DIPLOMA PROJECT

Do-It-Yourself Solar Water Purifier

Sponsor : Icarus Design and Branding Pvt.Ltd, Bangalore

STUDENT : **KUNAL SINGH**

PROGRAMME : **Graduate Diploma Programme in Design**

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INDUSTRIAL DESIGN FACULTY (PRODUCT DESIGN)

National Institute of Design Ahmedabad

The Evaluation Jury recommends KUNAL SINGH for the

Graduate Diploma of the National Institute of Design

in INDUSTRIAL DESIGN (PRODUCT DESIGN)

herewith, for the project titled "Do-It-Yourself Solar Water Purifier"

on fulfilling the further requirements by *

Chairperson

Members :

*Subsequent remarks regarding fulfilling the requirements :

Registrar (Academics)

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I would like to thank all the people who gave me the possibility to successfully complete this project.

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Thank you Manasi for always being there for me. And finally I thank all my friends for being a part of my life and letting me be a part of yours.

God bless you all.

Preface

Why Product Design as a profession?

As a kid I dreamt of innovating and inventing new things. I was always keen on knowing how stuff works, how things are made but never knew I would become a designer.

I always enjoyed solving problems laid in front of me, regardless of them being mathematical or a technical or even social. I was preparing myself for engineering and architecture when I got to know product design as a professional course at NID and I was extremely overwhelmed and applied for it.

Why the Solar Water Purifier (S.W.P.) Project?

I always believe in giving importance to the function more than the form of a product. I always wanted to design new sustainable solutions as a whole and not just a product. Sustainability and ecological problems always caught my attention more than the others. And I always had a keen interest in the vast opportunities related to our environment and renewable resources. The s.w.p. was an ideal project for me not only because it was challenging but also because I knew it would help millions of people get clean drinking water.

The s.w.p project demanded more than just design and innovation. It was an engineering challenge that had to be overcome. The solar water purifier was a project which required technical as well as design assistance simultaneously at every step of the project. Not only was it a challenge in making the product but also making the product with low investment in manufacturing it.

What is Indian design?

India works in a very different way in terms of design. One part of Indian design really fascinates me. It is commonly known as ‘jugad’ in Hindi which means improvisation. This jugad can be seen in many Indian day-to-day products. The Indian terracotta pots nowadays have been fitted with plastic taps for easy pouring of cold water. Instead of putting a vessel in the pot you can get the water out without the extra effort.

Indians often figure out how to utilise the product to its fullest potential. The term “missed call” in India has been used to communicate more than just an unanswered call. It is sometimes used to communicate a question and sometimes an answer and sometimes a simple yes or no. People in India make the most of what they have in the most economical way possible.

Design is a part of everyday life of people across India. More value is given to the affordability, sustainability and use of a product rather than the look of it. In design terms it is called “form follows function” function here being cheap, efficient and durable.

Abstract

This project was initiated on 15th of April 2009 in Bangalore by Icarus Design Private Limited. The project demanded an industrial designer with an interest in innovative thought process and a good technical knowledge.

The idea was to get pure water using solar energy with minimal cost of construction. I was briefed about the project and was specifically told that the project involves high risk of failure. Work began immediately on the project with initial concept sketches. The project required large amounts of research and field study. Large number of experiments were conducted to verify the concepts. Every experiment required a working model with minimal expenditure. We contacted and visited Auroville to discuss the project and get good amount of feedback and suggestions. The designs were broken down into three components namely collector, boiler and condenser. After conducting a number of experiments finally there was the required amount of water output. Next came the economics and manufacturing part of the product. Because of constraints of low budget for manufacturing and low cost of assembly, a large number of market visits were conducted and different types of utensils, products, etc were experimented with. Further detailing was done to the final prototype and finally aesthetics for the cover was carried out.

Design alterations and accessories were introduced in the design and finally a working prototype was made. The product was then tested in the sun. It provided eight litres of purified water using eight hours of sun during clear skies. After a few tweaks and improvements the concept was then taken further for a system-wide use and implementation.

This was a non-profitable project and the designs will be finally uploaded online as open source to enlighten people all over the world and to implement such products without large manufacturing setups and processes.

This project document is a self help guide to get the purest form of water known to man.

Contents

Introduction

This document is a compilation of the design process, experiments and conclusions conducted during a period of five months.

Research: The initial part of the document is the research in which a general study is conducted regarding the history of distillation and existing water purification, distillation and solar technologies.
This research was then used to theoretically validate the project and provide data which became the base on which the project was taken forward.

User study: Next came the user study and market analysis to understand the user's backgrounds and requirements.

Concept development: After the user analysis the concept development began with rough concepts later segregated into collectors, boilers and condensers. These concepts were backed up with experiments and working models.

Integration: After getting satisfying results in the three categories of concepts the conclusions were then taken forward for integration, evolution and modification to suit the user and make it more efficient.

Form and aesthetics: Once the working of the design was figured out and finalized the next part was the form and aesthetics of the design. After conducting a large number of explorations four designs were selected for appropriate user segments.

Final design: After the aesthetics were decided the next part was prototyping which included construction, assembly, installation and working of the product. And finally the next level of product design, which is designing systems and awareness of the product.

Motivation

Clean drinking water is the basic necessity for every human being, but about 1.1 billion people in the world lack proper drinking water. Over large parts of the world, humans drink water that contains disease vectors or pathogens or contain unacceptable levels of dissolved contaminants or solids in suspension. Drinking such waters or using them in cooking leads to widespread acute and chronic illnesses and is a major cause of death in many countries.

There are many processes by which clean drinking water can be obtained but the most reliable way to kill microbial pathogenic agents is to heat water to a rolling boil. This requires abundant sources of fuel which is unaffordable for many people specially those living in rural India. Other methods are either inefficient in long term use or require electricity, which is not available in rural areas. However solar energy is one of the most abundant, free and clean source of energy available here. A simple and cost efficient system is required which allows you to boil water using only solar energy at high efficiency. Boiling and distillation processes are the most efficient ones because the high temperatures required for these processes kill bacteria and other microbes present in the water. Even though there are other water purification systems and processes the W.H.O. recommends distillation process as other systems are inefficient and may tend to stop functioning after a period of time.

There are many methods and processes of solar distillation and many solar distillation devices are available in the market, but these devices are very bulky, expensive or not very efficient.
There is a requirement for a device which is highly efficient, economical, simple to manufacture and maintain. This can be achieved through understanding theory, experimentation and learning from existing products.

Project brief

The brief of the project was to design a product which would use only solar energy for distillation of water. Due to the initial expense and cost of maintenance these products have not reached places where there is scarcity of drinking water. Also due to the complexity of the devices uneducated and illiterate people are unable to use it properly and hence avoid it.

The product development and implementation required more than just a working product. The product should involve the user before and during its construction. The user should be able to built or assemble it all by himself. He should be able to modify and repair it without much technical assistance.

The device was to be designed to cater to the needs of people living in underdeveloped regions.

The project duration was for five months during which a number of experiments were to be conducted time to time, by the end of which a working product was to be presented. The product should provided sufficient amount of water comparable to its cost of construction and efficiency.

Design specifications

The design was to be-

• Easy to manufacture
• Easy to assemble
• Easy to use
• Made up of locally available parts
• Inexpensive to buy
• Easy to repair and maintain
• Simple in design
• More efficient than existing products
• Movable
• Multi-functional

Technical specifications

The design had to deliver the following-

• A high water temperature.
• A large temperature difference between feed water and condensing surface.
• Low absorption glazing and a good radiation absorbing surface.
• Low heat losses from the floor and walls .

Design process and methodology

This project being technical in nature had a unique design process and methodology.

The project went through procedures of research, study of scientific theory, and practical experimentation. Simultaneously the design processes of conceptualization, human factors, product manufacturing and usage were conducted. The scope of the project was technical which meant *form follows function*. The construction and working was given higher priority than aesthetics.

The whole project was carried out under an experienced designer working in the industry as well as guided by an internal faculty in NID. There was constant communication and interaction for valuable feedback and advice from the guides. Research was conducted regarding availability of existing technologies and new innovative ways of bringing all of them together to form one single unit. Many visits were conducted to various vendors and shops to figure out the most economical equipment for getting pure distilled water using the solar energy. Further many experiments were conducted with hit and trial methods and further refining them to get the most efficient setup.

Figure 1.1 shows the method and process followed during the project over a period of 5 months.

Process

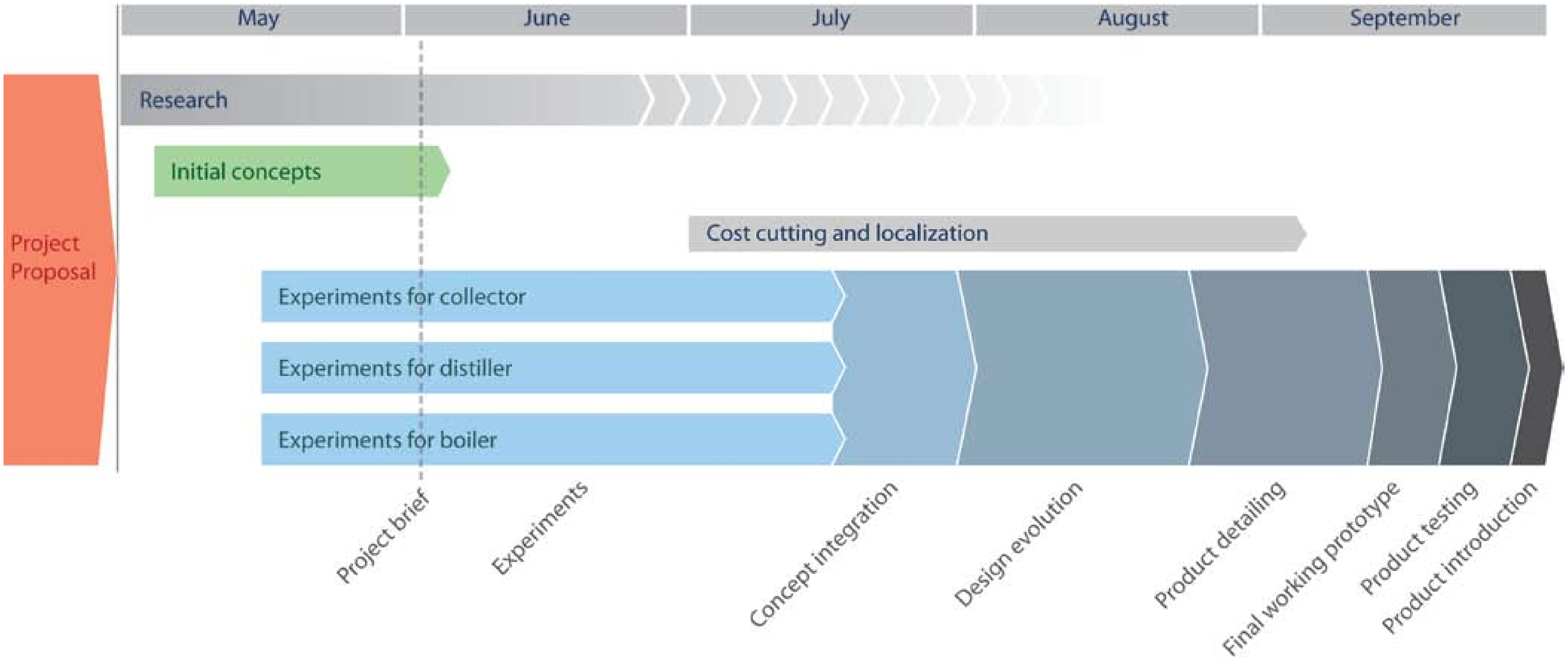
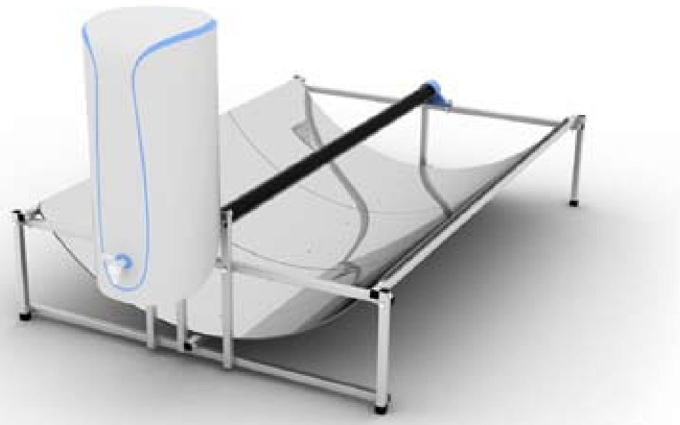


Figure1.1

Project results



The Solar Water Purifier is designed to purify 8 to 10 liters of water during 8 hours on a sunny day using only solar energy. It uses boiling and distillation to purify water for the purpose for drinking. The cost of the product is roughly around 3,000 Rupees which is the most important feature of the product.

It is designed to cater to the needs of people in villages and towns where there is a shortage of clean drinking water. The unique features which make it different from the other purifiers are its simplicity in design and its low cost of manufacturing. The S.W.P. is easy to construct and assemble locally. Most of the components are locally available and requires minimal technical assistance to assemble.

It is open to modifications and adjustments according to one's needs and requirements. Furthermore it is fully independent from any system and only requires solar energy. The design can be multiplied to meet the demands for communities and villages in remote areas.

RESEARCH

This chapter consists of research conducted over a period of 3 months on portable water, solar energy, water purification methods, distillation, etc.

Drinking water

Research

According to a 2007 World Health Organization report[1], 1.1 billion people lack access to an improved drinking water supply, 88% of the 4 billion annual cases of diarrheal disease are attributed to unsafe water and inadequate sanitation and hygiene, and 1.8 million people die from diarrheal diseases each year. The WHO estimates that 94% of these diarrheal cases are preventable through modifications to the environment, including access to safe water. Simple techniques for treating water at home, such as chlorination, filters, and solar disinfection, and storing it in safe containers could save a huge number of lives each year.
Drinking water or potable water is water of sufficiently high purity that it can be consumed or used without risk of immediate or long term harm. In most developed countries, the water supplied to households, commerce and industry is all of drinking water standard, even though only a very small proportion (often 5% or less) is actually consumed or used in food preparation

Over large parts of the world, humans have inadequate access to potable water and use sources contaminated with disease vectors, pathogens or unacceptable levels of dissolved chemicals or suspended solids. Such water is not potable. Drinking or using such water in food preparation leads to widespread chronic illness and is a major cause of death in many countries.
Most water requires some type of treatment before use, even water from deep wells or springs. The extent of treatment depends on the source of the water. Appropriate technology options in water treatment include both community-scale and household-scale point-of-use (POU) designs.

The United States Environmental Protection Agency has determined that the average adult actually ingests 2.0 litres per day.

Sources of water

Groundwater: The water emerging from deep ground water may have fallen as rain many tens, hundreds, thousands or in some cases millions of years ago. Soil and rock layers naturally filter the ground water to a high degree of clarity before it is pumped to the treatment plant. Such water may emerge as springs, artesian springs, or may be extracted from bore holes or wells. Deep ground water is generally of very high bacteriological quality (i.e., pathogenic bacteria or the pathogenic protozoa are typically absent), but the water typically is rich in dissolved solids (TDS).

Upland lakes and reservoirs: Typically located in the headwaters of river systems, upland reservoirs are usually sited above any human habitation and may be surrounded by a protective zone to restrict the opportunities for contamination. Bacteria and pathogen levels are usually low, but some bacteria, algae and protozoa might be present.

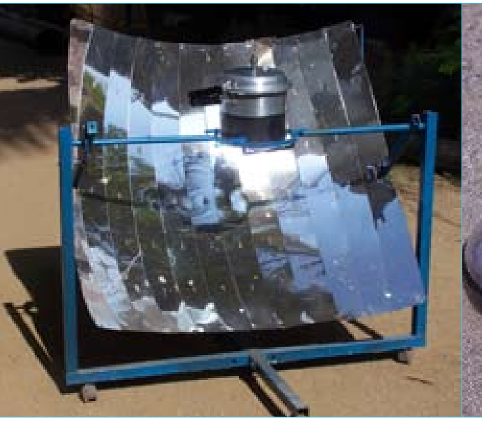
Rivers, canals and low-land reservoirs: Low-land surface waters have a significant bacterial load and may also contain algae, suspended solids and a variety of dissolved constituents.

Atmospheric water generation: it is a new technology that can provide high quality drinking water by extracting water from the air by cooling the air and thus condensing water vapor.

Rainwater harvesting or fog collection which collects water from the atmosphere can be used especially in areas with significant dry seasons and in areas which experience fog even when there is little rain.

Desalination of seawater by distillation or reverse osmosis.

Existing solar products and technologies


Solar stills: A solar still is a low tech way of distilling water, powered by the heat of the sun. Two basic types of solar stills are box, and pit. In a solar still, impure water is contained outside the collector, where it is evaporated by the sun through clear plastic. The pure water vapor (and any other included volatile solvent) condenses on the cool inside plastic surface and drips down off the low point (pebble), where it is collected and removed. The box type is more sophisticated.

Solar cookers: A solar cooker is a device which uses sunlight as its energy source. Because they use no fuel and they cost nothing to run, humanitarian organizations are promoting their use worldwide to help slow deforestation and decertification, caused by using wood as fuel for cooking. Solar cookers are also sometimes used in outdoor cooking, especially in situations where minimum fuel consumption or fire risk is considered highly important.

Distillers: A distiller is a device which uses electricity to boil water and condense it to give pure distilled water. It is not widely use because it has a high running cost as large amount of energy is required to boil water.

Solar distiller: There has been a lot of research and experimentation on solar distils. These use energy from the sun to evaporate water at normal temperatures. There are many drawbacks in the design. The cost of manufacturing or construction is very high. The water is not boiled hence bacterial and other organisms in water may not perish. The extensive number of parts can lead to errors and leaks which might result in impure water. The whole process takes longer time then boiling.

Traditional water filtration methods

Boiling: Historically, boiling is what has been used to disinfect water from microorganisms. In fact it can kill most bacteria. Bacteria and protozoa are killed at the first bubble, and it takes about three minutes to kill the rest of the microorganisms. The drawbacks to this method however are that it can require lots of fuel and cooking equipment. Secondly, water cannot be then used immediately, as it needs to cool down. Thirdly, since it is so hot, some of the water may evaporate before its use. Fourth, the water can still contain particles; so further filtering through a handkerchief could be necessary. Finally, boiling water does not eliminate chemical pollutants (including chlorine), poor taste of foul odors, and in fact can leave a stale taste.

Chemical: There are two primary chemicals used to purify water: iodine and chlorine. Both are lightweight, low-cost and easy to use. Iodine has been proven effective in killing off viruses, bacteria and protozoa. However, the colder the water is, the more time it will take to purify with iodine. Iodine can also absorb into the dirt and debris naturally found in water, so the dosage will always vary. Also, pregnant women or those with thyroid conditions should not drink water with the chemical. Usually, iodine is just used for short-term purposes, and should not be used for more than three consecutive months.

Chlorine bleach[2] is the second chemical purifier. The process of chlorination will cause dirt and debris to settle to the bottom of the water container and make the water visually clearer. There are many drawbacks to the chlorination method. If the household bleach is over six months old, it may not have enough potency to disinfect. Also, chlorine is poisonous and adding too much can cause illness, internal organ damage and even death. Seeing the drawbacks of these traditional filtration methods brings us to why more advanced water purification may be required nowadays.

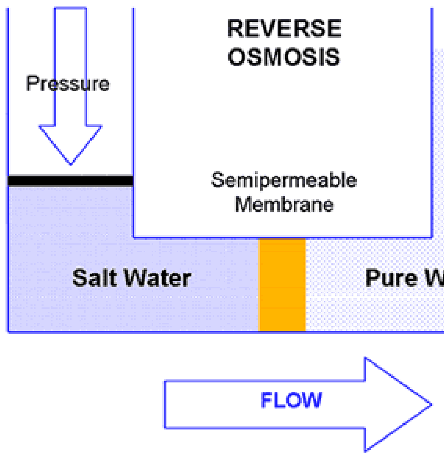
Granular Activated Carbon filtering: a form of activated carbon with a high surface area adsorbs many compounds including many toxic compounds. Water passing through activated carbon is commonly used in municipal regions with organic contamination, taste or odors. Many household water filters and fish tanks use activated carbon filters to further purify the water. Household filters for drinking water sometimes contain silver to release silver ions which have an anti-bacterial effect.

Reverse osmosis: Mechanical pressure is applied to an impure solution to force pure water through a semi-permeable membrane. It will be discussed later in detail.

Distillation involves boiling the water to produce water vapor. The vapor contacts a cool surface where it condenses as a liquid. Because the solutes are not normally vaporized, they remain in the boiling solution. Even distillation does not completely purify water, because of contaminants with similar boiling points and droplets of unvaporised liquid carried with the steam. However, 99.9% pure water can be obtained by distillation.

Direct contact membrane distillation (DCMD): Applicable to desalination. Heated seawater is passed along the surface of a hydrophobic polymer membrane. Evaporated water passes from the hot side through pores in the membrane into a stream of cold pure water on the other side. The difference in vapor pressure between the hot and cold side helps to push water molecules through.

Gas hydrate crystals centrifuge method: If carbon dioxide gas is mixed with contaminated water at high pressure and low temperature, gas hydrate crystals will contain only clean water. This is because the water molecules bind to the gas molecules at molecule level. The contaminated water is in liquid form.



The Process

The reverse osmosis process depends upon a semi-permeable membrane through which pressurized water is forced. Reverse osmosis, simply stated, is the opposite of the natural osmosis process of water. Osmosis is the name for the tendency of water to migrate from a weaker saline solution to a stronger saline solution, gradually equalizing the saline composition of each solution when a semi-permeable membrane separates the two solutions. In reverse osmosis, water is forced to move from a stronger saline solution to a weaker solution, again through a semi-permeable membrane. Because molecules of salt are physically larger than water molecules, the membrane blocks the passage of salt particles. The end result is desalinated water on one side of the membrane and a highly concentrated, saline solution of water on the other side. In addition to salt particles, this process will remove a select number of drinking water contaminants, depending upon the physical size of the contaminants. For this reason, reverse osmosis has been touted as an effective drinking water purification method.

Pros and Cons

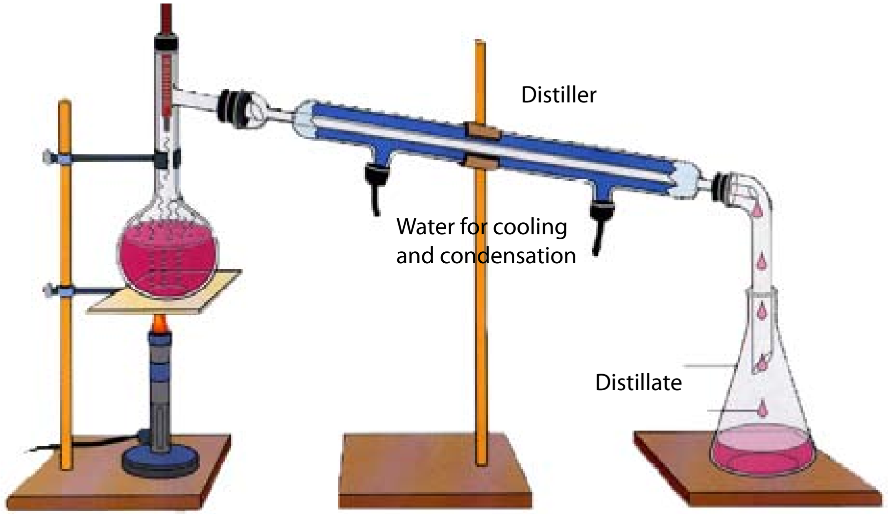
Reverse osmosis is a valuable water purification process when mineral-free water is the desired end product. Most mineral constituents of water are physically larger than water molecules. Thus, they are trapped by the semi-permeable membrane and removed from drinking water when filtered through a reverse osmosis system. Such minerals include salt, lead, manganese, iron, and calcium. Reverse osmosis will also remove some chemical components of drinking water, including the dangerous municipal additive fluoride.

Reverse osmosis, also, by removing alkaline mineral constituents of water, produces acidic water. Acidic water can be dangerous to the body system.

Reverse osmosis, although it is less wasteful than distillation, is still an incredibly inefficient process. On average, the reverse osmosis process wastes three gallons of water for every one gallon of purified water it produces.

Distillation

Distillation is a method of separating mixtures based on differences in their volatilities in a boiling liquid mixture. Distillation is a unit operation, or a physical separation process, and not a chemical reaction.
The process of distillation has been known and used for millennia. Although it has primarily been employed as a method of producing alcoholic beverages like whisky and vodka, distillation also works as a technique of water purification. In the 1970s, distillation was a popular method of home water purification, but its use is now largely confined to science laboratories or printing industries.

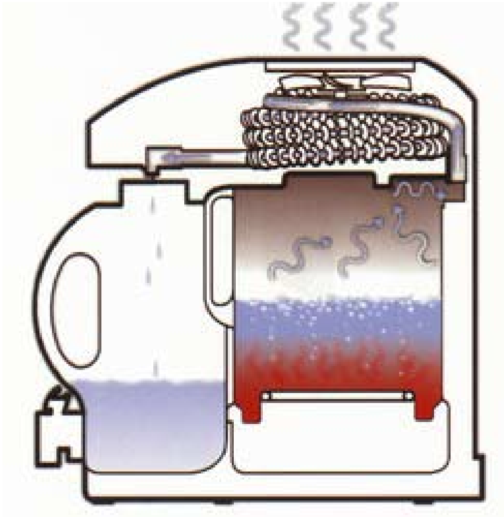


The Process

The distillation process utilizes a heat source to vaporize water. The object of distillation is to separate pure water molecules from contaminants with a higher boiling point than water. In the distillation process, water is heated until it reaches its boiling point and begins to evaporate. The temperature is then kept at a constant. The stable temperature ensures continued water vaporization, but prohibits drinking water contaminants with a higher boiling point from evaporating. Next, the evaporated water is captured and guided through a system of tubes to another container. Finally, removed from the heat source, the steam condenses back into its original liquid form. Contaminants having a higher boiling point remain in the original container.

This process removes most minerals, most bacteria and viruses, and any chemicals that have a higher boiling point than water from drinking water. For this reason, distillation is sometimes valued as a method of obtaining pure drinking water. Distillation, similarly to reverse osmosis, provides mineral-free water to be used in science laboratories or for printing purposes, as both functions require mineral-free water. It removes heavy metal materials like lead, arsenic, and mercury from water and hardening agents like calcium and phosphorous. Distillation is often used as the preferred water purification method in developing nations, or areas where the risk of waterborne disease is high, due to its unique capabilities to remove bacteria and viruses from drinking water.

Although distillation processes remove mineral and bacterial drinking water contaminants, they do not remove chlorine, by-products. These chemicals, which have a lower boiling point than water, are the major contaminants of municipally treated water. Most dangerous metals and bacteria are removed from water prior to its arrival at a home's plumbing system. Thus, a distillation system, targeted at the removal of these contaminants, is unnecessary and irrelevant for most people. Furthermore, distillation is an incredibly wasteful process because it consumes large amount of energy.



The advantages of Distillation

- A good distillation unit produces very pure water. This is one of the few practical ways to remove nitrates, chlorides, and other salts that carbon filtration cannot remove.
- Distillation also removes pathogens in the water, mostly by killing and leaving them behind when the water evaporates. If the water is boiled, or heated just short of boiling, pathogens would also be killed.
- As long as the distiller is kept clean and is working properly the high quality of treated water will be very consistent regardless of the incoming water - no drop in quality over time.
- No filter cartridges to replace, unless a carbon filter is used to remove volatile organic compounds.

The disadvantages of Distillation

- Distillation takes time to purify. It can take two to five hours to make a gallon of distilled water.
- A distiller uses electricity all the time the unit is operating.
- A distiller requires periodic cleaning of the boiler, condensation compartment, and storage tank.
- Counter-top distillation is one of the more expensive home water treatment methods. The cost of ownership is high because you not only have the initial cost of the distillation unit to consider, but you also must pay for the electrical energy for each gallon of water produced. Most home distillation units require electricity, and will not function in an emergency situation when electrical power is not available.

Myths about distillation

• Drinking distilled water leaches minerals from my body.
Fact. Some manufacturers use this myth to sell their product and want you to believe this because distilled water is so pure and drinking it will leach minerals from your body, thereby robbing you of good health and nutrition. Please, be sure, there is no proven or documented fact in this myth.

• Drinking distilled water for long periods of time cause deterioration of my teeth.
Fact. The negative message a filter sellers wants you to believe is that drinking distilled water for long periods, will destroy your teeth by deteriorating them. But the fact is that distilled water removed all traces of fluoride. And today many people want the fluoride be removed from their drinking water and distillation is an excellent way of doing it!

• Distillation takes out all the beneficial minerals need to live for the body.
Fact. Distillation process removes minerals from the water, but mostly all of the beneficial minerals your body receives are not from water. They come from food: fruits, meat, poultry, vegetables, nuts, grains and dairy products are where the body gets its beneficial minerals from. The amount of minerals in water is so insignificant that you need have to drink about 600 8-ounce glasses of tap water to obtain the recommended daily allowance of calcium.

Facts about distillation[3]

• Distillation is not a new process but a very old method of purifying water.

• Water distillation is the most effective remover of contaminants over any other water treatment system.

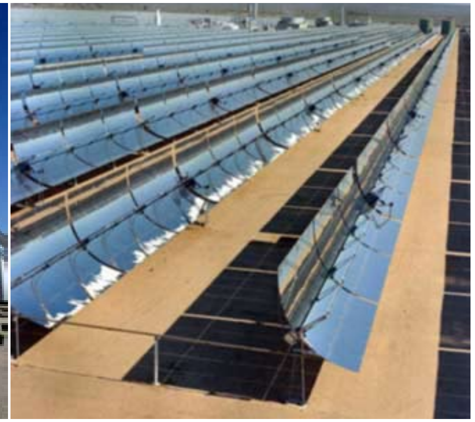
• Distilled water can be compared to the definition of pure drinking water (H_20), it is consistent.

• Water distillation removes the broadest range of organic, inorganic and biological (bacteria, viruses, etc.) contaminants.

• Distillation is more effective and removes a greater percentage of these impurities than filtering, reverse osmosis, ultraviolet etc. Moreover, these methods must be serviced and are not as consistent as water distillation.

• Distilled water is reactive because of its purity hence should be stored in food grade copper or stainless steel or even terra cotta and should always be covered.

• Distilled water is tasteless hence certain kinds of herbs, flavours, sweetener could be added to the water.



Sunlight

Sunlight is Earth's primary source of energy. The solar constant is equal to approximately 1,368 W/m^2 on earth. Sunlight on the surface of Earth is attenuated by the Earth's atmosphere so that less power arrives at the surface—closer to 1,000 W/m^2.
Solar energy can be harnessed via a variety of natural and synthetic processes—photosynthesis by plants captures the energy of sunlight and converts it to chemical form (oxygen and reduced carbon compounds), while direct heating or electrical conversion by solar cells are used by solar power equipment to generate electricity or to do other useful work. The energy stored in petroleum and other fossil fuels was originally converted from sunlight by photosynthesis in the distant past.

Energy from the sun

Solar energy, radiant light and heat from the Sun, has been harnessed by humans since ancient times using a range of ever-evolving technologies. Solar radiation, along with secondary solar-powered resources such as wind and wave power, hydroelectricity and biomass, account for most of the available renewable energy on Earth. Only a minuscule fraction of the available solar energy is used.

The Earth receives 174 petawatt (174×10^{15} watts) of incoming solar radiation at the upper atmosphere. Approximately 30% is reflected back to space while the rest is absorbed by clouds, oceans and land masses. This heat keeps the oceans at a constant temperature of 14 degree Celsius. By photosynthesis green plants convert

Solar energy into chemical energy, which produces food, wood and the biomass from which fossil fuels are derived. The total solar energy absorbed by Earth's atmosphere, oceans and land masses is approximately 3,850,000 exajoules (EJ) per year. Photosynthesis captures approximately 3,000 EJ per year in biomass. The amount of solar energy reaching the surface of the planet is so vast that in one year it is about twice as much as will ever be obtained from all of the Earth's non-renewable resources of coal, oil, natural gas, and mined uranium combined[4].

Harnessing solar energy

Solar energy refers primarily to the use of solar radiation for practical ends. However, all renewable and non-renewable energies, other than geothermal and tidal, derive their energy from the sun.
Solar technologies are broadly characterized as either passive or active depending on the way they capture, convert and distribute sunlight. Active solar techniques use photovoltaic panels, pumps, and fans to convert sunlight into useful outputs. Passive solar techniques include selecting materials with favorable thermal properties, designing spaces that naturally circulate air, and referencing the position of a building to the Sun. Active solar technologies increase the supply of energy while passive solar technologies reduce the need for alternative resources.

Given below are the different ways in which solar energy can be harnessed .

Architecture and urban planning: Sunlight has influenced building design since the beginning of architectural history. Advanced solar architecture and urban planning methods were first employed by the Greeks and Chinese, who oriented their buildings toward the south to provide light and warmth.
The common features of passive solar architecture are orientation relative to the Sun, compact proportion, selective shading (overhangs) and thermal mass.

Solar thermal: Solar thermal technologies can be used for water heating, space heating, and space cooling and process heat generation. Solar thermal energy is a technology for harnessing solar energy for thermal energy (heat).

Water heating: Solar hot water systems use sunlight to heat water. In low geographical latitudes (below 40 degrees) from 60 to 70% of the domestic hot water use with temperatures up to 60 °C can be provided by solar heating systems. The most common types of solar water heaters are evacuated tube.

Heating, cooling and ventilation: Thermal mass is any material that can be used to store heat—heat from the Sun in the case of solar energy. Common thermal mass materials include stone, cement and water. Historically they have been used in arid climates or warm temperate regions to keep buildings cool by absorbing solar energy during the day and radiating stored heat to the cooler atmosphere at night.

A solar chimney: a passive solar ventilation system composed of a vertical shaft connecting the interior and exterior of a building. As the chimney warms, the air inside is heated causing an updraft that pulls air through the building. Performance can be improved by using glazing and thermal mass materials in a way that mimics greenhouses.

Solar Water treatment: Solar distillation can be used to make saline or brackish water potable. A large-scale solar distillation project was first constructed in 1872 in the Chilean mining town of Las Salinas. The plant, which had solar collection area of 4,700m^2, could produce up to 22,700 L per day and operated for 40 years.

Solar water disinfection (SODIS) involves exposing water-filled plastic polyethylene terephthalate (PET) bottles to sunlight for several hours. Exposure times vary depending on weather and climate from a minimum of six hours to two days during fully overcast conditions. SODIS is recommended by the World Health Organization as a viable method for household water treatment and safe storage. Over two million people in developing countries use SODIS for their daily drinking water, although new research indicates that plastic bottles can be harmful if kept in the sunlight.

Solar cookers: Solar cookers use sunlight for cooking, drying and pasteurization. They can be grouped into three broad categories: box cookers, panel cookers and reflector cookers.

The simplest solar cooker was the box cooker built by Horace de Saussure in 1767. A basic box cooker consists of an insulated container with a transparent lid. It can be used effectively with partially overcast skies and will typically reach temperatures of 90–150 °C. Panel cookers use a reflective panel to direct sunlight onto an insulated container and reach temperatures comparable to box cookers. Reflector cookers use various concentrating geometries (dish, trough, Fresnel mirrors) to focus light on a cooking container. These cookers reach temperatures of 315°C and above but require direct light to function properly and must be repositioned to track the Sun.

Solar bowls: The solar bowl is a concentrating technology employed by the Solar Kitchen in Auroville, Pondicherry, India, where a stationary spherical reflector focuses light along a line perpendicular to the sphere's interior surface, and a computer control system moves the receiver to intersect this line. Steam is produced in the receiver at temperatures reaching 150 °C and then used for process heat in the kitchen.

