Energy Efficiency and Environment Improvement

-An Exploration in Chinese Industrial Buildings

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1. Current Situation of Industrial Buildings in China

- There are nearly all kinds of industries in China.
- The building type and requirement of indoor environment for all industries are of remarkable difference.

- The rapid development of industrial buildings exceeds that of environment control level.
- Although more attention has been paid to the environment, there are still many unsolved problems due to lack of theory, technique and equipment.

- In General, the energy efficiency of environment control in industrial buildings is still quite low.

- As we all know, the study and application of building energy efficiency started since the energy crisis in last century. While the basic theory of environment control for industrial buildings formed before that.

- Now, the main methods for energy efficiency of buildings only aim at civil buildings and can’t be simply used in different industrial buildings.

- Therefore, it’s necessary to explore that how to improve the environment and reduce the energy consumption in industrial buildings .

- It is urgent in developing China

2. Our Study and Exploration

- In some industries (metallurgy, casting, etc.), the characteristics of indoor environment in industrial buildings are significantly different from that of civil buildings.

The significant difference from Civil Buildings include：

Building types

Characteristics of heating and contaminant sources

ventilation mode

——Our group aims at this type of industrial buildings

How to improve environment with lower energy consumption in the process of rapid develop?

① The main influence factors and scientific mechanisms have been analyzed.

② The high-efficiency technology system has been applied, based on the above-mentioned analysis.

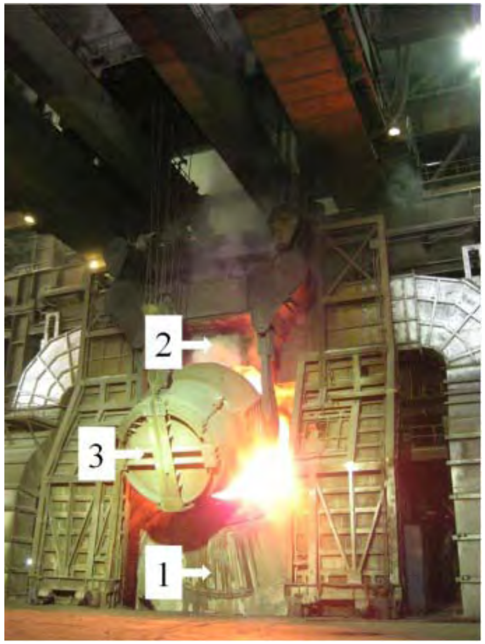
Research Method 1

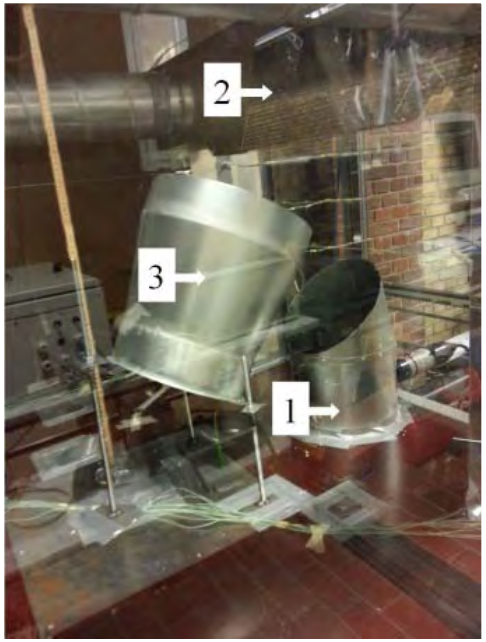
Field test

Discussion with workers

Research Method 2 : Reduced-scale experiment

Experimental results can reveal flow field characteristics and may be helpful for validation and accuracy assessment of CFD simulations.

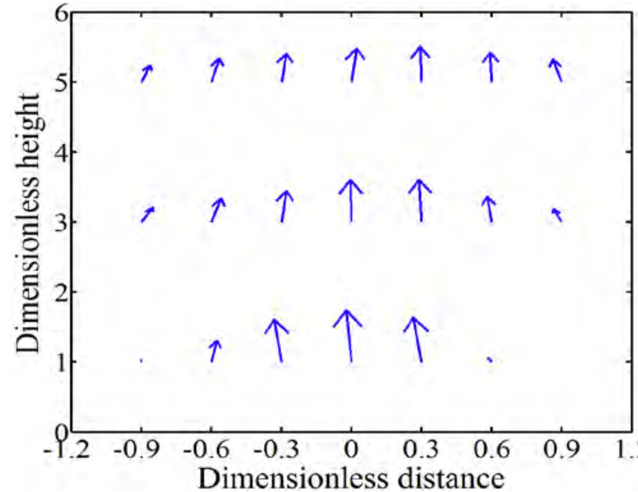




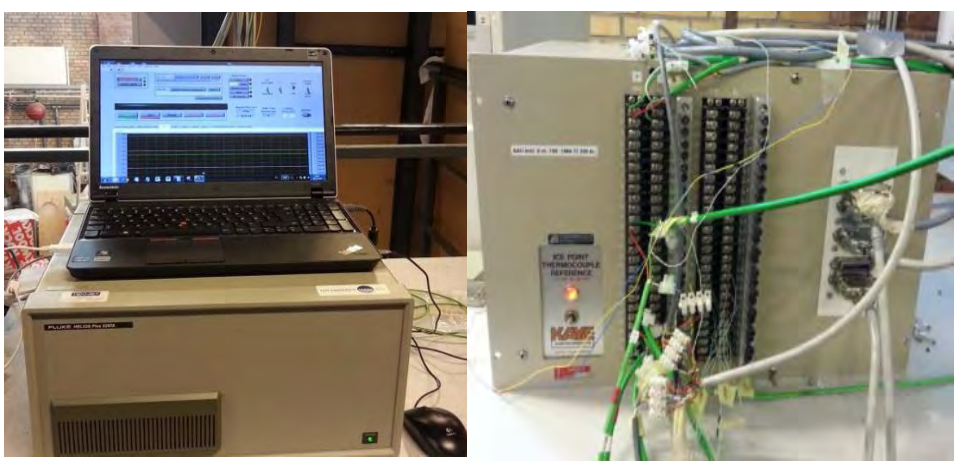
Photos from part of blast furnace workshops (Left) and reduced-scale model (Right) in laboratory

Experimental facilities of reduced-scale experiment

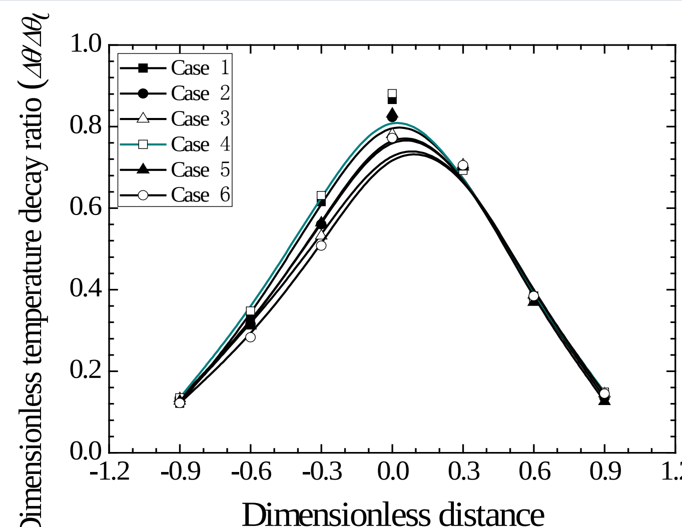
Laser Doppler Anemometer (LDA)



Measured velocity vectors

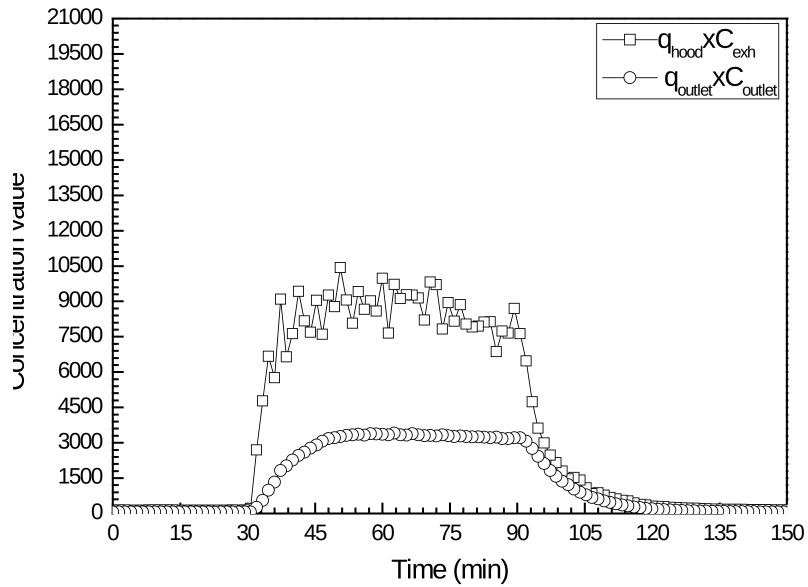


Thermocouple temperature measurement system



Dimensionless temperature variations

Experimental facilities of reduced-scale experiment



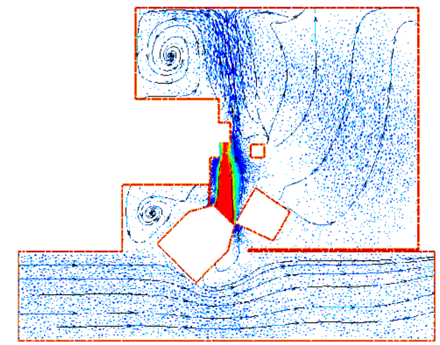
Tracer gas measurement system

Captured dynamic contaminant amount variations

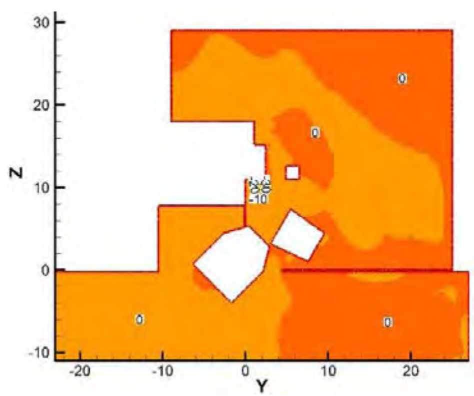
Research Method 3: Numerical Simulation (CFD)

Some factors are difficult to be reproduced in the experiment, then it can be supplemented by CFD as follows:

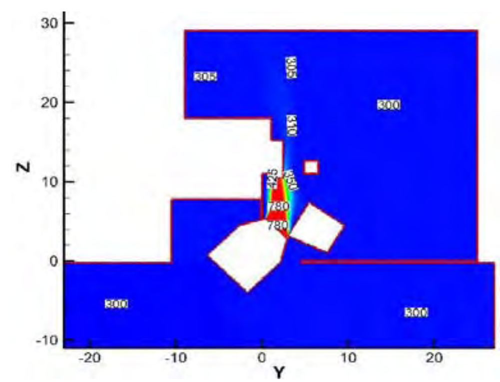
- High-temperature heat source
- Movement characteristics of two-phase flows
- Complicated and various boundary conditions.



