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Subject: Israel Putnam Refectory
Noise Treatment Recommendations
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Summary

This document makes acoustic noise control recommendations that should assist in meeting the acoustic noise concerns during the operation of two Doosan 460 KW fuel cells on the UConn site near 2358 Alumni Drive in Storrs, CT. An acoustic assessment plan was developed and executed to acquire acoustic information useful in explaining and mitigating the potential airborne noise issues associated with the future operation of two Doosan 460 KW fuel cells at the site in Storrs. This has been accomplished and the results show that the acoustic impact of operating the two Doosan 460 KW fuel cells will be minimal with the recommended mitigation.

The airborne noise levels expected to be generated by the two Doosan fuel cells operating at the UConn site were simulated by exciting a Soundboks speaker at the nominal fuel cells' Power and Cooling Module positions[1]. The speakers produced average overall A-weighted sound pressure levels of 99.8 dBA at 5 meters and 94 dBA at 10 meters (reference 20 microPascals) near the proposed fuel cells' location. The airborne noise levels from the speakers were measured at nearby property lines at noise levels from 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 on the fan side and 58.6 dBA on the side without fans.[2,6]

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 1 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 southwest is only about 10 meters from cooling module #1 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 below 45 dBA for Nathan Hale Hall across the street from the two fuel cells. Other nearby UConn facilities should have acceptable airborne noise levels.

Efforts to reduce the fuel cell airborne noise at the Alumni Drive location should be directed at adding a sound barrier treatment to block the fuel cells' noise from reaching the closest residential properties and Nathan Hale Hall. The performance of a commercially available noise barrier, from Acoustical Solutions, called ABBC-EXT-R Sound Curtains can be used to provide the necessary mitigation. While the barrier treatment is expected to be helpful when deployed in a ten-foot height, a greater height of 12 feet will increase the performance to ensure the 2358 Alumni Drive location meets the 45 dBA noise limit for the properties on Cheney Drive. Table 2 shows the expected performance of fence heights from 10 to 20 feet. A fence of height 12 feet is also recommended along Alumni Drive in order to reduce the night time noise levels at Nathan Hale Hall to below 45 dBA. The two fuel cells should be completed enclosed with a 12-foot noise barrier on all four sides to prevent airborne noise from escaping to the north and south.

Introduction

Acoustical Technologies Inc. was tasked with an assessment of potential acoustic issues associated with fuel cell airborne noise reaching the properties adjacent to the UConn site near 2358 Alumni Drive in Storrs, CT[1] Responding to a request from Walter Bonola, a site visit was made on April 7, 2024. During the visit, measurement of the simulated airborne noise expected to be produced by two Doosan 460 KW fuel cells was made in order to identify potential noise issues. This document provides recommendations for a noise control approach that will mitigate the acoustic noise concerns during the operation of the two Doosan 460 KW fuel cells.

The purpose of this effort is to utilize the available acoustic information to mitigate the potential airborne noise issues associated with the operation of two Doosan Fuel cells at 2358 Alumni Drive in Storrs, CT. The State of Connecticut and the Town of Manfield Noise Ordinances have been consulted to assess the impact of the estimated acoustic levels. (The night time airborne noise levels should be kept below 45 dBA reference 20 μPa). Noise mitigation is required and would be appropriate in order to reduce the airborne noise propagated by the fuel cells to the closest neighbor's properties on Cheney Drive directly to the west of the fuel cells' location.

Acoustic Measurement Program

Airborne sound pressure measurements and audio tape recordings were conducted at the UConn site on and near 2358 Alumni Drive on April 7, 2024 during the morning hours. The purpose was to measure both background and airborne noise levels with the Soundboks speaker simulating the operation of two Doosan 460 KW fuel cells. Speaker and background airborne noise measurements were taken at each neighbor's property line at nine locations surrounding the UConn site (see Table 1 below). Measurements at 5 and 10 meters from the Site 2 Power Module location were simultaneously taken with a sound level meter and two microphones recording on a digital tape recorder. Overall airborne noise levels were calculated and reported.

