Computational Fluid Dynamics Analysis - Application on the Air Flow Prediction Behavior from the Cooling Tower or Radiator Exhaust for the Hong Kong Government Pilot Scheme Submission

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ABSTRACT

The pilot scheme for wider use of fresh water in evaporative cooling towers for energy-efficient air conditioning systems was first launched in 2000. From statistical data up to the end of 2005, the number of accumulated application is 201 and only 39 applications were approved. The less than 20% successfully approved applications are due to my reasons. One of the reasons is the insufficient separation distance between the cooling tower exhaust and the location of public access (or the operable window). The specified distance is 7.5m according to the Code of Practice Part 1. For situations having the separation distance less than 7.5m, the author creates an approach in engineering reasoning by using the Computational Fluid Dynamics (CFD) analysis to tackle the problem. The methodology is clear and the argument is objective. By using the reasoning, it is believed that most of the unresolved projects having the aid of CFD analysis will have a high chance of being accepted

Keywords: Computational Fluid Dynamics, Comparison Base

INTRODUCTION

With reference to the pilot scheme for wider use of fresh water in evaporative cooling towers for energy-efficient air conditioning systems and the related code of practice Part 1 [1], there is a requirement, in clause 4.13, of a minimum horizontal separation distance between the cooling tower exhaust and the location of public access, or the operable window. The specified distance is 7.5m which is considered not easily achieved due to the very densely built urban areas in Hong Kong. If the project is of retrofit nature, it is even most difficult to achieve this separation requirement since most of the adjacent buildings are all in place. Therefore, most of the pilot scheme submissions are unable to be approved for some years due to this separation requirement.

In the following sections, a methodology with reasoning approach is introduced so that it can provide the basis of analysis to enable approval.

1. APPROACH

It is to study the case of having the existing air-cooled chillers or air-cooled radiators to be converted to water-cooled chillers with cooling towers. If this is a retrofit project, there is an existing air exhaust system, either from air-cooled chillers or from air-cooled radiators. The exhaust air is hot and dry. For the new system, the exhaust air from cooling tower will be less hot and wet.

The analysis is to compare the new exhaust air system with the existing system. The existing air exhaust system is considered as the 'Comparison Base' since it is understood that there was no complaints from residents for some years. The parameters of the exhaust air for analysis are temperature, wind velocity and moisture content (or relative humidity).

Methodology:

(i) To analyze the existing exhaust air parameters in the problem area/location as the "Comparison Base".

(ii) To analysis the new exhaust air parameters in the problem area/location for comparison.

(iii) If the CFD data are analyzed, the effect of new system compared with the existing system does not constitute a big difference, the installation will be considered as acceptable.

2. RAW DATA

2.1 WIND DATA

The wind velocity and direction for the project location can be obtained from the information published by the Hong Kong Observatory. To be fresh, the available information for the most recent year should be adopted for the analysis. In each year, there is a breakdown of data for each month. The mean wind velocities and directions also vary every month.

2.2 TEMPERATURE & RELATIVE HUMIDITY

The mean air temperature and relative humidity (RH) are to be used for analysis.

These mean temperatures and RHs also vary every month.

