Bolting of High Pressure Urea Equipment

Part 1-4

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Introduction

When we in 1986 started with the manufacturing of High Pressure (HP) Urea equipment we had to build the equipment in accordance with the Licensor's or enduser's specifications. One of the items that were strictly specified was the design of the man way covers.
Over the years we gained not only a lot of experience with the gaskets for man way covers but also with bolting down these gaskets. In these technical papers we share our experience of some forty years with you.

The most common used gasket design in HP Urea Equipment is the flat type gaskets.
For a long and reliable service of these gaskets, it is essential that not only the gasket and bolting are engineered correctly but also that the maintenance of this bolting is performed correctly. Throughout the years problems with this bolting is reported, leading to a delay in start up and consequential to that, loss of production. From the number of failures reported one can conclude that bolting is a critical issue.

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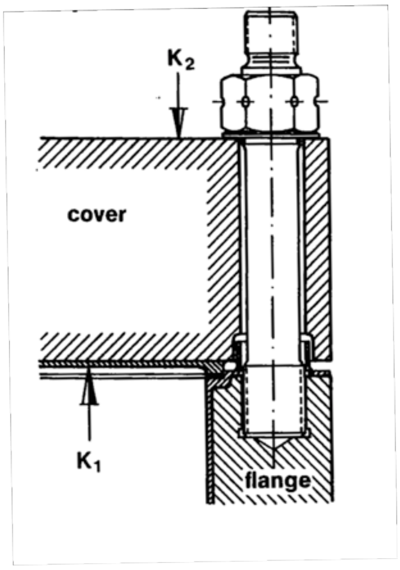
Common causes of gasket failures are:

- ✓ Excessive tolerances of the flanges
- ✓ Damage of the gasket chambers
- ✓ Inadequate storage of the bolts and nuts during a turnaround
- ✓ Inadequate care in storing and handling the gaskets
- ✓ Inadequate care during assembly
- ✓ Wrongly applied bolt load
- ✓ Inadequate boxing up, insulation

One should take in mind that a gasket failure will lead to quite some downtime and also one cannot exclude damage in the form of corrosion to the flange faces and gasket; loss in production is a consequence.



Flat type gaskets provide a passive seal that means the gasket pressure decreases as the process pressure (k1) increases. That implies that the bolt load (k2) and the process pressure (k1) determine the ultimate gasket pressure and that in turn, means that the elongation of the bolts and the compression of the cover is not a static situation but is a dynamic (elastic) process.

Bolt Tightening

In fact the bolting is designed so that elongation of the bolts and the compression of the cover are elastic. This means that one can compare the cover and the bolts with a spring.
This situation may be illustrated by the load/compression curve of the cover and the load/elongation curve of the bolts.

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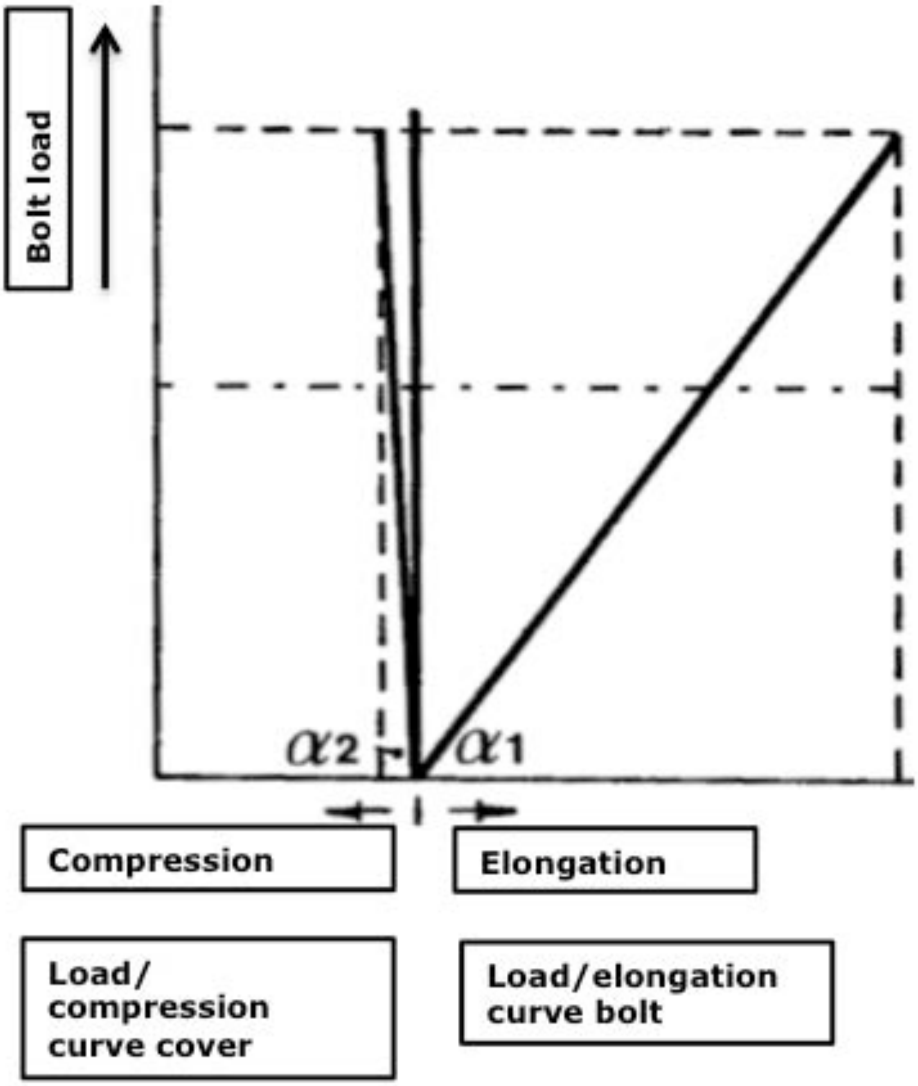

