Air Containment Design Choices and Considerations

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Introduction

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- Air containment design must consider many different factors to ensure a solution that achieves the required cooling, is flexible for expansion or changes, and considers other infrastructure

- It has been proven that containment provides increased efficiency for traditional and newer free-cooling solutions that utilize air side economizing air handlers, whereas some cooling solutions would not benefit from containment

- There are reasons for selecting hot aisle containment over cold aisle containment that do not hold true for all situations
- Containment cannot compromise fire suppression effectiveness and cable trays and overhead power cannot compromise containment effectiveness

Speaker Introduction

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- Principal of Racon Data Centres, a professional engineering firm specializing in data centre design and construction
- Certified by BICSI as a Data Centre Design Consultant, US Department of Energy as a Data Centre Energy Practitioner, and Uptime Institute as an Accredited Tier Specialist with over twenty years of extensive Data Centre Design and Construction experience
- Sits as a member on the BICSI-002 Data Centre Design standard and as section editor of BICSI-009 Data Centre Operations standard for Emergency Operating Procedures

References

Reference

- *BICSI-002-2014 Data Center Design and Implementation Best Practices*

Session Topics

Background Information

- Cooling Solution Options
- Hot Aisle/Cold Aisle
- Raised Floors And Plenums
- Heat Rejection And CRAC/CRAH Airflow

Containment

- Effectiveness Of Containment
- Hot Aisle Containment Vs. Cold Aisle Containment
- Roof Vs. Chimney
- Components Of Containment
- Materials Used

Design Considerations

- Supply Air Path And Return Air Path
- Cable Pathways And Power Distribution
- Fire Detection And Suppression
- Dropping Panels – Why And When

Summary

- Types Of Contained
- When To Use
- Design Considerations Affecting Containment

Goals of Session

- Select a containment solution that augments each type of cooling system
- Recommend style and components of a containment system
- Identify where coordination with others is required to ensure all systems operate harmoniously
- Determine which situations best utilize containment systems
- Determine if solution should be hot aisle contained or cold aisle contained
- Identify other infrastructure that is affected by containment systems

Module #1

Background Information

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Topics in Module

- Cooling Solution Options
- Hot Aisle/Cold Aisle
- Raised Floors And Plenums
- Heat Rejection And CRAC/CRAH Airflow

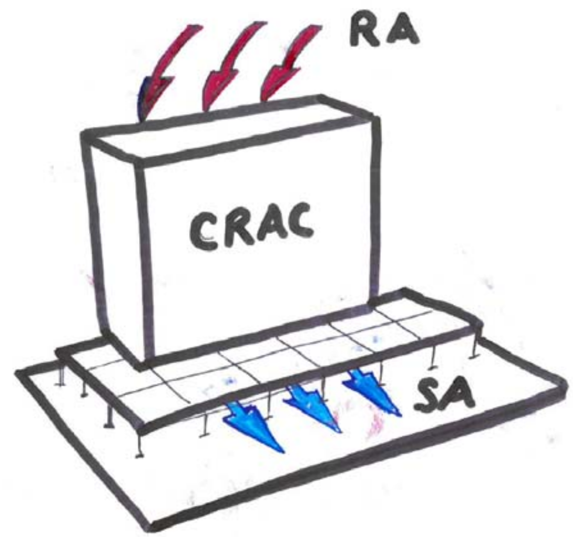
1.1 Cooling Solution Options

Cooling Considerations

- PUE - Removing heat closer to the load can reduce mechanical load
- Scalability – Smaller units are more quickly deployed
- Density – Not all loads are equal
- Interim Solution - Supplemental cooling may mitigate large construction

Perimeter Cooling

- A room configuration where the CRAC/CRAH units are placed along the perimeter blowing air toward the server cabinets via a plenum space (e.g. ductwork, raised floor plenum, flooded room plenum)



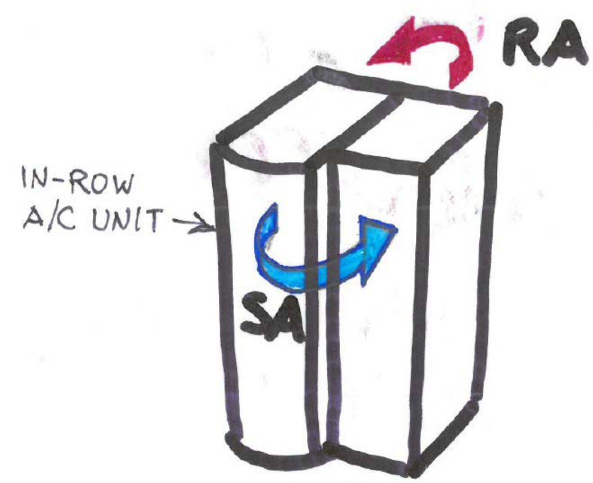
Perimeter Cooling - Typical Applications

- Traditional configuration of computer room cooling
- Varied IT load density applications
- Desire to separate mechanical from IT equipment

In-Row Cooling

- A room configuration where the CRAC/CRAH units are placed “in row” between the server cabinets

- The airflow is discharged from the front of the unit and circulates through the cabinets to the return on the rear of the unit



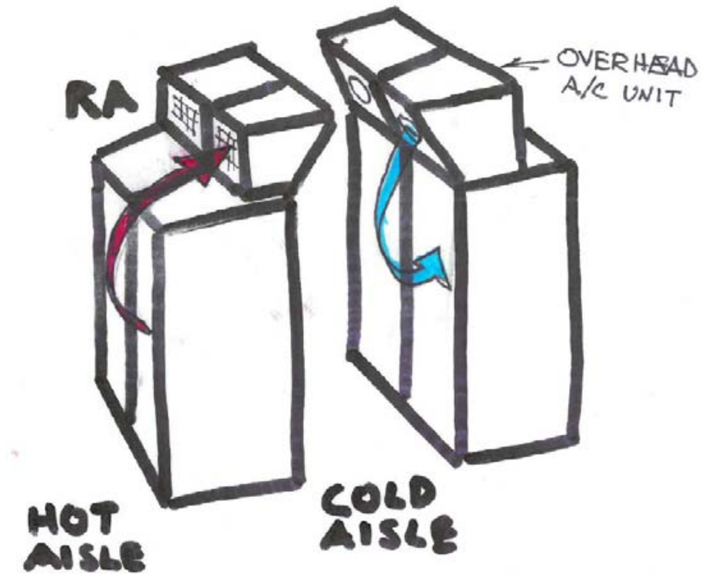
In-Row Cooling - Typical Applications

- Higher power density (7kW to 10kW per cabinet)
- Space concerns (no room for ductwork or raised floor)
- Good for "pod" design – modular deployment
- Limited horizontal air throw (approximately 6' each way)

