4.0 INTRODUCTION TO ACOUSTICAL BREADTH

The Prothro Family Theatre is a small and intimate space with a maximum seating capacity of approximately 130 persons. Actual seating capacity varies depending on room configuration for the particular event. The use of this space also varies considerably; student university organizations are restricted from using the theatre, and consequently scheduled events are specific from year to year. Generally this space is used for presentations, ceremonies, and intimate theatrical performances.

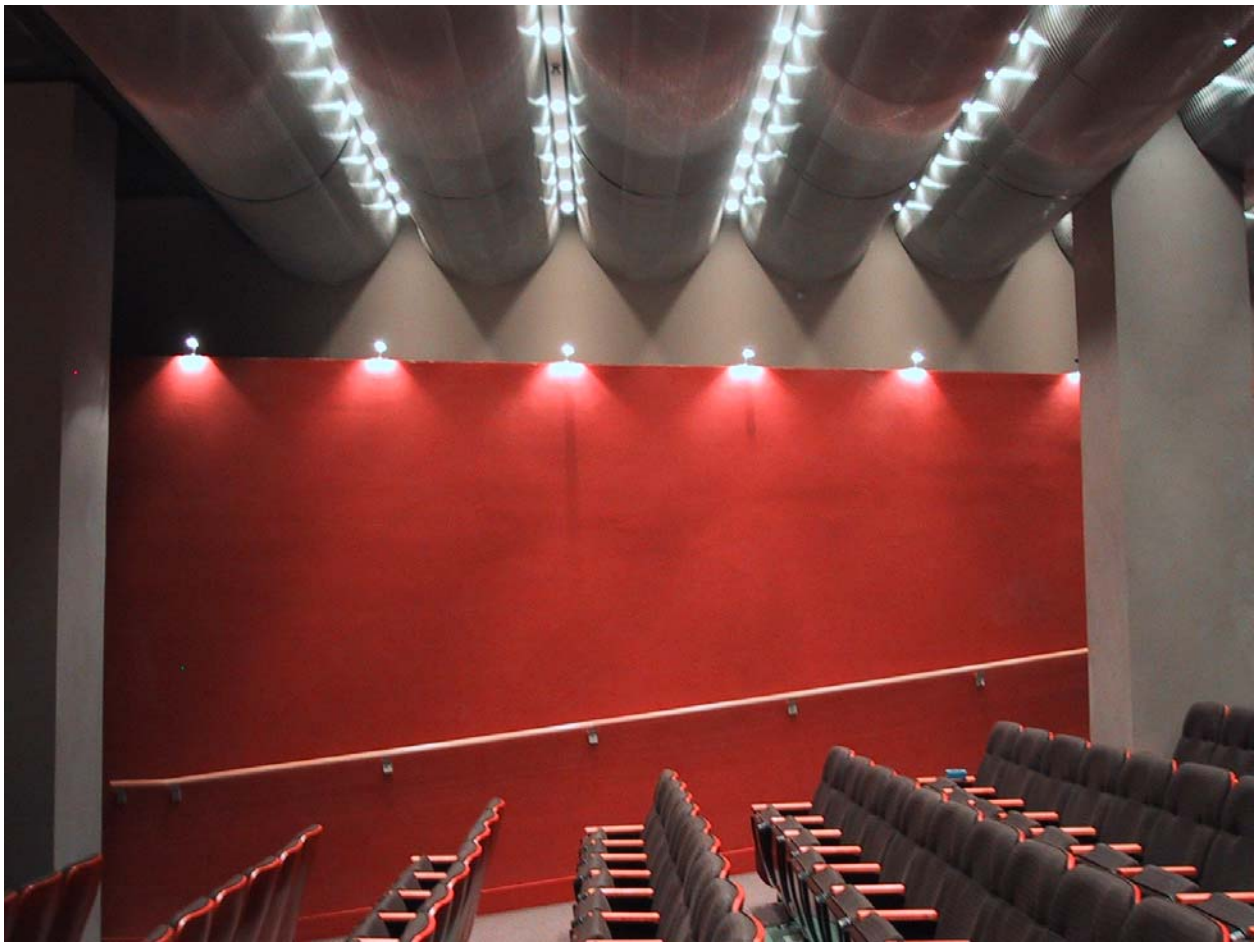
The objective of this study is to first calculate existing room reverberation time and then compare it to recommended time. The calculated reverberation time will determine whether revisions should be made to the construction of the space. If the reverberation time is within the specified criteria, modifications to the new lighting system will try to preserve existing conditions. A calculation with the redesigned lighting will then be completed to confirm that changes in room acoustics were minimal. If existing room conditions are less than desirable, the space will be redesigned and the new lighting system will be specified to compliment this design. A second reverberation calculation will be needed to assess the effectiveness of the design.

