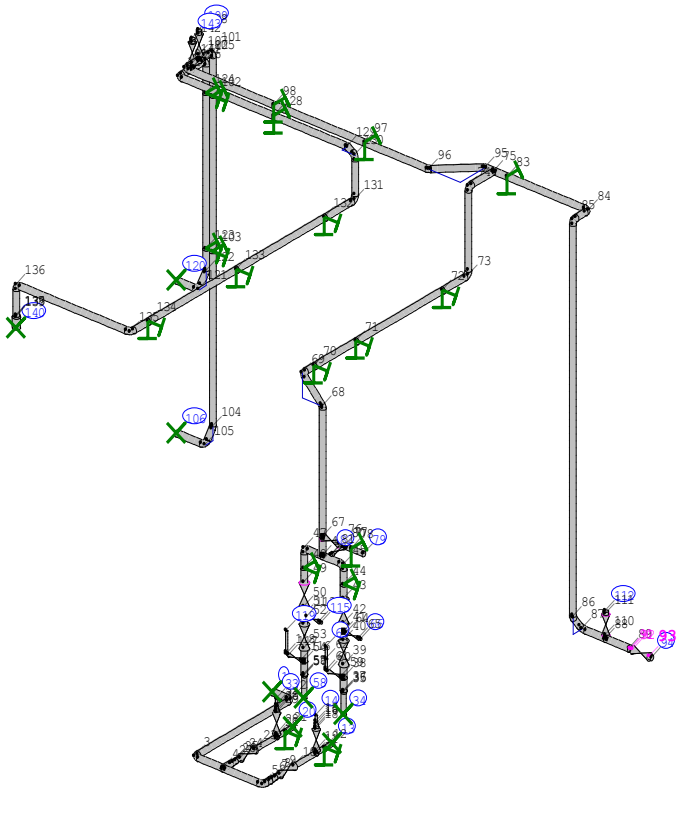
Project	Client project	Document	Rev.	Page	Pages
PVDF – chemical supply piping		**report_e.rtf**	0	1	22

Titel

Engineerging Services - Calculation report
Georg Fischer Piping Systems Ltd.



Client: **GF USA**

Created by: **Georg Fischer Piping Systems Ltd.**

Ebnatstrasse 111
CH - 8201 Schaffhausen
Switzerland

Created:	Approved by:		Created by:
10/02/2017	**Hanspeter Müller**		**Sven Fuegner**

Contents

1 Scope of work and results

1.1 Scope of work

For the calculation system

PVDF chemical supply piping

a pipe stress calculation has been carried out, to evaluate the system with regard to dead load, thermal expansion and additional loads.

This calculation covers the analysis of:

- flexibility of the pipe system geometry
- stresses in pipes and fittings
- pipe displacement
- pipe deformations
- loads on components
- loads on supports

1.2 Summary of results

1.2.1 Stresses

In consideration of the assumptions mentioned in this report the calculations result in 286.2% maximum stress overrun.

In consideration of the changes mentioned in this report the calculations result in no stress overrun.

2 Calculation Basics

2.1 Calculation program

The pipe stresses have been calculated using the program ROHR2, rev. 32.0.

A detailed description of both, the theoretical aspects and its practical application is given in the ROHR2-manual. The program provides solutions for static and dynamic analysis of 3-D pipe systems and general framework structures.

2.2 Calculation rule

The calculation was carried out acc. to **VGLSR - Vergleichsspannungen für Rohre.**

According to EN ISO 12162 Georg Fischer Piping Systems recommends the following safety factors C:

C_{min} for industrial applications is 1.6.
C_{min} for water applications is 1.25.

Thermoplastic Piping Systems	C_{min}
ABS	1.8
PE 100	1.6
PP-H	2.0
PVC-U + PVC-C	2.5
PVDF	2.0
PB	1.5

Georg Fischer Piping Systems is following the technical code DVS 2210-1 rev. April 1997 for planning and execution of above-ground Pipe Systems. This standard covers industrial pipelines made of Thermoplastics in metric standard. DVS 2210-1 refers to the following further applicable documents:

- DIN 8077
- DVS 2205-1
- DVS 2205-2
- AD-B9
- DIN 4279-8
- DIN 4279-9
- DIN 4279-10
- DIN 8061 with suppl.
- DIN 8062
- DIN 8063 ff.
- DIN 8074
- 8075 with suppl.
- DIN 8076 ff.
- DIN 8077
- DIN 8078 with suppl.
- DIN 8079
- DIN 8080
- DIN EN ISO 9000 - 9004
- DIN EN 10204
- DIN 16450
- DIN 16887
- DIN 16888 ff.
- DIN 16928
- DIN 16960
- DIN 16962 ff.
- DIN 16963 ff.
- DIN 18200
- DIN 32502
- DIN 53457
- DVS 2201-2
- DVS 2203-1
- DVS 2203-2
- DVS 2203-3
- DVS 2203-4
- DVS 2203-5
- DVS 2204-1
- DVS 2204-2
- DVS 2205-1
- DVS 2207-1
- DVS 2207-3
- DVS 2207-3 suppl.
- DVS 2207-4
- DVS 2207-4 suppl.
- DVS 2207-11
- DVS 2207-15
- DVS 2208-1
- DVS 2208-2
- DVS 2209-1
- DVS 2212-1
- DVS 2212-2
- DVS 2213
- DVS 2221-1
- DIN EN 1778
- DIN 1910-1
- DIN 2401-1
- DIN 2402
- DIN 2403
- DIN 2501-1
- DIN 3441 ff.
- DIN 3441-4
- DIN 3442 ff.
- DIN 3535-3
- DIN 3543-3
- DIN 3543-4
- DIN 3544-1
- DIN 4102 ff.
- DIN 4279-1
- DIN V 4279-1

