Thermal cooling basin exploration for thermal calculations

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Abstract: There are a number of cooling systems known across the world. For decades they have undergone development, changing coolants and their chemical composition, but water has, thanks to its universal properties, remained an undying presence in this technology. Water is used as a carrier heat or cold for cooling spaces and some cooling equipment itself, for accumulating and radiating heat to an environment with lower heat potential, for heat evaporation, and as a solvent which is great at dissolving substances we know as cooling agents.

Pools are an especially practical and aesthetically appealing execution of a co oling system – provided appropriate temperature modes and external air temperature during the operational season. In centralised heat supply conditions, heat production companies choose to install cogeneration engines to increase energy production efficiency and profitability, allowing both electricity and heat to be produced from one type of fuel. However, the world at large has also seen trigeneration systems: such large urban areas as New York and Tokyo have long been using one type of fuel to produce electricity and, adjusting to weather patterns, either heat or cold energy. Of course, these enormous cities and their energy delivery patterns cannot be compared to those of small cities and rural towns which are common in the Baltic and CIS countries. Conversion of heat into cold energy takes place at heat absorption cooling facilities. Heat absorption facilities require a fluid overcooling cycle to store a concentrated fluid. The temperature modes of this cycle (which vary between producers) produce low-potential heat which cannot be reused to produce heat energy, e.g. 35-29*C. To support such a temperature schedule, producers generally recommend installing heat evaporation towers, but they are expensive and will often clash visually with the landscape. A cooling pool may be used instead for both practical and aesthetic reasons, using water sprayers to promote evaporation. Water spraying is necessary to increase the surface area of water-to-air contact: this way, the surface area is equal to the combined areas of all water droplets. The depth of a pool must be no less than 1.5 m, preventing heating by sun rays. Pool cooling properties improve with finer droplet size, although this carries higher electricity expenses to produce adequately high pressure before pulverisation. Such pools may use fountains which serve both as a cooling facility and an attractive landscaping piece. An evaporation pool is also significantly cheaper to build than an evaporation tower, although water loss may be higher.

In consideration of the facts described above, a pool with a water spraying device was built for this research project. With appropriate air temperature, pressure and relative humidity, heat yield and yield changes were measured.

The goal of this study was to compare the research and experimental parts of the project to similar studies performed previously, in order to determine the practical viability of using heat evaporation pools as well as to develop a complete prototype which may be used as the basis for building similar structures.

Keywords: *cooling systems, heat evaporation pools*

1. Introduction

Latvia is located in a climate region where heat is necessary not only for improving quality of life, but also as a prerequisite for survival during the winter, which lasts for about 200 calendar days. Therefore, heat supply is a particularly important part of Latvia's power industry, as evident from the fact that over 60% of the country's energy resource consumption goes into heating. Increasing the efficiency of heat supply, especially centralised heat supply, which provides 30% of the heat required within the country by households and technological facilities (the proportion of centralised heat supply in the housing sector exceeds 45%). Increasing the efficiency of centralised heat supply systems also has a d eciding role in ensuring the competitive ability of heat supply companies, which in turn is a requirement for using the possibilities and advantages of centralised heat supply systems. In the large part of country (one-third of the primary energy consumption) as the raw material for the energy production (including centralized heating) is used natural gas. It increases the dependence of the energy import and the energy purchase price. There is as a large potential of renewable energy in Latvia, it could be used in energy production, but in many cases necessary investment for communication shift are hardly to attract, that's way there musts be done everything to improve current centralised heat supply, to make maximum benefit for the energy supplier ad it's user.

2.1. Purpose of Introducing a Trigeneration System

One of the solutions for improving the efficiency of the centralised heat supply system might be introducing a trigeneration system in the centralised municipal heat supply system. Traditional producers of electricity produce electricity from fuel, such as fuel oil, diesel or natural gas, however this process is inefficient: it produces waste heat, which may be converted into various types of energy and put to use. At cogeneration facilities, this heat is used to supply nearby household or industrial demand. In case of trigeneration, fuel is used to produce electricity, heat, and, if necessary, convert the heat into cold energy, to be used for household or industrial cooling; additional heat is removed from smoke and gas before they are emitted into the atmosphere, producing additional heat for heating or cooling of spaces. Trigeneration systems in large urban areas as New York and Tokyo have long been using one type of fuel to produce electricity and, adjusting to weather patterns, either heat or cold energy, but it is a great challenge to adjust this system in areas that do not requires such great energy consumption.
Purpose of introducing a trigeneration system:

