Three-way loudspeaker system — the 4000/2

Second in our line of quality hi-fi speakers for the do-it-yourself enthusiast.

David Tilbrook —

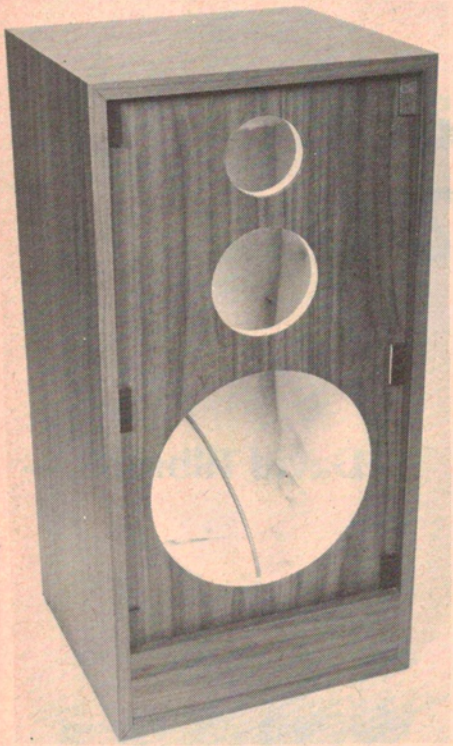
IN FEBRUARY THIS YEAR, we published the first in a range of loudspeaker projects, the ETI 4000/1. This was a four-way loudspeaker that used a separate driver and mid-range enclosure to cover the frequency range of 150 Hz to 700 Hz. The objective of this design was to remove the lower mid-range portion of the audio spectrum from the woofer so that the large cone excursions typical of bass reproduction would not cause intermodulation distortion by mixing with the mid-range. This technique works very well and the 4000/1 is capable of some of the cleanest sound possible with present technology.

There is, however, a demand for a lower-priced system and we are introducing the 4000/2 loudspeaker to meet this requirement. Much of the cost of the bigger loudspeaker was involved in the lower mid-range unit and its enclosure, and in the complexity of the crossover. The 150 Hz crossover point between the woofer and the lower mid-range necessitated the use of very large inductors and capacitors, and these are expensive.

By eliminating the lower midrange unit and its associated hardware and using a more conventional design approach, we have been able to keep the cost of the 4000/2 to a minimum, while still achieving a loudspeaker capable of excellent results.

Like the four-way loudspeaker, the 4000/2 is housed in a sealed enclosure. Crossover points are at 700 Hz and 3 kHz, and the crossover is a 12 dB per octave constant-K design. (See "Principles and problems in loudspeaker design", published in ETI, Jan & Feb 1980.)

View of the completed speakers, with and without the front grille. We secured the latter to the front baffle using Velcro strips stapled in appropriate positions.



The completed box, prior to mounting the drivers and crossover network. The box lining is placed in position after the crossover unit, tweeter and mid-range drivers are placed in position. The whole box is then stuffed with waste wool before mounting the woofer to the front baffle.

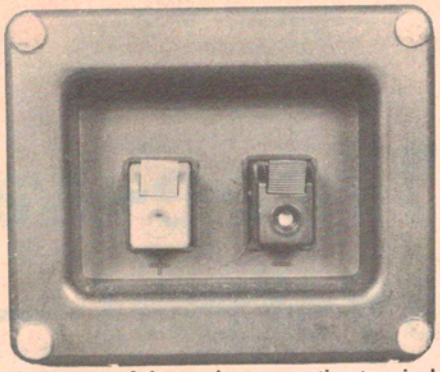
The drivers used here are part of the new range of Philips loudspeakers. We chose these drivers only after a thorough look at the price, availability and quality of drivers presently available in Australia. There is some relationship between power handling and price of a driver but there is *little relationship between sound quality and price*. Some of the best tweeters I have heard, for example, have been amongst the cheapest devices available. A complete set of drivers for this project will cost around $240, and at this price are a bargain.

