CIRCULAIR ONDERHOUD: LEKVERLIEZEN BEPERKEN

Effect of flange tightening methods on bolt load scatter

Use Cases
Update: 14 Mei 2020

Circulair Onderhoud*

Project voorstel '**Effect of flange tightening methods on bolt load scatter**'

PROJECT LEAD — DIJKGRAAF SUPPORT

PROJECT SUPPORTER — PROGRESSO GROUP

PROJECT SUPPORTER — HYTORC

PROJECT OBJECTIVES

The flange diffuse emission rate is determined by the combination of many contributing factors.
The key variables are listed below:

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

The selected tightening method is one of these key variables and has a direct influence on the generated bolt loads. The bolt load scatter is one of the contributing factors with respect to the diffuse emission rate (See appendix I: table B.1 of NEN-EN 1591-1).

The main project objectives are:

- Measuring the accuracy of the most applied tightening methods in our industry.
- Determining the optimum work range of the different tightening methods with respect to:
  - Effectiveness: average bolt load and bolt load scatter as a function of bolt size, tightening sequence / method.
  - Efficiency : required labour / time span to tighten the flange with selected tightening method.

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

KEY TIGHTENING METHODS / VARIABLES

- Tools : hand torqueing, electric/hydraulic/pneumatic torqueing, hydraulic tensioning.
  - Option for hydraulic/pneumatic torqueing: no reaction arm (Hytorc washer).
- Tightening pattern : single- and multi tooling.
- Tightening steps : steps to be taken to tighten to the 100% of the final torque [Nm].

CURRENT SITUATION

- Hand torqueing is applied to a very high torque moment (indication: up to 500. [Nm]):
  - The hand torque wrench is too large to handle in practice, resulting in high inaccuracies.
  - The hand force is too large for accurate control.
- Our industry is not aligned with respect to the accuracy of the different tightening methods.
  - Because of a lack of full scale testing data, the selection of the tightening method to be used is in many cases arbitrary.
  - By sub-optimal tightening, the diffuse emission is higher as practical feasible.
  - The effect of variations in friction factor between the different tightening methods is insufficient defined.

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

PROJECT EXECUTION

Full scale bolt load testing with load cells: measuring system

Network with PDI

With the PDI box and a network of CM-1000 boxes, you can visualize the bolt load continuous. You can assemble up to eight BoltSafe sensors at one CM-1000 box and you can use up to 31 CM-1000 boxes in a network to one PDI box in combination with a PC. You can analyze the continuous bolt load data with the special software called "BS2000 Network Monitoring".

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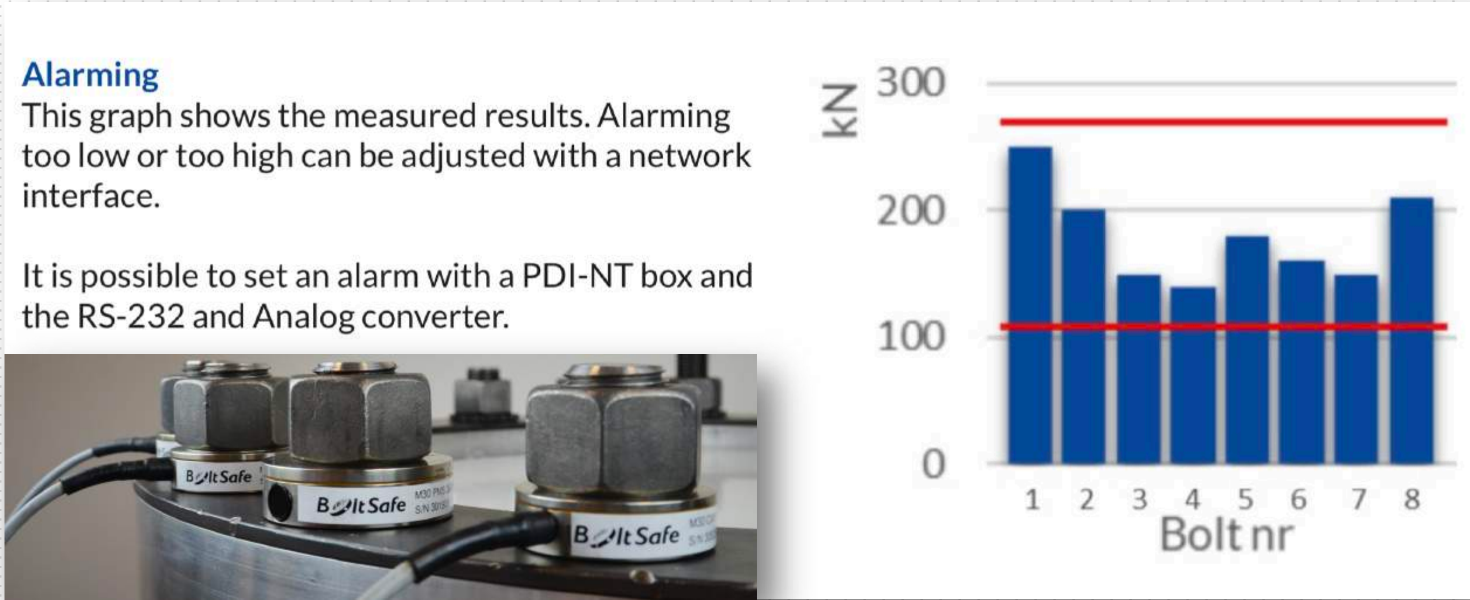
Flange/Piping Design	Material Qualities	Flange Procedure	Tightening Method	QA/QC Process	Execution Quality	Operational Conditions

