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  - ✓ Compile the attendee rating on the Event Summary Critique
  - ✓ Send the completed Event Summary Critique to your CTTC RVC and ASHRAE Headquarters

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ASHRAE
ORLANDO
2020 WINTER CONFERENCE
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Energy Efficient Embedded Tube Radiant Cooling Systems

Devin A. Abellon, PE
Business Development Manager
Uponor North America

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uponor

LEED v4.1

New Construction & Major Renovations

LEED Topic	Possible Points
LOCATION & TRANSPORTATION	16
SUSTAINABLE SITES	17
WATER EFFICIENCY	13
ENERGY & ATMOSPHERE	38
MATERIALS AND RESOURCES	18
INDOOR ENVIRONMENTAL QUALITY	21
INNOVATION	7
REGIONAL PRIORITY	8

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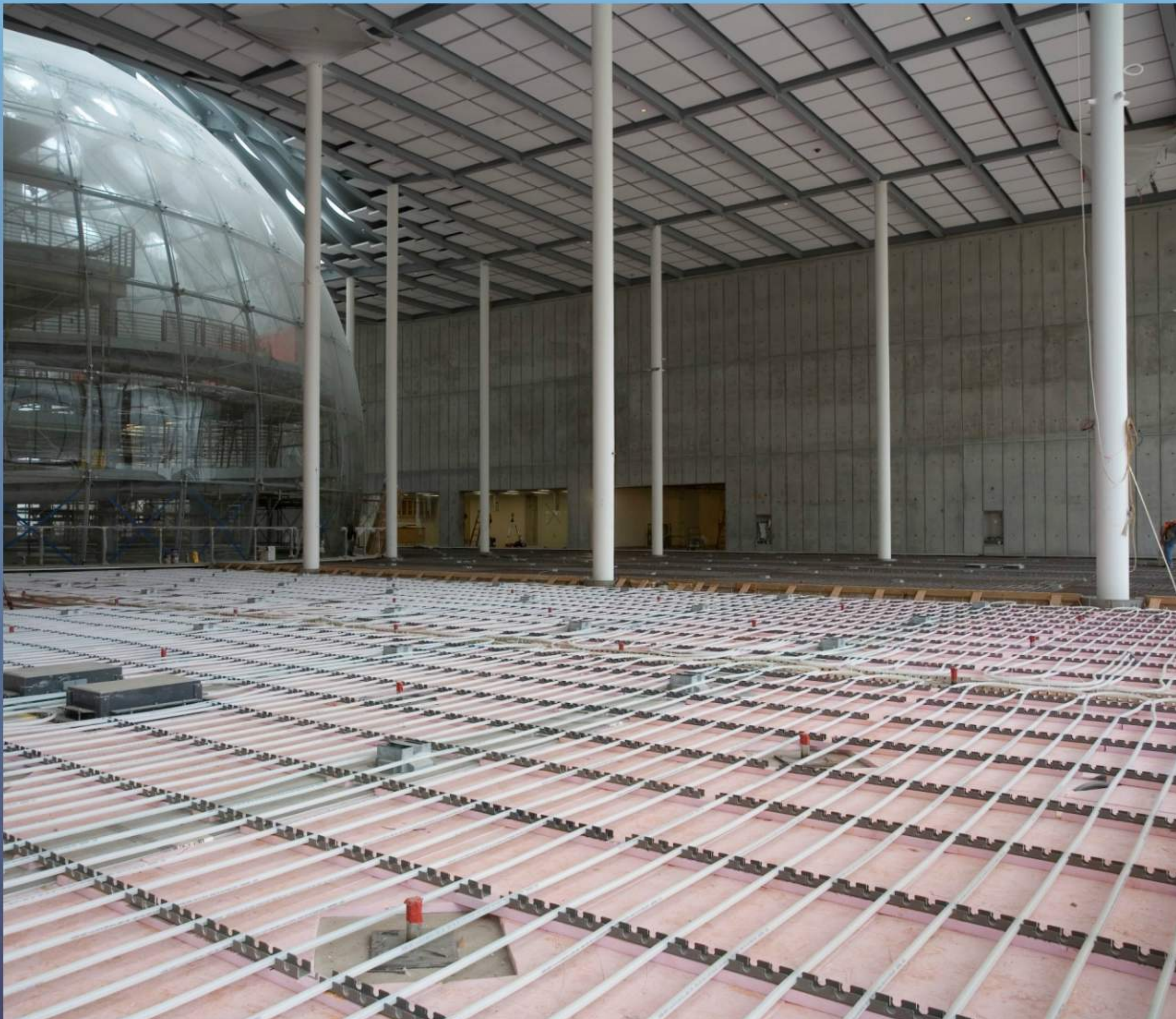
LEED v4.1

New Construction & Major Renovations

LEED Topic	Possible Points
ENERGY & ATMOSPHERE Optimize Energy Performance Enhanced Commissioning Enhanced Refrigerant Management	25
INDOOR ENVIRONMENTAL QUALITY Enhanced IAQ Strategies Construction IAQ Plan IAQ Assessment Thermal Comfort Acoustic Performance	7
WATER EFFICIENCY Cooling Tower Efficiency	2




uponor

Radiant Fundamentals

Slab & Construction Details

Slab on Grade

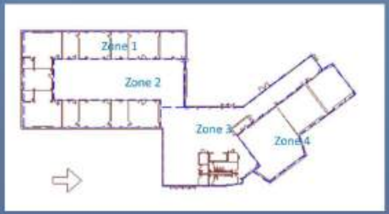
Suspended Slab

Topping Slab

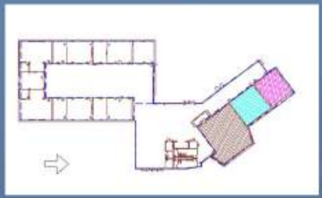
Wood Deck

Zoning

Zoning

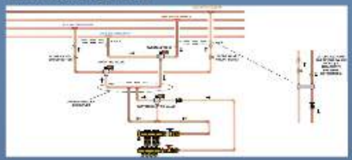


Local Zoning

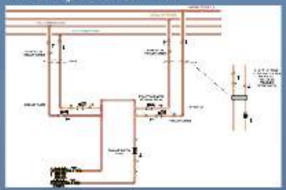


Piping & Controls

Switchover Control



Local Injection Control



Control Points

- Space Temperature
- Indoor Relative Humidity
- Operative Temperature
- Operating Water Temperatures
- Slab Temperature
- Control Valves
- Circulating Pumps
- Outdoor Temperature
- Outdoor Relative Humidity

Control Strategies

- Base load with radiant cooling system and operate as a differential to air setpoint
- Utilize indoor adaptive reset strategy to optimize target water temperature for maximum effectiveness
- Continuously monitor indoor relative humidity for condensation control
- Maintain constant slab temperature

Condensation Control

Condensation Control

Condensation

Solution

Controllability

- High thermal mass provides "inertia" against temperature fluctuations
- Heat transfer from the thermal mass to the space is instantaneous whenever there is a temperature difference
- Thermal mass evens out fluctuations in internal temperature
- Secondary system used to handle high load densities

Cost

Typical Cost Factors

Reduced Cost

Reduced Maintenance Cost

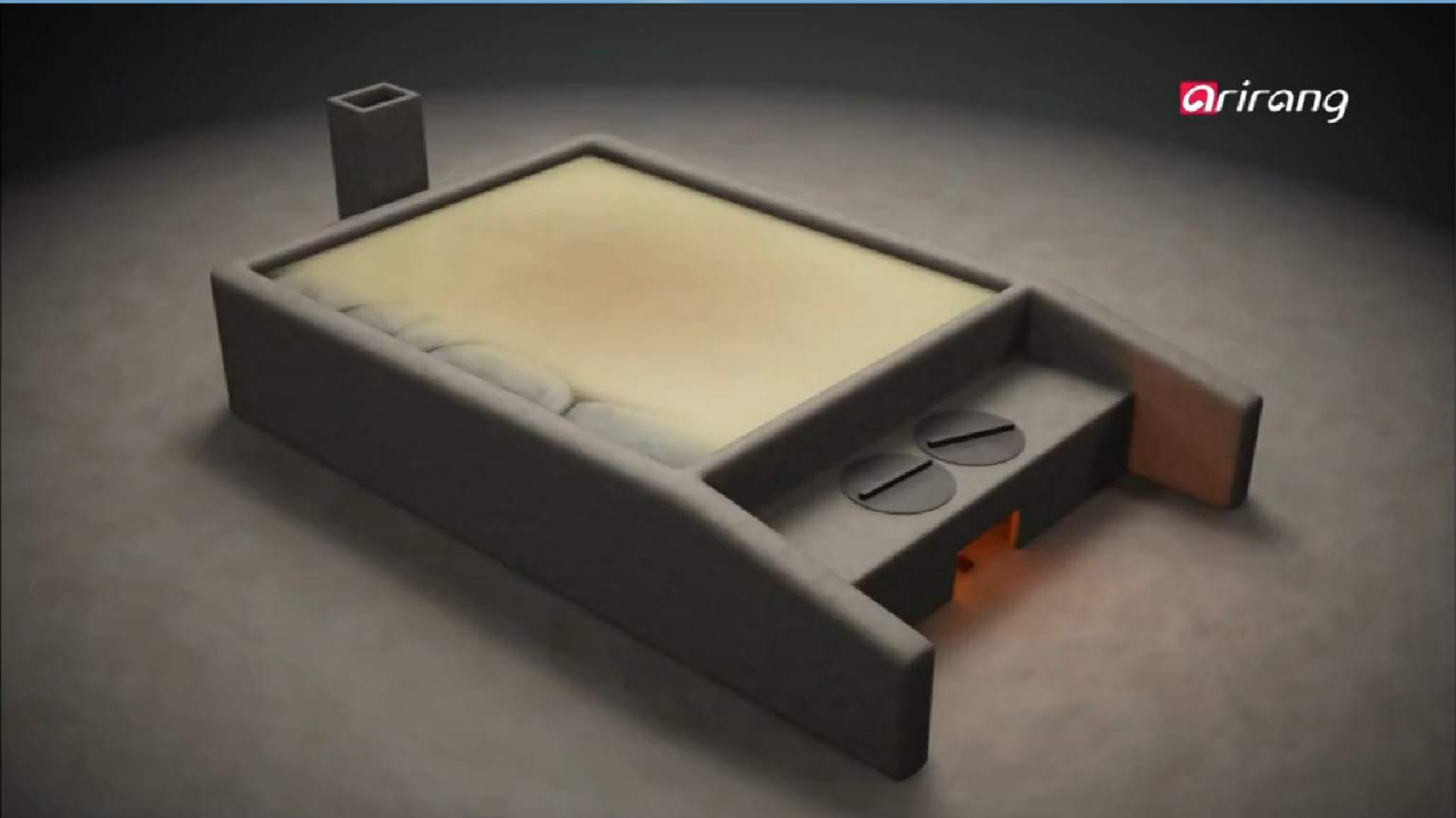
Typical Cost Factors

Pacific Northwest National Laboratory Study

2019 Cost Data

Innovations for Reduced Cost

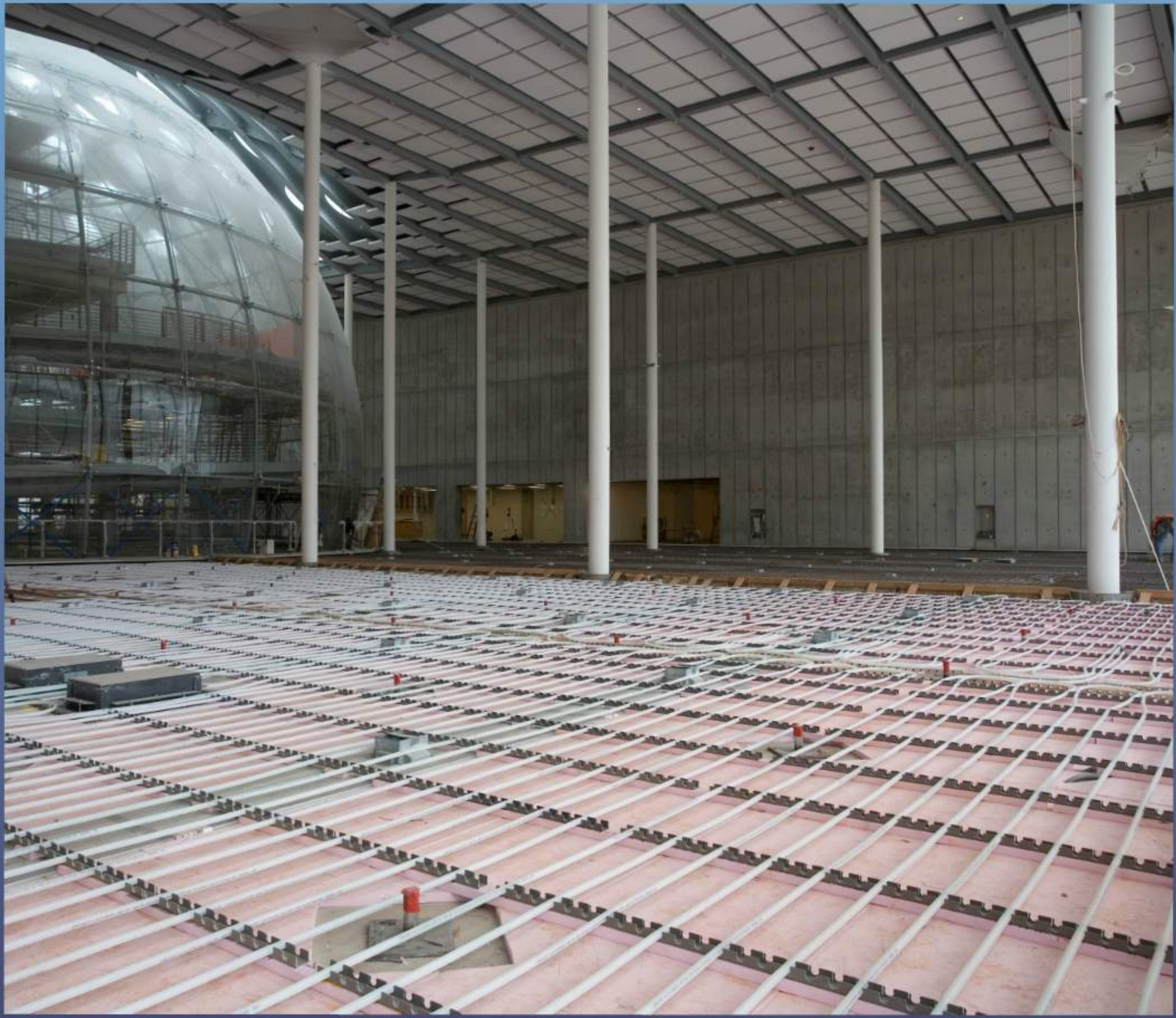
Radiant Fundamentals


arirang

Radiant Heating - Roman Hypocaust

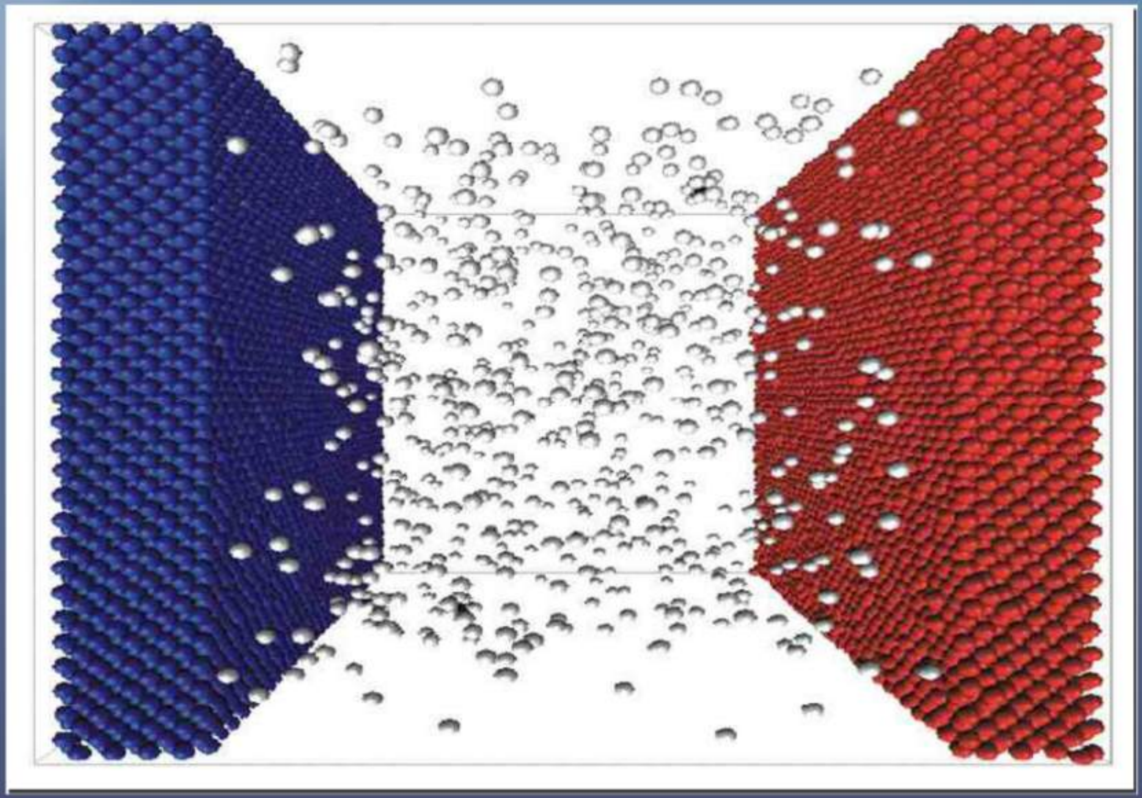
Radiant Cooling - Jelmoli Department Store