- Consumption of heat load during the summer period
- Economically advantageous conditions for using the heat source
- Constant loading of the cogeneration facility year-round
- Potential for reducing heat energy tariffs

The centralised heat supply system works according to a specific temperature schedule adapted to changes in external air temperature. The city boiler house works according to such a temperature schedule. The boiler house generally services not only tenement and private houses, but also office spaces, utility consumers and often production facilities interested in heat absorption capacities for their cooling equipment during the summer. There is no need for heating inside the city's residential spaces; the heat supply system works according to a 65-40°C temperature schedule (not Riga). The heat producer considers the issue of profitable heat carrier temperature during summer months – it is well known that with increased heat carrier temperature, heat carrier surface heat loss increases as well (the temperature schedule for trigeneration heat absorption equipment is 95-70°C). Here, one must consider the usefulness of maintaining adequate heat carrier temperature for heat absorption equipment, while at the same time providing the same temperature to tenement houses, which only use hot water. On the other hand, it is useful because cogeneration facilities may be operated at higher loads during the summer period. An assessment of issues related to introducing a trigeneration system must consider the possibility of dividing the heat supply network into primary and secondary circuits. This means that a heat source would produce heat both for delivering hot water to consumers during the summer period and for cooling spaces. The principal layout of a trigeneration system is shown in Figure No. 1. However, the following obstacles complicate the introduction of a trigeneration system:

- Heating network configuration must be adjusted
- A heat supply and temperature schedule must be specified for consumers
- Daily heat consumption patterns must be analysed
- Strategic choice of absorption equipment (centralised, decentralised)
- **Building an evaporation tower**

