Doosan Fuel Cell America, Inc.
195 Governor's Highway
South Windsor, CT 06074
T - 860 727 2200

February 17, 2017

RE: PETITION NO. 1263- Response to Interrogatories;
Doosan Fuel Cell America, Inc. petition for a declaratory ruling that no Certificate of Environmental Compatibility and Public Need is required to replace an existing customer – side 400 kilowatt (kW) fuel cell with a 440-kW customer-side fuel cell facility located at Mount Sinai Hospital, 500 Blue Hills Avenue, Hartford, Connecticut.

Dear Siting Council,

Please find attached the responses to Council Interrogatories - (along with corresponding exhibits), requisitioned on 12/08/2016 for PE 1263 by the CT Siting Council.

Additional questions may be addressed to:
Walter Bonola
195 Governor's Highway
South Windsor, CT 06074
(860) 727-2010
Walter.Bonola@doosan.com

Thank you for your consideration and time.

Sincerely,

Doosan Fuel Cell America, Inc.

Dawn Mahoney

Dawn Mahoney, Esq.
General Counsel
Doosan Fuel Cell America, Inc.

VIA ELECTRONIC MAIL

December 8, 2016

Dawn Mahoney, Esq.
General Counsel
Doosan Fuel Cell America Inc.
195 Governor's Highway
South Windsor, CT 06074

RE: **PETITION NO. 1263** - Doosan Fuel Cell America, Inc. petition for a declaratory ruling that no Certificate of Environmental Compatibility and Public Need is required to replace an existing customer-side 400 kilowatt (kW0 fuel cell facility with a 440-kW customer-side fuel cell facility located at Mount Sinai Hospital, 500 Blue Hills Avenue, Hartford Connecticut.

Dear Attorney Mahoney:

The Connecticut Siting Council (Council) issued interrogatories on the above-referenced petition on November 9, 2016 and requested responses to be filed not later than November 23, 2016 (see attachment). The Council did not receive any responses to date.

The Council is therefore reissuing these interrogatories and requests your responses to the enclosed questions **no later than December 22, 2016.** To help expedite the Council's review, please file individual responses as soon as they are available.

Please forward an original and 15 copies to this office, as well as send a copy via electronic mail. In accordance with the State Solid Waste Management Plan and in accordance with Section 16-50j-12 of the Regulations of Connecticut State Agencies the Council is requesting that all filings be submitted on recyclable paper, primarily regular weight white office paper. Please avoid using heavy stock paper, colored paper, and metal or plastic binders and separators. Fewer copies of bulk material may be provided as appropriate.

Yours very truly,

Melanie Bachman
Acting Executive Director

MB/CW

c: Council Members

Petition No. 1263
Doosan Fuel Cell America, Inc.
500 Blue Hills Avenue
Hartford, CT
Interrogatories

15 Please submit a noise analysis report to demonstrate compliance with the Connecticut Department of Energy and Environmental Protection (DEEP) noise control standards. In the Petition, Doosan predicts a noise level of not more than 62 dBA at 100+ feet away for the fuel cell. Is the cooling module included in this noise prediction? If no, please update this noise prediction and ensure compliance with DEEP noise control standards.

R15. Please see attached Mt. Sinai -1 Noise Study & Mt. Sinai - 2 Noise Treatment Recommendations, which address the Council's question regarding the cooling module's inclusion in the noise prediction. Please note that Doosan will implement the recommendations in Mt. Sinai – 2 Noise Treatment Recommendations in order to ensure compliance with all noise control standards.

MT. SINAI -1

DETAILED NOISE STUDY

Prepared For: Doosan Fuel Cell America Inc.

Point of Contact: Walter Bonola

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

Subject: Mount Sinai Rehabilitation Hospital
Airborne Noise Assessment

Author: Carl Cascio

Date: January 26, 2017

Revision: 1

Table of Contents

Summary

This document makes an acoustic assessment that should assist in meeting the acoustic noise concerns during the operation of a Doosan 400 KW fuel cell at the Mount Sinai Rehabilitation Hospital in Hartford, 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 operation of the Doosan 400 KW fuel cell. It is important to show that the airborne noise generated by the fuel cell will not significantly impact the hospital's neighbors.

The airborne sound pressure levels produced by the fuel cell were measured at distances from five to eighty meters from the fuel cell. The fuel cell produced overall A-weighted sound pressure levels from 70 to 74 dBA reference 20 microPascals at distances of 5 and 10 meters from the fuel cell. The airborne noise levels at nearby north, south and east property lines varied from 42 to 52 dBA reference 20 microPascals as well as being undetectable on the west side of the hospital. Only the nearby north side airborne noise levels were found to be significantly above the city and the state nighttime noise requirements. Airborne noise levels at the two property lines of homes at 660 and 664 Tower Avenue (nearest to the fuel cell) were 6 and 7 dB above the 45dBA nighttime limit. Three other homes on Tower Avenue are also estimated to be slightly above the nighttime noise limit. All the airborne noise measurements met the city and state day time 55dBA requirement at all the locations.

The Connecticut's Noise Code (Reference 1) and the City of Hartford Regulations (Reference 2) also call for review of acoustic issues associated with impulse noise, prominent discrete tones, infrasonic and ultrasonic noise. Operation of the fuel cell met all of these requirements at all of the measured locations at all of the nearby property lines.

When the Cooling Module was turned off the airborne noise levels at 5 and 10 meters from the Power and Cooling Modules dropped to levels from 52 to 54 dBA. The exhaust fan on the Power Module was observed to be running. Turning this exhaust fan off would probably drop the nearby background level below 50 dBA. 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 either reducing the Cooling Module noise or adding a sound barrier treatment to block the Cooling Module's noise from reaching the nearby property lines.

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 Mount Sinai Rehabilitation Hospital site in Hartford CT. Responding to a request from Walter Bonola, a site visit was made on January 18, 2017. During the visit a survey of the airborne noise levels produced by the Doosan Fuel Cell was made in order to identify potential noise issues. The fuel cell was operating in a maximum cooling mode with the cooling fans in the highest operating speed. Noise measurements were taken to quantify the "source on,, airborne noise levels. In was not possible to turn the unit off on January 18 so a return trip was made on January 19 to measure the background airborne noise levels with the cooling fans off. This document provides an acoustic assessment to assist in meeting acoustic noise concerns during operation of the fuel cell on the Mount Sinai Rehabilitation Hospital property.

Development of the Acoustic Assessment Plan

The purpose of this effort is to acquire acoustic information useful in explaining and mitigating the potential airborne noise issues associated with the operation of the Doosan Fuel Cell at Mount Sinai Rehabilitation Hospital in Hartford, CT. The site on Blue Hills Avenue is adjacent to the National Multiple Sclerosis Society building to the east and the nearest neighbors are along Tower Avenue and Lebanon Street to the north. The closest homes to the south are on Woodstock Street. Neighbors to the west are blocked by the multi-story hospital building. It is important to determine whether the airborne noise generated by the fuel cell equipment will impact these neighbors.

The acoustic impact is assessed in the following way. There was a straight forward measurement of the airborne sound pressure level produced by the operating fuel cell at distances from 5 to 80 meters from the fuel cell hardware. This approach follows the traditional "What is the airborne noise level at the neighbor's property line?,,. The fuel cell Power and Cooling Modules were run and airborne measurements made near the fuel cell and at the neighbor's property lines. This site data for the fuel cell can be used to estimate noise levels at other neighbor's property lines as well. The City of Hartford noise ordinance and the State of Connecticut Noise Code have been consulted to assess the impact of the measured and estimated acoustic levels. Noise mitigation may be needed if the airborne noise produced by the fuel cell exceeds the city and state noise requirements at the neighbor's property lines.

Acoustic Measurement Program

The acoustic data necessary to assess the impact of the Doosan Fuel Cell is described below: Airborne sound pressure measurements and audio tape recordings were conducted at 490 Blue Hills Avenue on the nights of January 18 and 19, 2017 to establish both background airborne noise levels and airborne noise levels with the equipment operating. The overall A-weighted airborne noise measurements were made with an ExTech model 407750 Digital Sound Level Meter (s/n 3072577) that had been calibrated just prior to the test and 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 conducted with a Sony Digital Audio Tape Recorder (model TCD-D8 s/n 579588 on channels 1 and 2). Two PCB microphones (model 130C10 s/n 11283 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 just prior to the test and after the test with a Quest model QC-10 Calibrator (s/n Q19080194). All measurements were made with the microphones at a height between four and five 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.

At the hospital site "source on,, and background airborne noise measurements were taken at each neighbor's property line on Tower Avenue and Woodstock Street and also at the property line at the east end of the hospital parking lot. Measurements were also made on Blue Hills Avenue across the street from the front entrance to the hospital. Measurements near the operating fuel cell were simultaneously taken with a sound level meter and two microphones recording on the digital tape recorder. See Figures 1 and 2 below for photographs of the Fuel Cell Power and Cooling Modules. Figure 3 has a Google Map of the hospital site with the measurement locations identified in black as P1 through P11. The Power Module is identified in black as Location A and the Cooling Module as Location B. Because the Blue Hills Avenue site is adjacent to major city streets, the background noise levels are strongly influenced by traffic levels. Measurements were taken at night to take advantage of reduced traffic volume (9:00 pm to 11:50 pm). At locations A and B two minute records of the acoustic noise were stored.

Airborne noise measurements taken outside are corrupted by rain and wind so two nights were selected when the weather was dry and the winds were 10 miles per hour or less. Table 1 provides the weather data in Hartford for the measurements on January 18 and 19, 2017. Measurements were taken over the period from 9:00 pm until 10:40 pm on January 18 and from 10:30 pm to 11:50 pm on January 19. The table below shows the temperature and wind speeds in hourly intervals on both nights. Wind conditions were excellent and the wind did not affect the operating and background airborne noise measurements. Motor traffic was light and it was possible to wait for periods when no traffic was seen or heard at the measurement locations. Some background data on Woodstock Street is missing due to very high airborne noise from continuous automobile operation by one of the neighbors.

Data Analysis

This section compares the measured noise levels to the regulations in the Connecticut and City of Hartford noise ordinances. Both background noise levels at the Mount Sinai site and Doosan Fuel Cell equipment operating noise levels have been analyzed. Comparing these Mount Sinai Hospital measurements with the state and city noise requirements will identify which nearby locations are quiet and meet the requirements and which locations are not quiet enough. The set of measured overall A-weighted airborne noise levels are given in Table 2 below. The CT and City of Hartford daytime requirement is 55 dBA and the nighttime requirement is 45 dBA.

