Radiant Cooling System Classification & Basics of Slab Cooling

CONTENTS

Radiant cooling systems - classification

Based on system integration

- Structure integrated systems (Slab, Wall)
- Panel cooling systems (Ceiling suspended, Wall mounted)
- Embedded surface system

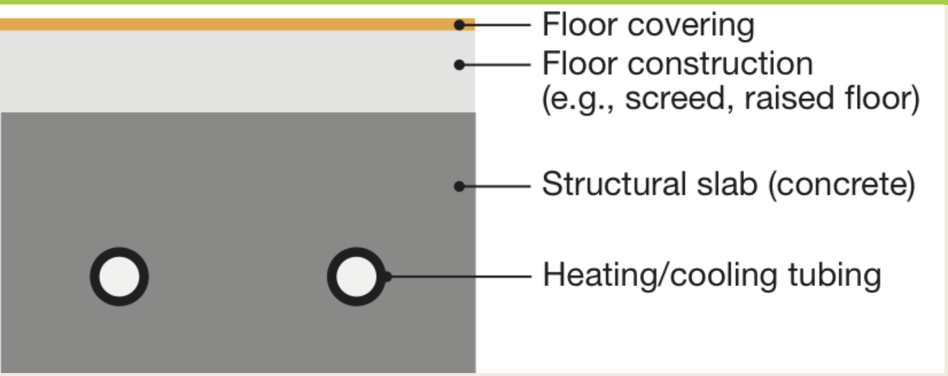
Structure integrated systems (Slab, Wall):

- Better coupling with the thermal mass of the building structure
- Lower cost per unit area of active surface

Panel cooling systems (Ceiling suspended, Wall mounted):

- Zoning and installation flexibility
- Better responsiveness and control

Radiant cooling systems - classification



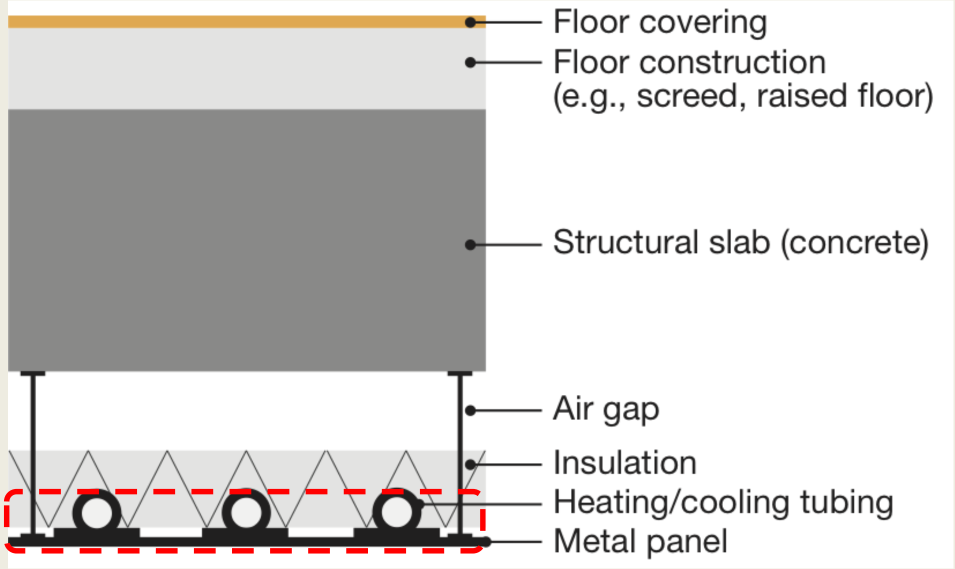
Structure integrated systems (Slab, Wall)

Thermally active building system (TABS)

Source: Jingjuan Feng, PhD Thesis, “Design and Control of Hydronic Radiant Cooling Systems”, University of California, Berkeley

Source: Infosys

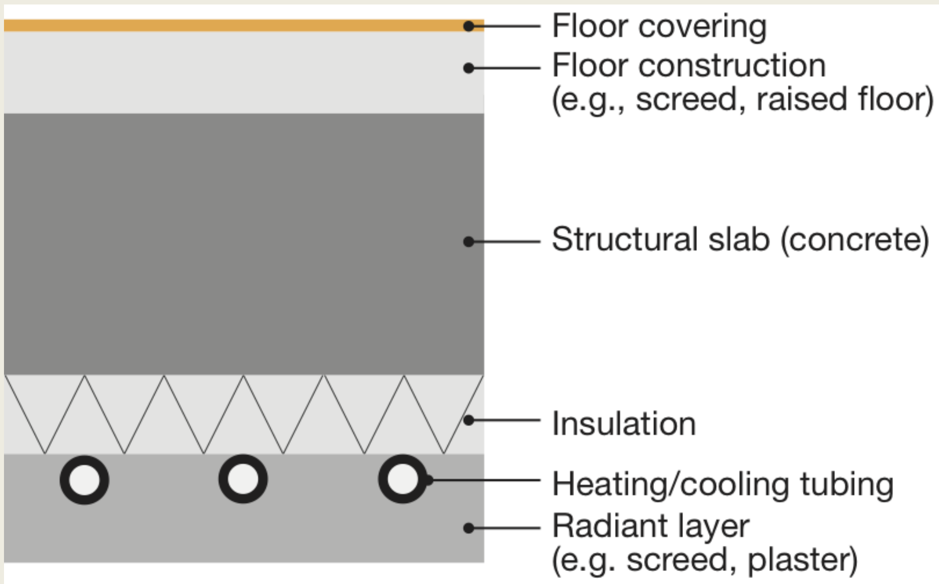
Radiant cooling systems - classification



Panel cooling systems

Source: Jingjuan Feng, PhD Thesis, “Design and Control of Hydronic Radiant Cooling Systems”, University of California, Berkeley

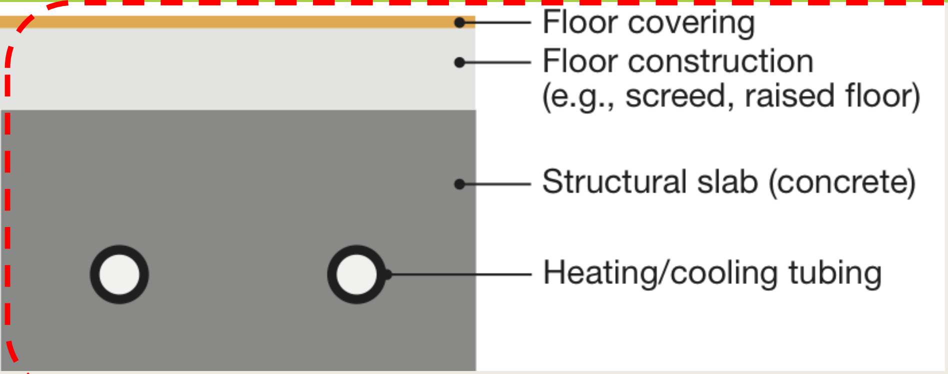
RADIANT COOLING SYSTEMS - CLASSIFICATION



Embedded surface system

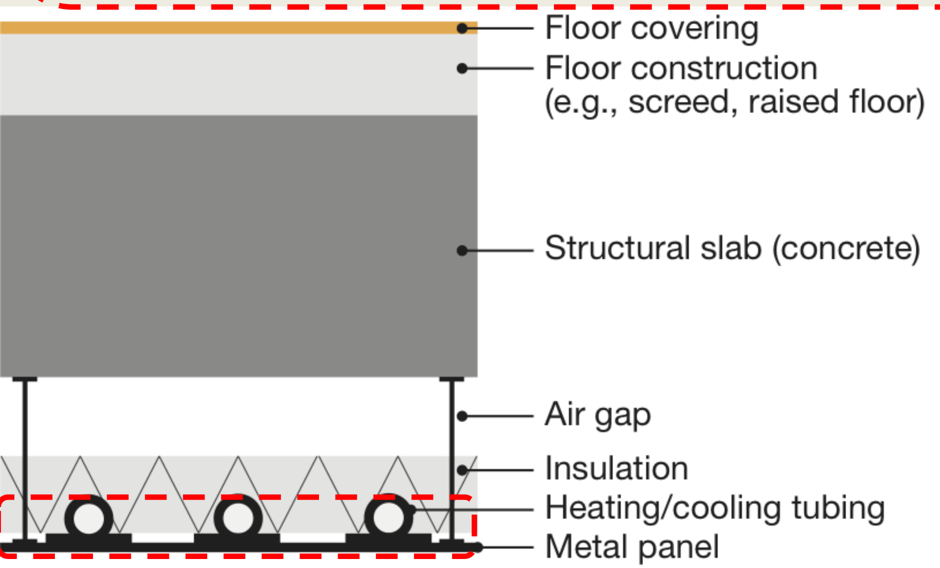
Source: Jingjuan Feng, PhD Thesis, "Design and Control of Hydronic Radiant Cooling Systems", University of California, Berkeley