By moving the load/compression curve of the cover to the right hand side of the load/elongation curve of the bolts, a triangular load diagram is formed that shows the eventual elongation of the bolts.

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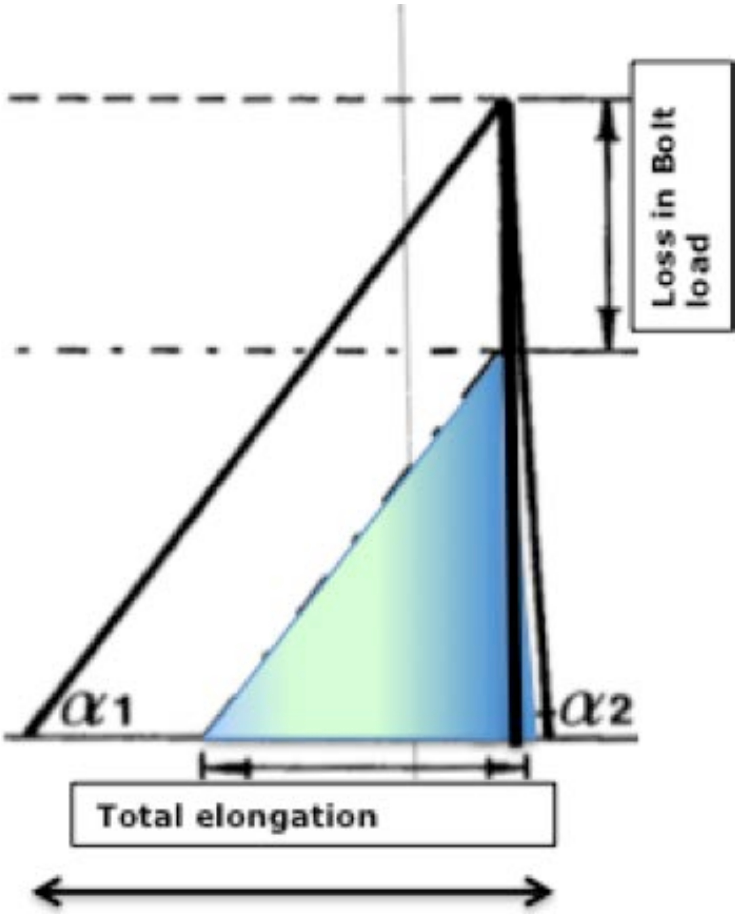

This triangular load diagram also helps to visualize the effect of relaxation, which results in loss of bolt load. The left part of the diagram relates to the elastic energy stored in the bolt while the right part relates to the cover.

Basically, it is important to apply a specified preload and to ensure that that this load will be retained in order to maintain the spring effect.
Obviously, any loss of bolt load will result in a reduction of bolt elongation. This is also illustrated in the triangular load diagram.

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Load losses may be due to:

- ✓ Relaxation
- ✓ Faulty bolt tightening
- ✓ Extraneous forces

These causes will individually contribute to a loss of bolt load. But of course when several of these factors occur together, the consequences will become even worse. This will be detailed out in our next technical papers.

Relaxation

The preload set up during assembly causes a minor deformation of the mating faces of the bolts and nuts and of the nuts and cover.

The amount of deformation depends on the surface roughness of the thread and of the contact faces between the nuts and the cover.
Mating faces with a high surface roughness will result in more relaxation than mating faces with less surface roughness.
This relaxation process takes place due to local plastic deformation as a result of local high stresses.

