TALLINNA TEHNIKAÜLIKOOL
TALLINN UNIVERSITY OF TECHNOLOGY

Department of Mechanical and Industrial Engineering

MARINA SERVICE PEDESTAL DEVELOPMENT

SADAMAKAI TEENINDUSPOSTI ARENDAMINE

MASTER THESIS

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AUTHOR'S DECLARATION

Hereby I declare, that I have written this thesis independently.
No academic degree has been applied for based on this material. All works, major viewpoints and data of the other authors used in this thesis have been referenced.

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THESIS TASK

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1. Compile product specification based on market expectations.
2. Develop technical solution for the pedestal design.
3. Assess the designs viability for further development.

Thesis tasks and time schedule:

No	Task description	Deadline
1.	Service pedestals use and market analysis	04.03
3.	Concept development	17.03
5.	3D modeling	10.04
7.	Generating production drawings	24.04
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PREFACE

This thesis topic was initiated by the author – Sander Vislapuu. Large part of the thesis was done at the studio of Keha4 OÜ in close consultation with rest of the Keha4 OÜ team. Great assistance with data collection was provided by board member Ago Altjõe. The supervision from the university was provided by Docent Toivo Tähemaa.

The thesis starts with the overview of the marina service pedestal construction and use. Market research is carried out – which culminates with the creation of product specification. The main body of the thesis focuses on the electrical and mechanical design of the pedestal. Stress calculations are made for the structural elements of the pedestal. Last chapters focus on manufacturing and cost calculations. Thesis concludes with a summary.

I would like to thank all my colleges from Keha4 OÜ for their support. Also I would like to thank my supervisor Toivo Tähemaa for all this guidance and help. Special thanks go to my course members and friends for their intense support. Most importantly however, I would like to thank Margus Triibmann for all his inspiration and wisdom.

List of abbreviations and symbols

IP – ingress protection

IK – Impact protection rating

UV – ultraviolet light

LED – Light emitting diode

MCB -Miniature circuit breaker

RCCB – Residual current circuit breaker

RCBO - Residual Current Circuit Breaker with Over Current Protection

INTRODUCTION

The purpose of this thesis is to develop a new marina service pedestal for company Keha4 OÜ based on industrial designer Margus Triibmann original sketch. Author will apply his knowledge of product development while honoring the original design intent of late Mr. Triibmann.

The outcome of this thesis will include a technical solution for the service pedestal and economical information for subsequent decision making.

Keha4 OÜ is an Estonian company that designs and sells outdoor luminaires. In 2017 company also entered the service pedestal market with “Coral” which was originally produced for Kakumäe marina. Coral was a major success in the design circles, winning multiple design awards in Estonia and generating interest in foreign media and attracting resellers from Germany and Scandinavia. Inspired by this success and based on resellers input – work started on a new, more conservative design. Unfortunately, this work was left unfinished when the designer died in 2018.

Firstly, an overview is given of the marina service pedestal construction and function. Secondly market research is carried out. Based on the gathered info – product specification can be created. Subsequently multiple design concepts are created and compared. Winning concept is assessed more closely, and important aspects tested in necessary. The construction design of pedestal is broken into two parts: electrical design and mechanical design. Electrical design will determine what electrical components will have to be fit into the service pedestal and how they will be dimensioned. Mechanical design will determine how to meet all technical requirements imposed to the marina service pedestal. Solidworks 2018 CAD software will be used for modeling and drafting. Attention is given to various environmental requirements that the pedestal must be able to meet – including ingress protection and impact resistance. Several key aspects of the design are assessed in more detail. Using ANSYS 16 simulation software the structural integrity of the pedestal is simulated against environmental forces. In the manufacturing chapter information is given on how the production of the pedestal will be arranged and what costs in time and resources can be expected. Specification gives overview of pedestals mechanical and electrical parameters. Economical calculations part will determine the profitability of this design. Investment costs are calculated. Production costs and sales costs are also determined. The thesis ends with a conclusion – where the goals are compared with the outcome and viability of further development is assessed.

1. MARINA SERVICE PEDESTAL OVERVIEW

Marina service pedestals also known as marina power pedestals are distribution devices used in marinas to provide various utilities to berthing vessels. The most important utilities are electrical power and fresh water. Other utilities may include internet, cable TV, phone connection etc. Often pedestals also include integrated lighting that helps people navigate the pier where these pedestals are installed. Marinas service recreational vessels with size varying between small boats with no electrical systems to luxury yachts with multiple electrical systems and large power demands. Because of this variation in vessel sizes and corresponding power requirements – most pedestal manufacturers provide multiple models for the marina operator to choose from.

1.1 Construction

Following is a brief overview of marina service pedestals design practices.

1.1.1 Enclosure

Marina power pedestal construction is defined by an outer shell constructed from stainless steel, aluminum or plastic. Often these materials are used in combinations with each other. All materials including fixing elements must be resistant to marine environment. Most popular plastics are polypropylene and polyethylene. The interior of the power pedestal will have an IP rating of IPX6 or greater. IPX6 will protect against low pressure water jets from all directions [1].

If the power pedestals also function as a water distribution point, then the water line is separated from electronics by a sub housing. Pedestal is generally fixed to the mounting surface with bolts.

Figure 1 Different pedestal housing types. Source: Plusmarina; Talleykey A/S

1.1.2 Electricity

Power cables enter from below the pedestal and attach to the input terminals where they are connected to the pedestals circuit. Through wiring from one pedestal to another is also a common feature.

Stranded wires are used due to vibration and movement present on marinas.

The exterior of the power pedestal will usually display several power outlets. In some models these outlets are hidden under splash covers. The number of power outlets varies, but commonly it´s between 2 and 6. The output power is single phase or triple phase alternating current. In European market outputs are rated at 16A, 32A. In some specialty pedestals 63A and 125A are also available.

Circuit breakers are used to protect the wiring against wires overheating, electrical current leakage as well as risk of shock and electrocution. Access to the circuit breakers is made possible for the user.

Sometimes surge protectors are used to protect solid state equipment on board vessels as well as equipment installed on the pedestal.

1.1.3 Water

Power pedestals can also include one or more water faucets. Different faucet designs are used. Some pedestals include means for storing hoses. In many designs water lines and connections are kept in a separate sub-housing from the electrical components. Water metering can be integrated. Water systems are emptied for the duration of winter period if there is danger of freezing. Some pedestals include foam insulation against unexpected temperature drops.

1.1.4 Lighting

Many power pedestals include lighting for the surrounding area and pedestals connections points. LED light source is most commonly used, some designs can also use compact fluorescent lamps. Control of the lights can be achieved by a switches on the pedestal itself or through a photocell sensor.

Figure 2: Rolec Spinnaker service pedestals at night. Source: Rolec Ltd

1.1.5 Internet

Internet access can be provided through a CAT5 socket on the pedestal or by an integrated WIFI router.

1.1.6 Metering

The consumption of electricity and water can be monitored through metering. Meters can be integrated into the service pedestals and visually or remotely read. IoT solutions exist that enable Marina operator to switch on or off individual service pedestals water and electricity. These solutions also enable full overview of consumption and this information can be accessed by clients in real time. Aftermarket solutions are available that allow older service pedestal to be retrofitted. Most marinas still use low cost solutions that only enable visual monitoring.

1.1.7 Special purpose pedestals

Different modifications are also available that fill specialized functions (storing emergency equipment, storing bilge pumps). In this case the pedestal doesn´t include the usual functions and is marked with special colors and labels.

Figure 3: Specialized service pedestals. Source: Rolec Ltd

1.2 CE marking

In order to sell goods in the European Economic Area, certain products must bear the CE mark which implies that the product is in conformity with health, safety and environmental protection standards outlined in EC directives. The mark consists of the CE logo and identification number of the Notified Body involved in the conformity assessment procedure, if applicable. Some CE markings are fully self-declared, and no external conformity assessment is needed. The manufacturer must attach the CE mark to the product or if not possible, then to the packaging of the product. Additionally, the manufacturer must produce 2 documents. [2]

Figure 4: CE Mark. Source: Europa.eu

- **Technical document**. This file will include every aspect related to conformity and will include information about design, development and manufacturing of the product. It´s advised to include the creation of such documentation in the overall product development process. The technical documentation, also refer to as technical file, will have to be retained for 10 years after the manufacturing of the last unit. The manufacturer is not obligated to show this file to anyone except EU enforcement authorities.

- **EU declaration of conformity**. This is a legal document where the manufacturer declares that the product or products are in full conformity with EC directives and lists all applicable sectoral Directives and standards that have been applied. The document is signed by high level representatives who can be held responsible for any misuse of CE marking.

1.2.1 CE marking requirements for marina service pedestals

Marina service pedestal must conform with following directives and applicable standards:

2014/35/EU Low Voltage

2004/108/EC Electromagnetic Compatibility

EN 61439-3 Low-voltage switchgear and control gear assemblies – Part 3: Distribution boards intended to be operated by ordinary persons.

2. MARKET RESEARCH

2.1 Target market

Keha4 OÜ has exported product to as far as Japan, but vast majority of products are still sold within the European Union. This product development project will focus on the European Union market. Keha4 OÜ reseller network for marine products is already being established in several EU countries and there is relatively lot of disposable wealth in this region. Logistical and legislative barriers are also minimal.

In total Europe has over 27,000 km of inland water ways and more than 70,000 km of coastline. Recreational marine activities are practiced by 48 million European citizens. Over 6 million recreational boats are kept in European waters – 2 million out of those are in Scandinavian and Baltic waters [3].

Access to marine related services are provided by 4500 marinas with 1,75 million berths. It´s estimated that about 65% of these marinas are coastal marinas and about 1,1 berths are coastal [3]. The core activity of these marinas is to provide berthing services and related utilities to mostly recreational vessels. Often marinas also include restaurants, repair shops, tourism services. The marinas sector in the EU is estimated to have a turnover of between €3 billion and €4 billion and employ between 40 000 and 70 000 people [4]. An average marina size in Europe is 250 berths [5]. The average amount of service pedestals is not known and must be found through market survey.

Marinas and Berths EUROPE	The Mediterranean (European part)	West Europe/Transatlantic (below the Arctic Circle)	The Baltic and the countries around the Arctic Circle	Continental part of Europe (freshwaters)	TOTAL
0-100	59	102	105	465	731
101-500	236	237	92	101	666
501-1000	78	75	5	2	160
1001-2000	24	20	1	2	47
2001-5000	3	2	-	-	5
> 5001	1	0	-	-	1
Berth total	171,158	153,896	33,060	44,739	402,853
Number of marinas	401	436	203	570	1,610
Average number of berths per marina	426.83	352.97	162.86	78.49	250.22

Source: ADAC, „Marinaführer, Deutschland, Europa", 2010

Figure 5: Average marina size in Europe. [5]

Market survey

In order to develop accurate specifications for power pedestal a market research was carried out. Market research aimed to engage all interest groups who interact with the power pedestals through the products life cycle.

2.1.1 Client

The client for this product is the marina who is responsible for the final purchase decision and who will assume the ownership of the service pedestals. Client will make his decision based on different variables including input from specialists. Clients decision making will include such aspects as: Price, design, ease of use, maintenance, service support, environmental factors etc. This group most likely has the best overview of the needed technical parameters since they have direct contact with the users and full overview of technical problems that can be expected.

In order to get an overview on clients needs and wants – survey was carried out. Survey included 9 marinas from 6 European countries (APPENDIX 1 Marina survey results). Additionally, information was found from homepages and promotion material.

Results summary

- Average surveyed marina size was ~ 558 berths;
- On average ~4 berths for every service pedestal;
- 4x16A most common, 2x16A common, any combination with 32A is rare, any combination with 63A or 125A is very rare;
- In all marinas 16A outlets make up majority of pedestals;
- All include lighting;
- most include water;
- Electricity metering on the pedestal is rare;
- Remote metering systems where not used in any questioned marinas. No interest was shown for such a function;
- Integrated Wi-Fi not used on any questioned marina. No interest was shown;

2.1.2 Specifiers/specialists

This is usually the group who is responsible for getting the power pedestals included into projects. These are specialists who the client approaches for advice. This group includes architects, electrical contractors, consultants. Some of these specialists will have conflicting interest. While architects are very much focused on aspects of design, electrical contractors will be much more focused on delivery times, price, ease of installation. The possible conflict between these interests will eventually be decided by the client.

Interviews were carried out with 2 architects and 2 resellers. Architects where mostly approached with questions regarding the design and marina projects in general and resellers were approached with questions regarding issues important to installers since they have a lot of contact with electrical contractors.

Results summary

- Most marinas prefer to include the price of electricity and water into berthing fees.
- Most pedestals sold include both water and lighting.
- Aluminum and steel enclosures are seen as premium quality products.
- Interest for IoT solutions is low.
- Bilge pumps and emergency service pedestals are mandatory in all service providing marinas.
- Most common reclamation cases involve faults in electricity and water supply due to unprofessional installation
- Many reclamation cases involve physical damage to the pedestal due to mechanical force.

2.1.3 User

The end user for our product is the yacht owner who uses the service pedestals utility services to power his vessels electrical systems, to acquire water and other utilities. Yacht rental company was approached with questions. Online resources (forums, product reviews) were also analyzed for yacht owners experiences regarding power pedestals.

Results summary

- Circuit breakers have tendency to trip in hot weather condition

- Residual current devices tend to drip with older vessels

2.2 Competitors

The amount of service pedestal manufacturers operating in European market in hard to estimate. Barriers of entry into the market are mediocre. Any company with tooling and experience with electrical control enclosures could enter this market with minimal effort. Biggest problem would be finding resellers who operate in this market place. A few larger companies do stand out: Rolec Services Ltd (UK), Talleykey A/S (DK), CPES Ltd (UK). These companies and their sales materials where researched. Two of them have resellers in Estonia, who where contacted for sales price and sales conditions. The service pedestal market is B2B market dominated by project sales. Pedestals are rarely produced into stock and manufacturers are very flexible with their designs. Number and type of outputs, extra functionalities, color can be customized. Manufacturers work close with their clients.

2.2.1 Product segmentation

Products are usually segmented based on the material of the enclosure: Stainless steel, Aluminum or Plastic. Plastic is often combined with galvanized steel and offered as a „economical“ solution. Stainless steel and aluminum is sold as a premium option. This is not always true however - Sometimes plastic is used to achieve design effects that are not possible with other methods in which case it can be offered at premium prices.

Further segmentation is done based on the electrical output which is measured in Amps. Power pedestal with six 16 A outputs would be referred as a 100 A pedestal.

2.2.2 Pricing

Pricing data was sourced from 2 resellers in Estonia.

Table 1 Service pedestal price comparison.

	product	**Product 1**	**Product 2**	**Product 3**
	Housing type	Plastic/ galvanized steel	Plastic	Aluminum
	Market positioning	Economy	Premium	Premium
	Light	LED	LED	LED
	water	1 tap	1 tap	1 tap
	metering	Not included	Not included	Not included
version	2x16A outlets	689 €	1074 €	1121 €
	4x16A outlets	816 €	1198 €	1170 €
	6x16A outlets	900 €	1300 €	N/A

Table 2: Premium Marina service pedestal comparison. [6] [7] [8]

Product	Properties	Picture
Original pedestal by RMCS	• Polyethylene and stainless steel • 16 A to 125 A outlets • LED lighting with photocell sensor • water outlet • Ta -30°C… 60°C • IK10 • IPX6 • **1170 € (4x16A model)**	
Platinum pedestal by RMCS	• Aluminum enclosure • IPX6 • 16 A to 125 A outlets • LED lighting • water outlet • IK10 • **1198 € (4x16A model)**	
Keha4 Coral	• Polyethylene enclosure • IPX6 • 16 A to 64 A outlets • IK10 • water outlet • **1600 € (4x16A model)**	

2.3 Market positioning

Keha4 OÜ entered the service pedestal market at a request of a client who wished for a more aesthetically pleasing and interesting service pedestal. Similarly, the design for the new power pedestal was started at a request of a reseller who found Coral too extreme and felt that his clients would prefer something similarly exclusive but more conservative. Based on our experience with Coral, we believe that there is a niche market for designer service pedestals. The new service pedestal will be aiming for the same market segment. We will be offering our clients a power pedestal with superb design, solid build quality at an above average price point.

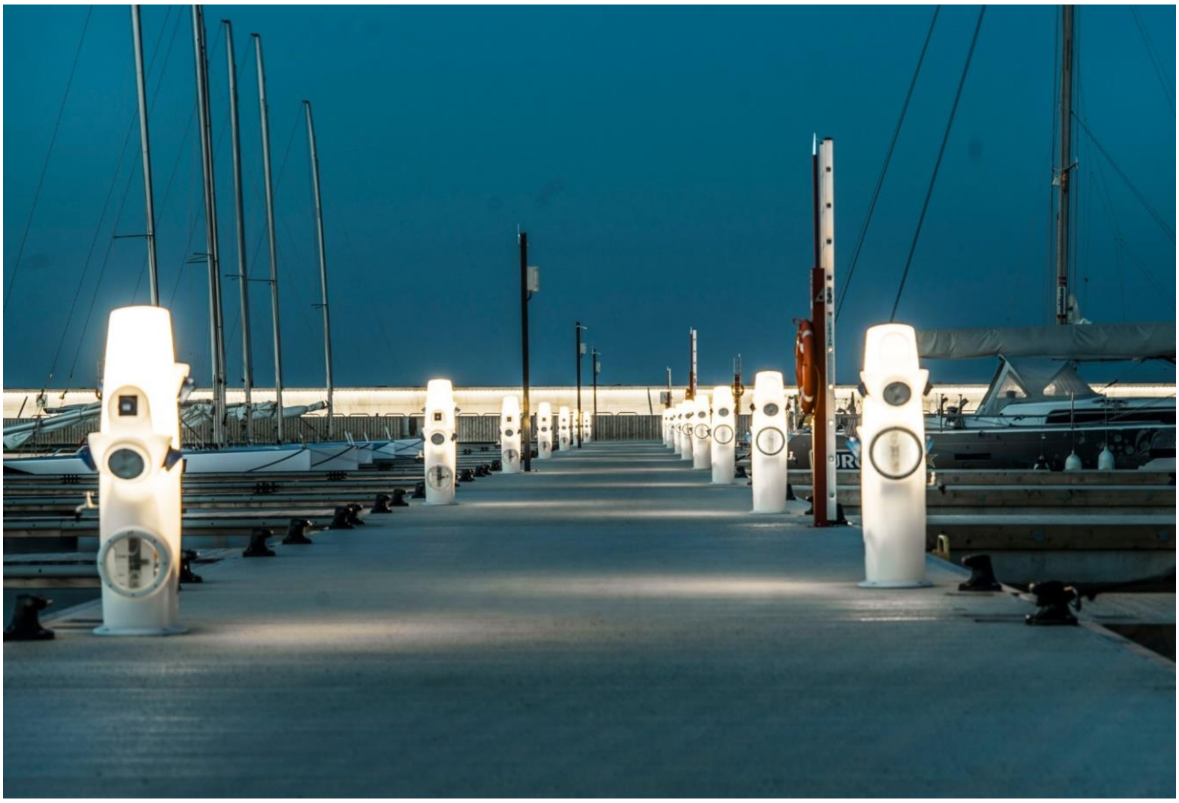


Figure 6: Coral service pedestals at night. Source: Keha4 OÜ

Figure 7: Market positioning for the new pedestal. Source: Author

3. SPECIFICATIONS

Based on market research, previous experience with “Coral” service pedestal and the apparent design limitations of the original design sketch – technical specifications for the marina service pedestal where compiled.

