Research Report

EFFECTS OF HEAD SIZE ON THE PERFORMANCE OF TWIST-OFF BOLTS

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EFFECTS OF HEAD SIZE ON THE PERFORMANCE OF TWIST-OFF BOLTS

1. PURPOSE

The head diameter of button-head type twist-off bolts necessary for adequate and reliable performance has been brought into question. Following the RCSC Specification, F436 washers are not required under the bolt head when the bolt head diameter equals or exceeds the diameter of a standard ASTM F436 washer, when used on oversized and slotted holes. The same is true for A490 strength bolts that are used with steels that have minimum specified yield strengths less than 40 ksi. The intent of this study was to determine if the RCSC Specification should be modified to allow for ASTM F1852 minimum diameter twist-off bolts.

Minimum head diameters that are smaller than an ASTM F436 washer are allowed under the ASTM F1852 specification. Some manufacturers produce twist-off bolts that have head diameters that are larger than that required by ASTM F1852, but are less than the ASTM F436 washer diameter. These diameters would be required to have a washer under the bolt head on oversized and slotted holes if the current RCSC Specification was followed.

The purpose of this research was to determine if bolts with ASTM F1852 minimum head diameters are comparable to those with a diameter equal to or larger than an ASTM F436 washer. Testing was done on bolt diameters ranging from 5/8 in. to 1-1/8 in., including both A325 and A490 strength bolts. Bolt heads having the minimum required diameter permitted by ASTM F1852 were tested against those having larger head diameters. Plates were used with various hole sizes including standard, oversized, excessively oversized and slotted holes.

2. PREVIOUS RESEARCH

Previous research dealing with twist-off bolts is very limited. Much of this work did not deal specifically with the effects of bolt-head size on pretension forces. However, some work is related to the findings contained in this report.

Research was conducted by Chesson and Munse in the early 1960's at the University of Illinois dealing with the effect of washers on the clamping force of 3/4 in. A325 bolts. Regular and heavy semi-finished hexagon head bolts were used along with finished, heavy, and flanged nuts. Hole sizes ranged from a standard 13/16 in. diameter hole to an oversized hole of 7/8 in. diameter. The majority of the bolts were tightened using turn-of-nut method. The tightening procedure involved snugging the bolt with an impact wrench to approximately 5,000 pounds, then turning the nut or bolt head an additional one-half turn. Bolts that were tightened with washers under the bolt head were compared to those tightened without washers.

Test results showed that the presence of a washer under the bolt head had no significant effect on the clamping or pretension force achieved in the bolts for all hole sizes. The type and hardness of the nut had a greater effect on the clamping force than the washers. The torque required to achieve the pretension forces measured was found to be higher for the bolts without washers due to the galling of the nut into the soft plate material. Hole size did not influence the achieved pretension by a significant amount. All clamping forces on oversized holes without washers were well above the required minimum, and comparable to the tests conducted on standard holes with washers. Long term relaxation of the bolts forces was also studied and found that the inclusion or exclusion of washers had no influence on relaxation. The major difference between the testing conducted by the University of Illinois and the testing contained in this report deals with the kind of bolts used and the method of tightening that was employed -- hexagon head bolts compared to twist-off bolts and turn-of-nut procedure versus twist-off torque control.

Allan and Fisher performed studies on oversized and slotted holes in the late 1960's. They were primarily concerned with holes having larger clearances, above the 1/16 in. and 1/8 in. tested by Chesson and Munse. Bolts of 1 in. diameter and A325 strength were tested in hole sizes of 1/4 in. and 5/16 in. above the nominal bolt diameter and compared against the standard 1/16 in. clearance. The bolts were installed with and without washers using the turn-of-nut method. The results obtained were analyzed to observe the effects of oversized and slotted holes had on achieved bolt pretension, bolt relaxation, and joint slip resistance. The data was used to determine if washers should be required under the bolt head.

Bolts tested in the 1-1/16 in. standard hole without washers were able to attain pretensions well above the minimum, as shown in the previous tests by Chesson and Munse. Bolts tested in the 1-1/4 in. oversized hole without washers had the same average pretension as bolts tested with washers in the same hole size. These pretensions however were slightly lower than those obtained in the 1/16 in. hole size. The increased hole size increased galling around the hole in the test setups that did not include washers under the bolt head. The 5/16 in. oversized holes required washers under both the head and nut to attain the necessary pretension. The relaxation of the bolts was not affected by oversized and slotted holes. Allan and Fisher also concluded that the slip coefficient for the 1-1/4 in. holes were comparable to the standard holes, however the coefficient decreased for the 1-5/16 in. and slotted holes. Omitting washers from the 1-1/4 in. oversized hole did not affect bolt pretension greatly but they were suggested to be used to prevent plate galling.

Other research relating hole size and joint slip coefficients can be found in "Bolted Connections with Varied Hole Diameters" by Shoukry and Haisch. Their tests involved determining the effects oversized holes had on bolted connections. 3/4 in. and 7/8 in. A325 bolts were used in butt and lap joints and were tightened using the calibrated wrench and the turn-of-the-nut methods with washers only under the turned element. Hole clearances ranged from 1/16 in. up to 1/4 in. Testing concentrated on the initial slip of the joints which was needed for slip coefficient calculations. After this data was collected, the specimens were loaded until failure to find the ultimate shear load and shear stress of the joint. Results showed that the slip coefficients and ultimate shear strengths of the joints were not significantly affected by hole clearances up to 3/16 in. This is true for the 3/4 in. and 7/8 in. A325 bolts tested in the butt and lap joints.

More recent testing specifically with twist-off bolts was performed by Kulak and Undershute in the late 1990's, studying factors that affect the achievable pretension force in twist-off bolts. They stated that, "Factors that affect the preload of a tension control bolt are bolt material strength, thread conditions (such as lubrication, dirt, and thread damage), the diameter of the annular groove at the splined end, and friction conditions at the nut-washer interface." The main factors investigated included the effects of storage and aging conditions as well as friction conditions on the achieved pretension force in the bolt. Bolts of 3/4 in. diameter and A325 strength were received from seven different manufacturers. These bolts were of different ages upon receipt and were purposely subjected to different storage conditions prior to tightening. Some of these conditions included sealing the bolts in a container for up to 4 weeks, fully exposing others to the elements and subjecting additional bolts to humid environments. The friction tests involved testing bolts with different lubrication arrangements.

All of the bolts in the storage tests were able to attain the required pretension force. Sealing in containers and exposing to humidity had little effect on the ultimate pretension. Average values for these were 16% to 20% higher than required. Full exposure to weather, and weathered snugged bolts in a steel joint produced the lowest pretension values, around 5% to 10% above that required. The friction tests revealed how loss of lubrication on the assembly affects pretension values. These bolts were an average of 20% below the required preload force. On the high end, bolts and washers that were cleaned and relubricated resulted in a pretension 52% above required. The tests performed by Kulak and Undershute show how important storage conditions and proper lubrication is on the ultimate pretension force in twist-off bolts.

Research by Oswald, Dexter and Brauer dealt with large-diameter bolts and the effects of grip length on pretension forces. Their work found that many 1 in. and 1-1/8 in. bolts that had grip lengths longer than 7 in. were unable to attain the necessary preload required. Shorter length bolts had no problem attaining this value. Reasons for the low pretensions attained were stated as, "greater difficulty in snugging the plies in the connections with the longer bolts and the very high pretension forces that the large-diameter, high-strength bolts required to develop specified pretension stresses…". They suggested that "designers should consider alternatives to the use of large diameter A490 bolts in slip-critical joints, especially if the bolts have a long effective bolt length (greater than 178 mm or 7 in.) and are installed through more than one interface".

The research that is most related to this study is that performed by Chesson and Munse and by Allan and Fisher. Both tests looked at the need for washers under the bolt head in oversized holes. The main difference is the type of tightening procedure used and the type of bolts tested. The work by Allan and Fisher and Shoukry and Haisch added information on effects of hole size on pretension forces and slip coefficients.

Kulak and Undershute's analysis show how storage conditions and lubrication amounts alter the attainable ultimate preload. All bolts tested in this study were kept in closed lid boxes inside the laboratory and were received with proper lubrication prior to tightening. The study by Oswald, Dexter and Brauer demonstrated one more factor that can affect a bolt's pretension force. Although no bolts in this test had a grip of 7 in., it is still important to recognize the potential reduction of attained preload as bolt diameter, grip, and strength increase.

3. DESCRIPTION OF BOLTS

A single twist-off bolt manufacturer provided all of the bolts tested in the project. They supplied both ASTM F1852 minimum head diameter and their standard head diameter in both F1852/A325 and A490 strengths. Specifics for these bolts can be found in the bolt certificates that are provided in Appendix A.

The minimum head diameter bolts that were used during testing had to be manufactured on a special basis by the manufacturer. The bolts were machined from the manufacturer's standard head diameters down to the minimum ASTM F1852 diameter. Table 3.1 provides average measured head diameters for the minimum head diameter and the as-manufactured bolts, and the nominal F436 washer diameters. Figure 3.1 shows photos of minimum and standard head diameters, as supplied.

Bolt Diameter	Minimum Head Diameter (ASTM F1852)	Manufacturer's Standard Head Diameter	F436 Washer Diameter
5/8" (A325)	1.099"	1.166"	1.313"
3/4"	1.340"	1.394"	1.469"
7/8"	1.534"	1.578"	1.750"
1"	1.771"	1.846"	2.000"
1-1/8"	1.992"	2.178"	2.250"

Table 3.1: Average Head Diameters for Supplied F1852/A325 & A490 Strength Bolts, and F436 Washer Diameters

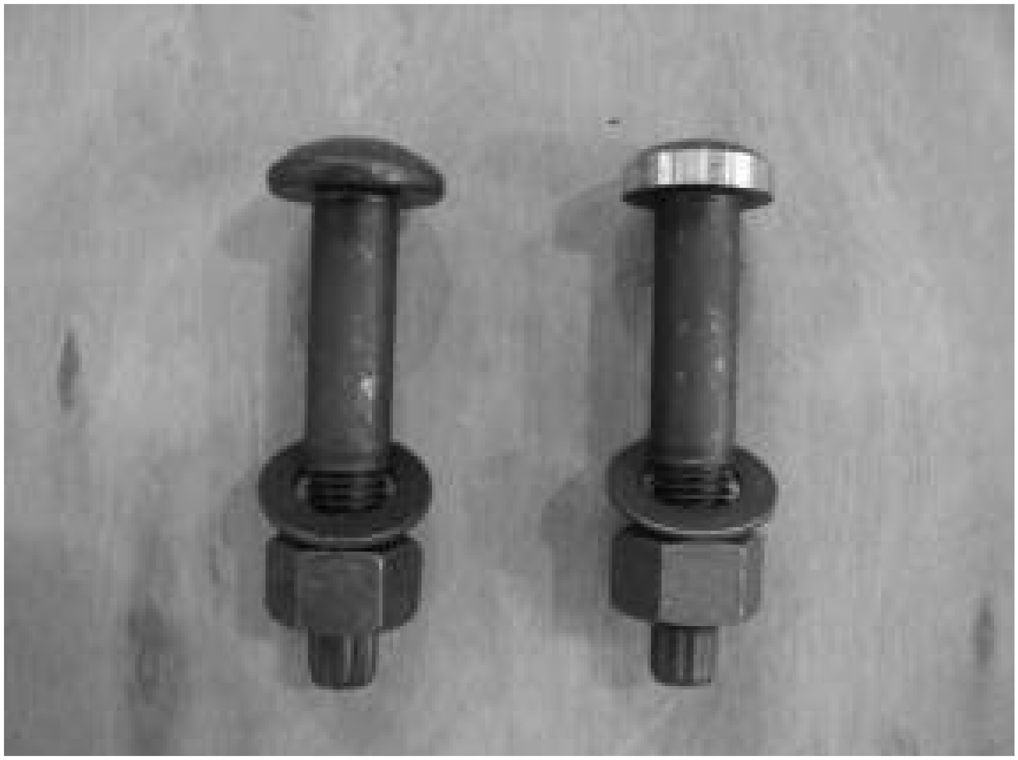

Figure 3.1: Photo of Manufacturer's Standard and F1852 Minimum Diameter 1-1/8" Bolts

4. TEST SETUP AND PROCEDURE

The standard of comparison between the minimum ASTM F1852 and the manufacturer's standard head diameters was the achieved pretension force in the bolt after tightening. A Skidmore Wrench Calibrator, (Model ML), was used to measure the tension in the bolt. Bolts ranging from 5/8 in. to 1-1/8 in. were tested with plates having standard, oversized, grossly oversized, and slotted holes. These plates were steel of A36 minimum yield strength and measured 4 in. square by 1/4 in. thick. Plate holes ranged from 1/16 in. to 3/8 in. greater than the bolt diameter. Testing of specimens produced an average plate yield strength of 34.89 ksi and tensile strength of 51.27 ksi. All plate holes were measured prior to testing to ensure correct diameters.

The test setup involved placing the bolt head along with a plate on the front of the Skidmore with a flat bushing on the rear. A washer and nut was placed on the bolt and tightening was done from the back on the Skidmore. Figure 4.1 shows a typical setup from the front of the Skidmore. Additional pictures of the test setup can be found in Appendix E. Two different electrically powered Tone wrenches were used for tightening the bolts, Model S-60EZA for the 5/8 in. through 7/8 in. bolts, and Model S-110EZ for the 1 in. and 1-1/8 in. bolts.

Once the bolts were installed in the Skidmore, the wrench was used to snug the bolts against the plate. After waiting several seconds, the wrench was then used to tighten the bolts until the splined end sheared off. An initial measurement of bolt pretension was taken 5-10 seconds after tip twist-off. A second reading was taken 30-45 seconds later after most of the bolt relaxation had occurred. After the two readings were recorded, the bolt was then removed using an air impact wrench. All bolts and plates were visually inspected after testing for concerns such as plate embedment depths.

Tables 4.1 and 4.2 show the test plate matrix used for each bolt diameter. Bolt strengths of F1852/A325 and A490 were tested for bolt diameters ranging from 3/4 in. through 1-1/8 in. The 5/8 in. diameter bolts were tested with F1852/A325 strength only, due to the lack of availability of A490 strength twist-off bolts.

The first set of tests were conducted with the bolts centered in the middle of the hole. The holes in these plates were punched, which resulted in a slightly larger hole diameter on one side of the plate. All bolt diameters except the 7/8 in. were placed in the Skidmore with the larger diameter facing the bolt head. The plates used for the 7/8 in. bolts were reversed so that the smaller hole diameter was now facing the bolt head. This was done to determine if there would be any noticeable difference in performance.

After the first set of tests were finished, a second set of tests were conducted placing the bolt to one side of the hole diameters. This was done to determine if there were any deviations in performance compared to tests performed with the bolts centered in the holes. 3/4 in. through 1-1/8 in. bolts were used for these tests, as outlined in Table 4.2. The holes in these plates were punched in some as well as drilled or punched and flame-slotted in others. All plates were placed with the larger hole diameter facing the bolt head.

Table 4.1: Test Matrix with Bolts Centered in Holes

Bolt Diameter	Standard Holes	3/16" Oversized	1/4" Oversized	5/16" Oversized	3/8" Oversized	Long-Slotted
5/8" (A325)	11/16"	13/16"	7/8"	15/16"		11/16" x 1-9/16"
3/4"	13/16"		1"	1-1/16"		13/16" x 1-7/8"
7/8"	15/16"		1-1/8"	1-3/16"		15/16" x 2-3/16"
1"	1-1/16"		1-1/4"	1-5/16"		1-1/16" x 2-1/2"
1-1/8"	1-3/16"			1-7/16"	1-1/2"	1-3/16" x 2-13/16"

As previously explained, the F1852 minimum and manufacturer's standard bolt heads were tested in standard, oversized, grossly oversized and long-slotted holes in centered and off-centered positions. With the change in hole size along with bolt position, comes a change in the bearing area between the plate and the underside of the bolt head. The influence of bearing area on the achievable pretension force in twist-off bolts will be discussed further in the coming sections.

Table 4.2: Test Matrix with Bolts Placed to One Side of Hole

Bolt Diameter	5/16" Oversized	3/8" Oversized	Short-Slotted
3/4"			1-1/16" x 1-5/16"
7/8"	1-3/16"		
1"			1-3/16" x 1-9/16"
1-1/8"		1-1/2"	

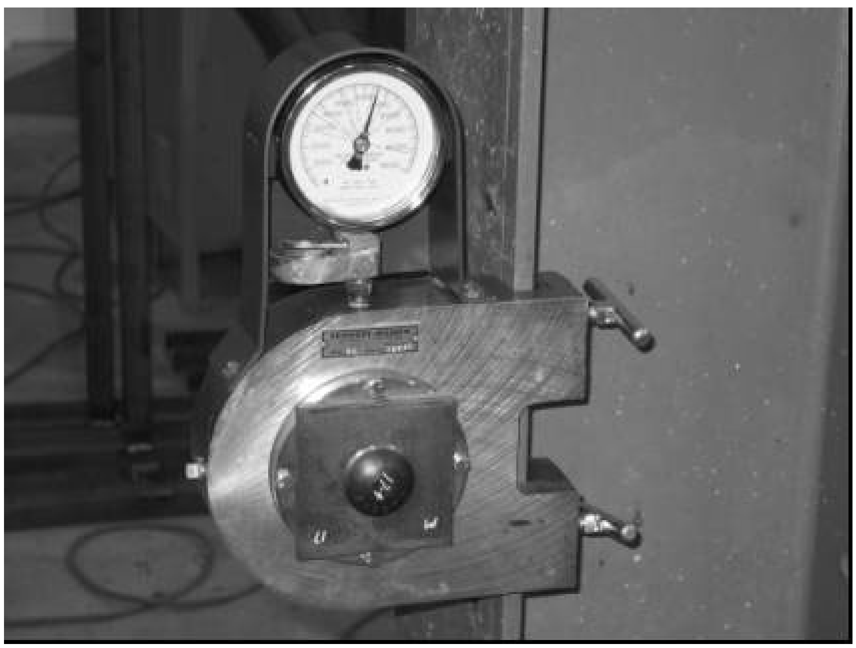

Figure 4.1: Typical Skidmore Setup with Test Sample

5. EXPERIMENTAL RESULTS

5.1 Overview

Results for the tests on the F1852/A325 and A490 strength bolts can be found in Appendices C and D, respectively. The data shows initial and relaxed bolt tension strengths that were read directly from the Skidmore. Usually a drop of one to two kips occurred between the initial and relaxed readings.

