

20180315HN/02

28 March 2018

# Water and air tightness of NOFIRNO sealing system

Assessment Report



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**20180315HN/02**

28 March 2018

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## Assessment Report

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**Kiwa Nederland B.V.**  
Sir Winston Churchilllaan 273  
Postbus 70  
2280 AB RIJSWIJK  
The Netherlands

Tel. +31 88 998 44 00  
Fax +31 88 998 44 20  
[info@kiwa.nl](mailto:info@kiwa.nl)  
[www.kiwa.nl](http://www.kiwa.nl)

## Colophon

<b>Title</b>	Water and air tightness of NOFIRNO sealing system
<b>Project Number</b>	140101157
<b>Project Manager</b>	Hans Naus
<b>Contractor</b>	Beele Engineering B.V.
<b>Quality Assurance</b>	Jaap Havinga
<b>Author(s)</b>	Hans Naus

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# Preface

This report describes the assessment of the water and air tightness of the NOFIRNO sealing system for pipe and cable penetrations at static pressurised conditions.

This report replaces assessment report 20180315HN/01 dated 15 March 2018.



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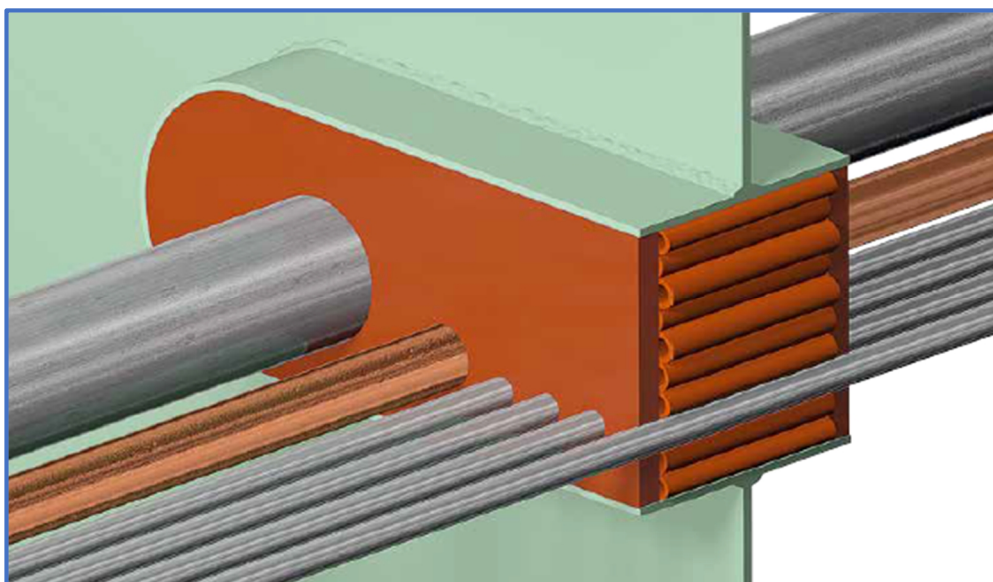
# 1 NOFIRNO sealing system

## 1.1. Description of the NOFIRNO sealing system

The sealing system consists of a combination of rubber filler sleeves and a sealant. Ducted cables are provided with rubber cable insert sleeves. The aperture between penetrating pipes and/or cables and wall of the transit is filled with filler sleeves and on both sides the conduit opening is sealed with a sealant. The thickness of the sealant layer is 15 or 20 mm, depending on the specific application. For special applications the sealant layer may only be present at one side.

## 1.2. Intended use

The sealing system is intended to be used for the sealing of the transit of multi-pipes and multi-cables through a penetration in rigid walls, floors, bulkheads and decks. The sealing system is applied in an opening in a concrete wall or floor, or a metal or glass-reinforced plastic conduit frame. The conduit frame is pre-installed in the wall, floor, bulkhead or deck by means of a proper method (e.g. installed during casting a concrete wall or welded in a metal bulkhead).