Radiant cooling systems - classification

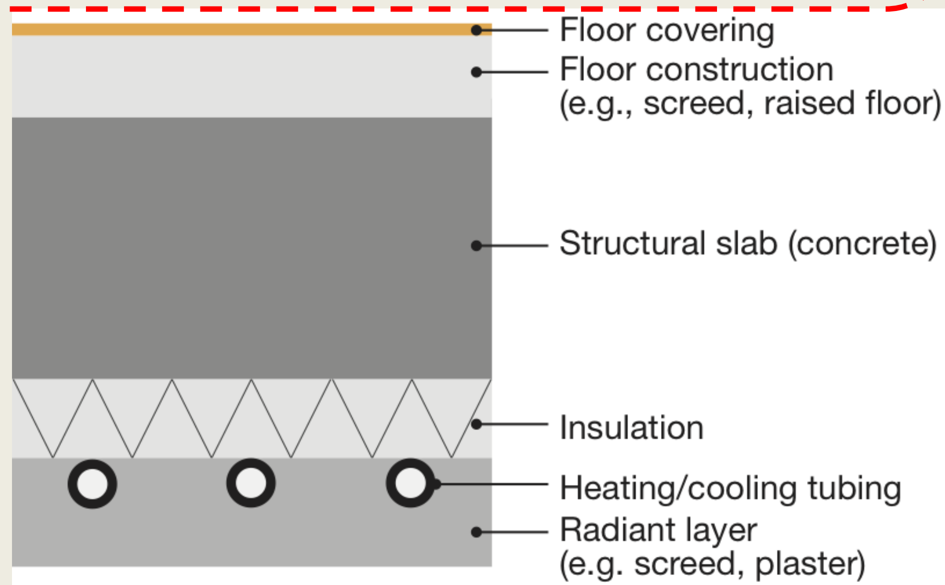


Structure integrated systems (Slab, Wall)

Thermally active building system (TABS)



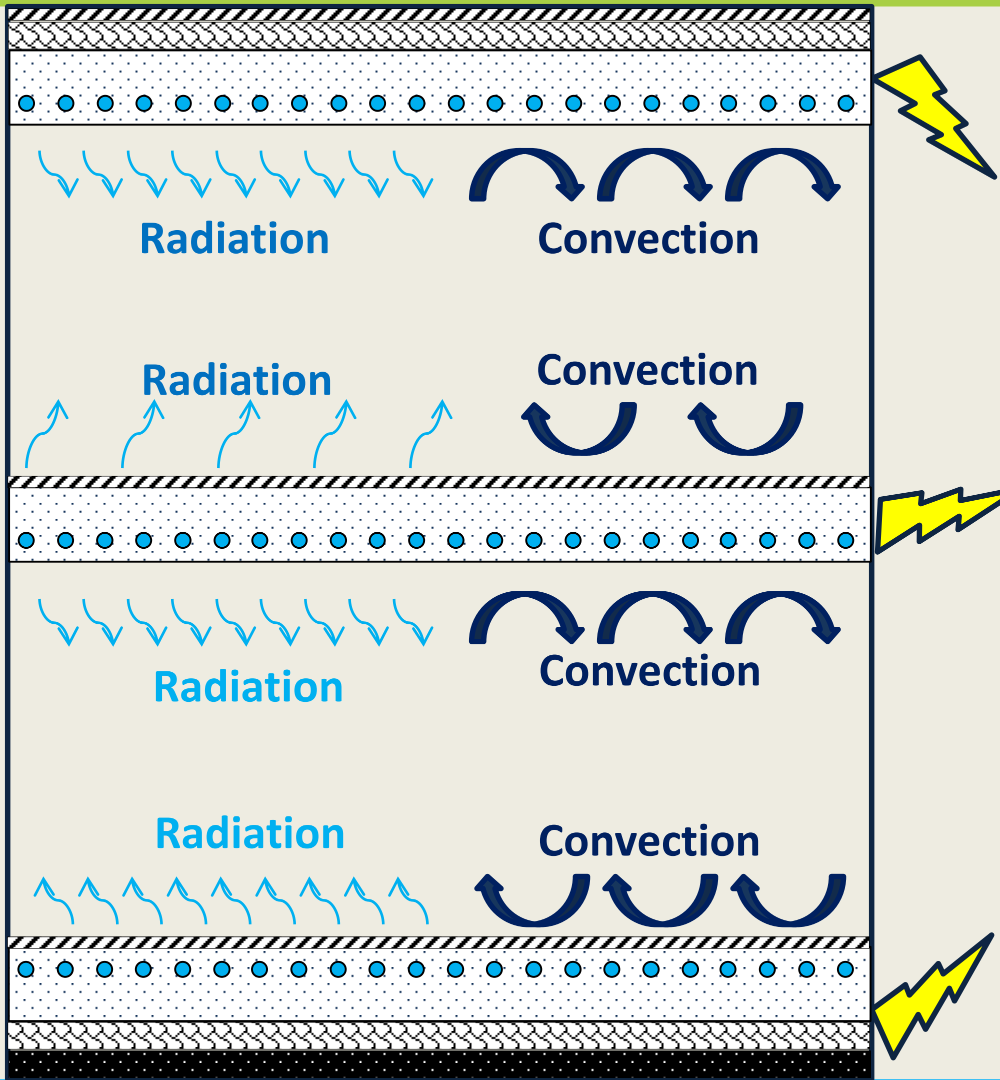
Panel cooling systems

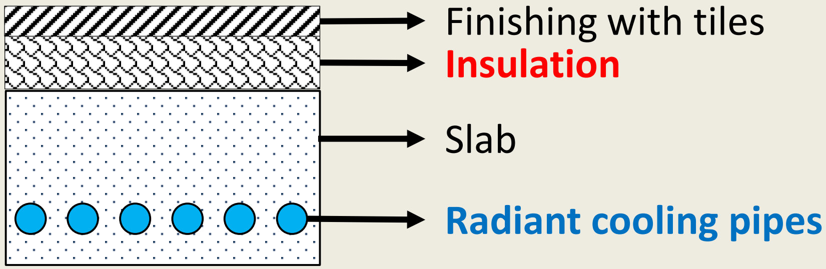


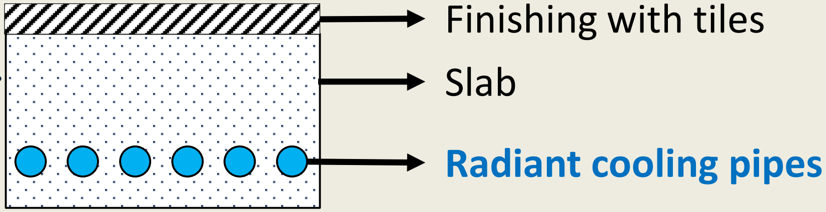
Embedded surface system

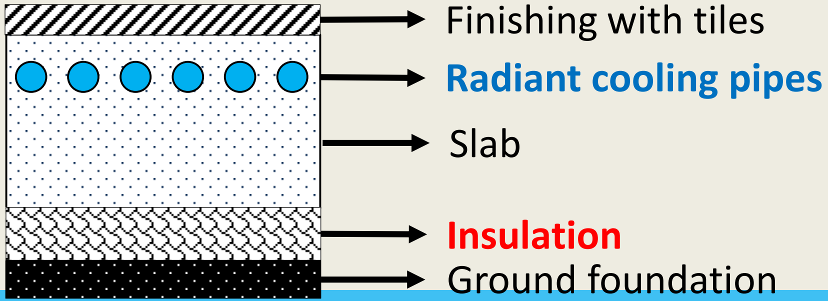
Source: Jingjuan Feng, PhD Thesis, "Design and Control of Hydronic Radiant Cooling Systems", University of California, Berkeley