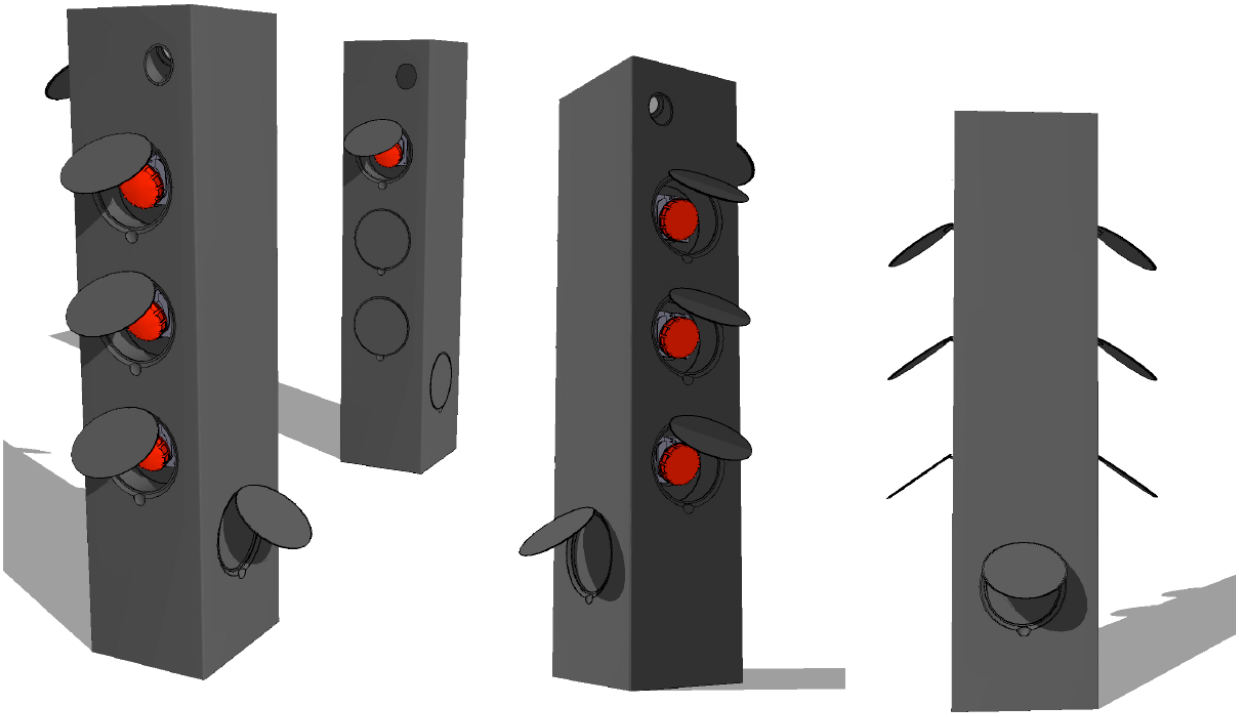


Figure 8: Original sketch for the pedestal. Source: Margus Triibmann

Table 3: Marina service pedestal specifications

Property	Target value	Fixed	Desired
Enclosure	1500x360x360 (mm)	X	
	Resistant to marine environment	X	
	Resistant to sun exposure	X	
Ingress protection	IPX6 [9]	X	
Impact protection	IK07 [9]	X	
Temperature range	-25 … +40 °C	X	
Lighting	LED	X	

	Photosensor	X	
	Light effect above competition	X	
Water	Single ½” faucet	X	
	Insulation against sudden temp. drops		X
	Separate sub housing for water	X	
Power input	3 x 230 V / 400 V 50 Hz triple phase	X	
Power outputs	2 x 16 A; 4 x 16 A; 6 x 16 A	X	
	2 x 16 A and 2 x 32 A	X	
	2 x 32 A and 4 x 16 A		X
Electrical safety	Circuit breakers [9]	X	
	Current leakage protection [9]	X	
Metering	Electric meter with value displayed on pedestal	X	
	Remote reading capability		X
	Water metering capability		X
Internet	Integrated Wi-Fi router		X
Maintenance	Circuit breakers and meters must be accessible to users with minimal effort and no disassembly.	X	
	Access to wiring and electrical components must be possible with minimal disassembly for repairs/ inspection.	X	
Installation	Installation must be possible with common tools and minimal instructions.		X
Certificates	Must meet CE marking standards	X	
Environmental impact	Minimal environmental impact.		X
	Components must be recyclable at the end of lifetime.	X	
	Previously recycled materials used		X
Production patch size	60	X	
Production cost	700 €		X
Sales price	1300 €	X	

4. CONCEPT DEVELOPMENT

4.1 Concept A - Extruded aluminum enclosure

First concept involves two extruded aluminum profiles that are connected with each other with an integrated hinge on one connection point and with an integrated latch system on the other connection point. If the latch system is too difficult to open, then a captive pin could also work.

When closed – two profiles will create an IPx6 confinement in the center of housing (gaskets not shown).

When opened – users will have very good access to all components. There will not be too much space between the panels, so careful planning must be done. Mounting plate and top of the pedestal are separate.

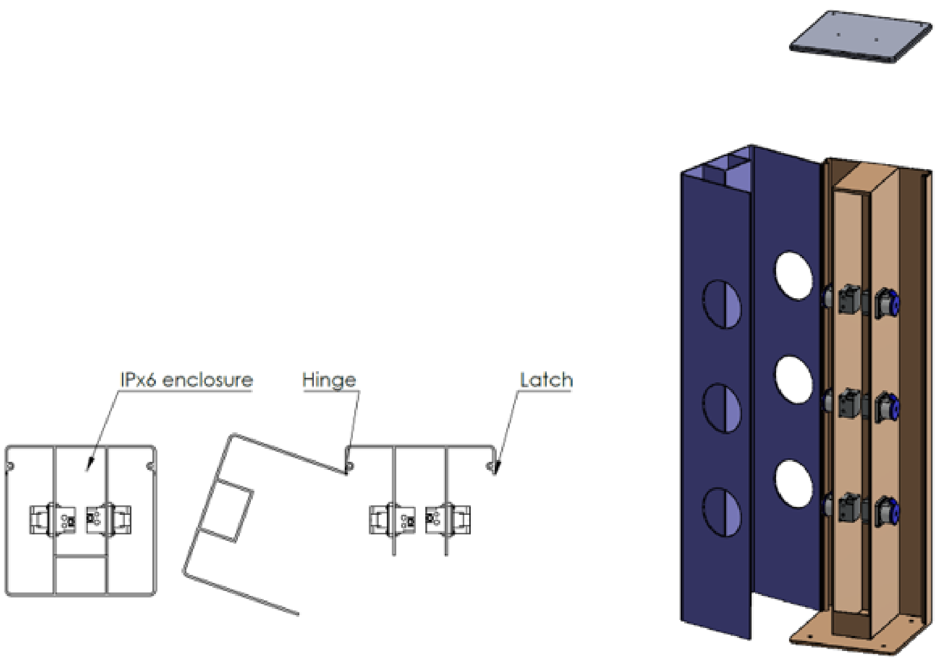


Figure 9: Extruded aluminum concept

Table 4: Concept initial analysis

Advantages	Disadvantages
Simple assembly	Visible separation lines between panels
Good heat dissipation	Large min. order for extrusion
Easy maintenance and installation	Cramped space for components
	Significant development costs
	Panel can´t be opened when sockets are in use

4.2 Concept B - Plastic enclosure

Second concept involves an aluminum or stainless-steel frame that is used to secure the pedestal to the surface and mount all the electrical components. The housing is made from plastic similarly to Coral. Access way to electrical outlets is through aluminum or stainless-steel tubes. These tubes also secure the housing to the frame and provide proper IP rating to the internal space. Similarly, to Coral, this design can be illuminated internally for a great visual effect. This effect will not work with dark housing colors in which case alternative lighting solution must be used.

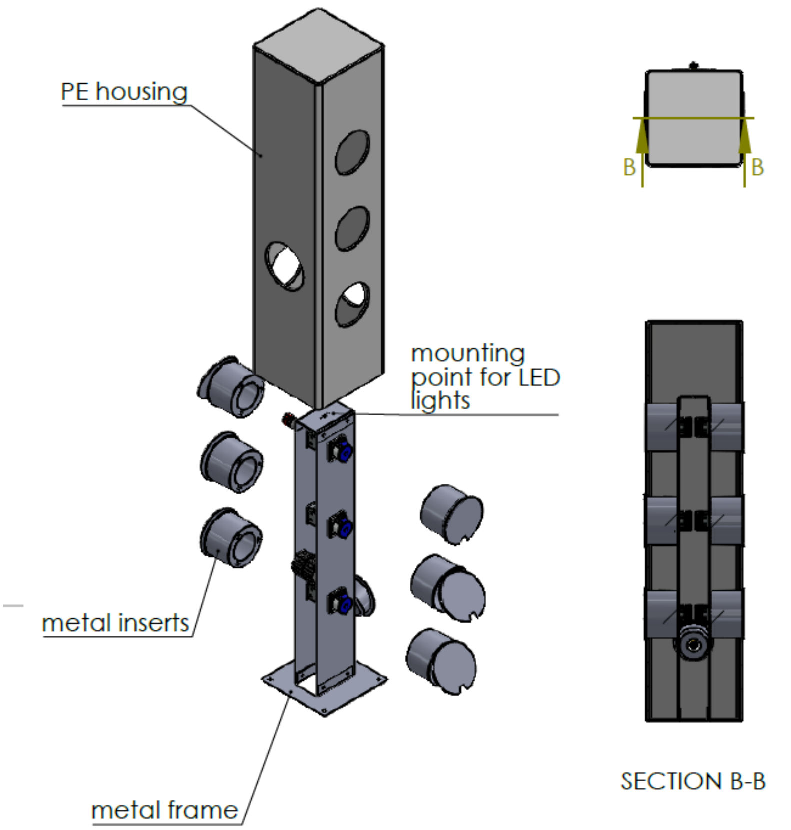


Figure 10: Plastic enclosure concept

Table 5: Initial concept analysis

Advantages	**Disadvantages**
Best lighting effect	Heat dissipation
Seamless exterior	Significant development costs
Recycled plastic as selling point	Maintaining IP rating
Experience with PE	Possible internal shadows
	Photosensor placement issues

4.3 Concept C - Stainless steel enclosure

Third concept is enclosure from stainless steel. Housing is produced from sheet metal using laser cutting and then bent into correct shape using a bending machine. Individual components can be welded and bolted together. Large door will allow for access into the housing to reset circuit breakers. Extra separation panel should be used (not shown) to separate circuit breaker controls from other electronic components. Construction is straightforward and many Estonian companies possess tooling and know-how for this design.

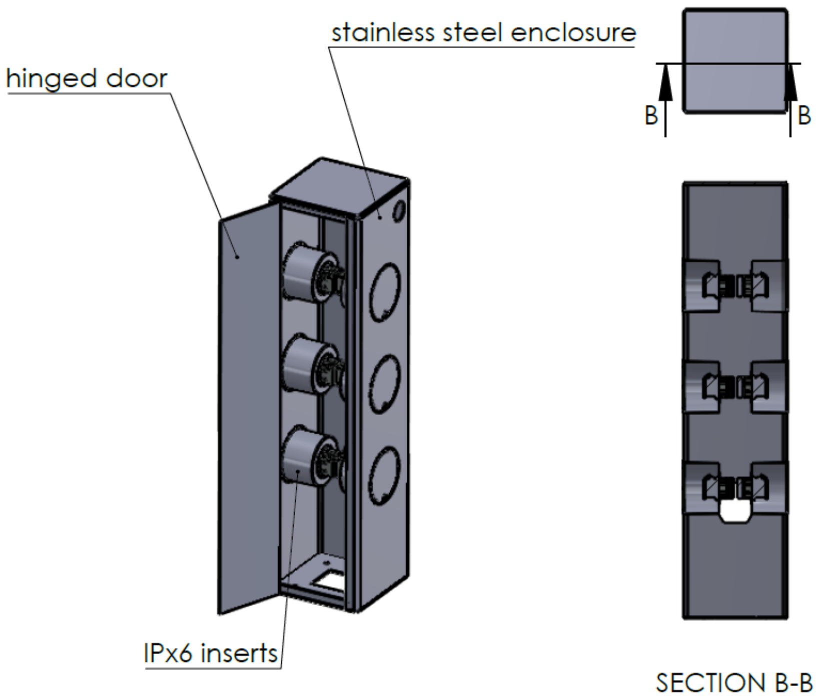


Figure 11: Stainless steel enclosure concept

Table 6: Initial concept analysis

Advantages	**Disadvantages**
Low development costs	Difficult material to process
Long lifetime	Expensive material
Flexible design	

4.4 Comparative matrix

In order to compare the different design concepts, comparative matrix is produced. The results will be shown and explained to the decision-making group within Keha4 OÜ.

Table 7: Comparative matrix between concepts

Criteria	**weight**	**Concept A**	**Concept B**	**Concept C**
Design fit and finish	**5**	1	3	2
Lighting effect	**5**	2	3	2
Design flexibility	**4**	1	2	3
User friendliness	**4**	2	2	2
Ease of maintenance	**3**	3	1	2
Ease of assembly	**3**	3	2	1
Development costs	**3**	1	1	3
Product lifetime	**3**	3	2	3
Environmental impact	**4**	2	3	2
Total score:		**63**	**73**	**73**

The comparative matrix shows that we have 2 competitive design approaches. Ultimately Concept B is chosen because of few important considerations.

- The integrated diffuser concept was pioneered by Keha4 OÜ with the Coral design. No competitor offers such a solution, and this adds to the Exclusivity of our product.
- The aluminum frame and the plastic enclosure are both highly recyclable. Theoretically diffuser could be made from already recycled plastic – at the expense of optical capabilities. This must be tested in practice.

4.5 Illumination testing

The main reasons why Concept B was chosen is because of the expected illumination qualities. compared to the Coral design – there is less free space inside the housing and thus less room for the light to properly diffuse. It´s expected that the internal components will cast shadows on to the exterior of the pedestal. It´s necessary to simulate the expected lighting qualities of the pedestal.

The test results will be assessed by an internal panel. The result of the test will decide whether to move on with concept B or revert to alternative solutions.

Illumination test model

For the purpose of this test, a scaled model of the pedestal with scale factor 1:2,8 was constructed. The housing is made from the same PE plastic used for the pedestal, manufactured using the same rotational forming method. The frame is made from 0,8 mm galvanized steel with similar reflective properties as stainless steel. Internal components are made from cardboard and plasticine – mimicking the size and location of circuit breakers, energy meters, wires etc.

Illumination of the full-size pedestal will be preferably provided by E27 LED lamps. Such solution is preferred because LED lamps with E27 sockets are very common, very affordable, have integrated drivers and work on 220 V / 50 Hz. This solution would demand least amount of after sales service from our company. In the illumination model LED lamps with G4 sockets are used to simulate E27 LED lamps. These lamps have similar photometric patterns in a smaller form factor and at a lower light output.

Figure 12: LED lamp used in the illumination test: Source: Author

Table 8: Properties of the LED lamp used in the test

Property	Value
Name	Leduro G4 1,5 W
Light output	100 lm
color temperature	2700 K
Color rendering index	80

Results

It was concluded that the best solution would be achieved by 2 LED lamps mounted on top of the frame. The internal opening in the original frame design would produce shadows. Light blocking cover will be included into the frame design.

The results are not ideal, but they are sufficient to prove that the concept works, and author is confident that with some testing, sufficient light quality will be reached. This testing must be done on a full-sized prototype.

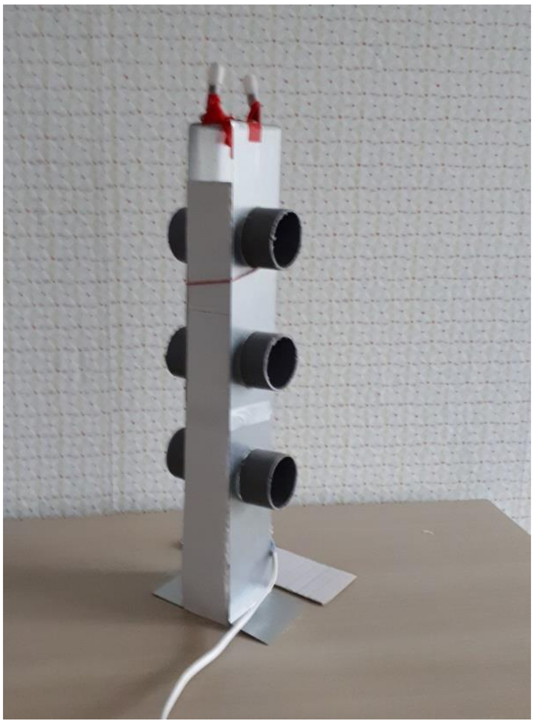


Figure 13: Test frame with two LED lamps and light cover (white). Authors photo

Figure 14: Illumination test with two LED lamps and light cover. Authors photo

5. ELECTRICAL DESIGN

Since marina power pedestal market is dominated by project sales, then every „product“ can have many different versions. For the purposes of this thesis – most technically challenging version is used.

Table 9: properties of the pedestal version that electrical and mechanical design will be performed

Property	**Value**
Electrical sockets	2 x 32 A and 4 x 16 A
Light	YES
Water	YES
Metering	YES, On pedestal

5.1.1 Internal temperature

The internal temperature of the service pedestal must not exceed the maximum working temperature of electrical components. High internal temperature will lead to shortened lifetime for the electronics or possibly catastrophic failure. In marina power pedestals common problem is the premature tripping of protective devices. This is due to temperature sensitive design of MCB-s.

Desired ambient temperature (Ta) for the pedestal is 40 ^{0}C, this represents the temperature outside the pedestal enclosure. Temperature inside the enclosure (Ti) is higher due to heat retention of the +
-enclosure and power losses from electrical components.
Before CE marking can be fixed to the assembly – Thermal rise must be determined. For partially type tested enclosures – this can be calculated. For a new design such as this pedestal – temperature rise must be tested.
For the purposes of the electrical calculations – internal temperature (Ti) is assumed 55 ^{0}C.
This number is based on the highest allowed ambient temperature for circuit breakers.

5.1.2 Function structure diagram

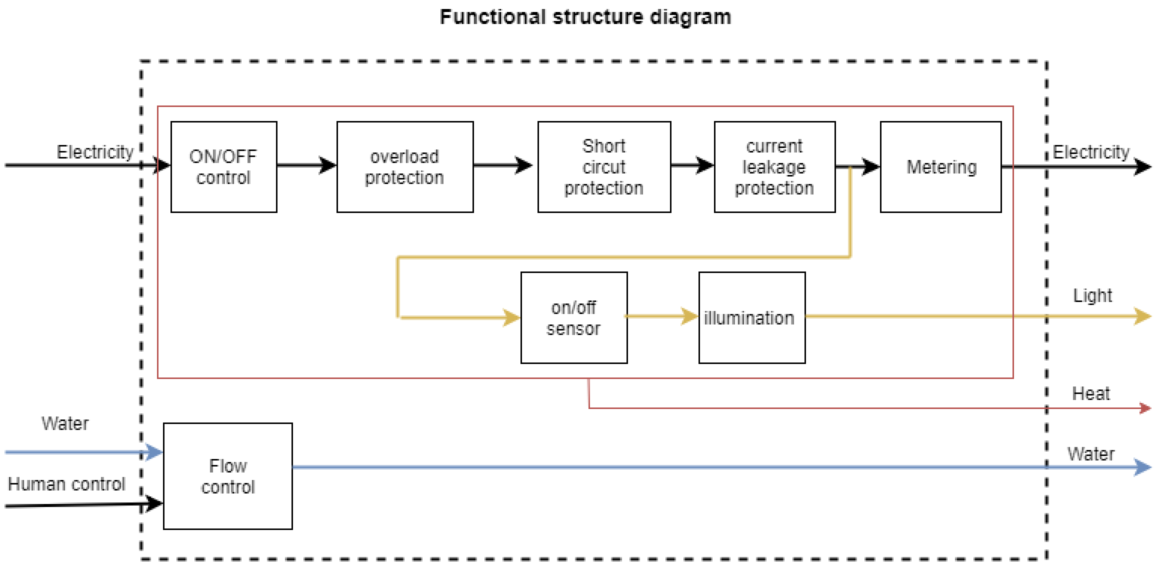


Figure 15: Functional structure diagram

5.1.3 Wiring sketch

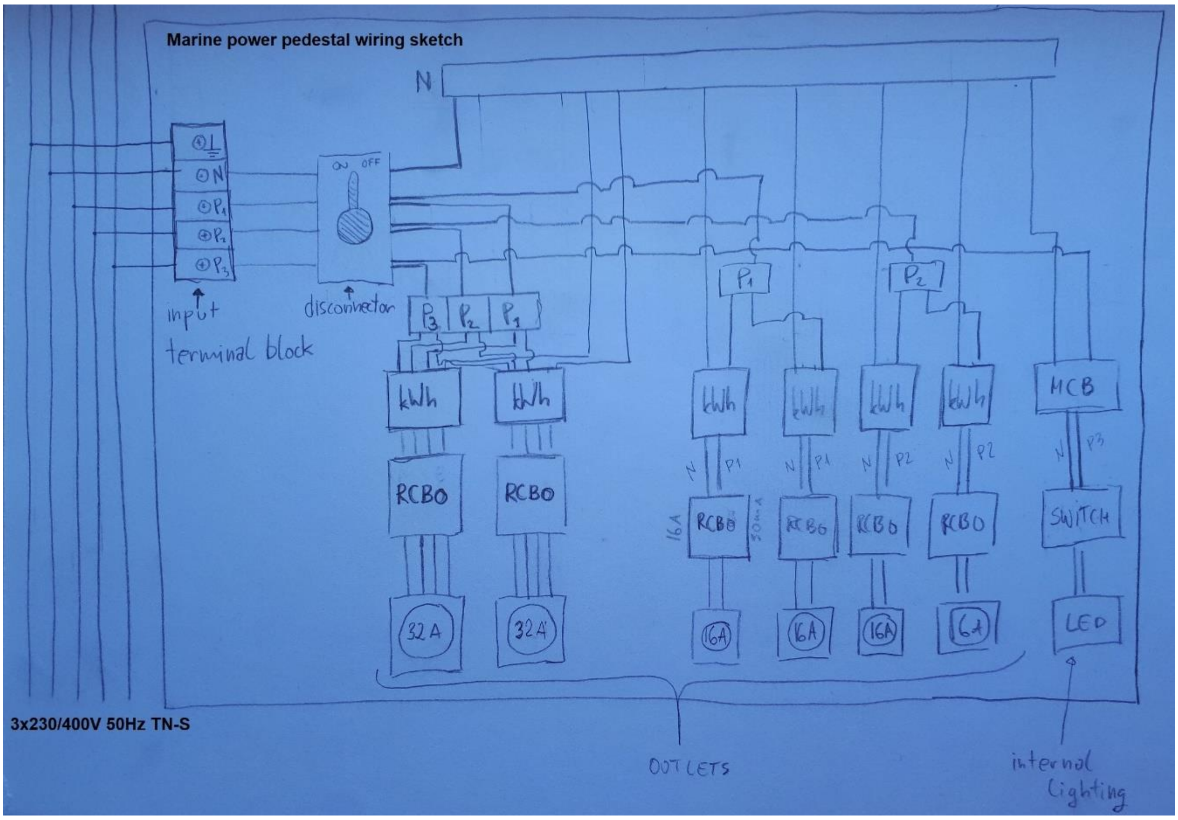


Figure 16: Initial wiring sketch. Source: authors photo

5.2 Calculation of conductors and protective devices

5.2.1 Power demand

In order to design an installation, the actual maximum load likely to be imposed on the power-supply system must be calculated.

It´s unlikely that all circuits will be working at the full capacity and it´s also unlikely that all circuits will be working at the same time. For this purpose, Maximum utilization factor (ku) and Diversity factor (ks) will be considered [10]. The values of Ku and Ks are usually not set in stone and depend on the experience and knowledge of the designer. If information is lacking, then IEC61439-2 offers guidance.