Above Row Cooling

- A CRAC unit configuration where the units are placed above or on top of the server cabinets, ejecting air downwards in front of the cabinets

- The air circulates through the server cabinets to the return on the rear of the unit

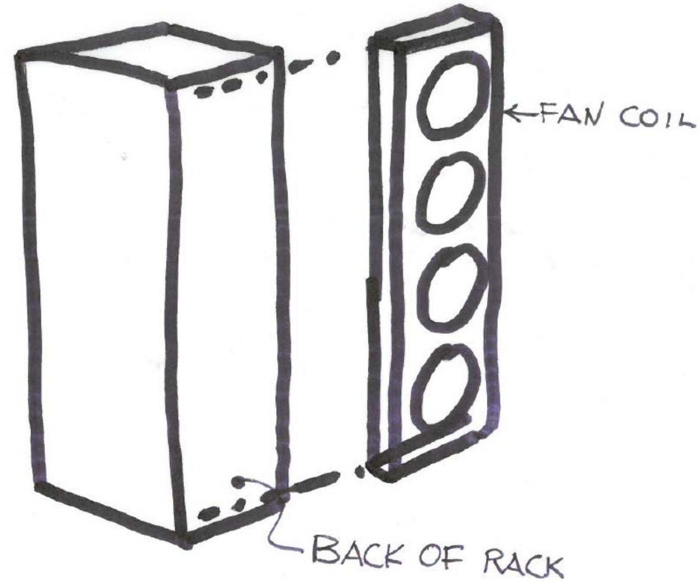


Above Row Cooling - Typical Applications

- High power density (10kW to 25kW per cabinet)
- Little space for equipment (i.e. no footprint required)
- High head room available

Back-of-Rack Cooling

- A CRAC/CRAH unit configuration where the units are mounted on the rear doors of the server cabinets
- The hot air from the server cabinet passes though the CRAC and cooled (neutral) air will circulate around the room to the front of the cabinet again
- These units may be passive (i.e. no fans)



Back-of-Rack Cooling - Typical Applications

- No space for mechanical equipment
- Redundancy typically not a design criteria (costly for 2N solution)
- Good for extreme loads (>25kW/cabinet)
- Clusters for R&D applications where loads are extreme but availability is not as important
- Dew point may be an issue

Other Cooling Solution (Non-Air)

- PUE - Removing heat closer to the load can reduce mechanical load
- Scalability – Smaller units are more quickly deployed
- Density – Not all loads are equal
- Interim Solution - Supplemental cooling may mitigate large construction

Submersed – Non-Conductive Liquid (Mineral Oil, Novec, Etc.)

- The servers are submersed in a cooled non-conductive liquid as a cooling medium rather than air
- The liquid is pumped through the server cabinets to a heat rejection system (dry cooler, chiller, etc.)
- Since the specific heat capacity of liquids are typically higher than air, it allows more energy to be transferred per volume of heat transfer medium (better heat transfer)

Submersed – Non-Conductive Fluid (Mineral Oil, Novec, Etc.)

- Servers fully immersed
- No airflow required
- Similar mechanical plant:
  - Circulation pumps
  - Heat exchanger
  - Filters
  - Cooling tower
- Other design considerations:
  - Higher live load
  - Lower quantity of servers/sq. ft.
  - Proprietary cabinets
  - Proprietary servers or modifications

Liquid Cooled Servers

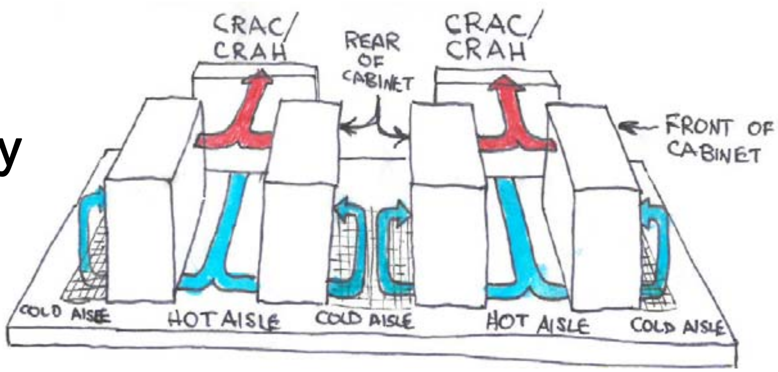
- No fans - heat sinks are directly piped to a heat rejection system
- Liquid is pumped between each server and a heat rejection system (dry cooler, chiller, etc.)
- Similar to a submersed system, the specific heat capacity of liquids are typically higher than air, it allows more energy to be transferred per volume of heat transfer medium (better heat transfer)
- Needs modification of server heat sinks to be liquid cooled vs. air cooled

Liquid Cooled Servers

- Direct to the chip cooling
- Piping to server requires the following:
  - Flexible
  - Strong
  - Individual isolation
  - Quick connection
- Requires proprietary heat sinks
- In this example, power supply is still air cooled
- Redundancy would be difficult at the component level

1.2 Hot Aisle/Cold Aisle

Hot Aisle/Cold Aisle



- The aisles/rows of server cabinets are oriented in a way that the front and rear of adjacent rows are facing each other
- Data centre class equipment has front intake, rear discharge (there are exceptions, such as switches with side to side airflow)
- Cold Aisle = ITE Intake
- Hot Aisle = ITE Discharge

1.3 Raised Floors and Plenums

Raised Floors and Plenums

- A raised floor provides a plenum space underneath the floor to transfer supply air from the CRAC/CRAH units to the server cabinets
  - This replaces the need for supply air ducting

- A suspended ceiling provides a plenum space above the ceiling to transfer discharge air from servers to the return air of a CRAC/CRAH unit
  - This replaces the need for return air ducting

Note: The presence of a raised floor may allow the running of power and telecommunication cabling below, but is not the primary purpose.

