MECHANICAL EQUIPMENT ANALYSIS
ACOUSTIC REPORT

ENERGY FACILITY CONVERSION
AND EXPANSION PROJECT - TIGER

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INTRODUCTION

ZGF is currently designing a new TIGER building for Princeton University. The new facility will house mechanical equipment associated with a central utility facility such as chillers, pumps, and exhaust fans. A generator may be included at a later date. The following report details the predicted noise levels surrounding the site based on this new equipment as well as the ambient noise levels that are currently present. The ambient noise levels are based on noise surveys that were performed on January 19, 2020 and November 14, 2020.

EXECUTIVE SUMMARY

This report summarizes our review of the mechanical systems associated with the proposed TIGER building at Princeton University. It includes both current ambient noise levels measured at the site as well as predicted noise levels at identified locations around the site once the building is operational.

Existing noise levels were measured on January 19, 2020 from 12:30 PM to 4:00 PM and on November 14, 2020 from 7:00-8:00 PM. Noise levels were captured without any activities taking place (ambient noise levels) as well as discrete events such as car pass bys and helicopter flyovers. The ambient measurements during the day showed that noise levels on site were in the range of 45-50 dBA with no activities taking place. At night, these levels were in the 40-45 dBA range. Discrete events could increase those noise levels into the 60-65 dBA range with some noise as high as 70 dBA for louder events such as the helicopter flyover. These noise levels are typical for a residential/campus site.

Predicted noise levels were also calculated based on the basis of design equipment for the new TIGER building. This included equipment such as chillers, pumps, a generator, and exhaust fans. Factors such as barrier effects due to the TES Tanks and the building itself were considered as well as distance from the measurement locations. Predicted noise levels for all of the equipment together, except the generator as this will only operate every once in a while for testing or in an emergency situation, were at or below the New Jersey noise code.

The noise levels measured on site are typical for a residential/campus environment. While noise levels from the facility have been predicted to be equal to or less than ambient noise levels (depending on time of day), we would anticipate that any audible sounds at the property line will not be disruptive and will be less than discrete events such as car pass bys and helicopter flyovers. Predicted noise levels from the facility will meet the New Jersey noise code.

Also included in this report are recommendations for appropriate vibration isolation for each piece of equipment in order to limit the propagation of vibration to spaces within the TIGER / Athletic Ops building as well as recommendations to reduce noise levels to the occupied interior spaces.
3 ACOUSTICAL STANDARDS

The recommendations presented in this report are consistent with the criteria and design standards listed below.

3.1 2019 ASHRAE APPLICATIONS HANDBOOK

Chapter 49 “Noise and Vibration Control” from the 2019 ASHRAE Applications Handbook is the industry standard for mechanical, electrical, and plumbing noise control related to building HVAC systems. Mechanical system treatments and design guidelines presented in this report are primarily based upon this document. Wherever possible, the mechanical system design should follow this standard, which is the most current version of the document.

3.2 PRINCETON NOISE CODE

The Princeton Noise Code Chapter 21 ‘Loud, Continuous or Excessive Noise’ states the following with regards to property line noise:

Sec. 21-1. Loud, continuous or excessive noise.

It shall be unlawful for any person to make, continue or cause to be made or continued any loud, continuous or excessive noise or any noise which endangers the health, safety or welfare of the community, or which annoys, disturbs, injures or endangers the comfort, repose, health, peace or safety of others within Princeton. (Ord. No. 2014-35)

This type of noise code is very difficult to enforce as what is considered excessive or annoying to one resident may not be considered so by another resident. We therefore recommend that the project follow the State of New Jersey noise code noted below.

