Introduction of two demonstration projects using IEC technologies in China

Reporter: Ce Zhao, Zejin Chen

Conductor: Xiaoyun Xie, Yi Jiang

The support from National key research and development program of China (key projects of international cooperation in science and technology innovation) (Grant number 2019YFE0102700)

Part 1: A test of IEC water chillers in a data center in Xinjiang in July

Reporter: Ce Zhao, Zejin Chen
Conductor: Xiaoyun Xie, Yi Jiang

Content

- Data Center Information
- Equipment Introduction
- Field Test Results & Modeling Simulation
- Conclusions

Content

- Data Center Information
- Equipment Introduction
- Field Test Results & Modeling Simulation
- Conclusions

Data Center Information

The tested data center is located in Urumqi, Xinjiang Province, China.
The construction area is about 21373m^2, with a total of four floors.
The final cooling system load will reach 16.47MW.

A data center in Urumqi, Xinjiang Province, China

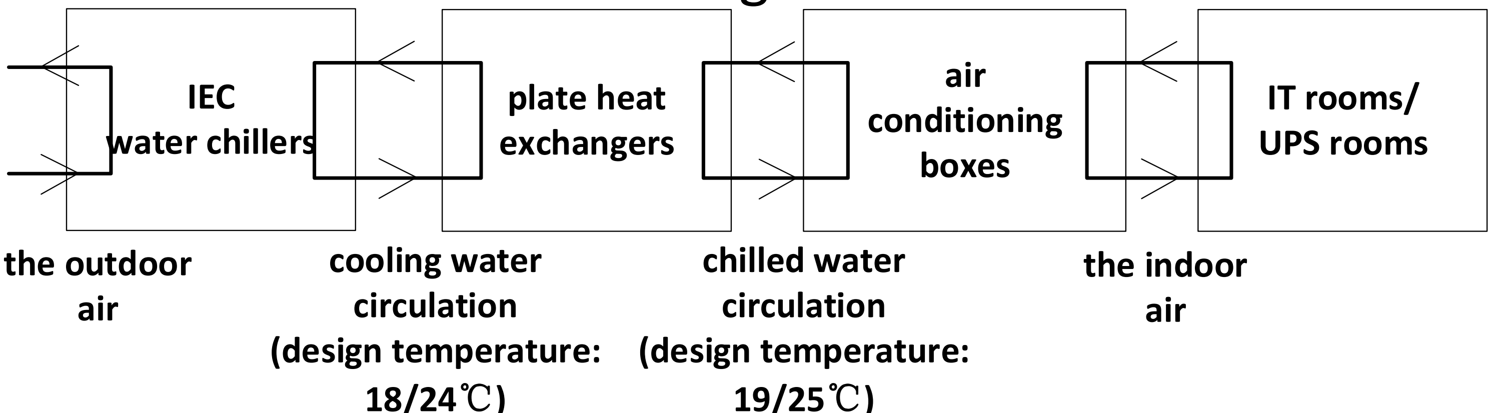
summer design parameters:

- dry-bulb temperature: 33.4℃
- wet-bulb temperature: 18.3℃
- relative humidity:23.7%
- moisture content:8.42g/kg

The climate is dry and hot !

Data Center Information

The main cooling process can be described as: IEC water chillers - cooling water circulation - plate heat exchangers - chilled water circulation - air conditioning boxes



IEC water chillers on the roof

Control system of the cooling system

Content

- Data Center Information
- Equipment Introduction
- Field Test Results & Modeling Simulation
- Conclusions

Equipment Introduction

IEC water chillers：

- Each chiller is designed to dissipate 366kW of heat.
- 55 units are planned and connected in parallel.
- 33 units divided in 3 groups have been constructed.
- 6 units in one group are turned on.
- The fan runs by frequency conversion according to the water temperature.
- the outlet water temperature is set at 17℃.

IEC water chillers

Plate heat exchangers:

- 3 water-water heat exchangers are built.
- All three are in use when operating.
- The single design heat exchange is 4800kW.

nameplate of
a plate heat exchanger

Equipment Introduction

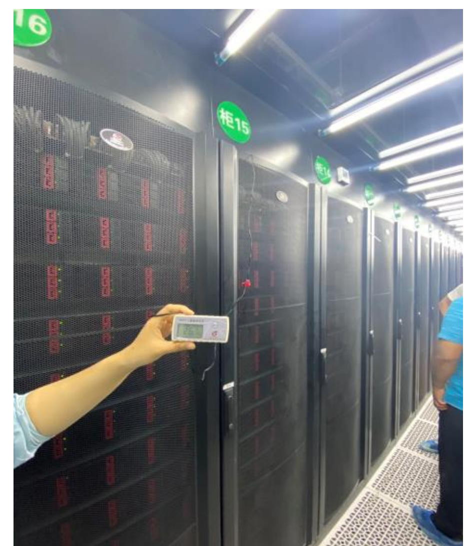
Air conditioning boxes of IT rooms:

- Each data room is equipped with nine air conditioners and a humidifier.
- Four air conditioners are in operation in a data room.

IT device:

- Only three IT rooms are in use.
- IT load rate is about 4.5% currently.

Air conditioning boxes



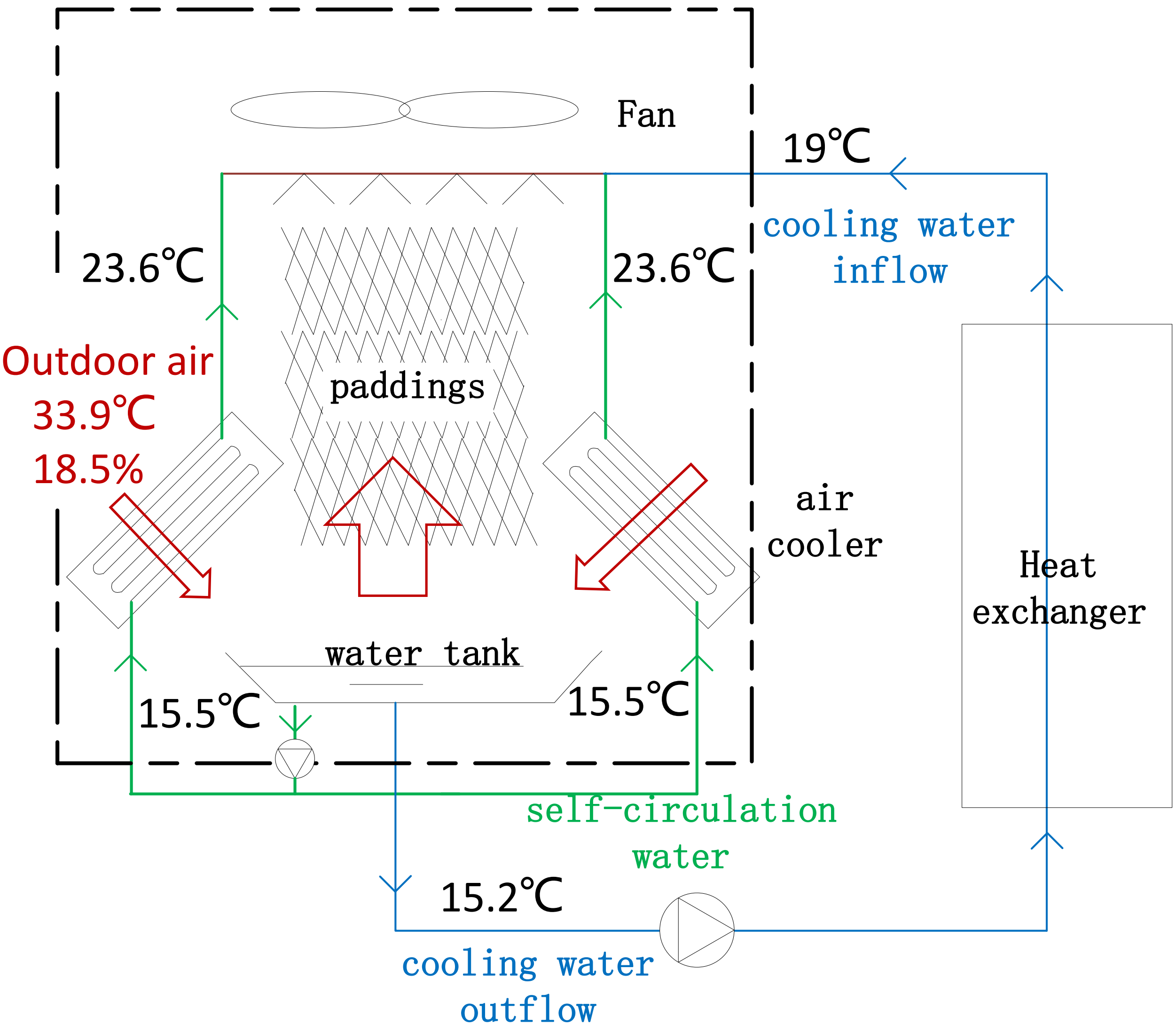
IT device room

Content

- Data Center Information
- Equipment Introduction
- Field Test Results & Modeling Simulation
- Conclusions