Radiant Cooling

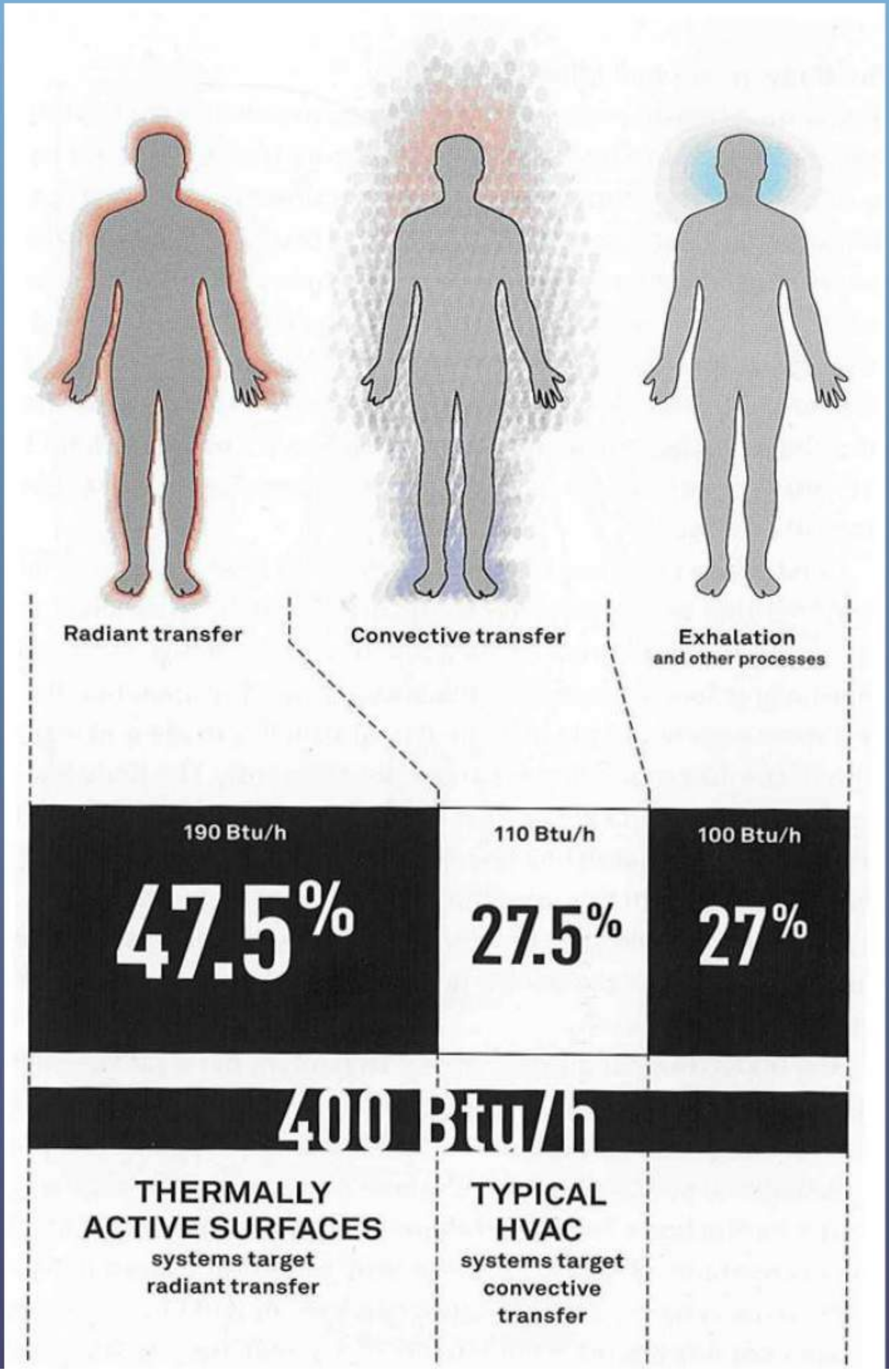


2nd Law of Thermodynamics

Clausius Statement: "Heat generally cannot flow spontaneously from a material at a lower temperature to a material at a higher temperature."



Human Comfort



Human Comfort
ASHRAE Standard 55

- Air Temperature
- Air Movement
- Clothing
- Relative Humidity
- Radiant Temperature
- Metabolism

Air Temperature

Air Movement

Relative Humidity

Radiant Temperature

Radiant Temperature

Average Uncontrolled Surface Temperature

Area weighted average of the surface temperatures of all uncontrolled surface

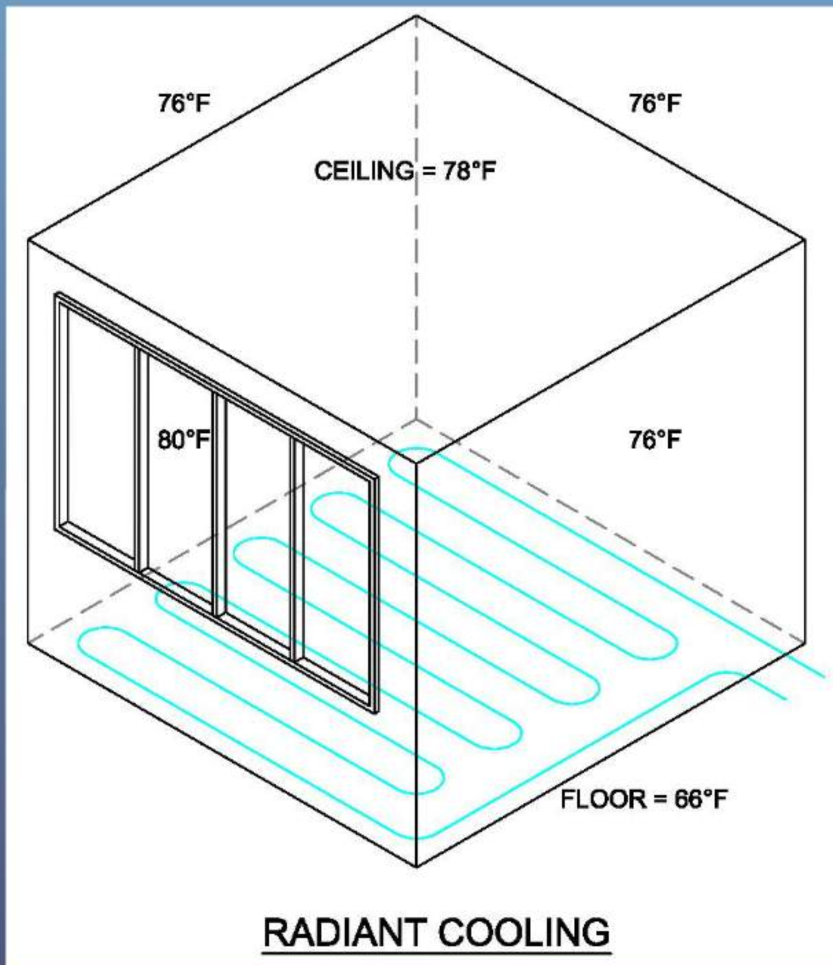
Mean Radiant Temperature

Area weighted average of the AUST and the surface temperature of the controlled surface

