Introduction of thermal environment measurement and evaluation standards

--GB/T 50785 2012 from Chongqing University

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Contents

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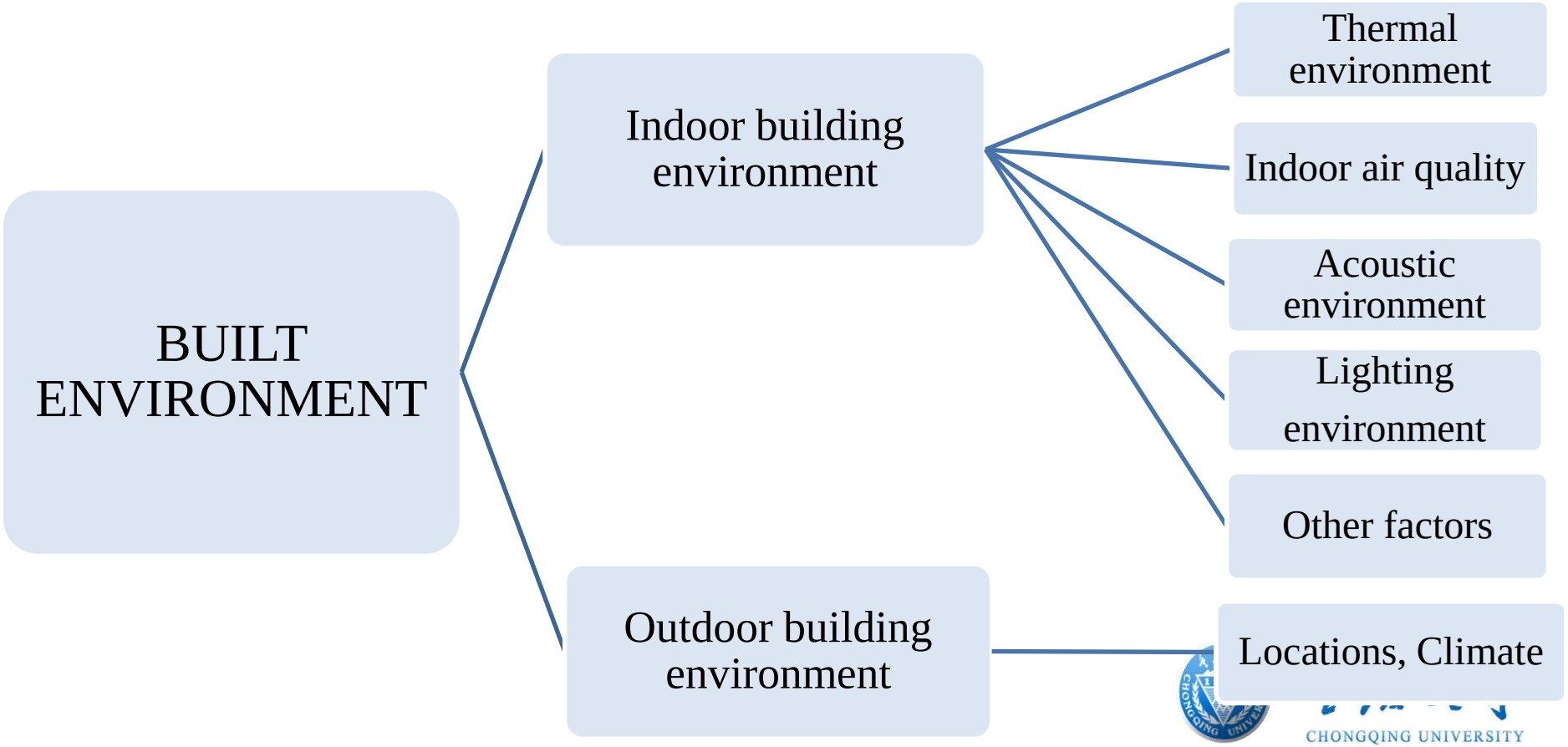
Background

建筑热环境是一门反映人--建筑--自然环境三者之间关系的科学，是了解人和生产过程需要何种室内外热环境，掌握室内外热环境形成的特征和影响因素，通晓改变或控制特别是室内热环境的基本原理与方法，为创造舒适环境提供理论基础。



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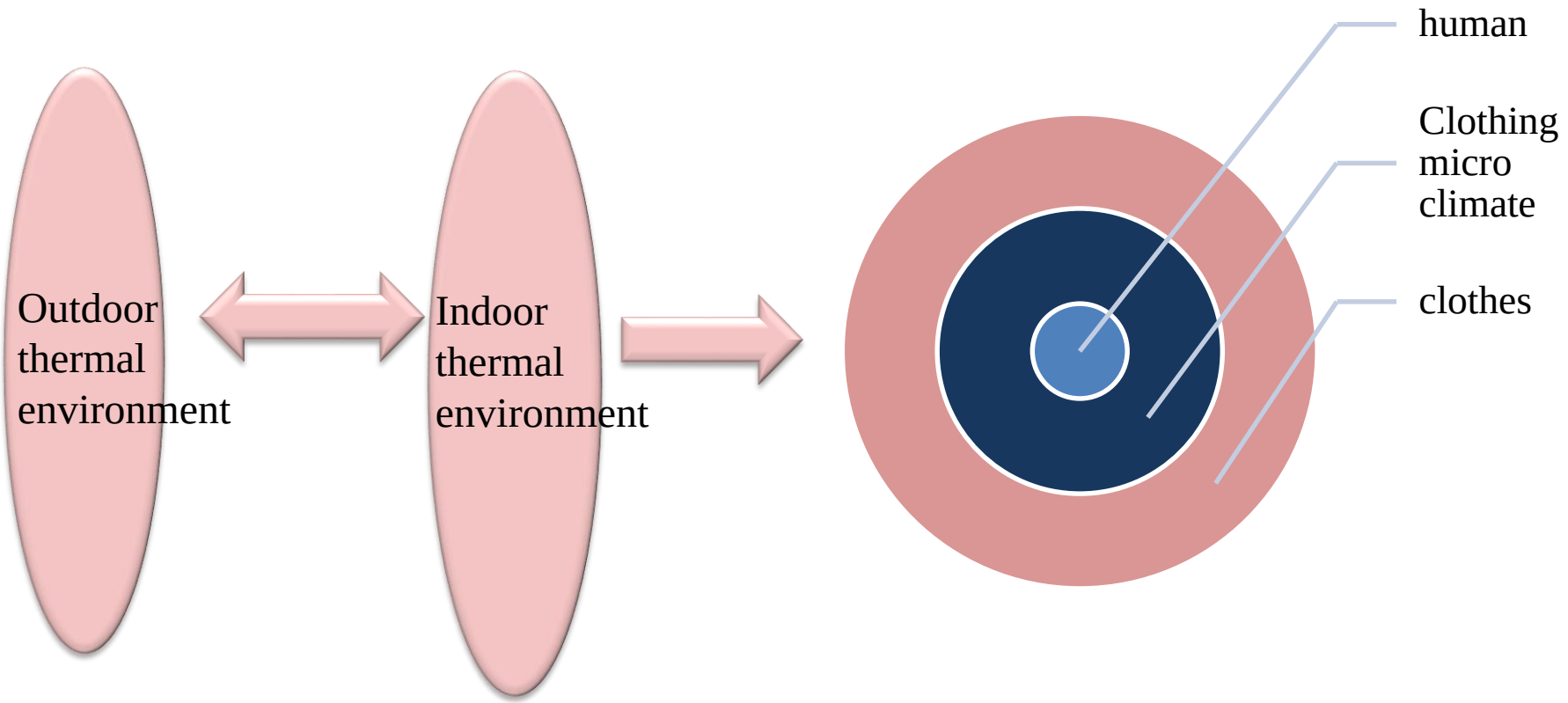
Background

Human Micro environment-Indoor thermal environment



Human-clothes-indoor thermal environment—outdoor thermal environment
服装---室内热环境---室外热环境系统

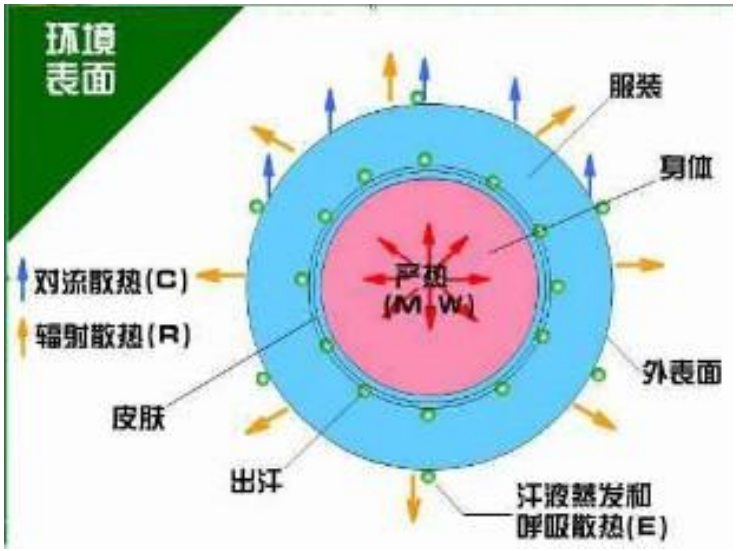
Human Thermal Comfort Theory

Human body heat balance equation

$$M-W-C-R-E=S$$

M: Metabolic Rate
W: Mechanical Work
C: conviction
R: Radiation
E: Evaporation, Water Vapor Diffusion, Respiration