A reflector developed by Wolfgang Scheffler in 1986 is used in many solar kitchens. Scheffler reflectors are flexible parabolic dishes that combine aspects of trough and power tower concentrators. Solar tracking is used to follow the Sun's daily course and the curvature of the reflector is adjusted for seasonal varia-

tions in the incident angle of sunlight. These reflectors can reach temperatures of 450–650 °C and have a fixed focal point, which simplifies cooking. The world's largest Scheffler reflector system in Abu Road, Rajasthan, India, is capable of cooking up to 35,000 meals a day.

Process heating: Solar concentrating technologies such as parabolic dish, trough and Scheffler reflectors can provide process heat for commercial and industrial applications. The first commercial system was the Solar Total Energy Project (STEP) in Shenandoah, Georgia, USA where a field of 114 parabolic dishes provided 50% of the process heating, air conditioning and electrical requirements for a clothing factory. This grid-connected cogeneration system provided 400 kW of electricity plus thermal energy in the form of 401 kW steam and 468 kW chilled water, and had a one hour peak load thermal storage.

Evaporation: Ponds are shallow pools that concentrate dissolved solids through evaporation. The use of evaporation ponds to obtain salt from sea water is one of the oldest applications of solar energy. Modern uses include concentrating brine solutions used in leach mining and removing dissolved solids from waste streams. Clothes lines and clothes racks dry clothes through evaporation by wind and sunlight

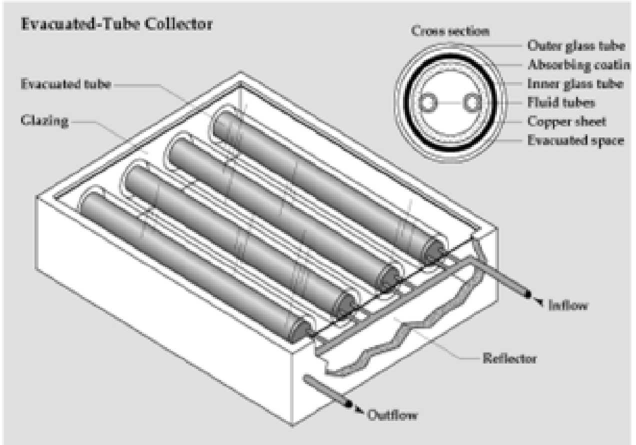
Electrical generation: Sunlight can be converted into electricity using photovoltaics (PV), concentrating solar power (CSP), and various experimental technologies. PV has mainly been used to power small and medium-sized applications, from the calculator powered by a single solar cell to off-grid homes powered by a photovoltaic array. For large-scale generation, CSP plants have been the norm but recently multi-megawatt PV plants are becoming common.

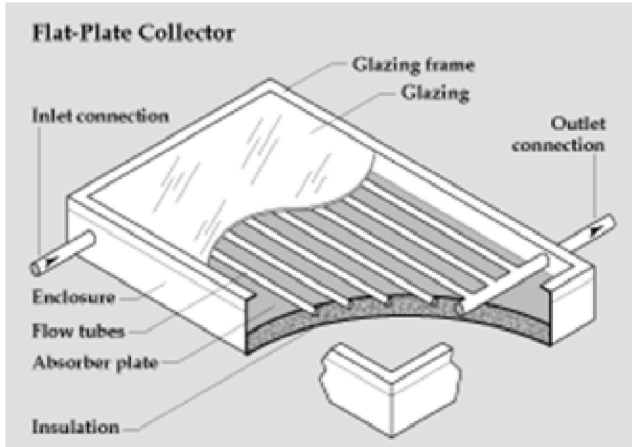
Solar collectors

Solar collectors are the key component of active solar-heating systems. Solar collectors gather the sun's energy, transform its radiation into heat, and then transfer that heat to water, solar fluid, or air. The solar thermal energy can be used in solar water-heating systems, solar pool heaters, and solar space-heating systems. There are several types of solar collectors:

- Flat-plate collectors
- Evacuated-tube collectors
- Integral collector-storage systems

Residential and commercial building applications that require temperatures below 200°F typically use flat-plate collectors, whereas those requiring temperatures higher than 200°F use evacuated-tube collectors.





Flat-plate collectors

Flat-plate collectors are the most common solar collector for solar water-heating systems in homes and solar space heating. A typical flat-plate collector is an insulated metal box with a glass or plastic cover (called the glazing) and a dark colored absorber plate. These collectors heat liquid or air at temperatures less than 180°F. Flat-plate collectors are used for residential water heating and hydronic space-heating installations. Liquid flat-plate collector heat liquid as it flows through tubes in or adjacent to the absorber plate. The simplest liquid systems use potable household water, which is heated as it passes directly through the collector and then flows to the house.

Evacuated-tube collectors

Evacuated-tube collectors can achieve extremely high temperatures (170°F to 350°F), making them more appropriate for cooling applications and commercial and industrial application. Evacuated-tube collectors are efficient at high temperatures. The collectors are usually made of parallel rows of transparent glass tubes. Each tube contains a glass outer tube and metal absorber tube attached to a fin. The fin is covered with a coating that absorbs solar energy well, but which inhibits radiative heat loss. Air is removed, or evacuated, from the space between the two glass tubes to form a vacuum, which eliminates conductive and convective heat loss.

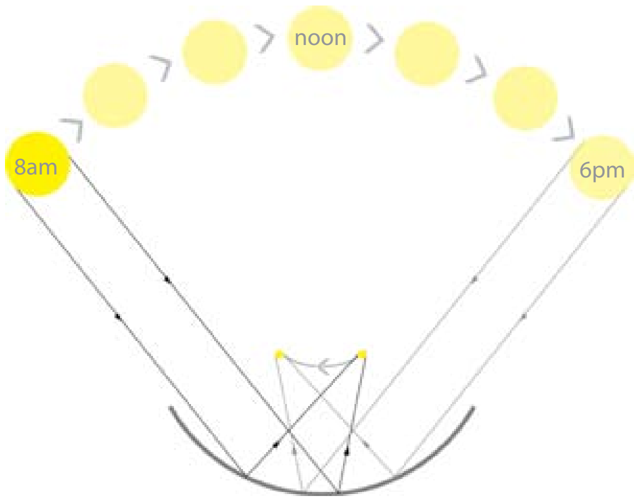
The "dewar" design features a vacuum contained between two concentric glass tubes, with the absorber selective coating on the inside tube. Water is allowed to thermosyphon down and back out the inner cavity to transfer the heat to the storage tank. There are no glass-to-metal seals. This type of evacuated tube has the potential to become cost-competitive with flat plates.

Integral collector-storage systems

Integral collector-storage systems, also known as ICS or "batch" systems, are made of one or more black tanks or tubes in an insulated glazed box. Cold water first passes through the solar collector, which preheats the water, and then continues to the conventional backup water heater[5].

Fundamentals of solar radiation

It is interesting to consider that the source of all solar energy, the sun, is a massive sphere 1.4 million kilometers (0.87 million miles) in diameter, and 150 million km (93 million miles) from the earth.
The radiation or solar power reaching the earth outside its layer of atmosphere, or extraterrestrial is about 1.7 x 10^{15} kilowatts. In terms of power per area, called solar flux e.g., watts per square meter, the earth outside of the atmosphere receives a flux of about 1353 W/m^2 , which is called the solar constant. Solar flux hitting a horizontal surface on the surface of the earth is much less than the extraterrestrial solar flux because of certain factors. These factors are briefly discussed below.



Absorption of radiation by the atmosphere

As the solar radiation passes through the atmosphere, some is absorbed and scattered by atmospheric substances such as ozone, oxygen, water, and dust. When solar rays pass through the atmosphere, the solar flux is reduced by around 15 to 30%, depending on time of year.

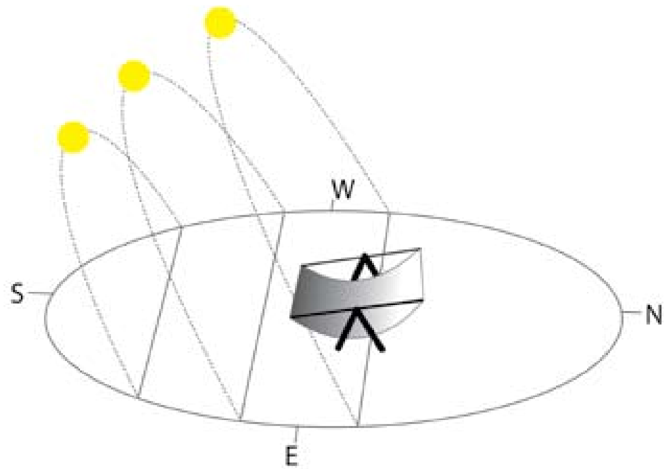
Time of day

The earth rotates, causing the relative position of the sun to vary from sunrise to sunset, and making the altitude angle vary from zero at sunrise to a maximum at solar noon, and again to zero at sunset. Altitude angle is the angle between the horizontal and the sun, while zenith angle is the angle between the vertical and the sun. Altitude angle affects the radiation on a horizontal surface from two important effects. When altitude angle is less than 90°, the horizontal surface area is not "aimed" at the sun, so the solar rays hit at an angle. The solar flux received by the surface is then reduced by the sine of the angle , compared to a surface facing the sun.

The second effect comes from the fact that when the sun is not directly overhead, the rays must pass through more distance of atmospheric layer to reach the ground, resulting in more atmospheric attenuation. For example, when altitude angle is 30°, the longer path through the atmosphere results in another 15% or so reduction in solar flux compared to overhead sun.
Note, the reduction in flux caused by the surface not aimed at the sun can be corrected by tilting the surface so that the solar rays hit the surface perpendicularly.

Latitude on the earth

North and south positions on the earth are measured by latitude angle, L, going from -90° at the South Pole, to zero at the equator, to +90°at the North Pole. Horizontal surfaces at different latitudes at any given time have different solar altitude angles, which affect the solar flux on the surface. In the region of the earth between L +23.50 and 23.50, the Torrid Zone, the



sun can be directly overhead (a = 90°) at noon for certain times of the year. North of latitude 23.50 or south of latitude -23.5° the sun is never directly overhead.

Date of the year

The axis of the earth's rotation is tilted by 23.5° from the perpendicular to the plane of revolution around the sun. In one revolution around the sun the angle of solar rays to a horizontal surface changes. The summer solstice (approximately June 21 for northern and December 21 for the southern hemisphere) is the day when the noon sun has greatest altitude outside of the torrid zone, and is the day with longest time of sunlight.

Altitude of location

Higher altitudes on the earth have a thinner layer of atmosphere for solar rays to travel through, so other things being equal, less of the extraterrestrial solar flux would be absorbed and scattered before hitting a surface on the ground, and the flux at ground level would be higher for higher elevations. For the first few kilometers of increasing elevation above sea level, the solar flux increases about 190 W/m^2 for every kilometer.

Meteorological conditions

All of the above influences on solar power can be fairly accurately calculated or known, however at any location and time, local meteorological conditions such as clouds, dust, rain have a great effect on solar power available for cooking.

Solar still design variations

Although there are many designs for solar stills, and four general categories, (concentrating collector stills; multiple tray tilted stills; tilted wick solar stills; and basin stills) 95 percent of all functioning stills are of the basin type.

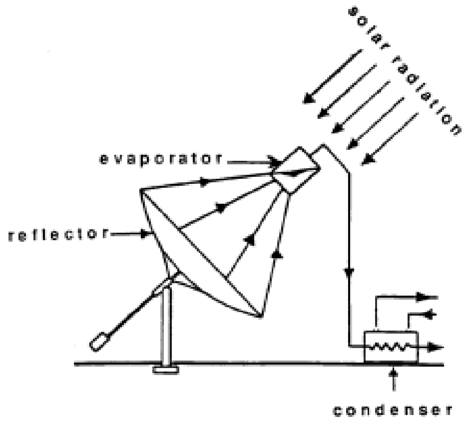


Figure 2. A Concentrating Collector Still

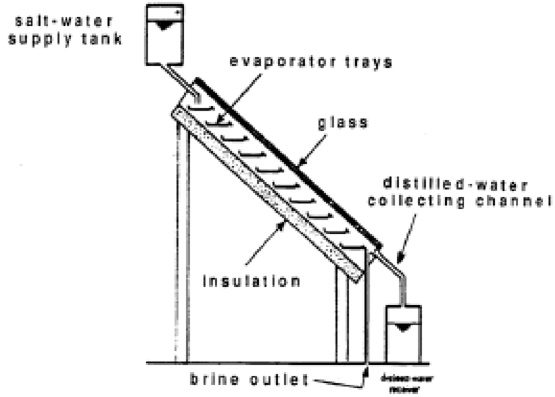


Figure 3. A Multiple Tray Tilted Still

Concentrating collector still

A concentrating collector still, as shown in Figure 2, uses parabolic mirrors to focus sunlight onto an enclosed evaporation vessel. This concentrated sunlight provides extremely high temperatures which are used to evaporate the contaminated water. The vapor is transported to a separate chamber where it condenses, and is transported to storage. This type of still is capable of producing from .5 to .6 gallons per day per square foot of reflector area. This type of output far surpasses other types of stills on a per square foot basis. Despite this still's outstanding performance, it has many drawbacks; including the high cost of building and maintaining it, the need for strong, direct sunlight, and its fragile nature.

Multiple tray tilted still

A multiple tray tilted still (Figure 3), consists of a series of shallow horizontal black trays enclosed in an insulated container with a transparent top glazing cover. The vapor condenses onto the cover and flows down to the collection channel for eventual storage. This still can be used in higher latitudes because the whole unit can be tilted to allow the sun's rays to strike perpendicular to the glazing surface. Even though efficiencies of up to 50 percent have been measured, the practicality of this design remains doubtful due to the complicated nature of construction involving many components and increased cost for multiple trays and mounting requirements.

Tilted wick solar still

A tilted wick solar still draws upon the capillary action of fibres to distribute feed water over the entire surface of the wick in a thin layer. The water is then exposed to sunlight. (See Figure 4)
A tilted wick solar still allows a higher temperature to form on this thin layer than can be expected from a larger body of water.

This system is as efficient as the tilted tray design, but its use in the field remains questionable because of increased costs due to mounting requirements and essential insulation, the need to frequently clean the cloth wick of built-up sediments, highlighting the need for an operable glazing cover, the need to replace

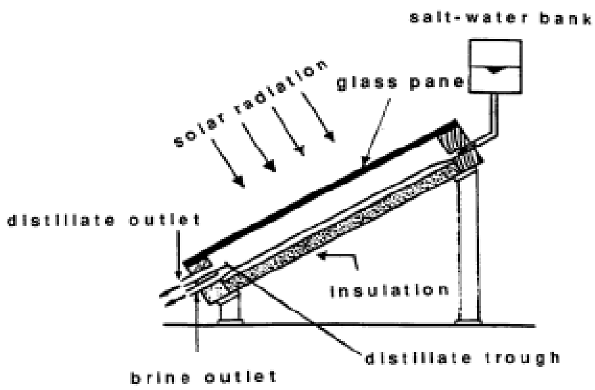


Figure 4. A Tilted Wick Solar Still

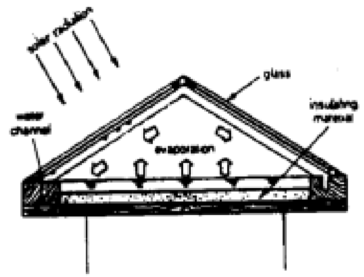


Figure 5. A Basin Still

the black wick material on a regular basis due to sun bleaching and physical deterioration, uneven wetting of the wick which will result in dry spots, leading to reduced efficiency, and the unnecessary aspect of the tilt feature except where it is required higher latitudes.

Basin still

A basin still (See Figure 5), is the most common type in use, although not in current production. While the basic design can take on many variations, the actual shape and concept have not changed substantially from the days of the Las Salinas, Chile stills built in 1872. The greatest changes have involved the use of new building materials, which may have the potential to lower overall costs while providing an acceptably long useful life and better performance.

DESIGN ANALYSIS

This chapter comprises of theoretical data that support the project and is the base on which the dimensions of the product will depend.

Theoretical data

Factors affecting evaporation

- Higher concentration of vapour in air reduces evaporation.
- Greater the surface area of water greater the evaporation.
- Greater the temperature of water, higher the kinetic energy of water molecules, more the evaporation.
- Higher the altitude at which water is boiled, lower the atmospheric pressure, more the evaporation.
- Boiling point of water decreases by decreasing the pressure.
- Pressure may be decreased by going "above sea level".
- Pressure may be decreased by "applying a vacuum".
- Boiling point of water may be increased by adding solute.

Factors affecting condensation

- Relatively cooler surface increases condensation.
- High vapour pressure of liquid reduces condensation
- Low temperature increases the amount of condensation.
- Higher vapor pressure of the atmosphere more condensation.

Solar flux and energy received by collectors

Solar flux is the radiation or solar power reaching the earth outside its layer of atmosphere is 1.7 x 10 kilowatts or 4 x 10^{15} kilowatt hours per day.
Solar flux at the outermost layer of the atmosphere= 1353 watt per square meter
(Assuming 7% atmospheric loss solar energy reaching the ground)
Solar flux at sea level or collector surface = 1000 W/m^2
Energy from the sun per square meter per hour
= 1000 Watts
= 1000 x 3600 joules = 3600 kilo joules

Energy required to distil water

Heat absorbed by water

Heat of vaporization of water = 2257 kilo joules/kg
Specific heat of water = 4.19 kilo joule /kg/Kelvin

Heat absorbed q= C x M x dT
C = specific heat
M = mass
dT = temperature difference in Celsius

Total energy required for distillation (Q) = energy to reach boiling point (E1) + energy required for phase transaction (E2)

Q = E1 + E2

E1 = C x M x dT
C = specific heat of water
M = mass
dT= temperature difference in Celsius
E2 = M x L
M = mass of water
L = heat of vaporisation of water

Hence Q =(C x M x dT) + (M x L)
= M (CdT + L)
=M (4.19 x (100-30) + 2257)
=M x 2550.3
Usable energy = energy from the sun (Es) x effective surface area x efficiency

Area required = energy for distillation/usable solar energy

These formulas will be used to determine the size of the collector depending on the amount of distilled water required.

Water output and energy relationship

The energy required to distil a particular amount of water depends on the mass of water. The energy harnessed from the sun is directly proportional to the effective surface area on which the sunlight is collected. Hence the amount of water that can be distilled depends on the effective surface area of the collectors. Using the derived formulas a table was generated which shows the relation between the water output, energy required for distillation, power and the area required for generation that amount of distilled water.

Water quantity (liters)	**Energy required to distil (KJ)**	**Area required (m^2)**	**Power (KW)**
0.5	1275.2	1.4	1.2
1	2550.3	2.5	2.5
2	5016.8	5.0	5.0
3	7650.9	7.5	7.5
4	9000.6	10.0	10.0
5	12751.5	12.5	12.5
6	15301.8	15.0	15.0

Time and solar energy relationship

The table below shows the fraction of solar energy received by the ground as a fraction of the solar energy incident upon the earth during the hours for the day over a year in the city of Ahmedabad. It is evident from the table that there is at an average eight hours of full solar energy reaching the ground level.

The conclusions derived form this table are that on an average day in a city like Ahmedabad we get eight hours of proper sunlight which could be used for distillation.

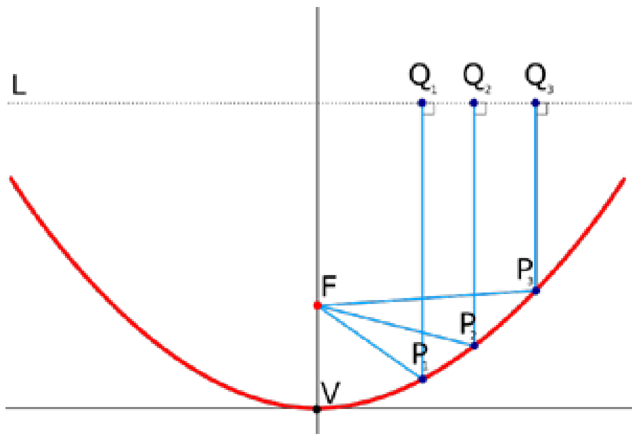
	6am	7am	8am	9am	10am	11am	12pm	1pm	2pm	3pm	4pm	5pm	6pm	7pm
January	0.0	0.2	0.8	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	0.8	0.2	0.0
February	0.1	0.3	0.9	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	0.9	0.3	0.2
March	0.2	0.2	0.8	1.0	1.0	1.0	1.0	1.0	1.0	1.0	0.9	0.8	0.2	0.0
April	0.0	0.5	0.9	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	0.9	0.5	0.4
May	0.2	0.6	0.9	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	0.9	0.6	0.2
June	0.1	0.5	0.8	0.8	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.8	0.5	0.2
July	0.4	0.4	0.6	0.6	0.6	0.6	0.6	0.6	0.7	0.7	0.6	0.6	0.3	0.3
August	0.0	0.3	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.4	0.2
September	0.0	0.2	0.7	0.8	0.9	0.8	0.9	0.9	0.9	0.8	0.8	0.7	0.2	0.0
October	0.0	0.3	0.8	1.0	1.0	1.0	1.0	1.0	1.0	1.0	0.9	0.8	0.3	0.0
November	0.2	0.2	0.8	1.0	1.0	1.0	1.0	1.0	1.0	1.0	0.9	0.8	0.2	0.0
December	0.0	0.2	0.7	0.9	1.0	1.0	1.0	1.0	1.0	1.0	0.9	0.7	0.2	0.1

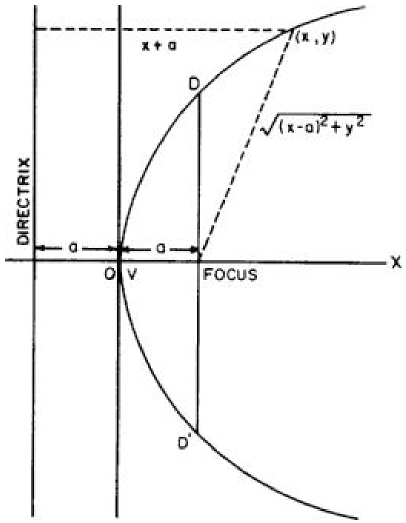
Area and time relation

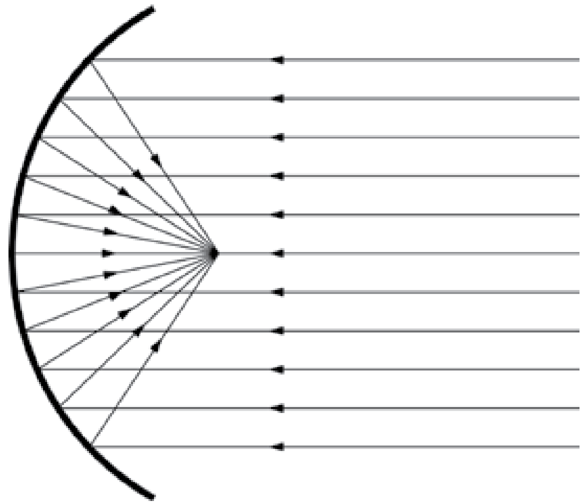
To get the appropriate water output a study was conducted and the requirement of drinking water for a family of four was around found out to be eight liters per day. Hence taking eight liters of pure distilled water output as constant the effective surface area and time in the sun was taken into consideration.
The table shows the relation between the duration of solar energy and area of collector for a constant output of 8 liters of water. Total energy requirement is 20,067.6 KJ to boil 8 liters of water. The energy output of a collector 1m^2 in area in one hour is 1000 kJ.

Hours	Area of collector to boil 8l of water (m^2)
1	20.0
2	10.0
3	6.7
4	5.0
5	4.0
6	3.3
7	2.8
8	2.5

Geometry of a parabolic reflector







Parabola is a the name given to the shape generated when a conic section is cut by a plane along its side. Mathematical analysis of the cut surface shows a distinct property, every point on a parabolic curve is equidistant from a point and a line. The point is called Focus and the line is called Directrix (See above left). This property of a parabolic curve leads us to an equation

$x^2=4ay$,which is used to describe a parabola, where 'x' and 'y' are cartesian coordinates and 'f' is the focal point of the curve and a is the distance of the focus from the apex of the parablola. This formula would be further used to determine the length of the reflector, effective area etc.

Focal point a of a dish can be calculated using the given formula

$a=D^2/16d$

Where F = focal point of dish, D=diameter and d= depth

The value of y is the height of the curve at the focus or the distance from the focus to point D. The width of the curve at the focus, which is the distance from point D to point D', is equal to 4a. This width is called the focal chord. The focal chord is one of the properties of a parabola used in the analysis of a parabola or in the sketching of a parabola.

USER ANALYSIS

The product will be designed keeping the users in mind. This chapter consists of the market study, user study and user profile for which the product will be developed.

Market analysis

There are a large number of products for purifying water. Reverse osmosis is the most efficient and most popular purifying process in India. Most of the water purifiers available in the market are affordable to the middle class. The efficiency of these products rapidly decreases with time and hence they need to be serviced quite often.

There are not many products in the market offering solar distillation. There has been a large amount of research and experimentation done in the field of solar distillation. The solar distillation products available are quite expensive. Most common distillation plants are for community purpose and require large amount of investment for construction and maintenance.

There are many existing solar water distillation products but due to the following reasons these are not being implemented

- High construction cost
- Expensive parts
- High maintenance
- Bulky and immovable
- Complicated to use
- Not very efficient
- Do not boil the water hence does not sterilize.
- Slow process of distilling

User

The users were then characterized into 4 sets based upon economic status-the upper class, the middle class, the lower class and the rural user.

The upper and middle class is highly concerned about the purity of water they are drinking. They are willing to spend money on compact systems like the R.O. purifiers.

The lower class and the rural population firstly are unaware of the quality of water they drink. The water purification methods accessible to them are not good enough. The purifiers which they can afford are simple filters. Most of the time electricity isn't available in many parts of rural India. Their main concern is affordability and maintenance.

After a thorough analysis of the Indian market and how the consumer thinks and what are their expectations and demands a few points were taken under consideration, these were-

- **Cheaper the better**
- **Consumers want affordable products**
- **Purity is the first priority**
- **Complexity in working with the product is highly discouraged.**

User profile

The following personas were given to represent the people for which the product or system has to be developed and to keep them in mind while working on the project.

Rajesh is a farmer in the central part of Gujarat. Every day his wife has to walk 5 to 8 km to fetch 2 buckets of water from the nearest river or other water sources. His house has no electricity and his income is barely enough to provide food for his family. He knows for a fact that the water he drinks isn't pure and is aware of the dangers of it, but his financial state as well as his location doesn't allow him to buy any of the products available in the market as they are of no use without electricity. He isn't skilled enough technically but is aware and most of the time he is free.

Aakash is a skilled worker on the outskirts of Delhi. He has a steady pay to support his family who live in a slum where the quality of water is way below the drinking standards. He is smart enough to know the potential of the sun's energy but has no technical background or the financial support to invent something which could solve his problem. His budget will get him a normal filter and nothing more, exposing his family to all the water borne diseases in the contaminated water.

Mr Druv Sanchari is a teacher and works for an NGO. He is very concerned about the quality of water the kids drink in the village he teaches in and has been asking the Government to install a purifier plant. But due to high cost of construction and maintenance this is almost impossible. He wants a product which would be cheap to manufacture, easy to maintain and hopefully doesn't require electricity.

Classification of product range

After thoroughly studying the market and user segment the project was categorized into four user segments that the product should cater to.

The lowest one ranging to a max of 1,500 rupees would cater a single person's daily need of water. It should incorporate features like light, portable and easy to use. Next was the mid-range segment catering to almost a family of four. The high end and community range would cater to large groups of people with features like kitchen supply lines, etc.

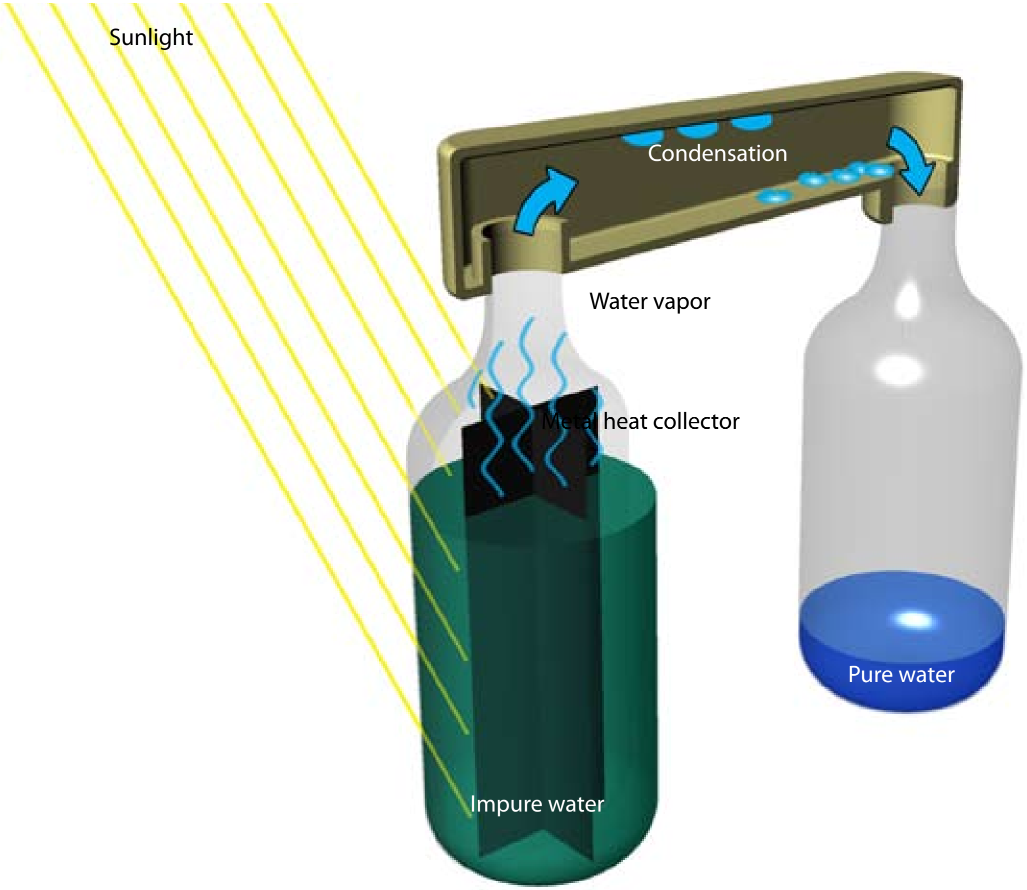
Range	**Quantity of water**	**Estimate cost**	**Features**
Lowest end	2	Less than 1500	Concentrator and structure
Mid range	5 to 10	1500 to 4000	Concentrator, structure, condenser
High end	20	4000 to 8000	Concentrator, structure, condenser, storage, extensions
Community (5 families)	150 to 200	8000 to 15000	Concentrator, structure, condenser, storage, supply line

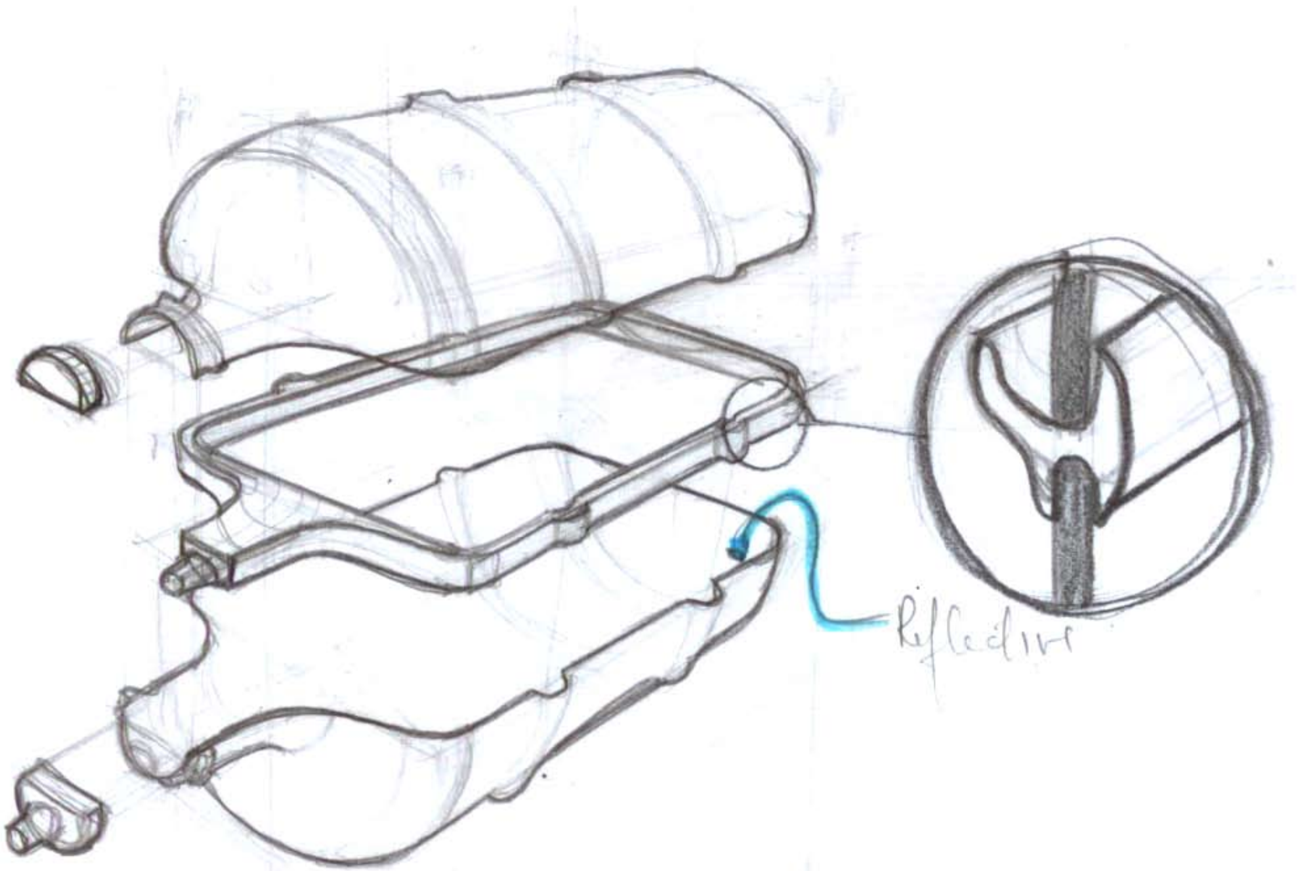
CONCEPT DEVELOPMENT

This chapter comprises of initial design ideas and concepts out of which some of them were taken forward for experimentation and prototyping.

The concept was to use plastic or glass bottles and combine with a device which connects two bottles in a way that one bottle contains impure water and the other bottle is used to collect distilled water.

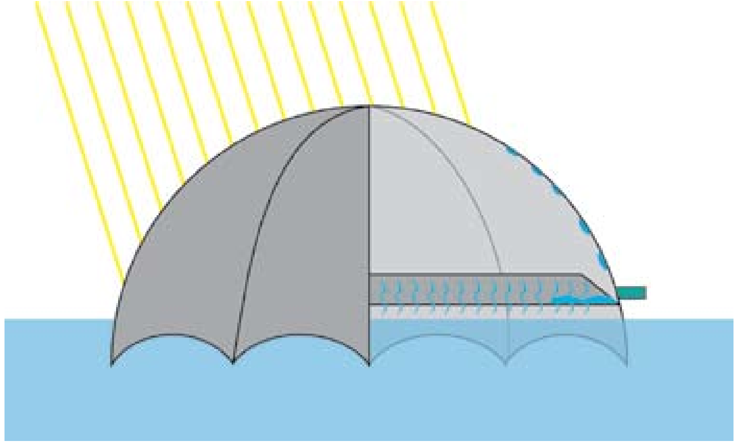
The arrangement is kept in the sun. When the suns rays hits the heat collector inside the bottle which contains the impure water it causes the water to heat up and evaporate . The vapors then get condensed in the device (as shown in figure on the side) and drip down in the other bottle.

