



RA Cooling System Review

October 19, 2016

Current Status of RA Cooling System Development

Presentation Agenda

Review of Accomplishments

1. Prototype development
2. Last year's testing and results

General Overview of Current Approach

1. Cooling capacity modulation capability
 - a. One design covers all portable shelter types and sizes up to 35 occupants.
2. Battery bank sized to support the cooling for full 96 hours.

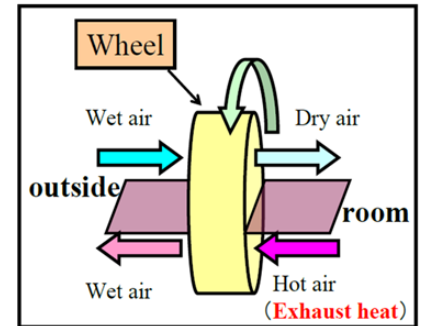
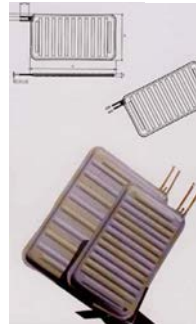
Challenges Going Forward

1. Develop a single cooling system capable of providing at least 96 hours of operation without connection to external electric power that can be easily adapted to hard and soft refuge alternatives having occupancies between 6 and 34.
2. Cooling system design must be acceptable to MSHA for use in underground mines.
3. Finished product must meet a reasonable price point.

Review of Accomplishments

Prototype Development Phase

- Several cooling methods / technologies were considered before settling on vapor compression:
- Phase change materials
- Zeolite adsorption
- Expendable refrigerants
- Eutectic plates
- Evaluated options for a battery regeneration capability to minimize the size of battery bank.
- Manual generator
- Fuel cell
- Both options costly and / or limited suitability.



Review of Accomplishments

Prototype Development Phase

- Based the prototype system on a commercial off the shelf product.
- DRS modified the commercial system for mine refuge application.



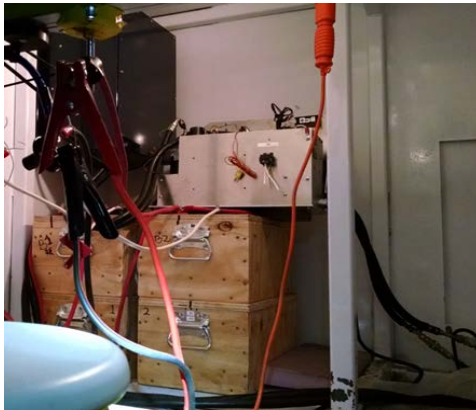
Power Conditioner



Condensing Unit



Air Handler



Modified System During Mine Testing

Chemical Desiccant Added to RA Interior



Review of Accomplishments

December 2015

Testing:

- Prototype cooling system installed in the six person RA at NIOSH.
- Operated for 96 hours at prevailing mine ambient temperature.

Results:

- Cooling system maintained temperature control set points below 95° F apparent temperature.
- Prototype system demonstrated sufficient capacity for at least 10 person load in a cool mine ambient.



Review of Accomplishments – January 2016

Testing:

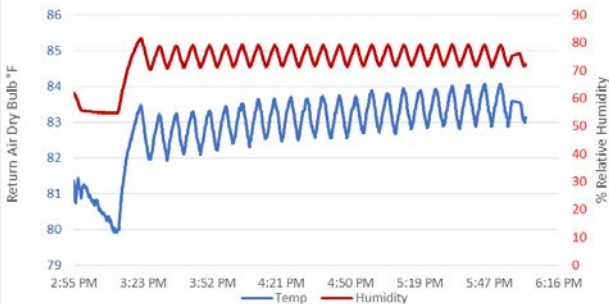
Ambient air temperature surrounding the steel RA was increased to 85° F using portable heaters to create representative warm mine environment.

Results:

Cooling system maintained temperature / humidity control set points and kept the shelter interior well below 95° F apparent temperature in the warm mine condition.

Expendable desiccant mitigated power consumption by addressing 10% of latent cooling load.

Temp Cycle with Humidistat Active



Overview of Current Split System Approach

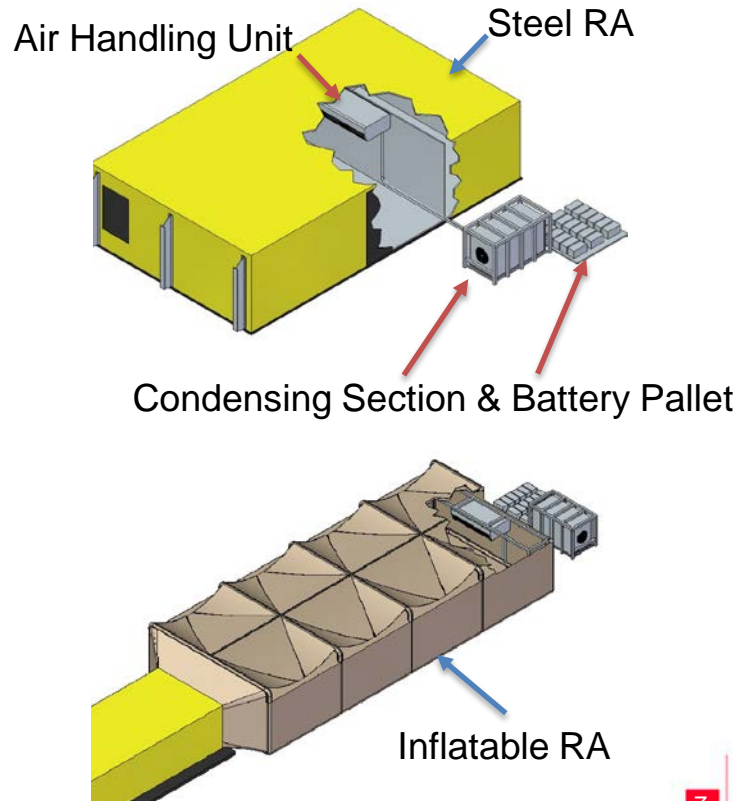
Design goal is to provide one system that is applicable to steel and inflatable RA needs.

