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Subject: Israel Putnam Refectory
Airborne Noise Assessment
2358 Alumni Drive
Storrs, CT 06269

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Date: April 12, 2024

Revision: 0

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Summary

This document makes a positive acoustic assessment that should assist in meeting any acoustic noise concerns during the operation of two VFS, LLC 460 KW fuel cells on the site at 2358 Alumni Drive in Storrs, CT. An acoustic assessment plan was developed and executed to acquire airborne acoustic information useful in explaining and mitigating the potential airborne noise issues during operation of the two 460 KW fuel cells. It is important to show that the airborne noise generated by the fuel cells will not significantly impact the facility's neighbors.

The airborne noise levels expected to be generated by the VFS, LLC fuel cells operating at the Storrs site were simulated by exciting a Soundboks speaker at the proposed fuel cell position. The Soundboks speaker produced an overall airborne level that was 29 dB higher than the levels measured for a single VFS, LLC fuel cell installed at Montville, CT. One-third octave band analysis showed the speakers' level to be near the Montville fuel cell airborne noise levels at low frequencies where the airborne noise levels were low and to exceed the fuel cell signature by about 29 dB at higher frequencies where the fuel cell signature was higher in noise level.

Airborne noise levels with the speaker operating were measured at distances from 5 to 91 meters from the proposed fuel cell location. The speaker produced overall A-weighted sound pressure levels of 99.8 dBA at 5 meters and 94 dBA at 10 meters (reference 20 microPascals) at the proposed fuel cell location. The airborne noise levels from the speaker received at nearby properties were measured at noise levels of 63 to 89 dBA. Measurement locations at the adjacent properties to the north, east and south were too far away to be able to measure the airborne noise with the speaker on. Analysis of the speaker data indicated propagation losses of 5 to 31 dB from the fuel cells' location to the nearby properties to the west. Based on the operation of a VFS, LLC fuel cell at Montville, each cooling module was modeled at a 10-meter source level of 65 dBA while each power module was modeled at a 10-meter source level of 61dBA.[3]

The Storrs site is located in an Institutional Zone on Alumni Drive and is surrounded to the west and south by a Residential Zone. Based on the analysis displayed in Table 4 the airborne noise from the two new fuel cells should be below the 45 dBA noise limit at distances greater than 50 meters (the homes on Cheney Drive). All other nearby residential properties at greater distances are expected to be well below the day time and night time Residential Zone noise limits for an emitter in an Institutional Zone. The property line to the west is only about 5 meters from the cooling module so noise mitigation will be required to bring the property line noise level below the night time noise limit of 45 dBA. While not required, noise mitigation to the east is needed to bring the night time noise levels below 45 dBA for the Nathan Hale Hall across the street from the two fuel cells. Other nearby UConn facilities should have acceptable airborne noise levels.

Operation of the two VFS, LLC fuel cells with noise mitigation should have no significant acoustic impact at all of the nearby properties to the VFS, LLC fuel cell site on Alumni Drive.

The CT's Noise Code[1] and Mansfield's Noise Code[2] also call for review of acoustic issues associated with impulse noise, prominent discrete tones, infrasonic and ultrasonic noise. Operation of the fuel cells is expected to meet all of these requirements at all of the nearby residences. Discrete tone levels above the 40 dBA limit at the property line will be mitigated.

Acoustical Technologies Inc.

Introduction

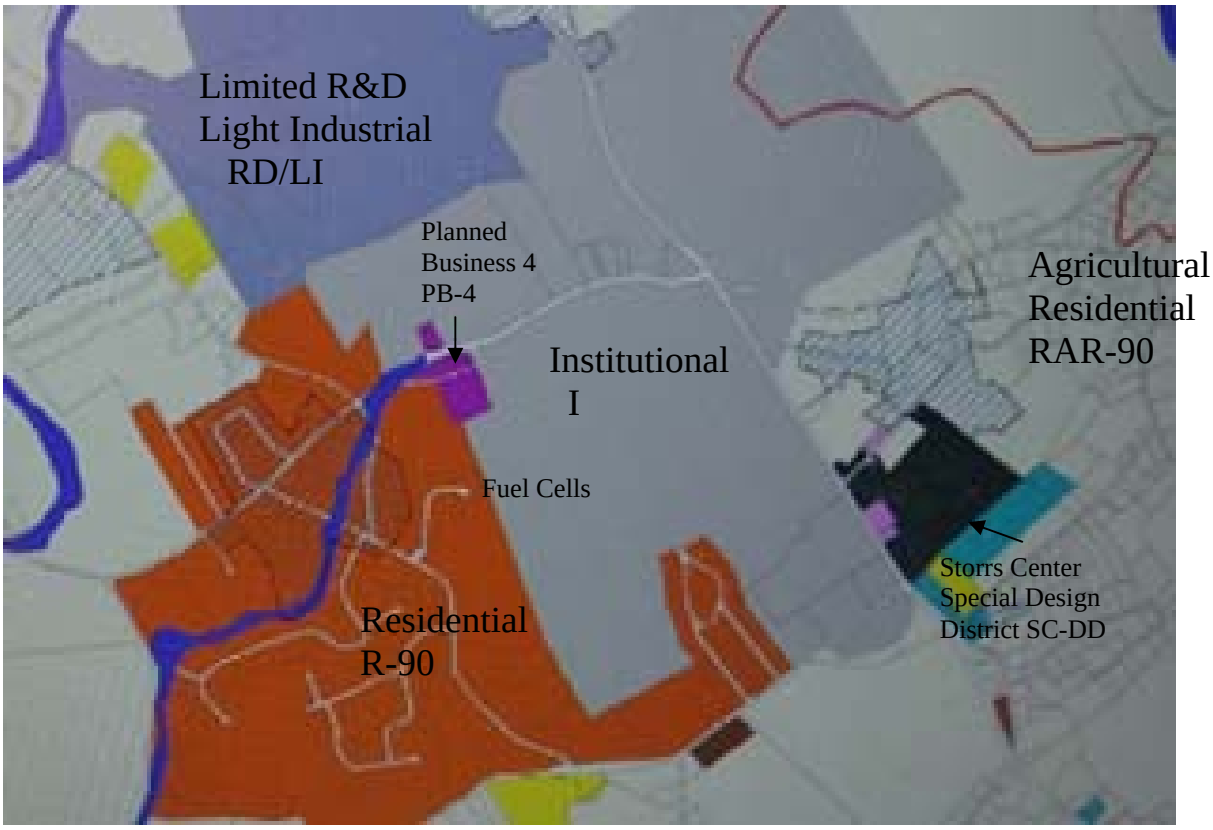
Acoustical Technologies Inc. was tasked as part of a VFS, LLC site permitting process with an assessment of potential acoustic issues associated with fuel cell airborne noise reaching the properties adjacent to the Israel Putnam Refectory site at 2358 Alumni Drive in Storrs, CT. Responding to a request from Walter Bonola, a site visit was made on April 7, 2024. During the visit, a survey of the airborne noise levels produced by a Soundboks speaker simulating the airborne noise produced by two VFS, LLC Fuel Cells was made in order to identify potential airborne noise issues. Airborne noise measurements were taken to quantify the propagation of the simulated fuel cell airborne noise to the adjacent properties. Background airborne noise levels were also made with the speaker off. This document provides an acoustic assessment to assist in meeting the acoustic noise concerns during the permitting process for the siting of two VFS, LLC fuel cells at the 2358 Alumni Drive site.

