AXIAL TURBINE
GUIDE TO MANUFACTURE

Produced by: Programa de Energía de ITDG-Peru

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PRESENTATION

This guide is intended to enable the reader to make appropriate and efficient use of the set of manufacturing plans for the axial turbine, the specifications of which are set out in the first chapter (introduction). It has been produced in order to provide guidelines and pointers for the construction process and for the purchasing and use of materials.

It is therefore recommended that manufacturers embarking on construction of the device have the guide to hand, for use in parallel with the plans. This will enable swifter access to the plans themselves, and minimum wastage of materials. This is particularly important when first constructing the devices. Once experience has been gained, limited usage is likely to be required, although it may prove helpful as a point of reference.

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INTRODUCTION

The aim of this guide is to assist manufacturers in the process of constructing a low-cost axial turbine, thereby helping provide rural families with access to this type of equipment, in order to facilitate the availability of electrical power.

The guide covers the process of manufacture of a vertical axis turbine with a specific number of revolutions (ns = 151) The design parameters are:

- Rate of flow (Q) = 0.524 m3/s
- Height (H) = 7 m
- Rotational speed = 900 rpm.

This model is, without significant modifications, capable of operating in different working conditions as illustrated in the table below. For lower power ratings the main problem would be the cost-benefit issue, as this is a large device, while for higher power ratings than those contained in the table, the design would require revision, in particular in terms of the resistance of certain parts such as the bearings, axle, etc.

AXIAL TURBINE OPERATING RANGES			
Wheel diameter = 400 mm, ns = 151			
H (m)	N (r.p.m.)	Q (m3/s)	P.(kW)
5	761	0.443	15
6	833	0.485	20
7	900	0.524	25
8	962	0.560	30
9	1021	0.594	36

In the event that higher power ratings are required, the resistance of components and other aspects would require examination, such as: axle, bearings, transmission system, blades, etc. Strictly under the responsibility of the manufacturer.

I. TURBINE PARTS 1.1

Wheel

The wheel is the moving part of the turbine which, as it receives the water, rotates at a given velocity depending on the design conditions. This mechanical energy is then transmitted to the generator by direct transmission or an intermediate transmission system. The wheel is made up of a solid part, known as the hub, and the blades, positioned symmetrically around the hub. (Fig. 1)

Figure 1: Stainless steel wheel mounted on guide blades

1.2 Housing

This is the casing of the turbine, and has a spiral form. In this case the housing serves to distribute the flow of water through the guide blades. These guide blades have the following specifications: 24 blades with a variable angle position and 6 fixed blades. (Fig. 2).

Figure 2: Turbine housing and guide blades

1.3 **Axle**

This is the component to which the wheel is mounted, and in the case of this turbine is the drive pulley, rotating as a unit and supported on two bearings.

1.4 Bearings

These serve to support the axle and facilitate its rotation. For this turbine we are using two swivel roller bearings which will support radial and axial loads.

1.5 Distributor

This has a spiral or snail-shell form, and has the function of directing the flow of water before it comes into contact with the turbine wheel.

1.6 Suction tube

This is the component responsible for channelling the water after it passes by the turbine wheel, as far as the outlet channel. The suction tube is used on reaction-type turbines. (Fig. 3)

Figure 3: Suction tube manufactured from sheet steel

1.7 Transmission

This system is responsible for transmitting the movement and mechanical power of the turbine to the generator. As a result of design conditions, the speed of the turbine (900 r.p.m.) does not coincide with the speed of the generator (1800 r.p.m.), meaning that the speed needs to be stepped up. In this case a flexible transmission system is employed, using belts and pulleys: 3 trapezoidal belts, a guided 8-inch diameter pulley on the generator axle and a 16-inch diameter drive pulley fitted to the turbine axle.

1.8Valve

The valve serves to control the flow of water. For this axial turbine a 600 mm diameter gate-type valve has been produced, to be fitted upstream of the intake of water into the turbine. (Fig. 4)

1.9Dresser coupling

This device serves to connect the turbine to the pressure pipes, and is therefore referred to as a mounting joint. This mounting joint also corrects any possible slight misalignment between the two elements.

Figure 4: Gate-type valve

II. MANUFACTURING PROCESS

2.1. Manufacturing the housing (spiral)

The housing has a spiral form, and is manufactured in accordance with the construction plans: Plans 01, 01-1 and 01-2.