Field Test Results

test results of an IEC water chiller: daytime condition



Test time:12:30-15:30

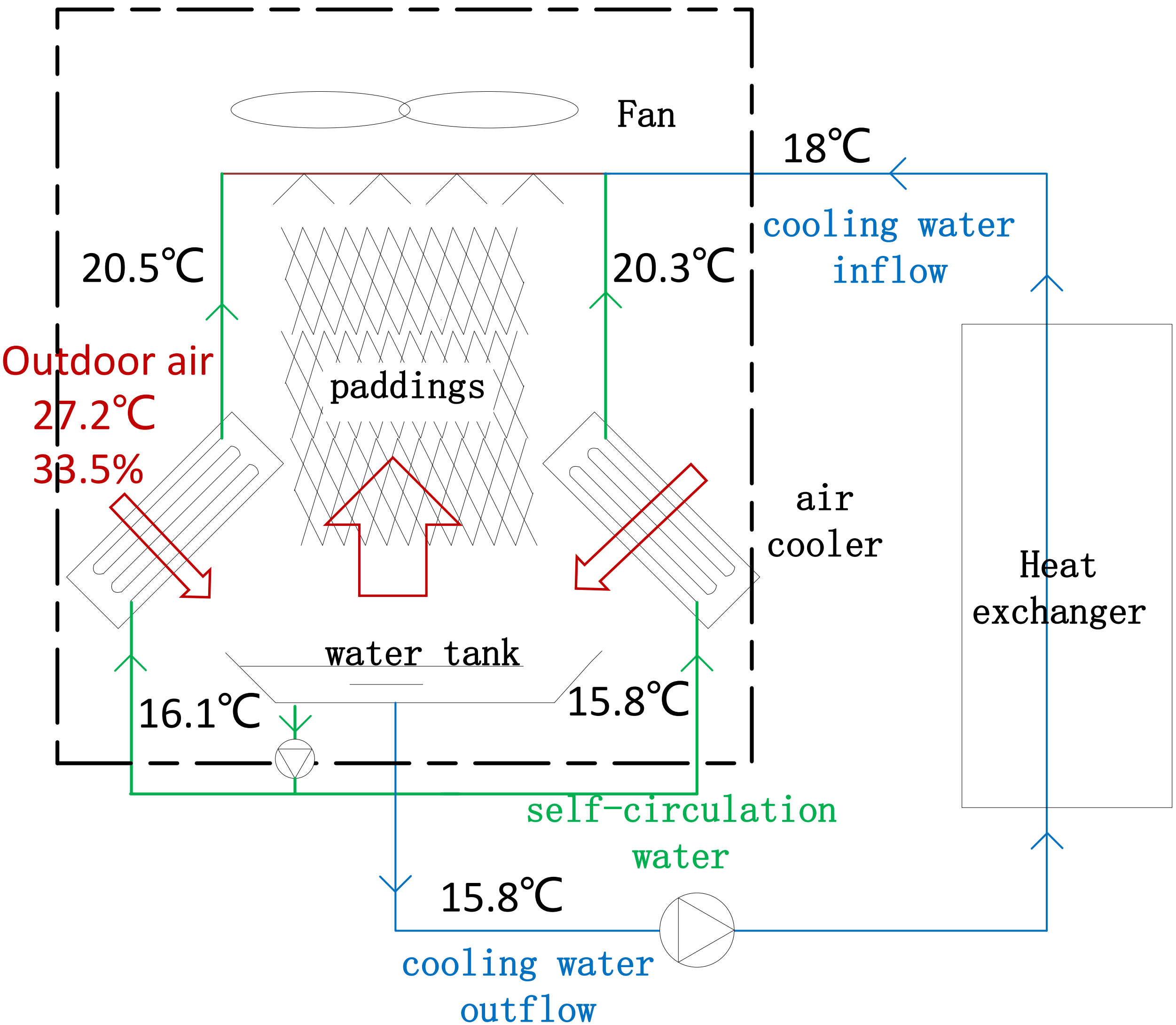
Outdoor air parameters：
- dry-bulb： 33.9℃
- relative humidity:18.5%
- moisture content:6.45g/kg
- wet-bulb:17.2℃
- dew point： 6.7℃

The air past air cooler：
- dry-bulb： 20.4℃
- wet-bulb: 12.5℃

The outlet temperature of the cooling tower is 15.2℃,

Field Test Results

test results of an IEC water chiller: night condition



Test time:1:30-3:30

Outdoor air parameters：

- dry-bulb： 27.2℃
- relative humidity:33.5%
- moisture content:8.36g/kg
- wet-bulb:16.3℃
- dew point： 9.8℃

The air past air cooler：

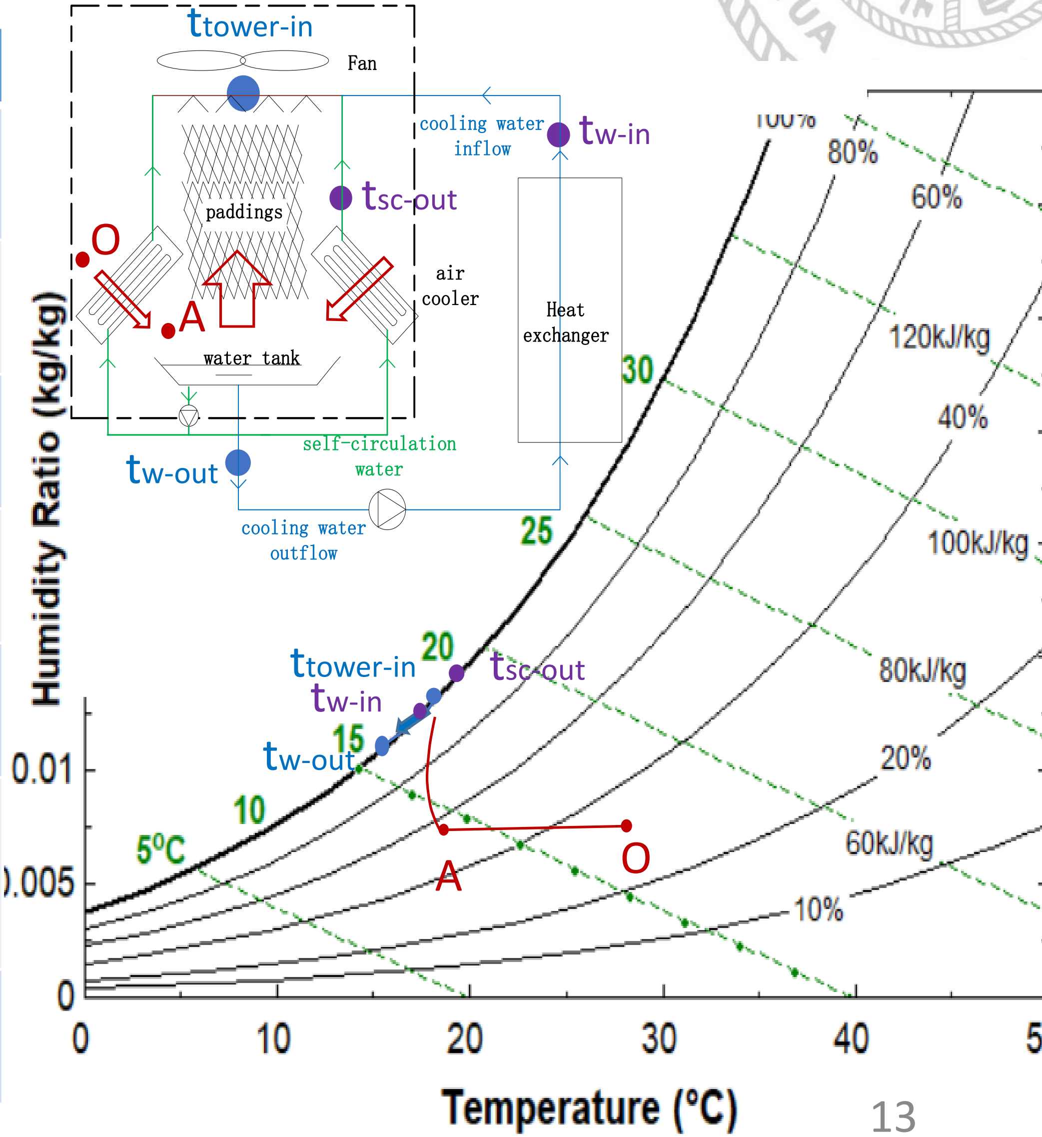
- dry-bulb： 18.8℃
- wet-bulb: 13.3℃

The outlet temperature of the cooling tower is 15.8℃

Field Test Results

test results of an IEC water chiller:

