EVERSOURCE ENERGY

107 Selden Street
Berlin, CT 06037

June 15, 2017

ORIGINAL

Mr. Robert Stein
Connecticut Siting Council
10 Franklin Square
New Britain, CT 06051

Re: Petition No. Petition 1140 - Barbour Hill to Manchester SS and 1763 Line

Dear Mr. Stein:

This letter provides the response to requests for the information listed below.

Response to CSC-01 Interrogatories dated 06/01/2017
CSC-001, 002, 003, 004

Very truly yours,

Kathleen Shanley /tr

Kathleen Shanley
Manager
Siting and Permitting, Transmission
As Agent for CL&P
dba EversourceEnergy

cc: Service List

CL&P dba Eversource Energy
Petition No. Petition 1140

Data Request CSC-01
Dated: 06/01/2017
Q-CSC-001

Witness: NO WITNESS
Request from: Connecticut Siting Council

Question:
Please provide the referenced sound studies that were performed at the property boundaries of Barbour Hill Substation that show non-compliance of the existing conditions at the substation with state noise regulations.

Response:
The sound study is attached and can also be found at the below link to the Town of South Windsor's Website:
http://www.southwindsor.org/sites/southwindsorct/files/uploads/eversource_sound_assessment_study_barber_hill.pdf

BURNS McDONNELL

Sound Assessment Study

EVERSOURCE

Eversource

Barbour Hill Substation
Project No. 90026

October 14, 2016

Sound Assessment Study

prepared for

Eversource
Barbour Hill Substation
South Windsor, Connecticut

Project No. 90026

October 14, 2016

prepared by

Burns & McDonnell Engineering Company, Inc.
Kansas City, Missouri

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LIST OF ABBREVIATIONS

Abbreviation	Term/Phrase/Name
ANSI	American National Standards Institute
Burns & McDonnell	Burns & McDonnell Engineering Company, Inc.
CSC	Connecticut Siting Council
dB	decibels
dBA	A-weighted decibels
Eversource	Eversource Energy
Hz	hertz
IEEE	Institute of Electrical and Electronics Engineers
kV	kilovolt
MVA	mega-volt amperes
Substation	Barbour Hill Substation

1.0 EXECUTIVE SUMMARY

In February, 2015, Eversource filed a Petition with the Connecticut Siting Council (CSC) to, among other things, add an additional transformer bank comprised of three, single-phase 345-kilovolt (kV) to 115-kV autotransformers. In April, 2015, the CSC approved the Petition. Construction began in May, 2015.

The Barbour Hill Substation now consists of two sets of three, single-phase autotransformers (1x and 2x units); four smaller, three-phase distribution transformers; circuit breakers; and switchyard equipment (Substation). In support of the additional autotransformer Eversource commissioned Burns & McDonnell Engineering Company, Inc. (Burns & McDonnell) to conduct an environmental sound assessment study for the Barbour Hill Substation.

The objective of the Burns & McDonnell work has been two fold – to prepare a sound study to be used in support of the CSC filing as well as to measure operational noise levels in and around the Substation once the autotransformers were installed to determine if the Substation exceeds the State or local noise regulations.

Both the State of Connecticut and the Town of South Windsor have regulations which define and govern permissible sound levels. The Town of South Windsor's regulations are similar to those defined by the State of Connecticut in Control of Noise Section 22a-69-3. Meeting the limits defined by the State of Connecticut will also satisfy the Town of South Windsor regulation.

Pursuant to the Burns and McDonnell environmental sound assessment, continuous sound monitoring was conducted during multiple time periods for a total of 125 days under various operating conditions. The Sound monitoring that took place from January 26 to February 16, 2016, measured sound with both the 1x and the 2x autotransformers in service but without the anti-vibration pads having been installed under the 1x autotransformer. The sound monitoring that took place from May 10 to June 21, 2016, measured the sound of the 2x while the 1x was out of service to accommodate the installation of the anti-vibration pads. The final round of sound monitoring took place from June 21 to August 22, 2016, and measured both the 1x and 2x during what is typically the peak demand for electrical use. Sound levels collected at the property line measured dominant frequencies that were typical of those near an operational substation. The amount of data collected provides confidence that the generally loudest property line sound levels were captured during this study.

Measurements showed the sound levels of the single-phase autotransformers can vary significantly over time. The sound levels measured at different locations varied based on distance to the Substation, time of day, and amount of local roadway traffic. The Substation is audible at offsite locations during times of low background sound. When the autotransformers were operating normally, at their specified sound levels, the Substation was well below the applicable noise limits. However, during the autotransformer's short-duration peak sound levels, the Substation exceeded the State sound level limits on several occasions.

As a result of this occasional exceedance, various mitigation installations have been explored to determine ways to achieve compliance with the regulations at all times. A preliminary review of the available and feasible mitigation options shows full enclosures of the autotransformers may be the optimum solution to bring the Substation into full compliance with the applicable noise regulations. The following chapters provide background information and describe the study in further detail.

2.0 ACOUSTICAL TERMINOLOGY

The term "sound level" is often used to describe two different sound characteristics: sound power and sound pressure. Every source that produces sound has a sound power level. The sound power level is the acoustical energy emitted by a sound source and is an absolute number that is not affected by the surrounding environment. The acoustical energy produced by a source propagates through media as pressure fluctuations. These pressure fluctuations, also called sound pressure, are what human ears hear and microphones measure.

Sound is physically characterized by amplitude and frequency. The amplitude of sound is measured in decibels (dB) as the logarithmic ratio of a sound pressure to a reference sound pressure (20 microPascals). Sound waves can occur at many different wavelengths, also known as the frequency. Frequency is measured in hertz (Hz), and is the number of wave cycles per second that occur. The typical human ear can hear frequencies ranging from approximately 20 to 20,000 Hz. The A-weighting scale was developed to simulate the frequency response of the human ear to sounds at typical environmental levels.

