KiK|MPi
Kennis- en innovatiecentrum Maintenance Procesindustrie

BEMAS

Interreg
EUROPESE UNIE
Vlaanderen-Nederland
Europees Fonds voor Regionale Ontwikkeling

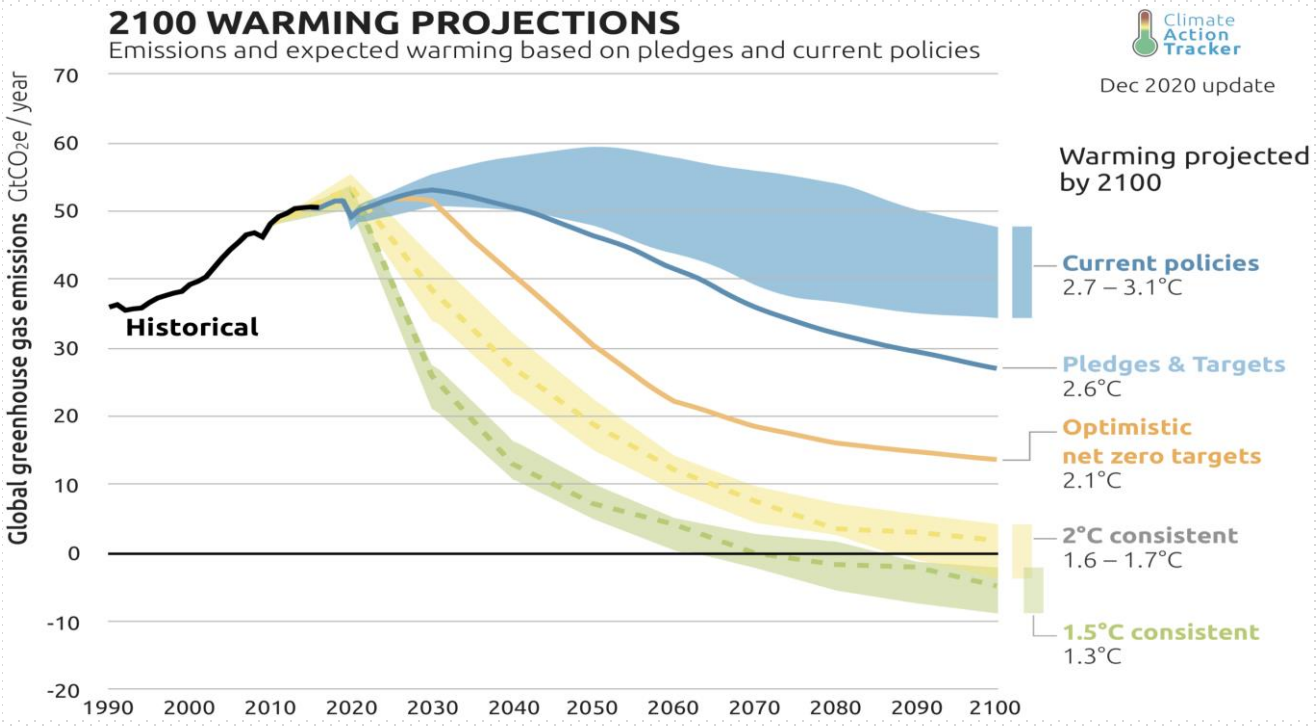
# De nauwkeurigheid van diverse flens aanhaal-methoden berekend op basis van de gemeten boutkrachten

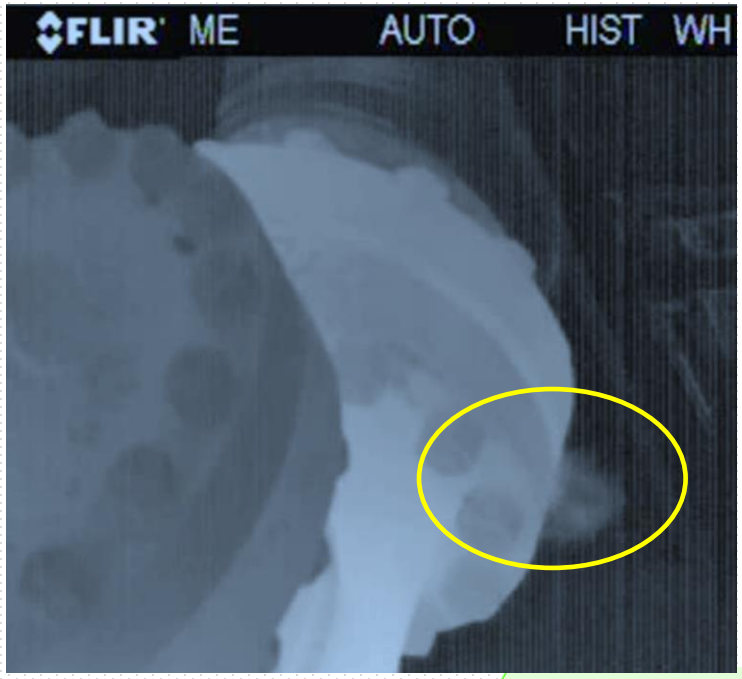
Slotevent
Circulair Onderhoud
15 november 2022

Presentatie: Peter Dijkgraaf

# BEPERKING LEKVERLIEZEN FLENSVERBINDINGEN

## Reductie 'green house gasses'




<u>Elke flens lekt!!</u>

- Een flens is technisch dicht als de diffusie voldoet aan de vereiste lekkage klasse.

<u>Diffuse emissie te meten met bijv. gas detectie camera</u>

- Via 'witte rookpluimen' wordt de diffuse emissie zichtbaar gemaakt.

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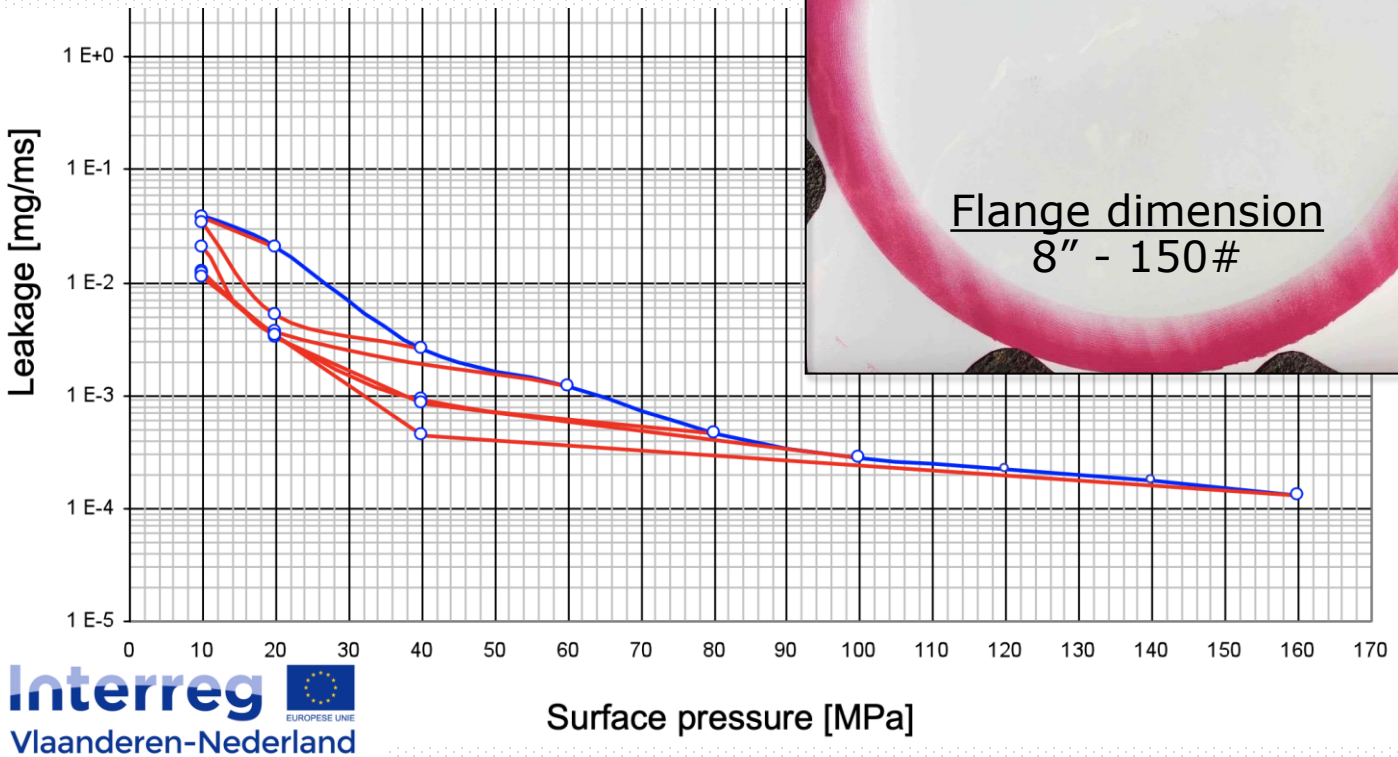
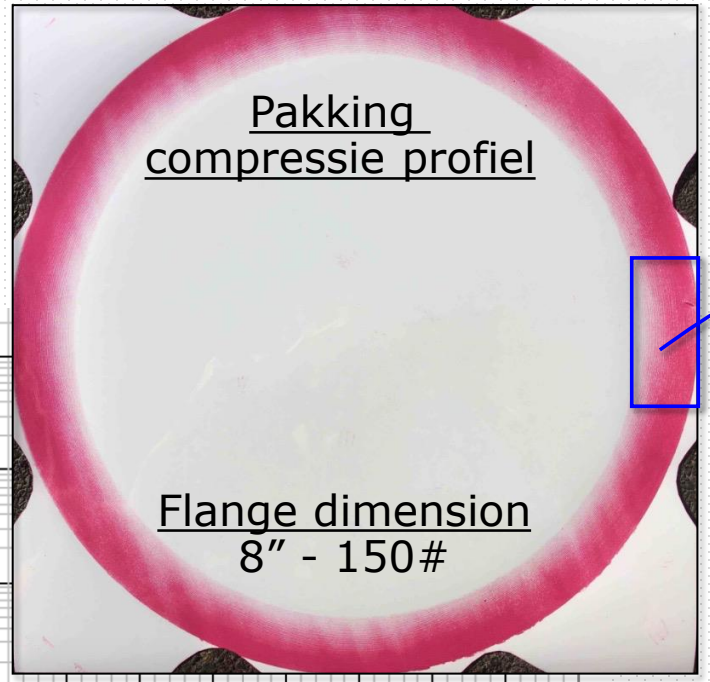
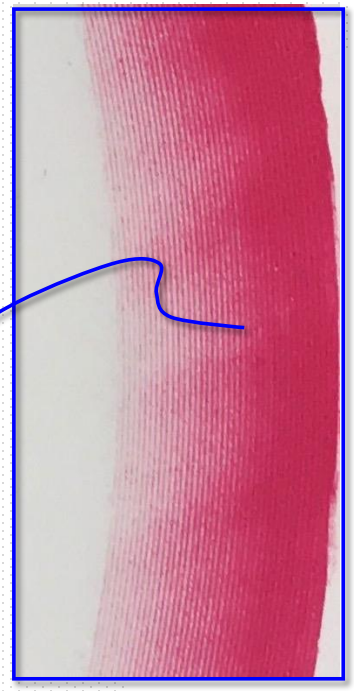
## BEPERKING LEKVERLIEZEN FLENSVERBINDINGEN