Graphs have also been included in Appendices C and D as well as below. Unacceptable and acceptable regions for all of the bolts are shown on the graphs.

5.2 Results for F1852/A325 Strength, Centered Bolts

In Figures 5.1 through 5.3, A325 strength, ASTM F1852 minimum head diameter bolts are compared against the manufacturer's standard bolts. The three figures are divided into standard, oversized, and long-slotted holes, with all of the bolts centered in the holes. Each of these figures clearly indicates that the F1852 minimum head diameter bolts are able to achieve the same pretension as the manufacturer's standard bolt. All of the F1852/A325 bolts, minimum and standard, were above the necessary required bolt pretension force. The minimum head diameter bolts are all within the reasonable scatter that is expected.

More significantly, the size of the hole in the plate showed no significant effect on the achieved bolt pretensions. The bolt forces developed in the standard, oversized, excessively oversized and long-slotted holes are all randomly distributed within the normal scatter for both minimum and standard bolt diameters. Figures C.1 and C.2 in Appendix C illustrate these results. A more in-depth look at the pretension forces for each bolt diameter is available in Figures C.3 through C.7 in Appendix C. Individual graphs for each F1852/A325 bolt diameter are provided which show the achieved pretension for each specific hole size. F1852 minimum and the manufacturer's standard bolt heads are compared against each other. Averages of the pretension force per bolt head and hole clearance are also shown.

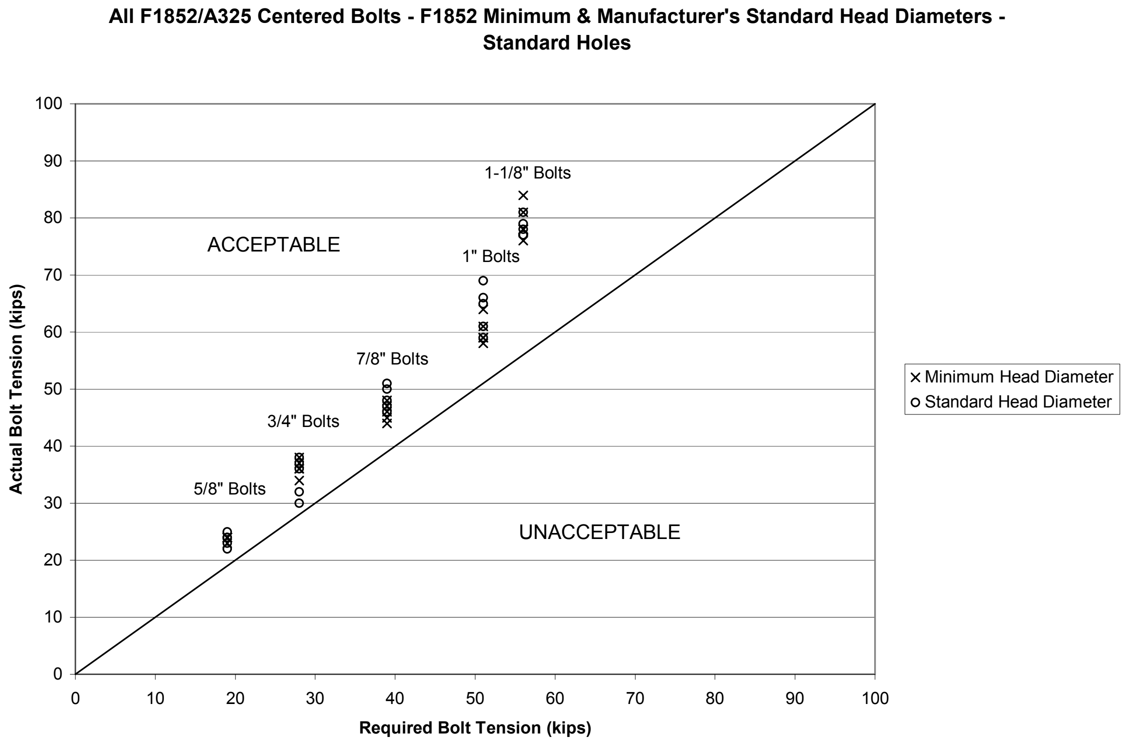

Figure 5.1: F1852/A325 Strength, Centered Bolts, Standard Holes

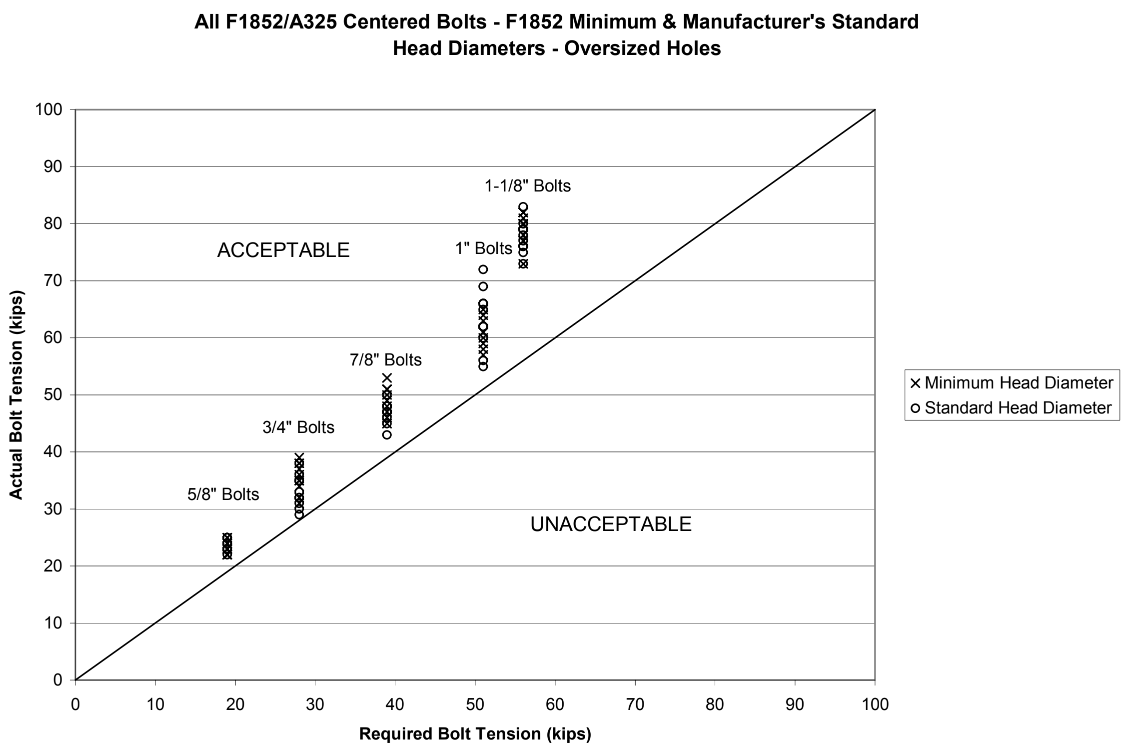

Figure 5.2: F1852/A325 Strength, Centered Bolts, Oversized Holes

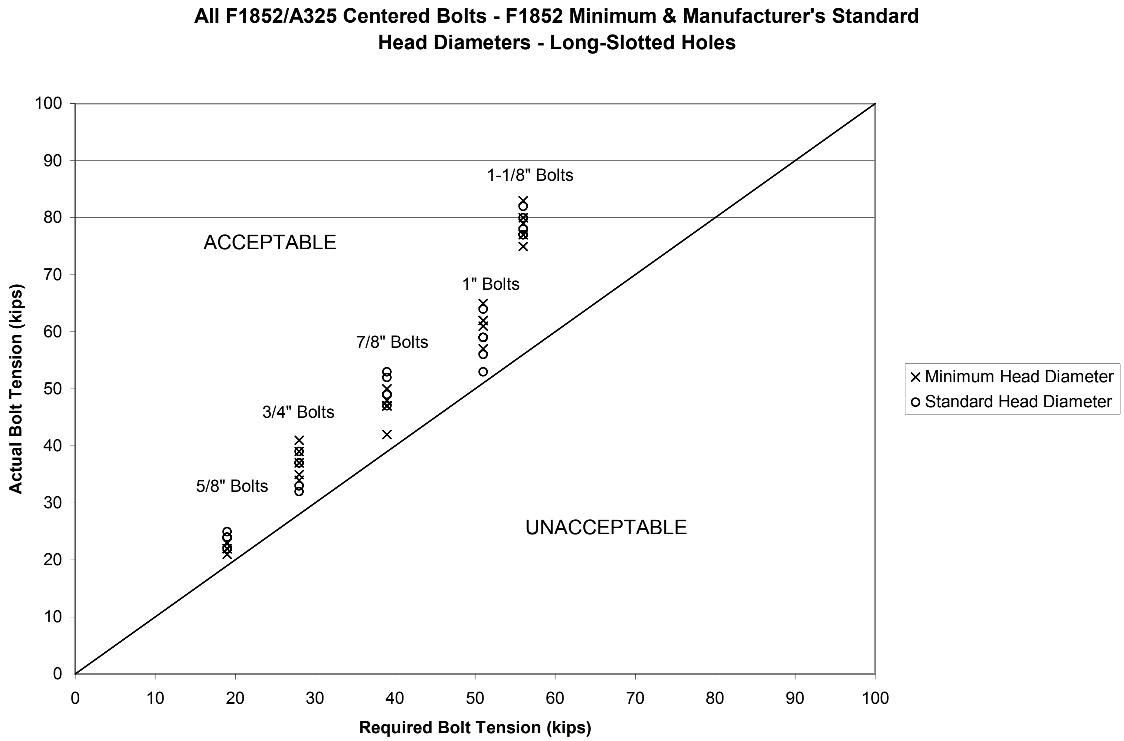

Figure 5.3: F1852/A325 Strength, Centered Bolts, Long-Slotted Holes

5.3 Results for A490 Strength, Centered Bolts

In Figures 5.4 through 5.6, A490 strength bolts with the ASTM F1852 minimum head diameter are compared against the manufacturer's standard. The figures are divided by standard, oversized, and long-slotted holes with all of the bolts centered in the holes. All three plots are consistent with the results from the F1852/A325 tests. The minimum head diameter bolts show no indication that they are unable to achieve as much pretension as the manufacturer's standard head bolt. A single 7/8 in. bolt was found to have a relaxed pretension of 42 kips which is well below the required pretension of 49 kips. It is believed that this bolt was damaged in some way, and therefore it has been recorded but excluded from the averages. The 7/8 in. bolts were closest to the required pretension for both the minimum and manufacturer's standard bolt heads. The range of minimum and maximum pretension increased as the hole sizes increased from standard to oversized to long-slotted. This is most evident for the 1-1/8 in. bolts.

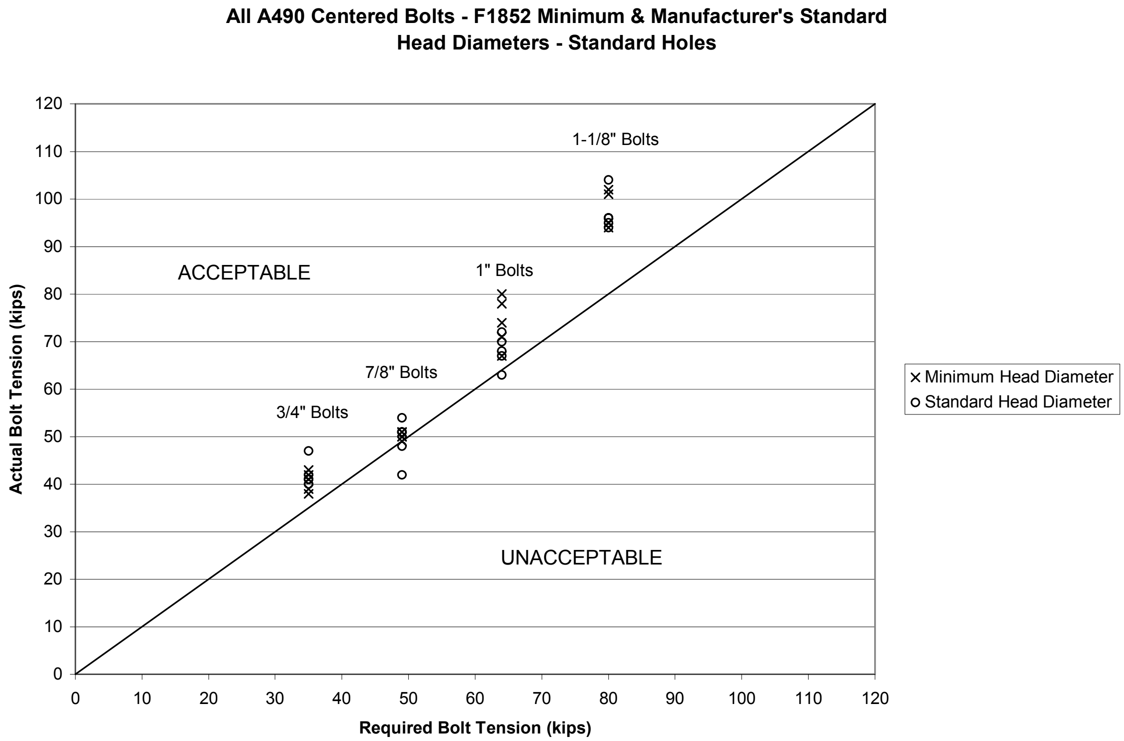

Figure 5.4: A490 Strength, Centered Bolts, Standard Holes

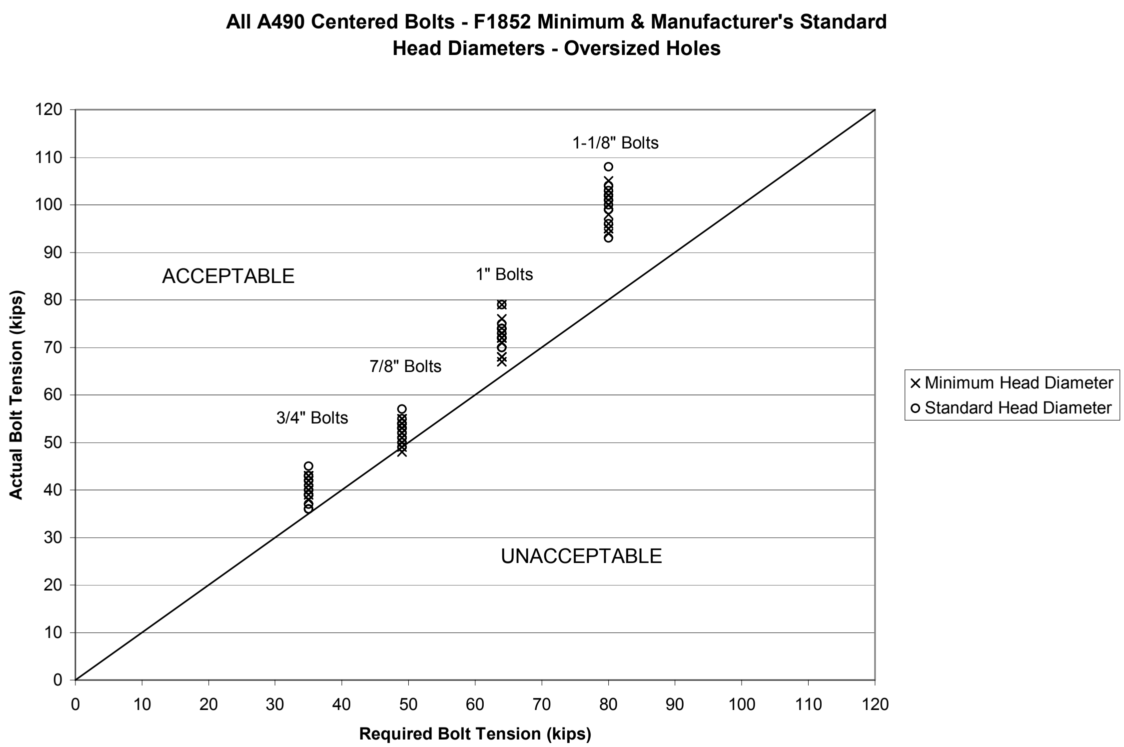

Figure 5.5: A490 Strength, Centered Bolts, Oversized Holes

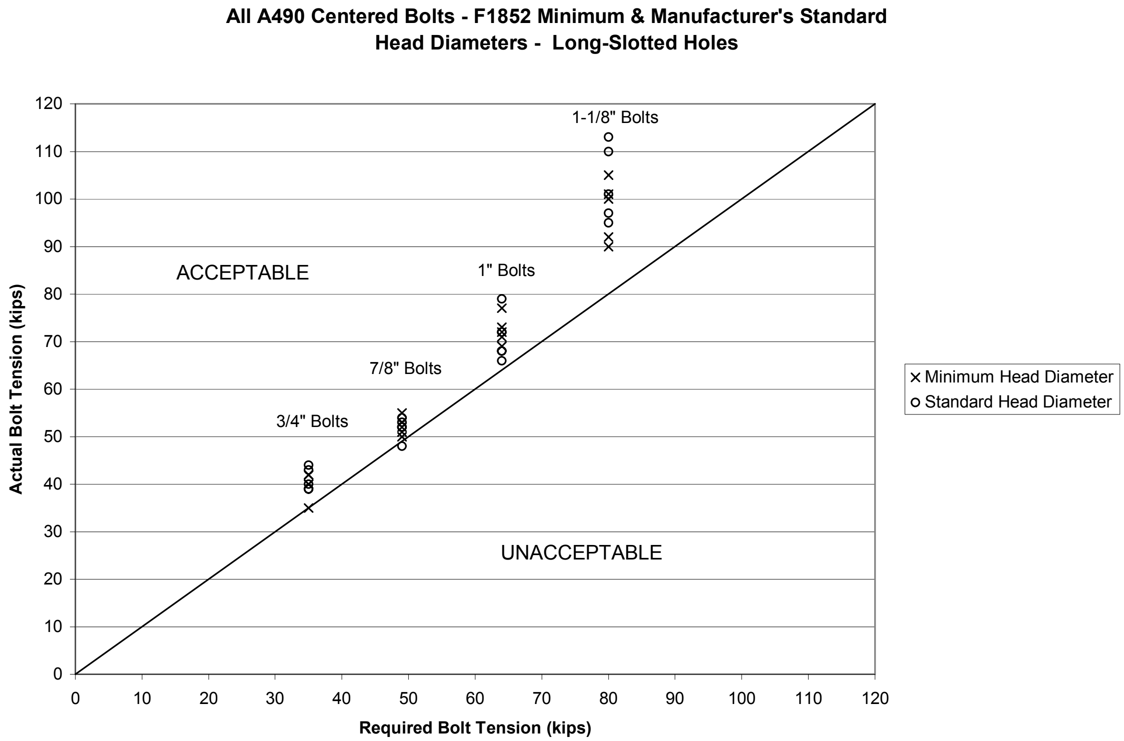

Figure 5.6: A490 Strength, Centered Bolts, Long-Slotted Holes

More significantly, the effect of hole size on the A490 bolts can be seen in Figures D.1 and D.2 in Appendix D. The effect of standard, oversized, grossly oversized and long-slotted holes on pretension forces is minimal. The achieved pretensions for all four hole sizes are within the regular expected distribution, for both the minimum and standard head diameters. Additional graphs of pretension forces for each bolt diameter are available in Figures D.3 through D.6 in Appendix D. Individual graphs for each A490 bolt diameter are provided which show the achieved pretension for each specific hole size. F1852 minimum and the manufacturer's standard bolt heads are compared against each other. Averages of the pretension force per bolt head and hole clearance are also shown.

