These notes are intended to provide general guidance for the construction of loudspeaker enclosures in home workshops. Topics such as choice of materials, panel damping, acoustic absorbents and cabinet finishing are dealt with in terms which the hi-fi enthusiast will readily understand. Detailed information on specific loudspeaker systems in the KEF Constructor Series is given in individual design leaflets which are listed on the last page of this brochure.

**CHOICE OF MATERIALS**

The choice of material from which loudspeaker cabinets are constructed affects the overall performance in a subtle way. An ideal enclosure should remain completely inert contributing nothing whatever to the subjective performance of the loudspeaker by way of colouration whether due to panel resonances or other effects. However, complete inertness is impossible to achieve in a practical design. Therefore it is necessary to specify materials and design the construction so that residual vibrations of the structure are subjectively inaudible.

**CHIPBOARD**

Nowadays the great majority of loudspeaker cabinets are made from chipboard, sometimes called particle board. This material is in general use within the building industry and furniture trade because it can be produced to consistent specification at a reasonable cost. Chipboard is dimensionally stable within the normal range of temperature variation and it is resistant to attack by insects and fungi. Density and damping are key properties in loudspeaker enclosure materials and therefore only the higher densities should be used. Chipboard is available with a wide variety of specifications covering both interior and exterior applications. For loudspeaker cabinet work interior grades are adequate. However, exterior grades should be chosen for enclosures intended for operation over prolonged periods in humid tropical conditions or damp locations.

Most chipboards are produced by pressing resin-coated chips between steel plates - 'platten pressing' - although some are made by extrusion methods. Platten pressed chipboards are defined by their structure which results from the way the chips are spread or 'snowed'. There are four basic types, Fig. 1.

**Single Layer**

The board is formed from chips of the same size or mixture of sizes throughout, so that it has a consistent density.

**Three Layer**

This board is constructed of relatively high density surface layers, between 1mm and 3mm thick, composed of fine, or long thin chips or thin flakes with a core of larger chips. The density will therefore be higher at the outer faces than in the centre.

**Multi-Layer**

This is similar to three layer except for an increase in the number of layers. A core of higher density can be introduced for improved flexural strength and frequently a finer surface layer is included.

**Graded density**

The size of the wood chips varies gradually across the thickness of the board giving smooth high density surfaces with a relatively low density core. Multi-layer or graded density boards are satisfactory for general cabinet work but single layer boards of homogeneous high density are a better choice for a front baffle which may involve machining rebated apertures and counterbored holes. Alternatively plywood may be used for this particular purpose.

A good idea of chipboard quality is conveyed by reference to its density which is usually expressed in kilograms per cubic metre. Densities vary from 400 to 900 kg/m³ though some cement loaded boards go as high as 1150 kg/m³. It is advisable to use densities of at least 600 kg/m³ for all loudspeaker work.

**FIBRE BOARDS**

Another wood product that is being used quite widely for loudspeaker enclosures is fibreboard. In this case, the wood is reduced to fibres which are then felted and hot-pressed into sheet form. Little or no supplementary resin is used. The primary bond is derived from the felting and inherent adhesive properties of the fibres. Tempered hard-boards are further impregnated with hot oil or resin and subsequently heat cured.

Density is appreciably higher than for chipboard ranging from 800 to 1200 kg/m³ and inherent damping is improved due to increased frictional stresses between the wood fibres.

Surface texture is usually smooth on one side with a fine mesh pattern on the other, but duo-faced tempered hardboards having two smooth faces are also available.

The range of thicknesses available for tempered hardboard is restricted to about 13mm maximum.

Another type of wood-fibre product now coming into use is medium density fibreboard (MDF). Less dense than standard hardboard but available in greater thickness, the densities of these materials lie in the range 640 – 860 kg/m³ with thicknesses from 5 – 38 mm. Its damping properties are excellent. Surface texture is normally smooth on both sides and therefore ideally suited to high class cabinet work.
PLYWOOD

Plywood is an excellent material for constructing loudspeaker enclosures and its use has only diminished in recent times because of a great increase in its cost and the better availability of chipboard. Plywood has great strength, good dimensional stability and very good machining properties.

It is available in exterior grades which, due to their greater resistance to moisture and protection against fungal and insect attack, are suitable for tropical use. Plywood is available in a wide variety of types which include blockboard and laminboard. Multi-ply and laminboard are best suited to loudspeaker cabinet work on account of their better damping properties, Fig. 2.