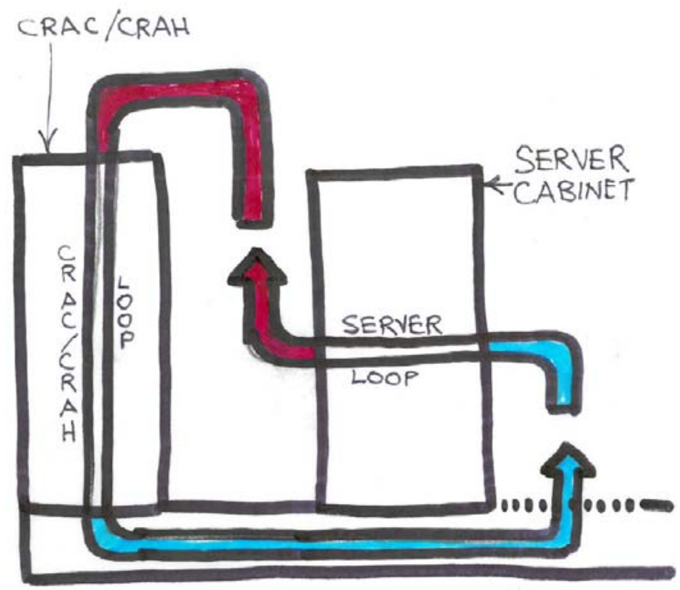
1.4 Heat Rejection and CRAC/CRAH Airflow

Flow Loops

- Airflow in the typical data center consists of two flow loops:
  - CRAC units (a few big fans) circulate air within the entire room
  - Servers (many little fans) circulate air between cold and hot aisles

- These loops are "decoupled"

- Each loop operates with different temperature difference between inlet and supply

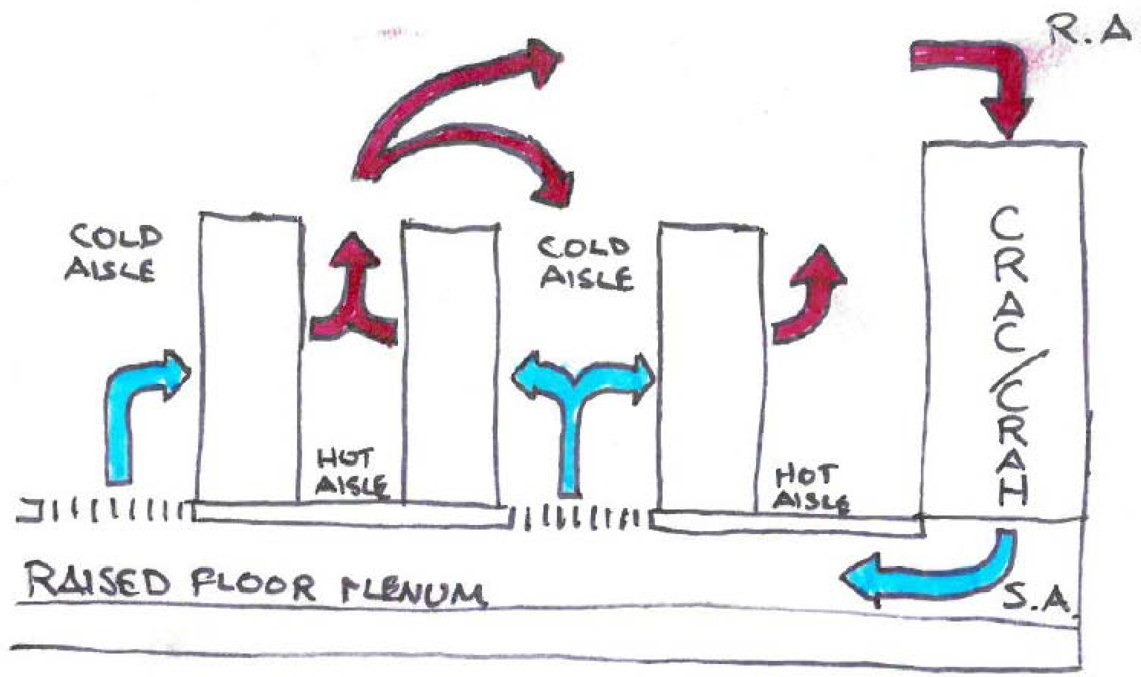


Flow Loops

- All of the heat rejected from the servers must be further rejected in the CRAC unit
- "Ideal" design:
  - Supply air at the server inlet at the desired inlet temperature and at a volume that matches the server fans
  - All hot aisle air returned to the air-handling units with no mixing or recirculation between hot and cold aisles

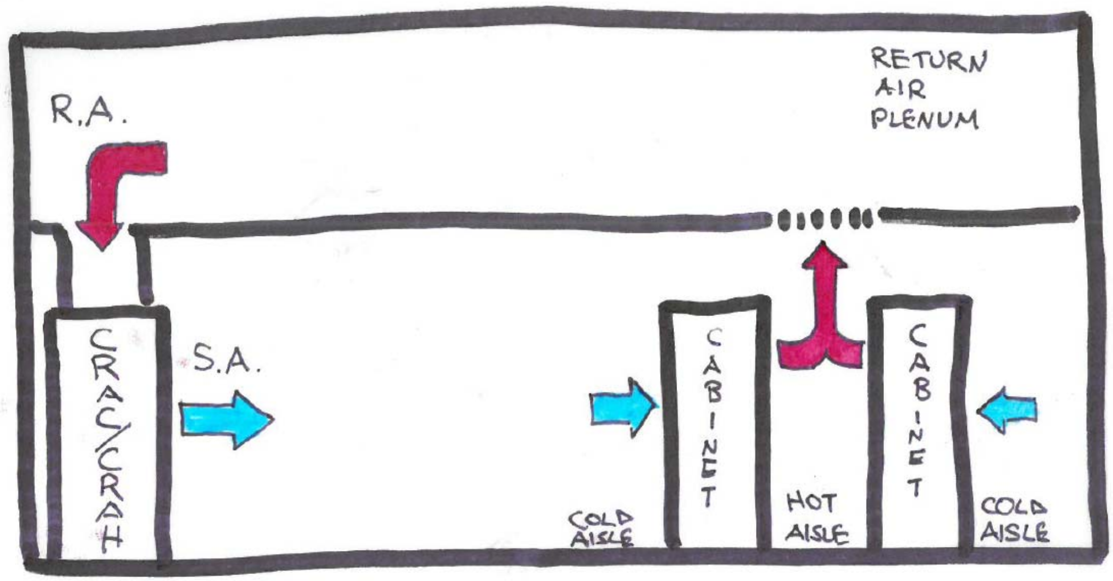
Room Return (Flooded)