4.1 EXISTING ROOM ACOUSTICS

OVERVIEW

The room height is approximately sixteen feet and seating area depth is nearly thirty-seven feet. These figures do not include the stage area, which is approximately fifteen feet deep and fourteen feet in height. Approximately 130 persons will occupy this space at full capacity. Existing features of the space include a large three-quarter wall along the aisle (approximate height 9 feet) and custom perforated mesh ceiling tiles. The room seating area and isles are carpeted, and the seats have heavy cushioning.

Photograph of Existing Theatre Conditions



4.2 CALCULATIONS FOR EXISTING REVERBERATION TIME

OVERVIEW
The Sabins formula was used to calculate reverberation time. M. David Egan's Book *Architectural Acoustics* summarizes the Sabins formula as follows:

T = (0.05 V) / a
Where "T" represents time in seconds, "V" is room volume, and "a" is sound absorption in Sabins.

Absorption in Sabins was calculated based on assumed absorption coefficients and surface area: A = α /SA.
220 Sabins of absorption was assumed for air.

Reverberation Time - Existing Conditions

		125 Hz		500 Hz		4000 Hz	
Material	**Area (Sq.ft.)**	**α**	**sabins**	**α**	**sabins**	**α**	**sabins**
Fully Occupied							
Ceiling							
Mesh Ceiling Panels	9037	0.10	904	0.65	5874	0.40	3615
Concrete	772	0.01	8	0.02	15	0.02	15
Glass	27	0.18	5	0.04	1	0.02	1
Side and Rear Walls							
Veneer Plaster	1532	0.14	214	0.06	92	0.03	46
Columns							
concrete, rough	247	0.01	2	0.04	10	0.10	25
Aisles							
Carpet, heavy on Concrete	426	0.02	9	0.14	60	0.65	277
Proscenium Opening	448	0.15	67	0.10	45	0.07	31
Air	1732	-		-		-	220
Doors	175	0.19	33	0.09	16	0.05	9
Audience							
seated in upholstered seats	576	0.39	225	0.80	461	0.87	501
Total Absorption			**1467**		**6573**		**4740**
One-Half Occupied							
Total absorption in auditorium less audience absorption from fully occupied calculation			1242		6113		4238
Seats, upholstered	300	0.19	57	0.56	168	0.59	177
Audience in upholstered seats	350	0.39	137	0.80	280	0.87	305
Total Absorption			**1436**		**6561**		**4720**

Theatre Volume (ft^3) 27770

	Reverberation Time (s)		
Conditions	**125 Hz**	**500 Hz**	**4000 Hz**
Fully Occupied	0.95	0.21	0.29
One-half Occupied	0.97	0.21	0.29
500-4000 Hz Average, Fully Occupied	0.25		
500-4000 Hz Average, Half Occupied	0.25		