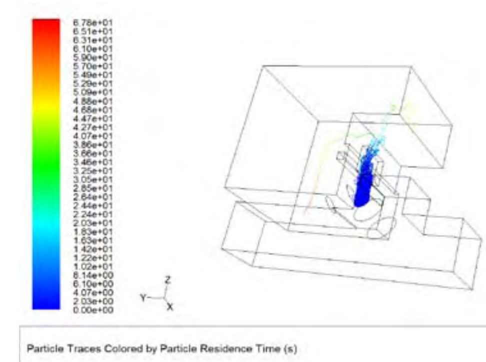
Velocity stream lines



Distribution of air pressure



Distribution of air temperature



Particle trajectories

① Project 1——airflow characteristics

Case1-4

② Project 2——two-phase airflow characteristics

Case 5

③ Project 3——thermal environment characteristics

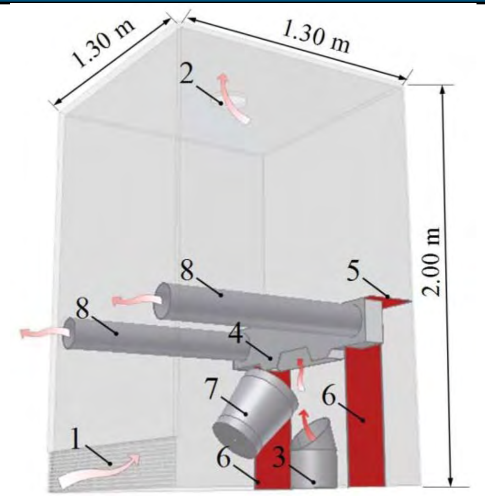
Case 6

Case 1- Ventilation performance of a local exhaust hood in an industrial plant

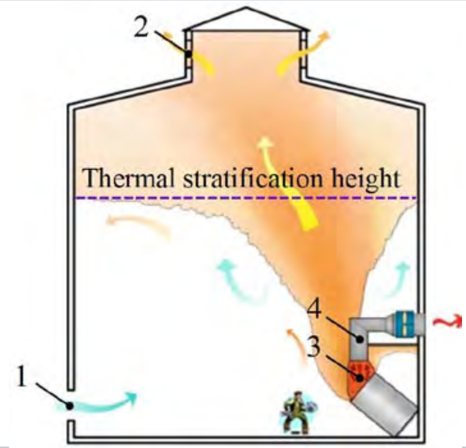
- Local ventilation systems are widely used to capture heat release and/or gaseous/particulate contaminants.

- This study aimed to determine important empirical factors on local pollutant capture efficiency and characteristics of thermal stratification in the working areas of industrial plants.

- Reduced-scale experiments were conducted with a geometric scale of 1:15 corresponding to a portion of the blast furnace workshop of a steel plant.



Experimental facility sketch

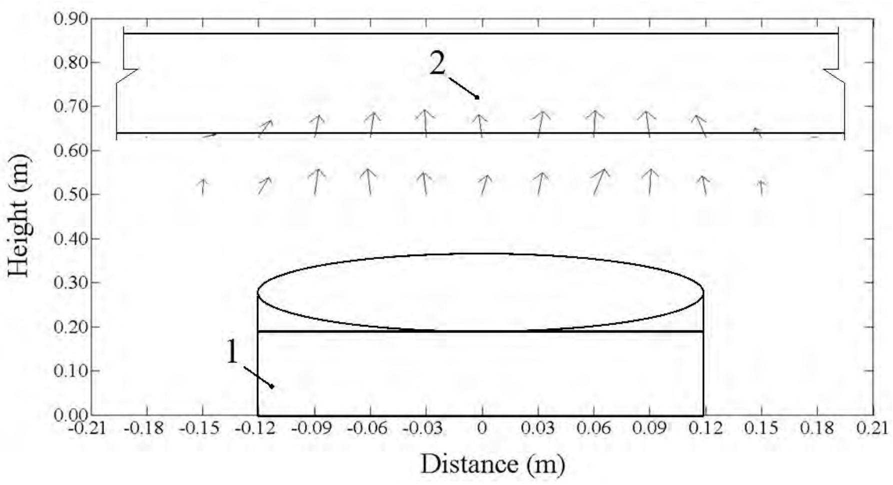


Thermal stratification development

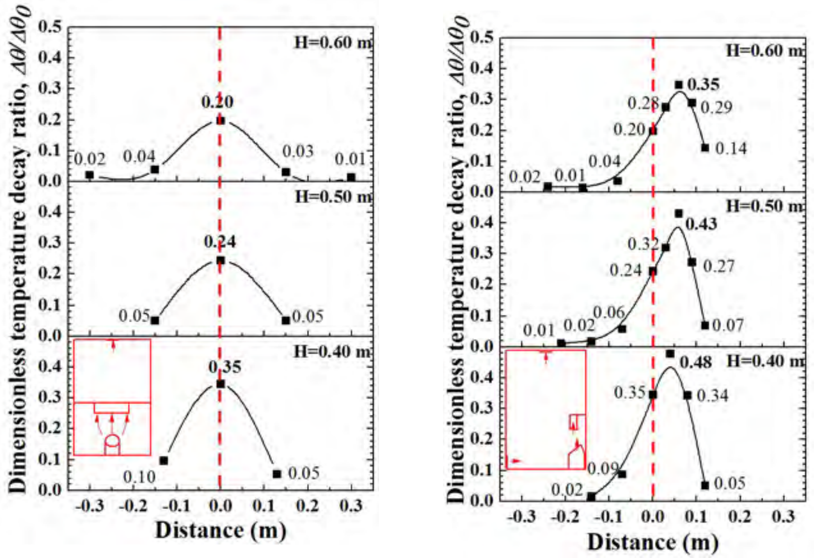
Published in *Building and Environment*, *Yanqiu Huang* , *Yi Wang*, *Li Liu* , *Peter V. Nielsen et al.*

Case 1

- Shape and size of the exhaust hood often affects flow-field characteristics and pollutant capture efficiency.
- The dimensionless temperature profiles indicates that there may be the Coanda effect in this plane.



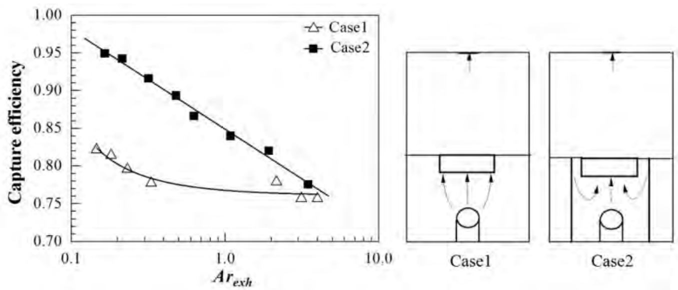
Velocity vectors



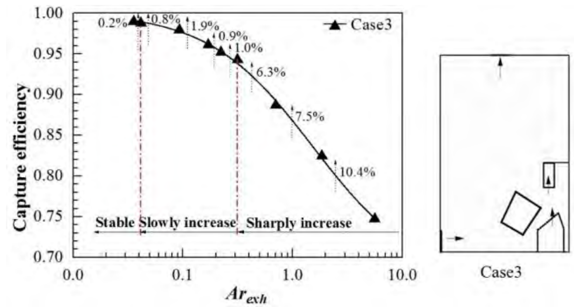
Dimensionless temperature variations

Case 1

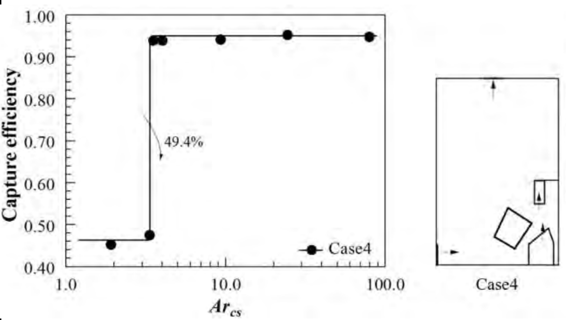
● Confined airflow boundaries, the flow rate of the exhaust hood and source strengths are important empirical factors on pollutant capture efficiency.