When S=0，there is a heat balance between heat loss and heat production。



Figures of Human body heat balance

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Background

Effect Factors

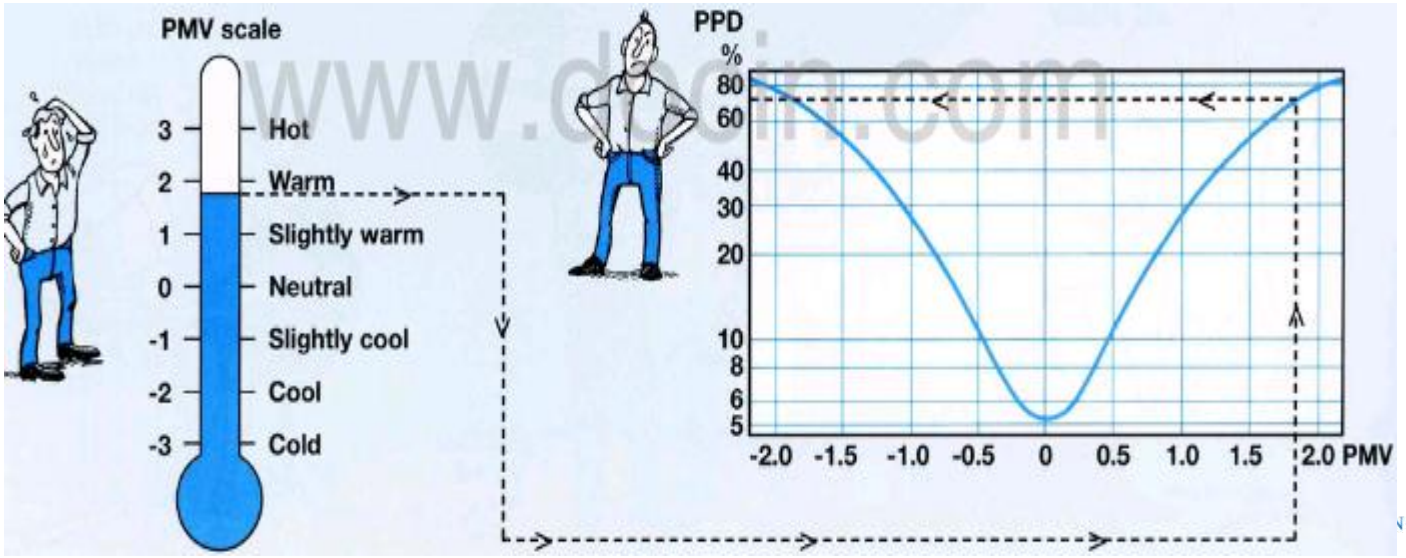
室内空气温度（Air Temperature） 相对湿度（Relative Humidity） 气流速度（Air Velocity）

平均辐射温度（Mean Radiant Temperature） 人体活动量（Metabolic Rate）

人体服装热阻（Clothing Insulation）

预测平均评价 → **PMV-PPD**

$$PMV=[0.303\exp(-0.036M)+0.0275]TL$$



- ✓ How do the thermal comfort standards come
- ✓ What physical parameters are there to evaluate thermal environments and how to
- ✓ What are the differences between air-conditioning buildings and free-running building?

Human response to dynamic thermal environment

--Laboratory experiment

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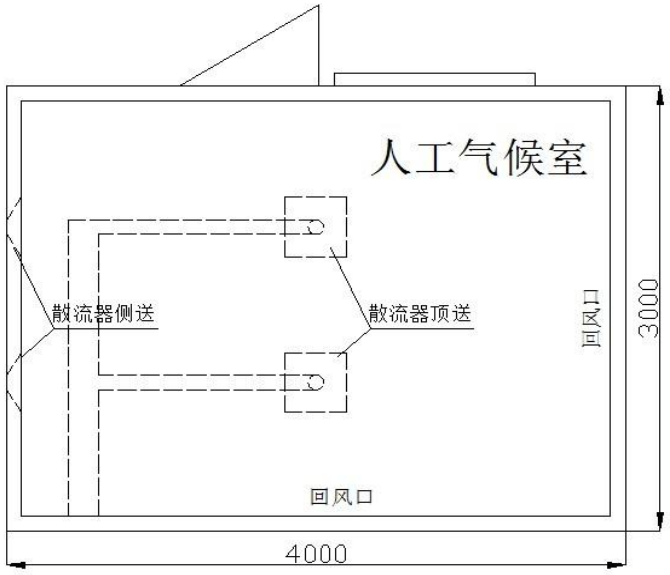
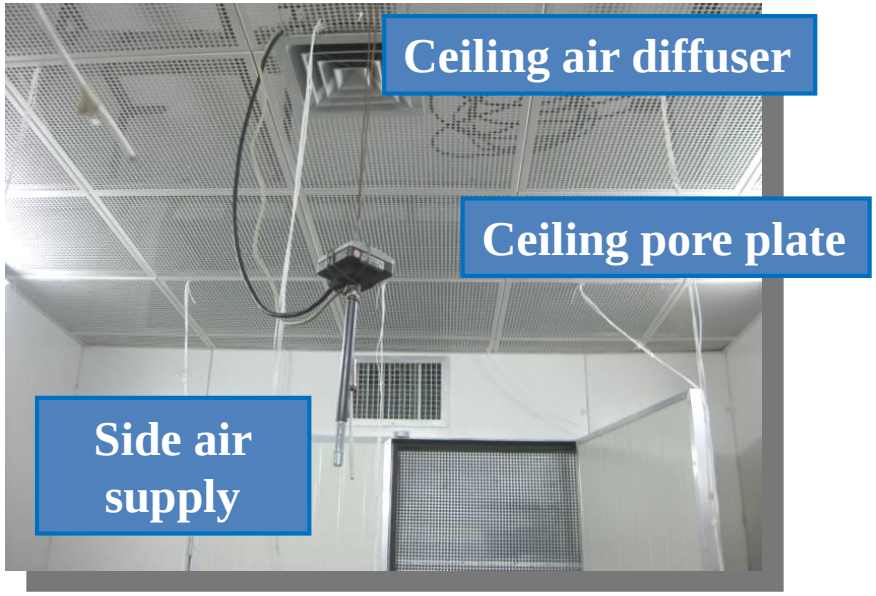
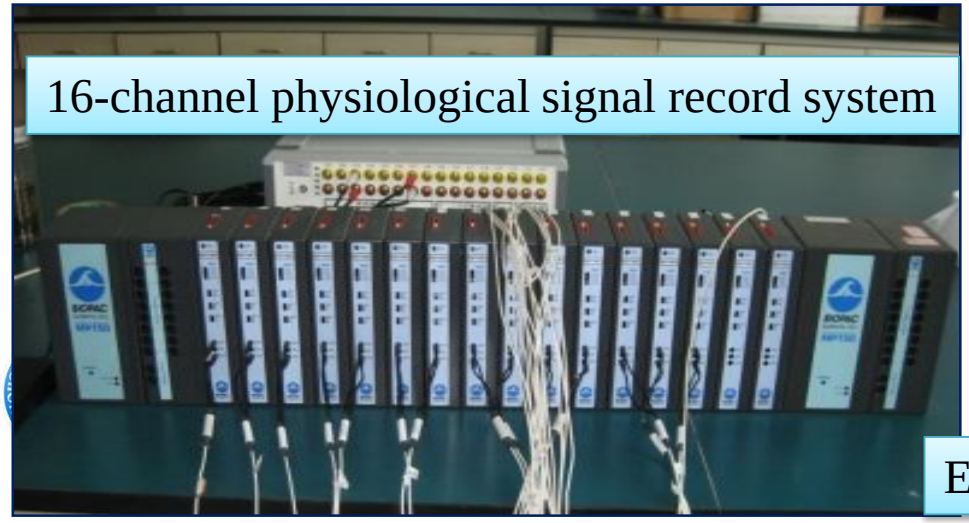
Climate chamber—Chongqing University



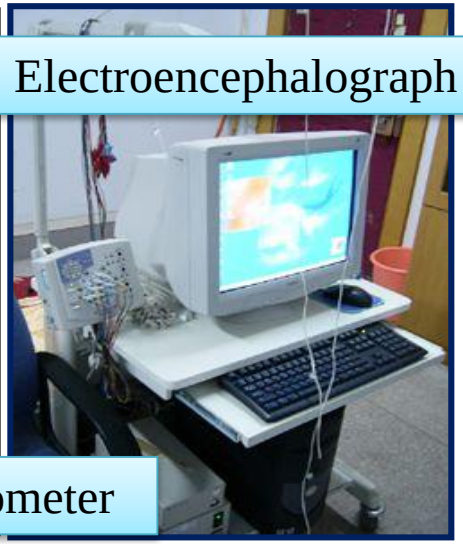


Main Instruments

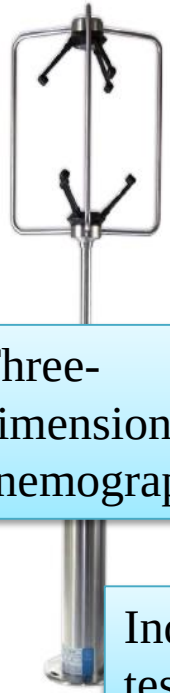
16-channel physiological signal record system



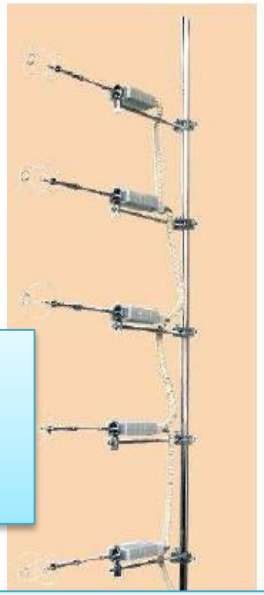
Electroencephalograph



Electrical/trigger potentiometer



Three-dimension anemograph

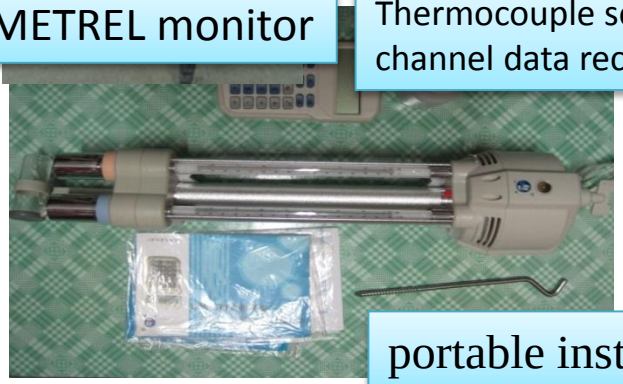


Indoor air distribution test system

LSI thermal comfort instrument

METREL monitor

Thermocouple sensor and 4 channel data recorder



portable instrument

Natural and Artificial Environments

Vital signs parameters

Metabolic parameters

Nervous system

Electrophysiological testing…….