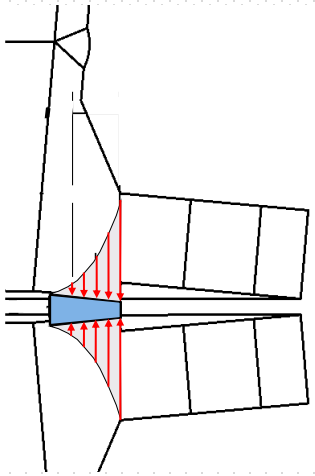
### Vereiste voor 'low emission' flensverbinding

Lekkage curve SWG (graphite filler)





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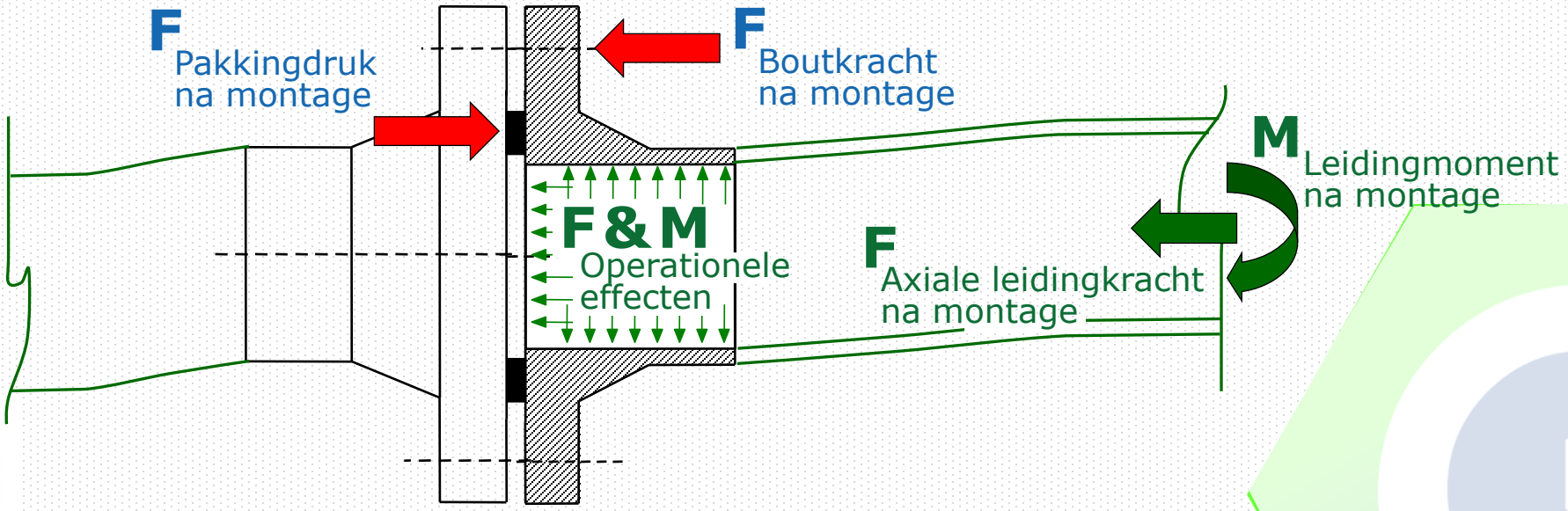
# BEPERKING LEKVERLIEZEN FLENSVERBINDINGEN

## Veelheid van invloedsfactoren m.b.t. (diffuse) lekverliezen flensverbindingen

| Flange/Piping Design | Material Qualities | Flange Procedure | Tightening Method | QA/QC Process | Execution Quality | Operational Conditions |
|---|---|---|---|---|---|---|

## Boutkracht is eveneens bepaald door veelheid van invloedsfactoren

- Boutkracht na montage ≠ pakkingdruk na montage
- Boutkracht na montage ≠ boutkracht tijdens bedrijf

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**Test: flens aanhaalmethoden / gereedschappen**

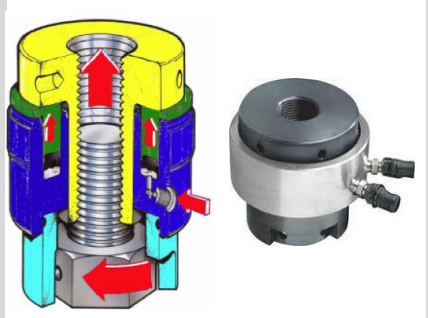
Interreg testen beperkt zich tot het bepalen van de nauwkeurigheid van de volgende gereedschappen

Hand torquing (single)

Electric torquing (single)

Hydraulic Torquing (single)

Hydraulic Tensioning



Electric torquing (Multi)

Hydraulic Torquing (multi)

(50% - 50%)

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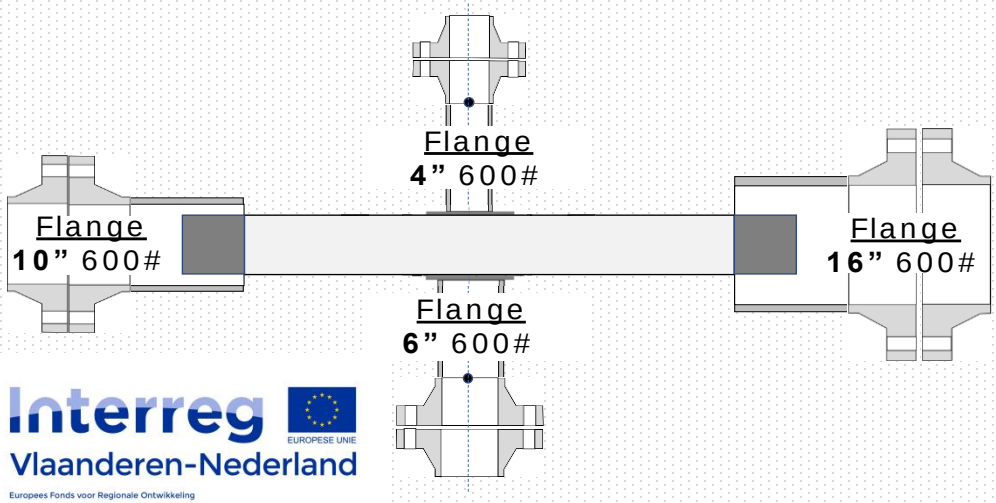
## BEPERKING LEKVERLIEZEN FLENSVERBINDINGEN

### Test skid: type flenzen & aanhaalmomenten

| Viertal flenzen | Test aanhaalmoment | Boutkracht: μ(t) = 0,12 & μ(n) = 0,14 |
|---|---|---|
| 4" 600# (studbolts 8 x 7/8") | M(torque)= 400. [Nm] | F(bolt) = 102,13 [kN] |
| 6" 600# (studbolts 12 x 1" ) | M(torque)= 600. [Nm] | F(bolt) = 134,70 [kN] |
| 10" 600# (studbolts 16 x 1.1/4") | M(torque)= 1200. [Nm] | F(bolt) = 220,20 [kN] |
| 16" 600# (studbolts 20 x 1.1/2") | M(torque)= 2200. [Nm] | F(bolt) = 341,35 [kN] |

Gemiddelde range M(torque) in industrie

4" 600# M(torque)= 330. - 460. [Nm]
6" 600# M(torque)= 530. - 690. [Nm]
10" 600# M(torque)= 1100. - 1420. [Nm]
16" 600# M(torque)= 2000. - 2320. [Nm]



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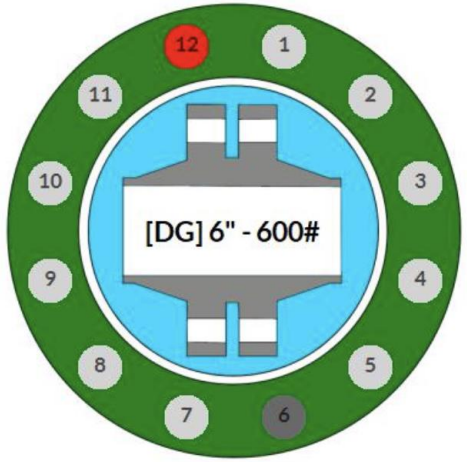
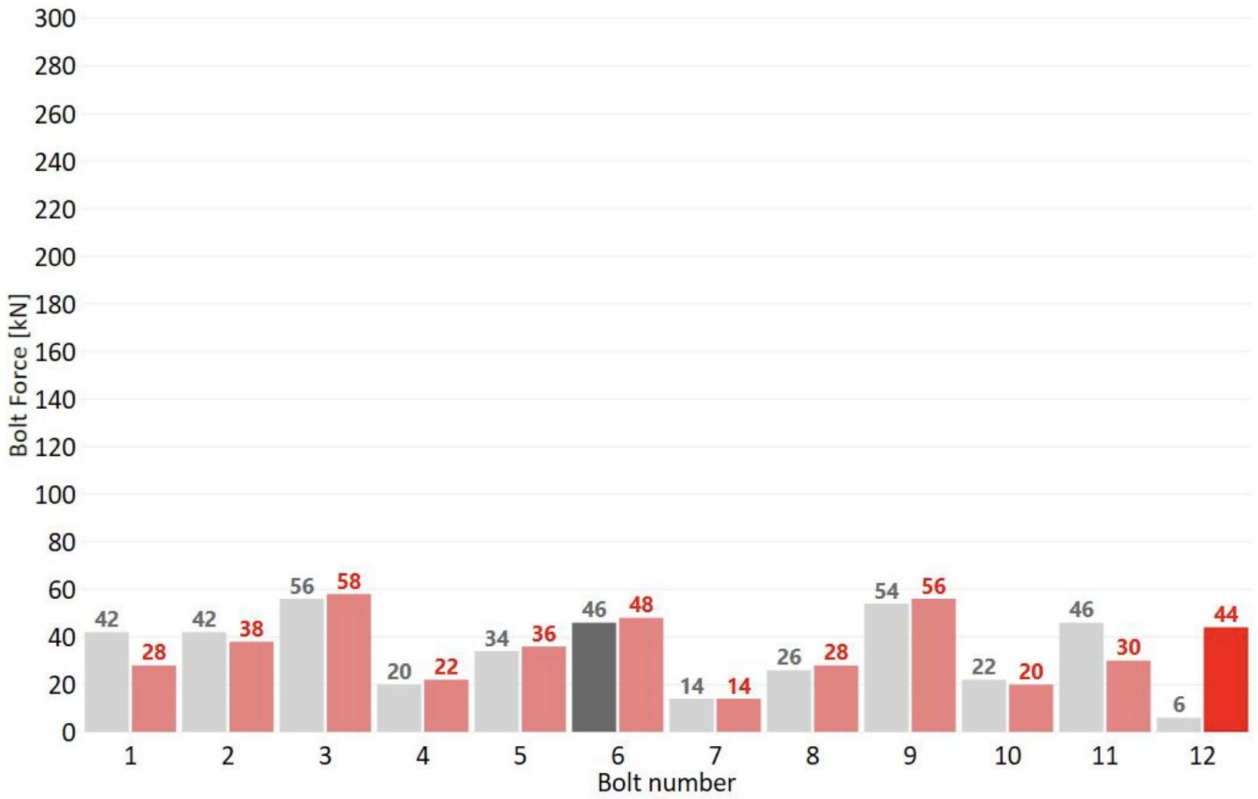
## Screenshots test 6" flange – Gasket SPW – Greased P37