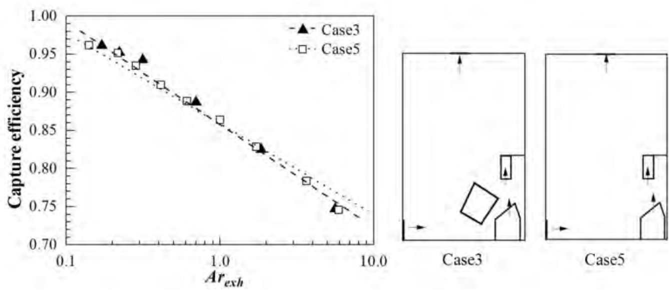
Impacts of confined airflow boundaries



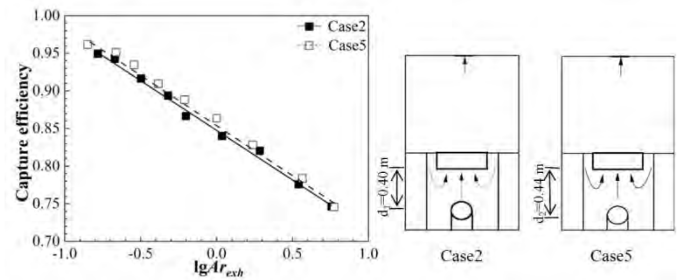
Impacts of flow rate of the exhaust hood



Impacts of source strengths



Impacts of airflow obstacles

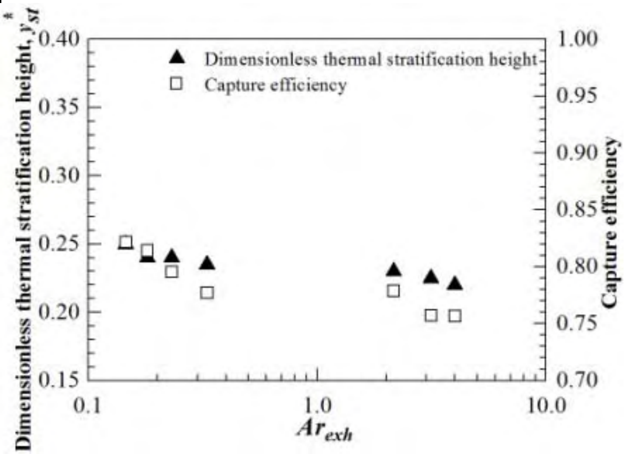


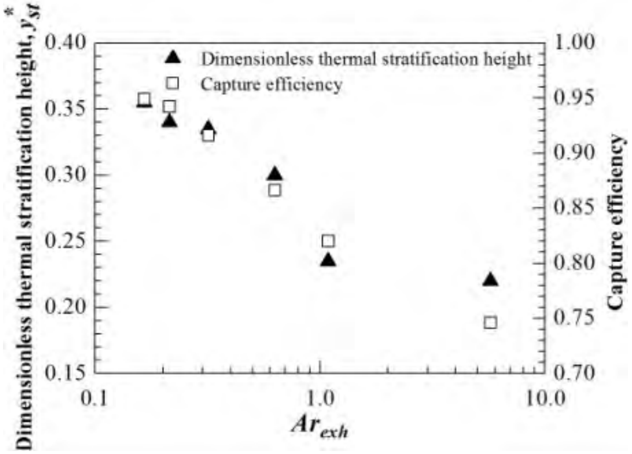
Impacts of distance

Case 1

- The thermal stratification heights are affected by capture efficiency and their variation trends are consistent.

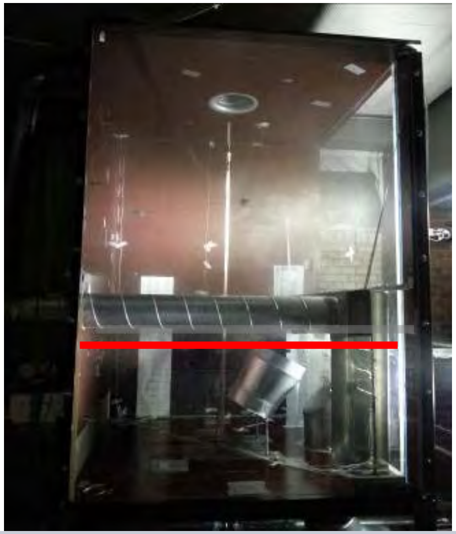
- To ensure the health of workers who operate in the upper space of a plant, safe operation heights should be lower than the corresponding thermal stratification heights.





(a) Case1; (b) Case2;

Variations of dimensionless thermal stratification heights and corresponding capture efficiency



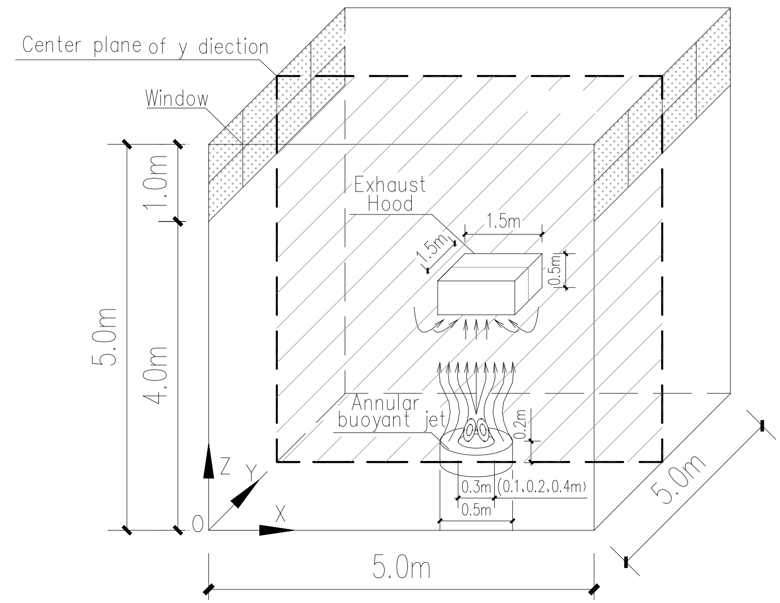
Measurement of thermal stratification heights

Case 2- Flow-field characteristics of high-temperature buoyant jets

- High-temperature heat source induced buoyant jets in large space widely exists in the iron and steel, coking and machinery industries.

- This study aimed to investigate the flow characteristics of high-temperature buoyant jets and their development laws influenced by ventilation system.

- The geometry of the simulated chamber with high-temperature buoyant jets was established corresponding to a portion of the deslagging plant.

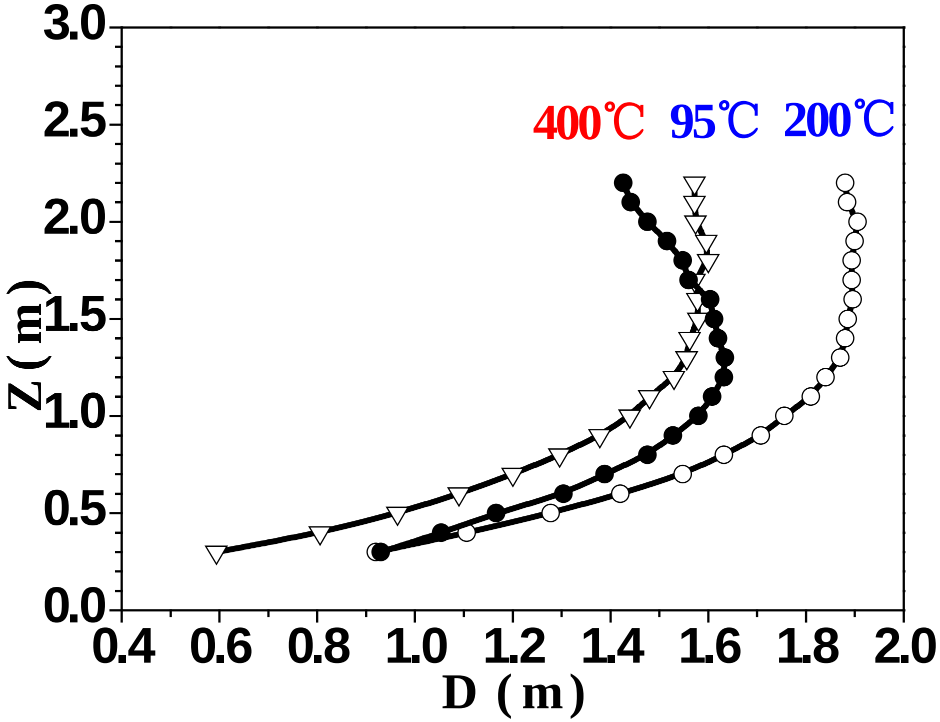


Configuration of the simulated chamber

Published in *The Scientific World Journal*, *Yi Wang, Yanqiu Huang , Jiaping Liu et al.*

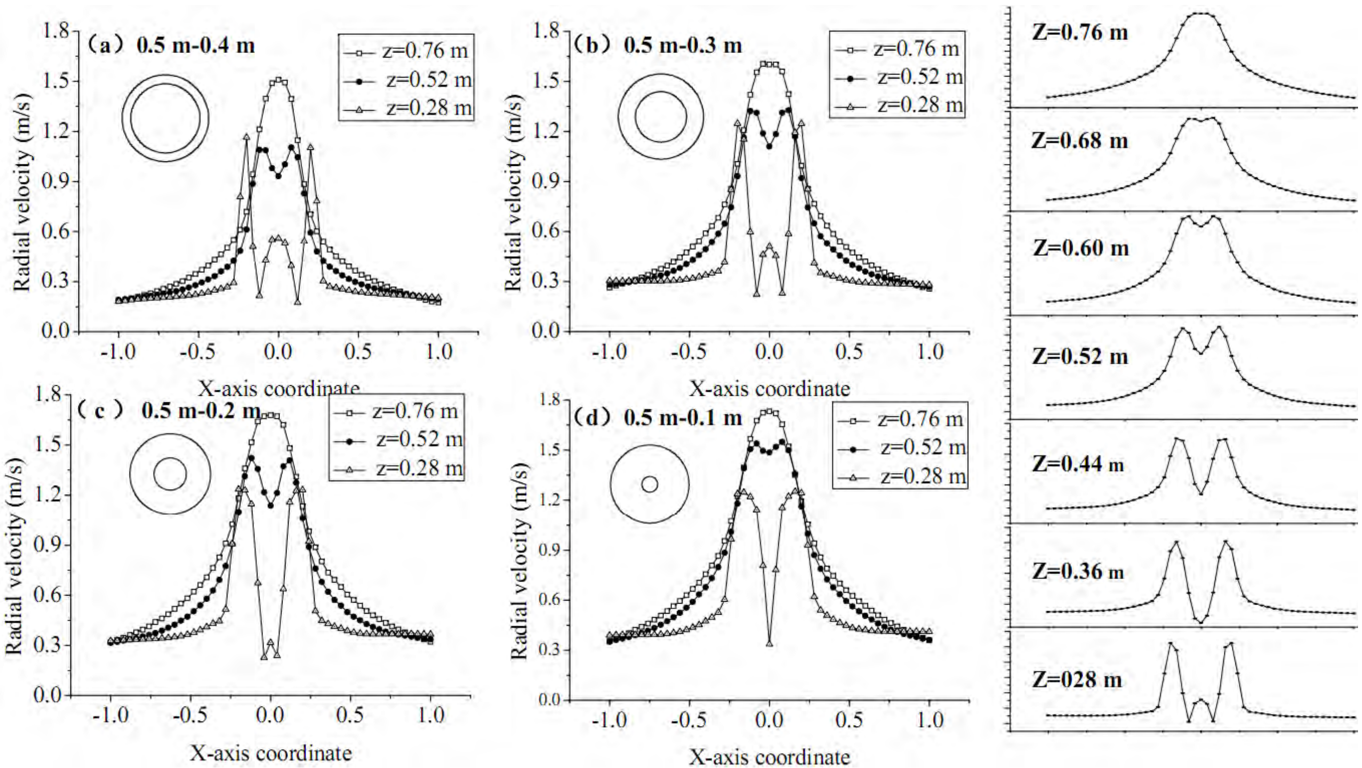
Case 2

- The characteristics of high temperature buoyant jets are quite different.