Major differences from prototype:

- More capacity.
- Reduced power consumption.
- Condensing unit & batteries on an external pallet.
- Single cooling system expected to address cooling capacity needs of RA sizes from 6 to 34 occupants.

Advantages of split configuration:

- Prevents the need for flexible duct work on RA exterior.
- Offers a smaller cooling system package external to RA since AHU is inside the RA.



Overview of and Alternate Approach

Package unit concept would also work for steel and inflatable RA applications.

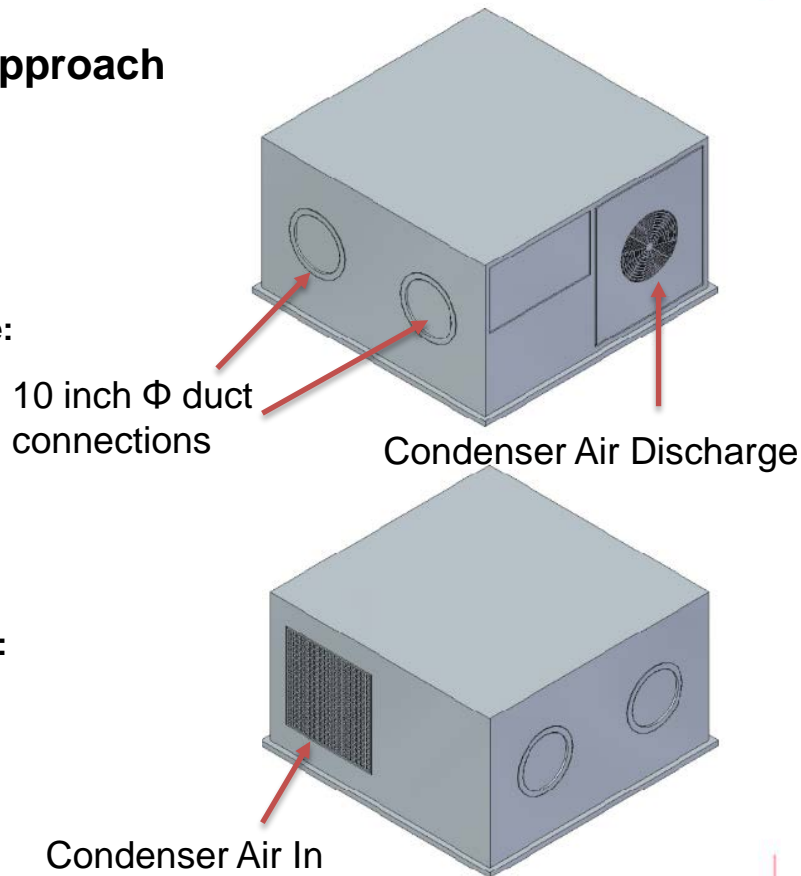
Same major differences from prototype:

- More capacity
- Reduced power consumption
- Single package configuration

However, conditioned air is delivered via flexible ducts.

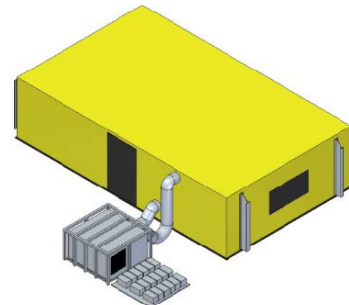
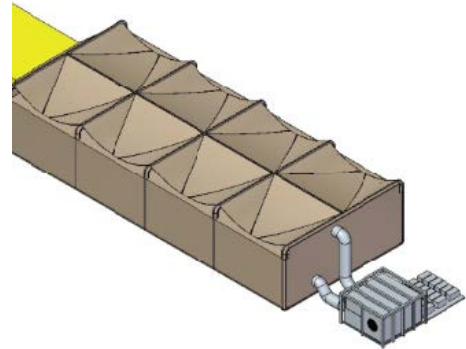
Advantages to packaged configuration:

- Overcomes the challenge of mounting evaporator section inside RA's.
- Eliminates refrigerant hoses.



Overview of Alternate Approach

- Single packaged cooling system expected to cover the full range of capacity requirements from 6 to 34 person occupancy.
- Capacity modulation will automatically vary cooling system performance to match demand.
- Conditioned air connects to RA via short flexible ducts.
- Initial concept described in BAA SOW is a split system however a packaged system is also an option.
- Final configuration needs to satisfy the widest range of user needs.



Conclusions

Concept of a battery powered cooling system has been proven to eliminate interior condensation and maintain occupant space below 95° F apparent temperature.

Next Phase Under Current BAA will:

- Finalize a cooling system configuration suitable for steel and inflatable RAs.
- Result in a system developed in concert with regulatory agencies that generates a tailored approval application.