Table 1. Hartford Weather on January 18 and 19, 2017

Date	Time (EST)	Wind (mph)	Visibility (mi.)	Weather	Air Temp	Humidity	Barometer
Wednesday							
Jan 18	**5:53 PM**	**8 mph**	**10 mi**	**Overcast**	**37 °F**	89%	30.03 "Hg
	6:53 PM	**6 mph**	**10 mi**	**Overcast**	**36 °F**	92%	30.04 "Hg
	7:53 PM	**6 mph**	**9 mi**	**Low Clouds**	**36 °F**	92%	30.05 "Hg
Jan 18	**8:53 PM**	**6 mph**	**10 mi**	**Overcast**	**36 °F**	89%	30.03 "Hg
	9:53 PM	**5 mph**	**9 mi**	**Low Clouds**	**36 °F**	89%	30.02 "Hg
	10:53 PM	**6 mph**	**10 mi**	**Mostly Cloudy**	**36 °F**	89%	30.03 "Hg
Jan 18	**11:53 PM**	**5 mph**	**10 mi**	**Mostly Cloudy**	**35 °F**	92%	30.01 "Hg
Thursday							
Jan 19	**12:35 am**	**5 mph**	**10 mi**	**Overcast**	**35 °F**	**92%**	**30.02 "Hg**
	5:53 PM	**10 mph**	**10 mi**	**Overcast**	**43 °F**	**65%**	**30.01 "Hg**
	6:53 PM	**7 mph**	**10 mi**	**Overcast**	**42 °F**	**68%**	**30.02 "Hg**
Jan 19	**7:53 PM**	**5 mph**	**10 mi**	**Overcast**	**42 °F**	**68%**	**30.03 "Hg**
	8:53 PM	**6 mph**	**10 mi**	**Overcast**	**42 °F**	**65%**	**30.04 "Hg**
	9:53 PM	**6 mph**	**10 mi**	**Overcast**	**41 °F**	**67%**	**30.03 "Hg**
	10:53 PM	**6 mph**	**10 mi**	**Overcast**	**41 °F**	**67%**	**30.01 "Hg**
Jan 19	**11:53 PM**	**5 mph**	**10 mi**	**Overcast**	**40 °F**	**70%**	**30.02 "Hg**

Weather by CustomWeather, © 2017

Figure 1. Doosan Fuel Cell Power Module

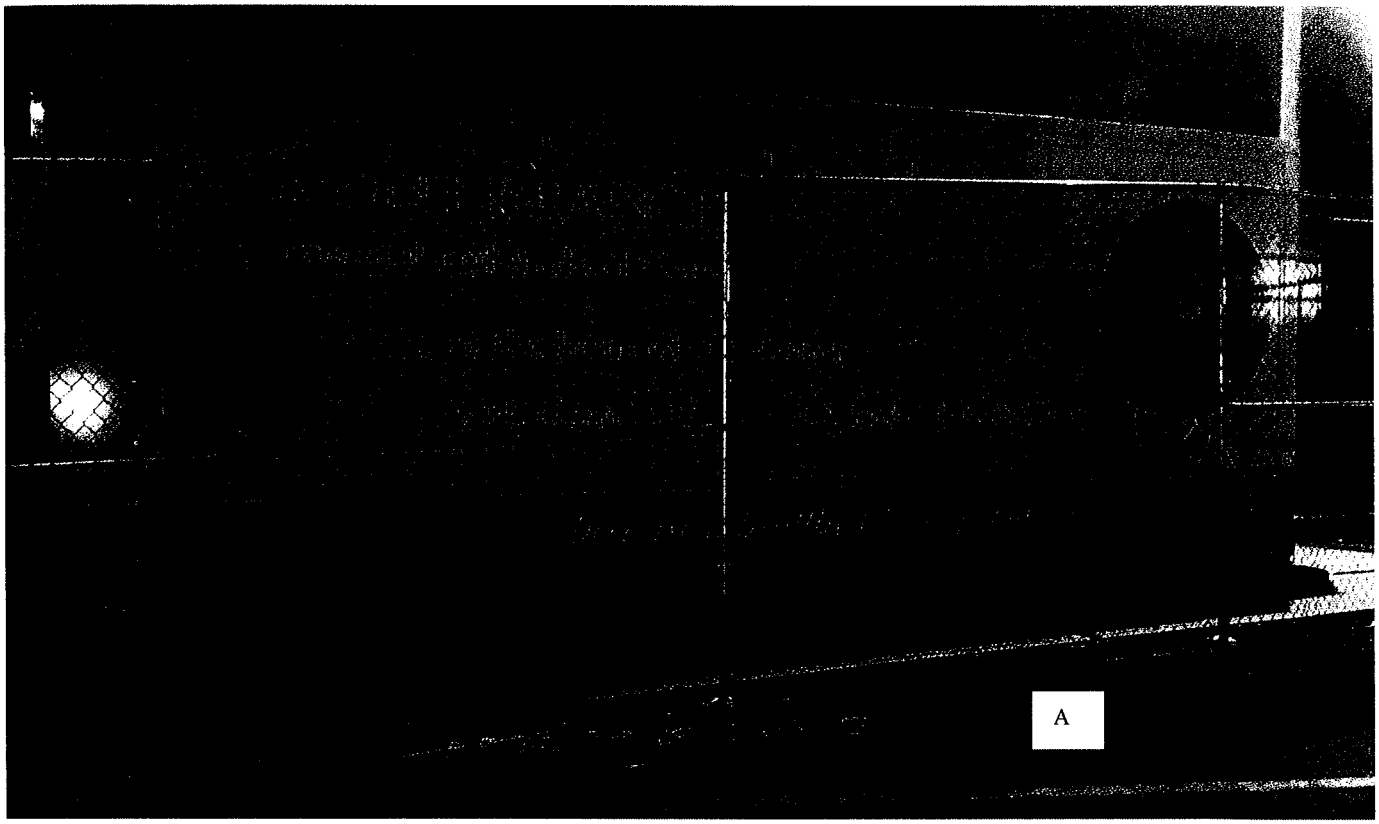


Figure 2. Doosan Fuel Cell Cooling Module

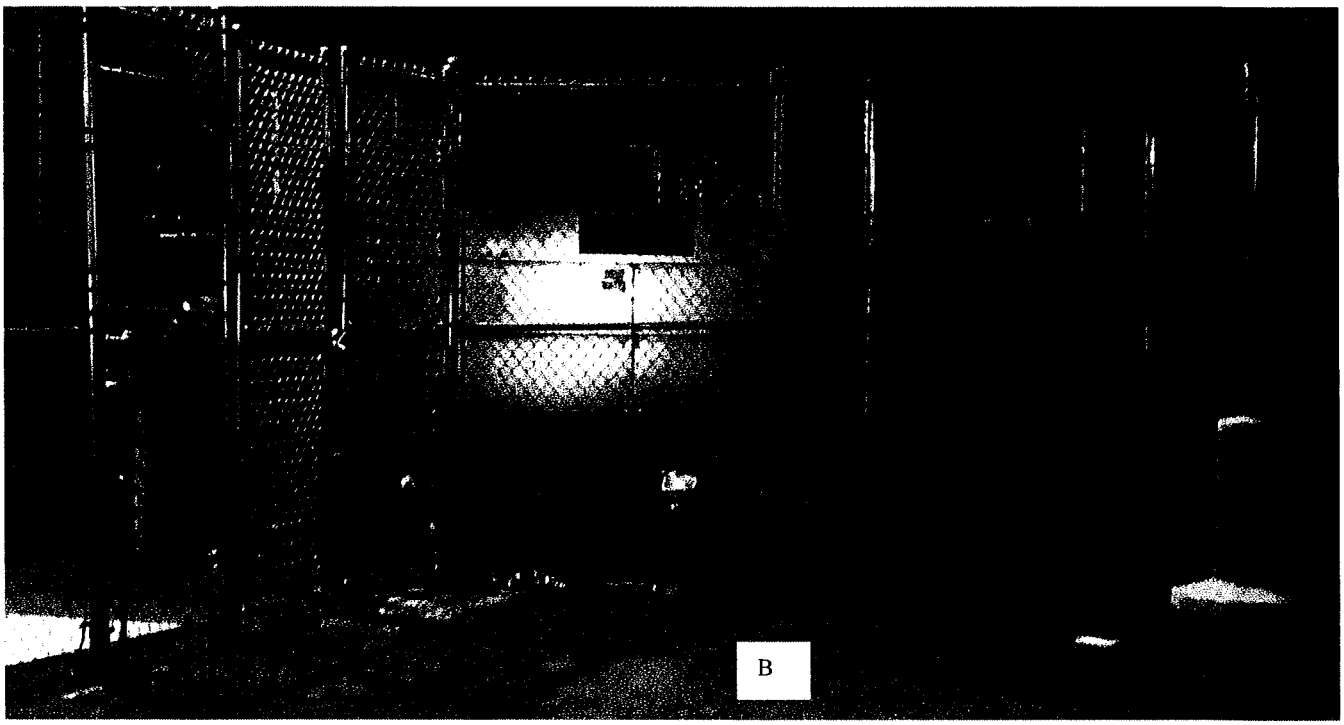


Figure 3. Mount Sinai Site Map from Google

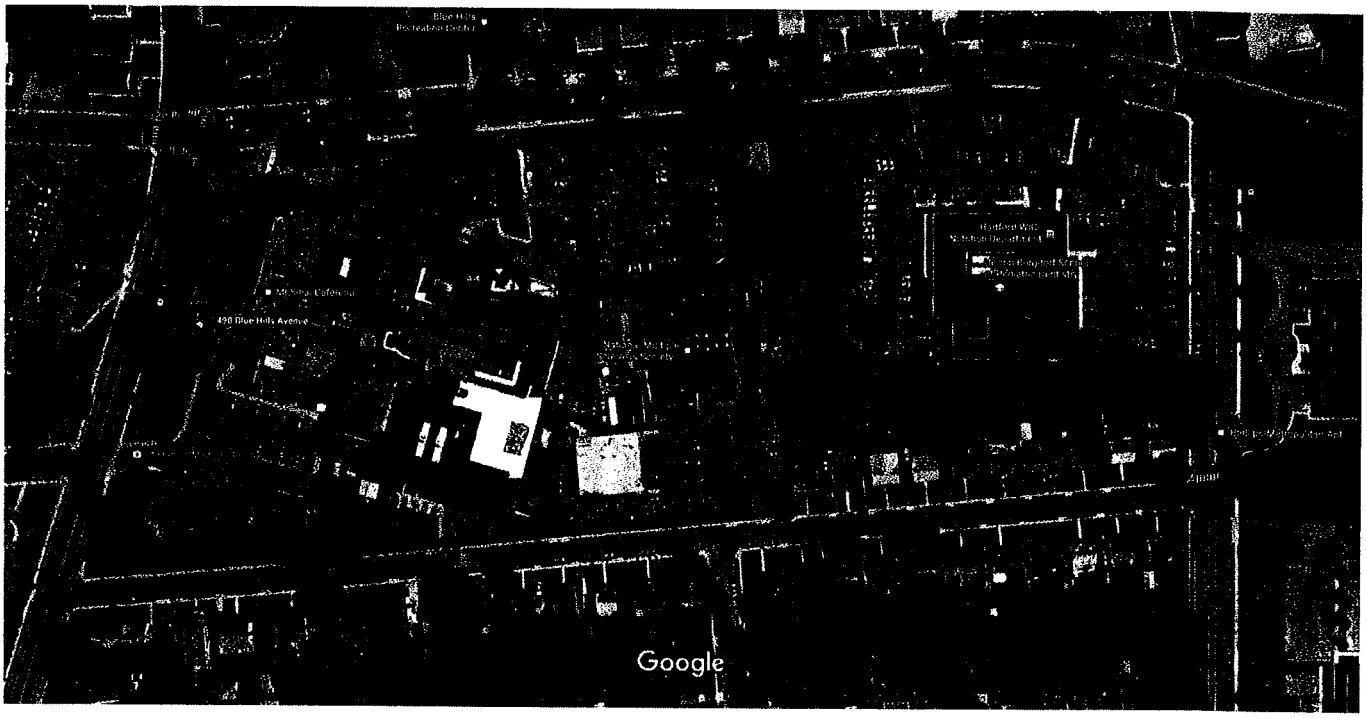


Table 2. Overall Sound Pressure Measurements near Mount Sinai Rehabilitation Hospital

