STEELWORK STEP BY STEP

2400 mm DIAMETER RECIPE

Hugh Piggott June 2011

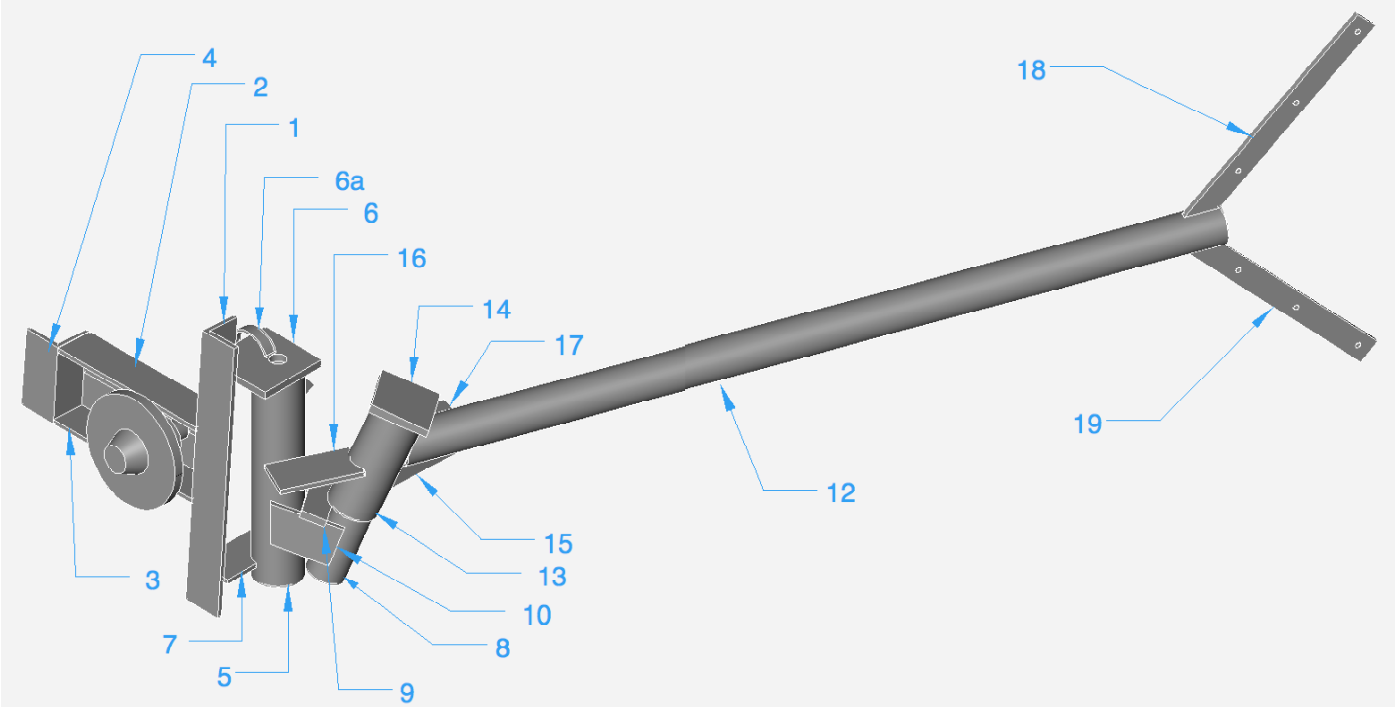
Material section	Length required	Parts cut from this material
50 x 6 angle	900	1 to 4
2" pipe, 60.3 O.D.	450	5, 13 and 20
1 ½" pipe, 48.3 O.D.	1250	8 and 12
50 x 6 flat-bar	900	6,7,10,11,14,15,16,17
30 x 8 flat-bar	700	9,18,19

In most cases you can substitute other materials to produce something that will fit. Be aware that the weight of the tail affects the behaviour of the turbine in strong winds, so it is unwise to make the tail much heavier. The offset distance between the alternator shaft and the yaw bearing is designed to suit a 2400 diameter blade rotor and the frame is laid out to suit stator mounts around a 300 mm magnet rotor as in the Recipes.

CUTTING LIST

This is the total list. Parts of this list are reproduced again at each step.
This list does not include the tower that supports the wind turbine.

Part no.	Section	Length	Notes
1	50 x 6 angle	353	At least 353 long and not critical otherwise (Recipe piece A)
2 and 3	50 x 6 angle	216 each	(Recipe piece B and C) Cut +/- 1 mm. Exact same lengths and ends exactly square. You may wish to prepare a cut-out for the shaft before welding 2 and 3 together.
4	50 x 6 angle	100	At least 100 long and not critical otherwise (Recipe piece D)
Optional	50 x 6 flat-bar	88	Cut some pieces to reinforce the connection of shaft to frame.
5	2" pipe 60.3 O.D.	280	Yaw pipe. Length +/- 5 mm Top end needs to be cut square.
6	90 x 90 x 6		Yaw cap plate minimum dimensions 90 x 90 x 6 Could be made with two pieces of (50 x 6 x 90) flat-bar welded side-by-side. Drill hole for tower wires before welding to yaw pipe top.
6a	2" pipe 60.3 O.D.	15	Support hoop for tower wiring. Cut into ¾ circle and welded to yaw head.
7	50 x 6	100	Could be any size and shape that maintains correct spacings 24 and 45 mm from yaw pipe, and provides good welding opportunity.
8	1 ½" pipe 48.3 O.D.	250	Tail hinge inner pipe (Recipe pipe length E), length at least 250. Top end square.
9	30 x 8	75	Width 30 is important. Length and thickness nominal. Welded centrally and squarely to 8, 85 mm from bottom end.
10,11	50 x 6	85 (60)	Cut at an angle and welded to side of pipes to brace the connection. Shape not critical at all
12	1 ½" pipe 48.3 O.D.	1000	Tail boom. (Recipe boom length A) One end shaped to fit part 13, at 110 degree angle.
13	2" pipe 60.3 O.D.	150	Tail hinge outer part (Recipe hinge pipe length C) Not more than 150 mm long and square at the top end.
14	70 x 70 x 6		Square or circular plate at least 70 x 70 x 6 mm could be made from two pieces.
15	50 x 6	60	Triangular gusset (sizes nominal) angle 110 degrees to support tail boom
16	50 x 6	90	'Low end' stop. End hollowed to fit part 13 (60.3 diameter). Length nominal.
17	50 x 6	33	'High end' stop. Welded to side of part 12. 33 mm projecting to hit yaw pipe.
18,19	30 x 8	300	Ends cut at 45 degrees. Size nominal. Welded at end of part 12 in vertical plane. Drilled for bolting on plywood vane.



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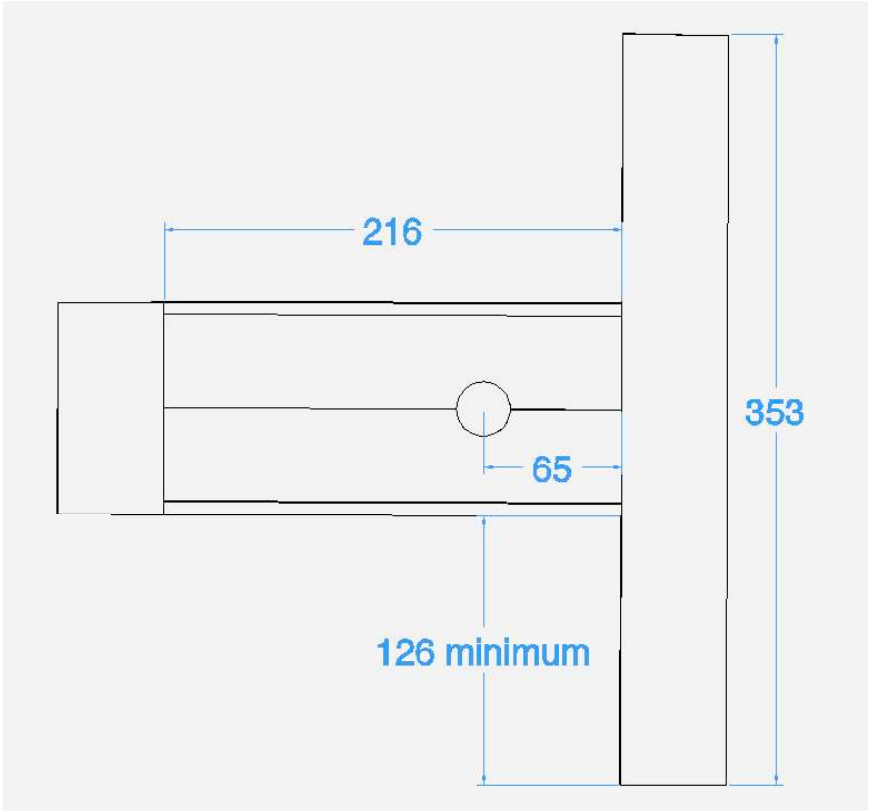
Step 1 the Alternator Frame