PROJECT EXECUTION

Full scale bolt load testing with load cells: measuring results

For each test, the bolt loads / bolt load scatter is measured:

- Based on the measuring data, the accuracy of the tightening method can be determined.



PROJECT EXECUTION

Full scale bolt load testing with load cells: specification test flanges

The flanges are selected as such that the range is included for:

- All tightening methods to be tested.
- All bolt dimensions / bolt forces to be tested.
- Testing the effectiveness / efficiency of multi-tooling.

Flange Dimension	Flange Rating	Number of bolts Bolt diameter	Flange weight [kg]
4"	600#	8 x D = 7/8"	2 x 17,4
6"	600#	12 x D = 1"	2 x 34,9
10"	600#	16 x D = 1 1/4"	2 x 86,5
16"	600#	20 x D = 1 1/2"	2 x 170,0

PROJECT EXECUTION

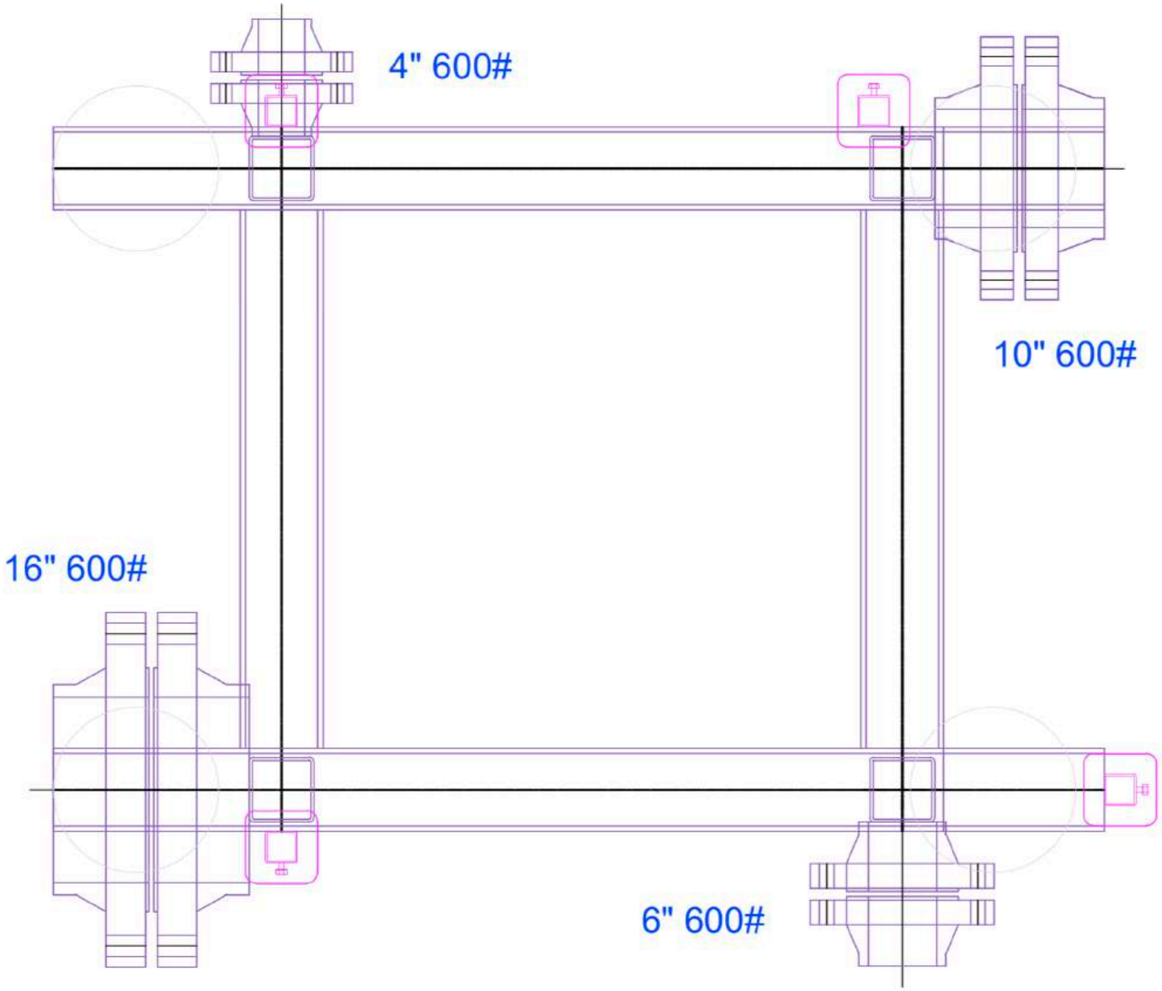
Full scale bolt load testing with load cells: Tightening methods / testing scheme

	Hand Torque	Electric Torquing	Hydraulic Torque With Reaction arm Standard patron	Hydraulic Torque Without Reaction arm Standard patron	Hydraulic Tensioning
Tightening Method	**(A)**	**(B)**	**(C)**	**(D)**	**(E)**

Note
Multi-tooling is an option for testing during a follow-up project.

Flange	Bolts	Tightening Methods to be tested on flange / bolt size				
4"	8 x D = 7/8"	(A)	(B)	(C)	(D)	(E)
6"	12 x D = 1"		(B)	(C)	(D)	(E)
10"	16 x D = 1 1/4"			(C)	(D)	(E)
16"	20 x D = 1 1/2"			(C)	(D)	(E)

