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INLET-OUTLET ARRANGEMENT EFFECTS ON ICE BATH COOLING SYSTEM FOR ATHLETE'S INJURY RECOVERY PROCEDURE

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ABSTRACT

In sport therapy, ice bath cooling is a treatment to rehabilitate soft tissue and muscle trauma after a period of intense exercise. Rehabilitation is important for an athlete to maintain their performance at all time. This project is aimed to introduce a proper arrangement of inlet and outlet nozzles of a square athlete ice-bath pool system currently used at the National Sports Institute (ISN), Malaysia. The challenge is to have the most efficient arrangement to lower the temperature of the water from ambient temperature to11°C. In this study, the system is constructed based on the ambience, dimensions and cooling system used in the national institute. Analysis is performed for four (4) arrangements according to different position of inlet and outlet of the water to the pool. Amazingly, analysis shows that the common arrangement of placing the flow inlet and outlet adjacent to each other gives the most inefficient result. The study also prove that the optimum arrangement is a placement that has the longest distance between inlet and outlet of the water. This finding agrees well with the pre-assumption where the higher difference between the inlet water temperature as compared to the outlet water temperature will give higher cooling effect to the system. Quantitatively, 21% improvement of efficiency was achieved by rearranging the inlet-outlet nozzles from adjacent to diagonal corners of the pool. Without any complicated modification of the system, a significant improvement was achieved through this work.

Keywords: ice bath therapy, inlet and outlet, water temperature.

INTRODUCTION

Recovery is an important aspect for any physical programme. With this fact however, there are still many athletes that train extremely hard without giving their body enough time to recover. This misleading ignorance is often lead to overreaching, burnout or poor performances. Without a proper rehabilitation, it is hard for any athlete to maintain their high performance and furthermore, it can lead to riskier injuries. Countless effort had been done to spread the importance of this recovery process so that the athlete could continue exercising with controlled fatigue. The recovery methods are varies and can be classified as physical, physiological and nutritional rehabilitation. All for one purpose which is to speed up the recovery process.

Alternating hot–cold water immersion is one of the method that is very popular and can increase the speed of recovery after physical training and competition. According to research this treatment can accelerate the recovery of peripheral circulation by removing the body waste and stimulating the nerve system. Besides, it also can improve the blood circulation to the muscle and slower down the metabolism rate [4].

The most common means used for this treatment is ice cube, appropriate container and water. In National Sport Institute (ISN), Malaysia, there is a technology that have been used to lowering the temperature without the use of ice cube. The technology used is Icool machines from Australia. The working principle of this machine is similar to the commonly used ice bath cooling technology i.e. Vapor Compression Cooling System where the time required to change the temperature from 30 °C to 10 °C for 350 L of water is between 2 hours - 2 hours 30 minutes.

As it takes quite a long time to reduce the temperature, this technology is considered too inefficient for its purpose. Futhermore, the price is relatively expensive. The objective of this study is to investigate the effect of the position of water inlet and outlet on the cooling efficiency. The study was done in a canvas pool with dimension of 2m x 2m x 0.5m and the volume of water of 350 L. The study was conducted during day time with an ambient temperature range from 25-31°C. The minimum change in the method of operation was expected to be able to have a positive impact on the efficiency of the cooling system.

ICE BATH COOLING SYSTEM

Ice bath treatment

Pain that occurs in muscles usually caused by strenuous exercise known as "Delayed Onset Muscle soreness" (DOMS) [1]. Among the symptoms that can be felt in a reduction in the ability of the muscles to generate force and carry out [2]. During the last decade the ice bath treatment has become a popular treatment for overcoming DOMS [3]. This treatment usually be done after an intense exercise. The athlete will be immersed in the mixture of water and ice. The alternative way for this treatment is by interlace submerge in the cold and hot water.

Alternative of cooling technology

There are more than 10 alternatives of refrigeration technologies being developed to replace gas compression technology [4] including Solar Sorption Cooling. There are also simpler Absorption and adsorption cooling systems that operate almost similar to the conventional vapor compression refrigeration cycle where the main difference is that the thermal energy is the principle driver of the cycle instead of mechanical work [5]. Another interesting alternative is desiccant cooling. In cooling systems, the desiccant removes water from an incoming airstream, which is subsequently cooled by an evaporative cooler or air conditioner [6].

There also more uncommon concepts such as magnetic cooling which is based on the magnetocaloric effect (MCE). For normal (most) magnetocaloric materials, magnetization will lead to heating of the material, and demagnetization will lead to cooling of the material [6]. Another good example is called transcritical CO2 refrigeration cycle. A vapor compression refrigeration cycle whose heat rejection occurs above the critical temperature of the working fluid.

