snowy hydro Limited renewable energy	
Snowy Technical Standards	
SHL-MEC-115	***Threaded Fasteners***
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1. Executive Summary

The purpose of this standard is to ensure a consistent approach to the application, type, materials, method of locking and function of threaded fasteners used across Snowy Hydro Limited (SHL) Assets and to address the inconsistencies in tightening bolted joints.

This standard is to ensure a consistent method for calculating the bolt preload forces, and a consistent method of bolt tensioning, and to overcome the following:

- The principle behind determination and application of bolt preload is not always well understood by those responsible for reassembly of equipment.
- Reliance on application by torque setting has been widespread, but is an inaccurate method of applying preload.
- In many cases preload applied has been determined by the maximum setting of the hydraulic torque wrench or simply by flogging.
- Preload requirements are not usually well documented by OEM equipment suppliers, and procedures are not developed and maintained in house.
- Free lengths of bolts in service are not well recorded, making checking of preloads in service impossible.
- The correlation between the torque required to fully tension a bolted connection and the required preload is materially affected by.
- The actual condition of the thread and the bearing face surface and their lubrication.
- The occurrence of galling during tightening

2. Scope

This standard applies to the design and installation of all bolts and studs on all plant which can potentially cause a significant damage if come undone in service.

This Standard applies to the design and installation of all critical bolts and studs on hydro plant in excess of 36mm. In addition all top cover bolts are included. The use of tensioning by direct measurement of extension is also recommended for medium sized bolts in other critical applications.

Bolts and Studs for which correct preload is important:

- Penstock, MIV, Dismantling joints and make-up piece flange bolts
- Turbine top cover studs
- Shaft coupling studs
- Runner and nose cone bolts

- Guide vane and MIV servomotor flange studs or bolts
- Generator top and bottom bracket hold down bolts
- Thrust bracket hold down bolts
- Valve bonnet studs
- Studs on Nozzles on Pelton machines (JPS Starting turbine, M1 standby generator)
- Pressure Relief Valve body and top cover studs/bolts

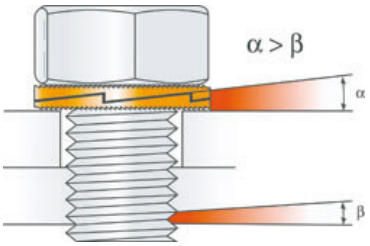
2.1. Applicable Standards

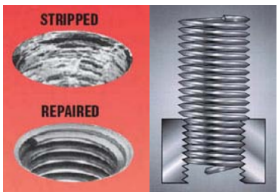
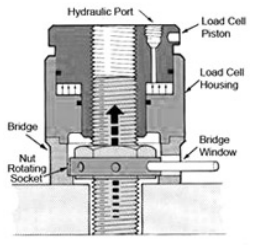
- AS1110 Pts 1-2 - ISO Metric Hexagon Bolts and Screws – Product Grades A and B – Screw/Bolts
- AS1112 Pts 1-4 - ISO Metric Hexagon Nuts
- AS1214 - Hot-dip Galvanised Coatings on Threaded Fasteners (ISO Metric Coarse Thread Series)
- AS1237 - Plain washers for metric bolts, screws and nuts for general purposes
- AS/NZS1252 - High Strength Steel Bolts with Associated Nuts and Washers for Structural Engineering
- AS1275 - Metric Screw Threads for Fasteners
- AS1420 - ISO Metric Hexagon Socket Head Cap Screws
- AS1721 - General Purpose Metric Screw Threads
- AS/NZS2312 - Guide to the Protection of structural Steel against Atmospheric Corrosion by the use of protective coatings
- AS4291 - Mechanical properties of fasteners made of carbon steel and alloy steel
- AS1275:1985 - Metric Screw Threads for Fasteners
- AS3501:1987 - Parallel Screw Threads of Whitworth Form (BSW and BSF) and Associated Gauges and Gauging Practice
- AS2528:1982 - Bolts, studbolts and nuts for flanges and other high and low temperature applications
- BS3580:1964 - Guide to Design Considerations on the Strength of Screw Threads
- AS4100:1998 - Steel Structures

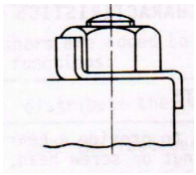
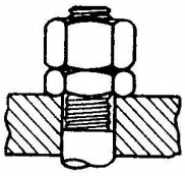
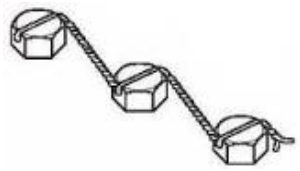
3. Definitions

Anti-friction Coating	AF coatings are dry lubricants consisting of suspensions of solid lubricants, such as graphite, PTFE or molybdenum disulphide of small particle size in a binder. Such coatings can be applied to fastener threads to replace metallic coatings such as zinc and cadmium and offer maintenance free permanent lubrication. By careful selection of the lubricants, AF coatings can be designed to meet specific applications. The coatings are permanently bonded to the metal surface and provide a lubricating film preventing direct metal to metal contact.
Anti-seize Compound	An anti-seize compound is used on the threads of fasteners in some applications. The purpose of the compound depends upon the application. It can prevent galling of mating surfaces - such compounds are frequently used with stainless steel fasteners to prevent this effect from occurring. In some applications it is used to improve corrosion resistance to allow the parts to be subsequently dis-assembled. Thirdly, it can provide a barrier to water penetration since the threads are sealed by use of the compound.

Anaerobic Adhesive	An adhesive which hardens in the absence of air, such adhesives are often used as a thread locking medium.
Angle Controlled Tightening **NOT RECOMMENDED**	A tightening procedure in which a fastener is first tightened by a pre-selected torque (called the snug torque) so that the clamped surfaces are pulled together, and then is further tightened by giving the nut an additional measured rotation. Frequently bolts are tightened beyond their yield point by this method in order to ensure that a precise preload is achieved. Bolts of short length can be elongated too much by this method and the bolt material must be sufficiently ductile to cater for the plastic deformation involved. Because of the bolt being tightened beyond yield, its re-use is limited.
Bearing Stress	The surface pressure acting on a joint face directly as a result of the force applied by a fastener.
Black Bolts And Nuts	The word black refers to the comparatively wider tolerances employed and not necessarily to the colour of the surface finish of the fastener.
Bolt	A bolt is the term used for a threaded fastener, with a head, designed to be used in conjunction with a nut.
Breakaway Torque	The torque necessary to put into reverse rotation a bolt that has not been tightened.
Breakloose Torque	The torque required to effect reverse rotation when a pre-stressed threaded assembly is loosened.
BSF	British Standard Fine. A thread form based upon the British Standard Whitworth form but with a finer thread (more threads per inch for a given diameter). This thread form was first introduced in 1908, the thread form is specified in BS 84: 1956.
BSW	British Standard Whitworth. A thread form developed by Sir Joseph Whitworth in 1841. The thread form has rounded roots and crests; the thread form is specified in BS 84: 1956. This thread form was superseded by the Unified thread in 1948 and then the metric thread form.
Cadmium electroplating	Coating of threaded fasteners with cadmium can provide the parts with excellent corrosion resistance. The appearance of the coating is bright silver or yellow if subsequently passivated. The friction values associated with this coating are also comparatively low. A chromate conversion coating is frequently applied to the surface to improve corrosion resistance. Cadmium is not now frequently used because of the environmental and worker health problems associated with the coating process and should not be used in applications above 250C or when contact with food is possible.
Clamping force	The compressive force which a fastener exerts on the joint.
Class of fit	The Class of Fit is a measure of the degree of fit between mating internal and external threads. Three main Classes of Fit are defined for metric screw threads : FINE: This has a tolerance class of 5H for internal threads and 4h for external threads. MEDIUM: This has a tolerance class of 6H for internal threads and 6g for external threads. COARSE: This has a tolerance class of 7H for internal threads and 8g for external threads. For Unified threads, a similar designation as for metric threads is used. The thread classes used are 1A, 2A and 3A for external threads and 1B, 2B and 3B for internal threads.
Coefficient of friction	A dimensionless number representing the ratio of the friction force to normal force.

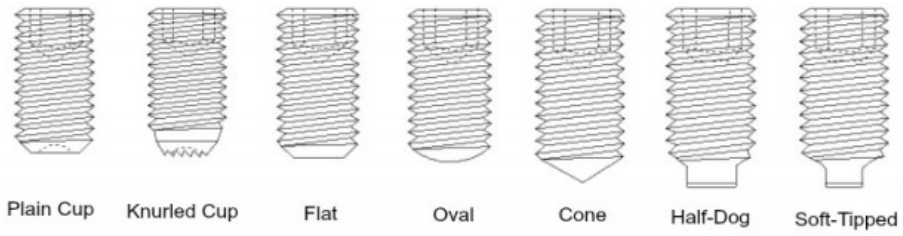
	Typically for threaded connections it is between 0.10 to 0,18 but can vary significantly depending upon the materials used and whether a lubricant has been used. In relation to threaded fasteners, the coefficient of friction can be further subdivided into the coefficient of friction between the threads and the coefficient of friction under the nut face. There is in general a difference in values between the two coefficients due to typically the contact surfaces being different. For example, a zinc plated nut on a zinc plated bolt, the thread coefficient of friction would be due to zinc plating contacting zinc plating. The nut face coefficient of friction would be due to zinc plating contacting the joint surface finish.
Disc lock washer (also called nord lock) 	A specifically designed washer to solve the problem of fastener failure, is a heavy duty structural self-locking product, which prevents loosening caused by shock or vibration in high stress applications. Unlike conventional washers, the DISC-LOCK Washer is fitted in pairs.  **Tension makes the bolt self-locking** The key is the difference in angles. Since the cam angle " **α** " is larger than the thread pitch " **β** ", the pair of washers expand more than the corresponding pitch of the thread. NORDLOCK washers positively lock the fastener in a joint which is subjected to extreme vibration or dynamic loads.
Elongation Extension	Change in length of bolt/stud achieved by tightening. ie: elongation = final length – free length
Electroless nickel	A relatively thin, hard coating that can be applied to threads and deposited uniformly. Bright metallic in appearance this coating has excellent resistance to wear and corrosion.
External force or load	Forces exerted on a fastener as a result of an applied loading to the joint.
External thread	A screw thread which is formed on an external cylinder, such as on bolts, screws, studs etc.
Free Length	Length of bolt/stud prior to tightening
Final Length	Length of bolt/stud on completion of tightening
Fluoro-carbon thread Coating (eg TEFLON, PTFE)	A low friction coating applied to threads. This type of coating is frequently used to prevent thread fouling when an assembly containing threaded fasteners is painted. Unless masked in some way before painting, electro deposited primers can cover the threads. If this occurs assembly difficulties can result unless the expensive chore of cleaning the threads is completed. A fluoro-carbon thread coating eliminates the need for masking or cleaning since paint will not adhere to the coating. This type of coating can also prevent problems caused by weld splatter obstructing the threads of weld nuts during their placement. Such coatings also have the property of reducing the torque-tension scatter during tightening.
Friction	Mechanical resistance to the relative movement of two surfaces. There are two main

