(12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(19) World Intellectual Property Organization
International Bureau

(43) International Publication Date
21 September 2006 (21.09.2006)

PCT

(10) International Publication Number
WO 2006/098662 A2

(51) International Patent Classification: Not classified

(21) International Application Number:
PCT/SD2006/000002

(22) International Filing Date: 15 March 2006 (15.03.2006)

(25) Filing Language: English

(26) Publication Language: English

(30) Priority Data:
1221 17 March 2005 (17.03.2005) SD

(71) Applicant and
(72) Inventor: **HASSAN, Nazar, M.** [SD/SD]; Block #3, House #383, Ash-Shagara, Khartoum (SD).

(74) Agent: **HASSAN, Nazar, M.**; P.O.Box 471, Khartoum (SD).

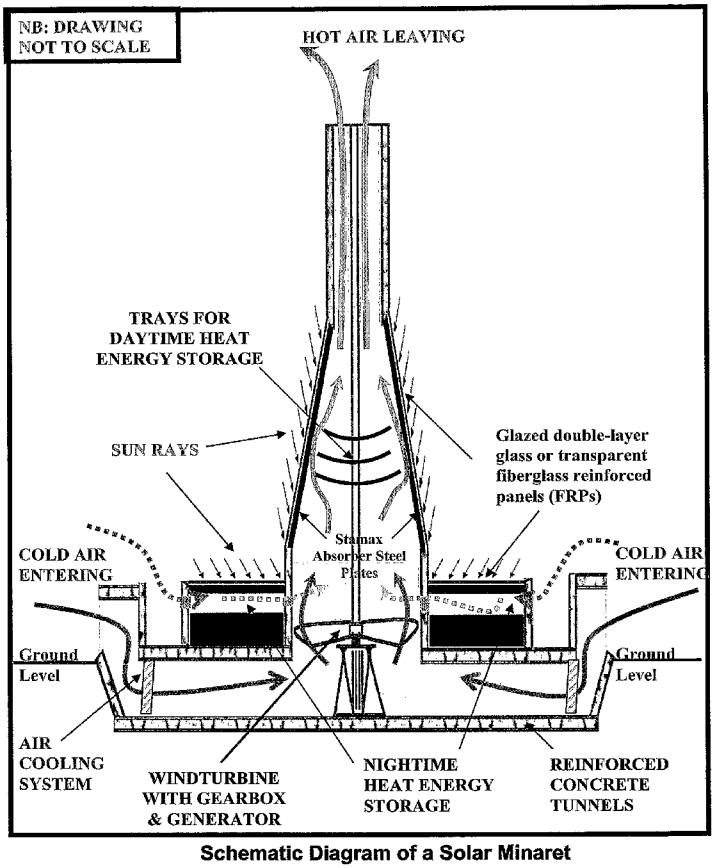
(81) Designated States *(unless otherwise indicated, for every kind of national protection available)*: AE, AG, AL, AM, AT, AU, AZ, BA, BB, BG, BR, BW, BY, BZ, CA, CH, CN, CO, CR, CU, CZ, DE, DK, DM, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, HR, HU, ID, IL, IN, IS, JP, KE, KG, KM, KN, KP, KR, KZ, LC, LK, LR, LS, LT, LU, LV, LY, MA, MD, MG, MK, MN, MW, MX, MZ, NA, NG, NI, NO, NZ, OM, PG, PH, PL, PT, RO, RU, SC, SD, SE, SG, SK, SL, SM, SY, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, YU, ZA, ZM, ZW.

(84) Designated States *(unless otherwise indicated, for every kind of regional protection available)*: ARIPO (BW, GH, GM, KE, LS, MW, MZ, NA, SD, SL, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European (AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HU, IE, IS, IT, LT, LU, LV, MC, NL, PL, PT, RO, SE, SI, SK, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, ML, MR, NE, SN, TD, TG).

Published:
— *without international search report and to be republished upon receipt of that report*

For two-letter codes and other abbreviations, refer to the "Guidance Notes on Codes and Abbreviations" appearing at the beginning of each regular issue of the PCT Gazette.

