Integrated Energy Systems Program

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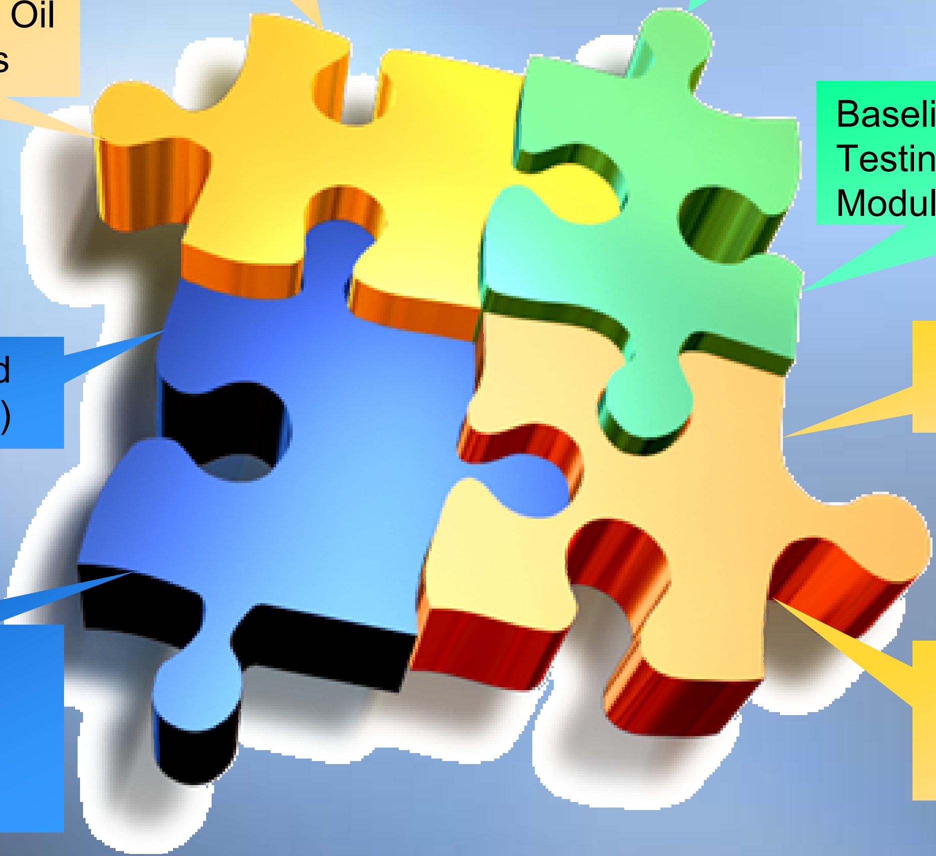
INTEGRATED
ENERGY SYSTEMS

DER
DISTRIBUTED ENERGY RESOURCES

US DOE
OFFICE OF POWER TECHNOLOGIES

Integrated Energy Systems Program



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Thermally-Activated Technologies and Packaged CHP Systems

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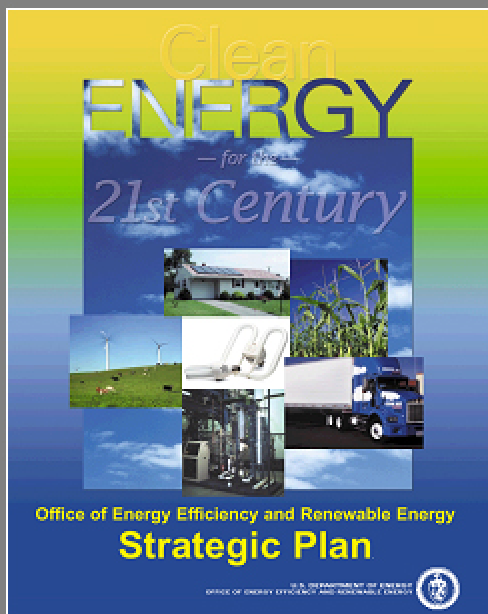
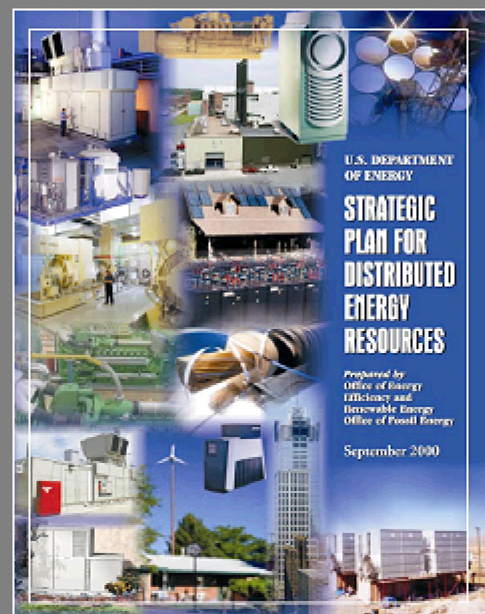
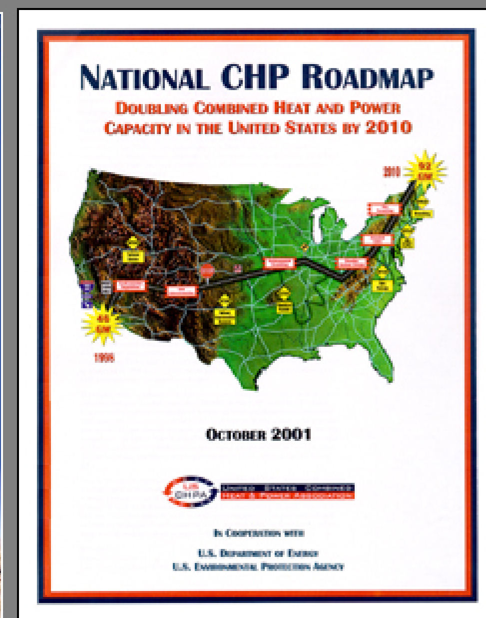
Integral Part of EERE, DER, CHP Strategic Plans







Three Key Activities

- Thermally Activated Technology
  - Absorption Cooling
  - Ventilation Air Conditioning – Humidity Control
  - Heat Recovery Technologies
- Systems Integration
  - Modular and Packaged System Development
  - Building Load/End-Use Integration
- Evaluation, Education and Technical Assistance
  - Measurement and Verification
  - Regional Application Center(s)

Building on a Strong Foundation

- 5 MW gas turbine system with heat recovery, chiller
- 1,000 RT double-effect absorption chiller
- Inlet air cooler uses 300 RT of Chilled water output
- Operating since 1996
- O&M costs reduced from
  - $3 million /yr "pre-BCHP"
  - After CHP to $2 million/yr

OPRYLAND Hotel and Convention Center

Case Study provided by: IC Thomason Associates, Inc., Consulting Engineers, Nashville, TN

Building on a Strong Foundation

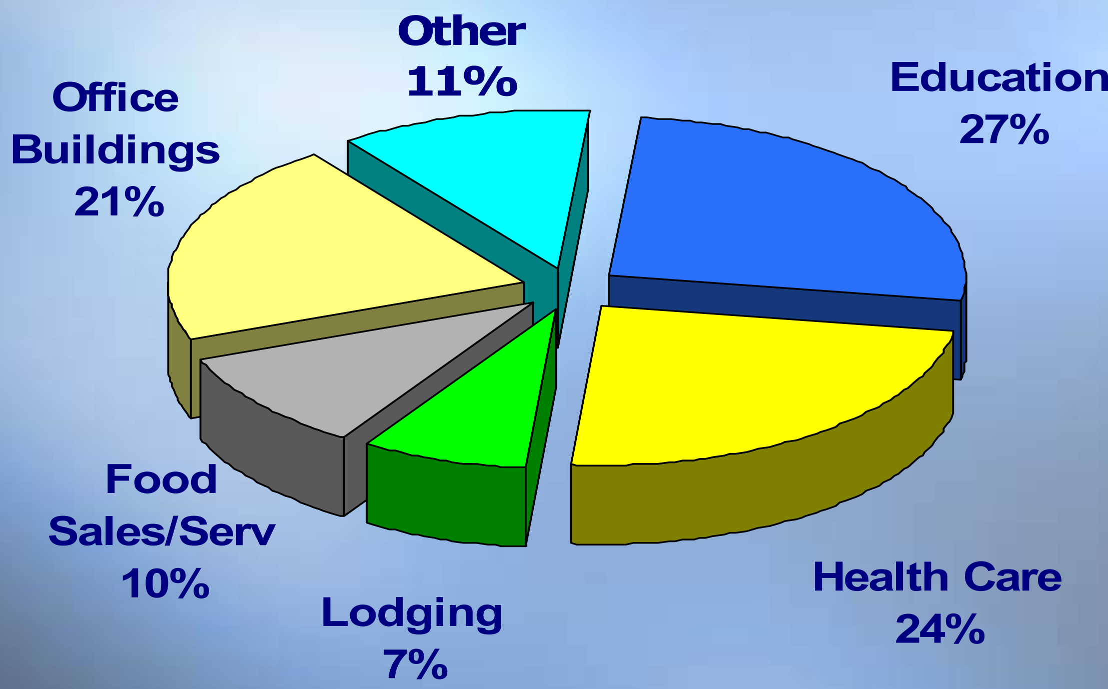
Commercial District Cooling Plants

- District energy systems are in place in 38 states
- Serving major U.S. cities and college, university campuses
- District energy network is important infrastructure to nation's mayors and college presidents

President Bush Announcing His Energy Plan

Market Focus and Potential

CHP Potential: 75,000 MW



Source: U.S. DOE-EIA and Onsite-Sycom

Partnerships

C H P FOR BUILDINGS INITIATIVE

US CHPA

INTERNATIONAL DISTRICT ENERGY ASSOCIATION

AGA

gti

PROPANE EXCEPTIONAL ENERGY

EPRI

NORA NATIONAL OILHEAT RESEARCH ALLIANCE

OAK RIDGE NATIONAL LABORATORY U. S. DEPARTMENT OF ENERGY

BROOKHAVEN NATIONAL LABORATORY

NREL

- Industry led effort to develop Thermally Activated Technologies (TAT)
- Integrated DG and TAT equipment into cooling, heating, and power systems
- Integrate CHP into buildings, campus facilities and district energy plants

