

OPERATION AND MEASUREMENTS RESULTS OF THE SOLAR COOLING INSTALLATION IN THE RETHYMNON VILLAGE HOTEL

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ABSTRACT

The solar cooling plant in the Rethymno village Hotel supplies cooling energy to the dinning room as well as it supplies hot water to its central Domestic Hot Water (DHW) network. The solar cooling system is based on an absorption type machine, LiBr/H₂O, able to be generated at the level of 80°C, since it is of single effect.

The environmental impact of the installation is highly important since the oil displacement by the solar energy yields to high CO₂ emissions reduction. The article displays the results of the operation of the plant and of the measurements made in field during September 2004. A successful day with good results (the 16th Sept. 2004) is given fully documented and it shows the availability of the system as well as it proves its field efficiency.

More particularly, three water loops are measured:

1. the cold water loop (supply to the building load)
2. the cooling water loop (rejection to the cooling tower)
3. the hot water loop (which generates the absorption machine)

According to the results, the hot water from the solar field achieves the 70°C and 30 minutes later the cooled water loop achieves temperatures down to 11°C, able to provide cooling during 5 day-hours (until 18:00)

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1. INTRODUCTION

The work concerns the central air-conditioning of the hotel Rethymno Village, which uses solar energy. The solar energy is applied for space cooling of the hotel, by using modern equipment and an innovative method for refrigeration production as well as for the operation of the whole installation.

1.1 Visits to the hotel Rethymno Village

Several technical visits in the hotel Rethymno Village were carried out on September 2004. The hotel is in Rethymno in Crete island and especially in the area of "Platania". The hotel uses one solar air-conditioning system, of central type, absorption, single effect and coupled with fan coils. The visits comprised the following events:

- one detailed technical tour in the hotel, from the boiler room to the roof of the hotel,
- one short background of the operation results of the solar air-conditioning system made by the hotel maintenance manager.
- Development of one measurement programme which comprised recordings (every 30 minutes) of the various water temperatures mainly on the chiller absorption.

The aim of the visits was to obtain measurements of water temperatures and to conclude in an evaluation of the project.

1.2 Description of the building of hotel Rethymno Village

The hotel Rethymno village is belonging to B hotel category (equivalent to three stars) and it has seasonal operation schedule. It comprises 100 rooms and 209 beds and it occupies a whole area of 600m². It uses a solar air-conditioning system connected to a solar field of 500m², since it has 250 solar collectors with 2m² surface each (manufactured by the SOLE SA). It also uses it for space cooling and for swimming-pool heating purposes.

2. THE SOLAR AIR-CONDITIONING SYSTEM IN RETHYMNO VILLAGE HOTEL

2.1 General description of solar air-conditioning system

Technical aspects

The solar air-conditioning installation comprises the following main systems and components:

- 1) Solar collectors
- 2) Solar absorption chiller

- 3) Hot water storage tank
- 4) Piping and distribution system
- 5) Control system and
- 6) Cooling tower

Description:

(1) The solar collectors provide, as source of energy, with hot water the chiller absorption through the hot water storage tanks. The collectors are manufactured with technologies that can provide hot water at high temperature level (90-150°C).

The collectors (see figure 1) have been placed south orientation, tilted roughly 30°. This tilt for Crete seems to be the most optimal value for highest energy collection in annual base. Also, they are placed in rows so that shading effect is minimised and in a way that the access in each one separately becomes easy for any isolation, repair or maintenance needed. They are connected with special pipes and switches to form groups. One primary pump circulates the water within the collectors in order to transfer



Figure 1. Solar collector field in the hotel Rethymno Village for solar cooling application



Figure 2. The solar driven absorption chiller in the Rethymnon village hotel, sized 105 kW

the collected heat from the sun, supplying water at 70-75°C. The solar driven chiller, 105 kW, (see figure 2), is an absorption technology one, which uses as source of energy the hot water in order to produce cooling capacity to cover the cooling loads.