5.4 Results for F1852/A325 & A490 Strength, Off-Centered Bolts

After all of the testing was complete with the various bolts centered in the plate holes, a second set of tests was run with bolts set in off-centered positions. This was done with 3/4 in. through 1-1/8 in. bolts with the plate holes shown in Table 4.2. Results of these tests are in Appendix C and D as well as in Figures 5.7 and 5.8 below. The achieved pretensions for minimum and standard bolt diameters were not affected significantly by this alteration. All of the F1852/A325 strength bolts were well above the required pretension. A few of the A490 strength, 7/8 in. bolts were just below the required strength, which is consistent with the previous tests. The 3/4 in. and 1 in. bolts were not affected significantly by the short-slotted holes. Average pretensions for both of these were well within the expected scatter. Comparing Figures 5.7 and 5.8 with Figures C.1, C.2, D.1 and D.2 also shows the minor effects of off-centering the bolt.

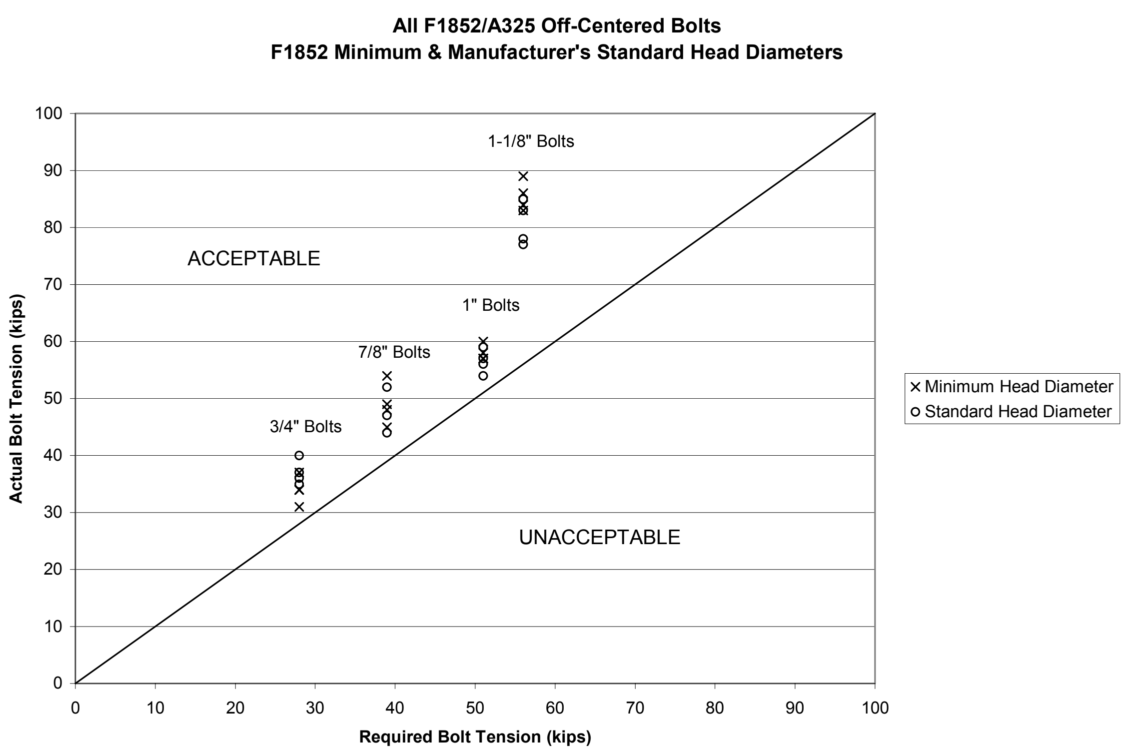

Figure 5.7: F1852/A325 Strength, Off-Centered Bolts

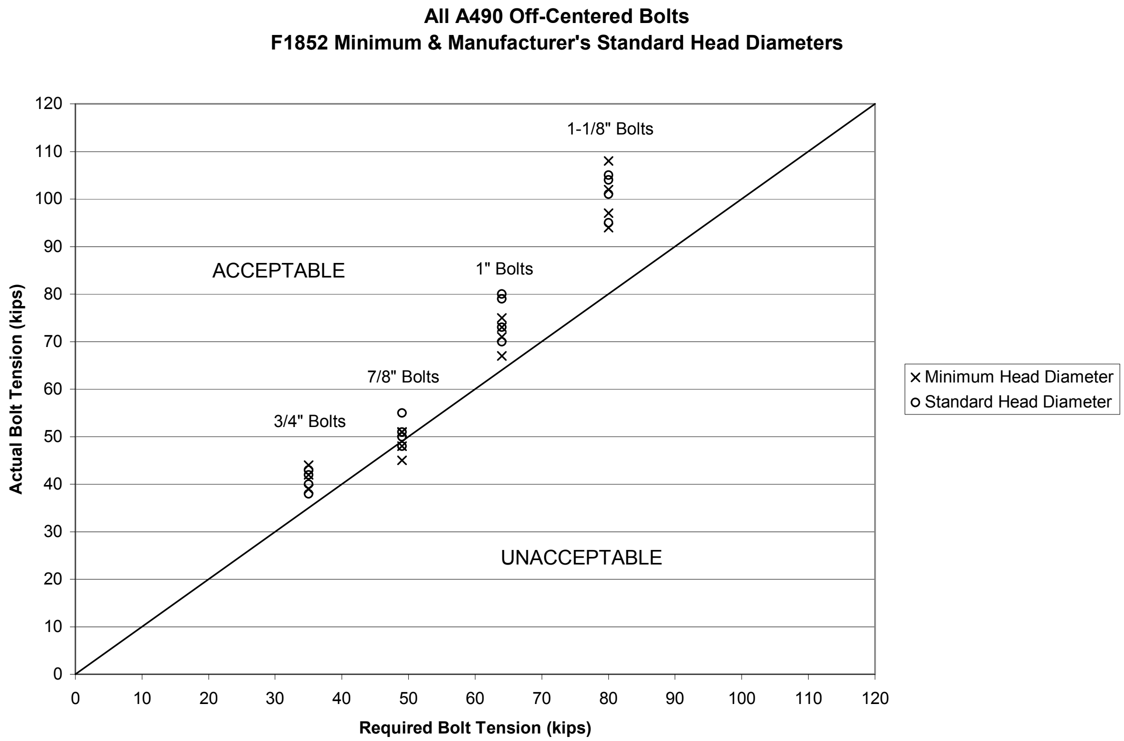

Figure 5.8: A490 Strength, Off-Centered Bolts

The tests conducted on the A325 and A490 centered bolts along with the tests on the A325 and A490 off-centered bolts demonstrates the lack of influence that hole diameter has on achieved pretension. The hole diameter, whether standard, oversized, grossly oversized or long-slotted relates directly to bearing area under the twist-off bolt head. Whether the bearing area is large or small, it will not affect the achieved pretension force in a twist-off bolt. This is due to the type of bolts used along with the method needed for tightening – torque control.

6. CONCLUSIONS

The purpose of this investigation was to determine if RCSC Specification should be modified to allow for smaller bolt heads on twist-off bolts. The current specification removes washer requirements for bolts with a head bearing diameter equal to that of an F436 washer. The ASTM F1852 specification allows for smaller bolt head diameters.

Testing was conducted on bolts with both minimum and a manufacturer's standard head diameter. The bolts ranged in size from 5/8 in. to 1-1/8 in., and included both F1852/A325 and A490 strength. These bolts were tested on various hole sizes in both centered and off-centered positions. A total of 434 bolts were tested, half with minimum head diameter, the other half with the manufacturer's standard head diameter. Of the 217 minimum head diameter bolts, only three were under the required pretension force and deemed unacceptable. Of those with the manufacturer's standard head diameter, five of the 217 bolts were found to be unacceptable. Overall, both head diameters performed well in all circumstances, regardless of hole size and type.

Final analysis of the data has shown that there is no significant difference in the achieved pretension force between the manufacturer's standard head and minimum bolt head diameter. The data clearly indicates that the minimum head diameter is able to attain the same pretension force as the manufacturer's standard head diameter.

More significantly to the issue of the RCSC Specification provisions regarding twist-off bolt head diameter, the size of the hole is also shown to not affect the pretension force in the bolt. The pretension expected to be achieved with a bolt with the minimum F1852 head diameter is the same as that of a bolt with a larger head diameter equal to the size of a F436 washer, if the hole size meets the RCSC Specification limitations on hole size.

This conclusion can be drawn from the fact that amount of bearing surface under the twist-off bolt head does not affect achieved bolt pretension. This was demonstrated by measuring bolt pretension in grossly oversized round holes, when used centered in long-slotted holes, and when off-centered in slotted holes, without the presence of a washer beneath the head as called for in the RCSC Specification. There was no significant reduction in achieved bolt pretension from that of a standard hole diameter, even with minimum bolt head diameters, when these bolts were used in bolt holes that exceeded the oversized diameter permitted by the RCSC Specification. Similarly, the bolt bearing area was at a minimum when used centered in long-slotted holes, yet the achieved bolt pretension was virtually identical to that achieved in a standard hole.

Tests using A490 strength level twist-off bolts in very low-strength steel plate also demonstrated that the achieved pretension was not significantly reduced with either oversized or slotted holes, compared to standard holes.

Because the twist-off bolt uses torque control to establish the shearing of the bolt spline, it is not affected by the amount of embedment in the steel plate that occurs beneath the bolt head. There is a reduction in achieved pretension if turn-of-nut methods are used, as embedment depths increase, as demonstrated by prior University of Illinois tests. The amount of embedment of the steel beneath the bolt head increases with smaller bolt head size, with increasing bolt hole diameter, higher strength (A490 strength compared to F1852/A25 strength) bolts, and lower strength material, but there is no correlation with bolt pretension associated with the amount of embedment when the twist-off bolt method is used.

The RCSC Specification footnote (a) to Table 6.1 should be revised to reflect that washers are not required beneath the bolt head of a twist-off bolt provided that the bolt head diameter meets the minimum head diameter requirements of ASTM F1852, rather than provide a bearing circle equal to or greater than that of an F436 washer. Similarly, section 6.2.1 should be revised to state that a washer is not required beneath the head of an A490-strength twist-off bolt when used in steels with a specified minimum yield strength less than 40 ksi, provided the bolt head diameter meets the minimum head diameter requirements of ASTM F1852.

7. REFERENCES

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APPENDIX A

BOLT INSPECTION CERTIFICATES

60501A

INSPECTION CERTIFICATE

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

SET LOT NO. 60501A

Specification	Size	Quantity
ASTM F1852 Type 1 -00 ASTM A563 Grade DH -00 ASTM F436 Type 1	5/8-11 UNC X 3	7,920 pcs.

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

Date: Aug. 26, '02

BOLT LOT NO. 60501

	Mechanical Property of Full Size Bolts: Tensile Strength, Load (lbf)	Tensile Strength, Position of fracture	PROOF LOAD 19200 lbf. (Length Method)	Hardness HRC	Heat Treatment °F (°C), Quench	Heat Treatment, Temper	IDENTIFICATION	Chemical Composition %: C x 100	Si x 100	Mn x 100	P x 1000	S x 1000	Cu x 100	Ni x 100	Cr x 100	Mo x 100	B x 10,000
Spec.	Min. 27100	Part of Screw	Max. +/- 0.0005 in.	25 - 34	--	Min. 800	Heat No.	30 52	--	Min. 60	Max. 40	Max. 50	--	--	--	--	5 30
Average	34972	Part of Screw	ALL PASS	32.7	1580	860	7325902	30	25	82	11	14	1	2	8	2	18

NUT LOT NO. 05051

	Hardness (HRC)	Hardness After 24 hr x 1000° F HRB	Proof Load (Lbf)	Heat Treatment °F (°C), Quench	Heat Treatment, Temper	IDENTIFICATION	Chemical Composition %: C X 100	Si X 100	Mn X 100	P X 1000	S X 1000	Cu X 100	Ni X 100	Cr X 100
Spec.	24 - 38	Min. HRB 89	0	--	Min. 850	Heat No.	20 55	—	Min. 60	Max. 40	Max. 50	--	--	--
Mean/5pcs.	26.9	—	ALL PASS	1562	1067	7309118	44	22	75	13	20	1	2	6

Thread Accuracy (Bolt & Nut)	
Bolt	ASME B1.1 Class 2A
Nut	ASME B1.1 Class 2B

WASHER LOT NO. J823

	Hardness (HRC)	IDENTIFICATION	Chemical Composition %: C x 100	Si x 100	Mn x 100	P x 1000	S x 1000	Cu x 100	Ni x 100	Cr x 100
Spec.	38 - 45	Heat No.	--	--	--	Max. 40	Max. 50	--	--	--
Mean/5 Pcs.	39.6	208143	48	12	70	7	4	-	-	-

Fastener Tension

Fastener Tension	
Spec. (lbf.)	Min. 19950
Mean / 5 sets.	22512
Standard Deviation	977

REMARKS

Material used for the bolt, nut and washer were melted & manufactured in the USA.
The product was manufactured in the USA to ASTM specifications. The bolt and nut are manufactured by Unytite.
We hereby certify that the material described has been manufactured and inspected satisfactory with requirement of the above specification.

Chief of Quality Assurance Section

Figure A.1: Bolt Certificate for 5/8", F1852/A325 Strength Bolts

INSPECTION CERTIFICATE

SET LOT NO. 66201A

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

Specification	Size	Quantity
ASTM F1852 Type 1 -00 ASTM A563 Grade DH -00 ASTM F436 Type 1 -00	3/4-10 UNC X 3-1/4	12,464 pcs.

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

Date: Nov.15,'02

BOLT LOT NO. 66201

	Mechanical Property of Full Size Bolts				Heat Treatment °F (°C)		IDENTIFICATION	Chemical Composition %									
	Tensile Strength Load (lbf)	Tensile Strength Position of fracture	Proof Load 28400 lbf. (Length Method)	Hardness HRC	Quench	Temper		C x 100	Si x 100	Mn x 100	P x 1000	S x 1000	Cu x 100	Ni x 100	Cr x 100	Mo x 100	B x 10,000
Spec.	Min. 40100	Part of Screw	Max. +/- 0.0005 in.	25 - 34	--	Min. 800	Heat No.	30 52	--	Min. 60	Max. 40	Max. 50	--	--	--	--	5 30
Average	48484	Part of Screw	ALL PASS	31.4	1580	900	7240470	30	25	82	11	13	1	3	8	2	14

NUT LOT NO. 08051

	Hardness (HRC)	Hardness After 24 hr x 1000° F HRB	Proof Load (Lbf)	Heat Treatment °F (°C) Quench	Heat Treatment °F (°C) Temper	IDENTIFICATION	Chemical Composition % C X 100	Si X 100	Mn X 100	P X 1000	S X 1000	Cu X 100	Ni X 100	Cr X 100
Spec.	24 - 38	Min. HRB 89	58450	--	Min. 850	Heat No.	20 55	—	Min. 60	Max. 40	Max. 50	--	--	--
Mean/5pcs.	28.7	—	ALL PASS	1562	1112	7242139	46	21	79	7	24	5	10	11

Thread Accuracy (Bolt & Nut)	
Bolt	ASME B1.1 Class 2A
Nut	ASME B1.1 Class 2B

WASHER LOT NO. J921

	Hardness (HRC)	IDENTIFICATION	Chemical Composition % C x 100	Si x 100	Mn x 100	P x 1000	S x 1000	Cu x 100	Ni x 100	Cr x 100
Spec.	38 - 45	Heat No.	--	--	--	Max. 40	Max. 50	--	--	--
Mean/5 Pcs.	42.2	125495	33	18	78	14	5	-	-	-

Fastener Tension

Fastener Tension	
Spec. (lbf.)	Min. 29400
Mean / 5 sets.	37324
Standard Deviation	1727

REMARKS

Material used for the bolt, nut and washer were melted & manufactured in the USA.
The product was manufactured in the USA to ASTM specifications. The bolt and nut are manufactured by Unytite.
We hereby certify that the material described has been manufactured and inspected satisfactory with requirement of the above specification.

Chief of Quality Assurance Section

Figure A.2: Bolt Certificate for 3/4", F1852/A325 Strength Bolts

INSPECTION CERTIFICATE

SET LOT NO. 71821A

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

Specification	Size	Quantity
ASTM A490 Type 1 -00 ASTM A563 Grade DH -00 ASTM F436 Type 1 -00	3/4-10 UNC X 3-1/4	300 pcs.