2.3 Drawings and documents

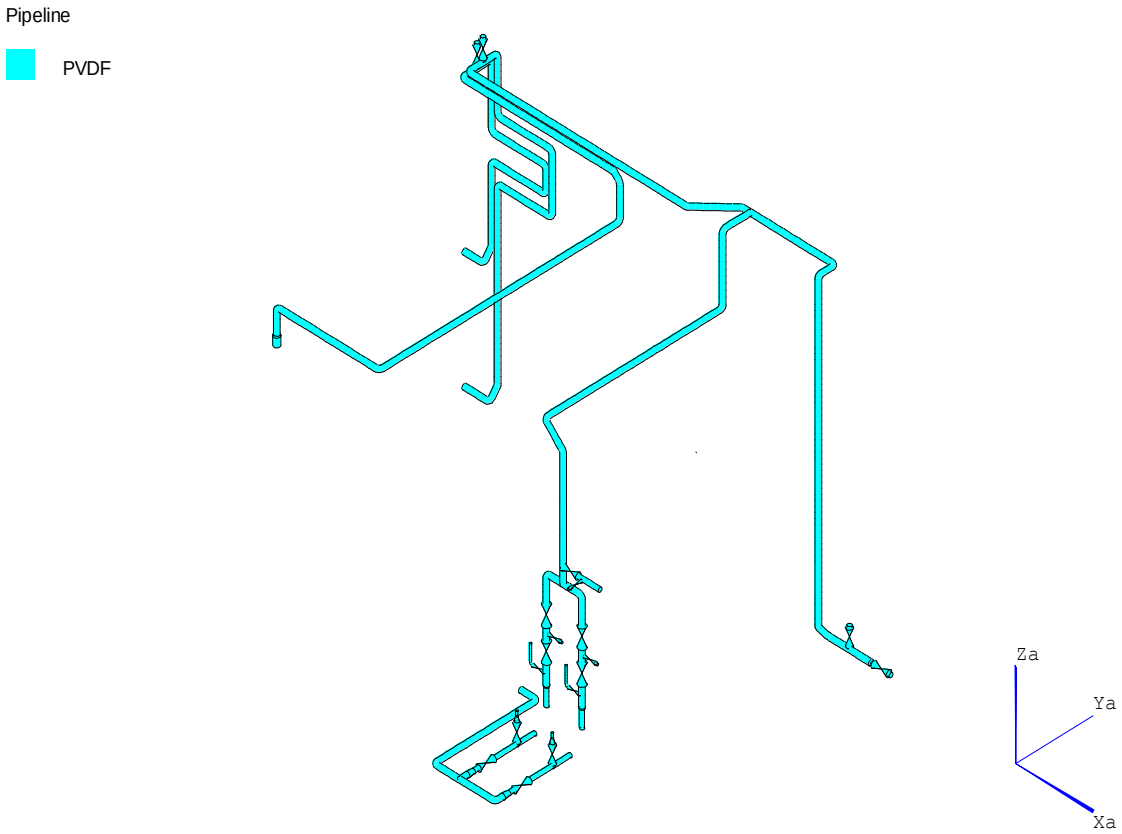
This calculation is based on the following documents:

- Isometrics

3 System description

This calculation includes the following lines / drawings:

PVDF



The following general parameters were considered:

- Density of medium: 1823.0 kg/m³
- Assembly temperature: 25.0 °C

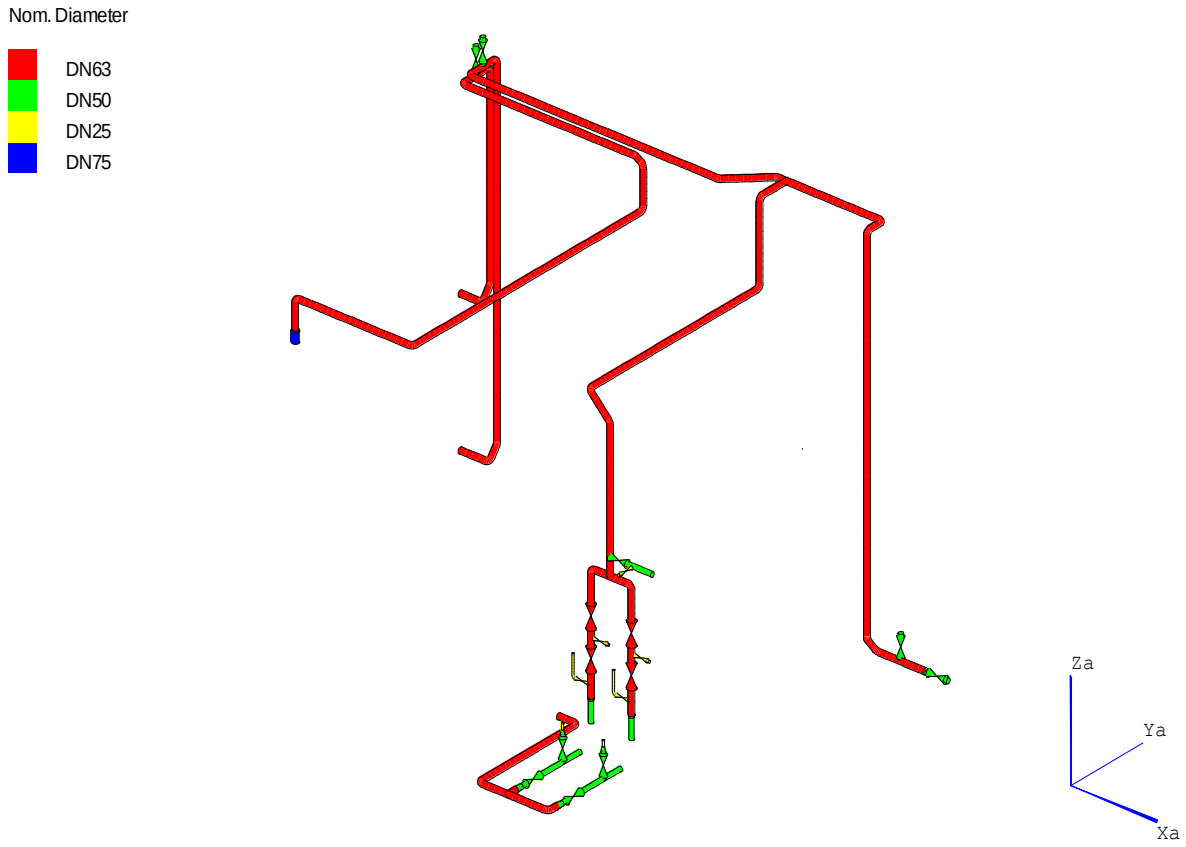
The density of medium is considered for the calculation of the line masses of the pipes. The thermal expansion is calculated due to the difference between assembly temperature and operation temperature.

3.1 Dimensions and calculation data:

3.1.1 Pipe dimensions

Dimension	Da [mm]	s [mm]	Material	Insulation [mm]	Tin-plate [mm]	Calc. temp. [°C]	Calc. pressure [bar]
DN63	63.00	3.00	PVDF_GF	0.00	0.00	70.0	4.15
DN50	50.00	3.00	PVDF_GF	0.00	0.00	70.0	4.15
DN25	25.00	1.90	PVDF_GF	0.00	0.00	70.0	4.15
DN75	75.00	3.60	PVDF_GF	0.00	0.00	70.0	4.15

3.1.2 Structural section dimensions



3.2 Line masses

The following table shows the line masses of the pipes consisting of pipe weight and insulation weight.

