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Discussion and Measurement of Applying a Cooling Fogging Air-Conditioning System for Working Environment Cooling and Air Quality Improvement

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ABSTRACT
The traditional blowing spray cooling system uses turbulent fan and mist at ambient temperature to cool an open space based on the principle of evaporative cooling. However, its cooling effect is affected by the mist temperature, spray capacity and ambient wet-bulb temperature. If the spray particle temperature is not reduced, the cooling effect is limited. Before reaching the preset target ambient temperature, the spray capacity of the system needs to be increased, thus may overwet the environment and affect its applicability. This study used the refrigerating air conditioning technology to modify a water chiller to a cooling fogging chiller for the blowing spray cooling system. The system can spray 8°C low temperature mist under high pressure, thus improving the poor cooling efficiency of the conventional design. The on/off of the cooling fogging air-conditioning system can be controlled by the ambient humidity, thus avoiding excessive ambient humidity. The measurement results showed that the system can reduce the ambient temperature by an average of 5.5°C or more, ensure the stability of the humidity change, increase the number of anions in the environment during operation, thus effectively improving the ambient air quality.

Key words: Blowing spray system, cooling fogging cooling, evaporative cooling

INTRODUCTION

Located in subtropical zone, Taiwan has wet and hot climate. According to the statistical analysis of the Central Weather Bureau on Taiwan's climate change in the last century, the average air temperature has increased by 1.4°C which is twice the global average warming rate. Moreover, the summer period is extending gradually (Central Weather Bureau, 2008). For workers who are exposed to hot working environments, the probability of heat stress caused by high temperature increases over the years. In order to maintain the quality of working environments, the common methods to control the ambient temperature and humidity include ventilation, refrigerating air conditioning circulation system, waterwall system and blowing spray cooling system.

Ventilation is the most popular and least expensive cooling mode. Theoretically, the minimal cooling degree of natural ventilation or forced ventilation equals to the atmospheric temperature. Hence, insufficient cooling is likely to occur when the outside air temperature is high (Huang, 1999). In contrast, the refrigerating air-conditioning cycle system is the most efficient and comfortable cooling mode but its cost is very high. For an open working environment with persistent high temperature heat source, the load is multiplied and the power consumption is enormous. Thus, it is not commonly used unless it is cost efficient. The waterwall system pumps air forcibly to reduce the temperature by heat exchange between the outside air and the circulating waterwall, so as to regulate indoor temperature. The cost is low and the cooling efficiency is stable. However, it is difficult to clean and mold may easily grow on the waterwall structure, thus affecting the health of indoor animals and plants. Moreover, it is likely to cause indoor temperature gradient and the difference increases with the indoor length (Huang, 1999). The blowing spray cooling system that combines turbulent fans with mist nozzles is extensively used for cooling operation in greenhouse and open working environment (Chou, 1997). Its precision nozzle produces mist and the fan increases the surface area and migration distance of the spray particles. The heat exchange efficiency is thus increased. The advantage is that the temperature distribution is uniform and the cost is low (Huang, 2000). Among conventional technologies, mist at ambient temperature is often used for evaporative cooling in the environment. Its cooling efficiency is affected by the mist temperature, spray capacity and ambient wet-bulb temperature. As the spray particle temperature cannot be reduced, if the temperature of the operating environment has not reached the preset target temperature, the system needs to extend the spray time to increase the spray capacity but it may overwet the environment which decreases the human comfort and workpiece accuracy declines. Therefore, its applicability is limited.

This study used a water chiller to produce the chilled water to be sprayed and regulated the spray water temperature according to the environmental operation requirements. The lowest temperature could be 8, so as to remedy the defects of limited cooling effect and the overwet problem in the traditional blowing spray system. Moreover, a negative pressure fan was constructed in an open working environment, so as to uniformize the temperature distribution in the space, remove dust and pollutants and prevent overwet environment. After constructing the facility, the cooling operation was carried out under the spraying pressure of 100 kgf cm^{-2} at the construction site. The environmental and air quality indexes of ambient temperature and humidity distribution, as well as the quantity of anions, were measured to analyze the effectiveness of environmental improvement.

MATERIALS AND METHODS

Principle of evaporative cooling: In the application of air conditioning engineering, the composition of atmosphere can be divided into dry air and vapor. When the liquid water removes the latent heat in the air, it evaporates into vapor. The relative humidity increases while the air is cooled. This process is called evaporative cooling. Figure 1 shows the application of different situations of contact between water and air to the humid air line graph (Wang, 2007a). Process A is the water heats and humidifies the air at a temperature higher than the air (DB). Process B is the water contacts the air at a temperature lower than DB but higher than the air (WB). Process C is the water temperature equal to air WB. Process D is water temperature lower than WB of air but higher than air (DP). Process E is the water contacts the air at a temperature lower than the air DP, this is cooling dehumidification. Processes B, C and D are evaporative cooling. The traditional spray cooling system uses ambient temperature water to cool the air. The characteristics of the cooled air are mostly between B' and D'. The water temperature even increases to Condition A as the water storage system receives solar heat and pumping pressure, thus increasing the ambient temperature.

