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Evaluation of basin type solar still by optimizing the condenser

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ABSTRACT

Productivity enhancement of solar still has been one of the main goals of the researchers. The purpose of this research is to design a water distillation system that can purify water from nearly any source, a system that is relatively cheap, portable, and depends only on renewable solar energy. To improve the performance external condenser was used. In this research work, two design of solar still was compared experimentally, one with external condenser and other without condenser. The effect of adding external condenser to the still is to decrease the heat loss. To improve this the addition of external condenser in simple solar still was definitely positive in improving the thermal performance of the still by increasing the overall water collection over 24 h. This paper contains the experimental work and comparison.

Keywords*—Solar still, Different design, External Condenser*

1. INTRODUCTION

Due to rapid population growth and industrial developments, the need for a quantum of drinking water increased. So far the only possible way of getting drinking water is from rivers, lakes, wells, etc., which must be purified as they may contain harmful microorganisms and mineral contents, so solar water distillation. The basic principles of solar water distillation are simple yet effective, as distillation replicates the way nature makes rain. The sun's energy heats water to the point of evaporation. As the water evaporates, water vapor rises, condensing on the glass surface for collection. This process removes impurities such as salts and heavy metals as well as eliminates microbiological organisms. The end result is water cleaner than the purest rainwater. This principle of evaporation and condensation in the presence of sun ultimate solar radiation, we can purify water and the process called solar distillation and system called solar still. Solar still is one of the best solutions to solve water scarcity.

1.1 Water can be purified for drinking purpose by different methods:

- **Boiling** is the least complex procedure among water refinement strategies to wash down water that is risky in view of smaller scale living being defilement, for eg. Inflections, parasites, or microscopic organisms.
- **Iodine treatment** slaughters different yet not the majority of the most widely recognized pathogens existent in regular crisp water sources.
- **Water chlorination** is a crisis water sanitization where water can be made safe for drinking by helping with fluid chlorine blanch. The family unit dye is typically somewhere in the range of 5% and 6% chlorine, and this uncompromising oxidant that quickly murders numerous hurtful small-scale life forms.
- **Ozonation** technique uses ozone, a plate blue gas with an exceptionally harsh smell, as a disinfectant. This is made nearby and added to the water by air pocket contact so as to separate a wide assortment of non-living, natural and microbiological issue and taste and smell issues. This requires higher gear and operational expense, and likely fire dangers and poisonous quality concerns are connected with ozone age.
- **Ultraviolet water refinement** is a purification procedure that utilizes bright light at a suitable short wavelength to annihilate or dormant microorganisms. UV water cleaning is quick and contrasts decidedly and another water purifier as far as expense and work.
- **Solar sanitization** is a sort of versatile water cleaning that utilizes sun-based vitality to make naturally tainted water safe to drink. There are three principle subsets of sun-powered water sterilization- Electric water purifier, Heat purging, and UV Cleansing.
- **Reserve osmosis (RO)** water purifier items utilize a procedure wherein inorganic strong, for eg. Salts are expelled from an answer by applying weight in overabundance of the osmotic weight. This is generally known for its utilization in drinking water filtration from seawater.
- Various **Filtration** process like by fabric, plant material, by film filtration and some more.

- **Flocculation process** comprises essential part in treatment of surface water or of water with an abnormal state of defilement.
- **Aeration** is connected for the most part to groundwaters, for evacuation of iron and after that of manganese, and furthermore to dispense with gases from surface bearing groundwater.
- **Sedimentation** is physical water treatment process utilizing gravity to expel suspended solids from water. This is essential treatment of sewage in the evacuation of gliding solids.
- **Desalination** system alludes to the expulsion of salts and minerals. This is presently costly contrasted with UV water purifier and different procedures.
- For sanitization, **Chemical oxidation** strategy is additionally utilized.
- Here we are **Solar distillation** process and system called Solar still. It is a practical manner of distilling water using the heat of the sun.

2. HOW DO SIMPLE SOLAR STILL WORK?

A Solar still distills water, utilizing the warmth of the sun to vanish water with the goal that it might be gathered and cooled, subsequently cleansing it. They are utilized in zones where drinking water is inaccessible, so perfect water is gotten from messy water or from plants by presenting them to daylight. There are numerous kinds of sun based as yet, including vast scale concentrated sun based still and Condensation traps/Moisture traps.

