INSTALLATION PROCEDURE FOR GREENKOTE AND WEATHERING STEEL TENSION CONTROL BOLTS AND STUDS

Contents

Introduction

This booklet is for steel erectors and inspectors and should be referred to as a guide when making structural bolted connections.

Tension Control Bolts (TCBs) are HRC (High Resistance Calibrated) high strength structural bolting assemblies for preloading and conform to BS EN 14399-1. TCBs provide an easily installed and inspected method of bolting.

The TCB concept is a simple and uncomplicated system that completely takes the responsibility away from the erector to attain the correct preload in bolting assemblies and eliminates the use of *k*-factors, torque values or DTIs. Electrically powered, non-impacting shear wrenches are virtually vibration-free, light in weight and quiet to use.

TCB bolting assemblies conform to BS EN 14399-1, are UKCA and CE marked, and applicable Declaration of Performances (DoPs) are available to download from our website.

Technical advice is always available and if required, on-site training can be provided. Installation videos are available on the TCB website, Media Centre.

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LRQA CERTIFIED ISO 9001 UKAS MANAGEMENT SYSTEMS 0001

UKCA CE

NHSS national highway sector schemes LRQ 4006595

RISQS Verified

Types of Preloaded Bolting Systems

There are two preloaded bolting systems specified within the BS EN 14399 series; system HR (that includes TCBs) and the system HV.

- System HV assemblies have a short bolt thread and use a thinner nut to obtain ductility by plastic deformation of the threads within the nut. This system is sensitive to over-tightening and presents little indication of failure during installation. HV bolting assemblies are not advocated within the UK.
- System HR (including TCB) assemblies have longer bolt threads, thicker nuts and achieve the necessary ductility primarily by plastic deformation of the bolt threads. This system of bolting is less susceptible to overtightening during preloading however if assemblies are subject to overtightening, the ductile failure mode is by bolt breakage and is therefore easily detectable.

Washer Rules and Regulations

BS EN 1090-2 cl 8.2.4

- *Unless the use of washers under both the bolt head and nut is specified, for class 10.9 bolts used with steel grades above S235, washers shall be used under the bolt head or nut, whichever is to be rotated.*
- *For 10.9 bolts used with steel grade S235, washers shall be used under both the bolt head and the nut.*
- *In addition to the minimum specified washer(s), up to two additional washers or one plate washer or one washer and one plate washer may be used to adjust the grip length for preloaded assemblies.*
- *The combined thickness of any additional washers shall not exceed 12mm.*
- *Plate washers shall be used for connections with slotted and oversized holes unless otherwise specified.*

BS EN 1090-2 cl 5.6.9.3

- *Plate washers shall be dimensioned with normal clearances and with dimensions that ensure that the washer overlaps the connected component by at least as much as a standard plain washer would when used with normal round holes.*

Quality Assurance

TCB preloaded bolting assemblies are manufactured and supplied in accordance with BS EN 14399-1 and UKCA/CE marked in accordance with the Construction Products Regulation (CPR). Bolts and HRD nuts are manufactured in accordance with BS EN 14399-10 with washers manufactured in accordance with BS EN 14399-6. Assemblies are typically supplied unassembled as extended bolting assembly lots however weathering grade assemblies are supplied assembled. Both bolts and nuts have an indented/embossed 3-digit heat code to facilitate traceability of manufacturing lots.

Inspection Certificates

TCB assemblies are tested in accordance with BS EN 14399-2, BS EN 14399-10, and certified in accordance with BS EN 14399-1. The relevant DoP can be downloaded via the QR code found on packaging labels or delivery documentation. Type 3.1 Material Test Certificates in accordance with BS EN 10204 are available upon request.

Storage

TCB bolting assemblies shall be stored in a clean and dry condition.

Shear Wrenches

Shear wrenches are non-impacting, lightweight, low noise tools available in various models all of which meet the appropriate regulations.