TESTING SKID
Horizontal view



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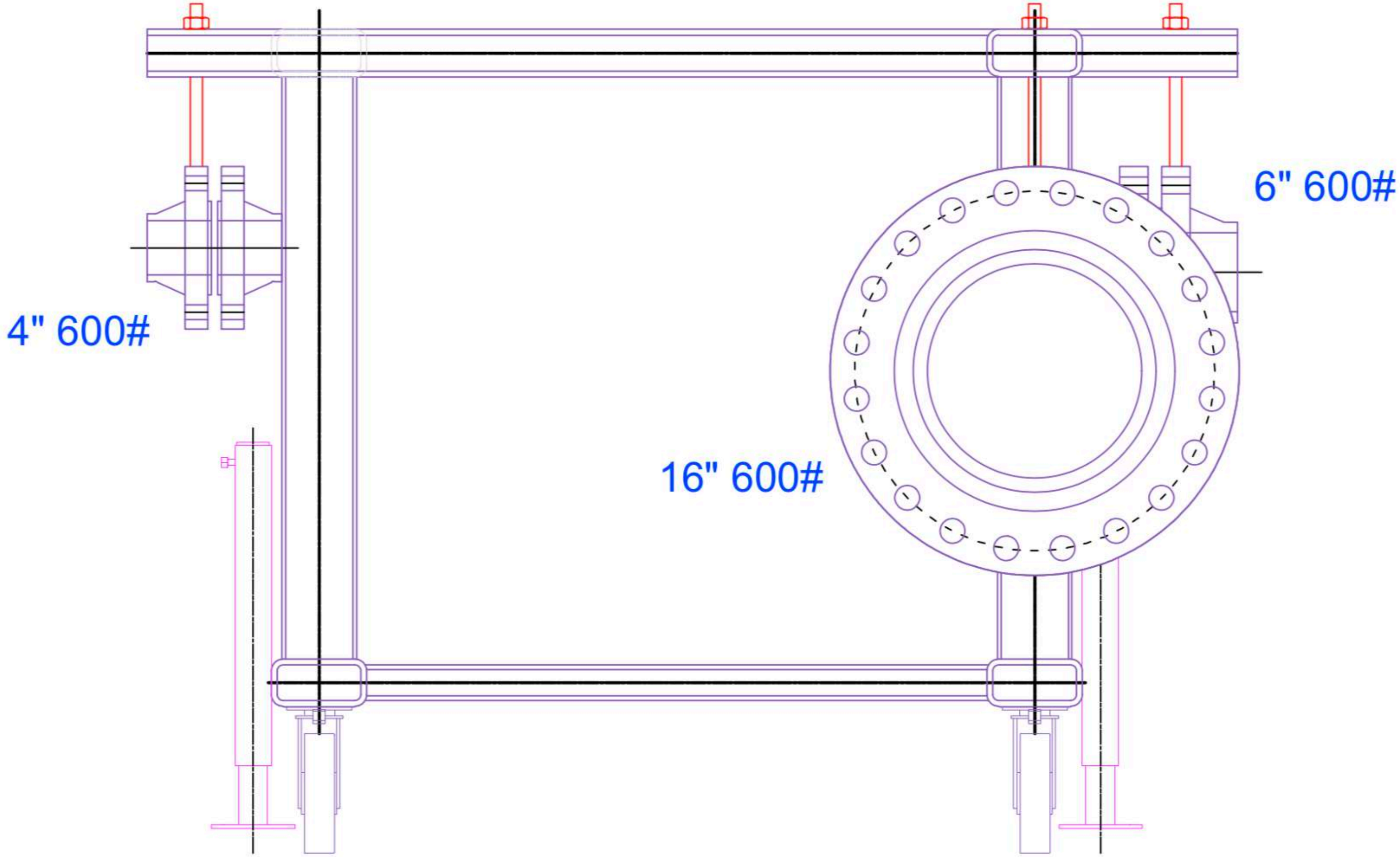
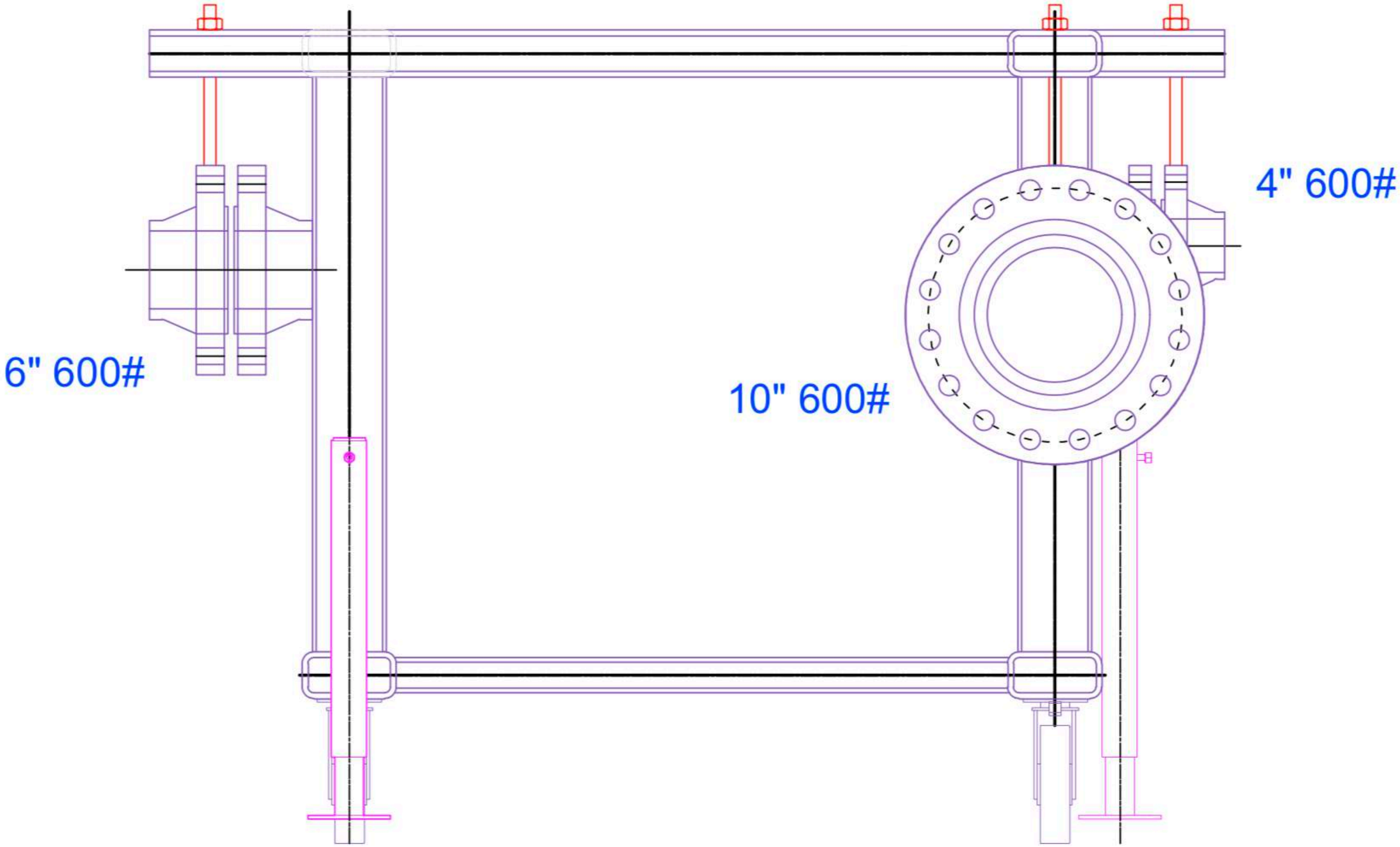
TESTING SKID

