The Art of Illusion and Distraction in Integrating Loudspeakers Within Themed Environments

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1. Abstract:

Loudspeakers can be cumbersome objects to integrate into themed environments, and a sound designer's desire to keep sound images on stage or aligned with a particular aural aesthetic can conflict with a scenic designer's drive to shape the visual narrative. This paper explores techniques used to craft illusions for hiding loudspeakers in a wide variety of themed environments, but with a particular focus on methods for executing hides in diverse materials, diverting audience attention away from loudspeakers, balancing tradeoffs like cost or longevity, and team consensus building to ensure that themed speaker grilles are seamlessly integrated and sounding great.

2. <u>Scope and Purpose:</u>

This document is not a scientific research document. While some of this experience was gathered from best practices informed by scientific method, this paper does not explore scientific measurement. This is a document intended to share our experience designing and building immersive environments.

We have a collective combined working experience of more than 60 years working for Walt Disney Imagineering, Universal Studios, Adena Corporation, Meow Wolf, Arup, and other world class design studios. But this document couldn't possibly be treated as an authoritative how-to document. This is intended to be a sharing of our own personal perspectives on what we felt was successful. The working experience and institutional knowledge of the organizations we have been privileged to be a part of is vast. This paper reflects a fraction of the experience that these organizations and their portfolios encompass.

3. Design:

A well-integrated loudspeaker begins long before design sketches are circulating, or conversations occur about the means and methods of hiding devices. These illusions begin with a discussion between the creative director and the design teams about the world that is being envisioned. Without solid foundations grounded in story and the team's shared values, it will be difficult to stay aligned with your collaborative partners through the difficult process. Well integrated loudspeakers are an all-hands on deck situation, and mutual respect and trust in each other's expertise is the necessary collaborative lubricant that enables subtle loudspeakers hides.

3.1. Approach

"The Script is ground zero for informing everything in the Show."

– Jodi McLaughlin, Portfolio Executive Producer at WDI

Know your story. The script is a narrative tool that details and breaks down the Story to outline the time, period, and place; there will likely be ways of interpreting the script that can drive your choices with any loudspeaker hides. Through the story, you can interpret the need and develop a technical approach to delivering the illusion.

3.2. Team

The show set designer crafts the visual composition of the world and helps to integrate the technical requirements of each specialty design discipline into a thematic environment. So, for any design discipline to be visually successful, they often rely on close collaboration with the show set designer. The show set's mission is a faithful and scaled reproduction of the elements shown in design concept to reflect a particular scene, place, locale, time period and other attributes which contributes to the fulfillment of the image to be conveyed to the visitor. The show set translates the creative vision into greater detail, crafting a visual narrative. Through scalable and buildable models, drawings, and coordination packages, the show set package shows the integration of all show equipment and building systems to support the sensory journey for the story. This includes what we see, smell, feel and of course what we hear. Without buy-in from the team on the storytelling vision, the carefully coordinated worlds our show set designers build may begin to break narrative.

Consider the following examples just a few of the team members will need to rally behind the design in order to get a good hide:

- Without an invested lighting designer, they may unknowingly shine a light directly into a speaker grille illuminating the device inside.
- Without a skilled themed painter, the blending of the colors of a completely solid set piece to the perforated grille, you may get an obvious color difference when your materials transition.

- Without production management on board, the money may not be in the budget for the thematic execution and the loudspeaker may get cut.
- Without buyoff from the maintenance and operations team, they may decide the proposed location is too difficult to access and not repair or replace the device when it fails.
- Without buyoff from the safety team, they may determine that the proposed design is not safe to access and the device may be removed before opening.
- Without close collaboration with the facility design team, the show building may not correctly land necessary wall positions.
- Without a properly specified loudspeaker and a willingness to compromise sound quality with the grille design, the sound design cannot be properly conveyed.

Should any one of those elements fail, the illusion of the hide may likely fail. Without a mutual understanding on the team why a loudspeaker hide is important for the success of the show, it will be difficult for each member of the creative team to make the necessary compromises or design accommodations in order to achieve a well-hidden device.
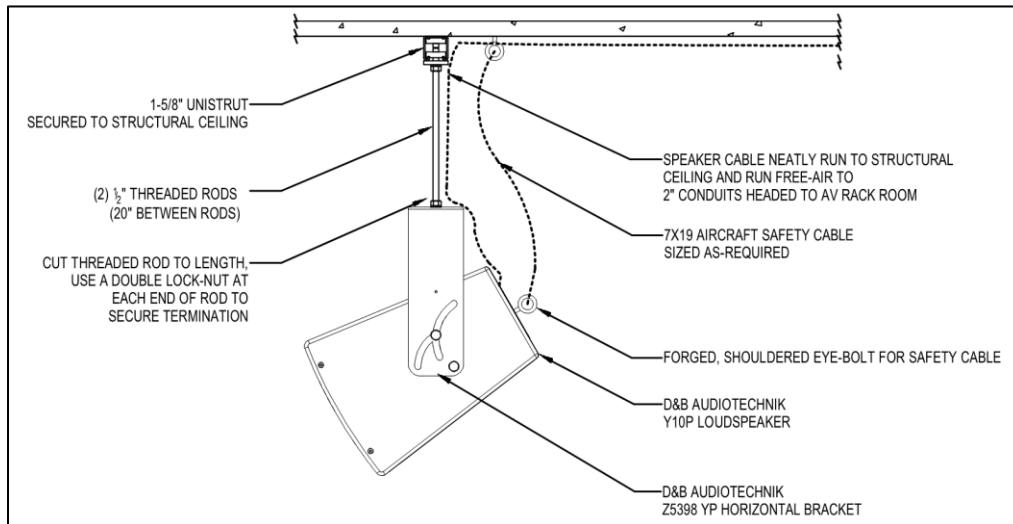
3.3. Process

Building a team consensus around complex hides is an ambiguous and sometimes very difficult process, especially when key team members are new to loudspeaker hides. Be measured on what you are requesting of your collaborators. Never ask for more than you need, and work hard to acknowledge the costs that others incur for the shared vision.

As the visual design concepts and models begin to circulate, it is helpful to quickly have discussions about how to integrate the massing of the loudspeaker. As one or two design elements begin to settle, momentum will quickly develop behind an idea. If the massing of the loudspeaker isn't considered at this early stage, it may be impossible to recover (especially when the sound design calls for very large devices).
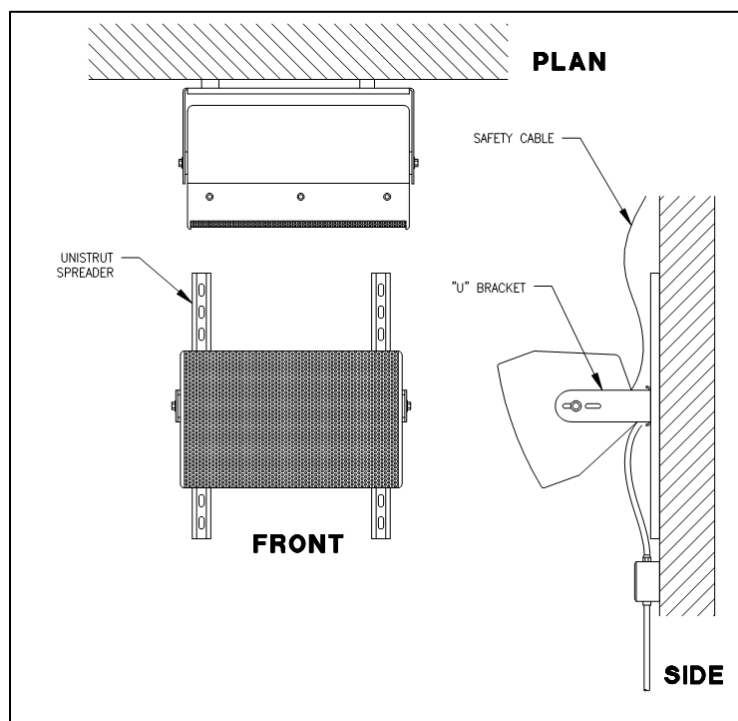
In the end, a well-integrated loudspeaker sometimes requires no effort. With the final show conditions in mind, it may be possible to bolt a speaker to a wide-open wall in a fade to black zone and the audience will never be the wiser under final show lighting conditions. There may be natural locations behind trees where a painted loudspeaker will disappear with no additional effort. The goal of the hide may not be integration into the themed environment, but instead simply to keep the technology from distracting from the story. Before going down the rabbit hole on integrating loudspeakers behind thematic grilles, make sure it is necessary for the sound design. Production managers, producers, and directors will thank you for keeping costs low and complexity to a minimum. Stand your ground on what you believe is important to the story, but also try to not be too precious about finer details that aren't important. This is easier said than done.
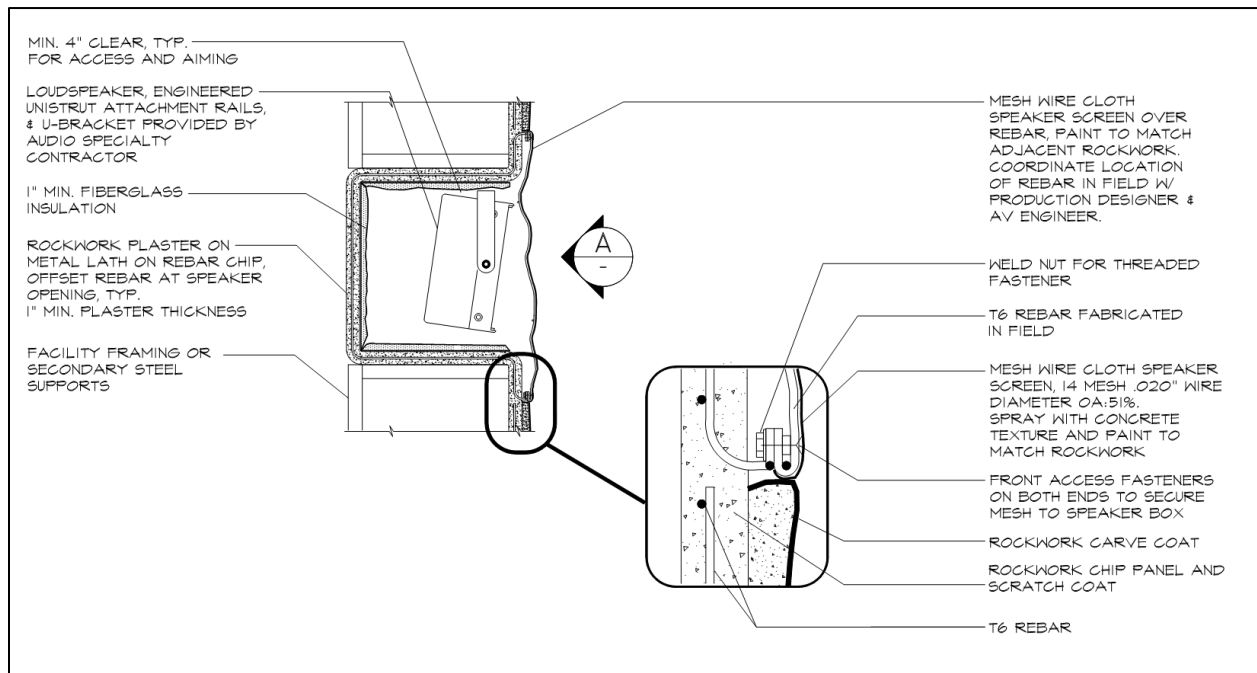
4. <u>Anatomy of an Installed Loudspeaker:</u>