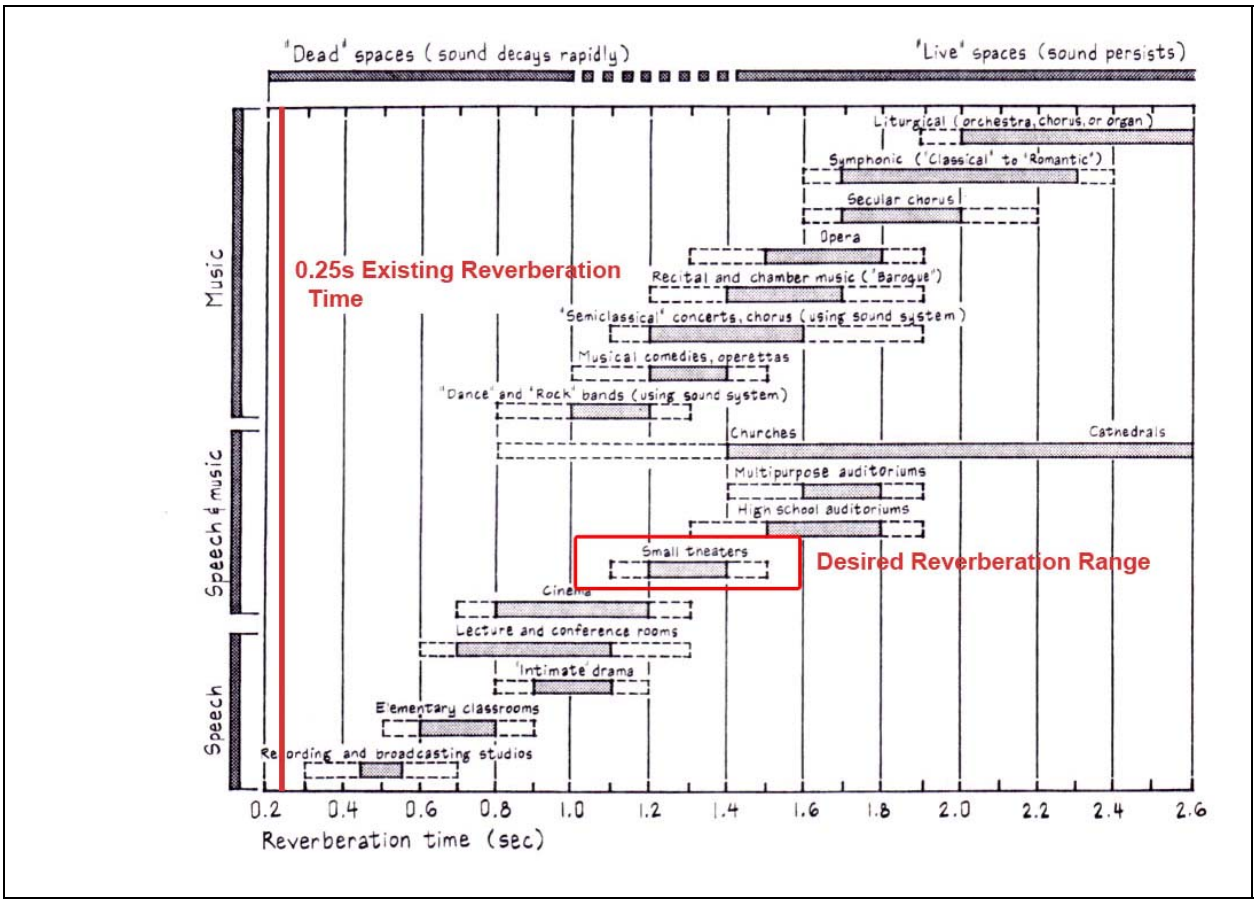
ASSESSMENT

The average of 500 Hz and 4000 Hz reverberation times were used to assess existing conditions. The existing reverberation time was calculated to be 0.25 seconds for both fully occupied and half occupied conditions.

Based upon the use and size of the Prothro Family Theatre, this space was categorized as a "small theatre." This category recognizes the fact that long reverberation times are difficult to implement in small spaces. The category also overlaps with the the category "multipurpose auditorium" and should provide acceptable reverberation time for speaking events.

The calculated reverberation time for existing conditions is considerably below the desired range for this space. Consequently, room materials and shape will be selected to improve acoustics.

Diagram with Existing and Target Reverberation Times



4.3 ACOUSTICAL REDESIGN

OVERVIEW
There is a need for considerable changes to the Prothro Family Theatre to improve room acoustics. To speed the redesign process, a concept image was used when redesigning the space (figure 4.2-1).