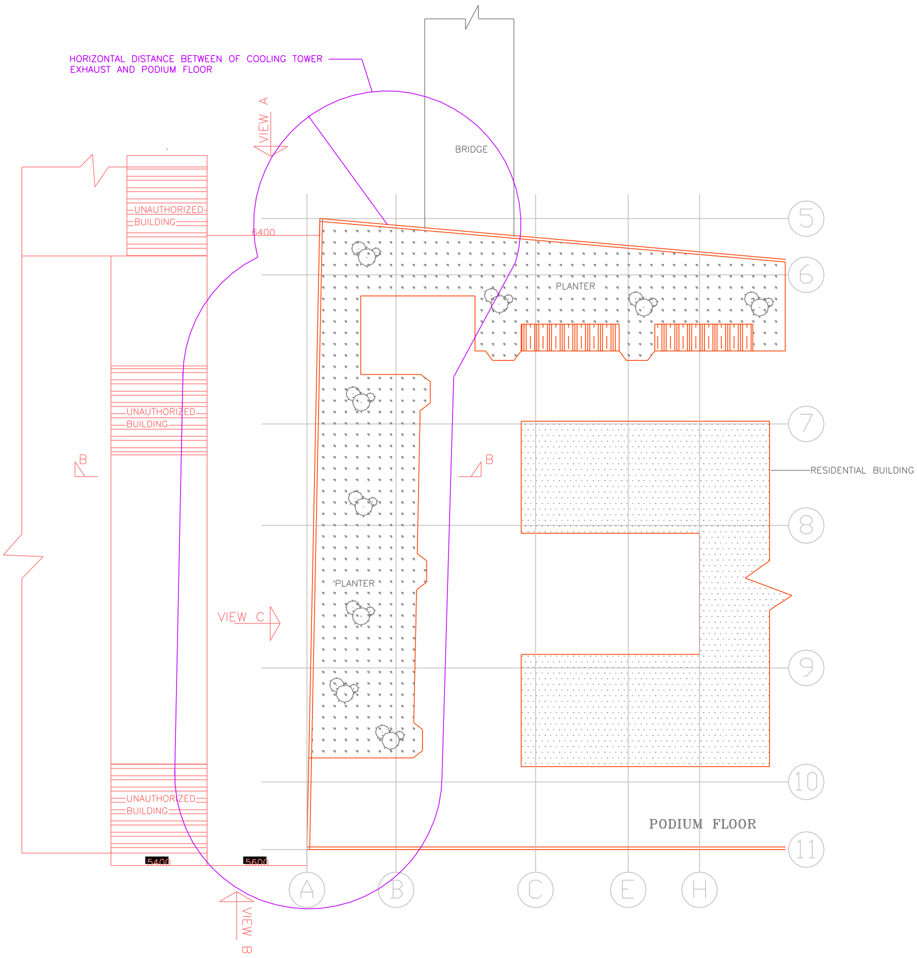
2.3 AREA/LOCATION FOR ANALYSIS

To begin with the analysis, it is readily to identify the problem location or areas for analysis. These areas are within the 7.5m separation distance. It is necessary to identify these areas on the drawings.

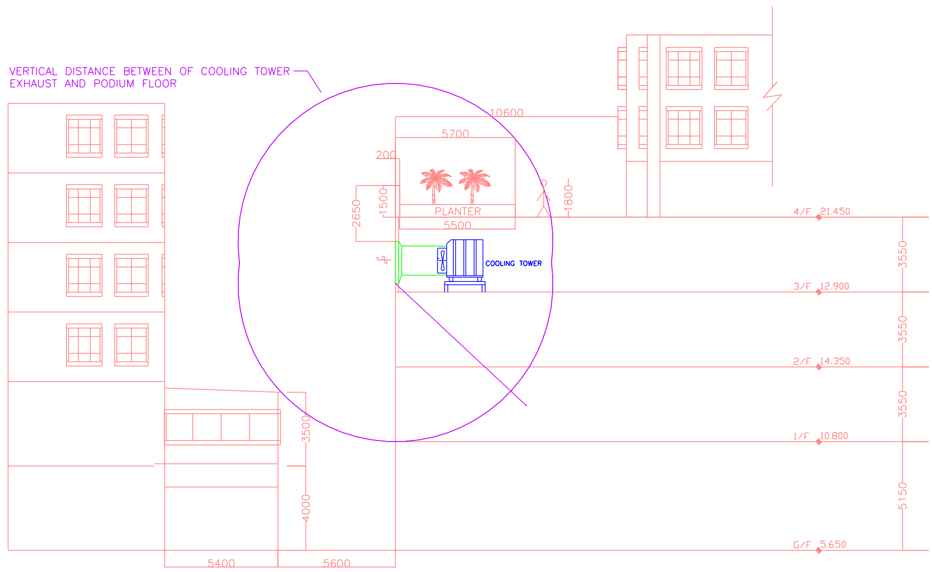
3. CASE STUDY

There is project at New Territory currently having air-cooled radiators to be converted to cooling towers for energy saving purpose. It is found that on the plan drawing there are some areas of access within 7.5m on the podium floor. Please refer to Drawing no. 1 and 2.

