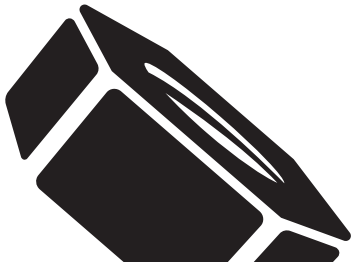
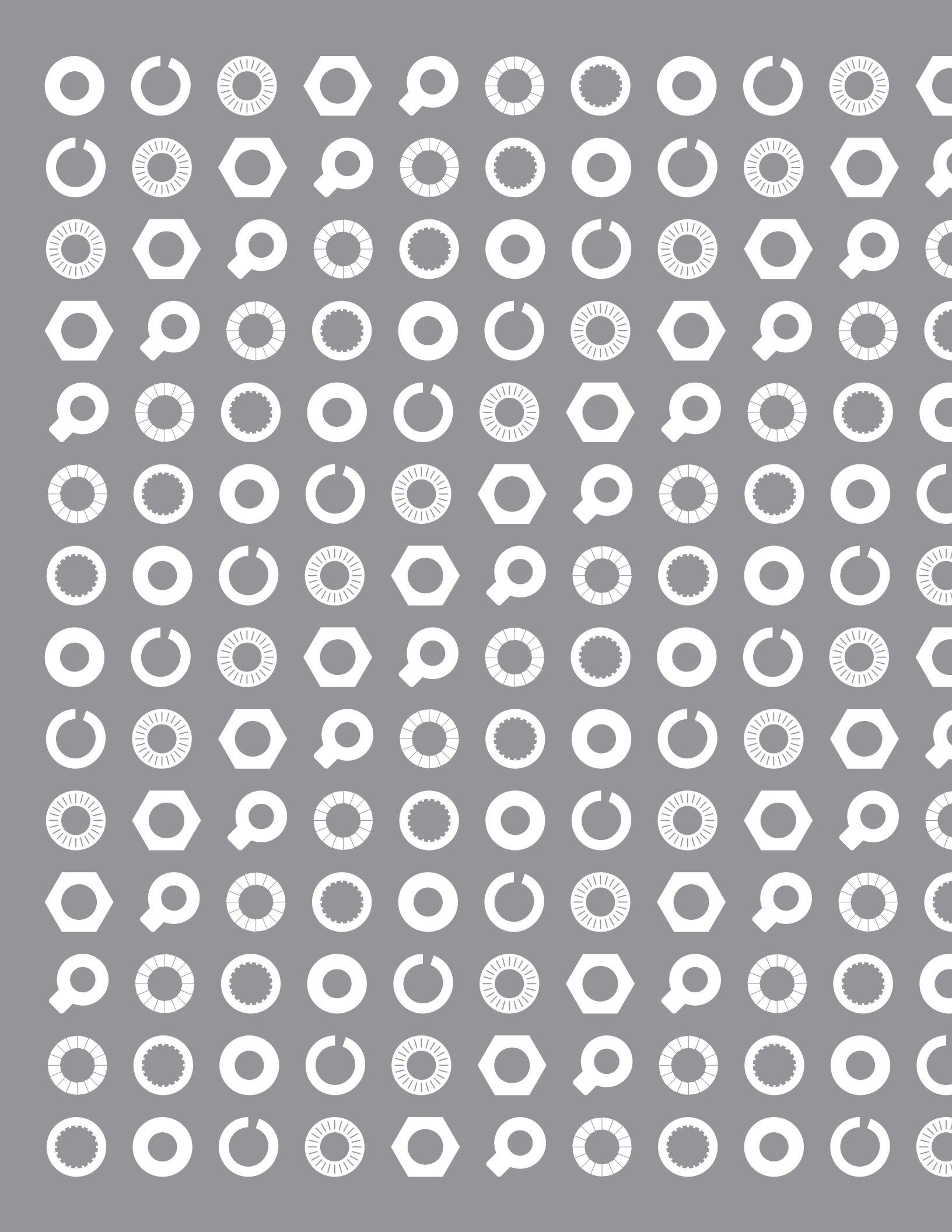
NORD-LOCK GROUP

