

## ***VACONODOME***

Clear-Span Aluminium Dome Roofs for storage Tanks  
And Waste Water Treatment Basins

A Technical Commentary

## VACONODOME - Clear-Span Aluminium Dome Roofs for Storage Tanks

### 1. Introduction

Aluminium Rheinfelden GmbH – Global Unit VACONO, the sole manufacturer of the all aluminium geodesic dome roof VACONODOME, belonging for many years to one of the largest European aluminium producers, the Alusuisse Group located in Zurich, Switzerland, has established an impressive track record in the use of aluminium structures for oil and petrochemical industry applications. A complete range of products, comprising VACONODOME (clear-span aluminium geodesic dome roofs), VACONODECK (internal floating covers), VACONOSEAL (seal systems for floating covers and floating roofs) as well as VACONOCORE (recovery systems for hydrocarbon vapours) has given Aluminium Rheinfelden GmbH an excellent reputation in the oil industry.

All products in the VACONO range are manufactured in compliance with the relevant safety regulations and expert reports confirming this have been issued by the organization in Germany responsible for matters of safety, the „Physikalisch-Technische Bundesanstalt“ (PTB) in Braunschweig. Further the Global Unit VACONO of Aluminium Rheinfelden GmbH has been certified according to DIN EN ISO 9001 as well as SCC by Bureau Veritas.

The quality assurance policy of Aluminium Rheinfelden GmbH – Global Unit VACONO has as its objectives the development, production and marketing of perfect products for its customers. Therefore it was decided to undertake a complete review of the design of the VACONODOME, the improvements of which can be seen in this summary as well as an outlay of a 55.0 m - dome as an example for a large structure conceived for a project in the petrochemical field.

### 2. The Improved VACONODOME –Technology

#### 2.1 International Regulations

The VACONODOME as a 3-dimensional space structure consists of a clear span aluminium framework covered with triangular aluminium sheets. The dome is designed, manufactured and installed in accordance with national and international regulations for the oil industry as well as with the latest developments of the new European standards:

- API 650, 9th edition, July 1993 including Appendix E, G
- Eurocode 1, July 1994 based on e.g. ECCS TC 12, 1987

Based on the above mentioned regulations and requirements the following load assumptions were considered leading to the VACONODOME - design data:

- Wind speed: 160 km/h or according to local requirements
- Live (snow) load: 1200 N/m<sup>2</sup> or according to local requirements
- Seismic load: according to locally applicable design response spec/time history
- Design pressure: atmospheric, alternatively if requested low pressure
- Design temperature: -35°C to 90°C

## 2.2 Structural Analysis

The structural analysis of the VACONODOME is based on three different areas of investigation:

### A) Stress analysis

- Internal / external stresses and deformations

### B) Analysis of local stability effects (local buckling)

- Euler buckling
- Torsional buckling
- (Panel buckling)
- (Crippling)

### C) Analysis of global stability effects (global buckling)

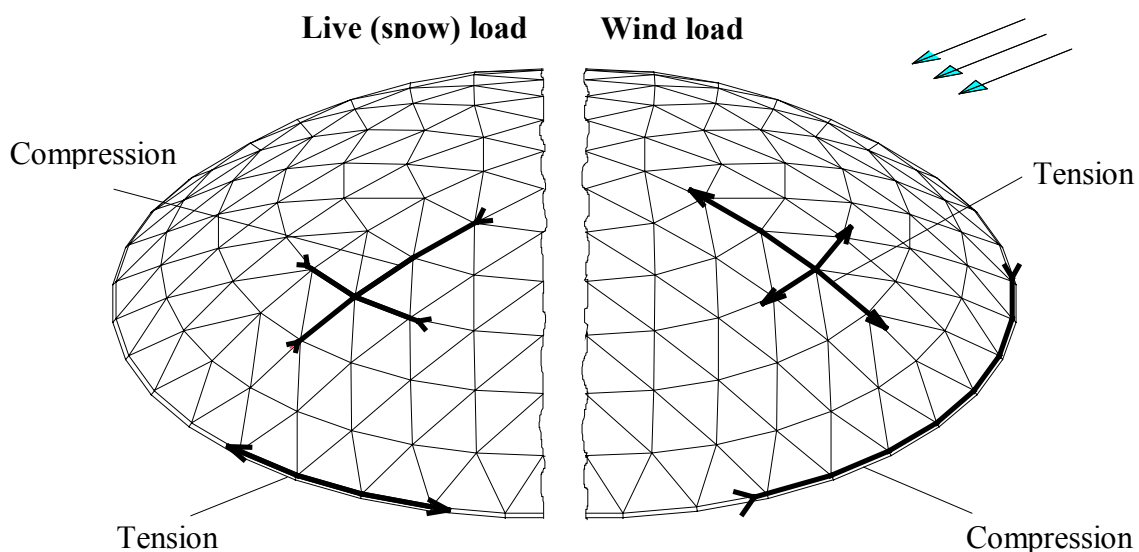


Fig. 1: Distribution of internal forces due to wind and live load

Based on the given load assumptions in paragraph 2.1, assuming a wind speed of 160 km/h as well as a live (snow) load of 1250 N/m<sup>2</sup>, there will be a stress distribution in the skeletal structure that, dependant on the type of load, tension and compression will also affect the inner area of the dome (Fig. 1). For a  $\varnothing$  55.0 m-dome the forces will lie in the range of -60 kN to 140 kN.

It is therefore necessary to investigate how the local stability of the dome is affected by the compressive loads whereby on safety grounds torsional buckling is to be prevented. Aluminium Rheinfelden GmbH has therefore developed a profile that fulfills the requirements for torsional stiffness that is up to 50 times higher than that of the traditional I-beam (Fig. 2).

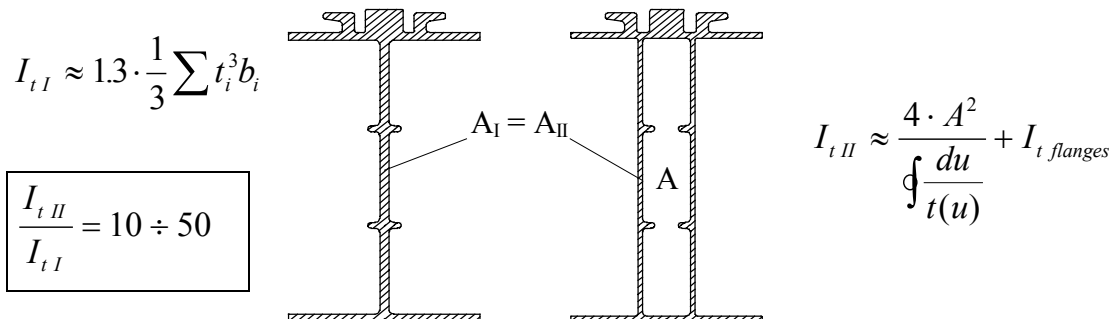


Fig. 2: Comparison of the torsional stiffness of I- and II-profile

Further this profile guarantees that a failure caused by Euler-buckling around the weaker of the two main axes is impossible if the cover sheets have been correctly fastened. Therefore only stainless steel screws as tested and approved by the Institut für Bautechnik, Berlin (Z-14.1-4) are used to attach the panels.

### 2.3 Boundary conditions

The VACONODOME is equipped with either

- an integral aluminium tension ring and sliding supports or
- a steel tension ring as tank reinforcement and fixed supports

In both cases a **pin-jointed** support is used

- to minimize roll-up moments acting on the tank shell.
- to compensate thermal effects.
- to simplify the erection.

To highlight the influences of both types of support on the dome structure itself and especially on large diameters, a table (Tab. 1) of internal forces as well as reaction forces has been formulated from the wind and live loads given in the specification for the  $\varnothing 55.0$  m-tanks which can be seen in Fig. 3 below. For both cases a significant reduction in the stress is possible through the use of fixed supports complete with a steel tension ring mounted on the tank rim.

An alternative, using sliding supports complete with an integral aluminium tension ring, is possible though for domes of large diameter the necessary aluminium profiles are difficult or impossible to obtain, notwithstanding the extremely high cost of using such material making it a much more expensive option than that of fixed supports and steel tension ring. However, whichever system is decided upon the vertical and tangential forces acting upon the tank wall will be virtually the same.

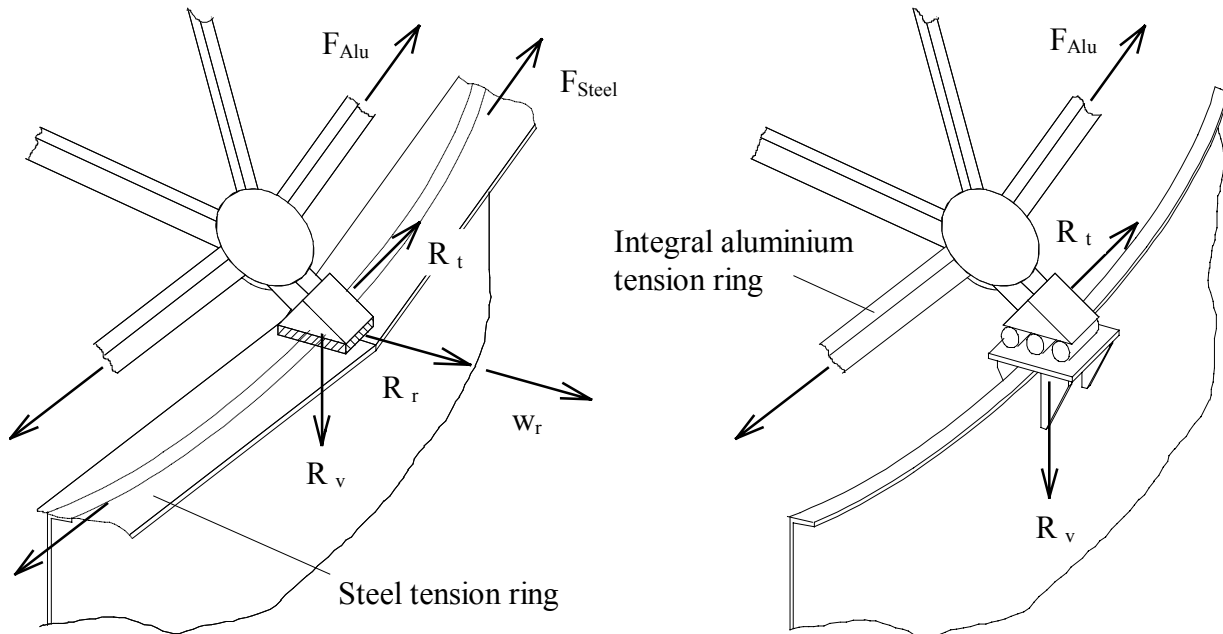


Fig. 3: VACONODOME with fixed and sliding supports

		Wind load: $v = 160 \text{ km/h}$		Live (snow) load: $q = 1250 \text{ N/m}^2$	
		Fixed support	Sliding support	Fixed support	Sliding support
$F_{Steel}$	[kN]	-540	----	650	----
$F_{Alu}$	[kN]	-60	-544	68	700
$R_t$	[kN]	66	36	0	0
$R_v$	[kN]	-54	-54	64	60
$R_r$	[kN]	-68 *)	0	77 *)	0
$W_r$	[mm]	-10	-48	10	53

Tab. 1: Internal forces of the dome roof  $\varnothing 55.0 \text{ m}$  and reaction forces acting on the tank shell  
\*)  $R_r$  is completely carried by the steel tension ring (mathematical model).

## 2.4 Lockbolts

The VACONODOME is designed as a space frame whereby the individual struts are connected to each other through the use of aluminium gusset plates. The jointing of these carriage profiles and the consequent transfer of force-flows takes place via the HV-HUCK-lockbolts  $\varnothing$  9.6 mm which connect and tighten the carriage profiles to the gusset plates.

As laboratory tests have proved, the use of high strength aluminium profiles e.g. 6005, 6082 and 6061, with highly pre-stressed lockbolts, will give a first-rate joint. An added factor thereto, is that mild steel lockbolts should be used as, when compared to stainless or aluminium bolts the tensile strength based on the Young's modulus is much higher. A further factor to be considered is the quality of the bolt collars whereby tests have proved that a combination of mild steel aluminised bolts complete with mild steel aluminised collars achieve far higher pre-stress strength results effectively 2 to 2.4 times than that of a stainless steel / aluminium combination which was one of the worst cases tested to date.

As already indicated above aluminised mild steel lockbolts and collars are preferred by Aluminium Rheinfelden GmbH not only because of the high values obtained but also because they are least affected by the different environments in which they could be found. A stainless steel lockbolt when used with an aluminium construction in an extremely salty environment (close to the sea) can lead to corrosion problems as reported by the research division of Alusuisse Technology & Management AG (Schweizerische Aluminium AG - Forschung und Entwicklung), Switzerland and the HUCK Technical Center.

## 2.5 Seals and Gaskets

An important construction detail that has been considered in designing the VACONODOME as a weatherproof roof is the integral sealing systems i.e. the clamp bar gaskets, the stainless steel screw washers and also especially the gusset cover gaskets.

All sealing systems are fabricated from extruded EPDM material which has been successfully used for many years in window and automotive industry and is also recommended as seal material by API 650 App. G paragraph 2.5.2.

The use of EPDM seal material has the following advantages:

- Excellent resistance to all climatic conditions
- Excellent UV- and ozone resistance
- Temperature stability: -40° C to 120° C

Further the gusset cover / sheet cover joint has been designed complete with an integral seal.

Additionally, through its unique design, the requirement of a flame-proof connection as detailed by the PTB (Physikalisch-Technische Bundesanstalt, Braunschweig) is met.

### 3. Conclusions

Aluminium Rheinfelden GmbH a company with 100 years experience in the production and uses of aluminium as well as its Global Unit VACONO with almost 25 years experience in the manufacture and installation of aluminium constructions in the petrochemical industry, has completely re-designed its *VACONODOME* aluminium geodesic dome roof to meet the evermore stringent requirements of the industry. This revised design has taken into account and reflects the latest ideas and concepts in the lightweight construction industry for which they are now the norm.

