Night School 27: Fundamentals of Welding and Bolting

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Bolting Part 1 – Bolting Background and Basic Concepts
November 2, 2021 | Chad Larson

Smarter. Stronger. Steel.

AISC Night School

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AISC Night School

Course Description

Fundamentals of Bolting and Welding

Bolting Part 1 – Bolting Background and Basic Concepts
November 2, 2021

This session will introduce the general terms and functional elements of structural fasteners. Standards and requirements for structural fasteners will be explained including new standards. This session is intended to equip participants with a conversational understanding of physical and mechanical properties, including basic fastener behavior and terms.

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Learning Objectives

- Define basic bolting terms.
- List the steps of how bolts are made.
- Bolting basic concepts.
- Bolt and nut threads.
- Learn about torque and define "K" or torque factor.

Night School 27: Fundamentals of Welding and Bolting

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About the Presenter

Current and Past Committee Work

- AISC - Task Committee 6 on Connection Design
- AISC - Task Committee 10 on Materials
- RCSC - Secretary and Treasurer
- RCSC - Executive Committee
- RCSC - Specification Committee
- RCSC - Task Group 1 on General Requirements
- RCSC – Chair, Task Group 4 on Installation
- RCSC/ASTM Liaison
- RCSC/AISC Liaison
- AIA - Accredited Speaker and Presenter
- JSS - Committee on the English Translation of JSSII 09-2015
- ASTM - Award of Merit Selection Committee
- Author of ASTM F3125 and ASTM F3148

Current and Past Committee Work

- ASTM - Chair, F16 Committee on Fasteners
- ASTM - Vice Chair, F16 Committee on Fasteners
- ASTM - Chair, F16.02 Subcommittee on Steel Bolts, Nuts and Washers
- ASTM - Chair, F16.02.02 Task Group on Structural Bolts
- ASTM - F16.01 Fastener Test Methods
- ASTM - F16.02 Subcommittee on Steel Bolts, Nuts and Washers
- ASTM - F16.03 Coatings on Fasteners
- ASTM - F16.90 Executive
- ASTM - F16.93 Quality Assurance Provisions for Fasteners
- ASTM - F16.97 Coordination with NA TAGs to ISO TC2 on Fasteners
- ASTM - A01.22.01 Bolting
- ASTM - Chair, F16 Award Committee
- ASTM F16 Fred F. Weingruber Award Recipient

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Session 1

- Basic Background and Basic Concepts
  - Terms
  - How they are made
    - Cold Forming
    - Hot Forming
    - Thread Rolling
  - Threads and dimensions
    - Shear plane location
  - Lubrication
    - K – Factor

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Session 2

- Organizations, Specifications, and Connections
  - Key events in structural bolting history
  - Engineer responsibility
  - Standards Organizations
  - Structural bolt standards
  - F3125, F3148, F3043 and F3111
  - Failure modes
  - Basic Connections
  - Practical tips

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Session 3

- Ordering, Storing, Installing, and Inspecting
  - Ordering information
  - Storage and Handling
  - Pre-installation testing
  - Turn of nut installation
  - Twist-off bolt installation
  - DTI installation
  - Calibrated wrench installation
  - Part-turn methods
  - Inspection and arbitration inspection

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Session 4

- Supplementary Requirements, Rotational Capacity Testing, New Standards and Changes to Existing Standards
  - Coating on structural bolts
  - Bolt reuse
  - A325T – fully threaded bolts
  - Surface discontinuities
  - Non-conforming material handling
  - Bolt banging
  - Problem solving and prevention

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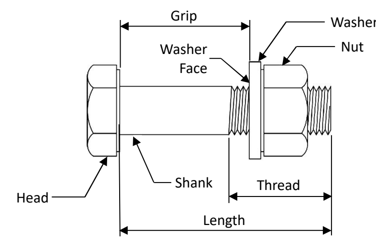
Parts of the Bolt Assembly



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Terms – ASTM F1789

- **Bolt—**headed and externally threaded fastener designed to be assembled with a nut.
- **Bolt-nut-washer assembly—**a combination of bolt, nut, and washer components from singular lots that have been assembled, lubricated as necessary, tested as required, and prepared for shipment to a customer creating a unique set and certifiable lot.

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Terms

- **Clamp load—**sometimes called preload or initial load. It is a tension on a bolt or screw, which results in equal and opposite forces which exist at the interface between two members generated through the cumulative effect of tightening one or more fasteners.
- **Cold forming—**process of forming material below the recrystallization temperature by forcing or pressing metal into various dies.

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Terms

- **Fastener tensile stress area—**assumed cross sectional area of a threaded fastener (usually) through the thread, which is used when computing the load a fastener can support in tension.
- **Lot—**quantity of product of one part number that has been processed essentially under the same conditions from the same heat treatment lot and produced from one mill heat of material and submitted for inspection at one time.

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Terms

- **Nut—**internally threaded product intended for use on external or male screw threads such as a bolt or a stud for the purpose of tightening or assembling two or more components.
- **Proof load, externally threaded fastener—**tension applied load that the fastener must support without evidence of permanent deformation (for most carbon or alloy steel fastener strength grades or property classes, proof loads are established at approximately 90% to 93% of the expected minimum yield strength).