WHY DO BOLTS LOOSEN

A brief look at technologies designed to prevent this from happening





CONTENT

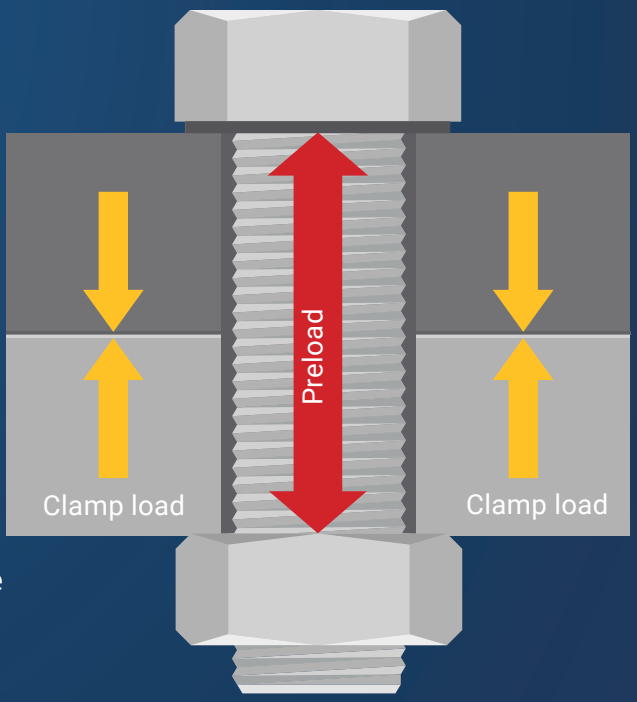
WHY DO BOLTS LOOSEN?

Bolted joints are designed to maintain the integrity of an application by preventing the different components from loosening, even when subjected to conditions such as vibration, dynamic loads, flexing and temperature changes. Although, in theory, tightening a bolted joint with the correct preload should be enough to prevent it from loosening, this does not always work in practice.

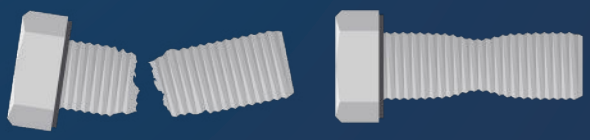
This book will assess and compare common methods of securing bolted joints against loosening over the lifetime of the assembly. It will provide guidance regarding the most appropriate securing method to choose for the joint in question. Securing methods such as FRICTION, MECHANICAL, ADHESIVE AND GEOMETRY will be outlined and evaluated using specific criteria including performance, cost and worker safety.

CHALLENGES & CONSEQUENCES

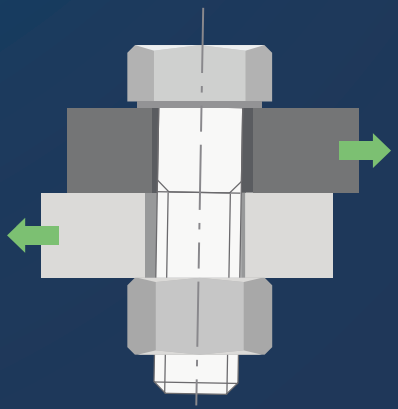
Depending on the application, bolt loosening can have profound consequences both in terms of cost and safety. Therefore, the most important thing for a bolted joint is that the preload remains intact throughout its entire lifetime since without proper preload the joint will fail.



Preload is tension created in a fastener when it is tightened. Its function is to prevent slippage and opening of the clamped parts. The more accurate the preload the more protected the bolt should be from loosening. As the bolt stretches, the components between the bolt and the nut compress, thus increasing the clamp load until the end of the tightening process.