*Example of multi-pipe transit with NOFIRNO sealing system*



## 2 Performance tests

### 2.1 Testing of water and air tightness

Hydrostatic pressure tests have been carried out on various transit designs with various dimensions (circular transits up to ID 400 mm, rectangular transits up to 1000 x 600 mm), blank transits and transits with various numbers of ducted pipes and cables in different diameters.

The tests have been carried out according to the test methods as described in Kiwa test protocols – Water tightness Version 2015-10-16 – Protocol A (initial) and B (after ageing) and Gas tightness Version 2015-10-16 – Protocol A (initial) and B (after ageing).

The test methods comply with the principles of the test methods according to Germanischer Lloyd - Rules for Classification and Construction (VI Additional Rules and Guidelines – Part 7 Guidelines for the Performance of Type Approvals – Chapter 4 Test Requirements for Sealing Systems of Bulkhead and Deck Penetrations – Section 3 Test requirements - C Water tightness and D Gas tightness, Edition 2014), and to

DNVGL-CP-0165 Edition February 2016 (Section 2, chapter 4).

### 2.2 Dynamic testing of axial movements

Dynamic tests have been carried out on various transits with single ducted pipe (circular conduit sleeves ID 72 to 102 mm, ducted pipe OD 42), sealed with NOFIRNO sealing system. The pipe was displaced in axial direction up till 50 mm; total amount of cycles 100, speed of displacement up till 750 mm/min.

### 2.3 Test reports

- Static pressure tests  
ABS report RO2497866-G (WT 1312-127), ABS report RO2607120-B (WT 1404-131), RO2607103-B (WT 1404-133) WT 1408-140, WT 1411-142, WT 1412-116, ABS report RO2793456 (WT 1412-146), WT 1502-147, WT 1512-172 – long term, WT 1603-182 – long term, WT 1603-185, WT 1603-186, WT 1606-193 – long term, WT 1709-224.

These tests have been witnessed by ABS or Kiwa.

- Dynamic tests  
Report 1506-158

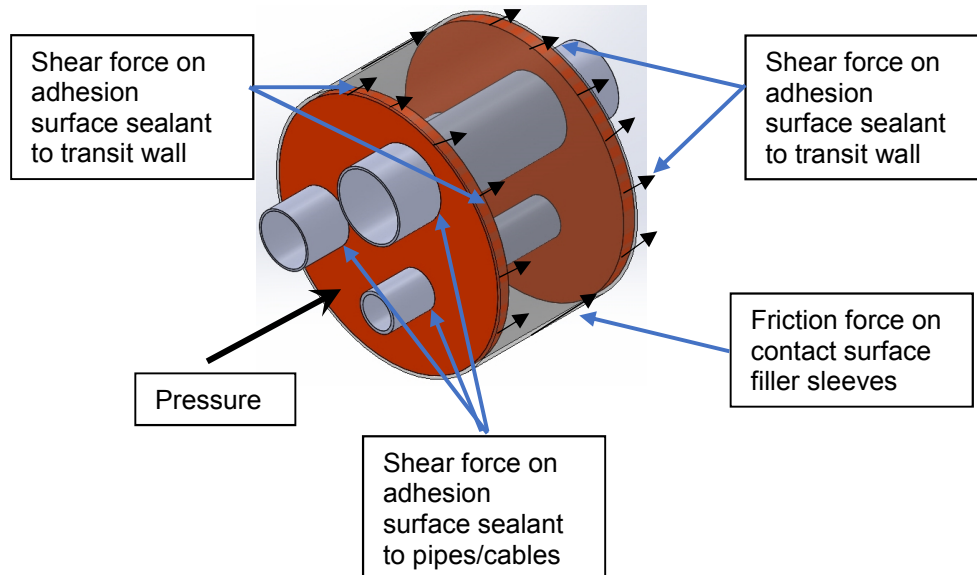
These tests have been witnessed by Kiwa.



## 3 Assessment

### 3.1 Evaluation

The physical principles of the forces working on the sealing system due to a static pressure at one side of the transit can be described as follows.



The sealant layers are bonded to the surface of the transit wall. The sealant layers are also bonded to the filler sleeves. The filler sleeves are not bonded to the surfaces of the transit wall and the ducted pipes and/or cables.