Structure integrated systems: Slab cooling







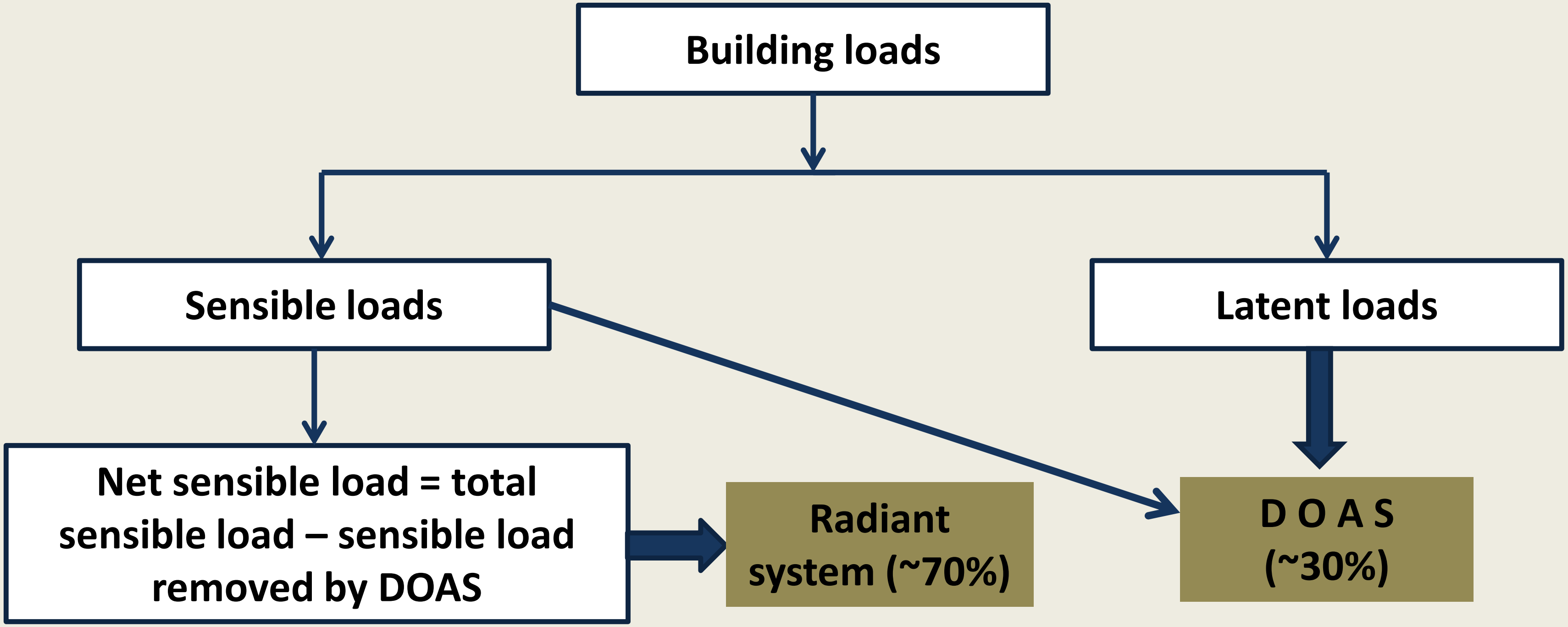


BASICS OF SLAB COOLING SYSTEM DESIGN

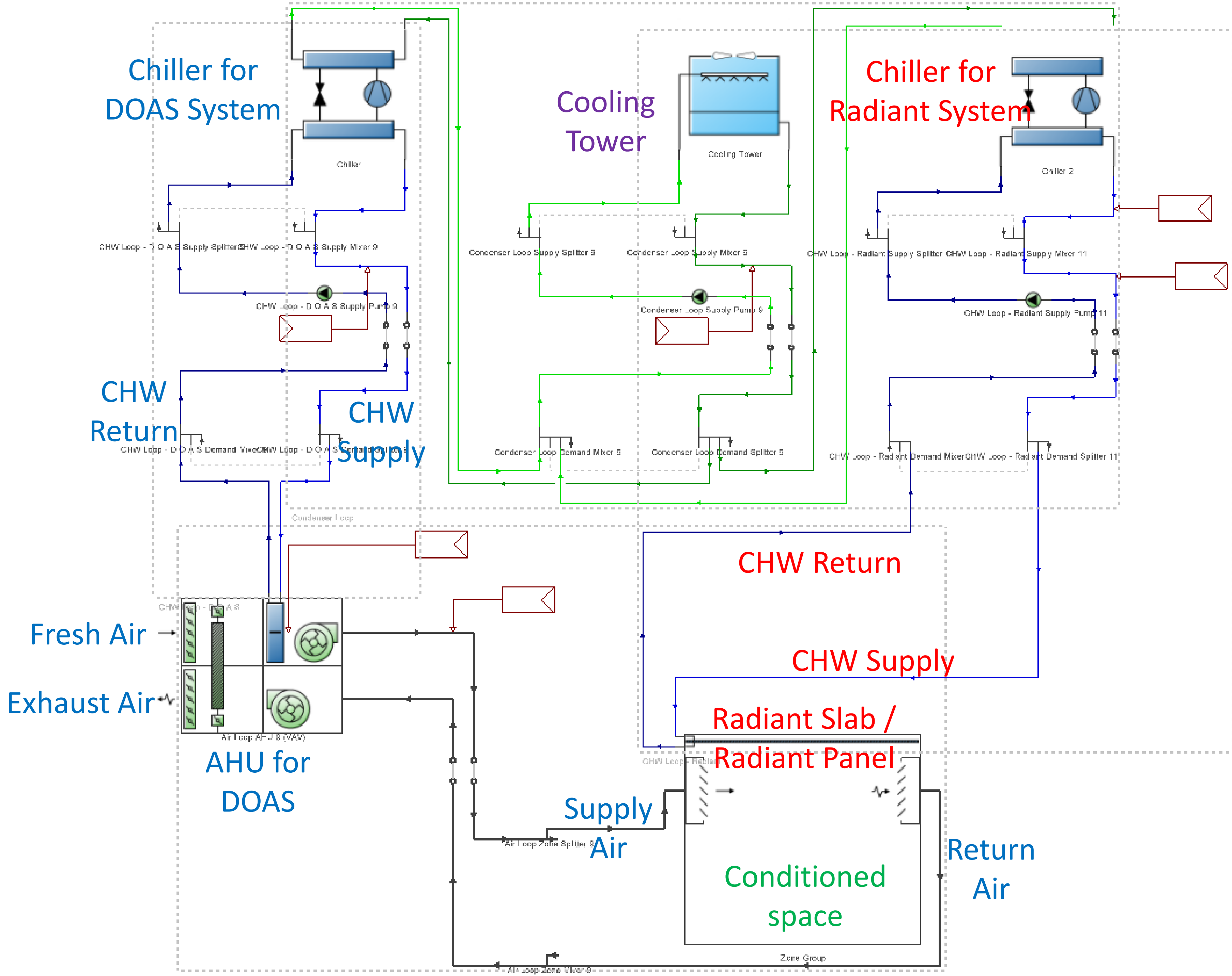
Radiant cooling – Basics

- Radiant cooling is <u>often part of a hybrid system</u> that includes conditioning of ventilation air to address internal latent loads (humidity) from occupants and infiltration, plus sensible and latent loads associated with outside ventilation air.
- An actively controlled surface is considered a "radiant system" if <u>at least 50% of the design heat transfer</u> is by thermal radiation (2004 ASHRAE Handbook)

Radiant system sizing



- D O A S cools the fresh air to lower temperatures to remove the moisture
- Cooled air supply removes some part of the sensible loads



Chiller for DOAS System
Chiller
Cooling Tower
Cooling Tower
Chiller for Radiant System
Chiller 2
CHW Return
CHW Supply
CHW Return
CHW Supply
Radiant Slab / Radiant Panel
Fresh Air
Exhaust Air
AHU for DOAS
Supply Air
Return Air
Conditioned space
Condenser Loop
Zone Group

DESIGN PROCEDURE

Estimate cooling capacity

- Based on possible surface temperature to avoid condensation

For each zone, calculate total tubing length required

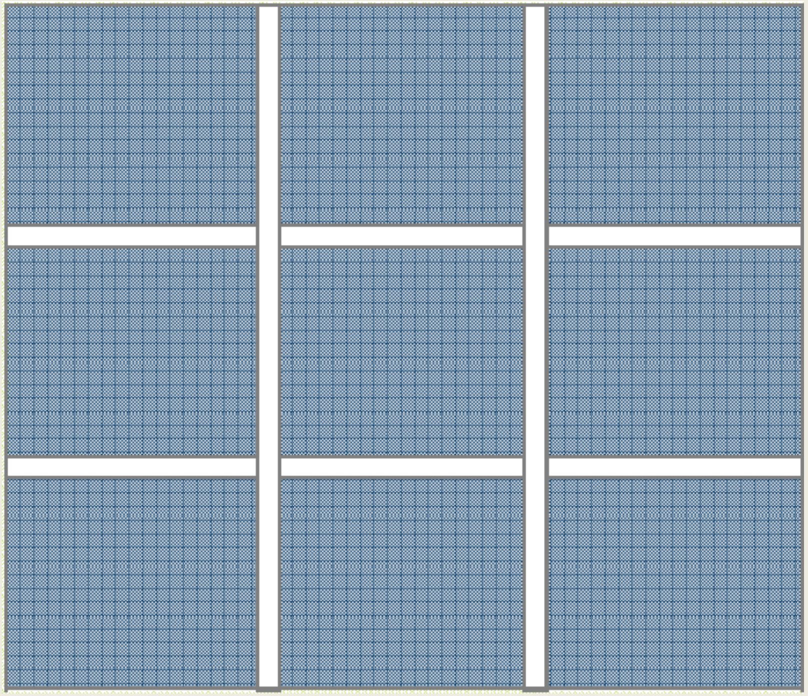
Based on tubing required, estimate the number of loops

Arrangements of loops

Based on number of loops, determine number of manifolds

What is Active Area?