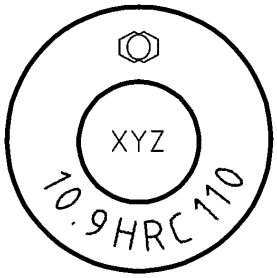
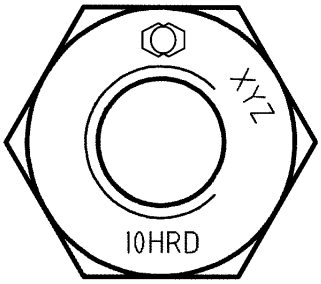
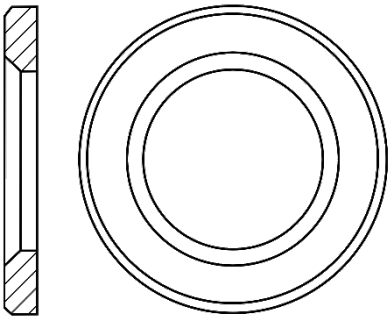
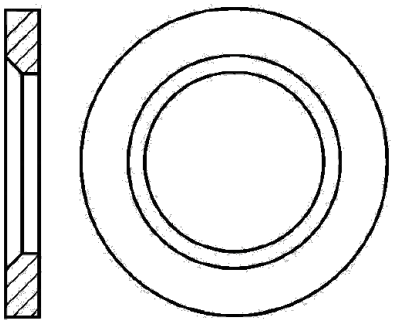
NOTE - SHEAR WRENCHES ARE 'DUMB' TOOLS AND REQUIRE NO CALIBRATION

Bolting Assembly Components

Greenkote bolting assemblies are typically supplied unassembled whereas Weathering Grade TCB assemblies are supplied assembled.

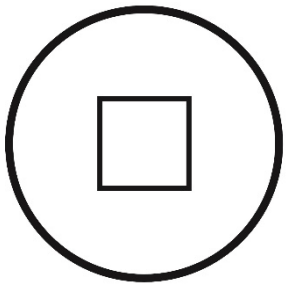
Both bolts and nuts have an indented or embossed 3-digit heat code added during production to identify manufacturing lot numbers plus bolts also have their nominal length embossed on the head.

Bolting assemblies comprise of one each bolt, nut, and washer. Should an extra washer be required under the bolt head, these are supplied as additional items.

	TC Bolt Head markings showing the manufacturers mark (conjoined hexagons), property class (10.9), bolt type (HRC), length (in this example) 110 and heat code mark (XYZ) Note: Weathering grade bolts are marked with 10.9W
	Nut markings showing the manufacturers mark (conjoined hexagons), property class (10), nut type (HRD), heat code mark (XYZ) Weathering grade nuts are marked with 10W
	Hardened washer showing inner and outer chamfer on one side. Manufacturers mark and product mark (H or HD) are indented on the non-chamfered side (not shown)
	Weathering grade washers showing inner chamfer on one side and product mark indented with W on the non-chamfered side (not shown)

Stud Assembly Components

	TCB Studs manufactured in large quantities have markings embossed into the threaded end showing the manufacturers mark (conjoined hexagons), property class (10.9), and heat code mark (XXX)

<table>
<tr><td>  </td><td rowspan="2">TCB Studs have a left-hand threaded nut that replaces the bolt head.

TCB Studs manufactured in small quantities from blanks have a square marking embossed into the threaded end as the alternative marking for property class 10.9, in accordance with ISO 898-1 table 21.

