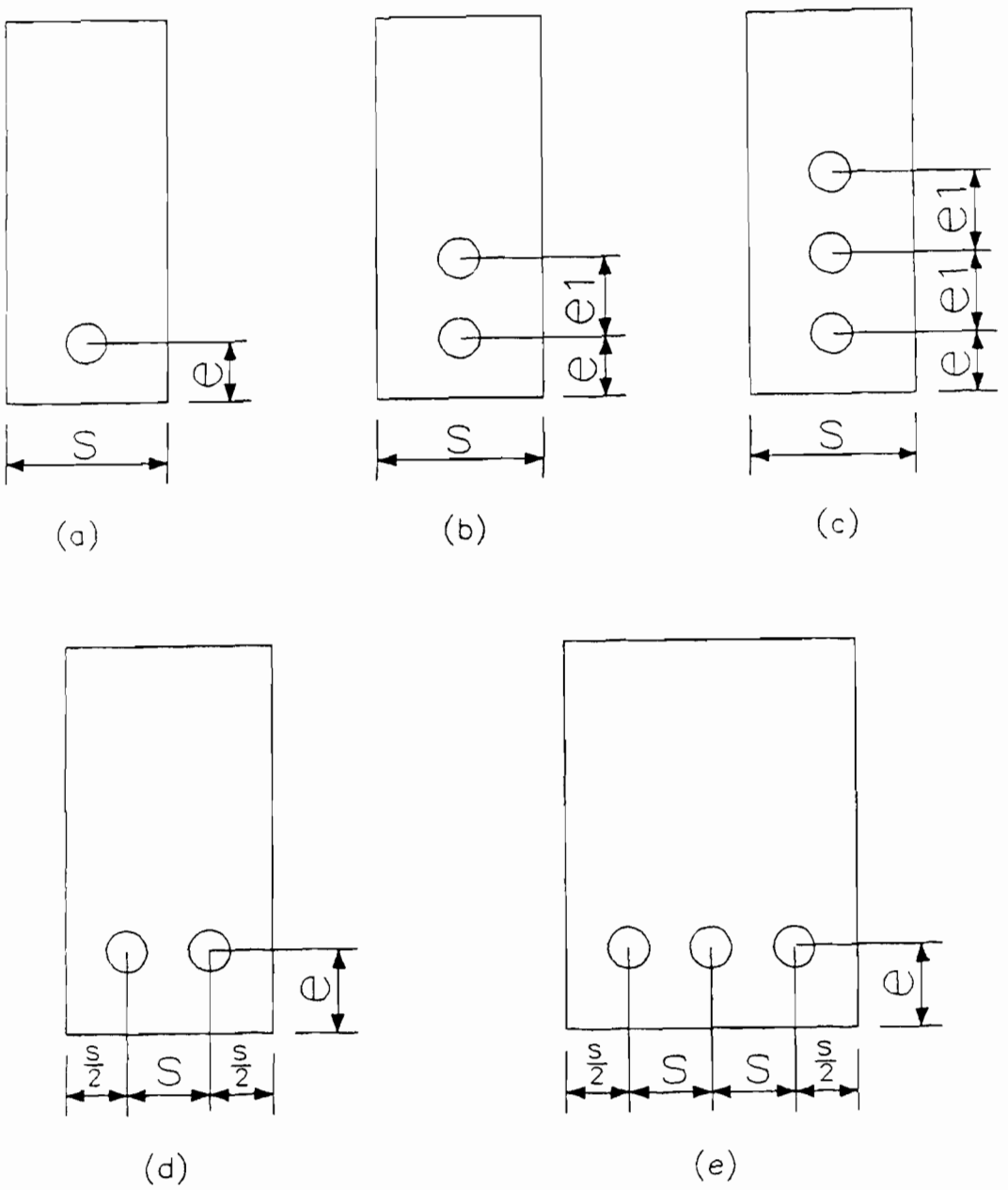


Figure 2. Test Specimens Of The Available Data.

Winter's[7,8] results also indicated that when the e/d ratio is less than 3.5, longitudinal shearing of the sheet, Type I failure mode, will occur.

The following allowable bearing stress, F_p, given in the 1968 AISI Specification[15] was derived from Equation 1 by applying a safety factor of 2.33:

$$F_p = 2.1F_y \qquad \text{(Eq. 2)}$$

Based on their studies, Dhalla et al.[16,17] indicated that connections may be one of the most critical problem areas for low ductility steels. Usings Dhalla's findings, McKinney, Liu and Yu[18] showed that the ultimate load capacity from bearing tests for both low and high ductility steel can be predicted using a single equation, provided the proper ductility factor is used. The ductility factor, C_2 was determined as:

$$C_2 = 1.0 \text{ for } F_u/F_y \geq 1.35 \qquad \text{(Eq. 3)}$$

$$C_2 = 1.43(F_u/F_y)-0.93 \geq 0.643 \text{ for } 1.05 < F_u/F_y < 1.35 \qquad \text{(Eq. 4)}$$

McKinney, Liu and Yu[18]recommended that Equations 1 and 2 be modified to express the ultimate bearing stress (Eq. 5) and allowable bearing stresses (Eq. 6) for any steel:

$$\sigma_b = 4.9C_2F_y \qquad \text{(Eq. 5)}$$

$$F_p = 2.1C_2F_y \qquad \text{(Eq. 6)}$$

Yu and Mosby[19] studied the effect of e/d on the bearing stress, and showed that when e/d is equal to 3.5, the experimental values of σ_b/C_2F_y for both single shear and double shear connections can be predicted by Equation 5. They also showed that Equation 5 provides a better prediction of σ_b/C_2F_y for single shear connections than for double shear connections; double shear connections gave more conservative results of bearing strength.

The 1968 AISI Specification[15] provisions for allowable bearing stress were based on tests performed at Cornell on bolted connections with washers under the bolt head and nut. To study the influence of washers on the bearing stress of bolted connections, Chong and Matlock[20] conducted experimental studies on bolted connections without washers. The maximum bearing stress at failure for connections without washers was found to be approximately 45% less than for connections with washers. The following expression was proposed to predict ultimate bearing stress of connections without washers:

$$\sigma_b = 2.7F_y \text{ for } e/d > 2.5 \qquad \text{(Eq. 7)}$$

Considering the effects of ductility on the bearing strength of bolted connections, Yu and Mosby[19] proposed the following modification to Equation 7 to account for the affect of ductility on bearing strength:

$$\sigma_b = 3.5C_2F_y \text{ for } e/d > 2.5 \qquad \text{(Eq. 8)}$$

where C_2 is given by Equations 3 and 4. Using a factor of safety of 2.3, Yu and Mosby[19] also proposed Equation 9 to predict the allowable bearing stress of bolted connections without washers:

$$F_p = 1.5C_2F_y \text{ for } e/d > 2.5 \qquad \text{(Eq. 9)}$$

From tests conducted at the University of Missouri-Rolla, Yu and Mosby[9] found that for single shear and double shear connections composed of thin sheets, the ultimate

bearing stress can be determined accurately in terms of the ultimate tensile strength, F_u, instead of the yield point of the sheet, F_y. Two separate design formulas were proposed for connections with washers (Eq. 10) and without washers (Eq. 11).

$$\sigma_b = 3.00F_u \qquad \text{(Eq. 10)}$$

$$\sigma_b = 2.22F_u \qquad \text{(Eq. 11)}$$

The revised provisions for bearing stress in bolted connections in the 1980 AISI Specification[21]were based on Equations 10 and 11.

Since the diameter of the bolt to the thickness of the steel sheet, d/t, is considerably larger for cold-formed steel bolted connections than for hot-rolled steel connections, it was once believed that the d/t ratio might affect the bearing strength of bolted connections. From their investigation, Yu and Mosby[19] determined that an increase in the d/t ratio will result in a slight increase in the ultimate bearing stress for single shear connections and a slight decrease in the ultimate bearing stress for double shear. They concluded that the effect of d/t on bearing stress is relatively small and noted that only a limited number of data was available in the region $9 \leq d/t \leq 15$.

C. TENSILE CAPACITY STUDIES

For hot-rolled steel sections it is often assumed that for the design of steel shapes in tension, the average stress on the net section can reach the yield point of the steel. This assumption is based on the idea that the effect of stress concentrations at bolt holes are made insignificant by plastic stress redistribution. Based on his research, Winter[7,8]

concluded that for cold-formed steel bolted connections with the ratio d/s ≤ 0.3, the effect of stress concentrations can not be neglected. Winter[7,8] developed the following equation for the ultimate tension stress for single bolt connections:

$$\sigma_{net} = (0.1 + 3.0d/s)F_u \leq F_u \qquad \text{(Eq. 12)}$$

For connections with multiple bolts in the line of stress, Popowich[22] found that the sharp stress concentrations in cold-formed steel bolted connections can be significantly relieved when more than one bolt in the line of stress is used. His test results showed that failure in the net section for connections with two and three bolts in the line of stress occurred at a much higher stress than for single bolts. Popowich[22] developed the following equation to predict the failure stress in the net section for single and multibolt connections:

$$\sigma_{net} = (1\text{-}0.9r + 3.0rd/s)F_u \leq F_u \qquad \text{(Eq. 13)}$$

where, r is the force transmitted by the bolt or bolts at the section considered, divided by the force in the member at that section. If r is 1.0, Equation 13 will be identical to Winter's equation for tension stress (Equation 12).

Yu and Mosby[19] showed that Equation 12 gives a good prediction of the tensile strength for high and low ductility single shear and double shear cold-formed steel bolted connections. The study by Yu and Mosby[19] also showed that Equation 13 gave a conservative prediction of their test results.

The effect of ductility on cold-formed steel connections was studied by Dhalla[16]. From his studies, Dhalla concluded that the ultimate tensile stress of cold-formed bolted connections is not affected by ductility of the steel.

Yu and Mosby[19] investigated the effect of d/t ratio on the tensile strength of cold-formed steel bolted connections. From these studies, they showed that the d/t ratio has no significant effect on tensile strength and suggested that more studies for combination of $d/t > 10$ and $d/s < 0.15$ be performed.

The 1968 AISI Specification[15] equations for tensile strength were based on tests where washers were used under both the bolt head and nut. Chong and Matlock[20], studied cold-formed bolted connections without washers and developed the following equation for tension in the net section:

$$\sigma_{net} = (0.60\text{-}0.66r + 2.92d/s)F_u \leq F_u \qquad \text{(Eq. 14)}$$

Yu and Mosby[19] noted the following difference between Equation 13 and Equation 14. Equation 13 depended on the parameter "r" and "rd/s" and Equation 14 depended on "r" and "d/s".

Yu and Mosby[23] studied the effect of washers on the tensile capacity of bolted connections and developed the following allowable tensile stress equations:

for double shear with washers,

$$F_t = (1.0\text{-}0.9r + 3.0rd/s)0.5F_u \leq 0.5F_u \qquad \text{(Eq. 15)}$$

for single shear with washers,

$$F_t = (1.0\text{-}0.9r + 3.0rd/s)0.45F_u \leq 0.45F_u \qquad \text{(Eq. 16)}$$

when washers are not used or when only one washer is used,

$$F_t = (1.0\text{-}r + 2.5rd/s)0.45F_u \leq 0.45F_u \qquad \text{(Eq. 17)}$$

Equations 15, 16 and 17 were included in the revised 1980 AISI Specification[21]. Yu and Mosby[23] noted a 13% strength increase in the 1980 AISI Specification[21] over the 1968 AISI Specification[15] for the allowable tension stress.

A study performed by LaBoube[24]demonstrated that the tensile stress in the net section is not influenced by the use of washers. In this study, LaBoube also showed that the ultimate tensile force, P_n, can be predicted by Equation 18:

$$P_n = F_u A_e \qquad \text{(Eq. 18)}$$

where A_e is the effective net area through the section, perpendicular to the line of force. LaBoube[24] pointed out that the data used to derive the current AISI Specification[1] provisions for tension in the net section, Equations 15,16 and 17, was from tests that failed by tension in the net section or a combination of tension in the net section and bearing. Therefore, Equations 15, 16 and 17 estimate the combined bearing and tension in the net section limit state, in addition to the limit state of tension in the net section.

A study by Macadam[25] indicated that a tensile failure will eventually occur in a test specimen, following excessive bearing deformation. Macadam agreed with LaBoube[24] in that the failure mode of tension in the net section could be predicted by Equation 18.

D. COMBINED BEARING AND TENSILE CAPACITY STUDIES

A very limited amount of data was found on the combined failure mode of bearing and tension in the net section. As previously mentioned, LaBoube[24] pointed out that Equations 15, 16 and 17 actually predicted the failure modes of tension in the net section and the combination of tension in the net section and bearing. LaBoube[24] studied the combined failure mode and developed the following equation for the combined stress condition:

$$f_p = (3.41\text{-}0.0224F_u)CF_u \qquad \text{(Eq. 19)}$$

where C is taken as 1.0 when no washers are used, or when washers are used under only the bolt head or nut. When washers are used under the bolt head and nut and the bolt diameter is greater than or equal to 3/4 inch, C is taken as 1.2, when the bolt diameter is less than 3/4 inch, C is taken as 1.5. LaBoube[24] concluded that the sheet tearing may be perpendicular or parallel to the direction of loading.

E. DESIGN SPECIFICATIONS

Internationally recognized design specifications, standards and reports have been reviewed and studied. These specifications are as follows:

1. AISI Specification[1]
2. AISC Specification[2]
3. ECCS Recommendations[3]
4. British Standard[4]
5. Canadian Standard[5]
6. Zadanfarrokh's Method[6]

A detail explanation of these documents is presented in Section III.

III. EVALUATION OF EXISTING DATA

A. GENERAL

A compilation of the available test data[7-9, 11-13, 16, 18, 20, 24-27] is listed in the tables of Appendices A through G. This data represents the results of flat sheet connections as illustrated by Figure 2. Each table includes the following dimensions and test results for each test specimen:

1. Dimensions

   a) Single or double shear connections

   b) Number of bolts

   c) Use of washers

   d) Bolt diameter, d

   e) Thickness of connected sheets, t

   f) Edge distance, e

   g) Bolt spacing parallel to the direction of stress, e1

   h) Bolt spacing normal to the direction of stress, s.

   i) Yield Stress, F_y

   j) Tensile strength, F_u

   k) e/d, d/t, d/s and F_u/F_y ratios

2. Results

   a) Tested ultimate tensile force of the connection, P_{ult}

b) Calculated nominal capacity, which corresponds to the failure mode of each specimen. The nominal capacity was evaluated for the following: AISI Specification[1], AISC Specification[2], ECCS Recommendations[3], British Standard[4], Canadian Standard[5] and Zadanfarrokh's method[6].

c) The ratio P_{ult}/calculated nominal capacity

d) The mean, standard deviation and coefficient of variation of the ratio P_{ult}/calculated nominal capacity.

The tables of Appendices A through G are organized according to failure mode, connection type (single or double shear), use of washers, bolt pattern and number of bolts per connection. Single shear and double shear connections, with and without washers, which failed by Type III failure mode, are listed in the tables in Appendix A. Single shear connections, with and without washers, which failed by Type II failure mode, are listed in the tables in Appendix B; no data was found for double shear connections failing by Type II failure mode. The tables in Appendix C are the results of single shear connections which failed by a combination of Type II and III failure modes; there was no data available for double shear connections failing by the combination of Type II and III failure modes. Appendix D tables list single shear and double shear connections, with and without washers, for the combination failure modes of Type I and II. Single shear and double shear connections with and without washers, which failed by the combination of Type I and III failure modes, are listed in the tables of Appendix E. The tables in Appendix F list single shear and double shear connections, with and without washers, which failed by the combination of failure Type II and V. Appendix G

lists single shear connections which failed by the combination of Type I, II and III; for this combination of failure modes, no data on double shear connections was found.

A summary of the statistical data, i.e. mean and coefficient of variation, from the tables in Appendices A through G is given in Subsection D.

B. TENSILE CAPACITY EVALUATION

The predicted nominal tensile capacity of the test specimens, identified as exhibiting a Type III failure mode, was computed using the AISI Specification[1], AISC Specification[2], ECCS Recommendations[3], British Standard[4] and Canadian Standard[5]. The following discussion summarizes these standards and specifications.

1. AISI Specification[1]: For the AISI Specification[1] , the nominal tensile force was calculated by first determining whether yielding or fracture controlled. The allowable yielding force, T_a, is given in Section C2 as:

$$T_a = T_n/\Omega_t \qquad \text{(Eq. 20)}$$

where,

$T_n = A_n F_y$ (kip)

Ω_t = Factor of safety for tension = 1.67

A_n = Net area of cross section (in.^{2})

F_y = Yield stress of material (ksi)

The allowable tensile force corresponding to a fracture failure, P_a, is given in Section E3.2 as:

$$P_a = P_n/\Omega_t \qquad \text{(Eq. 21)}$$

where,

P_n = $A_n F_t$ (kip)

A_n = Net area of the cross section (in.^{2})

Ω_t = Factor of Safety for tension on the net section

= 2.0 for double shear with washers

= 2.22 for double shear without washers

= 2.22 for single shear with or without washers

F_t = Nominal tensile stress on the net section (ksi), and is determined as follows:

When t < 3/16 inch and washers are provided under the bolt head and nut:

$$F_t = (1.0\text{-}0.9r+3rd/s)F_u \leq F_u \qquad \text{(Eq. 22)}$$

When t < 3/16 inch and either washers are not provided under the bolt head and nut, or only one washer is provided under either the bolt head or nut:

$$F_t = (1.0\text{-}r+2.5rd/s)F_u \leq F_u \qquad \text{(Eq. 23)}$$

In Equations 22 and 23:

t = The thickness of the thinnest connected part (in.)

r = Force transmitted by the bolt or bolts at the section considered, divided by the tension force in the member at that section. If r is less than 0.2, it may be taken equal to zero.

d = Nominal bolt diameter (in.)

s = Spacing of bolts perpendicular to the line of stress. In the case of a single bolt, s is taken as the width of the sheet (in.)

F_u = Tensile strength of connected part (ksi)

To determine if fracture or yielding controls the allowable tensile force for design, Equations 20 and 21 were set equal:

$$A_n F_y/1.67 = A_n F_t/\Omega_t \qquad \text{(Eq. 24)}$$

The ratio of F_t/F_y was determined using Equation 24. If yielding controls, the ratio of F_t/F_y will be greater than 1.33 for single shear with or without washers, and double shear without washers; and greater than 1.20 for double shear with washers. The controlling calculated ultimate tensile force is listed in Appendix A corresponding to a Failure Type III.

2. AISC Specification[2]: For the AISC Specification[2], the nominal tensile force was also calculated by first determining whether fracture or yielding is the controlling failure mode. The allowable yielding force, T_a, is given in Section D1 as:

$$T_a = 0.6A_gF_y \qquad \text{(Eq. 25)}$$

where,

A_g = Gross cross-sectional area (in.^{2})

F_y = Yield stress of material (ksi)

The allowable fracture force, T_a, given in Section D1 is:

$$T_a = 0.5A_eF_u \qquad \text{(Eq. 26)}$$

where,

A_e = The effective net cross section area, but is limited to 85% of the gross cross section area, for connections using flat sheets (in.^{2})

A_e = UA_n when the load is transmitted by bolts through some, but not all, of the cross-sectional elements

A_n = Net area of the member (in.^{2})

U = Reduction coefficient

F_u = Tensile strength of connected part (ksi)

The critical failure mode is determined by setting the allowable yielding force equal to the allowable fracture force as follows:

$$0.6A_gF_y = 0.5A_eF_u \qquad \text{(Eq. 27)}$$

Using Equation 27, the ratio of A_gF_y/A_eF_u was computed. If it is less than 0.83, yielding controls the allowable design force. If the ratio is greater than 0.83, fracture controls the allowable design force. The controlling ultimate tensile force is also listed in Appendix A, for Type III failure mode.

3. Canadian Standard[5]: The ultimate tensile force based on Section 6.3.1 of the Canadian Standard[5] is determined similar to the AISC Specification[2]. The nominal yielding force, T_n, is given as:

$$T_n = A_g F_y \qquad \text{(Eq. 28)}$$

where,

A_g = Gross cross-sectional area (mm^2)

F_y = Yield stress of material (KN/mm^2)

The nominal fracture force, T_n, is given as:

$$T_n = A_n F_u \qquad \text{(Eq. 29)}$$

where,

A_n = Net cross-sectional area (mm^2)

F_u = Tensile strength of connected part (KN/mm^2)

Similar to the AISC Specification[2], it is assumed that if the ratio of $A_g F_y / A_n F_u$ is less than 0.83, yielding controls the allowable design load. If the ratio is greater than 0.83, fracture controls. The controlling ultimate tensile force is also listed in Appendix B, for Type III failure.

4. ECCS Recommendations[3]: For the ECCS Recommendations[3], the nominal tensile force is given as:

$$F^*_n = A_n f_n \qquad \text{(Eq. 30)}$$

where,

f_n = $(1-0.9r+3rd/u)f_y \leq f_y$ (KN/mm^2)

u = Minimum of $2u_1$ and u_2 (mm)

u_1 = Distance between edge and center of fastener perpendicular to the load direction (mm)

u_2 = Center-to-center spacing of fasteners perpendicular to the load direction (mm)

A_n = Net cross-sectional area of the plate material (mm^2)

d = Nominal diameter of the bolt hole (mm)

r = The force transmitted by the bolt or bolts of the section considered, divided by the tension force in the member at that section.

f_y = Yield strength of material (KN/mm^2)

5. British Standard[4]: The nominal tensile force, T, is given in Section 8.2.6 of the British Standard[4] as the smaller of Equations 31 and 32:

$$T = A_n(0.1 + 3d/s)p_y \qquad \text{(Eq. 31)}$$

$$T = A_n p_y \qquad \text{(Eq. 32)}$$

where,

A_n = Net cross-sectional area (mm^2)

p_y = Yield stress of material (KN/mm^2)

d = Nominal diameter of bolt (mm)

s = Spacing of bolts perpendicular to the line of stress. In the case of single bolt, s equals the width of the sheet (mm)

6. Comparison of Tested to Computed Capacity: The nominal tensile forces as calculated from the AISI Specification[1], AISC Specification[2], ECCS Recommendations[3], British Standard[4] and Canadian Standard[5] are listed in the tables in Appendices A, C, E and G. The ratio of the tested ultimate tensile force to the calculated nominal tensile force, along with the mean, standard deviation, and coefficient of variation is also listed in these tables.

C. BEARING CAPACITY EVALUATION

The predicted bearing capacity of the test specimens that manifested a Type II failure mode was computed using the AISI Specification[1], AISC Specification[2], ECCS Recommendations[3], British Standard[4] Canadian Standard[5] and Zadanfarrokh's method[6].

1. AISI Specification[1]: The nominal bearing strength, P_n, based on Section E3.3 of the AISI Design Specification[1] is determined as:

$$P_n = F_p dt \qquad \text{(Eq. 33)}$$

where,

F_p = Nominal bearing stress given in Tables I and II (ksi)

d = Nominal bolt diameter (in.)

t = Thickness of the thinnest connected sheet (in.)

Table I. Nominal Bearing Stress For Bolted Connections With Washers Under Both Bolt Head and Nut[1]

Thickness of Connected Part (in.)	Type of Joint	F_u/F_y Ratio of Connected Part	Nominal Bearing Stress, F_p
≥ 0.024 but < 3/16	Inside sheet of double shear connection	≥ 1.15	3.33 F_u
		< 1.15	3.00 F_u
	Single shear and outside sheet of double shear connections	No limit	3.00 F_u
≥ 3/16	See AISC Specification[2]		

Table II. Nominal Bearing Stress For Bolted Connections Without Washers Under Both Bolt Head and Nut, or With Only One Washer[1]

Thickness of Connected Part (in.)	Type of Joint	F_u/F_y Ratio of Connected Part	Nominal Bearing Stress, F_p
≥ 0.036 but < 3/16	Inside sheet of double shear connection	≥ 1.15	3.00 F_u
	Single shear and outside sheets of double shear connection	≥ 1.15	2.22 F_u
≥ 3/16	See AISC Specification[2]		

2. AISC Specification[2] The nominal bearing strength based on Section J3.7 of the AISC Specification[2], is given as follows if the deformation around the hole is not a design consideration and adequate spacing and edge distance are provided:

$$P_n = 3dtF_u \qquad \text{(Eq. 34)}$$

where,

d = Nominal bolt diameter (in.)

t = Thickness of the thinnest connected sheet (in.)

F_u = Tensile strength of connected part (ksi)

When deformation around the hole is a design consideration, a lower ultimate bearing strength may be obtained as follows:

$$P_n = 2.4dtF_u \qquad \text{(Eq. 35)}$$

where d, t and F_u are previously defined. For this study, the available test data was analyzed using Equation 34.

3. Canadian Standard[5]: Based on Section 7.3.5 of the Canadian Standard[5], the nominal bearing strength for a single fastener, B_n, is determined as:

$$B_n = etF_u \leq CdtF_u \qquad \text{(Eq. 36)}$$

where,

t = Thickness of the thinnest connected sheet (mm)

d = Nominal diameter of the bolt (mm)

F_u = The tensile strength of the connected part (KN/mm^2)

e = The distance from the hole center to the edge toward which the force is directed (mm)

C = The appropriate value from Table III

Table III. Factor C, For Bearing Resistance Of Fasteners[5]

Ratio of Fastener diameter to sheet thickness, d/t	C
$d/t \leq 10$	3
$10 < d/t < 15$	30 t/d
$d/t \geq 15$	2

For groups of fasteners, B_n shall be taken as the lesser value determined by (a) and (b):

(a) The nominal bearing strength of a group of fasteners, in which the center-to-center distance between fasteners is at least Cd, is equal to the sum of the individual resistances as determined by Equation 36. If the spacing is less than Cd, but not less than 2.5d, the resistance shall be reduced proportionally.

(b) The nominal bearing strength is given as:

$$B_n = t[(m-1)(g-d) + (n-1)(s-d) + e]F_u \qquad \text{(Eq. 37)}$$

where,

g = Spacing of fastener measured perpendicular to the direction of force (mm)

s = Spacing of fastener measured parallel to the direction of force (mm)

m = Number of bolts in the first row perpendicular to the direction of force

n = Number of rows of bolts which are perpendicular to the direction of force

e = Edge distance of the first row measured parallel to the direction of force; if e > Cd, replace e by Cd in the formula (mm)

d = The diameter of the hole (mm)

C = The value from Table III

t = The thickness of the sheet (mm)

F_u = The tensile strength of the connected part (KN/mm^2)

4. ECCS Recommendations[3]: The nominal bearing strength, F_b, according to the ECCS Recommendations[3] is given as:

$$F_b = \alpha f_y d_n t \qquad \text{(Eq. 38)}$$

where,

f_y = The yield strength of the connected part (KN/mm^2)

d_n = Nominal diameter of the fastener (mm)

e_1 = The edge distance parallel to the direction of stress

t = Thickness of the thinnest sheet (mm)

α is determined as follows:

For $t \leq 1$ mm, $\alpha = 2.1$

For 1 mm $< t <$ 3 mm and $e_1 / d_n \leq 6$,

$$\alpha = 2.6 - 0.5t + 0.9(t-1)\ln(e_1 / d_n)$$

For 1 mm $< t <$ 3 mm and $e_1 / d_n > 6$,

$$\alpha = 1.0 + 1.1t$$

For $t \geq 3$ mm and $e_1 / d_n \leq 6$,

$$\alpha = 1.1 + 1.8\ln(e_1 / d_n)$$

For $t > 3$ mm and $e_1 / d_n > 6$,

$$\alpha = 4.3$$

5. British Standard[4]: According to Section 8.2.5.2 of the British Standard[4], the nominal bearing strength for each bolt of a connection, with washers under both the bolt head and nut, P_{bs}, is given as:

For $t \leq 1$ mm:

$$P_{bs} = 2.1dtp_y \qquad \text{(Eq. 39)}$$

For 1 mm $< t \leq 3$ mm:

(a) for $d_e / d \leq 3$,

$$P_{bs} = [2.1 + (0.3d_e / d - 0.45)(t-1)]dtp_y \qquad \text{(Eq. 40)}$$

(b) for $d_e / d > 3$,

$$P_{bs} = (1.65 + 0.45t)dtp_y \quad \text{(Eq. 41)}$$

For 3 mm < t ≤ 8 mm:

(a) for $d_e/d \leq 3$,

$$P_{bs} = (1.2 + 0.6\, d_e/d)dtp_y \quad \text{(Eq. 42)}$$

(b) for $d_e/d > 3$

$$P_{bs} = 3.0\, dtp_y \quad \text{(Eq. 43)}$$

where,

t = Minimum thickness of the connected material (mm)

d = The nominal diameter of the bolt(mm)

p_y = The design strength (KN/mm^2)

d_e = The distance from the center of the bolt to the end of the connected element in the direction of the bolt force (mm)

For connections having only a single washer or no washers, the nominal bearing capacity shall be 75 % of the value determined for connections with a washer under both the bolt head and the nut.

6. Zadanfarrokh's Method[6]: According to a recent study conducted by Zadanfarrokh[6], the nominal bearing capacity can be determined as:

$$P_{bs} = \alpha dt\sigma_{ult} \quad \text{(Eq. 44)}$$

where,

σ_{ult} = Design ultimate stress of the sheet(N/mm^2)

t = Thickness of the thinnest connected sheet (mm)

e = The distance from the center of the bolt to the end of the connected element in the direction of the bolt force (mm)

d = The nominal bolt diameter (mm)

$\alpha = k_1 k_2 k_3 k_4 k_5 k_6 k_7$

$k_1 = (16/d)^{1/2}$

k_2 is determined as follows:

For $t \leq 3$ mm, $k_2 = (1.9 + 0.2t)$

For $3 < t \leq 8$ mm, $k_2 = 2.5$

$k_3 = (390/\sigma_{ult})^{1/2}$

k_4 is determined as follows:

For normal diameter washers, $k_4 = 1.0$

For large diameter washers,

for $t \leq 2$ mm, $k_4 = 1.15$

for $2 < t \leq 3$ mm, $k_4 = 1.05$

for $t > 3$ mm, $k_4 = 1.0$

k_5 is determined as follows:

When washers are provided on both the bolt head and nut,

$k_5 = 1.0$

When one washer is provided under the bolt head or nut,

$k_5 = 0.8$

When no washers are provided

$k_5 = 0.7$

k_6 = The lesser of e/2.5d and 1, where $e/d \geq 1.5$

k_7 is determined as follows:

When the shear plane occurs over the full shank diameter,

$k_7 = 1.15$

Otherwise, $k_7 = 1.0$

7. Comparison of Tested to Computed Capacity: The nominal bearing capacity as specified by AISI Specification[1], AISC Specification[2], ECCS Recommendations[3], British Standard[4], Canadian Standard[5] and Zadanfarrokh's method[6] are listed in the tables in Appendices B, C, D, F and G. The ratio of the tested ultimate tensile force to the calculated nominal bearing force, the mean, standard deviation, and coefficient of variation are also listed in these tables.

D. RESULTS

The results of the analytical study are summarized in Tables IV through X. These tables are a compilation of the statistical data from the tables in Appendices A through G. Tables IV through X list the number of data points considered, the mean value of the ratio of the tested ultimate force to the calculated nominal force and the corresponding coefficient of variation.

Tables IV through X are separated according to failure mode. Table IV summarizes the tables in Appendix A for failure Type III; Table V summarizes the tables in Appendix B for Type II failure mode; Table VI summarizes the tables in Appendix C for the combination of Type II and III failure mode; Table VII summarizes the tables in Appendix D for the combination of Type I and II failure mode; Table VIII summarizes the tables in Appendix E for the combination failure mode Type I and III; Table IX

summarizes the tables in Appendix F for the combination Type II and V failure mode; and Table X summarizes the table in Appendix G for the combination Type I , II and III failure mode.

In reviewing the statistical data, the following observations are made regarding the AISI Specification[1]:

(a) Based on the safety index adopted by the AISI LRFD Specification[28], the AISI Specification for allowable stress design[1] is adequate for tension failure alone in bolted connections using one bolt with washers. This design provision is slightly conservative for some other cases.

(b) The AISI Specification[1] design provisions for bearing failure alone, in bolted connections using one bolt, may be slightly unconservative, considering the relatively large scatter of the test data. This design provision should also be further studied by considering serviceability.

(c) For the combination of two or more failure modes, the AISI Specification[1] may be unconservative for some cases, however, the AISI Specification[1] provided a better prediction than AISC and Canadian Specifications[2,3].

(d) In general, European design formulas[3, 4] were found to be more conservative than the AISI Specification[1].

(e) In general, for Type III failures of single bolt configurations, the AISI Specification[1] provides a better prediction of the failure load, than does the AISC Specification[2] or Canadian Specifications[2]. For other bolt configurations, the AISI Specification[1] is more conservative than the AISC Specification and the Canadian Specifications[2,3]

Table IV. Summary Of Statistical Data For Type III Failure Mode From Appendix A

Table Description	No. of Data Pts.	Mean AISI	COV AISI	Mean AISC	COV AISC	Mean ECCS	COV ECCS	Mean BS 5950	COV BS 5950	Mean CAN/ CSA	COV CAN/ CSA
SS-W-1B	29	1.021	0.170	0.735	0.306	1.234	0.251	1.302	0.272	0.736	0.303
SS-W-2BP	13	1.237	0.166	1.094	0.059	1.372	0.106	1.393	0.091	1.094	0.059
SS-W-3BP	8	1.098	0.028	1.082	0.026	1.231	0.017	1.249	0.014	1.082	0.026
SS-W-2BL	8	1.147	0.022	0.905	0.072	1.329	0.024	1.917	0.091	0.901	0.078
SS-W-3BL	8	1.136	0.019	0.969	0.042	1.330	0.020	2.137	0.096	0.964	0.046
DS-W-1B	30	1.309	0.170	0.896	0.164	1.551	0.222	1.643	0.244	0.895	0.166
DS-W-2BP	23	1.410	0.092	1.245	0.119	1.589	0.083	1.641	0.071	1.245	0.119
DS-W-3BP	47	1.330	0.123	1.096	0.053	1.429	0.096	1.510	0.100	1.096	0.053
DS-W-2BL	12	1.186	0.076	1.117	0.128	1.414	0.075	1.565	0.117	1.117	0.128
DS-W-3BL	77	1.123	0.064	0.982	0.104	1.353	0.066	2.035	0.168	0.978	0.105
SS-WO-1B	8	1.318	0.035	1.098	0.035	1.388	0.033	1.388	0.033	1.098	0.035

Table IV. Continued

Table Description	No. of Data Pts.	Mean AISI	COV AISI	Mean AISC	COV AISC	Mean ECCS	COV ECCS	Mean BS 5950	COV BS 5950	Mean CAN/ CSA	COV CAN/ CSA
SS-WO-2BP	2	1.225	0.024	1.024	0.024	1.184	0.024	1.184	0.024	1.024	0.024
SS-WO-3BP	2	1.017	0.007	0.953	0.007	1.142	0.007	1.142	0.007	0.953	0.007
SS-WO-2BL	5	1.288	0.048	1.078	0.044	1.520	0.071	1.697	0.161	1.078	0.044
SS-WO-3BL	1	1.030	N.A.	0.820	N.A.	1.130	N.A.	1.730	N.A.	0.820	N.A.
DS-WO-2BP	14	1.458	0.139	1.009	0.047	1.236	0.071	1.298	0.121	1.009	0.047
DS-WO-3BP	45	1.563	0.089	1.070	0.039	1.387	0.086	1.465	0.094	1.070	0.039
DS-WO-2BL	9	1.220	0.034	1.022	0.103	1.323	0.061	1.496	0.143	1.022	0.103
DS-WO-3BL	74	1.193	0.033	0.970	0.067	1.340	0.053	2.025	0.172	0.966	0.070

N.A. = Not Applicable
COV = Coefficient of Variation
SS = Single Shear
DS = Double Shear
W = With Washers
WO = Without Washers

1B = One Bolt
2BP = Two Bolts Perpendicular To The Line Of Stress
3BP = Three Bolts Perpendicular To The Line Of Stress
2BL = Two Bolts In The Line Of Stress
3BL = Three Bolts In The Line Of Stress

Table V. Summary Of Statistical Data For Type II Failure Mode From Appendix B

Table Description	No. of Data Pts.	Mean AISI	COV AISI	Mean AISC*	COV AISC*	Mean ECCS	COV ECCS	Mean BS 5950	COV BS 5950	Mean CAN/ CSA	COV CAN/ CSA	Mean F.Z.	COV F.Z.
SS-W-1B	26	1.002	0.202	1.002	0.202	1.381	0.345	1.516	0.309	1.097	0.255	1.274	0.174
SS-WO-1B	4	1.252	0.166	0.927	0.166	1.596	0.163	2.159	0.164	0.995	0.157	1.643	0.165
SS-WO-2BP	1	0.890	N.A.	0.660	N.A.	1.160	N.A.	1.660	N.A.	1.320	N.A.	1.310	N.A.
SS-WO-3BP	2	0.999	0.014	0.740	0.014	1.129	0.014	1.635	0.014	0.740	0.014	0.973	0.014

N.A. = Not Applicable
COV = Coefficient Of Variation
F.Z. = Farzin Zadenfarrokh's Thesis
SS = Single Shear
DS = Double Shear
W = With Washers
WO = Without Washers
1B = One Bolt
2BP = Two Bolts Perpendicular To The Line Of Stress
3BP = Three Bolts Perpendicular To The Line Of Stress
2BL = Two Bolts In The Line Of Stress
3BL = Three Bolts In The Line Of Stress
* = Deformation Around The Bolt Hole Is Not A Design Consideration

Table VI. Summary Of Statistical Data For Combination Type II & III Failure Mode From Appendix C

Table Description	No. of Data Pts.	FM	Mean AISI	COV AISI	Mean AISC *	COV AISC *	Mean ECCS	COV ECCS	Mean BS 5950	COV BS 5950	Mean CAN/ CSA	COV CAN/ CSA	Mean F.Z.	COV F.Z.
SS-W-1B	39	III	0.914	0.265	0.568	0.456	1.046	0.301	1.139	0.307	0.565	0.462	N.A.	N.A.
		II	0.927	0.423	0.918	0.209	1.351	0.316	1.423	0.282	1.074	0.238	1.241	0.216
SS-WO-1B	6	III	0.974	0.114	0.554	0.267	0.858	0.097	0.903	0.079	0.554	0.267	N.A.	N.A.
		II	0.828	0.213	0.606	0.223	0.965	0.300	1.351	0.229	0.781	0.385	1.012	0.313

FM = Failure Mode
COV = Coefficient Of Variation
F.Z. = Farzin Zadenfarrokh's Thesis
SS = Single Shear
DS = Double Shear
W = With Washers
WO = Without Washers
1B = One Bolt
* = Deformation Around The Bolt Hole Is Not A Design Consideration

Table VII. Summary Of Statistical Data For Combination Type I & II Failure Mode From Appendix D

Table Description	No. of Data Pts.	Mean AISI	COV AISI	Mean AISC*	COV AISC*	Mean ECCS	COV ECCS	Mean BS 5950	COV BS 5950	Mean CAN/ CSA	COV CAN/ CSA	Mean F.Z.	COV F.Z.
SS-W-1B	23	1.107	0.151	1.107	0.151	1.744	0.294	1.780	0.269	1.151	0.133	1.267	0.157
DS-W-1B	69	1.268	0.207	1.359	0.184	2.118	0.207	2.181	0.191	1.518	0.191	1.693	0.202
SS-WO-1B	9	0.921	0.200	0.681	0.200	1.050	0.135	1.466	0.126	0.865	0.246	1.473	0.121
SS-WO-2BP	1	0.980	N.A.	0.730	N.A.	1.160	N.A.	1.610	N.A.	0.740	N.A.	1.210	N.A.
SS-WO-3BP	2	0.884	0.015	0.654	0.015	1.338	0.015	1.772	0.015	0.981	0.015	1.616	0.015
DS-WO-1B	39	1.223	0.168	1.217	0.170	1.941	0.242	2.673	0.214	1.386	0.382	2.081	0.237

COV = Coefficient Of Variation
* = Deformation Around The Bolt Hole Is Not A Design Consideration
F.Z. = Farzin Zadenfarrokh's Thesis
SS = Single Shear
DS = Double Shear
W = With Washers
WO = Without Washers
1B = One Bolt
3BP = Three Bolts Perpendicular To The Line Of Stress
2BP = Two Bolts Perpendicular To The Line Of Stress
N.A. = Not Applicable

Table VIII. Summary Of Statistical Data For Combination Type I & III Failure Mode From Appendix E

Table Description	No. of Data Pts.	Mean AISI	COV AISI	Mean AISC	COV AISC	Mean ECCS	COV ECCS	Mean BS 5950	COV BS 5950	Mean CAN/ CSA	COV CAN/ CSA
SS-W-1B	9	0.865	0.061	0.443	0.205	1.100	0.072	1.185	0.069	0.435	0.223
DS-W-1B	7	0.946	0.203	0.548	0.346	1.171	0.255	1.263	0.261	0.548	0.340
DS-W-2BP	11	1.233	0.130	0.895	0.127	1.357	0.139	1.471	0.130	0.895	0.127
DS-W-3BP	10	1.267	0.092	0.994	0.078	1.380	0.065	1.482	0.071	0.994	0.078
DS-WO-2BP	12	1.657	0.129	0.852	0.101	1.307	0.128	1.414	0.117	0.852	0.101
DS-WO-3BP	8	1.513	0.078	0.968	0.041	1.346	0.057	1.446	0.680	0.968	0.041

COV = Coefficient of Variation
SS = Single Shear
DS = Double Shear
W = With Washers
WO = Without Washers
1B = One Bolt
2BP = Two Bolts Perpendicular To The Line Of Stress
3BP = Three Bolts Perpendicular To The Line Of Stress

Table IX. Summary Of Statistical Data For Combination Type II & V Failure Mode From Appendix F

Table Description	No. of Data Pts.	Mean AISI	COV AISI	Mean AISC*	COV AISC*	Mean ECCS	COV ECCS	Mean BS 5950	COV BS 5950	Mean CAN/ CSA	COV CAN/ CSA	Mean F.Z	COV F.Z.
SS-W-1B	16	0.902	0.159	0.902	0.159	1.454	0.156	1.495	0.146	1.067	0.206	1.200	0.162
SS-WO-1B	10	0.752	0.091	0.556	0.091	0.972	0.091	1.296	0.091	0.759	0.091	1.447	0.091
DS-WO-1B	2	0.876	0.049	0.877	0.049	1.549	0.049	2.065	0.049	1.218	0.049	1.493	0.049

COV = Coefficient of Variation
F.Z. = Farzin Zadenfarrokh's Thesis
SS = Single Shear
DS = Double Shear
W = With Washers
WO = Without Washers
1B = One Bolt
* = Deformation Around The Bolt Hole Is Not A Design Consideration

Table X. Summary Of Statistical Data For Combination Type I & II & III Failure From Appendix G

Table Descript.	No. of Data Pts.	FM	Mean AISI	COV AISI	Mean AISC*	COV AISC*	Mean ECCS	COV ECCS	Mean BS 5950	COV BS 5950	Mean CAN/ CSA	COV CAN/ CSA	Mean F.Z.	COV F.Z.
SS-W-1B	6	III	0.885	0.122	0.745	0.202	0.868	0.125	0.912	0.117	0.745	0.202	N.A.	N.A.
		II	0.774	0.720†	0.718	0.162	0.817	0.108	0.865	0.086	0.842	0.110	1.124	0.137

FM = Failure Mode
COV = Coefficient of Variation
F.Z. = Farzin Zadenfarrokh's Thesis
SS = Single Shear
W = With Washers
1B = One Bolt
* = Deformation Around The Bolt Hole Is Not A Design Consideration
† = Unreasonable Coefficient Of Variation, Possibly Due To The Use Of Gr. E Steel

IV. PRESENT EXPERIMENTAL INVESTIGATION

A. GENERAL

To evaluate the effect of hole deformation on the load capacity of bolted connections, experimental work was conducted to investigate further the bearing strength and tensile strength of bolted connections made of thin flat sheets. The test specimens were designed such that joint failure would occur due to bearing (failure Type II), fracture in the net section (failure Type III), or a combination of bearing and fracture in the net section. The specimens were designed for the following parameters: (1) thickness of steel: 0.04 inches, 0.07 inches and 0.12 inches; (2) ratios of d/s: 0.12, 0.15 and 0.31; (3) 1/2 inch diameter A325T bolts; (4) bolt pattern configurations, as shown in Figure 3; and (5) with and without washers. All tests were single shear connections and were performed using the 120,000 pound Tinius Olsen Universal Testing machine (Fig. 4) located in the Engineering Research Laboratory of the University of Missouri-Rolla.

B. MECHANICAL PROPERTIES OF STEEL SHEETS

Tensile coupon tests were conducted to obtain the mechanical properties of the steel sheets. Table XI shows the mechanical properties and thicknesses of the test specimens used in the investigation. The mechanical properties were determined by standard coupon tests per ASTM A370 procedures.

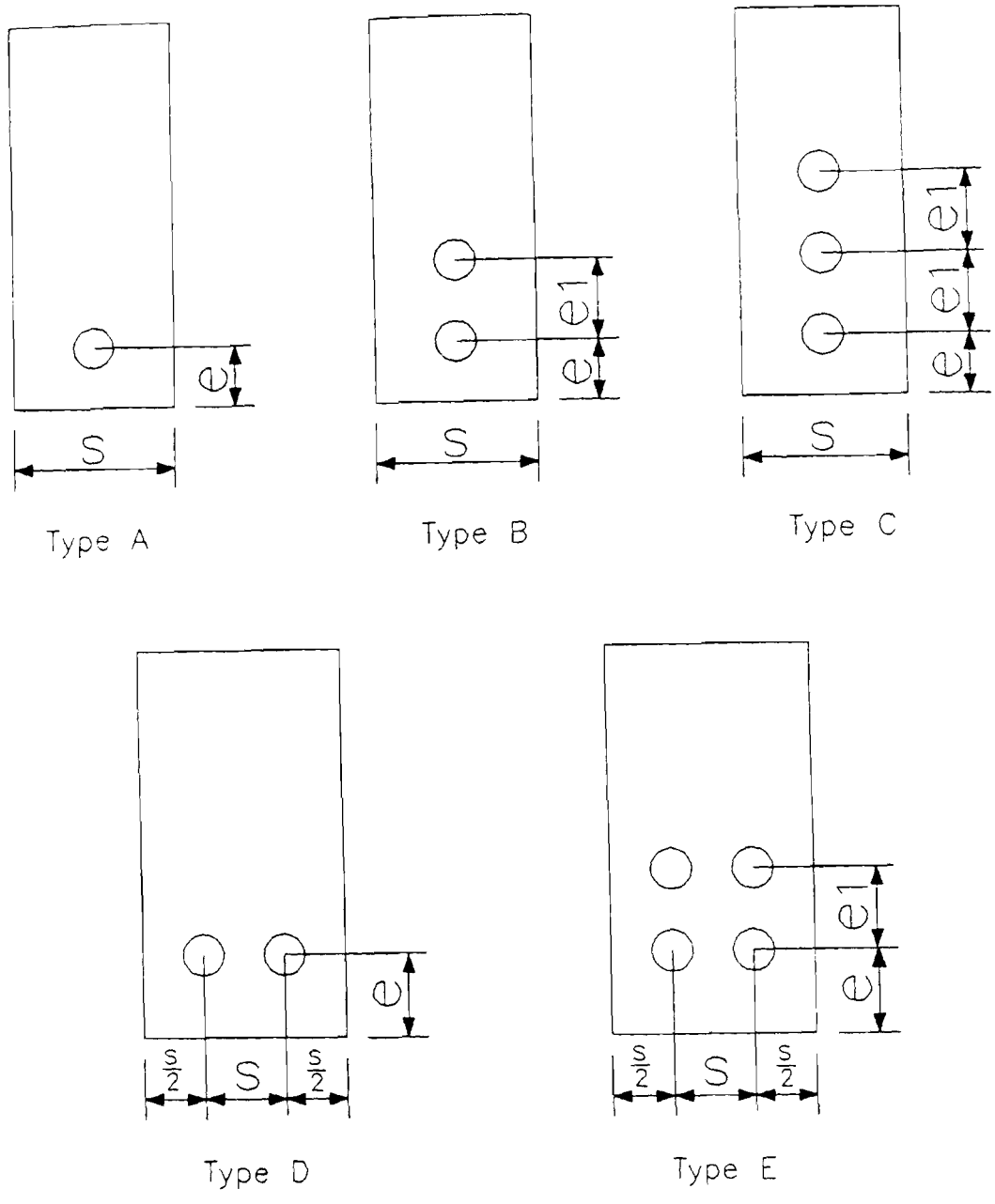


Figure 3. Test Specimens Used In The Present Experimental Studies.

C. PREPARATION OF TEST ASSEMBLIES

One hundred and two test assemblies were fabricated for this phase of the experimental investigation. This allowed for the testing of three identical tests of the thirty-four different bolted connections. Each assembly consisted of two identical flat sheet test specimens, bolted together (Figure 5). Figure 3 shows the various types of specimens tested. Type A is a one bolt, Type B is two bolts in the line of stress, Type C

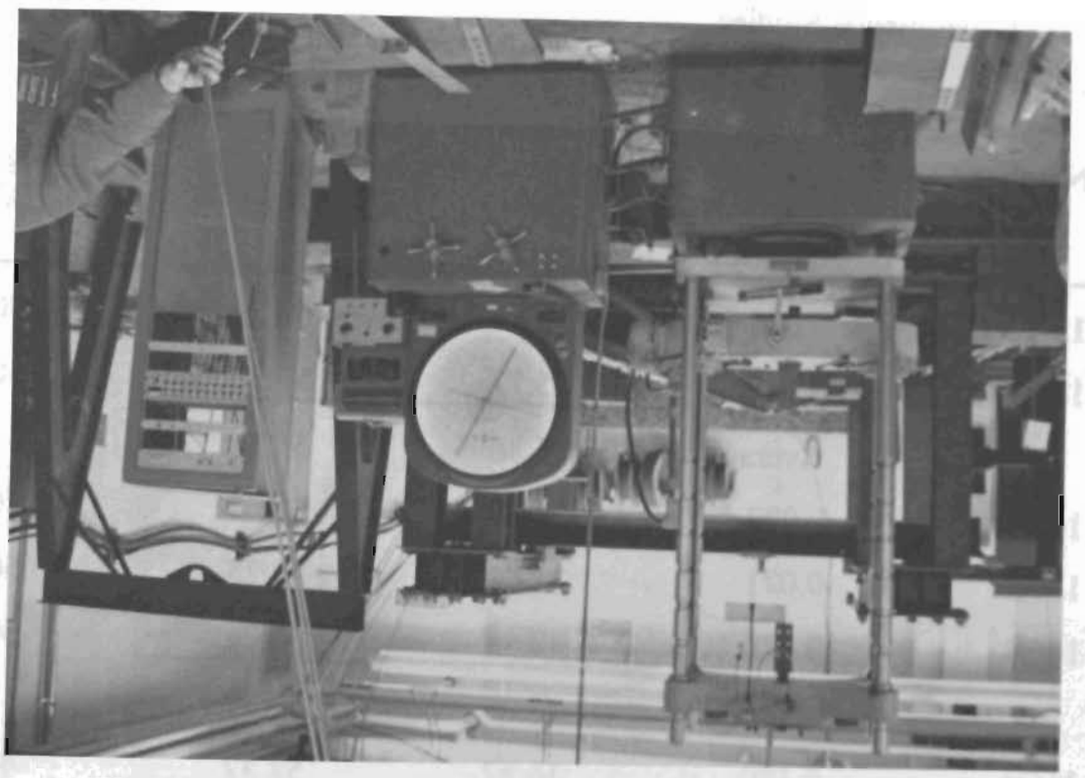


Figure 4. Photograph Of The Tinius Olsen Testing Machine.

is three bolts in the line of stress, Type D is two bolts perpendicular to the line of stress and Type E is two rows of two bolts perpendicular to the line of stress.

