

FULLY SOLAR BUILDING BASIC DESIGN SPECIFICATIONS

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ABSTRACT

The Fully Solar Building is to serve heating in winter and hot water around-year with off-season solar energy storage, to provide cooling with thermal storage in winter, to supply the electric power with the solar energy $H_2O \leftrightarrow H_2 + O_2$ power cycle, and to take the hydrogen as the fuel. This technical scheme can be served as the main way for solar energy building in future. And what is more, this system can be used for military affairs, space, and special building in other planets. It will lead the architecture science and technology into pure solar energy ages, with which the total energy consumption worldwide will be reduced 28%

Keywords: design specifications, fully solar building, standalone energy system

1. DEFINITION

The concept of Fully Solar Building is the building in which the building heating in winter, cooling in summer, gas, electrical power and hot water are only supplied with the solar energy, and the indoor environment can meet the requirement of people's living and working.

2. PHYSICAL MODEL, SYSTEM

STRUCTURE & DESIGN METHOD

2.1 Physical Model As Fig .1:

2.2 System Structure

Electrical power/gas supplement system with solar energy $H_2O \leftrightarrow H_2 + O_2$ power cycle is consisted of ①solar cell ⑧water electrolysis H_2/O_2 generator ⑤ H_2 container ⑥ O_2 container ⑦fuel cell. It supplies electrical power ⑩ (11) (15) (12) and gas (14) for the building ⑨.

Building heating system with anti-season solar energy thermal storage is consisted of ②solar collector ③heat cellar heat loop, which supplies heating and hot water ⑬ for the building ⑨.

Building cooling system with anti-season thermal storage is consisted of ⑨ cooling storage with natural convection in winter and ④cool cellar, which can supplies cooling for the building ⑨.

2.3 Design Method

①Effective area of solar cell:

$$Sp = (Wch + WF/\eta_{we}/\eta_{FC}) / \eta_p/\bar{E}_s + QH_2/k_1$$

②Effective area of solar collector: See REFERENCE [1]

$$Sk = (1 - \lambda \cdot \eta K) \cdot QH / Q_{sw} + Q_t / k_2$$

③ Thermal storage volume of heat cellar:

$$VK = \lambda \cdot \eta K \cdot QH / Cp(T_H - T_{18})$$

④ Cold storage volume of cool cellar:

$$VC = QC / \eta' K / Cp(T_{26} - T_C)$$

⑤ Volume of H₂ container: designed according to the maximum energy consumption needed for the continuing cloudy days in heating or cooling period.

⑥ Volume of O₂ container: half of H₂ container volume

⑦ Fuel cell efficiency: η_{FC} ,

$$\text{output power: } W_F = W_s + \text{Max}(W_h, W_c)$$

⑧ Capacity of water electrolysis H₂/O₂ generator: designed according to the maximum power of solar cell when solar radiation reaches the top at local area in summer. The efficiency of H₂ producing is η_{we}

⑨ Building: energy consumption for heating in winter is Q_H, and energy consumption for cooling in summer is Q_C

⑩ Power of heat collection circle pump, W_{ch}: the power needed for the maximum water flux when the outside air temperature is taken as the highest monthly mean temperature at local area plus 1/2 diurnal range, and the water temperature at the exit of solar collector is 60°C, and the solar radiation reaches the top.

(11) Power of circulating pump for heating, W_h: the power needed for circulating pump when the outside air temperature is taken as the lowest monthly mean temperature plus 1/2 diurnal range, and the indoor air temperature is 18°C. Then the pipe diameter, flux, pressure head and heat exchange area should be determined.

(12) Fan power for cooling in summer, W_c: the fan power for building cooling when the outside air temperature is taken as the highest monthly mean temperature plus 1/2 diurnal range, and the indoor air temperature is 26°C. Then the pipe diameter, wind rate, pressure head and heat exchange area should be determined.

(13) Area of solar collector for hot water is Q_t/

k₂, here, Q_t (m³/d) is the hot water consumption index when the temperature of hot water is 40°C, and k₂ is the yearly hot water (40°C) output per unit area of solar collector at local area.