A. **Materials**

The material employed to produce the housing are as follows:

- **Steel sheeting.** The steel sheeting used to construct the spiral and suction tube is 1/8" thickness (equivalent to 3 mm), of heat-laminated commercial quality. In this case ADC-C manufactured by Siderperú, equivalent to ASTM A569. The sheet dimensions are 1.20m x 2.40m. Electrically cut and welded steel sheeting is being used in the manufacture of the housing and also of the suction tube, although they can be manufactured using other methods, such as casting. Nonetheless, a prior analysis of costs is required taking into consideration the location of manufacture, series manufacture or other aspects considered significant.
- **Oxygen** and **acetylene.** The steel plates are oxygas cut, mainly using oxygen and acetylene, although propane gas could be used in place of acetylene.
- **Electrodes.** The electrodes used to weld the housing parts together are: E6011 for penetration, Cellocord AP/P (Oerlikon) or similar, and E6013 for finishing: Overcord F/M (Oerlikon) or similar
- **Paintwork.** A base coat of anticorrosive paint is applied (zincromat), with a finishing coat of vinyl or other metal paint.
- **Other:** Grinder discs, abrasive paper with a range of grit grades (60, 100, 120, 140, 240), vinyl thinners and plastic putty.

B. Method

The process of manufacturing the housing and suction tube includes marking and cutting the materials (oxygas cutting) and the paint finish, as well of course as the process of welding the parts or segments together.

Marking. In order to save materials and facilitate the marking of parts, templates should ideally be used. These may be made from tin or cardboard, and are placed on the steel sheeting to be cut, with a minimum separation between parts of 1/8" when cutting, attempting not to waste materials. One method of marking out the housing and suction tube parts on a sheet of 1.20 m x 2.40 m is presented in the following figures: Fig. 5 and 6 for the housing and Fig. 7, 8 and 9 for the suction tube.

Oxygas cutting. Oxygas cutting is performed by positioning the cutting nozzle at the outer part of the indicated part markings, with the quantity of oxygen and acetylene regulated appropriately. If there is too much oxygen the flame tends to go out, while if there is not sufficient oxygen the flame turns yellowish and the cut will be defective.

If the cut parts become warped as a result of heating during the cutting process they will need straightening, using a mallet and wooden blocks, attempting to avoid denting the metal.

The nozzles used in cutting the steel plates will depend on the thickness of the metal. For the 3 mm sheeting, nozzle number 1 should be used.

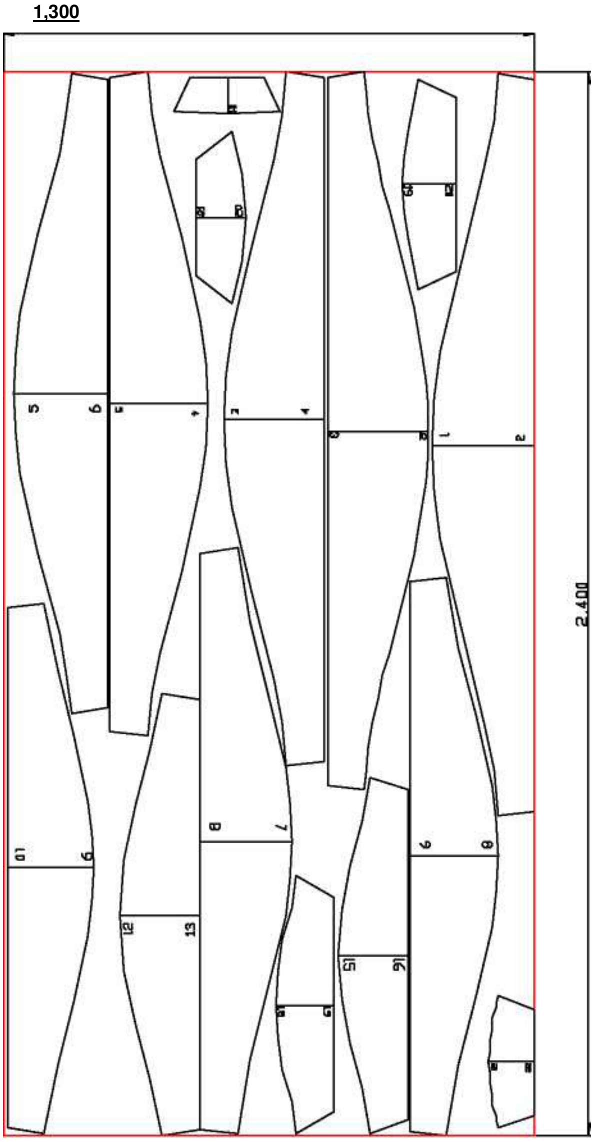

Fig. 5 Positioning of the spiral templates on the steel sheeting for marking and cutting (Segments as indicated)

