Prepared For: Doosan Fuel Cell America Inc.

Point of Contact: Walter Bonola

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Subject: Bristol Treatment Plant
Airborne Noise Assessment
At 75 Battisto Road

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Summary

This document makes a positive acoustic assessment that should assist in meeting any acoustic noise concerns during the operation of a Doosan 440 KW fuel cell at the Bristol Treatment Plant site at 75 Battisto Road in Bristol, 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 Bristol 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 17 to 19 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 160 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 190 meters from the proposed fuel cell location at the Treatment Plant. The speakers produced overall A-weighted sound pressure levels of approximately 93 dBA at 5 meters and 87 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 50 to 68 dBA. Residential measurement locations to the west were too far away to be able to measure the airborne noise with the speakers on. Business and Industrial measurement locations to the east were background limited in most cases because of the high noise levels from the other equipment at the Treatment Plant. Analysis of the speaker data indicated propagation losses of at least 27 dB from the fuel cell location to the nearby property lines on Middle Street. 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 Bristol fuel cell airborne noise estimates.

Operation of the Doosan fuel cell should produce airborne noise levels well below the Business and Industrial Zone noise limits at all of the nearby property lines. The highest expected airborne noise level of 41 dBA will be at the Middle Street vacant lot northeast about 98 meters from the fuel cell Cooling Module. The other Business and Industrial properties should see airborne noise levels no higher than 40 dBA. All of the nearby residential property lines are expected to be below both the day time and night time residential noise limits because of the very large distances to the homes. 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 Bristol Treatment Plant site at 75 Battisto Road in Bristol, CT. Responding to a request from Walter Bonola, a site visit was made on April 17, 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 75 Battisto Road in Bristol, 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 Bristol Treatment Plant site in Bristol, CT. The Treatment Plant at 75 Battisto Road is located in an Industrial Zone near Middle Street. This industrial zone is surrounded by Business zones to the northeast and west, Residential zones to the west and north and another Industrial zone to the east. (The Bristol 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 15 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 Bristol 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 proposed fuel cell site to the nearest Business 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. The nearest Residential area is more than 300 meters away, too far to be affected by fuel cell noise.

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 Bristol site on and near 75 Battisto Road on April 17, 2019 during the morning 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.

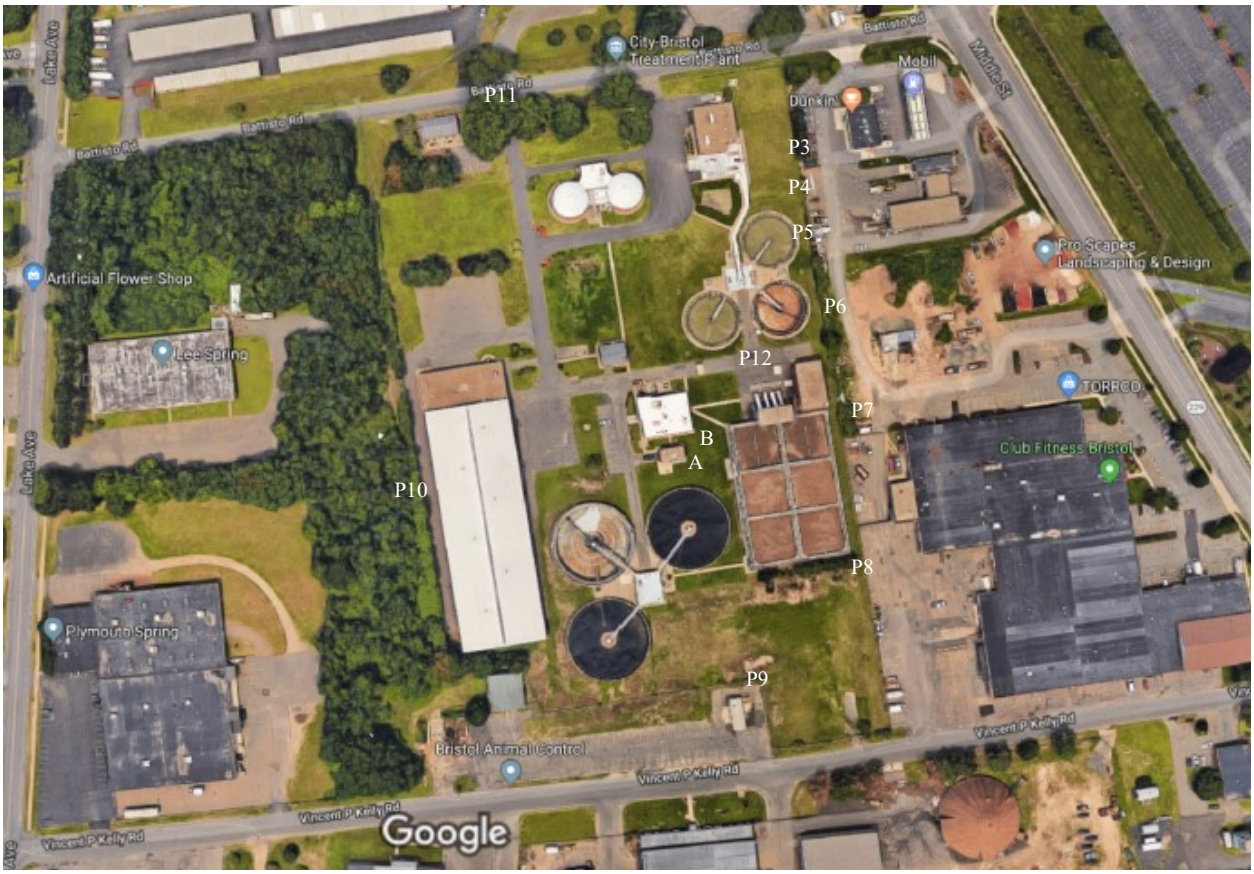
At the Bristol site "speaker on" and background airborne noise measurements were taken at the following nine nearby property lines in the Industrial and Business Zones:

Location	**Business**	**Distance**	**Zone**	**Type**
P1 – 5 meters on site	Bristol Treatment	5 meters	I	Industrial
P2 – 10 meters on site	Bristol Treatment	10 meters	I	Industrial
P3 – 330 Middle Street	Dunkin Donuts	136 meters	BG	Business
P4 – 334 Middle Street	Car Wash	126 meters	BG	Business
P5 – 338 Middle Street	Vacant Lot	98 meters	BG	Business
P6 – 342 Middle Street	Proscapes	86 meters	I	Industrial
P7 – 346 Middle Street	Landscaping	68 meters	I	Industrial
P8 – 400 Middle Street	Torrco	86 meters	I	Industrial
P9 – 126 Vincent P Kelly Road	Animal Control	91 meters	I	Industrial
P10 – 281 Lake Avenue	Plymouth Spring	121 meters	I	Industrial
P11 - 75 Battisto Road South	Treatment Entrance	190 meters	I	Industrial
P12 – 50 meters on site	Settling Tanks	58 meters	I	Industrial

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 Cooling and Power modules, respectively. Site A represents the Cooling Module that is further from Middle Street than the Power Module. Site B represents the Power Module that is closer to Middle Street. 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 0.3 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. Bristol Treatment Plant 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 Bristol for the acoustic measurements on April 17, 2019. Measurements were taken over the period from 8:50 am until 12:08 pm. Table 1 shows the temperature and wind speeds in hourly intervals. Wind conditions were very good all morning. Also, there was no rain during the testing. The Treatment Plant generated most of the background noise causing high background noise levels near the plant buildings and settling ponds. Motor traffic along the nearby roads was light and very few of the measurements had to be delayed until traffic was absent. Background noise levels at all of the measurement positions were high with levels from 50 to 68 dBA. The background noise was generated by pumping water and the use of compressed air in the plant’s treatment systems. At all of the property lines it was not possible to audibly hear the airborne noise from the speakers over that from the plant’s background noise. A site within the plant (P12) at 50 meters from the Power Module speaker location was selected to determine propagation loss. At this site the speaker noise could be heard well above the plant background noise and noise loss versus range could be determined.