A base-level description of what a typical loudspeaker install looks like is probably useful before digging into the weedy details of theming and integration. Below are some design details for some simple and complex integrations, but there are principles here that could be applied to many contexts.
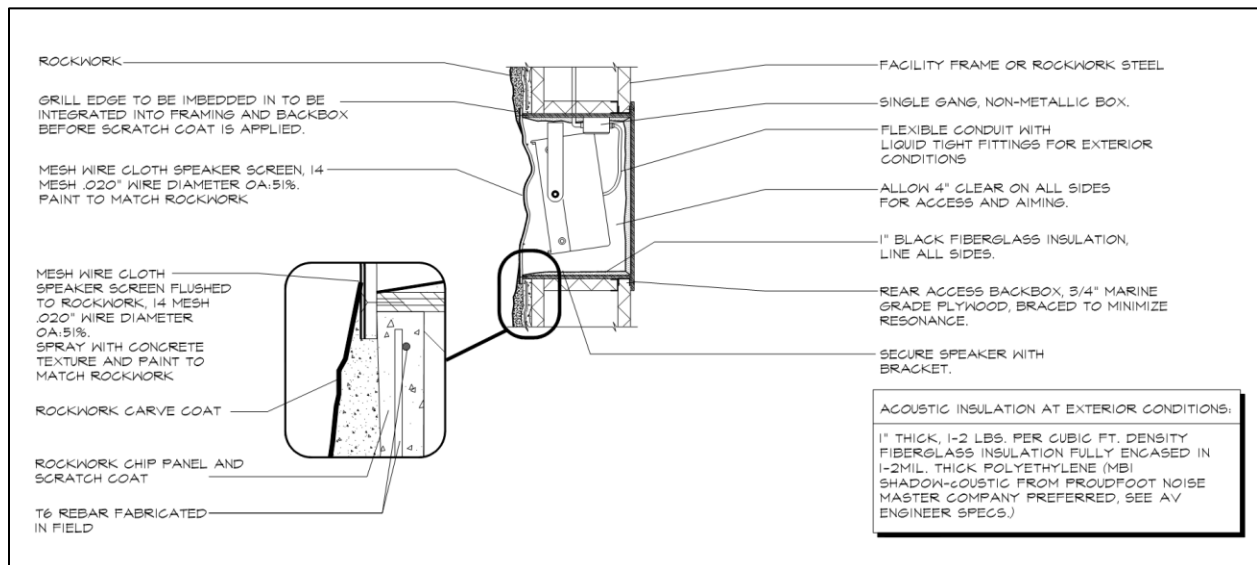

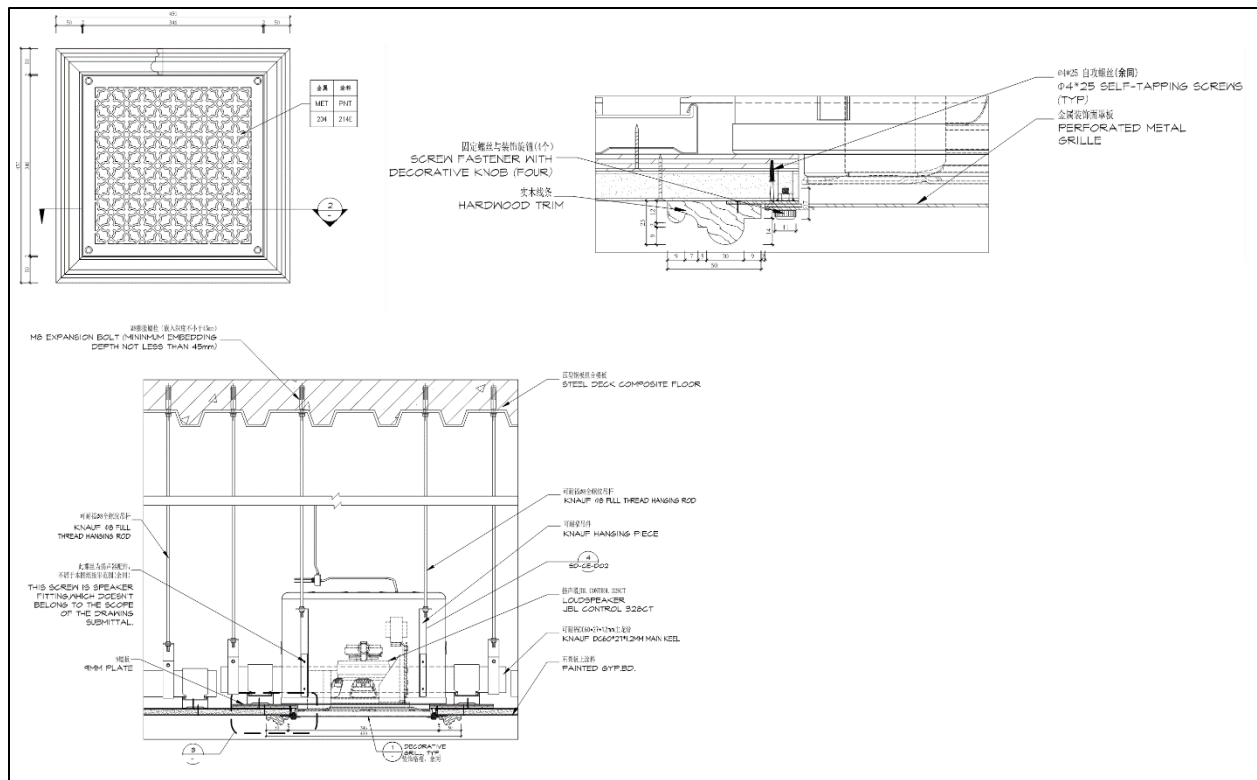**Figure 1:** Exposed surface mount loudspeaker, hung from structural ceiling

Figure 2: Exposed surface mount loudspeaker, mounted to wall

Figure 3: Integrated front access rockwork loudspeaker, concrete backbox

MIN. 4" CLEAR, TYP. FOR ACCESS AND AIMING

LOUDSPEAKER, ENGINEERED UNISTRUT ATTACHMENT RAILS, & U-BRACKET PROVIDED BY AUDIO SPECIALTY CONTRACTOR

1" MIN. FIBERGLASS INSULATION

ROCKWORK PLASTER ON METAL LATH ON REBAR CHIP, OFFSET REBAR AT SPEAKER OPENING, TYP. 1" MIN. PLASTER THICKNESS

FACILITY FRAMING OR SECONDARY STEEL SUPPORTS

MESH WIRE CLOTH SPEAKER SCREEN OVER REBAR, PAINT TO MATCH ADJACENT ROCKWORK. COORDINATE LOCATION OF REBAR IN FIELD W/ PRODUCTION DESIGNER & AV ENGINEER.

WELD NUT FOR THREADED FASTENER

T6 REBAR FABRICATED IN FIELD

MESH WIRE CLOTH SPEAKER SCREEN, 14 MESH .020" WIRE DIAMETER OA:51%. SPRAY WITH CONCRETE TEXTURE AND PAINT TO MATCH ROCKWORK

FRONT ACCESS FASTENERS ON BOTH ENDS TO SECURE MESH TO SPEAKER BOX

ROCKWORK CARVE COAT

ROCKWORK CHIP PANEL AND SCRATCH COAT

T6 REBAR

Figure 4: Integrated rear access rockwork loudspeaker, FR Plywood

ROCKWORK

GRILL EDGE TO BE IMBEDDED IN TO BE INTEGRATED INTO FRAMING AND BACKBOX BEFORE SCRATCH COAT IS APPLIED.