- When a plenum is used to direct cold air to the server cabinets, the CRAC/CRAH unit can have a return grille open to the room to allow the hot air to circulate back to the unit
- This is common with a perimeter configuration with a ducted supply



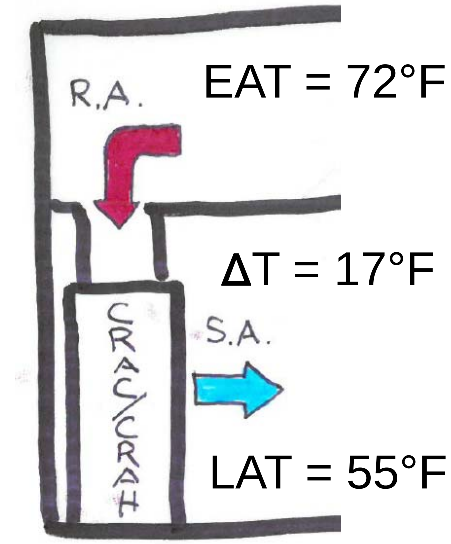
Ceiling Return

- When there are return grilles in the suspended ceiling, the hot air from the server cabinets can return to the CRAC/CRAH via a ceiling plenum



Delta T

- The difference, or “delta” in temperature across a certain component (cooling coil, server board, etc.)
- Represented as ΔT
- Example: CRAC unit with supply air at 55°F and return air of 72°F has a $\Delta T = 17°F$



ASHRAE TC9.9-2011

- 2011 Thermal Guidelines for Data Processing Environments – Expanded Data Center Classes and Usage Guidance

- Main Initiatives:
  - Manufacturer independent “recommended” and “allowable” environmental ranges by class
  - Establish ITE air inlet as the common measurement point
  - Expanding the environmental ranges achieves higher data center operating efficiency and lower operational expenditure

ASHRAE TC9.9-2011

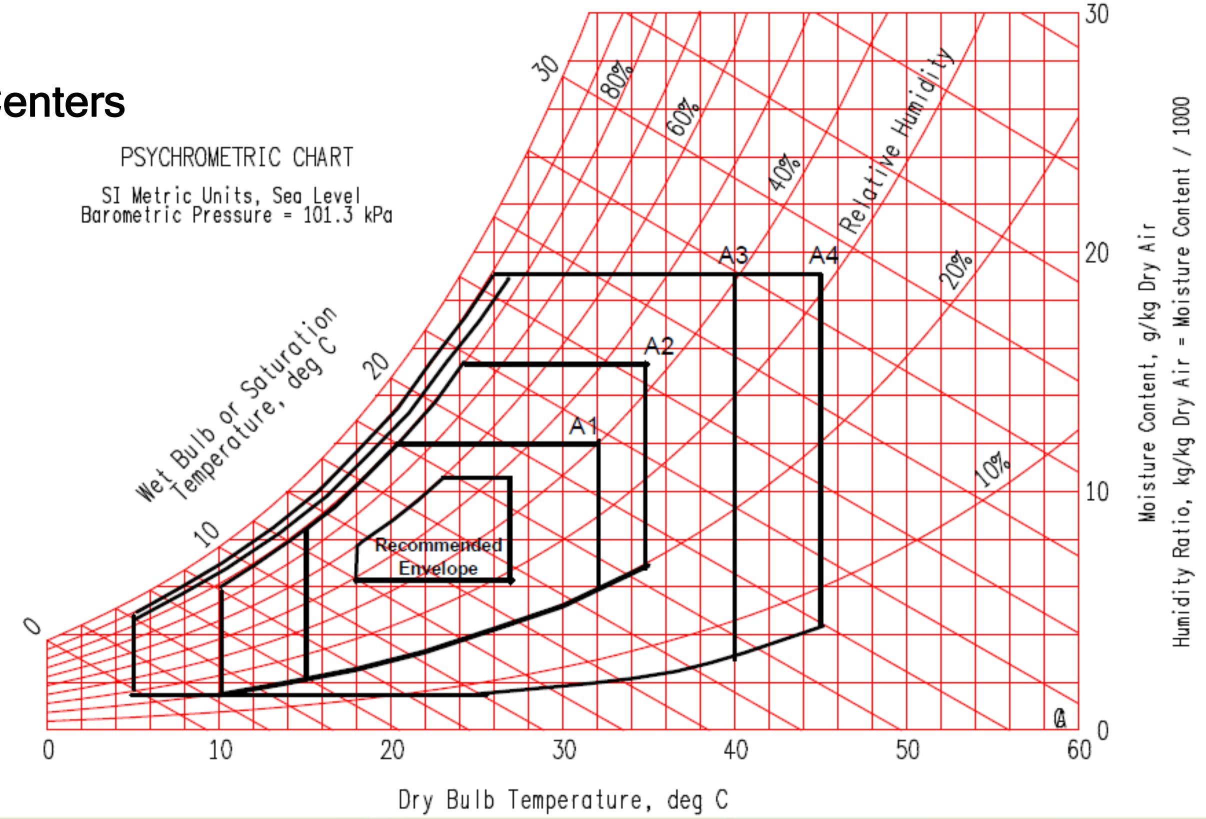
Thermal Guidelines for Data Processing Environments – Expanded Data Center Classes and Usage Guidance

Class	Applications	IT Equipment	DB (˚C)	Humidity	Max DP (˚C)
A1 to A4	Data Center – Recommended		18 to 27	5.5˚C DP to 60% RH and 15˚C DP	
A1	Data Center – Allowable	Enterprise servers, storage products	15 to 32	20% to 80%	17
A2		Volume servers, storage products, PC's, workstations	10 to 35	20% to 80%	21
A3			5 to 40	-12˚C DP & 8% to 85%	24
A4			5 to 45	-12˚C DP & 8% to 85%	24
B	Office, home, portable, etc.	PC's, workstations, laptops, and printers	5 to 35	8% to 80%	28
C	Point-of-sale, industrial, factory, etc.	POS equipment, ruggedized controllers, PC's and PDAs	5 to 40	8% to 80%	28