Drawing no. 1 – Section



Drawing no. 2 – Plan



It is necessary to carry CFD study to find out the simulated parameters of temperature and humidity at the area within 7.5m.

4. ASSUMPTIONS

For the CFD study, temperature and relative humidity for different months will have to be simulated by Finite Element Method. The Computational Fluid Dynamics problem is to be solved by the 3-dimensional Navier-Stokes Equation. Also, the Moisture Concentration is to solved by a modified Diffusion and Convection Equation. A simplified Conduction and Convection Equation was used for studying the temperature of exhaust air.

The below Table 1 is the equation and assumptions used in the CFD analysis.

Table 1 – Equation and Assumptions

Parameter	Value
For 3-D Incompressible Navier Stokes Equation $\eta\nabla^2 u + \rho(u\cdot\nabla)u + \nabla p = 0$ $\nabla\cdot u = 0$	η = kinematic viscosity **u** = velocity at x and y direction ρ = density of air p = pressure of air
Density of air (kg/m^3)	1.2
Kinematic viscosity of air (m^2/sec)	14.8 x10^{-6}
Wind velocity (m/s)	Accordingly to monthly data
Exhaust air velocity (m/s)	5.4 m/s (water cooled system)
For Diffusion and Convection Equation $u\cdot\nabla c = 0$	**u** = velocity at x and y direction c = concentration of moisture content
Ambient relative humidity	Accordingly to monthly data
Exhaust air relative humidity	100% (Horizontal)
For Conduction and Convection Equation $\rho C_p u\cdot\nabla T = 0$	ρ = density of air C_p = specific heat capacity of air **u** = velocity at x and y direction T = Temperature
Density of air (kg/m^3)	1.2
Specific heat capacity of air (J/(Kg K))	1,000
Air temperature	Accordingly to monthly data
Exhaust air temperatures	42°C (radiator system) 37°C (cooling tower system)

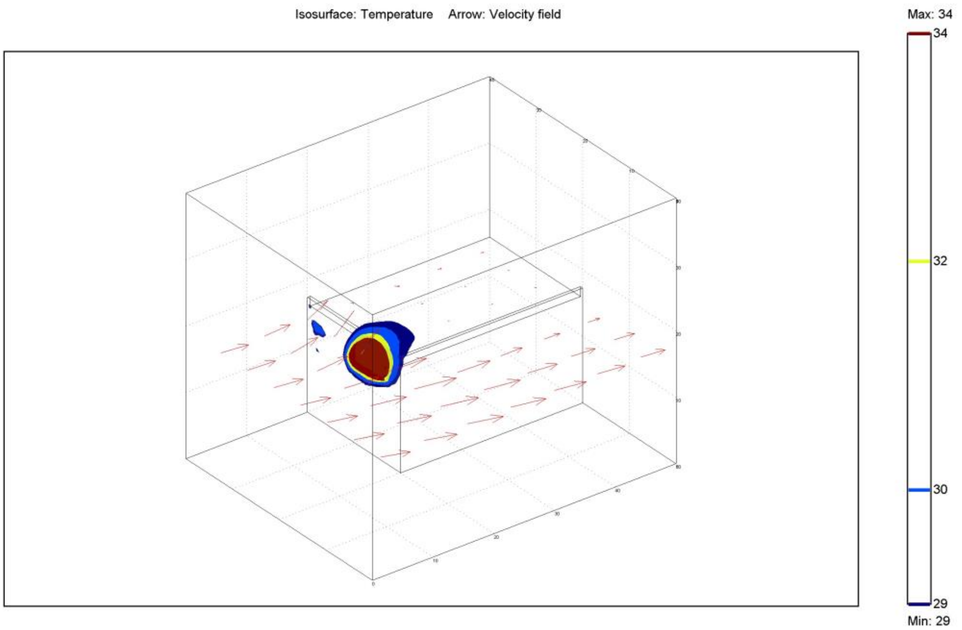
5. FINDINGS

Upon checking the 2005 wind directions data from the Hong Kong Observatory, it is found that for the months of January, February, March, April, May, June, July, August and September, the wind direction blew to the back-side of the building. Hence, there is no wind direction effect since the building serves as a huge obstacle blocking the effect. No simulation is required.

