

# Acoustical Analysis

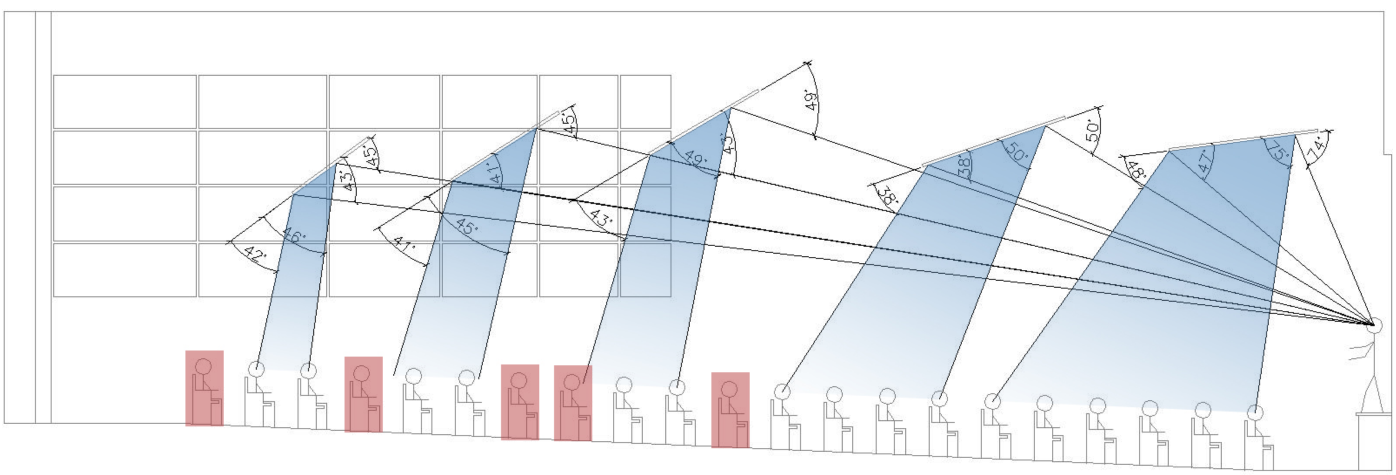
**Analysis Description:**

In the Auditorium of Licking County Joint Vocational School, several attributes were added to the space for better acoustical performance. This analysis will check to see if these additions are beneficial to the room acoustics, and will make suggestions for changes if problems are found with the acoustics of this space.

