Solar thermal water disinfection plant (SOWADI)

IOG-Code: DEU-IOG02

Product datasheet

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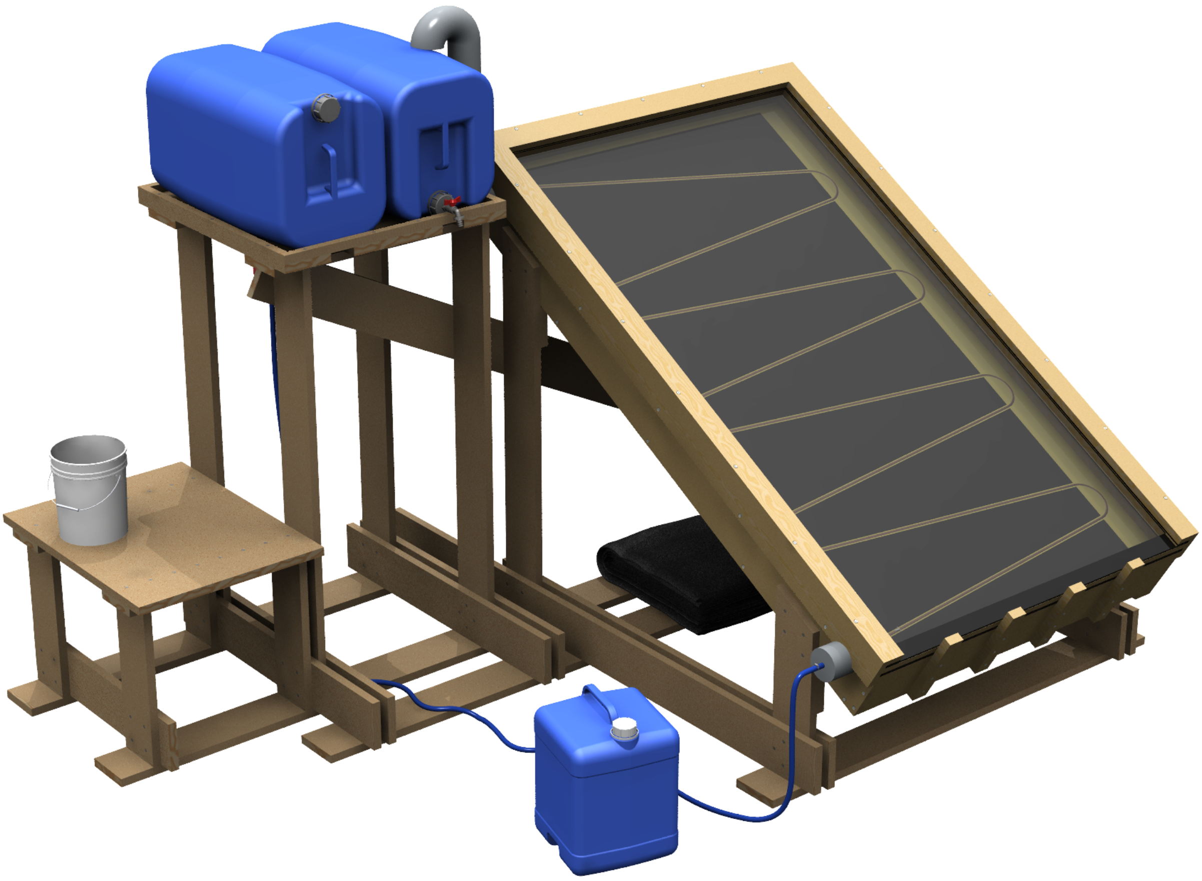

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1 Application, liability

This is a product datasheet, which summarizes the properties and boundary conditions of the solar thermal water disinfection plant, as it is constructed following the associated construction manual. The following sections serve to increase comprehension and to work as a planning guide. Due to numerous unpredictable influences the given information should rather be seen as a rough benchmark than exact performance numbers. Based on the limitations described in the following chapters this plant does not ensure that the water is drinkable after being processed by the plant. The author of this text does not guarantee the correct functioning of the plant. He is not liable for damage or harm on objects or persons resulting from a plant built in conformity with the construction manual or from the activities described in that manual. He is also not liable for damage or harm on objects or persons resulting from a plant operated as described in the user manual.

2 Important also prevailing documents

- Design drawings / CAD model
- Calculation documents, simulation results
- Results of the microbiological study
- Construction manual for the user
- Operation and maintenance manual for the user

3 Scope

Based on rainwater stored in tanks the small plant is to reduce the microbiological contamination of water through solar thermal heating. The developed plant is supposed to enable independent buildup with local material and basic tools.