Operative Temperature

Average of the Mean Radiant Temperature and the Air Temperature

Radiant Temperature

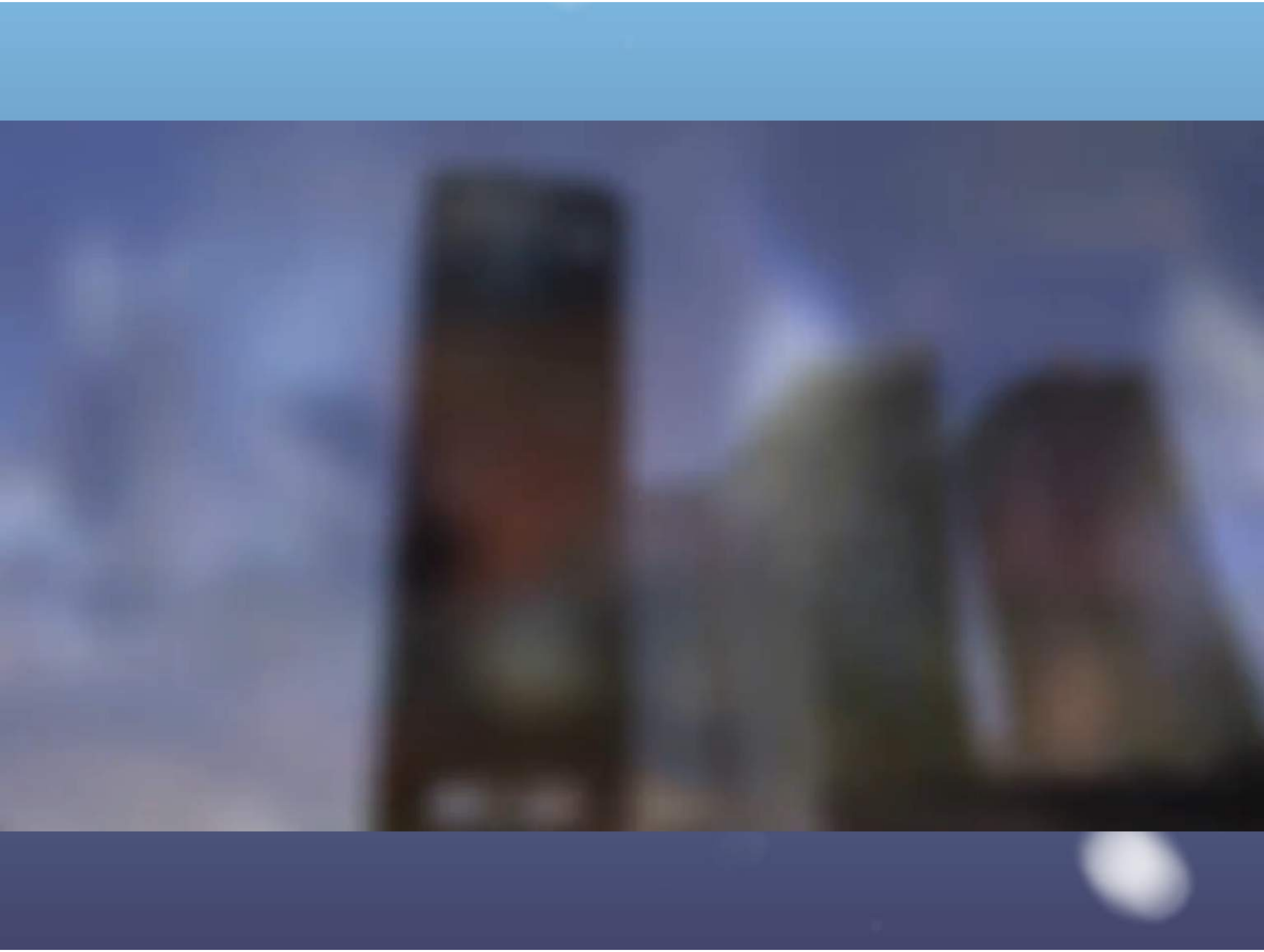


Room Temp. = 78.0°F

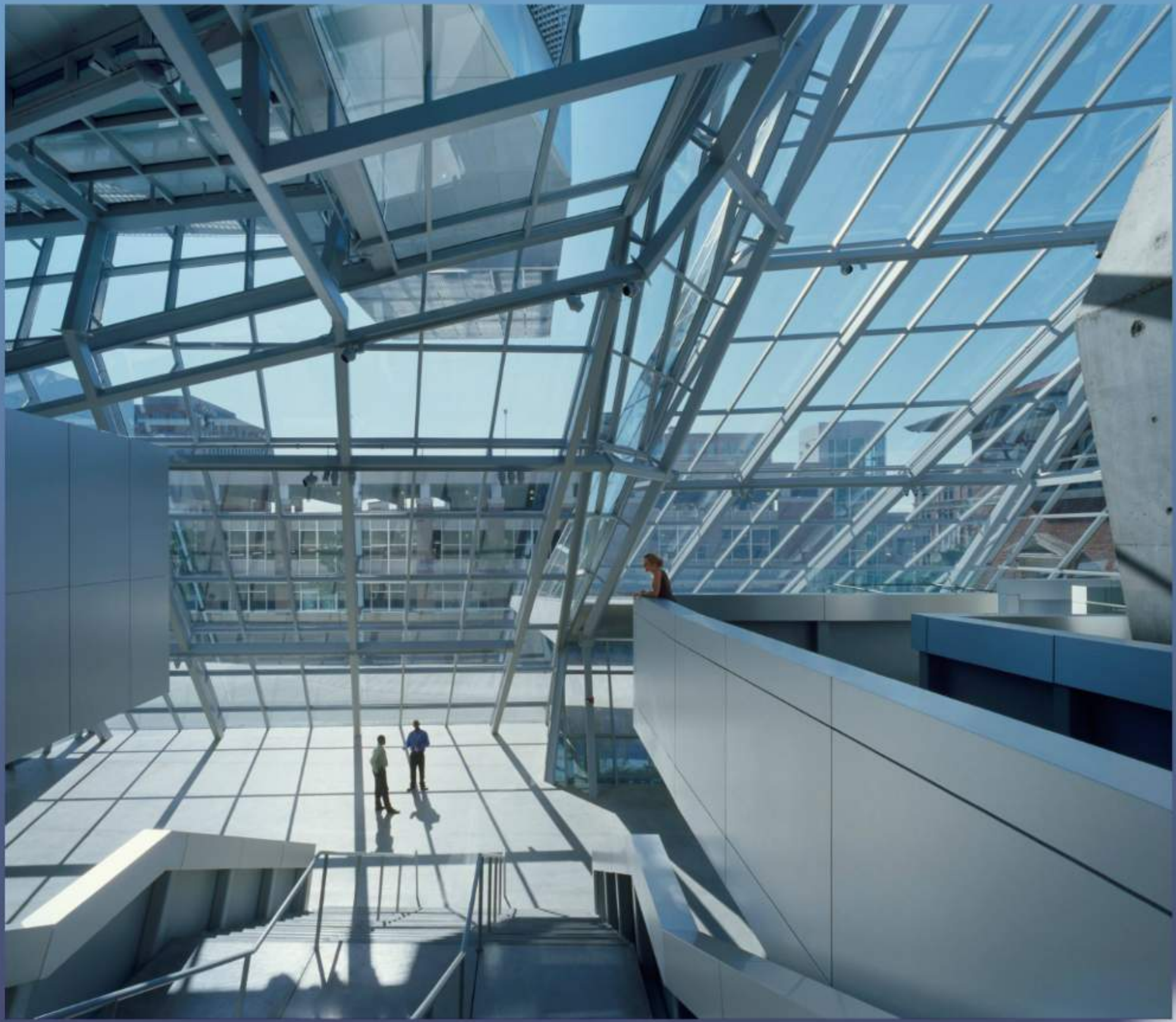
AUST = 78.0°F

MRT = 72.0°F

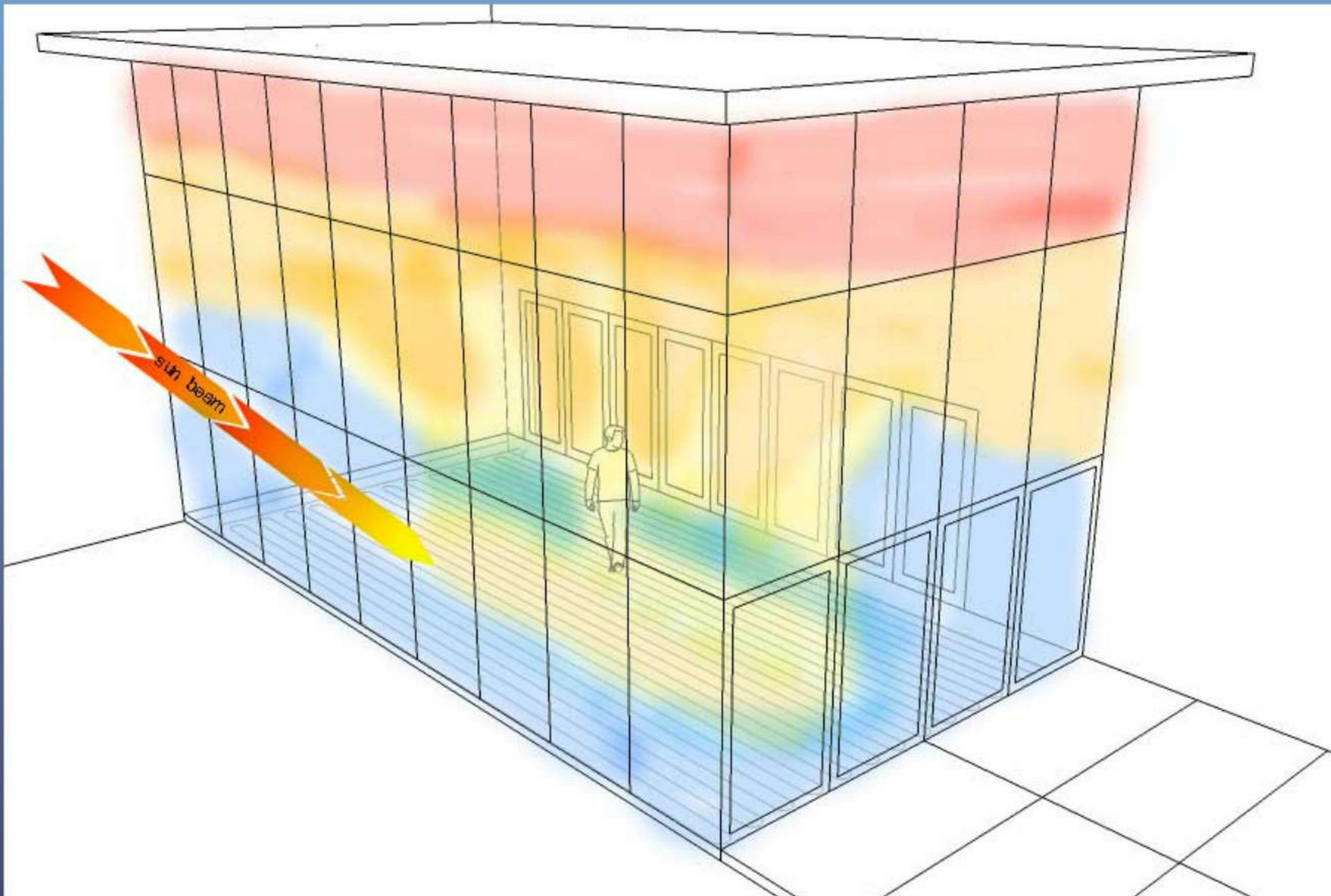
Operative Temp. = 75.0°F



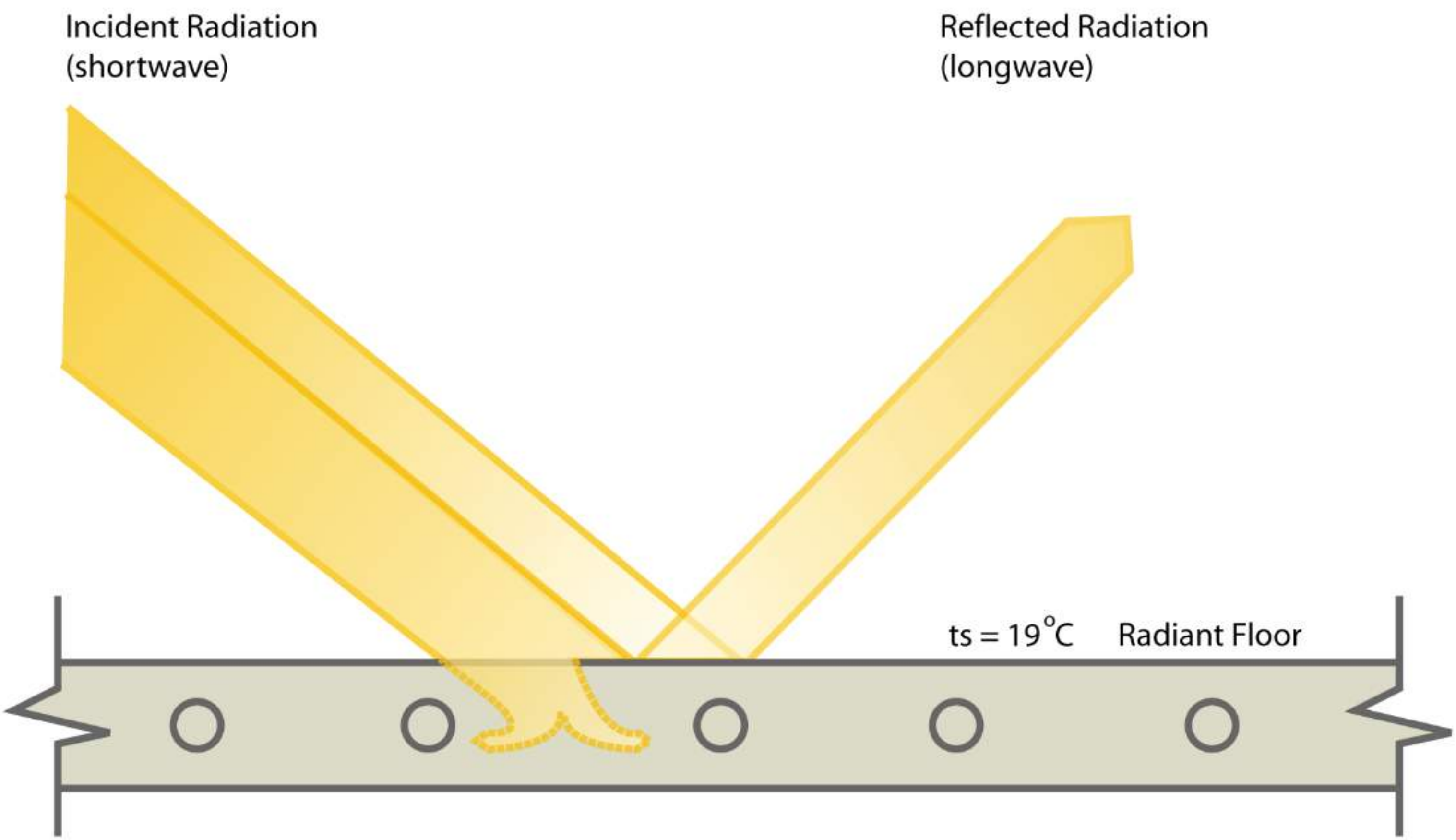
Solar Gain



Solar Gain



Solar Gain



Absorbed Radiant Floor

System Advantages

Ability to Deal with High Direct Solar Gains

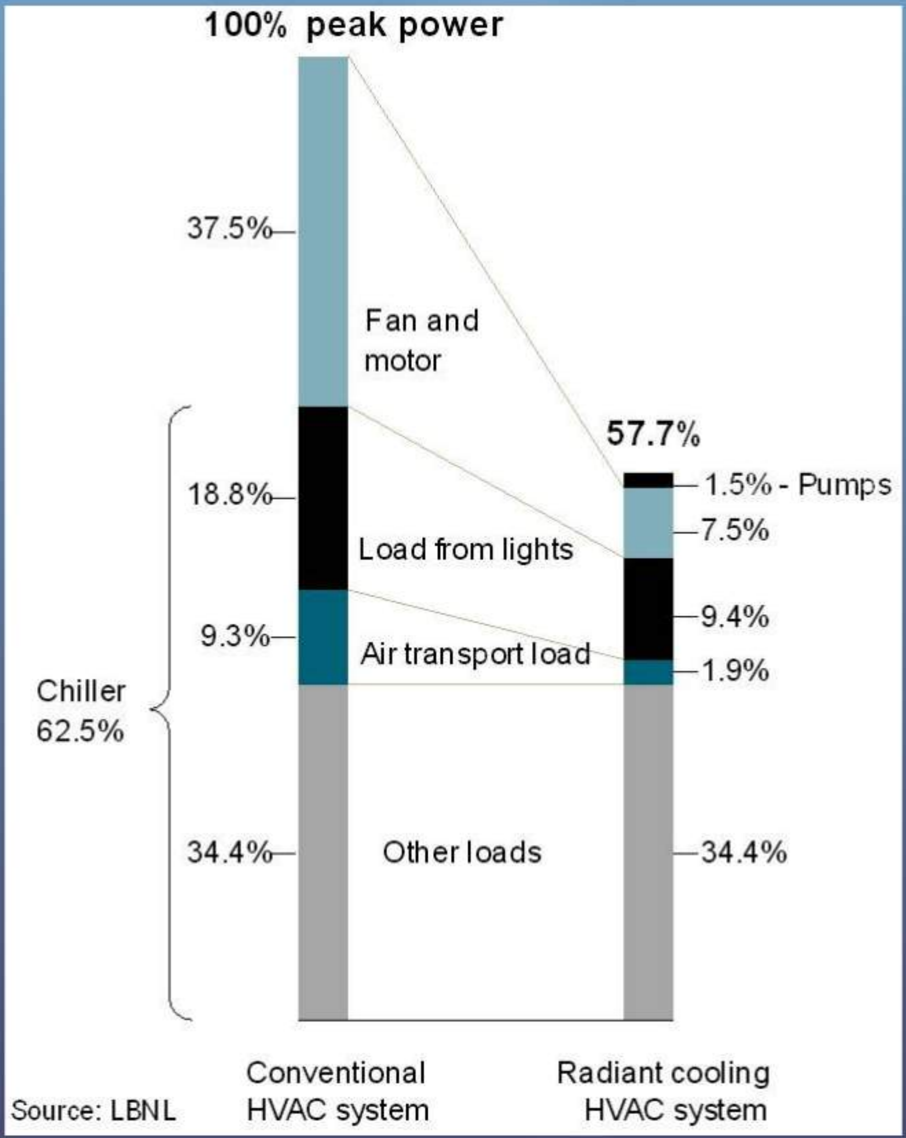
Superior Human Comfort

Greater Architectural Freedom

Reduced Drafts and Noise

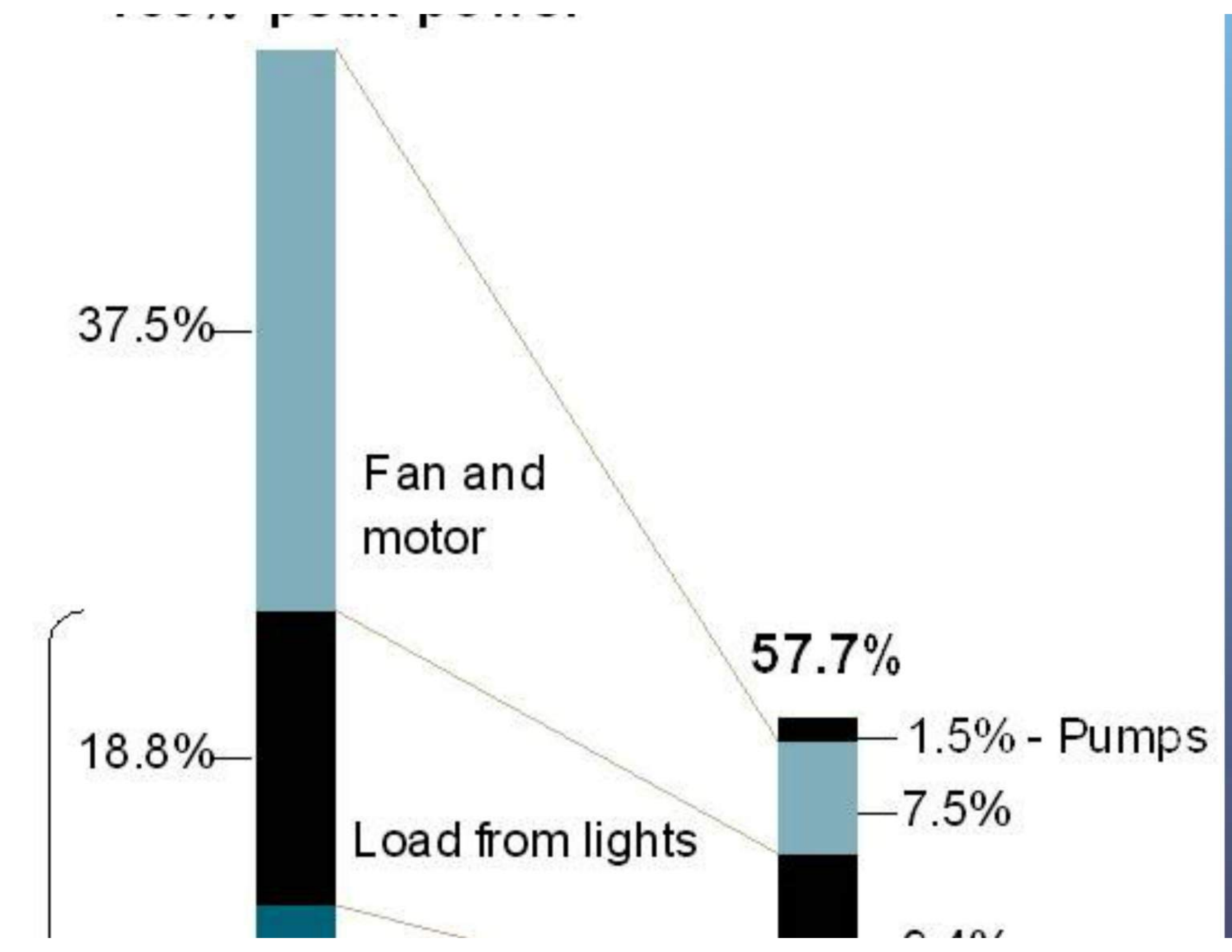
Energy Efficiency

Energy Efficiency



LBNL Findings:

Depending on the climate, a radiant cooling system in conjunction with a dedicated outside air system (DOAS) could save between 17% - 42% over the baseline VAV system


37.5%
Fan and motor
18.8%
Load from lights
57.7%
1.5% - Pumps
7.5%

Energy Efficiency

Pacific Northwest National Laboratory

A radiant cooling system in conjunction with a dedicated outside air system (DOAS) could save 50% over the baseline ASHRAE 90.1-2004 HVAC System

National Renewable Energy Laboratory / U.S. Department of Energy

50% Energy Savings over ASHRAE 90.1 can achieved using a radiant heating and cooling system

American Institute of Architects

Case Studies

Suvarnabhumi Bangkok
Airport Bangkok, Thailand
30.5% Energy Savings

IDeAs Z Squared Design
Facility San Jose, California
LEED Platinum / Net Zero

Western Science Center
Hemet, California LEED
Platinum

Cooper Union New York,
New York LEED Platinum

NREL Research Support
Facility Golden, Colorado
LEED Platinum

David Brower Center
Berkeley, California LEED
Platinum

Manitoba Hydro Place
Winnipeg, Manitoba LEED
Platinum

Clemson University Lee Hall Clemson,
South Carolina
50% Energy Savings
Net Zero Energy

Left This collaborative architecture and landscape architecture studio overlooks an undergraduate landscape architecture studio and review space. It is framed by the faculty offices (upper level) and seminar spaces (lower level).

Eric Piasecki/OTTO

BUILDING AT A GLANCE

Name Clemson University Lee III

Location Clemson, S.C. (28 miles WSW of Greenville, S.C.)