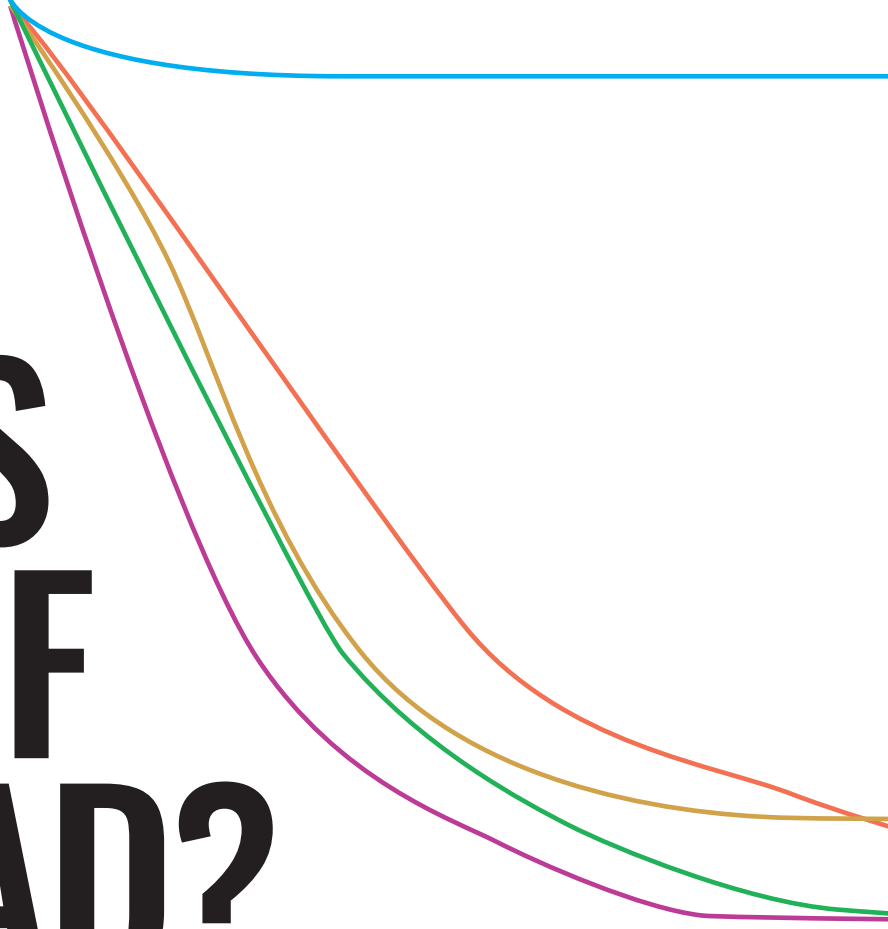


If the preload is too high there is a risk of damaging the clamped parts. There is also a risk of overstretching the bolt which in worst case could cause it to break.



If the preload is too low there is a risk of parts moving in the joint which could cause bolt shearing. When exposed to external cyclic forces there will be large load variations within the bolt causing it to break even though the loads have not been exceeding the limits of the bolt material.

WHAT CAUSES LOSS OF PRELOAD?



The biggest challenges for a bolted joint, causing it to lose preload and fail, is spontaneous loosening.

Spontaneous loosening: shock, vibration, dynamic loads

Spontaneous loosening occurs when a bolt rotates loose due to external factors such as **vibration, shock and dynamic loads (flexing)**. The most demanding applications are continually subjected to dynamic loads and even a slight rotation of the fastener can be enough for the joint to lose much of its preload.

Slackening: settlement, creep, relaxation

Settlement is permanent deformation of the clamped material. Settlement often occurs where there are surface irregularities or soft surfaces. **Creep** is permanent deformation that occurs due to long term exposure to high levels of stress below the yield strength of the materials in the joint. It is more severe in high temperature applications. **Relaxation** is deformation of the material due to a combination of load and time which causes the microstructure in the materials of the joint to restructure. It often occurs in soft metallic materials, polymers and composites. Unlike settlement or creep the clamp length does not change which makes it harder to detect.

BOLT LOCKING METHODS

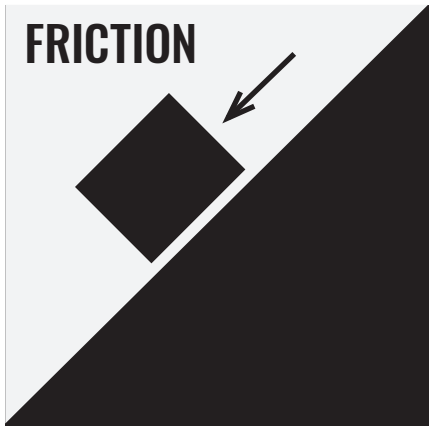
When choosing a method for preventing bolts from loosening in an assembly there are many different options.

One needs to assess the risk of joint failure and the dynamic loads the joint will meet during the life of the assembly. Only then can one choose from some of the more commonly used principles and from there find a solution that will be suitable for the unique assembly at hand.

All bolted joints are unique and should be treated as such.

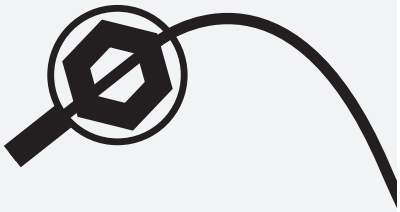
From a more advanced technical perspective there are other considerations to every unique bolted connection, ranging from lubrication, settlements, mating surface and operating conditions.

FRICTION



Friction locking methods are based on preventing surfaces from sliding against each other by increasing the resistance (friction) between these contact surfaces. Increased friction between the male and female threads, or between the fastener and contact surface, creates a resistance to loosening. Locking devices that use this principle include split ring, serrated and tooth washers. Nylon insert nuts fall into this category.

MECHANICAL



Mechanical locking utilises a physical barrier with the aim of preventing the fastener from rotating. Mechanical locking devices include tab washers, which have a side tab that can be bent upwards to lock the nut in place, and locking wire, which can be threaded through a hole in the bolt head/nut and tightened to another fastener close by. Both can prevent the fastener from rotating fully, but it should be noted that a proportion of the preload can be lost over time under dynamic load conditions.

ADHESIVE

This method uses a liquid, known as thread locking adhesive, to prevent a bolted joint from loosening. The adhesive is applied to the thread of the fastener. Adhesives are not restricted by the size of the fastener used; however, they do pose a risk of chemical exposure and may be hazardous to health. They can also have a significant adverse effect upon the torque / load ratio, resulting in uncontrolled preload during tightening.

GEOMETRY

The geometry method utilizes the shape of the fastener to secure the bolted joint in place when subjected to vibration and dynamic loads. The most common system, wedge-locking washer, is composed of a pair of washers with cams on one side and serrations on the other. The serration forces any rotational movement to occur between the washers and the geometry of the cams introduces a need for increase in tension in the bolt if the bolts want to rotate loose.
This safely secures the joint.