Side view



TESTING SKID

Side view



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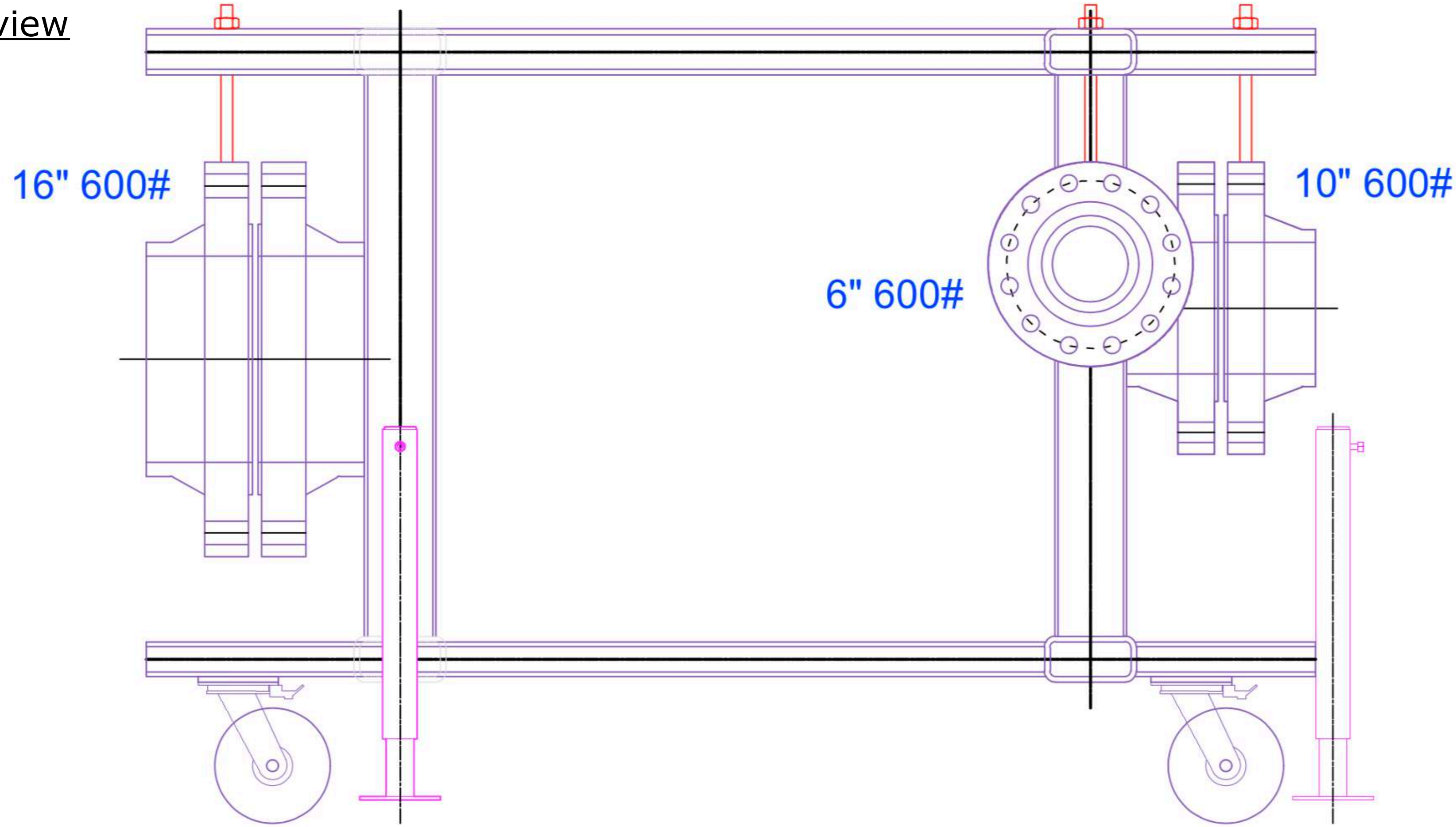
TESTING SKID