Location	Distance (meters)	Fuel Cell On	Cooling Modules Off (Background)	Background Corrected	Excess dBA
Power Module At 5 meters	5	70	52.5	69.9	n/a
Power Module At 10 meters	10	69.5	52.5	69.4	n/a
Cooling Module At 5 meters	5	74	54	74	n/a
Cooling Module At 10 meters	10	70	54	69.9	n/a
P1 Parking Lot	62	53	48	51.4	6.4
P2 2 Lebanon	37	48.5	44	46.6	1.6
P3 664 Tower	42	52.5	44	51.8	6.8
P4 660 Tower	45	51.5	43	50.8	5.8
P5 490 Blue Hills	76	50.5	52	Not Heard	OK
P6 488 Blue Hills	79	53.5	54	Not Heard	OK
P7 57 Woodstock	58	45			OK
P8 53 Woodstock	59	46	38	45.3	0.3
P9 49 Woodstock	63	45	42	42	OK
P10 43 Woodstock	69	45			OK
P11 40 Woodstock	69	45			OK

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 City of Hartford Noise Code (Ref. 2) adopts similar provisions and will be used to evaluate the noise generated by the Doosan Fuel Cell Power and Cooling Modules. The following subsections discuss each type of noise and describe the results obtained from the measurements at the Mount Sinai Hospital site.

Impulse Noise

The Connecticut regulation for the control of noise 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 nighttime to any class A Noise Zone. Class A Noise Zones are residential and hotel areas. Nighttime hours are defined as 10 pm to 7 am. The City of Hartford regulation for the control of noise states in *section 23-3 Noise Levels* that no person shall cause or allow the emission of impulse noise in excess of 80 dB peak sound pressure level during the nighttime to any residential noise zone. Hartford nighttime hours are defined as 10 pm to 7 am except for Saturday night where nighttime hours are defined as 10 pm to 9 am.

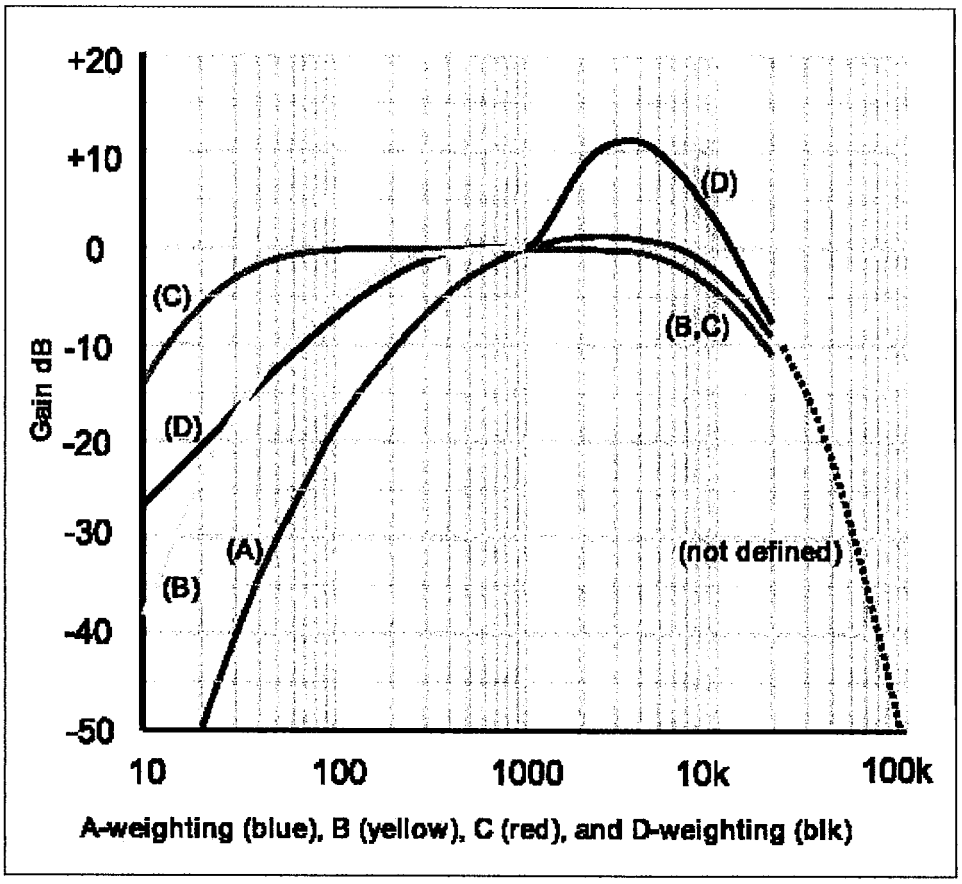
Both the CT section 22a-69-3.2 (part b) Impulse Noise and Hartford noise code in Section 23-3 state that no person shall cause or allow the emission of impulse noise in excess of 100 dB peak sound pressure level at any time to any Noise Zone.

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 4 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 by 10 dB at 20 kiloHertz.

Impulse noise in excess of 80 dB was not observed during any of the measurements made at Mount Sinai on 18 and 19 January, 2017. Given the steady state nature of the fuel cell's noise signature there should be no acoustic issue with the city and state's impulse noise requirements.

Figure 4. Acoustic Weighting Curves

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



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 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 such as ADP are in Class B. Forestry and related services are in Class C. By my reading of the Regulations Mount Sinai Hospital is a Class A emitter. The noise zone standards general 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 55 dBA 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 requirements for operating at the Mount Sinai Hospital site for discrete tones would be

50 dBA for the surrounding properties during the day and 40 dBA at night.

The photo in figure 5 plots the airborne noise measured 10 meters from the Cooling Module for frequencies from 0 to 1000 Hertz. This curve shows the two largest discrete tones produced by the 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. 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 at a distance 10 meters from the Cooling Modules. Table 2 shows a transmission drop of 18 dB from the overall source level of 70 dBA 10 meters from the Cooling Module to the neighbor with the highest overall noise level (52 dBA). If this transmission loss is applied to the discrete tones the nearest neighbor should see levels of 26 dB at 86 Hertz and 36 dB at 630 Hertz. Both levels fall below the 40 dBA limit and there should be no issue with discrete tones.

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 common 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.

Narrow bandwidth sound pressure spectrums in dB reference 20 microPascals at the 10 meter Cooling Module location can be used to compare with these noise requirements. Data was processed in the 100 Hertz and 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 6. The maximum level at 10 meters is 57 dB reference 20 microPascals. The entire 20 Hertz band power sums to 66 dB reference 20microPascals. The ultrasonic noise for frequencies up to 100 KiloHertz is given in Figure 7. The maximum level at 10 meters is 20dB reference 20 microPascals. The entire 80 KiloHertz band power sums to 31 dB reference 20microPascals. Both levels fall well below the 100 dB limit 10 meters from the Cooling Module. The noise levels at the neighbors will be approximately 18 dB or more lower and there should be no issue with either infrasonic or ultrasonic noise. It should be noted that while the spectrum analysis covers frequencies up to 100 kiloHertz, the microphone sensors lose sensitivity above 25 kiloHertz. The flat response below 25 kiloHertz changes to a roll off that reduces the amplitudes at the very high frequencies. Fortunately, the measured noise levels are very low at 20 kiloHertz and decrease with frequency above that and thus, no ultrasonic acoustic issues are expected above 25 kiloHertz.

Figure 5. Discrete Tones Produced by the Fuel Cell Cooling Module (0 dBV = 88.6 dB re 20uPa)

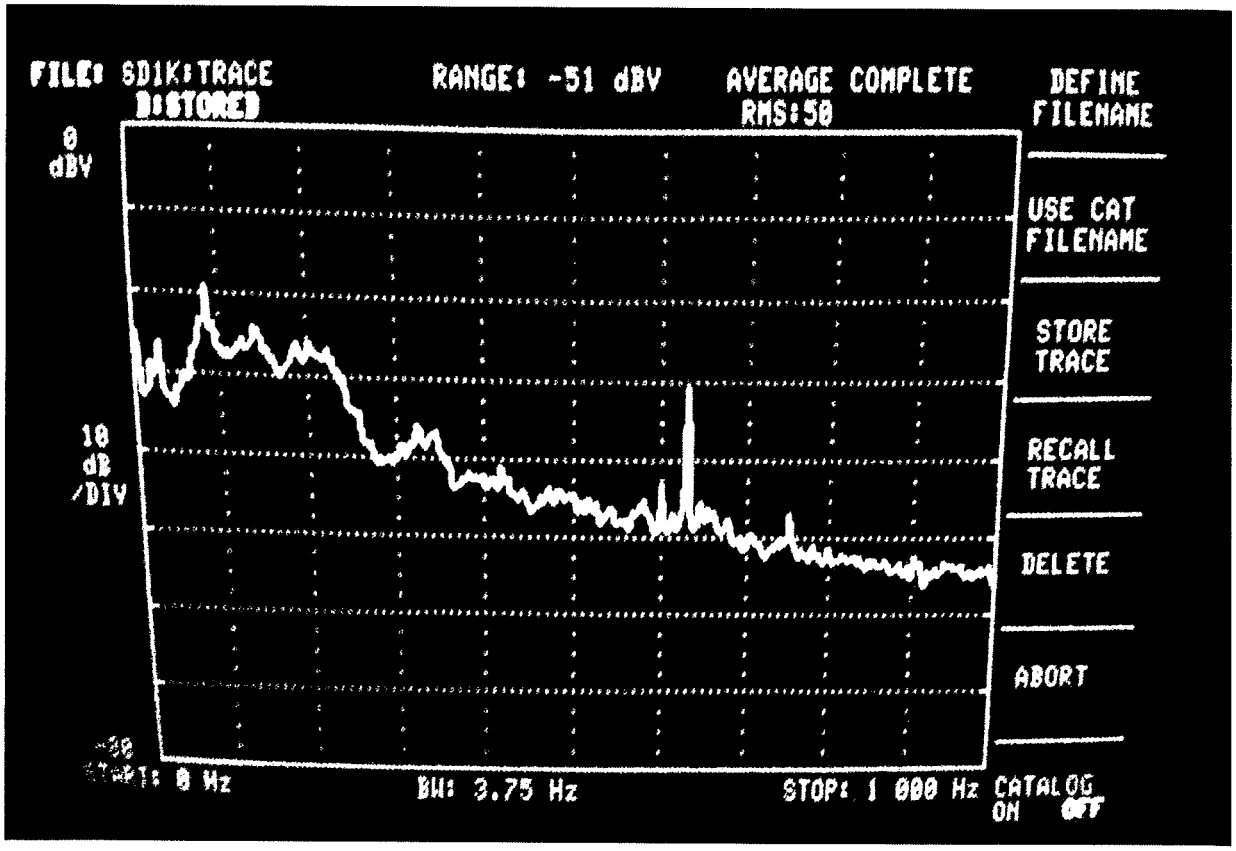


Figure 6. Infrasonic Noise from the Fuel Cell Cooling Module (0 dBV = 88.6 dB re 20uPa)