The purpose of fabricating three identical test assemblies of the thirty-four different bolted connections was to provide consistent results in identical bolted connection tests. Initially all three identical test assemblies were tested. As the testing program proceeded, it became apparent that if the first and second tests gave consistent results, the third test was not providing any additional useful information. Therefore, in order to provide for a more efficient testing program, it was decided that if the first and second tests gave consistent results, the third test would not be conducted. Of the 102 test

Table XI. Material Properties And Thicknesses Of Steel Sheets Used In The Present Experimental Studies

Test Number	t (in.)	F_y (ksi)	F_u (ksi)	Elongation (%)*
18G2	0.042	35.83	56.29	50
18G3	0.042	35.77	55.39	50
	Average =	35.80	55.84	
14G1	0.073	31.89	52.40	50
14G2	0.071	31.72	52.25	50
14G3	0.070	32.58	52.76	50
	Average =	32.06	52.47	
11G1	0.120	36.97	53.37	44
11G2	0.120	36.38	53.32	44
11G3	0.120	36.48	52.36	44
	Average =	36.61	53.02	

* Elongation was measured over a 2-in. gage length

assemblies fabricated, it was only necessary to test seventy-five assemblies. Table XII lists the dimensions and mechanical properties of the seventy-five tests that were conducted.

All tests used 1/2 inch diameter A325T bolts with 9/16 inch diameter punched bolt holes. Washers were used on some of the assemblies, but since it is more common in practice not to use washers under the head and nut of a bolted connection, the majority of the tests did not include washers. Of the seventy-five assemblies tested, twenty-five were tested with washers as indicated in Table XII.

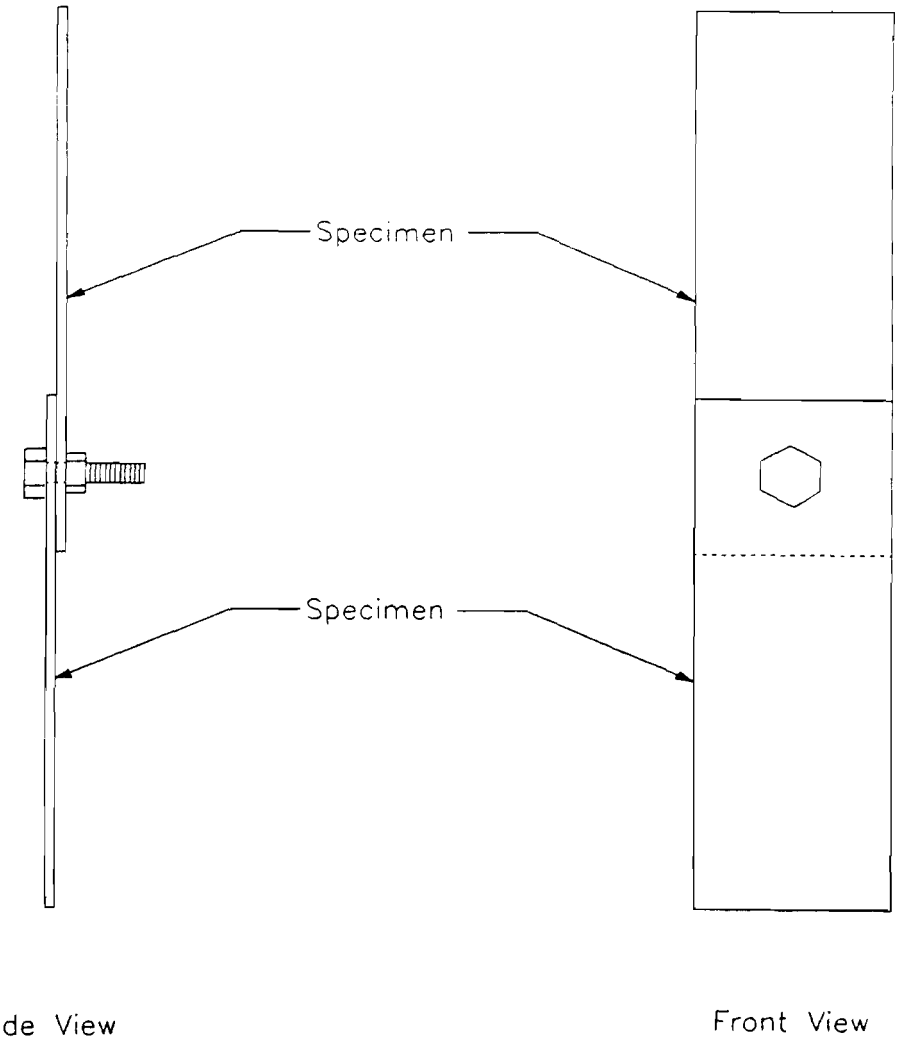


Figure 5. Typical Test Assembly (Type A Specimens Shown).

D. TESTING OF TEST ASSEMBLIES

1. Attachment of Test Assembly to Testing Machine: Because most of the test specimens that were used were too wide to be gripped by the testing machine, specially designed grip plates were connected to each end of the test assembly to transmit the applied loads (Figure 6). Two different types of grip plates were required due to the different bolts configurations (Figure 7). Type 1 grip plate was used for Type A, B and C test specimens and Type 2 grip plate for Type D and E test specimens. The specimens were connected to the grip plates using 1/2 inch diameter A325T bolts.

Table XII. Dimension And Mechanical Properties Of Test Assemblies

Assembly Number	d (in.)	t (in.)	e (in.)	e1 (in.)	s (in.)	e/d	d/t	d/s	F_y (ksi)	F_u (ksi)	F_u / F_y
AY22-1	0.5	0.072	1.992	N.A.	3.268	3.984	6.944	0.153	32.06	52.47	1.64
AY22-2	0.5	0.070	1.999	N.A.	3.260	3.998	7.143	0.153	32.06	52.47	1.64
AY23-1	0.5	0.070	2.006	N.A.	4.019	4.012	7.143	0.124	32.06	52.47	1.64
AY23-3	0.5	0.070	2.002	N.A.	4.025	4.004	7.143	0.124	32.06	52.47	1.64
BY13-1	0.5	0.042	2.009	1.994	4.001	4.018	11.905	0.125	35.80	55.84	1.56
BY13-2	0.5	0.043	2.007	1.989	4.007	4.014	11.628	0.125	35.80	55.84	1.56
BY13-3	0.5	0.044	2.008	1.988	4.006	4.016	11.364	0.125	35.80	55.84	1.56
AN32-1	0.5	0.118	2.003	N.A.	3.266	4.006	4.237	0.153	36.61	53.02	1.45
AN32-2	0.5	0.116	2.000	N.A.	3.260	4.000	4.310	0.153	36.61	53.02	1.45
AN33-1	0.5	0.118	2.001	N.A.	4.013	4.002	4.237	0.125	36.61	53.02	1.45
AN33-2	0.5	0.120	2.002	N.A.	4.013	4.004	4.167	0.125	36.61	53.02	1.45
BN33-1	0.5	0.119	2.002	2.000	4.019	4.004	4.202	0.124	36.61	53.02	1.45
BN33-2	0.5	0.119	2.004	2.002	4.019	4.008	4.202	0.124	36.61	53.02	1.45
DN12-2	0.5	0.043	1.998	N.A.	3.255	3.996	11.628	0.154	35.80	55.84	1.56
DN12-3	0.5	0.042	1.998	N.A.	3.255	3.996	11.905	0.154	35.80	55.84	1.56

Table XII. Continued

Assembly Number	d (in.)	t (in.)	e (in.)	e1 (in.)	s (in.)	e/d	d/t	d/s	F_y (ksi)	F_u (ksi)	F_u / F_y
DN22-1	0.5	0.070	2.001	N.A.	3.259	4.002	7.143	0.153	32.06	52.47	1.64
DN22-2	0.5	0.071	1.996	N.A.	3.258	3.992	7.042	0.153	32.06	52.47	1.64
AY12-1	0.5	0.042	2.001	N.A.	3.242	4.001	11.905	0.154	35.80	55.84	1.56
AY12-2	0.5	0.043	2.001	N.A.	3.244	4.002	11.628	0.154	35.80	55.84	1.56
BY12-1	0.5	0.045	2.003	1.996	3.239	4.005	11.111	0.154	35.80	55.84	1.56
BY12-2	0.5	0.045	2.003	2.001	3.242	4.006	11.111	0.154	35.80	55.84	1.56
BY12-3	0.5	0.042	2.004	1.999	3.242	4.008	11.905	0.154	35.80	55.84	1.56
BY22-1	0.5	0.071	2.002	1.992	3.266	4.004	7.042	0.153	32.06	52.47	1.64
BY22-2	0.5	0.070	2.001	2.004	3.264	4.002	7.143	0.153	32.06	52.47	1.64
BY22-3	0.5	0.070	1.999	2.003	3.267	3.998	7.143	0.153	32.06	52.47	1.64
BN32-1	0.5	0.118	2.001	2.001	3.262	4.002	4.237	0.153	36.61	53.02	1.45
BN32-2	0.5	0.117	2.004	2.002	3.254	4.008	4.274	0.154	36.61	53.02	1.45
DN32-1	0.5	0.120	2.001	N.A.	3.263	4.002	4.167	0.153	36.61	53.02	1.45
DN32-2	0.5	0.118	2.001	N.A.	3.261	4.002	4.237	0.153	36.61	53.02	1.45
EN12-1	0.5	0.043	2.003	2.000	3.255	4.006	11.628	0.154	35.80	55.84	1.56

Table XII. Continued

Assembly Number	d (in.)	t (in.)	e (in.)	e1 (in.)	s (in.)	e/d	d/t	d/s	F_y (ksi)	F_u (ksi)	F_u / F_y
EN12-2	0.5	0.043	2.001	2.000	3.257	4.002	11.628	0.154	35.80	55.84	1.56
EN22-1	0.5	0.071	2.003	1.998	3.258	4.006	7.042	0.153	32.06	52.47	1.64
EN22-2	0.5	0.072	2.001	2.001	3.253	4.002	6.944	0.154	32.06	52.47	1.64
EN32-1	0.5	0.118	1.996	1.998	3.262	3.992	4.237	0.153	36.61	53.02	1.45
EN32-2	0.5	0.117	1.998	1.995	3.261	3.996	4.274	0.153	36.61	53.02	1.45
AY11-1	0.5	0.042	1.999	N.A.	1.610	3.998	11.905	0.311	35.80	55.84	1.56
AY11-2	0.5	0.042	2.001	N.A.	1.607	4.002	11.905	0.311	35.80	55.84	1.56
AY21-1	0.5	0.071	1.995	N.A.	1.646	3.990	7.042	0.304	32.06	52.47	1.64
AY21-2	0.5	0.071	2.000	N.A.	1.635	4.000	7.042	0.306	32.06	52.47	1.64
BY11-1	0.5	0.042	2.002	2.003	1.608	4.004	11.905	0.311	35.80	55.84	1.56
BY11-2	0.5	0.044	2.002	2.003	1.612	4.004	11.364	0.310	35.80	55.84	1.56
BY11-3	0.5	0.043	1.995	2.004	1.612	3.990	11.628	0.310	35.80	55.84	1.56
BY21-1	0.5	0.070	1.993	2.008	1.646	3.986	7.143	0.304	32.06	52.47	1.64
BY21-2	0.5	0.072	1.996	2.005	1.643	3.992	6.944	0.304	32.06	52.47	1.64
BY21-3	0.5	0.072	1.998	2.004	1.648	3.996	6.944	0.303	32.06	52.47	1.64

Table XII. Continued

Assembly Number	d (in.)	t (in.)	e (in.)	e1 (in.)	s (in.)	e/d	d/t	d/s	F_y (ksi)	F_u (ksi)	F_u / F_y
AN31-2	0.5	0.116	1.998	N.A.	1.644	3.996	4.310	0.304	36.61	53.02	1.45
AN31-3	0.5	0.117	1.998	N.A.	1.633	3.996	4.274	0.306	36.61	53.02	1.45
BN31-1	0.5	0.118	1.999	2.003	1.630	3.998	4.237	0.307	36.61	53.02	1.45
BN31-2	0.5	0.118	1.997	2.005	1.627	3.994	4.237	0.307	36.61	53.02	1.45
CN11-1	0.5	0.043	2.000	1.997	1.611	4.000	11.628	0.310	35.80	55.84	1.56
CN11-2	0.5	0.043	2.002	1.997	1.612	4.004	11.628	0.310	35.80	55.84	1.56
CN12-1	0.5	0.043	2.004	1.997	3.240	4.008	11.628	0.154	35.80	55.84	1.56
CN12-2	0.5	0.043	2.002	2.000	3.239	4.004	11.628	0.154	35.80	55.84	1.56
CN21-1	0.5	0.071	1.995	1.996	1.647	3.990	7.042	0.304	32.06	52.47	1.64
CN21-2	0.5	0.072	1.998	1.996	1.640	3.996	6.944	0.305	32.06	52.47	1.64
CN21-3	0.5	0.072	1.998	1.997	1.641	3.996	6.944	0.305	32.06	52.47	1.64
CN22-1	0.5	0.071	2.003	1.997	3.262	4.006	7.042	0.153	32.06	52.47	1.64
CN22-2	0.5	0.072	2.004	1.996	3.266	4.008	6.944	0.153	32.06	52.47	1.64
CN22-3	0.5	0.071	2.002	1.995	3.266	4.004	7.042	0.153	32.06	52.47	1.64
CN31-2	0.5	0.120	2.000	1.998	1.636	4.000	4.167	0.306	36.61	53.02	1.45

Table XII. Continued

Assembly Number	d (in.)	t (in.)	e (in.)	e1 (in.)	s (in.)	e/d	d/t	d/s	F_y (ksi)	F_u (ksi)	F_u / F_y
CN31-3	0.5	0.121	1.994	1.996	1.636	3.988	4.132	0.306	36.61	53.02	1.45
CN32-1	0.5	0.121	2.002	1.998	3.264	4.004	4.132	0.153	36.61	53.02	1.45
CN32-2	0.5	0.120	2.002	1.996	3.254	4.004	4.167	0.154	36.61	53.02	1.45
DN31-1	0.5	0.120	2.001	N.A.	1.628	4.002	4.167	0.307	36.61	53.02	1.45
DN31-2	0.5	0.116	2.000	N.A.	1.631	4.000	4.310	0.307	36.61	53.02	1.45
EN11-1	0.5	0.044	1.996	2.002	1.618	3.992	11.364	0.309	35.80	55.84	1.56
EN11-2	0.5	0.043	1.994	2.005	1.622	3.988	11.628	0.308	35.80	55.84	1.56
EN21-1	0.5	0.072	1.995	2.000	1.635	3.990	6.944	0.306	32.06	52.47	1.64
EN21-2	0.5	0.072	1.999	2.002	1.632	3.998	6.944	0.306	32.06	52.47	1.64
EN31-1	0.5	0.117	1.999	2.004	1.630	3.998	4.274	0.307	36.61	53.02	1.45
EN31-2	0.5	0.118	1.994	2.011	1.630	3.988	4.237	0.307	36.61	53.02	1.45
DN11-1	0.5	0.041	2.001	N.A.	1.622	4.002	12.195	0.308	35.80	55.84	1.56
DN11-2	0.5	0.042	1.995	N.A.	1.620	3.990	11.905	0.309	35.80	55.84	1.56
DN21-1	0.5	0.072	2.001	N.A.	1.633	4.002	6.944	0.306	32.06	52.47	1.64
DN21-2	0.5	0.071	2.000	N.A.	1.633	4.000	7.042	0.306	32.06	52.47	1.64

Table XII. Continued

N.A. = Not Applicable

AY22-1
A: Specimen Type (A, B, C, D or E)
Y: Washers (Y = Yes, N = No)
2: Sheet Thickness (1= 0.04 in., 2 = 0.07 in., 3 = 0.12 in.)
2: "s" (1 = 1.625 in., 2 = 3.250 in., 3 = 4.000 in.)
1: Test Number

Figure 6. Photograph Of Grip Plates Attached To The Test Assembly And Testing Machine (Type 1 Shown).

2. Installation of Bolts: Two identical test specimens were bolted together to form a test assembly. The bolts were snugged tight to simulate the bolt tightening procedure in practice. To insure the approximate same bolt tightness between test assemblies, the same individual tightened the bolts for the test assemblies.

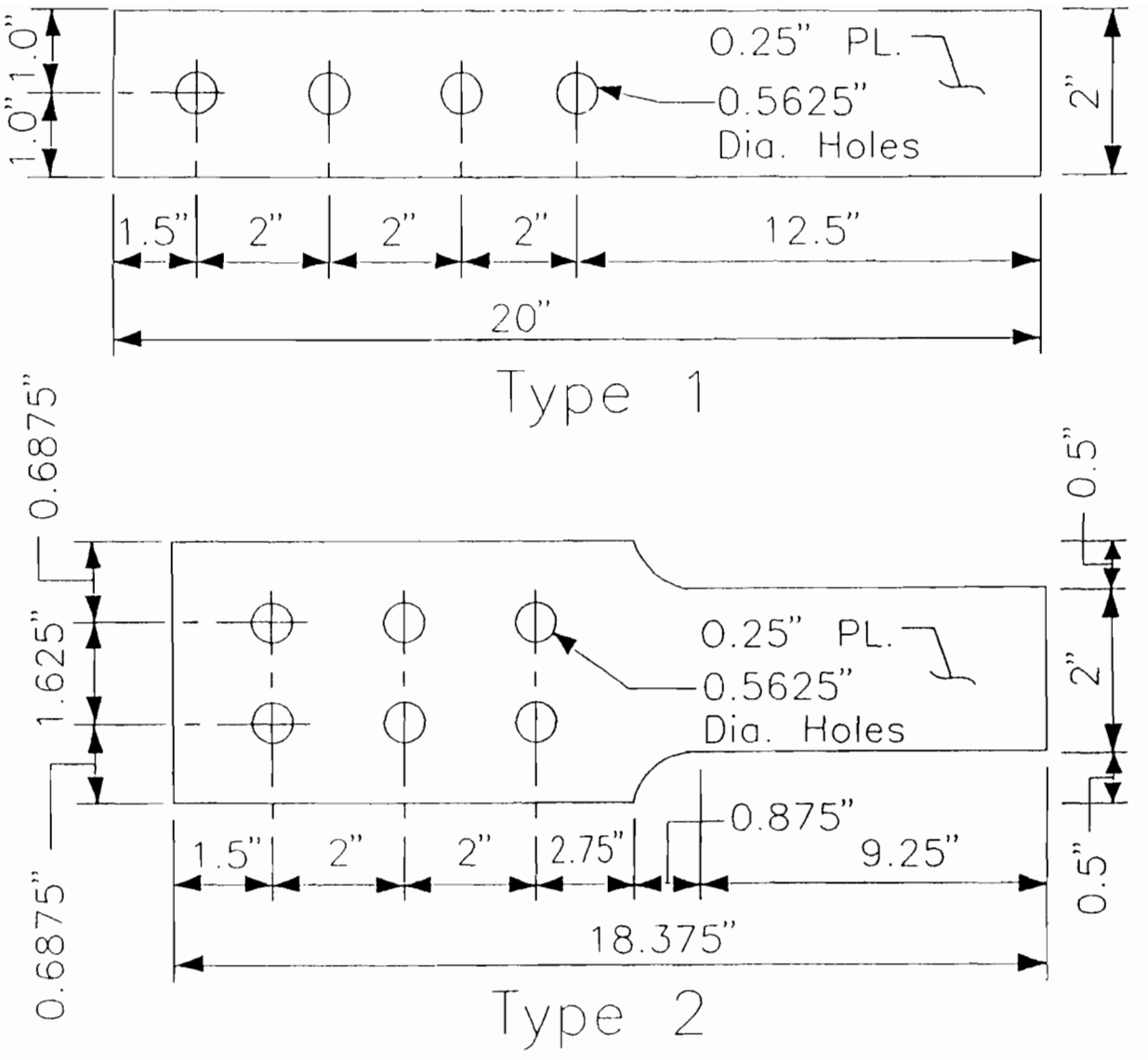


Figure 7. Detail Of Grip Plates.

Slippage between the two identical flat sheet test specimens was acceptable, but slippage between the test specimens and the grip plates was not. Therefore, the ends of the specimens, which were to be attached to the grip plates, were roughened using sandpaper. The test assembly was bolted to the grip plates using 1/2 inch diameter A325T bolts with washers. These bolts were tightened to achieve a tightness much greater than snug, to aid in preventing slippage between the test specimens and the grip plates.

3. Measurement of Load and Elongation: The elongation of the bolted connections was measured using a LVDT attached to the test assembly as shown in Figure 8. A detail of the attachment is shown in Figure 9. The applied load and elongation readings of the connection were recorded at one second intervals, using a computer data acquisition system. Typical load deflection curves are given in Appendix H. The failure load, P_{ult}, was recorded for each test assembly and is given in Section V. The failure load per bolt can be computed by dividing P_{ult} by the number of bolts in the connection.

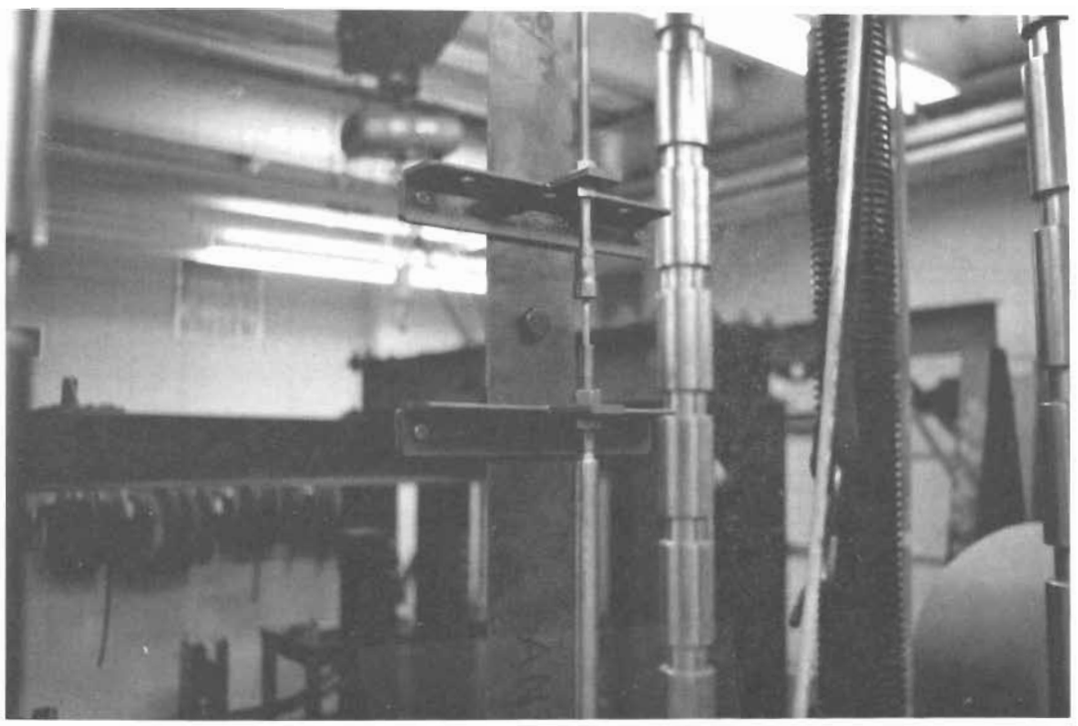


Figure 8. Photograph Of LVDT Attached To A Typical Test Assembly (Type A Specimens Shown).

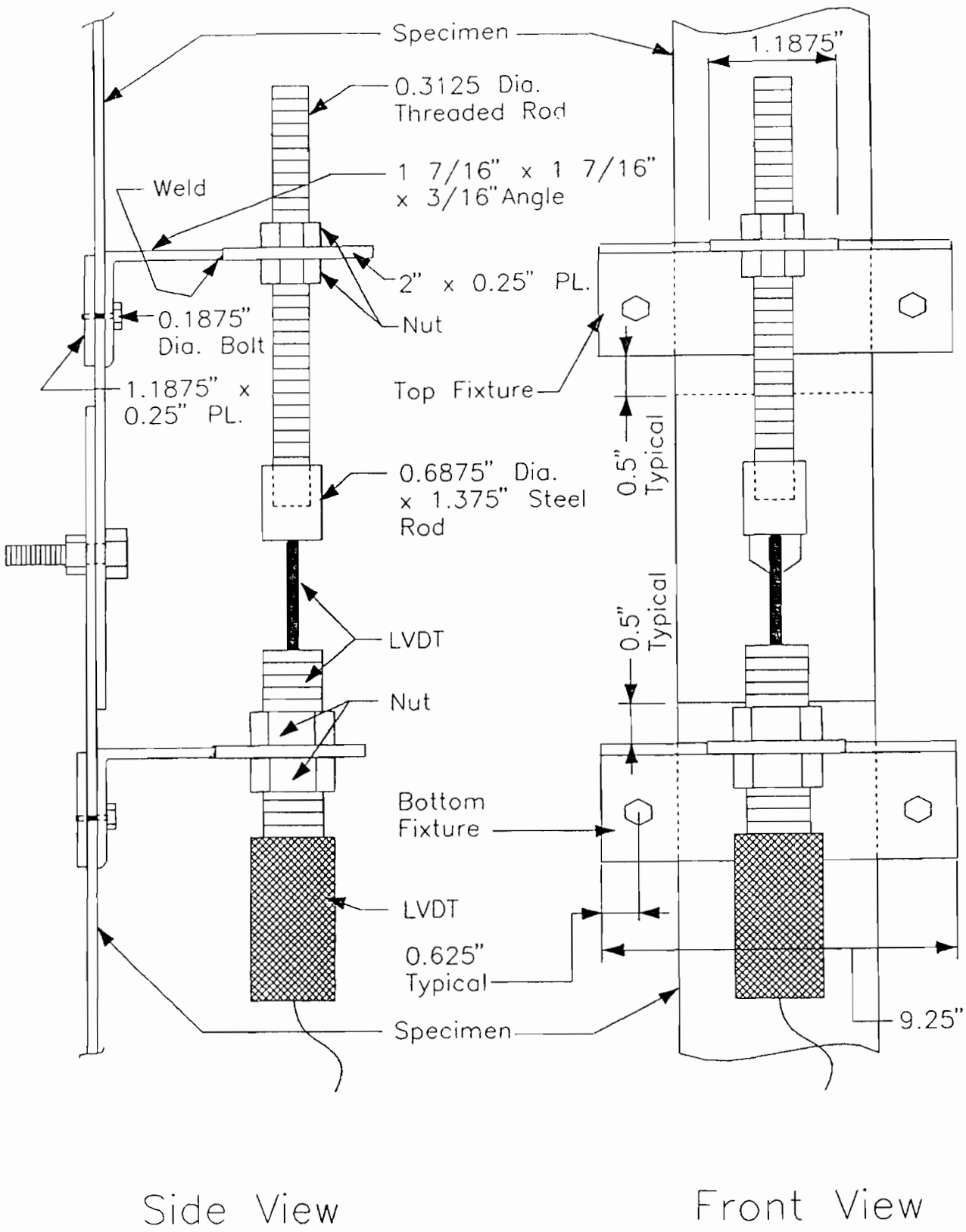


Figure 9. Detail Of LVDT Attached To A Typical Test Assembly (Type A Specimens Shown).

V. TEST RESULTS AND EVALUATION OF DATA

A. GENERAL

The results of the recent connection tests are summarized in Table XIII. Table XIII lists the assembly number, failure type, tested ultimate tensile force, P_{ult}, and the tested tensile force at 0.25 in. connection elongation, P'. This data is classified by failure type and is presented in Subsections B and C. A comparison of P_{ult} to the current AISI Specification[1]and AISC Specification[2] is also discussed.

The evaluation of test data was divided into two parts. The first part focused on bearing capacity and the development of a hole deformation or serviceability limit. The second part focused on determining if the AISI Specification[1] or the AISC Specification[2] was a better predictor of the nominal tensile capacity for fracture in the net section.

B. BEARING CAPACITY EVALUATION

1. Comparison of Design Specifications: The nominal bearing capacity according to the AISI Specification[1] and AISC Specification[2], defined in Section III as Equations 33 and 34, respectively, were reviewed and compared to the test results (Tables XIV through XVII). Tables XIV through XVII compare the test results with the AISI Specification[1] and the AISC Specification[2] for the assemblies which failed by Type II failure mode, or a combination failure mode that included Type II. Each table lists the tested ultimate force, P_{ult}; the calculated nominal capacity corresponding to the failure mode; the ratio of P_{ult} to the calculated nominal capacity and the statistical data for the ratio of P_{ult} to the calculated nominal capacity.

Table XIII. Test Results

Assembly Number	Failure Type	P_{ult} (kips)	P' (kips)
AY22-1	II	5.80	3.90
AY22-2	II	5.73	3.87
AY23-1	II	5.96	3.85
AY23-3	II	6.00	4.12
BY13-1	II	4.85	4.82
BY13-2	II	5.08	4.24
BY13-3	II	4.79	4.00
AN32-1	II	8.09	7.09
AN32-2	II	8.20	7.62
AN33-1	II	9.00	7.29
AN33-2	II	8.95	7.10
BN33-1	II	14.60	12.62
BN33-2	II	14.38	12.52
DN12-2	II	4.74	3.71
DN12-3	II	4.74	3.95
DN22-1	II	8.43	7.17
DN22-2	II	8.50	7.00
AY12-1	II & III	2.45	2.32
AY12-2	II & III	2.42	2.17
BY12-1	II & III	5.37	4.43
BY12-2	II & III	5.13	4.17
BY12-3	II & III	5.33	4.03
BY22-1	II & III	9.63	6.82
BY22-2	II & III	9.53	6.79
BY22-3	II & III	9.53	7.58
BN32-1	II & III	14.46	13.74

Table XIII. Continued

Assembly Number	Failure Type	P_{ult} (kips)	P' (kips)
BN32-2	II & III	14.69	13.68
DN32-1	II & V	15.75	13.42
DN32-2	II & V	16.08	13.17
EN12-1	II & V	8.65	7.33
EN12-2	II & V	8.70	7.17
EN22-1	II & V	15.77	12.59
EN22-2	II & V	15.74	12.77
EN32-1	II & V	28.83	23.17
EN32-2	II & V	29.00	22.17
AY11-1	III	2.42	2.10
AY11-2	III	2.27	2.15
AY21-1	III	3.86	3.47
AY21-2	III	4.03	3.37
BY11-1	III	2.44	2.04
BY11-2	III	2.64	2.56
BY11-3	III	2.33	2.17
BY21-1	III	4.11	3.56
BY21-2	III	4.12	3.92
BY21-3	III	4.26	4.14
AN31-2	III	6.58	5.58
AN31-3	III	6.54	5.77
BN31-1	III	6.60	*
BN31-2	III	6.60	6.54
CN11-1	III	2.29	2.26
CN11-2	III	2.33	2.26
CN12-1	III	5.74	4.85

Table XIII. Continued

Assembly Number	Failure Type	P_{ult} (kips)	P' (kips)
CN12-2	III	5.74	4.70
CN21-1	III	4.09	3.94
CN21-2	III	4.06	3.92
CN21-3	III	4.03	3.96
CN22-1	III	9.60	8.45
CN22-2	III	9.63	8.11
CN22-3	III	9.63	8.15
CN31-2	III	6.92	6.87
CN31-3	III	6.75	*
CN32-1	III	16.00	14.54
CN32-2	III	15.83	14.42
DN31-1	III	12.40	10.87
DN31-2	III	12.00	10.27
EN11-1	III	4.81	4.45
EN11-2	III	4.83	4.45
EN21-1	III	8.41	7.64
EN21-2	III	8.41	7.55
EN31-1	III	13.23	13.23
EN31-2	III	13.54	13.54
DN11-1	III & V	4.07	3.52
DN11-2	III & V	4.21	3.35
DN21-1	III & V	7.19	5.92
DN21-2	III & V	7.08	5.75

* P_{ult} Reached Before 0.25-in. Connection Elongation

Table XIV. Comparison Of Test Results With AISI Specification[1] And AISC Specifications[2] For Failure Type II

Assembly Number	P_{ult} (kips)	AISI Eq. 33 Washers (kips)	AISI Eq. 33 No Washers (kips)	AISC Eq. 34 (kips)	P_{ult} / AISI Eq. 33 Washers	P_{ult} / AISI Eq. 33 No Washers	P_{ult} / AISC Eq. 34
AY22-1	5.80	5.667	N.A.	5.667	1.024	N.A.	1.024
AY22-2	5.73	5.509	N.A.	5.509	1.040	N.A.	1.040
AY23-1	5.96	5.509	N.A.	5.509	1.082	N.A.	1.082
AY23-3	6.00	5.509	N.A.	5.509	1.089	N.A.	1.089
BY13-1	4.85	7.036	N.A.	7.036	0.689	N.A.	0.689
BY13-2	5.08	7.203	N.A.	7.203	0.705	N.A.	0.705
BY13-3	4.79	7.371	N.A.	7.371	0.650	N.A.	0.650
AN32-1	8.09	N.A.	6.945	9.385	N.A.	1.165	0.862
AN32-2	8.20	N.A.	6.827	9.226	N.A.	1.201	0.889
AN33-1	9.00	N.A.	6.945	9.385	N.A.	1.296	0.959
AN33-2	8.95	N.A.	7.063	9.544	N.A.	1.267	0.938
BN33-1	14.60	N.A.	14.007	18.929	N.A.	1.042	0.771
BN33-2	14.38	N.A.	14.007	18.929	N.A.	1.027	0.760
DN12-2	4.74	N.A.	5.331	7.203	N.A.	0.889	0.658
DN12-3	4.74	N.A.	5.207	7.036	N.A.	0.910	0.674
DN22-1	8.43	N.A	8.154	11.019	N.A.	1.034	0.765
DN22-2	8.50	N.A	8.270	11.176	N.A.	1.028	0.761
				Mean	1.008		0.842
				Std. Dev.	0.184		0.150
				COV	0.182		0.178

N.A. = Not Applicable

Table XV. Comparison Of Test Results With AISI Specification[1] And AISC Specification[2] For Combination Failure Type II and III (Bearing)

Assembly Number	P_{ult} (kips)	AISI Eq. 33 Washers (kips)	AISI Eq. 33 No Washers (kips)	AISC Eq. 34 (kips)	P_{ult} / AISI Eq. 33 Washers	P_{ult} / AISI Eq. 33 No Washers	P_{ult} / AISC Eq. 34
AY12-1	2.45	3.518	N.A.	3.518	0.696	N.A.	0.696
AY12-2	2.42	3.602	N.A.	3.602	0.672	N.A.	0.672
BY12-1	5.37	7.539	N.A.	7.539	0.712	N.A.	0.712
BY12-2	5.13	7.539	N.A.	7.539	0.681	N.A.	0.681
BY12-3	5.33	7.036	N.A.	7.036	0.758	N.A.	0.758
BY22-1	9.63	11.176	N.A.	11.176	0.862	N.A.	0.862
BY22-2	9.53	11.019	N.A.	11.019	0.865	N.A.	0.865
BY22-3	9.53	11.019	N.A.	11.019	0.865	N.A.	0.865
BN32-1	14.46	N.A.	13.890	18.770	N.A.	1.041	0.770
BN32-2	14.69	N.A.	13.772	18.611	N.A.	1.067	0.789
					Mean 0.822		0.767
					Std. Dev. 0.137		0.073
					COV 0.167		0.095

N.A. = Not Applicable
Std. Dev. = Standard Deviation
COV = Coefficient of Variation

Table XVI. Comparison Of Test Results With AISI Specification[1] And AISC Specification[2] For Combination Failure Type II And III (Tension, Fracture Through The Net Section)

Assembly Number	Pult (kips)	AISI Washers (kips)	AISI No Washers (kips)	AISC(1) (kips)	AISC(2) (kips)	Pult / AISI Washer	Pult / AISI No Washers	Pult / AISC (1)	Pult / AISC (2)
AY12-1	2.45	3.533	N.A.	6.278	6.132	0.694	N.A.	0.390	0.400
AY12-2	2.42	3.616	N.A.	6.430	6.280	0.669	N.A.	0.376	0.385
BY12-1	5.37	5.252	N.A.	6.719	6.562	1.023	N.A.	0.799	0.818
BY12-2	5.13	5.254	N.A.	6.724	6.567	0.976	N.A.	0.763	0.781
BY12-3	5.33	4.904	N.A.	6.276	6.129	1.087	N.A.	0.849	0.870
BY22-1	9.63	7.859	N.A.	10.081	9.848	1.225	N.A.	0.955	0.978
BY22-2	9.53	7.742	N.A.	9.928	9.698	1.231	N.A.	0.960	0.983
BY22-3	9.53	7.748	N.A.	9.939	9.709	1.230	N.A.	0.959	0.982
BN32-1	14.46	N.A.	11.687	16.899	16.508	N.A.	1.237	0.856	0.876
BN32-2	14.69	N.A.	11.558	16.700	16.312	N.A.	1.271	0.880	0.901
					Mean	1.064		0.779	0.797
					Std. Dev.	0.214		0.208	0.213
					COV	0.201		0.267	0.267

N.A. = Not Applicable
Std. Dev. = Standard Deviation
COV = Coefficient of Variation
(1) = Cross-Sectional Area Equal To Net Cross-Sectional Area
(2) = Cross-Sectional Area Determined Assuming Bolt Hole Dia. Equal To Actual Bolt Hole Dia. Plus 1/16-in.

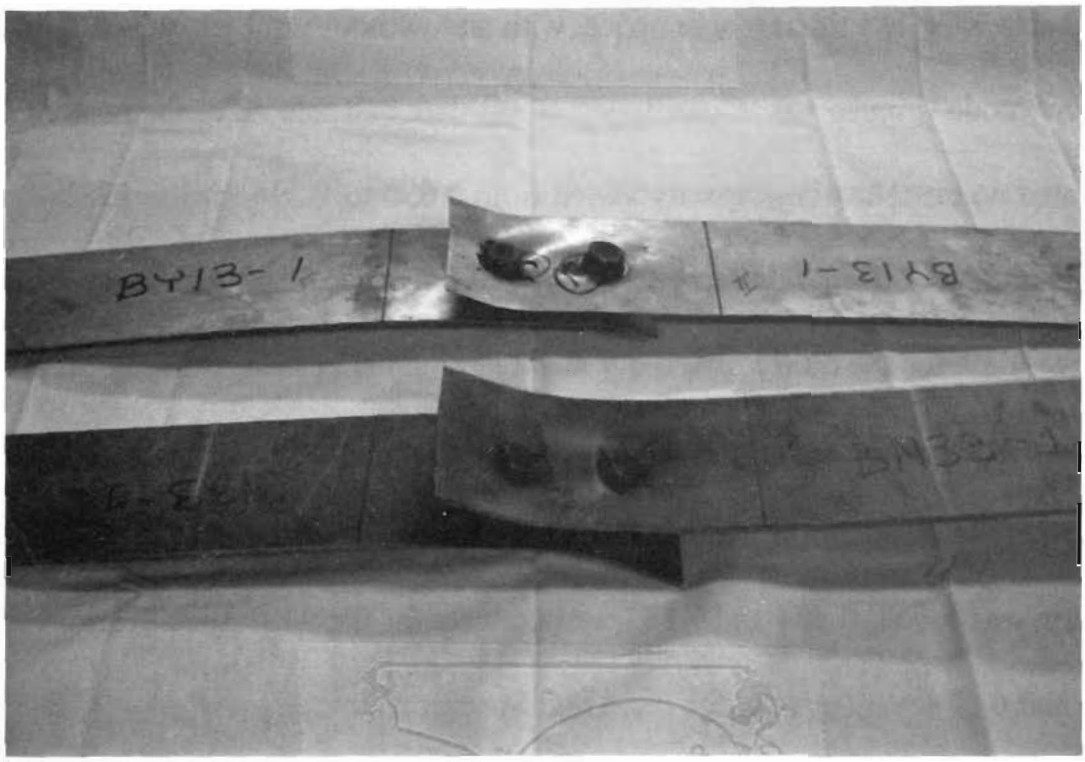
Table XVII. Comparison Of Test Results With AISI Specification[1] and AISC Specification[2] For Combination Failure Type II and V (Bearing)

Assembly Number	P_{ult} (kips)	AISI Eq. 33 No Washers (kips)	AISC Eq. 34 (kips)	P_{ult} / AISI Eq. 33 No Washers	P_{ult} / AISC Eq. 34
DN32-1	15.75	14.125	19.088	1.115	0.825
DN32-2	16.08	13.890	18.770	1.158	0.857
EN12-1	8.65	10.661	14.407	0.811	0.600
EN12-2	8.70	10.661	14.407	0.816	0.604
EN22-1	15.77	16.541	22.352	0.953	0.706
EN22-2	15.74	16.774	22.667	0.938	0.694
EN32-1	28.83	27.779	37.540	1.038	0.768
EN32-2	29.00	27.544	37.221	1.053	0.779
			Mean	0.985	0.729
			Std. Dev.	0.120	0.089
			COV	0.122	0.122

N.A. = Not Applicable
Std. Dev. = Standard Deviation
COV = Coefficient of Variation

Table XIV lists the test assemblies, with and without washers, which failed by Type II failure mode (Figure 10). Considering all the data in Table XIV, the ratio of P_{ult} to the calculated nominal bearing capacity varied from 0.650 to 1.296 for the AISI Specification[1] and from 0.650 to 1.089 for the AISC Specification[2]. Comparing the statistical data for the ratio P_{ult} to the calculated nominal bearing capacity for all the data, showed that the AISI Specification[1] correlates slightly better with P_{ult} than does the AISC Specification[2] for this data. The mean, standard deviation and coefficient of variation was 1.008, 0.184 and 0.182, respectively for the AISI Specification[1] and 0.842, 0.150 and 0.178 respectively, for the AISC Specification[2].

Tables XV and XVI list the test assemblies which failed by a combination of Type II and III failure modes (Figure 11). Table XV compares the test results against the AISI Specification[1] and AISC Specification[2] calculated nominal bearing capacity; Table XVI compares the test results with the AISI Specification[1] and AISC Specification[2] calculated nominal tensile capacity for fracture in the net section. The ratio of P_{ult} to the calculated nominal bearing capacity varied from 0.672 to 1.067 and from 0.672 to 0.865 for the AISI Specification[1] and AISC Specification[2], respectively. The AISI Specification[1] ratio of P_{ult} to the calculated nominal tensile force ranged from 0.669 to 1.271. The ratio of P_{ult} to the calculated nominal tensile capacity for the AISC Specification[2] (1) varied from 0.376 to 0.960; for AISC Specification[2] (2) the ratio varied from 0.385 to 0.983. The low values are for single bolt connections having failed by a combined failure mode, which is not covered in the AISC Specification[2]. This type of connection is not typical for hot-rolled construction. For tests conducted in this study, both the AISI Specification[1] and the AISC Specification[2] calculated nominal



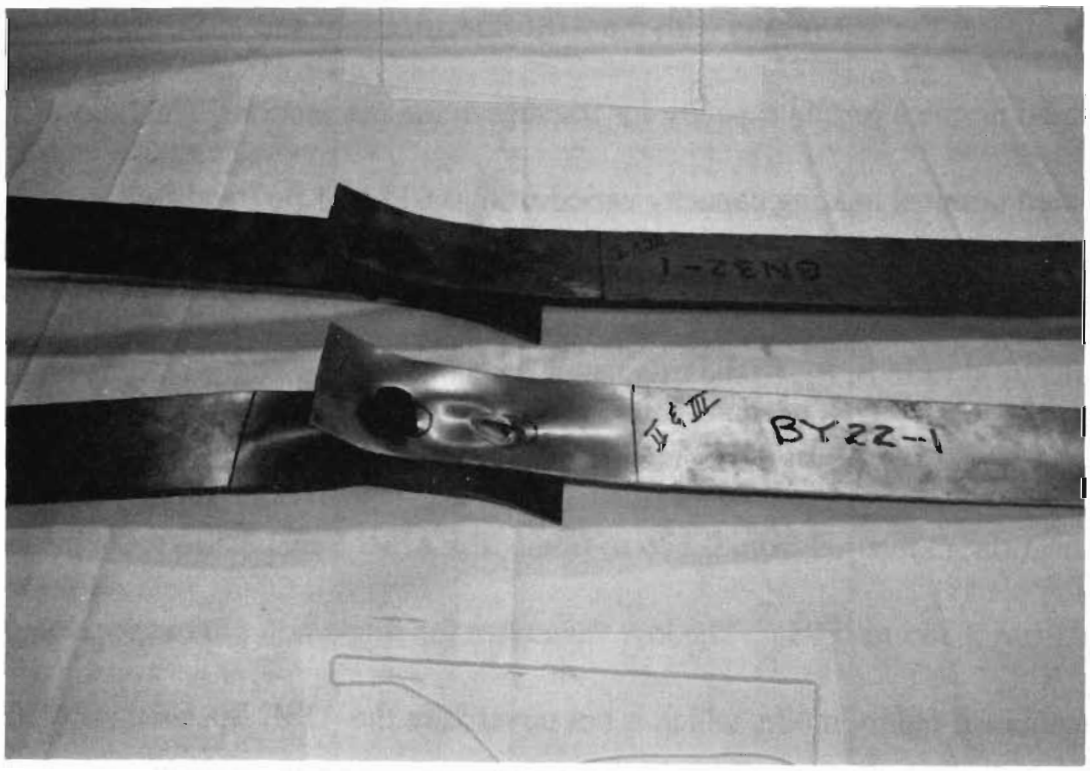


Figure 11. Photograph Of A Typical Test Assembly Failing By Combination Type II And III Failure Mode (Type B Specimens Shown).

tensile capacities provided better correlation to the ultimate tested load, P_{ult}, than did the nominal bearing capacities; this can be seen by observing the statistical data for the ratio of P_{ult} to the calculated nominal capacities. The AISI Specification[1] mean, standard deviation and coefficient of variation for the ratio P_{ult} to the calculated nominal capacity was 0.822, 0.137 and 0.167 respectively for bearing and 1.064, 0.214 and 0.201 respectively for tension. The AISC Specification[2] mean, standard deviation and coefficient of variation for the ratio of P_{ult} to the calculated nominal bearing capacity was 0.767, 0.073 and 0.095, respectively; the AISC Specification[2] mean, standard deviation and coefficient of variation of the ratio of P_{ult} to the calculated nominal tensile capacity was 0.779, 0.208 and 0.267, respectively for (1) and 0.797, 0.213 and 0.267 for (2).

Table XVII lists the assemblies which failed by the combination failure Type II and V (Figure 12). The ratio of the tested ultimate tensile force, P_{ult}, to the calculated nominal bearing capacity varied from 0.811 to 1.158 for the AISI Specification[1] and from 0.600 to 0.857 for the AISC Specification[2]. For this data, the AISI Specification[1] showed better correlation with P_{ult} than did the AISC Specification[2]. This is shown by comparing the statistical data for the ratio P_{ult} to the calculated nominal bearing capacity. The mean, standard deviation and coefficient of variation was 0.985, 0.120 and 0.122 respectively, for the AISI Specification[1] and 0.729, 0.089 and 0.122 respectively, for the AISC Specification[2].

2. Development of Deformation or Serviceability Limit: The results of the tests which failed in bearing (Type II failure mode) or any combination that included bearing were considered for the serviceability evaluation. The results of the test assemblies whose failure mode included bearing are listed in Tables XVIII. Table XVIII also lists

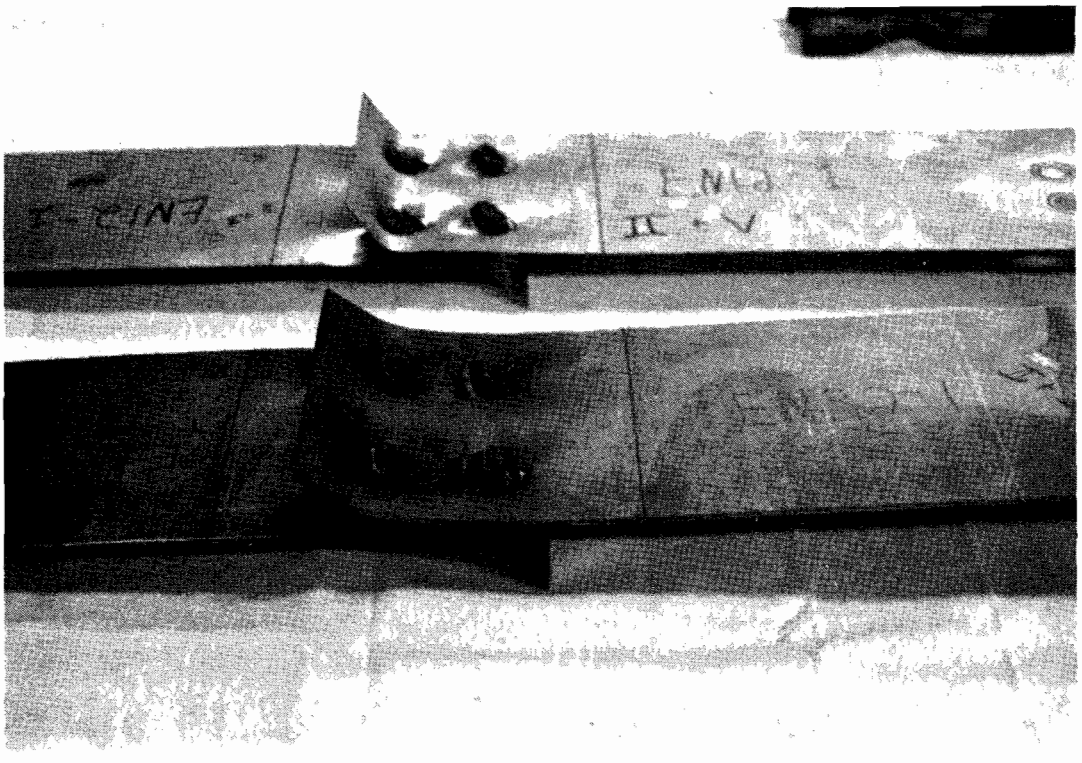


Figure 12. Photograph Of A Typical Test Assembly Failing By Combination Type II And V Failure Mode (Type E Specimens Shown).

the ratio of the tested ultimate tensile force at 0.25 in. connection elongation, P', to Equation 35. Equation 35, as defined in Section III, is AISC's nominal bearing capacity when deformation around the bolt hole is a design consideration. As indicated by the statistical data for the ratio P'/Eq. 35, Equation 35 is a poor predictor of a deformation limit for cold-formed steel connections; the mean, standard deviation and coefficient of variation were 0.805, 0.102 and 0.127, respectively.