The static water or air pressure causes a shear force on the contact surfaces of the sealant with the transit wall and the ducted pipes and/or cables, as well as friction forces on the surface of the filler sleeves.

Static water pressure tests on relatively large blind transits sealed with the NOFIRNO sealing system showed a bulging of the sealant surface at the non-exposed side at high pressures, resulting in a combination of shear and strain of the sealant and shear deformation of the filler sleeves. After releasing the pressure, the sealing system returned to its initial position without showing permanent deformation.

Dynamic tests with axial movements of ducted pipes showed no failure of the sealant layers (rupture or loss of adhesion) at large strains. No permanent deformation of the sealing system was observed after return of the pipes to their initial positions.

The tests showed that the total sealing system, consisting of the sandwich of two layers of sealant and filler sleeves, acts as one system under static pressure and dynamic axial pipe (or cable) movements.

For a set of blind, (multi-)pipe and (multi-)cable transits the water pressure was raised in steps of 0,5 bar each 30 minutes until leakage occurred. For transits of minimum length 100 mm with minimum 15 mm sealant layer on both sides the maximum water pressure showed to be independent of the length of the transit, i.e. the length of the filler sleeves. Increasing the pressure until failure always resulted in a small leakage along the contact surface between sealant layer and transit wall. This means that the maximum pressure is ruled by the adhesion performance of the sealant and not by the friction performance of the filler sleeves.

The total shear load (force times surface area) on the sealant is compensated by the total adhesion strength of the sealant. The system is water and air tight until the adhesion of the sealant fails.



Using the results of these tests the maximum allowed shear load per unit adhesion surface of the sealant was calculated.  
The physical relation of the maximum pressure that the sealing system can resist as a function of the shape factor <sup>1</sup> was derived.  
This relation was validated by conducting pressure tests on various blind, (multi-)pipe and (multi-)cable transits until the calculated maximum pressure.  
All tested transits met this criterion.

The maximum allowed water or air pressure is set on 90 % of the tested criterion for each shape factor.

The derived relation between allowed pressure and shape factor S is

$$P = 5/S$$

See the figure on page 7.

