Sustainable equipment

Hamro Gaun project

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Nepal

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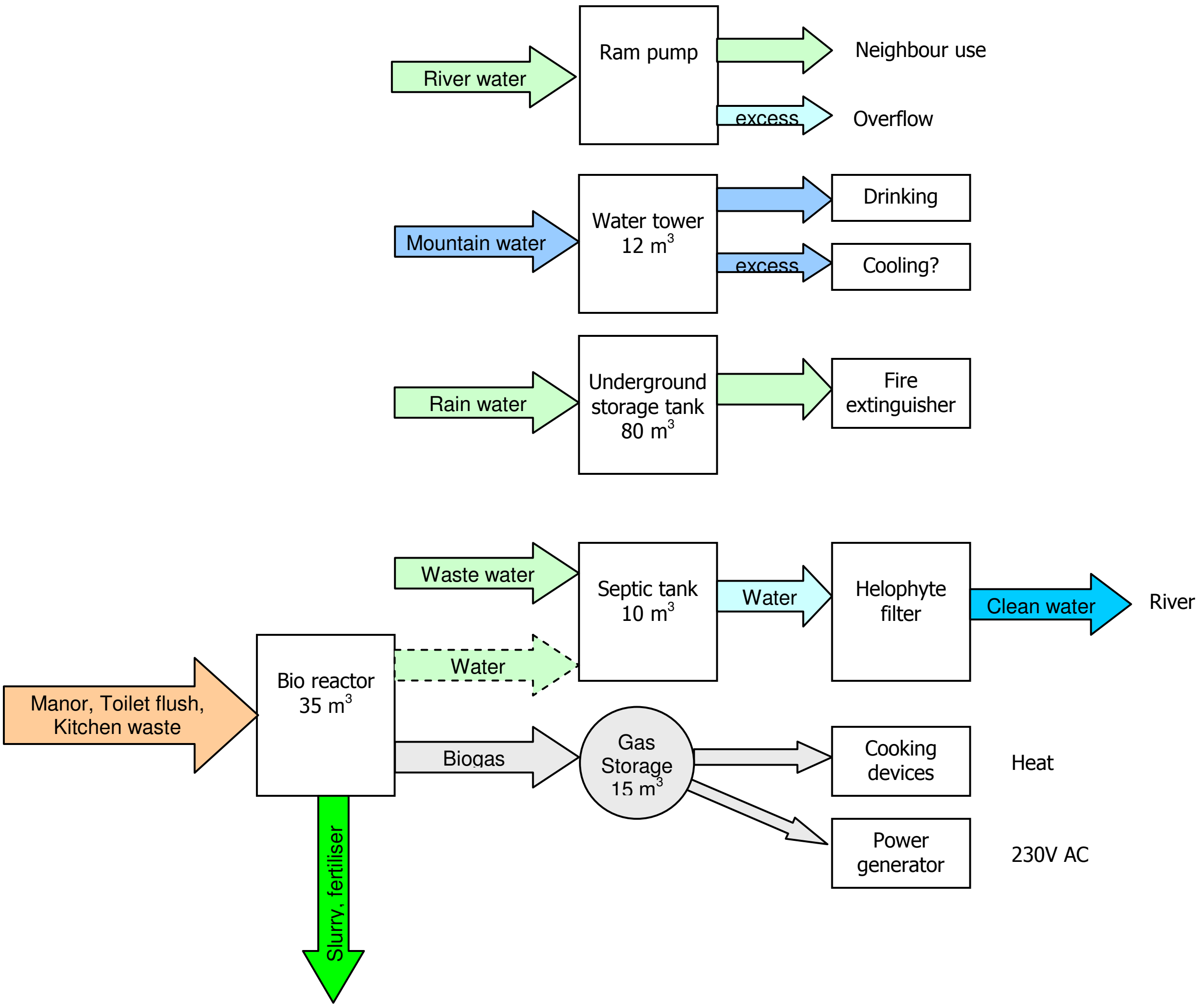
1 Introduction

The purpose of this working document is to:

- Summarize technical issues that are dealt with when designing and installing technical systems in the Hamro Gaun project in order to support future developments of these systems;
- Support developments with similar technologies in other projects;
- Give instructions for adequate use of these systems;
- Give instructions for adequate maintenance of these systems.

It is suggested to continuously update this document with further essential information by future users and technicians.

1.1 Planned water treatment and storage



In order to exchange clean mountain water with polluted river water with the neighbors, a ram-pump has been installed.

2 Micro Hydropower

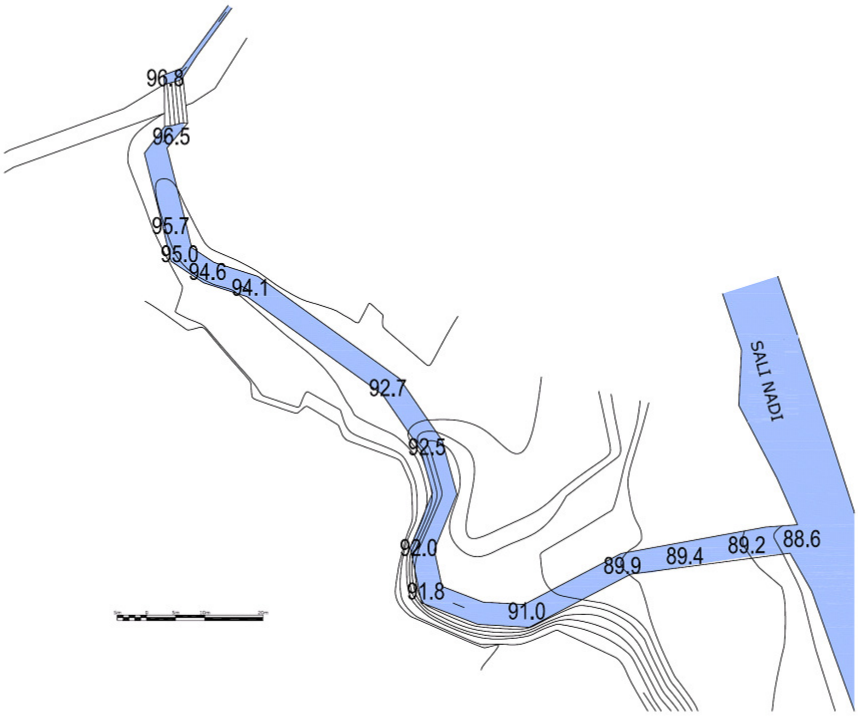
The Micro Hydropower equipment is based on the design of Jan Portegijs ('The Firefly micro hydro system', 2003). Basically, the total system consists of:

- The supply of pressurized water (in this document);
- The nozzle, runner and generator (see for detailed design drawings the document of Jan Portegijs);
- The electric circuit (in this document).

The total length of the river with a height difference (*head*) of 6.2m amounts to 130m. The relatively long distances of the transportation of both water and electrical power is dealt with in particular in the two sections below.

2.1 Optimizing low head long distance water flow

In Hamro Gaun the river slope is only 5% (tube length from dam to generator: 130 m, head: 6.2 m).

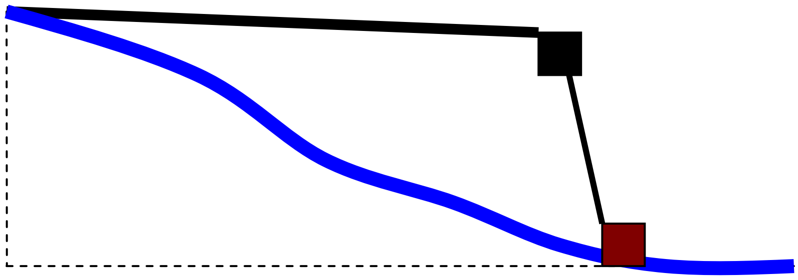


Power loss during water transport is therefore critical. There are several options that can be chosen, but which is the optimum solution? Calculations below are based on the values in the following table (flow and power are a result of penstock pipe diameter and length, runner geometry and nozzle geometry):

Head (m)	Optimum speed, (rpm)	Flow (l/s)	Power (W)
(3	940	5.3	46)*
(4	1080	6.1	71)*
5	1210	6.8	100
6	1330	7.4	131
7	1430	8.0	165
8	1530	8.6	202

2.1.1 Open canal

Open canal flow as drawn below is recommended in the Portegijs documentation.

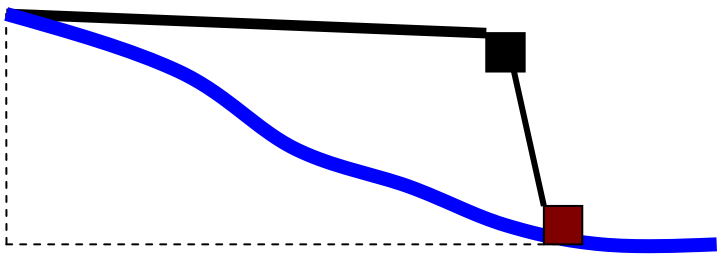


For one micro hydropower (8 l/s) + 5 l/s seepage spill the canal dimensions should be at a minimum slope of 0.9%, with a width of 0,23 m and a height of 0,28 m.

Remarks:
- Head loss is substantial: minimum slope should be 0.9 % (1.2 m). To minimize sedimentation, a slope of 3% (4m) is required, making the head loss unacceptable;
- Concrete or plastic foil lining is necessary to prevent seepage and soil weakening. When using plastic foil it must be prevented in any case that water comes under the foil;
- Maintenance is crucial to remove sedimentation, obstructions or weed;
- The canal must be deep in the Hamro Gaun situation (rising land-area), which can be dangerous to fall into.

2.1.2 Horizontal tube

A buried tube instead of a canal would improve some of the disadvantages (no seepage, less maintenance, invisible / not dangerous to fall into).



The hydraulic radius of the open canal equals a tube diameter d of 0.22 m:

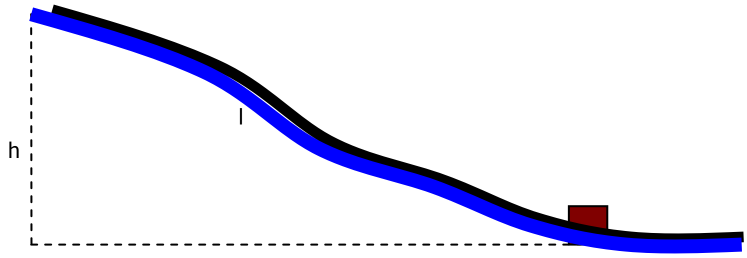
$$d = 4 \cdot \frac{b \cdot h}{b + 2h}$$

The diameter of a completely filled tube should therefore be 0.25 m. Note that 'horizontal flow' would be optimal when the tube is filled for 80%.

Remarks:
- Head loss should be 3% to minimize sedimentation (4 m);
- Minimal maintenance, but if cleaning of the tube is required, this can be difficult;
- Material costs may be higher than for a canal;
- When not buried the tube should firmly be supported since the filled tube is heavy (50 kg per meter).

2.1.3 In-river tube

If the penstock tube is not vertical but starts right at the inlet, every height drop builds up more pressure.