Position of inlet and outlet of water

Inlet and outlet flow positioning in water cooling system has long been studied in other applications. For power plants that adopt once-through cooling water system drawing cooling water from natural water area, there are commonly three kinds of water inlet-outlet arrangements: march-past method, differential method and eclipsed form method. The traditional march-past method has been used to improve the cooling efficiency by enlarging the spacing between inlet and outlet in the horizontal plane, usually with large investment [7].

The differential method is generally employed in power plants near tidal rivers and sea bays. The eclipsed form method is a kind of cooling water inlet-outlet arrangement used in China first, whose inlet is under the outlet and there is no horizontal distance between them. With the advantage of thermal stratified flow characteristics, such design is economical, compact and convenient to operate, and thus superior to march-past method if it is designed properly [7]. Knowing the effect of inlet-outlet positioning, this work has suggested four inlet-outlet arrangements for the said square athlete pool for the efficiency analysis.

METHODOLOGY

For the purpose of this work, an actual Icool machine from ISN was used, together with a full-scaled canvas pool, thermocouple data logger and a laptop to transfer all the data. The size of the pool was 2m x 2m x 0.5m and the capacity of water that was 350 liter. Thermocouple type K was used to obtain temperature measurement. Five of the thermocouples C3-C7 were placed in the pool as shown in Figure-1. The other two C1 and C2 are attach at the inlet and outlet of the machine. The remaining adjacent point values were just interpolated.

There were four arrangements conducted for this study. For the first arrangement, both inlet and outlet pipe were arranged next to each other as shown in Figure-2. The distance between two of them only 10cm. Both of them were directed in the same direction. This is the most common arrangement conducted by the practitioners based on the manufacturer's design and limitations.

C5	$\frac{C5+C6+C7}{3}$	C6
$\frac{C4+C5+C6}{3}$	C7	$\frac{C3+C6+C7}{3}$
C4	$\frac{C3+C4+C7}{3}$	C3

Figure-1. Position of thermocouple in pool.

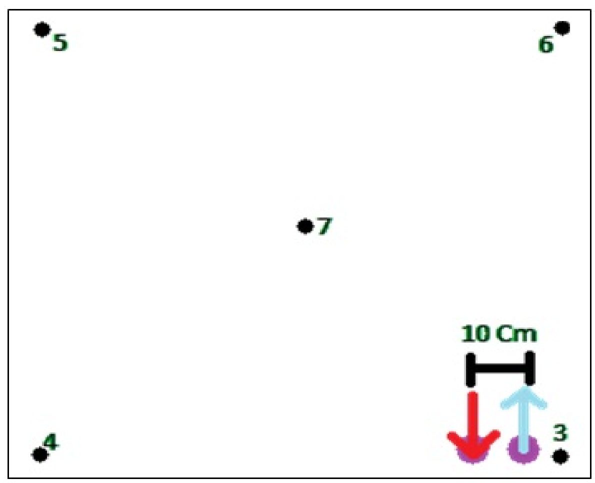

Figure-2. Arrangement 1.

The second arrangement was set up as shown in Figure-3, the distance between inlet and outlet pipe was about 43 cm, the direction of the inlet directed relatively to the north while the outlet was directed to the east of the pool. For the third arrangement the outlet pump was placed at the center of the pool while the inlet was just the same as 1 and 2 as shown in Figure-4. The distance between inlet and outlet was 141 cm.

The forth arrangement had the longest distance between inlet and outlet which was 282 cm. The position of the outlet pump is at the corner of the pool which was opposite to the inlet pump. The direction of the inlet pump was directed at the corner of the pool as shown in Figure-5.

After the equipment was installed, thermocouple data logger was set to record the data and transfer it to the

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laptop. The Temperature-Time data couple was then plotted and superimposed in a single plotting to clearly visualize the temperature variance between all observed points throughout the same period. Temperature distributions within the pool area along the period were also simulated in terms of 3D Bar by using Matlab Software.

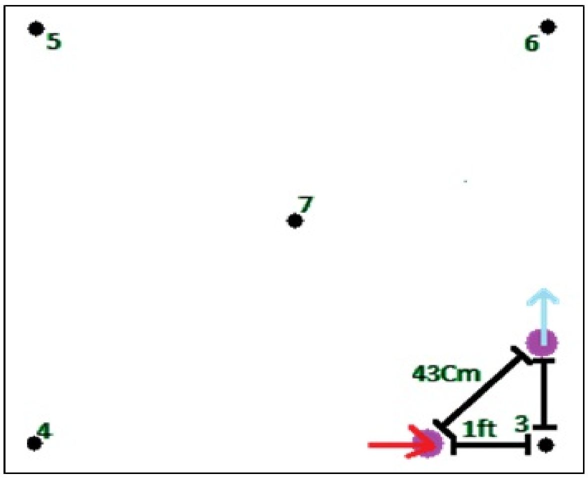

Figure-3. Arrangement 2.

