Utilization of Solar Energy in Heating System of Lhasa Railway Station

China Architectural Design & Research Group
Pan Yungang

Utilization of Solar Energy in Heating System of Lhasa Railway Station

I. Overview

Location: Lhasa, Tibet Autonomous Region
Design date: October 2004 - May 2005
Building area: 19504 m^2
Architectural nature: traffic building, officially put into operation in July 2006.

Designer: China Architectural Design & Research Group

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I. Overview

Building situation：

◆ The building has 2 floors above ground with a total height of 21.4 m.

◆ Ground floor: arrival hall, waiting hall, ticket hall, departure hall, VIP lounge, luggage claim, office rooms and others. Except for the lobby, the floor height is 4.5 m.

◆ First floor: comprehensive business, restaurant, office room, luggage warehouse and others. The floor height is 4.5 m.

◆ Main rooms of B1: mechanical and electrical rooms, civil air-defence works combined with peacetime and wartime, etc.

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I. Overview

Building thermal engineering:

- ◆ Outer glass: Low-E glass with heat transfer coefficient of 2.5 W/(m^2 K).
- ◆ Exterior walls: heat transfer coefficient 0.50 W/(m^2 K).
- ◆ Roof: heat transfer coefficient of 0.65 W/(m^2 K).
- ◆ Elevated floor slab: heat transfer coefficient of 0.50 W/(m^2 K)

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II. Heating Design Parameters and Heat Load

Indoor temperature and heat load of main rooms

S/N	Room name	Calculated temperature (℃)	heat load (W)	Sensible temperature (℃)	Remarks
1	Meeting Room	12℃	2474	15℃	Place for relatively-long-time stay
2	Ticket hall	10℃	58111	12℃	Place for short-time stay
3	General waiting hall	12℃	63441	14℃	Place for relatively-long-time stay
4	Shop, coffee room	12℃	48222	15℃	Place for relatively-long-time stay
5	Visitor entry plaza	12℃	63438	13℃	Place for short-time stay
6	Mother and baby waiting room	14℃	4690	16℃	Relatively high standard of use
7	VIP lounge	14℃	4123	16℃	Relatively high standard of use
8	Departure hall	8℃	46496	10℃	Place not for stay

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II. Heating Design Parameters and Heat Load

Values for interior design temperature:

1. The outdoor air is very dry, with a relative humidity of only 28%.If the design room temperature is high and the indoor relative humidity is very low, people will feel uncomfortable (same problem found during the field research).

2. Some main rooms in this building are for temporary stay and the design temperature can be reduced appropriately.

3. In this project, floor radiant heating is considered as the main method, so the "sensible temperature" of people shall be higher than room temperature. The calculated room temperature can be 2 °C lower than the specified value according to the "Regulations on the Application of Low Temperature Radiant Floor Heating in Beijing".

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II. Heating Design Parameters and Heat Load

Hourly calculation of daily heating heat load by typical design (in kW)

Hour	0：00	1：00	2：00	3：00	4：00	5：00	6：00	7：00
Heat load	762	806	839	861	880	884	880	847
Hour	8：00	9：00	10：00	11：00	12：00	13：00	14：00	15：00
Heat load	788	707	618	534	461	418	399	392
Hour	16：00	17：00	18：00	19：00	20：00	21：00	22：00	23：00
Heat load	396	403	421	439	465	494	520	549

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III. Design of Indoor Heating Systems

Radiant floor heating:

- Solar collector water is a "low level" heat source.
- Radiant floor heating requires only low temperature hot water, which is a perfect "match".

Heating hot water temperature: 41/36° C:

- The spacing between plastic pipes is calculated at 150 mm to obtain the required supply/return water temperature for each room. Calculation results: Only 3 rooms require water temperature greater than 41/ 36℃。
- This approach reduces the temperature of the water supply for floor heating as much as possible and facilitates the design principle of better use of solar energy.