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Terms

- **Shear strength—**maximum load applied through the body or through the threads that can be supported prior to fracture. Single shear is load occurring in one transverse plane, thus cutting the fastener into two pieces; double shear is load applied in two planes so that, at fracture, the fastener would be cut into three pieces.
- **Test report—**written document or electronic record, signed by an authorized party, which contains sufficient data and information to verify that the tested fastener properties conform to specification requirements.

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Terms

- **Ultimate tensile load—**maximum tensile-applied load or force a fastener can support prior to or coincidental with its fracture, and normally expressed in terms of Pounds or Newtons.
- **Wedge tensile test—**tensile test performed on various headed fasteners and studs using a wedge of prescribed dimensions and hardness, and in a prescribed manner for the purpose of verifying good head quality or ductility, or both.

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Terms

- **Yield strength—**tension-applied load at which the fastener experiences a specific amount of permanent deformation, that is, the bolt has been stressed beyond its elastic limit and is in the plastic zone. It is very difficult to test full size bolts for yield strength. Because of different strain rates in the threaded section, thread runout and unthreaded shank which together comprise the stressed length, a "proof load" concept was introduced.
- **Elastic Interaction:** in a bolted joint with multiple fasteners, variation in individual fastener preload due to tightening of the other fasteners.

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Terms

- **Embedment:** localized yielding of bolted joint components resulting in a change of grip length consequently causing relaxation of the bolted joint.
- **Grip Length:** the combined thickness of all components joined together between the bolt head and nut.

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Terms

- **Nut Factor: (K Factor)** an empirically determined constant that models many variables, such as friction, that affect the torque-tension relationship.
- **Preload:** the tensile force developed during installation.

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Terms

- **Plastic deformation—**permanent distortion of a material under the action of applied stresses.
- **Hot forged—**formed by hammering or pressing of metal at a temperature which allows recrystallization to occur simultaneously with deformation and avoids strain hardening.

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Where Are They Made

- Everywhere
  - $80 Billion USD Dollar Worldwide
  - $28 Billion in Asia
  - $18 Billion in Europe
  - $15 Billion in US
  - About $350 Million North American Structural Bolt Market
- There are structural bolt producers in every developed region of the world (and some undeveloped)

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Made With What?

- Virtually everything you can imagine, but…
  - Structural bolts are typically
    - Medium Carbon Steel
    - Carbon Boron Steel
    - Alloy Steel
    - Weathering Steel

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How Are Bolts and Nuts Made

- Cold Forming
  - Usually large runs – ½” to 1-1/8” or 1-1/4” diameter bolts
  - Lengths up to 6” or 8”
  - Smaller nuts
- Hot Forging
  - Specials
  - Long lengths
  - Large diameters
  - Most nuts are hot forged
  - Hot forging can also make “normal” product, just not as efficiently
- Washers stamped, sometimes cold formed

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Cold Forming

- http://youtu.be/3kxcw08p_oY
- Cold Forming
  - Good for high volume runs, often highly automated
  - Typically done on 4 or 5 station high speed cold forming machines, with 60 to 120 ppm typical
  - Expensive tooling
  - Long changeover time
  - Very good tolerance control
  - Longer tool life than hot forging
  - Almost always rolled threads
  - Generally clean surface finish

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Cold Forming

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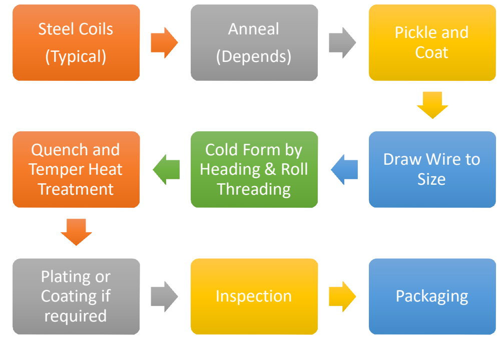
Cold Forming Process



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Typical Cold Forming Progression

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Hot Forging/Forming

- Hot Forging/Hot Forming
  - Better for low volume runs, large diameters or long lengths
  - High temperature via electric induction heaters or gas
  - Hot forged bolts more likely to have seams, fins or swells
  - Hot forged bolts more likely to have cut threads, but rolled threads are available from many manufacturers
  - Greater range of diameters and lengths available with hot forging
  - Bolts often made from blanks to speed delivery, often cut and threaded later
  - Some mill and heat scale

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Bolt Hot Forging

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Thread Rolling

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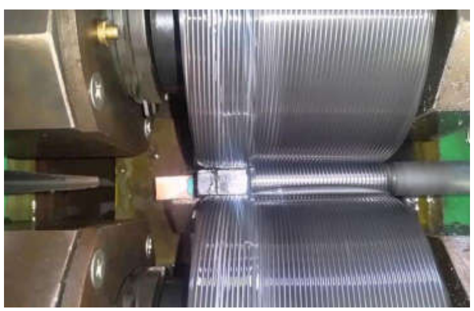
Thread Rolling



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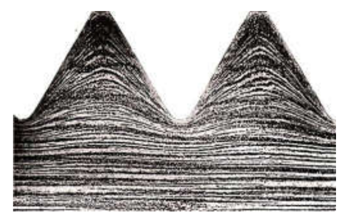
Thread Rolling



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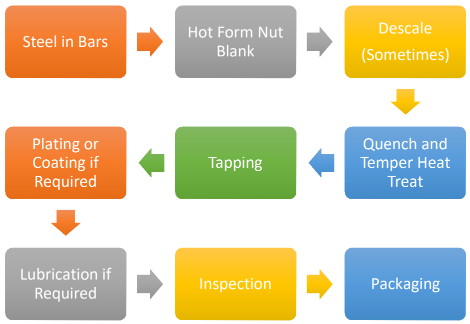
Hot Forming Progression



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How Are Nuts Made?

