

The NEBB Professional

July 2012

- **Top Ten Reasons Building HVAC Systems Do Not Perform as Intended**
- **Health Care Facilities Measuring Isolation Room Pressure—What Do the CDC Guidelines Say?**
- **Creating Audible Sound from Sloppy Pump Motor Replacement**
- **Designing for Proper Testing, Adjusting & Balancing of Air & Hydronic Systems**
- **RECENT NEBB HIGHLIGHTS**



The official magazine of the
National Environmental Balancing Bureau

Real-Time Solutions for HVAC Professionals

The full line of TSI and Alnor industrial ventilation test instruments are designed to accurately and reliably measure a wide variety of parameters important in monitoring and maintaining indoor environments.



Feature-Rich, VELOCICALC® 9565 Multi-Function Ventilation Meters

- Accommodates a variety of plug-in probes
- Displays up to five measurements simultaneously
- On-screen messages and instructions
- Multiple data logging formats
- Bluetooth communications for transferring data or remote polling



Industry-Leading Alnor® EBT721 Capture Hood

- Ergonomic design and ultra light weight for easy one person operation
- Detachable digital manometer for use in other applications
- Use with pitot, air flow, temperature, or relative humidity probes
- Data logging for easy report generation



Highly Accurate PAN200 Series Duct Leakage Testers

- Positive and Negative Duct Leakage Testing in one system
- Generates a Pass/Fail result based on SMACNA's duct leakage test manual
- High accuracy gives confidence in measurements
- Pressurizes duct quickly, allowing testing to begin in minutes
- Includes TSI VELOCICALC® Model 9565-P and DP-CALC™ 5825

Request a Free HVAC Assessment Handbook
at www.tsi.com/hvac_handbook





Letter from the NEBB President

One of the greatest pleasures in running a successful organization like NEBB is serving people who are part of the NEBB community. Our members have a reputation for assisting building owners, architects and contractors in producing and maintaining buildings with systems that perform as they were visualized and designed. This reputation is a result of our strict adherence to NEBB Procedural Standards supported year round by training seminars, publications and NEBB's Quality Assurance Program.

I was fortunate to meet many NEBB professionals at the 2012 NEBB Annual Conference in Anaheim, California. I am deeply touched by their excitement and resolve to continue to deliver exceptional service to meet the sustainability goals set by industry.

As someone with more than 30 years of experience in the HVAC industry, my goal is to promote further knowledge and performance of our professionals in this growing marketplace. There is a lot of focus on sustainability issues that are addressed by each of NEBB's eight disciplines as they help meet sustainability goals of building systems. There is growing awareness and acceptance of NEBB's procedural standards as the leading source in the industry not only in the United States but also around the world. We continue our quest to lead the industry in developing the best standards designed to optimize building systems performance through ongoing feedback and support of our customers.

In the United States, the Federal government mandated that all federal facilities reduce energy consumption by 30% by 2020. Several agencies, Air Force, Veterans Hospitals, Navy and the Air National Guard, have already implemented retro-commissioning (RCx) projects to meet these requirements. These agencies have specified the use of NEBB's Retro-Commissioning Procedural Standards. The NEBB RCx Certified Firm enjoys a natural head start.

The NEBB BSC Committee appointed task forces to upgrade the Procedural Standards to make them clearer and accentuate the technical competency possessed by NEBB BSC and RCx Certified Firms.

These NEBB disciplines could provide another source of income to the NEBB Certified Firm and Certified Professional willing to make any changes necessary to become additionally certified. Watch for these new Procedural Standards to be published this summer.

Neil Marshall
President

Index of Articles

■ Top Ten Reasons Building HVAC Systems Do Not Perform as Intended	2
■ Health Care Facilities Measuring Isolation Room Pressure—What Do the CDC Guidelines Say?	7
■ Creating Audible Sound from Sloppy Pump Motor Replacement	11
■ Designing for Proper Testing, Adjusting & Balancing of Air & Hydronic Systems	14
■ Recent NEBB Highlights	19

The NEBB Professional is a quarterly magazine published by the National Environmental Balancing Bureau.

Mandy Kaur, Editor | 8575 Grovemont Circle, Gaithersburg, MD 20877 | Tel: 301.977.3698 | Email: marketing@nebb.org

Top Ten Reasons Building HVAC Systems Do Not Perform as Intended

Dave McFarlane, Chairman | NEBB's Retro Commissioning Committee

The Heating, Ventilating and Air Conditioning Contractor (HVAC) and the Sheet Metal Journeyman's roles in the construction of new and existing building projects can play a major part in the final comfort and energy efficiency of a building. There appear to be many issues prevalent in the HVAC industry that directly affect energy usage, sound and comfort levels in buildings.

This article will show several problem areas our firm finds recurring on projects. It is always easier to correct problems before the problems are built into the system. The knowledgeable contractor who understands the applicable standards will install these items per the proper standards or notify the engineer before performing work that could create a potential problem. This will reduce problems and reduce chances for an adversarial relationship to develop between the design engineer and the contractor once the project is completed.

Issue # 1

Ductwork is not reinforced for the proper SMACNA pressure classifications.

The Sheet Metal and Air Conditioning Contractors National Association (SMACNA) is the association that has published duct construction standards that designate the proper way to fabricate and install ductwork, duct accessories and air handling equipment. These standards are so prevalent that most construction documents and specification say to the effect "Install ductwork to SMACNA standards".

However, it is the very familiarity with the term SMACNA standards that has led engineers, contractors and sheet metal journeymen to forget to examine current SMACNA documents. These standards have been continually upgraded and improved over the years. The current SMACNA standard is the 3rd edition dated 2005. We still find many engineers and contractors specifying and installing ductwork exactly like they did 25 years ago.

SMACNA pressure classifications now specify ductwork reinforcing for specific duct pressures from ½ inch to 10 inches of static pressure. It is the design engineer's responsibility to specify the systems design static pressure. If the design engineer does not specify an exact static pressure, but instead states "*Install ductwork to SMACNA standards*", SMACNA standards compliance will have ductwork built to a 1 inch pressure class, with the exception of ductwork upstream of a VAV box which should be constructed to 2 inch pressure.

This lack of clarification by the design professional or failure of the installing contractor to follow the required pressure classifications shown in the specifications is the main reason ductwork collapses or blows apart. The duct failure is invariably due to the fact that the proper pressure class was not specified or the ductwork was not constructed to the proper pressure classification. It is relatively inexpensive insurance for the installing contractor to check the pressure classification to verify that a reasonable pressure has been specified for the ductwork and that the actual current SMACNA pressure classifications are being followed in the field.

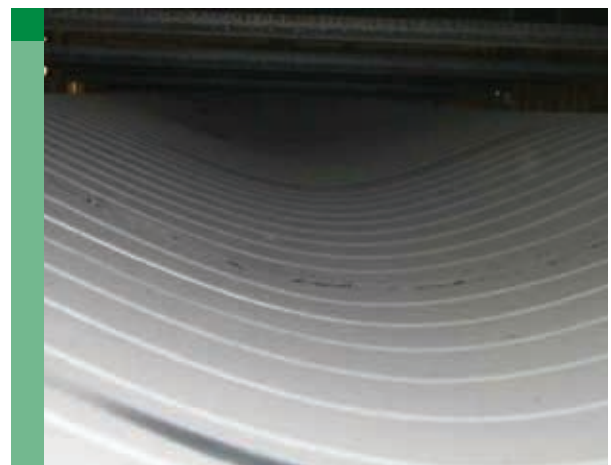


Figure 1. Collapsed ductwork hanger rod inadequate reinforcement



Figure 2. Ductwork blown out and bending

Issue # 2

Failure to adequately seal ducts.

Duct leakage refers to the fact that air inside a supply duct under positive pressure will leak out of the Pittsburgh or Snap lock seams, from the slip, drive or TDC connector joints or out of wall penetrations from damper rods, screws used in hanging ducts or any other wall penetrations.

This leakage causes two problems. When air leaks out of a duct system, some areas at the end of the run may be short of airflow because the air has leaked from the system before it reaches its intended location. This lack of air can cause over heating in the summer or the inability to heat in the winter.

In some cases the fan has the ability to supply enough air to overcome the leakage rate and still meet the room requirements. Excessive fan energy is used to provide the required flow to spaces. The fan energy increases as the cube of the air leakage. For example if a system has 10% leakage and the fan design was originally 20 Horsepower (HP), the new motor required to overcome the 10% loss will be $20 \text{ HP} \times (1.1)^3 = 26.6 \text{ HP}$. In this case, the owner pays for an additional 6.6 HP fan operation for the life of the building.