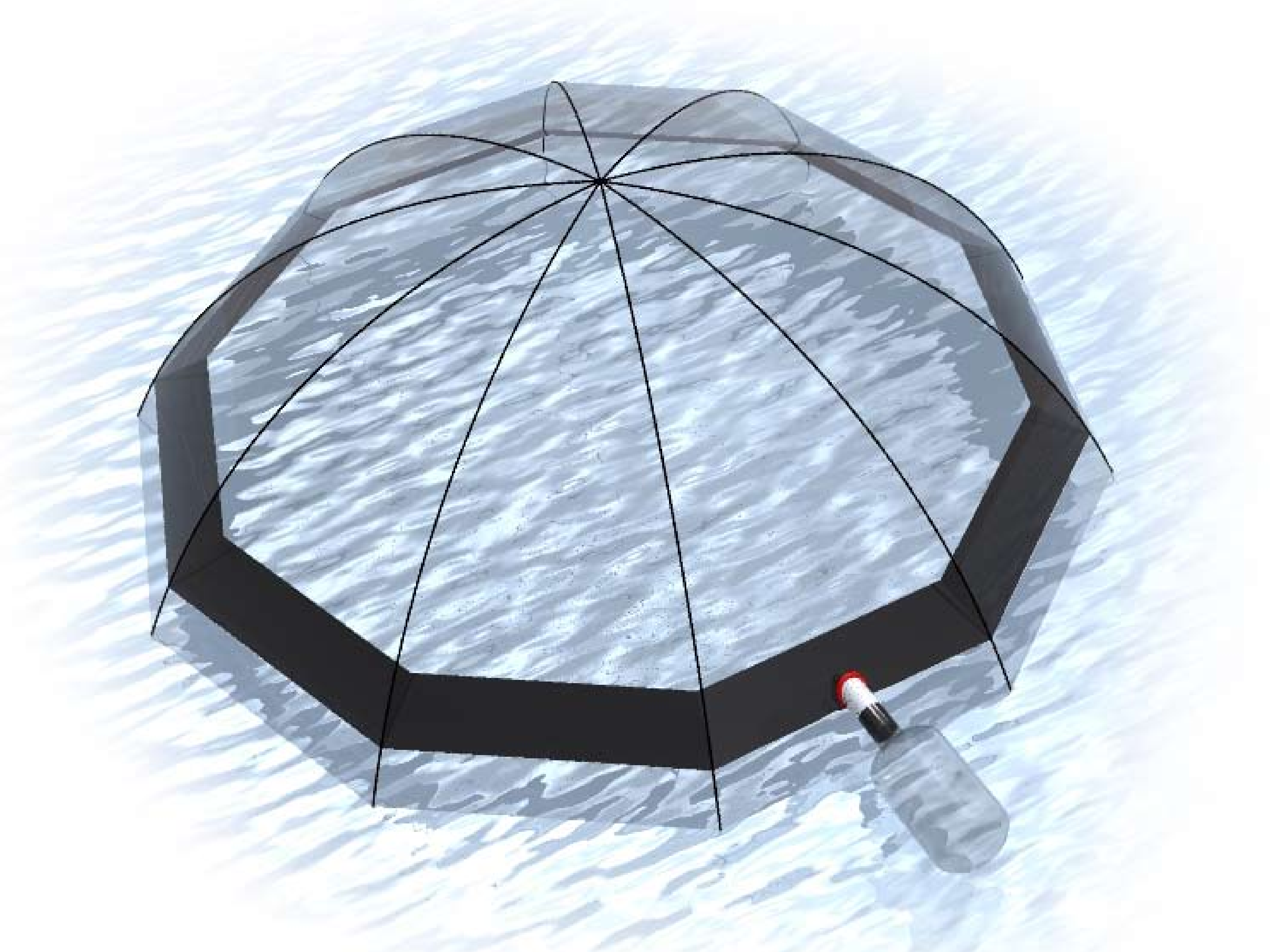




The idea was to use existing water barrels readily available in the Indian market and modify it with some additional components and use it to distill water.
The concept was to split the bottle into two parts and connect them together using a channel which would collect the distilled water and channel it out. The lower part would be incorporated with a heat-absorbing material which would then heat the water inside the lower half. These vapors will then condense on the top part and slid down to the channels.
Due to the fact that plastic may dissolve in water in the presence of the sun, the concept was not pursued further.

The design was inspired by the umbrella. This collapsible structure could be used over swamps or muddy waters to get clean distilled water with the help of sunlight.
The water would evaporate and condense on the inner surface of the umbrella from where it will slide down into a channel from where it could be collected from an opening.

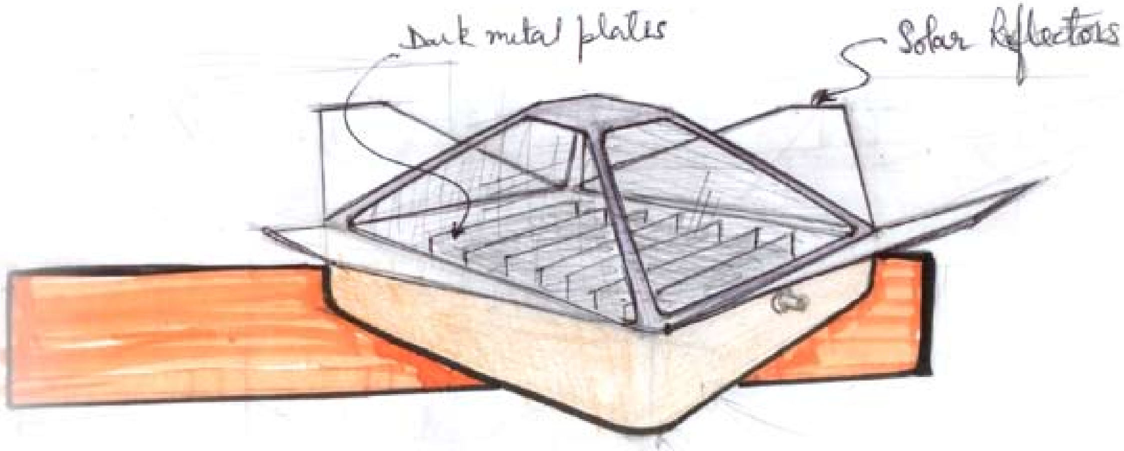


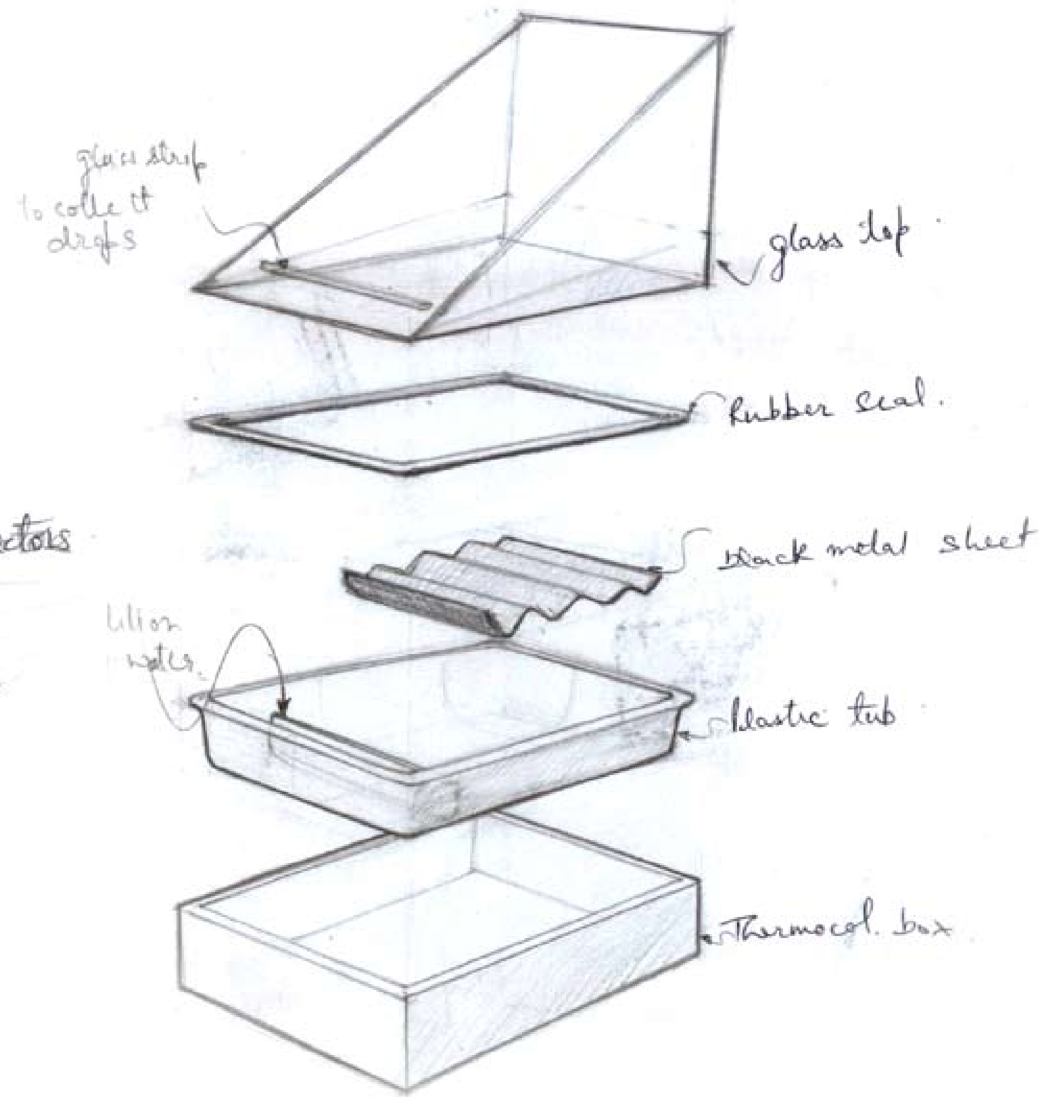


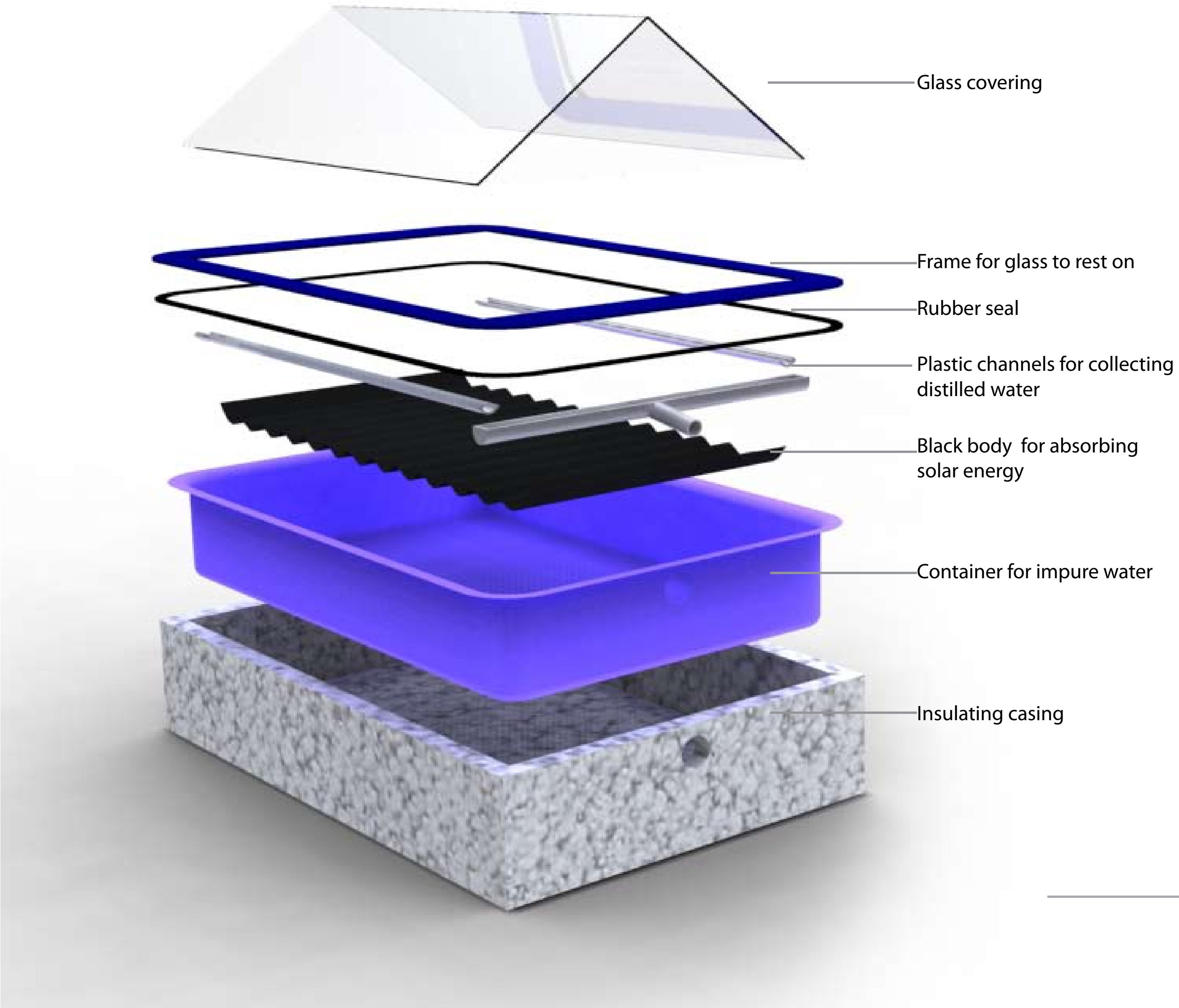
Simple distiller

This distiller's design is the most common and basic design to get distilled water. The process is slow and takes a lot of time. These kind of designs are used all over the world to get distilled water.

The drawbacks for such a design is the low temperature for distillation, which doesn't destroy harmful organisms, and the large number of parts in contact with water.



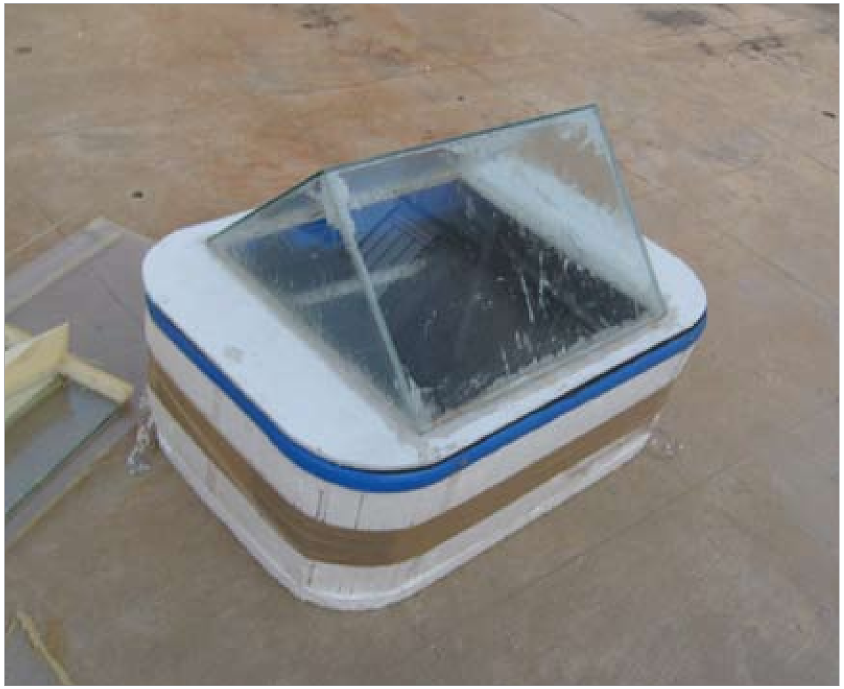




Process

As the sunlight hits the black sheet it heats it up transferring the heat to the water around it. This water then evaporates and rises. As these vapors touch the cooler glass surface they condense and convert to water droplets and trickle down the surface of glass and get collected through the channels.
This distilled water then can be collected and used for drinking.

The distiller at work.

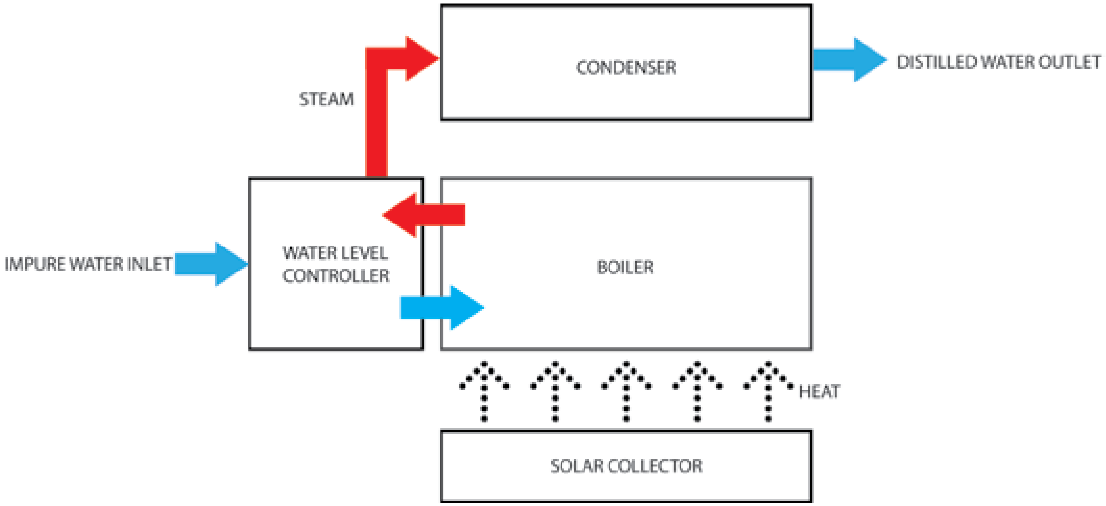


The rubber seal to make the distiller air tight.

The black sheet which absorbs the sunlight.

After initial conceptualization and understanding it was decided to segregate the distillation process into three parts for concept development namely-

- Collector
- Boiler
- Condenser



Collector
The collector will be the part which would be collecting the energy from the sun and transfer it to the boiler.

Design specifications-

- Should collect and concentrate maximum amount of solar energy
- Light to use
- Durable and weather resistant
- High efficiency
- Minimal cost of construction

Boiler
The boiler will be using the heat provided by the collector to boil water until it evaporates and is sent to the condenser.

Design specifications-

- Highly efficient
- Minimal loss of heat via radiation or convection
- Least reactive
- Withstand high temperatures

Condenser
The condenser would then condense the steam and water vapors to pure water.

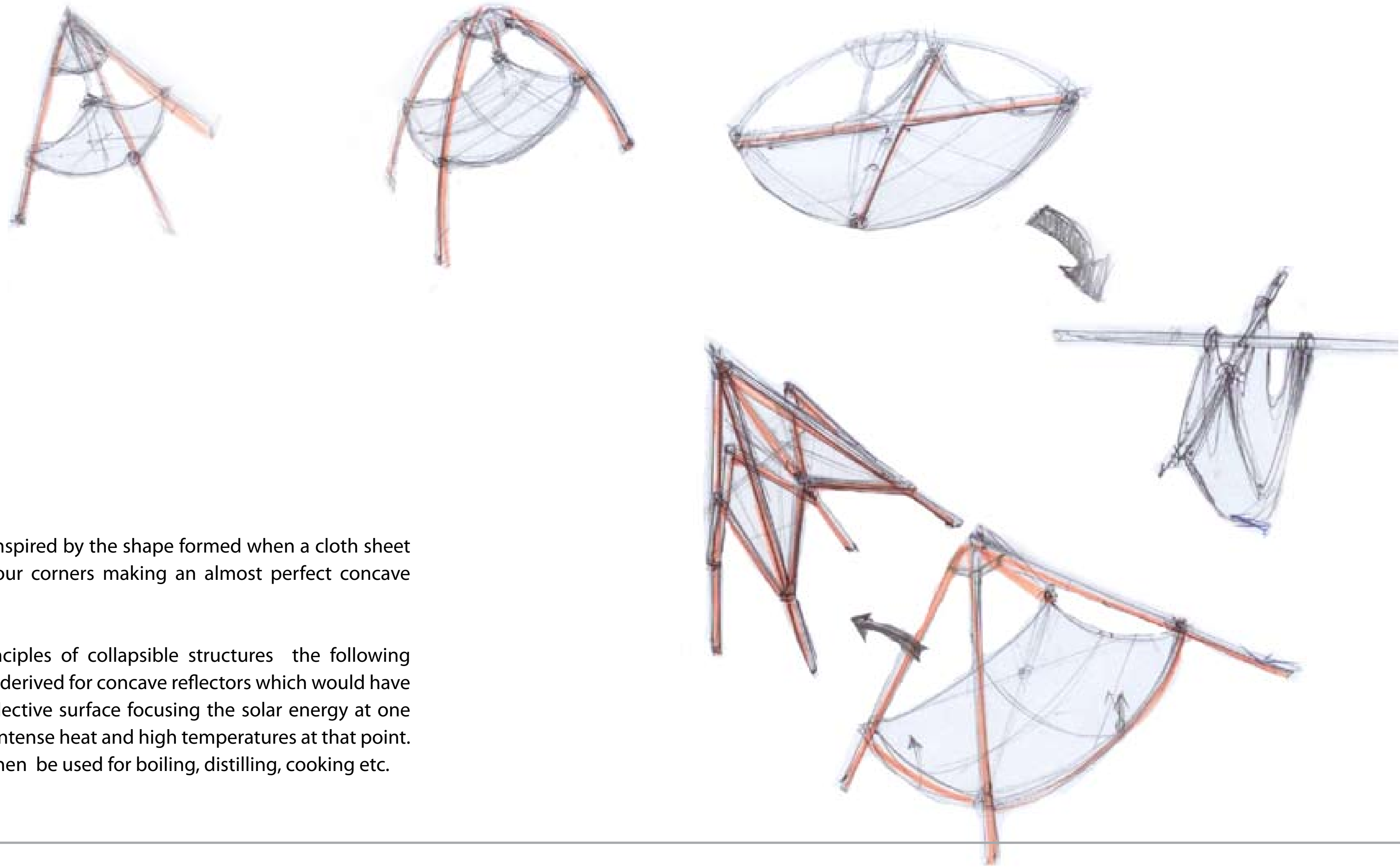
Design specifications-

- High heat conductivity
- Highly efficient in loosing heat
- Non reactive to steam
- Almost sealed
- Withstand high temperatures

CONCEPTS FOR SOLAR COLLECTORS

This chapter consists of concepts and prototypes of solar collectors and different kinds of reflectors.

Expandable structures for reflectors



The idea was inspired by the shape formed when a cloth sheet is held from four corners making an almost perfect concave reflector.

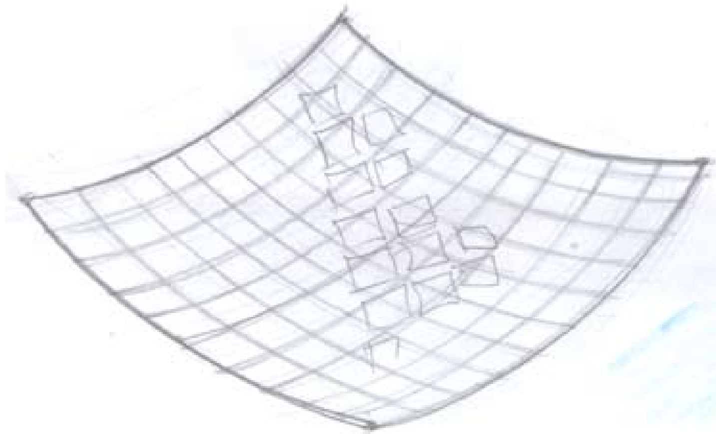
Using the principles of collapsible structures the following concepts were derived for concave reflectors which would have a cloth like reflective surface focusing the solar energy at one point causing intense heat and high temperatures at that point. This heat will then be used for boiling, distilling, cooking etc.

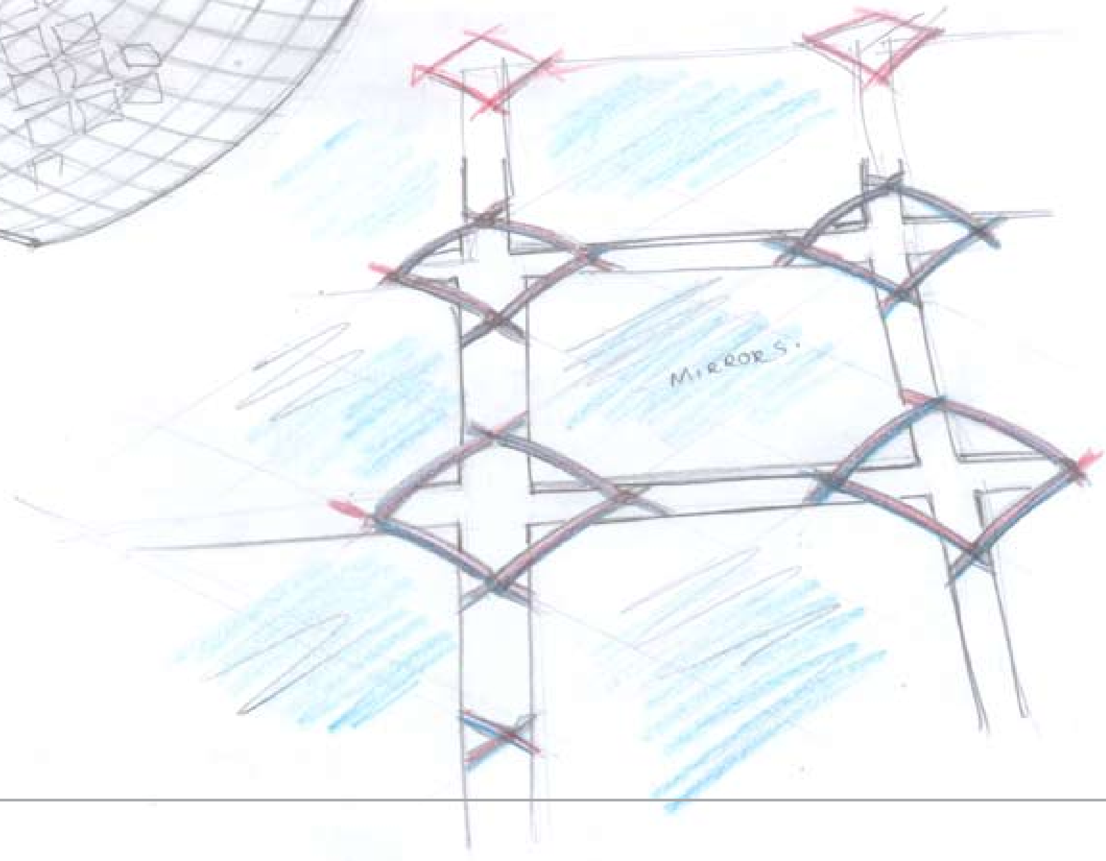
Concepts for solar collector

The image on the right shows how the design would look and work. The heat is concentrated at the centre where the heating vessel will be kept.

The image shows the hinge mechanism

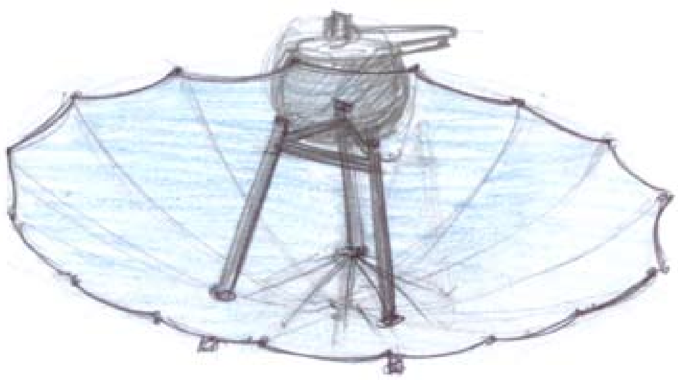
Net structure concept





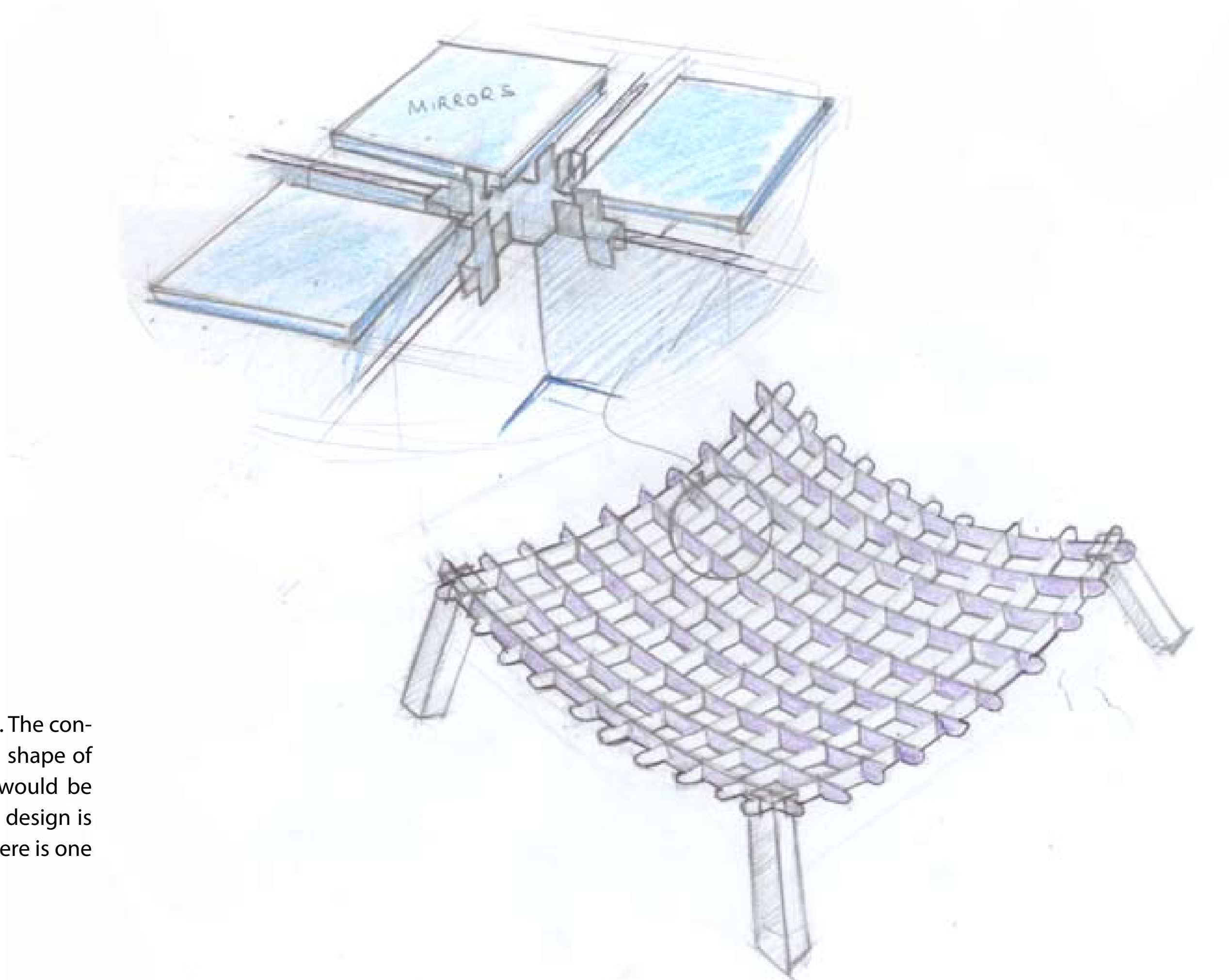
Using the previous concept of cloth curvature and using net structure with glass pieces fixed in the net the same concave reflector can be achieved. The glass is cut in square pieces which are then place on a net as shown in the figure on the right.

It would be produced in the villages itself creating employment and integrating craft, design and technology. The point of focus would then be used for boiling, distillation and cooking etc.



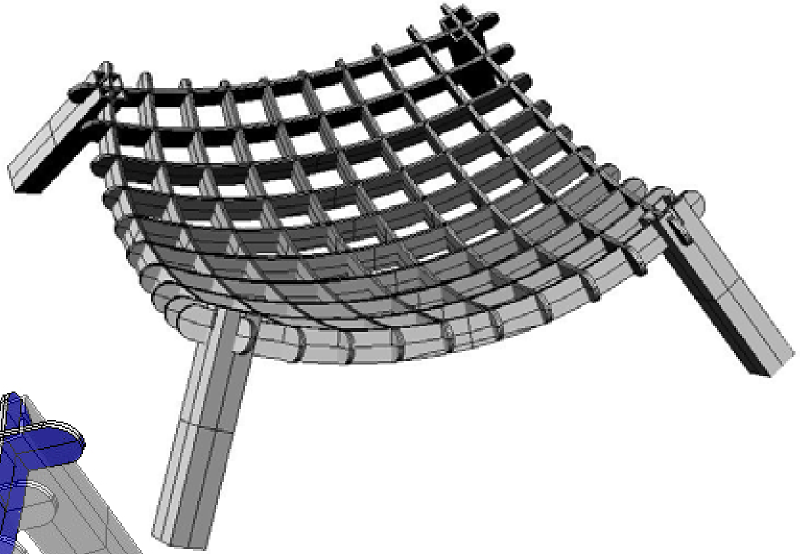
Inspired by an umbrella this concept was specifically designed for travel use. With features like collapsibility and lightness of weight, it can be carried wherever there is abundant sunlight. It would then concentrate sunlight at the focal point where boiling, distillation or cooking could be carried out.

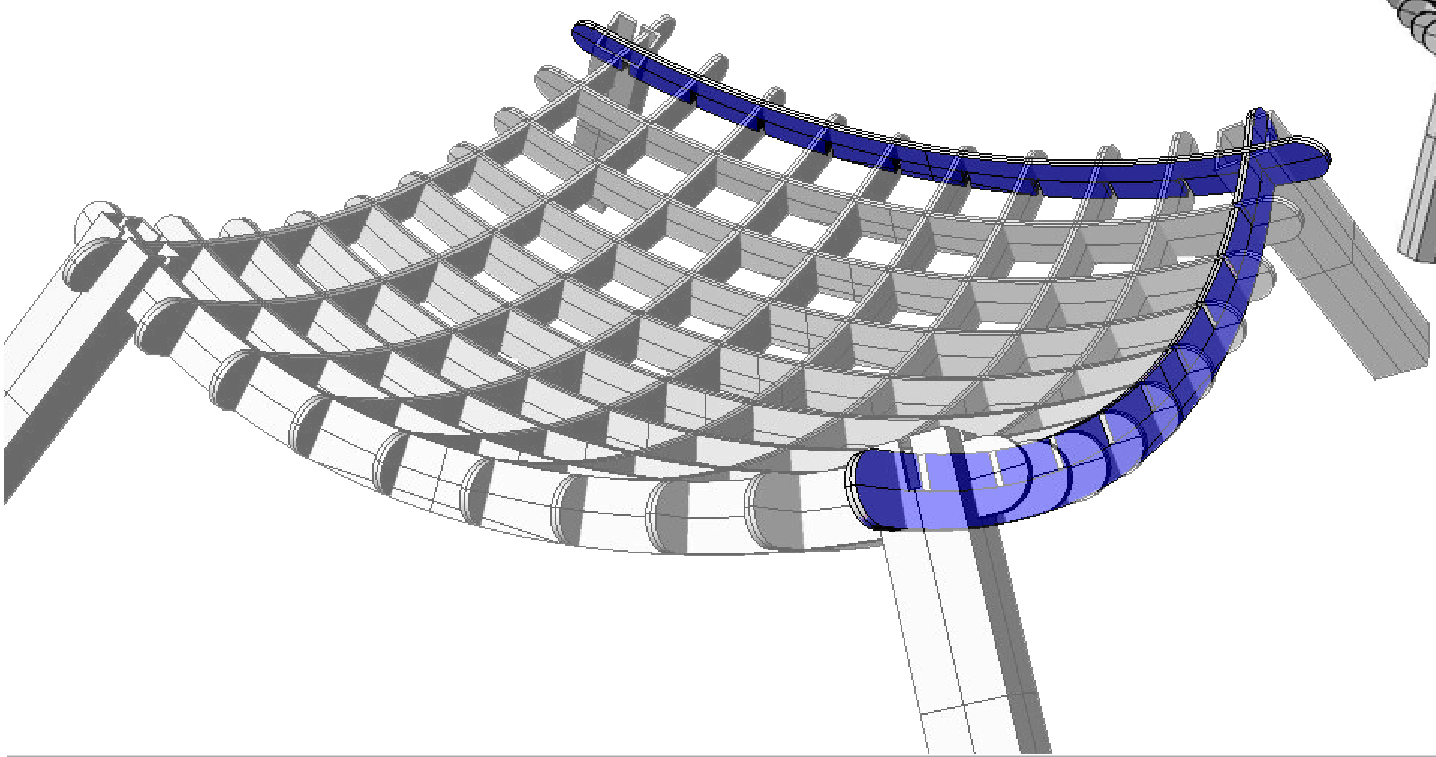
Glass dome structure concentrator



This design was specifically for stable and rigid setups. The concept was to have a inter-locking grid structure in the shape of a concave dome in between which square mirrors would be placed. It would focus solar energy at one point. This design is easy to setup and has less production cost because there is one unit which tessellates to form a grid.

