1. Mast

The mast is a stable truss construction. It is 10 m high and weighs about 430 kg. It makes the assembly the highest and heaviest construction of the plant. The mast connects nacelle, foundation and pump and fulfils several tasks. On the one hand, it carries the weight of the nacelle and the rotor as well as the control and cross vanes. On the other hand, the height of the mast is decisive for the energy yield. The higher the rotor is positioned, the higher the wind currents can be achieved. Due to its pyramidal shape, the mast protects, stabilizes and guides the pump rods. It runs centrally through the mast from the nacelle to the pump. In windy areas the mast can be made shorter. Windy areas include coastal areas.

Figure 1 shows the mast assembly. The mast consists of a frame. This is about 10 m high. The four mast feet with their hinges are welded to the lower end of the mast. These connect the mast to the foundation. A working platform is attached to the upper part of the mast. This allows a safe stand during commissioning and later maintenance work on the upper assemblies.
At the upper end of the mast is the three-part azimuth bearing between mast and nacelle pipe. The nacelle pipe rests on the azimuth thrust bearing at the bottom. This azimuth bearing made of a brass, copper or bronze plate is a plain bearing, just like the other two radial bearings. The two wide bearing sleeves of the radial bearings transfer the bending forces between the mast pipe and the nacelle pipe. They are glued to the top and bottom of the mast pipe to prevent them from slipping.

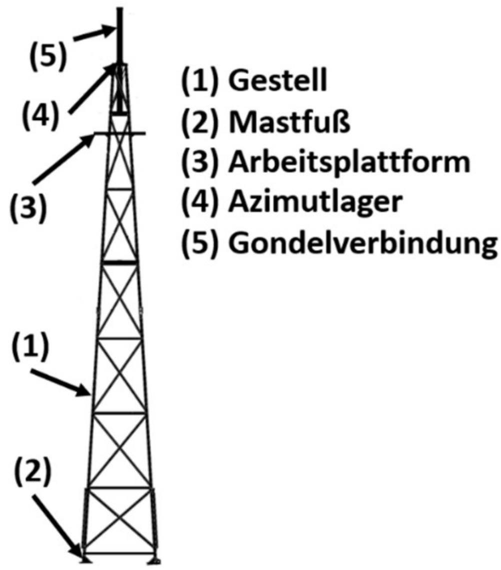


Figure 1 – Assemblies of the mast

0.1 Mast structure

Figure 2 shows the frame of the mast. The mast consists of four equal sides. In the middle of the mast, as well as at the top are connected by screws. That way the mast can be transported to the installation site in three parts and screwed together on site. Two different sizes of L-profiles are used for the construction. The four corner posts are also called longitudinal struts. They are made of profile steel of 50 × 50 × 5 mm. The inner struts are called diagonal struts. These struts have the dimensions of 40 × 40 × 4 mm. The horizontal struts, which connect the stems with each other like a frame, are called cross struts. These eight frames divide the mast into seven segments. The lowest cross struts are made of a profile steel of 50 × 50 × 5 mm, as these have to withstand higher forces when the system is erected. All others are made of 40 × 40 × 4 mm profile steel. The uppermost segment has a height of 1 m. All segments below are distanced by 1.50 m each. In order to guarantee the stability of the entire plant, the six uppermost segments are provided with one diagonal strut per side. The lowest segment is stabilized with two crossed struts on each side. The struts are welded to the stems.

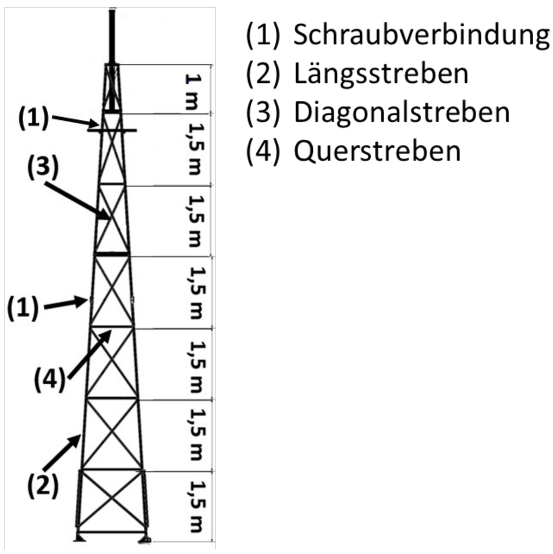
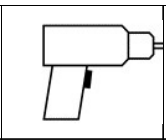
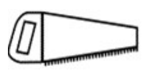
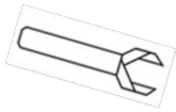
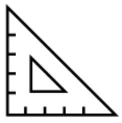
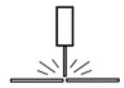
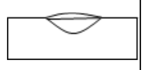


Figure 2 – Classification of the struts

Tools

						
	6,6; 12	Metal	WS18	90°		

Material

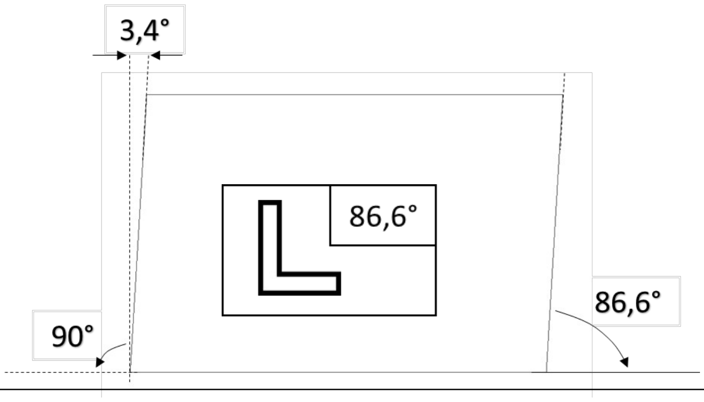
Pos	Raw material	Name	Standard	Dimensions	Qty	Material
1.1 -1	**R - 22**	L-Profile	DIN EN 10056-1	50x50x5x5009mm	4	S235
-2	**R - 22**	L-Profile	DIN EN 10056-1	50x50x5x5227mm	4	S235
-3	**R - 22**	L-Profile	DIN EN 10056-1	50x50x5x1465mm	4	S235
-4	**R - 28**	L-Profile	DIN EN 10056-1	40x40x4x1310mm	4	S235
-5	**R - 28**	L-Profile	DIN EN 10056-1	40x40x4x1132mm	4	S235
-6	**R - 28**	L-Profile	DIN EN 10056-1	40x40x4x952mm	4	S235
-7	**R - 28**	L-Profile	DIN EN 10056-1	40x40x4x773mm	4	S235
-8	**R - 28**	L-Profile	DIN EN 10056-1	40x40x4x594mm	4	S235
-9	**R - 28**	L-Profile	DIN EN 10056-1	40x40x4x389mm	4	S235
-10	**R - 28**	L-Profile	DIN EN 10056-1	40x40x4x278mm	4	S235
-11	**R - 28**	L-Profile	DIN EN 10056-1	40x40x4x380mm	2	S235
-12	**R - 28**	L-Profile	DIN EN 10056-1	40x40x4x1789mm	4	S235
-13	**R - 28**	L-Profile	DIN EN 10056-1	40x40x4x1789mm	4	S235
-14	**R - 28**	L-Profile	DIN EN 10056-1	40x40x4x1800mm	4	S235
-15	**R - 28**	L-Profile	DIN EN 10056-1	40x40x4x1676mm	4	S235
-16	**R - 28**	L-Profile	DIN EN 10056-1	40x40x4x1565mm	4	S235
-17	**R - 28**	L-Profile	DIN EN 10056-1	40x40x4x1468mm	4	S235
-18	**R - 28**	L-Profile	DIN EN 10056-1	40x40x4x1131mm	4	S235
-19	**R - 28**	L-Profile	DIN EN 10056-1	40x40x4x834mm	4	S235
-20	**R - 22**	L-Profile	DIN EN 10056-1	50x50x5x300mm	8	S235
-21		hexagon head screw	ISO 4017	M12x35-8.8	88	
-22		hex nut with torque part	DIN EN ISO 7040	M12-8.8	88	
-23		washer	ISO 7091	12	176	
-24		hexagon head screw	ISO 4017	M10x35-8.8	6	
-25		hex nut with torque part	DIN EN ISO 7040	M10-8.8	6	
-26		washer	ISO 7091	10	12	

Table 1 – Bill of material 1.1 Mast structure

Construction

Template

In order to align the mast as precisely as possible, it is advisable to build a template. This can be made from a simple wooden or metal plate. It is important that the edges keep the indicated angles. The edge length should be at least 700mm. From now on the use of the template is marked with the following symbol

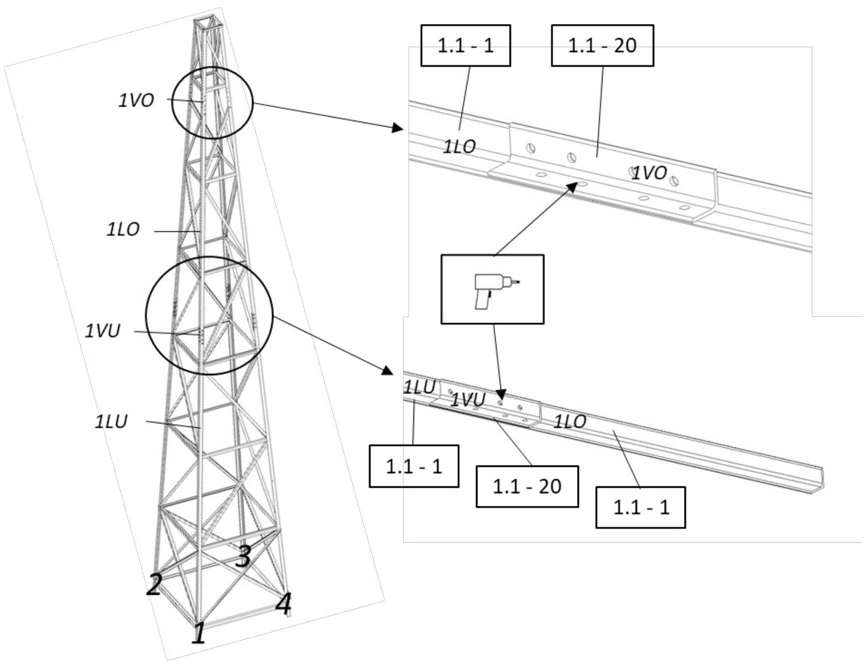


1. All parts are sawn first. The lengths of all required L-sections can be taken from the material list. If possible, the diagonal braces can also be cut with a plasma cutter.

Mast construction

2. After sawing, the individual components should be numbered. It is a good idea to use the numbering used here.

First, two 5009mm long mast stems [1.1-1] each are connected to each other using an angle iron [1.1 - 20] or two flat irons (40mm x 6mm, not shown) each with the connecting angle profiles.



Connecting angle iron

Before the connecting angle irons can be screwed on, the outer edge must be provided with a 7mm radius. Only then will their profile surfaces of the angle profile fit exactly to the inner surfaces of the stem profiles.

Fix with screw clamps

Fix exactly with screw clamps.

