STRATEGY WATER-BASED CONDENSER :
An Experimental Scale Model for Hybrid Passive Cooling Systems to Improve Indoor Temperature and Hot Water Utilities in Surabaya-Indonesia

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ABSTRACT

This paper makes a case of energy saving research, to system water-based condenser for the use of energy efficient with involvement of forced fluid hybrid passive cooling and water heating in building systems. Our argument is based on the fact that series of water copper pipes are to be cooled enough by nocturnal radiant cooling of the night cool air to lower the indoor air temperature at the daytime. We describe the model of working to which we use and to which we believe that series of cool water copper pipes as evaporator allows effectively reducing the energy used for indoor cooling and for water heating utilization. We then measure the model indoor temperature, and water temperature inside the series of copper pipes. Kinds of water coolant used for cooling are an essential factor. Finally, we will discuss some of the achieving of the effective cooled water, setting up the pipes water-based condenser hybrid system on the top of the outside roof as well as setting up the evaporator coils at ceiling.

Keywords : water-based condenser, passive cooling, indoor temperature.

ABSTRAK

Penulisan ini merupakan suatu penelitian pada golongan sistem penghematan energi yang berupakan kondensor dengan bahan media air dengan bantuan tenaga gerak pompa atau tanpa tenaga pompa air. Pipa-pipa yang berisi air yang diletakkan diatas atap terbuka untuk mendapatkan air yang dingin melalui proses konduksi, konveksi, dan radiasi dari udara alami sepanjang malam, dimana media air yang telah dingin tersebut untuk dimanfaatkan sebagai media pendingin ruangan dengan melalukan ke pipa-pipa dalam ruangan--diatas plafon, sebagai evaporator. Selain media air akan diteliti air pendingin radiator (water coolent) apakah akan mendapatkan efek pendinginan yang melebihi media air. Juga akan diteliti cara proses mendapatkan media air dingin, yaitu proses dengan air tenang (still water) dan air bergerak (forced fluid), sistim mana yang lebih efektif dalam mendapatkan media air dingin dan percepatan mendapatkan air dingin.

Kata kunci : *kondensor sistim air, pendinginan pasip, temperatur ruangan.*

INTRODUCTION

The earth gains heat coming from the radiation of the sun. According to Szokolay (1992), 24% of the radiation reaches the ground level as direct beam radiation, and 22% as diffuse radiation whilst 23% is absorbed in the atmosphere. Radiation causes to heat. The greater the atmosphere absorbed the emitted radiation, the smaller the net emission dispatched from the surface temperature. In order to compensate this phenomena, it has to be restored the equilibrium. The equilibrium is from one state to another state that is thermodynamic or heat transfer. See more details in heat transfer principles discussusion that relates to conduct water-based condenser systems.

Problems

Indonesia locates at tropical region with the latitude ranging from 6^{o}8’ North to latitude 11^{o}15’ South and the longitude ranging from 94^{o}45’ East to 141^{o}5’ East. The hot and humid climate is almost throughout the year (Mangunwijaya, 1987). The wet or rainy season is approximate from the month of October to the month of April. Meanwhile, the dry or hot humid season starts from the month of May to the month of September. The Surabaya city is situated at latitude 7°15' South and longitude 112°45' East. And Surabaya experiences thermal condition with high temperature and humidity throughout the day and the year, even during the rainy season. *Figure 1* shows the Average weather condition measured by the Bureau of Meteorology Indonesia at Perak I & II as well as Djuanda stations from the year of 1996 to the year of 2001. Noticeable, the highest outdoor temperatures, mostly occur during the hot seasons that are month of October to December and, could reach around 35.0°C, nevertheless the lowest outdoor temperatures over the nighttimeduring that hot season could amazingly reach from 21.3°C to 22.0°C.

This condition would be quite beneficial to apply radiant cooling during the night. According to Givoni (1994), to be of any value as cooling system the radiator's stagnation temperature (cooling tool strategy) should be lower than the ambient night air by some minimum temperature drop to at least 5°C. Another natural cooling is the traditional ventilation cooling which would be the simplest strategy in warm, humid regions with relying on cross ventilation throughout the day with the exception of the outdoor maximum temperature does not exceed about 28°C to 32°C, and the diurnal temperature range is less than about 10°C. Surabaya experiences outdoor temperature of above 32.0°C during the daytime (see figure 1).

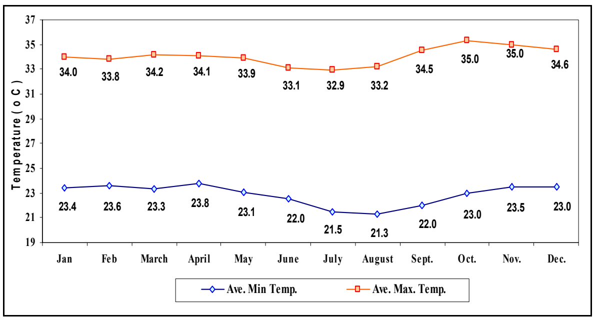


Figure 1. Average Minimum and Maximum Temperature of Surabaya from the year of 1976 to 2001. (Meteorology Indonesia at station Perak I & II & Djuanda-Surabaya)

In accordance with Nugroho (2001), that why so many people tend to use the air condition systems in their houses or buildings in Indonesia.

