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PAPER PRESENTATION
ON

<u>SOLAR CHIMNEY</u>

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INDEX

SOLAR CHIMNEY

ABSTRACT

A solar chimney, often referred to as a thermal chimney is a way of improving the natural ventilation of buildings by using convection of air heated by passive solar energy. A solar chimney can also be used for electricity generation A simple description of a solar chimney is that of a vertical shaft utilizing solar energy to enhance the natural stack ventilation through a building. Here, we focus on the recent work on solar chimneys; their structure, formation, usage and their application.

1. INTRODUCTION

In its simplest form, the solar chimney [3] consists of a black-painted chimney. During the day solar energy heats the chimney and the air within it, creating an updraft of air in the chimney. The suction created at the chimney's base can be used to ventilate and cool the building below [4]. In most parts of the world it is easier to harness wind power, but on hot windless days a solar chimney can provide ventilation where otherwise there would be none.

There are however a number of solar chimney variations. The basic design elements of a solar chimney are:

- The solar collector area: This can be located in the top part of the chimney or can include the entire shaft. The orientation, type of glazing, insulation and thermal properties of this element are crucial for harnessing, retaining and utilizing solar gains
- The main ventilation shaft: The location, height, cross section and the thermal properties of this structure are also very important.
- The inlet and outlet air apertures: The sizes, location as well as aerodynamic aspects of these elements are also significant.

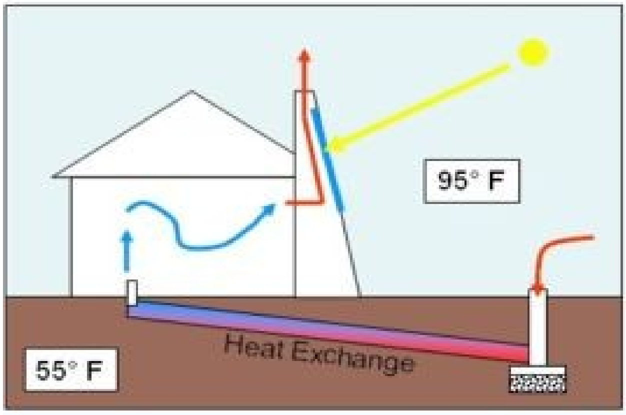
A principle has been proposed for solar power generation, using a large greenhouse at the base rather than relying solely on heating the chimney itself

2. SYSTEM DISCRIPTION

2.1 SUSTAINABLE ARCHITECTURE

Air conditioning and mechanical ventilation have been for decades the standard method of environmental control in many building types especially offices. Global warming, pollution and dwindling energy supplies have led to a new environmental approach in building design. Innovative technologies along with bioclimatic principles and traditional design strategies are often combined to create new and potentially successful design solutions. The solar chimney is one of these concepts currently explored by scientists as well as designers, mostly through research and experimentation.

A Solar chimney can serve many purposes. Direct gain warms air inside the chimney causing it to rise out the top and drawing air in from the bottom. This drawing of air can be used to ventilate a home or office, to draw air through a geothermal heat exchange, or to ventilate only a specific area such as a composting toilet.



This solar chimney draws air through a geothermal heat exchange to provide passive home cooling. [2]

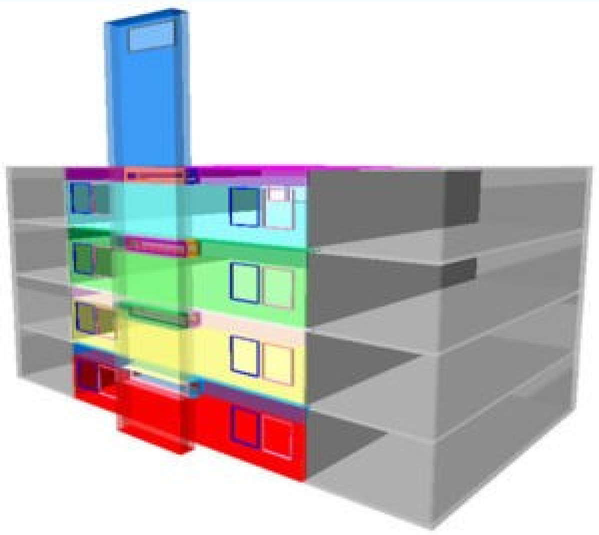
Natural ventilation can be created by providing vents in the upper level of a building to allow warm air to rise by convection and escape to the outside. At the same time cooler air can be drawn in through vents at the lower level. Trees may be planted on that side of the building to provide shade for cooler outside air.