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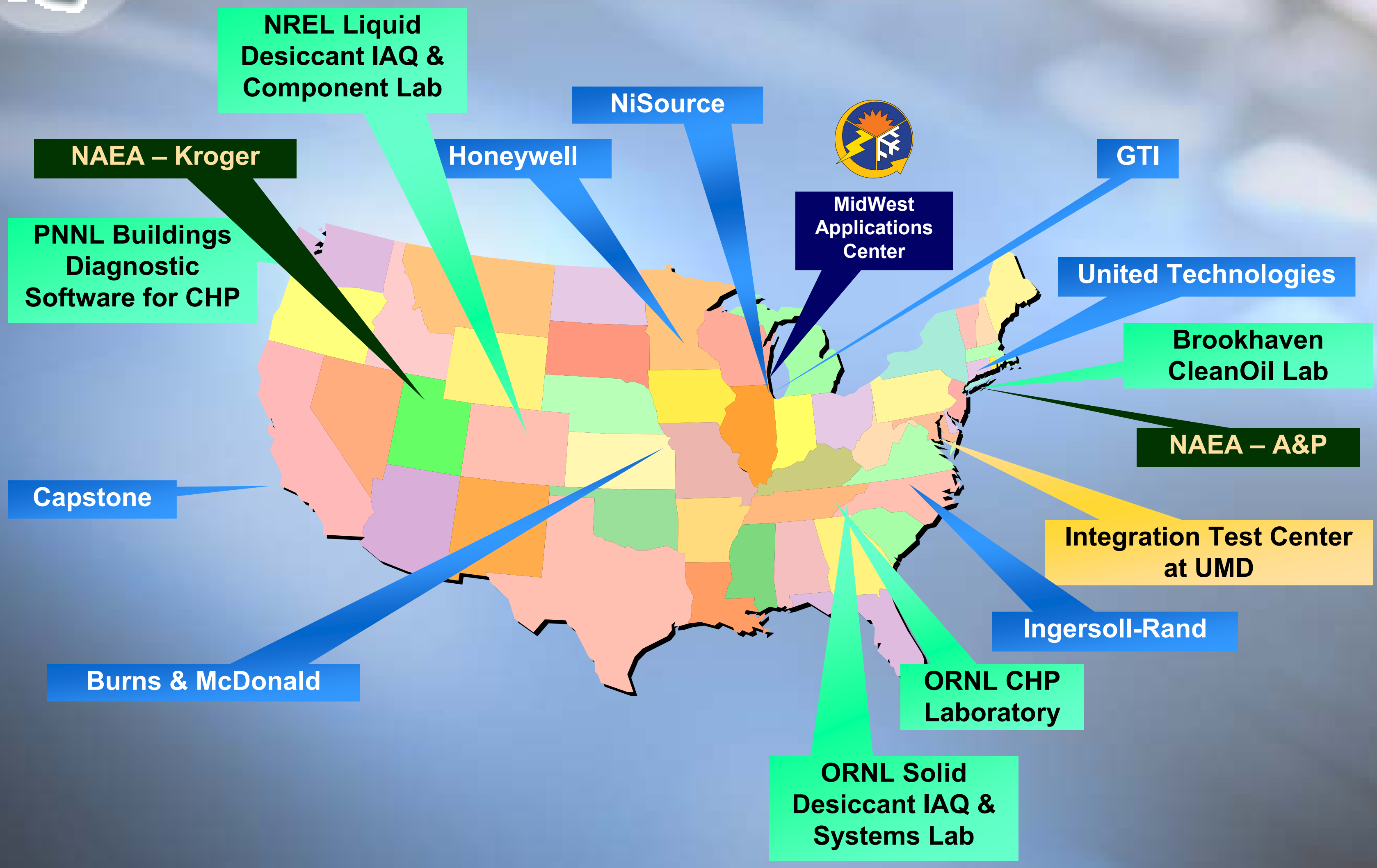
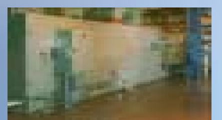
Partnerships - Diversified Portfolio

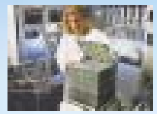


Thermally-Activated HVAC Technologies are Key to Improving Overall Efficiency of DG

Distributed Generation Technologies



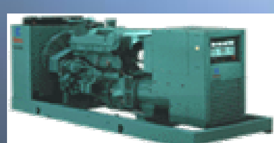
Gas-turbine



Solid Oxide Fuel Cell

Micro-turbine

Phosphoric Acid Fuel Cell



I.C. Engine

PEM Fuel Cell

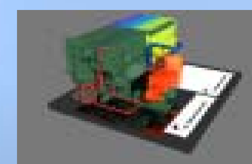
950ºF

600ºF

360ºF

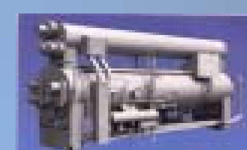
180ºF

Thermally-Activated HVAC Technologies



Triple-Effect Absorption

Double-Effect Absorption



Single-Effect Absorption

Desiccant Technology

Recoverable Energy Quality (Temperature) and HVAC Technology Match

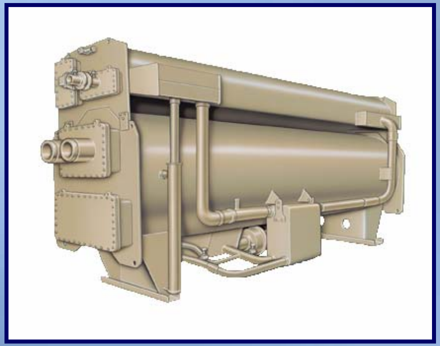
Thermally Activated Technology

- Absorption Cooling
- Ventilation Air Conditioning – Humidity Control
- Heat Recovery Devices

Absorption Chillers – Near Term

- Adapting existing technology for CHP
  - Exhaust-fired absorption chiller integration
  - Co-fired double-effect chillers
- Evaluating advanced triple-effect chillers

Exhaust Gas-Fired Single-Effect Broad USA Chiller



Trane Single Effect Steam/Hot Water Chiller

York 450 RT Triple Effect Chiller Prototype

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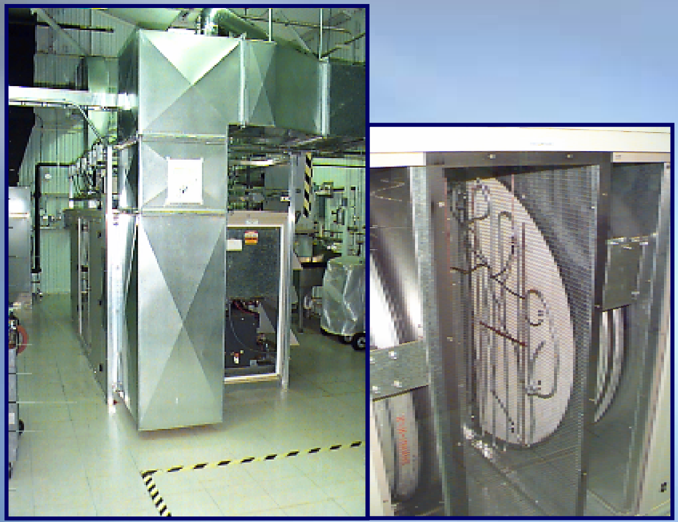
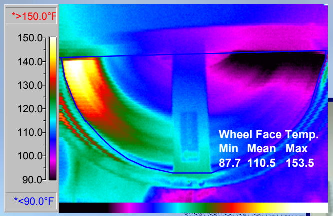
Absorption Chillers – Midterm

- Air-cooled absorption chillers < 150 RT for onsite power installations 400 kW
- Generator redesign to accept lower temperature/higher mass-flow exhaust gas streams

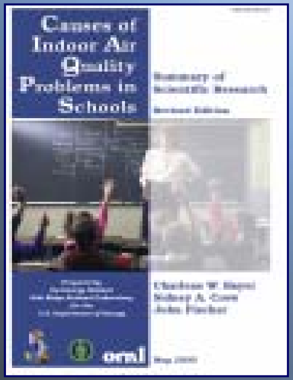
Desiccant Technologies – Near Term



Desiccant System Testing
ORNL



Desiccant Component Test Facility
NREL



Fundamental Field Research in Moisture, Ventilation, IAQ and Desiccant System Technology
ORNL

Liquid Desiccant Development
NREL

Desiccant Technologies – Midterm

- Combined ERV, hybrid and liquid desiccant system technologies
- Lower regeneration temperatures to match waste heat
- CHP system integration
- Indoor air protection (details later in this presentation)

Advanced Desiccant Prototype

Indoor Air Quality and Protection

Microturbine Regenerated Desiccant Concept

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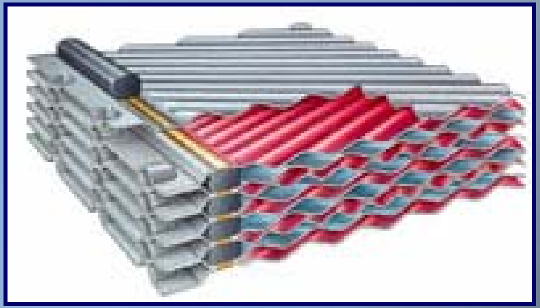
Heat Recovery Technologies

- Improve thermal efficiencies (e.g. microchannel, rotating HX's enhanced)
- Advanced materials (e.g. carbon foam)
- Reduce component costs
- CHP integration packaging

Potential Exhaust Gas/Jacket Water Heat Recovery HX



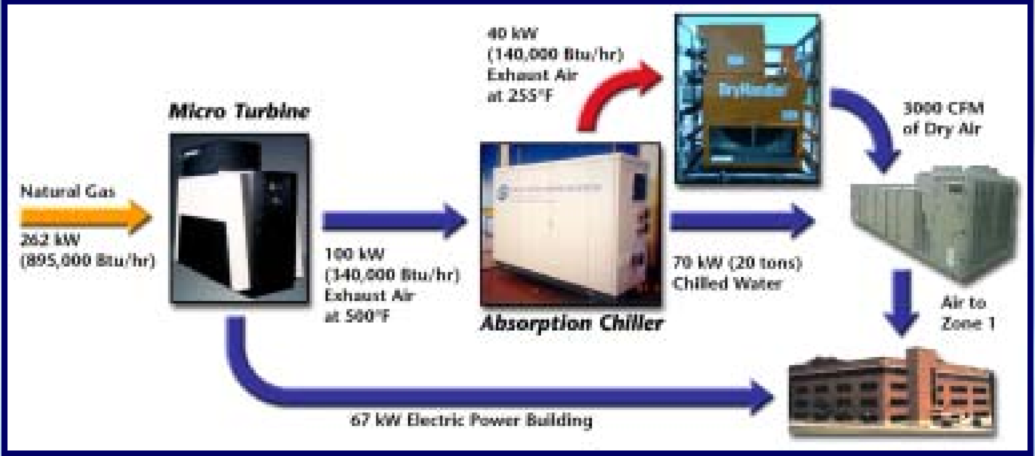
System Integration

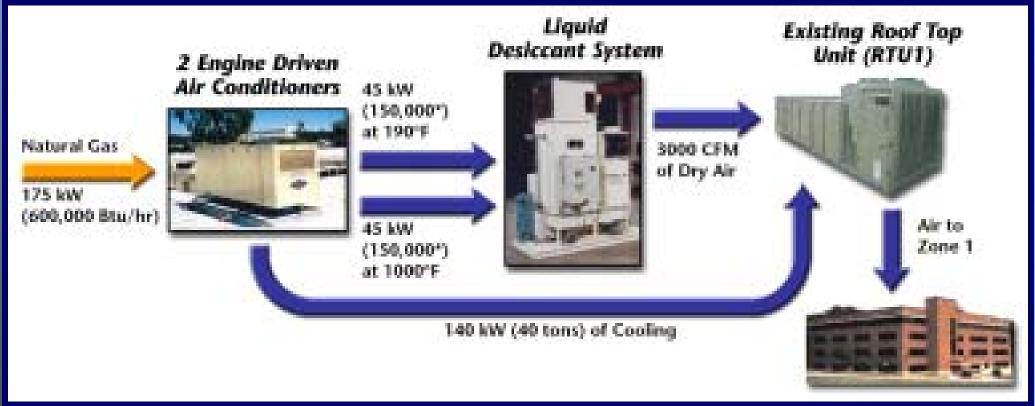
- Equipment Integration Research
- Building Integration Research
- Modular and Packaged System Development

