High Power Lithium-ion Battery Technology

For

- Plug-in-Hybrid Electric Vehicles
- Power Tools
- Medical Devices
- Consumer Electronics

- Adaptable to any existing lithium-ion technology
- Requires no additional instrumentation setup
- 20-50% power performance improvement
- 10% volumetric energy density improvement
- Promised longer lifetimes

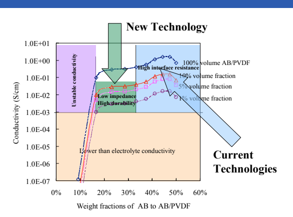
Researchers at Berkeley Lab:
Gao Liu, Vince Battaglia, and Honghe Zheng

The Technology:

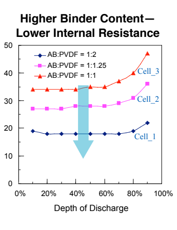
A few percent change of existing formulation brings significant power performance improvement.

Three Types of Full Lithium-ion Cells
Cathode: AB, PVDF, active material, same graphite anode

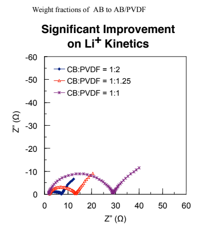
	Cell_1	Cell_2	Cell_3
AB (w)	4%	4%	4%
PVDF (w)	8%	5%	4%
Active material (w)	88%	91%	92%
AB:PVDF	1:2	1:1.25	1:1
Electrode thickness (?m)	35	39	31
Porosity	35%	35%	35%
Capacity (mAh/cm²)	1.3	1.58	1.30
Counter electrode	MCMB10-28	MCMB10-28	MCMB10-28



Higher Binder Content—Lower Internal Resistance



Significant Improvement on Li+ Kinetics



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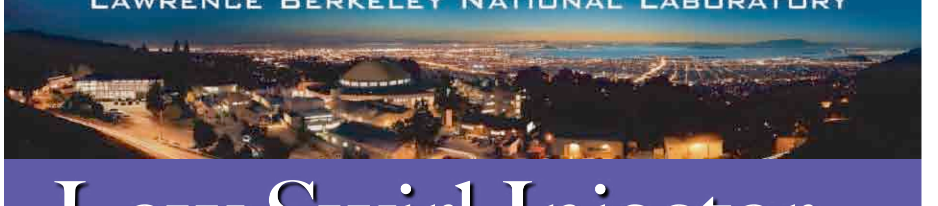
Lawrence Berkeley National Laboratory

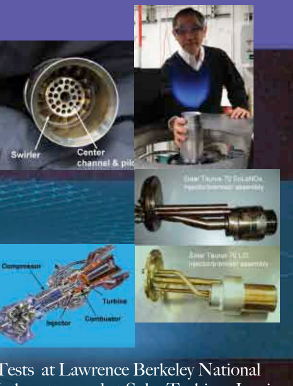


Low Swirl Injector

for Fuel-Flexible, Near-Zero Emissions Gas Turbines

The Low Swirl Injector (LSI):

- is a simple and cost-effective ultrlow-emissions combustion technolgy
- burns a variety of fuels, including natural gas, biogas, syngas, and hydrogen
- adaptable to gas turbines and heating equipment of all sizes
- could eliminate millions of tons of carbon dioxide and thousands of tons of nitrogen oxides (NO_2) from clean-coal IGCC power plants each year



Tests at Lawrence Berkeley National Laboratory and at Solar Turbines Inc. in its Taurus 70 gas turbine for electricity generation showed that the combustors with the LSI emit 2 parts per million of NO_X (corrected to 15% oxygen)—more than five times less than current low-NO_X technology.