The problems would be, first, the air conditioning systems consume a high proportion of parasitic energy that could be came from many sources such as, coals, oils, gases, and nuclear powers. All that energies could be lasted and harmed the environmental ecosystem in the world, including us as human being that live within these ecosystems. Secondly, in order to save our worlds and to accomplish clean and green architecture environments, we, consequently, have the responsibility to conduct more passive low energy systems both for the cooling and heating, instead of active ones. Passive cooling systems are the control function of the building itself or cooling techniques that enable the indoor temperatures of buildings to be lowered through the use of natural energy sources, and the term "passive" does not exclude the use of a fan or pump when their application might enhance performance. The active systems, that is the various installations relying on some forms of man-made energy input. Meanwhile, the hybrid systems, that are relying various installation on man-made energy input devices but it is still using the passive cooling strategies—relying on the local weather conditions (mean outdoor temperature).

Hypotesis

Series of Water Pipes as Condenser Unit relying to Nocturnal Long-wave Radiation are to be Cool enough to reduce Indoor Temperatures during the daytime.

RELATED WORKS

This is little past research to improve room temperature on passive cooling for the summer and heating for the winter. Sweden researcher's Gudni Johannesson och Dietrich Schmidt (2001) carried out an experiment for saving energy and reducing dependency on oil and electricity for wall heating low quality energy—the lowest possible quality energy used from the nature. In order to use low temperature heat transfer, the large surfaces have to be used by supplying heat through coils or air ducts in floors, walls and ceilings. (see Figure 2).

A second experiment has done by Givoni (1994) for radiant cooling. He uses series of pipes as unglazed solar collectors on concrete roof as nocturnal radiators. During the summer night, the cooled water is circulated through the roof material—the concrete with series of pipes inside the structure. In this way the roof serves as the thermal storage element and the ceiling as a radiant cooling panel above the space to be cooled. The moveable panels are covered the pipes during the day. On the other hand, in winter unglazed solar pipes collectors are used to collect thermal heat and re-circulated in the room—convective & radiant effects—to warm the inhabitants at night. (see Figure 3).

Figure 2. Wall heating low quality energy that stored in the Ground. (Schmidt, 2001)

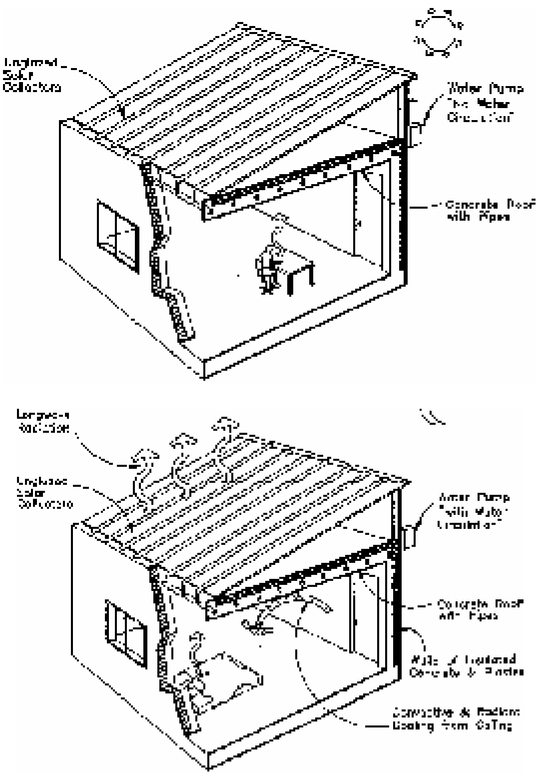


Figure 3. Unglazed solar collector functioning as a nocturnal radiator. (Givoni, 1994)

METHODOLOGY

Scope of this Research

The research will mostly be done experimentally, and is an overview of the hybrid passive cooling systems that are intended mainly for energy conservation as well as to designers who are considering their application to specific houses in a given climate. Due to the energies crisis in the world and the economics crisis in Asian, particular in Indonesia to which the economic has not been recovered fully yet, this research will emphasize the use of less energy.

The main purpose of the research is seeking the applicability of the systems—a condenser and evaporator units without using ordinary compressor and refrigerant as coolant—to lower indoor temperature within the suggested tropical comfort zone during the daytime.

The research will test and look for:

* The degrees Celsius that water-based condenser could reduce the indoor temperature.
* The right strategy for cooling water, and kinds of water as coolent fluid.
* The time of cooled water coils maintained in the scale model during the cooling time.
* The accomplishing of degrees Celsius that water coils condenser at the outdoor roof as hot water unit during the day.

The Materials of the Research

*** The Model**

The model is used for testing the room temperature and getting the Celsius degrees difference between the cooled water-coils and the room temperatures. The model has a scale of 1:8 to real size of 4.00 meter length, 4.00 meter width, and 4.00 meter height (0.5m x 0.5m x 0.5m). The total net areas are $0.25m^2$, and the total volume is $0.125m^3$. The dimension assumes as one of the regular room such as family, dining or bedroom in typical houses. In order to make the perimeters of the model as closely as possible to residence envelope properties (the resistance R, the conductance C, and the coefficients of transmission U), two unit plywoods of 12 mm each are used to obtain the R-value of 2.09, and the total coefficient of transmission U = 0.478. Meanwhile, the common residence walls that consist of 15 cm of common brick and two layer cement plasters of 2.5 cm each at both sides of the brick wall, have the R-value of 2.05, and the U value of 0.488.