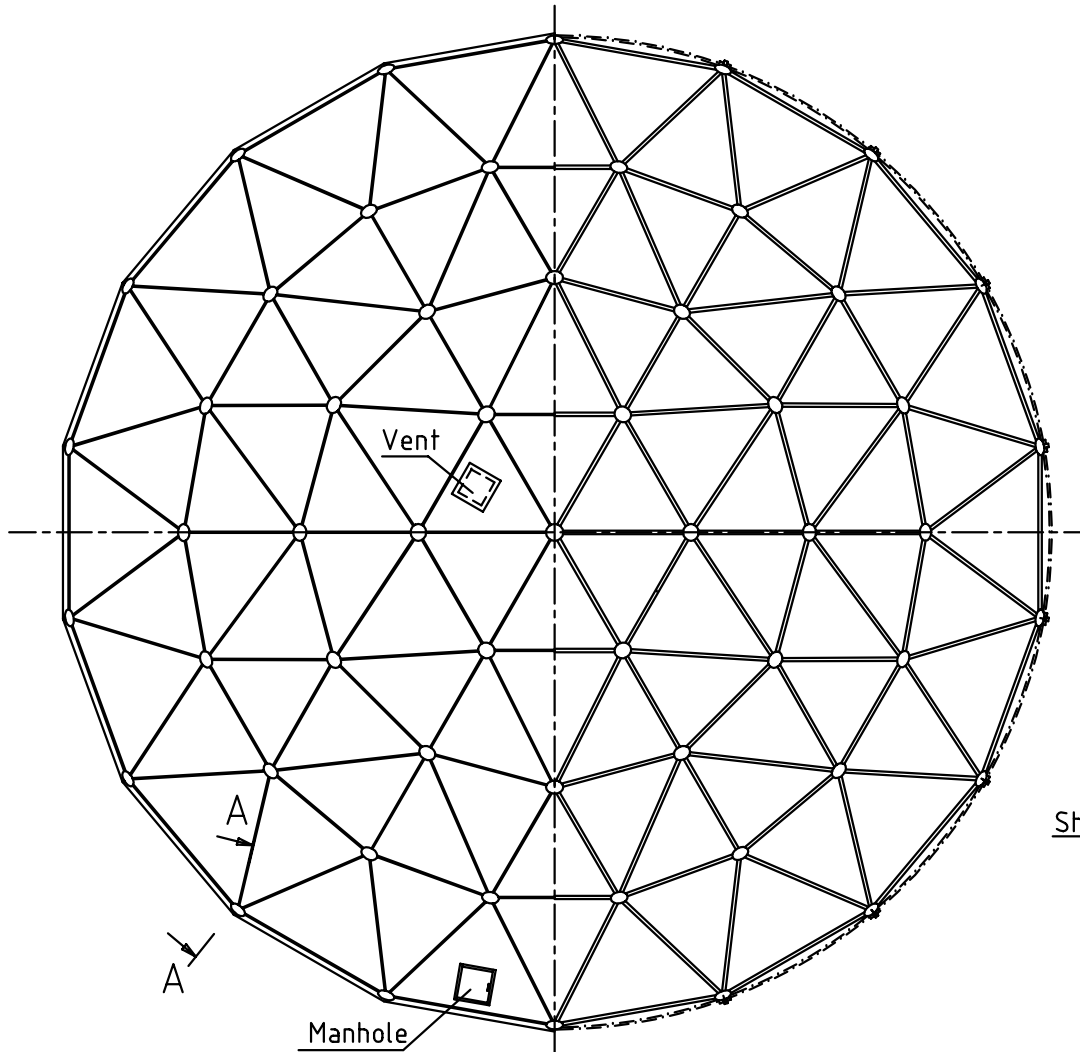
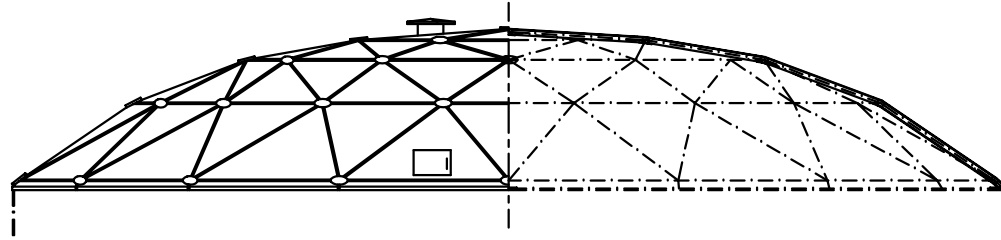
These points can be listed as follows:

- Latest European regulations e.g. Eurocode 1
- Newly designed carriage profile to prevent torsional buckling
- Fasteners approved by the Institut für Bautechnik, Berlin
- Pin-jointed supports in fixed or sliding format
- Highly pre-stressed aluminised HV-HUCK-lockbolts for use in any environment including salty atmospheres
- Weather, UV, ozone and temperature resistant sealing systems

Based on the specifications as well as the environmental conditions required for a certain project an improved maintenance free *VACONODOME* has been designed incorporating the newest developments in the industry.

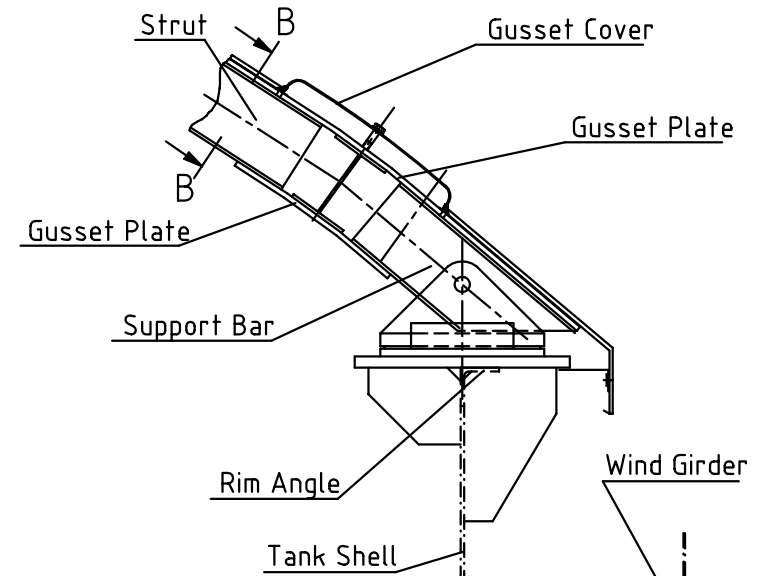
# VACONODOME

General View

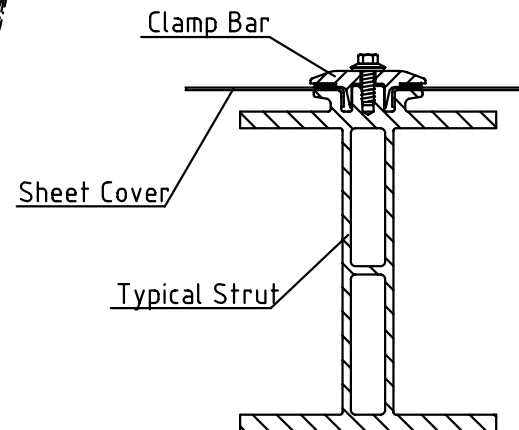


-Reservation for modifications-

Section A-A



Section B-B



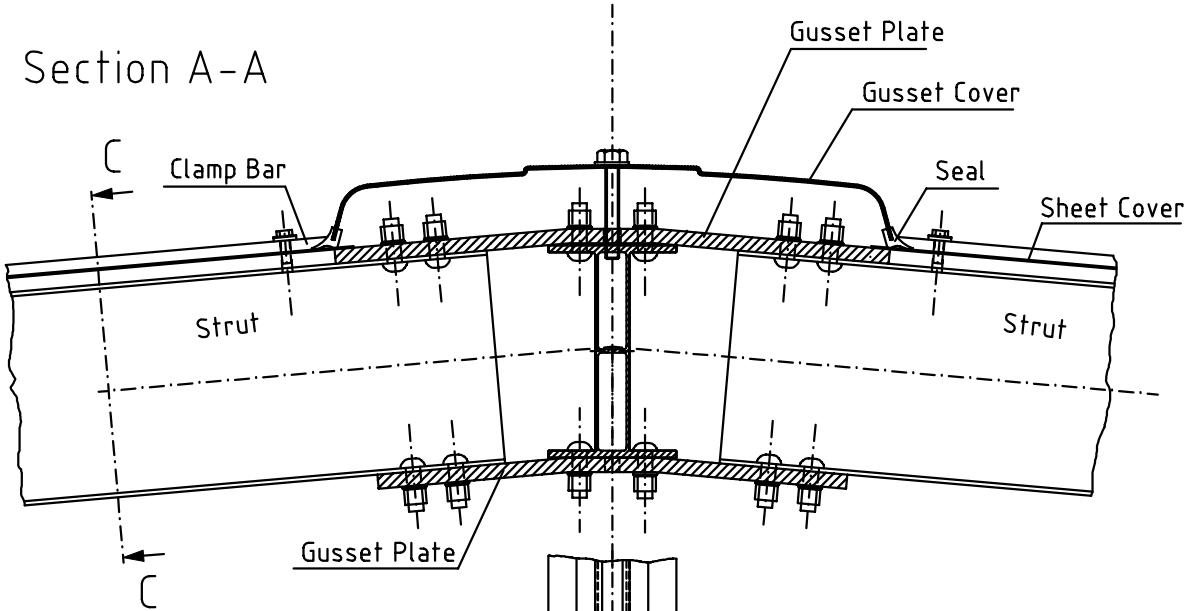
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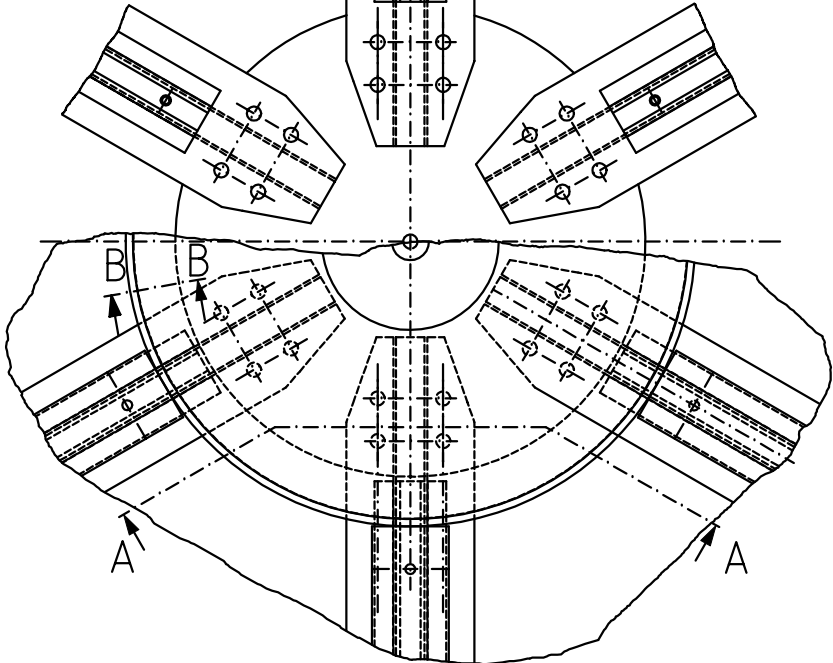
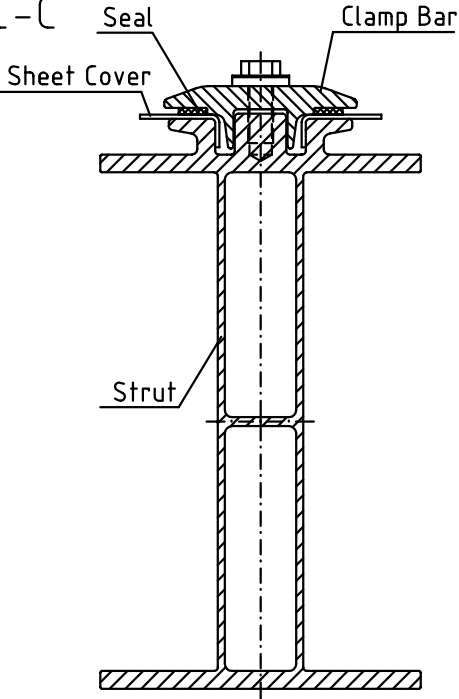
# VACONODOME