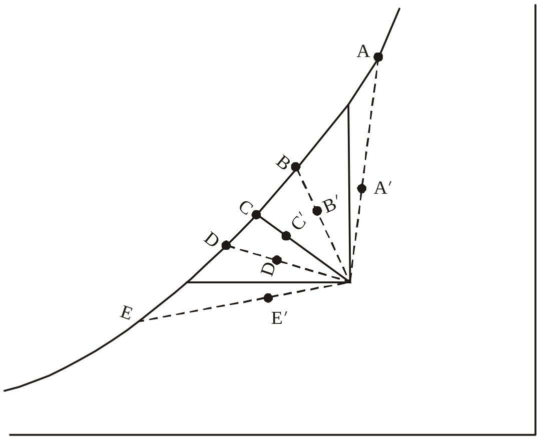


Fig. 1: Change of the state when water at different temperatures contact the air

Influencing factors in cooling efficiency of spray system: When the evaporative cooling equipment is used for cooling the environment, the dry-bulb temperature and relative humidity of outside air has considerable influence on the cooling efficiency. When the environmental conditions are eliminated, the system influencing factors include the atomization capacity of nozzle, ventilation mode, system control strategy and water quality parameters.

Atomization capacity of nozzle: When mist is used as the evaporative cooling medium, the atomization capacity of the nozzle is an important index. The water spray particle size is generally defined as single statistical mean diameter. The common definitions of mean particle size include.

When VMD is marked as Dv (50), it means that there are 50% of total liquid volume in water droplets in small diameter. SMD is defined as the mean diameter calculated by dividing the spray volume by the surface area of fog droplets, namely, the ratio of the total surface area of fog droplets to the amount of sprayed water. The smaller the diameter of water droplets is, the larger the surface area of mist and the heat exchange area are. The friction resulted from the fog cluster through the air increases accordingly, so that the atomized particles stay in the air longer and have enough time to evaporate. Hence, the vaporization efficiency is increased. The National Fire Protection Association (NFPA) 750 expresses the mist by volumetric method and defines it as water spray volume content of 99% (Dv 0.99) in a diameter less than 1000 μm which is measured on the plane 1 m away from the nozzle under the minimum design pressure of the nozzle. The working pressure of the nozzle is directly related to the atomization effect. Larger pressure results in smaller atomized particle size. The working pressure of general low-pressure spray system without extra pressure generating equipment is 3-4 kgf cm^{-2}, whereas the working pressure of high-pressure system is 35-100 kgf cm^{-2}. Its vaporization and cooling efficiencies are better than low-pressure system but the economic cost is higher.

Ventilation mode: When the spray method is used to cool the environment, the ventilation rate in the field is low, the temperature and humidity distribution is likely to be nonuniform and the temperature is likely to rise despite of the solar radiation quantity. As a result, natural ventilation is inapplicable and the mechanical ventilation should be used to improve the above circumstances.

Influence of system control strategy and water quality: The cooling capacity of evaporative cooling is closely related to relative humidity of the environment. Continuous spray is likely to cause the environment to be overwet and increase the temperature (Huang, 2000). Insufficient spray capacity will result in poor cooling effect. Thus, the spray control strategy is the decisive key technology for regulation and control of temperature and humidity. In addition, the spray system has very strict requirement for water quality. There must be a water filter in front of the high pressure pump, so as to avoid pipeline or nozzle blockage and equipment wear (Wu, 2004).

Mathematical model for evaporation time of mist: In the application of spray cooling, the evaporation rate of mist is a very important parameter. When a fog droplet leaves the nozzle, it evaporates and shrinks gradually in the process of friction and heat absorption resulted from high speed motion in the air. The life cycle of atomized particles can be calculated by Langmuir equation, as shown in Eq. 1 (Jeng and Liu, 2001):

$$t = \frac{\rho RT(d^2)}{8DM(P_s - P_L)} \tag{1}$$

Where:

$$D \approx D_0\left(\frac{T_f + 273}{T_0}\right)^{1.94} \tag{2}$$

where, ρ is the water density (g cm^{-3}), R is the gas constant: 62360 (cm^3 mmHg/°k mole), T is the ambient temperature (°C)+273 (K), d is the initial particle diameter of atomized particle (cm), t is the period from d to complete evaporation of mist (s), D is the diffusion coefficient of vapor in the air, D_0 is the diffusion coefficient of vapor under 1 atmospheric pressure at 0 (0.219 cm^2 sec^{-1}), T_f is the temperature of mist (°C), T_0 is 273.15 K, M is the molecular mass of water: 18 g mole^{-1}, P_s is the saturated vapor pressure (mmHg) at mist temperature (T_f), P_L is the vapor pressure (mmHg) at ambient temperature. The steam pressure at different temperatures on a liquid plane (Ps) can be found in the vapor-pressure table in Lange's Handbook of Chemistry or estimated by Antoine equation, as shown in Eq. 3:

$$\ln P_\infty(T) = A - \frac{B}{T} \tag{3}$$

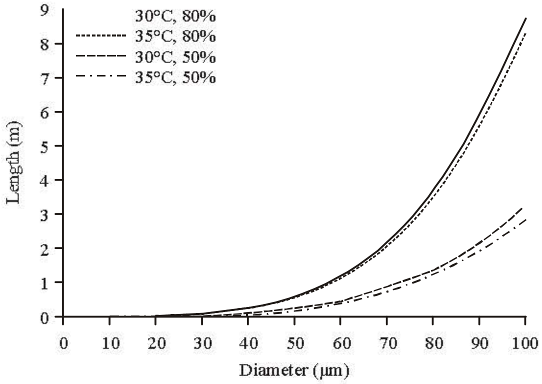


Fig. 2: Sinking distance of complete evaporation of mist under different air conditions

where, T is the liquid temperature (°C)+273(K), A and B are constant values (water at 20°C).