Some sounds contain many frequencies while others contain a singular frequency, or groupings of frequencies, that stand out from adjacent frequencies. Those sounds that contain a singular frequency that is louder than the adjacent frequency bands are sometimes called prominent discrete tones or pure tones.

Sound can be analyzed for frequency components. These frequency components are described in the American National Standards Institute (ANSI) S1.11 and are commonly referred to as the octave band center frequency and the 1/3 octave band. The octave band is a set of frequencies used to describe a sound by lumping the entire spectrum of frequencies measured into specific frequency groups. These groups include any sound measured in any frequency, but the sound meter combines the discrete, adjacent frequencies together, as defined by ANSI.

A more detailed explanation of acoustical terminology, which is appropriate to this study, can be found in Appendix A.

3.0 APPLICABLE REGULATIONS

The regulation of noise falls within the responsibilities of the Connecticut Department of Environmental Protection and the Town of South Windsor. Both entities have applicable noise ordinances, as described below.

3.1 State of Connecticut Noise Regulations

The Connecticut regulation for the Control of Noise Section 22a-69-3 defines the allowable noise levels for the State of Connecticut. The regulation defines land that is generally industrial as a Class C noise zone, and land that is generally residential as a Class A noise zone. This regulation defines excessive noise from a Class C noise zone to a receiving Class A noise zone as sound levels in excess of 61 dBA during the day and 51 dBA at night, measured at the property line of the receiving property. The regulation defines nighttime as the hours between 10:00 P.M. and 7:00 A.M.

This regulation also includes a penalty for sources that emit prominent discrete tones. Prominent discrete tones are defined as the presence of acoustic energy concentrated in a narrow frequency range. Excessive noise is identified as any tone that, first, produces a 1/3 octave band sound-pressure level greater than that of either adjacent 1/3 octave band and, second, exceeds the arithmetic average of the two adjacent 1/3 octave-band levels by an amount greater than those listed in Section 22a-69-1.2(r). When prominent discrete tones are present, the daytime and nighttime sound level limits are reduced by 5 dBA. This changes the overall daytime and nighttime sound level limits for the Substation to 56 dBA and 46 dBA, respectively. Discrete tones at points with sound levels below these limits are not considered excessive noise under this regulation.

3.2 Town of South Windsor Noise Regulations

The Town of South Windsor Code of Ordinances, Chapter 50, Article III provides sound level limits for industrial properties adjacent to residential properties. The regulation states that noise emitted from an industrial zone beyond the boundary of the lot or parcel onto a residential zoned property shall not exceed a daytime limit of 61 dBA and a nighttime limit of 51 dBA. The regulation defines daytime hours as between 7:00 A.M. and 8:00 P.M. on every day but Sunday and the hours of 9:00 A.M. and 8:00 P.M. on Sundays. Nighttime hours are defined as between 8:00 PM and 7:00 AM each day from Sunday evening through Saturday morning and between 8:00 P.M. Saturday and 9:00 A.M. Sunday. The Town of South Windsor noise regulation does not address prominent discrete tones with a penalty as the Connecticut noise regulation does. Meeting the Connecticut noise regulation during nighttime hours will satisfy the Town of South Windsor noise ordinance.

4.0 FIELD MEASUREMENTS

Field measurements were taken to quantify sound levels in the area surrounding the Substation. The neighboring residents communicated that noise generated by the Substation reaches their houses and causes discomfort. In an effort to determine how sound generated at the Substation affects the neighboring properties, both near-field and far-field measurements were taken.

Near-field measurements are those taken close to the autotransformers. Near-field measurements reduce the influence of extraneous background sounds. Since the Substation is not operating in a controlled environment, it is nearly impossible to measure only the autotransformers' sound levels without significant isolation techniques that would potentially be unsafe for testing personnel. However, the near-field sound levels are considered generally representative of each piece of equipment's operational sound levels, as most background sounds have little influence this close to the autotransformers.

Far-field measurements are those taken outside the Substation fenceline. Far-field measurements are affected more by extraneous sources of sound than are near-field measurements, but they provide information on how sound potentially propagates outward from the Substation.

Five continuous, long-term sound monitors were installed at various locations in and around the substation to monitor sound during three multi-week time periods. One meter was placed 15 feet from the northern edge of the operational 1x autotransformer (Meter 1). This meter acted as a "control meter" for the 1x autotransformer since it was unlikely to be significantly affected by extraneous sounds. A second control meter was installed 15 feet from the northern edge of the 2x autotransformer (Meter 2). This meter acted as a control meter for the 2x autotransformer. Sound levels at the control meters were used as the basis for comparison to the offsite meters. Three other sound meters (Meter 3, Meter 4, and Meter 5) were installed at various locations along the Substation property line in the directions of the closest neighboring residences. Figure 4-1 shows the locations of the sound meters used for the study.

Figure 4-1: Continuous Monitoring Points

4.1 Noise Monitoring Summary

According to the Institute of Electrical and Electronics Engineers (IEEE) Standards C57.12.90 and C57.136, the principal sources of sound in transformers and autotransformers are the core sound and sound from cooling equipment. The core sound is caused by magnetostriction effects and inter-laminar magnetic forces. It is influenced by the flux density, core material, core geometry, and excitation voltage waveform. The sound from cooling equipment is generally caused by the cooling fans. The fan noise is influenced by the blade-tip speed, blade design, and number of fans. Pump noise is typically insignificant when fans are running. According to the autotransformer manufacturer sound level guarantee, the autotransformers are guaranteed to 62 dBA at 120 mega-volt amperes (MVA), 64 dBA at 160 MVA, and 65 dBA at 200 MVA. Therefore, the units should meet a spatially averaged sound level of 65 dBA at 3 feet at any load. This sound level includes the effects of both the core and the cooling equipment.