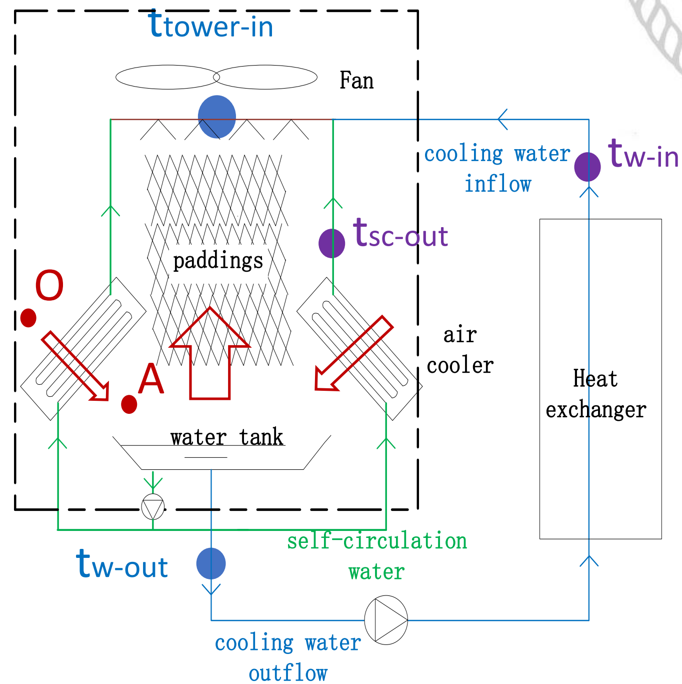
symbol	implication	value
t_o	Point O dry bulb temperature	27.2℃
t_a	Point A dry bulb temperature	18.8℃
$t_{a,wb}$	Point A wet bulb temperature	13.3℃
$t_{w\text{-}out}$	Cooling water outlet temperature	15.8℃
$t_{w\text{-}in}$	Cooling water inlet temperature	18℃
$t_{sc\text{-}out}$	Self-circulation outlet water temperature	20.4℃
$t_{tower\text{-}in}$	Mix water temperature	18.8℃



Field Test Results

test results of an IEC water chiller:

symbol	implication	value
t_o	Point O dry bulb temperature	27.2℃
t_a	Point A dry bulb temperature	18.8℃
$t_{a,wb}$	Point A wet bulb temperature	13.3℃
$t_{w\text{-}out}$	Cooling water outlet temperature	15.8℃
$t_{w\text{-}in}$	Cooling water inlet temperature	18℃
$t_{sc\text{-}out}$	Self-circulation outlet water temperature	20.4℃
$t_{tower\text{-}in}$	Mix water temperature	18.8℃



The efficiency of the air cooler (1)

$= (t_o - t_a) / (t_o - t_{w\text{-}out})$

= 73.7%

The efficiency of paddings (2)

$= (t_{tower\text{-}in} - t_{w\text{-}out}) / (t_{tower\text{-}in} - t_{a,wb})$

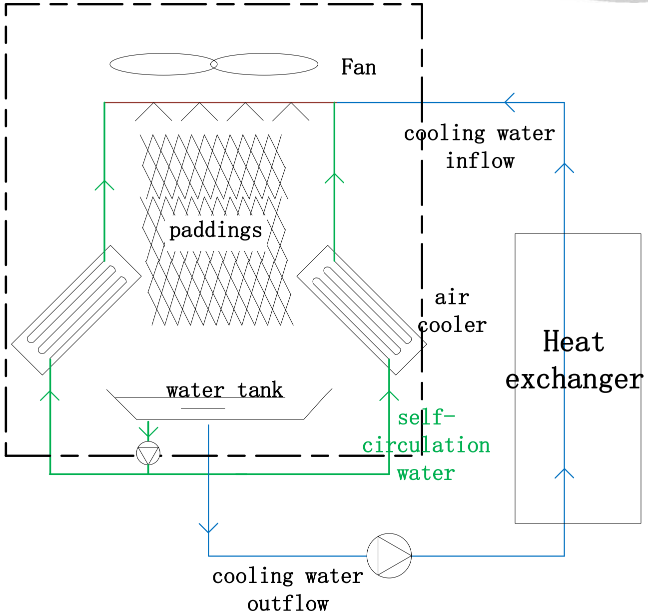
= 58.5%

Modeling Simulation

Using EES software simulates the process of the IEC water chillers.
Both air cooler model and padding model are all countercurrent structures.

The following input parameters are measured values:

- Cooling inlet water temperature is 18 ℃
- Cooling outlet water temperature is 15.8 ℃
- Self-circulation outlet water temperature is 20.4℃
- Inlet air temperature is 27.2 ℃
- Air flowrate is 11 kg/s
- Cooling water flowrate is 6.94 kg/s
- Self-circulation water flowrate is 3.4 kg/s



Modeling Simulation

File Edit Search Options Calculate Tables Plots Wi

```
cpa=1.005
cpw=4.18
r0=2500
 {冷却水温度}
tw_in1=18    {回水温度}
tw_in2=20.4
tw_out=15.8
(Gw_b+Gw)*tw_in=Gw_b*tw_in2+Gw*tw_in1
{Gw tw_in1回水，Gw_b tw_in2表冷器，混合进塔水温tw_in}
Gw=50/3.6/2     {回水水量}
Q1=Gw*4.18*(tw_in1-tw_out)*2
Q2=Ga*(Ha[1]-h0)*2
Ga=66000/3600*1.2/2
Ga1=Ga*2/1.2*3600
Gw_b=24.5/3.6/2 {表冷器水量}
{进风参数}
ta_o=27.2
da_o=0.00836
P1=91.12
ta_wet=wetbulb(AirH2O, T=ta_o, w=da_o, P=P1)
rh=relhum(AirH2O, T=ta_o, B=ta_wet, P=P1)
dp=dewpoint(AirH2O, T=ta_o, R=rh, P=P1)
h0=enthalpy(AirH2O, T=ta_o, R=rh, P=P1)
da_in=da_o
ta_in=ta_o
ntu_tianliao=KsA/Ga/cpa
KdA=KsA/cpa
ntu_biao=KAL/Ga/cpa
{划分网格}
n=50
m=100
{表冷器处}
Duplicate i=1,n
ta[0,i]=ta_o
End
tw[1,0]=tw[2,0]
tw[2,n]=tw[3,n]
tw[3,0]=tw[4,0]
tw[4,n]=tw[5,n]
tw[5,0]=tw[6,0]
tw[6,n]=tw_out
tw[1,n]=tw_in2
```

```
tw[1,n]=tw_in2
ta_out1=sum(ta[6,i],i=1,n-1)/(n-1)
{ta_out1=18.8}
Duplicate i=1,n
 (ta[1,i]-ta[0,i])*cpa*Ga/n=4.18*Gw_b*(tw[1,i-1]-tw[1,i])
4.18*Gw_b*(tw[1,i-1]-tw[1,i])=KAL/n*(tw[1,i]-ta[1,i])
End
Duplicate i=1,n
 (ta[2,i]-ta[1,i])*cpa*Ga/n=4.18*Gw_b*(tw[2,i]-tw[2,i-1])
4.18*Gw_b*(tw[2,i]-tw[2,i-1])=KAL/n*(tw[2,i]-ta[2,i])
End
Duplicate i=1,n
 (ta[3,i]-ta[2,i])*cpa*Ga/n=4.18*Gw_b*(tw[3,i-1]-tw[3,i])
4.18*Gw_b*(tw[3,i-1]-tw[3,i])=KAL/n*(tw[3,i]-ta[3,i])
End
Duplicate i=1,n
 (ta[4,i]-ta[3,i])*cpa*Ga/n=4.18*Gw_b*(tw[4,i]-tw[4,i-1])
4.18*Gw_b*(tw[4,i]-tw[4,i-1])=KAL/n*(tw[4,i]-ta[4,i])
End
Duplicate i=1,n
 (ta[5,i]-ta[4,i])*cpa*Ga/n=4.18*Gw_b*(tw[5,i-1]-tw[5,i])
4.18*Gw_b*(tw[5,i-1]-tw[5,i])=KAL/n*(tw[5,i]-ta[5,i])
End
Duplicate i=1,n
 (ta[6,i]-ta[5,i])*cpa*Ga/n=4.18*Gw_b*(tw[6,i]-tw[6,i-1])
4.18*Gw_b*(tw[6,i]-tw[6,i-1])=KAL/n*(tw[6,i]-ta[6,i])
End
ta1_wet=wetbulb(AirH2O, T=ta_out1, w=da_o, P=P1)

KA=KAL*6
beta_v=KdA*3600/3.5/3.5/3.5*2
```

```
{填料处}
{进水tw_in,出水tw_out}
ta_out1=Ta_c[m]
da_in=Da[m]
tw_in=Tw_c[1]
tw_out=Tw_c[m]
Ha[m]=Enthalpy(AirH2O, T=Ta_c[m], w=Da[m], P=P1)
Dwa[m]=HumRat(AirH2O, T=Tw_c[m], R=1, P=P1)
Hwa[m]=Enthalpy(AirH2O, T=Tw_c[m], R=1, P=P1)

Duplicate i=1,m-1
    (Gw+Gw_b)*cpw*(Tw_c[m-i+1]-Tw_c[m-i])=KdA/m*(Ha[m-i+1]-Hwa[m-i+1])
    Ga*(Ha[m-i]-Ha[m-i+1])=KdA/m*(Hwa[m-i+1]-Ha[m-i+1])
    Dwa[m-i]=humrat(AirH2O, T=Tw_c[m-i], R=1, P=P1)
    Hwa[m-i]=enthalpy(AirH2O, T=Tw_c[m-i], R=1, P=P1)
End

Duplicate i=1,m-1
    2*Ga*cpa*(Ta_c[m-i]-Ta_c[m-i+1])=KsA/m*(Tw_c[m-i+1]-Ta_c[m-i+1])+KsA/m*(Tw_c[m-i]-Ta_c[m-i])
    2*Ga*(Da[m-i]-Da[m-i+1])=KdA/m*(Dwa[m-i+1]-Da[m-i+1])+KdA/m*(Dwa[m-i]-Da[m-i])
End

Duplicate i=1,m
        Twb_a[i]=wetbulb(AirH2O, T=Ta_c[i], w=Da[i], P=P1)
End
```