See Figures 1 and 2 below for photographs of the Storrs measurement locations. Figures 3 and 4 provide Google and Property Maps of the UConn site with the property line measurement locations identified as P3 through P11. The expected site of the Power Module # 2 next to Cheney Drive is identified in yellow, near P1 and P2. Table 1 provides estimates of the expected Doosan fuel cell airborne noise at each of the eleven measurement locations. Column 6 provides the total airborne noise estimates for the two fuel cells.

Table 1. 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

Figure 1. Soundboks Speaker at PM-2 Position and Sound Level Meter at Nathan Hale Hall

The Chaney Drive estimates are at the homes and not the property line.

The Soundboks speaker is next to the telephone pole.

Nathan Hale Hall is directly Behind the sound level meter.

Figure 2. Sound Level Meter at 83 Cheney Drive

The home in the background is 78 Cheney Drive.

Allowable Noise Levels

CT section 22a-69-3.1 (Ref. 2) 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 Town of Mansfield and the CT noise ordinances have been used to evaluate the noise generated by the Doosan Fuel cells' Power and Cooling Modules. The following subsection discusses the overall noise requirement and discusses the results obtained from the measurements at the UConn site in order to determine whether noise controls need to be applied. The Impulse, Prominent Discrete Tones, Infrasonic and Ultrasonic measurements of fuel cells airborne noise showed no acoustic concerns and will not be discussed further as no acoustic treatment is needed. The Town's noise limits are the same as the CT noise limits.

Overall Sound Pressure Levels

The Connecticut regulation for the control of noise states in *CT section 22a-69-3.5 Noise zone standards (c) No person in a Class A Noise Zone shall emit noise exceeding the levels stated herein and applicable to adjacent Noise Zones:*

Class C emitter to C 62 dBA B 55 dBA A/day 55 dBA A/night 45 dBA

The nearby neighbors are classified as residential and have a Residential Zone noise limit of 55 dBA during the day and 45 dBA at night. All of the nearby residential homes are expected to meet the nighttime and day time residential airborne noise limits with the exception of the closest homes on Cheney Drive. Operation of the Doosan fuel cells may have a minor acoustic impact by exceeding 45 dBA at the property line adjacent to the Cooling Module at the closest Cheney Drive locations (P8 – P11). (The airborne noise levels in Column 5 of Table 1 are actually calculated at the home and not the property line. The west property line is expected to be around 65 dBA without noise mitigation.) The airborne noise level at Nathan Hale Hall (P4) is also expected to exceed the 45 dBA night time noise limit by 20 dB without noise mitigation.

Figure 3. Google Map Showing Measurement Positions P1 through P11, P1 & P2 at Fuel Cell