This natural ventilation process can be augmented by a solar chimney. The chimney has to be higher than the roof level, and has to be constructed on the wall facing the direction of the sun. Absorption of heat from the sun can be increased by using a glazed surface on the side facing the sun. Heat absorbing material can be used on the opposing side. The size of the heat-absorbing surface is more important than the diameter of the chimney. A large surface area allows for more effective heat exchange with the air necessary for heating by solar radiation. Heating of the air within the chimney will enhance convection, and hence airflow through the chimney. Openings of the vents in the chimney should face away from the direction of the prevailing wind.

To further maximize the cooling effect, the incoming air may be led through underground ducts before it is allowed to enter the building. The solar chimney can be improved by integrating it with a trombe wall the added advantage of this design is that the system may be reversed during the cold season, providing solar heating instead.

A variation of the solar chimney concept is the solar attic. In a hot sunny climate the attic space is often blazingly hot in the summer. In a conventional building this presents a problem as it leads to the need for increased air conditioning. By integrating the attic space with a solar chimney, the hot air in the attic can be put to work. It can help the convection in the chimney, improving ventilation.

The use of a solar chimney may benefit natural ventilation and passive cooling strategies of buildings thus help reduce energy use, CO_2 emissions and pollution in general. Potential benefits regarding natural ventilation and use of solar chimneys are:



CAD (TAS) Solar Chimney model

- Improved ventilation rates on still, hot days
- Reduced reliance on wind and wind driven ventilation
- Improved control of air flow though a building
- Greater choice of air intake (i.e. leeward side of building)
- Improved air quality and reduced noise levels in urban areas

- Increased night time ventilation rates
- Allow ventilation of narrow, small spaces with minimal exposure to external elements

Potential benefits regarding passive cooling may include:

- Improved passive cooling during warm season (mostly on still, hot days)
- Improved night cooling rates
- Enhanced performance of thermal mass (cooling, cool storage)
- Improved thermal comfort (improved air flow control, reduced draughts)

2.2 HOW IT WORKS

Solar chimneys are constructed to actively promote ventilation of unwanted heated or stale air by drawing fresh cooler air from vents at lower levels.

The exchange and movement of air cools the building by driving heat to the outside. The process by which this movement of air occurs is called natural convection [1]. Natural convection is created by solar energy heating air within the chimney.

The heated air escapes out the top of the chimney and is replaced by air from the outside (through windows or vents elsewhere in the building).In winter the chimney vents to the outside can be closed and heated air in the chimney forced (using fans, or other air handling system) into the building for heating purposes.

3. CONVERSION RATE OF SOLAR ENERGY TO ELECTRICAL ENERGY

The solar chimney does not convert all the incoming solar energy into electrical energy. Many designs in the (high temperature) solar thermal group of collectors have higher conversion rates. The low conversion rate of the Solar Tower is balanced to some extent by the low investment cost per square meter of solar collection [5].

According to model calculations, a simple updraft power plant with an output of 200 MW would need a collector 7 kilometers in diameter (total area of about 38 km²) and a 1000-metre-high chimney. One 200MW power station will provide enough electricity for around 200,000 typical households and will abate over 900,000 tons of greenhouse producing gases from entering the environment annually. The 38 km² collecting area is expected to extract about 0.5 per cent, or 5 W/m² of 1 kW/m², of the solar power that falls upon it. Note that in comparison, concentrating thermal (CSP) or photovoltaic (CPV) [2] solar power plants have an efficiency ranging from 20-40%. Because no data is available to test these models on a large-scale solar tower there remains uncertainty about the reliability of these calculations.

The performance of a solar tower may be degraded by factors such as atmospheric winds, by drag induced by bracings used for supporting the chimney, and by reflection off the top of the greenhouse canopy.

Location is also a factor. A Solar updraft power plant [3] located at high latitudes such as in Canada, only if sloped towards the south, would produce up to 85 per cent of the output of a similar plant located closer to the equator

4. NEED FOR IMPROVEMENT

The overall conversion efficiency from solar energy [7] to electricity is 2-3%. Where does the other 97% go?

1. There is a temperature drop with altitude of about 10° C for a 1000-meter chimney. Large quantities of warm air have to be lifted from the ground to

chimney top. This is gravitational energy lost.
2. The air that leaves the chimney is above ambient temperature at that altitude. This is thermal energy lost.
3. Ambient air that is drawn into the collector and is warmed expands with little increase in pressure. The majority of solar input is lost in the simple expansion of air before it reaches the turbine. None of this is surrendered to the turbine.