CHP Integration Laboratory at ORNL
(part of DER Laboratory Network)

- **Evaluate electric/thermal parameters, design tools and analysis, integrate components to optimize DG/CHP system**


University Test Beds & CHP Applications





Dr. Reinhard Radermacher

- Integrate CHP into building, HVAC System
- Test advanced controls, diagnostics, operating strategies

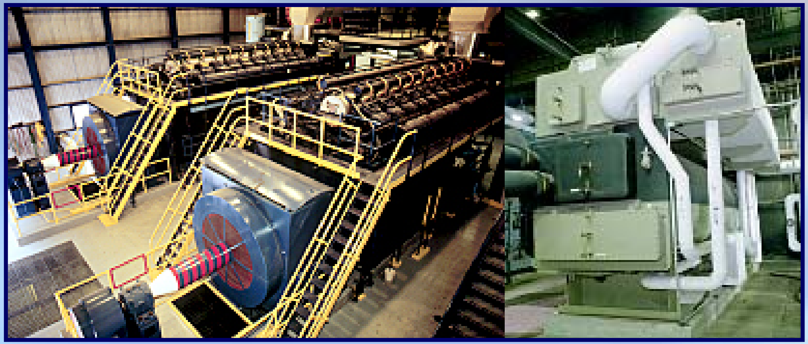
University of Illinois-Chicago: Midwest Regional CHP Applications Center

- Facilitate CHP projects, technical assistance
- Region-specific information, application knowledge

Building on a Strong Foundation

East Campus CHP Equipment

- 2 - 6.3 MWe Cooper engine-generators
- 2 - 3.8 MWe Wärtsilä engine generators
- 4 - Exhaust gas heat recovery systems
- 2 - Jacket water heat recovery systems
- 3 - Remote absorption chillers (1,500 RT)
- 1 - 1,000 RT Trane absorption chiller
- 3 - High temperature hot water generators
- 3 - York 2,000 RT electric chillers



East Campus Cooper Engine and Trane Absorber

Under 7-year Payback for operating savings

West Campus Equipment (New)

- 3 - 5.4 MWe Wärtsilä generators
- 3 - 7.0 MWe Solar turbine-generators
- 3 - HRSG – for the Solar Turbines

West Campus Solar Gas Turbine and Wartsilla Engine

Case Study provided by: Mid-West Application Center, University of Illinois - Chicago

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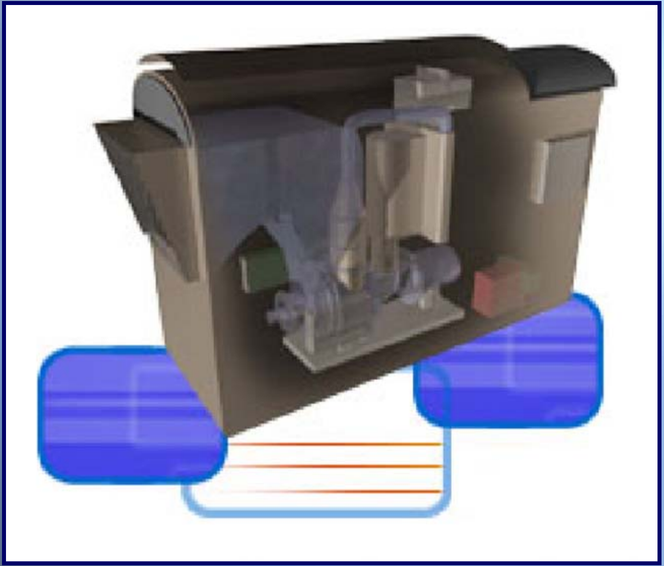
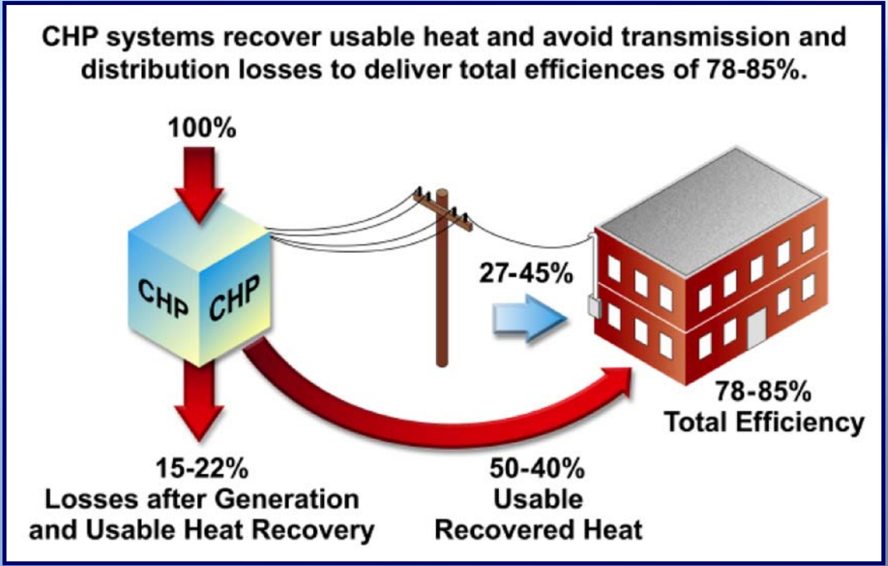
"First Generation" Packaged Cooling, Heating and Power Systems





Research, Development & Testing

Benefits of Packaged CHP Systems

- Compared to today's custom engineered CHP systems, packaged systems should:
  - Improve performance (efficiency)
  - Increase reliability
  - Reduce first (capital plus installation) cost
  - Reduce maintenance cost
- Packaged Systems will simplify the evaluation, specification, bidding and purchasing of CHP systems.
- This will enable many more architects, engineers, developers, and building owners to easily consider and use these systems.

Seven Industry Teams Selected for Award

- Honeywell Laboratories
- Burns and McDonnell
- Gas Technology Institute
- United Technologies Research Center
- Ingersoll Rand
- NiSource Energy Technologies
- Capstone Turbine Corporation

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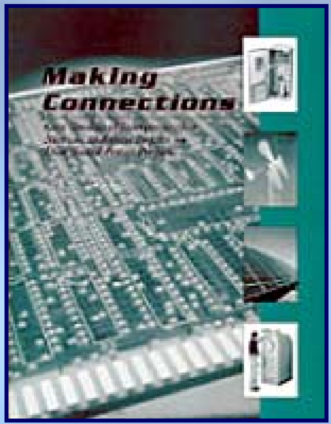
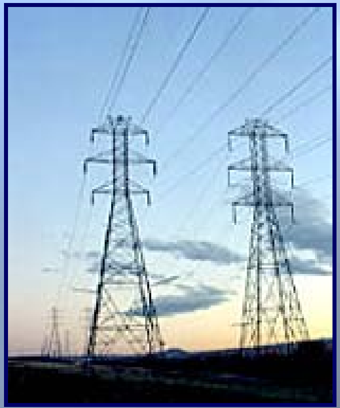
Distributed Energy Resources

INTEGRATING TECHNOLOGIES INTO PACKAGES

END-USE INTEGRATION



INTEGRATING DISTRIBUTED RESOURCES WITH GRID



ADVANCED RELIABLE ELECTRIC POWER

DER

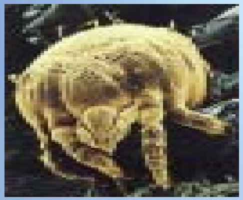
The Growing Importance of Desiccant Air Treatment Systems

Ren Anderson
Center for Program Planning and Technology Management
National Renewable Energy Laboratory

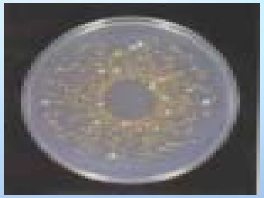
Desiccant Technology Program

- The DER Program is developing solid and liquid desiccant technology to
  - Recover thermal energy from building exhaust air
  - Pre-condition building ventilation air
  - Recover waste heat from onsite power generation
- In addition to reducing energy use, desiccant technology improves indoor environmental quality
  - Controls indoor humidity and reduces potential for mold and mildew growth
  - Increases ventilation
  - Removes airborne contaminants