The intent of this investigation was to develop an equation for the nominal bearing capacity, P_n, of a bolted connection that would limit the amount of deformation around a bolt hole to an acceptable limit. For consistency with the AISC Specification[2], a

Table XVIII. Evaluation Of Test Results For Deformation Limit

Assembly Number	P ' (kips)	P ' / Eq. 35	c Eq. 46	P ' / Eq. 47
AY22-1	3.90	0.860	2.065	1.070
AY22-2	3.87	0.878	2.107	1.092
AY23-1	3.85	0.874	2.096	1.086
AY23-3	4.12	0.935	2.243	1.162
BY13-1	4.82	0.856	2.055	1.065
BY13-2	4.24	0.736	1.766	0.915
BY13-3	4.00	0.678	1.628	0.844
AN32-1	7.09	0.944	2.266	1.174
AN32-2	7.62	1.032	2.478	1.284
AN33-1	7.29	0.971	2.330	1.207
AN33-2	7.10	0.930	2.232	1.156
BN33-1	12.62	0.833	2.000	1.036
BN33-2	12.52	0.827	1.984	1.028
DN12-2	3.71	0.644	1.545	0.801
DN12-3	3.95	0.702	1.684	0.873
DN22-1	7.17	0.813	1.952	1.011
DN22-2	7.00	0.783	1.879	0.974
AY12-1	2.32	0.824	1.978	1.025
AY12-2	2.17	0.753	1.807	0.937
BY12-1	4.43	0.735	1.763	0.913
BY12-2	4.17	0.691	1.659	0.860
BY12-3	4.03	0.716	1.718	0.890
BY22-1	6.82	0.763	1.831	0.949
BY22-2	6.79	0.770	1.849	0.958

Table XVIII. Continued

Assembly Number	P ' (kips)	P ' / Eq. 35	c Eq. 46	P ' / Eq. 47
BY22-3	7.58	0.860	2.064	1.069
BN32-1	13.74	0.915	2.196	1.138
BN32-2	13.68	0.919	2.205	1.143
DN32-1	13.42	0.879	2.109	1.093
DN32-2	13.17	0.877	2.105	1.091
EN12-1	7.33	0.636	1.526	0.791
EN12-2	7.17	0.622	1.493	0.774
EN22-1	12.59	0.704	1.690	0.876
EN22-2	12.77	0.704	1.690	0.876
EN32-1	23.17	0.772	1.852	0.959
EN32-2	22.17	0.745	1.787	0.926
	Mean	0.805	1.930	1.001
	Std. Dev.	0.102		0.127
	COV	0.127		0.127

deformation limit of 0.25 inches was selected as an acceptable limit. To be consistent with existing design expressions, it was desired to have an equation in the form of:

$$P_n = cdtF_u \qquad \text{(Eq. 45)}$$

where,

c = Constant recognizing serviceability limit

d = Nominal bolt diameter (in.)

t = Thickness of the thinnest connected sheet (in.)

F_u = Tensile strength of connected part (ksi)

The constant c for each test was determined using Equation 46 and is shown in Table XVIII:

$$c = P'/dtF_u n_b \qquad \text{(Eq.46)}$$

where,

P' = Tested tensile load at 0.25 in. connection deformation (kips)

d = Nominal bolt diameter (in.)

t = Thickness of the thinnest connected sheet (in.)

F_u = Tensile strength of connected part (ksi)

n_b = Number of bolts

The constant c varied from 1.493 to 2.478 for the different connections shown in Table XVIII. However, the mean, considering all the tests in Table XVIII, was found to be 1.93. Therefore, a proposed bearing strength equation that would limit the deformation around the bolt hole to approximately 0.25 in. is given as follows:

$$P_n = 1.93dtF_u \qquad \text{(Eq. 47)}$$

where d, t and F_u are defined for Equation 46.

The accuracy of Equation 47 to provide a 0.25 inch deformation limit is indicated by the ratio of P' to Equation 47 (Table XVIII); the ratio ranged from 0.774 to 1.284, with a mean of 1.001, a standard deviation of 0.127 and a coefficient of variation of 0.127.

C. TENSILE CAPACITY EVALUATION

1. Comparison of Design Specifications: The nominal tensile capacity for fracture in the net section, as defined in Section III, was evaluated for both the AISI Specification[1] and AISC Specification[2] and compared to the test results. Tables XIX and XX separate the specimens with and without washers which failed by failure Type III (Figure 13) and the combination of Type III and V failure modes (Figure 14). Tables XIX and XX list the ratio of the ultimate tested tensile load, P_{ult}, to the AISI Specification[1] and AISC Specification[2] calculated nominal tensile capacity for fracture in the net section, along with the corresponding mean, standard deviation and coefficient of variation.

Table XIX summarizes the results of the test assemblies tested with washers. The ratio of P_{ult} to the calculated nominal tensile capacity ranged from 0.957 to 1.037 for both the AISI Specification[1] and the AISC Specification[2] (1). For the AISC Specification[2] (2), the ratio ranged from 0.987 to 1.101.

Table XX lists the results for those assemblies without washers. The ratio of P_{ult} to the calculated nominal tensile capacity varied from 0.984 to 1.302 for the AISI Specification[1]. This ratio ranged from 0.842 to 1.039 and for AISC Specification[2] (1) and from 0.895 to 1.104 for the AISC Specification[2] (2).

2. Correlation of Design Specifications with Test Results: The statistical data for the AISI Specification[1] and the AISC Specification[2], given in Tables XIX and XX, show good correlation between the existing design models and the test results. The statistical data for the assemblies with washers was approximately the same for both the AISI Specification[1] and the AISC Specification[2]. The mean, standard deviation and

Table XIX. Evaluation of Test Results For Computed Tensile Capacity With Washers (Fracture Through The Net Section)

Assembly Number	Failure Type	Pult (kips)	AISI Washers (kips)	AISC (1) (kips)	AISC (2) (kips)	Pult / AISI Washers	Pult / AISC (1)	Pult / AISC (2)
AY11-1	III	2.42	2.453	2.453	2.307	0.986	0.986	1.049
AY11-2	III	2.27	2.446	2.446	2.300	0.928	0.928	0.987
AY21-1	III	3.86	4.035	4.035	3.802	0.957	0.957	1.015
AY21-2	III	4.03	3.994	3.994	3.761	1.009	1.009	1.072
BY11-1	III	2.44	2.451	2.451	2.304	0.996	0.996	1.059
BY11-2	III	2.64	2.572	2.572	2.419	1.026	1.026	1.091
BY11-3	III	2.33	2..541	2.514	2.364	0.927	0.927	0.986
BY21-1	III	4.11	3.981	3.981	3.752	1.032	1.032	1.095
BY21-2	III	4.12	4.084	4.084	3.848	1.009	1.009	1.071
BY21-3	III	4.26	4.107	4.107	3.870	1.037	1.037	1.101
					Mean	0.991	0.991	1.053
					Std. Dev.	0.039	0.039	0.041
					COV	0.039	0.039	0.039

Std. Dev = Standard Deviation
COV = Coefficient of Variation
(1) = Cross-Sectional Area Equal To Net Cross-Sectional Area
(2) = Cross-Sectional Area Determined Assuming Bolt Hole Dia. Equal To Actual Bolt Hole Dia. Plus 1/16-in.

Table XX. Evaluation of Test Results For Computed Tensile Capacity Without Washers (Fracture Through The Net Section)

Assembly Number	Failure Type	Pult (kips)	AISI No Washers (kips)	AISC (1) (kips)	AISC (2) (kips)	Pult / AISI No Washers	Pult / AISC (1)	Pult / AISC (2)
AN31-2	III	6.58	5.055	6.649	6.264	1.302	0.990	1.050
AN31-3	III	6.54	5.086	6.644	6.256	1.286	0.984	1.045
BN31-1	III	6.60	5.909	6.688	6.297	1.117	0.987	1.048
BN31-2	III	6.60	5.897	6.670	6.278	1.136	1.005	1.067
CN11-1	III	2.29	2.326	2.514	2.364	0.984	0.911	0.969
CN11-2	III	2.33	2.326	2.514	2.364	1.002	0.927	0.986
CN12-1	III	5.74	5.112	6.428	6.278	1.123	0.893	0.914
CN12-2	III	5.74	5.110	6.426	6.275	1.123	0.893	0.915
CN21-1	III	4.09	3.721	4.046	3.813	1.099	1.011	1.073
CN21-2	III	4.06	3.750	4.073	3.836	1.083	0.997	1.058
CN21-3	III	4.03	3.753	4.076	3.840	1.074	0.989	1.049
CN22-1	III	9.60	7.993	10.062	9.829	1.201	0.954	0.977
CN22-2	III	9.63	8.116	10.219	9.983	1.186	0.942	0.965
CN22-3	III	9.63	8.007	10.081	9.848	1.203	0.955	0.978

Table XX. Continued

Assembly Number	Failure Type	Pult (kips)	AISI No Washers (kips)	AISC (1) (kips)	AISC (2) (kips)	Pult / AISI No Washers	Pult / AISC (1)	Pult / AISC (2)
CN31-2	III	6.92	6.920	6.827	6.429	1.100	1.014	1.076
CN31-3	III	6.75	6.343	6.884	6.483	1.080	0.995	1.057
CN32-1	III	16.00	13.770	17.335	16.934	1.162	0.923	0.945
CN32-2	III	15.83	13.617	17.135	16.737	1.163	0.924	0.946
DN31-1	III	12.40	10.416	13.565	12.770	1.191	0.914	0.971
DN31-2	III	12.00	10.078	13.150	12.381	1.191	0.913	0.969
EN11-1	III	4.81	4.603	5.194	4.887	1.045	0.926	0.984
EN11-2	III	4.83	4.507	5.090	4.780	1.072	0.949	1.008
EN21-1	III	8.41	7.166	8.122	7.650	1.174	1.035	1.099
EN21-2	III	8.41	7.145	8.092	7.620	1.177	1.039	1.104
EN31-1	III	13.23	11.717	13.263	12.488	1.129	0.997	1.059
EN31-2	III	13.54	11.817	13.377	12.595	1.146	1.012	1.075
DN11-1	III & V	4.07	3.726	4.835	4.549	1.092	0.842	0.895
DN11-2	III & V	4.21	3.815	4.944	4.651	1.104	0.852	0.905

Table XX. Continued

Assembly Number	Failure Type	Pult (kips)	AISI No Washers (kips)	AISC (1) (kips)	AISC (2) (kips)	Pult / AISI No Washers	Pult / AISC (1)	Pult / AISC (2)
DN21-1	III & V	7.19	6.194	8.092	7.620	1.161	0.889	0.944
DN21-2	III & V	7.08	6.108	7.980	7.514	1.159	0.887	0.942
					Mean	1.135	0.952	1.002
					Std. Dev.	0.069	0.053	0.062
					COV	0.061	0.056	0.061

Std. Dev = Standard Deviation
COV = Coefficient of Variation
(1) = Cross-Sectional Area Equal To Net Cross-Sectional Area
(2) = Cross-Sectional Area Determined Assuming Bolt Hole Dia. Equal To Actual Bolt Hole Dia. Plus 1/16-in.

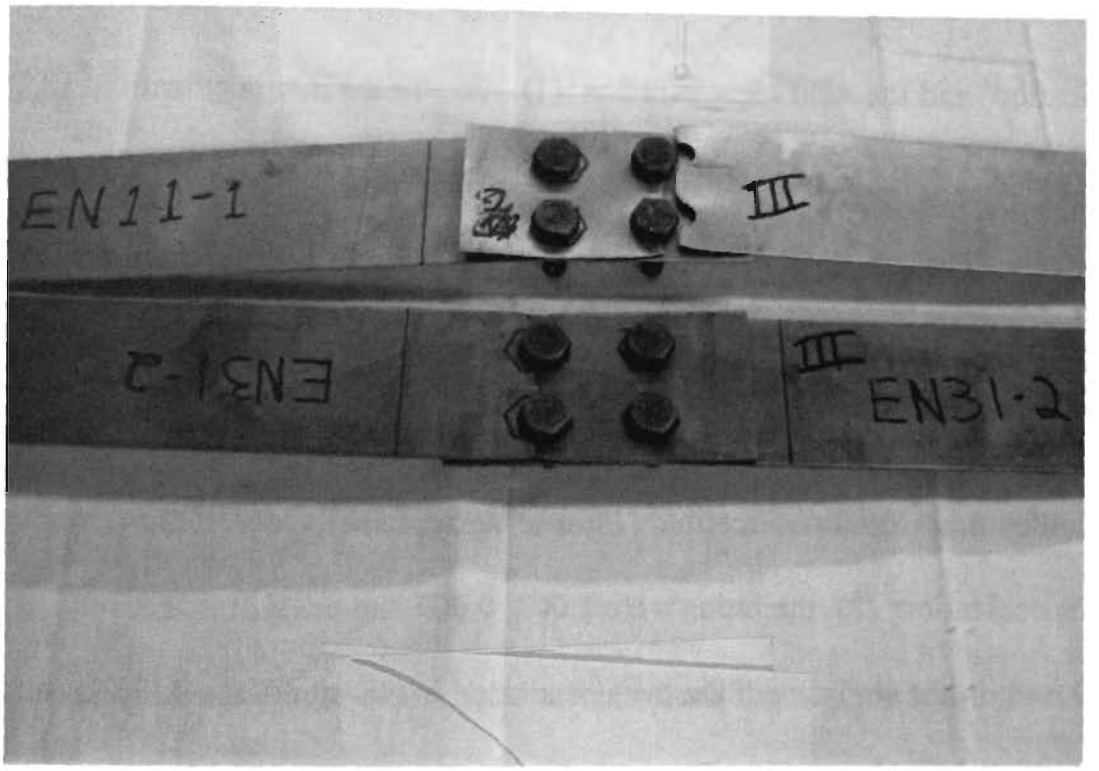


Figure 13. Photograph Of A Typical Test Assembly Failing By Type III Failure Mode (Type E Specimens Shown).

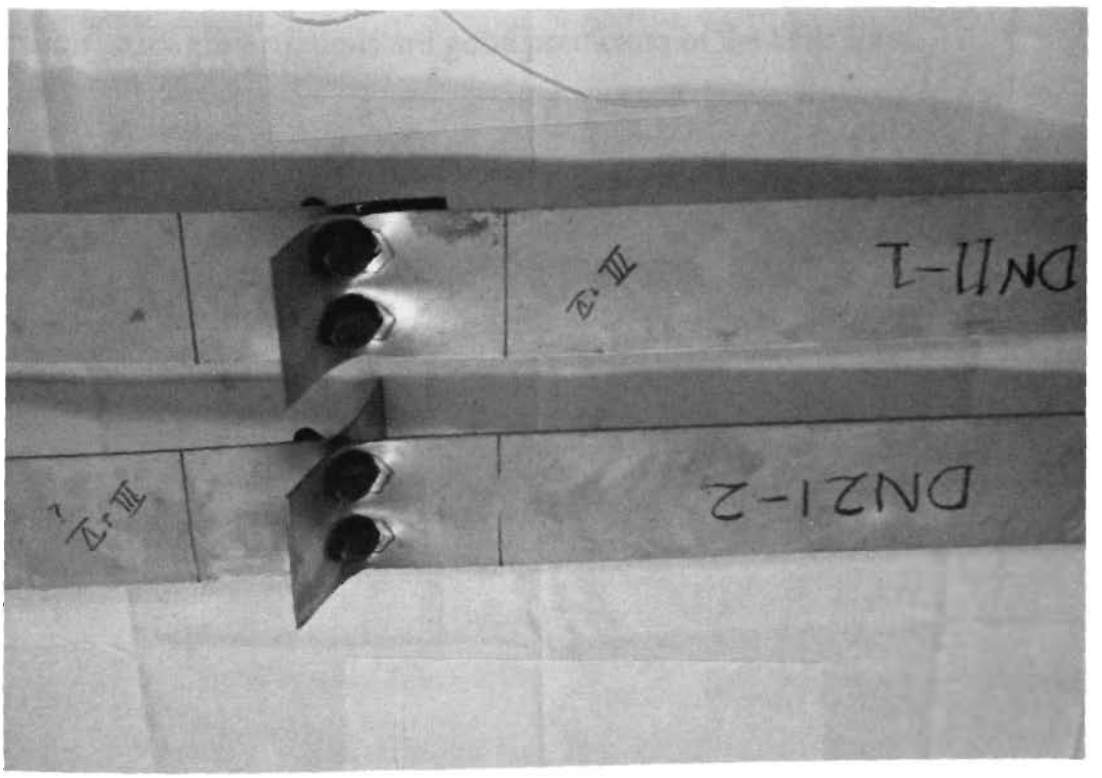


Figure 14. Photograph Of A Typical Test Assembly Failing By Combination Type III And V Failure Mode (Type D Specimens Shown).

coefficient of variation were 0.991, 0.039 and 0.039, respectively, for the AISI Specification[1] and the AISC Specification[2] (1). For the AISC Specification[2] (2), the mean, standard deviation and coefficient of variation were 1.053, 0.041 and 0.039, respectively. The statistical data for the assemblies without washers varied slightly. The mean, standard deviation and coefficient of variation for the AISI Specification[1] were 1.135, 0.069 and 0.061, respectively. The mean, standard deviation and coefficient of variation for the AISC Specification[2] (1) were 0.952, 0.053 and 0.056, respectively; for AISC Specification[2] (2) the ratios were 1.002, 0.062 and 0.061, respectively.

Based on the statistics of the tests conducted in this study, the AISI Specification[1] and the AISC Specification[2] are both good predictors of the nominal tensile force for fracture in the net section; however, the AISI Specification[1] was slightly more conservative based on the mean value of the test results, i.e. 1.135 verses 1.002.

VI. CONCLUSIONS

Based on 75 additional tests of single sheet bolted connections, the following was discovered:

(1) For bearing, the existing AISI Specification[1] strength equations are good predictors of the strength limit state for bolted connections failing in pure bearing (Type II failure mode). The AISC Specification[2] did not predict the ultimate bearing capacity as good as the AISI Specification[1].

(2) A design equation for bearing and combinations that include bearing was developed based on the serviceablilty limit which was defined as 0.25 inches of connection deformation.

(3) For fracture in the net section, the existing AISI Specification[1] and AISC Specification[2] strength equations are good predictors of the limit state.

APPENDIX A

Dimensions And Results Of Bolted Connections Used In The Evaluation Of Existing Data - Type III Failure Mode

Dimensions and Results of Single Shear Bolted Connections with Washers - Tensile Strength Study (One Bolt) - Failure Type III

Spec.	d in.	t in.	e in.	s in.	e/d	d/t	d/s	Fy ksi	Fu ksi	Fu/Fy	Controlling AISC kip	Controlling AISI kip	ECCS KN	BS 5950 KN	CAN\CSA KN
20A41SS1	0.250	0.0346	1.125	4.00	4.50	7.23	0.063	32.11	41.85	1.30	4.92	1.55	5.71	5.28	19.77
20A41SS2	0.250	0.0349	1.125	4.00	4.50	7.16	0.063	32.11	41.85	1.30	4.97	1.56	5.76	5.33	19.94
20A32SS2	0.375	0.0342	1.313	4.00	3.50	10.96	0.094	32.11	41.85	1.30	4.87	1.96	7.10	6.69	22.88
20A42SS3	0.375	0.0360	1.688	4.00	4.50	10.42	0.094	32.11	41.85	1.30	5.12	2.07	7.48	7.04	24.08
20A43SS3	0.500	0.0361	2.250	4.00	4.50	13.90	0.125	32.11	41.85	1.30	5.14	2.47	9.25	8.42	23.10
20A34SS	0.625	0.0359	2.188	4.00	3.50	17.40	0.156	32.11	41.85	1.30	4.98	2.83	10.46	9.66	22.14
20A44SS	0.625	0.0353	2.813	4.00	4.50	17.70	0.156	32.11	41.85	1.30	4.89	2.78	10.28	9.50	21.77
20A25SS1	0.750	0.0357	1.875	4.00	2.50	21.00	0.188	32.11	41.85	1.30	4.76	3.16	11.53	10.77	21.18
20A35SS1	0.750	0.0357	2.625	4.00	3.50	21.00	0.188	32.11	41.85	1.30	4.76	3.16	11.53	10.77	21.18
16C305SS	0.750	0.0591	2.250	4.00	3.00	12.70	0.188	32.00	44.00	1.38	8.29	5.50	19.02	17.76	36.87
16C505SS	0.750	0.0591	3.750	4.00	5.00	12.70	0.188	32.00	44.00	1.38	8.29	5.50	19.02	17.76	36.87
14B25SS1	0.750	0.0798	1.875	4.00	2.50	9.40	0.188	29.80	43.40	1.46	11.04	7.33	23.92	22.34	49.10
14B35SS1	0.750	0.0771	2.625	4.00	3.50	9.73	0.188	29.80	43.40	1.46	10.67	7.08	23.11	21.58	47.44
14B45SS	0.750	0.0814	3.375	4.00	4.50	9.21	0.188	29.80	43.40	1.46	11.26	7.48	24.40	22.78	50.09
14B26SS1	1.000	0.0768	2.500	4.00	2.50	13.00	0.250	29.80	43.40	1.46	9.79	8.32	26.82	25.42	43.55
14B36SS1	0.750	0.0741	2.625	4.00	3.50	10.12	0.188	29.80	43.40	1.46	10.25	6.81	22.21	20.74	45.60
14B46SS1	0.750	0.0789	3.375	4.00	4.50	9.51	0.188	29.80	43.40	1.46	10.91	7.25	23.65	22.08	48.55
12A34SS1	0.625	0.0922	2.188	4.00	3.50	6.78	0.156	26.00	41.15	1.58	9.59	7.14	21.74	20.09	42.65
12A44SS1	0.625	0.0922	2.813	4.00	4.50	6.78	0.156	26.00	41.15	1.58	9.59	7.14	21.74	20.09	42.65
12Y-L19	0.8750	0.104	3.001	3.530	3.430	8.41	0.248	72.40	72.80	1.01	19.63	16.56	77.86	73.25	87.31
7Y-T3	0.7500	0.183	0.625	1.500	0.833	4.10	0.500	86.40	91.30	1.06	11.49	11.49	48.35	48.35	51.09
12Y-L27	0.3750	0.105	1.999	0.872	5.330	3.57	0.430	87.00	88.10	1.01	4.31	4.31	18.92	18.92	19.16
12Y-L28	0.6250	0.105	2.500	1.500	4.000	5.95	0.417	87.00	88.10	1.01	7.52	7.52	33.01	33.01	33.43
7Y-T30	0.7500	0.183	2.498	1.870	3.330	4.10	0.401	87.00	91.00	1.05	17.61	17.61	74.89	74.89	78.33
7Y-L20	0.7500	0.183	1.125	1.500	1.500	4.10	0.500	83.10	83.80	1.01	10.54	10.54	46.50	46.50	46.90
7Y-L21	0.7500	0.183	2.400	2.500	3.200	4.10	0.300	83.10	83.80	1.01	25.88	25.88	114.15	114.15	115.11
20Z-L1	0.5000	0.039	1.750	1.500	3.500	12.82	0.333	75.50	81.70	1.08	2.99	2.99	12.28	12.28	13.29
20Z-T10	0.5000	0.039	1.750	1.500	3.500	12.82	0.333	94.40	99.80	1.06	3.65	3.65	15.35	15.35	16.23
1605X-L1	0.7500	0.065	2.250	2.500	3.000	11.54	0.300	83.25	83.25	1.00	9.13	9.13	40.62	40.62	40.62

Dimensions and Results of Single Shear Bolted Connections with Washers - Tensile Strength Study (One Bolt) - Failure Type III - Cont

Spec.	Pult kips	Pult/AISI	Pult/AISC	Pult/ECCS	Pult/BS 5950	Pult/(CAN\CSA)	Reference
20A41SS1	1.994	1.29	0.41	1.55	1.68	0.45	12
20A41SS2	1.930	1.24	0.39	1.49	1.61	0.43	12
20A32SS2	2.451	1.25	0.50	1.53	1.63	0.48	12
20A42SS3	1.695	0.82	0.33	1.01	1.07	0.31	12
20A43SS3	2.550	1.03	0.50	1.23	1.35	0.49	12
20A34SS	2.930	1.04	0.59	1.25	1.35	0.59	12
20A44SS	2.561	0.92	0.52	1.11	1.20	0.52	12
20A25SS1	2.879	0.91	0.60	1.11	1.19	0.60	12
20A35SS1	2.860	0.90	0.60	1.10	1.18	0.60	12
16C305SS	5.893	1.07	0.71	1.38	1.48	0.71	12
16C505SS	5.712	1.04	0.69	1.34	1.43	0.69	12
14B25SS1	6.390	0.87	0.58	1.19	1.27	0.58	12
14B35SS1	5.847	0.83	0.55	1.13	1.21	0.55	12
14B45SS	6.801	0.91	0.60	1.24	1.33	0.60	12
14B26SS1	7.519	0.90	0.77	1.25	1.32	0.77	12
14B36SS1	7.868	1.16	0.77	1.58	1.69	0.77	12
14B46SS1	9.029	1.25	0.83	1.70	1.82	0.83	12
12A34SS1	11.361	1.59	1.18	2.32	2.52	1.18	12
12A44SS1	7.422	1.04	0.77	1.52	1.64	0.77	12
12Y-L19	14.169	0.86	0.72	0.81	0.86	0.72	16
7Y-T3	10.661	0.93	0.93	0.98	0.98	0.93	16
12Y-L27	4.157	0.96	0.96	0.98	0.98	0.96	16
12Y-L28	7.567	1.01	1.01	1.02	1.02	1.01	16
7Y-T30	18.694	1.06	1.06	1.11	1.11	1.06	16
7Y-L20	10.644	1.01	1.01	1.02	1.02	1.01	16
7Y-L21	25.662	0.99	0.99	1.00	1.00	0.99	16
20Z-L1	3.111	1.04	1.04	1.13	1.13	1.04	16
20Z-T10	2.589	0.71	0.71	0.75	0.75	0.71	16
1605X-L1	8.918	0.98	0.98	0.98	0.98	0.98	16
Mean		1.021	0.735	1.234	1.302	0.736	
Standard Deviation		0.173	0.225	0.310	0.354	0.223	
Coefficient of Variation		0.170	0.306	0.251	0.272	0.303	

Dimensions and Results of Single Shear Bolted Connections with Washers -Tensile Strength Study
(Two Bolts Perpendicular to the Line of Stress) - Failure Type III

Spec	d in.	t in.	e in.	s in.	e/d	d/t	d/s	Fy ksi	Fu ksi	Fu/Fy	Controlling AISC kip	Controlling AISI kip	ECCS KN	BS 5950 KN	CAN\CSA KN
H2SSC26	0.750	0.058	0.750	2.00	1.0	12.931	0.375	44.60	53.2	1.1928	7.33	7.33	27.33	27.33	32.60
H2SSC27	0.750	0.058	0.750	2.00	1.0	12.931	0.375	44.60	53.2	1.1928	7.33	7.33	27.33	27.33	32.60
H2SSC29	0.750	0.058	1.500	2.00	2.0	12.931	0.375	44.60	53.2	1.1928	7.33	7.33	27.33	27.33	32.60
H2SSC30	0.750	0.058	1.500	2.00	2.0	12.931	0.375	44.60	53.2	1.1928	7.33	7.33	27.33	27.33	32.60
H2SSC33	0.750	0.058	2.250	2.00	3.0	12.931	0.375	44.60	53.2	1.1928	7.33	7.33	27.33	27.33	32.60
H2SSC34	0.750	0.058	2.250	2.00	3.0	12.931	0.375	44.60	53.2	1.1928	7.33	7.33	27.33	27.33	32.60
H2SSC37	0.750	0.058	3.000	2.00	4.0	12.931	0.375	44.60	53.2	1.1928	7.33	7.33	27.33	27.33	32.60
H2SSC38	0.750	0.058	3.000	2.00	4.0	12.931	0.375	44.60	53.2	1.1928	7.33	7.33	27.33	27.33	32.60
H2SSD5	0.500	0.058	1.500	2.00	3.0	8.621	0.250	44.00	49.7	1.1295	8.29	7.04	30.80	27.74	36.86
H2SSD6	0.500	0.058	1.500	2.00	3.0	8.621	0.250	44.00	49.7	1.1295	8.29	7.04	30.80	27.74	36.86
14G25SS	0.750	0.0766	1.875	2.00	2.50	9.80	0.375	29.80	43.40	1.4564	7.90	5.42	24.11	24.11	35.12
14C35SS	0.750	0.0753	2.625	2.00	3.50	9.96	0.375	29.80	43.40	1.4564	7.76	5.33	23.70	23.70	34.52
14G45SS	0.750	0.0795	3.375	2.00	4.50	9.43	0.375	29.80	43.40	1.4564	8.19	5.63	25.03	25.03	36.45

Dimensions and Results of Single Shear Bolted Connections with Washers -Tensile Strength Study
(Two Bolts Perpendicular to the Line of Stress) - Failure Type III - Cont.

Spec	Pult kips	Pult/AISI	Pult/AISC	Pult/ECCS	Pult/BS 5950	Pult/(CAN\CSA)	Reference
H2SSC26	7.790	1.06	1.06	1.27	1.27	1.06	27
H2SSC27	7.640	1.04	1.04	1.24	1.24	1.04	27
H2SSC29	8.320	1.14	1.14	1.35	1.35	1.14	27
H2SSC30	7.960	1.09	1.09	1.30	1.30	1.09	27
H2SSC33	8.160	1.11	1.11	1.33	1.33	1.11	27
H2SSC34	8.080	1.10	1.10	1.32	1.32	1.10	27
H2SSC37	9.140	1.25	1.25	1.49	1.49	1.25	27
H2SSC38	8.420	1.15	1.15	1.37	1.37	1.15	27
H2SSD5	8.300	1.18	1.00	1.20	1.33	1.00	27
H2SSD6	8.200	1.16	0.99	1.18	1.31	0.99	27
14G25SS	8.987	1.66	1.14	1.66	1.66	1.14	13
14C35SS	8.405	1.58	1.08	1.58	1.58	1.08	13
14G45SS	8.780	1.56	1.07	1.56	1.56	1.07	13
Mean		1.237	1.094	1.372	1.393	1.094	
Standard Deviation		0.205	0.065	0.146	0.127	0.065	
Coefficient of Variation		0.166	0.059	0.106	0.091	0.059	

Dimensions and Results of Single Shear Bolted Connections With Washers-Tensile Strength Study - (Three Bolts Perpendicular to the Line of Stress) - Failure Type III

Spec	d in.	t in.	e in.	s in	e/d	d/t	d/s	Fy ksi	Fu ksi	Fu/Fy	Controlling AISC kip	Controlling AISI kip	ECCS KN	BS 5950 KN	CAN\CSA KN
H3SSB5	0.500	0.107	1.000	1.333	2.000	4.673	0.375	60.6	72.60	1.1980	17.96	17.96	66.70	66.70	79.90
H3SSD5	0.375	0.058	0.938	1.333	2.501	6.466	0.281	44.00	49.70	1.1295	8.02	7.57	31.57	29.80	35.66
H3SSD6	0.375	0.058	0.938	1.333	2.501	6.466	0.281	44.00	49.70	1.1295	8.02	7.57	31.57	29.80	35.66
H3SSD7	0.500	0.058	1.000	1.333	2.000	8.621	0.375	44.00	49.70	1.1295	6.67	6.67	26.25	26.25	29.65
H3SSD8	0.500	0.058	1.000	1.333	2.000	8.621	0.375	44.00	49.70	1.1295	6.67	6.67	26.25	26.25	29.65
H3SSD9	0.500	0.058	1.500	1.333	3.000	8.621	0.375	44.00	49.70	1.1295	6.67	6.67	26.25	26.25	29.65
H3SSD10	0.500	0.058	1.500	1.333	3.000	8.621	0.375	44.00	49.70	1.1295	6.67	6.67	26.25	26.25	29.65
H3SSD11	0.500	0.058	1.500	1.333	3.000	8.621	0.375	44.00	49.70	1.1295	6.67	6.67	26.25	26.25	29.65

Dimensions and Results of Single Shear Bolted Connections With Washers-Tensile Strength Study - (Three Bolts Perpendicular to the Line of Stress) - Failure Type III- Cont.

Spec	Pult kips	Pult/AISI	Pult/AISC	Pult/ECCS	Pult/BS 5950	Pult/(CAN\CSA)	Reference
H3SSB5	18.45	1.03	1.03	1.23	1.23	1.03	27
H3SSD5	8.58	1.13	1.07	1.21	1.28	1.07	27
H3SSD6	8.46	1.12	1.06	1.19	1.26	1.06	27
H3SSD7	7.32	1.10	1.10	1.24	1.24	1.10	27
H3SSD8	7.24	1.09	1.09	1.23	1.23	1.09	27
H3SSD9	7.48	1.12	1.12	1.27	1.27	1.12	27
H3SSD10	7.34	1.10	1.10	1.24	1.24	1.10	27
H3SSD11	7.32	1.10	1.10	1.24	1.24	1.10	27
Mean		1.098	1.082	1.231	1.249	1.082	
Standard Deviation		0.030	0.028	0.022	0.018	0.028	
Coefficient of Variation		0.028	0.026	0.017	0.014	0.026	

Dimensions and Results of Single Shear Bolted Connections With Washers-Tensile Strength Study
(Two Bolts in the Line of Stress) - Failure Type III

Spec	d in.	t in	e in.	el in.	s in	e/d	d/t	d/s	Fy ksi	Fu ksi	Fu/Fy	Controlling AISC kip	Controlling AISI kip	ECCS KN	BS 5950 KN
P2SSC12	0.500	0.058	1.500	1.500	4.00	3.0	8.621	0.125	44.6	53.2	1.1928	10.49	7.82	30.10	18.79
P2SSC13	0.500	0.058	1.500	1.500	4.00	3.0	8.621	0.125	44.6	53.2	1.1928	10.49	7.82	30.10	18.79
P2SSC17	0.500	0.058	1.750	1.500	4.00	3.5	8.621	0.125	44.6	53.2	1.1928	10.49	7.82	30.10	18.79
P2SSC18	0.500	0.058	1.750	1.500	4.00	3.5	8.621	0.125	44.6	53.2	1.1928	10.49	7.82	30.10	18.79
P2SSC25	0.750	0.058	1.500	2.250	4.00	2.0	12.931	0.1875	44.6	53.2	1.1928	9.84	8.18	31.35	24.30
P2SSC26	0.750	0.058	1.500	2.250	4.00	2.0	12.931	0.1875	44.6	53.2	1.1928	9.84	8.18	31.35	24.30
P2SSC29	0.750	0.058	2.250	2.250	4.00	3.0	12.931	0.1875	44.6	53.2	1.1928	9.84	8.18	31.35	24.30
P2SSC30	0.750	0.058	2.250	2.250	4.00	3.0	12.931	0.1875	44.6	53.2	1.1928	9.84	8.18	31.35	24.30

Dimensions and Results of Single Shear Bolted Connections With Washers-Tensile Strength Study
(Two Bolts in the Line of Stress) - Failure Type III - Cont

Spec	CAN\CSA KN	Pult kips	Pult/AISI	Pult/AISC	Pult/ECCS	Pult/BS 5950	Pult/(CAN\CSA)	Reference
P2SSC12	47.18	8.98	1.15	0.86	1.33	2.13	0.85	27
P2SSC13	47.18	8.68	1.11	0.83	1.28	2.06	0.82	27
P2SSC17	47.18	8.88	1.14	0.85	1.31	2.10	0.84	27
P2SSC18	47.18	8.76	1.12	0.83	1.29	2.07	0.83	27
P2SSC25	43.75	9.44	1.15	0.96	1.34	1.73	0.96	27
P2SSC26	43.75	9.34	1.14	0.95	1.33	1.71	0.95	27
P2SSC29	43.75	9.62	1.18	0.98	1.37	1.76	0.98	27
P2SSC30	43.75	9.74	1.19	0.99	1.38	1.78	0.99	27
Mean			1.147	0.905	1.329	1.917	0.901	
Standard Deviation			0.025	0.066	0.031	0.174	0.070	
Coefficient of Variation			0.022	0.072	0.024	0.091	0.078	

Dimensions and Results of Single Shear Bolted Connections with Washers-Tensile Strength Study (Three Bolts in the Line of Stress) - Failure Type III

Spec	d in	t in.	e in.	el in.	s in.	e/d	d/t	d/s	Fy ksi	Fu ksi	Controlling AISC kip	Controlling AISI kip	ECCS KN	BS 5950 KN	CAN\CSA KN
P3SSC13	0.500	0.058	1.500	1.500	4.00	3.0	8.621	0.125	44.6	53.2	10.49	8.75	33.25	18.79	47.18
P3SSC14	0.500	0.058	1.500	1.500	4.00	3.0	8.621	0.125	44.6	53.2	10.49	8.75	33.25	18.79	47.18
P3SSC15	0.500	0.058	1.500	1.500	4.00	3.0	8.621	0.125	44.6	53.2	10.49	8.75	33.25	18.79	47.18
P3SSC18	0.500	0.058	1.750	1.750	4.00	3.5	8.621	0.125	44.6	53.2	10.49	8.75	33.25	18.79	47.18
P3SSC23	(.25	0.058	1.500	1.500	4.00	2.4	10.776	0.156	44.6	53.2	10.22	8.75	33.23	21.68	45.46
P3SSC24	(.25	0.058	1.500	1.500	4.00	2.4	10.776	0.156	44.6	53.2	10.22	8.75	33.23	21.68	45.46
P3SSC26	(.50	0.058	0.750	2.250	4.00	1.0	12.931	0.188	44.6	53.2	9.84	8.73	33.12	24.30	43.75
P3SSC27	0.750	0.058	0.750	2.250	4.00	1.0	12.931	0.188	44.6	53.2	9.84	8.73	33.12	24.30	43.75

Dimensions and Results of Single Shear Bolted Connections with Washers-Tensile Strength Study (Three Bolts in the Line of Stress) - Failure Type III - Cont

Spec	Pult kips	Pult/AISI	Pult/AISC	Pult/ECCS	Pult/BS 5950	Pult/(CAN\CSA)	Reference
P3SSC13	9.88	1.13	0.94	1.32	2.34	0.93	27
P3SSC14	9.74	1.11	0.93	1.30	2.31	0.92	27
P3SSC15	9.74	1.11	0.93	1.30	2.31	0.92	27
P3SSC18	10.04	1.15	0.96	1.34	2.38	0.95	27
P3SSC23	9.96	1.14	0.97	1.33	2.04	0.97	27
P3SSC24	9.74	1.11	0.95	1.30	2.00	0.95	27
P3SSC26	10.08	1.15	1.02	1.35	1.85	1.02	27
P3SSC27	10.28	1.18	1.05	1.38	1.88	1.05	27
Mean		1.136	0.969	1.330	2.137	0.964	
Standard Deviation		0.022	0.041	0.026	0.204	0.045	
Coefficient of Variation		0.019	0.042	0.020	0.096	0.046	

Dimensions and Results of Double Shear Bolted Connections With Washers-Tensile Strength Study
(One Bolt) - Failure Type III

Spec	d in.	t in.	e in.	s in.	e/d	d/t	d/s	Fy ksi	Fu ksi	Fu/Fy	Controlling AISC kip	Controlling AISI kip	ECCS KN	BS 5950 KN	CAN\CSA KN
1605X-L2	0.750	0.065	2.250	2.500	3.000	11.540	0.300	83.25	83.25	1.00	9.16	9.13	40.73	40.73	40.73
1205X-L11	0.750	0.105	2.250	2.500	3.000	7.140	0.300	80.50	80.50	1.00	14.25	14.26	63.38	63.38	63.38
16FAX-L12	0.750	0.060	2.250	2.500	3.000	12.500	0.300	30.10	45.90	1.52	4.64	3.05	13.52	13.52	20.62
16FAX-L13	0.750	0.060	2.625	2.500	3.500	12.500	0.300	30.10	45.90	1.52	4.64	3.05	13.52	13.52	20.62
1610XL18	0.750	0.060	2.250	2.500	3.000	12.500	0.300	78.40	81.50	1.04	8.23	8.25	35.22	35.22	36.61
12FAXL18	0.750	0.107	2.250	2.500	3.000	7.010	0.300	28.10	44.10	1.57	7.98	5.07	22.62	22.62	35.50
1210XL32	0.750	0.107	2.250	2.500	3.000	7.010	0.300	70.10	72.80	1.04	13.18	13.14	56.44	56.44	58.61
1215XL26	0.750	0.107	2.250	2.500	3.000	7.010	0.300	65.20	69.30	1.06	12.54	12.51	52.49	52.49	55.79
1225X-L30	0.750	0.107	2.250	2.500	3.000	7.010	0.300	36.60	50.00	1.37	9.05	6.61	29.47	29.47	40.25
20A33DS1	1.00	0.036	1.750	4.000	3.500	13.900	0.125	32.11	41.85	1.30	5.12	2.46	9.22	8.40	23.04
20A43DS	1.00	0.036	2.250	4.000	4.500	14.040	0.125	32.11	41.85	1.30	5.07	2.43	9.12	8.30	22.78
20A34DS	1.025	0.035	2.188	4.000	3.500	17.660	0.156	32.11	41.85	1.30	4.91	2.79	10.31	9.53	21.83
20A44DS1	0.625	0.036	2.813	4.000	4.500	17.360	0.156	32.11	41.85	1.30	4.99	2.84	10.49	9.69	22.20
20A25DS	0.750	0.036	1.875	4.000	2.500	21.130	0.188	32.11	41.85	1.30	4.74	3.14	11.46	10.71	21.06
20A35DS1	0.750	0.036	2.625	4.000	3.500	21.010	0.188	32.11	41.85	1.30	4.76	3.16	11.53	10.77	21.18
16C403DS1	0.500	0.059	2.000	4.000	4.000	8.460	0.125	32.00	44.00	1.38	8.84	4.25	15.09	13.74	39.76
16C503DS1	0.500	0.059	2.500	4.000	5.000	8.460	0.125	32.00	44.00	1.38	8.84	4.25	15.09	13.74	39.76
14A43DS1	0.500	0.077	2.250	4.000	4.500	6.490	0.125	29.80	43.40	1.46	9.18	5.46	18.31	16.67	40.83
14B25DS1	0.750	0.080	1.875	4.000	2.500	9.410	0.188	29.80	43.40	1.46	11.03	7.30	23.89	22.31	49.04
14B35DS1	0.750	0.077	2.625	4.000	3.500	9.740	0.188	29.80	43.40	1.46	10.65	7.06	23.08	21.55	47.38
14B26DS1	1.000	0.076	2.500	4.000	2.500	13.230	0.250	29.80	43.40	1.46	9.69	6.65	26.54	25.15	43.10
14B36DS1	1.000	0.073	3.500	4.000	3.500	13.620	0.250	29.80	43.40	1.46	9.36	6.43	25.63	24.29	41.62
12A34DS1	0.625	0.092	2.188	4.000	3.500	6.780	0.156	26.00	41.15	1.58	9.59	7.15	21.74	20.09	42.65
12A44DS1	0.625	0.092	2.813	4.000	4.500	6.780	0.156	26.00	41.15	1.58	9.59	7.15	21.74	20.09	42.65
8B35DS1	0.750	0.197	2.625	4.000	3.500	3.810	0.188	32.00	46.00	1.44	28.89	19.14	63.40	59.21	128.48
8B45DS1	0.750	0.181	3.375	4.000	4.500	4.150	0.188	32.00	46.00	1.44	26.51	17.56	58.19	54.34	117.92
8B45DS1	1.000	0.191	2.500	4.000	2.500	5.240	0.250	32.00	46.00	1.44	25.81	17.95	71.62	67.88	114.80
14E25DS1	0.750	0.078	1.875	4.000	2.500	9.600	0.188	54.44	70.40	1.29	17.53	11.61	42.76	39.94	77.95
14E45DS1	0.750	0.078	3.375	4.000	4.500	9.540	0.188	54.44	70.40	1.29	17.53	11.61	42.76	39.94	77.95
10E46DS1	1.000	0.141	4.500	4.000	4.500	7.090	0.250	59.50	71.85	1.21	29.78	25.31	98.38	93.24	132.46

Dimensions and Results of Double Shear Bolted Connections With Washers-Tensile Strength Study
(One Bolt) - Failure Type III - Cont.

Spec	Pult kips	Pult/AISI	Pult/AISC	Pult/ECCS	Pult/BS 5950	Pult/(CAN\CSA)	Reference
1605X-L2	9.40	1.03	1.03	1.03	1.03	1.03	16
1205X-L11	13.70	0.96	0.96	0.96	0.96	0.96	16
16FAX-L12	4.66	1.53	1.00	1.53	1.53	1.00	16
16FAX-L13	4.68	1.53	1.01	1.54	1.54	1.01	16
1610XL18	8.54	1.03	1.04	1.08	1.08	1.04	16
12FAXL18	8.14	1.60	1.02	1.60	1.60	1.02	16
1210XL32	14.03	1.07	1.06	1.11	1.11	1.06	16
1215XL26	11.92	0.95	0.95	1.01	1.01	0.95	16
1225X-L30	9.68	1.46	1.07	1.46	1.46	1.07	16
20A33DS1	2.92	1.19	0.57	1.41	1.55	0.56	12
20A43DS	3.55	1.46	0.70	1.73	1.90	0.69	12
20A34DS	4.20	1.50	0.86	1.81	1.96	0.86	12
20A44DS1	4.12	1.45	0.83	1.75	1.89	0.83	12
20A25DS	3.38	1.08	0.71	1.31	1.40	0.71	12
20A35DS1	4.06	1.29	0.85	1.57	1.68	0.85	12
16C403DS1	6.36	1.50	0.72	1.88	2.06	0.71	12
16C503DS1	7.11	1.67	0.80	2.09	2.30	0.80	12
14A43DS1	7.88	1.44	0.86	1.91	2.10	0.86	12
14B25DS1	7.21	0.99	0.65	1.34	1.44	0.65	12
14B35DS1	8.41	1.19	0.79	1.62	1.74	0.79	12
14B26DS1	8.39	1.26	0.87	1.41	1.48	0.87	12
14B36DS1	9.14	1.42	0.98	1.59	1.67	0.98	12
12A34DS1	9.72	1.36	1.01	1.99	2.15	1.01	12
12A44DS1	11.26	1.58	1.17	2.30	2.49	1.17	12
8B35DS1	26.00	1.36	0.90	1.82	1.95	0.90	12
8B45DS1	26.80	1.53	1.01	2.05	2.19	1.01	12
8B45DS1	24.32	1.35	0.94	1.51	1.59	0.94	12
14E25DS1	10.48	0.90	0.60	1.09	1.17	0.60	13
14E45DS1	16.78	1.45	0.96	1.75	1.87	0.96	13
10E46DS1	28.76	1.14	0.97	1.30	1.37	0.97	13
Mean		1.309	0.896	1.551	1.643	0.895	
Standard Deviation		0.222	0.147	0.345	0.402	0.149	
Coefficient of Variation		0.170	0.164	0.222	0.244	0.166	

Dimensions and Results of Double Shear Bolted Connections With Washers-Tensile Strength Study (Two Bolts Perpendicular to ·.e Line of Stress) -Type III Failure

Spec	d in.	t in.	e in.	s in.	e/d	d/t	d/s	Fy ksi	Fu ksi	Fu/Fy	Controlling AISC kip	Controlling AISI kip	ECCS KN	BS 5950 KN	CAN\CSA KN
H2DSC29	0.375	0.058	1.688	2.000	4.501	6.466	0.188	44.60	53.20	1.19	9.84	6.52	26.02	24.30	43.75
H2DSC30	0.375	0.058	1.688	2.000	4.501	6.466	0.188	44.60	53.20	1.19	9.84	6.52	26.02	24.30	43.75
H2DSC45	0.500	0.058	1.500	2.000	3.000	8.621	0.250	44.60	53.20	1.19	8.87	7.54	31.22	28.12	39.46
H2DSC46	0.500	0.058	1.500	2.000	3.000	8.621	0.250	44.60	53.20	1.19	8.87	7.54	31.22	28.12	39.46
H2DSC49	0.500	0.058	1.750	2.000	3.500	8.621	0.250	44.60	53.20	1.19	8.87	7.54	31.22	28.12	39.46
H2DSC50	0.500	0.058	1.750	2.000	3.500	8.621	0.250	44.60	53.20	1.19	8.87	7.54	31.22	28.12	39.46
H2DSC53	0.500	0.058	2.250	2.000	4.500	8.621	0.250	44.60	53.20	1.19	8.87	7.54	31.22	28.12	39.46
H2DSC54	0.500	0.058	2.250	2.000	4.500	8.621	0.250	44.60	53.20	1.19	8.87	7.54	31.22	28.12	39.46
H2DSC61	0.625	0.058	1.250	2.000	2.000	10.776	0.313	44.60	53.20	1.19	8.10	8.10	30.20	30.20	36.03
H2DSC62	0.625	0.058	1.250	2.000	2.000	10.776	0.313	44.60	53.20	1.19	8.10	8.10	30.20	30.20	36.03
H2DSC63	0.625	0.058	1.250	2.000	2.000	10.776	0.313	44.60	53.20	1.19	8.10	8.10	30.20	30.20	36.03
H2DSC64	0.625	0.058	1.563	2.000	2.501	10.776	0.313	44.60	53.20	1.19	8.10	8.10	30.20	30.20	36.03
H2DSC65	0.625	0.058	1.563	2.000	2.501	10.776	0.313	44.60	53.20	1.19	8.10	8.10	30.20	30.20	36.03
H2DSC68	0.750	0.058	1.125	2.000	1.500	12.931	0.375	44.60	53.20	1.19	7.33	7.33	27.33	27.33	32.60
H2DSC69	0.750	0.058	1.125	2.000	1.500	12.931	0.375	44.60	53.20	1.19	7.33	7.33	27.33	27.33	32.60
H2DSC70	0.750	0.058	1.125	2.000	1.500	12.931	0.375	44.60	53.20	1.19	7.33	7.33	27.33	27.33	32.60
H2DSC73	0.750	0.058	1.500	2.000	2.000	12.931	0.375	44.60	53.20	1.19	7.33	7.33	27.33	27.33	32.60
H2DSC74	0.750	0.058	1.500	2.000	2.000	12.931	0.375	44.60	53.20	1.19	7.33	7.33	27.33	27.33	32.60
H2DSC77	0.750	0.058	1.875	2.000	2.500	12.931	0.375	44.60	53.20	1.19	7.33	7.33	27.33	27.33	32.60
H2DSC78	0.750	0.058	1.875	2.000	2.500	12.931	0.375	44.60	53.20	1.19	7.33	7.33	27.33	27.33	32.60
14G25DS1	0.750	0.077	1.875	2.000	2.500	9.770	0.375	29.80	43.40	1.46	7.90	5.44	24.12	24.12	35.13
14G35DS	0.750	0.076	2.625	2.000	3.500	9.870	0.375	29.80	43.40	1.46	7.86	5.38	23.99	23.99	34.94
14G45DS	0.750	0.076	3.375	2.000	4.500	9.930	0.375	29.80	43.40	1.46	7.77	5.34	23.73	23.73	34.55

Dimensions and Results of Double Shear Bolted Connections With Washers-Tensile Strength Study (Two Bolts Perpendicular to the Line of Stress) -Type III Failure - Cont.