(14) Effective area of solar cell for water electrolysis is Q_{H2}/k₁, Q_{H2} (m³/d) is the gas consumption index when it is 25°C and 1kg/cm², and k₁ is yearly H₂ output by water electrolysis per unit area of solar cell.

(15) Electrical power needed for illuminating, household electrical appliance or office equipment, W_s

□ Heating loop in winter: the circulating intensity can be adjusted with the change of outside temperature during heating period in order to keep indoor temperature to be T₁₈±2°C. The solar energy in winter should be used firstly for the system design.

□ Cooling loop in summer: the circulating intensity can be adjusted with the change of outside temperature during cooling period in order to keep indoor temperature to be T₂₆±2°C.

□ Heat collection loop: its circulating pump is directly driven by solar cell and can adjust the circulating flux with the change of solar radiation intensity in order to keep needed outlet water temperature.

3. DESIGN CRITERIA (THREE ENERGY BALANCE EQUATIONS FOR POWER CYCLE)

Yearly solar energy thermal storage quantity = heat for building heating in winter + yearly heat for hot water supplying + yearly thermal loss of heat storage

Cooling storage quantity in winter = cold consumption in summer + the thermal loss of cold storage

Solar energy H₂O↔H₂+O₂ power system can satisfy the need of instantaneous max supplement, supplement during continuing

cloudy days, and total supplement quantity of electrical power & gas for the building.

Considering the climate difference between the different locations, the design margin should be 1.5 to 2 times according to the mean-square deviation between the weather data during heating period & cooling period in recent 30 years and the Average Year Weather Data.

4. INPUT OF DESIGN

4.1 Weather Data

Use the TMY Data at local area as the design weather data. It can be replaced by average value of weather data in recent 30 years if there is no TMY Data.

Daily average illuminance of total solar radiation on horizontal level: $E_s(d)=E_s(d+365)$, direct radiation component, diffuse component; daily average air temperature: $t_e(d)=t_e(d+365)$, yearly average temperature, diurnal range, annual range; the dates and the beginning & ending day when the daily average temperature is $\leq 5^{\circ}\text{C}$ ($\geq 25^{\circ}\text{C}$) during heating period (cooling period); monthly average temperature and relative humidity in the hottest month (the coldest month); extreme maximum (minimum) temperature; the number of continuing cloudy days during heating & cooling period.

4.2 Local Geographic Data

Altitude, latitude, longitude, average temperature in superficial geological layer (0-50m), the heat conductivity coefficient of geological materials, maximum depth of frozen ground, the solar angle of incidence (at Winter Solstice, Severe Cold, Summer Solstice, Vernal Equinox and Autumn Equinox).

4.3 Building envelope

The overall heat transfer coefficient fits the requirements of energy consumption in GB50176-93, JGJ26-95 and JGJ134-2001.

4.4 Indoor Design Index

The requirements of indoor air temperature & humidity during heating & cooling period, the requirements of electrical power/gas/hot water supplement.

4.5 Efficiency Of Heat Storage In Heat Cellar

Efficiency of heat storage in heat cellar should be not less than 70%. The cost-effectiveness analysis should be made when the thermal insulation construction is designed.

4.6 Efficiency Of Cold Storage In Cool Cellar

Efficiency of cold storage in cold cellar should be not less than 80%. The cost-effectiveness analysis should be made when the thermal insulation construction is designed

4.7 Solar Collector

The performance parameters (efficiency & photo-thermal property) of solar collector fit the requirements in GB/T17581-2006, GB/T6424-2006 and GB/T4271-2006. Design azimuth & inclination of horizontal plane.

4.8 Solar Cell

The performance parameters (efficiency & Photovoltaic Property) of solar cell fit the requirement in IEC 62124. Design azimuth & inclination of horizontal plane.

4.9 Water Electrolysis H₂/O₂ Generator

The performance parameters (efficiency, electrolysis voltage, H₂ output per kilowatt-

hour) of water electrolysis H₂/O₂ generator fit the requirement in GB/T19774-2005.

4.10 Fuel Cell

The performance parameters (efficiency, output voltage, H₂ consumption per kilowatt-hour) of fuel cell fit the requirement in IEC 62282-2.