Table 10: Diversity factors (ks) for pedestal circuits

Type of load	**Assumed loading factor**
Distribution – 6 and 9 circuits	0,7*
Lighting	0,6**

* IEC61439-2 table 101

** based on expected on/off time of lighting

Table 11: Circuit list

Description	**Ku***	**Rated current I_Z (A)**	**Ks**	**Total load of the pedestal (A)**
32A socket outlet	1	32		
32A socket outlet	1	32		
16A socket outlet	1	16		
16A socket outlet	1	16	0,7	89,7
16A socket outlet	1	16		
16A socket outlet	1	16		
LED Illumination	1	0,27	0,6	

* IEC61439-2 table 101

Lighting circuit apparent power (S_{LED})

E27 LED lamps are used for the service pedestal lighting. Total power consumption is considered up to 30W and power factor for E27 LED lamps is 0,5 [11]. Additionally, the circuit contains a photosensor switch with 1,5W power consumption, power factor is unknown but can be assumed 0,5.

Ku=1 ; Ks_L=0,6 ; power factor PF= 0,5; P=30 W

S_{LED}= Apparent power

(5.1)

$$S_{LED} = \frac{\mathrm{P(W)}}{1000 \times \mathrm{PF} \times \mathrm{K}u_l}$$

$$S_{LED} = \frac{31{,}5\ \mathrm{W}}{1000 \times 0{,}5 \times 1} = 0{,}063\ kVA$$

Maximum current (I_{LED})

(5.2)

$$I_{Z1} = \frac{1000\mathrm{x}\ S_{LED}}{\mathrm{V}}$$

$$I_{Z1} = \frac{1000\ \mathrm{x}\ 0{,}063\ kVA}{230\ \mathrm{V}} = 0{,}273\ A$$

Maximum current in 32A circuit (I_{32A})

(5.3)

I_{32A}= I_Z x ku = 32 A

Maximum current in 16A circuit(I_{16A})

I_{16A}= I_Z x ku = 16 A

Maximum current (I_P) for the pedestal

(5.4)

$$I_p = (2 \times I_{32A} + 4 \times I_{16A}) \times 0{,}7 + I_{LED} \times ks_{LED}$$

$$I_p = (2 \times 32A + 4 \times 16A) \times 0{,}7 + 0{,}27A \times 0{,}6 = 89{,}7\ A$$

5.2.2 Sizing of conductors

When the service conditions of the installation are considered, the correct current carrying capacity can be found. For this purpose – correction factors are used.

$$I'_z = I_z \times k_1 \times k_2 \times \ldots \times k_n \tag{5.5}$$

I_Z = current carrying capacity of a cable

I'_Z = "corrected" current carrying capacity of the cable in real installation conditions

k_1, k_2 ... = corrections factors

Following correction factors will apply for this installation [12]

k_1 – correction factor for ambient air temperature

k_4- correction for grouping of conductors

All cables will be single core PVC cables installed by directly clipping to the installation frame.

Conductor size for LED lighting circuit

I_r= 0,26 A k_1=0,76 k_4=0,80

$$I_{Zmin} = \frac{I_{LED}}{k_1 \times \mathrm{k}_4} \tag{5.6}$$

$$I_{Zmin} = \frac{0{,}27\ A}{0{,}76 \times 0{,}80} = 0{,}44\ A$$

Where $I_{Z\,min}$ = minimum current carrying capacity needed under installation conditions

1mm^2 copper cable has I_Z= 11 A [13]

I'_Z = 11 A x 0,76 x 0,80 = 6,6 A > I_{LED}

The cables current carrying capacity is sufficient! PVC cable with 1 mm^2 copper core is chosen.

Conductor size for 32A circuit

I_{32A}= 32 A k_1=0,76 k_4=0,70

$$I_{Zmin} = \frac{I_{32A}}{k_1 \times \mathrm{k}_4}$$

$$I_{Zmin} = \frac{32\ A}{0{,}76 \times 0{,}70} = 60{,}1\ A$$

10mm^2 copper cables has I_Z= 63A [13]

I'_Z = 63 x 0,76 x 0,70 = 33,5 A > I_{32A} = 32 A

The cables current carrying capacity is sufficient! XLPE cable with 10 mm^2 copper core is chosen

Conductor size for 16A circuit

I_r= 16 A k_1=0,76 k_4=0,80

$$I_{Zmin} = \frac{I_{16A}}{k_1 \times \mathrm{k}_4}$$

$$I_{Zmin} = \frac{16\ A}{0{,}76 \times 0{,}8} = 26{,}3\ A$$

2,5mm^2 copper cables has I_Z= 36A [13]

I'_Z = 36 A x 0,76 x 0,80 = 21,8 A > I_{16A} = 16 A

The cables current carrying capacity is sufficient! XLPE cable with 2,5 mm^2 copper core is chosen [14]

Conductor size for pedestal power input cables

I_P= 89,7 A ; k_1=0,76 ; k_4=0,70

$$I_{Zmin} = \frac{I_P}{k_1 \times \mathrm{k}_4}$$

$$\mathrm{I_{Zmin}} = \frac{89{,}7\ \mathrm{A}}{0{,}76 \times 0{,}70} = 168{,}6\mathrm{A}$$

35mm^2 copper cable has I_Z= 169 A [13]

I'_Z = 169 A x 0,76 x 0,70 = 89,9 A > I_P = 89,7A

The cables current carrying capacity is sufficient! XLPE cable with 35 mm^2 copper core is chosen

Conductor size for disconnector to terminals cables

In the pedestal wiring scheme, there are wires connecting the disconnector to terminal block for 32A circuits and 16A+LED circuits respectively. Since the ladder has a bigger load and longer wires, then it will be the basis of calculation.

$I_{DT} = 4x\ I_{16A} \times ku + \ I_{LED}$
$I_{DT} = 4x\ 16\ x\ 0{,}8 + \ 0{,}26 = 51{,}46\ A$

64,26 A ; k_1=0,76 ; k_4=0,70

$I_{Zmin} = \frac{I_P}{k_1 \times \mathrm{k}_4}$

$\mathrm{I}_{\mathrm{Zmin}} = \frac{51{,}46\ \mathrm{A}}{0{,}76 \times 0{,}70}$ = 96,7A

16 mm^2 copper cable has I_Z= 107 A [13]

I'_Z = 107 A x 0,76 x 0,70 = 56,9 A > I_P = 51,46 A

The cables current carrying capacity is sufficient! XLPE cable with 16 mm^2 copper core is chosen

Sizing of neutral conductors

Neutral conductors are sized same to the phase conductors of the corresponding circuit. [15]

Sizing of earthing conductors

Following simplified formula applies [16]:

(5.7)

If $S_{ph} \leq 16$ mm^2 , then $S_{PE} = S_{ph}$

If $16 < S_{ph} \leq 35$ mm^2 , then S_{PE} = 16 mm^2

If $S_{ph} > 35$ mm^2 , then SPE = S_{ph} / 2

, where S_{ph} = phase conductor cross section in circuit; S_{PE} = Earthing conductor cross section in circuit.

Table 12: Earthing conductor cross section sizes

Circuit	**LED**	**16A**	**32A**	**DT**	**input**
Conductor (mm^2)	1	2,5	10	16	16

5.2.3 Voltage drop

Permissible voltage drop between the origin of installation to point of load is 8% in private LV supply. [10]

$$Vd = \frac{mVAm \times I_b \times L}{1000} \quad (5.8)$$

Table 13: Voltage drop

Circuit	mV/A/m [13]	I_b (A)	L (m)	Drop (V)	In %
LED	46	0,26	1,5	0,017	0,007
16A	19	16	1,5	0,456	0,19
32A	4,7	32	0,5	0,06	0,015
DT	2,9	51,46	0,5	0,074	0,018
Pedestal input	1,35	89,7	0,2	0,016	0,004
Larges drop				**0,55**	**0,212**

Voltage drop is within acceptable parameters : 0,2% > 8%

5.2.4 Short circuit current

Short circuit current is dependent on power source. Power source parameters are unknown. Short circuit current is assumed 10kA. This value must be reviewed at an installation to make sure that the power sources short circuit current doesn´t exceed the short-circuit current-breaking rating of the protection devices used in the installation.

5.2.5 Circuit protection devices

Marina power pedestals need to include protective devices against short circuit, overload and current leakage on all socket outlet circuits. Furthermore, protective devices must disconnect all live conductors including the neutral. Every marina service pedestal shall include an isolation device that can disconnects all live conductors from the pedestal including the neutral. [9]

MCB –A Miniature Circuit Breaker is an electromechanical device designed to protect an electric circuit from overload and short circuit. MCBs do not protect humans against electrical shock caused by earth leakage. MCB has three principle characteristics, Amperes, Kilo Amperes and Tripping Curve. Amperage shows the maximum working current for the circuit breaker. If this rating is exceeded and overload situation occurs than the circuit breaker will trip. Kilo Amperes show the maximum fault current. In case of short circuit situation, the current in the conductors will raise rapidly. This number shows the maximum what the circuit breaker can handle. 6kA is common in house hold circuits. Finally the Tripping curve is used to differentiate between circuit breakers with same current rating but different applications. Three distinct categories are used: Type A, Type B and Type C. These types differ in their tripping characteristic. [17]

RCCB – Residual current circuit breaker. This device is used to protect people and animals against dangerous electric shock. It measures current flowing between the conductors and if it notices difference then it cuts the flow of electricity. RCCB has three principle characteristics, Amperes, Kilo Amperes and milliampere. Amperage shows the designed circuit current where this device is suitable to be used in. Kiloampere shows the maximum fault current in can withstand and the milliampere rating shows the minimum amperage difference that the device is able to detect between the conductors.30mA is considered the maximum allowed for life injury protection. RCCBs with higher mA rating exist that are designed for fire protection and protection of machinery. These devices do not react to overload and short circuit. [14]

RCBO – residual-current circuit breaker with overload protection. This device combines two previously mentioned devices into a single device. They provide significant space savings but have a higher price. [14]

Disconnector – device that isolates the installation from every source of electric energy for the reasons of safety. Has two working positions – open (OFF) and closed (ON). Doesn´t provide any fault protection to the circuit. [14]

Circuit protection component selection

For this service pedestal design - space is very limited. Not only by physical volume, but also by possible access points. All these protective devices must be serviceable by user. From design perspective it´s desirable to keep the amount of access panels to minimum. For this reason, RCBO´s are used in most circuits. In LED circuit there is no need for fault current protection, so an MCB will be sufficient. Type B is considered suitable for lighting and general-purpose socket-outlets [10].

Table 14: Circuit protection devices

Circuit	**Voltage**	**Rated current**	**Device**	**No of poles**	**Cable size (mm^2)**
32A	3x230/400 V	32 A	RCBO 32 A 10 kA Type B	4P	10
16A	230 V	16 A	RCBO 16 A 10 kA Type B	2P	2,5
LED	230 V	0,5 A	MCB 6 A 10 kA Type B	2P	1

Manufacturer consideration

It´s advisable to use the same manufacturer for all circuit protection devices in a circuit. This will ensure maximum compatibility between the components.

The internal volume of the service pedestal will experience higher temperature maximums then the surrounding environment. Components with highest operating temperature range are preferred.

Other considerations include price, manufacturer reliability, available warranty period.

Table 15: circuit protection devices selected

Name	**Description**	**Ta (C°)**	**manufacturer**
DS202C M B16 A30 [18]	RCBO 32 A 10 kA Type B	55	ABB
DS204 A-B32/0,03	RCBO 16 A 10 kA Type B	55	ABB
S201M-C6	MCB 6 A 10 kA Type B	55	ABB

5.3 Other electrical components

Disconnector

Disconnector is selected form ABB product portfolio. This will assure maximum compatibility with all circuit protection devices. Disconnector must disconnect all current carrying conductors – including neutral.

Product	rating	voltage	poles	manufacturer
OT100F4N2	100 A	415 V	4	ABB

Socket outlets

Socket outlets are located in the socket housing. This will provide protection from direct water contact and allow less costly IP44 outlets to be used. Multiple suppliers are available for these components. Selection criteria include price, quality, dimensions and design. The socket should be at a 90^o angle with the mounting surface for easy operation.

Product	Rating	Voltage	IP	manufacturer
Panel mounted socket 1366	16A	230V/50-60 Hz	44	Menneke
Panel mounted socket 1276	32A	400V/50-60 Hz	44	Menneke

Lighting switch

Lighting is controlled through a photosensor switch integrated to the lighting circuit.
The light sensitive head of the switch is mounted in one of the socket housings. The slit in the housing lid will allow for light to reach the sensor head.
Mounting the sensor fully in the plastic enclosure is not possible since the reflected light from the LED bulbs would great a positive feedback loop and the switch would not be able to turn off.

Figure 17: Photosensor switch. [19]

Table 16: Technical properties of the switch

Feature	value
Model	JL-101B
Rated voltage	220-240 V 50Hz
Rated load	600W
Light level for "ON"	15 lx
Light level for "OFF"	60 lx
Ambient temperature	-40°C … +70°C
Power consumption	1,5W

Metering

Modeling in Solidworks shows that it´s not possible to provide the chosen pedestal model with metering on all outlets. Three phase energy meters are too bulky to fit into the access panel in a way that they could be effectively read. This issue could be solved by using remote metering devices that don´t need to be accessed.

Product	Voltage	Rating	Accuracy	Ta (°C)	manufacturer
C11 110-300	230V / 50 Hz	40A	Active Energy Class ±1%	-25 … 70	ABB

6. MECHANICAL DESIGN

After obtaining detailed information about the electrical components that need to be installed into the pedestal – it´s possible to start refining the original design concept B.

The design of the pedestal is complicated by several limitations:

Space – since the enclosure works also as a lighting diffuser, then there is a need for some space between the enclosure (1) and frame (9). This limits the frame dimensions and space available for electronical components.

Access – Users must be able to access the circuit breakers and the metering devices. Hatches must be installed to the pedestal for that purpose. There is a limit to how many hatches (2) can be installed before it starts negatively impacting the design.

Maintenance – The internal components must be accessible for periodical service. Plastic enclosure must be removable without massive disassembly.

Strength – Unlike in Coral service pedestal. In this design, all forces applied to the enclosure will be transferred to the frame through socket housings. These structural elements must be tested for expected loads.

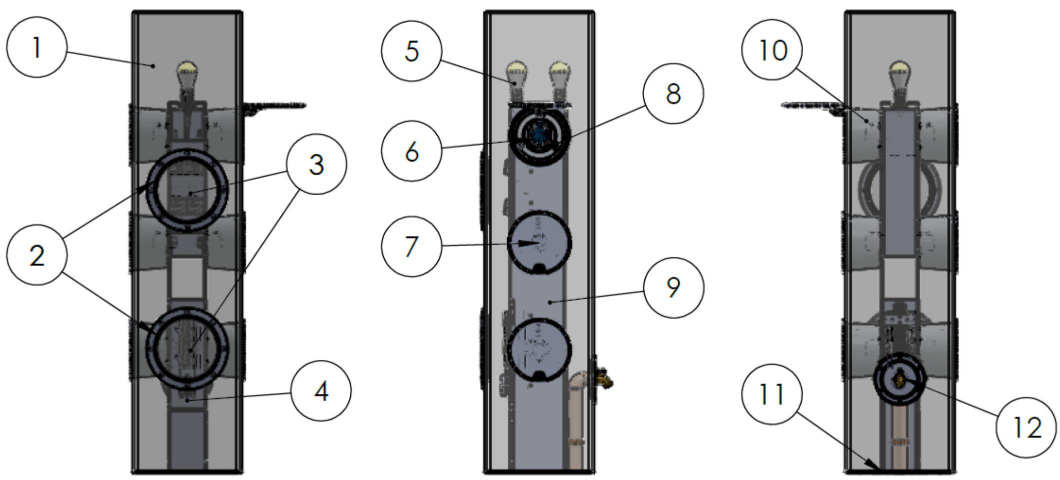


Figure 18: Pedestal overview: 1-Enclosure, 2-Service hatch, 3-Circuit protection devices, 4-Disconnector, 5-E27 LED lights, 6-Outlet, 7-Outlet lid, 8-Photosensor, 9-Frame, 10-Outled housing, 11 – Mounting flange, 12-Water faucet.

6.1.1 Ingress protection

Marina service pedestal must meet Ingress protection rating IPX6.

Test is conducted by fixing the test piece as it would in normal use.

Test duration: 1 minute per square meter for at least 3 minutes

Water volume: 100 L/m Pressure: 100 kPa at distance of 3 m

Table 17: IPX6 definition by EVS-EN 60529:2001

Level	Test Success criteria
IPX6	Water projected in powerful jets (12.5 mm nozzle) against the enclosure from any direction shall have no harmful effects.”

High IP rating is complicated by following factors:

- Thermal expansion and contraction of plastic housing will create water vapor condensation in the enclosure over time. Pressure valve would be needed to mitigate this problem.
- Enclosure openings need tight tolerances for gaskets
- Gaskets will eventually weather and fail – shortening the lifetime of the product.

It´s more reasonable to manage water ingress instead of trying to fully block it.

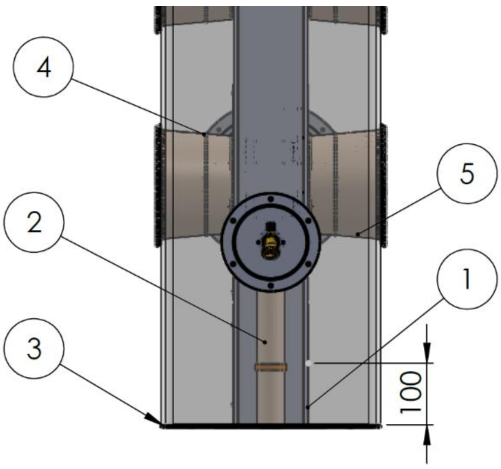


Figure 19: Water system

The connection area between the frame flange and frame beam (1) is waterproof by at least 100mm. If the pedestal water system (2) experiences any leakage or rupture, then the water can drain away from the gap between the enclosure and frame flange (3).
There is a rubber O-ring glued to the outside surface of the socket enclosure (4). This will collect any water entering from the socket housing opening and directs water droplets to fall down on the frame flange. The conical shape of the socket housing will allow for the drainage of any water that may enter the socket housing (5). Electronic components, which are located inside the frame beam, are not directly exposed to water at any time – thus the design should meet IPX6 criteria. Ingress rating must be verified in controlled test, before CE conformity can be declared.

6.1.2 External mechanical impact resistance

Service pedestal must meet IK07 requirements. Based on authors previous experience with IK testing – one can feel confident that this test will be passed. Polycarbonate is often use for vandal proof products due to its superb toughness and self-extinguishing properties.

Testing methodology [20]:

- Installation – pedestal is attached to a surface as it would be under normal conditions. Service pedestal is attached to a horizontal surface with 4 x M12 anchor bolts.
- Performing the impact test – impact test is performed by dropping a test weight on horizontal surface or swinging the weight at the end of a pendulum arm in case of vertical surfaces. All surfaces that are exposed in normal use must be tested. Drop height for IK07 is 0,408m and test weight is 0,5kg (shape and material is specified in the standard). Areas with side shorter than 1m will receive 3 impacts. Surfaces with a longer side will receive 5 impacts. Impacts must be evenly distributed.
- Hinges, locks etc. are excluded from test.

Table 18: Impact energies used in IK testing

IK Code	**IK01**	**IK02**	**IK03**	**IK04**	**IK05**	**IK06**	**IK07**	**IK08**	**IK09**	**IK10**
Impact energy (Joule)	0,14	0,2	0,35	0,5	0,7	1	2	5	10	20

6.2 Enclosure

The enclosure of the service pedestal is multifunctional. It´s main function is to provide mechanical protection for the internal components from rain, snow, sunlight and foreign bodies of varying sizes. Secondly it stops users from coming in contact with live parts. Thirdly it functions as a light diffuser for the internal lighting system.

Table 19: Enclosure parameters

Property	Value
Dimensions	1500x360x360 (mm), Min thickness: 6mm
Material	Semi-transparent plastic
Ingress protection	IPX6
Shock resistance	IK07

6.2.1 Manufacturing methods

Table 20: Comparison between plastic enclosure manufacturing methods.

Process	Advantages	Disadvantages
Extrusion	Low part cost, Low tool price	Limited geometry, large patch size,
Injection molding	Low part cost, good part tolerances, wider range of materials, good mechanical properties	Expensive tooling, Large patch size, small volume parts
Rotational forming	Small to medium production patches; Large volume parts; Low mold price;	Limited materials, low tolerances, long cycle time
Vacuum forming	Low tool costs	Thin walls, limited geometry

Rotational molding

Rotational molding is the most suitable manufacturing method for the pedestal enclosure. This is common method used for large volume hollow bodies like pontoons, buoys and large contains. Keha4 has an extensive experience with this technology – owning more than 5 molds.

In rotational molding, rigid, resilient hollow bodies are formed by powdered plastic material in heated molds, which are rotated simultaneously in two planes perpendicular to each other. The plastic particles make contact and melt on the inner surfaces of the hot molds and fuse in layers until all the powder is fused and the desired end product and wall thickness is obtained. The wall thickness is controlled by the amount of powder placed in the mold [21].

The molded part doesn´t have any openings. These features must be added later. Usually manufacturers provide such a service. It´s also possible to embed certain features into the mold including logo plates, threaded bushings, bolts.

6.2.2 Material

Table 21: Comparison between commonly used materials in rotational molding. [22]

Material	Advantages	Disadvantages
Polyethylene	common, cost effective, easy to mold, UV resistant, good low temp. performance, chemical resistance, good optical properties	Low impact resistance, high thermal expansion
Polyvinyl chloride	Flexible, paintable,	Low stiffness, expensive, narrow temp. range,
Nylon	High heat resistance	Expensive, hard to mold,
polycarbonate	Toughness, fire retardant, cost effective	More difficult to work than PE, needs additives for diffusing light.
polypropylene	Durable,	Prone to cracking, hard to work with, low impact strength at low temp.