Spec	Pult kips	Pult/AISI	Pult/AISC	Pult/ECCS	Pult/BS 5950	Pult/(CAN\CSA)	Reference
H2DSC29	10.24	1.57	1.04	1.75	1.87	1.04	27
H2DSC30	10.08	1.55	1.02	1.72	1.85	1.02	27
H2DSC45	9.74	1.29	1.10	1.39	1.54	1.10	27
H2DSC46	9.92	1.32	1.12	1.41	1.57	1.12	27
H2DSC49	10.28	1.36	1.16	1.46	1.63	1.16	27
H2DSC50	10.50	1.39	1.18	1.50	1.66	1.18	27
H2DSC53	10.28	1.36	1.16	1.46	1.63	1.16	27
H2DSC54	10.12	1.34	1.14	1.44	1.60	1.14	27
H2DSC61	10.70	1.32	1.32	1.58	1.58	1.32	27
H2DSC62	9.94	1.23	1.23	1.46	1.46	1.23	27
H2DSC63	9.76	1.20	1.20	1.44	1.44	1.20	27
H2DSC64	10.60	1.31	1.31	1.56	1.56	1.31	27
H2DSC65	9.68	1.20	1.20	1.43	1.43	1.20	27
H2DSC68	10.90	1.49	1.49	1.77	1.77	1.49	27
H2DSC69	10.88	1.48	1.48	1.77	1.77	1.48	27
H2DSC70	10.28	1.40	1.40	1.67	1.67	1.40	27
H2DSC73	10.48	1.43	1.43	1.71	1.71	1.43	27
H2DSC74	10.24	1.40	1.40	1.67	1.67	1.40	27
H2DSC77	11.10	1.51	1.51	1.81	1.81	1.51	27
H2DSC78	10.12	1.38	1.38	1.65	1.65	1.38	27
14G25DS1	8.72	1.60	1.10	1.61	1.61	1.10	13
14G35DS	8.72	1.62	1.11	1.62	1.62	1.11	13
14G45DS	8.91	1.67	1.15	1.67	1.67	1.15	13
Mean		1.410	1.245	1.589	1.641	1.245	
Standard Deviation		0.130	0.149	0.131	0.117	0.149	
Coefficient of Variation		0.092	0.119	0.083	0.071	0.119	

Dimensions and Results of Double Shear Bolted Connections With Washers -Tensile Strength Study
(Three Bolts Perpendicular to the Line of Stress) - Failure Type III

Spec	d in.	t in.	e in.	s in.	e/d	d/t	d/s	Fy ksi	Fu ksi	Fu/Fy	Controlling AISC kip	Controlling AISI kip	ECCS KN	BS 5950 KN	CAN\CSA KN
H3DSA16	0.313	0.064	1.0940	1.333	3.50	4.883	0.235	54.4	70.7	1.30	13.43	10.77	40.20	36.96	59.72
H3DSA17	0.313	0.064	1.0940	1.333	3.50	4.883	0.235	54.4	70.7	1.30	13.43	10.77	40.20	36.96	59.72
H3DSA21	0.313	0.064	1.4180	1.333	4.53	4.883	0.235	54.4	70.7	1.30	13.43	10.77	40.20	36.96	59.72
H3DSA22	0.313	0.064	1.4180	1.333	4.53	4.883	0.235	54.4	70.7	1.30	13.43	10.77	40.20	36.96	59.72
H3DSA23	313	0.064	1.4180	1.333	4.53	4.883	0.235	54.4	70.7	1.30	13.43	10.77	40.20	36.96	59.72
H3DSA27	.313	0.064	1.7190	1.333	5.50	4.883	0.235	54.4	70.7	1.30	13.43	10.77	40.20	36.96	59.72
H3DSA28	313	0.064	1.7190	1.333	5.50	4.883	0.235	54.4	70.7	1.30	13.43	10.77	40.20	36.96	59.72
H3DSA29	0.313	0.064	1.7190	1.333	5.50	4.883	0.235	54.4	70.7	1.30	13.43	10.77	40.20	36.96	59.72
H3DSA53	0.375	0.064	0.9380	1.333	2.50	5.859	0.281	54.4	70.7	1.30	12.58	9.68	43.07	40.66	55.98
H3DSA54	0.375	0.064	0.9380	1.333	2.50	5.859	0.281	54.4	70.7	1.30	12.58	9.68	43.07	40.66	55.98
H3DSA58	0.375	0.064	1.1250	1.333	3.00	5.859	0.281	54.4	70.7	1.30	12.58	9.68	43.07	40.66	55.98
H3DSA59	0.375	0.064	1.1250	1.333	3.00	5.859	0.281	54.4	70.7	1.30	12.58	9.68	43.07	40.66	55.98
H3DSA60	0.375	0.064	1.1250	1.333	3.00	5.859	0.281	54.4	70.7	1.30	12.58	9.68	43.07	40.66	55.98
H3DSA64	0.375	0.064	1.3130	1.333	3.50	5.859	0.281	54.4	70.7	1.30	12.58	9.68	43.07	40.66	55.98
H3DSA65	0.375	0.064	1.3130	1.333	3.50	5.859	0.281	54.4	70.7	1.30	12.58	9.68	43.07	40.66	55.98
H3DSA66	0.375	0.064	1.3130	1.333	3.50	5.859	0.281	54.4	70.7	1.30	12.58	9.68	43.07	40.66	55.98
H3DSA70	0.375	0.064	1.6880	1.333	4.50	5.859	0.281	54.4	70.7	1.30	12.58	9.68	43.07	40.66	55.98
H3DSA71	0.375	0.064	1.6880	1.333	4.50	5.859	0.281	54.4	70.7	1.30	12.58	9.68	43.07	40.66	55.98
H3DSA72	0.375	0.064	1.6880	1.333	4.50	5.859	0.281	54.4	70.7	1.30	12.58	9.68	43.07	40.66	55.98
H3DSA76	0.375	0.064	2.0630	1.333	5.50	5.859	0.281	54.4	70.7	1.30	12.58	9.68	43.07	40.66	55.98
H3DSA77	0.375	0.064	2.0630	1.333	5.50	5.859	0.281	54.4	70.7	1.30	12.58	9.68	43.07	40.66	55.98
H3DSA78	0.375	0.064	2.0630	1.333	5.50	5.859	0.281	54.4	70.7	1.30	12.58	9.68	43.07	40.66	55.98
H3DSA85	0.500	0.064	1.3130	1.333	2.60	7.813	0.375	54.4	70.7	1.30	10.46	8.05	35.81	35.81	46.54
H3DSA86	0.500	0.064	1.3130	1.333	2.60	7.813	0.375	54.4	70.7	1.30	10.46	8.05	35.81	35.81	46.54
H3DSA87	0.500	0.064	1.3130	1.333	2.60	7.813	0.375	54.4	70.7	1.30	10.46	8.05	35.81	35.81	46.54
H3DSA90	0.500	0.064	1.6880	1.333	3.40	7.813	0.375	54.4	70.7	1.30	10.46	8.05	35.81	35.81	46.54
H3DSA91	0.500	0.064	1.6880	1.333	3.40	7.813	0.375	54.4	70.7	1.30	10.46	8.05	35.81	35.81	46.54
H3DSA94	0.500	0.064	2.0630	1.333	4.10	7.813	0.375	54.4	70.7	1.30	10.46	8.05	35.81	35.81	46.54
H3DSA95	0.500	0.064	2.0630	1.333	4.10	7.813	0.375	54.4	70.7	1.30	10.46	8.05	35.81	35.81	46.54
H3DSB1	0.313	0.107	1.3750	1.333	4.40	2.921	0.235	60.6	72.6	1.20	23.05	18.49	74.86	68.84	102.53
H3DSB2	0.313	0.107	1.3750	1.333	4.40	2.921	0.235	60.6	72.6	1.20	23.05	18.49	74.86	68.84	102.53
H3DSB3	0.313	0.107	1.3750	1.333	4.40	2.921	0.235	60.6	72.6	1.20	23.05	18.49	74.86	68.84	102.53
H3DSB13	0.375	0.107	0.9380	1.333	1.50	3.505	0.281	60.6	72.6	1.20	21.61	20.37	80.22	75.72	96.10
H3DSB14	0.375	0.107	0.9380	1.333	2.50	3.505	0.281	60.6	72.6	1.20	21.61	20.37	80.22	75.72	96.10

Dimensions and Results of Double Shear Bolted Connections With Washers -Tensile Strength Study
(Three Bolts Perpendicular to the Line of Stress) - Failure Type III - Cont.

Spec	Pult kips	Pult/AISI	Pult/AISC	Pult/ECCS	Pult/BS 5950	Pult/(CAN\CSA)	Reference
H3DSA16	14.86	1.38	1.11	1.64	1.79	1.11	27
H3DSA17	15.28	1.42	1.14	1.69	1.84	1.14	27
H3DSA21	15.02	1.39	1.12	1.66	1.81	1.12	27
H3DSA22	13.39	1.24	1.00	1.48	1.61	1.00	27
H3DSA23	13.94	1.29	1.04	1.54	1.68	1.04	27
H3DSA27	15.02	1.39	1.12	1.66	1.81	1.12	27
H3DSA28	13.96	1.30	1.04	1.54	1.68	1.04	27
H3DSA29	15.39	1.43	1.15	1.70	1.85	1.15	27
H3DSA53	14.54	1.50	1.16	1.50	1.59	1.16	27
H3DSA54	12.18	1.26	0.97	1.26	1.33	0.97	27
H3DSA58	13.60	1.40	1.08	1.40	1.49	1.08	27
H3DSA59	14.50	1.49	1.14	1.49	1.58	1.14	27
H3DSA60	13.26	1.37	1.05	1.37	1.45	1.05	27
H3DSA64	14.62	1.51	1.16	1.51	1.60	1.16	27
H3DSA65	14.60	1.51	1.16	1.51	1.60	1.16	27
H3DSA66	14.36	1.48	1.14	1.48	1.57	1.14	27
H3DSA70	14.59	1.51	1.16	1.51	1.60	1.16	27
H3DSA71	13.84	1.43	1.10	1.43	1.51	1.10	27
H3DSA72	13.80	1.43	1.10	1.43	1.51	1.10	27
H3DSA76	14.68	1.52	1.17	1.52	1.61	1.17	27
H3DSA77	13.82	1.43	1.10	1.43	1.51	1.10	27
H3DSA78	14.80	1.53	1.18	1.53	1.62	1.18	27
H3DSA85	12.68	1.57	1.21	1.57	1.57	1.21	27
H3DSA86	12.38	1.54	1.18	1.54	1.54	1.18	27
H3DSA87	11.74	1.46	1.12	1.46	1.46	1.12	27
H3DSA90	12.64	1.57	1.21	1.57	1.57	1.21	27
H3DSA91	12.24	1.52	1.17	1.52	1.52	1.17	27
H3DSA94	12.36	1.54	1.18	1.54	1.54	1.18	27
H3DSA95	11.60	1.44	1.11	1.44	1.44	1.11	27
H3DSB1	23.40	1.27	1.02	1.39	1.51	1.02	27
H3DSB2	23.80	1.29	1.03	1.41	1.54	1.03	27
H3DSB3	23.30	1.26	1.01	1.38	1.51	1.01	27
H3DSB13	23.20	1.14	1.07	1.29	1.36	1.07	27
H3DSB14	22.90	1.12	1.06	1.27	1.35	1.06	27

Dimensions and Results of Double Shear Bolted Connections With Washers -Tensile Strength Study
(Three Bolts Perpendicular to the Line of Stress) - Failure Type III - Cont.

Spec	d in.	t in.	e in.	s in.	e/d	d/t	d/s	Fy ksi	Fu ksi	Fu/Fy	Controlling AISC kip	Controlling AISI kip	ECCS KN	BS 5950 KN	CAN\CSA KN
H3DSB15	0.375	0.107	0.9380	1.333	2.50	3.505	0.281	60.6	72.6	1.20	21.61	20.37	80.22	75.72	96.10
H3DSB16	0.375	0.107	0.9380	1.333	2.50	3.505	0.281	60.6	72.6	1.20	21.61	20.37	80.22	75.72	96.10
H3DSB17	0.375	0.107	0.9380	1.333	2.50	3.505	0.281	60.6	72.6	1.20	21.61	20.37	80.22	75.72	96.10
H3DSB23	0.375	0.107	1.3130	1.333	3.50	3.505	0.281	60.6	72.6	1.20	21.61	20.37	80.22	75.72	96.10
H3DSB24	0.375	0.107	1.3130	1.333	3.50	3.505	0.281	60.6	72.6	1.20	21.61	20.37	80.22	75.72	96.10
H3DSB25	0.375	0.107	1.3130	1.333	3.50	3.505	0.281	60.6	72.6	1.20	21.61	20.37	80.22	75.72	96.10
H3DSB26	0.375	0.107	1.3130	1.333	3.50	3.505	0.281	60.6	72.6	1.20	21.61	20.37	80.22	75.72	96.10
H3DSB27	0.375	0.107	1.3130	1.333	3.50	3.505	0.281	60.6	72.6	1.20	21.61	20.37	80.22	75.72	96.10
H3DSB33	0.375	0.107	1.6880	1.333	4.50	3.505	0.281	60.6	72.6	1.20	21.61	20.37	80.22	75.72	96.10
H3DSB34	0.375	0.107	1.6880	1.333	4.50	3.505	0.281	60.6	72.6	1.20	21.61	20.37	80.22	75.72	96.10
H3DSB35	0.375	0.107	1.6880	1.333	4.50	3.505	0.281	60.6	72.6	1.20	21.61	20.37	80.22	75.72	96.10
H3DSB36	0.375	0.107	1.6880	1.333	4.50	3.505	0.281	60.6	72.6	1.20	21.61	20.37	80.22	75.72	96.10
H3DSB37	0.375	0.107	1.6880	1.333	4.50	3.505	0.281	60.6	72.6	1.20	21.61	20.37	80.22	75.72	96.10

Dimensions and Results of Double Shear Bolted Connections With Washers -Tensile Strength Study
(Three Bolts Perpendicular to the Line of Stress) - Failure Type III - Cont

Spec	Pult kips	Pult/AISI	Pult/AISC	Pult/ECCS	Pult/BS 5950	Pult/(CAN\CSA)	Reference
H3DSB15	23.00	1.13	1.06	1.28	1.35	1.06	27
H3DSB16	22.80	1.12	1.06	1.26	1.34	1.06	27
H3DSB17	22.90	1.12	1.06	1.27	1.35	1.06	27
H3DSB23	23.20	1.14	1.07	1.29	1.36	1.07	27
H3DSB24	22.80	1.12	1.06	1.26	1.34	1.06	27
H3DSB25	22.90	1.12	1.06	1.27	1.35	1.06	27
H3DSB26	22.40	1.10	1.04	1.24	1.32	1.04	27
H3DSB27	22.50	1.10	1.04	1.25	1.32	1.04	27
H3DSB33	22.90	1.12	1.06	1.27	1.35	1.06	27
H3DSB34	23.40	1.15	1.08	1.30	1.37	1.08	27
H3DSB35	23.10	1.13	1.07	1.28	1.36	1.07	27
H3DSB36	22.90	1.12	1.06	1.27	1.35	1.06	27
H3DSB37	22.30	1.09	1.03	1.24	1.31	1.03	27
Mean		1.330	1.096	1.429	1.510	1.096	
Standard Deviation		0.163	0.058	0.136	0.151	0.058	
Coefficient of Variation		0.123	0.053	0.096	0.100	0.053	

Dimensions and Results of Double Shear Bolted Connections With Washers-*Tensile* Strength Study (Two Bolts in the Line of Stress) - Failure Type III

Spec.	d in.	t in.	e in.	el in	s in.	e/d	d/t	d/s	Fy ksi	Fu ksi	Fu/Fy	Controlling AISC kip	Controlling AISI kip	ECCS KN	BS 5950 KN
P2DSA13	0.750	0.064	2.250	2.250	4.000	3.000	11.719	0.188	54.40	70.70	1.30	14.42	11.99	42.19	32.70
P2DSA14	0.750	0.064	2.250	2.250	4.000	3.000	11.719	0.188	54.40	70.70	1.30	14.42	11.99	42.19	32.70
P2DSA15	0.750	0.064	2.250	2.250	4.000	3.000	11.719	0.188	54.40	70.70	1.30	14.42	11.99	42.19	32.70
P2DSE1	0.500	0.051	1.500	1.500	2.000	3.000	9.804	0.250	44.60	53.00	1.19	3.89	3.59	14.13	12.36
P2DSE2	0.500	0.051	1.500	1.500	2.000	3.000	9.804	0.250	44.60	53.00	1.19	3.89	3.59	14.13	12.36
P2DSE3	0.500	0.051	1.500	1.500	2.000	3.000	9.804	0.250	44.60	53.00	1.19	3.89	3.59	14.13	12.36
P2DSE6	0.625	0.051	1.875	1.880	2.000	3.000	12.255	0.313	44.60	53.00	1.19	3.55	3.55	13.28	13.28
P2DSE7	0.625	0.051	1.875	1.880	2.000	3.000	12.255	0.313	44.60	53.00	1.19	3.55	3.55	13.28	13.28
P2DSE8	0.625	0.051	1.875	1.880	2.000	3.000	12.255	0.313	44.60	53.00	1.19	3.55	3.55	13.28	13.28
P2DSE11	0.750	0.051	2.250	2.250	2.000	3.000	14.706	0.375	44.60	53.00	1.19	3.21	3.21	12.01	12.01
P2DSE12	0.750	0.051	2.250	2.250	2.000	3.000	14.706	0.375	44.60	53.00	1.19	3.21	3.21	12.01	12.01
P2DSE13	0.750	0.051	2.250	2.250	2.000	3.000	14.706	0.375	44.60	53.00	1.19	3.21	3.21	12.01	12.01

Dimensions and Results of Double Shear Bolted Connections With Washers-Tensile Strength Study (Two Bolts in the Line of Stress) - Failure Type III - Cont.

Spec	CAN\CSA KN	Pult kips	Pult/AISI	Pult/AISC	Pult/ECCS	Pult/BS 5950	Pult/(CAN\CSA)	Reference
P2DSA13	64.15	13.34	1.11	0.92	1.41	1.81	0.92	27
P2DSA14	64.15	13.46	1.12	0.93	1.42	1.83	0.93	27
P2DSA15	64.15	13.52	1.13	0.94	1.43	1.84	0.94	27
P2DSE1	17.28	4.14	1.15	1.07	1.30	1.49	1.07	27
P2DSE2	17.28	4.30	1.20	1.11	1.35	1.55	1.11	27
P2DSE3	17.28	4.33	1.20	1.11	1.36	1.56	1.11	27
P2DSE6	15.78	4.16	1.17	1.17	1.39	1.39	1.17	27
P2DSE7	15.78	4.00	1.13	1.13	1.34	1.34	1.13	27
P2DSE8	15.78	3.88	1.09	1.09	1.30	1.30	1.09	27
P2DSE11	14.28	4.58	1.43	1.43	1.70	1.70	1.43	27
P2DSE12	14.28	4.16	1.30	1.30	1.54	1.54	1.30	27
P2DSE13	14.28	3.86	1.20	1.20	1.43	1.43	1.20	27
		Mean	1.186	1.117	1.414	1.565	1.117	
		Standar	0.090	0.143	0.105	0.183	0.143	
		Coeffici	0.076	0.128	0.075	0.117	0.128	

Dimensions and Results of Double Shear Bolted Connections With Washers -Tensile Strength Study (Three Bolts in the Line of Stress) - Failure Type III

Spec	d in.	t in.	e in.	el in.	s in.	e/d	d/t	d/s	Fy ksi	Fu ksi	Fu/Fy	Controlling AISC kip	Controlling AISI kip	ECCS KN	BS 5950 KN	CAN\CSA KN
P3DSA18	0.500	0.064	1.250	1.500	4.000	2.500	7.813	0.125	54.40	70.70	1.30	15.38	12.83	44.75	25.29	69.18
P3DSA19	0.500	0.064	1.250	1.500	4.000	2.500	7.813	0.125	54.40	70.70	1.30	15.38	12.83	44.75	25.29	69.18
P3DSA20	0.500	0.064	1.250	1.500	4.000	2.500	7.813	0.125	54.40	70.70	1.30	15.38	12.83	44.75	25.29	69.18
P3DSA24	0.500	0.064	1.750	1.750	4.000	3.500	7.813	0.125	54.40	70.70	1.30	15.38	12.83	44.75	25.29	69.18
P3DSA25	0.500	0.064	1.750	1.750	4.000	3.500	7.813	0.125	54.40	70.70	1.30	15.38	12.83	44.75	25.29	69.18
P3DSA26	0.500	0.064	1.750	1.750	4.000	3.500	7.813	0.125	54.40	70.70	1.30	15.38	12.83	44.75	25.29	69.18
P3DSA30	0.500	0.064	2.250	2.250	4.000	4.500	7.813	0.125	54.40	70.70	1.30	15.38	12.83	44.75	25.29	69.18
P3DSA31	0.500	0.064	2.250	2.250	4.000	4.500	7.813	0.125	54.40	70.70	1.30	15.38	12.83	44.75	25.29	69.18
P3DSA32	0.500	0.064	2.250	2.250	4.000	4.500	7.813	0.125	54.40	70.70	1.30	15.38	12.83	44.75	25.29	69.18
P3DSA36	0.625	0.064	0.938	1.880	4.000	1.501	9.766	0.156	54.40	70.70	1.30	14.99	12.83	44.73	29.18	66.67
P3DSA37	0.625	0.064	0.938	1.880	4.000	1.501	9.766	0.156	54.40	70.70	1.30	14.99	12.83	44.73	29.18	66.67
P3DSA38	0.625	0.064	0.938	1.880	4.000	1.501	9.766	0.156	54.40	70.70	1.30	14.99	12.83	44.73	29.18	66.67
P3DSA42	0.625	0.064	1.563	1.880	4.000	2.501	9.766	0.156	54.40	70.70	1.30	14.99	12.83	44.73	29.18	66.67
P3DSA43	0.625	0.064	1.563	1.880	4.000	2.501	9.766	0.156	54.40	70.70	1.30	14.99	12.83	44.73	29.18	66.67
P3DSA44	0.625	0.064	1.563	1.880	4.000	2.501	9.766	0.156	54.40	70.70	1.30	14.99	12.83	44.73	29.18	66.67
P3DSA48	0.625	0.064	2.188	2.190	4.000	3.501	9.766	0.156	54.40	70.70	1.30	14.99	12.83	44.73	29.18	66.67
P3DSA49	0.625	0.064	2.188	2.190	4.000	3.501	9.766	0.156	54.40	70.70	1.30	14.99	12.83	44.73	29.18	66.67
P3DSA50	0.625	0.064	2.188	2.190	4.000	3.501	9.766	0.156	54.40	70.70	1.30	14.99	12.83	44.73	29.18	66.67
P3DSA54	0.750	0.064	1.125	1.500	4.000	1.500	11.719	0.188	54.40	70.70	1.30	14.42	12.80	44.58	32.70	64.15
P3DSA55	0.750	0.064	1.125	1.500	4.000	1.500	11.719	0.188	54.40	70.70	1.30	14.42	12.80	44.58	32.70	64.15
P3DSA56	0.750	0.064	1.125	1.500	4.000	1.500	11.719	0.188	54.40	70.70	1.30	14.42	12.80	44.58	32.70	64.15
P3DSA57	0.750	0.064	1.125	1.500	4.000	1.500	11.719	0.188	54.40	70.70	1.30	14.42	12.80	44.58	32.70	64.15
P3DSB22	0.500	0.107	1.250	1.500	4.000	2.500	4.673	0.125	60.60	72.60	1.20	26.41	22.03	83.34	47.09	118.78
P3DSB23	0.500	0.107	1.250	1.500	4.000	2.500	4.673	0.125	60.60	72.60	1.20	26.41	22.03	83.34	47.09	118.78
P3DSB26	0.500	0.107	1.250	1.500	4.000	2.500	4.673	0.125	60.60	72.60	1.20	26.41	22.03	83.34	47.09	118.78
P3DSB27	0.500	0.107	1.250	1.500	4.000	2.500	4.673	0.125	60.60	72.60	1.20	26.41	22.03	83.34	47.09	118.78
P3DSB28	0.500	0.107	1.250	1.500	4.000	2.500	4.673	0.125	60.60	72.60	1.20	26.41	22.03	83.34	47.09	118.78
P3DSB32	0.500	0.107	1.250	1.500	4.000	2.500	4.673	0.125	60.60	72.60	1.20	26.41	22.03	83.34	47.09	118.78
P3DSB33	0.500	0.107	1.250	1.500	4.000	2.500	4.673	0.125	60.60	72.60	1.20	26.41	22.03	83.34	47.09	118.78
P3DSB34	0.500	0.107	1.250	1.500	4.000	2.500	4.673	0.125	60.60	72.60	1.20	26.41	22.03	83.34	47.09	118.78
P3DSB38	0.500	0.107	1.250	1.500	4.000	2.500	4.673	0.125	60.60	72.60	1.20	26.41	22.03	83.34	47.09	118.78
P3DSB41	0.500	0.107	1.750	1.750	4.000	3.500	4.673	0.125	60.60	72.60	1.20	26.41	22.03	83.34	47.09	118.78
P3DSB42	0.500	0.107	1.750	1.750	4.000	3.500	4.673	0.125	60.60	72.60	1.20	26.41	22.03	83.34	47.09	118.78
P3DSB43	0.500	0.107	1.750	1.750	4.000	3.500	4.673	0.125	60.60	72.60	1.20	26.41	22.03	83.34	47.09	118.78

Dimensions and Results of Double Shear Bolted Connections With Washers -Tensile Strength Study (Three Bolts in the Line of Stress) - Failure Type III - Cont.

Spec	Pult kips	Pult/AISI	Pult/AISC	Pult/ECCS	Pult/BS 5950	Pult/(CAN\CSA)	Reference
P3DSA18	14.60	1.14	0.95	1.45	2.57	0.94	27
P3DSA19	15.35	1.20	1.00	1.53	2.70	0.99	27
P3DSA20	13.68	1.07	0.89	1.36	2.41	0.88	27
P3DSA24	15.14	1.18	0.98	1.50	2.66	0.97	27
P3DSA25	14.52	1.13	0.94	1.44	2.55	0.93	27
P3DSA26	15.40	1.20	1.00	1.53	2.71	0.99	27
P3DSA30	13.52	1.05	0.88	1.34	2.38	0.87	27
P3DSA31	14.08	1.10	0.92	1.40	2.48	0.91	27
P3DSA32	13.76	1.07	0.89	1.37	2.42	0.88	27
P3DSA36	14.25	1.11	0.95	1.42	2.17	0.95	27
P3DSA37	14.14	1.10	0.94	1.41	2.16	0.94	27
P3DSA38	14.06	1.10	0.94	1.40	2.14	0.94	27
P3DSA42	14.14	1.10	0.94	1.41	2.16	0.94	27
P3DSA43	14.34	1.12	0.96	1.43	2.19	0.96	27
P3DSA44	13.98	1.09	0.93	1.39	2.13	0.93	27
P3DSA48	13.90	1.08	0.93	1.38	2.12	0.93	27
P3DSA49	14.22	1.11	0.95	1.41	2.17	0.95	27
P3DSA50	15.20	1.18	1.01	1.51	2.32	1.01	27
P3DSA54	12.38	0.97	0.86	1.24	1.68	0.86	27
P3DSA55	12.80	1.00	0.89	1.28	1.74	0.89	27
P3DSA56	12.82	1.00	0.89	1.28	1.74	0.89	27
P3DSA57	12.32	0.96	0.85	1.23	1.68	0.85	27
P3DSB22	25.30	1.15	0.96	1.35	2.39	0.95	27
P3DSB23	25.00	1.13	0.95	1.33	2.36	0.94	27
P3DSB26	24.80	1.13	0.94	1.32	2.34	0.93	27
P3DSB27	25.70	1.17	0.97	1.37	2.43	0.96	27
P3DSB28	24.40	1.11	0.92	1.30	2.30	0.91	27
P3DSB32	25.40	1.15	0.96	1.36	2.40	0.95	27
P3DSB33	25.20	1.14	0.95	1.34	2.38	0.94	27
P3DSB34	25.50	1.16	0.97	1.36	2.41	0.95	27
P3DSB38	25.60	1.16	0.97	1.37	2.42	0.96	27
P3DSB41	24.70	1.12	0.94	1.32	2.33	0.92	27
P3DSB42	24.80	1.13	0.94	1.32	2.34	0.93	27
P3DSB43	25.25	1.15	0.96	1.35	2.38	0.95	27

Dimensions and Results of Double Shear Bolted Connections With Washers -Tensile Strength Study (Three Bolts in the Line of Stress) - Failure Type III - Cont

Spec	d in.	t in.	e in.	el in	s in	e/d	d/t	d/s	Fy ksi	Fu ksi	Fu/Fy	Controlling AISC kip	Controlling AISI kip	ECCS KN	BS 5950 KN	CAN\CSA KN
P3DSB44	0.500	0.107	1.750	1.750	4.000	3.500	4.673	0.125	60.60	72.60	1.20	26.41	22.03	83.34	47.09	118.78
P3DSB45	0.500	0.107	1.750	1.750	4.000	3.500	4.673	0.125	60.60	72.60	1.20	26.41	22.03	83.34	47.09	118.78
P3DSB49	0.500	0.107	1.750	1.750	4.000	3.500	4.673	0.125	60.60	72.60	1.20	26.41	22.03	83.34	47.09	118.78
P3DSB50	0.500	0.107	1.750	1.750	4.000	3.500	4.673	0.125	60.60	72.60	1.20	26.41	22.03	83.34	47.09	118.78
P3DSB51	0.500	0.107	1.750	1.750	4.000	3.500	4.673	0.125	60.60	72.60	1.20	26.41	22.03	83.34	47.09	118.78
P3DSB55	0.625	0.107	1.125	2.250	4.000	1.800	5.841	0.156	60.60	72.60	1.20	25.73	22.03	83.30	54.34	114.46
P3DSB56	0.625	0.107	1.125	2.250	4.000	1.800	5.841	0.156	60.60	72.60	1.20	25.73	22.03	83.30	54.34	114.46
P3DSB57	0.625	0.107	1.125	2.250	4.000	1.800	5.841	0.156	60.60	72.60	1.20	25.73	22.03	83.30	54.34	114.46
P3DSB61	0.625	0.107	1.125	2.250	4.000	1.800	5.841	0.156	60.60	72.60	1.20	25.73	22.03	83.30	54.34	114.46
P3DSB62	0.625	0.107	1.125	2.250	4.000	1.800	5.841	0.156	60.60	72.60	1.20	25.73	22.03	83.30	54.34	114.46
P3DSB63	0.625	0.107	1.125	2.250	4.000	1.800	5.841	0.156	60.60	72.60	1.20	25.73	22.03	83.30	54.34	114.46
P3DSB67	0.625	0.107	1.125	2.250	4.000	1.800	5.841	0.156	60.60	72.60	1.20	25.73	22.03	83.30	54.34	114.46
P3DSB68	0.625	0.107	1.125	2.250	4.000	1.800	5.841	0.156	60.60	72.60	1.20	25.73	22.03	83.30	54.34	114.46
P3DSB69	0.625	0.107	1.125	2.250	4.000	1.800	5.841	0.156	60.60	72.60	1.20	25.73	22.03	83.30	54.34	114.46
P3DSB73	0.750	0.107	0.750	2.250	4.000	1.000	7.009	0.188	60.60	72.60	1.20	24.76	21.98	83.03	60.91	110.14
P3DSB74	0.750	0.107	0.750	2.250	4.000	1.000	7.009	0.188	60.60	72.60	1.20	24.76	21.98	83.03	60.91	110.14
P3DSB75	0.750	0.107	0.750	2.250	4.000	1.000	7.009	0.188	60.60	72.60	1.20	24.76	21.98	83.03	60.91	110.14
P3DSB79	0.750	0.107	1.125	2.250	4.000	1.500	7.009	0.188	60.60	72.60	1.20	24.76	21.98	83.03	60.91	110.14
P3DSB80	0.750	0.107	1.125	2.250	4.000	1.500	7.009	0.188	60.60	72.60	1.20	24.76	21.98	83.03	60.91	110.14
P3DSB83	0.750	0.107	1.125	2.250	4.000	1.500	7.009	0.188	60.60	72.60	1.20	24.76	21.98	83.03	60.91	110.14
P3DSB84	0.750	0.107	1.125	2.250	4.000	1.500	7.009	0.188	60.60	72.60	1.20	24.76	21.98	83.03	60.91	110.14
P3DSB85	0.750	0.107	1.125	2.250	4.000	1.500	7.009	0.188	60.60	72.60	1.20	24.76	21.98	83.03	60.91	110.14
P3DSB89	750	0.107	1.125	2.250	4.000	1.500	7.009	0.188	60.60	72.60	1.20	24.76	21.98	83.03	60.91	110.14
P3DSB90	750	0.107	1.125	2.250	4.000	1.500	7.009	0.188	60.60	72.60	1.20	24.76	21.98	83.03	60.91	110.14
P3DSB91	0.750	0.107	1.125	2.250	4.000	1.500	7.009	0.188	60.60	72.60	1.20	24.76	21.98	83.03	60.91	110.14
P3DSB95	0.750	0.107	1.125	2.250	4.000	1.500	7.009	0.188	60.60	72.60	1.20	24.76	21.98	83.03	60.91	110.14
P3DSB96	0.750	0.107	1.125	2.250	4.000	1.500	7.009	0.188	60.60	72.60	1.20	24.76	21.98	83.03	60.91	110.14
P3DSB97	0.750	0.107	1.125	2.250	4.000	1.500	7.009	0.188	60.60	72.60	1.20	24.76	21.98	83.03	60.91	110.14
P3DSB101	0.750	0.107	1.875	2.250	4.000	2.500	7.009	0.188	60.60	72.60	1.20	24.76	21.98	83.03	60.91	110.14
P3DSB102	0.750	0.107	1.875	2.250	4.000	2.500	7.009	0.188	60.60	72.60	1.20	24.76	21.98	83.03	60.91	110.14
P3DSB103	0.750	0.107	1.875	2.250	4.000	2.500	7.009	0.188	60.60	72.60	1.20	24.76	21.98	83.03	60.91	110.14
P3DSB107	0.750	0.107	2.625	2.630	4.000	3.500	7.009	0.188	60.60	72.60	1.20	24.76	21.98	83.03	60.91	110.14
P3DSB108	0.750	0.107	2.625	2.630	4.000	3.500	7.009	0.188	60.60	72.60	1.20	24.76	21.98	83.03	60.91	110.14
P3DSB109	0.750	0.107	2.625	2.630	4.000	3.500	7.009	0.188	60.60	72.60	1.20	24.76	21.98	83.03	60.91	110.14

Dimensions and Results of Double Shear Bolted Connections With Washers -Tensile Strength Study (Three Bolts in the Line of Stress) - Failure Type III - Cont.

Spec	Pult kips	Pult/AISI	Pult/AISC	Pult/ECCS	Pult/BS 5950	Pult/(CAN\CSA)	Reference
P3DSB44	25.40	1.15	0.96	1.36	2.40	0.95	27
P3DSB45	24.70	1.12	0.94	1.32	2.33	0.92	27
P3DSB49	25.80	1.17	0.98	1.38	2.44	0.97	27
P3DSB50	25.60	1.16	0.97	1.37	2.42	0.96	27
P3DSB51	25.60	1.16	0.97	1.37	2.42	0.96	27
P3DSB55	23.80	1.08	0.92	1.27	1.95	0.92	27
P3DSB56	25.00	1.13	0.97	1.33	2.05	0.97	27
P3DSB57	24.50	1.11	0.95	1.31	2.01	0.95	27
P3DSB61	25.50	1.16	0.99	1.36	2.09	0.99	27
P3DSB62	25.50	1.16	0.99	1.36	2.09	0.99	27
P3DSB63	24.00	1.09	0.93	1.28	1.96	0.93	27
P3DSB67	24.40	1.11	0.95	1.30	2.00	0.95	27
P3DSB68	23.60	1.07	0.92	1.26	1.93	0.92	27
P3DSB69	24.40	1.11	0.95	1.30	2.00	0.95	27
P3DSB73	24.30	1.11	0.98	1.30	1.77	0.98	27
P3DSB74	23.70	1.08	0.96	1.27	1.73	0.96	27
P3DSB75	24.00	1.09	0.97	1.29	1.75	0.97	27
P3DSB79	23.30	1.06	0.94	1.25	1.70	0.94	27
P3DSB80	23.25	1.06	0.94	1.25	1.70	0.94	27
P3DSB83	24.20	1.10	0.98	1.30	1.77	0.98	27
P3DSB84	23.65	1.08	0.96	1.27	1.73	0.96	27
P3DSB85	24.10	1.10	0.97	1.29	1.76	0.97	27
P3DSB89	24.10	1.10	0.97	1.29	1.76	0.97	27
P3DSB90	24.00	1.09	0.97	1.29	1.75	0.97	27
P3DSB91	23.40	1.06	0.95	1.25	1.71	0.95	27
P3DSB95	24.30	1.11	0.98	1.30	1.77	0.98	27
P3DSB96	23.90	1.09	0.97	1.28	1.75	0.97	27
P3DSB97	24.50	1.11	0.99	1.31	1.79	0.99	27
P3DSB101	24.00	1.09	0.97	1.29	1.75	0.97	27
P3DSB102	24.00	1.09	0.97	1.29	1.75	0.97	27
P3DSB103	24.10	1.10	0.97	1.29	1.76	0.97	27
P3DSB107	23.70	1.08	0.96	1.27	1.73	0.96	27
P3DSB108	23.80	1.08	0.96	1.28	1.74	0.96	27
P3DSB109	23.90	1.09	0.97	1.28	1.75	0.97	27

Dimensions and Results of Double Shear Bolted Connections With Washers -Tensile Strength Study (Three Bolts in the Line of Stress) - Failure Type III - Cont

Spec	d in	t in	e in	e1 in	s in	e/d	d/t	d/s	Fy ksi	Fu ksi	Fu/Fy	Controlling AISC kip	Controlling AISI kip	ECCS KN	BS 5950 KN	CAN\CSA KN
P3DSB113	1.000	0.107	1.500	3.000	4.000	1.500	9.346	0.250	60.60	72.60	1.20	22.82	21.68	81.81	72.01	101.50
P3DSE1	0.500	0.051	1.500	1.500	2.000	3.000	9.804	0.250	44.60	53.00	1.19	3.89	3.69	14.27	12.36	17.28
P3DSE2	0.500	0.051	1.500	1.500	2.000	3.000	9.804	0.250	44.60	53.00	1.19	3.89	3.69	14.27	12.36	17.28
P3DSE3	0.500	0.051	1.500	1.500	2.000	3.000	9.804	0.250	44.60	53.00	1.19	3.89	3.69	14.27	12.36	17.28
P3DSE7	0.625	0.051	1.563	1.880	2.000	2.501	12.255	0.313	44.60	53.00	1.19	3.55	3.55	13.28	13.28	15.78
P3DSE8	0.625	0.051	1.563	1.880	2.000	2.501	12.255	0.313	44.60	53.00	1.19	3.55	3.55	13.28	13.28	15.78
P3DSE11	0.750	0.051	1.500	2.250	2.000	2.000	14.706	0.375	44.60	53.00	1.19	3.21	3.21	12.01	12.01	14.28
P3DSE12	0.750	0.051	1.500	2.250	2.000	2.000	14.706	0.375	44.60	53.00	1.19	3.21	3.21	12.01	12.01	14.28
P3DSE13	0.750	0.051	1.500	2.250	2.000	2.000	14.706	0.375	44.60	53.00	1.19	3.21	3.21	12.01	12.01	14.28

Dimensions and Results of Double Shear Bolted Connections With Washers -Tensile Strength Study (Three Bolts in the Line of Stress) - Failure Type III - Cont.

Spec	Pult kips	Pult/AISI	Pult/AISC	Pult/ECCS	Pult/BS 5950	Pult/(CAN\CSA)	Reference
P3DSB113	22.80	1.05	1.00	1.24	1.41	1.00	27
P3DSE1	4.31	1.17	1.11	1.34	1.55	1.11	27
P3DSE2	4.28	1.16	1.10	1.33	1.54	1.10	27
P3DSE3	4.54	1.23	1.17	1.42	1.63	1.17	27
P3DSE7	4.63	1.31	1.31	1.55	1.55	1.31	27
P3DSE8	4.54	1.28	1.28	1.52	1.52	1.28	27
P3DSE11	4.23	1.32	1.32	1.57	1.57	1.32	27
P3DSE12	4.64	1.45	1.45	1.72	1.72	1.45	27
P3DSE13	4.02	1.25	1.25	1.49	1.49	1.25	27
Mean		1.123	0.982	1.353	2.035	0.978	
Standard Deviation		0.072	0.102	0.090	0.342	0.103	
Coefficient of Variation		0.064	0.104	0.066	0.168	0.105	

Dimensions and Results of Single Shear Bolted Connections Without Washers-Tensile Strength Study (One Bolt) - Failure Type III

Spec	d in	t in.	e in.	s in	e/d	d/t	d/s	Fy ksi	Fu ksi	Fu/Fy	Controlling AISC kip	Controlling AISI kip	ECCS KN	BS 5950 KN	CAN\CSA KN
A	0.500	0.167	1.50	1.50	3.00	2.99	0.333	43.58	55.58	1.2754	8.70	7.25	30.35	30.35	38.71
A	0.500	0.167	1.50	1.50	3.00	2.99	0.333	43.58	55.58	1.2754	8.70	7.25	30.35	30.35	38.71
A	0.500	0.167	1.50	1.50	3.00	2.99	0.333	43.58	55.58	1.2754	8.70	7.25	30.35	30.35	38.71
A	0.500	0.167	1.50	1.50	3.00	2.99	0.333	43.58	55.58	1.2754	8.70	7.25	30.35	30.35	38.71
A	0.500	0.167	1.50	1.50	3.00	2.99	0.333	43.58	55.58	1.2754	8.70	7.25	30.35	30.35	38.71
A	0.500	0.167	1.50	1.50	3.00	2.99	0.333	43.58	55.58	1.2754	8.70	7.25	30.35	30.35	38.71
A	0.500	0.170	1.50	1.50	3.00	2.94	0.333	46.24	56.85	1.2295	9.06	7.55	32.78	32.78	40.30
A	0.500	0.170	1.50	1.50	3.00	2.94	0.333	46.24	56.85	1.2295	9.06	7.55	32.78	32.78	40.30

Dimensions and Results of Single Shear Bolted Connections Without Washers-Tensile Strength Study (One Bolt) - Failure Type III - Cont.

Spec	Pult kips	Pult/AISI	Pult/AISC	Pult/ECCS	Pult/BS 5950	Pult/(CAN\CSA)	Reference
A	8.85	1.22	1.02	1.30	1.30	1.02	24
A	9.78	1.35	1.12	1.43	1.43	1.12	24
A	9.88	1.36	1.14	1.45	1.45	1.14	24
A	9.33	1.29	1.07	1.37	1.37	1.07	24
A	9.46	1.30	1.09	1.39	1.39	1.09	24
A	9.65	1.33	1.11	1.41	1.41	1.11	24
A	10.37	1.37	1.14	1.41	1.41	1.14	24
A	9.92	1.31	1.10	1.35	1.35	1.10	24
Mean		1.318	1.098	1.388	1.388	1.098	
Standard Deviation		0.046	0.038	0.046	0.046	0.038	
Coefficient of Variation		0.035	0.035	0.033	0.033	0.035	

Dimensions and Results of Single Shear Bolted Connections Without Washers -Tensile Strength Study (Two Bolts Perpendicular to the Line of Stress) - Type III Failure

Spec	d in	t in	e in	s in.	e/d	d/t	d/s	Fy ksi	Fu ksi	Fu/Fy	Controlling AISC kip	Controlling AISI kip	ECCS KN	BS 5950 KN
B	0.500	0.046	1.000	1.500	2.000	10.870	0.333	37.92	43.84	1.16	3.77	3.15	14.51	14.51
B	0.500	0.046	1.000	1.500	2.000	10.870	0.333	37.92	43.84	1.16	3.77	3.15	14.51	14.51

Dimensions and Results of Single Shear Bolted Connections Without Washers -Tensile Strength Study (Two Bolts Perpendicular to the Line of Stress) - Type III Failure - Cont

Spec	CAN\CSA KN	Pult kips	Pult/AISI	Pult/AISC	Pult/ECCS	Pult/BS 5950	Pult/(CAN\CSA)	Reference
B	16.77	3.95	1.26	1.05	1.21	1.21	1.05	24
B	16.77	3.77	1.20	1.00	1.15	1.15	1.00	24
Mean			1.225	1.024	1.184	1.184	1.024	
Standard Deviation			0.030	0.025	0.029	0.029	0.025	
Coefficient of Variation			0.024	0.024	0.024	0.024	0.024	

Dimensions and Results of Single Shear Bolted Connections Without Washers-Tensile Strength Study (Three Bolts Perpendicular to the Line of Stress) - Failure Type III

Spec	d in.	t in.	e in.	s in	e/d	d/t	d/s	Fy ksi	Fu ksi	Fu/Fy	Controlling AISC kip	Controlling AISI kip	ECCS KN	BS 5950 KN	CAN\CSA KN
H3SSB6	0.500	0.107	1.000	1.333	2.000	4.673	0.375	60.60	72.60	1.20	17.96	16.84	66.69	66.69	79.89
H3SSB7	0.500	0.107	1.000	1.333	2.000	4.673	0.375	60.60	72.60	1.20	17.96	16.84	66.69	66.69	79.89

Dimensions and Results of Single Shear Bolted Connections Without Washers-Tensile Strength Study (Three Bolts Perpendicular to the Line of Stress) - Failure Type III - Cont

Spec	Pult kips	Pult/AISI	Pult/AISC	Pult/ECCS	Pult/BS 5950	Pult/(CAN\CSA)	Reference
H3SSB6	17.24	1.02	0.96	1.15	1.15	0.96	27
H3SSB7	17.00	1.01	0.95	1.13	1.13	0.95	27
Mean		1.017	0.953	1.142	1.142	0.953	
Standard Deviation		0.007	0.007	0.008	0.008	0.007	
Coefficient of Variation		0.007	0.007	0.007	0.007	0.007	

Dimensions and Results of Single Shear Bolted Connections Without Washers - Tensile Strength Study (Two Bolts in the Line of Stress) - Failure Type III

Spec	d in	t in	e in	el in	s in	e/d	d/t	d/s	Fy ksi	Fu ksi	Fu/Fy	Controlling AISC kip	Controlling AISI kip	ECCS KN	BS 5950 KN
D	0.500	0.241	1.000	2.000	1.720	2.000	2.075	0.291	40.49	62.22	1.54	17.36	14.99	50.25	48.85
D	0.500	0.170	1.500	3.000	1.500	3.000	2.941	0.333	46.24	56.85	1.23	9.06	8.31	32.78	32.78
D	0.500	0.170	1.500	3.000	1.500	3.000	2.941	0.333	46.24	56.85	1.23	9.06	8.31	32.78	32.78
D	0.500	0.180	1.500	3.000	2.500	3.000	2.778	0.200	56.93	78.20	1.37	27.27	20.45	78.38	61.82
D	0.500	0.181	1.500	3.000	2.470	3.000	2.762	0.202	56.93	78.20	1.37	27.00	20.33	77.95	61.84

Dimensions and Results of Single Shear Bolted Connections Without Washers - Tensile Strength Study (Two Bolts in the Line of Stress) - Failure Type III - Cont.

Spec	CAN\CSA KN	Pult kips	Pult/AISI	Pult/AISC	Pult/ECCS	Pult/BS 5950	Pult/(CAN\CSA)	Reference
D	77.21	18.65	1.24	1.07	1.65	1.70	1.07	24
D	40.30	10.22	1.23	1.13	1.39	1.39	1.13	24
D	40.30	10.27	1.24	1.13	1.39	1.39	1.13	24
D	121.31	27.93	1.37	1.02	1.59	2.01	1.02	24
D	120.09	27.72	1.36	1.03	1.58	1.99	1.03	24
	Mean		1.288	1.078	1.520	1.697	1.078	
	Standard Deviation		0.062	0.047	0.108	0.273	0.047	
	Coefficient of Variation		0.048	0.044	0.071	0.161	0.044	

Dimensions and Results of Single Shear Bolted Connections Without Washers-Tensile Strength Study (Three Bolts in the Line of Stress) - Failure Type III

Spec	d in.	t in.	e in.	el in.	s in.	e/d	d/t	d/s	Fy ksi	Fu ksi	Fu/Fy	Controlling AISC kip	Controlling AISI kip	ECCS KN	BS 5950 KN
P3SSC25	0.625	0.058	1.500	2.250	4.000	2.400	10.776	0.156	44.60	53.20	1.19	10.21	8.14	33.21	21.66

Dimensions and Results of Single Shear Bolted Connections Without Washers-Tensile Strength Study (Three Bolts in the Line of Stress) - Failure Type III - Cont.

Spec	CAN\CSA KN	Pult kips	Pult/AISI	Pult/AISC	Pult/ECCS	Pult/BS 5950	Pult/(CAN\CSA)	Reference
P3SSC25	45.43	8.42	1.03	0.82	1.13	1.73	0.82	27

Dimensions and Results of Double Shear Bolted Connections Without Washers-Tensile Strength Study (Two Bolts Perpendicular to the Line of Stress) - Failure Type III

Spec	c in	t in.	e in.	s in.	e/d	d/t	d/s	Fy ksi	Fu ksi	Fu/Fy	Controlling AISC kip	Controlling AISI kip	ECCS KN	BS 5950 KN	CAN\CSA KN
H2DSC47	0.500	0.058	1.500	2.00	3.000	8.621	0.250	44.60	53.20	1.19	8.87	5.54	31.22	28.12	39.46
H2DSC48	0.500	0.058	1.500	2.00	3.000	8.621	0.250	44.60	53.20	1.19	8.87	5.54	31.22	28.12	39.46
H2DSC51	0.500	0.058	1.750	2.00	3.500	8.621	0.250	44.60	53.20	1.19	8.87	5.54	31.22	28.12	39.46
H2DSC52	0.500	0.058	1.750	2.00	3.500	8.621	0.250	44.60	53.20	1.19	8.87	5.54	31.22	28.12	39.46
H2DSC55	0.500	0.058	2.250	2.00	4.500	8.621	0.250	44.60	53.20	1.19	8.87	5.54	31.22	28.12	39.46
H2DSC56	0.500	0.058	2.250	2.00	4.500	8.621	0.250	44.60	53.20	1.19	8.87	5.54	31.22	28.12	39.46
H2DSC66	0.625	0.058	1.563	2.00	2.501	10.776	0.313	44.60	53.20	1.19	8.87	6.33	33.08	33.08	39.46
H2DSC67	0.625	0.058	1.563	2.00	2.501	10.776	0.313	44.60	53.20	1.19	8.87	6.33	33.08	33.08	39.46
H2DSC71	0.750	0.058	1.125	2.00	1.500	12.931	0.375	44.60	53.20	1.19	8.87	6.87	33.08	33.08	39.46
H2DSC72	0.750	0.058	1.125	2.00	1.500	12.931	0.375	44.60	53.20	1.19	8.87	6.87	33.08	33.08	39.46
H2DSC75	0.750	0.058	1.500	2.00	2.000	12.931	0.375	44.60	53.20	1.19	8.87	6.87	33.08	33.08	39.46
H2DSC76	0.750	0.058	1.500	2.00	2.000	12.931	0.375	44.60	53.20	1.19	8.87	6.87	33.08	33.08	39.46
H2DSC79	0.750	0.058	1.875	2.00	2.500	12.931	0.375	44.60	53.20	1.19	8.87	6.87	33.08	33.08	39.46
H2DSC80	0.750	0.058	1.875	2.00	2.500	12.931	0.375	44.60	53.20	1.19	8.87	6.87	33.08	33.08	39.46

Dimensions and Results of Double Shear Bolted Connections Without Washers-Tensile Strength Study (Two Bolts Perpendicular to the Line of Stress) - Failure Type III - Cont.