Cross-section diameter variations of high-temperature buoyant jets

- Radial velocity developments of four annular jet widths reveal that annular buoyant jets could not be simplified as circular buoyant jets, when the ratio of outer diameter to inner diameter of the annulus is smaller than 5/2.



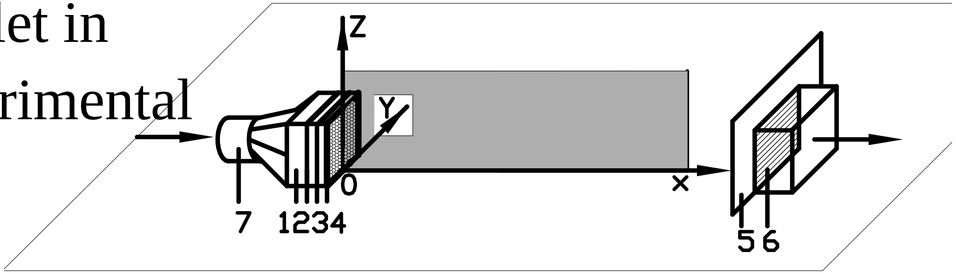
Variations of radial velocity distribution of four annular jet widths

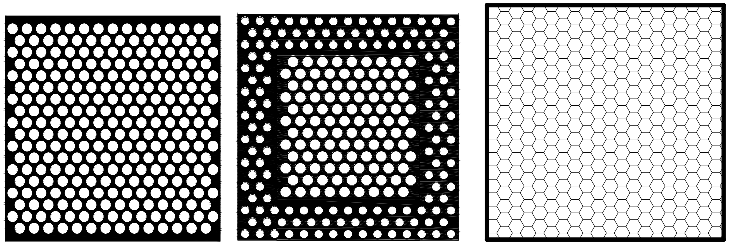
Case 3- Study on jets from a parallel-flow outlet in a push-pull ventilation system

- Push-pull ventilation system has flexible control domain and high ventilation efficiency.

- This study aimed to analyze one-side confined jets from a parallel-flow outlet in push-pull ventilation systems by experimental methods.

- Full-scale experiments were conducted in an environmental chamber equipped with a parallel-flow outlet with a two-tier perforated plate and a honeycomb in a push-pull ventilation system.



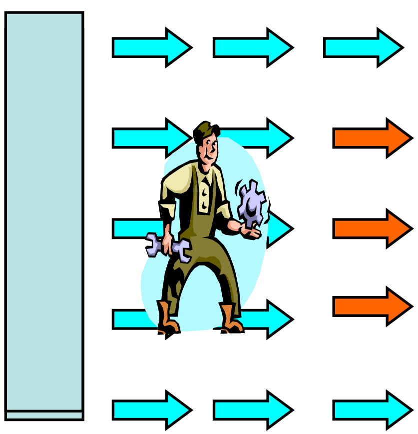


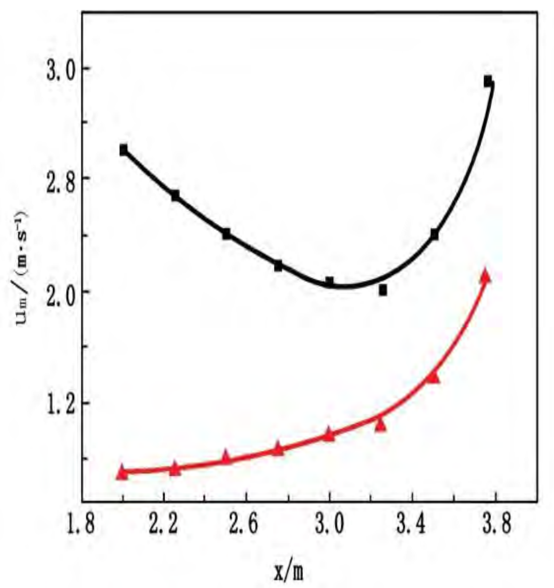
Schematic views of the planes of measurements on the floor and the structural details of the supply outlet

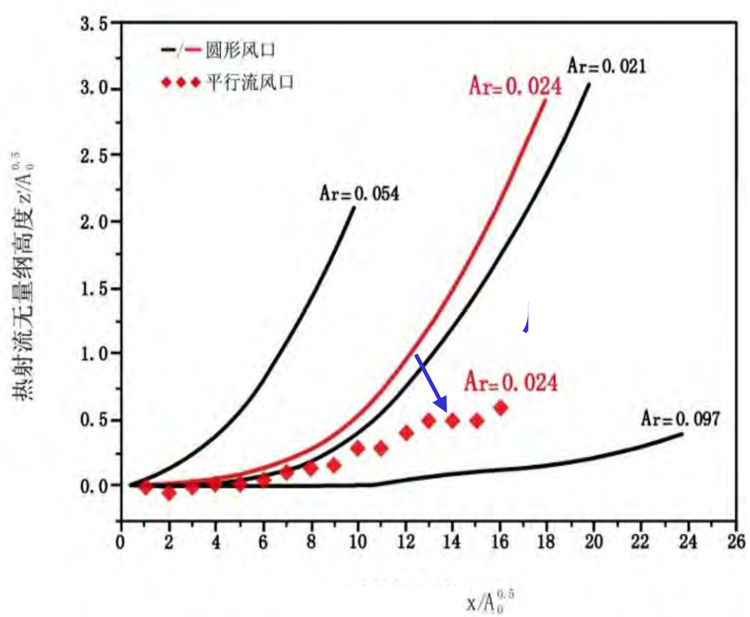
Published in *Indoor and Built Environment*, *Yi Wang*, *Yanqiu Huang* , *Yu Zhou et al.*

Case 3

- The results reveals that there is significant difference on trajectories of hot air jets between parallel-flow outlet and traditional circular aperture.





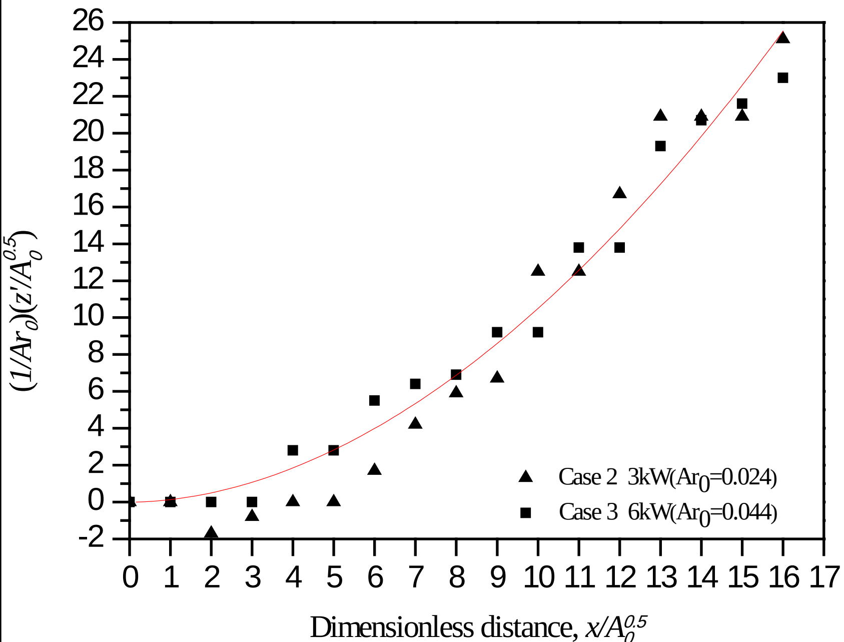


Trajectories for the hot circular and parallel-flow outlet’s wall jets

Case 3

- A semi-empirical equation for a parallel-flow outlet of the push-pull ventilation system is established to describe the trajectory of hot jets at different locations when *Ar0* ranges from 0.024 to 0.044.

- The established equation would contribute to guidelines for push-pull ventilation systems for improving design accuracy.