*** The Condenser and Evaporator**

The material of copper pipe has been chosen due to its high thermal conductivity and diffusivity. According to Yunus (1998), the copper's conductivity k = 401 W/m^{2} • ^{o}C is higher than aluminum k = 237 W/m^{2}•^{o}C and the thermal diffusivity— another material property that appears in the transient heat conduction analysis which represents how fast heat diffuses through a material, again copper has the greater thermal diffusivity a = 113x10^{-6} than aluminum a = 97.5x10^{-6}. (see Table 1 & 2)

Table1 1. The Thermal Conductivities of some materials at room temperature

Material	k, W/m • °C*
Diamond	2300
Silver	429
Copper	401
Gold	317
Aluminum	237
Iron	80.2
Mercury (l)	8.54
Glass	0.78
Brick	0.72
Water (l)	0.613
Human Skin	0.37
Wood (oak)	0.17
Helium	0.152
Soft rubber	0.13
Refrigerant -12	0.072
Glass fiber	0.043
Air (g)	0.026
Urethane, rigid form	0.026

Multiply by 0.5778 to convert to Btu/

Table1 2. The Thermal Diffusivities of some materials at room temperature

Material	α, m^{2}/s*
Silver	149 x 10^{-6}
Glod	127 x 10^{-6}
Copper	113 x 10^{-6}
Aluminum	97.5 x 10^{-6}
Iron	22.8 x 10^{-6}
Mercury (l)	4.7 x 10^{-6}
Marble	1.2 x 10^{-6}
Ice	1.2 x 10^{-6}
Concrete	0.75 x 10^{-6}
Brick	0.52 x 10^{-6}
Heavy soil (dry)	0.52 x 10^{-6}
Glass	0.34 x 10^{-6}
Glass Wool	0.23 x 10^{-6}
Water (l)	0.14 x 10^{-6}
Beef	0.14 x 10^{-6}
Wood (oak)	0.13 x 10^{-6}

Multiply by 10.76 to convert to ft^{2}/s

Figure 4 illustrates the build scale model and the condenser unit of copper coils that consist of 9 meters long of 0.95 cm (3/8 in) diameter, and the thickness of the copper pipe is 0.05 cm. The heat transfer areas of the copper tubes are 0.26847m^{2} (it is equal to pDL for a circular pipe of length L). The net volume of the 9 meters copper coils is 0.5 liter. With the same model and size of the copper coils are to be used as evaporator unit inside the room.

Figure 4. (A) The scale model & condenser copper coils on top. (B) The evaporator copper coils inside the scale model.

*** The Coolant**

Water is to be used as refrigerant inside the condenser coils. There are several reasons, first of all, water is universal material, secondly, it's environmentally save and clean (green archi-tecture). Finally, water is a high conductivity material with k = 0.613 W/m^{2} • ^{o}C. Note that the thermal conductivity k is a measure of material's ability to conduct and absorb heat.

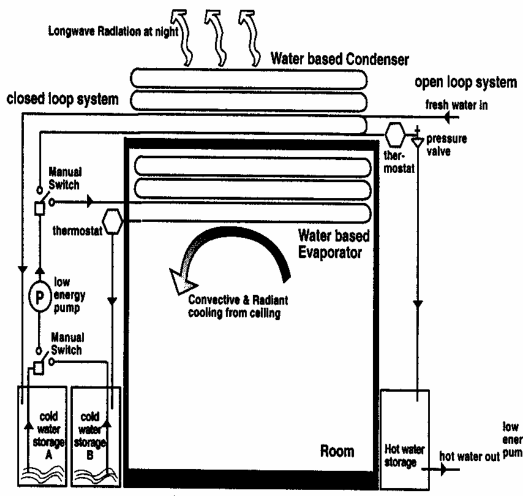
Figure 5. Proex thermometer DT-100.1S

*** The Measurement Tools**

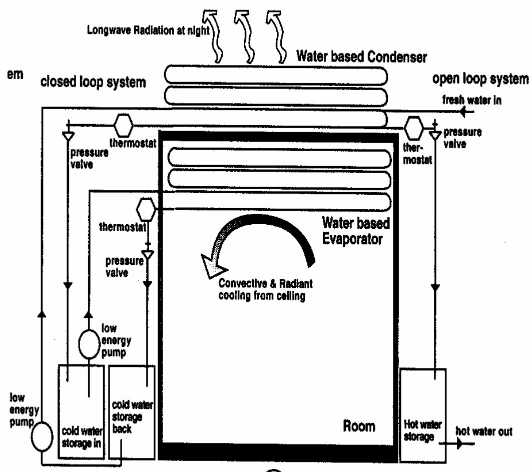
Measuring equipment are three units of "Proex" thermometer DT-100.1S with speci-fication of –40^{o}C/70^{o}C and two low energy aquarium filter pumps—25 watts low speed pump and 40 watts high speed pump. One small low energy fan is used for mixing indoor air temperature homogeneously.