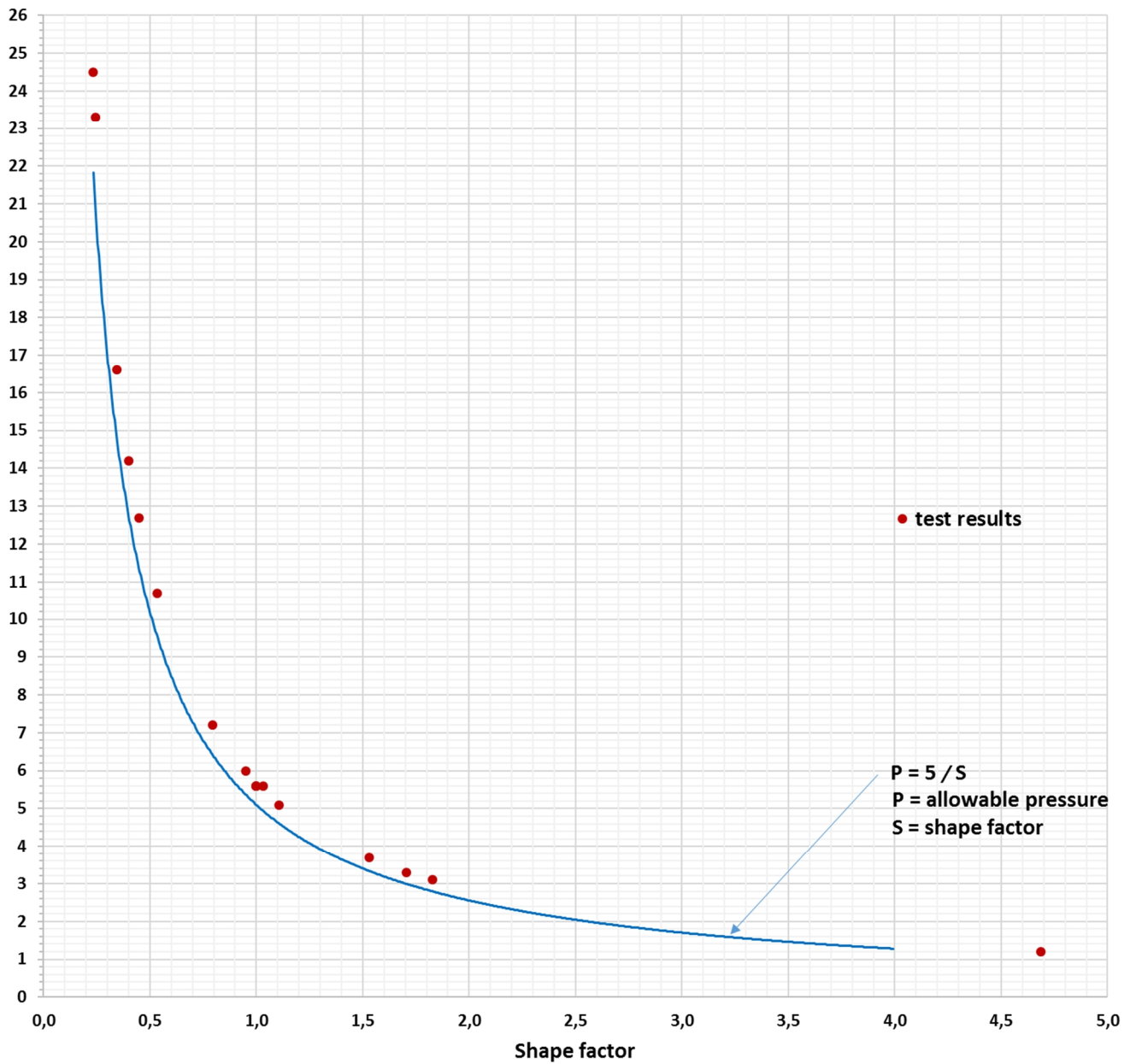
<sup>1</sup> see page 8 for the explanation of the shape factor.





allowable water pressure against shape factor for NOFIRNO sealing system  
blind, multi-pipe and multi-cable penetrations in transits of any design

Pressure [bar]





### 3.2 Relation between maximum pressure and penetration design

The maximum static pressure that a penetration that is sealed with round rubber sleeves and covered with elastomeric sealant layers is depending on the shape factor.

The shape factor is the ratio of the sealant surface facing the pressure and the total adhesion surface of the sealant.

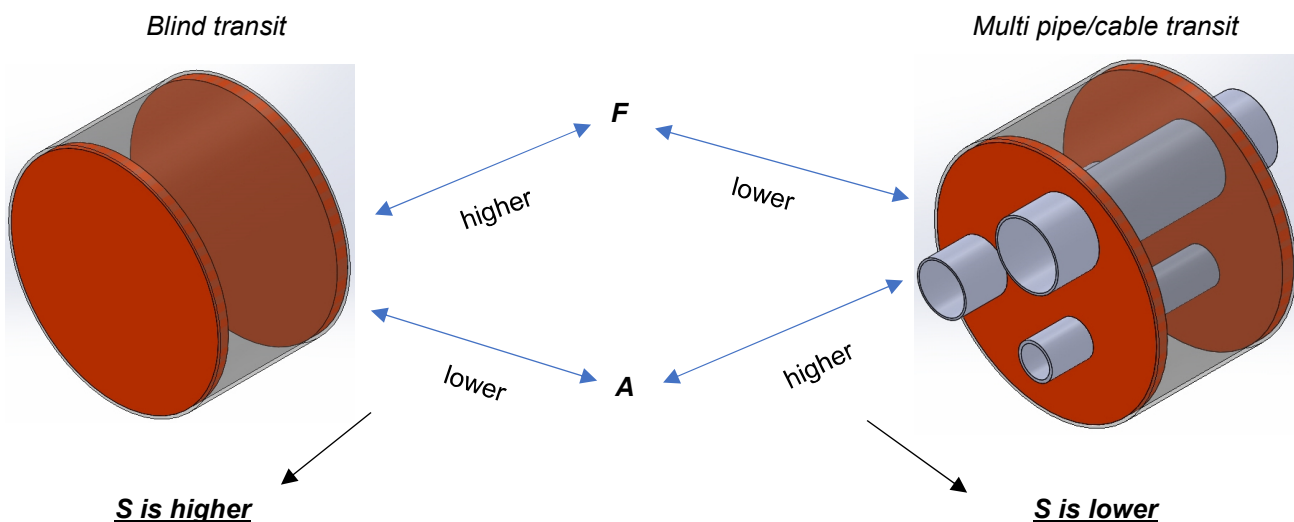
$$\text{Shape factor } (S) = \frac{\text{Pressurised sealant surface } (F)}{\text{Sealant adhesion surface } (A)}$$