Development of the Acoustic Assessment Plan

The purpose of this effort is to acquire acoustic information useful in explaining the potential airborne noise issues associated with the operation of two VFS, LLC 460 KW fuel cells at the Israel Putnam Refectory site on Alumni Drive. The proposed site at 2358 Alumni Drive is located in an Institutional Zone (I). This Institutional Zone is next to a Residential Zone (R-90) to the west and south. The south easterly direction has a small Storrs Center Special Design District (SC-DD). The northerly direction has a Limited R&D / Light Industrial Zone (RD/LI). Further away to the east is a Rural Agricultural Residential Zone (RAR-90). Figure 1 shows these zones on a section of the Mansfield CT zoning map. It is important to determine whether the airborne noise generated by the two VFS, LLC fuel cells will impact these neighbors.

The acoustic impact is assessed in the following way. The fuel cells are yet to be installed so there is no way to measure fuel cell operating airborne noise levels at the new site. The fuel cell's airborne noise has been measured at other sites and both overall and one-third octave band airborne noise data of a typical VFS, LLC 460 KW fuel cell are available (Reference 3). Using this data, a Soundboks speaker has been programmed through a set of filters to generate a noise spectrum similar to that of the 460 KW fuel cells. (It is assumed that the Cooling and Power Module noise in the existing measured 460 KW fuel cell are similar to the new units.) This spectrum will then be played through an audio amplifier to create the electrical voltage necessary to drive the Soundboks speaker. In order to overcome the potentially high background noise at the Storrs site the speaker output will be increased to a level more than 25 dB higher than the overall dBA noise level measured on a 460 KW fuel cell at a distance of 10 meters. With the speaker on, this approach then follows the traditional "What is the airborne noise level at the neighbor's property line?" The speaker will be run and airborne measurements made near the proposed fuel cell location and at several of the nearest neighbor's properties. This measured site data can also be used to estimate noise levels at other neighbor's property lines. The State of Connecticut's Noise Ordinance[1] and the Town of Mansfield Noise Ordinance[2] will then be consulted to assess the impact of the measured and estimated acoustic levels. Because of the closeness of the proposed fuel cell site to the nearest residential properties noise mitigation may be recommended if the airborne noise estimated for two fuel cells comes near or exceeds the noise requirements at the neighbors' property lines.

Figure 1. West Central Part of Mansfield Zoning Map Showing the Area near the Two Fuel Cells



Acoustic Measurement Program

The acoustic data necessary to assess the impact of two 460 KW VFS, LLC Fuel Cells are described below: Airborne sound pressure measurements were conducted at the 2358 Alumni Drive site on April 7, 2024 during the afternoon hours (1 to 4 pm). This testing established both background airborne noise levels and simulated airborne noise levels with the speaker operating. The overall A-weighted airborne noise measurements were made with an ExTech model 407780A Digital Sound Level Meter (s/n 140401544) that had been calibrated prior to and just after the test with a Quest model QC-10 Calibrator (s/n Q19080194). Measurements were taken with A-weighting (frequency filtering that corresponds to human hearing) and with the sound level meter in a Slow response mode. Audio tape recordings were made with a Sony Digital Audio Tape Recorder (model TCD-D7 s/n 142000) with microphones on channels 1 and 2. The two PCB microphones (model 130F20 s/n 53994 and 130F20 s/n 53997) were powered by two Wilcoxon P702B power supply/amplifiers (s/n 1992 and 2063 respectively). The PCB microphones were also calibrated prior to and after the test with the Quest model QC-10 Calibrator (s/n Q19080194). A Hewlett Packard model HP3561A Dynamic Signal Analyzer, s/n 2338A00659, was used to perform A-weighted spectral analysis on the tape-recorded data. For reference, a noise level increase of 1 dB is equal to an airborne sound pressure increase of 12.2 per cent. All measurements were made with the microphone at a height above ground between five and six feet. The sound pressure data reported herein are all given in dB reference 20 microPascals. The tape recorded data confirmed the accuracy of the ExTech SLM data.

One minute of background noise data was also analyzed at 10 meters from the speaker position and at two of the nine nearby property lines. Vehicle traffic on Alumni Drive was too heavy for meaningful background acoustic measurements for other locations. When vehicle traffic was not present, background airborne noise levels were at least 20 dB below "speaker on" noise levels at all the measurement positions. As a result, no background corrections were necessary.

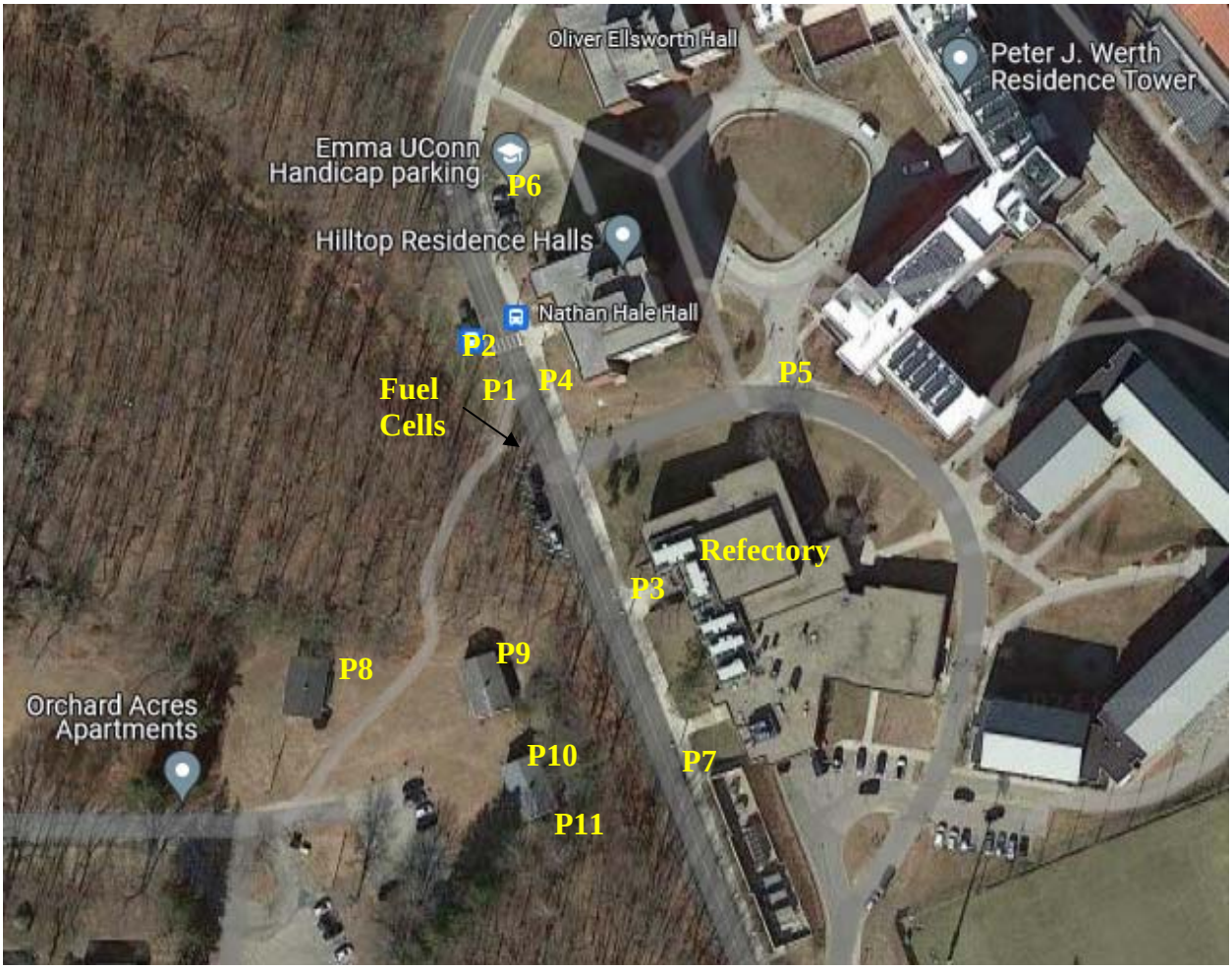
See the Google satellite map in Figure 2 for the approximate measurement locations.
The speaker was located at the proposed fuel cell site. Sound pressure data were taken with the ExTech sound level meter. Figures 3 and 4 provide photographs of two measurement locations for the speaker position at the north end of the site location. At this location, a one-minute record of the acoustic noise at each location was analyzed for the speaker in the "on" condition. In Storrs "speaker on" and background airborne noise measurements were taken at 5 and 10 meters from the proposed 460 KW fuel cell site and at the following nine nearby properties.