Human physiological and psychological experiments

Body temperature

Blood pressure

Heart rate

Blood flow

Nerve conduction

Skin conductivity

Oxygen concentration

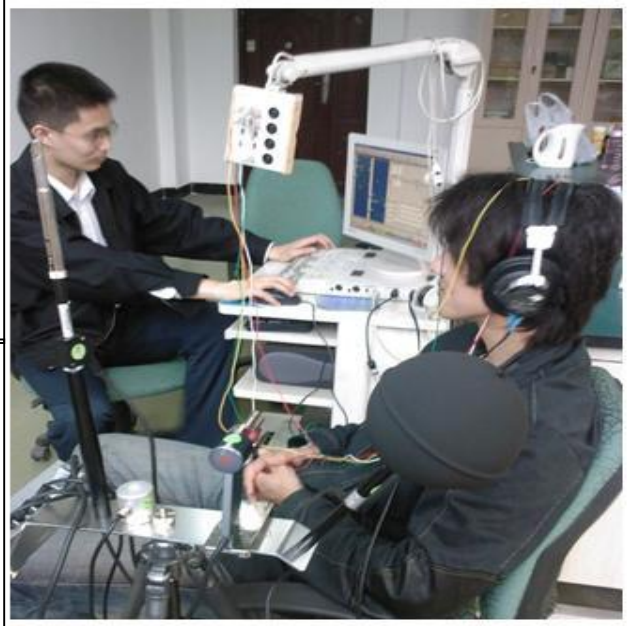
Eccrine secretion

Skin temperature

EEG

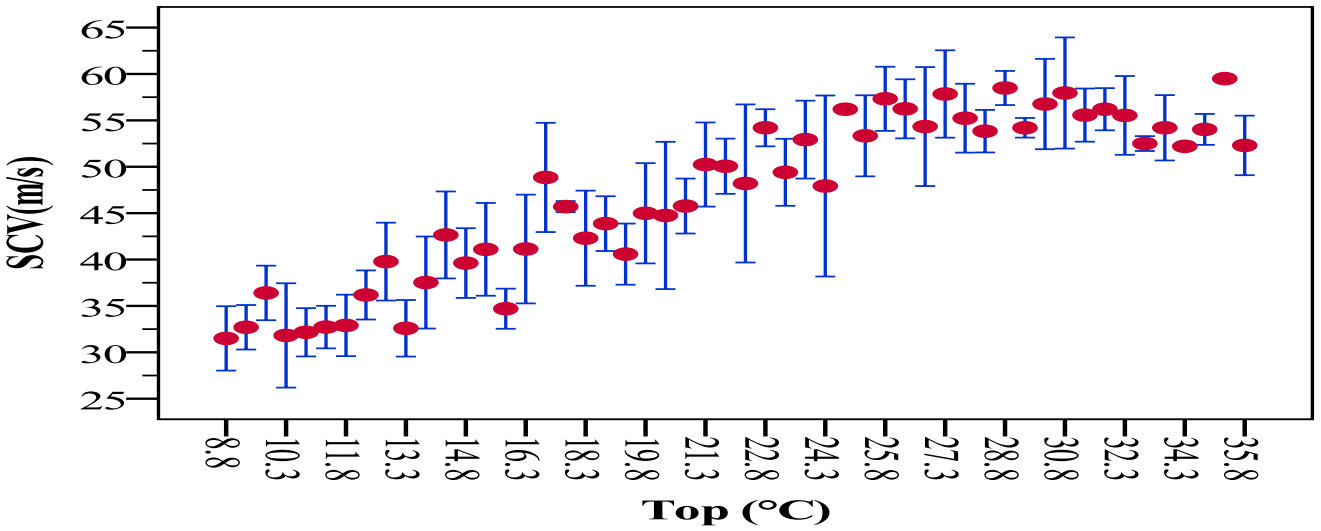
ECG

P300



SCV Response to Temperature

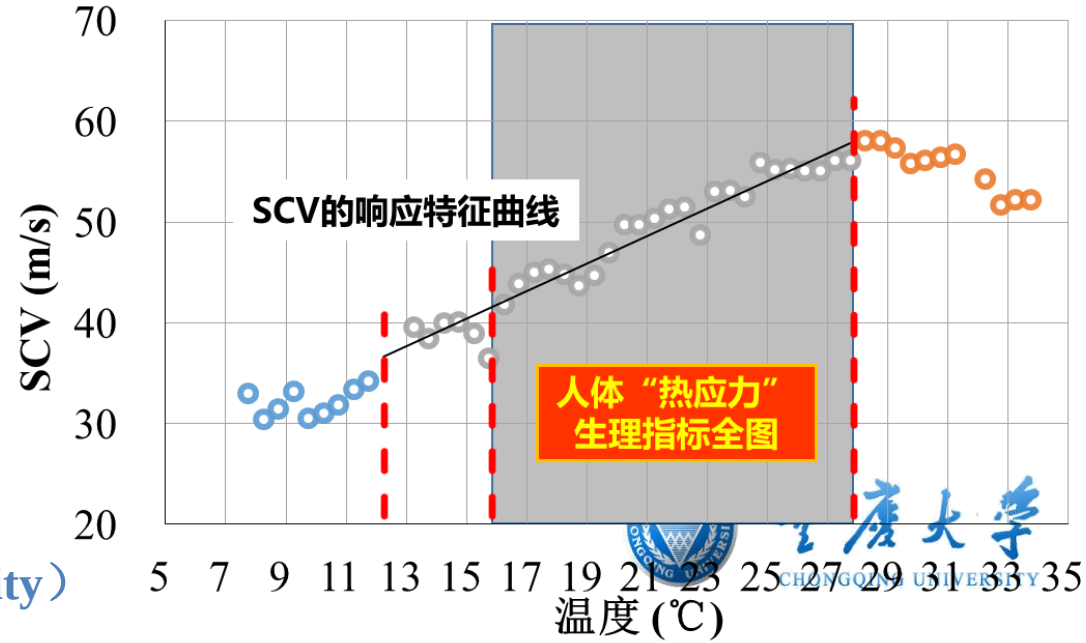
physiological test



response characteristic curve of SCV

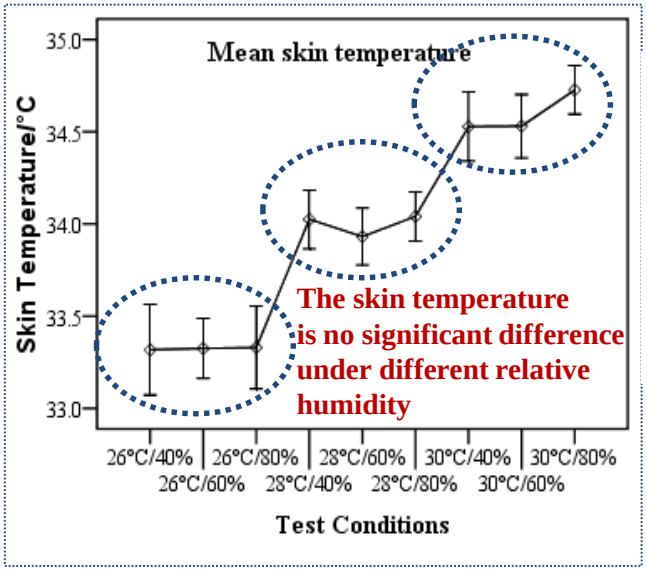
首次确定人体对热环境响应的生理指标

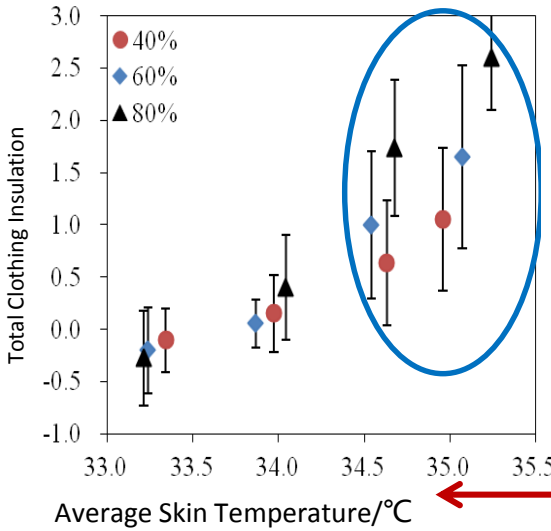
The impact of nerve conduction velocity on the human

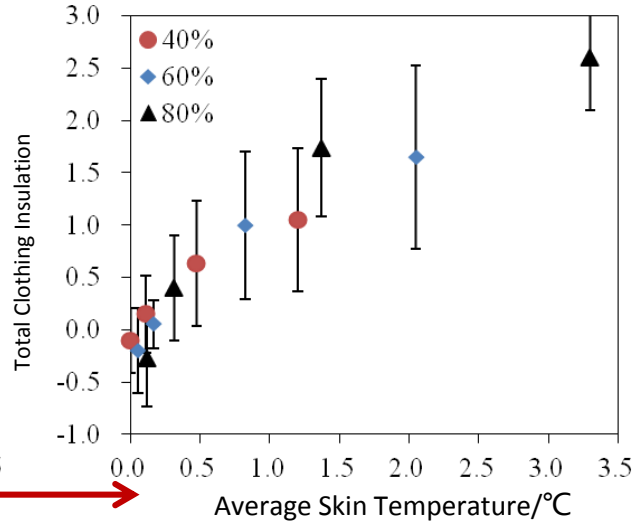


SCV(sensory nerve conduction velocity）

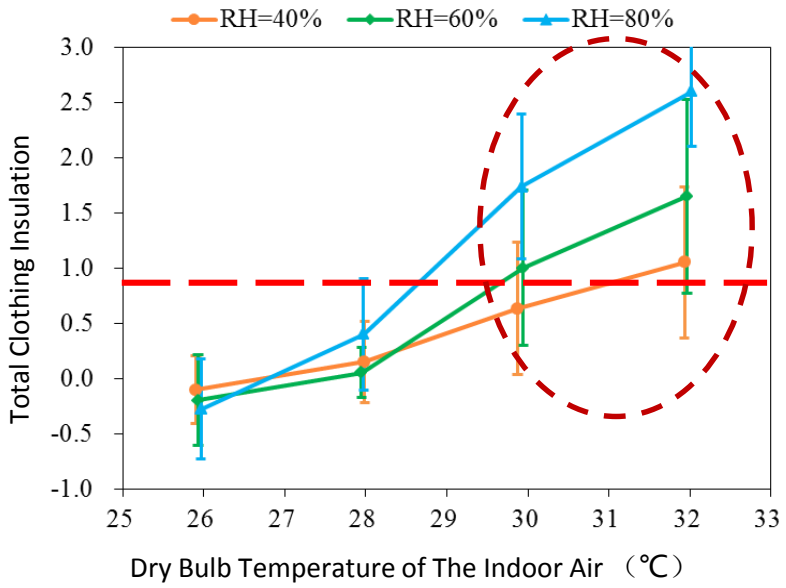
Human physiological and psychological response to humidity







In partial thermal environment . the main reason for relative humidity affect thermal sensation is sweating regulation .