The strips are of the same shape and size but half have cutouts on the top and the other half have it at the bottom. These cut-outs then fit into each other forming the concave dome shaped structure in which the glass pieces are placed (sketch on the previous page).

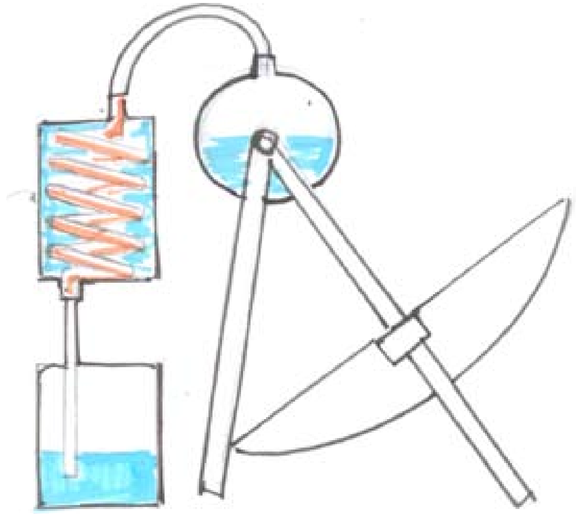




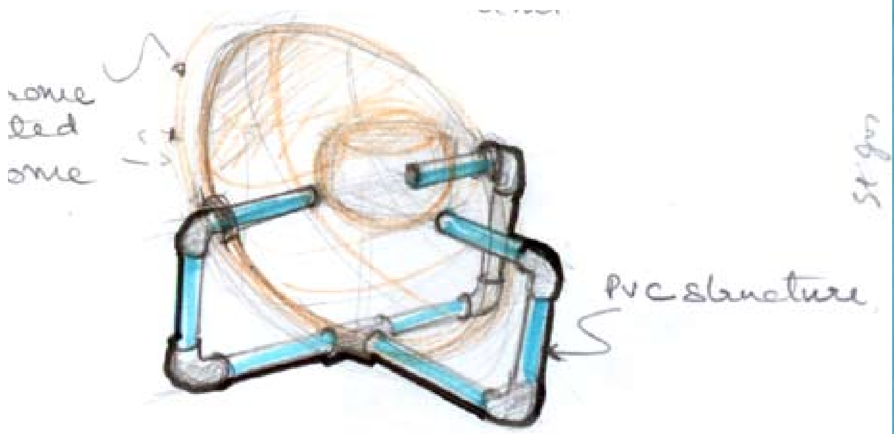
Satellite dish as concave reflector

Using existing dome-shaped objects (such as a satellite dish receiver) as reflectors was one of the key design innovations during the project .

Below you can see the process of making the dish reflective by putting glossy silver paper on it.



The dish was then mounted on a structure and tested. The setup consisted of the dish., a metal frame structure and a vessel painted black filled with water.
It took about 30 minutes of continuous solar energy for the water to start boiling.



Below are a few experiments conducted to see the temperature, heat intensity and time of boiling.

The figure on the left shows the boiling process of making tea using solar energy. The figure in the centre shows the heat intensity under the vessel. The figure on the right shows a burning wooden stick, which catches fire when kept at the focal point for as little as five seconds.

Parabolic stainless steel sheet reflectors

The design comprises of a reflective stainless sheet curved to form a parabola which would concentrate a line of intense sunlight at the focal line of the parabolic sheet. This heat would then be harnessed for distillation.

The advantage of a parabolic reflector over a dome reflector is that the focal point of a dome reflector keeps on changing relative to the direction of the sun whereas in a sheet reflector whose axis is kept aligned to the movement of the sun, the focal shift would be relatively lesser.

Parabolic acrylic mirror sheet reflectors

Using acrylic mirror as parabolic reflectors was more efficient then stainless steel as the curvature formed was smoother, the manual formability to the desired curved shape for the available gauges of material was better for acrylic than for stainless steel, and the price of stainless steel was higher than that of acrylic even though the life of steel would be more then acrylic.

In the diagram on the right you can see the intense focal line which is also used for alignment of the device (explained later in the document).

Conclusions

After a through understanding of the needs and feasibility of the designs and considerations of availability of material near the project site it was decided to go ahead with acrylic mirror sheet reflector. Using parabolic sheets would be more efficient than dome concentrators even though the dome's concentration of solar energy is more then that of the sheets because the dome focuses on a point where as the parabolic sheet focuses on a line. Due to the fact that no sunlight trackers would be required for the sheets as the focal line doesn't shift much as compared to that of a dome concentrator, sheet reflector was chosen over the dome reflector.

CONCEPTS FOR BOILERS

This chapter discuses all the concepts of how to use the concentrated heat of the sun to boil water and convert it into steam.

Steel vessels

The initial concept was to use a steel vessel for boiling and using pipes take the steam out of the vessel and distilling the steam. The vessel was painted black to increase absorption of heat concentrated by the dish concentrator.

Although the water started boiling within 30 minutes there was no steam coming out of the pipes because of the small opening at the top of the vessel.

GI pipe

The concept of using pipe came up when parabolic sheet reflector was used as it could provide the long cylindrical shape to harness the line of intense heat generated by the reflector. G.I. pipes are easily available and are a lot cheaper then copper or steel pipes.

The setup was simple, there would be a water inlet and a water outlet from either sides of the GI pipe. The GI pipe would be placed at the focal line of the reflector. Water would be filled in the pipe up to half its cross-section to allow space for the steam to escape from the outlet. This level would be controlled externally (right image). The steam would then pass through the curved steel pipe where it would get condensed to form pure distilled water.

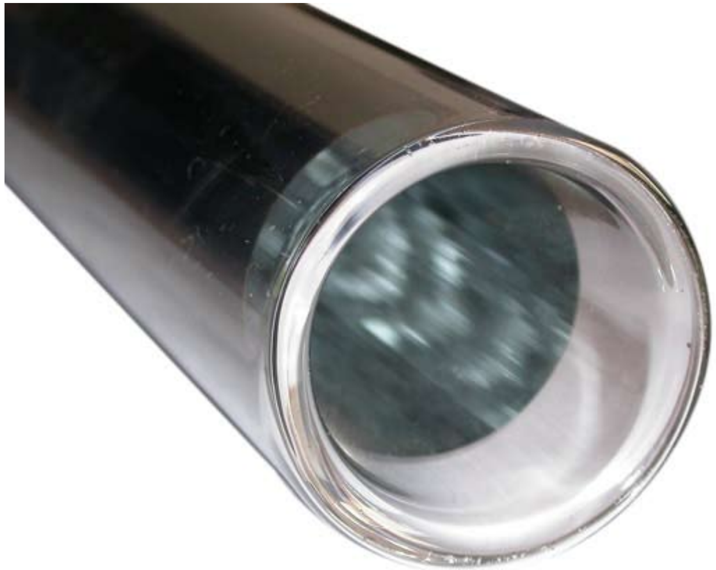
Although the water started boiling there was large amount of heat loss because of the low heat retention and high specific heat of the pipe. This was a major drawback of the G.I. pipe.

Insulated G.I pipe

Due to excessive loss of heat in the GI pipe different types of insulation methods were tried to reduce the heat loss .These methods include covering the pipe with rubber insulation on the upper part, and using air conditioning insulation.

Vacuum tube

Vacuum tubes are made of borosilicate glass and are vacuum heat insulated. There is coating in outer area of the inner tube, which has a property of high absorption, low emission and good temperature keeping.
Vacuum tubes have a higher advantage of insulation. Hence using a vacuum tube instead of a GI pipe was favorable for the design. The water in the tube starts to boil within 15 minutes and large amounts of steam is generated. The only disadvantages are that the vacuum tubes are open from one side, are very delicate and expensive compared to a GI pipe.



Conclusions

After conducting further practical experiments it was decided to go forward with the concept of a vacuum tube because firstly it fitted with the parabolic sheet reflector's geometry and secondly it is highly efficient in generating steam.

CONCEPTS FOR CONDENSER

This chapter discusses the different methods and experiments conducted during the project to get pure distilled water out of steam via condensation.

Steel pipe

The first experiment was to use a simple food grade steel pipe bent and attached to the boiler. The concept was that as the steam touches the cool surface of the steel it would condense to water, but the results were not satisfactory as not much condensation happened due to the low surface area for condensation.

Radiator as condenser

This experiment was to see if a car radiator would be an appropriate condensing unit . This experiment used an electric steamer to generate steam and a car radiator to see the efficacy and output of the radiator. Although the efficacy of the radiator was outstanding and almost all the steam condensed into water but the idea was dropped due to the fact that it involved using a car radiator in a water purification system, being an industrial no food-grade component the radiator didn't fit the bill for a component for a water purifier.

Steam vessels

Stainless steel steam vessels like the idli maker are amazing examples of safe condensers as they have a large volume to incorporate the expanding steam and a large surface area which helps in radiating heat and condensation. The stainless steel vessel being food grade doesn't react with the steam which is a high advantage over other condensers.

Conclusions

After a through study and experimentation it was decided to go ahead with the steam vessel (idli maker) and further accessories and customize it to the need of the design.

INTEGRATION OF DESIGN CONCEPTS

This chapter discusses the process of combining the individual design components and concepts to form an integrated design and further prototyping it.

Integration of design concepts

Using the best of all the experiments conducted and assimilating all the knowledge gained from them a unified design was made which was simple, highly efficient and economical.

There were a few new components which needed further experimentation such as the water level controller.

Below are the features taken forward for further refinement and experimentation for the final design. On the next page the diagrammatic representation of the components and process are shown.

Reflector
Acrylic mirror sheets would be used bent in the shape of a parabola to give a perfect line of focus. Acrylic sheets are far more reflective then any other material available easily (98% reflective). They are easy to cut and install and form perfect curves without any external casing.

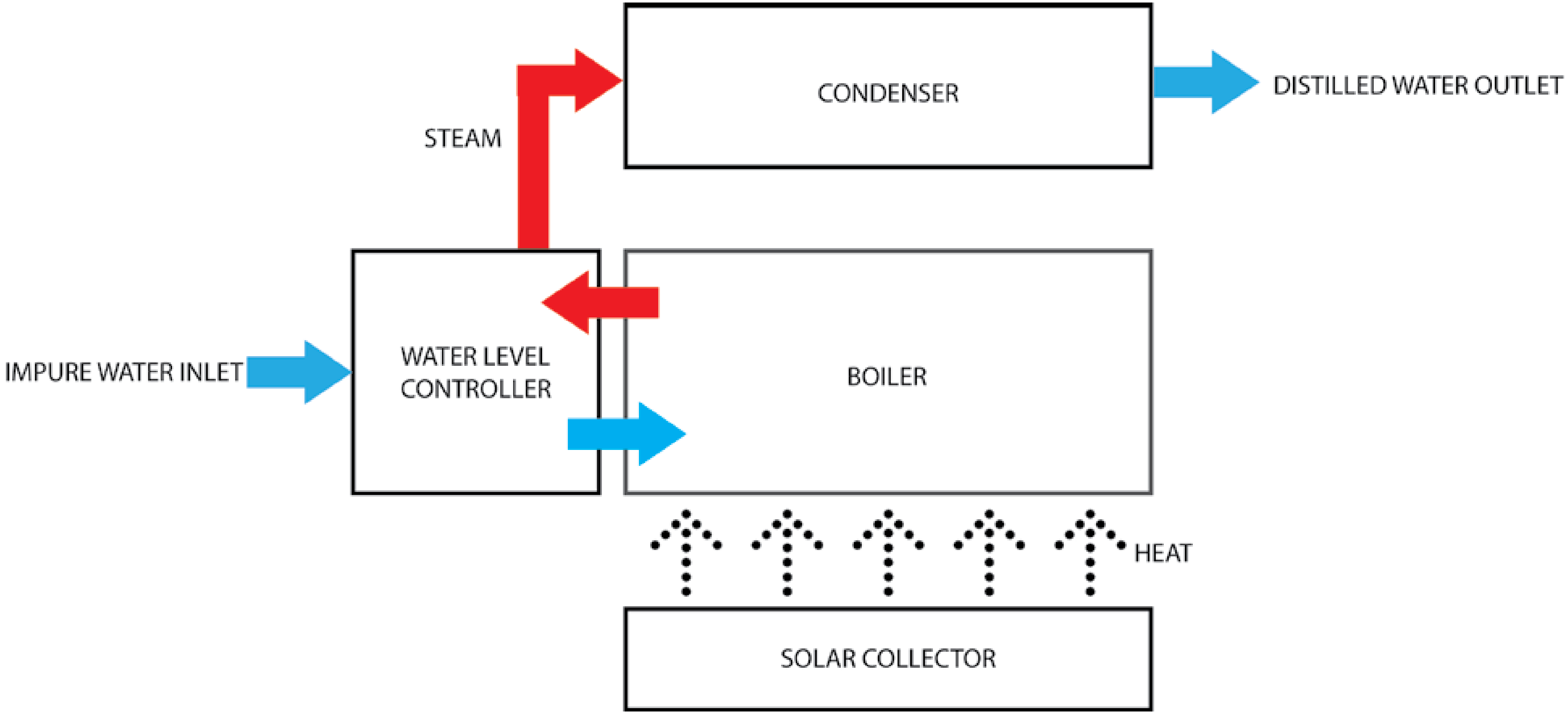
The parabolic curve has to be determined according to the surface area required and factors such as the length of the tube, capacity of the condensers, etc. The structural dimensions would be totally dependent on the reflector dimensions.

Boiler
A vacuum tube would be used for boiling water as there is almost no heat loss and the dimensions are a match for parabolic reflective sheets.

The standard dimensions of these tubes have to be taken under consideration as this would be the basic standard size around which the whole setup will be based.

Condenser
Stainless steel steam vessel would be used for condensation as it is non-reactive to steam and has a large surface area and volume for conduction of heat.

The dimensions have to be carefully chosen according to the needs of the design. Multiple vessels could be used instead of one to increase condensation and heat transfer.


CONDENSER
DISTILLED WATER OUTLET
STEAM
WATER LEVEL
CONTROLLER
IMPURE WATER INLET
BOILER
HEAT
SOLAR COLLECTOR

The first prototype of the idea was a rough integration of the reflector, boiler and condenser. The three components were arranged on a metal frame connected to a box containing the water level controller.

The inlet water is connected to the box through a float valve which keeps the water level and inlet constant. The water then enters the vacuum tube where it gets heated up and the steam then enters the box from where it goes to the condenser through an outlet at the top of the box. The condenser is covered to avoid the sunlight. The water then condenses and comes out of the distiller as pure water.

The output of the setup was low because of loss of heat through the plastic box, inadequate amount of condensation and the excessive length of the vacuum tube.

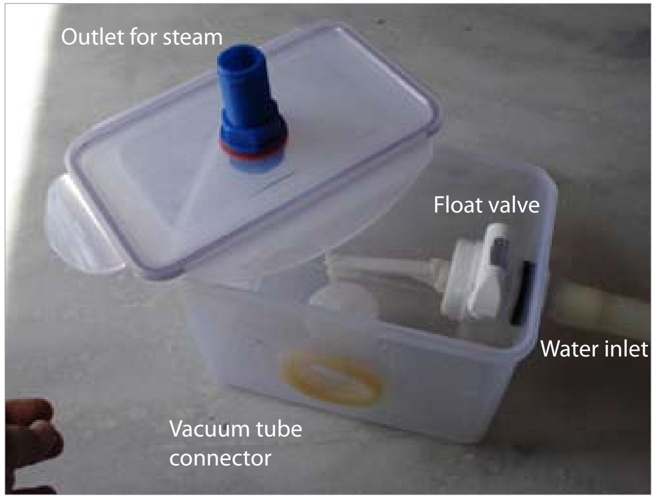
Condenser

The condenser had to be drilled and two connectors were installed, one for inlet of steam and the other for outlet of distilled condensed water. The black pipe in the right figure shows the arrangement of the condenser and the connectors. The black pipe is the inlet pipe for the steam and the white one is the outlet (right figure).

Water level controller (Connector box and float valve)

The connector box was a microwave-safe plastic box in which three holes were made according to the sizes required, one for the float valve at the water inlet, second for the vacuum tube and third for the connector for steam outlet.

The design of the water level controller should be such that it is compact easy to work with, and can stand boiling water. The plastic box was not the appropriate solution because of the fact that it was bulky, thin walled and conducted heat to the surrounding.



DESIGN EVOLUTION AND MODIFICATION

In this chapter the basic design would be worked on and improved to achieve the required amount of distilled water in the most logical ways.

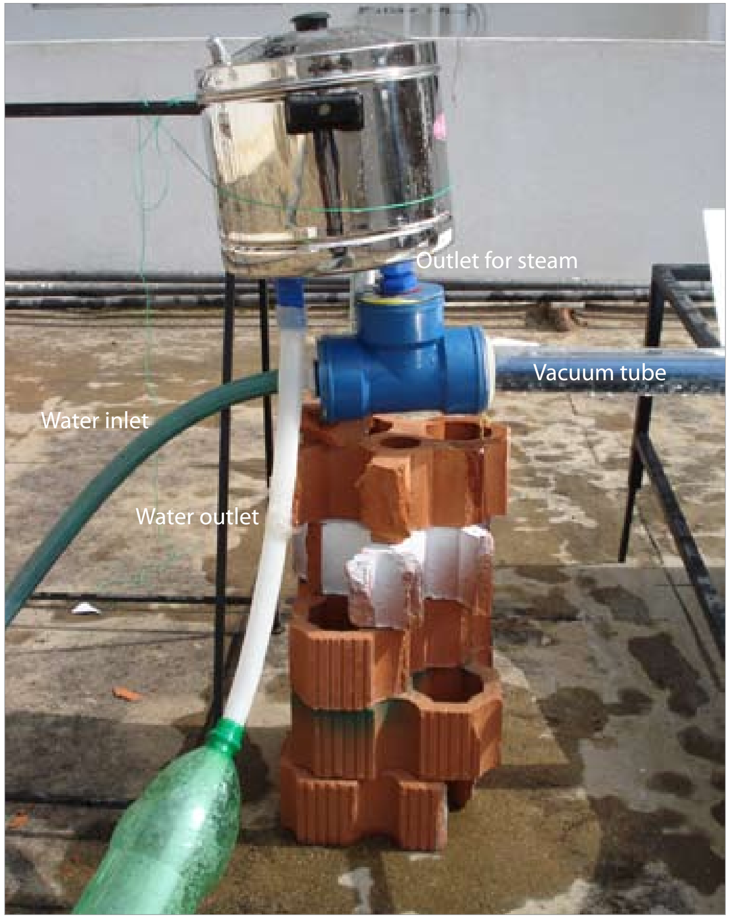
Component enhancements

The drawbacks of the first prototype (connector box) led to further experimentation and market research to figure out perfect substitutes for the connector box.

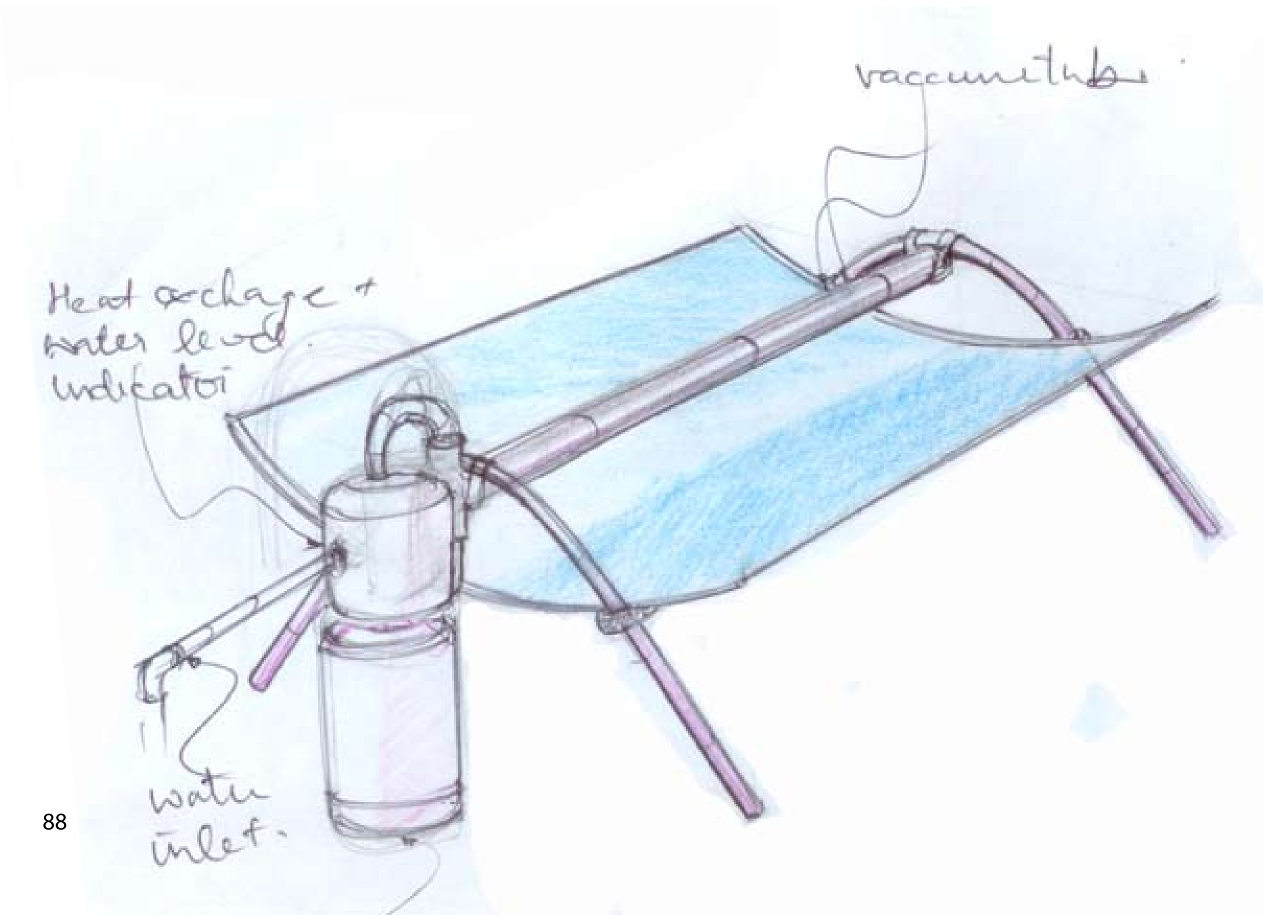
The T-joint was a perfect solution and substitute for the connector box as it was thick, sturdy and conducted less heat to the surroundings reducing heat loss and withstand high temperatures.

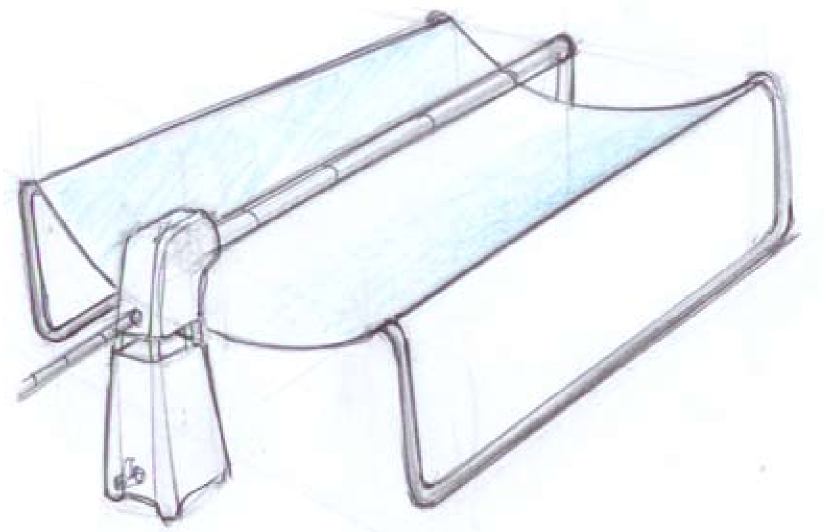
The number of condensers were doubled to increase condensation.

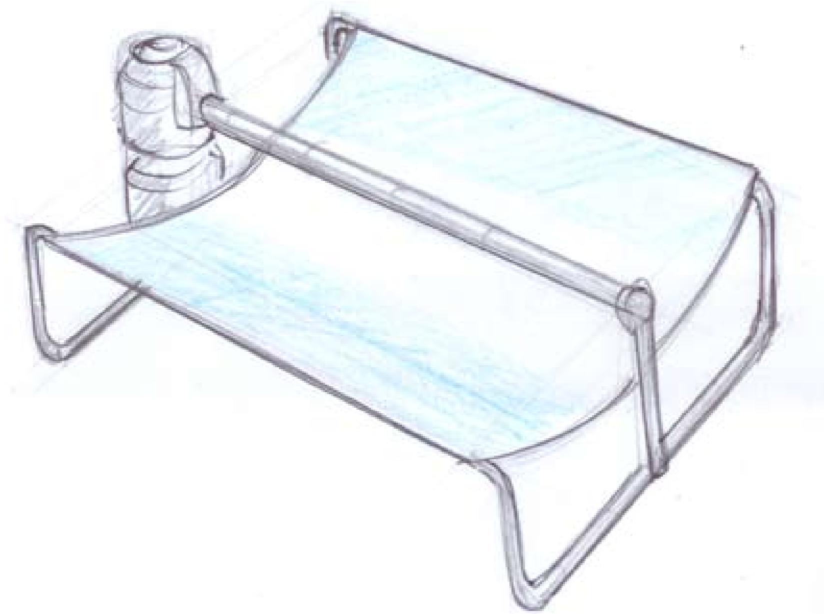
The plastic T-joint was appropriate solution for the idea of a connector box as it has three connections required for the water inlet, vacuum tube and steam outlet. The T-caps were drilled according to the different diameter required. The float valve was installed inside the joint very precisely on one of its covers. The top cover was used for the steam outlet and the other side was fitted with the vacuum tube.



While designing the structure there were a few points kept in mind such as the weight, stability and the ease of transportation and assembly. Many concepts were generated to achieve such a structure.

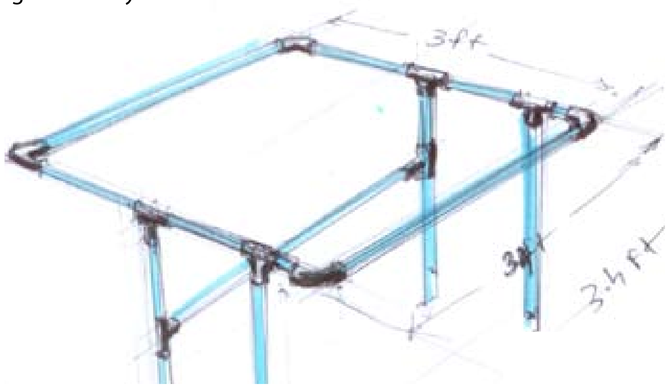


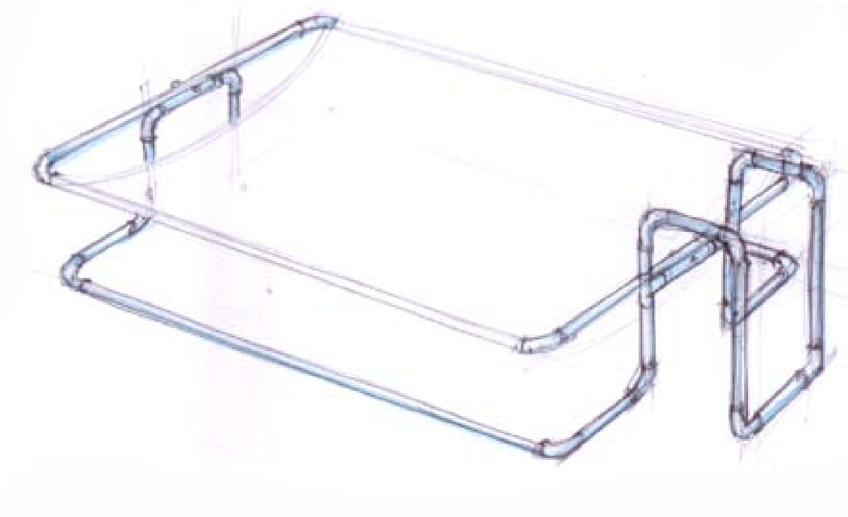


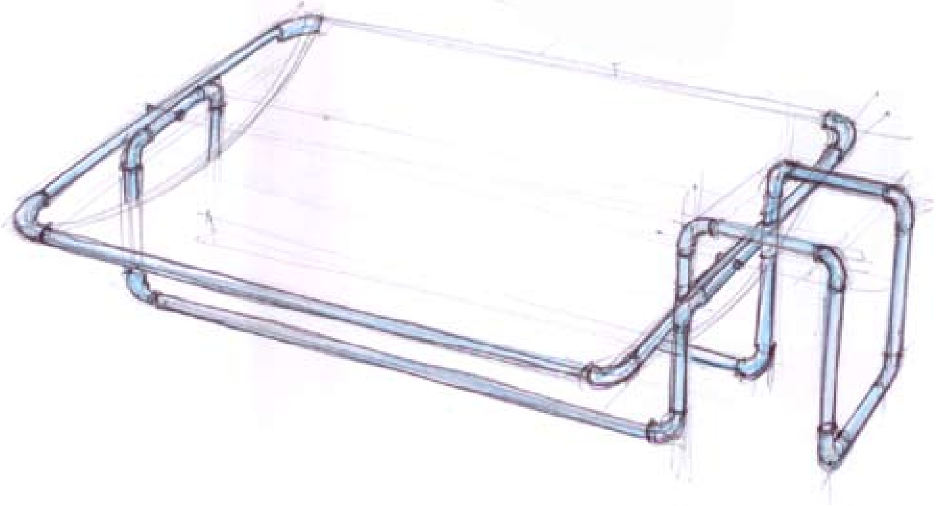


Structural design concepts- PVC pipe structures

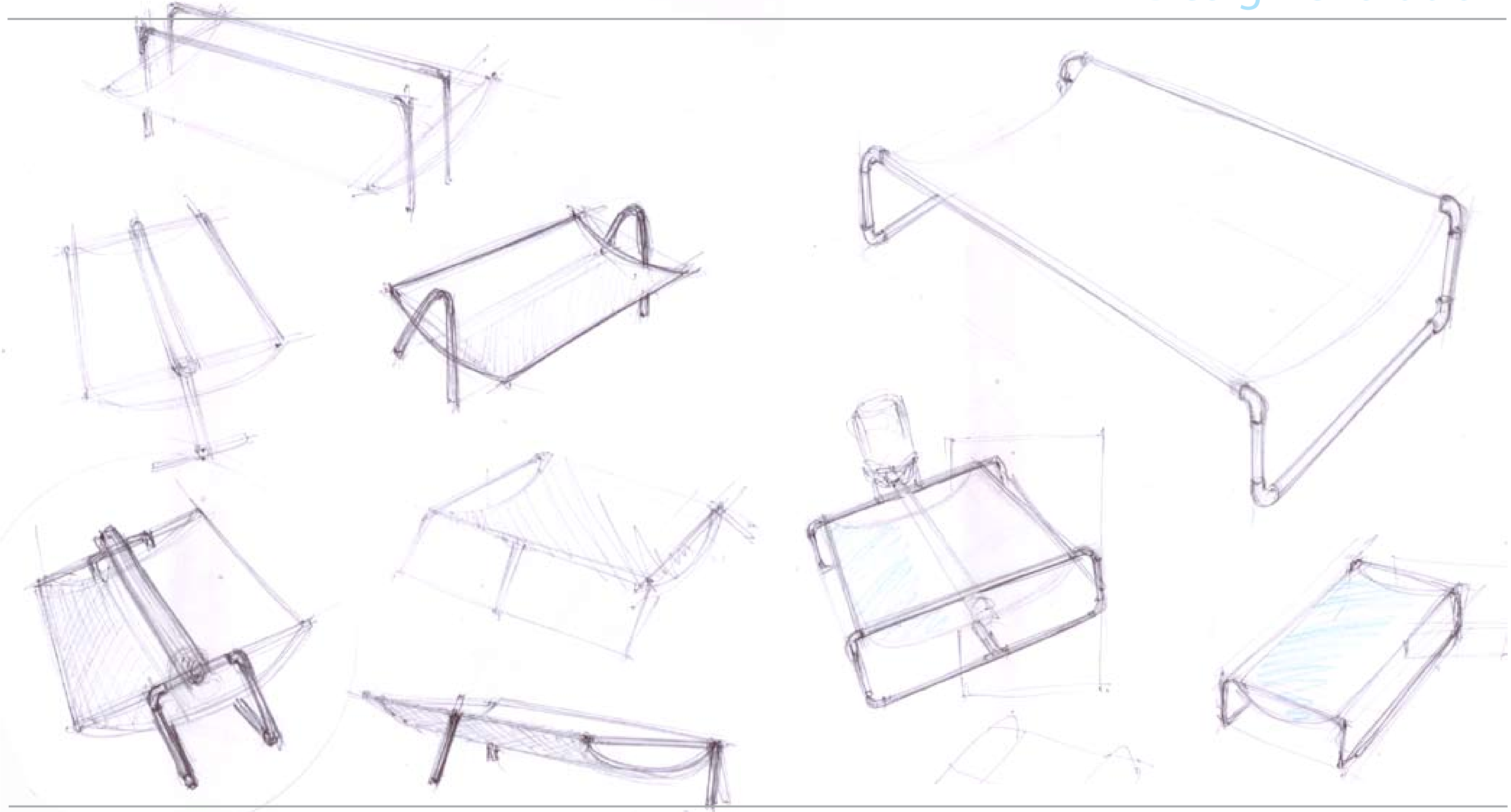
The advantages of PVC pipe are that it is easy to assemble and easily available. After initial concepts and sketches it was decided to not use PVC pipe because compared to aluminum structure it is more expensive and not as strong and sturdy.