Figure 2. Doosan Cooling Module Location at the Bristol Treatment Plant Site

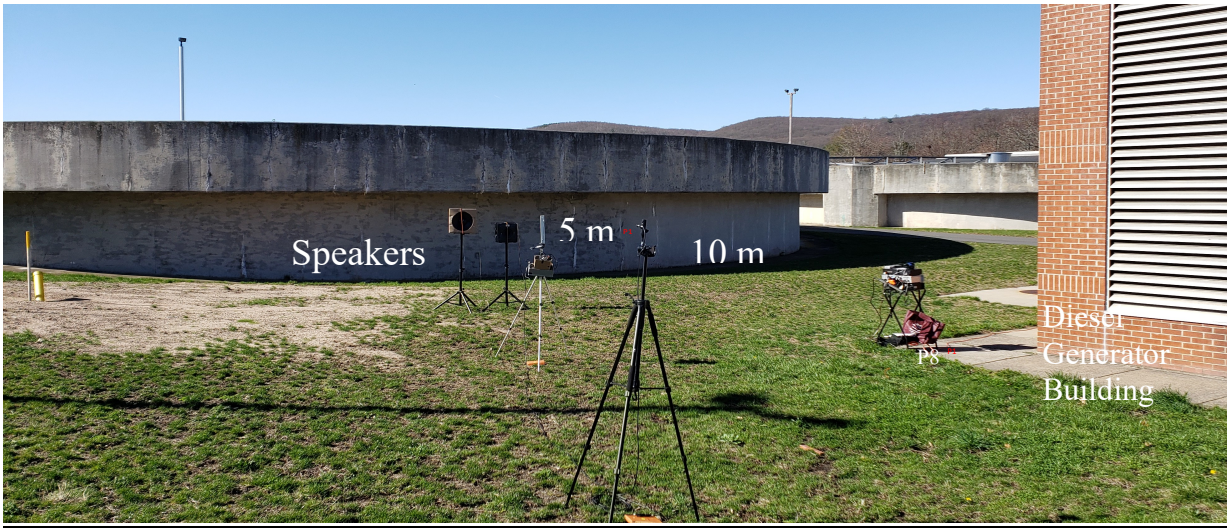


Figure 3. Doosan Power Module Location at the Bristol Treatment Plant Site

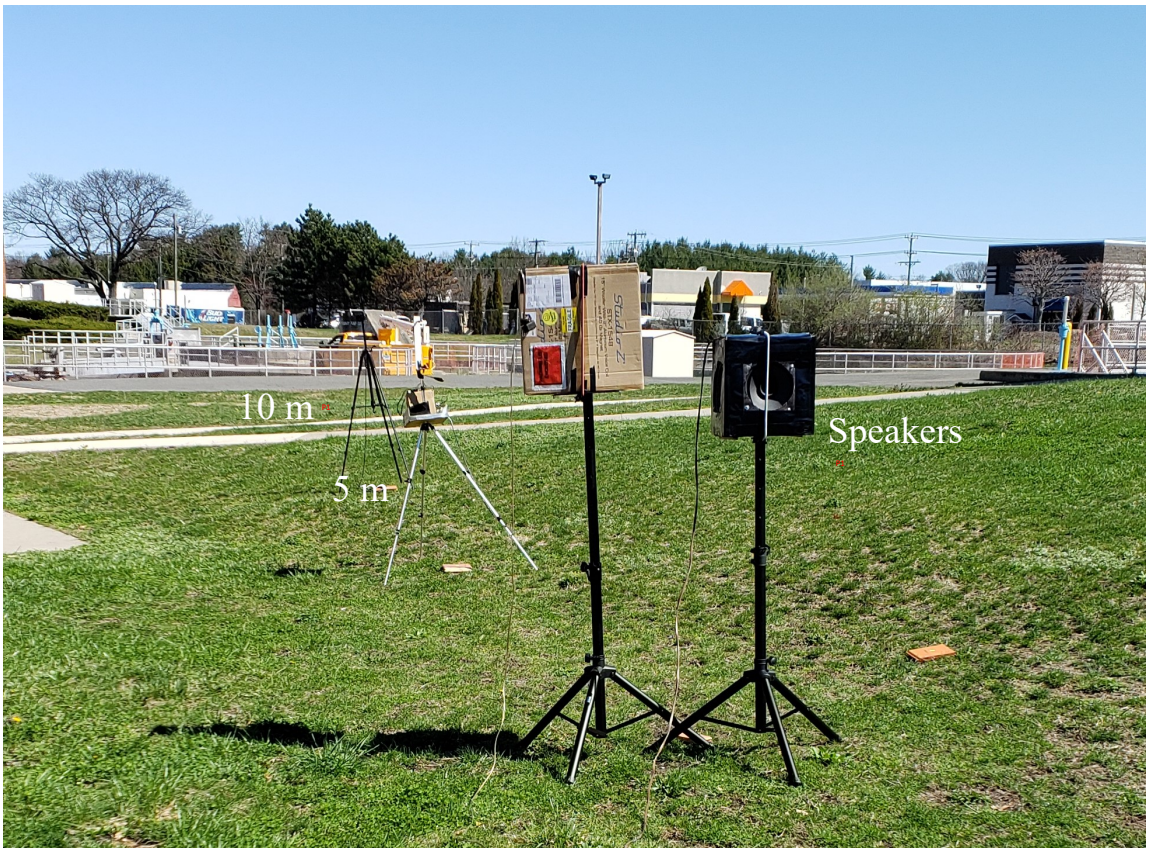


Table 1. Bristol Weather Data on April 17, 2019
https://www.wunderground.com/history/daily/us/ct/windsor-locks/KBDL/date/2019-4-17

Time (EST)	Temp. (°F)	Humidity (%)	Dew Point (°F)	Barometer (in HG)	Wind Speed (mph)	Wind Direction	Condition
6:51 AM	57 F	28%	24 F	30.0 in	7 mph	NNW	Fair
7:51 AM	59 F	25%	23 F	30.0 in	10 mph	NNE	Fair
8:51 AM	60 F	24%	23 F	29.9 in	7 mph	ENE	Fair
9:51 AM	63 F	23%	24 F	29.9 in	9 mph	NNE	Mostly Cloudy
10:51 AM	64 F	22%	24 F	29.9 in	5 mph	VAR	Mostly Cloudy
11:51 AM	63 F	22%	23 F	29.9 in	3 mph	VAR	Fair
12:51 PM	63 F	21%	22 F	29.9 in	5 mph	VAR	Mostly Cloudy
1:51 PM	63 F	22%	23 F	29.9 in	5 mph	SE	Mostly Cloudy
2:51 PM	61 F	24%	24 F	29.9 in	8 mph	SSE	Fair
3:51 PM	58 F	28%	25 F	29.9 in	8 mph	SSW	Fair
4:51 PM	55 F	31%	25 F	30.0 in	13 mph	S	Fair

Data Analysis

This section analyzes the airborne noise levels measured at the Bristol 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 Bristol and Connecticut noise ordinances. Both background noise levels at the Bristol site and the measured speaker operating noise levels are reported in Table 2. The background data are 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 Bristol 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.