Modeling Simulation

The output parameters are shown as follows:

- ✓ air cooler heat-transfer capability:

  KA=11.65kW/K
- ✓ Volume mass transfer coefficient of paddings:

  βv=5840kg/m^3/h
- ✓ Water consumption:

  W=476 kg/h

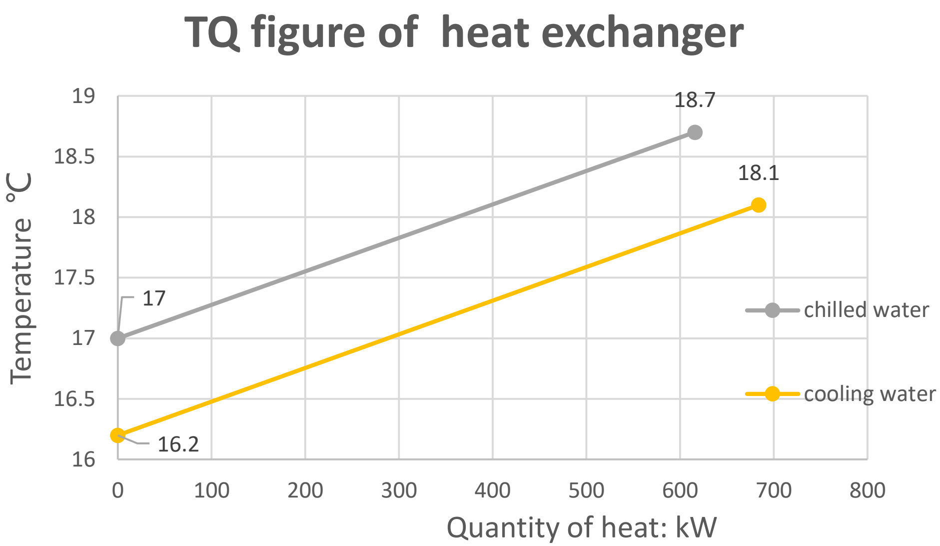
Unit Settings: SI C kPa kJ mass deg

β_v = 5840	cpa = 1.005	cpw = 4.18	da_{in} = 0.00836
da_o = 0.00836	dp = 9.761	Ga = 11	Ga1 = 66000
Gw = 6.944	Gw_b = 3.403	h0 = 48.64	KA = 11.65
KAL = 1.942	KdA = 34.78	KsA = 34.95	m = 100
n = 50	ntu_{biao} = 0.1756	$ntu_{tianliao}$ = 3.162	P1 = 91.12
Q1 = 127.7	Q2 = 125.8	r0 = 2500	rh = 0.3348
$ta1_{wet}$ = 14.23	ta_{in} = 27.2	ta_o = 27.2	ta_{out1} = 21.28
ta_{wet} = 16.27	tw_{in} = 18.79	tw_{in1} = 18	tw_{in2} = 20.4
tw_{out} = 15.8			

Click on this line to see the array variables in the Arrays Table window

Field Test Results

test results of heat exchangers:



Chilled water

flowrate:312m3/h

heat dissipating capacity:616kW

Chilled water pump power:15.8kW

The distribution coefficient=616/15.8=39.0

Cooling water

flowrate:310m3/h

heat dissipating capacity:684kW

Cooling water pump power:27kW

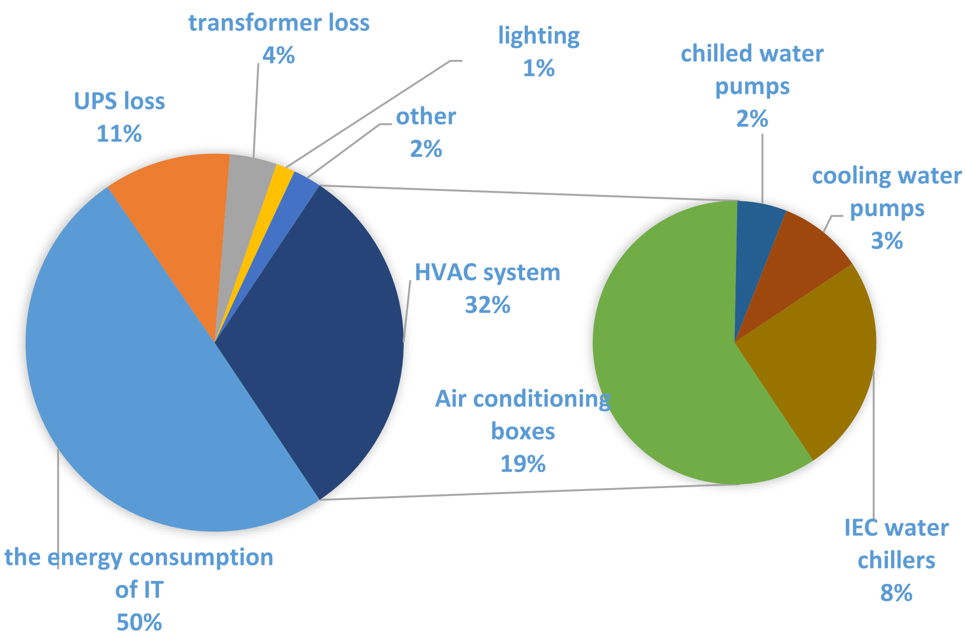
The distribution coefficient=684/27=25.3

- Flowrate and temperature are all measured data.
- Heat dissipating capacity is calculated by flowrate and temperature
- Power is exported by electricity meters

- heat transfer temperature difference of the exchanger is 0.7℃ (logarithmic mean temperature difference)
- The COP of cooling system
  =heat dissipating capacity /(the cooling pump energy consumption + IEC water chillers energy consumption)
  =7.05

Field Test Results

7.19 Single-day energy consumption split:



7.19 Single-day energy consumption split

unit: kW

Total energy consumption	895.1	
IT part	445.6	49.8%
UPS loss	97.4	10.9%
Transformer loss	36.1	4.0%
Lighting	14.6	1.6%
Other	21.6	2.4%
Air conditioning box	167.0	18.7%
The chilled water pump	15.8	1.8%
The cooling water pump	27.0	3.0%
IEC water chiller	70.0	7.8%

PUE = total energy consumption / IT energy consumption
= 2.01

The air conditioning boxes account for 59% of the whole HVAC system energy consumption. IEC water chillers account for 25%.