5. DEVLOPMENT

Would a regenerator improve efficiency? The modified solar chimney where the paramount consideration is the rigorous elimination of all energy losses. The solar collector is sealed and double-glazed [8] with low emissivity glass. The entire floor area has a solar absorber. The chimney is well insulated and incorporates a heat exchanger along most of its length.

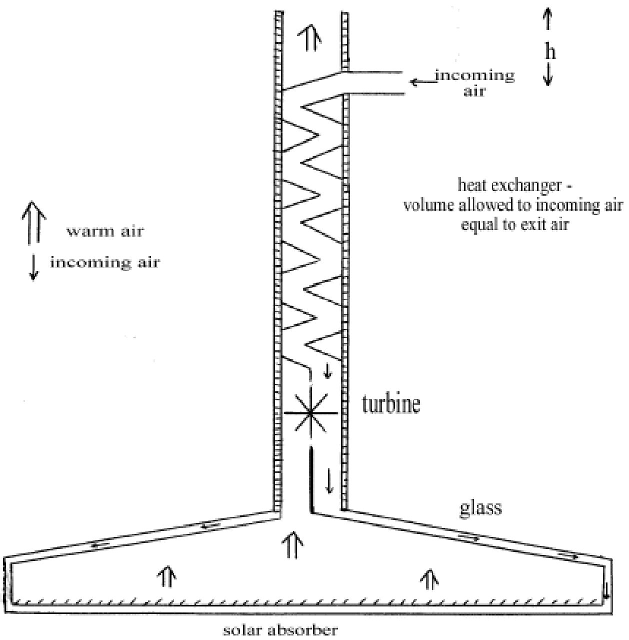


Fig 3: Structural view of a solar chimney

Warm air rises from the solar collector and drives the turbine. Its residual energy is then transferred to incoming air in the heat exchanger – such energy recovery can be over 95% efficient. Incoming air enters well up the chimney at a level ‘h’ from the top, which is needed to drive the system. The incoming air is warmed as it travels down the chimney. It passes through the turbine and then between the two layers of glass to ground level, entering the solar collector from underneath the absorber.

There are no pumps. The chimney is open to the air and at atmospheric pressure. The driver is gravity – air in the collector is warmed by solar energy and rises because it is lighter. This will draw in colder, ambient air which is heavier.

The author claims that the energy losses listed earlier will be dramatically reduced in this proposal:

1. The loss of potential energy for the exit air is virtually compensated by the gain in potential energy for the incoming air, except that due to ‘h’.
2. The loss in thermal energy for exit air should be dramatically reduced by the regenerator.
3. If the regenerator was 100% efficient, then the volume of air entering the chimney per second will equal the volume of air leaving the chimney per second. There will be no nett loss due to the expansion of air.

There will be some energy losses through the double-glazing, through the walls of the chimney and to gravitation due to the height ‘h’. Any losses in the turbine or due to friction in the heat exchanger will be recycled as heat into the incoming air.

The main energy loss will be in the regenerator and will manifest itself in the exit air having a higher temperature that ambient air at that altitude, a higher velocity and a greater volume than incoming air. The challenge would be to construct a regenerator of ever higher efficiency.

The modifications suggested would perhaps double the capital cost of the solar chimney. It is the author's assertion, however, that its efficiency will be increased several fold.

6. APPLICATION

Solar chimneys can be integrated into a building with open stairwells and atria, however be aware of potential heat loss and heating difficulties in winter.

Solar chimneys are most effective in hotter climates with high cooling load.

Sunrooms can also be designed to function like solar chimneys.

Generation of electrical energy is also possible.

7. CONCLUTION

Considerable air ventilation can be generated by solar induced temperature difference if the system is properly designed. The use of solar chimneys in buildings is one way to increment natural ventilation and, as a consequence, to improve indoor air quality. A thermal chimney employs convective currents to draw air out of a building. By creating a warm or hot zone with an exterior exhaust outlet, air can be drawn into the house ventilating the structure. Thermal chimneys can be constructed in a narrow configuration (like a chimney) with an easily heated black metal absorber on the inside behind a glazed front that can reach high temperatures and be insulated from the house. The system may be applied to more than one storey building. It is however, useful to be incorporated with a stand-alone building or with a cluster of buildings. Along with that electricity generation is also possible by solar towers. The technology could become the cheapest method for the large scale generation of solar electricity.

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