Moisture Problems in Buildings



DUST MITES



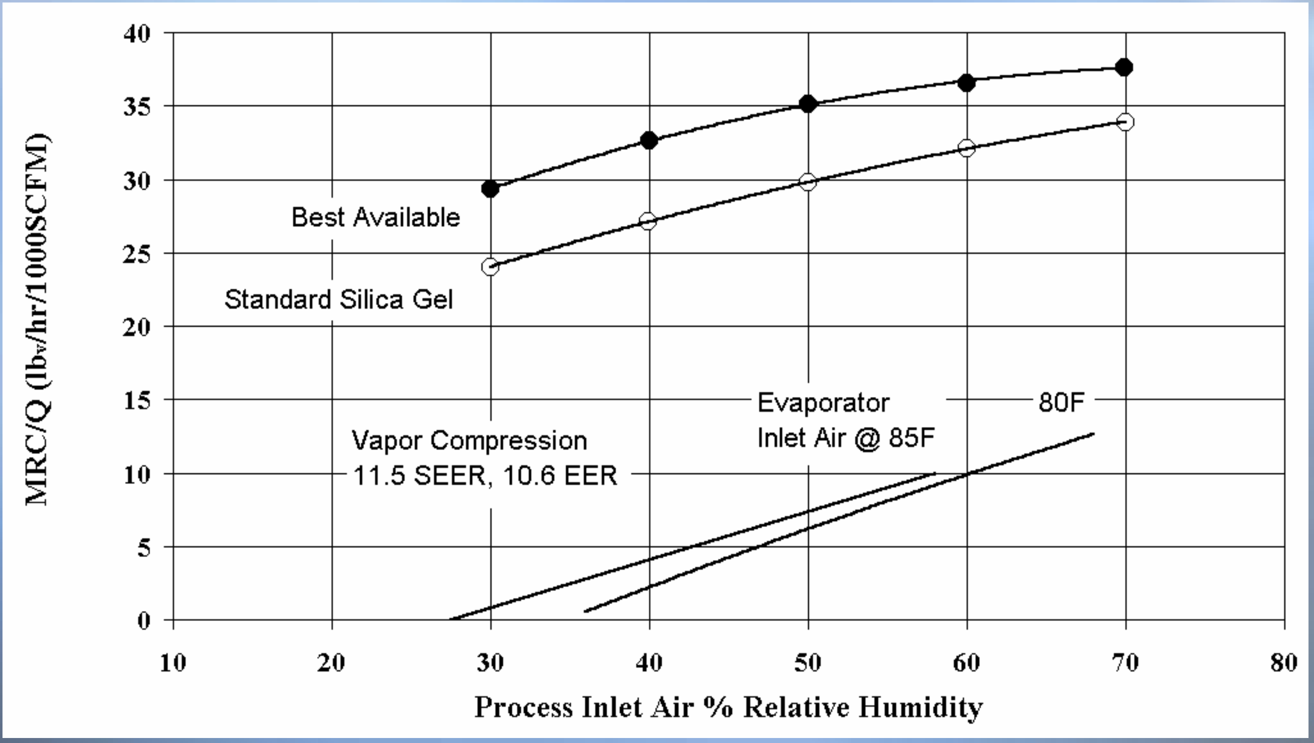
BACTERIA

FUNGUS

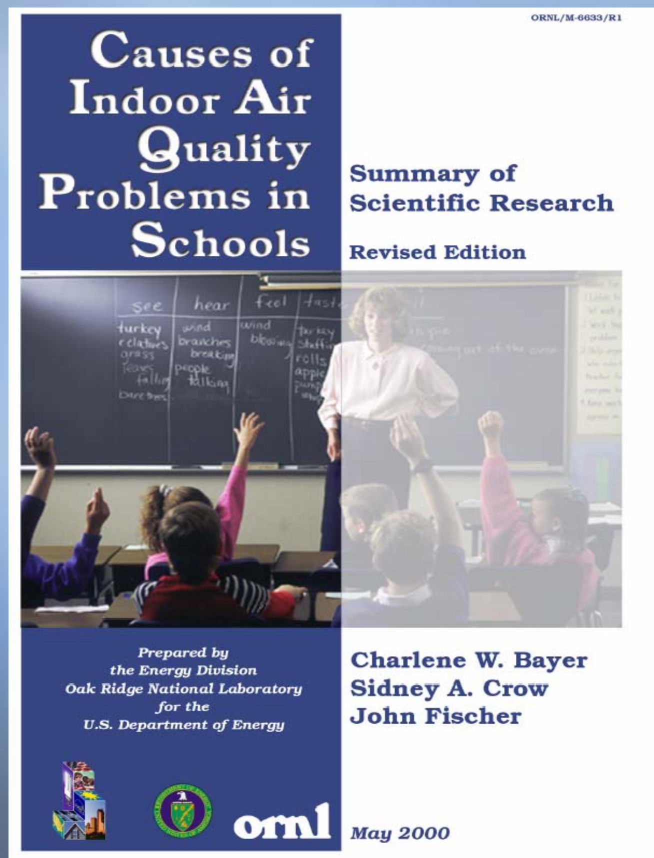
MOLD DAMAGE

CORROSION

Desiccant Moisture Control Benefits



Desiccant Moisture Control Benefits

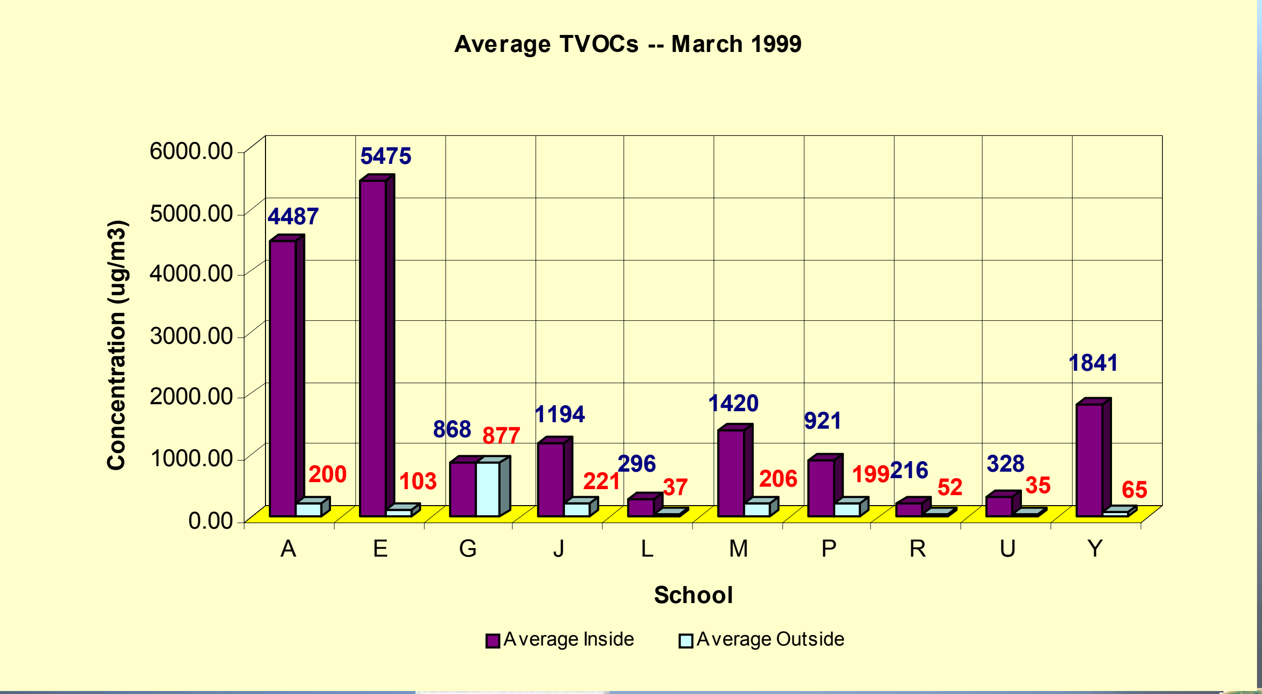


One in five U.S. schools have indoor air quality (IAQ) problems, a real concern in schools because

- *children are still developing physically and are more greatly affected by pollutants;*
- *the number of children with asthma is up 49% since 1982;*
- *children up to the age of 10 have three times as many colds as adults;*
- *poor IAQ can lead to drowsiness, headaches, and a lack of concentration.*

Desiccant Ventilation Benefits

The findings of the research project demonstrate that active humidity control and continuous ventilation will improve indoor environmental quality in schools.



Desiccant Component Energy Benefits

- Latent (moisture) loads account for about 30% of overall building cooling loads
- Heat recovery wheels can recover up to 90% of energy from building exhaust air and onsite power waste heat streams
- Desiccant components can reduce peak loads and AC equipment sizing requirements

Desiccant Energy Benefits

- Preconditioning of the outdoor air during the cooling season reduced chiller plant requirements by 440 tons.
- Preconditioning during the heating season reduced boiler plant requirements by 400 boiler horsepower.
- Boiler and chiller downsizing saved $500,000
- Demand and energy charges for the school were reduced by $120,000 annually.

NREL Advanced HVAC Test Facility

(DER Lab Network)