Spec	Pult kips	Pult/AISI	Pult/AISC	Pult/ECCS	Pult/BS 5950	Pult/(CAN\CSA)	Reference
H2DSC47	9.06	1.63	1.02	1.29	1.43	1.02	27
H2DSC48	9.32	1.68	1.05	1.33	1.47	1.05	27
H2DSC51	9.26	1.67	1.04	1.32	1.46	1.04	27
H2DSC52	9.40	1.70	1.06	1.34	1.49	1.06	27
H2DSC55	9.24	1.67	1.04	1.32	1.46	1.04	27
H2DSC56	9.64	1.74	1.09	1.37	1.52	1.09	27
H2DSC66	8.74	1.38	0.99	1.18	1.18	0.99	27
H2DSC67	8.74	1.38	0.99	1.18	1.18	0.99	27
H2DSC71	9.20	1.34	1.04	1.24	1.24	1.04	27
H2DSC72	8.66	1.26	0.98	1.16	1.16	0.98	27
H2DSC75	8.60	1.25	0.97	1.16	1.16	0.97	27
H2DSC76	8.48	1.23	0.96	1.14	1.14	0.96	27
H2DSC79	8.98	1.31	1.01	1.21	1.21	1.01	27
H2DSC80	8.00	1.16	0.90	1.08	1.08	0.90	27
Mean		1.458	1.009	1.236	1.298	1.009	
Standard Deviation		0.202	0.048	0.088	0.157	0.048	
Coefficient of Variation		0.139	0.047	0.071	0.121	0.047	

Dimensions and Results of Double Shear Bolted Connections Without Washers-Tensile Strength Study (Three Bolts Perpendicular to the Line of Stress) - Failure Type III

Spec	d in	t in.	e in	s in	e/d	d/t	d/s	Fy ksi	Fu ksi	Fu/Fy	Controlling AISC kip	Controlling AISI kip	ECCS KN	BS 5950 KN
H3DSA20	0.313	0.064	1.094	1.333	3.495	4.883	0.235	54.4	70.7	1.2996	13.43	7.85	40.20	36.96
H3DSA24	0.313	0.064	1.418	1.333	4.530	4.883	0.235	54.4	70.7	1.2996	13.43	7.85	40.20	36.96
H3DSA25	0.313	0.064	1.418	1.333	4.530	4.883	0.235	54.4	70.7	1.2996	13.43	7.85	40.20	36.96
H3DSA26	0.313	0.064	1.418	1.333	4.500	4.883	0.235	54.4	70.7	1.2996	13.43	7.85	40.20	36.96
H3DSA31	0.313	0.064	1.719	1.333	5.500	4.883	0.235	54.4	70.7	1.2996	13.43	7.85	40.20	36.96
H3DSA32	0.313	0.064	1.719	1.333	5.500	4.883	0.235	54.4	70.7	1.2996	13.43	7.85	40.20	36.96
H3DSA56	0.375	0.064	0.938	1.333	2.500	5.859	0.281	54.4	70.7	1.2996	12.58	8.84	43.07	40.66
H3DSA57	0.375	0.064	0.938	1.333	2.500	5.859	0.281	54.4	70.7	1.2996	12.58	8.84	43.07	40.66
H3DSA61	0.375	0.064	1.125	1.333	3.000	5.859	0.281	54.4	70.7	1.2996	12.58	8.84	43.07	40.66
H3DSA62	0.375	0.064	1.125	1.333	3.000	5.859	0.281	54.4	70.7	1.2996	12.58	8.84	43.07	40.66
H3DSA63	0.375	0.064	1.125	1.333	3.000	5.859	0.281	54.4	70.7	1.2996	12.58	8.84	43.07	40.66
H3DSA67	0.375	0.064	1.313	1.333	3.500	5.859	0.281	54.4	70.7	1.2996	12.58	8.84	43.07	40.66
H3DSA68	0.375	0.064	1.313	1.333	3.500	5.859	0.281	54.4	70.7	1.2996	12.58	8.84	43.07	40.66
H3DSA69	0.375	0.064	1.313	1.333	3.500	5.859	0.281	54.4	70.7	1.2996	12.58	8.84	43.07	40.66
H3DSA73	0.375	0.064	1.688	1.333	4.500	5.859	0.281	54.4	70.7	1.2996	12.58	8.84	43.07	40.66
H3DSA74	0.375	0.064	1.688	1.333	4.500	5.859	0.281	54.4	70.7	1.2996	12.58	8.84	43.07	40.66
H3DSA75	0.375	0.064	1.688	1.333	4.500	5.859	0.281	54.4	70.7	1.2996	12.58	8.84	43.07	40.66
H3DSA79	0.375	0.064	2.063	1.333	5.500	5.859	0.281	54.4	70.7	1.2996	12.58	8.84	43.07	40.66
H3DSA80	0.375	0.064	2.063	1.333	5.500	5.859	0.281	54.4	70.7	1.2996	12.58	8.84	43.07	40.66
H3DSA81	0.375	0.064	2.063	1.333	5.500	5.859	0.281	54.4	70.7	1.2996	12.58	8.84	43.07	40.66
H3DSA82	0.500	0.064	0.938	1.333	1.900	7.813	0.375	54.4	70.7	1.2996	10.46	8.05	35.81	35.81
H3DSA83	0.500	0.064	0.938	1.333	1.900	7.813	0.375	54.4	70.7	1.2996	10.46	8.05	35.81	35.81
H3DSA84	0.500	0.064	0.938	1.333	1.900	7.813	0.375	54.4	70.7	1.2996	10.46	8.05	35.81	35.81
H3DSA88	0.500	0.064	1.313	1.333	2.600	7.813	0.375	54.4	70.7	1.2996	10.46	8.05	35.81	35.81
H3DSA89	0.500	0.064	1.313	1.333	2.600	7.813	0.375	54.4	70.7	1.2996	10.46	8.05	35.81	35.81
H3DSA92	0.500	0.064	1.688	1.333	3.400	7.813	0.375	54.4	70.7	1.2996	10.46	8.05	35.81	35.81
H3DSA93	0.500	0.064	1.688	1.333	3.400	7.813	0.375	54.4	70.7	1.2996	10.46	8.05	35.81	35.81
H3DSB4	0.313	0.107	1.375	1.333	4.400	2.921	0.235	60.6	72.6	1.1980	23.05	13.48	74.86	68.84
H3DSB5	0.313	0.107	1.375	1.333	4.400	2.921	0.235	60.6	72.6	1.1980	23.05	13.48	74.86	68.84
H3DSB6	0.313	0.107	1.375	1.333	4.400	2.921	0.235	60.6	72.6	1.1980	23.05	13.48	74.86	68.84
H3DSB18	0.375	0.107	0.938	1.333	2.500	3.505	0.281	60.6	72.6	1.1980	21.61	15.18	80.22	75.72
H3DSB19	0.375	0.107	0.938	1.333	2.500	3.505	0.281	60.6	72.6	1.1980	21.61	15.18	80.22	75.72
H3DSB20	0.375	0.107	0.938	1.333	2.500	3.505	0.281	60.6	72.6	1.1980	21.61	15.18	80.22	75.72
H3DSB21	0.375	0.107	0.938	1.333	2.500	3.505	0.281	60.6	72.6	1.1980	21.61	15.18	80.22	75.72

Dimensions and Results of Double Shear Bolted Connections Without Washers-Tensile Strength Study (Three Bolts Perpendicular to the Line of Stress) - Failure Type III - Cont.

Spec	CAN\CSA KN	Pult kips	Pult/AISI	Pult/AISC	Pult/ECCS	Pult/BS 5950	Pult/(CAN\CSA)	Reference
H3DSA20	59.72	14.52	1.85	1.08	1.61	1.75	1.08	27
H3DSA24	59.72	14.63	1.86	1.09	1.62	1.76	1.09	27
H3DSA25	59.72	14.56	1.85	1.08	1.61	1.75	1.08	27
H3DSA26	59.72	14.40	1.83	1.07	1.59	1.73	1.07	27
H3DSA31	59.72	14.64	1.86	1.09	1.62	1.76	1.09	27
H3DSA32	59.72	13.90	1.77	1.04	1.54	1.67	1.04	27
H3DSA56	55.98	14.26	1.61	1.13	1.47	1.56	1.13	27
H3DSA57	55.98	14.40	1.63	1.14	1.49	1.58	1.14	27
H3DSA61	55.98	13.02	1.47	1.03	1.34	1.42	1.03	27
H3DSA62	55.98	13.54	1.53	1.08	1.40	1.48	1.08	27
H3DSA63	55.98	14.20	1.61	1.13	1.47	1.55	1.13	27
H3DSA67	55.98	14.42	1.63	1.15	1.49	1.58	1.15	27
H3DSA68	55.98	13.00	1.47	1.03	1.34	1.42	1.03	27
H3DSA69	55.98	14.34	1.62	1.14	1.48	1.57	1.14	27
H3DSA73	55.98	13.62	1.54	1.08	1.41	1.49	1.08	27
H3DSA74	55.98	12.94	1.46	1.03	1.34	1.42	1.03	27
H3DSA75	55.98	14.26	1.61	1.13	1.47	1.56	1.13	27
H3DSA79	55.98	13.70	1.55	1.09	1.41	1.50	1.09	27
H3DSA80	55.98	14.34	1.62	1.14	1.48	1.57	1.14	27
H3DSA81	55.98	12.48	1.41	0.99	1.29	1.37	0.99	27
H3DSA82	46.54	11.00	1.37	1.05	1.37	1.37	1.05	27
H3DSA83	46.54	11.80	1.47	1.13	1.47	1.47	1.13	27
H3DSA84	46.54	11.68	1.45	1.12	1.45	1.45	1.12	27
H3DSA88	46.54	11.18	1.39	1.07	1.39	1.39	1.07	27
H3DSA89	46.54	11.88	1.48	1.14	1.48	1.48	1.14	27
H3DSA92	46.54	11.62	1.44	1.11	1.44	1.44	1.11	27
H3DSA93	46.54	10.96	1.36	1.05	1.36	1.36	1.05	27
H3DSB4	102.53	23.00	1.71	1.00	1.37	1.49	1.00	27
H3DSB5	102.53	23.70	1.76	1.03	1.41	1.53	1.03	27
H3DSB6	102.53	23.40	1.74	1.02	1.39	1.51	1.02	27
H3DSB18	96.10	21.90	1.44	1.01	1.21	1.29	1.01	27
H3DSB19	96.10	22.40	1.48	1.04	1.24	1.32	1.04	27
H3DSB20	96.10	22.60	1.49	1.05	1.25	1.33	1.05	27
H3DSB21	96.10	22.90	1.51	1.06	1.27	1.35	1.06	27

Dimensions and Results of Double Shear Bolted Connections Without Washers-Tensile Strength Study (Three Bolts Perpendicular to the Line of Stress) - Failure Type III - Cont

Spec	d in	t in.	e in	s in	e/d	d/t	d/s	Fy ksi	Fu ksi	Fu/Fy	Controlling AISC kip	Controlling AISI kip	ECCS KN	BS 5950 KN
H3DSB22	0.375	0.107	0.938	1.333	2.500	3.505	0.281	60.6	72.6	1.1980	21.61	15.18	80.22	75.72
H3DSB28	0.375	0.107	1.313	1.333	3.500	3.505	0.281	60.6	72.6	1.1980	21.61	15.18	80.22	75.72
H3DSB29	0.375	0.107	1.313	1.333	3.500	3.505	0.281	60.6	72.6	1.1980	21.61	15.18	80.22	75.72
H3DSB30	0.375	0.107	1.313	1.333	3.500	3.505	0.281	60.6	72.6	1.1980	21.61	15.18	80.22	75.72
H3DSB31	0.375	0.107	1.313	1.333	3.500	3.505	0.281	60.6	72.6	1.1980	21.61	15.18	80.22	75.72
H3DSB32	0.375	0.107	1.313	1.333	3.500	3.505	0.281	60.6	72.6	1.1980	21.61	15.18	80.22	75.72
H3DSB38	0.375	0.107	1.688	1.333	4.500	3.505	0.281	60.6	72.6	1.1980	21.61	15.18	80.22	75.72
H3DSB39	0.375	0.107	1.688	1.333	4.500	3.505	0.281	60.6	72.6	1.1980	21.61	15.18	80.22	75.72
H3DSB40	0.375	0.107	1.688	1.333	4.500	3.505	0.281	60.6	72.6	1.1980	21.61	15.18	80.22	75.72
H3DSB41	0.375	0.107	1.688	1.333	4.500	3.505	0.281	60.6	72.6	1.1980	21.61	15.18	80.22	75.72
H3DSB42	0.375	0.107	1.688	1.333	4.500	3.505	0.281	60.6	72.6	1.1980	21.61	15.18	80.22	75.72

Dimensions and Results of Double Shear Bolted Connections Without Washers-Tensile Strength Study (Three Bolts Perpendicular to the Line of Stress) - Failure Type III - Cont.

Spec	CAN\CSA KN	Pult kips	Pult/AISI	Pult/AISC	Pult/ECCS	Pult/BS 5950	Pult/(CAN\CSA)	Reference
H3DSB22	96.10	23.00	1.52	1.06	1.28	1.35	1.06	27
H3DSB28	96.10	22.60	1.49	1.05	1.25	1.33	1.05	27
H3DSB29	96.10	22.90	1.51	1.06	1.27	1.35	1.06	27
H3DSB30	96.10	22.50	1.48	1.04	1.25	1.32	1.04	27
H3DSB31	96.10	23.20	1.53	1.07	1.29	1.36	1.07	27
H3DSB32	96.10	22.50	1.48	1.04	1.25	1.32	1.04	27
H3DSB38	96.10	22.70	1.50	1.05	1.26	1.33	1.05	27
H3DSB39	96.10	22.60	1.49	1.05	1.25	1.33	1.05	27
H3DSB40	96.10	22.70	1.50	1.05	1.26	1.33	1.05	27
H3DSB41	96.10	22.50	1.48	1.04	1.25	1.32	1.04	27
	96.10	22.40	1.48	1.04	1.24	1.32	1.04	27
	Mean		1.563	1.070	1.387	1.465	1.070	
	Standard Deviation		0.138	0.042	0.119	0.138	0.042	
	Coefficient of Variation		0.089	0.039	0.086	0.094	0.039	

Dimensions and Results of Double Shear Bolted Connections Without Washers-Tensile Strength Study (Two Bolts in the Line of Stress) - Failure Type III

Spec	d in	t in	e in	el in	s in	e/d	d/t	d/s	Fy ksi	Fu ksi	Fu/Fy	Controlling AISC kip	Controlling AISI kip	ECCS KN	BS 5950 KN
P2DSA16	0.750	0.064	2.250	2.250	4.000	3.000	11.719	0.188	54.40	70.70	1.30	14.42	10.59	42.19	32.70
P2DSA17	0.750	0.064	2.250	2.250	4.000	3.000	11.719	0.188	54.40	70.70	1.30	14.42	10.59	42.19	32.70
P2DSA18	0.750	0.064	2.250	2.250	4.000	3.000	11.719	0.188	54.40	70.70	1.30	14.42	10.59	42.19	32.70
P2DSE4	0.500	0.051	1.500	1.500	2.000	3.000	9.804	0.250	44.60	53.00	1.19	3.89	3.16	14.13	12.36
P2DSE5	0.500	0.051	1.500	1.500	2.000	3.000	9.804	0.250	44.60	53.00	1.19	3.89	3.16	14.13	12.36
P2DSE9	0.625	0.051	1.875	1.880	2.000	3.000	12.255	0.313	44.60	53.00	1.19	3.55	3.16	13.28	13.28
P2DSE10	0.625	0.051	1.875	1.880	2.000	3.000	12.255	0.313	44.60	53.00	1.19	3.55	3.16	13.28	13.28
P2DSE14	0.750	0.051	2.250	2.250	2.000	3.000	14.706	0.375	44.60	53.00	1.19	3.21	3.11	12.01	12.01
P2DSE15	0.750	0.051	2.250	2.250	2.000	3.000	14.706	0.375	44.60	53.00	1.19	3.21	3.11	12.01	12.01

Dimensions and Results of Double Shear Bolted Connections Without Washers-Tensile Strength Study (Two Bolts in the Line of Stress) - Failure Type III - Cont

Spec	CAN\CSA KN	Pult kips	Pult/AISI	Pult/AISC	Pult/ECCS	Pult/BS 5950	Pult/(CAN\CSA)	Reference
P2DSA16	64.15	13.18	1.24	0.91	1.39	1.79	0.91	27
P2DSA17	64.15	13.34	1.26	0.92	1.41	1.81	0.92	27
P2DSA18	64.15	12.62	1.19	0.88	1.33	1.72	0.88	27
P2DSE4	17.28	4.04	1.28	1.04	1.27	1.45	1.04	27
P2DSE5	17.28	3.92	1.24	1.01	1.23	1.41	1.01	27
P2DSE9	15.78	3.68	1.16	1.04	1.23	1.23	1.04	27
P2DSE10	15.78	3.62	1.15	1.02	1.21	1.21	1.02	27
P2DSE14	14.28	3.83	1.23	1.19	1.42	1.42	1.19	27
P2DSE15	14.28	3.81	1.23	1.19	1.41	1.41	1.19	27
Mea			1.220	1.022	1.323	1.496	1.022	
Stan rd Deviation			0.042	0.105	0.081	0.213	0.105	
Coefficient of Variat			0.034	0.103	0.061	0.143	0.103	

Dimensions and R.. ..lts of Double Shear Bolted Connections Without Washers -Tensile Strength Study (Three Bolts in the Line of Stre: .. - Failure Type III

Spec	d in.	t in.	e in.	el in.	s in.	e/d	d/t	d/s	Fy ksi	Fu ksi	Fu/Fy	Controlling AISC kip	Controlling AISI kip	ECCS KN
P3DSA21	0.500	0.064	1.250	1.500	4.000	2.500	7.813	0.125	54.40	70.70	1.30	15.38	11.99	44.75
P3DSA22	0.500	0.064	1.250	1.500	4.000	2.500	7.813	0.125	54.40	70.70	1.30	15.38	11.99	44.75
P3DSA23	0.500	0.064	1.250	1.500	4.000	2.500	7.813	0.125	54.40	70.70	1.30	15.38	11.99	44.75
P3DSA27	0.500	0.064	1.750	1.750	4.000	3.500	7.813	0.125	54.40	70.70	1.30	15.38	11.99	44.75
P3DSA28	0.500	0.064	1.750	1.750	4.000	3.500	7.813	0.125	54.40	70.70	1.30	15.38	11.99	44.75
P3DSA29	0.500	0.064	1.750	1.750	4.000	3.500	7.813	0.125	54.40	70.70	1.30	15.38	11.99	44.75
P3DSA33	0.500	0.064	2.250	2.250	4.000	4.500	7.813	0.125	54.40	70.70	1.30	15.38	11.99	44.75
P3DSA34	0.500	0.064	2.250	2.250	4.000	4.500	7.813	0.125	54.40	70.70	1.30	15.38	11.99	44.75
P3DSA35	0.500	0.064	2.250	2.250	4.000	4.500	7.813	0.125	54.40	70.70	1.30	15.38	11.99	44.75
P3DSA39	0.625	0.064	0.938	1.880	4.000	1.501	9.766	0.156	54.40	70.70	1.30	14.99	11.94	44.73
P3DSA40	0.625	0.064	0.938	1.880	4.000	1.501	9.766	0.156	54.40	70.70	1.30	14.99	11.94	44.73
P3DSA41	0.625	0.064	0.938	1.880	4.000	1.501	9.766	0.156	54.40	70.70	1.30	14.99	11.94	44.73
P3DSA45	0.625	0.064	1.563	1.880	4.000	2.501	9.766	0.156	54.40	70.70	1.30	14.99	11.94	44.73
P3DSA46	0.625	0.064	1.563	1.880	4.000	2.501	9.766	0.156	54.40	70.70	1.30	14.99	11.94	44.73
P3DSA47	0.625	0.064	1.563	1.880	4.000	2.501	9.766	0.156	54.40	70.70	1.30	14.99	11.94	44.73
P3DSA51	0.625	0.064	2.188	2.190	4.000	3.501	9.766	0.156	54.40	70.70	1.30	14.99	11.94	44.73
P3DSA52	0.625	0.064	2.188	2.190	4.000	3.501	9.766	0.156	54.40	70.70	1.30	14.99	11.94	44.73
P3DSA53	0.625	0.064	2.188	2.190	4.000	3.501	9.766	0.156	54.40	70.70	1.30	14.99	11.94	44.73
P3DSA58	0.750	0.064	1.125	1.500	4.000	1.500	11.719	0.188	54.40	70.70	1.30	14.42	11.87	44.58
P3DSA59	0.750	0.064	1.125	1.500	4.000	1.500	11.719	0.188	54.40	70.70	1.30	14.42	11.87	44.58
P3DSA60	0.750	0.064	1.125	1.500	4.000	1.500	11.719	0.188	54.40	70.70	1.30	14.42	11.87	44.58
P3DSB24	0.500	0.107	1.250	1.500	4.000	2.500	4.673	0.125	60.60	72.60	1.20	26.41	20.58	83.34
P3DSB25	0.500	0.107	1.250	1.500	4.000	2.500	4.673	0.125	60.60	72.60	1.20	26.41	20.58	83.34
P3DSB29	0.500	0.107	1.250	1.500	4.000	2.500	4.673	0.125	60.60	72.60	1.20	26.41	20.58	83.34
P3DSB30	0.500	0.107	1.250	1.500	4.000	2.500	4.673	0.125	60.60	72.60	1.20	26.41	20.58	83.34
P3DSB31	0.500	0.107	1.250	1.500	4.000	2.500	4.673	0.125	60.60	72.60	1.20	26.41	20.58	83.34
P3DSB35	0.500	0.107	1.250	1.500	4.000	2.500	4.673	0.125	60.60	72.60	1.20	26.41	20.58	83.34
P3DSB36	0.500	0.107	1.250	1.500	4.000	2.500	4.673	0.125	60.60	72.60	1.20	26.41	20.58	83.34
P3DSB37	0.500	0.107	1.250	1.500	4.000	2.500	4.673	0.125	60.60	72.60	1.20	26.41	20.58	83.34
P3DSB39	0.500	0.107	1.250	1.500	4.000	2.500	4.673	0.125	60.60	72.60	1.20	26.41	20.58	83.34
P3DSB40	0.500	0.107	1.250	1.500	4.000	2.500	4.673	0.125	60.60	72.60	1.20	26.41	20.58	83.34
P3DSB46	0.500	0.107	1.750	1.750	4.000	3.500	4.673	0.125	60.60	72.60	1.20	26.41	20.58	83.34
P3DSB47	0.500	0.107	1.750	1.750	4.000	3.500	4.673	0.125	60.60	72.60	1.20	26.41	20.58	83.34
P3DSB48	0.500	0.107	1.750	1.750	4.000	3.500	4.673	0.125	60.60	72.60	1.20	26.41	20.58	83.34

Dimensions and Results of Double Shear Bolted Connections Without Washers -Tensile Strength Study (Three Bolts in the Line of Stress) - Failure Type III - Cont.

Spec	BS 5950 KN	CAN\CSA KN	Pult kips	Pult/AISI	Pult/AISC	Pult/ECCS	Pult/BS 5950	Pult/(CAN\CSA)	Reference
P3DSA21	25.29	69.18	14.32	1.19	0.93	1.42	2.52	0.92	27
P3DSA22	25.29	69.18	13.98	1.17	0.91	1.39	2.46	0.90	27
P3DSA23	25.29	69.18	12.88	1.07	0.84	1.28	2.27	0.83	27
P3DSA27	25.29	69.18	14.78	1.23	0.96	1.47	2.60	0.95	27
P3DSA28	25.29	69.18	14.60	1.22	0.95	1.45	2.57	0.94	27
P3DSA29	25.29	69.18	15.18	1.27	0.99	1.51	2.67	0.98	27
P3DSA33	25.29	69.18	14.12	1.18	0.92	1.40	2.48	0.91	27
P3DSA34	25.29	69.18	13.98	1.17	0.91	1.39	2.46	0.90	27
P3DSA35	25.29	69.18	14.46	1.21	0.94	1.44	2.54	0.93	27
P3DSA39	29.18	66.67	14.24	1.19	0.95	1.42	2.17	0.95	27
P3DSA40	29.18	66.67	14.70	1.23	0.98	1.46	2.24	0.98	27
P3DSA41	29.18	66.67	14.04	1.18	0.94	1.40	2.14	0.94	27
P3DSA45	29.18	66.67	14.14	1.18	0.94	1.41	2.16	0.94	27
P3DSA46	29.18	66.67	14.06	1.18	0.94	1.40	2.14	0.94	27
P3DSA47	29.18	66.67	14.54	1.22	0.97	1.45	2.22	0.97	27
P3DSA51	29.18	66.67	14.87	1.24	0.99	1.48	2.27	0.99	27
P3DSA52	29.18	66.67	14.18	1.19	0.95	1.41	2.16	0.95	27
P3DSA53	29.18	66.67	15.18	1.27	1.01	1.51	2.31	1.01	27
P3DSA58	32.70	64.15	14.30	1.20	0.99	1.43	1.95	0.99	27
P3DSA59	32.70	64.15	12.46	1.05	0.86	1.24	1.69	0.86	27
P3DSA60	32.70	64.15	14.26	1.20	0.99	1.42	1.94	0.99	27
P3DSB24	47.09	118.78	24.45	1.19	0.93	1.30	2.31	0.92	27
P3DSB25	47.09	118.78	24.85	1.21	0.94	1.33	2.35	0.93	27
P3DSB29	47.09	118.78	24.90	1.21	0.94	1.33	2.35	0.93	27
P3DSB30	47.09	118.78	25.50	1.24	0.97	1.36	2.41	0.95	27
P3DSB31	47.09	118.78	24.90	1.21	0.94	1.33	2.35	0.93	27
P3DSB35	47.09	118.78	25.30	1.23	0.96	1.35	2.39	0.95	27
P3DSB36	47.09	118.78	24.90	1.21	0.94	1.33	2.35	0.93	27
P3DSB37	47.09	118.78	25.30	1.23	0.96	1.35	2.39	0.95	27
P3DSB39	47.09	118.78	25.30	1.23	0.96	1.35	2.39	0.95	27
P3DSB40	47.09	118.78	24.50	1.19	0.93	1.31	2.31	0.92	27
P3DSB46	47.09	118.78	25.15	1.22	0.95	1.34	2.38	0.94	27
P3DSB47	47.09	118.78	24.40	1.19	0.92	1.30	2.30	0.91	27
P3DSB48	47.09	118.78	23.80	1.16	0.90	1.27	2.25	0.89	27

Dimensions and Results of Double Shear Bolted Connections Without Washers -Tensile Strength Study (Three Bolts in the Line of Stress) - Failure Type III - Cont.

Spec	d in.	t in.	e in.	el in.	s in.	e/d	d/t	d/s	Fy ksi	Fu ksi	Fu/Fy	Controlling AISC kip	Controlling AISI kip	ECCS KN
P3DSB52	0.500	0.107	1.750	1.750	4.000	3.500	4.673	0.125	60.60	72.60	1.20	26.41	20.58	83.34
P3DSB53	0.500	0.107	1.750	1.750	4.000	3.500	4.673	0.125	60.60	72.60	1.20	26.41	20.58	83.34
P3DSB54	0.500	0.107	1.750	1.750	4.000	3.500	4.673	0.125	60.60	72.60	1.20	26.41	20.58	83.34
P3DSB58	0.625	0.107	1.125	2.250	4.000	1.800	5.841	0.156	60.60	72.60	1.20	25.73	20.51	83.30
P3DSB59	0.625	0.107	1.125	2.250	4.000	1.800	5.841	0.156	60.60	72.60	1.20	25.73	20.51	83.30
P3DSB60	0.625	0.107	1.125	2.250	4.000	1.800	5.841	0.156	60.60	72.60	1.20	25.73	20.51	83.30
P3DSB64	0.625	0.107	1.125	2.250	4.000	1.800	5.841	0.156	60.60	72.60	1.20	25.73	20.51	83.30
P3DSB65	0.625	0.107	1.125	2.250	4.000	1.800	5.841	0.156	60.60	72.60	1.20	25.73	20.51	83.30
P3DSB66	0.625	0.107	1.125	2.250	4.000	1.800	5.841	0.156	60.60	72.60	1.20	25.73	20.51	83.30
P3DSB70	0.625	0.107	1.125	2.250	4.000	1.800	5.841	0.156	60.60	72.60	1.20	25.73	20.51	83.30
P3DSB71	0.625	0.107	1.125	2.250	4.000	1.800	5.841	0.156	60.60	72.60	1.20	25.73	20.51	83.30
P3DSB72	0.625	0.107	1.125	2.250	4.000	1.800	5.841	0.156	60.60	72.60	1.20	25.73	20.51	83.30
P3DSB76	0.750	0.107	0.750	2.250	4.000	1.000	7.009	0.188	60.60	72.60	1.20	24.76	20.38	83.03
P3DSB77	0.750	0.107	0.750	2.250	4.000	1.000	7.009	0.188	60.60	72.60	1.20	24.76	20.38	83.03
P3DSB78	0.750	0.107	0.750	2.250	4.000	1.000	7.009	0.188	60.60	72.60	1.20	24.76	20.38	83.03
P3DSB81	0.750	0.107	1.125	2.250	4.000	1.500	7.009	0.188	60.60	72.60	1.20	24.76	20.38	83.03
P3DSB82	0.750	0.107	1.125	2.250	4.000	1.500	7.009	0.188	60.60	72.60	1.20	24.76	20.38	83.03
P3DSB86	0.750	0.107	1.125	2.250	4.000	1.500	7.009	0.188	60.60	72.60	1.20	24.76	20.38	83.03
P3DSB87	0.750	0.107	1.125	2.250	4.000	1.500	7.009	0.188	60.60	72.60	1.20	24.76	20.38	83.03
P3DSB88	.750	0.107	1.125	2.250	4.000	1.500	7.009	0.188	60.60	72.60	1.20	24.76	20.38	83.03
P3DSB92	.750	0.107	1.125	2.250	4.000	1.500	7.009	0.188	60.60	72.60	1.20	24.76	20.38	83.03
P3DSB93	.750	0.107	1.125	2.250	4.000	1.500	7.009	0.188	60.60	72.60	1.20	24.76	20.38	83.03
P3DSB94	0.750	0.107	1.125	2.250	4.000	1.500	7.009	0.188	60.60	72.60	1.20	24.76	20.38	83.03
P3DSB98	0.750	0.107	1.125	2.250	4.000	1.500	7.009	0.188	60.60	72.60	1.20	24.76	20.38	83.03
P3DSB99	0.750	0.107	1.125	2.250	4.000	1.500	7.009	0.188	60.60	72.60	1.20	24.76	20.38	83.03
P3DSB100	0.750	0.107	1.125	2.250	4.000	1.500	7.009	0.188	60.60	72.60	1.20	24.76	20.38	83.03
P3DSB104	0.750	0.107	1.875	2.250	4.000	2.500	7.009	0.188	60.60	72.60	1.20	24.76	20.38	83.03
P3DSB105	0.750	0.107	1.875	2.250	4.000	2.500	7.009	0.188	60.60	72.60	1.20	24.76	20.38	83.03
P3DSB106	0.750	0.107	1.875	2.250	4.000	2.500	7.009	0.188	60.60	72.60	1.20	24.76	20.38	83.03
P3DSB110	0.750	0.107	2.625	2.630	4.000	3.500	7.009	0.188	60.60	72.60	1.20	24.76	20.38	83.03
P3DSB111	0.750	0.107	2.625	2.630	4.000	3.500	7.009	0.188	60.60	72.60	1.20	24.76	20.38	83.03
P3DSB112	0.750	0.107	2.625	2.630	4.000	3.500	7.009	0.188	60.60	72.60	1.20	24.76	20.38	83.03
P3DSE4	0.500	0.051	1.500	1.500	2.000	3.000	9.804	0.250	44.60	53.00	1.19	3.89	3.40	14.27
P3DSE5	0.500	0.051	1.500	1.500	2.000	3.000	9.804	0.250	44.60	53.00	1.19	3.89	3.40	14.27

Dimensions and Results of Double Shear Bolted Connections Without Washers -Tensile Strength Study (Three Bolts in the Line of Stress) - Failure Type III - Cont.

Spec	BS 5950 KN	CAN\CSA KN	Pult kips	Pult/AISI	Pult/AISC	Pult/ECCS	Pult/BS 5950	Pult/(CAN\CSA)	Reference
P3DSB52	47.09	118.78	25.35	1.23	0.96	1.35	2.39	0.95	27
P3DSB53	47.09	118.78	25.20	1.22	0.95	1.34	2.38	0.94	27
P3DSB54	47.09	118.78	25.20	1.22	0.95	1.34	2.38	0.94	27
P3DSB58	54.34	114.46	24.40	1.19	0.95	1.30	2.00	0.95	27
P3DSB59	54.34	114.46	24.70	1.20	0.96	1.32	2.02	0.96	27
P3DSB60	54.34	114.46	24.00	1.17	0.93	1.28	1.96	0.93	27
P3DSB64	54.34	114.46	24.90	1.21	0.97	1.33	2.04	0.97	27
P3DSB65	54.34	114.46	24.40	1.19	0.95	1.30	2.00	0.95	27
P3DSB66	54.34	114.46	24.00	1.17	0.93	1.28	1.96	0.93	27
P3DSB70	54.34	114.46	24.60	1.20	0.96	1.31	2.01	0.96	27
P3DSB71	54.34	114.46	23.50	1.15	0.91	1.25	1.92	0.91	27
P3DSB72	54.34	114.46	24.30	1.19	0.94	1.30	1.99	0.94	27
P3DSB76	60.91	110.14	23.80	1.17	0.96	1.28	1.74	0.96	27
P3DSB77	60.91	110.14	24.30	1.19	0.98	1.30	1.77	0.98	27
P3DSB78	60.91	110.14	24.10	1.18	0.97	1.29	1.76	0.97	27
P3DSB81	60.91	110.14	23.70	1.16	0.96	1.27	1.73	0.96	27
P3DSB82	60.91	110.14	23.50	1.15	0.95	1.26	1.72	0.95	27
P3DSB86	60.91	110.14	23.70	1.16	0.96	1.27	1.73	0.96	27
P3DSB87	60.91	110.14	25.00	1.23	1.01	1.34	1.83	1.01	27
P3DSB88	60.91	110.14	24.15	1.19	0.98	1.29	1.76	0.98	27
P3DSB92	60.91	110.14	23.50	1.15	0.95	1.26	1.72	0.95	27
P3DSB93	60.91	110.14	23.30	1.14	0.94	1.25	1.70	0.94	27
P3DSB94	60.91	110.14	23.30	1.14	0.94	1.25	1.70	0.94	27
P3DSB98	60.91	110.14	24.20	1.19	0.98	1.30	1.77	0.98	27
P3DSB99	60.91	110.14	24.10	1.18	0.97	1.29	1.76	0.97	27
P3DSB100	60.91	110.14	24.20	1.19	0.98	1.30	1.77	0.98	27
P3DSB104	60.91	110.14	24.00	1.18	0.97	1.29	1.75	0.97	27
P3DSB105	60.91	110.14	23.40	1.15	0.95	1.25	1.71	0.95	27
P3DSB106	60.91	110.14	25.30	1.24	1.02	1.36	1.85	1.02	27
P3DSB110	60.91	110.14	23.65	1.16	0.96	1.27	1.73	0.96	27
P3DSB111	60.91	110.14	23.35	1.15	0.94	1.25	1.71	0.94	27
P3DSB112	60.91	110.14	23.60	1.16	0.95	1.26	1.72	0.95	27
P3DSE4	12.36	17.28	4.08	1.20	1.05	1.27	1.47	1.05	27
P3DSE5	12.36	17.28	4.06	1.19	1.04	1.27	1.46	1.04	27

Dimensions and Results of Double Shear Bolted Connections Without Washers -Tensile Strength Study (Three Bolts in the Line of Stress) - Failure Type III - Cont.

Spec	d in.	t in.	e in.	el in	s in.	e/d	d/t	d/s	Fy ksi	Fu ksi	Fu/Fy	Controlling AISC kip	Controlling AISI kip	ECCS KN
P3DSE6	0.500	0.051	1.500	1.500	2.000	3.000	9.804	0.250	44.60	53.00	1.19	3.89	3.40	14.27
P3DSE9	0.625	0.051	1.563	1.880	2.000	2.501	12.255	0.313	44.60	53.00	1.19	3.55	3.29	13.28
P3DSE10	0.625	0.051	1.563	1.880	2.000	2.501	12.255	0.313	44.60	53.00	1.19	3.55	3.29	13.28
P3DSE14	0.750	0.051	1.500	2.250	2.000	2.000	14.706	0.375	44.60	53.00	1.19	3.21	3.14	12.01
P3DSE15	0.750	0.051	1.500	2.250	2.000	2.000	14.706	0.375	44.60	53.00	1.19	3.21	3.14	12.01
P3DSE16	0.750	0.051	1.500	2.250	2.000	2.000	14.706	0.375	44.60	53.00	1.19	3.21	3.14	12.01

Dimensions and Results of Double Shear Bolted Connections Without Washers -Tensile Strength Study (Three Bolts in the Line of Stress) - Failure Type III - Cont.

Spec	BS 5950 KN	CAN\CSA KN	Pult kips	Pult/AISI	Pult/AISC	Pult/ECCS	Pult/BS 5950	Pult/(CAN\CSA)	Reference
P3DSE6	12.36	17.28	4.02	1.18	1.03	1.25	1.45	1.03	27
P3DSE9	13.28	15.78	4.10	1.25	1.16	1.37	1.37	1.16	27
P3DSE10	13.28	15.78	4.14	1.26	1.17	1.39	1.39	1.17	27
P3DSE14	12.01	14.28	3.66	1.16	1.14	1.36	1.36	1.14	27
P3DSE15	12.01	14.28	3.63	1.15	1.13	1.34	1.34	1.13	27
P3DSE16	12.01	14.28	4.08	1.30	1.27	1.51	1.51	1.27	27
		Mean		1.193	0.970	1.340	2.025	0.966	
		Standard Deviation		0.039	0.065	0.071	0.348	0.067	
		Coefficient of Variation		0.033	0.067	0.053	0.172	0.070	

APPENDIX B

Dimensions And Results Of Bolted Connections Used In The Evaluation Of Existing Data - Type II Failure Mode

Dimensions and Results of Single Shear Bolted Connections with Washers (One Bolt) - Failure Type II

Spec.	(in)	t (in)	e (in)	s (in)	e/d	d/t	Fy (ksi)	Fu (ksi)	Fu/Fy	Pult kip	ECCS KN	BS 5950 KN	CAN\CSA KN	F. Zadanfarrokh KN
20A41SS	0.250	0.036	1.125	4.000	4.500	6.940	32.11	41.83	1.30	1.87	2.70	2.70	5.02	6.44
14A43SS	0.500	0.080	2.250	4.000	4.500	6.250	29.81	43.40	1.46	7.10	15.81	13.60	23.17	22.82
10E36SS	1.000	0.143	3.500	4.000	3.500	6.980	59.47	76.84	1.29	24.63	126.91	113.48	146.63	83.21
12Y-L8	0.375	0.106	1.500	2.530	4.000	3.540	72.40	72.80	1.01	9.74	43.08	36.63	38.61	35.86
12Y-L9	0.500	0.106	1.750	3.410	3.500	4.720	72.40	72.80	1.01	14.15	53.97	48.84	51.49	41.41
12Y-L16	0.500	0.106	1.750	2.040	3.500	4.720	72.40	72.80	1.01	11.18	53.97	48.84	51.49	41.41
12Y-L18	0.750	0.106	2.650	3.040	3.530	7.080	72.40	72.80	1.01	12.16	81.32	73.26	77.23	50.71
20ZT12	0.188	0.038	0.660	2.080	3.500	4.930	99.40	99.80	1.00	1.85	6.62	6.62	9.49	9.14
SS2	0.875	0.116	3.060	8.000	3.500	7.540	35.49	49.44	1.39	16.09	53.19	47.68	66.96	50.43
SS2-1	0.875	0.116	3.060	8.000	3.500	7.540	35.49	49.44	1.39	12.31	53.19	47.68	66.96	50.43
SS3	0.875	0.116	4.400	8.000	5.000	7.540	35.49	49.44	1.39	15.15	63.39	47.68	66.96	50.43
SS5	1.000	0.116	3.500	8.000	3.500	8.620	35.49	49.44	1.39	15.53	60.82	54.49	76.53	53.91
SS5-1	1.000	0.116	3.500	8.000	3.500	8.700	35.49	49.44	1.39	13.64	60.82	54.49	76.53	53.91
SS6	1.000	0.116	3.500	8.000	5.000	8.620	35.49	49.44	1.39	15.34	60.82	54.49	76.53	53.91
SS8	0.875	0.181	3.060	8.000	3.500	4.830	38.10	62.08	1.63	33.00	90.01	80.52	131.20	88.55
SS8-1	0.875	0.181	3.060	8.000	3.500	4.830	38.10	62.08	1.63	24.80	90.01	80.52	131.20	88.55
SS9	0.875	0.185	4.375	8.000	5.000	4.730	38.10	62.08	1.63	32.75	109.65	82.30	134.10	90.51
SS11	1.000	0.184	3.500	8.000	3.500	5.430	38.10	62.08	1.63	36.80	104.62	93.55	152.42	96.23
SS11-1	1.000	0.184	3.500	8.000	3.500	5.430	38.10	62.08	1.63	30.30	104.62	93.55	152.42	96.23
SS12	1.000	0.184	5.000	8.000	5.000	5.430	38.10	62.08	1.63	35.30	124.64	93.55	152.42	96.23
16FAXL17	0.500	0.062	1.750	5.000	3.500	8.060	30.10	45.90	1.52	4.28	10.21	9.79	18.99	17.47
B-1-8-3-T-SS	0.375	0.025	1.313	5.220	3.500	15.000	45.00	52.00	1.16	1.37	3.94	3.94	4.34	5.94
B-1-8-3-T-SS	0.375	0.025	1.313	5.230	3.500	15.000	45.00	52.00	1.16	1.22	3.94	3.94	4.34	5.94
B-1-9-1-T-SS	0.375	0.024	1.658	5.220	4.420	15.630	45.00	52.00	1.16	1.44	3.78	3.78	4.16	5.69
B-1-9-2-T-SS	0.375	0.024	1.688	5.220	4.500	15.630	45.00	52.00	1.16	1.24	3.78	3.78	4.16	5.69
B-1-9-3-T-SS	0.375	0.024	1.688	5.220	4.500	15.630	45.00	52.00	1.16	1.71	3.78	3.78	4.16	5.69

Dimensions and Results of Single Shear Bolted Connections with Washers (One Bolt) - Failure Type II - Cont.

Spec.	Bearing Pn AISI E3.3-2 kip	Bearing Pn AISC kip	Pult/AISI	Pult/AISC	Pult/ECCS	Pult/BS 5950	Pult/(CAN\CSA)	Pult/F. Zadanfarrokh	Reference
20A41SS	1.13	1.13	1.66	1.66	3.09	3.09	1.66	1.30	12
14A43SS	5.21	5.21	1.36	1.36	2.00	2.32	1.36	1.38	12
10E36SS	32.96	32.96	0.75	0.75	0.86	0.97	0.75	1.32	13
12Y-L8	8.68	8.68	1.12	1.12	1.01	1.18	1.12	1.21	12
12Y-L9	11.58	11.58	1.22	1.22	1.17	1.29	1.22	1.52	12
12Y-L16	11.58	11.58	0.97	0.97	0.92	1.02	0.97	1.20	12
12Y-L18	17.36	17.36	0.70	0.70	0.67	0.74	0.70	1.07	12
20ZT12	2.13	2.13	0.87	0.87	1.25	1.25	0.87	0.90	12
SS2	15.05	15.05	1.07	1.07	1.35	1.50	1.07	1.42	18
SS2-1	15.05	15.05	0.82	0.82	1.03	1.15	0.82	1.09	18
SS3	15.05	15.05	1.01	1.01	1.06	1.41	1.01	1.34	18
SS5	17.21	17.21	0.90	0.90	1.14	1.27	0.90	1.28	18
SS5-1	17.21	17.21	0.79	0.79	1.00	1.11	0.79	1.13	18
SS6	17.21	17.21	0.89	0.89	1.12	1.25	0.89	1.27	18
SS8	29.50	29.50	1.12	1.12	1.63	1.82	1.12	1.66	18
SS8-1	29.50	29.50	0.84	0.84	1.23	1.37	0.84	1.25	18
SS9	30.15	30.15	1.09	1.09	1.33	1.77	1.09	1.61	18
SS11	34.27	34.27	1.07	1.07	1.56	1.75	1.07	1.70	18
SS11-1	34.27	34.27	0.88	0.88	1.29	1.44	0.88	1.40	18
SS12	34.27	34.27	1.03	1.03	1.26	1.68	1.03	1.63	18
16FAXL17	4.27	4.27	1.00	1.00	1.86	1.94	1.00	1.09	16
B-1-8-3-T-SS	1.46	1.46	0.94	0.94	1.55	1.55	1.41	1.03	9
B-1-8-3-T-SS	1.46	1.46	0.83	0.83	1.38	1.38	1.25	0.91	9
B-1-9-1-T-SS	1.40	1.40	1.03	1.03	1.69	1.69	1.54	1.13	9
B-1-9-2-T-SS	1.40	1.40	0.88	0.88	1.46	1.46	1.32	0.97	9
B-1-9-3-T-SS	1.40	1.40	1.22	1.22	2.01	2.01	1.83	1.34	9
Mean			1.002	1.002	1.381	1.516	1.097	1.274	
Standard Deviation			0.203	0.203	0.476	0.468	0.280	0.222	
Coefficient of Variation			0.202	0.202	0.345	0.309	0.255	0.174	

Dimensions and Results of Single Shear Bolted Connections without Washers (One Bolt) - Failure Type II

Spec	d (in)	t (in)	e (in)	s (in)	e/d	d/t	Fy (ksi)	Fu (ksi)	Fu/Fy	Pult (kip)	Pn AISI E3 3-2 kip	Pn AISC kip	ECCS KN	BS 5950 KN	CAN\CSA KN
B-0-7-1-T-SS	0.500	0.046	1.750	6.800	3.500	10.870	43.83	55.73	1.27	2.86	2.85	3.85	9.89	7.32	15.74
B-0-7-2-T-SS	0.500	0.046	1.750	6.800	3.500	10.870	43.83	55.73	1.27	3.19	2.85	3.85	9.89	7.32	15.74
B-0-7-3-T-SS	0.500	0.047	1.750	6.844	3.500	10.640	43.83	55.73	1.27	4.51	2.91	3.93	10.18	7.52	16.43
B-0-7-4-T-SS	0.500	0.047	1.750	6.844	3.500	10.640	43.83	55.73	1.27	3.87	2.91	3.93	10.18	7.52	16.43

Dimensions and Results of Single Shear Bolted Connections without Washers (One Bolt) - Failure Type II - Cont.

Spec.	F. Zadanfarrokh KN	Pult/AISI	Pult/AISC	Pult/ECCS	Pult/BS 5950	Pult/(CAN\CSA)	Pult/F. Zadanfarrokh	Reference
B-0-7-1-T-SS	9.63	1.01	0.74	1.29	1.74	0.81	1.32	9
B-0-7-2-T-SS	9.63	1.12	0.83	1.43	1.94	0.90	1.47	9
B-0-7-3-T-SS	9.86	1.55	1.15	1.97	2.67	1.22	2.03	9
B-0-7-4-T-SS	9.86	1.33	0.98	1.69	2.29	1.05	1.75	9
Mean		1.252	0.927	1.596	2.159	0.995	1.643	
Standard Deviation		0.208	0.154	0.261	0.354	0.156	0.272	
Coefficient of Variation		0.166	0.166	0.163	0.164	0.157	0.165	

Dimensions and Results of Single Shear Bolted Connections without Washers (Two Bolts Perpendicular to the Line of Stress) - Failure Type II

Spec	d (in)	t (in)	e (in)	s (in)	e/d	d/t	Fy (ksi)	Fu (ksi)	Fu/Fy	Pult (kip)	Pn AISI E3.3-2 kip	Pn AISC kip	ECCS KN	BS 5950 KN	CAN\CSA KN
2	0.500	0.061	1.970	2.000	3.940	8.200	50.50	74.10	1.47	8.98	10.03	13.56	34.30	24.12	30.16

Dimensions and Results of Single Shear Bolted Connections without Washers (Two Bolts Perpendicular to the Line of Stress) - Failure Type II - Cont.

Spec.	F. Zadanfarrokh KN	Pult/AISI	Pult/AISC	Pult/ECCS	Pult/BS 5950	Pult/(CAN\CSA)	Pult/F. Zadanfarrokh	Reference
2	30.50	0.89	0.66	1.16	1.66	1.32	1.31	20

Dimensions and Results of Single Shear Bolted Connections without Washers (Three Bolts Perpendicular to the Line of Stress) - Failure Type II

Spec	d (in)	t (in)	e (in)	s (in)	e/d	d/t	Fy (ksi)	Fu (ksi)	Fu/Fy	Pult (kip)	Pn AISI E3.3-2 kip	Pn AISC kip	ECCS KN	BS 5950 KN	CAN\CSA KN
3	0.313	0.051	2.050	1.350	6.560	6.130	40.60	50.10	1.23	5.24	5.32	7.19	20.94	14.46	31.96
3	0.313	0.051	2.070	1.350	6.620	6.130	40.60	50.10	1.23	5.39	5.32	7.19	20.94	14.46	31.96

Dimensions and Results of Single Shear Bolted Connections without Washers (Three Bolts Perpendicular to the Line of Stress) - Failure Type II - Cont.