MESH WIRE CLOTH SPEAKER SCREEN, 14 MESH .020" WIRE DIAMETER OA:51%. PAINT TO MATCH ROCKWORK

MESH WIRE CLOTH SPEAKER SCREEN FLUSHED TO ROCKWORK, 14 MESH .020" WIRE DIAMETER OA:51%. SPRAY WITH CONCRETE TEXTURE AND PAINT TO MATCH ROCKWORK

ROCKWORK CARVE COAT

ROCKWORK CHIP PANEL AND SCRATCH COAT

T6 REBAR FABRICATED IN FIELD

FACILITY FRAME OR ROCKWORK STEEL

SINGLE GANG, NON-METALLIC BOX.

FLEXIBLE CONDUIT WITH LIQUID TIGHT FITTINGS FOR EXTERIOR CONDITIONS

ALLOW 4" CLEAR ON ALL SIDES FOR ACCESS AND AIMING.

1" BLACK FIBERGLASS INSULATION, LINE ALL SIDES.

REAR ACCESS BACKBOX, 3/4" MARINE GRADE PLYWOOD, BRACED TO MINIMIZE RESONANCE.

SECURE SPEAKER WITH BRACKET.

ACOUSTIC INSULATION AT EXTERIOR CONDITIONS:

1" THICK, 1-2 LBS. PER CUBIC FT. DENSITY FIBERGLASS INSULATION FULLY ENCASED IN 1-2MIL. THICK POLYETHYLENE (MBI SHADOW-COUSTIC FROM PROUDFOOT NOISE MASTER COMPANY PREFERRED, SEE AV ENGINEER SPECS.)

Figure 5: Integrated front access architectural ceiling can speaker grille

Figure 6: Photo example of a rockwork backbox with rear cover removed.

5. <u>Material Specifications:</u>

A speaker grille is just a carefully perforated material, but how the holes are generated and preserved is often the trick. It is usually easier to start with a perforated medium and add theming textures to get the desired look rather than starting with a solid finished medium with your desired look and cutting holes.

5.1. Grille Openness:

The speaker grille perforation sizing is a crucial material spec to get right, and this is often specified by "percent openness." However, that single number is not the whole picture when constraining openness. Without an additional number constraining hole spacing, it would be possible to have a 40% open "grille" with only a handful of large holes that could result in large chunks of solid material blocking the tweeter, and that will not sound good.

A good place to start when thinking about grille openness is with cinema screen specifications. These are commonly perforated as low as 4% open, very fine closely spaced perforations (1.2mm to 0.3mm). However, these screens require specialty speakers, careful installation, and meticulous tuning on the loudspeakers to achieve good sound. Themed grilles using typical loudspeakers will need to be much more open than this.

When designing a themed grille, good hides with excellent fidelity are very achievable with the following base targets:

- 40% open target for finished grille.
  - There may be texture and paint added to the top of the grille, and it may be possible to go to 20% open or less, but with significant cost.
- 1mm hole size target
  - Micro perforations on grilles tend to sound better and make more convincing hides at a distance.
  - Holes smaller than 1mm begin to be easy to bridge with paint.
  - Holes larger than 5mm will start to create larger facets between holes.
- Avoid grilles with 8mm or larger solid obstructions between holes, especially around the tweeter.
  - The ¼ wavelength of 10kHz is about 8.5mm, so this hole size will result in grilles that look like reflectors to high frequency sound.

When firing through a themed speaker grille, it is best to remove the stock perforated metal grille that is shipped with loudspeakers. Firing a loudspeaker through one speaker grille will incur fewer penalties in sound quality than two, especially if they align to create large blockages. However, caution is advised when removing outdoor speaker grilles. Often manufacturers have carefully specified weather protection for the systems, and you will want to make sure you don't void your warranty on the loudspeaker by stripping the weather protection systems with the grille.

5.2. Grille Base Substrates:

5.2.1. Fabric:

One of the simplest and cheapest choices is stretched fabrics and scrims. Seek out fabrics marketed for their acoustic transparency; Vintage speaker grille fabrics, fabrics designed for wrapping acoustical absorption, and light grade drapery can all be found with excellent performance characteristics. It is also possible to find PVC coated fabrics commonly used for sun shading that last for long periods of time in the outdoors. These can even be printed on with UV resistant inks and used to carry digitally created artwork or camouflage patterns.

A simple but imperfect test for assessing acoustic transmission through a fabric is to bring a fabric sample to your lips and create a seal with your mouth and try pushing air through the fabric when you exhale. The more resistance you feel, the more likely it will resist passing sound.

5.2.2. Wire Cloth:

Wire cloth is probably one of the more difficult grille substrates to get right, but when done right, it can last for years, look incredible, and sound very good. Two numbers are needed for the specification of wire cloth, wire thickness and hole spacing (sometimes called "mesh"). Some wire cloth can be rigid enough to be used as industrial fencing or architectural metals, and it can be so fine that, when held in a cup shape, water's own surface tension will prevent it from passing.

Wire cloth material properties can vary wildly, so it is probably best to order a few sample varieties and sculpt with them before ordering your bulk material. Wire cloth

specified with flimsy characteristics can be sewn together with wires as thread to create dimensional shapes or tied to a pencil-rod forms with tywire. The types of wire cloth used in strainers often have enough rigidity to hold their form on their own, so they can be hammered and molded to organic shapes like rocks or inorganic, rough-hewn, repeating forms like bricks.

Corrosion is another factor to contend with when specifying wire cloth. Avoid mild or carbon steel in any circumstance where the grille is outdoors or even in a humid environment, and it is a risk to use it in any situation where it may want to last for more than a year. Copper, brass, and type 304 stainless steel can be quite durable in humid environments, but a type 316 stainless steel or aluminum may be needed in wet environments.

A good place to start for wire cloths for shaping and bending shapes are the more rigid types between 20 mesh and 10 mesh that have wire sizes at about 0.5mm. The finest wire meshes of over 80 mesh can still be quite open and relatively strong, but could also find use as a partial water repellant. Because wire cloth grilles are often heavily textured, starting with 50% open material is a good idea.
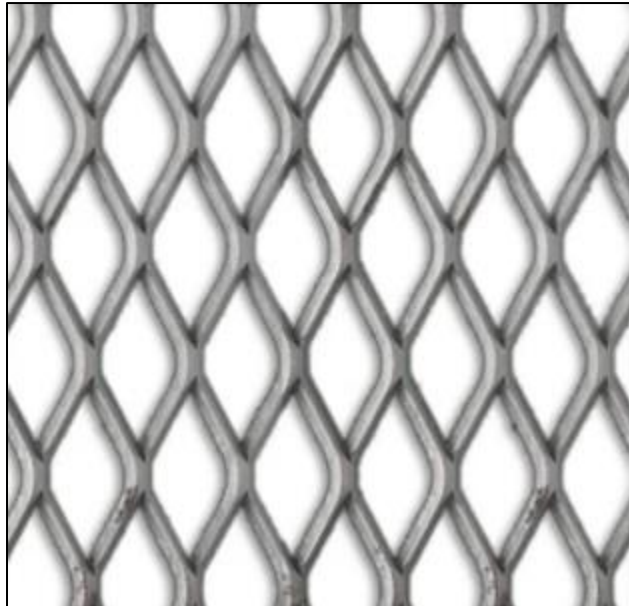
5.2.3. Perforated Metal
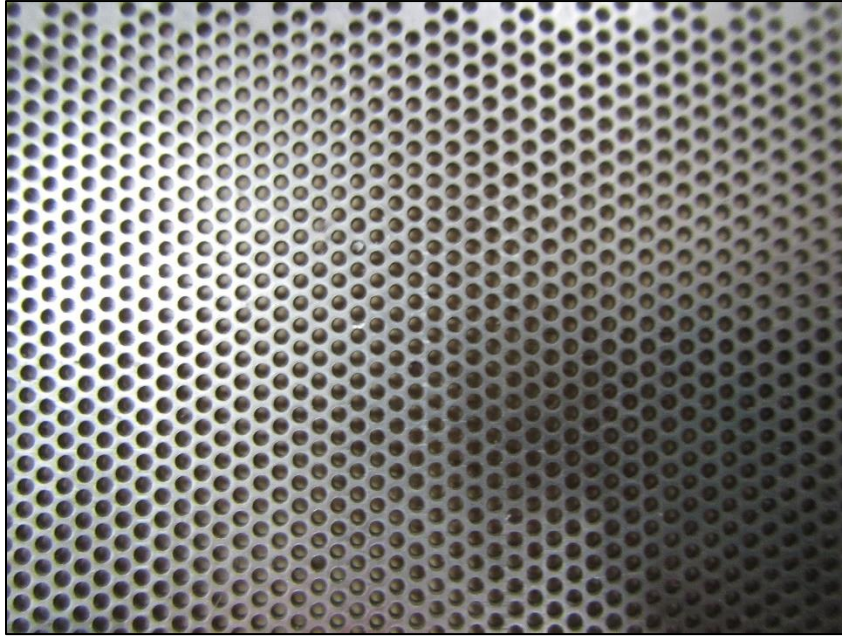
Perforated metal is simply sheet metal with punched holes and there are a wide variety of hole options and decorative patterned metals. It is a very durable and relatively straightforward material to use. This may be the best balance of ease of use, durability, and sound quality.