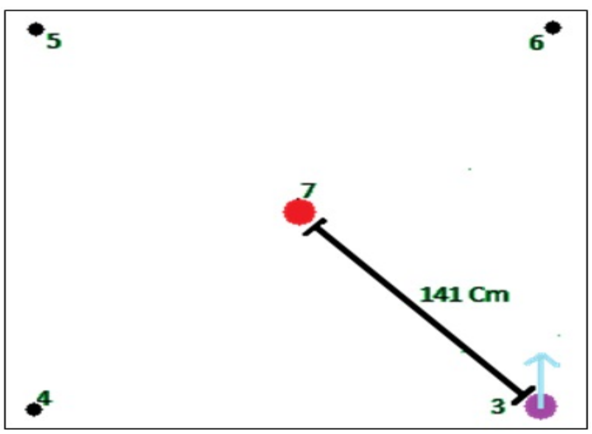

Figure-4. Arrangement 2.

RESULT AND DISCUSSION

Based on the data of the first arrangement, the most commonly used inlet-outlet placement took the longest time to lowering the time from 22 to 11 °C, which was 380 minutes. The total temperature drop in this experiment was about 10.52 °C. This phenomena agrees well with our initial hypothesis where the closer the inlet to the outlet, the less efficient the heat exchange will be. Most of the cold water that exit from the inlet was immediately pumped back into the machine without spreading evenly throughout the pool. The graph is as shown in Figure-6 for all five observed points.

The second longest time taken to lower the same temperature range was arrangement 2. It took about 360 minutes to lower the temperature from 22-11 °C. The average temperature lost from this experiment was 10.83°C. The distance between the inlet and outlet in this arrangement was not so significant as compared to the first arrangement. The efficiency difference however was due to the directions of both nozzles. It allowed the cold water from the inlet pump to flow smoothly around the wall without being pump immediately to the outlet pump. The swirl of the water against the clock direction however forced the cooling effect to be concentrated near the wall of the pool rather than the center location. The graph is as shown in Figure-7.

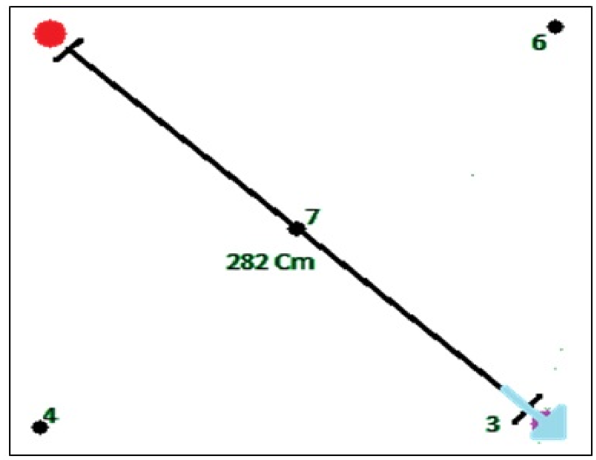

Figure-5. Arrangement 4.

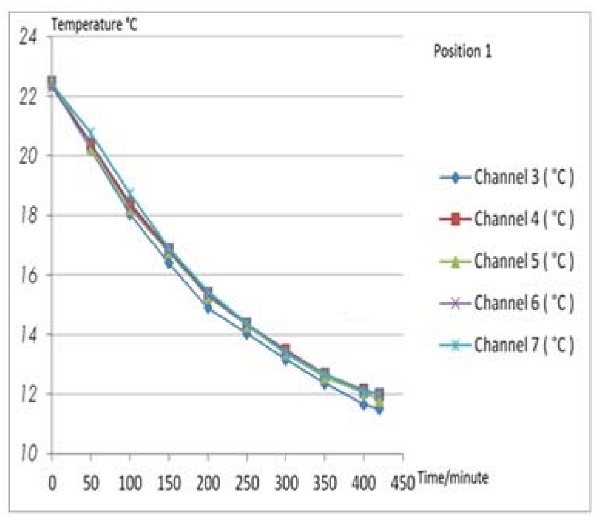

Figure-6. Graph of temperature against time for arrangement 1.

For the arrangement 3, it took about 340 minutes to lower the temperature from 22-11 °C. The average temperature lost from this experiment was about 11.16 °C. It was more efficient than the earlier two because the position of the outlet pump was placed at the center of the pool. As compared to the arrangement 1 and 2, this outlet pump was directed vertically, allowing the water to enter

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from all directions. This chaotic flow allowed more even heat exchange throughout the pool and resulted in more efficient cooling effect. The graph is as shown in Figure-8.