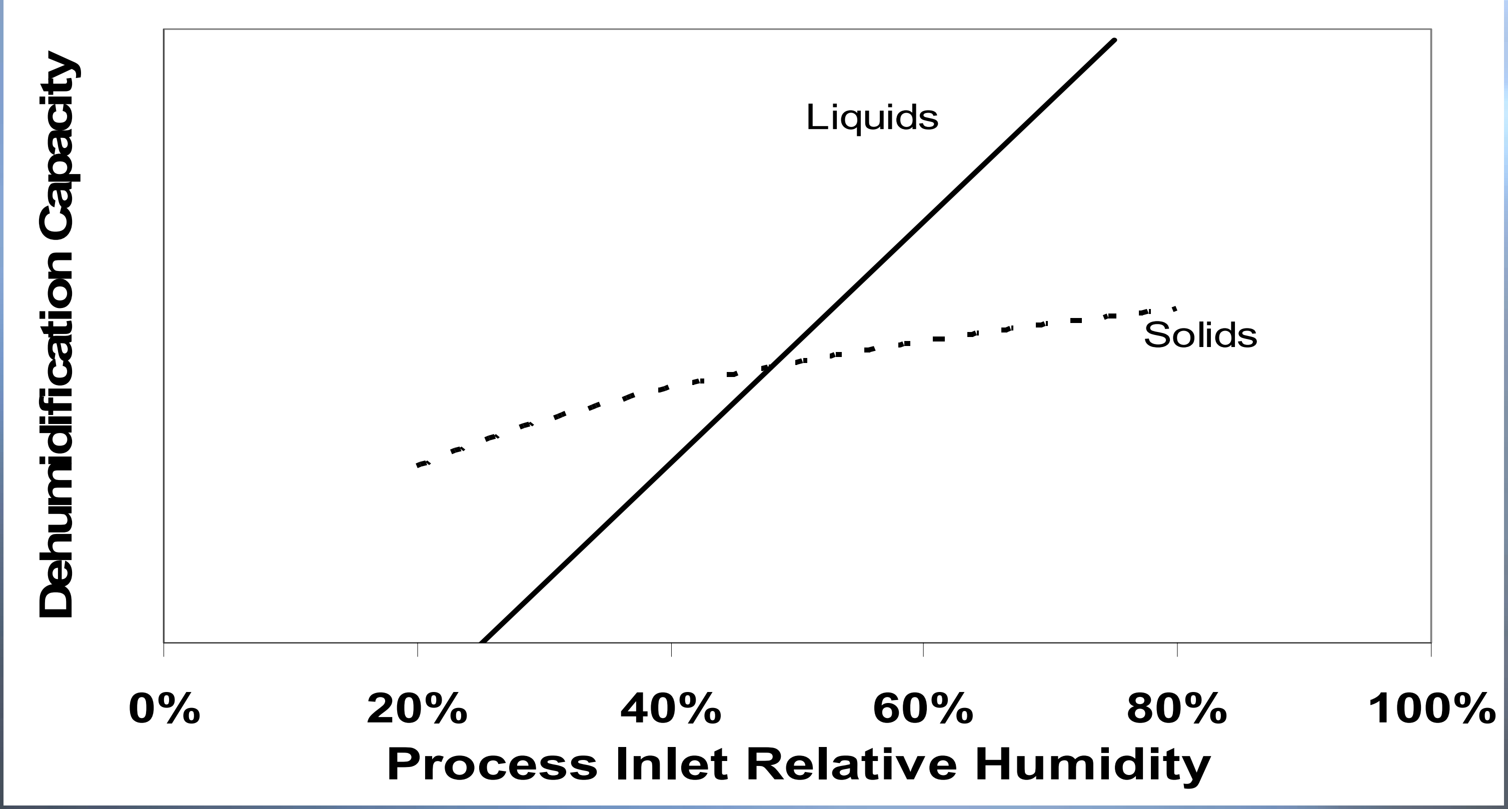
DER

Advanced HVAC Test Facility

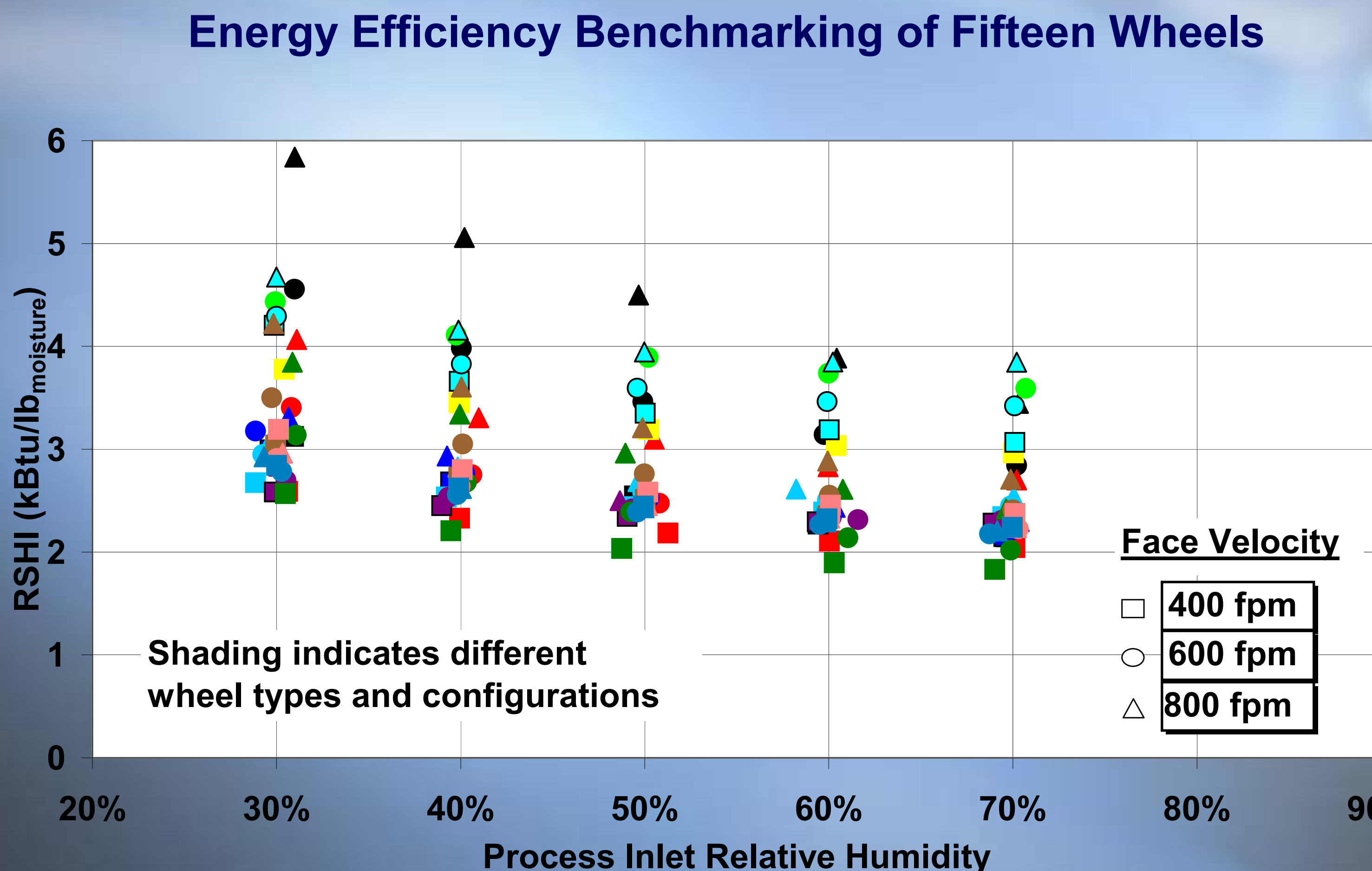
- Moisture removal capacity accuracy of 4-7%
- Flow rates from 100 to 5,000 SCFM
- Process temperatures: freezing to over 100 F
- Regeneration temperatures over 400 F
- Humidities from 20 to 280 +/-2 gr/lb
- Dewpoints measured to within +/- 0.27 F
- Solid and liquid desiccant test capability
- Contaminant removal test capability

Desiccant Component Characteristics

- Solids provide near term solutions
- Liquids promise long term performance enhancements

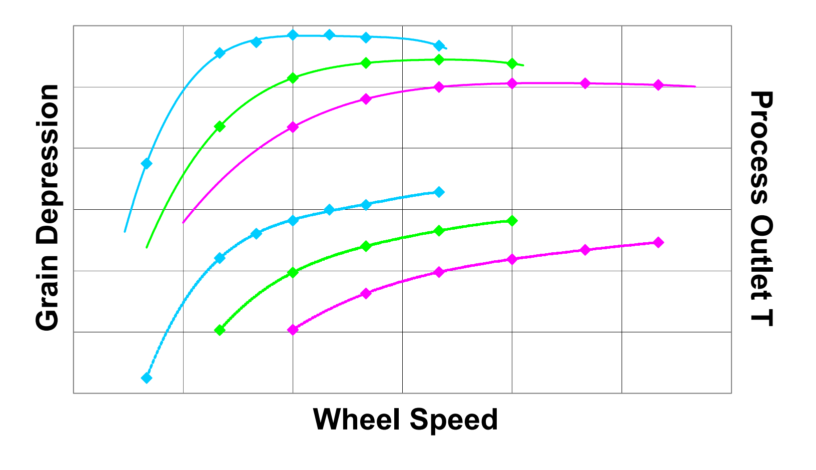


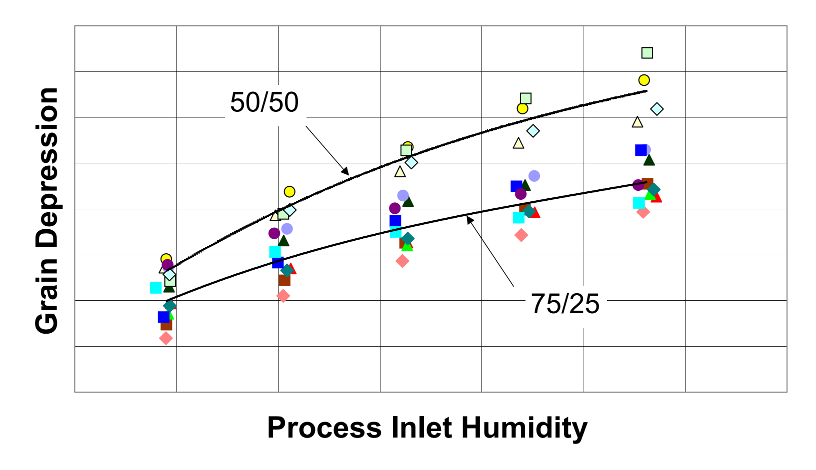
Solid Desiccant R&D

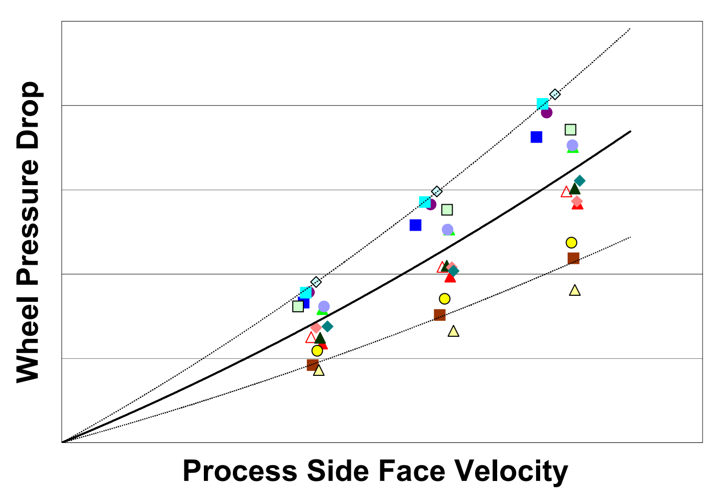


Solid Desiccant R&D

- Broad dehumidification performance maps, energy-efficiency, pressure drops, speed optimization, etc.
- Facilitated 10%-60% increase in enthalpy wheel latent effectiveness