Perforated metal come in all types, but the two most common choices for speaker grilles would be type 304 stainless steel and aluminum.

- Type 304 stainless steel is a good choice for general indoor use but will rust over time in humid environments. In any wet or outdoor environments (especially ones with chlorine), type 316 stainless steel or aluminum are the best choices.
    - Substrate thicknesses between .5mm and 1mm will likely yield good performance and stiffness of large grilles.
- Aluminum tends to be a great choice because it is lightweight and will not rust, however it is much more brittle, so it is difficult to form dimensional shapes without cracking the material. It is also more difficult to find in microperforated sheets, so expect to require holes of 1.5mm or larger with aluminum.
    - Substrate thicknesses between 1mm and 2mm is a good place to start.

When the design calls for a flat surface, the material itself is easiest to work with when bought in sheets rather than rolls because rolls have a tendency to retain that curved shape and it can be challenging to bend them perfectly flat without damaging or breaking the material.

5.2.4. Expanded Metal

Expanded metal is very similar to perforated metal, but the main difference it is not made by punching holes in a flat sheet, but instead it is made from flat sheet metal that is cut and pulled apart.

5.2.5. 3D printing

At the time of writing, all of the work we have done has been with commercially available items in perf metal, wire cloth, or fabric. However, for a one-off custom specialty item or for a desktop mockup purpose, 3D printing could be a good way of achieving a desired look. This may become a more common means of production with the rise in industrial 3D printing shops.

5.2.6. Perforated Acoustical Wood Products

Many manufacturers of acoustical products have perforated or slotted wood products that are designed for architectural environments. These are designed to be backed with acoustical materials and are a way to allow acoustic treatments in spaces designed with wood details. If the plan is to leverage these products as speaker grilles, there are a few things to keep in mind. They are not designed to be high fidelity grilles; they are only designed to provide a path for sound to pass and be absorbed. Sound may be severely colored or distorted in ways that speaker processing cannot correct. Before using this material, make sure to order a sample and test it, and it would be strongly recommended to take a very conservative approach to thickness, percent openness, and the facet size between holes.

5.2.7. Custom perforation on solid materials

While the recommended methods we discussed above involve starting a grille with a perforated material and adding layers to achieve the desired look, it isn't the only way to work. Waterjet cutters, 3D printers, CNC machines, and laser cutters are becoming more and more common, and are often used to cut decorative perforated patterns in metals.

It needs to be mentioned that hand-drilling is an option for creating custom perforations but is not a recommended path. If the hand drilling seems like the only option available, it is a very challenging one. We have seen successful execution of self-drilled grilles in fiberglass, but those grilles required a lot of skilled labor to drill out hundreds of tiny evenly spaced holes. Attempting this method with wood or stone would be difficult because of the material fragility, and because drilling out fine holes in sheet metal on a drill press would be difficult due to how tough that material is. Make sure to bring a lot of spare drill bits, a few backup grille blanks, and a lot of patience.

5.3. Grille Surface Treatments

5.3.1. Painting

Wire cloth and perforated metals takes paint and other coating mediums well. However, paints will fill up a grille and significantly degrade acoustic performance if not treated with care. For example, if the paint system plan is for the grille to be primed, 2-coat painted, and clear coated, you may lose 20% of your openness on a 14 mesh wire cloth grille. If it is cement with a rocky aggregate, you may lose more than 20%. You will want to aim at higher openness ratings than you may have initially planned for and expect a scenic treatment to knock it back. Grilles may call for alternate painting systems and technique; dry-brush is very common theme painted grilles.
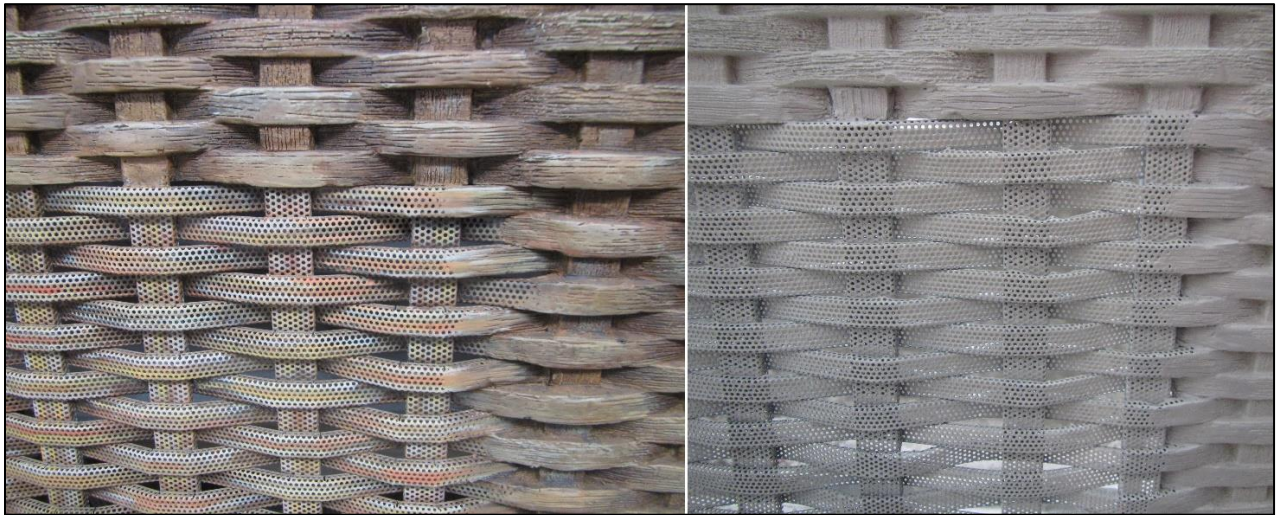
Figure 7: Painted Perforated metal bent and woven into strips, imbedded into a fiberglass substrate, and then painted with over-saturated colors.
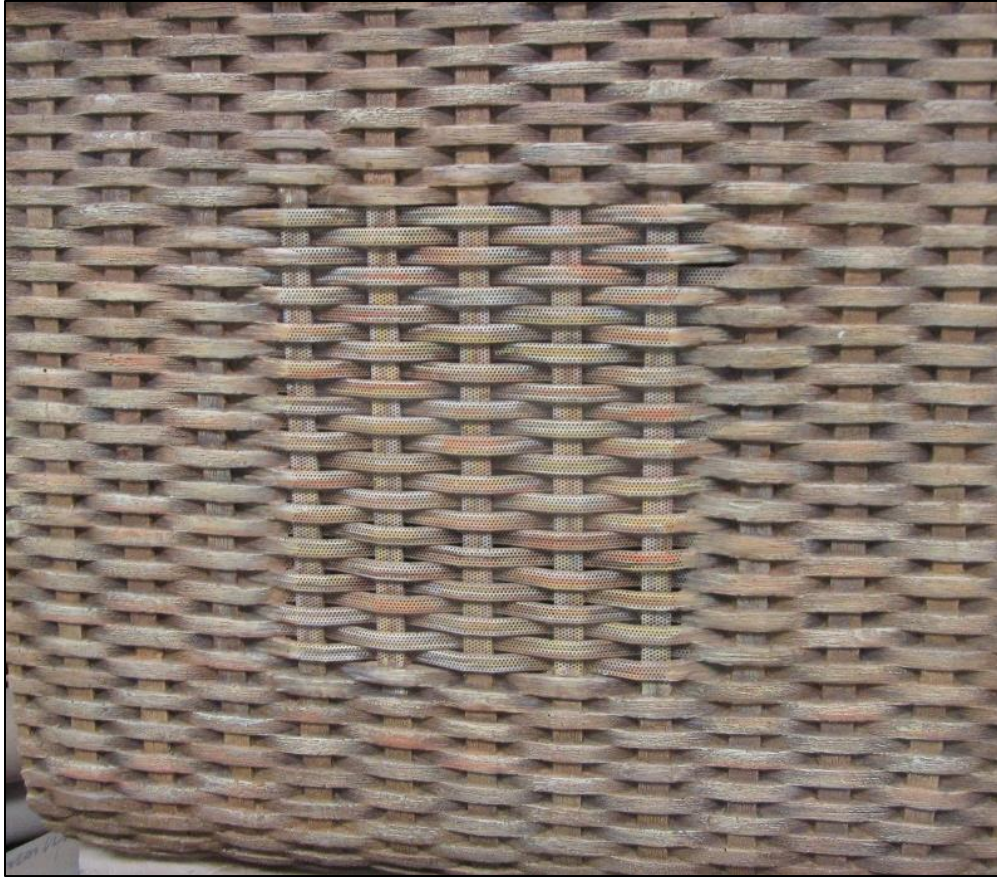
Figure 8: The dark holes in the perforated metal darken the saturated colors resulting in a seamless blended look at a distance. If the grille is painted with the same technique as the surrounding solid materials, it will result in a clearly darker grille.

