Industrial Process Heat Applications of Solar Energy

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ABSTRACT: *Concentrating solar collectors of low concentration ratio can supply hot water or process heat at intermediate temperatures, i.e. 80 to 180 ^{0}C, where flat plate collectors are not effective, and for which there are a number of industrial, domestic and rural applications. This paper studies the potential applications of this technology and presents case studies to prove its feasibility.*

Keywords: *Concentrating solar collector; cooling; desalination; industrial process heat; water pumping*

I. INTRODUCTION

Large amounts of energy are spent for industrial heat generation in many countries. India uses 100 million tons of oil annually, of which 40 % is consumed in industries. 60 – 70 % of this use is in the form of thermal energy, out of which 70 % is used for applications below 250 ^{0}C. 30 % of this requirement can be met through solar concentrating collectors, leading to savings of about 4.5 million tons of furnace oil, LDO or diesel [1]. India has a large number of small, decentralized industrial units, where this technology can be used, leading at the same time to a reduction in oil imports. The development of solar thermal systems for industrial heat and for other applications like solar cooling is a thrust area of the Ministry of New and Renewable Energy, Government of India. This paper studies the potential application areas for concentrating solar collectors and presents a review of actual operating systems or research work proving potential application areas.

II. APPLICATIONS OF SOLAR ENERGY IN MEDIUM TEMPERATURE RANGE

There are several potential fields of application of solar thermal energy in the temperature range of 60°C to 180 °C, like heat production for industrial processes in the food, textile, wine and chemical industries, solar cooling and air conditioning, solar drying and seawater desalination, thermal detoxification of drinking water, and small power generation and water pumping through medium temperature Rankine cycle systems.
An overview of the potential of solar industrial process heat in the food industry is presented below [2]. The applications require heat in the temperature range 60 – 180 ^{0}C:

Industry	Process	Temp. Range, ^{0}C
Dairy	Pasteurisation	60 - 85
	Sterilisation	130 - 150
	Drying of milk powder	60 - 180
Food Preservation	Sterilisation of vegetables, fish, meat, baby food	Hot water at 130- 150 ^{0}C or steam
	Cooling by solar energy	Hot water or steam
Meat	Washing	Upto 90
	Sterilisation	Upto 100

Worldwide energy consumption for cooling and air-conditioning is rising rapidly and the market potential for solar thermal cooling is very large. Solar energy has the advantage that cooling is generally required when solar radiation is available. This is the main reason for sustained research into solar cooling devices for at least three decades. These studies include solar energy technologies operating with absorption, adsorption, and desiccant cycles to produce cooling and refrigeration using medium to high-temperature solar technologies (from 80 to 250 ^{0}C)
However, the market is still very much at an initial stage, with only around 500 solar cooling systems installed globally, and has been largely dominated by Europe so far [3].
Small scale water pumping systems are widely used in India for pumping drinking and irrigation water from wells, and for lifting drinking water to roof-based tanks in urban housing societies. This is accomplished by electrical or diesel-engine driven pumps, or in case of renewable energy systems, by solar photovoltaic or biomass gasifier- IC engine pumpsets. The area of solar thermal water pumping systems has been the subject of development work by researchers around the world [4], though such systems are not widely used in India. Stationary concentrators like the CPC give the option of operating a Rankine cycle system at temperatures above that permitted by flat-plate solar collectors.

III. CONCENTRATING SOLAR COLLECTORS

Solar concentrating collectors are used to increase the incident flux of sunlight on a receiver which has a smaller area than the aperture of the collector. Due to the smaller surface area of the receiver, it has a lower heat loss, and therefore reaches a higher temperature than non-concentrating collectors. They use reflective surfaces to reflect and concentrate sunlight onto a

small area, where it is absorbed and used as heat or, in the case of solar photovoltaic devices, it is converted into electricity. Refractive media like Fresnel lenses are also used for the concentration of solar thermal energy, and concentrators using Fresnel lenses in conjunction with photovoltaic cells are also under development.
Concentrating collectors can be used for high-temperature applications such as steam production for power generation, for industrial process heat and other applications.
One of the most well known concentrators is the parabolic trough collector or cylindrical parabolic concentrator (Fig. 1). It concentrates beam radiation of the sun onto a tubular receiver- absorber at the focus of the parabolic mirror. The tube carries the heat transfer fluid. This system therefore needs a clear sky as well as tracking of the movement of the sun during the daytime.

Fig. 1 Cylindrical parabolic concentrating solar collector

Compound parabolic concentrating solar collectors [5] (CPC) are non-imaging concentrators, which consist of two reflectors which are segments of two parabolas, which focus the sunlight entering its aperture onto a smaller, flat or round absorber surface, where it heats up the working fluid (Fig.2).