F is a function of:

- dimensions of aperture opening in transit frame (aperture surface)
- number and outer diameters of ducted pipes and cables (total ducted surface)

A is a function of:

- dimensions of aperture opening in transit frame (aperture circumference)
- number and outer diameters of ducted pipes and cables (total circumference)
- total thickness of sealant layers (both sides)



## 4 Signature

Rijswijk, March 2018

Hans Naus  
Senior Consultant Rubber

Kiwa Nederland B.V.

Jaap Havinga  
Authorisation



# Annex A. Examples of allowed static water pressure for pipe transits

Calculation based on derived model in the assessment.

Configuration #1													
Area	Configuration	Pipe Material	Pipe Diameter	OD			OD			Clearance for Nofirno Seal	Chartek 7 Thickness on Exposed Side	Coat back Length on Exposed Side	Allowed static water pressure [bar]
				Pipe ND	Pipe Actual Diameter	Pipe Wall Thickness	Sleeve Diameter	Sleeve Wall Thickness					
-	-	-	NPS	ND	mm	mm	mm	mm	mm	mm	mm		
Steel Deck	Config 1	STEEL	1"	25	33,4	4,55	114,3	8,60	31,85	10	386	10,1	
Steel Deck	Config 1	STEEL	1-1/2"	40	48,3	5,08	141,3	9,50	37,00	10	469	8,8	
Steel Deck	Config 1	STEEL	2"	50	60,3	3,91	168,3	10,97	43,03	10	529	7,5	
Steel Deck	Config 1	STEEL	2"	50	60,3	5,54	168,3	10,97	43,03	10	529	7,5	
Steel Deck	Config 1	STEEL	2"	50	60,3	8,74	168,3	10,97	43,03	10	529	7,5	
Steel Deck	Config 1	STEEL	2"	50	60,3	11,07	168,3	10,97	43,03	10	529	7,5	
Steel Deck	Config 1	STEEL	3"	80	88,9	3,05	168,3	10,97	28,73	10	656	10,3	
Steel Deck	Config 1	STEEL	3"	80	88,9	7,62	168,3	10,97	28,73	10	656	10,3	
Steel Deck	Config 1	STEEL	3"	80	88,9	15,24	168,3	10,97	28,73	10	656	10,3	
Steel Deck	Config 1	STEEL	4"	100	114,3	3,05	219,1	12,70	39,70	10	762	7,8	
Steel Deck	Config 1	STEEL	4"	100	114,3	6,02	219,1	12,70	39,70	10	762	7,8	
Steel Deck	Config 1	STEEL	4"	100	114,3	13,49	219,1	12,70	39,70	10	762	7,8	
Steel Deck	Config 1	STEEL	4"	100	114,3	18,00	219,1	12,70	39,70	10	762	7,8	
Steel Deck	Config 1	STEEL	8"	200	219,1	8,18	323,9	17,48	34,92	10	1163	7,8	
Steel Deck	Config 1	STEEL	8"	200	219,1	12,70	323,9	17,48	34,92	10	1163	7,8	
Steel Deck	Config 1	STEEL	12"	300	323,8	9,53	425,0	15,00	35,60	10	1543	8,1	
Steel Deck	Config 1	STEEL	12"	300	323,8	33,32	425,0	15,00	35,60	10	1543	8,1	
Steel Deck	Config 1	STEEL	14"	350	355,6	25,40	476,0	15,00	45,20	10	1657	6,8	
Steel Deck	Config 1	STEEL	3/8"	T10	10,0	2,18	114,3	8,60	43,55	10	304	7,8	
Steel Deck	Config 1	STEEL	1/2"	T12	12,0	2,11	114,3	8,60	42,55	10	304	8	
Steel Deck	Config 1	STEEL	1"	T25	25,0	5,56	114,3	8,60	36,05	10	386	9,1	
Steel Deck	Config 1	Cu/Ni	2"	50	60,3	2,50	168,3	10,97	43,03	10	618	7,5	
Steel Deck	Config 1	Cu/Ni	10"	250	273,1	5,50	406,4	19,05	47,60	10	1587	6,1	
Steel Deck	Config 1	GRP	4"	100	114,3	5,00	219,1	12,70	39,70	10	3000	8,8	