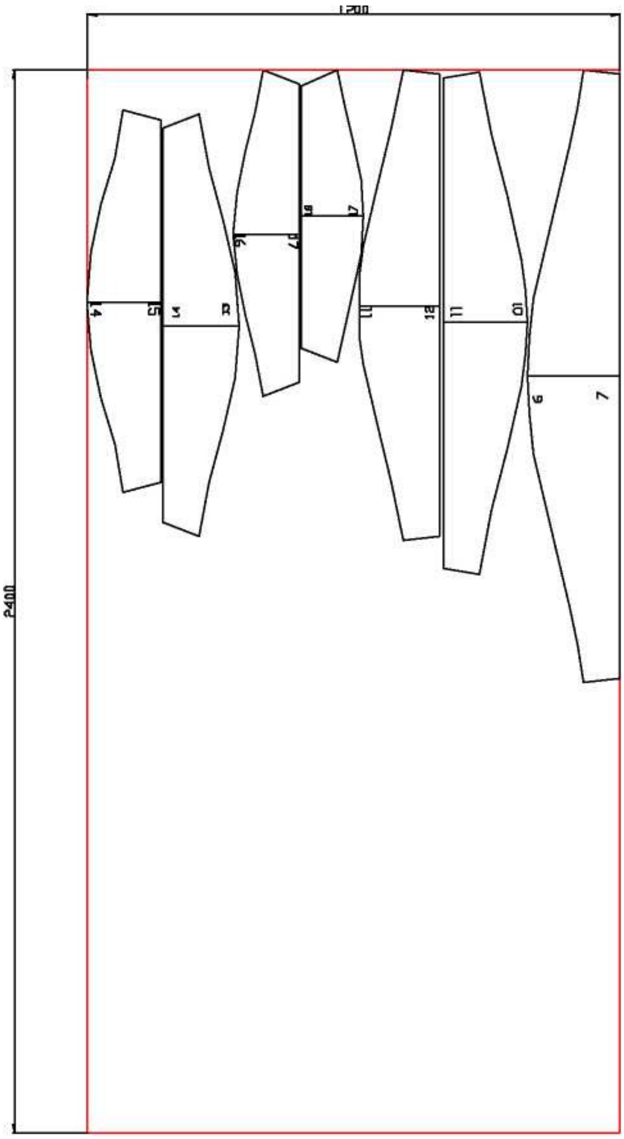

Fig. 6 Positioning of the spiral templates on the steel sheeting for marking and cutting (Segments as indicated)

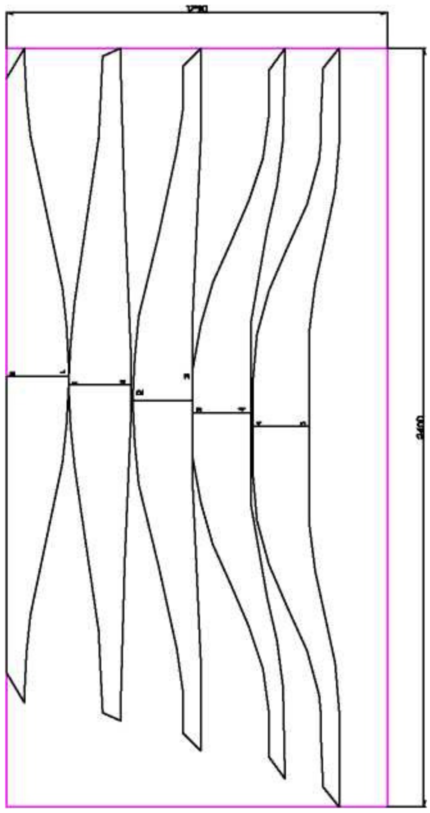

Fig. 7 Positioning of the suction tube templates on the steel sheeting for marking and cutting (Segments 0-1 to 4-5)