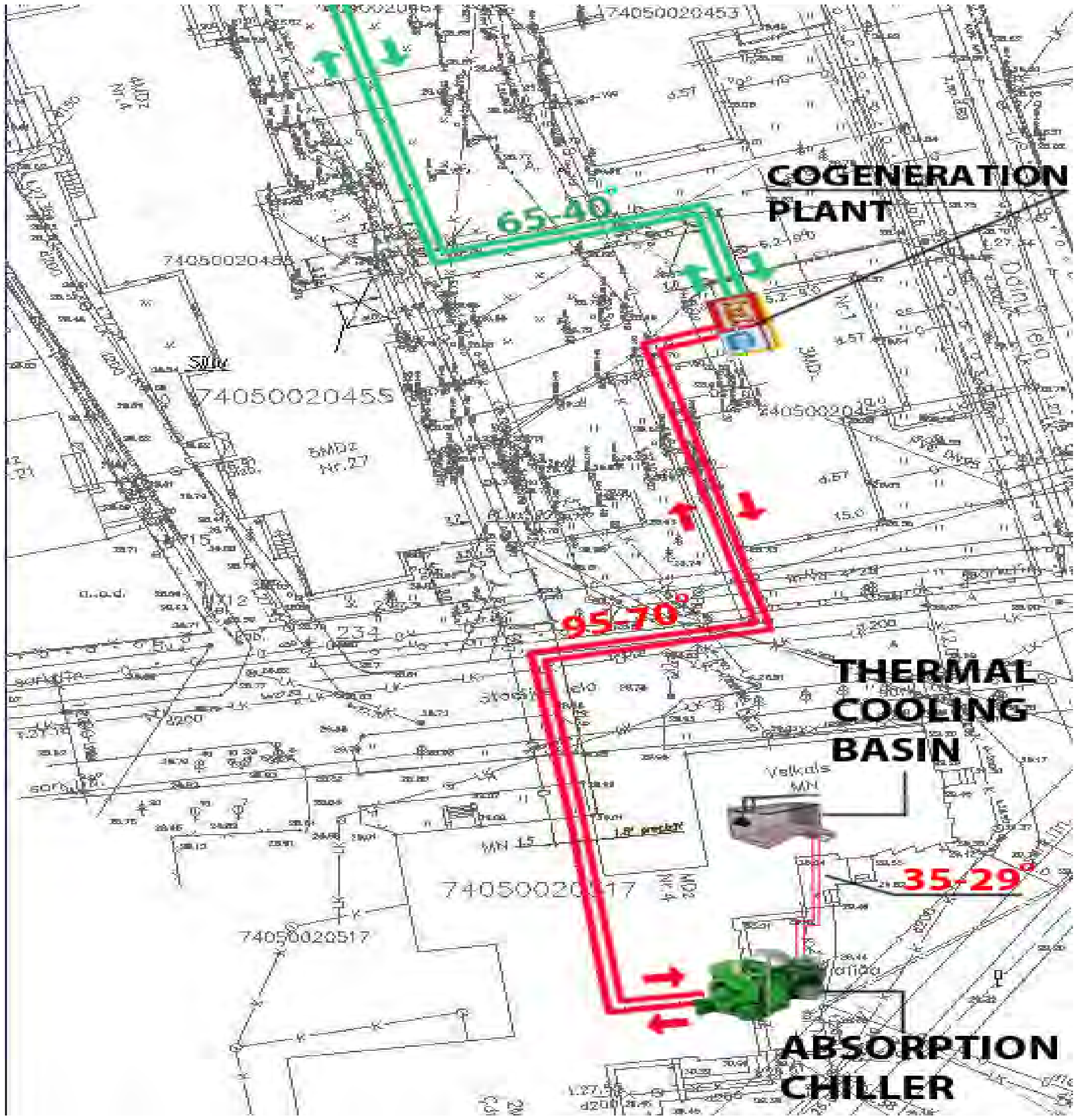

Fig. 1. Principal layout of a trigeneration system

2.2. Heat Evaporation Pools as an Alternative to Cooling Towers

Heat conversion into cold energy takes place at heat absorption chillers. A heat absorption chiller can be seen in Figure No. 2. Two connection points to the cooling tower are shown on the layout, the heat absorption facility may instead be connected to a heat evaporation pool. In order to contain a concentrated fluid, heat absorption facilities require a fluid supercooling cycle. The heat carrier temperatures within this cycle (depending on the manufacturer, this value may vary) are usually low, such as 35-29°C. In order to ensure a temperature schedule for such a cycle, the manufacturer usually recommends building heat evaporation towers, although these are expensive and often clash with the landscape. For practical as well as aesthetic reasons, a heat evaporation pool may be used here, employing water sprinklers to boost cooling efficiency. Water sprinkling is necessary for increasing the area of contact between water and air because the area of contact is equal to the sum of the areas of all airborne droplets of water.