Configuration #2												
Area	Configuration	Pipe Material	Pipe Diameter	Pipe ND	Pipe Actual Diameter	Pipe Wall Thickness	Sleeve Diameter	Sleeve Wall Thickness	Clearance for Nofirno Seal	Pyrogel XTF Thickness on Unexposed Side	Coat back Length on Unexposed Side	Allowed static water pressure [bar]
Steel Deck	Config 2	STEEL	1"	25	33,4	4,55	114,3	8,60	31,85	3 x 10	386	10,1
Steel Deck	Config 2	STEEL	1-1/2"	40	48,3	5,08	141,3	9,50	37,00	3 x 10	469	8,8
Steel Deck	Config 2	STEEL	2"	50	60,3	3,91	168,3	10,97	43,03	3 x 10	529	7,5
Steel Deck	Config 2	STEEL	2"	50	60,3	5,54	168,3	10,97	43,03	3 x 10	529	7,5
Steel Deck	Config 2	STEEL	2"	50	60,3	8,74	168,3	10,97	43,03	3 x 10	529	7,5
Steel Deck	Config 2	STEEL	2"	50	60,3	11,07	168,3	10,97	43,03	3 x 10	529	7,5
Steel Deck	Config 2	STEEL	3"	80	88,9	3,05	168,3	10,97	28,73	3 x 10	656	10,3
Steel Deck	Config 2	STEEL	3"	80	88,9	7,62	168,3	10,97	28,73	3 x 10	656	10,3
Steel Deck	Config 2	STEEL	3"	80	88,9	15,24	168,3	10,97	28,73	3 x 10	656	10,3
Steel Deck	Config 2	STEEL	4"	100	114,3	3,05	219,1	12,70	39,70	3 x 10	762	7,8
Steel Deck	Config 2	STEEL	4"	100	114,3	6,02	219,1	12,70	39,70	3 x 10	762	7,8
Steel Deck	Config 2	STEEL	4"	100	114,3	13,49	219,1	12,70	39,70	3 x 10	762	7,8
Steel Deck	Config 2	STEEL	4"	100	114,3	18,00	219,1	12,70	39,70	3 x 10	762	7,8
Steel Deck	Config 2	STEEL	8"	200	219,1	8,18	323,9	17,48	34,92	3 x 10	1163	7,8
Steel Deck	Config 2	STEEL	8"	200	219,1	12,70	323,9	17,48	34,92	3 x 10	1163	7,8
Steel Deck	Config 2	STEEL	12"	300	323,8	9,53	425,0	15,00	35,60	3 x 10	1543	8,1
Steel Deck	Config 2	STEEL	12"	300	323,8	33,32	425,0	15,00	35,60	3 x 10	1543	8,1
Steel Deck	Config 2	STEEL	14"	350	355,6	25,40	476,0	15,00	45,20	3 x 10	1657	6,8
Steel Deck	Config 2	STEEL	3/8"	T10	10,0	2,18	114,3	8,60	43,55	3 x 10	304	7,8
Steel Deck	Config 2	STEEL	1/2"	T12	12,0	2,11	114,3	8,60	42,55	3 x 10	304	8
Steel Deck	Config 2	STEEL	1"	T25	25,0	5,56	114,3	8,60	36,05	3 x 10	386	9,1
Steel Deck	Config 2	Cu/Ni	2"	50	60,3	2,50	168,3	10,97	43,03	3 x 10	618	7,5
Steel Deck	Config 2	Cu/Ni	10"	250	273,1	5,50	406,4	19,05	47,60	3 x 10	1587	6,1
Steel Deck	Config 2	GRP	4"	100	114,3	5,00	219,1	12,70	39,70	3 x 10	3000	8,8