- Surface area available for heat transfer (cooling)
- Cooling capacity must be calculated with active area; not with the ceiling area (particularly for radiant panels)



For slab cooling, active area 80-95%

Image Source: Ecophit Radiant Ceilings, Germany

Radiant surface temperature

- Objective: Avoid condensation
- Minimum allowable surface temperature is decided w.r.t. dew point temperature

$$T_{surface} \geq Tde_{wpoint} + 2^{o}C$$

E.g. with 25°C air temperature & 55% RH; the dew point temperature is ~16°C.

$$T_{surface} \geq 18^{o}C$$

Operative Temperature

$$T_{\text{op}} = \frac{h_{\text{r}} T_{\text{MRT}} + h_{\text{c}} T_{\text{air}}}{h_{\text{r}} + h_{\text{c}}}$$

$$T_{op} \approx \frac{T_{MRT} + T_{air}}{2}$$

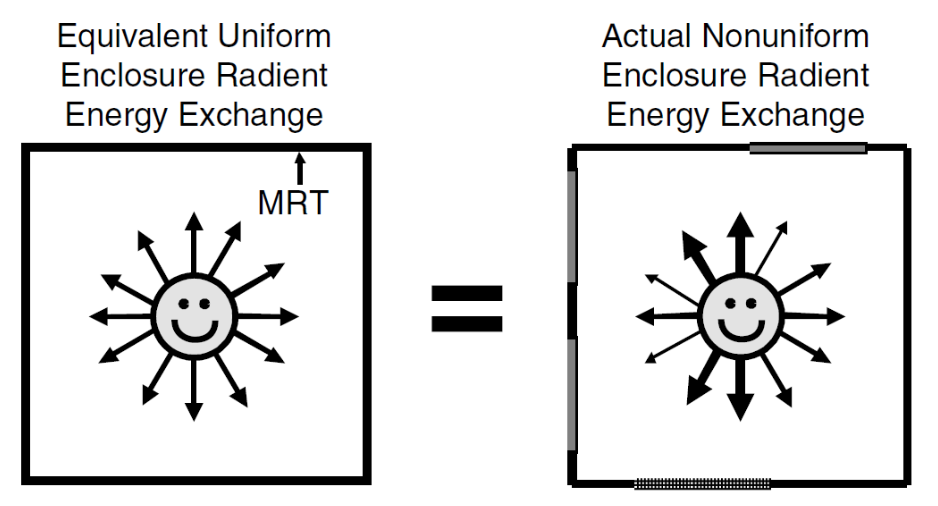
The temperature of a uniform isothermal black enclosure in which the occupant exchanges the same amount of heat by radiation and convection as in the actual non-uniform environment

For air velocities of 0.4 m/s (1.3 ft/s) and an MRT of 50°C (122°F) or less, the operative temperature is approximately the average of the air temperature and MRT

Source: Radiant Cooling and Heating Handbook (Richard D Watson, Kirby S Chapman)

Radiant cooling – Basics

Mean Radiant Temperature



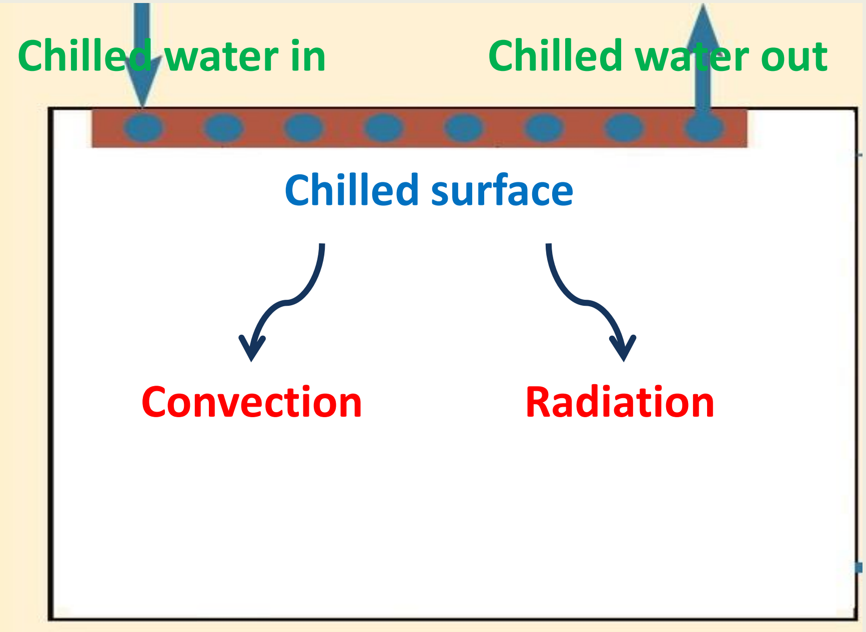
The uniform surface temperature of an imaginary black enclosure in which the radiation from the occupant equals the radiant heat transfer in the actual non-uniform enclosure

Source: Radiant Cooling and Heating Handbook (Richard D Watson, Kirby S Chapman)

Determining cooling capacity

- Cooling capacity of chilled slab:

  $$Q = h_{rad+conv} \times \Delta T \times \text{Active area}$$



- $h_{rad+conv}$ = Combined Heat transfer coefficient
- ΔT = Operative temperature – ceiling surface temperature

Operative temperature = 25°C

Cooling surface	Combined Heat transfer coefficient $h_{rad+conv}$ (W/m².K)	Allowable surface temperatures (°C)	Capacity per unit chilled surface area (W/m²)
Slab	8 - 11	18	56 - 77

Source: Uponor_Products & ASHRAE Handbook

DESIGN PROCEDURE

Estimate cooling capacity

For each zone, calculate total tubing length required

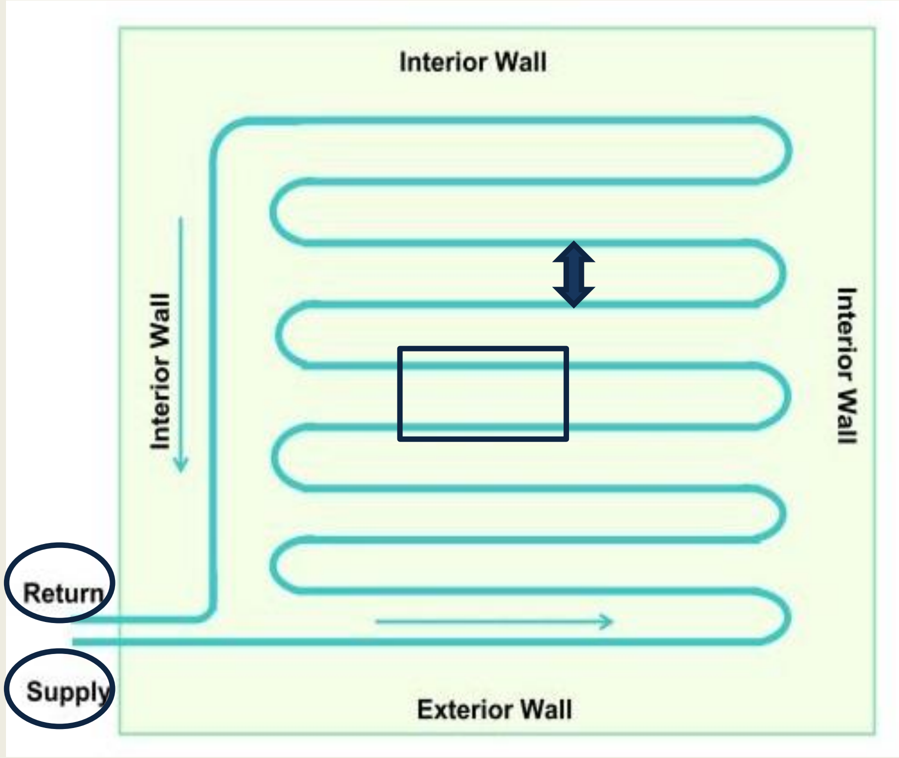
Based on tubing required, estimate the number of loops