NOTES & VALUES
GUIDANCE FOR SELECTION

Guide Notes

FUNCTIONALITY

LOCKING ABILITY
The method or products resistance to loosening, caused by joint flexing, vibration, dynamic loading or thermal cycling.

REUSABILITY
Can the method or product be reused, for example during planned maintenance, or must it be discarded and replaced with new?

BOLTED JOINT SAFETY

WORKER SAFETY
Some bolt securing methods and products have been linked to health and safety issues. For example, there is an established link between the use of tab washers and hand injuries.

COST RELATED TO METHOD OR TYPE

INITIAL COST
The combined cost of purchasing and first fit of the method or product.

TOTAL LIFETIME COST
The combined cost of purchasing, fitting and maintaining the method or product over the lifetime of the application. It should be noted that repeated inspection, maintenance and retightening can be a significant cost to the operator / owner. Breakdowns and repair can add significantly to these costs, but they are not included here.

Using the Guidance for selection

Each product group in the selection guide is based upon a range of products (of the same general type) from different manufacturers.

It must be recognised that within each group, some products may work better, or worse than others. We have therefore considered an average value for each of the headings in each product group.

For example, even within a product group with a high rating for locking ability, there may be low quality manufacturers who's products do not work when tested.

Buyer beware always applies.

Evaluation Values

●●●●● SUITABLE / YES

● UNSUITABLE / NO

○ NOT APPLICABLE

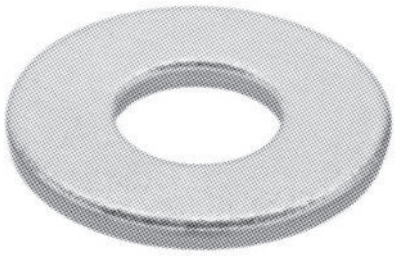
GUIDANCE FOR SELECTION

5 DOTS Suitable/ Yes. **1 DOT** Unsuitable / No. **0** = Not applicable.

	Steel material	LOCKING ABILITY	REUSABILITY	WORKER SAFETY	INITIAL COST	TOTAL LIFETIME COST
FRICTION	**Plain washer**	○	●●●●	●●●●	Low	High
	Disk spring washer	○	●	●●●●	Medium	High
	Serrated lock washer	●●●	●	●●●●	Medium	Medium
	Split ring washer	●	○	●●●●	Low	High
	Tooth lock washer	●	○	●●●●	Low	High
	Nylon insert lock nut	●●◖	●	●●●●	Medium	Medium
	Double nut	●●	●●●●	●●●●	Medium	Medium
MECHANICAL	**Tab washer**	●●●	○	●●	High	Medium
	Locking wire	●●●	○	●●●	High	Medium
ADHESIVE	**Adhesive**	●●●	○	●●	Medium	Medium
GEOMETRY	**Wedge-locking washer** Nord-Lock Washers	●●●●●	●●●●	●●●●	High	Low

PLAIN WASHER

PROS
PROTECTS THE MATING SURFACE



CONS
NO LOCKING FUNCTION

Plain washers, also known as flat washers, are the most common type of washer. Plain washers do not have a locking function, rather they are used to protect the mating surface from damage. They do this by increasing the surface area in order to help distribute the load, in particular on soft materials or over large or slotted holes. Plain washers are installed between the bolt head/nut and the mating surface. The bolted joint is then tightened in the same way as an unsecured bolt.

EVALUATION PLAIN WASHERS

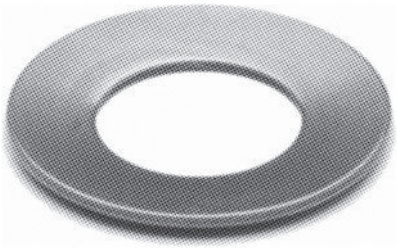
- Functionality
- User safety
- Costs related to product & method
- Not applicable

5 DOTS Suitable / Yes. **1 DOT** Unsuitable / No. **0** = Not applicable.

DISK SPRING WASHER

PROS

COUNTERACTS SETTLEMENTS



CONS

NO LOCKING FUNCTION

HIGH MAINTENANCE COST

Spring washers, also called disc springs or conical washers, use spring loads to create axial flexibility. This counteracts settlements and maintains an initial level of preload. The washers are installed between the bolt head/nut and the mating surface. Spring washers mechanical capabilities rely on the shape of the material. When subject to load, the washer undergoes elastic deformation, and then returns to the pre-deflected shape. They can be stacked, so deflection and load capacity can vary without materially affecting the forces. The forces created by the washers can differ depending on the thickness of the material, curve and size - meaning that the operator can customize the spring loads used.