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

BOLT LOT NO. 71821

Date: Mar. 07,'03

	Mechanical Property of Full Size Bolts				Heat Treatment		IDENTIFICATION	Chemical Composition %								
	Tensile Strength		Proof Load	Hardness	°F (°C)		A490 USA									
	Load (lbf)	Position of fracture	40,100lbf. (Length Method)	HRC	Quench	Temper		C x 100	Si x 100	Mn x 100	P x 1000	S x 1000	Cu x 100	Ni x 100	Cr x 100	Mo x 100
Spec.	50,100 56,800	Part of Screw	Max. +/- .0005 in.		–	Min. 800	Heat No.	30 52	..	Min. 60	Max. 40	Max. 50	–	–	–	–
Average 8 pcs	54636	Part of Screw	ALL PASS	33.5	1580	1031	7442286	40	24	93	8	4	2	6	102	22

NUT LOT NO. 09682

Hardness (HRC)		Hardness After 24 hr x 1000° F HRB	Proof Load (Lbf)	Heat Treatment °F (°C)		IDENTIFICATION	Chemical Composition %							
				Quench	Temper	U DH	C X 100	Si X 100	Mn X 100	P X 1000	S X 1000	Cu X 100	Ni X 100	Cr X 100
Spec.	24 - 38	Min. HRB 89	58450	–	Min. 850	Heat No.	20 55	–	Min. 60	Max. 40	Max. 50	–	–	–
Mean/5pcs	28.2	—	ALL PASS	1562	1220	S55542	45	21	71	11	28	25	9	14

Thread Accura[cy] (Bolt & Nut)

Bolt ASME [...] Class 2
Nut ASME [...] Class 2

WASHER LOT NO. J926

Hardness (HRC)		IDENTIFICATION	Chemical Composition %							
		E	C x 100	Si x 100	Mn x 100	P x 1000	S x 1000	Cu x 100	Ni x 100	Cr x 100
Spec.	38 - 45	Heat No.	–	–	–	Max. 40	Max. 50	–	–	–
Mean/5 Pcs.	41.4	221761	34	20	79	15	5	–	–	–

Fastener Tension

Fastener Tension	
Spec. (lbf.)	Min. 36,750
Mean / 5 sets.	41,200
Standard Deviation	2,200

REMARKS

THESE BOLTS HA[VE] BEEN MAGNETIC PARTICLE INSPECT[ED] IN ACCORDANC[E] WITH THE REQUIREMENTS OF SPECIFICATIO[N] ASTM A490

Material used for the bolt, nut and washer were melted & manufactured in the USA.
The product was manufactured in the USA to ASTM specifications. The bolt and nut are manufactured by Unytite.
We hereby certify that the material described has been manufactured and inspected satisfactory with requirement of the above specification.

Chief of Quality Assurance Section

Figure A.3: Bolt Certificate for 3/4", A490 Strength Bolts

INSPECTION CERTIFICATE

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

SET LOT NO.

Specification	Size	Quantity
ASTM F1852 Type 1 -00 ASTM A563 Grade DH-00 ASTM F436 Type 1	7/8- 9 UNC X 3-1/2	5,425 pcs.

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

Date: Aug. 08, '02

BOLT LOT NO. 60871

	Mechanical Property of Full Size Bolts				Heat Treatment °F (°C)		IDENTIFICATION	Chemical Composition %									
	Tensile Strength		PROOF LOAD	Hardness			A325TC USA	C	Si	Mn	P	S	Cu	Ni	Cr	Mo	B
	Load (lbf)	Position of fracture	39250 lbf. (Length Method)	HRC	Quench	Temper		x 100	x 100	x 100	x 1000	x 1000	x 100	x 100	x 100	x 100	x 10,000
Spec.	Min. 55450	Part of Screw	Max. +/- 0.0005 in.	25 - 34	--	Min. 800	Heat No.	30 52	--	Min. 60	Max. 40	Max. 50	--	--	--	--	5 30
Average	71363	Part of Screw	ALL PASS	32.9	1580	869	7241885	32	23	79	6	8	3	4	7	2	17

NUT LOT NO. 06151

Hardness (HRC)		Hardness After 24 hr x 1000° F HRB	Proof Load (Lbf)	Heat Treatment °F (°C)		IDENTIFICATION	Chemical Composition %							
				Quench	Temper	U DH	C X 100	Si X 100	Mn X 100	P X 1000	S X 1000	Cu X 100	Ni X 100	Cr X 100
Spec.	24 - 38	Min. HRB 89	80850	--	Min. 850	Heat No.	20 55	—	Min. 60	Max. 40	Max. 50	--	--	--
Mean/5pcs.	26.9	—	ALL PASS	1562	1256	S52747	43	20	69	11	28	24	8	13

Thread Accuracy (Bolt & Nut)	
Bolt	ASME B1.1 Class 2A
Nut	ASME B1.1 Class 2B

WASHER LOT NO. J910

Hardness (HRC)		IDENTIFICATION	Chemical Composition %							
			C x 100	Si x 100	Mn x 100	P x 1000	S x 1000	Cu x 100	Ni x 100	Cr x 100
Spec.	38 - 45	Heat No.	--	--	--	Max. 40	Max. 50	--	--	--
Mean/5 Pcs.	40.7	123110	33	18	85	14	9	-	-	-

Fastener Tension

Fastener Tension	
Spec. (lbf.)	Min. 40950
Mean / 5 sets.	54832
Standard Deviation	4082

REMARKS

Material used for the bolt, nut and washer were melted & manufactured in the USA.
The product was manufactured in the USA to ASTM specifications. The bolt and nut are manufactured by Unytite.
We hereby certify that the material described has been manufactured and inspected satisfactory with requirement of the above specification.

Chief of Quality Assurance Section

Figure A.4: Bolt Certificate for 7/8", F1852/A325 Strength Bolts

SET LOT NO. ____

INSPECTION CERTIFICATE

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

Specification	Size	Quantity
ASTM A490 Type 1 -00 ASTM A563 Grade DH+00 ASTM F436 Type 1	7/8- 9 UNC X 3-1/2	2,725 pcs.

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

BOLT LOT NO. 62371

Date: Sep.20,'02

	Mechanical Property of Full Size Bolts: Tensile Strength, Load (lbf)	Position of fracture	PROOF LOAD 55450 lbf. (Length Method)	Hardness HRC	Heat Treatment °F (°C) Quench	Temper	IDENTIFICATION (A490 USA)	C x 100	Si x 100	Mn x 100	P x 1000	S x 1000	Cu x 100	Ni x 100	Cr x 100	Mo x 100	B x 10,000
Spec.	69300 78550	Part of Screw	Max. +/− 0.0005 in.		--	Min. 800	Heat No.	30 52	–	Min. 60	Max. 40	Max. 50	--	--	–	–	5 30
Average 8 pcs	75827	Part of Screw	ALL PASS	35.7	1580	1022	7440952	40	27	89	9	9	4	5	99	21	0

NUT LOT NO. 06541

Hardness (HRC)		Hardness After 24 hr x 1000° F HRB	Proof Load (Lbf)	Heat Treatment °F (°C) Quench	Temper	IDENTIFICATION	C X 100	Si X 100	Mn X 100	P X 1000	S X 1000	Cu X 100	Ni X 100	Cr X 100
Spec.	24 - 38	Min. HRB 89	80850	--	Min. 850	Heat No.	20 55	–	Min. 60	Max. 40	Max. 50	--	--	--
Mean/5pcs.	26.8	—	ALL PASS	1562	1049	299684	44	18	70	6	26	4	3	3

Thread Accuracy (Bolt & Nut)	
Bolt	ASME B1.1 Class 2A
Nut	ASME B1.1 Class 2B

WASHER LOT NO. J917

Hardness (HRC)		IDENTIFICATION	C x 100	Si x 100	Mn x 100	P x 1000	S x 1000	Cu x 100	Ni x 100	Cr x 100
Spec.	38 - 45	Heat No.	--	--	--	Max. 40	Max. 50	--	--	--
Mean/5 Pcs.	40.5	221344	34	18	77	12	2	–	–	–

Fastener Tension

Fastener Tension	
Spec. (lbf.)	Min. 51450
Mean / 5 sets.	55090
Standard Deviation	2360

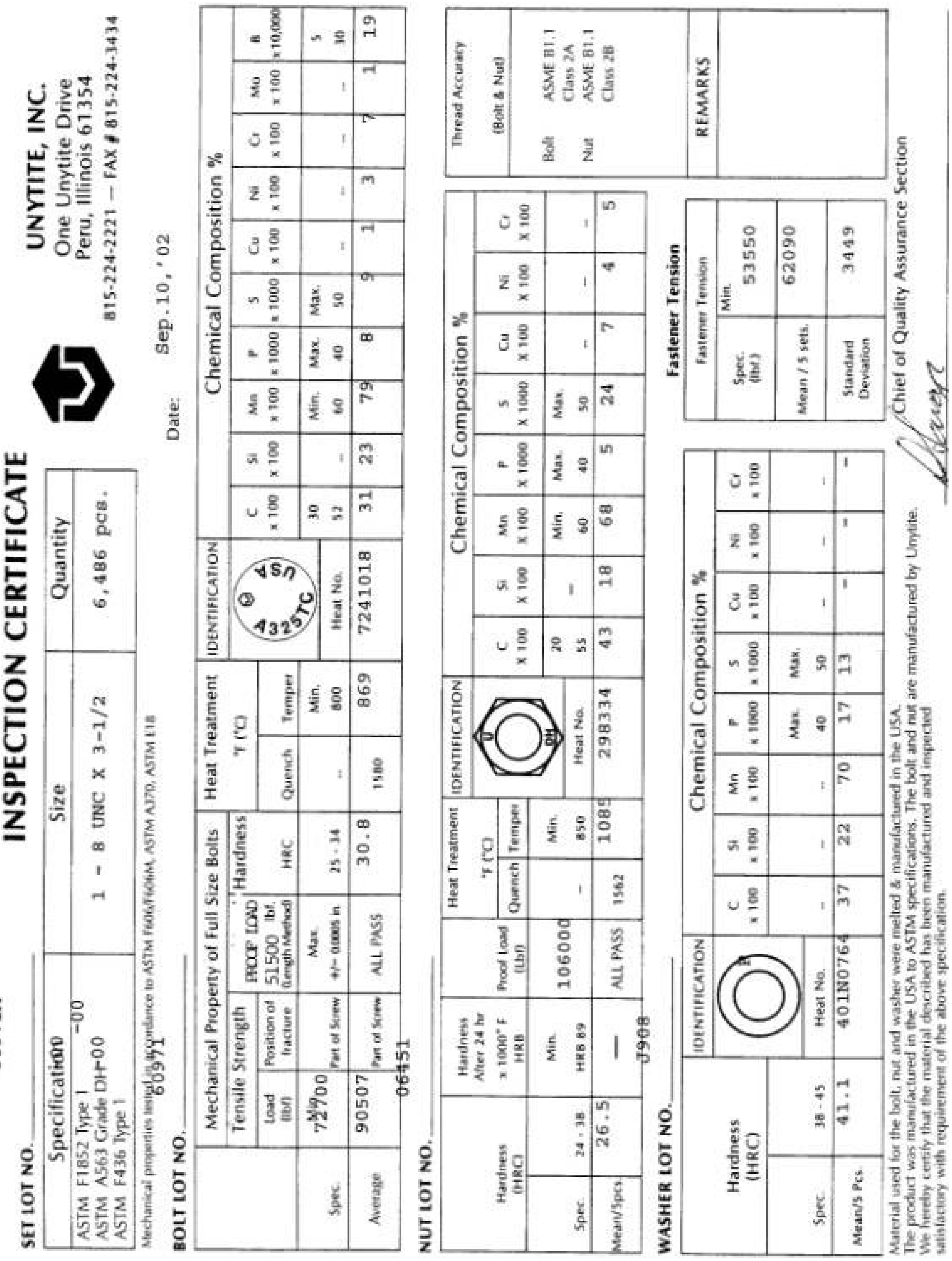
REMARKS

THESE BOLTS HAVE BEEN MAGNETIC PARTICLE INSPECTION IN ACCORDANCE WITH THE REQUIREMENTS OF SPECIFICATION ASTM A490

Material used for the bolt, nut and washer were melted & manufactured in the USA.
The product was manufactured in the USA to ASTM specifications. The bolt and nut are manufactured by Unytite.
We hereby certify that the material described has been manufactured and inspected satisfactory with requirement of the above specification.

Chief of Quality Assurance Section

Figure A.5: Bolt Certificate for 7/8", A490 Strength Bolts



60971A

INSPECTION CERTIFICATE

SET LOT NO.

Specification	Size	Quantity
ASTM F1852 Type 1 -00 ASTM A563 Grade DH-00 ASTM F436 Type 1	1 - 8 UNC X 3-1/2	6,486 pcs.

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

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

BOLT LOT NO. 60971

Date: Sep.10,'02

	Mechanical Property of Full Size Bolts				Heat Treatment °F (°C)		IDENTIFICATION	Chemical Composition %									
	Tensile Strength Load (lbf)	Position of fracture	PROOF LOAD 51500 lbf. (Length Method)	Hardness HRC	Quench	Temper	A325TC USA	C x 100	Si x 100	Mn x 100	P x 1000	S x 1000	Cu x 100	Ni x 100	Cr x 100	Mo x 100	B x 10,000
Spec.	Min. 72700	Part of Screw	Max. +/− 0.0005 in.	25 - 34	--	Min. 800	Heat No.	30 52	--	Min. 60	Max. 40	Max. 50	--	--	--	--	5 30
Average	90507	Part of Screw	ALL PASS	30.8	1580	869	7241018	31	23	79	8	9	1	3	7	1	19

NUT LOT NO. 06451

Hardness (HRC)		Hardness After 24 hr x 1000° F HRB	Proof Load (Lbf)	Heat Treatment °F (°C) Quench	Temper	IDENTIFICATION	C X 100	Si X 100	Mn X 100	P X 1000	S X 1000	Cu X 100	Ni X 100	Cr X 100
Spec.	24 - 38	Min. HRB 89	106000	–	Min. 850	Heat No.	20 55	–	Min. 60	Max. 40	Max. 50	–	–	–
Mean/5pcs.	26.5	—	ALL PASS	1562	1085	298334	43	18	68	5	24	7	4	5

Thread Accuracy (Bolt & Nut)
Bolt ASME B1.1 Class 2A
Nut ASME B1.1 Class 2B

WASHER LOT NO. J908

Hardness (HRC)		IDENTIFICATION	C x 100	Si x 100	Mn x 100	P x 1000	S x 1000	Cu x 100	Ni x 100	Cr x 100
Spec.	38 - 45	Heat No.	–	–	–	Max. 40	Max. 50	–	–	–
Mean/5 Pcs.	41.1	401N0764	37	22	70	17	13	-	-	-

Fastener Tension

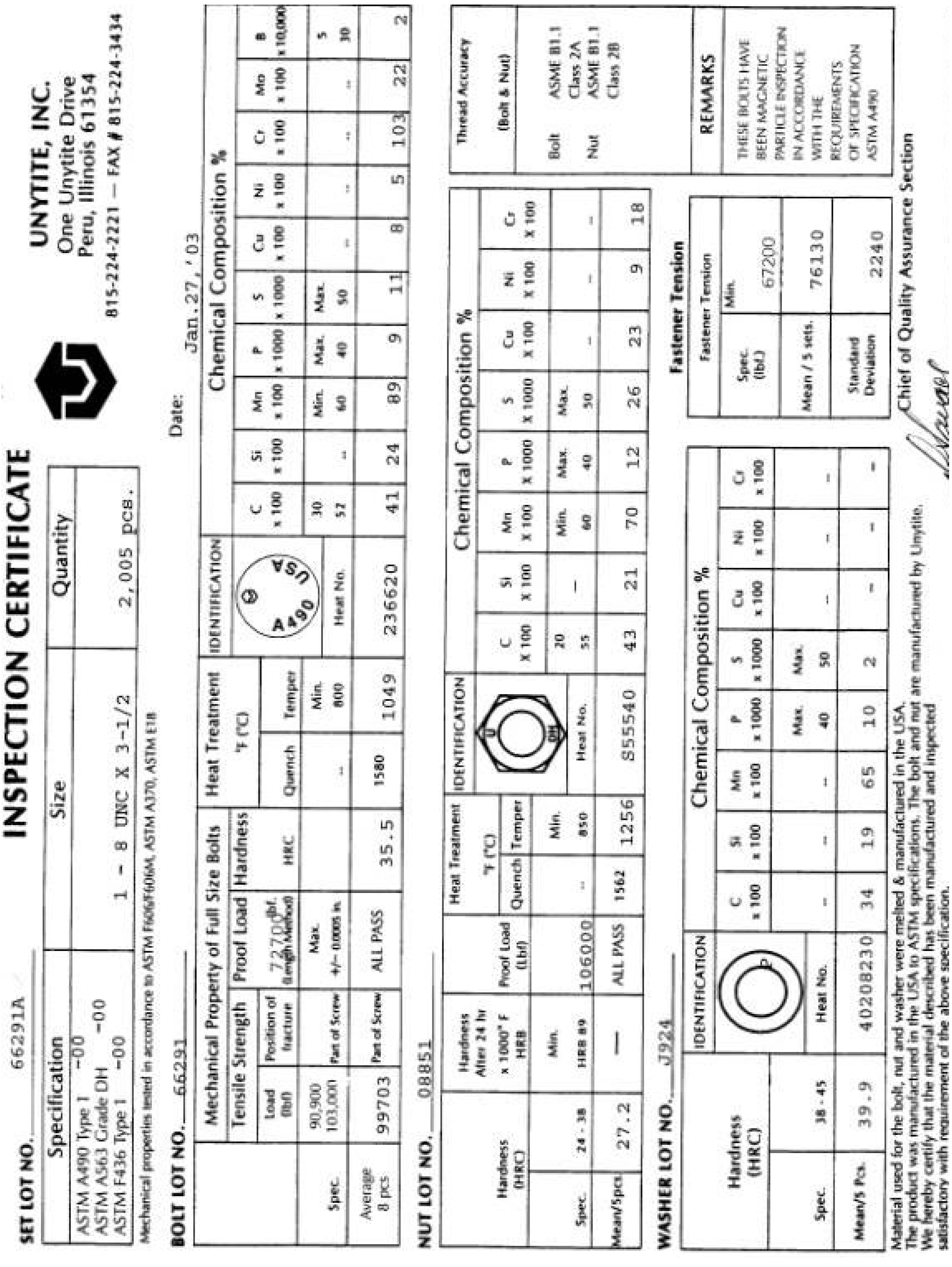
Fastener Tension	
Spec. (lbf.)	Min. 53550
Mean / 5 sets.	62090
Standard Deviation	3449

REMARKS

Material used for the bolt, nut and washer were melted & manufactured in the USA.
The product was manufactured in the USA to ASTM specifications. The bolt and nut are manufactured by Unytite.
We hereby certify that the material described has been manufactured and inspected satisfactory with requirement of the above specification.