Location	**Business**	**Distance**	**Zone**	**Type**
1 & 2– Speaker	VFS, LLC	5 & 10 meters	I	Institutional
3 – Israel Putnam Refectory	UConn	50 meters	I	Institutional
4 – Natham Hale Hall	UConn	15 meters	I	Institutional
5 – Worth Residence Tower	UConn	68 meters	I	Institutional
6 – Volley Ball Court	UConn	53 meters	I	Institutional
7 – Ball Field	UConn	91 meters	I	Institutional
8 – Home	78 Cheney Drive	68 meters	R-90	Residential
9 – Home	83 Cheney Drive	52 meters	R-90	Residential
10– Home	85 Cheney Drive	75 meters	R-90	Residential
11 – Home	87 Cheney Drive	87 meters	R-90	Residential

The property around the Israel Putnam Refectory site is shown in Figure 5. The large size of the UConn property and the location of the fuel cells at the west side of the property means the fuel cell noise will not be an issue to the northern, southern and eastern neighbors. The boundary to the north is a PB-4 parking lot 275 meters away. The boundary to the east is more than 1,000 meters away. The southern boundary is about 640 meters away. The fuel cell site is right at the western boundary of the UConn Institutional Zone and the adjacent R-90 Residential Zone so the nearby homes on Cheney Drive are expected to be the only properties affected by the fuel cells.

Airborne noise measurements taken outside are corrupted by rain and wind so a day was selected when the winds were expected to be 10 miles per hour or less. Table 1 provides the weather data in Storrs for the acoustic measurements on April 7, 2024. Measurements were taken over the period from 1:00 pm until 3:30 pm. Table 1 shows the temperature and wind speeds in hourly intervals. Wind conditions were not as advertised by the weathermen with winds out of the north at up to 15 mph. Fortunately, the measurement locations were shielded by buildings and the wind did not interfere with the measurements. Also, there was no rain during the testing. Many of the measurements along Alumni Drive had to be delayed until all visible traffic was absent. Because of the rural location, background noise levels at all of the measurement positions were moderate with levels from 43 to 45 dBA (absent vehicle traffic). Parked cars at the fuel cell site prevented use of a second speaker location. Airborne noise loss versus range was determined at all nine of the measurement locations (P3 – P11).

Figure 2. Google Map Showing Measurement Positions P1 through P11



The highest airborne noise levels were obtained at the Nathan Hale Hall across the street from the speaker. Transfer functions from column 5 of Table 4 were then applied to the 460 KW data from Montville[3] in order to estimate the received levels for the new 460 KW fuel cells in Storrs. Two fuel cells could make as much as 3 dB more noise than one fuel cell if they were both in one place. Since they are spread out, a conservative level could be calculated by assuming they are all at the closest distance. Reasonable estimates for this and the other locations were calculated by using the transfer function based on relative distances to the property line for each of the locations. Each cooling module will be modeled at a 10-meter source level of 65 dBA while each power module will be modeled at a 10-meter source level of 61dBA.[3]

As stated above, a conservative estimate of the airborne source level from both fuel cells (Ls) can be obtained by power summing the contributions of both power modules and both cooling modules. This source level becomes for the far field where the distances are all similar:

Ls = 10*log (10^(65/10) + 10^(65/10) +10^(61/10) +10^(61/10)) = 69.5 dBA

Because the four noise sources are not physically at the same location, the actual source level will be lower depending on the module location and direction to the neighbor. At the 5 meter property line the power summation of the four modules adds 1dB at most instead of 4.5 dB.