Impact of kinetic pressure is small
Without the vertical penstock tube, the question is whether the water contains less power. Energy density of the water is directly related to the pressure. The pressure can be calculated by the following equation, in which the nozzle pressure contains a hydrostatic and a kinetic component:

$$\text{Nozzle pressure} = \rho.g.h + 0.5\ \rho.v^2 \qquad \text{(Bernoulli)}$$

Where ρ = density (1000 kg/m3) and g = gravitation (9.8 m/s2).

Water speed v in the nozzle is approximately 1.75 m/s under optimum conditions for the micro hydropower. This means that 97% of the nozzle pressure is determined by hydrostatic pressure only.

Choosing tube diameter
Due to friction losses the tube diameter must be much larger than de nozzle-input diameter of 3 inch. The head loss h_v caused by friction losses can be calculated by

$$h_v = \lambda \frac{l}{d} \frac{\langle v \rangle^2}{2g} \qquad \text{(Darcy-Weisbach)}$$

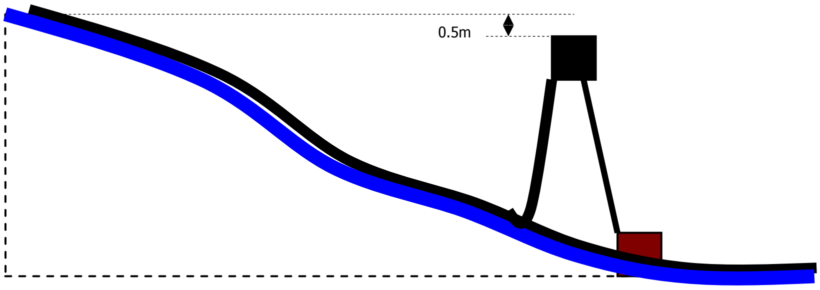
Where l is the tube length (134 m) and d the inner tube diameter. λ is a 'resistance factor', which is approximately 0.026 for smooth long tubes (see appendix for proper value).

With a tube diameter of 0.20 m, approximately 0.05 m is lost due to friction. An additional second micro hydro power would double the flow speed, causing a head loss of 0.17 m (0.63 for a tube of 0.15 m).

Remarks:
- Head loss is minimal compared to other options;
- Easier to install;
- The tube is costly (approximately 7 euro/m without installation);
- Sedimentation will occur in the narrowing before the nozzle, requiring regular cleaning;
- A secondary micro hydropower will not automatically 'switch off' when water supply is insufficient and two inlet levels are used;
- No forebay basin is needed.

2.1.4 In-river tube with vertical end

If a forebay basin is desired, the bay could also be filled using the 'communicating vessels' principle. A vertical tube at the end would fill the basin.



A tube diameter of 2 cm should be sufficient since friction losses are negligible. The required head loss between inlet and bay is estimated to be 0.5 m.
Remarks:

- A secondary micro hydropower will automatically be 'switched off' with a higher tube than the primary micro hydro power;
- Easier installation: digging or ' hanging' the tube is not necessary
- Sedimentation in the lower part will require regular cleaning (flushing).

2.1.5 Effective head losses

The effective head can be calculated by subtracting all head losses from the total head. With aforementioned equations the following head losses due to tube friction can be calculated.

	50 m	**100 m**	**200 m**
1. Open-canal, slope 0.9%	0.45	0.90	1.8
2. Horizontal tube, slope 3%	1.5	3	6
3. In-river, Ø 0.07 m*	2.770	-	-
3. In-river, Ø 0.15 m*	0.090	0.15	-
3. In-river, Ø 0.20 m*	0.025	0.041	0.056
3. In-river, Ø 0.25 m*	0.009	0.015	0.025
4. In-river + upward, Ø 0.15 m	1.5 + 0.099	3.8 + 0.159	-
4. In-river + upward, Ø 0.25 m	0.2 +0.010	0.5 + 0.016	1.0+0.026

Values (in meters) are based on 8 l/s, at 7 m effective head.
* When flow increases (e.g. two micro hydropowers are connected) head loss increases with the square (4 times higher)

Additional head losses are caused by obstacles in the tube like bends or thickness changes. These can be calculated with

$$h_v = \Sigma \zeta \frac{v^2}{2g}$$

Where ζ is a geometry dependent constant.

Most relevant values are summarized below.

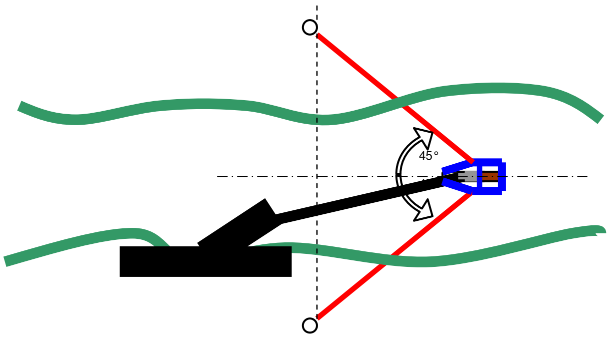
		Tube diameter			
	ζ	**0.07**	**0.15**	**0.20**	**0.25**
45°, sharp	0.25	0.0551	0.0026	0.0008	0.0003
90°, sharp	1.15	0.2535	0.0120	0.0038	0.0016
Narrowing before nozzle	0.05	0.0110	0.0005	0.0002	0.0001
T coupling inlet	0.3	0.0661	0.0031	0.0010	0.0004

ζ values and head losses in m for different obstructions at a flow of 8 l/s.

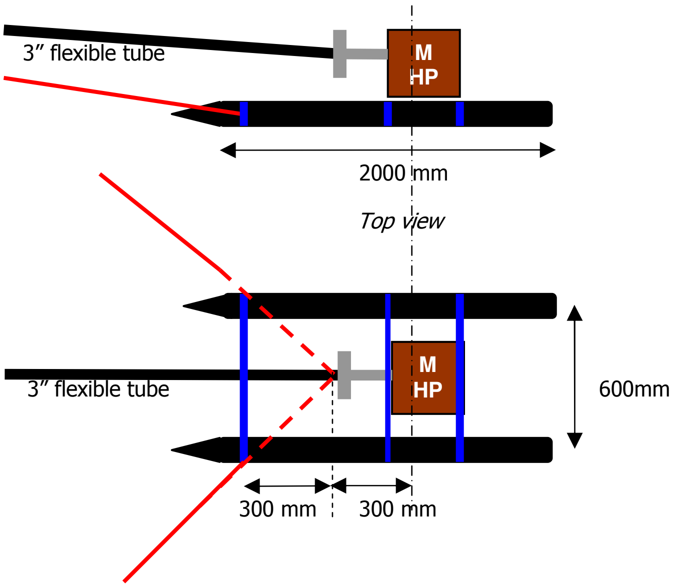
2.1.6 Floating micro hydropower to improve head

Under the given conditions, head loss of 0.5 m (8% head) reduces the generated power with ca. 16W (21% electrical power). So the impact of reducing head loss is significant.

If the alternator would be floating according to the drawings below, the head loss can be reduced to a minimum amount. Furthermore the equipment is protected against severe floods. The major part of the equipment can remain exactly the same as for the stationary design. Only the supports have to be replaced with the floating system.



Side view



Top view

- Two floating pillars of 200 mm diameter are used.;
- The blue frame should connect the pillars firmly, and should have mounting holes to fixate the micro hydropower;
- Two junction holes to connect the red ropes should be mounted on the sides of the floating unit;
- The two red ropes should make an angle of 45° with the shore to prevent horizontal oscillation;
- Distance between mounting holes at the shore: 2,8m;
- Maximum length of the flexible hose should be 3m. Head loss amounts to 0,23 m;
- The bottom of the runner should be approximately 15 cm above the water level;
- Total downward force amounts to 720 N. The two floating pillars should be 2,3 m in length, resulting in an upward force of 1450 N;
- Connection to the main pipe: 200 mm Y-piece with flange for 3" flexible hose and end piece at the straight side.

2.2 Optimizing long distance electric power transportation

2.2.1 Where to place the long wires?

When the generated current is substantial, power losses in the cables become important if the generator is not close to the user. One needs to choose where to place which component, and choose the proper cable thickness. Below a case is discussed for a total distance between a 12V alternator and a user 150 m away, with an average power consumption of 120 W.

Alternator	Voltage regulator	Battery	Inverter	User

Ideally, all components are placed close to each other. If a distance should be chosen between one of the components, there are the following options.

Distance between Alternator and Voltage regulator
The battery gets best loaded when the voltage is around 14.4 V. Since the alternator is not designed to produce much higher voltages, it is technically impossible to load a battery when the voltage drop over the wire is too large. It is not likely to get a working system when the voltage drop is larger than 2 V. If the resistance of the cable is too high, the only solution is a higher voltage alternator or a lower voltage battery & user circuit. In the case of a Maruti alternator, the voltage regulator is built-in.

Distance between Voltage regulator and battery
The components are designed for a cable resistance of 0,028 ohm to the battery. If the resistance of the cable is too high, an improvement can be to let the voltage regulator be regulated by an additional wire that comes from the battery. The constraint of point 1 remains valid.

Distance between Battery and user
The user might have a variable consumption, and so may the current and losses be variable. As long as generated power is very spare, one would not easily accept a power loss of more than 10%.

If the power loss in the cable is larger than 10%, there are the following options:

- Accept it; you only need little power, if necessary at a lower voltage;
- Buy an inverter that delivers 230 V. Current will drop to 0,5 A, which means that the allowable cross section is 20 times lower.

Abovementioned constraints result in the table below.

	Wire thickness between (power load: 120 W, 12V)					
Distance* (m)	Alternator and voltage regulator		Voltage regulator and Battery		Between Battery and user	
	mm2	mm	mm2	mm	mm2	mm
2	2,5	1,8	2,5	1,8	2,5	1,8
3,2	2,5	1,8	4	2,3	2,5	1,8
4,8	2,5	1,8	6	2,8	3	2,0
10	4	2,3	12,5	4,0	5	2,5
100	18	4,8	125	12,6	15	4,4
150	27	5,9	190	15,6	21	5,2
250	44	7,5	315	20,0	36	6,8
Constraint:	Max. voltage drop 2V		Resistance = 0,028 ohm		Max. powerloss 10%	

* values in this table account for double wire length: to AND from destination

Notes:
- The 'mass' or 'ground' does not have to be isolated, so that the distance can be doubled (cross section halved) when the ground is made from cheaper material, e.g. some thick metal construction that might be available, like a steel bridge over the river.
- With twice the current you need twice the cross section (NOT twice the thickness!).
- With an alternator of 24 V you need half the wire cross section at 120 W.
- The specific resistance (0,0175) of copper used in this table: R = 0,0175 * l / A.
- Prices Netherlands, 2008:

:

Cross section mm2	Price Euro/m
1,5	0,4
2,5	1,25/2
4	0,92
6	1,14
16	4,91
25	6,6
35	8,16

2.2.2 Options for long distance electric power transportation

12V transportation is poor
In the Hamro Gaun village, the distance between alternator and user is 100 m and power to be transmitted is larger than 120 W. Required cables are unacceptably expensive. We do not have more water power (minimum is 13 l/s @ 6.2 m) during the year and we desire to use the maximum possible power. On a daily basis there is some power from the local grid available. The following options were considered.