Bolt loads after 30% final torque cross-wise (step 12)




| Test id | F6-HY-T39 |
|---|---|
| Torqueing / Tensioning | Torqueing |
| Tool(s) | 1 |
| Equip. manufacturer | Hytorc |
| Equip. technology | Hydraulic |
| Equip. type | st2 slw41 |
| Final torque | 600 [Nm] |
| Current torque | 30% = 180 [Nm] |
| Total steps | 96 |
| Current step | 12 |
| Current bolt(s) | 12 |
| Gasket type | SPW/Graphite |
| Bolt diamter | 1 |
| Bolt condition | New |
| Lubricant | P37 |

| Boltforce [kN] | |
|---|---|
| 1 | 28 |
| 2 | 38 |
| 3 | 58 |
| 4 | 22 |
| 5 | 36 |
| 6 | 48 |
| 7 | 14 |
| 8 | 28 |
| 9 | 56 |
| 10 | 20 |
| 11 | 30 |
| 12 | 44 |
| **Average [kN]** | |
| 35 | |
| **Scatter [kN]** | |
| 44 | |





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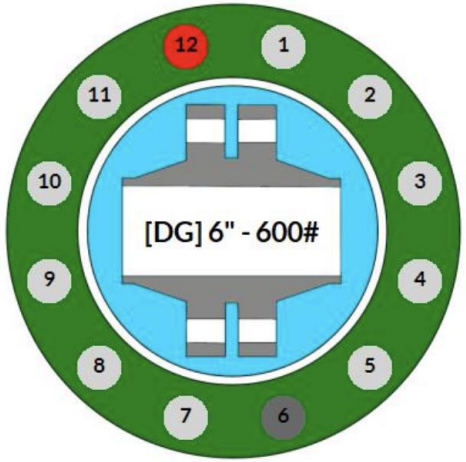
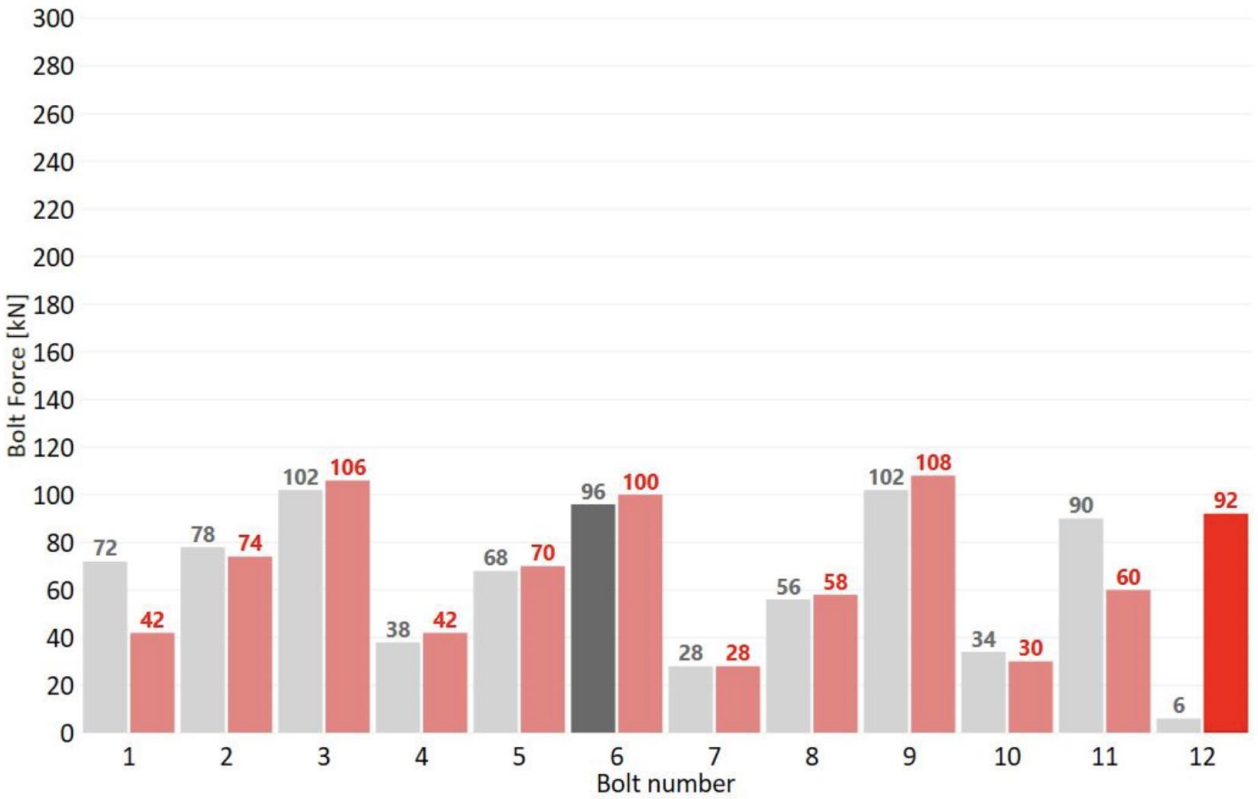
## Screenshots test 6" flange – Gasket SPW – Greased P37

Bolt loads after 60% final torque cross-wise (step 24)




| Test id | F6-HY-T39 |
|---|---|
| Torqueing / Tensioning | Torqueing |
| Tool(s) | 1 |
| Equip. manufacturer | Hytorc |
| Equip. technology | Hydraulic |
| Equip. type | st2 slw41 |
| Final torque | 600 [Nm] |
| Current torque | 60% = 360 [Nm] |
| Total steps | 96 |
| Current step | 24 |
| Current bolt(s) | 12 |
| Gasket type | SPW/Graphite |
| Bolt diamter | 1 |
| Bolt condition | New |
| Lubricant | P37 |

| Boltforce [kN] | |
|---|---|
| 1 | 42 |
| 2 | 74 |
| 3 | 106 |
| 4 | 42 |
| 5 | 70 |
| 6 | 100 |
| 7 | 28 |
| 8 | 58 |
| 9 | 108 |
| 10 | 30 |
| 11 | 60 |
| 12 | 92 |
| **Average [kN]** | |
| 68 | |
| **Scatter [kN]** | |
| 80 | |





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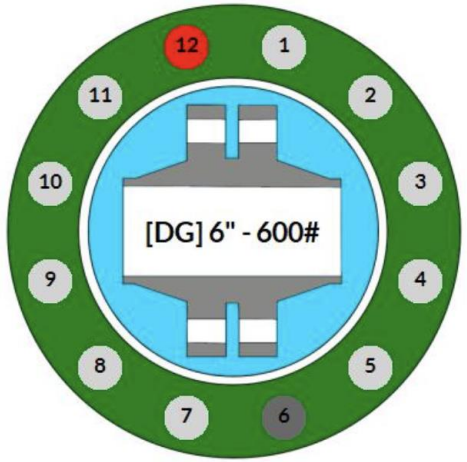
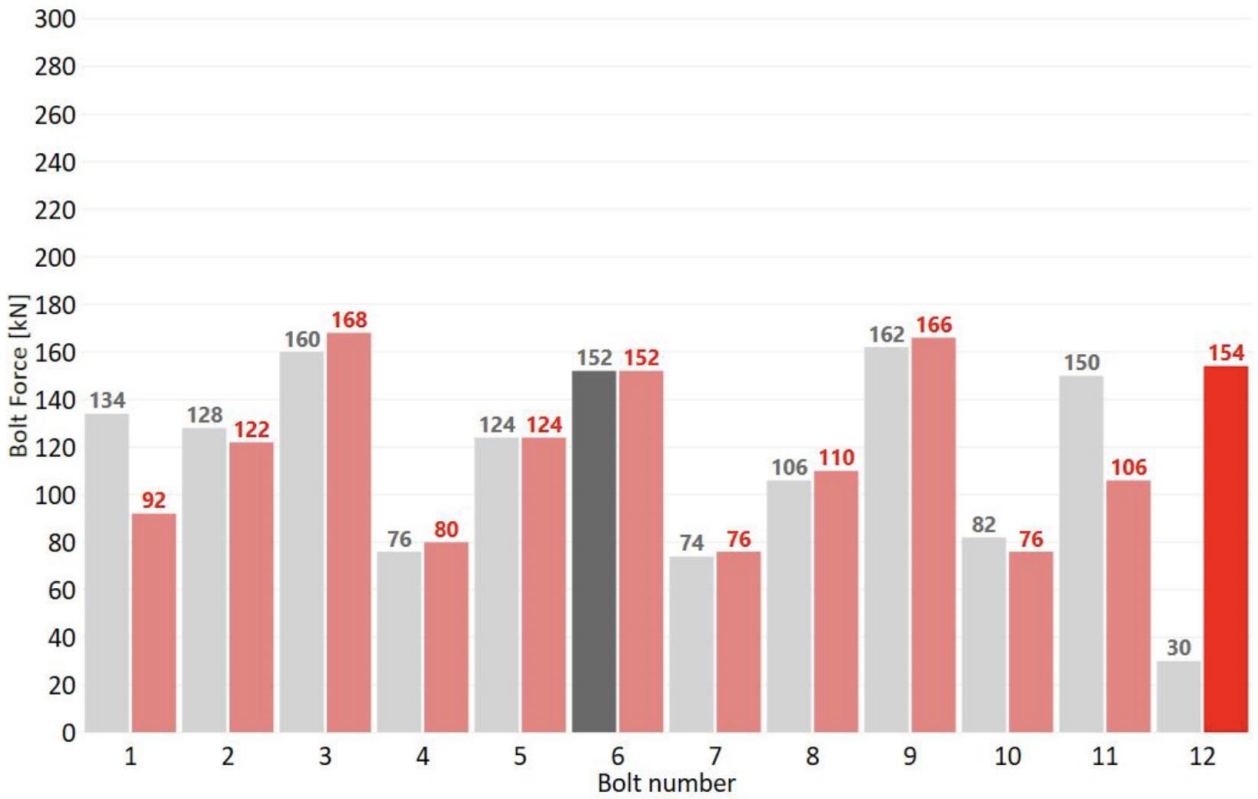
## Screenshots test 6" flange – Gasket SPW – Greased P37

Bolt loads after 100% final torque cross-wise (step 36)




| Test id | F6-HY-T39 |
|---|---|
| Torqueing / Tensioning | Torqueing |
| Tool(s) | 1 |
| Equip. manufacturer | Hytorc |
| Equip. technology | Hydraulic |
| Equip. type | st2 slw41 |
| Final torque | 600 [Nm] |
| Current torque | 100% = 600 [Nm] |
| Total steps | 96 |
| Current step | 36 |
| Current bolt(s) | 12 |
| Gasket type | SPW/Graphite |
| Bolt diamter | 1 |
| Bolt condition | New |
| Lubricant | P37 |

| Boltforce [kN] | |
|---|---|
| 1 | 92 |
| 2 | 122 |
| 3 | 168 |
| 4 | 80 |
| 5 | 124 |
| 6 | 152 |
| 7 | 76 |
| 8 | 110 |
| 9 | 166 |
| 10 | 76 |
| 11 | 106 |
| 12 | 154 |
| **Average [kN]** | |
| 119 | |
| **Scatter [kN]** | |
| 92 | |