	types of friction; STATIC FRICTION and DYNAMIC FRICTION. Typically static friction is greater than dynamic friction.
Galling	A severe form of adhesive wear which occurs during sliding contact of one surface relative to another. Clumps of one part stick to the mating part and break away from the surface. (Can frequently occur when both the nut and bolt are made from stainless or high alloy steels, titanium or zinc coated fasteners.)
Hardened washers	The force under the head of a bolt or nut can exceed, at high preloads, the compressive yield strength of the clamped material. If this occurs excessive embedding and deformation can result in bolt preload loss. To overcome this hardened washers under the bolt head can be used to distribute the force over a wider area into the clamped material. A more modern alternative is to use a flange headed nuts and bolts.
Heat tightening	Heat tightening utilises the thermal expansion characteristics of the bolt. The bolt is heated and expands: the nut is indexed (using the angle of turn method) and the system allowed to cool. As the bolt attempts to contract it is constrained longitudinally by the clamped material and a preload results. Methods of heating include direct flame, sheathed heating coil and carbon resistance elements. The process is slow, especially if the strain in the bolt is to be measured, since the system must return to ambient temperature for each measurement. This is not a widely used method and is generally used only on very large bolts.
Helical spring washer **NOT RECOMMNDED**	A split type of spring washer whose purpose is to prevent self loosening of the nut or the bolt. The idea or principle behind the helical spring washer is for one end of the tang of the washer to indent into the fastener (the nut or bolt head) and the other into the joint surface so that any loosening rotation is prevented. **Junker in his paper in 1969 on the cause of self-loosening of fasteners (reference:Junker, G., New criteria for self-loosening of fasteners under vibration. SAE Paper 690055, 1969) concluded that this type of lock washer has no ability to lock.** This type of washer is sometimes called a spring lock washer or sometimes a standard lock washer.
“Helicoil” 	A helical insert made of coiled wire. Another common generic name is screw thread insert (STI), although many users persist in calling them all by a prominent brand name, the registered trademark Heli-Coil. Used to “reclaim” a damaged internal thread. In essence, the damaged internal thread is drilled out, and the hole is re-tapped (threaded) to suit a special Helicoil insert. Then the Helicoil is “wound” into place, leaving the hole with a new thread of the same size and pitch as the original.
Hydraulic tensioner 	A hydraulic tool used to tighten a fastener by stretching it rather than applying a large torque to the nut. After the fastener has been stretched, the nut is run down the thread to snug up with the joint, the hydraulically applied load is then removed resulting in tension being induced into the fastener.

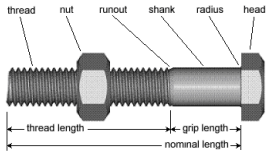
Impact wrench	A wrench, usually powered by electricity or air, in which repeated blows from little hammers are used to generate torque to tighten fasteners. The torque applied to the fastener depends upon the time and the air pressure applied to the tool (for pneumatic wrenches). The torque applied by an impact wrench to a fastener is influenced by the joint stiffness.
Internal thread	A screw thread which is formed in holes, such as in nuts.
Jam nuts	See LOCKNUT
Joint control tightening	See YIELD CONTROLLED TIGHTENING
K factor	The factor in the torque tightening equation: T=KDF where T is the fastener tightening torque in Newton metres, D is the fastener diameter in metres, F is the fasteners preload in Newtons and K is a factor whose value is often taken as 0.2. The formula gives the approximate tightening torque for standard fasteners used under normal conditions. The K factor is also known as the nut factor and the torque coefficient.
Left hand thread	A screw thread that is screwed in by rotating counter clockwise.
Length of engagement	The axial distance over which an external thread is in contact with an internal thread.
Lock Tab 	Locking plate where one tab is bent down over an edge of an assembly and a second tab bent up to lock the nut in position
Lock nut (or Jam Nut) 	There are two common usage's of this term: 1. A nut which provides extra resistance to vibration loosening by either providing some form of prevailing torque, or, in free spinning nuts, by deforming and/or biting into mating parts when fully tightened. 2. The term is sometimes used for thin (or jam) nuts used to lock a thicker nut. When used in this way the thin nut should be adjacent to the joint surface and tightened against the thick nut. If placed on top of the thick nut the thin nut would sustain loads it was not designed to sustain.
Lock wire 	A type of positive locking device that prevents fasteners from loosening or falling out due to vibration and other forces. Typically the wire is threaded through a hole drilled into a fastener then twisted and anchored to a second fastener, then twisted again.
“Loctite”	Cyano-acrylate anaerobic adhesives (one trade name is Loctite) have become increasingly popular as a locking medium. Joints made with Loctite are generally intended to be detachable (although possible with some difficulty in practice). It is only necessary to apply a few drops of the Loctite compound, which hardens and secures in the absence of oxygen.
Major diameter	This is the diameter of an imaginary cylinder parallel with the crests of the thread; in other words it is the distance from crest to crest for an external thread, or root to root for an internal thread.

Metal to metal contact flange joint	A flanged joint in which a gasket is compressed by bolts - the gasket being located in a recess within the joint so that it is compressed by the bolt loads until metal to metal contact occurs. Unlike the FLOATING TYPE FLANGE JOINT, for metal to metal type joints there are no standardised gasket factor definitions, test procedures, nor generally acknowledged calculation procedures available.
Minor diameter	This is the diameter of an imaginary cylinder which just touches the roots of an external thread, or the crests of an internal thread.
Molybdenum disulphide	A solid lubricant that acts as a high pressure resistant film. Can be used by itself as a dry lubricant as well as in with other solid lubricants and in oils and greases. Used in threads, such lubricants act as a separating film to prevent corrosion formation on the thread surface (even under adverse temperature and environmental conditions) ensuring the release of the threaded connection. Such films can also act as friction stabilisers.
Nicked threads	Nicks or indentations in threads can occur during the manufacturing process and during fastener transportation. In general, nicked thread problems tend to increase as the thread diameter increases and for fine pitches. There are acceptance tests for nicked threads that involve measuring the maximum torque required to drive a GO gauge down the thread. Examples of acceptance tests are SAE J123 and the Ford Motor specification WA990 1993. Nicks and indentations in threads are sometimes referred to as gouges.
Nominal diameter	The diameter equal to the external diameter of the threads.
Nord lock washer	Refer to DISC LOCK WASHER
Nyloc nut  Nyloc Nut	A torque prevailing nut that uses a nylon patented insert to provide a locking feature. The nylon insert, it is claimed, helps to seal the bolt thread against seepage of water, oil, petrol, paraffin and other liquids. The nut is covered by UK patent 8028437 and European patent 81303450-1. Nyloc is a registered trade name of Forest Fasteners.
Pitch	The nominal distance between two adjacent thread roots or crests.
Ply	A single thickness of steel forming part of a structural joint.
Preload	The force applied to the bold/stud by tightening. For bolts/studs subject to repetitive or cyclic loading, the preload on the bolt must be higher than the load (in tension) that the bolt/stud will see in service. To achieve the benefits of the preloading, the clamping force must be higher than the joint separation load. Typically preload is between 75% and 90% of the Proof stress
Prevailing torque	The torque required to run a nut down a thread on certain types of nuts designed to resist vibration loosening. The resistance can be provided by a plastic insert or a noncircular head.
Proof Stress (Proof Load)	The applied tensile load that the fastener must support without permanent deformation (ie. The bolt returns to its original shape once the load is removed), typically 85% of yield stress of the bolt material.
Property class	A designation system which defines the strength of a bolt or nut. For metric fasteners, property classes are designated by numbers where increasing numbers generally represent increasing tensile strengths. The designation symbol for bolts consists of two parts: 1. The first numeral of a two digit symbol or the first two numerals of a three digit symbol approximates 1/100 of the minimum tensile strength in MPa.

	2. The last numeral approximates 1/10 of the ratio expressed as a percentage between minimum yield stress and minimum tensile stress. Hence a fastener with a property class of 8.8 has a minimum tensile strength of 800 MPa and a yield stress of 0.8x800=640 MPa. The designation system for metric nuts is a single or double digit symbol. The numerals approximate 1/100 of the minimum tensile strength in MPa. For example a nut of property class 8 has a minimum tensile strength of 800 MPa. A bolt or screw of a particular property class should be assembled with the equivalent or higher property class of nut to ensure that thread stripping does not occur.
Reduced shank bolt	A bolt whose shank diameter is smaller than the nominal diameter of the bolt (normally the shank diameter of such a bolt is approximately equal to the effective diameter of the thread).
Relaxation	The loss of clamping force in a bolt that occurs typically without any nut rotation occurring. Commonly occurs as a result of embedment but can also be due to gasket creep, metal creep (at elevated temperatures), differential thermal expansion and stress relaxation.
Right hand thread	A screw thread that is screwed in by rotating clockwise. The majority of screw threads are right handed.
Rolled thread	A thread formed by plastically deforming a blank rather than by cutting. The majority of standard fasteners have their threads formed by rolling. Most threads are rolled before any heat treatment operation. Significant improvements in fatigue life can be achieved by rolling the thread after heat treatment, this improvement is due to compressive stresses being induced in the roots of the thread. However, because of the increased hardness of the bolt blank, the die life can be significantly reduced. Rolling the thread also generally improves the surface finish which can have a beneficial effect on fatigue life.
Root diameter	Identical to MINOR DIAMETER
Screw	A headed threaded fastener that is designed to be used in conjunction with a pre formed internal thread or alternatively forming its own thread. Historically, it was a threaded fastener with the thread running up to the head of the fastener that has no plain shank. However this definition has largely been superseded to avoid confusion over the difference between a bolt and a screw.
Screw thread	A ridge of constant section which is manufactured so that a helix is developed on the internal or external surface of a cylinder.
Self-loosening	Threaded fasteners can come loose on occasions without human intervention. This loosening can be due to creep, embedding, stress relaxation or the fastener self rotating (which is often called vibration loosening). Creep, embedding and stress relaxation will generally not completely loosen a fastener, these loosening mechanisms occur without the nut rotating relative to the bolt. The term self loosening is sometimes used for the nut rotating relative to the bolt without human intervention. It is know that the fastener can self-rotate under the action of transverse joint movement that can completely loosen a tightened fastener such that the nut will become detached from the bolt.
Set screw	A set screw is a threaded fastener that is typically used to hold a sleeve, collar or gear on a shaft to prevent relative motion. It is a threaded member that normally does not have a head. Unlike most other threaded fasteners it is basically a compression device normally used to generate axial thrust. Various socket types are provided to allow the set screw to be rotated. These types include hexagon socket, fluted socket, screwdriver slot and square head. Various point designs are available