The cold water is supplied to a fan-coil network in the rooms as well as in the lobby and in the dining room. The back up system for the heating is a propane-boiler (290 kW). A smaller propane-boiler (174,6 kW) is used in order to cover the needs of sanitary hot water, when the solar collectors cannot cover the cooling load or when it is a cloudy day.

During four seasons (middle seasons before and after summer, since during winter the hotel is closed) the solar collectors produce lower temperature hot water, at 55°C, which again circulates in the fan coils in order to make space heating.

The hot water is kept in seven tanks (with a total volume 7000 lit). From the storage tanks the hot water is supplied to the absorption chiller, which operates 7 to 8 hours daily. At that temperature (75-80°C) the chiller operates with a COP about 60% (coefficient of performance).

(2) The absorption chiller supplies cold water to the central installation of the air-conditioning system at a temperature level roughly equal to 10-12°C. The cooling installation also includes a cooling tower in order to reject the heat of the condenser of the absorption chiller. The additional source of heat (LPG back up boiler) or the additional source of cooling (the existing electrically driven chiller) provides support. According the design, the absorption chiller is used to cover the 65% of the load. An additional electric energy is also consumed to operate the primary and secondary pump, which uses minimal electric energy (0,5kW).

2.2 Results of measurements

The aim of the visits was to obtain measurements of water temperatures and to conclude in an evaluation of the project during the duration of the air-conditioning system operation.

In the table 1 below are mentioned the water temperatures measured relevant to three water loops, while in the figure 3 we locate the point pair by loop measured.

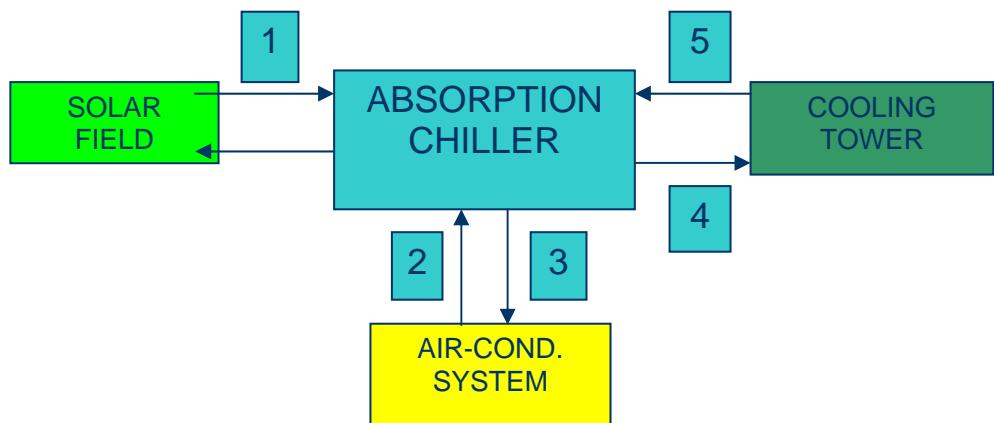
TABLE 1: Measurements of 3 water loop temperatures (on 16th Sept 2004).

Hour	Hot water temp °C Point (1)	Cold water in temp °C Point (2)	Cold water out temp °C Point (3)	Cooling water in temp °C Point (4)	Cooling water out temp °C Point (5)
12:18	67,5	30,2	27,5	29,6	29
12:20	68	27	25	29	29
12:55	64,2	15,8	13,1	27,9	17,6
13:30	65	14,5	12,3	29,4	16,4
14:00	68,3	15	12,1	29	16,8
14:30	68	15	12,8	29	17
15:00	67	14,5	12,6	29	16,5
15:30	67	15	12,2	28,5	16,6
16:00	65,5	16	12,3	28,6	17
16:30	61,5	17	13,5	27	17,5