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IV. Solar and Heating System Design

(I) Conditions and requirements

-- Lhasa's requirements for environmental protection;
-- Energy efficiency in buildings is one of the key measures in the national energy strategy
--Energy situation in the Lhasa area: Energy is in short supply and all energy, mainly fuel oil, needs to be transported from outside.
-- High solar radiation: total radiation sometimes even
exceeds the solar constant (due to the double effect of clouds on solar radiation), with a winter insolation rate of 77%
and an average flux density of about 197 W/m^2 of total solar radiation in winter (only 110 W/m^2 in Beijing) and a total solar radiation intensity of a typical design day in winter: 21740 $kJ/(m^2\ d)$.

View of Lhasa River

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IV. Solar and Heating System Design

(II) Collectors

Flat plate collectors in one camp site

Concentrating solar collectors - Real-time tracking type

Non-concentrating solar collectors:

- Sun heating type: low cost and low efficiency.

- Flat plate type: Flat plate collectors with all-copper and copper-aluminium cores, fully enclosed with high pressure-bearing.

- Vacuum tube type: higher efficiency, lower pressure-bearing.

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IV. Solar and Heating System Design

(III) Solar energy system

Collector system and collector layout

- The heat collection is closely related to the installation angle. According to the height of the floor, the layout is divided into high and low zones: reduce the pressure-bearing requirements and reduce the imbalance of water resistance between high and low zones.

- The collector system is an open system with full drainage capability at night.

- The inlet/outlet water temperature of the collector is required to be 40/50°C.

--The collector type is not specified for the sake of tendering.

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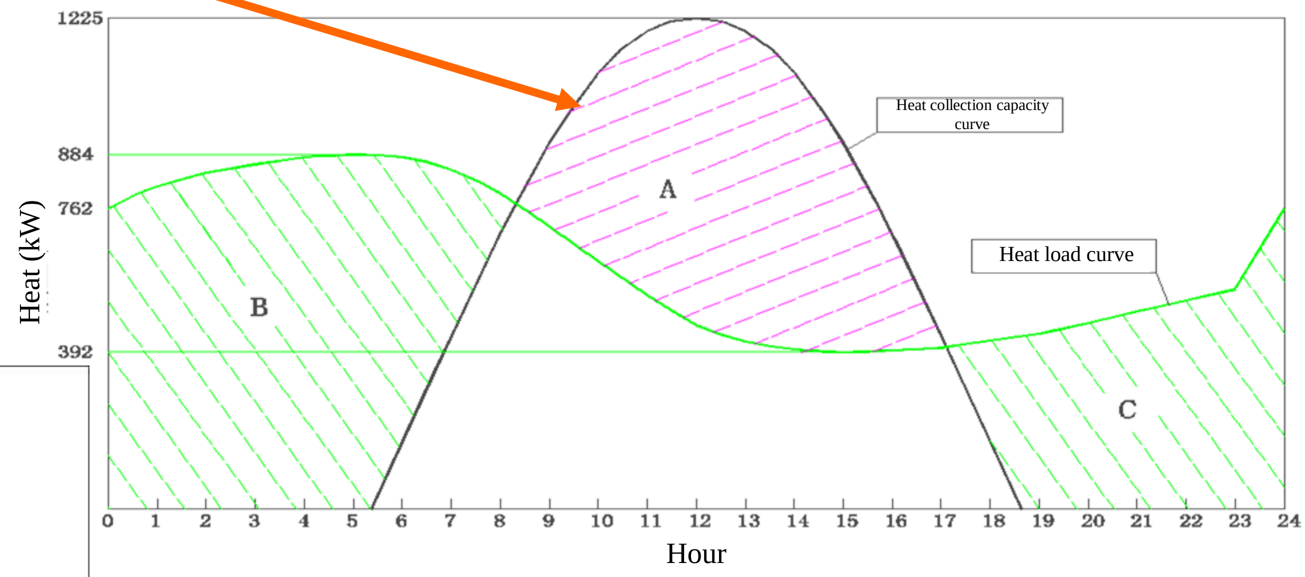
In fact, this is a direct conversion of the irradiation of a typical design day to a fixed efficiency, without taking into account the concept of "effective irradiation".