High relaxation may also result from dirt and from corrosion of the bolts, nuts and/or the contact faces of the cover.

Thread lubricants provide only little help here.
It is also good to know that this relaxation process will typically be completed within eight hours after tensioning.

The use of bolts with a reduced shank is helpful to a certain extent. The bolt has the smallest diameter at the location of the reduction and that means that the elongation in the bolt takes place between that nut and the channel flange.

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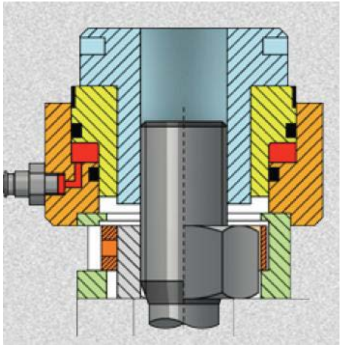
Faulty Bolt Tightening

It is common practice to preload the bolts with a hydraulic bolt tensioning device.



With this method, an axial tensile force is transmitted to the bolts with help of a hydraulic jack, which rest on the cover and is transferred to the bolt.
Subsequently the nuts are tightened until they abut against the cover surface and will then take over the load from the hydraulic jack.
Then the temporarily axial force is removed and the jack dismantled.

If well performed, this method is more accurate than all other methods for the following reasons:

- ✓ It involves less risk of variations of the preload in the bolts.
- ✓ The preload is distributed more even because more bolts can be tightened simultaneously and with equal force.
- ✓ The bolts are not subjected to torque loads so that the friction between the threads does not have an effect.
- ✓ Bolting does not depend on the physical condition of the technician.

However with this method, losses of bolt load will mainly occur when the nut is screwed down and takes over the load from the hydraulic jack.
Potential causes here are relaxation and unevenly loaded nuts because of an oblique position of their contact faces.

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A more practical cause is the failure to tighten the nuts adequately. This may be due to:

- Insufficient clearance of the thread flanks between bolt and nut
- The way in which the nut is tightened
- Transmission losses

Insufficient clearance of the thread flanks between bolt and nut

If there is insufficient clearance between the threads of the bolts and nuts, in other words if we have a close running fit, it may be difficult if not impossible to rotate the nuts after the bolts are preloaded (stretched).
Realize that the pitch of the bolt thread increases as the bolt is stretched; the pitch of the nut thread in contrast does not increase until subjected to any preload.
Consequently the technician is fooled to believe that he has tightened the nuts sufficiently and goes on with the job, while in effect the nuts are not nearly tight enough.
Corrosion of the thread flanks and excessive lubrication may have similar consequences.

The way in which the nut is tightened

The pre-load can be transmitted from the jack to the nut more effectively by tightening the nut as firmly as possible after the jack is hydraulically pressurized.
This is usually done by hitting a pin, which is put into one of the blind holes in the nut. If this is repeated several times the pin might bend and the hole in the nut worn out.

Transmission losses

This diagram shows the transmission losses versus bolt diameter.