<----Dimension [mm]---->				<----Density [kg/m³]---->				<-----Line mass [kg/m]----->			
DA	S	Ins	Jack	Pipe	Ins	Jack	Med	Pipe	Ins	Med	Total
75.00	3.60	0	0.0	1760	0	0	0	1.4	0.0	0.0	1.4
63.00	3.00	0	0.0	1760	0	0	0	1.0	0.0	0.0	1.0
50.00	3.00	0	0.0	1760	0	0	0	0.8	0.0	0.0	0.8
25.00	1.90	0	0.0	1760	0	0	0	0.2	0.0	0.0	0.2

Under consideration of the density of the medium from load case Dead weight the following line masses are determined:

<----Dimension [mm]---->				<----Density [kg/m³]---->				<-----Line mass [kg/m]----->			
DA	S	Ins	Jack	Pipe	Ins	Jack	Med	Pipe	Ins	Med	Total
75.00	3.60	0	0.0	1760	0	0	1823	1.4	0.0	6.6	8.0
63.00	3.00	0	0.0	1760	0	0	1823	1.0	0.0	4.7	5.6
50.00	3.00	0	0.0	1760	0	0	1823	0.8	0.0	2.8	3.6
25.00	1.90	0	0.0	1760	0	0	1823	0.2	0.0	0.6	0.9

3.3 Components

The following components are considered by the calculation:

Instruments:

outer diameter	Design pressure [bar]	Length [mm]	Weight [kg]	Description
d50	4.15	194	1.65	diaphragm-valve
d63	4.15	223	2.57	diaphragm-valve
d25	4.15	144	0.43	diaphragm-valve

4 Load cases

4.1 Overview

The calculation includes the following load cases (LC):

Loadcase	Category	Type of Calculation
Dead load	Primary loads - Dead load	Theory 1. order
Operation	Secondary loads - Thermal expansion	Nonlinear boundary conditions 1. order
Shutdown	Secondary loads - Thermal expansion	Nonlinear boundary conditions 1. order

4.2 Global loads

The following global loads are taken into consideration for the different loadcases:

Loadcase	axial thermal expansion	axial expansion due to operation pressure	Upward bend due to operation pressure	Acceleration due to gravity	Friction	Forces due to internal pressure
Dead load				x		x
Operation	x	x		x	x	x
Shutdown	x	x		x	x	x

4.3 Specific loads of load cases

Dead load

This load case includes loads from internal pressure, and weight from pipe, insulation and medium. In addition loads from internal pressure and forces due to internal pressure at axial expansion joints are taken into consideration.

Load Case Dead load

Operation data

Operation pressure [bar]	Operation temperature [°C]	Density medium [kg/m³]	used in Pipeline
4.15	70.0	1823.0	PVDF

Load Case Operation

Operation data

Operation pressure [bar]	Operation temperature [°C]	Density medium [kg/m³]	used in Pipeline
4.15	70.0	1823.0	PVDF

Load Case Shutdown

Operation data

Operation pressure [bar]	Operation temperature [°C]	Density medium [kg/m³]	used in Pipeline
0.00	20.0	1823.0	PVDF

5 Remarks and changes

5.1 Remarks

The calculation was made with the following assumptions:

- SDR 21 PVDF pipe with diameter of d75, d63, d50, d25
- PN 16
- Installation temperature: 25°C
- Operation temperature: 70°C
- Operation pressure: 4.15 barg
- BCF-welded: weld factor 1
- Supports get the friction coefficient of 0.1
- Sulphuric acid concentration = 93%
- The terms and conditions listed in Appendix 7 apply

5.2 Changes

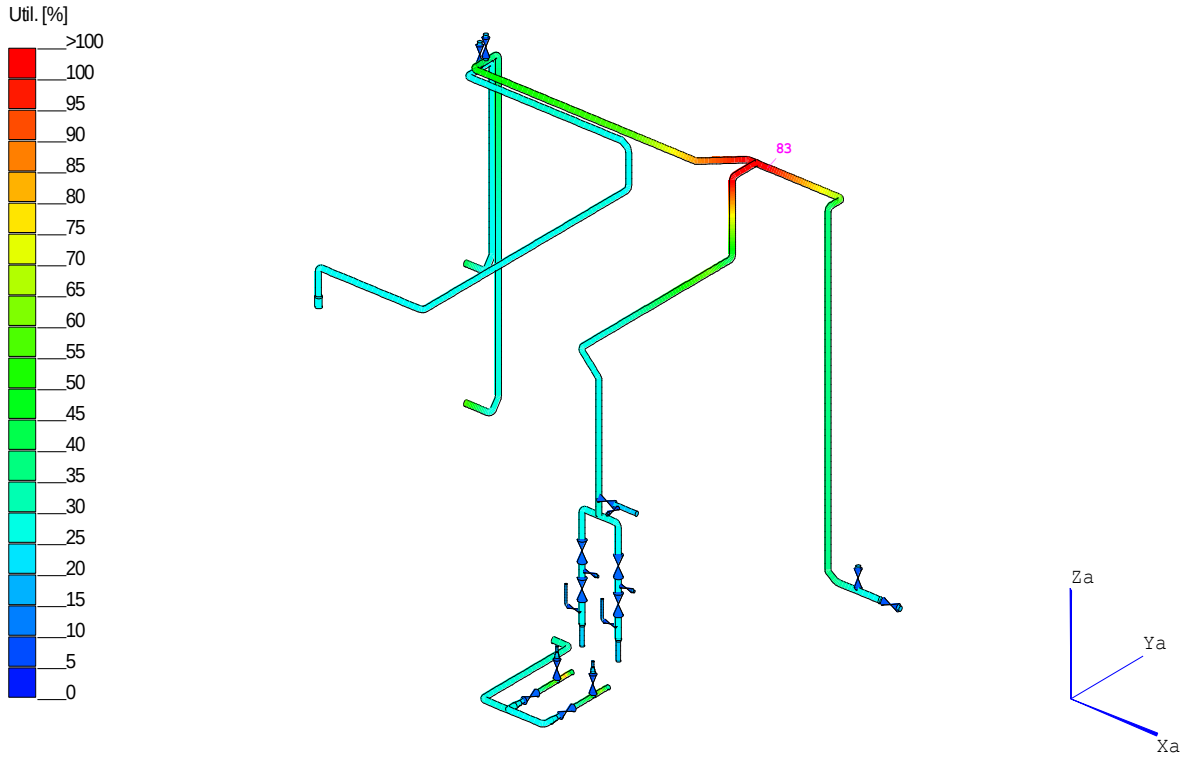
It is recommended to use additional supports according to chapter 6.4.