PROCEDURES

The water-based condenser has two applying systems. One is called the closed-loop system that is cooling strategies, and the other one is identified as opened-loop system that is the water heating strategy. Both the closed and opened-loop systems will use water as fluid cooling and heating. In the cooling strategies (closed-loop system), the water will be circulated through the tubes—condenser—to let heat radiated by long-wave radiation effect to the night sky. In an attempt to obtain cooled water with "Forced Convection of Liquid" expressed in part A schematic (*figure 6 part A*), less energy either low or high speed pumps is utilized to circulate an one-gallon (18 liters as randomly chosen) of water continuously through condenser unit time by time till morning. Then the pump is switched manually to evaporator unit to reduce the room temperature during the daytime. The stream back of the water is then controlled with or without a thermostat to water storage. Two low energy pumps (on the measurement is using a 25 & 40 watt aquarium filter water pumps) are to be used to pump cooled water from the storage to the evaporator (coil pipes on the ceiling of the room) during the daytime—the effect of convection and radiant cooling with the room air occurred. It expects to reduce several degree indoor temperatures to enhance the human thermal comfort needed with passive cooling strategy. Alternatively, with "Steady Convection of Liquid" expressed in part B schematic (*figure 6 partB*), a thermostat and a pressure valve are utilized to control the flow of cooled water from the condenser and evaporator to the storage at a certain degree temperatures set.



(A)



(B)

Figure 6. (A) Schematic work of condenser coils with pump (forced convection). (B) Schematic work of condenser coils with thermostat (the conduction).

For collecting the hot water during the daytime, both the schematic part A and B systems of the condenser at the roof start gainning solar radiation as hot water which are controlled by heat thermostat and pressure valve for a certain degree temperatures down to hot water storage for household utilization used.

The process of taking cool-water measu-rement are under the bare sky location that is on the roof with many kinds of measurement tools. The recording of the timely temperature is recorded manually every hour started from 6.oo pm through 6.00 in the morning. *Figure 7* shows the process ing and tools in the morning to obtain the cooled water as well as the hot-water in coils condenser on the roof top. The *figure 8* indicates the processing of measurement of inner scale model temperatures dropped at one room house which acting as a thermal chamber to reduce as small as possible the influence of ouside temperature to the inner scale model temperature. *Figure 9* shows the condenser coils unit at ceiling of inner model.

Figure 7. Measuring process and tools at roof needed to obtain cool-water and hot-water

Figure 8. Measuring process and tools at room needed to measure scale model temperature dropped

Figure 9. Condenser coils unit inside the model acting as evaporator to reduce the model temperature

HEAT TRANSFER PRINCIPLES

The science of thermodynamics deals with the amount of heat transfer as a system undergoes a process from one equilibrium state to another, and make no reference to how long the process will take. Heat can be transfer in three different ways: conduction, convection, and radiation. *Conduction* is the transfer of energy from the more energetic particles of a substance to the adjacent less energetic ones as result of interactions between the particles.

In the meantime, *convection* is another mode of energy transfer between a solid surface and the adjacent liquid or gas that is in motion, and it involves the combined effects of conduction and fluid motion. Heat Transfer through the fluid layer will be by convection when the fluid involves some motion and by conduction when the fluid layer is motionless. The faster the fluid motion, the greater the convection heat transfers. Forced convection is the use of external means such as fan, pump, or the wind to force the fluid to flow over the surface. In contrast, natural convection is called if buoyancy forces that are induced by density differences due to the variation of temperature in fluid cause the fluid motion. Despite the complexity of convection, the rate of convection heat transfer is observed to be proportional to the temperature difference..

Radiation is the energy emitted by matter in the form of electromagnetic waves or photon as a result of the changes in the electronic configurations of the atoms or molecules.

THE MEASUREMENT RESULTS

* The Water-Cooled

Obtaining as low as possible cooled water to certain degrees Celsius is the main subject. The subject to water-based condenser to reduce as much as possible the room temperatures to several degrees Celsius depends on radiant as well as conduction and convection cooling processes. Any surface emits radiation with a spectrum of wavelengths, which depends on its temperature. At the ordinary temperature found on the earth the emitted radiation is in the long-wave range. The downward flux of atmospheric long-wave radiation is weaker than the radiation emitted upward by ordinary surface. The result is a process of net long-wave radiant heat loss and a surface cooling to the sky. Taking that nature phenomena manner, the coils condenser filled with water on the roof is going to process with long-wave radiant—a process depending on night sky temperatures. Besides the radiant cooling, the conduction and convection effects are also taking place to cool the water. The larger the areas of the condenser at roof-top, the larger amount of cooled water will be obtained at once time.

There are Four Types of Measurement to Collect Cooled Water as Coolant. The first type of measurement to get cooled water is with still water that remains motionless in the copper coils till morning. *Figure 10* explains the mean cooled water obtained by the process of convection and conduction—motionless water inside the copper coils during the July month. The coils water-condenser temperature from the begining to over night temperature are almost the same even at 6 o'clock in the morning. The water is cooled to 26.8^{O}C.

The second type of measurement of getting cooled water is still conduction and convection but using radiator coolant—Top 1 long life formula—instead of ordinary water. With respect to the chemical contained in the radiator coolant to prevent over heated, the more cooler temperature will be obtained than the ordinary water temperature. The reality shows in *figure 11* that the radiator coolant gives no much action to lower the temperature than ordinary water temperature, nevertheless, it speeds up the heat transfer rate by 8 hours (the lowest temperature of 26.4^{O}C for ordinary water temperature reaches at 6 o'clock in the morning, and for the same temperature of 26.4^{O}C for radiator coolant only reaches at 10 pm). The radiator coolant is still relying on the nocturnal temperature.