## Details Hub Connections

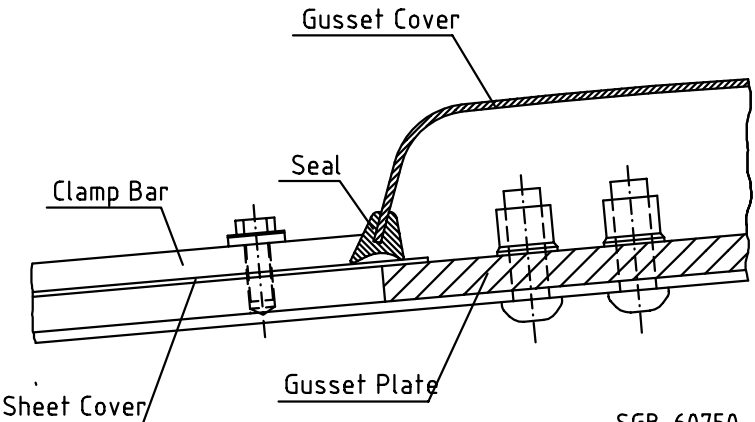
Section A-A



Section C-C



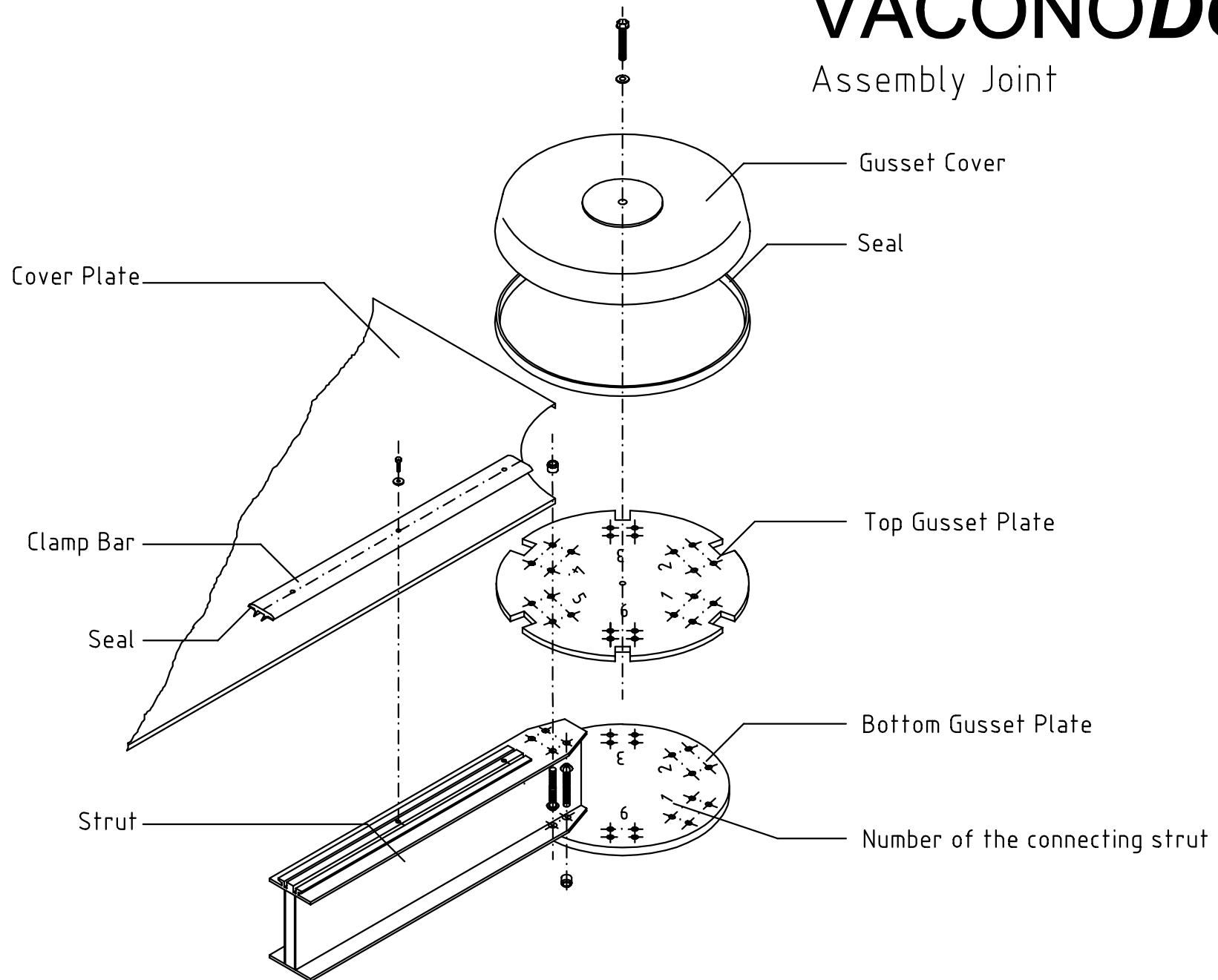
Section B-B



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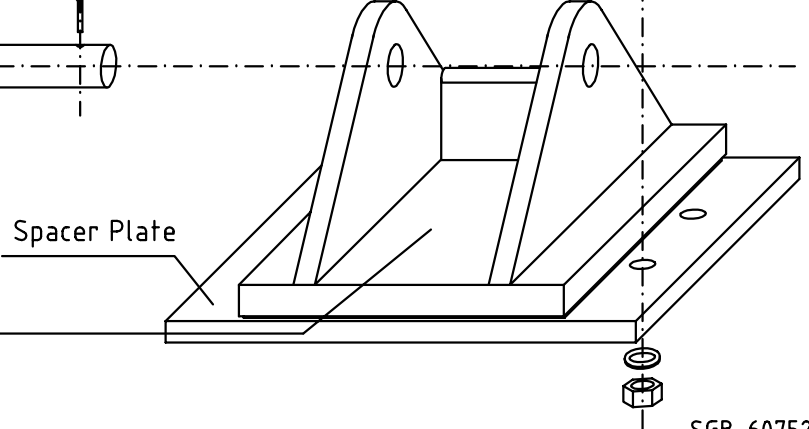
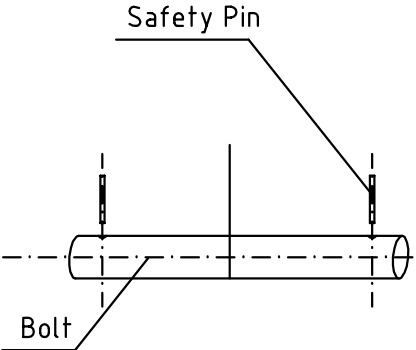
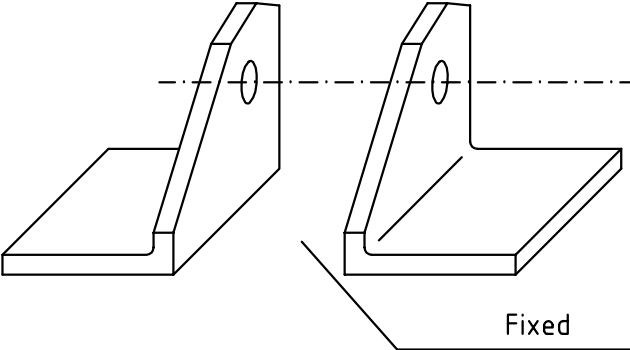
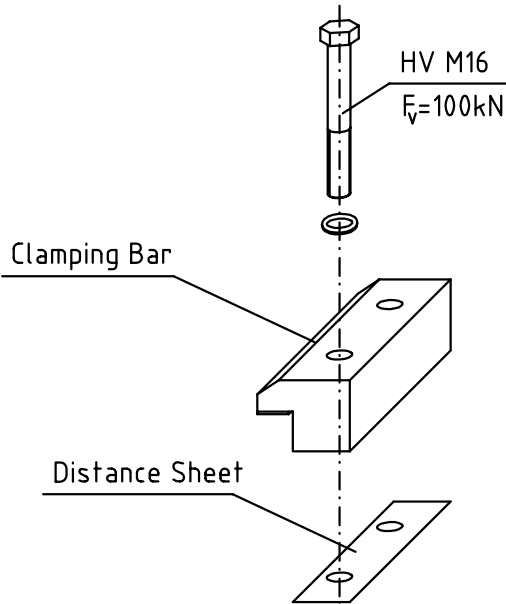
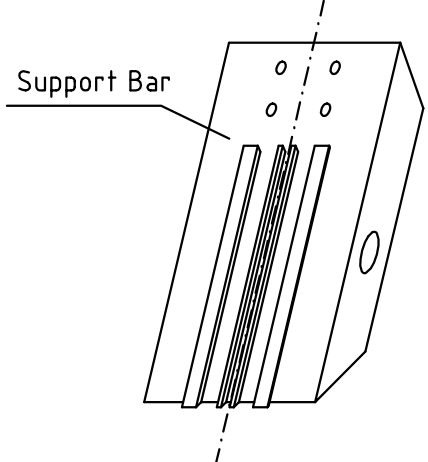
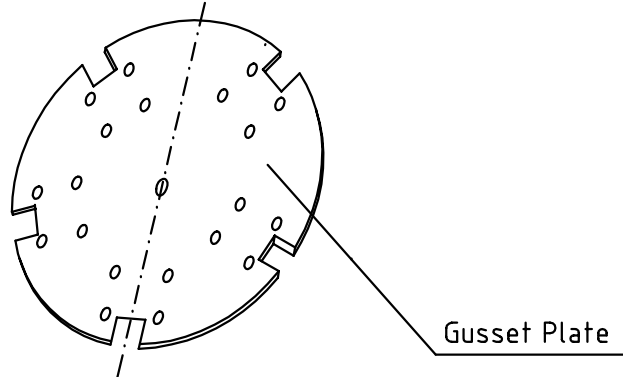
# VACONODOME

## Assembly Joint



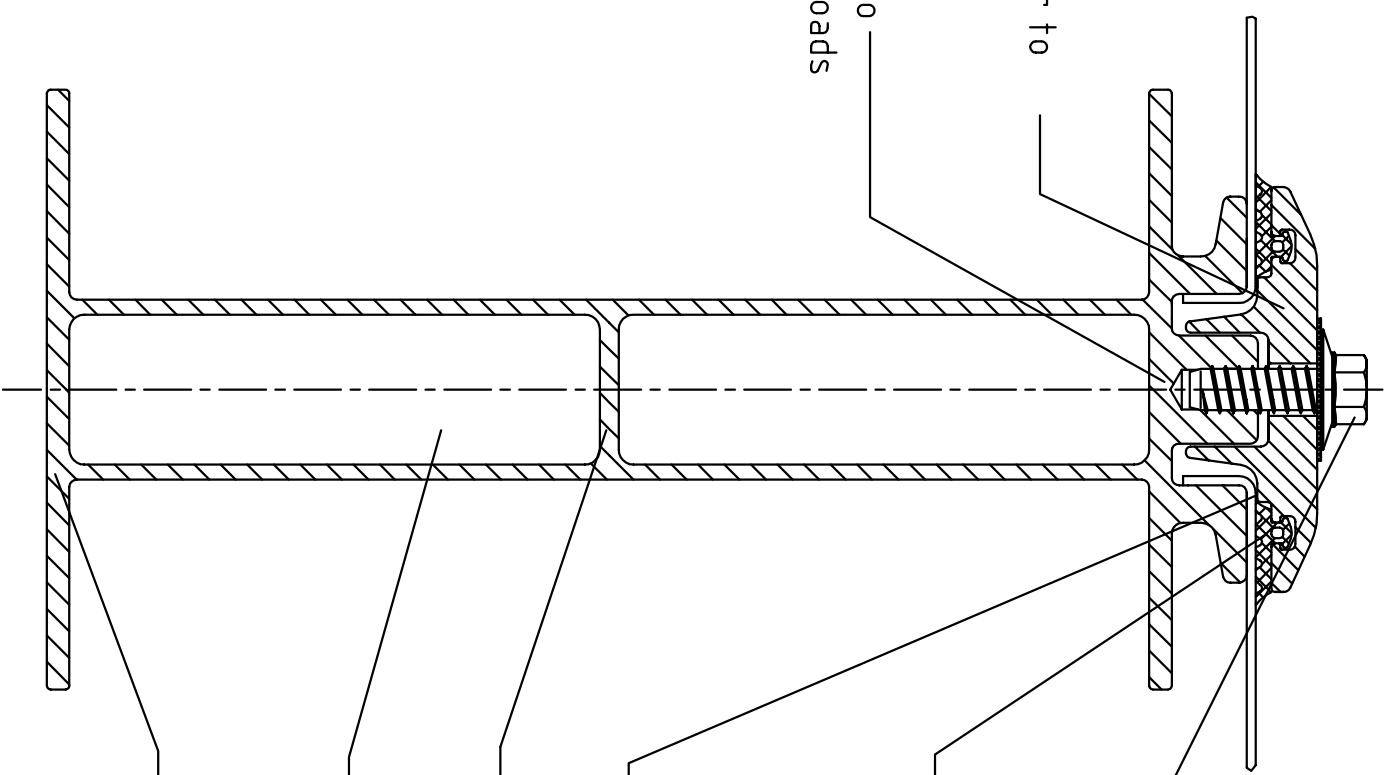
# VACONODOME

## Supports



# VACONODOME

## Typical Beam Cross- Section



Aluminium clamp bar to clamp sheet covers

Pre- drilled holes to transfer defined loads

Stainless steel (1.4301) sealing screws with EPDM gasket, authorized by "Institut für Bautechnik, Berlin" (Reg. No.: Z-14.1-4)

Extruded EPDM gaskets according to ASTM D 1418  
- Excellent general climate and ozone resistance

Flame proof connection

Reinforcement to prevent local buckling of the profile

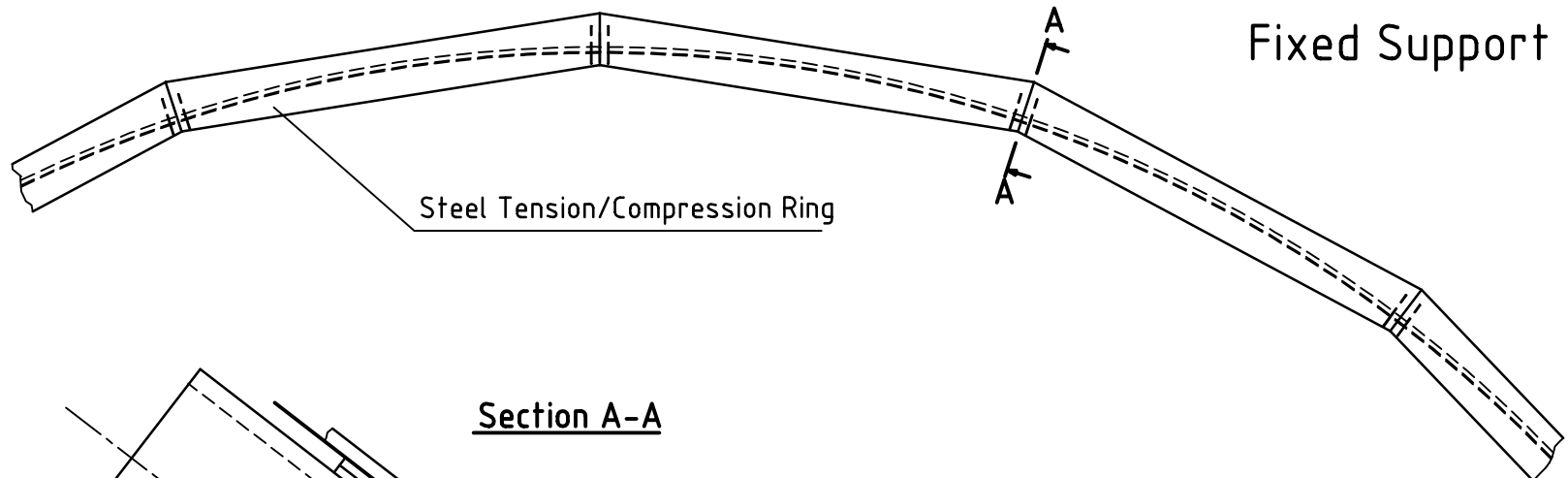
Box beam- type aluminium strut extrusion with high torsional stiffness to prevent torsional buckling

Corrosion resistant high strength AlMgSi aluminium alloy for carriage profile and clamp bar