Spring washers are used in applications where assemblies need to take up space, maintain tension, eliminate rattle, compensate for expansion/contraction, absorb shock, and/or control reaction under dynamic loads. They are common on pipe flanges to combat flange leakage from high temps and varying pressure. As temperature increases, the elasticity of the material and the load capacity of the washer decreases.

EVALUATION DISK SPRING WASHERS

- Functionality
- User safety
- Costs related to product & method
- Not applicable

Locking ability ○

Reusability ●

Worker safety ●●●●

Initinal cost **Medium**

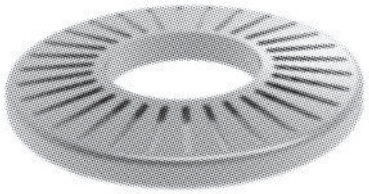
Total lifetime cost **High**

5 DOTS Suitable / Yes. **1 DOT** Unsuitable / No. **0** = Not applicable.

SERRATED LOCK WASHER

PROS

QUICK AND EASY TO INSTALL



CONS

INCONSISTENT LOCKING ABILITY

SHOULD NOT BE LUBRICATED

SINGLE PART SERRATED WASHERS DAMAGE THE MATING SURFACE

Serrated lock washers increase the friction between the bolt head/nut and the mating surface. They do this by gripping into the mating surfaces. Serrated lock washers are installed between the bolt head/nut and the mating surface. The bolted joint is then tightened in the same way as an unsecured bolt. If the bolted joint experiences a loss of tension, the washer is no longer effective and must be replaced.

Single part serrated washers can damage painted/coated surfaces because they have a tendency to rotate with the fastener. This risks damaging the surface, cracking the paint/coating and causing corrosion.

This principle works best on softer materials, as it is easier for the serrations to dig into them.

EVALUATION SERRATED LOCK WASHERS

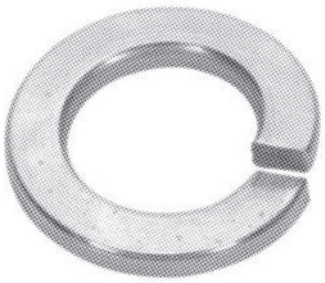
- Functionality
- User safety
- Costs related to product & method
- Not applicable

5 DOTS Suitable / Yes. **1 DOT** Unsuitable / No. **0** = Not applicable.

SPLIT RING WASHER

PROS
LOW PURCHASE COST

QUICK AND EASY TO INSTALL



CONS
POOR LOCKING FUNCTION

SHOULD NOT BE LUBRICATED

DAMAGES CONTACT SURFACE

Split ring washers use friction to prevent bolted joints from loosening. They feature a ring that has been split and twisted - creating two sharp edges. These washers are installed between the bolt head/nut and mating surface, the bolted joint is then tightened in the same way as an unsecured bolt. When the nut is tightened, the washer flattens down, pushing the sharp edges into the mating surface.

Any locking ability works best on softer materials as it is easier for the edges to dig into them. It is ineffective at locking bolted joints experiencing higher levels of dynamic loads. It is also ineffective when the bolted joint requires lubrication, which promotes sliding and rotation of the bolt.

It can even be counter-productive as low quality split-ring washers crack over time in the compressed area of the spring and can accelerate loosening by spring effect.

EVALUATION SPLIT RING WASHERS

- Functionality
- User safety
- Costs related to product & method
- Not applicable

5 DOTS Suitable / Yes. **1 DOT** Unsuitable / No. **0** = Not applicable.

TOOTH LOCK WASHER

(ELECTRICAL CONTACT WASHERS)

PROS

LOW PURCHASE COST

CONS

UNRELIABLE

VERY POOR LOCKING FUNCTION

CANNOT BE REUSED

Tooth lock washers are designed to prevent bolted joints from loosening using friction. Similarly to serrated washers, tooth lock washers feature teeth-like-serrations either internally or externally. They are installed between the bolt head/nut and the mating surface, and the bolted joint is then tightened in the same way as an unsecured nut. When the bolted joint is tightened, these teeth bite into the mating surface.

These washers work best with soft surfaces as hard surfaces will flatten the teeth – preventing them from successfully biting into the surface and securing the joint. The smaller surface area of the internal tooth lock washers mean that they are less effective than those with external teeth.

EVALUATION TOOTH LOCK WASHERS

- Functionality
- User safety
- Costs related to product & method
- Not applicable

Locking ability ●

Reusability ○

Worker safety ●●●●

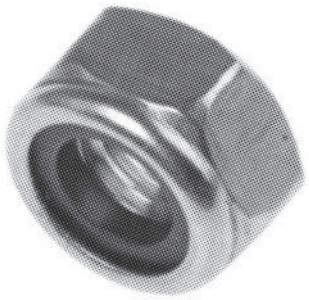
Initinal cost **Low**

Total lifetime cost **High**

5 DOTS Suitable / Yes. **1 DOT** Unsuitable / No. **0** = Not applicable.

NYLON INSERT LOCK NUT

PROS
ENSURES THAT BOLTS AND NUTS DON'T FALL OFF



CONS
POOR LOCKING ABILITY

LOCKING ABILITY DECREASES WHEN REUSED

SHOULD NOT BE LUBRICATED

Locking nuts work to secure bolted joints by adding friction to the thread of the bolt. Different varieties of locking nut exist, those that utilize metal to create friction, such as the all metal nut, and those that incorporate a polymer in the design, such as the nylon insert nut. Locking nuts follow the same installation procedure as normal nuts. The nylon insert nut features an internal nylon washer or patch.