Owner Clemson University

Principal Use University academic building
Includes Studio space, seminar rooms, faculty and administrative offices

Occupancy
Peak Transient Occupancy 292
Daily Average 657
Peak Full-Time Equivalent (FTE) 32
Total Peak Building Users (FTE + Peak Transient) 324

Gross Square Footage 53,441
Conditioned Space 50,249 (does not include mechanical room)
Mechanical Room 3,192

Distinctions/Awards AIA National Honor Award for Architecture, 2013; LEED Gold-NC v3, 2012

Total Cost $16 million (excludes site work)
Cost Per Square Foot $300

Substantial Completion/Occupancy Dec. 16, 2011

COLLABORATIVE LEARNING

BY MICHAEL G. TALBOT, P.E., MEMBER ASHRAE

Architecture students at Clemson University enjoy a leg up on their peers: the building where they study. Lee III's open plan situates students from four different disciplines side-by-side, providing them with organic opportunities to work with and learn from each other in this net zero energy-ready building—something that will reap rich dividends after they graduate.

"Students, when they emerge from these disciplines, are going to be working together the rest of their professional lives," said John Jacques, professor emeritus of architecture and a member of the design team.

"Having a building that openly invites and promotes the whole idea of collaborative learning and collaborative work between disciplines will most likely create a student body that graduates to collaborate in later life."

The 55,000 ft² space, located in the rolling foothills of the Blue Ridge Mountains in upstate South Carolina, roughly doubles the space of the two other sections of the building, known as Lee I and Lee II. The new space is home to 12 professional degree programs in the schools of architecture and of planning, development, preservation and landscape architecture, as well as the departments of art and construction science and management.

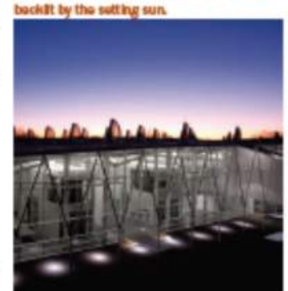
The building also serves as an example of how future buildings should be built sustainably, incorporating new technologies and "outside the box" thinking.

Design

Design studios, faculty offices and classrooms are mixed together in Lee III, which cultivates a sense of community in the two-story building and promotes teaching through discovery and discovery-based learning.

Students learn from their professors, as well as through their studio activities and by chatting with students in other departments. Carefully detailed glazing between spaces supports this type

Below Early evening in the east plaza looking through the north porch and façade into the open studio bays and enclosed office and seminar spaces. The skylights and "shrouds" are illuminated from within and backlit by the setting sun.



Annemarie Jacques

Figure 1: Infosys SDB-1 Hyderabad. Half of the building has radiant cooling and half has VAV cooling.

VAV vs. Radiant

Side-by-Side Comparison

BY [illegible], P.E., FELLOW ASHRAE

Infosys, one of India's top three software companies, implemented a program in 2011 to find the best way to cool its buildings, while creating lower energy buildings that better suited the needs of its employees. The resulting building, Software Development Block 1 (SDB-1) in Hyderabad, not only became the first radiantly cooled building in India, but also resulted in the world's largest HVAC side-by-side comparison.

Performance

Sensible Cooling

A radiant cooling system can effectively manage a portion of building's sensible load

12 – 14 BTUH/SF – Radiant Floor
25 – 32 BTUH/SF – Radiant Ceiling

Direct Solar Loads

In areas with high direct solar loads, the systems capacity can significantly increase to

25 – 32 BTUH/SF

Typical Parameters

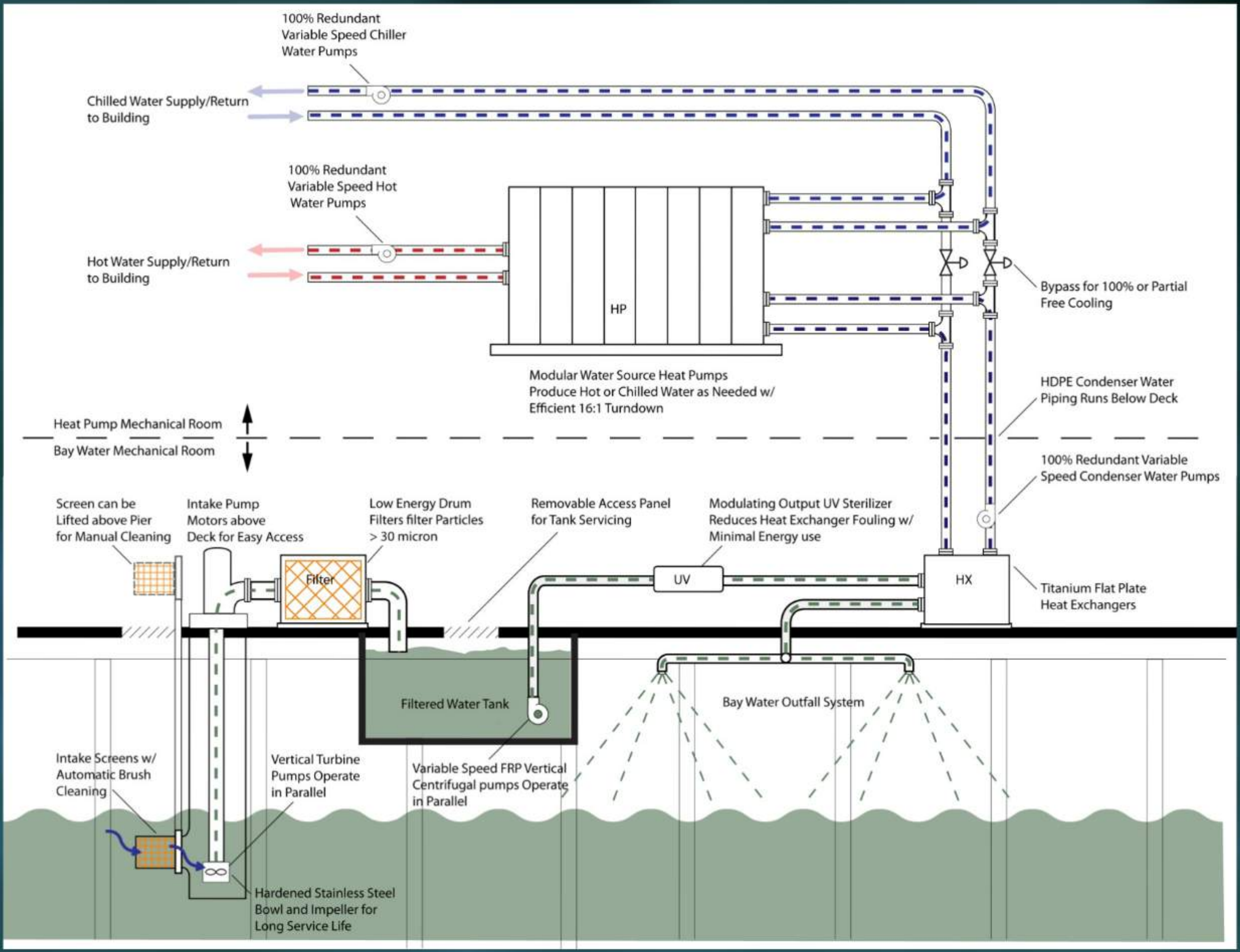
Tubing: Cross-linked polyethylene (PEX) barrier tubing
5/8" diameter
6" to 9" on center spacing
Typical tubing length per loop – 350'-500'

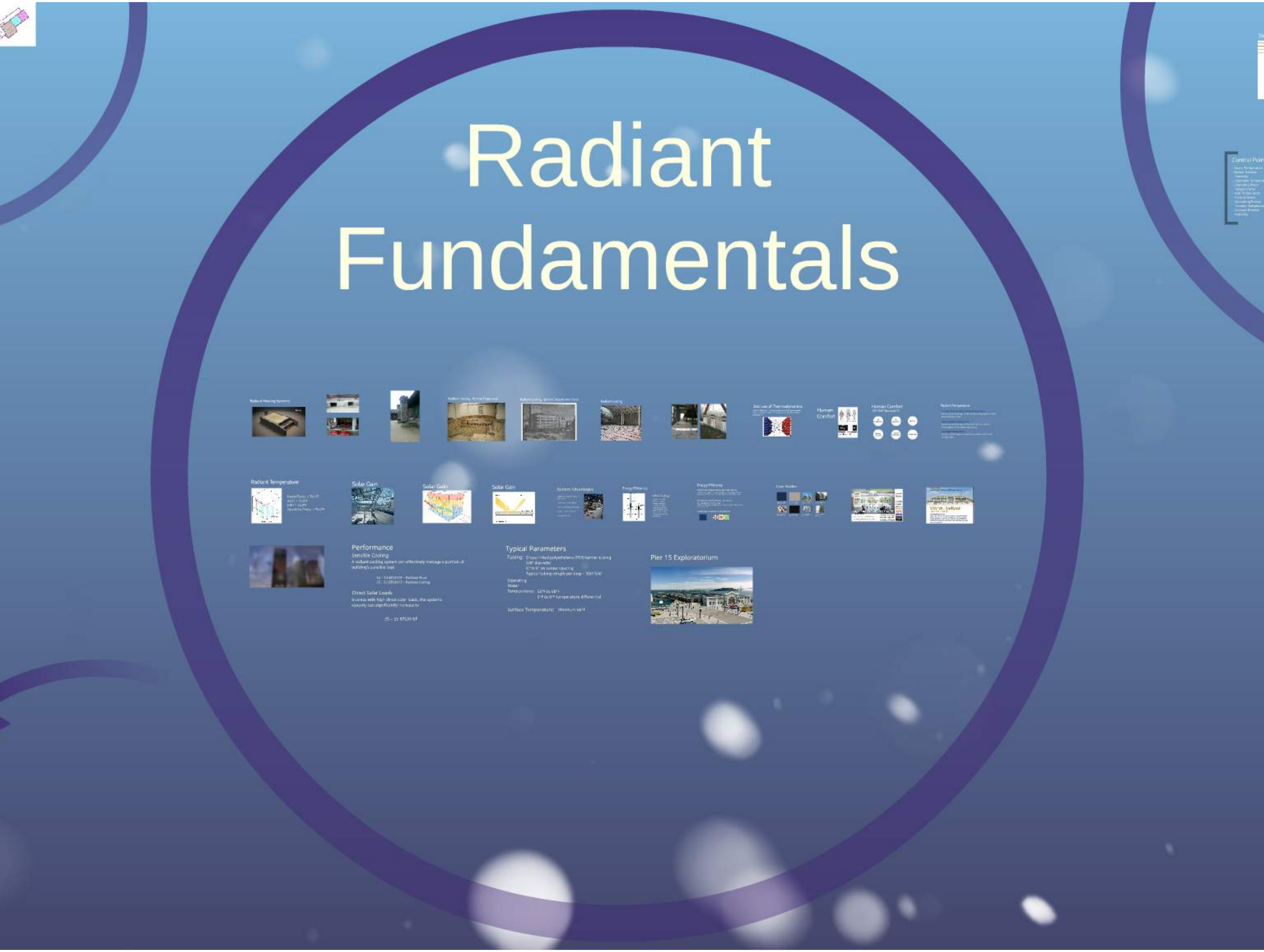
Operating Water Temperatures: 55°F to 58°F
5°F to 8°F temperature differential

Surface Temperature: Minimum 66°F

Pier 15 Exploratorium

Pier 15 Exploratorium



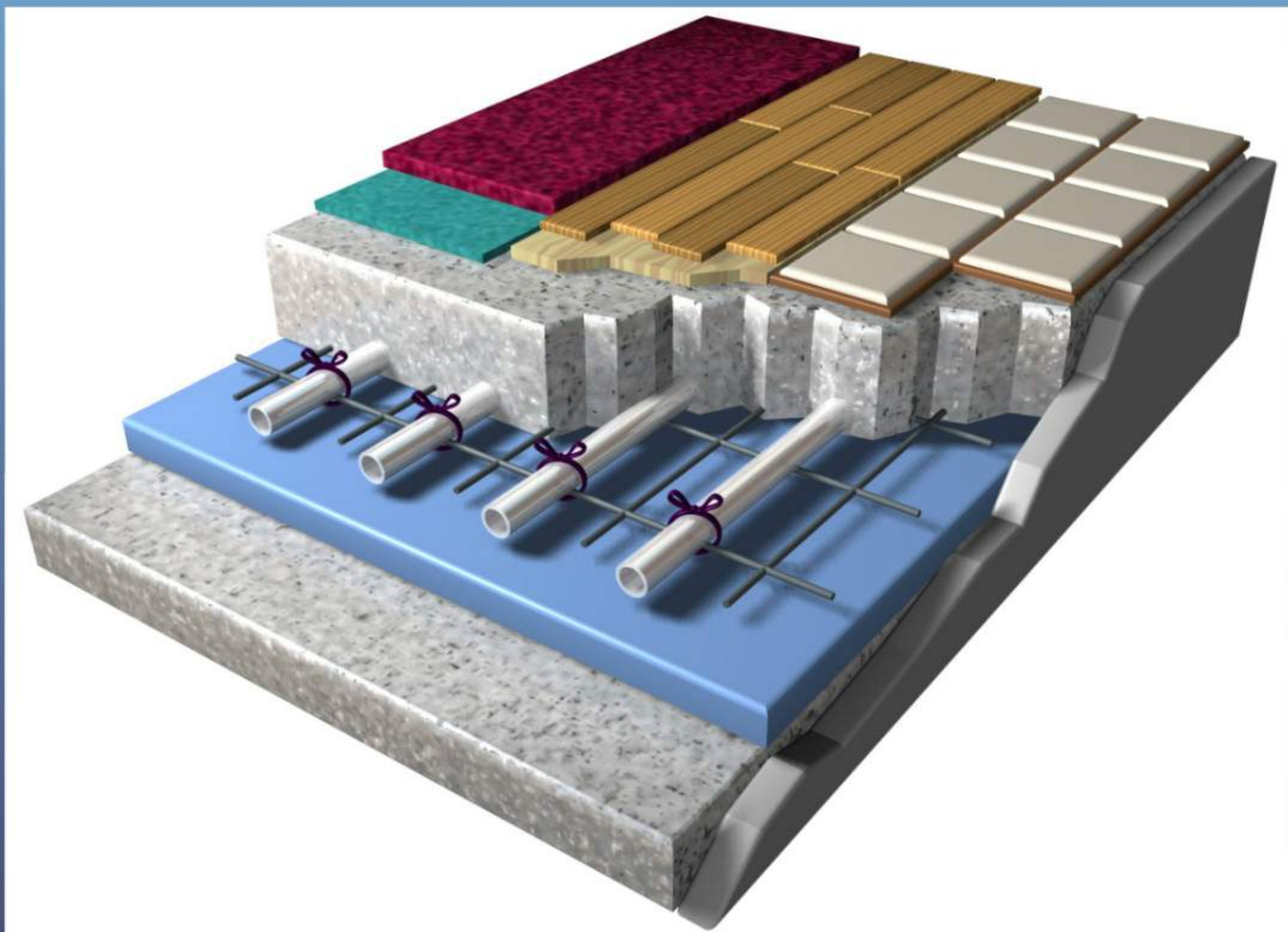

Radiant Fundamentals
Radiant Temperature
Solar Gain
Solar Gain
Solar Gain
Performance
Sensible Cooling
Direct Solar Loads
Typical Parameters
Pier 15 Exploratorium