SMACNA has specified the duct sealing requirements for duct systems. If ductwork is not sealed, leakage rates of 25% on 2 inch plus ductwork can be expected.

SMACNA seal classes of Seal Class A, B and C define the degree of sealing required to be completed. Seal Class

C means that all Transverse joints (Slip, Drive, and TDC) connections need to be sealed. Seal Class B means that all longitudinal seams (Pittsburg and Snap lock) and all joints as above need to be sealed. Seal Class A is the most stringent and means that all wall penetration (damper rods, screws and duct accessories) must be sealed in addition to all seams and joints as defined above.

Failure to properly specify sealing or to actually seal ducts in the field are the primary reasons ductwork systems leak.

Issue # 3

Failure to understand the need to seal return and exhaust ducts.

Air will leak into the ductwork through the same openings described above. When excessive leakage occurs in exhaust ducts, it is sometimes impossible to obtain the required exhaust air at the needed location. We encounter many cases where the exhaust air flow at the fan is 15% over design and the exhaust flow at the register or hood location is 20% under design. This discrepancy is due to the fact that air is leaking into the duct systems along the duct route and not at the specified exhaust point. This can lead to stuffy, stagnant rooms or laboratory exhaust systems not performing as required. System operating costs are also increased by the amount as calculated in Item 2 above.

Issue # 4

Failure to adequately pressure test ductwork to prove that duct sealing is effective.

Ductwork pressure testing is a method to determine how well ducts are constructed to prevent air leakage. Duct leakage testing pressurizes a closed section of ductwork to a known pressure. The amount of leakage at a specific pressure is calculated by measuring the amount of air that is measured as it is blown into the closed duct system.

SMACNA has defined duct leakage rates as Leakage Class 24, 12 or 6. These numbers simply mean that at 1 inch of test pressure ducts can be expected to leak 24, 12 or 6 CFM per square foot of duct surface. The mere presence of duct sealing material on a joint or seam is no guarantee that proper sealing has been achieved.

Once the installing contractor has leak tested several sections of ductwork and has adequate documentation that the duct sealing procedures being used actually keep leakage within the specified ranges, the frequency of sealing can be reduced.

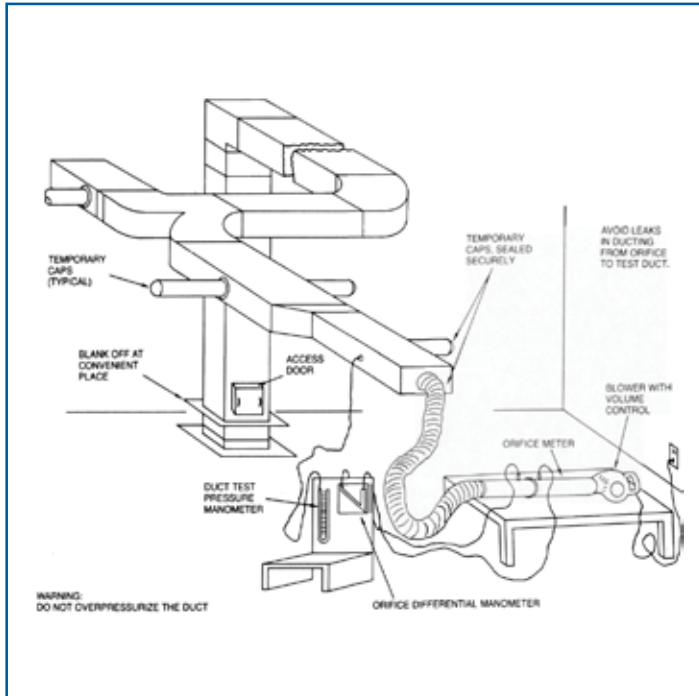


Figure 3. Proper Duct Leakage Testing Apparatus

Issue # 5

Failure to understand SMACNA Duct Construction Standards in the fabrication and installation process.

While SMACNA standards are almost always used as a project reference, our experience has shown that proper techniques are not understood by both the engineers and contractors. Design engineers often do not allow sufficient room to install proper sized transitions or offsets. In many cases when there is insufficient room, journeymen overlook the applicable standard and install transitions or offsets that are choked or do not have proper slope.

When SMACNA standards on fittings are not followed, the entire system has imposed restrictions that the fan must overcome. This extra fan energy is an operating cost the owner bears for the lifetime of the project. In some cases, the addition of several improper fittings can cause air flow noise and lack of adequate air flow to occupied spaces.

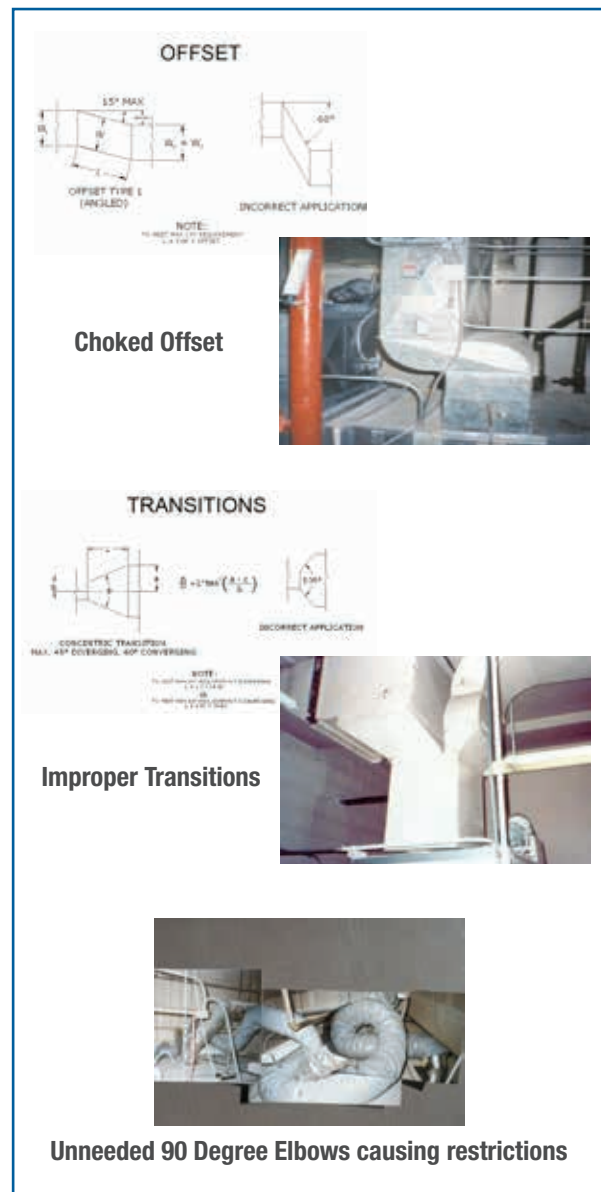


Figure 4. Ductwork fittings that do not comply with SMACNA fabrication standards

Issue # 6

Failure to properly install turning vanes.

Air flowing in ducts has the same restriction whether it is flowing away from the fan or flowing to the fan. Vanes are required in all ducts where the air velocity is greater than 1000 feet per minute (fpm). While most contractors understand the importance of installing vanes in supply duct, a misconception seems to exist in the industry that implies return ducts and exhaust ducts do not require turning vanes.

The previous six issues involved contractor related concerns in duct installation and fabrication. Many

design engineers continue to unknowingly make similar missteps in preparing design documents and specifications.

The HVAC contractor that understands the problems these issues create can stop potential problems that will show up during startup by informing the design engineer of the concerns before ducts and systems are installed.

Issue # 7

Duct velocities approaching 2500 fpm may create noise and will cause increased pressure drops in fittings and ductwork.

Duct velocity can be calculated by dividing the design air flow in a duct at any location by the area of the duct in that location. For example, if a fan is rated at 6000 Cubic Feet per Minute (CFM) and the duct size at the fan discharge is 24 x 12, the velocity is $6000 \text{ CFM} / (24" \times 12") / 144 \text{ sq inches per sq ft} = 3000 \text{ fpm}$.

When velocities are over 2500 fpm, it is good practice to notify the engineer and voice your concerns. It is much easier to solve a potential problem by increasing duct size before the duct is installed. Whenever potential problems can be addressed and corrected before they are found during the Test and Balance phase of the project, the design engineer and installing contractor remove a potential issue that has the chance to become adversarial.

Issue # 8

The detrimental impact on fan capacity caused by fan system effect is a problem not fully understood by the design industry.