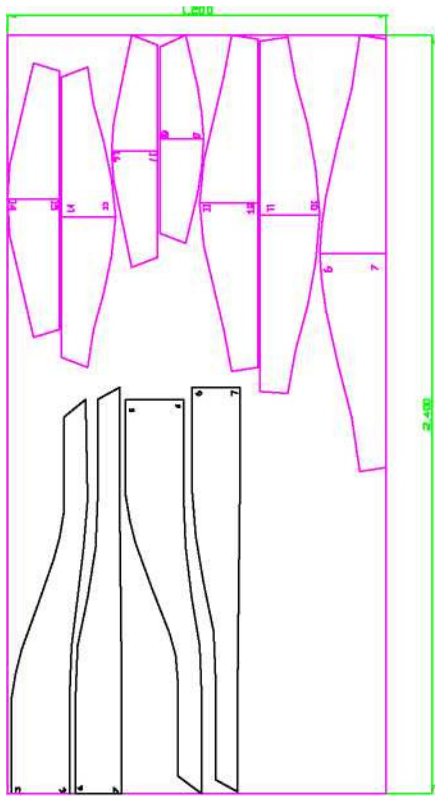

Fig. 8 Positioning of the suction tube templates on the steel sheeting for marking and cutting (Segments 5-6 and 6-7; the segments of the upper part are segments of the spiral

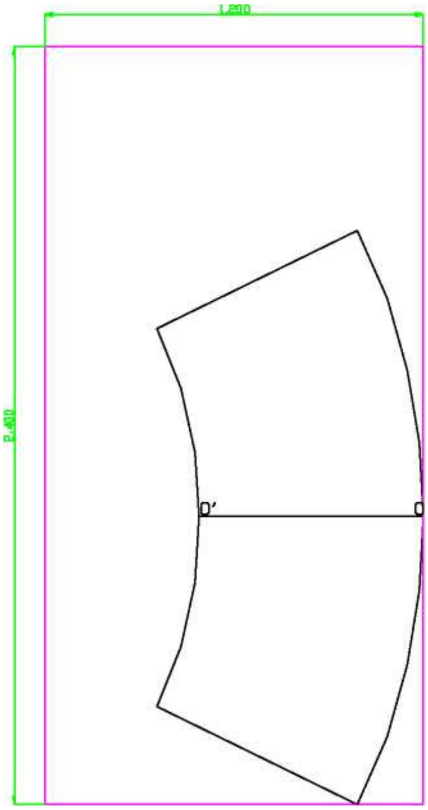

Fig. 9 Positioning of the 0'-0 suction tube template on the steel sheeting for marking and cutting

Rolling. The dimensions of each piece must be followed when assembling the spiral and suction tube in order to shape each part correspondingly, using a roller press (Fig. 10 and 11), and preferably using templates as a guide. The templates need to be for each of the two sections corresponding to each segment. These sections of the spiral are circular in form up until section 13. From section 14 to section 21 they are elliptical. Section 23 is the transition section, and sections 23 and 24 correspond to the nose (see plan 01-2 in the set of plans). On the suction tube the sections are indicated in plan number 04. As with the spiral, each section of the suction tube requires either a cardboard or tin template.

Figure 10: Portable roller press

Figure 11: Rolling process

- **Welding.** The joint between the segments of both the spiral and the suction tube is arc-welded, given the widespread prevalence of this technique in small-scale workshops. The welding process begins by securing the segments or parts with spot welds, checking the dimensions and that they are truly square, before finally bead-welding them together, attempting to keep any buckling caused by the welding process itself to a minimum. Such buckling occurs as a result of localised overheating, making it advisable to weld in sections, allowing other parts to cool down on an alternate basis. (Fig. 12 and 13)

  The electrodes used for spot welding and joining the sections are penetration electrodes (E6011), and E6013 electrodes for finishing. 1/8" E6011 and 3/32" E6013 electrodes should preferably be used for the 1/8" sheeting, although this depends on the welding equipment and the skill of the welder.

Figure 12: Welding of the spiral segments

Figure 13: Spiral after the process is complete

Filing down. When both the housing and the suction tube segments are arc-welded together, the end result will have burring and small protrusions caused by the welding bead both inside and outside the housing and suction tube. This must be removed. Removing any burring and proud seams on the interior is advisable in order to reduce water friction, thereby limiting any loss in the area, while on the outside it serves an aesthetic purpose.

The filing process involves using a hand grinder with grinding discs and circular abrasives (for the grinder), followed by files and abrasive paper as required, beginning with a coarse grain and finishing off with finer grains.

Painting. The surface should be completely cleaned before painting, using a clean rag and thinners or any other substance to remove any build-up of dirt and grease.