Various damping materials are suitable but the most convenient is polyester foam of the type used for cushions and general upholstery. It can be purchased ready cut into pieces of different thicknesses from specialist shops. Alternative materials include resin-bonded fibreglass (from builders merchants), stone wool, acetate fibre and wool waste. Loose materials may be packed into cotton bags and secured in place by fabric tape or string. Foam plastics and fibreglass can be self-supporting in some cases or otherwise fixed in place with adhesive.

Caution
Expanded polyester foams are inflammable and produce highly toxic fumes when they burn. All such materials should therefore be handled and stored with great care.

GRILLE MATERIALS

Every loudspeaker works best without its grille, but some form of covering is usually desirable to obscure and protect delicate drive units. Knitted semi-elastic textiles are most suitable because they have a high percentage open area offering little obstruction to sound and they stay taut.

Woven cloth can also be used but this must have an open weave and be free from fuzzy threads which attenuate the higher frequencies.

Perforated or expanded metal sheet is sometimes used. Here also performance is related to percentage open area and those which are sufficiently transparent acoustically do not conceal the drivers.

Grille frameworks should be as thin as possible consistent with adequate strength and they should never encroach upon the drive units – tweeters in particular. A heavy structure round the front of the enclosure will give rise to sound reflections and may cause colouration.

CONSTRUCTION

JOINTS

Traditional jointing methods are satisfactory and any of the types illustrated in Fig. 3. may be used.

It is however important to ensure that all joints are adequately glued and that they are also airtight, therefore adhesives must be of the high viscosity gap-filling type. The use of glue blocks is recommended to further strengthen corner joints as in Fig. 3f

ADHESIVES

Joints in chipboard and plywood are best made with urea-formaldehyde adhesives as these contain no water which could cause local swelling of the boards. Alternatively a polyvinyl acetate (PVA) adhesive can be used but it must be of high viscosity to avoid glue-starved joints. Where boards are used which have low density cores it is good practice to precoat the joints with adhesive allowing it to dry thoroughly before the final bonding process. This prevents the bonding coat from soaking into the interstices.
PANEL VIBRATION
The total surface area of a loudspeaker enclosure is many times greater than that of the drive unit diaphragm. If the panels vibrate, however slightly, they may colour the overall sound output to some extent. Panel vibration can be reduced by bracing and damping.

Internal bracing is of value in large cabinets where dimensions exceed about 400mm. Effective bracing not only strengthens the cabinet but also makes it more rigid and reduces the possibility of warping. A strongly preferred method takes the form of a bracing partition which is perforated to allow an unrestricted flow of air between internal compartments. Struts and battens have little effect.

The application of sound deadening material is beneficial in reducing the amplitude and Q of panel vibrations. Suitable materials include bituminous impregnated felt and high density unvulcanised rubber compounds. These materials are produced in sheet form, sometimes with an intervening layer of soft polyurethane foam, and they are bonded to the inside surfaces of the loudspeaker enclosure.

The pads should be of sufficient size to cover at least half the area of each cabinet panel. There is however little to be gained by covering the entire surface.

The sound deadening pads must be flat. Warped pads should be softened in a warm oven and flattened under pressure before bonding. Suitable adhesives are high viscosity polynuclear acetate emulsions and rubber-based compounds.

ASSEMBLY
Designs in which drive units are mounted behind the front baffle are made with loose backs to provide access. Otherwise it makes for a more rigid structure if all the panels are glued in position during assembly. Absorbent materials and wiring harnesses can then be inserted through one of the larger apertures in the front baffle. However damping pads will need to be fixed in position prior to assembling the cabinet.

TERMINALS
Colour coded binding posts are recommended not less than 4mm in diameter. Some types of spring loaded terminal connectors are also suitable but these must have low contact resistance and be large enough to accept connecting cables of adequate diameter.

FINISHES
The most popular cabinet finish is wood veneer as this can be stained, polished or oiled to match existing furniture. Admittedly, the application of veneer is difficult to achieve at home and should not be attempted without previous experience. However a wide choice of ready veneered panels is available with substrates of chipboard or plywood.

The simplest treatment for teak and walnut is rubbing with raw linseed oil. Three coats are usually sufficient allowing twelve hours drying time between coats. For a really superfine finish a daily application of oil is recommended over a period of five or six weeks, each coat being well smoothed with fine steel wool.

French polishing with shellac and methylated spirit also gives a fine traditional finish but skill, patience and practice are needed to produce a first-class result.