According to Eq. 1, the factor promoting the evaporation of fog droplets and the latent heat exchange with the air is the pressure difference between two partial vapor pressures. The lower the temperature, the lower the partial vapor pressure. When the water vapor pressure of mist is lower than the pressure of vapor in the air, the vapor in the air is condensed on the boundary layer of mist. On the contrary, the vapor on the boundary layer of mist evaporates to the air, increasing the ambient humidity. If the atomized particles are not evaporated completely, the water droplets are likely to adhere to human body or workpieces, thus reducing human comfort in operation and the yield of finished products. Therefore, the migration distance and vaporization efficiency of atomized particles should be increased by forced ventilation in application. Figure 2 shows the results of sinking distance for complete evaporation of mist in different particle diameters under different air conditions which can be used as height reference for nozzle fixing (Huang, 1999).

Equation of heat exchange between mist and air: There are two cases in the heat exchange quantity resulted from the contact between air and mist. One is the sensible heat exchange quantity resulted from the temperature difference between water droplets and air, such as heat transfer, heat convection and heat radiation. The other one is the latent heat exchange quantity caused by mass transfer which is resulted from the pressure difference between water droplets and partial vapor pressure of ambient air. Their algebraic sum is the total heat transfer capacity between air and water droplets. The energy equations are Eq. 4 and 5 (Yen *et al*., 2012; Ke and Chuang, 2005):

Sensible heat exchange quantity of air and mist:

$$Q_c = h_c(T_a - T_w)dA \tag{4}$$

where, Q_c is the sensible heat quantity (W), h_c is the heat transfer coefficient of air and water surface (W m^{-2} K), T_a is the air temperature (K), T_w is the mist temperature (K), dA is the surface area of mist (m^2).

Latent heat exchange quantity resulted from evaporation of mist:

$$Q_e = h_{fg}\times\Delta m_{fg} = h_{fg}\times\sigma(\omega_a-\omega_s)\ dA \qquad (5)$$

where Q_e is the latent heat quantity (W), h_{fg} is the vaporization (solution) heat of unit mass of mist (i.e., enthalpy, kJ kg^{-1}), Δm_{fg} is the mass change of mist in the process of phase change (i.e., mass transfer rate, kg sec^{-1}), σ is the mass transfer coefficient (kg m^{-2} sec), ω_a is the humidity ratio of air (kg kg^{-1} dry air), ω_{ws} is the humidity ratio of air of boundary layer, i.e., saturated humidity ratio of mist temperature (kg kg^{-1} dry air).

In Eq. 5, the humidity ratio or saturated humidity ratio can be found in the psychrometric chart when the ambient temperature and humidity are given or calculated by Eq. 6:

$$\omega_{a,(ws)} = 0.62198\frac{P_{W,(WS)}}{P-P_{W,(WS)}} \qquad (6)$$

where, P is the atmospheric pressure (mmHg), $P_{w,(ws)}$ is the saturated partial vapor pressure (mmHg) corresponding to partial vapor pressure or mist temperature in the air.

In application, if the mass transfer rate is positive, the moisture in the air will be condensed; if it is negative, the water droplets will evaporate to the air and the moisture in the air will increase. The total heat exchange quantity Q_t of mist and air can be obtained from the above two equations.

$$Q_t = Q_c+Q_e = [h_c(T_a-T_w)+\sigma(\omega_a-\omega_{w,s})\ h_{fg}]\ dA \qquad (7)$$

The movement of vapor in the air meets the theory proposed by Lewis that the heat transfer coefficient (h_c) approximately equals to the mass diffusion coefficient for the adiabatic humidification process of air. The ratio of h_c to σ (Lewis number) approximates to 1 and equals to the specific heat of humid air (C_p). Hence, Eq. 4 can be changed to Eq. 8 and substituted into Eq. 7 to obtain the total heat exchange quantity, as shown in Eq. 9.

$$Q_c = C_p\sigma(T_a-T_w)dA \qquad (8)$$

$$Q_t = \sigma(h_a-h_w)dA \qquad (9)$$

where, h_a is the enthalpy of ambient air (kJ/kg dry air), h_w is the enthalpy of air on boundary layer of fog droplets (kJ/kg dry air) where:

$$h_{a,(w)} = C_pT_{a,(w)}+h_{fg}\omega_{a,(w,s)} \qquad (10)$$

The mass transfer coefficient can be estimated by the concentration boundary layer of material, defined as follows (Hou *et al*., 2007):

$$\sigma_m = \frac{D_{AB}\frac{\partial\rho_A}{\partial y}\Big|_{Y=0}}{\rho_{A,S}-\rho_{A,\infty}} \qquad (11)$$

where, σ_m is the convective mass transfer coefficient (m sec^{-1}) calculated by molecular concentration of water vapor, D_{AB} is the double diffusion coefficient (m^2 sec^{-1}) between water and air, $\rho_{A,S}$ is the mist surface density (kg m^{-3}), $\rho_{A,\infty}$ is the density of mist in free flow (kg m^{-3}).

Equation 9 expresses the influence of the enthalpy difference between the air nearby boundary layer and the environment when the atomized particle temperature is T_w, i.e., the enthalpy potential and the mist surface area on the total heat exchange quantity. The dA in spray system is the sum of surface area of all water droplets. It is observed that when the surface area of water droplets is increased by high pressure atomization, the total heat exchange quantity can be increased directly. When the mean particle size of mist and the spray capacity are given, a volume of water for spray can be divided into i water droplets of the same volume, in order to estimate the total heat exchange area of atomized particles:

$$V_{total} = i\times\frac{\pi d^3}{6} \qquad (12)$$

$$S_{total} = i\times\pi d^2 \qquad (13)$$

where, V_{total} is the total volume of spray (L), i is the total number of water droplets of the same volume, S_{total} is the total heat exchange area (m^2).

