

Prepared For: Doosan Fuel Cell America Inc.

Point of Contact: Donald Emanuel

**Prepared by: Acoustical Technologies Inc.
50 Myrock Avenue
Waterford, CT 06385-3008**

**Subject: Carla's Pasta
Airborne Noise Assessment
At 280 Nutmeg Road South**

Author: Carl Cascio

Date: April 20, 2019

Revision: 0

Table of Contents

	Page
Summary	3
Introduction	4
Development of the Acoustic Assessment Plan	4
Acoustic Measurement Program	5
Data Analysis	8
Allowable Noise Levels	12
Impulse Noise	13
Prominent Discrete Tones	14
Infrasonic and Ultrasonic Noise	15
Overall Sound Pressure Levels	16
Conclusions	19
References	19

Summary

This document makes a positive acoustic assessment that should assist in meeting any acoustic noise concerns during the operation of a Doosan 440 KW fuel cell at the Carla's Pasta site at 280 Nutmeg Road South in South Windsor, CT. An acoustic assessment plan was developed and executed to acquire airborne acoustic information useful in explaining and mitigating the potential airborne noise issues associated with operation of the Doosan 440 KW fuel cell. It is important to show that the airborne noise generated by the fuel cell will not significantly impact the facility's neighbors.

The airborne noise levels expected to be generated by the Doosan fuel cell operating at the South Windsor site were simulated by exciting a set of five co-located speakers at the fuel cell Cooling and Power Module positions. (The Cooling Module is the dominant noise source.) The five speakers produced an overall airborne noise level that was about 12 dB higher than the levels measured for a similar Doosan fuel cell installed at Mount Sinai Hospital in Hartford, CT. One-third octave band analysis showed the speakers to be near the Mount Sinai fuel cell airborne noise levels at frequencies up to 250 Hertz where the airborne noise levels were low and to exceed the fuel cell signature by 10 to 20 dB at higher frequencies where the fuel cell signature was higher in noise level. Airborne noise levels with the speakers operating were measured at distances from 5 to 245 meters from the proposed fuel cell location at Carla's Pasta. The speakers produced overall A-weighted sound pressure levels of approximately 86 dBA at 5 meters and 81 dBA at 10 meters (reference 20 microPascals) from the proposed fuel cell Cooling Module location. The airborne noise levels from the speakers at nearby property lines were measured at levels from 40 to 75 dBA. Residential measurement locations to the east were very quiet with levels below 43 dBA with the speakers on. Industrial measurement locations to the south, north and west were high because of the short distance to the speakers along Nutmeg Road. Analysis of the speaker data indicated propagation losses from 4.6 to 41 dB from the fuel cell location to the nearby Industrial property lines. The source level at 10 meters from the operation of a Doosan fuel cell at Mount Sinai Hospital in Hartford, CT was then used as a basis for making the South Windsor fuel cell airborne noise estimates.

Operation of the Doosan fuel cell by itself should produce noise levels below the Industrial Zone noise limit of 70 dBA at all of the nearby Industrial property lines. The highest expected airborne noise level of 64 dBA will be at the 284 - 298 Nutmeg Road vacant lot due west about 22 meters from the fuel cell Cooling Module. The other Industrial properties should see levels no higher than 58 dBA. All of the nearby residential property lines are expected to be below both the day time and night time residential noise limits with expected airborne noise below 30 dBA with the fuel cell on. An eight-foot high acoustic barrier isolating the Cooling Module on the west and north sides of the fuel cell location is recommended to eliminate the possibility of a noise issue with the two closest neighbors to 280 Nutmeg Road. With this noise barrier in place there should be no acoustic issues present during operation of the Doosan 440 KW fuel cell.

The Connecticut's Noise Code (Reference 1) also calls for review of acoustic issues associated with impulse noise, prominent discrete tones, infrasonic and ultrasonic noise. Operation of the fuel cell is expected to meet all of these requirements at all of the nearby property lines.

Introduction

Acoustical Technologies Inc. was tasked as part of a Doosan site permitting process with an assessment of potential acoustic issues associated with fuel cell airborne noise reaching the properties adjacent to the Carla's Pasta site at 280 Nutmeg Road in South Windsor, CT. Responding to a request from Donald Emanuel, a site visit was made on April 14, 2019. During the visit, a survey of the airborne noise levels produced by a set of speakers simulating the airborne noise produced by a Doosan Fuel Cell 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 speakers off. This document provides an acoustic assessment to assist in meeting acoustic noise concerns during the permitting process for the siting of a Doosan fuel cell at 280 Nutmeg Road in South Windsor, CT.

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 a Doosan 440 KW fuel cell at the Carla's Pasta site in South Windsor, CT. The South Windsor site at 280 Nutmeg Road is located in an Industrial Zone near Governor's Highway. This industrial zone is surrounded by residential zones to the northeast and east, a Multi-Family zone to the south and a residential zone to the west. (The South Windsor zoning map is given below.) It is important to determine whether the airborne noise generated by the Doosan fuel cell will impact these neighbors.

The acoustic impact is assessed in the following way. The fuel cell is yet to be installed so there is no way to measure fuel cell operating airborne noise levels at the new site. The fuel cell airborne noise has been measured at other sites and both overall and one-third octave band airborne noise data of a typical Doosan 400 KW fuel cell are available (Reference 2). Using this data, a set of five speakers have been programmed through a set of octave and one-third octave band filters to generate a noise spectrum similar to that of the new fuel cell. (It is assumed that the Cooling and Power Module noise in the existing measured units 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 five speakers. In order to overcome the potentially high background noise at the site the speaker output will be increased to a level more than 10 dB higher than the overall dBA noise level measured on a fuel cell at a distance of 10 meters. With the speakers on, this approach then follows the traditional "What is the airborne noise level at the neighbor's property line?". The five speakers were run and airborne measurements made near the proposed fuel cell locations and at several of the nearest neighbor's property lines. This measured site data can also be used to estimate noise levels at other neighbor's property lines. The Town of South Windsor has a Noise Ordinance (Reference 3) with similar requirements to the State of Connecticut's Noise Code and both have been consulted to assess the impact of the measured and estimated acoustic levels. Because of the closeness of the Carla's Pasta fuel cell site to the nearest property lines noise mitigation may be recommended if the airborne noise estimated for the fuel cell comes near or exceeds the noise requirements at the neighbors' property lines.

Acoustic Measurement Program

The acoustic data necessary to assess the impact of the 440 KW Doosan Fuel Cell are described below: Airborne sound pressure measurements and audio tape recordings were conducted at the South Windsor site on and near 280 Nutmeg Road on April 14, 2019 during the daylight hours. This testing established both background airborne noise levels and simulated airborne noise levels with the speakers 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. For reference, a noise level increase of 1 dB is equal to an airborne sound pressure increase of 12.2 per cent. The 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 130C10 s/n 10638 and 130C10 s/n 10641) were powered by two Wilcoxon P702B power supply/amplifiers (s/n 1992 and 1995 respectively). The PCB microphones were also calibrated prior to and after the test with the Quest model QC-10 Calibrator (s/n Q19080194). All measurements were made with the microphones at a height above ground between five and six feet. A Hewlett Packard model HP3561A Dynamic Signal Analyzer, s/n 2338A00659, was used to perform A-weighted spectral analysis on the tape-recorded data. The tape-recorded data were also used to verify the ExTech sound level meter overall dBA readings.

At the South Windsor site “speaker on” and background airborne noise measurements were taken at the following thirteen nearby property lines in the Industrial and Residential Zones:

Location	Business	Distance	Zone	Type
P1 - 280 Nutmeg Road South	Carla's Pasta	5 meters		Industrial
P2 - 280 Nutmeg Road South	Carla's Pasta	10 meters		Industrial
P3 – 282-298 Nutmeg Road South	Empty Lot	19 meters		Industrial
P4 - 274 Nutmeg Road South	Total Fitness	53 meters		Industrial
P5 – 250 Nutmeg Road South	Hexcel	224 meters		Industrial
P6 – 255 Nutmeg Road South	Skillcraft	132 meters		Industrial
P7 - 279 Nutmeg Road South	RMC Engineering	127 meters		Industrial
P8- 283 Nutmeg Road South	Macys	126 meters		Industrial
P9 – 345 Nutmeg Road South	NDT Technologies	220 meters		Industrial
P10 – 330 Nutmeg Road South	Commercial Heating	144 meters		Industrial
P11 - 310 Nutmeg Road South	Office C-9	46 meters		Industrial
P12 - 310 Nutmeg Road South	Office C-8	65 meters		Industrial
P13- 310 Nutmeg Road South	CT Tints	59 meters		Industrial
P14 – 30 Talbot Lane	Harris Rebar	169 meters		Industrial
P15 – 134 Edgewood Drive	Open Space	243 meters	A-20	Residential

See the Google satellite map in Figure 1 for the approximate measurement locations. Measurements near the proposed operating Power and Cooling Module sites at positions 1 and 2 were simultaneously taken with the ExTech sound level meter and two microphones recording on the digital tape recorder. Figures 2 and 3 provide photographs of the site locations for the

Acoustical Technologies Inc.

Cooling and Power modules, respectively. Site A represents the Cooling Module that is further from Nutmeg Road than the power module. Site B represents the Power Module that is closer to Nutmeg Road. At locations A and B, a one-minute record of the acoustic noise was stored for the speakers in the “on” condition at the start and at the end of the airborne noise measurements. There is a slight decrease (about 0.5 dB) in sound output from the speakers as they warm up. One minute of background airborne noise data were also recorded at the two speaker positions.