Chief of Quality Assurance Section

Figure A.6: Bolt Certificate for 1", F1852/A325 Strength Bolts



SET LOT NO. 66291A

INSPECTION CERTIFICATE

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

Specification	Size	Quantity
ASTM A490 Type 1 -00 ASTM A563 Grade DH -00 ASTM F436 Type 1 -00	1 - 8 UNC X 3-1/2	2,005 pcs.

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

BOLT LOT NO. 66291

Date: Jan.27,'03

	Mechanical Property of Full Size Bolts				Heat Treatment °F (°C)		IDENTIFICATION	Chemical Composition %									
	Tensile Strength		Proof Load	Hardness			A490 USA										
	Load (lbf)	Position of fracture	72700 lbf. (Length Method)	HRC	Quench	Temper		C x 100	Si x 100	Mn x 100	P x 1000	S x 1000	Cu x 100	Ni x 100	Cr x 100	Mo x 100	B x 10,000
Spec.	90,900 103,000	Part of Screw	Max. +/− 0.0005 in.		--	Min. 800	Heat No.	30 52	--	Min. 60	Max. 40	Max. 50	--	--	--	--	5 30
Average 8 pcs	99703	Part of Screw	ALL PASS	35.5	1580	1049	236620	41	24	89	9	11	8	5	103	22	2

NUT LOT NO. 08851

Hardness (HRC)		Hardness After 24 hr x 1000° F HRB	Proof Load (Lbf)	Heat Treatment °F (°C)		IDENTIFICATION	Chemical Composition %							
				Quench	Temper		C X 100	Si X 100	Mn X 100	P X 1000	S X 1000	Cu X 100	Ni X 100	Cr X 100
Spec.	24 - 38	Min. HRB 89	106000	--	Min. 850	Heat No.	20 55	—	Min. 60	Max. 40	Max. 50	–	–	–
Mean/5pcs	27.2	—	ALL PASS	1562	1256	S55540	43	21	70	12	26	23	9	18

Thread Accuracy (Bolt & Nut)	
Bolt	ASME B1.1 Class 2A
Nut	ASME B1.1 Class 2B

WASHER LOT NO. J924

Hardness (HRC)		IDENTIFICATION	Chemical Composition %							
			C x 100	Si x 100	Mn x 100	P x 1000	S x 1000	Cu x 100	Ni x 100	Cr x 100
Spec.	38 - 45	Heat No.	--	--	--	Max. 40	Max. 50	--	--	--
Mean/5 Pcs.	39.9	40208230	34	19	65	10	2	–	–	–

Fastener Tension

Fastener Tension	
Spec. (lbf.)	Min. 67200
Mean / 5 sets.	76130
Standard Deviation	2240

REMARKS

THESE BOLTS HAVE BEEN MAGNETIC PARTICLE INSPECTION IN ACCORDANCE WITH THE REQUIREMENTS OF SPECIFICATION ASTM A490

Material used for the bolt, nut and washer were melted & manufactured in the USA.
The product was manufactured in the USA to ASTM specifications. The bolt and nut are manufactured by Unytite.
We hereby certify that the material described has been manufactured and inspected satisfactory with requirement of the above specification.

Chief of Quality Assurance Section

Figure A.7: Bolt Certificate for 1", A490 Strength Bolts

SET LOT NO. 52201A

INSPECTION CERTIFICATE

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

Specification	Size	Quantity
ASTM F1852 Type 1 - 00 ASTM A563 Grade DH - 00 ASTM F436 Type 1 - 00	1-1/8" - 7 X 5-1/2"	3,250

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

BOLT LOT NO. 52201

Date: 03-27-02

COPY

	Mechanical Property of Full Size Bolts				Heat Treatment °F (°C)		IDENTIFICATION	Chemical Composition %									
	Tensile Strength		Proof Load	Hardness			USA A325TC										
	Load (lbf)	Position of fracture	56450 lbf. (Length Method)	HRC	Quench	Temper		C x 100	Si x 100	Mn x 100	P x 1000	S x 1000	Cu x 100	Ni x 100	Cr x 100	Mo x 100	B x 10,000
Spec.	Min. 80100	Part of Screw	Max. +/- 0.0005 in.	25 - 34	--	Min. 800	Heat No.	30 52	--	Min. 60	Max. 40	Max. 50	--	--	--	--	5 30
Average	102560	Part of Screw	ALL PASS	27.2	1580	923	7224455	31	25	81	10	12	2	2	7	1	-

NUT LOT NO. 01951

Hardness (HRC)		Hardness After 24 hr x 1000° F HRB	Proof Load (Lbf)	Heat Treatment °F (°C) Quench	Temper	IDENTIFICATION	Chemical Composition % C X 100	Si X 100	Mn X 100	P X 1000	S X 1000	Cu X 100	Ni X 100	Cr X 100
Spec.	24 - 38	Min. HRB 89		--	Min. 850	Heat No.	20 55	—	Min. 60	Max. 40	Max. 50	--	--	--
Mean/5pcs	28.9	—	ALL PASS	1562	1112	298007	43	18	74	23	24	10	4	2

Thread Accuracy (Bolt & Nut)	
Bolt	ASME B1.1 Class 2A
Nut	ASME B1.1 Class 2B

WASHER LOT NO. 3756

Hardness (HRC)		IDENTIFICATION	Chemical Composition % C x 100	Si x 100	Mn x 100	P x 1000	S x 1000	Cu x 100	Ni x 100	Cr x 100
Spec.	38 - 45	Heat No.	--	--	--	Max. 40	Max. 50	--	--	--
Mean/5 Pcs.	40.9	A82240	52	17	70	11	3	-	-	-

Fastener Tension

Fastener Tension	
Spec. (lbf.)	Min. 58,800
Mean / 5 sets.	80,300
Standard Deviation	2,200

REMARKS

Material used for the bolt, nut and washer were melted & manufactured in the USA.
The product was manufactured in the USA to ASTM specifications. The bolt and nut are manufactured by Unytite.
We hereby certify that the material described has been manufactured and inspected

Chief of Quality Assurance Section

Figure A.8: Bolt Certificate for 1-1/8", F1852/A325 Strength Bolts

SET LOT NO. 56921A

INSPECTION CERTIFICATE

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

Specification	Size	Quantity
ASTM A490 Type 1 ASTM A563 Grade DH ASTM F436 Type 1	1-1/8" - 7 X 5-1/2"	1,825 PIECES

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

BOLT LOT NO. 56921

Date: 05-15-02

	Mechanical Property of Full Size Bolts				Heat Treatment °F (°C)		IDENTIFICATION	Chemical Composition %									
	Tensile Strength		Proof Load	Hardness			A490 USA										
	Load (lbf)	Position of fracture	91,550 lbf. (Length Method)	HRC	Quench	Temper		C x 100	Si x 100	Mn x 100	P x 1000	S x 1000	Cu x 100	Ni x 100	Cr x 100	Mo x 100	B x 10,000
Spec.	114,450 129,700	Part of Screw	Max. +/- 0.0005 in.		--	Min. 800	Heat No.	30 52	--	Min. 60	Max. 40	Max. 50	--	--	--	--	5 30
Average 8 pcs	124,771	Part of Screw	ALL PASS	34.2	1580	1013	7440952	40	27	89	9	9	4	5	99	21	-

NUT LOT NO. 03651

Hardness (HRC)		Hardness After 24 hr x 1000° F HRB	Proof Load (Lbf)	Heat Treatment °F (°C)		IDENTIFICATION	Chemical Composition %							
				Quench	Temper	U DH	C X 100	Si X 100	Mn X 100	P X 1000	S X 1000	Cu X 100	Ni X 100	Cr X 100
Spec.	24 - 38	Min. HRB 89		--	Min. 850	Heat No.	20 55	—	Min. 60	Max. 40	Max. 50	--	--	--
Mean/5pcs.	29.2	—	ALL PASS	1562	1220	552030	44	22	71	12	18	27	11	13

Thread Accuracy (Bolt & Nut)	
Bolt	ASME B1.1 Class 2A
Nut	ASME B1.1 Class 2B

WASHER LOT NO. J890

Hardness (HRC)		IDENTIFICATION	Chemical Composition %							
		B	C x 100	Si x 100	Mn x 100	P x 1000	S x 1000	Cu x 100	Ni x 100	Cr x 100
Spec.	38 - 45	Heat No.	--	--	--	Max. 40	Max. 50	--	--	--
Mean/5 Pcs.	41.8	B53602	54	18	81	14	2	--	--	--

Fastener Tension

Fastener Tension	
Spec. (lbf.)	Min. 84,000
Mean / 5 sets.	99,100
Standard Deviation	2,800

REMARKS

THESE BOLTS HAVE BEEN MAGNETIC PARTICLE INSPECTION IN ACCORDANCE WITH THE REQUIREMENTS OF SPECIFICATION ASTM A490

Material used for the bolt, nut and washer were melted & manufactured in the USA.
The product was manufactured in the USA to ASTM specifications. The bolt and nut are manufactured by Unytite.
We hereby certify that the material described has been manufactured and inspected satisfactory with requirement of the above specification.

Chief of Quality Assurance Section

Figure A.9: Bolt Certificate for 1-1/8", A490 Strength Bolts

APPENDIX B

GRAPHICS OF BOLT AND PLATE LAYOUTS

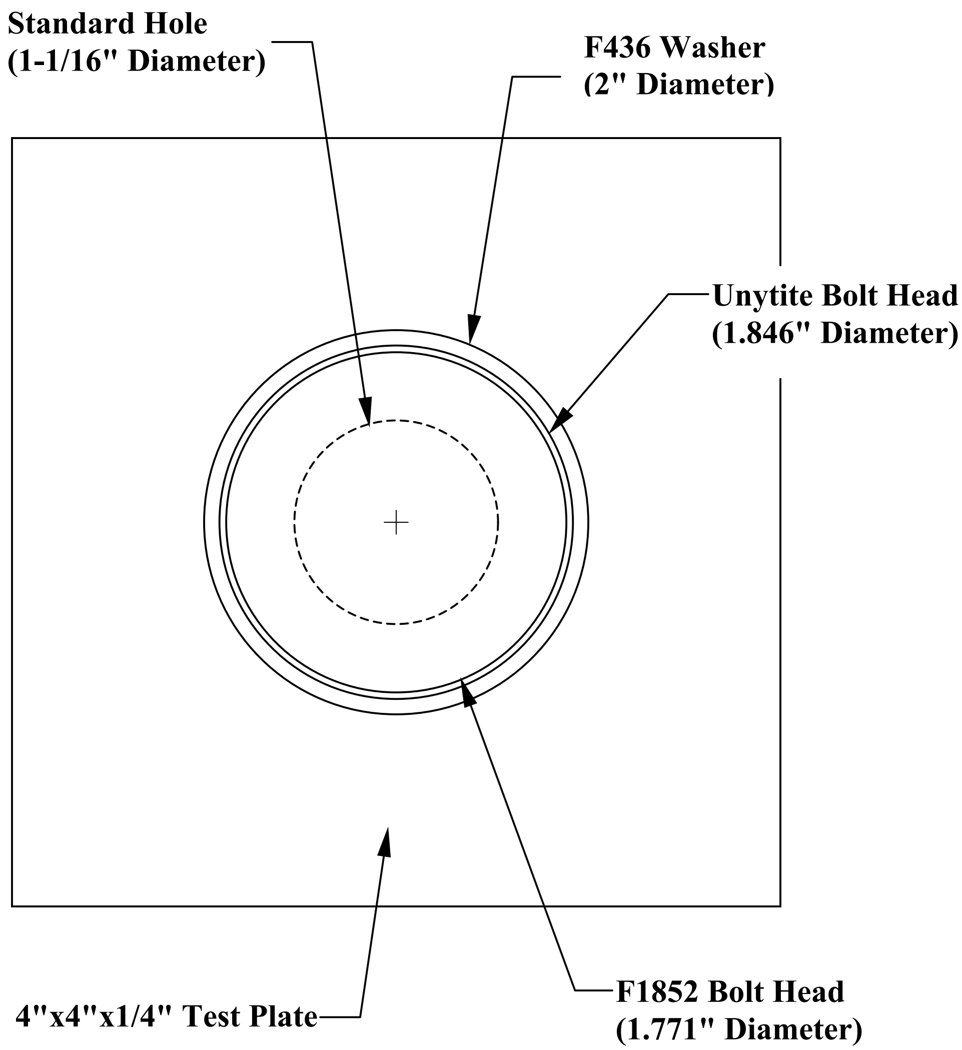


Figure B.1: Bolt and Plate Layout for 1" Bolt in Standard Hole
(Drawn to Scale)

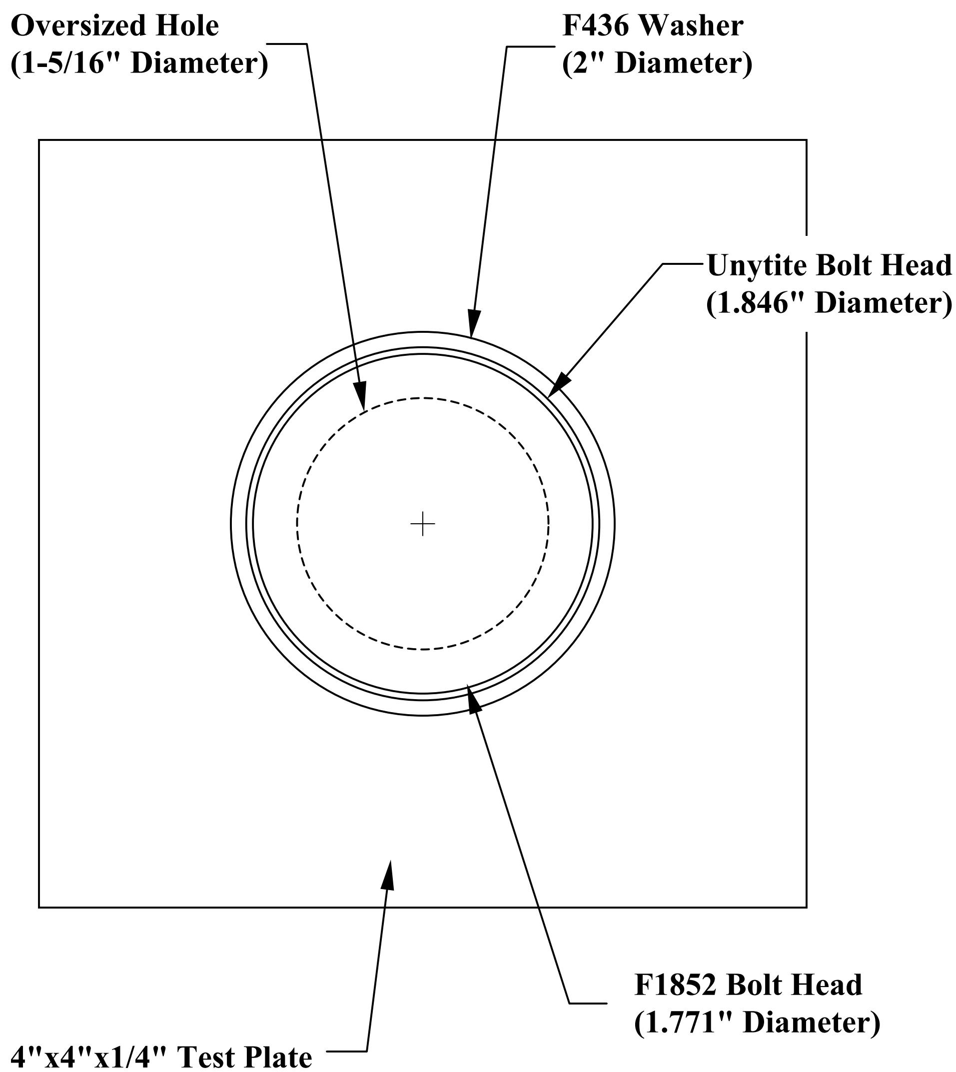


Figure B.2: Bolt and Plate Layout for 1" Bolt in Oversized Hole
(Drawn to Scale)

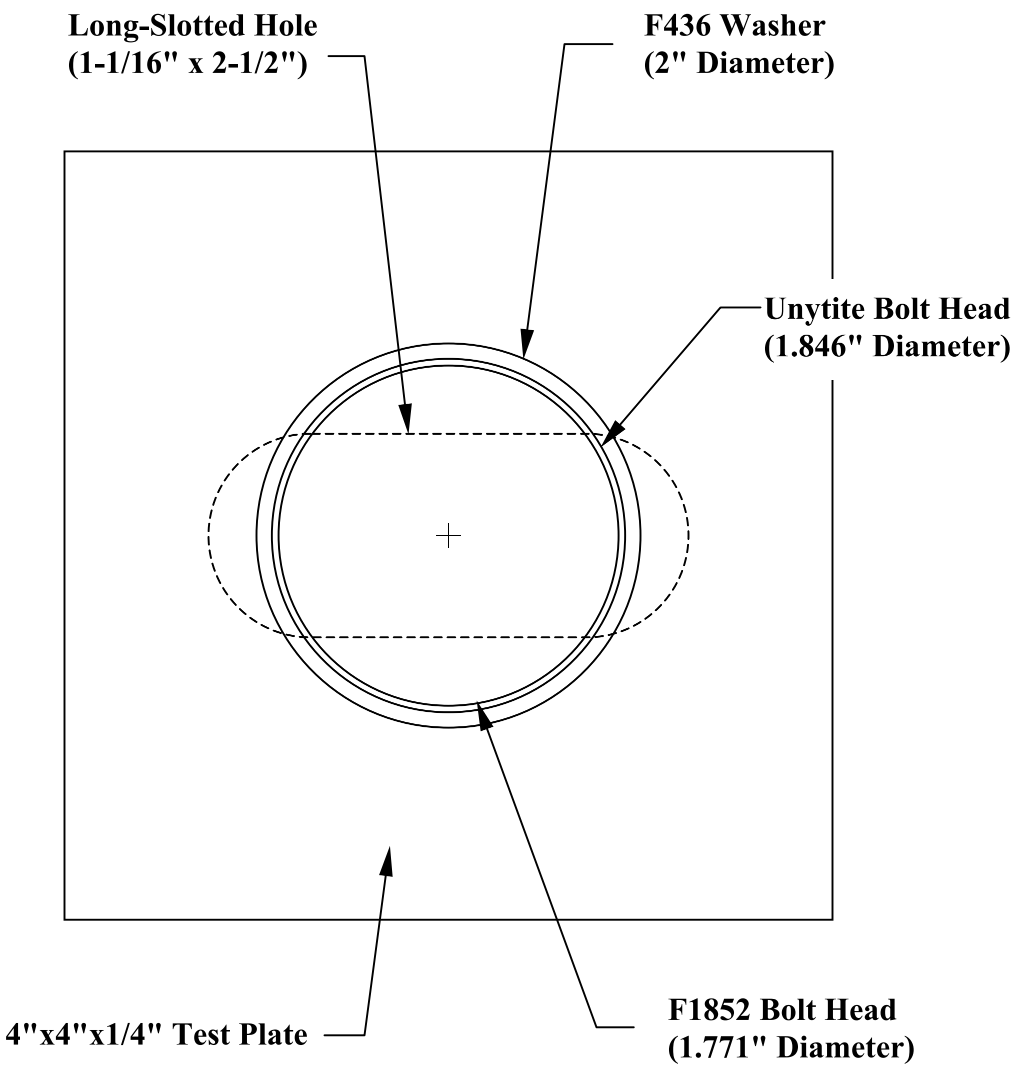


Figure B.3: Bolt and Plate Layout for 1" Bolt in Long-Slotted Hole
(Drawn to Scale)