ASHRAE TC9.9-2011

ASHRAE Environmental Classes for Data Centers

- Increasing the environmental ranges increased the opportunity to use compressor-less cooling solutions
- Class A3 and A4 allows for increased energy optimization normally with increased cost of equipment



Module #2

Containment

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Purpose of Containment

- Optimize cooling system efficiency
- Eliminate mixing of supply and return air
- Allow higher density of ITE
- Increase cooling capacity

2.1 Effectiveness of Containment

Benefits

- Increased set points
- Elimination of hot spots
- Increase in economizer hours
- Reduction in condensation
- Increased infrastructure utilization

Energy Savings Opportunities

- 10-40% improvement with containment system (BICSI-002-2011)

- 25% improvement with containment system (leading manufacturer)
  - Same manufacturer completed a study and found that just the end of row doors contributed to 80% of the effectiveness of a containment system (blank off panels installed)

- 5% improvement for use of blanking panels

What Containment Does

- Containment solutions eliminate:
  - Bypass Air
  - Recirculation Air (through servers)
  - Short Cycling of Air

- Once through rule – air should travel once through both flow loops

- BICSI-002 recommends that hot aisle/cold aisle concept for arrangement of computer equipment in the computer room should be used, regardless of whether air distribution is overhead or supplied from an access floor plenum. This is true for both cold and hot aisle containment solutions

2.2 Hot Aisle Containment vs. Cold Aisle Containment

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Hot Aisle Containment

- Captures all of the discharge air from the ITE and ensures it is returned directly to the cooling system
- Hot aisle is contained
- Remainder of space acts as a supply (cold air) plenum
- Temperature of hot aisle can exceed 100°F (assuming server inlet in recommended TC9.9 requirements of 80.6°F and 89.6°F allowable)

Cold Aisle Containment

- Forces all of the discharge air from the cooling system to directly enter the front of the ITE
- Cold aisle is contained
- Remainder of space acts as a return (hot air) plenum
- Temperature of hot aisle could still exceed 100°F, but would expect mixing of air as it returns to the cooing system

Work Conditions

- To provide a comfortable working condition, the following systems should be accessible from the cold aisle, regardless of configuration:
  - Cable trays
  - Power distribution
  - Front of servers
  - PDU power panels

- The hot aisle will require people to enter for the following:
  - Affixing server mounting rails
  - Plugging in server to in-rack power distribution
  - Patching server to local patch panel or top of rack switch
  - Dressing cables

Working Conditions For People

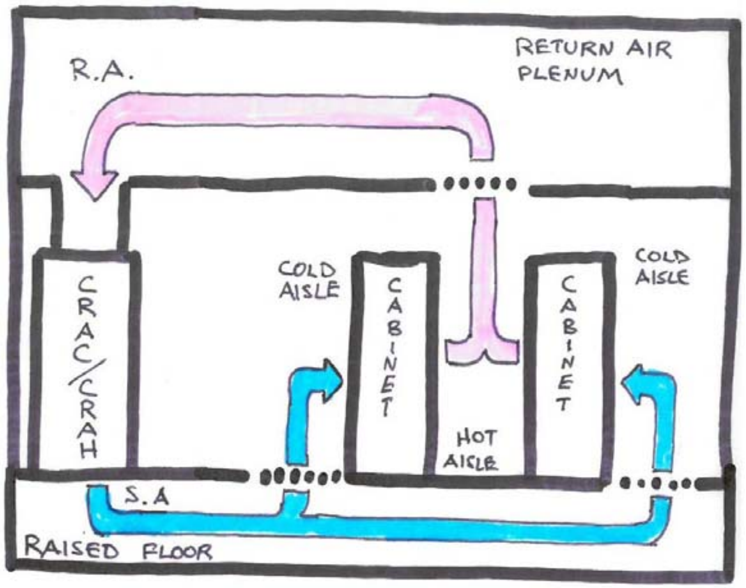
- Contained Hot Aisle can approach 100°F (if 80°F in cold aisle)
- Contained Cold Aisle can be as cool as 68°F (if 88°F in hot aisle)
- OHSA regulations to not exceed wet-bulb globe temperature (WBGT):
  - Continuous work: 86°F
  - 25% work, 75% rest: 90°F
- Note: Data centers are environments for ITE, not people. While it should be a consideration to make the space comfortable for people, all efforts should be made to keep the facility lights out and do work remotely, thus minimizing the time needed to occupy the data centre.

Why Pick One Solution Over Another?

- Hot air must return to the cooling system
- Cold air must supply to the server inlet
- Containment reduces the amount of air not circulating properly in the data room
- It forces the air to travel through the servers and back to the CRAC unit, reducing short cycling and mixing of hot and cold air, increasing the overall room efficiency

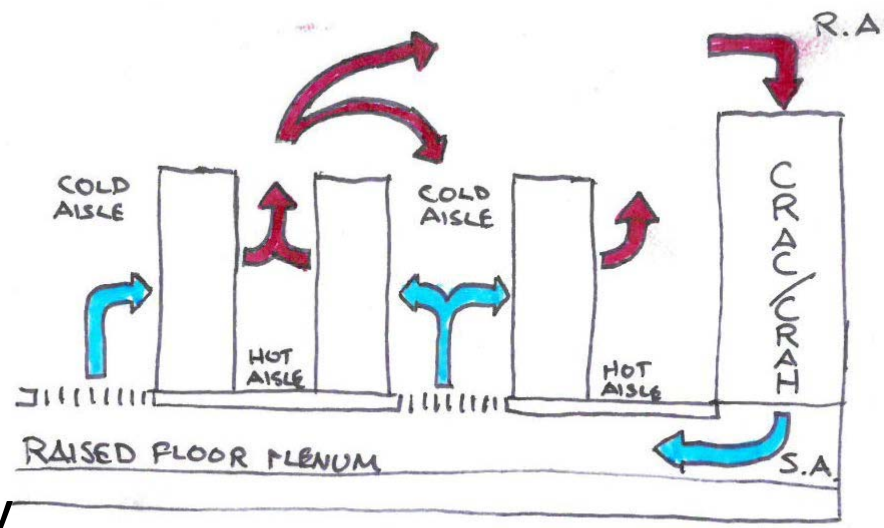
Example 1 - Raised Floor With Suspended Ceiling

- Supply air choices:
  - Raised floor
- Return air choices:
  - Suspended ceiling
- Probably hot aisle containment