Figure 1. South Windsor Carla’s Pasta Site Map from Google Maps



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 South Windsor for the acoustic measurements on April 14, 2019. Measurements were taken over the period from 9:30 am until 1:54 pm. The table below shows the temperature and wind speeds in hourly intervals. Wind conditions were very good early but appear to have doubled in speed for the last two hours of testing. This increase in wind speed was not noticed during the testing and did not affect the operating and background airborne noise measurements. This was

Acoustical Technologies Inc.

probably due to the local blockage of the wind by the nearby buildings. Also, there was no rain during the testing on April 14. The refrigeration systems in the buildings at Carla's Pasta generated most of the background noise raising the background levels near the Carla's Pasta buildings. The other businesses were quiet. Motor traffic along the nearby roads was very light and very few of the measurements had to be delayed until no traffic was present. Background noise levels at all of the measurement positions were acceptable with levels from 42 to 53 dBA.

Figure 2. Doosan Cooling Module Location at the South Windsor Carla's Pasta Site



Figure 3. Doosan Power Module Location at the South Windsor Carla's Pasta Site



Table 1. South Windsor Weather Data on April 14, 2019

[www.wunderground.com/weather/us/ct/south windsor](http://www.wunderground.com/weather/us/ct/south-windsor) - History

Time (EST)	Temp. (°F)	Humidity (%)	Dew Point (°F)	Barometer (in HG)	Wind Speed (mph)	Wind Direction	Condition
7:51 AM	66 F	48%	46 F	29.7 in	6 mph	ENE	Mostly Cloudy
8:51 AM	70 F	41%	45 F	29.7 in	5 mph	SE	Mostly Cloudy
9:51 AM	73 F	39%	47 F	29.7 in	0 mph		Cloudy
10:51 AM	76 F	43%	52 F	29.6 in	8 mph	SSE	Cloudy
11:51 AM	73 F	55%	56 F	29.6 in	17 mph	S	Cloudy
12:51 PM	71 F	61%	57 F	29.6 in	15 mph	S	Cloudy
1:27 PM	70 F	68%	59 F	29.6 in	14 mph	S	Cloudy
1:51 PM	68 F	73%	59 F	29.6 in	12 mph	S	Cloudy
2:34 PM	65 F	87%	61 F	29.5 in	9 mph	S	Light Drizzle
2:51 PM	64 F	90%	61 F	29.5 in	13 mph	SSE	Cloudy
3:29 PM	64 F	87%	60 F	29.5 in	10 mph	S	Cloudy

Data Analysis

This section analyzes the airborne noise levels measured at the South Windsor site and then estimates the source level and transmission loss to nearby property lines expected during actual fuel cell operation. These estimated levels will be compared to the noise limits in the South Windsor and Connecticut noise ordinances. Both background noise levels at the South Windsor site and the measured speaker operating noise levels are reported in Table 2. The background data is used to correct the speaker levels providing estimates of only the speaker noise contribution at each location. Table 3 then reports estimated fuel cell equipment operating noise levels. Comparing these South Windsor fuel cell estimated levels with the town and state noise limits will identify which nearby locations do or do not meet the airborne noise requirements.

The complete set of overall A-weighted airborne noise levels that were measured in South Windsor are provided in Table 2 for the conditions with the speakers on and off. Figure 4 is a map showing the South Windsor zoning districts in the Carla's Pasta area. The position locations were calculated using the Pocket Ranger GPS App from the CT State Parks & Forests. The indicated GPS accuracy varied from 3 to 10 meters. The GPS range from the speakers to the

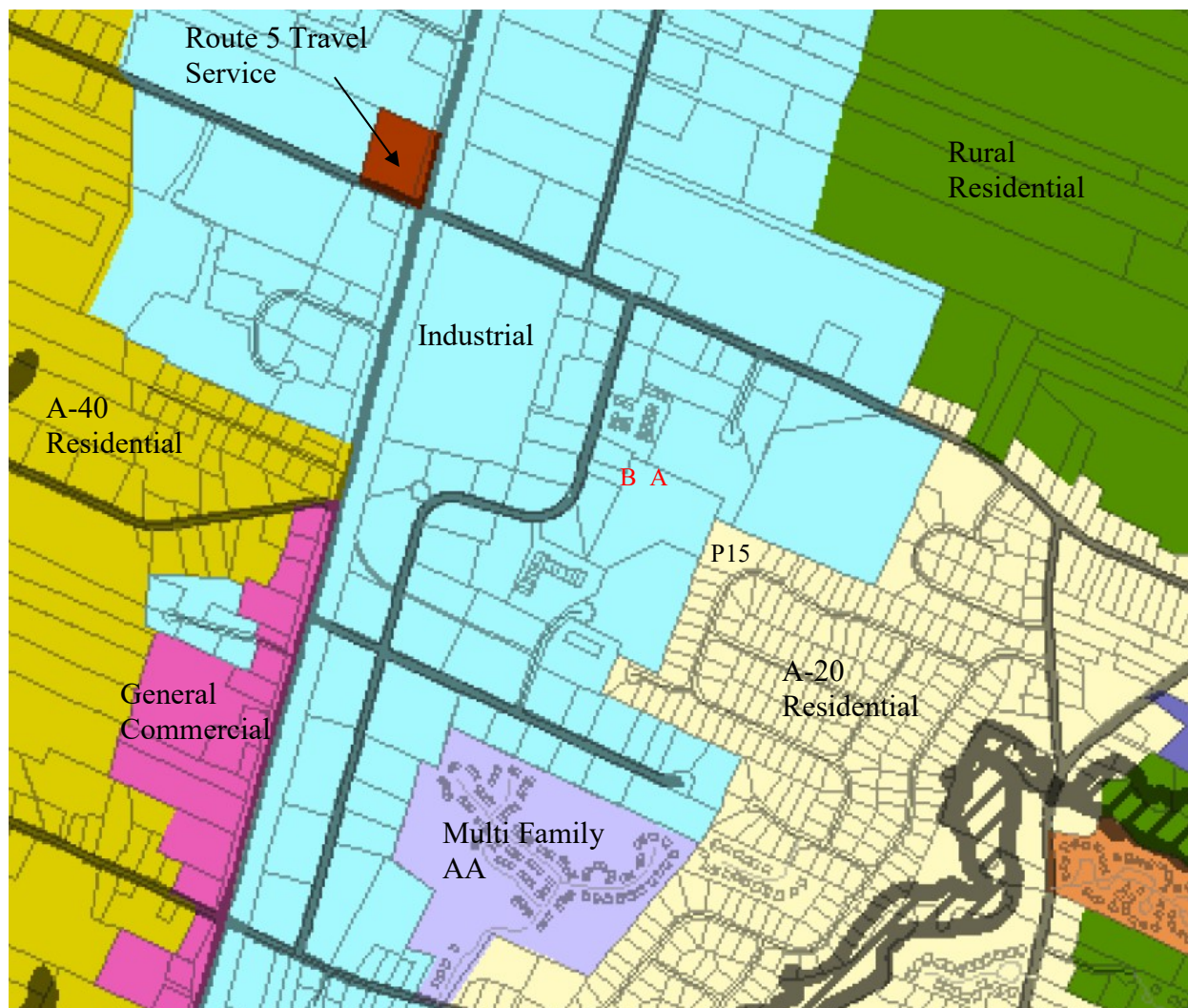
microphone locations that are shown in Table 2 were calculated with an application found at <https://gps-coordinates.org/distance-between-coordinates.php> and then checked with Google Maps. The estimates of the range in meters to each location are given in Table 2 and also in Table 3. The first value is the range to the center of the Cooling Module site A location and the second value is the range to the center of the Power Module at site B. The closest measurement location for both modules is P3, which is about 19 / 22 meters west to the vacant lot abutting the Carla's Pasta property at 280 Nutmeg Road. The next closest measurement location is P11, which is about 46 / 48 meters north to the neighboring office center at 310 Nutmeg Road. Neighboring industrial properties along Nutmeg Road are 50 to 224 meters away. P15, the closest residential property is 243 meters away on Edgewood Drive. Airborne noise at the residential locations could not be heard when the speakers were operating at Site A. Since the residential noise levels were below 43 dBA and Site B was at a slightly larger distance from the residences, it was not necessary to repeat the speaker measurements operating at Site B.

Table 2. Overall Sound Pressure Levels in dBA ref. 20 microPascals measured at Carla's Pasta

Location	Range in Meters	Speakers Cooling	Background	Bkgd Corrected	Speakers Fuel	Background	Bkgd Corrected
P1 at 5 m	5	86.4	68.9	86.3	88.6	64.1	88.6
P2 at 10 m	10	80.8	63.9	80.7	79.9	64.2	79.9
P3 – 282-298 Nutmeg Road	22/19	-	-	74.3 (estimate)	75.3	51.5	75.3
P4 - 274 Nutmeg Road	53/50	65.8	50.8	65.7	58.0	49.3	57.4
P5 – 250 Nutmeg Road	224/221	51.8	46.8	46.8	48.0	47.3	40.0
P6 – 255 Nutmeg Road	132/128	49.3	45.7	46.8	44.3	42.8	39.0
P7 - 279 Nutmeg Road	127/123	52.3	46.3	51.1	47.8	46.3	42.5
P8- 283 Nutmeg Road	126/128	50.8	44.8	49.6	49.8	43.3	48.4
P9 – 345 Nutmeg Road	220/222	43.8	43.4	<40	40.7	41.8	<40
P10 – 330 Nutmeg Road	144/146	47.4	47.5	<40	48.3	44.1	46.2
P11 - 310 C9 Nutmeg Road	46/48	63.8	50.8	63.6	69.9	51.6	69.8
P12 - 310 C8 Nutmeg Road	65/67	61.3	53.5	60.6	67.3	51.8	67.2
P13- 310 CT Nutmeg Road	59/61	62.3	53.1	61.8	60.8	50.0	60.4
P14 – 30 Talbot Lane	169/172	51.5	49.8	46.7	49.4	48.3	46.5
P15 – 134 Edgewood D.	243/245	42.3	42.3	<40	-	-	<40