6 Results

The determined results of the calculated system are based on the assumptions mentioned in this document. If the execution deviates from that assumptions (e.g. geometry, bracket spacing, operation conditions, etc.) other results could be expected. For such considerable changes a recalculation is recommended.

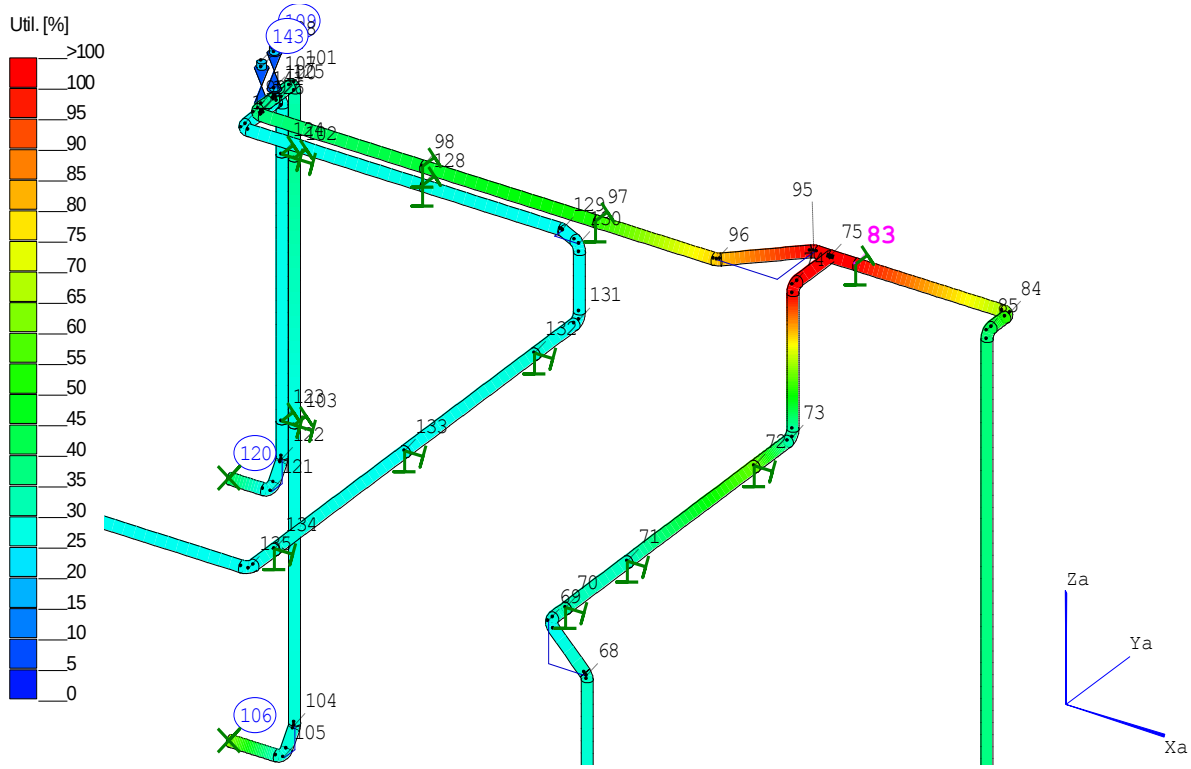
6.1 Stress evaluation VGLSR - Vergleichsspannungen für Rohre acc. to von Mises

Analysis	Eq.	Description	Load cases	Node	S-total [N/mm²]	S-allow. [N/mm²]	Util. [%]
01	SVM	Equivalent stress acc. to von Mises	Dead load	83	42.4	14.8	286.2
02	SVM	Equivalent stress acc. to von Mises	Operation	83	42.4	14.8	286.2
03	SVM	Equivalent stress acc. to von Mises	Shutdown	83	42.2	27.2	155.4



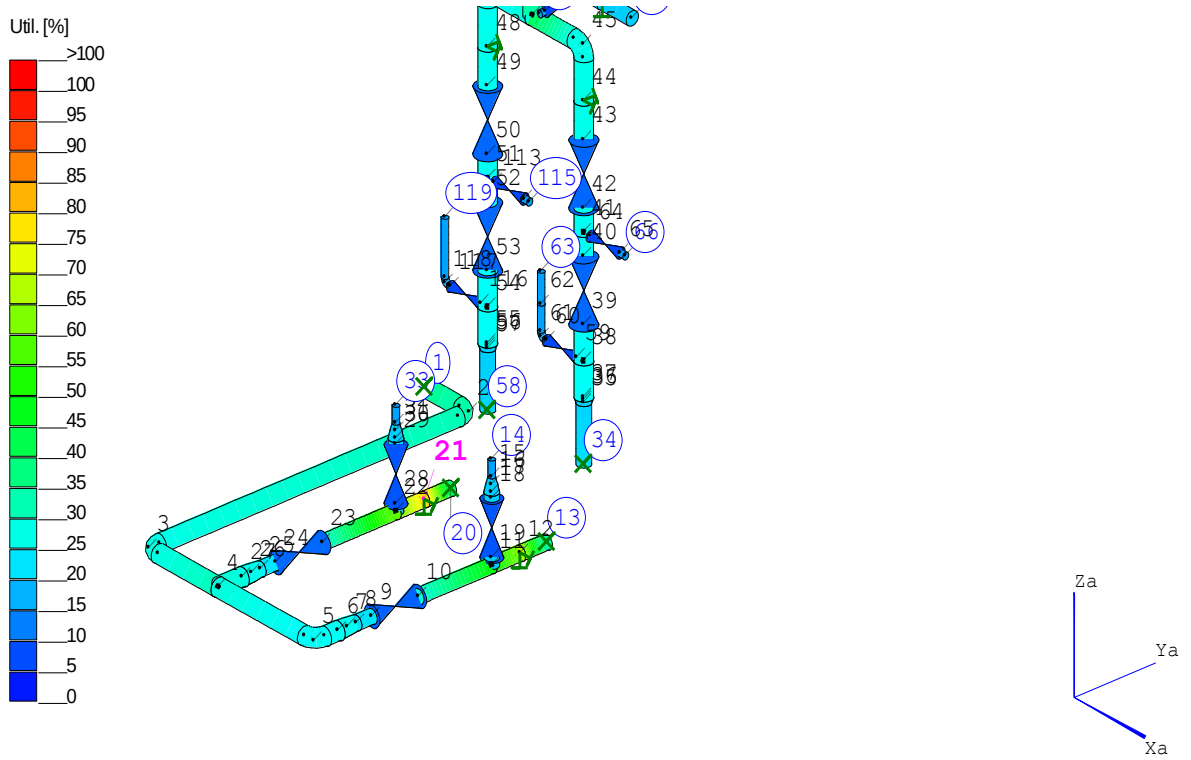
Results Stress analysis acc. to VGLSR - Vergleichsspannungen für Rohre:
Utilisation Analysis 01 Equation SVM (Equivalent stress acc. to von Mises): Max. utilisation 286.2 % at node 83

