Economics and Engineering: Improving Buildings with Resiliency Engineering

Taking the long-term economic effects of constructing, renovating, and maintaining a building into account in the design process

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Evaluating measures intended to improve building performance from a narrow perspective may have unintended results. A new approach to facilities design, operation, maintenance, commissioning, and analysis—*resiliency engineering*—employs a broad perspective on buildings, systems, and occupants to develop cost-effective strategies for achieving high performance in new and existing buildings. By considering the full range of potential impacts of proposed building performance measures, one can avoid unintended results. Viewing buildings as assets and applying sound economic analysis tools to understand proposed building performance measures allows one to avoid the self-limiting context of economic analysis limited to first cost or simple payback considerations.

While energy conservation measures may have a potential adverse impact on indoor air quality, energy conservation and indoor air quality concerns need not be conflicting goals for facility owners and operators. Measure-by-measure cost/benefit analysis of building automation system strategies, HVAC system modifications, cleaning and filtration upgrades, staff training, commissioning or start-up protocols, and other measures improves building performance projects.

What is resiliency engineering?

A definition of *resiliency* is "the ability to recover quickly from illness, change, or misfortune; buoyancy."* The concept of resiliency engineering is simple—systems should be engineered so that they are resilient to conditions that happen frequently in buildings, such as lack of maintenance; changes in operating conditions, occupancies, and uses; and less-than-optimal cleanliness and housekeeping. The term implies that recommendations, design specifications, equipment selection, and recommended operating and maintenance procedures should be made so that buildings operate within acceptable parameters over long periods of time with minimal intervention of trained technical personnel. A resilient building bounces back from changes and performs under less-than-optimal care. Its opposite, a "brittle" building, breaks down and fails to serve its occupants when uses change or system maintenance is below optimum.

The concept of resiliency engineering presents a challenge for performance contracting: how to balance the need for economic return on specific cost-reduction projects with the long-term needs of making a building resilient. The value of thinking about indoor environmental challenges and opportunities with an eye toward providing resilient solutions is cost effective over the long haul. Long-term thinking, combining the tenets of life-cycle costing, total quality management, and standards of care, leads to an effective approach to asset management. The result is maximized value for the building owner and good conditions for building occupants. In that sense, resiliency engineering plays into the concept that performance contracting can play a role in the overall asset management strategy of the property owner.

Core technical concepts

Resiliency engineering represents an opportunity to demon-

**The American Heritage Dictionary, 2nd College ed., Houghton Mifflin Co., Boston, 1991.*

strate the kind of broad-ranging, long-term, holistic thinking that adds real value to construction, renovation, and energy efficiency projects. Within that vast creative horizon, a few very specific areas surface as critical to think about to make buildings resilient instead of brittle: 1) management of air pressure relationships between the building and outdoors and between zones and special use areas within the building, 2) application of air filtration and cleaning technology, and 3) management of outdoor air for dilution ventilation and makeup air.

These three topics stand out among the many aspects of operating and maintaining a building because they are often forgotten in both the design and operation of buildings today. In the practice of performance contracting and consulting for improved indoor air quality, the greatest number of mistakes and the greatest controversy surround these three areas. By understanding and applying the principles of resiliency engineering in these three areas, one can achieve a balance between short-term operational cost reduction requirements and long-term management of the building as a capital asset.

- ***Air pressure management***— Buildings in all but very specialized circumstances should be designed and operated to maintain a slight positive pressure to the outdoors. This is especially true in hot and humid environments. This is one of the most frequently overlooked design principles in existing buildings today, and it is one of the most expensive aspects to overlook. Table 1 summarizes the effects of both properly and poorly managed air pressure on various factors.

- ***Filter selection***— Experienced indoor environmental professionals will immediately point out that some filter recommendations may carry a very high price tag and be perceived as "gold plating" by clients. This perception need not be true. Incorporating resiliency engineering principles into the design philosophy of a system can result in equivalent first cost and lower operating costs when a wider range of technology options is considered.

A good example is the upgrading of filters to 95 percent ASHRAE dust spot efficiency. This increases energy efficiency and eliminates long-term needs for coil cleaning. These filters, which only require changing about every six months in most applications, will also prevent much of the dirt buildup that encourages biological growth in the heating, ventilating, and air conditioning (HVAC) system. These 95 percent ASHRAE dust spot efficiency filters have an economic payback of less than half of their economic life compared to cheap filters.

Careful evaluation of air filters for any specific air handling unit (AHU) can result in significant energy and indoor air quality improvements. It is not unusual to find filters in poor condition and to find dirty coils and ducts downstream of poor filters. Often the recommendation is to change filters more frequently, clean the coils, and sometimes clean the ducts.

Resiliency engineering principles dictate that the evaluation include a review of the filter selection and the capability of an AHU to accommodate improved filtration. Typically, such units are operating with minimal "angel hair" or "furnace" filters that fail to protect the equipment as well as the people. The unit should be evaluated for space for added filtration and the ability of the unit to handle various pressure drops.

From a resiliency engineering perspective, the complete recommendation would include specification of an easily maintained high-efficiency filter system; initial cleanup of the HVAC unit and ducts; routine inspection to verify that filtration has sustained a clean system; plus a specific and simple method, such as a magnihelic gauge calibrated to a filter change point on the unit, or an automated monitoring and alarm system, to alert facility maintenance personnel of the need for filter changes.

- ***Outdoor air management***— Outdoor air serves three critical purposes in a resilient building: pressurization of the building shell, dilution ventilation, and makeup air for exhaust fans used for source management. To achieve these three critical purposes, one must

TABLE 1—Effects of properly and poorly maintained building air pressure.

Factor	With properly managed air pressure	With poorly managed air pressure
Energy use	Controlled	Fluctuates with infiltration load
Comfort	Controlled	Problems with odor and hot and cold areas from infiltration
Moisture transport	Controlled when combined with proper humidity control in air handler	Uncontrolled entry with infiltration, condensation planes in wall cavity and materials; mold growth in interstitial spaces
Indoor air quality	Controlled when part of overall quality program	Uncontrolled with constituents entering with infiltrated air, risk of indoor sources especially from combustion gases, and increased risk of biological contamination
Building longevity	Maximized	At risk to rot, oxidation, biological contamination from moisture incursion

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