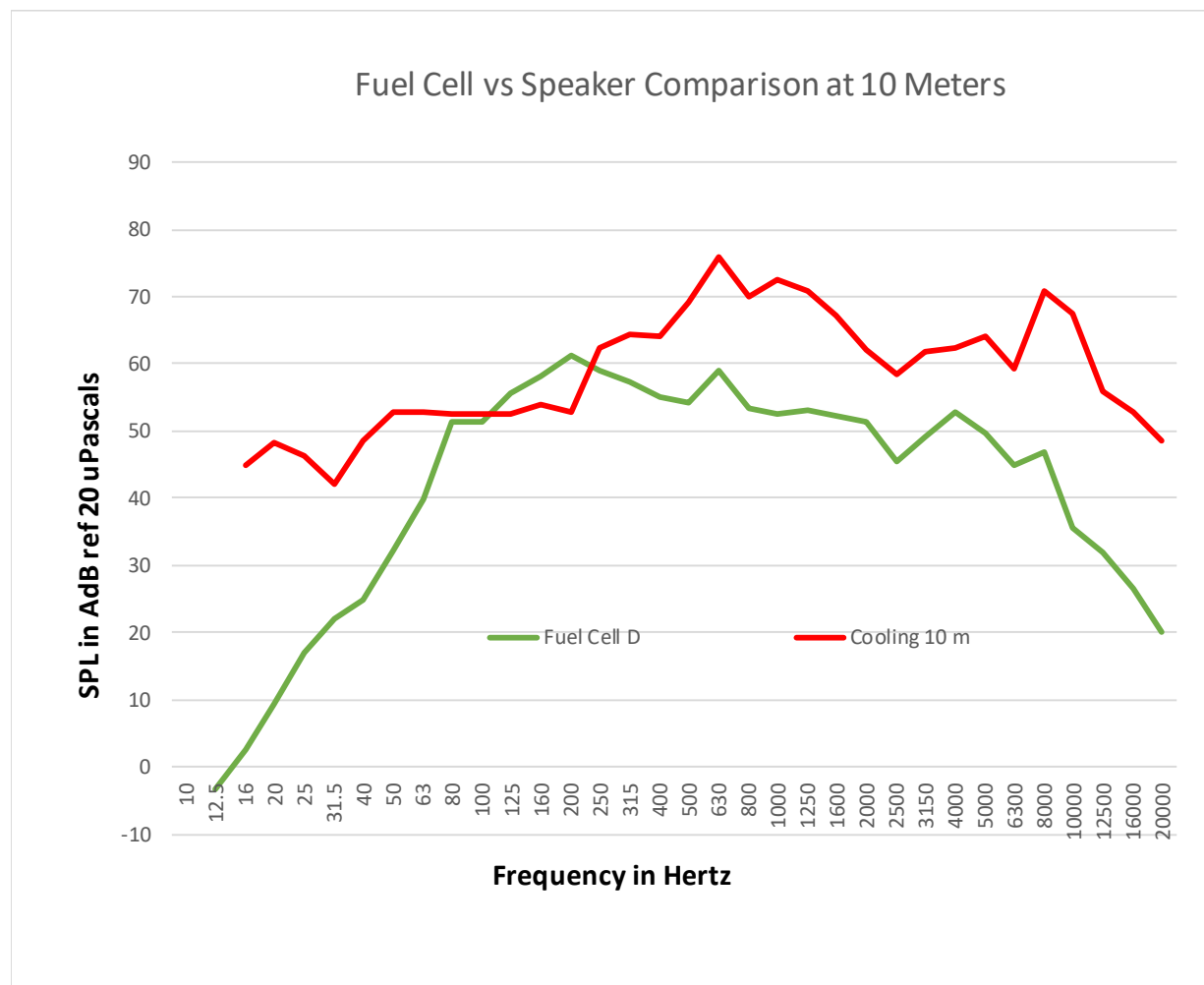
Acoustical Technologies Inc.

Figure 4. South Windsor Zoning Map Showing Speaker Location at Positions A & B



A comparison of the airborne noise produced at 10 meters by the Doosan fuel cell on the Mount Sinai Hospital site with the airborne noise produced by the speakers at the South Windsor site is shown in Figure 5. The speakers roughly match the fuel cell airborne noise for frequencies below 250 Hertz and greatly exceed the fuel cell airborne noise at higher frequencies where the fuel cell airborne noise levels are the highest. The overall airborne noise levels are 12.7 dB and 11.5 dB higher for the speakers at Site A and Site B locations, respectively, as compared to what is expected from the Doosan 400 KW fuel cell that was measured at Mount Sinai Hospital in Hartford, CT. The 12.7 and 11.5 dB differences in level were subtracted from the South Windsor measured levels to estimate the expected fuel cell' acoustic signature at each location. These calculations are displayed in Table 3 below. The 10-meter Mount Sinai airborne noise levels were used with the South Windsor transmission loss data to estimate the expected fuel cell airborne noise for nearby neighbors at the Carla's Pasta property lines.

Figure 5. The Five Speakers Generate Airborne Noise Above That of a Single Fuel Cell



The estimated airborne noise levels to be produced by the Doosan fuel cell are shown in Table 3. For each of the thirteen locations the South Windsor measurements are corrected to account for the higher speaker levels. The fuel cell noise correction at the Site A Cooling Module location is estimated to be 12.7 dB because the speaker levels are that much higher than the Mount Sinai fuel cell levels. The speakers at the Site B Cooling Module were estimated to be 11.5 dB higher. (These estimates are based on the overall dBA readings for the two sets of measurements. If individual one-third octave band values were calculated and then averaged over the frequencies of interest, the result would be numbers about 1 dB larger. The more conservative overall noise level values were used in this report to scale the speaker data.)

The measurements at Carla's Pasta were taken at various distances from the speakers and then background corrected. Close to the speakers at 280 Nutmeg Road the maximum airborne noise values are expected to be approximately 64 dBA, slightly below the Industrial noise limit. The other Industrial properties are expected to be below 58 dBA depending on how close the locations are to the fuel cell. The residential properties are all expected to have airborne noise levels due to the fuel cell that are below 30 dBA.

Table 3. Estimated South Windsor Overall Sound Pressure Levels in dBA ref. 20 microPascals

Location	Range in Meters	Speakers at Cooling	Correction	Cooling Estimated SPL in dBA	Speakers at Fuel	Correction	Power Mod. Estimated SPL in dBA
P3 – 282-298 Nutmeg Road	22/19	74.3 (estimate)	-12.7	61.6	75.3	-11.5	63.8
P4 - 274 Nutmeg Road	53/50	65.7	-12.7	53	57.4	-11.5	45.9
P5 – 250 Nutmeg Road	224/221	46.8	-12.7	34.1	40.0	-11.5	28.5
P6 – 255 Nutmeg Road	132/128	46.8	-12.7	34.1	39.0	-11.5	27.5
P7 - 279 Nutmeg Road	127/123	51.1	-12.7	38.4	42.5	-11.5	31
P8- 283 Nutmeg Road	126/128	49.6	-12.7	36.9	48.4	-11.5	36.9
P9 – 345 Nutmeg Road	220/222	<40	-12.7	<28	<40	-11.5	<29
P10 – 330 Nutmeg Road	144/146	<40	-12.7	<28	46.2	-11.5	34.7
P11 - 310 C9 Nutmeg Road	46/48	63.6	-12.7	50.9	69.8	-11.5	58.3
P12 - 310 C8 Nutmeg Road	65/67	60.6	-12.7	47.9	67.2	-11.5	55.7
P13- 310 CT Nutmeg Road	59/61	61.8	-12.7	49.1	60.4	-11.5	48.9
P14 – 30 Talbot Lane	169/172	46.7	-12.7	34	46.5	-11.5	35
P15 – 134 Edgewood D.	243/245	<40	-12.7	<28	<40	-11.5	<29

Red indicates locations above the Industrial airborne noise limit of 70 dBA – there are none

Allowable Noise Levels

The Connecticut regulation for the control of noise provides in *CT section 22a-69-3* (Ref. 1) the requirements for noise emission in Connecticut. *CT 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 Town of South Windsor has a noise ordinance (Ref. 3) with the same decibel noise limits as the CT Code. These two ordinances will be used to evaluate the noise generated by the Doosan Fuel Cell. Following sections discuss each type of noise using the results obtained from the Mount Sinai fuel cell measurements and the recent airborne noise measurements at the South Windsor site.

Acoustical Technologies Inc.

The southern part of the South Windsor zoning map is given in Figure 4. As stated above, the South Windsor site at 280 Nutmeg Road is located in an Industrial Zone. This site is adjacent to a Rural Residential Zone to the northeast, an A-20 Residential Zone to the east and a Multi-Family AA Residential Zone to the south, respectively. The closest home is 243 meters away at 134 Edgewood Road in an A-20 Residential Zone. The Mount Sinai Hospital report (Ref. 2) showed that its fuel cell's airborne noise was estimated to be below the 45 dBA Hartford residential noise limit at about 75 meters from the fuel cell. Using the South Windsor speaker measurements, the airborne noise level expected at the 134 Edgewood Road property line (at a distance of 243 meters) should be about 30 dBA. Other nearby residential properties at greater distances are also expected to be well below the night time residential noise limit of 51 dBA for an emitter in an industrial zone.