OR

TCB Studs manufactured in small quantities from blanks may have an arrow indicating LH thread and property class 10.9.</td></tr>
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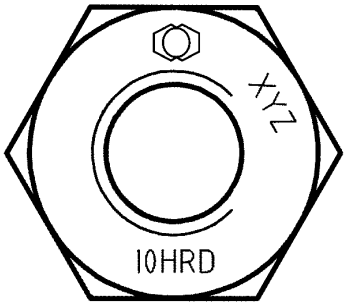
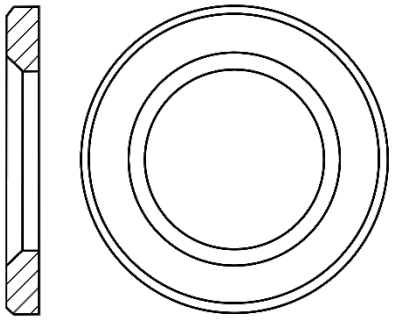
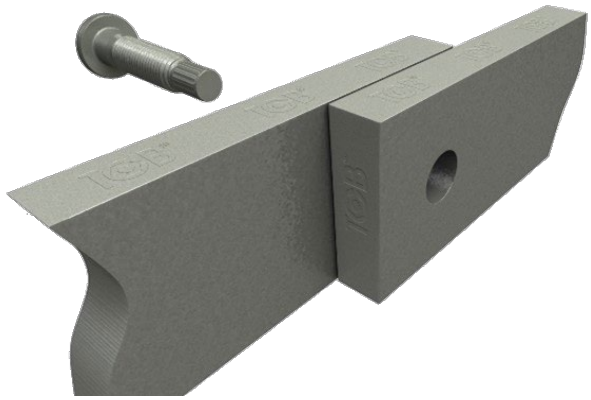
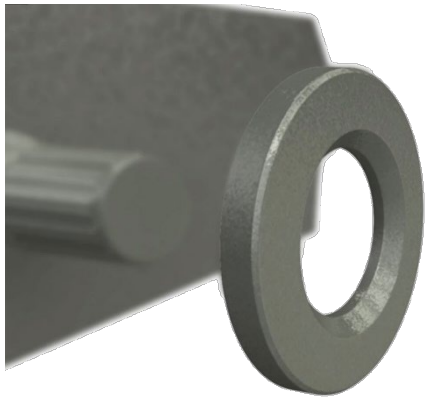
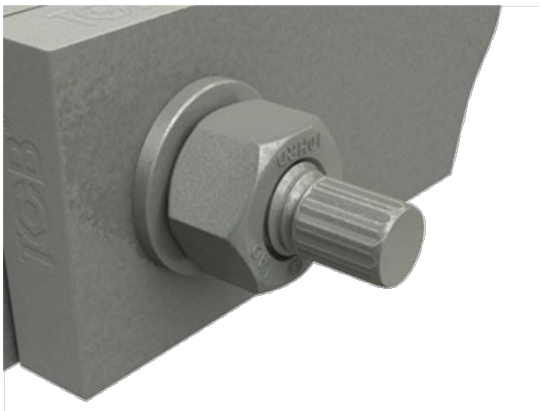
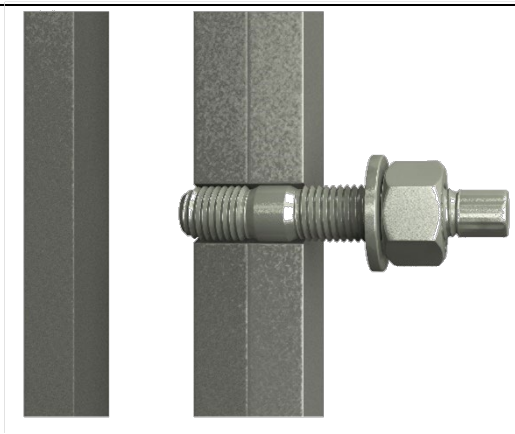
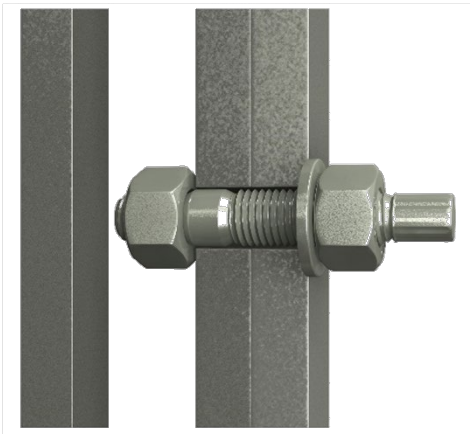
<tr><td> 
</td><td>Nut markings showing the manufacturers mark (conjoined hexagons), property class (10), nut type (HRD), heat code mark (XYZ)</td></tr>
<tr><td> 
</td><td>Nut markings showing the manufacturers mark (conjoined hexagons), property class (10), nut type (HRD), heat code mark (XXX) and an arrow indicating a left-hand thread.</td></tr>
<tr><td>  </td><td>Hardened washer showing inner and outer chamfer on one side. Manufacturers mark and product mark (H or HD) are indented on the non-chamfered side (not shown)</td></tr>
</table>