4 Technical realization

4.1 Schematic drawing

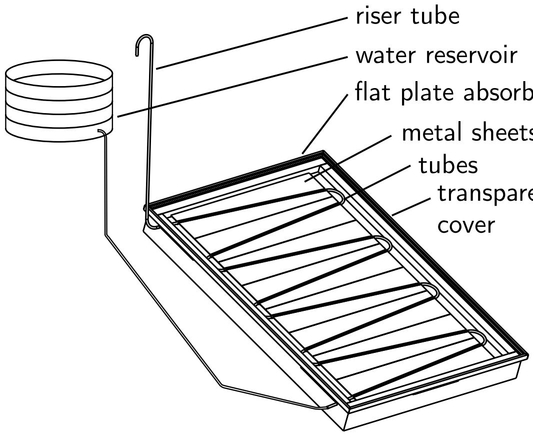

Figure 1: Schema of the plant

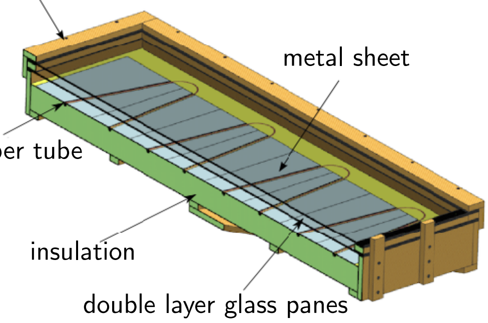

Figure 2: Longitudinal section of the plant

4.2 Functional description

The thermal treatment of the water is driven solely through solar radiation. A flat plate collector is responsible for the heating process. This technology is already well-established on a global scale. To control the water output we developed a new concept, whose process is illustrated in fig. 3.

The shown hydrodynamic system can be divided into two sections. On one side the cold section with a reservoir filled with the water which is to be treated (fig. 3, right side respectively). On the other side the heated section being connected to the cold section. Here the water is heated up. The initial state is shown in fig. 3a. With a homogeneous temperature the water reaches on both sections (almost) the same level according to the principle of communicating vessels. After a heating process (fig. 3b) a fraction of the water in the heated section evaporates (fig. 3c). Due to sufficiently small pipe diameters in this section the water vapor cannot

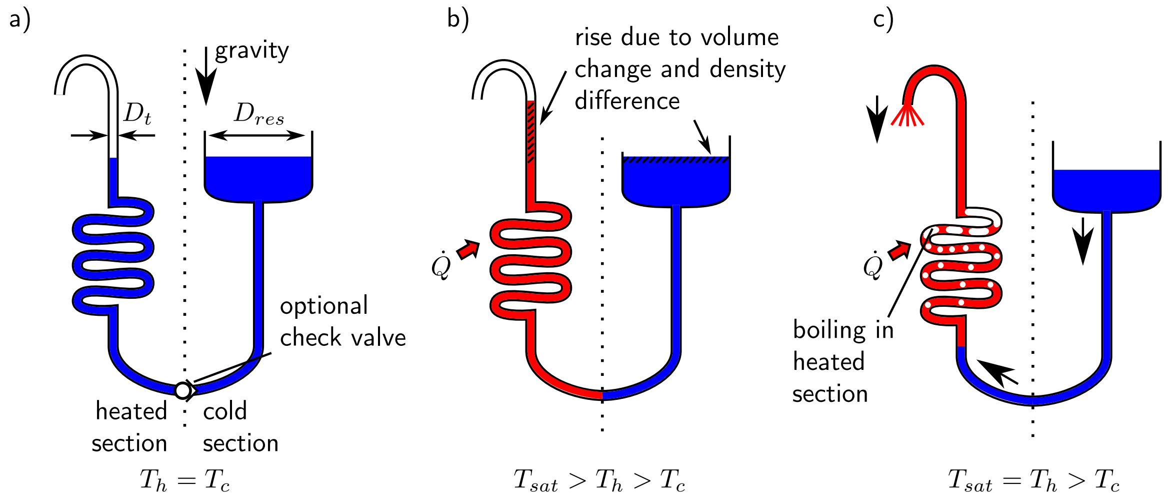

Figure 3: Concept to control water output

pass the the water above and thus cannot escape the system prematurely. A density difference between the cold and the heated section (including the vapor) arises and therefore gravity then forces hot water together with vapor out of the system (fig. 3c, depicted through the black arrow in the upper left corner). In the following step cold water flows from the reservoir to the heated section and the cycle begins anew (fig. 3a). The heated section is integrated into a flat plate absorber. A schematic drawing is shown in fig. 1. A more detailed explanation of the functional principle as well as the dimensioning of the plant and particular components is given in the following publication:

Dietl, Jochen ; Engelbart, Hendryk ; Sielaff, Axel (2015). *A Novel Type of Thermal Solar Water Disinfection Unit.* http://tuprints.ulb.tu-darmstadt.de/4460/.