Higher temperature， Humidity changes will significantly affect the thermal sensation；
sit-in state（1.0met）,clothing insulation is about 0.32clo,static wind ; environment temperature is 30℃, relative humidity is 60% or above 60%, Thermal environment is unacceptable

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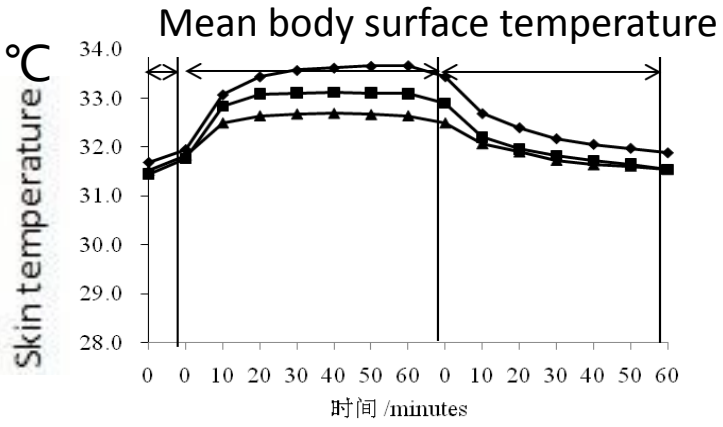
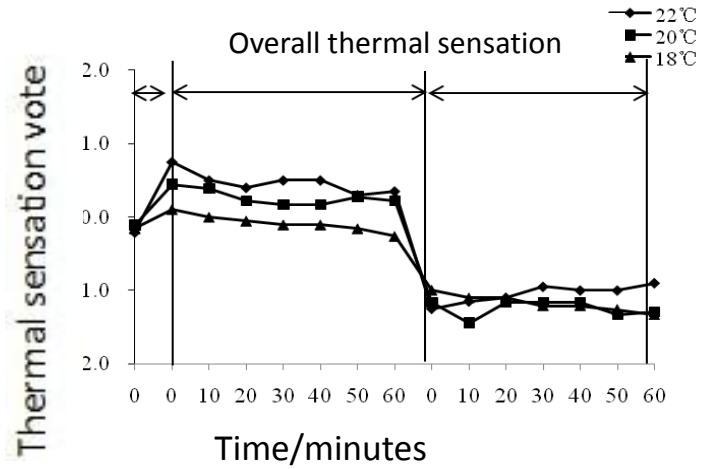
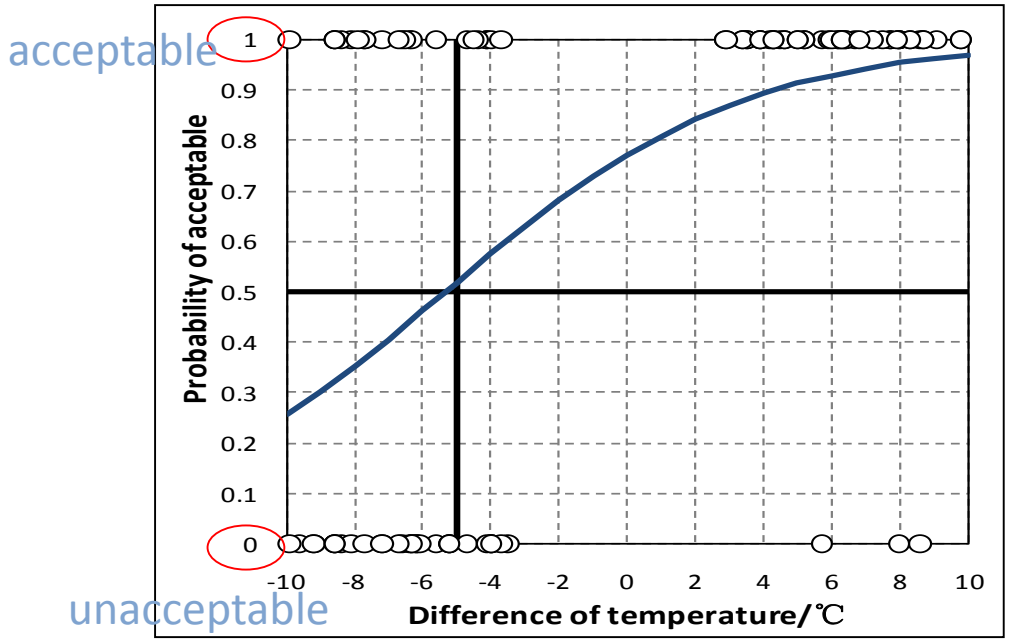
Temperature Step-change Experiment

Mutations in the environment on human thermal response characteristics







Mutations in the temperature difference before and after

In winter (warm—cold) : Acceptable mutations temperature difference is 5.2 ℃

In winter (cold—warm) : mutation in 10 ℃ temperature range are acceptable.

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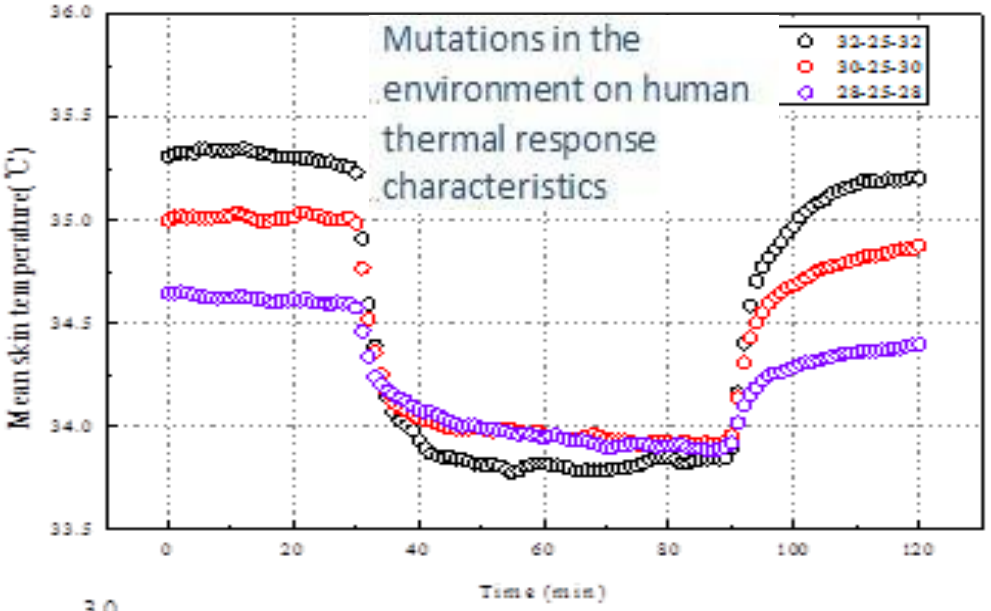
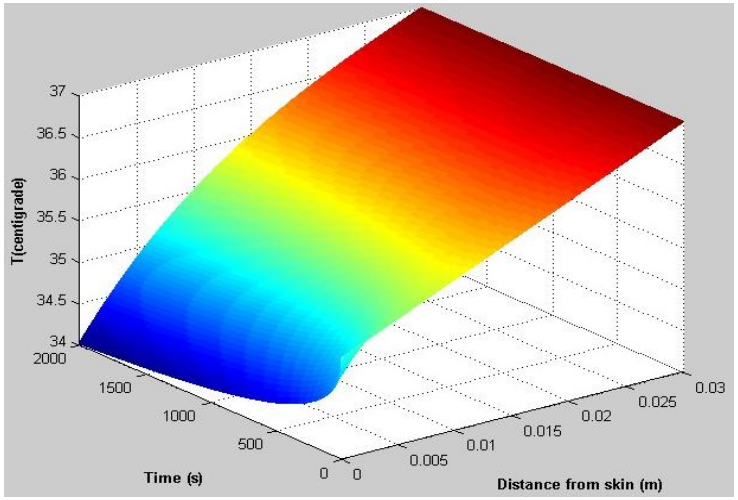
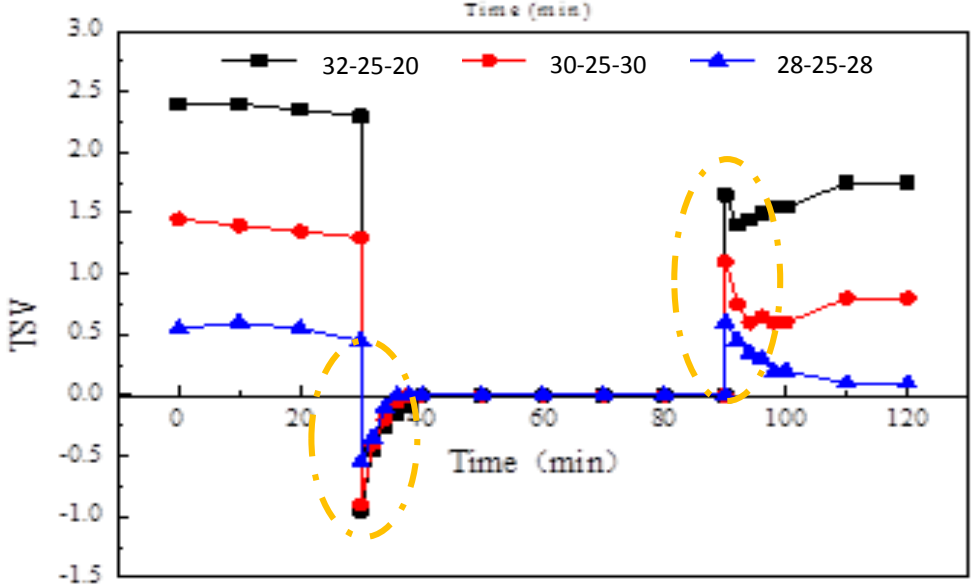
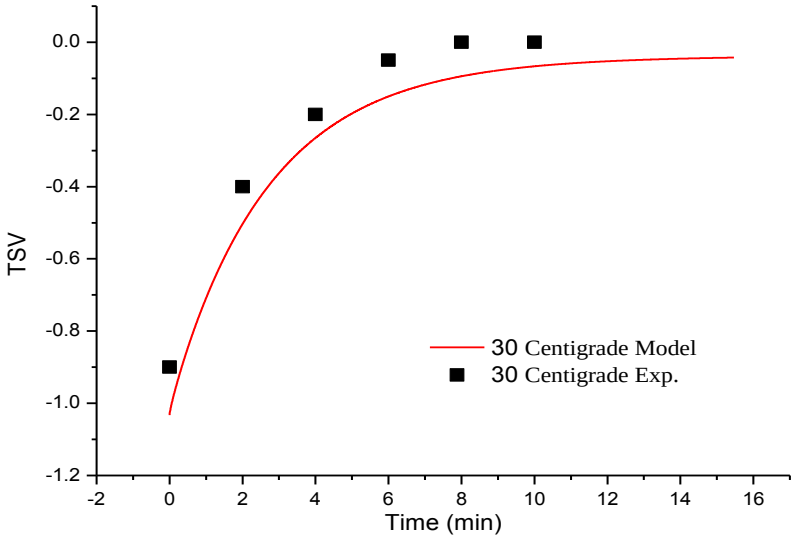
Skin-Temp and TSV Prediction Model