(54) **Title:** THE SOLAR MINARET



Schematic Diagram of a Solar Minaret

(57) **Abstract:** The solar chimney has been redesigned to perform with an improved technical as well as economical feasibility. The new design named the "Solar Minaret" comprises one or more modified flat-plate solar collectors within the draft tube (chimney) to increase the working temperature of the rising air up to four folds. The flat-plate collector is also designed with a conical shape, which results in a converging passage to the rising air. This will ensure the introduction of a pull-up force exerted on the rising air, which will balance the pressure drop caused by the wind turbine. Utilizing underground tunnels fitted with evaporative and/or fog cooling systems, the new higher working air density will also contribute to the increase of the air mass passing through the pressure turbine. In our new design and for a chimney height not exceeding 40 meters, the air speed could be increased up to 25 folds. And for a much shorter chimney/draft tube (ratio ≈ 1:7), the construction cost of the solar minaret becomes more economically feasible for the same electricity output

WO 2006/098662 A2

Invention Title: The SOLAR MINARET

Description: The SOLAR MINARET is a modified version of the so called "SOLAR CHIMNEY". While it works on the same basic principle of hot air draft through a long chimney, there are a number of fundamental changes that makes the SOLAR MINARET unique and qualifies it for a new design patent.

Figure [1] represents a demo/pilot project of a SOLAR CHIMNEY that was built in Manzanares Town, located 150km south of Madrid, Spain. It consisted of a field of solar collectors (basically a glass cover raised about 2 meters from the ground level. In the middle of the solar field, a 200 meters giant chimney 10 meters in diameter stood to transport the hot air from beneath the solar collector through the chimney to the higher atmosphere. The difference between the ambient temperature and the temperature of the hot air inside the draft tube forces the air up at a reasonable air speed that allows a wind turbine to rotate at a sufficient speed to produce electricity. With a height of 200 meters this solar chimney design is only capable of generating about 50 KW, making it an uneconomical alternative for electricity generation with an overall efficiency of < 2%.

The three fundamental design changes of the SOLAR MINARET take advantage of two thermo-fluid concepts to improve on the solar chimney's efficiency.

Firstly, the draft tube or the chimney is fitted with one or more solar collectors (see figure [2]), each acting as a separate stage for heating up the rising air. Each modified flat plate solar collector comprises of a glazed double-layer glass or transparent fiberglass reinforced panels (FRPs) to add heat energy to the system. Underneath, Stamax Absorber (AISI 304L) steel plates are fitted to absorb the heat added, which is then transferred by conduction and convection to the air stream that rubs these Stamax plates on its way to the top of the draft tube. Within each solar collector a number of trays are installed to carry heat storage material such as molten salt.

While the solar collector assembled as part of the chimney structure is used to heat the air inside the chimney during the daytime, the solar collector at ground level is solely used to store heat energy for nighttime use. The area of the ground collector and the associated heat storage required capacity is then calculated on the basis of the power generation needed during the nighttime. Utilizing the ejector effect, the air rising through the chimney during the nighttime will force air through the ground solar collector into the chimney to heat up the rising air.

Another important fact is that increasing the air temperature inside the draft tube exerts a pull force upwards on the rising air, and hence partially balances the pressure drop that was caused in the wind turbine. This is the case with the old design of the solar chimney.

Secondly, the conical shape of the solar collectors and part of the draft tube wall allows a substantial increase in the air speed. This translates into more kinetic energy being extracted by the wind turbine and hence more electricity generation is hence possible.

Thirdly, Since a pressure turbine is used, the power extractable from the airflow entering the turbine is given by [$^1/_2$ x air density x (air velocity)^3]. Therefore the maximum power will be achieved at the maximum air density that could be attained. Unlike the conventional solar chimney, the solar minaret ensures that the maximum attainable air density will occur at the point when the air mass enters the wind turbine. This is achieved in the new design by making the air enters the chimney system through a set of underground tunnels, and locating the wind turbine well before the process of air heating starts.

Wherever appropriate (i.e. water availability is not an issue), the air mass entering the wind turbine is increased up to 5 folds by further using the concept of evaporative cooling and/or fog cooling. This is achieved by pushing the dry air through shutters fitted with evaporative wet mattresses or air mist sprays installed at the entrance of each underground tunnel. Figure [3] is a schematic diagram of a solar minaret with details of its components.