System effect is the fact that fans are tested with a specific amount of straight duct connected to the inlet or discharge. Whenever installation conditions differ from the test installation, the fan will suffer reduction in capacity.

The drawing Figure 5 shows that airflow leaving a fan does not reach a uniform flow profile for several duct diameters from the fan discharge. The distance required to reach uniform flow is dependent of the velocity of the air. The higher the duct velocity, the greater the distance required before this uniform flow is attained.

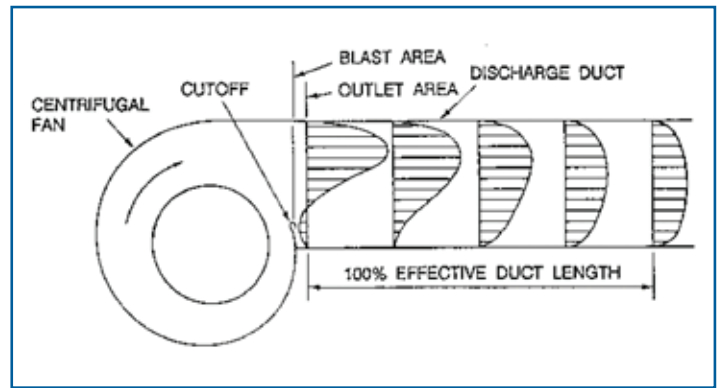


Figure 5. Fan outlet velocity profile

Any item installed before 100% effective length is attained, will reduce the capacity of the fan

All duct accessories (fire dampers, control dampers, sound attenuators, etc) are all tested with uniform flow conditions when their design pressure drop is determined. Whenever any one of these components is installed in a portion of ductwork where the flow is not uniform (See the above Figure 5), the actual pressure drop will always be greater than the design pressure drop.

When system effect imposed pressure drops are not counted in design calculations, fans have greater static pressure than calculated and the fans do not generate the required air flow.

Elbows installed in the zone of non-uniform air flow also create a system imposed pressure drop.



Figure 6. Offset installed in the turbulent area of a fan discharge

The American Movement and Control Association (AMCA) has documented the various additional pressure drops that should be added to the calculated pressure drops.

System effect is a phenomenon that cannot be measured, but it is real and is one of the reasons many fans cannot develop the required capacity shown in manufactures catalog data. The owner and design engineer will all benefit if the contractor or journeyman will take a close look at fan inlets and discharges during shop drawing approval or the field measuring phase of the project. During this time it is advisable to determine if any duct accessory or elbow has been installed within the first 4-6 duct diameters from the fan inlet or discharge. If this situation exists, the design engineer should be notified and informed of the potential problem.

Issue # 9

Drawings with missing dimensional sizes are usually interpreted improperly. Undersized ductwork is usually installed.

The problem is usually seen on VAV box inlets where duct sizes are omitted from the drawings.

It has been our experience that when inlet sizes are not shown on the drawings, the installing contractor invariably installs ductwork that is sized for the inlet size of the VAV box.

In many instances the VAV inlet is sized for velocities that exceed 2500 fpm. While this velocity may be satisfactory for the 6 inch inlet length of a VAV box, the same problems shown in Item 7 will again surface on the ducts leading to the VAV box. The problems are compounded when extended lengths of inlet duct and numerous elbows are installed. Inlet static pressure to the VAV box can be reduced to the point that the box will be starved for air. To compensate for this, the fan speed is increased and the owner pays excessive energy over the life of the project just because one or two VAV inlets are undersized.

Issue # 10

Most specifications and details call for four duct diameters of straight duct before the inlet to a VAV box, but the actual duct drawings do not have sufficient room to allow for this installation.

When sufficient lengths of straight ducts are not installed, the air flow sensors on a VAV box do not read properly. This causes the VAV box to hunt and cause the VAV controller to be hard to control. Unstable control

can cause noise and cause the fan to operate at higher static pressures than necessary.

The following example shows the cost to operate two systems for the same sized building. While each building is the same size and has the same heating and cooling capacity, Building II will show the increase in energy costs because various items in the article listed above list exceeded those in Building I.

Cost example:

Assume a system with the following components:

- 100,000 sq ft, 5 Story Office Building
- Occupied 16 hours per day 6 days per week
- \$.10 KW –hr
- \$12.00 KW demand

	Example 1	Example 2
Air Flow (Duct Leakage)	105,000 CFM	115,000 CFM
System Effect Fan Discharge		
Elbow Placement	.5 in	1.5 in
Sound Attenuator Placement	.25 in	.75 in
Ductwork Restrictions	2.5 in	3.5 in
Missing Turning Vanes	1.0 in	1.75 in
Total System Pressure	4.25 in	7.50 in

HP = CFM x SP / (6356 x Fan Eff)

Horsepower System I 105,000 x 4.25 / 6356 x .65 = 108 HP

Horsepower System II 110,000 x 7.50 / 6356 x .65 = 200 HP

Fan Operation 16 hours per day 6 days per week

Electrical Cost \$.10 KW –hr

200 HP – 108 HP = 92 HP

92 HP x .746 KW Hr / HP = 68.6 KW-hrs

68.6 KW –hrs x 16 hours / day x 6 days / week x 52 wks per year = 342,500 KW –hrs / year

342,500 KW –hrs / year x \$.10 / KW –hr = \$ 34,250 per year of extra electrical KW usage

Increase in demand Charge

200 HP – 108 HP = 92 HP

92 HP x .746 KW Hr / HP = 68.6 KW –hrs x 1 hour = 68.6 KW demand

68.6 KW demand x \$12.00 x 12 months = \$ 9,878 per year

Total cost per year = \$ 34,250 + \$ 9,878 = \$ 41,000

The potential savings to eliminate restrictions and reduce static pressure over the 25 year life of the project is over \$1,000,000. ■

Health Care Facilities Measuring Isolation Room Pressure—What Do the CDC Guidelines Say?

David Ruhland, Senior Global Product Manager | TSI

Introduction

What should health care facilities do to reduce the risk of *Mycobacterium tuberculosis* transmission in their facilities? Specifically, how do they monitor the pressure differential between the TB isolation room and the corridor? To help answer those questions and others regarding TB, the Centers for Disease Control and Prevention (CDC) issued “Guidelines for Preventing the Transmission of *Mycobacterium Tuberculosis* in Health-Care Settings, 2005” published on December 30, 2005. The document updated and replaced all previously published guidelines on this subject.

What section applies?

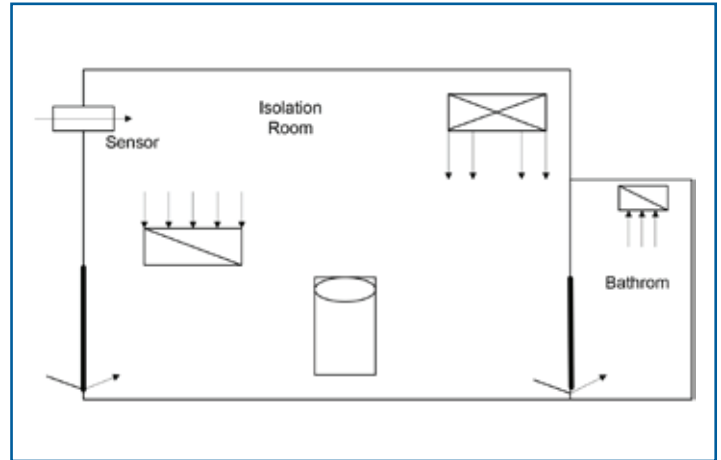
Owners, engineers, contractors, architects, and health care workers should know how the CDC guidelines impact the TB isolation room design and operation. The guideline has many sections covering a variety of TB transmission issues. The Environmental Controls section deals with those general ventilation concerns of utmost interest to the design and facility engineer. Excerpts from the CDC guidelines appear in italics.

Why use environmental controls?

Proper use of environmental controls can prevent the spread of the infectious droplet nuclei and reduce the concentration of contaminated air in the health care facility. Using pressure sensing devices to monitor TB isolation room pressure is one example discussed in the guidelines.

Why worry about airflow direction?

“The general ventilation system should be designed and balanced so that air flows from less contaminated



(i.e., more clean) to more contaminated (less clean) areas. For example, air should flow from corridors (cleaner areas) into TB isolation rooms (less clean areas) to prevent spread of contaminants to other areas.”

*“In certain rooms in which surgical and invasive procedures are performed and in protective environment (PE) rooms, the direction of airflow should be from the room to the hallway. ... Surgical suites require special infection control considerations for preventing transmission of *M. tuberculosis*. Normally, the direction of airflow should be from the operating room (OR) to the hallway (positive pressure) to minimize contamination of the surgical field. Certain hospitals have procedure rooms with reversible airflow or pressure, whereas others have positive-pressure rooms with a negative pressure anteroom.”*

How is directional airflow achieved?

“The direction of airflow is controlled by creating a lower (negative) pressure in the area into which the flow of air is desired. ... To achieve negative pressure in a room that has a normally functioning ventilation system, first measure and balance the supply and

exhaust airflows to achieve an exhaust flow higher than the supply flow. ... Next, measure the pressure differential across the closed door. ... Although the minimum pressure difference needed for airflow into a room is substantially small (approximately 0.001 inch of water gauge), a pressure differential of ≥ 0.01 inch of water gauge (≥ 2.5 Pascals [Pa]) is recommended.”

“This higher pressure differential is easier to measure and offers a margin of safety for maintaining negative pressure as the pressure in surrounding areas changes because of the opening and closing of doors, operation of elevators, stack effect (rising of warm air, similar to a chimney), ventilation system fluctuations, and other factors. ... The higher pressurization value is consistent with the most recent AIA recommendations for airborne precautions in health-care settings and is the generally accepted level of negative pressurization for microbiology and biomedical laboratories”.

Is an offset maintaining ≥ 0.01 in. H₂O (≥ 2.5 Pa) pressure differential adequate to guarantee negative pressure at all times?

No.

This criterion only establishes your initial offset. A hospital is a dynamic, not a static, environment and setting an initial offset does not guarantee that negative pressure is always present. In fact, the guidelines state, “Negative pressure in a room can be altered by changing the ventilation system operation or by the opening and closing of the room’s doors, corridor doors, or windows. When an operating configuration has been established, it is essential that all doors and windows remain properly closed in the isolation room and other areas (e.g., doors in corridors that affect air pressure) except when persons need to enter or leave the room or area.”

The only way to guarantee negative pressure is to continuously measure the pressure differential between the isolation room and the corridor.

How is negative pressure monitored in a room?

“Negative pressure must be monitored to ensure that air is always flowing from the corridor (or surrounding area) into the All (airborne infection isolation) room. ... The negative pressure in a room can be monitored by visually observing the direction of airflow (e.g., using smoke tubes) or by measuring the differential pressure between the room and its surrounding area.”

When you use smoke to check the room for negative pressure you are only monitoring the room at that precise moment. Using a smoke test does not guarantee that the room is under negative pressure two seconds, two minutes, or two hours later. Also, as described in the American National Standards Institute (ANSI) standard Z9.5 “at air velocities below 50 fpm, a small temperature difference between rooms will cause cold air to flow one way through the bottom of the opening and warm air the other way through the top.” Thus, if air velocities into the isolation room are low (e.g., less than 50 fpm) the smoke test may indicate negative pressure at the bottom of the door but the air is actually moving out of the room at the top of the door.

Can a differential pressure-sensing device be used to monitor negative pressure?

Yes.

“Differential pressure-sensing devices also can be used to monitor negative pressure; they can provide either periodic (noncontinuous) pressure measurements or continuous pressure monitoring. The continuous monitoring component may simply be a visible and/or audible warning signal that air pressure is low. In addition, it may also provide a pressure readout signal, which can be recorded for later verification or used to automatically adjust the facility’s ventilation control system.”

Some room pressure monitors and controllers on the market today, such as TSI’s PRESSURA™ Room Pressure Monitor, measure the pressure differential

continuously, provide visual and audible alarms, and a continuous analog output for recording the pressure differential. The controllers can also adjust the room ventilation system.

Where should the measurement be taken?

“Pressure-measuring devices should sense the room pressure just inside the airflow path into the room (e.g., at the bottom of the door). Unusual airflow patterns within the room can cause pressure variations; for example, the air can be at negative pressure at the middle of a door and at positive pressure at the bottom of the same door.”

However, locating a sensor at the bottom of the door may be impractical in most health care facilities. Also, as mentioned previously, low velocities into a room can also cause problems regarding measurements taken at the bottom of a door.

Can the sensor be in a different location?

Yes

“If the pressure-sensing ports of the device cannot be located directly across the airflow path, validating that the negative pressure at the sensing point is and remains the same as the negative pressure across the flow path might be necessary.”

Pressure monitors and controllers can be calibrated to meet this requirement. TSI locates the sensor above the door and uses a through-the-wall sensor to measure the airflow into the room.

What alarms are needed?

“Pressure-sensing devices should incorporate an audible warning with a time delay to indicate an open door. When a door is open, the negative pressure cannot be maintained, but this situation should not generate an alarm unless the door is left open. Therefore, the time delay should allow adequate time for persons to enter or leave an All room without activating the alarm.”

Room pressure monitors and controllers that provide both visual and audible alarms are available, including remote visual alarms for nurses' stations. Some models include time delays that are adjustable from 20 to 600 seconds.

Isn't there a problem with using pressure-sensing devices?

Maybe.

“The pressure differentials used to achieve low negative pressure (<0.005 inch) require the use of substantially sensitive mechanical devices, electronic devices, or pressure gauges to ensure accurate measurements. ... A negative pressure differential of ≥ 0.01 inch of water gauge (compared with the previously recommended 0.001 inch of water gauge) might help to minimize this problem.”

TSI's room pressure monitors and controllers avoid this problem by using a thermal anemometer and a patented bi-directional sensor. We have used proven thermal anemometer technology to accurately measure and control pressure differentials of 0.001 inch of water or lower in laboratory rooms and hospital rooms since 1986. TSI has used thermal anemometer technology in other industrial and commercial applications since 1961.

How often is the room checked for negative pressure?

“Periodic checks are required to maintain the desired negative pressure and the optimal operation of monitoring devices.

- *All rooms should be checked for negative pressure before occupancy.*
- *When occupied by a patient, an All room should be checked daily with smoke tubes or other visual checks for negative pressure.*
- *If pressure-sensing devices are used in All rooms occupied by patients with suspected or confirmed TB disease, negative pressure should be checked daily by using smoke tubes or other visual checks.*

- *If the All rooms are not being used for patients who have suspected or confirmed TB disease but potentially could be used for such patients, the negative pressure should be checked monthly.*
- *Laboratories should be checked daily for negative pressure. ”*

This means verifying the unit. If smoke tubes are used instead of pressure-sensing devices to monitor negative pressure in the TB isolation room, then the TB isolation room needs to be checked daily with a smoke tube. By using a pressure-sensing device you eliminate the need for a staff person to conduct a smoke test every day. TSI's room pressure monitors and controllers continually measure the pressure differential between the TB isolation room and the corridor.

Does this cover everything in the guidelines?

No.

This article only covers the portion dealing with room pressure. The guideline also covers various design issues including air changes per hour, air flow mixing, and filtration. Many other issues are addressed in the guideline including administrative measures and personal respiratory protection. Since the guidelines are extensive, it is important to understand those areas impacting the HVAC design and operation of the health-care facility TB isolation room.

How do I obtain a copy of the guidelines?

Guidelines can be obtained by calling the Centers for Disease Control at (800-232-4636) or by visiting their website at <http://www.cdc.gov>. ■



25-2500 cfm Range
Fast, Accurate, Easy, Auto-Range and Zero
Backpressure Compensated Air Balance System
Automatic Density Correction
Custom Tops Made to Order



Shortridge Instruments, Inc.
7855 E. Redfield Road Scottsdale, AZ 85260
480-991-6744 Fax: 480-443-1267
www.shortridge.com

Got Technical Updates?

We're always looking for
quality articles for
The NEBB Professional.

Please submit topic idea
with a brief description to
marketing@nebb.org




Creating Audible Sound from Sloppy Pump Motor Replacement

Stuart McGregor, Chairman | NEBB's Sound and Vibration Committee

How many times have each of us been involved in a project where everything seemed to go wrong? Then, at the end of the project we look back and find exactly how and why everything did go wrong. This is one of those tales.

Background:

16-story condominium building about 30-years old, constructed of cast in place concrete and noise from a water pump in the top floor mechanical room is generating an audible tone in a unit 5-stories below. Buildings constructed of cast in place concrete or post tension concrete are great at transmitting vibration and hence noise throughout the structure; that is a person on the 12th floor can hear someone on the 1st floor drilling a hole in the concrete.

In this case, the water pump drive motor that circulates water up to the open cycle roof top cooling is inputting a vibration into the building structure that is clearly audible on the 12th floor; motor drive RPM is 1750 (~29 Hz). The pump is on spring isolated concrete inertia base and the inlet and discharge have metal braided flex connectors.

Four additional and anecdotal pieces of information are: one, the mechanical system in the building has significant deferred maintenance and the mechanical room is not or has never been kept clean. Figure 1 shows the motor / pump assembly on its isolated inertia base and Figure 2 shows the state of how dirty and corroded the pump spring isolators are. Two, the population of the building, especially the upper floors of the building, is advanced in age and most likely has some level of hearing loss. Three, the building maintenance person (building engineer) lives in the building and part of his compensation is a free apartment. Four, the building HOA is frugal to a fault in not spending money, unless absolutely necessary.

Issue:

A younger tenant, maybe in her mid 60's (most of the other tenants in the building are in there late 70's



Figure 1. Re-Circulation Pump and Drive Motor Assembly



Figure 2. State of Deferred Maintenance in Mechanical Room

or 80's, so young is relative), moved into a unit five floors below the mechanical room and had no noise complaints for several years. Then early 2011 the noise started. The noise is a discrete tone and, while not a high level, it is clearly audible above the background within the unit of 26 to 27 dB(A); very quiet.

Figure 3 shows a 1/3-octaveband plot of the background noise and the tonal noise in the unit.

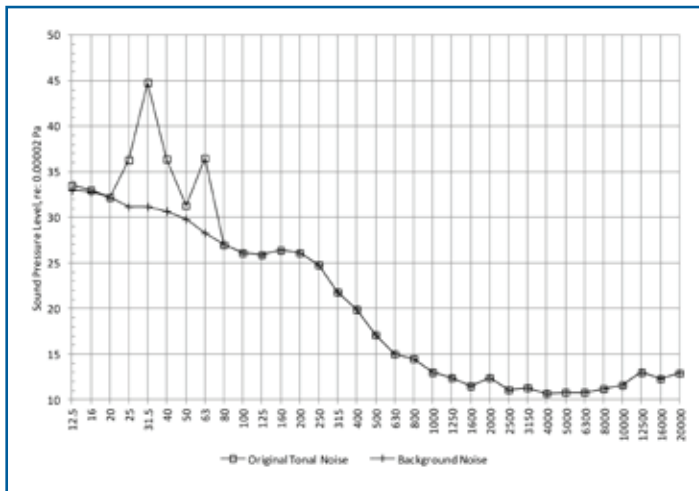


Figure 3. Motor Pump Tonal Noise with No Remediation and Background Noise, in Condominium Unit

What is important to notice in Figure 3 is how quiet the background noise is in the condominium unit. Look at Figure 3 and compare the Original Tonal Noise plot versus the Background plot. The A-weighted sound level in the condominium, with the Original Tonal components is 26.6 dB(A) and the Background without the tonal components is 26.4 dB(A); both very quiet. Hence, why the tonal components were so clearly audible.

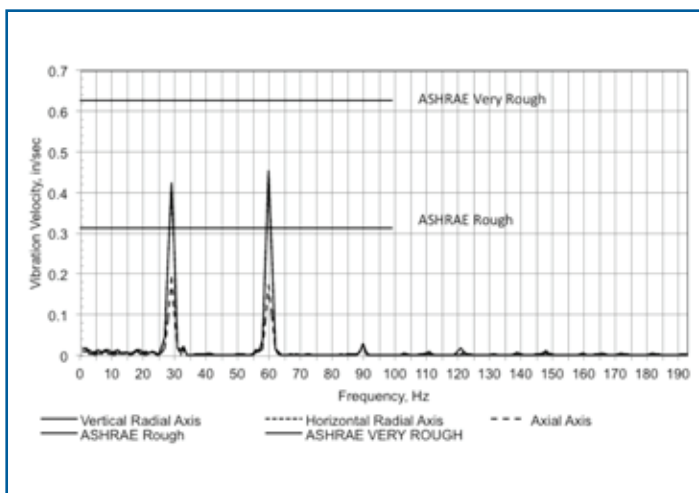


Figure 4. Vibration Measurement Plot on Pump Drive Motor

Calls from the tenant to the building engineer, received a response of nothing has changed in the building. Similar calls from the tenant to the HOA president received similar response; nothing has been done in the building. At this time EDI was called to see what might be creating this noise. EDI made a site visit and found several issues. First, there was an old motor on the

roof next to the cooling tower and a brand new cooling tower motor. EDI then inspected the mechanical room and immediately noticed a motor making a significant noise. This motor drives the cooling tower recirculation pump. This was also, a brand new motor (there was no dust on the motor). EDI then made vibration measurements on the cooling tower recirculation pump motor, see Figure 4.

Figure 4 clearly shows a significant vibration peak at the motor rotation frequency of 29 Hz and at two and three times the motor rotation frequency. This harmonic behavior is indicative of component misalignment (drive motor and pump misalignment). Diagnosis of these harmonic peaks, the second harmonic being greater than the fundamental indicates that the misalignment is predominately Parallel Misalignment. Also, shown in Figure 4 are the 'ASHRAE Equipment Vibration Severity Ratings for Vibration Measured on Equipment Structure or Bearing Cap', Rough and Very Rough Curves. The drive motor vibration levels exceeded the ASHRAE Rough Ratings.

The tenant then took EDI's report to the HOA president, who indicated that the building engineer forgot to mention that these two motors had been replaced. At this point it is important to interject information regarding the individual who replaced the motors. This person had been in the mechanical business for years, however, he was not highly skilled or in good health, and also a close friend of the building engineer; not that this should have made a difference. Soon after EDI's report was given to the building engineer the tonal noise significantly decreased. Again inquiries from the tenant to the building engineer and the HOA president received a response of nothing has changed or was done.

EDI was then called back to measure the tonal noise in the tenants unit and it had significantly decreased; see Figure 3. At this time a meeting was set-up with the building engineer, HOA president, EDI and an independent mechanical contractor, to assess possible solutions. Immediately upon entering the mechanical room it was obvious something had been done, because noise from the pump motor was significantly less. EDI made a comment about the motor being much quieter, at this point the building engineer let it slip out that an independent mechanical contractor had been called in and the

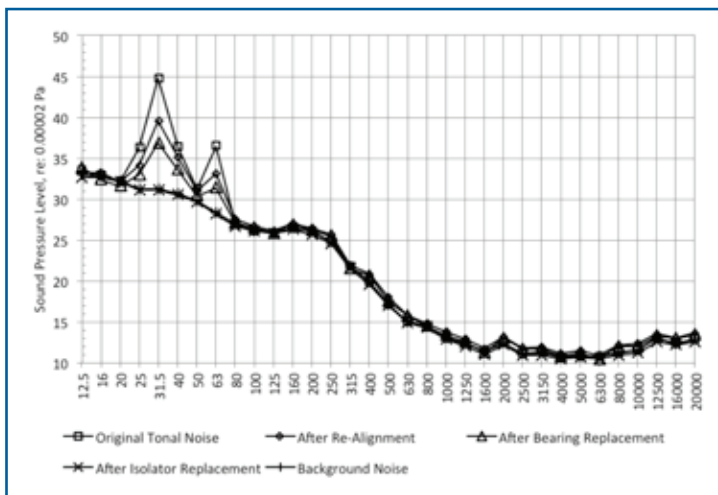


Figure 5. Motor Pump Tonal Noise at Various Stages of Remediation and Background Noise, in Condominium Unit

alignment of the motor to pump coupling was found to be out of tolerance (not data was given how out of tolerance), the motor and pump had been aligned. A telephone call to the mechanical balancing / alignment contractor.

During the meeting two additional vibration mitigation options were discussed. First, was to replace the motor bearings, which had been damaged from running misaligned, and second to replace the existing vibration isolators; see Figure 2. Figure 3 shows the tonal noise decrease in the condominium unit for each step of the process and the original tonal noise as well.

During installation of the new spring isolators it was determined that during installation of the new motor the mechanical technician installing the motor had bumped the inertia base and shifted the isolators so that they were not properly aligned and shorting out against the isolator side wall.

While, this tale had a happy ending, in that the tonal noise was no longer audible in the condominium unit, it is a lesson in the importance of competent well trained people to do mechanical equipment maintenance. Improper installation cost the HOA three to four times the initial replacement cost of the motor; costs for alignment and bearing replacement, engineering time and installation of new vibration isolators. The hidden costs here are the building engineers', the HOA presidents and the condominium owners' time. ■

Keep up-to-date with the latest in industry technology by visiting the NEBB online publications site.

