

Total Barrier Management Reduces Airborne Infection Risk in Healthcare

By Andrew J. Streifel, MPH, REHS

We consider controlled ventilation for comfort as truly the objective for the majority of hospital patients. However, without proper ventilation management, airborne spread of infectious diseases becomes a major concern as a mode of transmission extremely difficult to control. Infectious disease outbreaks in hospitals are now documented and their mitigation is dependent on triage to recognize and isolate for the purpose of successful control.

Also, today with H7N9 in China showing a potential uncertain mode of transmission we must be vigilant with regard to new variants of such diseases as they continue to evolve.

CDC Environmental Infection Control Guidelines 2003

Table 4. Microorganisms associated with airborne transmission*

	Fungi	Bacteria	Viruses
Numerous reports in health-care facilities	Aspergillus spp.+ Mucorales (Rhizopus spp.)	Mycobacterium tuberculosis	Measles (rubeola) virus Varicella-zoster virus
Atypical, occasional reports	Acermonium spp. Fusarium spp. Pseudoallescheria boydii Scedosporium spp. Sporothrix cyanescens	Acinetobacter spp. Bacillus spp. Brucella spp. Staphylococcus aureus Group A Streptococcus	Smallpox virus (variola) Influenza viruses Respiratory syncytial virus Adenoviruses Norwalk-like virus
Airborne in nature; airborne transmission in health care settings not described	Coccidioides immitis Cryptococcus spp. Histoplasma capsulatum	Coxiella burnetii (Q fever)	Hantaviruses Lassa virus Marburg virus Ebola virus Crimean-Congo virus
Under investigation	Pneumocystis carinii		

The efforts to manage the above listed diseases will also help hospitals prepare for the uncertain presentation of patients whose potential for propagating airborne spread disease is uncertain. Within the past year for example, marked increases in measles and drug resistant tuberculosis among homeless persons in Minnesota and North Dakota have strained the preparedness management to provide a sufficient number of airborne infection isolation rooms. In addition, 4500 TB exposed homeless in Los Angeles and 2200 measles exposures in England show these events continue to occur around the world (CDC-MMWR).

Droplet nuclei <5um particles		
		EMERGENT DISEASES
*Tuberculosis	*Measles	SARS
*Chicken pox	*Smallpox	MONKEY POX
*Disseminating H. zoster		ANTIBIOTIC RESISTANT MICROBES

The medical literature has numerous examples of diseases spread due to lack of ventilation control.

Airborne chicken-pox transmission was discovered by LeClarie at Boston Children's in 1984. This outbreak was due to open doors and windows.

Small pox transmission occurred in Germany in 1972. This outbreak was due to an uncontrolled hospital ventilation system and a highly infected patient spewing out infectious particles due to oral lesions caused by a smallpox infection.

Patients to day are carefully screened but still most hospitals are faced with challenges from resurgent diseases like tuberculosis, measles and occasionally polio. But while the exposure potential in general is diminished through better public health this doesn't address the specific safety concern associated with assurance that a hospital is

ready for a patient or group of patients at any given time.

Saravia provided a state-wide service to evaluate AIIR rooms in Minnesota hospitals to determine the functionality of those rooms in light of pandemic preparedness. The observed lack of functionality was an eye-opening experience, which made clear the need to assure through validation the functionality of AIIRs.

The parameter necessary for control of aerosol movement is pressure. Pressure management is contingent on consistent airflow direction from the clean air quality source to a less clean air quality environment. An inconsistent airflow direction will create time consuming epidemiological analysis if

a patient becomes infected with an airborne spread disease such as measles, because once discovered the patient's exposure contacts also become a potential spreading for a secondary cluster of disease amongst patients and employees. If the airflow is inconsistent, then those passing in the corridor around the malfunctioning AIIR must also be "worked up" for exposure/disease potential.

Hermans in 1994 used a term quanta derived from infectious disease experts to help define an infecting dose of infectious particles. A patient generates particles that could be infectious through the generation of droplet nuclei that move with the air currents. Quanta generation depends on the airborne disease presentation in patients.

If the patient has mouth sores the potential for airborne transmission from the mouth is enhanced. Quanta generation rates range from 1 q/hr with a TB patient resting to 249 for a TB patient during coughing after bronchoscopy. These uncertain exposures can catch a hospital off guard in the preparation for patient isolation.