Figure.: Stress analysis, load case operation



Results Stress analysis acc. to VGLSR - Vergleichsspannungen für Rohre:
Utilisation Analysis 02 Equation SVM (Equivalent stress acc. to von Mises): Max. utilisation 286.0 % at node 83

Figure.: Stress analysis, load case operation, detail at node 83



Results Stress analysis acc. to VGLSR - Vergleichsspannungen für Rohre:
Utilisation Analysis 02 Equation SVM (Equivalent stress acc. to von Mises): Max. utilisation 83.0 % at node 21

Figure.: Stress analysis, load case operation, detail at node 21

For the lifetime independent equations the allowable loads were determined, based on 7000 load cycles.
The calculation of the allowable and calculated stresses are listed in ROHR2 output ”Stresses”.

According to chapter 2.2 a minimum Safety-Factor of 1.6 is required (industry application).

Additionally a chemical reduction-ratio of 1.3 for usage of PVDF with sulphuric acid at 70°C has to be applied accordingly to the chemical resistance table of Georg Fischer Piping Systems.

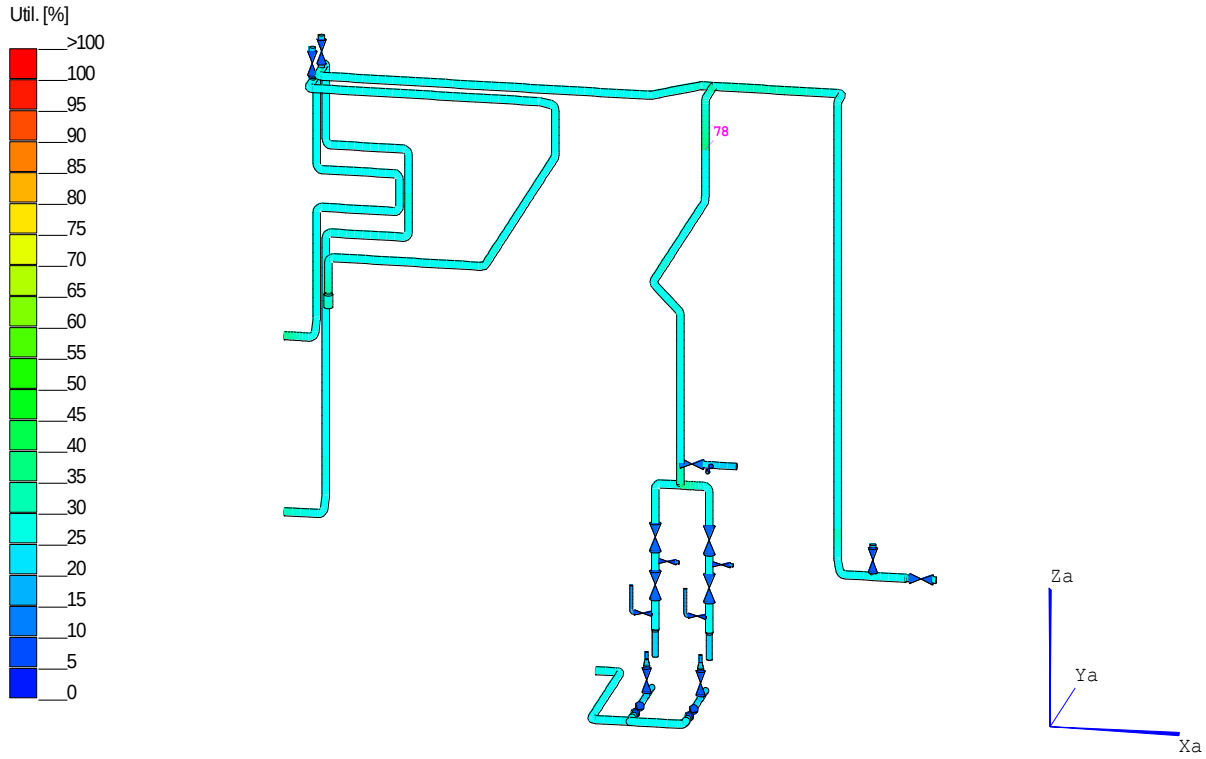
Therefore a safety factor of 1.6 * 1.3 = 2.08 is required

The maximum ratio of the system of S_{zul}/S_{ges} = 14.8 / 42.4 = 0.4 is at node 83 and 14.8 / 12.3 = 1.2 at node 21.

The determined Safety-Factor **does not meet** Georg Fischer Piping Systems’ requirements.