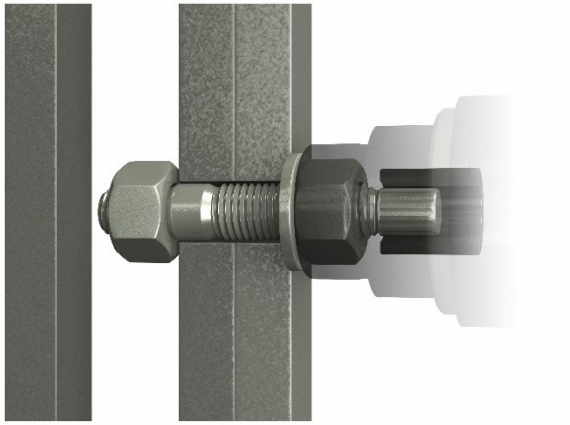
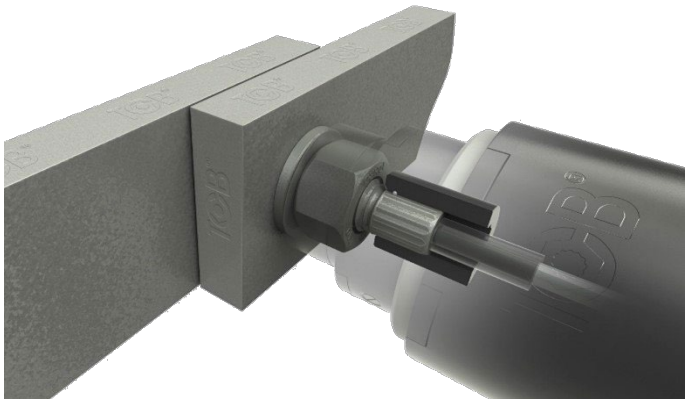
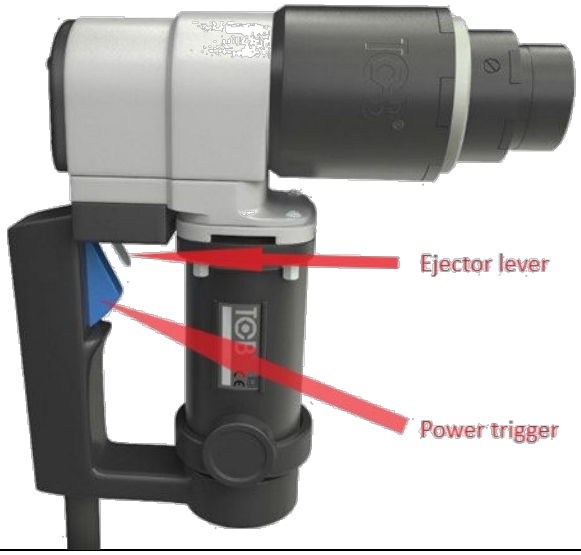
Installation Procedure - General

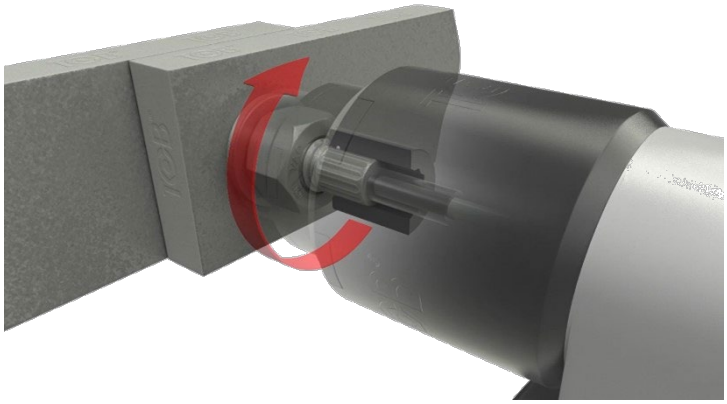
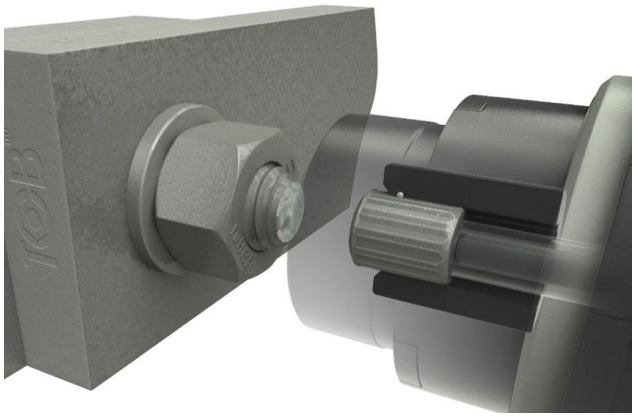
- Tightening of a connection needs the components to be brought into a snug tight condition before commencement of preloading. Both snug and full preload tightening shall be carried out from the most rigid part of the connection to the least rigid part.
- When a bolt group comprises more than four bolts, tightening should be from the centre of the joint outwards and ensuring all plies are properly pulled together in full contact.
- To achieve uniform preloading, more than one cycle of tightening may be necessary.