3.3 NEW JERSEY NOISE CODE

The state of New Jersey noise code Chapter 29 ‘Noise Control’ states the following with regards to property line noise:

7:29-1.2 Industrial, commercial, or community service facilities

a) No person shall cause, suffer, allow, or permit sound from any industrial, commercial, or community service facility that, when measured at any residential property line of any affected person, is in excess of any of the following:

1. From 7:00 AM to 10:00 PM
   i. Continuous airborne sound which has a sound level in excess of 65 dBA; or
   ii. Continuous airborne sound which has an octave band sound pressure level in decibels which exceeds the values listed below in one or more octave bands

<table>
<thead>
<tr>
<th>Frequency (Hz)</th>
<th>31.5</th>
<th>63</th>
<th>125</th>
<th>250</th>
<th>500</th>
<th>1000</th>
<th>2000</th>
<th>4000</th>
<th>8000</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sound Pressure Level (dB)</td>
<td>96</td>
<td>82</td>
<td>74</td>
<td>67</td>
<td>63</td>
<td>60</td>
<td>57</td>
<td>55</td>
<td>53</td>
</tr>
</tbody>
</table>

   iii. Impulsive sound in air which has a maximum sound level in excess of 80 dBA

2. From 10:00 PM to 7:00 AM
   i. Continuous or airborne sound which has a sound level in excess of 50 dBA; or
   ii. Continuous airborne sound which has an octave band sound pressure level in decibels which exceeds the values listed below in one or more octave bands
### 4 AMBIENT SITE NOISE LEVELS

On January 19, 2020, The Sextant Group performed a site survey of the proposed location for the new TIGER building. The survey was conducted between 12:30 PM and 4 PM and encompassed both the proposed site of the new building and mechanical equipment at the existing Central Utility Plant (CUP). Measurements of ambient conditions on site were recorded as well as any discrete events (such as car pass bys, helicopters, etc) that were noted while on site.

Additional measurements were recorded by Princeton University on November 14, 2020. The purpose of these measurements was to record both weekend and nighttime ambient readings.

#### 4.1 MEASUREMENT LOCATIONS AND EQUIPMENT

The diagram below shows the measurement locations. These locations were selected by the client to represent the boundaries of the property as well as some of the more acoustically sensitive areas surrounding the property.

<table>
<thead>
<tr>
<th>Frequency (Hz)</th>
<th>31.5</th>
<th>63</th>
<th>125</th>
<th>250</th>
<th>500</th>
<th>1000</th>
<th>2000</th>
<th>4000</th>
<th>8000</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Sound Pressure Level (dB)</strong></td>
<td>86</td>
<td>71</td>
<td>61</td>
<td>53</td>
<td>48</td>
<td>45</td>
<td>42</td>
<td>40</td>
<td>38</td>
</tr>
</tbody>
</table>

iii. Impulsive sound in air which has a maximum sound level in excess of 80 dBA and such impulse sound shall not be repeated more than four times in any hour. Impulsive sound which repeats more than four times in any hour shall not exceed 50 dBA.
4.2 MEASUREMENT RESULTS

The table below shows the ambient noise levels at each location during the time of the surveys.

<table>
<thead>
<tr>
<th>Measurement Location</th>
<th>Ambient Noise Level Daytime (dBA)</th>
<th>Ambient Noise Level Evening / Weekend (dBA)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>45-50</td>
<td>42-45</td>
</tr>
<tr>
<td>2</td>
<td>45-50</td>
<td>43-46</td>
</tr>
<tr>
<td>3</td>
<td>45-50</td>
<td>41-44</td>
</tr>
<tr>
<td>4</td>
<td>45-50</td>
<td>40-43</td>
</tr>
<tr>
<td>5</td>
<td>45-50</td>
<td>41-46</td>
</tr>
</tbody>
</table>

The measurements above represent the noise level when there was very little activity on the site and no cars passing by. The following table shows the increase in noise levels due to discrete events.