The third measurement strategy to get lower cooled water is using a low-speed aquarium filter pump—circulating amount of water (18 liters at tested) continuously till morning. The forced convection—conduction and radiation cooling effects are to be used to gain as low as possible the water-cooled temperature and faster heat transfer rate. Noticed at the *figure 12* at which the temperature of 24,7^{O}C is reached at 9 pm. Along with circulated water, the faster heat transfer time is obtained with 9 hours difference to conduction mainly. And there is only an hour faster than using radiator coolant. The big different is in the lowest cooled water temperature in coils condenser of 22.7^{O}C obtained in the morning at July month with the lowest outdoor temperature of 25.8^{O}C which is higher than the lowest outdoor temperature of 24.9^{O}C measured with water coolent and, it only got cooled water coils condenser of 24.3^{O}C in the morning.

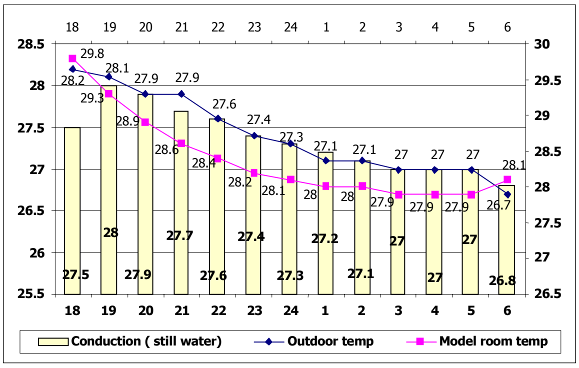


Figure 10. Cooled water temperature obtained by still mode (conduction) at July month

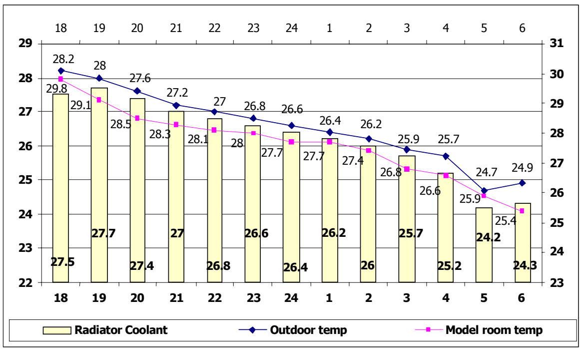


Figure 11. Cooled water temperature obtained by using radiator coolant in still mode at July month

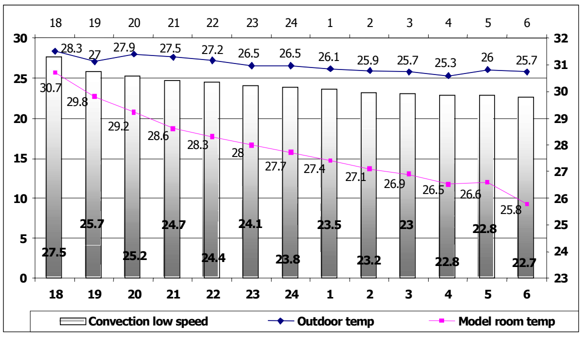


Figure 12. Cooled water temperatures obtained by using low speed filter pumpat July month

The last measurement strategy is to use a low energy but high-speed aquarium filter pump to increate the rate of heat transfer. Forced convection is happened when it involved fluid motion. The fluid motion will enhances heat transfer, since it brings hotter and cooler chunks of fluid into contact with the copper coils, initiating higher rates of conduction at a greater number of sites in a fluid. Therefore, the rate of heat transfer through a fluid is much higher by convection than is by conduction. The higher the fluid velocity, the higher the rates of heat transfer. The results could be seen in *Figure 13* which indicates the fluid flown with high pump to get lower cooled water temperature in the morning, also to get faster heat transfer rates with compared to conduction (still water and radiator coolant). Observed that the temperature of 24,7^{o}C is reached at 8 pm which is an hour faster than using low speed pump and the lowest outdoor temperature in the morning reached to 25.7^{o}C.

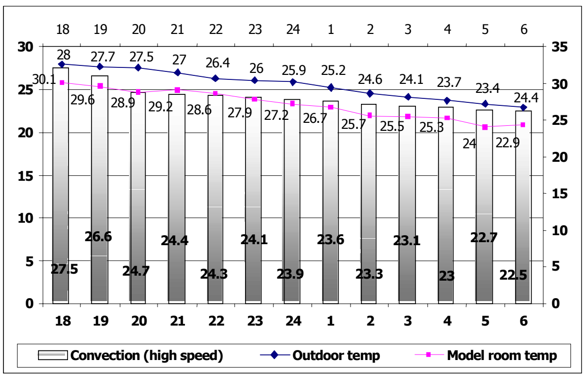


Figure 13. Cooled water temperatures obtained by using high speed filter pumpat July month

In order to obtain the average cooled water coils condenser temperatures for testing the inner model temperature reduced levels and time consuming, several measurement have been conducted on four kinds of parameters which are still mode, water coolant, low speed pump, and high speed pump within one year. The conducted months taken are in January, May, July, and November. Each month could be represented the two natural seasons--wet and hot happened in Indonesia's climate condition. Measurement conducted in January had the purpose to get the cooled water coils condenser during the peak rainy seasons time. Then, one measurement in month of May was conducted due to the month of May is almost come to the end of the rainy seasons. Another measurement was taken in July that because of cooler weather over the nighttime and in the morning influenced by winter wind blown from Australia. The other measurements tested on November is because of the November is not only the last hottest seasons month but also the beginning of the rainy seasons.