With 24V the cable cross section can be halved with the same power loss
If one would desire to use 12V, the voltage can be easily split at the user side to 2x12 V when transportation voltage is 24V.
We choose not to do so because:
1. This would require a 24V alternator that needs more water power. 13 l/s @ 6.2 m supply might not be sufficient, and the runner (schoepenrad) would need to be redesigned.
2. Superposition of the voltage of two 12V alternators would be impossible under the considered (wet) conditions.
3. Wire requirements are still exotic: probably hard to find and expensive.

Transportation of the battery
The battery can be manually exchanged with a second battery and vice versa.
We do not choose for this option because:
- Use of an additional expensive battery is needed;
- Exchange should be done regularly by someone;
- When using a 100Ah battery, the battery needs to be exchanged twice a day when the average current that is used amounts to 10A (120 W);
- Battery life will shorten extremely when it is completely emptied frequently.

Conversion to 230V AC
The total power loss would be in this case below 10% caused by:
- Inverter loss: 8%
- Power loss in wires of 2,5 mm2 amounts to 0,5% (for 0,8 mm2: 1,6%); at 150 m, 120 W.
- Some additional losses of devices that need to bring down the voltage again, like laptops, etc. (see 'Power consumption of devices').

Disadvantages are:
- Additional investment of approx. 100 euro for the inverter is required (but wires will be much cheaper);
- Special care should be taken for the voltage risks.

We choose for this option, because:
- The users only need one type of devices and connectors, working at 230V;
- Sometimes even more power can be used when the local grid is enabled;

- In case of maintenance we can have local grid power at the alternator downstream;
- Still energy efficient devices at 12V can be used when they are placed close to the battery;
- If available anyway, the wire price per meter will be 4,3 euro lower. We have more (and necessary) power efficiency for a lower price.

Connection with the grid
If you have power, and the grid is working, why not deliver 'back to the grid' and earn money? We decide not to choose for this option because:

- We have little water power and want to use all the power that is generated. Any excess of alternator power (also during up-time of the local grid) will be used to load the battery;
- We need to negotiate with the power supplier.

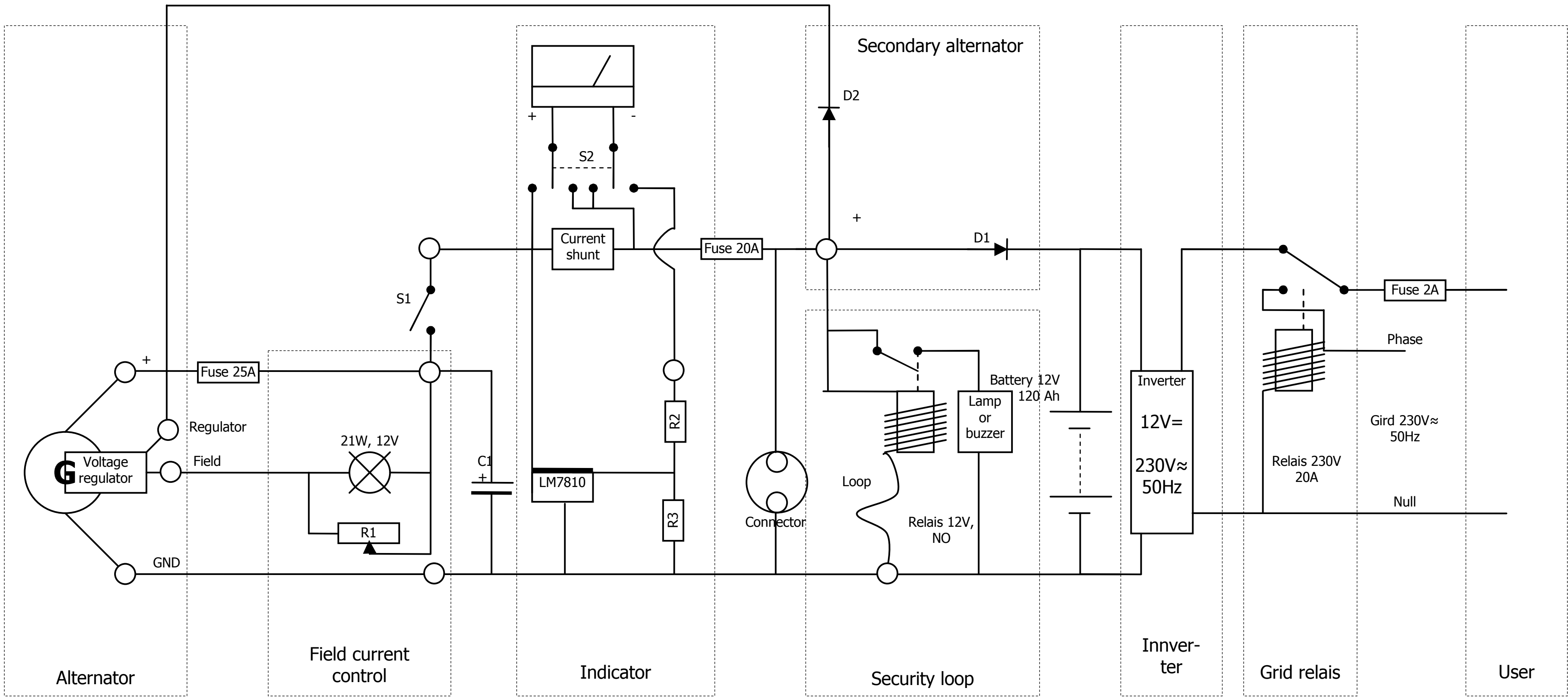
2.3 Electric circuit

Basically, the electric circuit consists of just an alternator and a battery. However, additional components are either recommended or required under specific conditions. Below the electric circuit for the Hamro Gaun project is drawn, including an overview of when/why components are used.

List of components

R1 100Ω, 60W, potentiometer	To reduce field current
R2 100Ω, 0,25W	To adjust range to 10-20V of 0.6Ω indicator
R3 214 ohm, 0,5 W	To set indicator offset to 10V
C1 Elco 100µF	Recommended to compensate for voltage spikes
D1 SKR45-1200 (20 A)	To install hydropowers in parallel
D2 1N4001	Used when D1 is there
S1	Main switch, 20A, enkelpolig
S2	Switch indicator: Tweepolig, drie standen
Lamp 12V 21 W, including fitting	To reduce field current
LM 7810	Makes offset voltage 10V for indicator
Indicator 100mA, internal resistance 0.6Ω	Used for the indicator
Current shunt 0.003 Ω, 1.5 W	4 x 194 mm copper wire, 0.6 mm
Fuse 16A	In-wire, porcelain (recommended)
Fuse 20A	On-board, plug-in (recommended)
End-user fuse 2A	
Connector 12V	For local power use
Battery 12V, 50 - 120Ah	
Relais 230V, NO+NC	To switch to local grid when available
Relais 12V, NO	To enable warning device
Lamp or buzzer	For security loop

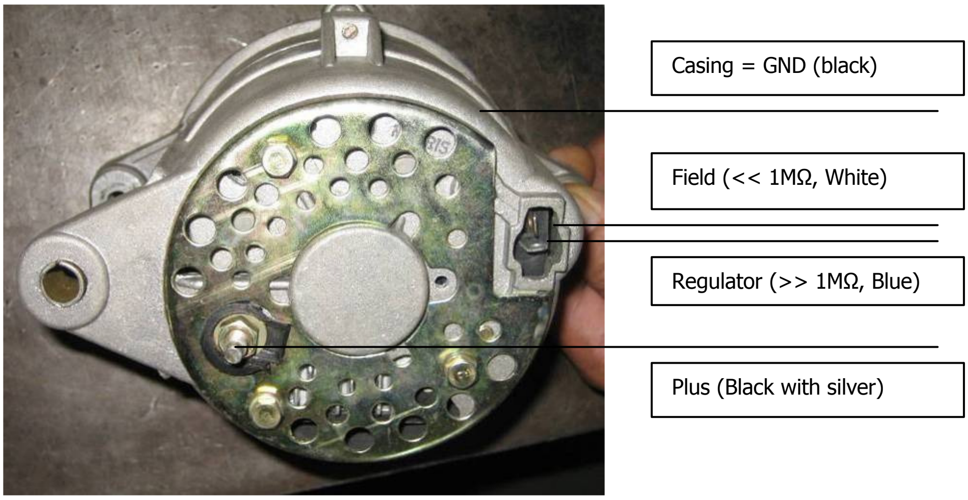
Take care of proper wire thicknesses as discussed in the former section.



Secondary alternator
D2
+
-
S2
+
Current shunt
Fuse 20A
D1
S1
+
Fuse 25A
Regulator
21W, 12V
Field
Voltage regulator
G
C1
+
LM7810
R2
R3
Connector
Loop
Relais 12V, NO
Lamp or buzzer
Battery 12V 120 Ah
Inverter
12V=
230V≈ 50Hz
Fuse 2A
Phase
Relais 230V 20A
Gird 230V≈ 50Hz
Null
R1
GND
Alternator
Field current control
Indicator
Security loop
Innver-ter
Grid relais
User

2.3.1 Alternator connections

The alternator used is of a Suzuki Maruti 800. This type of alternator has a built-in voltage regulator.



The regulator wire should measure the voltage at the location of the battery pole, in order to regulate the proper loading voltage of 14.4V.

2.3.2 Field current control

The field current should be reduced by a (pair of) series-resistor(s) for the following reasons:

- When the alternator starts running or has low water power, too strong field currents might block the alternator to turn;
- Without resistance the field consumes substantial power (approx. 40W). Because the alternator was originally developed for higher rotation speeds, the efficiency is better when field current is reduced;
- The field circuit of the alternator is less vulnerable to damage when the alternator is not turning.

When de lamp lights up, this indicates that the field is enabled and that the alternator is loading.
In other applications a different resistor instead of the potentiometer can be used, since the 60W variable resistor (potentiometer) is an expensive and hard-to-get component. Attention should be paid to the power capability of the resistor (e.g. three parallel resistors of 10W in place of the variable resistor and lamp should do).

2.3.3 Indicator to measure voltage and current

The circuit of the indicator is optional. The current shunt for the used components should be 0.003 Ω. 4 parallel wires of thickness 0.6mm are used with a length of 194 mm. This makes the current indication range 0 – 20 A. Note that for voltage measurement the scale should be compensated for 500mV if diode D1 is in place. Calibrate the scale with a voltage meter.

2.3.4 Diodes for additional loading devices

When connecting two or more alternators in parallel (or when adding another loading devices like an battery loader), a high-current diode D1 is required. The systems can be joined at the battery side of the diode.

When only one single alternator is used, but is idle, the current flowing to the alternator should also be blocked. In that case the diode is also useful, because it makes it unnecessary to switch off the alternator manually using S1.

The voltage drop over the high current diode is 500mV. In both cases the diode D2 is recommended to 'fool' the regulator and acquire a proper loading voltage of 14.4 V. This is a low-cost component. (Do NOT use D2 if D1 is not there). Note that the resistance between the diode and the battery should be negligible (use short thick wires!).

When no secondary alternator is used, one may choose however not to use the diodes, since the costs of the high current type (20A) amounts to 10 Euro. Care should be taken that the switch S1 must be used in that case, when the alternator is not in use.

In order to provide the field with current a start-up button may be required to short- circuit the diode during start-up. For this testing is required.

2.3.5 Inverter to make 230V AC

- Switch off at battery voltage of 11 V
- Hoog rendement, zowel laag wattage als max. Ca. 500 W
- A cheaper version is available,\withou loading unit.