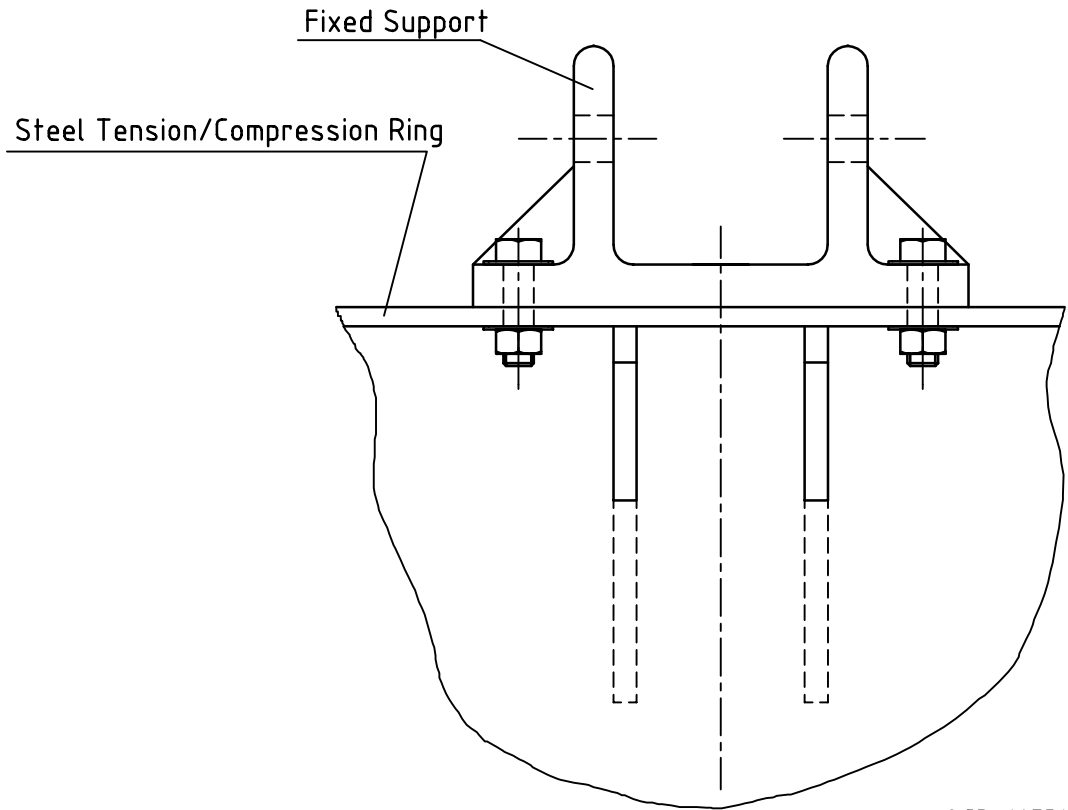
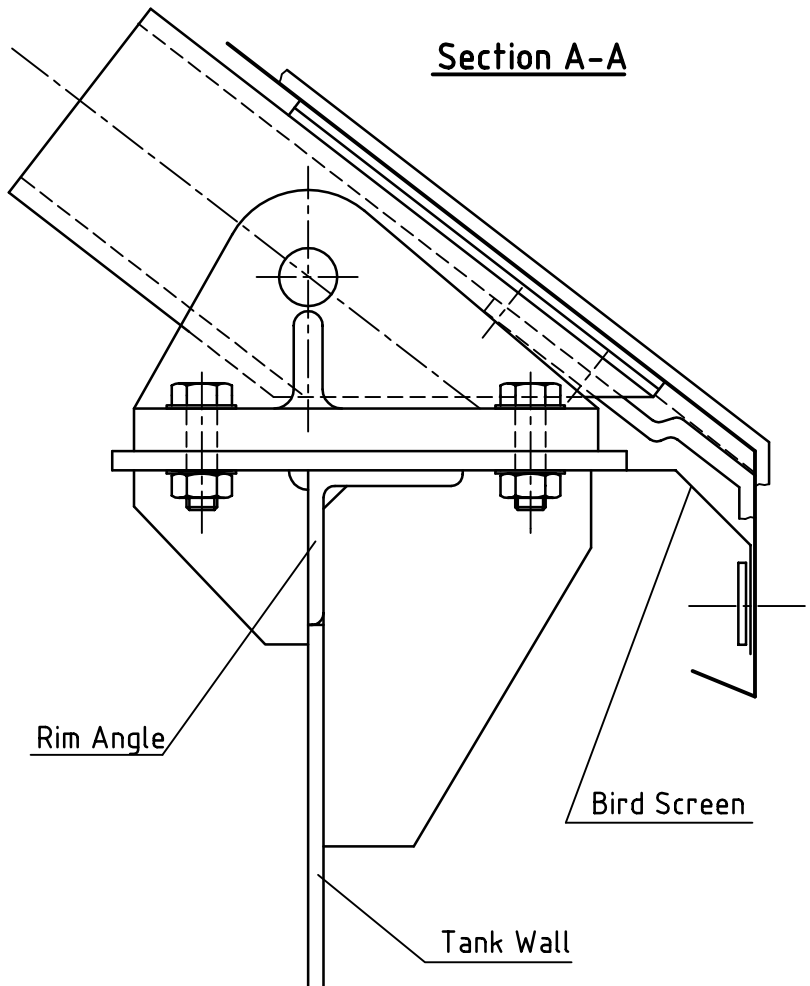
-Reservation for modifications-