Spec	F. Zadanfarrokh KN	Pult/AISI	Pult/AISC	Pult/ECCS	Pult/BS 5950	Pult/(CAN\CSA)	Pult/F. Zadanfarrokh	Reference
3	24.29	0.99	0.73	1.11	1.61	0.73	0.96	20
3	24.29	1.01	0.75	1.14	1.66	0.75	0.99	20
	Mean	0.999	0.740	1.129	1.635	0.740	0.973	
	Standard Deviation	0.014	0.010	0.016	0.023	0.010	0.014	
	Coefficient of Variation	0.014	0.014	0.014	0.014	0.014	0.014	

APPENDIX C

Dimensions And Results Of Bolted Connections Used In The Evaluation Of Existing Data - Combination Type II & III Failure Mode

Dimensions and Results of Single Shear Bolted Connections With Washer -Tensile Strength Study (One Bolt) - Combination Failure Type II & III

Spec.	d (in.)	t (in.)	e (in.)	s (in.)	e/d	d/t	d/s	Fy (ksi)	Fu (ksi)	Fu/Fy	Tension Controlling AISC (kip)	Tension Controlling AISI (kip)	Tension ECCS (KN)
16FAXL16	0.500	0.062	1.75	2.50	3.50	8.06	0.200	30.10	45.90	1.5249	5.51	6.85	12.45
12Y-L12	0.5000	0.106	1.750	2.66	3.50	4.72	0.188	72.40	72.80	1.0055	16.16	10.75	52.50
12Y-L15	0.3750	0.106	1.500	1.52	4.00	3.54	0.247	72.40	72.80	1.0055	8.59	7.22	34.27
7Y-L6	0.7500	0.183	3.750	3.75	5.00	4.10	0.200	83.10	83.80	1.0084	45.08	31.53	149.15
16FAX-L16	0.5000	0.062	1.750	2.50	3.50	8.06	0.200	30.10	45.90	1.5249	5.51	3.86	12.45
12Y-L12	0.5000	0.104	1.75	2.660	3.500	4.81	0.188	72.40	72.80	1.0055	15.88	10.54	51.59
12Y-L14	0.7500	0.104	2.595	3.930	3.460	7.21	0.191	72.40	72.80	1.0055	23.60	15.87	75.20
7Y-L6	0.7500	0.183	3.75	3.750	5.000	4.10	0.200	83.10	83.10	1.0000	44.67	31.27	149.02
20Z-T11	0.5000	0.039	1.5	2.500	3.000	12.82	0.200	94.40	99.80	1.0572	7.54	5.28	24.59
16FAX-L16	0.5000	0.060	1.75	2.500	3.500	8.33	0.200	30.10	45.90	1.5249	5.34	3.74	12.06
12Y-L18	0.7500	0.104	2.6475	3.040	3.530	7.21	0.247	72.40	72.80	1.0055	16.86	14.17	67.28
1W	0.500	0.035	2.00	2.00	4.00	14.29	0.250	35.4	47.8	1.3503	2.39	2.04	7.43
2W	0.375	0.035	2.00	1.50	5.33	10.71	0.250	35.4	47.8	1.3503	1.82	1.56	5.46
3W	0.500	0.108	2.50	2.00	5.00	4.63	0.250	33.7	47.4	1.4065	7.35	6.26	21.93
4W	0.625	0.108	3.00	2.50	4.80	5.79	0.250	33.7	47.4	1.4065	9.29	7.89	27.18
B-1-16-1-0-SS	0.500	0.036	1.75	4.0	3.50	13.89	0.125	39.50	48.85	1.2367	5.98	2.87	11.35
B-1-16-2-0-SS	0.500	0.036	1.75	4.0	3.50	13.89	0.125	39.50	48.85	1.2367	5.98	2.87	11.35
B-1-16-3-L-SS	0.500	0.036	1.75	4.0	3.50	13.89	0.125	39.50	48.85	1.2367	5.98	2.87	11.35
B-1-16-4-L-SS	0.500	0.036	1.75	4.0	3.50	13.89	0.125	39.50	48.85	1.2367	5.98	2.87	11.35
B-1-24-5-0-SS	0.750	0.074	2.66	5.25	3.54	10.135	0.143	48.11	53.70	1.1162	17.63	9.32	39.65
B-1-24-6-0-SS	0.750	0.074	2.66	5.25	3.54	10.135	0.143	48.11	53.70	1.1162	17.63	9.32	39.65
B-1-24-7-L-SS	0.750	0.074	2.69	5.25	3.58	10.135	0.143	48.11	53.70	1.1162	17.63	9.32	39.65
B-1-24-8-L-SS	0.750	0.074	2.63	5.25	3.50	10.135	0.143	48.11	53.70	1.1162	17.63	9.32	39.65
B-1-24-9-H-SS	0.750	0.074	2.63	5.25	3.50	10.135	0.143	48.11	53.70	1.1162	17.63	9.32	39.65
B-1-24-10-H-SS	0.750	0.074	2.66	5.25	3.54	10.135	0.143	48.11	53.70	1.1162	17.63	9.32	39.65
B-1-36-1-0-SS	0.500	0.031	1.75	4.25	3.5	16.129	0.118	59.22	74.51	1.2582	8.34	3.86	14.97
B-1-36-2-0-SS	0.500	0.031	1.75	4.25	3.5	16.129	0.118	59.22	74.51	1.2582	8.34	3.86	14.97
B-1-36-3-L-SS	0.500	0.031	1.75	4.25	3.5	16.129	0.118	59.22	74.51	1.2582	8.34	3.86	14.97
B-1-36-4-L-SS	0.500	0.031	1.75	4.25	3.5	16.129	0.118	59.22	74.51	1.2582	8.34	3.86	14.97
B-1-36-5-0-SS	0.500	0.031	1.75	4.25	3.5	16.129	0.118	59.22	74.51	1.2582	8.34	3.86	14.97
B-1-36-6-0-SS	0.500	0.031	1.75	4.25	3.5	16.129	0.118	59.22	74.51	1.2582	8.34	3.86	14.97
B-1-36-7-L-SS	0.500	0.031	1.75	4.25	3.5	16.129	0.118	59.22	74.51	1.2582	8.34	3.86	14.97

Dimensions and Results of Single Shear Bolted Connections With Washer -Tensile Strength Study (One Bolt) - Combination Failure Type II & III - Cont

Spec	Tension BS 5950 (KN)	Tension CAN\CSA (KN)	Pult (kip)	Bearing Pn AISI E3 3-2 (kip)	Bearing Pn AISC (kip)	Bearing ECCS (KN)	Bearing BS 5950 (KN)	Bearing CAN\CSA (KN)	Bearing F. Zadanfarrokh (KN)	Tension Pult/AISI	Tension Pult/AISC
16FAXL16	11.25	24.50	4.80	4.27	4.27	10.21	9.79	18.99	17.47	0.70	0.87
12Y-L12	47.46	71.89	11.18	11.58	11.58	53.97	48.84	51.49	41.41	1.04	0.69
12Y-L15	31.93	38.21	7.71	8.68	8.68	43.08	36.63	38.61	35.86	1.07	0.90
7Y-L6	139.20	200.54	42.14	34.50	34.50	202.77	152.19	153.48	96.30	1.34	0.93
16FAX-L16	11.25	24.50	4.72	4.27	4.27	10.21	9.79	18.99	17.47	1.22	0.86
12Y-L12	46.64	70.64	11.116	14.79	11.36	52.42	47.54	50.52	40.46	1.05	0.70
12Y-L14	70.22	104.99	22.903	14.79	17.04	78.20	71.31	75.77	49.55	1.44	0.97
7Y-L6	139.09	198.70	42.467	14.79	34.22	202.77	152.19	152.19	95.90	1.36	0.95
20Z-T11	22.21	33.54	3.040	14.79	5.84	17.19	17.19	20.26	15.35	0.58	0.40
16FAX-L16	10.89	23.73	4.801	14.79	4.13	9.76	9.38	18.37	16.83	1.29	0.90
12Y-L18	62.68	75.01	12.097	14.79	17.04	78.94	71.31	75.77	49.55	0.85	0.72
1W	6.69	10.63	2.410	2.10	2.51	5.79	5.79	7.81	9.44	1.18	1.01
2W	5.09	8.08	1.820	1.66	1.88	4.34	4.34	7.81	8.18	1.17	1.00
3W	19.75	32.68	7.240	6.73	7.68	30.38	23.35	34.16	34.18	1.16	0.99
4W	24.97	41.32	9.300	8.84	9.60	37.33	29.19	42.69	38.22	1.18	1.00
B-1-16-1-0-SS	10.33	26.89	3.37	2.64	2.64	6.64	6.64	8.45	9.84	1.17	0.56
B-1-16-2-0-SS	10.33	26.89	3.21	2.64	2.64	6.64	6.64	8.45	9.84	1.12	0.54
B-1-16-3-L-SS	10.33	26.89	2.64	2.64	2.64	6.64	6.64	8.45	9.84	0.92	0.44
B-1-16-4-L-SS	10.33	26.89	2.795	2.64	2.64	6.64	6.64	8.45	9.84	0.97	0.47
B-1-24-5-0-SS	37.14	78.43	7.200	8.94	8.94	31.62	29.64	39.24	28.38	0.77	0.41
B-1-24-6-0-SS	37.14	78.43	7.150	8.94	8.94	31.62	29.64	39.24	28.38	0.77	0.41
B-1-24-7-L-SS	37.14	78.43	7.550	8.94	8.94	31.73	29.64	39.24	28.38	0.81	0.43
B-1-24-8-L-SS	37.14	78.43	6.800	8.94	8.94	31.51	29.64	39.24	28.38	0.73	0.39
B-1-24-9-H-SS	37.14	78.43	8.700	8.94	8.94	31.51	29.64	39.24	28.38	0.93	0.49
B-1-24-10-H-SS	37.14	78.43	8.000	8.94	8.94	31.62	29.64	39.24	28.38	0.86	0.45
B-1-36-1-0-SS	13.64	37.89	2.6	3.46	3.46	8.57	8.57	10.27	10.34	0.67	0.31
B-1-36-2-0-SS	13.64	37.89	2.49	3.46	3.46	8.57	8.57	10.27	10.34	0.65	0.30
B-1-36-3-L-SS	13.64	37.89	2.94	3.46	3.46	8.57	8.57	10.27	10.34	0.76	0.35
B-1-36-4-L-SS	13.64	37.89	2.96	3.46	3.46	8.57	8.57	10.27	10.34	0.77	0.35
B-1-36-5-0-SS	13.64	37.89	2.37	3.46	3.46	8.57	8.57	10.27	10.34	0.61	0.28
B-1-36-6-0-SS	13.64	37.89	2.29	3.46	3.46	8.57	8.57	10.27	10.34	0.59	0.27
B-1-36-7-L-SS	13.64	37.89	2.46	3.46	3.46	8.57	8.57	10.27	10.34	0.64	0.29

Dimensions and Results of Single Shear Bolted Connections With Washer -Tensile Strength Study (One Bolt) - Combination Failure Type II & III - Cont

Spec	Tension Pult/ECCS	Tension Pult/BS 5950	Tension Pult/(CAN\CSA)	Bearing Pult/AISI	Bearing Pult/AISC	Bearing Pult/ECCS	Bearing Pult/BS 5950	Bearing Pult/(CAN\CSA)	Bearing Pult/F. Zadanfarrokh	Reference
16FAXL16	1 71	1 90	0 87	1.12	1 12	2.09	2.18	1.12	1.22	16
12Y-L12	0.95	1 05	0.69	0.97	0.97	0.92	1 02	0.97	1.20	16
12Y-L15	1 00	1.07	0.90	0.89	0.89	0.80	0.94	0.89	0.96	16
7Y-L6	1.26	1.35	0 93	1 22	1 22	0 92	1.23	1.22	1.95	16
16FAX-L16	1.69	1.87	0 86	1.11	1 11	2.05	2.14	1.11	1.20	16
12Y-L12	0.96	1.06	0.70	0.75	0 98	0 94	1.04	0.98	1.22	16
12Y-L14	1.35	1.45	0 97	1.55	1.34	1.30	1.43	1.34	2.06	16
7Y-L6	1.27	1.36	0.95	2 87	1 24	0.93	1 24	1.24	1.97	16
20Z-T11	0.55	0.61	0 40	0 21	0.52	0.79	0 79	0.67	0.88	16
16FAX-L16	1.77	1.96	0 90	0 32	1 16	2.19	2 28	1.16	1.27	16
12Y-L18	0 80	0 86	0.72	0.82	0.71	0 68	0 75	0.71	1.09	16
1W	1 44	1 60	1 01	0 87	0.96	1 85	1 85	1.37	1.14	25
2W	1 48	1.59	1 00	0 91	0 97	1 87	1.87	1 04	0 99	25
3W	1 47	1 63	0 99	0 93	0 94	1 06	1 38	0.94	0.94	25
4W	1 52	1 66	1 00	0.95	0 97	1 11	1 42	0.97	1 08	25
B-1-16-1-0-SS	1 32	1 45	0 56	1 28	1.28	2 26	2 26	1 77	1.52	26
B-1-16-2-0-SS	1 26	1 38	0 53	1 22	1 22	2 15	2 15	1.69	1.45	26
B-1-16-3-L-SS	1 03	1 14	0 44	1 00	1 00	1 77	1 77	1.39	1 19	26
B-1-16-4-L-SS	1 10	1 20	0 46	1 06	1 06	1 87	1 87	1 47	1.26	26
B-1-24-5-0-SS	0 81	0 86	0 41	0 81	0 81	1 01	1.08	0 82	1 13	26
B-1-24-6-0-SS	0 80	0 86	0 41	0 80	0 80	1 01	1 07	0 81	1 12	26
B-1-24-7-L-SS	0 85	0 90	0 43	0 84	0 84	1 06	1 13	0.86	1 18	26
B-1-24-8-L-SS	0 76	0 81	0 39	0 76	0 76	0 96	1 02	0 77	1 07	26
B-1-24-9-H-SS	0 98	1 04	0 49	0 97	0 97	1 23	1 31	0 99	1 36	26
B-1-24-10-H-SS	0 90	0 96	0 45	0 89	0 89	1 13	1 20	0 91	1 25	26
B-1-36-1-0-SS	0 77	0 85	0 31	0 75	0 75	1 35	1 35	1 13	1 12	26
B-1-36-2-0-SS	0 74	0 81	0 29	0 72	0 72	1 29	1 29	1 08	1 07	26
B-1-36-3-L-SS	0 87	0 96	0 35	0 85	0 85	1 53	1 53	1 27	1 27	26
B-1-36-4-L-SS	0 88	0 97	0 35	0 85	0 85	1 54	1 54	1 28	1 27	26
B-1-36-5-0-SS	0 70	0 77	0 28	0 68	0 68	1 23	1 23	1 03	1 02	26
B-1-36-6-0-SS	0 68	0 75	0 27	0 66	0 66	1 19	1 19	0 99	0 99	26
B-1-36-7-L-SS	0 73	0 80	0 29	0 71	0 71	1 28	1 28	1 07	1 06	26

Dimensions and Results of Single Shear Bolted Connections With Washer -Tensile Strength Study (One Bolt) - Combination Failure Type II & III - Cont.

Spec.	d (in.)	t (in.)	e (in.)	s (in.)	e/d	d/t	d/s	Fy (ksi)	Fu (ksi)	Fu/Fy	Tension Controlling AISC (kip)	Tension Controlling AISI (kip)	Tension ECCS (KN)
B-1-36-8-L-SS	0.500	0.031	1.75	4.25	3.5	16.129	0.118	59.22	74.51	1.2582	8.34	3.86	14.97
B-1-36-10-H-SS	0.500	0.031	1.75	4.25	3.5	16.129	0.118	59.22	74.51	1.2582	8.34	3.86	14.97
B-1-43-1-0-SS	0.500	0.071	1.656	4.25	3.13	7.042	0.118	52.43	69.28	1.3214	17.77	8.22	30.35
B-1-44-4-L-SS	0.750	0.071	2.625	6.00	3.5	10.563	0.125	52.43	69.28	1.3214	25.09	12.12	43.48
B-1-44-5-0-SS	0.750	0.071	2.625	6.00	3.5	10.563	0.125	52.43	69.28	1.3214	25.09	12.12	43.48
B-1-44-8-L-SS	0.750	0.071	2.625	6.00	3.5	10.563	0.125	52.43	69.28	1.3214	25.09	12.12	43.48
B-1-44-9-H-SS	0.750	0.071	2.625	6.00	3.5	10.563	0.125	52.43	69.28	1.3214	25.09	12.12	43.48

Dimensions and Results of Single Shear Bolted Connections With Washer -Tensile Strength Study (One Bolt) - Combination Failure Type II & III - Cont.

Spec.	Tension BS 5950 (KN)	Tension CAN\CSA (KN)	Pult (kip)	Bearing Pn AISI E3.3-2 (kip)	Bearing Pn AISC (kip)	Bearing ECCS (KN)	Bearing BS 5950 (KN)	Bearing CAN\CSA (KN)	Bearing F. Zadanfarrokh (KN)	Tension Pult/AISI	Tension Pult/AISC
B-1-36-8-L-SS	13.64	37.89	2.36	3.46	3.46	8.57	8.57	10.27	10.34	0.61	0.28
B-1-36-10-H-SS	13.64	37.89	3.32	3.46	3.46	8.57	8.57	10.27	10.34	0.86	0.40
B-1-43-1-0-SS	27.66	80.68	6.575	7.38	7.38	21.23	20.38	32.82	25.08	0.80	0.37
B-1-44-4-L-SS	40.80	113.50	11.550	11.07	11.07	32.34	30.57	46.60	30.72	0.95	0.46
B-1-44-5-0-SS	40.80	113.50	8.250	11.07	11.07	32.34	30.57	46.60	30.72	0.68	0.33
B-1-44-8-L-SS	40.80	113.50	8.150	11.07	11.07	32.34	30.57	46.60	30.72	0.67	0.32
B-1-44-9-H-SS	40.80	113.50	8.500	11.07	11.07	32.34	30.57	46.60	30.72	0.70	0.34
									Mean	0.914	0.568
									Standard Deviation	0.242	0.259
									Coefficient of Variation	0.265	0.456

Dimensions and Results of Single Shear Bolted Connections With Washer -Tensile Strength Study (One Bolt) - Combination Failure Type II & III - Cont.

Spec.	Tension Pult/ECCS	Tension Pult/BS 5950	Tension Pult/(CAN\CSA)	Bearing Pult/AISI	Bearing Pult/AISC	Bearing Pult/ECCS	Bearing Pult/BS 5950	Bearing Pult/(CAN\CSA)	Bearing Pult/F. Zadanfarrokh	Reference
B-1-36-8-L-SS	0.70	0.77	0.28	0.68	0.68	1.22	1.22	1.02	1.02	26
B-1-36-10-H-SS	0.99	1.08	0.39	0.96	0.96	1.72	1.72	1.44	1.43	26
B-1-43-1-0-SS	0.96	1.06	0.36	0.89	0.89	1.38	1.44	0.89	1.17	26
B-1-44-4-L-SS	1.18	1.26	0.45	1.04	1.04	1.59	1.68	1.10	1.67	26
B-1-44-5-0-SS	0.84	0.90	0.32	0.75	0.75	1.13	1.20	0.79	1.19	26
B-1-44-8-L-SS	0.83	0.89	0.32	0.74	0.74	1.12	1.19	0.78	1.18	26
B-1-44-9-H-SS	0.87	0.93	0.33	0.77	0.77	1.17	1.24	0.81	1.23	26
Mean	1.046	1.139	0.565	0.927	0.918	1.351	1.423	1.074	1.241	
Standard Deviation	0.315	0.350	0.261	0.392	0.192	0.426	0.401	0.256	0.268	
Coefficient of Variation	0.301	0.307	0.462	0.423	0.209	0.316	0.282	0.238	0.216	

Dimensions and Results Single Shear Bolted Connectioions Without Washers-Tensile Strength Study
(One Bolt) - Combination Failure Type II & III

Spec.	d (in)	t (in)	e (in)	s (in)	e/d	d/t	d/s	Fy (ksi)	Fu (ksi)	Fu/Fy	Tension Controlling AISC kip	Tension Controlling AISI kip	Tension ECCS KN	Tension BS 5950 KN	Tension CAN\CSA KN
1	0.500	0.035	2.000	1.750	4.000	14.286	0.286	35.40	47.80	1.35	2.01	1.42	6.61	6.33	8.93
2	0.375	0.035	1.750	1.250	4.667	10.714	0.300	35.40	47.80	1.35	1.43	1.06	4.72	4.72	6.38
3	0.500	0.108	2.250	1.750	4.500	4.630	0.286	33.70	47.40	1.41	6.07	4.34	19.19	18.36	26.99
4	0.625	0.108	2.750	2.190	4.400	5.787	0.285	33.70	47.40	1.41	7.68	5.49	24.28	23.22	34.16
B-0-32-9-H-SS	0.250	0.015	0.560	2.000	2.250	16.234	0.125	70.64	80.84	1.14	2.10	0.67	4.26	3.88	9.35
B-0-32-10-H-SS	0.250	0.015	0.550	2.000	2.200	16.234	0.125	70.64	80.84	1.14	2.10	0.67	4.26	3.88	9.35

Dimensions and Results Single Shear Bolted Connectioions Without Washers-Tensile Strength Study
(One Bolt) - Combination Failure Type II & III - Cont

Spec	Pu test (kips)	Bearing Pn AISI kip	Bearing Pn AISC kip	Bearing ECCS KN	Bearing BS 5950 KN	Bearing CAN\CSA KN	Bearing F. Zadanfarrokh KN	Tension Pult/AISI	Tension Pult/AISC	Tension Pult/ECCS	Tension Pult/BS 5950	Tension Pult/(CAN\CSA)	Bearing Pult/AISI
1	1.33	0.97	2.51	5.79	4.34	7.81	6.61	0.94	0.66	0.89	0.93	0.66	0.73
2	0.98	0.70	1.88	4.34	3.25	7.81	5.72	0.92	0.68	0.92	0.92	0.68	0.72
3	3.86	2.70	7.68	29.04	17.51	34.16	23.93	0.89	0.64	0.89	0.93	0.64	0.70
4	4.99	3.49	9.60	35.95	21.89	42.69	26.75	0.91	0.65	0.91	0.96	0.65	0.70
B-0-32-9-H-SS	0.81	0.69	0.93	2.54	1.91	2.77	2.28	1.21	0.39	0.85	0.93	0.39	1.18
B-0-32-10-H-SS	0.65	0.69	0.93	2.54	1.91	2.77	2.24	0.97	0.31	0.68	0.75	0.31	0.94
					Mean			0.974	0.554	0.858	0.903	0.554	0.828
					Standard Deviation			0.111	0.148	0.084	0.072	0.148	0.177
					Coefficient of Variation			0.114	0.267	0.097	0.079	0.267	0.213

Dimensions and Results Single Shear Bolted Connectioions Without Washers-Tensile Strength Study
(One Bolt) - Combination Failure Type II & III - Cont.

Spec.	Bearing Pult/AISC	Bearing Pult/ECCS	Bearing Pult/BS 5950	Bearing Pult/(CAN\CSA)	Bearing Pult/F. Zadanfarrokh	Reference
1	0.53	1.02	1.36	0.76	0.90	25
2	0.52	1.00	1.33	0.56	0.76	25
3	0.50	0.59	0.98	0.50	0.72	25
4	0.52	0.62	1.01	0.52	0.83	25
B-0-32-9-H-SS	0.87	1.42	1.90	1.30	1.58	26
B-0-32-10-H-SS	0.70	1.14	1.52	1.04	1.29	26
Mean	0.606	0.965	1.351	0.781	1.012	
Standard Deviation	0.135	0.290	0.310	0.300	0.317	
Coefficient of Variation	0.223	0.300	0.229	0.385	0.313	

APPENDIX D

Dimensions And Results Of Bolted Connections Used In The Evaluation Of Existing Data - Combination Type I & II Failure Mode

Dimensions and Results of Single Shear Bolted Connections with Washers (One Bolt) - Combination Failure Type I & II

Spec.	d (in)	t (in)	e (in)	s (in)	e/d	d/t	Fy (ksi)	Fu (ksi)	Fu/Fy	Pult (kip)	Pn AISI E3.3-2 (kip)	Pn AISC (kip)	ECCS (KN)	Pult/BS 5950 (KN)
12Y-L7	0.500	0.106	1.750	4.000	3.500	4.720	72.40	72.80	1.01	12.67	11.58	11.58	53.97	48.84
12Y-L11	0.375	0.106	1.490	2.000	4.000	3.540	72.40	72.80	1.01	8.59	8.68	8.68	42.95	36.63
20A24SS	0.625	0.036	1.560	4.000	2.500	17.400	32.11	41.83	1.30	2.82	2.82	2.82	6.75	6.75
14E25SS	0.750	0.078	1.880	4.000	2.500	9.600	54.44	70.40	1.29	10.00	12.36	12.36	34.29	33.95
12Y-L10	0.625	0.106	2.110	4.120	3.370	5.900	72.40	72.80	1.01	13.52	14.47	14.47	66.29	61.05
7Y-T5	0.750	0.183	1.750	3.000	2.330	4.100	86.40	91.30	1.06	25.53	37.59	37.59	138.47	137.14
B-1-15-1-0-SS	0.250	0.036	0.875	2.470	3.500	6.940	39.50	48.85	1.24	1.55	1.32	1.32	3.32	3.32
B-1-15-2-0-SS	0.250	0.036	0.875	2.470	3.500	6.940	39.50	48.85	1.24	1.55	1.32	1.32	3.32	3.32
B-1-15-3-L-SS	0.250	0.036	0.891	2.500	3.560	6.920	39.50	48.85	1.24	1.79	1.32	1.32	3.32	3.32
B-1-15-4-L-SS	0.250	0.036	0.875	2.470	3.500	6.940	39.50	48.85	1.24	1.67	1.32	1.32	3.32	3.32
B-1-15-5-H-SS	0.250	0.036	0.875	2.470	3.500	6.940	39.50	48.85	1.24	1.83	1.32	1.32	3.32	3.32
B-1-15-6-H-SS	0.250	0.036	0.875	2.500	3.500	6.940	39.50	48.85	1.24	1.85	1.32	1.32	3.32	3.32
B-1-24-1-0-SS	0.750	0.074	2.690	5.250	3.580	10.135	48.11	53.70	1.12	9.00	8.94	8.94	31.73	29.64
B-1-24-2-0-SS	0.750	0.074	2.690	5.250	3.580	10.135	48.11	53.70	1.12	9.28	8.94	8.94	31.73	29.64
B-1-24-4-L-SS	0.750	0.074	2.660	5.250	3.540	10.135	48.11	53.70	1.12	10.75	8.94	8.94	31.62	29.64
B-1-35-1-0-SS	0.250	0.031	0.875	2.250	3.500	8.065	59.22	74.51	1.26	1.88	1.73	1.73	4.29	4.29
B-1-35-2-0-SS	0.250	0.031	0.875	2.250	3.500	8.065	59.22	74.51	1.26	2.00	1.73	1.73	4.29	4.29
B-1-35-3-L-SS	0.250	0.031	0.875	2.250	3.500	8.065	59.22	74.51	1.26	2.05	1.73	1.73	4.29	4.29
B-1-35-4-L-SS	0.250	0.031	0.875	2.250	3.500	8.065	59.22	74.51	1.26	1.83	1.73	1.73	4.29	4.29
B-1-35-5-H-SS	0.250	0.031	0.875	2.250	3.500	8.065	59.22	74.51	1.26	2.07	1.73	1.73	4.29	4.29
B-1-35-6-H-SS	0.250	0.031	0.875	2.250	3.500	8.065	59.22	74.51	1.26	2.03	1.73	1.73	4.29	4.29
B-1-44-1-0-SS	0.750	0.071	2.625	6.000	3.500	10.563	52.43	69.28	1.32	11.10	11.07	11.07	32.34	30.57
B-1-44-3-L-SS	0.750	0.071	2.625	6.000	3.500	10.563	52.43	69.28	1.32	12.20	11.07	11.07	32.34	30.57

Dimensions and Results of Single Shear Bolted Connections with Washers (One Bolt) - Combination Failure Type I & II - Cont.

Spec. No.	CAN\CSA (KN)	F. Zadanfarrokh (KN)	Pult/AISI	Pult/AISC	Pult/ECCS	Pult/BS 5950	Pult/(CAN\CSA)	Pult/F. Zadanfarrokh	Reference
12Y-L7	51.49	41.41	1.09	1.09	1.04	1.15	1.09	1.36	16
12Y-L11	38.61	35.86	0.99	0.99	0.89	1.04	0.99	1.07	16
20A24SS	8.37	10.16	1.00	1.00	1.86	1.86	1.50	1.23	12
14E25SS	45.92	34.56	0.81	0.81	1.30	1.31	0.97	1.29	13
12Y-L10	64.36	46.29	0.93	0.93	0.91	0.98	0.93	1.30	16
7Y-T5	130.05	93.82	0.68	0.68	0.82	0.83	0.87	1.21	16
B-1-15-1-0-SS	5.87	6.96	1.18	1.18	2.08	2.08	1.18	0.99	26
B-1-15-2-0-SS	5.87	6.96	1.18	1.18	2.08	2.08	1.18	0.99	26
B-1-15-3-L-SS	5.87	6.96	1.36	1.36	2.40	2.40	1.36	1.14	26
B-1-15-4-L-SS	5.87	6.96	1.27	1.27	2.24	2.24	1.27	1.07	26
B-1-15-5-H-SS	5.87	6.96	1.39	1.39	2.45	2.45	1.39	1.17	26
B-1-15-6-H-SS	5.87	6.96	1.40	1.40	2.47	2.47	1.40	1.18	26
B-1-24-1-0-SS	39.24	28.38	1.01	1.01	1.26	1.35	1.02	1.41	26
B-1-24-2-0-SS	39.24	28.38	1.04	1.04	1.30	1.39	1.05	1.45	26
B-1-24-4-L-SS	39.24	28.38	1.20	1.20	1.51	1.61	1.22	1.68	26
B-1-35-1-0-SS	7.71	7.31	1.09	1.09	1.95	1.95	1.09	1.15	26
B-1-35-2-0-SS	7.71	7.31	1.15	1.15	2.08	2.08	1.15	1.22	26
B-1-35-3-L-SS	7.71	7.31	1.18	1.18	2.13	2.13	1.18	1.25	26
B-1-35-4-L-SS	7.71	7.31	1.06	1.06	1.90	1.90	1.06	1.11	26
B-1-35-5-H-SS	7.71	7.31	1.19	1.19	2.15	2.15	1.19	1.26	26
B-1-35-6-H-SS	7.71	7.31	1.17	1.17	2.11	2.11	1.17	1.24	26
B-1-44-1-0-SS	46.60	30.72	1.00	1.00	1.53	1.62	1.06	1.61	26
B-1-44-3-L-SS	46.60	30.72	1.10	1.10	1.68	1.78	1.16	1.77	26
	Mean		1.107	1.107	1.744	1.780	1.151	1.267	
	Standard Deviation		0.168	0.168	0.514	0.479	0.153	0.199	
	Coefficient of Variation		0.151	0.151	0.294	0.269	0.133	0.157	

Dimensions and Results of Double Shear Bolted Connections With Washers (One Bolt) - Combination Failure Type I & II

Spec.	d (in.)	t (in.)	e (in.)	s (in.)	e/d	d/t	Fy (ksi)	Fu (ksi)	Fu/Fy	Pult (kip)	Pn AISI E3.3-2 (kip)	Pn AISC (kip)	ECCS (KN)	BS 5950 (KN)	CAN\CSA (KN)
B-1-19-1-0-DS	0.250	0.036	0.875	3.250	3.500	6.940	39.50	48.85	1.24	1.92	1.47	1.32	3.32	3.32	5.87
B-1-19-2-0-DS	0.250	0.036	0.891	3.250	3.560	6.940	39.50	48.85	1.24	1.82	1.46	1.32	3.32	3.32	5.87
B-1-19-3-L-DS	0.250	0.036	0.875	3.250	3.500	6.940	39.50	48.85	1.24	2.12	1.47	1.32	3.32	3.32	5.87
B-1-19-4-L-DS	0.250	0.036	0.875	3.250	3.500	6.940	39.50	48.85	1.24	2.09	1.46	1.32	3.32	3.32	5.87
B-1-19-5-0-DS	0.250	0.036	0.891	3.250	3.560	6.940	39.50	48.85	1.24	1.96	1.47	1.32	3.32	3.32	5.87
B-1-19-6-0-DS	0.250	0.036	0.875	3.250	3.500	6.940	39.50	48.85	1.24	1.55	1.46	1.32	3.32	3.32	5.87
B-1-19-7-L-DS	0.250	0.036	0.875	3.250	3.500	6.940	39.50	48.85	1.24	1.98	1.47	1.32	3.32	3.32	5.87
B-1-19-8-L-DS	0.250	0.036	0.875	3.250	3.500	6.940	39.50	48.85	1.24	2.17	1.46	1.32	3.32	3.32	5.87
B-1-19-9-H-DS	0.250	0.036	0.875	3.250	3.500	6.940	39.50	48.85	1.24	2.44	1.46	1.32	3.32	3.32	5.87
B-1-19-10-H-DS	0.250	0.036	0.875	3.250	3.500	6.940	39.50	48.85	1.24	2.33	1.46	1.32	3.32	3.32	5.87
B-1-20-1-0-DS	0.500	0.036	1.750	6.250	3.500	13.890	39.50	48.85	1.24	3.04	2.93	2.64	6.64	6.64	8.45
B-1-20-2-0-DS	0.500	0.036	1.750	6.250	3.500	13.890	39.50	48.85	1.24	2.94	2.93	2.64	6.64	6.64	8.45
B-1-20-3-L-DS	0.500	0.036	1.750	6.250	3.500	13.890	39.50	48.85	1.24	3.86	2.92	2.64	6.64	6.64	8.45
B-1-20-4-L-DS	0.500	0.036	1.750	6.250	3.500	13.890	39.50	48.85	1.24	3.74	2.93	2.64	6.64	6.64	8.45
B-1-20-5-0-DS	0.500	0.036	1.813	6.250	3.625	13.890	39.50	48.85	1.24	2.89	2.93	2.64	6.64	6.64	8.45
B-1-20-6-0-DS	0.500	0.036	1.750	6.250	3.500	13.890	39.50	48.85	1.24	3.38	2.93	2.64	6.64	6.64	8.45
B-1-20-8-L-DS	0.500	0.036	1.750	6.250	3.500	13.890	39.50	48.85	1.24	4.11	2.92	2.64	6.64	6.64	8.45
B-1-20-9-H-DS	0.500	0.036	1.780	6.250	3.500	13.890	39.50	48.85	1.24	4.42	2.93	2.64	6.64	6.64	8.45
B-1-20-10-H-DS	0.500	0.036	1.750	6.250	3.500	13.890	39.50	48.85	1.24	4.47	2.92	2.64	6.64	6.64	8.45
B-1-27-1-0-DS	0.500	0.074	1.875	6.500	3.750	6.757	48.11	53.70	1.12	7.28	5.96	5.96	21.43	19.76	26.51
B-1-27-2-0-DS	0.500	0.074	1.813	6.500	3.630	6.757	48.11	53.70	1.12	7.48	5.95	5.96	21.22	19.76	26.51
B-1-27-3-L-DS	0.500	0.074	1.875	6.500	3.750	6.757	48.11	53.70	1.12	10.55	5.96	5.96	21.43	19.76	26.51
B-1-27-4-L-DS	0.500	0.074	1.906	6.500	3.810	6.757	48.11	53.70	1.12	10.25	5.96	5.96	21.53	19.76	26.51
B-1-27-5-0-DS	0.500	0.074	1.813	6.500	3.630	6.757	48.11	53.70	1.12	7.20	5.96	5.96	21.22	19.76	26.51
B-1-27-6-0-DS	0.500	0.074	1.813	6.500	3.630	6.757	48.11	53.70	1.12	7.63	5.96	5.96	21.22	19.76	26.51
B-1-27-7-L-DS	0.500	0.074	1.813	6.500	3.630	6.757	48.11	53.70	1.12	10.75	5.91	5.96	21.22	19.76	26.51
B-1-27-8-L-DS	0.500	0.074	1.780	6.500	3.560	6.757	48.11	53.70	1.12	9.75	5.96	5.96	21.10	19.76	26.51
B-1-27-9-H-DS	0.500	0.074	1.840	6.500	3.680	6.757	48.11	53.70	1.12	10.35	5.95	5.96	21.31	19.76	26.51
B-1-27-10-H-DS	0.500	0.074	1.875	6.500	3.750	6.757	48.11	53.70	1.12	9.65	5.95	5.96	21.43	19.76	26.51
B-1-28-1-0-DS	0.750	0.074	2.470	10.000	3.290	10.135	48.11	53.70	1.12	10.85	8.92	8.94	30.92	29.64	39.24
B-1-28-2-0-DS	0.750	0.074	2.563	10.000	3.420	10.135	48.11	53.70	1.12	13.30	8.92	8.94	31.27	29.64	39.24
B-1-28-3-L-DS	0.750	0.074	2.500	10.000	3.330	10.135	48.11	53.70	1.12	13.45	8.94	8.94	31.04	29.64	39.24
B-1-28-4-L-DS	0.750	0.074	2.470	10.000	3.290	10.135	48.11	53.70	1.12	14.30	8.94	8.94	30.92	29.64	39.24
B-1-28-5-0-DS	0.750	0.074	2.625	10.000	3.500	10.135	48.11	53.70	1.12	10.75	8.94	8.94	31.50	29.64	39.24

Dimensions and Results of Double Shear Bolted Connections With Washers (One Bolt) - Combination Failure Type I & II - Cont

Spec	F Zadanfarrokh (KN)	Pult / AISI	Pult / AISC	Pult/ECCS	Pult/BS 5950	Pult/(CAN\CSA)	Pult/F Zadanfarrokh	Reference
B-1-19-1-0-DS	6 96	1 31	1 45	2 57	2 57	1 45	1 22	26
B-1-19-2-0-DS	6 96	1 24	1 38	2 44	2 44	1 38	1 16	26
B-1-19-3-L-DS	6 96	1 45	1 61	2 84	2 84	1 61	1 36	26
B-1-19-4-L-DS	6 96	1 43	1 58	2 80	2 80	1 58	1 34	26
B-1-19-5-0-DS	6 96	1 34	1 49	2 63	2 63	1 49	1 25	26
B-1-19-6-0-DS	6 96	1 06	1 18	2 08	2 08	1 18	0 99	26
B-1-19-7-L-DS	6 96	1 35	1 50	2 65	2 65	1 50	1 26	26
B-1-19-8-L-DS	6 96	1 48	1 65	2 91	2 91	1 65	1 39	26
B-1-19-9-H-DS	6 96	1 66	1 85	3 26	3 26	1 85	1 56	26
B-1-19-10-H-DS	6 96	1 59	1 76	3 11	3 11	1 76	1 49	26
B-1-20-1-0-DS	9 84	1 04	1 15	2 03	2 03	1 60	1 37	26
B-1-20-2-0-DS	9 84	1 00	1 11	1 97	1 97	1 55	1 33	26
B-1-20-3-L-DS	9 84	1 32	1 46	2 59	2 59	2 03	1 74	26
B-1-20-4-L-DS	9 84	1 27	1 42	2 50	2 50	1 97	1 69	26
B-1-20-5-0-DS	9 84	0 99	1 10	1 94	1 94	1 52	1 31	26
B-1-20-6-0-DS	9 84	1 15	1 28	2 26	2 26	1 78	1 53	26
B-1-20-8-L-DS	9 84	1 41	1 56	2 75	2 75	2 16	1 86	26
B-1-20-9-H-DS	9 84	1 51	1 67	2 96	2 96	2 32	2 00	26
B-1-20-10-H-DS	9 84	1 53	1 69	2 99	2 99	2 35	2 02	26
B-1-27-1-0-DS	23 17	1 22	1 22	1 51	1 64	1 22	1 40	26
B-1-27-2-0-DS	23 17	1 26	1 25	1 57	1 68	1 25	1 44	26
B-1-27-3-L-DS	23 17	1 77	1 77	2 19	2 37	1 77	2 03	26
B-1-27-4-L-DS	23 17	1 72	1 72	2 12	2 31	1 72	1 97	26
B-1-27-5-0-DS	23 17	1 21	1 21	1 51	1 62	1 21	1 38	26
B-1-27-6-0-DS	23 17	1 28	1 28	1 60	1 72	1 28	1 46	26
B-1-27-7-L-DS	23 17	1 82	1 80	2 25	2 42	1 80	2 06	26
B-1-27-8-L-DS	23 17	1 64	1 64	2 05	2 19	1 64	1 87	26
B-1-27-9-H-DS	23 17	1 74	1 74	2 16	2 33	1 74	1 99	26
B-1-27-10-H-DS	23 17	1 62	1 62	2 00	2 17	1 62	1 85	26
B-1-28-1-0-DS	28 38	1 22	1 21	1 56	1 63	1 23	1 70	26
B-1-28-2-0-DS	28 38	1 49	1 49	1 89	2 00	1 51	2 08	26
B-1-28-3-L-DS	28 38	1 50	1 50	1 93	2 02	1 52	2 11	26
B-1-28-4-L-DS	28 38	1 60	1 60	2 06	2 15	1 62	2 24	26
B-1-28-5-0-DS	28 38	1 20	1 20	1 52	1 61	1 22	1 68	26

Dimensions and Results of Double Shear Bolted Connections With Washers (One Bolt) - Combination Failure Type I & II Cont

Spec	d (in.)	t (in.)	e (in.)	s (in.)	e/d	d/t	Fy (ksi)	Fu (ksi)	Fu/Fy	Pult (kip)	Pn AISI E3.3-2 (kip)	Pn AISC (kip)	ECCS (KN)	BS 5950 (KN)	CAN/CSA (KN)
B-1-28-6-0-DS	0.750	0.074	2.656	10.000	3.540	10.135	48.11	53.70	1.12	11.95	8.93	8.94	31.61	29.64	39.24
B-1-28-7-L-DS	0.750	0.074	2.625	10.000	3.500	10.135	48.11	53.70	1.12	13.85	8.94	8.94	31.50	29.64	39.24
B-1-28-8-L-DS	0.750	0.074	2.563	10.000	3.420	10.135	48.11	53.70	1.12	12.95	8.93	8.94	31.27	29.64	39.24
B-1-28-9-H-DS	0.750	0.074	2.625	10.000	3.500	10.135	48.11	53.70	1.12	15.70	8.94	8.94	31.50	29.64	39.24
B-1-28-10-H-DS	0.750	0.074	2.656	10.000	3.540	10.135	48.11	53.70	1.12	13.65	8.94	8.94	31.61	29.64	39.24
B-1-40-1-0-DS	0.500	0.031	1.750	6.500	3.500	16.129	59.22	74.51	1.26	2.76	3.85	3.46	8.57	8.57	10.27
B-1-40-2-0-DS	0.500	0.031	1.750	6.500	3.500	16.129	59.22	74.51	1.26	2.83	3.85	3.46	8.57	8.57	10.27
B-1-40-3-L-DS	0.500	0.031	1.750	6.500	3.500	16.129	59.22	74.51	1.26	4.07	3.84	3.46	8.57	8.57	10.27
B-1-40-4-L-DS	0.500	0.031	1.750	6.500	3.500	16.129	59.22	74.51	1.26	3.95	3.85	3.46	8.57	8.57	10.27
B-1-40-5-0-DS	0.500	0.031	1.750	6.500	3.500	16.129	59.22	74.51	1.26	2.80	3.84	3.46	8.57	8.57	10.27
B-1-40-6-0-DS	0.500	0.031	1.750	6.500	3.500	16.129	59.22	74.51	1.26	2.83	3.85	3.46	8.57	8.57	10.27
B-1-40-7-L-DS	0.500	0.031	1.750	6.500	3.500	16.129	59.22	74.51	1.26	4.09	3.84	3.46	8.57	8.57	10.27
B-1-40-8-L-DS	0.500	0.031	1.750	6.500	3.500	16.129	59.22	74.51	1.26	4.04	3.84	3.46	8.57	8.57	10.27
B-1-40-9-H-DS	0.500	0.031	1.750	6.500	3.500	16.129	59.22	74.51	1.26	4.48	3.85	3.46	8.57	8.57	10.27
B-1-40-10-H-DS	0.500	0.031	1.750	6.500	3.500	16.129	59.22	74.51	1.26	4.63	3.85	3.46	8.57	8.57	10.27
B-1-39-1-0-DS	0.250	0.031	0.875	3.250	3.500	8.065	59.22	74.51	1.26	1.70	1.93	1.73	4.29	4.29	7.71
B-1-39-2-0-DS	0.250	0.031	0.875	3.250	3.500	8.065	59.22	74.51	1.26	1.75	1.92	1.73	4.29	4.29	7.71
B-1-39-3-L-DS	0.250	0.031	0.875	3.250	3.500	8.065	59.22	74.51	1.26	2.50	1.92	1.73	4.29	4.29	7.71
B-1-39-4-L-DS	0.250	0.031	0.875	3.250	3.500	8.065	59.22	74.51	1.26	2.49	1.92	1.73	4.29	4.29	7.71
B-1-39-5-H-DS	0.250	0.031	0.875	3.250	3.500	8.065	59.22	74.51	1.26	2.41	1.92	1.73	4.29	4.29	7.71
B-1-47-1-0-DS	0.500	0.071	1.813	6.875	3.630	7.042	52.43	69.28	1.32	10.10	8.18	7.38	21.77	20.38	32.82
B-1-47-2-0-DS	0.500	0.071	1.813	6.875	3.630	7.042	52.43	69.28	1.32	10.00	8.19	7.38	21.77	20.38	32.82
B-1-47-3-L-DS	0.500	0.071	1.750	6.700	3.500	7.042	52.43	69.28	1.32	10.10	8.18	7.38	21.56	20.38	32.82
B-1-47-4-L-DS	0.500	0.071	1.781	6.700	3.560	7.042	52.43	69.28	1.32	10.58	8.18	7.38	21.66	20.38	32.82
B-1-47-5-H-DS	0.500	0.071	1.813	6.700	3.630	7.042	52.43	69.28	1.32	11.43	8.18	7.38	21.77	20.38	32.82
B-1-48-1-0-DS	0.750	0.071	2.625	10.000	3.500	10.563	52.43	69.28	1.32	11.75	12.30	11.07	32.34	30.57	46.60
B-1-48-2-0-DS	0.750	0.071	2.625	10.000	3.500	10.563	52.43	69.28	1.32	12.35	12.29	11.07	32.34	30.57	46.60
B-1-48-3-L-DS	0.750	0.071	2.625	10.000	3.500	10.563	52.43	69.28	1.32	14.68	12.29	11.07	32.34	30.57	46.60
B-1-48-4-L-DS	0.750	0.071	2.625	10.000	3.500	10.563	52.43	69.28	1.32	14.25	12.26	11.07	32.34	30.57	46.60
B-1-48-5-0-DS	0.750	0.071	2.625	10.000	3.500	10.563	52.43	69.28	1.32	12.45	12.28	11.07	32.34	30.57	46.60
B-1-48-6-0-DS	0.750	0.071	2.625	10.000	3.500	10.563	52.43	69.28	1.32	13.15	12.27	11.07	32.34	30.57	46.60
B-1-48-7-L-DS	0.750	0.071	2.625	10.000	3.500	10.563	52.43	69.28	1.32	12.92	12.31	11.07	32.34	30.57	46.60
B-1-48-8-L-DS	0.750	0.071	2.625	10.000	3.500	10.563	52.43	69.28	1.32	13.85	12.30	11.07	32.34	30.57	46.60
B-1-48-9-H-DS	0.750	0.071	2.625	10.000	3.500	10.563	52.43	69.28	1.32	15.68	12.30	11.07	32.34	30.57	46.60

Dimensions and Results of Double Shear Bolted Connections With Washers (One Bolt) - Combination Failure Type I & II - Cont

Spec	F Zadanfarrokh (KN)	Pult / AISI	Pult / AISC	Pult/ECCS	Pult/BS 5950	Pult/(CAN\CSA)	Pult/F Zadanfarrokh	Reference
B-1-28-6-0-DS	28.38	1.34	1.34	1.68	1.79	1.35	1.87	26
B-1-28-7-L-DS	28.38	1.55	1.55	1.96	2.08	1.57	2.17	26
B-1-28-8-L-DS	28.38	1.45	1.45	1.84	1.94	1.47	2.03	26
B-1-28-9-H-DS	28.38	1.76	1.76	2.22	2.36	1.78	2.46	26
B-1-28-10-H-DS	28.38	1.53	1.53	1.92	2.05	1.55	2.14	26
B-1-40-1-0-DS	10.34	0.72	0.80	1.43	1.43	1.19	1.19	26
B-1-40-2-0-DS	10.34	0.73	0.82	1.47	1.47	1.23	1.22	26
B-1-40-3-L-DS	10.34	1.06	1.17	2.11	2.11	1.76	1.75	26
B-1-40-4-L-DS	10.34	1.03	1.14	2.05	2.05	1.71	1.70	26
B-1-40-5-0-DS	10.34	0.73	0.81	1.45	1.45	1.21	1.20	26
B-1-40-6-0-DS	10.34	0.73	0.82	1.47	1.47	1.23	1.22	26
B-1-40-7-L-DS	10.34	1.06	1.18	2.12	2.12	1.77	1.76	26
B-1-40-8-L-DS	10.34	1.05	1.16	2.09	2.09	1.75	1.74	26
B-1-40-9-H-DS	10.34	1.16	1.29	2.32	2.32	1.94	1.93	26
B-1-40-10-H-DS	10.34	1.20	1.34	2.40	2.40	2.00	1.99	26
B-1-39-1-0-DS	7.31	0.88	0.98	1.76	1.76	0.98	1.03	26
B-1-39-2-0-DS	7.31	0.91	1.01	1.82	1.82	1.01	1.06	26
B-1-39-3-L-DS	7.31	1.30	1.44	2.59	2.59	1.44	1.52	26
B-1-39-4-L-DS	7.31	1.29	1.43	2.58	2.58	1.43	1.51	26
B-1-39-5-H-DS	7.31	1.25	1.39	2.50	2.50	1.39	1.47	26
B-1-47-1-0-DS	25.08	1.23	1.37	2.06	2.20	1.37	1.79	26
B-1-47-2-0-DS	25.08	1.22	1.35	2.04	2.18	1.35	1.77	26
B-1-47-3-L-DS	25.08	1.23	1.37	2.08	2.20	1.37	1.79	26
B-1-47-4-L-DS	25.08	1.29	1.43	2.17	2.31	1.43	1.88	26
B-1-47-5-H-DS	25.08	1.40	1.55	2.33	2.49	1.55	2.03	26
B-1-48-1-0-DS	30.72	0.95	1.06	1.62	1.71	1.12	1.70	26
B-1-48-2-0-DS	30.72	1.00	1.12	1.70	1.80	1.18	1.79	26
B-1-48-3-L-DS	30.72	1.19	1.33	2.02	2.14	1.40	2.12	26
B-1-48-4-L-DS	30.72	1.16	1.29	1.96	2.07	1.36	2.06	26
B-1-48-5-0-DS	30.72	1.01	1.12	1.71	1.81	1.19	1.80	26
B-1-48-6-0-DS	30.72	1.07	1.19	1.81	1.91	1.26	1.90	26
B-1-48-7-L-DS	30.72	1.05	1.17	1.78	1.88	1.23	1.87	26
B-1-48-8-L-DS	30.72	1.13	1.25	1.90	2.02	1.32	2.01	26
B-1-48-9-H-DS	30.72	1.27	1.42	2.16	2.28	1.50	2.27	26

Dimensions and Results of Double Shear Bolted Connections With Washers (One Bolt) - Combination Failure Type I & II - Cont

Spec	d (in.)	t (in.)	e (in.)	s (in.)	e/d	d/t	Fy (ksi)	Fu (ksi)	Fu/Fy	Pult (kip)	Pn AISI E3.3-2 (kip)	Pn AISC (kip)	ECCS (KN)	BS 5950 (KN)	CAN\CSA (KN)
B-1-48-10-H-DS	0.750	0.071	2.625	10.000	3.500	10.563	52.43	69.28	1.32	13.50	12.28	11.07	32.34	30.57	46.60

Dimensions and Results of Double Shear Bolted Connections With Washers (One Bolt) - Combination Failure Type I & II - Cont

Spec	F Zadanfarrokh (KN)	Pult / AISI	Pult / AISC	Pult/ECCS	Pult/BS 5950	Pult/(CAN\CSA)	Pult/F Zadanfarrokh	Reference
B-1-48-10-H-DS	30.72	1.10	1.22	1.86	1.96	1.29	1.95	26
Mean		1.268	1.359	2.118	2.181	1.518	1.693	
Standard Deviation		0.262	0.250	0.438	0.417	0.290	0.343	
Coefficient of Variation		0.207	0.184	0.207	0.191	0.191	0.202	

Dimensions and Results of Single Shear Bolted Connections without Washers (One Bolt) - Combination Failure Type I & II

Spec	d (in)	t (in)	e (in)	s (in)	e/d	d/t	Fy (ksi)	Fu (ksi)	Pult (kip)	Pn AISI E3 3-2 (kip)	Pn AISC (kip)	ECCS (KN)	BS 5950 (KN)	CAN\CSA (KN)
I	0.500	0.061	0.510	4.000	1.020	8.200	50.50	74.10	2.77	5.02	6.78	12.57	10.38	10.25
I	0.500	0.061	0.520	4.000	1.040	8.200	50.10	74.10	3.09	5.02	6.78	12.54	10.32	10.45
I	0.750	0.079	3.000	4.000	4.000	9.500	52.80	65.90	8.60	8.67	11.71	39.69	26.64	52.10
I	0.750	0.079	3.010	4.000	4.000	9.500	52.80	65.90	8.15	8.67	11.71	39.74	26.64	52.10
I	0.750	0.079	3.000	4.000	4.000	9.500	52.80	65.90	9.17	8.67	11.71	39.69	26.64	52.10
I	0.750	0.104	3.030	4.060	4.040	7.200	59.30	70.60	12.50	12.23	16.52	68.76	43.80	73.48
I	0.500	0.051	2.060	4.030	4.120	9.800	40.60	50.10	2.89	2.84	3.83	10.72	7.71	17.05
I	0.500	0.051	2.010	4.030	4.020	9.800	40.60	50.10	2.98	2.84	3.83	10.69	7.71	17.05
I	0.500	0.051	2.010	4.030	4.020	9.800	40.60	50.10	2.94	2.84	3.83	10.69	7.71	17.05

Dimensions and Results of Single Shear Bolted Connections without Washers (One Bolt) - Combination Failure Type I & II - Cont

Spec	F. Zadanfarrokh (KN)	Pult/AISI	Pult/AISC	Pult/ECCS	Pult/BS 5950	Pult/(CAN\CSA)	Pult/F. Zadanfarrokh	Reference
I	--------	0.55	0.41	0.98	1.19	1.20	------	20
I	--------	0.62	0.46	1.10	1.33	1.31	------	20
I	23.76	0.99	0.73	0.96	1.44	0.73	1.61	20
I	23.76	0.94	0.70	0.91	1.36	0.70	1.53	20
I	23.76	1.06	0.78	1.03	1.53	0.78	1.72	20
I	34.16	1.02	0.76	0.81	1.27	0.76	1.63	20
I	10.24	1.02	0.75	1.20	1.67	0.75	1.25	20
I	10.24	1.05	0.78	1.24	1.72	0.78	1.30	20
I	10.24	1.04	0.77	1.22	1.70	0.77	1.28	20
Mean		0.921	0.681	1.050	1.466	0.865	1.473	
Standard Deviation		0.184	0.136	0.142	0.185	0.213	0.179	
Coefficient of Variation		0.200	0.200	0.135	0.126	0.246	0.121	

Dimensions and Results of Single Shear Bolted Connections without Washers (Two Bolts Perpendicular to the Line of Stress) - Combination Failure Type I & II

Spec	d (in)	t (in)	e (in)	s (in)	e/d	d/t	Fy (ksi)	Fu (ksi)	Pult (kip)	Bearing Pn AISI E3.3-2 (kip)	Bearing Pn AISC (kip)	ECCS (KN)	BS 5950 (KN)	CAN\CSA (KN)
2	0.500	0.051	1.970	2.020	3.940	9.800	40.60	50.10	5.57	5.67	7.67	21.34	15.42	33.61

Dimensions and Results of Single Shear Bolted Connections without Washers (Two Bolts Perpendicular to the Line of Stress) - Combination Failure Type I & II - Cont

Spec	F Zadanfarrokh (KN)	Pult/AISI	Pult/AISC	Pult/ECCS	Pult/BS 5950	Pult/(CAN\CSA)	Pult/F Zadanfarrokh	Reference
2	20.49	0.98	0.73	1.16	1.61	0.74	1.21	20

Dimensions and Results of Single Shear Bolted Connections without Washers (Three Bolts Perpendicular to the Line of Stress) - Combination Failure Type I & II

Spec	d (in)	t (in)	e (in)	s (in)	e/d	d/t	Fy (ksi)	Fu (ksi)	Fu/Fy	Pult (kip)	Pn AISI E3.3-2 (kip)	Pn AISC (kip)	ECCS (KN)	BS 5950 (KN)	CAN\CSA (KN)
3	0.500	0.061	1.000	4.030	2.000	8.200	50.10	74.10	1.48	13.10	15.05	20.34	44.21	33.37	60.32
3	0.500	0.061	1.000	4.060	2.000	8.200	50.10	74.10	1.48	13.50	15.05	20.34	44.21	33.37	60.32

Dimensions and Results of Single Shear Bolted Connections without Washers (Three Bolts Perpendicular to the Line of Stress) - Combination Failure Type I & II Cont.