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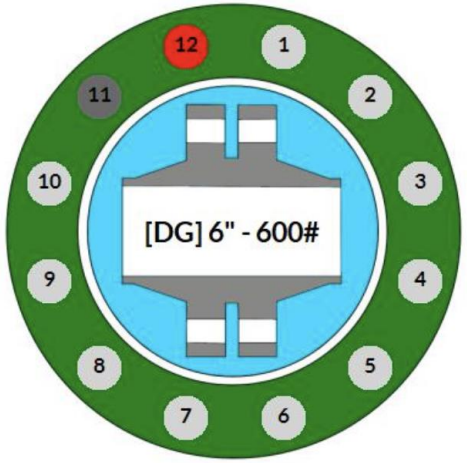
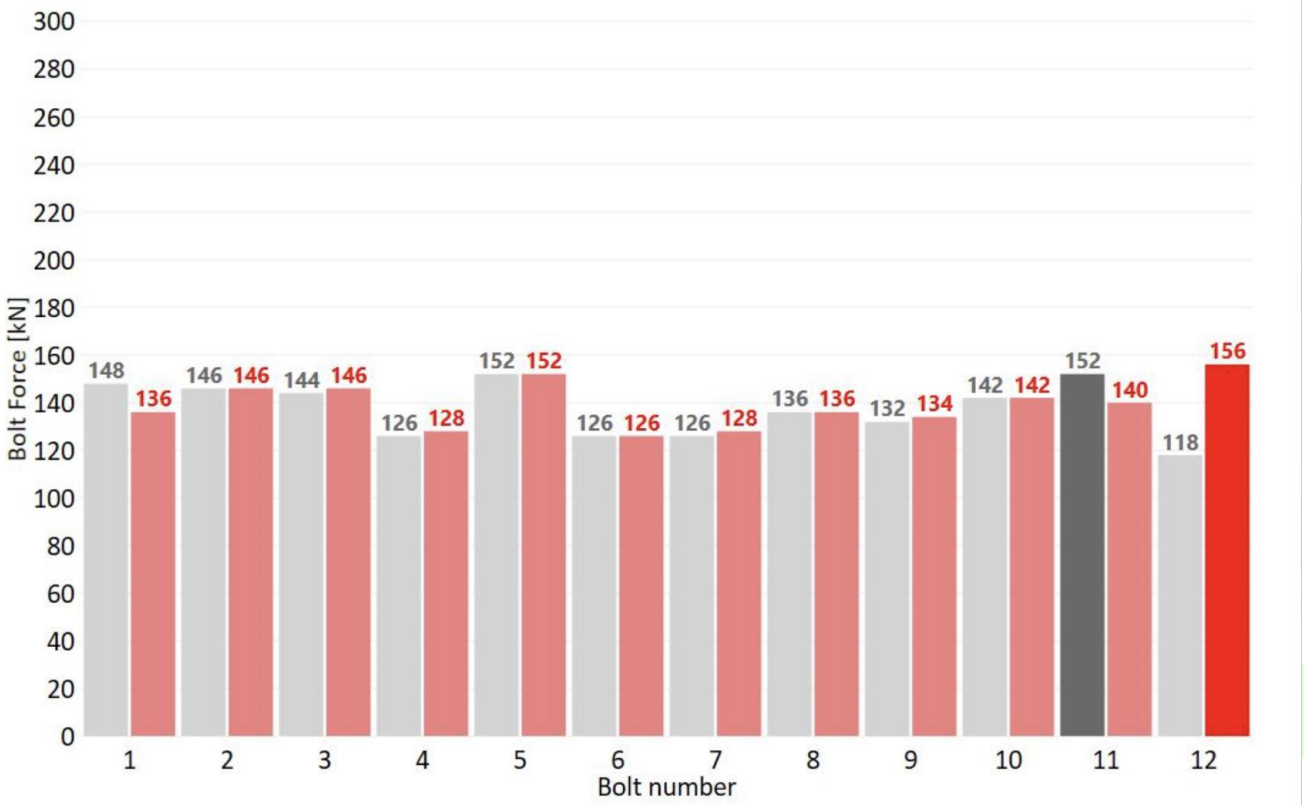
## Screenshots test 6" flange – Gasket SPW – Greased P37

Bolt loads after 100% final torque clock-wise 1st round (step 48)




| Test id | F6-HY-T39 |
|---|---|
| Torqueing / Tensioning | Torqueing |
| Tool(s) | 1 |
| Equip. manufacturer | Hytorc |
| Equip. technology | Hydraulic |
| Equip. type | st2 slw41 |
| Final torque | 600 [Nm] |
| Current torque | 100% = 600 [Nm] |
| Total steps | 96 |
| Current step | 48 |
| Current bolt(s) | 12 |
| Gasket type | SPW/Graphite |
| Bolt diamter | 1 |
| Bolt condition | New |
| Lubricant | P37 |

| Boltforce [kN] | |
|---|---|
| 1 | 136 |
| 2 | 146 |
| 3 | 146 |
| 4 | 128 |
| 5 | 152 |
| 6 | 126 |
| 7 | 128 |
| 8 | 136 |
| 9 | 134 |
| 10 | 142 |
| 11 | 140 |
| 12 | 156 |
| **Average [kN]** | |
| 139 | |
| **Scatter [kN]** | |
| 30 | |





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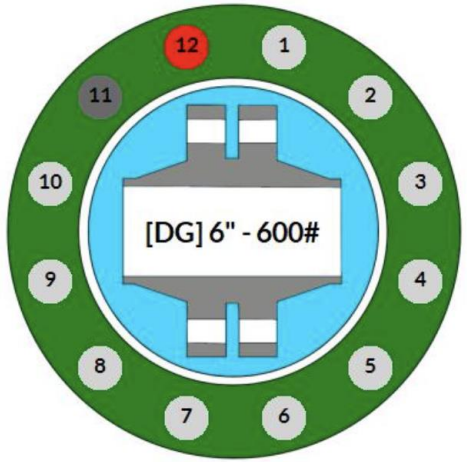
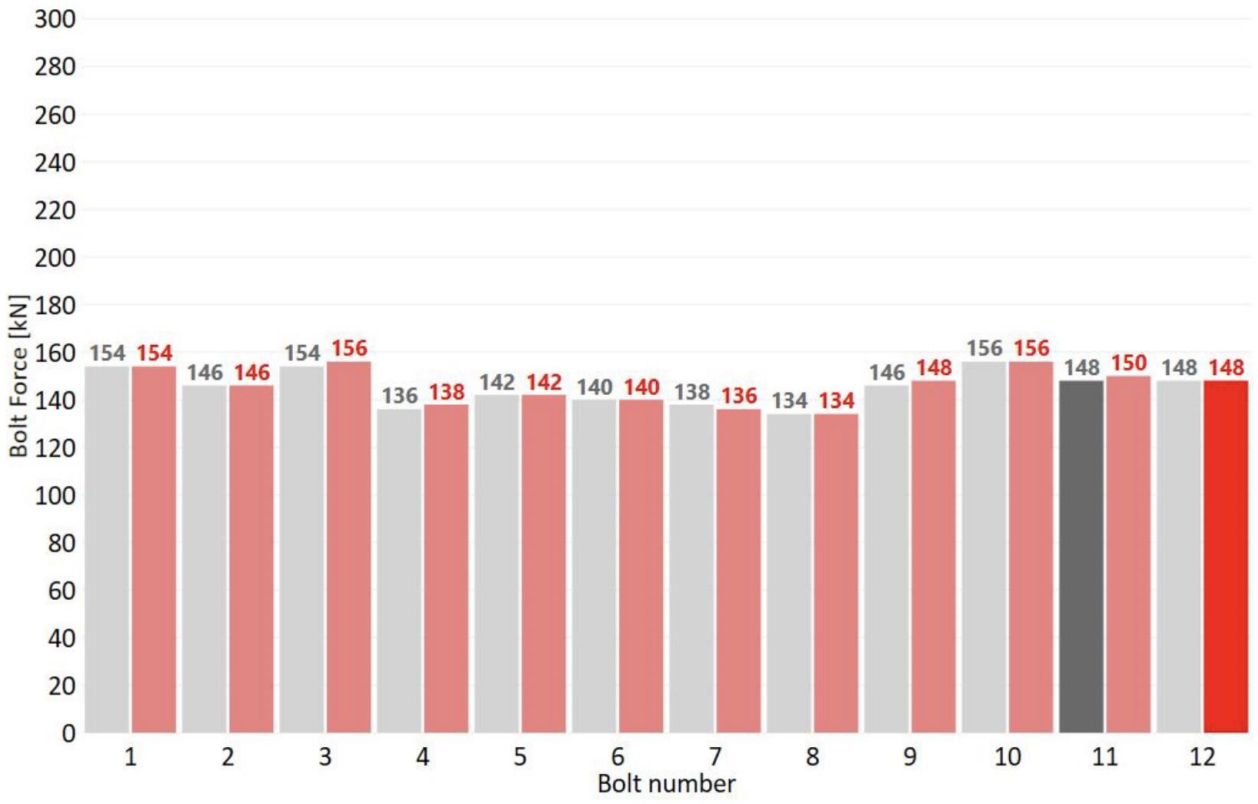
## Screenshots test 6" flange – Gasket SPW – Greased P37

Bolt loads after 100% final torque clock-wise 2nd round (step 60)




| Test id | F6-HY-T39 |
|---|---|
| Torqueing / Tensioning | Torqueing |
| Tool(s) | 1 |
| Equip. manufacturer | Hytorc |
| Equip. technology | Hydraulic |
| Equip. type | st2 slw41 |
| Final torque | 600 [Nm] |
| Current torque | 100% = 600 [Nm] |
| Total steps | 96 |
| Current step | 60 |
| Current bolt(s) | 12 |
| Gasket type | SPW/Graphite |
| Bolt diamter | 1 |
| Bolt condition | New |
| Lubricant | P37 |

| Boltforce [kN] | |
|---|---|
| 1 | 154 |
| 2 | 146 |
| 3 | 156 |
| 4 | 138 |
| 5 | 142 |
| 6 | 140 |
| 7 | 136 |
| 8 | 134 |
| 9 | 148 |
| 10 | 156 |
| 11 | 150 |
| 12 | 148 |
| **Average [kN]** | |
| 146 | |
| **Scatter [kN]** | |
| 22 | |





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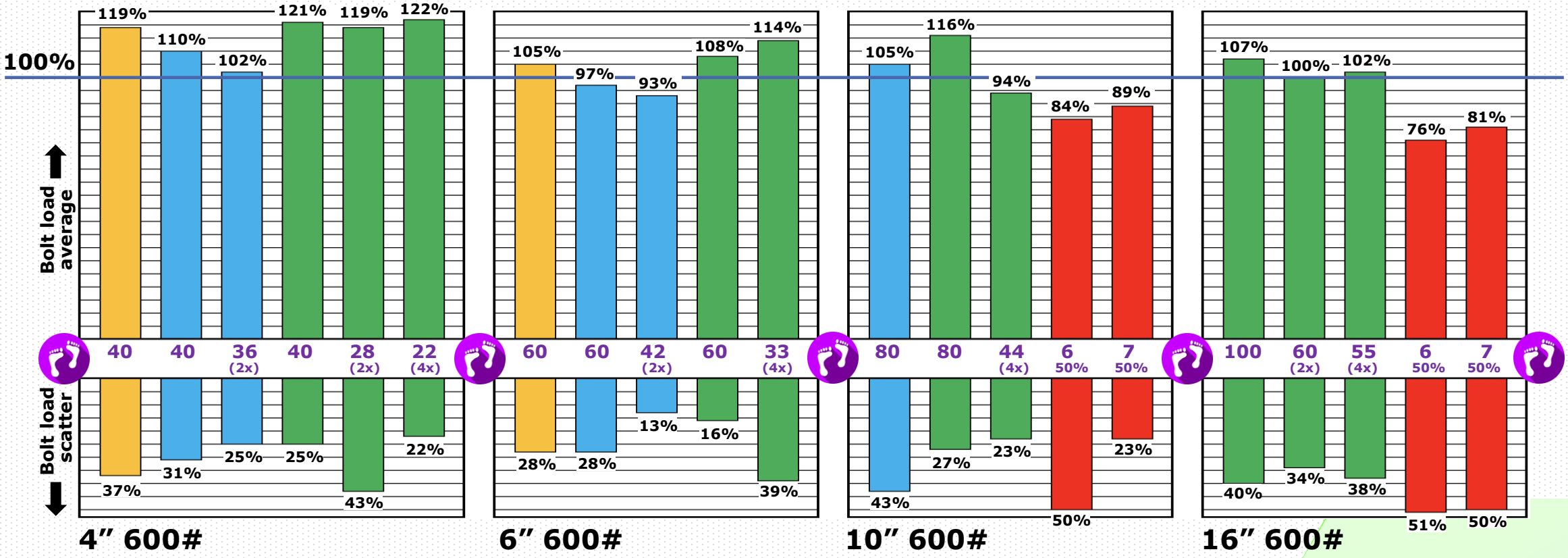
# BEPERKING LEKVERLIEZEN FLENSVERBINDINGEN

