Loudspeaker Enclosures Materials and Manufacturing Technology

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Earthquakes, fire, tornadoes...and glue are all factors to consider when building professional loudspeaker enclosures.

by Steven Saraceno

An old Arab proverb says, "Anything without foundation must fall." Anyone who has flown or installed a loudspeaker enclosure above someone's head can appreciate the importance of this concept. The modern loudspeaker enclosure is a complex structure that integrates steel, aircraft aluminum and manufactured wood products. How these materials are selected, shaped and joined is the foundation of reliable, durable, and above all safe performance.

CAD drawings are translated into numerical "tool paths" that guide computer-controlled woodworking machinery.

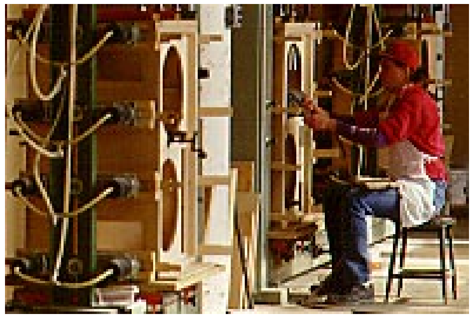
Acoustical considerations

Proper selection and machining of wood products is also important to the acoustical performance of the total loudspeaker system, because the enclosure is as much a part of the sound radiating system as the drivers it holds. Bracing must be designed to eliminate resonance on large panels. Driver baffles should minimize driver interaction, diffraction and other spurious radiations. When systems use multiple horns of different sizes, the structural issues become even more complex. "The name of the game is faithful reproduction of the original sound," says Sam Appleton, Design Engineering Manager at Eastern Acoustic Works in Whitinsville, Massachusetts. "You don't want any anomaly introduced by the cabinet."

To make sure that new designs achieve these goals, EAW builds as many as ten prototypes before a model is approved for production. Testing includes a variety of acoustical measurements at all power levels. Stroboscopic tests may be used to identify the location of baffle vibrations or other cabinet resonances that soak up the energy produced by the drivers within the enclosure instead of transmitting it to the air.

Computer precision

Computer technology that closely links the design and manufacturing processes is one of EAW's most powerful tools in the quest for acoustic neutrality. CAD (computer aided design) drawings from EAW engineering are converted to IGES format, then manipulated by CAM (computer-aided manufacturing) programs that create tool paths to drive CNC (computer numerically controlled) machinery in the woodshop. The tool paths specify exact cuts on the X, Y and Z axes that can be duplicated time after time with the same high degree of precision. The saws and routers are self-compensating: they measure their own blade wear and adjust to maintain dimensional accuracy.



EAW loudspeaker enclosures are built using modern manufactured wood products designed for high density and tensile strength.

Before the CAM system uploads the tool paths to plane saws and routers on the production floor, "Optimizer" software processes the data to get the most out of both wood and labor. "The operators don't have to stand there and say, 'Well, I've got to cut this part to this size, and how many will I get...?'"explains Kevin Stirk, general manager of the woodworking operation. "They just pull up a program number and go right through the pattern."

Large complex horn flares

EAW takes advantage of computer-driven manufacturing's precision and flexibility in a unique process for designing and building large midrange and low frequency horn flares. Horns are usually formed from molded plastic and fiberglass – thin flexible materials that easily adapt to the complex curves of true exponential flares. These materials will work in high frequency horns, as the resonant frequencies of the structure are outside the operating range of the horn. In large midbass horns, however, the resonant frequency of the structure falls within the passband. The resulting peaks and dips are extremely difficult to correct, and produce a sonic "character" or "color" which affects everything the speaker reproduces. Listeners do not hear the speech or music as it was intended: the sound of the speaker itself gets in the way.

Computer-programmed saws cut pieces to exacting tolerances.

Wood has high internal friction, which cuts down on resonance. But horns built of thick sheets of wood must simplify the flare in order to accommodate the limitations of the material, producing gross approximations of the true exponential expansion. EAW's process creates a complex flare using thin birch laminates. High density foam imparts structural rigidity and produces a reflective acoustical boundary.