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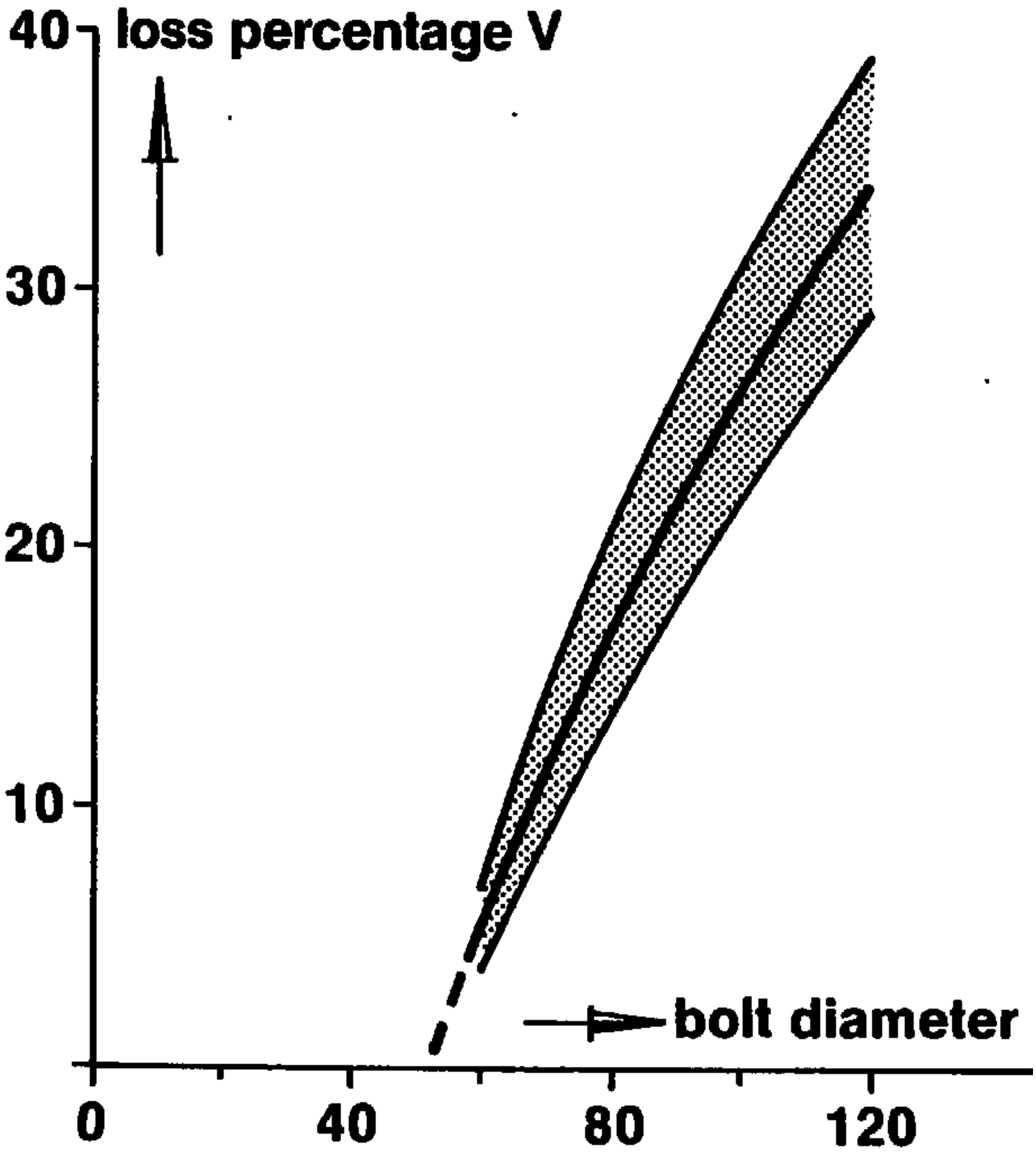

It indicates that the theoretically oil pressure of the hydraulic jack should be multiplied by a correction factor:

100/100-V,

where V is the loss percentage.

Transmission losses occur due to deformation of components at the flanges.

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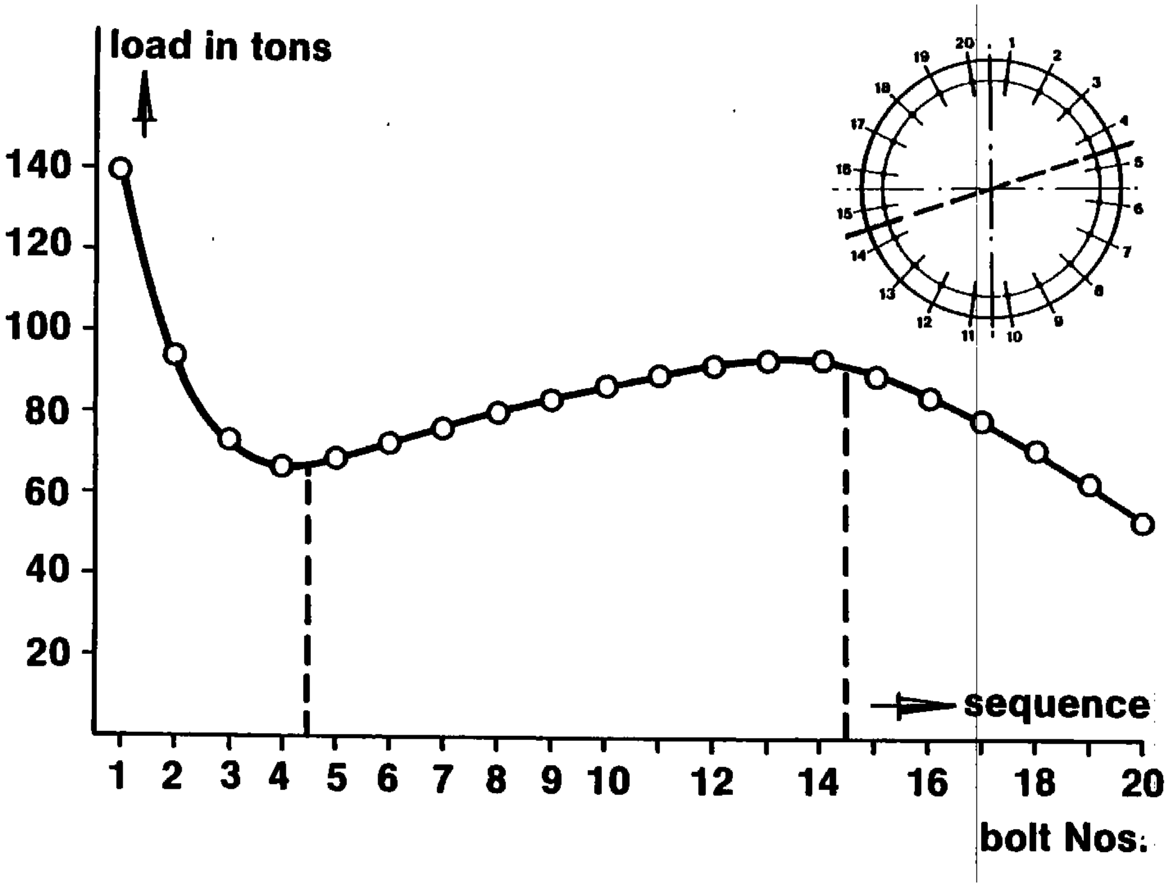
The load, which remains decreases even more when the adjacent bolts are tightened.

