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Comprehensive Review of Solar Crematorium

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Abstract: In Hindu community, Cremation is an important ritual practice from the ancient time. According to Hindu religion the cremation of dead body is permitted in day-time only. Fortunately India is blessed with ample amount of solar radiation. The variation in the radiation is 4 to 6 $kWhm^{-2}day^{-1}$ with about 1500–2000 sunshine hours per year (depending upon location). Due to availability of solar power in day time only, there is much more scope of solar crematorium in cremation ritual practice in India. Mostly wood is used in the cremation process. Wood required for the cremation of a dead body in a large quantity, because there is required large quantity of heat at the time of cremation process. Between 500 and 600 kg of wood are used to cremate a dead body. Many trees are cut - down to meet this requirement. By combustion of woods smoke is produced, this contains carbon dioxide, water vapor and other chemical as well as aerosol particulates. As a result wood firing may considerably contribute to air pollution and global warming. The human health problems like heart diseases and asthma can be result of particulate air pollution. As solar energy is a clean source of energy and it is inexhaustible and available free of cost everywhere. Therefore, solar crematorium prevents from problems of global dimming and global warming by reducing deforestation and indoor air pollution. In this paper, concept of solar crematorium and its feasibility in the India has been proposed.

Keywords: Crematorium, Concentration Ratio, Scheffler reflector, Solar, Tracking, Religion, Antim Samakara etc.

I. Introduction

The energy demand is exponentially increasing due to exponential rise in the world's population and resulting growth of industrial activities. Since fulfilling this energy requirement by using fossil fuels is not possible, so sources of energy which are cleaner, ecofriendly and renewable are required. Conversion of Solar energy to thermal energy is the most simple and efficient process. A number of applications such as cooking, drying, air-conditioning, desalination, and water heating etc. are done by using solar thermal energy. A crematorium too requires very large amount of heat energy which can be harnessed directly by solar concentrator. On the other hand, we can never suggest using of solar photo-voltaic panels to obtain such a large amount of heat indirectly for cremating a corpse. As firstly, PV panels convert only 20% (lighting effect) of solar energy into electricity, and then this electricity is converted into heat by passing through very high amount of resistance. This conversion of electricity into the heat is too associated with several losses. So employing solar PV panels will not be feasible for cremating a corpse. Although these PV panels can be used to get electricity for running the accessories like tubes, fans in office/cabins and necessary motors installed in tracking system.

II. Literature Review

After studying a lot of different popular journals not much extensive and dedicated work is seen on solar crematorium. In this paper few works has been reported and reviewed for solar furnaces and solar Crematorium. At Odeillo in the Pyrenees Mountains in the Basque region of the French/Spanish border largest solar furnace is located. Since 1970, it has been operational. This is the same area in which the world's first solar furnace was built; this solar furnace was put in place at Mont-Louis in 1949 by Professor Felix Trombe. Odeillo and Mont-Louis are within 15km of each other. The furnace makes use of an array of 10000 mirrors to reflect sunlight into a gigantic concave hemisphere which then focuses the energy onto an area roughly the size of a cooking pot. The flat mirrors track the sun in unison and redirect the solar thermal energy towards the crucible which is being used for melting steel.

World's first solar crematorium is being developed in our country at Goraj village (30 km East of Baroda) in Gujarat state by Muni Seva Ashram with the help of Ronnie Sabawalla of Rashron Energy and Auto limited. In 1998 they started with a specially designed Scheffler reflector with $50m^2$ mirror surfaces. But its initial concentration-factor of about C = 100 turned out to be by no means enough to allow proper cremation.

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III. Cremation Process

Cremation is the process of burning a dead body at very high temperatures and a crematorium is a furnace that is able to generate temperatures of 760–1150°C to ensure disintegration of the corpse. In a Cremation process a dead body burns at very high temperatures until there are only brittle, calcified bones left, which are then pulverized into "ashes." These ashes can be kept in an urn, buried, scattered or even incorporated into objects as part of the last rites of death. The heat raises the temperature of the cremator. During the cremation process, the greater portion of the body (especially the organs and other soft tissues) which is composed of 75 percent water is vaporized and oxidized by the intense heat; gases released are discharged through the exhaust system. As the soft tissues begin to tighten burn and vaporize from the heat, the skin becomes waxy, discolors, blisters and splits. The muscle begins to char, flexing and extending limbs as it tightens. The bones, which are the last to go, become calcified as they are exposed to the heat and begin to flake or crumble. The time required for cremation varies from body to body, and, in modern furnaces, the process may be as fast as one hour per 45 kg of body weight. An average human body takes from two to three hours to burn completely and will produce an average of 1.4 to 4.1 kg of ash.