2.3.6 Grid relais to switch to grid when power is available

This relais is optional and can only be used when an inverter is installed.
Since power is cut on a daily basis, the user devices switch to the grid when power is available. All hydropower is then used to load the battery. When the power is cut, the relais switches to the hydropower.

2.3.7 Protection against theft and misuse

The security loop is optional. It can be installed to give additional warning signals if:
- The door of the power station is opened when the door is wired with the loop;
- Any cable is cut or part is removed that is provided with the loop;
- The generator is not working or is being removed (only if D1 and D2 are installed).

For the signaling the main battery or a small additional battery can be used (just in case the main battery would be removed as well).

Additional protection measures can be taken:
- A movement detector added to the security loop;
- Locked powerhouse;
- Fence around the system;
- High voltage wire around the system;
- 'Danger'-signs.

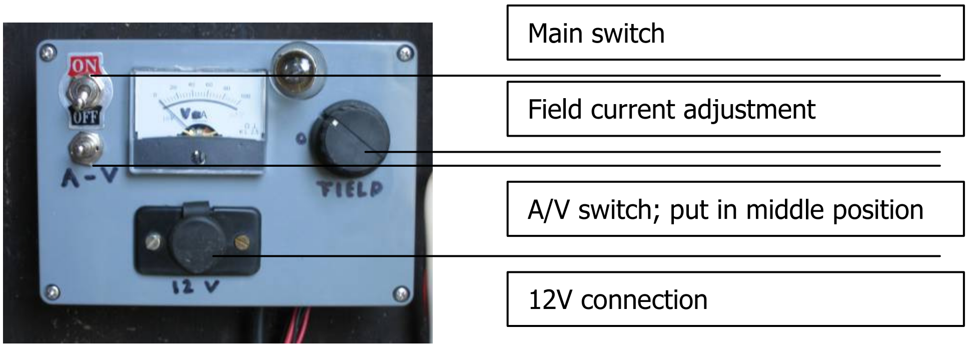
2.4 Installed equipment

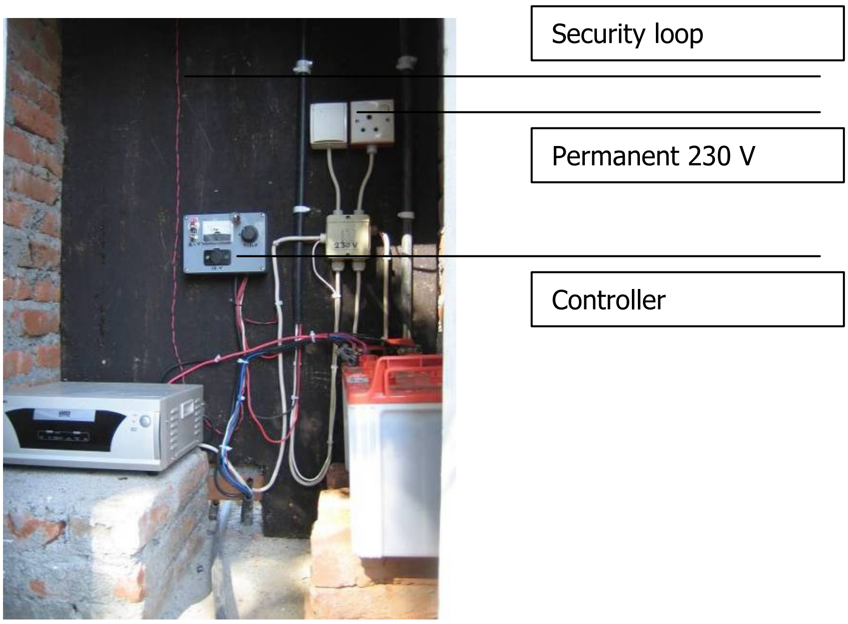
2.4.1 Differences with Portegijs design

Some improvements to the original Portegijs design were made:

- In-river tube instead of canal;
- Ventilation gaps at top of the generator housing;
- Wire inlet into the generator housing;
- Nylon washer at mounting side of the runner;
- Nozzle: fixture onto the frame, no hole in the nozzle;
- Messing as more durable seal material;
- Adjustable field current control;
- Simplification of the indicator electronics (LM 7810);
- Diode system for parallel alternators;
- Inverter to 230V;
- Grid relais to use grid power when available;
- Alarm system / Security loop;
- Floating system.

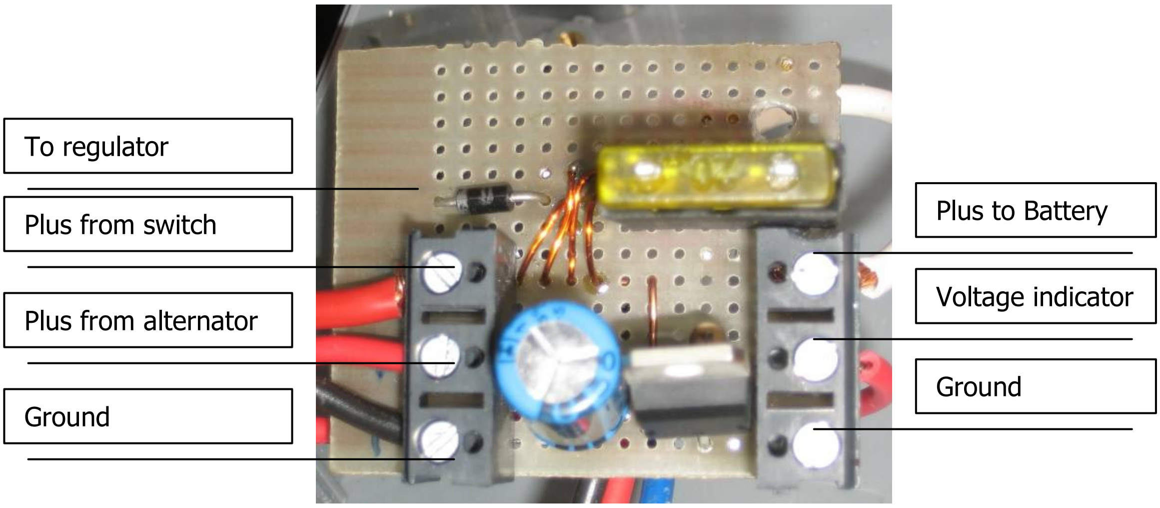
2.4.2 Power station and controller



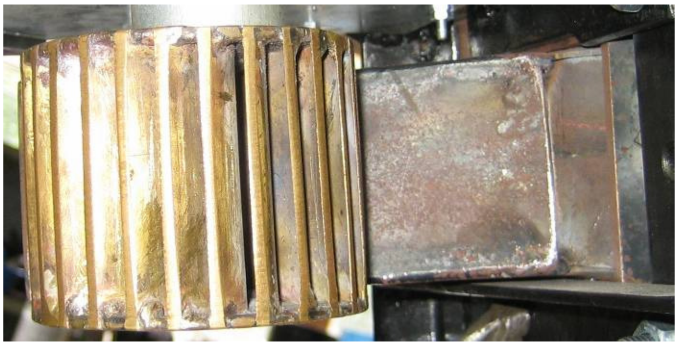


2.4.3 Generator connections

2.4.4 Circuit board in the controller

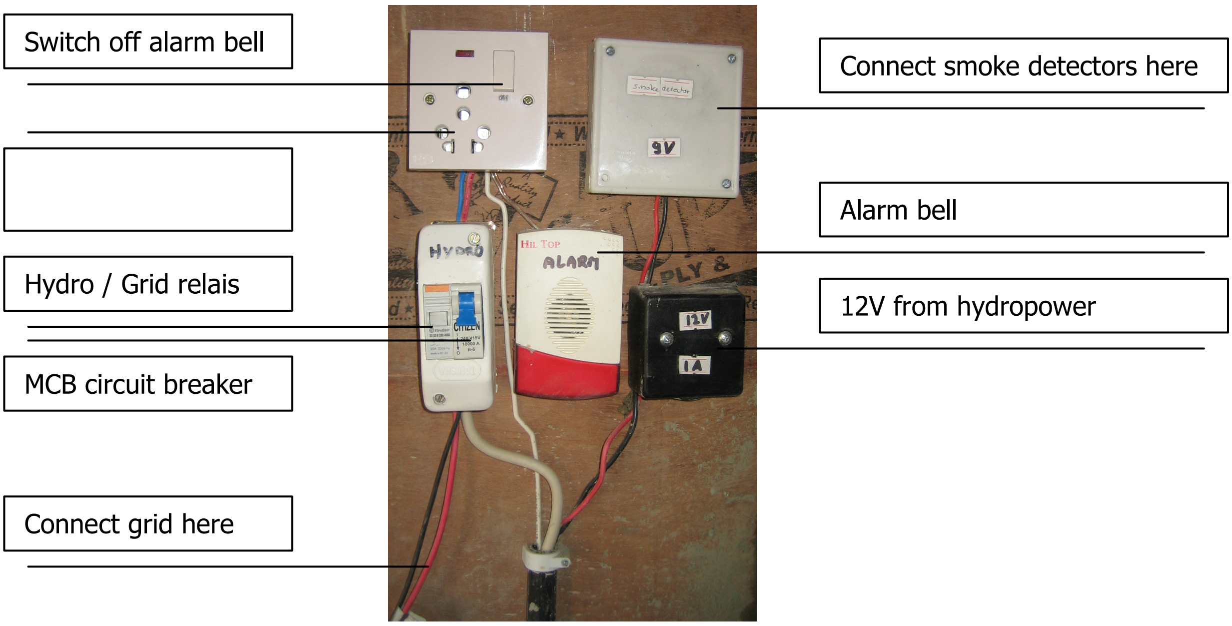


2.4.5 Runner and nozzle of the generator



2.4.6 Floating generator

2.4.7 Switchboard in the main building



2.4.8 Wiring to buildings

Six wires are connected to the main building:

Blue	Null
Brown	230V Phase from hydropower to main building
Yellow/green	230V Phase from main building to power station
Black	Ground
Red	Plus 12 V (max. 2A)
White	Alarm signal (230V)

2.4.9 Power losses of installed equipment

The generated power is limited. Theoretically max. 455 W is available, according to E = q * g * h, with q=7,5l/s, g=9,8 m/s^2; h=6.2m. Losses occur in every stage of the equipment:

Head losses	6,2	m					
Tube friction (20cm diameter)	0,06	m	1%	2	W*	
T coupling and narrowing	0,002	m	0%	0,1	W*	
Tube friction 3 inch hose (3m)	0,229	m	4%	7,4	W*	
Safety distance from river surface	0,20	m	3%	7	W*	
Nozzle, runner and alternator	unknown					
Loss electrical power equivalent:	*0,49*	*m*	*7,9%*	*16*	*W**	
Electrical power losses						
Wire to power station			2,3%	3	W	at 10A
Field current			9,1%	12	W	
Indicator			1,3%	1,7	W	current shunt + voltage inc
Wire to battery			1,1%	1,5	W	0.5 m, 10A
Security loop			0,9%	1,2	W	100 mA ?
Wire to converter			1,1%	1,5	W	0.25 m, 20A
Converter			8,0%	6,4	W	as specified
Wire to user			6,2%	8,2	W	90 m, 2A, 1,5 mm2
Total electrical power loss			*46,0%*	*35*	*W*	
Total delivered				80	W	
Total power delivered + lost				**131**	**W**	

* The equivalent electrical power can be deduced from the table in section 2.1: approx. 33W electrical power per m head loss.