6.2 Stress evaluation VGLSR - Vergleichsspannungen für Rohre, with recommended supports

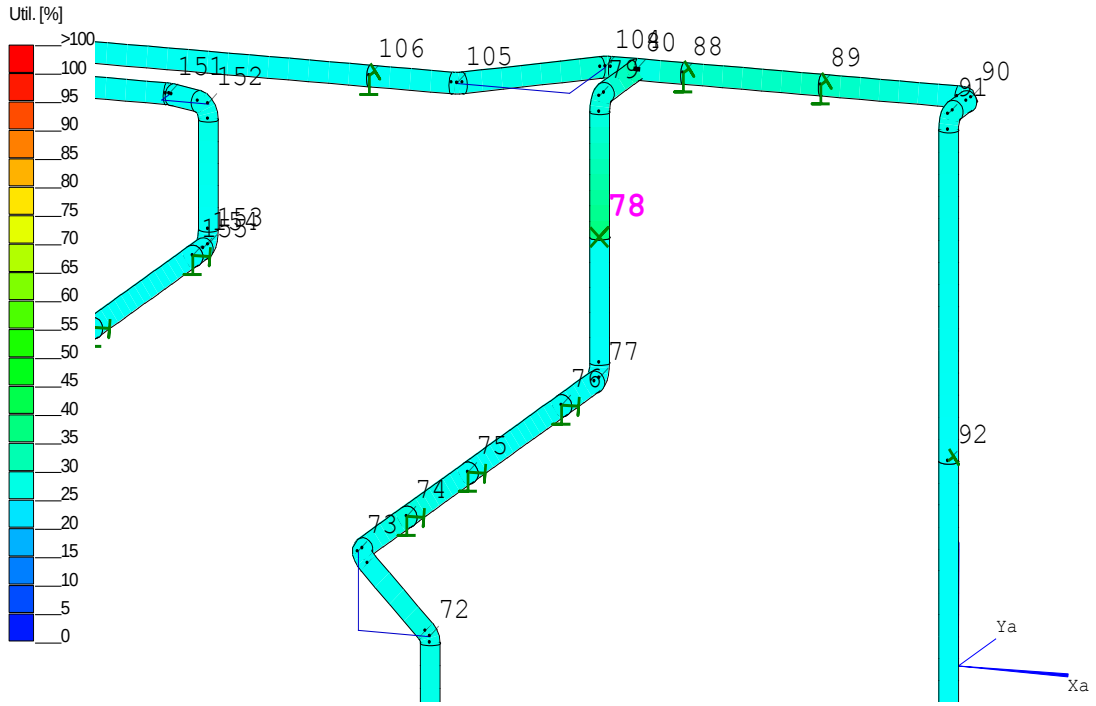
Analysis	Eq.	Description	Load cases	Node	S-total [N/mm²]	S-allow. [N/mm²]	Util. [%]
01	SVM	Equivalent stress acc. to von Mises	Dead load	147	4.0	14.8	27.1
02	SVM	Equivalent stress acc. to von Mises	Operation	78	5.5	14.8	37.1
03	SVM	Equivalent stress acc. to von Mises	Shutdown	103	1.7	27.2	6.4



Results Stress analysis acc. to VGLSR - Vergleichsspannungen für Rohre:
Utilisation Analysis 02 Equation SVM (Equivalent stress acc. to von Mises): Max. utilisation 37.1 % at node 78

Figure.: Stress analysis, load case operation

The maximum ratio of the system of S_{zul}/S_{ges} = 14.8 / 5.5 = 2.7 is at node 78.



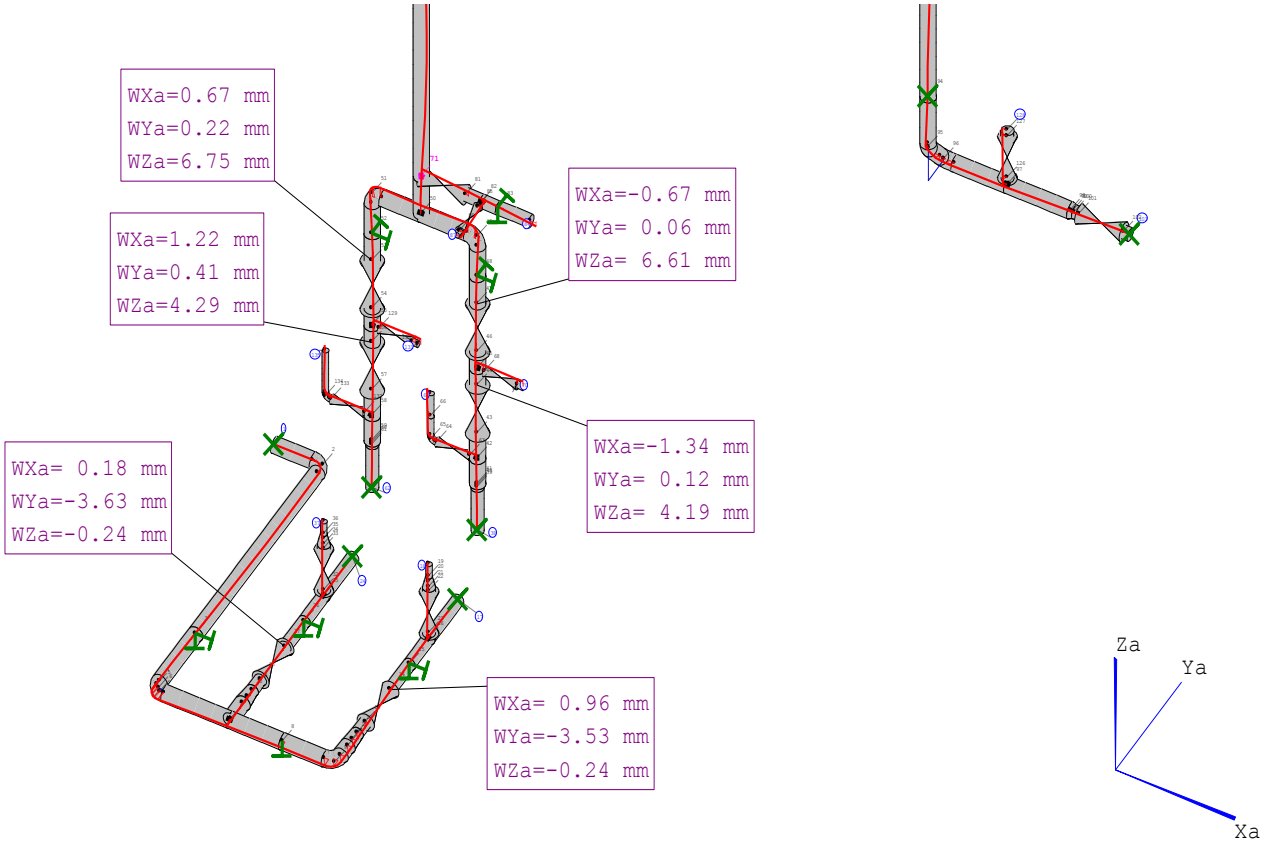
Results Stress analysis acc. to VGLSR - Vergleichsspannungen für Rohre:
Utilisation Analysis 02 Equation SVM (Equivalent stress acc. to von Mises): Max. utilisation 37.1 % at node 78

Figure.: Stress analysis, load case operation, detail node 78

The determined Safety-Factor **does meet** Georg Fischer Piping Systems' requirements.

6.3 Movement of Valves

The calculated movement of valves (case with recommended supports) can be found on the following figure. The maximum movement of 6.75 mm in z (WZa) direction is the topmost valve on the discharge side of the left pump.