Arrangements of loops

Based on number of loops, determine number of manifolds

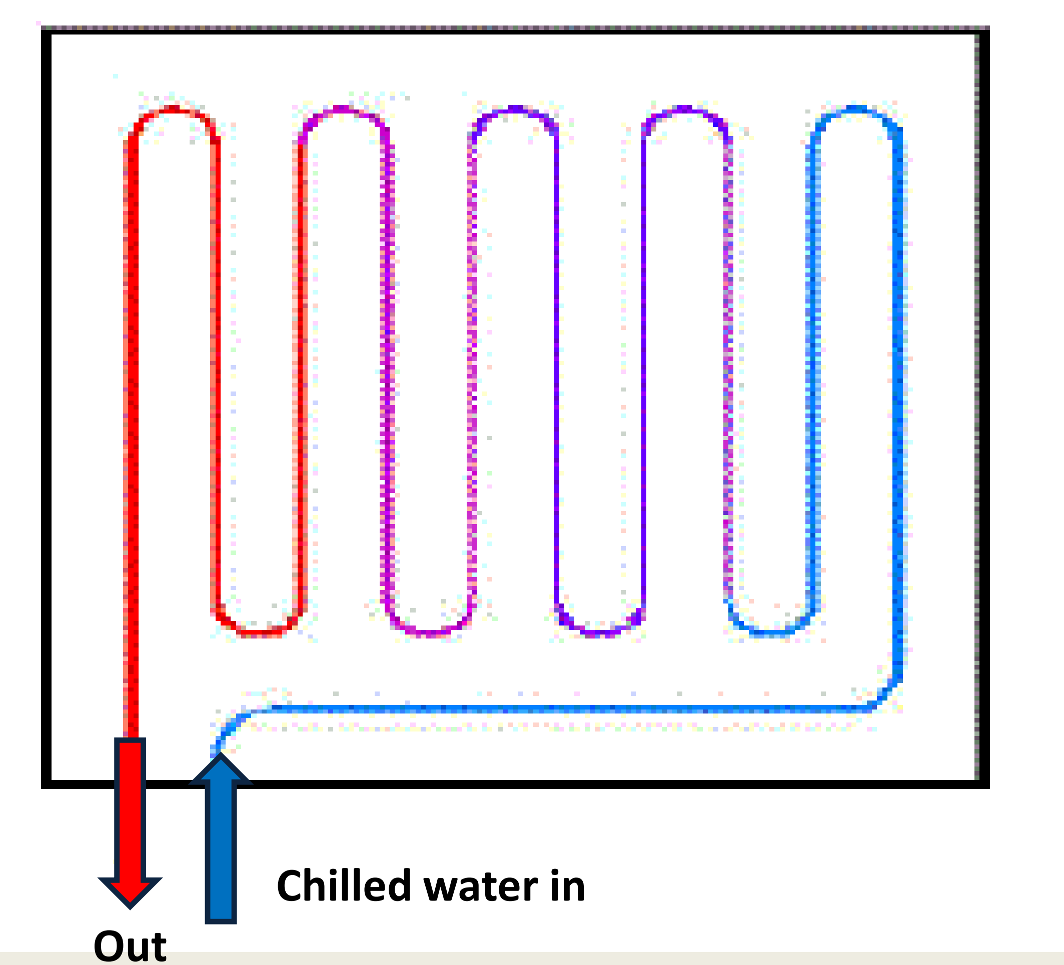
Estimating tubing length required per zone

- Length of the tubing from supply to return ports in a zone is called tubing length.
- Typical tubing diameter ranges from 12.5 to 20 mm (0.5 to 0.75 inch)
- Tube spacing is the distance between two tubes (center to center), typically it ranges from 150 to 450 mm (6-18 inch)
- Tube length per sq. ft. depends on tube spacing, it ranges from 2.2 to 6.6 m/m^2 (0.67 to 2 ft/ ft^2)
- Total tube length = Available surface area x tube length per sq.m.



Example for finding tube length

- Zone area = 500 m^2
- Available area = 400 m^2 (@80%)
- Tube spacing = 150 mm
- Tube length = 6.6 m/m^2
- Total tube length = 2625 m



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Example for finding tube length

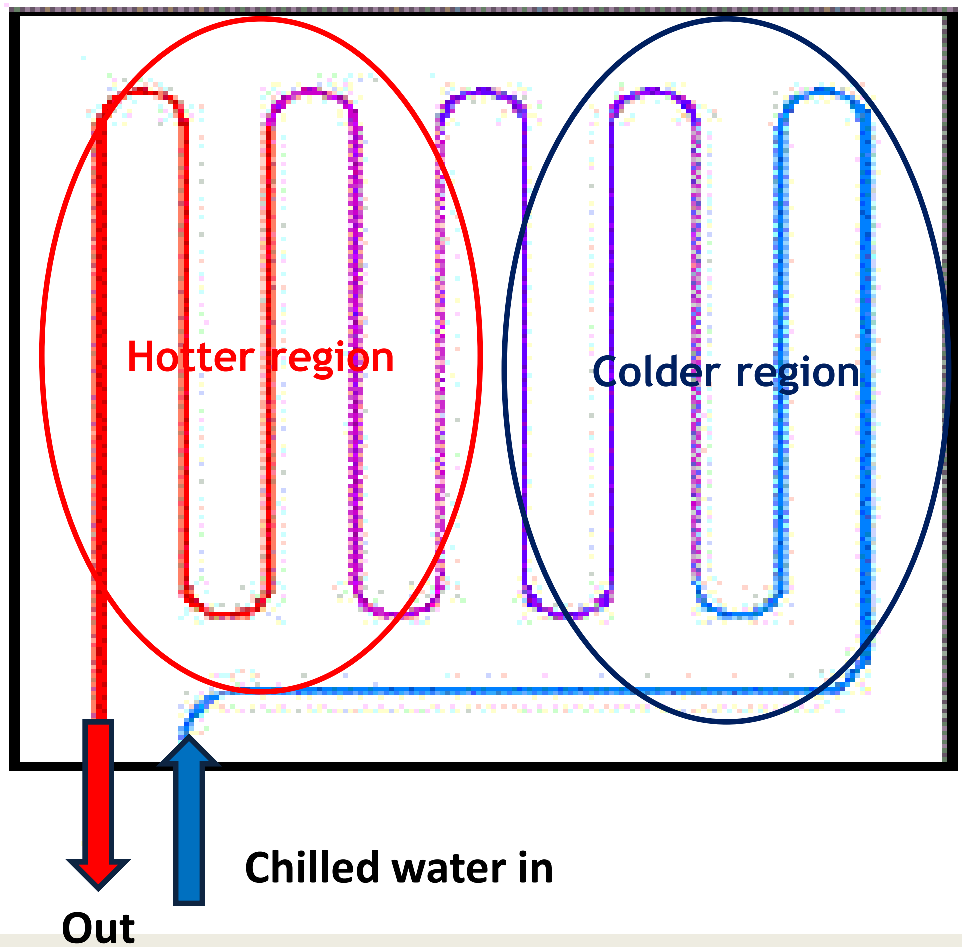
- Zone area = 500 m^2
- Available area = 400 m^2 (@80%)
- Tube spacing = 150 mm
- Tube length = 6.6 m/m^2
- Total tube length = 2625 m

Effects of long single piping layout:

- Higher temperature drop along the piping leads to uneven surface temperature
- High flow rates through pipes leads to higher pressure drop

Solution:

- Dividing the total tube length into multiple loops as suited for zone requirements