17:05	57	18,5	15	27	18,5
17:35	49,5	19	16	27,3	19,5
18:00	57	19,5	17,7	26	20,5
18:30	68	16,5	14,5	29	18,5
19:00	71,5	15,5	12,8	28,6	16,5
19:30	72	13,5	11,7	28	15,5
20:00	73	13,5	11,3	27,9	14,5
20:30	59,5	13,4	11,4	27,2	15
20:45	54	14,2	11,9	26,1	15

The following schematic diagram (figure 3) shows the points where temperatures have been measured for the evaluation of the absorption chiller of hotel Rethymno village. The points 1, 2, 3, 4 and 5 correspond to water temperatures, which also appear in the table 1.

Figure 3. Points of the measurements

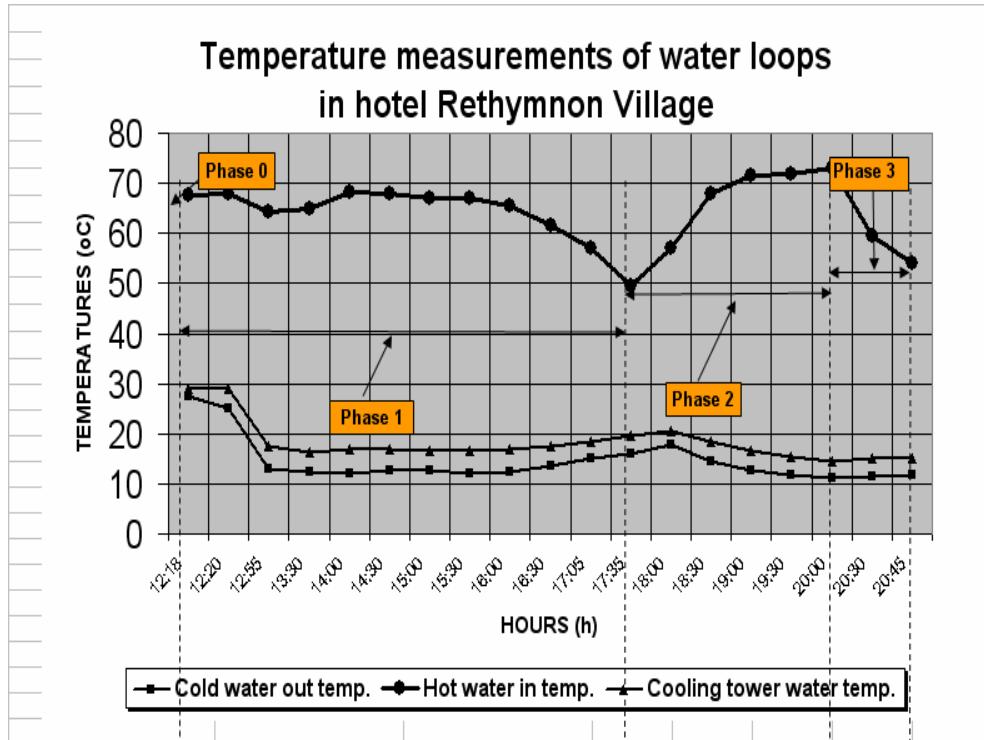


2.3 Analysis of the four operation phases

Phase 0

The absorption chiller is out of operation; however the primary pump opens about at 9:00 in the morning activated by the solar differential thermostat. The absorption chiller enters automatically in operation when the temperature of the hot water passes the level of 45°C. However, if there is no need for air-conditioning, for various reasons, the relative sensor may open when it would be necessary and not automatically when the temperature reaches 45°C.

Figure 4. Measurements of the solar cooling plant in the Rethymnon village



Phase 0

Before
12:00
The
absorption
chiller is
not in
operation
yet.

The absorption chiller is in operation. The fan-coils are on.
The hot water in temperature is about 70°C .
The cold water is about 12°C and it needs approx. 40 min. to be cooled down.
Around 16:00, the hot water-in temperature decreases, due to the decrease of the solar insulation.