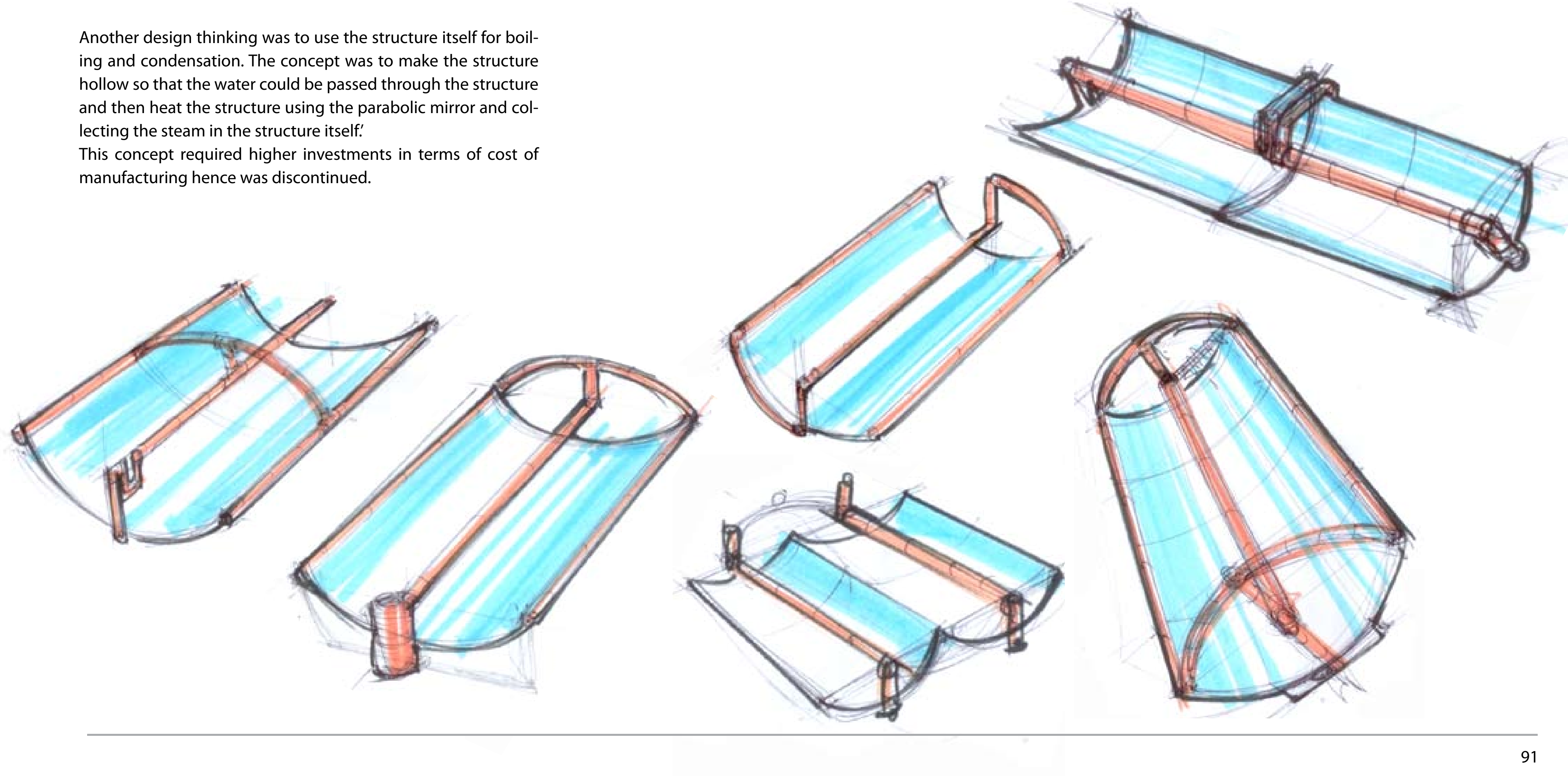


Structural design concepts- sketches



Structural design concepts- structural distillation

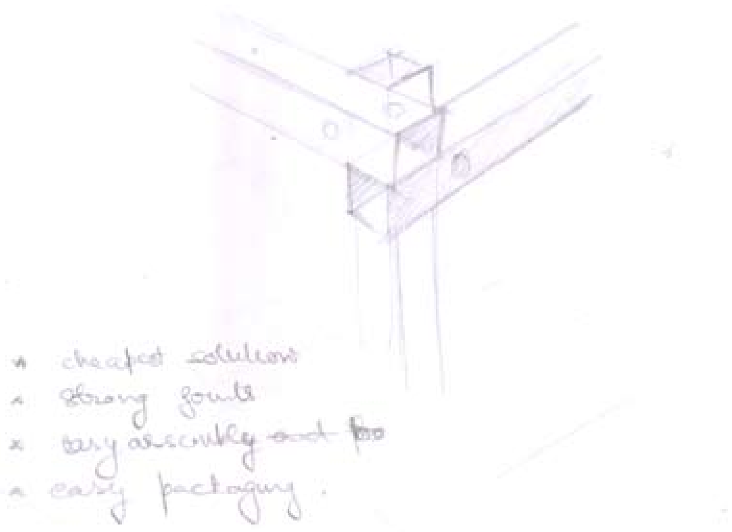
Another design thinking was to use the structure itself for boiling and condensation. The concept was to make the structure hollow so that the water could be passed through the structure and then heat the structure using the parabolic mirror and collecting the steam in the structure itself.'
This concept required higher investments in terms of cost of manufacturing hence was discontinued.



Structural design concepts- Aluminum structure

Aluminum is one of the best materials for structures because of its light weight and strength although the aluminum cannot be welded hence a special kind of joinery was devised for the joints in the structure.

The joinery was simple in terms of principle. The idea was to overlap the there pipes in three different axes and anchor each pipe to the other two using nuts and bolts. The structure formed is extremely rigid and sturdy.



FORM AND AESTHETICS

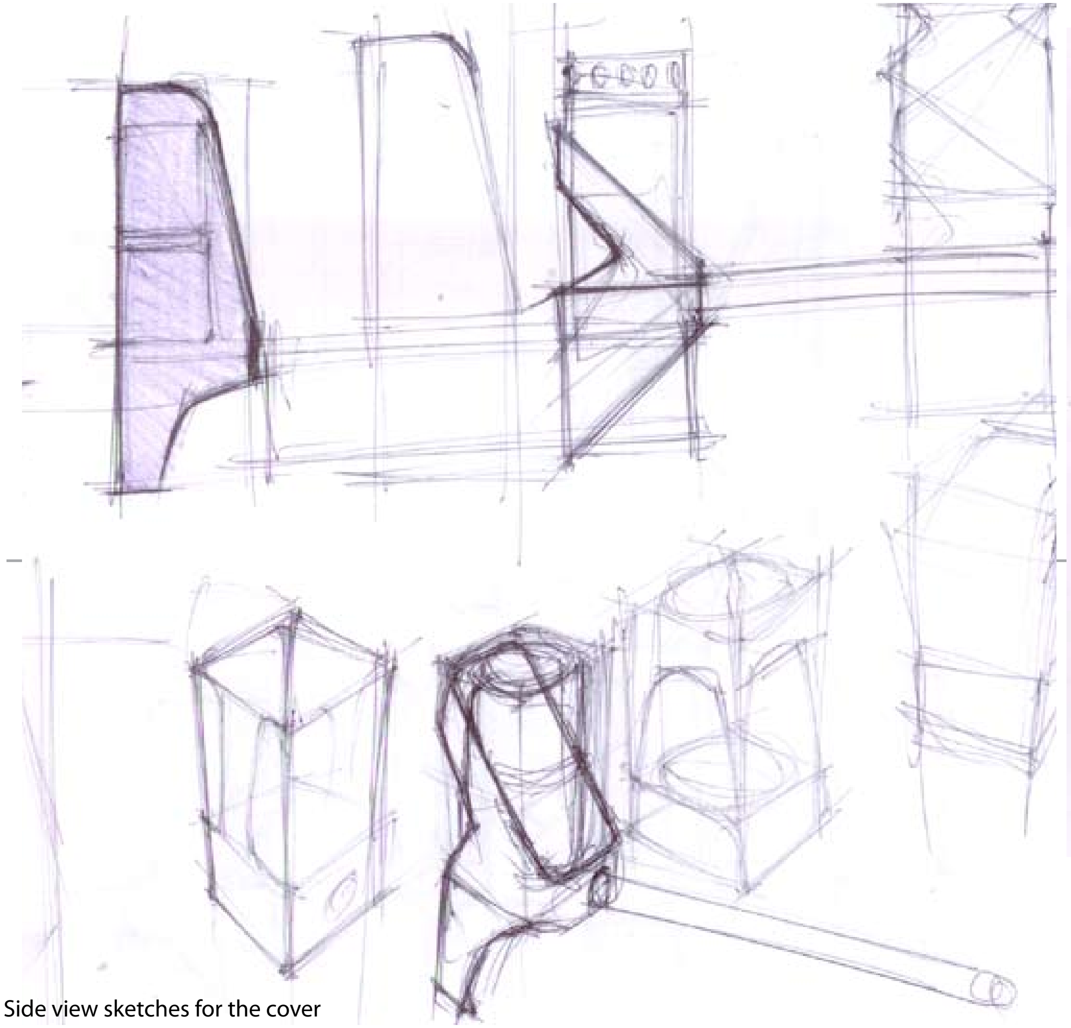
This chapter comprises of the form language and all the selected concept sketches and the selected final designs.

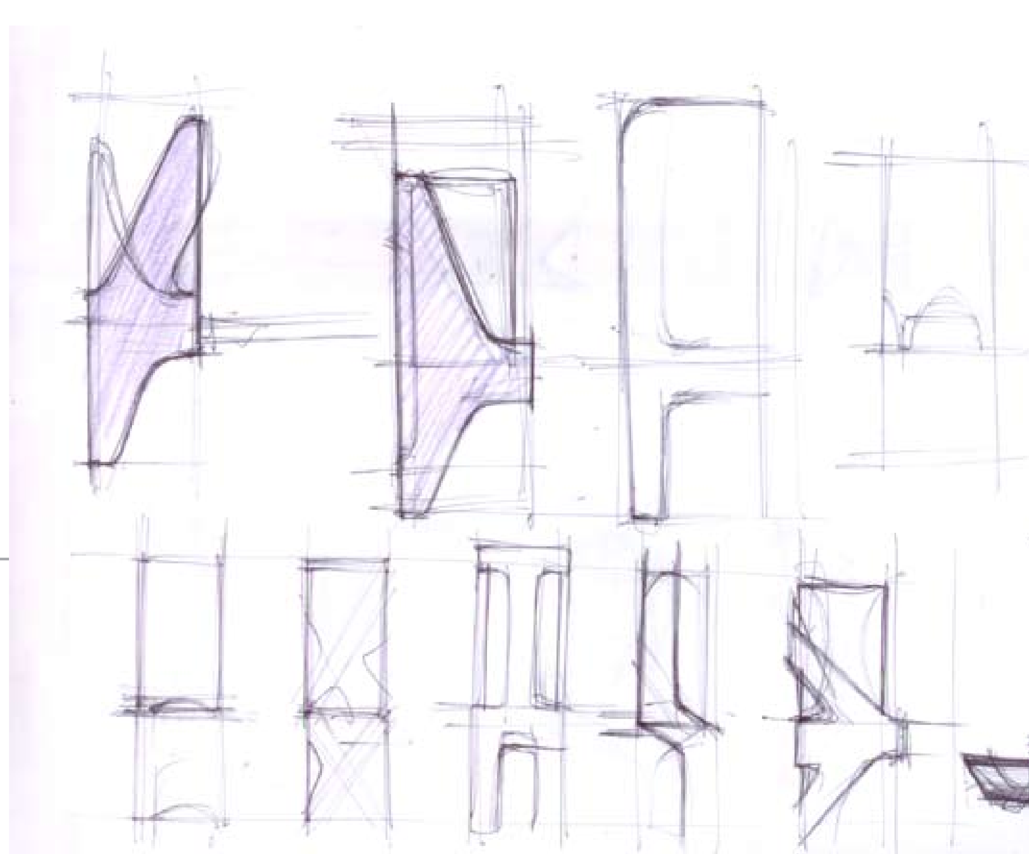
Form and aesthetics

The cover for the condensers was the main part which could be worked on regarding aesthetics and form. The main function of the cover is to protect the condensers from sunlight and cause convectional current (discussed later) in the system. Due to the cost constraint the form had to be simple curves and flat surfaces with chamfers etc. The form should provide a sense of a well finished consumer product.

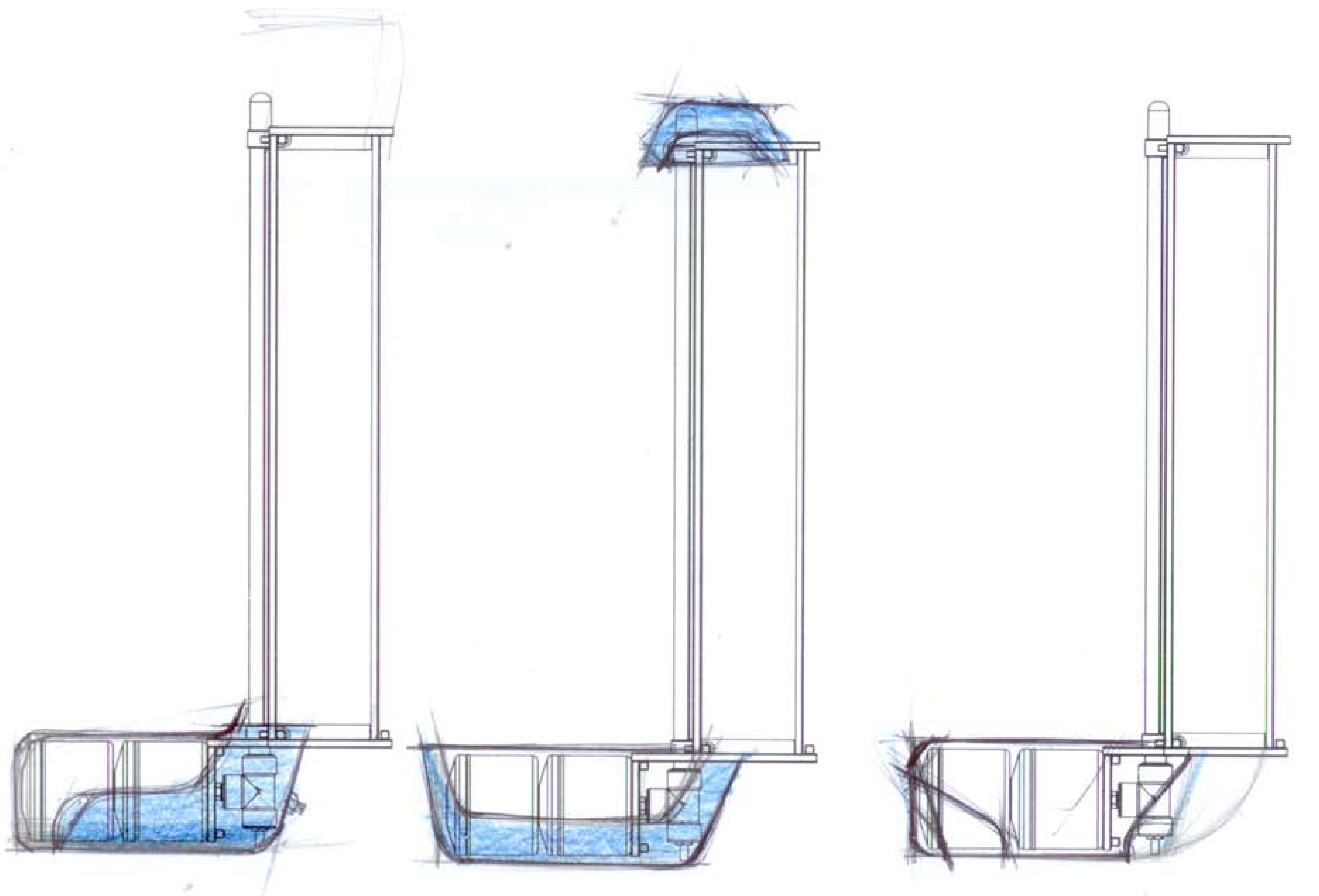
Due the fact that this is a do-it-your self product there cannot be a defined aesthetic for the product unless the product is purchased from Icarus design. In such a case where the user contacts Icarus to assemble the distiller for them icarus would offer four designs keeping in mind the four user segments discussed earlier. These designs had to be simple in looks and manufacturing. The colors should symbolise purity and simplicity.

Keeping these points in mind initial concept sketches were done from which selections were made for further refinement after which the final four forms were approved.