Curve fitting on trajectory of hot air jets

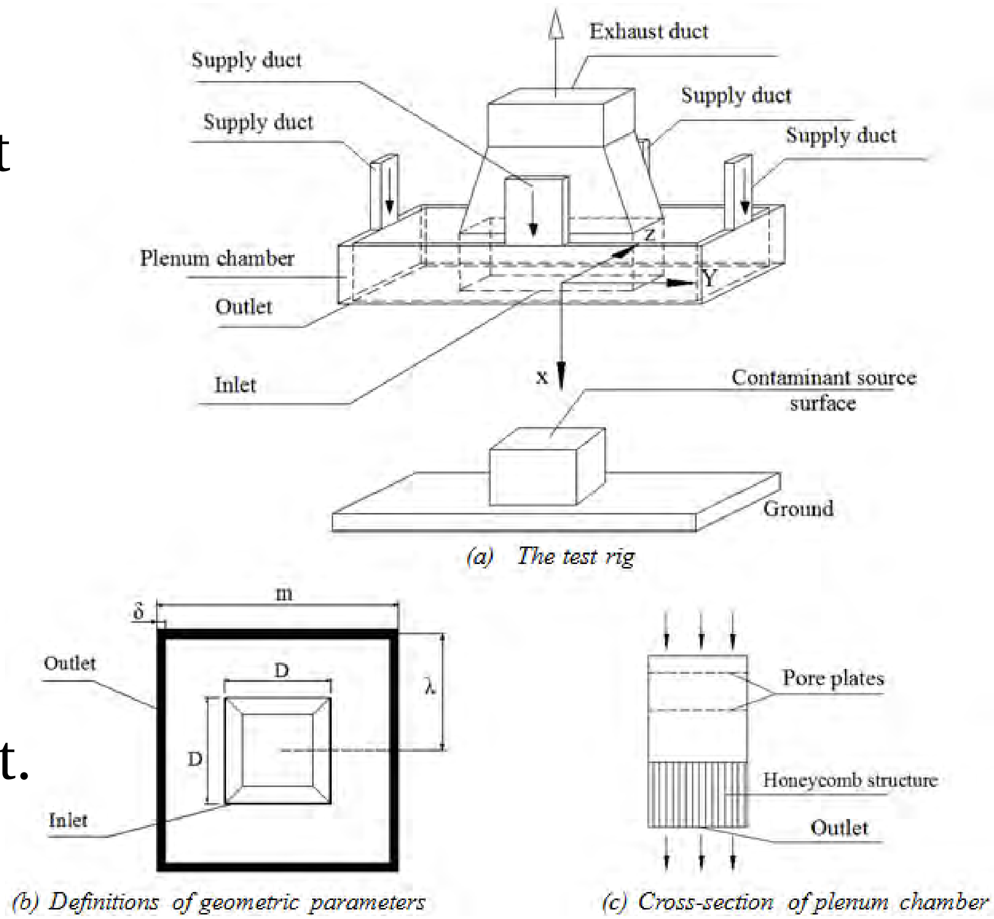
Carrying out a regression analysis on the measured data, the following equation is obtained:

$$z' / \sqrt{A_0} = 0.135\left(x / \sqrt{A_0}\right)^{1.89} Ar$$

Case 4- Flow Characteristics of an Exhaust Hood Assisted by a Jet

- An air curtain generated by a jet is usually used to enhance an exhaust hood's capture ability on local ventilation systems.

- Experimental methods are employed to investigate the flow characteristics formed by an exhaust hood associated with a jet.



The air curtain system

Published in *International Journal of Ventilation. Yi Wang,Yuanyuan Wei, Jiaping Liu et al*.

Case 4

- This kind of exhaust hood could work efficiently only when the effective air curtain is formed.

- The air curtain can separate the contaminants from the workspace directly.

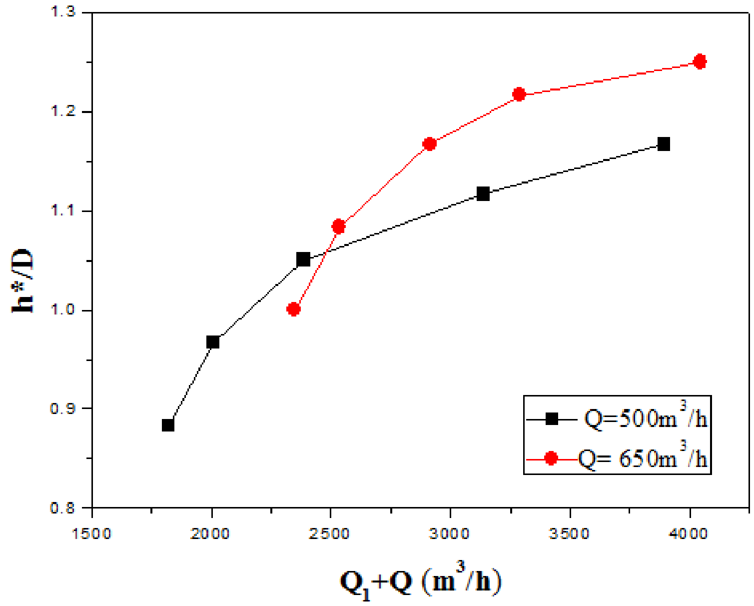
The air curtain is not formed

The air curtain is formed

Case 4

● When the air curtain is formed, increasing the exhaust flow rate or the supply air rate can increase the efficient capture distance.

● By contrast, the increase of the exhaust flow rate seems to be more high-efficient.

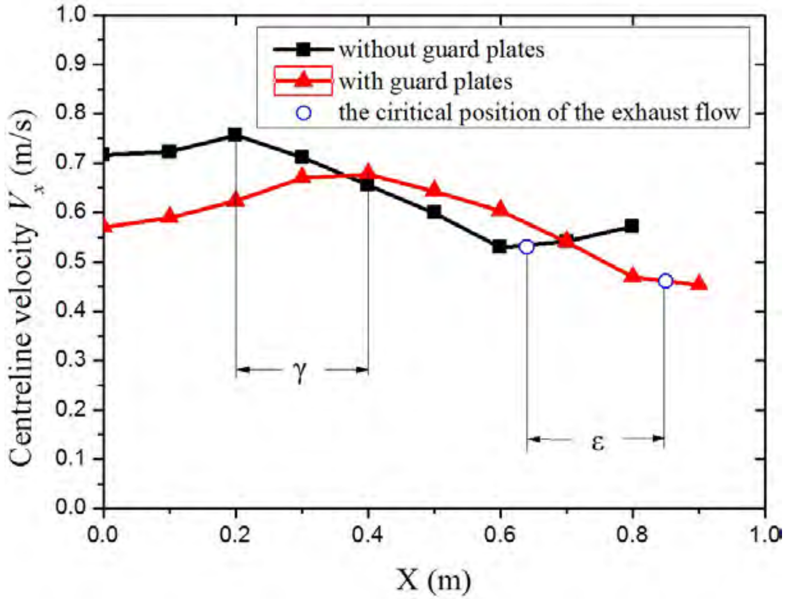


Dimensionless efficient capture distance

Case 4

- Vertical guard-plates between the inlet and the outlet can enhance the control effect.
- A longer capture distance will be obtained with increasing the guard plates width.

With guard plates



Centerline velocity decay

① Project 1——airflow characteristics

Case1-4

② Project 2——two-phase airflow characteristics

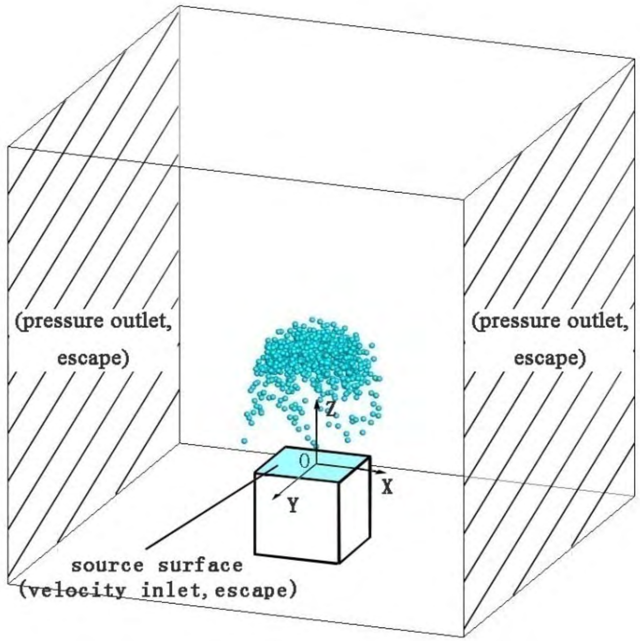
Case 5

③ Project 3——thermal environment characteristics

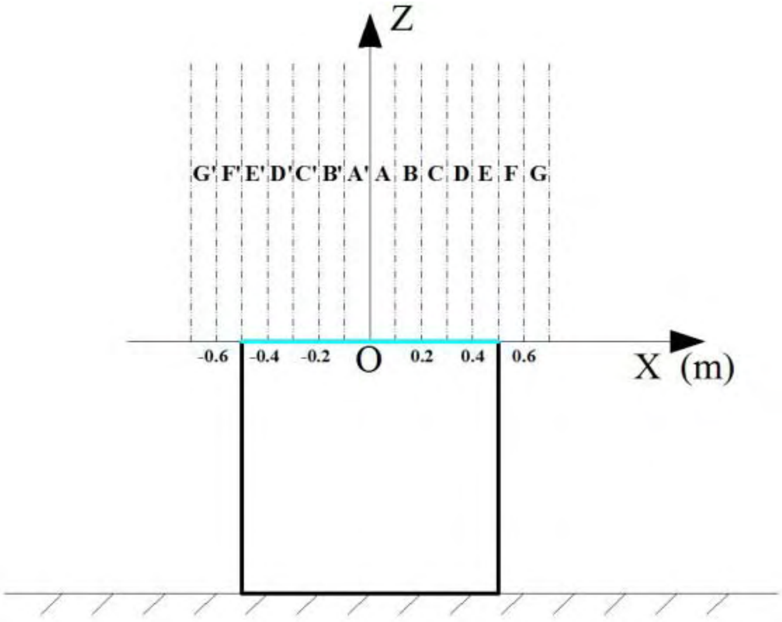
Case 6

Case 5- Evaporation and movement of droplets

- Droplets generated in industrial buildings may do harm to the workers, the construction and the environment.
- The evaporation and movement of droplet populations released from a tank in industrial buildings are discussed.