5 Technical requirements

5.1 Environmental conditions

Storage temperature 0 °C ... 70 °C
At temperatures below freezing point the plant has to be emptied completely. If the plant is not used it has to be covered to prevent very high Temperatures.

Operating (environmental) temperature $\geq 5\,°C$

Ground, angle of inclination, solar radiation

- The plant's angle of inclination against the ground is depending on the location 20 ° ... 30 °(e.g. Germany).
- An even ground is needed in case the pedestal suggested in the construction manual is used.
- The plant needs to be installed at a site where it is not covered by any shadows, preferably throughout the whole day.

Resistance against pest infestation
If pests exist locally, the plant has to be protected from an infestation of wood and insulation material (e.g. through treatment of the material, usage of a metal pedestal, or mounting to other objects on the site).

5.2 Adjacent systems

In addition to the plant itself, a correct operation requires:

- 1 pedestal (suggestion of construction is attached to the construction manual)
- 2 canister incl. tap/valve, ca. 60 L. The following dimensions of the canister were used for the design (as shown in the title image) WxHxD: 30 cm x 45 cm x 60 cm
- 1 bucket or container to fill the inlet tank with contaminated water
- 1 bucket or container with a small opening and/or a tap/valve to draw treated water from the outlet tank
- Cover to cover the plant so it will not overheat after shutdown (e.g. nontransparent canvas cover)
- Equipment to clean the containers/canisters

5.3 Construction

Procurement of parts and assembly
The parts procurement will be done locally. If necessary all water touching parts have to be cleaned before initial operation.

Tools

- Hammer
- Wood saw
- Drilling machine and drills, for wood and metal (electrical or manual)
- Screw driver / Screw drilling machine (electrical or manual)
- Wrench or Pliers (to build custom tools)

In addition, tools are needed to bend sheet metal and pipes. Many workshops are sufficiently equipped to at least allow for bending sheet metal. In case appropriate tools are not available to serve these two purposes there are appendices to the construction manual to build respective the tools listed above.
Further tools can be necessary if material cannot be obtained in the required condition (size, shape).

5.3.1 Persons

Quantity (number) ≥ 2
At least two people are needed for the construction. If more than three are working together some sections of the manual can be worked on in parallel. This can reduce the construction time.

Skills

- No specific training is required
- Extended basic technical understanding
- Capability of understanding technical drawings
- Somewhat talented in mechanical work
- Experienced handling of listed tools

5.3.2 Area, duration, cost

Area for construction activity $\approx 20\,m^2$

Duration of construction ≥ 2 days
An experienced team can build the plant within two days if all the material is present at the site.

Material cost $\leq$ 150 € ... 200 €
The cost of the material heavily depends on local prices. Additionally, the costs can be reduced drastically through reuse or alternative ways of acquisition. Therefore the total material cost can be assumed to be below 150 € .

6 Technical details

The technical details depend on the chosen plant dimensions. The following data refers to the dimensions in the construction manual.

6.1 Dimensions

Weight ca. 95 kg

The plant weights about 95 kg (empty without adjacent systems). The glass panes alone account for 40 to 45 kg off the 95 kg. Glass panes made of PMMA (Plexiglas) with the same dimensions would weight about half.

Size (WxHxD)

Without pedestal, without canisters:	135 cm x 55 cm x 195 cm
With pedestal:	270 cm x 200 cm x 190 cm

6.2 Performance

Water throughput $\leq$ 40 L/d ... 50 L/d

The quantity of treated water heavily depends on the environmental conditions. The water quantity output of a prototype in the area of Darmstadt, Germany is shown in fig. 4 (upper part in blue). Keep in mind that this diagram is meant for orientation purposes only. The better documented august was very unsettled that year which can be seen in the recorded hours of sunlight (lower part in orange) by the DWD (German Meteorological Service). The maximum throughput reached ca. 23 L/d. This amount is expected to be outperformed in equatorial regions so that an output of 40 to 50 L per day is estimated. Even though the plant uses diffuse solar radiation we do not expect any output in weather conditions like rainy seasons.