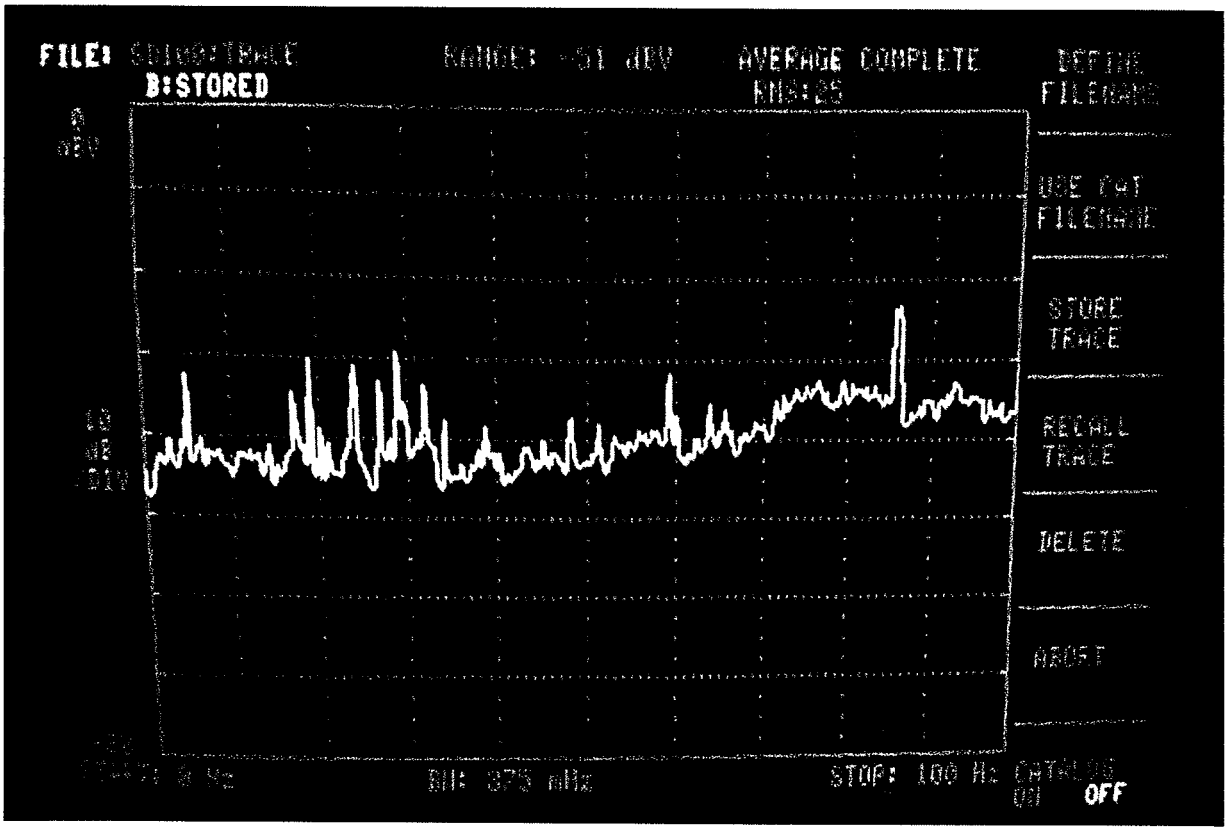
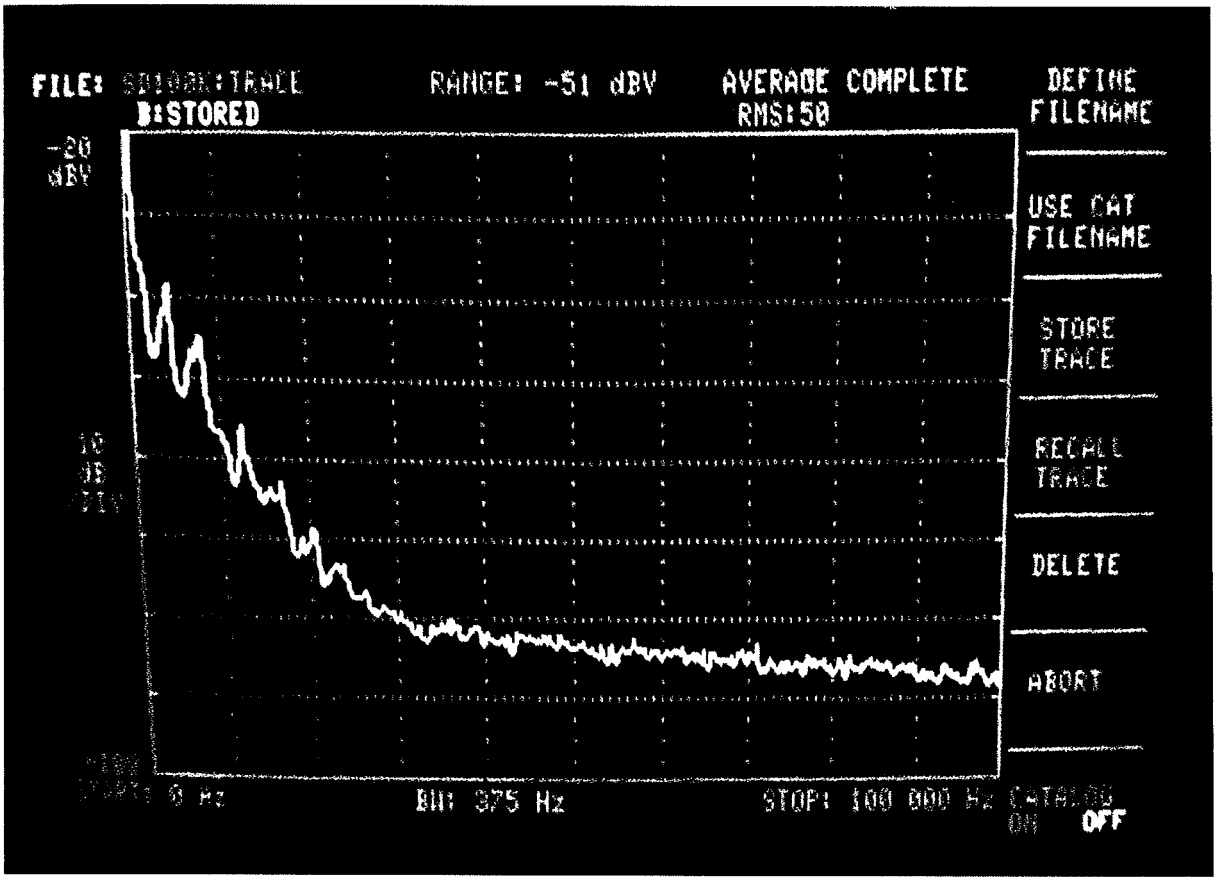


Figure 7. Ultrasonic Noise from the Fuel Cell Cooling Module (0 dBV = 88.6 dB re 20uPa)



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

This subsection is the most important noise requirement in the Connecticut noise ordinance. The Hartford noise ordinance uses the same noise levels modifying only the definition of nighttime hours on Sunday. Mount Sinai Hospital falls into Class A. Please see *CT section 22a-69.2 Classification of land according to use* of the Connecticut noise ordinance for details.

It is important to establish the adjacent noise zones. In this case the homes along Tower Avenue to the north and Woodstock Street to the south are Class A (Residential with the Hartford Zoning Codes labeled Neighborhood, N-4-1 and N-4-2). The Mount Sinai Hospital itself and the adjacent properties to the east and west are in a Mixed Use MX-2 zone which is also Class A.

The overall A-weighted sound pressure level measurements in dBA reference 20 microPascals are given in Table 2 above. The second column gives the approximate distance from the Cooling Module to the measurement location, identified by a P number in Figure 3. Column 3 gives the

noise levels measured with the Cooling Module fans at full speed while column 4 gives the levels with the Cooling Module off. Background corrections are applied to column 3 and the adjusted Cooling Module noise is given in column 5. These levels with the background noise removed are estimates of the contribution provided only by the Fuel Cell and Power Modules. The sixth and last column shows the amount by which the Fuel Cell noise exceeds the nighttime state and city requirements at five of the neighboring locations. On Tower Avenue, the levels are up to 7 dB above the 45 dBA limit. On Woodstock Avenue, the airborne noise levels are very close to the 45 dBA limit being 0.3 dB higher at one location. On Woodstock Avenue, it is very difficult to detect the operation of the fuel cells. The 46 dBA operational measurement at 53 Woodstock Avenue may have been a short-term increase in background noise rather than an increase due to the operation of the fuel cell. Operation of the fuel cell has no significant acoustic impact on Woodstock Avenue.

While only three locations were measured on Tower Avenue estimates can be made for the fuel cell noise reaching the remaining homes in the block opposite the hospital. Given the data at 664 and 660 Tower Avenue the distance spreading loss follows a 29 Log (receiver / source distance) formula. The following table shows that three more homes would have fuel cell levels above the nighttime limit of 45 dBA.

Table 3 Measured and Estimated Airborne Noise Levels Along Tower Avenue

House Number	664	660	656	652	648	644	640	636	632
Meters	42	45	51	58	66	75	83	92	100
dBA	51.8	50.8	49.5	47.9	46.2	44.6	43.3	42.1	41.0
	Actual	Actual	Est.	Est.	Est.	Est.	Est.	Est.	Est.

Reviewing Table 2 it is clear that the Cooling Module generates airborne noise levels that are above the state and city nighttime requirements at the nearby property lines on Tower Avenue. The fuel cell meets the daytime noise limit at all the measured locations. The background levels vary from 38 to 54 dBA depending on the location. Airborne noise levels at all the neighboring homes showed levels below 45 dBA when the Cooling Module was off. The property line on Blue Hills Avenue across the street from the Mount Sinai Hospital entrance displayed high airborne noise levels due to ventilation fans in the hospital. Airborne noise from the Cooling Module was not detected on Blue Hills Avenue and should not be an issue. The fuel cell airborne noise level of 51.4 dBA at the east end of the parking lot was also above the nighttime noise limit of 45 dBA.

Conclusions

The purpose of this effort is to evaluate the acoustical environment at the Mount Sinai fuel cell site in Hartford, CT. This has been accomplished and the results show that the acoustic impact on nearby homes on Tower Avenue may need to be addressed. Operation of the fuel cell meets all of the city and state noise requirements except for the overall nighttime limit. The five nearest homes on Tower Avenue maybe up to 7 dB above the nighttime 45 dBA limit.

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) Chapter 23, Hartford Municipal Code, Noise Code Amendment adding Section 23

MT. SINAI - 2

NOISE TREATMENT RECOMMENDATIONS

Prepared For: Doosan Fuel Cell America Inc.