- Still a substantial amount of power loss can not be retrieved in this table. Certainly the nozzle, runner and alternator account for a great deal of this loss, but are difficult to improve. Possibly efficiency can be improved by a redesign of the nozzle and runner, e.g. constructing side blades at the nozzle.
- The user load can be balanced with an intelligent system (BeNext).

2.5 Improvements

The following should be done:
- Improve tube fixation with concrete so that water can not flow behind or under it;
- Remake printed circuit board in the hydropower controller;
- Fence construction.

In order to gain more head, it is possible to elongate the tube upstream. The Hamro Gaun creek makes a height drop of approximately 1,70m at a distance of approx. 120 m before the dam to where the tube can be elongated. To save costs a tube diameter of 15 cm can be used instead of 20 cm, if no secondary hydropower will be installed. The resulting head loss is then 11%.

Extra head gain of 1m results in additional power of 32 W.

2.6 Usage

IMPORTANT NOTICE:
Switch off the main switch of the alternator if it is not running at full speed! If not, the field current will draw power from the battery and may get overheated.

2.6.1 Available power

The **maximum delivered power per day amounts to 2kWh** when the generator produces 80W (power * 24 hours).

The 120Ah battery can deliver 288W during 5 hours when completely charged. Hence the recommended **maximum peak consumption amounts to 288 + 80 = 368W**.

It takes 18 hours to recharge a completely empty 120Ah battery with 80W hydropower. But it is not recommended to completely discharge the battery, since battery life will be shortened dramatically.

2.6.2 Consumed power

The following components were installed.

	Amount	Power consumption (W)	Hours per day	Total (Wh)
1W LED Lamps main building	33	1	3	99
6W LED Lamps main building	10	6	4	240
Electric fence (schrikdraad), 12V	1	3	24	72
Fire alarm, 12V	1	1,2	24	29
Security loop (when activated: 155W)	1	1,2	24	29
Movement detector	1	0,8	24	19
Smoke detectors	18		24	0
TV 65W	1	65	3	195
Total power consumption per day (Wh)				**683**
Power cuts				60%
Total hydro power consumption per day (Wh)				410
Max. peak usage excl. 155W alarm (W)		164		

The hours per day are an estimated average. Power cut of 60% during usage is estimated.
For recommended peak power usage and allowable power consumption per day, see previous sub section.

2.7 Maintenance

Make sure the river bed under the micro hydropower is flat, so that it stands horizontally when there is little or no water.

2.7.1 Inspection of the filter system

The filters (upstream grid and the tube inlet) should be inspected visually every day and cleaned if dirt is present.

The tube inlet should be free of sand, so especially in the monsoon period remove the sand from the river frequently.

The fine grid of the tube inlet is subject to corrosion. Replace the grid every year (coarseness max. 1 mm).

2.7.2 Inspection of the battery

Check the condition of the battery every two weeks. The ‘water’ level of each of the 6 cells should be well above the metal plates. If this is not the case, add *distilled* water only. If the battery voltage is lower than 11 V, it should be reloaded or it is broken.

2.7.3 Reduced or no water power

If water power is reducing and there should be sufficient water, make sure the tube is totally clean at the inside, with the following procedure:

1. Switch off the alternator with the main switch;
2. Flush the river dam, so that no water enters the tube anymore;
3. Remove the end cap from the Y-connection just before the alternator;
4. If there is any dirt inside the tube, remove it manually;
5. Flush the tube by letting water into it at the dam side, for at least 10 minutes;
6. Flush the river dam again, so that no water enters the tube;
7. Restore the end cap and secure it tightly;
8. Let the water into the tube at the dam side;
9. Switch on the alternator with the main switch.

2.7.4 Reduced or no electrical power

If no or little power is available, check in the following sequence:

1. Check if the alternator is running properly;
2. Check the condition of the wire to the power station;
3. Check the loading Voltage and Current with the indicator:
   - If the loading current is high, power is consumed somewhere in the circuit. Turn off the alternator with the main switch and disconnect the battery. If the voltage is lower than 11V and the internal resistance of the battery is extremely low, the battery might be worn-out and needs to be replaced.
   - If the loading current is low and the voltage is above 12V, verify whether the inverter receives 12V power. If not, check the fuse in the inverter;
   - If there is no current and no voltage, check the fuse inside of he box, the in-wire fuse at the alternator and the alternator itself.
4. If power disappears a short time after a power cut:
   - Check how much power is consumed by all installed devices. Sum all consumed powers or measure the current;
   - If it turns out that the battery is getting empty quickly, verify first that the loading time and current (at the moment that there is no power cut) are sufficient to reload the battery completely (empty 120Ah batteries require 12 hours at 10 A). If the loading time and current are sufficient, the battery may be worn-out.

2.7.5 Adjusting the field current

The potentiometer can be used to optimize the loading current.

- This button should be at the default indication;
- If there is any doubt about proper functioning, check whether the set-off of the button is still correct, by turning it entirely to the left. The button should be vertically down;
- If the field current should be readjusted, switch on the current measurement of the indicator (I) while the alternator is running. Turn the button to the position where loading current is maximum.

2.7.6 Using the inverter to load the battery

The installed inverter has a built-in battery loader. If it is desired to load the battery in cases that grid s available, take good care of the following **to prevent damage**:

- **The alternator should be disconnected from the battery** after switching it off. The alternator and the inverter can only be connected in parallel to the battery if both systems are provided with a diode (see previous section).
- The supplied power to the power station must be disconnected from the power relais, so that the inverter does not 'load itself'.

2.7.7 Mechanical problems

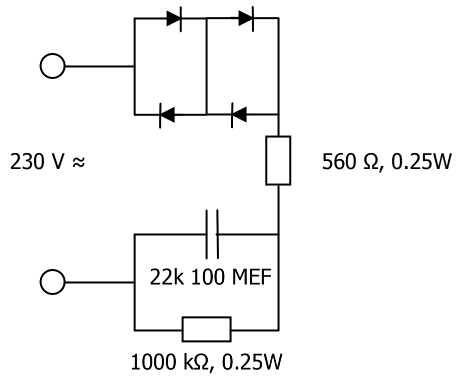
If mechanical changes or replacements should be made, the following address can be contacted:

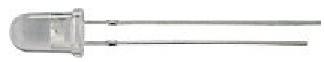
Sanepa, Lalitpur, Nepal
Solarpower.nepal@yahoo.de
Phone: 01-5523839 (Alois)
Email: stwnepal@mcmail.com.np

3 Low power devices

3.1 Design of a clustered four-LED lamp

It is intended to produce maximum light with minimum power consumption. Efficiency of LEDs is even higher than that of PL lamps. Problem is the required voltage of 3,4V. Available 230V lamps with a cluster of integrated LEDs are still expensive. A low-cost solution could be made with the following schedule:





Total power consumption of this system is approximately 2.4 Watt. The used components are low-cost, but still strong LEDs are costly. Prices of different white LED types, are:

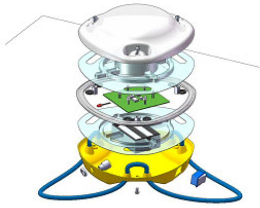
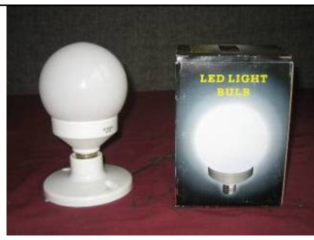
Luminous intensity (mcd = millicandela)	Emission angle	Specification	Price NL, 2008 (Euro)
Traditional coloured (3 mm)	60°	2.1V, 20mA	0.07
2,500 (5mm)	50°	3.6V, 20mA	2.44
10,000 (5 mm)	20°	3.2V, 20 mA	0.90
18,000 (5 mm)	20°	3.6V, 20 mA	1.60
30,000 (5 mm)	15°	3.3 V, 20 mA	1.99

These LEDs can cause eye damage when looking directly into the light!
To calculate cd (candela) to lm (lumen), divide the intensity (cd) by the factor below, depending of the emission angle:

Emission angle	*Divide by*
5°	167,22
10°	41,82
15°	18,50
20°	10,48
25°	6.71
30°	4,67
35°	3,44
40°	2,64
45°	2,09

3.2 Overview of low power 230V lamps

Currently LED technology is increasing. Prices start to drop and specifications have still a wide variety. Below some actual types of low power 230V lamps are listed as per October 2008.

	Luminous flux(lm)	*Power consumption at 230 V (A)*	*Color*	*Photo*	*Price*
Clustered LED lamps					
LED lamp 4 white LEDs 18000 mcd (for design details, see section 3.1.1)	7 lm	0.012	White		380 NRP
6 white LEDs (Kamworks design)	42 lm		White		
DP-124921-1, 3W 45 white SMD LEDs		0.013	White		
E27LB100, 1.8 W 27 or 70 LEDs (Sunsparkle)	250 lm (est.)	0.01 (approx.)	Warm white		25,50 euro
Decoled outdoor 1W G50 1CT (Philips)	5 lm	0.0043 (est.)	White		7,46 Euro
1 W IL R1W 22 LEDs (Interlight) 20W equivalent	35 lm	0.0043 (est.)	Warm White		6,45 Euro
6 WIL R1W (Interlight) 75W equivalent		0,0261	Warm White		
OSR LEDLAMP PAR16 2W E27 (Osram)		0.0086 (est.)	Clear white		20,00 euro
PL lamps (5 x more light than conventional lamps)					
PL lamp 18W (Myna) 100 W equivalent	810 lm (est.)	0.136			
PL lamp 5W (WIPRO) 25 W equivalent	225 lm	0.040	6500 K Cool daylight		110 NRP

In Nepal the ‘bayonet’ connection/fitting (B22) is used. Using the European screw fitting (E27) prevents users to connect other heavy-load devices.

3.3 Smoke detectors

A 9 Volt connection has been made from the hydropower in order to connect smoke detectors in the main building. The detectors of model 223/9HI (Kidde Fyrnetics / AJAX) were designed for use at 230V and fall back on the battery when power is interrupted. Since power consumption amounts to 20 W at the 230V connection, the power consumption is unacceptable when using hydropower. Power consumption with the backup-battery is however extremely low. Therefore the 9V connection should be used only. A wire for GND (black) and Plus (red) should be connected inside of the devices. The white connecting wire can still be used.

Regular check
Check the detectors for proper functioning regularly by pushing the *test* button. Because of the modification, the detectors always flash the red light (and not the green as stated in the manual). If a sound is heard every 30s, this indicates that there is a technical problem with the device.

Do NOT use batteries!
9V batteries should NOT be used in the smoke detectors that are connected to the 9V hydron power because of the modification! Make sure to disconnect the wired 9V power from the detectors first, before installing a battery.