Figure 4.2-1 Copenhagen Opera Theatre

Photo Courtesy Erco <http://www.erco.com>

MATERIAL SELECTIONS

To increase reverberation time, harder surfaces were selected for the theatre. These can be summarized as:

Floors: Replace carpet with wood over concrete foundation (match wood in gallery).
Seating area: Replace carpet with wood over concrete foundation (match wood in gallery).
Stage: Design and add (6) small acoustical sound reflectors.
Ceiling: Replace perforated custom ceiling tiles with custom sound-diffusing material.

SAMPLE MATERIALS

The following are sample selections of replacement material for the Prothro Family Theatre. These products or substitutes with similar properties should be selected.

Sample Sound Reflector (Custom Design Required)

Kinetics™

Ovation Reflector Panels

Download as PDF

Ovation Reflector Panels create superior acoustics in auditoriums, performance spaces and lecture halls.

Ovation Reflector Panel Resources

Technical Information

Specification

Installation Instructions

Ovation Layout Guidelines

Pre-Flex Ovation Reflector Panels

Ceiling Suspension (Bowed)

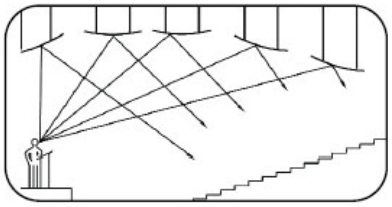
Ceiling Suspension (Flat)

Cleaning Instructions

Contact Information

6300 Irelan Pl.
Dublin, Ohio, U.S.A. 43017
Toll Free: 877.457.2695
Fax: 614.889.0540
E-Mail: **sales@kineticsnoise.com**

Designed for large spaces requiring improved sound directivity, strength, and timing of reflections from the ceiling area, this product is perfect for auditoriums, lecture halls, and performing arts centers.



Constructed of a 1/2" plywood core that is finished with a fiber reinforced gel coat, these curved panels are ceiling-suspended with attachment points on the steel framing. Laminate woodgrain or hardwood veneer finishes are available as an option. The sound reflector/diffuser is shipped as a flat panel and is bowed in the field to the architects' or acoustical consultants' specifications.

Panel radius and dimensions are variable to meet both acoustical and design requirements. The angle of reflection is adjusted in the field using turnbuckle and cable suspension. Colors are custom-selected.

Sample Ceiling Sound Diffusers

Quadratic Sound Diffusers are designed for any music facilities requiring outstanding acoustical performance. Quadratic Diffusers offer maximum sound diffusion with minimum sound absorption over a broad sound band providing for balanced sound throughout the room. They can be used in conjunction with AR's *Interactive System* absorber wall panels which help control room liveliness.

Our most efficient sound diffuser

Product Description:
Quadratic Sound Diffuser Panels are constructed of rigid fiberglass, molded in a one-piece special shape with a select set of well depths. Based on quadratic residue sequences of an elementary number theory, sound from any direction can be uniformly scattered into many directions with the quadratic diffuser. Diffusers help maintain the clarity and help to eliminate poor sound reflection patterns from flat ceiling surfaces.

Quadratic Diffuser Panel Patent #5969301
Overall Size: 47 3/4 x 47 3/4 W x 7" D
Weight: 50 lbs.
Lower Design Frequency: 600 HZ
Upper Design Frequency: 3340HZ
Well Width: 2"
Number of Different Well Depths: 4
Maximum Well Depth: 6 3/8"
Number of Wells per Sequence: 7
Largest Sequence: 4
Number of Sequences per Panel: 3
Finish: White Gel Coat
(Can be painted with acrylic paint. Contact manufacturer for instructions.)

