THE SOLAR AQUEDUCT:

Unlimited production of freshwater in hot, dry environments using solar energy

by

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Solar Aqueduct

Introduction

Water is a scarce commodity in many regions. Many countries are large, dry countries with huge expanses of barely habitable regions. If they were surrounded by fresh water the solution would be simple – just pipe it in! But, like all oceans, the surrounding water is salty. At present, desalination on a large scale is difficult because to distil then condense water takes huge amounts of energy and leaves a waste product of sea salt.

The Solar Aqueduct uses solar energy to distil water and natural ground coolness to condense it. It contains no moving parts (apart from pumps at the beginning and end of the system). To extract enough energy from the sun to distil large quantities of water would require a huge active surface area, which would make it impractical on a conventional basis – the solar panels would occupy a vast space. In this method however, the problem is solved simply – the conducting pipeline *is* the solar panel!

Working principles

As the water flows through the aqueduct, the top surface is heated by the sun's rays which heats the water within it, some of which evaporates, just as a puddle would do on a hot day. Steam and water are generated which flow up to the top of the chamber and then into a side panel following a heat gradient. Ceramic seals limit heat conduction from the main heating chamber to the collecting pipe. The collecting pipe (freshwater pipe) is colder than the heating chamber because it is insulated from the sun and ambient heat, and is directly connected to a large supporting vertical iron girder which is embedded to a depth of several metres. This means that most of the heat in the freshwater pipe is conducted to earth where temperatures are stable and cooler than above ground. Hence, a heat gradient exists between the main chamber and the freshwater pipe – steam and water vapour will tend to condense there. See Figure 1a and 1b.

It is likely that this system would not be very effective in small scale – it would take a long time to distil and condense a significant amount of water. However, this system relies on having a very long pipeline distilling and condensing water all along its length.

Additionally, the problem of salt waste is solved by leaving some of the water undistilled so that the effluent is liquid. At the end of the heating aqueduct, this is piped up its centre so any residual heat is passed back to the incoming seawater. See Figures 1a, 1b and 3b. It is then dumped back in the sea. Dumping very concentrated salt solution in the sea close to shore might be environmentally damaging so instead it is fed via a robust plastic pipeline several kilometres off shore and significantly off the sea floor directly into main ocean currents. This would dilute the effluent and minimise any environmental impact. See Figure 2a.

Meanwhile the freshwater pipe carries its condensed contents towards its destination down a gentle gravity gradient. The freshwater pipe would probably extend far beyond the end of the heating aqueduct; further supporting iron girders ensure that heat transference to earth continues along its length to make sure all the distilled water condenses. At the end of its journey, the water is collected, either directly into a reservoir, or into a tower with the aid of another pump. See Figure 3c.

Throughout the length of the Solar Aqueduct, the heating aqueduct – including afferent pipeline and the internal, efferent pipeline – and the freshwater pipe are as close to horizontal as possible. Water flow is ensured by the principle of filling a long trough from one end. A significant distance – say 10-20cm – exists between the top of the sea water in the afferent pipe and the lip of the chamber so allowing for error in construction and preventing overflow of sea water into the fresh water pipe.

Where the freshwater pipe continues after the heating aqueduct has terminated, a gentle gradient – say 1cm/100m – ensures flow of fresh water to the destination.

Construction materials

The heating aqueduct - which consists of the external afferent pipe and roof carrying seawater inland, and the efferent pipe which runs internally and carries effluent salt solution seaward - is constructed of galvanised steel designed to resist corrosion by warm, salty water. Alternatively, anti-corrosion paint might be used instead of galvanisation. The roof is angled to maximise exposure to the sun's rays and to provide an exit cap for steam/water vapour, and is painted externally matt black. The efferent pipe may be mounted on small galvanised steel struts within the afferent pipe as shown in the accompanying diagrams; alternatively, resting this pipe on ceramic bricks within the afferent pipeline might be an easier solution, and would allow some flexibility of movement within the structure.

Ceramic seals are sited along the top of the condensing chamber to limit heat conduction from the metal of the heating aqueduct to the freshwater pipe.

The walls of the condensing chambers and the freshwater pipe are made of stainless steel.

The freshwater pipe is built with a gas trap region to encourage condensation and so that warm water and steam in equilibrium does not cause steam to be lost back to the heating aqueduct. It is connected by solder or welding to the supporting iron girder to maximise heat conduction to earth.

The supporting iron girder is packed all around by soil or rocks where it is above ground to minimise heat transference between it and the atmosphere.

The heating aqueduct is supported by brick or concrete pillars.

All the metal parts of the aqueduct apart from the solar surface are covered with artificial pumice-type stone which is painted white. This minimises heat transference to the surrounding ambient conditions from any part of the aqueduct.