The autotransformers are rated to a maximum sound level of 65 dBA at 3 feet, but the sound measurements demonstrate that the units are capable of operating well above that level. At times, the sound meters located 15 feet from the units measured autotransformer-generated sound up to 80 dBA in short sound excursions. These increases were also measurable at the property line.

The autotransformers vary in loudness throughout the day and night. Control Meter 1 measured sound levels between 43 and 74 dBA, and Control Meter 2 measured sound levels between 48 and 80 dBA. The control meter locations are close enough to the units that common extraneous sounds would not have a significant effect on measured sound levels.

The autotransformers' sound levels were generally dominant in the 125- and 400-Hz 1/3 octave band frequencies. At times throughout the measurements, autotransformer sound levels spiked by as much as 25 dBA. The sound level spikes remained elevated for various amounts of time before eventually falling back to normal levels, which are generally between 55 and 65 dBA at the control meters. Some of the spikes in sound lasted for extended periods of time. The average control meter sound levels measured during the study are shown below in Table 4-1.

Table 4-1: Control Meter Average Sound Levels

Measurement Period	Average Meter 1 (1x)	Average Meter 2 (2x)
Winter 2016	56.5 dBA	61.6 dBA
Summer 2016	56.4 dBA	58.4 dBA

The control meters measured sound levels that fluctuated from day to day. The data shows the autotransformers can ramp up and down in sound over 15- to 30-minute periods. The Substation is audible offsite when background sounds subside and at times when the autotransformer sound levels ramp up. Substation sound is periodically measureable as a pure tone at the property line. Based on the far-field data collected, the Substation periodically exceeds the State of Connecticut noise regulations.

The property line meters fluctuated constantly due to extraneous sources. There were time periods where background sounds were low and the property line meters appeared to clearly follow changes in Substation sound measured at the control meters. Peak contribution to sound levels from the 125- and 400-Hz octave bands were measured during these times as well, consistent with Substation operation.

One instance of nighttime substation sound levels exceeding the State of Connecticut noise regulation was measured on July 12, 2016, at 12:24 AM. This was not a time when the loudest control meter sound levels were measured, but it was an instance where sound levels at the property line were clearly influenced by autotransformer sound and were in excess of the limits. During this time period, background sounds were minimal and winds were likely calm. Calm wind conditions are favorable for sound propagation from the Substation to neighboring residences. Favorable sound propagation, in combination with low background sound levels, generated prominent discrete tones measured at the property line. Under prominent discrete tone conditions, the State sound level limits are reduced by 5 dBA. At night the limit is reduced from 51 dBA to 46 dBA. The property line meters measured prominent discrete tones in the 400-Hz octave band during this time period, consistent with Substation operation. Table 4-2 provides the measured time period compared to State nighttime sound level limits.

Table 4-2: Sound Levels on July 12, 2016, at 12:24 AM

Meter	Date	Time	1-Min Leq (dBA)	Hourly Leq[a] (dBA)
Meter 1 Control meter (1x Auto)	7/12/2016	12:24 AM	70.2	66.8
Meter 2 Control meter (2x Auto)	7/12/2016	12:24 AM	76.9	74.2
Meter 3 South at Property Line	7/12/2016	12:24 AM	52.2	45.9 (limit 46 dBA)
Meter 4 Northwest at Property Line	7/12/2016	12:24 AM	56.0	50.0 (limit 46 dBA)
Meter 5 North at Property Line	7/12/2016	12:24 AM	56.4	52.3 (limit 46 dBA)

(a) Hourly sound level measured from 11:54 AM to 12:54 AM

These exceedances happen at irregular intervals. When the autotransformers are operating at their specified levels, the Substation is well below the State limits. However, there appears to be something causing the autotransformers to ramp up in sound for short periods of time. During these short-lived sound excursions, State sound level limits have been exceeded.

A more detailed explanation of sound monitoring study completed for the Barbour Hill Substation is included as Appendix B.

5.0 POTENTIAL MITIGATION OPTIONS

Various mitigation techniques could reduce sound impacts to the surrounding areas. The first consideration in reducing sound levels from the Substation is to address the autotransformers themselves. The autotransformers, when purchased, were specified to the low-sound option. Subsequently, anti-vibration pads were installed on both the 1x and 2x autotransformers to help reduce vibrations. Having addressed the physical autotransformer installations, there are multiple options that could be pursued, as detailed below.

5.1 Sound Walls

Sound walls can be effective at reducing sound levels experienced near a source and are fairly easy to install when compared to other options. Acoustic wall systems can be made of a variety of materials which may be chosen to address specific sound emission concerns. Burns & McDonnell has recently installed removable systems that use metal panels at substations.

This type of wall panel system is typically supported by steel, wide-flanged posts installed at approximately 15-foot spacing. The posts are usually supported by concrete foundations; however, a support framing system can be installed on existing firewalls or other existing structural framing to support the post and panel assembly. The panels are inserted between adjacent posts to create the wall. Systems of this type permit removal of panels and posts should equipment replacement or major work be necessary and require unrestricted personnel access for such operations.

Smaller, less intrusive barriers, generally 7 to 10 feet tall, could also be installed along the fenceline of the Substation. These barriers would not be as effective as barriers placed adjacent to the autotransformers, but they could help reduce some of the sound experienced at neighboring properties.

5.2 Autotransformer Enclosures

Enclosing the autotransformers would be similar to building sound walls adjacent to the autotransformer and then closing the top. Enclosing the top of the autotransformers would provide the maximum reduction in sound emissions, as the sound would not be able to escape over a wall. However, it also has significant construction implications. The enclosure may be an attenuating concrete block building with membrane roof, or a manufactured-panel system. To allow for the air flow needed to maintain the equipment's ratings and cooling capacity, either a ventilation system would need to be installed or louvers would need to be placed at the top and bottom of the enclosure. An enclosure with a ventilation system would reduce sound from the transformer in all directions, as well as not allowing sound to escape over the walls. Wall sections with louvers would not reduce sound as well as solid sections.