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Bolting Basics

- Some basic things you should understand about bolts

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Essentials

- Bolts are sometimes in tension, sometimes in compression, sometimes in shear, or in combinations of the above.
- For our purposes we consider bolts to be springs or pins for most applications.
- Clamp load, or pretension, is limited by tensile strength.
- Shear strength is limited by tensile strength.

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Essentials

- We generally classify bolts by strength level.
  - 60,000 psi, 120,000 psi, 144,000 psi, 150,000 psi
- There are numerous grades and types at each level.
  - SAE, JSS, ASTM, ISO, EN.
- The strength level is primarily a function of hardness.
- Hardness is primarily a function of material selection and heat treatment.

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Essentials

- Steel structures will generally use bolts between 60,000 psi and 150,000 psi tensile strength.
- Applied stress results in stretch and elongation (strain).
- Stress is virtually always applied using torque (measured or not).
- Bolts are one component of the overall design.

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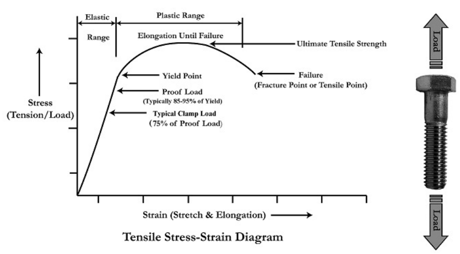
Understanding the Curve



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Essentials

- The helix angle of the threads produces a certain stretch when turned a certain amount. Stiffness results in a given load for a given elongation.
- We tend to think of bolts as things that we tighten, but in steel construction, clamp load is often irrelevant.
- This would normally be quite simple, but….

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Essentials

- Bolts are really two springs, with different spring rates.
- Threads in the grip can be variable but can greatly affect spring rate (clamp load).
- So can the stiffness of connected material, including coatings.
- Complex joint geometry and large connections can result in significant elastic interaction.
- Proper snugging can eliminate many problems.

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Bolting Basics

- Nuts should be stronger than bolts.
- The more bolt threads in the grip the better, worry more about shank-out than stick-out.
- Lubrication is essential to performance (if performing as clamps).
- Torque can be a good indicator of tension if controlled, but we do not directly control or recognize torque.
- Fine threaded bolts are stronger and more vibration resistant.

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Bolting Basics

- Large bolts and nuts are more difficult to heat treat properly.
- For large diameters be sure to consider die fins or possible body swells and hole size – (later) This has been largely resolved with recent hole size changes.
- Long bolts can be difficult to keep straight, consider this when going through many thick plies.
- Most stress is on the first few nut threads nearest the grip.
- Many quality problems are a result of poor heat treatment or thread quality/fit.

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Why Do We Need Clamp Load?

- Reduce the effect of applied forces on the fastener.
- Provide friction or slip resistance in slip-critical connections.

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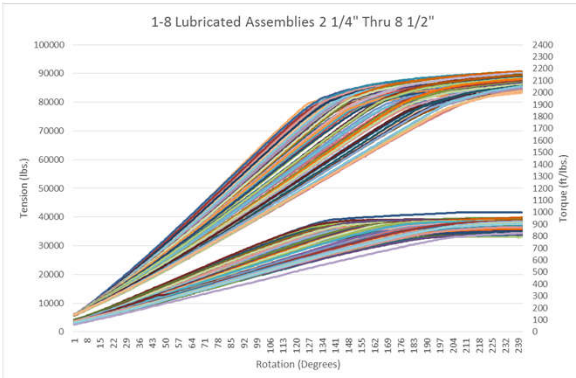

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The best bolts would be…

Best Scenario

- Medium strength level
- Fine threads
- Have many threads in the grip
- Well lubricated
- Tensioned below yield
- Installed only from the nut side
- Matched assemblies

Structural Bolts

- High strength level
- Coarse threads (UNC)
- Usually very few threads in the grip
- Lubrication sometimes
- Tensioned above yield often
- Installed from either side
- Often not matched

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Threads

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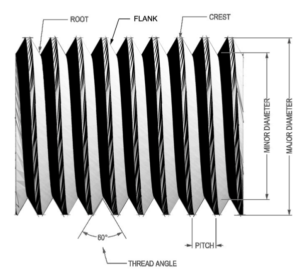
Basic Thread Terms



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Bolt and Nut Threads

- There are over 120 elements to thread design.
- Standards allow us to ignore most of those elements, but a few are important to understand.
- Inch series structural bolts are always "Unified Coarse", Class 2A tolerance.
- Threads do not load evenly.

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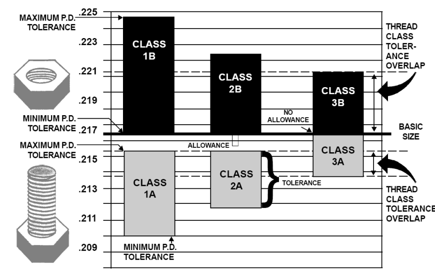
Thread Class



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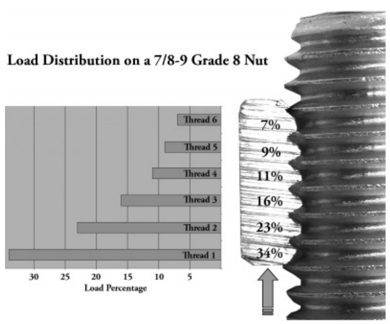
Thread Load Distribution



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Pitch vs. Pitch Diameter (P.D.)