# VACONODOME

Fixed Support - free vented -

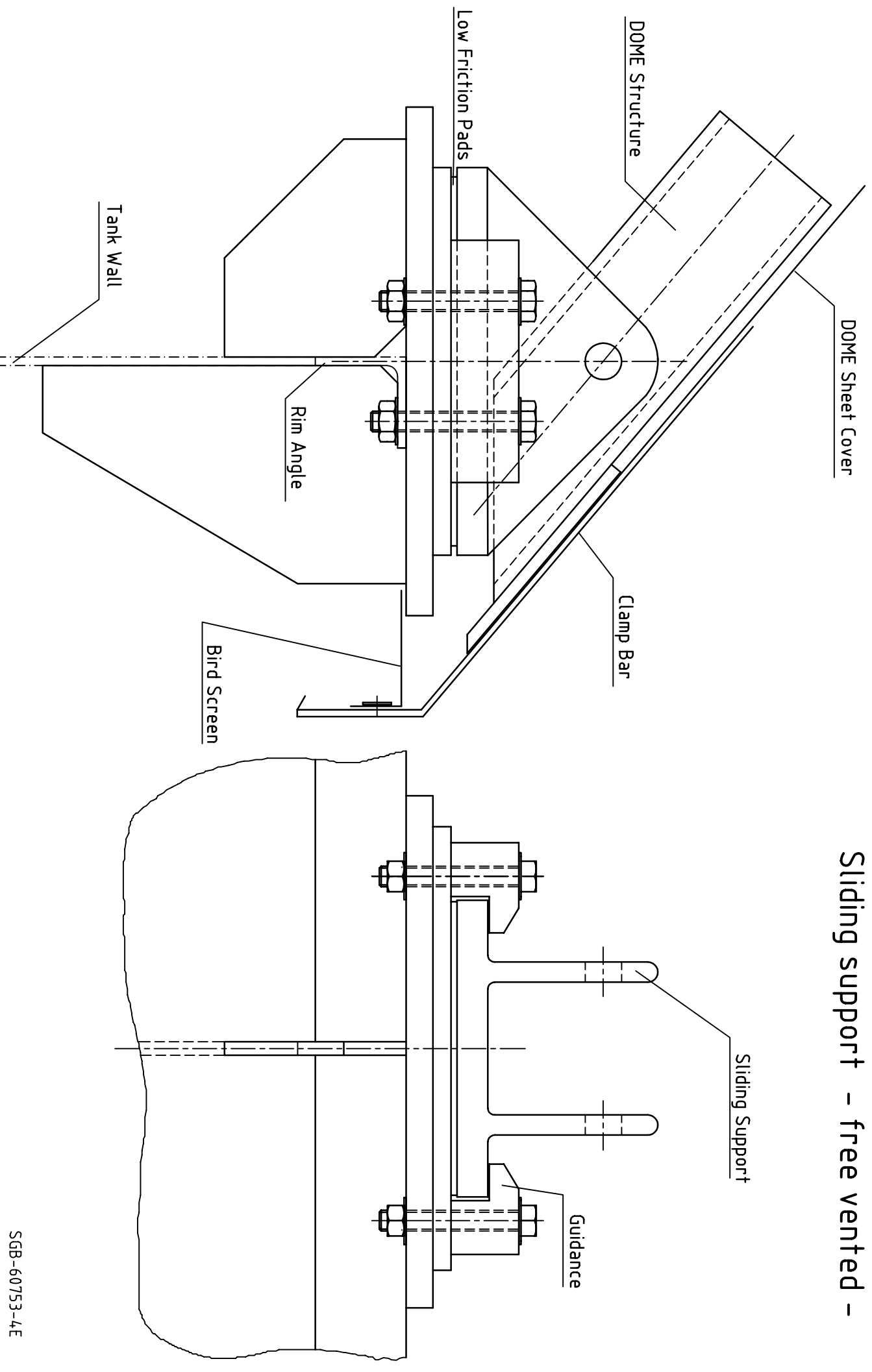


## Section A-A



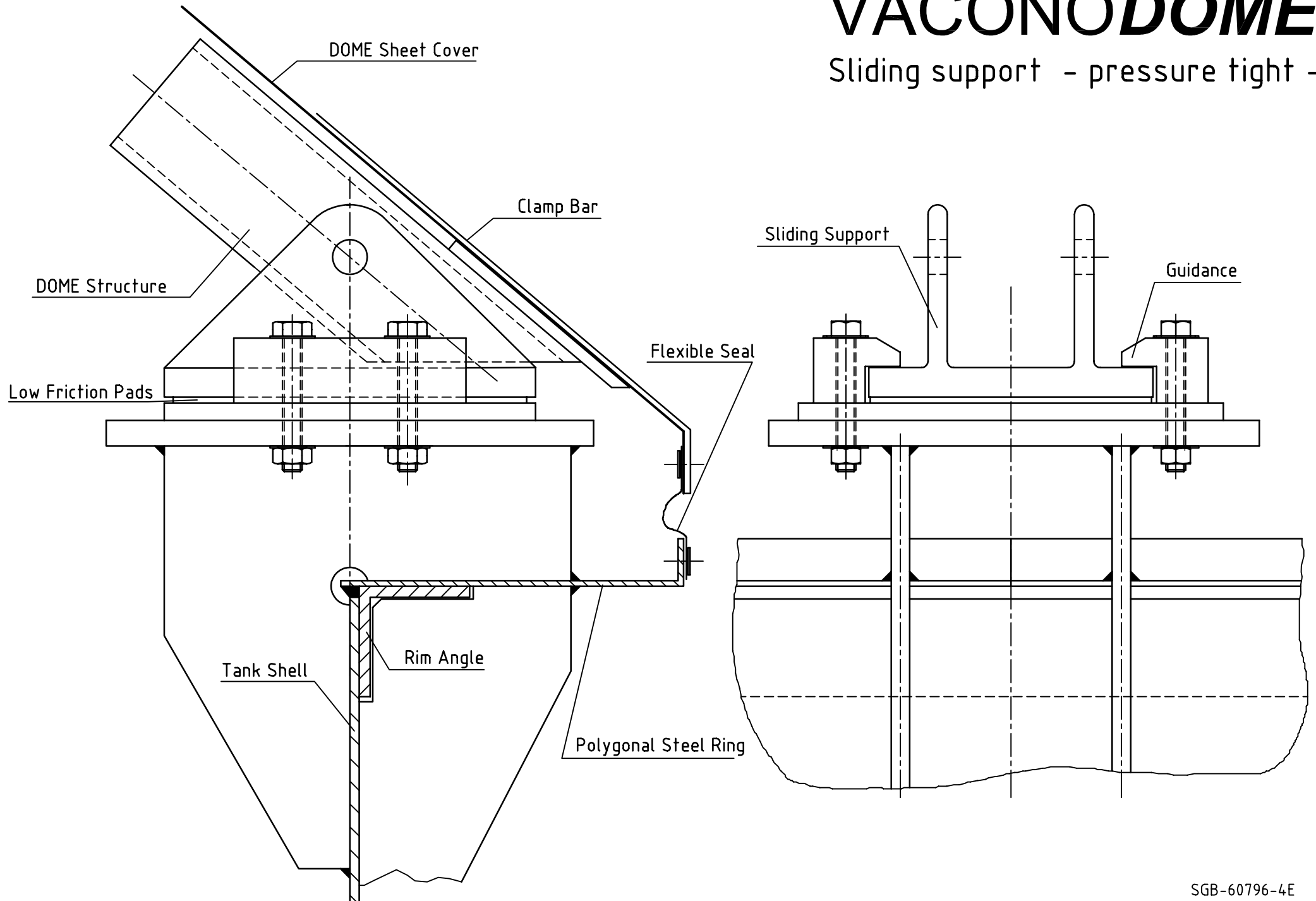
# VACCONODOME

Sliding support - free vented -



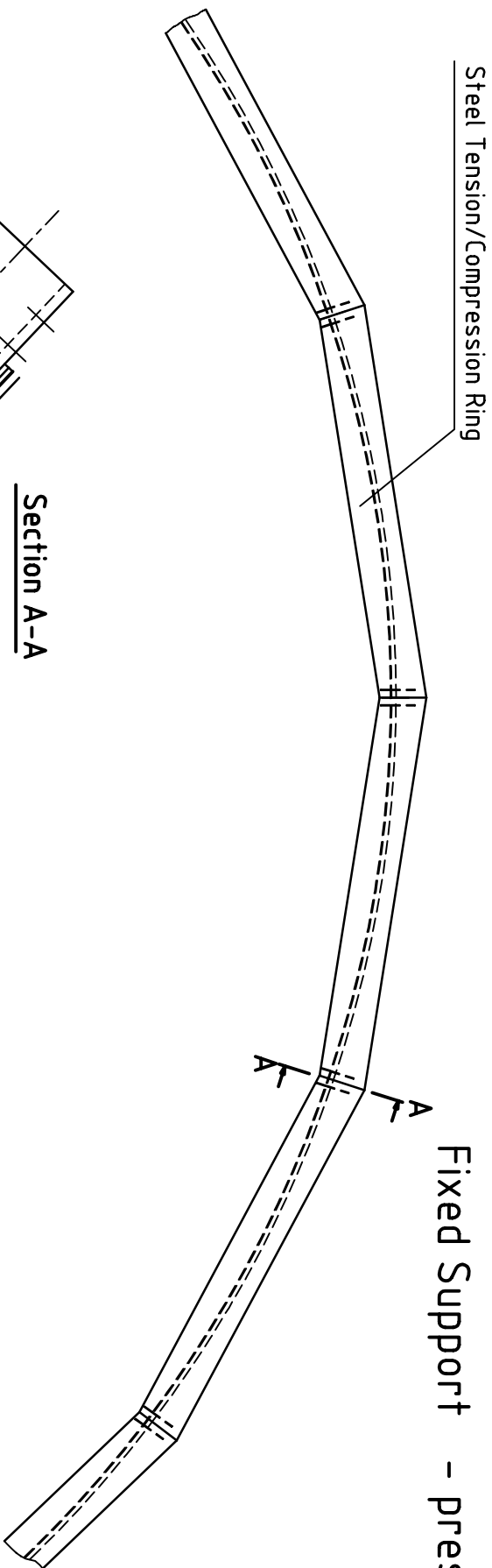
# VACONODOME

Sliding support - pressure tight -

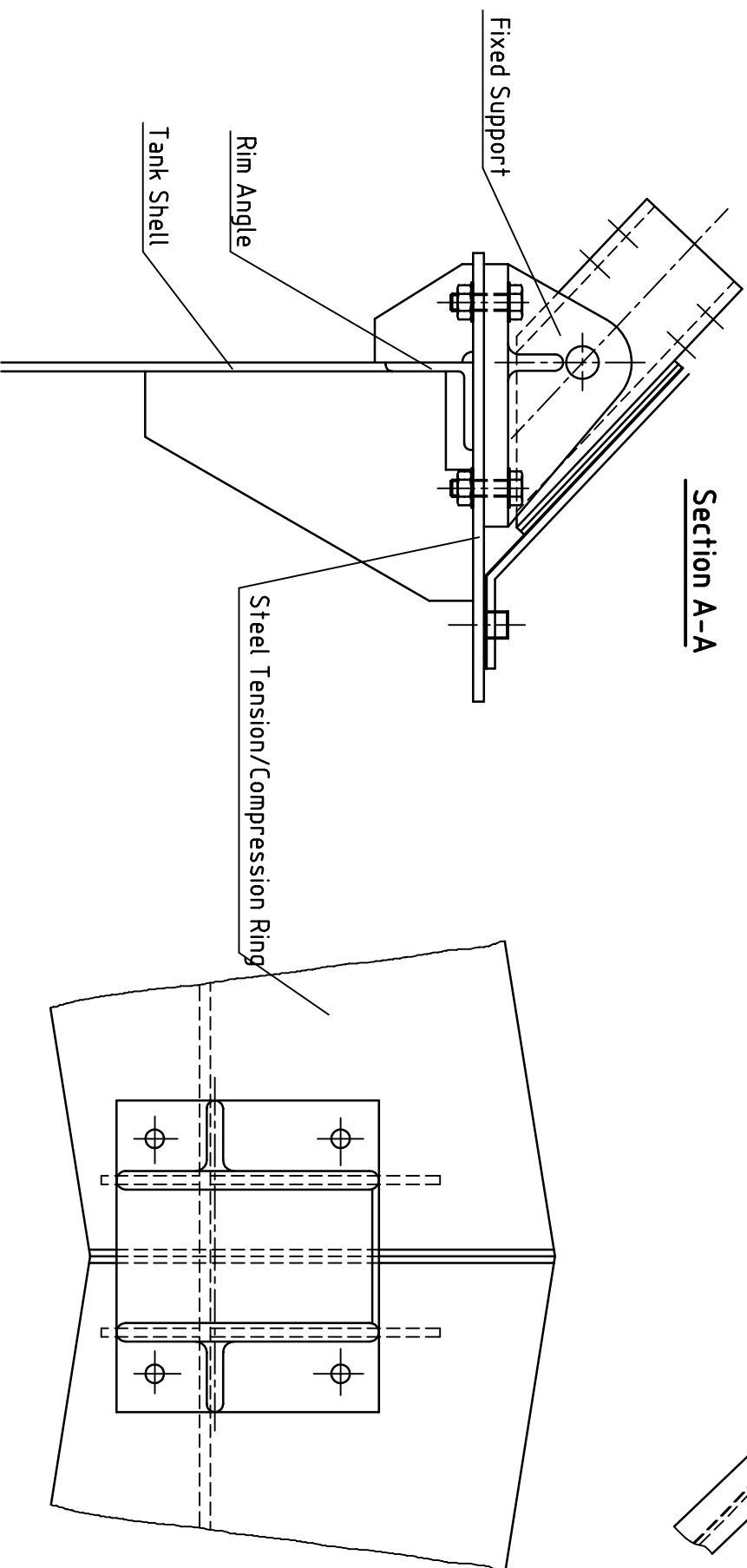


# VACCONODOME

Fixed Support - pressure tight -



Section A-A

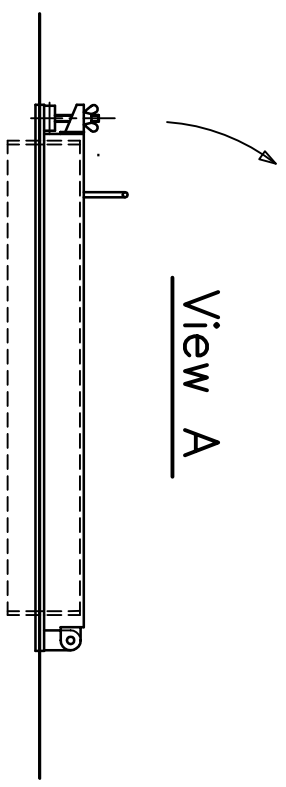




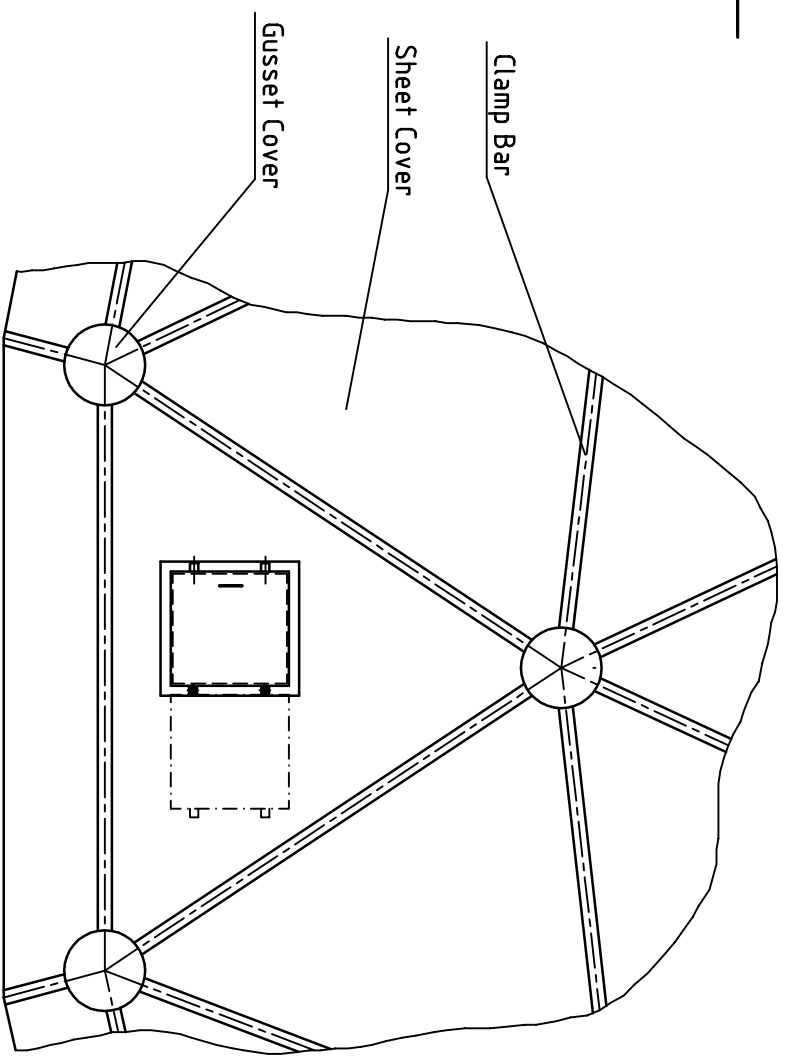
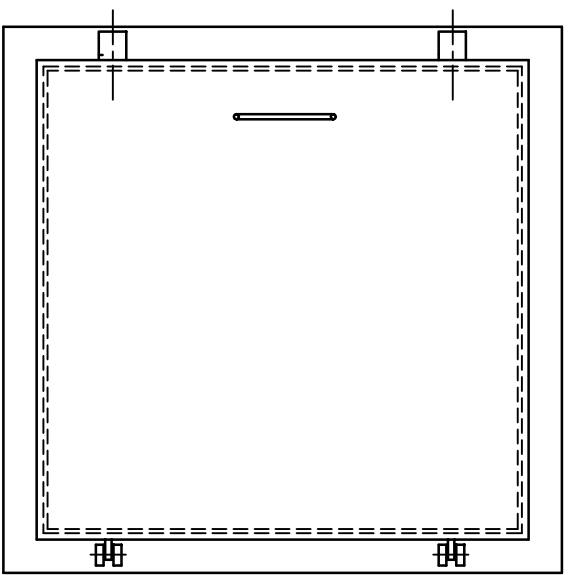
# VACCONODOME