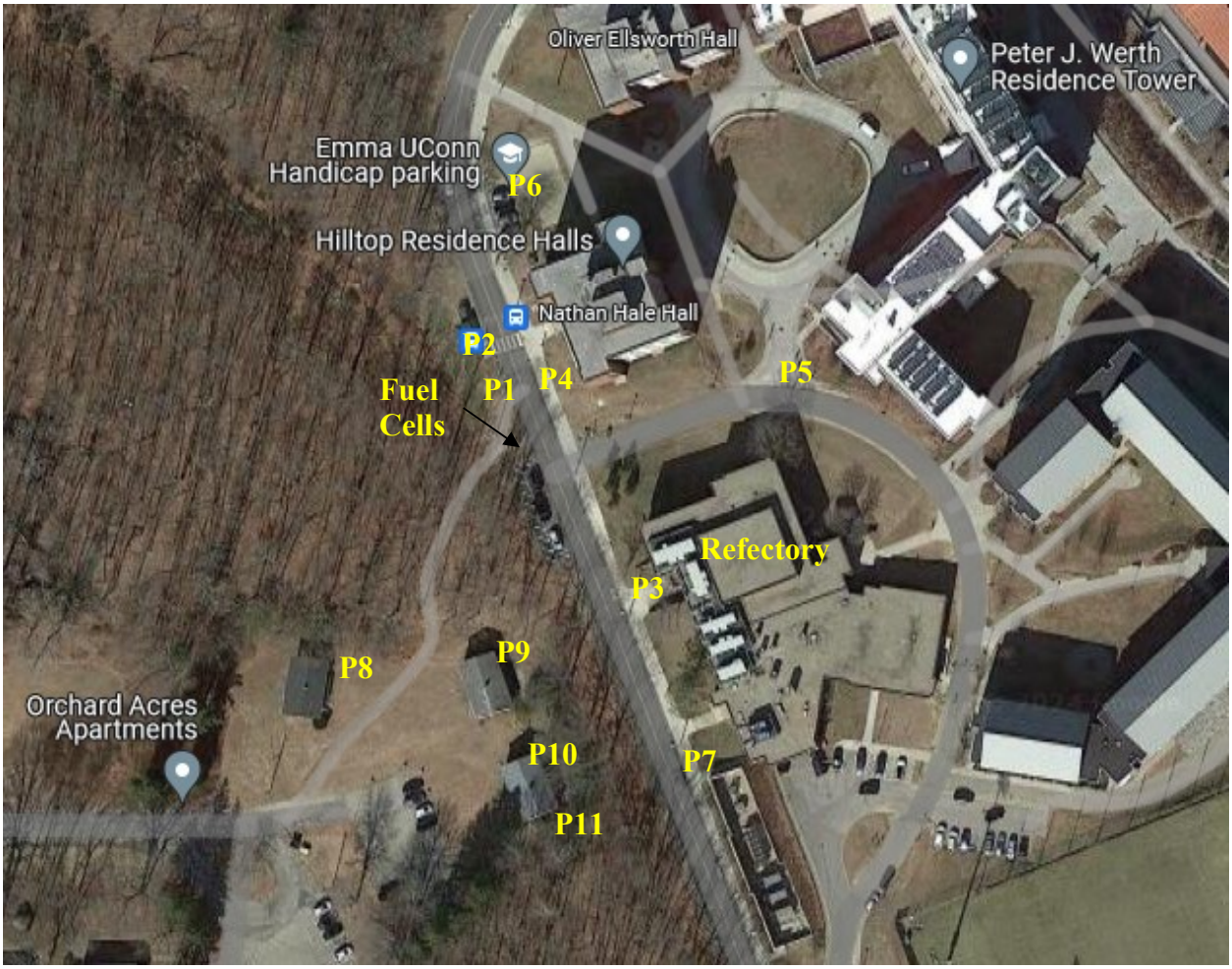
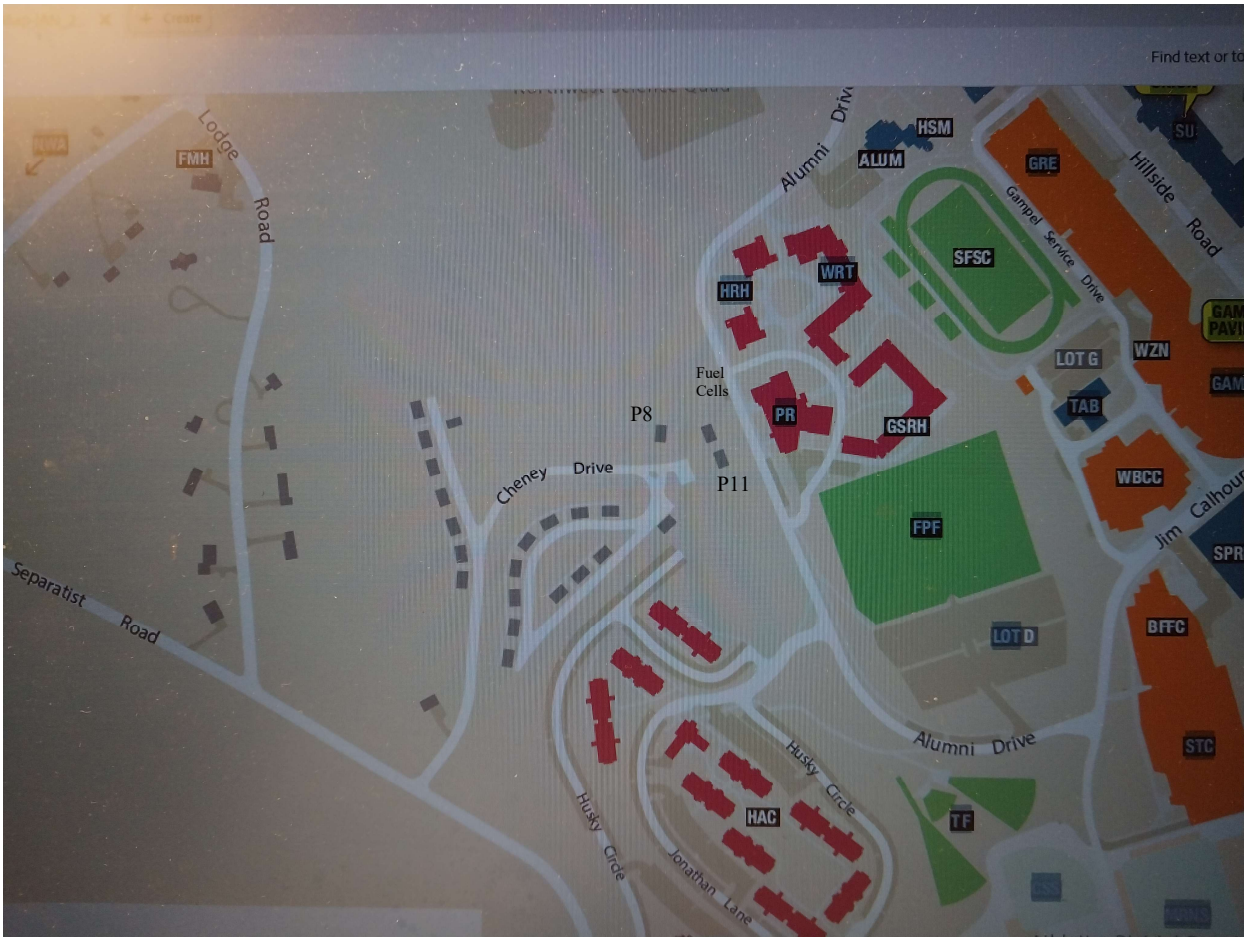