Point of Contact: Walter Bonola

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

Subject: Mount Sinai Rehabilitation Hospital
Noise Treatment Recommendations

Author: Carl Cascio

Date: February 17, 2017

Revision: 2

Table of Contents

Summary

This document makes acoustic noise control recommendations that should assist in meeting the acoustic noise concerns during the operation of a Doosan Purecell® Model 400 fuel cell at the Mount Sinai Rehabilitation Hospital in Hartford, 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 operation of the Doosan Purecell® Model 400 fuel cell

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 nearby property lines. 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 at least 37.7 linear feet of 8 foot high barrier material is needed on the front and north sides of the cooling module. This amount of barrier material should meet the nighttime noise limits at all the neighboring property lines. Additional margin is recommended and would be provided by adding another 10 feet of barrier material on the 10 foot fence section to the left of the gate. Given this noise treatment the airborne noise generated by the fuel cell will not significantly impact the hospital's neighbors and will be below all the requirements at all the property lines.

Introduction

Acoustical Technologies Inc. was tasked with an assessment of potential acoustic issues associated with installing a new Doosan Purecell® Model 400 Fuel Cell that could create airborne noise reaching the properties adjacent to the Mount Sinai Rehabilitation Hospital site in Hartford CT. Responding to a request from Walter Bonola, a site visit was made on January 18, 2017. During the visit a survey of the airborne noise levels produced by the Doosan Purecell® Model 400 Fuel Cell was made in order to identify potential noise issues. The fuel cell was operating in a maximum cooling mode with the cooling fans in the highest operating speed. Noise measurements were taken to quantify the fuel cell airborne noise levels. In was not possible to turn the Doosan unit off on January 18 so a return trip was made on January 19 to measure the background airborne noise levels with the cooling fans off. This document provides recommendations for the installation of a noise control treatment that will eliminate these acoustic noise concerns during operation of the fuel cell.

The purpose of this effort is to utilize the available acoustic information to mitigate the potential airborne noise issues associated with the operation of the Doosan Fuel Cell at Mount Sinai Rehabilitation Hospital in Hartford, CT. The City of Hartford noise ordinance and the State of Connecticut Noise Code have been consulted to assess the impact of the measured and estimated acoustic levels. Noise mitigation is needed to reduce the airborne noise propagated by the fuel cell to the neighbor's property lines on Tower Avenue

Acoustic Measurement Program

Airborne sound pressure measurements and audio tape recordings were conducted at and near 490 Blue Hills Avenue on the nights of January 18 and 19, 2017 to establish both background airborne noise levels and airborne noise levels with the Doosan Purecell® Model 400 fuel cell operating. At the hospital site fuel cell and background airborne noise measurements were taken at each neighbor's property line on Tower Avenue and Woodstock Street and also at the property line at the east end of the hospital parking lot. Measurements were made on Blue Hills Avenue across the street from the front entrance to the hospital. Measurements near the operating fuel cell were simultaneously taken with a sound level meter and two microphones recording on the digital tape recorder. See Figures 1 and 2 below for photographs of the Fuel Cell Power and Cooling Modules. Figure 3 has a Google Map of the hospital site with the measurement locations identified in black as P1 through P11. The Power Module is identified in black as Location A and the Cooling Module as Location B.