Geometric model



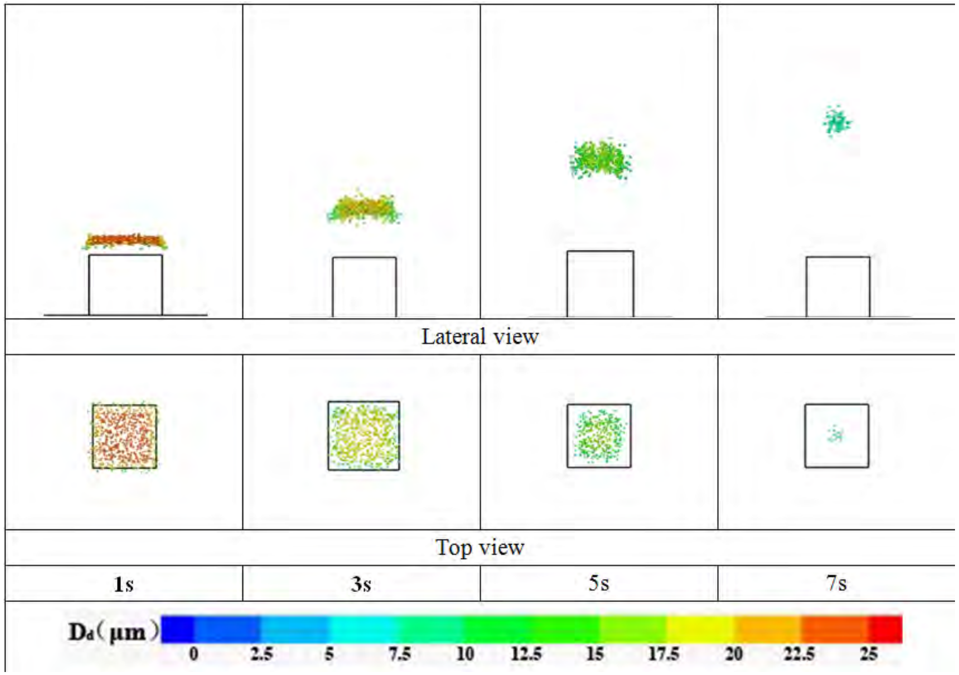
The region schematic above the opening

Published in *Aerosol and Air Quality Research. Yi Wang, Yang Yang, Yan Zou et al.*

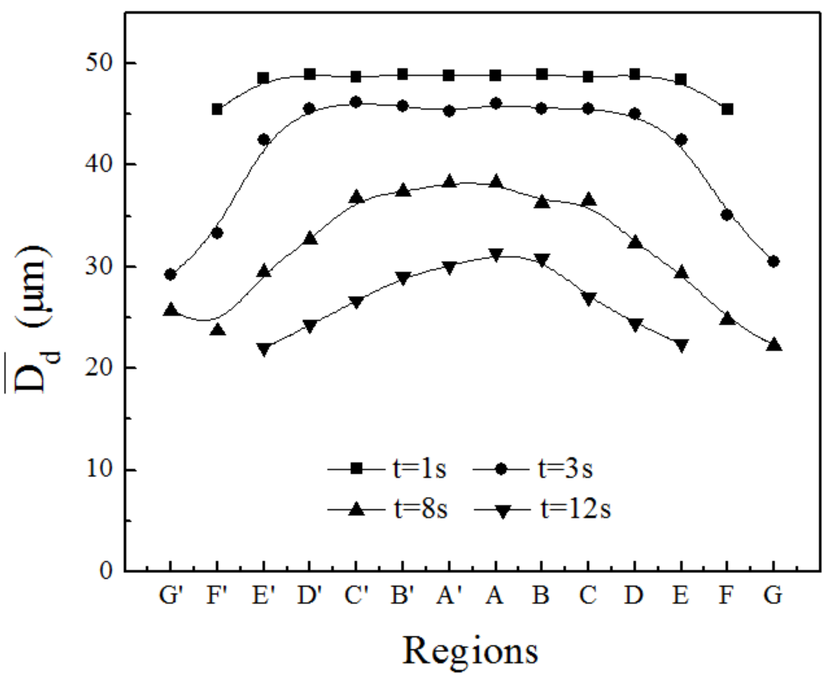
Case 5

- The evaporation and movement of the droplet populations present obviously non-uniform distributions

- The droplets closer to the centreline of the tank show a slower diameter decrease and have a longer evaporation time.



The droplet diameter change history

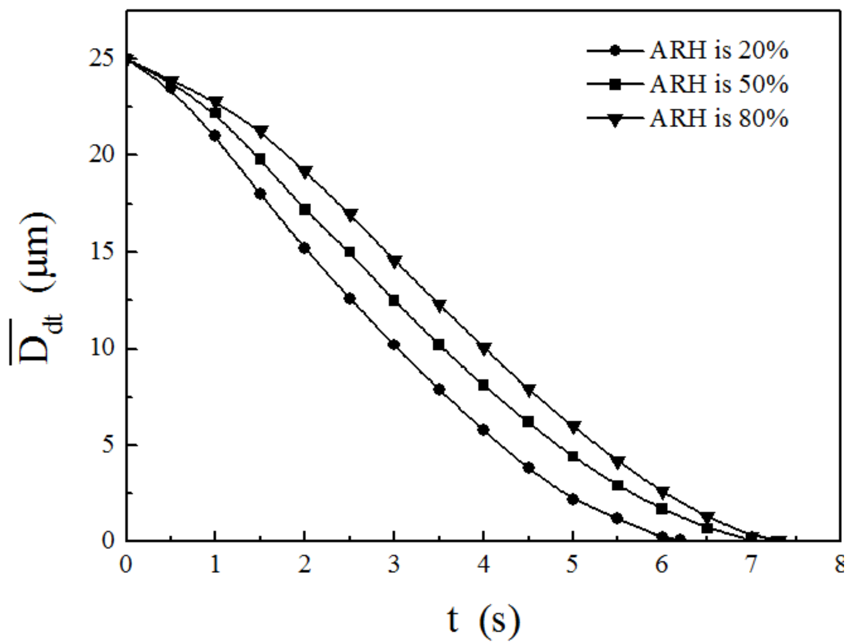


The mean diameter distribution

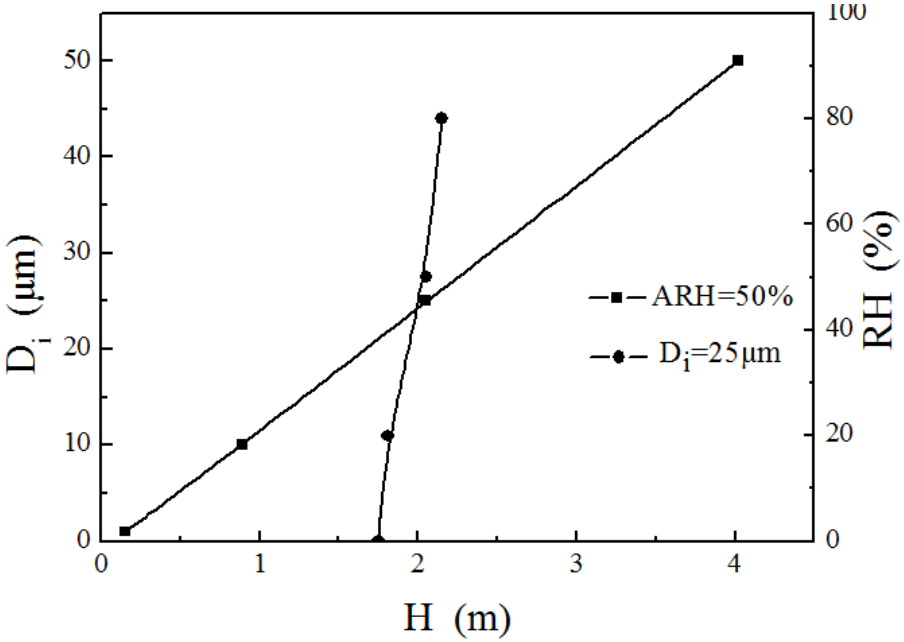
Case 5

- The relative humidity of the ambient air (ARH) has a rather limited effect on the evaporation and movement of droplets.

- The effect of ARH on the terminal height variation are merely 1/10 of the effects caused by the initial diameter variation (1µm -50µm).



The mean droplet diameter change



The maximum height

① Project 1——airflow characteristics

Case1-4

② Project 2——two-phase airflow characteristics

Case 5

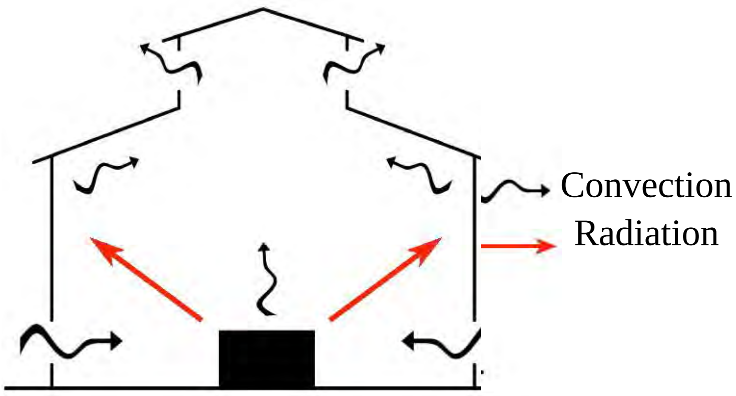
③ Project 3——thermal environment characteristics

Case 6

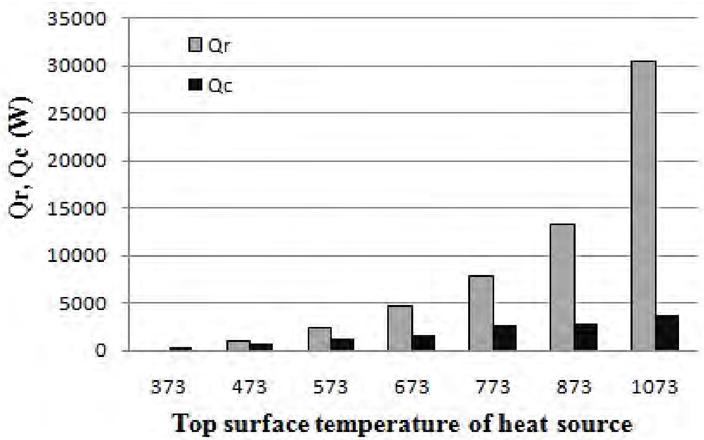
Case 6- Influence of convection and radiation on the thermal environment

- For an industrial building with high-temperature heat sources, the heat transfer modes of the heat source influence the thermal environment.