Ventilation parameters AC/hr, filtration and pressure are essential for maintaining air quality safety (Marshall). In addition

the dilution of air to achieve room air exchanges with highly filtered air does even more to reduce the probability of breathing an infectious particle. The ventilation offset with a greater exhaust than supply air volume will help to contain and move air towards the extractor part of the patient room. However assuring proper pressure with appropriate airflow direction is the essential component of containment or exclusion via the airborne route of infectious particles.

Maintaining these ventilation principals is difficult for a variety of reasons (Saravia). Most often a lack of priority was due to no immediate threat from an infectious disease event.

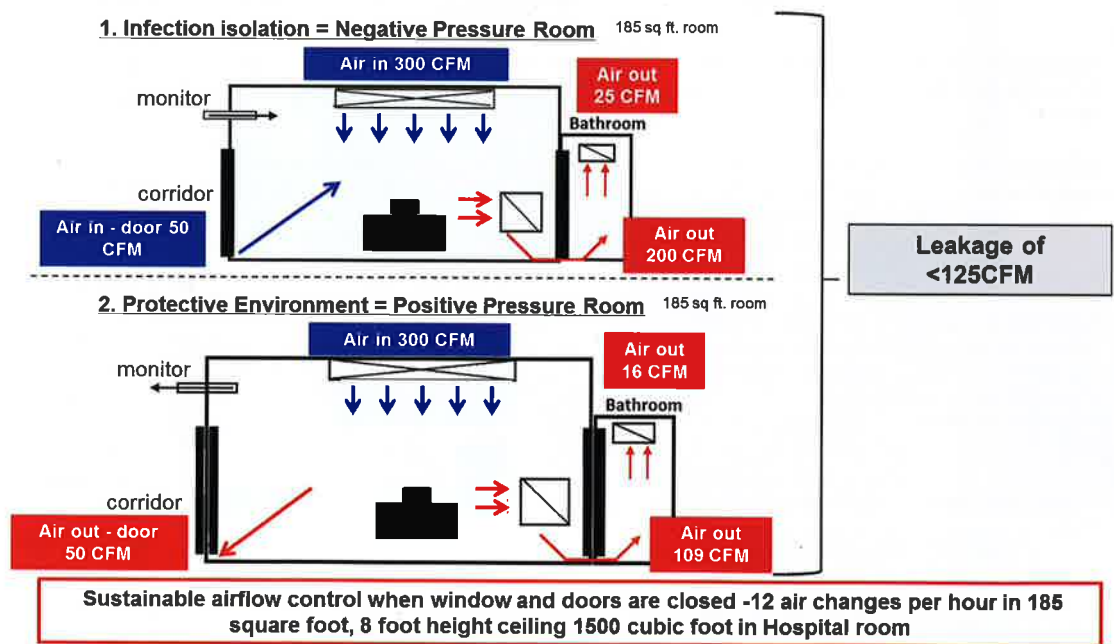
It is considered best practice to be sure that each hospital in the USA has a room for isolation of infectious disease that is a totally functional AIIR. Functional performance, which maintains a constant

pressure differential (especially in the negative pressure AIIR) is essential for containment of infectious patients. If the ventilation offset difference of the supply and exhaust is insufficient, the intensity of the pressure will be reduced.

Therefore, an offset of at least 125 cfm is recommended to control the airflow direction but if the room is not sealed and has leakage points that performance will not be satisfactory. When air volume is offset to have excess air extracted from a room, infiltrating air tries to fill the void caused by suction. But the air supply for such exhaust systems will be variable and uncontrolled in an unsealed room. Windows and doors must be self-closing for performance assurance. The offset of supply and pull air must be substantial, ideally enough to extract air under the door to the room and pull the difference in the offset volume there isn't enough supply air to the respective AIIRs.

Saravia's study was undertaken to prepare Minnesota for pandemic events by having performance validated airborne infection isolation rooms. Since the discovery of these AIIR inadequacies, means and methods for validation have been substantiated by regulatory agencies such as OSHA. We should trust good design but verify functional performance.

Air flow control CDC guidelines <125 CFM leakage.