Installation Procedure – simple connections

1		Insert the bolt into the connection.
2		Place the washer, chamfered side outermost, onto the bolt followed by the nut.
3		Nut markings should be outermost to ensure Quality Assurance is visible.

4		Where a bolt cannot be fitted due to restricted access, a TCB Stud can be used instead.
5		TCB Studs have a left-hand (LH) threaded end nut that replaces the bolt head. This enables the stud (without the LH nut) to be inserted from the side that has access.
6		The LH nut is then wound onto the LH threaded stud until it is thread-bound.
7		LH threaded nuts are marked with an arrow in addition to the mandatory markings.

8		From this stage, the installation process is identical to standard TC bolts.
9		The non-impacting electric shear wrench has two sockets which operate in opposing directions. <u>Only one socket turns at any one time.</u>
10		Engage the inner socket over the bolt spline and the outer socket over the nut. Ensure that both inner and outer sockets are fully engaged before proceeding.
11		The wrench is activated by pressing the large power trigger situated on the handle. A second lever located just above the power trigger is the ejector lever; this is used at the end of the installation procedure to eject the spline.

12		Press the power trigger. The outer socket rotates clockwise and tightens the nut whilst the inner socket holds the bolt spline. When the correct preload is reached the outer socket stops rotating, the inner socket counter-rotates and shears the spline off.
13		Release the power trigger and pull the socket off the nut. The spline is retained within the inner socket.
14		Pull the ejector lever to eject the spline safely. Ensure that the wrench motor has come to a stop prior to engaging the next bolt.

Installation Procedure – multi-bolt, multi-ply connections

The connected components shall be fitted together (step 1 to 3). The bolting assemblies shall then be brought to a pre-tightening or snug tight condition. This tightening process shall be carried out from bolt to bolt of the group starting from the most rigid part of the connection and moving progressively towards the least rigid part (contact to non-contact surfaces). In order to ensure that the preload in fully installed bolting assemblies meets the specified minimum preload requirement, the installation process consists of at least two tightening stages. The first stage applies a 'partial' or 'bedding' torque to the bolts to ensure a firm contact between components. This pre-tightening (or snug tightening) can be accomplished by two methods.

1. Using the shear wrench but only part tightening assemblies and not shearing off the splines. When using this method, the operator will notice a distinct change in the

sound/tone of the wrench motor. This indicates that pre-tensioning has commenced as the bedding load is being applied. If pre-tensioning has occurred, then when the power trigger is disengaged and the motor stops, the wrench gearing will backtrack and reverse allowing the tool to be easily removed from that particular bolt. This whole process can also be 'felt' by the operator or:

2. Using a standard nut runner/impact wrench with a deep socket to pull all surfaces into contact without involving the bolt spline.

NOTE – If mating surfaces are significantly distorted or misaligned then 'slave' bolts should be used. TCBs can be used as slave bolts but they must be clearly marked and then replaced prior to final completion of the joint.

The second tightening stage can only be achieved using a shear wrench. When the spline end of the bolt shears off at the break neck, full preload has been induced.

If the bolting assembly cannot be installed using shear wrenches, tightening shall be carried out in a conventional manner by either:

1. Using the torque method with the aid of the *k*-class K2 information (torque values are provided upon request).
2. Using a direct tension indicator (DTI).

Greenkote® PM1/3K

Greenkote® is a metal surface treatment for the prevention of corrosion and the name simply relates to the process. Greenkote® PM1/3K is a Thermo-Chemical Surface Modification (TCSM) process which provides greater protection than electro-galvanizing and zinc flake coating and comparable protection to a thicker hot dip galvanised coating.

Weathering Grade Steel (WS) TCB Assemblies

Bolting assemblies are supplied with a light coating of rust preventative oil and are to be installed in the 'as delivered condition'.