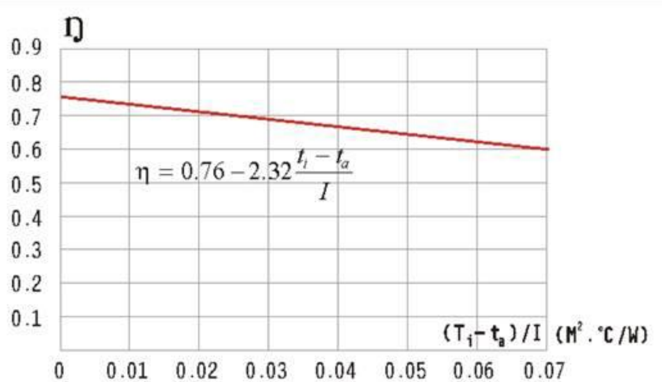
It only reflects the thinking and ideas of the designer at the time and is not entirely correct.

IV. Solar and Heating System Design

Heat collection and heat load for a typical design day



The actual heat collection efficiency is variable! Not all radiation can be converted into heat collection.



Efficiency curve of heat pipe evacuated tube collector

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IV. Solar and Heating System Design

(III) Solar energy system

Comparison of thermal storage system options:

——Partial load heat storage solutions;

——Soil heat storage: high heat loss and high investment.

——Water heat storage: a certain indoor area occupied, low investment, easy operation and management (the method used in this project).

(1) Heat storage tank capacity: 1500m^3 (considering the demands for heat storage water and the water capacity for full discharge at night).

(2) Thermal storage water temperature difference: 5° C.

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IV. Solar and Heating System Design

(IV) Solar collector and heating systems

Heat extraction and supply systems

- Enclosed systems;

- Plate heat exchangers;

- With auxiliary artificial heat source (880 kW): necessary for the use of solar energy.

- Solar energy utilization in summer:

(1) Considering the working needs of the station and the future surroundings (commercial needs, etc.), it can be heat source for domestic hot water in summer. It is still in the early stage of market research.

(2) Use hot water to heat the air in the vertical air ducts to improve indoor natural ventilation of the building.