Phase 1

Phase 2

An LPG boiler feeds the solar absorption chiller.
The hot water temperature rises up again to 72°C .
The cold water temperature decreases down to 10°C .

Phase 3

LPG boiler is off.
Absorption chiller is still on.
Still the hot water offers cooling energy to the hotel through the chiller.

Phase 1

As we observe in the figure 4, there is a start phase and transition cooling where the absorption chiller hasn't the highest contribution to the load because of the thermal inertia of the load block (from 12:20 up to 13:30). Then the hot water temperature decreases from 68°C down to 65°C. In a second sub-phase, the temperature of the hot water increases again progressively and it reaches 68,3°C at time about 14:00, where the hot water takes the highest temperature without any support from the backup boiler. At the end of the day, the temperature of the hot water begins to fall progressively about 16:00, and at 17:45 reaches its lowest temperature of the day, 49,5°C (without the intervention of any boiler). This happens because of the decrease of the solar insulation and therefore the solar collectors did not attribute accordingly. In the figure 4 we also observe that the highest the hot water temperature is, the lowest the temperature of the cold water is and reversibly. Indeed, this is the objective of solar air-conditioning, thus to create refrigeration from the sun. The cold water is then supplied to the air-conditioning apparatuses where the desired room temperature for space cooling is secured.

The moment (17:45) when the temperature of the cold water rises up according to the decrease of the solar insulation, we understand that the boiler should enter in operation in order to maintain the temperature of the cold water in a low level necessary for cooling production.

Phase 2

In this phase the boiler starts to operate, because the temperature of the hot water starts to decrease dramatically, down to 49,5°C, while the inlet temperature of cold water increases, up to 16°C (the outlet temperature up to 20 °C). The LPG boiler manages to maintain the temperature of the hot water in a high level in order to insure the regeneration of the absorption chiller and hence to keep in a low level the temperature of the cold water. Both the temperature of cold and hot water return back at the desired levels, immediately after the boiler begins to operate. We also observe that at 20:00 we have the higher temperature of hot water, 73°C, and respectively the cold water reaches the lowest temperature, 11,3°C. This happens because more the boiler operates better the output is. The temperatures of cold and hot water which have been reached, are very satisfactory for the particular hour (20:00), which is usually the hour of dinner for the customers of the hotel and wherever air-conditioning is necessary. So, the boiler could be turned out of operation after the desired temperatures are reached, since the inertia of the cooling system can insure a satisfactory level of space cooling for at least one hour after his cut out. Until the temperature of the hot water decreases again down and the temperature of the cold water rises up, air-conditioning still exist.

Phase 3

The boiler is out of operation; however the absorption chiller is still open, so there is refrigeration effect through the chiller. At the end of the phase the absorption chiller will stop automatically when the temperature of the hot water goes lower than 45°C. As soon as the chiller absorption stops operation, the pumps of solar collectors should open and the pumps of boiler should stop. The cold water can reach up to 25°C when the absorption chiller shuts down.

4. ESTIMATION OF THE COP OF THE SOLAR COOLING CHILLER

Apart temperature measurements in the table 1, we also measured the water flow rates, constant flow.

Cooling tower water loop: $m_{wct} = 15 \text{ m}^3/\text{h}$, cold water loop: $m_{wcold} = 4.2 \text{ m}^3/\text{h}$. The solar efficiency has not been evaluated yet. Nevertheless, it has been possible to calculate the COP of the chiller based on temperature and flow measurements following the following formulas:

$$\begin{aligned}\text{COP} &= 1/[Q_3/Q_2 - 1] \\ Q_3 &= m_{wct} C_p [\theta_4(t) - \theta_5(t)] \\ Q_2 &= m_{wcold} C_p [\theta_2(t) - \theta_3(t)] \\ t &= 15:00, \text{ when sensible inertia of system is minimized}\end{aligned}$$

The result is: **COP = 0.9**

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