Figure 3. P4 Nathan Hale Measurement Location Looking West Towards the Speaker

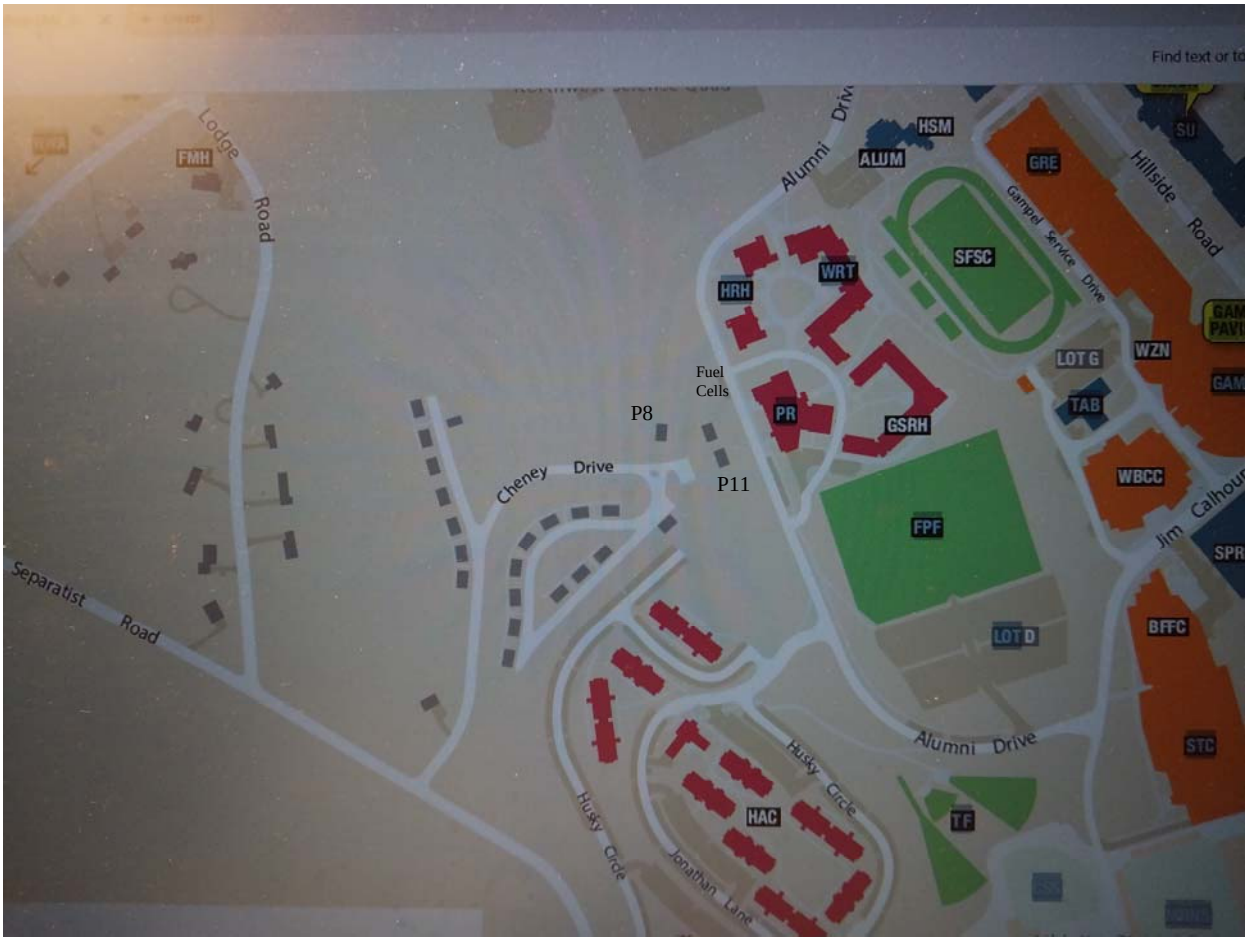
Each property line requires a combination of cooling module and power module noise. The west direction will produce the highest property line noise levels since the homes are closest (about 50 meters). The airborne noise at the closest properties on Cheney Road is calculated by combining two power modules and two cooling modules. Conservative calculations are made for the nine properties using the Storrs measured transfer functions and the Montville measured fuel cell noise levels using the formula: (69.5 dBA – transfer function).

Figure 4. P9 83 Cheney Drive Measurement Location Looking West at 78 Cheney Drive

Table 1. Weather Data near Storrs on April 7, 2024
https://www.wunderground.com/history/daily/us/ct/h windsor-locks/KHFD/date/2024-4-07

Time (EST)	Temp. (°F)	Humidity (%)	Dew Point (°F)	Barometer (in HG)	Wind Speed (mph)	Wind Direction	Condition
10:53 AM	45 °F	52 %	28 °F	30.04 in	15 mph	NNE	Cloudy
11:53 AM	46 °F	50 %	28 °F	30.05 in	14 mph	NNE	Cloudy
12:53 PM	48 °F	50 %	30 °F	30.04 in	10 mph	NNE	Cloudy
1:53 PM	50 °F	44 %	29 °F	30.04 in	15 mph	N	Partly Cloudy
2:53 PM	52 °F	45 %	31 °F	30.02 in	14 mph	NNE	Partly Cloudy
3:53 PM	54 °F	41 %	31 °F	30.01 in	13 mph	NNE	Fair
4:53 PM	54 °F	40 %	30 °F	30.02 in	9 mph	N	Partly Cloudy
5:53 PM	54 °F	38 %	29 °F	30.03 in	10 mph	N	Fair

Figure 5. UConn Property Map with Fuel Cell Location & Adjacent UConn Facilities in Color



Data Analysis

This section analyzes the airborne noise levels measured at the Storrs site and then estimates the received level and transmission loss to nearby properties expected during actual fuel cell operation. These estimated levels will be compared to the noise limits in the Connecticut and Mansfield noise ordinances. Speaker operating noise levels at the Storrs site are reported in Table 2. Background noise levels at the Storrs site are reported in Table 3. The background data did not need to be used to correct the speaker levels thereby providing estimates in Table 4 of the speaker only noise contribution at each location. Table 4 also reports the transfer functions and the operating noise levels estimated for the two new 460 KW fuel cells at the nine locations.

The site location along Alumni Drive may limit the arrangement of fuel cell modules to an end to end configuration. The power modules will then block some of the airborne noise coming from the cooling modules but only heading to the north or south directions. The higher cooling module noise would not be blocked heading to the west and east so the source level of 69.5 dBA is appropriate for a conservative estimate for the very closest properties to the west and east.

Table 2. Measured Overall Sound Pressure Levels in dBA ref. 20 microPascals with **Speaker On**

Location	Range in Meters	Direction	Leq	Max	Min	L90
1 - Speaker On	5	North	99.7	100.4	98.4	**99.8**
2 - Speaker On	10	North	94.6	95.2	93.5	**94.0**
3 - Israel Putnam Refectory	50	South East	80.4	82.9	77.4	**79.6**
4 - Natham Hall	15	North East	89.9	90.4	88.4	**89.3**
5 - Worth Residence Tower	68	East	70.4	73.5	67.2	**69.0**
6 - Volley Ball Court	53	North	76.9	91.0	70.2	**72.4**
7 - Ball Field	91	South	73.2	74.8	70.5	**71.5**
8 - 78 Cheney Drive	68	West	65.4	66.5	64.1	**64.6**
9 - 83 Cheney Drive	52	South West	68.2	72.8	66.8	**67.0**
10 - 85 Cheney Drive	75	South West	64.9	66.1	64.1	**64.3**
11 - 87 Cheney Drive	87	South West	63.8	65.3	62.8	**63.3**

Leq: Equivalent continuous sound level over the measurement period. – **This is normally the level to be identified as the value to be compared with the steady state overall noise requirement. Because of the intermittent traffic noise, the L90 value is used instead.**

SPL MAX: Maximum one-second sound level observed during the measurement period.
SPL MIN: Minimum one-second sound level observed during the measurement period.
L90: - 90% percentile sound level –L90 is the level that is exceeded 90% of the time.