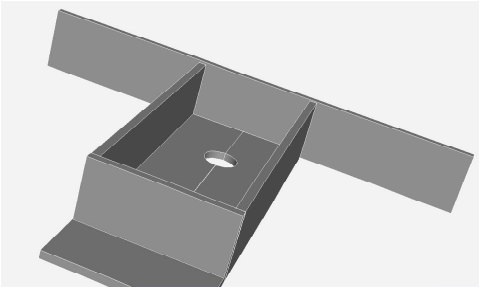
1	50 x 6 angle	353	At least 353 long and not critical otherwise (Recipe piece A)
2 and 3	50 x 6 angle	216 each	(Recipe piece B and C) Cut +/- 1 mm. Exact same lengths and ends exactly square. You may wish to prepare a cut-out for the shaft before welding 2 and 3 together.
4	50 x 6 angle	100	At least 100 long and not critical otherwise (Recipe piece D)
Optional	50 x 6 flat-bar	88	Cut some pieces to reinforce the connection of shaft to frame.

1. Cut pieces 1-4 from 50 x 6 mm steel angle. Note that pieces 2 and 3 need to be at least 216 mm long and square in both directions at each end.

1a. Make a cut-out for the shaft if necessary at a distance 65 mm from the ends.

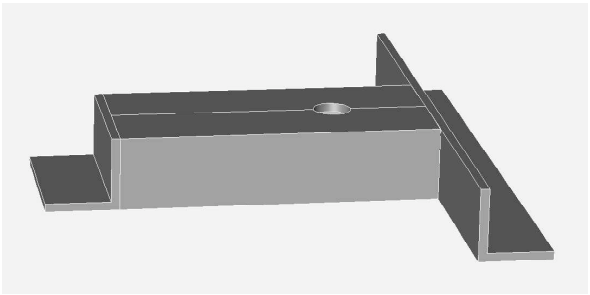


2. Place 2 and 3 on the bench as shown below, with ends aligned and square, and tack them together very lightly to avoid distortion.



NOTE THAT THE END PIECES ARE JUST KEEPING THINGS SQUARE IN THIS SET-UP SO DO NOT TACK THE ENDS.

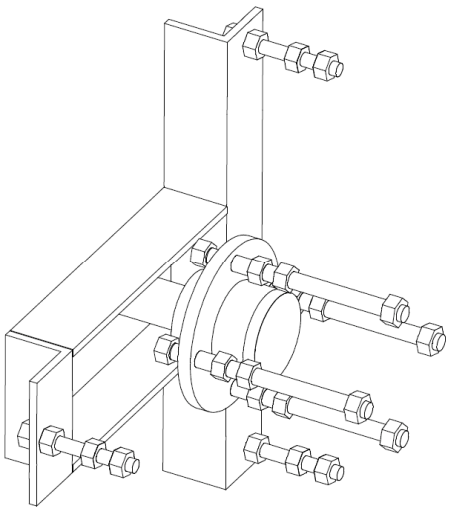
Now turn the assembled pieces 2 and 3 over, resting on a level surface that keeps the faces of 1 and 4 parallel.



Ensure that they are square to pieces 2 and 3.

Piece 1 must be symmetrically placed with at least 126 mm projecting in each direction.

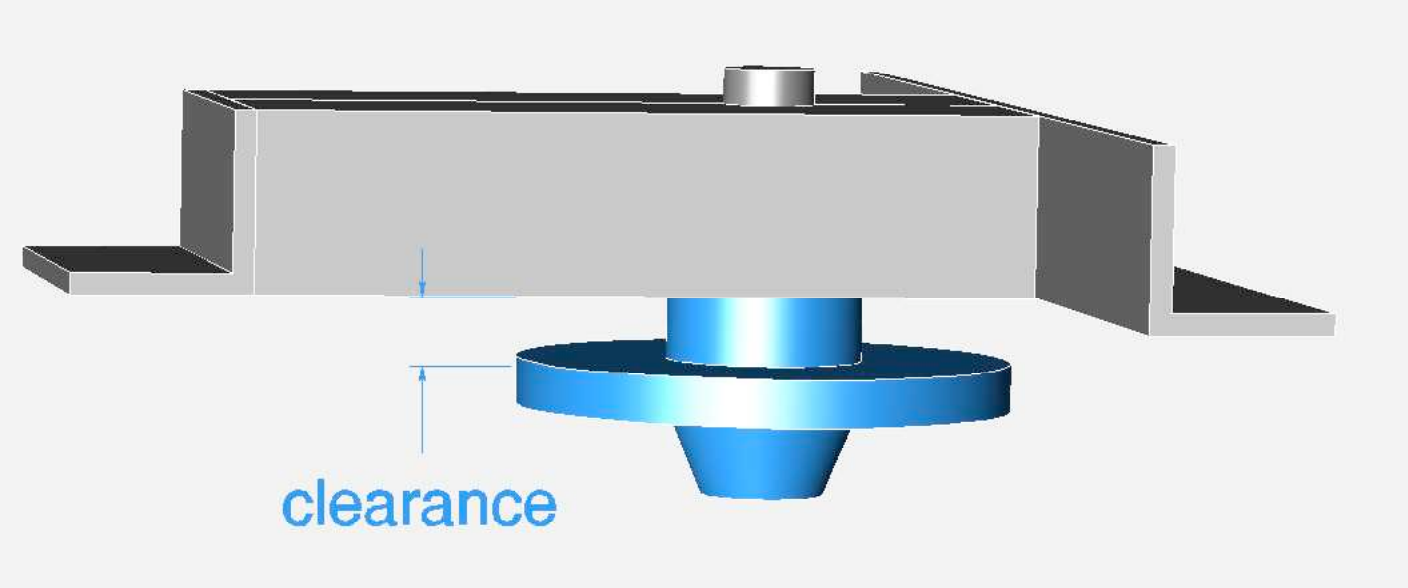
Faces of 1 and 4 must be in the same plane so that stator mounts will be parallel.



3. Tack pieces 1 and 4 on to the ends of 2 and 3.

Welding the shaft into the frame

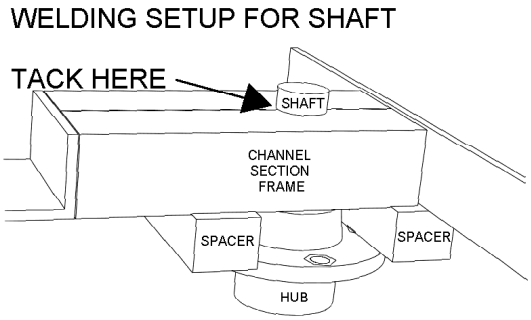
(Take care that the hub flange is correctly positioned and aligned)



Fit the hub to the shaft for the initial set up and tacking of the shaft.

Take care not to overheat the bearings or drop slag into them.

Position the shaft so that there is adequate clearance between the hub flange and the frame to allow for nuts that secure the main studs of the alternator.



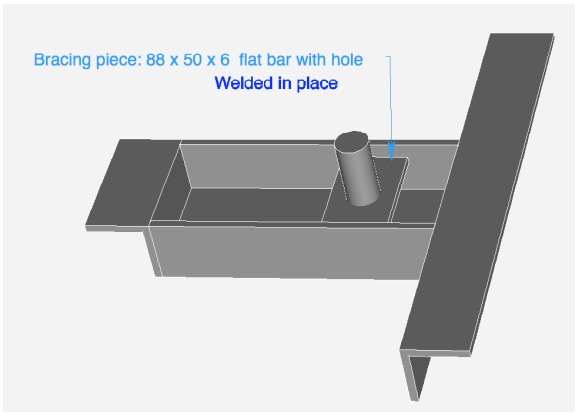
Clamp the hub and frame together using spacers so that the clearance is the same all round and hence the hub flange is parallel to the frame.