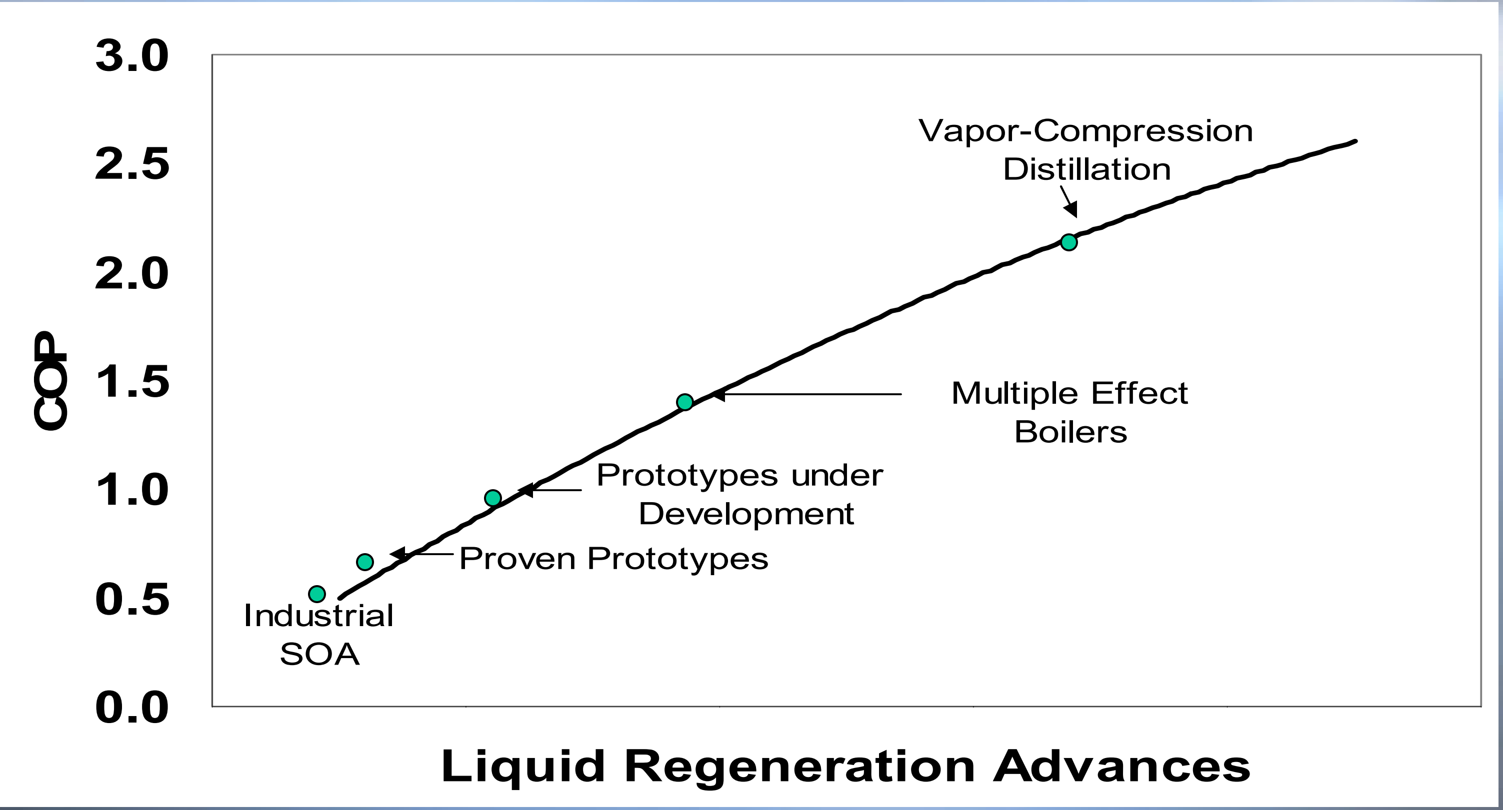


Liquid Desiccant R&D

- Proven high grain depression
- Excellent for DER
  - Distributed conditioning – centralized regeneration
  - Low temperature regeneration
- Biocidal air-cleaning capability

DER

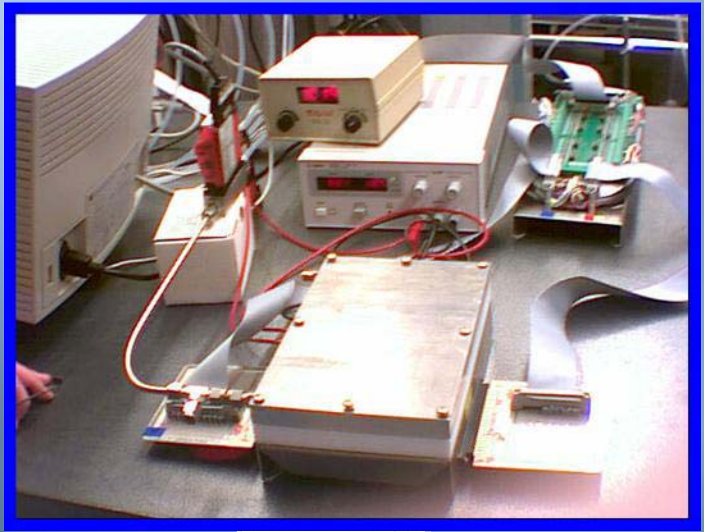
Liquid Desiccant R&D



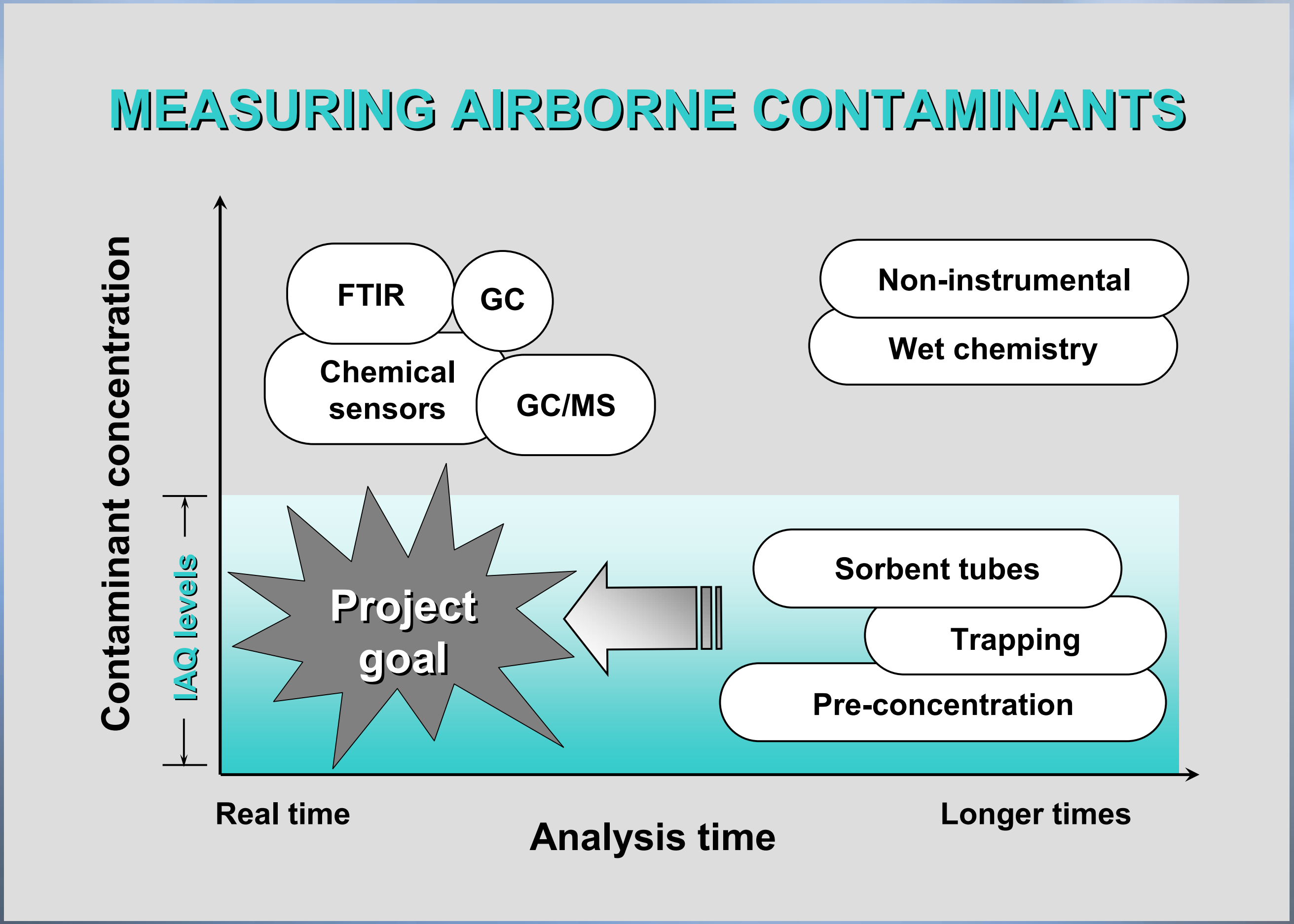
Actively Cooled Liquid Conditioner

Contaminant Sensing and Removal R&D

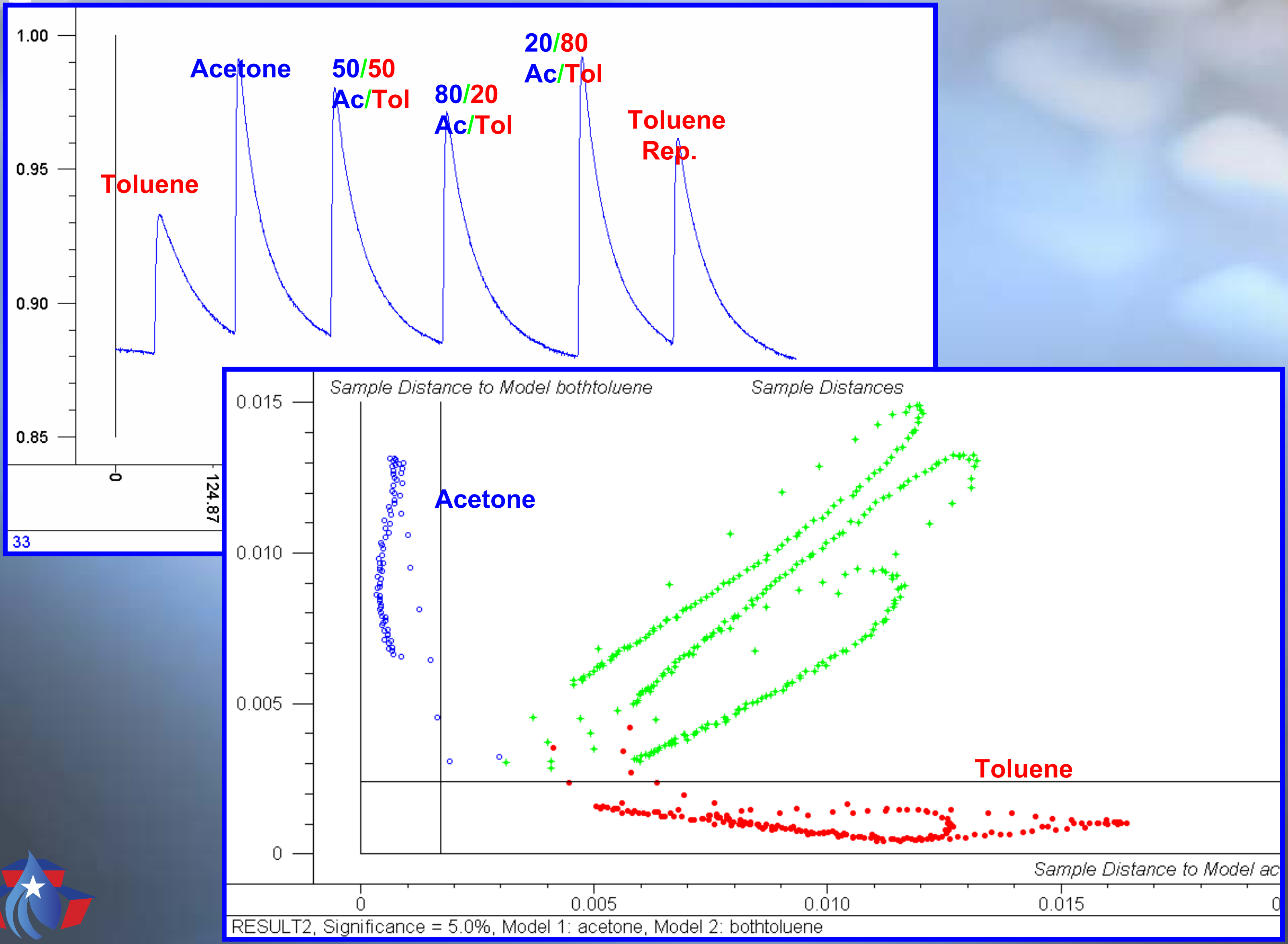
- Rapid laboratory evaluation of sorbents for contaminant removal performance at IEQ levels
- Contaminant removal performance validation of full-scale desiccant components
- Development of a real time IEQ analysis using commercial sensors and advanced data analysis (chemometrics)



Contaminant Sensing and Removal R&D



Contaminant Sensing and Removal R&D



Contaminant Sensing and Removal R&D

- Rapid contaminant removal performance data help improve sorbent formulation
- Full-scale performance validation of actual components at NREL will provide valuable information to component manufacturers
- A real-time IAQ sensor will provide critical information to building occupants and owners, saving energy through demand-controlled ventilation

Contaminant Sensing and Removal R&D

- EPA-compliant thermal desorption methods measure parts-per-billion (ppb) level contaminants in air
- Laboratory test rig and experimental protocol decreases sorbent evaluation times by a factor of 50
- Currently investigating the effect of humidity on "hydrophobic" sorbents

Post 9/11: A New Challenge for Liquid Desiccants: Indoor Environmental Security

Background

- The air cleaning benefits provided by liquid desiccant systems can be optimized to control the spread of bioaerosols.
- Liquid desiccant systems can play an important role as part of a comprehensive risk reduction strategy in anthrax and other airborne biological and chemical attacks.