5.3 Autotransformer Cladding

Attaching sound suppression cladding to the autotransformer themselves would be similar to building an enclosure very close to the units. The cladding would provide a reduction in sound emissions, as the sound would be suppressed in every direction. The cladding would be a manufactured-panel system that would be attached directly to the autotransformers themselves. The system would be engineered and designed by the cladding manufacturer. It would be comprised of removable noise suppression cladding sections to be fitted to the exterior of the autotransformer tanks. The direct cladding can be designed such that outlets for oil circulation pipes to the radiators and the conservator tank would remain external to the enclosure and would not be relocated. Access hatches can also be constructed as a part of the enclosure to allow for access to autotransformer gages or other components.

6.0 CONCLUSION

A sound assessment study for the Barbour Hill Substation, including near-field and far-field short-term measurements sound monitoring was completed to determine operational sound levels for the Substation. The Substation must meet the Connecticut regulation for the Control of Noise Section 22a-69-3 and the Town of South Windsor noise control regulations to maintain compliance with State and local codes.

Continuous sound monitoring was conducted during multiple time periods for a total of 125 days. Sound levels were monitored during winter, spring and summer months from January 26 to February 16, 2016; May 10 to June 21, 2016; and June 21 to August 22, 2016, under different operating conditions. Near-field data was collected approximately 15 feet from the autotransformers; the near-field noise meter locations are close enough to the autotransformers that common extraneous sounds would not have a significant effect on measured sound levels.

Measurements showed the sound levels of the single-phase autotransformers can vary significantly over time. The near-field measurements showed the autotransformers can vary in loudness and produce short-term excursions in sound. The sound levels measured at different locations varied based on distance to the Substation, time of day, and amount of local roadway traffic.

The Substation is audible at offsite locations during times of low background sound. When the autotransformers are operating normally, at their specified sound levels, the Substation is well below the applicable noise limits. However, during the autotransformer's short-duration peak sound levels, the Substation can be in excess of the State sound level limits. These exceedances happen at irregular intervals. There appears to be something acting on the electrical system that is causing the autotransformers to ramp up sound levels for short periods of time. State sound level limits have been exceeded during these short-lived sound excursions.

Since the Substation is exceeding the permissible property line sound level limits at times, sound mitigation is required. The sound mitigation will need to be sufficient to keep Substation sound levels below the State sound level limits during the autotransformer sound excursions measured during this study. There are various types of mitigation that could be used to reduce Substation sound levels. A preliminary review of the available and feasible mitigation options shows full enclosures of the autotransformers will likely be the optimum solution to bring the Substation into compliance with the applicable noise regulations. Enclosures can be designed to reduce sound levels from the units, but consideration would need to be made for the autotransformers cooling apparatus as well as other substation equipment. Further detailed engineering will be completed to provide a final solution.

APPENDIX A – ACOUSTICAL TERMINOLOGY

APPENDIX B – SOUND MONITORING STUDY

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CREATE AMAZING.

Burns & McDonnell World Headquarters
9400 Ward Parkway
Kansas City, MO 64114
O 816-333-9400
F 816-333-3690
www.burnsmcd.com

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APPENDIX A – ACOUSTICAL TERMINOLOGY

The term "sound level" is often used to describe two different sound characteristics: sound power and sound pressure. Every source that produces sound has a sound power level. The sound power level is the acoustical energy emitted by a sound source and is an absolute number that is not affected by the surrounding environment. The acoustical energy produced by a source propagates through media as pressure fluctuations. These pressure fluctuations, also called sound pressure, are what human ears hear and microphones measure.

Sound is physically characterized by amplitude and frequency. The amplitude of sound is measured in decibels (dB) as the logarithmic ratio of a sound pressure to a reference sound pressure (20 microPascals). The reference sound pressure corresponds to the typical threshold of human hearing. To the average listener, a 3-dB change in a continuous broadband sound is generally considered "just barely perceptible"; a 5-dB change is generally considered "clearly noticeable"; and a 10-dB change is generally considered a doubling (or halving, if the sound is decreasing) of the apparent loudness.

Sound waves can occur at many different wavelengths, also known as the frequency. Frequency is measured in hertz (Hz), and is the number of wave cycles per second that occur. The typical human ear can hear frequencies ranging from approximately 20 to 20,000 Hz. Normally, the human ear is most sensitive to sounds in the middle frequencies (1,000 to 8,000 Hz) and is less sensitive to sounds in the lower and higher frequencies. As such, the A-weighting scale was developed to simulate the frequency response of the human ear to sounds at typical environmental levels. The A-weighting scale emphasizes sounds in the middle frequencies and de-emphasizes sounds in the low and high frequencies. Any sound level to which the A-weighting scale has been applied is expressed in A-weighted decibels, or dBA. For reference, the A-weighted sound pressure level and subjective loudness associated with some common sound sources are listed in Table 1.

Sound in the environment is constantly fluctuating; for example, when a car drives by, a dog barks, or a plane passes overhead. Therefore, sound metrics have been developed to quantify fluctuating environmental sound levels. These metrics include the exceedance sound level, L_x, which is the sound level exceeded during "x" percent of the sampling period. The most common L_x value is L_{90}. The L_{90} is the sound level exceeded during 90 percent of the sampling period and represents the sound level without the influence of short-term, loud transient sound sources. The arithmetic average of the varying sound

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over a given time period is called the L_{eq}. L_{eq} and L_{90} levels are presented in various places throughout this study.