Figure 4. UConn Property Map with Fuel Cell Location & Adjacent UConn Facilities in Color



Noise Treatment Recommendations

The location of the Doosan fuel cells is shown in Figure 5. Estimates from the UConn testing indicate that the fuel cells' noise contribution may be about 20 dB above the night time noise limit at the adjoining property line. Treatment of the Cooling and Power Modules (i.e. reducing its noise by 20 dB) should mitigate the noise at the nearby property line and at Nathan Hale Hall.

The mitigation can be obtained by building an acoustic barrier around the Cooling and Power Modules. This approach places a transmission loss treatment on the chain link fence surrounding the Cooling and Power Modules as shown in Figure 9. The following paragraphs describe the analysis used in designing this barrier noise treatment.

The fuel cells were initially designed to be surrounded by a 10-foot-high chain link fence adjacent to the west property boundary and the noise control is provided by attaching an acoustic barrier material to the fence. Calculating the acoustic performance of the barrier requires an estimate of the transmission loss through the barrier as well as an estimate of the acoustic leakage over and around the barrier. Typical noise treatments will have at least 20 dB of performance for sound traveling through the treatment. The diffraction over the top of the

acoustic barrier has been calculated and the results are shown in Table 2 as a function of barrier height. A 10-foot-high barrier provides about 12 dB of mitigation to the west property line. Continuing the barrier along Alumni Drive would provide about 16 dB of mitigation for Nathan Hale Hall. This is not quite enough to meet the night time noise limit of 45 dBA.