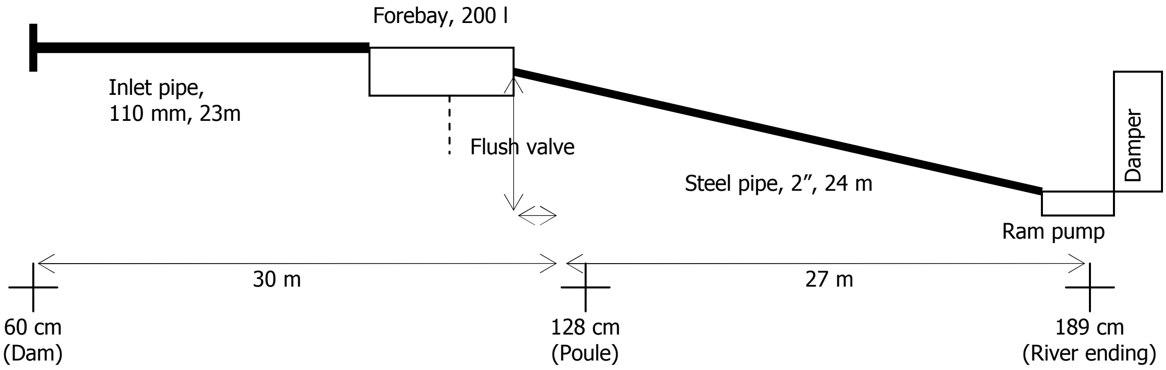
Using 230V
Still the smoke detectors can be connected to the mains (230V) if desired, e.g. when 9V hydropower is not readily available. It is important that the blue wire is connected to the NULL and the brown wire to the Phase (Life).

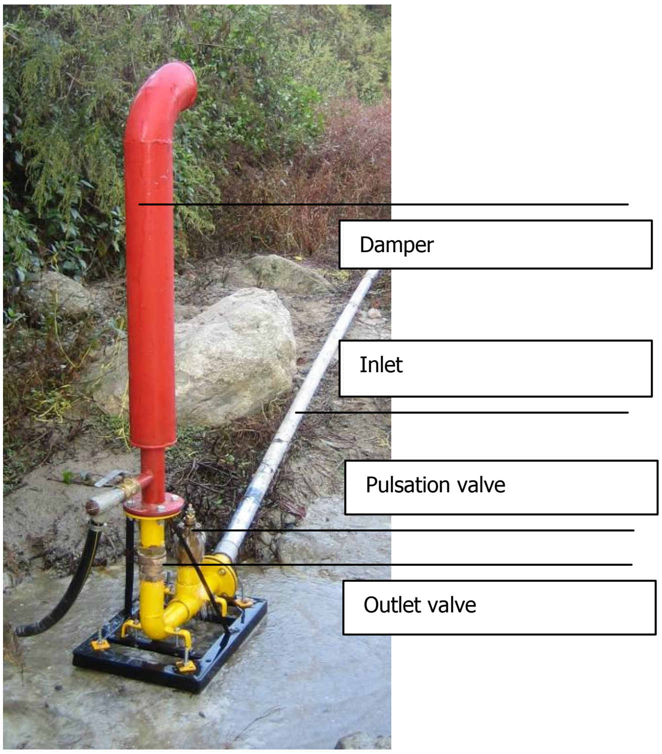
4 Ram pump

The purpose of the ram pump is to bring water from the river into the hills. The water is used for flooding the land. In return clean water from the hills is brought to the village for drinking purposes. The design of the ram pump is based on the 'Breur water-ram'concept and does not need any external power.

4.1 Installed equipment

Schematically, the system works as drawn below.



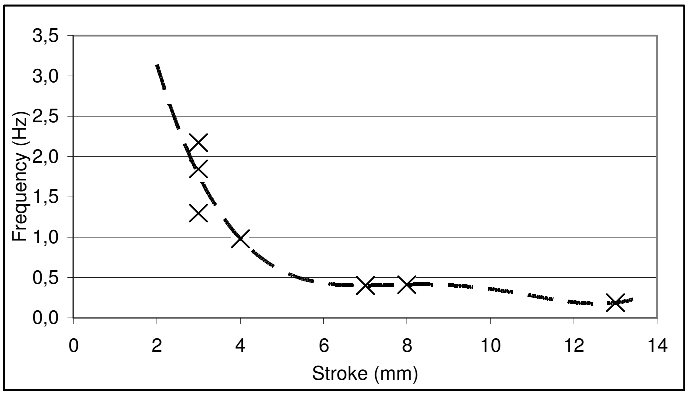


Water is flowing through the pulsation valve. The pulsation valve closes when the inlet water gains speed. The occurring pressure opens the outlet valve and water flows into the outgoing pipe. Pressure drops and the outgoing valve closes. The weight on the pulsation valve opens the valve, and the cycle restarts.

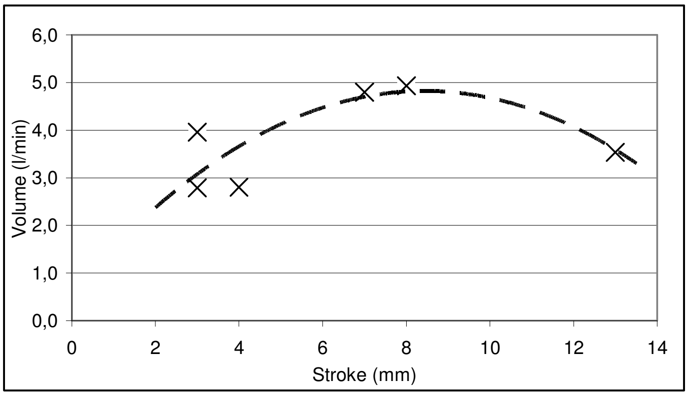
Design characteristics:

- Steel pipe length should be 500 times thickness;
- Maximum generated pressure 30 bar;
- Pumped volume amounts to approx. 10% of the inlet volume;
- Bolt connection of base frame onto concrete: 250 x 395 mm;
- Inlet pipe 110 mm polyethylene;
- Pump feed pipe diameter is 2". Outlet pipe diameter is 1";
- Pulsation frequency: approximately 0,4 Hz.

Measured characteristics with outgoing elevation of 5 m (0,5 bar) and with different stroke of the pulsation valve:



Frequency increases with smaller stroke.



Optimum output volume is at a stroke of 8 mm under the given conditions.

Measured output at 20 m (2 bar): 0,6 litre per minute (stroke: 10 mm).

Note that the pump characteristics are subject to several conditions.

1. Factors that improve outgoing water pressure:

- Longer stroke of the pulsation valve;
- More head / height difference of incoming pipe;
- More weight on pulsation valve.

2. Factors that improve water quantity:

- Frequency increase:
    - Decrease stroke of the pulsation valve;
    - More head / height difference of incoming pipe
    - Fewer weight on pulsation valve;
- Increase of quantity per pulsation:
    - More head / height difference of incoming pipe
    - Decrease height of outgoing pipe

4.2 Improvements

- Water inlet should be protected against damaging;
- It is necessary that the pump is protected against (big stones in) monsoon floods. It should be either placed into the ground, or protected by a wall;
- The barrel should be improved and fixed;
- The steel pipes should be fixed at three points with concrete against floods and theft;
- The pump can be placed in a closed well, with an outgoing pipe loosing water downstream. This will improve head and therefore incoming pressure.

4.3 Usage

4.3.1 Starting up the pump

- Close the pulsation valve by putting it in the upper position;
- Let the forebay be filled with water until the level is well above the outlet and no air bubbles are coming from the steel pipe into the forebay anymore. It is absolutely important that no air is in the steel pipe;
- Close the outgoing water tap and let the pulsation valve make max. 10 pulsations. NOTE: the outgoing water tap should not be closed longer, since the pressure can get very high;
- Open the outgoing water tap. If the up going water is not up to 5 m high in the outgoing pipe, it can be that the pulsation valve is not properly working because the pulsation valve needs 0.5 bar or more 'backpressure' in the outgoing pipe. So, during the first pulsations it can be that the valve must be opened manually several times.

4.4 Maintenance

Note: The small hole in the outlet valve is necessary to suck air for 0,1 s per cycle. This air is needed to fill the damper with air. So keep this hole open!

4.4.1 Daily

- Check the water inlet at the dam side. It should be clear from any kind of dirt;
- Check if the pump is working properly.

4.4.2 Weekly

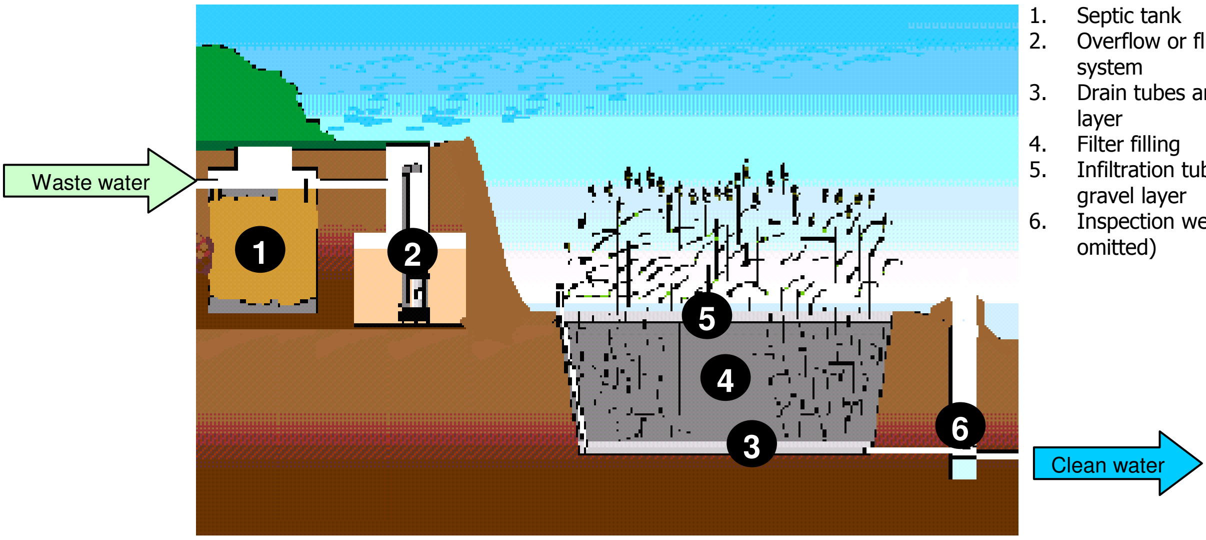
- Check the barrel (forebay). It should be clean from any dirt. If sand has deposited in the barrel, clean it, by taking out the plug at the bottom;
- Check the fixation of the equipment to make sure that river water is not washing away any part;
- Check if the pulsation valve is completely clean. It can be necessary to dismount it.

5 Helophyte filter

The purpose of the helophyte filter is to:
- Turn waste water into absolutely clean water;
- Clean the water in a cheap and environmental-friendly way.