Table 1: Typical Sound Pressure Levels Associated with Common Sound Sources

Sound Pressure Level (dBA)	Subjective Evaluation	Environment	
		Outdoor	Indoor
140	Deafening	Jet aircraft at 75 feet	--
130	Threshold of pain	Jet aircraft during takeoff at a distance of 300 feet	--
120	Threshold of feeling	Elevated train	Hard rock band
110	--	Jet flyover at 1,000 feet	Inside propeller plane
100	Very loud	Power mower, motorcycle at 25 feet, auto horn at 10 feet, crowd sound at football game	--
90	--	Propeller plane flyover at 1,000 feet, noisy urban street	Full symphony or band, food blender, noisy factory
80	Moderately loud	Diesel truck (40 mph) at 50 feet	Inside auto at high speed, garbage disposal, dishwasher
70	Loud	B-757 cabin during flight	Close conversation, vacuum cleaner
60	Moderate	Air-conditioner condenser at 15 feet, near highway traffic	General office
50	Quiet	--	Private office
40	--	Farm field with light breeze, birdcalls	Soft stereo music in residence
30	Very quiet	Quiet residential neighborhood	Inside average residence (without TV and stereo)
20	--	Rustling leaves	Quiet theater, whisper
10	Just audible	--	Human breathing
0	Threshold of hearing	--	--

Source: Adapted from *Architectural Acoustics*, M. David Egan, 1988, and *Architectural Graphic Standards*, Ramsey and Sleeper, 1994.

Some sounds contain many frequencies while others contain a singular frequency, or groupings of frequencies, that stand out from adjacent frequencies. Those sounds that contain a singular frequency that is louder than the adjacent frequency bands are sometimes called prominent discrete tones or pure tones.

At quieter sound levels, pure tones can be more noticeable to people than sounds that do not include a pure tone, depending on the frequencies involved. As with all sounds, however, experiencing pure tones can be subjective. Also, pure tones are defined differently in various locales across the country.

Sound can be analyzed for frequency components. These frequency components are described in the American National Standards Institute (ANSI) S1.11 and are commonly referred to as the octave band center frequency and the 1/3 octave band. The octave band is a set of frequencies used to describe a sound by lumping the entire spectrum of frequencies measured into specific frequency groups. These groups include any sound measured in any frequency, but the sound meter combines the discrete, adjacent frequencies together, as defined by ANSI.

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APPENDIX B - SOUND MONITORING STUDY

Field measurements were taken to quantify sound levels in the area surrounding the Substation. The neighboring residents communicated that noise generated by the Substation reaches their houses and causes discomfort. In an effort to determine how sound generated at the Substation affects the neighboring properties, both near-field and far-field measurements were taken.

Near-field measurements are those taken close to the autotransformers. Near-field measurements reduce the influence of extraneous background sounds. Since the Substation is not operating in a controlled environment, it is nearly impossible to measure only the autotransformers' sound levels without significant isolation techniques that would potentially be unsafe for testing personnel. However, the near-field sound levels are considered generally representative of each piece of equipment's operational sound levels, as most background sounds have little influence this close to the autotransformers.

Far-field measurements are those taken outside the Substation fenceline. Far-field measurements are affected more by extraneous sources of sound than are near-field measurements, but they provide information on how sound potentially propagates outward from the Substation.

Short-Term Measurements

Both near-field and far-field short-term measurements were taken at the facility.

Short-Term Near-Field Measurements

To quantify and qualify the sound of the autotransformers at the Substation, short-term near-field measurements were taken at the facility on January 27 and July 26, 2016. The autotransformers have firewalls installed between the individual units, but they do not have firewalls on the outsides of the autotransformer banks. Sound generated by the autotransformers is allowed to radiate in all directions.

Measurements were taken using an ANSI S1.4 type 1 sound-level meter (Larson-Davis Model 831). The sound-level meter was calibrated before and after each set of measurements. None of the calibration level changes exceeded ± 0.5 dB, which is within the acceptable variance per ANSI guidance. A windscreen was used at all times on the microphone to avoid the influence of wind-induced sound increases.

Short-term near-field measurements around the autotransformers were taken at both one-third and two-thirds of the height of the tanks along the equipment envelope, consistent with Institute of Electrical and Electronics Engineers (IEEE) C57.12.90 – Standard Test Code for Liquid-Immersed Distribution, Power,

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and Regulating Transformers. Measurements were taken with the fans off. It is not possible to safely measure sound levels directly above an energized autotransformer. The high-voltage nature of substations requires clearances be maintained from all energized equipment for safety reasons, and the IEEE standard does not prescribe measurements be taken there.

Short-Term Far-Field Measurements

Burns & McDonnell personnel took short-term far-field measurements near the Substation during four time periods on January 26 and 27 and June 22 and 23, 2016. Each set of measurements consisted of eight hours of monitoring over a 24-hour period. Measurements were taken at the property line continuous monitor locations to verify the accuracy of the continuous monitors. All sets of measurements were taken when meteorological conditions were favorable for conducting ambient sound measurements. The measured, A-weighted L_{eq} sound levels from the short-term far-field studies were compared to the continuous monitors to determine accuracy of the continuous monitors. The far-field measurements closely followed the respective continuous monitor location sound levels for the times when the measurements were taken. No exceedances of the applicable regulations were measured during the short-term far-field measurements.

Continuous Long Term Monitoring

Five continuous, long-term sound monitors were installed at various locations in and around the substation to monitor sound during three multi-week time periods. One meter was placed 15 feet from the northern edge of the operational 1x autotransformer (Meter 1). This meter acted as a "control meter" for the 1x autotransformer since it was unlikely to be significantly affected by extraneous sounds. A second control meter was installed 15 feet from the northern edge of the 2x autotransformer (Meter 2). This meter acted as a control meter for the 2x autotransformer. Sound levels at the control meters were used as the basis for comparison to the offsite meters. Three other sound meters (Meter 3, Meter 4, and Meter 5) were installed at various locations along the Substation property line in the directions of the closest neighboring residences. The locations of all five meters can be seen in Figure B-1.

Figure B-1: Continuous Monitoring Points

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The meters placed along the property line would potentially quantify any spikes in sound emitted by the Substation in the direction of neighboring houses. The meters were installed at an elevation of approximately 7 to 8 feet above the ground surface. Simultaneous measurements at the property line and the control meters could potentially demonstrate cause-and-effect relationships of the sound propagating from the Substation towards the neighboring residences (i.e., discernible trends measured at one noise meter location should correspond to trends at the other noise meter location if both noise meter locations are affected by the same sources).