Drill holes together

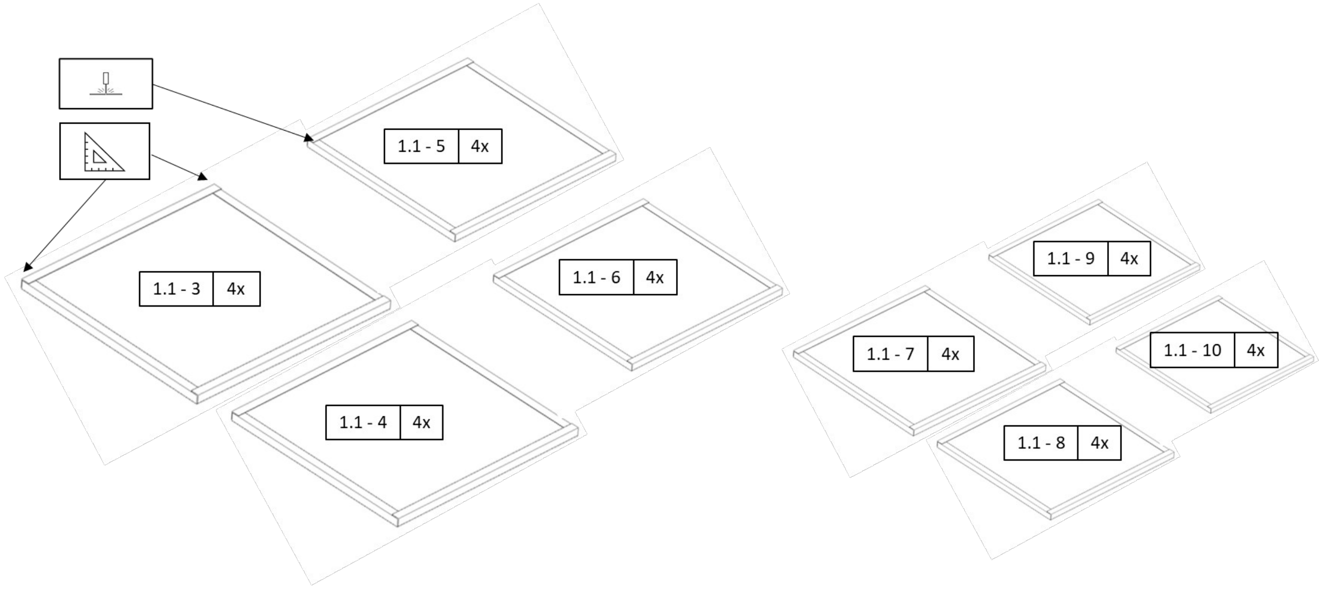
The holes are drilled together with the corresponding connecting profiles. This is the only way to drill the bottom and top longitudinal struts [1.1-1] together with the connectors [1.1-20] without errors.

Marking the connections

It is particularly important to clearly mark the positions of the components before drilling so that they can be correctly screwed together again later during assembly. The marking suggested here is composed as follows:

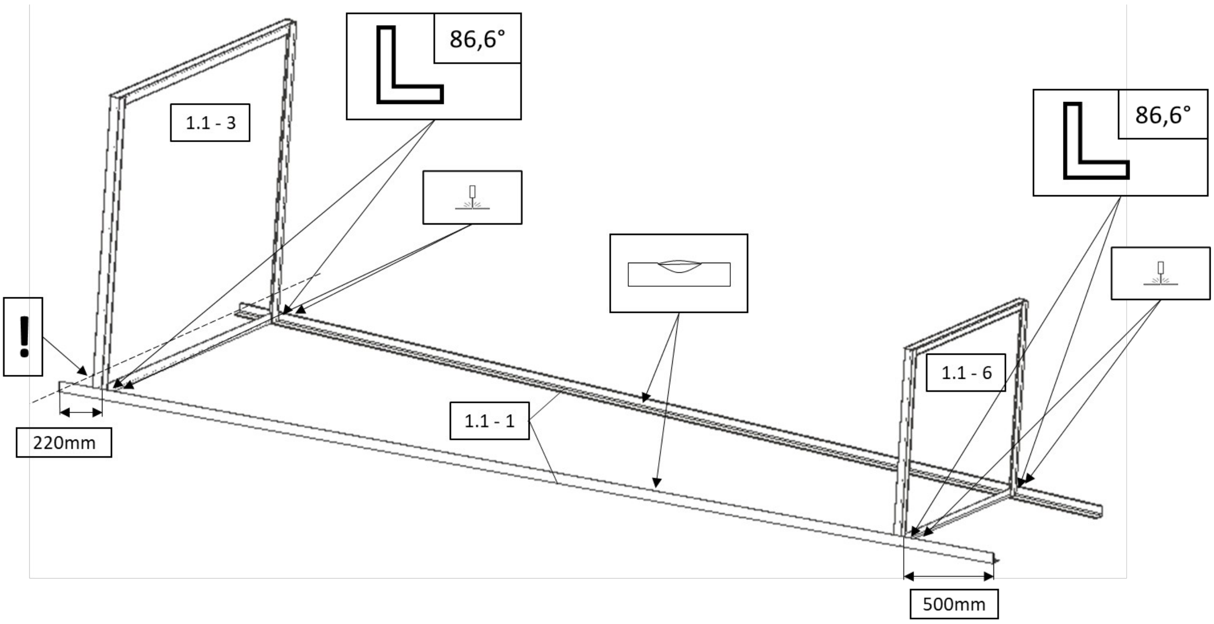
1 - Numbering of the mast corners
L - longitudinal struts
V - connecting piece
O - top
U - Bottom

3. **Welding the cross struts**
   The cross struts, which are sawn to within one millimeter, are laid out in squares and welded overlapping at the corners. Make sure that they are laid out at right angles. There are 8 squares in total.

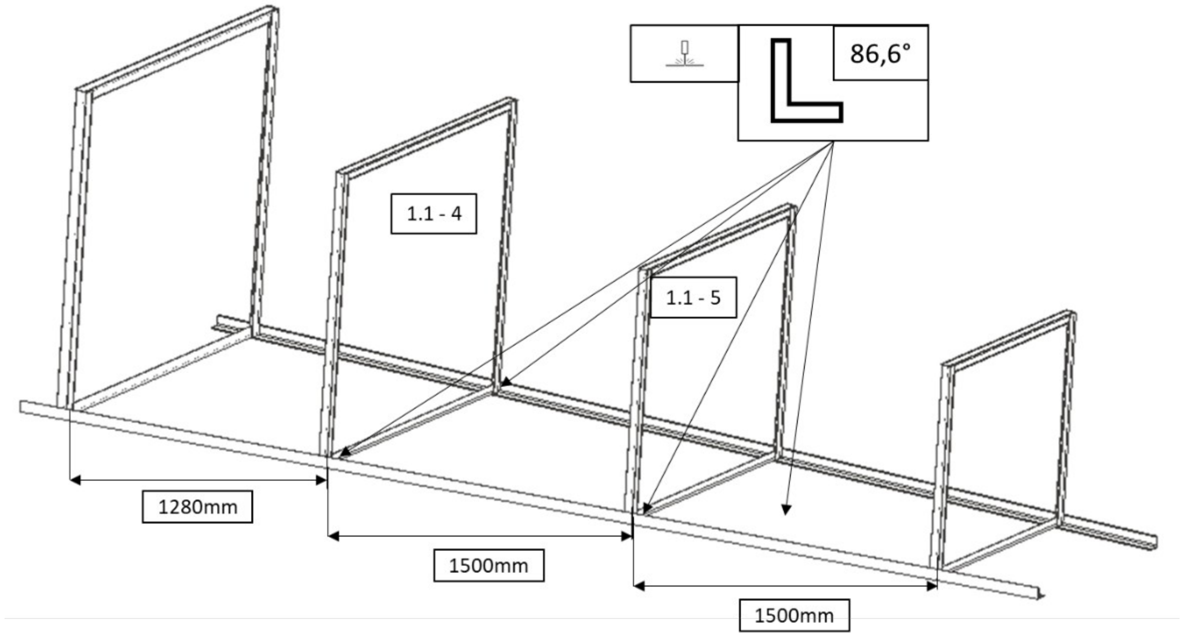


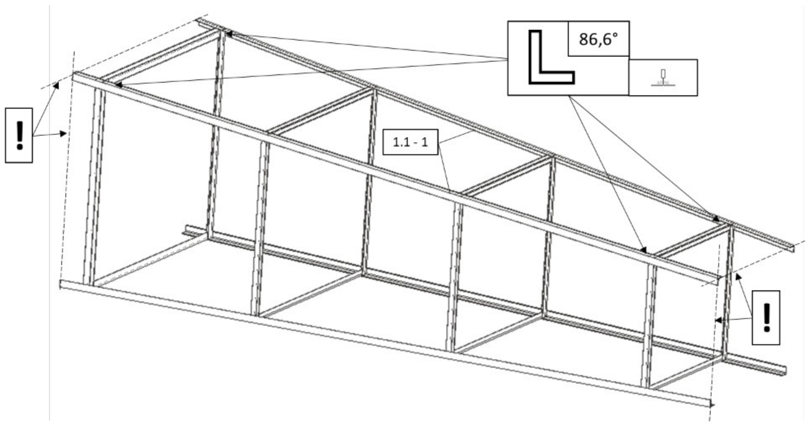
4. **The production surface shpuld be level and horizontal**
   Mark accurately on the floor
   On the floor, an 11m long line is drawn (with a string as an aid) and exactly (!!!) at right angles at the end a 2m long line, one meter to each side. This way you always have the symmetry of a center line to check. The mast will not be vertical later if mistakes are made here.
   Staple the lower mast stems to the cross brace frames
   First, build the lower part of the mast. To do this, lay out two longitudinal struts [1.1-1] on the ground and make sure that they are level and aligned horizontally, equally high and straight on the ground using a spirit level. To prevent damage to the mast and the ground, wooden blocks or plates of the same height should be placed under the struts for this purpose (prevent deflection due to the own weight!).

   Then insert the lower cross strut square [1.1-3] first, followed by the upper one [1.1-6], clamp it with screw clamps and staple it. <u>The angle between the cross strut frame and the corner posts plays a decisive role here and must also be checked and corrected repeatedly before and after tacking.</u> After alignment, spot tacking is carried out and then welded with short seams.



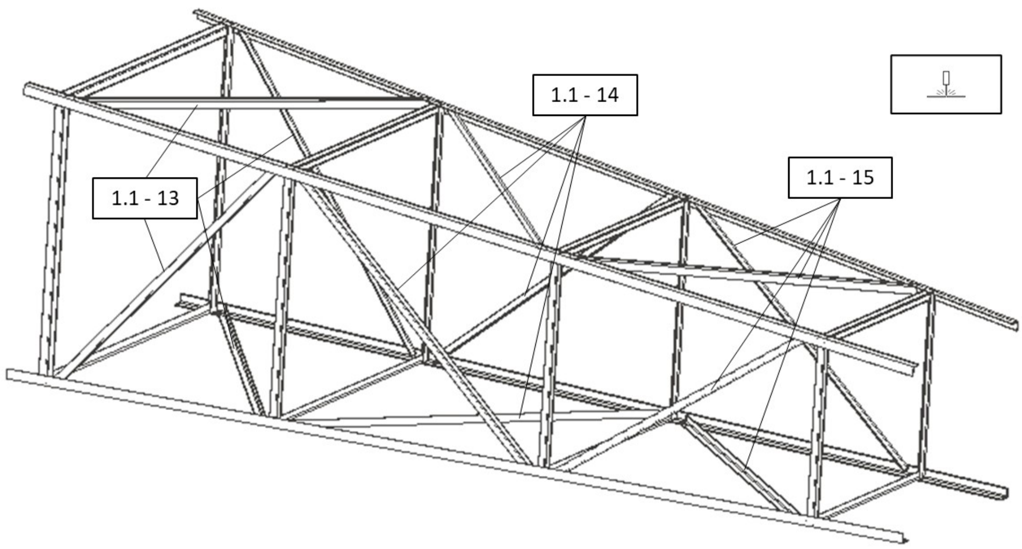
5. Then insert the middle crossbar squares [1.1-4 and 1.1-5] and also spot weld them.