	(the part of the set screw that rotates against the shaft being secured) and include: Cup - Hollowed end is the most commonly used point style. Used when the digging in of the point is not undesirable. Cone - Pointed end, this type generates the highest torsional holding power and is typically used for a permanent connection. Oval - Rounded end that is typically used when frequent adjustment is required. The oval end prevents/reduces indentation. Flat - Cause little damage to the shaft and are used when frequent adjustment is required. Dog - Flat end with the threads stopping short of the end with the end fitting into a hole. 
Shank	That portion of a bolt between the head and the threaded portion.
Snug torque	The torque required to pull plates together so that direct contact occurs; often used in angle control tightening. The snug torque ensures that metal to metal contact occurs at all the interfaces within the joint. It is only at this point that the required angle of rotation start in order that the bolt is tightened sufficiently. The snug torque is usually determined experimentally on the actual joint.
Snugging	The process of pulling parts of a joint together, most of the input turn during this process is absorbed in the joint with little tension being given to the bolt.
“Snug Tight”	“The tightness attained by the full effort of a person using standard hand tools”
Socket head cap Screw 	A screw with a round head, usually with a hexagon indentation in the head for tightening purposes. Used on machine parts and is typically made from high strength steel (grade 12.9 in metric). These fasteners are very similar to hex bolts. They differ mostly in that they are manufactured to tighter tolerances than the corresponding bolts.
Soft joint	A joint in which the plates and material between the nut and bolt bearing surfaces have a low stiffness when subjected to compression by the bolt load. In such a joint, the bolt (or nut) typically has to be tightened by two or more complete turns, after it has been torqued to the snug condition, before the full tightening torque is achieved. Often the placement of a gasket in a joint results in a soft joint.
Soft torque	An alternative name, used by some manufacturers, for snug torque.
Spiral wound gasket	A type of gasket that is made by winding V-section metal strip and a softer filler material together. Support or retaining rings, inside and/or outside the spiral, improve

	the gasket's handling and fitting. The filler material used is typically graphite or PTFE. The metal strip and retaining rings being typically made from stainless steel.
Strength grade	See PROPERTY CLASS
Stress area	The effective cross sectional area of a thread when subjected to a tensile force. It is based upon a diameter which is the mean of the pitch (or effective) and the minor (or root) diameters of the thread. The use of this diameter stems from the work of E. M. Slaughter in the 1930's. He completed carefully controlled tests using various sizes of standard threads and compared their strength with machined bars made from the same bar of material. He found that this mean diameter gave results that agreed with the tensile test results to within about 3%. The error on the minor and pitch diameters was about 15%. Tests completed subsequent to these by other investigators have also shown that the stress diameter is a reasonable approximation to a thread's tensile strength. (Reference: 'Tests on Thread Sections Show Exact Strengthening Effect of Threads.' by E. M. Slaughter, Metal Progress, vol 23, March 1933 pp. 18-20)
Stress relaxation	A significant problem with bolting at high temperatures is a phenomenon known as stress relaxation. Creep occurs when a material is subjected to high temperature and a constant load. Stress relaxation occurs when a high stress is present that is relieved over time; the stress is relaxed with a subsequent reduction in the bolt’s preload. The only way to minimise the effects of stress relaxation is to use materials that have an adequate resistance to it at the product’s operating temperature. The effect of bolt stress relaxation is to reduce the clamp force provided by the bolts; this phenomenon alone will not fully loosen a joint.
Structural bolt	A structural bolt is a heavy hexagon head bolt having a controlled thread length intended for use in structural connections and assembly of such structures as buildings and bridges. The controlled thread length is to enable the thread to stop before the joint ply interface to improve the fastener's direct shear performance. This term is used in civil and structural engineering but is not frequently used in mechanical engineering.
Stud	A fastener which is threaded at both ends with an unthreaded shank in between. One end (which often has a thread tolerance which results in more thread interference) is secured into a tapped hole; the other is used with a nut.
Tension washers	A general name given to spring washers, curved washers, Belleville washers and disc springs. This type of washer provides a relatively low stiffness (compared to the joint stiffness) and can be used to act as a spring take-up with a bolt to prevent movement between parts.
Tensioning	The direct axial stretching of the bolt/stud to achieve preload.
Thread crest	The top part of the thread. For external threads, the crest is the region of the thread which is on its outer surface, for internal threads it is the region which forms the inner diameter.
Thread flank	The thread flanks join the thread roots to the crest.
Thread height	This is the distance between the minor and major diameters of the thread measured radially.
Thread length	Length the portion of the fastener with threads.
Thread root	The thread root is the bottom of the thread, on external threads the roots are usually rounded so that fatigue performance is improved.

Thread runout 	The portion at the end of a threaded shank which is not cut or rolled to full depth, but which provides a transition between full depth threads and the fastener shank or head.
Threadlocker	Can be a term used for a number of vibration resistant products but is now usually reserved for thread locking adhesives. Specifically, a liquid anaerobic adhesive applied to nut or bolt thread, once hardened it fills the inner spaces between the threads to produce a solid plastic of known shear strength.
Tin/zinc alloy electroplating	Tin/zinc alloy coatings (typically 70% tin and 30% zinc) are applied to threaded fasteners to provide a corrosion resistant coating. One of the advantages of such coatings is that bimetallic corrosion will not occur when placed into contact with such metals as aluminium or steel.
Toothed lock washer, serrated washer or star washer 	A washer with serrations that extend radially inward or outward to bite into the bearing surface. This type of washer is especially effective as a lock washer when used with a soft substrate, such as aluminium or plastic, and can resist rotation more than a plain washer on hard surfaces, as the tension between washer and the surface is applied over a much smaller area (the teeth). There are four types: internal, external, combination, and countersunk. The internal style has the serrations along the inner edge of the washer, which makes them more aesthetically pleasing. The external style has the serrations around the outer edge, which provides better holding power, because of the greater circumference.The combination style has serrations about both edges, for maximum holding power.The countersunk style is designed to be used with flat-head screws. Tooth lockwashers are also used for ground bonding where a metal lug or object must be electrically bonded to a surface. The teeth of the washer cut through surface oxides, paints or other finishes and provide a gas-tight conductive path. In these applications the washer is not placed under the head of the screw (or under the nut), it is placed between the surfaces to be bonded. In such applications, the tooth washer does not provide any anti-rotation locking features.
Torque	A rotational moment; it is a measure of how much twisting is applied to a fastener. The units used to measure torque are in the form of force times length. Usually measured in newton-metres (Nm) if metric units are used or pounds feet (lb-ft) when imperial units are used.
Torque multiplier	A gearbox used to increase the torque produced by a small hand wrench.
Torque wrench	A manual wrench which incorporates a gauge or other method to indicate the amount of torque transferred to the nut or bolt.
Turn of the nut method	See ANGLE CONTROLLED TIGHTENING
U bolt	A U shaped fastener threaded at both ends used primarily in suspension and related areas of vehicles.
Ultrasonic extensometer	An instrument which can measure the change in length of a fastener ultrasonically as the fastener is tightened or measure the length before and after it is tightened).
Ultimate Tensile Strength	The maximum tension-applied load the fastener can support prior to failure.
UNC	Unified National Coarse (UNC) is a thread form with a 60 degree flank angle rounded roots and flat crests. For a given diameter it has a larger thread pitch than an equivalent diameter UNF thread. The unified thread is based on inch sizes and was first standardised in 1948 unifying the Whitworth and American standard thread forms.

UNEF	Unified National Extra Fine (UNEF) is a Unified thread form with a very fine (small) pitch that are typically used on instruments and parts requiring a fine adjustment.
UNF	Unified National Fine (UNF) is a thread form with a 60 degree flank angle rounded roots and flat crests. For a given diameter it has a smaller thread pitch than an equivalent diameter UNC thread.
UNR	Unified National (UN) thread form with a rounded root contour, applies only to external threads. (The UN thread form has a flat, or optionally, a rounded root contour.) The majority of fasteners with a Unified thread form have a rounded root contour i.e. are UNR threads.
"Whizlock" fastener 	A free running screw that locks itself in place with serrations or locking teeth under the head.
Wire thread insert See also "Helicoil"	A threaded insert that is typically used for tapped hole repair or to improve the thread stripping strength of softer metals such as zinc and aluminium. The inserts are assembled into a previously tapped hole using a special driving tool. A thread locking compound is frequently used to secure the insert if the assembly is subject to Vibration. See also "Helicoil"
Yield controlled tightening	A fastener tightening method which allows a fastener to be tightened to yield. The angle of rotation of the fastener is measured relative to the applied torque, yield being assessed when the slope of the relationship changes to below a certain value. Sometimes called joint controlled tightening.
Young's Modulus	Is a measure of the stiffness of an elastic material. Also known as the tensile modulus or elastic modulus. It is defined as the ratio of the stress (force per unit area) along an axis to the strain (ratio of deformation over initial length) along that axis
Zinc electroplating	Zinc electroplating is a common way to protect threaded fasteners from the effects of corrosion. Zinc electroplating can be completed in acid chloride, alkaline or cyanide baths. Supplemental coatings are frequently applied to zinc electroplating. These coatings, such as zinc phosphate or chromate conversion, provide a protective passivation layer on the zinc which assists in reducing the corrosion rate.
Zinc/cobalt alloy electroplating	This coating is similar to zinc electroplating completed in an acid chloride bath - a small amount of cobalt (typically about 1%) is added to increase the plating speed.
Zinc phosphate conversion coating	A zinc phosphate conversion coating is frequently added to zinc electroplated parts, such as bolt threads, to improve corrosion resistance. This type of chemical conversion coating provides a protective passivation layer on the zinc improving its corrosion resistance.