IV. Concept of a Solar Crematorium

The basic concept of solar crematorium is to ignite the dead body locally anywhere and anyhow with the help of a huge concentrating reflector having very high CR and to maintain the combustion of dead body by supplying the fresh atmospheric air with the help of blower. Once combustion of dead body starts within the cremation chamber, it also releases heat which automatically in combination with solar energy obtained from concentrating reflector maintains continuous burning of dead body until complete dead body gets converted into ash. Based on above mentioned concept, system of solar crematorium can be divided into following four components. Scheffler Reflector, Tracking System, Cremation Chamber and Backup system for non-sunny hours.

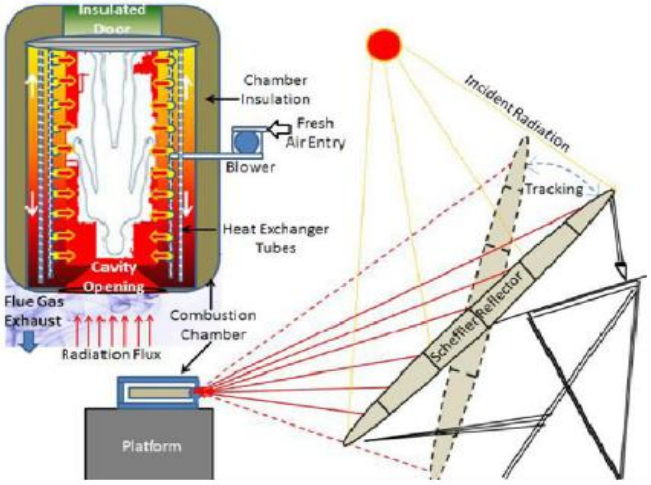

Fig. 1: Block Diagram of Solar Crematorium

V. Scheffler Reflector

Parabolic Scheffler Reflectors can provide (you with) high temperature heat for all types of cooking, steam generation and many other applications. Their speciality is a flexible surface curvature and a non-moving focal area. Designing of a Scheffler Reflector and material of Scheffler Reflector have an important role in manufacturing of solar crematorium.

Tracking System

Since combustion chamber of crematorium is stationary and not movable but solar concentrators require tracking the Sun, as a result a movable focus is obtained. This is major problem in designing a solar concentrator for the crematorium. This problem was shorted out by Wolfgang Scheffler who invented a new concentrator (Scheffler reflector) tracking the Sun without changing it focus. In this paper, Scheffler reflector is redesigned to determine required size (Aperture Area) of the concentrator to obtain sufficient heat energy for cremating a corpse. Since the speciality of Scheffler reflector is flexible surface curvature and a nonmoving focal area.

VI. Backup System for Non-Sunny Hours

The actual harnessing of the solar energy can happen unless you're in a very hot sunny climate days but the need for energy is often greater in rainy, cloudy or, colder climates. So it can be unreliable. On the other hand, as per Hindu ritual practice, there is an established sentimental fact of cremating the corpse completely at one goes. And there must not be left any un-burnt portion of the body. Otherwise the soul of that person will remain unsatisfied, and it will be converted into the devil or imp which will victimize or terrorize the concerned relatives for his/her satisfaction. Therefore there must be an arrangement of suitable and sufficient backup system to mitigate these situations. So the cremation chamber must be designed in such a way that other alternate fuels like Biogas/Biomass/LPG/CNG can be fired if required.

VII. Development of Solar Crematorium

As the main challenge is to have a very small focal area, the whole frame has to be adjustable for exact positioning during the different seasons of the year. Electrical DC motors with gear boxes have to be installed and tested for an improved seasonal adjustment (+/-23.5 Degree). All the parts have to become very precise in order to have minimum mistakes in the focal area.