The addition of the non-metal component means that the nylon insert nut is more temperature and chemical sensitive. It also necessitates the use of a tool for installation, however, the revolution speed must be less than 150 RPM in order to avoid over heating the nylon insert. All metal nuts do not have as many temperature/chemical restrictions, however, they are more likely to suffer from thread galling. The main benefit of the locking nut is its ability to stay on the bolt even if it has loosened.

EVALUATION NYLON INSERT LOCK NUT

- Functionality
- User safety
- Costs related to product & method
- Not applicable

5 DOTS Suitable / Yes. **1 DOT** Unsuitable / No. **0** = Not applicable.

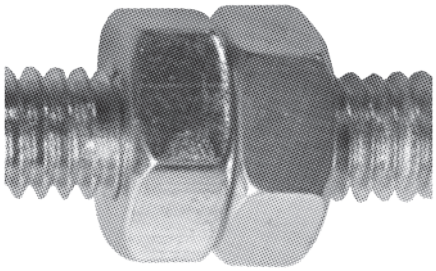
DOUBLE NUT

PROS

CONVENIENT

READILY AVAILABLE

INEXPENSIVE



CONS

POOR LOCKING ABILITY

REQUIRES A LONGER BOLT AND TWO NUTS

COMPLICATED ASSEMBLY PROCEDURE

The double nut, also known as jam nut, is a friction locking method that uses two separate nuts on top of each other.

Care must be taken during tightening of the second nut as overtightening will lead to thread stripping or tensile rupture of the bolt. Although the nuts used for this method require little investment, the installation process itself is time consuming and relies on the skill of the operator. It is also an unreliable locking method that protects poorly against vibration, which means it must be inspected and maintained often – increasing long-term costs. It is particularly ineffective when lubicration of the bolted joint is required.

EVALUATION DOUBLE NUT

- Functionality
- User safety
- Costs related to product & method
- Not applicable

5 DOTS Suitable / Yes. **1 DOT** Unsuitable / No. **0** = Not applicable.

TAB WASHER

PROS
GOOD LOCKING ABILITY
LOW PURCHASE COST
CAN BE LUBRICATED

CONS
LONG ASSEMBLY TIME
RELIES HEAVILY ON OPERATOR
CANNOT BE REUSED

Tab washers are a mechanical locking solution that secure bolted joints using a physical barrier. The washer itself is a thin piece of metal usually rectangular or circular. The tab washer is installed between the bolt head/nut and the mating surface, and the bolted joint is tightened like a regular bolt.

Once the bolt has been tightened, the tab section of the washer is knocked up around the bolt head/nut to lock it in place and prevent any rotation. The locking function of the washer is normally good, however, numerous cases of badly installed, thus inefficient, tab washers have been reported by large MROs and asset owners.

The major disadvantage is the complex assembly method. Not only does it increase the assembly time but it also means the locking ability of the tab washer can vary significally depending on the skill of the operator. Multiple injuries have also been reported by operators, especially during removal, as they must hammer the tab washers to remove them. Tab washers cannot be reused as they become deformed when they are removed from the bolted joint.

EVALUATION TAB WASHERS

- Functionality
- User safety
- Costs related to product & method
- Not applicable

Locking ability ●●●
Reusability ●○
Worker safety ●●
Initinal cost **High**
Total lifetime cost **Medium**

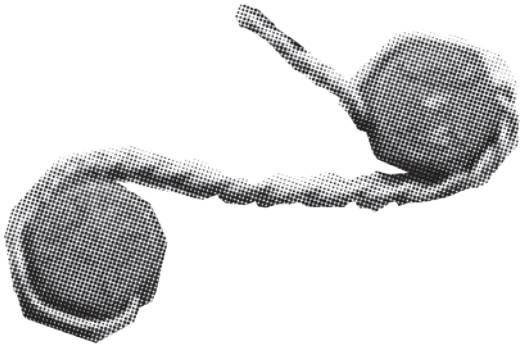
5 DOTS Suitable / Yes. **1 DOT** Unsuitable / No. **0** = Not applicable.