In a Solar still, debased water is contained outside the gatherer, where it is vanished by daylight radiating through clear plastic or glass. The unadulterated water vapor gathers on the chill inside surface and trickles off, where it is gathered and expelled.

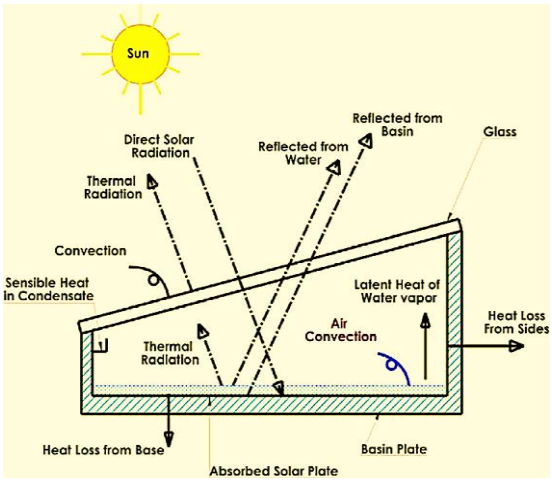


Fig. 1: Working of Solar still

Refining imitates the manner in which nature makes rain. The sun's vitality warm water to the point of vanishing. As the water dissipates, water vapor rises, consolidating into the water again as it cools and would then be able to be gathered.
This procedure abandons pollutions, for example, salts and substantial metals, and dispenses with smaller-scale natural life forms. The final products are "Unadulterated refined water".

3. CLASSIFICATION OF SOLAR DISTILLATION

Solar distillation processes can be divided in two main types: Direct and Indirect collection systems. The Direct method use of solar energy to produce distillate directly in the solar collector, whereas in Indirect collection systems, two sub systems are employed (one of solar energy collection and the other one for distillation).
The direct solar energy method uses a variety of simple stills which are appropriate for very small water demand; indirect methods use thermal or electrical energy and can be classified as; distillation methods using solar collectors or membrane methods using solar collectors and/or photovoltaic for generation.
The direct method solar still is called as passive solar still and the indirect method solar still is called as active solar still. The yield of passive solar still is very less compared to that of other desalination methods.

4. FACTORS AFFECTING PRODUCTIVITY OF SOLAR STILL

(a) Climate parameters: Solar radiation, Ambient temperature, Wind speed, Outside humidity, Sky condition
(b) Design parameters: Single and Double slope, glazing materials, Water depth in a basin, Bottom insulation, Orientation of still, Inclination of glazing, Spacing between water and glazing, Type of still
(c) Operational parameters: Water depth, Pre-heating of water, Coloring of water, Salinity of water, Rate of algae growth, Input water supply (continuously or in bathes)

5. LITERATURE REVIEWS REGARDING STILL WITH EXTERNAL CONDENSER

Khalifa et al. [1] directed investigations for the regular sun-powered still to upgrade the efficiency of distillate water utilizing interior condenser. The condenser was made of 10mm breadth with copper pipes every one of 1.2m long with Eight passes. The condensate water quality was examined and observed to be similar with "Water quality guidelines and against Rain and Mineral water". Expanded in cooling of divider surface prompts upgrading the build-up procedure. Finally, it was presumed that the normal productivity of still with the inner condenser was about 54%.

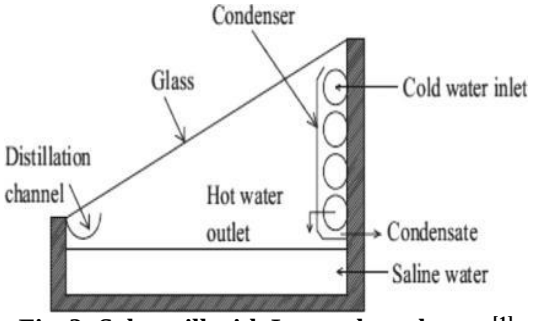


Fig. 2: Solar still with Internal condenser [1]

Husham M. Ahmed[2],2012 utilized uninvolved outside condenser and tested in summer, winter and harvest time and utilized three indistinguishable single bowl sun oriented still at tendency 20º to flat plane, with the compelling territory of $1m^2$.