<table>
<thead>
<tr>
<th>Event</th>
<th>Noise Level (dBA)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Car Pass by</td>
<td>60-65</td>
</tr>
<tr>
<td>Helicopter Flyover</td>
<td>65-70</td>
</tr>
<tr>
<td>Truck Pass by</td>
<td>60-65</td>
</tr>
</tbody>
</table>

Measurements were also recorded in the existing Central Utility Plant. These were of limited use as most of the equipment was not operational due to it being winter. One measurement that was useful was the measurement directly adjacent to an existing chilled water pump. This helped us to gain a better understanding of the frequency spectrum of the noise emanating from these pumps which helped our calculations, described below, be more accurate.

4.3 CONCLUSIONS

The noise levels measured on site are typical for a residential/campus environment. While noise levels from the facility have been predicted to be equal to or less than ambient noise levels (depending on time of day), we would anticipate that any audible sounds at the property line will not be disruptive and will be less than discrete events such as car pass bys and helicopter flyovers. Predicted noise levels from the facility will meet the New Jersey noise code.

5 EXTERNAL NOISE SUMMARY

This report will discuss multiple types of proposed mechanical equipment located in various locations in and around the TIGER building. These include the following:

- Chillers located in the Chiller Room
- Pumps located in the Chiller Room
- Exhaust Fans located on the roof
- Generator located adjacent to the building

Calculations consider noise data provided by the mechanical engineer as well as any structural items, such as the tanks or the building itself, that might provide some reduction of the noise. Calculations were performed for all locations noted in the site survey section above and conclusions have been drawn regarding the relationship between the predicted noise levels and the measured ambient noise levels. A summary at the end of this report discusses the overall noise impact on the surrounding area that is predicted based on operational noise generated by all of the different mechanical equipment.
5.1 CHILLERS

There will be four chillers located in the chiller room in the TIGER building. The sound pressure level at 3 feet for each unit is shown in the table below.

<table>
<thead>
<tr>
<th>Frequency (Hz)</th>
<th>63</th>
<th>125</th>
<th>250</th>
<th>500</th>
<th>1000</th>
<th>2000</th>
<th>4000</th>
<th>8000</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sound Pressure Level at 3 feet (dB)</td>
<td>81</td>
<td>85</td>
<td>83</td>
<td>80</td>
<td>79</td>
<td>81</td>
<td>76</td>
<td>69</td>
</tr>
</tbody>
</table>

The chiller room is located at the south end of the building. The building façade will be comprised of 1” IGU glass and CMU with metal panels. There will also be louvers, similar to Vibro-Acoustics ‘ALV-MV-18’ that will be used to allow air flow into the chiller room. The glass and the louvers will be the weak points of the construction. The currently selected louvers have the following insertion losses

<table>
<thead>
<tr>
<th>Frequency (Hz)</th>
<th>125</th>
<th>250</th>
<th>500</th>
<th>1000</th>
<th>2000</th>
<th>4000</th>
<th>8000</th>
</tr>
</thead>
<tbody>
<tr>
<td>Insertion Loss (dB)</td>
<td>10</td>
<td>14</td>
<td>18</td>
<td>25</td>
<td>24</td>
<td>23</td>
<td>22</td>
</tr>
</tbody>
</table>

Noise levels due to the Chillers have been calculated at each ambient measurement location. Locations 1-4 will not have any obstructions between them and the building, whereas at location 5, the noise path will be partially blocked by the TES Tank. Based on the information above, we predict noise levels due to the chillers to be the following, assuming the acoustical louvers shown in the schedule on the mechanical drawings will be included.

- Location 1: 40-45 dBa
- Location 2: 35-40 dBa
- Location 3: 35-40 dBa
- Location 4: 30-35 dBa
- Location 5: 20-25 dBa

Please also reference Figure 1 in Appendix A which shows a more detailed noise map. As can be seen from the noise information above, these levels will be below ambient noise levels.

5.2 PUMPS

There will be a number of pumps located in the chiller room that will also generate noise. Octave band sound power data was not available for these units, however; the following single number sound power ratings were provided by the mechanical engineer.

