Solar Thermal Collector integrated into a traditional Chinese roof

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Topic

Modular solar thermal collector, integrated into traditional roofs, made by specially shaped tiles.

Potential Use

Traditional architecture buildings have a degree of energy efficiency, that can be increased by the installation of a solar thermal system on the roof for hot water production.
The proposed system is totally integrated into the shape of the Chinese roof, in order to reduce (or totally cancel) any visual impact; so, it could be used also on historic buildings subject to protection.

Context Analysis

Right now, in China, there is great attention to energy saving and renewable resources.
At the same time, almost everywhere ancient buildings are under restoration (and sometimes full reconstruction) using the methods, materials and styles of the Traditional Chinese Architecture.
However, use of renewable sources and increase of thermal efficiency in traditional buildings is sometimes in contrast with the preservation of their architectural appearance.
For instance, installation of external solar collectors dramatically change their appearance: also forced circulation systems (with no tank on the roof), even if located in adherence to the cover, are visually disturbing for the different shapes and color than the tiles below.

Idea

The proposed solar system is specially suited to the shape of traditional Chinese roof made of black tiles.
It has to be assembled on site, modularly replacing to any number of tile rows. It is designed starting from the technology of vacuum tubes, which is more efficient than flat plate collectors; but uses innovative shape and technical solutions.

Reference Technology

The technology of vacuum tubes, although innovative, already has at least 5,000 suppliers worldwide, and is dominated by Chinese producers.
The temperatures reached in the collectors based on vacuum tubes allow, in addition to the production of hot water, not only heating of buildings, but also summer cooling by absorption systems: these systems have the obvious advantage of giving maximum production at the climatic conditions in which there is greater demand for cooling.
A collector is made of several vacuum tubes.

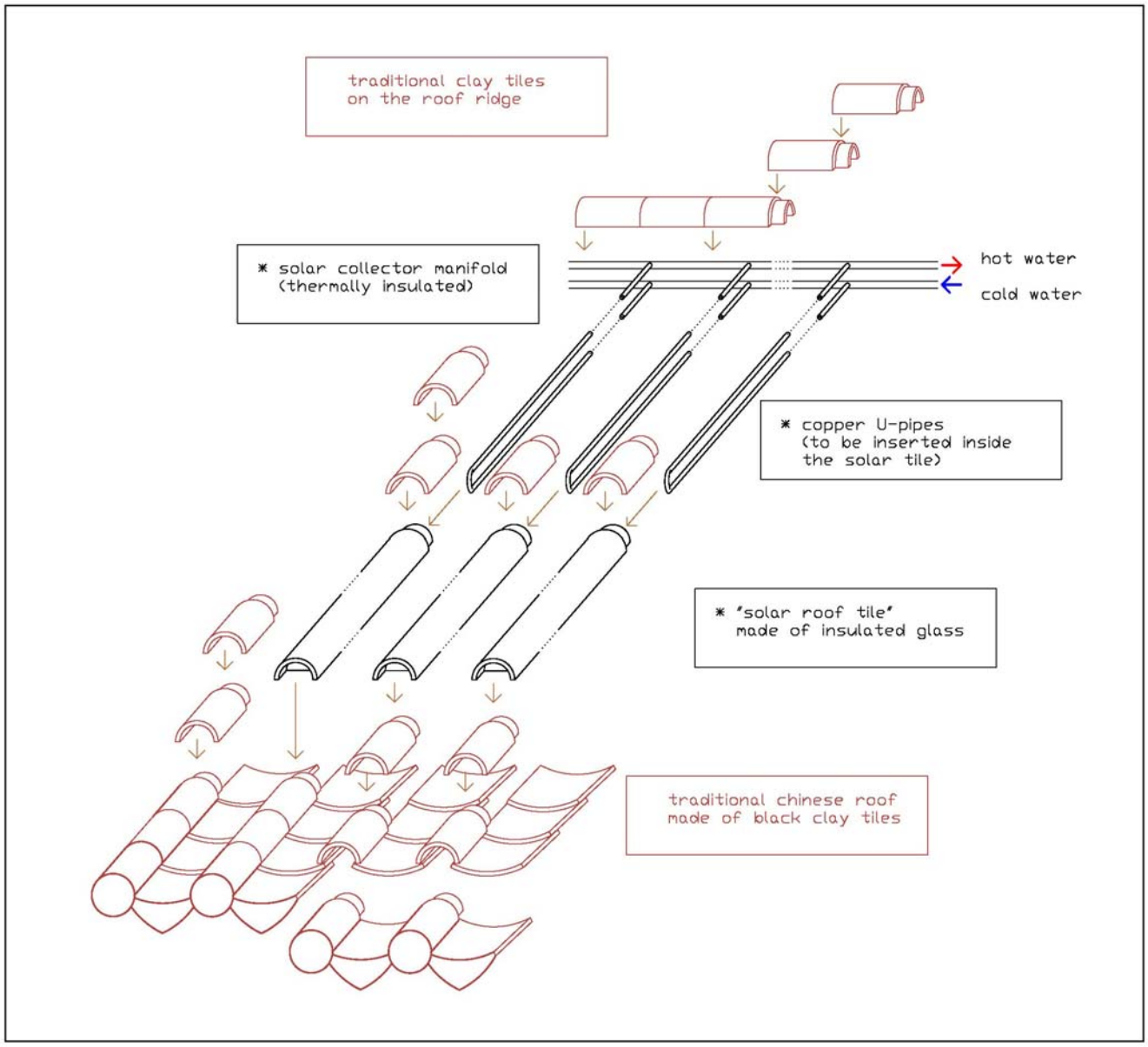
Lijiang, Yunnan Province, 2010 – Restoration of an ancient roof