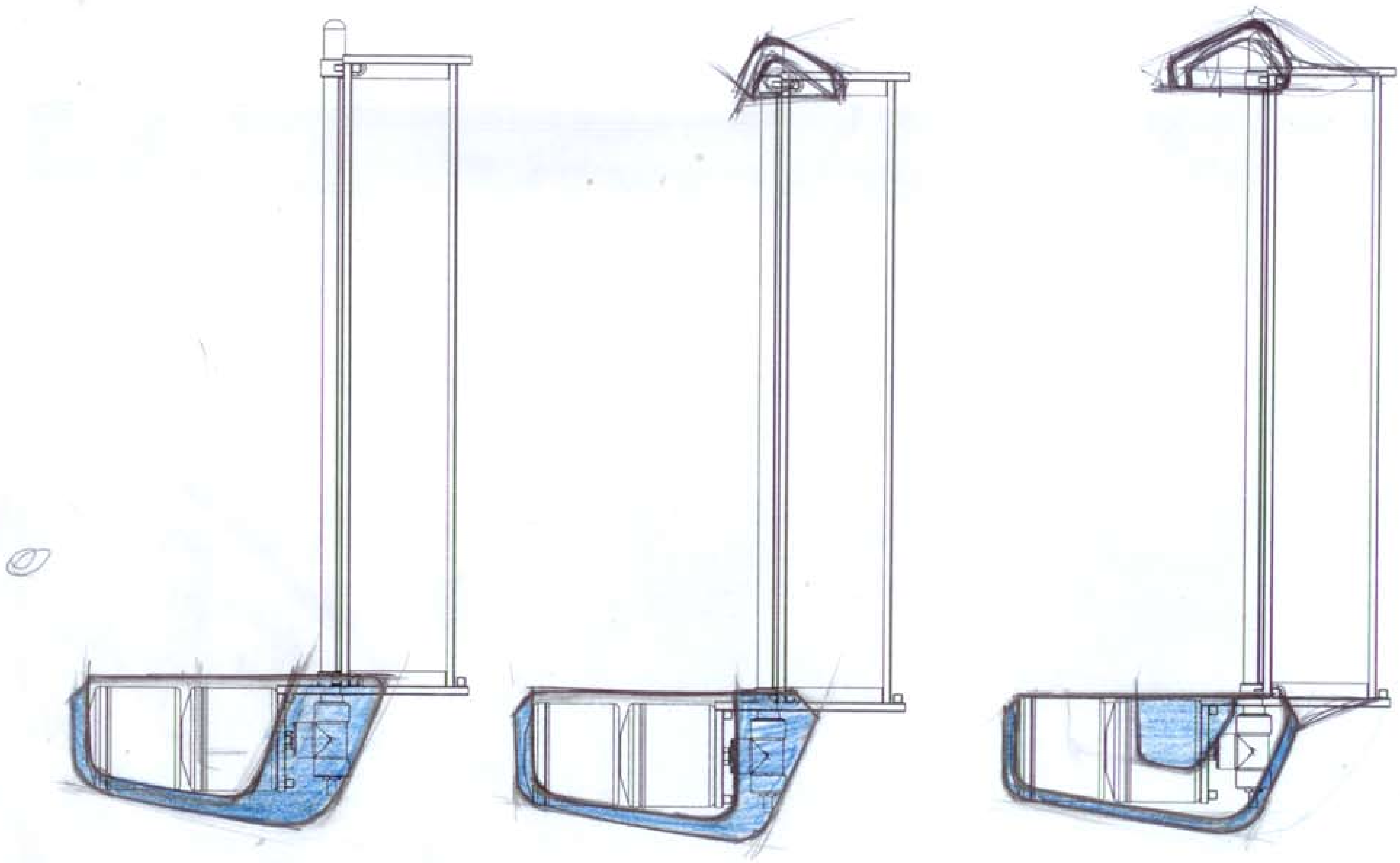




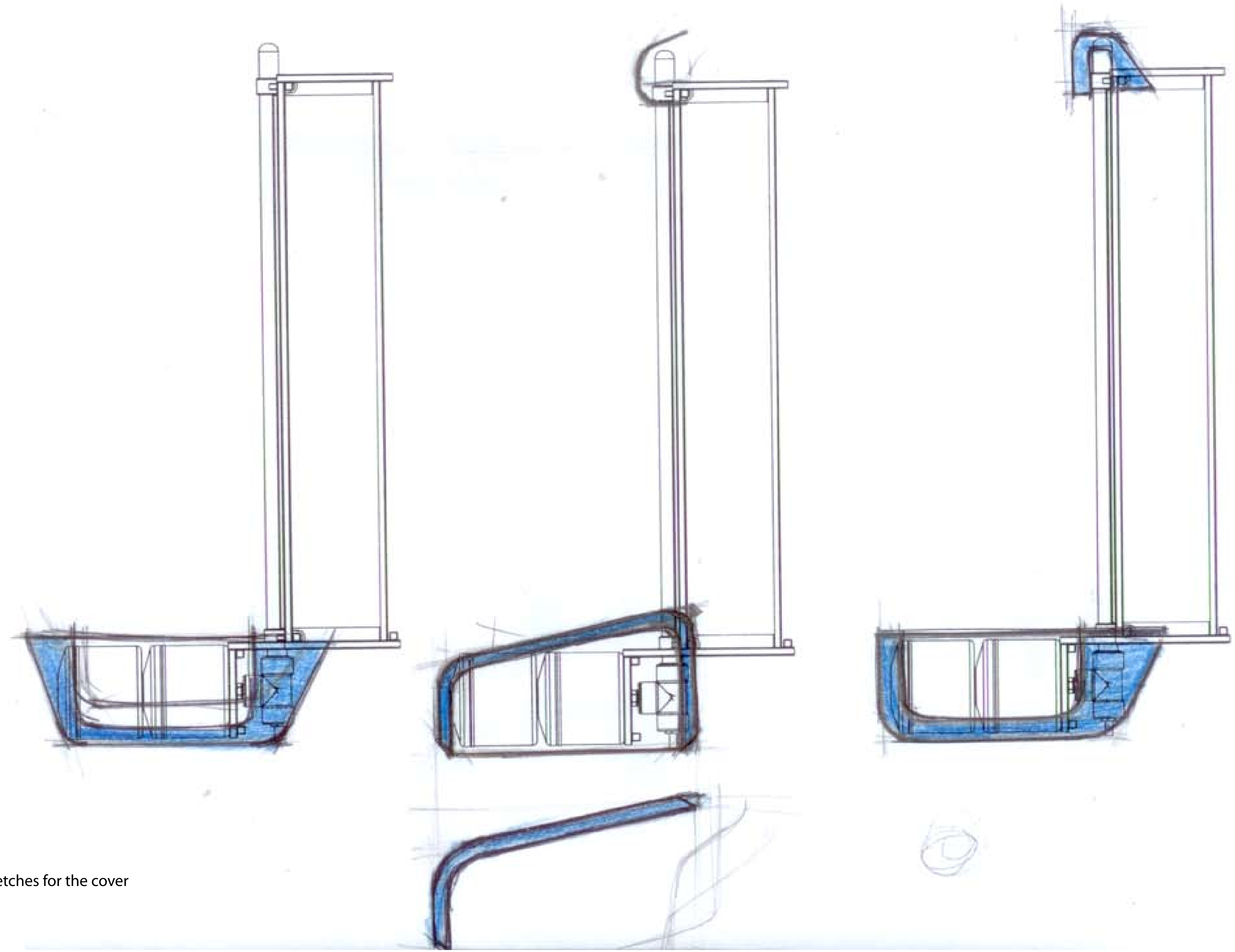
Side view sketches for the cover



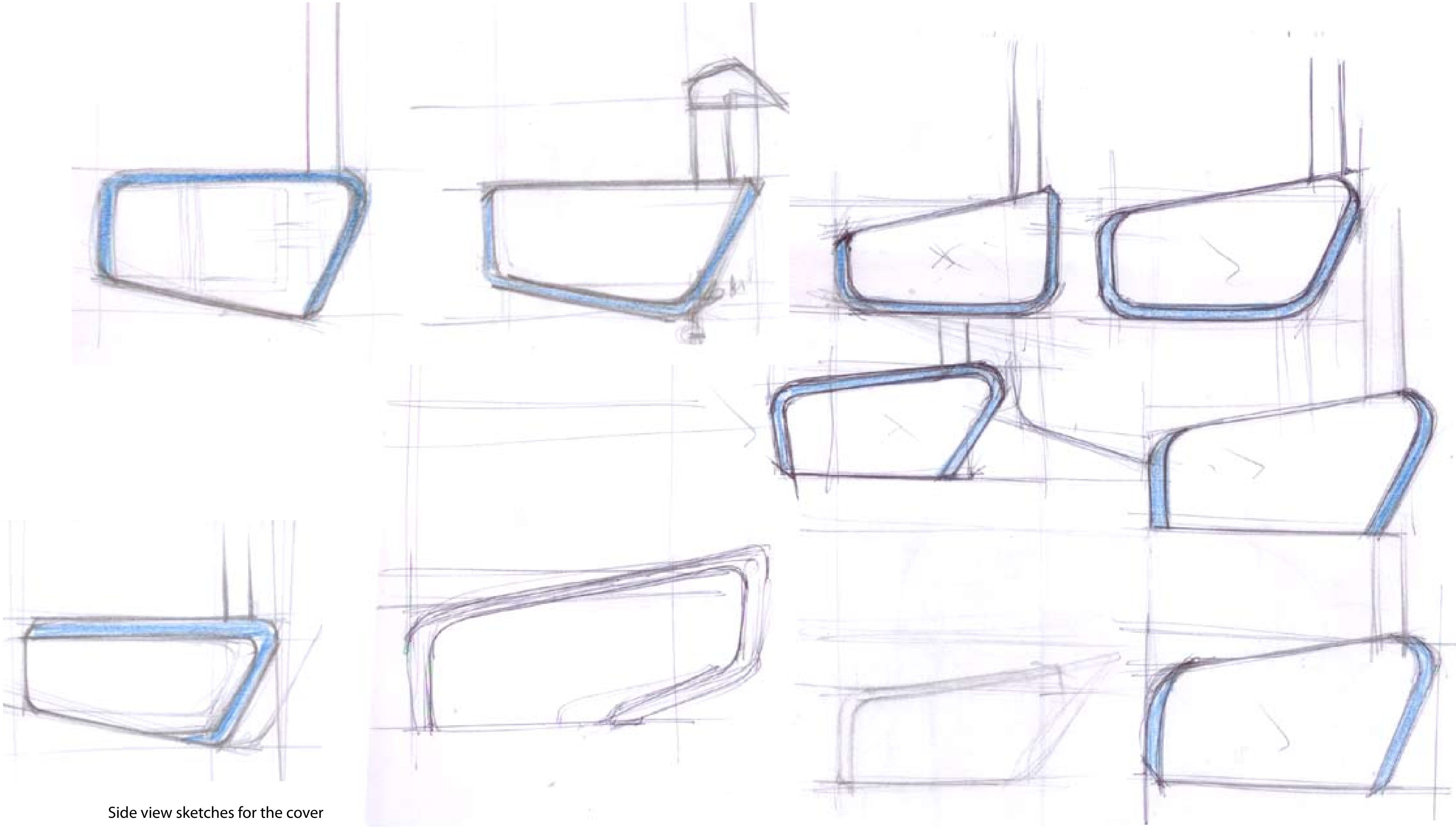
Side view sketches for the cover



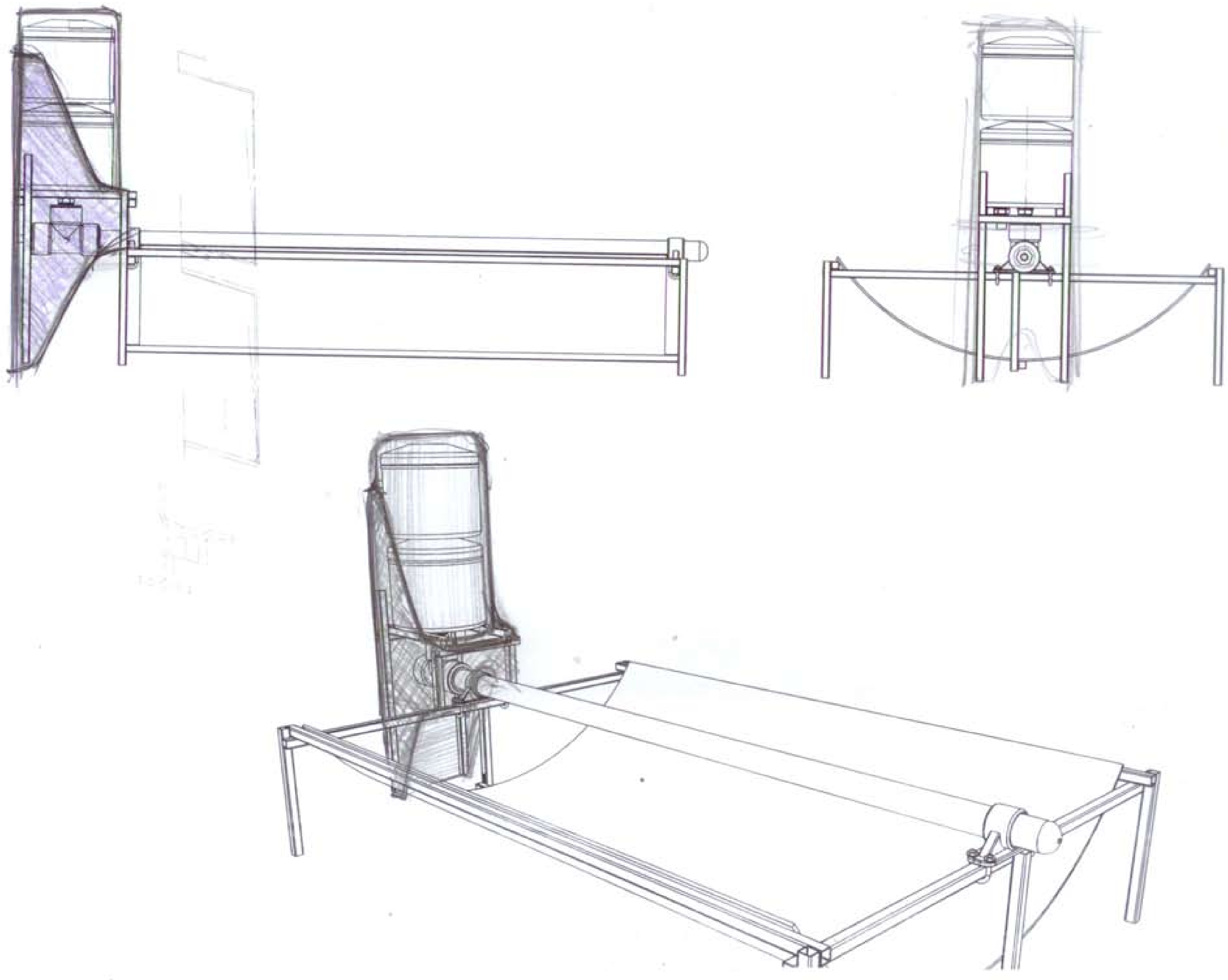
Side view sketches for the cover



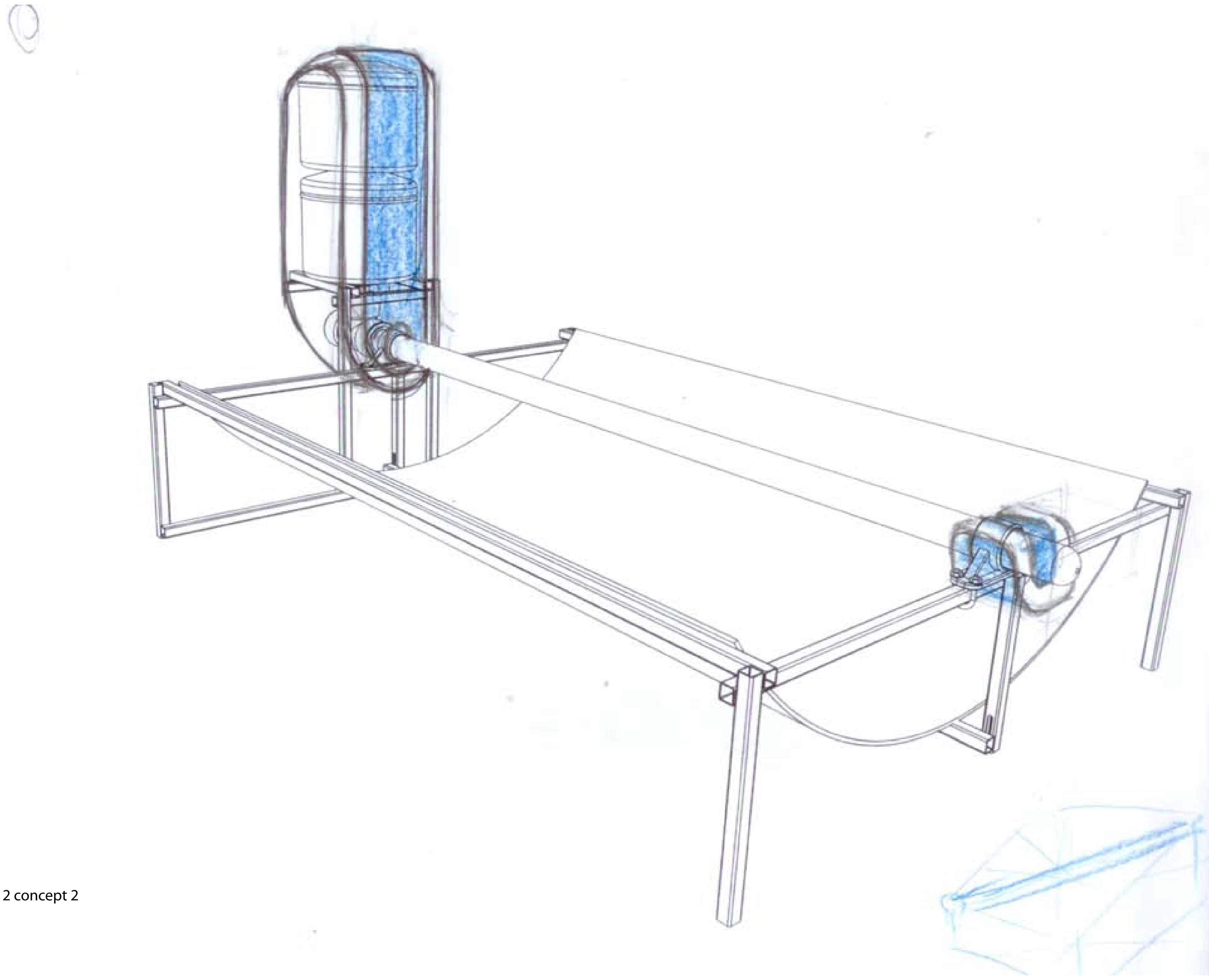
Side view sketches for the cover



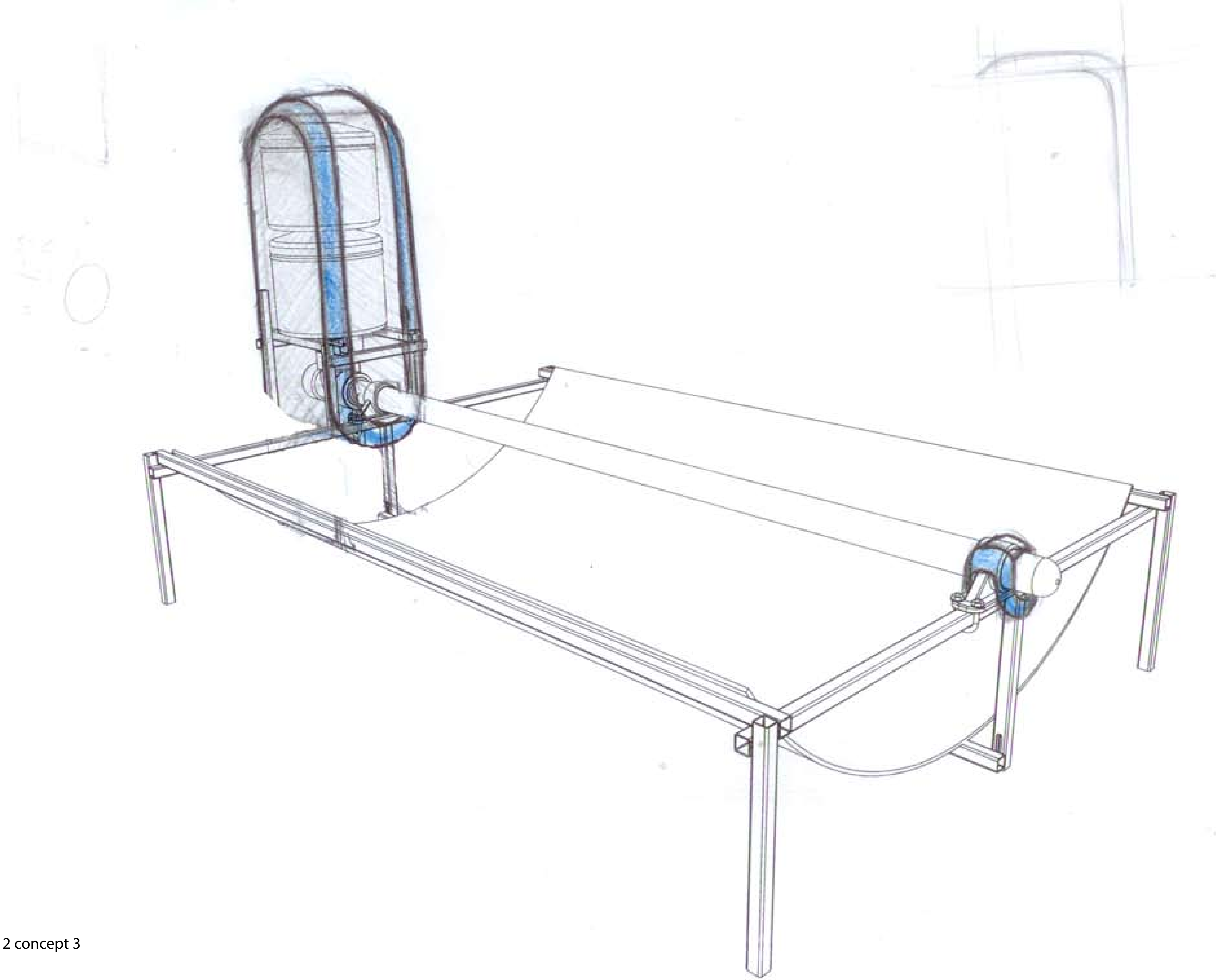
Side view sketches for the cover



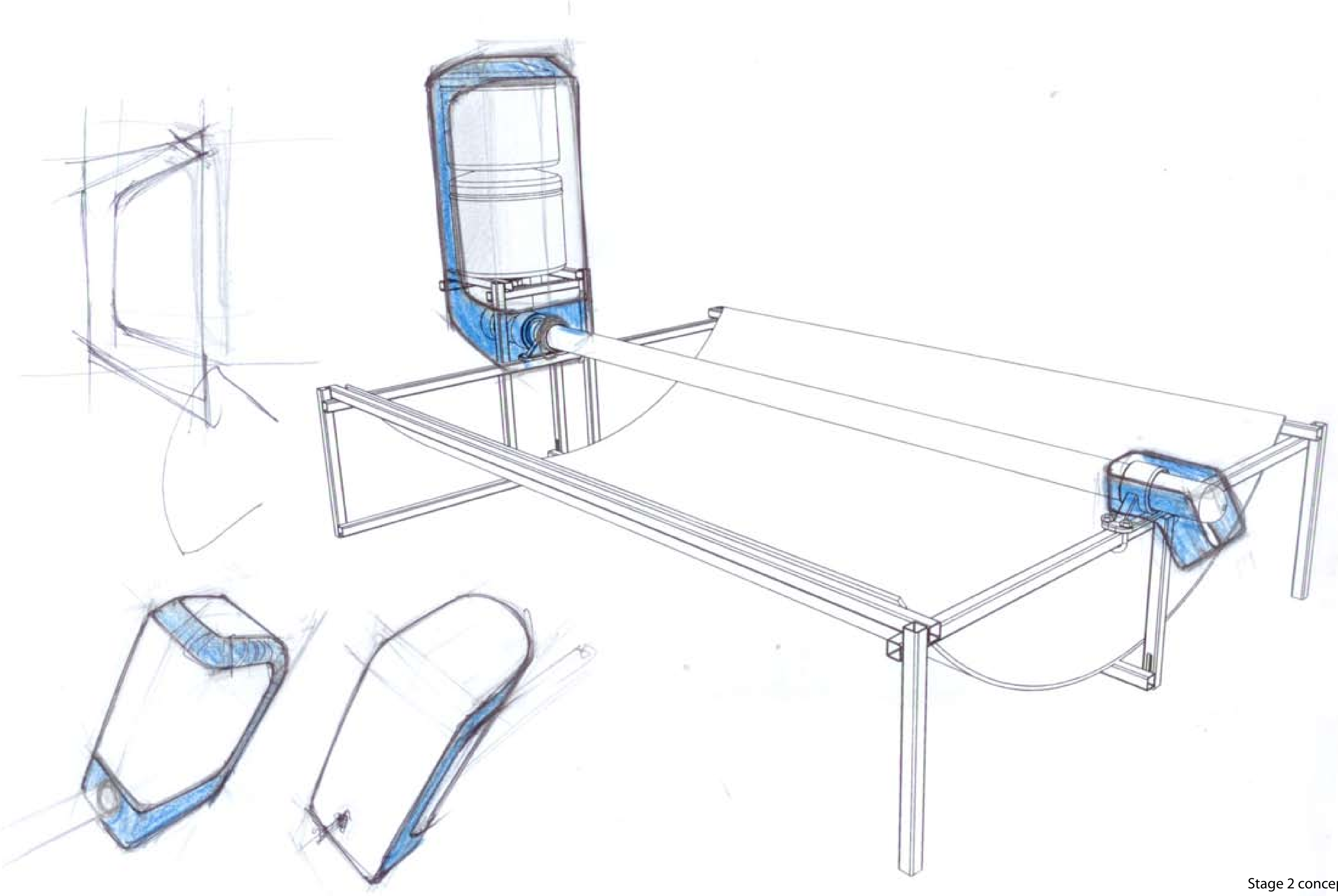
Stage 2 concept 1



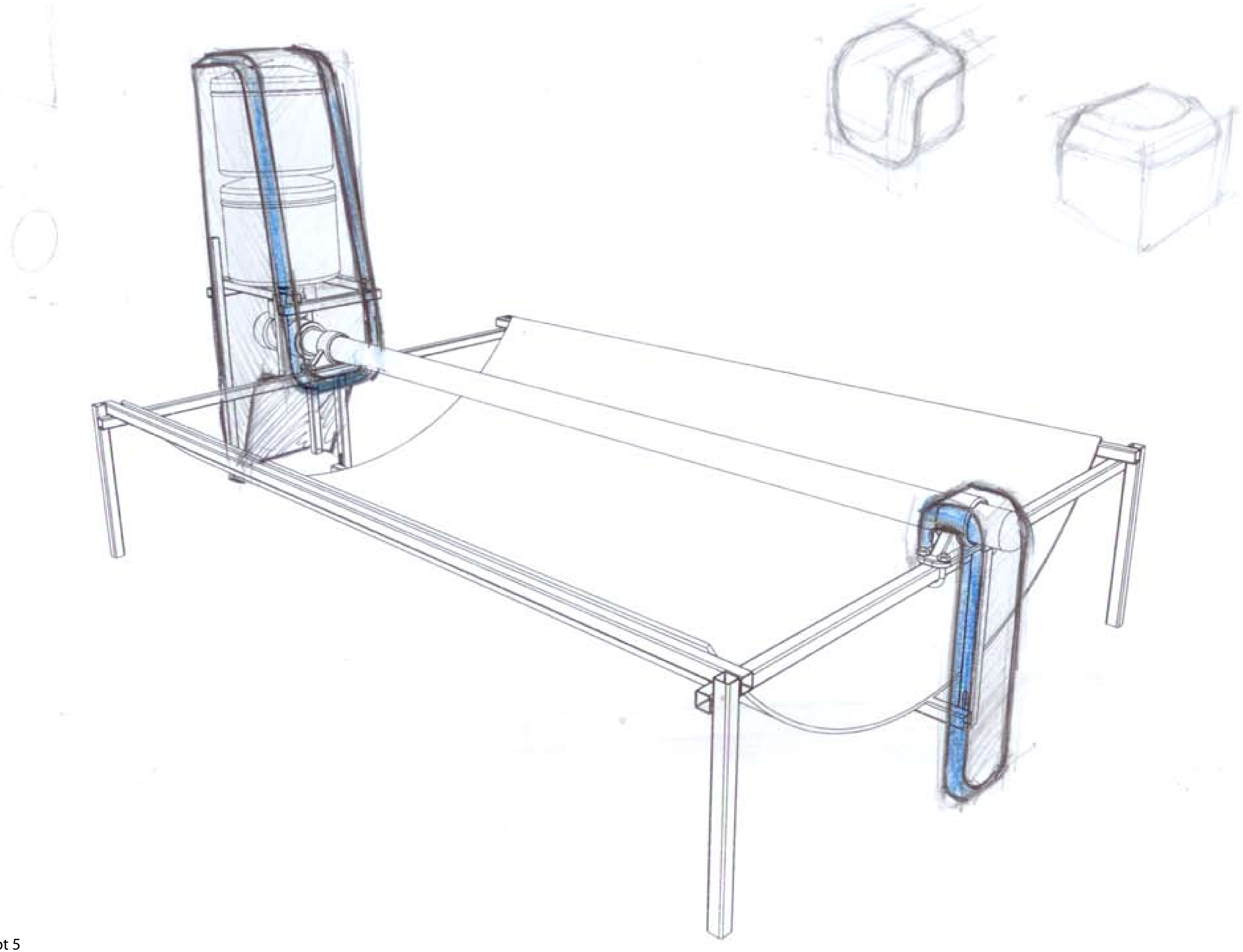
Stage 2 concept 2



Stage 2 concept 3

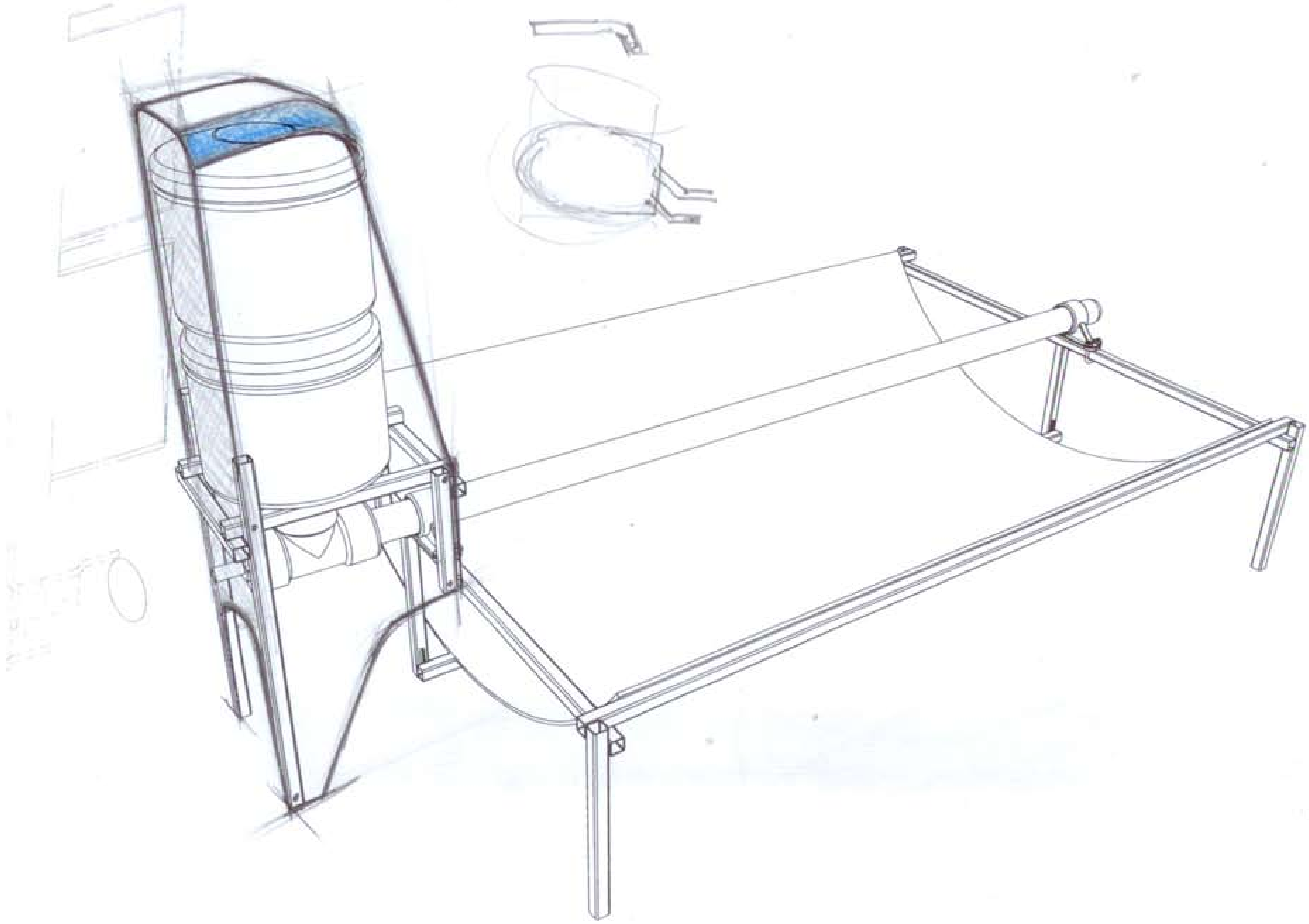


Stage 2 concept 4

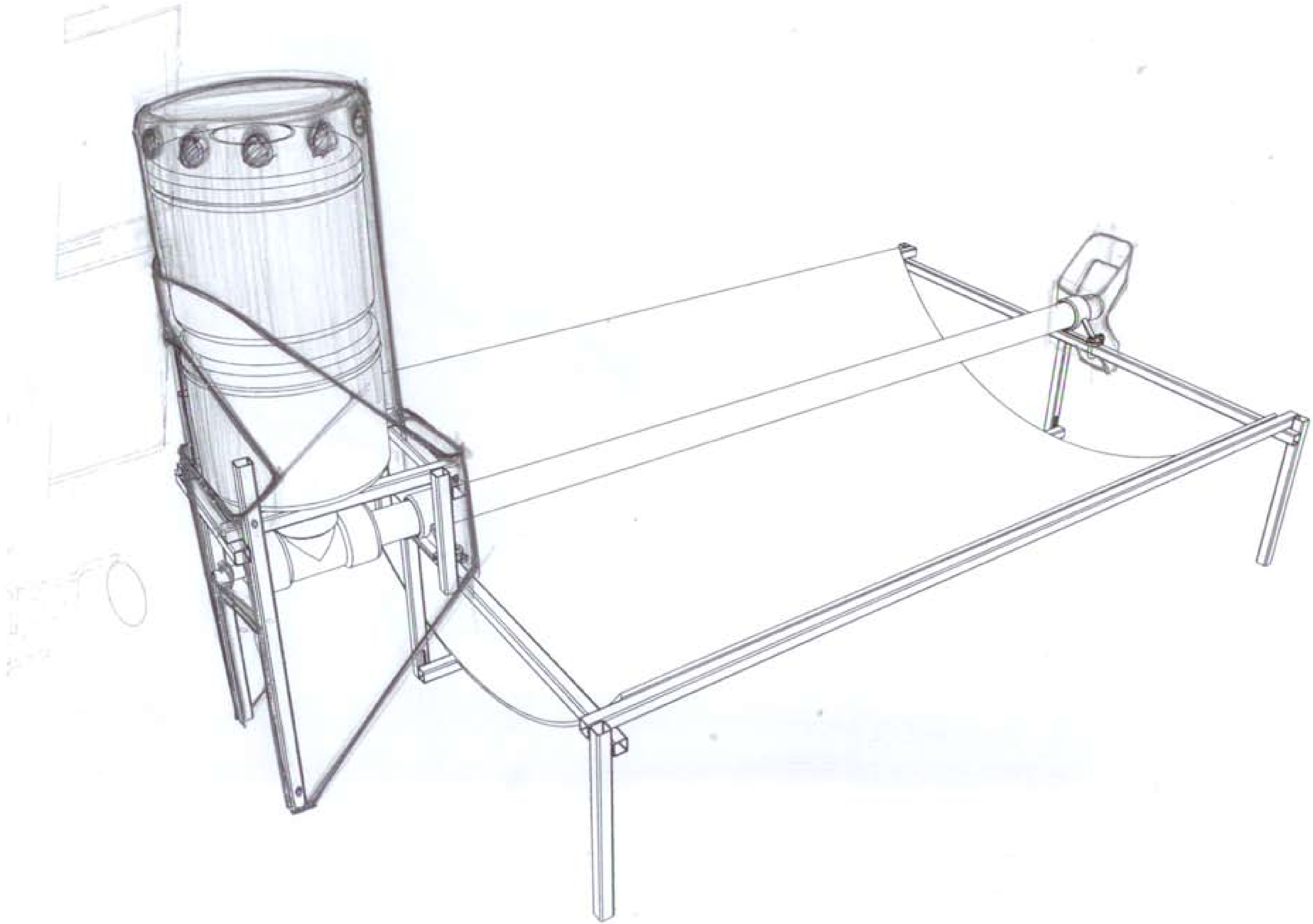


Stage 2 concept 5

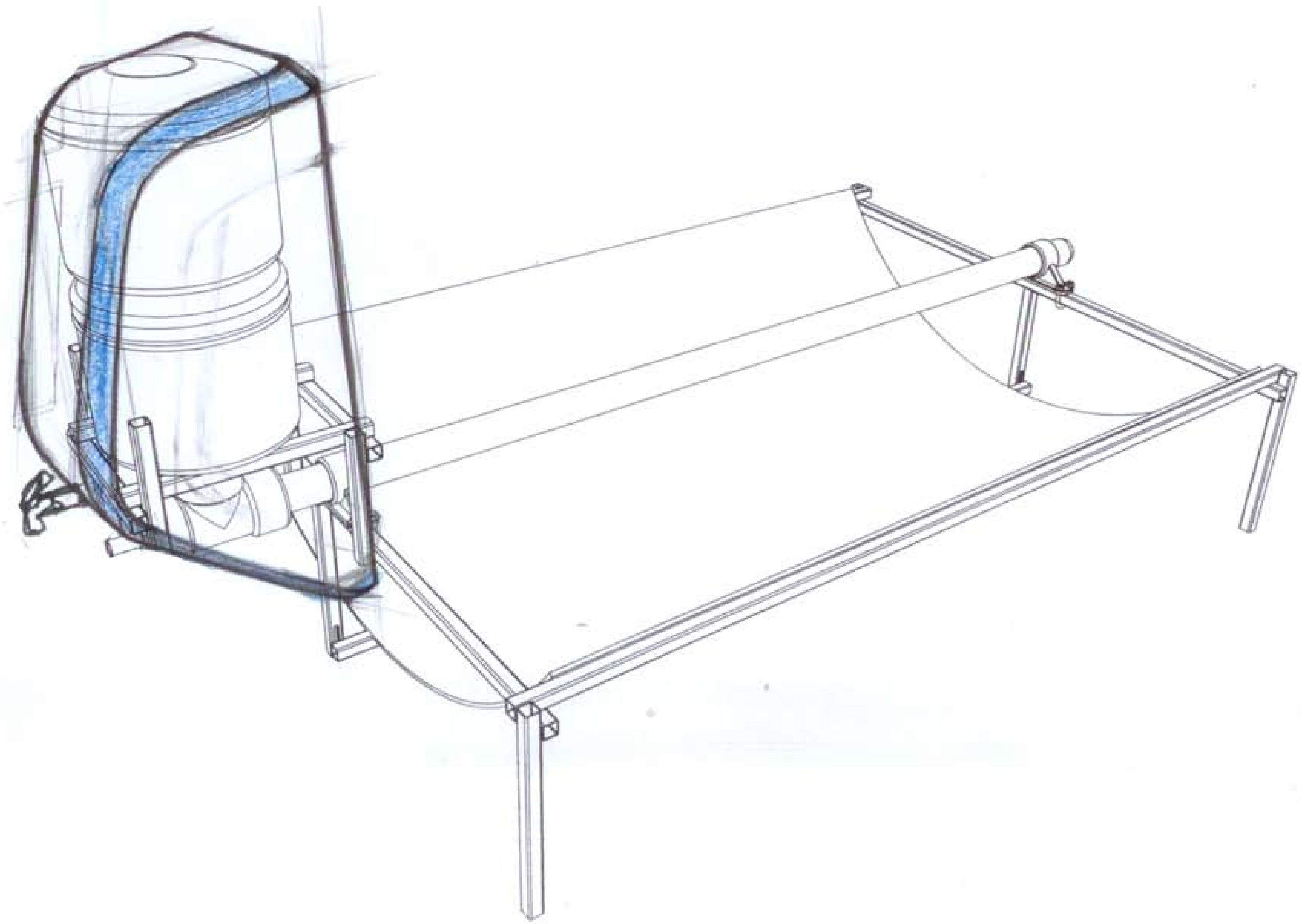
Stage 2 concept 6



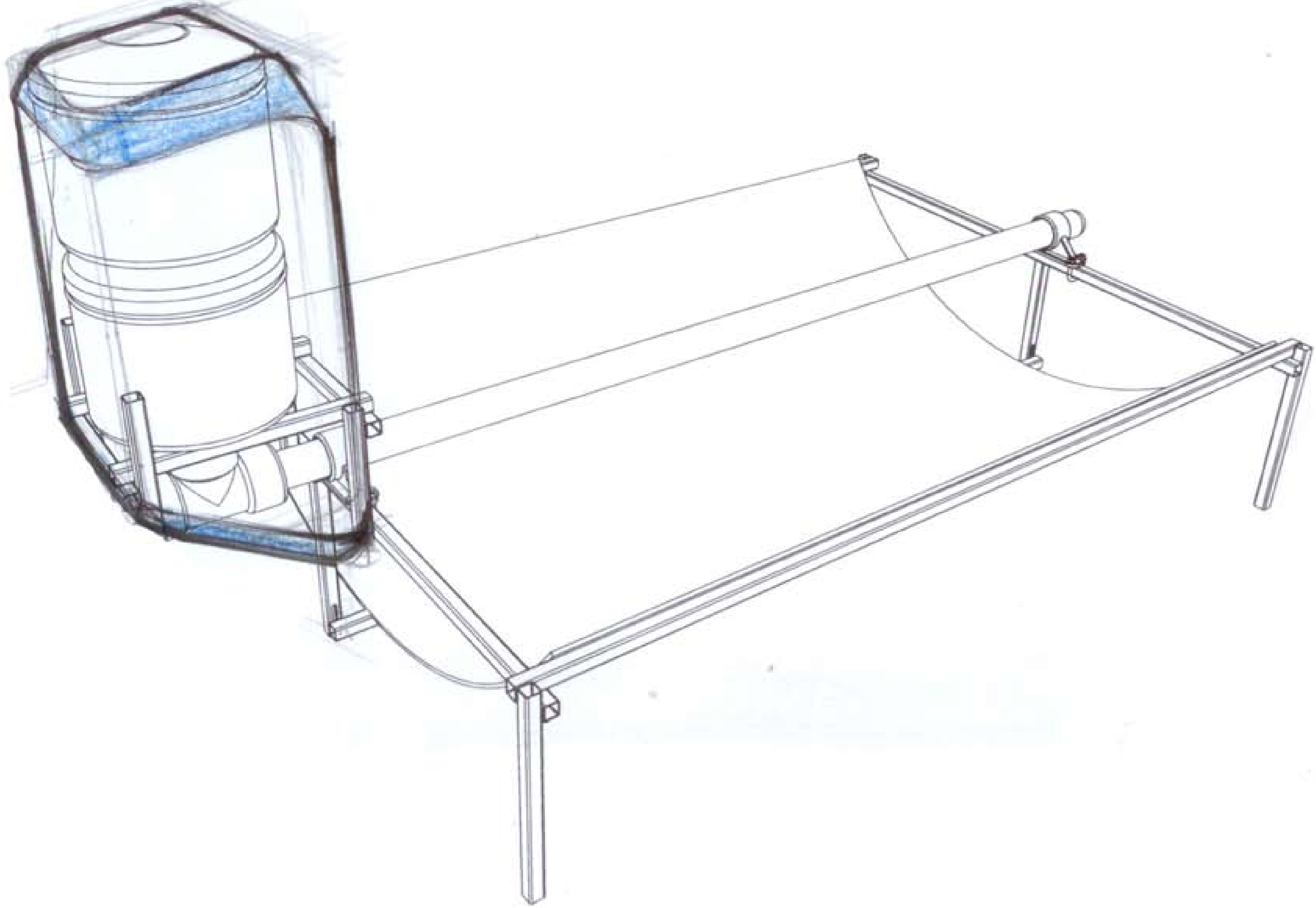
Stage 2 concept 7



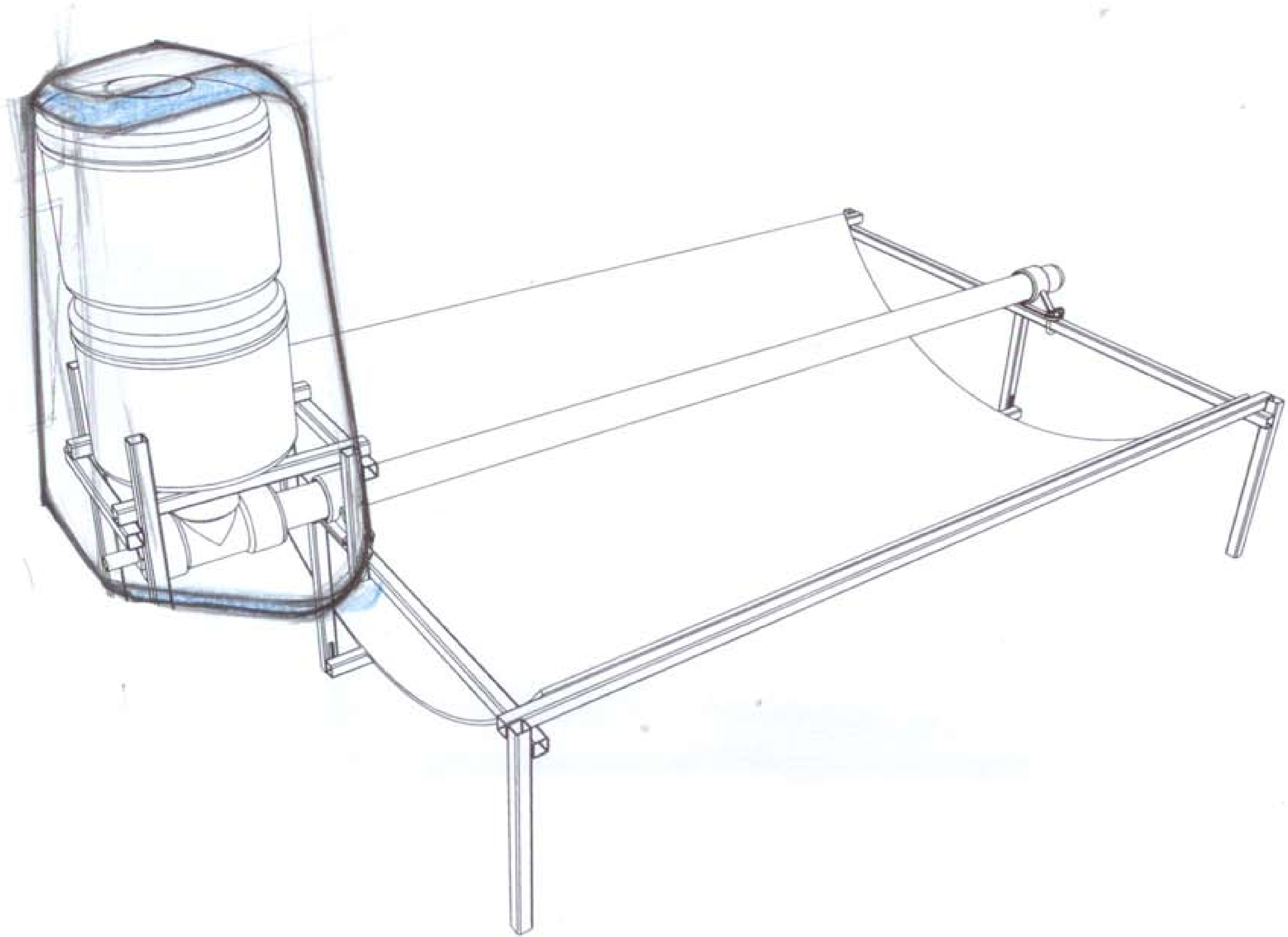
Stage 2 concept 8



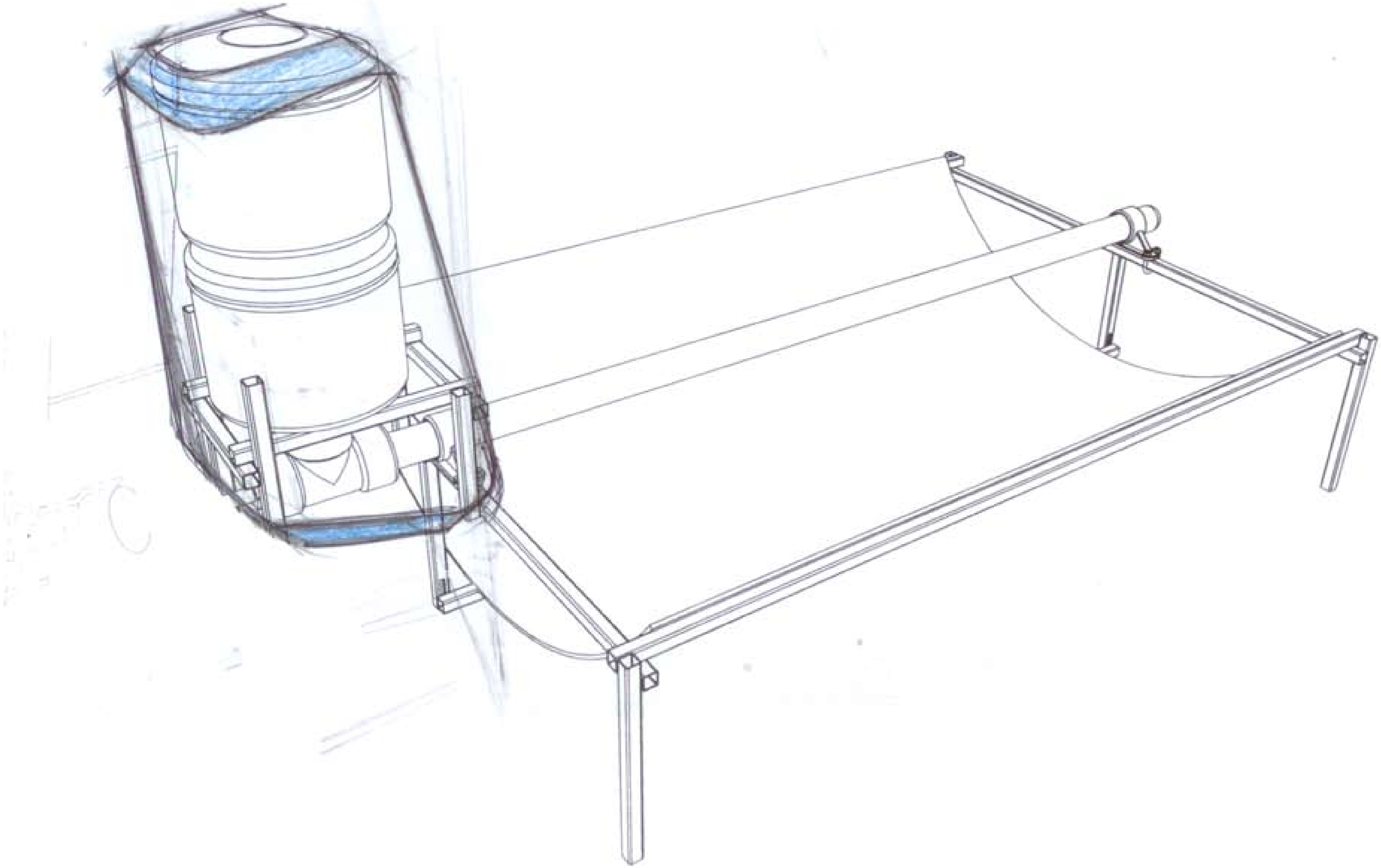
Stage 2 concept 9



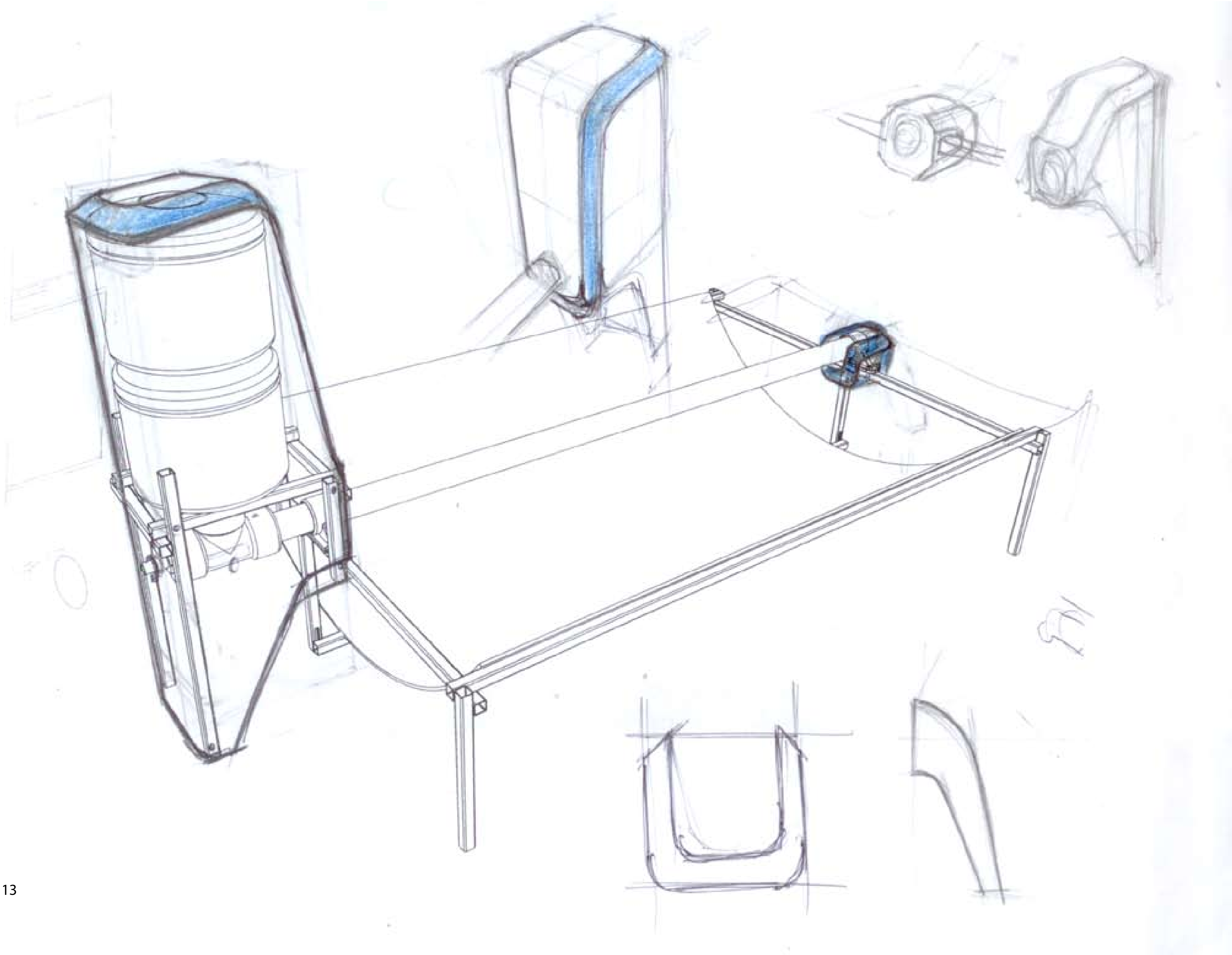
Stage 2 concept 10



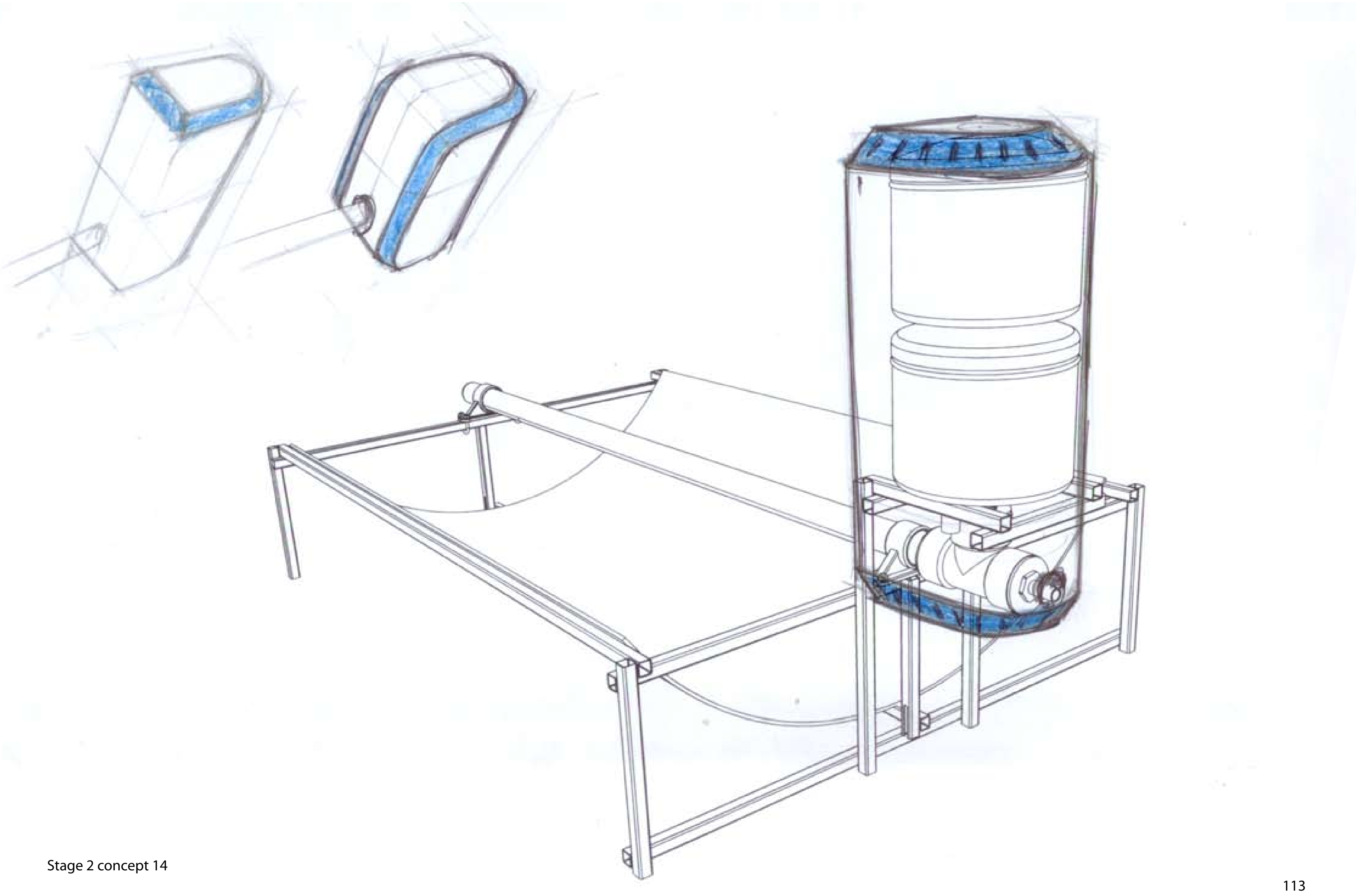
Stage 2 concept 11



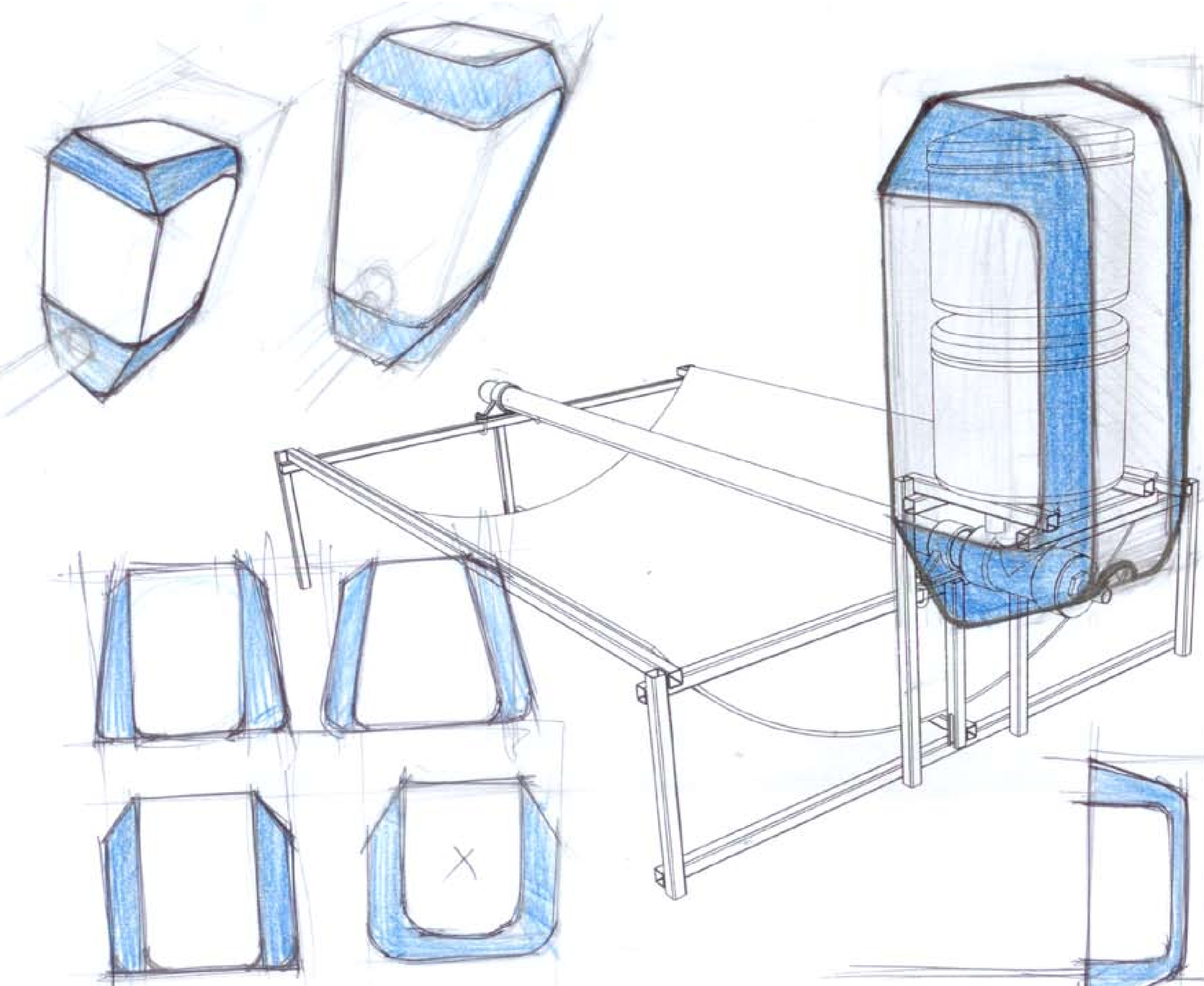
Stage 2 concept 12

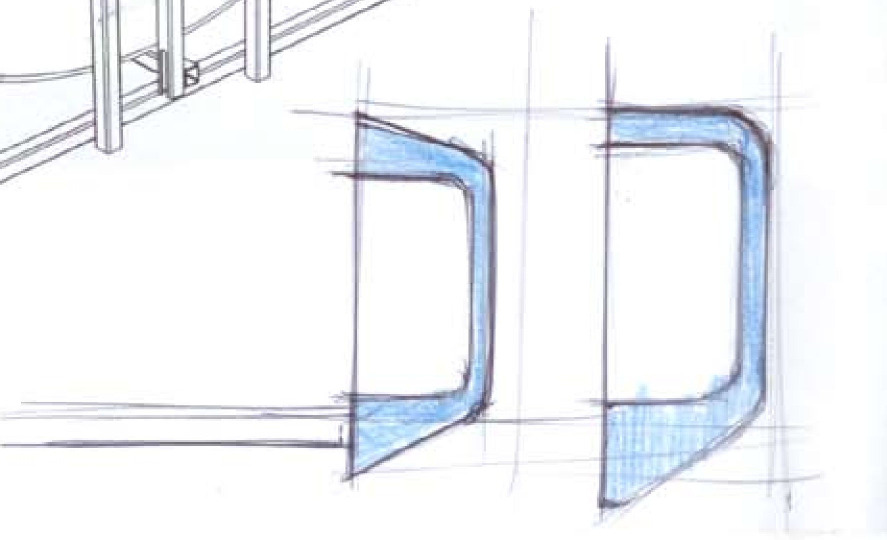


Stage 2 concept 13

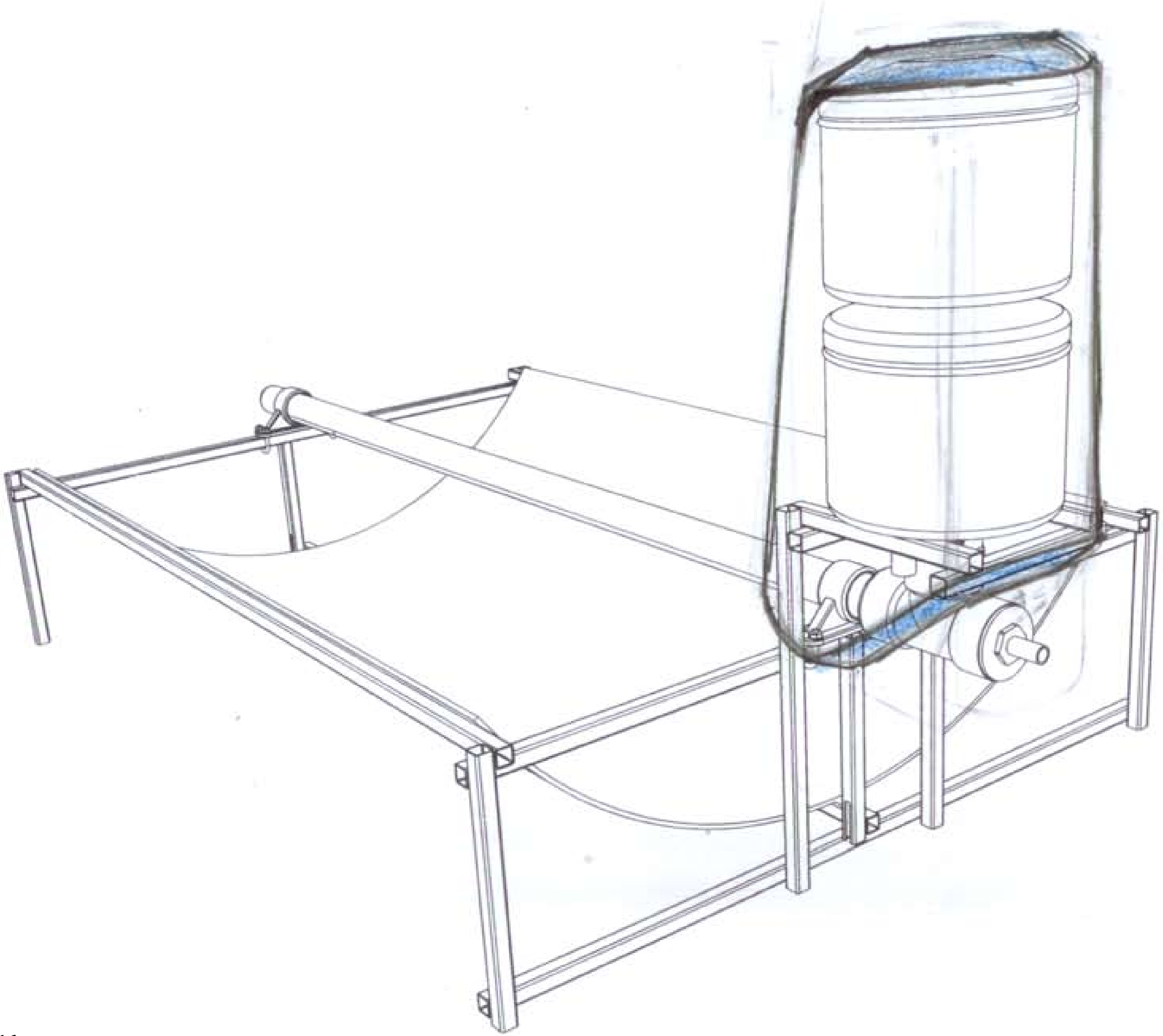


Stage 2 concept 14

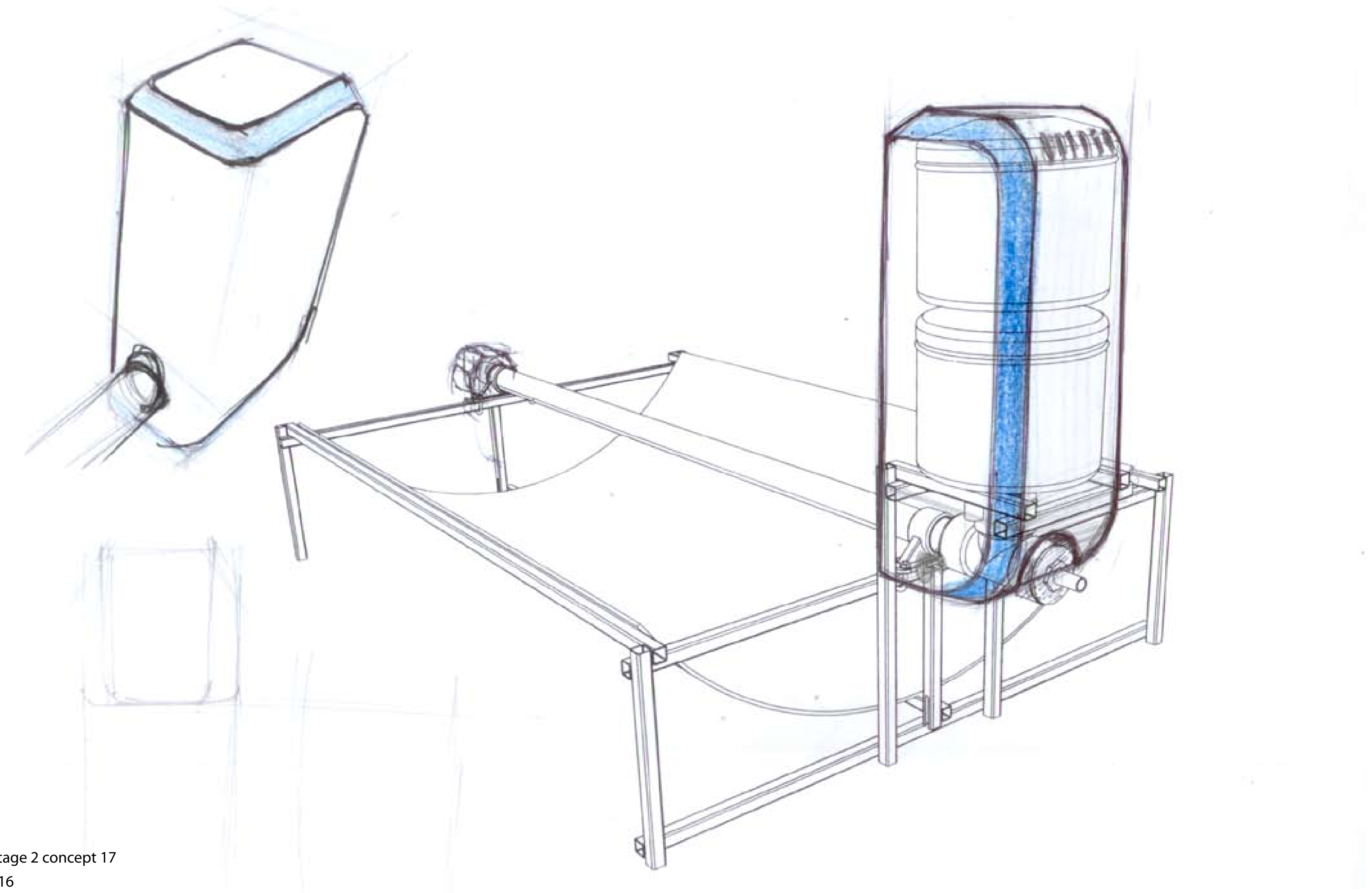




Stage 2 concept 15



Stage 2 concept 16



Stage 2 concept 17

Final designs

The final four forms were selected according to the user segments. These are as follows-

- •Economy
- •Pro1
- •Pro2
- •Elite

The first design could be arranged by the user without any external support. The Pro1 and 2 are possible for fabrication by icarus on small scale and the Elite design was designed for mass manufacturing if required in the future.

Economy

The Economy model is the basic, simplest and cheapest design in which the cover is a water storage drum or any other available cover which suits the need. Small holes on top of the drum are there to vent out hot air.

Form and aesthetics

The Pro-1 is designed to give aesthetic value to the product at a minimal cost of production.

The design is a simple cuboidal structure visually divided by a strip into equal halves reducing the visual weight of the product. The color symbolises water in its purest form and visually appeals as a product related to water use.

The Pro-2 is a more advanced design in terms of form and feasibility. The form is stretched out of a cuboidal form to wrap the components inside it. Visually it looks less bulky than the Pro-1 and is more dynamic and exciting.

As the name suggests the Elite design caters to the high end user segment interested in green design products and healthy living.

The design symbolizes flow of water and purity with multiple complex curves and a thin strip of blue closing in at the water outlet enhancing it visually. It would require higher cost of production than the previous models because of the more complex nature of the form and hence will cost more than the previous designs.

THE FINAL DESIGN

This chapter describes the final product in details such as the construction, assembly and working with technical drawings and instructions on how to use the product.

The DIY Solar Water Purifier is designed to cater to the need for pure water in remote and rural places and villages, where the only source of abundant energy is the sun.
The unique feature of this design is that it doesn't require any manufacturing, Simply collect all the parts required and assemble . The design is low-cost, high-value.

The DIY Solar Water Purifier has an output of eight liters of water per day which is adequate for a family of four for a day. The design can also be used to boil water or use steam to cook.
This design is completely open to customization and enhancements but the basic function is to use the solar energy to produce pure drinking water.

Joinery: The orthogonally bolted joinery is easy to construct and assemble.

Adjustable: The base on which the sheets are screwed is attached to the grooves which allow adjustment of the sheets to get a perfect focal line (discussed in assembly).

Safety: The sharp edges are rounded to give it a finished look and also to avoid any accidents.

Aesthetic: The pipe clamp is concealed between the cutouts to protect the end of the vacuum tube and add aesthetic value to the product.

Usability: The outlet for purified water is controlled by a water dispenser tap.

Maintainability: The cover for the vessels is screwed to the structure and can be easily disassembled for cleaning and maintenance.

Aluminium pipe
Locally available aluminium from the hardware store generally used for cupboards and racks. The pipe is 3/4th of an inch cross section and 2mm thickness.

Reflective acrylic sheet
Reflective sheets are available at hardware or glass stores. These sheet are available in different thickness. The thickness required for the parabolic shape should be around 2 to 3 millimeter.

Vacuum tube
Vacuum tubes are not easily available in local markets. But can easily be ordered in bulk from places such as auroville.
Evacuated Tube Basic Specifications

Length (nominal)	1500mm (1800mm also available)
Outer tube diameter	8mm
Inner tube diameter	47mm
Absorptive Coating	Al-N/Al
Absorptance	>92%
Stagnation Temperature	>200^{o}C

Condensing vessels
These are ordinary steam vessels available in any kitchen accessory shop in various shapes and sizes. The shape recommended would be around nine inches in diameter and ten inches (or more) in height . The basic rule is greater the surface area greater the condensation.

Plastic T-joint