The next figure shows the loss of bolt preload in any one bolt as the other bolts are tensioned one after each other, following in order of bolt numbering.



These transmission losses can be as high as some 40%.
Often these transmission losses are taken into account by the designer. It is strongly advised to inquire if this has been taken into account.

Extraneous Forces

Before the equipment is heated up and the plant is started up, it is very important to provide adequate insulation for the cover but also the bolts should be insulated to avoid large temperature difference between the bolts and the cover.
Large temperature differences here will have an impact on the thermal expansion of the materials and thus the preload.

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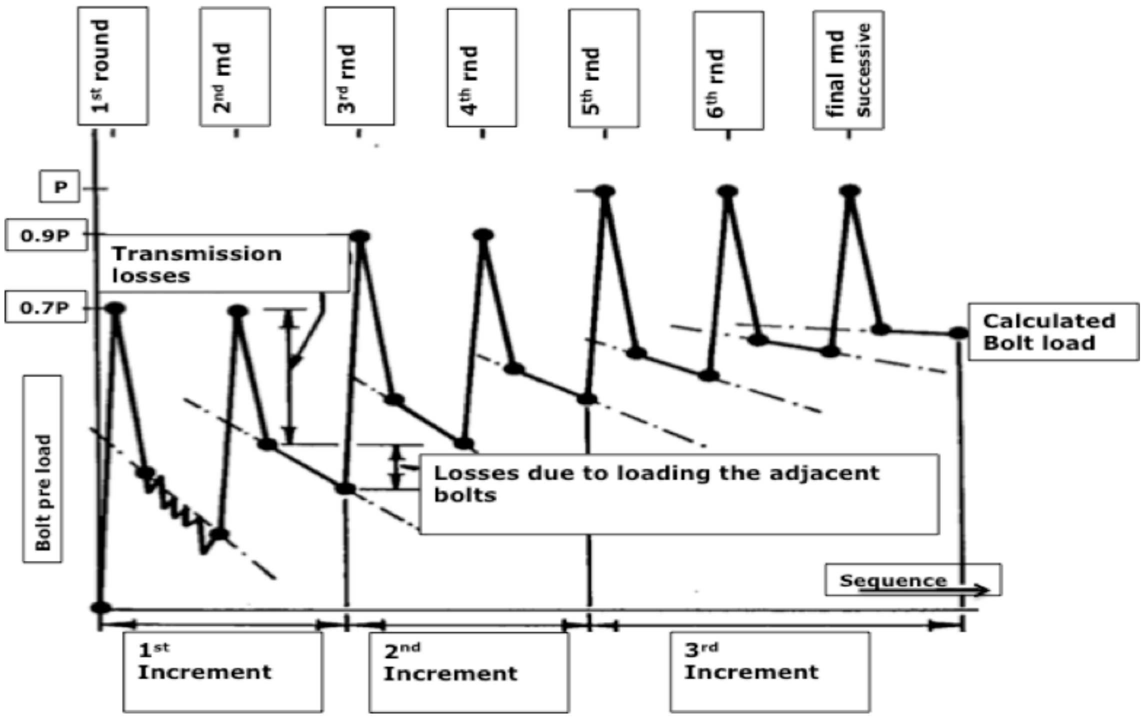
Tensioning Sequence

When one uses hydraulic bolt tensioning devices, the ideal situation with regard to the uniformity and amount of preload can be achieved if the number of jacks used is at least half the number of bolts present.