Figure 1. Doosan Fuel Cell Power Module

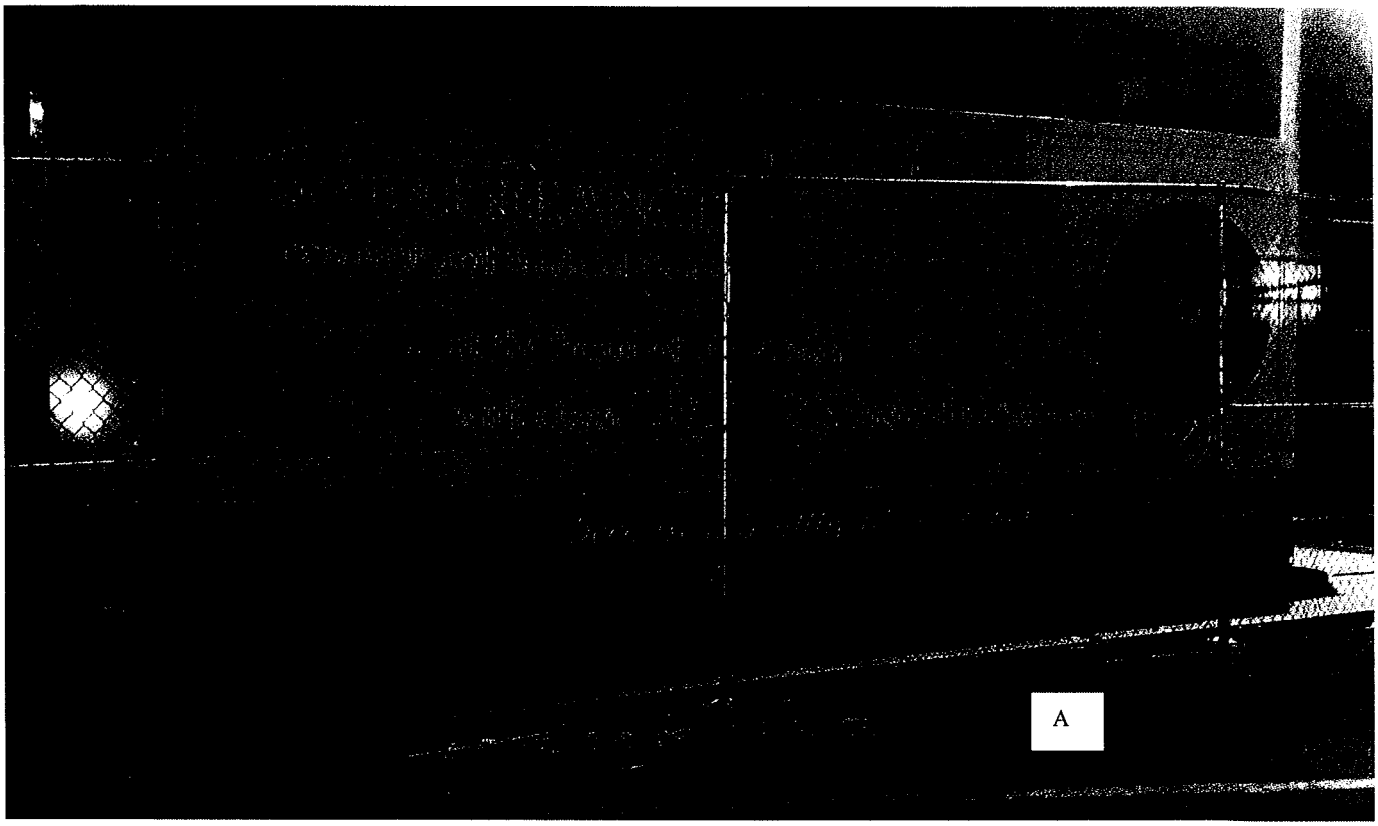


Figure 2. Doosan Fuel Cell Cooling Module

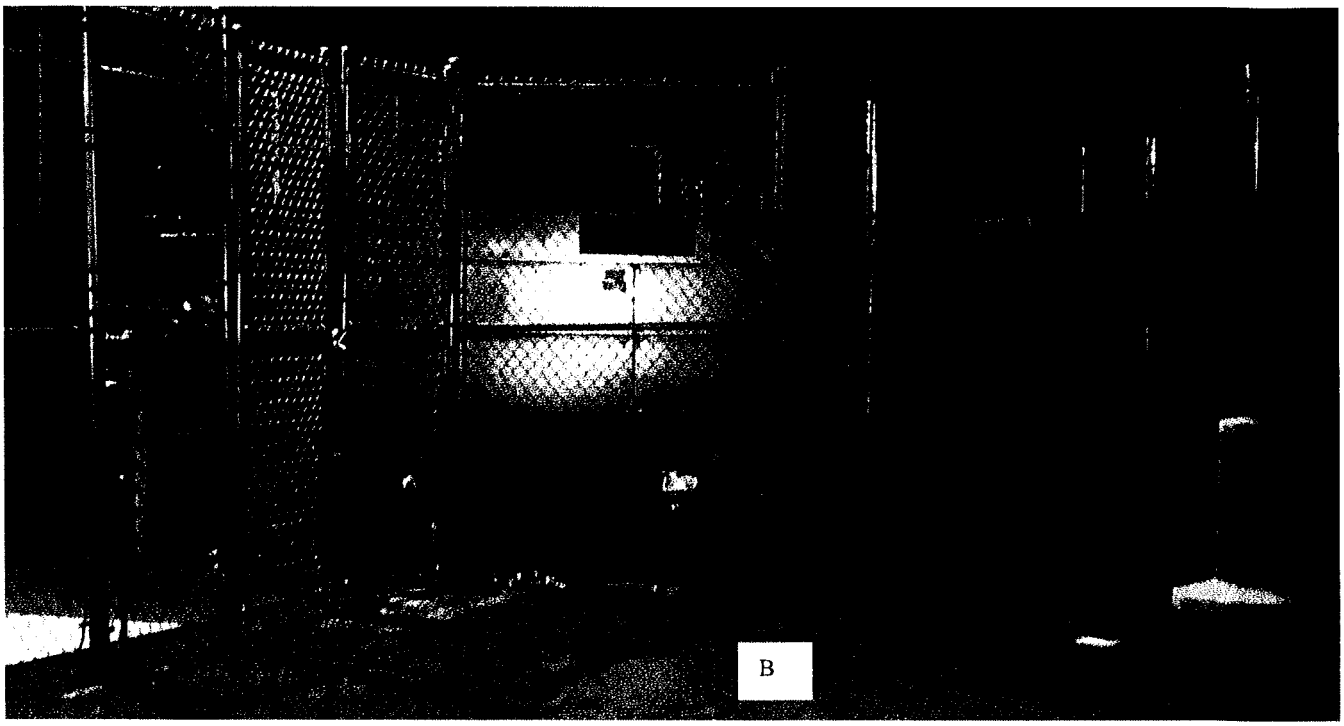


Figure 3. Mount Sinai Site Map from Google

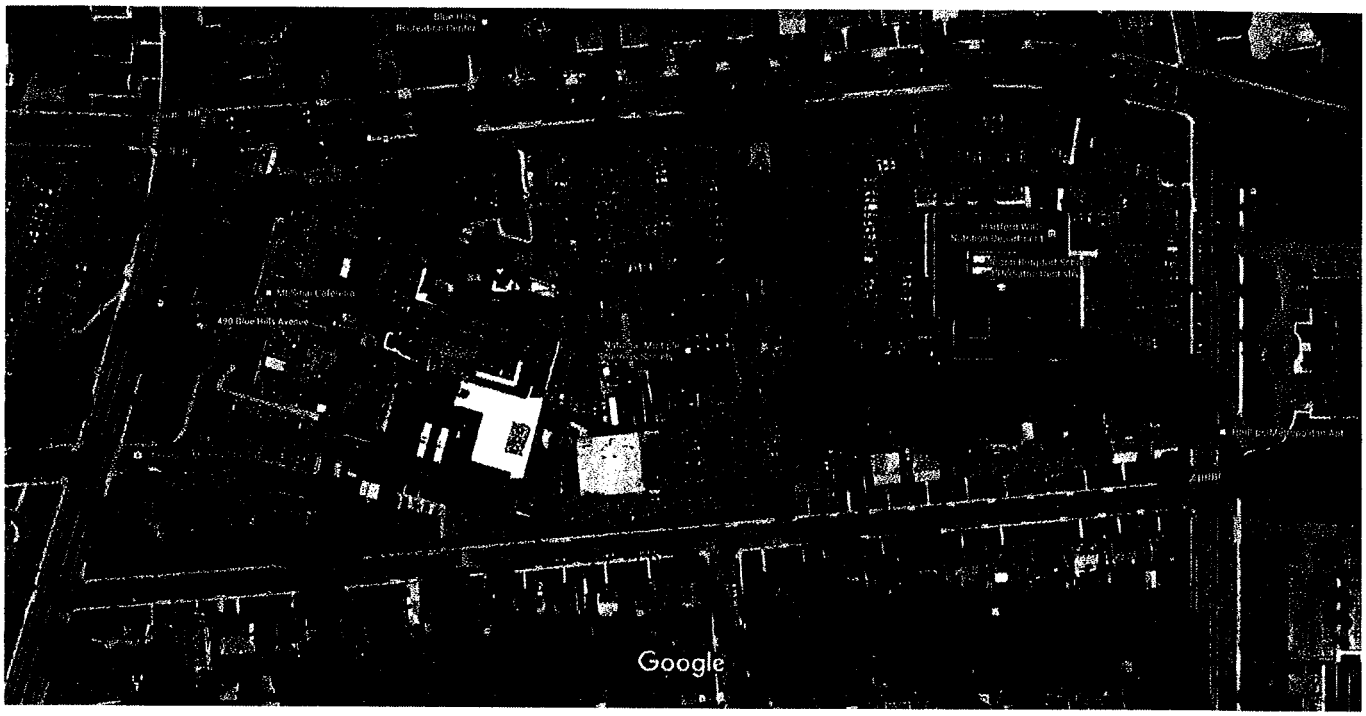


Table 1. Overall Sound Pressure Measurements near Mount Sinai Rehabilitation Hospital

Location	Distance (meters)	Fuel Cell On	Cooling Modules Off (Background)	Background Corrected	Excess dBA
Power Module At 5 meters	5	70	52.5	69.9	n/a
Power Module At 10 meters	10	69.5	52.5	69.4	n/a
Cooling Module At 5 meters	5	74	54	74	n/a
Cooling Module At 10 meters	10	70	54	69.9	n/a
P1 Parking Lot	62	53	48	51.4	6.4
P2 2 Lebanon	37	48.5	44	46.6	1.6
P3 664 Tower	42	52.5	44	51.8	6.8
P4 660 Tower	45	51.5	43	50.8	5.8
P5 490 Blue Hills	76	50.5	52	Not Heard	OK
P6 488 Blue Hills	79	53.5	54	Not Heard	OK
P7 57 Woodstock	58	45			OK
P8 53 Woodstock	59	46	38	45.3	0.3
P9 49 Woodstock	63	45	42	42	OK
P10 43 Woodstock	69	45			OK
P11 40 Woodstock	69	45			OK

Allowable Noise Levels

CT section 22a-69-3.1 (Ref. 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 Hartford Noise Code (Ref. 2) adopts similar provisions and both codes have been used to evaluate the noise generated by the Doosan Fuel Cell Power and Cooling Modules. The following subsections discuss the discrete tone and overall noise requirement sections and analyze the results obtained from the measurements at the Mount Sinai Hospital site in order to determine what noise controls may be applied. Impulse, Infrasonic and Ultrasonic measurements of airborne noise showed no acoustic concerns and will not be discussed further.

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. By my reading of the Regulations Mount Sinai Hospital is a Class A emitter. The requirements for operating at the Mount Sinai Hospital site for discrete tones are

50 dBA for the surrounding properties during the day and 40 dBA at night.

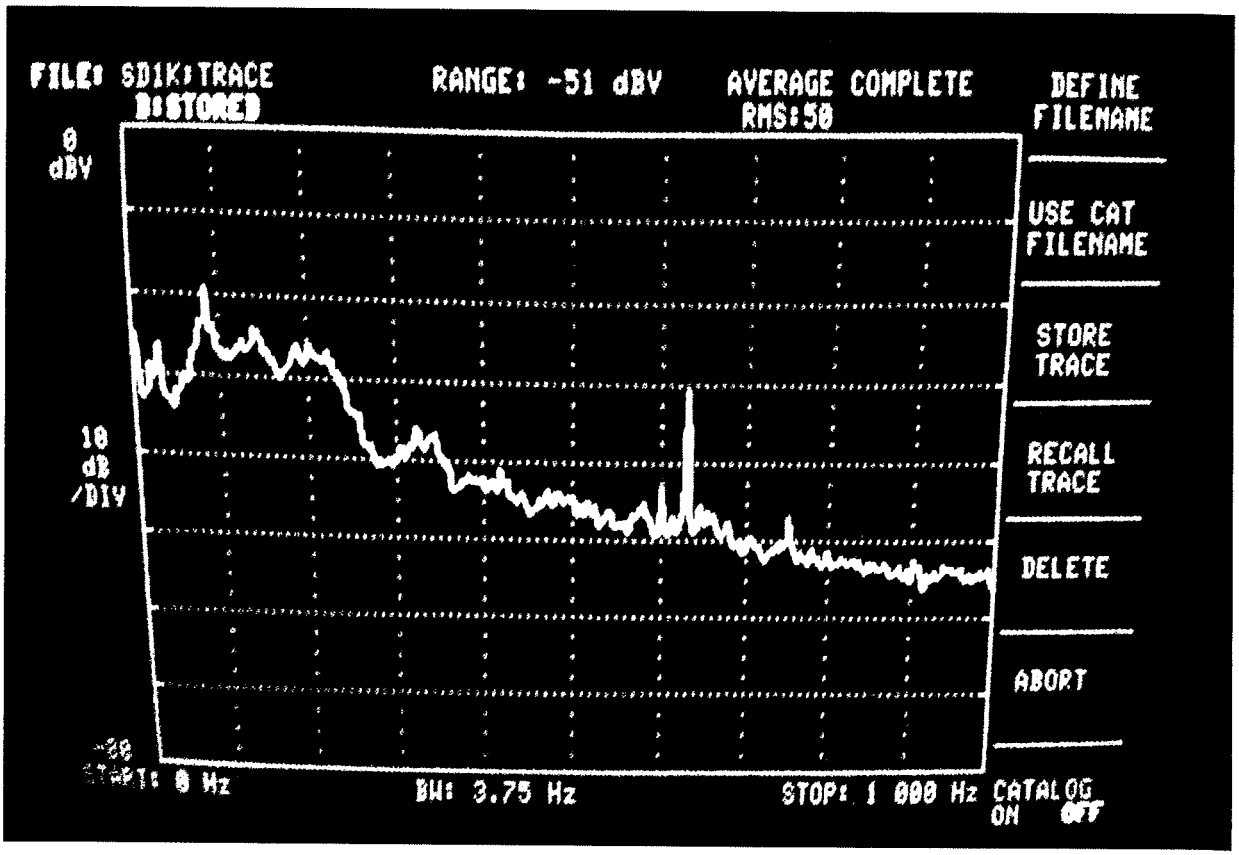
The photo in figure 5 plots the airborne noise measured 10 meters from the Cooling Module for frequencies from 0 to 1000 Hertz. This curve shows the two largest discrete tones produced by the Cooling Module. The first tone is at 86 Hertz at a level of 65 dB reference 20 microPascals. The second tone is at 630 Hertz at a level of 56 dB reference 20 microPascals. 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 at a distance 10 meters from the Cooling Modules. Table 1 shows a transmission drop of 18 dB from the overall source level of 70 dBA 10 meters from the Cooling Module to the neighbor with the highest overall noise level (52 dBA). If this same transmission loss is applied to the discrete tones the nearest neighbor should see levels of 26 dB at 86 Hertz and 36 dB at 630 Hertz. Both levels fall below the 40 dBA limit and there should be no issue with prominent discrete tones. Noise control treatments are not needed to meet the discrete tone requirement at any of the nearby neighbors.

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

Figure 5. Discrete Tones Produced by the Fuel Cell Cooling Module (0 dBV = 88.6 dB re 20uPa)



The Hartford noise ordinance uses the same noise levels modifying only the definition of nighttime hours on Sunday. Mount Sinai Hospital falls into Class A. It is important to establish the adjacent noise zones. In this case the homes along Tower Avenue to the north and Woodstock Street to the south are Class A (Residential with the Hartford Zoning Codes labeled Neighborhood, N-4-1 and N-4-2). The Mount Sinai Hospital itself and the adjacent properties to the east and west are in a Mixed Use MX-2 zone which is also Class A.

The Mount Sinai overall A-weighted sound pressure level measurements in dBA reference 20 microPascals are given in Table 1 above. The second column gives the approximate distance from the Cooling Module to the measurement location, identified by a P number in Figure 3. Column 3 gives the noise levels measured with the Cooling Module fans at full speed while column 4 gives the levels with the Cooling Module off. Background corrections are applied to column 3 and the adjusted Cooling Module noise is given in column 5. These levels with the background noise removed are estimates of the contribution provided only by the Fuel Cell and Power Modules. The sixth and last column shows the amount by which the Fuel Cell noise exceeds the nighttime state and city requirements at five of the neighboring locations. On Tower Avenue, the levels are up to 7 dB above the 45 dBA limit. On Woodstock Avenue, the airborne noise levels are very close to the 45 dBA limit being 0.3 dB higher at one location (the fuel cell noise is barely detectable). Operation of the fuel cell has no significant acoustic impact on Woodstock Avenue but does have an impact on Tower Avenue.

While only three locations were measured on Tower Avenue estimates can be made for the fuel cell noise reaching the remaining homes in the block opposite the hospital. Given the data at 664 and 660 Tower Avenue the distance spreading loss follows a 29 Log (receiver / source distance) formula. The following table shows that three more homes would have fuel cell levels above the nighttime limit of 45 dBA.

Table 3 Measured and Estimated Airborne Noise Levels Along Tower Avenue

House Number	664	660	656	652	648	644	640	636	632
Meters	42	45	51	58	66	75	83	92	100
dBA	51.8	50.8	49.5	47.9	46.2	44.6	43.3	42.1	41.0
	Actual	Actual	Est.	Est.	Est.	Est.	Est.	Est.	Est.

Reviewing Table 1 it is clear that the Cooling Module generates airborne noise levels that are above the state and city nighttime requirements at the nearby property lines on Tower Avenue. The fuel cell meets the daytime noise limit at all the measured locations. Airborne noise levels at all the neighboring homes showed levels below 45 dBA when the Cooling Module was off. The fuel cell airborne noise level of 51.4 dBA at the east end of the parking lot was also above the nighttime noise limit of 45 dBA. The airborne noise from the cooling module needs to be reduced by at least 7 dB to meet the nighttime residential noise limit.