Developed by:
Robert Cheng and David Littlejohn, Lawrence Berkeley National Laboratory
Kennth O. Smith and Wazeem Nazeer, Solar Turbines Inc., San Diego

2007 R&D 100 Award
Lawrence Berkeley National Laboratory

Office of Science
U.S. Department of Energy

Ventilation System Risk Factors for Building-Related Symptoms in U.S. Office Buildings—the U.S. EPA BASE Study

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ABSTRACT

Building-related symptoms in office workers worldwide are common, but of uncertain etiology. One cause may be contaminant exposures resulting from characteristics of heating, ventilating, and air-conditioning (HVAC) systems. We analyzed data from 97 representative air-conditioned U.S. office buildings collected by the U.S. EPA in the Building Assessment and Survey Evaluation (BASE) study. Using logistic regression models with generalized estimating equations, we estimated odds ratios (OR) and 95% conf dence intervals (CI) for associations between building-related symptom outcomes and HVAC characteristics.

Outdoor air intakes less than 60 m above ground (about 18 stories) were associated with increases in most symptoms; e.g., for upper respiratory symptoms, OR (CI) for intake heights 30 to 60 m, 0 to <30 m, and below ground were 2.7 (1.8-4.1), 2.0 (1.4-1.9), and 2.1 (1.4-3.2), respectively. Humidification systems in poor condition were associated with increased upper respiratory symptoms, eye symptoms, fatigue/difficulty concentrating, and skin symptoms, with OR (CI)=1.5 (1.1-2.0), 1.5 (1.0-2.0), 1.7 (1.2-2.3), and 1.6 (1.0-2.7), respectively. Cleaning of cooling coils and drain pans only annually was associated with increased eye symptoms and headache, with OR (CI)= 1.7 (1.2-2.4) and 1.6 (1.1-1.5).

Increased symptoms may be due to uncharacterized microbial exposures from poorly maintained ventilation systems, and to the documented greater levels of vehicular pollutants from air intakes nearer the ground.

Replication of these findings is needed. Development of prevention strategies could have important health benefits for the large, and increasing, population of indoor workers worldwide.

BACKGROUND

- The presence of central air-conditioning (AC) systems in office buildings has been consistently associated with increases in building-related symptoms (by 50–100%) among occupants. Symptoms include lower respiratory, upper respiratory, eye, skin, headache, and fatigue symptoms
- Exposures and biologic responses are not understood. Measured known contaminants do not explain these relationships. Associations are not due to decreased ventilation or decreased temperature control with AC
- Current hypothesis:
  - AC systems can produce or disseminate contaminants that cause health responses presenting as nonspecific symptoms
  - Responsible contaminants (microbiological or chemical) are not measured by conventional exposure assessment methods
  - Mechanism may parallel that underlying consistent associations of dampness in housing with respiratory effects—also not explained by conventional microbiologic assays
- The Building Assessment Survey and Evaluation (BASE) Study (by the U.S. Environmental Protection Agency) studied indoor environments and occupant responses in a representative sample of 100 U.S. office buildings, including:
  - building-related symptoms of occupants
  - demographic and job information on occupants
  - detailed description of ventilation systems and buildings
  - measured contaminants, ventilation rate, thermal parameters
- This analysis examined associations, in 97 buildings with AC, between building-related symptoms and features of heating, ventilating, and air-conditioning (HVAC) systems hypothesized to increase probability of:
  - moisture and microbiologic contamination, or
  - outdoor pollutants entering the indoor air

METHODS

HEALTH OUTCOMES

- Outcomes analyzed were "frequent, building-related symptoms," defined as:
  - Occurring at least one day a week at work
  - Improving when away from work
- Symptom outcomes analyzed
  - Lower respiratory symptoms—at least one of wheeze, shortness of breath, chest tightness
  - Upper respiratory—at least one of stuffy or runny nose, sneezing, or sore or dry throat
  - Eye symptoms—dry, itching, or irritated eyes
  - Fatigue or difficulty concentrating
  - Headache
  - Skin symptoms—dry, itching or irritated skin