For the months of October, November and December, the wind blew towards the building. It is necessary to carry out CFD simulation.

The simulated 3-D CFD result for October is presented below.

Fig. 1 - 3D temperature (Oct) air cooled system



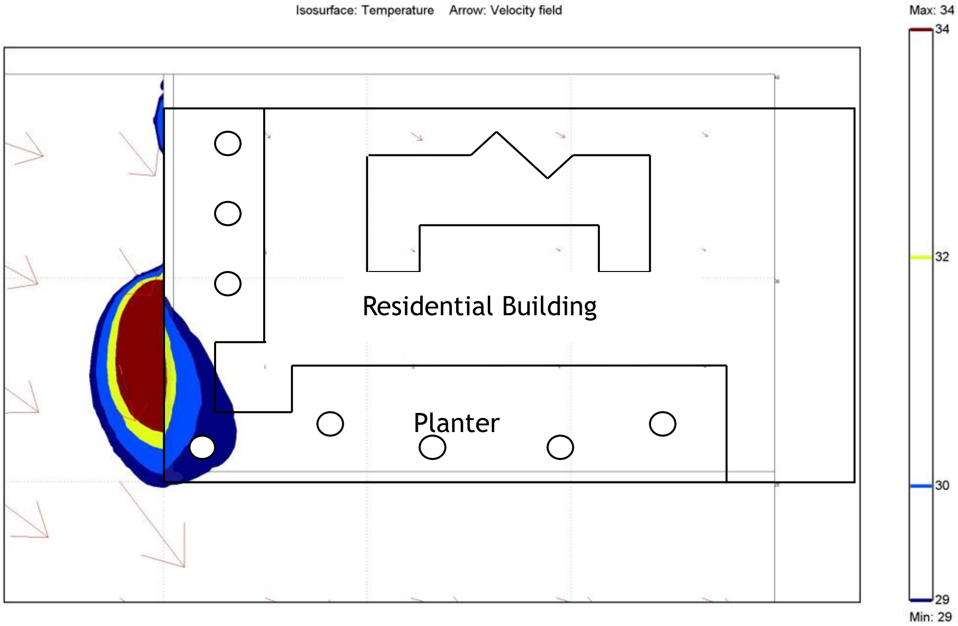


Fig.2 Plan view - temperature (Oct) air cooled system

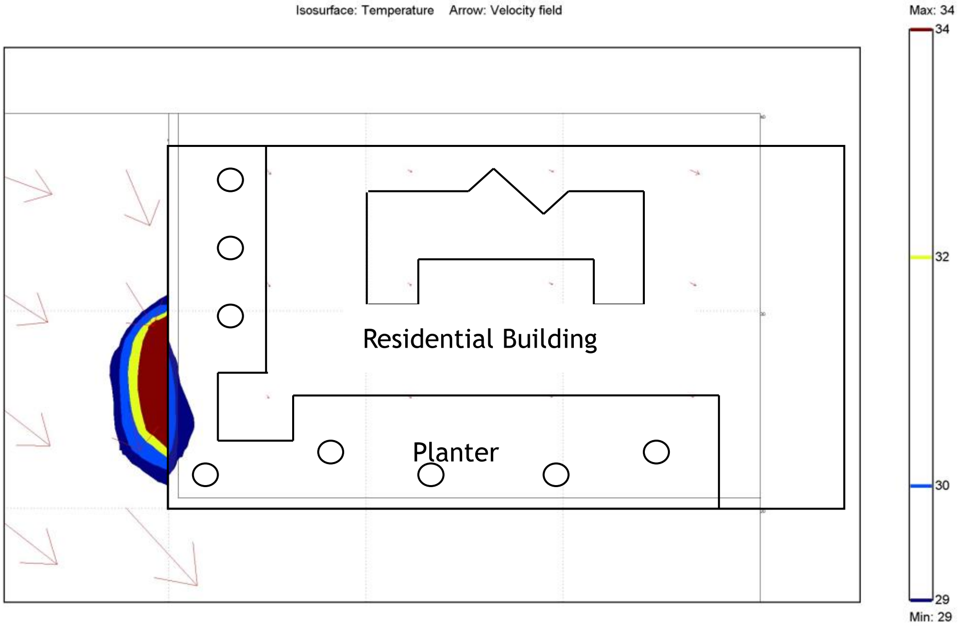


Fig. 3 Plan view - temperature (Oct) water cooled system

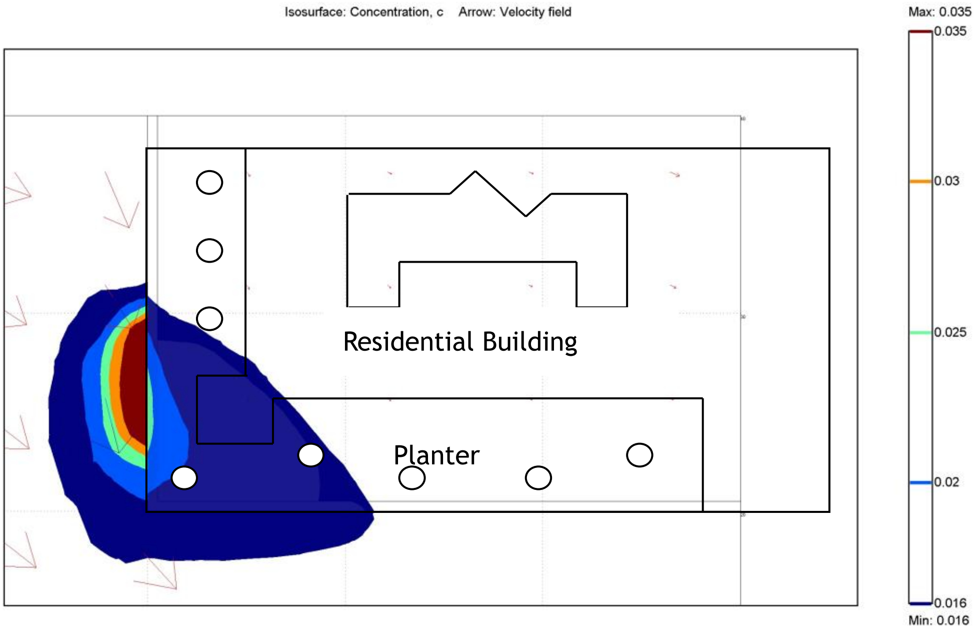


Fig. 4   Plan view - moisture (Oct) water cooled system

Similarly for October, the same simulation exercise was carried out for November and December.   Table 2 indicates the result after simulation.

Table 2 – Result of simulation

		October	November	December
Ambient	Temperature (°C)	26.1	23	17
	Relative Humidity (%)	67	69	54
Radiator	Temperature (°C)	27.6	24.3	18.7
	Relative Humidity (%)	61.4	63.9	48.6
Cooling Tower	Temperature (°C)	27.1	24.0	18.3
	Relative Humidity (%)	75.0	76.4	67.6
	Moisture content (kg/kg)	0.0169	0.0143	0.0088

From the result in Table 2, al the temperatures in the cooling tower study are lower than the existing radiator situation. Hence, the future temperatures at the simulated area will be better than the existing. No problem!

For the case of relative humidity together with temperature, the simulated points are plotted on the psychormetric chart in order to view their relative effects. As the simulated months are from late autumn to winter, the temperatures are from 18.3 to 27.1 °C with relative humidity from 67.6% to 75%. The relative humidity of about 75% with 27.1°C is entirely an acceptable outdoor weather. Please refer to Fig. 5 – Psychrometric chart of the 3 months and the 3 plots from Table 2.