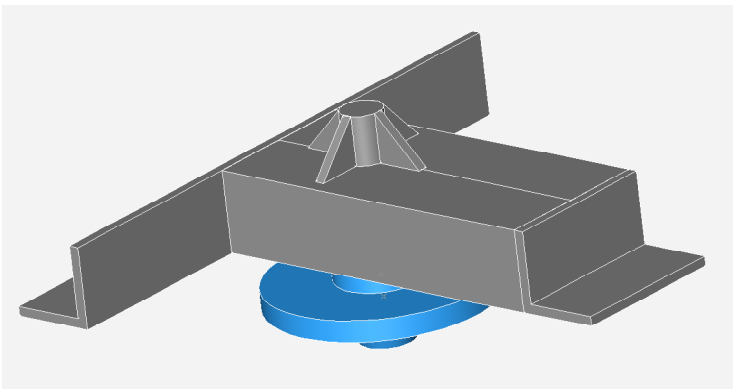
4. Tack the shaft on the outside of the frame and verify that it is still square to the frame, i.e. the hub flange has not moved. Remove the bearing hub.

5. Weld the shaft as strongly as possible on both sides, whilst protecting the machined surfaces of the shaft from weld spatter. You can protect it by slipping a metal sleeve over it, or wrapping with a wet rag or covering with copper grease.

Where possible it is a good idea to add gussets or bracing pieces to the shaft, because the area around the hole in the frame may well be subject to some fatigue loading over time.

The best choice depends on the length of the shaft, and the depth of the hub.





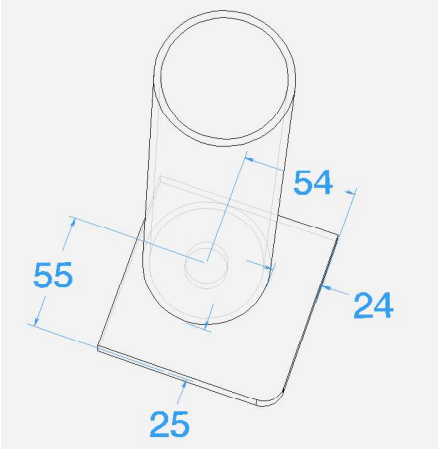
Step 2 the Yaw Bearing

5	2" pipe 60.3 O.D.	280	Yaw pipe. Length +/- 5 mm Top end needs to be cut square.
6	90 x 90 x 6		Yaw cap plate minimum dimensions 90 x 90 x 6
6a	2" pipe 60.3 O.D.	15	Support hoop for tower wiring. Cut into ¾ circle and welded to yaw head.
7	50 x 6	100	Could be any size and shape that maintains correct spacings

1. Cut the yaw pipe, (piece number 5) 280 mm long from 2" nominal bore pipe (60.3 mm overall diameter). This pipe will slip over the tower top an swivel around so the turbine can face different wind directions. The top end where the cap is welded on must be cut squarely.

The tower top will consist of a piece of 1 ½" nominal bore pipe (48.3 mm overall diameter). The top end of it will support the turbine, and bear against the yaw pipe cap. It's a good idea to fit a washer or two on top of the tower (well greased), to reduce wear on the cap. You can use 2" pipe (60.3 O.D.) or heavier for the tower itself, supported by guys close below the tips of the blades with guys at a 45 degree angle to the horizontal.

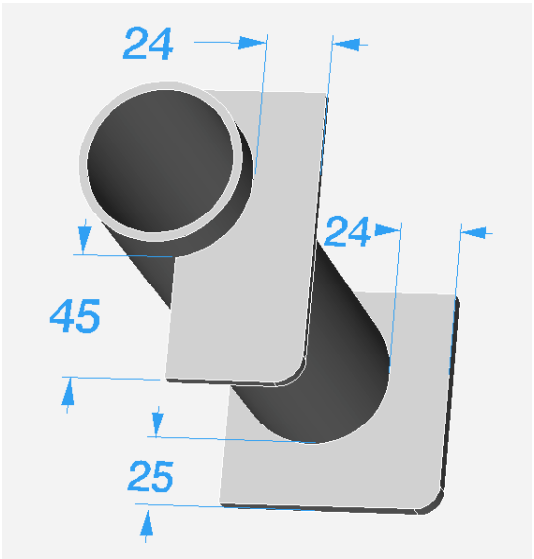
2. Cut out the cap (piece number 6). This is a flat plate that needs to be more than 80 mm square. It could for example consist of two pieces of 50 x 6 mm flat bar welded side by side to make 100 x 90 mm plate. The important measurements are taken from the faces that will weld to the inside of the upright steel angle (piece 1) to support the alternator. Thicker plate is also ideal. The corner that fits inside the angle can be rounded slightly as shown.



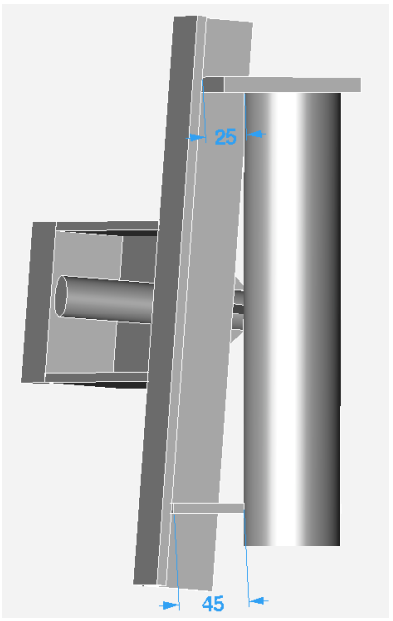
In the case of **12-volt turbines** there will be a box containing rectifiers mounted on top of this yaw cap. Make cap bigger in this case so as to provide for bolting this box on. See next page for details.

The cap needs to have a hole in it at the centre of the yaw pipe down which the wires can pass to enter the tower and descend to the ground. The size of this hole depends on the number and size of wires. In some cases a gland is fitted in a 20 mm hole. Or a hoop made from steel pipe can be used to guide and support the wires.

3. Mark the hole centre and draw the outline of the pipe (using a 30 mm radius on compasses) before drilling the hole.



The view above shows the underside of the cap. The pipe is welded on top of it. Note that the pipe must be 24 and 25 mm away from the two edges that will be welded to the alternator frame.



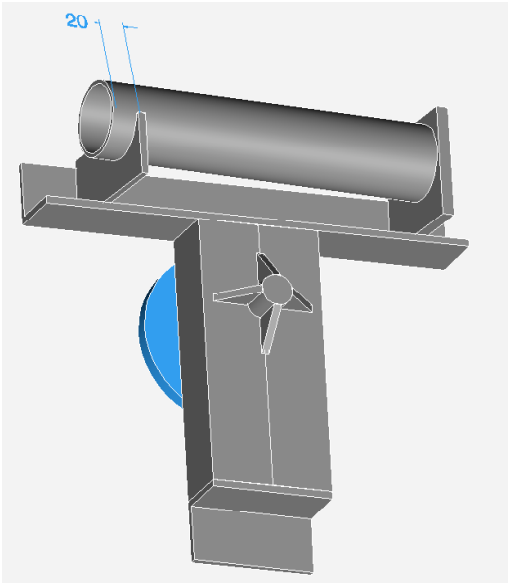
4. Tack the cap on in three or more places and check that it sits square on the end of the pipe before welding strongly.

Piece number 7 is a second bracket that connects the yaw pipe to the alternator frame. The view on the left shows it in the foreground welded near to the bottom of the yaw pipe.

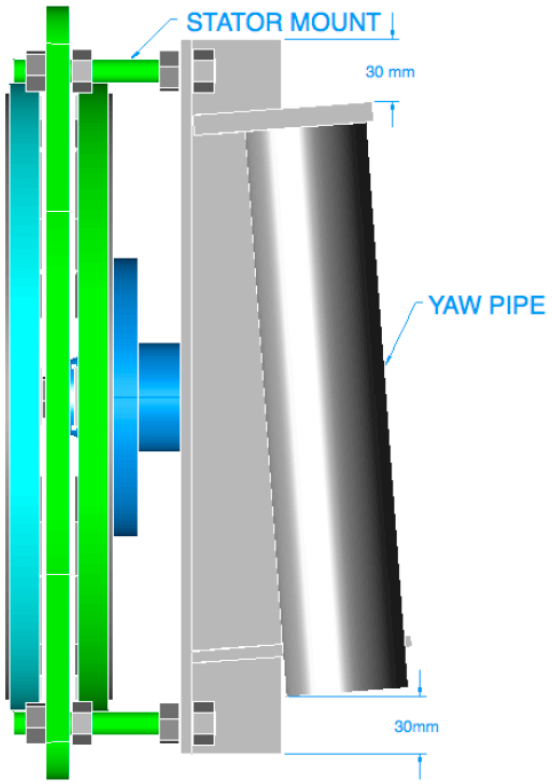
Again this view is from the underside of the yaw pipe.