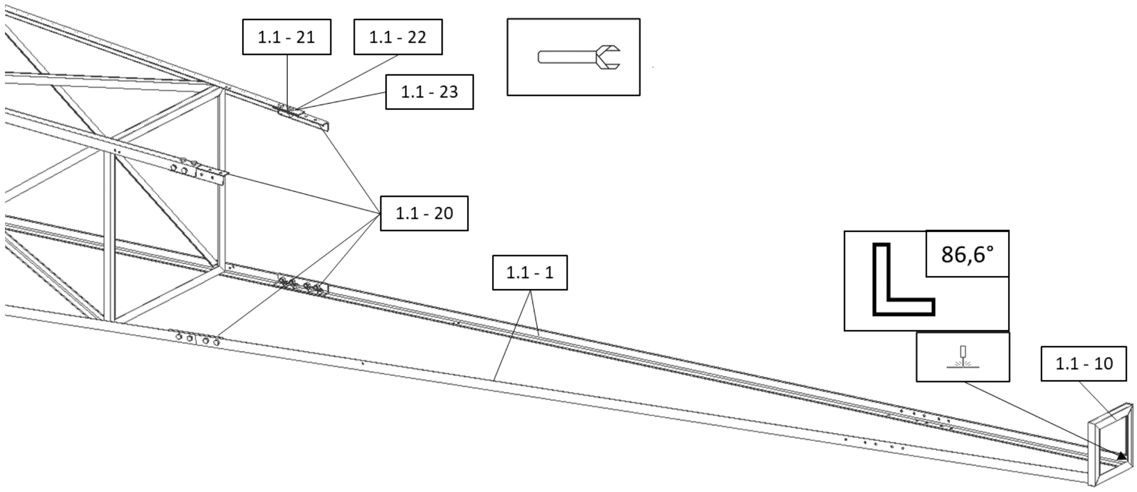


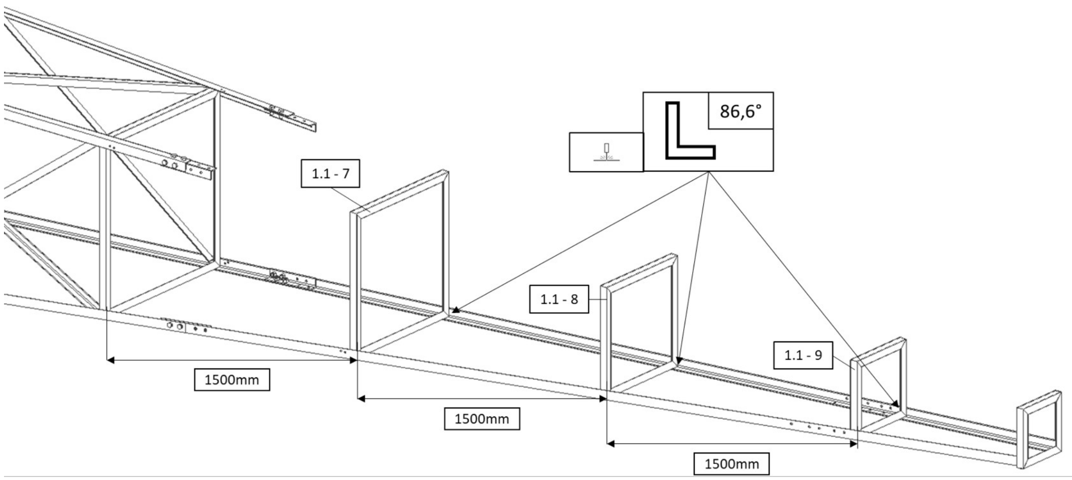
6. In the next step, the other two longitudinal struts are placed and dotted. Here, it is also very important to ensure that **the angle and distances of the longitudinal struts to each other and to the cross strut squares are maintained.** This must be done with particular care, otherwise the mast will not be straight.

7. Now check that all parts are accurately positioned and aligned. Next, the diagonal braces are inserted and spot-welded. In the case of the lower sector, only the four diagonal struts welded on the inside are installed for the time being.



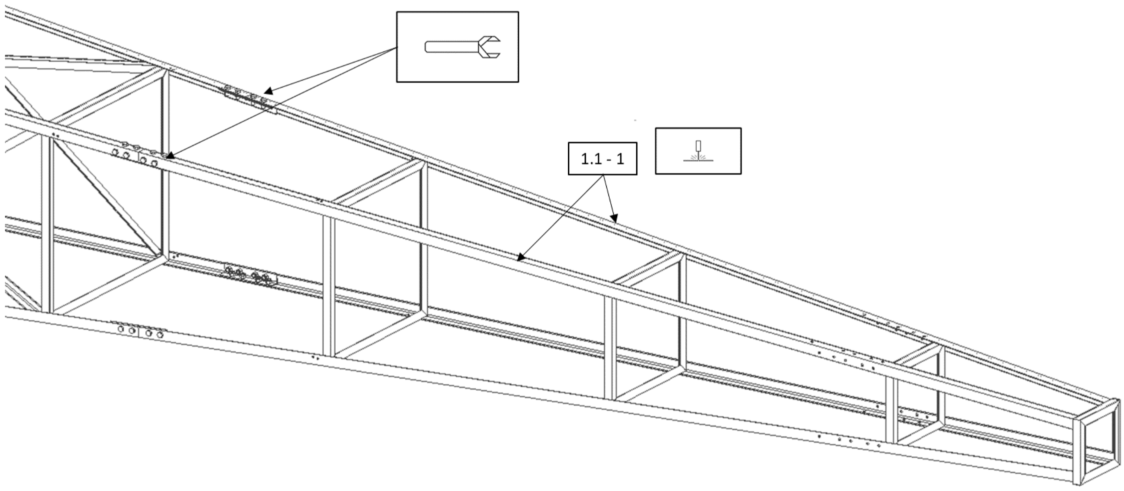
8. **Build upper half of the mast and connect it with the lower one**
   This completes the lower mast for the time being and the upper part can be adapted to it. First, the connecting pieces are screwed on. Then, two longitudinal struts [1.1-1] for the upper part of the mast are screwed to the connecting pieces. By attaching the top cross strut square [1.1-10], the longitudinal struts can be aligned. Make sure that the angle between the longitudinal struts and the cross struts is maintained. Likewise, the ends of the longitudinal struts are placed on the inside of the cross strut square. After alignment, spot welding is carried out for the time being.



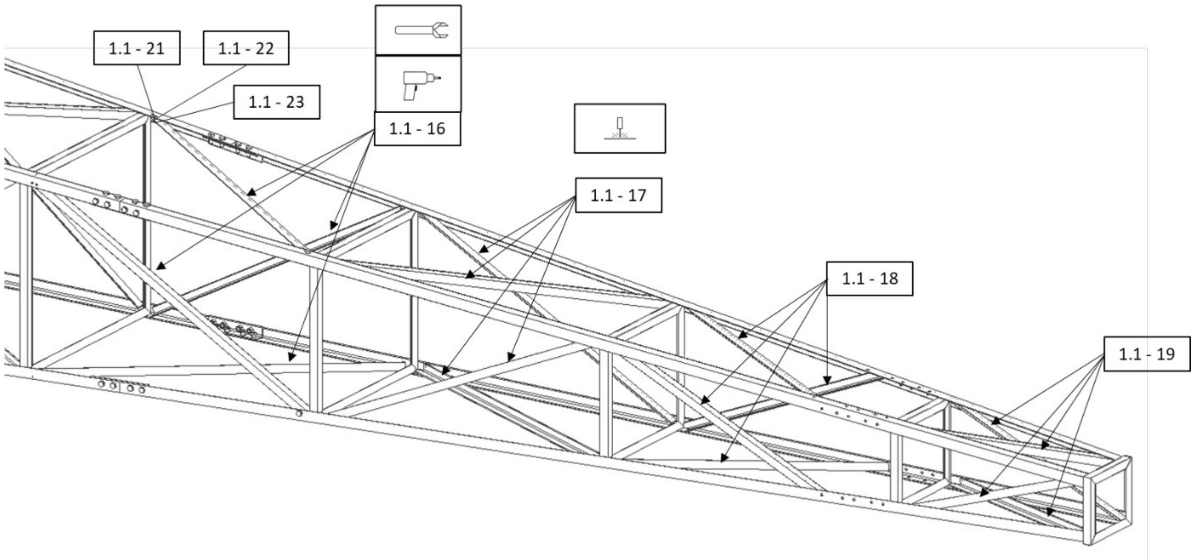


9. Keeping the angles 3.4 degrees and 86.6 degrees, respectively, the middle crossbar squares [1.1-7], [1.1-8] and [1.1-9] can now be positioned, aligned and punctured.

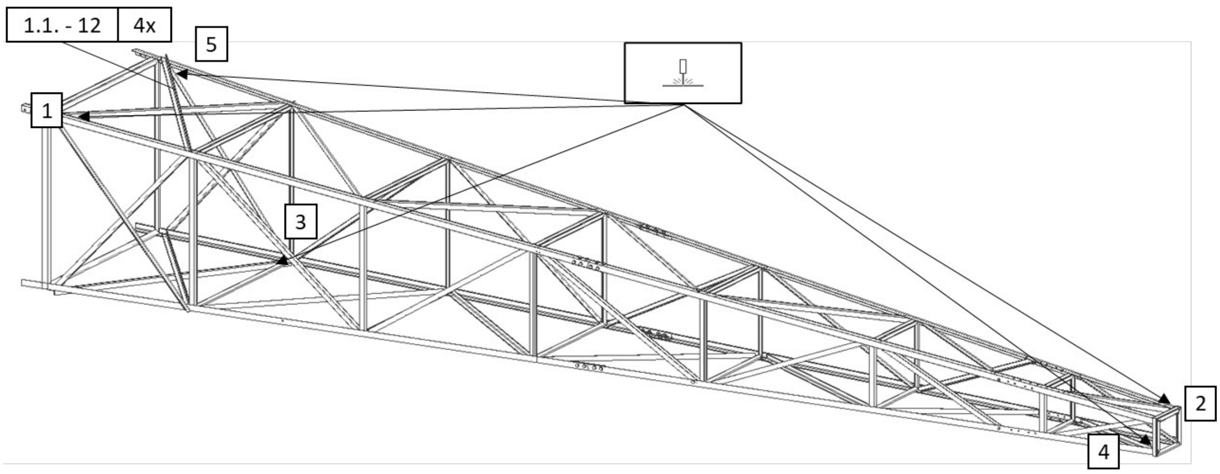
10. When placing and screwing down the upper longitudinal struts [1.1-1], the angles must be checked again carefully.


1.1 - 1

11. **Align diagonal braces tack and screw together**
 Subsequently, the diagonal struts made of 30x30x4mm angle profile are inserted, aligned and spot welded. The struts [1.1-16] are not welded but bolted. To do this, these struts are placed and aligned with their existing holes on the longitudinal struts, fixed with screw clamps, marked and drilled.



12. **Join with short welds, avoid distortions**
The last step is to weld all tack-welded joints. Special care must be taken to ensure that only short welds (20mm to 35mm) are ever used. The welding is always distributed diagonally across the mast. This avoids one-sided stresses. The mast is welded from the outer ends inwards to minimize the risk of distortion of the structure.



Weld the outer lower diagonal braces.
Finally, the four outer crossing diagonal braces [1.1-12] on the lower mast segment are also attached and wel-ded.

0.2 Narcelle connection

Figure 3 shows the nacelle connection. It consists of a tube, a three-part azimuth bearing and the upper part of the mast. **For this purpose, it is mandatory that the mast [1.1] has been manufactured beforehand.** The tube is mounted on the internal struts and passes through the top plate. This plate is welded to the upper frame with short welds. It serves as a guide for the tube and bearing surface for the lower axial thrust bearing. The nacelle tube is pushed onto the protruding tube (1).

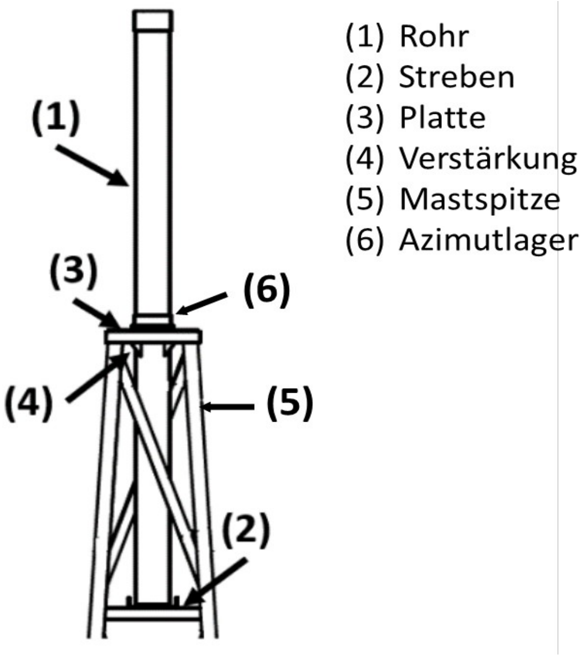


Figure 3 – Narcelle connection

Azimuth bearing

Exact explanation of the storage

The azimuth bearing is the connecting piece between the mast and the nacelle. The entire bearing consists of three plain bearings. The three bearings are pushed onto the tube of the mast from above. The axil bearing lying on the mast plate supports the nacelle and the assemblies mounted on it. The two bearing sleeves pushed onto the mast tube absorb the radial forces of the nacelle. The nacelle frame 2.2 is placed on the tube (1) during assembly. Its inner side is the sliding bearing surface in the area of the two bearing sleeves glued to the mast tube! It must be smoothed in the contact area for this purpose. <u>If necessary, the remains of a pipe weld must be carefully removed</u>. The upper cover plate and the reinforcing plates welded with short welds stabilize the mast tube.