Slab & Construction Details

Slab on Grade

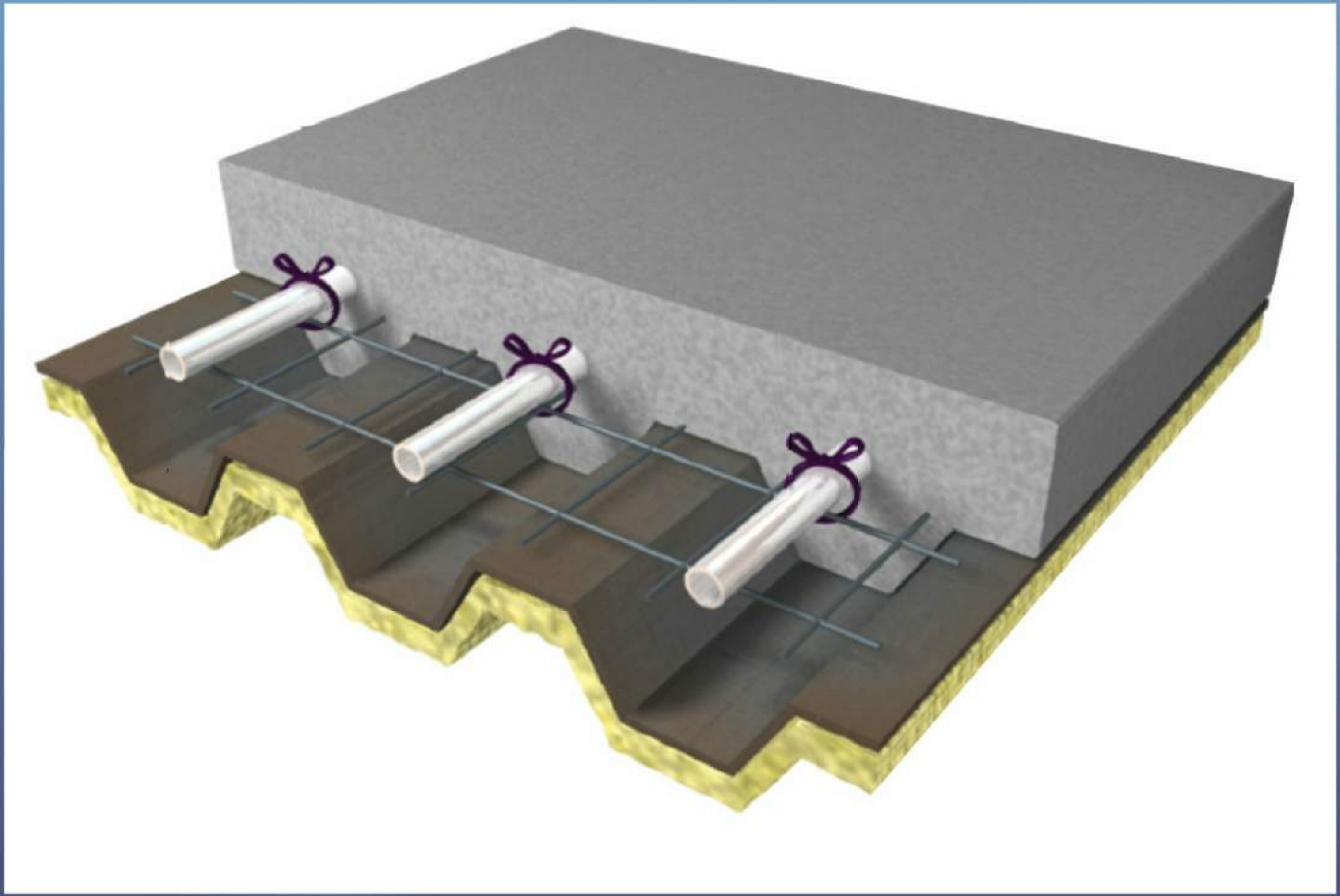
Suspended Slab

Slab on Grade



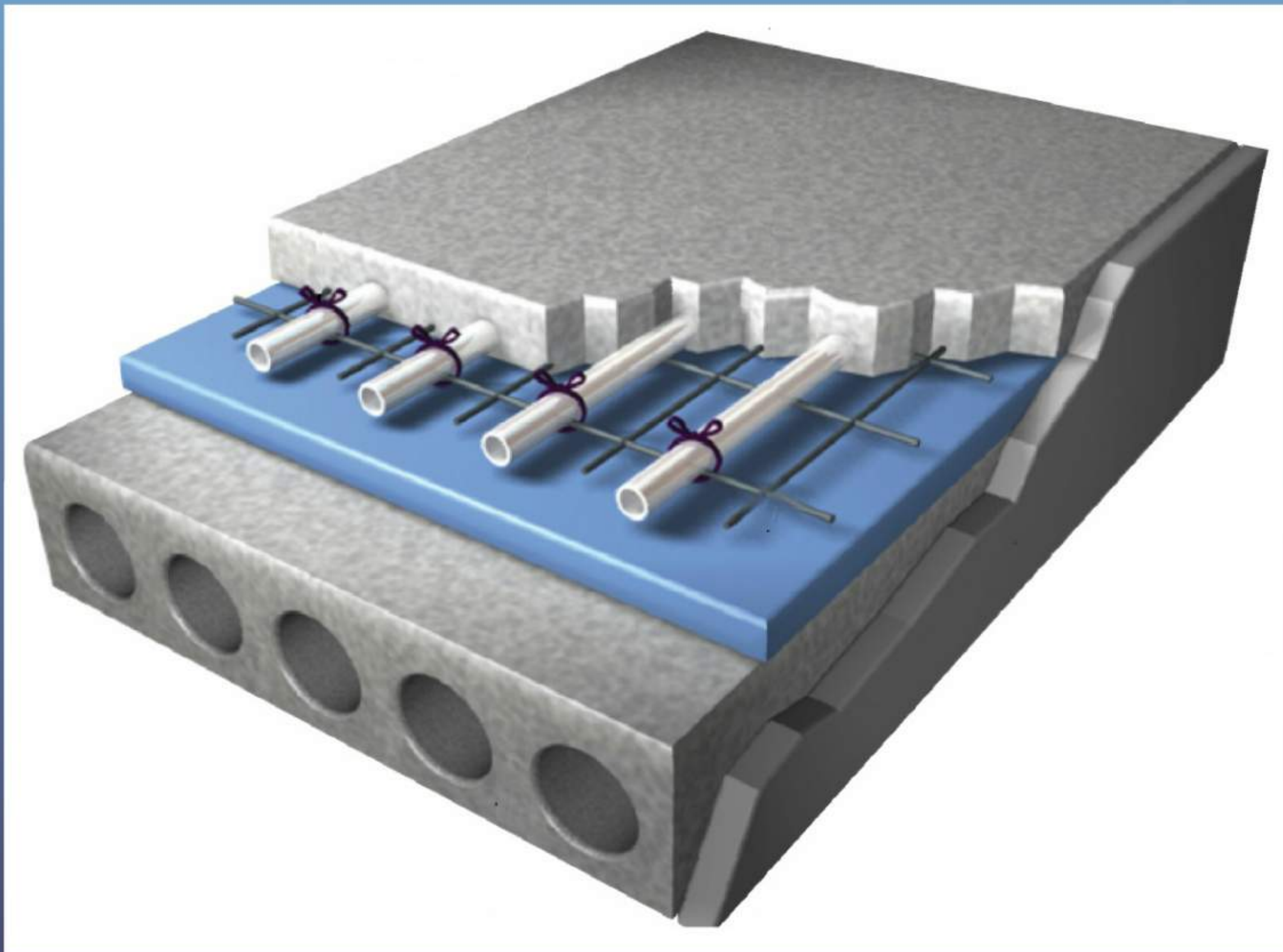
- Flooring
- Structural Slab
- PEX Tubing
- Wire Mesh / Rebar
- Insulation
- Compacted Grade