4. Technical Requirements - Threaded Fasteners

4.1. General

- Bolts and other threaded fasteners shall be to the same thread system as the existing fasteners that they replace or to AS1110 and AS1112 as approved by the relevant technical specialist.

Non-preferred threads shall be avoided, which include M3.5, M14, M18, M22, M27, M33, M39, M45, M52 and M60. Use of these threads are only allowed if approved by the relevant technical specialist.

- Fasteners/Steel bolts shall be forged unless otherwise approved by the relevant technical specialist.
- Steel bolts not greater than 39 mm shall be of property class 8.8 or above. The mating nuts shall be of class 8 or above. AS4291 shall be conformed to for material and its property.

  Steel bolts greater than 39 mm shall be manufactured as agreed between supplier and purchaser but generally shall be of class 5.6 or above.

  Class 4.8 is generally not recommended unless approved by the relevant technical specialist.

  Stainless Steel bolts not greater than 39 mm shall be of property class A4-50 or above. Stainless Steel bolts greater than 39 mm shall be manufactured as agreed between supplier and purchaser but generally shall be of class A2-50 or above.
- Steel fasteners greater than 8 mm diameter and with coarse threads shall be hot-dip galvanised in accordance with AS1214 except for those of stainless steel.
- Steel fasteners with fine threads and those with coarse threads less than 8 mm in diameter shall be of stainless steel or electroplated with zinc.
- Fasteners used in proprietary items shall be subject to the approval of the relevant technical specialist.
- Tapped holes shall not be used in sheet metal less than 6 mm thick.
- Fasteners of less than 6 mm diameter shall not be used except if specifically approved by the relevant technical specialist.
- Threaded fasteners shall have socket hexagon heads (These fasteners are very similar to hex bolts. They differ mostly in that they are manufactured to tighter tolerances than the corresponding bolts) except on pipe flanges or as otherwise approved by the relevant technical specialist.

  Hexagon headed bolts and nuts shall be used on pipe flanges.
- All threaded fasteners shall be locked in an approved manner. In selecting the locking arrangement, it is very important to consider the forces applied to the fastener, materials in contact, environment and potential damage it can cause if it comes loose.

  The prefered methods of locking are;

  1. Tack Welds,
  2. Lock Tabs or
  3. Lock wiring with Stainless steel wiring.

  Tack Welds are generally used on fasteners not expected to to be broken except in major overhauls or at the end of life. Weld procedures and removal procedures must be developed for tack welds. Refer to SHL-MEC-102 Welding Standard.

  Any other locking method identified below can be only applied if the above prefered methods cannot be applied for technical reasons or as a result of OEM recommendations.The relevant technical specialist's prior approval shall be obtained before deviating from the above prefered three locking methods.

  If the prefered three methods identified above cannot be used the order of preference for locking will be:

  1. Disc lock washers or Nord-Lock Washers
  2. Nylock nuts
  3. Toothed washers

4. “Whizlock” fasteners
5. Any other as approved by the relevant technical specialist

The above order of preference must be strictly followed in determining the locking system and deviation is allowed only with relevant technical specialists documented agreement.

The use of “LOCTITE” Threadlockers is not permitted unless approved by the relevant technical specialist.

- Fasteners greater than 50 mm diameter, shall be arranged for tightening by hydraulic tensioning devices. Exceptions are only allowed if approved by the relevant technical specialist
- Refer to Section 5 Bolt Tightening for the approved method of tensioning studs and bolts bigger than 36mm.
- Bolts smaller than 36mm, shall be tightened by calculating the required bolts torque using the bolt torque calculator
- To enhance tightening behaviour of the assembly, the threaded fasteners should be lubricated. Low viscosity mineral oil, such as Shell T32, could be used for general and non-critical lubrication. An engine oil such as 10W40 could also be used economically for general lubrication of smaller fasteners.

  When tightening and tensioning are performed as per Section 5 to critical connections of larger sized fasteners, a specific moly paste could be required. However if the content of molybdenum disulfide is greater than 50%, then that anti-seize compounds should be carefully assessed by the relevant technical specialist to determine the correct torque applied.
- Standards – All equipment supplied shall comply with the latest relevant Australian standard where such exist, and in their absence, with the latest internationally recognised standard.

4.2. Specific Applications

- Fasteners used in heavy magnetic fields shall be of non-magnetic stainless steel to prevent eddy current damage or damage to other equipment should the fasteners become loose.
- Fasteners used in areas subject to high vibrations shall be locked by tack welds , lock tabs or Lock wiring with Stainless steel wiring or a method recommended by OEM and approved by the relevant technical specialist.
- Fasteners used on or above high voltage rotating electrical equipment shall be locked by tack welds, lock tabs or Lock wiring with Stainless steel wiring or a method recommended by OEM and approved by the relevant technical specialist.

5. Technical Requirements - Bolt Tightening

5.1. General

- Proper joint design and bolt preload provides useful properties:
  - For cyclic tension loads, the fastener is not subjected to the full amplitude of the load; as a result, the fastener's fatigue life is increased or - if the material exhibits an endurance limit its life extends indefinitely.
  - As long as the external tension loads on a joint do not exceed the clamp load, the fastener is not subjected to motion that would loosen it, obviating the need for locking mechanisms. (Questionable under Vibration Inputs.)
- For the shear joint, a proper clamping force on the joint components prevents relative motion of those components and the fretting wear of those that would result in fatigue cracks.

- The preload target can be achieved by:
    - measuring bolt extension,
    - testing ultrasonically
    - heating to expand the bolt then turning the nut down, or
    - by applying a measured torque to the bolt,

  by a certain number of degrees of relative rotation of the threaded components.
- Each method has a range of uncertainties associated with it, some of which are very substantial, refer to next point..
- Torque wrenches do not give a direct measurement of the preload in the bolt.

  Much of the torque applied is lost overcoming friction under the torqued bolt head or nut (50%)and in the threads (40%). The remaining 10% of the applied torque does useful work in stretching the bolt and providing the preload.

  Initially, as the torque is applied, it must overcome static friction under the head of the bolt or nut (depending on which end is being torqued) and also in the threads. Finally, dynamic friction prevails and the torque is distributed in a 50/40/10 manner as the bolt is tensioned.
- Accuracy of Bolt Preload Based on Bolt Preload Method

Method	**Accuracy**
Torque wrench on lubricated bolts	± 35%
Torque wrench on unlubricated bolts	± 30%
Preload indicating washer	± 25%
Computer controlled wrench (below yield)	± 15%
Torque wrench on cad plated bolts	± 10%
Computer controlled wrench (yield sensing)	± 8%
Bolt elongation	± 5%
Ultrasonic sensing (of bolt elongation)	± 5%
Strain gauges	± 1%

- The preferred bolt preload for structural applications should be at least 75% of the fastener's proof load, for the higher strength fasteners and as high as 90% of the proof load for permanent fasteners. To achieve the benefits of the preloading, the clamping force must be higher than the joint separation load. For some joints, multiple fasteners are required to secure the joint; these are all hand tightened before the final torque is applied to ensure an even joint seating.
- Bolt extension, comparing bolt physical length pre and post tensioning, has a far more direct relationship to the load developed in the bolt than other methods such as torque or part turn of nut. This can be measured on bolts provided suitable end preparation exists (machined surface or dimple provided) and suitable access for measurement using an outside micrometer. For ‘studs’ in blind holes, a pilot hole is required in the stud for physical measurement

5.2. Detail

- The preferred method for tensioning critical bolts shall be by direct measurement of the bolt extension, either by micrometer or an ultrasonic tension device (“Ultrasonic Bolt Mic”).
- The preference is for all studs in critical applications to be prepared, tensioned, and monitored using bolt elongation, but at least 25% of bolts shall be tensioned in this manner as a calibration for setting the remainder by torque only.
- Any bolt subject to repetitive or cyclic loading shall be preloaded such that:
    - The preload on the bolt is in excess of the maximum load in tension the bolt will see in service; and
    - The preload is less than 65% of the bolt material yield stress for bolts which will be reused (0.75 x proof stress), or 75% for bolts which won’t (0.9 x proof stress).

  Note: Proof stress for the material should be obtained, if possible, but is typically 85% of Yield Stress, In practice, high strength bolting is typically loaded to the maximum load the bolt and joints can sustain, even if this is well in excess of the load it sees in service, but this is not necessarily a requirement. Preload, where not specified in extension by manufacturer’s information, shall be calculated or checked by an Engineer.
- All bolts or studs tensioned by extension shall be clearly numbered.

  The following parameters shall be recorded using the Bolt tightening - inspection record sheet and linked to the asset in Ellipse to allow future monitoring without re-tensioning:
    - date of tensioning
    - free length
    - final length
    - ambient temperatures at time of tensioning
    - bolt mic settings (material, length settings etc) recorded.
- Studs for use in critical applications, particularly those subject to fatigue loading should always be designed and fabricated without thread run out that is with a groove as shown in Figure 1.

  Studs to be tensioned by extension using ‘Bolt Mic” measurements shall have machined or ground ends (Ra 1.6µm or better)

  Stud end faces shall be parallel within 1°.

  Stud material designation shall be stamped, off centre, into the end face of the stud.