The power of CNC is essential to this process. The first step is to cut a precise, complicated curve into the top and bottom of each horn using the computer-driven router. Design Engineer Sam Appleton explains the approach. "We use very thin plywood, about three millimeters, cut to fit this complex curve. Of course the thin plywood is resonant and even transparent to low frequency sound waves. So we fill the cavity behind the flare wall with a high density polyurethane foam that soon hardens and makes an acoustically inert, reflective structure. It effectively becomes the side of the horn, just covered with a thin piece of plywood."

The modern adhesives that hold the cabinets together are stronger than wood screws, staples and even the wood itself.

Today, even wood comes from a factory

Computers and computer-controlled machinery are capable of precise, repeatable steps. But what are they machining? Every basement hobbyist knows that the wood Mother Nature produces is a highly variable substance, full of knots, blemishes, grain patterns that vary unpredictably and other surprises. Hardly the proper foundation for a high precision volume production process. Years ago, EAW turned to cross-grain laminated birch from Russian or Baltic forests and mills for the bulk of its enclosures. Other professional manufacturers have followed suit, and this manufactured wood product has become the industry standard for professional systems.

EAW's purchasing department specifies "void-free, cross grain laminated, 18 ply to the inch Baltic birch." Each part of that spec is important. Void-free material ensures uniformity from one enclosure to another – it is also essential in eliminating internal resonances. When each ply is rotated 90 degrees from the ply before it, so that the grains cross at right angles, strength is maximized in all directions. "The 18 ply to the inch lamination gives us a very uniform material," explains EAW Applications Engineer Andrew Rutkin. "When individual plys are made that thin, variations due to texture changes and humidity changes are minimized. There's not as much wood thickness to change, and also there's more glue in the wood, which adds to the stiffness." Material with fewer plys to the inch is cheaper, of course, but not as consistent. The same, unfortunately, goes for sheets produced by North American lumber mills. Softer woods than Baltic birch are available, but do not perform as well acoustically or structurally.

The shape of this horn flare has been cut by a CNC router. A 3mm sheet of birch ply will be inserted in the slot to form the flare, which is braced with wood formers. The cavity behind the flare will be filled with high density structural foam.

Outdoor installations and large portable touring systems test the limits of structural integrity. For these applications, EAW employs marine grade Baltic birch, in which waterproof glues are used in the manufacture of the plywood itself. As the glues are temperature-stable, they maintain adhesion at high temperatures and don't become brittle in cold weather.

For permanent indoor installations, where portability and weather resistance are not factors, medium density fiberboard (MDF) is sometimes used. MDF is absolutely consistent from batch to batch. Its wood fibers have been ground down to a soup much like paper pulp, then molded under high heat and pressure into board shape. MDF is not layered like plywood, but solid. "The acoustical properties are excellent," says Andrew Rutkin. "I believe if you put a piece of MDF in water, it will sink. And that's excellent because it has very high losses and high resonant frequency. It's a very 'dead' material— that is, acoustically inert." MDF requires minimal bracing to produce an acoustically inert structure, but its shear strength is lower than cross-grain laminated plywood, which is why it is not used for portable systems, or in front baffles that must support heavy cone transducers.

There are materials similar to MDF, such as chipboard or particle board, which EAW will not use. Made through the simple gluing together of castoff flakes, these materials have very low shear strength and are not consistent. These low density materials are prone to resonances that are difficult to control.

Work flow is organized around fleixble workstations that provide the agile manufacturing capability needed to respond to fast-changing customer requirements.

Production processes

Whether cross-grain laminated birch or MDF, the raw material for EAW enclosures arrives at the shipping dock in pallets of large sheets. Then it is moved to the production floor for cutting.

The main panel saw runs at 40 horsepower, with a 20 inch cutting plate and 5 inch cutting height. Seven sheets at a time can be stacked on its table. Pneumatically driven ball bearings allow the operator to move the heavy sheets easily. Once they are in position, the saw table and hold-down bar take over, lining up the sheets, positioning them precisely, and holding them perfectly still as the blade passes through as many as eight sheets at once. There is also a smaller saw, employing 13 horsepower, with a 13 inch blade and 3 inch height. Since the machining tolerances are so much tighter than the mills where the sheets are made, the first cut is always a squaring cut.