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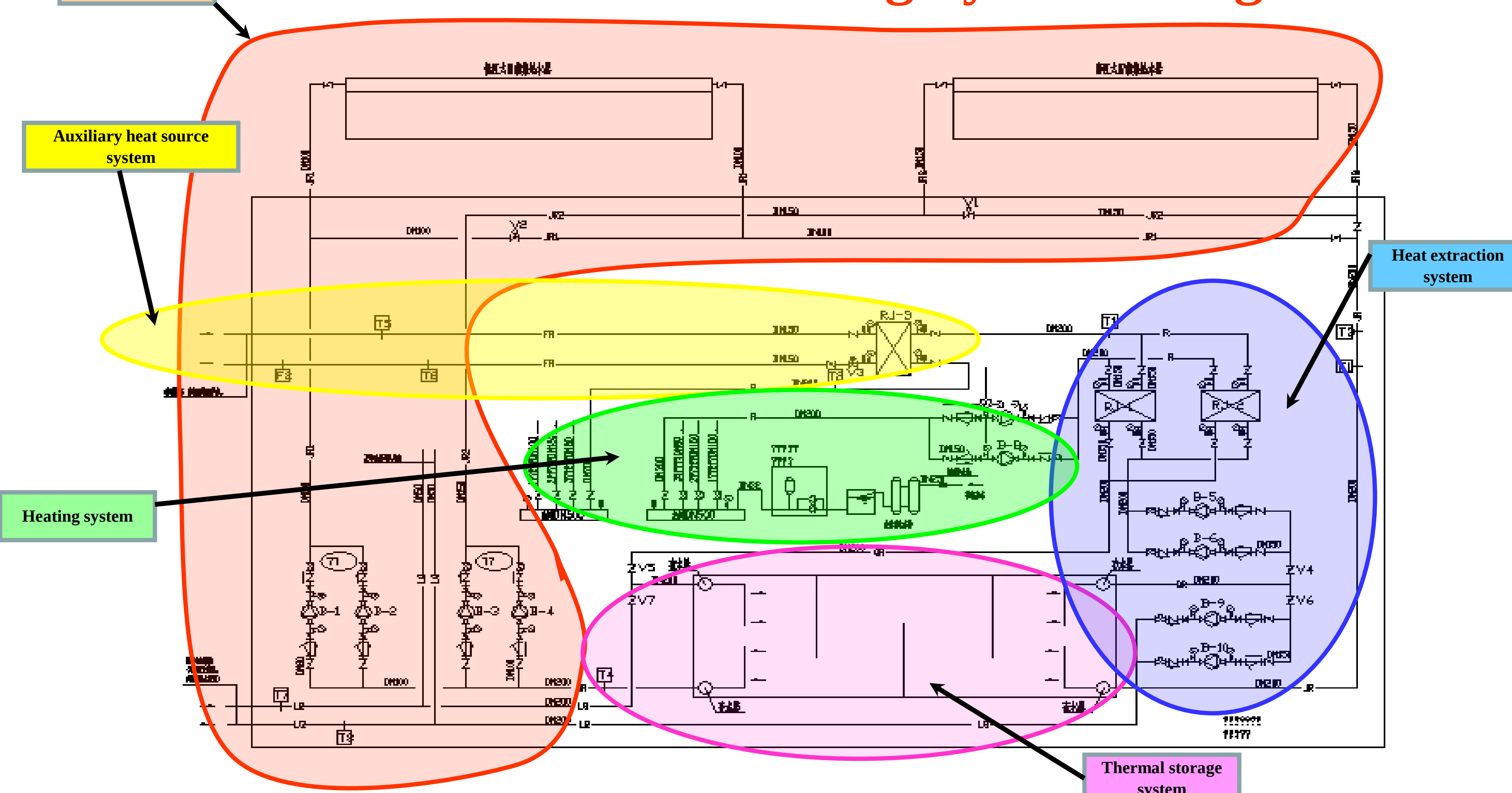
IV. Solar and Heating System Design



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V. Field Survey

Survey Team

China Architectural Design & Research Group
Xu Haisong, Xu Wenlong
Song Xiaochun, Wei Hang
Jin Jian and Pan Yungang

China SouthWest Architectural Design & Research Institute Corp. Ltd & Research Group
Rong Xiangyang and
Wang Lei

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V. Field Survey

Work of the test team

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V. Field Survey

Installation of solar collectors

System failure conditions (water leakage)

V. Field Survey

Survey instruments

Solar radiometer
Acoustic water flow tester
Hand-held laser wall temperature tester
Hand-held air temperature and humidity tester
Automatic recording air temperature and humidity tester
Hand-held laser range finder

Survey time

9 December, 2006

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16 December

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V. Field Survey (Data from the room temperature on 12 December)

Survey room	Waiting hall on the ground floor	Large VIP lounge on the ground floor	Waiting hall on the first floor	Mother and baby waiting room	Deputy stationmaster's office	Weather
8：00	14.5	20.0	14.5	17.5	19.5	Cloudy
9：00	14.5	20.0	14.5	17.0	19.5	Cloudy
10：00	14.0	19.5	14.0	17	19.5	Overcast
11：00	14.0	20.0	14.0	16.5	19.5	Overcast
12：00	13.5	20.0	13.5	16.5	19.5	Overcast
13：00	14.0	20.0	13.5	16.5	19.5	Overcast
14：00	14.0	20.0	13.5	16.5	19.5	Overcast
15：00	14.0	20.0	13.5	16.0	19.5	Overcast
16：00	13.5	20.0	13.0	16.0	19.5	Overcast
17：00	13.0	19.5	12.5	16.0	19.5	Snowy
18：00	12.5	19.5	12.5	16.0	19.5	Snowy
19：00	12.5	19.5	12.5	16.0	19.5	Snowy
Minimum temperature/time of day	12.0/23：30	19.0/23：30	12/23：00	15.5/23：30	19/21：00	