APPENDIX C

TEST RESULTS FOR F1852/A325 STRENGTH BOLTS

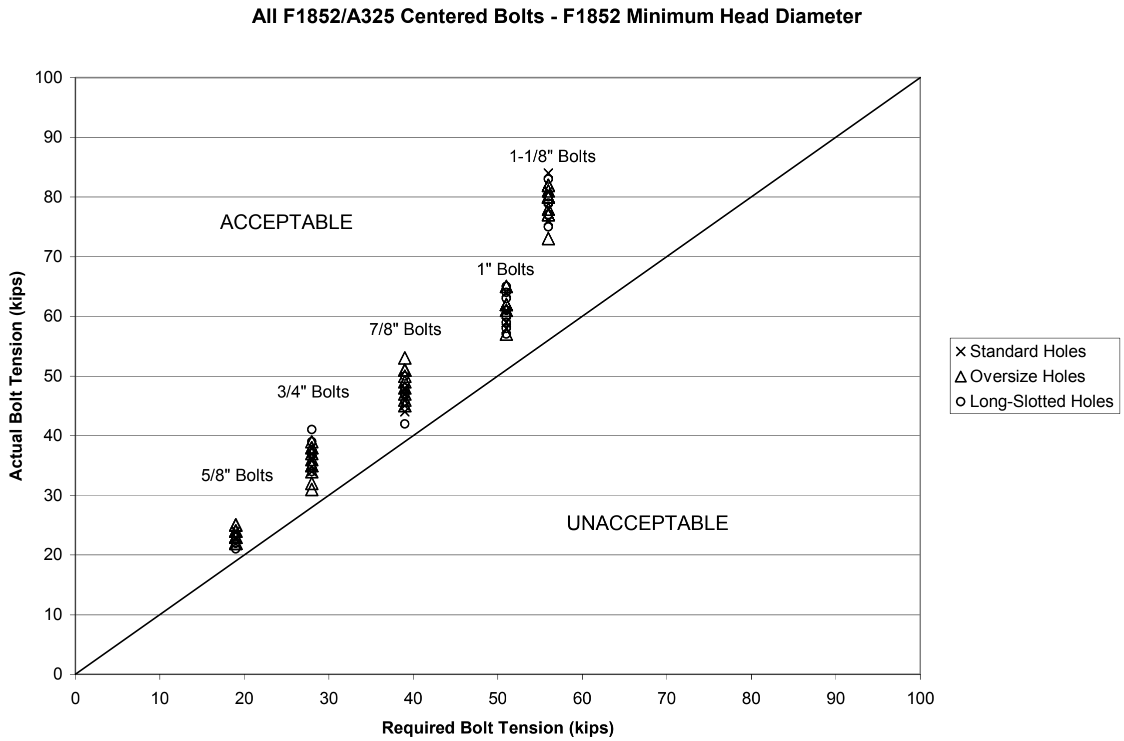


Figure C.1: All F1852/A325 Strength, Centered Bolts, Minimum Head

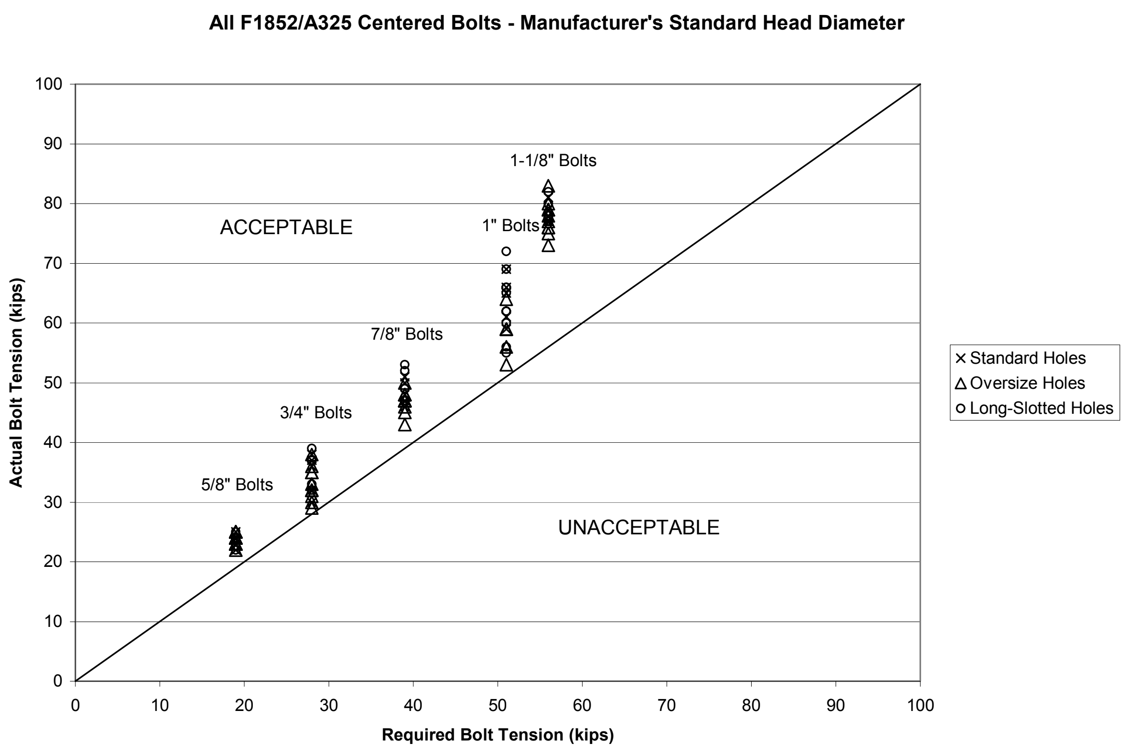


Figure C.2: All F1852/A325 Strength, Centered Bolts, Standard Head

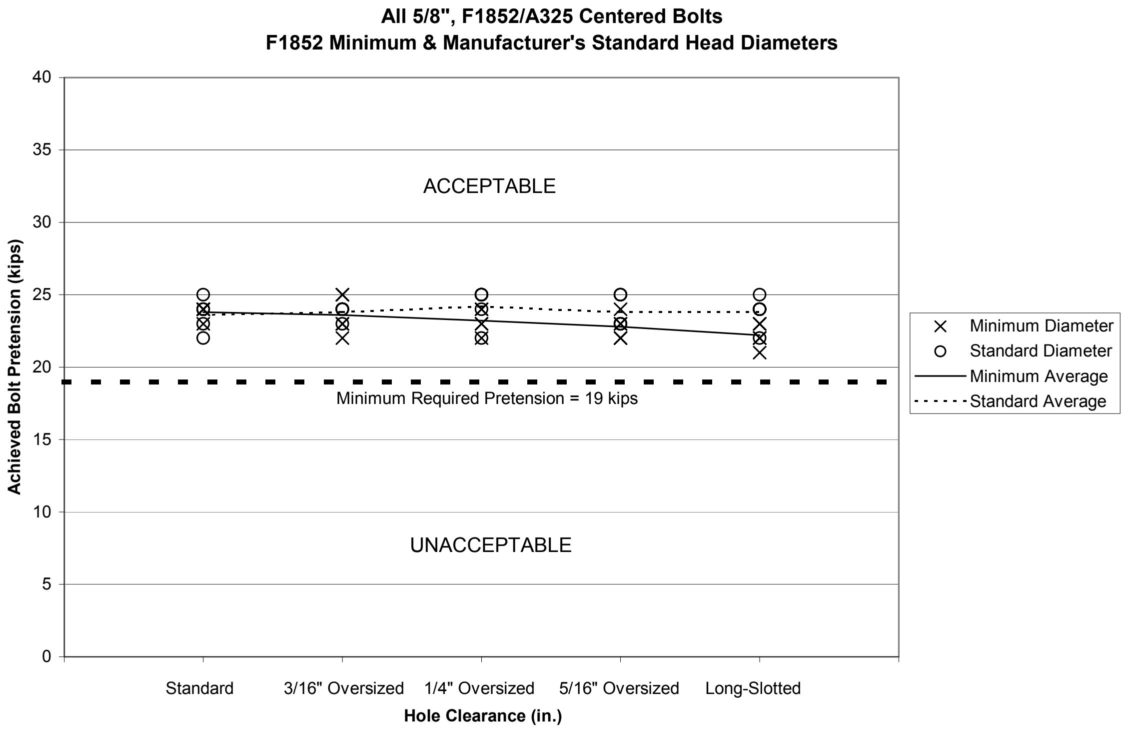


Figure C.3: Results for 5/8" F1852/A325 Strength, Centered Bolts, Minimum & Standard Heads

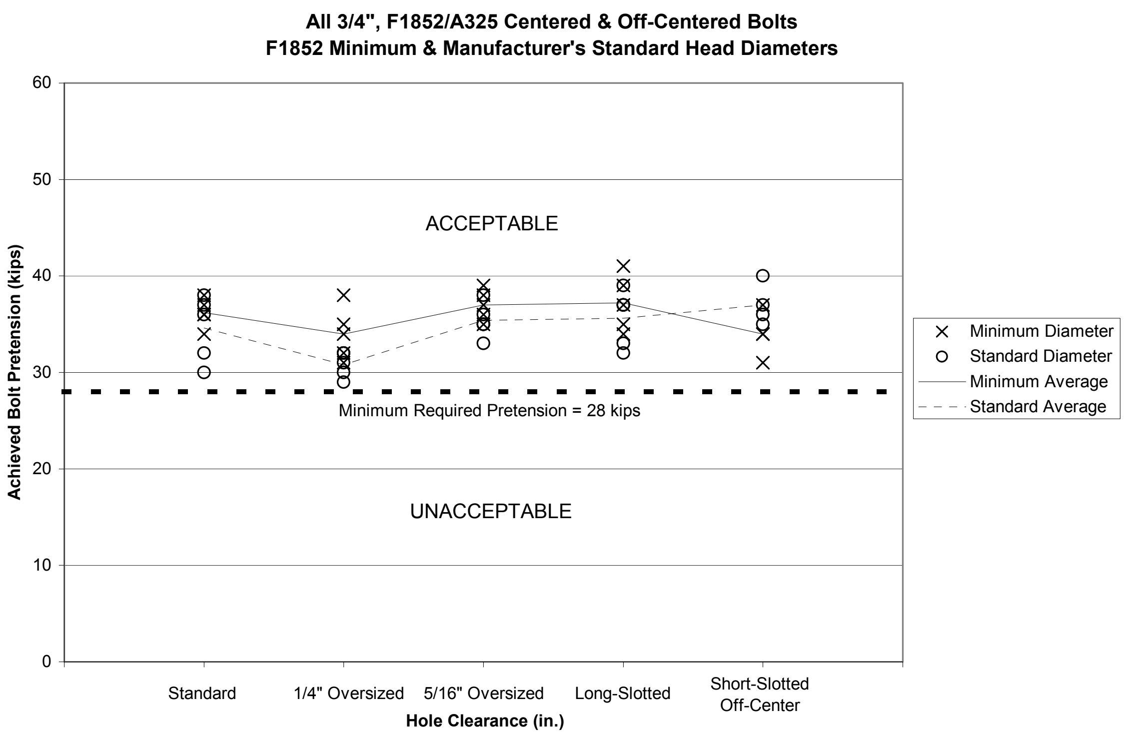


Figure C.4: Results for 3/4" F1852/A325 Strength, Centered & Off-Centered Bolts, Minimum & Standard Heads

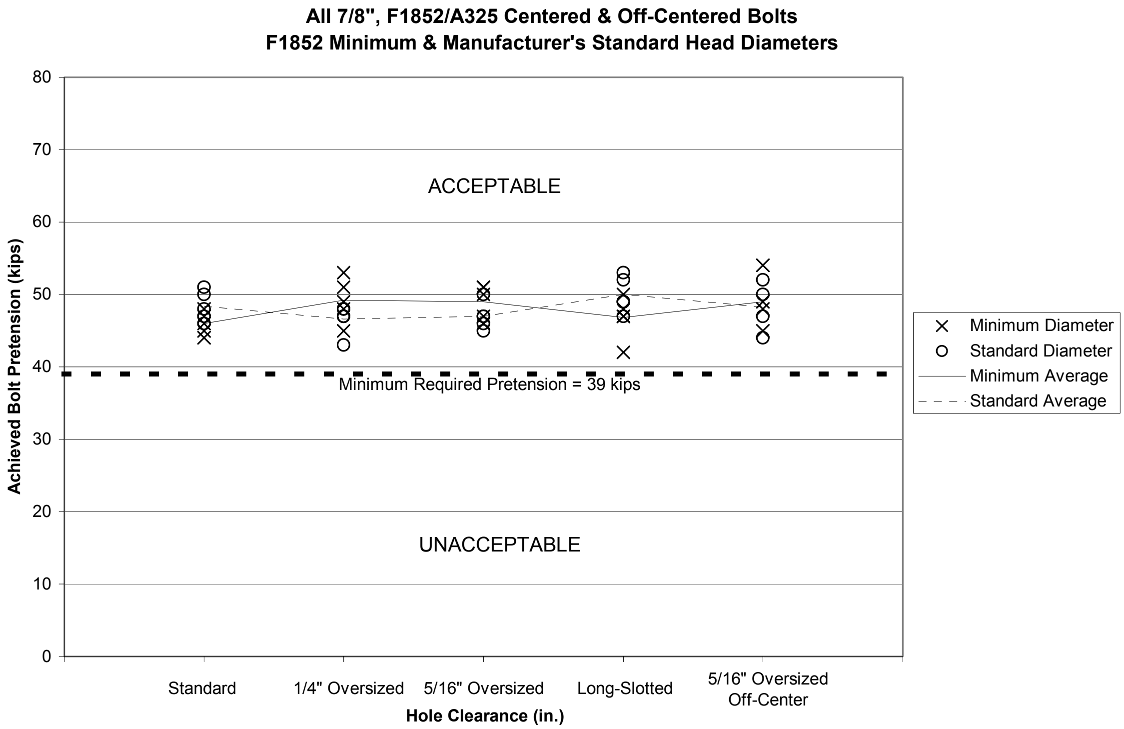


Figure C.5: Results for 7/8" F1852/A325 Strength, Centered & Off-Centered Bolts, Minimum & Standard Heads

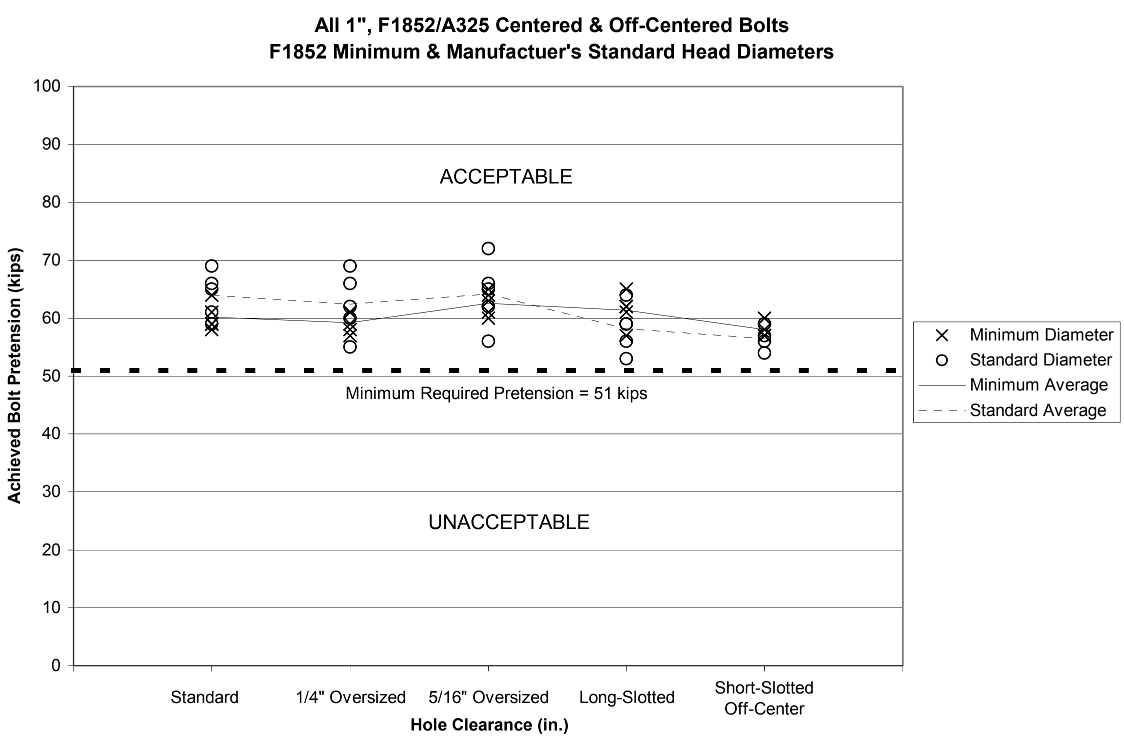


Figure C.6: Results for 1" F1852/A325 Strength, Centered & Off-Centered Bolts, Minimum & Standard Heads