Suspended Slab



Structural Slab
PEX Tubing
Wire Mesh / Rebar
Metal Deck
Insulation

Topping Slab



Topping Slab

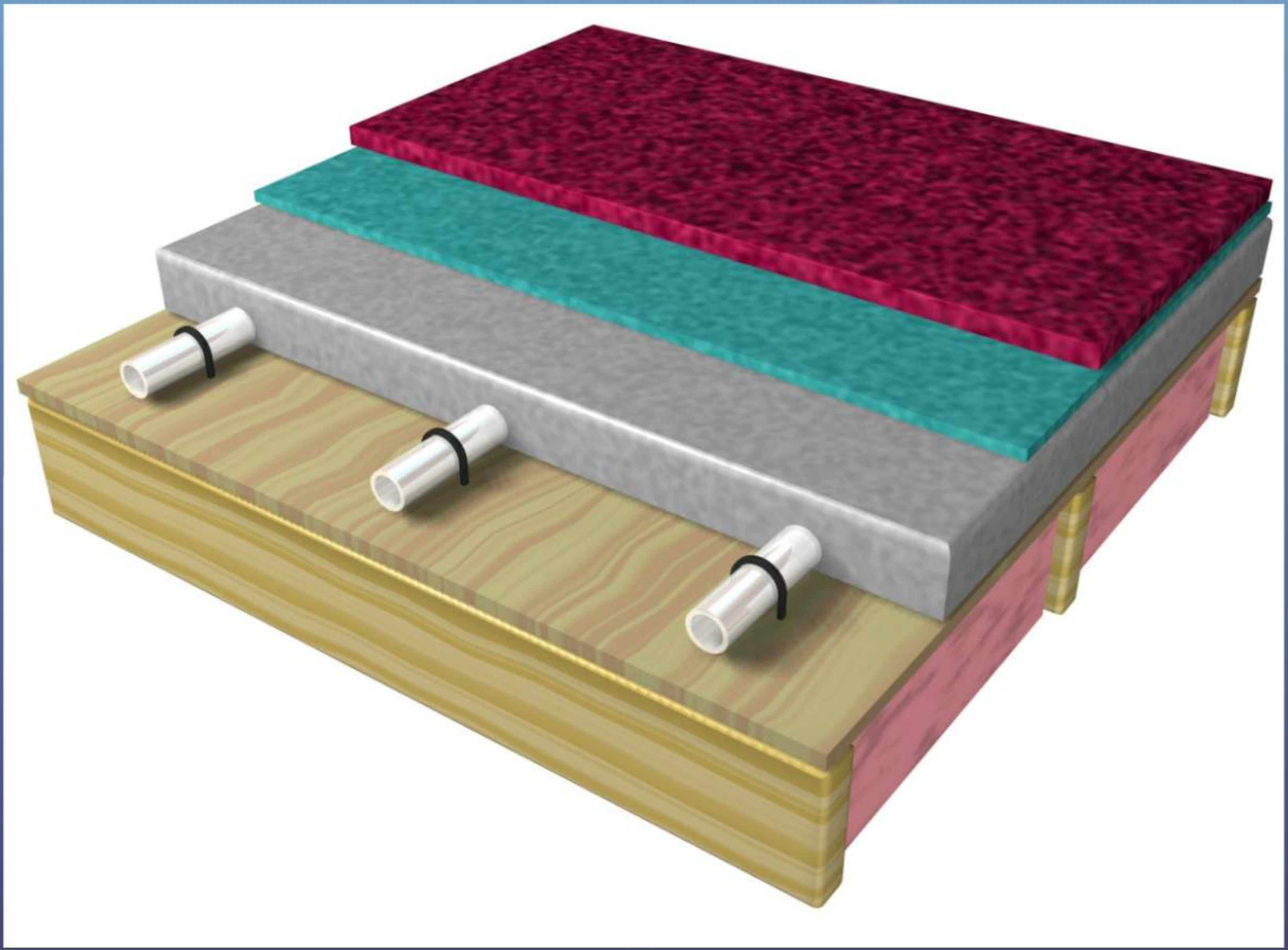
PEX Tubing

Wire Mesh

Insulation

Structural Slab

Wood Deck



Flooring

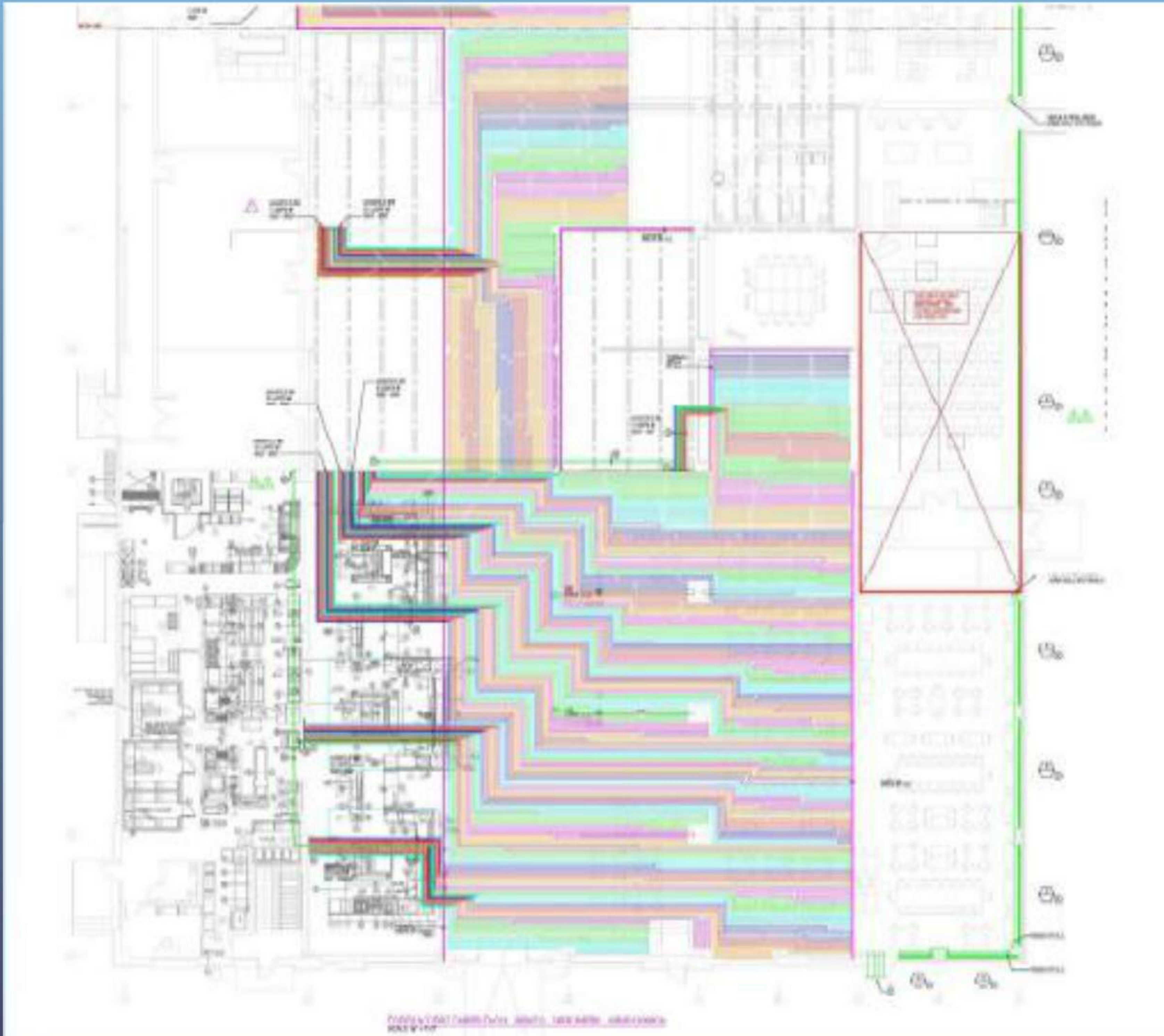
Topping Slab

PEX Tubing

Wood Deck

Insulation


AREA
#1



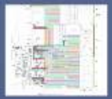
Slab & Construction Details

Slab on Grade

Suspended Slab

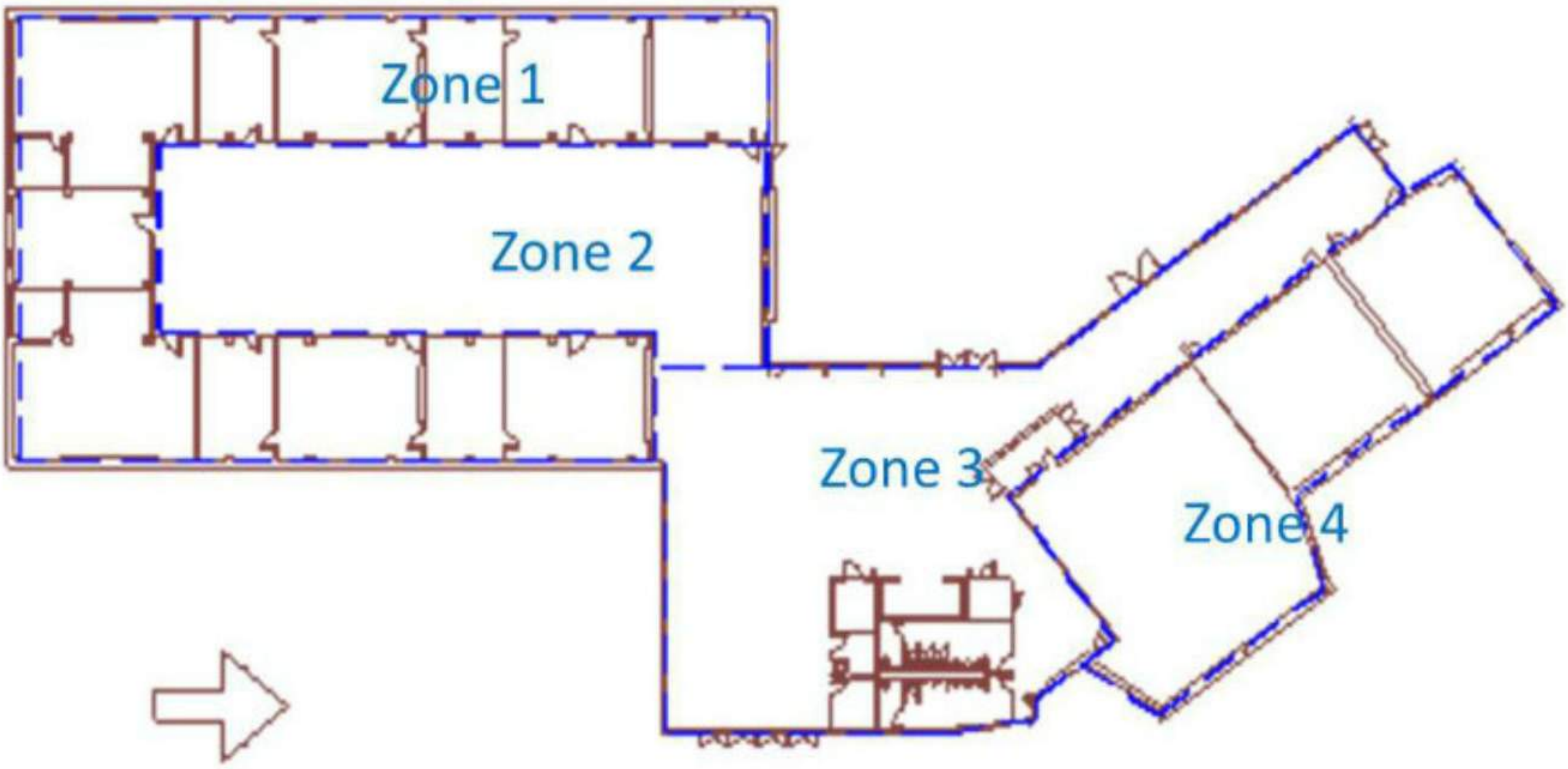
Topping Slab

Wood Deck

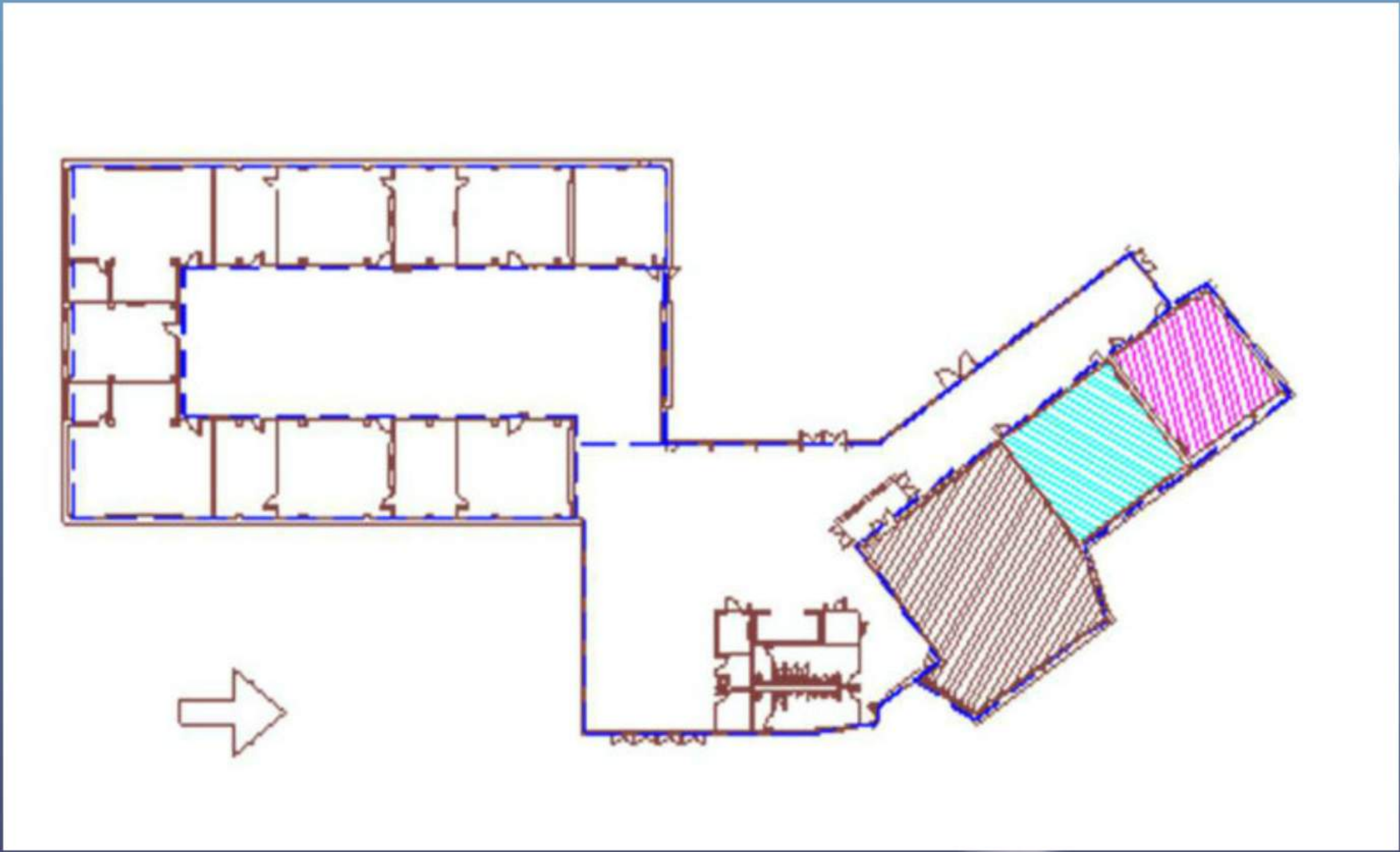


Zoning

Zoning



Local Zoning



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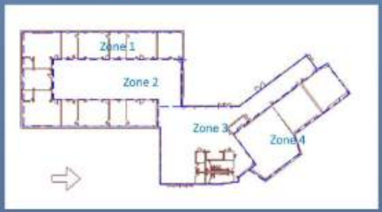

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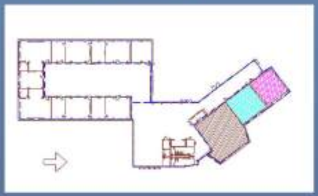
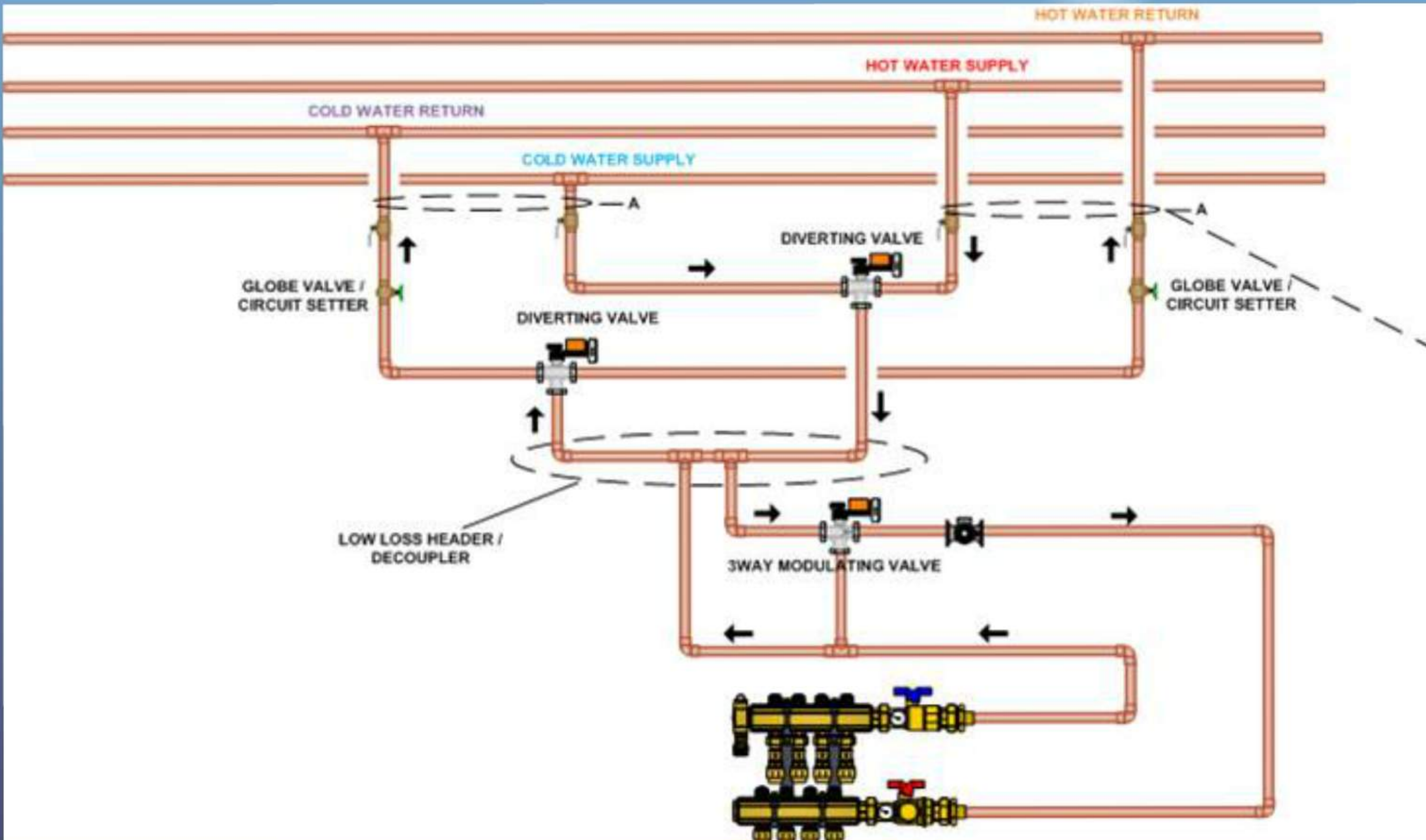
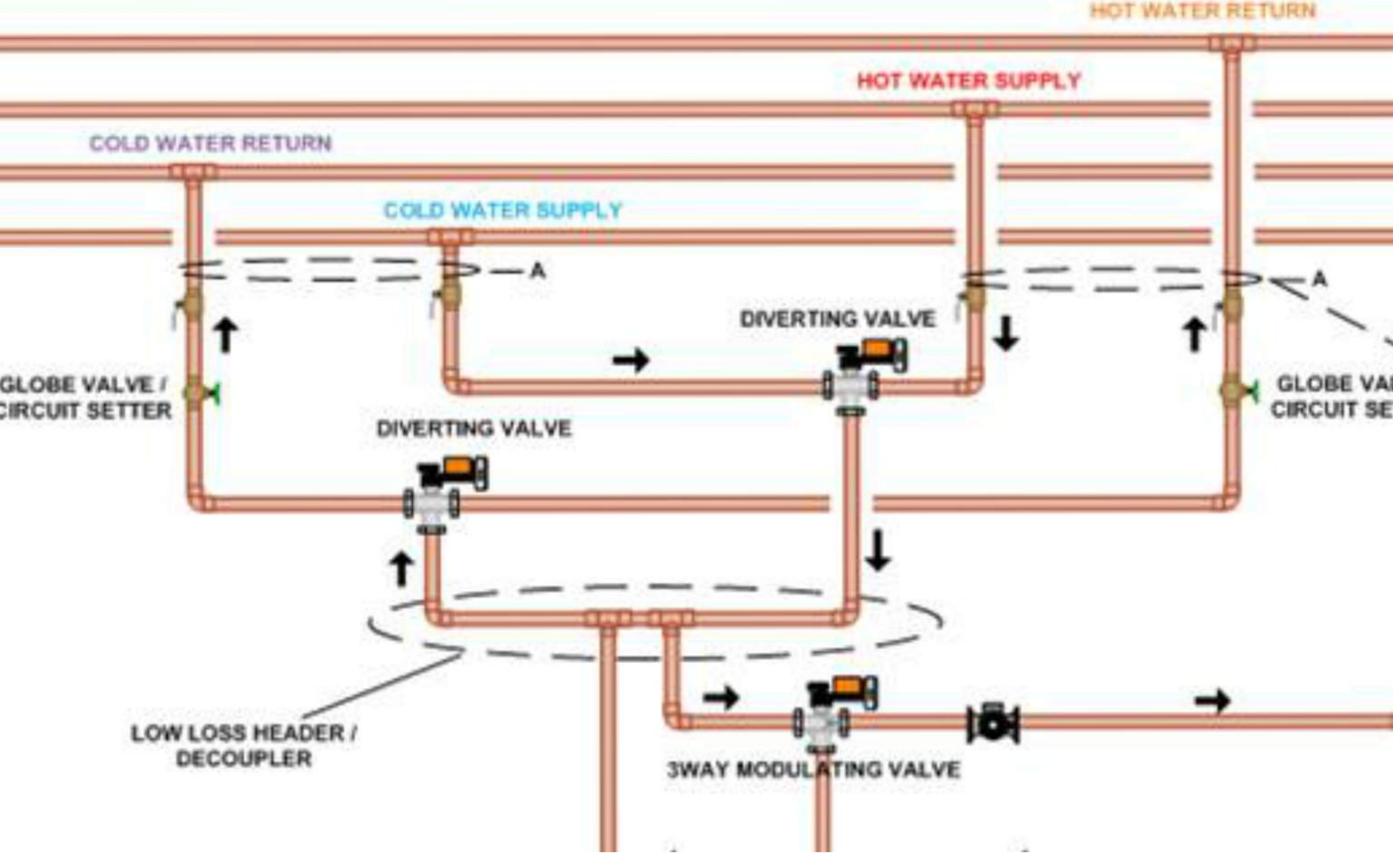