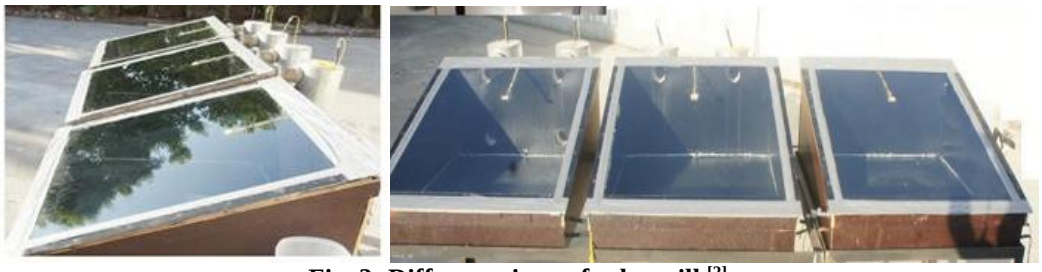


Fig. 3: Different views of solar still [2]

One was utilized for reference and other associated through channels. One with the upper part while other was associated both to "upper and lower" some portion of its back.

The trials were led and amid summer yield a normal of 42.9% more refined than in harvest time and 117.4% more than in winter.

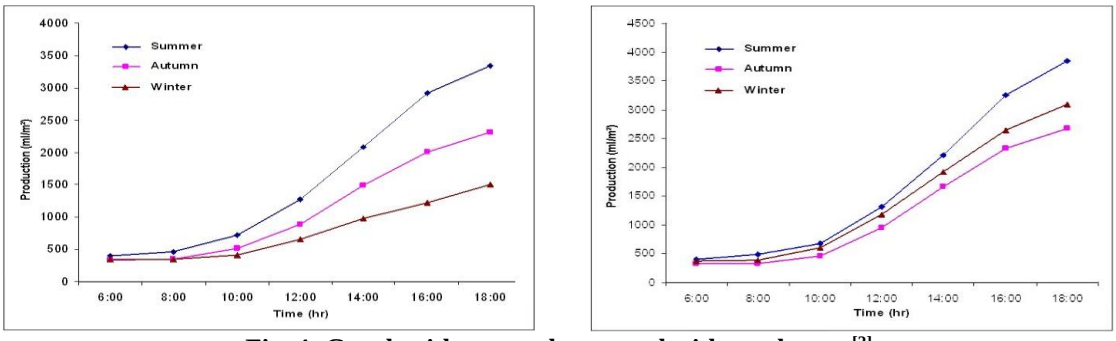


Fig. 4: Graph without condenser and with condenser [2]

The still associated through the upper part to the outside condensers, yield expansion in its creation rate of 15.1, 15.08 and 16.6% for the "Late spring, Autumn and Winter season" resp., contrasted with the straightforward CSS. The still associated with the upper and lower parts to condenser, yield an expansion underway rate of 30.5, 33.6 and 35.8% for "Summer, Autumn, and Winter" separately.

Nijegorodov et al. [3] tested the impact of adding an inactive condenser to expand the execution of the single slant sun oriented still. The sun-powered warm electrical technique was portrayed to decontaminate water by refining. The soaked air with water vapor was expelled from a bowl type sun based as yet utilizing a low power exhaust fan, and permitted to go through the condenser. The warm productivity of the still was expanded more than the warm proficiency of the CSS. The augmentation of distillate was almost multiplied.

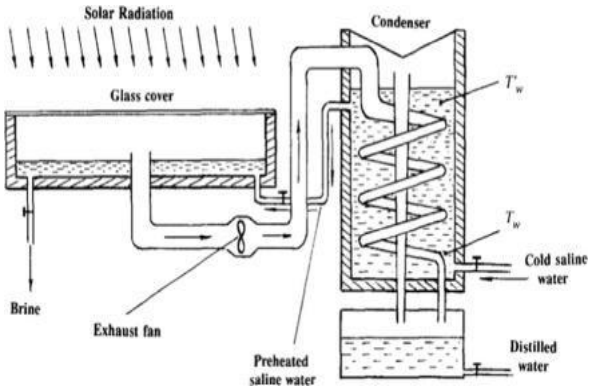


Fig. 5: Cross-section view of Thermal electrical solar still [3]

G. Tiwari, A. Kupfermann, S. Aggarwal [4] examined between, Solar still with condenser and Conventional sun based still. The condenser was planned and developed by G.I. Sheet and give little ports to upgrade the build-up rate. The examination demonstrated that bowl type still with independent condenser was more productive than Conventional sun-powered still for same water profundity. Every day profitability with a condenser was 19% more than regular still.

