# ACOUSTICAL ANALYSIS AND RESULTS

## 1. Introduction

The following sections outline acoustical design goals for the facility. Design goals and recommendations for HVAC noise control, sound isolation, and interior noise acoustics are outlined below.

The following standards and documents were referenced for this review:

- UFC 3-101-01
- UFC 3-450-01
- Architectural Drawings
- Mechanical Drawings

## 2. HVAC Noise Design Goals

Background noise level criteria for the spaces are recommended based in terms of Noise Criterion (NC) levels. The NC level refers to the maximum recommended background noise produced by all fixed mechanical equipment serving the space. The recommended noise level goals for the spaces are noted in Table 1.

Noise will transmit into spaces by the sound paths listed below.

1) *Duct-borne Noise* – Noise transmitted from the fan to the diffusers and grilles via the supply and return air ducts. Noise levels are typically highest at the diffusers and grilles closest to the fan.
2) *Duct Breakout Noise* – Noise that transmits through the sheet metal ductwork and into the spaces below.
3) *Air Handler Unit (AHU) Casing Radiated Noise* – Noise radiated from the AHU enclosure and into the space below, including noise transmission directly below the AHU and through adjacent roof transmission paths.
4) *Terminal Unit Noise* – Noise transmitted through the ductwork to the supply air diffusers (discharge noise) and noise transmitted to the space below through the plenum and ceiling tile (radiated noise).
5) *Diffuser and Grille Noise* – Noise generated by supply air diffusers and return air grilles, commonly due to high air velocities through the devices.
6) *Structure-borne Noise* – Noise transmitted by the equipment vibration that is coupled to the building structure and radiates as airborne noise.

The maximum recommended background noise levels or Noise Criterion (NC) values for various spaces are detailed in Table 1, for reference. Recommended NC levels were established from UFC 3-450-01 Table 3-1, and from UFC 3-101-01 Table 2-1 through Table 2-2. These levels should be considered by the mechanical engineers during duct layout design, mechanical unit selection, etc.

**TABLE 1 - RECOMMENDED NC VALUES FOR UNOCCUPIED SPACES**

| Type of Space | NC Value |
|---|---|
| Private Office | 30 |
| Open Office | 40 |
| Conference Room | 30 |
| Lobby/Waiting | 40 |
| Classroom | 30 |
| Research Laboratory | 50 |

To complete the analysis, the sound pressure levels in noise critical rooms were calculated using sound power data from the AHUs. Supply air, return air, and radiated noise were considered for all spaces analyzed. The predicted HVAC noise levels in the “worst case” rooms, or noise critical rooms have been reviewed, as these locations have the shortest duct path to the AHUs. The table below outlines the noise data utilized for the calculations.

**TABLE 2 –PROGRAMMED AHU SOUND POWER LEVELS**

| Unit | Data Set | 63 Hz | 125 Hz | 250 Hz | 500 Hz | 1 kHz | 2 kHz | 4 kHz |
|---|---|---|---|---|---|---|---|---|
| AHU-1 | Supply | 88 | 82 | 102 | 87 | 86 | 85 | 82 |
| | Return | 95 | 92 | 104 | 95 | 92 | 89 | 86 |
| AHU-2 | Supply | 88 | 83 | 101 | 86 | 84 | 83 | 80 |
| | Return | 93 | 91 | 103 | 93 | 90 | 88 | 83 |

Table 3 outlines the calculated NC levels for the “worst case” spaces, along with the corresponding AHU. This table displays the compliance with the design criteria from Table 1.

**TABLE 3 – HVAC BACKGROUND NOISE ANALYSIS**

| Unit Tag | Worst Case Area Served | NC Result | NC Goal | Meets NC Goal | Recommendations |
|---|---|---|---|---|---|
| AHU-2 | Classroom 1 | 28 | 30 | Yes | - |
| AHU-1 | Classroom 2 | 29 | 30 | Yes | - |
| AHU-1 | Classroom 3 | 28 | 30 | Yes | - |
| AHU-2 | Lab 1 | 43 | 50 | Yes | - |
| AHU-1 | Lab 2 | 57 | 50 | **No** | Provide a duct attenuator for the inlet of AHU-1. |
| AHU-2 | Open Office 1 | 35 | 40 | Yes | - |

The attenuator recommended for AHU-1 must meet the insertion loss requirements listed in Table 4, in order to meet the NC goals within Lab 2.

**TABLE 4 – INSERTION LOSS REQUIREMENTS FOR AHU-1 INLET DUCT ATTENUATOR**

| Area Served | Duct Path | Insertion Loss Required (dB) | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | 63 Hz | 125 Hz | 250 Hz | 500 Hz | 1 kHz | 2 kHz | 4 kHz | 8 kHz |
| Lab 2 | Return | - | - | 10 | 4 | 4 | 4 | 4 | - |

3. **Sound Isolation Design Goals**

Sound isolation between spaces is expressed in terms of the Sound Transmission Class (STC) ratings (for airborne sound transmission) and Impact Isolation Class (IIC) ratings (for structure borne sound transmission). The STC ratings are applicable for both partitions and floor/ceiling assemblies. Higher numerical values indicate better sound isolation. The recommended STC ratings for the noise critical spaces, as reported in UFC 3-450-01 Table 5-1 and UFC 3-101-01 Table 2-1 through Table 2-2, are listed in Table 5.