The nacelle weight rests on the thrust bearing plate. To increase the load-bearing area, a bearing ring is welded to the bottom of the nacelle tube (4). This lower bearing absorbs the weight forces of the nacelle. The radial bearing sleeves are bonded to the mast tube. These two bearing bushings (5) absorb the radial forces. These radial forces are caused by wind loads and a constantly changing center of gravity of the nacelle with its components.

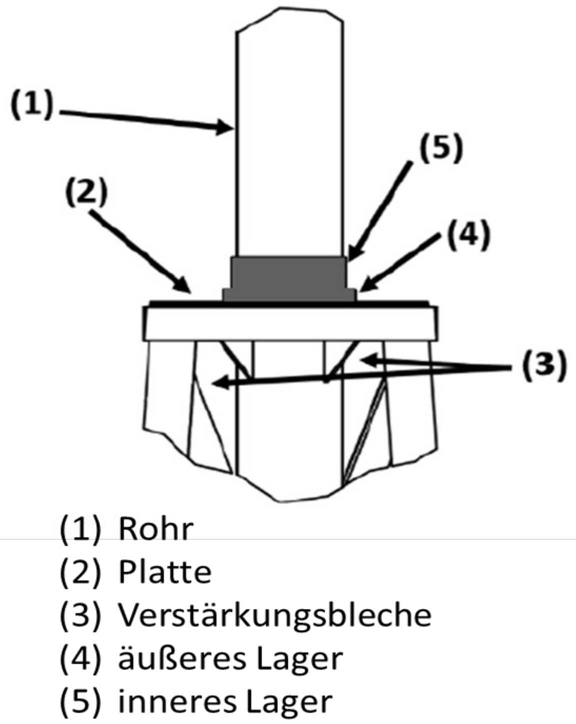


Figure 4 – Azimuth bearing

Manufacturing of the radial bearings

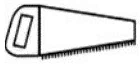
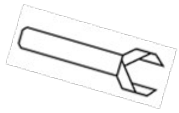
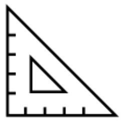
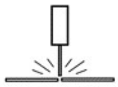
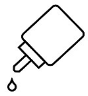
The two radial bearing sleeves consist of rolled brass or bronze sheets. The sheets must be rolled to the correct diameter beforehand and soldered at the contact seam.

<u>They must be manufactured as precisely round tubular sleeves with a super-smooth outer surface.</u>

It is important that the gap between the internally smoothed nacelle frame tube and the outer bearing sleeve diameter is as small as possible (1/10mm-to2/10mm clearance would be ideal). Only when everything fits exactly are the bearing sleeves glued to the top and bottom of the mast tube with a suitable adhesive. If there is still an intermediate gap between the insides of the plain bearing bushes and the mast tube, the mast tube must be wrapped with thin sheet metal - for example aluminum foil - over the entire contact area before gluing until the intermediate area is filled. A low frictional resistance of the well-lubricated bearings thus easily allows a rotational movement of the entire nacelle. These rotations are caused by wind forces and wind from different directions on the control and cross vane.

You can attach grease nipples to the outside of the nacelle frame tube at suitable points to press some grease into the area of the plain bearing sleeves every few months.

Tools

							
		Metal	WS18	90°			

Material

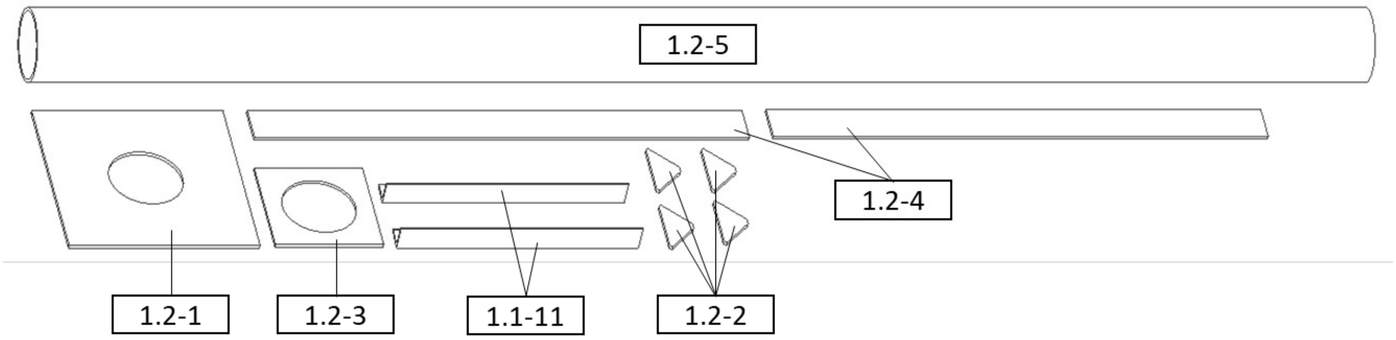
Pos		Raw material	Name	Standard	Dimensions	Qty	Material
1.2	**-1**	**R - 13**	Plate	EN 10051	700x700x10mm	1	S235
	-2	**R - 13**	Plate	EN 10051	65x65x6mm	4	S235
	-3		Sheet	EN 1652	170x170x5mm	1	Brass
	-4		Sheet	EN 1652	388x60x5mm	2	Brass
	-5		Pipe	DIN EN 10220-1	114,3x5x2100mm	1	S235
	-6		2-component adhesive		40ml	1	Epoxy resin
	-7	**R - 28**	L-Profile	DIN EN 10056-1	30x30x3x700mm	6	S235

Table 2 – Bill of material 1.2 narcelle connection

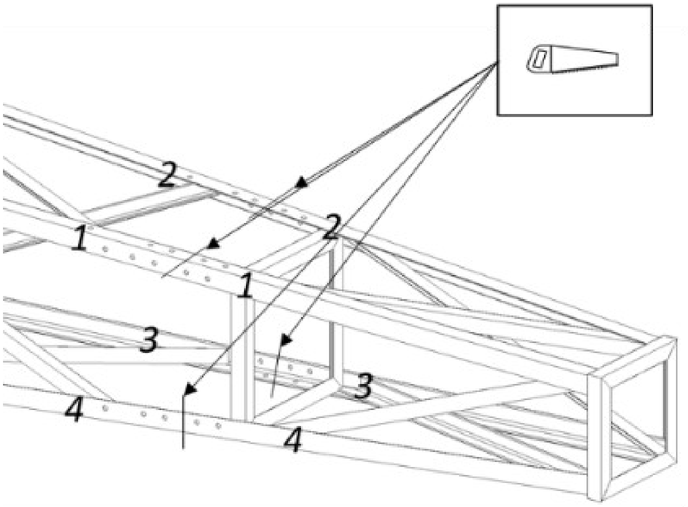
** The material for the pressure plate of the gondola bearing [1.2-3] may be between 5mm and 10mm thick. The thicker the better! The same plate is also needed for the thrust bearing of the control vane hinges [3.1-24].*
*** For a nacelle frame tube of 139.7 x 8mm 4mm brass sheet must be used for the plain bearing sleeves, for a nacelle frame tube of 139.7 x 7.1mm the brass sheet may be 5mm thick.*

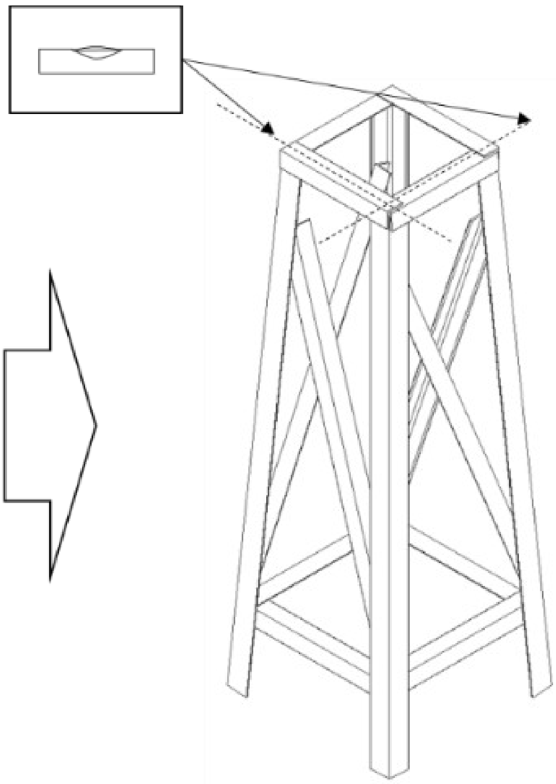
Construction

1. Saw out and cut to size narcelle bearing parts
   The components shown are first cut to size. When cutting out the brass thrust bearing [1.2-3], note that this is pushed onto the tube at a later stage. This thrust bearing absorbs the weight forces of the complete nacelle. The thickness of the plate [1.2-3] for the thrust bearing can be between 5mm and 15mm. It is recommended to first cut the diameter of the hole a little smaller, and then adjust it to the outer diameter of the tube with a file.
   In the parts list, the thickness of the wooden blocks for the sliding bearings of the piston rod is given as 30mm. You can also choose 40mm thickness. Since extends the time until the next replacement.

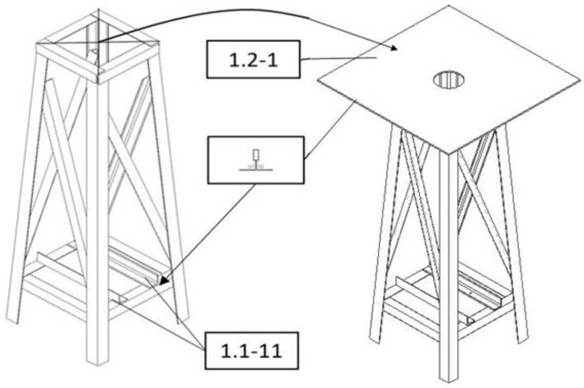


2. The next step is to saw off the top of the mast. To do this, it is imperative that the connections are sufficiently marked beforehand. This serves to ensure that the appropriate positions can be assigned when reassembling. The connections are made in the same way as those in the middle of the mast (at approx. 5m), either of adapted angles (filed on the outside with a 7mm radius) (see step 7 in chapter 1.1) or of two flat irons 40mm x 6mm in the length of the connecting angles for each mast stem. The mast top is then placed upright and aligned. Use a spirit level to align the sides shown horizontally.



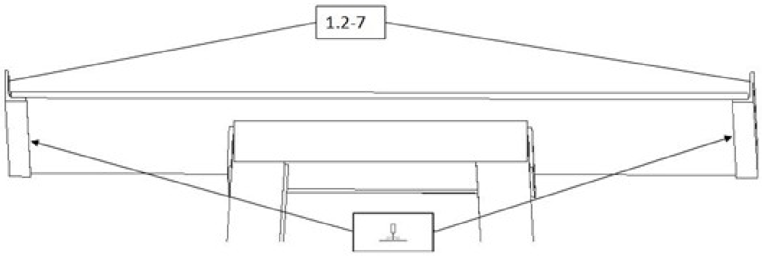


3. **Position the head plate very accurately and weld it in place**
   To measure the center of the head plate, two cords are attached diagonally across the top angles of the mast head. This allows the plate [1.2-1] to be positioned exactly symmetrically. Now it must be checked again with the help of the spirit level whether the plate is horizontal. If this is not the case, it must be aligned with small spacer plates. **After exact positioning**, the head plate is spot-welded to the upper frame of the mast end.