Configuration #3												
Area	Configuration	Pipe Material	Pipe Diameter	Pipe ND	Pipe Actual Diameter	Pipe Wall Thickness	Sleeve Diameter	Sleeve Wall Thickness	Clearance for Nofirno Seal	Chartek 7 Thickness on Exposed Side	Coat back Length on Exposed Side	Allowed static water pressure [bar]
-	-	-	NPS	ND	mm	mm	mm	mm	mm	mm	mm	
One-side Wall	Config 3	STEEL	1"	25	33,4	4,55	114,3	8,60	31,85	10	314	10,1
One-side Wall	Config 3	STEEL	1-1/2"	40	48,3	5,08	141,3	9,50	37,00	10	382	8,8
One-side Wall	Config 3	STEEL	2"	50	60,3	3,91	168,3	10,97	43,03	10	430	7,5
One-side Wall	Config 3	STEEL	2"	50	60,3	5,54	168,3	10,97	43,03	10	430	7,5
One-side Wall	Config 3	STEEL	3"	80	88,9	3,05	168,3	10,97	28,73	10	533	7,5
One-side Wall	Config 3	STEEL	3"	80	88,9	5,49	168,3	10,97	28,73	10	533	7,5
One-side Wall	Config 3	STEEL	3"	80	88,9	7,62	168,3	10,97	28,73	10	533	7,5
One-side Wall	Config 3	STEEL	3"	80	88,9	11,13	168,3	10,97	28,73	10	533	7,5
One-side Wall	Config 3	STEEL	3"	80	88,9	15,24	168,3	10,97	28,73	10	533	7,5
One-side Wall	Config 3	STEEL	4"	100	114,3	3,05	219,1	12,70	39,70	10	619	7,8
One-side Wall	Config 3	STEEL	4"	100	114,3	6,02	219,1	12,70	39,70	10	619	7,8
One-side Wall	Config 3	STEEL	6"	150	168,3	3,40	273,1	15,09	37,31	10	791	7,8
One-side Wall	Config 3	STEEL	6"	150	168,3	7,11	273,1	15,09	37,31	10	791	7,8
One-side Wall	Config 3	STEEL	6"	150	168,3	18,26	273,1	15,09	37,31	10	791	7,8
One-side Wall	Config 3	STEEL	8"	200	219,1	3,76	323,9	17,48	34,92	10	946	7,8
One-side Wall	Config 3	STEEL	8"	200	219,1	6,35	323,9	17,48	34,92	10	946	7,8
One-side Wall	Config 3	STEEL	8"	200	219,1	8,18	323,9	17,48	34,92	10	946	7,8
One-side Wall	Config 3	STEEL	10"	250	273,1	4,19	406,4	19,05	47,60	10	1106	6,1
One-side Wall	Config 3	STEEL	12"	300	323,8	4,57	425,0	15,00	35,60	10	1255	8,1
One-side Wall	Config 3	STEEL	16"	400	406,4	9,53	527,0	15,00	45,30	10	1494	6,8
One-side Wall	Config 3	STEEL	18"	450	457,0	7,92	600,0	15,00	56,50	10	1640	5,7
One-side Wall	Config 3	STEEL	18"	450	457,0	11,92	600,0	15,00	56,50	10	1640	5,7
One-side Wall	Config 3	STEEL	20"	500	508,0	12,70	686,0	15,00	74,00	10	1785	4,6
One-side Wall	Config 3	STEEL	24"	600	610,0	9,53	806,0	15,00	83,00	10	2074	4,2
One-side Wall	Config 3	STEEL	30"	750	762,0	12,70	1016,0	15,00	112,00	10	2056	3,2
One-side Wall	Config 3	STEEL	36"	900	914,0	12,70	1176,0	15,00	116,00	10	2936	3,1
One-side Wall	Config 3	Cu/Ni	6"	150	168,3	3,50	273,1	15,09	37,31	10	923	7,8
One-side Wall	Config 3	Cu/Ni	8"	200	219,1	4,50	323,9	17,48	34,92	10	1103	7,8
One-side Wall	Config 3	Cu/Ni	10"	250	273,1	5,50	406,4	19,05	47,06	10	1290	6,1
One-side Wall	Config 3	GRP	2"	50	60,3	5,00	168,3	10,97	43,03	10	3000	7,5
One-side Wall	Config 3	GRP	3"	80	88,9	5,00	168,3	10,97	28,73	10	3000	7,5
One-side Wall	Config 3	GRP	4"	100	114,3	5,00	219,1	12,07	39,70	10	3000	7,8
One-side Wall	Config 3	GRP	6"	150	168,3	5,00	273,1	15,09	37,31	10	3000	7,8