Results load case Operation - Displacements:
Extreme value: Xa=1.70 mm, Ya=-1.89 mm, Za=8.59 mm, Res=8.96 mm at node 71

Figure.: valve movement, load case operation, suction and discharge side of pumps

6.4 Recommendations

The following figures are showing the recommended measurements of the guides to avoid high strain. Also the new Fix-Points and new guides are shown.

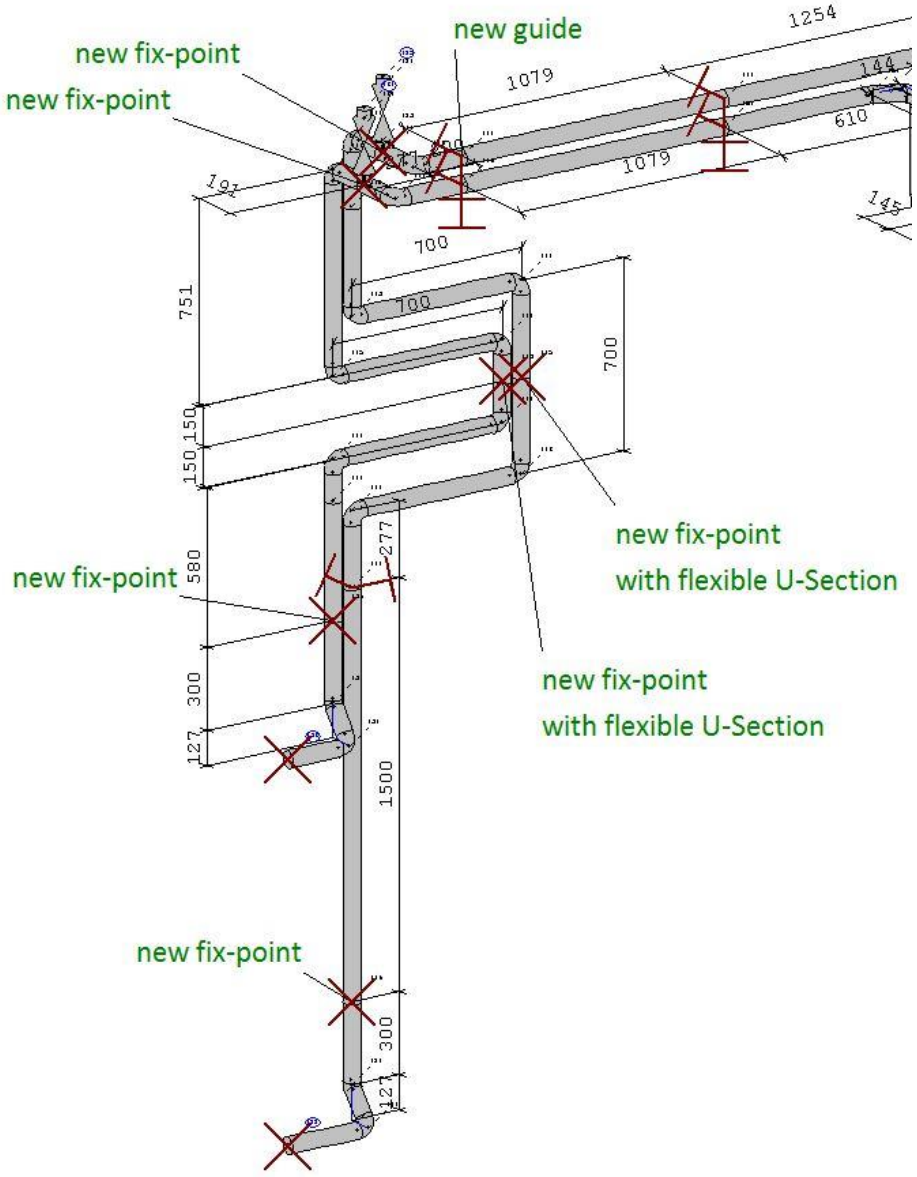


Figure.: recommended measurements of guides with a new flexible U-section