RISK FACTORS

- 37 risk factors initially considered
- Ventilation system design and configuration
  - physical characteristics predicted to increase risk of moisture or air contaminants
- Ventilation system condition and maintenance
  - condition and cleanliness levels (from inspection) predicted to increase risk of moisture/contamination
  - maintenance practices(from interviews with facility engineers) predicted to increase risk of moisture / contamination

ANALYSES

- Eliminated, combined, and collapsed risk factors as necessary (for missing values, small categories, etc.) for inclusion in analyses
- Constructed separate multivariate logistic regression models (SAS Proc Logistic) for each symptom outcome
- Final estimates from logistic models with Generalized Estimating Equation (GEE, SAS Proc Genmod) to adjust for potential correlation among workers in each building
- Estimated associations as odds ratios (ORs) and 95% confidence intervals (CIs)

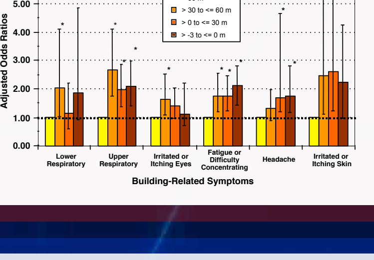
RESULTS

- Assessed 37 initial risk factors for association with 7 symptom outcomes (~260 assessments)
- Observed 23 associations with at least one categorical p-value <0.05 (all among 9 risk factors)
- Table 1 shows risk factors associated significantly with relatively larger numbers of symptoms (assuming that association of a risk factor with only one symptom is more likely to be by chance)
- Cough (the least frequent outcome) is not shown here, as no meaningful associations were found
- Humidification systems in good condition were not associated with increased symptoms (compared to no humidification), but were associated with a significant decrease in skin symptoms: OR (CI)=0.5 (0.2-0.96)

Table 1. Adjusted odds ratios (OR) and 95% confidence intervals (CI) for ventilation system risk factors and building-related symptoms in the EPA BASE data (* = p-value <0.05)

Risk Factor	Weekly, Building-Related Symptom Outcomes: Lower Respiratory		Upper Respiratory		Irritated or Itching Eyes		Fatigue or Difficulty Concentrating		Headache		Irritated or Itching Skin	
	OR	95% CI	OR	95% CI	OR	95% CI	OR	95% CI	OR	95% CI	OR	95% CI
Central humidification												
no humidification	. . .	. . .	1.00	. . .	1.00	. . .	1.00	. . .	1.00	. . .	1.00	. . .
humidified—good or fair maintenance/ condition	. . .	. . .	1.14	0.84, 1.55	0.91	0.64, 1.29	0.79	0.56, 1.10	1.34	0.98, 1.85	0.47*	0.23, 0.96
humidified—poor maintenance/ condition	. . .	. . .	1.49*	1.09, 2.05	1.46*	1.05, 2.03	1.67*	1.23, 2.26	1.34	0.97, 1.85	1.65*	1.02, 2.68
Cleaning of cooling coils/drain pans												
semi-annually or more	1.00	. . .	. . .	. . .	1.00	. . .	1.00	. . .	1.00	. . .	. . .	. . .
annually	1.92	0.89, 4.15	. . .	. . .	1.67*	1.15, 2.41	1.36	0.97, 1.91	1.57*	1.09, 2.25	. . .	. . .
as needed or none	1.56	0.71, 3.42	. . .	. . .	1.48*	1.01, 2.17	1.13	0.80, 1.59	1.47*	1.03, 2.11	. . .	. . .
Inspection of HVAC components												
semi-quarterly or more	1.00	. . .	1.00	. . .	1.00	. . .	1.00	. . .	1.00	. . .	. . .	. . .
quarterly to annually	1.17	0.80, 1.70	0.75	0.52, 1.07	0.94	0.76, 1.17	1.08	0.85, 1.36	0.75*	0.61, 0.91	. . .	. . .
as needed or none	1.50	0.95, 2.37	1.48	0.98, 2.24	1.60*	1.21, 2.10	2.18*	1.55, 3.06	0.88	0.67, 1.16	. . .	. . .
Height of outdoor air intake above ground												
> 60 m	1.00	. . .	1.00	. . .	1.00	. . .	1.00	. . .	1.00	. . .	1.00	. . .
> 30 to <= 60 m	2.04*	1.01, 4.11	2.67*	1.75, 4.09	1.64*	1.07, 2.53	1.74*	1.18, 2.56	1.32	0.88, 1.98	2.47*	1.11, 5.47
> 0 to <= 30 m	1.14	0.59, 2.21	1.98*	1.37, 2.86	1.40	0.96, 2.04	1.74*	1.23, 2.47	1.69*	1.18, 2.41	2.62*	1.22, 5.59
> -3 to <= 0 m	1.87	0.91, 3.86	2.11*	1.40, 3.18	1.13	0.70, 1.81	2.13*	1.41, 3.21	1.74*	1.15, 2.62	2.25	0.97, 5.22
Number of observations (occupants) in model	4,022		3,718		3,688		4,106		4,018		3,884	
Number of buildings in model	95		85		84		95		95		95	