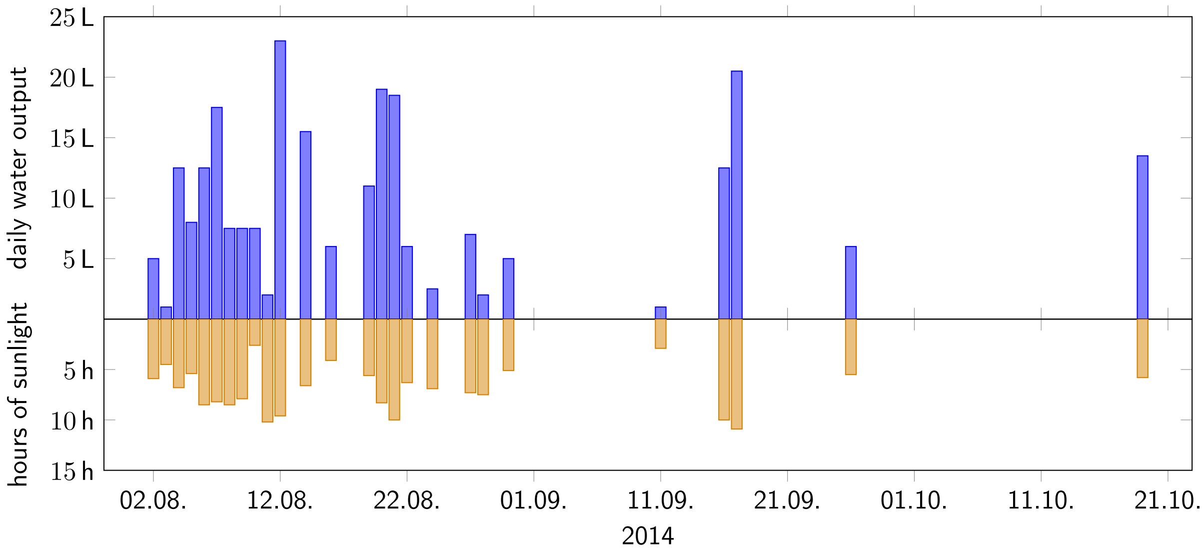

Figure 4: Daily water output of the plant (upper part) in comparison to the hours of sunlight (lower part) on a site close to Darmstadt. (On days with both values equal to zero the measurement of the output is not available.)

Water storage life $\leq$ 1 day

Since boiling water is a punctual treatment method the water can be recontaminated relatively soon after the treatment (depending on storage conditions). Therefore it is advised to consume the discharged water within one day.

6.3 Water quality

Extensive information about the considered parameters, threshold values and the reduction performance of the plant can be found in the following bachelor's thesis:

> Thiemann, Fabian (2015). *Untersuchung der Funktionsfähigkeit einer kleinskaligen und solarthermischen Trinkwasseraufbereitungsanlage*. Technische Universität Darmstadt.

6.3.1 Water quality at input (requirements)

Bacterial load
The maximum measured load of E. coli bacteria in our experiments was $6.6 * 10^6$ /100 ml (MPN) and of total coliforms $2.4 * 10^7$ /100 ml (MPN). Fig. 5 shows the contamination characteristics of the input water. In our experiments we used water with a very high pathogen concentration to identify performance limits of the plant. The pathogenic load of input water is normally lower.