LOCKING WIRE

PROS

GOOD LOCKING ABILITY

CAN BE LUBRICATED



CONS

RELIES HEAVILY ON OPERATOR SKILL

CANNOT BE REUSED

NEED EXTRA EQUIPMENT DURING ASSEMBLY/DISASSEMBLY

Locking wire, also known as safety wire, is a mechanical locking method. This method works by threading a wire through a hole in a bolt head/nut, twisting it to lock that bolt in place and then replicating the process through one or more bolt heads/nuts – essentially locking all the bolted connections together. Any excess wire is removed once the process is complete. It is imperative that the wire is installed so that tension in the wire only allows the bolt head/nut to turn in the direction of tightening. The tension of each section of wire must also be locked in place so as not to be affected by the accidental loosening of another bolt head/nut in the series.

Although this method provides reasonable loosening resistance, it is time consuming to assemble and the bolt head/nut must be drilled to create the holes for the locking wire - increasing the cost again. The only way to remove the locking wire is to cut it away – meaning that it cannot be reused and a new piece must be installed every time the bolted joint is maintained.

EVALUATION LOCKING WIRE

- Functionality
- User safety
- Costs related to product & method
- Not applicable

Locking ability ●●●

Reusability ○

Worker safety ●●●

Initinal cost **High**

Total lifetime cost **Medium**

5 DOTS Suitable / Yes. **1 DOT** Unsuitable / No. **0** = Not applicable.

ADHESIVE

PROS

GOOD LOCKING ABILITY

NOT RESTRICTED BY FASTENER SIZE

CONS

LOCKING ABILITY VARIES

INVOLVES CHEMICALS

DEPENDENT ON OPERATOR

The adhesive is applied to the thread of the bolt and tightened immediately. Adhesives cannot be directly applied to the fastener as they require a clean surface to ensure optimum bonding, which increases installation time.

Adhesive also requires curing time before they can be safely used, which can take up to 24 hours. There are a lot of different adhesive with different properties. It is important to chose the right adhesive for your application, material and temperature, to get the optimal locking ability. Indeed, some adhesives can be removed through heating so cannot be used at high temperatures.

Adhesives cannot be reused and some require complex disassembly that may damage or even break the fastener. Although this method offers a higher than average locking ability, the number of variables make it unreliable.

EVALUATION ADHESIVE

- Functionality
- User safety
- Costs related to product & method
- Not applicable

5 DOTS Very good/ Yes. **1 DOT** Very bad / No. **0** = Not applicable.

WEDGE-LOCKING WASHER

(NORD-LOCK WASHERS)

PROS

VERY GOOD LOCKING ABILITY

HIGH-LEVEL OF SECURITY AGAINST BOLT LOOSENING

SECURE LOCKING AT HIGH AND LOW PRELOAD

CONS

HIGHER UPFRONT COST

The wedge-locking principle uses tension rather than friction to secure the bolted joint in place. It involves a pair of washers, which have cams with a rise greater than the thread pitch of the bolt. The washer pair is installed cam face to cam face, between the bolt head/nut and the joint is tightened in the same way as an unsecured bolt. When the bolt head/nut is tightened, teeth grip and lock the mating surfaces, allowing movement only across the cam faces. Any rotation of the bolt/nut is blocked by the wedge effect of the cams. Wedge-locking washers require a higher than average upfront cost than other fasteners, however, they are also the most suitable for critical bolted joints facing vibration and dynamic loads and can be reused – leading to lower long-term costs.

Applications with large/slotted holes or soft underlying surfaces can use washers with an enlarged outer diameter to spread the load over a greater contact area. Wedge-locking washers can also be used on coated/painted surfaces in their enlarged version.

Wedge-locking washers are not recommended for mating surfaces that are not locked in place or applications with extreme settlements.

EVALUATION WEDGE-LOCKING WASHERS

- Functionality
- User safety
- Costs related to product & method
- Not applicable

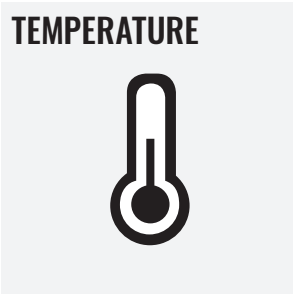
5 DOTS Suitable / Yes. **1 DOT** Unsuitable / No. **0** = Not applicable.

COMBATING CORROSION IN STEEL

Any metal product – especially those derived from iron or steel – will eventually rust and disintegrate over time when in contact with oxygen and water. Prevention is better than cure as corrosion can be delayed but never prevented. Choosing the right material and corrosion protection for fasteners is therefore crucial.