- To predict the thermal environment accurately with high-temperature heat sources, a method is required for conjugating convection and radiation.



The physical model



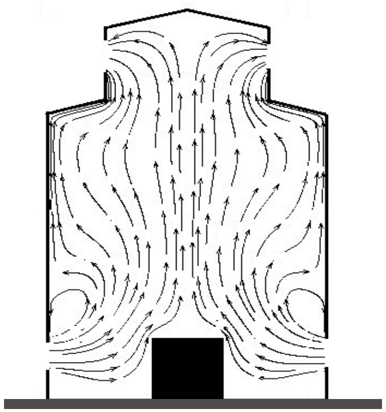
Ratios of convection heat and radiation heat

Published in *Energy and Buildings* *Yi Wang, Xiaojing Meng, Xiaoning Yang, Jiaping Liu.*

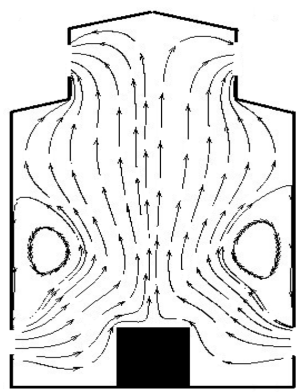
Case 6

- Radiation alters the temperature distribution and airflow through secondary convection near the sidewalls of the industrial building.

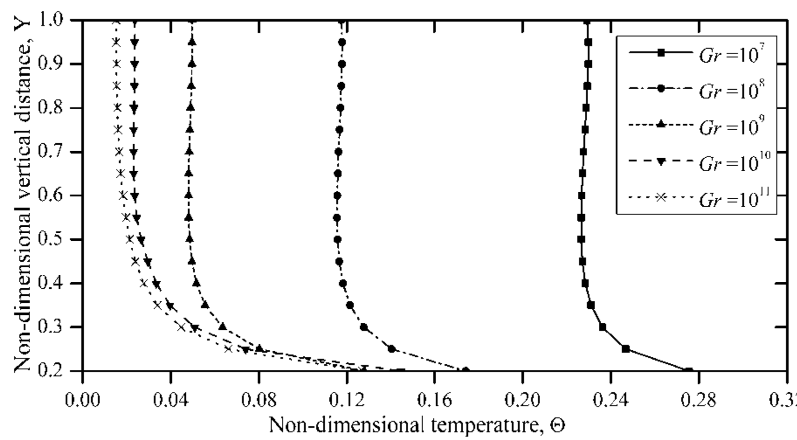
- The temperature distribution changes with Grash of number increasing are achieved.



Convection-radiation model



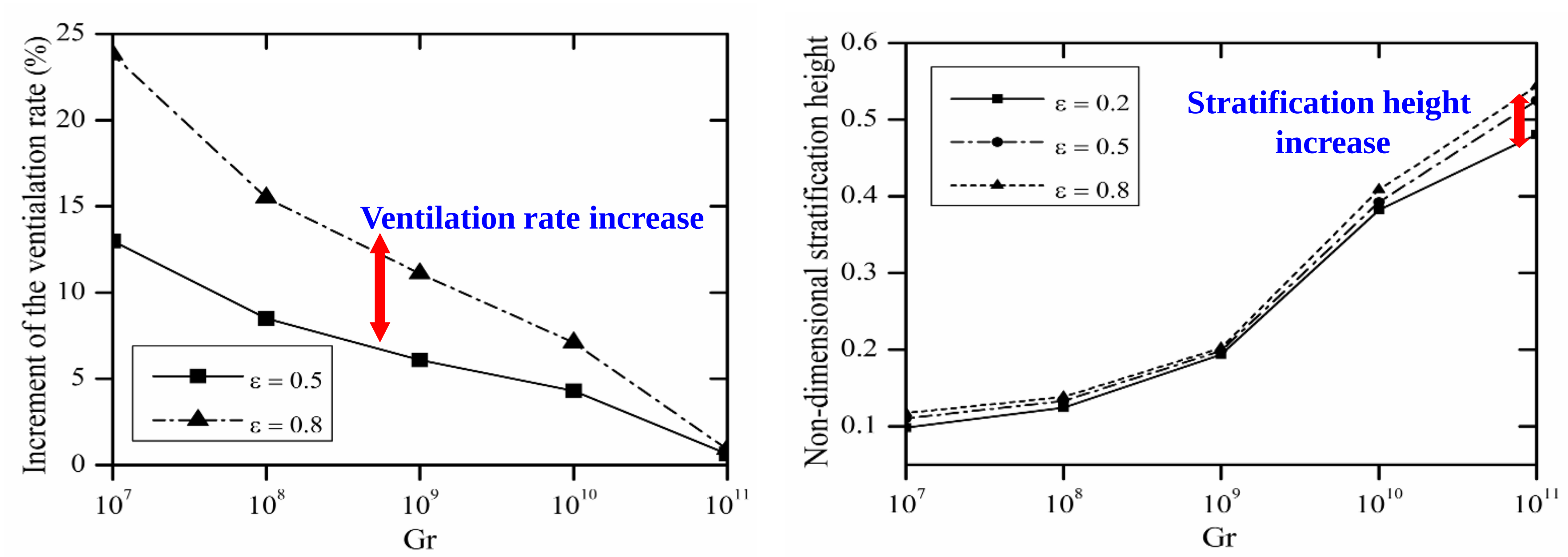
Only convection model



Temperature profiles above the heat source

Case 6

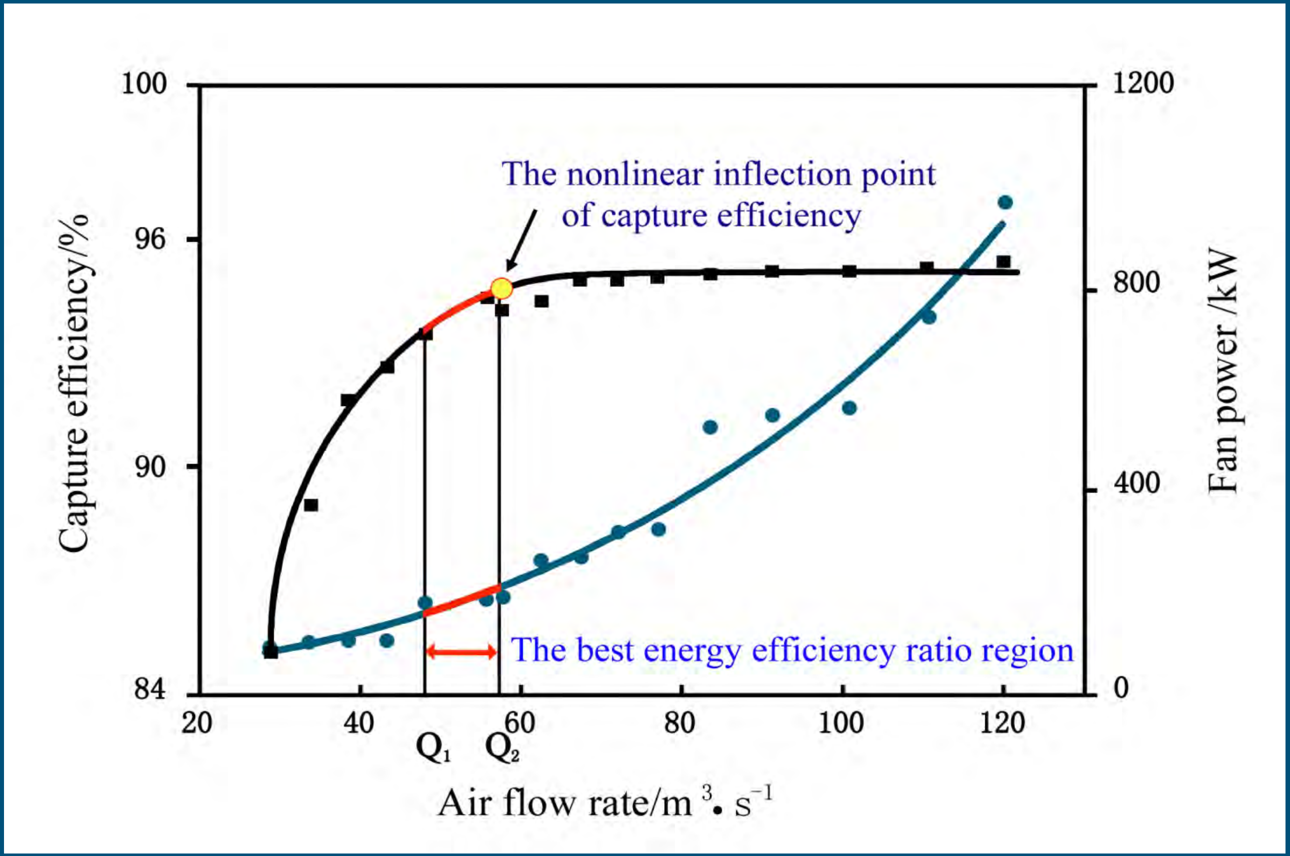
- The ventilation rate and stratification height are increasing functions of the Grash of number and the surface emissivity.



Ventilation rate and stratification height variations with *Gr*

Overall, the relation between ventilation rate and capture efficiency is nonlinear, thus, it is needed to find out the parameter domain for high-efficiency performance.

It is not a good way to enhance capture efficiency by increasing ventilation rate simply, and it will also increase energy consumption.



How to improve environment with lower energy consumption in the process of rapid develop?