The CT State Noise Ordinance[1] identifies the L90 acoustic calculation as useful in determining background airborne noise. **This value was used as the background noise level.**

The overall airborne noise levels are 29 dB higher for the speaker as compared to what was measured from the VFS, LLC 460 KW cooling module at Montville, CT. This 29 dB difference in level was subtracted from the Storrs measured levels to estimate the expected fuel cell acoustic transfer functions. Column 4 of Table 4 provides the background corrected data for the speaker. The transfer function to each property line is shown in column 5 and the estimated level for two fuel cells in shown in column 6. The 10-meter Montville airborne noise levels were used with the Storrs transmission loss data to estimate the expected two fuel cell airborne noise at the nine nearby neighbors. The residential locations closest to the fuel cells on Cheney Drive are near the night time 45 dBA noise limit. The highest expected level at the closest Residential Zone location is 2.5 dB below the 45 dBA requirement using the conservative source level.

Table 3. Measured Overall Sound Pressure Levels in dBA ref. 20 microPascals with Speaker Off

Location	Range in Meters	Direction	Leq	Max	Min	L90
Speaker On	5	North				
Speaker On	10	North	47.3	70.1	45.0	**45.4**
8 - 78 Cheney Drive	68	West	48.9	54.6	44.4	**45.1**
9 - 83 Cheney Drive	52	South West			42.8	**43.4**

The airborne noise levels to be produced by the VFS, LLC fuel cells are shown in Table 4. For each of the nine locations the Storrs measurements are corrected to account for the higher speaker levels. The fuel cell's noise correction for the speaker location is estimated to be about 29 dB because the speaker level is that much higher than the Montville Cooling Module level.

The measurements at Storrs were taken at various distances from the speaker and then corrected to estimate the expected noise from two fuel cells. The predicted airborne noise levels are all below 45 dBA, at least 2 dB below the lowest Residential Zone night time noise limit for the homes on Cheney Drive. These measurements were made near the homes and not on the property line. Google Maps indicates the UConn property line runs about 30 feet from the west edge of Alumni Drive. Typical plans for a fuel cell indicate a width dimension of about 19 feet leaving at most a distance of about 5 meters from the cooling module to the Residential Zone property line. Since the cooling module has a source level of 65 dBA at 10 meters[3] and about a source level of 71 dBA at 5 meters, the property line adjacent to the two fuel cells will see airborne noise levels above the day time limit of 55 dBA and well above the night time limit of 45 dBA. If required, this issue can be mitigated with a noise barrier running along the property line in the vicinity of the two fuel cells. Details of the cooling module and power module locations are needed to design and then calculate the noise mitigation and its performance.

The measurement locations on the UConn side of Alumni Drive in the Institutional Zone are near the daytime noise limit of 55 dBA while one is quite a bit higher than the night time noise limit of 45 dBA. Nathan Hale Hall located across the street has the highest predicted airborne noise levels with values about 20 dB above the night time noise limit. Since this is a residence hall these high noise levels should be addressed. Locations further away like the Refectory, volley ball court and ball field are able to meet the daytime noise limit of 55 dBA so should not be an issue since they would not typically be used overnight. The Worth Residence Tower and other nearby UConn residences are far enough away to meet both the day time and the night time noise limit without any noise mitigation.

Table 4 Background Corrected L90 Sound Pressure Levels in dBA ref. 20 microPascals

Location	Range in Meters	Direction	L90 Estimate	Transfer Function	Property Line	Over Spec
			In dBA	In dB	dBA	of
Speaker	5	North	99.8	-		45
Speaker	10	North	94.0	-		dBA
3 - Israel Putnam Refectory	50	South East	79.6	14.4	55.1	**10.1**
4 - Natham Hall	15	North East	89.3	4.7	64.8	**19.8**
5 - Worth Residence Tower	68	East	69.0	25	44.5	-0.5
6 - Volley Ball Court	53	North	72.4	21.3	48.2	**3.2**
7 - Ball Field	91	South	71.5	22.5	47.0	**2.0**
8 - 78 Cheney Dr	68	West	64.6	29.4	40.1	-4.9
9 - 83 Cheney Dr	52	South West	67.0	27	42.5	-2.5
10 - 85 Cheney Dr	75	South West	64.3	29.7	39.8	-5.2
11 - 87 Cheney Dr	87	South West	63.3	30.7	38.8	-6.2

Allowable Noise Levels

Connecticut's regulation for the control of noise provides in *CT section 22a-69*-3[1] the requirements for noise emission in Connecticut. *Section 22a-69*-3.1 states that no person shall cause or allow the emission of excessive noise beyond the boundaries of his/her Noise Zone so as to violate any provisions of these Regulations. The CT ordinance will be used to evaluate the noise generated by the VFS, LLC 460 KW Fuel Cells. (The Mansfield noise ordinance has the same noise limits.) Following sections discuss each type of noise using the results obtained from the April 7, 2024 speaker measurements in Storrs and the VFS, LLC 460 KW fuel cell test in Montville, CT reported on July 13, 2020[3].

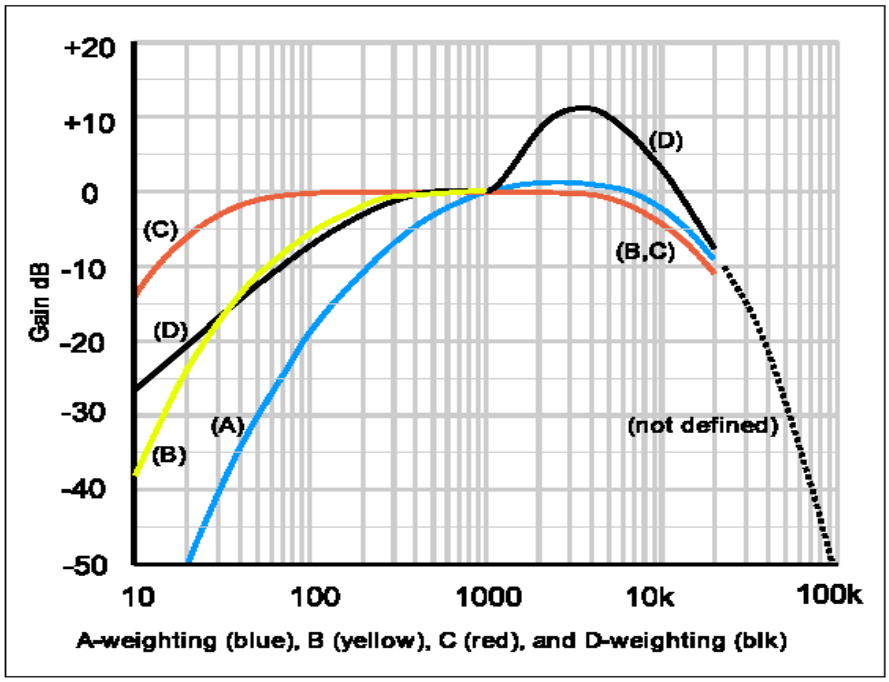
As stated above, the Storrs site is located in an Institutional Zone on Alumni Drive and is surrounded to the west and south by a Residential Zone. The closest Residential Zone is only about 5 meters away from the fuel cell. Based on the analysis shown in Table 4 the airborne noise from the two new fuel cells should be below the 45 dBA noise limit at distances greater than 50 meters (the homes on Cheney Drive). All other nearby residential properties at greater distances are expected to be well below the day time and night time Residential Zone noise limits for an emitter in an Institutional Zone. The property line to the west of the fuel cells is only about 5 meters from the cooling module so noise mitigation will be required to bring the property line noise level below the night time noise limit of 45 dBA. While not required, noise mitigation to the east is needed to bring the night time noise levels below 45 dBA for the Nathan Hale Hall across the street from the two fuel cells.