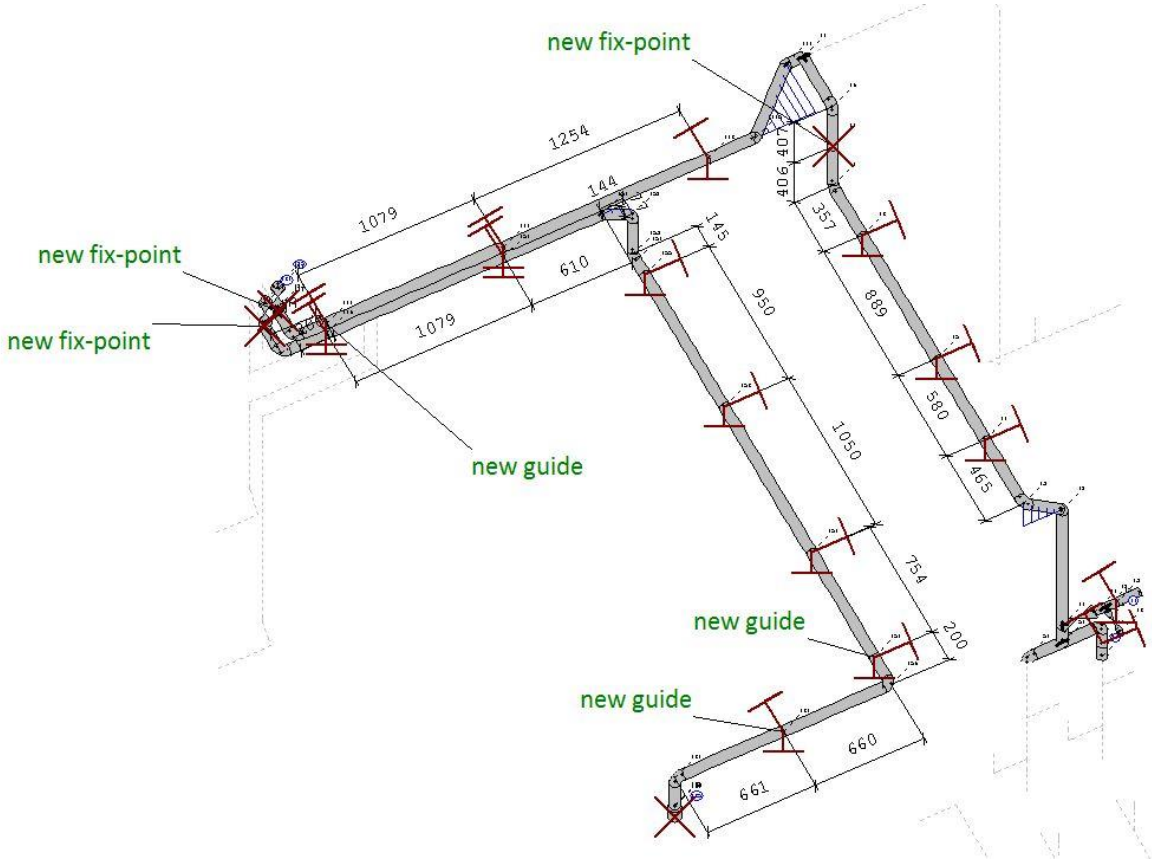


Figure.: recommended measurements of guides

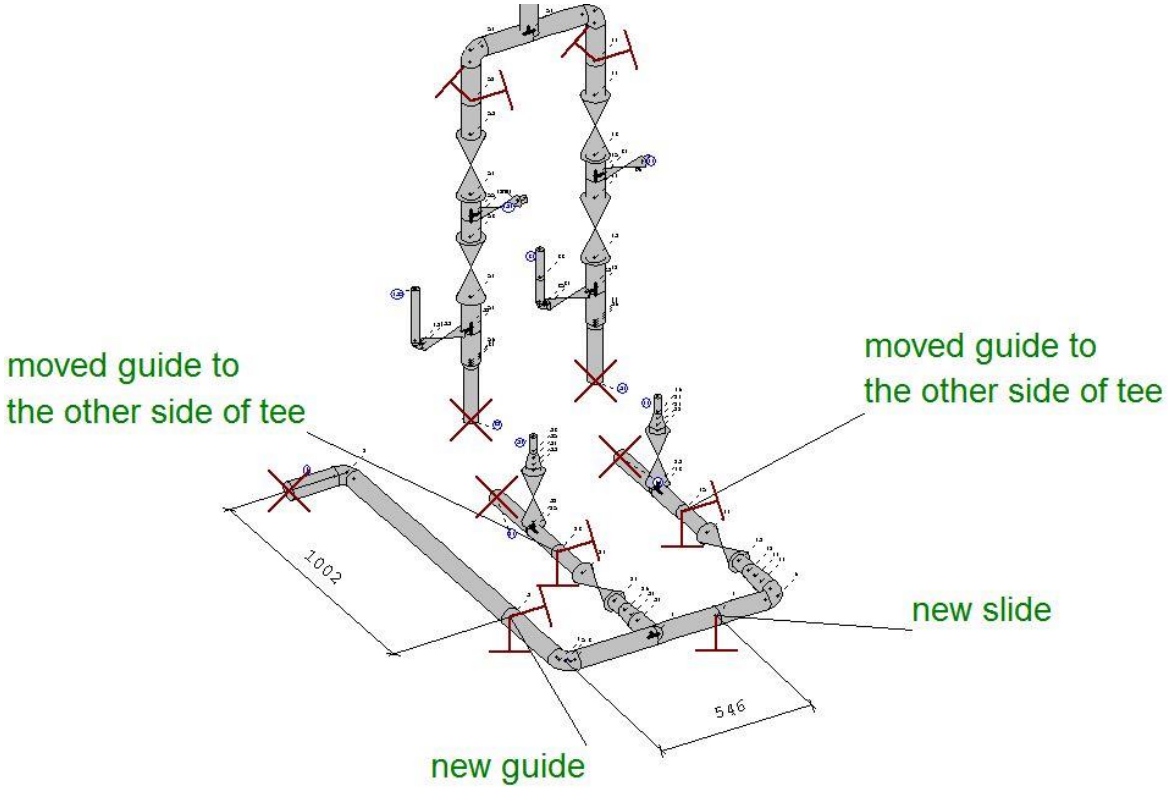


Figure.: recommended measurements of guides

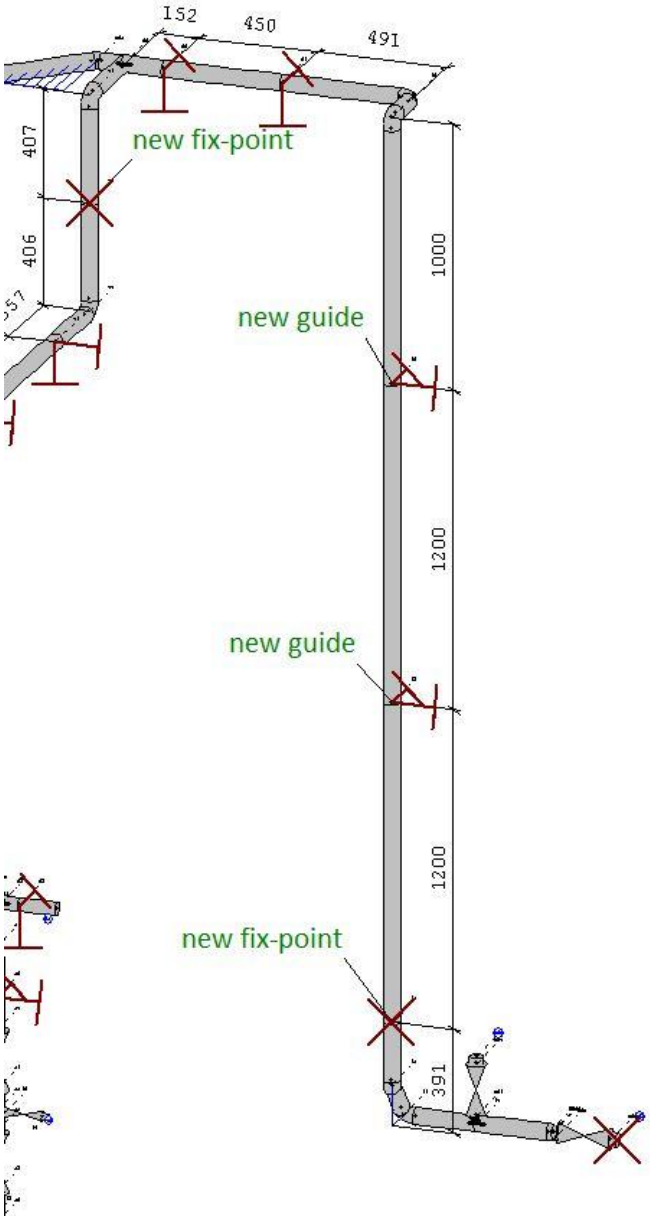


Figure.: recommended measurements of guides

7 Appendix

- System plots and detail plots
- Load cases
- Stresses
- Loads on supports
- Detail deflection table and figures

By using this report the following terms and conditions are accepted: