TAB Journal

THE MAGAZINE OF THE ASSOCIATED AIR BALANCE COUNCIL • FALL 2012

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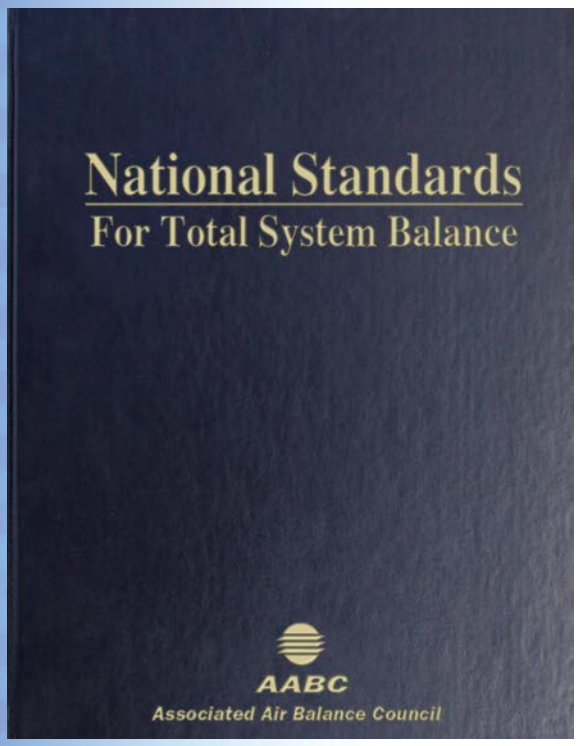

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TAB Journal

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From the Publisher

The fall 2012 issue of *TAB Journal* touches on many aspects of the test and balance industry, including healthcare facility testing, scrubber exhaust systems, and code requirements.

"Testing & Commissioning a Regional Bio-containment Lab: Lessons Learned" by Larry Poos, P.E., TBE, of Test and Balance Corporation, discusses the benefits of using independent TAB and commissioning firms, and some of the key issues that this arrangement helped uncover.

Wade A. Handley, TBE, of Technical Air Balance SW, Inc., provides insight on how including the mist eliminator and fan into the preventative maintenance schedule can avoid buildup and odor in "Scrubber Exhaust Systems."

"Test, Adjust and Balance Per National Standards and Codes", written by Gerald J. Kettler, P.E., TBE, of AIR Engineering and Testing, Inc., reviews codes and requirements for all systems to perform at their design intent and operate at the optimum level.

Beto Felix, TBE, from Penn Air Control, Inc., discusses how the use of UV-C/UVGI rays as disinfectant in conjunction with filtration, dilution, and purification, can be a highly effective method in killing bacteria in "Ultraviolet Lighting for HVAC Disinfection."

"Fan Rotation Conundrum" by Joseph Danis, TBE, from Danis Test and Balance, Inc., explains a contactor issue caused by value engineering.

Sean Green, TBE, of Environmental Test and Balance Company, stresses the importance of the FGI *Guidelines* and ASHRAE/ASHE Standard 170 to ensure the latest procedures and methodologies for infection control are being exercised in "Routine HVAC Testing in Healthcare Facilities."

We would like to thank all of the authors for their contributions to this issue of *TAB Journal*. Please contact us with any comments, article suggestions, or questions to be addressed in a future Tech Talk. We look forward to hearing from you!

Testing & Commissioning a Regional

Larry Poos, P.E., TBE, *Test and Balance Corporation*

This article discusses the lessons learned from a project that involved independent mechanical, electrical, and control systems commissioning, and failure scenario testing of bio-containment barriers (BCB) for three regional bio-containment laboratories (RBLs). These facilities housed operations that provided specialized research with biohazardous substances, in accordance with the U.S. Department of Homeland Security's efforts to prepare for and defend against possible domestic terrorist attacks.

This particular project involved ensuring that the facilities met requirements for a U.S. Centers for Disease Control & Prevention (CDC) certification to handle Level 3 biohazard chemicals. All three facilities were commissioned between October 2006 and July 2010, and each was located on a major university campus where containment breaches would be unacceptable. The RBLs each required between 9 and 17 months of Cx/FPT and intensive failure scenario testing, and between 15 and 20 weeks of complete commissioning. Each of the RBLs passed independent BCB certification on the first attempt, following the completion of the acceptance phase Cx/FPT services.

The RBL projects discussed in this article utilized both an ACG-certified commissioning agency and an AABC-certified TAB agency. While this was most likely costlier up front than using a non-independent team of personnel linked to the mechanical contractor or the installing contractor, it is highly unlikely that the lessons learned in these critical projects would have been recognized—let alone recorded for others' benefit—had two completely independent entities not been involved. When considering the number of serious issues identified and later corrected with the RBLs, it is evident that the costs of independent entities are warranted for projects that require a great deal of scrutiny.

Bio-containment Lab: LESSONS LEARNED

Advantages of Using Three Independent TAB Agencies for Each RBL

There were several advantages to utilizing the three separate AABC TAB firms on the RBL projects described in the article. For starters, all three of the agencies passed the 25% minimum TAB verification with no problem, which added credibility to the results published in the final TAB report. The commissioning firm was kept "in the loop" by the three agencies, and this allowed a quicker resolution for any deficiencies that were identified without adding delays to the project.

For example, the TAB work at one of the labs revealed excessive duct pressure losses which prevented the system from achieving duct static set-point. Subsequent duct static profiles allowed the Cx team to focus on the major "ΔP culprits," including major ductwork reconfiguration. The proactive communication of the agency prevented significant delays in the project. At a different RBL, the TAB agency was instrumental in helping to identify failed biodamper end switches on the bioseal valves (or "bubble-tight" dampers), providing supply air to all the lab spaces, which led to a full scale investigation that identified valve defects and/or failures in 43 of 46 bioseal dampers. Additionally, on two of the RBLs, the TAB agencies facilitated the crucial interface between the lab air valve controls contractor and the BAS controls contractor.

All three agencies conducted space-to-space pressurization checks of the lab spaces at the conclusion of the TAB fieldwork. The commissioning agency was able to use this information as a baseline for conducting data logging to establish if the bio-containment barrier was being maintained "negative" to the adjacent office spaces during normal operation of the lab.

Cx Lessons Learned: The Basics

The purpose of Cx/FPT is to verify that all MEP systems are functioning properly and in accordance with the owner's project requirements, the project documents, and the basis of design (BOD). Proper verification is dependent upon certain prerequisites and fully understanding the following guidelines:

1. Only whole systems can properly undergo Cx/FPT;
2. The subject system is fully operational, and all related equipment/systems have undergone proper startup and checkout by the manufacturer, the installing contractor, or both;
3. All controls for subject equipment/systems have undergone functional and point-to-point checkout by the controls technician;
4. A hard copy of the final TAB data on subject system has been submitted to the Cx agency prior to the scheduled start date for Cx/FPT, allowing sufficient time for the CxA's review; and
5. All deficiencies identified by TAB agency on subject system have been corrected and/or properly addressed.

"When considering the number of serious issues identified and later corrected with the RBLs, it is evident that the costs of independent entities are warranted for projects that require a great deal of scrutiny."

If Cx/FPT is started on incomplete systems, two undesirable results are likely: either the project will take longer than expected, requiring additional trips by the Cx agency to verify correction of deficiencies; and/or the project will cost more than originally anticipated. The sequential order of the Cx process cannot be altered (i.e. installation, setup, and pre-functional checkout/start-up first; TAB fieldwork next; and Cx/FPT third) without delaying/adversely impacting the project schedule, or creating extended time/impact change orders.

Shortcuts in the Cx process may delay the completion of the facility and will increase the likelihood of serious and unrecognized operational issues remaining within the facility's MEP systems. The Cx process is effective because it is systematic, and puts all facility equipment/systems through the same basic procedures and tests, thereby increasing the identifications and correction of system deficiencies.

The project design and/or construction documents need to be completed to the appropriate level of detail, with control sequences of operation and design intent sufficiently defined. If this is not done, the possibility exists that many of the design control sequences of operation will have to be revisited, possibly rewritten and/or modified during the Cx/FPT procedures. Laboratory Standard Operating Procedures (SOPs) and optimized General Lab Practices need to be in place by the start of the Cx/FPT Acceptance Phase testing, and must not be left-up to the Cx team to develop "on-the-fly" via trial and error methods.

The lead individual under the controls contractor should be experienced and completely familiar with the computer software being utilized. This will expedite the "debugging" process, and when combined with the Cx process, will result in optimizing the design control sequences and client-user SOPs. The lead employee should also be available to the Cx team throughout the construction and acceptance phases. The owner should provide a technician to learn the control system, in order to have their own representative trained on the project control sequences of operation and how to operate/troubleshoot the facility's control systems.

Other important general points are as follows:

- Proper sealing of all lab envelope penetrations is essential to maintaining proper space pressurizations. A separate, experienced sealing contractor and a knowledgeable supervisor should be hired to seal all such lab/BCB penetrations.
- BCB barrier and penetration inspections should occur before dry-in; and lab "envelope penetration" mock-ups should be approved before proceeding to BSL/ABSL-3 labs.
- Safe interstitial space and/or equipment mezzanine areas need to be planned and provided for in the construction team's initial coordination and sequencing. RBLs should be provided with the proper equipment to ensure that maintenance personnel can safely carry out their activities. If the maintenance personnel are required to spend a great deal of time in an area that is hazardous, shortcuts may be taken and the overall process extended.

Cx Lessons Learned: Mechanical Systems

If the operating pressure range limits of the venturi-type air valves are not accounted for in the design of the ductwork layout, it is highly probable that the system will simultaneously experience both under-ranged and over-ranged valves. Although this is not an issue if terminal boxes are utilized for supply air and exhaust air valves, terminal boxes have their own unique set of problems. Achieving system "steady-state" conditions with VAV terminals is much more difficult than with venturi-type air valves. While overcoming unbalanced ductwork branches can be accomplished with the use of strategically placed manual volume dampers (MVDs) at each exhaust air duct branch take-off, it may be better to incorporate equal pressure drop exhaust air branches into the project during the design phase, where the cost impact is more readily tolerated and absorbed.

The pressure taps provided with the venturi-type air valves for monitoring valve ΔP should be utilized for sensing/confirming the presence or absence of airflow. If this is done, it will greatly facilitate the implementation of interrelated control sequences. The actual pressure loss through HEPA filter boxes (with or without installed filter media) should be verified with factory and field performance tests, to confirm that actual HEPA box ΔP is similar to the pressure loss allotted for in the design documents. This will help the design engineer confirm whether or not the correct fan brake horsepower, VFD, and drive package have been provided. Final design airflows for process equipment should also be verified via factory performance tests in order to have confirmation that correct airflows have been specified.

There should be one duct branch per exhaust inlet. Avoid ganging or combining exhaust ductwork from adjacent rooms onto the same ductwork branch within the BSL-3/ABSL-3 spaces, as this complicates setup of the correct pressure relationships between rooms. Any ganged ductwork must incorporate MVDs for each exhaust inlet.

Design airflows for bio-safety cabinets (BSCs) should be based upon the airflow range that will ultimately appear on the actual BSC hood tag, which includes the manufacturer's requirements. The TAB agency should base the final airflow setting on the

mid-range point of the hood tag. Thimble connected type A2 BSC exhaust airflows do affect space pressurization depending upon whether the internal BSC fan is on or off. It is recommended that the fan be set for continuous operation. It should be noted that the ganging of ductwork in BSC rooms exacerbates the affect that a type A2 BSC has on space pressurization.

The TAB agency should be required to perform a final pass to confirm that no venturi-type air valves are over or under-ranged, and that the supply and exhaust air handlers are set to the minimum possible static pressure setpoint necessary for maintaining all venturis within their required operating range. Omitting this step will adversely impact the setup of proper lab pressurizations, and will also result in the owner incurring an annual energy penalty.

Cx Lessons Learned: Control Systems

Control system point-to-point checkout needs to be completed prior to the start of TAB fieldwork and Cx/FPT so that unnecessary delays are not encountered during acceptance testing. In reference to the RBL project, the supply air handling units were not initially interlocked to shut down in the event of an exhaust air handling unit failure. This resulted in positively pressurizing several BSL-2, BSL-3 & ABSL-3 lab spaces, and would have most likely led to a containment breach had this occurred in an occupied facility. In addition, several air handling unit control and/or safety devices were initially found to be non-functional or improperly set to perform the intended function (i.e. low-temperature trip, high discharge and or suction static pressure DP trip).

Several lab control function sequences and/or interlocks were working improperly during the initial Cx/FPT, because the revised sequence had not been "mapped" back to the BAS from the local control panel. The initial response times obtained during Cx/FPT of sequences of operation for both supply and exhaust air handling units resulted in both positive and negative pressure spikes being generated in the labs. An administrative area air handling unit designed to back up a containment area unit failed to energize during initial functional checkout, and as a result did not fulfill its assignment of providing redundancy to the lab air handling unit.

Fan interlocks should not be triggered by only VFD speed since a broken fan belt could fool the control system, as the VFD speed would not change even if a fan had a broken drive belt. This author recommends that a backup sensor such as a current transformer is also be utilized, so that an alarm will be generated if a fan belt breaks.

The points below include additional key discussions with regard to control systems.

- Low exhaust airflow should be utilized in lieu of zero airflow triggering the close of supply air isolation valves, because valve stroke timing is such that supply air could still reach the lab while the exhaust air valve is closing. Utilizing low airflow ensures that some exhaust remains after the supply air valve has closed. It also very helpful to provide spring return SA isolation valves, so that the SA is shutoff to the labs during a power outage.
- Decontamination Sequence of Operation: The venturi-type air valve control loops should be tuned to accelerate the valve to its minimum position upon initiation of sequence and accelerate it back to its previous position at the end of the control sequence.
- HEPA Filter Change-Out Sequence of Operation: Minimum and maximum airflow control loops should be pre-biased, via venturi-type air valve pressure drop, to facilitate the initiating and ending of this control sequence.
- On at least two of the RBLs it was found necessary, by the controls technician and the Cx authority, to initiate a low airflow event via the exhaust air valve low flow switch to ensure that the exhaust air valves could be reset to their minimum airflow position during various failure scenarios/ exhaust & supply fan switchovers when the lab spaces could go positive.

- Hot-wire anemometer type laboratory space ΔP sensors tend to respond too slowly and do not read accurately when 50% of the rated pressure range is exceeded (± 0.1 in. wg. for a maximum pressure range of 0.2 in. wg.). This same type pressure sensor can also indicate the opposite sign (i.e. positive vs. negative or vice versa) on their displays once they have been over-ranged.

Electrical Systems

The following points are some of the main lessons learned with regard to electrical systems.

- **Emergency Power:** Phase Sequence and rotation should be verified prior to final connections. It is possible in today's market to have the same type of transformers supplying feeds to the facility and provide different phasing.
- **Circuit Arrangement:** Equipment and circuit arrangement should be well developed. In one of the RBLs, the systems were arranged such that the control system was fed by a single ATS, and loss of this specific ATS would have endangered the facility and its operations, as it was the only source of emergency power. Emergency power feed to the HVAC controls should not be limited to a single ATS.
- **Control System UPS:** In many cases, a UPS for the control systems would protect against single point failure of systems (if on separate ATS) or inadvertent errors/loss of data.
- **Light Fixtures in BSL-3 Areas:** Light fixtures in BSL-3 areas could be serviced better if accessed/changed out from interstitial spaces. This would prevent sealant issues when lamps or ballast changes are required from the lab space. In general, it is much preferable that lights in these areas are surface mounted.
- **Fire Alarms in Labs:** Fire alarms notification is not required by codes for BSL-3 labs. However, this may be a life safety issue that warrants consideration. One RBL from the discussed project is currently retro-fitting due to an occupying researcher not being aware of a fire alarm evacuation notice during testing.
- **Security:** Zones, zone interlocks, pushbutton overrides and surveillance camera operations and labeling are crucial issues for the completion of an RBL. The security contractor should be required to participate early and the safety officer should require SOPs to be completed early enough for controls and security sequences to be determined and installed in a timely manner.

Unanticipated Findings

An unexpected finding in one of the RBL facilities was that approximately 10% of the bioseal dampers had failed. The failing BSDs had end-switch position status indicators that were indicating the opposite status of the actual valve position. This was deemed a significant finding, since the purpose of the BSD is to prevent flow reversal in the lab spaces by quickly and totally shutting down the SA airflow to the labs in the event of a power failure. Due to possible serious consequences of a flow reversal in a lab space, the Cx agency recommended an investigation of all BSDs, in order to determine the cause of the valve failure.

It was subsequently discovered that the BSDs had defective end switches when they were initially installed, which was discovered during valve startup. The defective end-switches were allowing the BSD worm drive actuators to continue applying closure torque to the BSD closure mechanism, even after the damper blades were actually closed. Because of the nature of this particular type of failure, a strong possibility existed that additional hidden damage could have been incurred by the BSDs.

The presence of an independent Cx agency forced additional investigation by the manufacturer to determine the extent of the damage, even though an already "tight" construction schedule made this an unpopular decision. The final result this recheck of all BSDs was that repair and/or service work needed to be carried out on 43 of 46 valves. This work included: removal, inspection and reinstallation of all BSDs; resetting of several BSD end switches; realignment of several BSD valve position indicators; cleaning and removal of construction debris found in the BSDs; and recertification of proper BSD shutoff against 10 in. wg. + applied test pressures.

Summary and Conclusion

The deficiency items identified and ultimately repaired at the three RBLs discussed and modified via the Cx process were extensive, but were all clearly documented in the final Cx reports. However, because of the presence of an independent Cx agency, whose impact was further strengthened by the presence of an independent TAB agency, all critical items identified and flushed-out by the Cx process were dealt with, retested where applicable and witnessed performing satisfactorily. The economic impact values were analyzed and calculated from data and circumstances included in the final Cx report, and are summarized below for the reader's information and reference.

The opening of all three of the RBLs discussed herein was not achieved without difficulty, without schedule delays, without frayed nerves or without the ultimate cooperation of all parties involved, but all were successfully certified and opened. The savings indicated above were only researched and calculated for the first RBL, but this author is confident that the order of magnitude shown is applicable for all three RBLs.

ITEM DESCRIPTION	CAPITAL INVESTMENT LOSS AVOIDANCE ($)	ANNUAL ENERGY PENALTY AVOIDANCE ($)	COMBINED FIRST YEAR SAVINGS ($)
MECHANICAL	749,800	47,183	796,983
ELECTRICAL	127,800		127,800
GRAND TOTAL	**877,600**	**47,183**	**924,783†**

†The author had no way of estimating the amount of dollars in federal and/or private research grants that could have been put on hold or canceled had this RBL begun operation any later than was achieved.

Crucial to the ultimate success of the RBL facilities was the utilization of an independent Cx agency, an independent TAB agency and the active leadership and involvement provided by the owner. The direction provided by the Cx team, and the cooperation of all team members, including quick responses to implementing repairs, all contributed to their successful completion of these projects.

Scrubber Exhaust Systems

Wade A. Handley, TBE, Technical Air Balance SW, Inc.

A client recently requested troubleshooting an air deficiency in a scrubber exhaust system, which was exhausting nitric acid. They had purchased a scrubber exhaust system from an HVAC scrap yard, and after the system was refurbished and installed, the customer was experiencing strong odors and discomfort in their new manufacturing warehouse. They had been told that the system would deliver 10,000 CFM at 3" static pressure at 60 Hz, and the manufacturing process required only 5,000 CFM.

Upon initial testing, the system was delivering only 3,578 CFM at 1.77" entering static pressure at 60 Hz. It was determined that a new drive combination was required to achieve 5,000 CFM. No fan curves or equipment submittals were available for the system, so the drive combination was calculated off of airflow. With the new drive combination installed, the unit would trip the circuit breakers for the fan, yet the motor was not over-amped. It was determined that the electrical service was on a 30 amp circuit, but should have been provided on a 40 amp circuit. The owner consulted with the electrical engineer, who determined that the 30 amp service should be adequate for the equipment and that there must be a problem with the unit. The drive combination was reset to the original.

The test and balance agency noticed salt build-up on all access doors, and asked what chemicals the customer was using to dilute the nitric acid. The answer was sodium hydroxide. Maintenance personnel were asked about their preventative maintenance schedules and what specific tasks they performed. Twice a week, they had to shut the system down and clean the basin out due to excessive sodium hydroxide build-up that restricted the inlet to the scrubber by 50%. Tests were scheduled to coincide with one of their preventative maintenance shutdowns. After the basin was cleaned, the system was retested and the airflow improved—but only by 4%.

The test and balance agency next asked for them to demonstrate their cleaning procedures. This revealed that their work was limited to the basin—no work was done on the mist eliminator or the fan. Removal of the inspection ports on the mist eliminator and the fan showed extreme build-up on those components as well.

The maintenance crew was advised to add the mist eliminator and fan to their preventative maintenance schedule. After the entire system had been cleaned, the fan was retested. With the VFD set at the proper frequency to deliver 5,000 CFM, the discomfort and odor had been eliminated. In retrospect, this inspection should have been carried out earlier, during the initial survey.

Tech tips

Filter Back Return Grilles

David Parker, TBE, Thermocline Corp.

The use of filter back return grilles is common in many commercial HVAC systems, and there are a number of issues to be aware of when they are present.

It is reasonable to assume that the grille size is determined by the airflow requirement, not necessarily the filter capacity. For systems using a variety of grille sizes, facility maintenance departments should retain a stock of multiple filter types. In several instances during design review, we have recommended standardizing the filter back grille size to improve efficiency and decrease the cost of filter maintenance.

Generally, there is not a gauge to indicate the condition of a filter. As a result, in some facilities the filters are changed during scheduled maintenance without regard to whether it is necessary, causing an additional expense to the facility's budget.

Sizing a return grille in the upper range of acceptable airflow may potentially result in early filter loading, which is why systems with multiple return grilles may experience unbalanced airflow. The probability of equal filter loading on systems with multiple filter back grilles is low; therefore, the balance of the return system can only be assumed to be correct when fresh filters are installed.

For systems without modulating outside air, the filter back return grille can cause considerable variations in the outside air volume. As the filters load, the outside air will increase, possibly exceeding specified cfm and coil capacity, which may result in high building pressure and undesirable indoor air quality.

Filter back grilles might never be phased out of commercial HVAC systems, therefore the effect they have on those systems needs to be understood and kept in mind during design, test and balance, and system maintenance.

Do you have a "Tech Tip" that you would like to share with our readers? If so, please contact AABC at:

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Test, Adjust and Balance
Per National Standards and Codes

Gerald J. Kettler, P.E., TBE
AIR Engineering and Testing, Inc.

Testing and balancing can be defined as the art and science of establishing air and water flows. It is the process of ensuring that the heating, ventilating, and air conditioning (HVAC) systems and sub-systems perform at the design intent and operate at the optimum level.

Total System Balance as defined by AABC includes a methodical approach to testing and balancing all systems to their optimal performance and verifiable test results, and includes construction observation and the review of design documents for balanceability.

The test and balance (TAB) process is divided into three definitions in chapter 38 of ASHRAE's *2011 Applications Handbook*. ASHRAE's definitions are as follows:

> **Test** – Determine quantitative performance of equipment.
>
> **Adjust** – Regulate the specific fluid flow rate and air patterns at terminal equipment, (e.g., reduce fan speed, or adjust a damper).
>
> **Balance** – Proportion flows in the distribution system (sub-mains, branches, and terminals) according to specified design quantities.
>
> **Balanced System** – A system designed to deliver heat transfer required for occupant comfort or process load at design conditions.

In short, TAB adjusts the air and water flows in HVAC systems to match the design, to provide comfort measures, and for optimum efficiency. Over many years, the TAB process has become a requirement from design professionals to ensure that their design is installed as intended, and that it operates correctly. The requirements are shown in specification section(s) or drawing notes in the construction documents.

Only recently have the construction standards and codes established a requirement for TAB (and also commissioning). Both air quality standards and energy efficiency standards and codes have established requirements for TAB.

The ASHRAE Standard 62.1-2010, *Ventilation for Acceptable Air Quality*, establishes the importance of TAB for air quality (in chapter 7, paragraph 7.2.2) as follows:

> "Air Balancing. Ventilation systems shall be balanced in accordance with ASHRAE Standard 111, SMACNA's HVAC systems-Testing, Adjusting and Balancing or equivalent at least to the extent necessary to verify conformance with total outdoor airflow and space supply airflow requirements of this standard."

The ASHRAE Standard 90.1, *Energy Standard for Buildings Except Low Rise Residential Buildings*, (chapter 6) establishes the following requirements:

> "**6.7.2.3.1 General.** Construction documents shall require that all HVAC systems be balanced in accordance with generally accepted engineering standards (see Informative Appendix E). Construction documents shall require that a written balance report be provided to the building owner or the designated representative of the building owner for HVAC systems serving zones with a total conditioned area exceeding 5000 ft^2.
>
> **6.7.2.3.2 Air System Balancing.** Air systems shall be balanced in a manner to first minimize throttling losses. Then for fans with fan system power greater than 1 hp, fan speed shall be adjusted to meet design flow conditions.
>
> **6.7.2.3.3 Hydronic System Balancing.** Hydronic systems shall be proportionately balanced in a manner to first minimize throttling losses; then the pump impeller shall be trimmed or pump speed shall be adjusted to meet design flow conditions.
>
> **Exceptions:** Impellers need not be trimmed nor pump speed adjusted
>
> a. pumps with pump motors of 10 hp or less, or
>
> b. when throttling results in no greater than 5% of the nameplate horsepower draw, or 3 hp, whichever is greater, above that required if the impeller was trimmed.
>
> **6.7.2.4 System Commissioning.** HVAC control systems shall be tested to ensure that control elements are calibrated, adjusted, and in proper working condition.

Requirements

"Testing and balancing can be defined as the art and science of establishing air and water flows."

For projects larger than 50,000 ft² conditioned area, except warehouses and semi-heated spaces, detailed instructions for commissioning HVAC systems (see Informative Appendix E) shall be provided by the designer in plans and specifications."

The 2012 version of the International Code Council (ICC) Energy Conservation Code (chapter 4, paragraph C408.2.2) uses similar language to establish requirements for test and balance. Thus, TAB will be code mandated as the new energy code is adopted.

Another new code, the ICC International Green Construction Code (IgCC) released earlier this year, also includes requirements (in chapter 6) for test and balance. These include:

"**612.1.2 Systems adjusting and balancing.** HVAC systems shall be balanced in accordance with generally accepted engineering standards. Air and water flow rates shall be measured and adjusted to deliver final flow rates within the tolerances provided in the product specifications. Test and balance activities shall include as a minimum, the provisions of Sections 612.1.2.1 and 612.1.2.2.

612.1.2.1 Air systems balancing. Each supply air outlet and zone terminal device shall be equipped with a means for air balancing in accordance with the International Mechanical Code. Discharge dampers are prohibited on constant volume fans and variable volume fans with motors of 10 hp (18.6 kW) and larger. Air systems shall be balanced in a manner to first minimize throttling losses then, for fans with system power of greater than 1 hp, fan speed shall be adjusted to meet design flow conditions.

Exception: Fans with fan motor horsepower of 1 hp or less.

612.1.2.2 Hydronic systems balancing. Individual hydronic heating and cooling coils shall be equipped with means for balancing and measuring flow. Hydronic systems shall be proportionately balanced in a manner to first minimize throttling losses, then the pump impeller shall be trimmed or pump speed shall be adjusted to meet design flow conditions. Each hydronic system shall have either the capability to measure pressure across the pump, or shall have test ports at each side of each pump.

Exceptions:

a. Pumps with pump motors of 5 hp or less.

b. Where throttling results in not greater than five percent of the nameplate horsepower draw above that required if the impeller were trimmed.

612.1.3 Functional performance testing. Functional performance testing shall be in accordance with the requirements of Sections 612.1.3.1, 612.1.3.2 and 612.1.3.3.

612.1.3.1 Equipment. Equipment functional performance testing shall demonstrate the installation and operation of components, systems, and system-to-system interfacing relationships in accordance with approved plans and specifications such that operation, function, and maintenance serviceability for each of the commissioned systems is confirmed. Testing shall include all specified modes of control and sequence of operation, including under full-load, part-load and all of the following emergency conditions:

- Each mode as described in the sequence of operation.
- Redundant or automatic back-up mode.
- Performance of alarms.
- Mode of operation upon a loss of power and restoration of power.

612.1.3.2 Controls. HVAC control systems shall be tested to document that control devices, components, equipment, and systems are calibrated adjusted and operate in accordance with the approved plans and specifications. Sequences of operation shall be functionally tested to document that they operate in accordance with the approved plans and specifications.

612.1.3.3 Economizers. Air economizers shall undergo a functional test to determine that they operate in accordance with manufacturer's specifications."

Thus we can see that the function and importance of testing and balancing is both recognized and required by the standards and code organizations.

Ultraviolet Lighting for HVAC Disinfection

Documented testing of UV disinfectant by a Danish physician, Dr. Niels Finsen, discovered in the 1880s that UV lighting destroyed pathogenic organisms.

Beto Felix, TBE, Penn Air Control, Inc.

Ultraviolet (UV) waves are just one of the many forms of radiation in the electromagnetic spectrum, and are commonly known for skin tanning, skin treatment, and seasonal affective disorder. These wavelengths are also used in food production, food storage, reduction of microbials on the surfaces of HVAC systems, and sterilization of medical equipment.

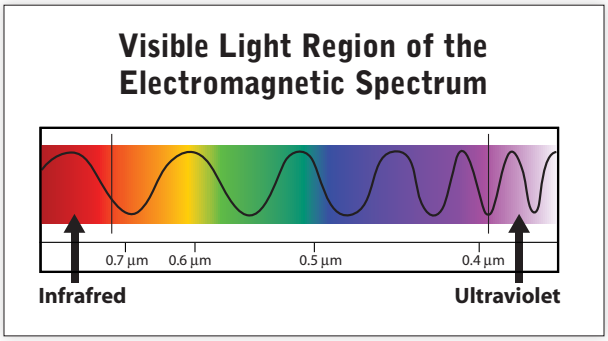
The first documented testing of UV disinfectant was by a Danish physician, Dr. Niels Finsen, who discovered in the 1880s that UV lighting destroyed pathogenic organisms. Finsen won the Nobel Prize in 1903, and his Finsen curative lamp was used to treat patients until the 1950s.

Today, UV lamps—particularly UV-C, also called UVGI (ultraviolet germicidal irradiation)—are becoming more common in the HVAC industry and continue to be tested and compared for the purpose of air purification.

Let's review UV wavelengths, their role in the HVAC industry, and studies testing their effectiveness.

UV rays are the Earth's special air purifier. UV-C/UVGI rays in particular destroy microorganisms present in the outdoor air. Each of the four UV waves has its own wavelength, just as the colors you would see when passing light through a prism (color spectrum). They are shorter than visible light but produce electromagnetic radiation.

- **UVA:** Largest UV wavelength in sunlight **(400-315 nm)**. Used for indoor/outdoor tanning and treatment of skin diseases.
- **UVB:** Middle wavelength in sunlight **(315-280 nm)**. Used to treat skin diseases
- **UV-C/UVGI:** Shortest wave of ultraviolet radiation **(200-290 nm)**. Used to destroy bacteria and other biological contaminants in air, liquids, food, and surfaces. This wavelength is responsible for destroying microorganisms in outside air.
- **Vacuum UV (VUV):** Combination of UV and ozone **(200-30 nm)**. This type can only be used in a vacuum.



UV-C/UVGI light fixtures are a source for HVAC air purification. The UV-C/UVGI rays reduce the amount of airborne and surface area microorganisms. Hospital infections and airborne microbials have been proven to be reduced when UV-C/UVGI is provided.

The process of UV-C/UVGI lighting (254 nm) attacks the DNA and RNA of bacteria, fungi, mold, and other microorganisms on a cellular level, which causes the death of the cell by preventing it from multiplying. *Pseudomonas aeruginosa*, for example, is a common type of bacteria found in hospitals and known for its versatility and growth in condensate drains, where they can become airborne. The Centers for Disease Control and Prevention states that ". . . overall incidence of *P. aeruginosa* infections in U.S. hospitals averages about 0.4 percent (4 per 1,000 discharges), and the bacterium is the fourth most commonly isolated nosocomial pathogen accounting for 10.1 percent of all hospital-acquired infections."[1]

Prior to 2006, there was no acceptable standard for aerosol and bio-aerosol inactivation testing in the air stream. Previous studies were conducted solely on surface areas like sterilization tables, cooling coils, and condensate pans. In 2006, the U.S. Environmental Agency's National Homeland Research Center conducted a series of tests to determine the effects of aerosol and bio-aerosol products being introduced into an Abracair 440 watt HVAC In-Duct UV light system. This test was based as a precaution for biological anti-terrorism. Three organisms were tested:

1. *Bacillus atrophaeus:* 6.9% inactivation efficiency
2. *Serratia marcescens:* 99.8% inactivation efficiency
3. Bacterial Virus MS2: 59% inactivation efficiency

The irradiation effectiveness varied, proving that not all types of organisms are 100% removed from the air stream under the testing conditions provided by the EPA's Technology Testing and Evaluation Program.

Calculation for intensity factor:

Dose (output of the UV lamp) = Lamp Output at 1 meter (microwatts/cm²) x Intensity Factor x Time (sec)

Intensity Factor Table [6]	
Distance (Inches)	Intensity Factor
2	32.3
3	22.8
4	18.6
6	12.9
8	9.85
10	7.94
12	6.48
14	5.35
18	3.6
24	2.33
36	1.22
39.37 (1 meter)	1.0
48	0.681
60	0.452
80	0.256
100	0.169
120	0.115

The installation and ventilation system parameters play a large role in the success of killing off microbials with an in-duct UVGI system. “Operating an in-duct UVGI system at air velocities above the design will degrade the system’s effectiveness because of the cooling effect of the air on the lamp surface . . .” [3] not to mention the time needed to destroy any airborne pathogens in its path.

UVGI lamps vary in velocity and temperature, so data from the lamp’s manufacturer should be considered during design. As discussed in the Carrier Corporation’s “Selection Guide” to their Ultraviolet Germicidal Lamp [4], the “intensity factor” refers to the strength of a UV-C/UVGI lamp’s output according to the distance between the lamp and a target area. Carrier’s guideline[5] includes an intensity factor table and calculation for evaluation a UV-C/UVGI lamp’s output strength. The basis of the table and calculation is that at 1 meter (39.27”) the intensity factor is 1.0. The calculation and table for intensity factor are listed at left.

Other studies have shown that the success of these lamps is determined by their location in relation to the filter. For example, a filter will not become microbe-free unless it is entirely in the path of irradiation. "For example, if two filters are placed in a system using 100 microW/cm², with one in the path of irradiation and one outside this path, the latter filter will appear to be more contaminated than the former[7].

Research shows that UVGI can be more successful in removing bacteria than the option of increasing air changes per hour. In 1994, the Centers for Disease Control and Prevention accepted the guidelines of 12 air changes/hr for newly and remodeled tuberculosis rooms, and six air changes per hour for existing facilities. This guidance was accepted as part of efforts to reduce the risk of tuberculosis in health care facilities.

A recent study by the National Institutes of Health tested 40 rooms with various in duct UVGI lamp intensities. The results concluded that increasing exhaust flow from 6 to 16 air changes/hr resulted in a 30% reduction in viable bacteria. But with UVGI

successful in removing bacteria than the option of increasing air changes per hour."

present and only 6 air changes, there was a 68% decrease in bacteria and airflow[8].

Another UVGI option is called "Upper-Air." UVGI lamps are hung at the "upper" portion of the rooms and require no alterations to the existing ventilation system(s). Upper-air UVGI systems assist in the purifying step of reducing airborne transmission such as tuberculosis. Success depends on using the correct amount of UV radiation, the length of exposure time, and the system's location in the room.

Safety around UV-C/UVGI rays is critical, as damage to the eyes can occur in a matter of seconds. A colleague once entered a package unit for a fan rpm reading and was exposed to the UV-C/UVGI rays for less than 10 seconds. He felt no discomfort until 30 minutes later, when he began to feel the sensation of sand in his eyes. The technician then made a trip to the ER, where gauze was placed over the more severely affected eye due to an increased sensitivity to light.

Other test and balance companies have similar stories. Although there are UV-approved goggles, it is recommended to shut down lamps prior to entering a duct or HVAC unit that utilizes this type of air purification. As the industry sees more and more of this type of purification, it is critical to train your technicians to protect against exposure.

The disinfection of airborne disease transmission in a hospital's waiting room or isolation room can be categorized in three steps:

1. **Filtration:** Filters
2. **Dilution:** Air changes
3. **Purification:** UVGI

UV-C/UVGI rays in the HVAC industry are proven to be effective as a disinfectant on surface areas, coils, filters, confined spaces, and isolation rooms. But UV-C/UVGI rays are not proven to be 100% effective and should be seen as a supplement.

Filtration, dilution, and purification all play an important role and should also come as part of the whole package. As with pre-filters and final filters in an air handler, more is better. In the future, we may find the California Mechanical Code Table 4.1 to have a new minimum air change column for systems containing minimum UV-C/UVGI ratings.

[1] *Kenneth Todar, Todar's Online Textbook of Bacteriology, http://textbookofbacteriology.net/pseudomonas.html (2001).*

[2] *U.S. Department of Environmental Protection, Biological Inactivation Efficiency by HVAC In-Duct Ultraviolet Light System, (2006).*

[3] *W. J. Kowalski, http:///www.medicalairsolutions.com/techref/psu/uvgi_design_basics.htm.*

[4] *Carrier Corporation, V-C Usage Calatog No. 811.287, (1999).*

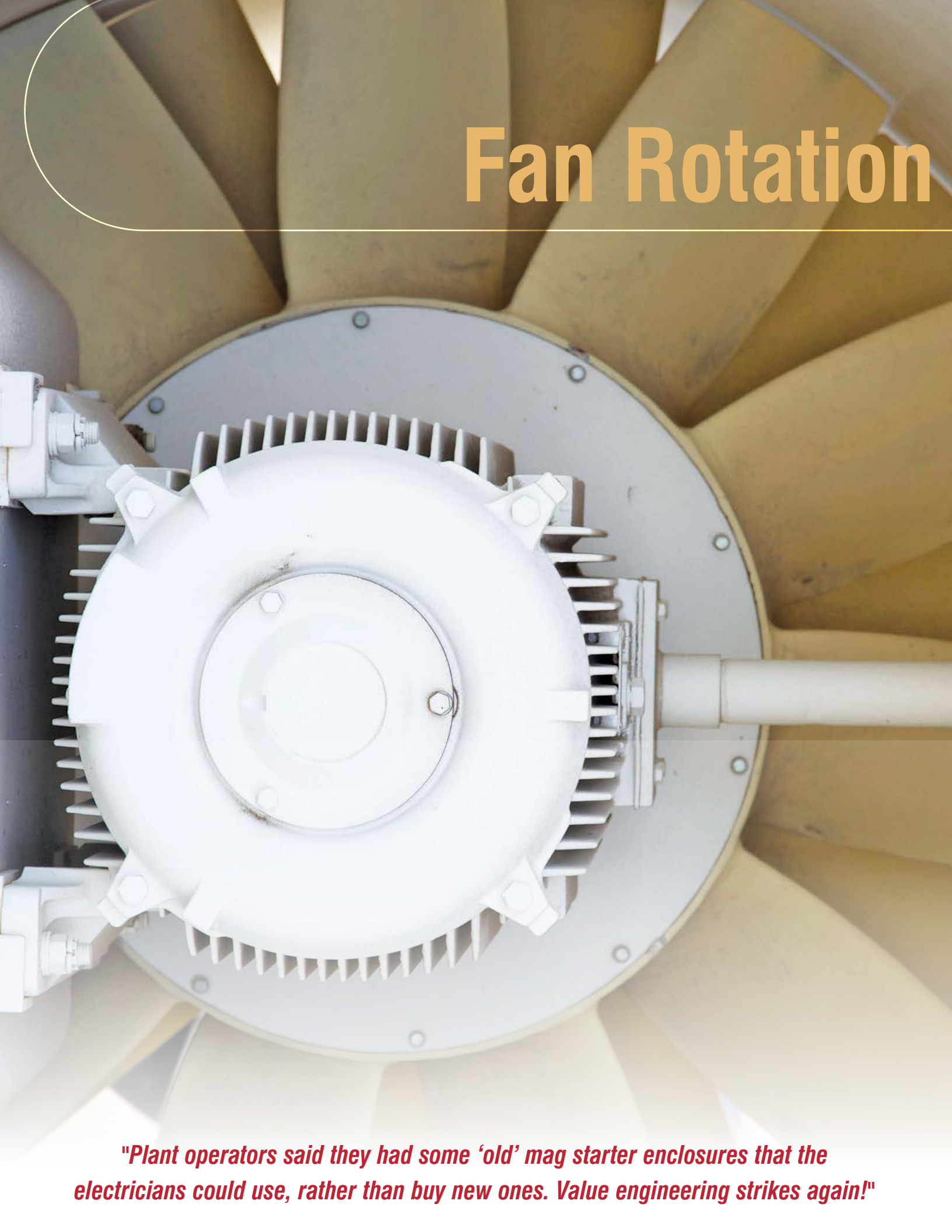
[5] *Carrier Corporation, Ultraviolet Germicidal Lamp/UV-C Information Guide, http://www.thermocontrol.net/images/upload/Products/UV_Lights/811-20030-082203.pdf, (2003).*

[6] *Carrier Corporation, Ultraviolet Germicidal Lamp/UV-C Information Guide, http://www.thermocontrol.net/images/upload/Products/UV_Lights/811-20030-082203.pdf, (2003).*

[7] *W. J. Kowalski, http:///www.medicalairsolutions.com/techref/psu/uvgi_design_basics.htm.*

[8] *D. Linamen, http://www.infectioncontroltoday.com/articles/2001 12/, (2001).*

Fan Rotation



"Plant operators said they had some 'old' mag starter enclosures that the electricians could use, rather than buy new ones. Value engineering strikes again!"

CONUNDRUM

Joseph Danis, TBE
Danis Test and Balance, Inc.

A recent test and balance job on an addition to a wastewater treatment plant posed some interesting challenges, in particular for a building on the premises that houses the solids dewatering equipment.

The main system for the building was a rooftop-mounted make-up air unit, which was designed to deliver 12,000 CFM into the actual dewatering room. There were also two wall-mounted propeller fans for relief air, with design air flows of 6,000 CFM each. These fans were interlocked with the make-up air unit.

Upon entering the building to begin the balancing, the TAB agency observed that one of the propeller fans had an incorrect rotation. This was corrected by shutting off the disconnect and reversing two of the leads to the three-phase motor. In addition to the disconnects located below the relief fans in the dewatering room itself, the fan's motors were controlled and protected with a mag starter enclosure, located in an adjacent electrical room.

After gathering and recording nameplate data, the TAB agency took initial airflow readings on the make-up air unit and the relief fans. Although the system was originally designed to utilize VFDs on the make-up air unit and the relief fans, the VFDs were "value engineered" out to reduce costs—making the system, in essence, a constant volume system.

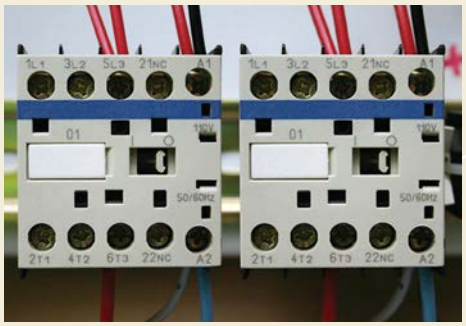
After getting the two relief fans set up where they needed to be, TAB personnel went to the roof to begin the checkout of the make-up air unit. In the process of gathering nameplate data from the supply fan's motors, drilling holes for static pressure readings across the system's components, and measuring the volts, amps, and static pressures, the unit's disconnect had to be turned off and on multiple times.

When the checkout of the rooftop unit was completed, it was noted that the rubber roof membrane was "puffed up" with air, indicating over-pressurization of the space. The relief fans had shut off for some reason, even though the motors were running well below their rated amps.

The roof access ladder was mounted on the side of the building, with one of the relief fan's louvers mounted just a foot or so away from the ladder. Surprisingly, the relief fan was running. When the door to the building was open, positive pressure was noted blowing through the opening. Inside, it was discovered that both relief fans were running, only both were running backwards.

How could this have happened? Both fans had proper rotation prior to the rooftop checkout of the make-up air unit. Eventually, the mag starter enclosures for each relief fans were examined.

As seen in the photo, each enclosure had two contactors. The contactor on the left had the adjustable thermal overload section attached to it, with the wires leaving the overload section to feed the disconnect located below the fans. After writing down the model number and performing an online search, it was found that the problem the agency was experiencing is referred to as a "reversing contactor."



Side-by-side mag starter enclosures

The electrician was contacted to talk about a possible solution. He said that the plant operators told him they had some "old" mag starter enclosures that the electricians could use, rather than buy new ones. (Value engineering strikes again!) The starters were previously used on large pumps with inlets that had periodically become clogged with waste. The reversing contactor would reverse the pump's rotation, kicking out the blockage, and allowing the pump to function properly.

The electrician studied the wiring diagrams, and finally figured out a way to prevent the reversing contactor from reversing rotation while allowing the primary contactor to remain closed to complete the circuit, and always have correct rotation. Problem solved.

As a result, while the job began as a bit of a stinker, it wound up smelling like a rose.

Routine HVAC Testing in Healthcare Facilities

Sean Green, TBE
Environmental Test and Balance Company

Annual and semiannual HVAC testing has become an important service for many testing and balancing firms. Over the last 25 years, routine testing requirements have increased considerably as a result of improved infection control measures in the healthcare industry.

New construction projects have design air quantities provided for each air handling unit, terminal unit, and air distribution device. A conscientious and thorough TAB firm will confirm that the design will satisfy the minimum industry standards for relative room pressurization and air change rates in the critical spaces.

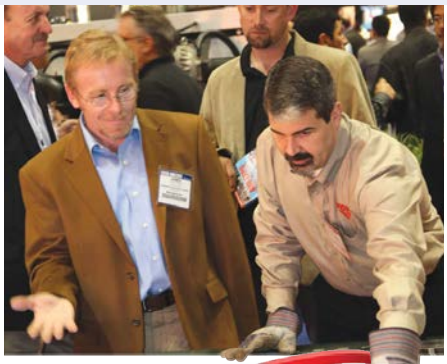
When performing periodic testing for existing facilities, where design air quantities may not be available, knowledge of relevant standards is especially useful. Testing of healthcare facilities will typically lead you to the Facility Guidelines Institute's (FGI) *Guidelines for Design and Construction of Healthcare Facilities* for reference material. This is an excellent source of knowledge for many areas in general, and in particular for information relating to ventilation requirements.

When testing these existing facilities, a clear understanding of the owner's ventilation requirements is vital. The facility managers and infection control departments will use this data as a record for actual conditions of the critical spaces within the hospital, and in most cases will present the TAB report to their governing body and/or the accreditation organization such as The Joint Commission on Accreditation of Healthcare Organizations. The Joint Commission does not provide the actual ventilation requirements or mandate the use of the FGI *Guidelines* if another state or national standard is being applied to a project, but does reference the 2010 FGI *Guidelines* in its latest accreditation manuals.