- We need a means of determining the physical thread size for a given pitch (spacing) and nominal diameter
  - The pitch diameter is the diameter of a cylindrical surface, axially concentric to the thread, which intersects the thread flanks at equidistant points.
    - Diameter across threads from theoretic thread centerlines
  - Pitch diameter is the functional size of a given thread form
    - Many manufacturers do not measure pitch directly. Go/NoGo
    - Coatings significantly change pitch diameter but not pitch

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Pitch vs. Pitch Diameter (P.D.)

- Pitch is simply thread spacing
  - Inch series in TPI or 7/8”-9 x 2” is 9 **T**hreads **P**er **I**nch
  - Metric series in individual spacing M22 x 2.5 x 40 is 2.5mm between threads
  - Ex. UNF is 7/8”-14 x 2”
  - Ex. UNC is 7/8”-9 x 2”

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Threads Continued…

- Rolled threads can be 5 to 15 percent stronger, depending on the grade of the fastener, but cut threads can also meet specifications.
- Many quality issues are the result of threads or functional thread fit.
- Structural bolts have much shorter threads than standard cap screws.
- Thread specification is 190 pages long.

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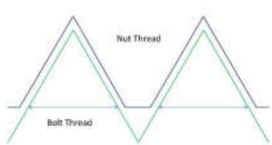
Thread Profile Standard Tap



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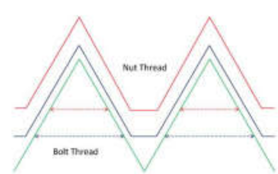
Thread Profile Over-Sized



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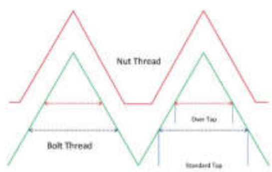
Thread Profile Over-Sized



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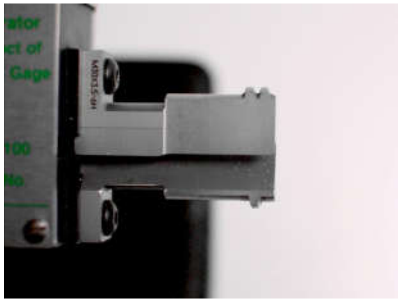
Single Point Measurement



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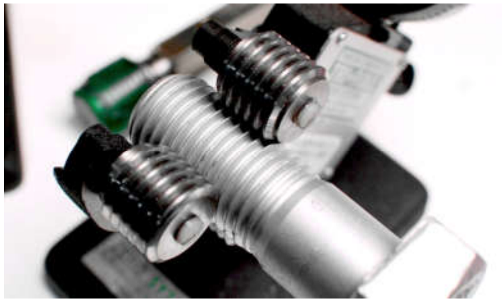
Multi Point Measurement



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Mating Components

- Improperly mated

- Improperly mated

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Shear

Threads Included and Threads Excluded

Thread Lengths – Not All Equal

Thread Length

Table 2.4
Dimensional Requirements for Bolting Components and Assemblies

Bolting Component or Assembly	Dimensional Standard
Group 120 and 150 heavy hex bolt	ASME B18.2.6
Group 120 and 150 *spline end twist-off matched bolting assembly*	ASME B18.2.6
Group 144 heavy hex bolt Group 144 *spline end fixed matched bolting assembly*	ASTM F3125 ASME B18.2.6 except for spline dimensions
ASTM A563 heavy hex nut ASTM A194 heavy hex nut	ASME B18.2.6 ASME B18.2.2
ASTM F436 washer	ASTM F436
ASTM F959 *direct tension indicator*	ASME B18.2.6

Dimensions

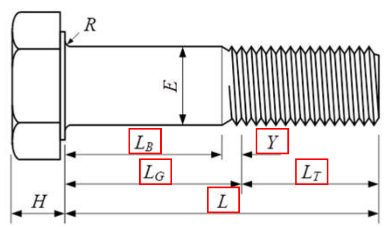

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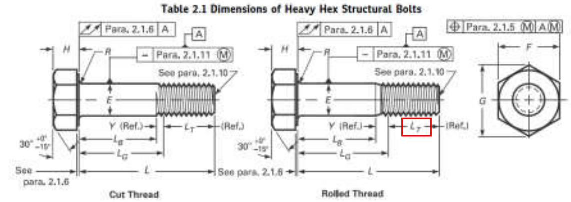
Table 2.1 Dimensions of Heavy Hex Structural Bolts