Again the exact overall size is not important. In this drawing it is 50 x 100 mm overall. The important measurements are again the clearances between the yaw pipe and the inside of the angle piece 1 to which is will be welded. If they were the same as those used for the cap then the frame would be parallel to the upright yaw bearing. Instead the lower bracket is 45 mm from the frame so as to kick it outward slightly, and create a 4 degree angle to the vertical.

Cut the curved shape of the yaw pipe out of the bracket piece so that it nestles against it ready for welding. Clamp it onto the alternator frame when actually welding it together so as to ensure that it is correctly aligned. It should be a nominal 10-20 mm from the bottom end of the yaw pipe

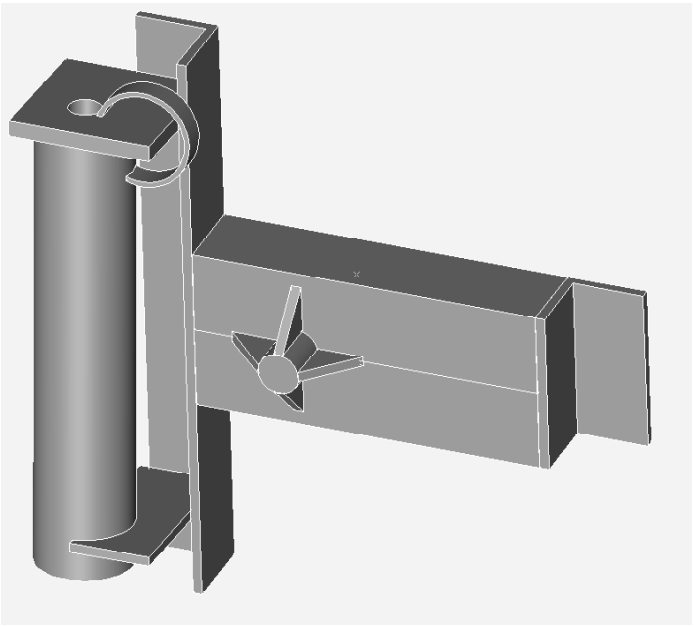


5. Weld the lower bracket (piece 7) to the yaw pipe.



Next is to weld the brackets to the inside of the angle (piece 1) of the alternator frame. Position the yaw pipe centrally so that there is about 30 mm of angle projecting top and bottom.

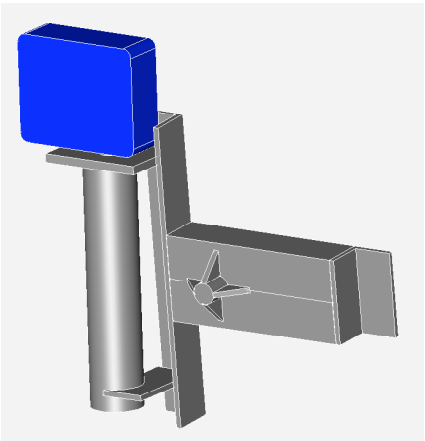
When preparing the stator to mount on the frame it will be useful to be able to drill the stator using the frame itself as a template. So allow enough clearance for a drill to pass through the frame from behind.



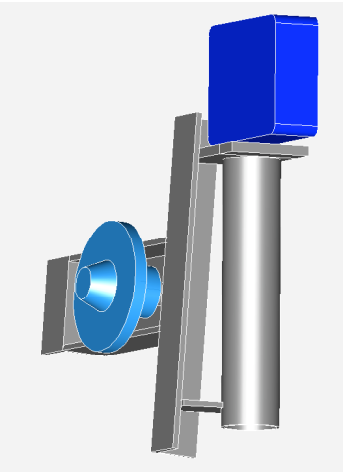
6. When it is well positioned, weld the top (6) and bottom (7) brackets of the yaw pipe to the alternator frame (piece 1).

One good way to support the wiring that drops down the middle of the tower is to cut a 15 mm length of 2" pipe (piece 6a) and remove ¼ of the circle to form a hoop as shown on the right. Weld it lightly in place so that the wires can be strapped onto it with cable ties.

In the 12V version of the machine you will need a rectifier box on top of the yaw bearing instead (shown blue on the right). The yaw bearing cap needs to be a little wider to accommodate the fixings for this box. I recommend using a die-cast metal box that doubles as a heatsink for the rectifiers within.



Do not mount this in direct contact with the steel. Fit plastic packing between the box and the yaw cap plate. Bolt together with stainless steel fixings. Position the box directly above the hole in the yaw cap so that the tower wiring enters the box directly and is suitable anchored within the box to support its weight.



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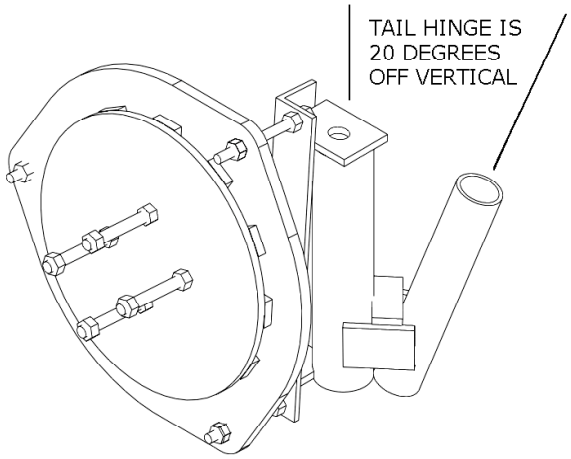
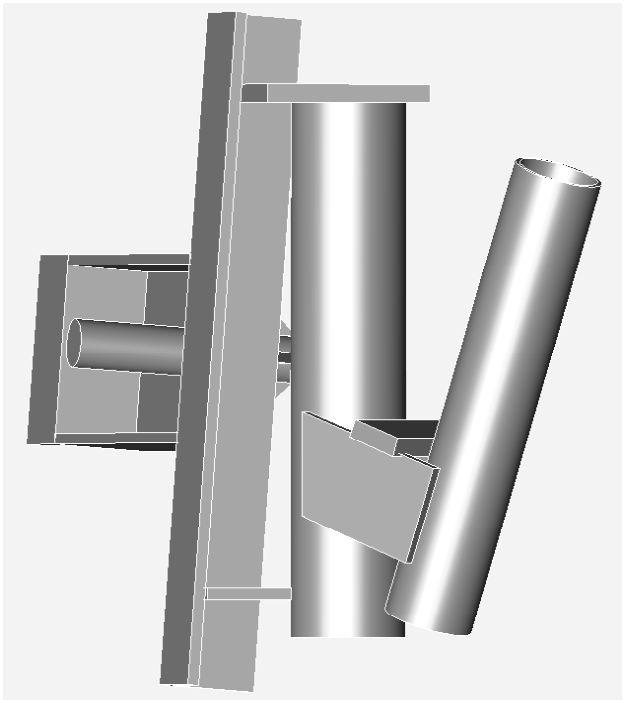
Step 3 the Tail Hinge

8	1 ½" pipe 48.3 O.D.	250	Tail hinge inner pipe (Recipe pipe length E), length at least 250. Top end square.
9	30 x 8	75	Width 30 is important. Length and thickness nominal.
10,11	50 x 6	85 (60)	Cut at an angle and welded to side of pipes to brace the connection. Shape not critical at all

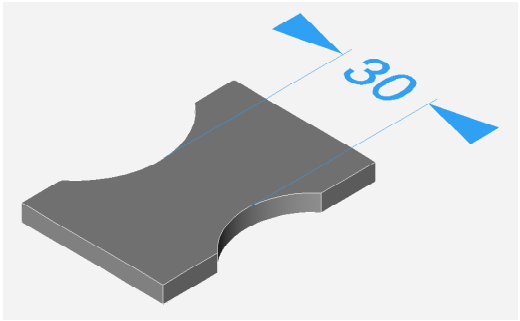
The tail hinge will be welded to the side of the yaw pipe at an angle.





