Continued M&V by BAS: A Method to Assure Building Performance in terms of IEQ & Energy efficiency

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Overview of the presentation

Section-01: Define IAQ / IEQ, its Fundamental objectives, drivers of IAQ ,Sources of contaminants & concerns and guidelines

Section-02: Identify the "Problem twins" & their conflicting relations with referred standards & guidelines.

Section-03: Introduce whole building concepts and consequences of Continuous Degradation, poor IAQ, Continuous Accountability, and Building Diagnostics

Section-04: Suggested ways of striking a balance between the "problem twins" to deliver IAQ at an optimal cost, Continued M&V using BAS for reporting and trend analysis.

Section1: What is IAQ / IEQ ?

- **Indoor air (environment) quality is a cumulative index of humidity and temperature including the contaminants, pollutants , of an indoor space (either mechanically ventilated OR air conditioned).**
- ***"The nature of air that affects the health and well-being of occupants"***
- **Its either GOOD (acceptable) or POOR IAQ/ IEQ, which can only be assessed by conducting continuous and real time checks, measurements and verifications, coupled with occupant survey.**

Section1:What is Health ?

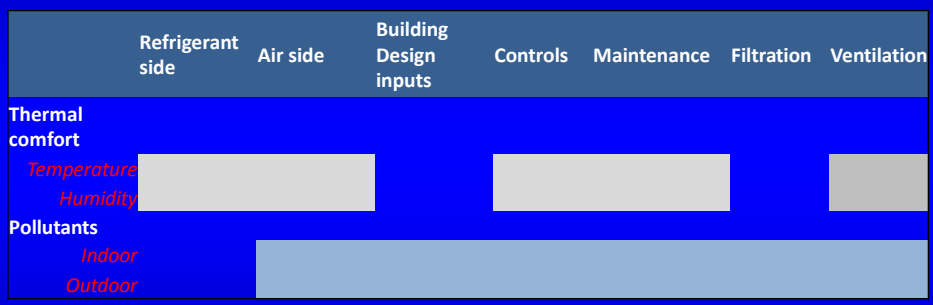
From the Constitution of the World Health Organization (1946):

"Health is a state of complete physical, mental, and social well-being and not merely the absence of disease or infirmity."

S-1 : Fundamental Objectives of Environmental Control

- **Prevent**
  - adverse health and safety effects
- **Provide**
  - desired conditions:
    - ✓ Human Response
    - ✓ Occupant Performance
    - ✓ Productivity
- **Achieve**
  - by simultaneous control of exposure parameters:
  - ✓ IAQ
    - ✓ Thermal
    - ✓ Ventilation
    - ✓ Lighting
    - ✓ Acoustics

S-1 : Drivers of IAQ



Sources of pollutants/contaminants

Pollutant or Pollutant Class	Potential Sources
Environmental Tobacco Smoke	Lighted cigarettes etc.
Combustion Contaminants	Furnaces, generators, tobacco products, outdoor air, vehicles.
Biological Contaminants	Wet or damp materials, cooling towers, humidifiers, cooling coils or drain pans, damp duct insulation or filters, condensation, re-entrained sanitary exhausts, cockroaches or rodents, dust mites on upholstery, body odors.
Volatile Organic Compounds (VOCs)	Paints, stains, varnishes, solvents, pesticides, adhesives, fuels, plastics, copy machines, printers, tobacco products, perfumes, etc.
Formaldehyde	Particle board, plywood, cabinetry, furniture, fabrics.
Soil gases (radon, sewer gas, VOCs, methane)	Soil and rock (radon), sewer drain leak, dry drain traps, leaking underground storage tanks, land fill
Particles and Fibers	Printing, paper handling, smoking and other combustion, outdoor sources, deterioration of materials, construction/renovation, vacuuming, insulation.