Although previous Keha4 products have been produced using Polyethylene, then Polycarbonate is the most appropriate material for this product. It is naturally fire retardant, has wide temperature range and is very tough. PC is the same plastic used in riot shields and airplane windshields among many other durable products. Second important factor is that Polycarbonate has a much lower thermal expansion – which can cause problems with the design. Polycarbonate is transparent in its natural form, so pigments and additives must be used. Suitable PC material is ReClear15 [23].

Thickness: It´s advantageous to keep the enclosure wall thickens to minimum. Material cost is the major part of the part cost for rotational molding. Thickness also adds to the heat insulation properties of the enclosure. The minimal thickness of the enclosure is 4 mm, due to technological limitations. Coral service pedestals are 6 mm thick and pass IK10 test. It´s reasonable to assume 6mm for the thickness of the enclosure based on that experience. Actual thickness will be determined through testing.

6.3 Frame

Frame serves as the main source of structural integrity of the service pedestal and provides the mounting points for all the electrical parts of the assembly. The frame of the service pedestal composes from 2 key parts. The flange is a 4mm thick rectangular piece of metal that attaches the frame to the mounting surface. The frame beam is a metal beam permanently welded to the flange – made from 4mm bent sheet metal with 4 bends. The bottom of the frame beam has a welded rectangular metal plate for extra support and to seal off 100mm of the bottom from liquids.   Inside the frame beam are 4 mounting brackets attached by screws or rivets offering additional support. DIN rails are attached to mounting brackets and provide mounting points for the electronical components. The frame also has multiple detachable covers made from thin sheet metal. These covers separate users from any live parts.

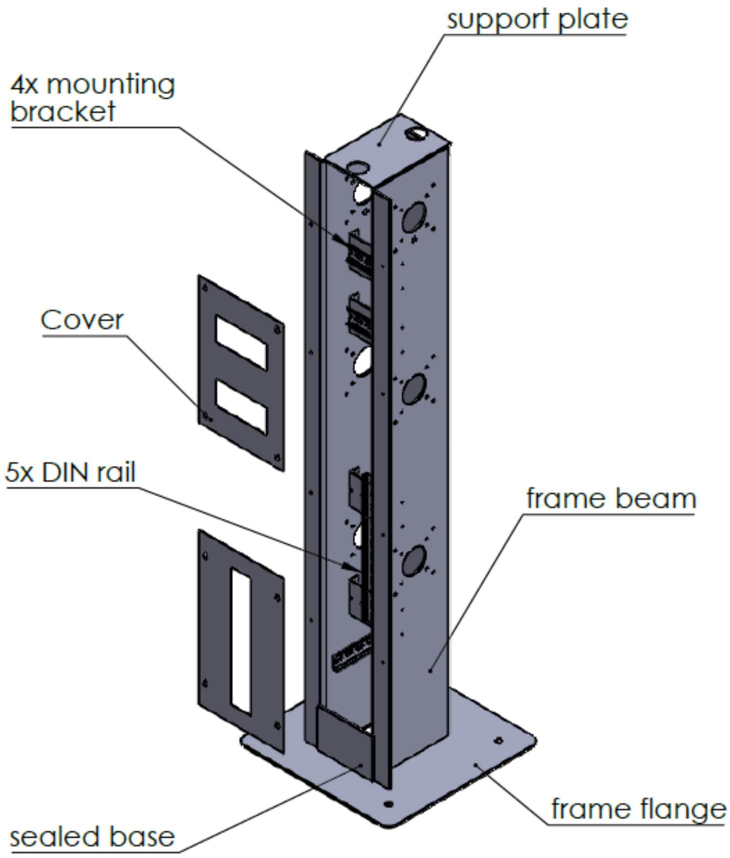


Figure 20: Frame assembly

Material:

Frame parts are manufactured from corrosion resistant sheet metal. Based on the ANSYS stress analysis for the frame (6.6.2) the minimum yield strength ($R_{v2.0}$) must exceeded 45,8 MPa.

Table 22: Material comparison for frame

Material	Advantages	Disadvantages	Thickness (mm)	Cost (m^2) *
Hot tip galvanized steel	Cost, easy to work with.	Lowest corrosion resistance,	4	42 €
Aluminum	Easy to work with, corrosion resistant, good heat dissipation	Lower strength than steel, Cost	5	99,8 €
Stainless steel	Very durable, best corrosion resistance	Cost, hard to work with	4	158 €

* based on 1 m^2 material after cutting operations. [24]

Galvanized steel is unsuitable for this application. There is need for many threaded holes on the pedestal. These threads must be created after the process of galvanizing and this will remove the galvanic layer and expose base metal to the elements. Stainless steel has the best strength properties and offers superb corrosion resistance. Ultimately Aluminum is chosen due to significantly lower cost in comparison to stainless steel. Aluminum is also easier to work with.

Table 23: Manufacturing method comparison for frame parts

Method	Material thickness	Accuracy	Cost	Note
Laser cutting	Steel 6mm	±0.025 mm	medium	
Punching machine	3mm steel; 6mm Aluminum	±0.5 mm positioning accuracy. ±0.25mm, punching accuracy.	Low to medium	Can add features to work piece (threads, ribs, rises). Longer set up time than laser
Water jet cutting	Up to 75mm	±0.1 mm	high	Slowest process
Plasma	Most metals, 80mm		low	

Both Punching and laser cutting are attractive manufacturing methods for these components. Key benefit to Punching machine is the cost. Punching also allows openings to be threaded. The frame has at least 18 opening that have to be threaded. Doing this manually will add costs. Punching however has limitations regarding material thickness-which makes it unsuitable for frame manufacturing. Furthermore, punching machine must have appropriate tools available for aluminum works – not all subcontractors have them. Laser cutting is used.

6.4 Socket housing

Socket housings are integral part of the design. They create the access way from the socket outlet to the pedestal exterior. Socket housings also connect the pedestal housing to the frame – thus they are structurally important components.
Additionally, each socket housing offers 0,08 m^2 of cooling surface for the pedestal (that's 0,48 m^2 in total for 6 outlet version).
Since the pedestal enclosure is made from PC plastic with very low thermal conductivity, then this can be very helpful for the design.

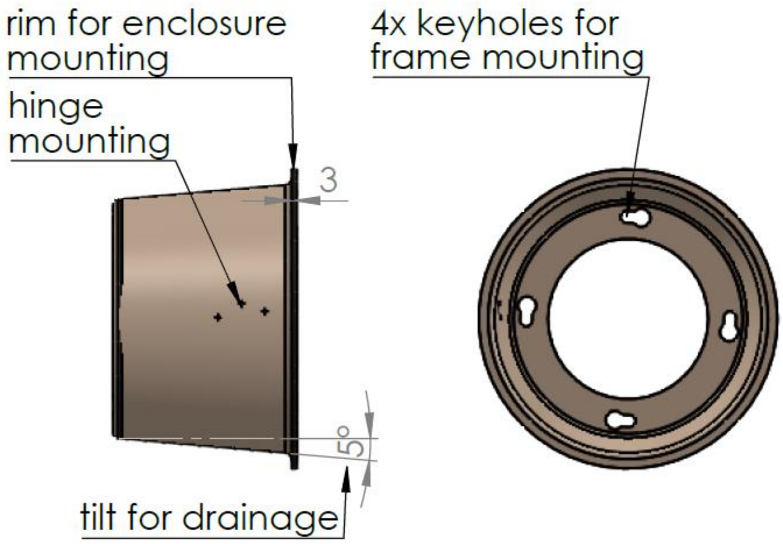


Figure 21: Socket housing sketch

Production

Table 24: Production method comparison for socket housing

Production method	Advantages	Disadvantages
Metal spinning	Suitable for low and medium volume, low tool cost	Accuracy
Sheet hydroforming	Suitable for thin walled deep parts, accurate	Costly tooling

The socket housings are produced using metal spinning. Metal spinning is a metalworking process where a sheet metal blank is rotated at a high speed and formed into an axially symmetrical part. The blank is locked between mandrel (1) and tailstock. The mandrel is attached to the chuck of a lathe machine. As the mandrel, blank and tailstock (2) spin – a tool (3) is pressed along the blank to give it the inner contour of the mandrel. Multiple passes are usually needed.
Spinning can be performed by hand or by machine. Common manufacturing method for lamp reflectors, cookware and even rocket parts. This method is suitable for low to medium patch production. Tooling is cheap. Any metal that is ductile enough to be cold formed can be spun.

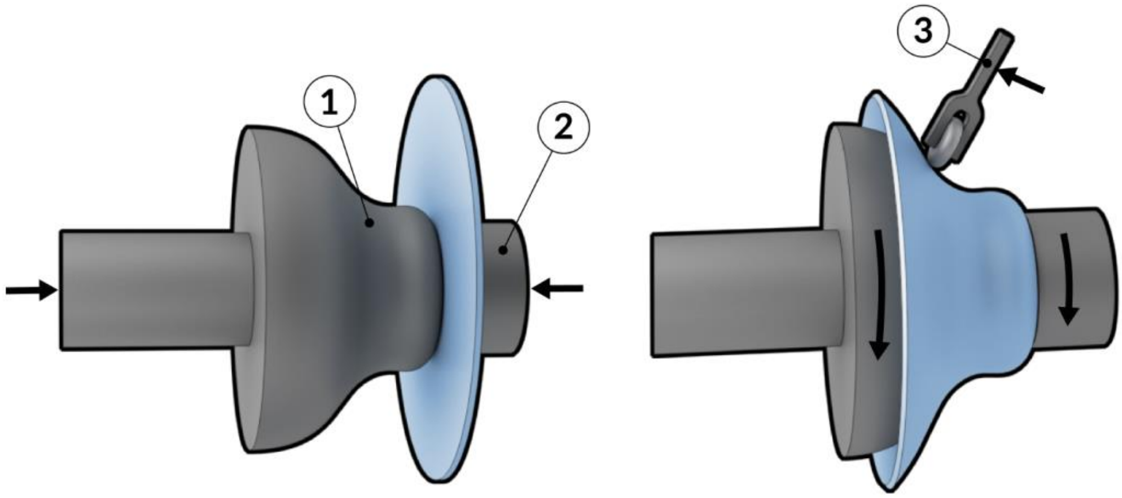


Figure 22: Metal spinning process. Source: www.manufacturingguide.com

Material

Socket housing is made from a sheet metal blank. According to ANSYS stress analysis (6.6.2) a socket housing made from 3mm material will experience maximum stress 37,8 MPa.

Table 25: Material comparison for socket housing

material	**advantages**	**disadvantages**
Stainless steel	Corrosion resistance	Price, difficult to hand spin
Aluminum	Corrosion resistance, heat dissipation	Strength properties
Copper	Corrosion resistant, good to work with, heat dissipation	Price

Aluminum offers most of the benefits of copper at less than half the price. Copper also has a very distinct color that can be difficult to integrate to the design. Socket housings should also be anodized to hide any imperfections left from the spinning process.

6.5 Water system

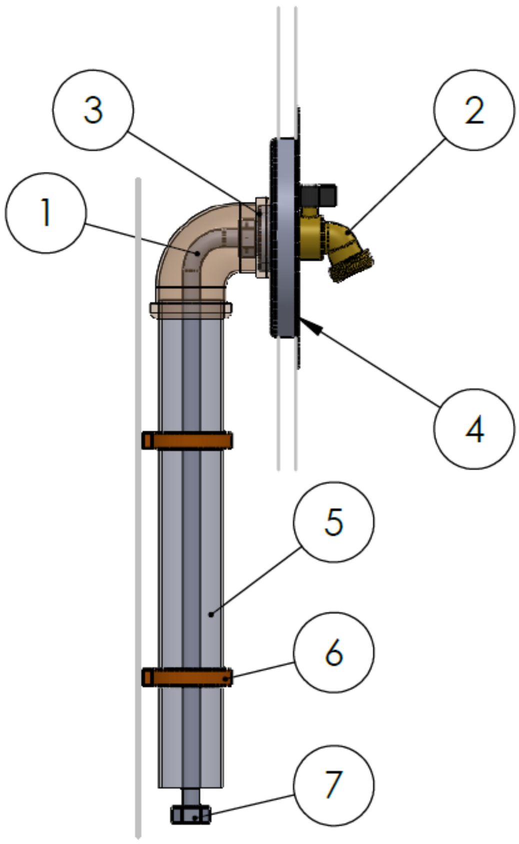


Figure 23: Water system assembly

Water system enables users to access freshwater from the exterior of the pedestal through a water faucet. The water system composes of a steel enforced rubber hose (1) that is connected to the faucet (2) through a connection piece (3). This connection piece is also responsible for connecting the assembly to the exterior of the pedestal. This is achieved with 4x M4 screws that attach to the decorative bezel (4). The plastic enclosure is fixed to the bezel with 6 screws. Around the house is another enclosure made from plastic pipes (5) and is attached to the frame with 2 brackets (6). The space between the hose and plastic pipe can be filled with insulation foam – this will protect the hose from unexpected night colds that might otherwise damage the hose. It will not protect from long periods of below freezing temperature – in this case water must be drained from the pipes. The hose is connected to the utilities network through the threaded connection (7).

Water metering is not possible with this design solution. It would be necessary to make the meter accessible to users and this needlessly complicates design. According to market research – water metering is very rarely used function.

If pedestal enclosure must be removed, then first the water pressure must be turned off. The screws connecting the bezel and connection piece is removed and the faucet is screwed off.

6.6 Wind loading

Marina service pedestals are mounted on piers and floating docks next to large bodies of water. Usually these locations are protected from large waves by jetties but the wind speed on coastal regions can raise to significant levels especially during storms. It´s reasonable to verify the structural integrity of the pedestal under such forces. Strength calculations will be done for windspeeds of 50 km/h or category 2 hurricane winds. Such weather events are extremely rare in Europe. Larges windspeed recorded in Estonia is 48 m/s.

Table 26: Saffir-Simpson Hurricane Category Chart

Category	**Wind speed**
Category 1	33-42 m/s, 119 – 153 km/h
Category 2	43-49 m/s, 154-177km/h
Category 3	50-58 m/s 178-208 km/h
Category 4	58-70 m/s 209-251 km/h
Category 5	>= 70 m/s, >= 252 km/h

6.6.1 wind force

Wind force will apply uniformly along the whole height of the pedestal. wind can blow from any direction, but for the purposes of this calculation 3 basic directions will be investigated.

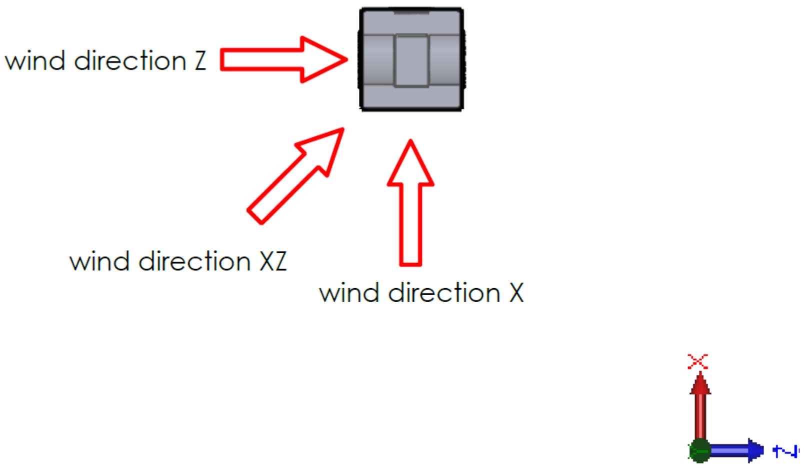


Figure 24: Wind loading directions. Top View

Basic formula for wind loading

$$F = A \times P \times Cd \tag{6.1}$$

, where A = surface area of the structure (m^2); P = dynamic wind pressure (N/m^2) ; Cd= drag coefficient of the structure

The dynamic pressure of a wind with air temperature 20 ^{0}C, density of air 1.2 kg/m^3 and wind speed 50 m/s can be calculated as

$$P = \frac{1}{2} \times \rho \times V^2 \tag{6.2}$$

$$P = \frac{1}{2} \times 1.2\ kg/m^3 \times (70\ m/s)^2 = 1500\ N/m^2$$

The drag coefficient of a body can be found experimentally, but tables are available for common shapes.

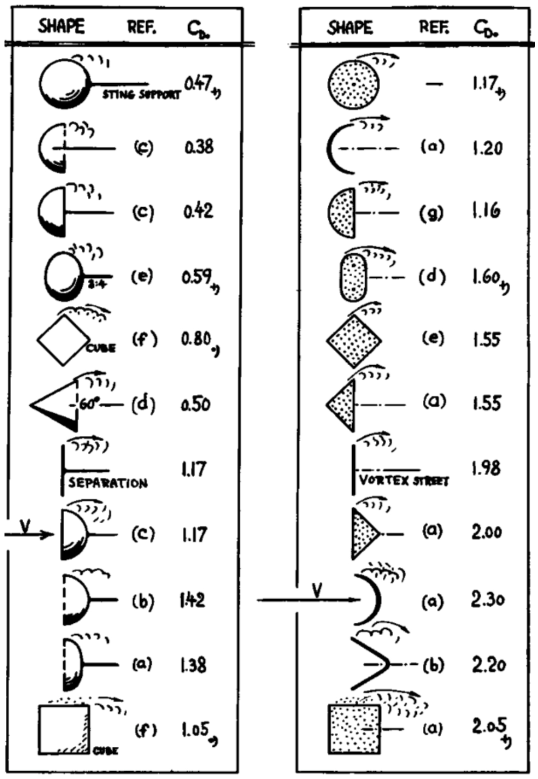


Figure 25: drag coefficient of shapes and cross sections. [25]

Table 27: Wind force results using simplified approach

Wind direction	**Surface area (A) in m^2**	**Drag coefficient (Cd)**	**Wind force (N)**
Wind direction 1 (Z)	0,54	2,05	1661
Wind direction 2 (XZ)	0,76	1,55	1767
Wind direction 3 (X)	0,54	2,05	1661

Using the drag coefficient tables, the strongest wind forces are achieved in wind direction 2. This doesn´t meet the original expectations, so the results are checked in Solidworks Flow Simulation.

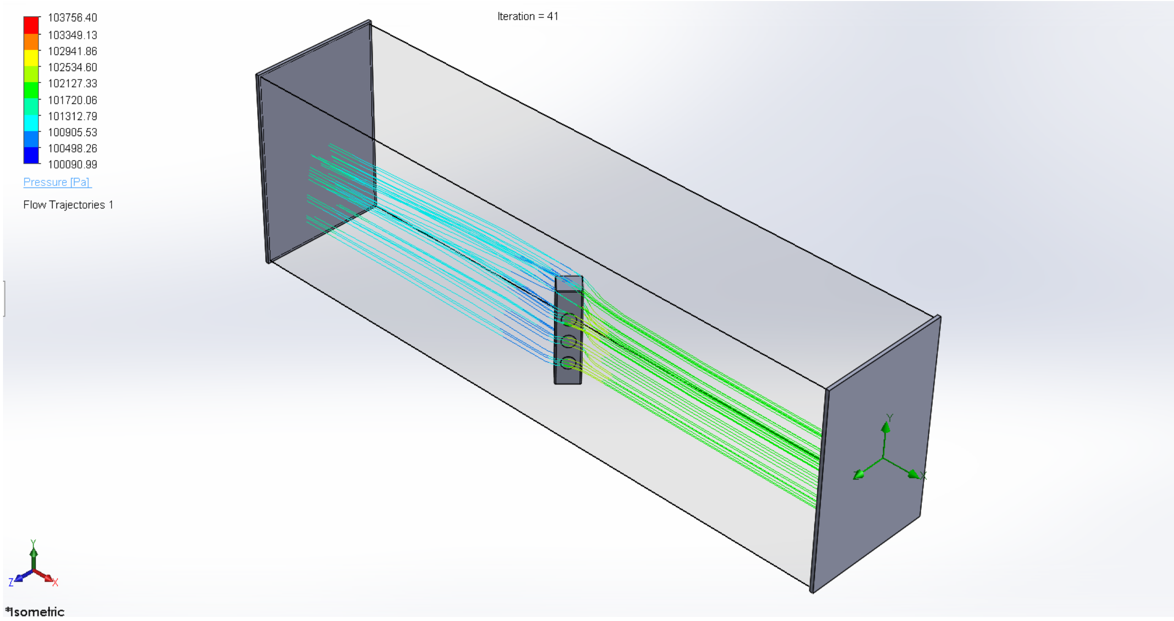


Figure 26: wind tunnel setup in Solidworks Flow Simulation

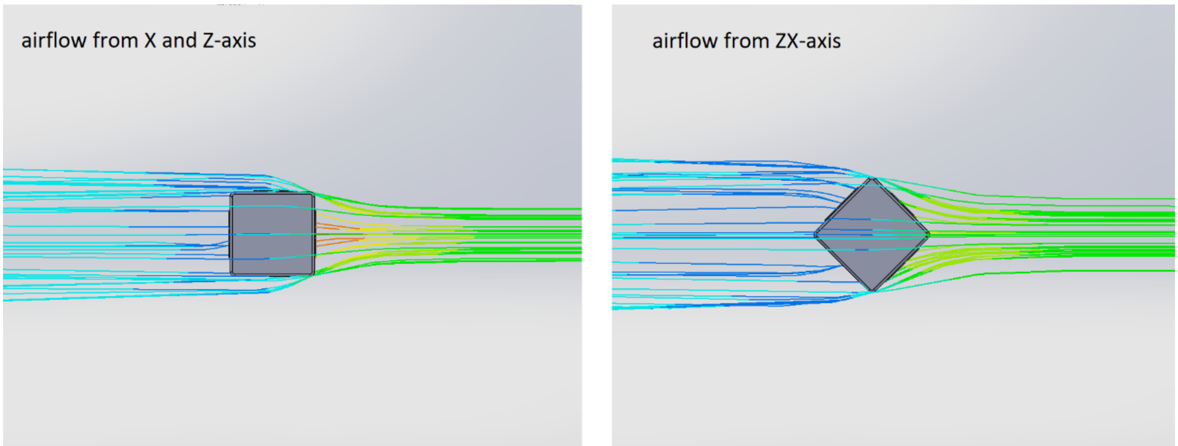


Figure 27: Solidworks Flow wind tunnel simulation. Top view

Table 28: Wind force comparison. Both methods

Wind direction	Surface area (A) in m²	Drag coefficient (Cd)	Wind force (N)	Wind force (N) SW Simulation	Result Difference %
Wind direction X	0,54	2.05	1661	1857	10,5
Wind direction ZX	0,76	1.55	1767	1582	11,6
Wind direction Z	0,54	2.05	1661	1857	10,5

The Solidworks Flow simulation test contradicts the original calculation results. Notably the forces achieved in Solidworks are bigger in X and Z-axis than in ZX-axis. In the following calculations Solidworks results are used.