4.11 The Pressure In H₂ Container & O₂ Container.

Pump: Efficiency And Characteristics.
Cooling Fan: Efficiency And

Characteristics.

Pipeline Thermal And Pressure Losses.

Motor: Efficiency And Characteristics.

To fit the requirement in "Energy conservation product Standard"

5. OUTPUT OF DESIGN

Power and effective area of solar cell, area of solar collector, the structure, material and volume of heat cellar, pump power of heat storage loop and heat supply loop, heat exchange area of heating system, average temperature of thermal storage.

Structure, material and volume of cool cellar, heat exchange area of cold storage with natural convection in winter, fan power for cooling in summer, average temperature of cold storage;.

Power of water electrolysis H₂/O₂ generator, the maximum output power of fuel cell, the volume of H₂ container & O₂ container.

6 TESTING AND PROJECT VALIDATION

Measure the instantaneous maximum capacity of solar heat collecting and the thermal storage quantity during no-heating period in real mounted position, and adjust the photo-thermal

property of solar collector and the direct electric propulsion transfer function of the photovoltaic property of solar cell.

Measure the temperature change in heat cellar and the thermal heat storage efficiency in 365 days.

Measure the maximum heating capacity in the coldest day in winter and check the heating capacity of anti-seasonal solar thermal storage system.

Measure the photovoltaic property of solar cell in real mounted position, and validate the instantaneous H₂ storage quantity with the maximum solar illuminance and the minimum illuminance to make H₂ storage.

Measure the maximum electrical power and gas supplement during continuing cloudy days.

Measure the lowest temperature of cold storage in winter, and adjust the heat exchange flux of cold storage with natural convection in winter.

Measure the temperature change in cool cellar and the cold storage efficiency in 210 days.

Measure the maximum cooling supply capacity in the hottest day in summer and to validate the cooling capacity of cold storage system in summer.

7 DESIGN CASE IN BEIJING

Take a 192 m² house of two floor building in Beijing as an example .

7.1 Input Of Design

Weather data in Beijing: As Table1:

Geographic data in Beijing:

Altitude:31.5m, Latitude:39.8°

Average temperature in superficial geological layer (2-50m): 11.4°C; The thermal conductivity coefficient of geological materials: 0.9W/(m·K)

The maximum depth of frozen ground: 850 mm

The solar angle of incidence: 26.7° at Winter Solstice, 30° at Severe Cold, 73.7° at Summer Solstice, 50.2° at Vernal Equinox and Autumn Equinox

Indoor design index:

Indoor heating design temperature in winter: 18°C

Indoor cooling design temperature in summer: 26°C

Power supplement: 1200kWh/a

Gas supplement: 60 m³ (H₂) /a

Hot water supplement: 500L/d (40°C)

Building envelope

The overall heat transfer coefficient: 20.6W/m²heating consumption, and 19.5 W/m² cooling consumption

Energy storage system

The heat storage efficiency of heat cellar in 365 days: 70%

The cold storage efficiency of cool cellar in 210 days: 90%

Yearly average efficiency of solar collector: 50% (facing south, and the included angle with horizontal plane equals local latitude)

Yearly average efficiency of solar cell: 15% (ditto)

Water electrolysis efficiency: 80%

Electrolysis voltage: 1.25V

H₂ output per kilowatt-hour: 0.22 m³

H₂/O₂ alkaline fuel cell efficiency: 70%, output voltage: 38V

Pressure in H₂ container & O₂ container: 0.5MPa

Pump efficiency: 70%

Cooling fan efficiency: 60%

Pipeline losses: 20%

Motor efficiency: 80%

Design margin: 1.5 times

7.2 Output Of Design

Effective area of solar cell: 8 m²

Effective area of solar collector: 28 m²

Volume of heat cellar: 125 m³

Structure & materials: underground, granite-concrete 20 m³+cobblestones 20 m³+water 85 m³+one-meter-thick chaff insulation layer

Pump power of heat storage loop/heating supply loop: 300W

Average temperature of heat storage: 60°C

Volume of cool cellar: 60 m³

Structure & materials: underground, granite-concrete 20 m³+water for ice storage in winter 36 m³+ expansion chamber 4 m³+ one-meter-thick chaff insulation layer