Content

- Data Center Information
- Equipment Introduction
- Field Test Results & Modeling Simulation
- Conclusions

Conclusions

1. IEA water chillers can meet the demands of the data center instead of electric chillers in Xinjiang province.
2. The outlet water temperature of IEA water chillers is between the dew point temperature and the wet-bulb temperature of outdoor air.
3. However, the current load mismatches with device capacity.
   - The selection of chilled water pump/cooling water pump is not considered in the transition stage with low load.
   - The large amount of cooling water leads to many cooling towers being opened. The energy consumption of cooling tower system increases further
4. Limited by low load rate and water pumps, there is still room for optimization of cooling system.

Thank you very much for your attention!

Case 2： Xinjiang Art Center

Zejin Chen，Tsinghua University

2021.09.17

Case 2:Brief Introduction

Xinjiang Art Center

Location： Northwest China, Urumqi

Floor area： 50,848m^2

Layers:1F， 1A， 2F， 2A， 3F

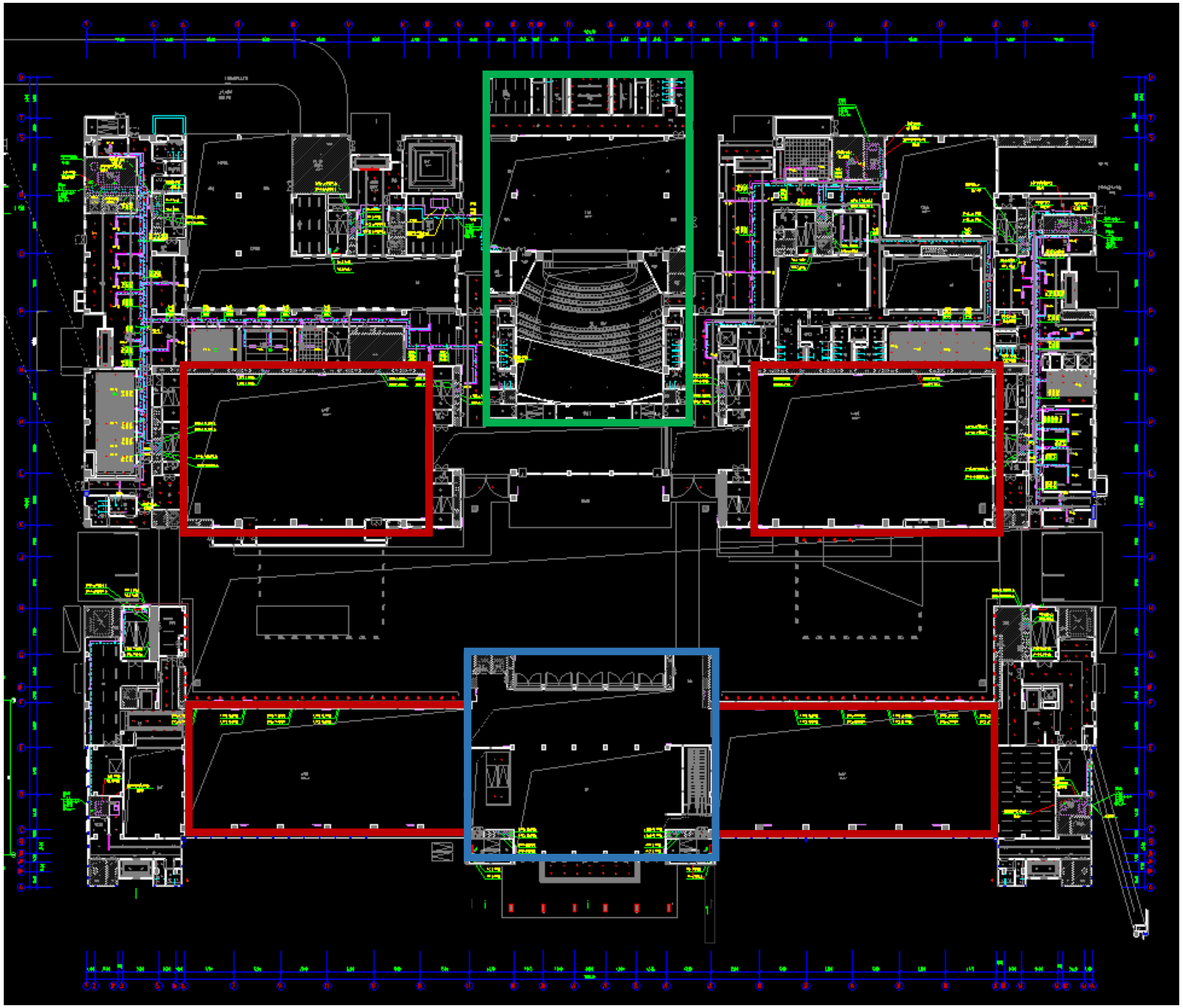
Design AC load： 3,291KW

Design unit area load： 65W/m2

Cooling method： fresh air/FCU/radiant floor

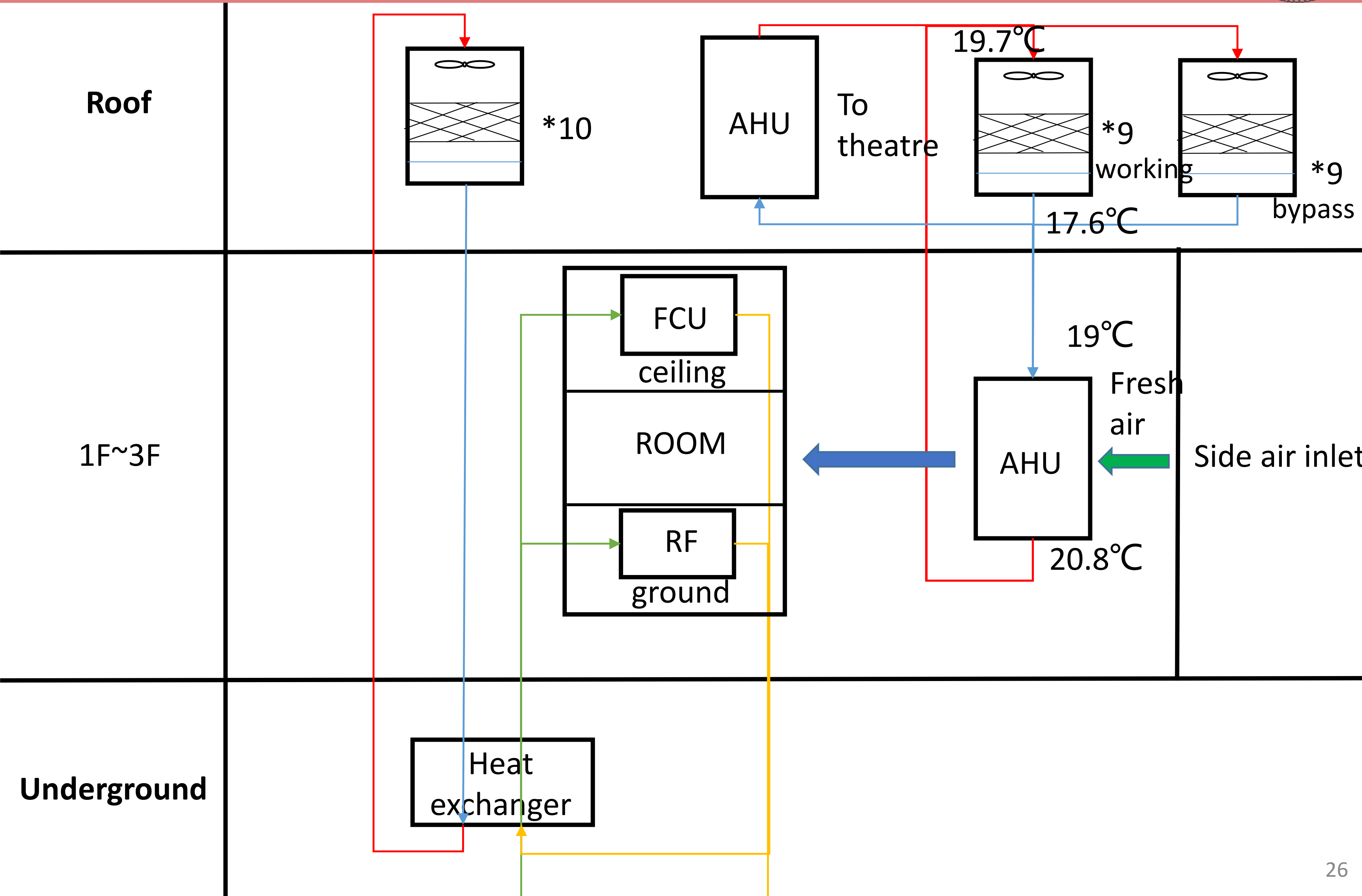
- Put into use for less than 1 year

Case 2:Function Partition

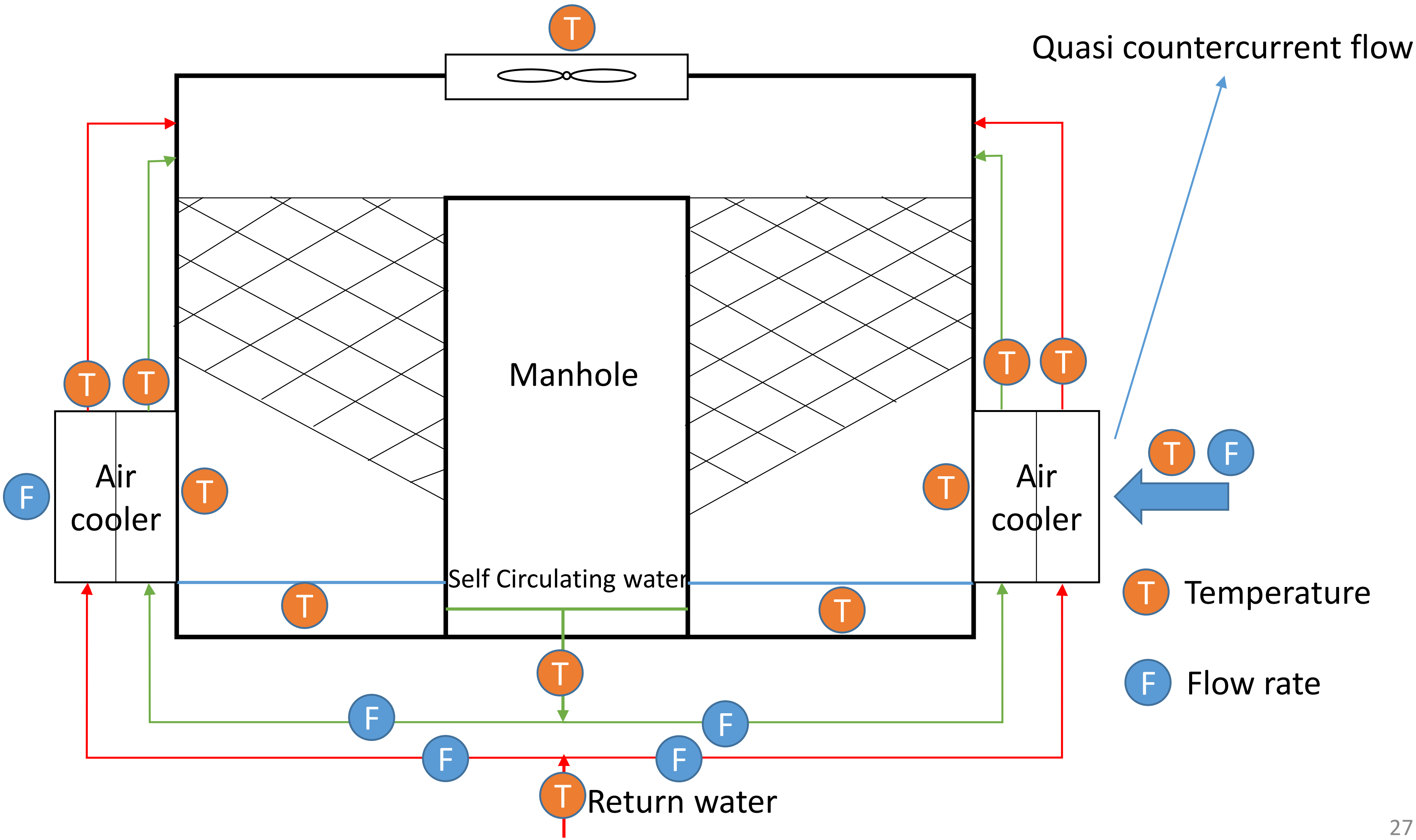


- 4 exhibition rooms, 1 lobby & meeting room, 1 theatre, the rest are office rooms
- Divided into two parts. In the south part there is no load in office rooms
- Some office rooms in northwest corner are tested