Impulse Noise

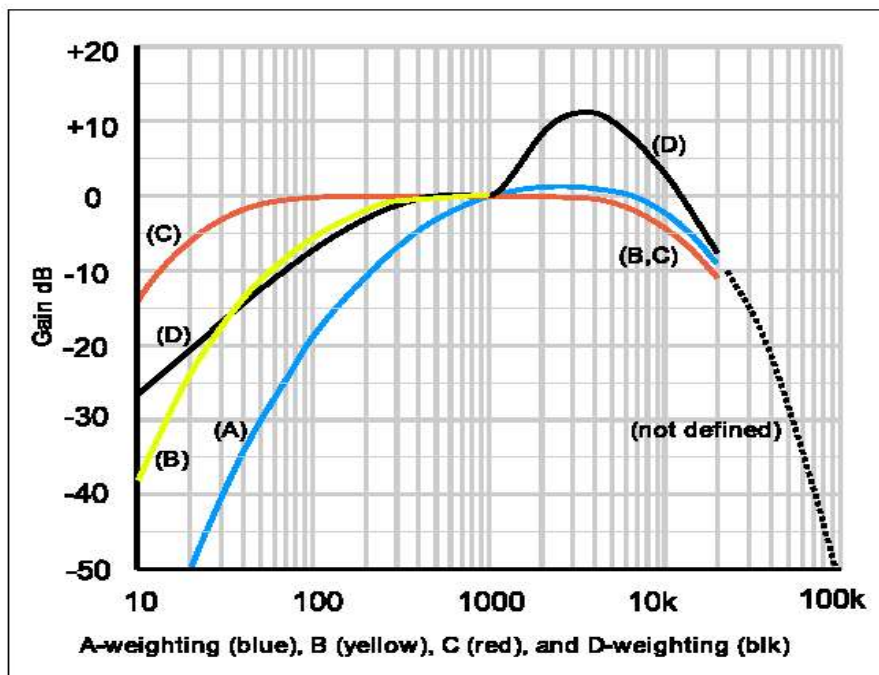
The Connecticut noise code states in *CT section 22a-69-3.2 (part a) Impulse Noise* that no person shall cause or allow the emission of impulse noise in excess of 80 dB peak sound pressure level during the night time to any class A Noise Zone. South Windsor has a similar subsection with Class A Noise Zones as residential. Night time hours are defined as 10 pm to 7 am in both the CT and South Windsor ordinances except for Sunday in South Windsor. Nighttime there extends to 9 am on Sunday morning. *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. South Windsor has a similar impulse noise requirement.

Impulse noise in excess of 80 dB was not observed on the tape-recorded data during any of the measurements of the Doosan 400 KW fuel cell made at the Mount Sinai Rehabilitation Hospital on 18 January, 2017. This fuel cell design is similar to the unit that will be installed in South Windsor. Given the steady state nature of the fuel cell's noise signature there should be no acoustic issues with the State of Connecticut's and South Windsor's impulse noise requirements.

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 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.

Figure 6. Acoustic Airborne Noise Weighting Curves

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



1 of 1

1/25/2013 9:35 PM

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. South Windsor's ordinance does not discuss *Prominent discrete tones*. The CT Regulations establish different noise limits for different land use zones. Residential (homes and condominiums) and hotel uses are in Class A. Schools, parks, recreational activities and services are in Class B. Forestry and related services are in Class C. By my reading of the regulations Carla's Pasta is a Class C emitter in an Industrial Zone. The noise zone standards in *CT section 22a-69-3.5* state that a Class C emitter cannot exceed the following overall sound pressure levels:

To Class C 70 dBA To Class B 66 dBA To Class A 61 dBA (day) 51 dBA (night)

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

To Class C 65 dBA To Class B 61 dBA To Class A 56 dBA (day) 46 dBA (night)

Acoustical Technologies Inc.

To address the discrete tone issue we use measured data from the January 18 testing of a similar Doosan fuel cell. This data does not have A-weighting. The photo in Figure 7 plots the airborne noise measured 10 meters from the Mount Sinai Cooling Module (Ref. 2) for frequencies from 0 to 1000 Hertz. This curve shows the two largest discrete tones produced by the Doosan Fuel Cell Cooling Module. The first tone is at 86 Hertz at a level of 65 dB reference 20 microPascals. The second tone is at 630 Hertz at a level of 56 dB reference 20 microPascals. (88.6 dB added to the dBV values in the figure.) The A-weighting corrections are -21.5 dB at 86 Hertz and -1.9 dB at 630 Hertz. Incorporating these corrections gives A-weighted levels of 44 dBA at 86 Hertz and 54 dBA at 630 Hertz (for the fuel cell) both at a distance 10 meters from the Cooling Module. The minimum transmission loss to the residential property lines on Edgewood Avenue is at least 40 dB so the maximum possible discrete tone would be about 14 dBA at the nearest residential property line. This level is well below the 46 dBA night time requirement in a Residential Zone. The minimum transmission loss to the Industrial property lines next to the Carla's Pasta site is at least 4.6 dB so the maximum possible discrete tone would be 49.4 dBA at the 282 - 298 Nutmeg Road property line. This level is well below the 65 dBA requirement in an Industrial Zone. Operating the Doosan fuel cell should produce airborne noise levels well below the CT discrete tone requirement at all the property lines. There should be no acoustic issue with the CT discrete tone noise requirements.

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. South Windsor's ordinance does not discuss Infrasonic or Ultrasonic Noise.

Narrow bandwidth sound pressure spectrums in dB reference 20 microPascals at the 10-meter Cooling Module location given in Reference 2 can be used to compare with these Infrasonic and Ultrasonic noise requirements. Mount Sinai Hospital airborne noise data were processed in the 0 to 100 Hertz and 0 to 100,000 Hertz frequency ranges. The bandwidth of each data point is 0.375 Hertz for the 100 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. The maximum level at 10 meters is 57 dB reference 20 microPascals for one fuel cell. The entire 20 Hertz band can be power summed and equals 66 dB reference 20 microPascals, well below the requirement at 10 meters. The minimum transmission loss to the nearest property line is at least 4.6 dB so the maximum possible infrasonic noise would be 61.4 dBA at the 282 - 298 Nutmeg Road property.

The ultrasonic noise for frequencies up to 100 KiloHertz is given in Figure 9. The maximum level at 10 meters is 20 dB reference 20 microPascals for one fuel cell. The entire 80 KiloHertz band from 20 to 100 kiloHertz has been power summed and equals a noise level value of 31 dB ref. 20 microPascals. Both of the infrasonic and ultrasonic noise levels will fall well below the 100 dB limit at a distance 10 meters from the Cooling Module. The ultrasonic airborne noise at all the Industrial property lines will be at least 4.6 dB lower. The noise levels at the residential

Acoustical Technologies Inc.

neighbors will be much lower based on the analysis in the previous section and there should be no issue with either infrasonic or ultrasonic noise at any of the neighboring properties.

Figure 7. Discrete Tones Produced by Fuel Cell Cooling Module (0 dBV = 88.6 dB re20μPa)



It should be noted that while the spectrum analysis covers frequencies up to 100 kiloHertz, the microphone sensors lose some sensitivity above 25 kiloHertz. There is a gradual roll off that reduces the amplitudes measured at higher frequencies. Fortunately, the measured noise levels are very low at 20 kiloHertz and decrease with higher frequencies and thus, no ultrasonic acoustic issues are expected above 25 kiloHertz.

Overall Sound Pressure Levels

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

<i>Class Emitter to</i>	<i>C 70 dBA</i>	<i>B 66 dBA</i>	<i>A/day 61 dBA</i>	<i>A/night 51 dBA</i>
-------------------------	-----------------	-----------------	---------------------	-----------------------

Carla's Pasta is in an Industrial Zone that is surrounded by residential zones to the northeast, east, south and west. Residential zones to the northeast, west and south are too far away (greater than 560 meters) to be affected by noise from the Carla's Pasta site. The nearby neighbors are classified as either residential or industrial with residential noise limits of 61 dBA during the day and 51 dBA at night. The airborne noise limit at the Industrial locations is 70 dBA. The airborne noise limit at the Commercial locations is 66 dBA but these locations are also too far away to be affected (the closest distance is greater than 630 meters).

Acoustical Technologies Inc.

Figure 8. Infrasonic Noise from the Fuel Cell Cooling Module (0 dBV = 88.6 dB re 20 μ Pa)