TheT-joint is a joint with three openings available in any hardware store but has to be of a high grade plastic so that it can withstand high temperatures (100°C). The T-joint ideally should be food grade plastic. The T-joint used in the setup has an inner diameter of three inches.

Plastic T-cap
The caps will be available with the T-joint.

Tank nipples
These are available in plastic and steel and in various standard sizes. These are used for linking vessels, tanks etc.

Float valve
The float valve keeps a check of the water level. These are easily available at hardware stores. Ideally the size should be small and it should be resistant to high temperatures. Such float valves are used in coffee making machines .

Plastic water dispenser tap
These taps are easily available in the market. These are of standard sizes.

Pipe clamp
The clamp size depends upon the outer diameter of the vacuum tube (85 mm diameter). It is available at any hardware store.

Nuts, bolts, washers and screws
These products easily available in standard sizes .

Cover
The cover can either be an existing drum, box etc, or it can be manufactured according to the user's needs and the cost of manufacturing.

Bill of materials

List of material	Quantity	Cost	Amount (Rs)
Domestic aluminium square pipe (1 inch)	32 ft.	Rs 15 /ft.	480
Reflective acrylic sheet (2mm)	3 pcs (1.5ft x 4 ft.)	Rs 45/sq. Ft.	810
Vacuum tube (1600mm , 47mm dia)	1 pcs	Rs 500/-	500
Condensing vessel	2 pcs	Rs 300/-	600
Plastic T. joint (3.5 inch pipe dia)	1 pcs	Rs 150/-	150
Plastic T. cover (3.5 inch pipe dia)	3 pcs	Rs 20/-	60
Plastic tank nipples (1 inch)	4 pcs	Rs 20/-	80
Float valve	1 pcs	Rs 90/-	90
Plastic tap	1pcs	Rs 50/-	50
Flexi pipe	3m	Rs 10/m	30
Nuts and bolts and washers (6 mm dia d 2.5inch)	32 pcs	Rs 3/-	96
1 inch screws (3 mm dia)	10 pcs	Rs 1/-	10
Sun board cover\cylinder cover	1 pcs	Rs 150/-	150
Pipe clamp	1 pcs	Rs 20/-	20
		Total	Rs 3,126/-

*All prices are as per rates in Bangalore on 15th September 2009

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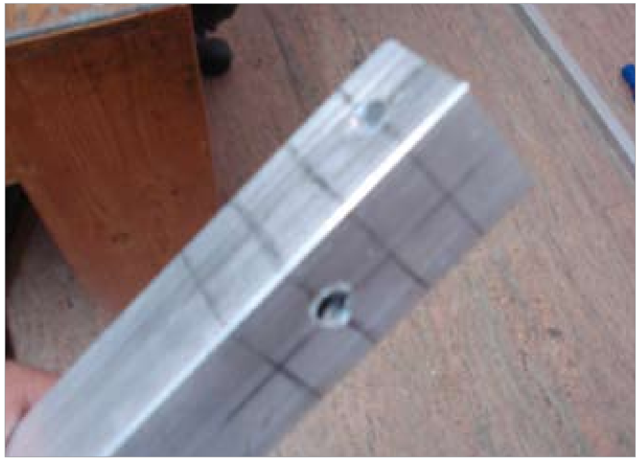
The tools required for construction are very basic like hack-saw, drill kit, wrench, screw drivers. The skill level required for the construction is very basic and hence can be done by basic skilled labour. The other option is to get the kit precut by either contacting Icarus or giving the designs to a skilled person.



Step 1: Cut the aluminum pipe according to the required length and sizes accurately.

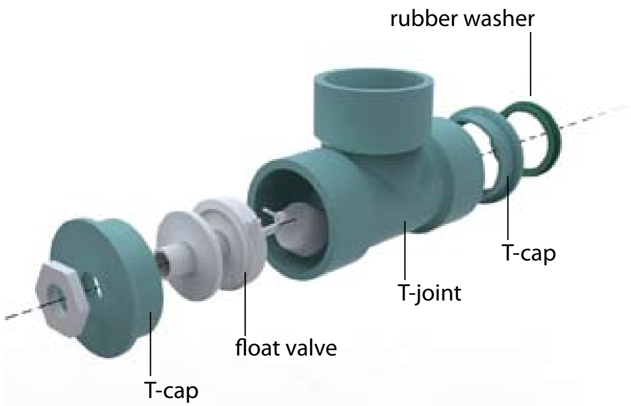
Step 2: Next with proper measurement drill holes for the joineries. The holes should a size bigger then the diameter of the screw to tolerate errors. The holes have to be on the alternate faces of the pipe depending on the assembly plan.

Step 3: After all the aluminium parts are cut and holes drilled next would be making holes in the stainless steel vessels.

Step 4: Next make holes in the T-caps according to the outer diameter of the vacuum tube and the tank nipples.

Step 5: Get the cover to fit the structure.

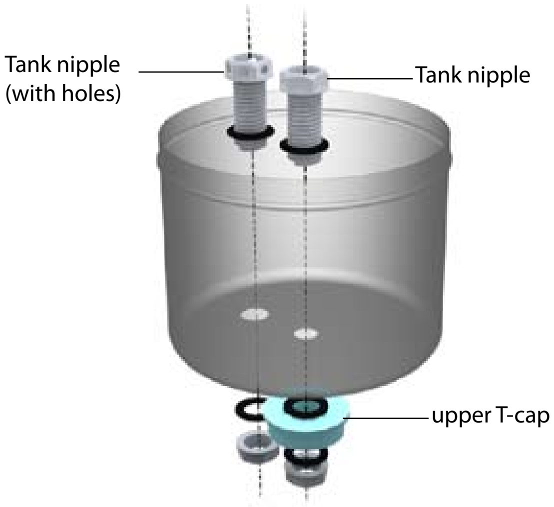
Now the assembly process can be initiated.

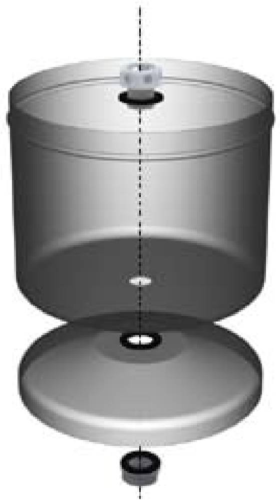


1) The image above describes the assembly of the aluminium pipes by locking each pipe with the other two with the help of nut and bolts creating a perfect rigid joint.

2) With the help of the plans and the technical drawings (from page140) assemble the entire structure.

3) Next assemble the T-joint with the float valve attached to the inside of the inlet cover and the rubber seal for the vacuum tube on the opposite side. Use adequate amount of sealant for a perfect seal.

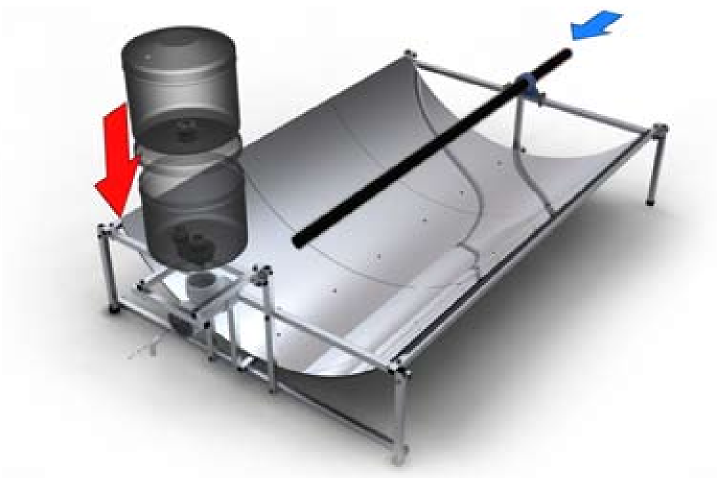


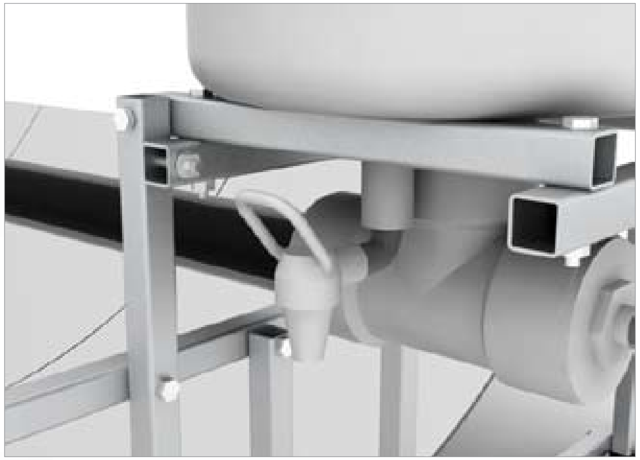


4) After making the holes in the lower vessel install the tank nipples as shown in the diagram above. Make sure that the nipple connected to the upper T-joint cover is at a higher level then the other nipple (outlet) or the outlet nipple has holes on the edges so that the distilled water doesn't flow back through the inlet nipple.

5) The top vessel is then connected to the cover of the lower vessel with the help of a tank nipple.

6) The pipe clamp is installed on the structure using the U-clamps as shown in the diagram above.





7) Install the acrylic sheet reflectors carefully on the structure using small screws at the base on which the sheet rests.

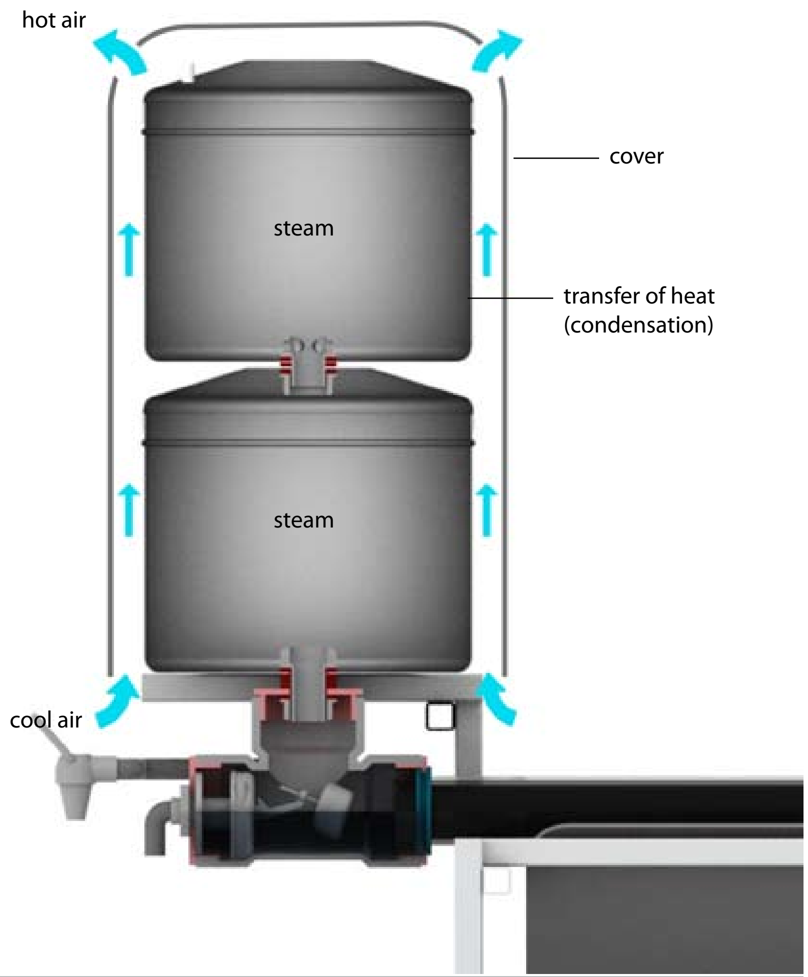
8) Next place the T-joint as shown in the figure and insert the vacuum tube from the other side. Then place the vessels from the top, connect the upper T-cap to the T-joint securely.

9) Finally install the outlet pipe and connect the tap and place the cover on top of the arrangement and securely screw it to the structure.

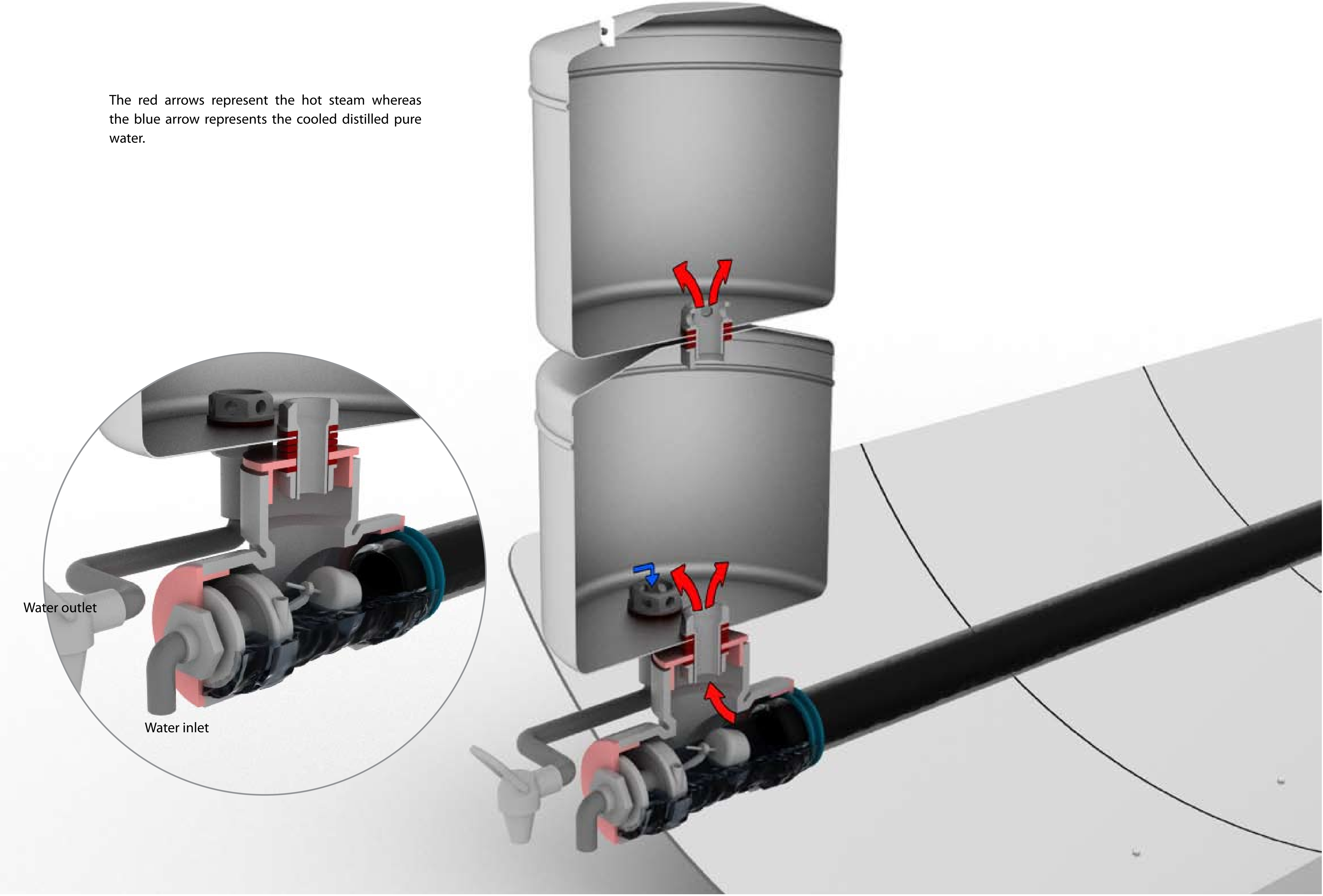
Working

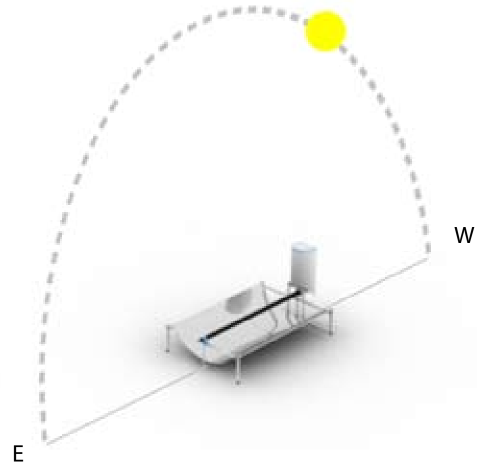
The impure water first enters the T-joint through the float valve and fills up inside the vacuum tube. When the vacuum tube is half filled the float valve turns off the water inlet. The acrylic mirror sheets reflect and concentrate solar heat on the vacuum tube and the water inside starts boiling in minutes. The steam generated in the vacuum tube escapes from the top part of the vacuum tube and enters the T-joint from where it again rises and enters the steel vessels where it expands and condenses into pure distilled water transferring the heat to the walls of the vessels. This water then trickles down into the water outlet from where it can be collected through a water dispenser tap. The process is diagrammatically explained on the next page.