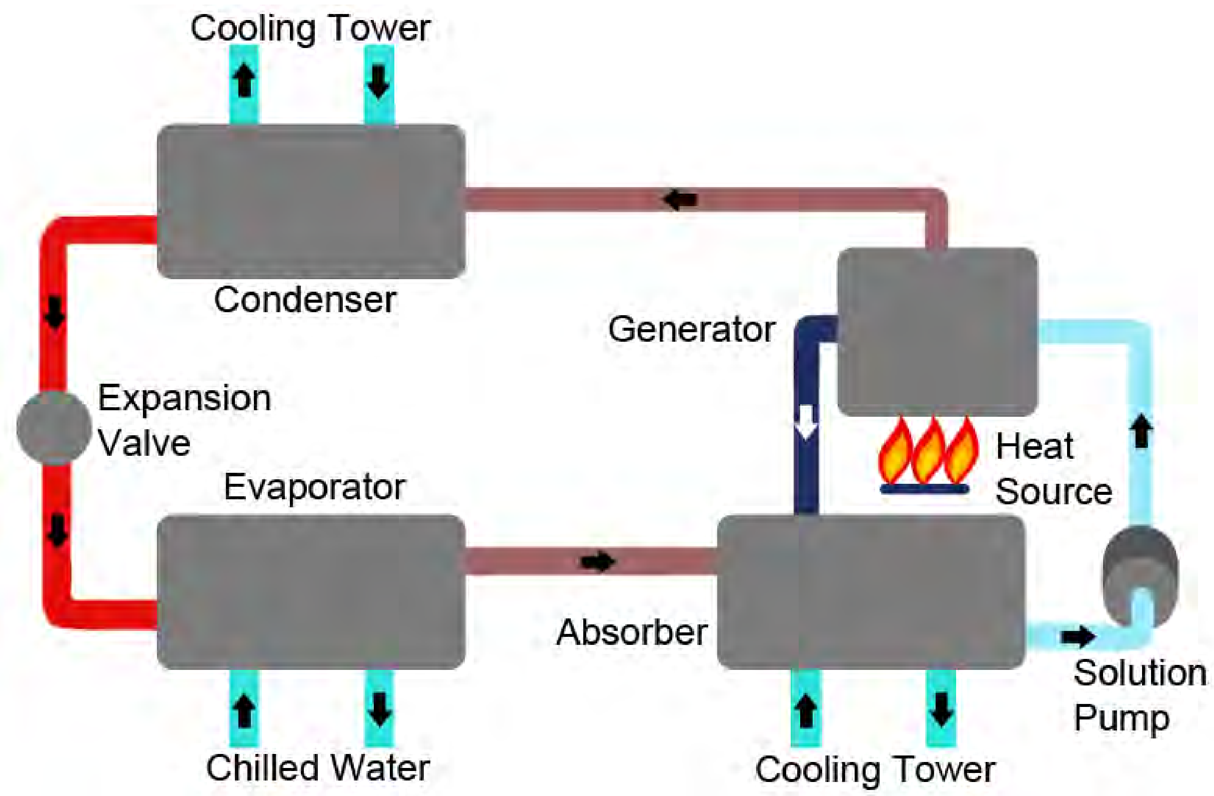

Fig. 2. Heat absorption chiller

The pool may not be shallower than 1.5 m, to prevent heating by solar rays. The cooling properties of the pool will improve with sprinkling of finer droplets, although this leads to higher water losses as well.
A heat evaporation pool (as seen in figure No. 3) may be a heat engineering structure; its advantages include:

- A heat evaporation pool is much cheaper to build than an evaporation tower
- An evaporation pool is a closed system which may therefore be located in public areas
- An evaporation pool is a significantly smaller structure than a tower
- An evaporation pool is more visually appealing and landscape-friendly than an evaporation tower.

2.3. Analysis of Heat Evaporation Pools for Heat Engineering Calculations

The purpose of this research is to perform a study and compare the experimental data to similar studies done previously across the world in order to determine the possibility of practically implementing a heat evaporation pool, as well as to develop a full prototype that would make the basis for building similar structures. In the past sever Russian scientist's worked at this scope, thermal cooling basins where located nearby nuclear and thermal power plants because turbine cooling required heat potential reduction. Those pools where open systems without heater. Water from turbines was supplied directly to the basin and sprinklers. In such a system it's easier to cool because heat potential is usually much higher than the outdoor air temperature (the coolant temperature is considerably higher). Remove maximum heat from the heater and refrigerate with the sprinkler spray in sufficient quantity within the prescribed limits is a challenge in closed – cycle refrigeration. Closed system allows locate basins in public places because the cooling circuit is protected against pollution.The research stand visualisation is provided in Figure No. 3.