For the more adventurous a wide variety of stains and synthetic finishes are now available from hardware stores and DIY shops and amazingly good results can be achieved with a little practice following the maker’s instructions. The performance of a loudspeaker is unaffected by the finishing process so the home constructor is free to experiment.

As an alternative to wood veneer and traditional finishes wood simulations printed on to plastic foil can be used. The best of these are now very convincing and almost indistinguishable from the real thing except by touch. Hardware stores are able to supply both the foil and suitable adhesives.

Printed or lacquered finishes can also be used. Matt or semi-matt surfaces are usually more successful as they do not reveal minor imperfections and blemishes.

TESTING
Rattle and Buzz check
Apply a sinusoidal signal of 2 to 3 volts from a beat-frequency oscillator or similar low harmonic source and sweep slowly through the audio frequency range listening for evidence of loose components, faulty joints or intermittent connections. Do not apply larger voltages at high frequencies as the drive units may be damaged by thermal overloading.

Polarity
Place the two speakers face to face 5mm apart. Apply a mono musical signal of equal amplitude and phase to both loudspeakers. On reversing the connections to one loudspeaker, the volume of sound should be noticeably reduced if the marked polarity is correct.

Matching
The face to face test described above is also a reliable test of overall performance and will reveal if the paired loudspeakers are similar to one another. With the connection to one loudspeaker reversed, apply a mono signal of the same strength to both systems. Very little sound output will be heard due to the antiphase cancellation if the loudspeakers are closely matched. Note that this test can only be used in cases where the drive units are arranged symmetrically or in mirror-image pairs.

Impedance
The modulus of impedance versus frequency is a useful check on electrical characteristics. The impedance of each loudspeaker should be measured under constant current conditions at approximately 100mA. The two curves should be similar to each other and in agreement with the impedance characteristic published in the relevant Constructor Series leaflet.

Dividing Networks
Curves showing how terminal voltages for each filter section vary with frequency are published for each Constructor Series design. Note that the curves are obtained with 8 ohm loads in place of the drive units. Faults in the filter sections, whether due to component failure or wiring discrepancies, will produce a marked change in the terminal voltages curvus.
**LOUDSPEAKER LOCATION**

Stereo images are formed by the sound received by the listeners directly from each loudspeaker. Confusing reflections from walls and large objects spoil the stereo effect due to the time delay involved. Therefore wherever possible loudspeakers should be placed at least 50cm from a rear wall and 1m from the nearest side wall. Fig. 4.

The space between the two loudspeakers and the distance from the listeners are important. If loudspeakers are placed too close together or too far apart, stereo images will not be fully developed. In average living rooms, speaker spacing between 2 and 4 metres will usually produce satisfactory results.

The listeners' distance from the loudspeakers should be at least equal to and preferably greater than the distance between the loudspeakers. Tests should be made with both speech and music before deciding upon final locations.

**CONNECTING CABLES**

Ideally, connecting cables should be as short as possible to avoid loss of power and high frequency response.

The total resistance should not exceed approximately 0.3 ohms.

The following tables show the maximum length that can be used in various gauges without audible effect on speaker performance.

Colour coded cable is recommended to assist checking polarity.

<table>
<thead>
<tr>
<th>Wire Type</th>
<th>spec.</th>
<th>max length in metres</th>
<th>max length in feet</th>
</tr>
</thead>
<tbody>
<tr>
<td>2.50</td>
<td>50/0.25mm</td>
<td>25</td>
<td>80</td>
</tr>
<tr>
<td>1.50</td>
<td>30/0.25mm</td>
<td>15</td>
<td>49</td>
</tr>
<tr>
<td>1.25</td>
<td>40/0.20mm</td>
<td>12</td>
<td>39</td>
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<tr>
<td>1.00</td>
<td>32/0.20mm</td>
<td>10</td>
<td>32</td>
</tr>
<tr>
<td>0.75</td>
<td>24/0.20mm</td>
<td>7</td>
<td>23</td>
</tr>
</tbody>
</table>

*Caution*

Certain exotic types of cable have high capacitance which can cause instability with some amplifiers. If in doubt, select a cable from the foregoing tables.

**KEF CONSTRUCTOR SERIES DESIGNS**

- **CSI**—A miniature two-way system based on the KEF Model 101.
  - Leaflet Part No. SL353 EN01

- **CSIA**—A miniature two-way system.
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