Impulse Noise

The Connecticut noise code states in *CT section 22a-69*-3.2 (part a) *Impulse Noise* that no person shall cause or allow the emission of impulse noise in excess of 80 dB peak sound pressure level during the night time to any class A Noise Zone. Night time is defined as 10 pm to 7 am. *CT section 22a-69-3.2 (part b) Impulse Noise* states that no person shall cause or allow the emission of impulse noise in excess of 100 dB peak sound pressure level at any time to any Noise Zone. The Mansfield noise ordinance sets the same limits for Impulse Noise.

Figure 6. Acoustic Airborne Noise Weighting Curves

http://upload.wikimedia.org/wikipedia/commons/3/39/Acoustic_weighting_curves_(1).svg



Impulse noise in excess of 80 dBA was not observed during any of the ten property line measurements of the 460 KW fuel cell made at the Montville site on 7 July, 2020[3]. The maximum level measured was 79.7 dBA at location P2 using the ExTech sound level meter. This and the other levels above 70 dBA were caused by vehicle traffic and not by the fuel cell. Unweighted impulse noise levels were determined using a Hewlett Packard HP3561A spectrum analyzer. (The maximum level ten meters from the fuel cell was 77 dBA.) The closest residential property showed 29 dB of transmission loss so the highest expected level would be below 50 dB. Given the steady state nature of the fuel cell's noise signature there should be no acoustic issues with the State of Connecticut's or the Town of Mansfield's impulse noise requirements. (Noise mitigation to meet the 45 dBA property line overall noise level limit will also help mitigate any impulse noise at the residential property line.)

A few words are in order to discuss the difference between A-weighted and un-weighted impulse noise. A-weighting emphasizes the middle and higher frequencies while reducing the influence of the low frequencies. Figure 6 above plots the A-weighting curve versus frequency in blue. Below a frequency of 1 kiloHertz the acoustic level is attenuated by increasing amounts. The reduction is about 10 dB at 200 Hertz, 20 dB at 90 Hertz and 30 dB at 50 Hertz. It also reduces the level at very high frequency being down in level by 10 dB at 20 kiloHertz. The fuel cell measurements show the unweighted overall levels to be about 9 dB higher than the A-weighted noise levels. Adding 9 dB to the Montville measured levels brings the peak impulse up to about 56 dB reference 20 microPascals. The impulse noise levels at the homes on Cheney Drive should be no higher than 60 dB reference 20 microPascals, well below the 80 dB night time limit. The property line impulse noise levels should also be below the 80 dB limit.

Prominent Discrete Tones

The Connecticut regulation for the control of noise states in *CT section 22a-69-3.3 Prominent discrete tones:* Continuous noise measured beyond the boundary of the Noise Zone of the noise emitter in any other Noise Zone which possesses one or more audible discrete tones shall be considered excessive noise when a level of 5 dBA below the levels specified in section 3 of these Regulations is exceeded. The CT Regulations establish different noise limits for different land use zones. Institutional (homes and condominiums) and hotel uses are in Class A. Schools, business, parks, recreational activities and government services are in Class B. Forestry and related services are in Class C. By my reading of the regulations the Storrs source is a Class A emitter in an Institutional Zone. (Some might argue that UConn is a school and should be considered Class B. I chose Class A because the fuel cell site is in a student residential area. Nonetheless, the relevant noise limits are the same for the two classes.) The noise zone standards in *CT section 22a-69-3.5* state that a Class A emitter cannot exceed the following overall sound pressure levels:

To Class C 62 dBA To Class B 55dBA To Class A 55 dBA (day) 45 dBA (night)

The discrete tones limits are 5 dBA lower so that no tone may be higher than the following:

To Class C 57 dBA To Class B 50 dBA To Class A 50 dBA (day) 40 dBA (night)

The Mansfield noise ordinance does not discuss discrete tones so the CT Noise Ordinance will be used. To address the discrete tone issue, we use measured spectral data from the Reference 3 Montville testing. The data is the maximum level received in 1/30 octave bands for frequencies from 0.32 to 100,000 Hz. Figure 7 plots the airborne noise measured 10 meters from the Cooling and Power Modules in 1-30th octave bands. This figure shows some discrete tones in the middle frequencies produced by the VFS, LLC Fuel Cell Cooling and Power Modules. The eight largest tones are given in Table 5. The highest is 55.1 dB reference 20 microPascals at 302 Hz. The second highest tone is at 213.8 Hz at a level of 54.3 dB reference 20 microPascals. All the remaining tones are below 53 dBA. The A-weighted discrete tone corrections are given in the 4th row of Table 5. Incorporating the transmission loss to the properties gives the A-weighted levels in the last four rows of Table 5 after the 3 dB correction for two units is added. All the frequencies at the nearest residences have levels that are below the 40 dBA requirement in a Residential Zone by at least 8 dB. All the nearby Institutional properties should meet all the discrete tone requirements except for Nathan Hale Hall. The 302 Hz tone is highest there with a level of 53 dB. There should be no acoustic issue with the CT discrete tone noise requirements at all of the other nearby Residential and Institutional Zone properties. Noise mitigation needed to meet the night time 45 dBA limit at Nathan Hale Hall will also address the 302 Hz and other discrete tones that are above 49 dBA at Nathan Hale Hall.

Figure 7. Montville Tones 460 KW Fuel Cell Cooling & Power Modules in 1-30th octave bands