- TGR-CHW-1PMP: 4 pumps, 89 dBa
- TGR-CHW-2PMP: 4 pumps, 106 dBa
- TGR-HW-1PMP: 4 pumps, 91 dBa
- TGR-HW-2PMP: 4 pumps, 106 dBa
- TGR-GEO-PMP: 4 pumps, 101 dBa
- TGR-HW-TES-PMP: 2 pumps, 103 dBa
- TGR-CW-TES-PMP: 2 pumps, 106 dBa

During our site survey on January 19, 2020, we were able to measure an existing pump located in the Central Utility Plant on campus. This pump was CHW Pump 7 Chilled Water and the client indicated that it would be similar in nature to the pumps that will be included in the TIGER building. From this data we can take the spectrum of noise from the measured pump and calibrate it to the sound levels noted above. This will provide us with a more accurate calculation.

As with the chillers noted above, the weak point in the façade construction will be the louvers that allow airflow into the chiller room. Locations 1-4 will not have any obstructions between them and the building whereas at location 5 the noise path will be partially blocked by the TES Tank.
Based on the information noted in this report, we predict the noise levels due to Pumps at the ambient noise locations to be the following assuming the acoustical louver is provided as noted on the mechanical drawings:

- Location 1: 50-55 dBA
- Location 2: 45-50 dBA
- Location 3: 45-50 dBA
- Location 4: 40-45 dBA
- Location 5: 25-30 dBA

Please also reference Figure 2 in Appendix A which shows a more detailed noise map. Some of the predicted noises levels may be above ambient noise levels at parts of the day, however; the facility conforms to the NJ noise code as the predicted noise levels at the closest neighboring property line are lower than the code required levels.

5.3 EXHAUST FANS

Based on the current mechanical plans, there will be four exhaust fans located on the roof of the chiller room. These fans will sit on 24” curbs and will be surrounded by a 42” tall parapet. Sound power levels provided by the mechanical engineer are shown in the table below.

<table>
<thead>
<tr>
<th>Fan</th>
<th>Exhaust Fan Sound Power Level (dB re: 10^-12 W)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Frequency (Hz)</td>
</tr>
<tr>
<td></td>
<td>63</td>
</tr>
<tr>
<td>BXX-EF5, 6, 7, &amp; 8</td>
<td>91</td>
</tr>
</tbody>
</table>

Based on the above noted sound power levels and the distances to the various measurement locations we would expect the following noise levels due to all 4 exhaust fans, assuming they run continuously:

- Location 1: 30-35 dBA
- Location 2: 25-30 dBA
- Location 3: 25-30 dBA
- Location 4: 25-30 dBA
- Location 5: 20-25 dBA

Please also reference Figure 3 in Appendix A which shows a more detailed noise map. These units should be below the ambient noise levels on site and are certainly below the noise code goals for the project.
5.4 **TRANSFORMERS**

There will be two transformers located exterior to the building to the north of the TES Tanks. The transformers selected will have a noise level of 72 dB as measured according to NEMA TR 1-2013.

Base on the above noted sound power levels, the predicted noise levels due to the transformers at the various measurement locations are as follows:

- Location 1: 45-50 dBA
- Location 2: 40-45 dBA
- Location 3: 45-50 dBA
- Location 4: 40-45 dBA
- Location 5: 45-50 dBA

All locations will be below both the day and nighttime criteria for the NJ noise code where applicable.

5.5 **EMERGENCY GENERATOR**

The emergency generator for the project will be located exterior to the building between the TES Tanks. This is beneficial as the Tanks will provide some attenuation to the more sensitive residential property lines to the east of the proposed building. The generator currently selected for the project has a sound rated enclosure that provides a noise level of 70 dBA at 23 feet.