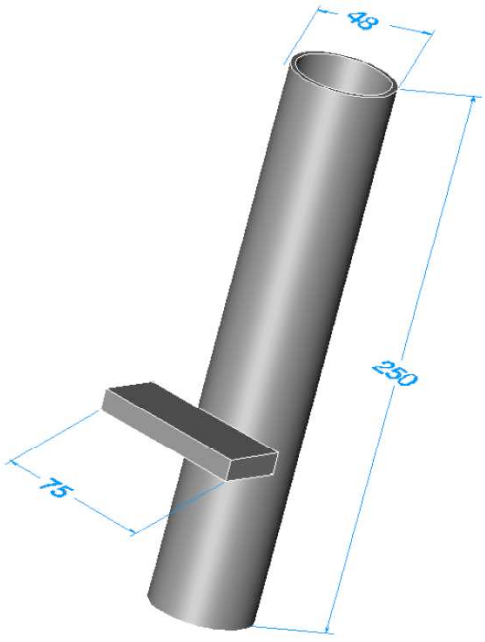
Piece 8 is the inner pipe of the hinge, 250 mm long.

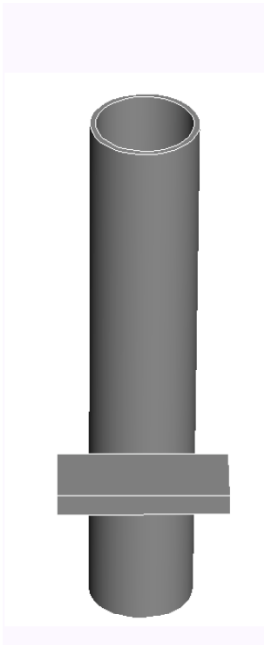
The first welding job is to attach piece 9 so that the pipe will sit at the correct 20 degree angle to the yaw pipe. Piece 9 is usually made from 30 x 8 mm flat bar but anything 30 mm wide will do. For example you could grind down a piece of 50 mm flat-bar.

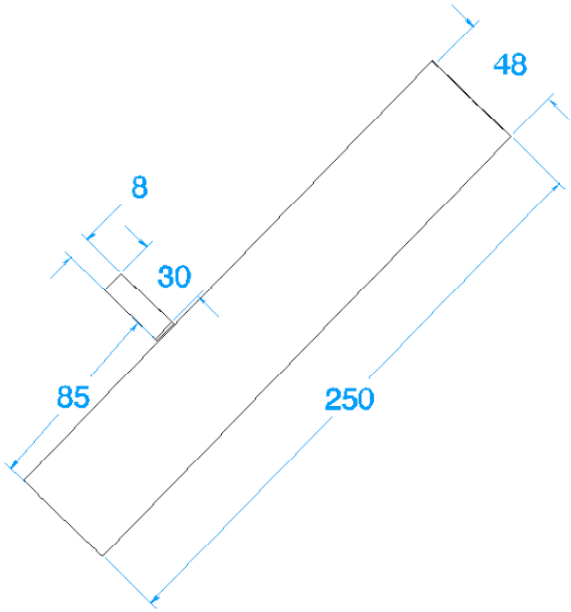


Try to set the 30 mm centrally on the pipe so that it projects equal amounts on each side as shown.

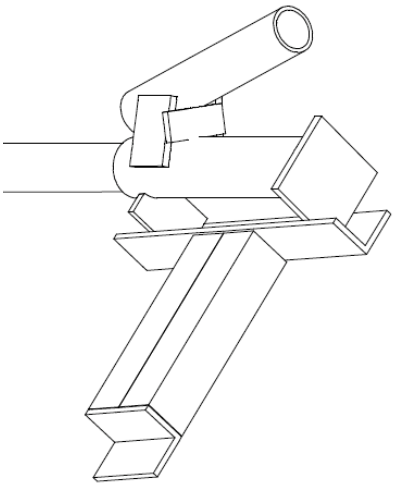
1. <u>Place the flat bar (piece 9) 85 mm from the end of the pipe (piece 8) and weld it on squarely as shown in the drawings below.</u>

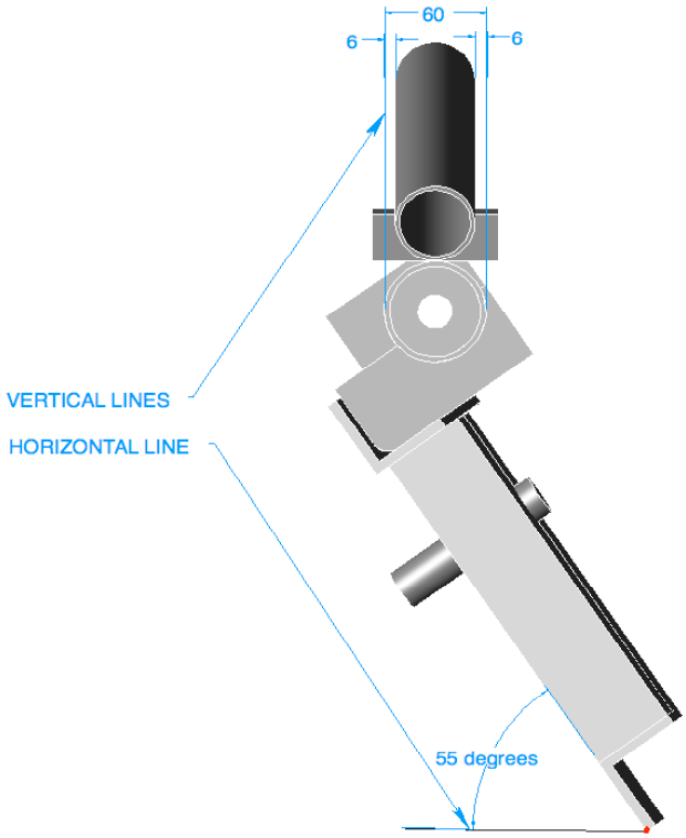






The next task is to set the frame of the turbine up at the correct angle so that this hinge pipe can be simply welded vertically above the yaw pipe.

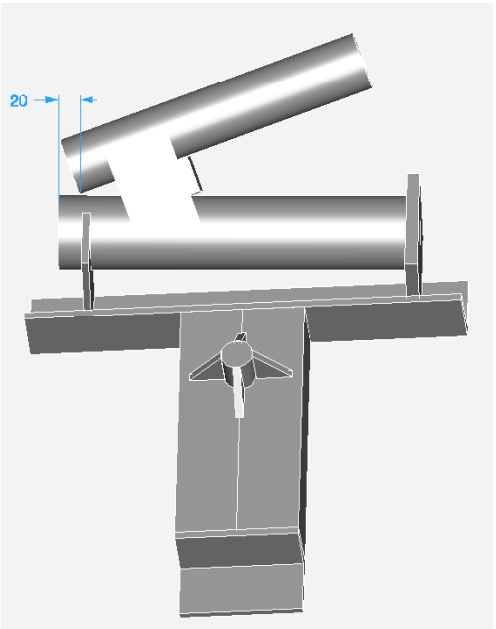


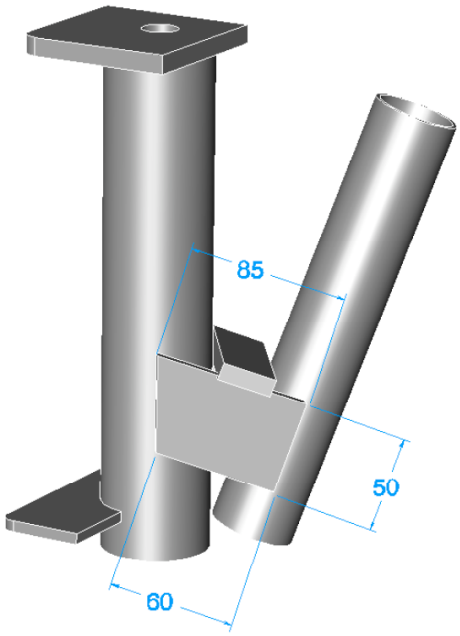


Clamp the two pipes together with vice-grips. The end of the hinge pipe should be welded to the yaw pipe about 20 mm from its end.

The centres of the two pipes should lie in the same vertical plane.

It can be helpful to place a level vertically against the larger pipe and against 6 mm packing at the side of the smaller pipe above. This should work at both sided of the pipes and at both ends.





2. Once you are satisfied that the pipes are correctly aligned to each other, weld the 30 mm cross-piece to the yaw pipe, remove the vice grips and weld the bottom of the hinge pipe to the yaw pipe.