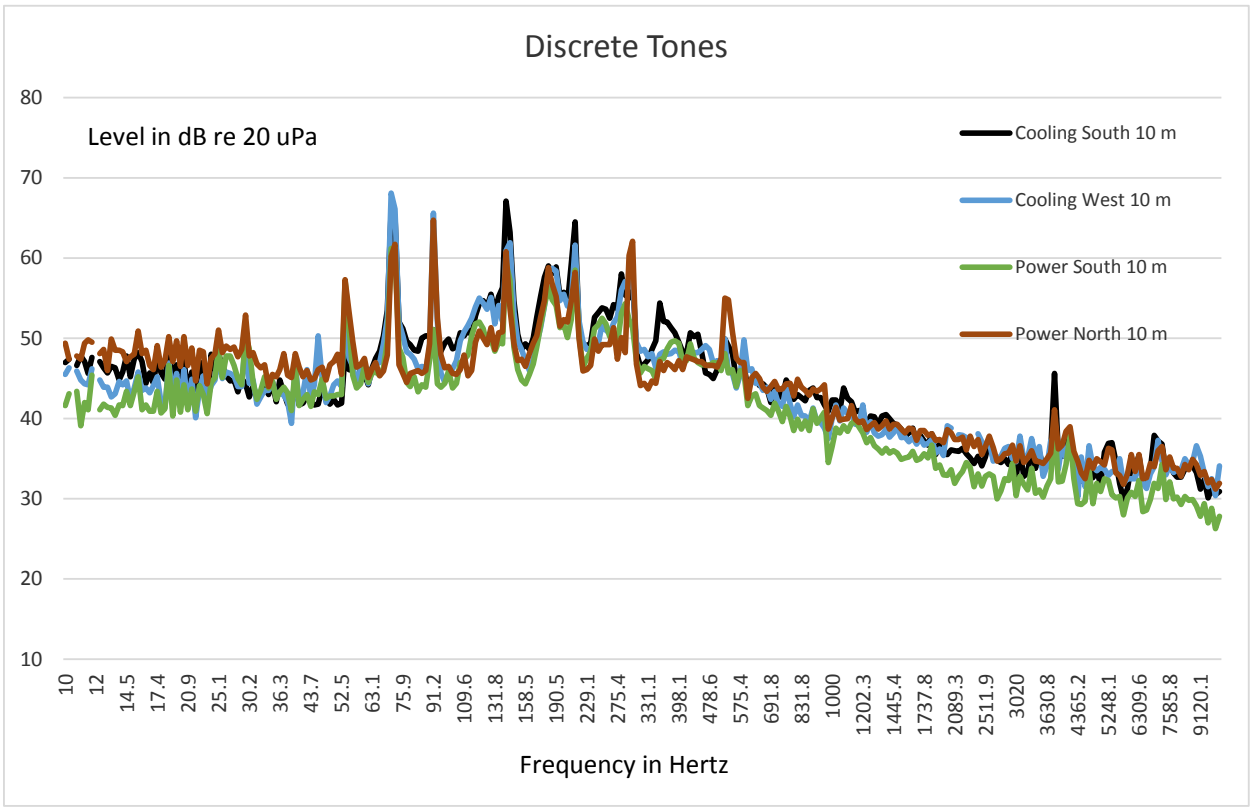


Table 5. Peak Discrete Sound Pressure Level Estimates in dB ref. 20 microPascals

Location	Range Meters	53.7 Hz	70.8 Hz	91.2 Hz	141.3 Hz	213.8 Hz	302 Hz	3801 Hz	4169 Hz
Allowed Level		**40**	**40**	**40**	**40**	**40**	**40**	**40**	**40**
Montville	10	57.3	68.1	65.6	67.1	64.5	62.1	45.6	39
A Weighting		-29.0	-24.3	-20.5	-14.7	-10.2	-7.0	1.0	0.9
Storrs 1 unit	10	28.3	43.8	45.1	52.4	54.3	55.1	46.6	39.9
2 Fuel Cells	10	31.3	46.8	48.1	55.4	57.3	58.1	49.6	42.9
P8–78 Cheney	68	1.9	17.4	18.7	26.0	27.9	28.7	20.2	13.5
P9–83 Cheney	52	4.3	19.8	21.1	28.4	30.3	31.1	22.6	15.9
P10–85 Cheney	75	1.6	17.1	18.4	25.7	27.6	28.4	19.9	13.2
P11–87 Cheney	87	0.6	16.1	17.4	24.7	26.6	27.4	18.9	12.2

Infrasonic and Ultrasonic Noise

The Connecticut regulation for the control of noise states in *CT section 22a-69-3.4 Infrasonic and Ultrasonic* that no person shall emit beyond his/her property infrasonic or ultrasonic sound in excess of 100 dB at any time. 100 dB with respect to the reference of 20 microPascals is a sound pressure of 2 Pascals or 0.00029 psi. Infrasonic sounds are sound pressure fluctuations below a frequency of 20 Hertz. Ultrasonic sounds are sound pressure fluctuations at frequencies above 20,000 Hertz. There is no mention in the Mansfield Noise Ordinance that limits infrasonic or ultrasonic noise so the State of CT Noise Ordinance will be used.

Narrow bandwidth sound pressure spectrums in dB reference 20 microPascals made at the Montville 10-meter Cooling Module location can be used to compare with the infrasonic and ultrasonic noise requirements. The Montville airborne noise data were processed in the 0 to 200 Hertz and 0 to 100,000 Hertz frequency ranges. The bandwidth of each data point is 0.75 Hertz for the 200 Hertz range and 375 Hertz for the 100,000 Hertz frequency range. The infrasonic noise for frequencies up to 20 Hertz is shown in Figure 8 for the 460 KW unit at Montville[3]. The maximum level at 10 meters is 48 dB reference 20 microPascals. The entire 20 Hertz band can be power summed and never exceeds 70 dB reference 20 microPascals at 10 meters in Montville. After adding 6 dB for the maximum transfer function correction at the western property line, the closest site, and adding the gain of 3 dB for two units, the 79 dB level is well below the Infrasonic requirement of 100 dB for the Storrs site. The noise levels at all the other nearby Institutional and Residential neighbors will be lower. There should be no issue with the infrasonic noise requirement at any of the neighboring Institutional properties.

The ultrasonic noise for frequencies up to 100 KiloHertz is given in Figure 9. The Montville data uses a microphone with flat high frequency performance and provides a good estimate for the 460 KW fuel cell. The entire 80 KiloHertz band from 20 to 100 kiloHertz has been power summed and never exceeds a noise level of 62 dB reference 20 microPascals 10 meters from the

fuel cell at Montville. After adding 6 dB for the maximum transfer function correction at the western property line, the closest site, and adding the gain of 3 dB for two units, the ultrasonic level of about 71 dB is well below the requirement of 100 dB for the Storrs site. The noise levels at all the other nearby Institutional and Residential neighbors will be lower and there should be no issue with ultrasonic noise at any of the neighboring properties.

Figure 8. Infrasonic Noise from Montville Fuel Cell Cooling Modules in 1-30th octave bands