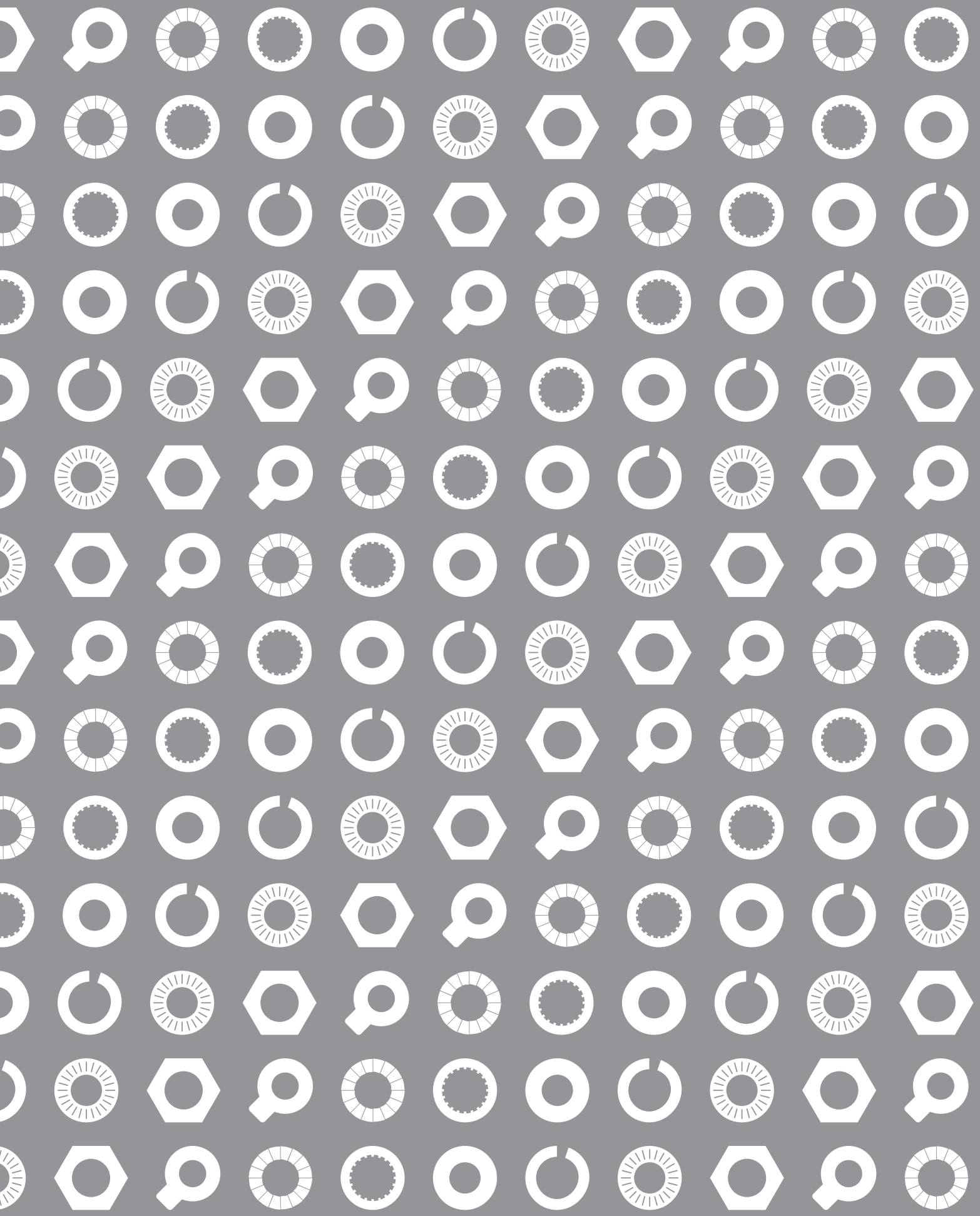
There are several common 'norms' to delay corrosion of fasteners: choose the most suitable materials for the environment and ensure they are of similar electrical potential to avoid Galvanic corrosion; use a special paint or coating to create a protective barrier; use sacrificial anodes to protect the product.

Zinc flake coatings are a very effective protection for steel bolts and washers. Such coatings are applied like a paint, then baked to create a sacrificial coating layer to protect the parts. A number of other options exist, including hot dip galvanizing.



HOW TO DESIGN AGAINST CORROSION

- Analyze the corrosive environment and requirements.
- Choose materials which have sufficient corrosion resistance (and similar galvanic potential).
- Choose a suitable corrosion protection method.
- Define requirements: For example, the ISO 9227 salt spray corrosion test, ASTM G48 electrochemical corrosion test for stainless steel, ISO 12944 corrosion classes for environments.



NORD-LOCK GROUP

WHY DO BOLTS LOOSEN is produced by the Nord-Lock Group.

The Nord-Lock Group believes that no one should have to question the integrity of the mechanical systems that play such a critical role in our way of life. We strengthen public and industrial infrastructures with high-quality, safe and innovative bolt securing solutions. Our mission is to safeguard human lives and customer investments and we hope this information will help you to choose the right bolt securing method for your application.

From a more advanced technical perspective there are other considerations to every unique bolted connection, ranging from lubrication, settlements, mating surface and operating conditions.

Would you like to discuss your bolting application with one of our engineers? bolting@nord-lock.com