**NEBB certification =
professional recognition
+ career advancement**

Visit: www.nebb.org



AirData Multimeter®

Differential & Absolute Pressure, Temperature
Density Corrected Air Flow and Velocity
English or Metric Units

Up to 2000 Reading Memory with Average, Total,
Minimum, Maximum, & Standard Deviation
Serial Output to Computer or Printer



Shortridge Instruments, Inc.

7855 E. Redfield Road Scottsdale, AZ 85260
480-991-6744 Fax: 480-443-1267
www.shortridge.com

Designing for Proper Testing, Adjusting & Balancing of Air & Hydronic Systems

Andrew P. Nolfo, PE

Testing, Adjusting and Balancing of Environmental Systems, like any other engineering application involved in the construction industry, is not an exact science. In designing a project, the design professional must pay attention to a numerous quantity of details. One of those details involves the requirements of designing the project with the Testing, Adjusting and Balancing in mind. This pertains to both the air systems and the hydronics systems. And, it pertains to both the drawings and the specifications.

The designer must keep the scope of the TAB work in mind. TAB, in its purest form, is not commissioning. The main purpose of the Testing, Adjusting, and Balancing effort is to adjust fluid flows, both air and water, to as close as is practical to the design requirements within design and installation limitations. That is the only function of the TAB firm. Designing those flows to satisfy comfort is the designer's responsibility. Adjusting flows beyond the design requirements is not the responsibility of the TAB firm. This article is part one of a three part series. Read future NEBB Professional issues for continuation of this article. In this article, I will explore the Air Systems.

AIR SYSTEMS

1. Fan Selection, Performance Curves, and System Effect:

The designer needs to be cognizant of System Effect. That is the single biggest issue to avoiding a problem project. System Effect must be accounted in fan selection, fan layout and even in the air distribution system design.

Start with fan selection. Most fan manufacturers have their equipment rated by Air Movement Control Association International (AMCA). Fans are tested and rated under very stringent requirements that are identified by ANSI/ASHRAE Standard 51-1999.

This publication is also the AMCA Standard 210-99, Laboratory Methods of Testing Fans for Aerodynamic Performance Rating. AMCA 201 states that the method of test setup for any fan "...is not intended to reproduce *exactly* any installation likely to be found in the field." The designer must be aware that an actual fan's performance in the field will seldom equate to laboratory performance that is catalogued. *This is the single most critical component that the designer must understand.* Unless there is an ideal condition, I can almost guarantee you that the fan measurements; i.e. airflow, fan rpm, static pressure, electrical data, etc, reported by TAB firm will not plot directly on a fan curve. They were never meant to. Let's examine some the reasons why.

The first item that the designer must identify is the condition that a particular fan was tested. Many centrifugal fans in air handling units are tested as a "Type A" setup; free inlet, straight ducted outlet. The ratings do not include the losses associated with placing the fan in the cabinet.

After this loss is considered, the next issue of System Effect concerns the discharge condition of the fan. There have been many articles in ASHRAE and other trade publications and presentations at AHRAE Meetings discussing System Effect at the fan discharge, many of today's designs seem to have little or no regard to the problem and "broken back" fans are still encountered on a daily basis by the TAB firm.

All of the fan discharge arrangements shown in Figure 1 have an associated System Effect and a corresponding pressure drop. The most forgiving condition is condition is Position A. *This figure brings us to the second most critical component that the designer must understand; the terms "fully developed flow" and "uniform velocity distribution".* This concept can be utilized by referring to Figure 2. If the distance between the fan discharge and any of the four positions in Figure 1 were long enough

(100% effective length) to have the flow fully developed, then the System Effect would be zero. ASHRAE Standard 111 and AMCA 203 are excellent reference materials for the designer to utilize. Both publications approximate the required distance to develop a uniform velocity profile. For systems operating below 2500 fpm, this distance can generally be assumed to be between 2.5 and 3 equivalent diameters of straight downstream ductwork.

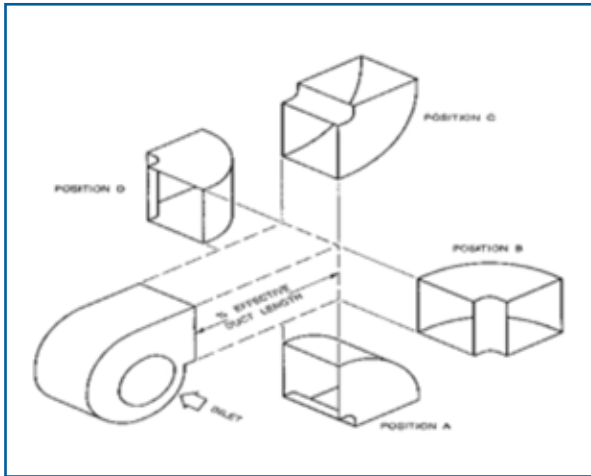


Figure 1. Fan Discharge – System Effect

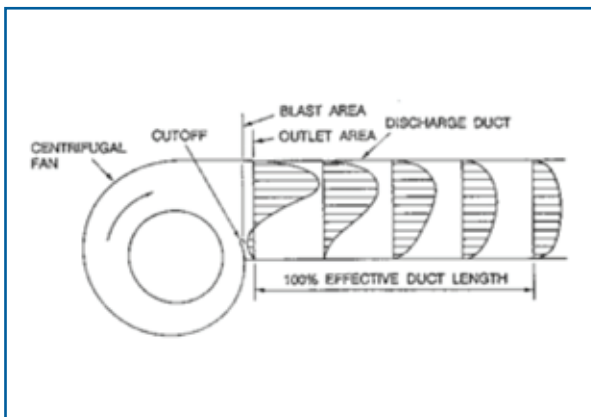


Figure 2. Fully Developed Flow

After considering the fan discharge, the designer must then focus on the fan inlet condition. For fans placed within a cabinet, such as a packaged air-handling unit, this item has already been addressed. The inlet condition must be addressed for free standing utility vent sets, or inline fans. Again, the designer must understand how the fan performance was tested and then apply the necessary adjustments for both the discharge and the inlet condition for his design. An improper or restricted inlet can and will produce a “swirl” that will adversely affect the fan’s performance.

2. Air Distribution Systems and System Effect:

Prior to selecting a fan to meet an intended application, the designer must determine the system’s overall resistance to flow; for packaged equipment, this is identified as the system’s external static pressure drop. *Before we discuss pressure drops associated with duct, fittings and accessories, the designer must be aware of the third critical component in the design process.* The common denominator to all published pressure drop ratings is fully developed flow, or a uniform velocity profile. Again, there is no System Effect associated with conditions that have fully developed flow. Let’s take a look at something as mundane as the TAB firm attempting to take a Pitot traverse in the main duct leaving an air handling system. ASHRAE Standard 111 clearly defines the location of an “ideal traverse plane”. Nothing in TAB work is as critical as determining a unit’s overall performance. Yet very few designs incorporate the means to accomplish this measurement with any degree of accuracy.

Tables for estimating duct fitting pressure drops are published in ASHRAE and other publications such as SMACNA. The tables for different styles and fitting configuration and the accuracy of a Pitot tube traverse both share this same concept. That concept is that fully developed flow is available at the entrance to the fitting or the traverse plane. Refer back to Figure 1. We previously discussed that a system could have a discharge Position C and suffer little or no System Effect if the flow was fully developed prior to placing the elbow. Fittings must be accounted for in the exact same manner. When arriving at the air distribution system’s total pressure drop, the designer must be cognizant of each fitting’s location relative to an adjacent condition.