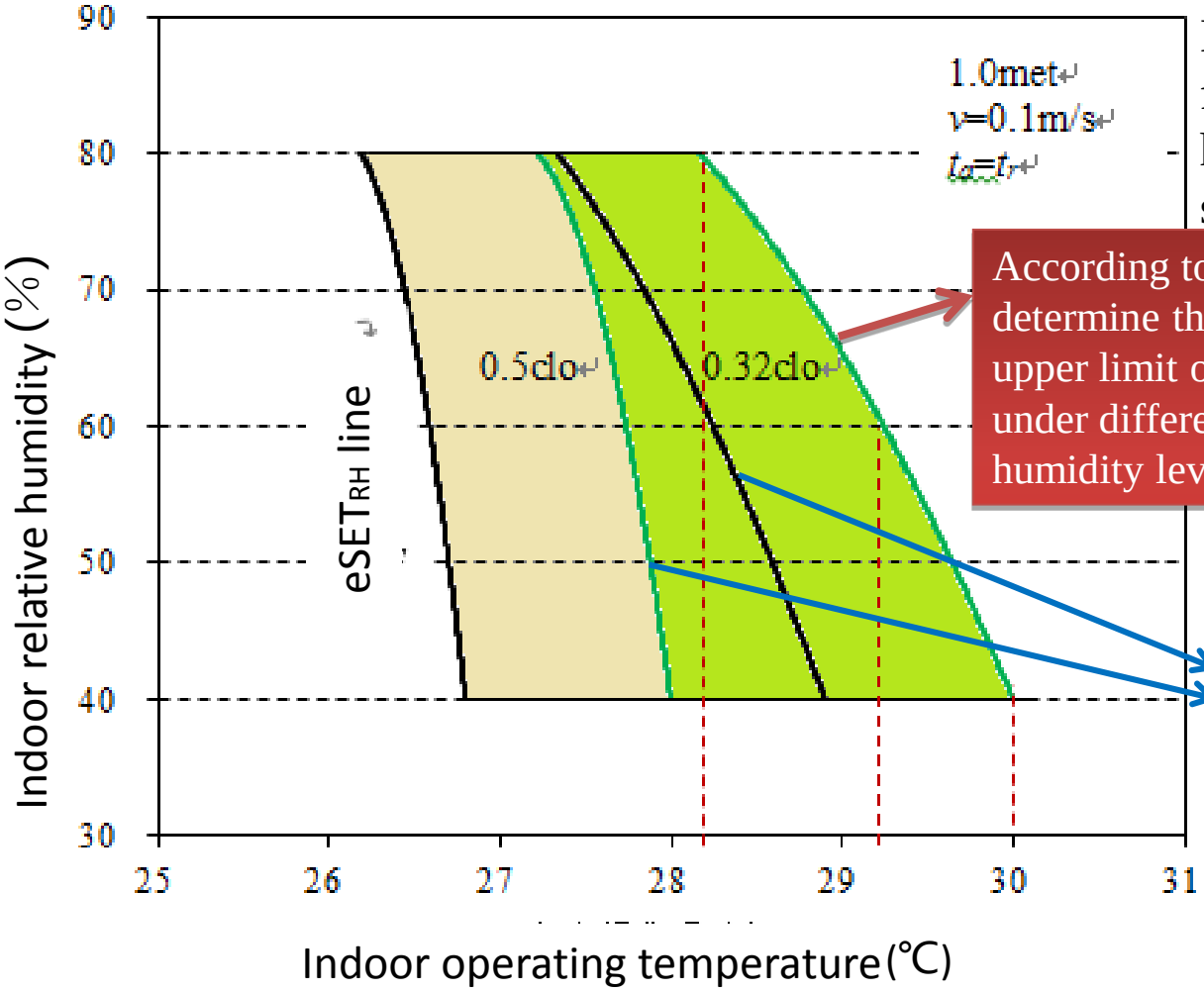
Physiological regulation model







Evaluation of the effect of humidity on thermal sensation



It reflect the comprehensive function of temperature and humidity on the thermal sensation.

According to the boundary to determine the acceptable upper limit of temperature under different relative humidity levels

On $eSET_{RH}$ line, each point represents the equal thermal sensation under different combinations of temperature and humidity

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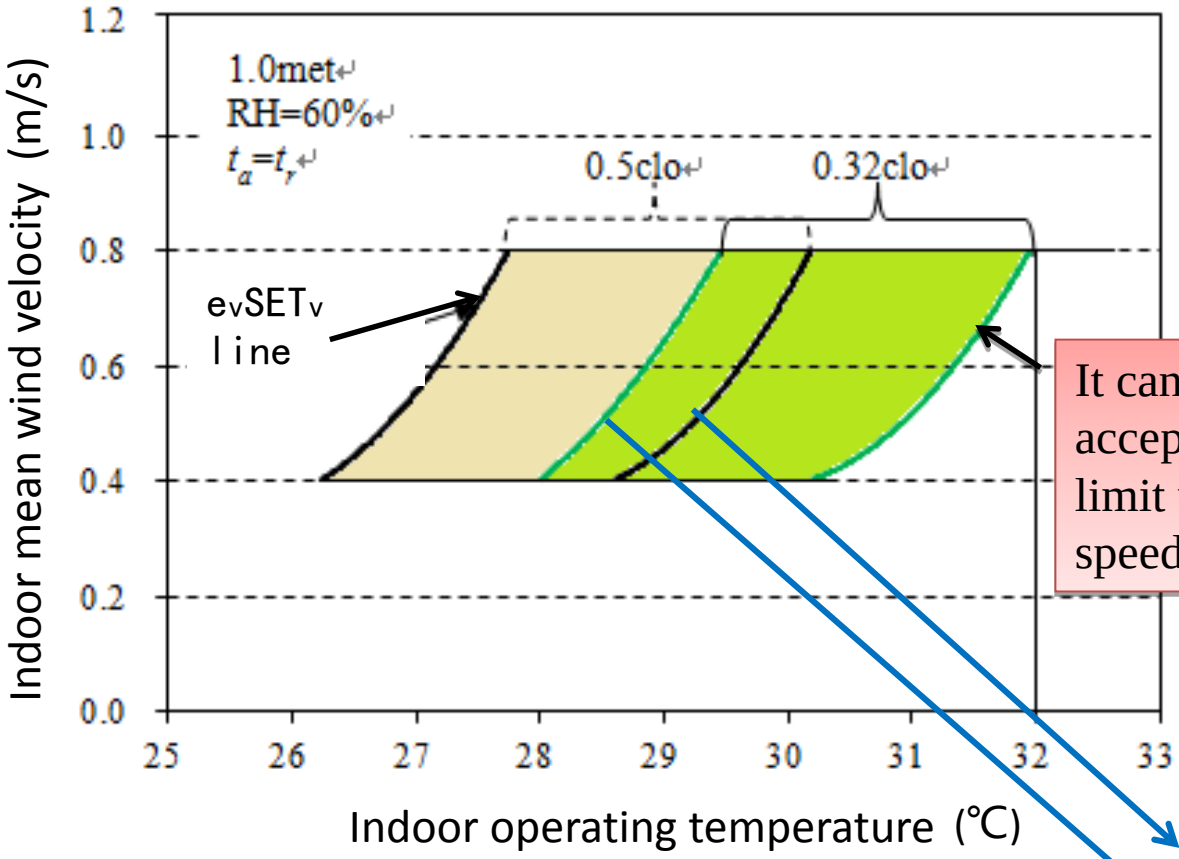
Evaluation of the effect of air velocity on thermal sensation



Reflect the comprehensive function of temperature and wind speed on the thermal sensation

It can determine the acceptable upper temperature limit under different wind speed level

On eSETv line, each point represents the equal thermal sensation under different combinations of temperature and humidity