S-1 : Concerns which surround IAQ

Safety and Environment

- Green Buildings
- Sustainability
- Global warming
- Moisture and Mold
- Environmental Security

Energy

- Reduced loads and capacities
- Advanced control strategies
- Changes in O&M procedures

Productivity

- Health awareness
- Occupant performance
- Health care costs
- Employee absences
- O & M costs
- Value Engineering

S-1 : Standards & Guidelines

Standards

- ✓ *ASHRAE Standards 55, 62, 90, and others*
- ✓ *ASTM Standards*
- ✓ *ANSI Standards*
- ✓ *Others (Green Seal etc.)*

Guidelines

- ✓ *TERI-Griha / LEED Criteria*
- ✓ *B.E.E.*

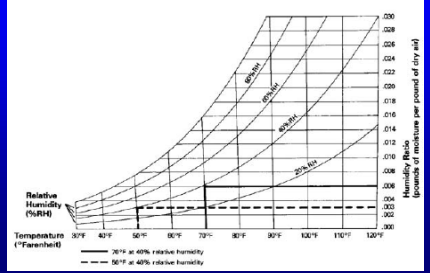
S-2 : I.A.Q./ I.E.Q. vs. Energy Efficiency

"Problem Twins"

- **Temperature & Humidity**
- **It's an axiom, that with optimal temperature and humidity, growth of molds, mildew and other biological contaminants can be controlled.**
- **The relationship between humidity and temperature is denoted by the psychometric representation.**
- **Higher temperature results in higher moisture holding capacity of air. Thus, this critical balance of temperature, moisture and energy comes to play.**

RH reading in a space will only give an accurate indication of the actual amount of moisture present if a corresponding temperature reading is taken.

Temperature	Humidity	Moisture
Deg F	RH	(pounds/pound of dry air)
70	40	0.006
50	40	0.003



S-2 : I.A.Q./ I.E.Q. vs. Energy Efficiency

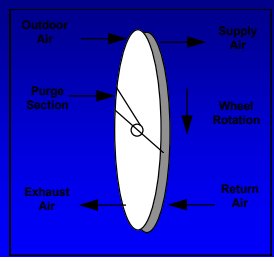
Taming the "problem twins"

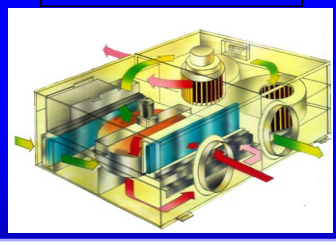
Increased ventilation means elevated temperatures and higher humidity levels in the occupied spaces. (**Besides higher penalty on operating cost)**

In Indian sub-continent, the Latent load component in the ventilation air comprises of 60-85% of the refrigeration demand.

While this problem with the chilled water systems is manageable, by virtue of controlling the ADP of the cooling coil, it becomes highly in-efficient in case of the DX systems.

Rotary Dessicant wheel (used in DOAS systems) is an example of intelligently maintaining the IAQ related with the temperature and RH component.





Pre-cooling, is another way of ,off-setting the penalties of increased ventilation, using such energy / enthalpy reclaim systems.

S-2 : I.A.Q./ I.E.Q. vs. Energy Efficiency

- **Problems besides the "problem twins"**

- **Pollutants**
  - *Indoor .*
  - *Outdoor.*
  - **Occupied spaces will have both the indoor and outdoor pollutants**

- **Studies have proved that level of contaminants in the indoor air can be often several times higher than outdoor air.**

- *Thus, a person's major source of exposure to airborne contaminants can be indoors rather than the outdoors, by virtue of time spent indoors.*

Historically speaking, the origin of poor IAQ / IEQ issue is well known and is attributable to the followings, besides the industrialization, population growth, and all other detriments to the **poor outdoor air quality**:

Stage-1: An emphasis on energy conservation after the oil embargo of 1970s resulted in tighter buildings with re-circulated air for building ventilation and minimum amounts of fresh air being brought into commercial buildings. This minimized the amount of air to be heated or cooled and hence conserved on energy.

Stage-2: Evolution of the construction industry embarked on various changes, and developed construction materials which were not natural, thus, the era of VOCs dawned.

S-2 : How to maintain and sustain good IAQ

Having identified the sources of poor IAQ (*"problem twins" & beyond*) , the ways and means to control emanates from the Basic principles :

- **Ventilation :**
  - **Higher the ventilation rate, HIGHER is the energy cost.**
- **Filtration :**
  - **More efficiency translates in higher energy bills.**

These may be referred to as 'source control' and 'removal' of pollutants/ contaminants. (to be discussed later)

BUT

It's easy to take the air in your building for granted until an issue arises that draws attention to it.