Bolting Assemblies either coated with Greenkote® or of WS are ready for installation and no additional treatments are required.

T-Washing

Do not use T-wash or etching mordant on bolting assemblies prior to installation as this will invalidate the preload. Greenkote® provides an excellent surface for paint adhesion (sample paint pull-off tests available upon request) whilst WS assemblies weather naturally to provide protection.

Paint

Faying surfaces along with surfaces under the bolt head and washer should be masked off and left unpainted. If bolting assemblies are installed with paint under the bolt head and/or washer, loss of preload in the bolting assembly could occur over time; for further information please see SCI Advisory Desk note AD300.

When a connection has been fully assembled with the bolts correctly installed (splines sheared off), either a zinc rich primer can be applied to protect the exposed bolt end until the painting contractors have access to the joint or plastic caps can be fitted over the bolt threads (and/or nuts).

Testing, Certification, and Inspection

Five bolting assemblies per extended lot are systematically tested in accordance with European standards. Axial loads are recorded onto the Material Test Certificates (MTCs) for TCB assemblies being delivered to site / works.

- After the spline of the bolt has sheared, the assembly preload should be equal to or greater than those values as required by the specification (see table 1).
- Since the quality assurance and integrity of the bolted connection is determined by the bolting assembly itself, visual inspection of the bolt spline removal is sufficient.

BS EN 1090-2

8.5 Tightening of preloaded bolts
8.5.1 General

Unless otherwise specified, nominal minimal preloading force $F_{p,c}$ shall be taken as:

$F_{p,c} = 0.7\, f_{ub}\, A_s$ where f_{ub} is the ultimate strength of the bolt material and A_s is the stress area of the bolt as defined in EN1993-1-8 and specified in Table 1. This level of preload shall be used for all slip resistant preloaded connections and for all the other preloaded assemblies unless a lower level of preload is specified.

Table 1 – Values of $F_{p,c}$ in kN

	Bolt diameter							
	M12	**M16**	**M20**	**M22**	**M24**	**M27**	**M30**	**M36**
10.9 HRC	59	110	172	212	247	321	393	572

‘Fail 2 Safe’ Bolts

As with any threaded fastener assembly, occasional failures can occur and as explained above, the ductile failure mode of the TCB system is by bolt breakage. Failure during the installation procedure is a direct consequence traceable to specific actions/effects relating to the assembly process. Factors can involve but are not limited to:

- Excessive paint thickness
- Using a TCB as a slave bolt
- Misalignment of steel
- Foreign materials in the threads such as grit, mastic, oil etc
- High temperatures
- Excessive moisture

All of these issues result in a reduction of the co-efficient of friction (CoF) between the mating threads. This results in a higher preload force being attained for the same input torque force and as a shear wrench operates on the basis of ‘easiest line of resistance’ during the installation process, this can lead to the following sequence of events:

- In a situation where the CoF has been lowered, the ‘dumb’ shear wrench continues to rotate the outer socket instead of the inner socket counter-rotating and removing the spline at the intended preload.
- As the outer socket continues to rotate, the tensile load in the bolting assembly increases, additional thread friction increases the temperature which reduces the CoF even more. If the bolt passes its yield point, it starts to permanently deform in the threads. This is the recognized failure mode of the HR bolting system.
- The socket of the shear wrench is still turning the nut so when the nut threads meet the elongated bolt threads it can no longer rotate, resulting in the nut jamming and the bolt fracturing from the torsional force.
- This failure mode occurs in the vast majority of ‘overtightening’ cases however occasionally it has been reported that the bolt and nut threads strip and meld together. The result is that the nut continues to turn (which consequently becomes extremely hot) and the spline remains intact.

In either case the operator will be aware that the assembly has either fractured and/or retained its spline and has therefore ‘failed-to-safe’ (F2S)

These assemblies must be removed and replaced with new.

Example of torsional fracture

Example of thread stripping

On inspection, if the spline has been sheared off a bolt/stud by a shear wrench, then the bolting assembly is installed correctly thus reinforcing the 'fail-to-safe' properties of this type of bolting system.

In addition, it is not possible to correctly remove a spline during the installation process and a bolt fail at a later date. If a bolt fails after a correct installation procedure, either additional forces have been applied or the fasteners mechanical properties are inadequate.

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