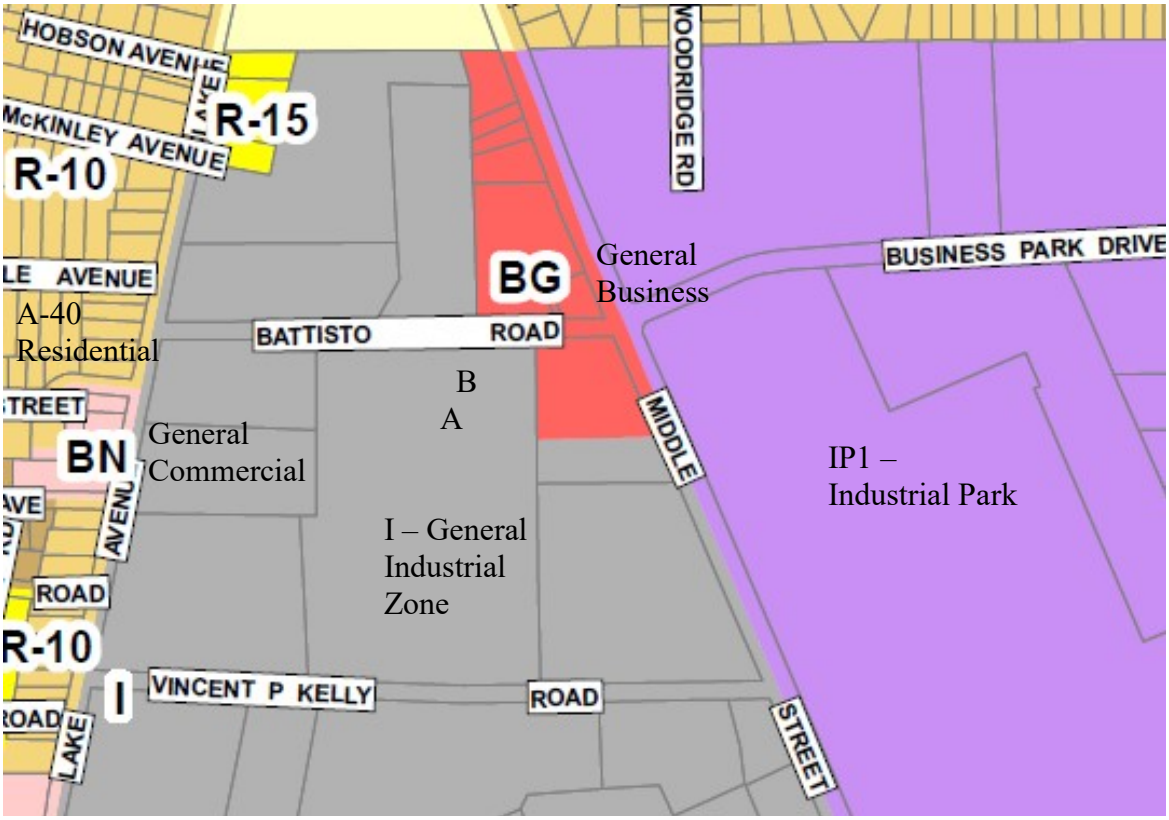
The complete set of overall A-weighted airborne noise levels that were measured in Bristol are provided in Table 2 for the conditions with the speakers on and off. Figure 4 is a map showing the Bristol zoning districts in the Treatment Plant area. The position locations were calculated using the Pocket 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 P7, which is about 68 / 72 meters northeast to the Proscapes Landscape business abutting the Treatment Plant property on Middle Street. The next closest measurement location is P8, which is about 86 / 92 meters east to the neighboring office center on Middle Street. Neighboring business properties along Middle Street are 68 to 136 meters away. The closest residential property is 308 meters away on Lake Avenue. Because of this great distance airborne noise at the residential locations would not be heard when the speakers were operating at either Site A or Site B. The airborne noise values at the property lines in the tables are upper limits on what the speaker noise might be. The speaker on noise levels exceeded the background at only two neighboring locations and by only 1 or 2 dB. Location P9 is 91 to 100 yards away from the speakers and it is very likely that the background noise level increased during the speaker on measurements. Location 5 is also 91 to 98 yards from the speakers and it is very likely that the background noise level also increased during the speaker on measurements. If so, this means all the property line data are background limited and form an upper limit.