Example 2 - Raised Floor With No Suspended Ceiling

- Supply air choices:
  - Raised floor
- Return air choices:
  - Ducted (expensive, needs head room which means a ceiling could have been possible)
  - Flooded room
- Probably cold aisle containment since no pathway provided for return air



Example 3 – No Raised Floor With Suspended Ceiling

- Supply air choices:
  - Ducted – supply air diffusers directly in cold aisle
  - Flooded – most likely as least cost endeavour

- Return air choices:
  - Suspended ceiling – least cost
  - Flooded – probably not, as it would require extensive use of containment and possible impediments

- Probably hot aisle containment

Example 4 – No Raised Floor And No Suspended Ceiling

- Supply air choices:
  - Ducted – supply air diffusers directly in cold aisle (needs headroom)
  - Flooded – least cost, less effective

- Return air choices:
  - Ducted – higher cost, but effective (needs headroom)
  - Flooded – least cost, less effective (cannot be done if supply is flooded)

- Probably S/A ducted with flooded return. Could be either but would need more containment if hot aisle vs. cold aisle

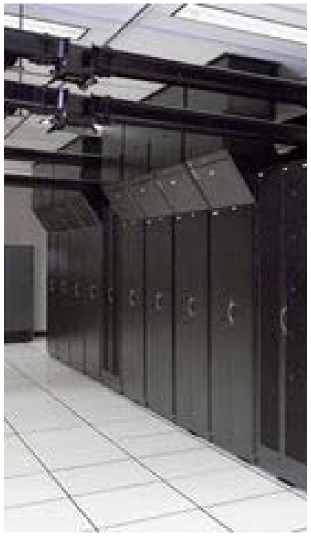
2.3 Roof vs. Chimney

Roof

Horizontal surface that prevents the rise of air

Chimney

Vertical pathway that promotes the rise of air



2.4 Components of Containment

Components of Containment

- End of Row Doors
- Full Height Panels
- Roof Panels
- Above Cabinet Baffle
- Below Cabinet Baffle
- Between Cabinet Gasket
- Blank-Off Panels

End Of Row Doors

- Doors to allow access to the contained aisle
- Prevents recycling of air from hot aisle to cold aisle
- Has been measured to be up to 80% of the effectiveness of a containment system

Full Height Panels

- Panels installed from finished floor to ceiling level (or to containment roof height) in locations where server cabinets have not yet been installed

- This allows a containment system to be installed on a partial row, before fully populated with cabinets

Above Cabinet Baffle

- Baffle installed from top of cabinet to underside of ceiling to prevent short cycling of air

Below Cabinet Baffle

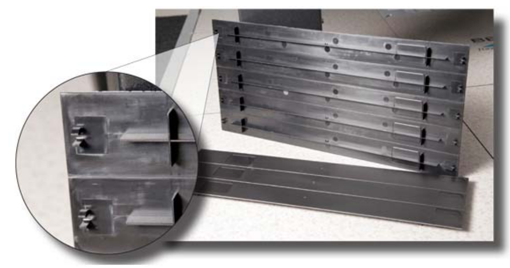
- Fills the gap between the bottom of the cabinet and the floor
- Can sometimes be closed with seismic/anti-tip plates

Between Cabinet Gaskets

- Gaskets to seal gaps between server cabinets to reduce bypass air
- Could be simple type such as self adhesive closed cell neoprene for small gaps

Blank-Off Panels

- Panels to install within server cabinets to close-off “U” spaces not in use
- This forces airflow through the servers rather than bypassing through empty spaces



2.5 Materials Used

Materials Used

- Power Coated Metal
- Aluminum Frames
- Lexan Panels
- Flexible Vinyl Curtains
- Panel Insert Material:
  - Polycarbonate
  - Polypropylene
  - ABS
  - Aluminum Composite
  - Acrylic
  - Tempered Glass

Powder Coated Metal

- Powder coated metal is a common material for baffles and full height panels
- Built to order (not field modified)
- Same material as cabinets

Aluminum Frame

- Rigid aluminum frame with filler panel of various materials
- Can be field modified to suit site conditions

Lexan Panels

- Similar to an aluminum frame system
- Panel strong enough to be self supporting
- Good for full height panels

Flexible Vinyl Curtain Panels

- Top track holds curtain; may have bottom track
- Very flexible solution for field modification
- Curtains may have ripples

Module #3

Design Considerations

Considerations

- Supply Air Path and Return Air Path
- Cable Pathways and Power Distribution
- Fire Detection and Suppression
- Dropping Panels/Curtains

3.1 Supply Air Path and Return Air Path

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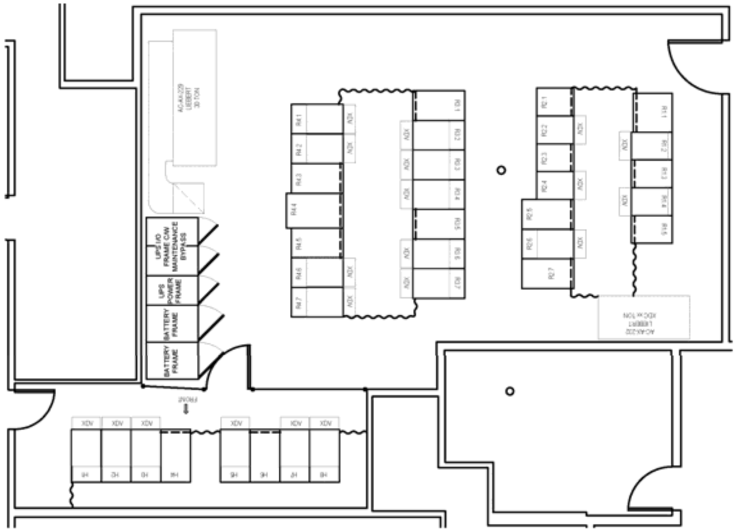
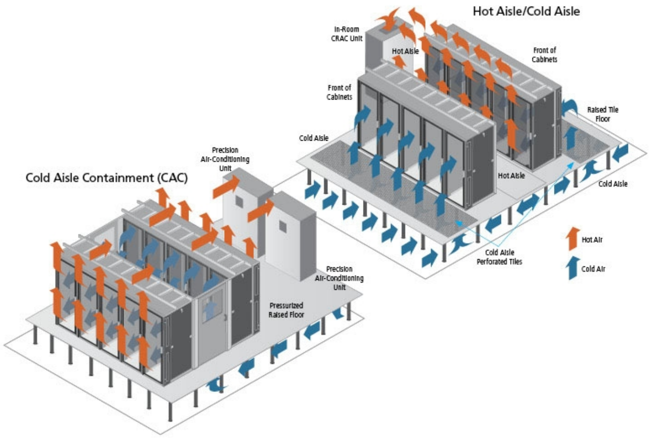
Supply Air Path and Return Air Path