If fewer jacks are available and that is normally the case (it is normal to have two or four jacks available), than the bolts should be tightened cross wise. It is also important to tighten the bolts in steps and to optimize the tightening, one should repeat each step at least once.

It is advisable to repeat the final step twice and in the final round tighten successively instead of cross wise. Repetition is very important as one can learn from the figure below.
Do not forget that one should also loose the nuts in increments for similar reasons. It is advisable to loosen in two steps, half the load and then loosen them.



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Superbolts

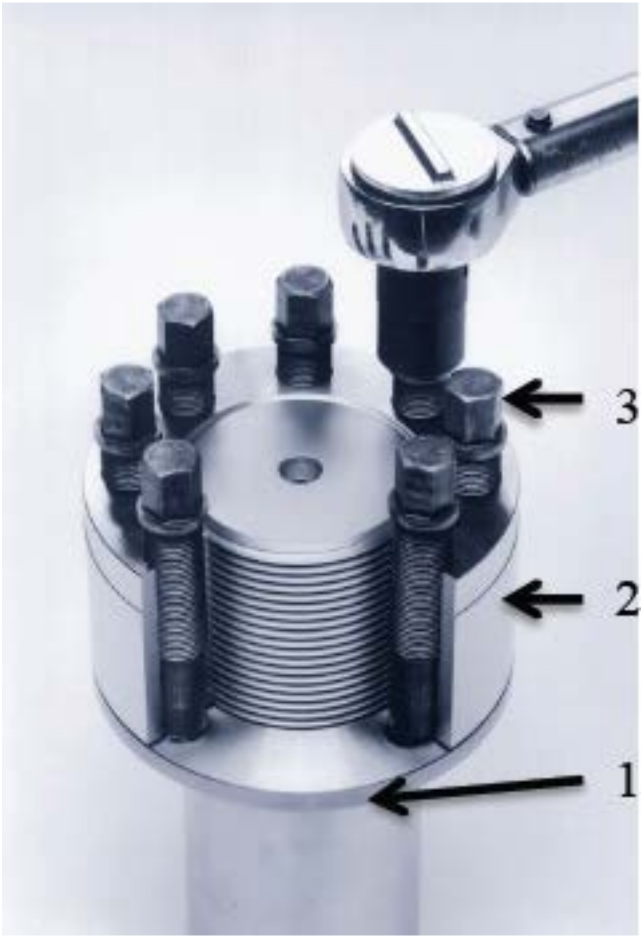
A for the urea industry relative new method for bolting is the use of superbolts.
A user requested to use superbolts for bolting the cover of a new manufactured urea reactor for one of their urea facilities in the US.
We investigated this technique and decided to use superbolts for this reactor.

A superbolt is a special type of mechanical fastener that is used to replace hex nuts and bolts. This type of bolt is normally used with larger nuts and bolts, which require a high amount of force to properly tighten.

By using a superbolt, the force required to tighten is spread over several smaller bolts, so that simple hand tools, wrenches, may be used. This method is an alternative for using hydraulic jacks, who are sometimes difficult to handle especially for bottom covers (down hand position) and heavy parts.

A superbolt consists out of three components:

- The first [1] is a hardened washer that provides a precision flat surface for smaller bolts to push against.
- The second [2] is the round-nut that is threaded onto the bolt and sits against the before mentioned washer.
- The third [3] is a series of smaller bolts, which are threaded through the nut body and are tightened.