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V. Field Survey (Data from the hot water system on 12 December)

08:30--solar heating system starting up, 9: 00~11: 30 water tank replenishment (12 December)												
Hour	Outdoor temperature	Outdoor relative humidity	Solar radiation intensity	Water supply temperature of the heat collection water system (to the collector)	Heat collection backwater temperature (from collector)		Heating system			Temperature of heat extraction water of solar heat collection system		Weather
					High zone	Low zone	Solar water supply temperature	Water supply temperature after heating	Heating backwater temperature	Heat extraction water supply temperature	Heat extraction backwater temperature	
Unit	° C	%	Wm^2	° C	° C	° C	° C	° C	° C	° C	° C	
11:00	3	30.7	497.5	28. 6	31.6	32	28.6	29.8	24. 9	30	27.3	Cloudy
11:30	3	28.7	618.4	28	32.2	33.1	28.3	29.9	24 .9	29.3	27.3	Cloudy
12:00	6.7	25. 8	465. 5	27.7	35.2	37.2	28.8	30.4	24.7	29.8	27.4	Cloudy
12:30	4.4	25.4	522.4	28.2	34.4	33.8	29.3	29.7	24.8	30.7	28.2	Overcast
13:00	4.9	21.6	255. 5	28.4	33	33.4	29.4	29.8	24. 6	30.6	28.2	Overcast
13:30	8.4	15.8	1013	28. 4	32.8	32.8	29.7	30.1	24.6	30.8	28. 2	Cloudy
14:00	8.2	16.3	269.7	28. 6	35.9	37.6	30	30.2	24.7	31.2	28.2	Overcast
14:30	7	16	163	29. 3	35.1	34.8	30.1	30.6	24.8	31.9	28.4	Overcast
15:00	4.1	12	17.1	29. 2	33.1	32.6	30.3	30.8	25.1	31.1	28.2	Overcast
15:30	2.9	15	13.6	29.1	31.9	30.9	29.6	30.6	24.9	30.3	28.2	Overcast
16:00	2.5	14.6	145.2	28.9	31.4	30.1	29.2	29.6	24.5	29.9	27.5	Overcast
16:30	0.5	31.5	27.8	28.8	31.1	30.2	29.3	29.4	24.5	29.7	27. 5	Snowy
17:00				28.6	30.7	29.7	29.1	29.6	24.5	29.4	27.3	Snowy
17:30				28.9	30.3	29.3	28.6	29.4	24.6	29.4	27.1	Snowy
Calculation flow m3/h		Hot water flow of heat collection system		High zone	81.35	Hot water flow of heat extraction system			Hot water flow of heating system			
				Low zone	27. 36	82.26			40. 08			

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V. Field Survey - on-site questionnaire

Location		Duty Office	Technical Safety Department	Planning Room
Overall situation	Thermal comfort	Moderate (18.5° C measured)	Hot (20° C measured)	Moderate (18℃ measured)
	Satisfaction	Unsatisfied (low temperature in waiting area)	Satisfied	Satisfied
Temperature	Satisfaction	Unsatisfied (as above)	Satisfied	——
	Desired temperature	22~24° C	——	22~24° C
Humidity	Satisfaction	Somewhat satisfied (16% measured)	Unsatisfied (23% measured)	- (15% measured)
	Desired humidity	50%~60%	——	50%~60%
Air freshness	Summer	Somewhat satisfied	Unsatisfied (poor ventilation)	Satisfied
	Winter	Somewhat satisfied	Unsatisfied (poor ventilation)	Somewhat satisfied
	Cleanliness	Somewhat satisfied	Satisfied	Somewhat satisfied
Economy of use		Somewhat satisfied	Satisfied	——
Reliability of use		Somewhat satisfied	Satisfied	——
Flexibility of use		Somewhat satisfied	Somewhat satisfied	——