Case 2:Air Conditioning System

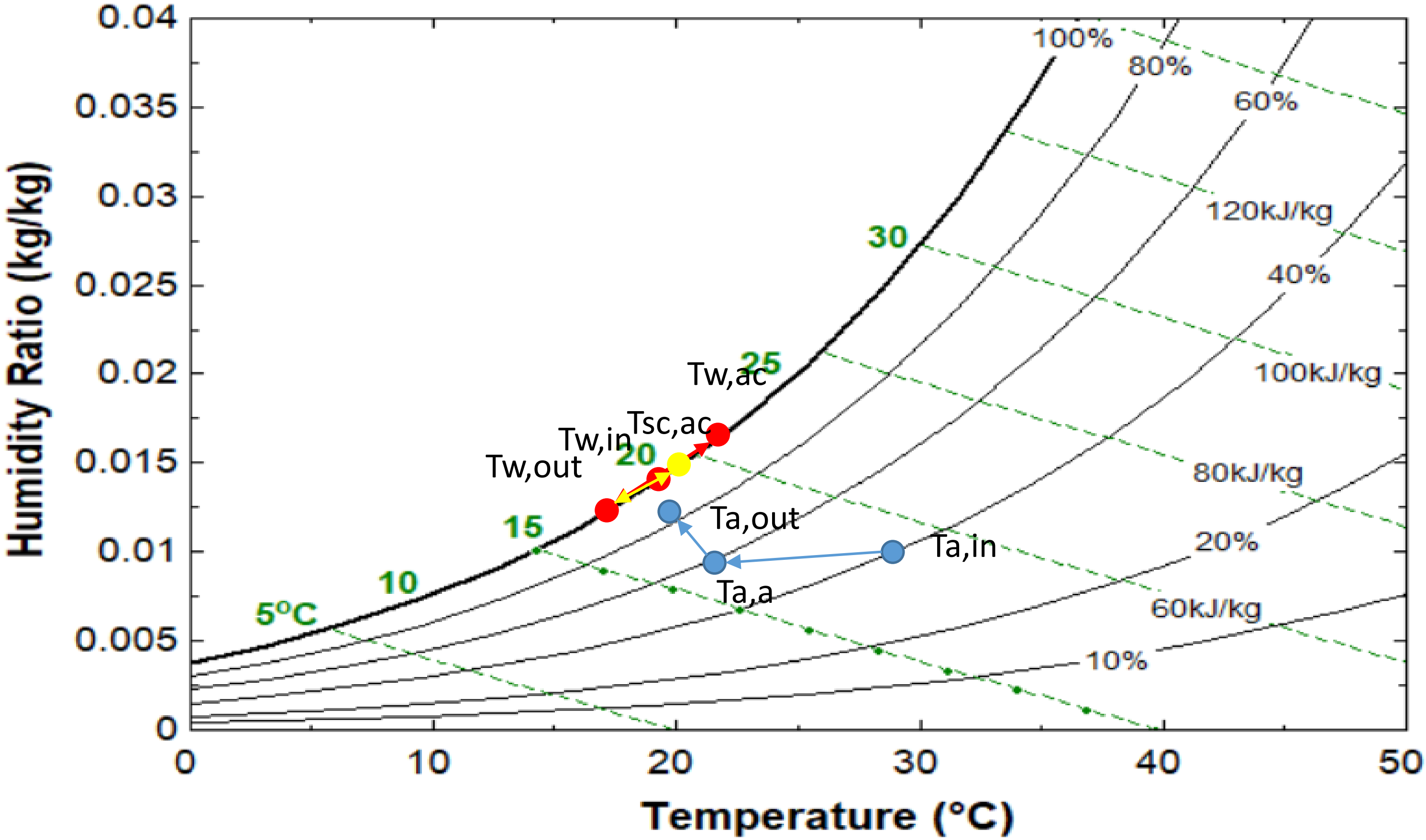


Layout of measuring point

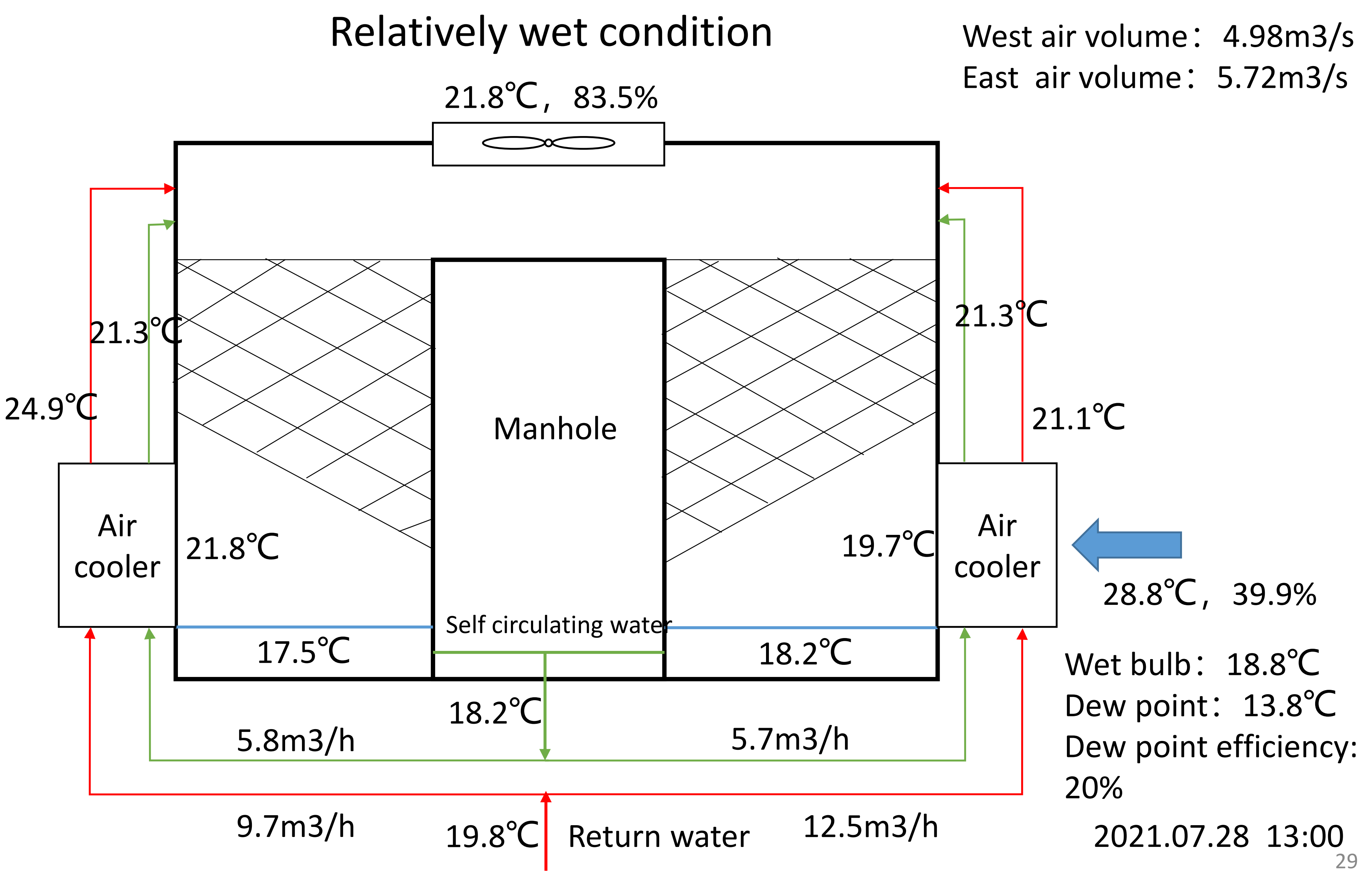


Case 2: Air Calculation formula and process

The efficiency of dew point= $(t_{tower\text{-}in} - t_{w\text{-}out}) / (t_{tower\text{-}in} - t_{a,dp})$



Case 2:Analysis of IEC water chillers



Case 2:Analysis of IEC water chillers

Heat balance check

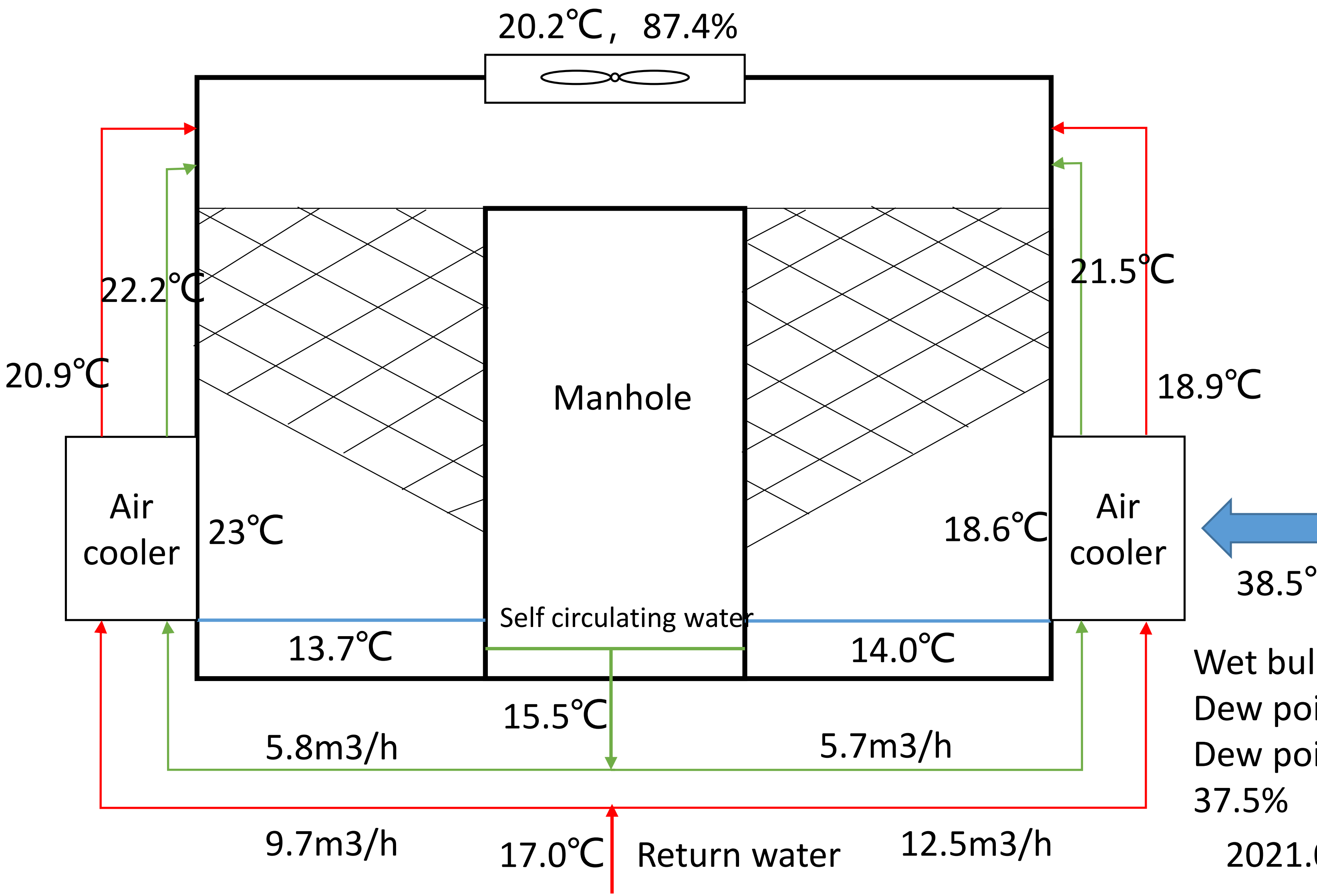
Heat exchange kw	Outer circulation kw	Self circulation kw	Wind kw	Balance rate
West air cooler	57.6	20.7	42.8	159.6%
East air cooler	18.8	20.5	64	61.4%
West packing	46.2		63.7	72.5%
East packing	54.7		88.0	62.2%
Total	50.2		44.8	112.1%

The west air cooler is directly exposed to the sun, resulting in more heat exchange on the water side.