A.E. Kabeel, Z.M. Omara, F.A. Essa [5],2017 has investigated utilizing Nano liquids and with condenser and afterward was contrasted and CSS (traditional sun oriented still), under same metrological conditions. Numerical computations were done on sun oriented still with various Nano liquids (Aluminium oxide and Cuprous oxide) materials fixation and giving low strain to think about the impact and parameters on day by day creation. Finally result demonstrated that the day by day productivity was 84.16% and 73.85% by cuprous and aluminum oxide, separately with a working fan. Also, while giving low weight, it was 46.23% and in CSS it was just 33%.

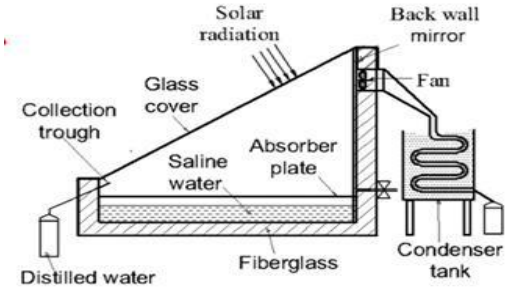


Fig. 6: Solar still with external condenser and fan [5]

Kamel Rabhi et al. [6] made a near report and presume that aggregate water creation gains of 41.95, 23.39 and 11% inferring an hourly gain of 12.9, 9.7 and 3.1% recorded for stick balance safeguard combined with condenser separately with regular still.
The gain of 32.18% is recorded for still with condenser contrasted with traditional still. Straightforward stick balance safeguard increases just 14.53% contrasted with traditional still.

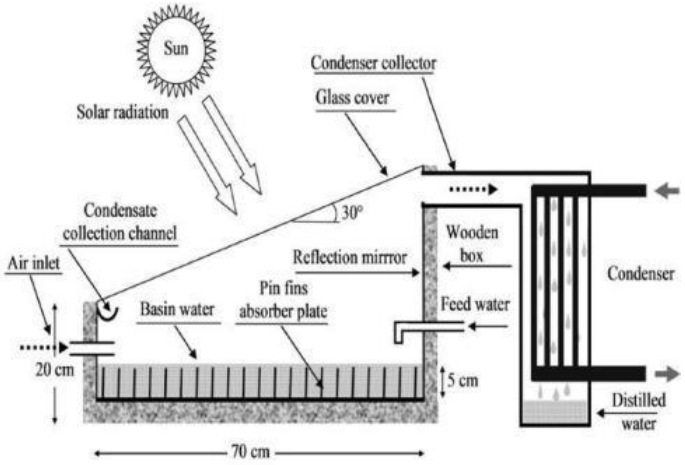


Fig. 7: Solar still with fins [6]

Sun-powered still with reflectors is additionally one of the techniques to expand the profitability of still where Internal reflectors are helpful apparatuses to think divert sun-oriented radiation. They are utilized when daylight is frail or the neighborhood temperature is moderately low. Outside reflectors are liked to be utilized to alter the course of sun-oriented bars to enhance adaptability of the safeguard plate setup, for example, vertical sunlight-based safeguard plate which is useful in recuperating vapor dormant warmth of build-up.

T. Suresh, A. Syed Abuthahir, A. Tamilazhagan, T.R. Sathishkumar, S. Jegadeeswaran[7] performed theoretical performance and experimental analysis of a conventional solar still, fin type solar still, solar pond integrated with fin type solar still. The addition of the fins in the mini solar pond was definitely a positive in improving the thermal performance of the single basin solar still by increasing the overall water collection over 24 h. When fins were attached at the basin of a still, the heat transfer rate from basin to water is increased**.**

Categorization	Authors	Location	Daily yield ($kg/m^3/d$)	Improvement	Observation
Built-in passive condenser					
Conventional still	Fath and Hosny[8]	Alexandria, Egypt	4.9	55%	The total yield 4.9 kg/m2/d with 2.1 for the condenser and 2.8 for glass cover
	Belhadj et al. [9]	Adrar, Algeria	7.15	68%	The contributions of the glass cover, metal plate, and condenser plate are 43%, 18% and 39% of the total distillate yield, respectively