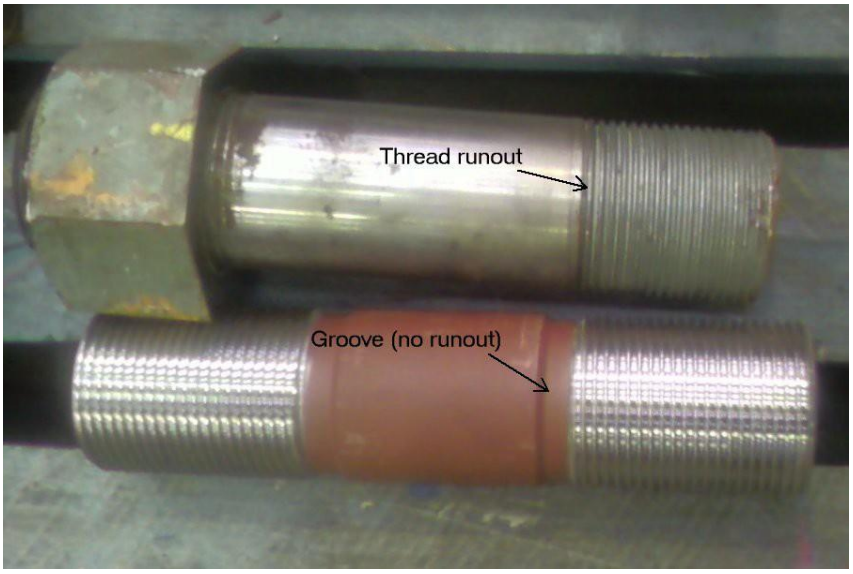


Figure 1

- The preload in a bolt/stud is the force applied by tightening. The elongation created in a bolt during tightening allows the fastener to clamp.

  Bolt elongation is a very accurate method the measure preload.

  Bolt Elongation is measured using Hook's Law:

$$\Delta = \frac{P \times L}{E \times A}$$

  Where:

  Δ = the elongation (mm)
  P = Proof Load (N)
  L = effective length of the bolt/stud (mm)
  E = Young's modulus of the bolt/stud material (MPa)
  A = the smallest cross section Area of the bolt/stud (mm^2) at the thread.
  TPI = Thread Per Inch

$$A = 0.7854 \times \left(bolt\ diameter - \frac{0.9743 \times 25.4}{TPI}\right)^2$$

  Bolt diameter in mm

  To assist with the determining the elongation, use the bolt elongation calculator spreadsheet.

6. References

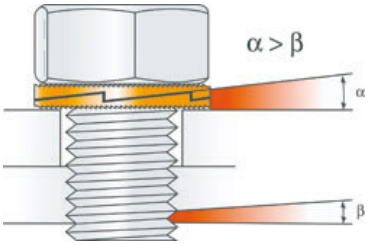
- Fasteners - bolt torque calculator
- Bolt tightening - elongation calculator
- SHL-MEC-102 Welding Standard
- Bolt tightening - inspection record sheet

APPENDIX A Fastener Terminology - For Reference

Acorn Nut 	A nut (so-called because of its shape) that has a domed top so that it prevents contact with the external thread.
Aerotight Nut 	A torque prevailing nut of all metal construction. The nut is slotted in two places which, after the nut has been tapped, are bent slightly inwards and downwards. When the nut is screwed onto the bolt thread the two slotted parts are forced back to their original position. Their stiffness causes the nut threads to bind onto the bolt threads and thus provides a prevailing torque. Aerotight is a registered trade mark of The Premier Screw and Repetition Co. Ltd of Woodgate, Leicester, United Kingdom, LE3 5GJ.
Anti-friction Coating	AF coatings are dry lubricants consisting of suspensions of solid lubricants, such as graphite, PTFE or molybdenum disulphide of small particle size in a binder. Such coatings can be applied to fastener threads to replace metallic coatings such as zinc and cadmium and offer maintenance free permanent lubrication. By careful selection of the lubricants, AF coatings can be designed to meet specific applications. The coatings are permanently bonded to the metal surface and provide a lubricating film preventing direct metal to metal contact.
Anti-seize Compound	An anti-seize compound is used on the threads of fasteners in some applications. The purpose of the compound depends upon the application. It can prevent galling of mating surfaces - such compounds are frequently used with stainless steel fasteners to prevent this effect from occurring. In some applications it is used to improve corrosion resistance to allow the parts to be subsequently dis-assembled. Thirdly, it can provide a barrier to water penetration since the threads are sealed by use of the compound.
Autolok Nut	A torque prevailing nut of an all metal construction. Covered by UK patent 1180842 the nut is marketed by GKN Screws and Fasteners Limited. Mainly used in automotive industry.
Allowance	An intentional clearance between internal or external thread and the design form of the thread when the thread form is on it's maximum metal condition. Not all classes of fit have an allowance. For metric threads the allowance is called the fundamental deviation.
Anaerobic Adhesive	An adhesive which hardens in the absence of air, such adhesives are often used as a thread locking medium.
Angle Controlled Tightening ***NOT RECOMMENDED***	A tightening procedure in which a fastener is first tightened by a pre-selected torque (called the snug torque) so that the clamped surfaces are pulled together, and then is further tightened by giving the nut an additional measured rotation. Frequently bolts are tightened beyond their yield point by this method in order to ensure that a precise preload is achieved. Bolts of short length can be elongated too much by this method and the bolt material must be sufficiently ductile to cater for the plastic deformation involved. Because of the bolt being tightened beyond yield, its re-use is limited.
Basic Thread Profile	This is the theoretical profile of external and internal threads with no manufacturing tolerance applied.
Bearing Stress	The surface pressure acting on a joint face directly as a result of the force applied by a fastener.
Bihexagon Head	A bolt or screw whose cross section of its head is in the shape of a 12 pointed star.
Black Bolts And Nuts	The word black refers to the comparatively wider tolerances employed and not necessarily to the colour of the surface finish of the fastener.
Bolt	A bolt is the term used for a threaded fastener, with a head, designed to be used in conjunction with a nut.
Breakaway Torque	The torque necessary to put into reverse rotation a bolt that has not been tightened.

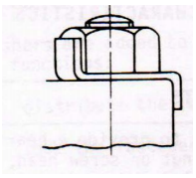
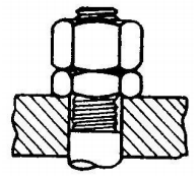
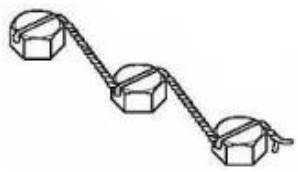
Breakloose Torque	The torque required to effect reverse rotation when a pre-stressed threaded assembly is loosened.
British standard brass	A specialist thread form based upon the Whitworth thread and consisting of 26 threads per inch whatever the thread diameter.
BSF	British Standard Fine. A thread form based upon the British Standard Whitworth form but with a finer thread (more threads per inch for a given diameter). This thread form was first introduced in 1908, the thread form is specified in BS 84: 1956.
BSW	British Standard Whitworth. A thread form developed by Sir Joseph Whitworth in 1841. The thread form has rounded roots and crests; the thread form is specified in BS 84: 1956. This thread form was superseded by the Unified thread in 1948 and then the metric thread form.
Bump thread	A modified thread profile patented and trade mark of the Bosco Tool Inc. The thread form has a small projection at the pitch diameter that eliminates the clearance from the thread assembly on both flanks. By doing this it is claimed that resistance to vibration loosening is significantly improved.
Cadmium electroplating	Coating of threaded fasteners with cadmium can provide the parts with excellent corrosion resistance. The appearance of the coating is bright silver or yellow if subsequently passivated. The friction values associated with this coating are also comparatively low. A chromate conversion coating is frequently applied to the surface to improve corrosion resistance. Cadmium is not now frequently used because of the environmental and worker health problems associated with the coating process and should not be used in applications above 250C or when contact with food is possible.
Clamping force	The compressive force which a fastener exerts on the joint.
Class of fit	The Class of Fit is a measure of the degree of fit between mating internal and external threads. Three main Classes of Fit are defined for metric screw threads : FINE: This has a tolerance class of 5H for internal threads and 4h for external threads. MEDIUM: This has a tolerance class of 6H for internal threads and 6g for external threads. COARSE: This has a tolerance class of 7H for internal threads and 8g for external threads. For Unified threads, a similar designation as for metric threads is used. The thread classes used are 1A, 2A and 3A for external threads and 1B, 2B and 3B for internal threads.
Cleveloc nut 	A torque prevailing nut of all metal construction. The collar of the nut is elliptical in cross section and it is this that provides the flexible locking element. The nut is prelubricated to reduce the torque needed when tightening and to minimise galling.
Coefficient of friction	A dimensionless number representing the ratio of the friction force to normal force. Typically for threaded connections it is between 0.10 to 0,18 but can vary significantly depending upon the materials used and whether a lubricant has been used. In relation to threaded fasteners, the coefficient of friction can be further subdivided into the coefficient of friction between the threads and the coefficient of friction under the nut face. There is in general a difference in values between the two coefficients due to typically the contact surfaces being different. For example, a zinc plated nut on a zinc plated bolt, the thread coefficient of friction would be due to zinc plating contacting zinc plating. The nut face coefficient of friction would be due to

	zinc plating contacting the joint surface finish.
Commingling	A term used to describe the undesirable practice of mixing fasteners from different batches that are the same size and grade in the same container.
Coneloc nut 	The Coneloc is an all metal prevailing torque type self-locking nut. The locking action is achieved by localised precision deformation of the thread in the cone section on top of the nut. When the nut is tightened onto the bolt, the thread is gripped on the flanks providing the locking action. Coneloc is a trade mark of NUTS BOLTS Limited
Cone proof load	This is an axial applied force applied to a nut when it is seated on a cone shaped washer which has an included angle of 120 degrees. Failure in this test is usually due to the nut splitting. The intention of the test is to introduce a nut dilation operation which will assess the potential detrimental effects of surface discontinuities. This type of test is sometimes applied to nuts which are intended for high temperature service.
Creep	Creep is deformation with time when a part is subjected to constant stress. Metals creep can occur at elevated temperature however with gasket materials it can occur at normal ambient temperatures. Creep resistance is an important property of gasket materials. Gasket materials are designed to flow under stress to fill any irregularities in the flange surface. The amount of creep sustained tends to increase with temperature. . However once the tightening is completed it is important that no further flow occurs since such deformation will lead to a reduction in bolt extension and subsequently the stress acting on the gasket. If this stress is reduced to below a certain minimum, which depends upon the type and construction of the gasket and the operating temperature, a high rate of leakage can be anticipated to occur.
Decompression point	The point at which there is zero pressure at the joint interface as a result of forces applied to the joint. If the applied force is increased beyond the decompression point, a gap will form at the interface. Analytically, a criteria of joint failure is often taken as when the applied force on the joint reaches the decompression point. This is because forces acting on the bolt(s) can dramatically increase at this point. Loading beyond this point can also result in fretting at the interface that will lead to bolt tension loss that will subsequently lower the decompression point. This process can continue until bolt failure does occur. The failure can be by fatigue or other mechanism but the underlying cause was loading of the joint beyond the decompression point. It is for this reason that it is frequently taken as a failure criteria in analysis work.
Dacromet	A high performance surface coating that can be applied to fasteners. The coating consists of passivated zinc flakes that are stoved onto the metal surface. The coating can be coloured and eliminates the risk of hydrogen embrittlement associated with electroplated metal. DACROMET is a registered trademark of Metal Coatings International, Inc. of Chardon Ohio
Design form of thread	The design form of an internal or external thread is the thread form in it's maximum metal condition. It is the same as the basic thread profile except that the thread roots are rounded. If either the internal or external thread form exceeds the design form of the thread profile then a potential interference exists.
Direct tension indicators	Direct Tension Indicators (DTI's) is a term sometimes used to describe load indicating washers. Projections on the face of the washer (usually on the face abuting the bolt head or nut) that deform under loading as the bolt is tensioned. An indication of the tension in the bolt can be made by measuring the gap between the washer face and the nut or bolt head. The smaller the gap - the greater the tension in the bolt. Commonly used in civil rather than mechanical engineering applications.
Disc lock washer (also called nord lock)	A specifically designed washer to solve the problem of fastener failure, is a heavy duty structural self-locking product, which prevents loosening caused by shock or vibration in high stress applications. Unlike conventional washers, the DISC-LOCK Washer is fitted in pairs.