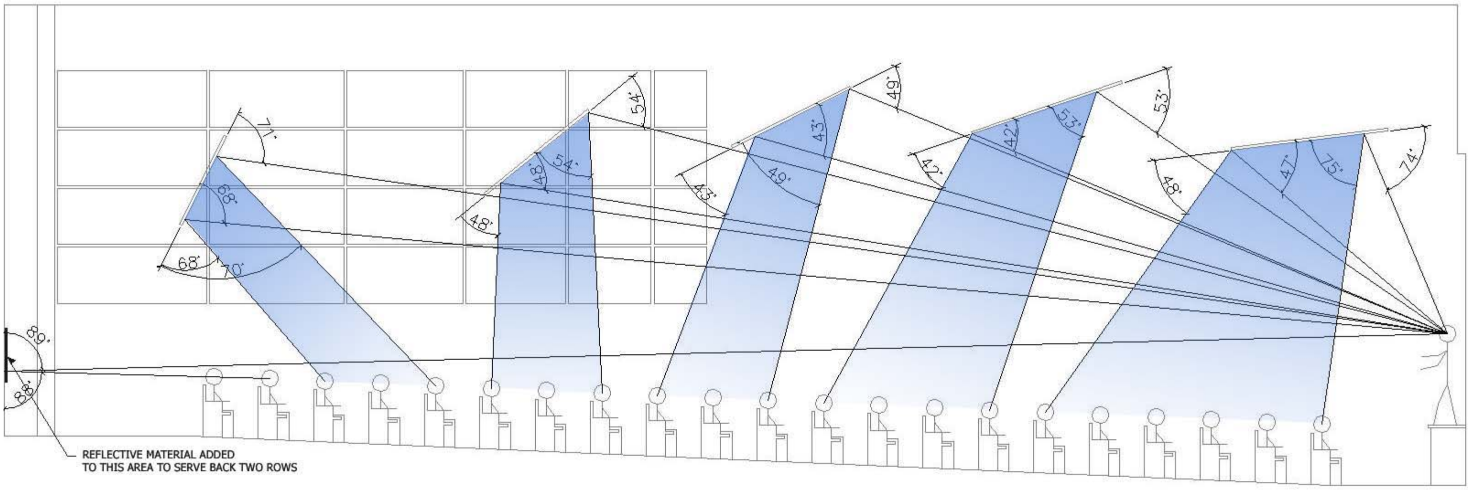
**Ray Diagrams:**

Ray diagrams are a method for analyzing whether or not reflected sounds would cause annoying echoes. If the sound path of the reflected sound is more than 34’ longer than the direct sound path, the listener will perceive a noticeable, and annoying, echo. Reflected sound can come from either the ceiling or the walls, and both will be analyzed.

In order to reflect sound effectively to the audience, sound reflecting panels suspended from the ceiling in this space. The first analysis will check whether or not these sound reflecting panels are effective.

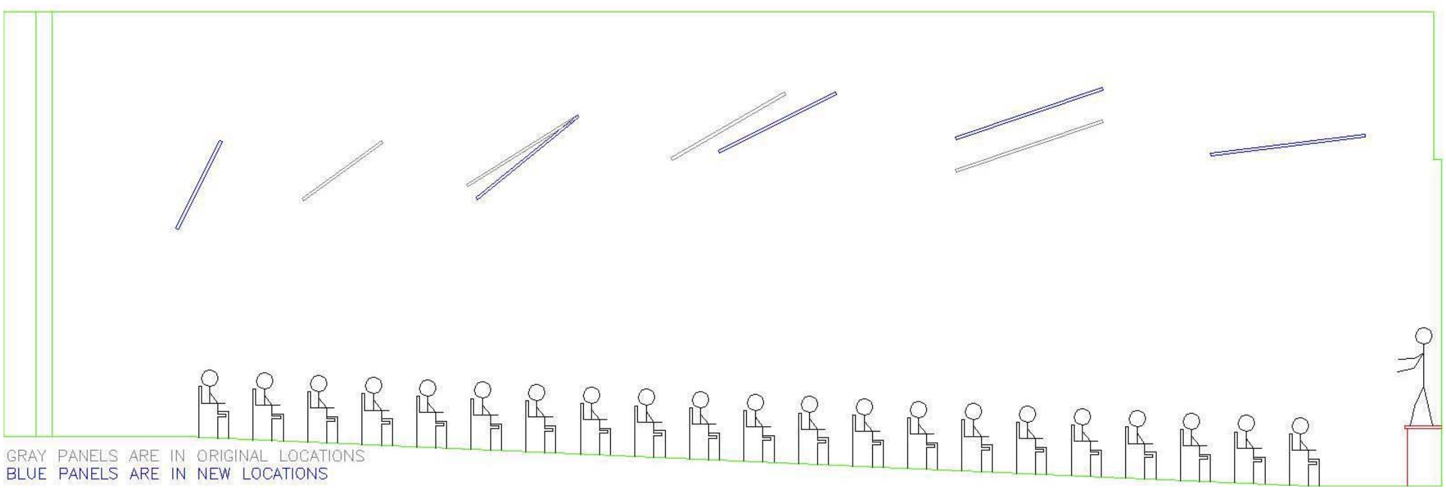


Areas distinguished by blue are “live” areas, while seats marked in red illustrate “dead” areas. This shows that the sound reflector panels are inefficiently designed to spread sound to all areas of the theater. The following image shows the panels in new locations that will reflect the sound to all areas of the audience and eliminate dead areas.

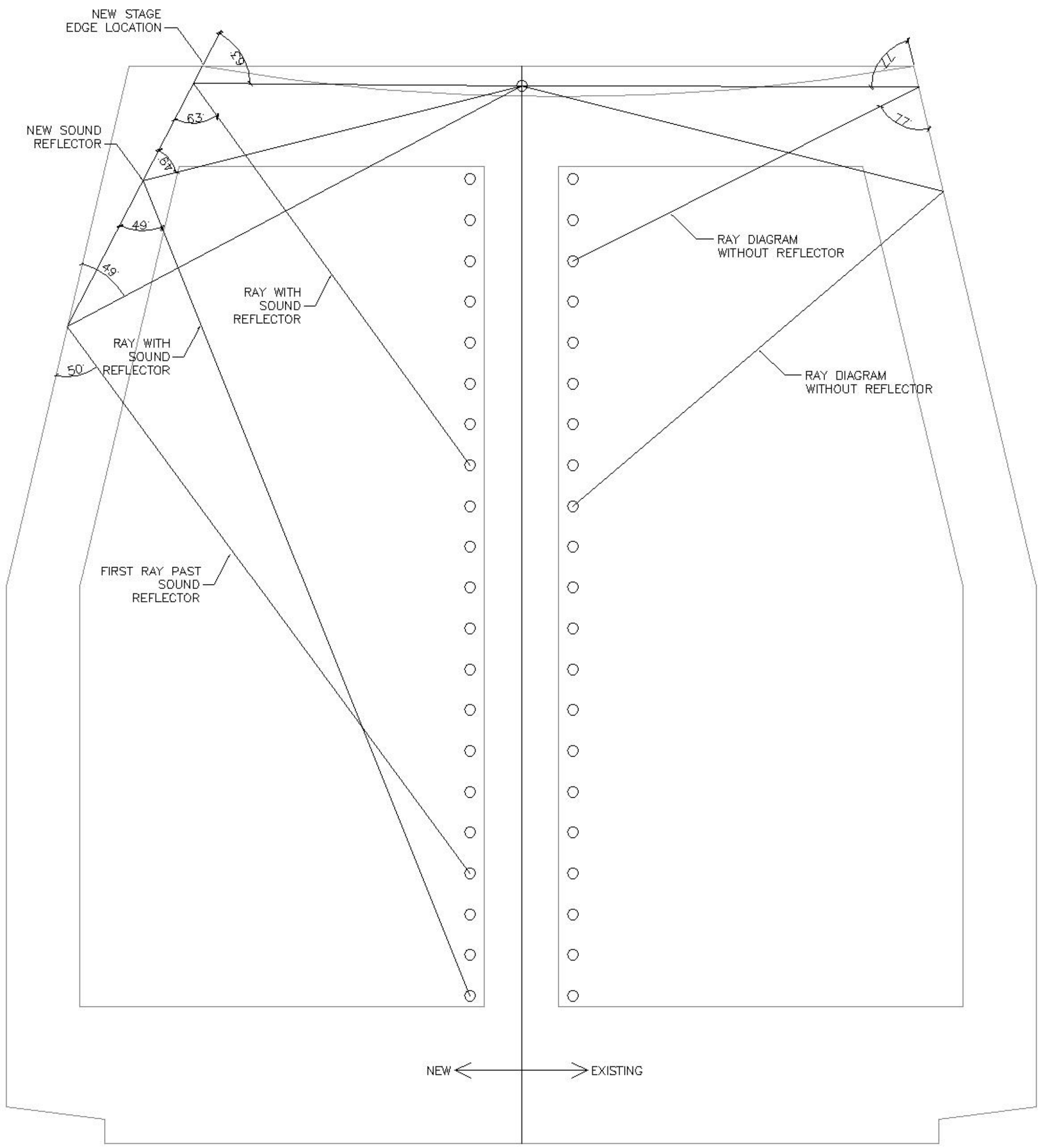



As evidenced by this illustration, there are no "dead" zones in the crowd where sound will not be reflected. In addition to zone checks, the reflective path distance was compared to the direct path distance for each sound path. The results found that there were no differences between the two paths greater than 34', which is acceptable for this space.

This image shows the original positions of the panels in grey, and the new position in blue.




The next area of analysis was the reflected sound from the walls. This analysis was done in the same way as the ceiling ray diagrams. On the right side of this image is the original design. The problem with this design was that the reflected sound path was considerably longer than the direct sound path. This would cause annoying echoes to be heard by the crowd. The left side of the image shows a new design with a 10' high gypsum board panel added at 9' above the finished floor. This panel will reflect the sound further back in the auditorium. This serves two purposes, first to eliminate echoes for the first few rows, and second to reflect more sound to the back of the auditorium where hearing could be difficult due to distance from the stage.