Table 2. Overall Sound Pressure Levels in dBA ref. 20 microPascals measured at Treatment Plant

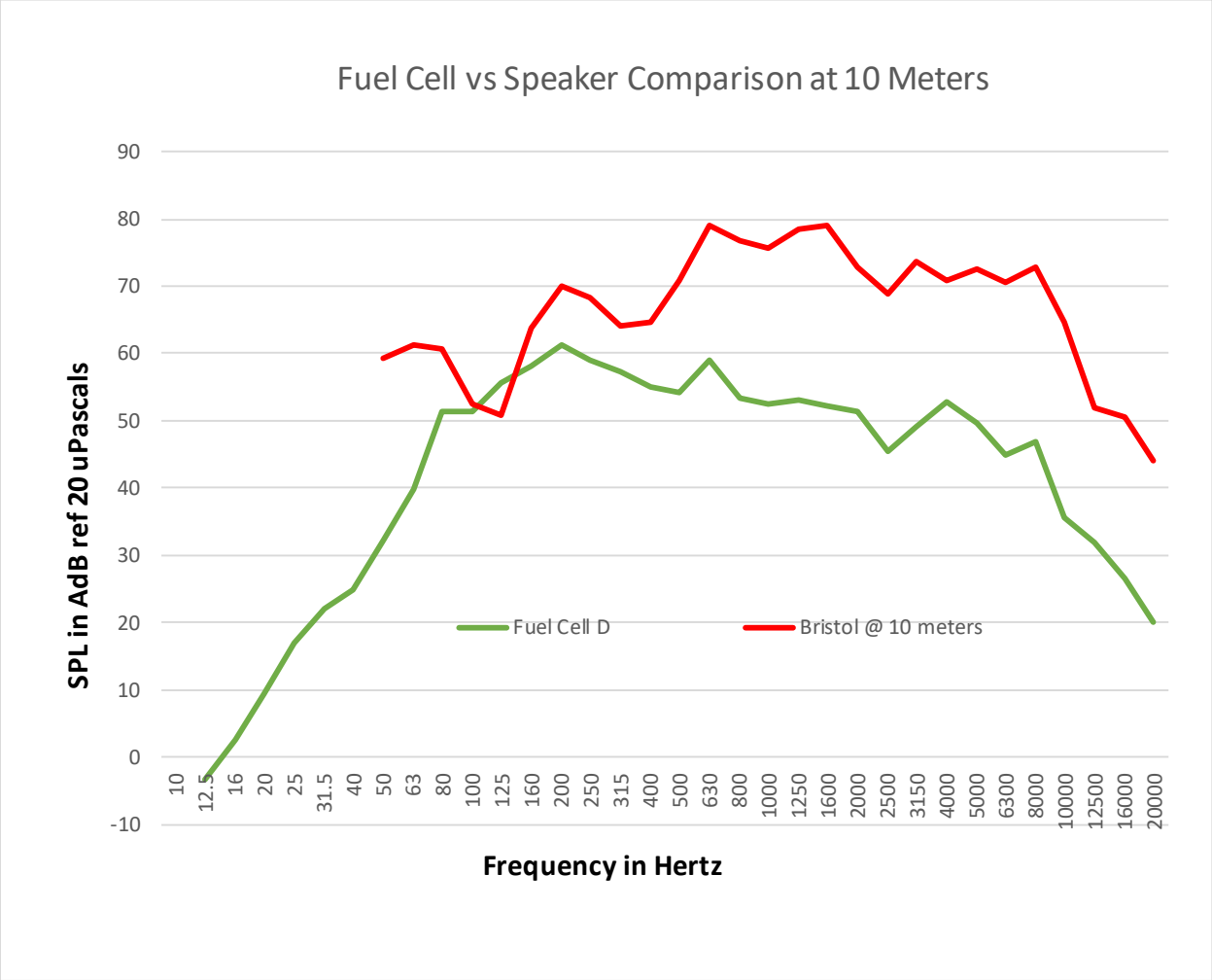
Location	Range in Meters	Speakers Cooling	Background	Bkgd Corrected	Speakers Fuel	Background	Bkgd Corrected
P1 at 5 m	5	92.8	61.8	92.8	90.9	62.5	90.9
P2 at 10 m	10	87.0	61.1	86.9	85.2	60.5	85.0
P3 – 330 Middle Street	136/127	58.5	58.2	< 48	58.5	58.2	< 48
P4 - 334 Middle Street	126/118	65.2	65.0	< 55	64.9	65.0	< 55
P5 – 338 Middle Street	98/91	66.2	65.2	59.5	65.8	65.2	< 57
P6 – 342 Middle Street	86/79	67.4	68.1	< 58	67.4	68.1	< 58
P7 - 346 Middle Street	68/72	61.7	61.7	< 52	61.4	61.7	< 52
P8- 400 Middle Street	86/92	62.5	62.6	< 53	62.5	62.6	< 53
P9 – 126 Vincent P Kelly Road	91/100	58.5	57.3	52.3	57.4	57.3	< 47
P10 – 281 Lake Avenue	121/122	56.1	55.8	< 44.5	57.8	55.8	53.5
P11 – 75 Battisto Road	190/181	49.9	50.3	< 40	49.2	50.3	<40
P12 – Settling Tanks	58/50				68.2		68

Figure 4. Bristol 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 Bristol site is shown in Figure 5. The speakers roughly match the fuel cell airborne noise for frequencies below 200 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 18.9 dB and 16.9 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 18.9 and 16.9 dB differences in level were subtracted from the Bristol 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 Bristol transmission loss data to estimate the expected fuel cell airborne noise for nearby neighbors at the Treatment Plant 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 nine locations the Bristol 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 18.9 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 16.9 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 1 to 2 dB larger. The more conservative overall noise level values were used in this report to scale the speaker data.)