Refer to Figure 3. In determining the estimated external pressure drop that the fan must overcome, the engineer would simply add the friction loss for every linear foot of duct and then add the estimated pressure drop for each of the four elbows. The pressure drop associated with each elbow is only applicable if you have fully developed flow at the entrance plane of each elbow. Now look at Figure 4. This figure identifies an air distribution system that is quite similar to Figure 3. Let’s compare the estimated external pressure drops of both systems:

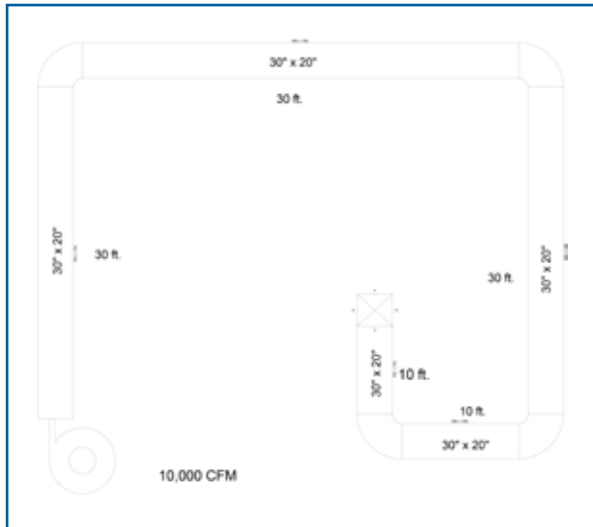


Figure 3. Fully Developed Flow



Figure 4. System Effect at 4th Elbow

Table 1. Comparison of System Pressure Drop

	Figure 2	Figure 3
System Airflow	10,000 cfm	10,000 cfm
Duct Size	30" x 20"	30" x 20"
Straight Duct Length	110'	90'
Straight Duct Friction Factor	0.3"/100'	0.3"/100'
Quantity of Elbows	4	4
Elbow ΔP Factor	0.07" w.c	0.07" w.c
Outlets	1	1
Estimated Pressure Drop		
Straight Duct	0.33" w.c	0.27" w.c
Elbows*	0.28" w.c	0.28" w.c.
System Effect @4 th Elbow	0.00" w.c	0.48" w.c**
Air Outlet	0.05" w.c	0.05" w.c
Total External Pressure	0.66" w.c	1.08" w.c

* Based on a smooth radius elbow without turning vanes

**Based on Type R System Effect Curve

Of course, the classic example of this concept is the offset under the beam fitting/obstruction as shown in Figure 5. This fitting combination is identified in both ASHRAE and SMACNA. Imagine that the contract drawings indicated a straight duct going directly under a steel or concrete beam, or other obstruction. Unfortunately, the designer may have neglected to check the dimensional data of the floor-to-floor height, beam type, depth, ceiling height, and/or other interferences. He assumed that there was adequate space to simply install the duct in a straight section. However during the Sheet Metal fabrication drawings, the superintendent realized that the condition existed and simply applied the combination of fittings to solve the "field" problem. Imagine the shock to the designer when he learns of this situation after the TAB firm has informed him that the system is 30% low of airflow. And, he will be in full cardiac arrest when he is informed that just this fitting combination with double thickness turning vanes is using 1.5" - 2.5" of static pressure. The last point is that this was never a "field problem". The problem existed in the designer's office and was a problem long before the contract documents started to become an actual building. Again, the issue is System Effect due to a lack of fully developed flow.

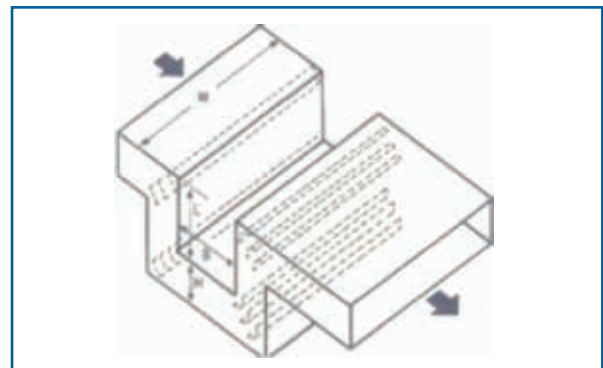


Figure 5. Rectangular Duct with 4-90° Mitered Ells to Avoid an Obstruction

Coefficient C

L/H Ratio	0.5	1.0	1.5	2.0
Single Blade Turning Vanes				
Double Blade Tuning Vanes				

3. Air Terminals, Air Outlets and System Effect:

The fourth and final critical component is that System Effect can be present at air terminals and at air devices;

both inlets and outlets when a uniform velocity profile does not exist at the entrance plane. Most common pressure independent air terminals (vav's, ftu's, dual duct, terminal reheat, etc) employ some method of determining airflow at the entrance to their unit. A common method is that the inlet houses an array tube that measures both total pressure and static pressure, and calculates the associated velocity pressure. Once the velocity pressure is known, airflow is only a function of the inlet cross sectional area. The airflow value is then used to reset the airflow based on the control set points. This value can be utilized by the TAB firm when taking their measurements and can be also transmitted and displayed in conjunction with a DDC system. The airflow can graphically show the airflow to each air terminal. The airflow value is only accurate when the inlet to the air terminal is a long straight run of duct. Again, the air terminal needs a uniform velocity profile to accurately read and adjust the airflow. The ideal method to achieve this requirement is by designing the system with 3 to 4 diameters of hard straight round duct at the entrance to the air terminal. This duct should be the same size as the air terminal inlet. You can then utilize flex duct to accomplish any offsets between the inlet duct and the main duct. Most of today's systems however are designed with the flex duct piped directly into the air terminal inlet.

Several recent discussions and articles on using flow hoods when taking airflow measurements at ceiling diffusers have also dramatically identified this concept. TAB firms, air device manufacturers and instrument suppliers are discovering the impact of System Effect at this connection. Now the system designer needs to address the connection between the air terminal downstream duct and the actual air device. The best example of the condition can be shown in Figure 6, which is an elevation of a vav downstream duct and the three diffusers that are served by this terminal. The specification will probably limit the amount of flex duct to 6'. That is a good start but it does not solve the problem.

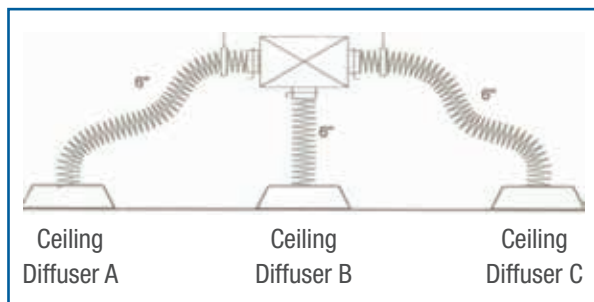


Figure 6. Ceiling Diffuser Elevation

The air outlets in this example could be perforated face, louvered face or even a sidewall grille mounted in a ceiling. For our example here, we are using 2'x2' perforated face diffusers. The condition at outlet "B" probably has little if any System Effect and the pressure drop for this condition is only associated with the actual length of flex duct. Conditions "A" and "C" will have even more pressure drop and possibly have a System Effect factor is the flex duct is connected at right angles to the neck of the diffusers. Remember, System Effect cannot be measured. It can only be calculated. Calculating the pressure drop and System Effect at Condition "A" or "C" is not extremely difficult. The real issue of System Effect comes into play when reading the airflow at these diffusers. Let's assume the TAB firm measures the airflow with a flow hood. Based on which direction the technician holds the hood can yield four distinct airflow values. These values could vary as much as 20 - 25%.

4. Other Issues for Air Distribution Systems:

In addition to the System Effect issues previously discussed, there are several other issues that have been discussed for many years, and we would be remiss if we didn't mention them again. It seems like some of today's designers tend to neglect these issues. These issues are diversity factors, duct leakage, turning vanes, damper location, and the use of parallel vs. opposed blade dampers at air handling units. There was a Symposium at the 1998 ASHRAE Annual Meeting in San Francisco that was sponsored by TC 7.7. The title of the symposium was "Engineering and Specifications for HVAC Systems Relating to Testing and Balancing". One of the papers at that symposium was presented by Mr. Richard Rose of Mechanical Technology, Inc. He discussed many of the same issues and the paper is an excellent reference. While these four items are not major issues when discussing Testing, Adjusting and Balancing, they still can play havoc with the TAB effort. Let's briefly look at each one of these items.

I can almost be assured of the overall quality of the design by immediately looking at the diversity applied to a vav air handling unit design. It takes only several minutes of reviewing the plans to identify the fan total airflow from the AHU schedule and then quickly sum the maximum airflow of the vav terminals on that AHU. Whenever I see a diversity factor smaller than 75%,

I begin to get very suspicious. Unless there are some highly unique characteristics of a facility, most projects will have a diversity of 80% to 85%. Yet, these projects are out there every day and the problems certainly get noticed during the TAB effort.

Duct leakage must be accounted in the overall design. We still see projects that specify 1%, or even 10%, duct leakage. It is impossible to achieve these types of results in today's projects. The system designer needs to refer to the excellent data in ASHRAE and SMACNA publications on this subject. One design that I saw recently listed the air handling unit performance, expected duct leakage, and maximum required airflow at the outlets. This firm's design was one of the best that I had witnessed. The project went very smoothly from the construction, startup, TAB and functional testing point of view.