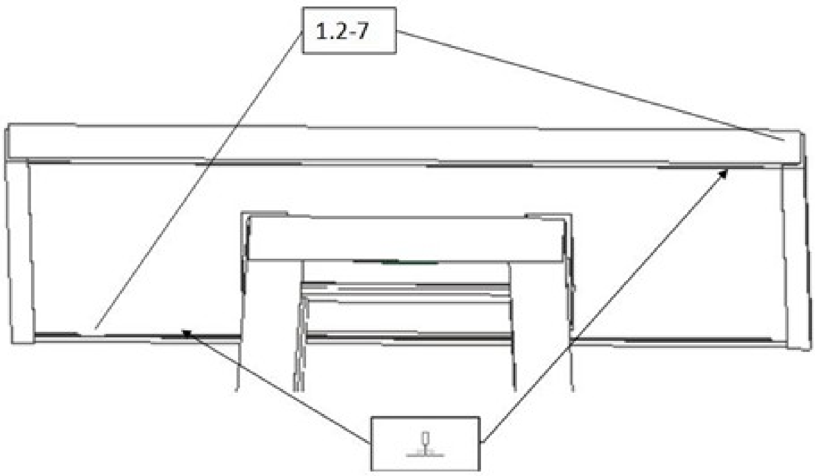
The upper steel plate [1.2-1] must be aligned **exactly parallel** in the plane of the mast feet at the bottom. The tube must be **exactly vertical** on the plate!
Only then can the wind later easily align the system using the control and side vane.
Aligning the tube
Next, this tube [1.2-5] is inserted from above and aligned. To do this, use a spirit level to check whether the tube is vertical and measure its perpendicularity to the plate by means of an angle.
At the lower end, the tube is centered on the two angles [1.1-11] welded into the frame.

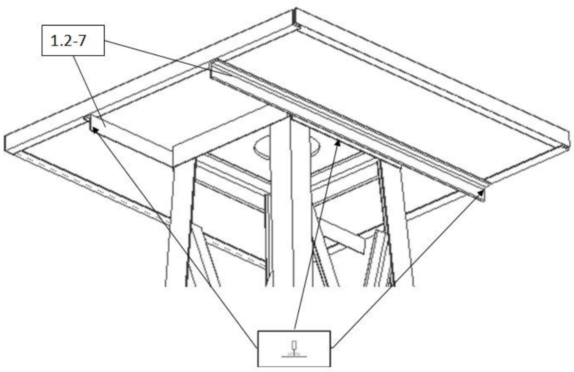
4. The head plate of the mast is also the working platform.



You can stand on the working platform when you want to check or work at the top of the wind pump. To prevent slipping with shoes, angle irons are welded around the perimeter. Their raised edges prevent slipping on the platform.

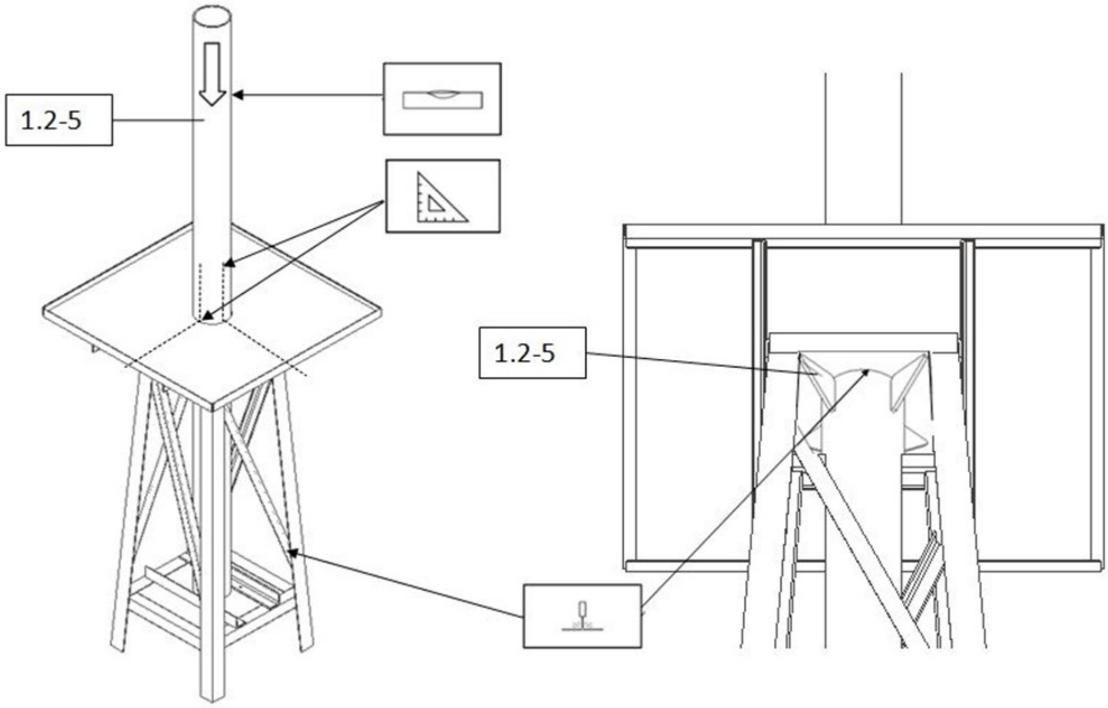
5. The 4 angle irons [1.2-7] are welded around the circumference. Two more are welded in parallel under the plate. They rest against the angles of the mast head.





6. **Weld pipe**

When the pipe is aligned, it is tack welded. It is important that the tube is welded ONLY on the lower side of the plate. At the top, the surface must remain flat because that is where the thrust bearing rests closely fitted.



Axial and radial bearings between mast and nacelle

Thrust bearing:

On top of the plate, the brass (or bronze) thrust bearing [1.2-3] lies close to the tube [1.2-5]. Therefore, welds around the pipe must be welded ONLY FROM BELOW. The reinforcing plates [1.2-2] are then attached point by point and welded alternately with SHORT welds. The top of the mast can now be carefully placed on its side, supported by wooden blocks, and the punctures completed with short welds.

In the next step, the radial bearings are manufactured and then glued onto the tube [1.2-5].

Considerations for bearing clearance: The mast tube [2.2.1-1] has an outer diameter of 114.3mm, the inner diameter of the nacelle frame tube [2.2.1-1] has an outer diameter of 139.7mm and a wall thickness of 8mm. If we subtract from 139.7mm (2x8mm), we get 123.7mm inner diameter. The difference in diameter is 9.4mm. If the brass bearing sleeve to be manufactured has a material thickness of 2x4mm, there would still be a bearing gap of 1.4mm. This is still too large!

For a nacelle frame tube of 139.7 x 8mm, 4mm brass plate must be used for the plain bearing sleeves, for a nacelle frame tube of 139.7 x 7.1mm, the brass plate can be 5mm thick, the bearing gap is then 11.3mm - 10mm = 1.3mm.

Note: The selected tubes are not precision steel tubes. Under no circumstances should welds interfere with the plain bearing area. If welds are present, they must be ground off in the plain bearing area. If the dimensions are not precise, improvisation is necessary.

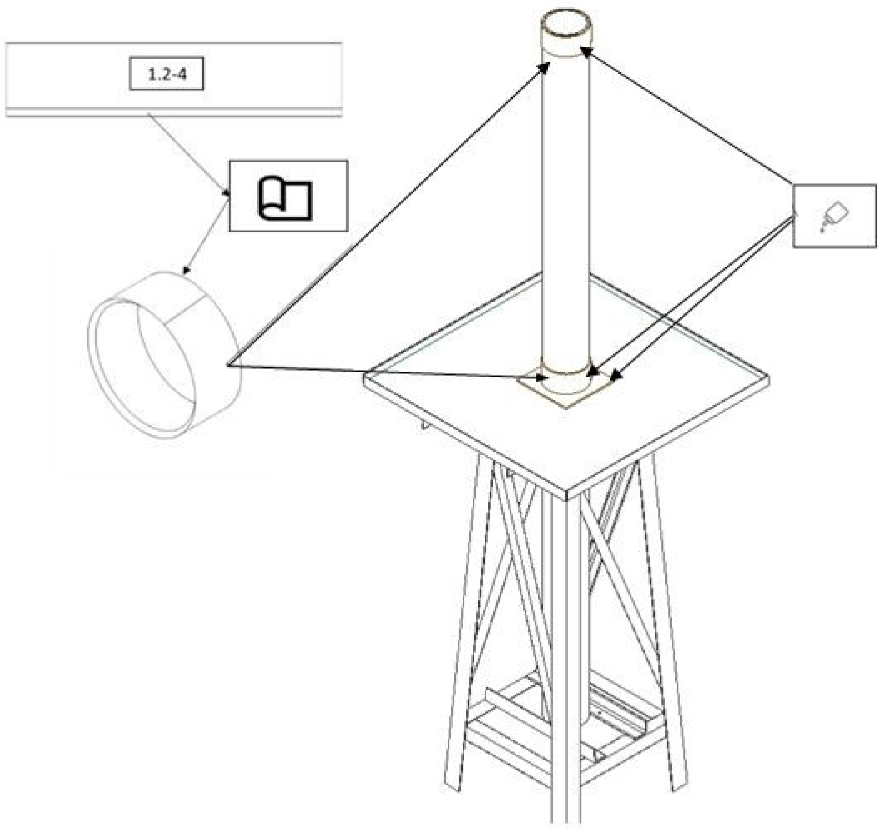
For the construction of the bearings, the two 4mm thick brass sheets [1.2-4] are bent or rolled to the outside diameter of this tube. In doing so, they must be manufactured as exactly round tube sleeves with a smooth outer surface.

7. The bearing sleeves are manufactured particularly well if the brazed seam is made at an angle to the tube axis (for example, at an angle of 30°). This avoids a weak point of the bearing in the seam area. The brass sheet must then be purchased larger. When the plain bearing has the correct outside diameter, the seam is brazed with brass or soft solder.

   Important: for long service life, the smallest possible clearance between the nacelle frame tube smoothed on the inside in the bearing areas and the outer bearing sleeve diameter (1/10mm-to a maximum of 2/10mm clearance for the bearing clearance would be ideal-but is difficult to realize).

   After positioning the brass plate as thrust bearing [1.2-3] on the plate [1.2-1] of the mast top, the brass plates bent into tube sleeves are pushed onto the tube and glued. Before gluing, you have to put the nacelle over the upper mast tube to test if the bearing is ok. The nacelle must rotate easily. It must still fit **tightly** as a bearing!

   One can make these bearing sleeves also gladly 100mm instead of 60mm long. Then they are not so heavily loaded and last much longer!

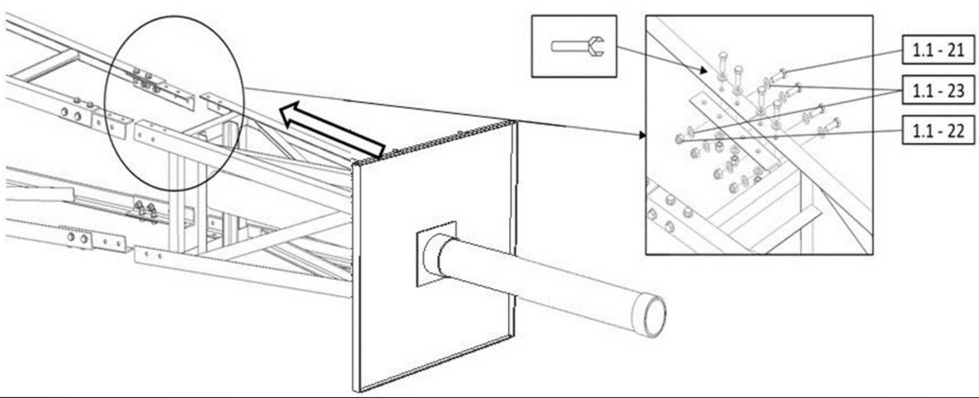


Only when everything fits exactly are the bearing sleeves glued to the top and bottom of the mast tube with a suitable adhesive.

If there is still too much space between the inside of the bushings and the mast tube, wrap the entire contact surface of the mast tube with thin metal foil (e.g. aluminium foil) until the space between the bushings and the mast tube is **tightly** filled (up to 1/10 - 2/10 mm).

If you do not want to solder the bearing sleeves, you can also leave a small gap open. A gap of max. ½mm may remain open in the bearing sleeves.