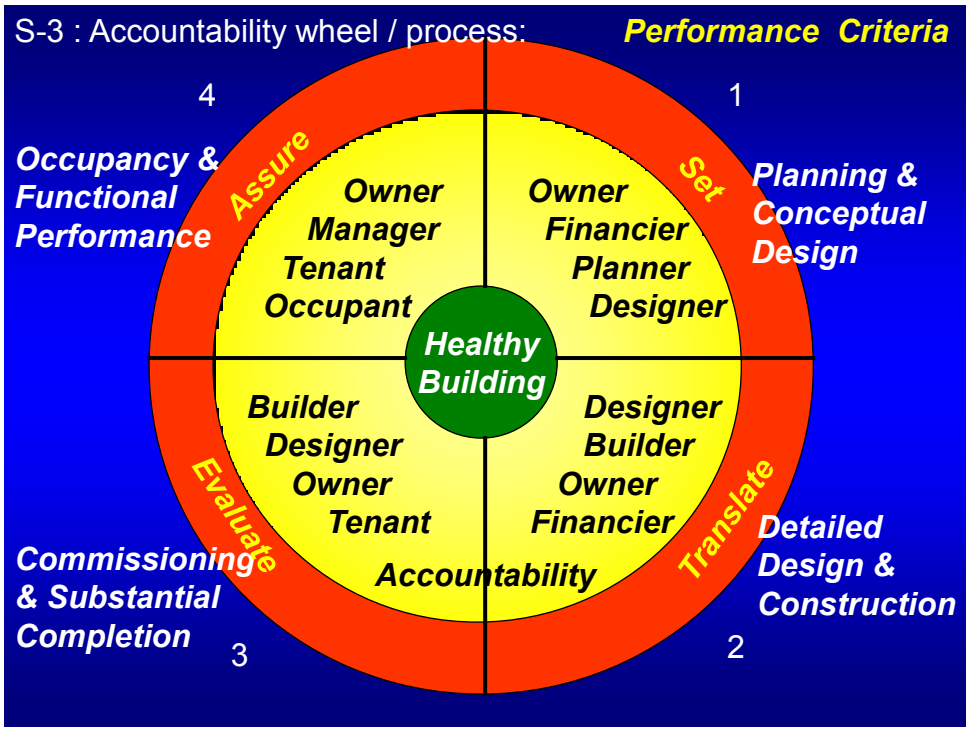
S-2 : Various filtration technologies

Air Filtration Technology Comparison

	HEPA Filter	Foam/Fiber Filter	Carbon Media Filter	Electrostatic Precipitator	Negative Ion Genetator	Ozone	UV	Electrostatic Generator	PHI	REME
Small Particulate	■			■	■			■		■
Medium Particulate	■	■	■	■	■			■		■
Large Particulate	■	■	■	■	■			■		■
Microbial	■	■			■	■	■		■	■
Fungi	■					■	■		■	■
Mold	■					■	■		■	■
Gases						■	■		■	■
Odors			■			■			■	■
Occupied zone hazard	Nil	Nil	Nil	Nil	Nil	Controversial	Nil	Nil	Nil	Nil
Penalty OR higher operating cost	High	High	High	Medium	Medium	Low	Low	Low	Low	Low

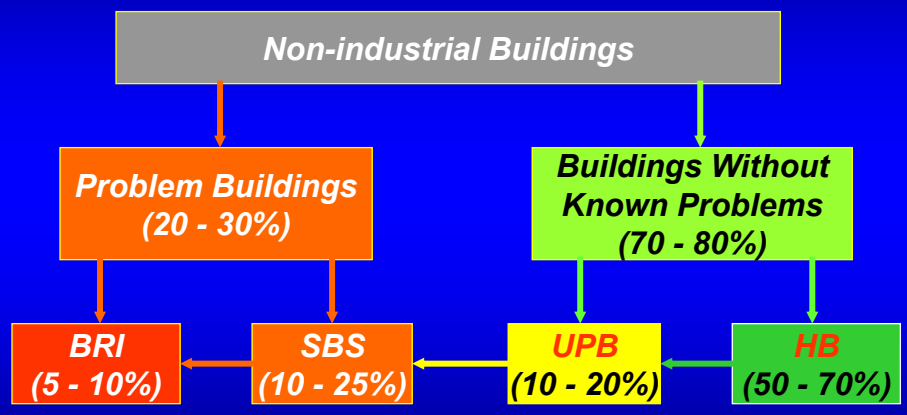
Reflective Electro Magnetic Energy utilizes an electro magnetic energy cell to create ionized hydrogen peroxide

■ **EFFECTIVE** ☐ **NOT EFFECTIVE**



S-3 : Concept of Continuous Degradation

Acceptable indoor air quality (IAQ) is much more than providing a prescribed volume of outdoor air per person. Its about maintaining and documenting IAQ, not only to avoid problems with condensate, building sickness, or noise issues, but to provide a clean and healthy working environment in the building.