Noise Treatment Recommendations

The two separate pieces of the Doosan hardware are shown in Figures 1 and 2 above. Airborne noise measurements have indicated that the cooling module is the dominant noise source. Since the power module noise levels are about 17 dB below the cooling module, a reduction of the noise level of the cooling module of 7 dB will still leave the cooling module dominant. The nearby property lines would see airborne noise from the cooling module at levels about 10 dB high than from the power module. As a result, we don't have to be as concerned with treating the power module. Treatment of the cooling module (i.e. reducing its noise by 7 dB) should result in about 7 dB less noise at the nearby property lines. If these numbers were exact the summation of a 35 dBA source from the power module and a 45 dBA source from the cooling module would result in airborne noise of 45.4 dBA at the property line. It would take a level of 44.5 dBA from the cooling module to give a 45 dBA summation at the property line. This increases the needed noise reduction in the cooling module by a small amount from 7 to 7.5 dB.

The cooling module is 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. The diffraction over the top of the acoustic barrier has been calculated and the results are shown in Figures 6 and 7 as a function of frequency. Figure 6 looks at the location of the receiver since the desired performance applies to the homes on Tower Avenue that have distances from the source of 37 to 51 meters. This distance range has almost no effect on the diffraction loss.

Figure 6. Acoustic Wall Performance for Different Receiver Locations

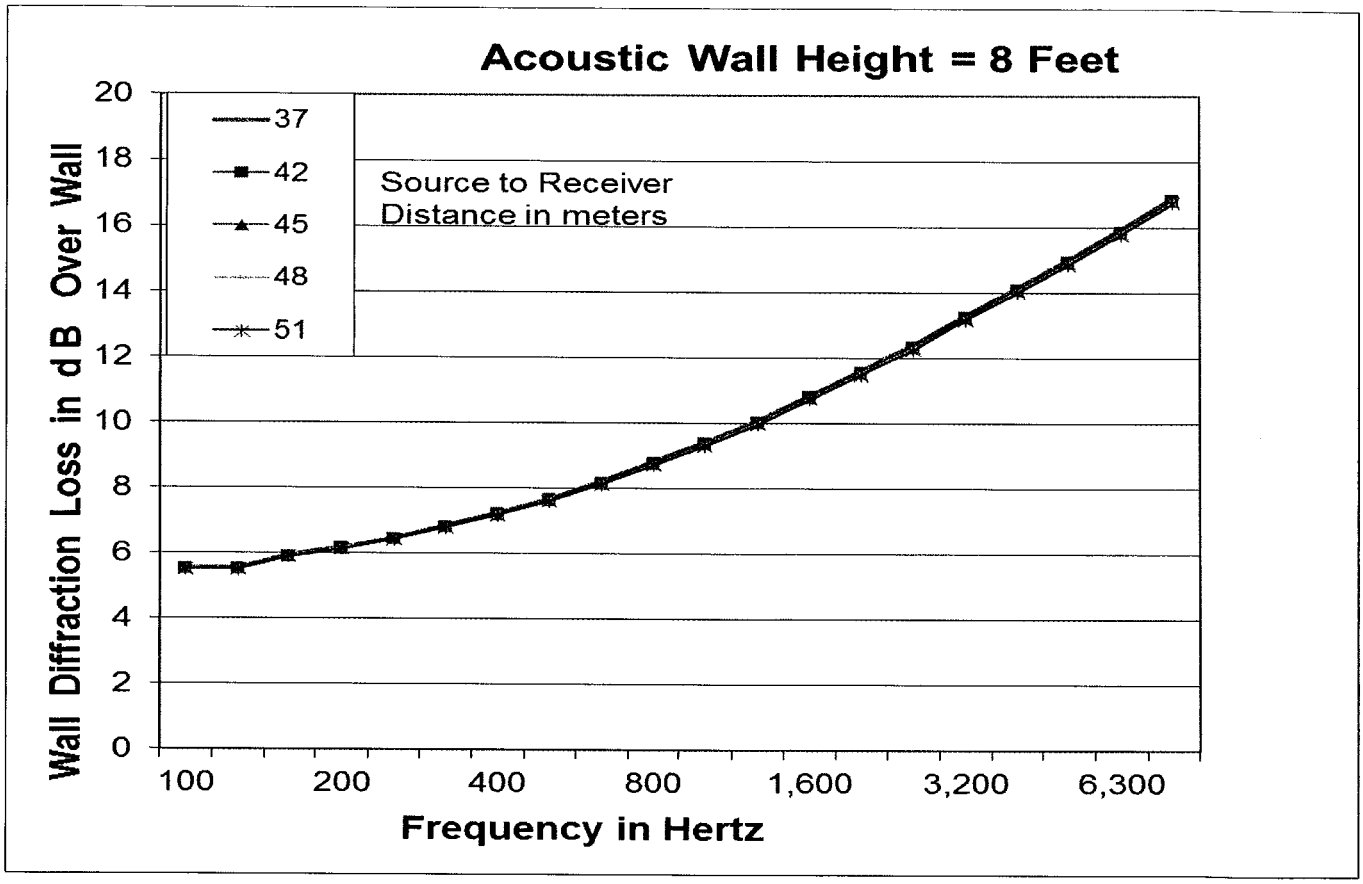


Figure 7. Acoustic Wall Performance for Different Treatment Heights

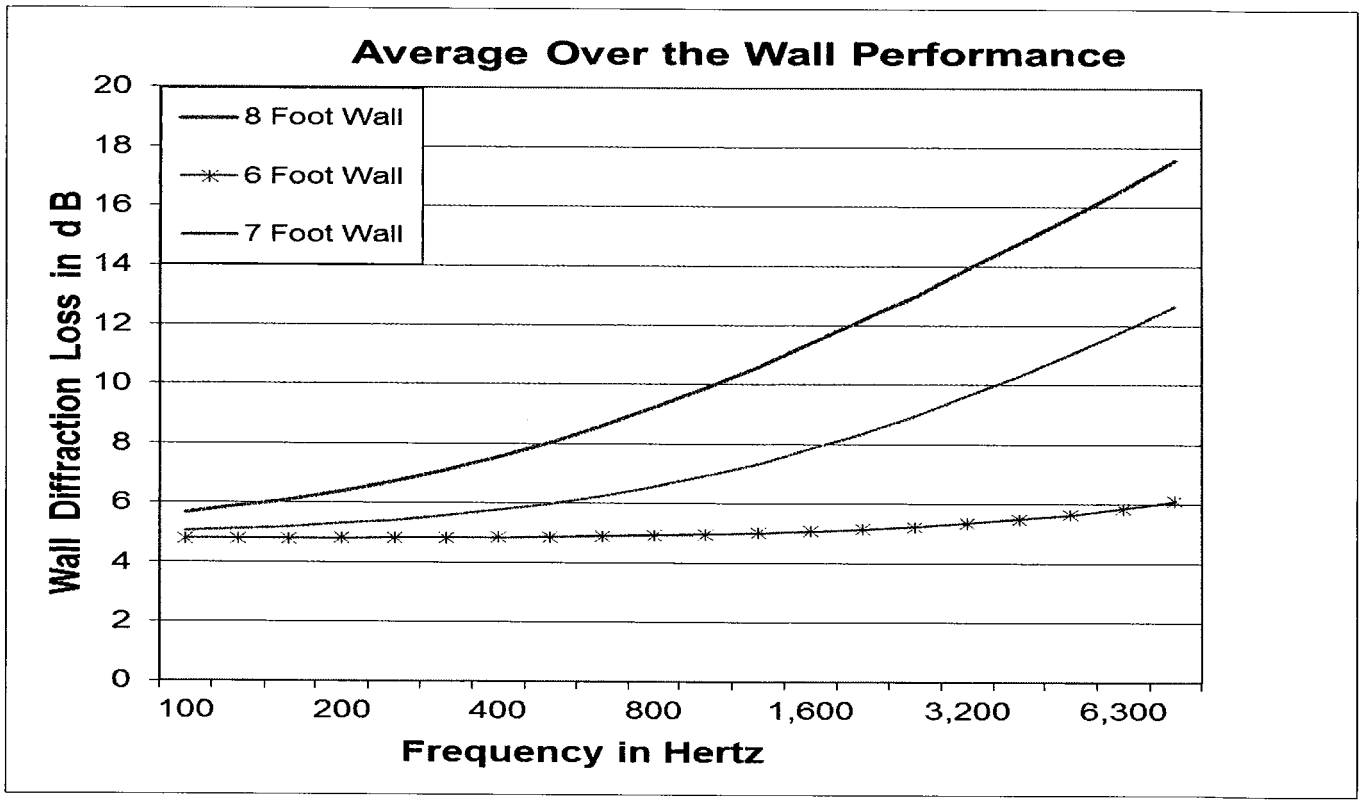


Figure 7 shows the importance of having the acoustic barrier higher than the cooling module. The top of the cooling module is about 6 feet above ground. The acoustic peformance of barriers of height 6, 7 and 8 feet have been calculated and show an ever increasing noise reduction as the height of the barrier increases. When the barrier height is the same as the cooling module height the performance is limited to about 5 to 6 dB. For another foot of barrier height the maximum performance at 8 KiloHertz increases to about 13 dB. Adding another foot causes the 8 foot barrier to increase this number to about 17 dB. We shall see that increases in performance at low frequency are very important as well, especially in the 160 to 250 Hertz region.

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 Curtains is shown in Figure 8 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.)

To evaluate the ability of this material to provide the 7.5 dB of performance we need requires the combination of both paths leading to an estimate of the airborne noise level at the property lines on Tower Avenue. This has been done and the results are shown in Figure 9. The calculation starts with the one-third octave airborne noise levels actually measured 10 meters from the cooling module. These levels are then attenuated by the barrier losses shown in Figure 8 to produce a direct and a diffraction component all at 10 meters. These two levels are then attenuated by 18 dB to account for the propagation loss measured at 664 Tower Avenue. The two results are then power summed to provide the estimate of airborne noise at the property line of 664 Tower Avenue as shown in Figure 9. The one-third octave bands are power summed to calculate the overall dBA for each material wall height with the calculated values shown in the figure caption. The estimate indicates that the material height of 8 feet just meets the nighttime noise limit while the 7 foot wall falls 1.4 dB short and the 6 foot wall falls 2.6 dB short. Note that 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.

Installation of an eight foot high acoustic barrier is recommended to mitigate the airborne noise reaching the property lines on Tower Avenue. Materials such as the ABBC-EXT-R Sound Curtains from Acoustical Solutions or equivalent should be sufficient to produce the 7.5 dB of sound reduction needed. Coverage should extend to the front and north side of the cooling module enclosure. Looking at Figure 2, the north side has two panels each about 8 feet wide. The front side has two large panels, 6 foot and 6 foot 8 inches next to the gate which has three sections that are about 3 feet wide. In looking at Figure 2 I would recommend covering these three panels so the treatment extends a couple of feet beyond the cooling module when looked at from the homes on Tower Avenue. This would make the diffraction performance around the side of the treatment similar to that over the top of the treatment. The length of the necessary treatment would be about 37 feet 8 inches with a height of 8 feet for a surface area of 301 square feet. To provide additional margin I would recommend covering the 10 foot panel next to the gate. This will block some of the noise coming from the exhaust fan on the west end of the power module as well as the cooling module noise diffracting around the side. The treatment coverage is shown in Figure 10 below requiring 47.7 linear feet by 8 feet high.