5.3.2. Acrylic Elastomeric Polymers
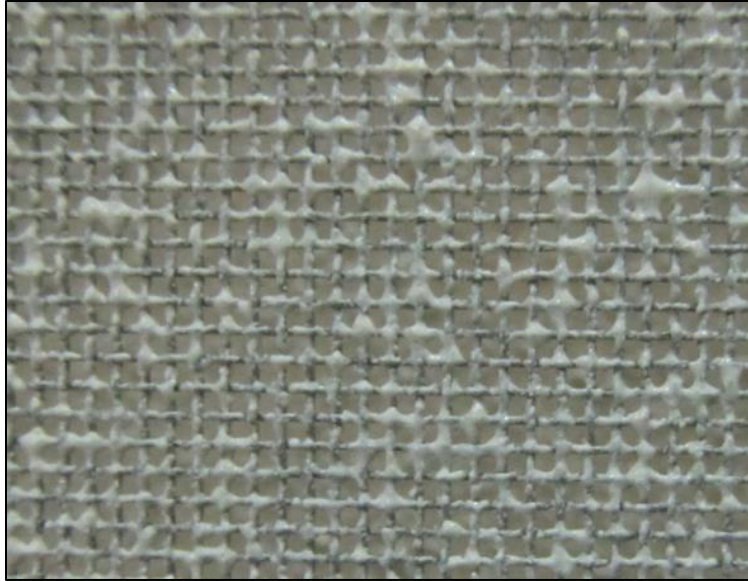
These are substrates that can take color but also have a high degree of durability and weather resistance. They most often used as surface treatments for texturing wire cloth grilles.

5.3.3. Sculpting Epoxy

See section 6.2 for detailed description of this material use on perforated metal.

5.3.4. Cement and Aggregates

Often useful when trying to create the appearance of stone, but can also be useful to create a textured surface finish as well.

5.3.5. Powder Coating

This is a specialized painting process involving evenly coating a metal in a powdered paint using electrostatic charge, and then baking the powdered metal part so that the powder melts to form a painted surface. This is one of the most durable paint finishes and is common on perforated grilles that ship with loudspeakers. Powder coat colors are often specified in RAL numbers.

5.3.6. Texture System Design

Many of the most effective hides come from a combination of multiple paint and texture systems, layered up upon one-another. A binding agent like acrylic elastomeric polymers may be combined with an aggregate with a particular texture, like crushed walnut shells, and sprayed onto a wire screen for a particular effect. Your creativity is the limit of where this can process can take you.
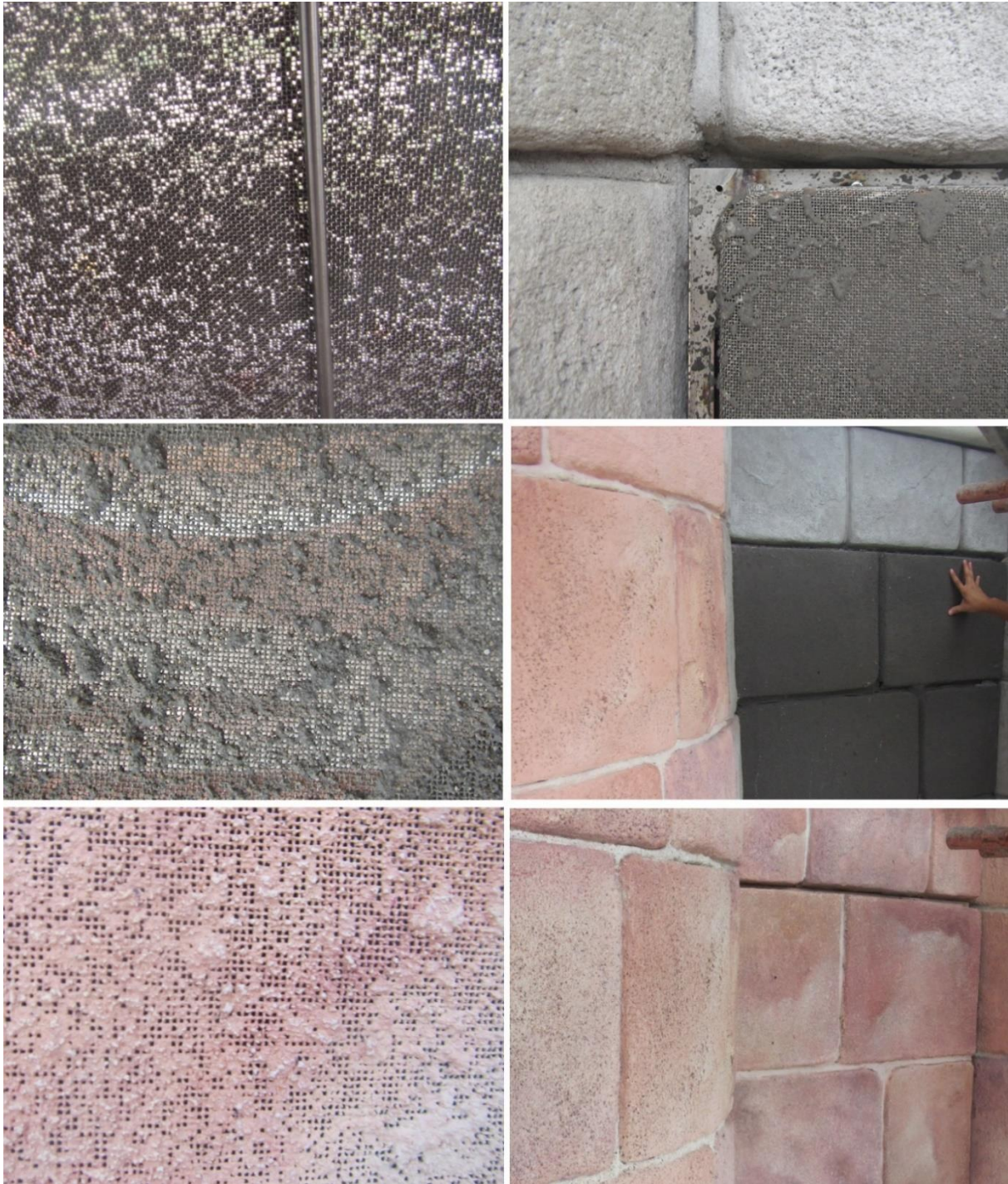
Figure 9: A series of photos illustrating a mixed-use approach to theming a loudspeaker grille. Here, cement was mixed with glue and sand, then sprayed onto a wire cloth surface using a hopper gun. Afterward it was painted with a base coat of paint and additional dry brush layers of color. The gaps between the transparent bricks were filled with solid grout to help the grille appear as brick. Under finished conditions, the gaps between the solid bricks and the removable front access grille were caulked and rubbed with sand; this would be replaced with every maintenance access.

pg. 18

5.4. Acoustics

The acoustics of a themed loudspeaker do not stop at the speaker grille. The air volume around a loudspeaker and the baffling around the opening (not to mention the room itself) are important factors in the final on-site sound of a loudspeaker. The speaker, the grille, the room, and even the audience are part of a complete electro-acoustic system that needs to be considered.

5.4.1. Backbox

A big part of themed loudspeaker integration is controlling what the grille does to the sound of a loudspeaker, but without control of the acoustics behind setwork, what is stopping unwanted sounds from traveling through the grille? The main way to control this is to seal off the back of the loudspeaker into the show set with a "back box." By doing this, your force the loudspeaker to exist in the acoustic air volume that is in front of the façade, where the audience is located.

The problems a properly built and sealed backbox can solve are numerous and we have tried to list the ones we are aware of below.

- Backboxes control sound reflections off of the back of a themed loudspeaker grille. These can freely activate space behind the set or a stage house flyloft and create undesired reverberance.
- Sound of multiple hidden adjacent loudspeakers may cross-pollenate. In the target listening area, this would sound no different than if you mixed the sound sources into your loudspeaker with random reverb and delay.
- All sound does not move forward from the front face loudspeakers. Mid and low frequency sound will wrap around the side of the box after the pattern control of the horns become ineffective. The backbox is crucial to the control of these frequencies and sometimes merits reinforcing the backbox with additional layers of plywood and low frequency dampening materials.
- Sound of mechanisms, doors, or show action equipment may be generating stray sound that could also travel through the grille.
- The backbox controls the lighting environment around a loudspeaker hide. Stray light can destroy the illusion when visible light appears to penetrate a solid surface from behind.
- All items within a backbox should be black to prevent light spilling through the grille and illuminating the materials within the box.

Introducing a backbox does introduce some complexity. The size of the backbox must have enough room to position the speaker, access the rigging points with tools, and yet keep the box as small as possible so that the backbox doesn't act as a resonant chamber. Clearance requirements will vary depending on the rigging type, access conditions, and the desired aiming, but here is a good place to start:

- 100mm (4") clear around all sides of the speaker is a good rule of thumb for 8-inch 2-way loudspeakers that weigh roughly 40 lbs.
- Less space is needed for 4-inch 2-way loudspeakers that weight 10 pounds.
- More space would be needed for 12-inch 3-way boxes that may weigh more than 100 pounds.

Types of materials that may be used for backboxes are detailed below.

5.4.1.1.   Plywood

¾ inch plywood is the go-to material for making speaker boxes. It is cheap, universal, and provides good acoustic performance. Marine grade plywood may be needed in wet environments.

5.4.1.2.   Cement board

Cement board can often be a preferred alternative to plywood. It is often cheaper, denser (good for acoustics), rot resistant, fire resistant, and some varieties can be cut and screwed together with similar methods as wood. Not all cement board is as easy to work with as plywood, so if you are planning this route, make sure to look at what is available in your region and try a sample first.