	Madhlop and Johnstone[10]	Glasgow, UK	6	62%	The daily efficiency of the CSS only (without condenser) is about 32%.
Conventional still with phase change material (PCM)	Al-Hamadani and Shukla[11]	Varanasi, India	5.71	33%	The daytime (4.823) and on night productivity (0.887 kg/m2/d) of modified still of 10PCM with 20 kg of water.
Double condensing chamber solar still (DCS)	Tiwari et al. [12]	Delhi, Indian,	2.6	44%	The performance of DCS gives a higher daily output of about 35–77% over the CSS, during a year.
External active condenser					
Stepped solar still with reflectors	El-Samadony et al. [13]	Kafrelsheikh , Egypt,	9	165%	The productivity of the stepped still with a condenser only is about 66% higher than that of the CSS. The daily efficiency is about 54%
Inclined solar still	Rahim[14]	Bahrain, Bahrain	4.2	180%	The efficiency of the condensation process depends mainly or, the temperature difference between the evaporating and condensing zone.
Conventional still with nano fluid (aluminum oxide)	Kabeel et al. [15]	Kafrelsheikh , Egypt	8.4	116%	The productivity of the CSS still with a condenser only is about 53.2% higher than that of the CSS only.
Conventional still with nanofluids (cuprous, and aluminum oxides)	Kabeel et al. [16]	Kafrelsheikh , Egypt	10.4%	133%	125% increase in productivity (aluminum oxides) higher than CSS.
Single slope solar still	Emad A.[17]	Riyadh, Saudi Arabia	9.23	55.41%	The thermal efficiency of the (SS) still without using condenser was on, an average, 54.4%
Internal passive condenser					
Conventional still	Kumar and Kasturibai[18]	Madurai Chennai	14	23%	Increased cooling on the wall surface was observed enhancing the condensation process.
	Ahmed[19]	Baghdad, Iraq,	5.9	10%	The daily efficiency of the still with internal condenser never exceeds 60%.

6. MATERIALS TO BE USED

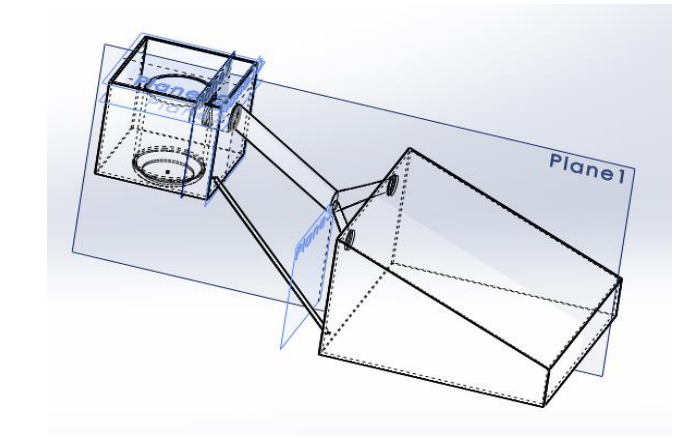
- Absorber plate/ Glass cover
- Thermocouples
- Condensers
- Measuring jar
- Temperature Indicators
- And last but not least the most important, PU foam material to prepare still

Polymeric foams can be found virtually everywhere due to their advantageous properties compared with counterparts' materials. Possibly the most important class of polymeric foams are polyurethane foams (PUFs), as their low density and thermal conductivity combined with their interesting mechanical properties make them excellent thermal and sound insulators, as well as structural and comfort materials.