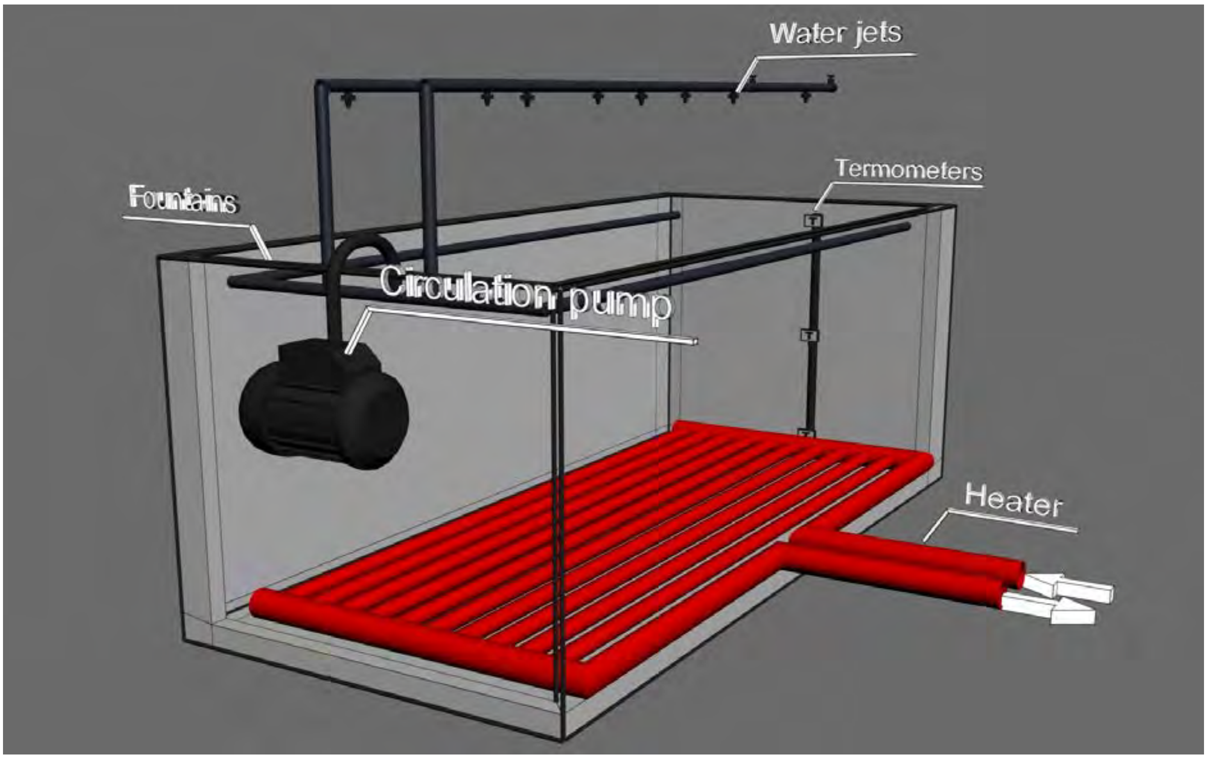

Fig. 3. Visualisation of Heat Evaporation Pool

The heat evaporation pool idea is based on the concept of uniting two systems; a heating element is placed inside the pool and a circulation pump is connected to deliver water inside the pool into sprinklers located above its surface. Compared to an evaporation tower, which is an open system, a pool is a closed system, which means that an evaporation pool may be located in inhabited areas, such as towns, parks, parking spaces etc.

Circulation pump: by adjusting the circulation pump's throughput, the intensity of droplet sprinkling may be adjusted, which will in turn be reflected in the cooling performance of the fluid. It should be considered that the cooling performance of a pool is also affected by a number of outside conditions, such as external air temperature, relative humidity, external wind speed; these parameters must are measured during the experiment, and the parameter value will be applied to the results of the heat engineering calculations. The heat transfer ratio must be adjusted depending on external air parameters. Near the basin is located weather detection station to obtain ear condition data during the experiment, up to now fully equipped experiment has lasted only for days in October 2010, when the outdoor air temperature at the ranged from +7 till +12° C per day. It was clear after comparing the temperature curves that at low outdoor air temperature cooling capacity was directly related the outdoor air temperature fluctuations, it can be seen in Figure No. 4. Graf shoes that basin cooling properties increases when outdoor temperature drops, it cannot be observed literally because of a heat storage. The other parameters made a minor impact on cooling capacity, except wind speed, it increases cooling properties and water loss. There are three thermometers placed in the basin to determine temperature changes in different strata. First is placed 0.3 m above the heater, the second 0.5 m below the air / water contact surface, the third is already over the air and water contact surface. All of these thermometers show the different temperatures.