Side view



Interreg Vlaanderen-Nederland
Europees Fonds voor Regionale Ontwikkeling

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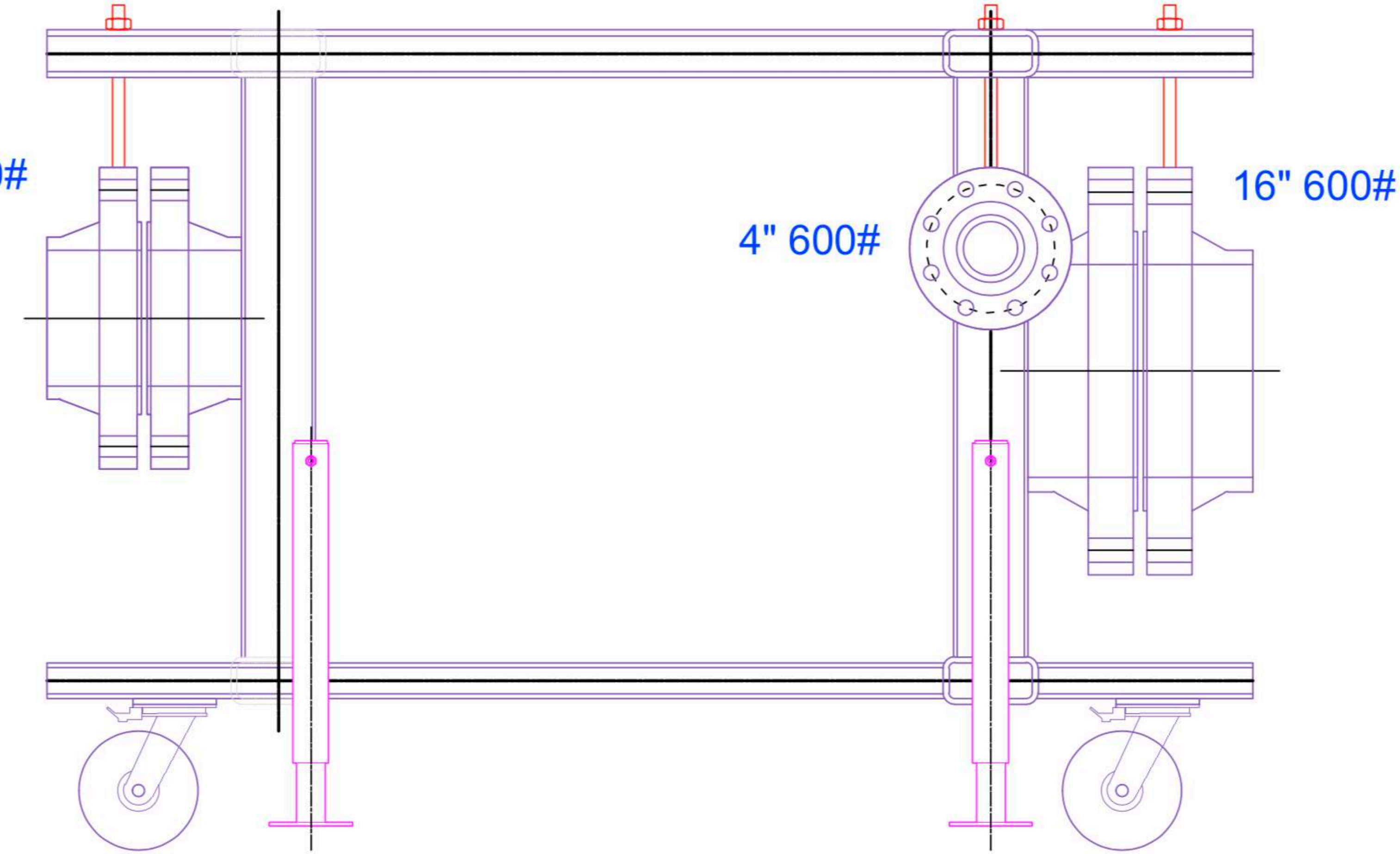
Side view



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Appendix I

NEN-EN 1591-1:2014

EN 1591-1:2013 (E)

Annex B
(informative)

Tightening

B.1 Scatter of initial bolt load of a single bolt — Indicative values ε_{1-} and ε_{1+} for a single bolt

Table B.1 — Scatter of initial bolt load of a single bolt — Indicative values ε_{1-} and ε_{1+} for a single bolt

Bolting up (tightening) method; Measuring method	Factors affecting scatter	Scatter value a, b, c, d	
		ε_{1-}	ε_{1+}
Wrench: operator feel or uncontrolled	Friction, Stiffness, Qualification of operator	0,3 + 0,5 x μ	0,3 + 0,5 x μ
Impact wrench	Friction, Stiffness, Calibration	0,2 + 0,5 x μ	0,2 + 0,5 x μ
Torque wrench = Wrench with measuring of torque (only)	Friction, Calibration, Lubrification	0,1 + 0,5 x μ	0,1 + 0,5 x μ
Hydraulic tensioner; Measuring of hydraulic pressure	Stiffness, Bolt length, Calibration	0,2	0,4
Wrench or hydraulic tensioner; Measuring of bolt elongation	Stiffness, Bolt length, Calibration	0,15	0,15
Wrench, Measuring of turn of nut (nearly to bolt yield)	Stiffness, Friction, Calibration	0,10	0,10
Wrench, Measuring of torque and turn of nut (nearly to bolt yield)	Calibration	0,07	0,07

[a] Very experienced operators can achieve scatter less than given values (e.g. ε = 0,2 instead of ε = 0,3 with torque wrench); for inexperienced operators scatter can be greater than shown.

[b] Tabulated scatter values are for a single bolt, the scatter of the total bolt load will be less, for statistical reasons, see B.2.

[c] With hydraulic tensioner, ε_{1+} et ε_{1-} are not equal, due to the fact that an additional load is supplied to the bolt while turning the unit to contact, prior to load transfer to the nut.

[d] μ is the friction coefficient which can be assumed between bolt and nut.