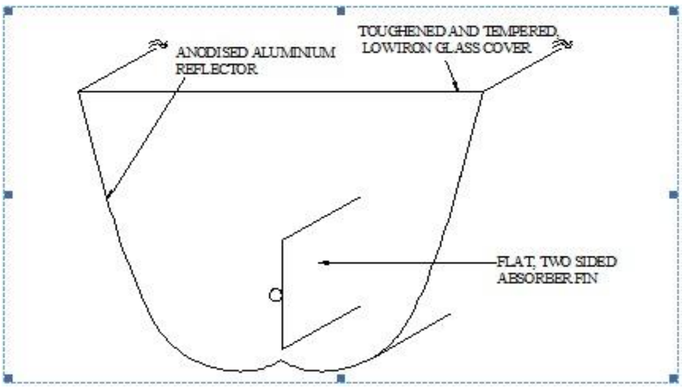

Fig. 2 CPC solar collector with vertical absorber

CPCs of low concentration ratio can supply hot water or process heat at intermediate temperatures, i.e. 80 to 180 ^{0}C, where flat plate collectors are not effective, and for which there are a number of applications. As they collect both beam and diffuse radiation, they can also be used under conditions of low insolation. They can be made at a relatively low cost as they are non-tracking devices when mounted east-west, and can be used with seasonal adjustment of the tilt angle.
Parabolic dish concentrators focus the beam radiation of the sun onto a point, and therefore require continuous, 2-axes tracking of the sun to keep its aperture plane perpendicular to the beam of the sun. They can be used with high concentration ratios to achieve temperatures of more than 400 ^{0}C at the focus.
Concentrating collectors are generally not used in domestic applications. An exception is the solar cooker based on a parabolic dish concentrator, used for community cooking.

IV. CASE STUDIES ON APPLICATION AND RESEARCH ON SOLAR CONCENTRATING COLLECTORS

Cases of research on and thermal applications of concentrating solar collectors are covered in the literature survey below.

4.1 Industrial process heat:

Solar concentrating collectors can be retrofitted to the existing boiler or heater system in the industry, substituting the use of furnace oil or electricity used for the heating application partially or fully.
One example of such an application is the 160 m^2 paraboloid concentrating dish based system installed at Mahanand Dairy, Latur by Clique Consultants Pvt. Ltd., Mumbai [6]. This system generates hot water at 180 ^{0}C and 18 bar pressure, to be used for milk pasteurization. It saves 70 – 90 litres of furnace oil on a clear sunny day.

Fig. 3: ARUN solar concentrator system, Clique Consultants

4.2 Desalination:

A study done in Spain [7] involves an experimental hybrid solar-gas fired seawater desalination plant based on a multi-effect distillation process (72 m^3/day distillate), with thermal input in the temperature range 60 – 70 ^{0}C. Part of its energy comes from a static solar field of stationary CPC collectors (500 m^2 surface area). Water is the heat transfer fluid for the collector field. The hot water is stored in storage tanks. The system can operate in one of three modes:

- Solar only mode: energy to the first distillation effect comes exclusively from the solar collector field
- Fossil only mode: the gas boiler operated double effect absorption heat pump supplies all the heat required by the distillation plant
- Hybrid mode: the energy comes from both the heat pump and the solar field

To optimize the plant operation, the authors have done a modelling study, validated by experimental data.

4.3 Cooling:

A study done for the hot climate of Nicosia, Cyprus [8], presents the optimisation of the various components of a lithium bromide-water absorption solar cooling system with a generator temperature of 75 ^{0}C, such as the type, slope and area of solar collector and storage tank size, for a house. The collector types considered by the authors are the flat plate, compound parabolic and evacuated tube collectors. The optimisation considers the amount of useful energy collected against the life cycle cost of the solar system, and is carried out using TRNSYS software. The solar system can be used during summer to provide part of the heat required by the absorption cooling unit and during winter to provide part of the heating load. The results indicate that due to the high cost of fuel a large part of the building load can be covered by solar energy. They found that the optimum system is one based on a CPC collector array.

4.4 Commercial CPC solar collectors:

Solargenix Energy [9], USA, offers their Winston Series CPC based solar collectors for use for hot water production, space heating and solar cooling applications requiring heat at upto 98 ^{0}C. It is a single glazed, non-evacuated collector with selectively coated tubular absorbers.

V. CONCLUSIONS

The literature survey presented above leads to the following conclusions:

i) There is good potential for replacement of petroleum derived oils and conventional electric power presently being used for industrial process heat applications, power generation and applications like cooling and water desalination, with solar energy by the use of concentrating solar collectors.

ii) A large number of these applications are likely to be at a small scale, for process heat in small and medium industries, for domestic cooling and drinking water production and for small scale agricultural water pumping.

iii) The studies described show that technically feasible solutions, which are economical under certain conditions, are available.

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