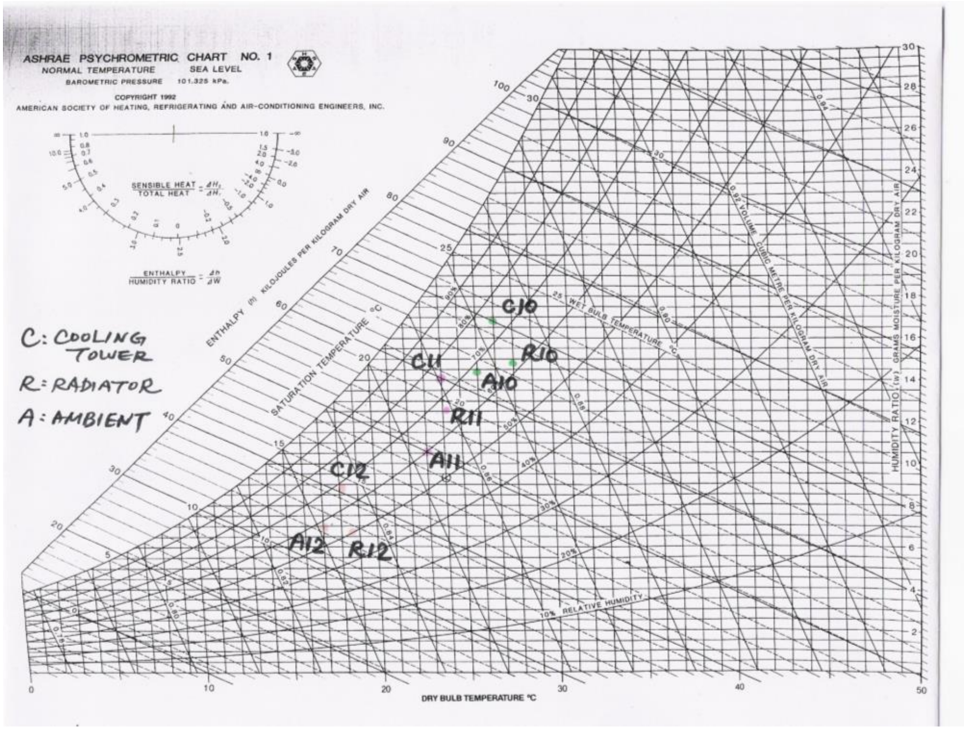


Fig. 2 – Psychrometric Chart of 3 months

6. CONCLUSION

Without carrying out the CFD simulation, nobody can tell the resultant temperatures and humidity at the areas concerned. Having done all the analysis, the results are so favourable that it has the high chance of getting approval from the authority.

7. REFERENCE

(i) Chow, K H L, Computational Fluid Dynamics Study on Ventilation Air Flow at Bus Terminal at Macau. 20 February, 2006.

(ii) Chow, K H L, Computational Fluid Dynamics Study on Cooling Tower Exhaust Air Flow at Island Place North Point, Hong Kong. 18 April, 2005.

(iii) Chow, K H L, Computational Fluid Dynamics Study on Emergency Cooling Tower Plant at Basement 5, Cityplaza Stage 10, Taikoo Shing, Hong Kong. 16 May 2002.

8. AUTHOR

Dr Leonard Chow is the Vice-chairman of HKAEE and he was the immediate past chairman of Asian Institute of Intelligent Buildings. He achieved the title of Certified Energy Manager (CEM) in 2005 and the Certified Building Commissioning Professional (CBCP) in 2006 granted by the Association of Energy Engineers (USA). He was graduated at the Mechanical Engineering Department with First Class Honors at the Imperial College of Science and Technology, University of London, U.K. He practices as a Mechanical and Building Services Engineer for over 20 years. Subsequently, he obtained his Master MSc and PhD degree in Engineering at the University of Hong Kong and University of Western Australia. Dr Chow is currently a chartered engineer in UK, a registered professional engineer in Hong Kong and a chartered professional engineer in Australia. He establishes his own company ISPL Consulting Ltd in the mid 1995 and celebrates the 10th year anniversary in 2005. His company is the consultants in Mechanical, Structure, Safety and Environmental (Energy & IAQ) aspects with about 25 employees. Dr. Chow is actively involved in professional institution contributions. He wrote over 30 technical papers, guidelines, manuals and conducted over 20 technical seminars in Hong Kong, Tokyo, Beijing, Xian, Shanghai and Singapore in the recent years.

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