Table 1: Advantages of PU Foam material

...vs. Rubber	...vs. Metal	...vs. Plastic
High abrasion resistance	Lightweight	High impact resistance
High cut & tear resistance	Noise reduction	Elastic memory
Superior load bearing	Abrasion resistance	Abrasion resistance
Thick section moldings	Less expensive fabrication	Noise reduction
Color ability	Corrosion resistance	Variable coefficient of friction
Oil resistance	Resilience	Resilience
Ozone resistance	Impact resistance	Thick section moldings
Radiation resistance	Flexibility	Lower cost tooling
Broader hardness range	Easily moldable	Low-temperature resistance
Cast able nature	Non-conductive	Cold flow resistance
Low-pressure tooling	Non-sparking	Radiation resistance

7. DESIGN AND SPECIFICATION



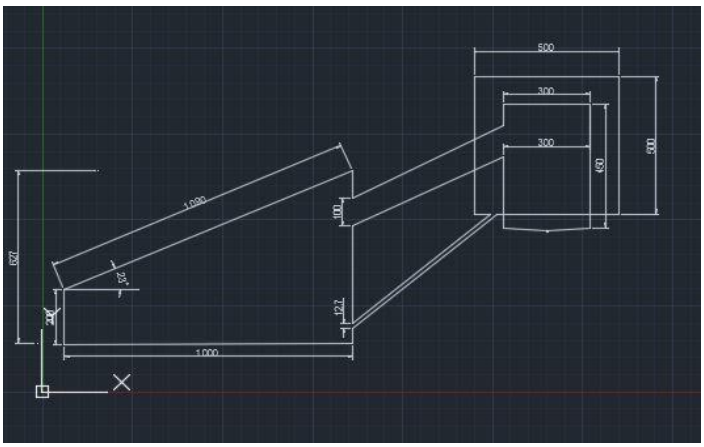


Fig. 8: Design in Solid work

Fig. 9: Left hand side view of fabricated model

Fig. 10: Right hand side view of fabricated model

Table 2: Materials selected and their specifications

Sr. No.	Part name	Material	Specification	Qty
1	FRP Tray	Fiber reinforced plastic	Size = 1.3 m x 1m x 0.015m	-
2	Absorber plate	Included in tray	Size = 1.3 m x 1m x 0.015m	-
3	Glass	-	Thickness = 0.004 m	1
4	Sealant	Silicon	-50º C to 150º C	1
5	Condenser	Aluminum and Copper plate	Size = 0.3m x 0.3m x 0.3m	1
6	Thermocouple		K type	6
7	Temperature Indicator	-	8 channels	1
8	Storage tank	Plastic	40 liters	1
9	Measuring jar	Plastic	Transparent plastic	1
10	Piping system	PVC	All connection and sealing and valve	-

8. SETUP, PROCEDURE AND RESULTS

Single basin single slope type solar still was fabricated and tested under field and climate conditions. And tested in the field of Mechanical Engineering department, Gandhinagar Institute of Technology, Moti-Bhoyan, Gandhinagar, India (Latitude: 23° 09` 52``N, Longitude: 72° 26` 27 ``E).

Now it's time that how it will work (procedure)?

- Here salted water will be sent to still. Then by solar energy, inside water will start evaporating.
- Some of that steam goes in upward direction and start condensing by the glass and some are transferred to the condenser.
- Here steam enters and stored.
- Outside the cylinder tank, water is placed.
- By this inside steam and outside water, there will be transfer of heat by which the inside steam will start condensing.
- At night time the condensation will be fast because of the outside temperature.
- For more heat transfer from cylinder to tank or say variation in temperature th outside tank is made up of aluminum and inside cylinder is made up of copper plate.

- These processes are done at different water depth (10, 15, 20, 25 &30mm).
- These will be starting from 9:00 am in morning till 3:00 pm.

Here are the calculated experimental readings are done with and without the condenser:

WD	10MM		15MM		20MM		25MM		30MM	
Time	Without Condenser	With Condenser	Without Condenser	With Condenser	Without Condenser	With Condenser	Without Condenser	With Condenser	Without Condenser	With Condenser
9:00 AM	0	0	0	0	0	0	0	0	0	0
9:30 AM	17.5	40	40	47.5	22.5	60	30	42.5	12.5	17.5
10:00 AM	65	67.5	75	90	80	105	65	70	60	75
10:30 AM	105	105	115	150	140	145	105	102.5	145	160
11:00 AM	130	160	150	250	175	265	180	132.5	215	235
11:30 AM	170	220	225	350	200	340	270	185	305	335
12:00 AM	245	305	280	460	255	440	370	245	400	420
12:30 PM	400	360	440	540	395	550	460	335	485	530
13:00 PM	510	525	525	595	505	665	555	475	570	645
13:30 PM	640	685	700	705	660	770	660	605	670	715
14:00 PM	760	845	800	920	800	850	760	855	765	770
14:30 PM	885	1040	875	1110	915	990	860	980	840	845
15:00 PM	1045	1250	985	1300	1105	1280	975	1170	930	945
09:00 AM Next Day	0	165	0	155	0	170	0	160	0	160

8.1 Experimental results at different water depth:

Productivity at **WD 10mm** for 24hrs. Here the total yield of still with condenser was 2.46L and still without condenser was 2.25L.