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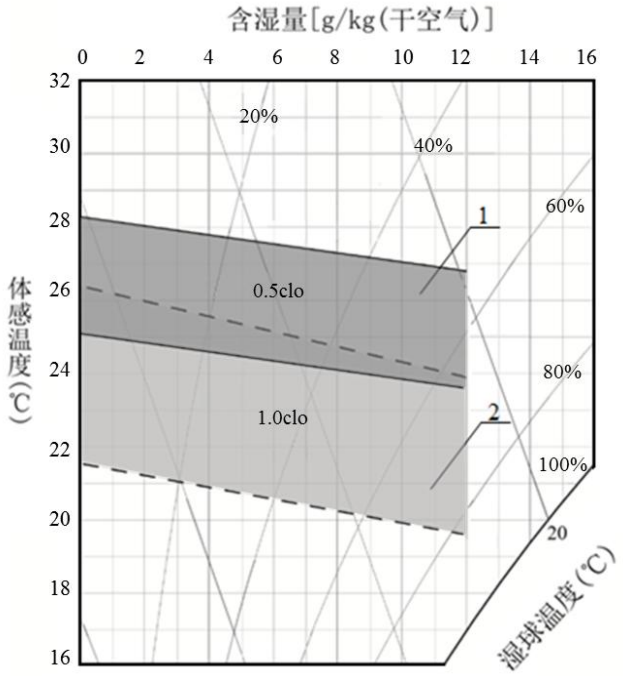
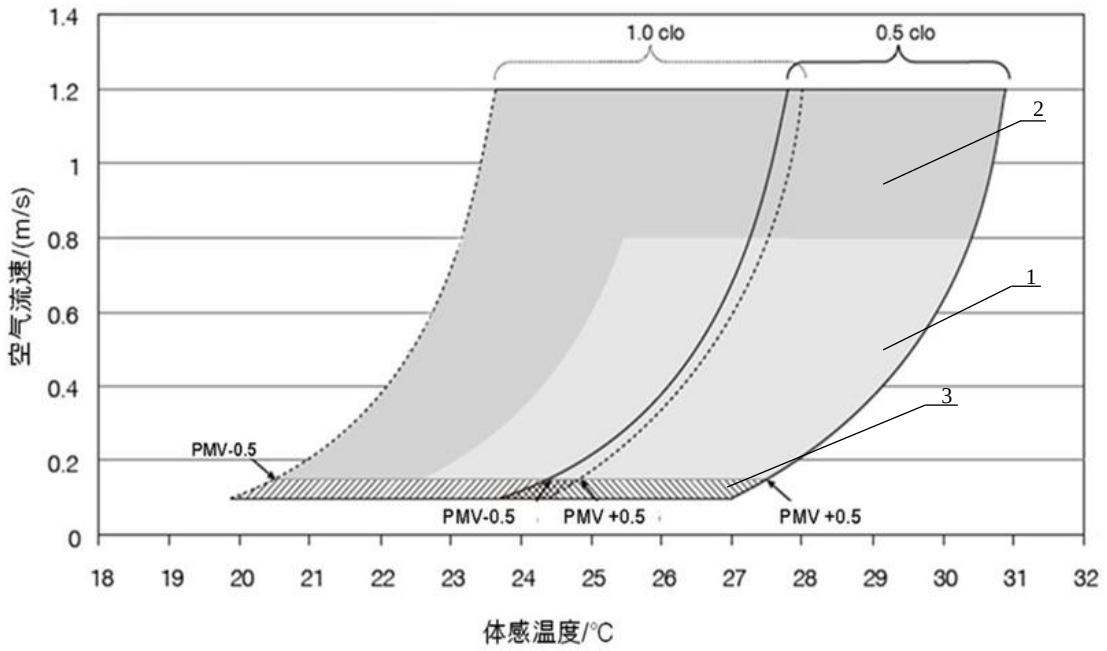
Thermal Comfort Assessment in HVAC Building

中国热舒适评价标准 GB/T50785-2012

Evaluation standard for indoor thermal environment in civil buildings

Reference to ISO 7730、ASHRAE 55





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Evaluation of the dynamic thermal comfort

--Field Study

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Field study of indoor thermal environment in civil building

Cooperation units and cities

Climate zone	City	cooperation units	Time
severe cold	Harbin	Harbin Institute of Technology	2009.7—2009.10
	Shenyang	Shenyang Jianzhu University	2008.12—2009.11
Cold	Beijing	Beijing University of Technology	2009.11—2010.9
	Xi'an	Xi'an Polytechnic University	2009.1—2009.10
Hot in summer and cold in winter	Chongqing	Chongqing University	2008.10—2009.9
	Wuhan	Huazhong University of Science and Technology	2008.10—2009.9
	Chengdu	Southwest Jiaotong University	2008.11—2009.10
	Changsha	Hunan University	2009.1—2009.11
	Nanjing	Nanjing University of Technology	2009.7—2009.12
	Hanzhou	Zhejiang Sci-Tech University	2009.3—2009.11
Hot Summer and Warm Winter	Fuzhou	Fujian University of Technology	2008.12—2009.11
	Guangzhou	Guangzhou University	2008.11—2009.9
Temperate	Kunming	Kunming University of Science and Technology	2008.12—2009.10

Measuring Methods and Instrument

➢Instrument

A531 environment test instrument

Testo 425 hot-wire anemometer

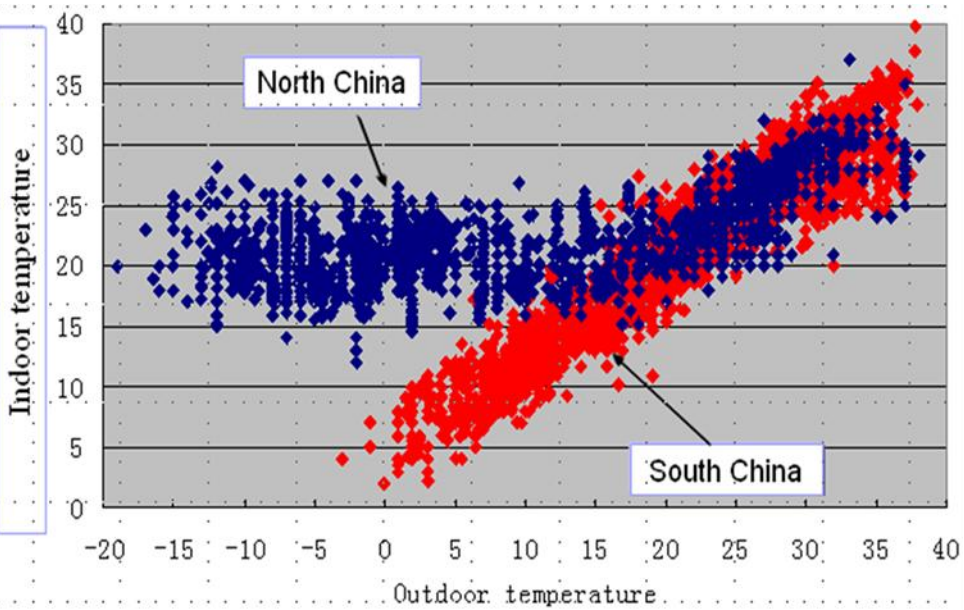
Dwyer digital temperature-humidity instrument

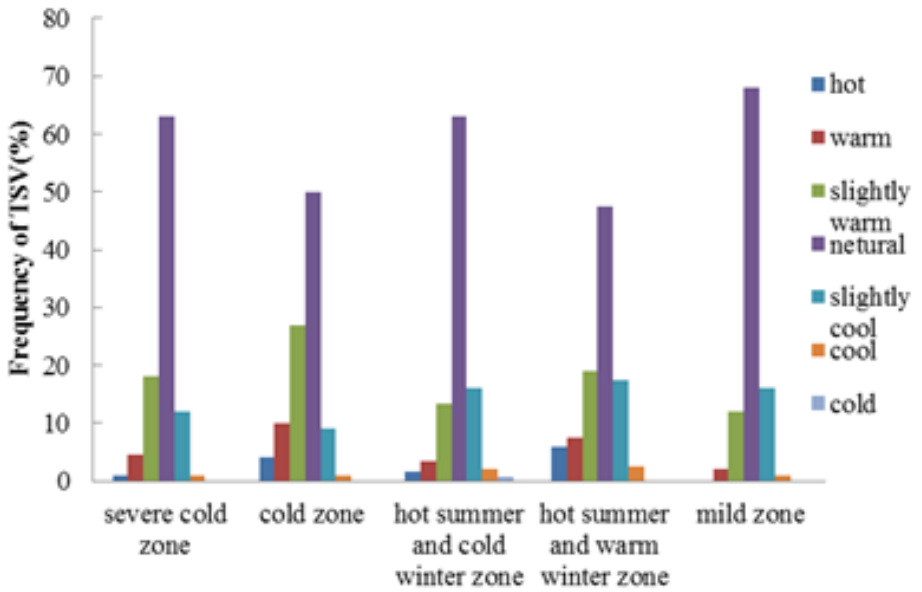
Black-bulb thermometer

➢Questionnaire

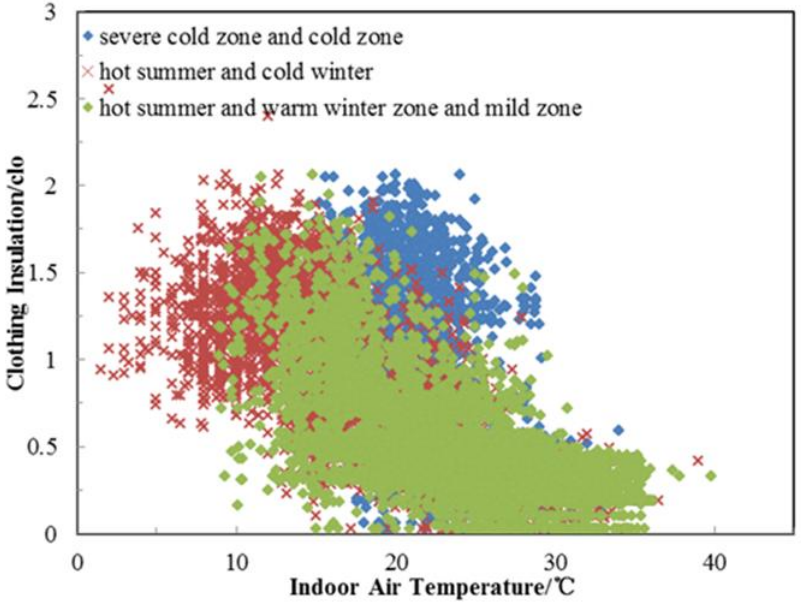
以下部分由被调查者填写	调查编号： 调查员：
1、 姓名：	11. 人员在室内的位置（请在下图用 X 标出工作时常在位置）
2、 日期：	
3、 时间：	
4、 室外空气温度：	
5、 天气：晴☐ 多云转晴☐ 阴天☐	
6、 季节：冬季☐ 春季☐ 夏季☐ 秋季☐	
7、 服装 上衣： 裤子： 其他：	以下部分由调查者填写： 服装热阻（clo）总和： I_{cl}=
8、 活动 ☐ 斜倚 ☐ 坐姿，放松 ☐ 坐姿活动（学校、办公室） ☐ 立姿，放松 ☐ 立姿，轻度活动（购物、实验室工作、轻体力工作） ☐ 立姿，中度活动（商店售货、家务劳动、机械工作） ☐ 重度活动	代谢率（met）： 1. 0.8met 2. 1.0met 3. 1.2met 4. 1.4met 5. 1.6met 6. 2.0met 7. 3.0met
9、 设备（散热设备、空调设备） 设备名称 / 型号、功率	热量汇总
10、整体热感觉 ☐ 热 ☐ 暖 ☐ 较暖 ☐ 适中 ☐ 较凉 ☐ 凉 ☐ 冷	整体热感觉： 1. +3 2. +2 3. +1 4. 0 5. - 1 6. - 2 7. - 3
11、对所处热湿环境总体评价：	面积： 房间/建筑形式： 室外相对湿度（%）： 空调设定温度（℃）： 相对湿度设定值（%）： 调查总人数：