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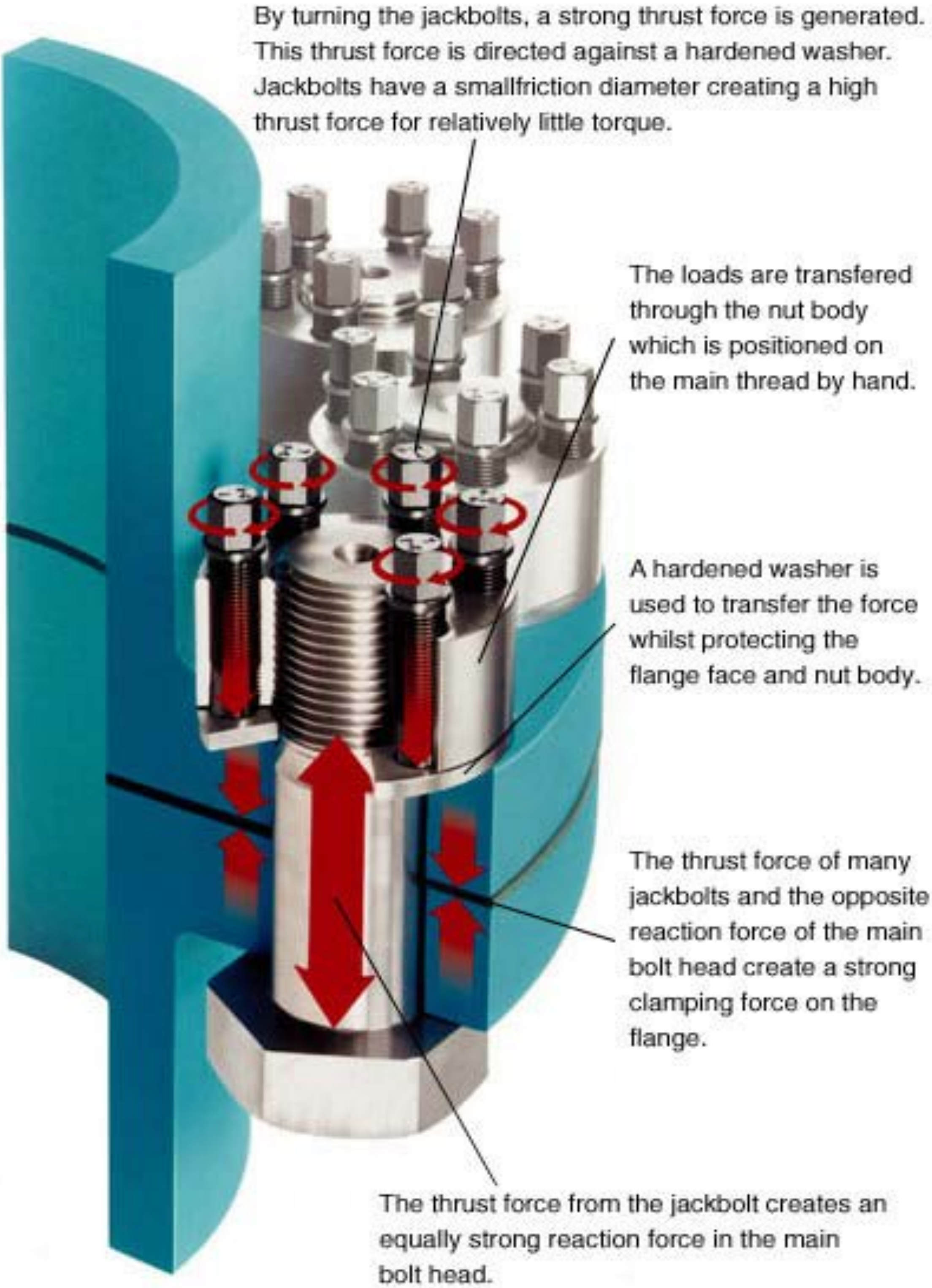

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The procedure to follow is that at first the washer will be positioned and the round nut will screwed hand tight onto the stud bolt.
When the jackbolts are tightened, they push against the hardened washer surface and secure the mechanical joint by placing the existing nut or bolt in pure tension.

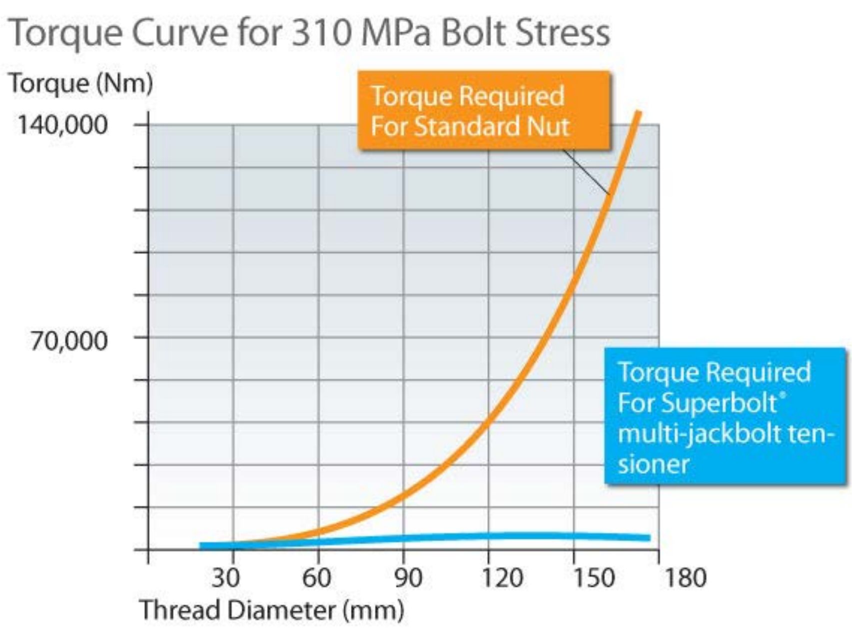
Tightening has to be done in increments. In step one the jackbolts are tensioned with help of a small wrench in order to centre the thread of the main nut and to eliminate backlash.
In the following steps the bolts are tightened crosswise with 50%, step 2 and 100% step 3; final step 3 should be repeated but then circular.