## Samenvatting testresultaten



Hand torquing

Electric torquing

Hydraulic Torquing

Hydraulic Tensioning

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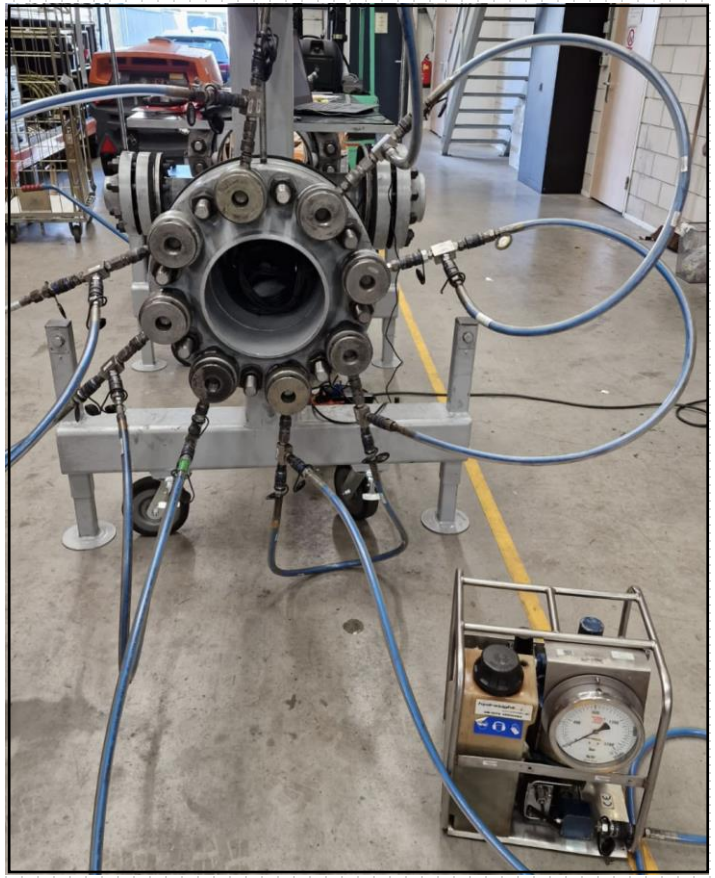
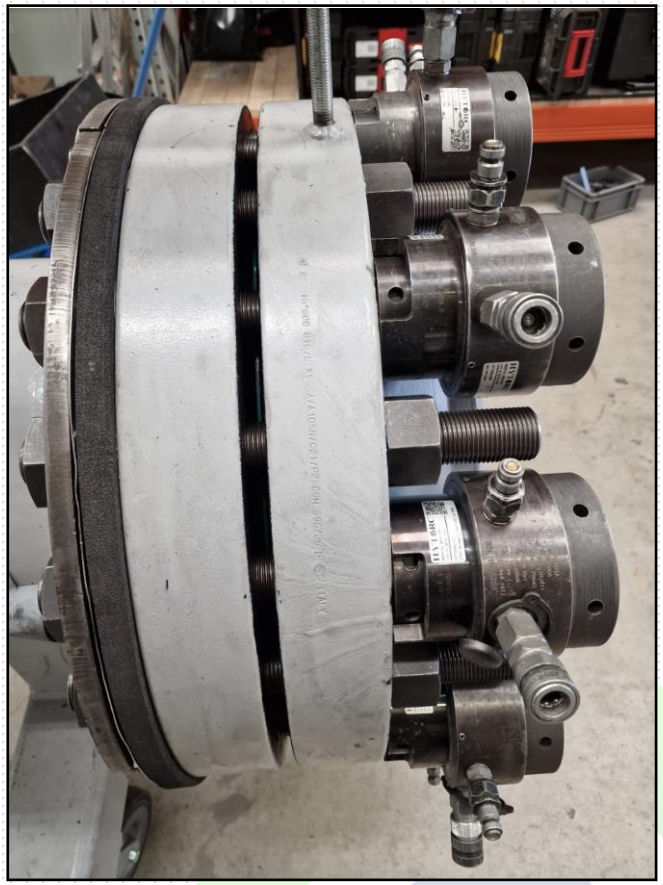
## Hydraulic Torqueing versus Hydralic Tensioning



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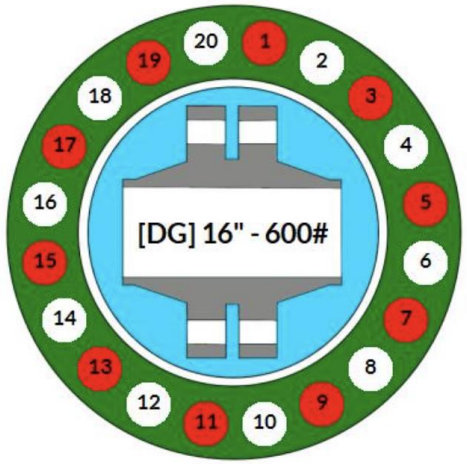
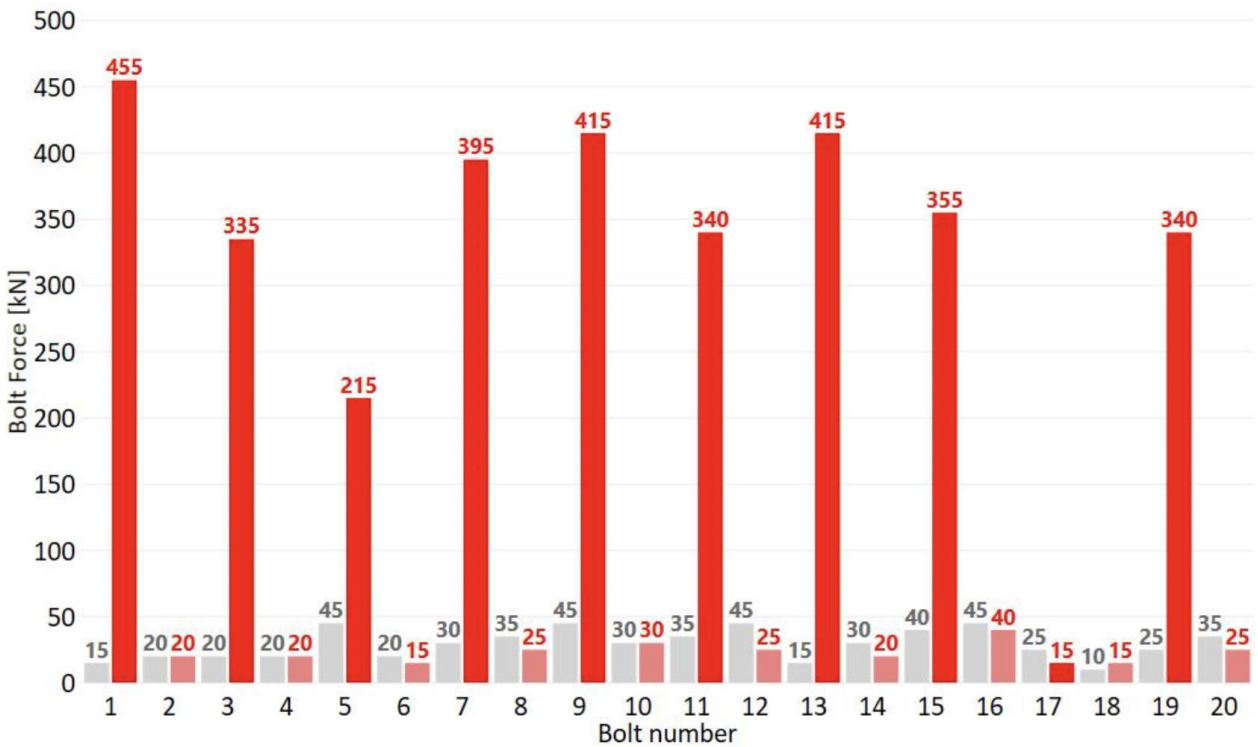
## Grootste afwijking bij Hydraulic Tensioning 16" flange




| Test id | F16-TE-T68 |
|---|---|
| Torqueing / Tensioning | Tensioning |
| Tensioners | 10 |
| Equip. manufacturer | Hytorq |
| Equip. technology | Hydraulic |
| Equip. type | tentec no:3 |
| Final boltforce | 341 [kN] |
| Current boltforce | 125% = 426 [kN] |
| Total steps | 7 |
| Current step | 1 |
| Current bolt(s) | 19,17,15,13,11,9,7,5 |
| Gasket type | SPW/Graphite |
| Bolt diamter | 1-1/2 |
| Bolt condition | New |
| Lubricant | None |
| Bolting Sequence | 16"-tensioning |

| Boltforce [kN] | |
|---|---|
| 1 | 455 |
| 2 | 20 |
| 3 | 335 |
| 4 | 20 |
| 5 | 215 |
| 6 | 15 |
| 7 | 395 |
| 8 | 25 |
| 9 | 415 |
| 10 | 30 |
| 11 | 340 |
| 12 | 25 |
| 13 | 415 |
| 14 | 20 |
| 15 | 355 |
| 16 | 40 |
| 17 | 15 |
| 18 | 15 |
| 19 | 340 |
| 20 | 25 |
| **Average [kN]** | |
| 176 | |
| **Scatter [kN]** | |
| 440 | |