Low temperature water droplets can increase the quantity of sensible heat exchange with the air and carry out latent heat exchange at the same time. If the mist temperature is lower than ambient DP, the ambient water vapor will be condensed on fog droplets first (cooling dehumidification) until the mist temperature rises to ambient WB before evaporation (cooling humidification). Then the whole heat exchanging process is completed. Therefore, using turbulent fan to increase the migration distance of atomized particles can extend the time of heat exchange between mist and air and avoid the atomized particles falling on the persons or products in the operating zone in the process, thus affecting human comfort and production yield.

System design and architecture

Design and architecture of cooling fogging system: This study used a water chiller as the design basis of cooling fogging air conditioning machine. The cooling medium tap water is filtered and stored in the first water tank and conveyed by the circulation motor to the evaporator to be changed into 2-3°C chilled water through heat exchange. It is filtered for the

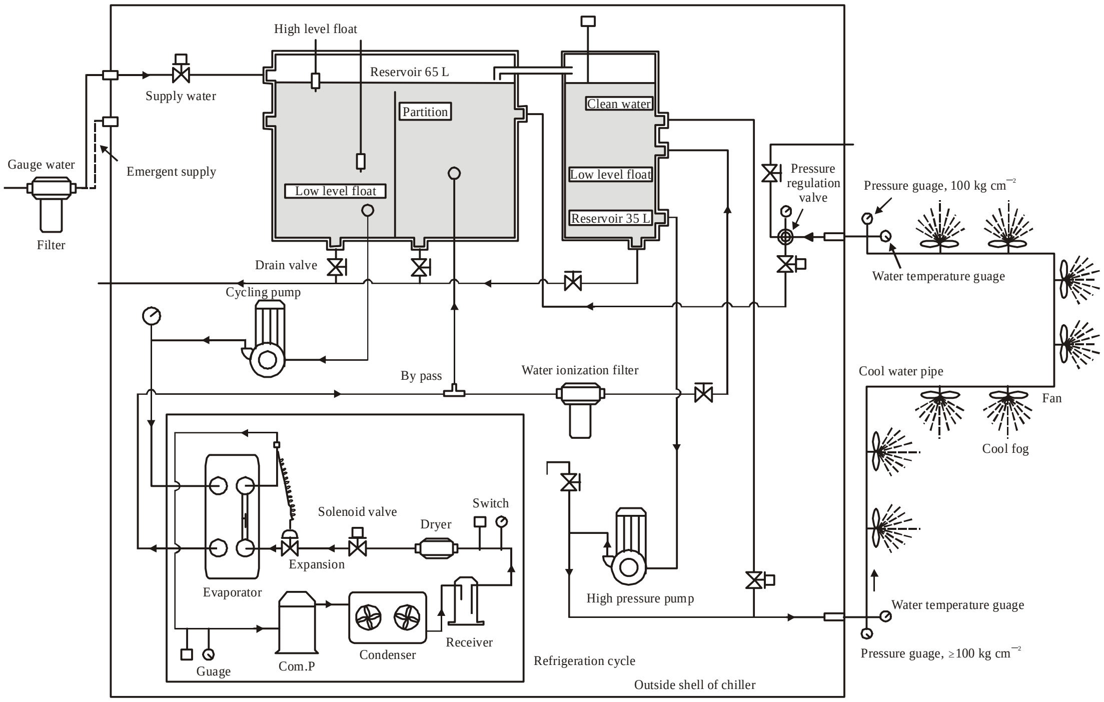


Fig. 3: Design drawing of cooling fogging air-conditioning system

second time by the water ionizer and resolved into finer ions for atomization. The ionized uncontaminated water is stored in the second water tank and finally delivered by the high-pressure hydraulic pump at the lower outlet to the chilled water pipeline and various nozzles for spray cooling operation. The turbulent fan at the nozzle end increases the heat exchange efficiency of mist by forced convection, thus enhancing the cooling effect. The design drawing of cooling fogging air-conditioning system is shown in Fig. 3.

The common heat exchangers used for refrigerating air conditioning include plate heat exchanger and shell-and-tube heat exchanger. Considering the uncontaminated water quality, space and weight, this study chose plate heat exchanger as the evaporator of cooling fogging chiller. At the same heat transfer rate, the volume of plate heat exchanger is 1/4~1/5 smaller than the shell-and-tube and the weight is 1/2 lighter. It is easy to be cleaned and maintained and it has no vibration and noise problems (Wang, 2007b).

Design of ventilation facilities: The negative pressure ventilating fan was mounted on the building roof at the construction site to increase the ambient ventilation rate, thus meeting the heat floating effect. As the air flow path is upward, there is no wind impact effect on human body. Turbulent fan and negative pressure ventilating fan are used for forced convection to increase the migration distance, heat exchange quantity and vaporization efficiency of low temperature mist.

Control strategy of system: In the application of the spray facility to evaporative cooling, the cooling degree is proportional to the spray capacity and the ambient humidity increases with the spray capacity. Thus, the temperature and humidity are controlled by intermittent spray. At present, the preferred control mode is to use the preset temperature as the condition of spray starting and the preset relative humidity as the stop condition, so as to reduce the temperature and to avoid overwet environment (Li *et al*., 2006).

In order to avoid over ventilation from carrying away the indoor cold air away and causing poor cooling effect, only the negative pressure ventilating fan on the roof is switched on during spray cooling. The hot air is pumped out of the room under the heat floating effect and the onsite set relative humidity is used as the spray stop condition. All the negative pressure ventilating fans are switched on meanwhile the spray is stopped to carry humid air out of the room, thus accelerating reducing indoor humidity.