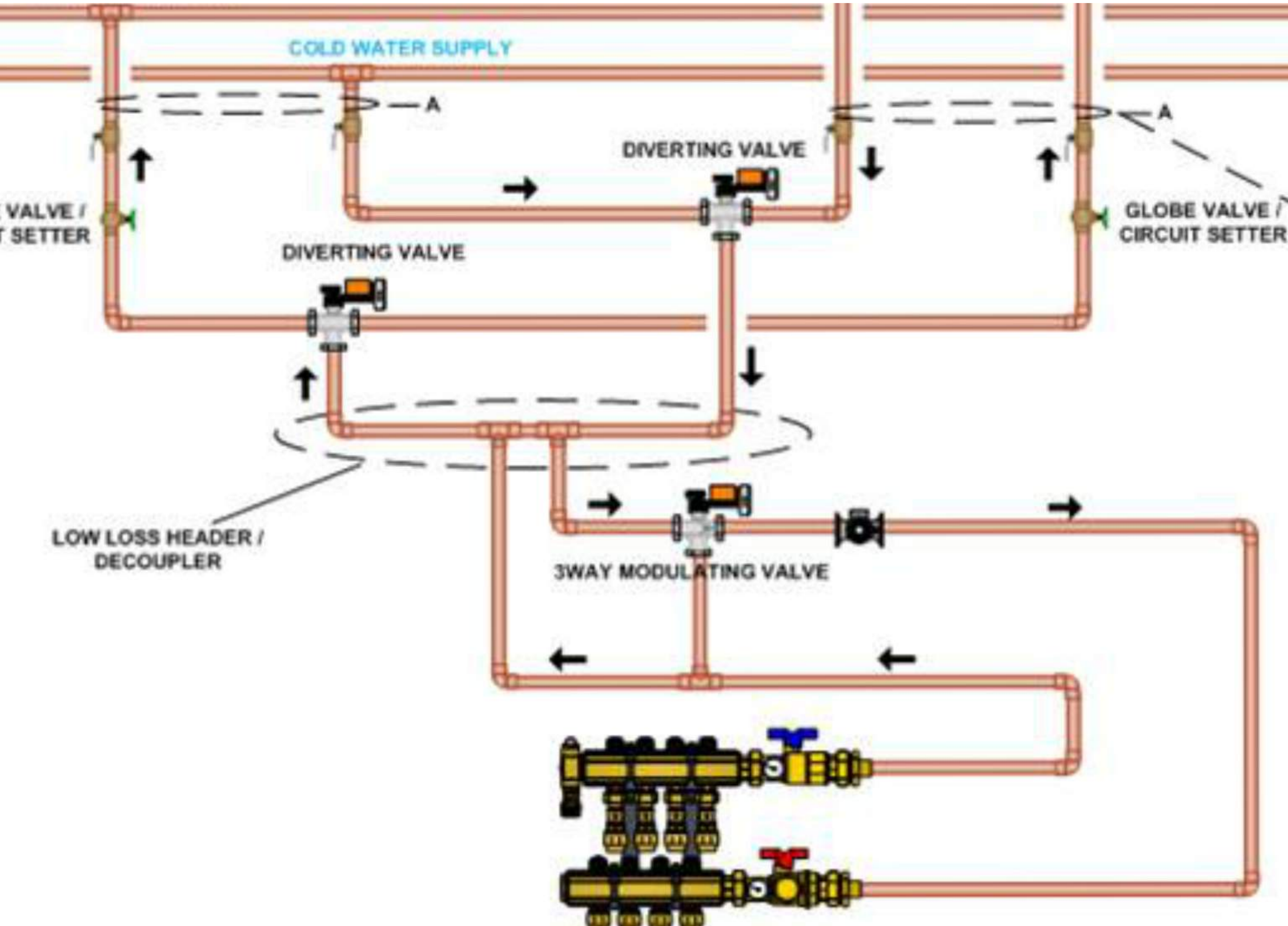
Piping & Controls

Switchover Control



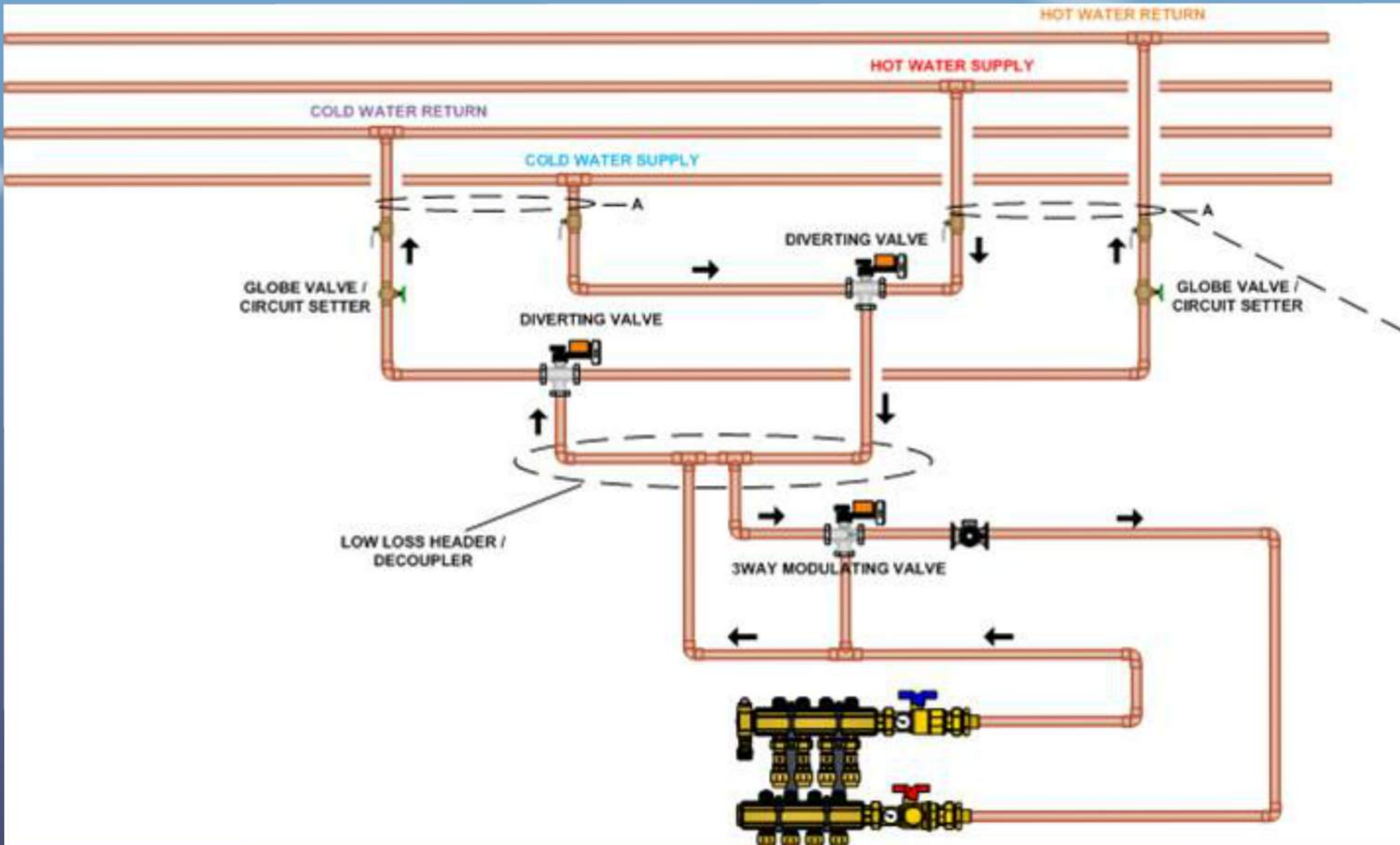
hover Control



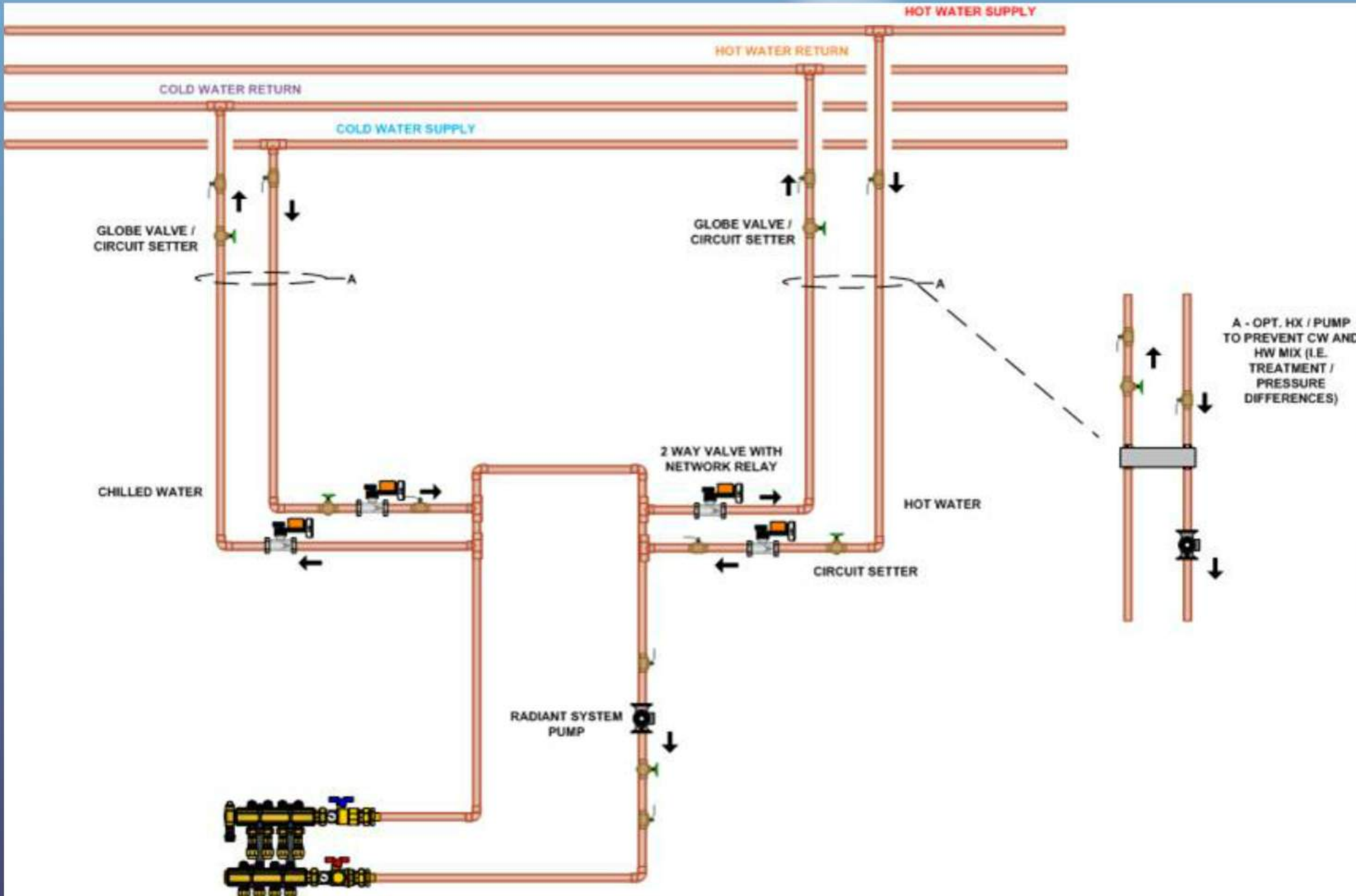


COLD WATER SUPPLY
A
A
DIVERTING VALVE
VALVE /
SETTER
GLOBE VALVE /
CIRCUIT SETTER
DIVERTING VALVE
LOW LOSS HEADER /
DECOUPLER
3WAY MODULATING VALVE