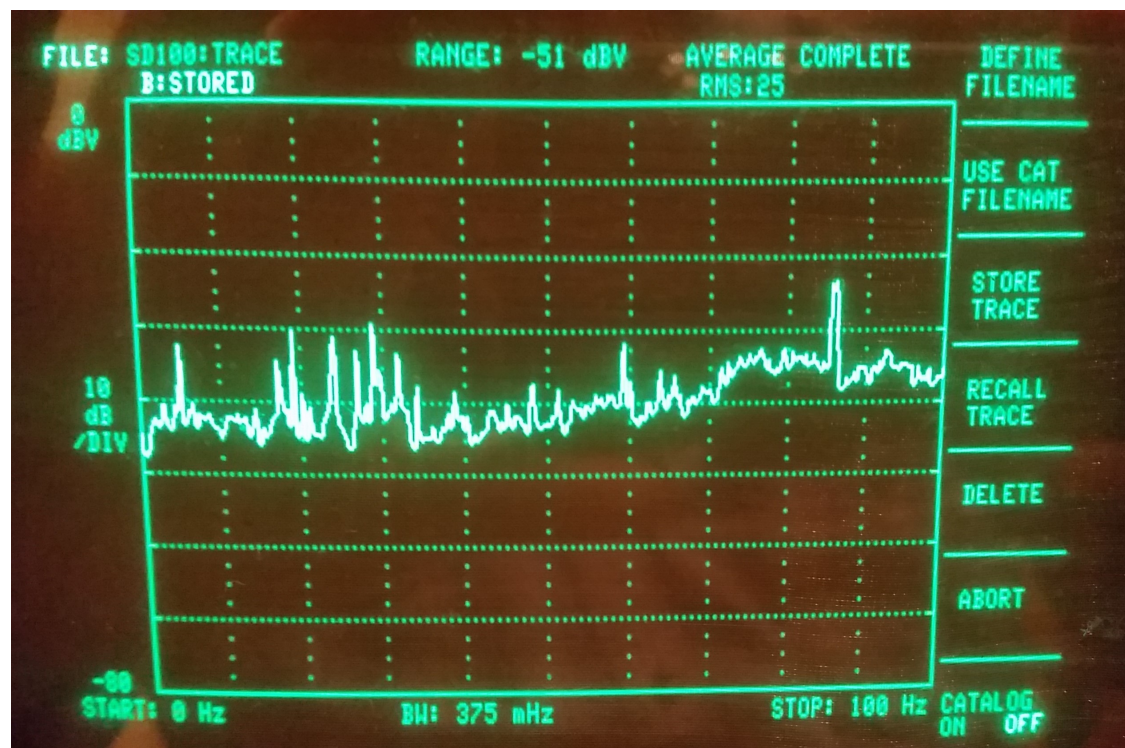
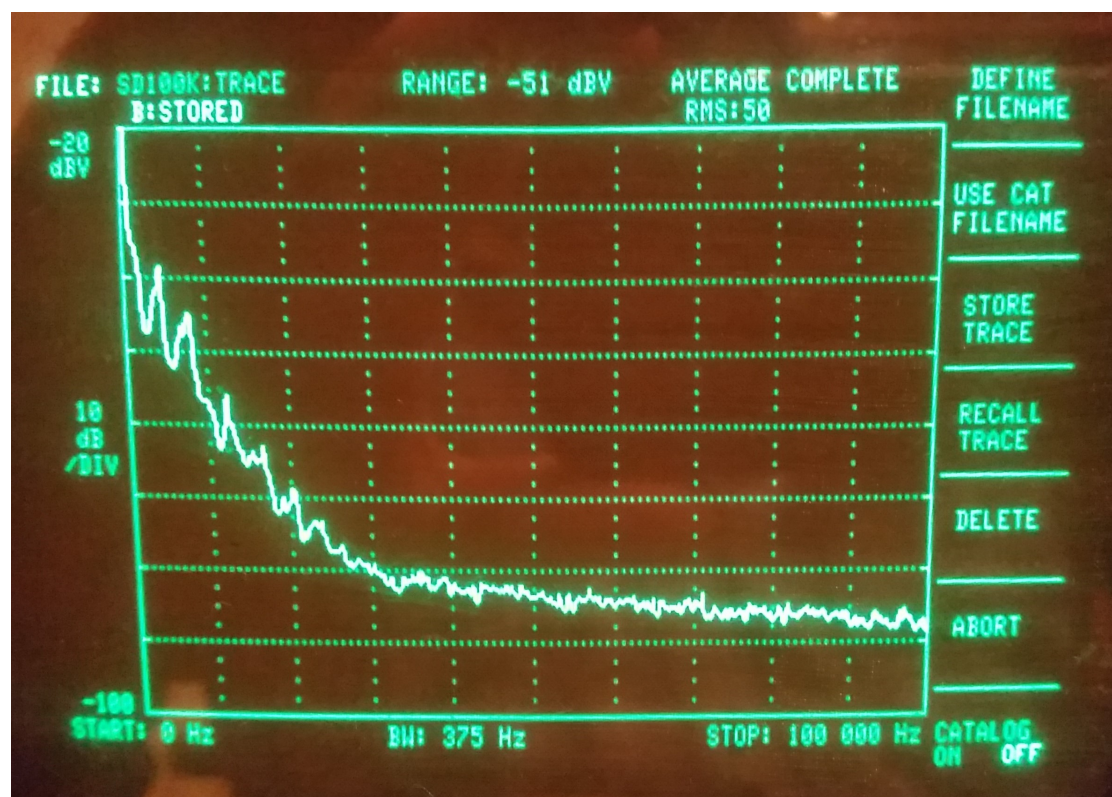


Figure 9. Ultrasonic Noise from the Fuel Cell Cooling Module (0 dBV = 88.6 dB re 20 μ Pa)



Acoustical Technologies Inc.

The estimated overall A-weighted sound pressure level measurements in dBA reference 20 microPascals are given in Table 3 above for the background corrected measurements made on April 14. The second column gives the approximate distance from the speakers to the measurement location, with locations identified by a P number in Figure 1. The first number is the approximate distance to the speaker at the site A Cooling Module position while the second number is the approximate distance to the site B Power Module position. Column 3 gives the noise levels measured with the speakers “on” at the site A Cooling Module while column 6 gives the noise levels measured with the speakers “on” at site B. Background levels before the speakers were turned on can be found in Table 2. Background corrections were applied in creating the values in Table 3. The background corrected speaker noise at 5 and 10 meters is also given in Table 2. The airborne noise values in Table 3 with the background noise removed are then corrected to estimate the contribution provided by the new fuel cell at both Cooling and Power Module locations. Column 5 has the site A Cooling Module estimates while column 8 has the site B Power Module estimates. Values shown in red would be above the industrial or residential night time noise requirements. All the estimated values are below the requirements.

Reviewing Table 2 and Table 4 below, it is clear that the airborne noise levels drop significantly in propagating to the nearby properties as the range increases. The highest property line background corrected speaker level was measured at 75 dBA at 282-298 Nutmeg Road, the property right adjacent to the speakers. The 282-298 Nutmeg Road property line should see airborne noise levels no higher than 64 dBA with the fuel cell operating by itself. Because of the increasing loss with distance to the remaining Industrial property lines the expected fuel cell noise levels will fall below 58 dBA for the other Industrial properties. The residential properties should all be lower than 30 dBA. All the expected maximum values (worse case between speaker locations) are shown in Table 4 below. All of the property line estimates will meet the 70 dBA Industrial and 51 dBA nighttime residential noise limits.

Table 4. Expected Airborne Noise Levels from Operating a Doosan Fuel Cell (ref. 20 μ PA)

P3	P4	P5	P6	P7	P8	P9	P10
64 dBA	53 dBA	34 dBA	34 dBA	38 dBA	37 dBA	<28 dBA	35 dBA
P11	P12	P13	P14	Industrial		Residential	P15
58 dBA	56 dBA	49 dBA	35 dBA	←		→	<28 dBA

Operation of the Doosan fuel cell will have no acoustic impact at all the residential properties adjacent to the Carla’s Pasta site at 280 Nutmeg Road. The Industrial property next to Carla’s Pasta at 282-298 Nutmeg Road (very close to the fuel cell) may see airborne noise levels from the fuel cell, by itself, up to 6 dB below the Industrial noise limit. The current background noise levels at the Carla’s Pasta site were seen to vary depending on which Carla’s machinery were running. Maximum background airborne levels of more than 65 dBA were measured during a normal working day at the 310 Nutmeg Road location in November 2017 (Reference 4). When combined with the noise from a fuel cell the airborne noise could reach 68 dBA. Industrial properties further away from the Cooling Module along Nutmeg Road are expected to be around 66 dBA and those sites would be less affected by the operation of the fuel cell. Nonetheless, the

Acoustical Technologies Inc.

closest offices at 310 Nutmeg would hear airborne noise from Carla's Pasta at airborne noise levels above the maximum permitted in a commercial zone (65 dBA), if not above the 70 dBA allowed in an Industrial zone. The existing Carla's Pasta site at 50 Talbot has parking places for three tractor trailers with refrigeration compressors and these units contribute significantly to the existing background noise at 310 Nutmeg. The new site at 280 Nutmeg has room for several more tractor trailers. It can be expected that when operational the refrigeration compressors of these tractor trailers will increase the background noise above the 65 dBA that was measured in the adjacent office park at 310 Nutmeg in November. If this background noise level increases by more than 4 dB then the addition of the expected fuel cell noise will raise the airborne noise at the 310 Nutmeg property line above the Industrial zone noise limit.

Conclusions

The purpose of this effort is to evaluate the acoustical environment at the proposed Carla's Pasta fuel cell site in South Windsor, CT. This has been accomplished and the results show that the operation of a Doosan 440 KW fuel cell by itself will meet all of the State of Connecticut and South Windsor airborne noise requirements on residential property lines to the east. Although not tested, residences to the northeast, west and south are also expected to meet all the noise requirements because they are either blocked by the new Carla's Pasta building or are more than 560 meters away from the new fuel cell. The closest Industrial zone properties at 282-292 Nutmeg Road and 310 Nutmeg Road which are adjacent to the new fuel cell may approach or exceed the noise requirement when other airborne noise generated by Carla's Pasta is included. An acoustic barrier lining the west and north sides of the fuel cell Cooling Module enclosure is recommended to eliminate the possibility of this minor noise issue along Nutmeg Road being caused by the Doosan 440 KW fuel cell.

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) Mount Sinai Rehabilitation Hospital Airborne Noise Assessment, Carl A. Cascio,
Acoustical Technologies Inc., January 26, 2017
- 3) South Windsor ARTICLE III Noise Control.docx, Chapter 50, Article III, Noise Control
<https://www.jud.ct.gov/lawlib/ordinances.htm>
- 4) Carla's Pasta Noise Assessment, Carl A. Cascio, Acoustical Technologies Inc.,
November 12, 2017

Prepared For: Doosan Fuel Cell America Inc.