A place near a river is chosen as place for the new crematorium. The correct geographic North-South alignment is marked and so we are able to prepare the layout for the foundations on this piece of land belonging to village. The focus should be around 240 mm diameter but in morning and evening positions the frame is twisted which results in a bigger focus. The stand, the rotating support and the wings of the frame and small parts got sandblasted and primer was sprayed twice as anti-corrosion measure. Finally painting is applied at the new place of erection (income generation in rural areas). The frame parts are mounted to the rotating support on the ground. As soon as the concrete is hardened, the stand and the back-crane of the stand (for lifting the stand up and down) got installed with the help of a mobile crane. The exact alignment of the stand (bearings parallel to polar axis) was adjusted. During the different phases of the project practical education is integrated in order to make the operator able to use the system properly. After the mirrors are all mounted on the crossbars of the frame (see Fig. : 3) we needed again a crane to lift the finished frame with the rotating support into the bearings of the stand. Before lifting up the stand with its back crane, all electrical installations have to be tested. The seasonal adjustments are now regulated so that the frame has the correct paraboloid for the day. On the right height and in the correct instance we prepare a provisorily stage for measuring the focal area because the platform for the chamber is not ready then. As mentioned in the Summary, the focal area has a diameter of 240 mm. In order to correct the twisting in the morning and the evening position, 8 instead of 4 wire ropes are connected to the 4 edges of the frame with an elastic telescope column in the middle of the frame.

As soon as the platform is ready, the chamber can be tested. If the temperature inside the chamber is reaching at 800 degree Celsius, then small animals like e.g. dead dogs can be cremated in order to see, if the system can start to benefit human families soon.

VIII. Feasibility Study in India

There is always the problem of decomposition of corpse of a dead body and it gradually increased during the last few decades. For a complete cremation of a dead body, we have to be cut three trees.
Some facts and recent survey taken by N.G.T. (National green tribunal) are described below.

- More than five carore trees were cut to perform cremation of dead bodies in India.
- 5 lakh ton ash and 80 lakh ton carbon gases are generated or exhausted in this process.

In Rajasthan 4.20 lakhs tree are cut and 2200 ton wood are fired for this process.
If these tree are alive then

- Trees which are grooving in one acaras, absorbs carbon-di-oxide which produced by running a vehicle 41843 Km in one year.
- Again in one year trees which are growing in one acaras gives oxygen to 18 peoples.
- A single tree supply 118 Kg oxygen per year.

Contrary to popular perception, electric crematoriums also lead to more pollution than the traditional

Hindu style of cremation, involving burning the body on a pyre. The UNDP report informs that electric cremation is nearly seven times more intensive in terms of emission of green house gases as compared to the traditional Hindu style. Solar crematorium also appears to be a viable option, suggests V Ramesh of Karnataka Renewable Energy Development Limited. India is the front runner in this regard, with Baroda, a city in Gujarat equipped with the world's first solar crematorium. It was developed by Wolfgang Scheffler, a Swiss national and Ronnie Sabbawala of Rashron Energy and Auto limited. The body is burned exclusively using solar energy. The second solar crematorium is to be erected in Patna, Bihar, by 2015.

But this method also has certain disadvantages. Solar crematoriums are impossible in many parts of India during the winters and monsoons. Also, they can be used only during the day as long as the sun shines. Built with an investment of Rs. 3 Crores, the solar crematorium does not need electricity or gas. It makes it an energy and cost efficient.

Applications in Remote villages where wood is scarce and no electricity; Solar Crematoriums have high potential to be used in Gram-Panchayats& municipal corporations.

In north India, solar crematorium can be constructed at Yamuna Ghat near Nigam-Bodh Ghat in Delhi, at Bass-Ghat near Ganga in Patna and in Banaras as well as Haridwar and other places.

8.1 Factors Influencing Crematorium

Key factors affecting demand for burial and cremation facilities are:

Population: Running cost of crematorium will be relatively where there is large population. Here in India, there is no problem of population as India is the second most populous country in the world. And population too is increasing at very high rate.