Commercial vacuum tubes are cylindrical, made in glass with two casings and a sealed cavity in which a vacuum is created; it has the function to absorb solar radiation, thanks to the inner surface treatments that give it a shiny black, and to reduce heat loss by conduction and convection through the cavity under vacuum.

Inside any tube, U-pipes made by copper are inserted; water (more properly a mixture of water and glycol) flows through and increases its temperature, receiving the sun's heat; all of the U-tubes are hydraulically connected in parallel at a manifold. Water movement is provided by a pump.
Additional accessories enable the clamping of the copper U-pipes into vacuum tubes, while optimizing the thermal performance. A metal panel below, with mirrored surface, allows the concentration of sunlight also to the portion of the pipe not directly illuminated.
Completes the circuit a circulation pump and a tank for hot water (not on the roof, but inside the building), equipped with internal heat exchanger.
These systems are factory made as pre-assembled panels and supplied ready for installation with a single interface at the manifold for the circulation of hydraulic fluid.

Project

The concept at the basis of innovation is given by the ability to achieve similar capabilities provided by concentrating solar vacuum tubes of cylindrical shape, by semi-cylindrical "tiles", made of insulating glass, having the appropriate treatment on the inner surface.
This allows integration of the solar collector into the roof, as it was a part of it, simply substituting to any number of roof tiles row, limiting the visual impact and offering extreme modularity to the designer .
The hydraulic system remains essentially the same, with the only variant that is not assembled in the factory but adapted locally. The cross interconnection manifold can be easily hidden under the ridge tiles. The so made solar collector must be obviously assembled on the pitch of the roof with the most favorable exposure (south face), preferably in its upper part. After assembly, the chamber created inside the "solar tile" should be as sealed as possible to prevent the leakage of heat.



For this system some additional components must be engineered. In particular: an appropriate profile that has the function of supporting the "solar tile", connecting the two adjacent rows of tiles below, clamping the copper U-pipes in the most efficient way for the best heat transfer;
A plastic element must finish top and bottom of the tile to allow tiles to overlap on the solar collector. See above figure for more details.
The appearance of the "solar tile" fits perfectly to the shape and also to color of traditional tiles used in many eastern countries. About the shape, we refer to the simplest and most distinctive element of the typical Chinese roof, evidenced by a red circle in the figure taken from a handbook of traditional Chinese architecture.

It has convex, semi-cylindrical shape, and has bayonet joints at the ends. In combination with a less concave curved tile (which has the function of our "flat tile") make almost the entire roof surface. Other special elements are used to refine the eaves, the ridge, the converse. All these elements have a high degree of dimensional uniformity throughout China and in large parts of the East.
About color, the bricks in East suffer from lack of oxygen while cooking; this does not give them the red brick color, as in the West, but matte black, darker than the raw clay.

Testing and Optimization

The heart of the project is the "vacuum solar tile".
Development of a prototype will allow the experimental verification of its effectiveness compared to that of commercially available vacuum tubes and traditional flat panels.
In case a semi-cylindrical shape would be too expensive to be realized, a cylindrical tile can be used, but with a reengineering of the whole joints and rainwater flow.
Additional experiments could be done to improve the appearance of color and surface treatments to make it as similar to traditional clay tiles without substantial loss of efficiency.