- Cold air must get to the ITE air inlet
- Hot air must leave the discharge



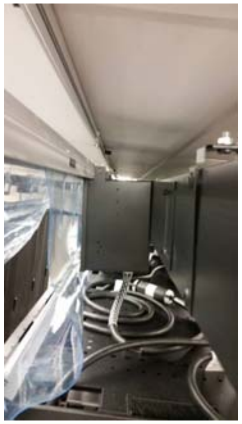


3.2 Cable Pathways and Power Distribution

Cable Pathways and Power Distribution

- Cable trays may have to enter contained areas
- Overhead power distribution may have to enter contained areas
- Curtains may need to drop on a fire event



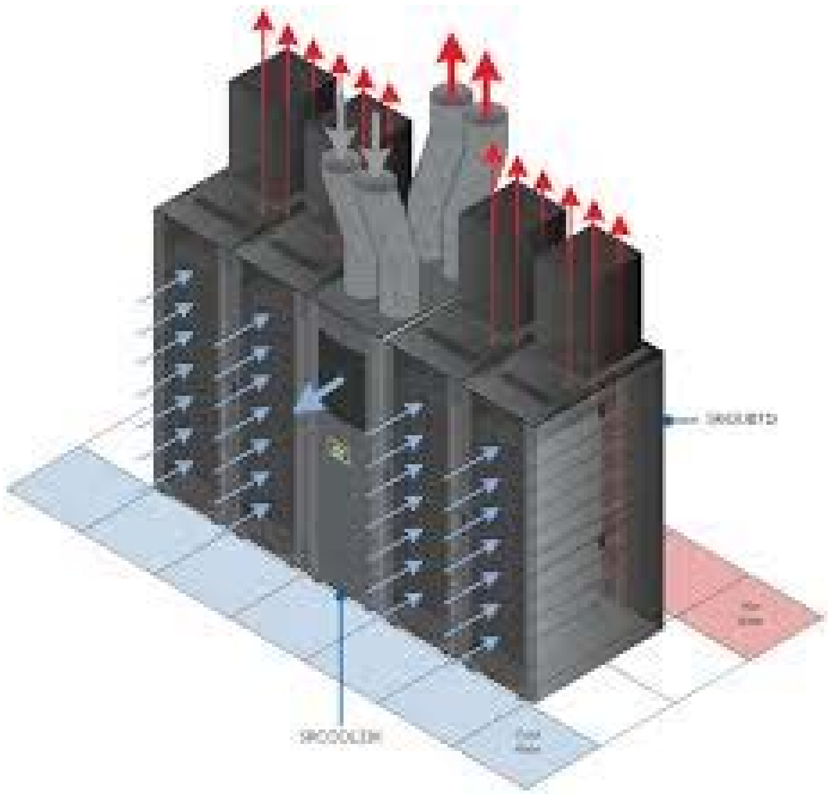
3.3 Fire Detection and Suppression

Fire Detection

- Recommended area covered by a early warning laser smoke detector is 400 sq. ft.
- Containment may prevent or delay airflow across a detector
- Difficult to determine where an alarm has taken place

Fire Detection Considerations

- Add detection inside a contained aisle
- Add detection at return air of between cabinet cooling
- How are chimneys or power vented cabinets protected?



Fire Suppression (Sprinklers)

- NFPA classifies a data centre as ordinary hazard

- Ordinary hazard sprinkler coverage: no more than 130 sq. ft.

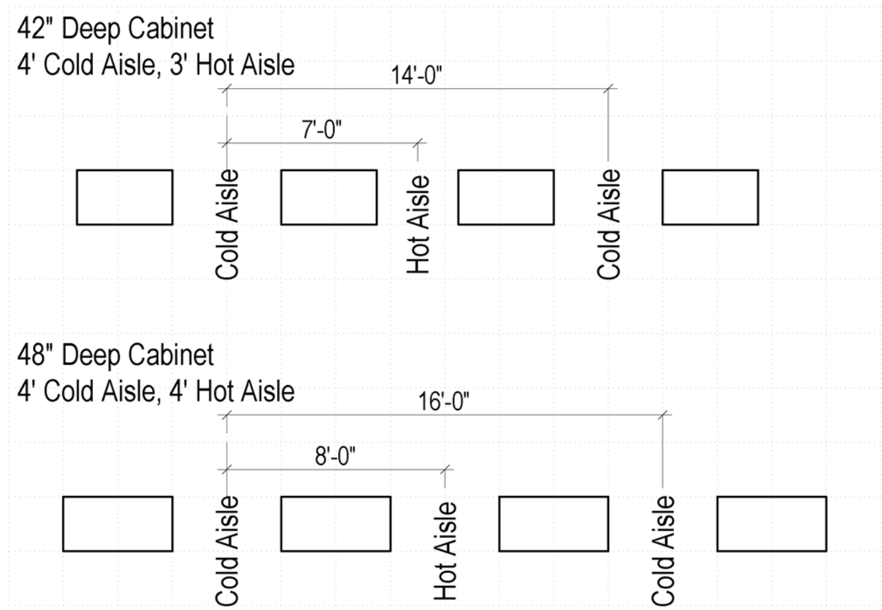
- Maximum space between heads: 15’
- Minimum space between heads: 6’
- Minimum space from wall: 4”

- Baffles or roof may prevent sprinklers from operating

- May require approval of local AHJ

Fire Suppression (Sprinklers) Considerations

- Add sprinklers in contained aisles
- Drop ceiling panels or top of cabinet baffle



Fire Suppression (Clean Agent)

- Hydraulically calculated
- Needs to be at concentration by set time (eg. 10 seconds)
- Baffles or roof may prevent proper dispersal

Fire Suppression (Clean Agent) Considerations

- Add suppression in contained aisles
- Add suppression at return air of between cabinet cooling
- Drop ceiling panels or top of cabinet baffles

3.4 Dropping Panels – Why, When, How

Why Drop Panels and Curtains?