## Manhole

View A



A

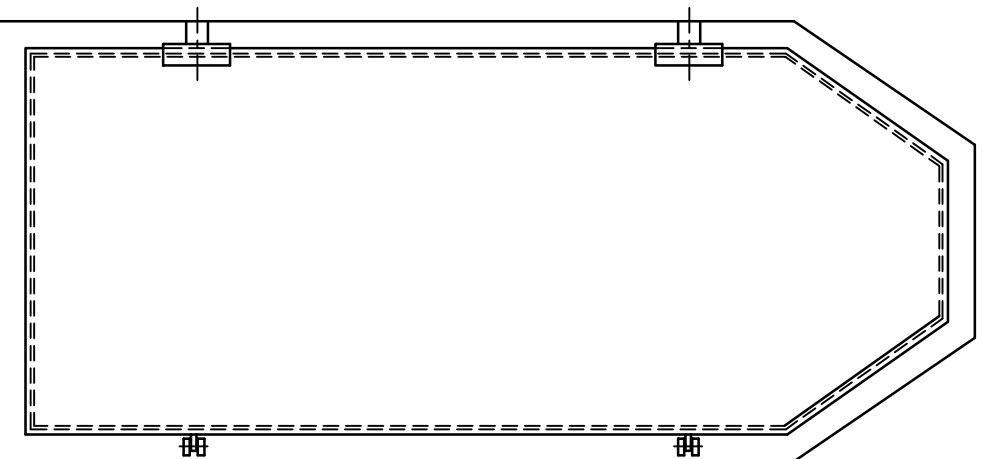


View A



# VACCONODOME

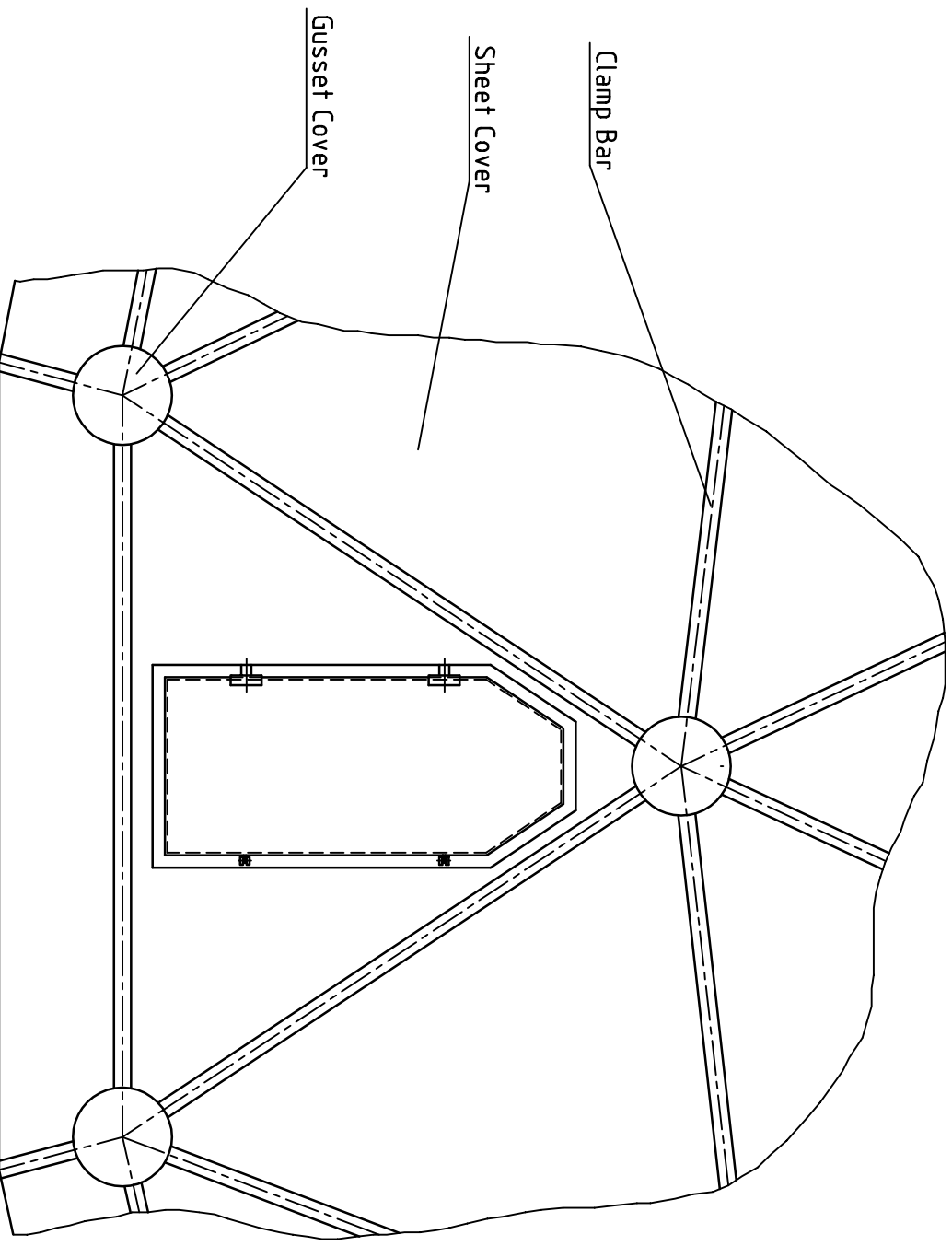
Door



Clamp Bar

Sheet Cover

Gusset Cover



-Reservation for modifications-

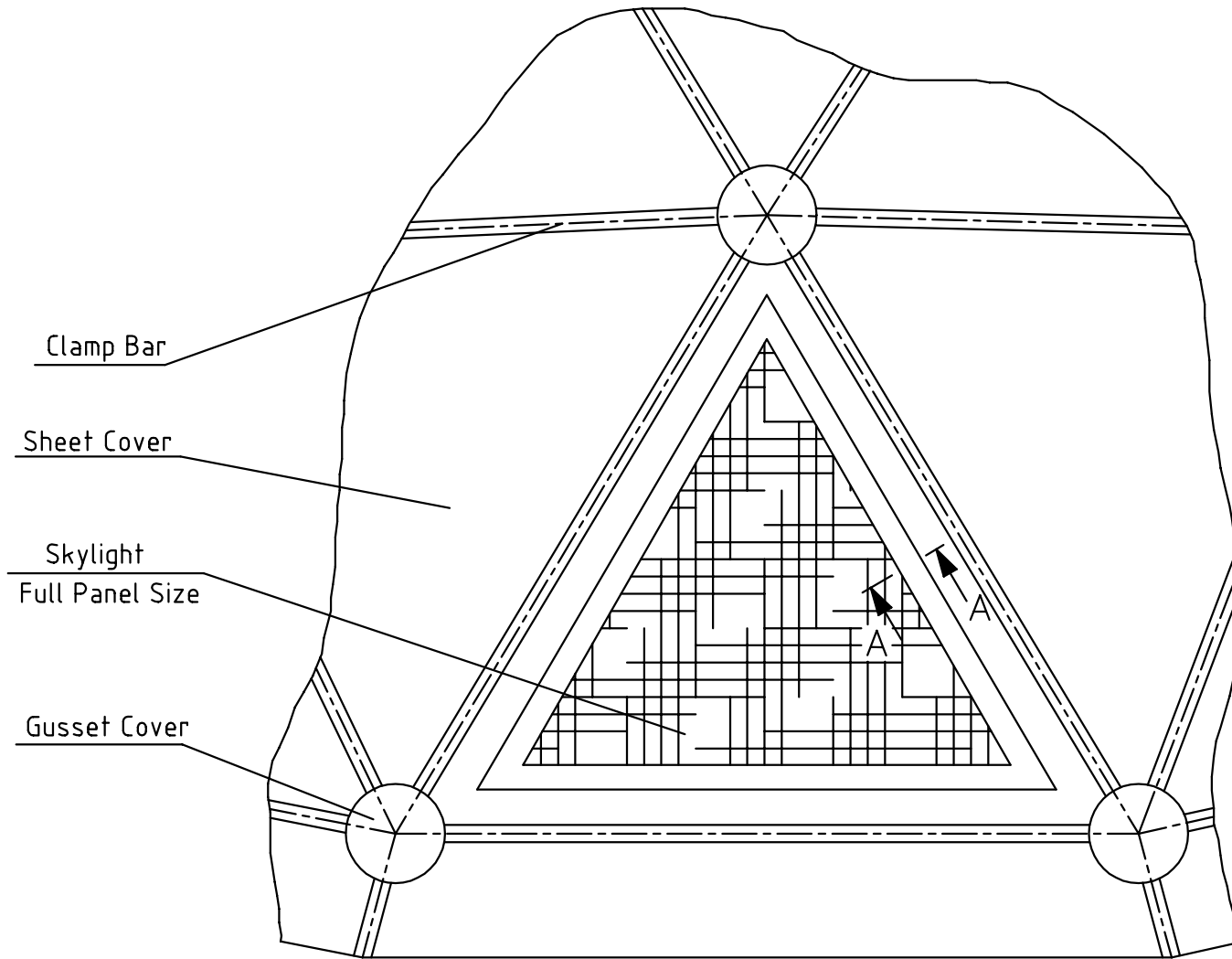
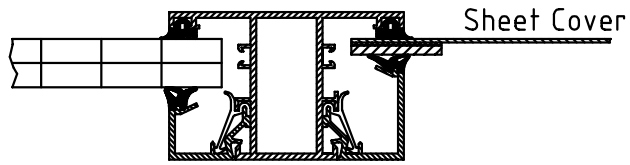
A

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# VACONODOME

## Triangular Skylight

Section A-A



Clamp Bar

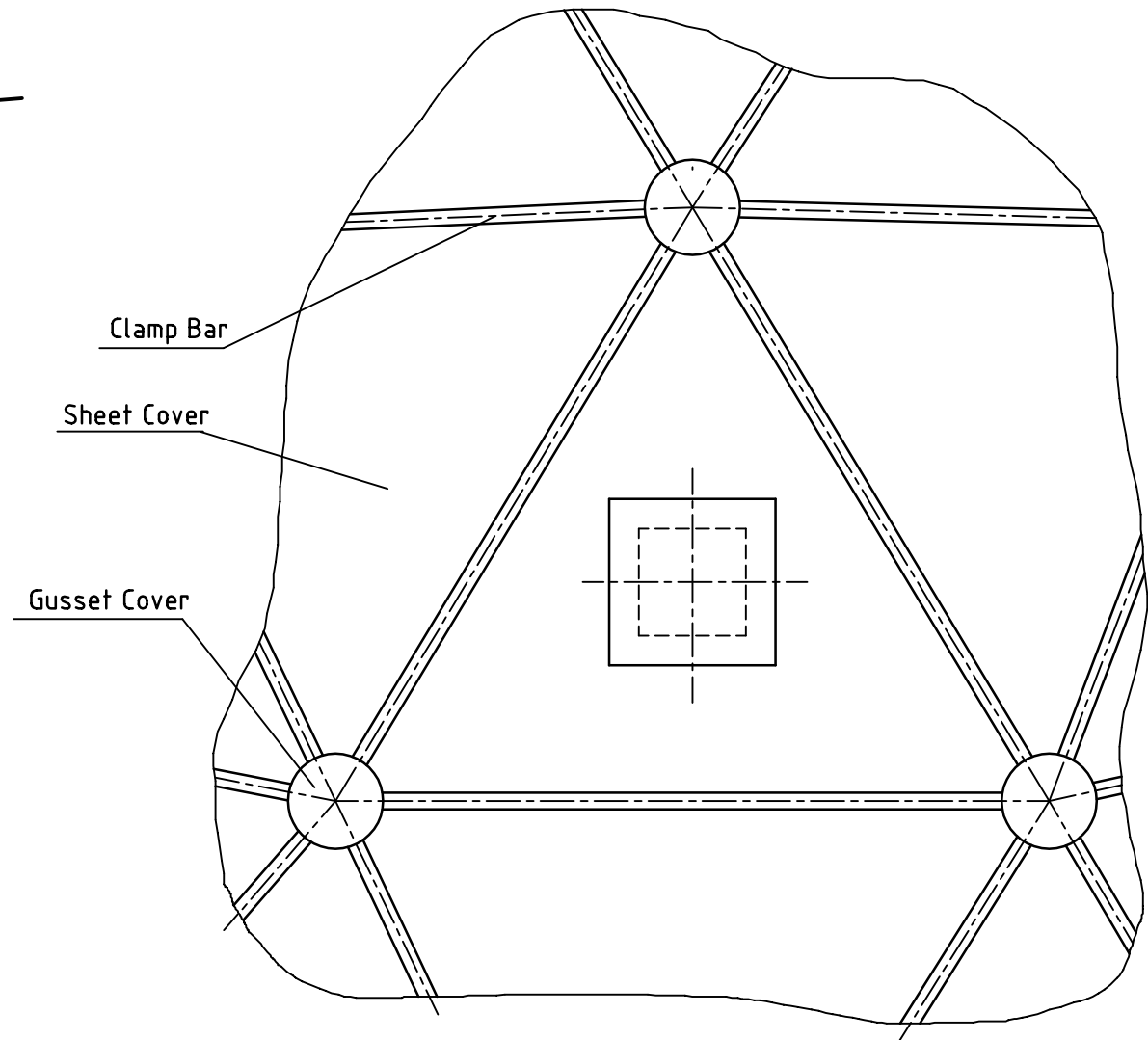
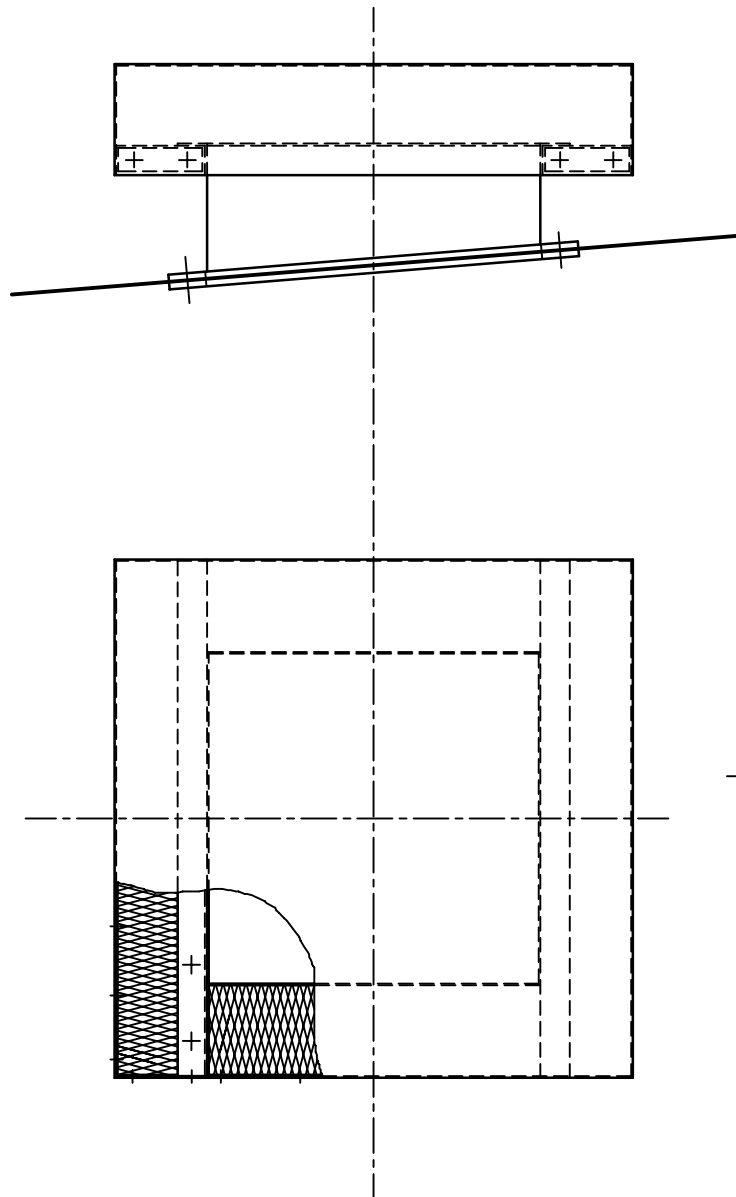
Sheet Cover