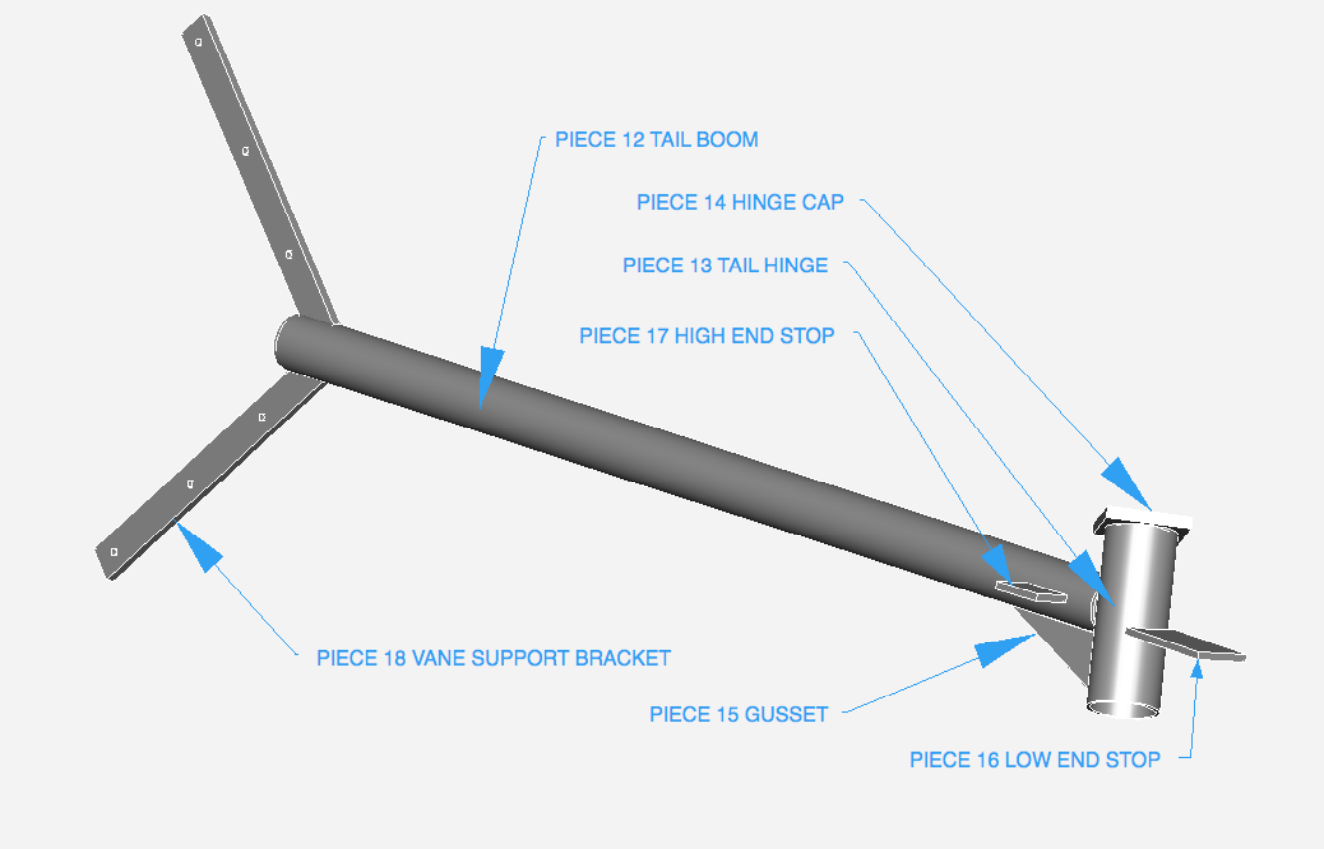
Finally add the two side pieces to strengthen the hinge pipe. These are pieces 10 and 11, made from flat-bar. The neatest way to cut them is square at one end and angled at the other with sides 85 and 60 mm long. One piece 50 x 6 x 145 mm long could be angle cut at the centre to produce the two pieces you need.

3. Weld on the two side pieces (10 and 11). Weld them to each pipe and also to the 30 mm wide piece (piece 9).

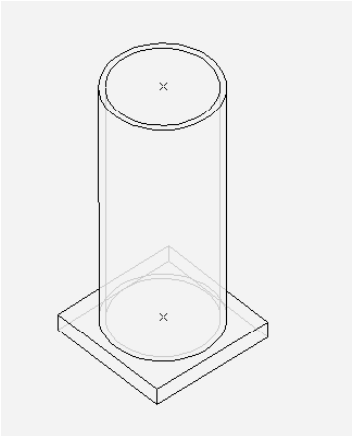
It's important to do a good job of these welds since they are the mostly likely to fail in the event of the blades running out of balance.

The Tail

12	1 ½" pipe 48.3 O.D.	1000	Tail boom. (Recipe boom length A) One end shaped to fit part 13, at 110 degree angle.
13	2" pipe 60.3 O.D.	150	Tail hinge outer part (Recipe hinge pipe length C) Not more than 150 mm long and square at the top end.
14	70 x 70 x 6		Square or circular plate at least 70 x 70 x 6 mm could be made from two pieces.
15	50 x 6	60	Triangular gusset (sizes nominal) angle 110 degrees to support tail boom
16	50 x 6	90	'Low end' stop. End hollowed to fit part 13 (60.3 diameter). Length nominal.
17	50 x 6	33	'High end' stop. Welded to side of part 12. 33 mm projecting to hit yaw pipe.
18,19	30 x 8	300	Ends cut at 45 degrees. Size nominal. Welded at end of part 12 in vertical plane. Drilled for bolting on plywood vane.

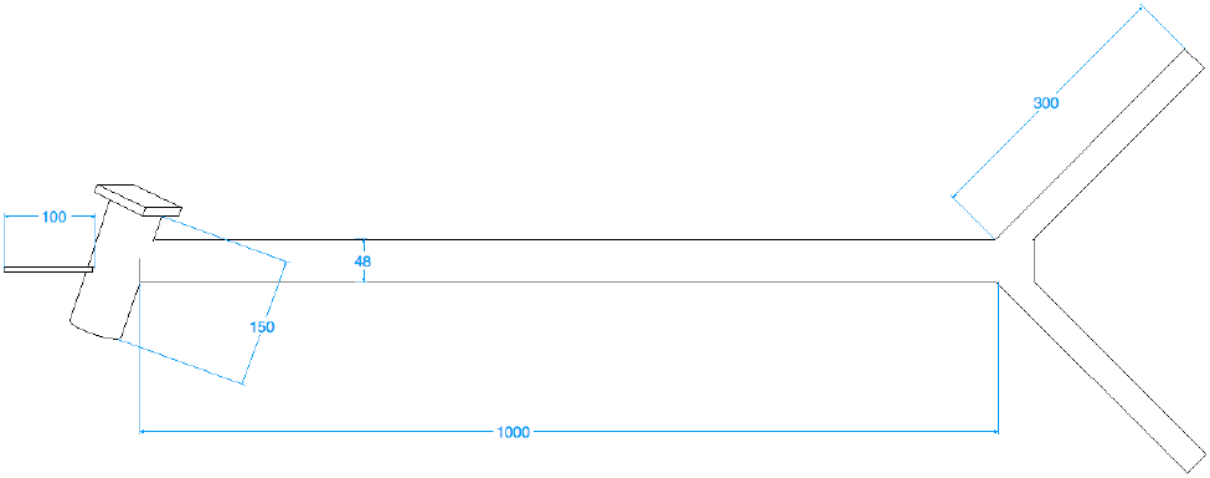


Start off by welding the cap onto the tail hinge pipe (pieces 13 and 14) . The hinge pipe (piece 13) is 150 mm length of 1 ½" pipe.



The pipe is just a little too wide (60 mm) for a piece of 50 mm flat bar to cover it, so you may need to weld two pieces together unless there is something else to hand that will fit.