Nominal Size or Basic Product Diameter [Note (1)]		Body Diameter, E [Notes (2) and (3)]		Width Across Flats, F [Note (4)]			Width Across Corners, G		Head Height, H [Note (5)]			Radius of Fillet, R		Thread Length, L_T [Note (6)]	Transition Thread Length, Y [Note (6)]	Maximum Total Runout of Bearing Surface FIM [Note (7)]
		Max.	Min.	Nominal	Max.	Min.	Max.	Min.	Nominal	Max.	Min.	Max.	Min.	Ref.	Ref.	
1/2	0.500	0.515	0.482	7/8	0.875	0.850	1.010	0.969	5/16	0.323	0.302	0.031	0.009	1.00	0.19	0.016
5/8	0.625	0.642	0.605	1 1/16	1.062	1.031	1.227	1.175	25/64	0.403	0.378	0.062	0.021	1.25	0.22	0.019
3/4	0.750	0.768	0.729	1 1/4	1.250	1.212	1.443	1.383	15/32	0.483	0.455	0.062	0.021	1.38	0.25	0.022
7/8	0.875	0.895	0.852	1 7/16	1.438	1.394	1.660	1.589	35/64	0.563	0.531	0.062	0.031	1.50	0.28	0.025
1	1.000	1.022	0.976	1 5/8	1.625	1.575	1.876	1.796	39/64	0.627	0.591	0.093	0.062	1.75	0.31	0.028
1 1/8	1.125	1.149	1.098	1 13/16	1.812	1.756	2.093	2.002	11/16	0.718	0.658	0.093	0.062	2.00	0.34	0.032
1 1/4	1.250	1.277	1.223	2	2.000	1.938	2.309	2.209	25/32	0.813	0.749	0.093	0.062	2.00	0.38	0.035
1 3/8	1.375	1.404	1.345	2 3/16	2.188	2.119	2.526	2.416	27/32	0.878	0.810	0.093	0.062	2.25	0.44	0.038
1 1/2	1.500	1.531	1.470	2 3/8	2.375	2.300	2.742	2.622	15/16	0.974	0.902	0.093	0.062	2.25	0.44	0.041

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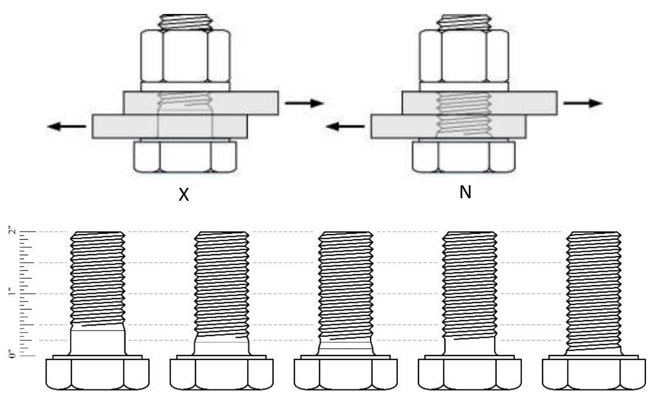

(a) (b) (c) (d) (e)

75 75

X Marks the Spot

- Confusion for the past 30+ years regarding bolt thread lengths.
- AISC, RCSC, and others have used a “reference” thread length by bolt diameter.
- Producers do not measure “reference lengths”.
- B18.2.6 calls out length of body, length of grip, and overall length.
- Thread length is simply what remains when the other conditions are met.
- Reference length does not consider the length tolerance and transition area.

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X Marks the Spot

- There is a requirement in B18.2.6 that short bolts with a body length under a certain length be fully threaded.
- *Bolts of nominal lengths that have a calculated L_B min. length equal to or shorter than 2.5 times the thread pitch for sizes 1 in. diameter and smaller, and 3.5 times the thread pitch for sizes larger than 1 in. diameter, shall be threaded for full length (see Table 2.1.9.2).*

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ASME B18.2.6-2019

Table 2.1.9.2 Maximum Grip Gaging Lengths and Minimum Body Lengths for Structural Bolts

	Nominal Diameter and Thread Pitch																	
	½-13		⅝-11		¾-10		⅞-9		1-8		1⅛-7		1¼-7		1⅜-6		1½-6	
Nominal Length, L	L_G Max.	L_B Min.	L_G Max.	L_B Min.	L_G Max.	L_B Min.	L_G Max.	L_B Min.	L_G Max.	L_B Min.	L_G Max.	L_B Min.	L_G Max.	L_B Min.	L_G Max.	L_B Min.	L_G Max.	L_B Min.
1¼	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
1½	0.50	0.31	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
1¾	0.75	0.56	0.50	0.28	...	...	...	...	...	...	...	...	...	...	...	...	...	...
2	1.00	0.81	0.75	0.53	0.62	0.37	...	...	...	...	...	...	...	...	...	...	...	...
2¼	1.25	1.06	1.00	0.78	0.87	0.62	0.75	0.47	...	...	...	...	...	...	...	...	...	...
2½	1.50	1.31	1.25	1.03	1.12	0.87	1.00	0.72	0.75	0.44	...	...	...	...	...	...	...	...
2¾	1.75	1.56	1.50	1.28	1.37	1.12	1.25	0.97	1.00	0.69	...	...	...	...	...	...	...	...
3	2.00	1.81	1.75	1.53	1.62	1.37	1.50	1.22	1.25	0.94	1.00	0.66	1.00	0.62	...	...	...	...
3¼	2.25	2.06	2.00	1.78	1.87	1.62	1.75	1.47	1.50	1.19	1.25	0.91	1.25	0.87	...	...	...	...
3½	2.50	2.31	2.25	2.03	2.12	1.87	2.00	1.72	1.75	1.44	1.50	1.16	1.50	1.12	1.25	0.81	1.25	0.81
3¾	2.75	2.56	2.50	2.28	2.37	2.12	2.25	1.97	2.00	1.69	1.75	1.41	1.75	1.37	1.50	1.06	1.50	1.06
4	3.00	2.81	2.75	2.53	2.62	2.37	2.50	2.22	2.25	1.94	2.00	1.66	2.00	1.62	1.75	1.31	1.75	1.31
4¼	3.25	3.06	3.00	2.78	2.87	2.62	2.75	2.47	2.50	2.19	2.25	1.91	2.25	1.87	2.00	1.56	2.00	1.56
4½	3.50	3.31	3.25	3.03	3.12	2.87	3.00	2.72	2.75	2.44	2.50	2.16	2.50	2.12	2.25	1.81	2.25	1.81
4¾	3.75	3.56	3.50	3.28	3.37	3.12	3.25	2.97	3.00	2.69	2.75	2.41	2.75	2.37	2.50	2.06	2.50	2.06

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Table 1. Comparison of minimum ASME body length with assumed AISC body length.