RESULTS AND DISCUSSION

Measurement of droplet size and estimation of refrigeration capacity: This study used laser diffraction particle size analyzer to measure the size of nozzle atomized particles of cooling fogging system in a well-ventilated open laboratory at an ambient temperature of 19 and a humidity of 73% RH. The experimental set was 1 RT cooling fogging chiller. The nozzle sample was 0.2 mm^2 mist nozzle. The water spray particle size measurement parameters are shown in Table 1. The measured conditions are shown in Fig. 4.

The SMD value of measurement results was 15.83 μm. The spray capacity was substituted in Eq. 8 and 9 to obtain the total heat exchange area of mist 28.42 m^2 min^{-1}. The heat

Fig. 4: Actual measurement of water spray particle size

Fig. 5: Measurement field

Table 1: Water spray particle size measurement parameters

Item	Type
Measuring instrument	Laser diffraction particle size analyzer
Testing machine	1RT cooling fogging chiller
Nozzle type	0.2 mm^2 stainless steel nozzle
Water pressure inside tube	100 kgf cm^{-2}
Water temperature at nozzle	8°C
Spray capacity	0.075 L min^{-1}
Measurement environment	Temperature 19°C, humidity 73% RH
Data sampling	Average of two test results

quantity the nozzle that can take away in 1 min was estimated at an ambient temperature of 35 and a relative humidity of 50%RH. The value resulted from parameters and psychrometric diagram is substituted in Eq. 9 to obtain the total heat exchange quantity 32.1 KW. The system configuration can be carried out according to the heat load of the factory building to improve the environment, so as to reach the temperature and humidity for the environment.

Summary of operating environment of measurement field: The field measurement was carried out in summer when the cooling fogging air-conditioning system was installed. The experimental site was a hardware and tools surface treatment plant (located in Taichung, Taiwan, east longitude 120.72°E, north latitude 24.11°N). The factory building was a single sheet iron house. The plant was specialized in processing metal hand tools using oscillating mill, so there was a large amount of heat energy. The 5RT cooling fogging air-conditioning system was built *in situ* and negative pressure ventilating fans were used for forced convection, hoping to reduce the temperature and improve the air quality.

Measurement records of improved ambient temperature and humidity: This study used temperature and humidity recorder to record the ambient temperature and humidity between 10 am and 5 pm. The *in situ* temperature and humidity changes were observed in the period from the startup of cooling fogging air conditioning at 10:30 am to the end of measurement. In order to analyze the mean temperature change inside the factory building, the onsite key operation area was equally divided into 15 distributed sampling points. the ambient and indoor ceiling temperatures were measured by temperature and humidity recorder and infrared laser temperature gauge at 10 am, 12 am and 5 pm, respectively. The top views of measurement field and distributed points in factory building are shown in Fig. 5 and 6. The histograms of temperature changes at distributed sampling points in operating zone, temperature changes at distributed sampling points on ceiling and changes in temperature difference between ceiling and distributed sampling points are shown in Fig. 7-9. The curves of ambient temperature and humidity changes in the operating field are shown in Fig. 10.

As shown in Fig. 7, after the cooling fogging air conditioning was switched on, the temperatures at various distributed sampling points change regularly and uniformly. The temperature differences were 0.5°C, proving that the blowing spray cooling system can reduce the ambient temperature obviously and does not cause nonuniform temperature distribution. Figure 8 shows the indoor ceiling temperature changes corresponding to the sampling points in different blocks in the same sunlight at the same time. The sampling point 10 has abnormal high temperature as the ceiling is stripped and the sheet iron is exposed, thus, it is ignored. Before startup and within 2 h after startup, the mean temperature of the ceiling of the first measurement and the second measurement was 42.6 and 43.4, respectively under intense radiant heat and indoor heat floating effect. However, in the third measurement which was 4 h later, the mean temperature of ceiling decreased to 34.4. As compared with Fig. 9, it is found that the temperature difference between upper and lower parts of indoor space is reduced obviously after the cooling fogging air conditioning has regulated indoor environment for a period of time. According to the record of relative humidity in Fig. 10, the relative humidity changes after 14:30 pm become stable, suggesting that the humidity in the whole space is in uniform distribution. Moreover, it is in inverse proportion to the temperature regularly, meaning that

