Sound Absorption in Air at 72°F			
Frequency, Hz	Relative Humidity	Attenuation, dB/km Sea Level (0 feet)	Attenuation, dB/km Santa Fe, NM (7,000 feet)
110	50%	0.33	0.50
110	10%	0.70	0.73
440	50%	2.60	2.40
440	10%	3.20	4.90
1000	50%	5.00	4.90
1000	10%	13.00	20.00
4000	50%	28.00	43.00
4000	10%	113.00	100.00

Table 1. Sound absorption at different altitudes for various frequencies and values of relative humidity

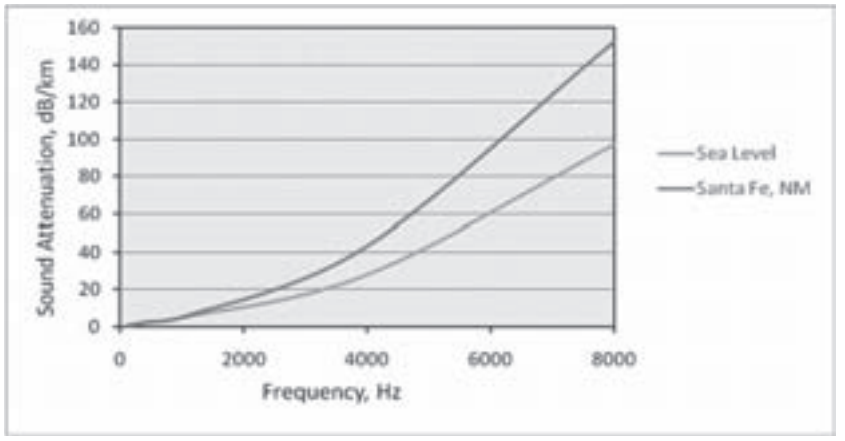

Figure 2. Sound attenuation in decibels/kilometer versus frequency at 50% relative humidity for sea level and Santa Fe, NM (7,000 feet). One kilometer is 3,281 feet.

During this time, the main HVAC blower was operating at 100% capacity (60 Hz) even though the blower system included a variable speed control. The following experiment was performed: the variable speed control was set to reduce the blower speed to 2/3 of full capacity (40 Hz), and the pressure differential between the sanctuary and the blower room was measured for both modes of operation—recycle with 15% air exchange and fresh air with 70% air exchange. The only change from the original HVAC settings is that the blower now operates at a lower speed. It was found that the pressure differential at 15% air exchange was ⅛ inch, and at 70% air exchange (recycle valve closed) was 1/16 inch. As expected, with the organ operating with the bellows regulating system set at 3¼ inches, the organ pressure was 3⅜ inches at 15% air exchange (recycle mode) and 3 5/16 inches at 70% air exchange.

The bellows regulating system is now set at 3 1/16 inches, yielding an organ-to-sanctuary pressure of 3 or 3 1/16 inches in the two modes of operation—a difference of 1/16 inch, small enough that tuning is now not adversely affected. In addition, HVAC noise has been greatly reduced, and the air circulation in the sanctuary, while quite adequate, is less drafty for those sitting in the ends of pews near the walls, where the supply air vents are located.

Sanctuary acoustics

FPC Santa Fe underwent major renovation before Fisk Opus 133 was installed. This included considerable acoustic work in the sanctuary to prepare it for this fine instrument; much of the focus was on steps to increase the reverberation time. The chancel has diamond plaster side walls, which diverge slightly to help sound radiate into the sanctuary. The sanctuary has hardwood floors with minimal carpeting, hard plaster walls, and hardwood pews with reasonably reflective pew cushions. The ceiling was rebuilt with heavy plywood above *latillas*, and fine sand one foot deep was poured onto the plywood to help contain low frequencies from the organ. Although the reverberation time has not been measured, it is estimated to be about 1.5–2.2 seconds.

In addition to sound energy absorption each time a sound wave encounters a surface, sound energy can be lost through absorption in air. Absorption in air is a rather complex phenomenon involving molecular dynamics, and it varies with air density and relative humidity in a manner that is counterintuitive: ***thin, dry air attenuates sound more than thick, wet air***. Furthermore, the attenuation varies with frequency. Table 1 provides values for attenuation at different frequencies for sea level and the Santa Fe altitude and for 10% and 50% relative humidity. Notice that absorption is greater at low humidity, high altitude, and higher frequency. At high altitude air is thinner and can hold less moisture; relative humidity of 12%–15% is not unusual on summer days in Santa Fe. To mitigate against the drying effects on organ components, a humidifying system is used to maintain relative humidity at around 40%; this also helps to reduce air absorption at higher frequencies.

In Table 1, the sound absorption is given in decibels per kilometer, which is just a little farther than sound travels during a reverberation time of 2.2 seconds. Figure 2 provides a plot of these attenuation data at sea level and in Santa Fe at 50% relative humidity.

Clearly, the attenuation is greater at high altitude and high frequency. However, to understand whether or not this will impact the sound of the organ in the sanctuary, the attenuation must be compared with reverberation decay, the decay in sound energy due to reflection off surfaces. This comparison showed that at 4 kHz, the air attenuation at sea level would be barely noticeable if at all, and would be completely negligible at lower frequencies. In Santa Fe a very astute listener might notice the lack of high frequency components after initial transients on a very dry day, but otherwise the sanctuary acoustics should be little affected by the high altitude.