BRI : Building related illness; SBS : Sick building syndrome; UPB : Unidentified problem building ; HB : Healthy building

Source : ASHRAE research papers (may not be applicable in specifics) : to be referred for understanding purposes only.

S-3 : Primary Causes of Continuous Degradation

- Lack of accountability for building performance
- Abdication of professional responsibility for building performance
- Lack of occupant awareness of consequences of problem buildings
- Lack of scientific quantitative data on building performance

S-3 : Types of Problem Buildings

Sick Building Syndrome (SBS)

- ✓ Persistence of symptoms
- ✓ Substantial percentage affected
- ✓ Rapid relief on exit
- ✓ Causes Unknown

Solve by System Performance

Building Related Illness (BRI)

- ✓ Clinical symptoms
- ✓ More than one affected
- ✓ Linkages to indoor exposures

Solve by Source Removal

S-3 : List of Major Systems, Components, and Processes to Consider

1. *Ventilation system operation.*
2. *Filter efficiency and bypass.*
3. *Quantity of outdoor air.*
4. *Control access to air handler components.*
5. *Isolate likely entry points.*
6. *Building shell and duct tightness.*
7. *Correct cooling.*
8. *Efficient condensate disposal plan.*
9. *Regular survey to identify molds, mildews.*
10. *Routine occupant survey.*
11. *Analyse the BAS trends on energy.*
12. *Never bye-pass / ignore a BAS alarm.*

HVAC maintenance & related causes of poor IAQ

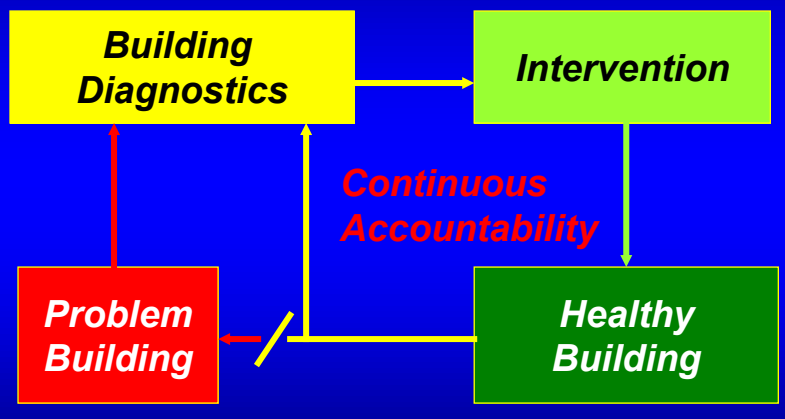
- **Inadequate maintenance of the HVAC system becomes a source of contamination, leading to:**
- **Increased load than designed.**
- **Inadequate fresh air/ventilation.**
- **Improperly located outdoor vents bringing in contaminated air from automobile exhausts or restrooms.**
- **Improper air balance and pressurization**
- **Common symptoms of poorly maintained HVAC system / installation:**
- Contaminated filters, contaminated duct lining, dirty drain pans, humidifiers, lubricants, refrigerants, mechanical room, maintenance activities, and combustion appliances (e.g., boilers/furnaces, DHW, generators, and stoves)

Tips for Mitigation and Control

- Perform HVAC preventive maintenance
- Use filter change protocol
- Clean drain pans; proper slope and drainage
- Use potable water for steam humidification
- Keep duct lining dry; move lining outside of duct if possible
- Fix leaks/clean spills (see filter change protocol)
- Avoid back drafting
- Check/maintain flues from boiler to outside
- Disallow unvented combustion appliances

Perform polluting activities during unoccupied hours

S-3 : Interception of Continuous degradation process



BAS and efficient controls is the only answer.

S-3 : Recommendations for Owners and Managers of Existing Buildings

1. Understand capabilities of your building and its systems.
2. Assure that your building is performing as intended.
3. Do not make changes to building performance unless the consequences are understood.

S-4 : Suggested ways to off-set higher energy costs associated with "Dilution" principle

- **Various circumventing measures to control energy bills while maintaining the IAQ are as under:**
  - Increased Ventilation (**Dilution**). And Energy / Enthalpy recovery using dessicant wheel.
  - Demand / occupancy based & Controlled ventilation.
  - Night pre-cooling and purging systems.
  - Air side economisers. (Not practical for hot and humid climatic zones)
  - Ozonization / Ionization / Photocatalytic hydro ionization.
  - Electrostatic precipitators
  - Etc.