For the property line to the west of the fuel cells, a barrier height of about 20 feet is needed to reduce the property line noise level to 45 dBA. The west property line is on a steep slope that is wooded extending about 25 meters before the woods open to a grassy area around the closest home at 83 Cheney Drive. Allowing some of this woody area to exceed the 45 dBA night time noise limit should be acceptable. The bottom line in Table 2 provides the number of yards at which the property line sees the fuel cell noise falls to 45 dBA. With a 10-foot barrier this number is 28.5 meters, within the grassy area next to the home at 83 Cheney Drive. Selecting a 14-foot-high barrier moves the distance for 45 dBA back to 9.5 meters from the property line, about 15 meters from the home and grassy area at 83 Cheney Drive. A 12-foot-high fence places the 45 dBA line 15.7 meters from the property line and about 10 meters from the home and grassy area. My recommendation is to install a 12-foot barrier completely around the cooling and power modules. As the right half of Table 2 shows, the 12-foot barrier along Alumni Drive will bring the Nathan Hale Hall levels below 45 dBA.

Figure 5. ICDS Drawing of Two Fuel Cells at UConn (5/28/2024)

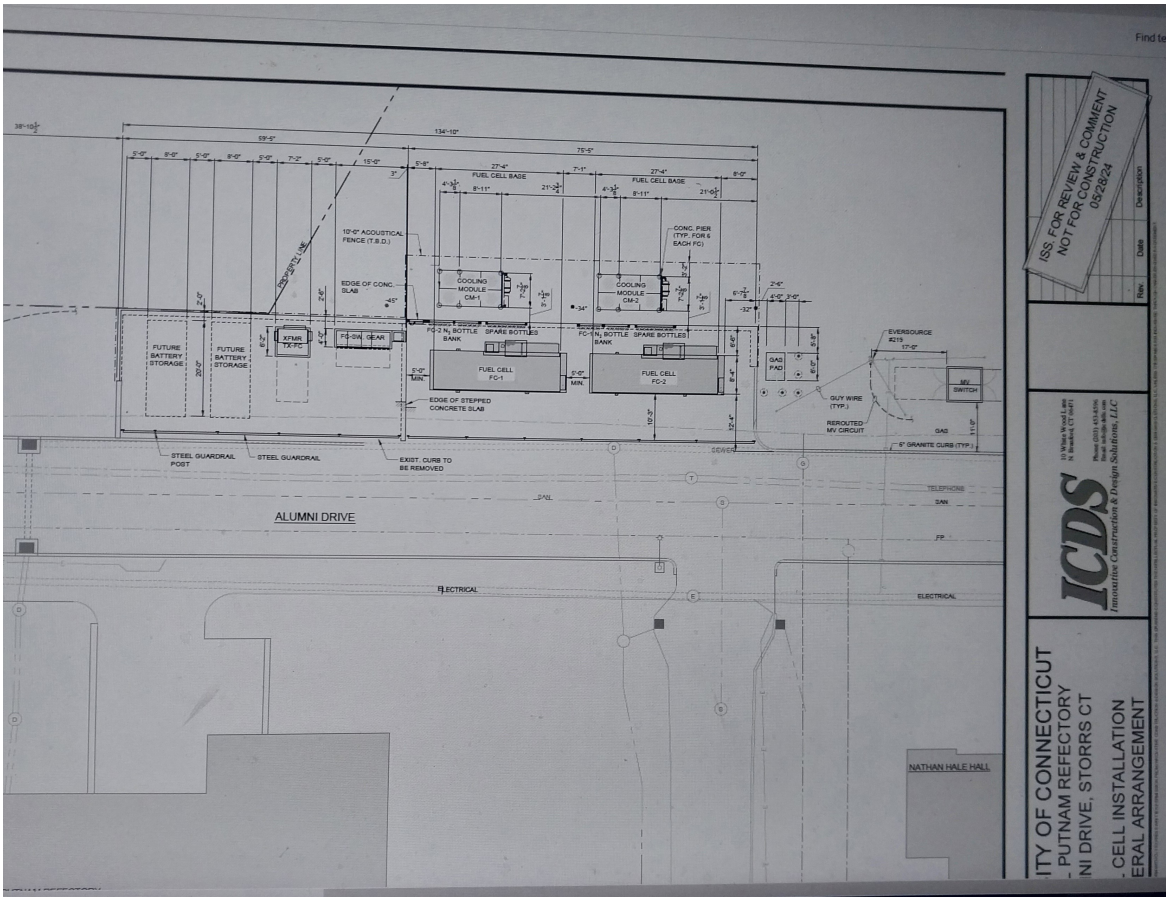


Figure 6. Sample Power Module #2 Calculation for Nathan Hale Hall with 12-foot Barrier