Conclusion

The differences in organ acoustics and operation between sea level locations and Santa Fe are real and observable, but not severe. Judicious choices of windchest pressure for pre-voicing and voicing and better understanding of the HVAC system both have contributed to a very successful installation: Fisk Opus 133 is now performing regularly and brilliantly. It is hoped that these observations will serve others who choose to install a fine organ at similar altitudes. ■

Jim Toevs has a doctorate in nuclear astrophysics. While a professor at Hope College, he taught and consulted in acoustics. A musician, for 20 years he was the principal trumpet in the Los Alamos (NM) Symphony Orchestra and has sung in and directed church choirs.

Notes

1. Editor's note: A more detailed version of this article, including equations, is available on THE DIAPASON website. See the "Learn More!" for this article (www.TheDiapason.com).

2. "Voicing for Higher Altitudes," Frederick L. Mitchell and David A. J. Broome, *The American Organist*, Vol. 13, No. 8, August 1979, page 23. Since atmospheric density is greater in the sea-level Fisk Gloucester shop, windchest pressure had to be increased during pre-voicing to keep blower output velocity the same as in Santa Fe.

New Organs

Fabry, Inc., Antioch, Illinois
First Presbyterian Church, Racine, Wisconsin

Located in one of southeast Wisconsin's oldest settlements, First Presbyterian Church's history closely follows that of Racine. While Racine was incorporated as a village in 1841, the group of men (and women) that made up the roots of the first Presbyterian church gathered in 1839. The current sanctuary was built in 1851, and the church recently celebrated its 150th anniversary.

There have been a few organs that have graced the church. The first organ, located in the balcony, a Johnson organ of two manuals and 10–20 ranks with an attached console, was installed around the late 1880s. Some of the current organ's pipes are from the original installation. From then on, history is sketchy, but the organ was rebuilt and then relocated to the front of the sanctuary in 1935 by the Besch Co., a small Milwaukee organ company, and a detached console was built. In 1988, R. A. Colby of Johnson City, Tennessee, built a new console and updated only the console combination action to a single-memory system. When Fabry, Inc. arrived to assume the maintenance of the instrument, in addition to addressing some easily noticeable concerns, the issue of multiple memories was brought up.

The church decided to proceed with an original plan to work our way from division to division releathering the primary pneumatics. After finishing the Swell pneumatics, primary and secondary double-box primaries, the church announced their plans to renovate the front of the sanctuary to make the pulpit more accessible, allow more room for ensembles, and improve the acoustic of the room by eliminating the carpet in the front third of the room and replacing it with hardwood floor.

It was at this time that it became clear the console would need new cables, and the church elected to have Fabry, Inc. install a new Peterson ICS-4000 system as well. The console was gutted with only the shell and keyboards kept. Completely new drawknob banks were constructed to incorporate the new drawknobs with those that were retained. A new coupler bracket was built into the nameboard as well. During the course of the job, we also replaced all of the cloth-covered wire, improved chamber lighting, installed new expression motors, and finished the primary releathering. The organist's previously purchased Ahlborn-Galanti Romantic MIDI Module was seamlessly integrated with the Peterson system. The organist now has 100 memories to play with.

While there are many people involved with a job that encompasses many aspects and facets that require constant attention, Fabry, Inc. had the pleasure to work with Jerry Buck, organist at First Presbyterian Church. He kept us up to date with scheduling conflicts and questions from the church members and committees. His attention to our details helped make this one job we won't soon forget.

—Phil Spressart

GREAT
8′ Principal
8′ Double Flute
8′ Viola d'Gamba
8′ Dulciana
4′ Octave
4′ Flute Traverso
4′ Violin
2′ Super Octave
Fourniture IV
8′ Tuba
Tremolo
Chimes
Zimbelstern
Great to Great 4
Great Unison Off
Great to Great 16

SWELL
16′ Bourdon
8′ Stopped Diapason
8′ Salicional
8′ Vox Celeste
4′ Principal
4′ Flauto
4′ Fugara
2⅔′ Nazard
2′ Flautino
Scharff III
8′ Trumpet
4′ Klarion
Harp
Tremolo
Swell to Swell 16
Swell Unison Off
Swell to Swell 4

CHOIR
8′ Violin Diapason
8′ Concert Flute
8′ Keraulophone
8′ Unda Maris
4′ Flute
2⅔′ Twelfth
8′ French Horn
8′ Krummhorn
Tremolo
Choir Unison Off
Choir to Choir 4

PEDAL
32′ Acoustic
32′ Resultant
16′ Double Open Diapason
16′ Subbass
16′ Gedeckt
8′ Octave
8′ Bass Flute
32′ Contra Fagotto
16′ Fagotto

Swell to Great 16, 8, 4
Choir to Great 16, 8, 4
Pedal to Great 8
MIDI to Great
Great to Pedal 8, 4
Swell to Pedal 8, 4
Choir to Pedal 8, 4
MIDI to Pedal
Swell to Choir 8, 4
MIDI to Choir
Choir to Swell 8
MIDI to Swell

Gt/Ch Manual Transfer