Potential Minimum ASME Body Length vs. Assumed AISC Body Length (L_B) in Inches														
	⅝"-11		¾"-10		⅞"-9		1"-8		1⅛"-7		1¼"-7		1½"-6	
Nominal Length, L	ASME L_B Min[1]	AISC Table 7-14[2]	ASME L_B Min[1]	AISC Table 7-14[2]	ASME L_B Min[1]	AISC Table 7-14[2]	ASME L_B Min[1]	AISC Table 7-14[2]	ASME L_B Min[1]	AISC Table 7-14[2]	ASME L_B Min[1]	AISC Table 7-14[2]	ASME L_B Min[1]	AISC Table 7-14[2]
1½	...	0.25	...	0.125	...	...	...	...	...	...	...	...	...	...
1¾	0.28	0.50	...	0.375	...	0.25	...	...	...	...	...	...	...	...
2	0.53	0.75	0.37	0.625	...	0.50	...	0.25	...	...	...	...	...	...
2¼	0.78	1.00	0.62	0.875	0.47	0.75	...	0.50	...	0.25	...	0.25	...	...
2½	1.03	1.25	0.87	1.125	0.72	1.00	0.44	0.75	...	0.50	...	0.50	...	0.25
2¾	1.28	1.50	1.12	1.375	0.97	1.25	0.69	1.00	...	0.75	...	0.75	...	0.50
3	1.53	1.75	1.37	1.625	1.22	1.50	0.94	1.25	0.66	1.00	0.62	1.00	...	0.75
3¼	1.78	2.00	1.62	1.875	1.47	1.75	1.19	1.50	0.91	1.25	0.87	1.25	...	1.00
3½	2.03	2.25	1.87	2.125	1.72	2.00	1.44	1.75	1.16	1.50	1.12	1.50	0.81	1.25
3¾	2.28	2.50	2.12	2.375	1.97	2.25	1.69	2.00	1.41	1.75	1.37	1.75	1.06	1.50
4	2.53	2.75	2.37	2.625	2.22	2.50	1.94	2.25	1.66	2.00	1.62	2.00	1.31	1.75
4¼	2.78	3.00	2.62	2.875	2.47	2.75	2.19	2.50	1.91	2.25	1.87	2.25	1.56	2.00
4½	3.03	3.25	2.87	3.125	2.72	3.00	2.44	2.75	2.16	2.50	2.12	2.50	1.81	2.25

[1] Potential minimum length of body (LB) per ASME 18.2.6 -19

[2] Calculated length of body (LB) using AISC Table 7-14—Nominal bolt length minus reference thread length

... Fully threaded (although some unthreaded portion under the head, in any configuration, may remain)

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Light Reading if Interested

steelwise

THE SHORT SHANK REDEMPTION

BY GIAN A. RASSATI, PhD, JAMES A. SWANSON, PhD, AND CHAD M. LARSON

Expert advice on bolt design for structural joints.

Gian Andrea Rassati (gian.rassati@uc.edu) and **James A. Swanson** (james.swanson@uc.edu) are both associate professors in the College of Engineering and Applied Science at the University of Cincinnati. **Chad M. Larson** (clarson@lejeunebolt.com) is president of LeJeune Bolt Company.

https://www.aisc.org/globalassets/modern-steel/archives/2020/december2020.pdf

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More Reading on Short Bolts

Dimensional Tolerances and Length Determination of High-Strength Bolts
https://www.aisc.org/Dimensional-Tolerances-and-Length-Determination-of-High-Strength-Bolts

A Reliability Study of Joints with Bolts Designed with Threads X but Installed with Threads N
https://www.aisc.org/A-Reliability-Study-of-Joints-with-Bolts-Designed-with-Threads-Excluded-but-Installed-with-Threads-N

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Lubrication and Torque

- Understanding the “K” or “Nut Factor”

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Torque

- We do not use or recognize torque directly as an installation method for structural bolts because it can be variable.
- We need a means to express this variability, which is applicable across diameters, pitches, coatings, lengths, etc.
  - So - we have the “K” Factor

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“K” – The Nut Factor

- Within the elastic range, before permanent stretch, the relationship between torque and tension is mostly linear.
- Over 50 variables influence this relationship: surface roughness, temperature, rate of installation, helix angle, stiffness, and humidity to name a few.
- **50/40/10 rule** – Bearing Face, Threads, Pretension.