5.4.1.3.   Loaded Vinyl
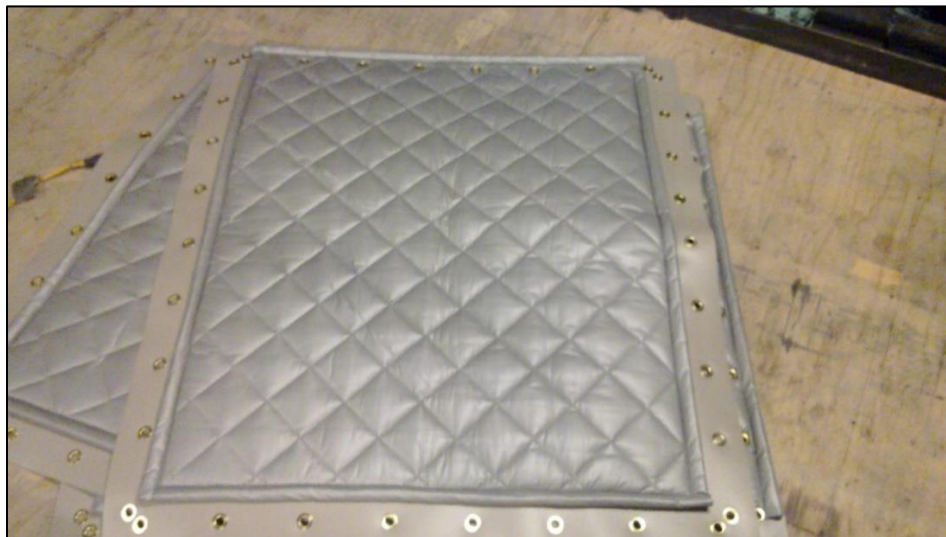
In circumstances where rigid backboxes aren't possible, thick sheets of loaded vinyl can be used to seal off the loudspeaker to the show set. These are often used in industrial environments as noise control but can be ordered in custom sizes.

5.4.2. Acoustic Absorption

The backbox helps to prevent uncontrolled acoustics behind a façade or show set from causing widespread unwanted distortion to your themed loudspeaker installation. However, the backbox and the grille also create small acoustic problems that need to be treated. Applying 1 or 2 inches of acoustic absorption to all interior surfaces within the back box will help to prevent the enclosure from resonating.

5.4.2.1. Coated Black Fiberglass

Acoustic absorption used for treating stage houses and production studios is typically fiberglass batting with black coated fibers and adhered to the wall with stick pins. This same approach is the most tried and true method for treating the inside of a backbox.

A common mistake is to purchase pink or yellow acoustic treatment and paint it black. By doing this, it will void the absorptive properties of the material. Instead, purchase black faced or integral color black products.

5.4.2.2. Rockwool

Rockwool is distinctly different material than fiberglass and it has better moisture and mold resistance than fiberglass. However, it does not commonly come in an integral black color, so look for sheets that are black faced yellow rockwool; this is common among roofing insulation. The yellow edges can be covered with a black fabric tape to help prevent the yellow edges from exposing the loudspeaker hide (as was done in the image above).

5.4.2.3.   Rigid Plastic Panel Acoustic Absorber

In situations where durability and moisture resistance are a concern, rigid plastic acoustical panels can be a good choice. Their acoustical properties are not nearly as high performance as rockwool or fiberglass, but this is a good choice in areas of high water or physical damage risk.

5.5. Safety

Safety needs to be a consideration for all loudspeaker installations. While it is not the focus of this paper, we felt it important to highlight a few key considerations. Access conditions, weight, fire ratings, overhead safety, and structural engineering should all be part of the design process when deciding how to integrate custom themed grilles.

5.5.1.   Engineering and Removable Grille Safety

Visual designers and sound designers are not often rigging and safety engineers. In the event that you are designing a custom removable grille, make sure the technical director and rigging experts know what you are doing and have approved the design. The loudspeakers and grilles may need their own primary restraint (which is often the base rigging) and a secondary restraint (which is a rated safety cable) but this will vary depending on local code and company norms.

5.5.2. Fire Ratings

There are often limitations to what types of flammable materials can be used in show design. This could impact your grille design, acoustic absorption, or backbox construction. Make sure you know about your requirements for FR Class A materials or application over fabric like fire resistant duvetyne fabric used to mitigate sound and light leaks. Ensure you have all of the information you need from your Authority Having Jurisdiction (AHJ) or technical director to know what kind of fire ratings are needed in your design.

6. <u>Analyzing Successful Hides</u>

In this section, we will explore a variety of examples of loudspeaker hides. The hope is to point to techniques and building methods that will illuminate new ways of designing grilles.

6.1. Themed Rockwork Installation

Rockwork integration has a long list of requirements in order to achieve a good hide, but the first principle is "less is more." When hiding a speaker screen in plain sight, the less you can draw attention to the screen the better. Due to the complexity, a whole paper could be written on rockwork integration alone, so what follows are some high-level points. However, the concepts here could be creatively modified to suit a wide variety of applications.

Loudspeaker integration into rockwork should begin at early design. Whether the loudspeaker is accessed from the front or the back of the rockwork is the first major decision, and it has huge implications on the cost and quality of the hide. In general, front access designs require a significant amount more extra fabrication labor, they are larger, and are generally less successful visually. If you have the choice, always go for rear access hides. See details in section 4 for detailed sections of loudspeakers integrated in rockwork.
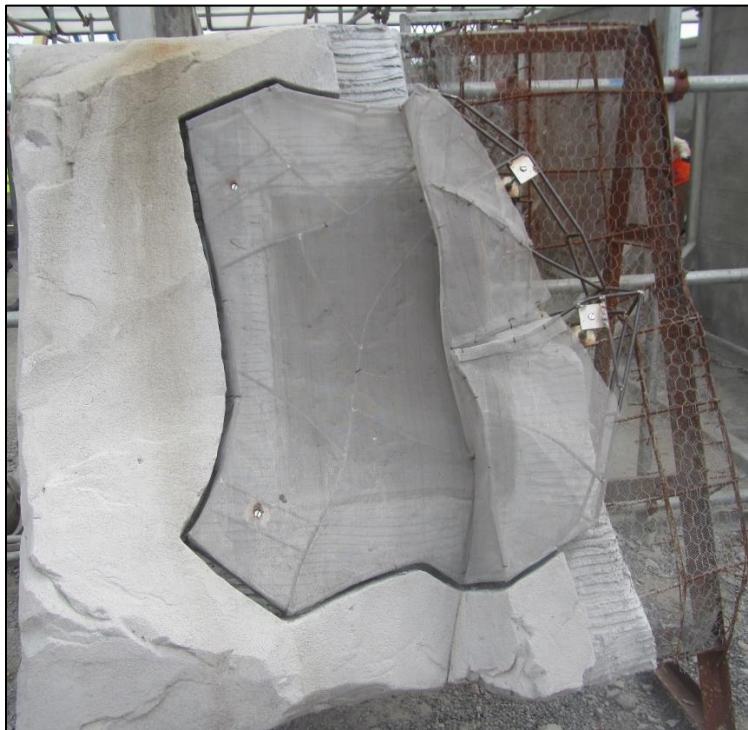
Figure 10: Front Access Grille Demonstration Panel

Figure 11: Rear Access Grille Demonstration Panel

Speaker grille integration begins when the rockwork cages are installed on-site. Plans need to be made for two different physical profiles, backbox profile and the grille profile (or grille break lines). The backbox size is primarily driven by the size of the loudspeaker and should have no effect on the shape of the grille. The grille seams are defined by the profiles of the scenic design and should never be made to follow the backbox. Rectangular shapes in rocks are unusual and only draw attention to themselves, so the grille shapes should be made as organic as possible to help conceal the grille break lines. It also helps to design ledges and rock features proud of the grille surface which can act to establish the illusion of depth, but they also have the added benefit of drawing the audience attention away from the loudspeaker grille.

Grille texturing is often done with a thin coat of liquid cement and glue mix that is sprayed on with a hopper gun or spattered by hand using a fleck brush. This is often feathered into the adjacent rockwork as well as the grille surfaces to create a seamless boundary between the metal grille and the rockwork. Before texture application, spray paint is a good tool for sound designers to communicate critical leave-out areas to the production teams. In the photos below, the solid black line indicated the rough outline of the loudspeaker. The dotted line indicated the extents of the area of concern for sound. The space between the two lines was treated as a fading region where the hopper gun can feather from a completely closed 0% open surface to roughly 40% open grille. It is often good for the sound designer or sound

associate to be present for the first grille texturing to ensure the production teams understand the needs of the sound designer. By the end of this process, it is not unusual to have started with a 50% open wire cloth that is reduced to roughly 25% after all layers are applied.

Figure 12: Photo illustrating a large textured screen, shown at a distance and up-close.

Figure 13: Photos above show rockwork at varying development stages.

Figure 14: Outdoor rear access rockwork speaker grille, shown zoomed into grille below. Note the cracks just to the left of the grille designed to draw your eye away from the grille.

Figure 15: Specialty tools for carving rockwork and texturing loudspeaker screens.
Top left: Flek brushes for spattering screens with texture
Middle left: Carving tools for wood grains and sculpting epoxies
Bottom left: Rockwork texturing brushes for stippling and scraping textures
Top right: Hopper gun for spraying wide varieties of textures and aggregates
Bottom right: Various trowels for shaping carve coats on rockwork

6.2. Character Wood Grille

Speaker grilles that look like wood are quite tricky, but when the wood has an exaggerated character, those rough-hewn accentuated features can be used to hide grilles. The darker wood grains can be left clear of sculpting epoxy, and after paint, the dark holes left by the speaker grille help that grille material fade into the background while the solid grains sculpted with the epoxy punch lighter. Theme painting can enhance this effect.