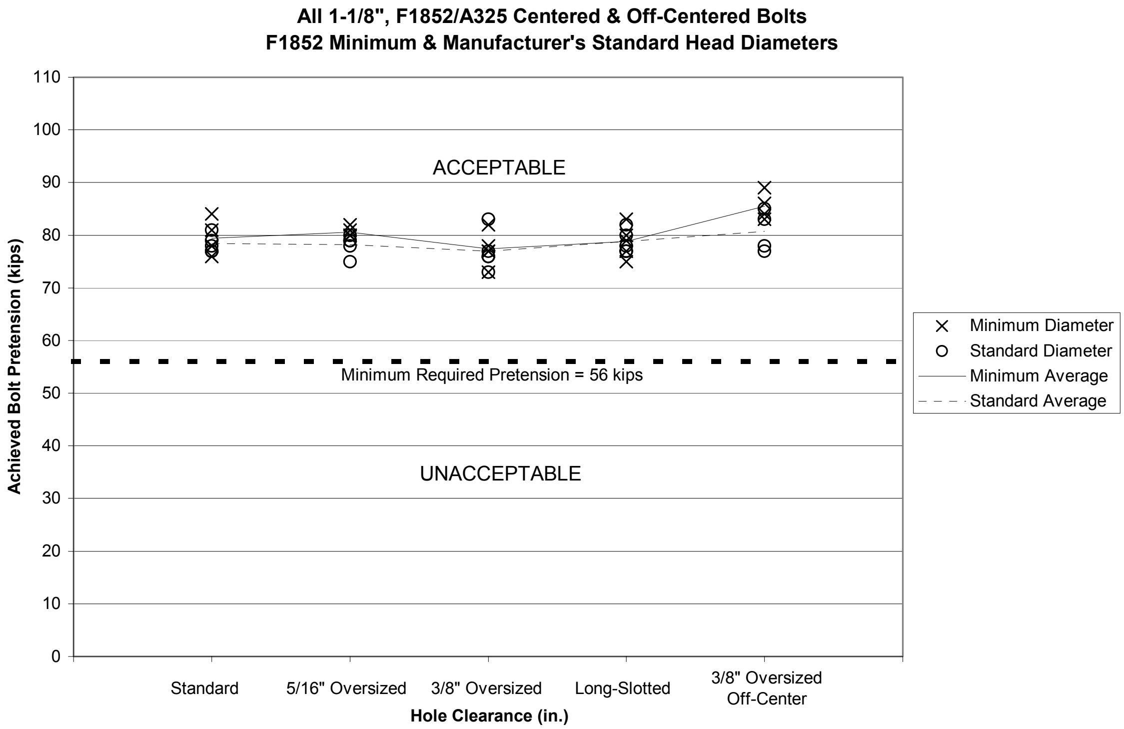


Figure C.7: Results for 1-1/8" F1852/A325 Strength, Centered & Off-Centered Bolts, Minimum & Standard Heads

Table C.1: Pretension Force in Kips for 5/8" Bolts (F1852/A325 Strength, F1852 Minimum Head Diameter)

	Hole Size in Plate				
Test #	11/16"	13/16"	7/8"	15/16"	11/16" x 1-9/16"
1	24	24	24	25	23
	24	23	24	24	22
2	24	25	23	23	22
	23	25	23	22	21
3	24	25	24	22	23
	24	25	24	22	22
4	24	23	22	24	23
	24	23	22	23	23
5	25	23	23	23	24
	24	22	23	23	23
Avg Initial	24.2	24.0	23.2	23.4	23.0
Avg Relaxed	23.8	23.6	23.2	22.8	22.2

Required Bolt Pretension = 19 kips

Table C.2: Pretension Force in Kips for 5/8" Bolts (F1852/A325 Strength, Manufacturer's Standard Head Diameter)

	Hole Size in Plate				
Test #	11/16"	13/16"	7/8"	15/16"	11/16" x 1-9/16"
1	25	24	25	23	25
	25	24	25	23	25
2	23	24	24	25	24
	23	24	24	25	24
3	22	24	25	25	24
	22	24	25	25	24
4	24	24	22	23	24
	24	24	22	23	24
5	24	23	25	23	22
	24	23	25	23	22
Avg Initial	23.6	23.8	24.2	23.8	23.8
Avg Relaxed	23.6	23.8	24.2	23.8	23.8

Required Bolt Pretension = 19 kips

Table C.3: Pretension Force in Kips for 3/4" Bolts (F1852/A325 Strength, F1852 Minimum Head Diameter)

	Hole Size in Plate				
Test #	**13/16"**	**1"**	**1-1/16"**	**13/16" x 1-7/8"**	**1-1/16" x 1-5/16" OC**
1	37	32	39	35	31
	36	31	38	34	31
2	34	32	36	36	35
	34	32	35	35	34
3	36	35	37	38	34
	36	34	37	37	34
4	38	38	36	39	37
	37	38	36	39	37
5	38	35	39	42	
	38	35	39	41	
Avg Initial	36.6	34.4	37.4	38.0	34.3
Avg Relaxed	36.2	34.0	37.0	37.2	34.0

Required Bolt Pretension = 28 kips

Table C.4: Pretension Force in Kips for 3/4" Bolts (F1852/A325 Strength, Manufacturer's Standard Head Diameter)

	Hole Size in Plate				
Test #	**13/16"**	**1"**	**1-1/16"**	**13/16" x 1-7/8"**	**1-1/16" x 1-5/16" OC**
1	36	31	34	33	36
	36	30	33	32	36
2	38	32	37	39	40
	37	32	36	39	40
3	38	32	39	37	35
	38	31	38	37	35
4	32	30	35	38	38
	32	29	35	37	37
5	31	33	36	33	
	30	32	35	33	
Avg Initial	35.0	31.6	36.2	36.0	37.3
Avg Relaxed	34.6	30.8	35.4	35.6	37.0

Required Bolt Pretension = 28 kips

Table C.5: Pretension Force in Kips for 7/8" Bolts (F1852/A325 Strength, F1852 Minimum Head Diameter)

	Hole Size in Plate				
Test #	**15/16"**	**1-1/8"**	**1-3/16"**	**15/16" x 2-3/16"**	**1-3/16" OC**
1	49	49	48	43	49
	48	49	47	42	48
2	48	49	51	48	50
	47	48	51	47	49
3	45	46	51	48	46
	44	45	50	47	45
4	47	52	52	50	55
	46	51	51	50	54
5	45	54	47	49	
	45	53	46	48	
Avg Initial	46.8	50.0	49.8	47.6	50.0
Avg Relaxed	46.0	49.2	49.0	46.8	49.0

Required Bolt Pretension = 39 kips

Table C.6: Pretension Force in Kips for 7/8" Bolts (F1852/A325 Strength, Manufacturer's Standard Head Diameter)

	Hole Size in Plate				
Test #	**15/16"**	**1-1/8"**	**1-3/16"**	**15/16" x 2-3/16"**	**1-3/16" OC**
1	46	48	47	52	48
	46	47	47	52	47
2	47	44	47	48	45
	47	43	46	47	44
3	51	49	48	49	53
	50	48	47	49	52
4	49	48	51	50	50
	48	47	50	49	50
5	52	48	46	54	
	51	48	45	53	
Avg Initial	49.0	47.4	47.8	50.6	49.0
Avg Relaxed	48.4	46.6	47.0	50.0	48.3

Required Bolt Pretension = 39 kips

Table C.7: Pretension Force in Kips for 1" Bolts (F1852/A325 Strength, F1852 Minimum Head Diameter)

	Hole Size in Plate				
Test #	**1-1/16"**	**1-1/4"**	**1-5/16"**	**1-1/16" x 2-1/2"**	**1-3/16" x 1-9/16" OC**
1	60	60	65	58	58
	59	59	64	57	57
2	66	62	64	63	59
	64	61	63	62	58
3	59	58	62	62	58
	58	57	61	61	57
4	62	62	61	66	61
	61	61	60	65	60
5	60	59	66	63	
	59	58	65	62	
Avg Initial	61.4	60.2	63.6	62.4	59.0
Avg Relaxed	60.2	59.2	62.6	61.4	58.0

Required Bolt Pretension = 51 kips

Table C.8: Pretension Force in Kips for 1" Bolts (F1852/A325 Strength, Manufacturer's Standard Head Diameter)

	Hole Size in Plate				
Test #	**1-1/16"**	**1-1/4"**	**1-5/16"**	**1-1/16" x 2-1/2"**	**1-3/16" x 1-9/16" OC**
1	60	70	63	54	57
	59	69	62	53	56
2	71	63	66	60	60
	69	62	65	59	59
3	62	67	74	65	55
	61	66	72	64	54
4	67	61	67	60	58
	66	60	66	59	57
5	66	56	57	57	
	65	55	56	56	
Avg Initial	65.2	63.4	65.4	59.2	57.5
Avg Relaxed	64.0	62.4	64.2	58.2	56.5

Required Bolt Pretension = 51 kips

Table C.9: Pretension Force in Kips for 1-1/8" Bolts (F1852/A325 Strength, F1852 Minimum Head Diameter)

	Hole Size in Plate				
Test #	1-3/16"	1-7/16"	1-1/2"	1-3/16" x 2-13/16"	1-1/2" OC
1	85	84	78	81	87
	84	82	77	80	86
2	82	83	74	85	85
	81	81	73	83	84
3	79	81	84	77	84
	78	80	82	75	83
4	79	82	79	78	90
	78	80	78	77	89
5	77	82	79	81	
	76	80	77	79	
Avg Initial	80.4	82.4	78.8	80.4	86.5
Avg Relaxed	79.4	80.6	77.4	78.8	85.5

Required Bolt Pretension = 56 kips

Table C.10: Pretension Force in Kips for 1-1/8" Bolts (F1852/A325 Strength, Manufacturer's Standard Head Diameter)

	Hole Size in Plate				
Test #	1-3/16"	1-7/16"	1-1/2"	1-3/16" x 2-13/16"	1-1/2" OC
1	79	80	77	79	78
	78	79	76	78	77
2	80	81	85	78	84
	79	79	83	77	83
3	82	76	77	81	79
	81	75	76	80	78
4	78	81	75	83	86
	77	80	73	82	85
5	78	79	78	79	
	77	78	77	77	
Avg Initial	79.4	79.4	78.4	80.0	81.8
Avg Relaxed	78.4	78.2	77.0	78.8	80.8

Required Bolt Pretension = 56 kips

APPENDIX D

TEST RESULTS FOR A490 STRENGTH BOLTS

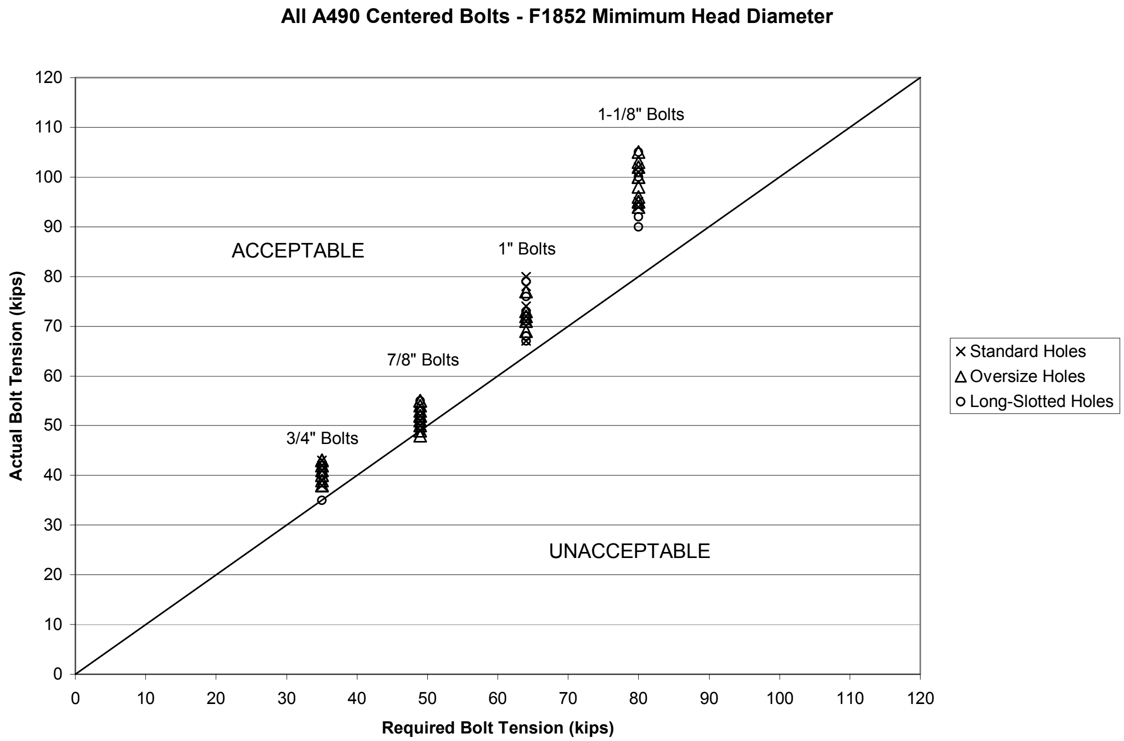


Figure D.1: All A490 Strength, Centered Bolts, Minimum Head

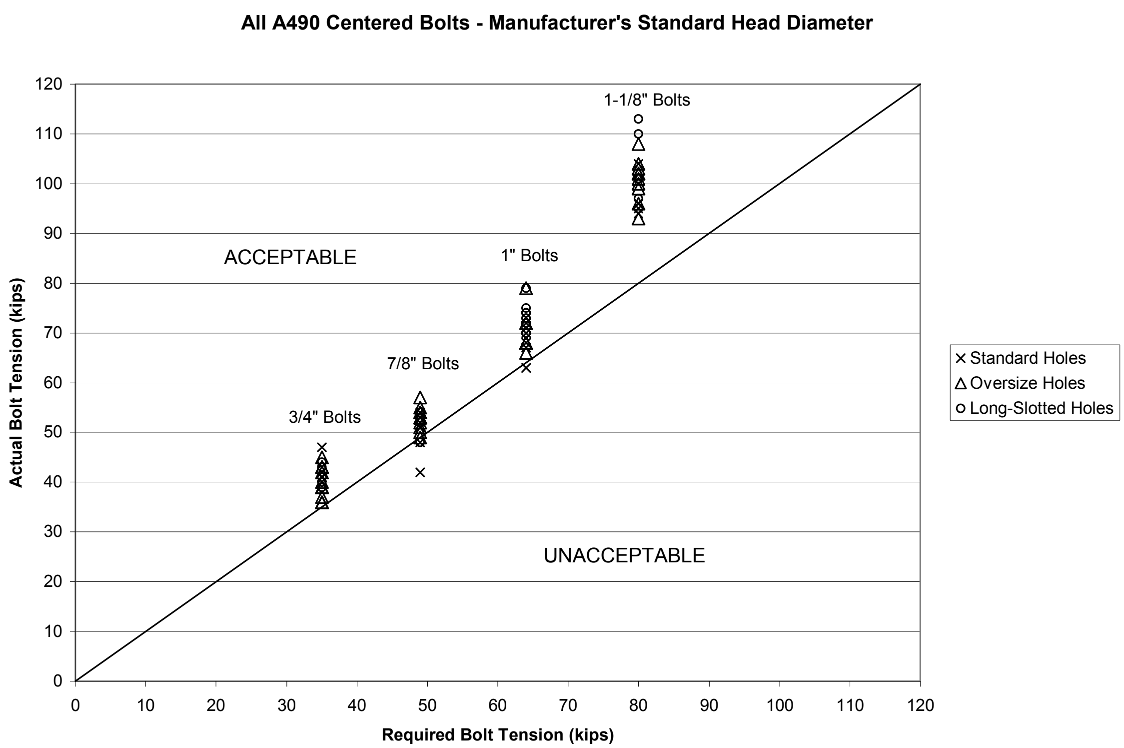


Figure D.2: All A490 Strength, Centered Bolts, Standard Head

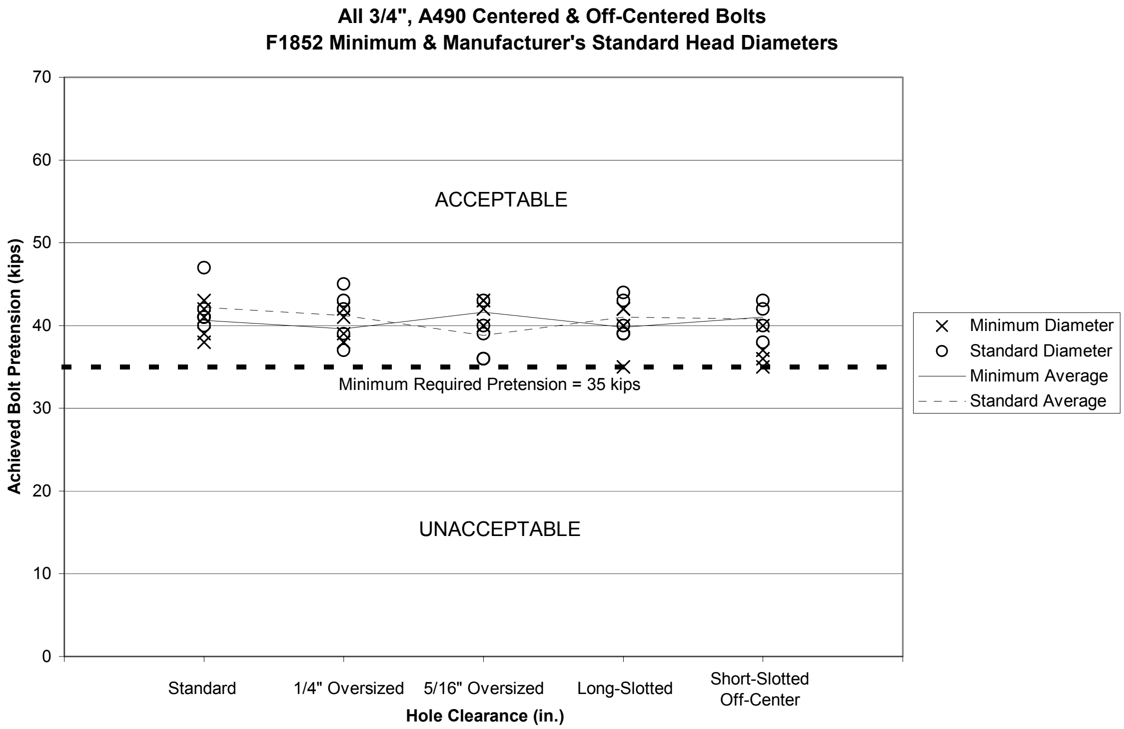


Figure D.3: Results for 3/4" A490 Strength, Centered & Off-Centered Bolts, Minimum & Standard Heads,