Contaminant Control Strategies

- Source Control Strategies
  - Source removal
  - Local air treatment
  - Contaminant dilution
- Liquid desiccant systems can be used to provide contaminant removal and local air treatment

Why Pursue Liquid Desiccants for IEQ?

- Cost-effective system based on existing industrial equipment
- Industrial air-washer systems proven to reduce colony-forming-units by > 94%
- Desiccant liquids proven to be stable for HVAC applications

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Why Pursue Liquid Desiccants for IEQ?

Liquid Desiccant Ventilation Air Unit
Operating at Integration Test Center

Why Pursue Liquid Desiccants for IEQ?

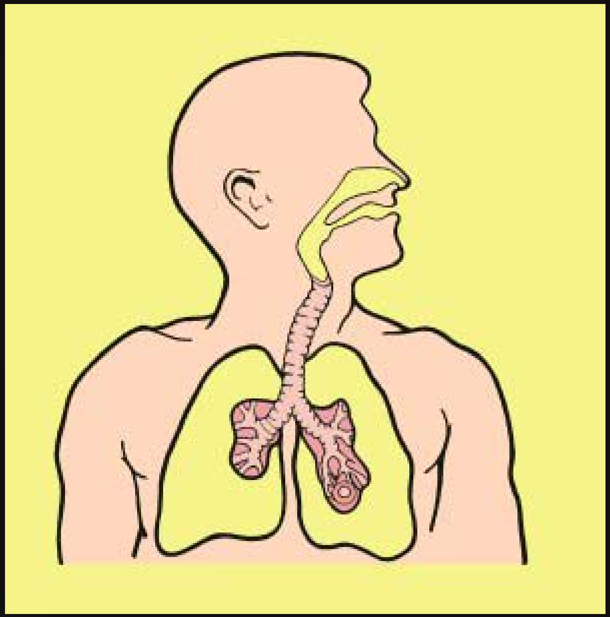
- Pathogens caught in air-washer cannot be shaken off and reintroduced into the building as with a filter
- Continuous agent destruction does not result in concentrated biohazard as with a filter
- Enhances other risk reduction strategies by preventing spread of contaminants

General Approach

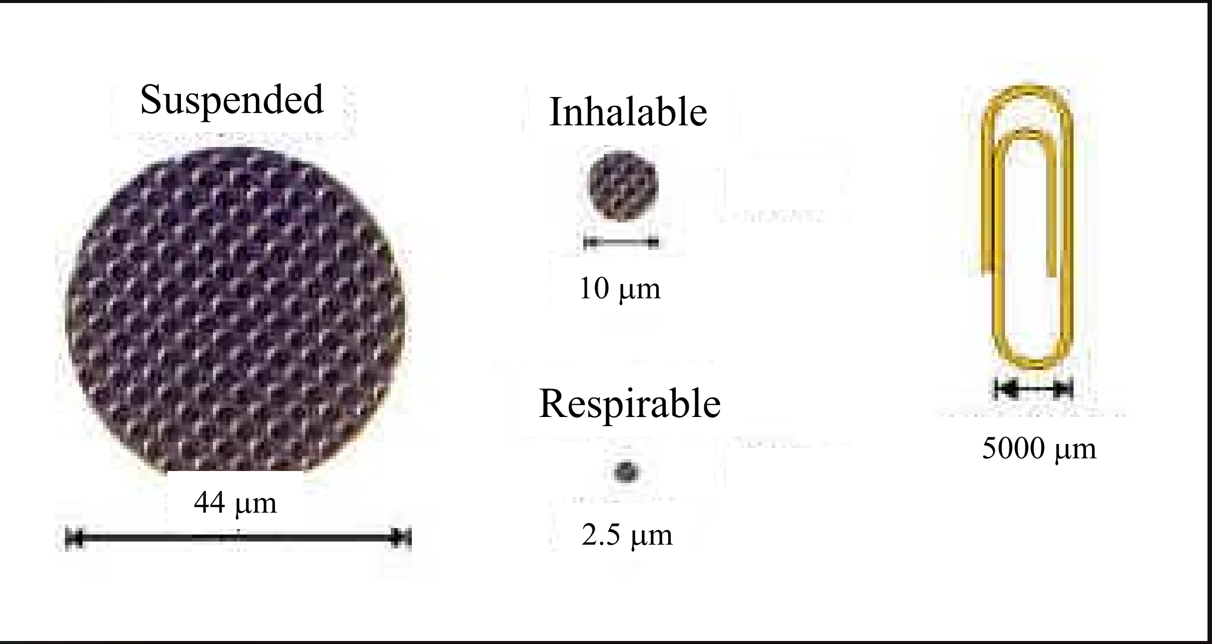
- Apply current technology to near-term applications protecting mailroom workers and ensuring clean makeup air, while working to enhance long term performance
  - Benchmark liquid desiccant systems ability to collect particles in the 0.1 micron to 5 micron range
  - Model HVAC zoning required to collect particles at emission source and protect the rest of the building
  - Benchmark liquid desiccant ability to destroy pathogens

Capture Approach

- Develop an air-cleaning system capable of removing airborne spores from fresh air supply and high-risk spaces (mailrooms)
- Primary health risks are associated with respirable particles less than 10 microns. Deep lung penetration is associated with particles smaller than 2.5 microns.



Capture Approach



2,000 particles, each 2.5 micrometers in diameter, when laid end-to-end, will stretch across the width of a small paper clip.

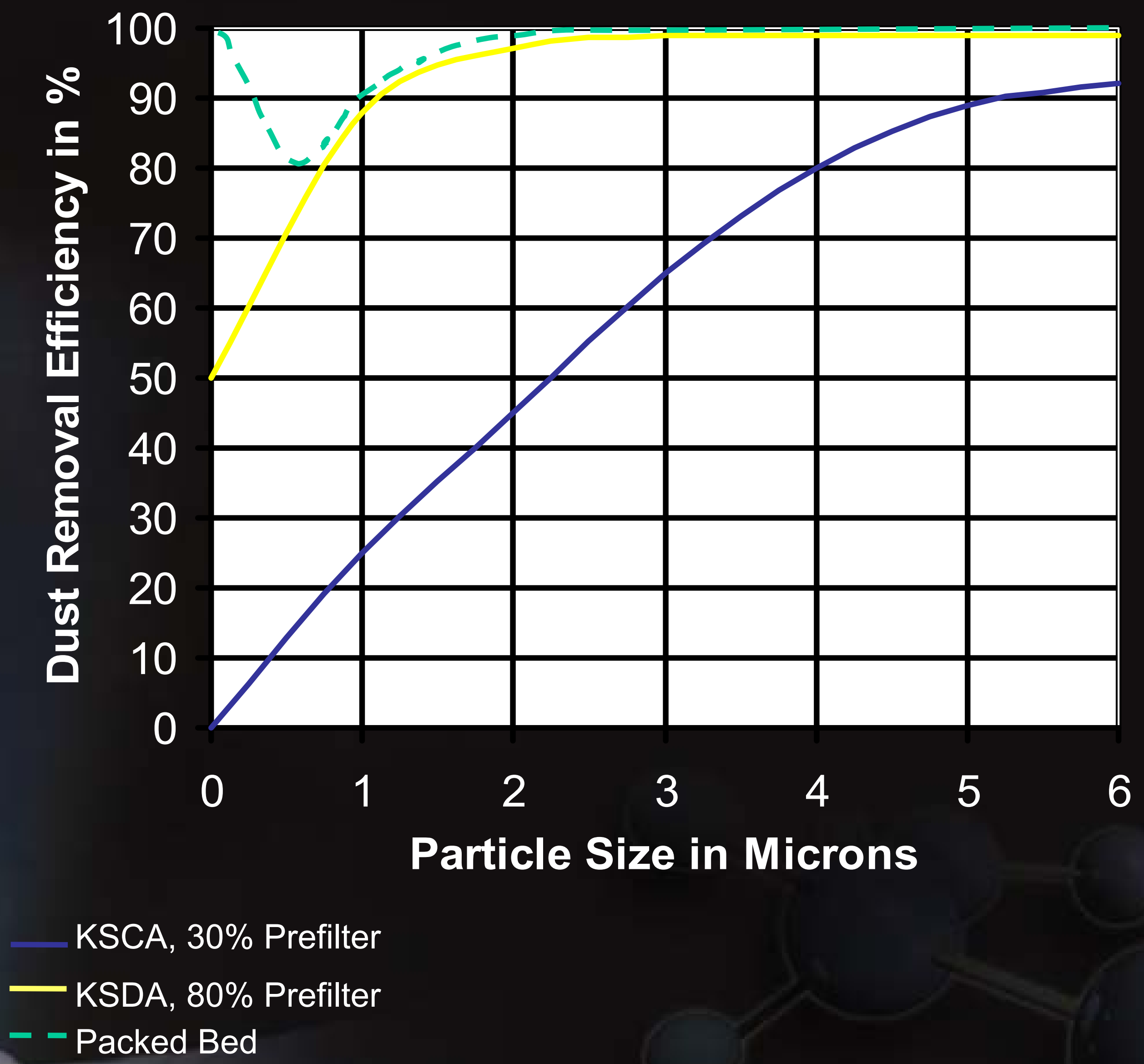
Capture Approach

- Inhalable particulate matter is the portion of the total air particulate matter that is 10 micrometers (μm) or less in diameter. Most particles with diameters greater than 10 μm will be caught in the nose and throat, never reaching the lungs.
- Particles between 2.5 and 10 μm will be caught by cilia lining the walls of the bronchial tubes; the cilia move the particles up and out of the lungs.
- Respirable particles are 2.5 μm or smaller in diameter and can penetrate deeper into the air sacs.