Point of Contact: Donald Emanuel

**Prepared by: Acoustical Technologies Inc.
 50 Myrock Avenue
 Waterford, CT 06385-3008**

**Subject: Carla's Pasta 280 Nutmeg
 Noise Treatment Recommendations**

Author: Carl Cascio

Date: April 21, 2019

Revision: 0

Table of Contents

	Page
Summary	3
Introduction	4
Acoustic Measurement Program	4
Allowable Noise Levels	6
Overall Sound Pressure Levels	8
Noise Treatment Recommendations	8
Conclusions	14
References	14

Summary

This document makes acoustic noise control recommendations that should assist in meeting the acoustic noise concerns during the operation of a Doosan 440 KW fuel cell on the Carla's Pasta site at 280 Nutmeg Road in South Windsor, 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 a Doosan 440 KW fuel cell at the site in South Windsor. This has been accomplished and the results show that the acoustic noise propagating to the two closest properties on Nutmeg Road should be addressed.

The airborne noise levels expected to be generated by the Doosan fuel cell were simulated by exciting a set of five co-located speakers at the Cooling and Power Module positions. (The Cooling Module is the dominant noise source.) Airborne noise was measured at distances from 5 to 245 meters from the fuel cell location with the speakers on. The speakers produced overall A-weighted sound pressure levels of 86 dBA at 5 meters and 81 dBA at 10 meters (reference 20 microPascals) from the Cooling Module location. The airborne noise levels from the speakers were measured at nearby property lines at noise levels from 40 to 75 dBA. Residential measurement locations to the east were very quiet with levels below 43 dBA with the speakers on. The closest Industrial measurement locations to the south, north and west were high because of the short distance to the speakers along Nutmeg Road. Analysis of the speaker data indicated propagation losses from 4.6 to 41 dB from the fuel cell location to the nearby Industrial property lines. The source level at 10 meters from the operation of a Doosan fuel cell at Mount Sinai Hospital in Hartford, CT was then used as a basis for making the Carla's Pasta fuel cell airborne noise estimates. The overall airborne noise estimates are all expected to meet the state and town nighttime 51 dBA requirement at all the Residential locations. Operation of the fuel cell by itself is expected to meet the state and town 70 dBA requirement for all the Industrial locations without any additional noise treatment. Operation of the fuel cell is also expected to meet all requirements associated with impulse noise, prominent discrete tones, infrasonic and ultrasonic noise at all of the nearby property lines without additional noise treatment.

As stated above, operation of the fuel cell produces airborne noise predominately from the Cooling Module. Efforts to reduce the fuel cell's airborne noise should be directed at adding a sound barrier treatment to block the Cooling Module's noise from reaching the closest Industrial Zone properties at 282-298 and 310 Nutmeg Road. The performance of a commercially available noise barrier, from Acoustical Solutions, called ABBC-EXT-R Sound Curtains was found to provide the necessary mitigation.

Installation of 36 linear feet of 8-foot-high barrier material is recommended on the north and west sides of the Cooling Module. (Figure 10 provides a sketch.) This amount of barrier material should meet the Industrial noise limits at the closest Nutmeg Road property lines with about 12 dB of margin. This margin allows other machinery noise from Carla's Pasta to stay within the overall noise requirements. Given this noise treatment the airborne noise generated by the fuel cell will not impact Carla's Pasta neighbors and will be below all state and town noise requirements at all the neighbor's property lines. The eight-foot-high acoustic barrier as described in this report should mitigate this minor noise issue and remove any acoustic concerns about siting and operating the 440 KW Doosan fuel cell at the 280 Nutmeg Road location.

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 Carla's Pasta site at 280 Nutmeg Road in South Windsor, CT (Reference 1). Responding to a request from Donald Emanuel, a site visit was made on April 14, 2019. During the visit, a measurement of the simulated airborne noise levels expected to be produced by the Doosan 440 KW Fuel Cell was made in order to identify potential noise issues. Estimated airborne noise levels along the closest nearby street (Nutmeg Road) were lower than the state and town noise requirement at all the locations. At two locations (282-298 and 310 Nutmeg Road) the estimated levels come close to the Industrial Zone noise requirement. This document provides recommendations for the installation of a noise control treatment that will eliminate the possibility of there being any acoustic noise concern during the operation of the Doosan 440 KW fuel cell.

The purpose of this effort is to utilize the available acoustic data to mitigate potential airborne noise issues associated with the operation of a Doosan Fuel Cell at 280 Nutmeg Road in South Windsor, CT. The State of Connecticut and the Town of South Windsor Noise Ordinances have been consulted to assess the impact of the estimated acoustic noise levels. Noise mitigation is recommended to reduce the airborne noise propagated by the fuel cell to the two closest nearby neighbor's properties on Nutmeg Road directly to the north and west of the fuel cell location.

Acoustic Measurement Program

Airborne sound pressure measurements and audio tape recordings were conducted at the South Windsor site on and near 280 Nutmeg Road on April 14, 2019 during the daylight hours. The purpose was to measure both background and airborne noise levels with the five speakers simulating the operation of a Doosan 440 KW fuel cell. Speaker and background airborne noise measurements were taken at each neighbor's property line at thirteen locations surrounding the Carla's Pasta site. Twelve measurements were made in the Industrial Zone closest to 280 Nutmeg Road. One measurement was made at the nearest Residential property to the east (see Table 1). Measurements at 5 and 10 meters from the five speakers' Site A Cooling Module location were simultaneously taken with a sound level meter and two microphones recording on a digital tape recorder. These tape recorder measurements were repeated for the Power Module Site B location. One-third octave and overall airborne noise levels were calculated and reported.

See Figures 1 and 2 below for photographs of similar Fuel Cell Power and Cooling Modules that have been installed at the Mount Sinai Hospital site in Hartford, CT. Figure 3 provides a Google Map of the Carla's Pasta site with the property line measurement locations identified as P1 through P15. The expected site of the Cooling Module furthest from Nutmeg Road is identified in white as Site A. The Power Module location is identified as Site B. Figures 4 and 5 provide photographs showing the speakers at the intended Cooling and Power Module locations where the fuel cell cooling system hardware will be placed. The photographs show the speakers at the center of the module locations and the two microphones at 5 and 10 meters from the speakers. Table 1 provides distances from the speakers and estimates of the expected Doosan fuel cell airborne noise at each of the thirteen nearby measurement locations. Positions 3 and 11 showed the highest airborne noise levels at distances that were closest to the speakers.

Acoustical Technologies Inc.

Figure 1. Doosan Fuel Cell Power Module at the Mount Sinai Hospital Site in Hartford CT



Figure 2. Doosan Fuel Cell Cooling Module at the Mount Sinai Hospital Site in Hartford CT



Acoustical Technologies Inc.

Figure 3. South Windsor Carla's Pasta Site Map from Google Maps



Allowable Noise Levels

CT section 22a-69-3.1 (Reference 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 South Windsor and the CT noise ordinances have been used to evaluate the noise generated by the Doosan Fuel Cell Power and Cooling Modules. The following subsection discusses the overall noise requirement and discusses the results obtained from the measurements at the Carla's Pasta site in order to determine what noise treatment needs to be applied. The Impulse, Prominent Discrete Tones, Infrasonic and Ultrasonic measurements of fuel cell airborne noise showed no acoustic concerns and will not be discussed further as no acoustic treatment is needed to meet these other requirements.

Acoustical Technologies Inc.

Figure 4. Doosan Cooling Module Location at the South Windsor Carla's Pasta Site



Figure 5. Doosan Power Module Location at the South Windsor Carla's Pasta Site



Acoustical Technologies Inc.

Overall Sound Pressure Levels

The Connecticut and South Windsor regulations for the control of noise state that

(a) No person in a Class C Noise Zone shall emit noise exceeding the levels below:

Class C emitter to C 70 dBA B 66 dBA A/day 61 dBA A/night 51 dBA

The nearby neighbors are classified as either Residential or Industrial with the Industrial noise limit at 70 dBA and the Residential noise limit at 61 dBA during the day and 51 dBA at night. Neighboring Industrial properties along Nutmeg Road are expected to meet the Industrial noise requirements. All of the nearby Residential locations are expected to meet the nighttime and day time Residential airborne noise limits. All the expected maximum values (worse case between the two speaker locations) are shown in Table 2 below. Operation of the Doosan fuel cell may have a minor acoustic impact by being close to or exceeding 70 dBA at the two properties closest to the Cooling Module at 282-292 and 310 Nutmeg Road if other Carla's Pasta noise is high.

Noise Treatment Recommendations

The two separate pieces of the Doosan hardware are shown in Figures 1 and 2 above. Mount Sinai airborne noise measurements have indicated that the Cooling Module is the dominant noise source (Reference 3). Since the Power Module noise levels are about 17 dB below the cooling module, a small reduction (6 dB) of the noise level of the Cooling Module noise will still leave the Cooling Module dominant. If the Cooling Module noise were reduced by 6 dB the nearby property lines would then see airborne noise from the Cooling Module at levels at least 12 dB lower than the requirement of 70 dBA. At this level the fuel cell would not be heard over the 65 dBA or higher background noise from the Carla's Pasta refrigeration equipment. (The Power Module component is then expected to be at least 10 dB below the Cooling Module so we don't have to be concerned with treating the Power Module.) Treatment of the Cooling Module (i.e. reducing its noise by 6 dB) will result in less noise at the nearby property lines. If these dBA numbers were exact the summation of a 48 dBA source from the Power Module and a 58 dBA source from the Cooling Module would result in airborne noise of 58.4 dBA at the property line, well below the limit. If we add in the 310 Nutmeg background noise generated by equipment at Carla's Pasta of 65 dBA (Reference 5), the total airborne noise expected at 310 Nutmeg Road would be 66 dBA, still 4 dB below the requirement. Given that there is probably some additional noise to be expected from more trailers at the new building this noise could increase to 69.5 dBA and fuel cell operation would still have total levels below the 70 dBA requirement. This improvement of 6 dB in the Cooling Module noise is recommended in order to achieve additional margin in the acoustic performance for all the noise generated by Carla's Pasta.