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"K" – The Nut Factor

- Typical values for applications are:
  - K = 0.20 as-received bolts and nuts with no supplemental lubrication (This can be highly variable)
  - K = 0.10 to 0.18 bolts and nuts with wax or other lubricant
  - K = 0.28 bolts with HDG coating and no lubricant

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Lubrication

Bolt Dia. 0.75		K - Factor	K - Factor	K - Factor	K - Factor	K - Factor	K - Factor	K - Factor	K - Factor	K - Factor
		0.09	0.11	0.13	0.15	0.17	0.19	0.21	0.23	0.25
Tension	1000	6	7	8	9	11	12	13	14	16
in lbs.	5000	28	34	41	47	53	59	66	72	78
	10000	56	69	81	94	106	119	131	144	156
	15000	84	103	122	141	159	178	197	216	234
	20000	113	138	163	188	213	238	263	288	313
	25000	141	172	203	234	266	297	328	359	391
	30000	169	206	244	281	319	356	394	431	469
	35000	197	241	284	328	372	416	459	503	547
	40000	225	275	325	375	425	475	525	575	625
	45000	253	309	366	422	478	534	591	647	703

Torque, ft./lbs.

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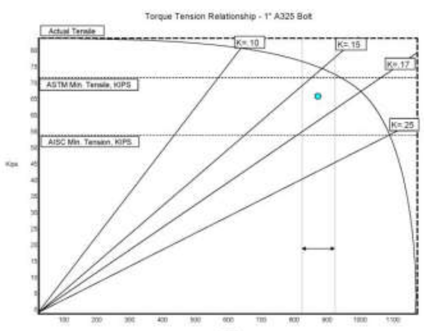
Lubrication or Coating "K" Factor



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"K" Factor or Nut Factor

Torque is the Twisting Force Applied to the Nut or Bolt during installation to tighten the joint.

T = K*D*N
T = Torque (Ft-Lb)
K= Friction Factor (dimensionless number)
D= Nominal Bolt Dia. (in Feet)
N= Clamp (Tensile) Force (Lbf)

Sample Calculation - 3/4" A325 Bolt Plain - Tightened to 28 kips

T= .20*.75/12*28,000 = 350 Ft-Lb

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“K” Factor or Nut Factor

The relationship or K-factor between applied torque and the resulting fastener tension.
The following formula can be used to get the K factor if the torque, tension and size are known.

K= T/N * 12/D
Where: K = K or nut factor
T = Torque
N = Clamp Force
D = Nominal bolt diameter

Example: ¾” x 2” TC Bolt. 300 ft. lbs. torque at 35,000 lbs. clamp load.

K= (300/35000) * (12/.750) = .137

Solving for Torque the equation becomes T= K*D*N (sometimes P, Sometimes F)

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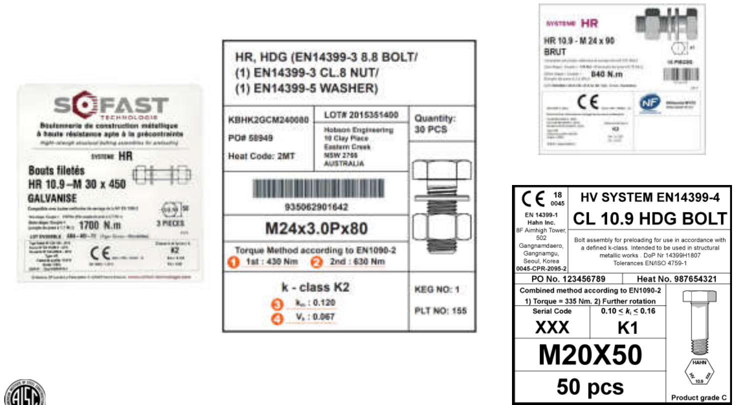

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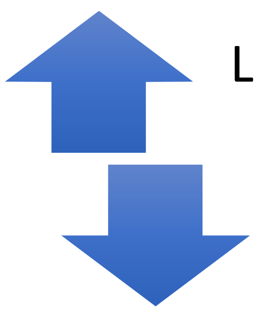
Lubrication



Lubrication

Paint adhesion

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Lubrication

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Torque is Valuable, but Complicated

- Torque is a great means of fit up and snugging.
- Torque can be accurate when controlled, but we have no provisions for torque control, so please don't ask what installation torque is.
- Torque can provide uniform initial loading, unlike angle.
- Torque when installing from the head can be quite different than torque when installing from the nut, how did you do your pre-installation test?
  - Friction and bearing

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Torque is Valuable, but Complicated

- Torque is wildly variable and cumbersome the way our industry uses it, so we don't use it. Unless…..
  - Using the calibrated wrench method
    - Daily calibration
  - Using twist-off bolts
    - Producer controls K
  - Performing rotational capacity testing (max torque)
  - Performing post-installation connection inspection (AASHTO/DOT)
  - Performing arbitration inspection
  - Defining vaguely "full effort of an iron worker", "a few impacts of a wrench"

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Thank You!

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Thank you!

AISC | Questions

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Stronger.
Steel.

Individual Session Registrants

PDH Certificates

- All WFH individuals associated with a group registration will be issued a certificate.
- All individuals attending at your connection: you will receive an email on how to report their attendance from: registration@aisc.org.
    - Be on the lookout: Check your spam filter! Check your junk folder!
    - Completely fill out online form. Don't forget to check the boxes next to each attendee's name!

8-Session Registrants

PDH Certificates

One certificate will be issued at the conclusion of all 8 sessions.

8-Session Registrants

Access to the quiz

Information for accessing the quiz will be emailed to you by Wednesday. It will contain a link to access the quiz. EMAIL COMES FROM NIGHTSCHOOL@AISC.ORG.

Quiz and attendance records

Posted Friday mornings. www.aisc.org/nightschool -- Click on Current Course Details.