Configuration #4												
Area	Configuration	Pipe Material	Pipe Diameter	Pipe ND	Pipe Actual Diameter	Pipe Wall Thickness	Sleeve Diameter	Sleeve Wall Thickness	Clearance for Nofirno Seal	Chartek 7 Thickness on Both Sides	Coat back Length on Both Side	Allowed static water pressure [bar]
-	-	-	NPS	ND	mm	mm	mm	mm	mm	mm	mm	
Both-side Wall	Config 4	STEEL	1"	25	33,4	4,55	114,3	8,60	31,85	10	314	10,1
Both-side Wall	Config 4	STEEL	1-1/2"	40	48,3	5,08	141,3	9,50	37,00	10	382	8,8
Both-side Wall	Config 4	STEEL	2"	50	60,3	3,91	168,3	10,97	43,03	10	430	7,5
Both-side Wall	Config 4	STEEL	2"	50	60,3	5,54	168,3	10,97	43,03	10	430	7,5
Both-side Wall	Config 4	STEEL	2"	50	60,3	11,07	168,3	10,97	43,03	10	430	7,5
Both-side Wall	Config 4	STEEL	3"	80	88,9	3,05	168,3	10,97	28,73	10	533	7,5
Both-side Wall	Config 4	STEEL	3"	80	88,9	5,49	168,3	10,97	28,73	10	533	7,5
Both-side Wall	Config 4	STEEL	3"	80	88,9	7,62	168,3	10,97	28,73	10	533	7,5
Both-side Wall	Config 4	STEEL	4"	100	114,3	3,05	219,1	12,70	39,70	10	619	7,8
Both-side Wall	Config 4	STEEL	4"	100	114,3	6,02	219,1	12,70	39,70	10	619	7,8
Both-side Wall	Config 4	STEEL	4"	100	114,3	8,56	219,1	12,70	39,70	10	619	7,8
Both-side Wall	Config 4	STEEL	6"	150	168,3	21,95	273,1	15,09	37,31	10	791	7,8
Both-side Wall	Config 4	STEEL	8"	200	219,1	8,18	323,9	17,48	34,92	10	946	7,8
Both-side Wall	Config 4	STEEL	8"	200	219,1	12,70	323,9	17,48	34,92	10	946	7,8
Both-side Wall	Config 4	STEEL	8"	200	219,1	25,40	323,9	17,48	34,92	10	946	7,8
Both-side Wall	Config 4	STEEL	12"	300	323,8	9,53	425,0	15,00	35,60	10	1255	8,1
Both-side Wall	Config 4	STEEL	12"	300	323,8	35,40	425,0	15,00	35,60	10	1255	8,1