CLAIMS

To protect, and to have the right to co-operate in a contractual agreement with others concerning the following:

1. **To protect the design idea of using separate solar collectors for daytime and nighttime use when designing and building solar chimneys/towers.**
2. **To protect the design idea of utilizing modified flat plate solar collectors when designing and building of solar chimneys/towers.**
3. **To protect the design idea of utilizing underground tunnels for air entering the chimney system when designing and building solar chimneys/towers.**
4. **To protect the design idea of using the concept of evaporative cooling and/or fog cooling of the dry air mass at the entrance of the tunnels when designing and building solar chimneys/towers.**
5. **To protect the design ideas of the shape and configuration presented in figure [3] when designing or building of solar chimneys/towers.**
6. **To protect all the above design ideas when designing or building solar chimneys/towers.**

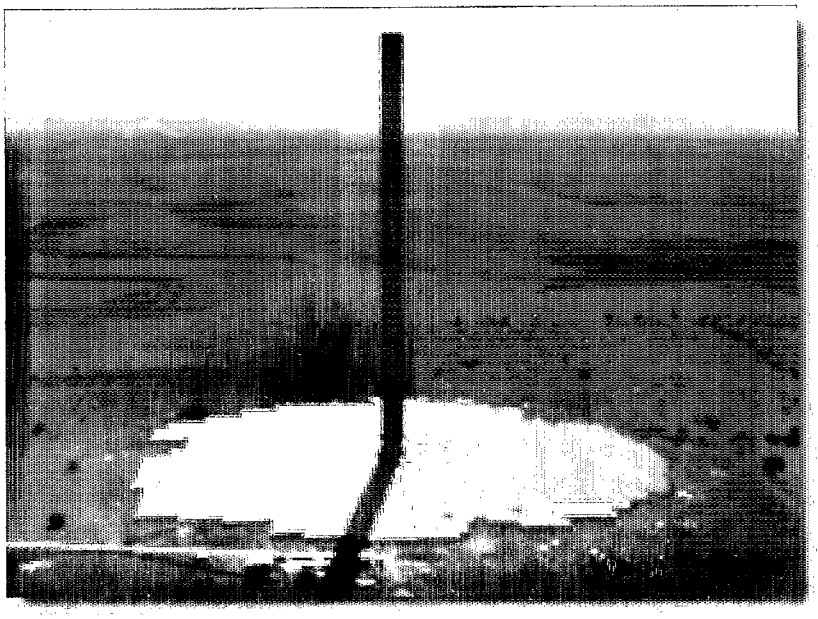


Figure [1]: Solar Chimney, Manzanares Town, Spain

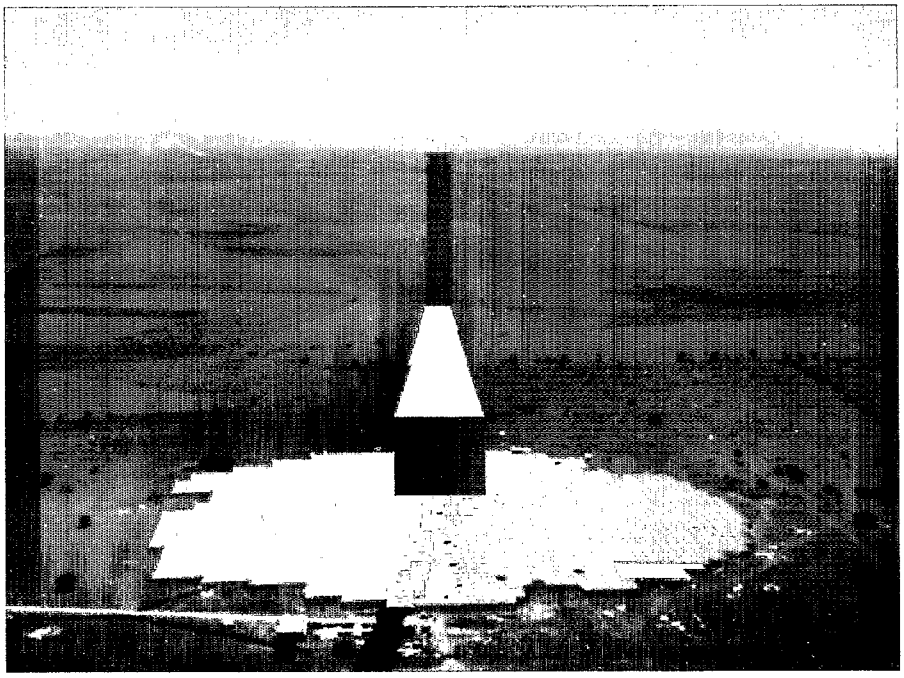


Figure [2]: The Solar Minaret

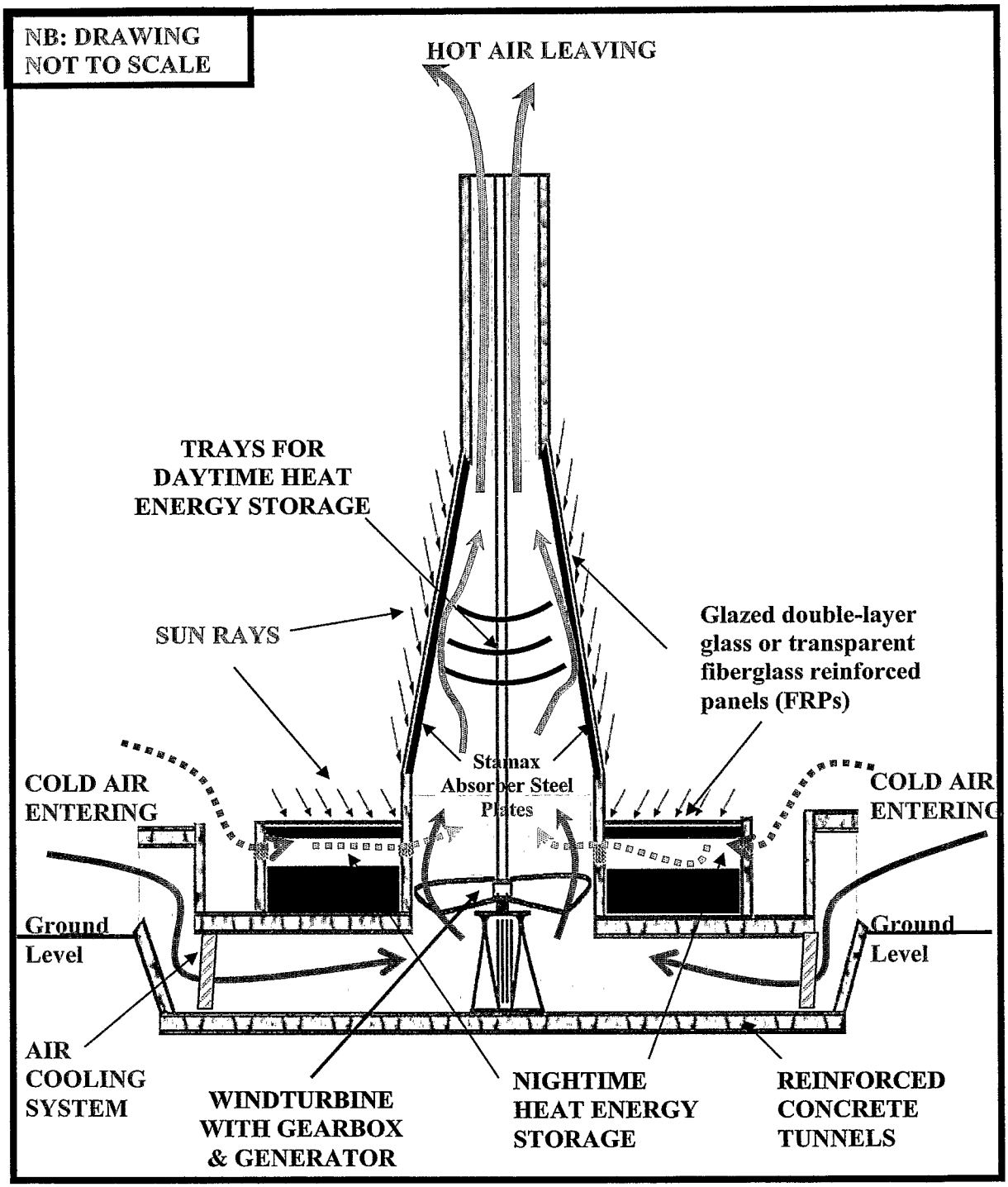


Figure [3]: Schematic Diagram of a Solar Minaret