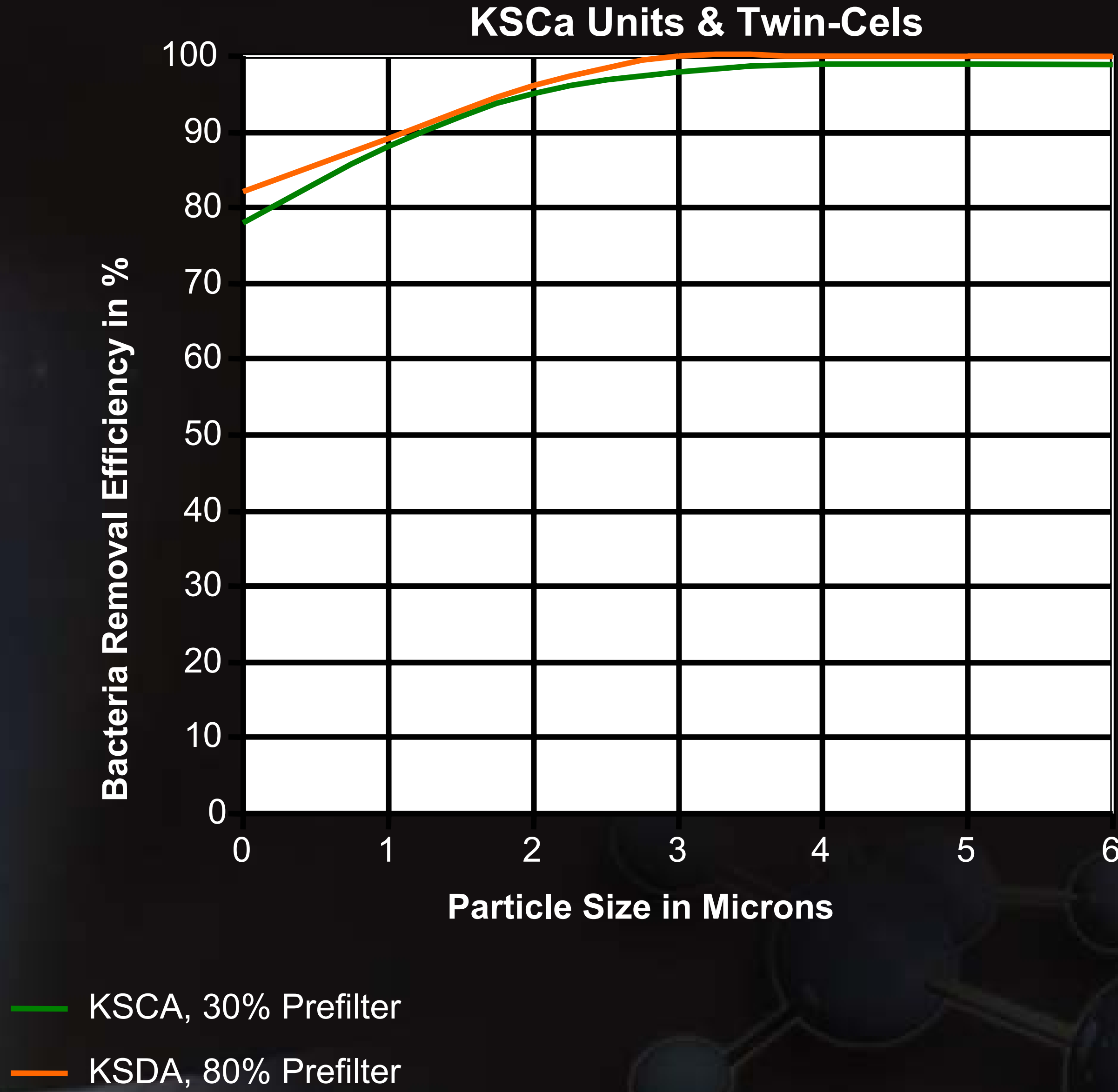
Capture Approach

- Current low-pressure packed bed conditioners are very efficient in removing particles over a broad size range and can be used for efficient first stage removal.
- Several second stage collector options are suited for efficient removal and treatment of smallest particles
  - Electrostatic precipitators
  - Electrostatically augmented scrubbers
  - Turbulent Filtration

Dust Removal Efficiency Vs. Particle Size



Bacteria Removal Efficiency Vs. Particle Size



Treatment Approach

- Benchmark liquid desiccants' ability to:
  - Directly attack pathogens/surrogates
  - Destroy pathogens as a function of time/temperature/ph
  - Evaluate methods of enhancing performance (conditioners, UV)
- Develop next generation liquid desiccant systems that meet commercial HVAC requirements:
  - First cost, operating cost
  - Maintenance, reliability
  - Develop real-time sensors to detect ultra-low concentrations of gases given off by active pathogens

Methods for Spore Inactivation

- Inactivation techniques fall into three categories:
  - **Chemical**
    - Ozone (O_3), Bleach, Hydrogen Peroxide (H_2O_2), Ethylene Oxide
  - **Thermal**
    - Dry Heat, Steam
  - **Radiative**
    - UV light, X-rays, g-rays, b-radiation, electron beam

- Inactivation mechanisms include DNA crosslinking and oxidative membrane damage

- Liquid desiccant systems are expected to collect and inactivate spores through a combination of exposure to elevated temperatures and chemical salts (lithium chloride).

Long Term Objectives

- Enhance liquid desiccant air-washing system's ability to trap and destroy a broad range of contaminants including VOC's, bacteria, viruses, and spores
- Design these devices to operate continuously as part of the normal HVAC system, protecting the fresh air supply and high-risk spaces like mailrooms
  - Low-cost, low-maintenance
  - Reliable, high efficiency, high IEQ
- Conduct field tests in Federal buildings

NREL IEQ Capabilities & Resources

- Team of Mechanical and Chemical Engineers, Chemists, Microbiologists, and Building Specialists
- Integration of HVAC and Air Quality Systems
- Catalyst and Adsorbent Chemistry, Engineering, and Evaluation
- Analytical Chemistry, Chemometrics, Microbiology
  - Identification of VOCs and microbial contaminants
  - GC, GCMS, HPLC, FTIR, Surface Science, Adsorption, Particle Size Analysis, Epifluorescence Microscopy, Culture Counting, Radio-Labeling of Cells and Spores,
  - Growth study and killing of bacteria and spores including Bacillus

NREL IEQ Capabilities & Resources

- Design and Modeling for Air Purification Systems
- Expertise and Test Facilities for Evaluation of Desiccant Systems
- Material Preparation and Coating Methodology
- Photocatalytic Processes and Engineering for VOC and Bioaerosol Control
- Effective Collaborations and Subcontracting with Industry, Universities, and Government Agencies
- CFD airflow modeling and airflow measurement

Photobiology Lab

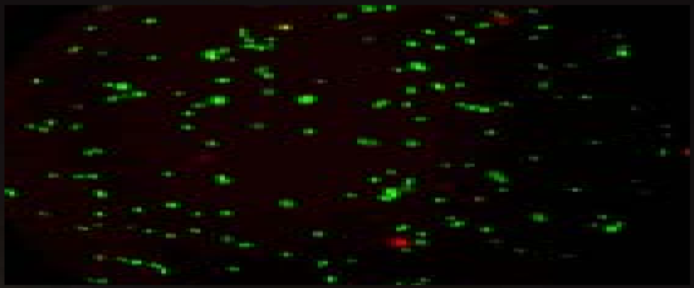
- Microbiological, biochemical, and molecular biological work
- Laminar flow hoods, UV-VIS-NIR spectrophotometers, HPLC, GC, microscopes, centrifuges, autoclave
- PCR systems to culture microorganisms, isolate sub-cellular fractions, and perform gene cloning
- Isolation of pure spores from Bacillus subtilis and subsequent inactivation by photocatalytic oxidation

Photobiology Lab

Microscope Documentation System (MDS)

- Nikon LabPhoto2 Epifluorescence Microscope
- Image analysis software
- Triple-band optical filter set (Chroma 61002

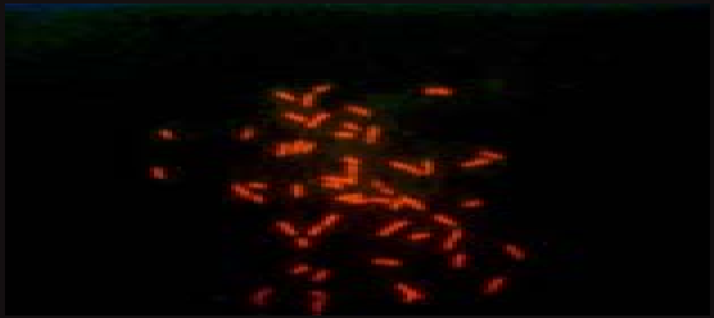
Real Time Evaluation of E. coli Viability



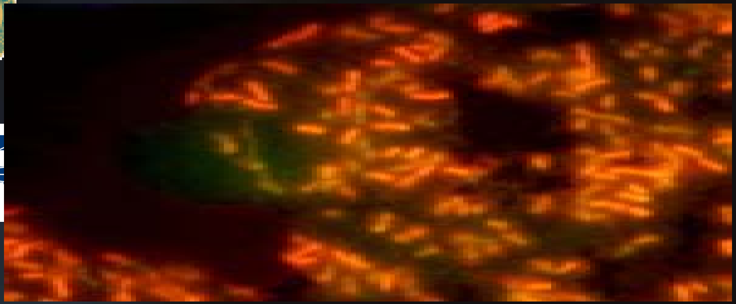
T = 0 MIN

Epifluorescence Microscopy is used to determine cell viability – green fluorescence indicates the cell membrane is intact and red indicates the membrane is damaged. At 45-60 min the cell structure is severely altered and the cells are dead.

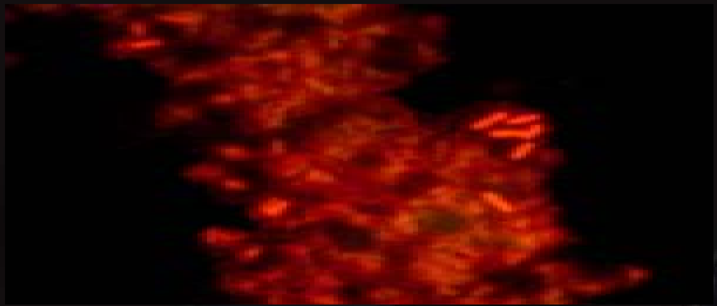
T = 15 MIN



T = 30 MIN



T = 45 MIN



T = 60 MIN

Questions