After the panels are cut to size, they are moved to the router for more complex machining. The largest of the routing machines cost over $250,000. But it does have two mechanized tables and eight heads. Four of the heads are fixed and four are smaller "piggyback" heads that

In the final assembly process, drivers and crossovers are installed in the painted enclosures.

make smaller cuts. Drills could be used for these operations, but the CNC router eliminates the need to change bits when cutting different size holes. Moreover, the self-adjusting unit measures blade wear and automatically compensates so that every cut is exactly the same. " The machine runs non-stop," says Stirk, " and there's very little downtime. We load one table and while that's cutting we load the other table." The routed panels now go either to secondary sawing, where dadoes and rabbets will be cut, or over to assembly. There pieces are put together much as one might arrange a jigsaw puzzle. Often, subassemblies are produced and sent back to the router for additional machining.

Each secondary saw is set up for a particular operation, such as dadoes, rabbets or angle joints for trapezoidal enclosures. At this stage, wood and steel or aircraft aluminum are integrated into a structure that is capable of safely bearing the loads involved in portable flying systems or permanent installations. "Professional audio systems have to be extremely versatile and always reliable," Stirk says. "A lot of these are road cabinets, and if the bracing was just done with wood screws, there's a good chance it'd just rip right out. These things go over peoples' heads, so they have to be structurally sound. There's no room for error." Anything designed to hang over people's heads must include steel or aircraft aluminum bracing as an integral structural element – to use anything less well constructed is to court disaster.

Superior materials, advanced manufacturing technology and company-wide attention to quality produce consistent, safe, dependable loudspeaker systems.

At the builder's table the various pieces are stacked in the order in which they will be assembled. The builder then staples and glues the parts together. "One of our big fortes, I think, is a heavy glue bead on every joint," says Stirk. "People have said 'Boy, that's messy!' But we consider that solid." Kevin is right – modern adhesives do create a joint that is far stronger and more durable than wood screws or staples can produce. Fasteners are used only to make sure that nothing moves while the glue joints are curing.

The glue bead is something Stirk and Ciampaglia look for whenever they walk the floor. "If you look down and see there's not a solid glue bead there," says Stirk, "well then, you've got to wonder—is there a solid glue bead between the joint? " Three different glues are commonly used: an easy-to-spread, brown-colored mixture intended for interior ; a weather-resistant glue for any joints which might be exposed to water; and an epoxy compound, impervious to moisture and heat, for permanent outdoor installations.

Assemblies are inserted in the gluing station while the glue is still wet. Pressures of up to 120 lbs. per square inch are applied in order to squeeze out any gaps and ensure a solid fit. After eight to twelve minutes, the piece is removed and set on a palette for curing. The final step of enclosure construction involves hand finishing. The edges of the cabinets are rounded. Putty is applied to any small imperfections. Eventually the whole piece is sanded.

The cabinets will go on to EAW's paint room. Weatherproof models will have a fiberglass coating. After the painting and sealing process, drivers and crossovers will be installed, and final testing undertaken.

Reliability is the sum of the parts

Do loudspeaker enclosures really need to be built from such expensive materials, machined to such close tolerances, designed with such attention to detail? When your business and the safety of your clients and their audiences depend on it, there are not short cuts. Kenton Forsythe, EAW's Executive Vice President of Engineering, often refers to the "unwritten rules of professional speaker design:

1. Make sound.
2. Keep making sound.
3. Make good sound.

In other words, the greatest speaker in the world does no good if it's not working. EAW's construction process has survived some very tough tests, including natural disasters. Several years ago, a tornado picked some CS103's belonging to PA rental company Carlos Sound off the stage and deposited them in a nearby creek. One enclosure was dropped on a fence post that went right through the displacement plug, the cone driver and the door on the rear panel. Service technicians replaced the door, the driver and the plug, and the system was "making good sound" that same night.

Even the Northridge earthquake failed to get the better of the EAW loudspeaker systems installed in Anaheim Stadium. "A couple of cabinets fell from where they were hung, and then there was a fire," says Dan Ciampaglia, who inspected the enclosures when they were returned to Whitinsville. "It was amazing. They fell all that way, got all charred up—but they were still intact." Mute – but effective – testimony to the value of manufactured wood products, state of the art adhesives, computer controlled machinery, and attention to detail at every construction stage.

Steven Saraceno is a freelance writer, based in New England, who covers a variety of technologies and related topics.