5.1 Design

The typical construction of a filter system is drawn below:



1. Septic tank
2. Overflow or flush system
3. Drain tubes and gravel layer
4. Filter filling
5. Infiltration tube and gravel layer
6. Inspection well (can be omitted)

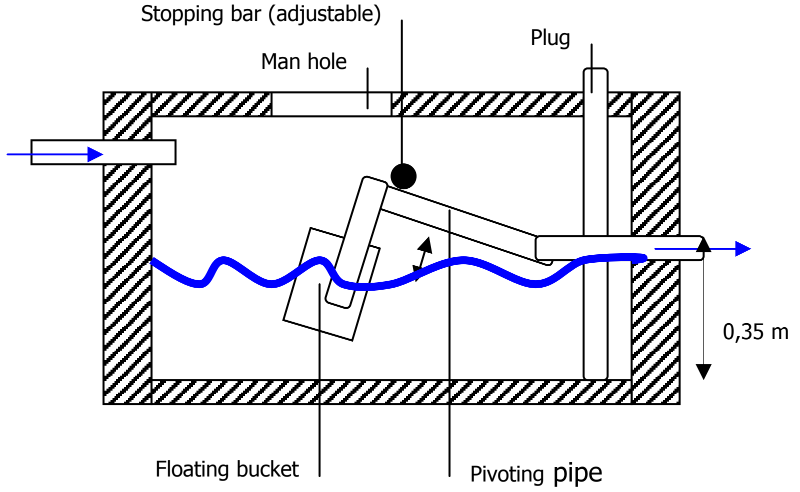
Waste water production is estimated at 3600 l/day;
- Generally a Dutch person produces 150 l waste water per day.
- Because the toilet waste water is entered into the biodigester and the water usage is much less for a Nepali person, the estimated waste water per person per day is 30 l/day in Hamro Gaun (120 persons).

5.1.1 Septic tank

The septic tank has been installed in compliance with drawing 'Septic tank 6.dwg' (June 2007). The total volume of the tank amounts to 10m^3 (1m20, 4.8m (16'), 2.4 m (8')).

5.1.2 Overflow or flush system

The flush system consists of a buffer well with a floating bucket (height 31 cm). A pivoting bended pipe is coming into the barrel and moves with the barrel; they are attached to each other. When the bucket is at it highest point, the bucket is stopped by a bar and fills with water. Then the barrel sinks and a pipe sucks out all the water until the water is flown out. A plug is required in order to empty the buffer to enter it for maintenance.



Dimensions:

- Length of buffer: 2,4 m
- Width of buffer: 0,9 m
- Inner height of buffer: 1,5 m
- Pivoting pipe: 1,7 m

The overflow system should flush every 3-4 hours. Since 3600 l waste water is produced during daytime, the flush volume amounts to 750 l per cycle. The stroke of the pivoting pipe should be between 0,31+0,14 (50 persons) and 0,31+0,46 cm (150 persons).

5.1.3 Filter system

A vertical filtration system is recommended. Horizontal filters require more surface area and have lower cleaning capacities.

The vertical filter can be built in the following steps:

- Dig out 1 m deep at a total surface area of 70m^2. (Approximately 1m^2 is required per 50l daily waste water).
- Build a wall around and under the filter bed. Make sure the filter bed is not flooded by rain water. You might need to dig a canal around it to redirect flooding water.
- Apply strong foil (0,8 mm) at the bottom and sides. You might decide to construct the floor and walls from concrete instead;
- Install drain tubes (distances...?). Slope 0-1%.
- Coarse gravel 50-70, mm layer, 20 cm thick
- Root cloth (Worteldoek) can be applied. This makes removal of the sand easier after several years and prevents migration of smaller gravel into the coarse gravel;
- Fill 60 cm with proper composition of sand (0,25 mm max. 2 mm). Mix with;
    - 0-10% calciumcarbonate
    - 1,5% mass percentage oil-free iron granulate (<5 mm) in upper part;
    - Max. 10% clay or straw in lower part, if it is free from humus (1 baal stro per 10 m^2).
- Coarse gravel 8/16 layer 15 cm thick;
- Install infiltration system 20 cm above the bed at a slope of 0%. Piping grid: 304 inch with holes at the bottom of 10 mm every 20 cm. At the end of the pipes make a vertical up going pipe of 1 m.. For maintenance purposes make sure the pipes can be dismounted;

- Plant young reed plants: 6 plants per m^2. Recommended plants are (a.o.): Riet (Phragmites Australis), Mattenbies (Scirpus lacustris) and Grote lisdodde (Typha latifolia). At the Sankhu hospital plants are used that can be found in Nepal. For some plant properties, see table below.

Eigen-schap	riet	matte-bies	grote lisdodde	kleine lisdodde	gele lis	rietgras	liesgras
Water-diepte	0.5 m	0.5-1 m	0.25 m.	0.50 m	<0.25 m	<0.25 m	<0.25 m
Groei-snelh.[1]	gering	gering	snel	snel	snel	snel	snel
Sten-gels/m^2	veel	veel	weinig	weinig	weinig	veel	veel
Diepte wortels	diep	diep	ondiep	ondiep	ondiep	ondiep	ondiep
Omvalle stengels[2]	niet	niet	wel	wel	niet	niet	wel
Legeren	moeilijk	moeilijk[3]	vlot	vlot	moeilijk	moeilijk	vlot

[1]= tijdens de opbouwfase, m.n. in het eerste groeiseizoen
[2]= tijdens de winter
[3]= gemakkelijk bij wisselende waterstand

At the Sankhu SKM Hospital, a filter is operating with the following properties. 1 horizontal filter, 2 vertical filters : 70 cm deep; 15 coarse, 40 fine and 15 coarse gravel. Note that this system was originally designed for 100 individuals, and is currently used by more than 200. Additional vertical filters have therefore been installed. The maintenance engineer of the SKM hospital is willing to help with the installation of the filter: Purusottam (cell phone 9841307213). It is recommendable to reinforce this contact.

5.1.4 Characteristics

The chemical composition of water from a properly working filter system has the following typical values:

	Influent concentration (mg/l)	Effluent concentration (mg/l)	Dutch effluent norm (mg/l)
Biochemical Oxygen consumption in 5 days (BZV)	279	6	40 (IBA 3)
Chemical Oxygen consumption	635	44	200 (IBA 3)
Total Phosphor	1	4.6	6 (IBA 3b)
Total nitrogen (including NH_4-N, NO_3 and NO_2)	82	53	60 (IBA 3)
N-Kjeldahl	81	5	-
NH_4-N	53	3	4 (IBA 3)
Floating dust	90	18	60-200
E-coli	17693	31	-
Oxygen	0.5	5.5	-

5.2 Installed equipment

Septic tank

5.3 Usage

- Strong detergents, oil products, paint products and ontstoppingsmiddelen should NEVER be used;
- The use of chloric substances should be limited to a low amount; some is acceptable;
- Regular cleaning chemicals like washing powder/ -liquid are allowed.

5.4 Maintenance

- Weekly removal of any dirt or leaves from the filter;
- Regular verification of condition of the plants;
- First year: regular removal of unwanted plants/weeds;
- Every year: empty septic tank;

- Once or twice a year (October and April): cutting of the reed. Keep one rod per plant unremoved;
- The filter can get saturated with phosphates after 25 years use. In that case the soil should be replaced. The saturated soil can be used as a fertiliser.
- Samples can be taken to be analysed in the Netherlands (e.g. by ECOFYT) to verify the quality of the filter.

Troubleshooting

- Suffocation of the filter:
  - Insufficient sedimentation in septic tank;
  - Filter is too anaerobe;
  - Too much waste water is flooded;
- Colouring of the filter or dieing of the plants:
  - Toxic materials occur in influent or in filter. Analyse influent and effluent.

6 Biogas power generation

In Hamro Gaun biogas can be produced from kitchen waste, cow dung and plants like rice straw.
The controlled generation of biogas has many advantages:
- Treat waste in order to reduce pollution;
- Reduce emission of the greenhouse gas methane;
- Energy consumption of cooking gas and electricity can be reduced.

Note: an alternative to biogas digestion is the production of briquettes out of manor.

6.1 Design

6.1.1 Bioreactor

A fixed dome bioreactor can be installed in compliance with the supplier's document 'Bal Khsetra Nepal 35m^3 reactor'. The supplier is responsible for a proper start-up of the fermentation process during the first year.

Typical specifications of this installation:
- Reactor volume: 35 m^3
- Operating at ambient temperature;
- Typical gas production when the reactor is completely loaded: 6.5 m^3/day, equalling 0,5 LPG cylinder or 12 kWh electrical power;
- Retention time approximately 100 days;
- Efficiency raw gas production: 0.05 m^3 per kg;
- Inlet mixer: 1kW.

The typical load of a reactor of 35 m^3 is 250 kg cow dung (25 cows) and 250 l water per day.

In efficient, modern, large scale reactors between 0.5 and 1 cubic metres of biogas can be extracted from 1 kg of dry organic material, depending on the substrate. Digesting only manure will produce ca. 1 cubic metre of biogas per cubic metre of reactor volume per day, whereas much more can be produced (2 to 3 m3 biogas per m3 per day) if more energy-rich substrates are used, for example different crop residues and food wastes.

Three outputs are generated:
- **Biogas:** As discussed in the next section. Biogas can be combusted for refrigerating, cooking, lighting or electricity production purposes.
- **Digestate:** The Digestate or slurry can be used as a fertiliser, to feed plants or fish. In China earthworms were cultured with the slurry to feed chicken. The Digestate contains Phosphates, Nitrates and potash. If the digestate contains too much ammonia, this can be harmful for plants.
- **Effluent:** The wastewater contains a high amount of oxygen demand, and can be further treated in the helophyte filter or can also be used as fermentiser.

The efficiency of the reactor is best when placed in the sun.

Typical costs of a bioreactor amount to 5000 NRP per m^3. Subsidy can possibly be obtained from the Nepal Government, amounting to 6500 NRP (sept. 2006). **According to the book 'Renewable energy technology in Nepal', the total cost of the 35 m^3 reactor should not exceed 180,000 NRP!**

6.1.2 Biogas conditioning

Typical composition of dried biogas:

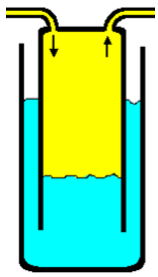
	Vol %
Methane, CH_4	50-75
Carbon dioxide, CO_2	25-50
Ammonia NH_3	1
Nitrogen, N_2	0-10
Hydrogen, H_2	0-1
Hydrogen sulfide, H_2S	0-3
Oxygen, O_2	0-2
Other	0.2

For the combustion of biogas, especially when using a power generator, it might be necessary to improve the gas quality:

1. Water vapour is present in the biogas, making it more corrosive and reducing combustion temperature. At least in a simple way water must be removed, e.g. by removing condensate in the storage tank. Additional drying can be recommendable.
2. Hydrogen sulphide (H_2S) gas can harm installations, because it is corrosive. If concentrations are too high, addition of $FeCl_3$ to the digester could reduce the production of this gas.
3. Volatile siloxanes can be harmful to the engine since abrasive SiO_2 can be created during the burning process.
4. Ammonia may be present in the gas. Ammonia has corrosive properties.
5. With a lower CO_2 concentration, the caloric value (total energy per m3) can be improved. Different methods to remove CO_2 exist. Water washing is the most used. The method is based on the fact that carbon dioxide is more soluble in water than methane.

6.1.3 Storage tank

The gas can be compressed and stored in a tank. The compressor should start compressing at an inlet pressure of 0.5 bar and pump until the pressure drops to 0 bar. Compressed gas should reach a pressure of 3 bar. Flaring of excess biogas might be necessary if gas production is larger than gas consumption. The recommended tank capacity is 15 m^3.



A pump less solution to buffer the gas (and hence without electrical power) can be to build a tank which is open at the bottom. If the tank is placed in a water basin, the water is pushed downward. The maximum pressure is reached when the tank is full. If the water level difference is 3 m, pressure is 0,3 bar. This solution is therefore suitable for low pressure applications. See the specifications of the combustion devices.