8. Finally, the top of the mast can be screwed to the stems of the mast.

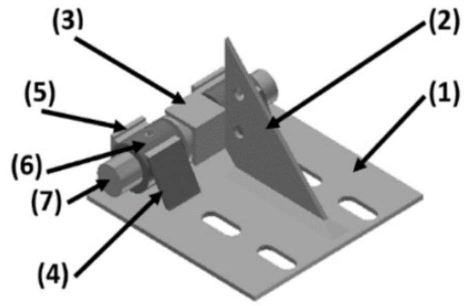


0.3 Mast feet

Important note: It is very practical to drill the base plates of the mast bases together with those of the foundation frame and to mark them clearly in pairs with center punches! The later position of the L-profiles of the foundation frame on the plates must be taken into account. The drawing dimensioning guarantees enough space for the L-profiles and the later screw connection.

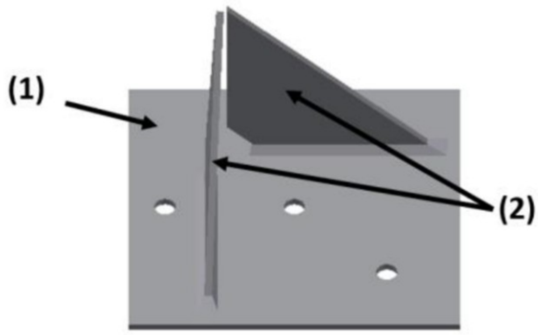
The mast bases are the connections between the mast and the foundation. This realizes the stability of the entire wind turbine. Furthermore, these mast feet fulfill a second task. They enable the mast to be raised and lowered by tilting. In order to realize both functions, two mast feet with hinges and two without hinges are designed. This construction serves as a fixed bearing in the truss. Figure 5 shows this mast foot. Two pipe sections [1.3-7] are welded to the base plate. A vertical reinforcement and an oblique reinforcement are welded to fix the pipe sections. The bolts [1.3-8] enable the tilting movement between the mast and the mast base. For this purpose, a bolt is inserted through the pipe sections. The mast is attached to the middle tube piece. In addition, a reinforcing plate is welded on. This is used to fix and stabilize the mast after erection by means of a screw connection. The base plate contains four oval screw holes. The pair of hinges is screwed to the foundation frame before the mast is erected.

The other two mast feet are also used to bolt the mast to the foundation frame after erection. Figure 16 shows the construction. These mast feet each consist of a base plate and two welded-on reinforcing gussets. These gusset plates are attached to the base plate with an angle between 86° and 87° inclination. These angles are adapted to the mast inclination. In addition, the base plate has drill holes for fastening to the foundation frame.



(1) Grundplatte
(2) Verstärkungsblech
(3) Mastverbindung
(4) schräge Verstärkung
(5) senkrechte Verstärkung
(6) Rohrstück
(7) Bolzen

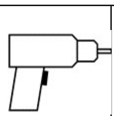
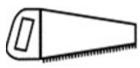
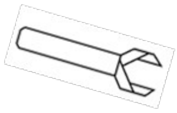
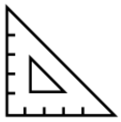
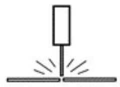
Figure 5 – Mast feet with hinges



(1) Grundplatte
(2) Verstärkungsblech

Figure 6 – Mast feet without hinges

Tools

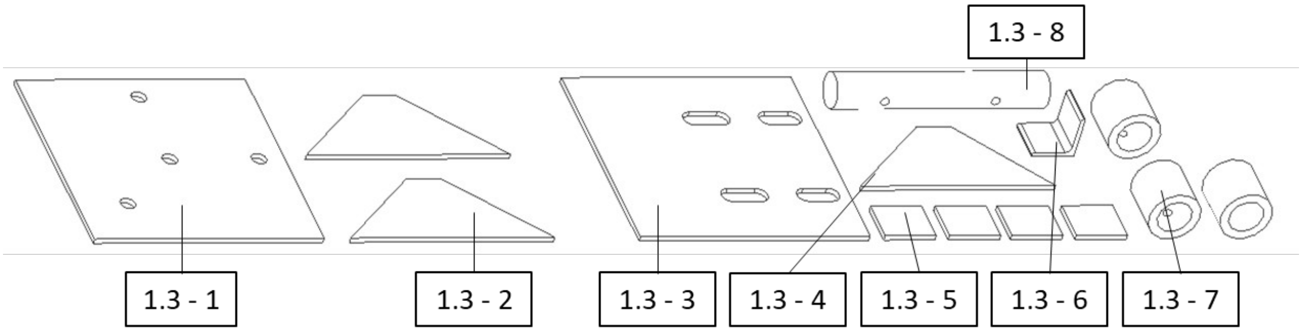
					
	10; 21	Metal	WS 8	90°	

Material

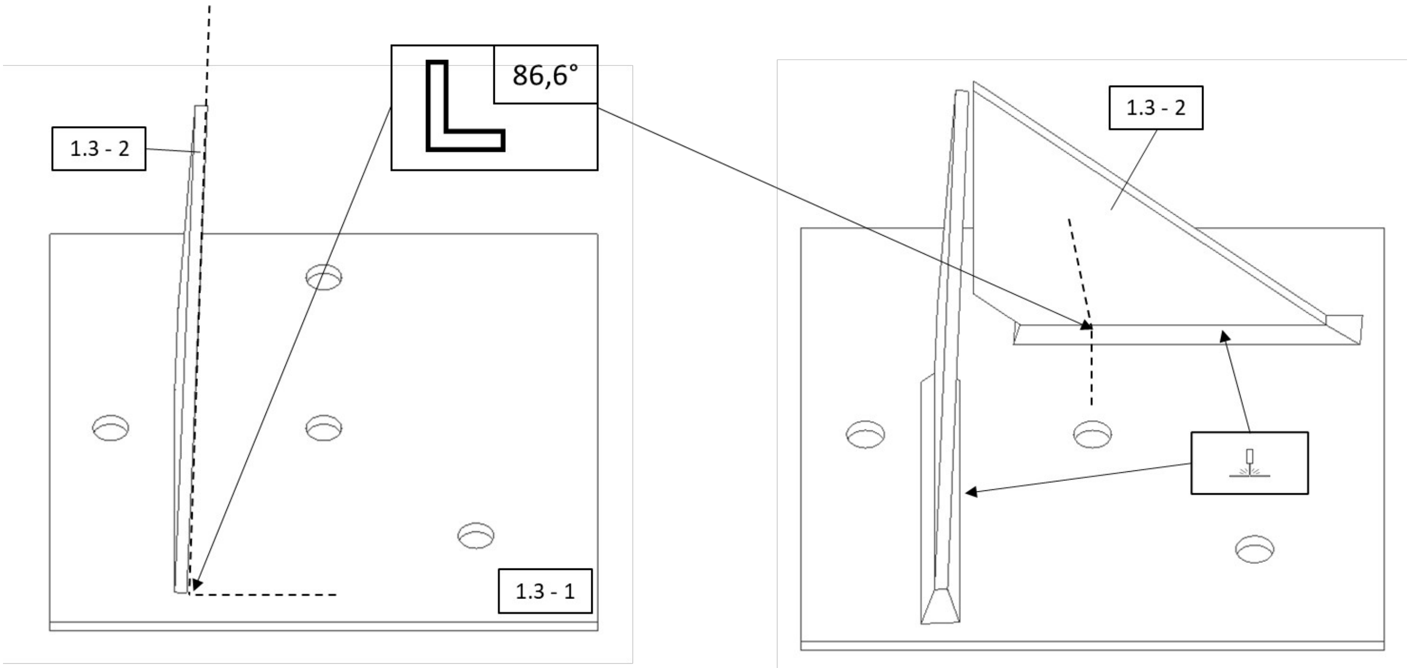
Pos		Raw material	Name	Standards	Dimensions	Qty	Material
1.3	**-1**	**R - 13**	Plate	EN 10051	270x270x6mm	2	S235
	-2	**R - 13**	Plate	EN 10051	240x100x6mm	4	S235
	-3	**R - 13**	Plate	EN 10051	270x270x6mm	2	S235
	-4	**R - 13**	Flat steel	EN 10051	230x100x6mm	2	S235
	-5	**R - 13**	Plate	EN 10058	60x50x6mm	8	S235
	-6	**R - 22**	L-Profile	DIN EN 10056-1	50x50x5x50mm	2	S235
	-7		Pipe	DIN2448	60,3x10x60mm	6	S235
	-8		Round steel	EN 10060	40x250mm	1	S235
	-9	**R - 23**	Flat steel	DIN EN 10058	120x40x5mm	2	S235
	-10		Grub screw	ISO 4026	M10x30mm	2	

Table 3 – Bill of material 1.3 Mast feet

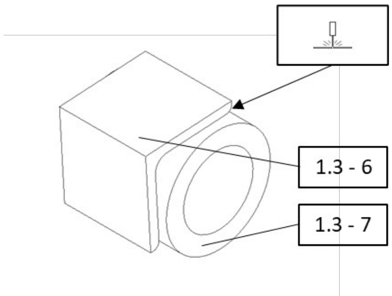
1. To begin, all parts are sawed to size and drilled. Since the mast requires a total of four feet, each component shown must be made twice.

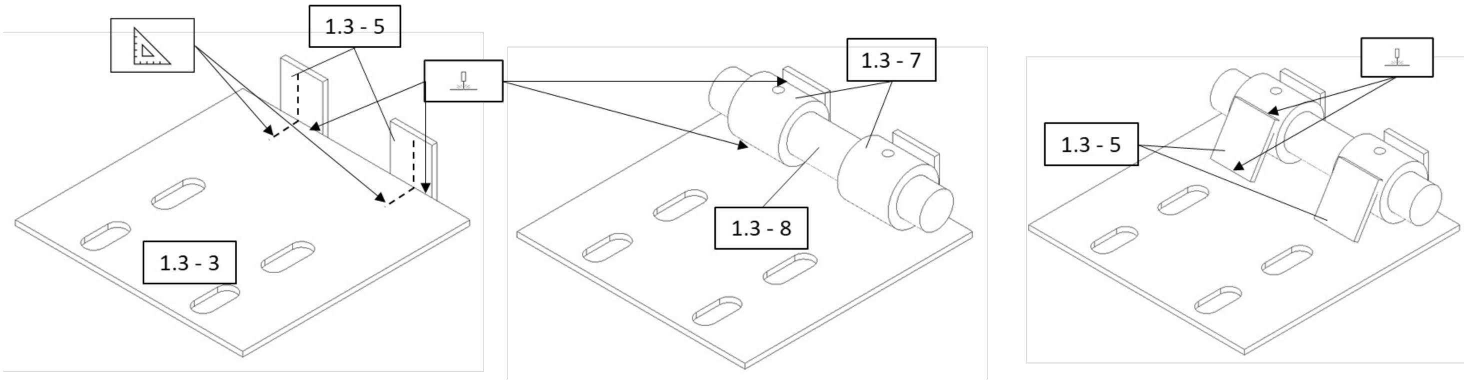


2. First, the two feet are made without hinges. After cutting the square plates, the prepared gusset plates [1.3-2] are placed on the base plate and aligned. It is important here that the arrangement of the holes on the base plate is exactly in the right position. Furthermore, the reinforcing plates must have an angle of approximately 86.6°. To align this angle, the wooden template from Chapter 1.1 can be used.
   After alignment, the stiffening brackets can be welded in place. With auxiliary angle irons and screw clamps, etc. must be carefully and accurately aligned, <u>even if the upper foundation frame to be fabricated later with its coupling plates is copied exactly to the foot plates attached to the mast and their holes in direct contact.</u>
   Until the weld is complete, welding must be carried out alternately in short sections (30mm - 40mm). There must be time between the individual welds to allow the construction to cool.
   This minimizes internal stresses and distortions.