	 **Tension makes the bolt self-locking** The key is the difference in angles. Since the cam angle " **α** " is larger than the thread pitch " **β** ", the pair of washers expand more than the corresponding pitch of the thread. NORDLOCK washers positively lock the fastener in a joint which is subjected to extreme vibration or dynamic loads.
Dynamic friction	Resistance to relative movement of two bodies that are already in motion.
Effective diameter	This is the diameter of an imaginary cylinder coaxial with the thread, which has equal metal and space widths. It is often referred to as pitch diameter. Sometimes referred to as the simple effective diameter to differentiate from the virtual effective diameter.
Effective nut diameter	Twice the effective nut radius.
Effective nut radius	The radius from the centre of the nut to the point where the contact forces, generated when the nut is turned, can be considered to act.
Electroless nickel	A relatively thin, hard coating that can be applied to threads and deposited uniformly. Bright metallic in appearance this coating has excellent resistance to wear and corrosion.
Embedment	Localized plastic deformation which occurs in the vicinity of clamped fasteners or in the fastener threads. . Embedding is local plastic deformations that occur under the nut face, in the joint faces and in the threads as a result of plastic flattening of the surface roughness. This occurs even when the loading is below the yield point of the bolt or limiting surface pressure of the joint material and is the result of the real area of contact between surfaces being less than the apparent area.
Environmentally assisted cracking (EAC)	A process that can occur with the use of high strength steel fasteners in which crack initiation and growth occurs in the fastener at a comparatively low stress level as a result of interactions that occur with the environment. Hydrogen is suspected of causing EAC in high strength steel fasteners, the hydrogen being produced as a result of chemical reactions (galvanic corrosion in a moist environment) or being present from a plating process that may have been applied to the fastener.
External force or load	Forces exerted on a fastener as a result of an applied loading to the joint.
External thread	A screw thread which is formed on an external cylinder, such as on bolts, screws, studs etc.
Floating type flange joint	A conventional flanged joint in which a gasket is compressed by bolts - the gasket is not rigidly located. Calculation methods such as the ASME code in the USA and the EN1591 code in Europe.
Fluoro-carbon thread coating	A low friction coating applied to threads. This type of coating is frequently used to prevent thread fouling when an assembly containing threaded fasteners is painted. Unless masked in some way before painting, electro deposited primers can cover the

	threads. If this occurs assembly difficulties can result unless the expensive chore of cleaning the threads is completed. A fluoro-carbon thread coating eliminates the need for masking or cleaning since paint will not adhere to the coating. This type of coating can also prevent problems caused by weld splatter obstructing the threads of weld nuts during their placement. Such coatings also have the property of reducing the torque-tension scatter during tightening.
Friction	Mechanical resistance to the relative movement of two surfaces. There are two main types of friction; STATIC FRICTION and DYNAMIC FRICTION. Typically static friction is greater than dynamic friction.
Friction stabilizers	Coating materials used on fasteners with the intention of reducing the scatter in the thread and bearing surface friction coefficients.
Fundamental deviation	An intentional clearance between internal or external thread and the design form of the thread when the thread form is on it's maximum metal condition. For metric threads the fundamental deviation are designated by letters, capitals for internal threads and small letters for external threads. Some tolerance classes have a fundamental deviation of zero. For imperial threads the fundamental deviation is called the allowance.
Fundamental triangle height	The fundamental triangle height is normally designated with the letter H. This is the height of the thread when the profile is extended to a sharp vee form. For 60 degree thread forms such as metric and Unified thread series, H equals 0.866025 times the thread pitch.
Galling	A severe form of adhesive wear which occurs during sliding contact of one surface relative to another. Clumps of one part stick to the mating part and break away from the surface. (Can frequently occur when both the nut and bolt are made from stainless or high alloy steels, titanium or zinc coated fasteners.)
Grip length	Total distance between the underside of the nut to the bearing face of the bolt head; includes washer, gasket thickness etc.
Hard joint	A joint in which the plates and material between the nut and bolt bearing surfaces have a high stiffness when subjected to compression by the bolt load. A joint is usually defined as hard if the bolt is tightened to its full torque and it rotates through an angle of 30 degrees or less after it has been tightened to its snug condition.
Hardened washers	The force under the head of a bolt or nut can exceed, at high preloads, the compressive yield strength of the clamped material. If this occurs excessive embedding and deformation can result in bolt preload loss. To overcome this hardened washers under the bolt head can be used to distribute the force over a wider area into the clamped material. A more modern alternative is to use a flange headed nuts and bolts.
Heat tightening	Heat tightening utilises the thermal expansion characteristics of the bolt. The bolt is heated and expands: the nut is indexed (using the angle of turn method) and the system allowed to cool. As the bolt attempts to contract it is constrained longitudinally by the clamped material and a preload results. Methods of heating include direct flame, sheathed heating coil and carbon resistance elements. The process is slow, especially if the strain in the bolt is to be measured, since the system must return to ambient temperature for each measurement. This is not a widely used method and is generally used only on very large bolts.
Helical spring washer	A split type of spring washer whose purpose is to prevent self loosening of the nut or the bolt. The idea or principle behind the helical spring washer is for one end of the tang of the washer to indent into the fastener (the nut or bolt head) and the other into the joint surface so that any loosening rotation is prevented. **Junker in his paper in 1969 on the cause of self-loosening of fasteners (reference:Junker, G., New criteria for self-loosening of fasteners under vibration. SAE Paper 690055, 1969) concluded that this type of lock washer has no ability to lock.** This type of washer is sometimes called a spring lock washer or sometimes a standard lock

	washer.
“Helicoil” 	A helical insert made of coiled wire. Another common generic name is screw thread insert (STI), although many users persist in calling them all by a prominent brand name, the registered trademark Heli-Coil. Used to “reclaim” a damaged internal thread. In essence, the damaged internal thread is drilled out, and the hole is re-tapped (threaded) to suit a special Helicoil insert. Then the Helicoil is “wound” into place, leaving the hole with a new thread of the same size and pitch as the original.
High strength friction grip bolts	Sometimes abbreviated to HSFG bolts. Bolts which are of high tensile strength used in conjunction with high strength nuts and hardened steel washers in structural steelwork. The bolts are tightened to a specified minimum shank tension so that transverse loads are transferred across the joint by friction between the plates rather than by shear across the bolt shank.
Hold and drive bolts	Special bolts that have a tang at the threaded end of the shank. This tang is gripped by the tightening tool during assembly so that the reaction torque is absorbed whilst the nut is tightened from the same side. Such bolts allow what used to have to be done by two men to become a one-man task.
Hot bolting	This term is used for the completion of maintenance work on a bolted joint when the joint is under loading. This can involve the replacement of individual bolts. There are risks both to the joint itself and to health and safety associated with this technique.
Hydraulic tensioner	A hydraulic tool used to tighten a fastener by stretching it rather than applying a large torque to the nut. After the fastener has been stretched, the nut is run down the thread to snug up with the joint, the hydraulically applied load is then removed resulting in tension being induced into the fastener.
Hydrogen embrittlement	Steel fasteners exposed to hydrogen can fail prematurely at a stress level well below the materials yield strength. Hydrogen embrittlement occurs in fasteners usually as a result of the part being exposed to hydrogen at some time during its manufacturing process but it can also occur through in-service corrosion. Electroplating is generally considered to be a major cause of hydrogen absorption in steel fasteners due to the release of hydrogen during this process. Higher strength steels are more susceptible to hydrogen embrittlement than lower strength steels, however it is considered that there is no lower strength limit. As a rule of thumb, steels below Rockwell C 35 are considered to be far less susceptible. Tests such as the incremental load hydrogen embrittlement test can be completed to assess if hydrogen embrittlement is present in a batch of fasteners.
Impact wrench	A wrench, usually powered by electricity or air, in which repeated blows from little hammers are used to generate torque to tighten fasteners. The torque applied to the fastener depends upon the time and the air pressure applied to the tool (for pneumatic wrenches). The torque applied by an impact wrench to a fastener is influenced by the joint stiffness.
Instantaneous centre of rotation	The point in space that an eccentrically shear loaded joint rotates about. The deformation and the load sustained by an individual bolt in a bolt group is dependent upon the distance that the bolt is from the instantaneous centre. The direction that the individual bolt force acts is perpendicular to a line joining that bolt to the instantaneous centre.
Integral fastener	A term used to describe types of fasteners which are highly resistant to vibration loosening and/or removal. Some types have special thread forms.
Internal thread	A screw thread which is formed in holes, such as in nuts.
Jam nuts	See LOCKNUT