Some temperature measuring points are wet by water, resulting in more heat exchange on the air side

Case 2:Analysis of IEC water chillers

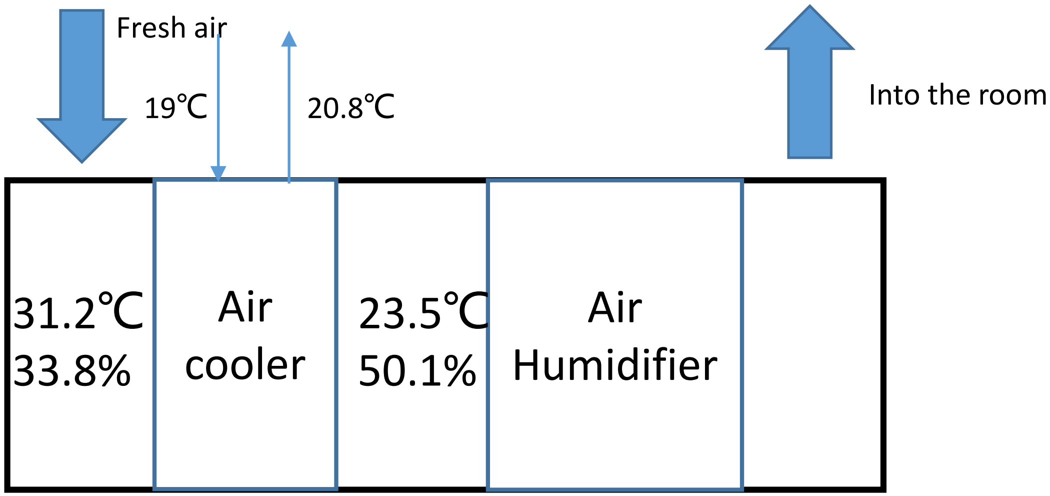
Relatively dry condition



Wet bulb： 19.5℃
Dew point： 9.0℃
Dew point efficiency: 37.5%

2021.07.27 13:00

Case 2:Analysis of AHU



31.2℃

Air volume： 1.54m3/s

Heat removal： 15.2kw

Flow rate： 10.4m3/h

24.7℃

Room temperature： 24.7℃

Heat exchange

Cooling capacity： 2.2kw

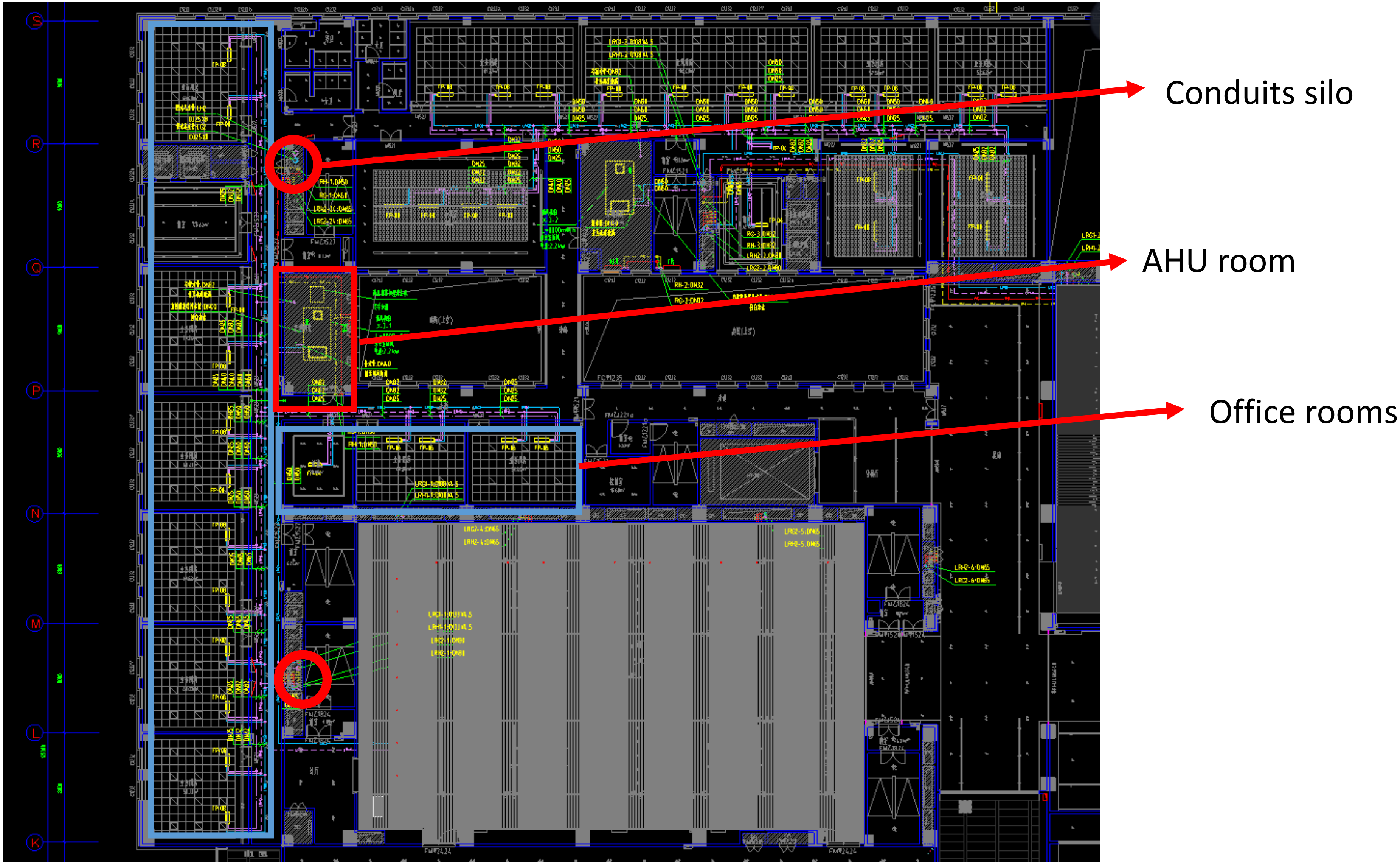
At wind side： 17.4kw

23.5℃

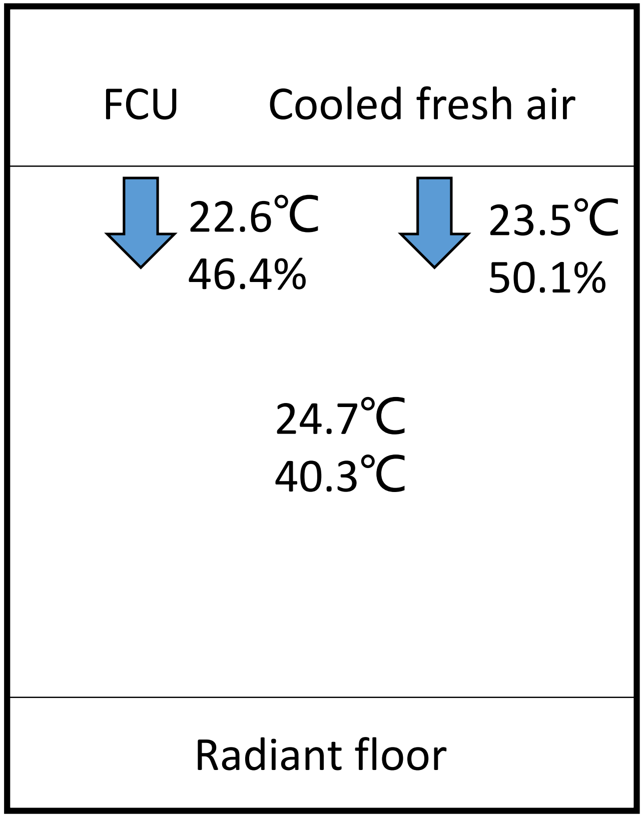
At water side： 21.7kw

Balance rate： 80.2%

Case 2: Analysis of terminal cooling system



Case 2:Analysis of terminal cooling system

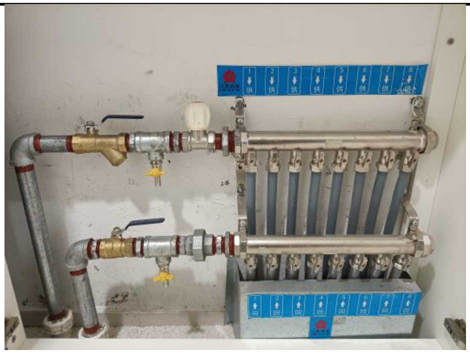


A meeting room

Coil direction

Case 2:Analysis of terminal cooling system

	Supply temperature ℃	Return temperature ℃	Flow rate m3/h	Heat exchange kw	Cooling area m2	Unit area load W/m2
RF	20.7	22.1	3.3	5.4	469	11.5
FCU	21.3	21.9	7.1	4.9	597	8.2
Fresh air cooling				2.2	388	5.7
To cool the air				15.2	388	39.2



The load per unit at the office rooms is 25.4W/m2. To cool the fresh air to room temperature, it is converted into 39.2W/m2 load . This means 64.6W/m2 in total.
The design unit area load is 65W/m2.

Case 2: Summary and improvement suggestions

Present： 1.The whole system works during the day and rests at night

2.Data acquisition system does not work

3.Many rooms are not in use, causing small water temperature difference

4.Hot fresh air brings large amount of heat

5.Nearly half of the IEC water chillers are not working and in bypass

Suggestion： 1.Adjust frequency of chillers’ fans uniformly to fit the load change.

2.Add valves to close the bypass waterway.

3.Minimize the fresh air volume within a reasonable range

Thanks for listening！