Based on the above noted sound power levels and considering any barrier effects from the proposed building and the TES Tanks, the predicted noise levels due to the emergency generator at the various measurement locations are as follows:

- Location 1: 30-35 dBA
- Location 2: 40-45 dBA
- Location 3: 35-40 dBA
- Location 4: 25-30 dBA
- Location 5: 55-60 dBA

Please also reference figure 4 in Appendix A which shows a more detailed noise map. The State of New Jersey noise code does permit the following as it relates to emergency generators:

*Section 7:29-1.5 Exceptions*

14. *Emergency electricity generators at an industrial, commercial, or community service facility in use during an electrical outage*

The generator at the TIGER facility would likely be included in this category, however; there is no provision that excludes the generator while it is being routinely tested. This should be scheduled for a time when it is least disruptive such as during the day on a weekday.
5.6 CUMULATIVE NOISE LEVELS

The following maps indicate the cumulative predicted noise levels at each of the measurement locations around the site. We have included three maps, one showing the Day 1 noise levels which include all of the equipment that will be operating when the facility first opens. The second noise map shows the future noise levels which represent all equipment that is planned for the facility. The third map shows the future noise levels with the addition of the future generator. In all cases, the noise levels reflect all equipment operating simultaneously. It is important to note that this full load condition occurs at a small percentage of annual hours, typically during the hottest and coldest days of the year. The difference between future and Day 1 noise levels is that on Day 1 there will be 2 chillers and 7 pumps that will not be installed yet. These will be installed at a later date.

These noise levels assume that the acoustical louver shown on the mechanical schedule is incorporated at the chiller room and that all units are operating simultaneously. The numbers in green indicate the current ambient daytime noise levels, the numbers in orange indicate the current ambient nighttime noise levels, and the numbers in blue indicate the predicted noise levels due to the proposed mechanical equipment running.

Since the generator will only run while it is being tested or during an emergency when it is exempted, it has not been included in these diagrams.

Day 1 Noise Contour Map
Future Noise Contour Map
As a reminder, New Jersey Noise Codes states that noise levels from the facility must be below 65 dBA during the day and 50 dBA at night for residential property lines.

It should be noted that noise levels due to future equipment increase only slightly from Day 1 noise levels. This is due to the pumps that are being added being located further from the louvers. Adding more chillers does not significantly increase the noise levels as the pumps are the dominant noise source for the building.

Please note that in areas where mechanical equipment noise is below ambient noise, ambient noise levels will dominate in this location. We do not anticipate a decrease in ambient noise levels.
Vibration due to the mechanical equipment has also been discussed as a concern for the client. Typically, if a piece of equipment is isolated per ASHRAE guidelines, vibration transmitted into the surrounding area will be minimal. The table below provides our recommended vibration isolation for each piece of equipment discussed in this report.

<table>
<thead>
<tr>
<th>Equipment</th>
<th>Recommended Isolation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chillers</td>
<td>Rubber mounts with a 0.25” static deflection</td>
</tr>
<tr>
<td>Pumps</td>
<td>Isolated per Princeton University’s requirements.</td>
</tr>
<tr>
<td>BXX.EF5, 6, 7, &amp; 8</td>
<td>No isolation required due to location over spaces that are not acoustically sensitive</td>
</tr>
<tr>
<td>Generator</td>
<td>Spring isolators with a 0.75” static deflection</td>
</tr>
</tbody>
</table>

This concludes our review of the mechanical equipment currently proposed for the new TIGER building. If you have any questions related to this report, please do not hesitate to contact us at ifischer@thesextantgroup.com or 202.753.5564.

Best regards,

Julie E. Fischer INCE, LEED AP BD+C

Senior Acoustical Consultant
7.1 FIGURE 1 - CHILLERS ONLY WITH ACOUSTICAL LOUVERS

7.2 FIGURE 2 - PUMPS ONLY WITH ACOUSTICAL LOUVERS
7.3 FIGURE 3 - EXHAUST FANS ONLY

7.4 FIGURE 4 - GENERATOR ONLY