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V. Field Survey

- Evaluation of the on-site questionnaire

(1) The person from the Duty Office is unsatisfied with the temperature because of the lower temperature in the waiting area rather than that in their office.
(2) Lack of winter humidification measures and low humidity in the room make some people feel the air is dry.
(3) The windows are airtight and the natural ventilation from the ventilation windows is relatively small, so some people feel that the amount of fresh air is insufficient.

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VI. Summary - Comparison of Design and Measured Data

(1) Rooms such as office, VIP lounge and mother and baby waiting room met or even exceeded the design requirements for room temperature, indicating that the solar heating system is of great use.

(2) The waiting hall (including the arrival hall, and departure hall and ticket hall under survey) did not meet the design room temperature at some times during the day.

(3) Although the site survey reflected that people wanted the temperature to be around 22 to 24° C, in fact 18° C was sufficient to make people comfort. If the temperature is higher, the dry air will inevitably increase adverse reactions (for example, during the survey it was found that some people in individual rooms had requested a room temperature of 22~24° C, but they had already expressed a feeling of overheat in the current environment, when the actual room temperature was measured less than 20° C at the time).It is, therefore, more realistic to consider the design of interior parameters in a targeted way rather than to follow the "rules".

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VI. Summary - Analysis of Existing Problems

(1) It is understood that due to reasons such as crashing, in the process of laying buried pipes in the waiting room, arrival hall, departure hall and ticket hall, there were cases where the laying was uneven or even individual pipes were damaged but not replaced (the valve of this branch is closed directly on the water classifier). It can also be seen from measurements on the ground temperature that the ground temperature in these rooms was uneven, with the highest temperature measured at 25-26° C and the lowest at 8-9° C!

(2) People went in and out of these rooms frequently, the external doors often opened and thus a large amount of cold air went in. It is also a cause of low room temperature.

(3) The current large temperature difference in several major areas was on the one hand related to the uneven arrangement of the above-mentioned buried pipes and on the other hand directly related to the uneven flow of water through the system.

(4) The test procedure was carried out with the auxiliary heat supply switched off, and all of the above room temperatures would have been increased considerably if the auxiliary heat supply had been run.

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VI. Summary - Measures for Improvement

(1) The buried pipes can no longer be changed, so it is necessary to re-test the heating water system so that regional temperature differences can be reduced. On this basis, if the room temperature is generally low, the solar system is no longer supplying enough heat and the room temperature can be increased by running an auxiliary heat source system to automatically supplement the heat.

(2) We used automatic door (originally designed automatic door, changed during construction) and hot air curtain to help maintain the room temperature.

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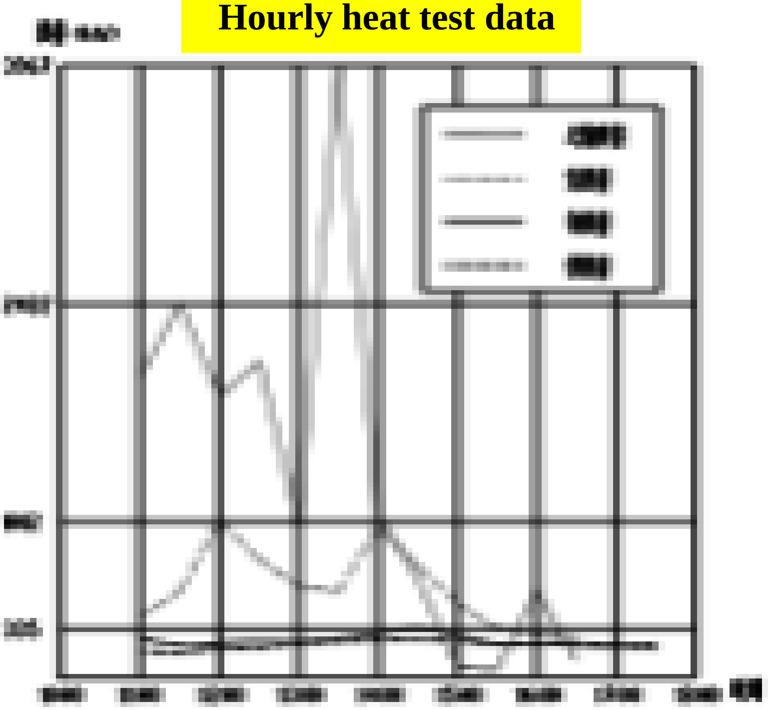
VI. Summary - Preliminary Conclusions