S-4 : Q.E.D.

- **Thus, IAQ comes at a premium, and it is paramount that the various contravening systems (dilution, wiz increased ventilation with DOAS , thermal comfort, and or other means of filtration, including the various maintainable nodes be monitored and kept as close as possible to the specified operating range).**
- **Sensors and control devices are the nerve center of a good air handling system. They provide timely, accurate feedback, allow consistent monitoring of performance and facilitating service thereby delivering a better IAQ.**
- **For example, good quality dampers with airflow monitoring stations can be coupled with a building management system to monitor, control and document ventilation airflow in compliance with ASHRAE 62 standard requirements.**
- **Integration with the chiller plant assures the precise amount of chilled water at exactly the right temperature. In these and many other ways.**

S-4 : Solution & recommendations : Continued monitoring, Measurement & Verification

Can proper indoor air quality be achieved without incremental operating costs or sacrificing thermal comfort?

YES.

Setup and setback setpoints (enabled by IBMS) play an important role in thermal comfort (IAQ) and effect energy savings, during unoccupied modes of operations.

Differential pressure sensing and control of building ventilation fans using variable speed drives, effect correct pressurization, air balance and avoid any ingress of un-treated outside air, thus, maintaining the acceptable IAQ.

The surrogate indices frequently deployed for IAQ monitoring , M&V:

1. Temperature and humidity sensors monitor thermal comfort.
2. Carbon dioxide (CO2) and carbon monoxide (CO) sensors monitor pollutants, ensuring the required minimum fresh air ventilation.

Depending on the nature of the contaminant / pollutant and the accepted levels of exposures, based on the guidelines of WHO / ASHRAE / etc.., the indoor IAQ can be controlled and maintained, by, the use of Demand controlled ventilation system connected to the IBMS.

S-4 : IAQ & BAS : Controls strategies and functions

Adaptive control :

An algorithm which is self tuning, that prevents / corrects an over-cycling control system in a building.

Derivative control:

An algorithm which determines the instantaneous rate of change of a controlled variable.

Proportional control:

An algorithm which positions a controlled component in response to the amount of offset experienced in a building automation system

Low / High limit controls:

Stops outside air dampers at a pre-determined position when ventilation air temperatures exceed (+/-) side of the preset.

Setup & setback setpoint controls:

Are the values that are active during the unoccupied mode of a building.

Setpoint :

Is the desired value to be maintained by a system with the desired accuracy.

S- 4 : IAQ & BAS : Controls strategies and functions

Differential pressure switches / sensors:
Devices which can monitor the health, duty set point etc. of any devices such as filter, pump, fan etc.

Humidistats:
Are digital input devices used to maintain the humidity of a space with the help of primary devices such as cooling coils, humidifiers etc.

Limit thermostats
Maintain the temperature below or above the adjustable setpoint.

Airflow measuring stations
To maintain the IAQ, differential pressure sensors or pitot tubes and temperature sensors in a duct can act as a air measuring station.

A comprehensive BMS can perform the following functions which can indeed bridge the gap between the various IAQ and energy standards, and deliver IAQ at an optimal cost:

- Monitor
- Control
- Measure
- Verify
- Alarm
- Report
- Keep track

Helps the owners team analyze the trends of energy bills while consistently deliver an acceptable IAQ

S- 4 : Features / controls possible by BAS

- Thermal comfort (temperature and humidity control).
- DOAS SAT, neutral or cold (based on DCV,Free cooling, night purge mode etc.).
- Envelope, Internal generation (high or low occ. Density)
- ADP control with low to very low air flow.
- Condensation control.
- Filter monitoring, thereby operating cost optimisation.
- Air flow management systems ensure optimal air intake, thus, conserving energy while ensuring IAQ.

S- 4 : Conclusion

- With emerging trends in energy efficiency, IAQ too is of paramount importance.
- That, to deliver IAQ, huge premium is to be paid, is a fallacy.
- That ,continued M&V of all equipment with adequate controls and accountability alone can subsidize the cost of delivering acceptable IAQ.
- That, BAS alone with BACnet / Web access to system and trend logs lead to discoveries and refinements, otherwise hard to realize.
- That BAS can facilitate occupant participation .

- THUS, BAS is the panacea to reducing operating costs on account of IAQ delivery while being energy efficient.