Figure 1. Association Between Height of Outdoor Air Intake and Building-Related Symptoms (* = p-value <0.05)



- Humidification systems in poor condition were associated with increased upper respiratory symptoms, eye symptoms, fatigue/difficulty concentrating, and skin symptoms, with significant ORs from 1.5–1.7
- Cleaning of cooling coils and drain pans scheduled no more than annually was associated with increased eye symptoms and headache, with ORs of 1.7 and 1.6. Lack of scheduled inspection for HVAC systems was associated with increased eye symptoms and fatigue—ORs of 1.6 and 2.2
- Unexpectedly, outdoor air intakes less than 60 m above ground (about 18 stories) were associated with increases in most symptoms (Figures 1, 2); e.g., for upper respiratory symptoms, OR (CI) for intake heights 30 to 60 m, 0 to <30 m, and below-ground were 2.7, 2.0, and 2.1. This pattern also paralleled outside pollutant concentrations (Figure 3)

Figure 2. Crude prevalence of building-related upper respiratory symptoms as a function of height above ground level of the outdoor intake, in U.S. office buildings

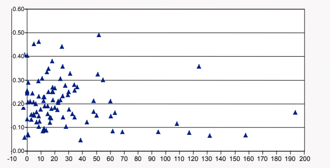
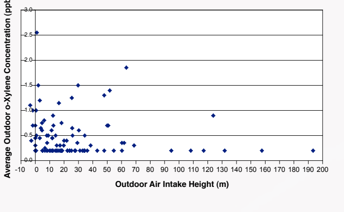


Figure 3. Average outdoor concentration of o-xylene (from SUMMA canisters at outdoor intake) as a function of height above ground level in U.S. office buildings



DISCUSSION

- The BASE Study is the largest study in the U.S. of symptoms and building environments in office buildings selected without regard to complaints
- The findings confirm some predicted increased risks for presence of AC components involving moisture: humidification and cooling coils/drain pans, but only in conjunction with poor condition or infrequent cleaning (Table 1)
- Some increased risk was identified for lack of scheduled inspection of ventilation system (Table 1)
- Surprisingly strong and consistent increased risks were found for outdoor air intakes less than 60 m above the ground (Table 1, Figure 1)
  - Vehicular pollutants at the outdoor air intake showed a similar pattern with height. Figure 2 shows o-xylene (patterns similar for benzene and toluene). Concentrations unexpectedly remained high up till 60 m, as did symptom prevalences
  - Outdoor and indoor concentrations of vehicular pollutants were also correlated (not shown)
  - These findings suggest that vehicular pollutants entering building ventilation systems, or pollants correlated with them, may be related to the unexpected increase in building-related symptoms associated with outdoor air intakes closer to the ground
- Objective methods to measure health outcomes and causal exposures are critical to improve effectiveness of this research, in order to better identify causal exposures and prevention strategies