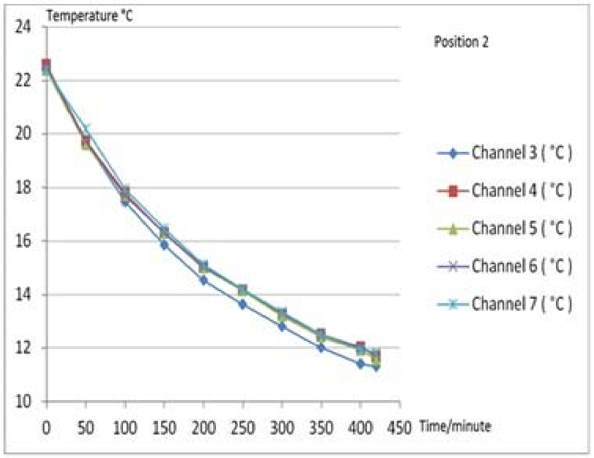

Figure-7. Graph of temperature against time for arrangement 2.

The fastest time taken to lower the temperature was recorded via arrangement 4. It took only 300 minutes to lower the temperature from 22-11 °C. The average temperature lost in this arrangement was about 11.39 °C. Similar to arrangement 3, this last arrangement was also applied the outlet nozzle vertically, allowing more turbulence to the water inside the pool.

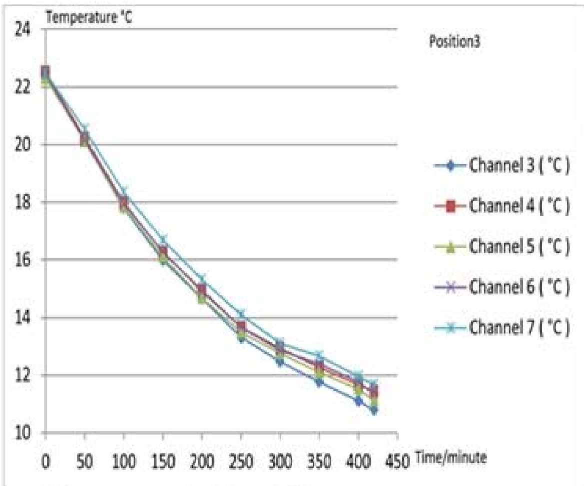

Figure-8. Graph of temperature against time for arrangement 3.

The fastest, most efficient arrangement recorded was mainly due to the longest placement distance and the direction of water from inlet to outlet. The inlet water was directed toward the corner of the pool allowing the water to split up into two contrasting directions. The graph is as shown in Figure-9.

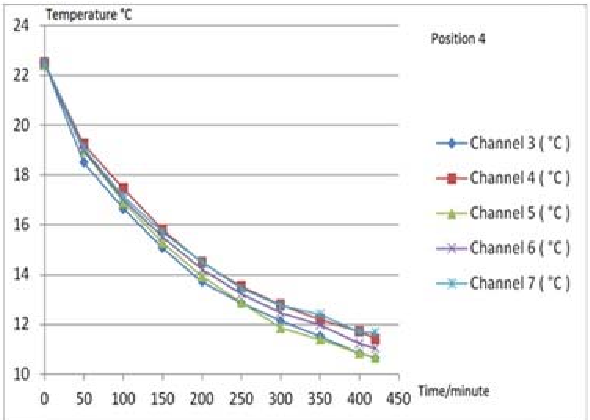

Figure-9. Graph of temperature against time for arrangement 4.

From the transient 3D temperature distribution bar simulation that was made using Matlab, it is observed that the fourth arrangement was way faster than the other arrangements in lowering the water temperature. A sample of the temperature bar distribution can be seen in Figure-10. The figure shows at time of 150 minutes, the pool center had slightly higher temperature than the surrounding points.

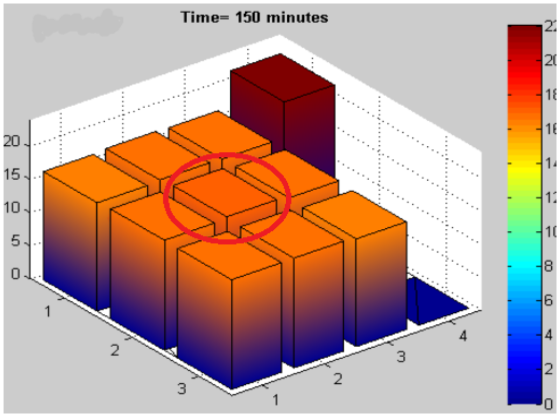

Figure-10. Low cooling effect at center of pool.

CONCLUSIONS

The results and analyses in this work have shown that the distance, position and flow direction has significant effect on the cooling system efficiency. The four arrangements have proven that the further the outlet from the inlet, the more efficient the system can be. This is most related to the fact that the efficiency of a cooling system is directly proportional to the water temperature difference between the inlet and outlet. The temperature difference can be optimized by means of inlet-outlet nozzle placements that determine the temperature distributions within the pool. The same concept can also be applied to other case studies that deal with water pool cooling system.

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