Spec.	F. Zadanfarrokh (KN)	Pult/AISI	Pult/AISC	Pult/ECCS	Pult/BS 5950	Pult/(CAN\CSA)	Pult/F. Zadanfarrokh	Reference
3	36.60	0.87	0.64	1.32	1.75	0.97	1.59	20
3	36.60	0.90	0.66	1.36	1.80	1.00	1.64	20
Mean		0.884	0.654	1.338	1.772	0.981	1.616	
Standard Deviation		0.013	0.010	0.020	0.026	0.015	0.024	
Coefficient of Variation		0.015	0.015	0.015	0.015	0.015	0.015	

Dimensions and Results of Double Shear Bolted Connections Without Washers(One Bolt) - Combination Failure Type I & II

Spec.	d (in.)	t (in.)	e (in.)	s (in.)	e/d	d/t	Fy (ksi)	Fu (ksi)	Pult (kip)	Pn AISI E3.3-2 (kip)	Pn AISC (kip)	ECCS (KN)	BS 5950 (KN)	CAN\CSA (KN)
B-0-21-1-0-DS	0.250	0.036	0.844	3.250	3.380	6.940	39.50	48.85	1.88	1.32	1.32	3.32	2.49	5.87
B-0-21-2-0-DS	0.250	0.036	0.875	3.250	3.500	6.940	39.50	48.85	1.90	1.32	1.32	3.32	2.49	5.87
B-0-21-3-L-DS	0.250	0.036	0.891	3.250	3.560	6.940	39.50	48.85	1.90	1.32	1.32	3.32	2.49	5.87
B-0-21-4-L-DS	0.250	0.036	0.875	3.250	3.500	6.940	39.50	48.85	1.92	1.32	1.32	3.32	2.49	5.87
B-0-21-5-0-DS	0.250	0.036	0.875	3.250	3.500	6.940	39.50	48.85	1.94	1.32	1.32	3.32	2.49	5.87
B-0-21-6-0-DS	0.250	0.036	0.906	3.250	3.620	6.940	39.50	48.85	2.03	1.32	1.32	3.32	2.49	5.87
B-0-21-7-L-DS	0.250	0.036	0.275	3.250	3.500	6.940	39.50	48.85	2.18	1.32	1.32	3.32	2.49	2.15
B-0-21-8-L-DS	0.250	0.036	0.875	3.250	3.500	6.940	39.50	48.85	2.05	1.32	1.32	3.32	2.49	5.87
B-0-21-9-H-DS	0.250	0.036	0.875	3.250	3.500	6.940	39.50	48.85	2.24	1.32	1.32	3.32	2.49	5.87
B-0-21-10-H-DS	0.250	0.036	0.875	3.250	3.500	6.940	39.50	48.85	2.00	1.32	1.32	3.32	2.49	5.87
B-0-22-1-0-DS	0.500	0.036	1.750	6.250	3.500	13.890	39.50	48.85	2.56	2.56	2.64	6.64	4.98	8.45
B-0-22-2-0-DS	0.500	0.036	1.750	6.250	3.500	13.890	39.50	48.85	2.49	2.64	2.64	6.64	4.98	8.45
B-0-22-3-L-DS	0.500	0.036	1.750	6.250	3.500	13.890	39.50	48.85	2.88	2.64	2.64	6.64	4.98	8.45
B-0-22-4-L-DS	0.500	0.036	1.750	6.250	3.500	13.890	39.50	48.85	2.43	2.64	2.64	6.64	4.98	8.45
B-0-22-7-L-DS	0.500	0.036	1.750	6.250	3.500	13.890	39.50	48.85	2.70	2.64	2.64	6.64	4.98	8.45
B-0-22-8-L-DS	0.500	0.036	1.750	6.250	3.500	13.890	39.50	48.85	2.72	2.64	2.64	6.64	4.98	8.45
B-0-22-9-H-DS	0.500	0.036	1.750	6.250	3.500	13.890	39.50	48.85	2.65	2.64	2.64	6.64	4.98	8.45
B-0-22-10-H-DS	0.500	0.036	1.780	6.250	3.560	13.890	39.50	48.85	2.86	2.63	2.64	6.64	4.98	8.45
B-0-49-1-0-DS	0.500	0.071	1.781	6.700	3.560	7.042	52.43	69.28	9.58	7.38	7.38	21.66	15.28	32.82
B-0-49-2-0-DS	0.500	0.071	1.813	6.700	3.630	7.042	52.43	69.28	8.40	7.37	7.38	21.77	15.28	32.82
B-0-49-3-L-DS	0.500	0.071	1.781	6.700	3.560	7.042	52.43	69.28	8.82	7.36	7.38	21.66	15.28	32.82
B-0-49-4-L-DS	0.500	0.071	1.781	6.700	3.560	7.042	52.43	69.28	8.95	7.36	7.38	21.66	15.28	32.82
B-0-49-5-H-DS	0.500	0.071	1.781	6.700	3.560	7.042	52.43	69.28	9.20	7.37	7.38	21.66	15.28	32.82
B-0-49-6-H-DS	0.500	0.071	1.781	6.700	3.560	7.042	52.43	69.28	9.50	7.37	7.38	21.66	15.28	32.82
B-0-50-1-0-DS	0.750	0.071	2.625	10.000	3.500	10.563	52.43	69.28	12.25	11.05	11.07	32.34	22.93	46.60
B-0-50-2-0-DS	0.750	0.071	2.625	10.000	3.500	10.563	52.43	69.28	11.90	11.05	11.07	32.34	22.93	46.60
B-0-50-3-L-DS	0.750	0.071	2.625	10.000	3.500	10.563	52.43	69.28	12.45	11.06	11.07	32.34	22.93	46.60
B-0-50-4-L-DS	0.750	0.071	2.625	10.000	3.500	10.563	52.43	69.28	11.65	11.05	11.07	32.34	22.93	46.60
B-0-50-5-0-DS	0.750	0.071	2.625	10.000	3.500	10.563	52.43	69.28	11.35	11.05	11.07	32.34	22.93	46.60
B-0-50-6-0-DS	0.750	0.071	2.625	10.000	3.500	10.563	52.43	69.28	10.85	11.05	11.07	32.34	22.93	46.60
B-0-50-7-L-DS	0.750	0.071	2.625	10.000	3.500	10.563	52.43	69.28	12.00	11.05	11.07	32.34	22.93	46.60
B-0-50-8-L-DS	0.750	0.071	2.625	10.000	3.500	10.563	52.43	69.28	10.08	11.08	11.07	32.34	22.93	46.60
B-0-50-9-H-DS	0.750	0.071	2.625	10.000	3.500	10.563	52.43	69.28	14.00	11.06	11.07	32.34	22.93	46.60

Dimensions and Results of Double Shear Bolted Connections Without Washers(One Bolt) - Combination Failure Type I & II - Cont.

Spec.	F. Zadanfarrokh (KN)	Pult / AISI	Pult / AISC	Pult/ECCS	Pult/BS 5950	Pult/(CAN\CSA)	Pult/F. Zadanfarrokh	Reference
B-0-21-1-0-DS	4.87	1.43	1.43	2.52	3.36	1.43	1.72	26
B-0-21-2-0-DS	4.87	1.44	1.44	2.55	3.39	1.44	1.74	26
B-0-21-3-L-DS	4.87	1.44	1.44	2.55	3.39	1.44	1.74	26
B-0-21-4-L-DS	4.87	1.45	1.45	2.57	3.42	1.45	1.75	26
B-0-21-5-0-DS	4.87	1.47	1.47	2.60	3.46	1.47	1.77	26
B-0-21-6-0-DS	4.87	1.54	1.54	2.72	3.63	1.54	1.85	26
B-0-21-7-L-DS	------	1.65	1.65	2.91	3.88	4.50	---	26
B-0-21-8-L-DS	4.87	1.55	1.55	2.75	3.66	1.55	1.87	26
B-0-21-9-H-DS	4.87	1.70	1.69	2.99	3.99	1.69	2.04	26
B-0-21-10-H-DS	4.87	1.52	1.52	2.68	3.57	1.52	1.83	26
B-0-22-1-0-DS	6.89	1.00	0.97	1.71	2.29	1.35	1.65	26
B-0-22-2-0-DS	6.89	0.94	0.94	1.66	2.22	1.31	1.60	26
B-0-22-3-L-DS	6.89	1.09	1.09	1.93	2.57	1.51	1.86	26
B-0-22-4-L-DS	6.89	0.92	0.92	1.62	2.17	1.28	1.57	26
B-0-22-7-L-DS	6.89	1.02	1.02	1.81	2.41	1.42	1.74	26
B-0-22-8-L-DS	6.89	1.03	1.03	1.82	2.43	1.43	1.76	26
B-0-22-9-H-DS	6.89	1.00	1.00	1.77	2.37	1.40	1.71	26
B-0-22-10-H-DS	6.89	1.09	1.08	1.92	2.55	1.51	1.85	26
B-0-49-1-0-DS	17.56	1.30	1.30	1.97	2.79	1.30	2.43	26
B-0-49-2-0-DS	17.56	1.14	1.14	1.72	2.44	1.14	2.13	26
B-0-49-3-L-DS	17.56	1.20	1.20	1.81	2.57	1.20	2.23	26
B-0-49-4-L-DS	17.56	1.22	1.21	1.84	2.60	1.21	2.27	26
B-0-49-5-H-DS	17.56	1.25	1.25	1.89	2.68	1.25	2.33	26
B-0-49-6-H-DS	17.56	1.29	1.29	1.95	2.76	1.29	2.41	26
B-0-50-1-0-DS	21.50	1.11	1.11	1.68	2.38	1.17	2.53	26
B-0-50-2-0-DS	21.50	1.08	1.08	1.64	2.31	1.14	2.46	26
B-0-50-3-L-DS	21.50	1.13	1.12	1.71	2.42	1.19	2.58	26
B-0-50-4-L-DS	21.50	1.05	1.05	1.60	2.26	1.11	2.41	26
B-0-50-5-0-DS	21.50	1.03	1.03	1.56	2.20	1.08	2.35	26
B-0-50-6-0-DS	21.50	0.98	0.98	1.49	2.11	1.04	2.24	26
B-0-50-7-L-DS	21.50	1.09	1.08	1.65	2.33	1.15	2.48	26
B-0-50-8-L-DS	21.50	0.91	0.91	1.39	1.96	0.96	2.08	26
B-0-50-9-H-DS	21.50	1.27	1.26	1.93	2.72	1.34	2.90	26

Dimensions and Results of Double Shear Bolted Connections Without Washers(One Bolt) - Combination Failure Type I & II - Cont

Spec	d (in.)	t (in.)	e (in.)	s (in.)	e/d	d/t	Fy (ksi)	Fu (ksi)	Pult (kip)	Pn AISI E3.3-2 (kip)	Pn AISC (kip)	ECCS (KN)	BS 5950 (KN)	CAN\CSA (KN)
B-0-50-10-H-DS	0.750	0.071	2.625	10.000	3.500	10.563	52.43	69.28	12.03	9.47	11.07	32.34	22.93	46.60
B-0-53-1-0-DS	0.750	0.184	2.625	10.000	3.500	4.076	54.16	70.69	35.50	29.19	29.27	111.54	74.80	130.17
B-0-53-2-0-DS	0.750	0.184	2.688	10.000	3.580	4.076	54.16	70.69	34.90	29.24	29.27	112.95	74.80	130.17
B-0-53-3-L-DS	0.750	0.184	2.625	10.000	3.500	4.076	54.16	70.69	36.40	29.28	29.27	111.54	74.80	130.17
B-0-53-4-L-DS	0.750	0.184	2.656	10.000	3.540	4.076	54.16	70.69	36.15	29.18	29.27	112.24	74.80	130.17
B-0-53-5-H-DS	0.750	0.184	2.563	10.000	3.420	4.076	54.16	70.69	36.10	29.25	29.27	110.10	74.80	130.17

Dimensions and Results of Double Shear Bolted Connections Without Washers(One Bolt) - Combination Failure Type I & II - Cont

Spec	F. Zadanfarrokh (KN)	Pult / AISI	Pult / AISC	Pult/ECCS	Pult/BS 5950	Pult/(CAN\CSA)	Pult/F Zadanfarrokh	Reference
B-0-50-10-H-DS	21 50	1 27	1 09	1 65	2 33	1 15	2.49	26
B-0-53-1-0-DS	62.25	1 22	1 21	1 42	2 11	1 21	2.54	26
B-0-53-2-0-DS	62.25	1 19	1 19	1 37	2.08	1 19	2 49	26
B-0-53-3-L-DS	62.25	1 24	1 24	1 45	2.16	1 24	2.60	26
B-0-53-4-L-DS	62 25	1 24	1 24	1 43	2 15	1 24	2 58	26
B-0-53-5-H-DS	62 25	1 23	1 23	1 46	2 15	1 23	2.58	26
lean		1 223	1 217	1 941	2 673	1 386	2 081	
tandard Deviation		0 206	0 207	0 469	0 572	0 530	0 493	
Coefficient of Variation		0 168	0 170	0 242	0 214	0 382	0 237	

APPENDIX E

Dimensions And Results Of Bolted Connections Used In The Evaluation Of Existing Data - Combination Type I & III Failure Mode

Dimensions and Results of Single Shear Bolted Connections With Washers -Tensile Strength Study (One Bolt) - Combination Failure Type I & III

Spec	d in.	t in.	e in.	s in.	e/d	d/t	d/s	Fy ksi	Fu ksi	Fu/Fy	Controlling AISC kip	Controlling AISI kip	ECCS KN	BS 5950 KN
20A22SSI	0.375	0.035	0.938	4.000	2.500	10.600	0.094	32.11	41.85	1.30	5.04	2.03	7.35	6.93
20A32SSI	0.375	0.034	1.313	4.000	3.500	11.200	0.094	32.11	41.85	1.30	4.77	1.92	6.96	6.56
20A42SSI	0.375	0.035	1.688	4.000	4.500	10.740	0.094	32.11	41.85	1.30	4.97	2.01	7.25	6.83
20A23SSI	0.500	0.035	1.250	4.000	2.500	14.200	0.125	32.11	41.85	1.30	5.01	2.41	9.02	8.21
20A43SSI	0.500	0.035	2.250	4.000	4.500	14.200	0.125	32.11	41.85	1.30	5.01	2.41	9.02	8.21
14A23SSI	0.500	0.083	1.250	4.000	2.500	6.000	0.125	29.80	43.40	1.46	9.92	5.90	19.78	18.01
8B45SSI	0.750	0.187	3.375	4.000	4.500	4.020	0.188	32.00	46.00	1.44	27.37	18.18	60.09	56.12
18E42SSI	0.375	0.045	1.688	4.000	4.500	8.310	0.094	46.75	68.00	1.45	8.43	4.21	13.64	12.85
18E24SSI	0.625	0.044	1.563	4.000	2.500	14.200	0.156	46.75	68.00	1.45	8.25	5.64	18.70	17.28

Dimensions and Results of Single Shear Bolted Connections With Washers -Tensile Strength Study (One Bolt) - Combination Failure Type I & III - Cont.

Spec	CAN\CSA KN	Pult kips	Pult/AISI	Pult/AISC	Pult/ECCS	Pult/BS 5950	Pult/(CAN\CSA)	Reference
20A22SSI	23.68	1.72	0.84	0.34	1.04	1.10	0.32	12
20A32SSI	22.41	1.77	0.92	0.37	1.13	1.20	0.35	12
20A42SSI	23.35	1.80	0.90	0.36	1.10	1.17	0.34	12
20A23SSI	22.52	2.08	0.86	0.41	1.02	1.12	0.41	12
20A43SSI	22.52	2.08	0.86	0.42	1.03	1.13	0.41	12
14A23SSI	44.11	5.14	0.87	0.52	1.16	1.27	0.52	12
8B45SSI	121.76	17.30	0.95	0.63	1.28	1.37	0.63	12
18E42SSI	37.51	3.38	0.80	0.40	1.10	1.17	0.40	13
18E24SSI	36.68	4.35	0.77	0.53	1.03	1.12	0.53	13
Mean			0.865	0.443	1.100	1.185	0.435	
Standard Deviation			0.053	0.091	0.079	0.082	0.097	
Coefficient of Variation			0.061	0.205	0.072	0.069	0.223	

Dimensions and Results of Double Shear Bolted Connections With Washers-Tensile Strength Study (One Bolt) - Combination Failure Type I & III

Spec		t in.	e in.	s in	e/d	d/t	d/s	Fy ksi	Fu ksi	Fu/Fy	Controlling AISC kip	Controlling AISI kip	ECCS KN	BS 5950 KN
20A21DS2	0.250	0.035	0.625	4.000	2.500	7.200	0.063	32.11	41.85	1.3033	4.94	1.55	5.73	5.30
20A22DS	0.375	0.034	0.938	4.000	2.500	10.900	0.094	32.11	41.85	1.3033	4.89	1.97	7.15	6.73
20A23DS1	0.500	0.035	1.250	4.000	2.500	14.120	0.125	32.11	41.85	1.3033	5.04	2.42	9.07	8.26
18E34DS1	0.625	0.045	2.188	4.000	3.500	13.860	0.156	46.75	68.00	1.4545	8.43	5.78	19.12	17.67
18E44DS1	0.625	0.045	2.813	4.000	4.500	13.800	0.156	46.75	68.00	1.4545	8.47	5.80	19.21	17.75
10E25DS1	0.750	0.135	1.875	4.000	2.500	5.550	0.188	59.50	71.85	1.2076	30.94	20.50	80.85	75.50
10E16DS1	1.000	0.142	1.500	4.000	1.500	7.040	0.250	59.50	71.85	1.2076	29.99	25.49	99.08	93.90

Dimensions and Results of Double Shear Bolted Connections With Washers-Tensile Strength Study (One Bolt) - Combination Failure Type I & III - Cont.

Spec	CAN\CSA KN	Pult kip	Pult/AISI	Pult/AISC	Pult/ECCS	Pult/BS 5950	Pult/(CAN\CSA)	Reference
20A21DS2	19.82	1.25	0.80	0.25	0.97	1.05	0.28	12
20A22DS	23.01	1.83	0.93	0.37	1.14	1.21	0.35	12
20A23DS1	22.65	2.53	1.05	0.50	1.24	1.36	0.50	12
18E34DS1	37.51	6.57	1.14	0.78	1.53	1.65	0.78	12
18E44DS1	37.68	6.88	1.19	0.81	1.59	1.72	0.81	13
10E25DS1	137.62	19.31	0.94	0.62	1.06	1.14	0.62	13
10E16DS1	133.40	14.78	0.58	0.49	0.66	0.70	0.49	13
Mean			0.946	0.548	1.171	1.263	0.548	
Standard Deviation			0.192	0.189	0.298	0.329	0.187	
Coefficient of Variation			0.203	0.346	0.255	0.261	0.340	

Dimensions and Results of Double Shear Bolted Connections With Washers-Tensile Strength Study (Two Bolts Perpendicular to the Line of Stress) - Combination Failure Type I & III

Spec	d in.	t in.	e in.	s in.	e/d	d/t	d/s	Fy ksi	Fu ksi	Fu/Fy	Controlling AISC kip	Controlling AISI kip	ECCS KN	BS 5950 KN
H2DSC15	0.375	0.058	0.938	2.000	2.501	6.466	0.188	44.60	53.20	1.19	9.84	6.52	26.02	24.30
H2DSC16	0.375	0.058	0.938	2.000	2.501	6.466	0.188	44.60	53.20	1.19	9.84	6.52	26.02	24.30
H2DSC19	0.375	0.058	0.938	2.000	2.501	6.466	0.188	44.60	53.20	1.19	9.84	6.52	26.02	24.30
H2DSC20	0.375	0.058	0.938	2.000	2.501	6.466	0.188	44.60	53.20	1.19	9.84	6.52	26.02	24.30
H2DSC21	0.375	0.058	0.938	2.000	2.501	6.466	0.188	44.60	53.20	1.19	9.84	6.52	26.02	24.30
H2DSC25	0.375	0.058	1.313	2.000	3.501	6.466	0.188	44.60	53.20	1.19	9.84	6.52	26.02	24.30
H2DSC26	0.375	0.058	1.313	2.000	3.501	6.466	0.188	44.60	53.20	1.19	9.84	6.52	26.02	24.30
H2DSC37	0.500	0.058	1.000	2.000	2.000	8.621	0.250	44.60	53.20	1.19	8.87	7.54	31.22	28.12
H2DSC38	0.500	0.058	1.000	2.000	2.000	8.621	0.250	44.60	53.20	1.19	8.87	7.54	31.22	28.12
H2DSC41	0.500	0.058	1.250	2.000	2.500	8.621	0.250	44.60	53.20	1.19	8.87	7.54	31.22	28.12
H2DSC42	0.500	0.058	1.250	2.000	2.500	8.621	0.250	44.60	53.20	1.19	8.87	7.54	31.22	28.12

Dimensions and Results of Double Shear Bolted Connections With Washers-Tensile Strength Study (Two Bolts Perpendicular to the Line of Stress) - Combination Failure Type I & III - Cont.

Spec	CAN\CSA KN	Pult kips	Pult/AISI	Pult/AISC	Pult/ECCS	Pult/BS 5950	Pult/(CAN\CSA)	Reference
H2DSC15	43.75	7.14	1.10	0.73	1.22	1.31	0.73	27
H2DSC16	43.75	6.94	1.07	0.71	1.19	1.27	0.71	27
H2DSC19	43.75	8.57	1.32	0.87	1.47	1.57	0.87	27
H2DSC20	43.75	8.20	1.26	0.83	1.40	1.50	0.83	27
H2DSC21	43.75	8.28	1.27	0.84	1.42	1.52	0.84	27
H2DSC25	43.75	10.00	1.53	1.02	1.71	1.83	1.02	27
H2DSC26	43.75	9.64	1.48	0.98	1.65	1.76	0.98	27
H2DSC37	39.46	7.80	1.03	0.88	1.11	1.23	0.88	27
H2DSC38	39.46	7.88	1.05	0.89	1.12	1.25	0.89	27
H2DSC41	39.46	9.32	1.24	1.05	1.33	1.47	1.05	27
H2DSC42	39.46	9.28	1.23	1.05	1.32	1.47	1.05	27
Mean			1.233	0.895	1.357	1.471	0.895	
Standard Deviation			0.160	0.113	0.189	0.191	0.113	
Coefficient of Variation			0.130	0.127	0.139	0.130	0.127	

Dimensions and Results of Double Shear Connection With Washers -Tensile Strength Study (Three Bolts Perpendicular to the Line of Stress) Combination Failure Type I & III

Spec	d in.	t in.	e in.	s in.	e/d	d/t	d/s	Fy ksi	Fu ksi	Fu/Fy	Controlling AISC kip	Controlling AISI kip	ECCS KN	BS 5950 KN	CAN\CSA KN
H3DSA8	0.313	0.064	0.783	1.333	2.502	4.883	0.235	54.40	70.70	1.30	13.43	10.77	40.20	36.96	59.72
H3DSA9	0.313	0.064	0.783	1.333	2.502	4.883	0.235	54.40	70.70	1.30	13.43	10.77	40.20	36.96	59.72
H3DSA10	0.313	0.064	0.783	1.333	2.502	4.883	0.235	54.40	70.70	1.30	13.43	10.77	40.20	36.96	59.72
H3DSA14	0.313	0.064	1.094	1.333	3.495	4.883	0.235	54.40	70.70	1.30	13.43	10.77	40.20	36.96	59.72
H3DSA15	0.313	0.064	1.094	1.333	3.495	4.883	0.235	54.40	70.70	1.30	13.43	10.77	40.20	36.96	59.72
H3DSA45	0.375	0.064	0.750	1.333	2.000	5.859	0.281	54.40	70.70	1.30	12.58	9.68	43.07	40.66	55.98
H3DSA46	0.375	0.064	0.750	1.333	2.000	5.859	0.281	54.40	70.70	1.30	12.58	9.68	43.07	40.66	55.98
H3DSA47	0.375	0.064	0.750	1.333	2.000	5.859	0.281	54.40	70.70	1.30	12.58	9.68	43.07	40.66	55.98
H3DSA48	0.375	0.064	0.750	1.333	2.000	5.859	0.281	54.40	70.70	1.30	12.58	9.68	43.07	40.66	55.98
H3DSA52	0.375	0.064	0.938	1.333	2.500	5.859	0.281	54.40	70.70	1.30	12.58	9.68	43.07	40.66	55.98

Dimensions and R.sults of Double Shear Connection With Washers -Tensile Strength Study (Three Bolts Perpendicular to the Line of Stress) Combination Failure Type I & III - Cont.

Spec	Pult kip	Pult/AISI	Pult/AISC	Pult/ECCS	Pult/BS 5950	Pult/(CAN\CSA)	Reference
H3DSA8	12.98	1.21	0.97	1.44	1.56	0.97	27
H3DSA9	12.48	1.16	0.93	1.38	1.50	0.93	27
H3DSA10	10.64	0.99	0.79	1.18	1.28	0.79	27
H3DSA14	13.52	1.26	1.01	1.50	1.63	1.01	27
H3DSA15	13.76	1.28	1.02	1.52	1.66	1.02	27
H3DSA45	13.24	1.37	1.05	1.37	1.45	1.05	27
H3DSA46	13.30	1.37	1.06	1.37	1.46	1.06	27
H3DSA47	13.06	1.35	1.04	1.35	1.43	1.04	27
H3DSA48	13.16	1.36	1.05	1.36	1.44	1.05	27
H3DSA52	12.96	1.34	1.03	1.34	1.42	1.03	27
Mean		1.267	0.994	1.380	1.482	0.994	
Standard Deviation		0.116	0.077	0.090	0.105	0.077	
Coefficient of Variatio		0.092	0.078	0.065	0.071	0.078	

Dimensions and Results of Double Shear Connection Without Washers -Tensile Strength Study (Two Bolts Perpendicular to the Line of Stress) - Combination Failure Type I & III

Spec	d in.	t in.	e in.	s in.	e/d	d/t	d/s	Fy ksi	Fu ksi	Fu/Fy	Controlling AISC kip	Controlling AISI kip	ECCS KN	BS 5950 KN
H2DSC17	0.375	0.058	0.938	2.000	2.501	6.466	0.188	44.60	53.20	1.19	9.84	4.61	26.02	24.30
H2DSC18	0.375	0.058	0.938	2.000	2.501	6.466	0.188	44.60	53.20	1.19	9.84	4.61	26.02	24.30
H2DSC22	0.375	0.058	0.938	2.000	2.501	6.466	0.188	44.60	53.20	1.19	9.84	4.61	26.02	24.30
H2DSC23	0.375	0.058	0.938	2.000	2.501	6.466	0.188	44.60	53.20	1.19	9.84	4.61	26.02	24.30
H2DSC24	0.375	0.058	0.938	2.000	2.501	6.466	0.188	44.60	53.20	1.19	9.84	4.61	26.02	24.30
H2DSC27	0.375	0.058	1.313	2.000	3.501	6.466	0.188	44.60	53.20	1.19	9.84	4.61	26.02	24.30
H2DSC28	0.375	0.058	1.313	2.000	3.501	6.466	0.188	44.60	53.20	1.19	9.84	4.61	26.02	24.30
H2DSC31	0.375	0.058	1.688	2.000	4.501	6.466	0.188	44.60	53.20	1.19	9.84	4.61	26.02	24.30
H2DSC39	0.500	0.058	1.000	2.000	2.000	8.621	0.250	44.60	53.20	1.19	8.87	5.54	31.22	28.12
H2DSC40	0.500	0.058	1.000	2.000	2.000	8.621	0.250	44.60	53.20	1.19	8.87	5.54	31.22	28.12
H2DSC43	0.500	0.058	1.250	2.000	2.500	8.621	0.250	44.60	53.20	1.19	8.87	5.54	31.22	28.12
H2DSC44	0.500	0.058	1.250	2.000	2.500	8.621	0.250	44.60	53.20	1.19	8.87	5.54	31.22	28.12

Dimensions and Results of Double Shear Connection Without Washers-Tensile Strength Study (Two Bolts Perpendicular to the Line of Stress) - Combination Failure Type I & III - Cont

Spec	CAN\CSA KN	Pult kip	Pult/AISI	Pult/AISC	Pult/ECCS	Pult/BS 5950	Pult/(CAN\CSA)	Reference
H2DSC17	43.75	7.03	1.52	0.71	1.20	1.29	0.71	27
H2DSC18	43.75	7.08	1.54	0.72	1.21	1.30	0.72	27
H2DSC22	43.75	8.12	1.76	0.83	1.39	1.49	0.83	27
H2DSC23	43.75	8.00	1.74	0.81	1.37	1.46	0.81	27
H2DSC24	43.75	7.98	1.73	0.81	1.36	1.46	0.81	27
H2DSC27	43.75	9.04	1.96	0.92	1.55	1.65	0.92	27
H2DSC28	43.75	8.96	1.94	0.91	1.53	1.64	0.91	27
H2DSC31	43.75	8.80	1.91	0.89	1.50	1.61	0.89	27
H2DSC39	39.46	7.26	1.31	0.82	1.03	1.15	0.82	27
H2DSC40	39.46	7.26	1.31	0.82	1.03	1.15	0.82	27
H2DSC43	39.46	8.72	1.57	0.98	1.24	1.38	0.98	27
H2DSC44	39.46	8.80	1.59	0.99	1.25	1.39	0.99	27
Mean			1.657	0.852	1.307	1.414	0.852	
Standard Deviation			0.213	0.086	0.167	0.166	0.086	
Coefficient of Variation			0.129	0.101	0.128	0.117	0.101	

Dimensions and Results of Double Shear Connections Without Washers -Tensile Strength Study (Three Bolts Perpendicular to the Line of Stress) - Combination Failure Type I & III

Spec	d in	t in.	e in	s in.	e/d	d/t	d/s	Fy ksi	Fu ksi	Fu/Fy	Controlling AISC kip	Controlling AISI kip	ECCS KN	BS 5950 KN
H3DSA12	0.313	0.064	0.783	1.333	2.502	4.883	0.235	54.40	70.70	1.30	13.43	7.85	40.20	36.96
H3DSA13	0.313	0.064	0.783	1.333	2.502	4.883	0.235	54.40	70.70	1.30	13.43	7.85	40.20	36.96
H3DSA18	0.313	0.064	1.094	1.333	3.495	4.883	0.235	54.40	70.70	1.30	13.43	7.85	40.20	36.96
H3DSA19	0.313	0.064	1.094	1.333	3.495	4.883	0.235	54.40	70.70	1.30	13.43	7.85	40.20	36.96
H3DSA49	0.375	0.064	0.750	1.333	2.000	5.859	0.281	54.40	70.70	1.30	12.58	8.84	43.07	40.66
H3DSA50	0.375	0.064	0.750	1.333	2.000	5.859	0.281	54.40	70.70	1.30	12.58	8.84	43.07	40.66
H3DSA51	0.375	0.064	0.750	1.333	2.000	5.859	0.281	54.40	70.70	1.30	12.58	8.84	43.07	40.66
H3DSA55	0.375	0.064	0.938	1.333	2.500	5.859	0.281	54.40	70.70	1.30	12.58	8.84	43.07	40.66

Dimensions and Results of Double Shear Connections Without Washers -Tensile Strength Study (Three Bolts Perpendicular to the Line of Stress) - Combination Failure Type I & III - Cont

Spec	CAN\CSA KN	Pult kips	Pult/AISI	Pult/AISC	Pult/ECCS	Pult/BS 5950	Pult/(CAN\CSA)	Reference
H3DSA12	59.72	12.18	1.55	0.91	1.35	1.47	0.91	27
H3DSA13	59.72	12.16	1.55	0.91	1.35	1.46	0.91	27
H3DSA18	59.72	13.44	1.71	1.00	1.49	1.62	1.00	27
H3DSA19	59.72	13.04	1.66	0.97	1.44	1.57	0.97	27
H3DSA49	55.98	12.57	1.42	1.00	1.30	1.38	1.00	27
H3DSA50	55.98	12.37	1.40	0.98	1.28	1.35	0.98	27
H3DSA51	55.98	12.82	1.45	1.02	1.32	1.40	1.02	27
H3DSA55	55.98	12.06	1.36	0.96	1.25	1.32	0.96	27
Mean			1.513	0.968	1.346	1.446	0.968	
Standard Deviation			0.118	0.040	0.077	0.098	0.040	
Coefficient of Variation			0.078	0.041	0.057	0.068	0.041	

APPENDIX F

Dimensions And Results Of Bolted Connections Used In The Evaluation Of Existing Data - Combination Type II & V Failure Mode

Dimensions and Results of Single Shear Bolted Connections With Washers (One Bolt) - Combination Failure Type II & V

Spec.	d (in.)	t (in.)	e (in.)	s (in.)	e/d	d/t	Fy (ksi)	Fu (ksi)	Pult (kip)	Pn AISI Eq E3 3-2 (kip)	Pn AISC (kip)	ECCS (KN)	BS 5950 (KN)	CAN\CSA (KN)
B-1-16-5-0-SS	0.500	0.036	1.750	4.000	3.500	13.890	39.50	48.85	1.95	2.64	2.64	6.64	6.64	8.45
B-1-16-6-0-SS	0.500	0.036	1.750	4.000	3.500	13.890	39.50	48.85	2.00	2.64	2.64	6.64	6.64	8.45
B-1-16-7-L-SS	0.500	0.036	1.750	4.000	3.500	13.890	39.50	48.85	2.08	2.64	2.64	6.64	6.64	8.45
B-1-16-8-L-SS	0.500	0.036	1.750	4.000	3.500	13.890	39.50	48.85	2.35	2.64	2.64	6.64	6.64	8.45
B-1-16-9-H-SS	0.500	0.036	1.750	4.000	3.500	13.890	39.50	48.85	2.58	2.64	2.64	6.64	6.64	8.45
B-1-16-10-H-SS	0.500	0.036	1.750	4.000	3.500	13.890	39.50	48.85	2.95	2.64	2.64	6.64	6.64	8.45
B-1-24-3-L-SS	0.750	0.074	2.660	5.250	3.540	10.135	48.11	53.70	10.70	8.94	8.94	31.62	29.64	39.24
B-1-36-9-H-SS	0.500	0.031	1.750	4.250	3.500	16.129	59.22	74.51	3.11	3.46	3.46	8.57	8.57	10.27
B-1-43-2-0-SS	0.500	0.071	1.688	4.250	3.380	7.042	52.43	69.28	6.91	7.38	7.38	21.34	20.38	32.82
B-1-43-3-L-SS	0.500	0.071	1.688	4.250	3.380	7.042	52.43	69.28	8.13	7.38	7.38	21.34	20.38	32.82
B-1-43-4-L-SS	0.500	0.071	1.688	4.250	3.380	7.042	52.43	69.28	7.12	7.38	7.38	21.34	20.38	32.82
B-1-43-5-H-SS	0.500	0.071	1.703	4.250	3.410	7.042	52.43	69.28	6.89	7.38	7.38	21.40	20.38	32.82
B-1-43-6-H-SS	0.500	0.071	1.719	4.250	3.440	7.042	52.43	69.28	6.83	7.38	7.38	21.45	20.38	32.82
B-1-44-6-0-SS	0.750	0.071	2.625	6.000	3.500	10.563	52.43	69.28	8.15	11.07	11.07	32.34	30.57	46.60
B-1-44-7-L-SS	0.750	0.071	2.625	6.000	3.500	10.563	52.43	69.28	8.00	11.07	11.07	32.34	30.57	46.60
B-1-44-10-H-SS	0.750	0.071	2.625	6.000	3.500	10.563	52.43	69.28	8.25	11.07	11.07	32.34	30.57	46.60

Dimensions and Results of Single Shear Bolted Connections With Washers (One Bolt) - Combination Failure Type II & V - Cont.

Spec.	F. Zadanfarrokh (KN)	Pult/AISI	Pult/AISC	Pult/ECCS	Pult/BS 5950	Pult/(CAN\CSA)	Pult/F. Zadanfarrokh	Reference
B-1-16-5-0-SS	9.84	0.74	0.74	1.31	1.31	1.03	0.88	26
B-1-16-6-0-SS	9.84	0.76	0.76	1.34	1.34	1.05	0.90	26
B-1-16-7-L-SS	9.84	0.79	0.79	1.39	1.39	1.10	0.94	26
B-1-16-8-L-SS	9.84	0.89	0.89	1.57	1.57	1.24	1.06	26
B-1-16-9-H-SS	9.84	0.98	0.98	1.73	1.73	1.36	1.17	26
B-1-16-10-H-SS	9.84	1.12	1.12	1.98	1.98	1.55	1.33	26
B-1-24-3-L-SS	28.38	1.20	1.20	1.51	1.61	1.21	1.68	26
B-1-36-9-H-SS	10.34	0.90	0.90	1.61	1.61	1.35	1.34	26
B-1-43-2-0-SS	25.08	0.94	0.94	1.44	1.51	0.94	1.23	26
B-1-43-3-L-SS	25.08	1.10	1.10	1.69	1.77	1.10	1.44	26
B-1-43-4-L-SS	25.08	0.96	0.96	1.48	1.55	0.96	1.26	26
B-1-43-5-H-SS	25.08	0.93	0.93	1.43	1.50	0.93	1.22	26
B-1-43-6-H-SS	25.08	0.93	0.93	1.42	1.49	0.93	1.21	26
B-1-44-6-0-SS	30.72	0.74	0.74	1.12	1.19	0.78	1.18	26
B-1-44-7-L-SS	30.72	0.72	0.72	1.10	1.16	0.76	1.16	26
B-1-44-10-H-SS	30.72	0.75	0.75	1.13	1.20	0.79	1.19	26
	Mean	0.902	0.902	1.454	1.495	1.067	1.200	
	Standard Deviation	0.144	0.144	0.227	0.218	0.220	0.195	
	Coefficient of Variation	0.159	0.159	0.156	0.146	0.206	0.162	

Dimensions and Results of Single Shear Bolted Connections Without Washers (One Bolt) - Combination Failure Type II & V

Spec.	d (in)	t (in)	e (in)	s (in)	e/d	d/t	Fy (ksi)	Fu (ksi)	Fu/Fy	Pult (kip)	Pn AISI E3.3-2 (kip)	Pn AISC (kip)	ECCS (KN)	BS 5950 (KN)
B-0-46-1-0-SS	0.750	0.071	1.650	4.250	2.20	10.563	52.43	69.28	1.32	5.825	8.19	11.07	28.17	21.13
B-0-46-2-0-SS	0.750	0.071	1.650	4.250	2.20	10.563	52.43	69.28	1.32	5.470	8.19	11.07	28.17	21.13
B-0-46-3-L-SS	0.750	0.071	1.650	4.250	2.20	10.563	52.43	69.28	1.32	6.000	8.19	11.07	28.17	21.13
B-0-46-4-L-SS	0.750	0.071	1.650	4.250	2.20	10.563	52.43	69.28	1.32	5.960	8.19	11.07	28.17	21.13
B-0-46-5-0-SS	0.750	0.071	1.650	4.250	2.20	10.563	52.43	69.28	1.32	5.870	8.19	11.07	28.17	21.13
B-0-46-6-0-SS	0.750	0.071	1.650	4.250	2.20	10.563	52.43	69.28	1.32	5.820	8.19	11.07	28.17	21.13
B-0-46-7-L-SS	0.750	0.071	1.650	4.250	2.20	10.563	52.43	69.28	1.32	6.690	8.19	11.07	28.17	21.13
B-0-46-8-L-SS	0.750	0.071	1.650	4.250	2.20	10.563	52.43	69.28	1.32	5.875	8.19	11.07	28.17	21.13
B-0-46-9-H-SS	0.750	0.071	1.650	4.250	2.20	10.563	52.43	69.28	1.32	7.500	8.19	11.07	28.17	21.13
B-0-46-10-H-SS	0.750	0.071	1.650	4.250	2.20	10.563	52.43	69.28	1.32	6.560	8.19	11.07	28.17	21.13

Dimensions and R· ılts of Single Shear Bolted Connections Without Washers (One Bolt) - Combination Failure Type II & V - Cont.

Spec.	CAN\CSA (KN)	F. Zadanfarrokh (KN)	Pult/AISI	Pult/AISC	Pult/ECCS	Pult/BS 5950	Pult/(CAN\CSA)	Pult/F. Zadanfarrokh	Reference
B-0-46-1-0-SS	36.10	18.92	0.71	0.53	0.92	1.23	0.72	1.37	26
B-0-46-2-0-SS	36.10	18.92	0.67	0.49	0.86	1.15	0.67	1.29	26
B-0-46-3-L-SS	36.10	18.92	0.73	0.54	0.95	1.26	0.74	1.41	26
B-0-46-4-L-SS	36.10	18.92	0.73	0.54	0.94	1.25	0.73	1.40	26
B-0-46-5-0-SS	36.10	18.92	0.72	0.53	0.93	1.24	0.72	1.38	26
B-0-46-6-0-SS	36.10	18.92	0.71	0.53	0.92	1.23	0.72	1.37	26
B-0-46-7-L-SS	36.10	18.92	0.82	0.60	1.06	1.41	0.82	1.57	26
B-0-46-8-L-SS	36.10	18.92	0.72	0.53	0.93	1.24	0.72	1.38	26
B-0-46-9-H-SS	36.10	18.92	0.92	0.68	1.18	1.58	0.92	1.76	26
B-0-46-10-H-SS	36.10	18.92	0.80	0.59	1.04	1.38	0.81	1.54	26
		Mean	0.752	0.556	0.972	1.296	0.759	1.447	
		Standard Deviation	0.069	0.051	0.089	0.119	0.069	0.132	
		Coefficient of Variation	0.091	0.091	0.091	0.091	0.091	0.091	

Dimensions and Results of Double Shear Bolted Connections Without Washers (One Bolt) - Combination Failure Type II & V

Spec	d (in.)	t (in.)	e (in.)	s (in.)	e/d	d/t	Fy (ksi)	Fu (ksi)	Fu/Fy	Pult (kips)	Pn AISI Eq E3.3-2 (kips)	Pn AISC (kips)	ECCS (KN)	BS 5950 (KN)
B-0-22-5-0-DS	0.500	0.036	1.750	6.250	3.500	13.890	39.500	48.850	1.237	2.425	2.639	2.638	6.641	4.981
B-0-22-6-0-DS	0.500	0.036	1.750	6.250	3.500	13.890	39.500	48.850	1.237	2.200	2.640	2.638	6.641	4.981

Dimensions and Results of Double Shear Bolted Connections Without Washers (One Bolt) - Combination Failure Type II & V - Cont

Spec	CAN\CSA (KN)	F. Zadanfarrokh (KN)	Pult / AISI	Pult / AISC	Pult/ECCS	Pult/BS 5950	Pult/(CAN\CSA)	Pult/F Zadanfarrokh	Reference
B-0-22-5-0-DS	8.448	6.888	0.919	0.919	1.624	2.166	1.277	1.566	26
B-0-22-6-0-DS	8.448	6.888	0.833	0.834	1.473	1.965	1.158	1.421	26
		Mean	0.876	0.877	1.549	2.065	1.218	1.493	
		Standard Deviation	0.043	0.043	0.075	0.100	0.059	0.073	
		Coefficient of Variation	0.049	0.049	0.049	0.049	0.049	0.049	

APPENDIX G

Dimensions and Results Of Bolted Connections Used In The Evaluation Of Existing Data - Combination Type I & II & III Failure Mode

Dimensions and Results of Single Shear Bolted Connections With Washer-Tensile Strength Study (One Bolt) - Combination Failure Type I & II & III

Spec.	d (in.)	t (in.)	e (in.)	s (in.)	e/d	d/t	d/s	Fy (ksi)	Fu (ksi)	Fu/Fy	Tension Controlling AISC (kip)	Tension Controlling AISI (kip)	Tension ECCS (KN)	Tension BS 5950 (KN)
12Y-L15	0.375	0.104	1.496	1.520	3.990	3.610	0.247	72.40	72.80	1.01	8.43	7.08	33.64	31.34
12Y-L17	0.625	0.104	2.125	2.548	3.400	6.010	0.245	72.40	72.80	1.01	14.09	11.77	56.67	52.08
7Y-L5	0.750	0.183	1.875	3.750	2.500	4.100	0.200	83.10	83.90	1.01	45.10	31.57	149.02	139.09
20Z-L2	0.500	0.039	1.000	1.500	2.000	12.820	0.333	75.50	81.70	1.08	2.99	2.99	12.28	12.28
20Z-L3	0.750	0.039	1.500	2.500	2.000	19.230	0.300	75.50	81.70	1.08	5.38	5.38	22.10	22.10
12Y-L13	0.625	0.104	2.175	3.330	3.480	6.010	0.188	72.40	72.80	1.01	20.01	13.27	63.67	58.68

Dimensions and Results of Single Shear Bolted Connections With Washer-Tensile Strength Study (One Bolt) - Combination Failure Type I & II & III - Cont.