Once the surface to be painted is completely clean, it should first be painted using anticorrosive paint, preferably a "zincromat"-type base coat, applied both inside and outside the spiral and suction tube. After the base coat has been applied, putty should be used to cover any parts requiring this in order to obtain an improved finish. Once the putty has dried it should be sanded down first with a course-grain abrasive followed by a fine grain and lastly a water abrasive. Before the finishing paintwork is applied, which could be with vinyl paint or any other type of paint for metal, the structure should again be cleaned with rags and thinner in order to remove any dirt and possible grease which may have built up during handling. Finally, the finishing paintwork is applied with the required uniformity. A spray gun should ideally be used, in which case this should first be inspected to ensure the nozzle is completely free of obstructions and paint residue. (Fig. 14)

Figure 14: Finished axial turbine

2.2 Manufacture of the suction tube

The suction tube is manufactured using the same materials as the spiral, and also the same equipment and tools.

The manufacturing process for the suction tube is similar to the process of manufacturing the spiral, as detailed in section 2.1. The following plans should be used in manufacturing the suction tube: Plans 02 and 02-1, along with the general assembly plan EG.

2.3. Turbine wheel manufacture

See plan 03.

A. **Materials.**

- **Chrome-nickel cast stainless steel (13% chrome and 4% nickel) from the foundry. The use of stainless steel is recommended given its greater resistance to corrosion caused by cavitation.**
- **Electrodes.** The electrodes used to weld the blades to the turbine wheel hub are E308-16 (AW Oerlicon Stainless Steel)
- **Other.** Grinding disc, files and fine and coarse abrasive paper.

B. Method

Manufacture of the turbine wheel begins with preparation of the models and moulds as an initial step. The models are produced in accordance with the plans, taking into consideration the tolerance values for contraction of the cast metal, and are in general made from wood, as the cheapest material, or other options such as: resin, fibreglass or aluminium. In this case models have been used for the blades and for the hub, which are cast separately. The blades are bead-welded to the hub using electrical welding equipment and stainless steel electrodes. The welding is performed blade by blade, taking into consideration the correct positioning of the defined angle. Once all the blades are in position they are welded completely to the hub, avoiding any overheating which could warp the parts, while also taking care to keep the blades in their correct position.

After the blades have been welded to the turbine wheel, final finishing involves polishing those parts of the wheel which will be in permanent contact with the water, while machining the parts which will be coupled to the axle with their respective key slots.

In order to polish the turbine wheel, a grinder is applied first, if necessary, or simply a small emery, files and abrasive paper, beginning with a coarse grain and finishing off with finer grains.

Once the turbine wheel is completely finished, including both machining and polishing, it requires dynamic balancing. This process will depend on the rotational speed at which it is to operate. Dynamic balancing is required since in the casting process the material is not uniformly distributed, and so this will reduce vibrations and increase the working life of the bearings and other components.

2.4. Manufacture of the axle

See plan 04

A. Materials.

- **Special hardened steel** for rotation and flexion uses (DIN: 34 CrNiMo 6, Boehler VCN 150), identifying colour: green

B. Method

A minimum oversize of 4 mm should be allowed for in the diameter of the axle, for machining. For the turbine discussed here, the axle will have a 60 mm diameter, and so the raw materials should be purchased with a diameter of 64 mm, in order during machining to remove the black shell and de-carburised layer which generally contains microfissures.

Machining, both on the lathe and of the key slots, is performed in accordance with the manufacturing plans.

2.5. Manufacture of the intake cone and turbine wheel casing

See plans 07-09 and 09

A. Materials.

- **SAE 1020 quality cast steel 1020**

B. Method

The approach adopted for the manufacture of these parts involves casting, followed by machining and polishing. Models will be required for casting, produced in accordance with the manufacturing plans, with the respective tolerance values for contraction of the material and machining.

The finished parts must be kept greased or protected with anti-corrosive paints to reduce the risk of corrosion.

2.6. Manufacture of the axle-bearing supports

See plans 08 and 13 of the set of plans

A. **Materials.**

- **Steel sheeting.** In accordance with dimensions A569 (ASTM) or ADC-C (Siderperú)
- **Electrodes.** The electrodes used to manufacture the axle-bearing supports are E6011 for penetration and E6013 for finishing.
- **Other**: Grinding disc, files and fine and coarse abrasive paper.

B. Method

They are manufactured in accordance with the specified plans, the other bearing support being an overhang supported on the side of the turbine structure, which is why the axle is in vertical position. For the lower bearing the abutment or support is manufactured allowing for the required distance in order for the water flowing out via the seal not to come into contact with the bearing.