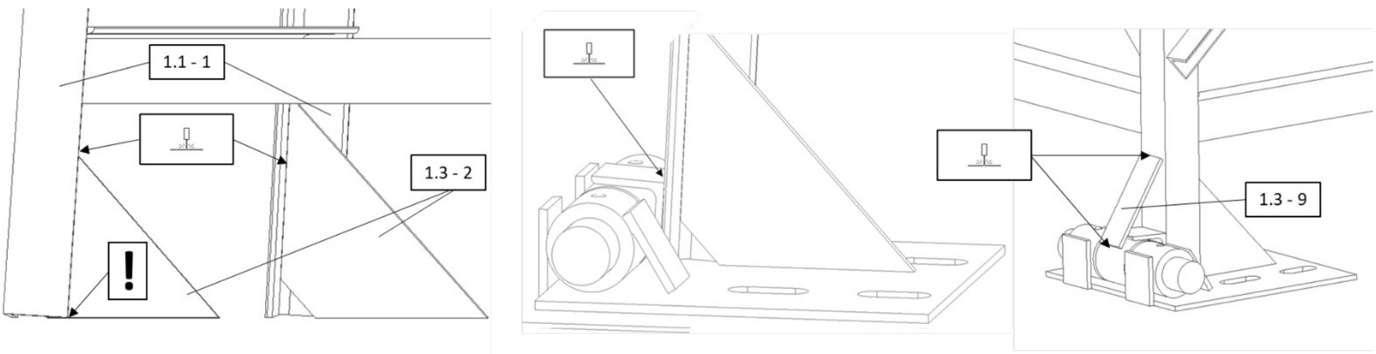


3. Next, the two mast bases with the hinges are fabricated. To do this, weld the plates [1.3-5] at right angles (90°) to the outer edge of the base plate [1.3-3]. Then the tubes [1.3-7] are placed and welded. Make sure that the center lines of the holes are aligned **exactly**.
 Therefore, it is recommended to push the tubes onto the bolt [1.3-8] beforehand. Since the bolt will be pushed in and out later, this ensures that this connection is aligned. The distance between the two hinge tubes should be 2mm greater than the length of the tube in between (from the other part of the hinge).
To achieve the necessary stability, another plate [1.3-5] is welded diagonally to each of the two tubes. For the connection to the mast, the tube [1.3-7] must be welded to the L-profile [1.3-6]. After that, this connection is fixed between the two tubes on the base of the mast with the bolt.

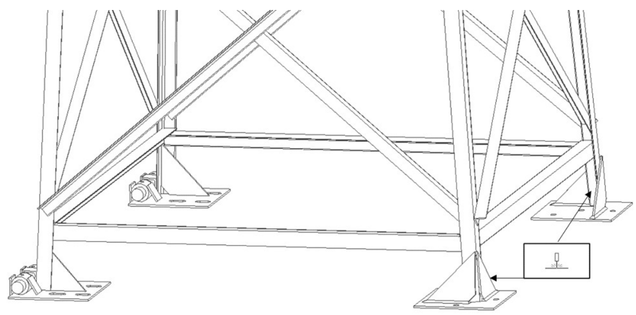




4. Then weld the two reinforcing plates [1.3-2] to the lower ends of the longitudinal struts [1.1-1] of the mast. Make sure that the shown point of the longitudinal struts is on one level with the gusset plates. Now the base of the mast can be aligned with the longitudinal struts on the mast and welded. By pulling out the bolt, the foot can be disassembled as desired. To align the hinges, it is helpful to insert a suitable tube or round solid material through both hinges over the entire length (approx. 1.7m long).



5. In the last step, the mast feet are welded to the mast without hinges. When fastening, observe the arrangement shown. Again, an angle iron or flat iron fastened with screw clamps across the entire distance between the feet is helpful in aligning them. Before aligning and welding the feet to the bottom of the pole, you can double check that the two distances diagonally between the stems are equal. If they are not, this is the last opportunity to make a true square between the four stems. No matter what is decided, align or not, it is mandatory to adjust the upper foundation frame to the hinges.



6.

0.4 Pump linkage bearing

The boom bearing serves to protect the 20 m long pump boom. This consists of aluminum tubes with 30mm outer diameter.
A total of 8 bearings prevent buckling. Figure 7 shows the bearings. 4
bearings are located above ground in the mast area and 4 underground in the well. Bearings 2 and 3 will be discussed in more detail in this chapter.

The others can be found in the corresponding assemblies and will not be considered further here. Figure 8 shows how bearing 2 is bolted to the pipe support [1.1-11]. Bearing 3 is positioned centrally on the 4th cross member square and welded in place.

We chose hardwood for the bearings because such bearings are easy to manufacture. Hardwood is easy to obtain. You can build the bearings yourself and replace them easily. Heartwood is the most suitable. The bri-nell hardness (lateral area, N/mm²) of the wood should be above 35. (Beech, hickory, olive wood, oak, walnut, bongossi, robinia, rosewood). If you can and want to, you can choose whatever you want for these plain bearings for the piston rod. They just have to work.

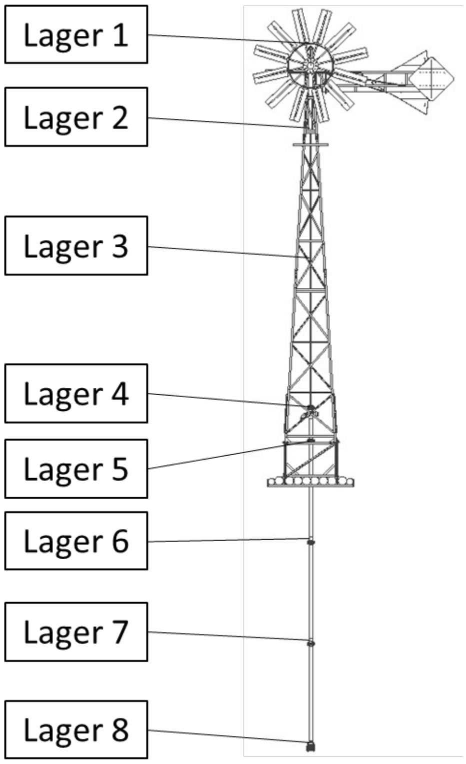


Figure 7 – Complete pump linkage bearing

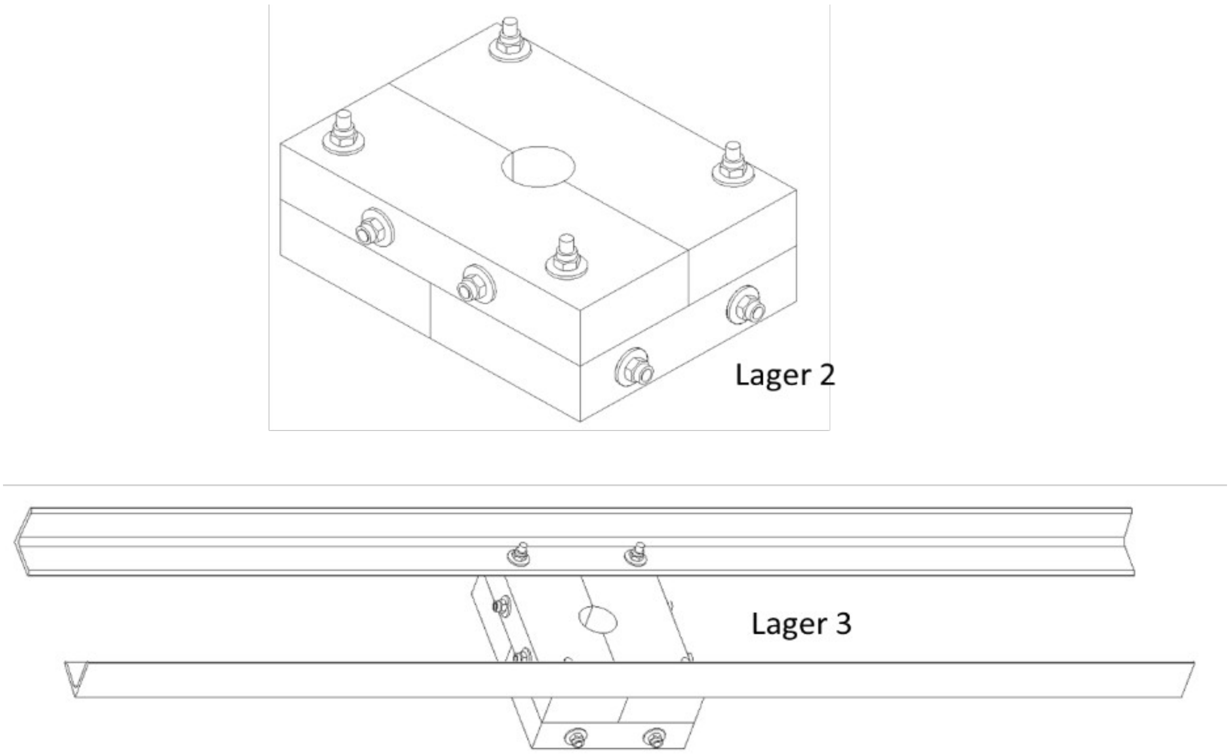
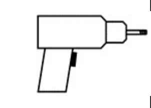
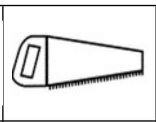
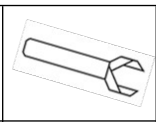
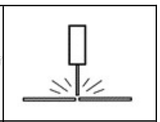


Figure 8 – Bearing 2 und bearing 3

Tools

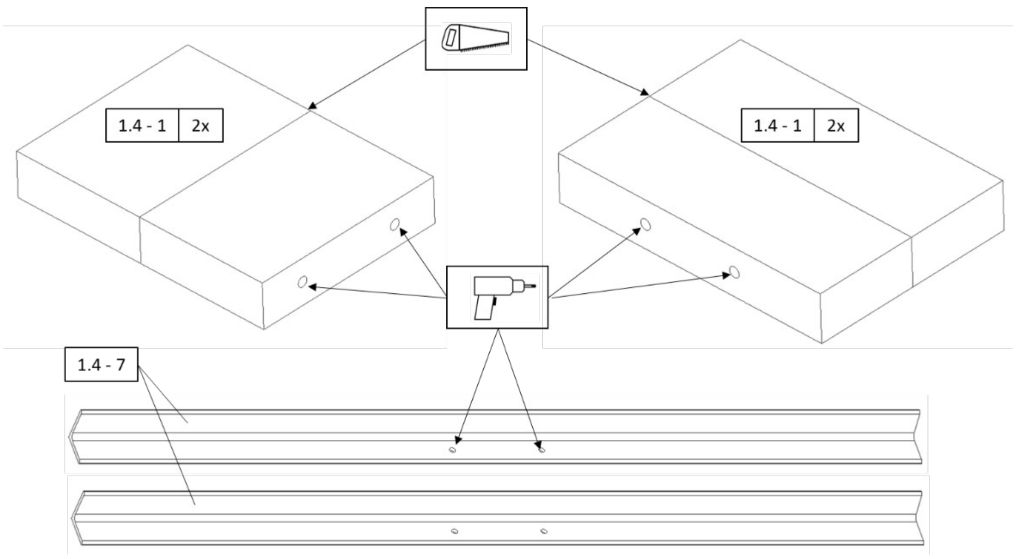
				
	6,6	Metal Wood	WS 10	

Material

Pos	Raw material	Name	Standard	Dimensions	Qty	Material
1.4 -1		Wooden block		130x180x30mm	8	Oak
-2	**R - 27**	Threaded rod	DIN 976 - A2	M6x90mm	8	S235
-3	**R - 27**	Threaded rod	DIN 976 - A2	M6x150mm	4	S235
-4	**R - 27**	Threaded rod	DIN 976 - A2	M6x200mm	4	S235
-5		Washer	DIN 9021 - A2	6	32	
-6		Hexagon nut with torque part	DIN EN ISO 7040	M6-8.8	32	
-7		L-Profile	DIN EN 10056-1	40x40x4x940mm	2	S235