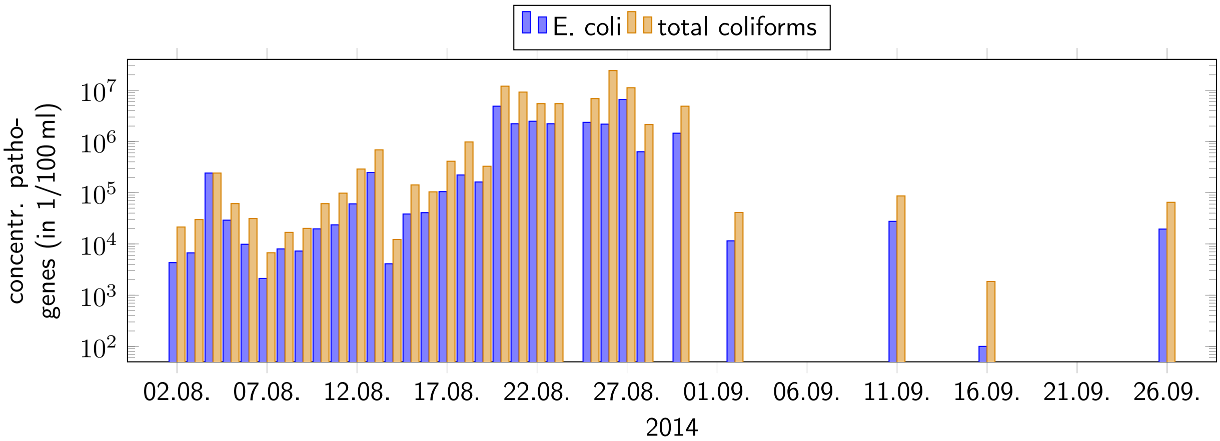

Figure 5: Concentration of E. coli and total coliforms in the input water. (On days with both values equal to zero the measurement of the concentration is not available.) The concentration of the output was always reduced below the detection limit.

Chemical load none
The water must not have any chemical contamination. The plant cannot treat chemical pollution.

Turbidity $\leq$ 5 NTU
The turbidity is not purposefully influenced, therefore the untreated water should already have a turbidity-level in accordance to the WHO-recommendation which is shown above. The literature regards a turbidity up to 200 NTU as acceptable for thermal treatment of water. A lower turbidity means generally a lower microbiological concentration.

Water hardness
There are no particular requirements on water hardness. The harder the water input the more limescale precipitates in heated sections of the plant.

pH ca. 6.5 ... 8.5
The WHO demands a pH in the range of 6.5 and 8.5 for drinkable water. When deciding on the water source it should be considered that on one hand the pH is raised through the plant in a small degree (see fig. 6), on the other hand an acidic environment increases the precipitation of limescale in the water (see chap. 7).

Water temperature $\geq 5\,^\circ$C

6.3.2 Water quality at output (performance)

Bacterial load
The concentration characteristics of E. coli and total coliforms in the input water shown in fig. 5 were reduced below the limit of detection (1 /100 ml (MPN)) in every taken composite sample. This indicates a reduction performance of E. coli bacteria of at least lg 6.8 and total coliforms of at least lg 7.4. For further information see the bachelor's thesis mentioned above.

Chemical load
Unaltered to the greatest extent

Turbidity
Unaltered to the greatest extent

Water hardness
Only small alteration

pH
pH rose during the experiments by an average of 0.84. This increase is attributed to the reduction of the CO_2 concentration in the water. Fig. 6 shows the pH characteristics of both the plant's in- and output.

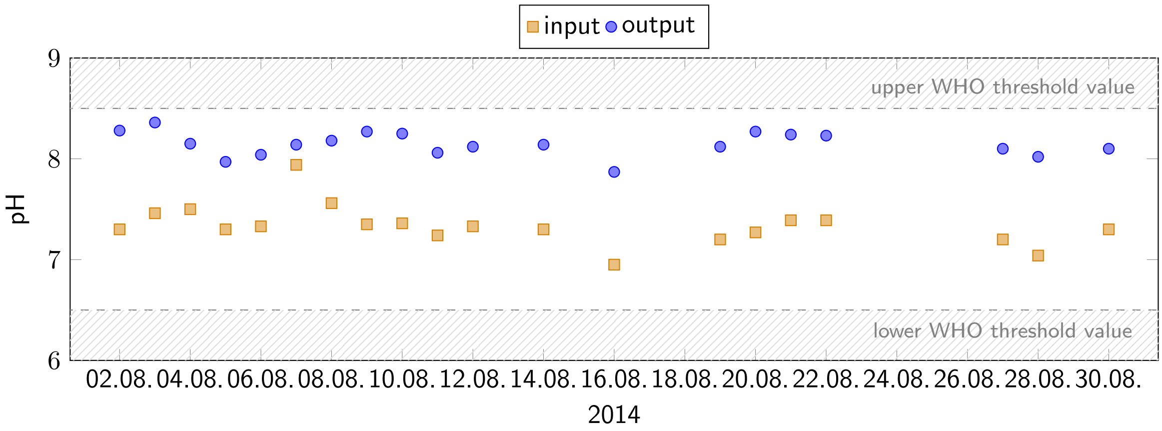

Figure 6: pH results of composite samples from in- and output.