Some sound types are more sensitive to the timbral imbalances heavily textured screens cause. Quieter BGM speakers, fill speakers, and some sound effect speakers can take a heavier grille theming than louder main music or dialog loudspeakers. Strategically planning for minimal blockages, particularly in front of the tweeter, can result in more intelligible dialog and less distorted music.

Figure 16: This character wood shroud was built to hide the loudspeaker in a rockwork nook instead of going through the trouble of integrating it into the rockwork itself. Under show lighting conditions, the perforated metal medium blends into the background.

Figure 17: This barrel design required less theming than the barrel above, it only received theme paint on the microperforated metal grille. Dimensionally sculpted metal banding was kept solid so that it to draw attention away from the grille, and the boards were kept continuous across the entire length of the barrel to keep visually with how a barrel is typically constructed. Finally, the perforated metal panels were bent to mimic the shape of wood planks, which created more convincing shadows in a wide variety of lighting conditions.

Figure 18: This is an example of a character wood grille that is exposed to daylight. Due to the reduced control of the lighting conditions, larger amounts of sculpting epoxy were used to create the lighter wood grains and knots.


Figure 19: This sculpted wood plank grille is in a lower light environment, and allowed for a more open sculpting epoxy wood grains. Notice the brighter painted wood adjacent to the darker grille, another trick in diverting attention away from the speaker screen.

6.3. Show Set Flat

In a situation where a loudspeaker is needed around show set flats, theme painted perforated metal flats are a simple method for great sounding loudspeakers hiding in plain sight. The flat can also be backed with acoustic absorption, which helps with room acoustic control and also helps to hide the fact that large portions of the scenery may be 40% open. Under carefully designed show lights, it is difficult to tell the difference between solid and perforated materials.

Perforated metal may also be treated as a printing medium. This can be an advantage because it allows digital artists to design with digital tools they are familiar with, but it also allows show set designers to plan for scaled manufacturing, close adherence to the thematic design, and may be a good choice if you don't have the skilled theme painters.
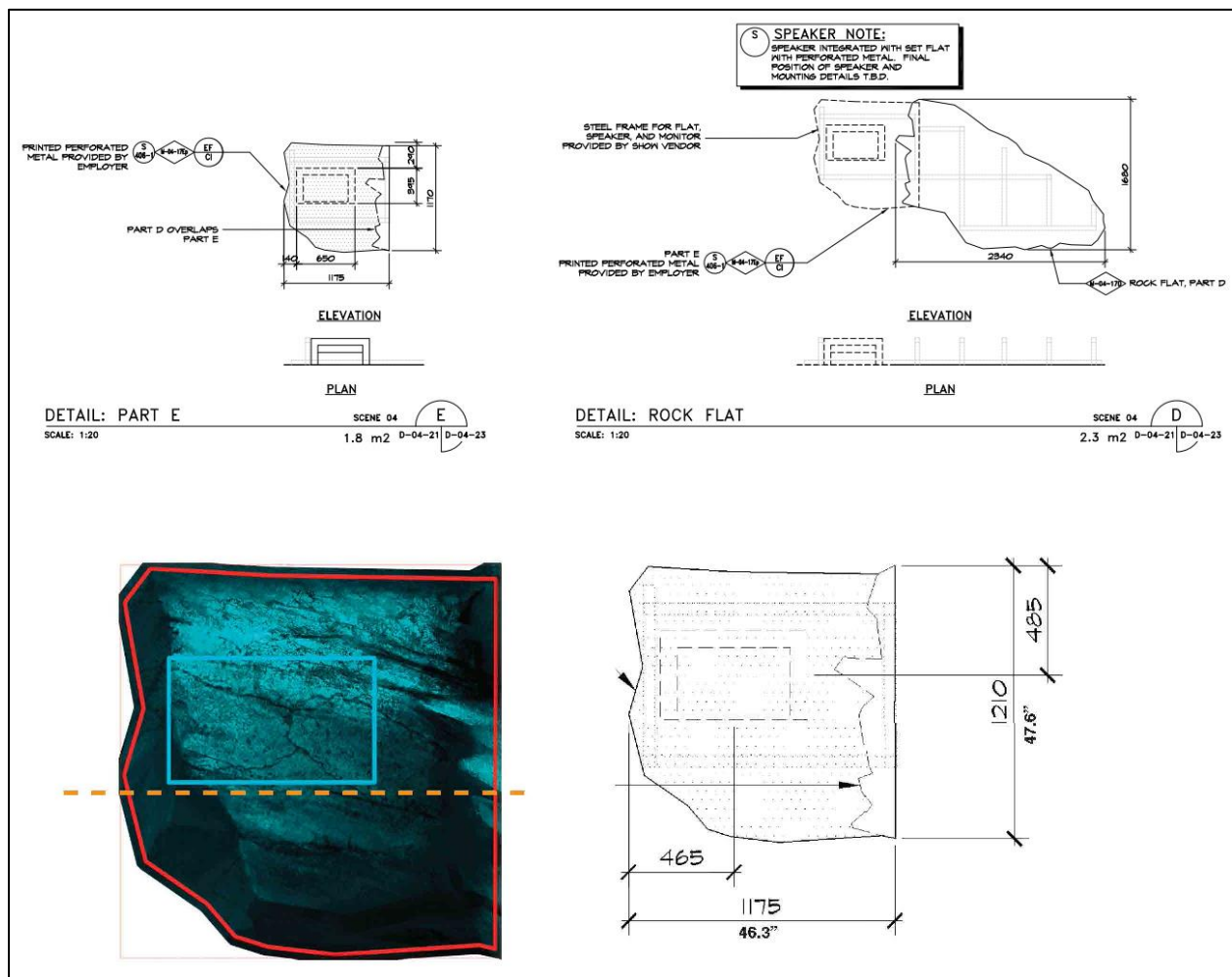
Figure 20: This show set drawing shows the development of digitally printed perforated metal scenic flats adjacent to solid digitally printed flats.

Figure 21: Under work light this illustrates the clear openness difference between the solid and perforated flats. In finished conditions, the entire grille would be backed with black absorption.
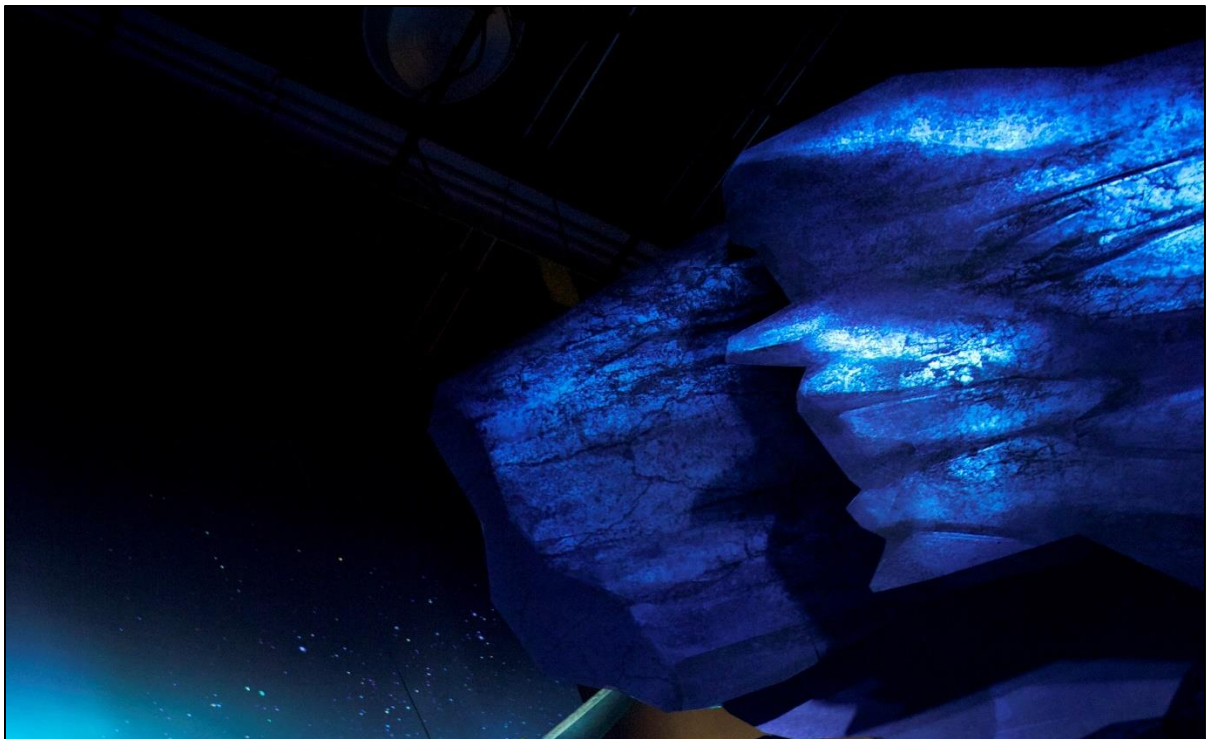
Figure 22: Under show lights this demonstrates how the grille disappears. Note how the solid flat is proud of the loudspeaker, diverting attention from the hide.

Figure 23: Closeup photo of digitally printed perforated metal.