Condenser	Total yield (in ml)	Efficiency increased
Without	2195	10.9 %
With	2465	

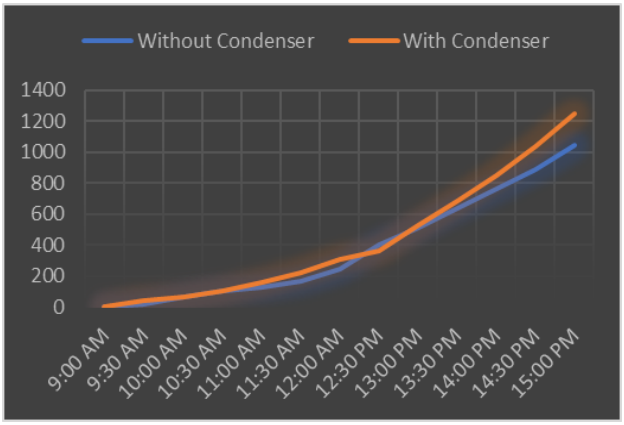


Fig. 11: Time vs Yield comparison for WD 10mm

Productivity at **WD 15mm** for 24hrs. Here the total yield of still with condenser was 2.5L and still without condenser was 1.95L.

Condenser	Total yield (in ml)	Efficiency increased
Without	1955	16.02 %
With	2328	

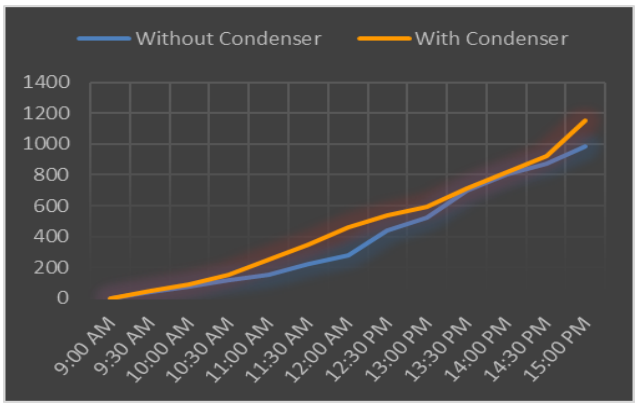


Fig. 12: Time vs Yield comparison for WD 15mm

Productivity at **WD 20mm** for 24hrs. Here the total yield of still with condenser was 2.39L and still without condenser was 2.04L.

Condenser	Total yield (in ml)	Efficiency increased
Without	2040	11.3 %
With	2300	

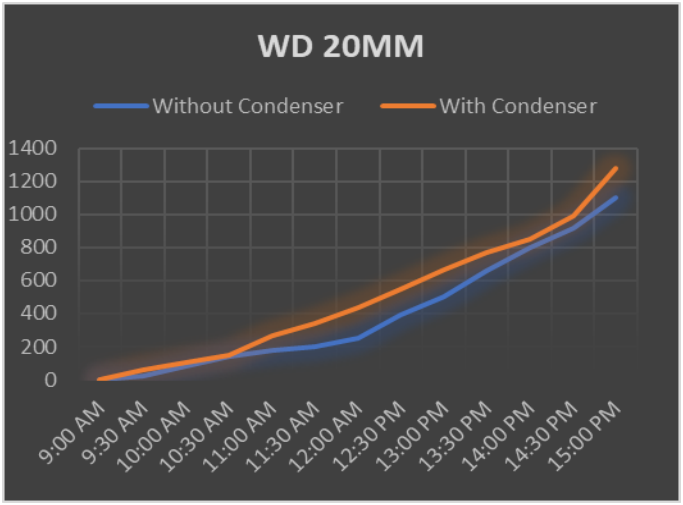


Fig. 13: Time vs Yield comparison for WD 20mm

Productivity at WD **25mm** for 24hrs. Here the total yield of still with condenser was 2.56L and still without condenser was 1.97L.