Water temperature 90 °C ... 100 °C

7 Safety

- The temperature of water and material at the water output (riser tube) reaches 100 °C. Risk of scalding persists in these areas. Additional insulation, protective barriers or warning notices can help reduce the risk. The output canister should be located as close to the riser tube output as possible. At best both are firmly connected to each other.
- The large-scaled glass panes can break. It should be payed attention so that no heavy objects drop on the glass panes or are placed on them. Preferably mount the plant at a safe/protected area.
- If infants or small children are among the users the water should be examined concerning potentially increased concentration of copper. In case of doubt, alternative means of supply should be sought for these persons.

8 Technical drawings of the plant

The title page shows a rendering of the plant including the necessary adjacent systems. Various technical drawings of the plant without the adjacent systems are presented in figure 7.

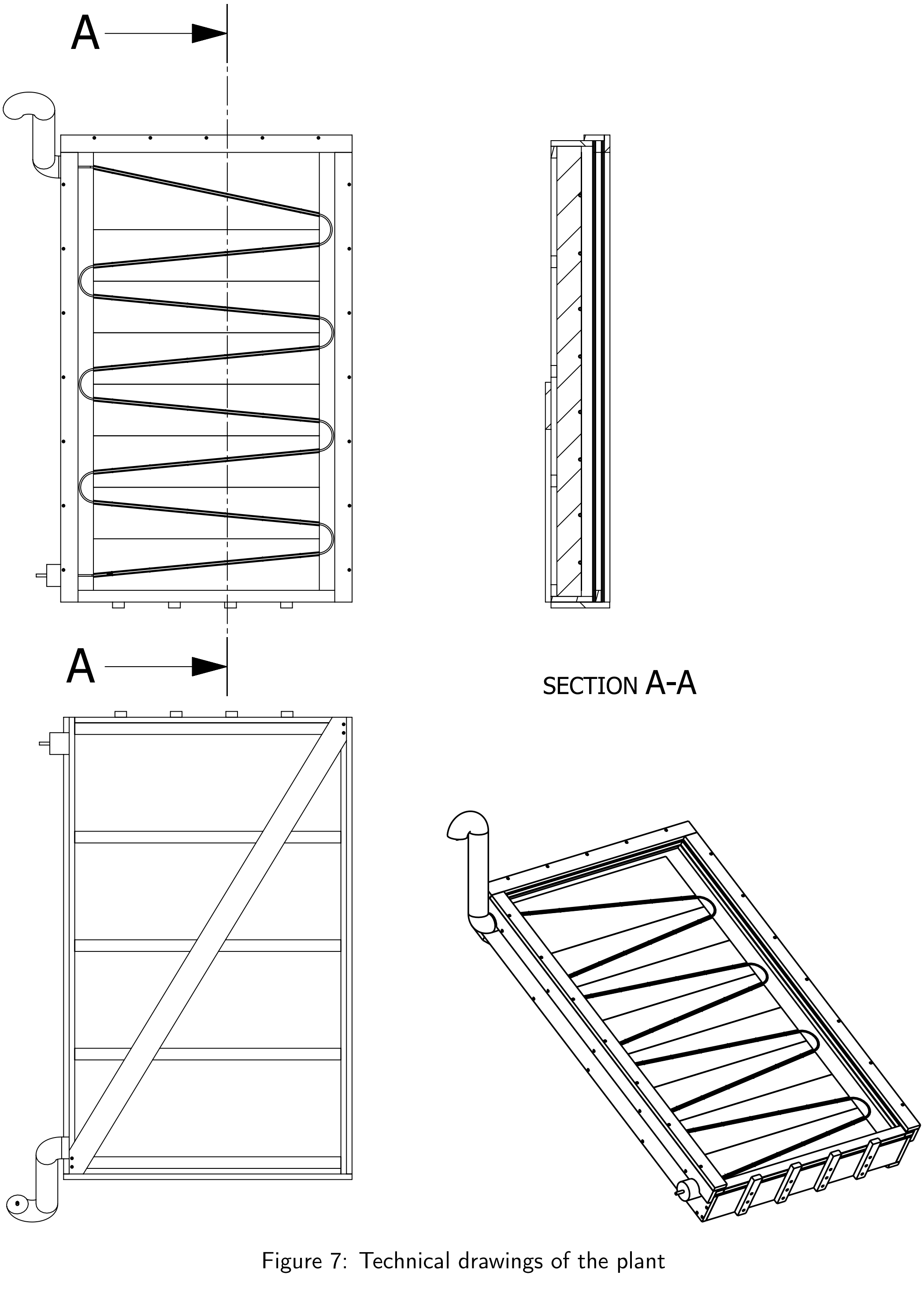

Figure 7: Technical drawings of the plant