Heat exchange area of cold storage with natural convection: 24 m²

Cooling fan power in summer: 200W

Average temperature of cold storage: 5°C

The maximum output of water electrolysis

H₂/O₂ generator: 0.18 m³(H₂)/h

The maximum output power of fuel cell: 2500W

The volume of H₂ container: 18 m³,

The volume of O₂ container: 9 m³,

Estimate of direct cost increment: 2,000 Yuan/m²

8 REFERENCE

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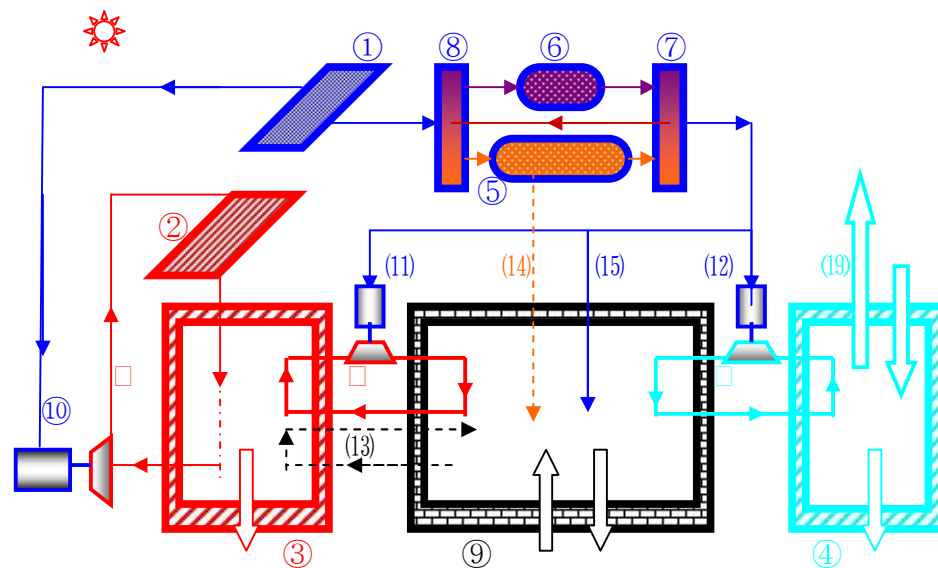


Fig. 1 Physical Model

TABLE.1 WEATHER DATA IN BEIJING

Month	1	2	3	4	5	6	7	8	9	10	11	12
Ta	-4.6	-2.2	4.5	13.1	19.8	24	25.8	24.4	19.4	12.4	4.1	-2.7
Ht	9.14	12.2	16.1	18.8	22.3	22.1	18.7	17.4	16.5	12.7	9.20	7.89
Hd	3.94	5.25	7.15	9.11	9.95	9.19	9.36	8.09	6.36	4.93	4.00	3.52
Hb	5.21	6.93	8.97	9.67	12.3	12.9	9.34	9.28	10.2	7.81	5.20	4.37
H	15.3	18.4	18.5	18.2	18.4	17.2	15.2	15.5	17.5	17.0	15.1	14.2

Ta: monthly average outside air temperature/°C

Ht: monthly average global solar irradiance on horizontal plane/MJ/(m²·day)

Hd: monthly average diffusive solar irradiance on horizontal plane/MJ/(m²·day)

Hb: monthly average beam solar irradiance on horizontal plane MJ/(m²·day)

H: monthly average global solar irradiance(on a plane whose obliquity equals to local latitude)/ MJ/(m²·day)

The number of days that daily average temperature <5°C: 125d

The number of days that daily average temperature >25°C: 50d

Yearly average outside air temperature: 11.4°C

Annual range: 30.4°C

Diurnal range: 11.3°C

Monthly average temperature in the hottest month: 25.9°C

Relative humidity in the hottest month: 77%

Monthly average temperature in the coldest month: -4.5°C

Relative humidity in the coldest month: 44%

Extreme maximum temperature: 40.6°C

Extreme minimum temperature: -27.4°C

The number of continuing cloudy days: 9 d

The maximum depth of frozen ground: 850 mm

Wind speed: 1.9(summer) ~2.8(winter) m/s