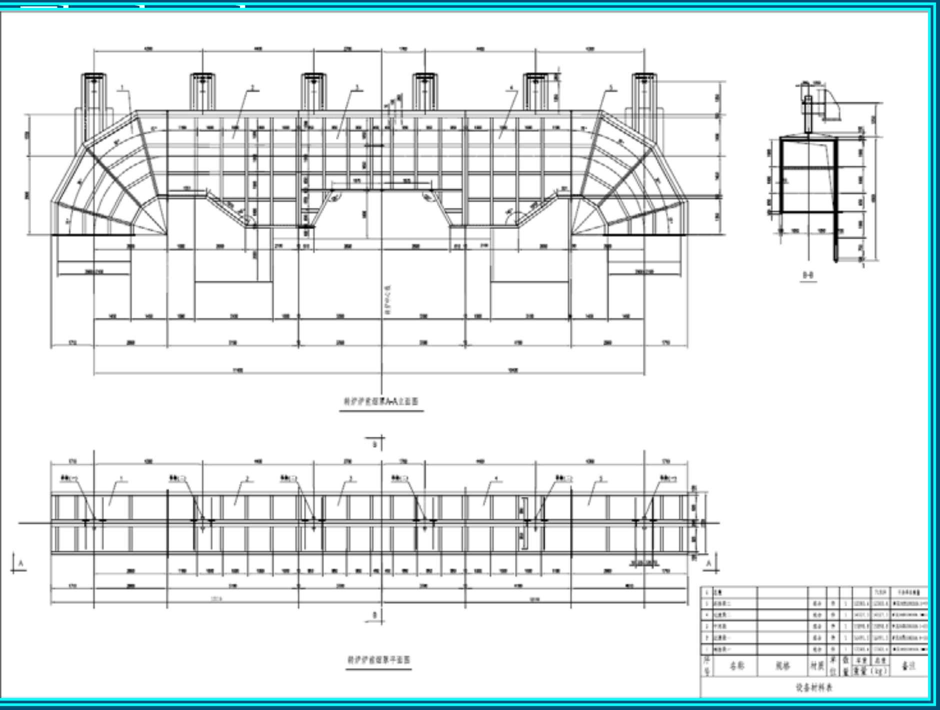
① The main influence factors and scientific mechanisms have been analyzed.

② The high-efficiency technology system has been applied, based on the analysis.

Application Effect of Refined Design

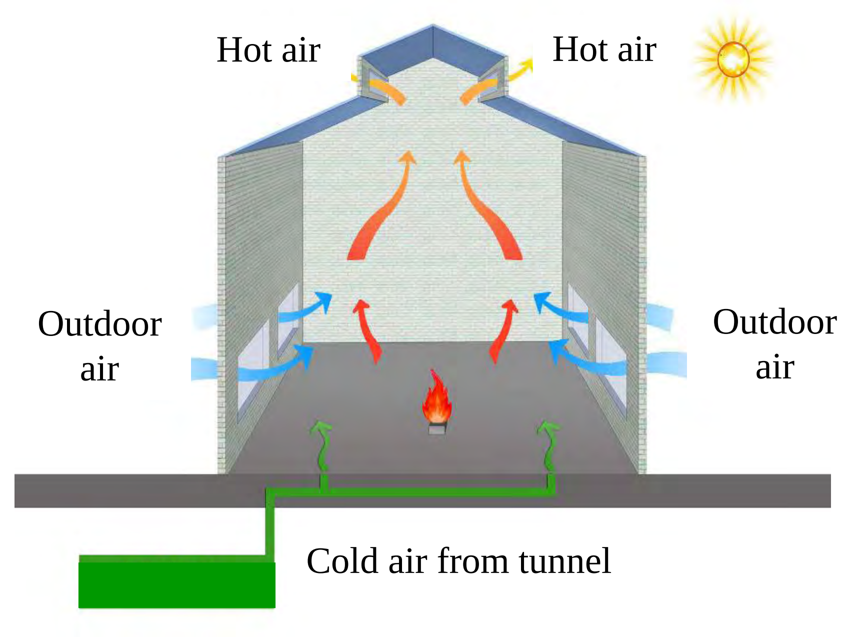
The main results were successively applied to some renovation projects in China, including ten new projects and seven of them are completed..

The capture efficiency increase obviously.



Building design of low energy-consuming could substantially save energy consumption of mechanical ventilation and air conditioning.

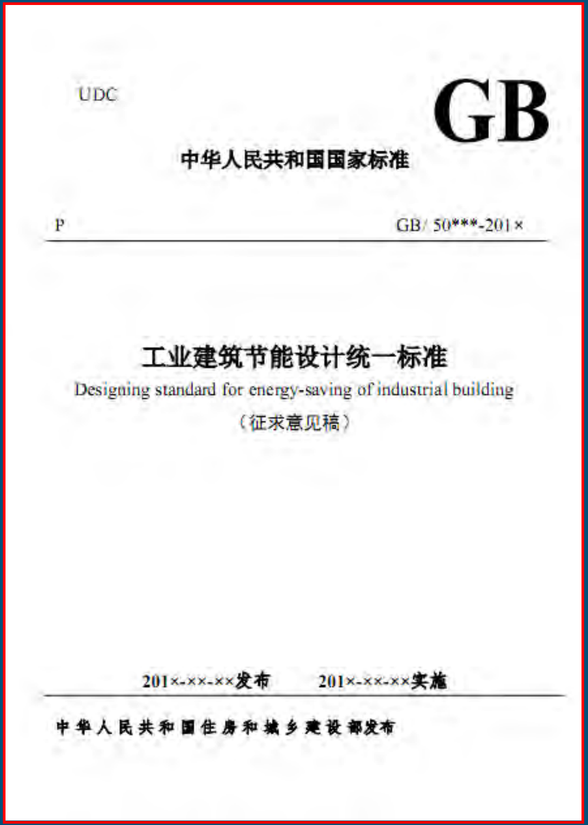
Tunnel ventilation becomes an ecological cooling methods and is applied in industrial and civil buildings.



- So far, there are over 10 designing standards for energy-saving of civil building in China, however, no corresponding standards for industrial buildings have been issued.

- Currently, Designing Standard for Energy-saving of Industrial Building (draft) is completed.

- Some of our research achievements have been applied to the draft of this standard.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工业建筑节能设计统一标准

Designing standard for energy-saving of industrial building

（征求意见稿）

201×-××-××发布　　201×-××-××实施

中华人民共和国住房和城乡建设部发布

The projects have won several awards

国家科学技术进步奖

证 书

为表彰国家科学技术进步奖获得者，特颁发此证书。

项目名称：西部低能耗建筑设计关键技术与应用

奖励等级：二等

获 奖 者：王 怡

证书号：2010-J-221-2-01-R03

陕西省科学技术奖

证 书

为表彰陕西省科学技术奖获得者，特颁发此证书。

项目名称：低能耗建筑通风设计关键技术研究与应用

奖励等级：壹等

获 奖 者：王 怡

二〇一三年十二月二日

证书号：13-1-27-R1

中国钢铁工业协会

中国金属学会

冶金科学技术奖

证书

为表彰对推动中国冶金行业科技进步做出突出贡献者，特颁此证，以资鼓励。

获奖项目：高炉出铁场烟尘控制关键技术研究与应用

获 奖 人：王 怡

获奖等级：叁等奖

获奖时间：贰零壹贰年

2012 年 8 月

No：2012-029-3-2

陕西高等学校科学技术奖

获 奖 证 书

项目名称：建筑自然通风设计理论及其工程应用

获奖等级：一等奖

获奖单位：西安建筑科技大学

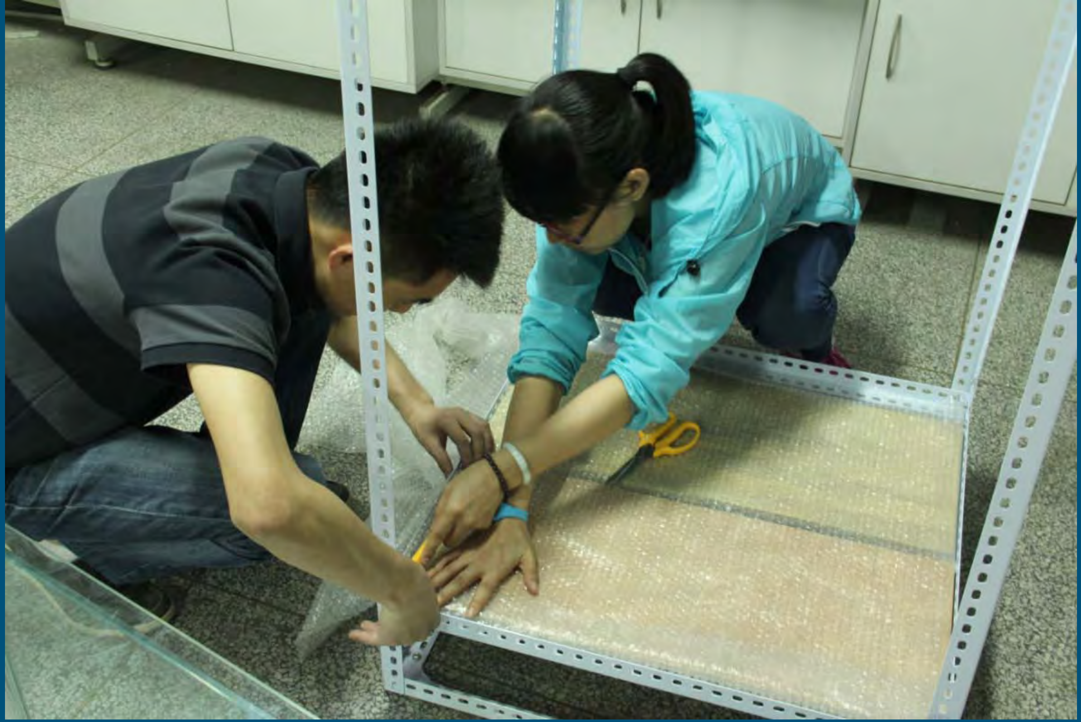
获 奖 者：王 怡（第1完成人）

项目编号：12I02

陕西省教育厅

二〇一二年五月

Young group




Conclusion

- There is significant difference between industrial buildings and civil buildings. The efficiency of existing technology system for environment control is non-sufficient in China, so it is necessary to explore technological innovation. While the corresponding energy saving standards are still in the preliminary stage.
- It is of great significance to improve cognitive level of indoor environment characteristics in industrial buildings, and then apply new technology to practical projects.

Thanks for your attention !