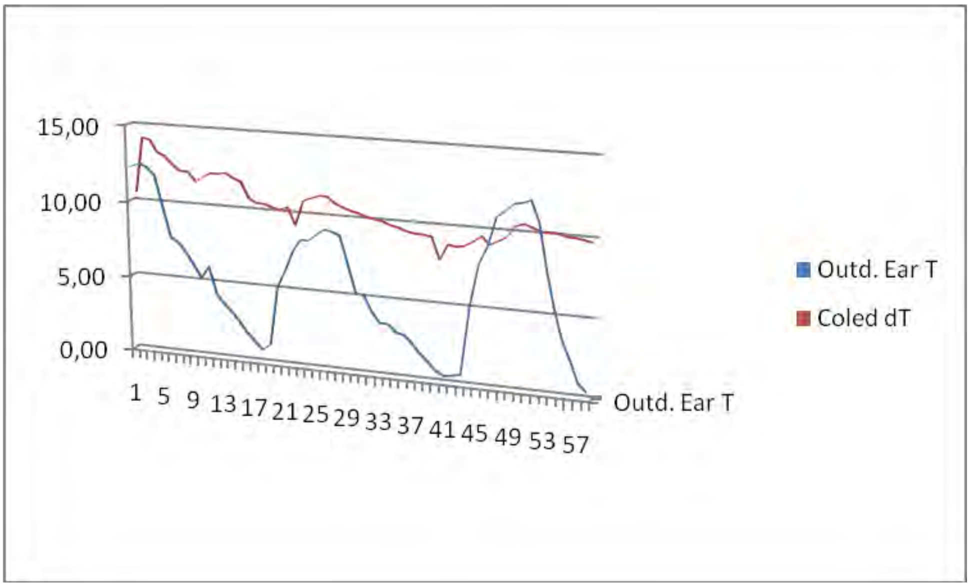

Fig. 4. *Outdoor air temperature impact on the cooling basin properties*

Heating element: a heating element is placed inside the pool, adapting it to the shape and area of the pool – in any case, the configuration of the heating element must be selected so as to create maximum heat carrier resistance and heat loss both as radiation and as hydraulic loss. The pool in question is connected to the boiler room's heat exchanger, which allows adjustment of heat carrier input temperature as well as heat carrier throughput.

The purpose of the heat evaporation pool is to retain the installed cooling parameters regardless of fluctuating external conditions.

Thermal cooling basin exploration for thermal calculations:

- Basin size $S = 11\text{m}^2$;
- Basin volume $v = 22\text{m}^3$;
- Basin temperature Schedule 35° – 29°C;
- Basin heat input $Q = 3.20\ \text{m}^3/\text{h}$;
- Circulation pump yield $Q = 8\ \text{m}^3/\text{h}$;
- Heat transition coefficient K kJ/m^2;
- Spray jet yield V m^3/s;
- Spray jet diameter $F = 0{,}001$m;
- Relative water weight $\alpha_p = 1\text{kg/m}^3$;
- Yield coefficient η - (0,6 – 0,75)
- Nozzle pressure drop $\Delta P = 0{,}00032\ \text{kg/m}^2$
- Gravitational force $g = 9{,}8\ \text{m/s}^2$;
- Pressure supply in lines 3,2 atm, 324240Pa;
- Relative air pressure P_g, Pa;
- Outdoor air temperature T_a, °C;
- Air relative moisture d, %;
- Wind speed v, m/s;

Water loss, depending on the outdoor temperature, coefficient k values shown in Table 1.

$$\Delta = k \cdot \Delta T, \% \qquad (1.)$$

Table 1. Coefficient k value depends on air temperature [2]

Air temperature, °C	0°	10°	20°	30°	35°
Coefficient *k*	0,10	0,12	0,14	0,16	0,17

Guided thermal basin volume:

$Q_{heat}=M \cdot C \cdot (T1 - T2)$; [3] (2.)

$Q_{heat}=22.34\ kW/h$;

Heat transition coefficient:

$K = Q/S \cdot \Delta T$; [3] (3.)

K= 0,33kW/m^2;

Sprayed water volume, changes depending on weather conditions:

$V = \eta \cdot F \cdot \sqrt{(2g)} \cdot \Delta P / \alpha_p$; [1] (4.)

$V = 1.5 \cdot 10^{-6}$ m^3/s;

3. Conclusions

Experimented will be repeated and basins cooling properties measured according with whether when the cooling is necessary – in summer.

Graf shoes there is minor influence on the basins cooling properties by wind speed, there must be assurance that fluctuating is insubstantial in suitable weather conditions.

Water jets and fountains musts be located to exclude terrorism danger.

There is a slight difference between the first and second thermometer readings, but significant deferent's with third thermometer readings because its located above ear and water contact area, but the deferent's between first and second thermometer is called by location, first thermometer located 0.3m above the heater and readings are 0.2-0.5°C higher, but when the heater is shut down readings shift and the second thermometer shoes 0.1-0.2°C higher temperature, this indicates heat flow change and basin heats from the outdoor ear and sunlight when the heater switched on basins heat potential is higher and heat flow changes.

The sprinkling intensity is determined and the heat transfer ratio is adjusted depending on external air parameter fluctuations in order to keep the Δ T value above the installed minimum.

The influence of external air parameters on Δ T changes must be determined during the study.

The most profitable sprinkling intensity must be determined considering the results.

Water volume has properties for heat accumulation, that's why after water jets are shouted down basins retains its cooling properties, for a while.

There musts be investigation before adapt thermal cooling basin to certain system, basins cooling properties changes depending on weather conditions.

Thermal cooling basin could be combined with equipment with absorption and compression cycles, solar collectors, PV and PVT solar cells.

Experiment will be continued and the results will be published.

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