(1) **Despite undesirable solar radiation conditions at the time of the test on 12 December (predominantly cloudy weather and even snowy), the room temperature remained at a largely reasonable level - with proper test run of the water system, it can be assumed that even on such cloudy days, the temperature requirements of the room can be met with essentially no or very little use of auxiliary heat sources.**

December 12, calculation of heat and heat collection efficiency (11: 00~16: 30)									
Calculated as per heat collection system side (total area of collector is 3916m^2)						Instantaneous heat collection efficiency calculated according to the manufacturer's formula (%)	Heat extraction capacity calculated as per the extraction side (W)	Heating capacity calculated as per the heating side (W)	
Heat collection (W)				Total radiation (W)	Heat collection efficiency calculated according to measured data (%)				
Hour	High zone	Low zone	Total heat					Heating (W)	Heat waste (W)
11:00	283.78	108.17	391.95	1948.21	0.201	0.416	258.26	172.44	85.82
11:30	397.29	162.25	559.54	2421.65	0.231	0.427	191.30	158.46	32.85
12:00	709.45	302.23	1011.68	1822.90	0.555	0.417	229.56	191.08	38.48
12:30	586.48	178.16	764.53	2045.72	0.374	0.419	239.13	209.72	29.41
13:00	435.13	159.07	594.20	1000.54	0.594	0.365	229.56	223.70	5.86
13:30	416.21	139.98	556.19	3966.91	0.140	0.451	248.69	237.68	11.01
14:00	690.53	286.33	976.85	1056.15	0.925	0.378	286.95	247.00	39.95
14:30	548.64	174.98	723.62	638.31	1.134	0.307	334.78	247.00	87.77
15:00	368.91	108.17	477.08	66.96	7.124	-1.315	277.39	242.34	35.04
15:30	264.86	57.27	322.13	53.26	6.048	-1.848	200.87	219.04	-18.17
16:00	236.48	38.18	274.66	568.60	0.483	0.267	229.56	219.04	10.52
16:30	217.56	44.54	262.10	108.86	2.408	-0.707	210.43	223.70	-13.27
17:00							200.87	214.38	-13.51
17:30							220.00	186.42	33.58
Total of the whole day (kW/h)	2577.66	879.66	3457.32	7849.03	Average heat-collecting efficiency throughout the day: 0.44	--	1678.68	1496.01	182.67

Hourly heat test data



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VI. Summary - Preliminary Conclusions

(2) It is learned at the scene that the solar collector system at Lhasa Railway Station has been in operation since mid-November 2006 and the collector water temperature used to reach over 55° C when the weather conditions were good. The contribution to solar heating will be further improved if appropriate inter-seasonal storage is considered (the project has a large capacity storage tank, which allows for partial inter-seasonal storage - e.g. running the solar collector system from October onwards).

(3) According to the current test results and the proposed winter sunshine rate of 77% in Lhasa, the contribution of solar energy in the heating system of this project can reach about 60%~70% during the whole winter heating period. Solar energy is an inexhaustible and clean energy source that does not cause environmental pollution in the process of utilization. In the context of China's energy shortage and vigorously promoting the construction of a "conservation-oriented society" and "four savings and one environmental protection", it is of positive significance to actively promote the use of solar energy.