Thus heat flows in the following manner: the sun's rays to the solar panel, to the afferent sea water, to the freshwater pipe, to the iron girder, to earth, and additionally from the efferent pipe to the afferent sea water. See Figure 1a.

At the primary end, a pump directs sea water into the top of the afferent pipe; this ensures gravitational water flow – See Figure 2a. This water is filtered to remove large particles. The efferent pipe exits at the same point and empties effluent salt solution into the plastic waste pipe previously described.

The rates at which water is poured into the afferent pipe and allowed to pour out of the efferent pipe are regulated to maximise water production. If water flows too quickly, the effluent will be too dilute indicating reduced water-production performance. If the water flows too slowly, the effluent will become too concentrated with a risk of flow impedance and potentially solid obstructions forming. At night, it might be possible to allow a rapid flow of sea water to flush the system through and remove solid impurities.

This design does not include certain practical considerations which might prove necessary, such as service hatches, since these are not relevant to the working principle.

Water generation calculation

Sea water is approximately 4% salt.

A concentrated solution which is reliably liquid could be 25% salt.

Therefore 1 litre sea water would contain 40g of salt.

40g of salt in 25% solution would have 160ml volume.

Hence 1 litre of sea water yields 0.84 litres of pure water and 0.16 litres of liquid effluent.

For safety, let's round the figures to 0.8 litres of water and 0.2 litres of effluent.

Assume the surface seawater at the intake is 20°C.

To heat 1 litre of water from 20°C to 100°C @ 4.2 joules/g/°C = 1000 x 4.2 x 80 = 336 kJ

To evaporate 1 litre of boiling water is 2,268 J/g = 2,268 x 1000 = 2.6MJ.

Assume solar energy is 500 Watts/m2/12 hours.

= 21.6MJ per day/ m2 equiv 8.3 litres per day.

If the heating aqueduct is 20km long with a solar panel 2m across, production of water is:

20,000 x 2 x 8.3 = 332,307 litres per day.

Therefore a 500km heating aqueduct with a 5m wide solar roof would produce 54 million litres per day.

It must be noted that these calculations are based on certain assumptions and are unlikely to be precise. To come up with more reliable figures would require complex computer models or even the practical building of a working version. However, the probability is that the system would work as it is so simple. Having understood the principles, water production can be increased by building longer, wider, larger aqueducts, or several aqueducts in parallel feeding into a single freshwater pipe. There is no theoretical limit to water production using this method, only possible practical issues with regard to construction.

Worldwide application

The Solar Aqueduct was designed with Australia in mind; it is a large country with vast areas of land deficient in water, with high summer temperatures and reliable direct sunlight. It also has a modern, Western legal and business environment, and first-rate engineering skills. However, many other countries would benefit from this system i.e. those which are hot, dry, with reliable sunshine and an absolute water requirement. These could include parts of the USA, Mexico and some other Latin American countries, much of Africa, Southern Europe and many Middle Eastern countries. Other countries might benefit less clearly; in some parts of the world, water deficiencies are due to very high population densities, poor infrastructure, pollution and so on, and the Solar Aqueduct would have less to offer.

Design variations

Although not intrinsic to the principles of the Solar Aqueduct, there are endless possible variations of design which might make for more effective operations.

For example, the version shown in Figure 1 shows the heating aqueduct consisting of a simple, sloping, black painted, corrugated, solar panel roof and a rectangular shaped afferent pipeline. The efferent pipeline consists of a simple tube on steel struts. Would other shapes be more effective? The sloping roof could be dipped or bowed, its surface could be flat instead of corrugated: these changes might maximise the absorption of solar energy. The efferent pipeline could be mounted freely on ceramic bricks or other supporting structures, which might limit internal physical stresses in such a large structure. The edge of the aqueduct could be be-lipped or rounded off to increase the amount of water being heated directly (See Figures 4a, 4b and 4c). Rather like the propeller in the 19th and 20th centuries, the basic working principle is very simple, but the possible variations unlimited and the most efficient design elusive at this time. Figure 5 shows an alternative positioning of the ceramic seals than other diagrams, and in fact might be simpler to construct: in this version, because the outer seal is placed along the top of the junction between the freshwater pipeline and the afferent pipeline, the side of the condensing chamber rises up to the same height as the top of the solar panel and might promote more effective condensation.

The internal efferent pipeline might also be improved: would changing its shape to oval maximise heat transference to the incoming seawater? Within the afferent pipeline, where would be the most efficient place to position it: near or far from the solar panel; near the water's surface or close to the floor of the afferent pipeline?

It is possible that additional metal structures within the afferent pipeline could increase heat transference from the solar panel to the seawater and also increase flow turbulence and thereby improve the distillation process.