Figure 14 marks the average coils temperatures on four different types of tested parameters. Noticed that the average coils temperatures with "still mode" was almost around 26^{o}C in January. When it rained, the temperature would drop fastly and then the temperature will raise back slightly after the rain stopped. During the rainy night, the coils temperature will almost constant to the outdoor night temperature. So with the average cooled water coils temperatures in May are slightly lower than cooled water coils temperatures in January, and the temperature differences between the cooled water coils and the outdoor night are almost similar and around 25^{o}C to 26^{o}C. Only in July month, the great temperature different occured between the coils water and the nocturnal temperature. Due to the cold winter wind blown from Australia to Indonesia, cooled water coils temperature will be obtained higher than lowest morning outdoor temperature. On the other hand, cooler water coils temperature with the still mode tested was below morning outdoor temperature. These indicated that in order to get cooled water over night with still mode strategy is less effective than using forced fluid strategies.

The last test conducted in November showed that all four types of modes would not be effective to gather the lowest cooled water coils temperature in the morning, just because of the nighttime temperatures are already high over the night. It will only get an average of cooled water temperature of around 28^{o}C to 29^{o}C. Those coils temperatures would not enought to cool or reduce the ventilated inner room temperature during the daytime around 29^{O}C to 31^{O}C.

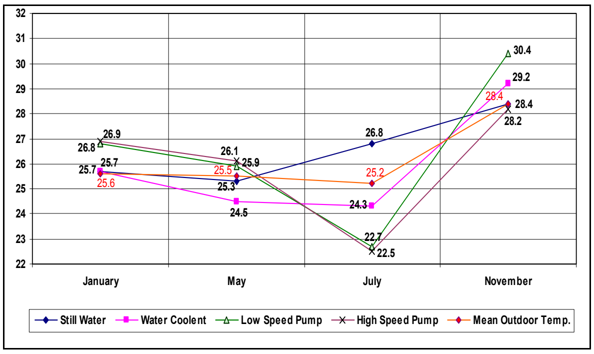


Figure 14. Average cooled water coils condenser temperature on four type of parameters

*** The Hot-Water**

The copper condenser coils used as nocturnal radiant cooling at rooftop have another function to collect hot water during the daytime. Fresh water from other water storages is pumped and kept in condenser coils on top of the roof until it reaches to certain heat degrees Celsius. The conduction effect is used to gain solar radiation from the sun at noon. *Figure 15* illustrates the cooper coils could reach to a 43^{O}C at noon with the mean outdoor temperature of 33.3^{O}C. In order to have large amount of hot water at once time, a larger condenser coils covered the roof is needed.

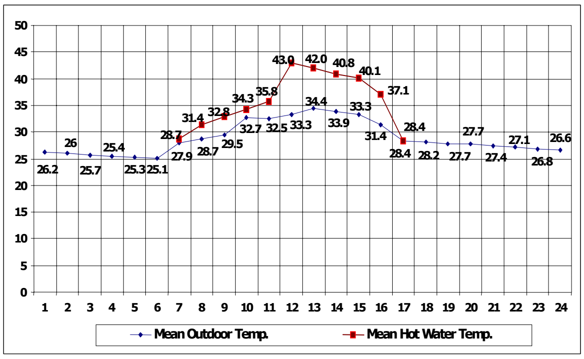


Figure 15. Heated Condenser Coils as Collecting Hot Water

*** The Inner Scale Model Temperature Reduced**

The collected cooled water can be utilized to reduce the indoor temperature by means of convection through evaporator unit. Referenced by Givoni (1994), in hot and humid regions with clear skies the expected temperature drop would only be about 2^{O}K to 3^{O}K and the moisture might be condensed out of the air as it flows under the condenser unit, or evaporator in the room. Meanwhile, in arid regions expectation of a temperature drop from 3^{O}K to 5^{O}K would be achieved.

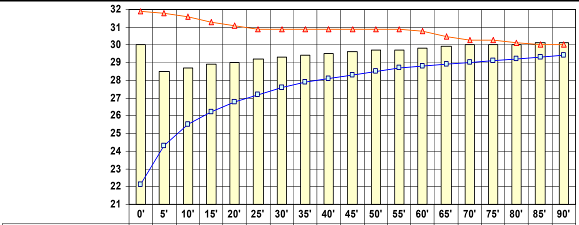
*** Reduce the Inner Model Temperature with Lowest Temperature of 22.1^{O}C**

Table 3 shows the collected cooled water coils temperatures either by still water mode only annually or by four types of tested modes within a year to obtain and determine a mean cooled water temperature of about 26.1^{O}C and the lowest cooled water obtained of 22.1^{O}C for reducing the inner model temperatures. Therefore, the indoor model temperature will be reduced with two type of cooled water temperature parameters. First, it is the 22.1^{O}C as the lowest cooled water obtained in a year, and secondly, it is the 26.1^{O}C as the mean cooled water temperature gained annually.