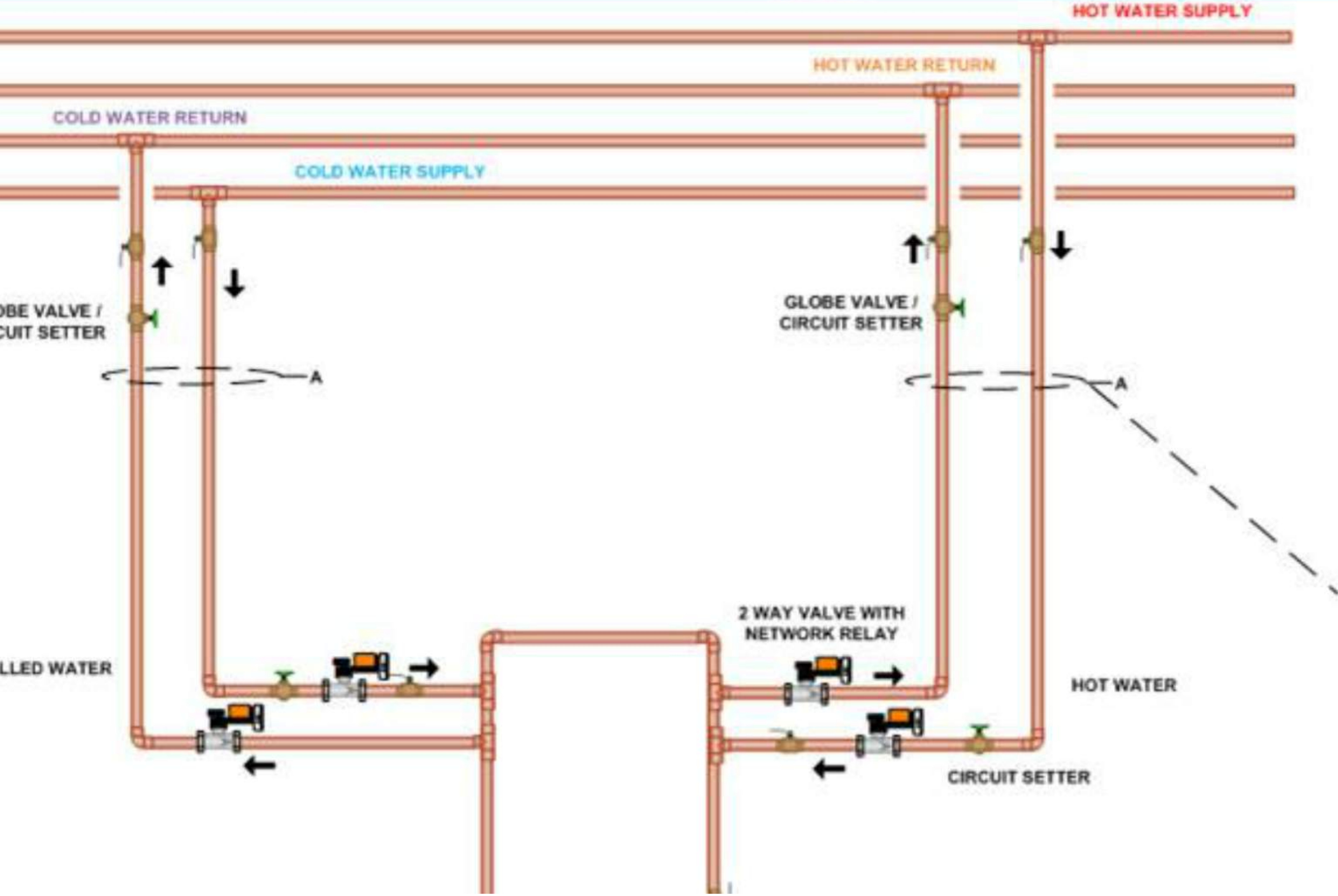
Switchover Control

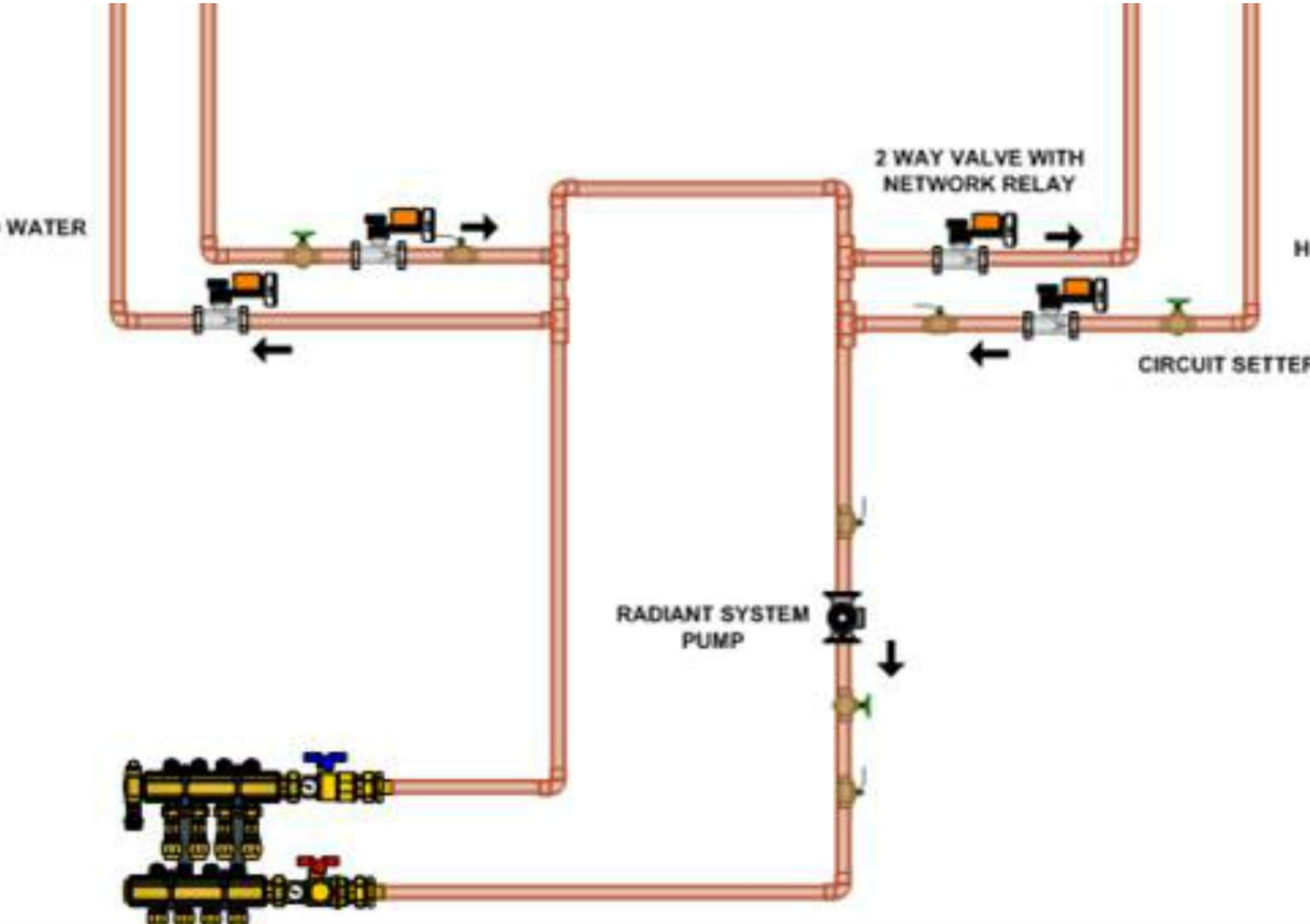


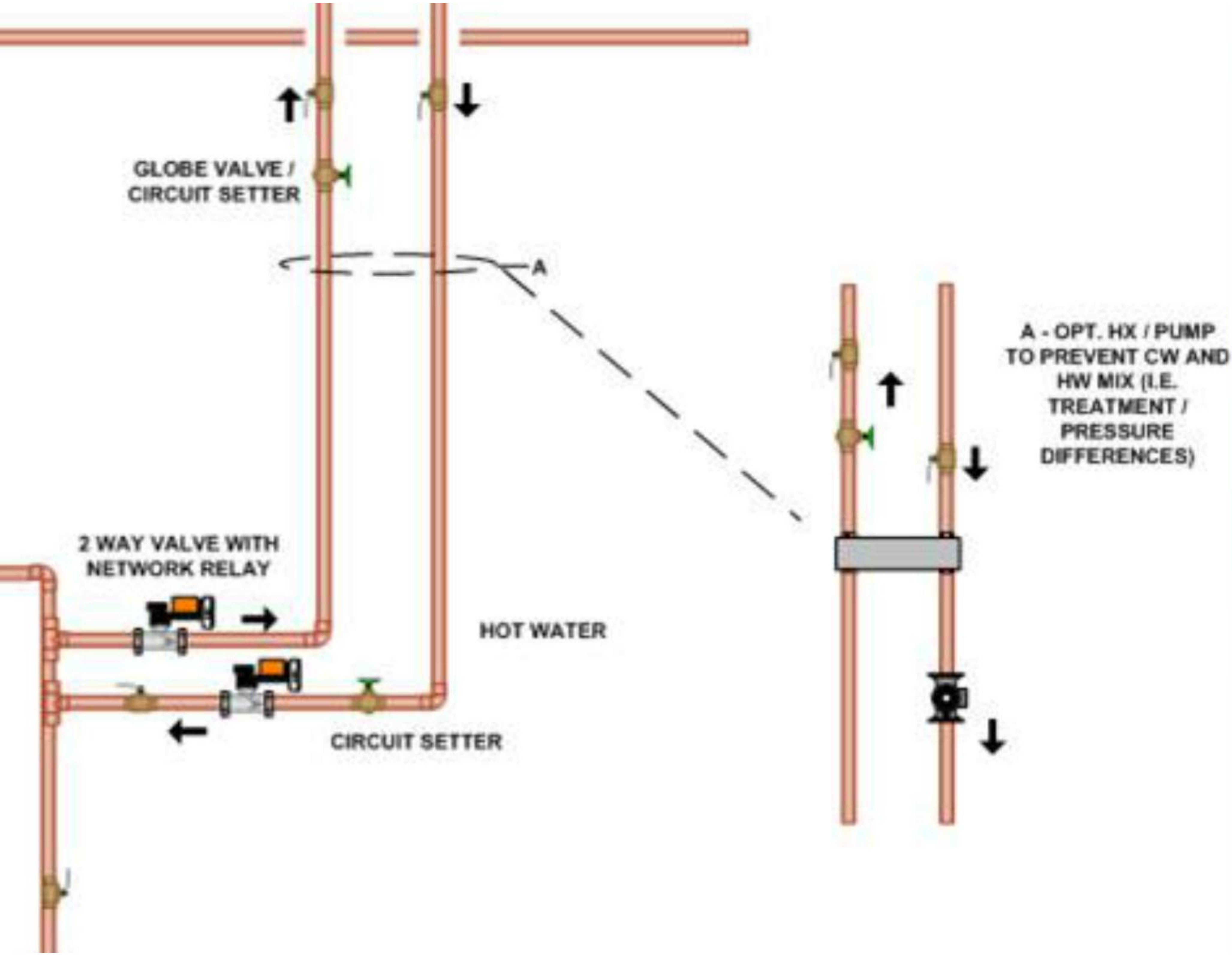
Local Injection Control



cal Injection Control

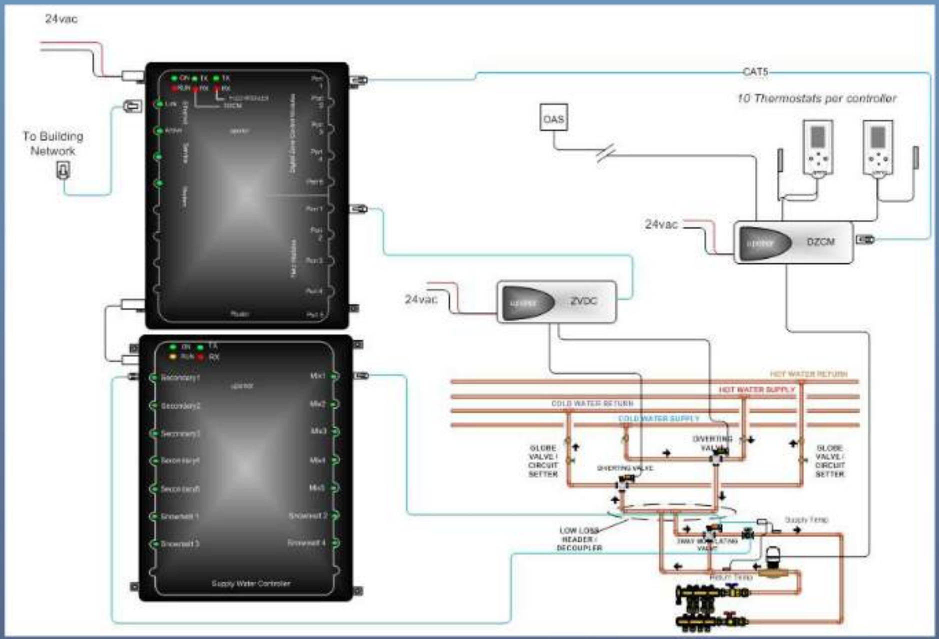



2 WAY VALVE WITH
NETWORK RELAY
WATER
H
CIRCUIT SETTER
RADIANT SYSTEM
PUMP


GLOBE VALVE /
CIRCUIT SETTER
A
A - OPT. HX / PUMP
TO PREVENT CW AND
HW MIX (I.E.
TREATMENT /
PRESSURE
DIFFERENCES)
2 WAY VALVE WITH
NETWORK RELAY
HOT WATER
CIRCUIT SETTER

Control Points

- Space Temperature
- Indoor Relative Humidity
- Operative Temperature
- Operating Water Temperatures
- Slab Temperature
- Control Valves
- Circulating Pumps
  Outdoor Temperature
- Outdoor Relative Humidity



Control Strategies

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- Continuously monitor indoor relative humidity for condensation control
- Maintain constant slab temperature

Condensation Control

"Although radiant cooling has been in successful use in Switzerland for about 15 years, very little, if any progress has been made in its use in America. The reason seems to be that many engineers believe that a radiant cooling system will necessarily carry with it objectionable and injurious condensation of water vapor on the cooling panels…"

F.E. Giesecke, PhD Founder of the Texas A&M University Architecture Program
Hot Water Heating and Radiant Heating and Radiant Cooling, 1946

Condensation Control

Condensation

Surface condensation will occur if the surface temperature drops below the dew point

Solution

Continuously monitor indoor relative humidity and maintain supply water temperature above dew point at all times

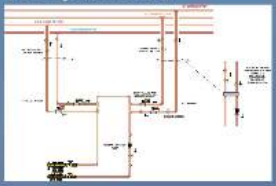
Controllability

- High thermal mass provides “inertia” against temperature fluctuations
- Heat transfer from the thermal mass to the space is instantaneous whenever there is a temperature difference
- Thermal mass evens out fluctuations in internal temperature
- Secondary system used to handle high load densities

Piping & Controls

Switchover Control

Local Injection Control



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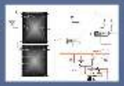
- Outdoor Relative Humidity



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Cost

Typical Cost Factors

No Cost

- Structural Slab already part of the construction budget
- Chilled water source typically already part of the budget

Additional Cost

- Cost of tubing, manifolds, fittings, circulators
- Insulation
- Increased Labor

Reduced Cost

- Smaller air handling units, ductwork, diffusers, etc.
- Reduced ceiling space requirements may allow for reduced floor to floor heights
- Potential to reduce electrical service size

Reduced Maintenance Cost

Less airside equipment to maintain

Typical Cost Factors

Pacific Northwest National Laboratory Study

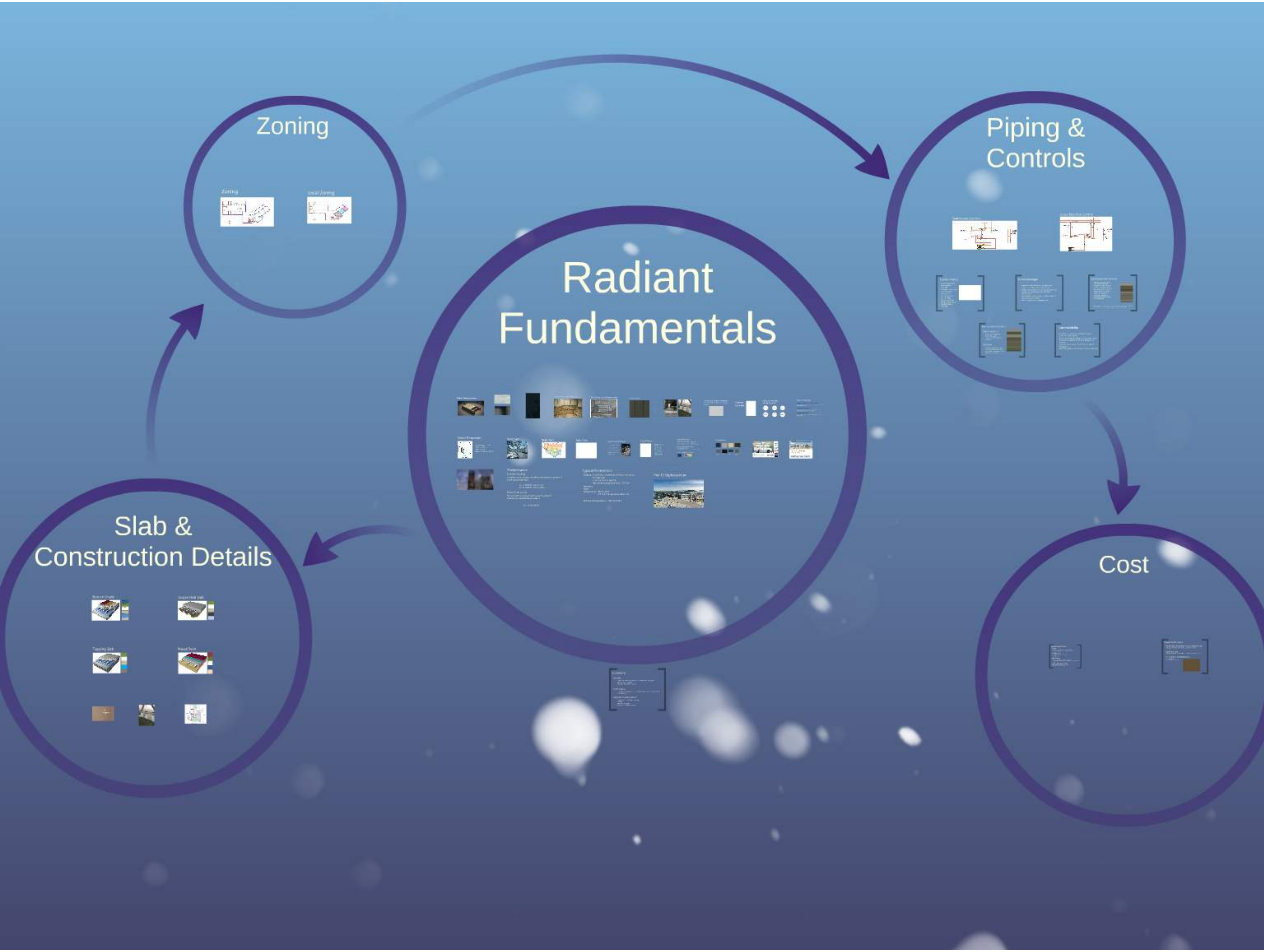
Average cost of the radiant system, including central plant $10-$12/ SF

2019 Cost Data

Average cost of materials & labor (excluding chilled water source) $12 - $14 / SF

Innovations for Reduced Cost

Installation Methods
Pre-manufactured solutions


Zoning
Piping &
Controls
Radiant
Fundamentals
Slab &
Construction Details
Cost

Summary

Benefits

- Can be used to dramatically reduce overall building energy use
- Superior Human Comfort
- Improved architectural freedom

Performance

12-14 BTUH/SF Sensible, up to 25-32 BTUH/SF with direct solar for radiant floor installations

Important Considerations

- Controlling Indoor Relative Humidity
- Controls
- Installation Methods
- Installation and Life-Cycle Costs

Energy Efficient Embedded Tube Radiant Cooling Systems

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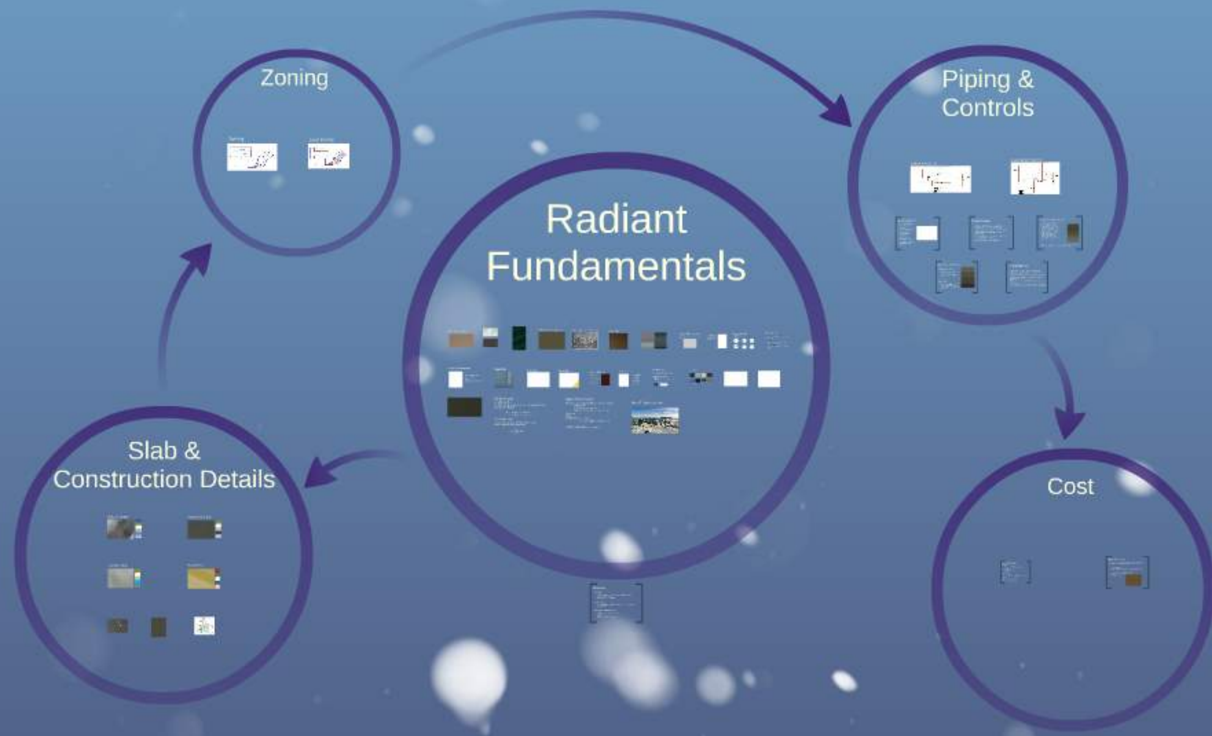
Business Development Manager
Uponor North America



Energy Efficient Embedded Tube Radiant Cooling Systems

Questions

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