Age Structure: The general mortality rate conceals great variation according to age. Hence there is very high importance of examining the age structure of the given area (locality). Whilst the population is projected to grow, particularly in the pensionable age groups which have the highest death rates, the reducing death rates will result in relatively small rise in the number of deaths.

Mortality Rates: Mortality rates have fallen considerably over the last hundred years and will continue to fall because of improved medical facilities, resulting in falling numbers of deaths.

Religion and Ethnicity: Religious belief can play a significant role in people's choice between burial of cremation. Demand for burial and cremation facilities is thus influenced by the religious beliefs of the residents of an area. Ethnic origin, like religious belief, can influence people's choice of burial or cremation. For example Cremation is permitted in Buddhism , Roman Catholic , Jews-Liberal, Roman Catholic, Church of Scotland, Church of England, Church in Wales, Church of Ireland, Presbyterians, Methodists where as it is necessary in Hindu and Sikh.

Availability of Cremation Facilities: People mind set are changing from burial to cremation. The same may be improved depending upon the available facility of cremation.

Location: A new crematorium has an opportunity to compete with existing crematoria on the basis not only of location, but also the quality of the facilities and the service it provides. Since as per religious ritual some burnt part of the dead body is allowed to flow in the water, therefore ideally, the new site should be located near the river, canal, pond, lake or sea. The main customers making the decision to use a particular crematorium are bereaved (whose relative is dead) people and the funeral directors. The influence of religious ministers is insignificant in my view, as the funeral location is usually chosen prior to their appointment to lead the service.

8.2 Case Study of a Solar Crematorium in Gujarat

A spiritual hermitage in Gujarat state, in the northwest of India, has become the home of the world's first solar-powered crematorium. The historic village of Goraj near the town of Waghodia, in Vadodara district of Gujarat state is located in our country where an existing, but non-operational, the first solar crematorium is installed near Ashram at the "panchayat land" under the authority of ecologically conscious *Muni Seva Ashram*.

Introduction to the Problems: This installed crematorium is non-operational. There may be faulty design of solar crematorium because of which required sufficient temperature is probably not achieved to completely burn corpses or, aperture of collector may be small to collect sufficient amount of solar heat energy for complete burning of dead body. Maybe people just don't come there because of any proper connectivity of road transport from nearby big cities like Vadodra and Ahemdabad or, maybe cremating cost per dead body is too high. Probably that place is geographically not suitable according to solar map or, there is no proper solar energy policy.

Geographical Suitability of the Place: Today world is moving towards the sustainable energy sources which are renewable in nature and biodegradable because in this modern era, a lot of problems of pollution and global warming have been encountered in almost all developed countries. Gujarat is most developed state of our country so there is also problem of pollution and global warming. Since Gujarat state is situated in such a solar belt where average annual solar irradiance is 5.5 to 6.0 kwh/m^2/day. This quantity of solar irradiance is more than sufficient for solar powered equipments. The solar crematorium installed at *Muni Seva Ashram* is on the bank of Dev River which is basically a tributary of Dhadhar River. So this crematorium is suitable for performing religious ritual of Antim-Sanskara.

Government Policy: Since Gujarat is most developed state of our country so there is also problem of pollution and global warming. This problem of pollution and global warming has been noticed by the state government of Gujarat. Since Gujarat state is situated in such a solar belt where average annual solar irradiance is much more

than sufficient for solar powered equipments therefore the GEDA have promoted installation of lot of solar powered projects in the state. Currently Gujarat is the state of most solar powered installations in the India.

Design and Development: At the ecologically conscious Muni Seva Ashram, a 50 m^2Scheffler dish will heat the oven which burns the dead bodies. The project was developed in cooperation with Wolfgang Scheffler (who designed the Scheffler mirrors from Germany) and Ronnie Sabawala (one of the owners of Vadodara-based Himalaya Engineering).

Opening Diameter of cremation chamber = d = 24cm
Receiver Area = 0.045238934 m^2
CR = A_a / A_r = **1105. 24266**

As per the above calculations of CR, the target temperature is above 1000°C which can burn the human body very easily within approximately 40 to 60 min during a bright sunny day. The crematorium has been built as a chamber with special scheffler reflector developed specifically for this concept. The special reflectors are designed to heat a 2m long crematorium chamber to above 800°C. The facility was made operational on an experimental basis only.