6.1.4 Gas combustion

- Combustion devices for cooking and for power generation should be suitable for biogas;
- From the generator ca. 2 kW electrical power is required;
- Dual combustion engines (Kirloskar, USha) exist, that burn both diesel (40%) and biogas (60%). **For power generation, further desk research is required.**

6.2 Maintenance

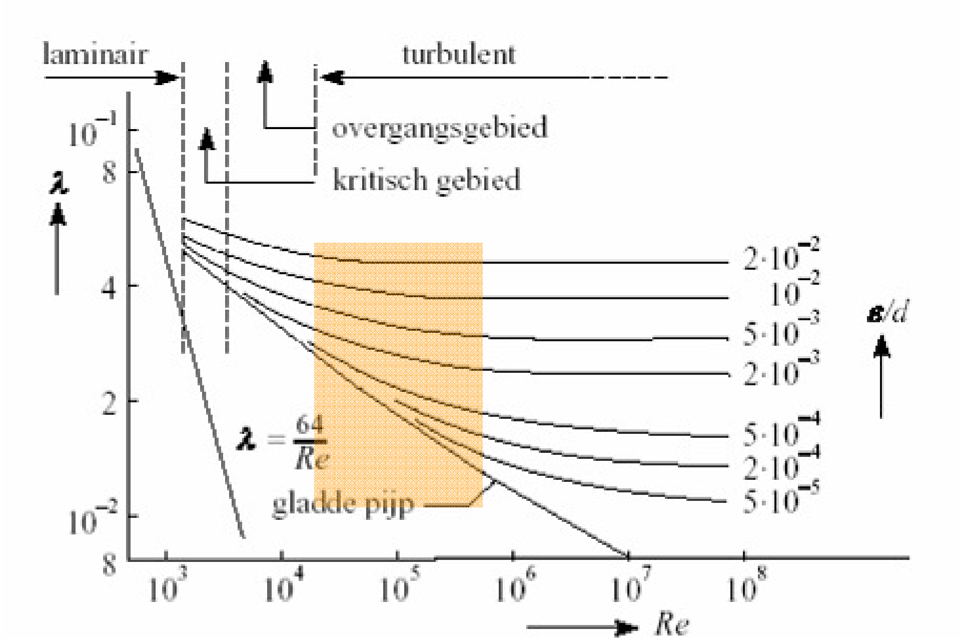
In general the following should be taken into account for a proper functioning of biogas equipment. Please refer to the manuals of the installations for further details.

- pH should be between 6.5 and 8 (7 is best). Foam production is an indication of potentially low pH (acidification);
- Since there is pressure in the digester, it is essential to check regularly that there is no leakage;
- The optimum reactor temperature is 35-41°C (Mesophilic). Below 10°C fermentation stops. If the temperature is much lower in the winter period, isolation (e.g. with rice straw) may be usefull. Also, compost addition increases the fermentation temperature. The inlet dung can also be pre-heated in the sun.

If gas production decreases, and aforementioned aspects are taken into account, this may be caused by:
- Very low temperature;
- Too salty (measure this by determining the electrical conduction of the slurry);
- Toxic materials.

7 Appendix

7.1 Resistance factor λ for cylindrical tubes



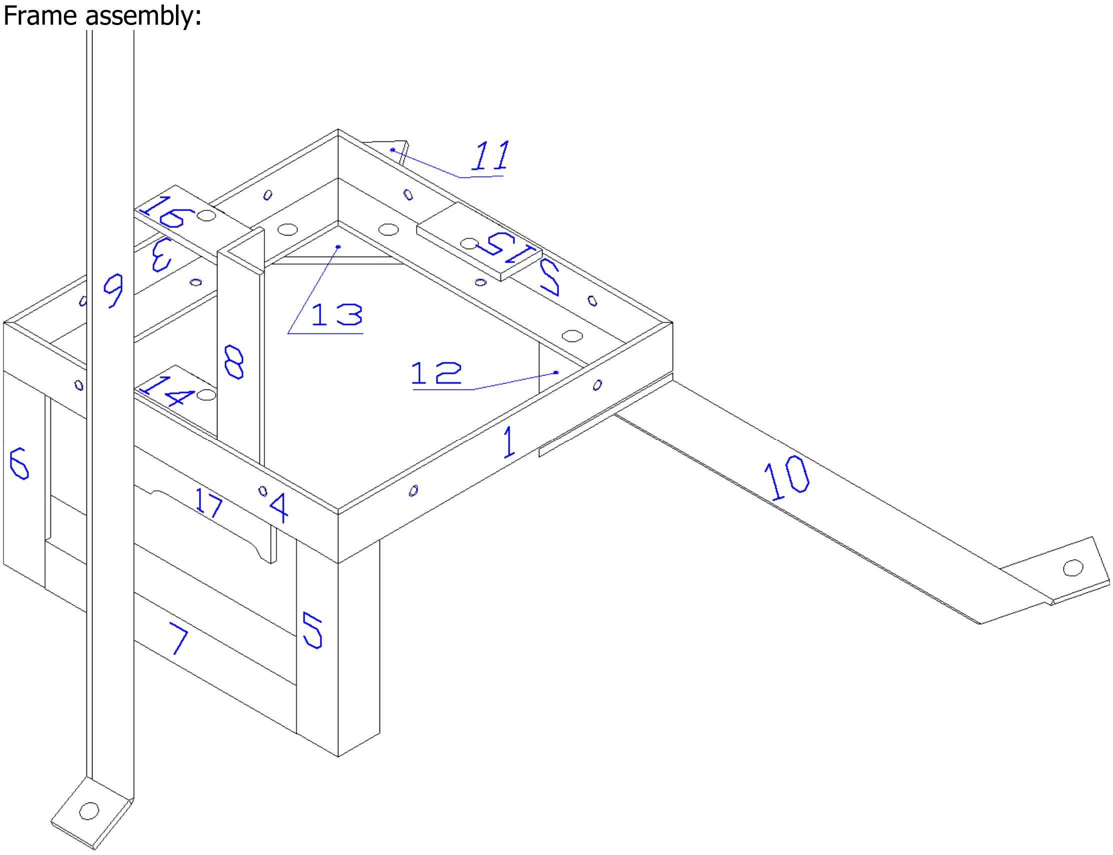
7.2 Power consumption of devices

	Buffering device; more suitable for interrupting power	Power consumption at 12 V (A)	Power consumption at 230 V (A)	Power loss at 230V (W)
LED lamp 4 white LEDs 18000 mcd		0.03 (est)	0.012	2.1
LED lamp DP-124921-1, 3W 45 LEDs, white			0.013	
LED lamp E27LB100, 1.8 W Warm white			0.0078	
1 W IL R1W, 22 LEDs, (Interlight)		0.0043 (est.)		
PL lamp 18W (Myna)			0.136	
PL lamp 5W			0.038 (est.)	
Smoke detector			0,080	
TV (12V: 37 cm 35W)		3		
TV 65W			0,28	
Sewing machine				
Small deskfan		0,35		
Electric fence (schrikdraad)		0,25		
Immersion heater 120W		10	0.5	none
Refrigerator 40 l, 105W	B	8.75		
Big refrigerator 100W; 0,7kWh/day	B		0,13	
Laptop power supply (Toshiba SP1600)	B		0.6	
Loading device PDA / mobile phone / camera	B		0.120 (Nokia)	
Cordless drilling machine	B			
Devices with batteries / adapter	B			

Values are indicative and brand/type dependent

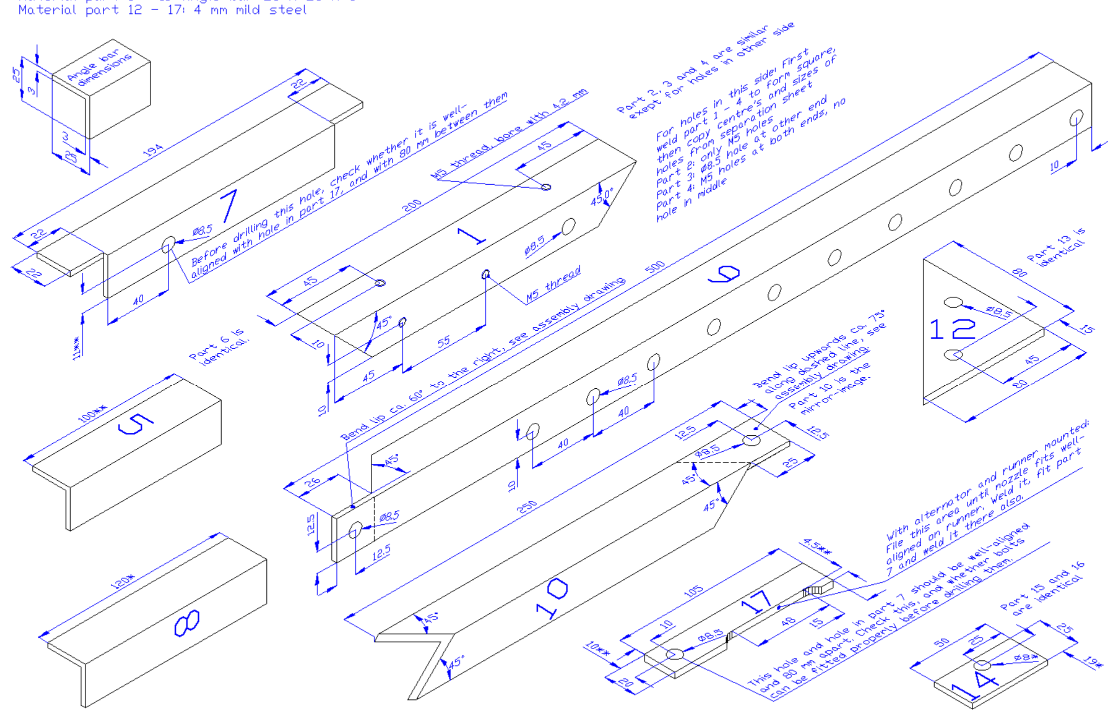
7.3 Frame dimensions hydropower

Frame assembly:



Frame parts:

Material part 1 - 11: Angle bar 25 x 25 x 3
Material part 12 - 17: 4 mm mild steel



Dimensions with '*': Adapt to connection points of alternator. The shaft should pass through centre of separation sheet and parts of seal should run free. If the alternator is too big, fit it with connection points diagonally in square (part 8, 14, 15 and 16).
Dimensions with '**': Adapt to distance of separation sheet to pulley rim (part 5, 6, 7 and 17).

Because of angled view: scale is different for different directions. Along main axis: scale 1:2.45

For other dimension see the Portegijs documentation.

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- Polytechnisch zakboekje

7.5 Addresses

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solarpower.nepal@yahoo.de
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Email: stwnepal@mcmail.com.np

Pipes and appendages:
Surya Enterprises
(0) 00977-1-4230814
KA-MA-PA 11, Tripureswor (opposite hotel Janak)
Kathmandu, Nepal

Example helophyte filter:
Christa Drigalla (general manager)
Sushma Koirala Memorial Hospital
Salambutar, Sankhu, Kathmandu, Nepal
www.nepal-hospital.de
+977 1 4450826
Maintenance engineer:
Gulsatham Bistha: 9841307213

Biogas supplier:
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