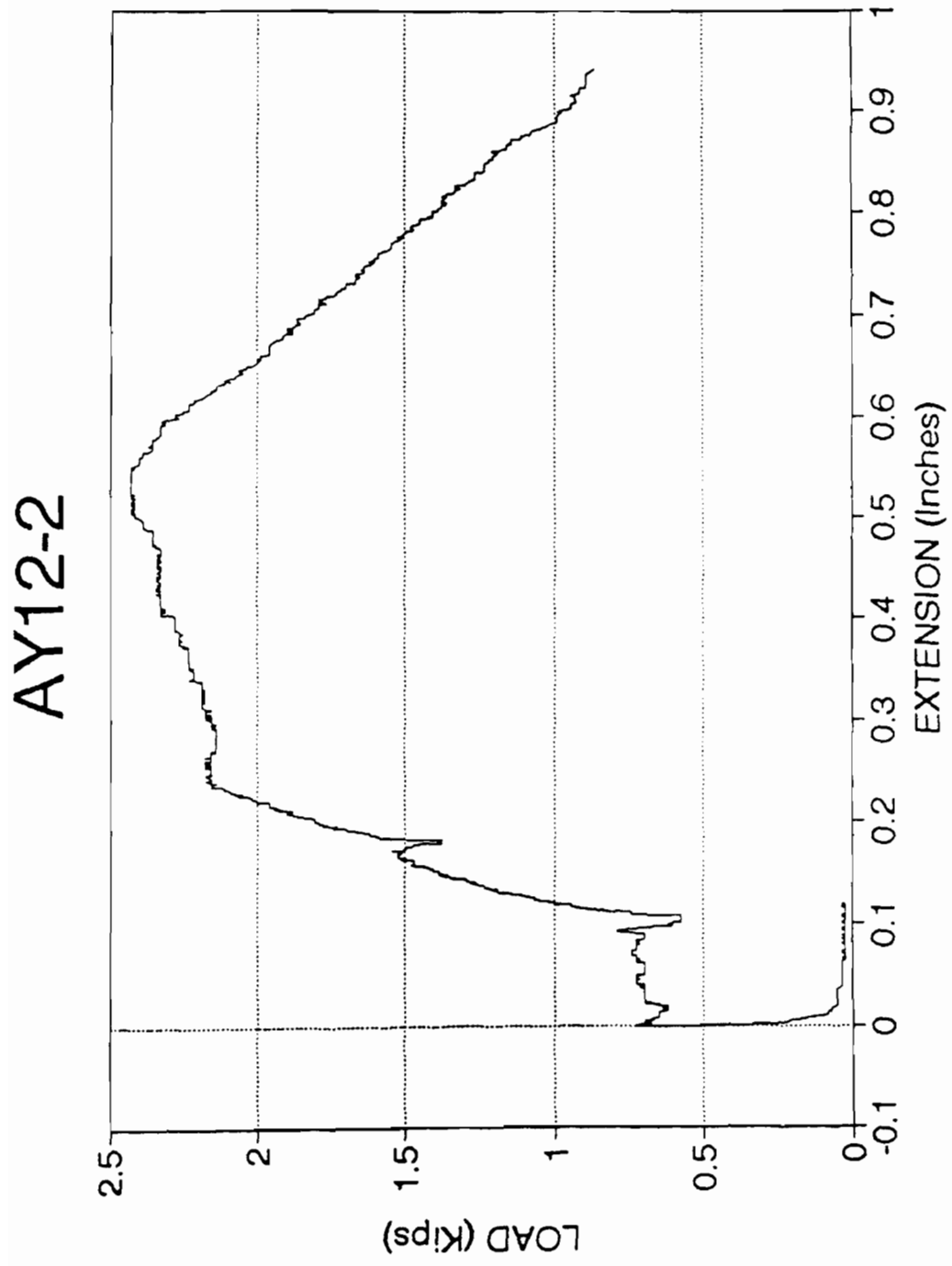
Spec.	Tension CAN\CSA (KN)	Pult (kip)	Bearing Pn AISI E3.3-2 (kip)	Bearing Pn AISC (kip)	Bearing ECCS (KN)	Bearing BS 5950 (KN)	Bearing CAN\CSA (KN)	Bearing F. Zadanfarrokh (KN)	Tension Pult/AISI	Tension Pult/AISC	Tension Pult/ECCS	Tension Pult/BS 5950
12Y-L15	37.51	7.66	8.52	8.52	41.74	35.65	37.89	35.04	1.08	0.91	1.01	1.09
12Y-L17	62.66	10.58	14.79	14.20	64.62	59.42	63.14	45.23	0.90	0.75	0.83	0.90
7Y-L5	200.61	27.95	14.79	34.55	139.48	136.98	128.05	96.36	0.89	0.62	0.83	0.89
20Z-L2	13.29	2.74	14.79	4.78	13.75	13.75	14.17	11.11	0.92	0.92	0.99	0.99
20Z-L3	23.92	4.20	14.79	7.17	20.63	20.63	21.26	13.61	0.78	0.78	0.85	0.85
12Y-L13	88.99	9.89	14.79	14.20	65.34	59.42	63.14	45.23	0.75	0.49	0.69	0.75
								Mean	0.885	0.745	0.868	0.912
								Standard Deviation	0.108	0.151	0.108	0.107
								Coefficient of Variation	0.122	0.202	0.125	0.117

Dimensions and Results of Single Shear Bolted Connections With Washer-Tensile Strength Study (One Bolt) - Combination Failure Type I & II & III - Cont.

Spec	Tension Pult/(CAN\CSA)	Bearing Pult/AISI	Bearing Pult/AISC	Bearing Pult/ECCS	Bearing Pult/BS 5950	Bearing Pult/(CAN\CSA)	Bearing Pult/F. Zadanfarrokh	Reference
12Y-L15	0.91	0.90	0.90	0.82	0.96	0.90	0.97	16
12Y-L17	0.75	0.72	0.75	0.73	0.79	0.75	1.04	16
7Y-L5	0.62	1.89	0.81	0.89	0.91	0.97	1.29	16
20Z-L2	0.92	0.19	0.57	0.89	0.89	0.86	1.10	16
20Z-L3	0.78	0.28	0.59	0.91	0.91	0.88	1.37	16
12Y-L13	0.49	0.67	0.70	0.67	0.74	0.70	0.97	16
Mean	0.745	0.774	0.718	0.817	0.865	0.842	1.124	
Standard Deviation	0.151	0.557	0.116	0.088	0.074	0.093	0.154	
Coefficient of Variation	0.202	0.720	0.162	0.108	0.086	0.110	0.137	

APPENDIX H

Typical Load Deflection Curves From Present Experimental Investigation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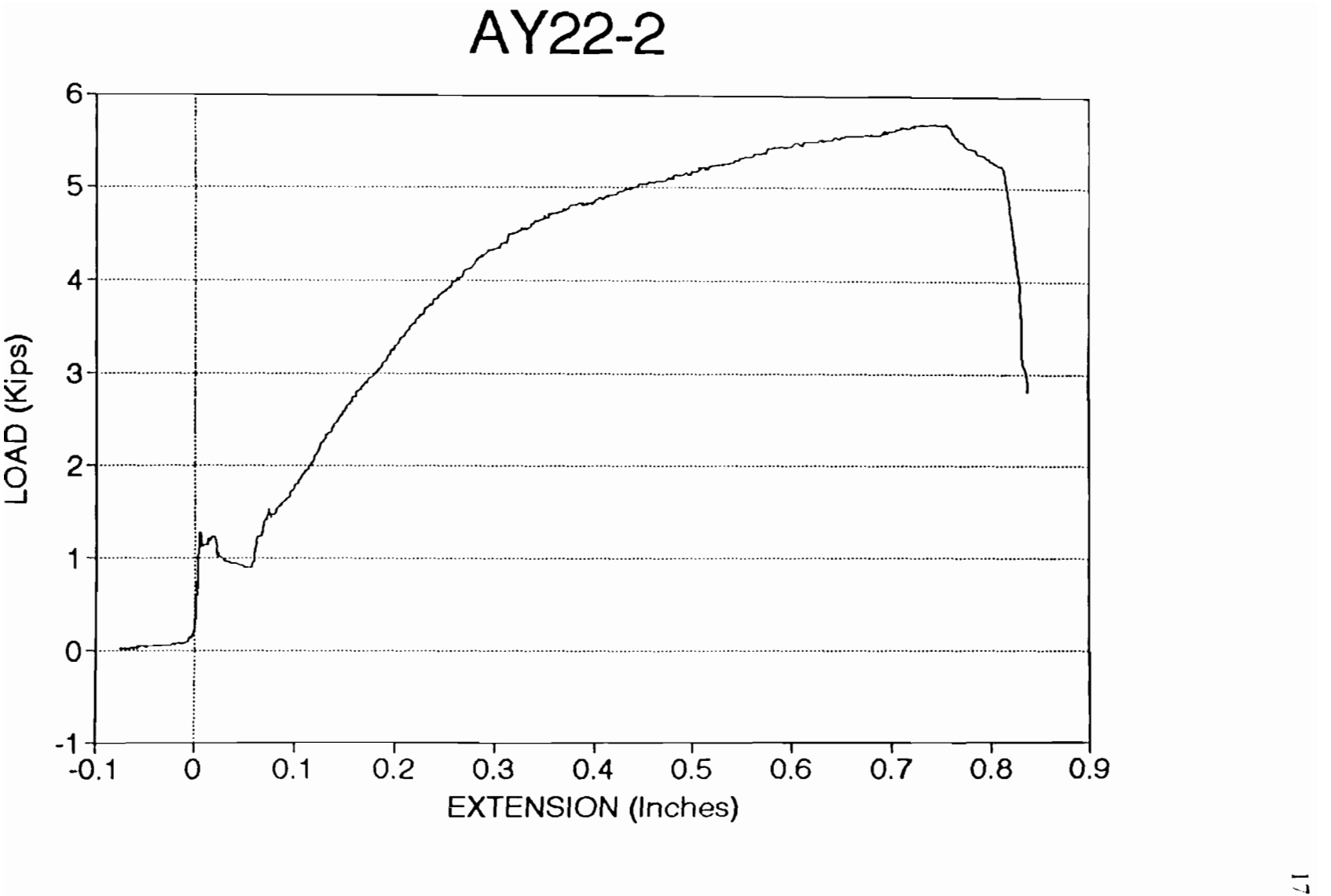
0.5
0.6
0.7
0.8
0.9
1
EXTENSION (Inches)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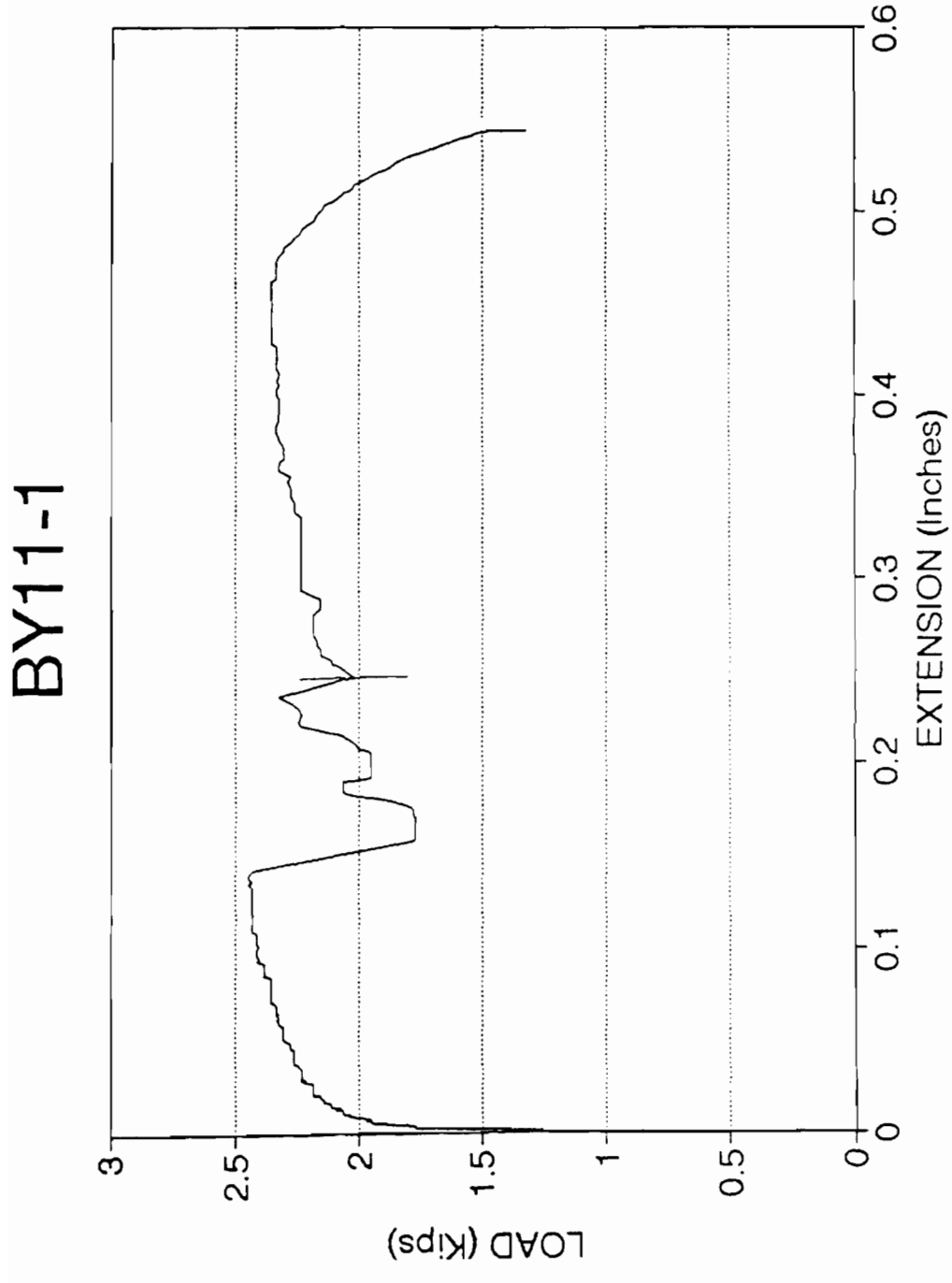
0.5
0.6
0.7
0.8
0.9
EXTENSION (Inches)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3
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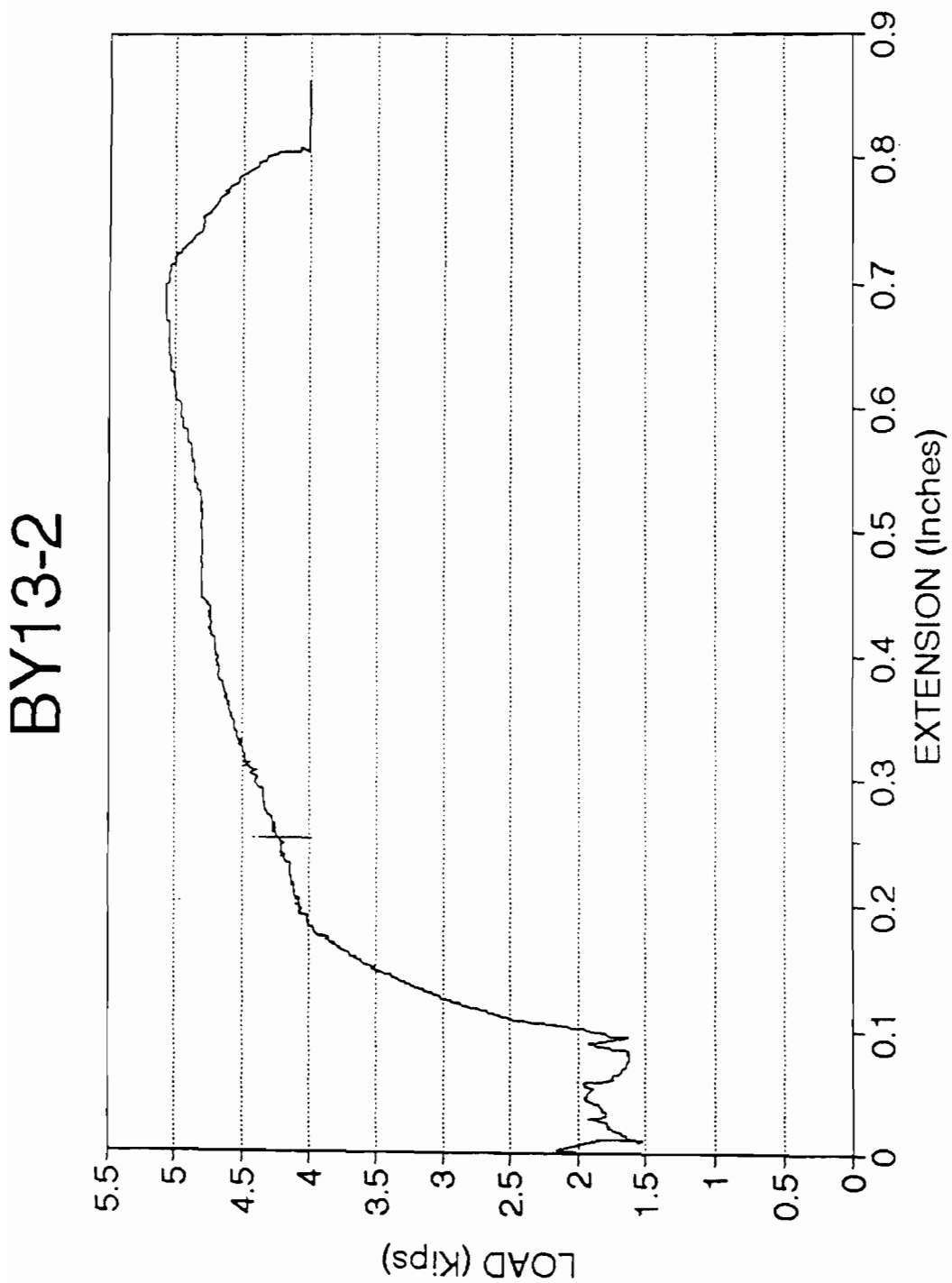
0.4
0.5
0.6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0.1
0.2
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0.6
0.7
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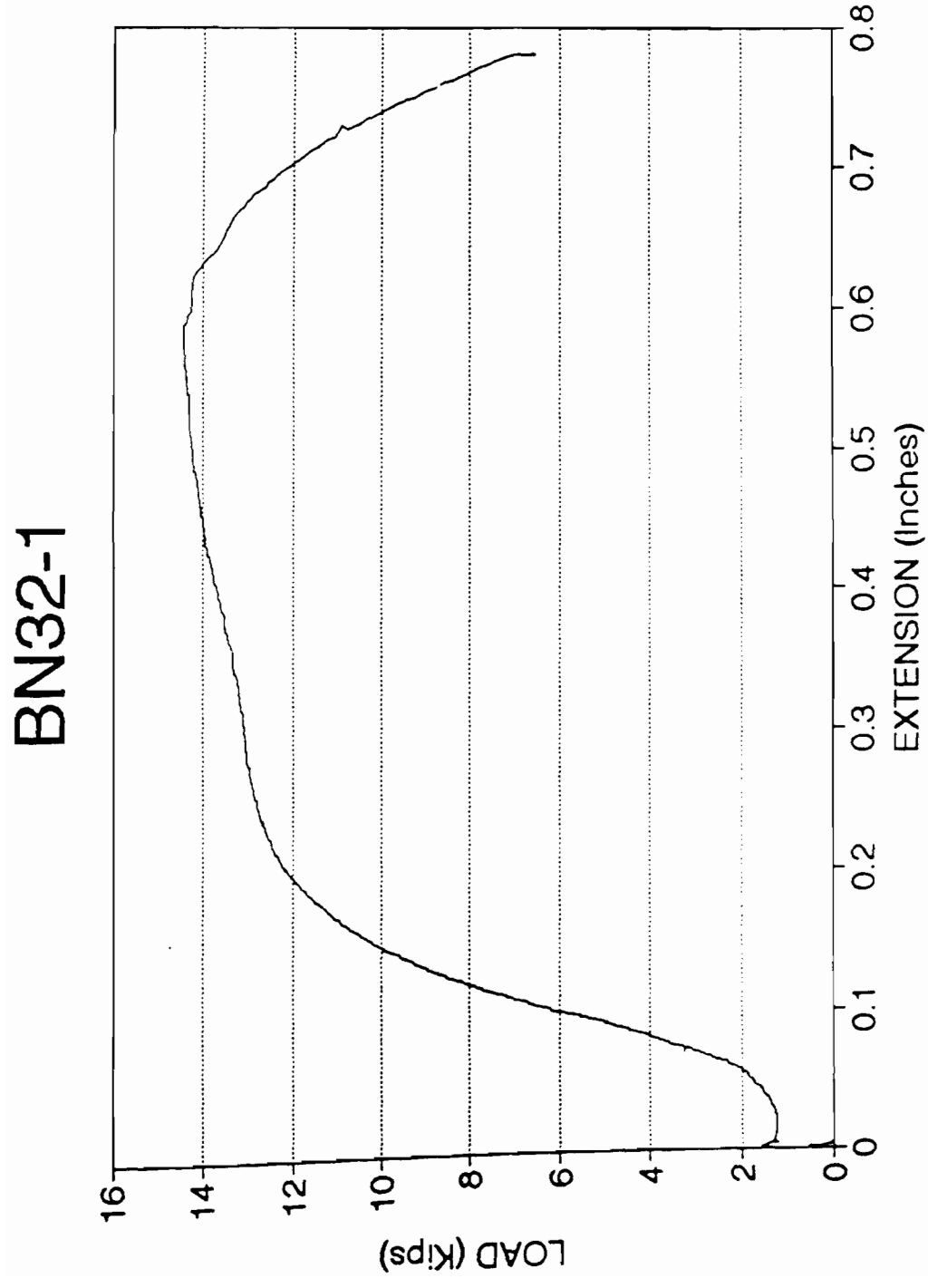
0.9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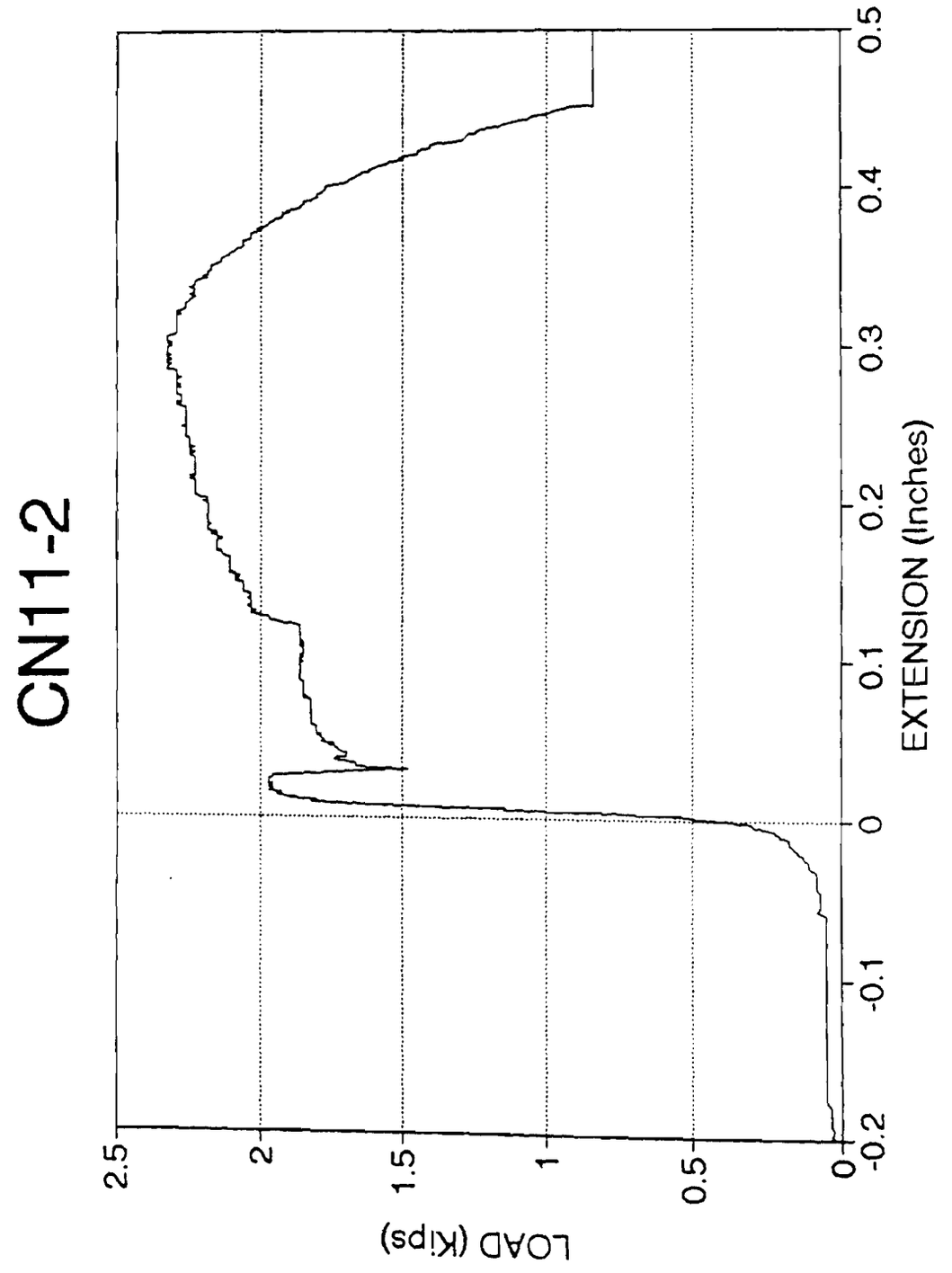
0.6
0.7
0.8
EXTENSION (Inches)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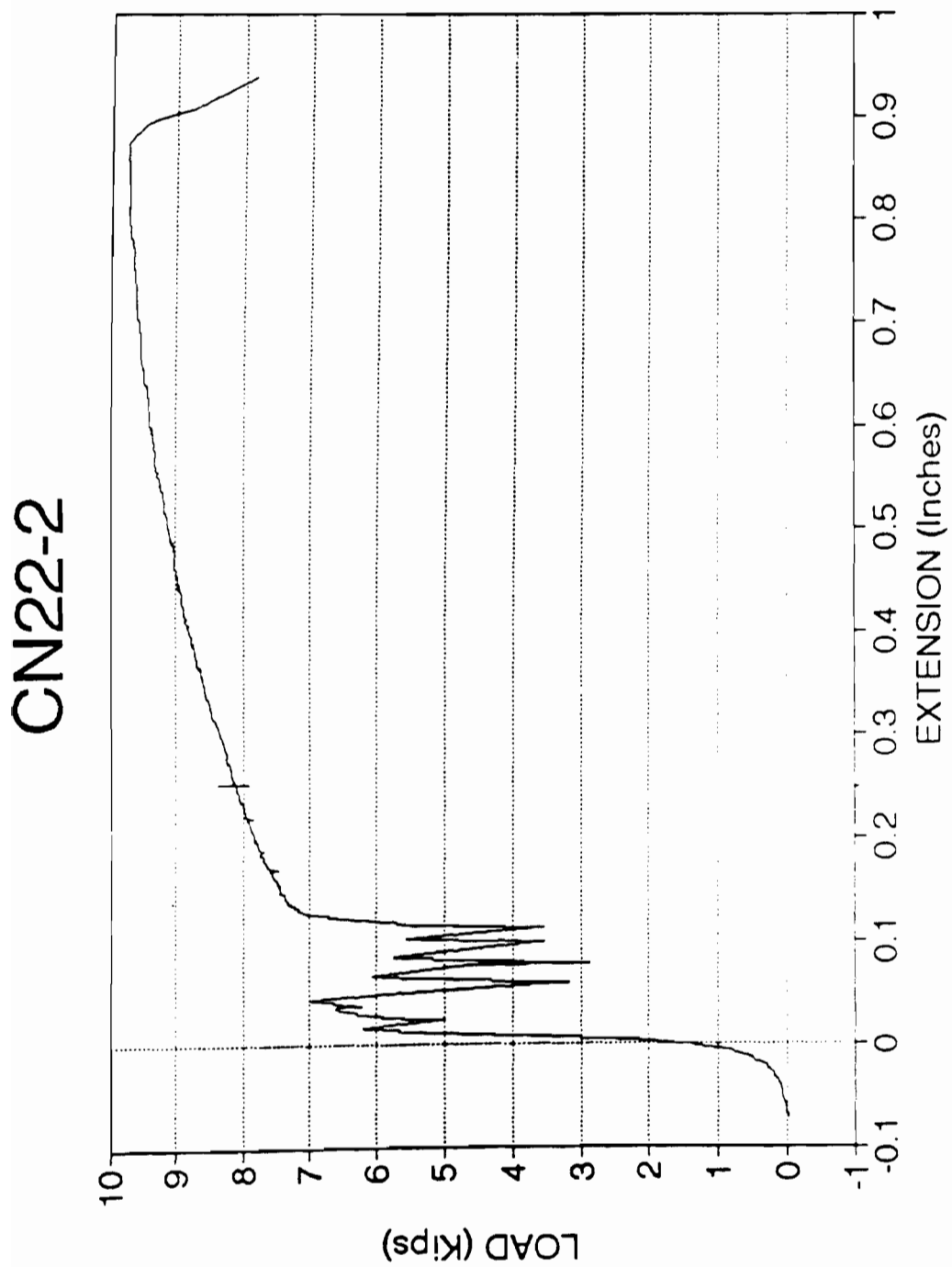
EXTENSION (Inches)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EXTENSION (Inches)
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0.8
0.9
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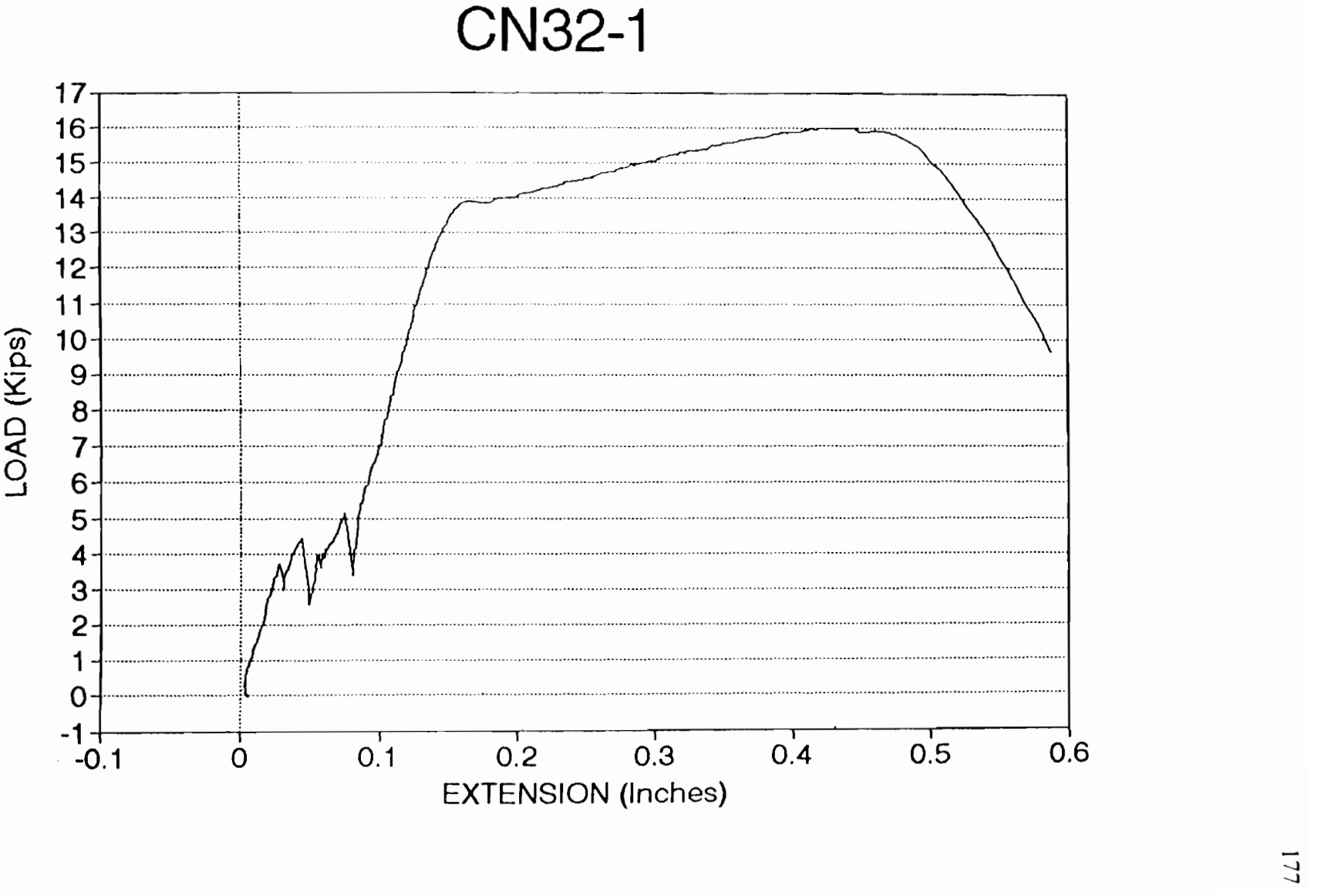
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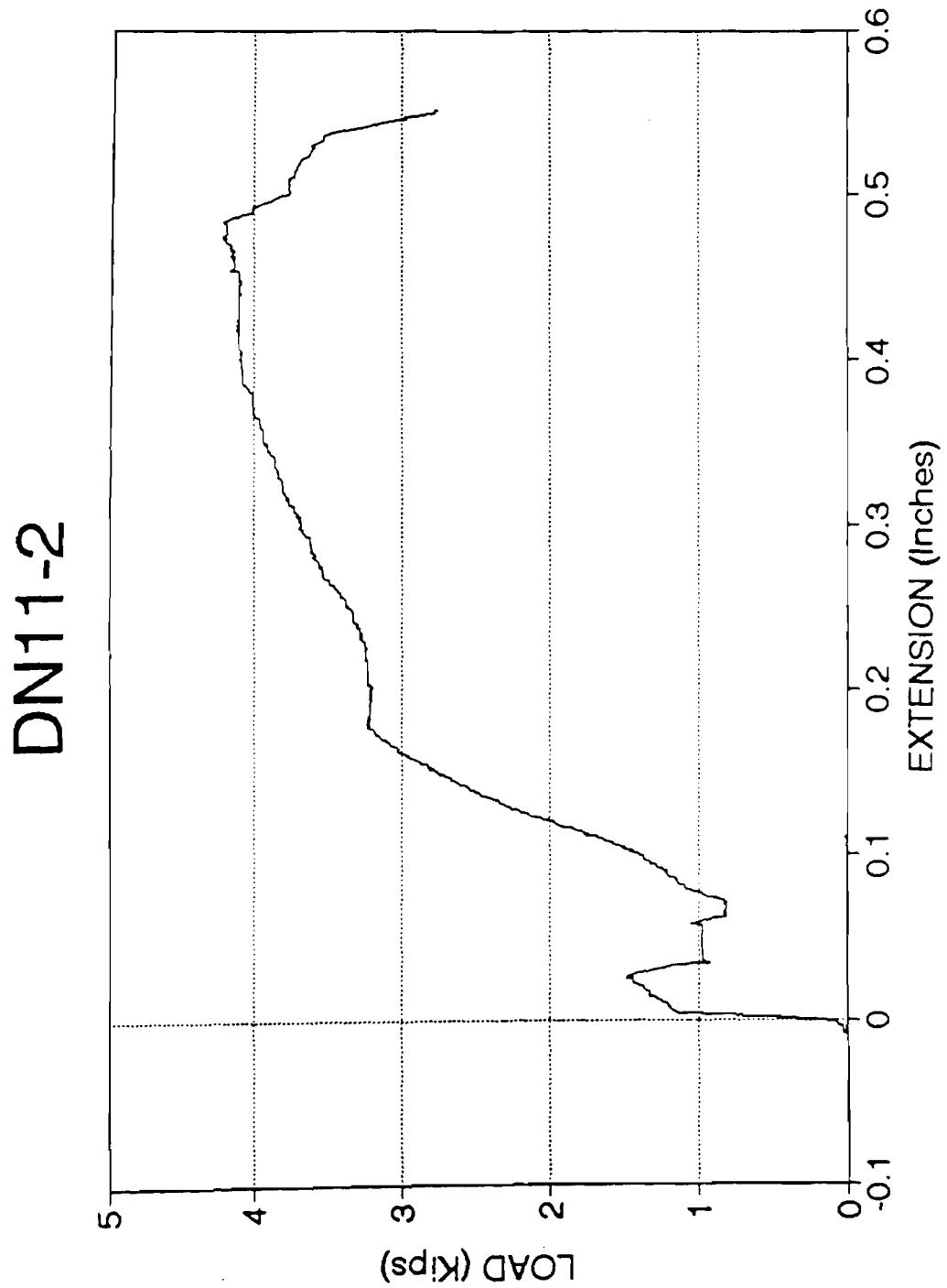
0.4
0.5
0.6
EXTENSION (Inches)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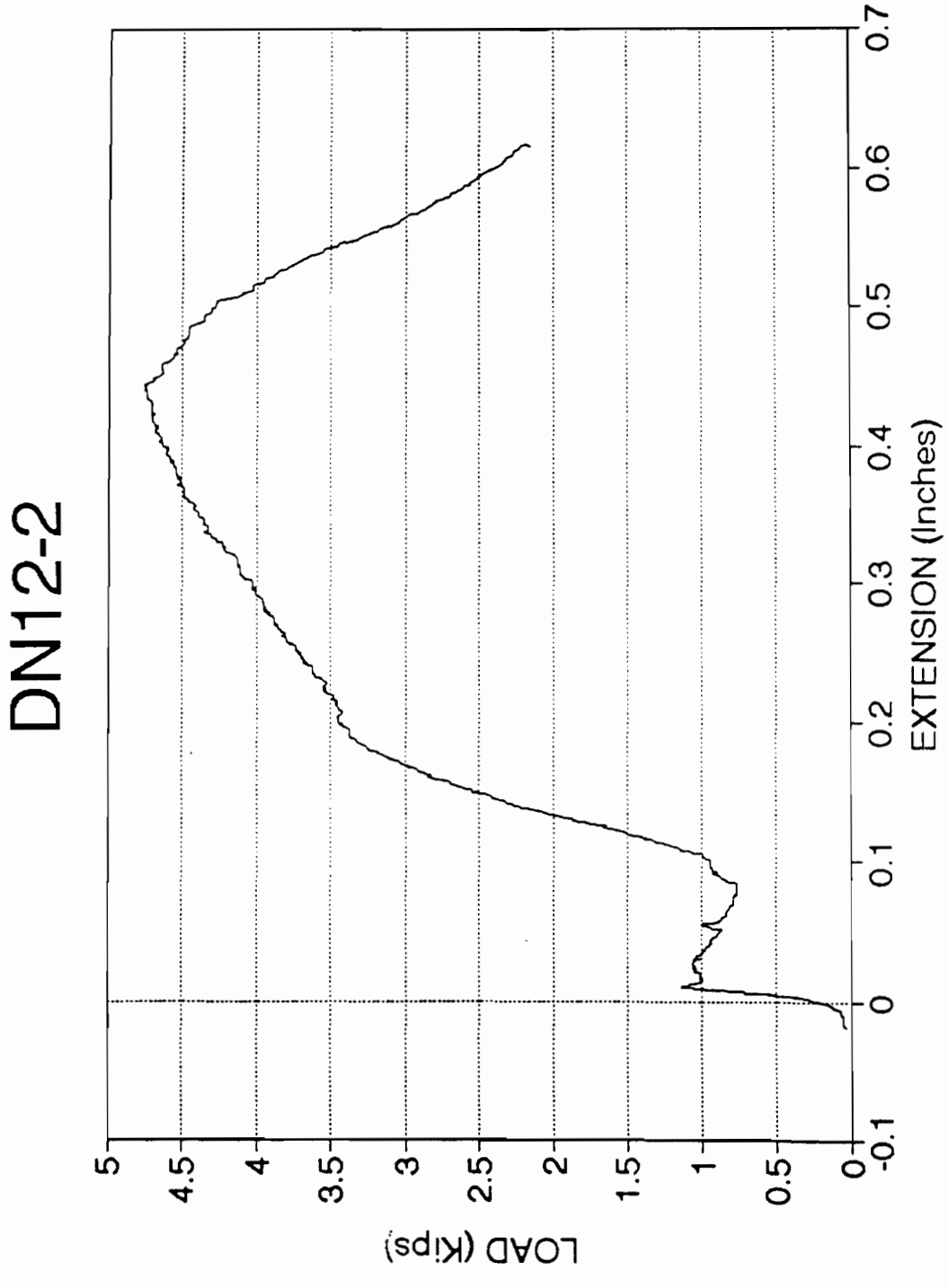
EXTENSION (Inches)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EXTENSION (Inches)
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-0.1
0
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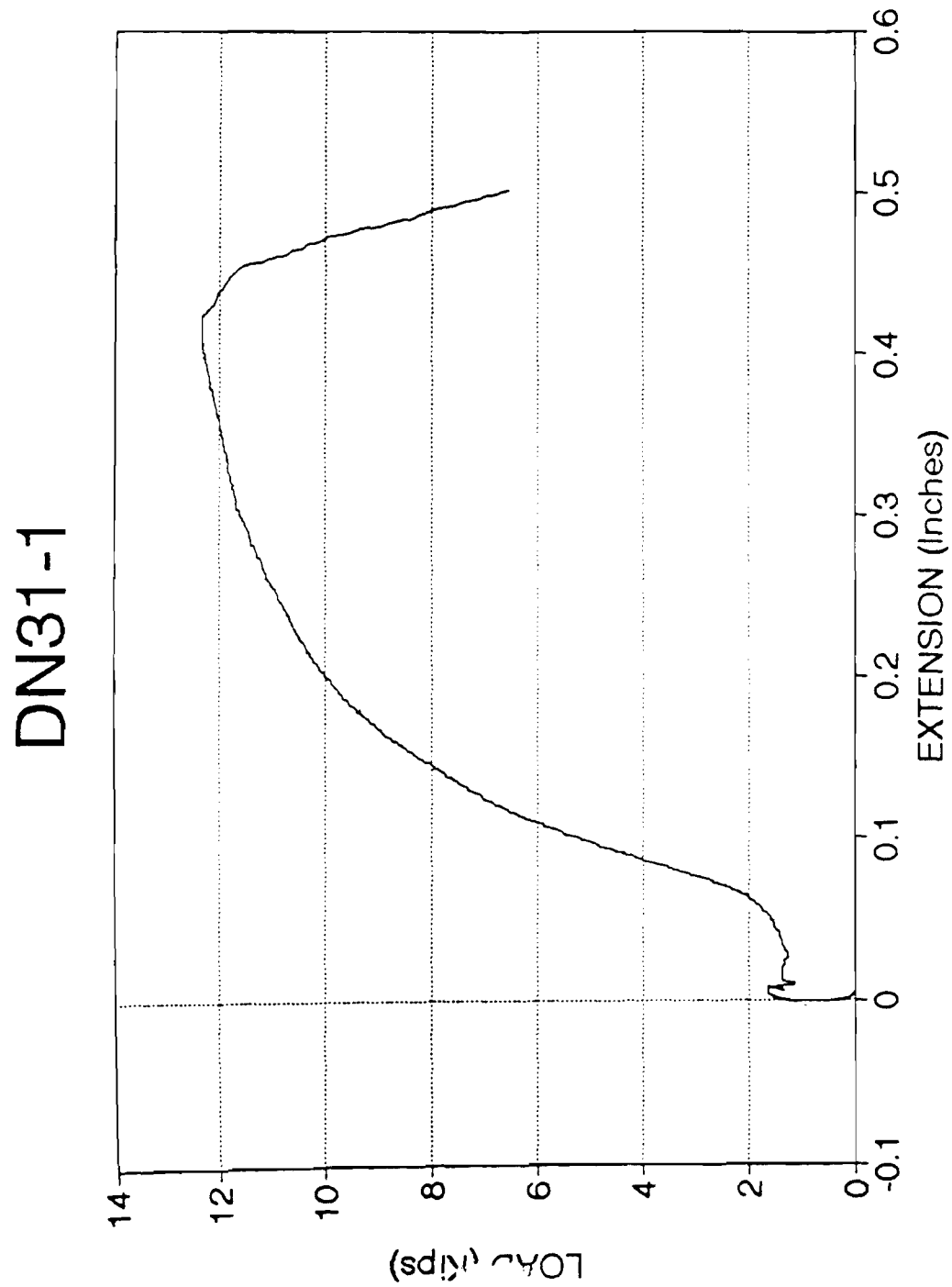
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0.4
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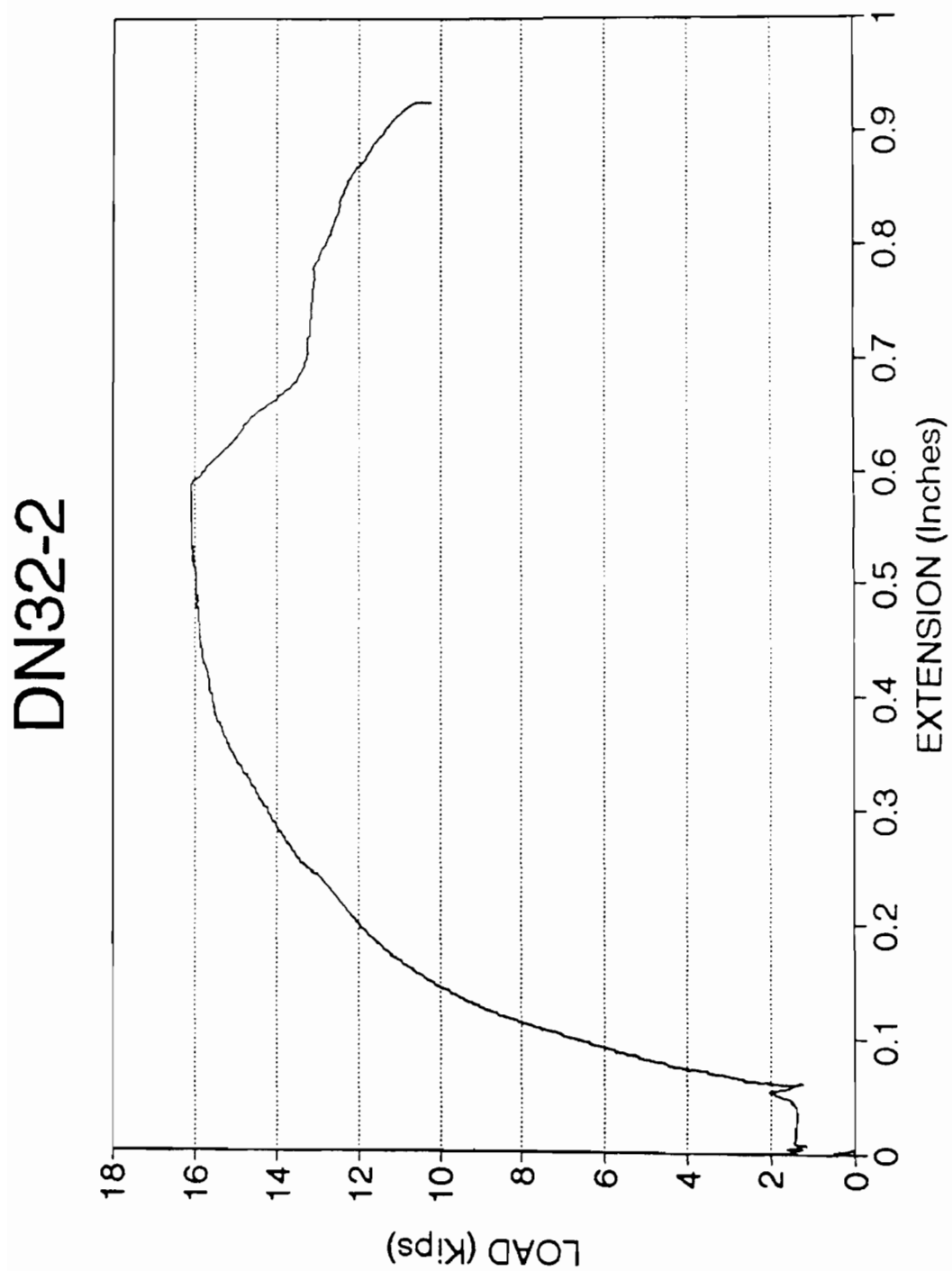
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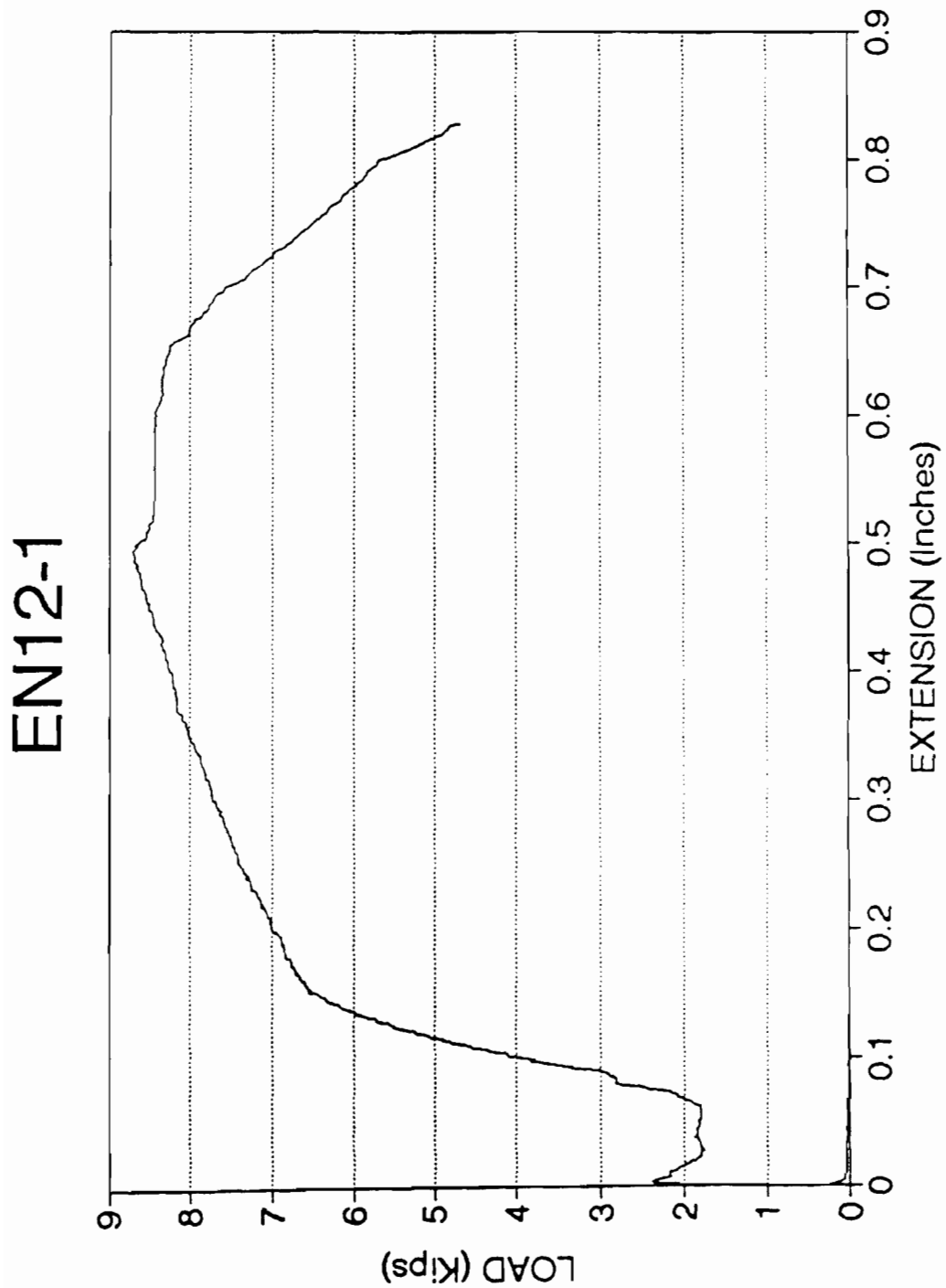
EXTENSION (Inches)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EXTENSION (Inches)
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8
9
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0.4
0.5
0.6
0.7
0.8
0.9

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