The measurements at the Treatment Plant were taken at various distances from the speakers and then background corrected. Close to the speakers at 75 Battisto Road the maximum airborne noise values are expected to be below 41 dBA, well below both the Business and Industrial noise limit. The other Industrial properties further away are expected to be below 37 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 25 dBA.

Table 3. Estimated Bristol 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 – 330 Middle Street	136/127	< 48	18.9	< 29	< 48	16.9	< 31
P4 - 334 Middle Street	126/118	< 55	18.9	< 36	< 55	16.9	< 38
P5 – 338 Middle Street	98/91	59.5	18.9	40.6	< 57	16.9	< 40
P6 – 342 Middle Street	86/79	< 58	18.9	< 39	< 58	16.9	< 41
P7 - 346 Middle Street	68/72	< 52	18.9	< 33	< 52	16.9	< 35
P8- 400 Middle Street	86/92	< 53	18.9	< 34	< 53	16.9	< 36
P9 – 126 Vincent P Kelly Road	91/100	52.3	18.9	33.4	< 47	16.9	< 30
P10 – 281 Lake Avenue	121/122	< 44.5	18.9	25.6	53.5	16.9	36.6
P11 – 75 Battisto Road	190/181	< 40	18.9	< 21	<40	16.9	< 23
P12 – Settling Tanks	58/50				68	16.9	51

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 Bristol 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 Bristol site.

The southern part of the Bristol zoning map is given in Figure 4. As stated above, the Treatment Plant at 75 Battisto Road is located in an Industrial Zone. This Industrial zone is surrounded by Business zones to the northeast and west, Residential zones to the west and north and another Industrial zone to the east. 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 Bristol speaker measurements, the airborne noise level expected at the Lake avenue property line (at a distance of 308 meters) should be about 25 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.

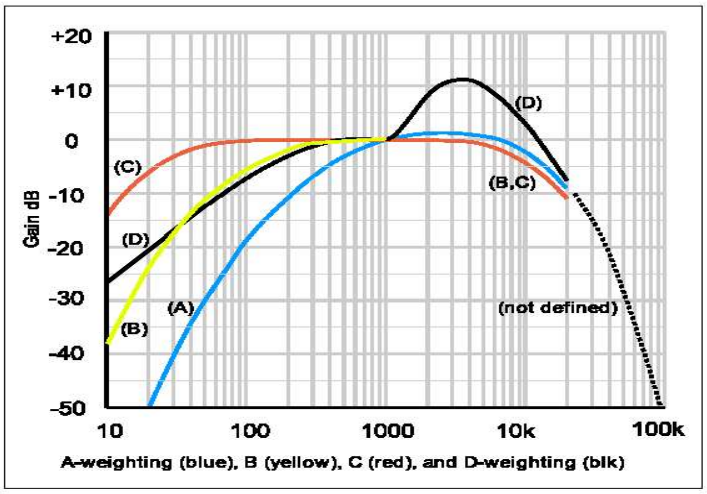
Impulse Noise

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. Bristol 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 Bristol ordinances except for Sunday in Bristol. 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. Bristol 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 Bristol. 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 Bristol'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



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. Bristol'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 the Treatment Plant 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)

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 was 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 Lake 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 Business property lines next to the Treatment Plant site is at least 27 dB so the maximum possible discrete tone would be 27 dBA at the 338 Middle Street property line. This level is well below the 61 dBA requirement in an Business 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

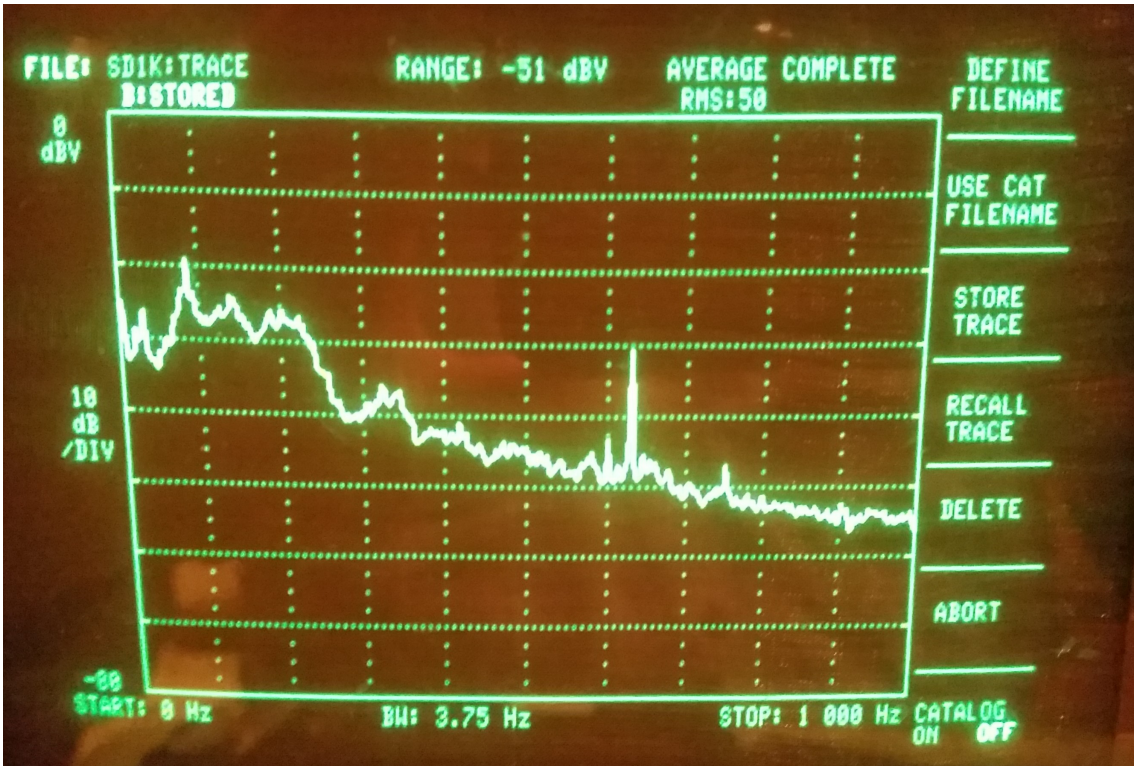
The Connecticut regulation for the control of noise states in *CT section 22a-69-3.4 Infrasonic and Ultrasonic* that no person shall emit beyond his/her property infrasonic or ultrasonic sound in excess of 100 dB at any time. 100 dB with respect to the reference of 20 microPascals is a