Condenser	Total yield (in ml)	Efficiency increased
Without	1975	12.8 %
With	2265	

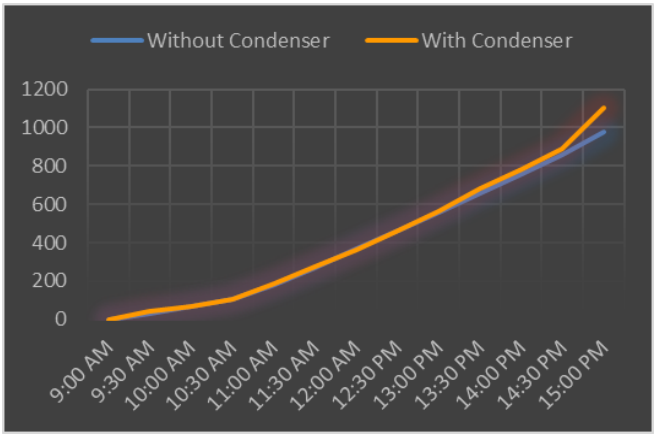


Fig. 14: Time vs Yield comparison for WD 25mm

Productivity at **WD 30mm** for 24hrs. Here the total yield of still with condenser was 2.25L and still without condenser was 1.98L.

Condenser	Total yield (in ml)	Efficiency increased
Without	1980	12.2 %
With	2255	

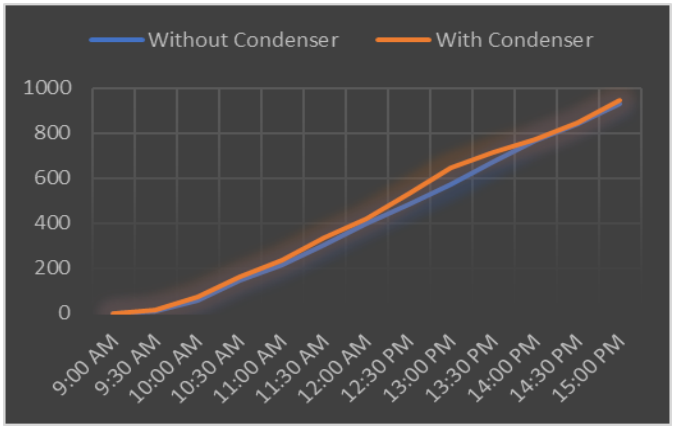


Fig. 15: Time vs Yield comparison for WD 30mm

9. TOTAL CAPITAL COST

PU Foam material	Rs.550/kg
Glass (Thickness 4mm)	Rs.190/m^2
Thermocouple wires (k-type)	Rs.35/m
Condenser (Copper with Stainless steel)	Rs.3000
Temperature indicator	Rs.850
Fiber-reinforced plastic	Rs.180/m^2
Sealant	Rs.25/m^2
Total	Around 12-13000 INR

10. PAYBACK PERIOD

As we know that the average life of solar still made with PU foam is 15-20 years. And fabricated condenser is one-time investment. Here in mine design we get around 2.5L daily. For 1-liter water market price is 20 INR. Our output is 2.5-liter that is 50 INR. By these we can say that we are saving Rs.30 daily. So, in 1-year we are saving Rs.10,950. So, in around 400 days we can get all our investment and after 15 year we will save around 1.5-2 lakh. Here the maintenance cost is 0. Because in these we only have to wash the glass daily.

11. CONCLUSION

- Compared to conventional solar still this advanced solar still made up of PU foam material with Additional condenser is more enhanced performance.
- Solar still with additional condenser is economically also affordable with respect to other high costly solar still.
- PU foam material is better insulating material compared to thermo coal, plastic, silver paper insulation and heavy wooden insulation.
- Additional condenser increases about 200ml daily comparing solar still without condenser made up of PU foam.
- Compared to other heavy material solar still like MS material, Galvanized Iron material this structure of PU solar still is way lighter in weight.
- Compared to conventional solar still this solar still made up of PU foam with additional condenser is about 17 % more efficient. (Conventional solar still efficiency is about 23% taken as reference from literatures)

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