Selecting loop length and diameter

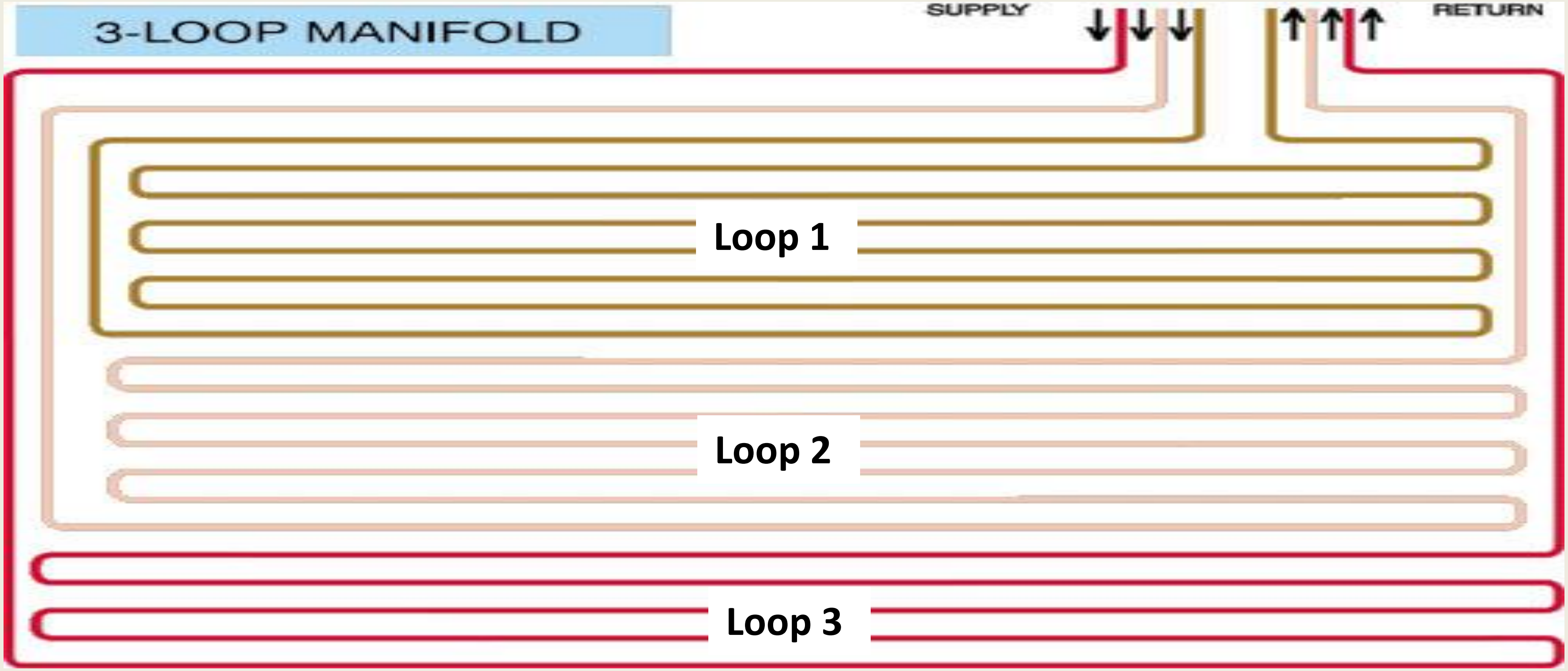
- Loop length & Tube Diameter
  - Affects temperature drop of the chilled water (important from surface temperature uniformity point of view)
  - Affects pressure drop of the loop (pump energy)

Tube diameter (inch)	Tube diameter (mm)	Tube length (ft)	Tube length (m)	Pressure drop (in WC)
3/8”	9.5	125 – 150	38 – 46	**Goal PD < 10 ft (3 m)**
1/2”	12.7	250 – 300	76 – 91	
5/8”	15.9	350 – 450	107 – 137	
3/4”	19.1	450 - 500	137 - 152	

Tube length and tube diameter decides Pump Energy and Slab Surface Temperature Uniformity