Mounting:
Installed in Heavy Duty 15/16" wide lay-in ceiling panel grid system. All grid to be ASTM C635

Absorption Coefficients for Sound Diffusers

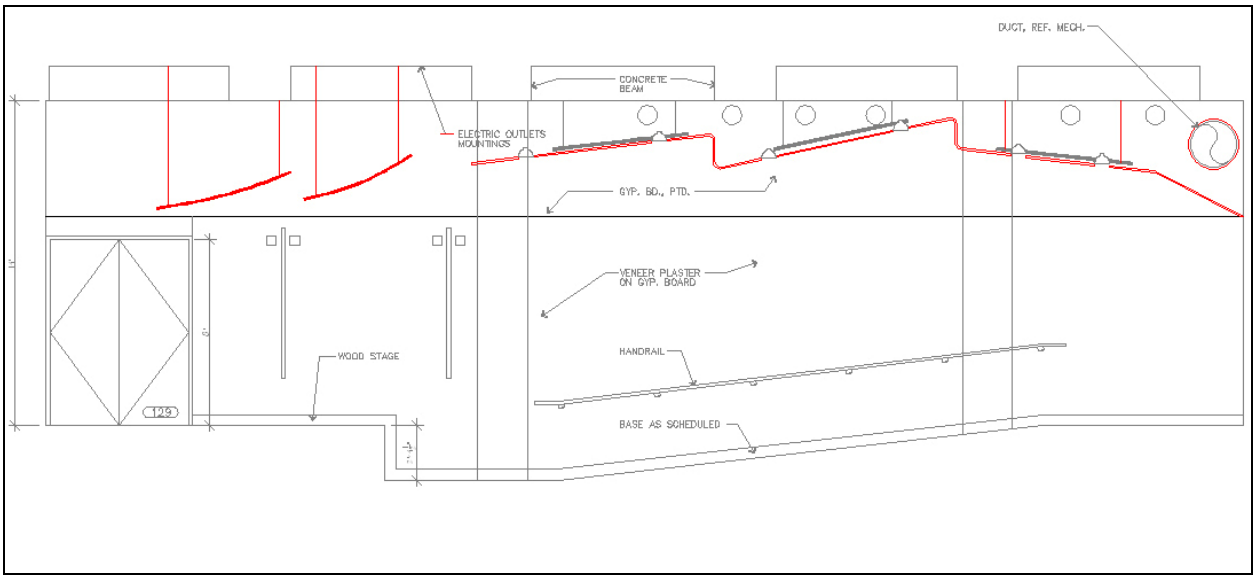
Acoustical:

	Octave Band (HZ)						
Finish	125	250	500	1000	2000	4000	**N.R.C.**
Gel-coat	.23	.43	40	.42	.20	.11	**.35**

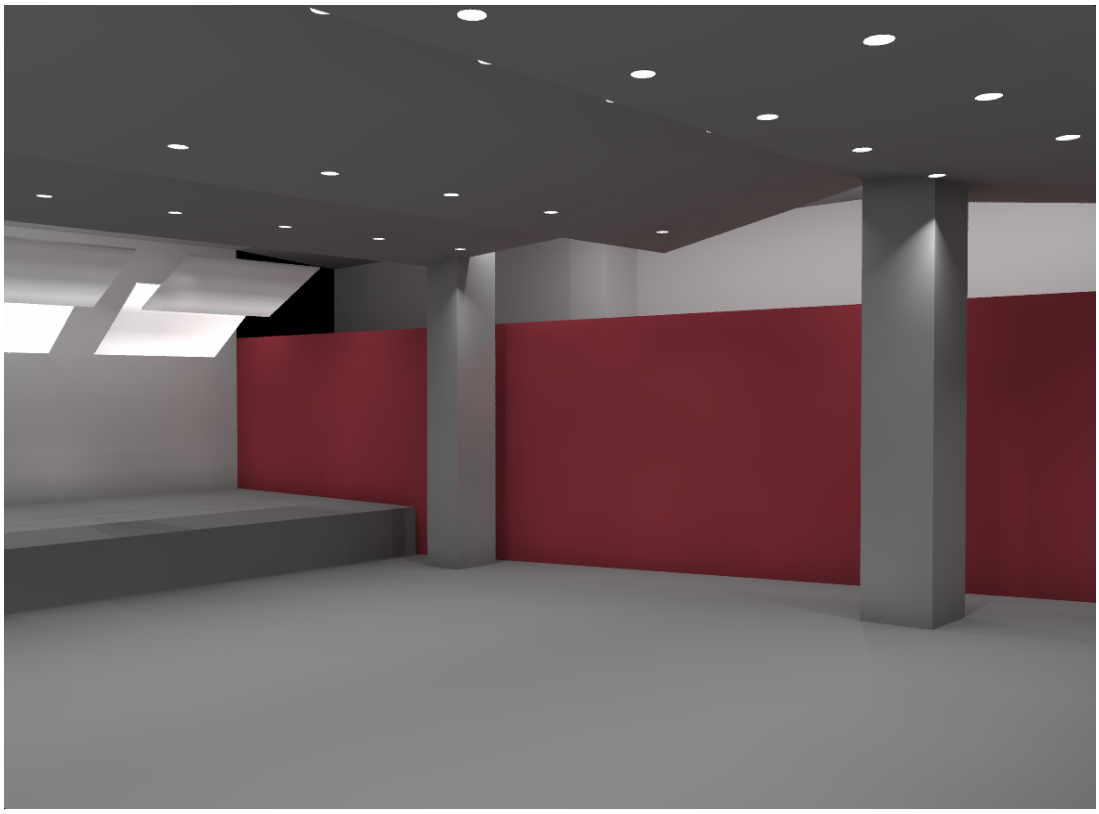
Tested in accordance with ASTM test procedures C-423.
Type "E-400" Mounting.
Actual test data available upon request (Q44).