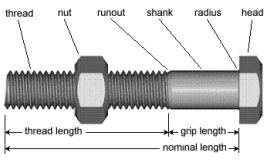
Joint control tightening	See YIELD CONTROLLED TIGHTENING
Jost effect	The name given to the reduction in the frictional resistance that occurs in a direction different to that in which slip is occurring. This effect is used in many applications including the removal of corks from bottles. If the cork is first rotated the force needed to pull the cork from the bottle is significantly reduced. It is also the fundamental reason why threaded fasteners experience self-loosening. Frictional resistance is first overcome in the transverse direction by slip occurring on the joint resulting in the frictional resistance in the circumferential direction reducing to a small value. The torque acting on the fastener in the loosening direction (as a result of its preload) that when coupled with the Jost Effect results in self-loosening occurring. The term is named after the Institute that completed research into this effect, the Jost Institute of Tribotechnology at the University of Central Lancashire in the UK.
K factor	The factor in the torque tightening equation: T=KDF where T is the fastener tightening torque in Newton metres, D is the fastener diameter in metres, F is the fasteners preload in Newtons and K is a factor whose value is often taken as 0.2. The formula gives the approximate tightening torque for standard fasteners used under normal conditions. The K factor is also known as the nut factor and the torque coefficient.
Keps	A pre-assembled nut and washer assembly (the washer is attached to the nut so that it won't fall off)- a trademark of ITW Shakeproof. The origin of the word came from Shakeproof. The s on the end being acquired due to them being purchased in quantities usually greater than one.
Left hand thread	A screw thread that is screwed in by rotating counter clockwise.
Length of engagement	The axial distance over which an external thread is in contact with an internal thread.
Lock Tab 	Locking plate where one tab is bent down over an edge of an assembly and a second tab bent up to lock the nut in position
Lock nut (or Jam Nut) 	There are two common usage's of this term: 1. A nut which provides extra resistance to vibration loosening by either providing some form of prevailing torque, or, in free spinning nuts, by deforming and/or biting into mating parts when fully tightened. 2. The term is sometimes used for thin (or jam) nuts used to lock a thicker nut. When used in this way the thin nut should be adjacent to the joint surface and tightened against the thick nut. If placed on top of the thick nut the thin nut would sustain loads it was not designed to sustain.
Lock wire 	A type of positive locking device that prevents fasteners from loosening or falling out due to vibration and other forces. Typically the wire is threaded through a hole drilled into a fastener then twisted and anchored to a second fastener, then twisted again.
“Loctite”	Cyano-acrylate anaerobic adhesives (one trade name is Loctite) have become increasingly popular as a locking medium. Joints made with Loctite are generally intended to be detachable (although possible with some difficulty in practice). It is only necessary to apply a few drops of the Loctite compound, which hardens and

	secures in the absence of oxygen.
Major diameter	This is the diameter of an imaginary cylinder parallel with the crests of the thread; in other words it is the distance from crest to crest for an external thread, or root to root for an internal thread.
Meanshift	The difference in tightening torque values produced by the same tightening tool on hard and soft joints. A hard joint typically gives a higher torque value than a soft joint. Generally speaking, the lower the meanshift of a tightening tool, the better it will be in achieving a specified torque value irrespective of the joint condition.
Metal to metal contact flange joint	A flanged joint in which a gasket is compressed by bolts - the gasket being located in a recess within the joint so that it is compressed by the bolt loads until metal to metal contact occurs. Unlike the FLOATING TYPE FLANGE JOINT, for metal to metal type joints there are no standardised gasket factor definitions, test procedures, nor generally acknowledged calculation procedures available.
Minor diameter	This is the diameter of an imaginary cylinder which just touches the roots of an external thread, or the crests of an internal thread.
Model engineers thread (m.e.)	A thread based upon the Whitworth thread form that was established in 1912. A very fine thread (a 3/32 inch thread having 60 tpi for example).
Molybdenum disulphide	A solid lubricant that acts as a high pressure resistant film. Can be used by itself as a dry lubricant as well as in with other solid lubricants and in oils and greases. Used in threads, such lubricants act as a separating film to prevent corrosion formation on the thread surface (even under adverse temperature and environmental conditions) ensuring the release of the threaded connection. Such films can also act as friction stabilisers.
Nicked threads	Nicks or indentations in threads can occur during the manufacturing process and during fastener transportation. In general, nicked thread problems tend to increase as the thread diameter increases and for fine pitches. There are acceptance tests for nicked threads that involve measuring the maximum torque required to drive a GO gauge down the thread. Examples of acceptance tests are SAE J123 and the Ford Motor specification WA990 1993. Nicks and indentations in threads are sometimes referred to as gouges.
Nominal diameter	The diameter equal to the external diameter of the threads.
Nord lock washer	Refer to DISC LOCK WASHER
Nut dilation	Under load, the wedging action of the threads causes dilation of the nut resulting in an increase in the minor diameter of the nut, and reducing the effective shear areas of both the external and internal threads.
Nut runner	A torque control fastener tightening tool that is usually powered by compressed air. The design of the tool is such that attempts are made to ensure that the applied torque is independent of joint stiffness.
Nyloc nut  Nyloc Nut	A torque prevailing nut that uses a nylon patented insert to provide a locking feature. The nylon insert, it is claimed, helps to seal the bolt thread against seepage of water, oil, petrol, paraffin and other liquids. The nut is covered by UK patent 8028437 and European patent 81303450-1. Nyloc is a registered trade name of Forest Fasteners.
Octagon head	A bolt or screw whose head cross section is a regular polygon with 8 sides.
Overtapping	Tapping of a thread following a plating operation so that the thread tolerances comply within specification allowing the internal and external threads to assemble. It

	is normal practice to overtap the internal rather than the external thread.
Piles	Term used in structural engineering for the joint plates.
Pitch	The nominal distance between two adjacent thread roots or crests.
Ply	A single thickness of steel forming part of a structural joint.
Pooching	Pooching is a term sometimes used to describe the effect of the area immediately surrounding a tapped hole being raised up as a result of the tension from the stud. Tapped holes are often bored out for the first couple of threads to eliminate this problem.
Preload	The tension created in a fastener when first tightened. Reduces after a period of time due to embedding and other factors.
Prevailing torque	The torque required to run a nut down a thread on certain types of nuts designed to resist vibration loosening. The resistance can be provided by a plastic insert or a noncircular head.
Proof load	The proof load of a nut is the axially applied load the nut must withstand without thread stripping or rupture. The proof load of a bolt, screw or stud is the specified load the product must withstand without permanent set.
Property class	A designation system which defines the strength of a bolt or nut. For metric fasteners, property classes are designated by numbers where increasing numbers generally represent increasing tensile strengths. The designation symbol for bolts consists of two parts: 1. The first numeral of a two digit symbol or the first two numerals of a three digit symbol approximates 1/100 of the minimum tensile strength in MPa. 2. The last numeral approximates 1/10 of the ratio expressed as a percentage between minimum yield stress and minimum tensile stress. Hence a fastener with a property class of 8.8 has a minimum tensile strength of 800 MPa and a yield stress of 0.8x800=640 MPa. The designation system for metric nuts is a single or double digit symbol. The numerals approximate 1/100 of the minimum tensile strength in MPa. For example a nut of property class 8 has a minimum tensile strength of 800 MPa. A bolt or screw of a particular property class should be assembled with the equivalent or higher property class of nut to ensure that thread stripping does not occur.
Prying	The amplification of an external force acting on a bolt by a lever action which can occur when that force is an eccentric tensile load.
Reduced shank bolt	A bolt whose shank diameter is smaller than the nominal diameter of the bolt (normally the shank diameter of such a bolt is approximately equal to the effective diameter of the thread).
Relaxation	The loss of clamping force in a bolt that occurs typically without any nut rotation occurring. Commonly occurs as a result of embedment but can also be due to gasket creep, metal creep (at elevated temperatures), differential thermal expansion and stress relaxation.
Right hand thread	A screw thread that is screwed in by rotating clockwise. The majority of screw threads are right handed.
Rolled thread	A thread formed by plastically deforming a blank rather than by cutting. The majority of standard fasteners have their threads formed by rolling. Most threads are rolled before any heat treatment operation. Significant improvements in fatigue life can be achieved by rolling the thread after heat treatment, this improvement is due to compressive stresses being induced in the roots of the thread. However, because of the increased hardness of the bolt blank, the die life can be significantly reduced. Rolling the thread also generally improves the surface finish which can have a

	beneficial effect on fatigue life.
Root diameter	Identical to MINOR DIAMETER
Screw	A headed threaded fastener that is designed to be used in conjunction with a pre formed internal thread or alternatively forming its own thread. Historically, it was a threaded fastener with the thread running up to the head of the fastener that has no plain shank. However this definition has largely been superseded to avoid confusion over the difference between a bolt and a screw.
Screw thread	A ridge of constant section which is manufactured so that a helix is developed on the internal or external surface of a cylinder.
Self-loosening	Threaded fasteners can come loose on occasions without human intervention. This loosening can be due to creep, embedding, stress relaxation or the fastener self rotating (which is often called vibration loosening). Creep, embedding and stress relaxation will generally not completely loosen a fastener, these loosening mechanisms occur without the nut rotating relative to the bolt. The term self loosening is sometimes used for the nut rotating relative to the bolt without human intervention. It is know that the fastener can self-rotate under the action of transverse joint movement that can completely loosen a tightened fastener such that the nut will become detached from the bolt.
Sems	A screw and washer assembly. A screw or bolt which has a captive washer. The washer is frequently loose on the plain shank of the fastener, the shank diameter being equal to the effective diameter of the thread; the thread being rolled from this diameter. The origin of the word is a frequent question. In the 1930's E. C. Crowther was a representative for a company that sold both shakeproof washers and screws. He came up with the idea of placing the washer on the screw before it was thread rolled. The major diameter of the screw being larger than the washer hole prevents it from coming off. The Illinois Tool Works made machines that produced these patented pre-assembled washers and screws. The s at the end of SEMs is thought to have been subsequently picked up because they are not usually purchased individually. In spite of the original patents and trademarks the word SEMS is generally recognised as a generic term applicable to screw and washer assemblies.
Set screw	A set screw is a threaded fastener that is typically used to hold a sleeve, collar or gear on a shaft to prevent relative motion. It is a threaded member that normally does not have a head. Unlike most other threaded fasteners it is basically a compression device normally used to generate axial thrust. Various socket types are provided to allow the set screw to be rotated. These types include hexagon socket, fluted socket, screwdriver slot and square head. Various point designs are available (the part of the set screw that rotates against the shaft being secured) and include: Cup - Hollowed end is the most commonly used point style. Used when the digging in of the point is not undesirable. Cone - Pointed end, this type generates the highest torsional holding power and is typically used for a permanent connection. Oval - Rounded end that is typically used when frequent adjustment is required. The oval end prevents/reduces indentation. Flat - Cause little damage to the shaft and are used when frequent adjustment is required. Dog - Flat end with the threads stopping short of the end with the end fitting into a hole.
Shank	That portion of a bolt between the head and the threaded portion.
Shoulder screws	A threaded fastener with a plain, precision machined shank that is used for location purposes. They are typically used for pulleys and linkages.