Survey Results





Distribution of thermal sensation votes of every climate zone



Relationships between indoor air temperature and clothing in five climate zones

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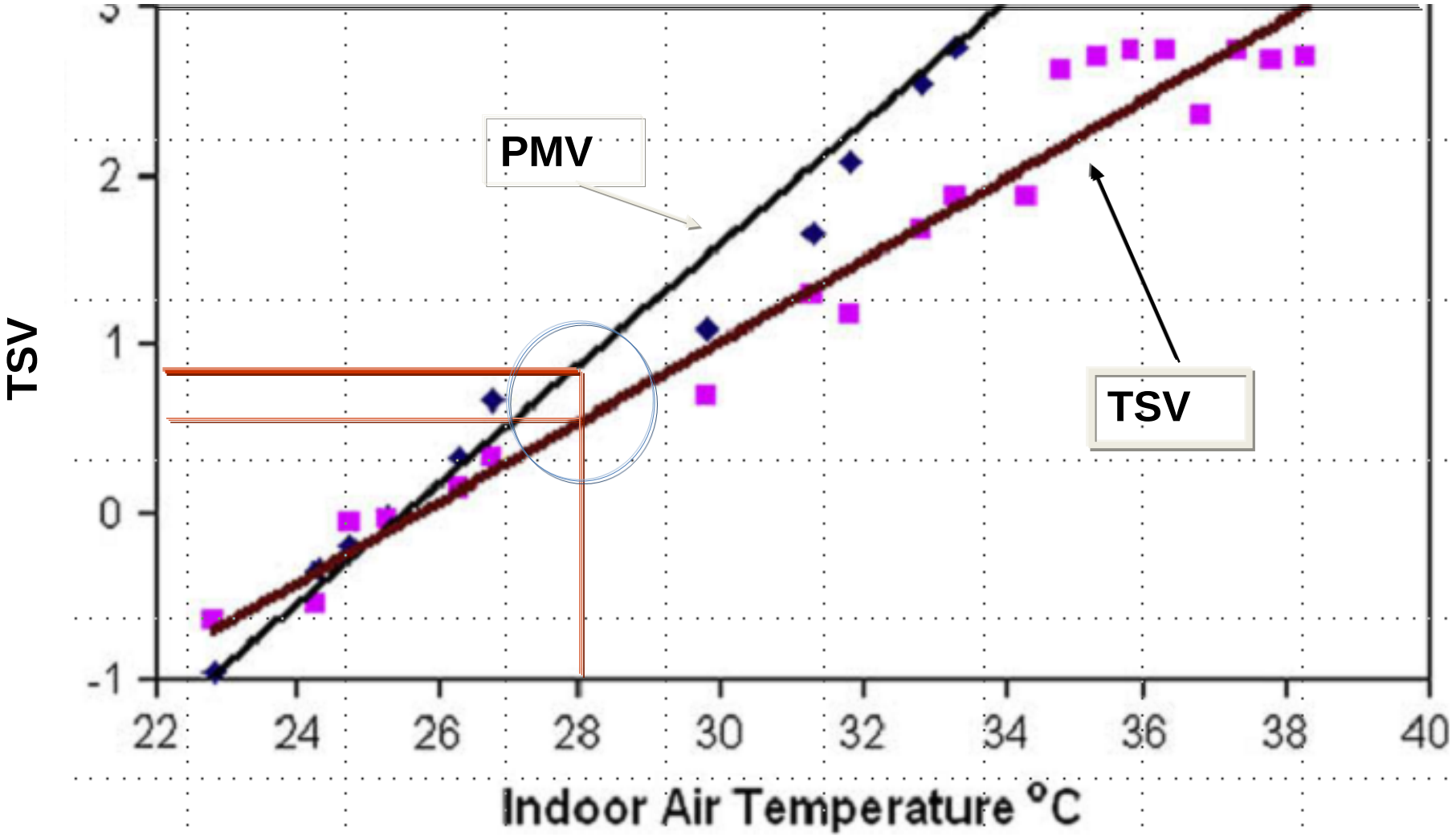
Deviation between PMV and TSV



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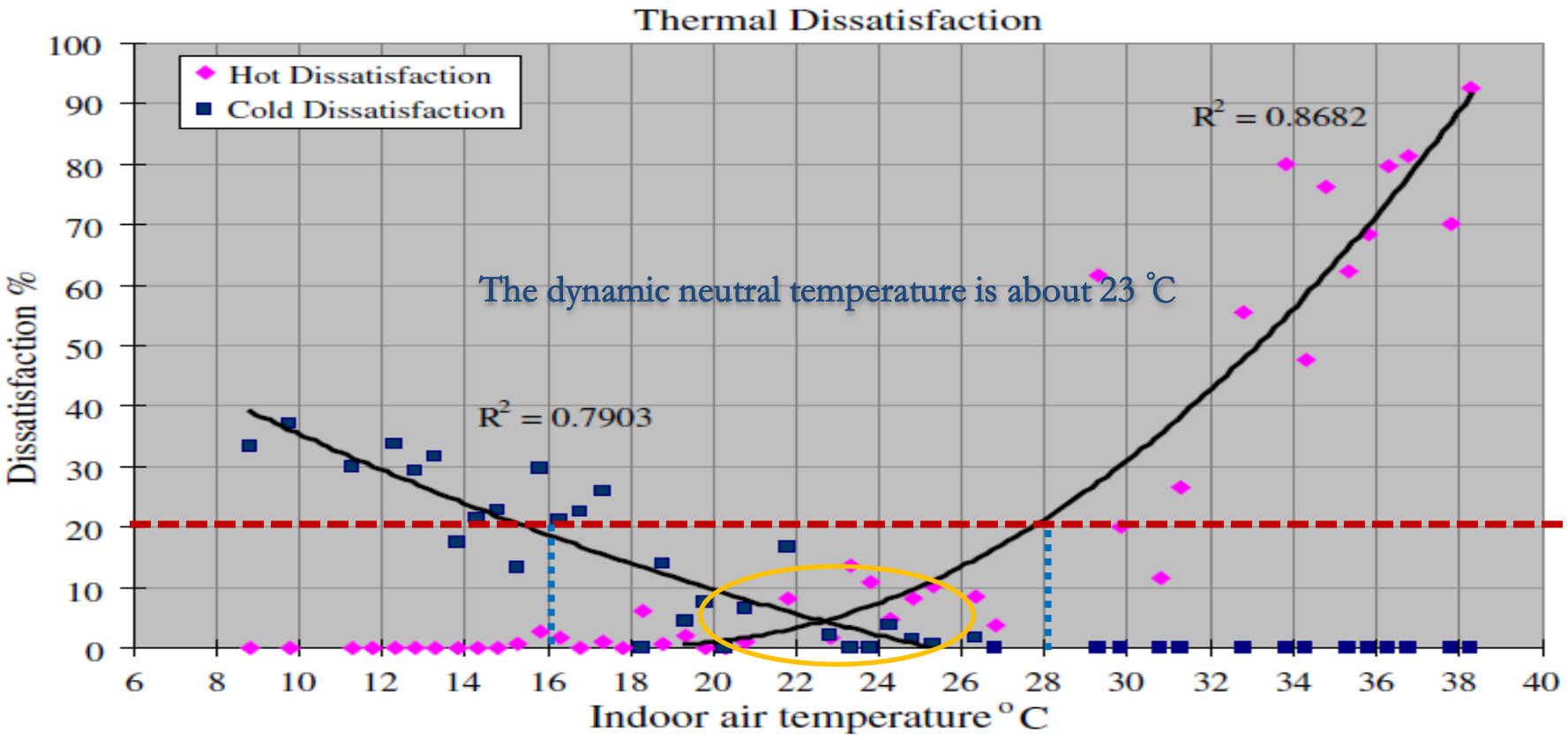
Asymmetric reaction of human body to the hot and cold



The dynamic changes of the thermal dissatisfaction

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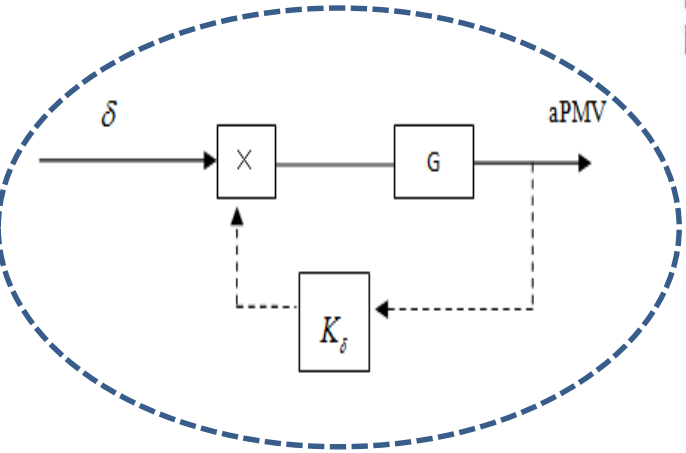
Adaptive Theory and Model of Thermal Comfort