6.6.2 Frame stress analysis

Frame stress analysis is conducted in ANSYS 16 using the static structural analysis system. Mesh contains 139595 elements and 292227 nodes. Maximum element sizing is set to 8 mm. Model is cleaned from excessive holes and checked for mesh quality.

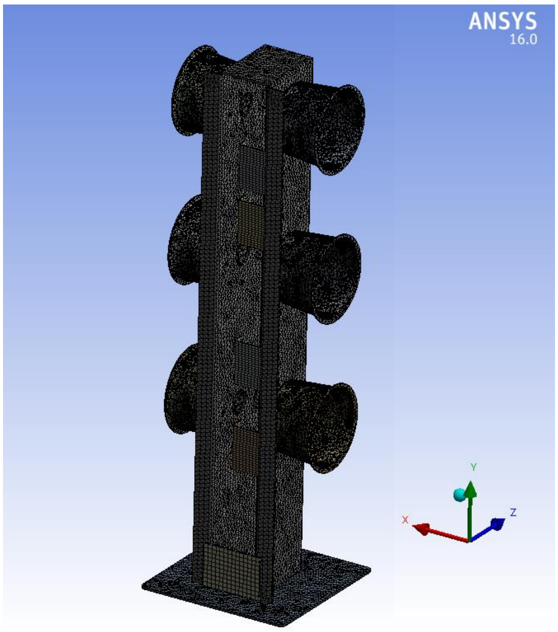


Figure 28: pedestal mesh in ANSYS 16

Wind loading in the X-axis

The external wind load is initially applied to the external wall of the enclosure. From the enclosure the load is carried to the external diameter of the socket housings. From the socket housing the force is carried to the bolts connecting the socket housings to the frame.

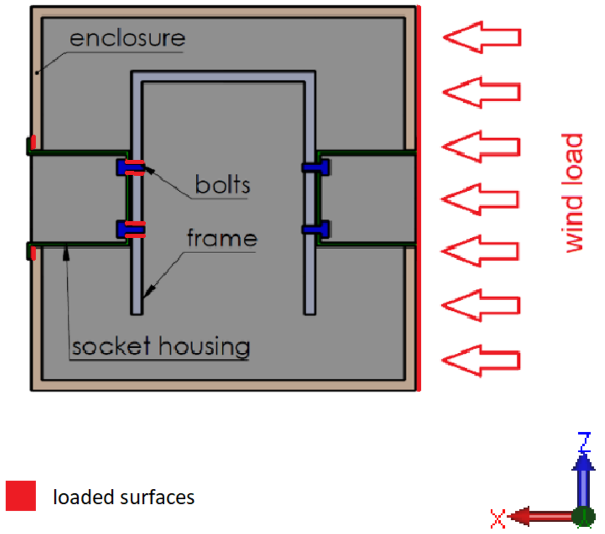


Figure 29: Simplified loading condition sketch. Wind force from X-axis. Top view

Force is placed on the rims of all 6 socket housings. Fixing is set for the bolt holes and frictionless fixing is set under the flange plate.

Force direction	Force	contact surfaces	Force per surface
X-axis	1857 N	3	619 N

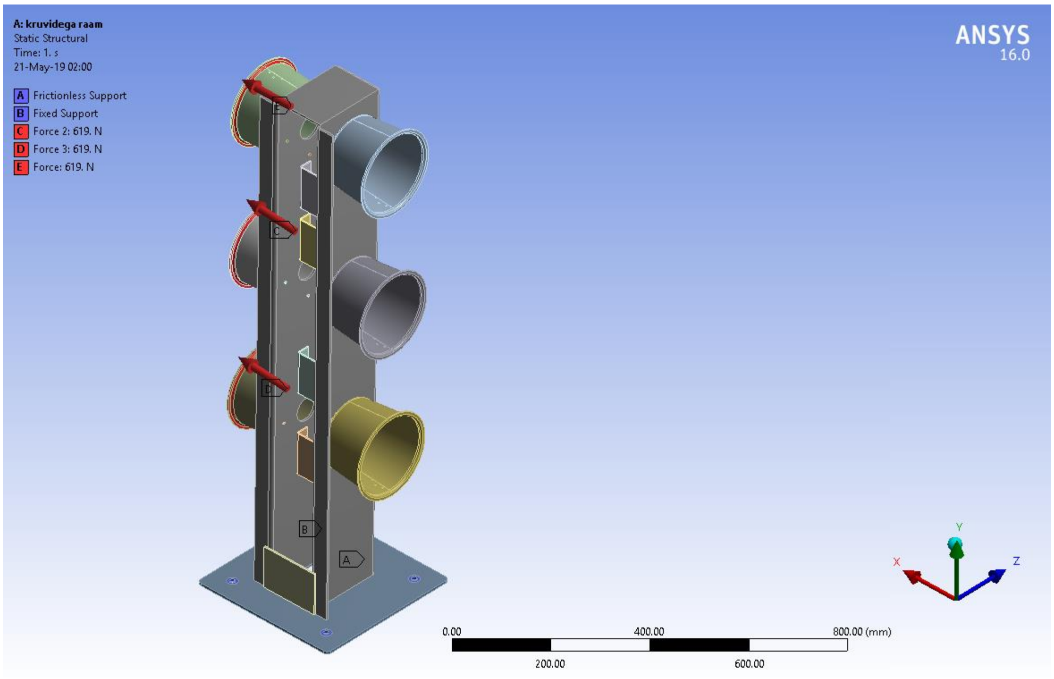


Figure 30: Forces and constraints for wind direction X

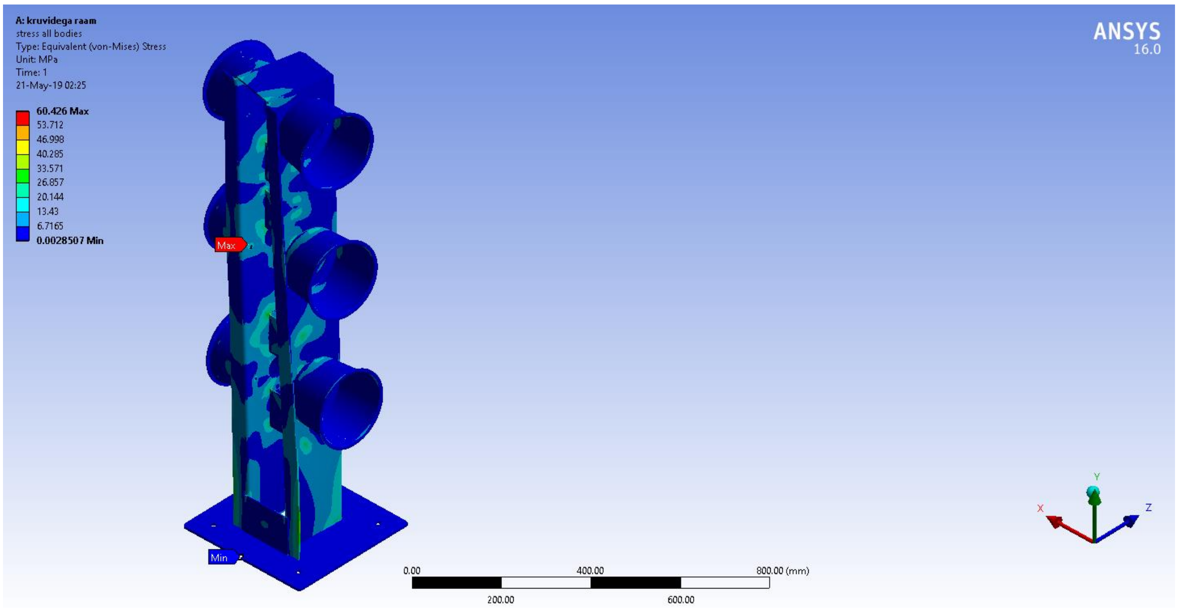


Figure 31: Equivalent stress for wind direction X

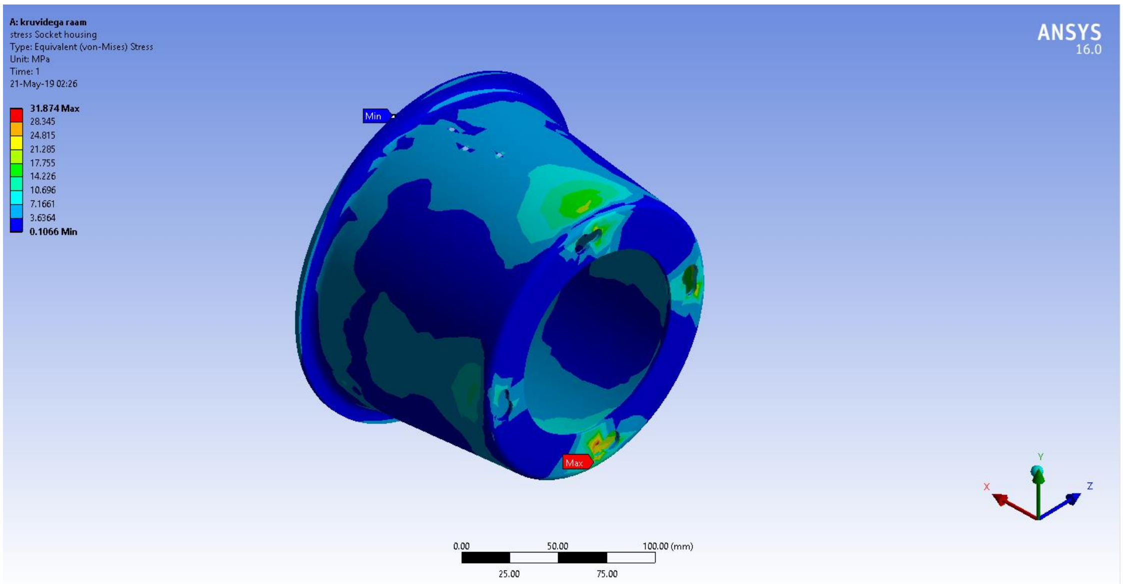


Figure 32: Equivalent stress for socket housing in wind direction X

Component	Maximum stress (MPa)	Displacement (mm)
Whole assembly	60,4	1,38
Frame	59,8	
Socket housing	31,8	
Socket screws	60,4	

Wind loading in the Z-axis

The external wind load is initially applied to the external wall of the enclosure. From the enclosure the load is carried to the flange of the socket housings on the opposite side of the pedestal. From the socket housings the force is carried to the bolts connecting the socket housings to the frame.

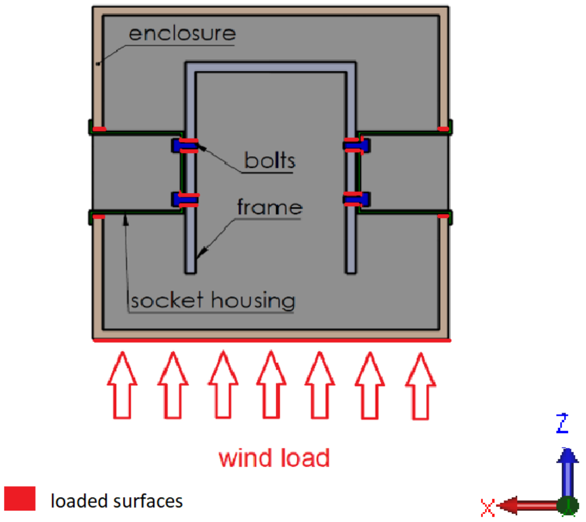


Figure 33: Loading sketch for wind loading in direction Z. Top View

Force is placed on the rims of 3 socket housings on the opposite side of where wind force contacts the pedestal enclosure. Fixing is set for the bolt holes and frictionless fixing is set under the flange plate.

Force direction	Force size	contact surfaces	Force per surface
X-axis	1857 N	6	310 N

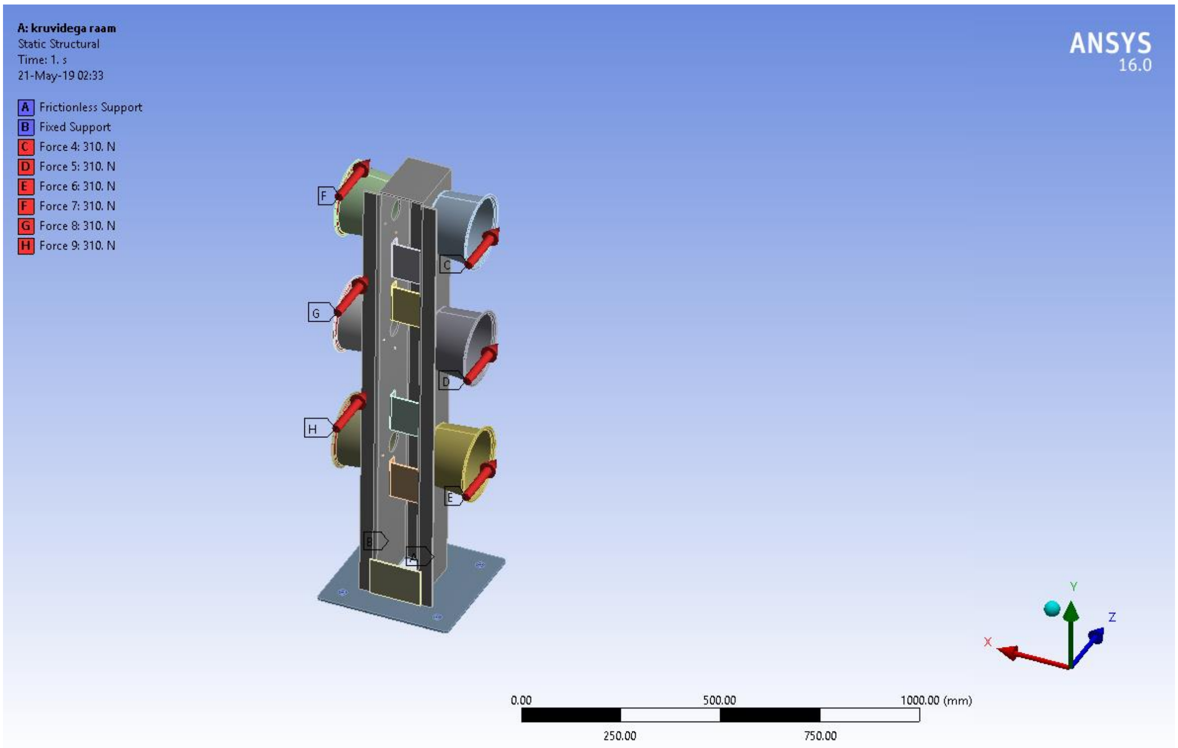


Figure 34: Forces and constraints for wind direction Z

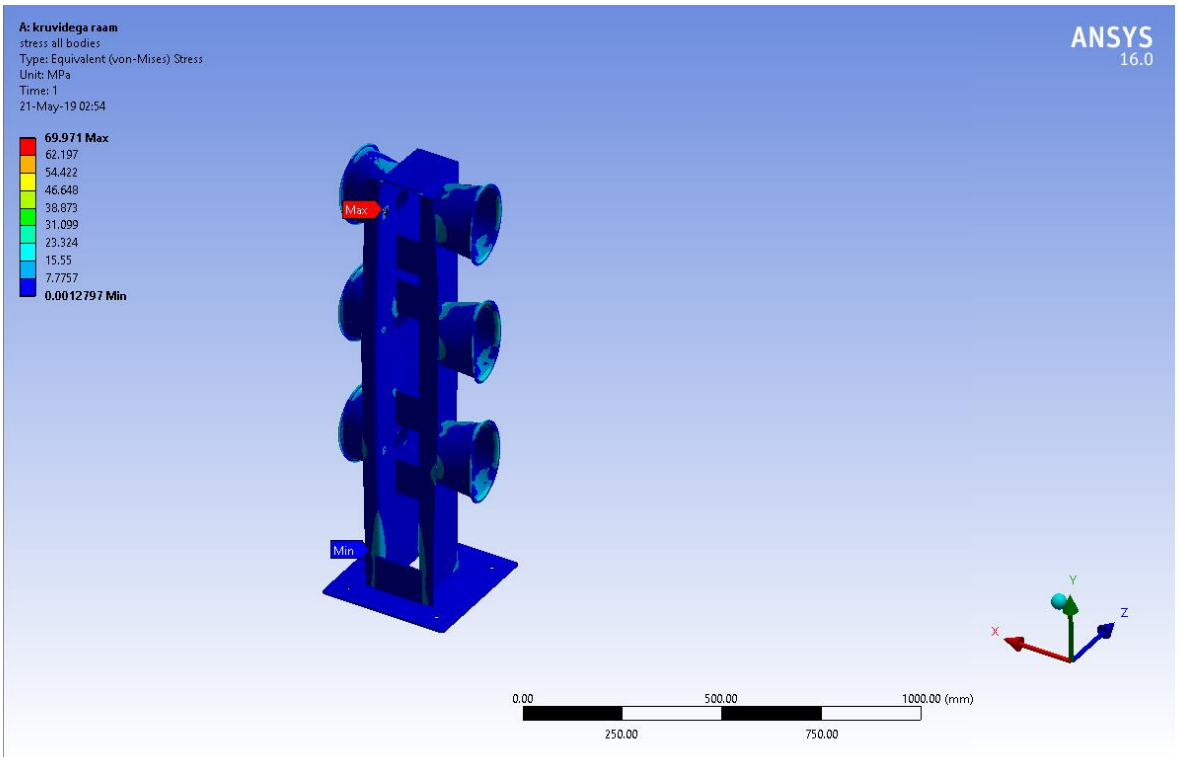


Figure 35: Equivalent stress for wind direction Z

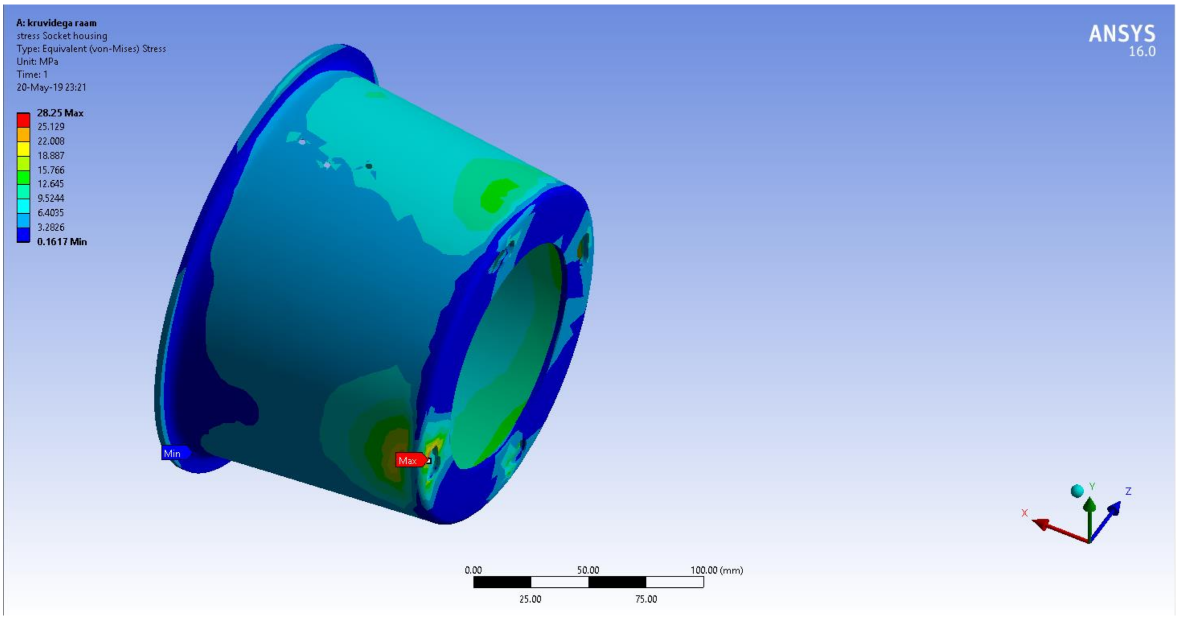
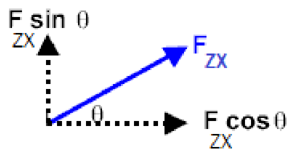