Skidmore bolt tension calibrator	The Skidmore-Wilhelm bolt tension calibrator is a hydraulic load cell used to determine the tension in a bolt or other threaded fastener. The tension in the bolt compresses fluid in a hydraulic cylinder, a pressure gauge connected to the cylinder is then calibrated to read in terms of force rather than pressure.
Snug torque	The torque required to pull plates together so that direct contact occurs; often used in angle control tightening. The snug torque ensures that metal to metal contact occurs at all the interfaces within the joint. It is only at this point that the required angle of rotation start in order that the bolt is tightened sufficiently. The snug torque is usually determined experimentally on the actual joint.
Snugging	The process of pulling parts of a joint together, most of the input turn during this process is absorbed in the joint with little tension being given to the bolt.
Socket head cap Screw 	A screw with a round head, usually with a hexagon indentation in the head for tightening purposes. Used on machine parts and is typically made from high strength steel (grade 12.9 in metric). These fasteners are very similar to hex bolts. They differ mostly in that they are manufactured to tighter tolerances than the corresponding bolts.
Soft joint	A joint in which the plates and material between the nut and bolt bearing surfaces have a low stiffness when subjected to compression by the bolt load. In such a joint, the bolt (or nut) typically has to be tightened by two or more complete turns, after it has been torqued to the snug condition, before the full tightening torque is achieved. Often the placement of a gasket in a joint results in a soft joint.
Soft torque	An alternative name, used by some manufacturers, for snug torque.
Spiral wound gasket	A type of gasket that is made by winding V-section metal strip and a softer filler material together. Support or retaining rings, inside and/or outside the spiral, improve the gasket's handling and fitting. The filler material used is typically graphite or PTFE. The metal strip and retaining rings being typically made from stainless steel.
Static friction	Friction at rest; a force is required to initiate relative movement between two bodies - static friction is the force that resists such relative movement. Sometimes referred to as stiction.
Step-Lock Bolt (SLB)	The Step-Lock Bolt (SLB) is a thread form that has been modified to resist vibration loosening. The thread has several horizontal portions (i.e. no lead angle) whose purpose is to prevent torsion being developed in the bolt as a result of the loosening purpose. It is these horizontal portions that are known as steps. Published literature indicates that the thread form performs well when tested on a transverse vibration test machine. However manufacturing difficulties may prevent its widespread adoption.
Stiffnut	A term used to describe a lock nut which has a prevailing torque.
Strength grade	See PROPERTY CLASS
Stress area	The effective cross sectional area of a thread when subjected to a tensile force. It is based upon a diameter which is the mean of the pitch (or effective) and the minor (or root) diameters of the thread. The use of this diameter stems from the work of E. M. Slaughter in the 1930's. He completed carefully controlled tests using various sizes of standard threads and compared their strength with machined bars made from the same bar of material. He found that this mean diameter gave results that agreed with the tensile test results to within about 3%. The error on the minor and pitch diameters was about 15%. Tests completed subsequent to these by other investigators have also shown that the stress diameter is a reasonable approximation to a thread's

	tensile strength. (Reference: 'Tests on Thread Sections Show Exact Strengthening Effect of Threads.' by E. M. Slaughter, Metal Progress, vol 23, March 1933 pp. 18-20)
Stress relaxation	A significant problem with bolting at high temperatures is a phenomenon known as stress relaxation. Creep occurs when a material is subjected to high temperature and a constant load. Stress relaxation occurs when a high stress is present that is relieved over time; the stress is relaxed with a subsequent reduction in the bolt's preload. The only way to minimise the effects of stress relaxation is to use materials that have an adequate resistance to it at the product's operating temperature. The effect of bolt stress relaxation is to reduce the clamp force provided by the bolts; this phenomenon alone will not fully loosen a joint.
Structural bolt	A structural bolt is a heavy hexagon head bolt having a controlled thread length intended for use in structural connections and assembly of such structures as buildings and bridges. The controlled thread length is to enable the thread to stop before the joint ply interface to improve the fastener's direct shear performance. This term is used in civil and structural engineering but is not frequently used in mechanical engineering.
Stud	A fastener which is threaded at both ends with an unthreaded shank in between. One end (which often has a thread tolerance which results in more thread interference) is secured into a tapped hole; the other is used with a nut.
Symmetrical thread	A symmetrical thread is one that has both flanks of the thread profile inclined at the same angle.
Taylor-forge method	A method developed by four engineers of the Taylor-Forge Company in Chicago in the 1930's that subsequently formed the basis of the ASME code for flanged joint design. The assumptions made by the method are now generally regarded as too simplistic. This method gives rise to the m and y gasket factors.
Tension washers	A general name given to spring washers, curved washers, Belleville washers and disc springs. This type of washer provides a relatively low stiffness (compared to the joint stiffness) and can be used to act as a spring take-up with a bolt to prevent movement between parts.
Thread crest	The top part of the thread. For external threads, the crest is the region of the thread which is on its outer surface, for internal threads it is the region which forms the inner diameter.
Thread flank	The thread flanks join the thread roots to the crest.
Thread height	This is the distance between the minor and major diameters of the thread measured radially.
Thread length	Length the portion of the fastener with threads.
Thread root	The thread root is the bottom of the thread, on external threads the roots are usually rounded so that fatigue performance is improved.
Thread runout 	The portion at the end of a threaded shank which is not cut or rolled to full depth, but which provides a transition between full depth threads and the fastener shank or head.
Threadlocker	Can be a term used for a number of vibration resistant products but is now usually reserved for thread locking adhesives. Specifically, a liquid anaerobic adhesive applied to nut or bolt thread, once hardened it fills the inner spaces between the

	threads to produce a solid plastic of known shear strength.
Tin/zinc alloy electroplating	Tin/zinc alloy coatings (typically 70% tin and 30% zinc) are applied to threaded fasteners to provide a corrosion resistant coating. One of the advantages of such coatings is that bimetallic corrosion will not occur when placed into contact with such metals as aluminium or steel.
Tolerance class	A combination of tolerance grade and a fundamental deviation which is given to an internal or external thread. A tolerance class for an internal thread when combined with the tolerance class for an external thread gives the class of fit for the mating threads.
Tolerance grade	The difference between maximum and minimum metal conditions for a tolerance applied to a screw thread. For metric threads the tolerance grade is given a number.
Torque	A rotational moment; it is a measure of how much twisting is applied to a fastener. The units used to measure torque are in the form of force times length. Usually measured in newton-metres (Nm) if metric units are used or pounds feet (lb-ft) when imperial units are used.
Torque multiplier	A gearbox used to increase the torque produced by a small hand wrench.
Torque wrench	A manual wrench which incorporates a gauge or other method to indicate the amount of torque transferred to the nut or bolt.
Turn of the nut method	See ANGLE CONTROLLED TIGHTENING
U bolt	A U shaped fastener threaded at both ends used primarily in suspension and related areas of vehicles.
Ultrasonic extensometer	An instrument which can measure the change in length of a fastener ultrasonically as the fastener is tightened or measure the length before and after it is tightened).
UNC	Unified National Coarse (UNC) is a thread form with a 60 degree flank angle rounded roots and flat crests. For a given diameter it has a larger thread pitch than an equivalent diameter UNF thread. The unified thread is based on inch sizes and was first standardised in 1948 unifying the Whitworth and American standard thread forms.
UNEF	Unified National Extra Fine (UNEF) is a Unified thread form with a very fine (small) pitch that are typically used on instruments and parts requiring a fine adjustment.
UNF	Unified National Fine (UNF) is a thread form with a 60 degree flank angle rounded roots and flat crests. For a given diameter it has a smaller thread pitch than an equivalent diameter UNC thread.
UNR	Unified National (UN) thread form with a rounded root contour, applies only to external threads. (The UN thread form has a flat, or optionally, a rounded root contour.) The majority of fasteners with a Unified thread form have a rounded root contour i.e. are UNR threads.
Virtual effective diameter	The effective diameter of a thread, but allowing for errors in pitches and flank angles.
Waisted shank bolt	A bolt whose diameter is less than the minor diameter of the thread. Frequently the shank of the bolt is 0.9 times the root diameter.
“Whizlock” fastener	A free running screw that locks itself in place with serrations or locking teeth under the head.
Wire thread insert	A threaded insert that is typically used for tapped hole repair or to improve the thread

	stripping strength of softer metals such as zinc and aluminium. The inserts are assembled into a previously tapped hole using a special driving tool. A thread locking compound is frequently used to secure the insert if the assembly is subject to Vibration. See also “Helicoil”
Yield controlled tightening	A fastener tightening method which allows a fastener to be tightened to yield. The angle of rotation of the fastener is measured relative to the applied torque, yield being assessed when the slope of the relationship changes to below a certain value. Sometimes called joint controlled tightening.
Zinc electroplating	Zinc electroplating is a common way to protect threaded fasteners from the effects of corrosion. Zinc electroplating can be completed in acid chloride, alkaline or cyanide baths. Supplemental coatings are frequently applied to zinc electroplating. These coatings, such as zinc phosphate or chromate conversion, provide a protective passivation layer on the zinc which assists in reducing the corrosion rate.
Zinc/cobalt alloy electroplating	This coating is similar to zinc electroplating completed in an acid chloride bath - a small amount of cobalt (typically about 1%) is added to increase the plating speed.
Zinc phosphate conversion coating	A zinc phosphate conversion coating is frequently added to zinc electroplated parts, such as bolt threads, to improve corrosion resistance. This type of chemical conversion coating provides a protective passivation layer on the zinc improving its corrosion resistance.