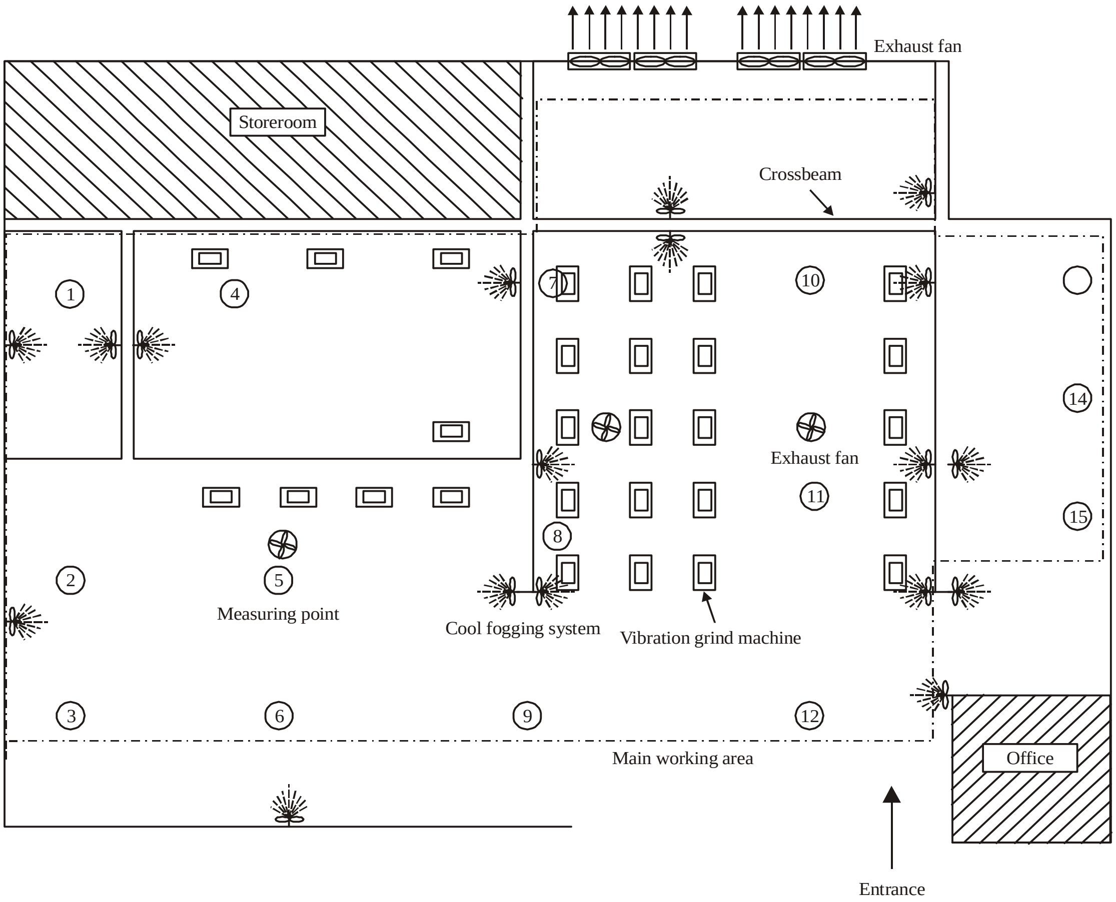


Fig. 6: Top view of distributed points in factory building

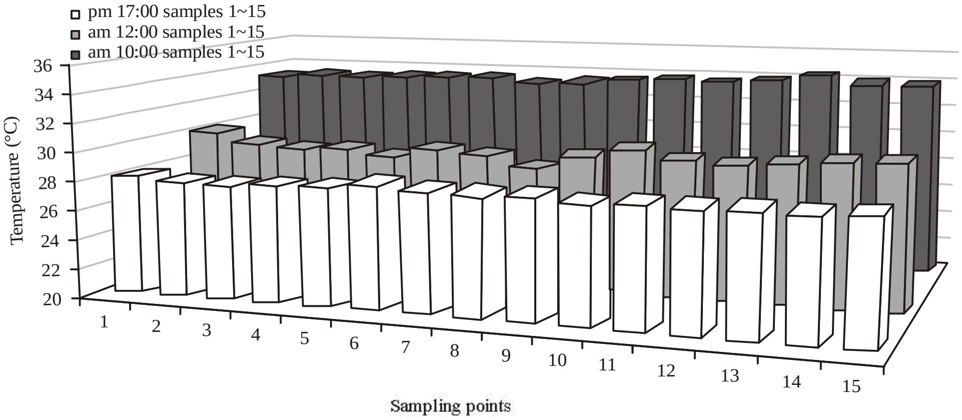


Fig. 7: Histogram of changes of temperature at distributed sampling points in operating zone

the whole space environment can be stabilized by using cooling fogging air conditioning and forced ventilation to regulate indoor humidity for a period of time. In addition, the temperature can be stabilized when this system has been switched on for 1 h, the cooling amplitude is above 5.5°C.

Change in number of anions in operating environment: The number of anions in the air is one of indexes of ambient air quality. The water body in high speed splashing generates Lenard effect, in which a large amount of anions is produced in the process (Wu and Lin, 2009). They can remove and control volatile organic pollutants in low concentration range and improve the ambient air quality (Wu, 2006), allowing the applicability of spray cooling to be extended. The tester for cations and anions in the air was used to measure the number of anions in the environment before and after the cooling

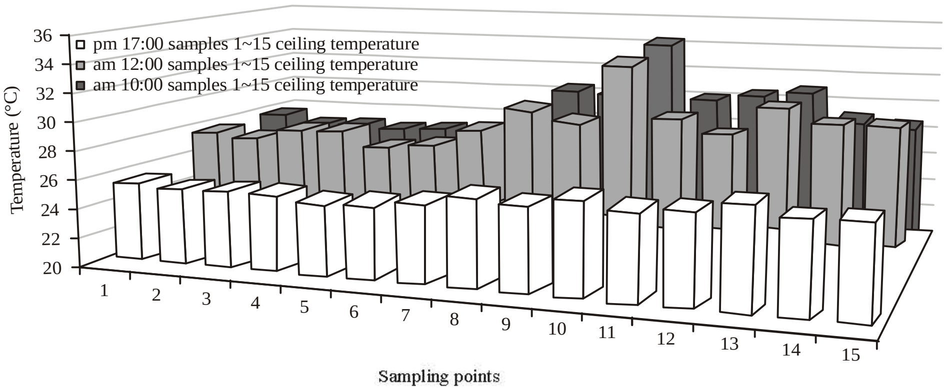


Fig. 8: Histogram of changes of temperature at distributed sampling points on ceiling of operating zone