DETERMINING NUMBER OF LOOPS PER ZONE

- No of loops = total tube length / single loop length



- No of loops depends on zone size, individual loop lengths and tube diameter

E.g. 16 mm tube diameter & 107 m tube length, No. of loops ~ 25

Source: Radiant floor company

DESIGN PROCEDURE

Estimate cooling capacity

↓

For each zone, calculate total tubing length required

↓

Based on tubing required, estimate the number of loops

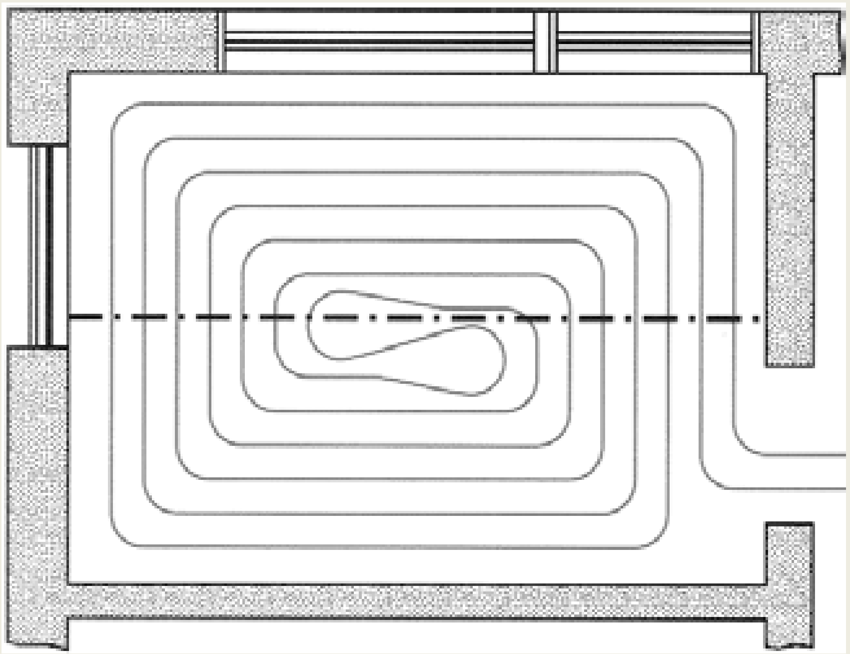
↓

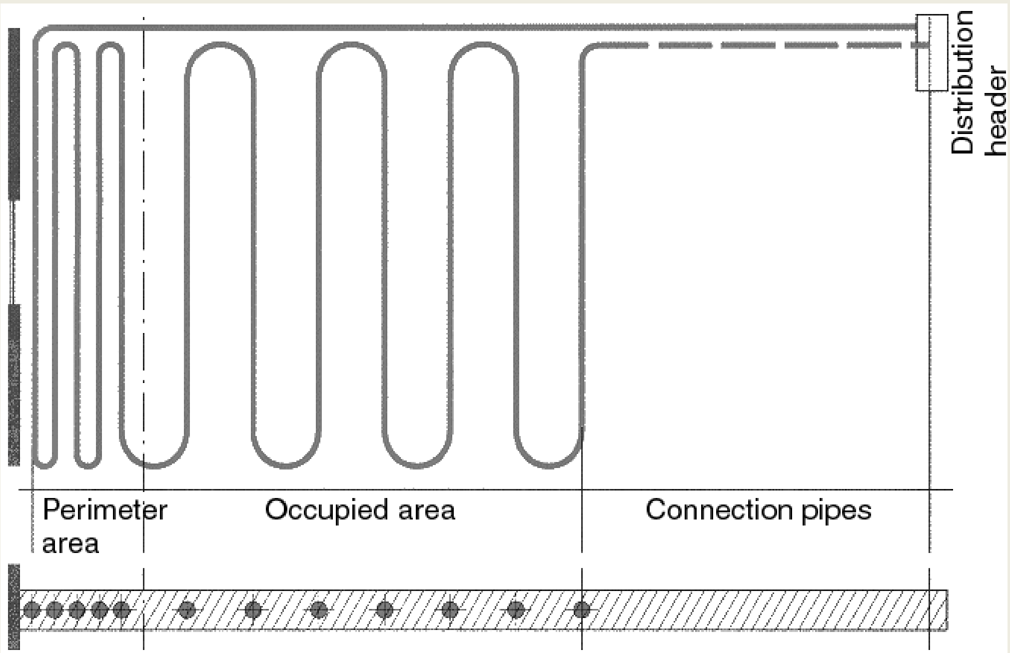
Arrangements of loops

↓

Based on number of loops, determine number of manifolds

Loop layouts arrangements



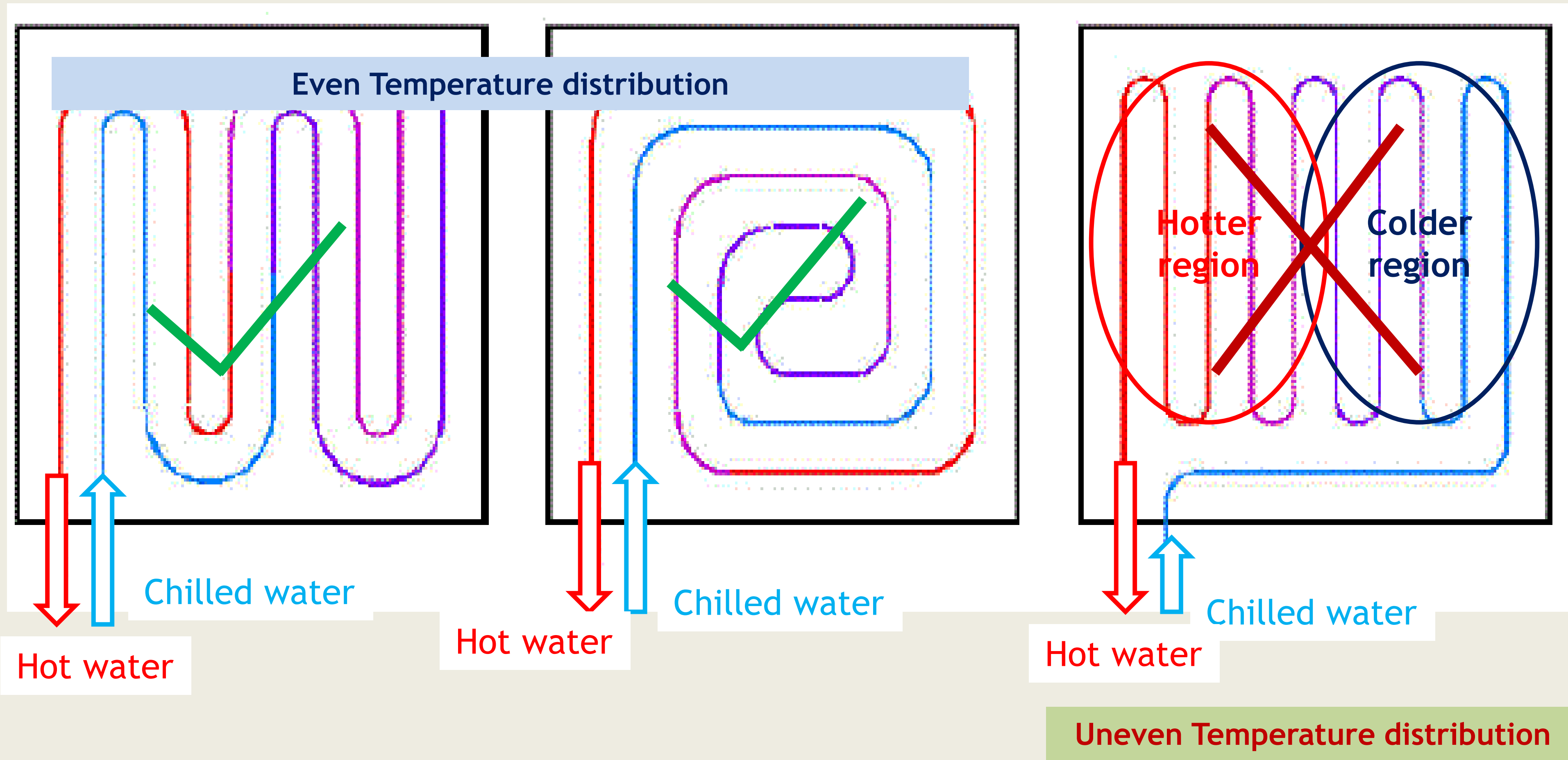


For uniform load
(Counter flow spiral conduit pattern)

For varying load within the space (Solar gains near façade)
(Serpentine conduit pattern)

Source: Radiant Cooling and Heating Handbook (Richard D Watson, Kirby S Chapman)

Loop layouts arrangements



DESIGN PROCEDURE

Estimate cooling capacity

For each zone, calculate total tubing length required

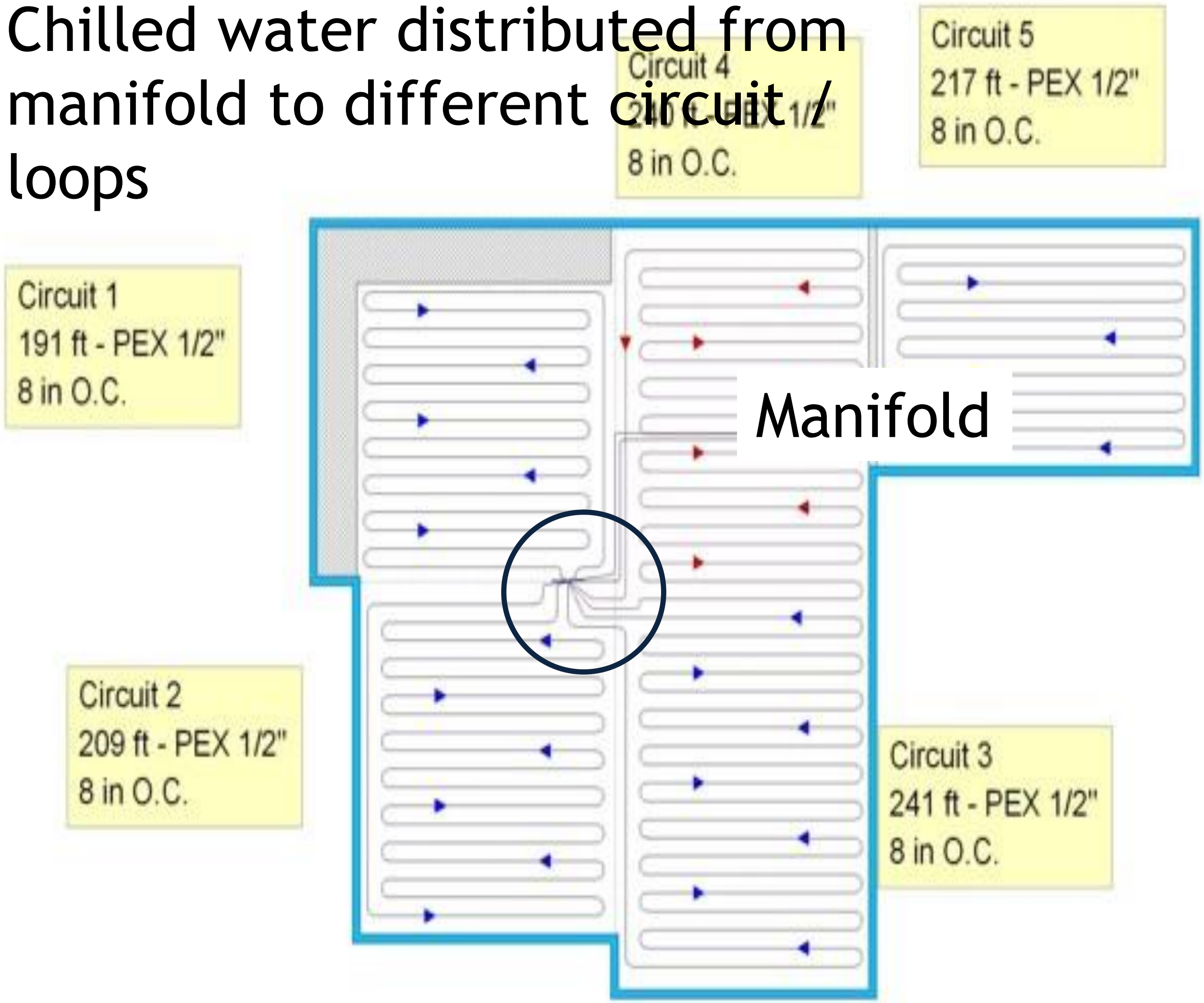
Based on tubing required, estimate the number of loops

Arrangements of loops

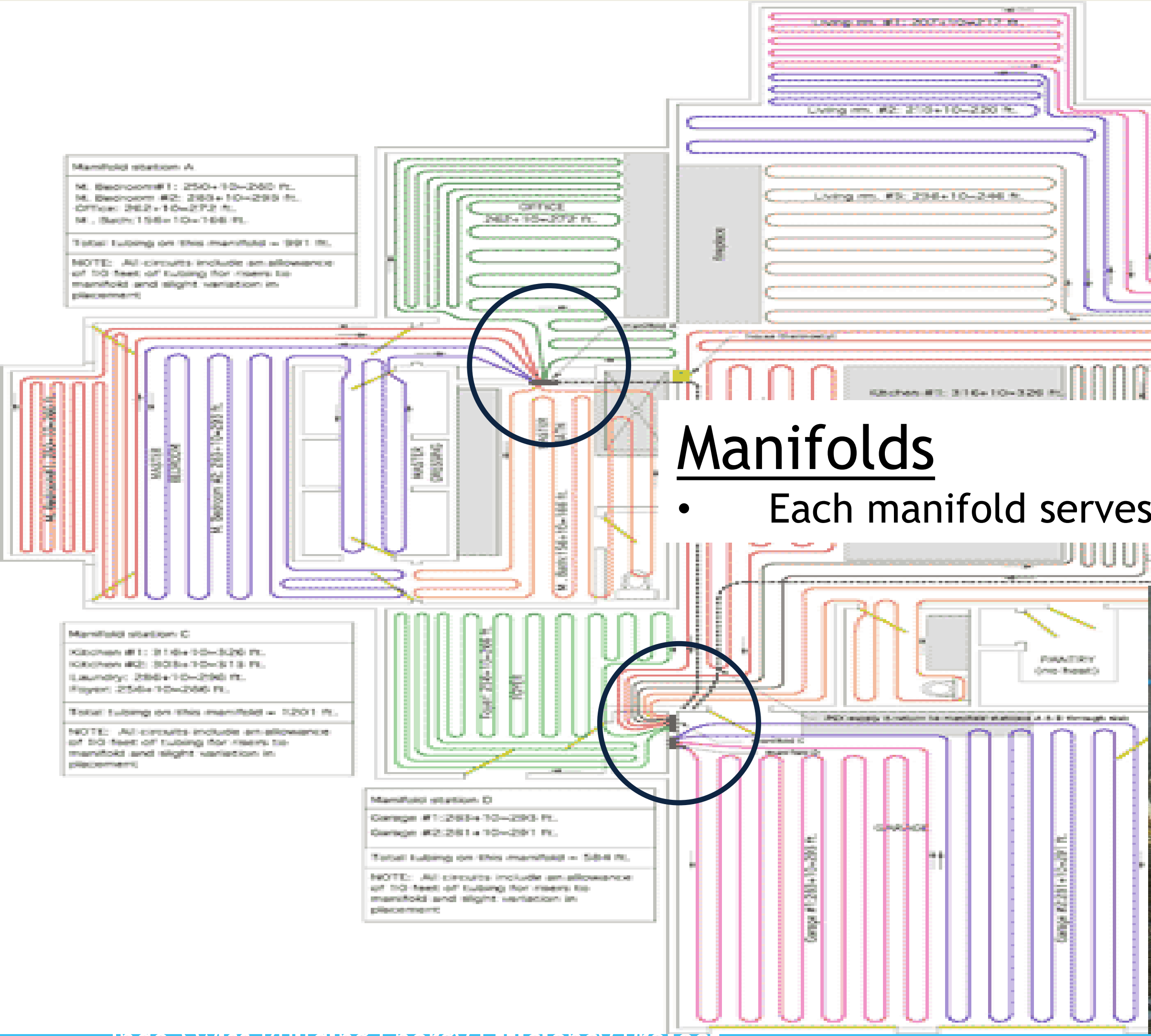
Based on number of loops, determine number of manifolds