Skylight  
Full Panel Size

Gusset Cover

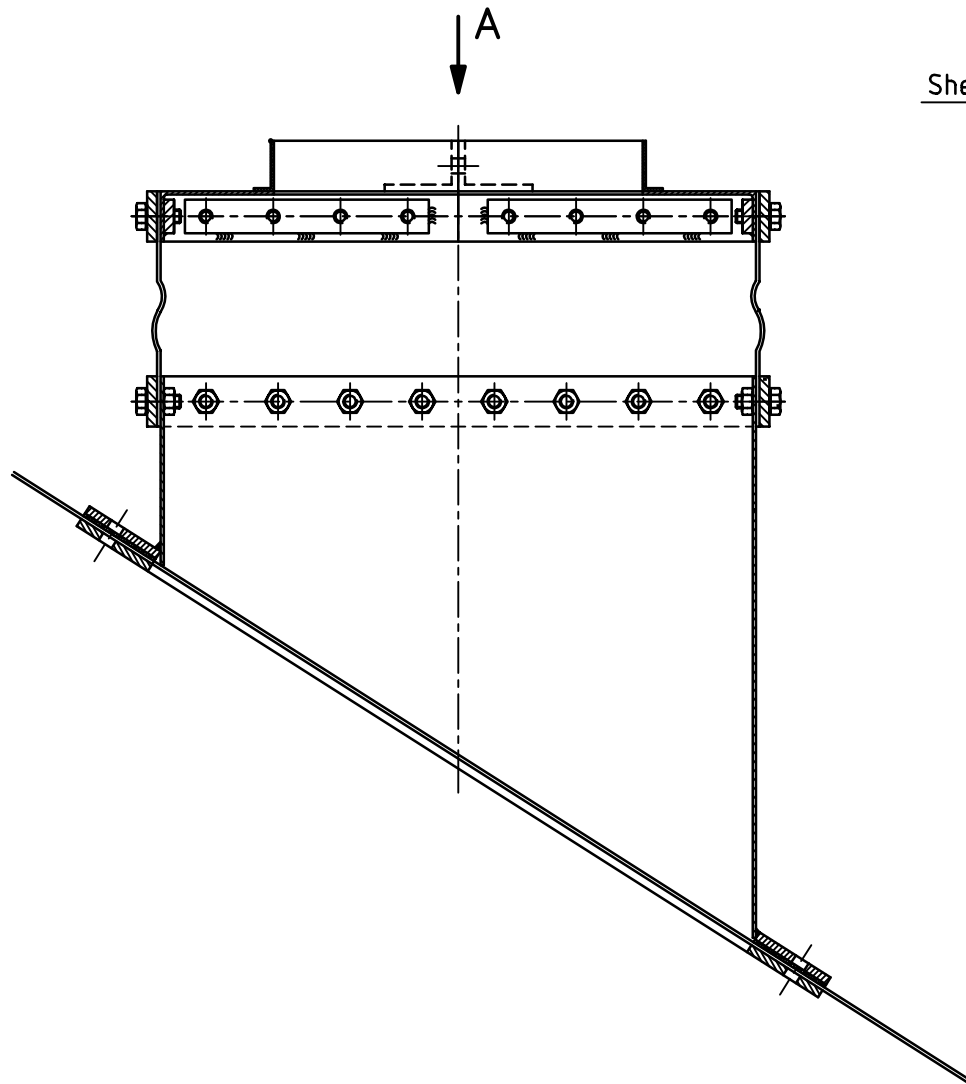
# VACONODOME

(Center) Vent



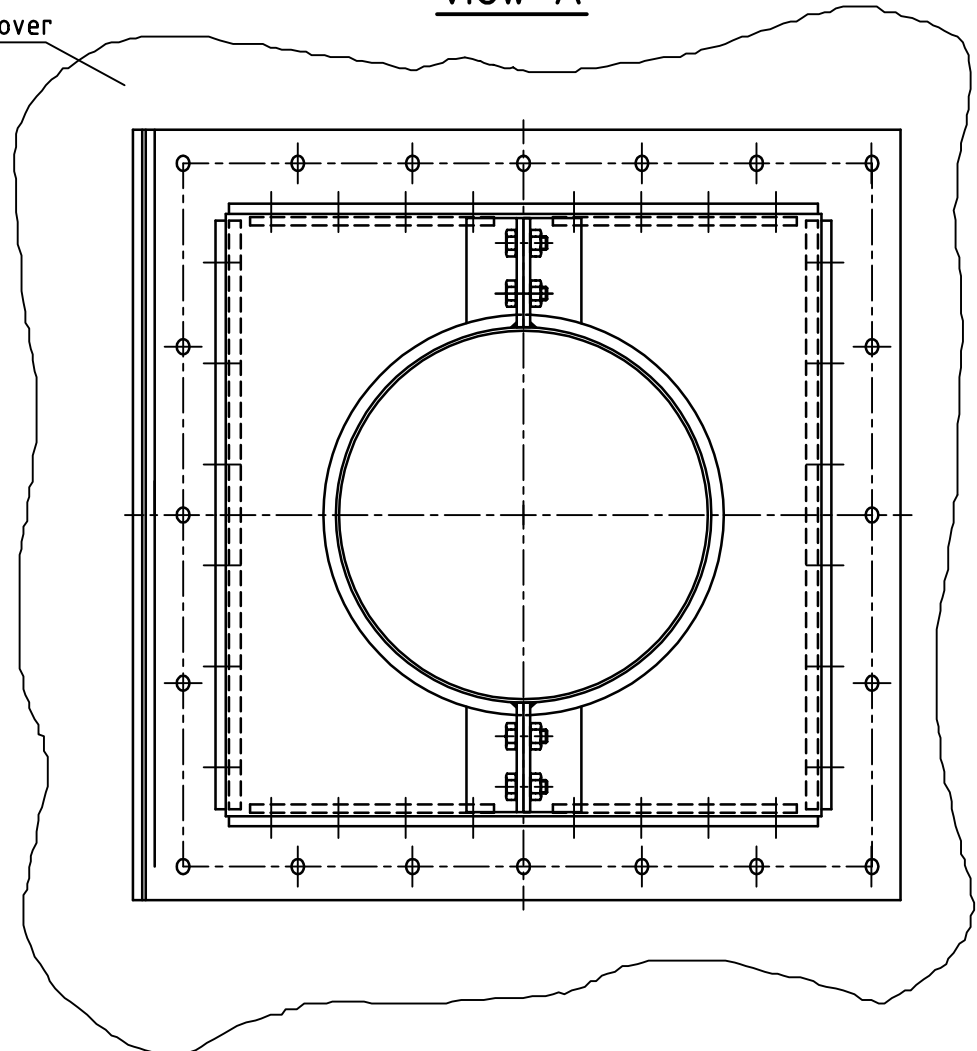
# VACONODOME

Pipe Negotiation Device



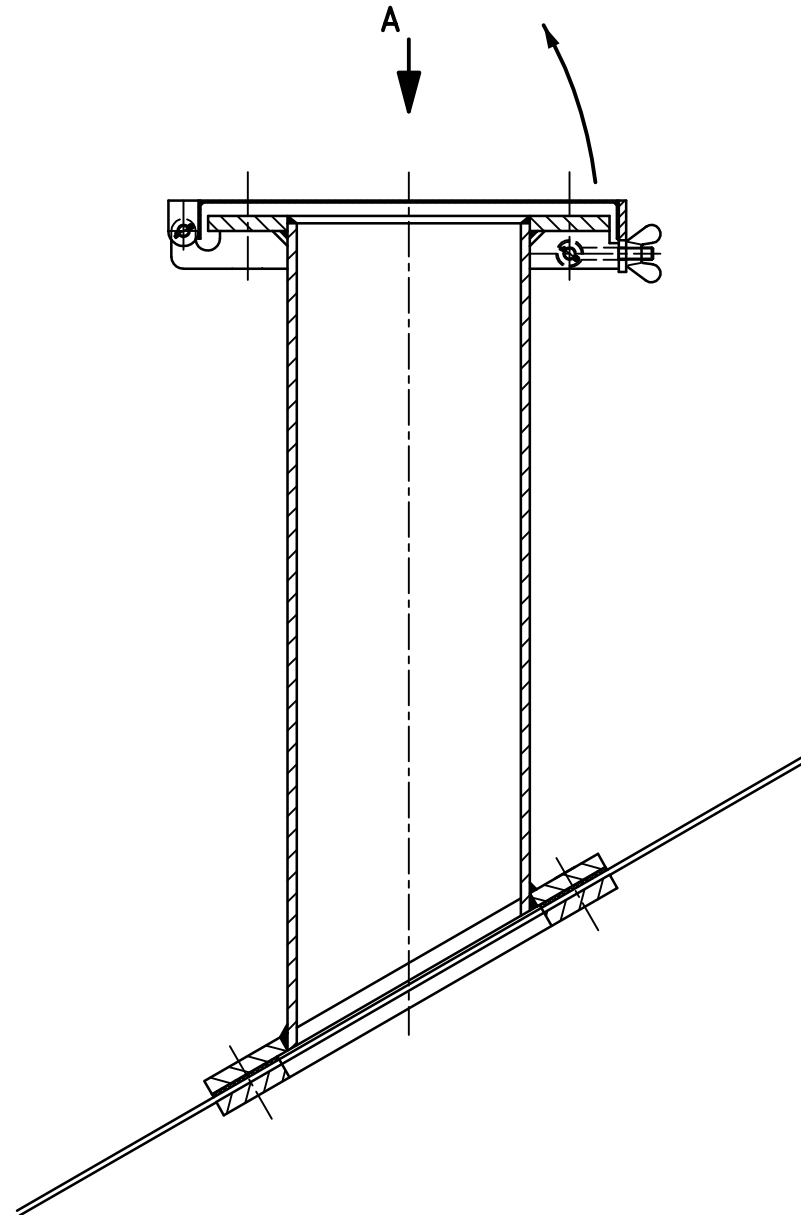
Sheet Cover

View A



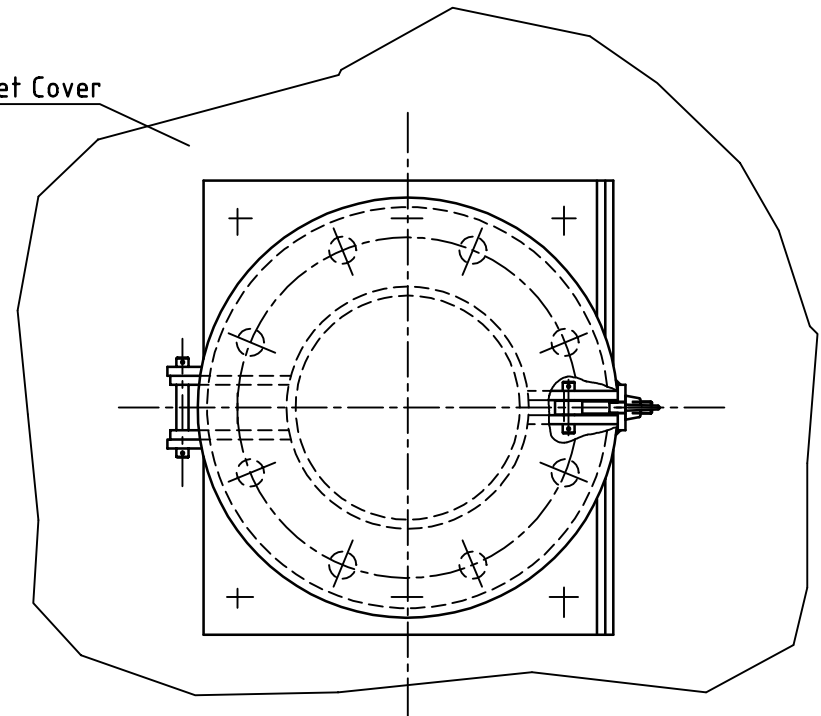
# VACONODOME

Gauge Hatch



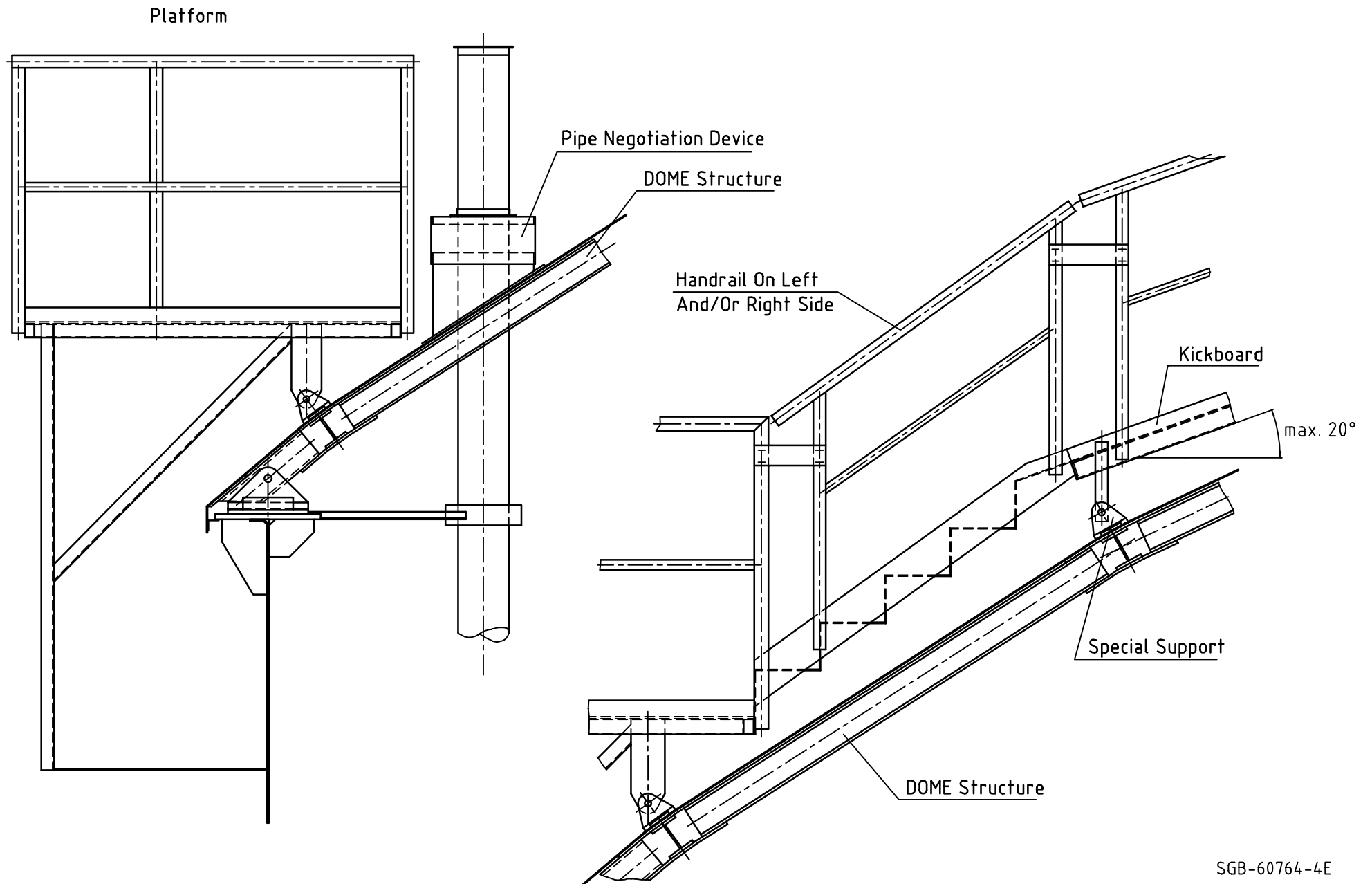
View A

Sheet Cover



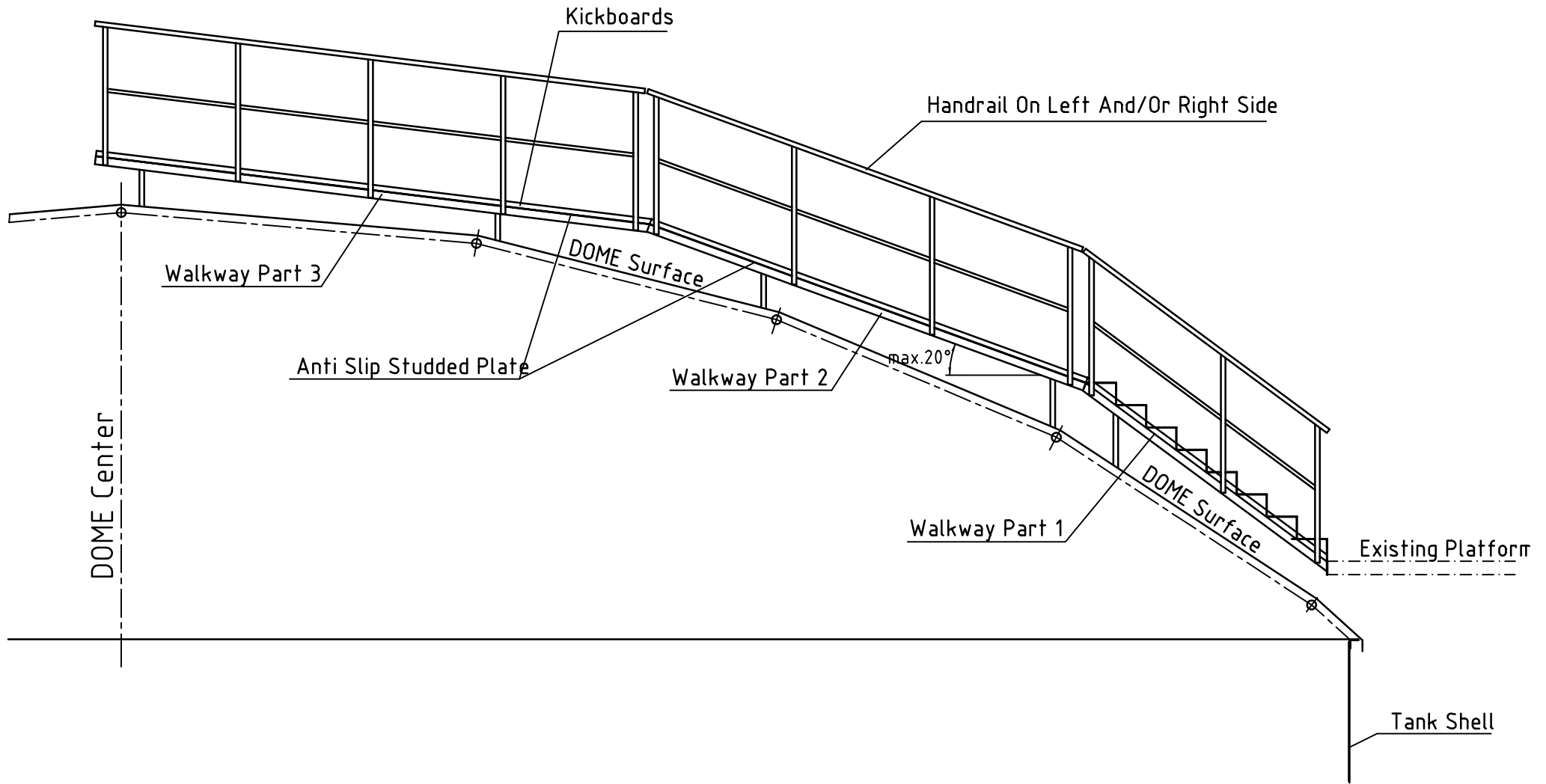