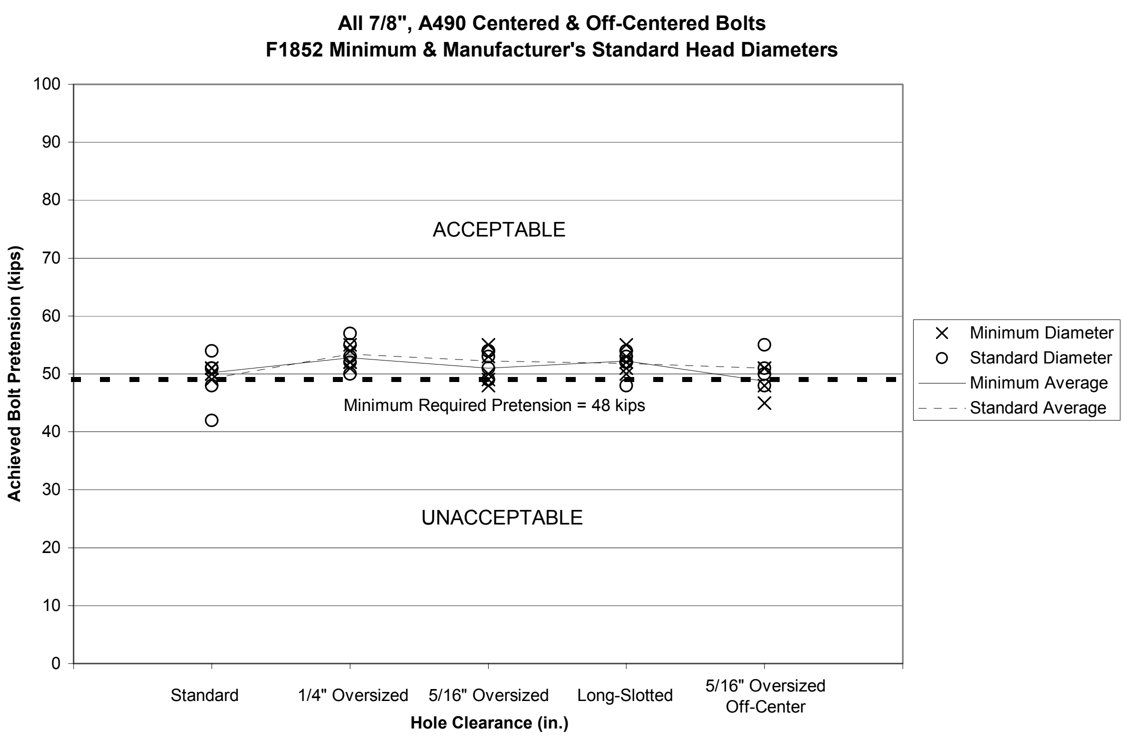


Figure D.4: Results for 7/8" A490 Strength, Centered & Off-Centered Bolts, Minimum & Standard Heads

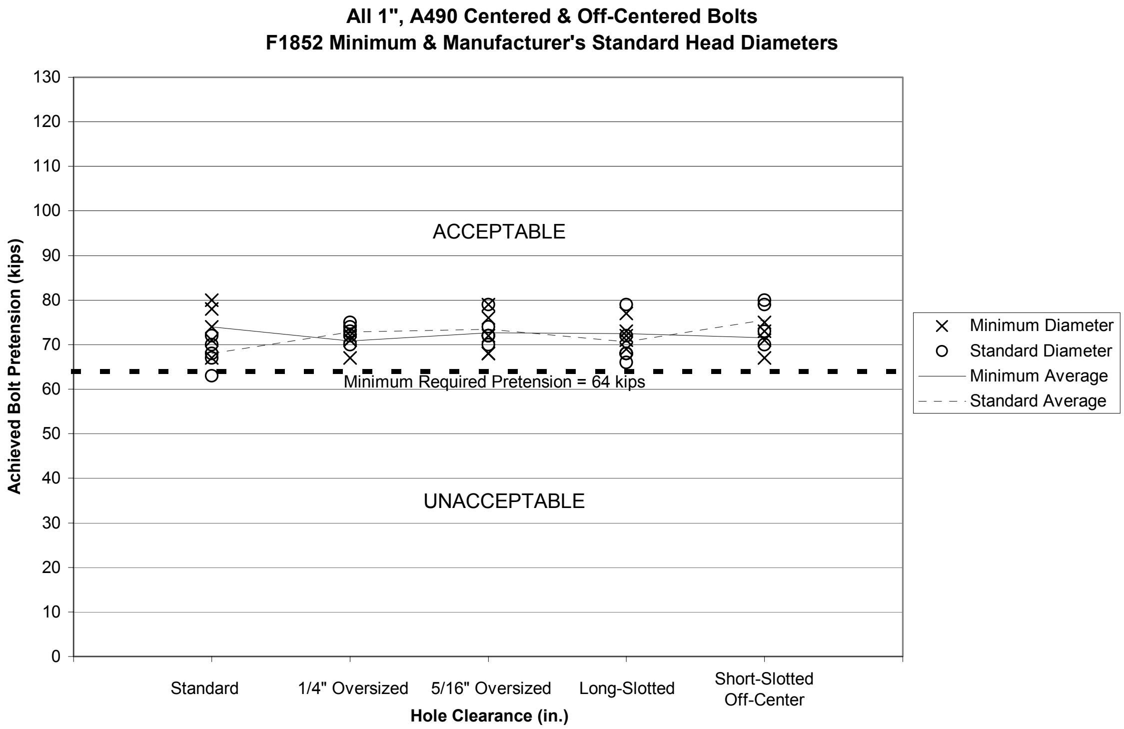


Figure D.5: Results for 1" A490 Strength,
Centered & Off-Centered Bolts, Minimum & Standard Heads

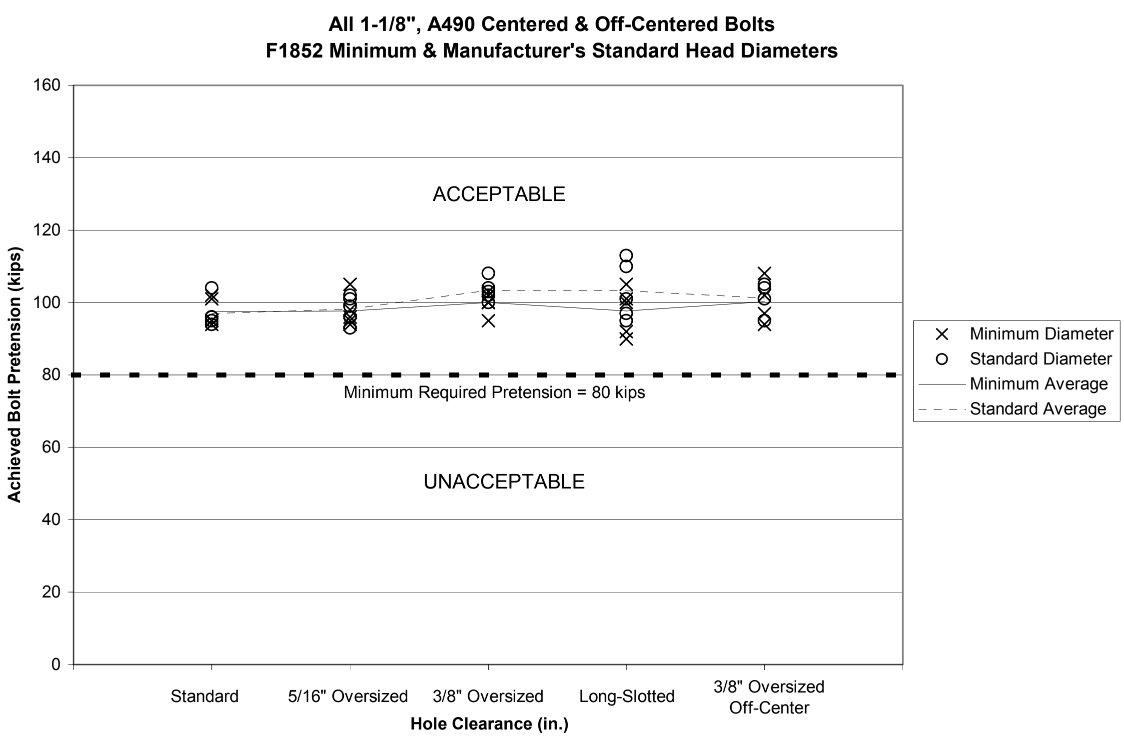


Figure D.6: Results for 1-1/8" A490 Strength,
Centered & Off-Centered Bolts, Minimum & Standard Heads

Table D.1: Pretension Force in Kips for 3/4" Bolts (A490 Strength, F1852 Minimum Head Diameter)

	Hole Size in Plate				
Test #	**13/16"**	**1"**	**1-1/16"**	**13/16" x 1-7/8"**	**1-1/16" x 1-5/16" OC**
1	39	39	40	35	44
	39	38	40	35	44
2	42	38	44	42	40
	42	38	43	42	39
3	44	42	41	41	42
	43	42	40	40	42
4	39	41	42	42	40
	38	41	42	42	39
5	42	39	44	41	
	41	39	43	40	
Avg Initial	41.2	39.8	42.2	40.2	41.5
Avg Relaxed	40.6	39.6	41.6	39.8	41.0

Required Bolt Pretension = 35 kips

Table D.2: Pretension Force in Kips for 3/4" Bolts (A490 Strength, Manufacturer's Standard Head Diameter)

	Hole Size in Plate				
Test #	**13/16"**	**1"**	**1-1/16"**	**13/16" x 1-7/8"**	**1-1/16" x 1-5/16" OC**
1	47	39	41	44	42
	47	39	40	43	42
2	40	42	44	45	41
	40	42	43	44	40
3	42	38	36	41	39
	42	37	36	40	38
4	42	44	36	40	43
	41	43	36	39	43
5	41	46	40	39	
	41	45	39	39	
Avg Initial	42.4	41.8	39.4	41.8	41.3
Avg Relaxed	42.2	41.2	38.8	41.0	40.8

Required Bolt Pretension = 35 kips

Table D.3: Pretension Force in Kips for 7/8" Bolts (A490 Strength, F1852 Minimum Head Diameter)

	Hole Size in Plate				
Test #	**15/16"**	**1-1/8"**	**1-3/16"**	**15/16" x 2-3/16"**	**1-3/16" OC**
1	52	53	50	55	46
	51	52	49	55	45
2	50	52	54	52	52
	49	52	53	51	51
3	52	52	50	51	49
	51	51	50	50	48
4	51	55	49	54	51
	50	54	48	53	51
5	51	56	56	53	
	50	55	55	52	
Avg Initial	51.2	53.6	51.8	53.0	49.5
Avg Relaxed	50.2	52.8	51.0	52.2	48.8

Required Bolt Pretension = 49 kips

Table D.4: Pretension Force in Kips for 7/8" Bolts (A490 Strength, Manufacturer's Standard Head Diameter)

	Hole Size in Plate				
Test #	**15/16"**	**1-1/8"**	**1-3/16"**	**15/16" x 2-3/16"**	**1-3/16" OC**
1	55	53	50	53	51
	54	52	49	52	51
2	42 *	56	55	54	51
	42 *	55	54	53	50
3	52	58	53	55	48
	51	57	53	54	48
4	51	54	51	49	56
	51	53	51	48	55
5	49	51	54	53	
	48	50	54	52	
Avg Initial	51.8	54.4	52.6	52.8	51.5
Avg Relaxed	51.0	53.4	52.2	51.8	51.0

Required Bolt Pretension = 49 kips
***Excluded from Averages**

Table D.5: Pretension Force in Kips for 1" Bolts (A490 Strength, F1852 Minimum Head Diameter)

	Hole Size in Plate				
Test #	1-1/16"	1-1/4"	1-5/16"	1-1/16" x 2-1/2"	1-3/16" x 1-9/16" OC
1	81	72	69	74	74
	80	71	68	73	73
2	72	72	69	73	72
	71	71	68	72	71
3	79	74	80	78	76
	78	73	79	77	75
4	75	68	77	72	68
	74	67	76	71	67
5	68	73	73	70	
	67	72	72	69	
Avg Initial	75.0	71.8	73.6	73.4	72.5
Avg Relaxed	74.0	70.8	72.6	72.4	71.5

Required Bolt Pretension = 64 kips

Table D.6: Pretension Force in Kips for 1" Bolts (A490 Strength, Manufacturer's Standard Head Diameter)

	Hole Size in Plate				
Test #	1-1/16"	1-1/4"	1-5/16"	1-1/16" x 2-1/2"	1-3/16" x 1-9/16" OC
1	73	73	75	73	74
	72	72	74	72	73
2	64	74	80	80	81
	63	73	79	79	80
3	68	76	73	69	80
	67	75	72	68	79
4	69	75	73	67	71
	68	74	72	66	70
5	71	71	71	69	
	70	70	70	68	
Avg Initial	69.0	73.8	74.4	71.6	76.5
Avg Relaxed	68.0	72.8	73.4	70.6	75.5

Required Bolt Pretension = 64 kips

Table D.7: Pretension Force in Kips for 1-1/8" Bolts (A490 Strength, F1852 Minimum Head Diameter)

	Hole Size in Plate				
Test #	**1-3/16"**	**1-7/16"**	**1-1/2"**	**1-3/16" x 2-13/16"**	**1-1/2" OC**
1	103	98	105	102	96
	101	96	103	100	94
2	96	96	102	107	104
	95	94	100	105	102
3	96	97	104	103	110
	94	95	102	101	108
4	103	107	102	92	99
	102	105	100	90	97
5	96	100	97	94	
	95	98	95	92	
Avg Initial	98.8	99.6	102.0	99.6	102.3
Avg Relaxed	97.4	97.6	100.0	97.6	100.3

Required Bolt Pretension = 80 kips

Table D.8: Pretension Force in Kips for 1-1/8" Bolts (A490 Strength, Manufacturer's Standard Head Diameter)

	Hole Size in Plate				
Test #	**1-3/16"**	**1-7/16"**	**1-1/2"**	**1-3/16" x 2-13/16"**	**1-1/2" OC**
1	98	98	105	103	106
	96	96	104	101	105
2	97	104	104	97	102
	96	102	102	95	101
3	96	103	110	115	96
	95	101	108	113	95
4	96	100	104	112	105
	94	99	103	110	104
5	106	95	102	99	
	104	93	100	97	
Avg Initial	98.6	100.0	105.0	105.2	102.3
Avg Relaxed	97.0	98.2	103.4	103.2	101.3

Required Bolt Pretension = 80 kips

APPENDIX E

PHOTOS TAKEN DURING TESTING

Figure E.1: Rear View of Typical Skidmore Setup

Figure E.2: Manufacturer's Standard and F1852 Minimum Bolt Heads

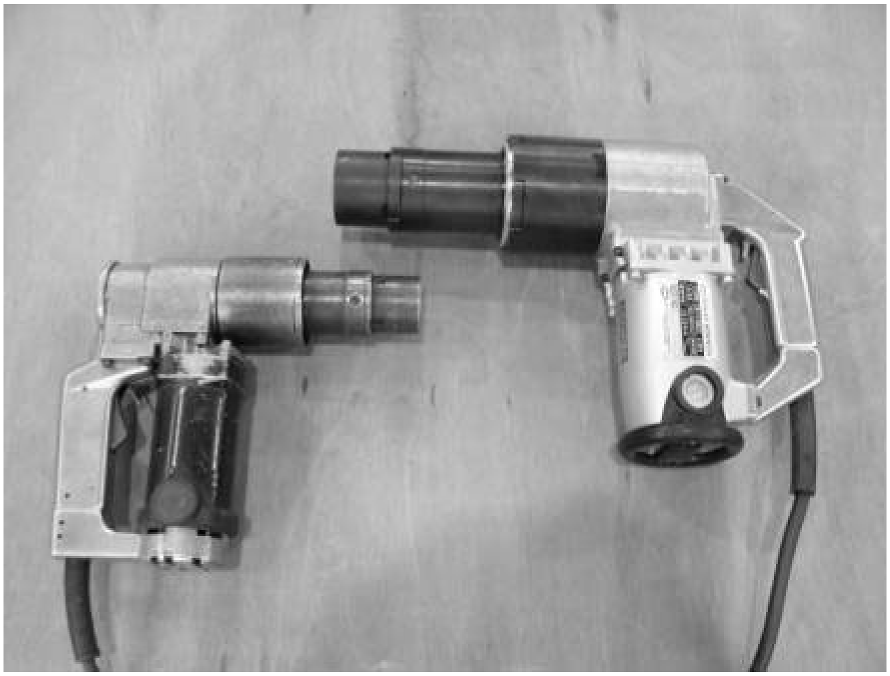


Figure E.3: Tone Wrenches Used for Tightening

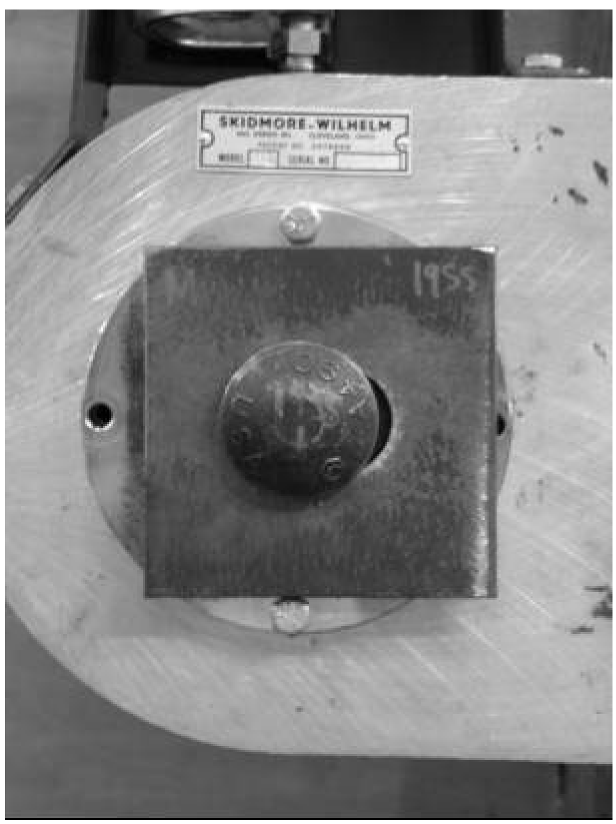


Figure E.4: Setup for 1" Bolt, A490 Strength, Off-Centered Test