As per our observation, size of scheffler collector is 50m^2 which doesn't suit as per our design of scheffler reflector described in preceding subsection. Since size (aperture area) of solar collector must be equal to 197m^2 otherwise, collector won't be able to collect sufficient amount of solar heat energy for complete burning of dead body within 2-3Hrs.

The Chamber is designed in such a way that the solar radiation gets reflected from its inner wall and concentrates on the plate where human body is kept. Thus, making full use of the solar energy and increasing the overall efficiency. Efficiency of cremation chamber insulation is about 80%.

Test with small pieces of meat was proved to be encouraging. However, Ashram will not be able to put the solar cremation chamber to use until a biogas/biomass/CNG/PNG backup burner is installed. People across the region made clear that they will welcome the chamber if a backup burner takes over operation during cloudy hours. Otherwise, a body may only be half burnt which will hurt the sentiments of concerned relatives.

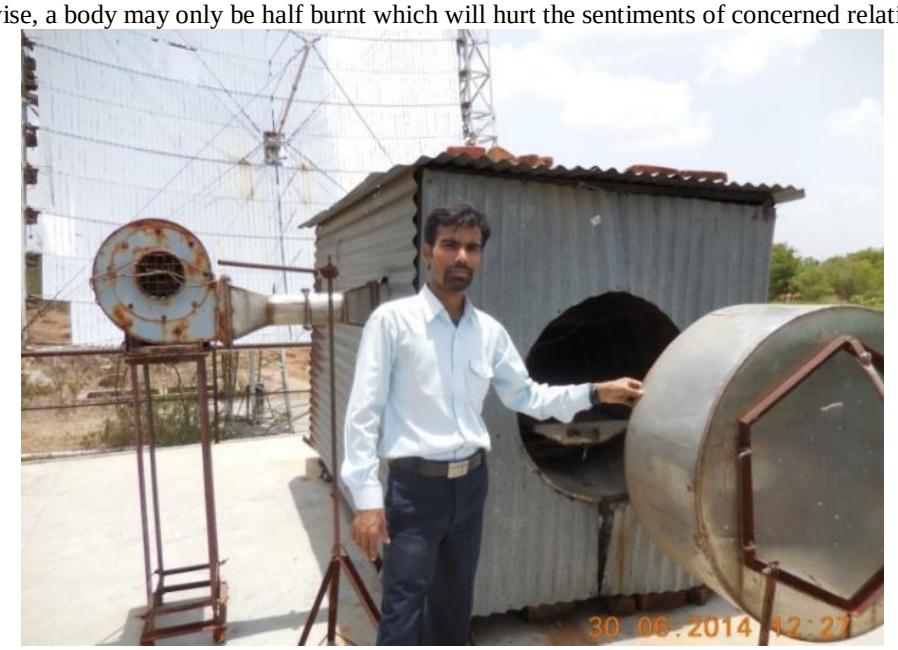

Fig. Solar Crematorium

IX. Economic Analysis

Although solar radiant energy is free, the equipment required to convert it into useful form (thermal or electrical) is not free. Therefore a cost must be assigned to solar thermal/electrical energy that reflects the conversion equipment cost pro-rated by no. of kwh delivered by solar equipment. If solar cost is less than that of other energy sources that can perform the same task, there is an economic incentive to solar energy. The purpose of economic analysis is to maximize savings resulting from use of solar energy.

It is rarely cost effective to provide all energy requirements of thermal or mechanical system by means of solar energy. If this done, solar system would be capable to provide 100% of energy demand for the worst set of operating conditions ever expected: inclement weather, maximum demand and no sunshine. A solar system capable of providing peak demand for lengthy period would be oversized for all sever conditions; it would thus

be greatly oversized. An oversized system delivers more energy than the requirement. A solar system with such a low load factor is uneconomical and impractical. Therefore best use of solar equipment is in conjunction with conventional fuels which are used auxiliary source for special high demand situations.

Non solar systems usually have relatively small initial costs and high operating costs reflecting lower lifetime. Solar systems however are relatively expensive initially but have negligible running cost during lifetime. Therefore if selection of equipment is made on basis of initial cost only, solar system would rarely be selected.