Tabelle 4 – Bill of material 1.4 Pump linkage bearing

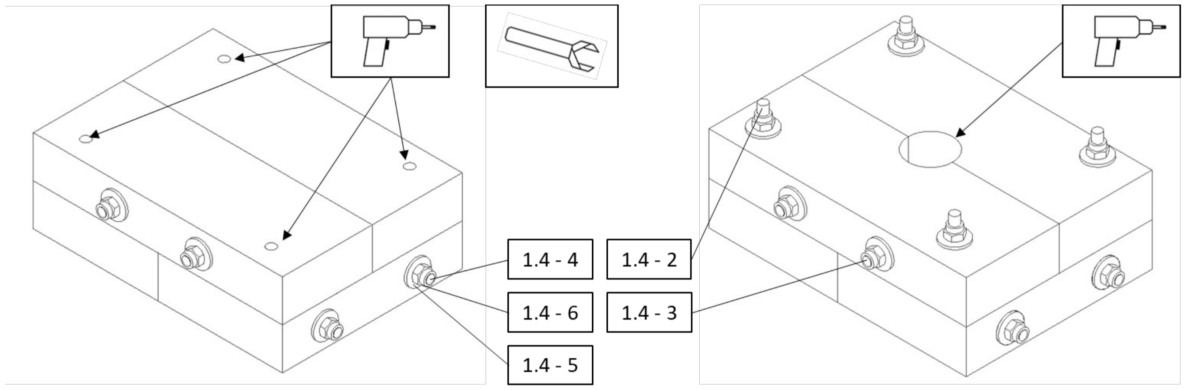
Construction

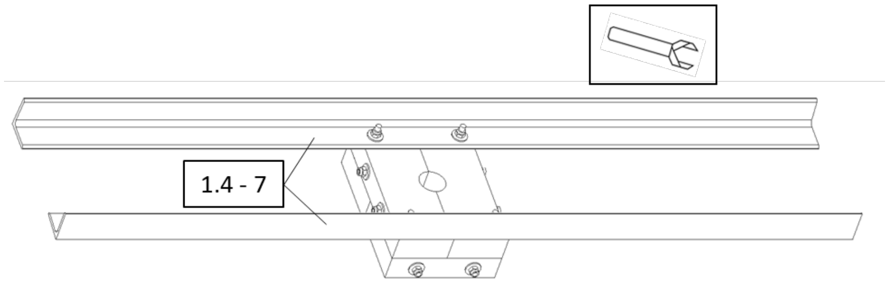


1. The boom bearing serves to protect the 20 m long pump boom. This consists of aluminum tubes with an outer diameter of 30mm. A total of 8 bearings prevents buckling. Figure 7Figure 7 shows the bearings. 4 bearings are located above ground in the mast area and 4 underground in the well. Bearings 2 and 3 will be discussed in more detail in this chapter.

   The others can be found in the corresponding assemblies and are not considered further here. Figure 8 shows how bearing 2 is bolted to the tube support [1.1-11]. Bearing 3 is positioned centrally on the 4th cross member square and welded in place.
   We chose hardwood for the bearings because such bearings are easy to manufacture. Hardwood is easy to make. You can build the bearings yourself and replace them easily. Heartwood is the most suitable. The brinell hardness (lateral area, N/mm²) of the wood should be above 35. (Beech, hickory, olive wood, oak, walnut, bongossi, robinia, rosewood). Who can and wants to, can choose what he wants for these bearings for the piston rod. They just have to work.

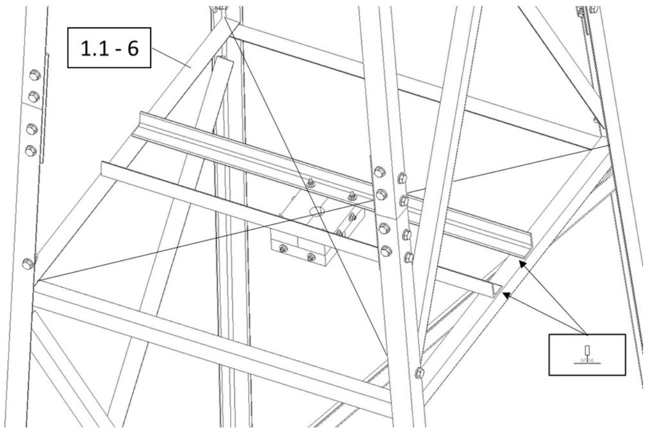
2. The bearing parts are then screwed together. After the upper and lower pieces of wood have been fixed flush at the outer edges, the connecting holes are drilled and screwed. Finally, the rod guide is drilled in the center.

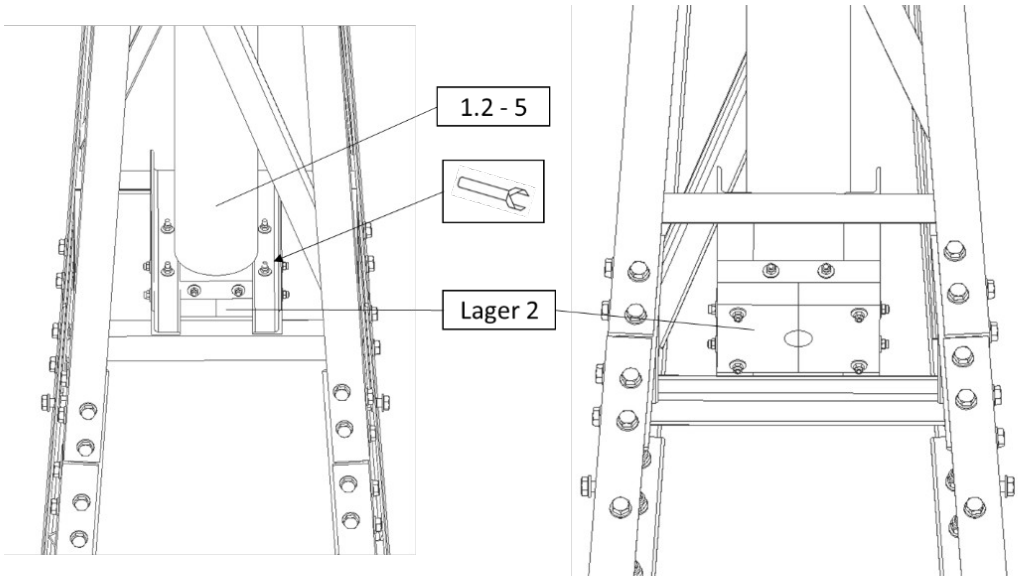




3. The bearing 3 is screwed to the matching holes of the L-sections [1.4-7].

4. To fix the bearing 3, it is recommended to stretch two strings diagonally between the corner points of the cross strut square [1.1-6]. This allows the center of the square to be plumbed to ensure that the pump linkage is centered. After alignment, the L-sections are welded to the cross strut square.





5. Finally, the bearing 2 is screwed to the L-sections at the lower tube end in the mast head [1.2-5].

0.5 Adjusting shear

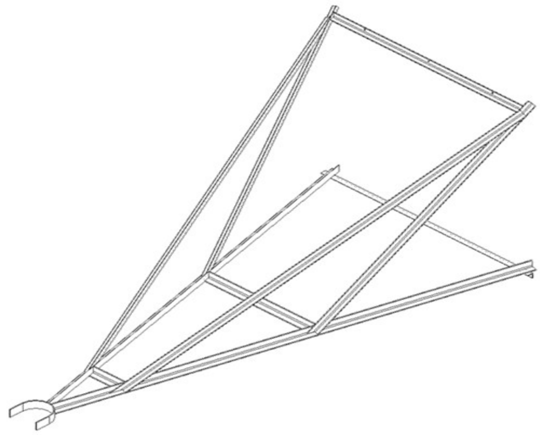


Figure 9 – Complete adjusting shear

The adjusting shear is a welded construction and serves as an aid for erecting the mast. It forms a lever arm for the lower angle range when the mast is erected or tilted with a rope.

The adjusting scissors bolted to the mast are only required if no crane or similar equipment is available for erecting the KUKATE34. Figure 19 shows the erection device. The scissors themselves are made of L-sections with dimensions of 50×50×5mm. The length of the shear is 3m.

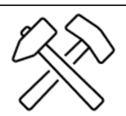
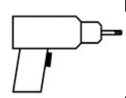
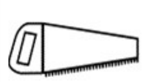
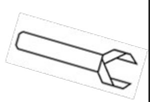
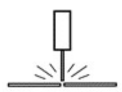
It is bolted next to the lowest chord of the mast opposite the hinges. The four arms are provided as reinforcement. They are bolted next to the second chord. The two long arms are welded to the adjusting shear at a height of 2.5m. The two short arms are welded at the height of 2m of the setting shear. The arms are made of 40x40x4mm L profile.

The rope is attached to the top of the gondola for erection and placed over the rope support at the top of the erecting shear. The rope support is made of U-shaped bent flat profile. The clear width of the rope support is 250mm. The installation procedure is described in more detail in Chapter 6. The smaller the angle of tilt, the greater the compressive forces which the scissors must be able to withstand.

The approximate order of magnitude of the rope pull forces for erecting the KUKATE34 is given in Chapter 7.13. It amounts to approx. 5000N

The traction rope must be designed accordingly. We recommend a rope with 25000N tensile strength to break (corresponding to 2.5 tons) for 5-fold safety.

Tools

				
	11	Metal	WS 16	

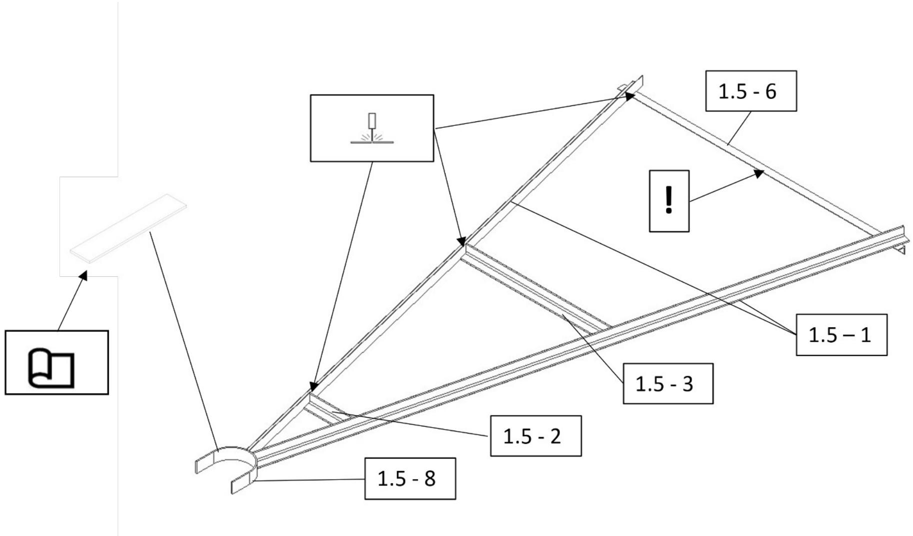
Material

Pos	Raw material	Name	Standard	Dimensions	Qty	Material
1.5 -1	**R - 22**	L-Profile	DIN 10056-1	50x50x5x3110mm	2	S235
-2	**R - 22**	L-Profile	DIN 10056-1	50x50x5x405mm	1	S235
-3	**R - 22**	L-Profile	DIN 10056-1	50x50x5x1000mm	1	S235
-4	**R - 28**	L-Profile	DIN 10056-1	40x40x4x1945mm	2	S235
-5	**R - 28**	L-Profile	DIN 10056-1	40x40x4x2942mm	2	S235
-6	**R - 28**	L-Profile	DIN 10056-1	40x40x4x1620mm	1	S235
-7	**R - 28**	L-Profile	DIN 10056-1	40x40x4x1488mm	1	S235
-8	**R - 24**	Flat steel	DIN EN 10058	300x60x6mm	1	S235
-9		Hexagon head screw	ISO 4017	M10x35-8.8	6	
-10		Hexagon nut with torque part	DIN EN ISO 7040	M10-8.8	6	
-11		Washer	ISO 7091	10	12	

Tabelle 5 – Bill of material 1.6 Adjusting shear

1. Die The bottom base of the adjusting scissors made of 50x50x5mm angle material [1.6-6] is aligned centrally with the cross strut of the lowest mast strap [1.1.-3]. According to the detailed illustration, the two stems of the adjusting shear are symmetrically aligned lying on the mast, fixed with screw clamps and then dotted together with the U-shaped rope support at the other end.

   After that, the two cross braces are placed in the same way as the lower base fitting on the flat side of the stem angles and stapled



2. Once this has been completed, the adjusting shears are erected on the mast using appropriate aids and positioned in accordance with the design. This can be done, for example, with the help of wooden slats tied to the mast and the positioning scissors or with the help of angle material and screw clamps. Now the cross brace for fixing the four arms is to be positioned at the height of the second mast strap and the four support arms are aligned and dotted against the two cross braces and the fixed base. Now, in the aligned state, the necessary screw holes are to be drilled. After that, the entire stay is separated from the mast and, so that the stay does not warp, carefully welded alternately.