1. When you have tacked the cap on, check that it sits squarely before welding strongly all round.

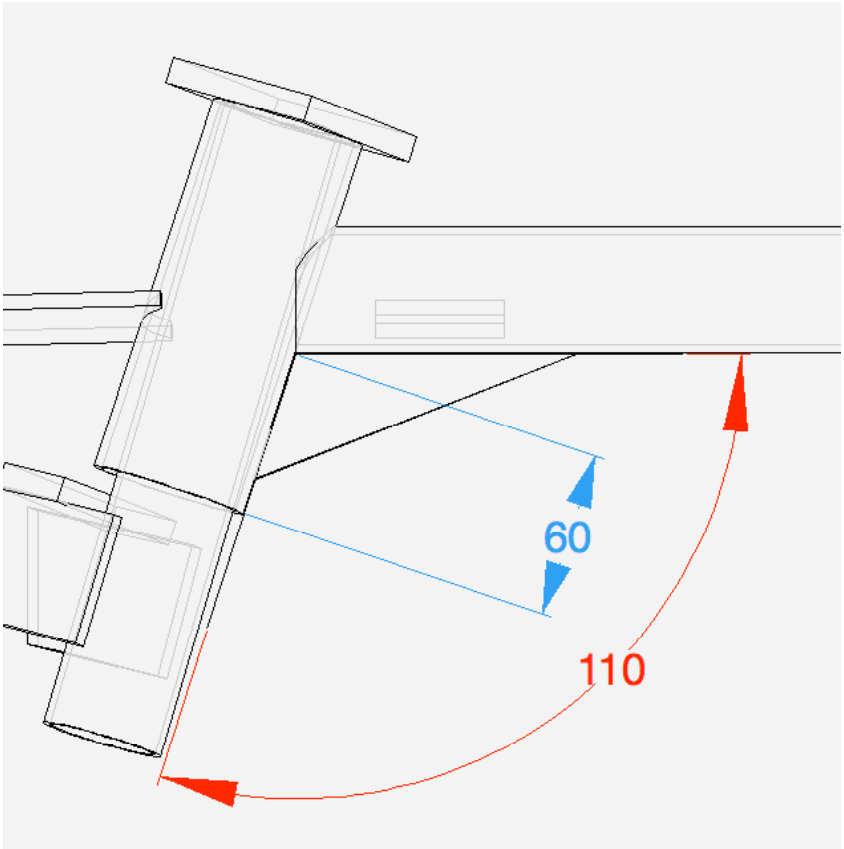


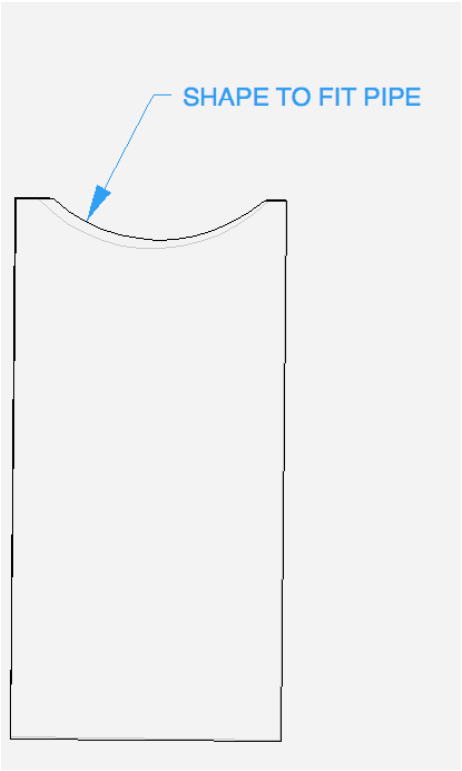
Cut the tail boom out of 1 ½" pipe 1000 mm long. Measure a point 15 mm from the end of the boom and cut at 45 degrees as shown on the right.

Further shape the end of the boom slightly with a grinder to improve the fit. Attaching the tail boom is the most difficult part of the welding in this project because the pipe wall is thin and the ends of the pipe tend to melt.

2. Weld the boom to the tail hinge about 60 mm from the bottom end at an angle of 110 degrees.

3. Strengthen the connection with a triangular gusset made from 6 mm flat-bar (piece 15)





The Low end stop (piece 16)

Cut a length of 50 x 6 mm flat-bar to make, the 'low end stop' for the tail. This will rest against the yaw pipe and determine the position in which the tail normally sits. Shape the end to fit the hinge pipe (piece 13) 60 mm diameter.

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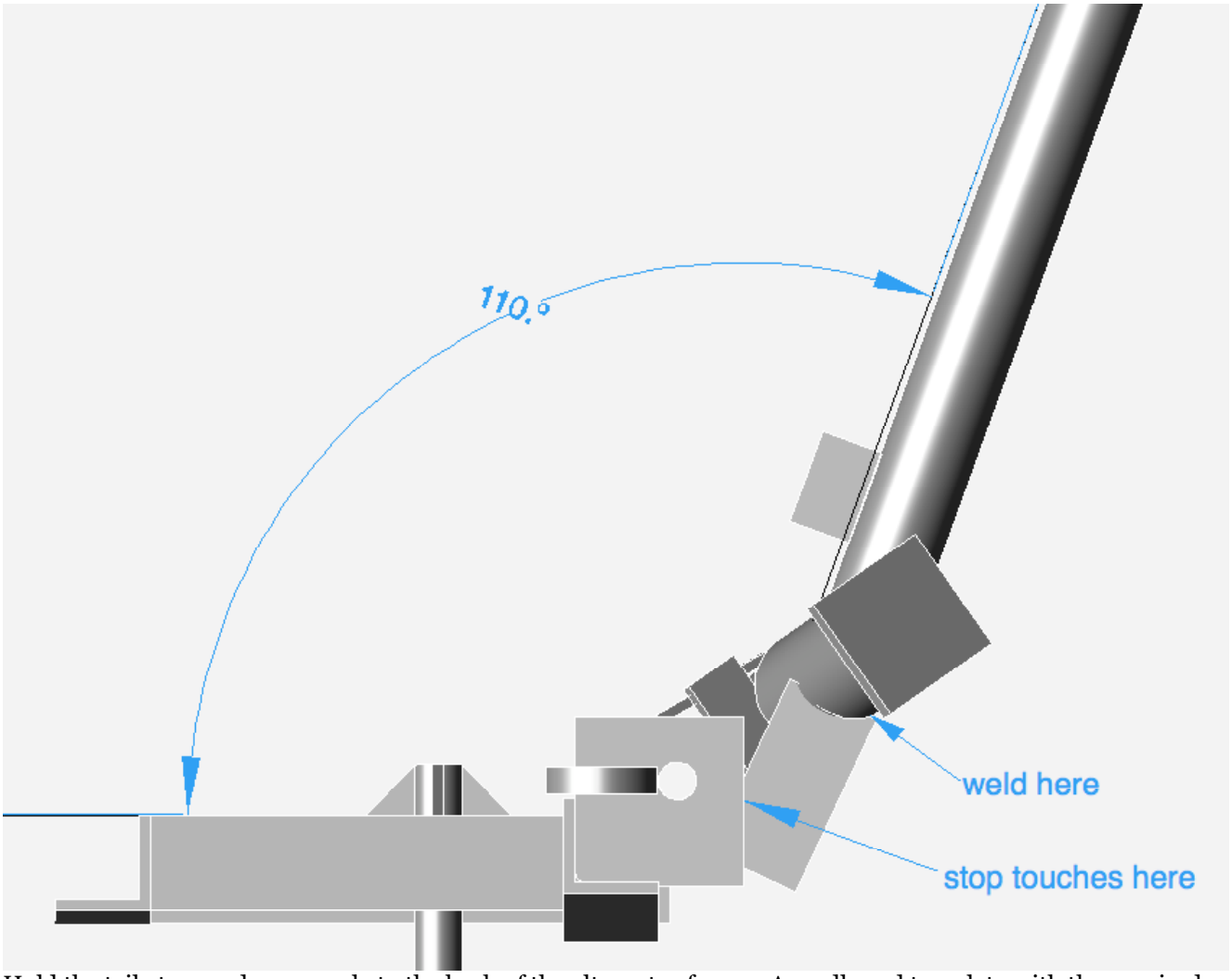
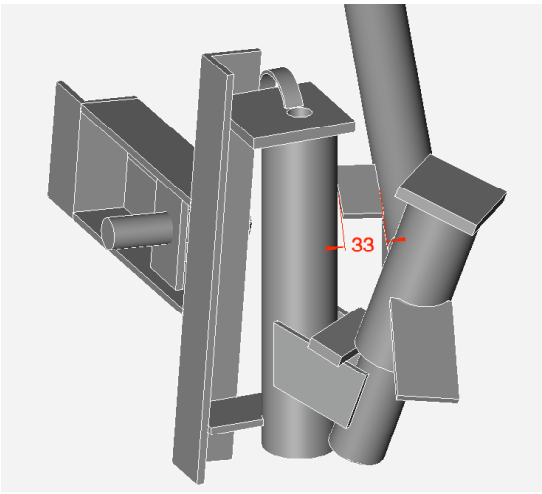
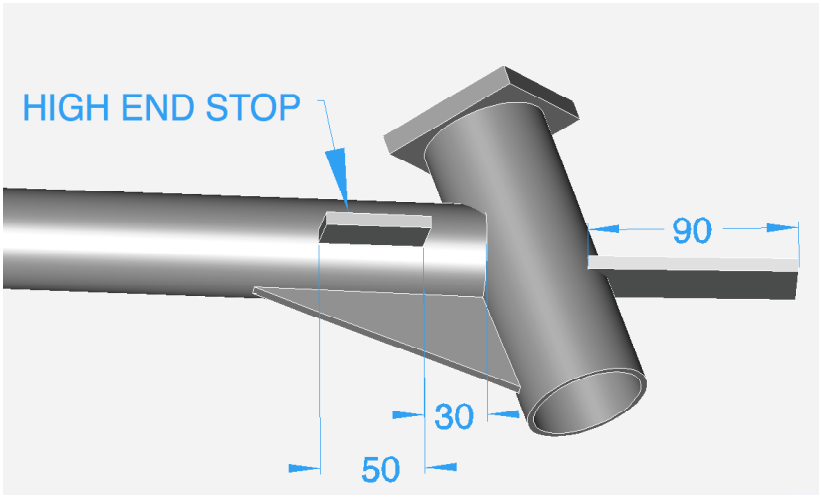