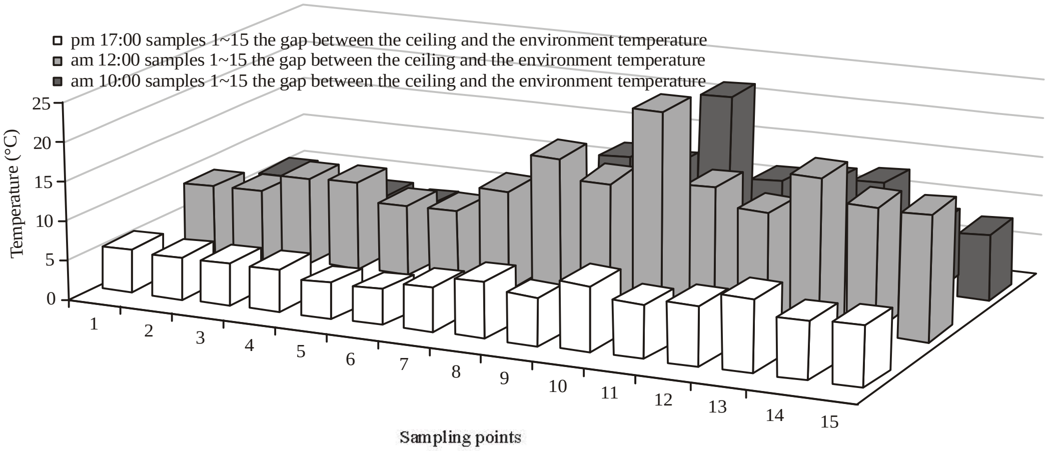


Fig. 9: Histogram of changes in temperature difference between ceiling of operating zone and distributed sampling points

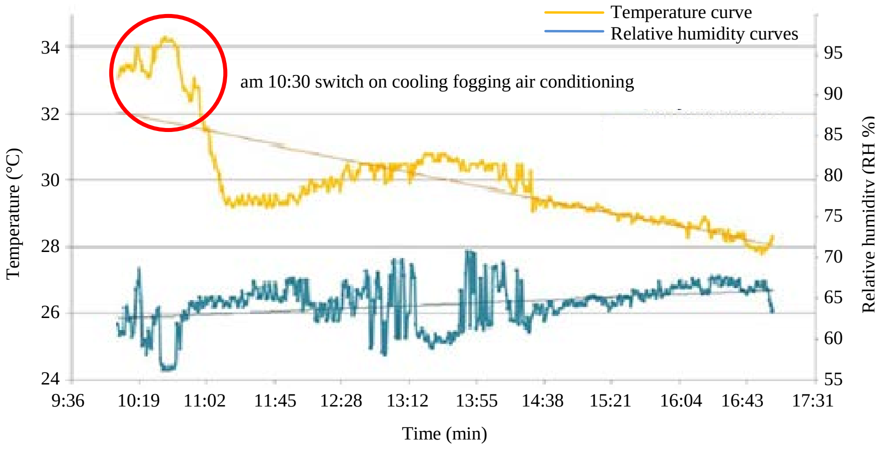
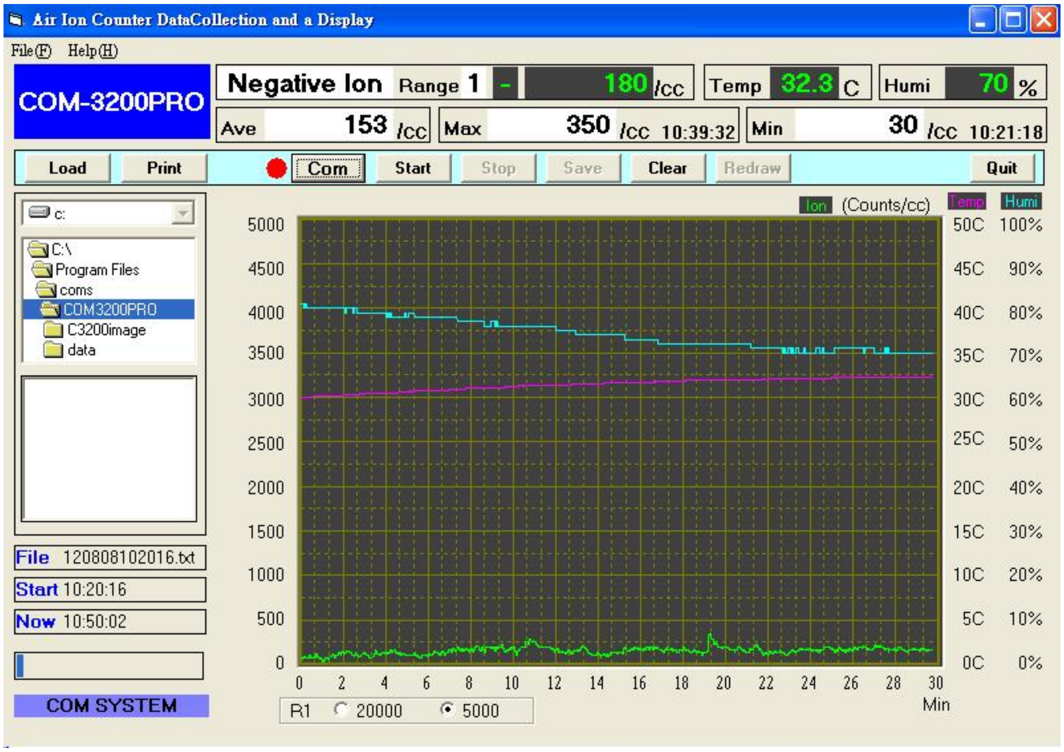