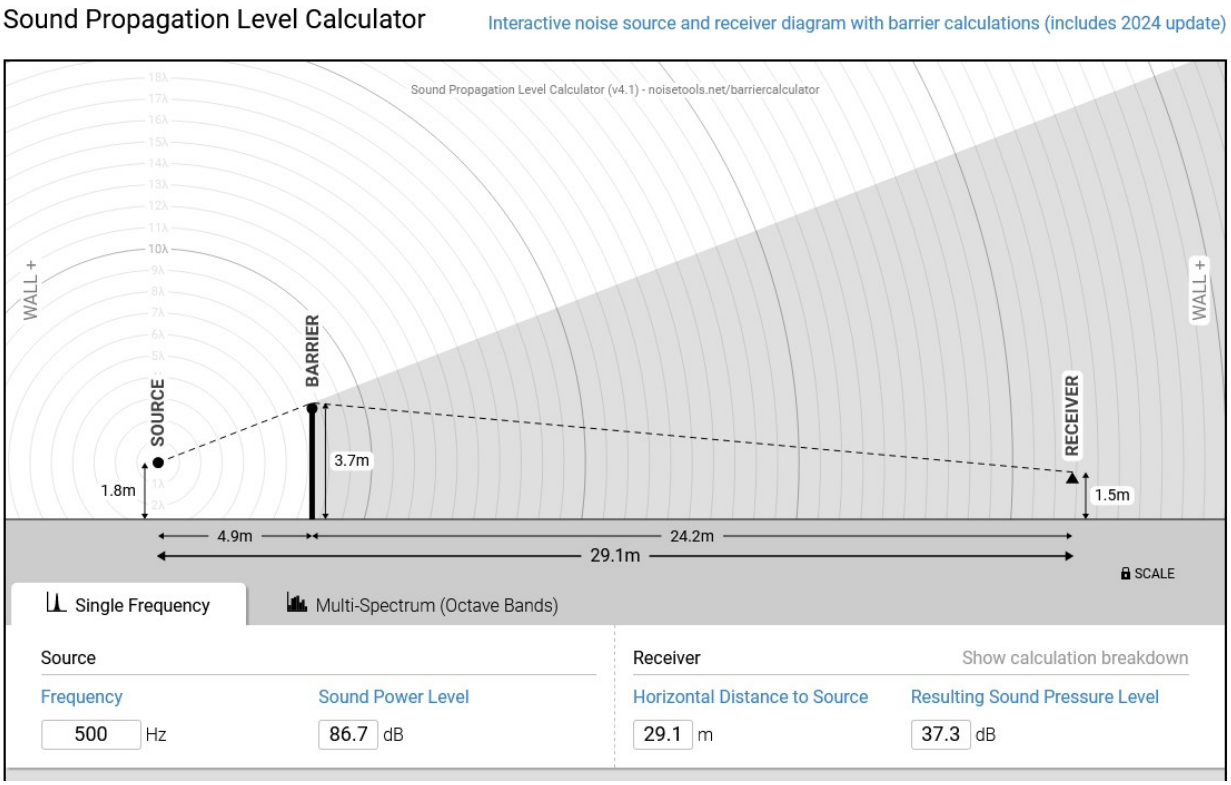


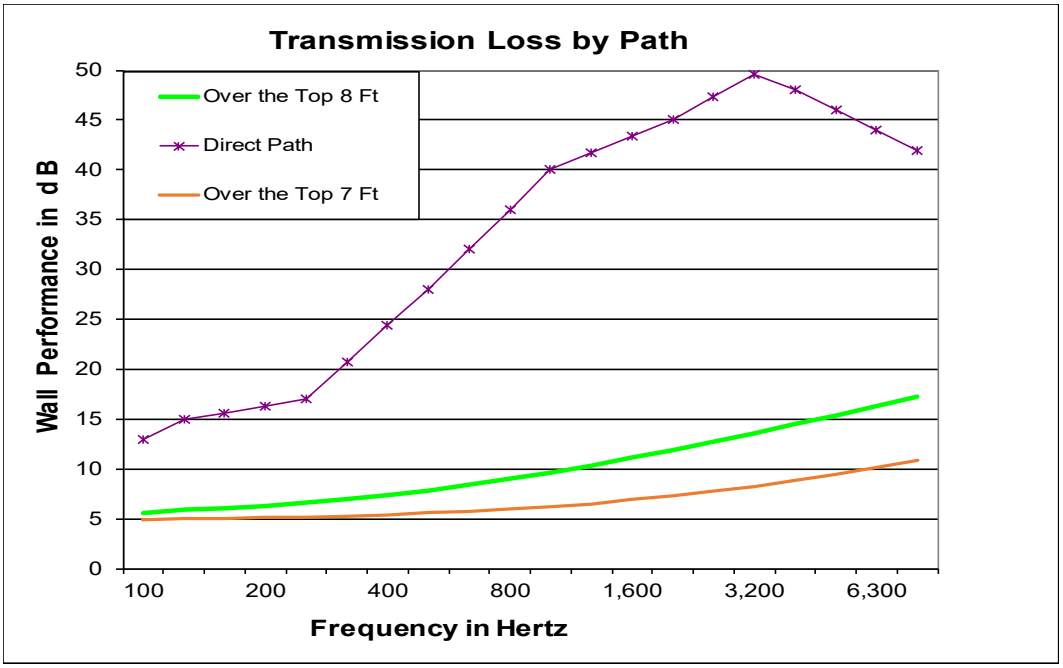
Table 2. Estimates of Fuel Cell Noise for Each Module Versus Fence Height

Barrier Calcs	West	West	West	West	West	East	East	East	East	East
Source Ht = 1.8 m	dBA	dBA	dBA	dBA	dBA	dBA	dBA	dBA	dBA	dBA
CM - 1	50	47.9	46.4	45.2	43.3	40.2	39.1	37.7	36.4	33.9
CM - 2	47.3	45	43.4	42.1	39.8	41.6	40.3	38.9	37.4	34.9
Source Ht = 2.4 m										
PM - 1	45.1	42.9	41.3	40	37.9	38.9	36	34.1	32.5	30
PM - 2	40	38.3	37	35.9	34.1	40.2	37.3	35.4	33.8	31.4
Total Power Sum	**52.9**	**50.8**	**49.2**	**48.0**	**46.0**	**46.4**	**44.5**	**42.9**	**41.5**	**39.0**
Fence Heigh in Feet	10	12	14	16	20	10	12	14	16	20
Sum Meets 45 dBA	28.5	15.7	9.5	5.2	0.2	7.6	0	0	0	0

Materials such as the ABBC-EXT-R Sound Curtains from Acoustical Solutions (Reference 5) or equivalent should be sufficient to produce about 20 dB of sound reduction. One path of noise transmission to consider is the path directly through the barrier. The transmission loss for a one-inch-thick material from Acoustical Solutions called ABBC-EXT-R Sound Curtains[5] is shown in Figure 7. The material has great high frequency performance and the lower frequencies still have 10 dB better performance than the diffraction of sound over the barrier.
An example of the noise treatment installation at Mt Sinai Hospital in Hartford, CT is shown in Figure 8. The ABBC-EXT-R Sound Curtains were hung from two sides of a security fence around the Cooling Module to mitigate the noise at the fuel cell site.

Coverage should extend around all the sides of the Cooling Module and Power Modules. See Figure 9 for a sketch of the recommended approach. The length of the necessary treatment would be about 232 feet and with a height of 12feet giving a surface area of 2784 square feet. (Doosan has purchased this material in the past for the Mount Sinai Hospital site in Hartford, CT.) If a fence of height less than 12-feet is chosen (i.e. 10 feet), there will be a small issue to the west and to Nathan Hale Hall as they both could be up to a couple of dB over the 45 dBA night time noise limit.

Figure 7. The Effect of an Acoustic Barrier on Transmission to Nearby Properties



It should be noted that the current design in Figure 5 shows the fans on the two Power Modules facing west. In this direction the source level for the Power Module is 61 dBA at 10 meters. This level was used in the calculations for Cheney Drive (West). The source level on the opposite side without fans was found to be 2.4 dB lower in testing done at New Britain High School[6]. This level was used for the Power Module calculations for Nathan Hale Hall (East).