Finish | Cancel | Previous Step | Save Step

**Step (1): A-pressure on 50% bolts (odd numbers)**

Screen-print after: Tighten nut and release (1st time)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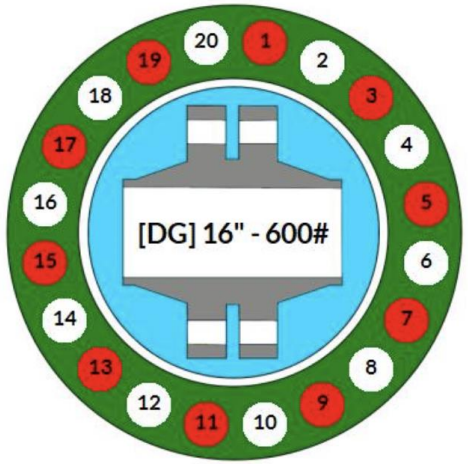
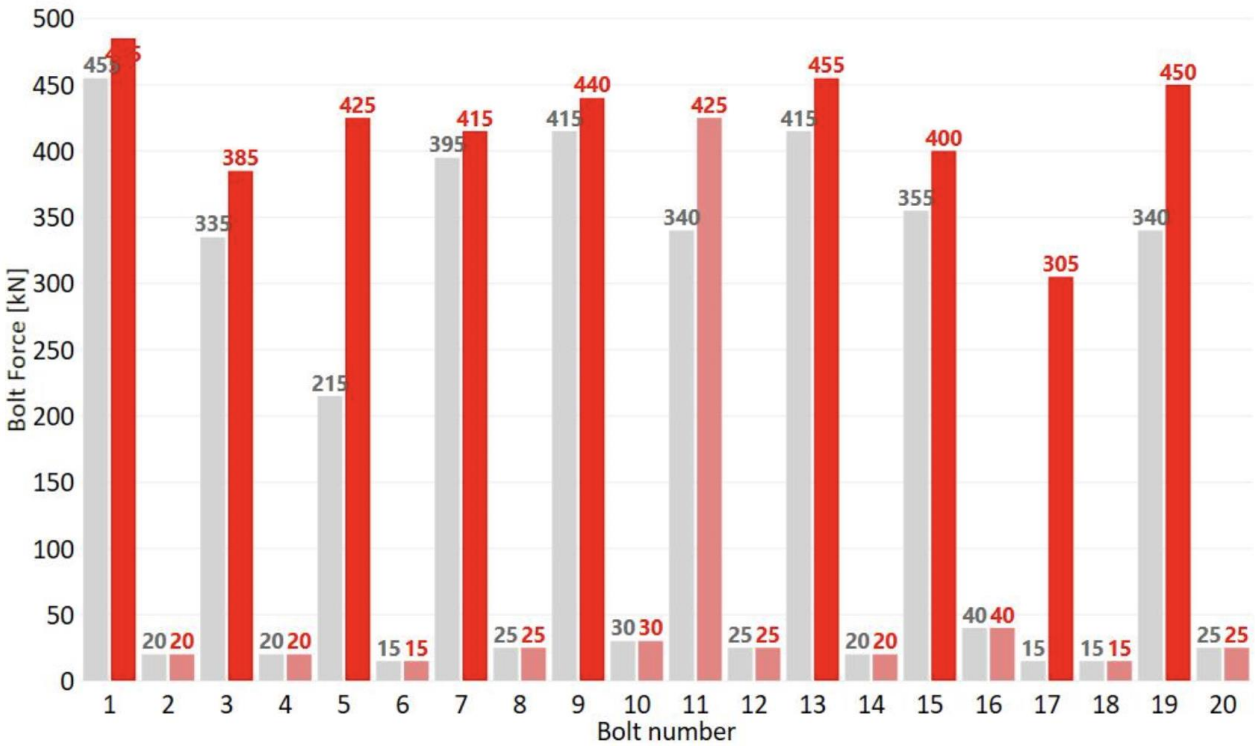
## Grootste afwijking bij Hydraulic Tensioning 16" flange




| Test id | F16-TE-T68 |
|---|---|
| Torqueing / Tensioning | Tensioning |
| Tensioners | 10 |
| Equip. manufacturer | Hytorq |
| Equip. technology | Hydraulic |
| Equip. type | tentec no:3 |
| Final boltforce | 341 [kN] |
| Current boltforce | 125% = 426 [kN] |
| Total steps | 7 |
| Current step | 2 |
| Current bolt(s) | 19,17,15,13,9,7,5,3,1 |
| Gasket type | SPW/Graphite |
| Bolt diamter | 1-1/2 |
| Bolt condition | New |
| Lubricant | None |
| Bolting Sequence | 16"-tensioning |

| Boltforce [kN] | |
|---|---|
| 1 | 485 |
| 2 | 20 |
| 3 | 385 |
| 4 | 20 |
| 5 | 425 |
| 6 | 15 |
| 7 | 415 |
| 8 | 25 |
| 9 | 440 |
| 10 | 30 |
| 11 | 425 |
| 12 | 25 |
| 13 | 455 |
| 14 | 20 |
| 15 | 400 |
| 16 | 40 |
| 17 | 305 |
| 18 | 15 |
| 19 | 450 |
| 20 | 25 |
| **Average [kN]** | |
| 221 | |
| **Scatter [kN]** | |
| 470 | |




**Step (2): A-pressure on 50% bolts (odd numbers)**

Screen-print after: Tighten nut and release (2nd time)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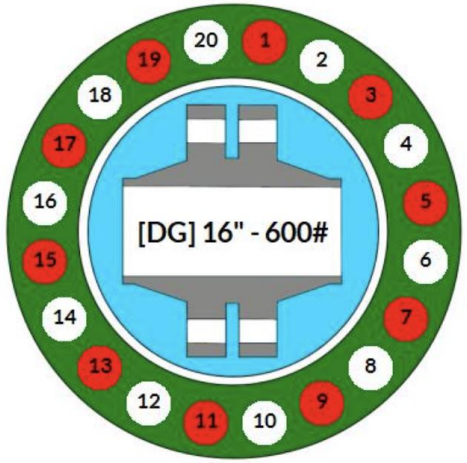
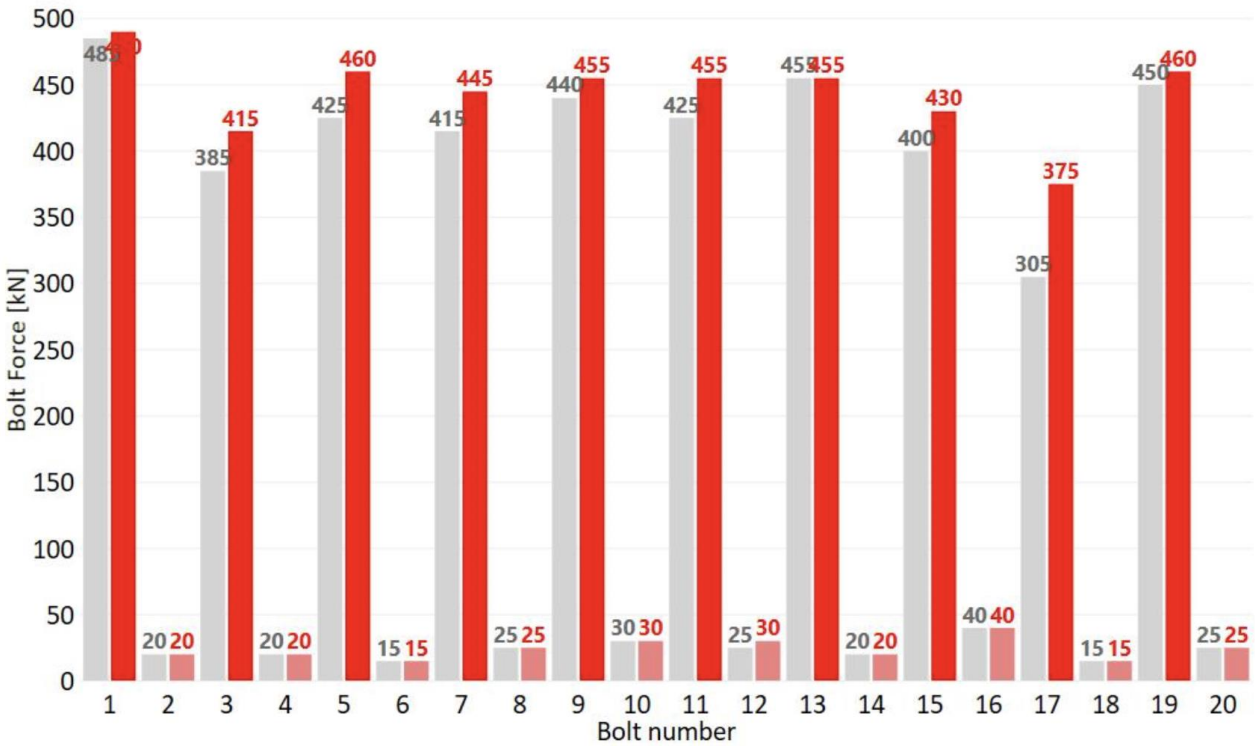
## Grootste afwijking bij Hydraulic Tensioning 16" flange




| Test id | F16-TE-T68 |
|---|---|
| Torqueing / Tensioning | Tensioning |
| Tensioners | 10 |
| Equip. manufacturer | Hytorq |
| Equip. technology | Hydraulic |
| Equip. type | tentec no:3 |
| Final boltforce | 341 [kN] |
| Current boltforce | 125% = 426 [kN] |
| Total steps | 7 |
| Current step | 3 |
| Current bolt(s) | 19,17,15,13,11,9,7,5 |
| Gasket type | SPW/Graphite |
| Bolt diamter | 1-1/2 |
| Bolt condition | New |
| Lubricant | None |
| Bolting Sequence | 16"-tensioning |

| Boltforce [kN] | |
|---|---|
| 1 | 490 |
| 2 | 20 |
| 3 | 415 |
| 4 | 20 |
| 5 | 460 |
| 6 | 15 |
| 7 | 445 |
| 8 | 25 |
| 9 | 455 |
| 10 | 30 |
| 11 | 455 |
| 12 | 30 |
| 13 | 455 |
| 14 | 20 |
| 15 | 430 |
| 16 | 40 |
| 17 | 375 |
| 18 | 15 |
| 19 | 460 |
| 20 | 25 |
| **Average [kN]** | |
| 234 | |
| **Scatter [kN]** | |
| 475 | |




**Step (3): A-pressure on 50% bolts (odd numbers)**

Screen-print after: Tighten nut and release (3th time)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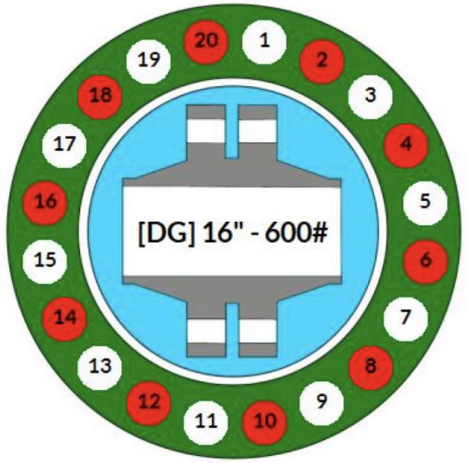
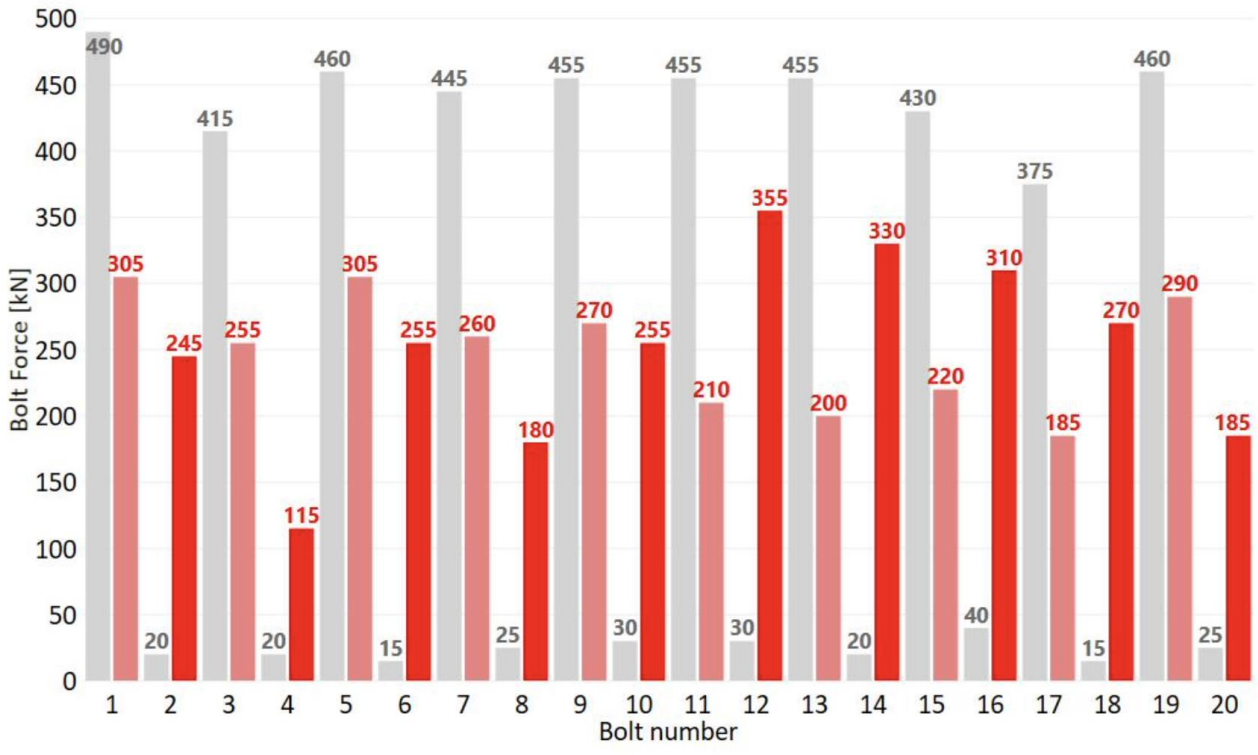
## Grootste afwijking bij Hydraulic Tensioning 16" flange