The woofer used is the AD12250/W8. This has a free air resonance at 26 Hz and a power handling figure of 100 watts. When in its enclosure the resonant frequency rises to around 35 Hz, which is quite good!

The mid-range unit is the latest Philips dome mid-range, the AD02161/SQ8. This is a 50 mm diameter textile dome unit with its own mid-range enclosure as an integral part of the driver. The tweeter is a 25 mm diameter textile dome unit, the AD01610/T8. These three drivers were used in the earlier 4000/1 loudspeaker and the mid-range and tweeter units were shown to work well together with a crossover point at 3 kHz.

The big problem encountered in the design of this loudspeaker was the lower crossover point between the woofer and mid-range. The resonant frequency of the mid-range unit is approximately 350 Hz, so it should not be used much below 700 Hz. This enables the crossover to give 12 dB of attenuation at the resonant frequency. Unfortunately, this means that the woofer must handle everything up to 700 Hz and, ideally, should have a usable frequency response to 1.4 kHz. The AD12250/W8 doesn't have a response this good, but it can be made to operate satisfactorily up to 1 kHz, which is a reasonable compromise. Since the woofer is handling a good part of the mid-range spectrum, a substantial amount of cabinet damping is necessary, otherwise cabinet resonances will severely impair the mid-range performance of the loudspeaker.

The prototype loudspeakers were first lined with a double layer of speaker innerbond material, then completely filled with waste wool. As always, the exact amount of filling needs to be established by experiment. During the development of the 4000 range of loudspeakers I have had a good look at the types of innerbond material available and most of them are definitely not dense enough. Unless the quality of innerbond improves rapidly, you can safely consider carpet underfelt and fibreglass bats as suitable alternatives!

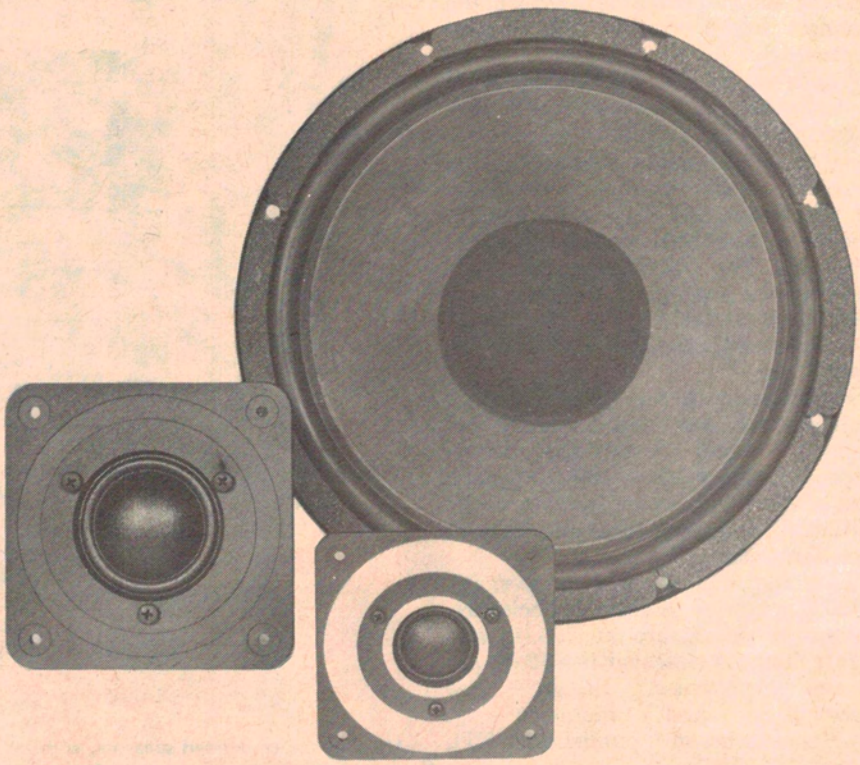


A close-up of the speaker connection terminals we used. This consists of two colour-coded spring-grip terminals mounted on a recessed plastic moulding. The assembly is screwed into a cutout in the rear baffle of the box.