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. Bristol'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 27dB so the maximum possible infrasonic noise would be 39 dBA at the Middle Street 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 Business and Industrial property lines will be at least 27 dB lower. The noise levels at the residential neighbors will be even 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 Bristol 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 Emitter to C 70 dBA B 66 dBA A/day 61 dBA A/night 51 dBA

The Treatment Plant is in an Industrial zone that is surrounded by Business zones to the northeast and west, Residential zones to the west and north and another Industrial zone to the east. The Residential zones are too far away (greater than 300 meters) to be affected by noise from the Treatment Plant site. The nearby neighbors are classified as either Business or Industrial with a Business noise limit of 66 dBA and an Industrial noise limit of 70 dBA.

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

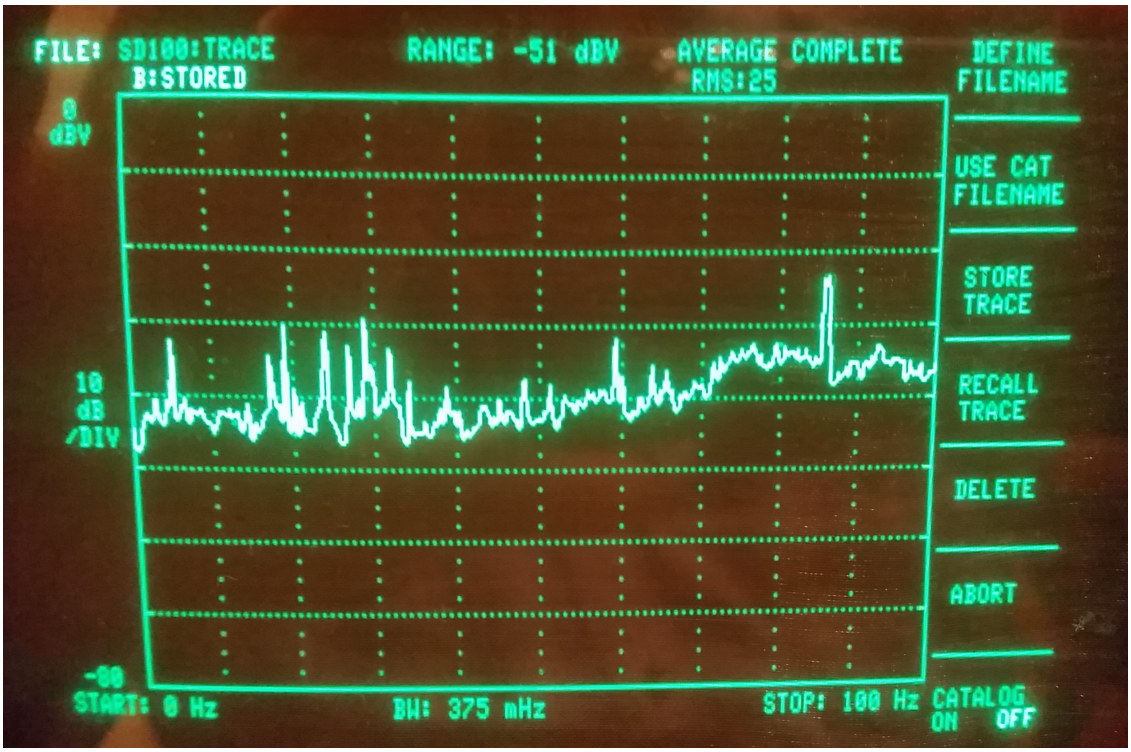


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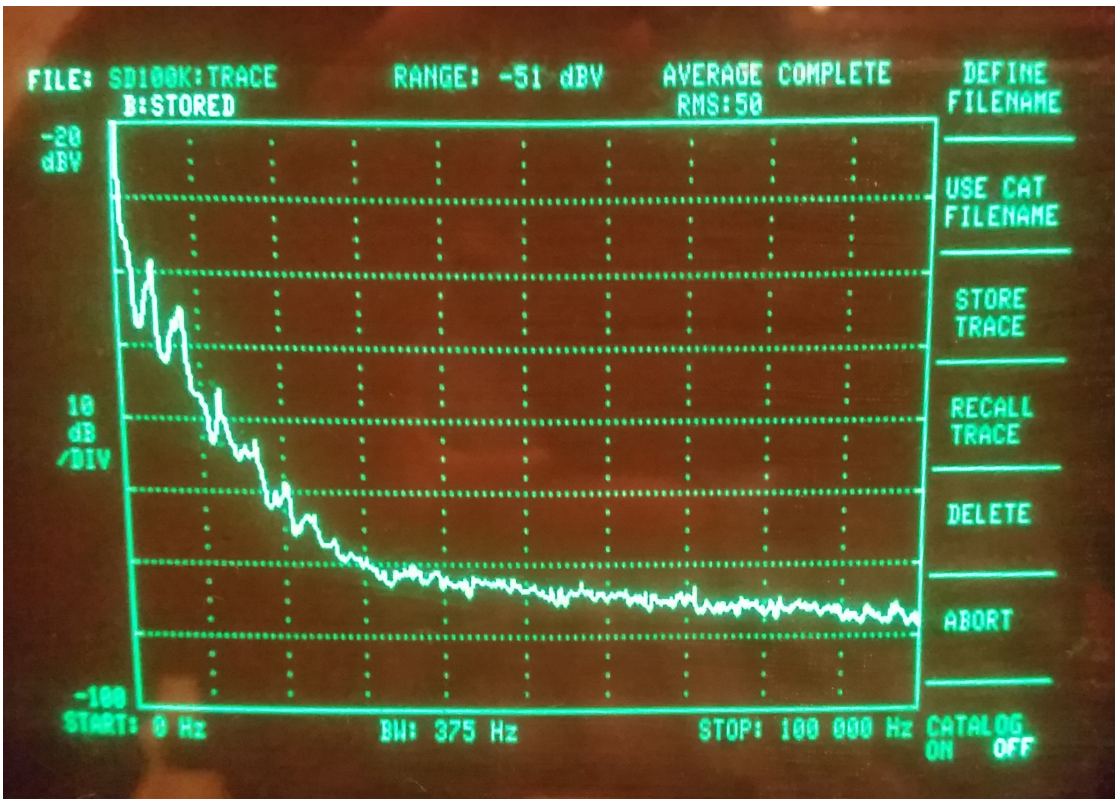
Figure 9. Ultrasonic Noise from the Fuel Cell Cooling Module (0 dBV = 88.6 dB re 20µPa)



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 propagating to the nearby properties are expected to be very low. The highest property line background corrected speaker level was measured at 59.5 dBA at Middle Street, the property right adjacent to the speakers. The nearby properties on Middle Street should see airborne noise levels no higher than 40.6 dBA with the fuel cell operating. Because of the increasing loss with distance to the remaining Industrial property lines the expected fuel cell noise levels will fall below 40 dBA for

the other Business and Industrial properties. The residential properties should all be lower than 25 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 66 dBA Business noise limits.