Reasons for quiz

- EEU – You must take all quizzes and the final exam to receive EEU.
- PDHs – If you watch a recorded session, you must pass quiz for PDHs.
- REINFORCEMENT – Reinforce what you learn tonight. Get more out of the course.

Note: If you attend the live presentation, you do not have to take the quizzes to receive PDHs

8-Session Registrants

Access to the recording

Information for accessing the recording will be emailed to you by Wednesday. The recording will be available for four weeks. (For 8-session registrants only.) EMAIL COMES FROM NIGHTSCHOOL@AISC.ORG.

PDHs via recording

If you watch a recorded session, you must take *and pass* the quiz for PDHs.

8-Session Registrants

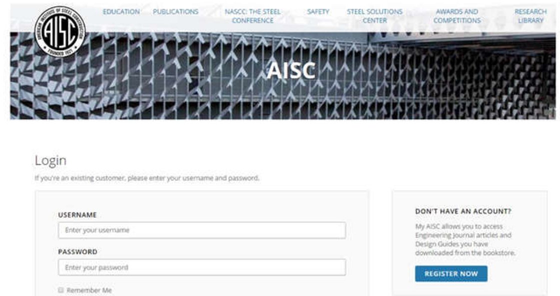
Night School Resources

Find all your handouts, quizzes and quiz scores, recording access, and attendance information all in one place!

8-Session Registrants

Night School Resources

Go to www.aisc.org and sign in.



8-Session Registrants

Night School Resources

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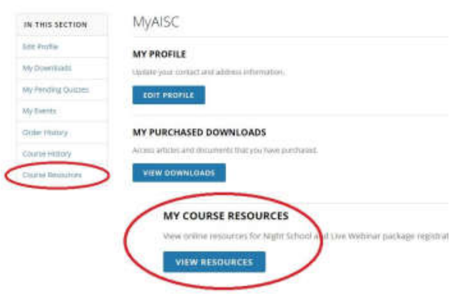
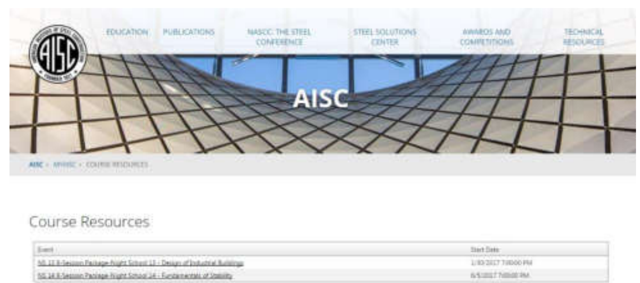


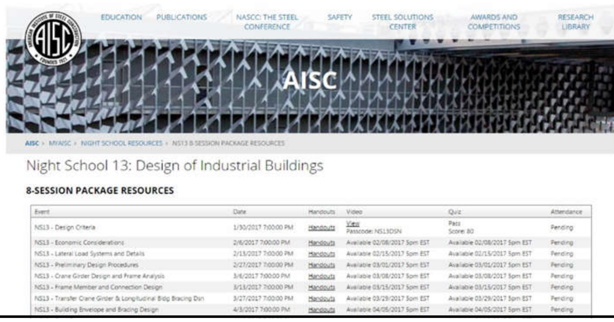
8-Session Registrants

Night School Resources



8-Session Registrants

Night School Resources



Night School 13: Design of Industrial Buildings

8-SESSION PACKAGE RESOURCES

Event	Date	Handouts	Video	Quiz	Attendance
NS13 - Design Criteria	1/30/2017 7:00:00 PM	Handouts	View Passcode: NS13DSN	Pass Score: 80	Pending
NS13 - Economic Considerations	2/6/2017 7:00:00 PM	Handouts	Available 02/08/2017 5pm EST	Available 02/08/2017 5pm EST	Pending
NS13 - Lateral Load Systems and Details	2/13/2017 7:00:00 PM	Handouts	Available 02/15/2017 5pm EST	Available 02/15/2017 5pm EST	Pending
NS13 - Preliminary Design Procedures	2/27/2017 7:00:00 PM	Handouts	Available 03/01/2017 5pm EST	Available 03/01/2017 5pm EST	Pending
NS13 - Crane Girder Design and Frame Analysis	3/6/2017 7:00:00 PM	Handouts	Available 03/08/2017 5pm EST	Available 03/08/2017 5pm EST	Pending
NS13 - Frame Member and Connection Design	3/13/2017 7:00:00 PM	Handouts	Available 03/15/2017 5pm EST	Available 03/15/2017 5pm EST	Pending
NS13 - Transfer Crane Girder & Longitudinal Bldg Bracing Dsn	3/27/2017 7:00:00 PM	Handouts	Available 03/29/2017 5pm EST	Available 03/29/2017 5pm EST	Pending
NS13 - Building Envelope and Bracing Design	4/3/2017 7:00:00 PM	Handouts	Available 04/05/2017 5pm EST	Available 04/05/2017 5pm EST	Pending

8-Session Registrants

Night School Resources

- Weekly "quiz and recording" email.
- Weekly updates of the master quiz and attendance record, found at www.aisc.org/nightschool27. Scroll down to Quiz and Attendance records.
    - Updated on Friday mornings.

8-Session Registrants

Night School Resources

- Webinar connection information
    - Reminder email sent out Monday mornings
- Links to handouts also found here

AISC | Thank you

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