Hold the tail at a 110 degree angle to the back of the alternator frame. A cardboard template with the required angle can be a useful tool to help find the correct position. Plus or minus 3 degrees is fine. Then hold the low end stop (piece 16) against the tail hinge pipe (piece 13) and swing it into contact with the yaw pipe (piece 5).

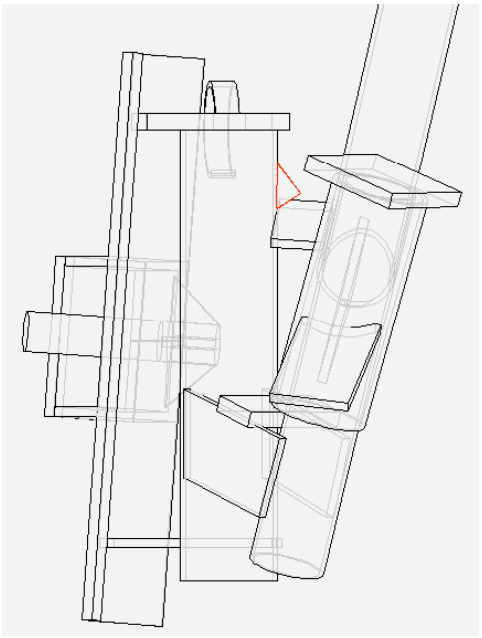
4. Tack the stop (piece 16) securely to the tail hinge. Then lift from the inner hinge, and weld the low end stop to the hinge pipe.





Cut out the high end stop (piece 17) 33 mm long. This is to be welded to the side of the tail boom such that it will contact the yaw pipe (piece 5) when the tail is lifted to its fullest extent.

5. Tack this stop piece to the side of the tail boom in position and then remove it and weld strongly.

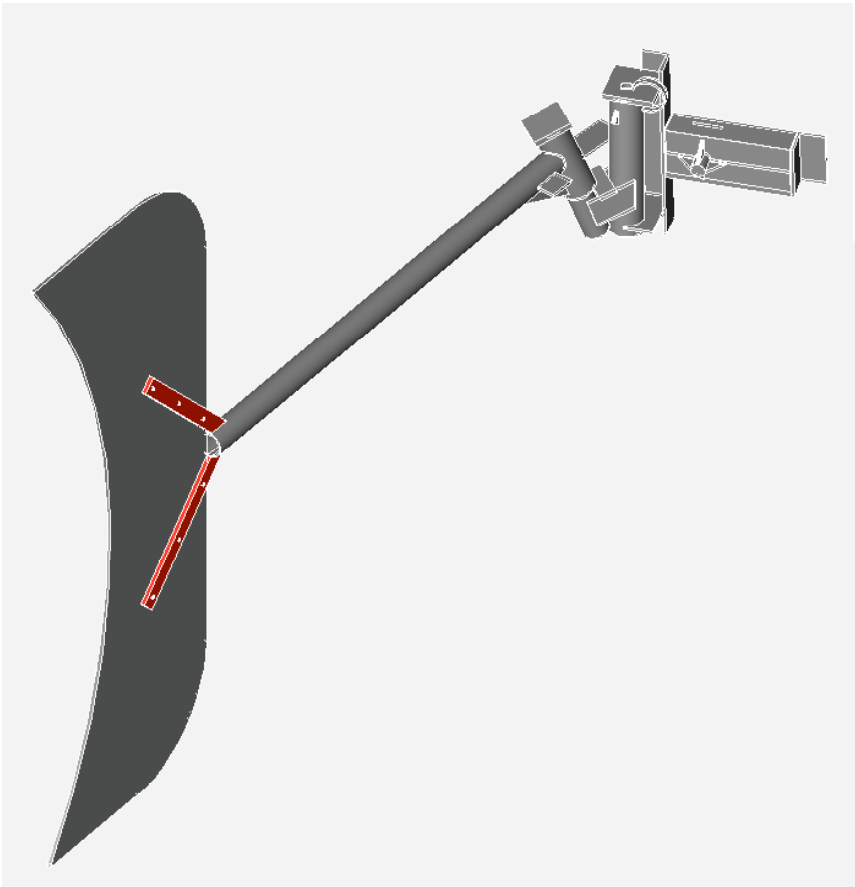


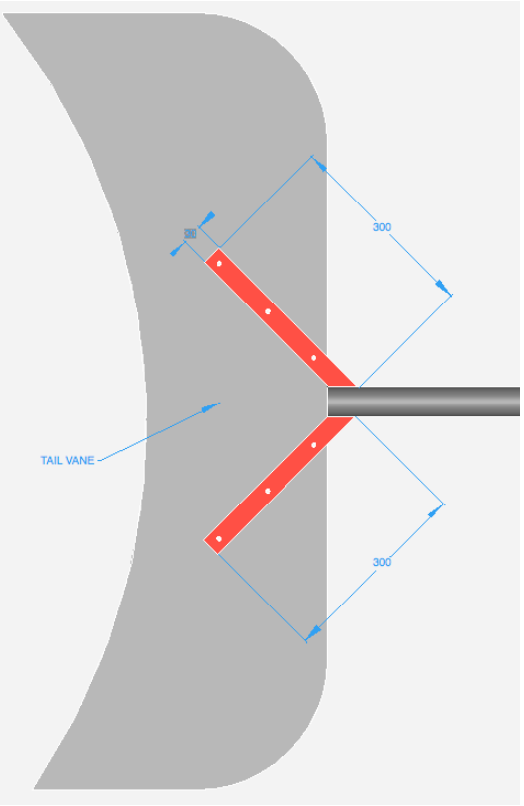
Safety catch

I like to put a little triangular stop above the point of contact of the high end stop to prevent the tail from lifting off its hinge when in this position. This safety stop is welded to the yaw pipe just above the point of contact of the high end stop. It is shown in red in the picture to the right.

Tail vane support brackets (pieces 18 and 19)

Cut the two pieces each 300 mm long from 30 x 8 flat bar. One end is cut at 45 degrees.





These brackets will be welded on the top and bottom of the tail boom (piece 12) to support the tail vane.

The tail vane looks best if it sits vertical when the tail is in its normal position. A good way to set the brackets up is to bolt them to a temporary piece of board. Mount the wind turbine on a stand so that it is vertical. Then hold this temporary board vertical whilst tacking them to the tail boom. You can use the final tail vane for this purpose if it is ready, but it may easily get burned by the welder so a temporary board is normally the best.

6. Tack and then weld the tail brackets on. Make sure these are good quality welds.

The shape of the plywood vane is nominal. Any shape around the recommended size (500 x 1200 mm overall) is fine. The vane needs to weigh about 1.8kg.

That's all the metalwork required for the 2400 wind turbine, except for the fabrication of the tower that supports it.