| Test id | F16-TE-T68 |
|---|---|
| Torqueing / Tensioning | Tensioning |
| Tensioners | 10 |
| Equip. manufacturer | Hytorq |
| Equip. technology | Hydraulic |
| Equip. type | tentec no:3 |
| Final boltforce | 341 [kN] |
| Current boltforce | 100% = 341 [kN] |
| Total steps | 7 |
| Current step | 4 |
| Current bolt(s) | 20,18,16,14,12,10,8, |
| Gasket type | SPW/Graphite |
| Bolt diamter | 1-1/2 |
| Bolt condition | New |
| Lubricant | None |
| Bolting Sequence | 16"-tensioning |

| Boltforce [kN] | |
|---|---|
| 1 | 305 |
| 2 | 245 |
| 3 | 255 |
| 4 | 115 |
| 5 | 305 |
| 6 | 255 |
| 7 | 260 |
| 8 | 180 |
| 9 | 270 |
| 10 | 255 |
| 11 | 210 |
| 12 | 355 |
| 13 | 200 |
| 14 | 330 |
| 15 | 220 |
| 16 | 310 |
| 17 | 185 |
| 18 | 270 |
| 19 | 290 |
| 20 | 185 |
| **Average [kN]** | |
| 250 | |
| **Scatter [kN]** | |
| 240 | |




**Step (4): B-pressure on 50% bolts (even numbers)**

Screen-print after: Tighten nut and release (1st time)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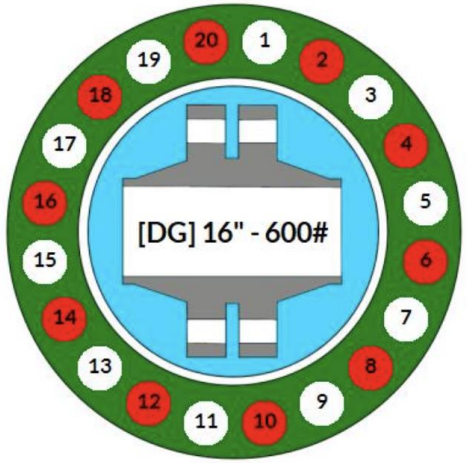
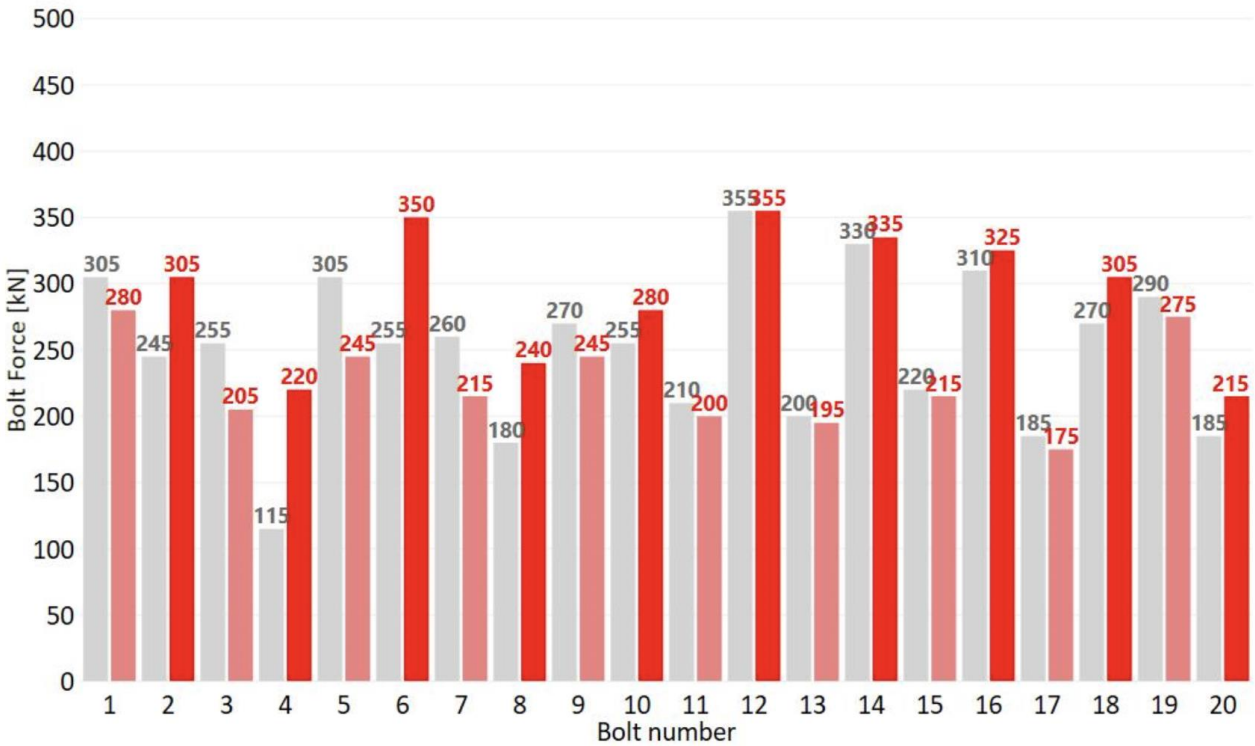
## Grootste afwijking bij Hydraulic Tensioning 16" flange




| Test id | F16-TE-T68 |
|---|---|
| Torqueing / Tensioning | Tensioning |
| Tensioners | 10 |
| Equip. manufacturer | Hytorq |
| Equip. technology | Hydraulic |
| Equip. type | tentec no:3 |
| Final boltforce | 341 [kN] |
| Current boltforce | 100% = 341 [kN] |
| Total steps | 7 |
| Current step | 5 |
| Current bolt(s) | 20,18,16,14,12,10,8, |
| Gasket type | SPW/Graphite |
| Bolt diamter | 1-1/2 |
| Bolt condition | New |
| Lubricant | None |
| Bolting Sequence | 16"-tensioning |

| Boltforce [kN] | |
|---|---|
| 1 | 280 |
| 2 | 305 |
| 3 | 205 |
| 4 | 220 |
| 5 | 245 |
| 6 | 350 |
| 7 | 215 |
| 8 | 240 |
| 9 | 245 |
| 10 | 280 |
| 11 | 200 |
| 12 | 355 |
| 13 | 195 |
| 14 | 335 |
| 15 | 215 |
| 16 | 325 |
| 17 | 175 |
| 18 | 305 |
| 19 | 275 |
| 20 | 215 |
| **Average [kN]** | |
| 259 | |
| **Scatter [kN]** | |
| 180 | |




Finish | Cancel | Previous Step | Save Step

**Step (5): B-pressure on 50% bolts (even numbers)**

Screen-print after: Tighten nut and release (2nd time)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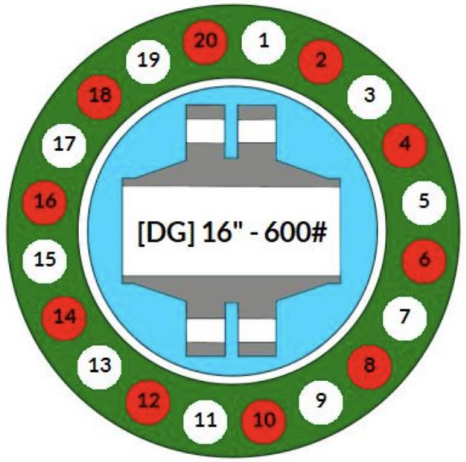
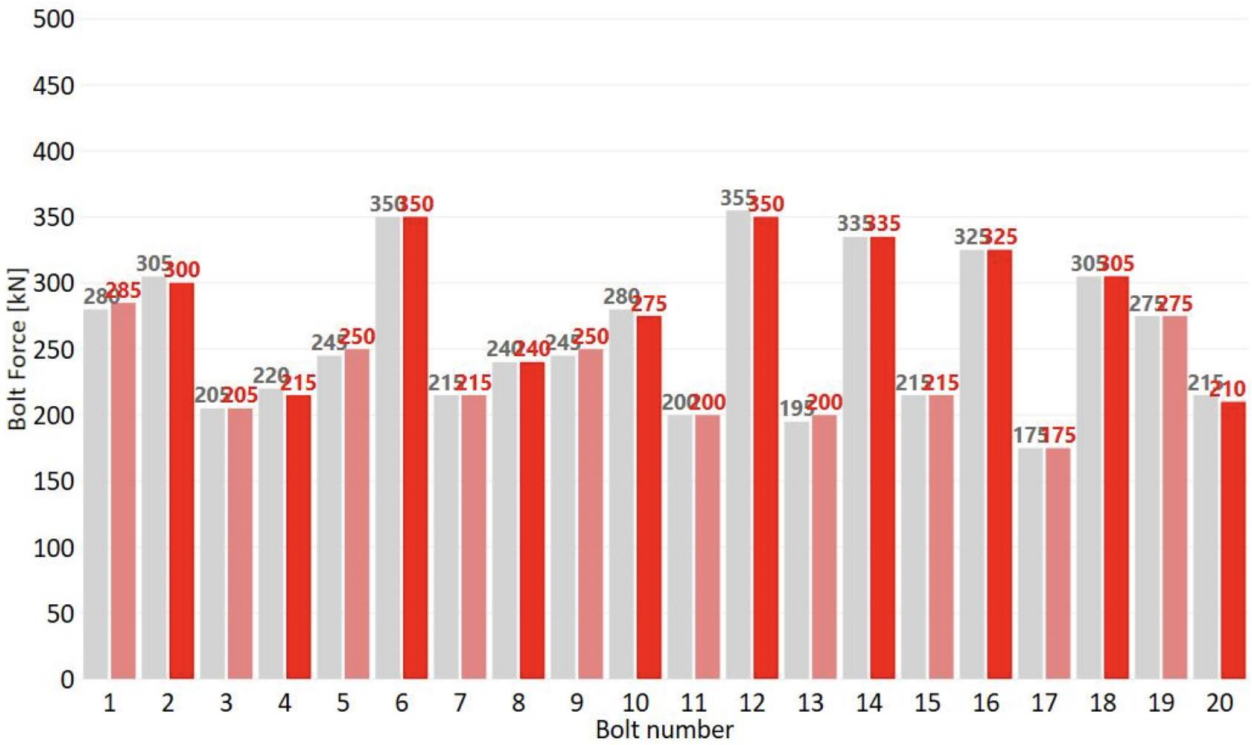
## Grootste afwijking bij Hydraulic Tensioning 16" flange




| Test id | F16-TE-T68 |
|---|---|
| Torqueing / Tensioning | Tensioning |
| Tensioners | 10 |
| Equip. manufacturer | Hytorq |
| Equip. technology | Hydraulic |
| Equip. type | tentec no:3 |
| Final boltforce | 341 [kN] |
| Current boltforce | 100% = 341 [kN] |
| Total steps | 7 |
| Current step | 6 |
| Current bolt(s) | 20,18,16,14,12,10,8, |
| Gasket type | SPW/Graphite |
| Bolt diamter | 1-1/2 |
| Bolt condition | New |
| Lubricant | None |
| Bolting Sequence | 16"-tensioning |

| Boltforce [kN] | |
|---|---|
| 1 | 285 |
| 2 | 300 |
| 3 | 205 |
| 4 | 215 |
| 5 | 250 |
| 6 | 350 |
| 7 | 215 |
| 8 | 240 |
| 9 | 250 |
| 10 | 275 |
| 11 | 200 |
| 12 | 350 |
| 13 | 200 |
| 14 | 335 |
| 15 | 215 |
| 16 | 325 |
| 17 | 175 |
| 18 | 305 |
| 19 | 275 |
| 20 | 210 |
| **Average [kN]** | |
| 259 | |
| **Scatter [kN]** | |
| 175 | |