## Reverberation Calculation:

The second acoustical analysis is a reverberation time calculation. Reverberation time is a calculation of the amount of time it takes the sound to diminish by 60 dB, or $T_{60}$ time. Ideal reverberation time for a high school auditorium is between 1.5 and 1.8 seconds. Room surfaces were analyzed to determine their absorption coefficients, and the overall space absorption was used to determine the $T_{60}$ reverberation time. This table is the analysis of the different room materials.

| Existing Conditions Room Absorption | | | | | | |
|---|---|---|---|---|---|---|
| **Room Surface** | **Material** | **Surface Area** | **SAC @ 500 Hz** | **SAC @ 1000 Hz** | **Absorption @ 500 Hz (sabines)** | **Absorption @ 1000 Hz (sabines)** |
| Ceiling | Concrete | 6751 | 0.02 | 0.02 | 135.02 | 135.02 |
| Wall | Gypsum Board | 1752 | 0.08 | 0.04 | 140.16 | 70.08 |
| Wall | CMU | 3064 | 0.06 | 0.07 | 183.84 | 214.48 |
| Wall | Wood Fiber Board | 1094 | 0.62 | 0.94 | 678.28 | 1028.36 |
| Wall | Steel Door | 42 | 0.1 | 0.1 | 4.2 | 4.2 |
| Stage | Opening | 1045 | 0.5 | 0.5 | 522.5 | 522.5 |
| Moving Partition | Carpet on Board | 1360 | 0.63 | 0.85 | 856.8 | 1156 |
| Window | Glass | 24 | 0.18 | 0.12 | 4.32 | 2.88 |
| Audience | Audience in Upholstered Seats | 4251 | 0.8 | 0.94 | 3400.8 | 3995.94 |
| Carpet | Carpet on Concrete | 2663 | 0.14 | 0.37 | 372.82 | 985.31 |
| | | | | | **Total Abs. @ 500 Hz** | **Total Abs. @ 1000 Hz** |
| | | | | | 6298.74 | 8114.77 |

The average absorption between 500 and 1000 Hz is 7206 sabins. The following equation was used to find the reverberation time given this absorption:

$T_{60} = 0.05\ V/a$

Where $T_{60}$ is the reverb time, V is room volume, and a is the absorption.

The $T_{60}$ time was found to be:

$T_{60}$ = (0.05 * 185652.5 $ft^3$)/7206 sabins = 1.29 seconds < 1.5 seconds

The existing T60 time of 1.29 seconds is too low for this space. The space would be acoustically "dead".

The addition of the panel in the front of the auditorium in the new design will reduce the volume from 185652.5 $ft^3$ to 184362.5 $ft^3$. Using this new volume, the new room absorption necessary for a $T_{60}$ time of 1.5 seconds would be 6145 sabins. This chart is the new room absorption with a few changes made to the system. First, the sound absorbing panels on the side walls have been removed, and replaced by the painted CMU. Second, a small panel of gypsum board is added to the rear moving partition to reflect sound to the back few rows.

**New Conditions Room Absorption**

| Room Surface | Material | Surface Area | SAC @ 500 Hz | SAC @ 1000 Hz | Absorption @ 500 Hz (sabines) | Absorption @ 1000 Hz (sabines) |
|---|---|---|---|---|---|---|
| Ceiling | Concrete | 6751 | 0.02 | 0.02 | 135.02 | 135.02 |
| Wall | Gypsum Board | 1752 | 0.06 | 0.07 | 105.12 | 122.64 |
| Wall | CMU | 4158 | 0.06 | 0.07 | 249.48 | 291.06 |
| Wall | Wood Fiber Board | **0** | 0.62 | 0.94 | 0 | 0 |
| Wall | Steel Door | 42 | 0.1 | 0.1 | 4.2 | 4.2 |
| Stage | Opening | 1045 | 0.5 | 0.5 | 522.5 | 522.5 |
| Moving Partition | Carpet on Board | 1020 | 0.63 | 0.85 | 642.6 | 867 |
| Rear Reflector | Gypsum Board | 340 | 0.06 | 0.07 | 20.4 | 23.8 |
| Window | Glass | 24 | 0.18 | 0.12 | 4.32 | 2.88 |
| Audience | Audience in Upholstered Seats | 4251 | 0.8 | 0.94 | 3400.8 | 3995.94 |
| Carpet | Carpet on Concrete | 2663 | 0.14 | 0.37 | 372.82 | 985.31 |
| | | | | | **Total Abs. @ 500 Hz** | **Total Abs. @ 1000 Hz** |
| | | | | | 5457.26 | 6950.35 |

Areas in red on the above chart are changes from the original design. These changes lead to average room absorption of 6204 sabins, which makes the new $T_{60}$ = 1.49 seconds. With the reduction of the volume of the space, it is very difficult to achieve 1.5 seconds, but 1.49 seconds is acceptable.

**Conclusion:**

By making a few changes to the original design, the sound will be more evenly distributed in the space, the echoes from wall sound reflections are reduced, and the space will be livelier acoustically. These changes will also likely save money due to the elimination of the absorptive paneling on the walls.