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

Industrial	P6	P7	P8	P9	P10	P11	P12
→	<41dBA	<35 dBA	<36 dBA	33.4 dBA	36.6 dBA	<23 dBA	51 dBA
							At 50 m
Business	P3	P4	P5				Inside
→	< 31 dBA	< 38 dBA	41 dBA				Plant

Operation of the Doosan fuel cell will have no acoustic impact at all the Residential, Business and Industrial properties adjacent to the Treatment Plant site at 75 Battisto Road. The current background noise levels at the Treatment Plant site were seen to vary depending on which Treatment Plant machinery were running. Maximum background airborne levels of 68 dBA were measured during a normal working day at the Treatment Plant at the property line. These background noise levels exceed the expected fuel cell noise of 51 dBA at 50 meters from the fuel cell by a wide margin. Since the property line is at least 68 meters away the airborne noise from the fuel cell at the property line will be at maximum 50 dBA at the closest property line. This number is 16 dB below the Business noise limit and 20 dB below the Industrial noise limit.

Conclusions

The purpose of this effort is to evaluate the acoustical environment at the proposed Treatment Plant fuel cell site in Bristol, 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 Bristol airborne noise requirements on all the nearby property lines. Although not tested, residences to the northeast and west are also expected to meet all the noise requirements because they are blocked by the Treatment Plant buildings and are more than 300 meters away from the new fuel cell. The closest Business and Industrial zone properties on Middle Street which are adjacent to the new fuel cell will be below the noise requirement by at least 16 dB.

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) Bristol Chapter 15, ARTICLE II Noises, Sec. 15 https://www.jud.ct.gov/lawlib/ordinances.htm - Bristol Ordinances