Note: This depiction indicates a minimum ventilation scheme for AIIR and PE rooms without the design considerations for cooling and heating loads. Volumes of air will vary but the offset should be similar.

So, if there are leaks around wall penetrations such as plumbing, lights, medical gas, electrical boxes, ethernet conduits and other unsealed penetrations like ventilation ducts, they should be sealed.

Typical Leakage Areas In Patient Rooms



Copper Medical Gas Lines



EMT Lines



Cable Bundles



Top-of-Wall Joints



Electrical Boxes



Bottom-of-Wall Joints
Author Photos

openings found in the ceilings. That is why ceiling must be properly planned and sealed.

A well-sealed room will pull about 100 CFM excess air from leakage at 0.01 inches WC. The issue is ventilation efficacy. If we can control the extraction we should be able to retain the infectious aerosol with greater efficiency. With adequate extraction comes the need for controlled intensity. How much pressure is really needed?

There is a discrepancy among experts as to exact pressures necessary to contain a

In 1997, Rice studied room pressure and found very weak pressures in a modern hospital. It was noted that substantial leakage in the rooms was found at the doors, ceilings and utility openings.

In an experiment using a blower door apparatus for testing for leakage, it was discovered that a well-sealed protective environment (PE) room was substantially sealed better than an AIIR. When a pressure of 50 Pascals was applied to the room the PE room leaked 150 cubic feet per minute while the AIIR leaked 1500 cfm with the same pressure. Perforated plate metal pan ceilings, unsealed doors and utilities comprised the majority of leaks.

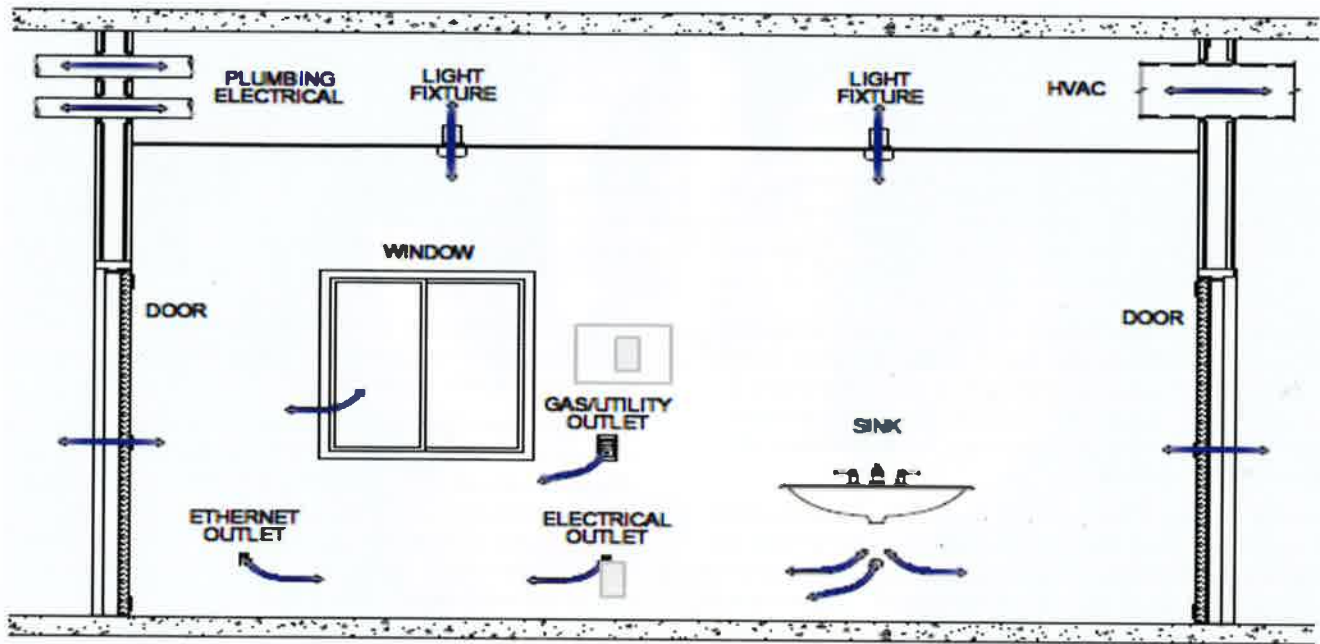
The PE rooms in the University of Minnesota Medical Center construction was supervised by this author in 1986. At that time, we had a crude understanding of the sealing process that existed in 1986 when the hospital was first occupied. But we did not understand the difficulty of maintaining the negative pressure AIIR as related to the concept mentioned above regarding leakage areas.