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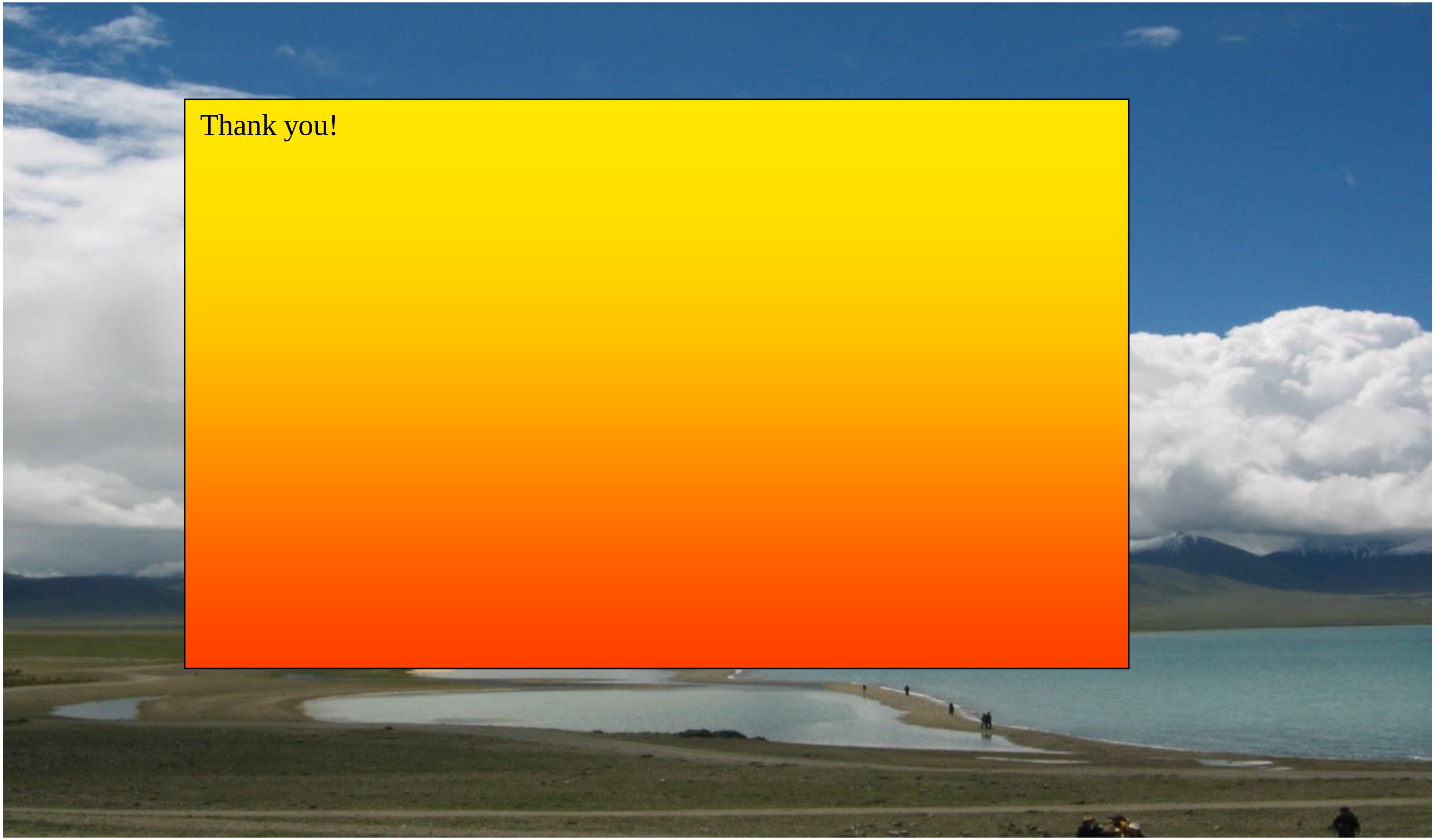

Thank you!