January to February 2016 Noise Monitoring

Continuous sound monitoring for the Substation was conducted from January 26 to February 16, 2016, to establish operating sound levels of the Substation and determine sound levels at the property line of the Substation during winter months. Both the 1X and the 2X autotransformers were in service. The anti-vibration pads had not yet been installed under the 1X autotransformer.

Onsite Control Meters

Two control meters were placed onsite, Meter 1 and Meter 2. Due to the proximity of the control meters to their respective autotransformers, the meters were not significantly affected by extraneous sources and represent operational sound levels of the autotransformers. The average, minimum, and maximum sound levels measured at the control meters are shown below in Table 1.

Table 1: Control Meter Sound Levels (Winter 2016)

1-Minute Leq	Meter 1 (1x)	Meter 2 (2x)
Minimum sound level	41.9 dBA	47.4 dBA
Three-week average sound level	56.5 dBA	61.6 dBA
Maximum sound level	77.0 dBA	81.3 dBA

The measurement data shows how sound levels fluctuated throughout the 3-week period. The average sound levels for the autotransformers are consistent with the rated sound levels. However, the data confirms that there are spikes in sound and significant variations in operating sound levels of the autotransformers.

The autotransformer sound levels were generally dominant in the 125- and 400-Hz octave bands. At times throughout the measurements, autotransformer sound levels spiked by as much as 20 to 25 dBA. The sound level spikes remained elevated for various amounts of time, generally around 15 minutes, before

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eventually falling back to normal levels. The loudest hourly-average sound level at Meter 2 reached 75.3 dBA on January 31, 2016, at 11:06 P.M. At that same time, Meter 1 recorded an hourly-average sound level of 63.3 dBA. During this hour, the sound levels peaked in the 400-Hz octave band. The overall sound levels during this time continually oscillated in amplitude by as much as 20 dB at Meter 2, and reached an overall 1-minute maximum of 81.3 dBA at Meter 2. During this time, period Meter 1 reached a peak 1-minute maximum of 69.1 dBA. Similar pulses in sound were measured at both control meters on February 8 and 16, 2016.

Property Line Meters

Three sound level meters were placed along the Substation property line: Meter 3, Meter 4 and Meter 5. The average, minimum, and maximum sound levels measured at the meters over the 3-week period are shown below in Table 2. It should be noted that the maximum sound levels recorded at each meter were attributed to offsite sound sources and were not consistent with Substation operation.

Table 2: Property Line Meter Sound Levels (Winter 2016)

1-Minute Leq	Meter 3	Meter 4	Meter 5
Minimum sound level	26.9 dBA	25.1 dBA	25.9 dBA
Average sound level	41.4 dBA	47.9 dBA	46.6 dBA
Maximum sound level[a]	71.5 dBA	80.3 dBA	87.1 dBA

(a) Maximum sound levels of property line meters were attributed to extraneous sources.

The property line meters fluctuated constantly due to extraneous sources. However, review of the data shows there were time periods where background sounds were low and the property line meters appeared to clearly follow changes in Substation sound measured at the control meters. During these times, the meters' peak frequencies were consistent with Substation operation (i.e., peak contribution to sound levels from the 125- and 400-Hz octave bands).

The maximum hourly nighttime sound levels at the property line meters that could be attributed to Substation operation were measured on February 8, 2016, at 2:25 AM for Meter 3, and on February 16, 2016, at 5:02 AM for Meter 5. Meter 4 provided additional data, but due to the meter's location, much of the data was heavily influenced by traffic sounds. During each of these time periods, all of the property line meters measured prominent discrete tones in the 400-Hz octave band, consistent with Substation operation. The tone was less readily apparent at Meter 4 due to traffic. As stated in Chapter 3, the overall

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sound level limit is reduced to 46 dBA at night in the presence of measured prominent discrete tones. Table 3 and Table 4 show the two measured peak time periods.

Table 3: Sound Levels on February 8, 2016, at 2:25 AM

Meter	Date	Time	1-Min Leq (dBA)	Hourly Leq[a] (dBA)
Meter 1 Control meter (1x Auto)	2/8/2016	2:25 AM	63.9	60.7
Meter 2 Control meter (2x Auto)	2/8/2016	2:25 AM	74.4	71.1
Meter 3 South at Property Line	2/8/2016	2:25 AM	50.1	47.8 (limit 46 dBA)

(a) Hourly sound level measured from 1:55 AM to 2:55 AM

Table 4: Sound Levels on February 16, 2016, at 5:02 AM

Meter	Date	Time	1-Min Leq (dBA)	Hourly Leq[a] (dBA)
Meter 1 Control meter (1x Auto)	2/16/2016	5:02 AM	63.6	59.2
Meter 2 Control meter (2x Auto)	2/16/2016	5:02 AM	74.0	67.2
Meter 5 North at Property Line	2/16/2016	5:02 AM	52.4	48.5 (limit 46 dBA)

(a) Hourly sound level measured from 4:32 AM to 5:32 AM

June to August 2016 Noise Monitoring

Continuous sound monitoring for the Substation was conducted from June 21 to August 22, 2016, to establish operating sound levels of the fully energized Substation and determine sound levels at the property line of the Substation during the summer months, which typically represent peak levels of demand. Both the 1X and 2X were in-service and both had the anti-vibration pads installed. This data has been collected to determine if there are significant changes in operation during different seasons of the year.

It should be noted that a berm was constructed south of the Substation between the fence and the property line. This berm was constructed after the January and February measurements, but before the June, July, and August measurements. Meter 3 was placed near the south property line approximately 75 feet south of the base of the berm. This berm helps block Substation-generated sound south of the Substation.