Figure 36: Equivalent stress for socket housing in wind direction Z

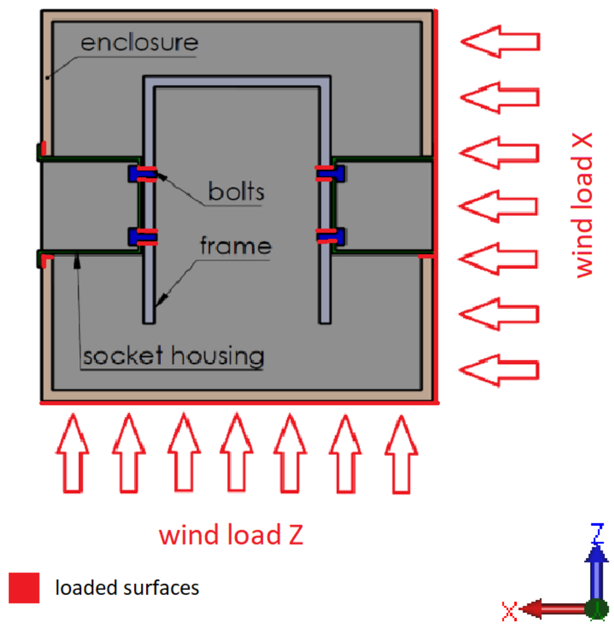
Component	Maximum stress (MPa)	Displacement (mm)
Whole assembly	69	0,3
Frame	28,8	
Socket housing	37,8	
Socket screws	69	

Wind loading in ZX axis

Wind loading in ZX axis is a combination of two previously simulated conditions.
The wind force in direction ZX can be broken down into its components in Z and X axis.



$$F_X = F_{ZX} \times \cos(45°)$$
$$F_Z = F_{ZX} \times \sin(45°)$$
$$F_Z = F_X = 1532\ N \times \cos(45°) = 1532\ N \times \sin(45°) \approx 1083\ N \tag{6.3}$$



Force direction	Force size (N)	contact surfaces	Force per surface (N)
X-axis	1083	3	361
Z-axis	1083	6	180,5

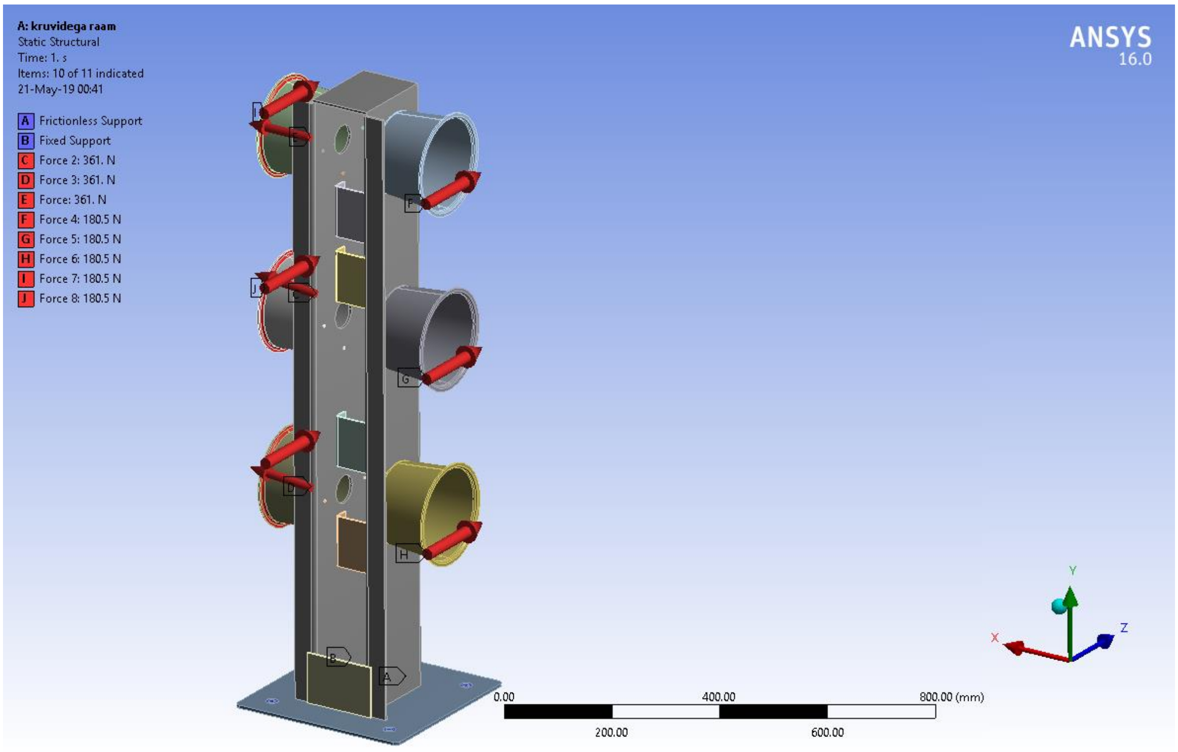


Figure 37: Forces and constraints for wind direction ZX

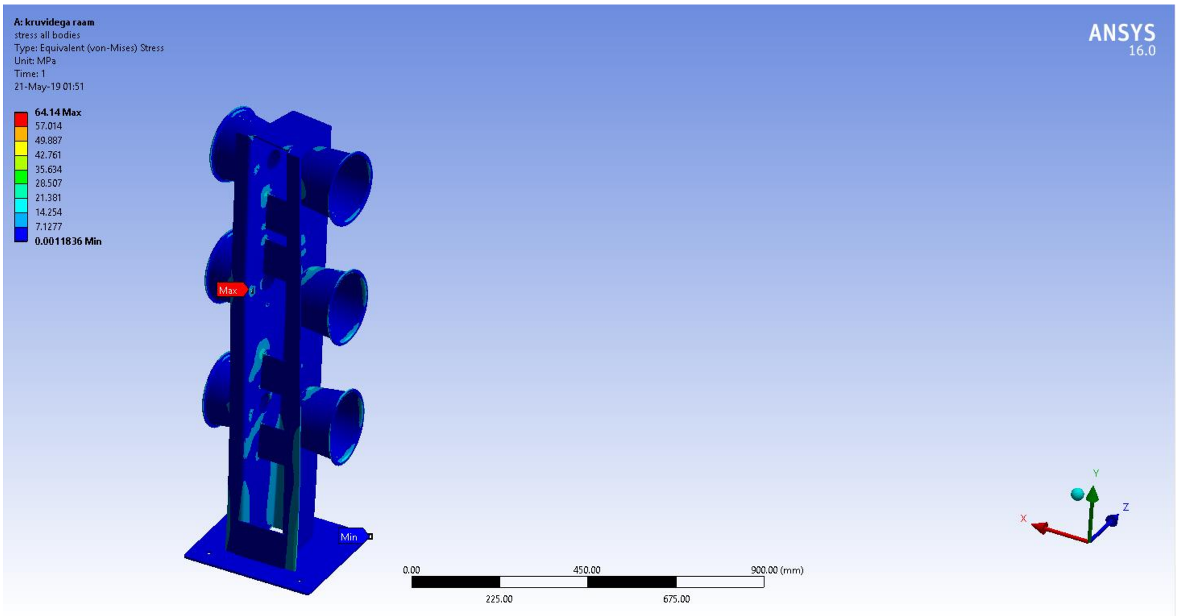


Figure 38: Equivalent stress for wind direction ZX

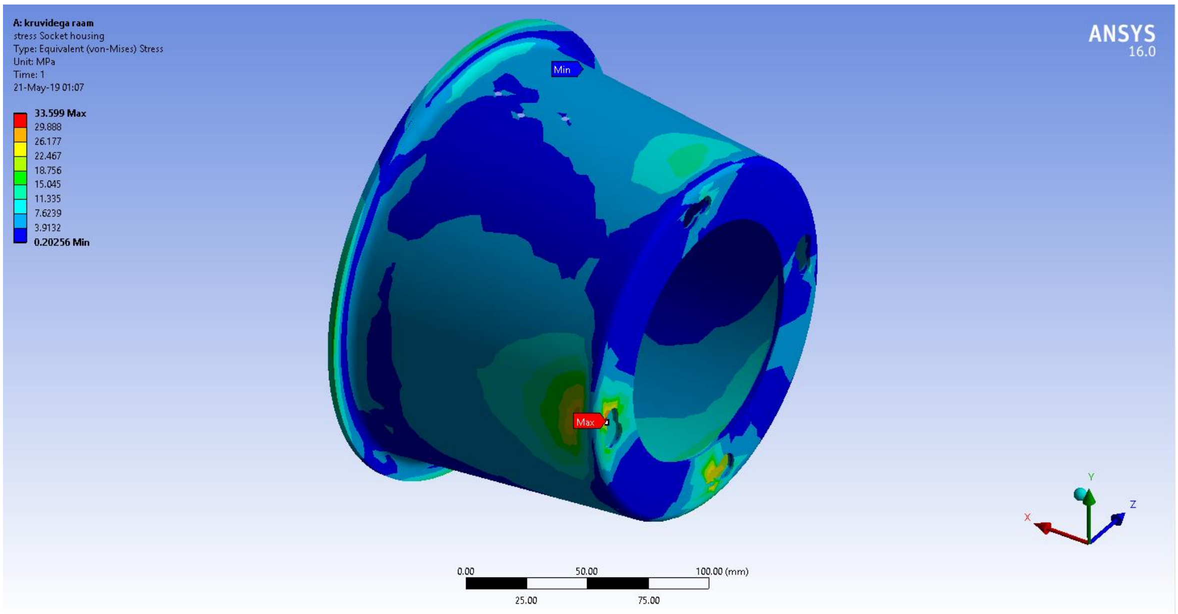


Figure 39: Equivalent stress for socket housing in wind direction ZX

Component	**Maximum stress (MPa)**	**Displacement (mm)**
Whole assembly	64	0,95
Frame	41,5	
Socket housing	33,6	
Socket screws	64	

Result summary

Table 29: Simulation results for frame and socket housing

	Stress (MPa)			
	Wind direction X	**Wind direction Z**	**Wind direction XZ**	**Maximum**
Frame	59,8	28,8	41,5	45,2
Socket housing	31,8	37,8	33,6	37,8
Socket screws	60,4	69	64	69

Maximum displacement of the whole assembly was 1,38mm, which is acceptable for assembly this size.

Frame - Maximum stress is 59,8 MPa in loading condition X. This is logical since the frame beam profile has lower axial strength in X-axis.
Material chosen for the frame beam must have higher yield strength than 59,8MPa.
Suitable material is Aluminum alloy 5083:

Table 30: Mechanical properties of Aluminum alloy EN AW-5083 H111 [26]

Property	**Value**
Tensile strength R_m	275 - 350 MPa
Yield strength $R_{p0.2}$	125 MPa

This alloy has great corrosion resistance, especially to sea water. Suitable for metal spinning and commonly available with Estonian suppliers [27]. Good weldability.

Factor of safety for the frame can be found:

$$FOS = \frac{R_{p0.2}}{S} \frac{125\ MPa}{59{,}8\ MPa} \sim 2 \qquad (6.4)$$

Factor of safety for the frame under maximum wind loading condition is 2.

Socket housing - Biggest stress is experience near the keyholes where the mounting screws are located. Maximum stress is 37,8 MPa. The biggest force was experienced under loading condition Z. This is logical since the loading condition greatest torque on the screws and the screws are not uniformly loaded. In loading condition X force is twice as big, but there is little to no torque and screws are more uniformly loaded – leading to lower stress.
Material chosen for the socket housing must have higher yield strength than 37,8 MPa. Suitable material is Aluminum Alloy 5754:

Factor of safety for the socket housing can be found:

$$FOS = \frac{R_{p0.2}}{S} = \frac{125\ MPa}{37{,}8\ MPa} \sim 3{,}3$$

Factor of safety for socket housing under maximum wind loading is 3,3.

Socket housing attachments screws – The most loaded component in the assembly are the screws attaching the socket housings to the frame. Maximum stress is 69 MPa in loading condition Z. In this loading condition screws are unevenly loaded and there is torque applied to the screw connection. The M5 screws used must have higher yield strength than 37,8 MPa. Material used for A4 stainless steel bolts has yield strength of 210 MPa [28].

Factor of safety for socket housing bolts can be found

$$FOS = \frac{R_{p0.2}}{S} = \frac{210\ MPa}{69\ MPa} \sim 3$$

Additionally, screw is increased from M5 to M6 to reduce stresses.

6.7 Specialized pedestal models

By law service providing marinas must enable their visitors access to certain specialized services– such as emergency equipment and bilge pumps [29]. One way to provide such services is to install emergency pedestals and pump out pedestals.

This means that any potential client who wishes to build a new marina or renovate an existing one will also have interest for specialized pedestals.

One benefit of the current design is that none of the surface features on the pedestal are defined in the molding process, this enables Keha4 to use the same enclosure for specialized models.

Design of these special pedestals exceeds the scope of this thesis but is still important consideration for future development.

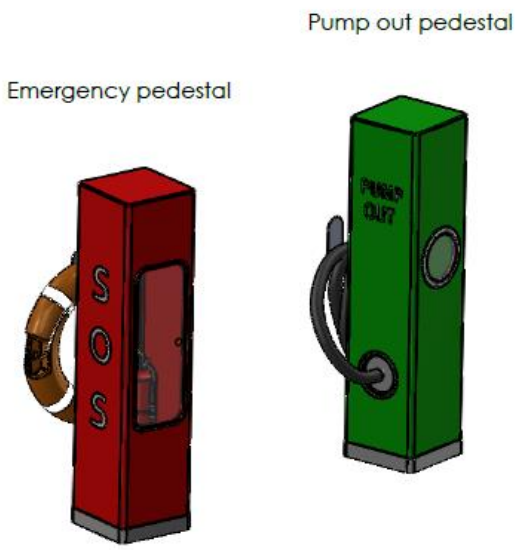


Figure 40: Specialized pedestal concept

6.8 Risk analysis

Risk assessment matrix is maintained throughout product development process and updated according to necessity. If any task reaches risk level 15+, then action must be taken to mitigate risks.

Table 31: Risk assessment matrix

No	Task	Probability 1-5	Impact 1-5	Risk 1 to 25	Possible action
1	Enclosure warping	3	5	**15**	Close co-operation with tool manufacturer and part manufacturer. Correct tolerances
2	Enclosure low stiffness	3	5	**15**	
3	Light quality low	3	4	**12**	Wide angle lens LEDs or strips.
4	Thermal expansion problems	3	4	**12**	Looser tolerances, extra fixing methods
5	IPX6 test failure	2	3	**6**	
6	IK07 test failure	1	4	**4**	Increase enclosure thickness
7	Thermal test failure	2	4	**8**	Reduce enclosure wall thickness, plastic additives, lower Ta
8	Galvanic corrosion	2	4	**8**	Insulate surfaces, different material selection
9	Fitting all parts in frame	2	3	**6**	Use minimal form factor components
29	EMC issues	1	4	**4**	

7. MANUFACTURING

Keha4 OÜ is a design-oriented company that has no internal production capacity. Only some testing and prototyping is done in-house. For most projects - manufacturing is outsourced to small and medium sized assembly companies in Harjumaa. Small warehouse is kept in Tallinn.

Table 32: comparison of potential subcontractors

	Company A	**Company B**
Size	3 workers	30+ workers
Focus	Small series production of specialized electronics	Assembly of distribution boards
Capability	Milling machine, saw, assembly, testing, MIG/MAG welding	Assembly, wire preparation, testing
Advantages	Willing to produce small quantities, flexible schedule	Purchasing power for switchgear components, extensive experience with distribution boards
Disadvantages	Not suitable for medium to large series production	Not suitable for small series production,
Offer for assembly 1pc	78€ - 4 outlet version	46 € - 2 outlet version 58 € - 4 outlet version 67 € - 6 outlet version

Company B offers significant benefits. Considering that average expected order size is 60 pcs. Marin service pedestal in its essence is also a distribution board, so the company is well equipped for production of this product.

Since Keha4 is a small company with limited product development budget, then tooling and prototyping will be financed by the project-0 budget. What this means is that product development will not be continued until an actual client is found. Lead time for very first project is going to be 12 weeks (Table 39). Any subsequent orders will have shorter lead time - since the product will have finished development and testing phase.

BOM

Stock is partly kept by Keha4 and partly by the manufacturer. Stock parts kept by Keha4 are usually product specific components (pedestal enclosure, frames, socket housing, hinges). This allows for Keha4 to shift its production between manufacturers when necessary. Additionally, most manufacturers are not interested in making large investments in other companies' stock. Parts purchased by the manufacturer can be standard components, especially if the manufacturer already has them on stock and is able to purchase them for better price than Keha4.

Table 33: BOM cost of different pedestal versions

Version	Assembly time*	BOM cost
2x16A, light, water	2,5 h	522 €
4x16A, light, water	3 h	683 €
6x16A, light, water	3,5 h	846 €

*Manufacturers estimation

It can be seen, that there is a considerable price difference between versions –dependent on the amount of socket outlets. This is due to 2 significant expensive items: RCBO (35 €/pc) and stainless-steel hinges (20,5 € /pc). The cost of switch gear components highlights the possible benefits offered by manufacturer B.

8. ECONOMICAL CALCULATIONS

Investments

Table 34: Investments

Tooling	
Enclosure mold	3000 €
Socket housing tooling	200 €
Water system bezel tooling	200 €
CE marking	
IP testing	400 €
IK testing	300 €
Ta testing	500 €
Budget reserve	800 €
Total	**5400 €**

Table 35: Estimated production costs

Version	C_B - BOM cost	CA - Assembly cost	C_A - Production cost
2x16A, light, water	522 €	48 €	570 €
4x16A, light, water	683 €	58 €	741 €
6x16A, light, water	846 €	68 €	914 €

*estimated

The pricing of our products is dependent on the competitors pricing and our market positioning. We position our product in the premium range and slightly above the average cost in that range. We position our price point 10% premium to market average.

Table 36: Price determination

Version	Market average M_a	Pedestal price P (M_a+10%)	Profit margin (P/C_A)	Profit ($P-C_A$)	Investment repayment (pcs)
2x16A, light, water	1097 €	1207 €	2,1	634 €	9
4x16A, light, water	1184 €	1302 €	1,75	561 €	10
6x16A, light, water	1300 €	1430 €	1,56	516 €	11

We can see that with this pricing method our profit margin drops fast with addition of every electricity socket. This is due to our mechanical design that uses expensive components in socket outlet design. Most notably stainless-steel hinges.
In the last column (Table 36) is the quantity of products that must be sold in order to repay the original investments. The market average for 6x16A version relies only on a single data point and should be investigated more.

9. SPECIFICATION

Characteristics

Materials:	UV resistant Polycarbonate enclosure. Flame retardant and impact resistant Marin grade aluminum frame
Dimensions (H x L x W):	1500 x 360 x 360 (mm)
Weight:	29 kg

Environment

Impact resistance rating:	IK07*
Ingress protection:	IPX6*
Operating temperature:	-25 ^{o}C to +40 ^{o}C*

Electrical

Electrical outlets:	Up to 6 x 16 A Single phase or 4x16 A and 2x 32 A Tripe phase
Voltage:	230 V to 400 V
Frequency:	50 Hz
Circuit Protection:	Circuit breakers with earth leakage protection
Metering:	On pedestal metering available for single phase

Lighting

Illumination:	Standard 2 x E27 socket LED lamps Photosensor controlled

Water

Water system:	Single ½” water faucet, housing separate from electronics Insulated for unexpected night freezes

Other

Compliances:	2014/35/EU Low Voltage
	2004/108/EC Electromagnetic Compatibility
	EN 61439-3 Low-voltage switchgear and control gear assemblies – Part 3: Distribution boards intended to be operated by ordinary persons.

* to be confirmed by testing

10. SUMMARY

The aim of the thesis was to develop a marina service pedestal based on Margus Triibmanns 3D sketch.

The scope of the development process was set to start with product specification and to conclude with technical and economic information that would enable Keha4 decision makers to determine future action.

First 3 chapters where about determining market demands and developing product specification.

Initially marina service pedestal state of art was established. Market survey was carried out and included such groups as: clients, specifiers and users. Most useful group being the specifiers who greatly helped with establishing the pricing situation and gave industry inside about client preferences. Competitors product offering was assessed including such aspects as market segmentation and pricing.

Based on these previous steps – it was possible to establish product specification. In the concept chapter, 3 different technical solutions where proposed. Decision making matrix was used to determine the most viable concept. The winning design used a semitransparent plastic enclosure that also functioned as a lighting diffuser for the LED lighting. This unique solution, only offered by Keha4, sets the final product apart from competitors. The lighting effect was tested with a scaled model – to make sure that the concept was viable. Results were sufficient to continue.

Electrical design chapter focused on sizing of the conductors and selecting correct switchgear to protect the circuit from overcurrent, fault current and earth leakage. RCBOs where chosen instead of more standard MCB+RCCB combination – mainly due to space limitations inside the enclosure. Even with these considerations – it was discovered that the small size of service hatches makes it difficult to use three phase energy meters. Solidworks Electrical and DraftSight 2018 were used to create a one-line diagram of the pedestal circuit.

In the mechanical design chapter challenges related to ingress protection and mechanical impact rating where addressed. Design solutions where explained. Ultimately these design aspects cannot be fully confirmed within the scope of this thesis, laboratory testing is needed. The unseen cornerstone of the mechanical design was the CAD model created in Solidworks.

Important structural elements such as frame, enclosure and socket housing where investigated more closely. Materials and production methods where determined. Water system assembly was explained. The frame structure was tested for wind loading. Suitable windspeed was selected 50 m/s which created maximum force of 1857 N. Wind force value was found by calculation and through simulation in Solidworks Flow. The stress calculations were carried out in ANSYS 16 LEM simulation software. The resulting information was used in determining suitable materials for frame assembly, socket housing and socket housing bolts. The construction was found to be sufficiently strong and aluminum alloy EN AW-5083 was used for structural elements.

The viability for future development of special purpose pedestals was addressed. The risk analysis chapter gives a brief overview of possible weak points of the design and proposes ways to mitigate possible risks. Manufacturing chapter explains the current state of Keha4 production and determines how the production of the marina service pedestal could be arranged. Gantt chart is generated to determine the time it would take to finish the development project and to fill a first order of 60 pcs. Economic calculations bring out the investment costs needed to finalize the development process. Production costs, sales prices, profit margins and investment repayment period was calculated. Finally, the product specifications where created. Based on the economical calculations it can be concluded that its possible to produce and sell this product with a profitable margin. Initial investments are relatively low and would probably be recuperated with first successful project.