The heated walls of the vessels heat the surrounding air inside the cover . This heated air being lighter starts rising creating a chimney effect by pulling cooler air from the bottom starting a convectional current which cools down the vessel continuously. This process is diagrammatically explained on the right side.



The red arrows represent the hot steam whereas the blue arrow represents the cooled distilled pure water.

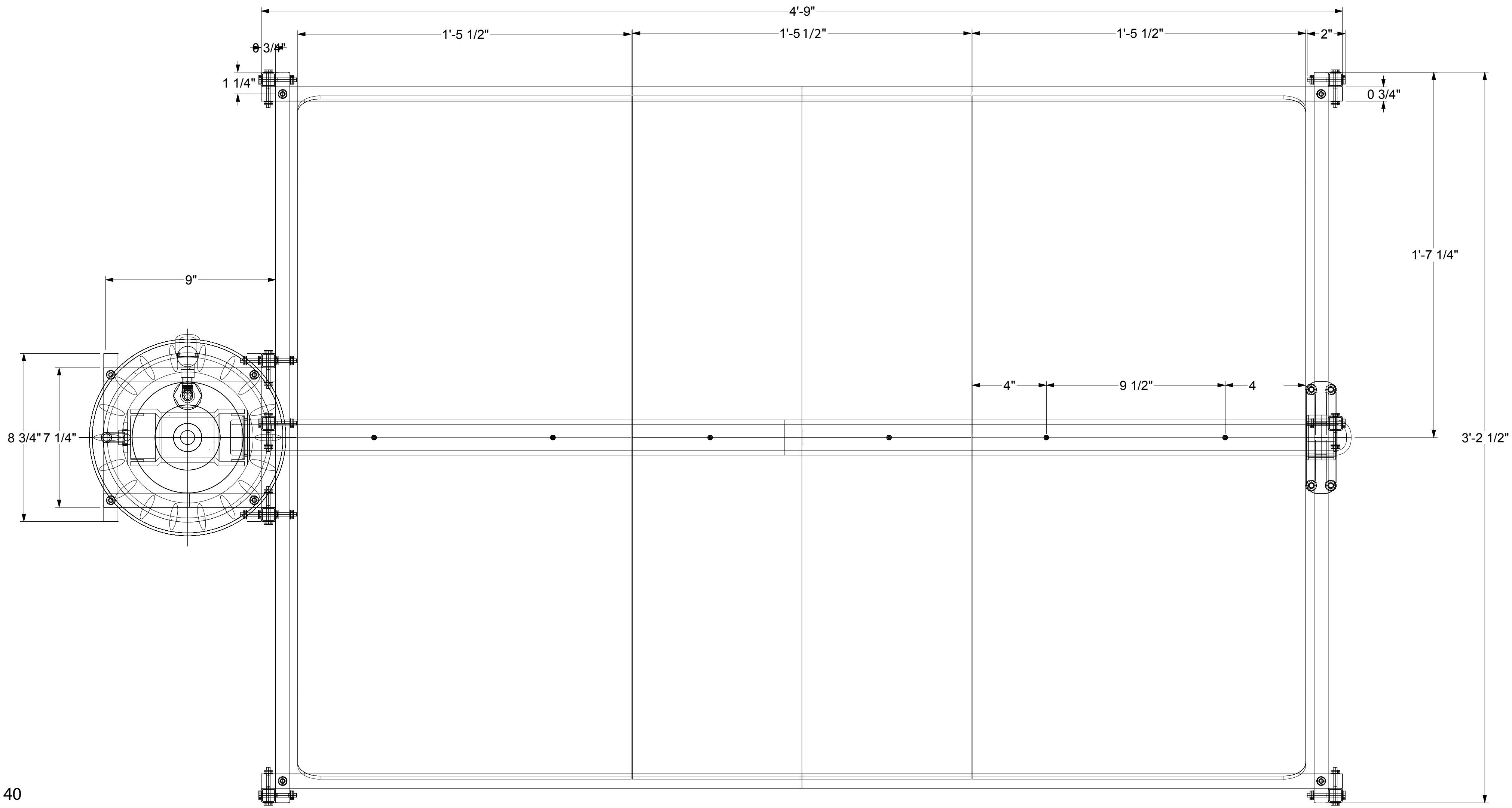


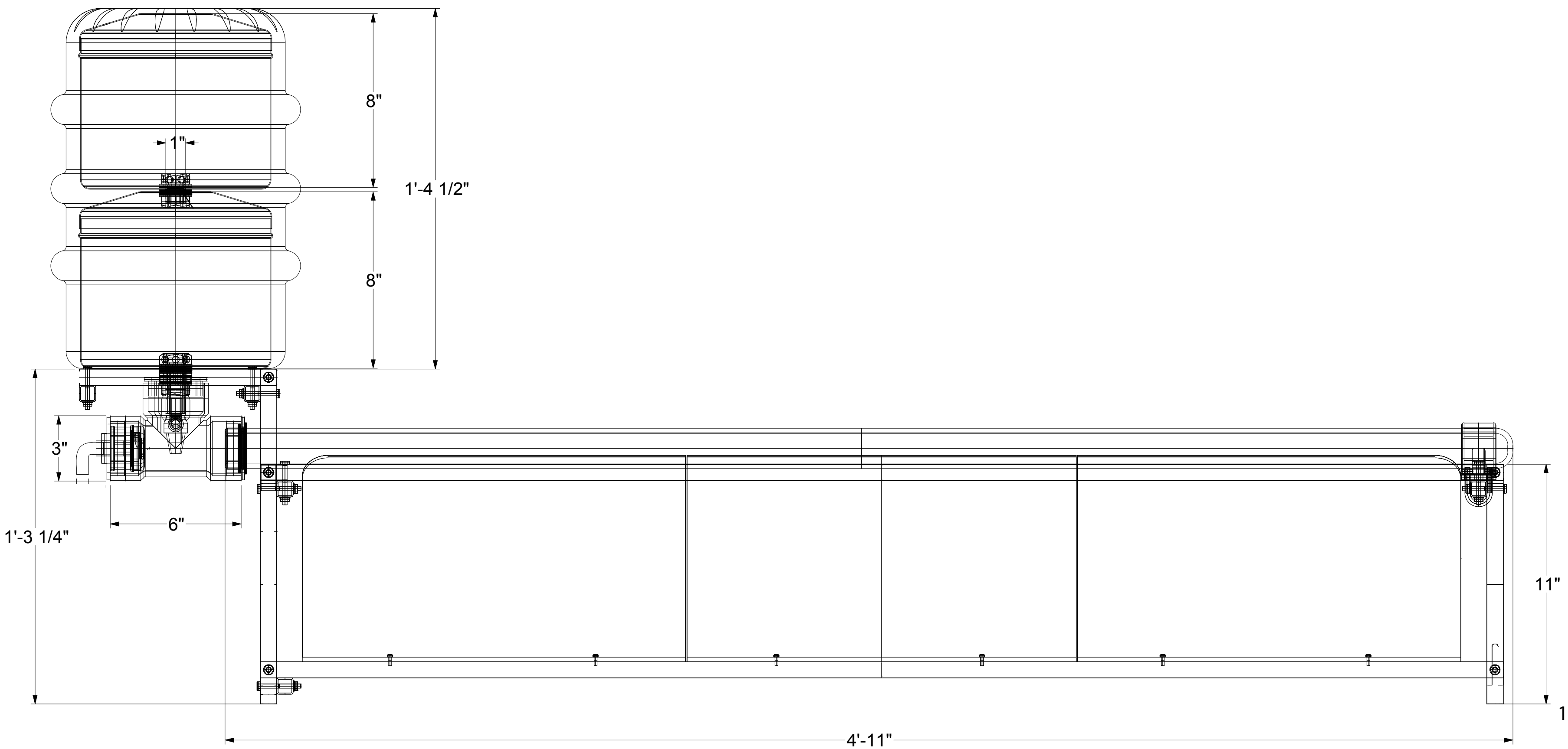


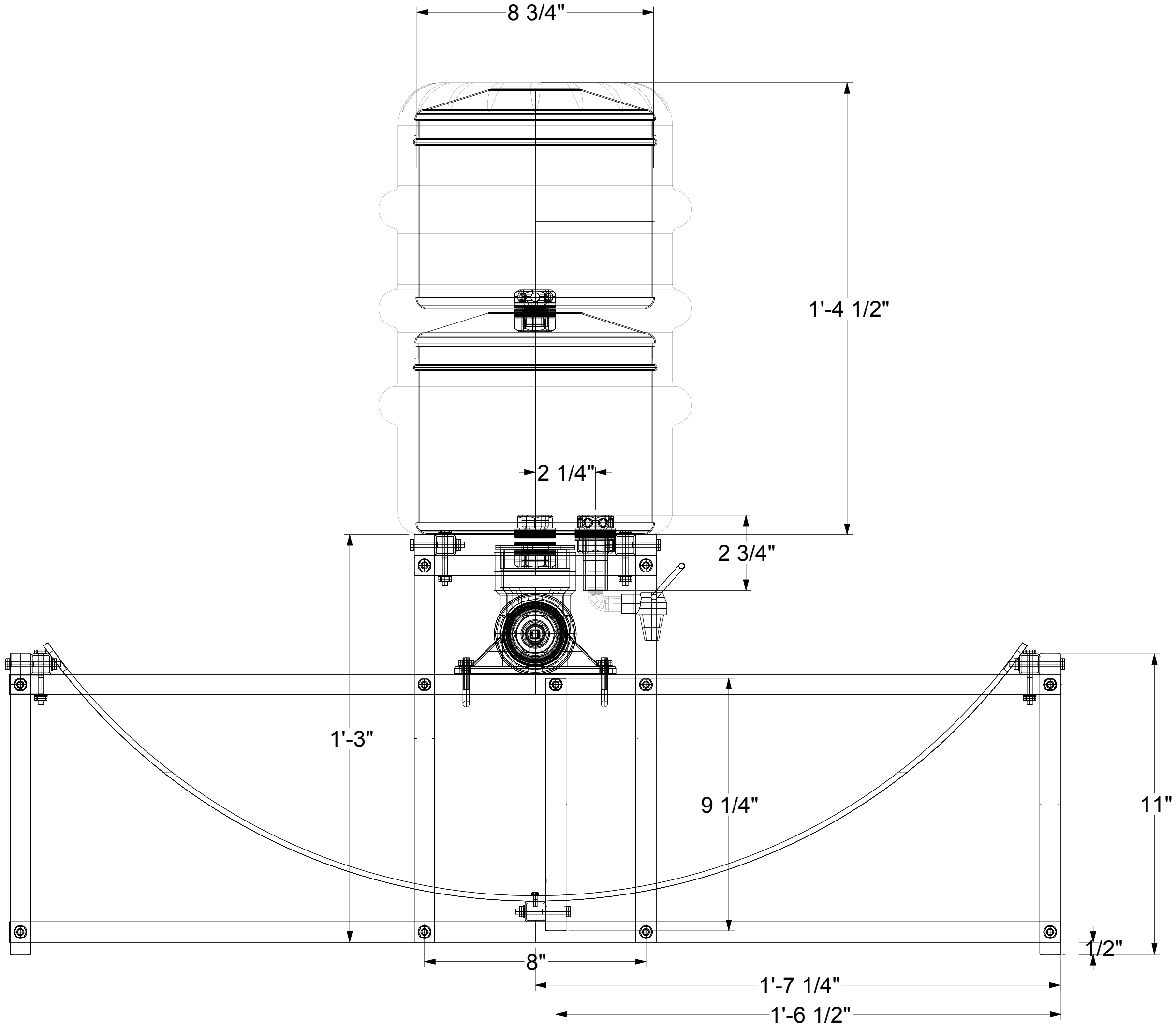
After the assembly of the product the setup has to be then installed careful keeping a few points in mind.
It is recommended that the product be either kept in a place with direct unobstructed sunlight thought the day. This can either be achieved on the roof or in the middle of an open area with no trees or other objects blocking the sunlight.

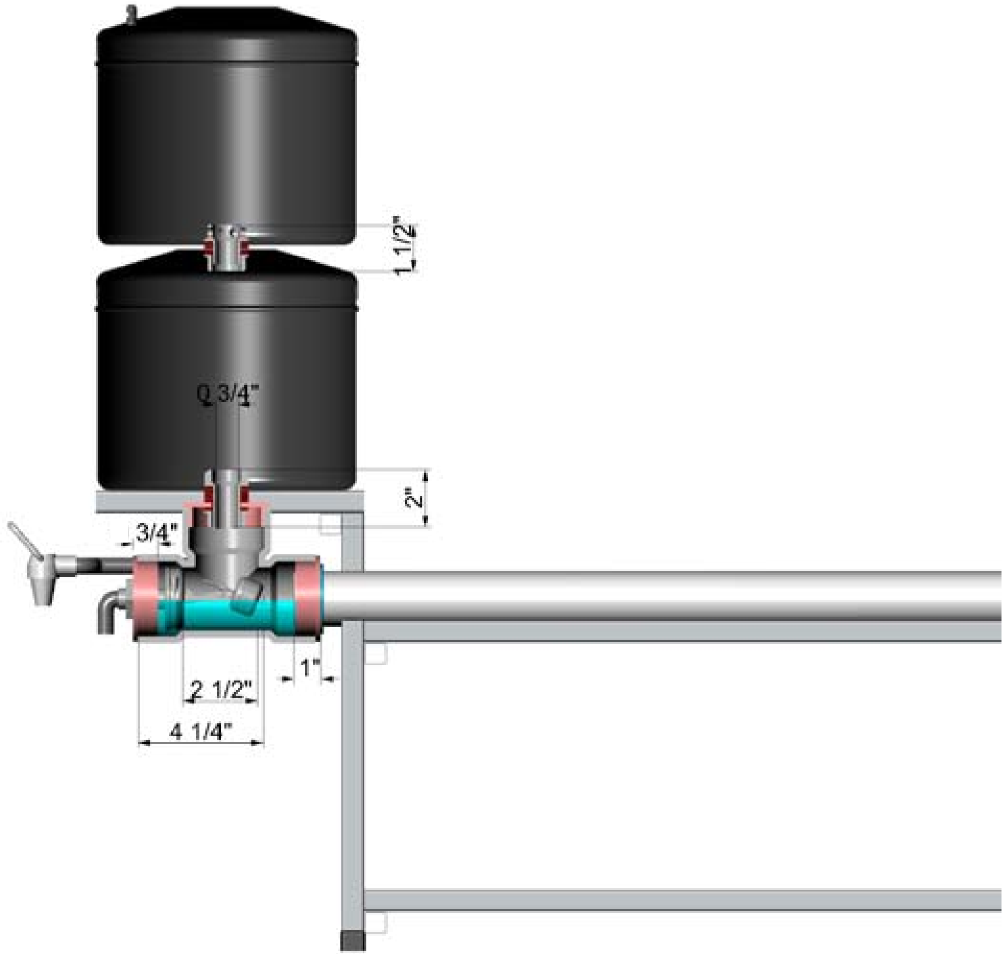
The axis of the vacuum tube should be exactly aligned parallel to the that of the moment of the sun during the day so that the focal line formed by the concentrator falls completely on the vacuum tube. This basically means that the one end of the vacuum tube should be facing east and the other end facing west or vise versa. This can be done using a compass to get a perfect alignment. To check this manually just align it to the sun in the morning and if it is aligned properly by evening the bright focal line will still be on the vacuum tube . (for image see page 64)

After the alignment with the sun the next step is to adjust the focal line by moving the base vertically (red arrow). If the focal line is falling out of the vacuum tube then adjust the swing arm (blue arrow) to get the line to fall on the tube. Once a straight line is achieved tighten the arm securely.
This arrangement needs to be checked monthly as the position of the sun's movement changes with the change in season.


4'-9"
1'-5 1/2"
1'-5 1/2"
1'-5 1/2"
2"
0 3/4"
1 1/4"
0 3/4"
1'-7 1/4"
9"
4"
9 1/2"
4
8 3/4"
7 1/4"
3'-2 1/2"

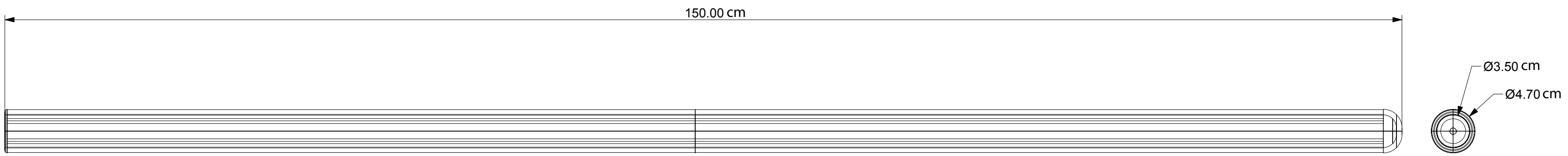

8"
1"
1'-4 1/2"
8"
3"
6"
1'-3 1/4"
11"
4'-11"


8 3/4"
1'-4 1/2"
2 1/4"
2 3/4"
1'-3"
9 1/4"
11"
1/2"
8"
1'-7 1/4"
1'-6 1/2"

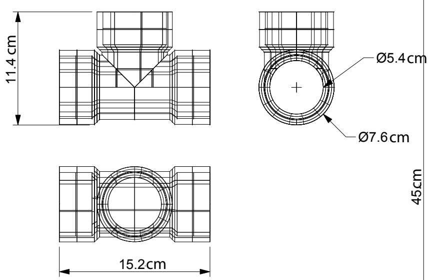

1 1/2"
Ø 3/4"
2"
3/4"
1"
2 1/2"
4 1/4"

Part details

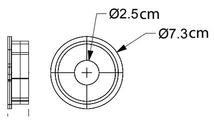
- A. Vacuum tube
- B. T-joint
- C. Acrylic sheet
- D. T-cap



(A)



(B)



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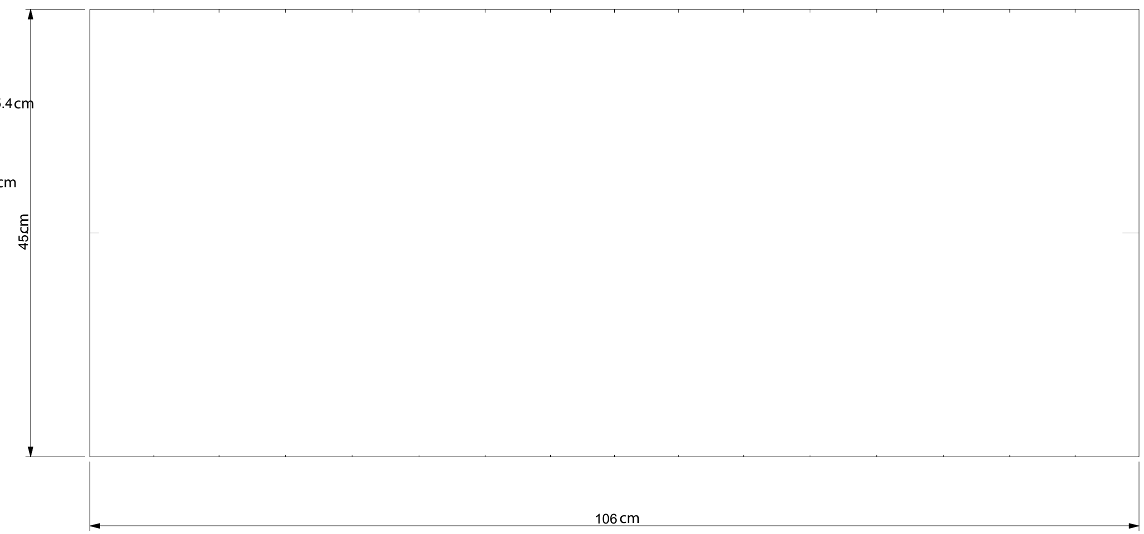
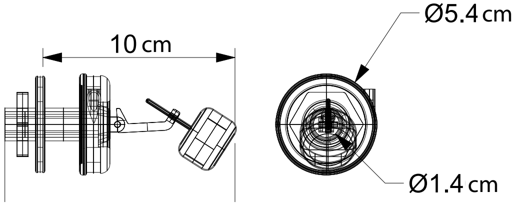
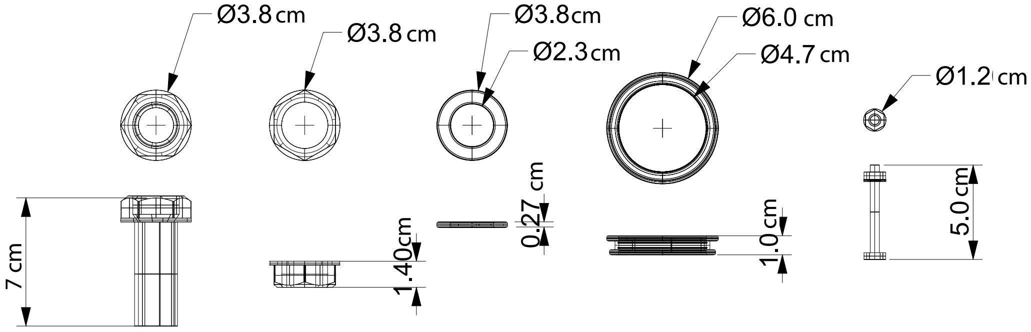


(C)

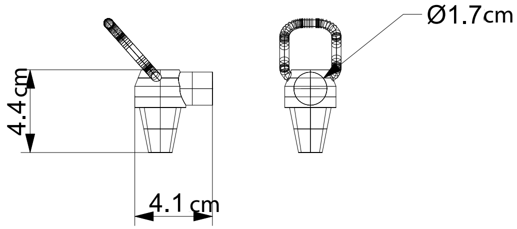
E. Float valve
F. Tap
G. Pipe clamp
H. Nipple
I. Nipple bolt
J. Washers
K. Vacuum tube rubber seal
L. Nut and bolt



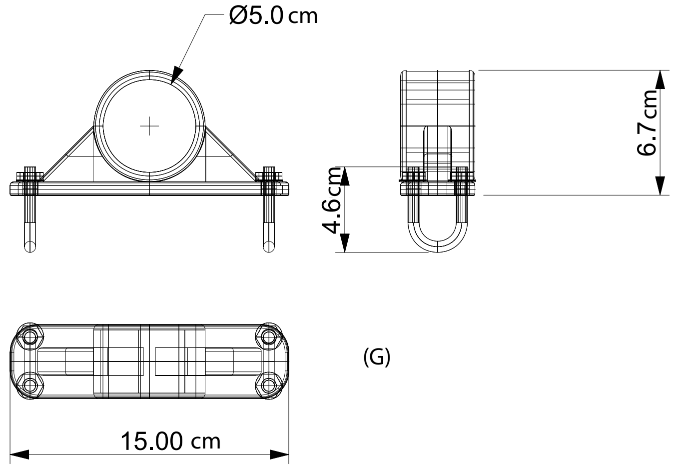
(E)



(H) (I) (J) (K) (L)



(F)



(G)

Accessories and customization

The design is customizable according to the user's need and can have attachments such as water storage tank wherever there is a scarcity of running water. This drum would be connected to the water inlet. Water can easily be store and poured when required.

The size of the reflectors and condensers can be changed and modified as required.

The design can also be used as a steamer for cooking steamed rice, idli by just placing the food to be steamed inside the condenser vessels. It can also be used to provide hot water without the need of burning wood by just removing the condensing vessels and taking the boiling water from the outlet.
The design is open to modifications and attachments but the basic principle is to use the solar energy to boil water.

Safety

There are certain precautions to be taken while using the D.I.Y. S.W.P.

• Firstly avoid direct exposure of any body part to the focal line as it might burn the contact area.

• The vacuum tube is very fragile and should be handled carefully and placed safely and covered when not in use.

• Strong wire mesh could be used to protect the vacuum tube.

• Make sure there is water at all times in the vacuum tube to avoid heat accumulation.

• When not in use the reflective sheets should be covered so that there is no heat generated.

Cleaning

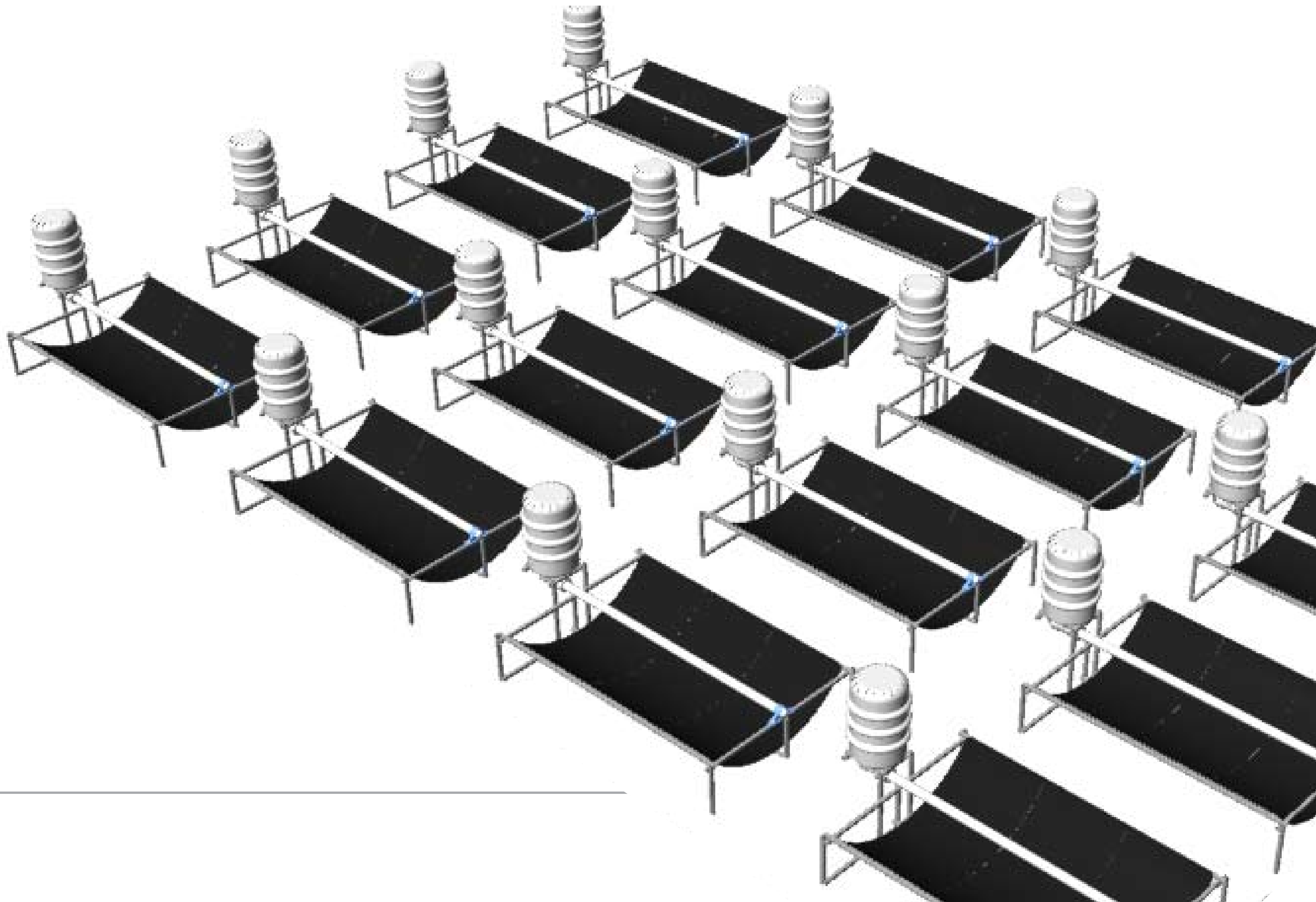
All the parts such as the vacuum tube, T-joint, steel vessels, etc have to be cleaned with water once a month so that there is no accumulation of dirt from the untreated water. The reflective mirror has to be cleaned regularly so that it doesn't lose its reflectivity. Covering the setup with a cloth would be advisable when not in use to protect it.

Spreading awareness
The idea of the project is to spread awareness of clean drinking in rural India and make it self-sustainable and independent for its survival. This would be done by involving NGOs and other social bodies, etc.

Multiple assemblies
To get large amount of pure water for a village the setup can be multiplied and connected to serve the entire colony or even a village. This setup would be cost efficient as the parts would be bought and constructed in bulk.

Government setups
The Government of India could take this product to a system level where a low-cost setup could be provided to villages in the remote regions where there is no electricity. These villagers could then be trained to use the setup and maintain it.

Package and parcel
The product can be prepared under the guidance of Icarus and can be packaged and delivered to the clients who are unable to procure the components themselves. These can then be assembled within a day and put to use.



Copyright and disclaimer

Notes

Glossary

Solar Constant
The solar constant is the average rate of solar energy arriving at the outer edge of the earth's atmosphere, before any losses. The generally-accepted value is 429.2 BTU per hour per square foot. The actual rate of radiation varies about 3 percent either way from the average. If all of this energy could be collected and used, it would take about three hours to collect all the energy used on earth for a full year!

Insolation
Isolation is the rate of solar energy arriving on a specific flat surface perpendicular to the line of the sun. At sea level, the least possible loss is 29 to 30 percent. The maximum possible insolation is therefore about 70 to 71 percent of the solar constant or about 320 BTU per hour per square foot.
The insolation of the sun can also be expressed in Suns, where one Sun equals 1,000 W/m^2 at the point of arrival, with $kWh/(m^2 \cdot day)$ displayed as hours/day
No solar collector, regardless of shape or design can deliver more than this maximum possible value, without energy input from some other source.

Efficiency
Efficiency of any energy-consuming device or system is the ratio of output divided by input, and can never be more than 1.0 or 100 percent.

Solar Fraction
The solar fraction is the ratio of solar energy used divided by total energy used in the same application. It cannot possibly be more than 1.0 (or 100%). Note that solar fraction is distinctly different from efficiency.

Greenhouse effect
Many transparent materials will pass light freely, but will not freely pass the longer wavelength "channel" of thermal (heat) energy. Greenhouses and many solar collectors use this effect by applying glass or plastic covers to prevent re-radiation of the thermal energy.

Black Body
A "black body" is any material capable of absorbing radiant energy, and therefore also is capable of re-radiating the energy. A "perfect" black body absorbs and re-radiates 100% of the radiant energy striking it. "Good" black bodies are used in solar collectors and they absorb and re-radiate (if not cooled) 90 to 96 percent of radiant energy arriving.

Selective Surface
Certain special coatings can be used in solar collectors to reduce the re-radiation ability without appreciably reducing energy-absorption ability. The only such "selective" surface now well-proven and in common use is a special black chrome electroplate.

Absorber
In a solar heating collector, the absorber is that portion of the collector which receives the radiant energy from the sun and converts it to heat at longer wavelengths. It is usually a flat black surface with high absorbance, i.e. a black body.

Collector
A solar collector is the entire assembly, including at least the absorber and heat exchanger, and any insulation, glazing, plumbing and enclosure.

Flat Plate Collector
The flat-plate solar collector is one of many possible types of solar collectors. It is the most efficient type of collector for use with temperatures between the freezing and boiling points of water and up to about 350 degrees F, when used with air as the working medium. Flat plate collectors are normally used with the flat surface facing south and tilted to an angle appropriate to the intended use.

Tracking Collector
A tracking collector is any type of collector installed to move and follow the sun, and may include flat plate collectors.

Concentrating Collector
Concentrating Collectors use a specially-shaped reflecting surface to concentrate radiation in an area smaller than the reflector, thus producing a higher temperature. Concentrating collectors must track the sun for full effectiveness, and cannot collect more solar energy than the same area flat plate collector.

Diffuse Radiation
Diffuse radiation is light energy arriving by reflection or scattering from some direction other than directly from the sun. Diffuse radiation is accepted by flat plate collectors but not by concentrating collectors. Therefore flat plate collectors will generate output 2on cloudy days while concentrating collectors will not.

Conduction
One of the three ways in which heat is transferred or lost. Conduction transfer or loss occurs due to the temperature difference between two surfaces of the same material, and the heat transfer is directly through the material.

Convection
The second of three forms of heat transfer. In this form of transfer, liquid or gas, such as air is heated, and then moves away from the source of heat, being replaced by cooler material which repeats the process of carrying away heat.

Radiation
The third method of heat transfer or loss. Radiation occurs by transfer of energy through empty space. The amount of heat transferred by radiation is proportional to the difference between the fourth powers of the absolute temperatures of the radiating surface and the radiation receiver surface. When black body solar collectors are operated at higher temperatures, the radiation losses increase very rapidly with temperature and are the largest losses responsible for loss of efficiency.

Temperature vs. Energy
Knowledge of temperature is necessary for knowledge of thermal energy, but is not enough. Both the temperature and quantity of material containing the energy must be known. We could not reasonably expect a match flame at 2,000 degrees to be able to heat a swimming pool, but solar collectors at 90 degrees will do it readily if we use enough of them.

Semi-permeable membrane
Semi-permeable membrane is a water purification system some pure water filters are based on. The membranes allow certain particles to pass through it while other particles are trapped.

Evaporation
Evaporation is the slow vaporization of a liquid and the reverse of condensation. A type of phase transition, it is the process by which molecules in a liquid state (e.g. water) spontaneously become gaseous (e.g. water vapor). Generally, evaporation can be seen by the gradual disappearance of a liquid from a substance when exposed to a significant volume of gas.

Condensation
Condensation is the change of the physical state of aggregation (or simply state) of matter from gaseous phase into liquid phase. When the transition happens from the gaseous phase into the solid phase directly, bypassing the liquid phase the change is called deposition.

Desalination
Desalination refers to any of several processes that remove excess salt and other minerals from water. More generally, desalination may also refer to the removal of salts and minerals, as in soil desalination.
Water is desalinated in order to be converted to fresh water suitable for human consumption or irrigation. Sometimes the process produces table salt as a by-product. Most of the modern interest in desalination is focused on developing cost-effective ways of providing fresh water for human use in regions where the availability of fresh water is limited.

Enthalpy of vaporization
The enthalpy of vaporization, (symbol Δv_H), also known as the heat of vaporization or heat of evaporation, is the energy required to transform a given quantity of a substance into a gas.
It is often measured at the normal boiling point of a substance; although tabulated values are usually corrected to 298 K, the correction is often smaller than the uncertainty in the measured value.

Enthalpy of condensation
The enthalpy of condensation (or heat of condensation) is numerically exactly equal to the enthalpy of vaporization, but has the opposite sign: enthalpy changes of vaporization are always positive (heat is absorbed by the substance), whereas enthalpy changes of condensation are always negative (heat is released by the substance).

Specific heat capacity
Specific heat capacity, also known simply as specific heat, is the measure of the heat energy required to increase the temperature of a unit quantity of a substance by a certain temperature interval.

Boiling point
The boiling point of an element or a substance is the temperature at which the vapor pressure of the liquid equals the environmental pressure surrounding the liquid. A liquid in a vacuum environment has a lower boiling point than when the liquid is at atmospheric pressure. A liquid in a high pressure environment has a higher boiling point than when the liquid is at atmospheric pressure. In other words, the boiling point of liquids varies with and depends upon the surrounding environmental pressure.

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