2.7. Manufacture of the seal

See plan 10 of the set of plans

A. Materials.

The main component is 90% brass (Cu 90% Zn 10%). This material is used as a result of its high corrosion resistance, since these parts will be in contact with water. Graphite tape will also be required. This can be bought by the meter.

B. Method

The metal parts of the seal are manufactured in accordance with the specified plans. First the models must be produced, before casting the pieces, which are then finished off by machining in accordance with the manufacturing plans.

2.8. Manufacture of the guide blades

See plans 01-4 and 01-5

A. Materials.

SAE 1020 quality cast steel. Grinding discs, files and fine and coarse abrasive paper.

B. Method

The guide blades are cast, for which models must first be created. The parts will be burred when they leave the foundry, and so will need grinding down and finally polishing with files and abrasive paper, taking particular care with the finishing process, as with the turbine blades, in order to maintain the aerodynamic form. A separate structure has been produced in order to fit them to the housing and make it easier to install the blades in the correct position in accordance with the design angle. The blades are welded to this structure.

The reason for having a separate structure is to allow the blades to be replaced if necessary, or to change their angle of positioning on a new structure (See Fig. 15 and 2)

Figure 15: Positioning of the guide blades

III. ASSEMBLY

Once the turbine components are complete, the device can then be assembled, in accordance with the instructions given in the plans, and in accordance with the mechanic's own judgement. (See plan EG)

IV. RECOMMENDATIONS

- The interior finish of the distributor should be of good quality (smooth) in order to avoid any excessive losses which would reduce power. Particular attention must also be paid to the surface finishing of the turbine wheel blades and all components which will be in contact with water in order to avoid any losses through friction or other factors.
- The bearings must not be exposed to water or dirt during assembly.
- Do not leave tools anywhere except their designated place, and avoid accidents.

LIST OF MATERIALS AND EQUIPMENT EMPLOYED IN MANUFACTURING THE AXIAL TURBINE

I. MATERIALS

Item	Description	Unit	Materials	Qty
01	1/8"x 1.2m x 2.4m steel sheeting	U	ADC-C STEEL (Siderperu) A569	09
02	Industrial oxygen	m^3		15
03	Acetylene or propane gas	m^3		10
04	1/8" electrodes	kg	E6011	30
05	Electrodes	kg	E6013	20
06	Electrodes	kg	E308-16 (AW Stainless	01
07	7" grinding disc	U		06
08	60 grit abrasive paper	U		10
09	100 grit abrasive paper	U		06
10	120 grit abrasive paper	U		06
11	180 grit abrasive paper	U		04
12	240 grit abrasive paper	U		04
13	Vinyl thinners	Gal		02
14	Plastic putty	kg		03
15	Zincromat base-coat paint	Gal		02
16	Vinyl paint	Gal		02
17	Rags	kg		05
18	Cast stainless steel for turbine	kg	Cr 13% Ni 4%	30
19	3" diameter hardened steel	m	DIN: 34CrNiMo6	0.9
20	Cast steel (intake cone and turbine wheel casing), according to model	kg	SAE 1020 quality cast steel	80
21	Cast steel (guide blades and fixed blades), according to	kg	SAE 1020 quality cast steel	38
22	1/4" x 1.2m x 2.4 steel sheeting	U	ADC-C steel (Siderperu) A569 (ASTM)	01
23	1/4" x 1.2m x 2.4 steel sheeting	U	ADC-C steel (Siderperu) A569 (ASTM)	01
24	Commercial cast brass for seal	kg	Cu 90%, Zn 10%	02
25	Graphite tape	m		03
26	Grease	kg		01

II. **EQUIPMENT**

Item	Description
01	220 A welding machine
02	Cutting machine
03	Bench drill
04	Hand drill
05	Grinder
06	Screw vice
07	Winch
08	Calliper or slide gauge
09	Mallet
10	Hammer
11	Horizontal hand level
12	Vertical hand level
13	Set of boilermaking squares and rulers
14	Set of open-end or mixed spanners from 1/4" to 1" (or metric)
16	1 tonne minimum hoist
17	Bow saw
18	Emery wheel
19	Set of drill bits from 1/16" to 1"
20	Set of taps:; 3/16", 1/4", 3/8", 1/2", 5/8"
21	Set of files
22	Protective and safety equipment
23	Painting equipment (compressor, spray gun, close)
24	Hand-operated roller press
25	Parallel lathe *
26	Brush *
27	Milling machine *
28	Furnace *

* Not indispensable. These services can be provided by third parties