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Onsite Control Meters

Two control meters were placed onsite at the same locations used in January and February 2016, Meter 1 and Meter 2. Due to the proximity of the control meters to their respective autotransformers, the meters were not significantly affected by extraneous sources and represent operational sound levels of the autotransformers themselves. The average, minimum, and maximum sound levels measured at the control meters are shown below in Table 5.

Table 5: Control Meter Sound Levels (Summer 2016)

1-Minute Leq	Control Meter 1 (1x)	Control Meter 2 (2x)
Minimum Sound Level	43.2	48.4
Two-Month Average Sound Level	56.4	58.4
Maximum Sound Level[a]	74.2	80.0

(a) A maximum sound level of 91 dBA at both meters was measured during the study. However, this maximum was attributed to extraneous sources because the property line meters showed the same overall sound levels as the control meters and a frequency analysis showed the sound was not the Substation. The maximum sound levels attributable to the autotransformers were measured on August 11 at 11:05 PM.

The measurement data shows how sound levels fluctuated throughout the 2-month period. The average sound levels for the autotransformers are similar to what was measured in January and February. This set of data confirms that there continue to be frequent spikes in sound and significant variations in operating sound levels of the autotransformers.

The autotransformer sound levels were generally dominant in the 125- and 400-Hz octave bands. At times throughout the measurements, autotransformer sound levels spiked by as much as 20 to 25 dBA. The sound level spikes remained elevated for various amounts of time, generally around 15 minutes, before eventually falling back to normal levels. The loudest hourly-average sound level at Meter 2 reached 75.4 dBA on July 14, 2016, at 2:36 A.M. At that same time, Meter 1 recorded an hourly-average sound level of 65.4 dBA. During this hour, the sound levels peaked in the 400-Hz octave band. The overall sound levels during this time continually oscillated in amplitude by as much as 25 dBA. During this peak hour, the sound level meters reached an overall 1-minute maximum of 79.0 dBA at Meter 2 and 69.0 dBA at Meter 1. Similar pulses in sound were measured at both control meters throughout the study.

Property Line Meters

Three sound level meters were placed along the Substation property line in the same locations used in January and February 2016. The average, minimum, and maximum sound levels measured at the meters over the 2-month period are shown below in Table 6. It should be noted that the maximum sound levels

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recorded at each meter were attributed to offsite sound sources, and were not consistent with substation operation.

Table 6: Property Line Meter Sound Levels (Summer 2016)

1-Minute Leq	Meter 3	Meter 4[a]	Meter 5
Minimum Sound Level	28.3	27.7	29.6
Average Sound Level	49.8	50.9	51.2
Maximum Sound Level[b]	87.3	75.0	91.8

(a) Meter 4 data after July 26, 2016, was corrupted. Average sound levels provided are from June 21 to July 26, 2016, only.
(b) Maximum sound levels of property line meters were attributed to extraneous sources.

The property line meters fluctuated constantly due to extraneous sources. Similar to the January and February measurements, there were time periods where background sounds were low and the property line meters appeared to clearly follow changes in Substation sound measured at the control meters. Peak contribution to sound levels from the 125- and 400-Hz octave bands were measured during these times as well.

The maximum hourly nighttime sound levels at the property line meters that could be attributed to Substation operation were measured on July 12, 2016, at 12:24 AM for Meter 4 and Meter 5, and on July 14, 2016, at 2:36 AM for Meter 3. The property line meters measured prominent discrete tones in the 400-Hz octave band, consistent with Substation operation, during each of these time periods. Table 7 and Table 8 show the two measured peak time periods.

Table 7: Sound Levels on July 12, 2016, at 12:24 AM

Meter	Date	Time	1-Min Leq (dBA)	Hourly Leq[a] (dBA)
Meter 1 Control meter (1x Auto)	7/12/2016	12:24 AM	70.2	66.8
Meter 2 Control meter (2x Auto)	7/12/2016	12:24 AM	76.9	74.2
Meter 3 South at Property Line	7/12/2016	12:24 AM	52.2	45.9 (limit 46 dBA)
Meter 4 Northwest at Property Line	7/12/2016	12:24 AM	56.0	50.0 (limit 46 dBA)
Meter 5 North at Property Line	7/12/2016	12:24 AM	56.4	52.3 (limit 46 dBA)

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(a) Hourly sound level measured from 11:54 AM to 12:54 AM

Table 8: Sound Levels on July 14, 2016, at 2:36 AM

Meter	Date	Time	1-Min Leq (dBA)	Hourly Leq[a] (dBA)
Meter 1 Control meter (1x Auto)	7/14/2016	2:36 AM	69.7	65.4
Meter 2 Control meter (2x Auto)	7/14/2016	2:36 AM	79.0	75.4
Meter 3 South at Property Line	7/14/2016	2:36 AM	49.5	46.0 (limit 46 dBA)
Meter 4 Northwest at Property Line	7/14/2016	2:36 AM	52.9	47.4 (limit 46 dBA)
Meter 5 North at Property Line	7/14/2016	2:36 AM	53.1	49.5 (limit 46 dBA)

(a) Hourly sound level measured from 2:06 AM to 3:06 AM

Individual Unit Noise Monitoring

An individual unit sound study was performed, consisting of near-field continuous sound monitoring for each autotransformer while the other autotransformer was out of service. This set of measurements was collected to determine how the individual autotransformers operate when the other is taken out of service. Measurements for the 2x unit were taken from May 10 through June 6, 2016. The monitor was moved to the 1x unit on June 7, 2016, and measured sound levels of that autotransformer until June 21, 2016. Each set of measurements established the operating sound levels of the respective autotransformer operating alone.

The measurement data shows that sound levels fluctuated throughout the two measurement periods. The average sound levels for the autotransformers are consistent with expected operational sound levels and each autotransformer's rated sound level. However, the sets of data confirm that there are frequent spikes in sound and significant variations in operating sound levels of the autotransformers, similarly to what was measured during the other sets of continuous monitoring.