SMACNA and other people have been advising the design community that turning vanes in duct fittings should be single thickness. Double thickness turning vanes offer no appreciable value. They are more costly to purchase/fabricate and install. They require more pressure to overcome, thus they require more energy. Many of today's contract documents still specify double thickness vanes.

If you want to save your client a small amount of money and have a quieter project, then delete the opposed blade dampers located directly behind all of the supply air devices. A good TAB firm does not use them. They only create noise. The proper method is to locate the damper at the branch takeoff serving that outlet. Refer to Figure 6. Notice the balancing damper at the spin-in connection at the vav downstream duct. A round spin-in with a volume damper is the most economical way to accomplish the proper damper location.

Mixing sections of packaged and built-up air handling units have been a source of coil freezing trouble for years. The first problem is that the airstreams never truly get mixed. Many of today's designers think the purpose of this section in the AHU is to control the proper amount of return/outside air and have opposed blade dampers specified for the mixing section. Opposed blade dampers are excellent for control but terrible for mixing. Parallel blade dampers on the other hand are excellent for mixing but have poor control or throttling

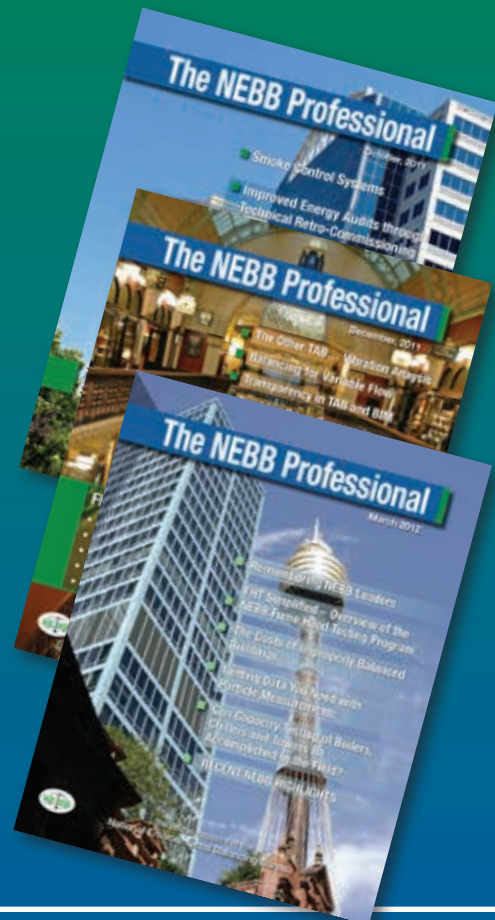
characteristics. If the system designer is using this section to achieve thorough mixing before the filters, then parallel blade dampers should be specified and the blades should open to direct the two airstreams directly into each other.

5. Summary of Air Distribution Systems:

The designer must be cognizant of System Effect in all of its forms. System Effect is NOT limited to the fan. System Effect can and does happen throughout the air distribution system; at the fan, at duct fittings, at terminal units and air terminal devices. ■

Interested to advertise in The NEBB Professional?

Contact marketing@nebb.org
or call 301.977.3698
for more information.



Recent NEBB Highlights

Eric Jenison Received the George B. Hightower Award



Eric Jenison was presented the George B. Hightower Award for his distinguished service to NEBB. Neil Marshall, President, NEBB, presented the award to Eric during the opening session of the 2012 NEBB Annual Conference, April 26-28, Anaheim, California.

The George B. Hightower Award is NEBB's most prestigious honor and is presented to people who have made outstanding achievements and contributions to the HVAC industry and to the success of NEBB.

Eric received the George B. Hightower Award based on his exemplary service to NEBB National and to the Florida Chapter of NEBB.

At the National level, Eric served with distinction by holding each Officer position on the Board of Directors, culminating as President of NEBB in 2006. He also served with distinction on the Chapter Affairs Committee, the TAB Committee, and in the Marketing Committee.

NEBB a Golden Circle Donator for 14 Years in a Row

NEBB donated \$10,000 to ASHRAE Research at the 2012 NEBB Annual Conference in Anaheim, California.

Neil Marshall, President, NEBB, handed the check to Ron Jarnagin, President, ASHRAE, at the opening session of the 2012 NEBB Annual Conference, continuing the long tradition of ASHRAE research support at NEBB. Among the research topics that money donated to ASHRAE will help fund is an ongoing project researching **“the effects of duct fittings on air velocity measurements”**.

NEBB's donations will help ASHRAE further research in high performance HVAC&R technologies in order to update standards and guideline.



Since 1919, ASHRAE's research has focused on the discovery of principals and is currently establishing a five-year research plan. Universities and other private enterprises conduct these research programs, and the findings are used to update ASHRAE's standards and guidelines. ASHRAE's guidelines then serve as a benchmark and help educate and promote uniform testing, ratings and safe practices throughout the entire HVAC&R industry.

Building Envelope Testing Beta Seminar

NEBB conducted a beta seminar for Building Envelope Testing certification on May 15-17, in Lenexa, Kansas. The instructors were Bill Neudorfer, Rodney Hilton, Jim Bochat, Stan Fleischer and Phil Emory.



The seminar provided the attendees an introduction to Building Envelope Testing concepts and included discussions of environmental safety enclosures such as air barrier enclosures, and review of the various testing methods that are currently being specified. The basic operation of the blower door equipment and their respective applications and features were also presented.

NEBB Holds TAB Seminar in Cairo, Egypt

The Capital MarVA chapter of NEBB recently held a TAB Technician's seminar and exam in Cairo, Egypt to accommodate the chapter's demand from the Middle East and Gulf regions for certified TAB technicians. The seminar was well attended and highly successful. Stan Fleisher, NEBB President-Elect and Jim Huber, NEBB Treasurer, facilitated this

course, with assistance from Tarek Omar of TAB Egypt, a local NEBB firm in Cairo. According to Jim Huber, "There is an increasing need for qualified Testing, Adjusting and Balancing technicians and professionals throughout the world. As high performance building systems continue to dominate the built environment, this demand will only grow in the coming years. NEBB Certified Firms are in a unique position to meet this growing demand through our training and education programs".

Stan Fleischer added, "NEBB's Certified Technician program has continued to grow, and this seminar is a great example of how NEBB Firms are investing in the necessary training and testing to have the most qualified technicians in the industry. I was very impressed by the knowledge of the people who attended the seminar. Not only were they technically astute, they were highly aware of NEBB's strict procedural requirements for the proper testing and balancing of building systems. I'd also like to add that the level of hospitality shown to us was nothing short of incredible!". ■



HydroData Multimeter®

0-250 PSI Gage & Differential Pressures
Associated High Side & Low Side Pressures
-67 to 250 °F Temperature

100 Reading Memory with Sequential Recall
English & Metric, Auto-Read



Shortridge Instruments, Inc.

7855 E. Redfield Road Scottsdale, AZ 85260
480-991-6744 Fax: 480-443-1267
www.shortridge.com

BUILDINGstart

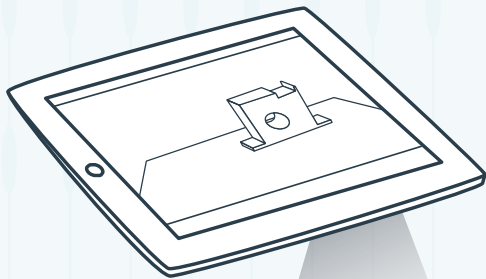


airNAB

energystART

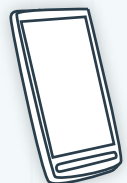
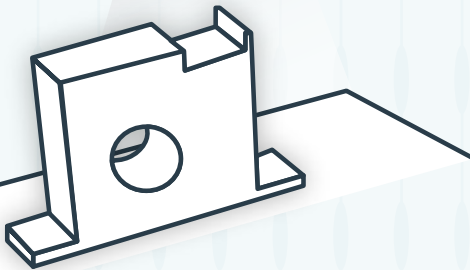
buildingTEST

New photo capture feature!



**Remember what issues
and equipment look
like with photos.**

Capture photos in the field with
your iPad or Android device and
synchronize the photos back to
your main project log.



We support Apple iPad™ and netbooks, laptops or tablets running Windows.
Android Support now available!





2013 NEBB ANNUAL CONFERENCE

Solutions for Optimizing High Performance Buildings



The 2013 Conference is being held in a place that can be summed up in a single word: relax. This is a place to stop-and-smell-the-roses. So take a moment. Breathe. Enjoy life. *À la Montréal.*

Conference Registration opens Fall 2012.

Visit www.nebb.org for updates.



***All travelers need passports
to enter Canada.**