**Step (6): B-pressure on 50% bolts (even numbers)**

Screen-print after: Tighten nut and release (3th time)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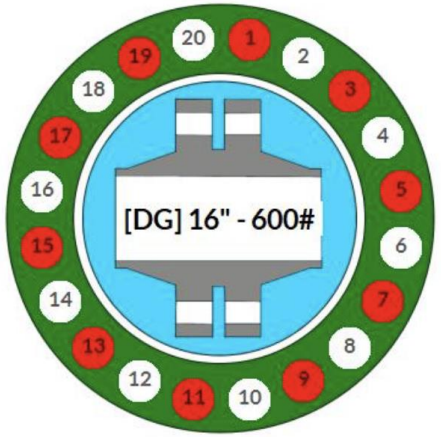
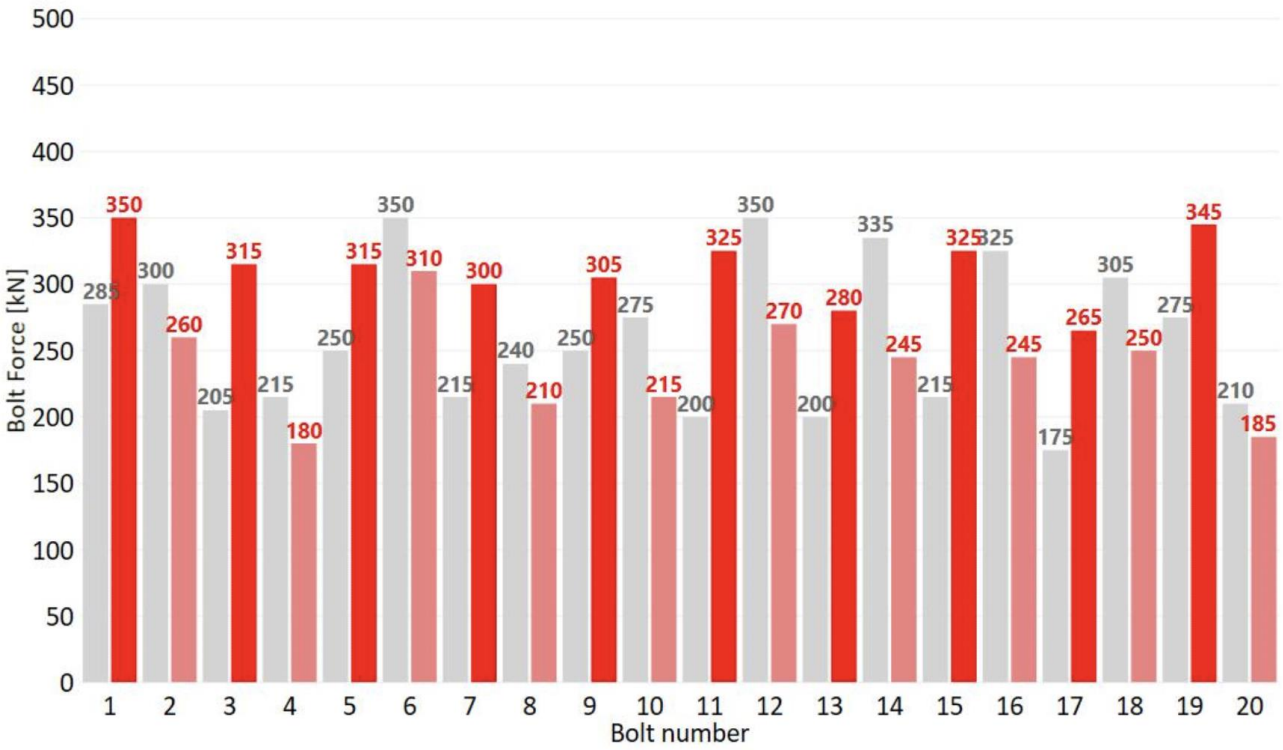
## Grootste afwijking bij Hydraulic Tensioning 16" flange




| Test id | F16-TE-T68 |
|---|---|
| Torqueing / Tensioning | Tensioning |
| Tensioners | 10 |
| Equip. manufacturer | Hytorq |
| Equip. technology | Hydraulic |
| Equip. type | tentec no:3 |
| Final boltforce | 341 [kN] |
| Current boltforce | 100% = 341 [kN] |
| Total steps | 7 |
| Current step | 7 |
| Current bolt(s) | 19,17,15,13,11,9, |
| Gasket type | SPW/Graphite |
| Bolt diamter | 1-1/2 |
| Bolt condition | New |
| Lubricant | None |
| Bolting Sequence | 16"-tensioning |

| Boltforce [kN] | |
|---|---|
| 1 | 350 |
| 2 | 260 |
| 3 | 315 |
| 4 | 180 |
| 5 | 315 |
| 6 | 310 |
| 7 | 300 |
| 8 | 210 |
| 9 | 305 |
| 10 | 215 |
| 11 | 325 |
| 12 | 270 |
| 13 | 280 |
| 14 | 245 |
| 15 | 325 |
| 16 | 245 |
| 17 | 265 |
| 18 | 250 |
| 19 | 345 |
| 20 | 185 |
| **Average [kN]** | |
| 275 | |
| **Scatter [kN]** | |
| 170 | |




**Step (7): A-pressure on 50% bolts for 2nd time (odd numbers)**

Screen-print after: Tighten nut and release (1st time)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## BEPERKING LEKVERLIEZEN FLENSVERBINDINGEN

# CONCLUSION

a) Met de handmomentsleutel is een acceptabele nauwkeurigheid te behalen tot circa 400. [Nm]

b) 'Torquen' door middel van accu- en hydraulisch gedreven tools hebben een acceptabele nauwkeurigheid over de gehele range van gemeten flenzen.

c) Met multi-tooling bij zowel accu- als hydraulisch gedreven tools is het mogelijk om door optimalisering van het aanhaalpatroon significante tijdswinst te bereiken zonder afbreuk te doen aan de nauwkeurigheid.

d) 'Tensioning' geeft bij de metingen de grootste onnauwkeurigheid in vergelijk met de andere aanhaalmethodieken.

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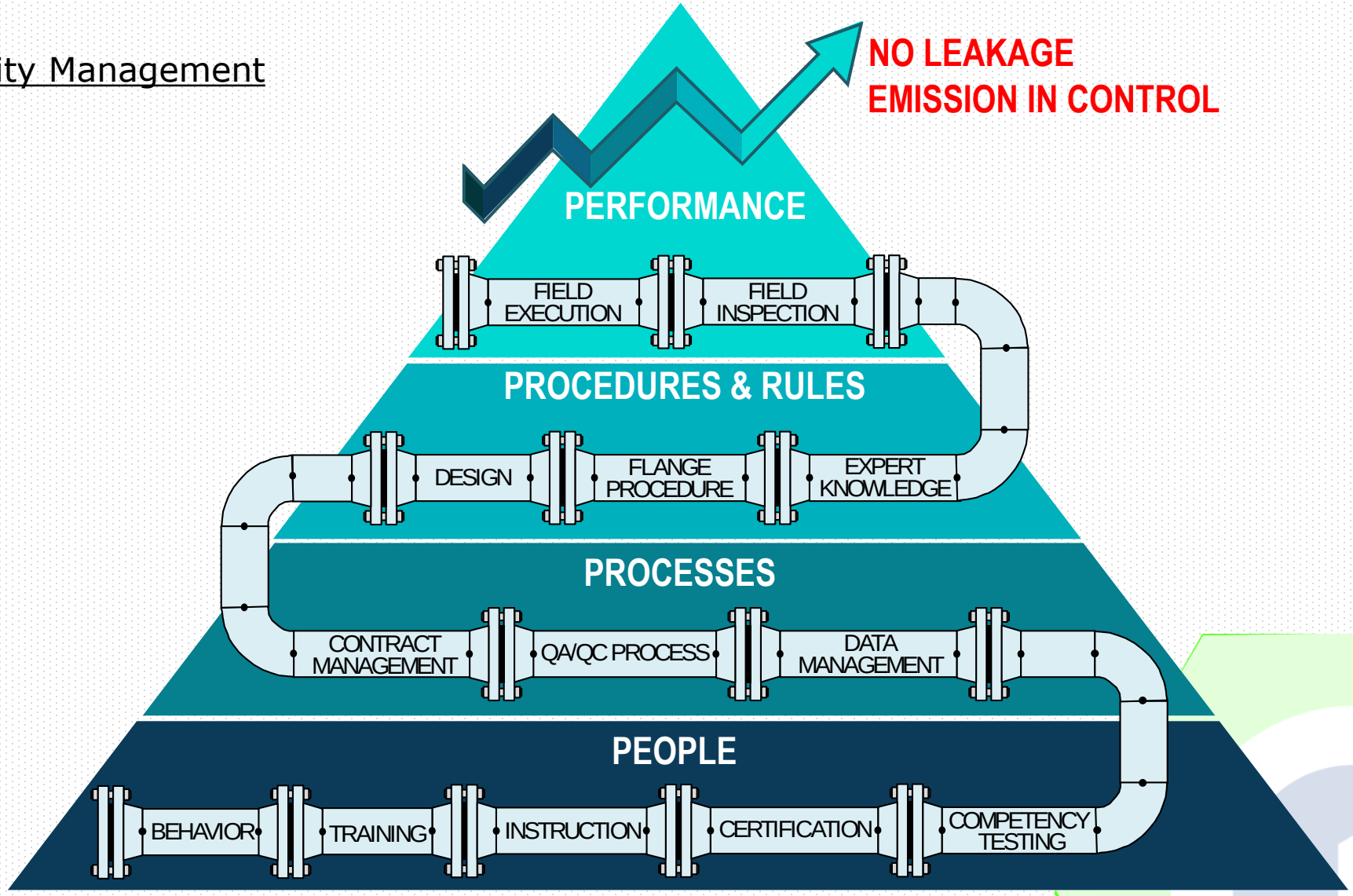
## BEPERKING LEKVERLIEZEN FLENSVERBINDINGEN

**FIM Model**

FIM = Flange Integrity Management

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## Project partijen

Interreg Vlaanderen-Nederland

Europees onderzoek subsidie

BEMAS

KIC MPi Kennis- en innovatiecentrum Maintenance Procesindustrie

Interreg project management

DIJKGRAAF SUPPORT

Project Lead
Financiering
Design
Analyse & Reporting

PROGRESSO GROUP - QUALITY - KNOWLEDGE - PERFORMANCE -

Project Supporter
Inbouw sensoren
Uitvoering testen

BoltSafe Load Measuring Systems

Project Supporter
Levering sensoren
Software meetsysteem

LASERDRIJF MINDERHOUD

Constructie test-skid

KLINGER The Netherlands

Afdichtingen

ERIKS

Bolting

HYTORC

STAHLWILLE

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