# VACONODOME

Platform - Walkway



# VACONODOME

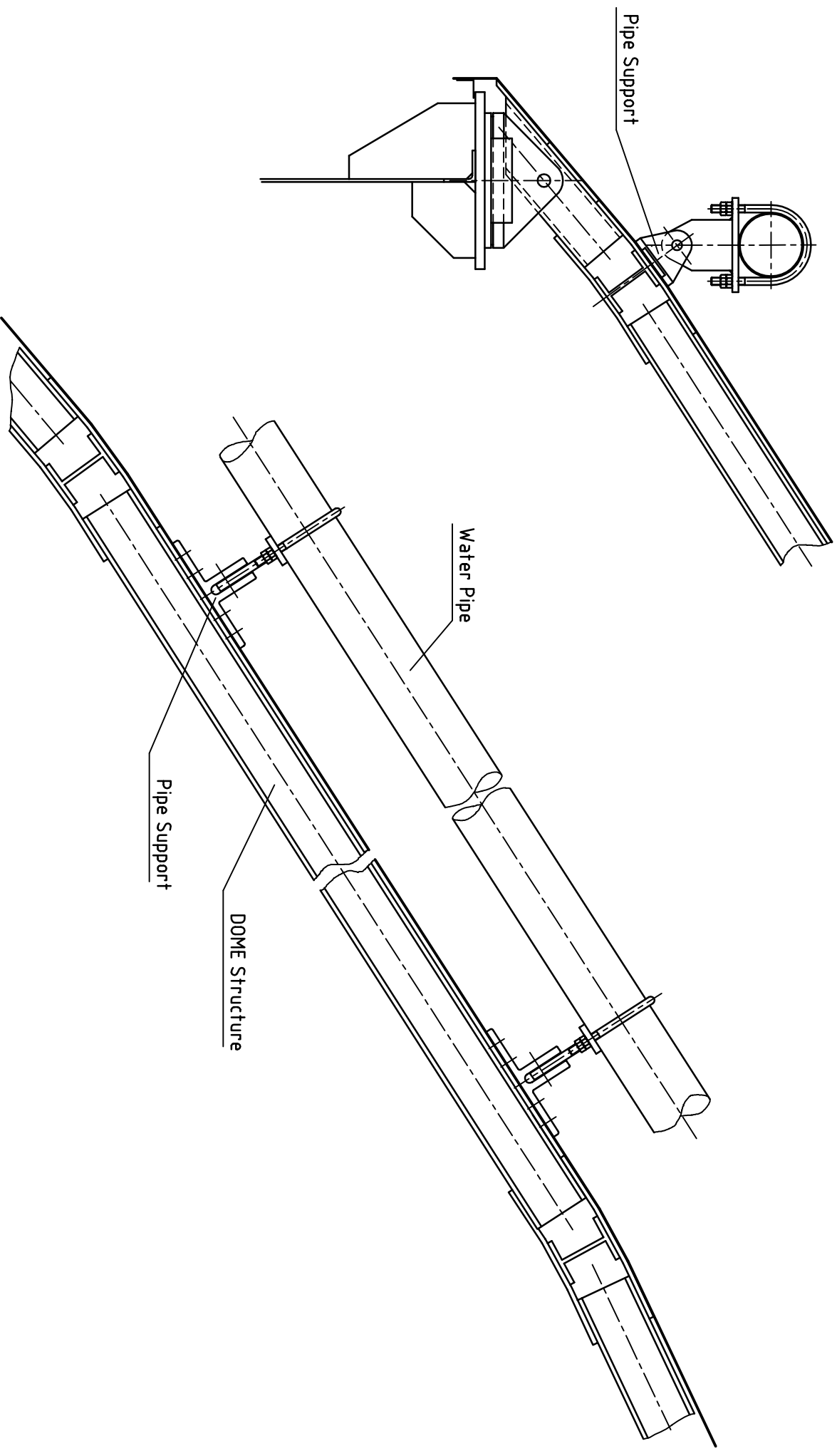
## Walkway





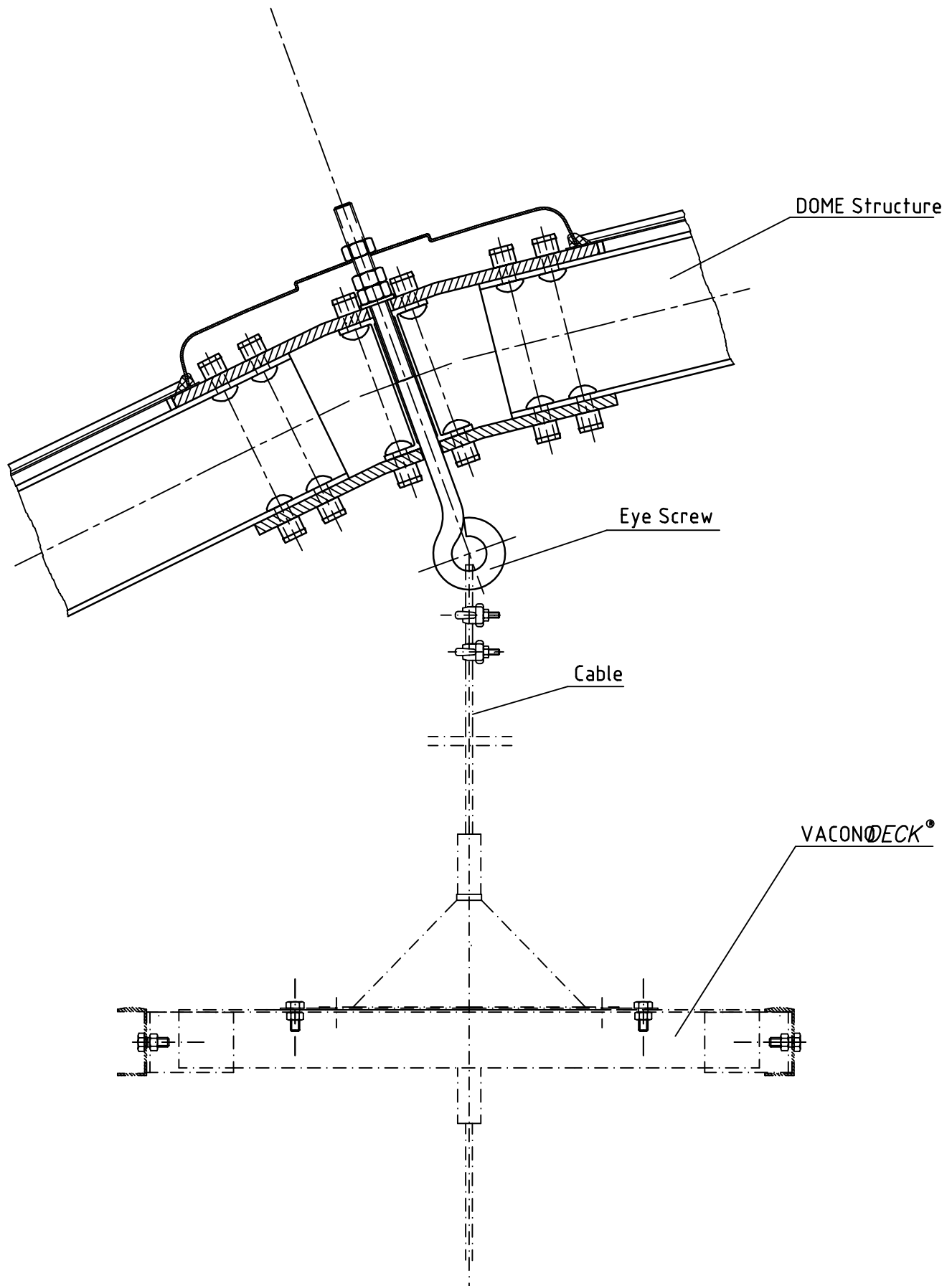
# VACONODOME

## Pipe Support



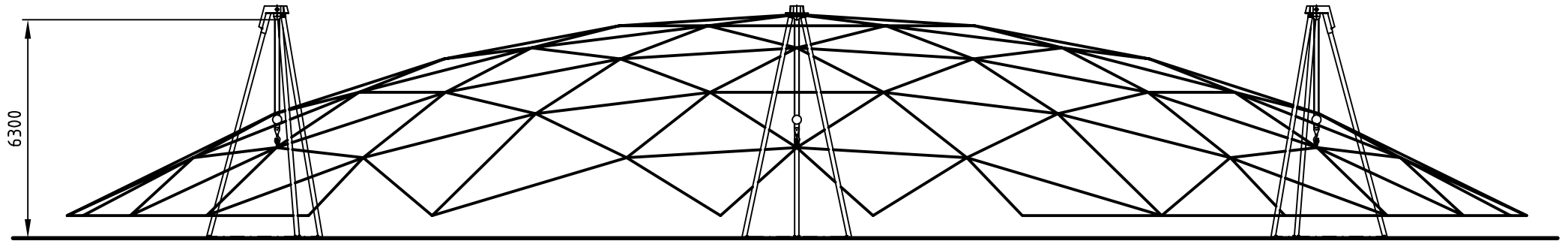
# VACONODOME

Suspension of Antirotation System



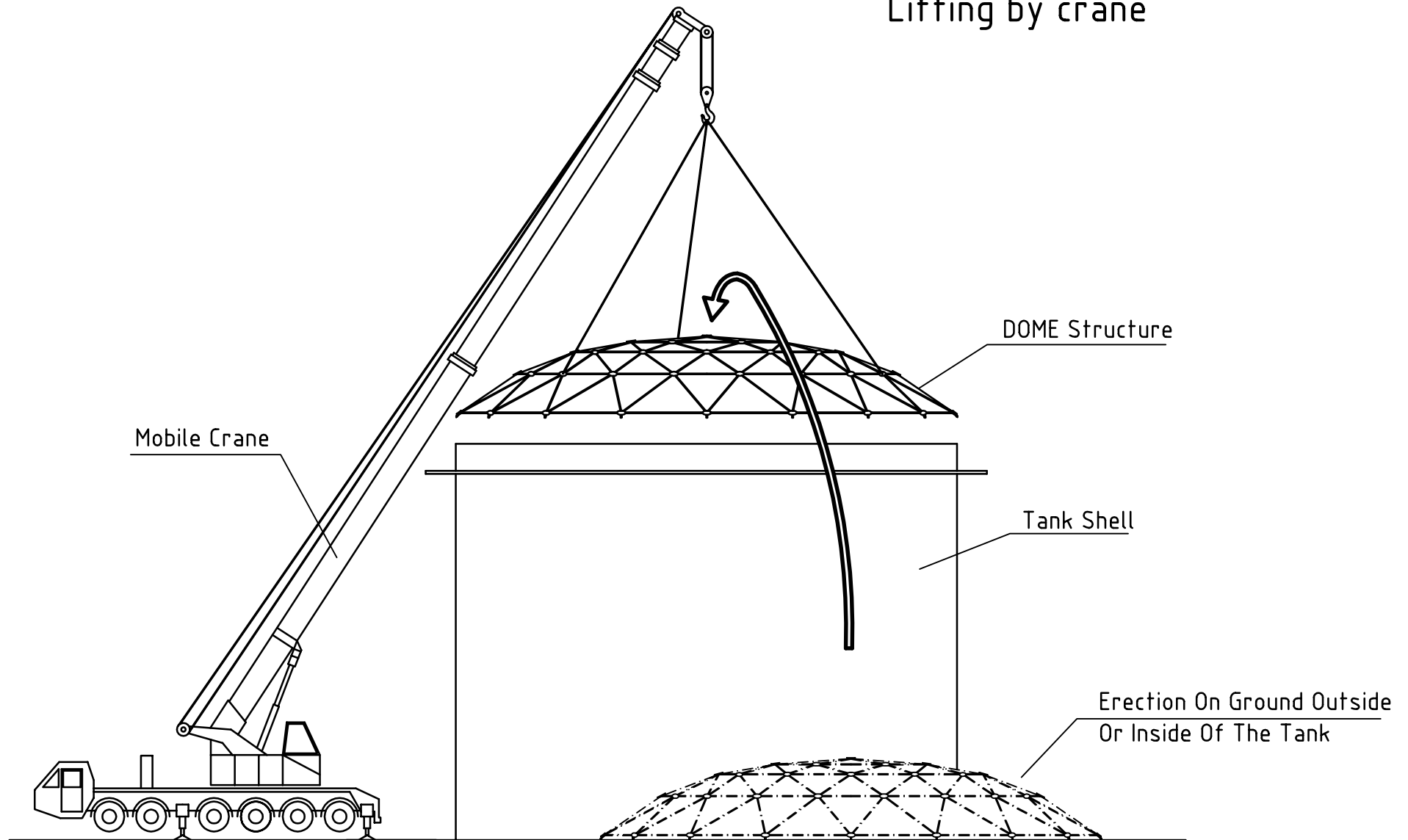
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Tripod



# VACONODOME

Lifting by crane



# VACONODOME

## Lifting Equipment