Since then, we have tested many rooms using the blower door methodology and found rooms used as AIIR had substantial leakage above the ceiling. For example, we attempted to demonstrate that with the lay-in ceiling completely closed and no special seal for the lay-in tile grid the room had 84 square inches of EQLA (Equivalent Leakage Area @ 10 Pascals) but when a tile was removed the EQLA went to 233 square inches and allowed for over 2100 CFM airflow out of the ceiling space. AIIR patient room air is exhausted but will short circuit the air it can suck from the

infectious aerosol. Aventis at Berkley was able to show control of common indoor air particles with pressures between 0.02(5 Pa) and 0.03(7.5Pa) inches water column to control ambient airborne particles. Particles can be a good surrogate to demonstrate containment. But it is difficult to suggest that 15 Pascals or event 30 Pascals would contain any better. Such pressures would be problematic in certain climates. Saravia did show increased particle counts in rooms used as AIIR. The higher counts indicate infiltration of untreated air being sucked into the patient care room through leaks. Observations by this author has seen excessive condensation promoting mold growth and very high particle counts in critical hospital areas due to imbalances caused by uncontrolled pressure management.

As we consider what happens to a room as it is sealed we should step through the process of sealing a room. In Minnesota the Local Brotherhood of Carpenters agreed to assist with a demonstration of room sealing in recognition of the potential importance of this concept in achieving better ventilation control. This room was constructed as a demonstration for "best practice" in construction management practice working in hospitals. It is common to specify a sealed room. Yet, how should it be specified for construction documents? ASHRAE STD 170 tries to define the requirement but it, too, is based on the functional performance of the PE and AII rooms.

Patient Room Leakage Application Areas



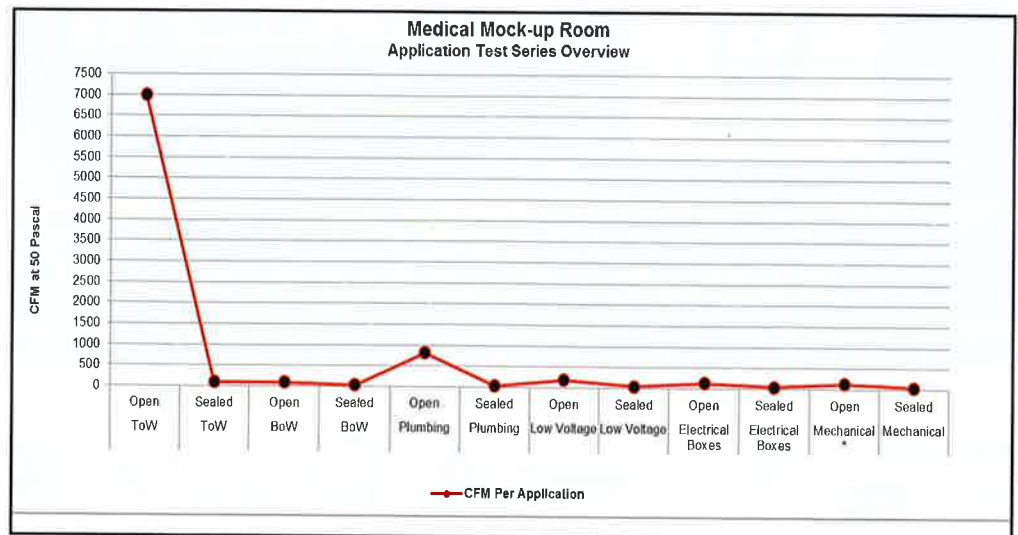
"The room envelope shall be sealed to limit leakage air flow at 0.01 in.wc (2.5Pa) differential pressure across the envelope." However, ASHRAE 170 definition is a not useful as an objective definition such defining the actual leakage in air volume as EQLA.