Outdoor Climates

Building Indoor Climates

室外

建筑

Physical Stimuli

室内环境

Human Physiology & Thermal Sensation

人体生理&热感觉

Actual Thermal Sensation of Human Body

实际

热感觉

行为适应性

Behavioural Adaptations

Social, Economical and Cultural Background

社会经济、文化背景

Psychological Adaptations

生理适应性

Thermal Expectations

热期望

Previous Thermal Experiences

热经历

Adaptations

适应性

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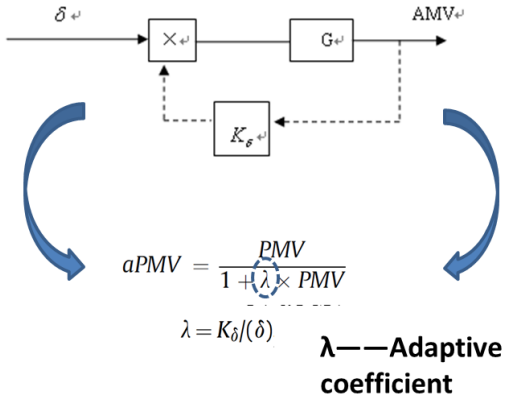
Evaluation in free-running buildings--Calculating Method

Dynamic environment adaptive model ---aPMV



Where, APMV—预计适应性平均热感觉指标(adaptive predicted mean vote)；
λ——自适应系数(adaptive coefficients)
PMV——预计平均热感觉指标(predicted mean vote)

λ——自适应系数：利用黑箱模型理论，用λ代表地区社会、经济、文化背景、生理特征、行为和心理调节对热感觉预测模型PMV的影响。

分地区分建筑类型的自适应系数
λ values in different zones and building types

Climate Zones		Residential, Markets, Hotels, Office buildings	Teaching buildings
Cold, Severe Cold Zones	PMV≥0	0.24	0.21
	PMV＜0	－0.50	－0.29
HSCW, HSWW, Mild zones	PMV≥0	0.21	0.17
	PMV＜0	－0.49	－0.28

非人工冷热源热湿环境评价等级
Evaluation grades in free running buildings

Grade	Index(APMV)
Ⅰ	－0.5≤APMV≤0.5
Ⅱ	－1≤APMV＜－0.5或0.5＜APMV≤1
Ⅲ	APMV＜－1或APMV＞1

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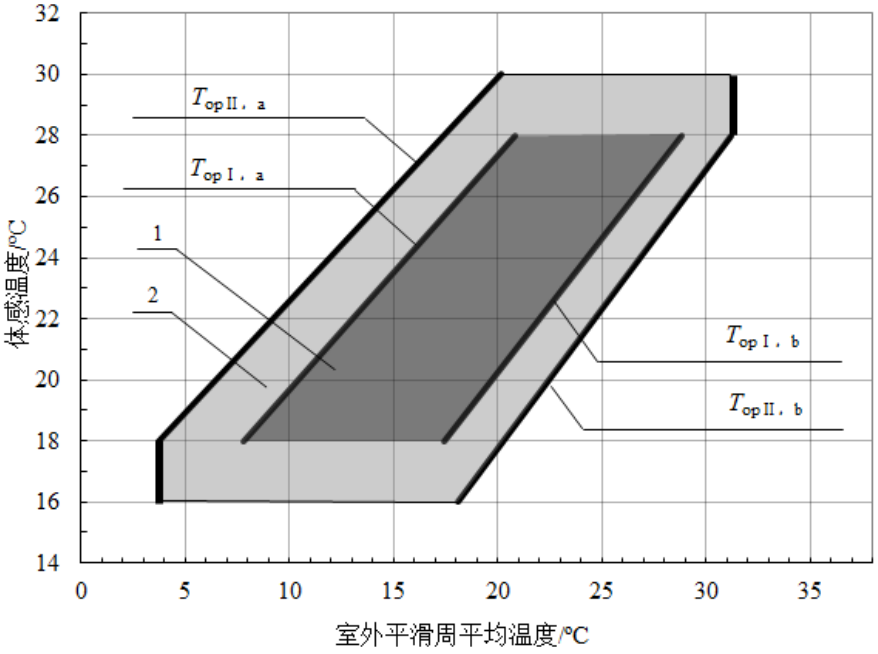
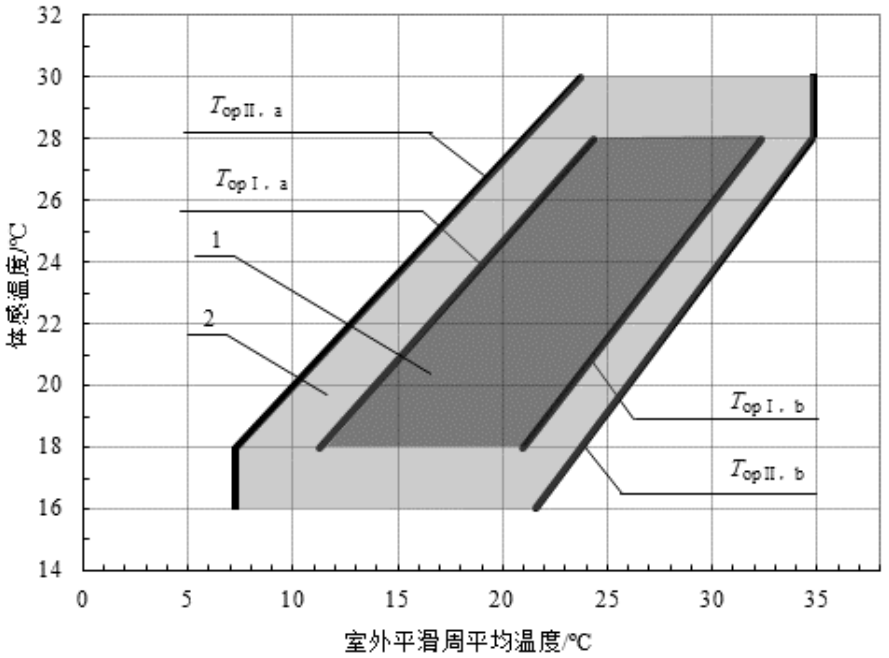
Evaluation in free-running buildings--Graphic Method

The comfort zone in free-running buildings based on the 80% and 90% upper and lower limits for acceptable temperatures in different climate zone



严寒及寒冷地区非人工冷热源热湿环境体感温度范围

The comfort zones in free-running buildings in Severe Cold Zone, Cold Zone

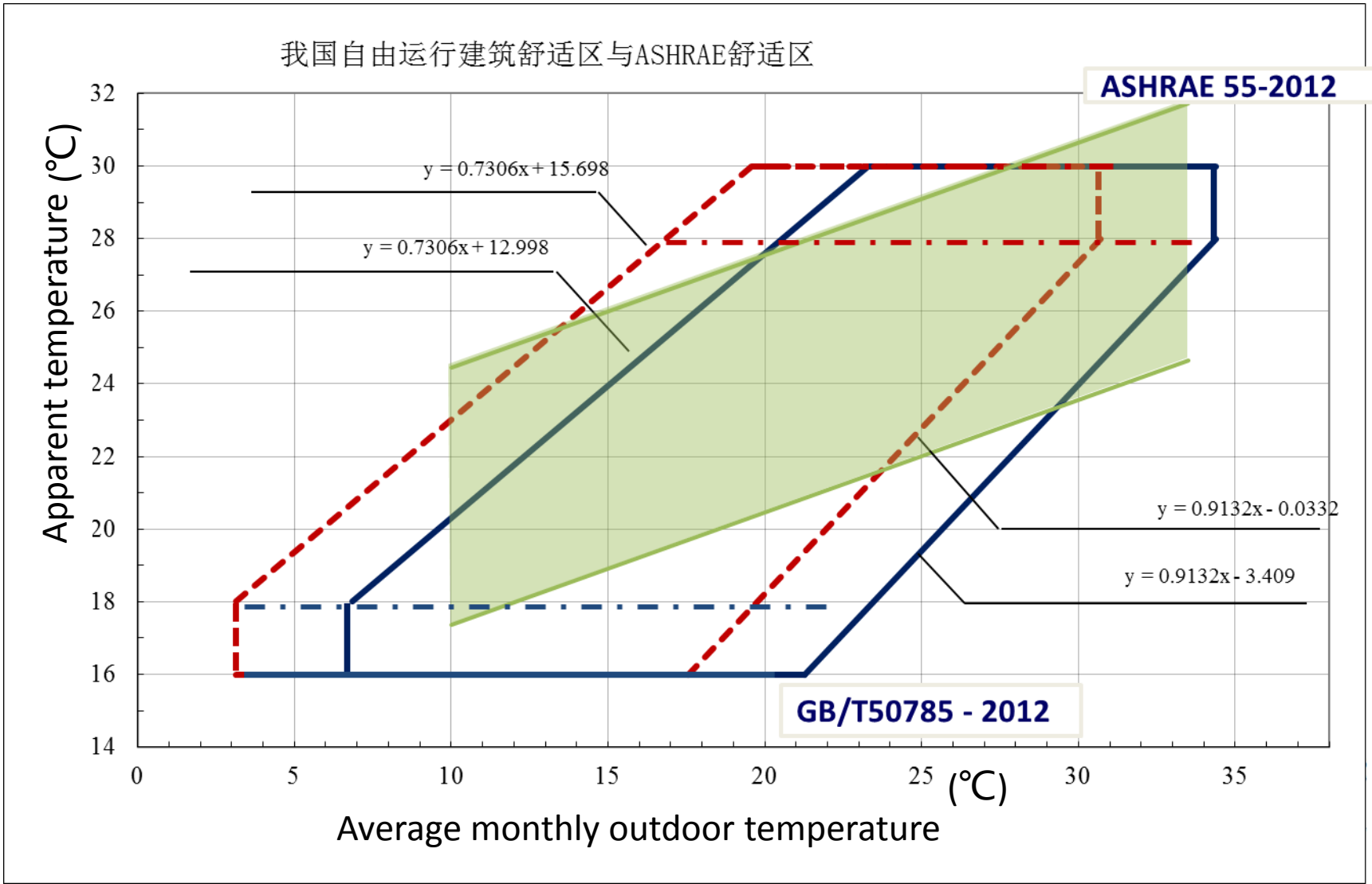


夏热冬冷、夏热冬暖、温和地区非人工冷热源热湿环境体感温度范围

The comfort zones in free-running buildings in Hot Summer and Cold Winter zone, Hot Summer and Warm Winter Zone, Mild Zone

Evaluation in free-running buildings--Graphic Method

Free-running construction comfort zone&ASHRAE comfort zone



Thanks !

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