Fig. 10: Curve diagram of ambient temperature and humidity changes in operating field

fogging air-conditioning system was started up for 30 min, respectively. The results are shown in Fig. 11 and 12. The average of anions in the air before switching on the cooling fogging air-conditioning system was 153/cc and the average after startup was 1685/cc. The ambient air quality is improved obviously. Figure 12 shows that for high pressure intermittent spray, the number of anions reaches its maximum. On the contrary, the number decreases to a boundary when the spray is stopped, but it is still much larger than that when the cooling fogging air conditioning is not



Negative Ion Range 1 - 180 /cc Temp 32.3 C Humi 70 %

Ave 153 /cc Max 350 /cc 10:39:32 Min 30 /cc 10:21:18

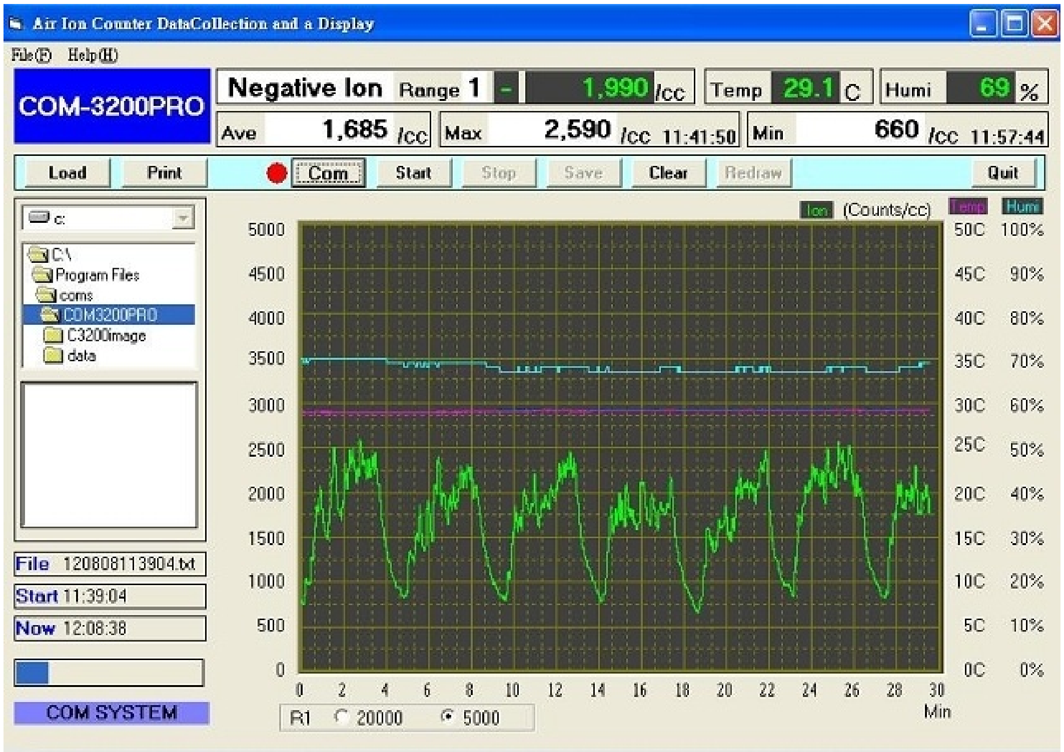
File 120808102016.txt

Start 10:20:16

Now 10:50:02

R1 ○ 20000 ● 5000

Fig. 11: Curve diagram of original ambient temperature and humidity and anion



Negative Ion Range 1 - 1,990 /cc Temp 29.1 C Humi 69 %

Ave 1,685 /cc Max 2,590 /cc 11:41:50 Min 660 /cc 11:57:44

File 120808113904.txt

Start 11:39:04

Now 12:08:38

R1 ○ 20000 ● 5000

Fig. 12: Curve diagram of ambient temperature and humidity and anion when cooling fogging air conditioning is switched on

switched on. The situation is continuous and stable, meaning that the ambient anion concentration is proportional to the spraying pressure.

CONCLUSION

The blowing spray cooling method has been universally used for air conditioning in open spaces such as greenhouse planting and market. It is advantageous to reducing indoor ambient temperature and humidity uniformly. Moreover, it saves energy as compared with refrigerating air conditioning system. However, it cannot regulate mist temperature, thus the cooling effect is limited. When the spray capacity is increased in order to meet the requirement for ambient temperature, the humidity is increased excessively, thereby influencing the applicability. This study used cooling fogging air-conditioning system to control the spray and on/off of negative pressure fan matching the ambient humidity, so as to increase the cooling efficiency and to avoid overwet environment.

The results of theoretical analysis and measurement are concluded as follows.

- In the conditions of ambient temperature 35 and relative humidity 50% RH in the factory building, this system sprayed 8 chilled water through 0.2 mm^2 stainless steel nozzle. The total heat carried away by one nozzle in 1 min was 32.1 KW. It can be used as the basis of system configuration in the operating field
- When the cooling fogging air-conditioning system works in the hot operation field, the cooling of the whole space is stable. The cooling distribution is uniform without temperature gradient. The relative humidity is stable after 4 h, suggesting that the whole space environment can be stabilized by using cooling fogging air-conditioning system and forced ventilation to regulate indoor humidity for a period of time
- According to onsite testing, the temperature can be stabilized when the system is switched on for 1 h, the cooling amplitude can reach 5.5
- According to actual measurement, the ambient anion concentration is proportional to the spraying pressure and ambient anion concentration after switching on the cooling fogging air-conditioning system is 11 times higher than the original state. This proves that the proposed can increase the ambient anion concentration and improve the air quality effectively

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