Factors Affecting cost of new Crematorium

Size, Type of construction and materials, Number of cremators and abatement equipment, Cost of land, Cost of access and internal roads and Cost of installing new utilities

Ideally, the new site should be 7 to 8 acres (2.83 to 3.24 hectare) and located near river, canal, pond, lake or sea as per religious ritual some burnt part of the dead body is allowed to flow in the water. The crematorium should have good connectivity to main roads. Land values vary tremendously, particularly where landowners hope to sell their land at some point in the future for housing development.

Installation of mains gas, electricity and water supplies can form a significant part of the budget, depending upon proximity to suitable supplies. For example, where suitable mains are available adjacent to the site, gas installation will costs in the region of Rs. 60000 and electricity Rs. 68000. However, costs can rise exponentially with distance: for example, an onsite electrical transformer can cost Rs. 216000. In broad terms, the construction costs of a crematorium would be grouped under the following headings with appropriate guide costs:

Installation Cost	
Items	Estimate in ☐
Professional fees	800000
Site survey, ground works, roads and car parking	3200000
Building structure	6000000
Building furniture and fittings	800000
Cremation equipment (single cremator)	4400000
Net total estimate	**15200000**

Expenditure Summary

In simple terms, the operational costs per cremation of the crematorium undertaking 1000 cremations per year would be between the following figures:

Item	**Cost in ☐**
Personnel	1140
Cremator Operation	1350
Cremator Maintenance	120
Total	**2610**

Additional costs would include capital charges, central support charges, business rates, buildings and grounds maintenance

Crematorium Income

Income is primarily received as charges for cremations and for memorials. There is variation in the type of provision and the charges made for these services. A new crematorium in India completing 1000 cremations per year could expect an annual income of Rs. 2610000 from a charge of Rs. 2610 per cremation. This fee would place India in a comparable yet competitive situation with other crematoria in the world.

X. Conclusion

- While cremation is an established Hindu ritual practiced since ancient times and the Hindu religion permits the cremation of dead body in day-time only, there is much scope of solar crematorium in this ritual; as solar power is also available in day-time only.
- Between 500 and 600 kg of wood are used to cremate a dead body. So we are significantly contributing in global warming and atmospheric air pollution much more and forest are depleting day by day. The most sustainable energy source is sunlight that too is totally inexhaustible and available free of cost. It mitigates all the above problems.

- India is situated in high solar insolation belt with about 300 clear sunny days in a year and the daily average solar energy incident over India varies from 4to 7 kWh/m^2. All these are an ideal combination for using solar power in India, So solar crematorium will be a viable option.
- We should never suggest of using solar photo-voltaic panels to obtain such a large amount of heat for cremation, as the sunlight has very little part, only 20% of its energy as lighting effect and large portion of 80% as thermal effect. So energy of solar radiation can be utilized more in solar thermal power generation than in solar photo-voltaic (which utilizes only lighting effect of sunlight) power.
- There must be an arrangement of suitable and sufficient backup system for non-sunny hours to meet the Hindu ritual sentiment of burning the corpse at one goes.
- Ideally the solar crematorium should be built near river, pond or lake and there must be facility to collect ashes for emerging in open flow of water.
- Building solar crematorium is very expensive, since solar reflector costs a great amount of money. But in solar cremation, since we don't have to pay for fuels, as in conventional cremation large amount of wooden pile or electricity are required. So money can saved in the long run.
- Central and state governments have several policies which promote using solar power by providing various subsidies, incentives and interest free loans.
- Cost of cremating a corpse solar crematorium is very genuine of Rs. 2610 on the basis of 1000 cremations per year, though it doesn't include land cost, capital charges, and central support charges.
- 800°C is at the low end of incineration temperatures, so this method would be more time consuming and adoption of this method may be difficult for families and operators. So to achieve high temperature, there is need of further research in the field of advance technologies for designing reflector and combustion chamber.

In conclusion, we will definitely be able to cremate a corpse through solar crematorium built with a well-designed Scheffler reflector and an efficient combustion chamber. The project may go through many stops and goes, but in the last we will be able to make working prototype Solar Crematorium.

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