Multiple zones – Single manifold

Chilled water distributed from manifold to different circuit / loops



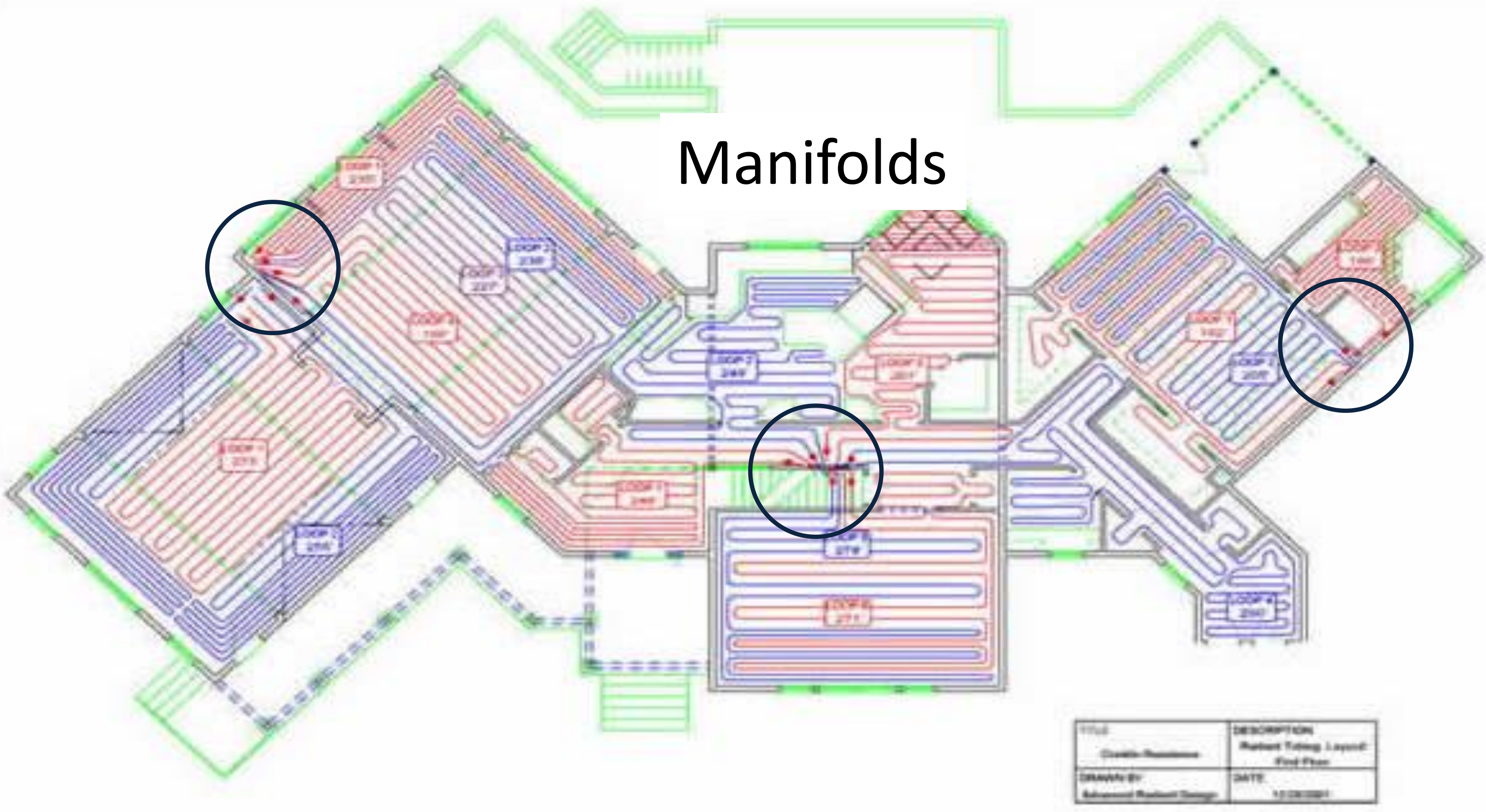
Loop layouts for large zones



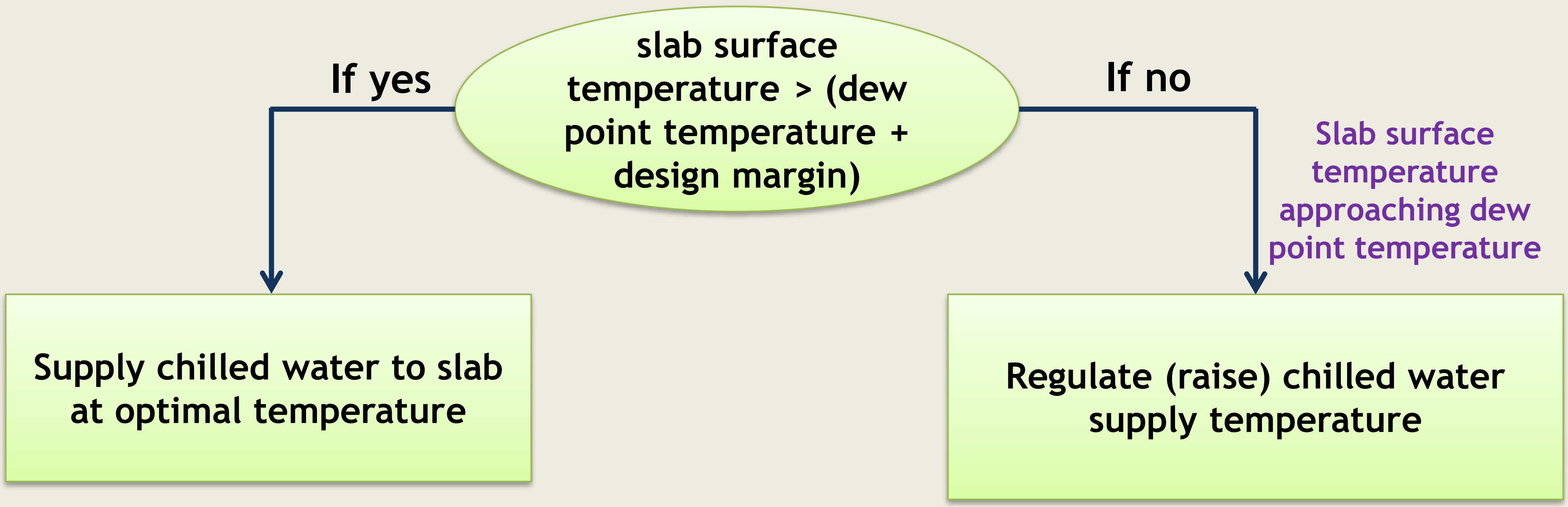
Manifolds

- Each manifold serves zone

Multiple zones – Multiple manifolds



Use of controls to avoid condensation



Installation procedure

- Laying pipe layouts
- Pressure testing
- Connecting radiant cooling pipes to chiller
- Commissioning the system

Installation procedure

Installation procedure

Installation procedure

Radiant slab cooling – India

Infosys – Software Development Block -1, Hyderabad

Indian Institute of Tropical Meteorology (IITM), Pune

THANK YOU