The fuel cell including the Cooling Module will be surrounded by an 8-foot-high chain link fence and the first option for noise control would be to attach 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 previously calculated and the results are shown in the following figures versus frequency.

Acoustical Technologies Inc.

Figure 6 looks at the sound diffraction over the top of an 8-foot wall showing the performance expected for the nearby properties on Nutmeg Road that have distances from the fuel cell of 16 to 168 meters. The curve labeled 16 is for the closest business at 282-298 Nutmeg Road. The curve labeled 168 is for the property at 30 Talbot Lane. (This location will be below the 70 dBA limit without treatment.) The spread in performance is small (less than 2 dB) for all the other businesses along Nutmeg Road and indicates that the noise treatment should be equally effective. Closer to the wall is slightly better because it is more in the acoustic shadow of the wall.

Another 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 Curtains⁴ is shown in Figure 7 as the Direct Path. 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. (Increasing the thickness to 2 inches would help the low frequencies.)

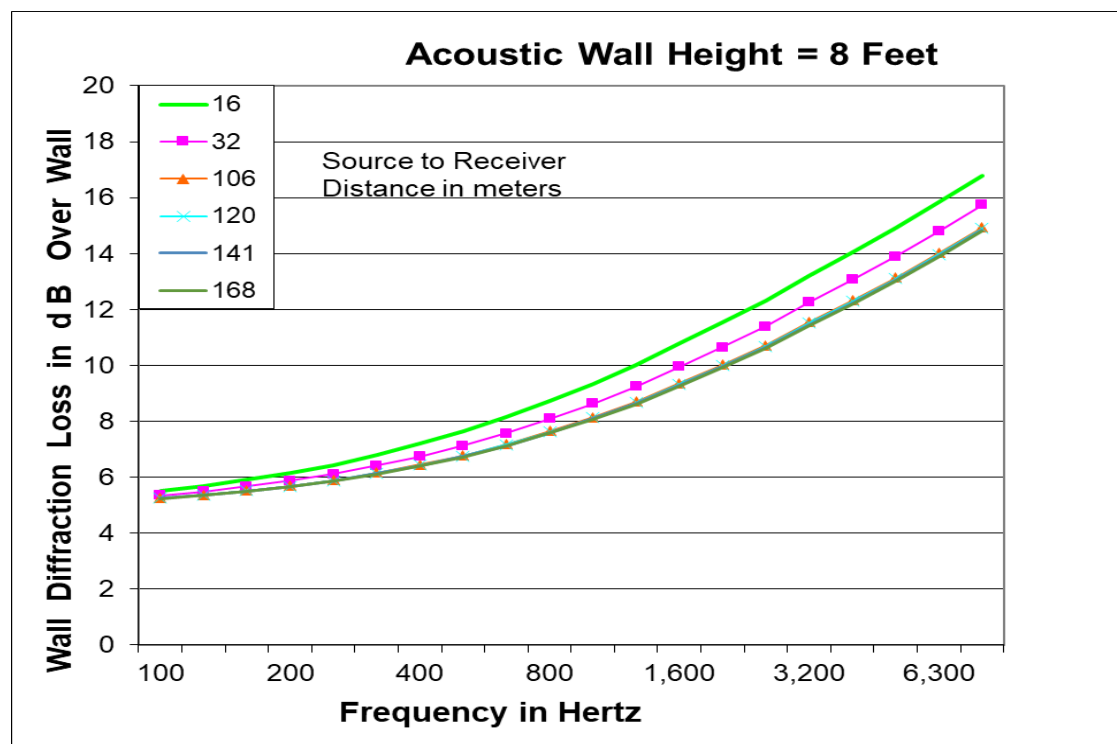
Table 1. Estimated South Windsor Overall Sound Pressure Levels in dBA ref. 20 microPascals

Location	Range in Meters	Speakers at Cooling	Correction	Cooling Estimated SPL in dBA	Speakers at Fuel	Correction	Power Mod. Estimated SPL in dBA
P3 – 282-298 Nutmeg Road	22/19	74.3 (estimate)	-12.7	61.6	75.3	-11.5	63.8
P4 - 274 Nutmeg Road	53/50	65.7	-12.7	53	57.4	-11.5	45.9
P5 – 250 Nutmeg Road	224/221	46.8	-12.7	34.1	40.0	-11.5	28.5
P6 – 255 Nutmeg Road	132/128	46.8	-12.7	34.1	39.0	-11.5	27.5
P7 - 279 Nutmeg Road	127/123	51.1	-12.7	38.4	42.5	-11.5	31
P8- 283 Nutmeg Road	126/128	49.6	-12.7	36.9	48.4	-11.5	36.9
P9 – 345 Nutmeg Road	220/222	<40	-12.7	<28	<40	-11.5	<29
P10 – 330 Nutmeg Road	144/146	<40	-12.7	<28	46.2	-11.5	34.7
P11 - 310 C9 Nutmeg Road	46/48	63.6	-12.7	50.9	69.8	-11.5	58.3
P12 - 310 C8 Nutmeg Road	65/67	60.6	-12.7	47.9	67.2	-11.5	55.7
P13- 310 CT Nutmeg Road	59/61	61.8	-12.7	49.1	60.4	-11.5	48.9
P14 – 30 Talbot Lane	169/172	46.7	-12.7	34	46.5	-11.5	35
P15 – 134 Edgewood D.	243/245	<40	-12.7	<28	<40	-11.5	<29

Table 2. Expected Airborne Noise Levels from Operating a Doosan Fuel Cell (ref. 20 μ PA)

P3	P4	P5	P6	P7	P8	P9	P10
64 dBA	53 dBA	34 dBA	34 dBA	38 dBA	37 dBA	<28 dBA	35 dBA
P11	P12	P13	P14	Industrial		Residential	P15
58 dBA	56 dBA	49 dBA	35 dBA	←		→	<28 dBA

Figure 6. Acoustic Diffraction Performance for Different Receiver Locations



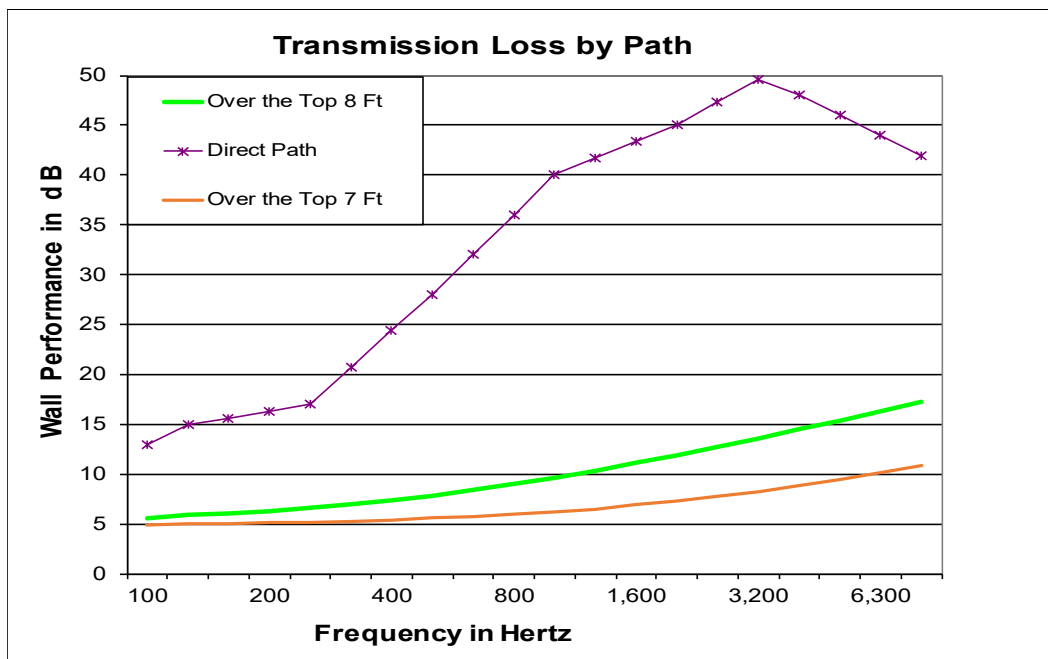
To evaluate the ability of this material to provide the performance we need requires the combination of both propagating paths leading to an estimate of the airborne noise level at the property lines on Nutmeg Road. This has been done and the results are shown in Figure 8. The calculation starts with the one-third octave airborne noise levels actually measured 10 meters from the Mount Sinai cooling module. These levels are then attenuated by the barrier losses shown in Figure 7 to produce a direct and a diffraction component all at 10 meters. These two levels are then attenuated by 4.6 dB to account for the minimum propagation loss measured at Nutmeg Road. The two results are then power summed to provide the estimate of airborne noise at the property line of 282-298 Nutmeg Road as shown in Figure 8. The one-third octave bands are power summed to calculate the overall dBA for each material wall height with the total dBA values shown in the figure caption). The estimates indicate that all of the three material heights meet the Industrial noise limit. The 8-foot height provides the most margin (11.3 dB) while the 7-foot wall has 10.2 dB margin and the 6-foot wall has the lowest margin with 9.5 dB. Note that

Acoustical Technologies Inc.

the peak airborne noise level falls in the 200 Hertz one-third octave band while a smaller peak shows up in the 630 Hertz band where the highest discrete tone was found. The other locations on Nutmeg Road would meet the 70 dBA Industrial noise limit with more than 15 dB of margin.