Complaint Time Period Analysis

One of the neighboring residents indicated specific times when the Substation appeared to be louder than normal during the course of the continuous long-term monitoring period. One specific instance occurred on August 4, 2016, around 1:00 A.M. Burns & McDonnell analyzed this specific time period to try to identify what the residents were experiencing.

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On August 4, 2016, the Substation was operating at normal sound levels until approximately 12:50 A.M. At this point in time, the control meters showed that the autotransformers began gradually getting louder until approximately 1:15 A.M. when the autotransformers reached their peak sound levels. The collected data shows that the control meter for each autotransformer measured approximately 72 dBA. Sound levels measured at Meter 3 (on the south property line) and Meter 5 (on the north property line) exceeded the hourly average L_{eq} limit of 46 dBA during this time period. The peak sound levels at each property line meter were in the dominant frequencies of the autotransformers. The data collected on Meter 4 during this time period was corrupted and could not be recovered. Therefore, only Meter 3 and Meter 5 were analyzed. During this time there were extraneous sound sources influencing the property line meters, but at 1:15 A.M. the meters showed significant influence from the autotransformers.

Noise Monitoring Summary

According to the IEEE Standards C57.12.90 and C57.136, the principal sources of sound in transformers and autotransformers are the core sound and sound from cooling equipment. The core sound is caused by magnetostriction effects and inter-laminar magnetic forces. It is influenced by the flux density, core material, core geometry, and excitation voltage waveform. The sound from cooling equipment is generally caused by the cooling fans. The fan noise is influenced by the blade-tip speed, blade design, and number of fans. Pump noise is typically insignificant when fans are running. According to the autotransformer manufacturer sound level guarantee, the autotransformers are guaranteed to 62 dBA at 120 mega-volt amperes (MVA), 64 dBA at 160 MVA, and 65 dBA at 200 MVA. Therefore, the units should meet a spatially averaged sound level of 65 dBA at 3 feet at any load. This sound level includes the effects of both the core and the cooling equipment.

The autotransformers are rated to a maximum sound level of 65 dBA at 3 feet, but the sound measurements demonstrate that the units are capable of operating well above that level. At times, the sound meters located 15 feet from the units measured autotransformer-generated sound up to 80 dBA in short sound excursions. These increases are measurable at the property line.

The autotransformers vary in loudness throughout the day and night. Control Meter 1 measured sound levels between 43 and 74 dBA, and Control Meter 2 measured sound levels between 48 and 80 dBA. The control meter locations are close enough to the units that common extraneous sounds would not have a significant effect on measured sound levels.

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The autotransformers' sound levels were generally dominant in the 125- and 400-Hz 1/3 octave band frequencies. At times throughout the measurements, autotransformer sound levels spiked by as much as 25 dBA. The sound level spikes remained elevated for various amounts of time before eventually falling back to normal levels. Some of the spikes in sound lasted for extended periods of time.

The control meters measured sound levels that fluctuated from day to day. The data shows the autotransformers can ramp up and down in sound over 15- to 30-minute periods. The Substation is audible offsite when background sounds subside and at times when the autotransformer sound levels ramp up. Substation sound is periodically measureable as a pure tone at the property line. Based on the far-field data collected, the Substation periodically exceeds the State of Connecticut noise regulations.

These exceedances are not common and happen at irregular intervals. When the autotransformers are operating at their specified levels, the Substation is well below the State limits. However, there appears to be something acting on the system that is causing the autotransformers to ramp up in sound for short periods of time. During these short-lived sound excursions, State sound level limits have the potential to be exceeded.

CL&P dba Eversource Energy
Petition No. Petition 1140

Witness: NO WITNESS
Request from: Connecticut Siting Council

Question:
What are the expected maximum sound levels at the property boundaries following completion of the permanent sound wall mitigation?

Response:
The sound levels of the autotransformers constantly fluctuate; therefore, the sound walls have been designed to limit the property line sound levels to 46 dBA or less at all points along the property lines and at all times. After the sound walls have been installed, the maximum sound level along the western boundary of the property is expected to be 45.9 dBA and the maximum sound levels along the other property boundaries are expected to be lower than 45.9 dBA.

CL&P dba Eversource Energy
Petition No. Petition 1140

Data Request CSC-01
Dated: 06/01/2017
Q-CSC-003

Witness: NO WITNESS
Request from: Connecticut Siting Council

Question:
Please provide a photographic example of what the sound wall material would look like.

Response:
Please see the attachment, which provides a depiction of the material for a similar sound wall. Please note that this is not an exact depiction of the final product that will be used and it is subject to change based on specific design parameters at Barbour Hill Substation:


||Petition No. Petition 1140
||Data Request CSC-01
||Dated 06/01/2017
||Q-CSC-003, Page 1 of 1

CL&P dba Eversource Energy
Petition No. Petition 1140

Data Request CSC-01
Dated: 06/01/2017
Q-CSC-004

Witness: NO WITNESS
Request from: Connecticut Siting Council

Question:
Could the increase in the height of the 115-kV conductor proposed in Attachment A of the petition amendment, be accomplished through tensioning of the conductor? Or some other method?

Response:
The 115-kV conductor specified within Attachment A is a rigid bus conductor; therefore, tensioning is not possible. The need to raise the referenced 115-kV conductor is not only to gain clearance over the new sound wall but also to facilitate the connection between the 115-kV bushing of the transformer and the 115-kV substation bus, with which the new sound wall would intersect. The design facilitates the connection of the two 115-kV points by routing a section 115-kV rigid bus higher, and over the sound wall.

Other design options (Gas Insulated Bus (GIB), insulated bus duct, underground cable, etc.) that could be installed under or directly through the sound wall were evaluated as a means to avoid increasing the 115-kV conductor height. However, due to the costs of the added design and construction work and the extra material, the alternatives were not pursued.