In conclusion, the original objective of the thesis was met. With this thesis – a technical solutions have been worked out. Investment costs and potential profits were determined.

As a bonus – a lot of important information about marina service pedestal was obtained. This will allow Keha4 to be more competitive in the future and improve our products to meet the market demand.

11. KOKKUVÕTE

Käesoleva lõputöö eesmärk oli arendada välja sadamakai teeninduspost disainer Margus Triibmanni 3D sketši põhjal.

Tootearenduse projekti haare ulatub spetsifikatsioonide genereerimisest kuni tehnilise ja majandusliku informatsiooni koostamiseni. Projekti raames teostatud arendustöö võimaldab Keha4 OÜ-l liikuda edasi tööriistade ja vormide tellimisega.

Esimesed kolm peatükki käsitlevad sadamakai teenindupostide turgu ja tootespetsifikatsiooni koostamist. Esimene peatükk annab ülevaate sadamakai teenindupostide ehitusest ja võimekustest. Teises peatükis kirjeldatakse töö käigus teostatud turu-uuringut, mis toetus läbi viidud küsitlusel. Küsitleti kolme huvigruppi: kliendid, mõjutajad ja kasutajad. Kõige huvitavamaks ja kasulikumaks osutus mõjutajate tagasiside – see aitas autoril paremini mõista turu nõudeid ja kehtivat hinnataset. Uuriti ka konkurentide tooteid ja pakkumisi. Eelneva põhjal oli võimalik koostada toote spetsifikatsioon. Toote kontseptsiooni peatükis pakkus autor välja kolm erinevat tootekontseptsiooni, mida võrreldi otsustusmaatriksi abil. Valituks osutus disain, mis sarnaselt sadamakai teeninduspostile „Coral" kasutab valgust läbilaskvast plastikust korpust - viimane töötab ühtlasi ka valgushajutina. Selline lahendus on Keha4 OÜ toodangule ainuomane ja taoline eripära suurendab toote eksklusiivsust. Valguslahenduse kontrollimiseks ehitati vähendatud mõõtmetega mudel – tulemused olid piisavalt head, et kontseptsiooniga jätkata.

Elektridisaini peatükk keskendub vooluahela dimensioneerimisele ja elektriahela kaitseseadmete valikule. Elektriahelas kasutatakse rikkevoolukaitsega automaatkaitselüliteid, mis tagavad kaitse liigvoolu, lühise ja rikkevoolu korral. Jooniste tegemisel kasutati programme Solidworks Electrical ja Draftsight 2018. Seadmete dimensioneerimise käigus selgus, et teenindusluukide väiksed mõõtmed seavad piirangu seadmete suurusele ja paigaldusele. Kolmefaasiliste energiaarvestite kasutamine ei ole iga versiooni juures võimalik.

Kõige mahukam on mehaanilise disaini osa. Peatüki alguses käsitletakse disaini kitsaskohti ja raskuspunkte. Seletatakse lahti kaitseastme- ja löögikindlustesti mõisted ja metoodika, seejärel vaadatakse üle disaini lahendused, mille abil on võimalik vajalikud tingimused täita.

Järgnevalt teostati materjali ja tootmismeetodi valik olulisematele struktuuri elementidele. ANSYS 16 simulatsiooni tarkvara abil teostati raami detailidele tuulekoormuse arvutus. Sobivaks tuule kiiruseks valiti 50 m/s ja suurimaks mõjuvaks jõuks osutus 1857 N. Tuule kiiruse leidmiseks kasutati kahte meetodit: käsitsi arvutamist ja arvutisimulatsiooni.

Tugevusarvutuse tulemustest lähtuvalt teostati materjali valik detailidele. Sobivaks materjaliks osutus Alumiiniumi sulam NE-AW5083.

Peatükis käsitleti veel ka erifunktsiooniga teenindusposte ja nende arendamise potentsiaali. Vaadati üle ka veesüsteemi lahendus.

Riskianalüüsi peatükk annab lühiülevaate potentsiaalsetest probleemidest ja pakub välja lahenduskäike riskide maandamiseks.

Tootmispeatükk kirjeldab Keha4 OÜ tootmiskorraldust ja laokorraldust. Gantti graafiku abil leiti tarneaeg esimese projekti jaoks, mis sisaldab ka lõplikuks arenduseks kuluvata aega.

Majandusliku arvutuse osas tuletati tootmiskulu ja müügihind. Arvutati välja investeeringu kulud ja leiti tagasimakse periood. Arvutustest võib järeldada, et projekteeritud toodet on võimalik toota ja müüa spetsifikatsioonis ettenähtud hindade juures. Vajalikud investeeringud on võrdlemisi madalad ja teenivad ennast tasa juba esimese suurema projektiga.

Kokkuvõtteks võib öelda, et lõputöö eesmärgid said täidetud. Töötati välja sadamakai teeninduspostì tehniline lahendus ja loodi ülevaade toote majanduslikust potentsiaalist. Lõputöö tegemise käigus omandatud teadmised on autori hinnangul väga väärtuslikud ja tulevad kindlasti abiks ka tulevikus.

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APPENDIX 1 Marina survey results

Table 37: Marina survey results

marina	country	berths	pedestals*		16A	32A	63A	water	Light	Other
Sonwik Yacht Harbour	GER	400	76	Aluminium	4			YES	YES	
Marina Muros	ES	210	53	stainless steel	4			YES	YES	
Perros-Guirec Marina	FR	700	120	stainless steel	4/6			YES	YES	
Poole Quay Boat Haven	UK	75	32	Galv. Steel, plastic	4	YES	NO	YES	YES	metering for long stays, limited 32A
Town Quay Marina	UK	150	70	Galv. Steel, plastic	4			YES	YES	limited water
Bangor Marina	UK	560	205	Galv. Steel, plastic	4			YES	YES	
Royal Quays Marina	UK	350	225	Galv. Steel, plastic	2x /4x	YES		YES	YES	45 pedestal have water, small number of 32A
Delta Marina	NL	720	200	plastic	4			YES	YES	
Pobla Marina	ES	700	165	Galv. Steel, plastic	2x			YES	YES	

APPENDIX 2 Market survey questionnaires

Questions to marina operators:

- What is the number of berths in your marina?
- How many service pedestals do you have?
- Are you using pedestals with plastic, aluminum or stainless-steel housing?
- What is the number of power outputs and amperage rating of your service pedestals (example*: 4x16A; 2x32A etc.*)?
- Do you also use (electricity) metering devices for your pedestals?
  - If YES, then what kind? *Metering on the pedestal, remote metering, etc.*
  - If NOT, then is there a plan to start using such systems in the future?
- Do your pedestals also include water?
  - If YES, then how many faucets do you use.
- Do your pedestals also include lighting?
  - If YES, then how are they activated? Photocell, timer, ON/OFF switch
- What are the most common technical problems you experience with your pedestals?
- What improvements would you like to see on your pedestals in the future?

Questions to resellers:

- What is the price level and structure of marina service pedestals in Europe?
- Pedestals with aluminum, stainless steel, plastic and combination of these materials are offered on the market. Are there any notable preferences from the client side?
- What would be the most popular combination of outlets that clients order (ex. 4x16A, 6x16A, 2x16A and 2x32A)
- Is there any interest for metering solutions for electricity and water?
- Is there any interest for IoT solutions such as smart metering, integrated Wi-Fi ? , any notable trends?
- Is there any clear logic to how many pedestals are installed in relations to berth places?
- How large is the interest towards pedestals with special function ? Bilge water pumps, Emergency supplies.
- What are typical problems experienced with service pedestals after installation?

APPENDIX 3 Bill of material

Table 38: BOM for version 2x32A 4x16A

Item	description	price (EUR)	Qt	unit	Total (EUR)	Manufacturer
Structure						
PC enclosure	PC, 6mm	120	1	tk	120	FP
Frame	Al 5754	102	1	tk	102	SM
socket housing	Al 5754 3mm	6	6	tk	36	LE
faucet rim	AL 1mm	4	1	tk	4	LE
socket lids	AL 1050 anodized	5,2	6	tk	31,2	AR
access hatches	plastic	15,1	2	tk	30,2	SW
cover A	Al 1050 1mm	1,39	1	tk	1,39	FR
cover B	Al 1050 1mm	1,39	1	tk	1,39	FR
Electronics						
Disconnector	OT100F4	35,5	1	tk	35,5	ABB
16A RCBO	DS202C M B16 A30	35,5	4	tk	142	ABB
32A RCBO	DS204 A-B32/0,03	55,37	2	tk	110,73	ABB
6A MCB	S201M-C6UC	4	1	tk	4	ABB
E27 sockets		0,7	2	tk	1,4	VOSSLOCH
16A IP44 socket	16 A/230 VAC	11,4	4	tk	45,6	Mennekes
32A IP44 socket	32 A/400 VAC	16,15	2	tk	32,3	Mennekes
photosensor	JL-101B	6	1	tk	6	
5w LED lamp	Luxon	1,75	2	tk	3,5	
terminalp. KE61SET	Ensto Clampo Pro Cu 2.5-50 mm²	11,9	2	tk	23,8	Ensto
terminalp. KE66.3T	Ensto Clampo Pro Cu 2.5-50 mm²	16,7	0,33	tk	5,511	Ensto
terminalp. KE66T	Ensto Clampo Pro Cu 2.5-50 mm²	4,6	1	tk	4,6	Ensto
Fixing elements						
Bolt M6x10	DIN7985 A4	0,216	24	tk	5,18	BB
Bolt M4x10	DIN7500 A4	0,107	35	tk	3,745	BB
Bolt M4x20	DIN7500 A4	0,116	24	tk	2,784	BB
Rivet D4	Al DIN 7337	0,0279	18	tk	0,5022	BB
Bolt M3x10	DIN7985 A4	0,066	18	tk	1,188	BB
Screw D4,2x13	DIN7981 D4,2	0,053	32	tk	1,696	
pipe clamp	plastic	0,9	2	tk	1,8	BB
cabling						
wire 1 mm2	Cu, stranded, 90°C	0,15	4,5	m	0,675	EV
wire 2,5 mm2	Cu, stranded, 90°C	0,3	12	m	3,6	EV
wire 10 mm2	Cu, stranded, 90°C	1,22	0,4	m	0,488	EV
wire 16 mm2	Cu, stranded, 90°C	1,7	0,9	m	1,53	EV
wire 25 mm2	Cu, stranded, 90°C	2,56	0,1	m	0,256	EV
piping						
water faucet	1/2"	4,75	1		4,75	BO
pipe elbow 90deg		2,1	1		2,1	BO

Item	description	Price (EUR)	qt	unit	Total (EUR)	Manufacturer
Pressure hose	1/2" 30cm	4,6	1		4,6	BO
Connection part	stainless steel	15	1		15	AR
pipe 40x1,8		1,5	1		1,5	BO
other						
hinge A2	Stainless steel A2	20,8	6	tk	124,8	IN
hinge washer A	3D printed	1,15	6	tk	6,9	OP
hinge washer B	laser cut plastic	1	6	tk	6	OP

APPENDIX 4 Gantt chart

Table 39: project-0 Gantt chart

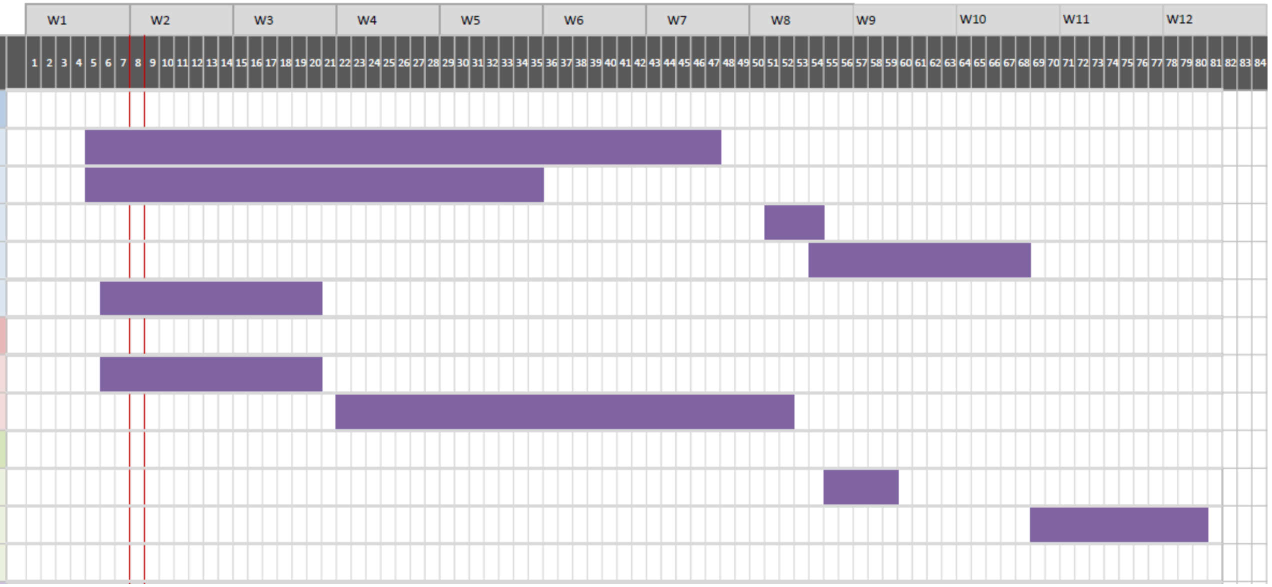
Marine service pedestal order

Project 0

4x16A marine servic pedestals - 60pcs
Delivery time: 12 weeks

The purpose of this Gantt chart is to determine the minimum delivery time for first project. subsequent project will have better lead times, since development processes are done and production has been established.

TASK	ASSIGNED TO	START	END
Development		day	day
Order enclosure mold	AA	1	43
Order spinning tools	AA	1	31
Prototype building	SV / CB	47	50
Labrotory tests (IK, IP, Ta)	INSP	50	64
Finalizee drawings, manuals	SV	2	16
Purchasing			
Updatet price offers for all components	SV	3	16
order parts	AA	17	48
Manufacturing			
Create production manuals	CB	51	55
Assembly	CB	64	79



APPENDIX 5 Product rendering

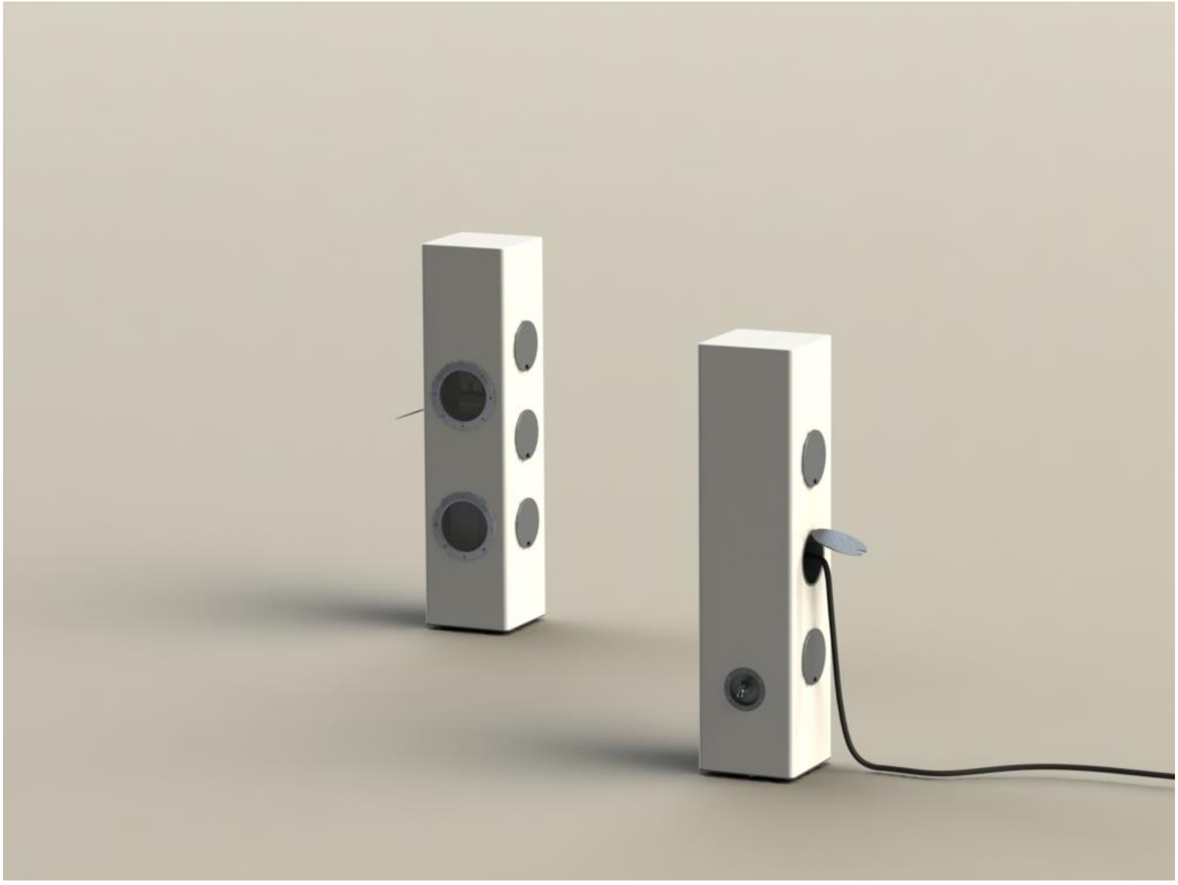
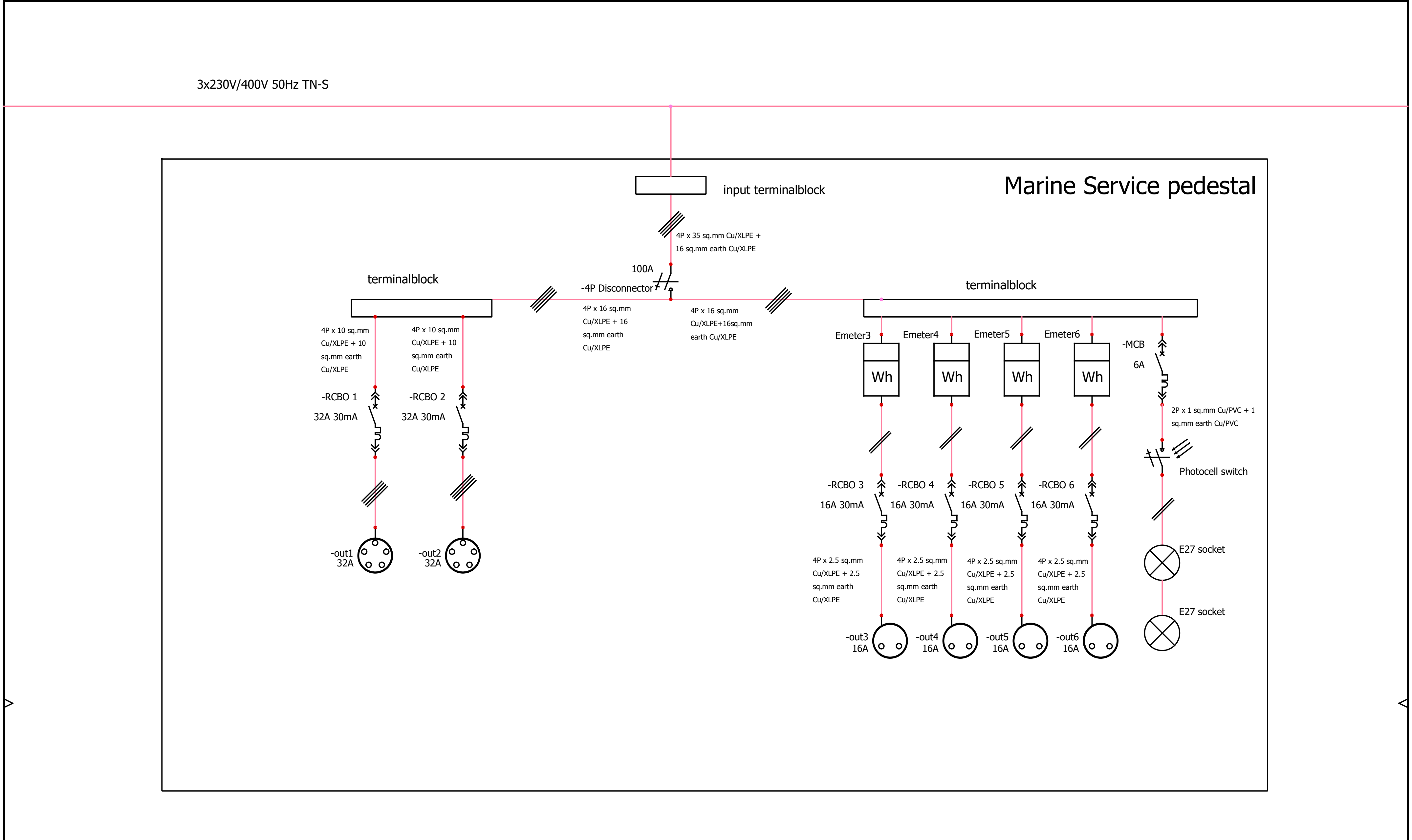


Figure 41: Rendering of the marina service pedestal. Authors image

GRAPHICAL MATERIAL



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CONTRACT: 123456

Marine service pedestal

LOCATION:

One line diagram 001

REV.	DATE	NAME	CHANGES
0	07.04.2019	Sander Vislapuu	

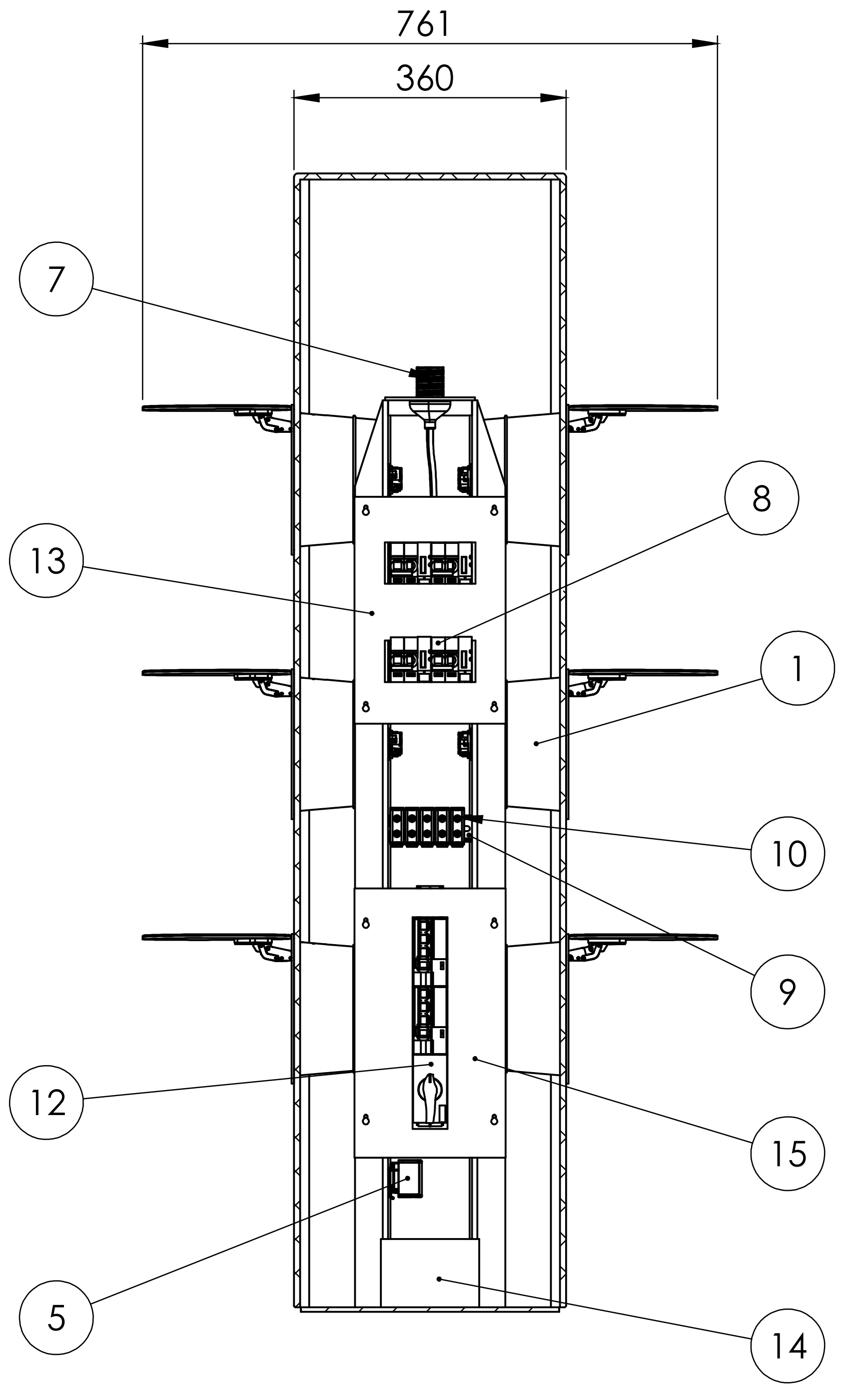
User data 1
A.B.

User data 2
07.04.2019

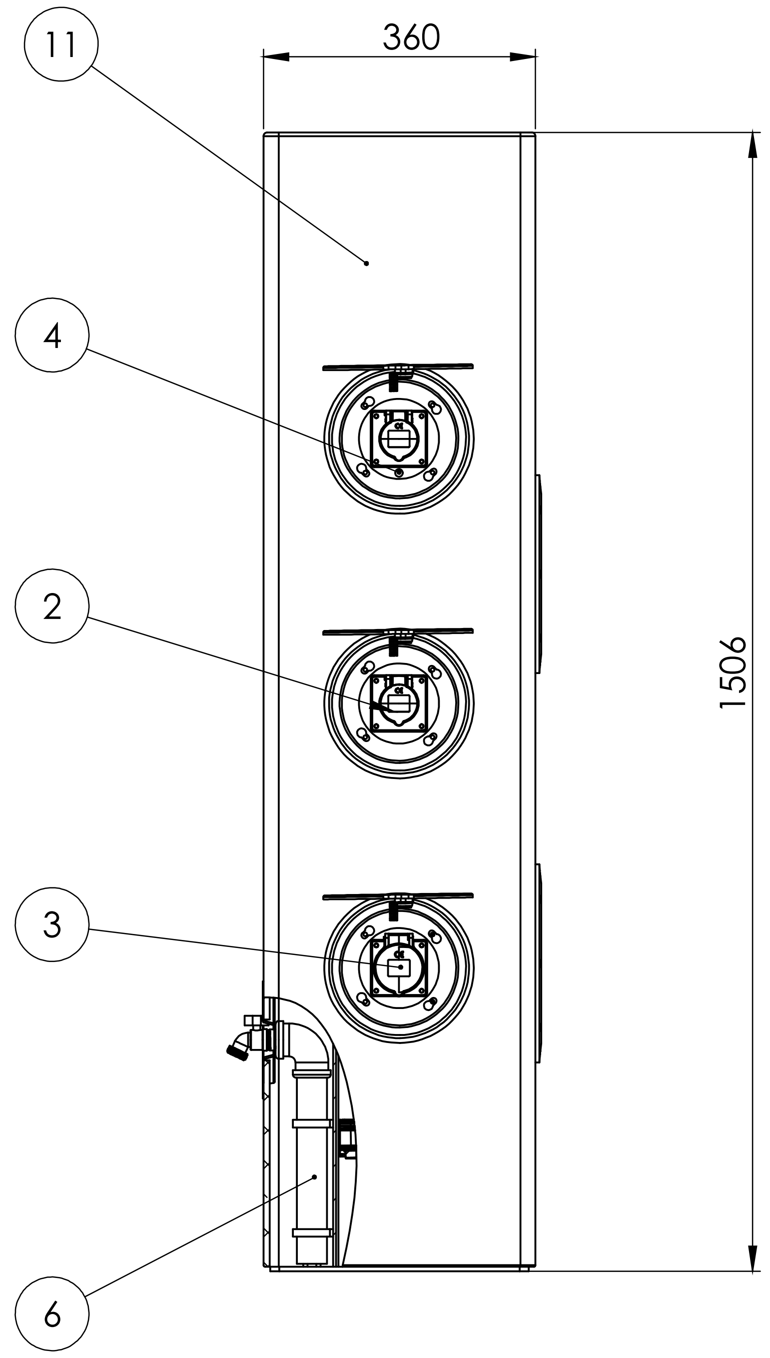
REVISION
0

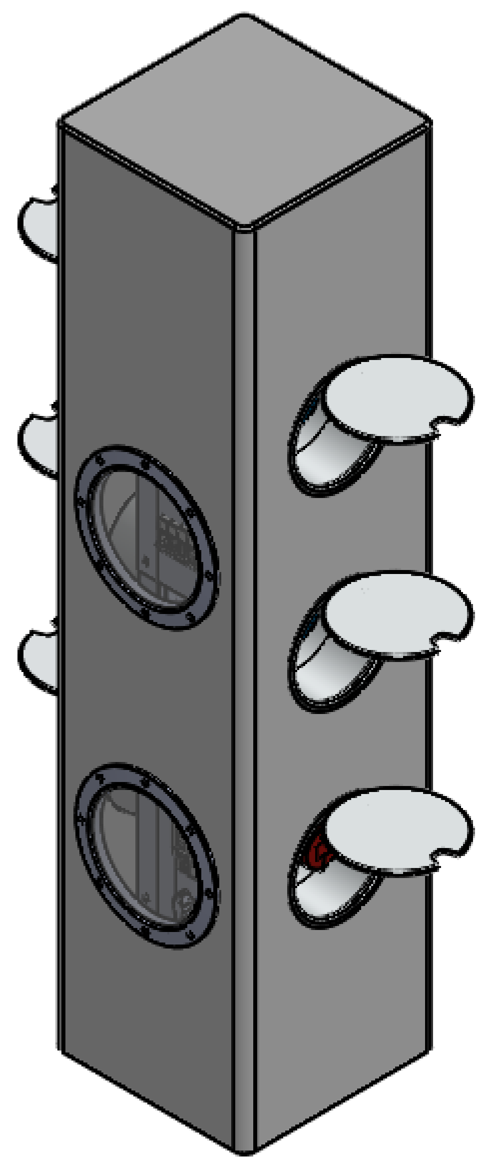
SCHEME
01

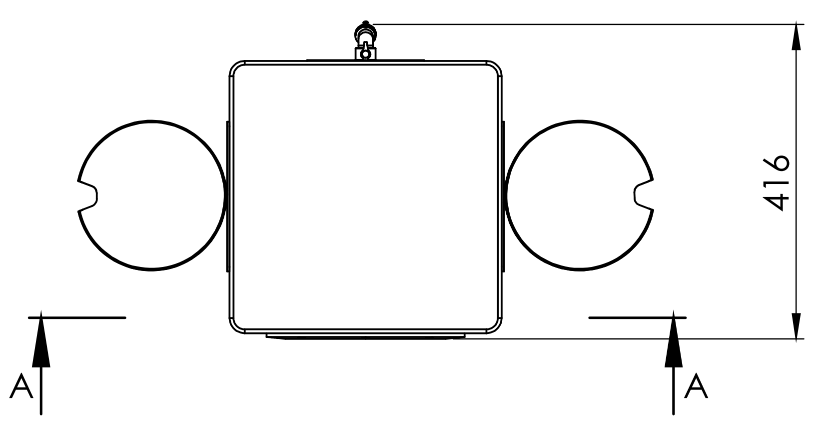
Document realized with version : 2018.0.3.18



SECTION A-A

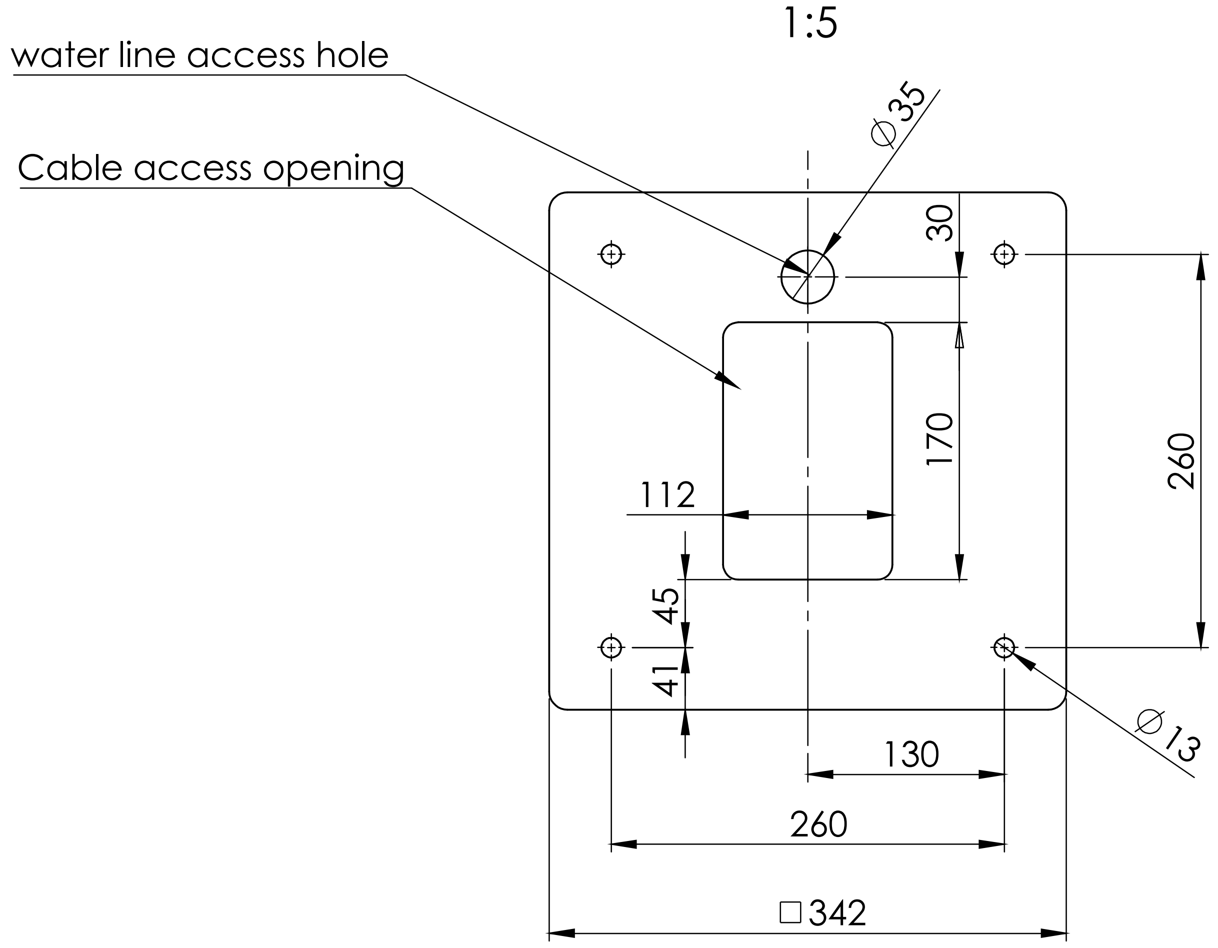






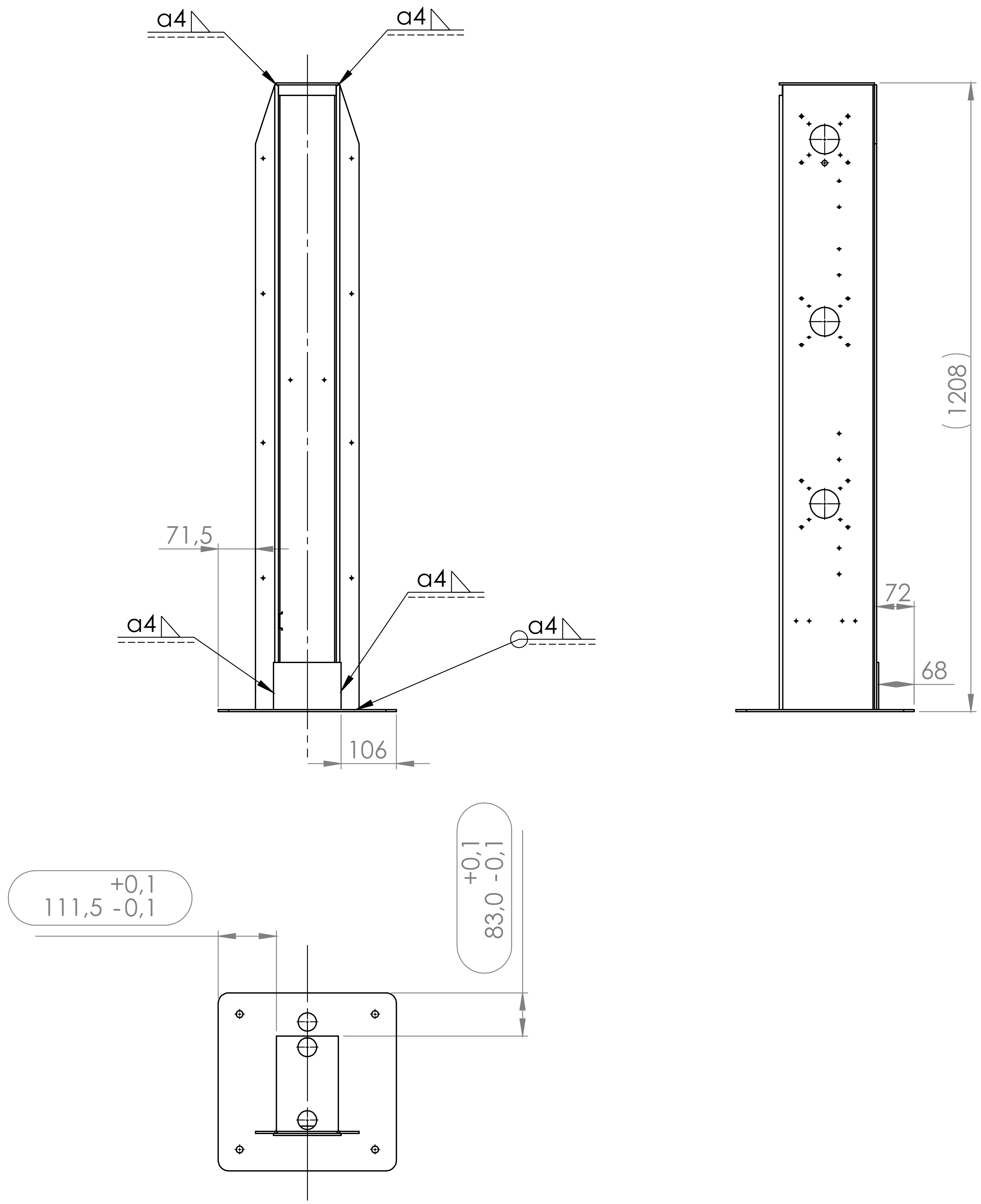
mounting flange dimensions

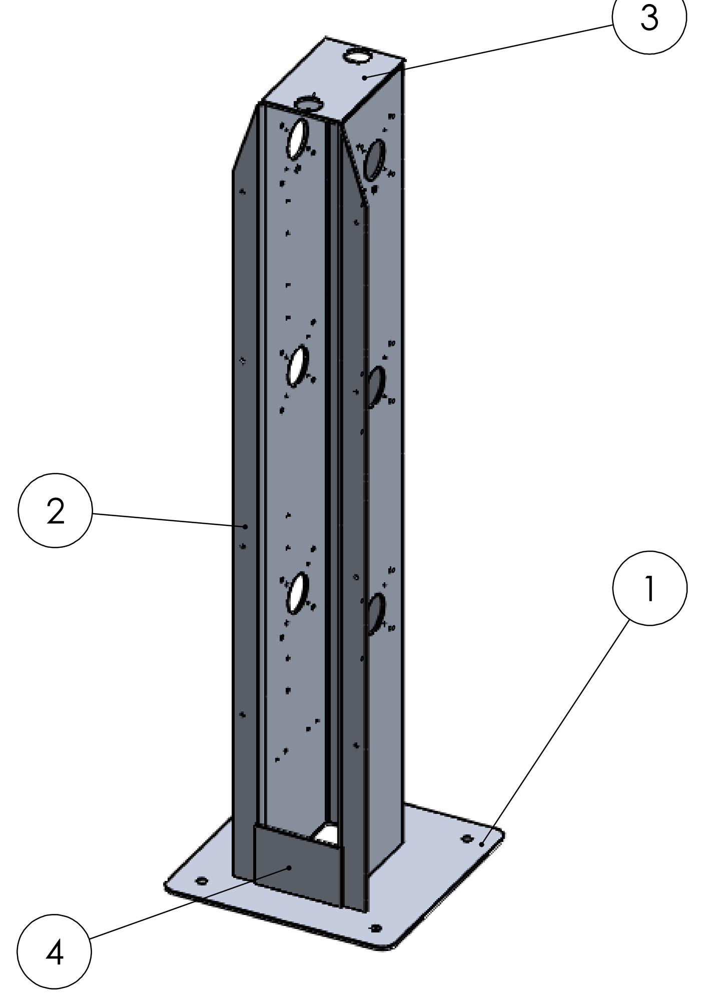
1:5



ITEM NO.	PART NUMBER	DESCRIPTION	QTY.
2	DP001-01-1366-16A socket	Socket 16A IP44 230V 50Hz	4
3	DP002-1276-32A socket	Socket 32A IP44 400V 50Hz	2
4	DP003-H35676-lightsensor	Photosensor 1,5W 220V 50Hz	1
5	DP022-KE61-02-PK1	Terminalblock 2P Ensto	5
6	APX03-01-water assembly	1/2" water tap assembly	1
7	DP004-102052-E27 socket	E27 lamp socket	2
8	APX20-01	Upper switchgear assembly 2x16A RCBO + Emeter	2
9	DC001-DIN rail 110	DIN rail EN60715 – 35 × 7.5	1
10	DP020-KE61-01-PK2	Terminalblock 1P Ensto	5
11	APX06-01 Enclosure ASM	Enclosure with hatches	1
12	APX21-01	Lower electrical assembly. 2x32A RCBO + disconnector	1
13	DC025-02	1mm Al1050	1
14	APX01-01-Frame	Welded frame assembly	1
15	DC025-01	1mm Al 1050	1

Material:	Unmarked tolerances:	Mass:	Scale: 1:10
Drafted: Sander Vislapuu	Description: Marina service pedestal		Fail name:
Checked: Toivo Tähemaa			
Approved: Toivo Tähemaa			
Tallinna Tehnikaülikool	Page: 1	Nr: PO-PX-001	Format: A2





ITEM NO.	PART NUMBER	DESCRIPTION	QTY.
1	DC010-01-Frame flange		1
2	DC011-01-Frame beam		1
3	DC012-01-Frame top		1
4	DC013-01-frame bottom plate		1

Material:	Unmarked tolerances:	Mass:	Scale:
Aluminium AW-5083 H111	H12; h12; IT 14/2	8,5 kg	1:10

Drafted	Sander Vislapuu	Title: APX01-Frame assembly
Checked	Toivo Tähemaa	
Approved	Toivo Tähemaa	
Tallinna Tehnikaülikool	Page: 01	Nr: APX01-01