Figure 8. The Effect of an Acoustic Barrier on Transmission to Nearby Properties

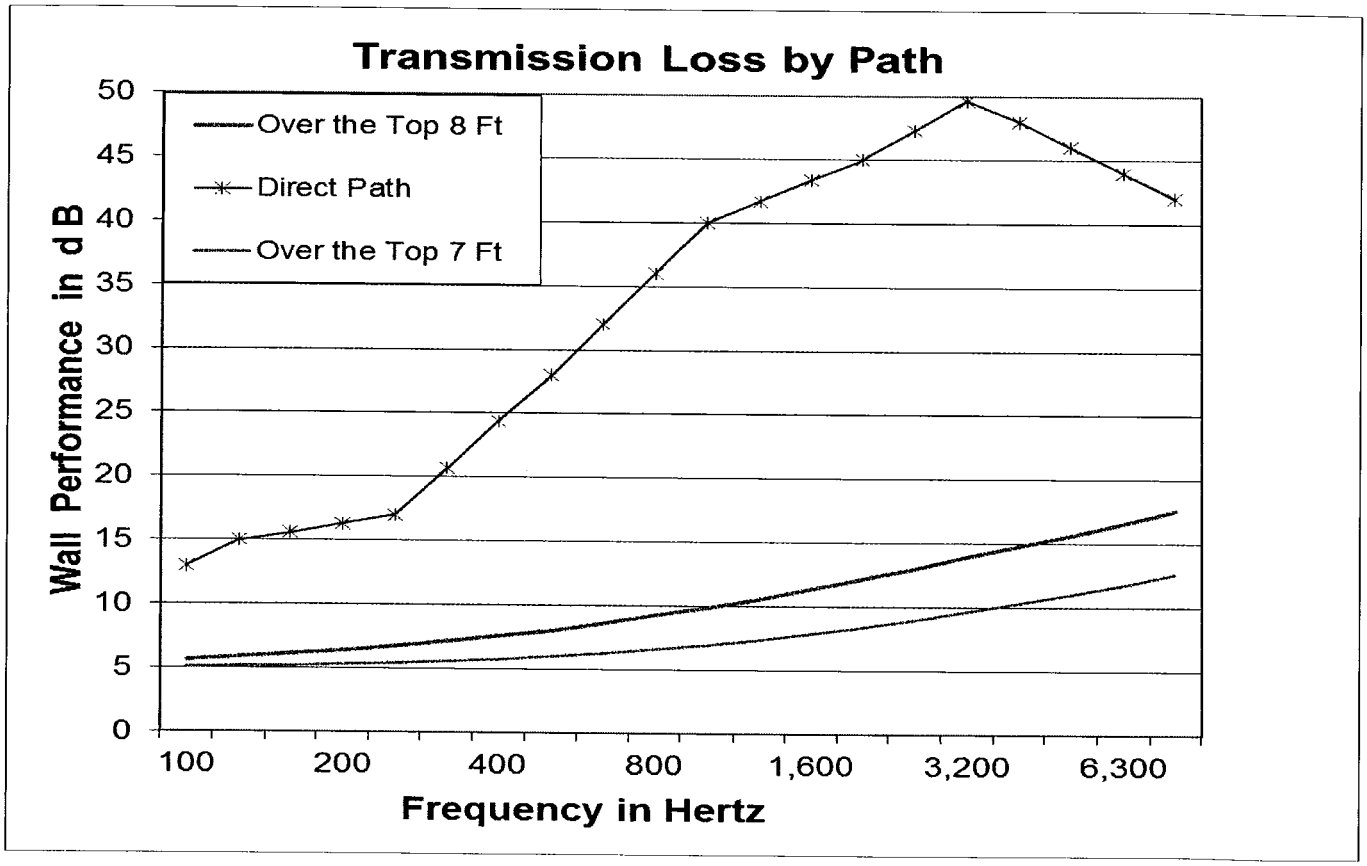


Figure 9 Estimated Tower Avenue Airborne Noise Levels versus Wall Height

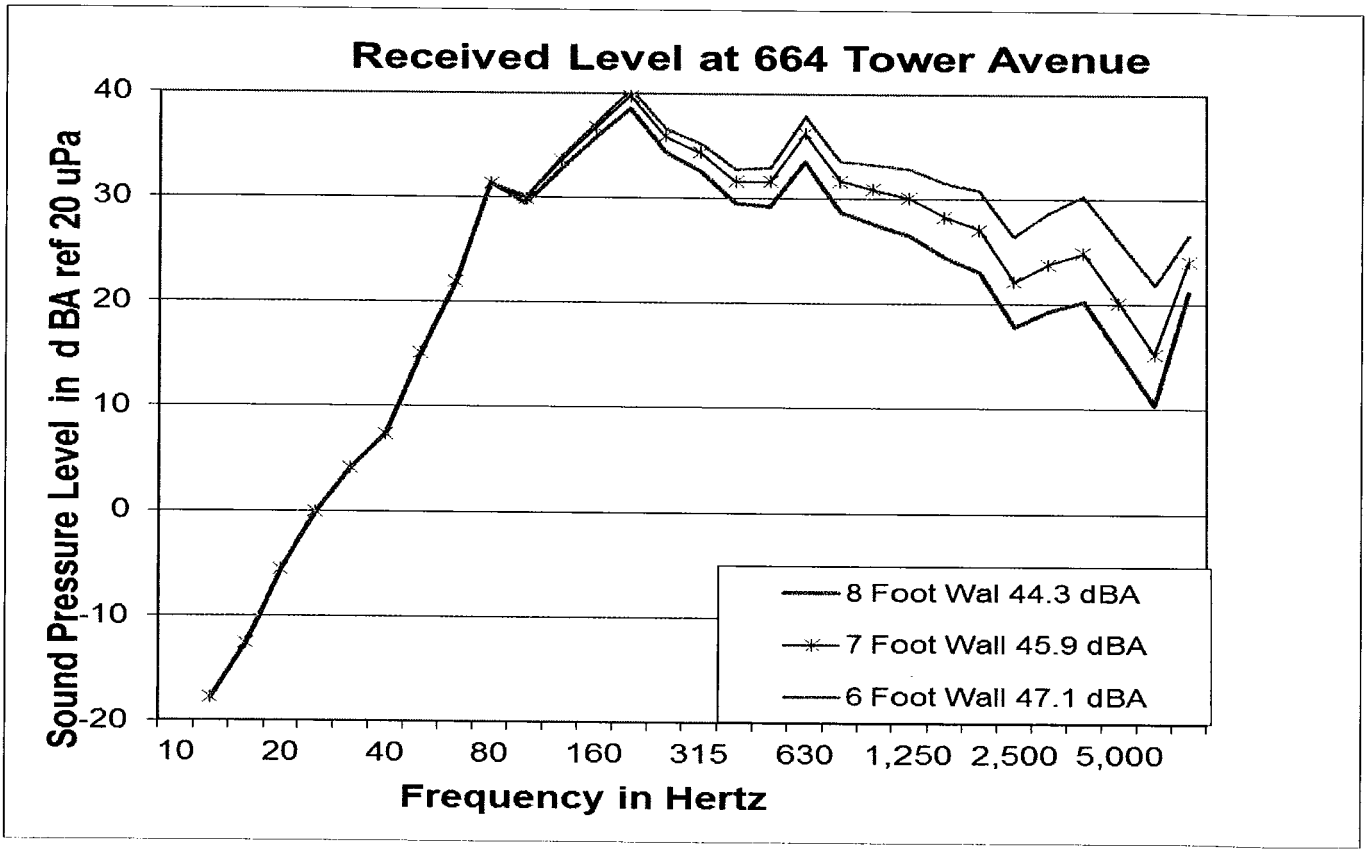
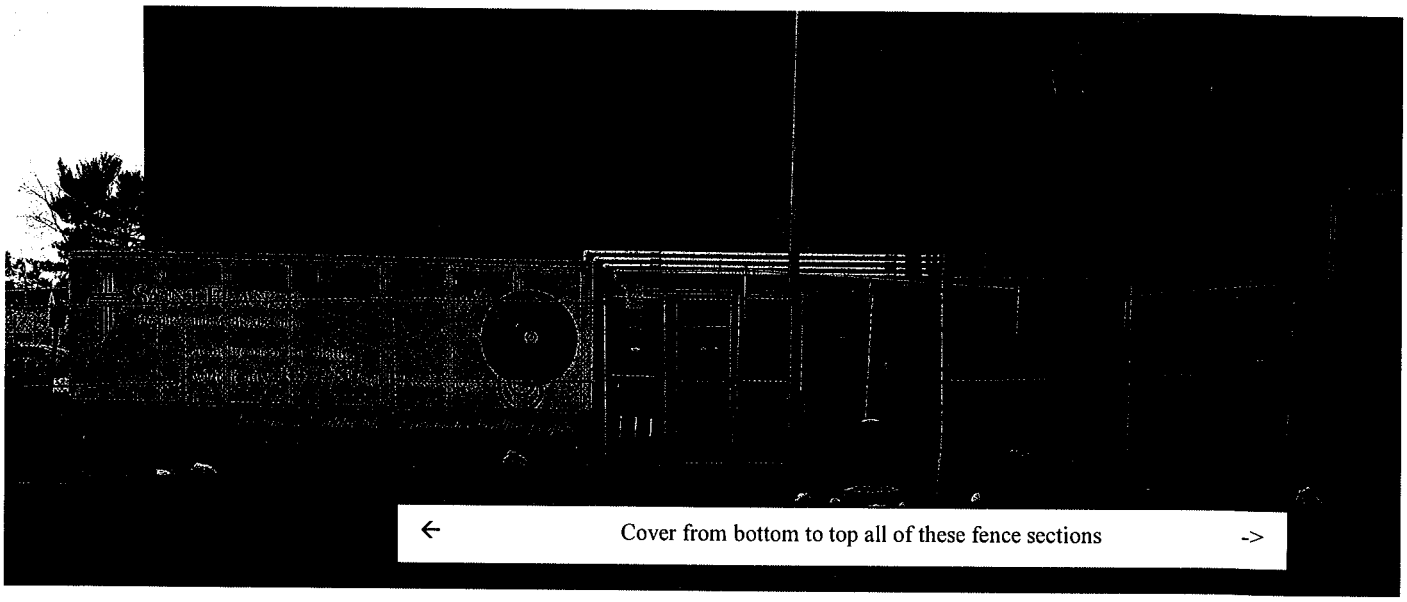


Figure 10. Doosan Power and Fuel Cell Modules Viewed from Tower Avenue



Conclusions

The purpose of this effort has been to evaluate the acoustical environment at the Mount Sinai fuel cell site in Hartford, CT. This has been accomplished and the results show that the acoustic impact on nearby homes on Tower Avenue needs to be addressed. Operation of the fuel cell meets all of the other city and state noise requirements except for the overall nighttime limit. The five nearest homes on Tower Avenue are up to 7 dB above the nighttime 45 dBA limit. An eight foot high acoustic barrier as described in this report should mitigate this noise issue.

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) Chapter 23, Hartford Municipal Code, Noise Code Amendment adding Section 23 www.ct.gov/deep/lib/deep/air/noise/ordinances/hartford_noise_ordinance.pdf

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