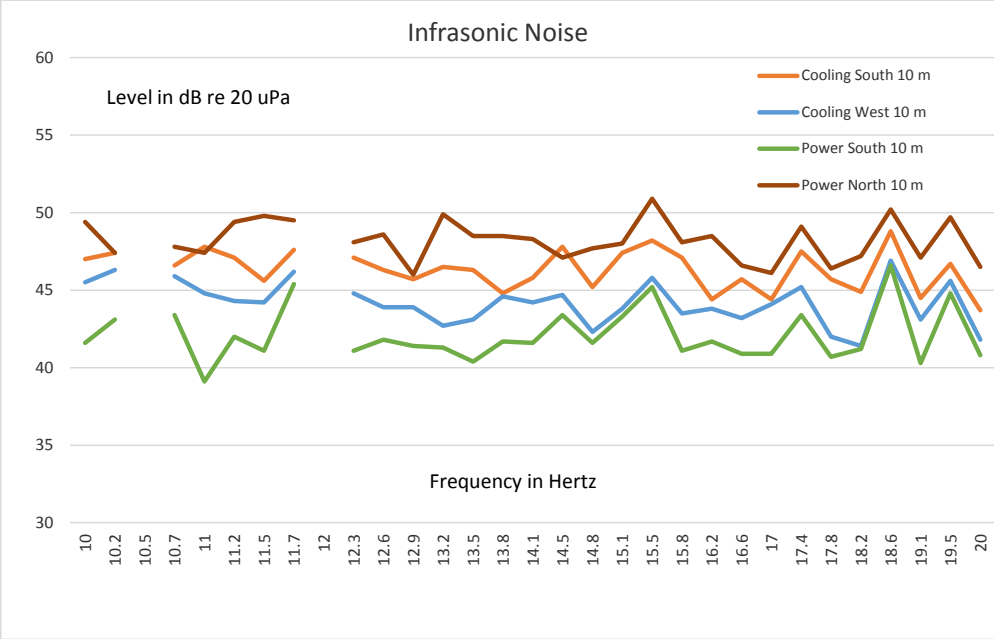
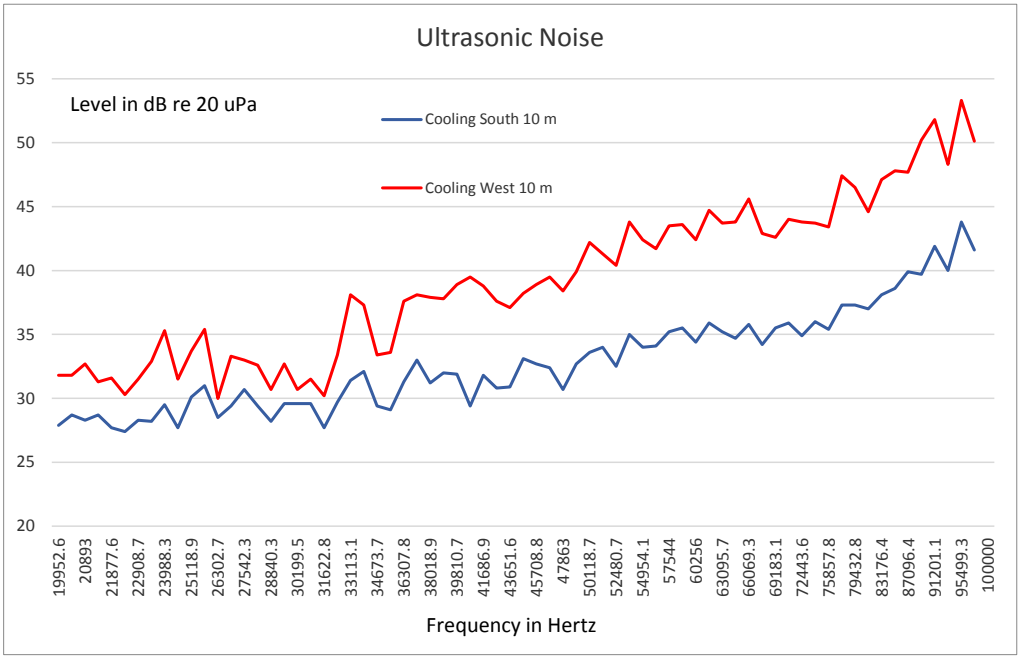


Figure 9. Ultrasonic Noise from Montville Fuel Cell Cooling Modules in 1-30th octave bands



Overall Sound Pressure Levels

The Connecticut regulations for the control of noise state that
(a) No person in a Class A Noise Zone shall emit noise exceeding the levels below:

To Class C 62 dBA To Class B 55 dBA To Class A 55 dBA (day) 45 dBA (night)

The Storrs site is in an Institutional Zone that has a nearby Residential Zone. The nearby neighbors have airborne noise limits of 55dBA during the day and 45 dBA at night.
The estimated overall A-weighted sound pressure levels for two fuel cells in dBA reference 20 microPascals are given in column 6 of Table 4 using the airborne noise measurements made on April 7, 2024. The second column gives the approximate distance from the fuel cells to the measurement location, with locations identified by a P number in Figure 2.

Column 3 gives the direction from the fuel cell to the property. The airborne noise values given in column 4 are the estimated background corrected received level for one speaker. The transfer functions in column 5 provide the loss in sound level from the fuel cells to the nine properties. The values in column 6 provide the predicted airborne noise levels at the properties with two fuel cells operating. The Cheney Drive home values are all below the Residential Zone noise limit for both day time and night time operation. The increasing loss with distance to the surrounding residential properties means all should be lower than 45 dBA reference 20 microPascals.

These measurements were made near the homes and not on the property line. Typical plans for a fuel cell indicate a width dimension of about 19 feet leaving at most, a distance of about 5 meters from the cooling module to the Residential Zone property line. Since the cooling module has a source level of 65 dBA at 10 meters[3] and a source level of about 71 dBA at 5 meters, the property line adjacent to the two cells will see airborne noise levels above both the day time limit of 55 dBA and the night time limit of 45 dBA. This issue can be mitigated with a noise barrier running along the property line in the vicinity of the two fuel cells.

Some of the properties may be able to hear the fuel cells when the background noise is very quiet and below a level of 45 dBA (no traffic is present). Operation of the two VFS, LLC fuel cells should have no significant acoustic impact at all the residential properties adjacent to the fuel cell site on Alumni Drive.

Institutional properties on Alumni Drive in the Institutional Zone are not expected to hear the fuel cells except for Nathan Hale Hall and the Israel Putnam Refectory. Nathan Hale Hall is located across the street and has the highest predicted airborne noise levels with values roughly 20 dB above the night time noise limit. Since this is a residence hall, these high noise levels should be addressed with noise mitigation. Locations further away like the Refectory, volley ball court and ball field are able to meet the daytime noise limit of 55 dBA so these locations should not be an issue since they would not be used overnight. All of the other nearby Institutional properties should not be affected by the operation of the two fuel cells.

Conclusions

The purpose of this effort is to evaluate the acoustical environment at the Storrs site during operation of the two VFS, LLC 460 KW fuel cells. This effort has been accomplished and the results show that the operation of the two VFS, LLC 460 KW fuel cells will meet the State of Connecticut and Town of Mansfield airborne noise requirements at all but two of the nearby properties. Because the fuel cells are to be placed very close to the property line across the street from a residence hall, the fuel cells will require noise mitigation to bring the airborne noise levels below the night time noise requirement at the property line and at Nathan Hale Hall. Other residential properties in all directions are expected to meet all the noise requirements because they are far enough away from the new fuel cells and have airborne noise levels below 45 dBA. Locations at distances greater than 100 meters should not hear the operating 460 KW fuel cells during conditions of low background noise.

References

1) CT DE&EP *Noise Control Regulation RCSA Section 22a-69*-1 to 22a-69-7.4 http://www.ct.gov/dep/lib/dep/regulations/22a/22a-69-1through7.pdf

2) Mansfield Noise Ordinance, Mansfield Chapter 134 Noise,

   https://ecode360.com/11768146

3) Town of Montville Water Pollution Control Authority Airborne Noise Test

   At 83 Pink Row, Acoustical Technologies Inc., July 13, 2020