Figure 24: This hand painted flat was sized specifically for the intended loudspeaker, so there was no need for additional baffle material. This is more of an example of theming a loudspeaker rather than integrating a loudspeaker into a themed show set. In this case, a back box probably would have done more damage than good, so the back of the loudspeaker was simply draped with fabric for control of stray lighting.

6.4. Digital Printed Fabric

The painting below was printed on a light felt that performed very well acoustically, but also read as a watercolor at distance. There are specialty print shops that own hot-rodded large format printers that can print on a wide variety of substrates and can account for situations like UV protection. Researching what is available locally, regionally, and nationally should yield many options.

Figure 25: It was determined that the loudspeaker needed a backbox in this case to prevent any light from bleeding in from behind the speaker, but also to hide a speaker that visible to the public from the side.

6.5. Architectural Façade

Parapets on 2 or 3 story buildings are often useful locations to locate loudspeakers but be prepared to work with your architect to develop a visual language to match the surrounding design. If there isn't room in the design for an alternative visual language, it is possible to simulate stone or brick with perforated metals or wire cloth grilles sprayed with textures similar to rockwork. One big advantage for parapet boxes are that rear-access is often quite straightforward from the roof and the boxes can be drained directly to the roof.

Figure 26: This parapet grille was two layers; perforated metal backed by a thick welded architectural metal.

Figure 27: Notice that the backbox has yet to be closed from behind, and in the picture on the left, it is possible to see light peeking through breaking the illusion that it is a solid surface.

Figure 28: This is a one-layer perf metal grille which was simply painted to match the facade.

6.6. Show Set Architectural panels

This FRP show set wainscot used the typical architecture details to establish a natural looking grille frame. In order to complete the hide, a wire cloth backing was chosen to further hide the loudspeaker's appearance through the large decorative metal holes. This was in an outdoor application, but were this for indoor use, fabric backing may have been a better choice because of the coarse and more restrictive decorative metal design.


Figure 29: These in-process photos illustrate a typical show set fabrication and AV integration review process with the manufacturer. Mockup materials are used to test the quality of the hide before final grilles are fabricated.

Figure 30: The show set panel design used material transitions to hide grille break lines. It would have been unusual to see a material transition within a wood panel, so the grille was designed to be much larger than was required by the sound design.

6.7. Architectural Ceiling Grille

For ceilings with a more classic look, contemporary speaker grilles built by modern manufacturers often do not fit the style. Decorative perforated metals with a high percent openness can be matched to the design aesthetics of the space. In the case below, the decorative perf was backed with an additional layer of perforated metal to help with the hide. These can be designed to integrate to hang with the ceiling system (as the grille below is detailed) and the grille types are often chose to match the rest of the other types of decorative louvers and grilles that were already designed for the HVAC system.
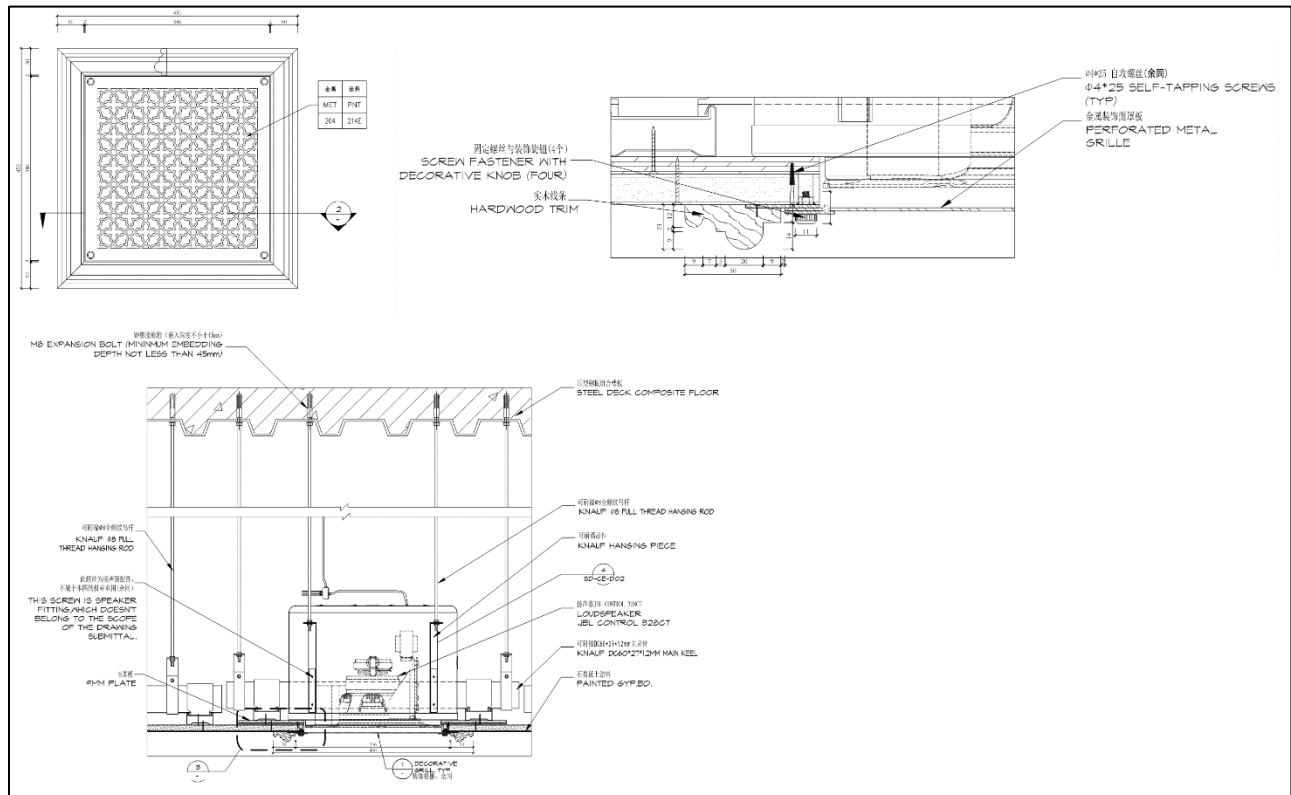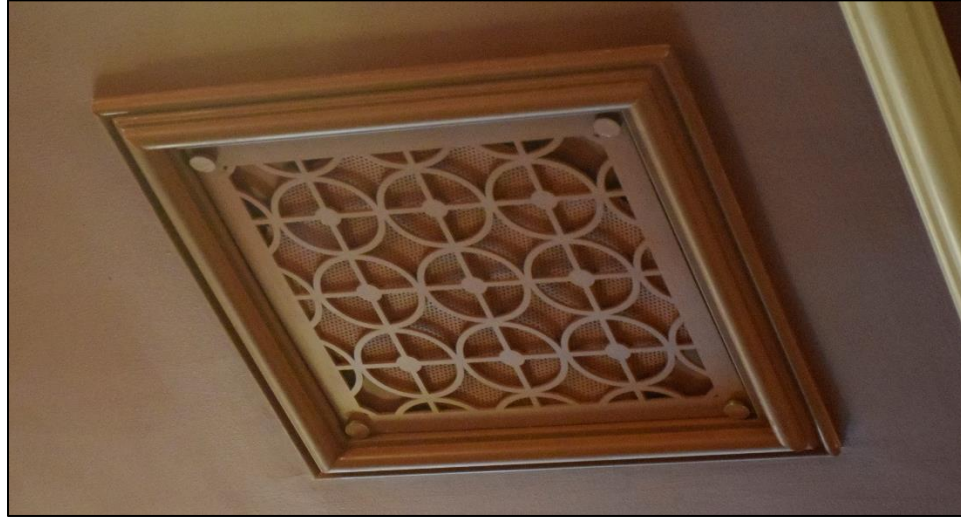
6.8. Loudspeakers Behind Painted Expanded Metal

Sometimes simple is best. In architectural spaces that do not require heavily themed surface treatments, expanded metal can work well for hiding large unsightly clusters. Perforated metal can also be a great choice for this. In this case, a large faux wall was created with expanded metal, and with careful light management, it will appear as a solid wall to the public.

7. <u>Conclusions</u>

Integrating loudspeakers into themed environments can be as simple or as complex as the story calls for, but in nearly all instances, it will require a team effort to integrate loudspeakers. This is especially true in highly themed environments where loudspeakers may be hidden behind all sorts of shrouding concoctions. Many examples discussed here were done with larger budgets and at large scale designed for show runs over 10 years, but the techniques and materials explored here can be scaled up or down to suit low budgets and short runs to great effect.

When the sound design need is clear for a thematically hidden loudspeaker, often large portions of the design team will need to collaborate to make a successful hide. When this is done well, the tradeoffs of a good hide can result in a seamless environment where sound seems to naturally exist in the thematic world, or it may effortlessly image to the precise location. All of the hard work may result in an audience who is unaware of all of the work that was done, but that is the point of it all. Through thoughtful understanding of the story, insightful integration of systems and design, we can manage the guests focus and pivot their experience through the art of illusion and distraction.

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Irene Lok	Eric Miller	Derek Pendergrass
Andrew Rutkin	Jodi McLaughlin	Michael Valentino
Tony (Bubba) Morris	Greg Combs	Andrew Sanchez

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Below are sample material references common to this work. None of these companies paid to promote the work or endorsed this paper; they provide resources, information, or products which the authors have found useful in the creation of themed speaker grilles.

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