Installation of an eight-foot-high acoustic barrier is recommended to mitigate the airborne noise reaching the property lines on Nutmeg Road. Materials such as the ABBC-EXT-R Sound Curtains from Acoustical Solutions (Reference 4) or equivalent should be sufficient to produce the 6 dB of sound reduction needed. An example of a noise treatment installation is shown in Figure 9. The ABBC-EXT-R Sound Curtains were hung from two sides of a security fence around the Cooling Module at the fuel cell installation at Mount Sinai Hospital in Hartford. Coverage at Carla's Pasta should extend around the west and north sides of the Cooling Module. Looking at Figure 2 and assuming the Carla's Pasta site will have approximately a 3-foot stand-off of the fence from the cooling system, the 4.4 by 2.3 meter cooling system foot print should have a noise treatment about 11 meters in length (36 feet). Locating the entrance gate on the south side will allow the gate and the rest of the south side to remain untreated. See Figure 10 for a sketch of the recommended approach. The north (5 panels) and west sides (3 panels) will have 54-inch-wide noise blanket panels hung from the fence. The length of the necessary treatment would be about 36 feet with a height of 8 feet for a surface area of 288 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 8-feet is chosen, it is acceptable to use a panel of the same height as the fence as long as it is at least 6-feet high.

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

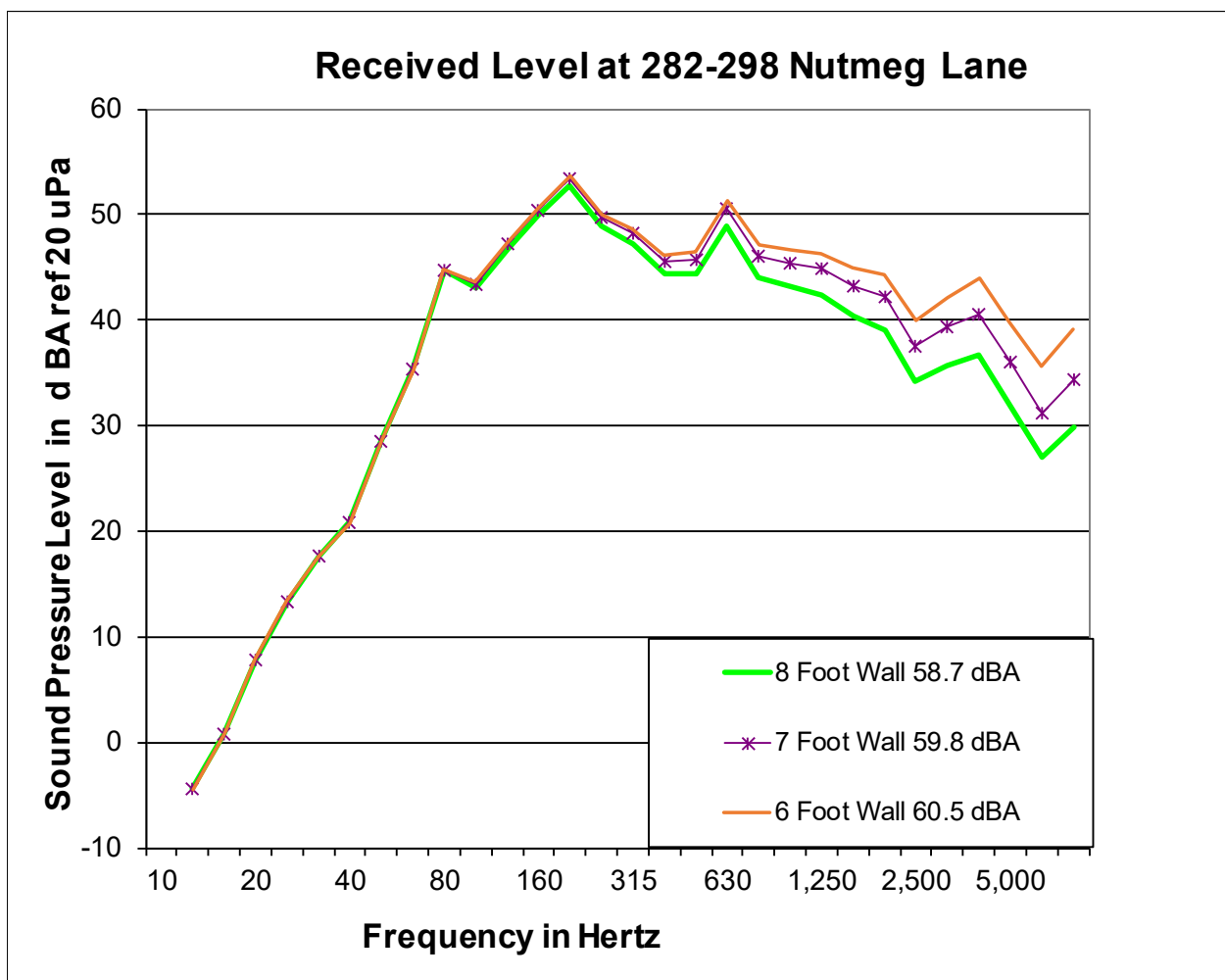


Drawings from Doosan indicated that the Cooling Module and Power Module would be placed side to side on the Carla's Pasta property. This arrangement leads to recommending a barrier acoustic treatment on the fence around two sides of the Cooling Module. If the Cooling Module

Acoustical Technologies Inc.

were separated there might be the need for additional panels on the south side to block the sound headed towards 274 Nutmeg Road depending on how close the Cooling Module was to 274 Nutmeg. The Power Module currently blocks this path. If the module arrangement shown in Figure 10 could be used, a minimum number of 8 panels would be needed along the north and west sides. An alternative approach to using sound baffling panels to block the Cooling Module noise would be to reverse the Cooling and Power Module locations. The 10-foot-high Power Module would be effective in blocking the Cooling Module sound propagating north to 310 Nutmeg Road if the Power Module was located between the Cooling Module and the adjacent property to the north. The Power Module would act as the noise barrier in the northerly direction removing the need for adding a noise treatment to the north of the Cooling Module. Treatment to the west would still be needed but this would reduce the number of panels to three.

Figure 8 Estimated 30 Nutmeg Road Airborne Noise Levels versus Wall Height

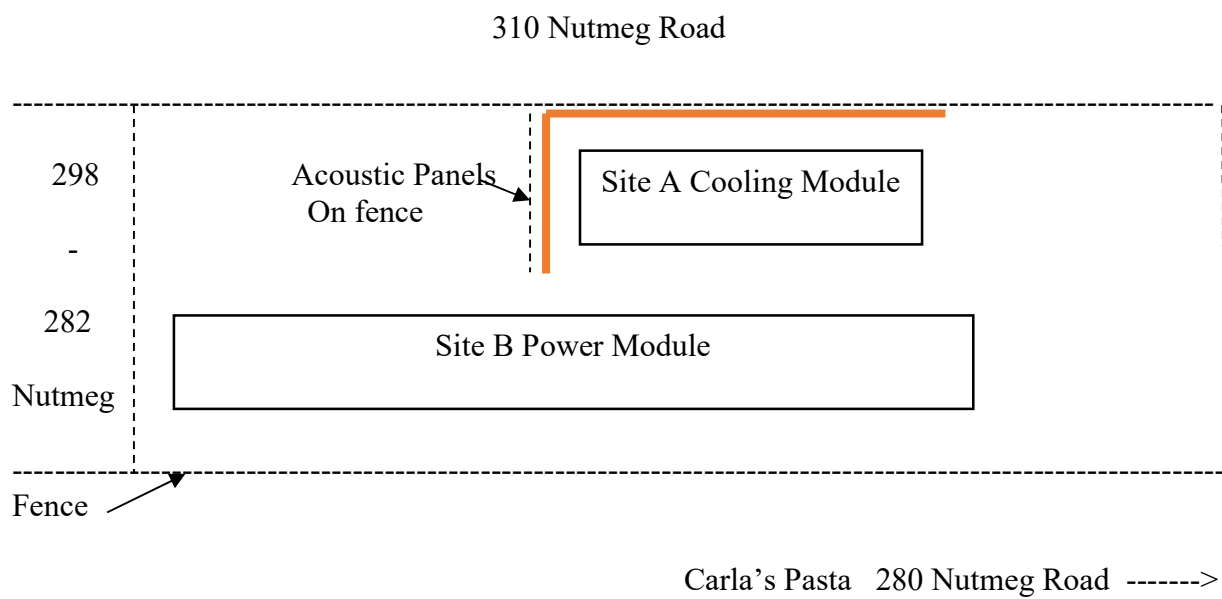


Acoustical Technologies Inc.

Figure 9. Eight Foot Fence Surrounding Doosan Cooling Module with Noise Treatment



Figure 10. Sketch of Recommended Noise Treatment Design



Conclusions

The purpose of this effort has been to evaluate the acoustical environment at the Carla's Pasta site at 280 Nutmeg Road in South Windsor, CT. This has been accomplished and the results show that the acoustic impact on the closest properties at 282-298 and 310 Nutmeg Road needs to be addressed. Operation of the fuel cell meets all of the other state and town noise requirements. The closest property on Nutmeg Road is expected to be within 6 dB of the Industrial Zone 70 dBA airborne noise limit. Other noise from Carla's Pasta will bring the total noise close to or above the limit. An eight-foot-high acoustic barrier as described in this report should mitigate this Cooling Module noise issue and remove any acoustic concerns about siting and operating the Doosan 440 KW fuel cell at the Carla's Pasta site.

References

- 1) Carla's Pasta Airborne Noise Assessment at 280 Nutmeg Road South, Carl A. Cascio, Acoustical Technologies Inc., April 20, 2019
- 2) 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>
- 3) Mount Sinai Rehabilitation Hospital Airborne Noise Assessment, Carl A. Cascio, Acoustical Technologies Inc., January 24, 2017
- 4) <https://acousticalsolutions.com/product/abbc-13-ext-audioseal-exterior-sound-blanket/>
- 5) Carla's Pasta Airborne Noise Assessment at 50 Talbot Lane, Carl A. Cascio, Acoustical Technologies Inc., November 12, 2017, page 10