The current design relies on heat transferring efficiently from the freshwater pipe and condensing space via the stainless steel of the pipeline through the solder/welded floor connecting it to the girder, through the iron girder and then to earth, all by heat conduction. It is possible that this could be improved without changing the actual principles involved. If the floor of the pipeline was indented to improve contact area for heat loss, or if the top of the girder actually projected into the freshwater pipe, would heat transference to earth improve? Currently, the heat is conducted to the thick, iron girder and then to earth. Sinking a girder vertically via a borehole is a relatively straightforward proposition, but heat conduction to earth might be improved if the girder was attached to flat metal panels underground so achieving a radiator effect; obviously this would require the digging of trenches rather than simple boreholes, and thus increase construction expense.

Potential practical pitfalls

The author is not a construction engineer, but there are obvious potential difficulties which need to be discussed.

Actually building the Solar Aqueduct so that it works would be challenging but not impossible with modern construction techniques. The flow of water within it would need to be finely controlled. As stated previously, the principle requires the heating aqueduct and freshwater pipeline to be horizontal for the flow to be controllable and to prevent seawater overflowing into the freshwater pipeline. It is anticipated that the heating aqueduct would be constructed in sections and then assembled one at a time; once each piece was secure and guaranteed horizontal, the next section would be added. The condensing space and freshwater pipeline would be added separately but in tandem with construction of the heating aqueduct. It might also be easier to achieve this by building the Solar Aqueduct following height-above-sea-level contours rather than straight lines as-the-crow-flies.

The issues of legalities and landownership have not been considered but would be important should construction be contemplated. The pipeline would require a shore-based pumping station to operate and would occupy a narrow but very long strip of land, much as railways do. Ownership of that land would need to be settled; this might be by compulsory purchase, annual leasing or so on. Rights of access where the Solar Aqueduct crosses land would surface, so when building one might need to consider this: livestock and wildlife would be able to walk freely under the Aqueduct, and the construction of underpasses or bridges should permit the movement of human traffic.

Although this proposal is based on sound ecological principles – the use of renewable energy to generate freshwater – there are potentially negative environmental implications. The construction of each Aqueduct would cut across large tracts of land and would disrupt the lives of people living there as well as possibly altering the land over which it comes to lie. The importation of large quantities of freshwater into regions which were previously desert would wreak permanent changes, first of all to the local ecology, and second due to the increased human activity (agriculture, urban development and so on) which would then result.

Furthermore, the Solar Aqueduct generates concentrated salt solution as its effluent to be returned to the sea. Handled clumsily, this could have a devastating environmental impact as concentrated salt solution would kill most marine life. It is proposed that by piping the effluent several kilometres off-shore, many metres off the sea floor and directly into main ocean currents, these impacts would be minimised. The only additional cost in increasing the distance and location of effluent dumping would be in the length of the effluent pipe and its initial laying; no additional energy would be required in terms of moving salt solution because the pipe would lie entirely beneath the sea's surface, and the weight of incoming effluent would be enough to move it along. It must be remembered that the effluent contains nothing that was not originally extracted from the sea; if discharged high above the sea floor, free-swimming marine life would be able to move around the increased salt gradient and bottom dwelling life would be undisturbed. Fast moving ocean currents would quickly dilute the effluent, no matter how concentrated, and flushing the system through at night would render any local changes temporary. The vast majority of the world's water is in the oceans so even if the Solar Aqueduct were adopted on a massive scale and worldwide, no permanent changes to the seas would result.

The novel idea in this invention is the Solar Aqueduct - the use of the sun's energy to distil water, and the ground's coolness to condense it, all within a flowing water pipeline. The pumps needed to supply it are effectively 'black boxes' – they do not need to be invented, merely installed. However, the energy needed to pump the water – which is effectively the energy needed to lift it from sea level to a specified height – would be considerable. At the moment it is assumed that conventional power with a large 'carbon footprint' would provide this energy. There is no reason, however, why renewable sources such as wind or solar could not be used instead. Additionally, it is possible that some of the gravitational potential energy could be recovered from the effluent salt solution being voided to the sea.

Last of all, the effort and expense involved in construction would be sizeable. However, by virtue of its simple design and its having no moving parts, plus by using robust construction materials, it is hoped that maintenance of the Aqueduct once in place would be minimal.

Summary

The Solar Aqueduct is a novel but extremely simple design which, if it worked, could transform vast areas of the Earth’s dry land. Desert regions in Australia, Africa, Southern North America, Southern Europe and the Middle East could be rendered green and productive. In a world in which climate change, growing populations, the need for green energy and increased food production all threaten global devastation, this simple technology could transform human fortunes.