**TABLE 5 – SOUND ISOLATION DESIGN GOALS (STC)**

| Adjacency | | STC |
|---|---|---|
| Private Office | Occupied Space | 50 |
| Open Office | Occupied Space | 50 |

| Adjacency | | STC |
|---|---|---|
| Conference Room | Occupied Space | 50 |
| Classroom/Lab | Occupied Space | 50 |
| Mechanical/Electrical/Boiler | Occupied Space | 60 |

## 4. Sound Isolation Analysis

Relevant partitions in both buildings were analyzed to determine compliance with the criteria outlined in Table 5. Table 6 shows the partition types and calculated STC ratings from the drawings used in the analysis. Table 7 outlines the results based on the partitions between noise critical rooms and the occupiable adjacent rooms. Partitions that do not meet the design criteria are listed in **bold**, and corresponding recommendations are provided.

**TABLE 6 – CALCULATED STC VALUES FOR PROGRAMMED PARTITIONS**

| Partition | STC |
|---|---|
| Type 1 | 49 |
| Type 2 | 55 |
| Type 3 | 55 |
| Type 4 | 57 |
| Type 5 | 68 |
| Type 6 | 53 |

**TABLE 7 – INTERIOR PARTITION ANALYSIS**

| Adjacency | | Partition Type | Calculated STC Rating | Design Goal | Comments |
|---|---|---|---|---|---|
| Private Office (typical) | Private Office | Type 1 | **49** | 50 | Increase stud spacing. |
| | Open Office | Type 1 | **49** | 50 | |
| | Classroom | Type 2 | 55 | 50 | - |
| Open Office (typical) | Corridor | Type 2 | 55 | 50 | - |
| | Lobby | Type 2 | 55 | 50 | - |
| | Open Office | Type 2 | 55 | 50 | - |
| Classroom (typical) | Classroom | Type 2 | 55 | 50 | - |
| | Corridor | Type 2 | 55 | 50 | - |
| | Lobby/Reception | Type 2 | 55 | 50 | - |

| Adjacency | | Partition Type | Calculated STC Rating | Design Goal | Comments |
|---|---|---|---|---|---|
| Lab (typical) | Lab | Type 3 | 55 | 50 | - |
| | Corridor | Type 4 | 57 | 50 | - |
| Conference Room (typical) | Private Office | Type 2 | 55 | 50 | - |
| | Open Office | Type 2 | 55 | 50 | - |
| | Corridor | Type 2 | 55 | 50 | - |

## 5. Interior Acoustics

The reverberation time of an enclosed space is a vital factor in determining its acoustical characteristics. Reverberation occurs when sound reflects from room surfaces, then reaches the listener after the original sound. This reverberant energy interferes with the direct sound at the listener's ear, which has negative implications for understanding speech. Reverberation time, expressed by the unit $RT_{60}$, represents the amount of time (in seconds) required for reverberant energy to decay to an inaudible level. Higher $RT_{60}$ values correspond to a greater amount of reverberation, which reduces speech intelligibility.

Reverberation time is based on the intended use of each space and typical room volume. Table 8 outlines recommended $RT_{60}$ values for noise-critical space types in the facility. These recommended $RT_{60}$ values are taken from UFC 3-101-01 Table 2-1 through Table 2-2 (per UFC 3-450-01).

**TABLE 8 - RECOMMENDED RT60 VALUES FOR UNOCCUPIED SPACES**

| Type of Space | $RT_{60}$ (seconds) |
|---|---|
| Classroom | < 0.6 |
| Lab | < 1.4 |
| Private Office | < 0.6 |
| Open Office | < 0.8 |
| Conference Rooms | < 0.5 |

## 6. Interior Acoustics Analysis and Recommendations

Typical noise critical spaces were analyzed to determine compliance with the design goals from Table 8. This analysis considered geometric room volume and finish materials to calculate the absorptive properties of the space. The $RT_{60}$ value at 500 Hz, 1000 Hz, and 2000 Hz was

estimated using Sabine's formula. Table 9 compares the recommended $RT_{60}$ to the calculated $RT_{60}$ values for each frequency. Results in **bold** represent reverberation times that do not meet the recommended $RT_{60}$ values and are followed by the calculated reverberation time if additional absorption is included. Recommendations for spaces that do not meet the recommendation are summarized in the final column. Spaces of similar size and finish materials are grouped into one line since they exhibit the same $RT_{60}$ results.

**TABLE 13 – CALCULATED $RT_{60}$ VALUES (SECONDS)**

| Room Name | $RT_{60}$ Goal | Calculated $RT_{60}$ (seconds) | Comments |
|---|---|---|---|
| Classroom (typical) | 0.6 | 0.51 | - |
| Lab (typical) | 1.4 | **3.3** | Provide 250 $ft^2$ of additional absorption (NRC 0.7). |
| P.O. (typical) | 0.6 | 0.44 | |
| Conference (typical) | 0.5 | 0.44 | |
| Open Office (typical) | 0.8 | 0.52 | |

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