REDESIGNED ROOM

Theatre Section with New Reflectors and Ceiling System (Red)



Rendering of Redesigned Space with Reflectors and Ceiling System



ASSESSMENT

The acoustics of the redesigned room function remarkably well for the resigned space. An average for 500 Hz and 4000 Hz reverberation times was calculated to be 1.29 seconds when fully occupied and 1.31 seconds at half occupancy. Averaging these two numbers (three-fourths full occupancy), the reverberation time is 1.3 seconds. This meets the target value of 1.3 seconds precisely.

Providing a cost analysis would better asses overall feasibility of the project. Substituting hardwood floors for the carpets may increase design cost, although there may be a desire to implement the same floor system as is present in the gallery area. The six (6) parabolic acoustical reflectors would also add to construction cost. The new ceiling system could be comparable in price to the existing. This redesign would significantly improve room acoustics and incorporates a more efficient lighting system.

Reverberation Time - Acoustical Redesign

		125 Hz		500 Hz		4000 Hz	
Material	**Area (Sq.ft.)**	**α**	**sabins**	**α**	**sabins**	**α**	**sabins**
Fully Occupied							
Ceiling							
Mesh Ceiling Panels	1200	0.23	276	0.40	480	0.11	132
Concrete	500	0.01	5	0.02	10	0.02	10
Reflectors	288	0.01	3	0.01	3	0.01	3
Side and Rear Walls							
Glass	27	0.18	5	0.04	1	0.02	1
Veneer Plaster	1532	0.14	214	0.06	92	0.03	46
Columns							
concrete, rough	247	0.01	2	0.04	10	0.10	25
Aisles							
Wood floors	426	0.15	64	0.10	43	0.07	30
Proscenium Opening	448	0.15	67	0.10	45	0.07	31
Air	1732	-		-		-	220
Doors	175	0.19	33	0.09	16	0.05	9
Audience							
seated in upholstered seats	576	0.39	225	0.80	461	0.87	501
Total Absorption			**895**		**1160**		**1007**
One-Half Occupied							
Total absorption in auditorium less audience absorption from fully occupied calculation			670		699		506
Seats, upholstered	300	0.19	57	0.56	168	0.59	177
Audience in upholstered seats	350	0.39	137	0.80	280	0.87	305
Total Absorption			**864**		**1147**		**988**

Theatre Volume (ft^3) **27770**

	Reverberation Time (s)		
Conditions	**125 Hz**	**500 Hz**	**4000 Hz**
Fully Occupied	1.55	1.20	1.38
One-half Occupied	1.61	1.21	1.41
500-4000 Hz Average, Fully Occupied	1.29		
500-4000 Hz Average, Half Occupied	1.31		

Diagram with Redesigned Reverberation Time, Existing Condition, and Target