Figure 8. Eight Foot Fence Surrounding Doosan Cooling Module with Noise Treatment

Figure 9. Sample of Recommended Noise Treatment Design

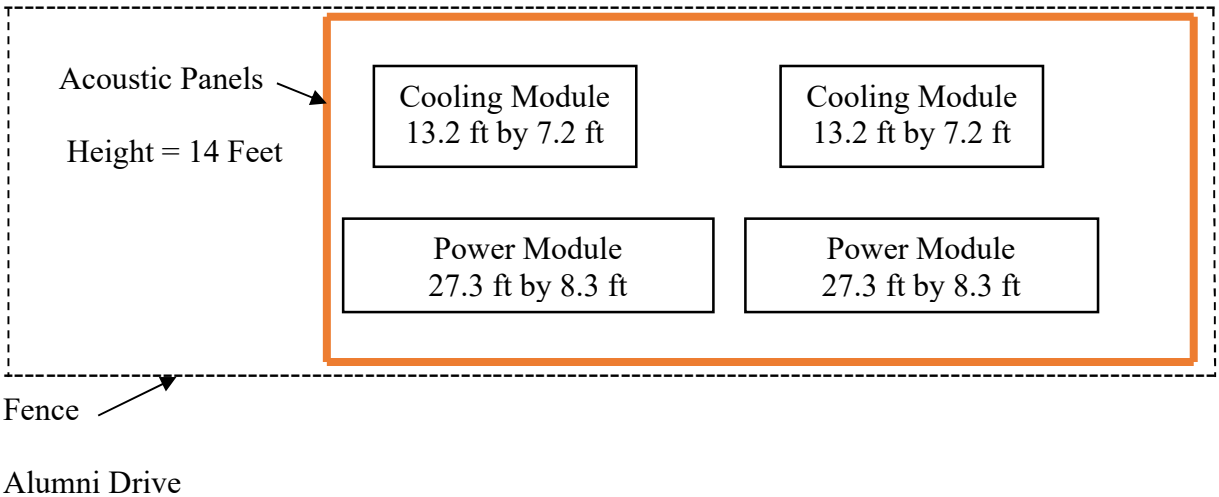


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Figure 10. Photo of the Fan Side of the Power Module in Bridgeport[7]

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Conclusions

The purpose of this effort has been to evaluate the acoustical environment at the UConn site near 2358 Alumni Drive in Storrs, CT. This has been accomplished and the results show that the acoustic impact on the closest property at 83 Cheney Drive needs to be addressed. Operation of the fuel cells is estimated to meet all of the state and town noise requirements with a 12-foot noise barrier. A twelve-foot-high acoustic barrier as described in this report should mitigate this noise issue on both the east and west sides of the fuel cells. A 12-foot-high wall on the Cooling Module side would be effective for Cheney Drive residences in blocking the Cooling and Power Module sound propagating to the west. A 12-foot wall along Alumni Drive is needed to mitigate the noise traveling east to Nathan Hale Hall. These noise control approaches should remove any acoustic concerns about siting and operating the two Doosan 440 KW fuel cells at UConn's Alumni Drive site.

References

1) Israel Putnam Refectory Airborne Noise Assessment, Carl A. Cascio, Acoustical Technologies Inc., April 12, 2024
2) Town of Montville Water Pollution Control Authority Airborne Noise Test

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

3) 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

4) Mount Sinai Rehabilitation Hospital Airborne Noise Assessment, Carl A. Cascio, Acoustical Technologies Inc., January 24, 2017

5) https://acousticalsolutions.com/product/abbc-13-ext-audioseal-exterior-sound-blanket/

6) New Britain High School Fuel Cell Acoustic Assessment, Carl A. Cascio, Acoustical Technologies Inc., August 8, 2018

7) Photo from Cherry Street Lofts Testing in Bridgeport, CT, Carl A. Cascio, Acoustical Technologies Inc., July 7, 2021