The Joint Commission is the nation's largest accrediting body, and accredits and certifies more than 19,000 healthcare organizations and programs in the United States. The Joint Commission, along with authorities in 42 states, utilizes the FGI *Guidelines* as a reference standard for new construction, renovations and routine audits of HVAC systems. For new construction projects, the design and actual data will be evaluated for the entire hospital; although annual and semiannual testing will typically address just the sensitive areas such as surgery and critical care spaces, special procedure rooms, infectious isolation, protective isolation rooms, laboratories, and support spaces. The frequency of testing will be determined by either the facility's regulatory body or their own standard operating procedures (SOP).

In 2010, the FGI Guidelines (formerly known as the AIA Guidelines) were updated and amended. Between the 2006 and 2010 editions, the AIA significantly reduced its publishing program and contributions; therefore, the 2010 edition was published under an agreement between FGI and American Society for Healthcare Engineering (ASHE). For this revision, the ANSI/ASHRAE/ASHE Standard 170-2008 *Ventilation of Healthcare Facilities* was adopted and is included in its entirety within the Guideline. This ventilation standard for healthcare facilities aims to improve environmental and infection control concerns in hospitals. Written by the American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE) and ASHE, Standard 170-2008 *Ventilation of Healthcare Facilities* covers the ventilation requirements that can be referenced for pressure relationships, total and outdoor air change rates, and temperature and humidity ranges for critical spaces in hospitals that are routinely tested during annual and semi-annual tests.

Continued on page 22.



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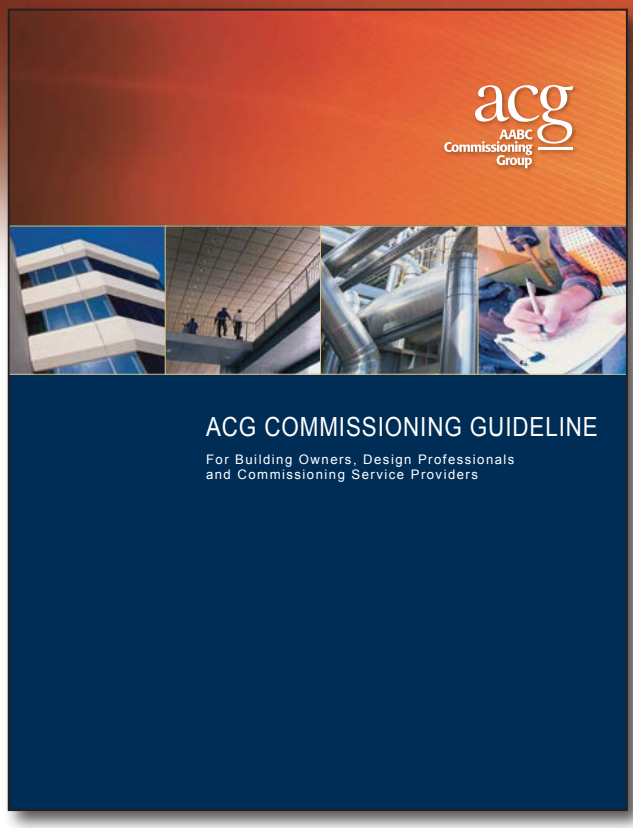

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"In many cases, the healthcare facility managers will not have the knowledge of the HVAC standards and will rely heavily on the test and balance firm for clarity of the ventilation requirements."

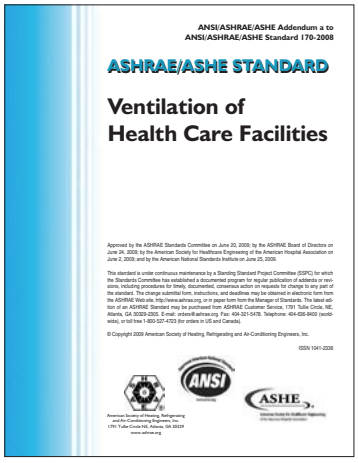
There are many differences in the 2006 *Guidelines* Table 2.1-2 versus the newly recognized Standard 170 Table 7-1 (Design Parameters). Several significant changes (and requirements) to observe when performing the routine HVAC tests include the following:

- Operating room air changes have increased from 15 per hour to 20 per hour.
- Endoscopy rooms have increased from 6 air changes per hour to 15 per hour. In addition, while AIA had no requirements for room pressure relationships, Standard 170 requires a positive room pressure.
- Minimum outdoor air change rates have increased for numerous areas and procedure rooms.

In order to have a clear understanding of the ventilation requirements, a thorough study of Standard 170 should be carried out by the TAB firm. In many cases, the healthcare facility managers will not have the knowledge of the HVAC standards and will rely heavily on the test and balance firm for clarity of the ventilation requirements. The test and balance firm is NOT contracted to certify the rooms, but will provide the information needed for routine surveys and audits. The test data furnished by the TAB firm is typically submitted to the facilities department who works in conjunction with the infection control managers to evaluate the data. This information can then be made available for routine (and unannounced) surveys by organizations, such as the Joint Commission.

As documented by the Joint Commission, new construction projects will need to comply with the 2010 FGI *Guidelines* (or similar a standard). Existing facilities that do not meet these guidelines should ensure that they maintain original design criteria to the maximum extent possible. In many cases, the original design data is not available, and the design parameters for procedure and treatment rooms will need to be determined by the owner and test and balance firm. It is our opinion, and practice, that compliance with the latest FGI *Guidelines* and Standard 170 (with addenda) will result in a successful HVAC survey, and insure that the latest procedures and methodologies for infection control are being exercised. It is also recommended that these tests are performed no less than twice per year, with some protective environment rooms for immunosuppressed patients tested as often as four times per year.

With infection control measures continuously evolving, the FGI and ASHRAE will continue to amend and update the standards with future revisions, with addendums submitted between the revision cycles. Currently, ASHRAE/ASHE has published seven addendums to the original Standard 170-2008 publication. All addendums are available for free download on their website at **www.ashrae.org.**



The FGI *Guidelines* are continuously maintained by the Health Guidelines Revision Committee and the revision cycle is every four years. It is highly recommended that firms performing these tests should update their libraries with the latest publications and addenda. As these documents and organizations represent the state-of-the-art thinking in the healthcare industry, it is expected that the FGI Guidelines and ASHRAE/ASHE Standard 170 will remain the standard of choice for accreditation organizations and state authorities.

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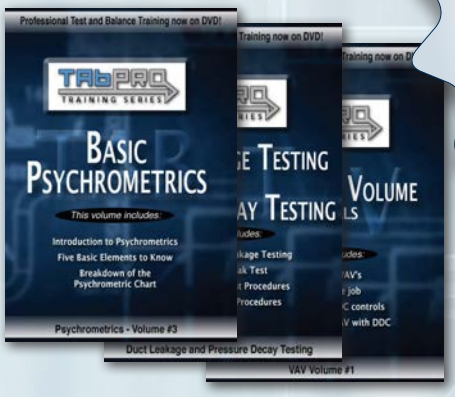

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