Table 3. Cooled water coils condenser temperature obtained annually

	Mean Still Water Temperature (oC)	Mean Water Coolant Temperature (oC)	Mean Low-speed Water Temp. (oC)	Mean High-speed Water Temp. (oC)	Mean Outdoor Temperature (oC)	Lowest Cooled Water Temp. (oC)
January	25.7	25.7	23.8	28.9	25.6	25.2
February	25.9	-	-	-	25.6	24.4
March	27.5	-	-	-	26.6	25.2
April	27.1		-	-	26.9	25.7
May	25.3	24.5	25.8	26.1	25.5	24.5
June	24.5	-	-	-	23.8	23.1
July	26.9	24.3	22.7	22.5	25.2	22.5
August	23.1	-	-	-	23.1	22.1
September	24.7			-	24.4	22.8
October	26.1	-	-	-	25.6	24.6
November	28.1	29.2	30.4	28.2	28.4	26.5
December	26.4	-	-	-	25.6	25.4
Average	26	25.9	26.5	25.9	25.6	

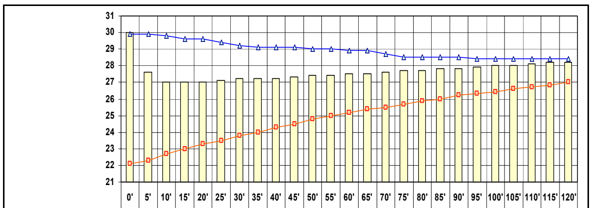
Figure 16 shows the lowest cooled water of about 22.1^{O}C as collected by condenser unit to cool the inner scale model temperatures by two kinds of strategies. Fist strategy is to apply the conduction cooling—still cooled water on evaporate unit. It takes about 5 minutes to reduce the room model temperatures from 30.0^{O}C to 28.5^{O}C. The difference of the temperature is about 1.5^{O}C with evaporator copper coils volume of 0.5 liter of cooled water and the scale model volume of about 0.125 m^3. Obviously the cooled water temperatures could remain for 70 minutes before the room scale model temperature was rising back to 30.0^{O}C.



	0'	5'	10'	15'	20'	25'	30'	35'	40'	45'	50'	55'	60'	65'	70'	75'	80'	85'	90'
Room Model Temp.	30	28.5	28.7	28.9	29	29.2	29.3	29.4	29.5	29.6	29.7	29.7	29.8	29.9	30	30	30	30.1	30.1
Water Radiator Temp.	22.1	24.3	25.5	26.2	26.8	27.2	27.6	27.9	28.1	28.3	28.5	28.7	28.8	28.9	29	29.1	29.2	29.3	29.4
Outdoor Temp.	31.9	31.8	31.6	31.3	31.1	30.9	30.9	30.9	30.9	30.9	30.9	30.9	30.8	30.5	30.3	30.3	30.1	30	30

Figure 16. Reducing inner model temperature with 22.1^{o}C and the length of time maintained by still fluid mode

The second strategy is to let the 12 liters cooled water of about 22.1^{o}C run continuously through the evaporator unit with high-speed aqurium filter pump. *Figure 17* indicates amazingly the room model temperature reduced and the length of time cooled water maintained longer. The room scale model temperature of 30.0^{o}C would be reduced with 12 liters of cooled water temperature of 22.1^{o}C by high-speed pump running continuously. Noticeable that the room model temperatures immediately reduced from 30.0^{o}C to 27.0^{o}C. It reduces the room scale model temperature of about 3^{o}C in 5 minutes, and maintains the 27.0^{o}C for almost 20 minutes. The whole 12 liters of cooled water running continuously have lasted over two hours before the cooled water temperature raised back to 30.0^{o}C.



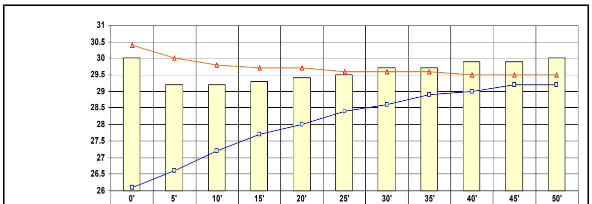
	0'	5'	10'	15'	20'	25'	30'	35'	40'	45'	50'	55'	60'	65'	70'	75'	80'	85'	90'	95'	100'	105'	110'	115'	120'
Room Model Temp.	30	27.6	27	27	27	27.1	27.2	27.2	27.2	27.3	27.4	27.4	27.5	27.5	27.6	27.7	27.7	27.8	27.8	27.9	28	28	28.1	28.2	28.2
Water Radiator Temp.	22.1	22.3	22.7	23	23.3	23.5	23.8	24	24.3	24.5	24.8	25	25.2	25.4	25.5	25.7	25.9	26	26.2	26.3	26.4	26.6	26.7	26.8	27
Outdoor Temp.	29.9	29.9	29.8	29.6	29.6	29.4	29.2	29.1	29.1	29.1	29	29	28.9	28.9	28.7	28.5	28.5	28.5	28.5	28.4	28.4	28.4	28.4	28.4	28.4

Figure 17. Reducing inner model temperature with 22.1^{o}C and the length of time maintained by high-speed aquarium pump continuousl

* Reduced the Inner Model Temperature with Mean Temperature of 26.1^{o}C

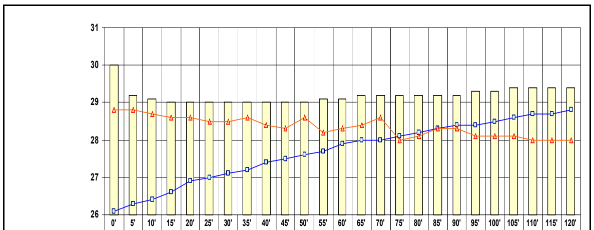
With the same procedures of reducing the room model temperatures described above, the first strategy is by applying still mode--no moving fluid on coils condenser with the mean cooled water temperature of 26.1^{o}C trying to reduce the room model temperature of 30.0^{o}C. The fact is that the room model temperature reduced only 0.8^{o}C during 5 minutes in progress, and then it raised back gradually to 30.0^{o}C within 50 minutes. *Figure 18* shows the collected mean cooled water coils temperature of 26.1^{o}C cooled the room model temperature by still mode only.