- Impediment to sprinklers and clean agent

When To Drop Panels and Curtains?

- Before you need suppression or sprinklers to work

How To Drop Panels and Curtains?

- Specific to fire system sequence of operation
- Will a fusible link work as required?
- Power and control maglocks to comply with UL

Dropping Panels and Curtains Considerations

- Battery back-up (probably an EPO event)
- Normally open or normally closed?
- When in the sequence?

Module #4

Summary

Summary

- Types of Containment
- When To Use
- Design Considerations
- Group Exercise #1
- Group Exercise #2
- Group Exercise #3

4.1 Summary – Types of Containment

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Types of Containment

- Hot Aisle Containment
- Cold Aisle Containment
- Roof Containment
- Chimney Containment

Note: There are many ways to make a solution work, and what works for one situation may not work for others

4.2 Summary – When to Use

When to Use Containment

- Hot Aisle Containment
  - Provides return air pathway
- Cold Aisle Containment
  - Provides supply air pathway
- Roof Containment
  - In hot aisle for in-row cooling or ducted return
  - In cold aisle for ducted supply, raised floor supply, or flooded room return
- Chimney Containment
  - To return air duct or return air plenum
  - Can be installed one rack at a time

4.3 Summary – Design Considerations Affecting Containment

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Design Considerations Affecting Containment

- Supply and Return Air Pathway
- Cable Pathways and Power Distribution
- Fire Detection and Suppression
- Dropping Panels / Curtains

Interactive Group Exercises

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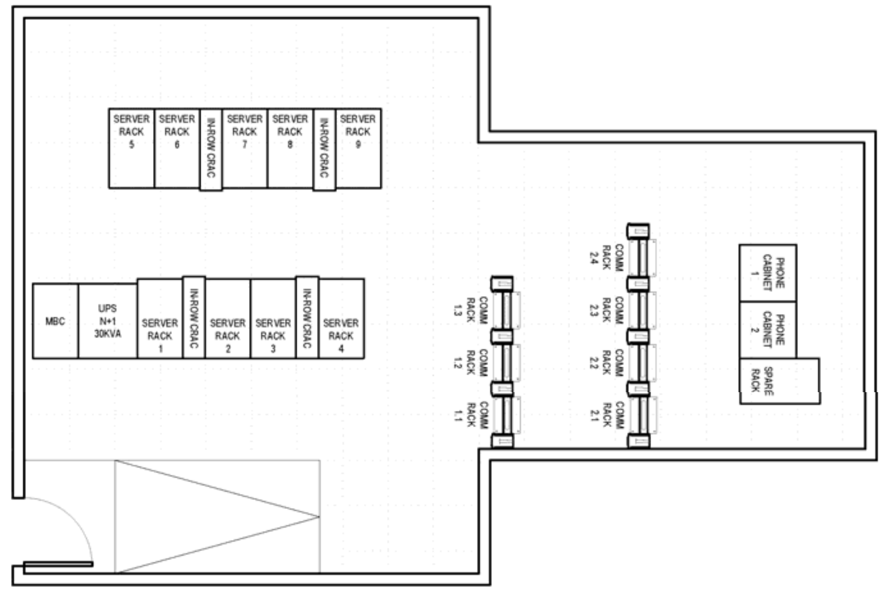
Exercise #1

- Convert 14 year old Class F1 to Class F2
- Perimeter CRAC
- 8” raised floor full of cables and power distribution
- In-row A/C units
- In-row UPS
- Cannot move Comm Racks or Phone System

- Type of Containment

- Other Considerations
  - How to get heat back from phone system

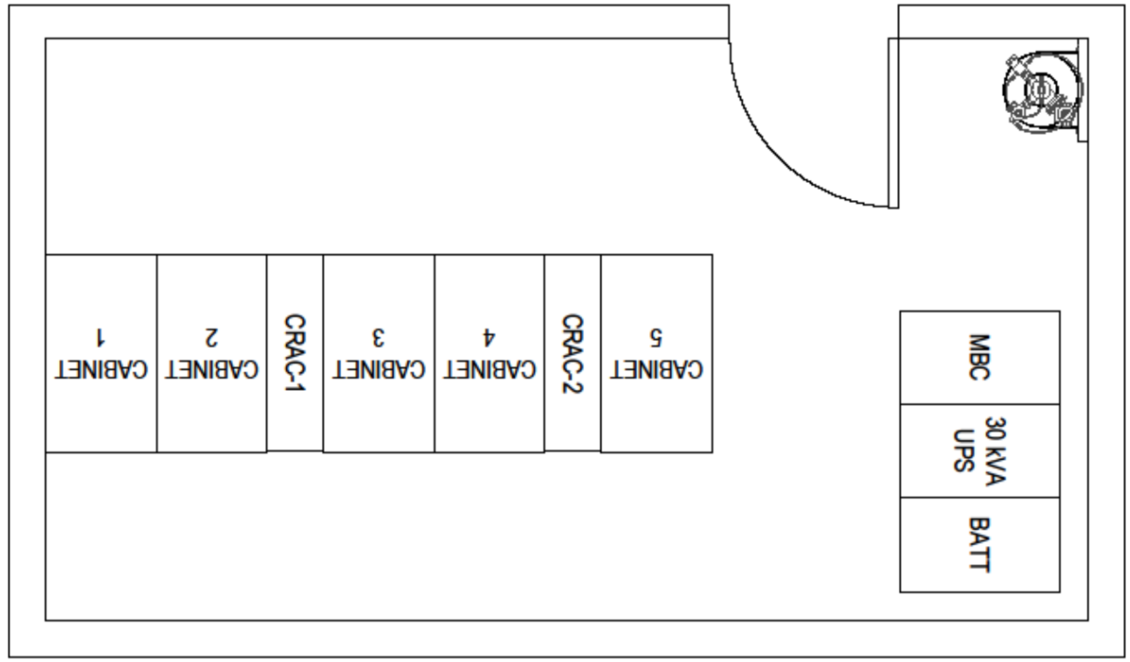


Exercise #2

- No raised floor
- In-row A/C units
- Suspended ceiling
- Pre-action and suppression

- Type of Containment

- Other Considerations
  - UPS
  - Detection, sprinklers & suppression



Exercise #3

- Information to follow