One of the advantages using the superbolt system is a significant timesaving when compared to other fastening methods because only hand tools are used and worker safety is improved.

Since a superbolt generates pure tension force when tightened, it also eliminates problems with seizing and thread galling that can occur with conventional fasteners.

Also the fact that the superbolt prevents loss of preload is certainly a major advantage. However, it stems from superbolt's ability to attain the proper preload in the first place. This is because, for a properly designed bolted joint, achieving the proper preload (clamping load) over the working load (separating force) is what keeps fasteners tight, the spring effect prescribed in the first part of this paper.
However, achieving proper preload is extremely difficult, especially when tightening large conventional nuts.
This is because as the bolt diameter increases, the torque required to reach a certain bolt stress increases, see part of this paper under the chapter "transmission losses".

On the other hand, the torque required to tighten superbolts, are low since the large preload is spread over many smaller bolts known as jackbolts, which need only to be torqued with simple hand tools as is shown in this graph.



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Also, with controlled lubrication and minimal frictional losses, superbolt reaches high preloads with superb accuracy and repeatability.

Integral to the design, superbolt adds desirable elasticity to the bolted joint, which helps maintain preload, especially in thermal or dynamic applications. Testing shows that superbolt tensioners maintain the preload even when subjected to a million cycles of high dynamic load at a level of 98% of the applied preload. Many other tests, including fatigue and vibration tests, have been successfully performed.

Technical data Reactor:
Overall length reactor 27.000 mm
Outer diameter 1.650 mm
Manhole diameter 800 mm
Design pressure 306 Barg
Design temperature 205 ^{0}C.
Bolt tightening loads: 20 bolts 4 ¼"- 8UN
Load per bolt: 1.295 kN
Load per jackbolt 108 kN (moment per jackbolt 396Nm)

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Reviewing the difference between conventional bolts and superbolts, we conclude that there is a significant gain in time to bolt up using superbolts in comparison to the hydraulic tightening with conventional bolts: Less than 50% of the time was only needed.

Another significant advantage is that one does not need to handle the heavy jacks and that of course counts even more when one has to tighten in the overhead position as is the case with bottom covers.

The overall conclusion is that we would prefer the use of superbolts over the hydraulic tensioning.

The picture shows the urea reactor with the superbolt design before shipment.

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Conclusions

This paper shows clearly that the bolting of HP urea Equipment is an important job and following points should be addressed:

- ✓ Tighten and loosen nuts in increments
- ✓ The flange faces should be protected carefully when the gasket has been removed
- ✓ Restoring of damaged flange faces should be done with care
- ✓ Gasket and flange faces should be clean
- ✓ Assemble nuts always on the same bolts (friction)
- ✓ Threads should not be damaged and well cleaned, lubricate only slightly
- ✓ Do not lubricate excessively (relaxation)
- ✓ Be sure that the cover fits properly and the flange faces are parallel, measure the distance
- ✓ Preload the bolts correct do it in steps and cross wise and finally circular
- ✓ The use of superbolts should be considered and are preferred over the hydraulic tensioning of a main bolt
- ✓ Insulate the cover inclusive the bolts before heating up starts

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Schoeller-Bleckmann Nitec (SBN) has been active in the fabrication of critical process equipment for ammonia and urea plants for now more than 40 years. In this period, SBN has not only acquired an unmatched level of expertise, but has also been instrumental in the development of materials and fabrication techniques for the various types of equipment geared to support the nitrogen fertilizer industry in its desire for larger capacity and higher efficiency plants coupled with longer plant life time. This has been achieved by closely co-operating with process licensors, engineering contractors, material suppliers and regulatory bodies for the design of pressure vessels and other non-pressure bearing critical components. In addition SBN has developed and implemented new improved fabrication and welding techniques vital for optimum fulfilment of customers' requirements, while focusing on highest possible quality and on-time delivery.

Comprehensive product range

To provide the best possible service to customers, SBN has streamlined its operations and focused on the fabrication of critical equipment for ammonia and urea plants including reactors, heat exchangers etc. designed for high pressures, high temperatures, corrosive process conditions, or a combination of these parameters.

Core competencies

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- Installation of equipment and in-situ repairs
- International certificates
- Organization of transports for extra heavy and large equipment