On the contrary, it could be seen on the *figure of 19* that the room model temperature has been reduced from 30.0^{o}C to 29.0^{o}C by forced fluid moving with high-speed aquarium filter pump. The inner model temperature reduced to 1^{o}C has been achieved with 15 minutes running continuously till 50 minutes before it was going to raise back to 30.0^{o}C for about two hours more. Noticed that the cooled water coils evaporator temperature for every 5 minutes time run on reducing inner model temperatures is slightly raising and, it sometime remains the same temperature for couples of another 5 minutes. Proving that the room for conducting model tested as a thermal chamber has been worked quite properly to about 0.1^{o}C lost for every 5 minutes runtime.



	0'	5'	10'	15'	20'	25'	30'	35'	40'	45'	50'
Room Model Temp.	30	29.2	29.2	29.3	29.4	29.5	29.7	29.7	29.9	29.9	30
Water Radiator Temp.	26.1	26.6	27.2	27.7	28	28.4	28.6	28.9	29	29.2	29.2
Outdoor Temp.	30.4	30	29.8	29.7	29.7	29.6	29.6	29.6	29.5	29.5	29.5

Figure 18. Reducing inner model temperature with 26.1^{o}C and the length of time maintained by still fluid mod.



	0'	5'	10'	15'	20'	25'	30'	35'	40'	45'	50'	55'	60'	65'	70'	75'	80'	85'	90'	95'	100'	105'	110'	115'	120'
Room Model Temp.	30	29.2	29.1	29	29	29	29	29	29	29	29	29.1	29.1	29.2	29.2	29.2	29.2	29.2	29.2	29.3	29.3	29.4	29.4	29.4	29.4
Water Radiator Temp.	26.1	26.3	26.4	26.6	26.9	27	27.1	27.2	27.4	27.5	27.6	27.7	27.9	28	28	28.1	28.2	28.3	28.4	28.4	28.5	28.6	28.7	28.7	28.8
Outdoor Temp.	28.8	28.8	28.7	28.6	28.6	28.5	28.5	28.6	28.4	28.3	28.6	28.2	28.3	28.4	28.6	28	28.1	28.3	28.3	28.1	28.1	28.1	28	28	28

Figure 19. Reducing inner model temperature with 26.1^{o}C and the length of time maintained by high-speed aquarium pump continuously

CONCLUSIONS

Using the cooled water on coils condenser and evaporator as cooling fuild is quite effective as a tool to reduce the room model temperature to about 3°C for the lowest cooled water temperatures by applying both the convective, conduction, and radiant cooling strategies—circulated water continuously either by collecting cooled water in condenser or diffusing the cooled water temperature by convection and radiant cooling from evaporator. But, It seems to be un-effective to cool or reduce inner room temperature if using the mean cooled water temperature of about 26.1°C either by still or forced fluid moving modes.

By observing the average tested results on obtaining the lowest cooled coils water condenser temperatures each month for a year, the cooled water coils temperatures around 25.0°C to 26.0°C are quite many months such as on January, Pebruary, March, April, May, October, and Nopember as well as December. Within these months, the collected cooled water coils temperatures could be used just to reduced inner room temperatures around 1°C merely. And only several months where having winter wind blown from Autralia could have cooled water temperatures as an effective cooled water to reduce room temperatures during the daytime.

On the daytime, the water coils condenser on top of the roof seems to be useful to collect hot water and the temperatures could be reached to 43.0°C at noon then it will cool down slightly till 37.1°C at 16.00 pm.

In the future, we expect to see another research for reducing the indoor temperature more with lasting longer as well as finding out the sum of the cooled water needed compared to the condenser coils areas. But anyway, realized that applying more passive cooling strategies, we not only save the world but also save the human-mankind in our world now.

REFERENCES

Bradshaw, Vaughn, *Building Control Systems*, John Wiley & Son, New York, 1985, pp 12–36.

Cengel, Yunus A., *Heat Transfer:A practical Approach*, McGraw-Hill, Boston, 1998, pp 22-32, pp 899-919.

Givoni, Baruch. *Passive and Low Energy Cooling of Buildings*, Van Nostrand Reinhold, New York. 1994.

http:/www.bom.gov.au/climate/environ/design/climzone.shtml

http:/202.159.18.43/data/kondisi-wilayah.htm

http:/www.wunderground.com/cgi-bin/findweather/getForecast?query=indonesia

Mangunwijaya,Y.B., *Pasal-pasal Pengantar Fisika Bangunan*, PT.Gramedia, Jakarta. 1980.

Sufianto, Heru, *Perilaku Thermal bangunan Rumah Tinggal di Surabaya*, Jurnal Teknik, Brawijaya University, 1996, pp 08-09.

Stein, Benjamin, John S. Reynolds and William J. McGuinness, *Mechanical and Electrical Equipment for Buildings,* John Wiley & Sons, New York, 1986, pp.23-27.

Swedish Research for *Sustainability* No. 3-4/ 2001, pp.8-9.

Szokolay, S.V., *Architecture and Climate Change*, RAIA Education Division, Australia, 1992, pp 08–10.