When we consider construction of a special ventilation room with all of the penetrations, we should know the importance of sealing of the walls, utility connections and other wall penetrations because of the understanding that the flow of air (infiltration/exfiltration) has on the impact on effective ventilation. The table below shows the different seal points (top or bottom of wall) before and after seal. Looking at the Top Wall data on the opening and closing of that hole around the utility connection. A sealed application will help maintain a consistent pressure of >0.01 " WC. As the room was sealed a sharp reduction in airflow leakage was observed. Once the obvious seals are eliminated, a basic room (as a box) final seal occurs at about 41 CFM @ 0.01"WC.

What is the ideal room seal at 0.01"WC? Ideally a leakage rate of around 50 cfm would profile a very tight room but realistically with the proper training of the installers should be able to seal the room to leakage of 125 cfm @ 0.01"WC, based on recommendations provided by the CDC. MMWR June 6, 2003. With a tight room seal we can

demonstrate open penetrations and once closed the various penetrations show an obvious difference.

A standard patient room may have up to 40 room utility penetrations. Penetrations in the room shall allow air to infiltrate in an AIIR due to the extractor air volume. For many years in a hospital occupied in 1986 AIIR did not work correctly because it was thought that there was little or no pressure differential in UMMC AIIR. Later it was revealed that 150 cfm differential was present with greater exhaust but the pressure was $<.001$ " WC pressure as a result of ceiling leaks. Further test leaks found >22 square inches of leakage in AIIR rooms.



Blower Test #	Test Application	Status	CFM Per Application
1	ToW	Open	7000
2	ToW	Sealed	98.85
3	BoW	Open	98.85
3	BoW	Sealed	40.63
4	Plumbing	Open	816.3
5	Plumbing	Sealed	41.3
6	Low Voltage	Open	191.8
7	Low Voltage	Sealed	45.96
8	Electrical Boxes	Open	135.6
9	Electrical Boxes	Sealed	46.52
10	Mechanical *	Open	135.6
11	Mechanical	Sealed	46.59

It becomes obvious that room performance for safety and cost effective management of the isolation room are important principals that could be problematic if not understood for better control. The performance spec enhances room performance for prevention of disease transmission.

Could it be that if the room is sealed, had appropriate air exchanges that we could negate disease spread via ventilation? A properly functioning room does provide safety to contain disease once identified. This would be 100% reduction in unexpected exposures by inclusion of a well-sealed performance verified airborne infection isolation room.

There is little to no research on the efficacy of a sealed room preventing infections with the use of vaporized chemicals for hospital room disinfection. While efficacious for preventing infections, this may pose a hazard to surrounding beds in hospitals. Here too ventilation efficacy though air balance for an AIIR and assurance that the gas will not seep to other spaces in the occupied hospital condition.

When an infectious disease event occurs what do we want to be assured of regarding the containment rooms? Personal experience during inspection by The Joint Commission (TJC) & Center for Medicare and Medicaid Services (CMS) surveyors and inspectors wanted assurance of functional performance of specific special ventilation (OR's, Protective Environments and Airborne Infection Isolation) rooms.

Of course this means proper air exchanges with enough air extraction to allow for sufficient pressure to contain any infectious particle released by the infected

patient. Or assuring airflow through designated relieve locations (door undercut) to keep infectious particles from susceptible patients.

We have described the rationale for sealing a room. It enhances ventilation efficacy for airborne infectious disease control. This will reduce unexpected airborne disease exposures to personnel not realizing the necessity for functional performance of an airborne infection isolation room. This uncertainty can be mitigated with design to include a sealed room by definition. At a leakage <125 cfm with 0.01"WC and less than 72 square inches equivalent leakage area will provide a specification to assure a consistent safe environment of care.

This concept of a sealed room for the mitigation of airborne spread diseases while safety oriented also provides additional benefits to be defined. 🔥

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EDITORS NOTE: Since 1994, some firestop products have been tested for quantified air leakage ("L" Rating) using UL 1479 for Penetrations and UL 2079 for Joints. In Canada, ULC-S-115 incorporates the "L" Rating. These tested and listed assemblies provide quantified air leakage values needed for 'sealing' areas to slow spread of airborne infections. As with all physical properties needed for conditions expected to occur in the building, verify performance with both the building owner and manager's industrial hygienist and also the manufacturer. Check out the article on "L" Ratings in the next issue of Life Safety Digest.