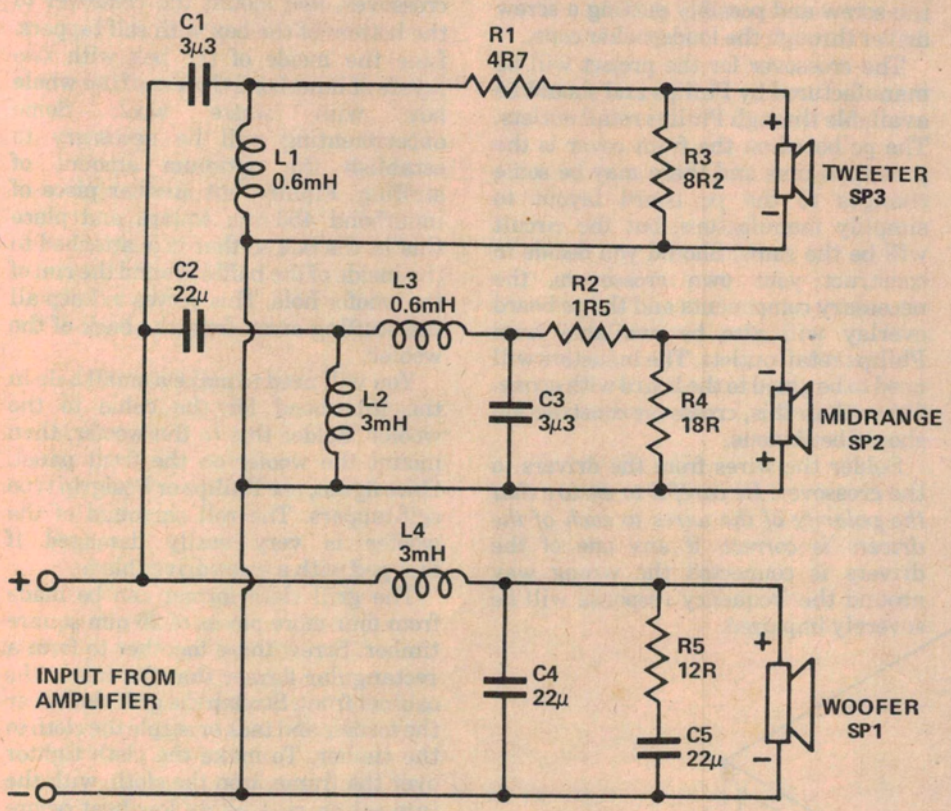
Construction

If you are building the boxes yourself, rather than buying a complete kit, start by cutting the back, top, bottom and sides. The material used in the prototype boxes is 19 mm particle board and the finished units do not suffer excessively from panel vibration in use,

A group photo of the three drivers used in this system. Clockwise, from the left: AD02161/SQ8 dome mid-range, AD12250/W8 woofer and the AD01605/T8 tweeter – note that this last one is the alternative driver to that shown in the picture of the assembled speaker on page 51.



4000/2 3-way speaker system



PARTS LIST - ETI 497

Drivers

SP1	Philips AD12250/W8
SP2	Philips AD02161/SQ8 or AD02160/W8
SP3	Philips AD01610/T8 or AD01605/T8

Inductors

L1	0.6mH,max.dc resist: 1 ohm
L2	3.0mH,max.dc resist: ½ ohm
L3	0.6mH,max.dc resist: 1 ohm
L4	3.0mH,max.dc resist: ½ ohm

Capacitors

C1	3u3 polycarbonate
C2	22u bipolar electrolytic, 50V
C3	3u3 polycarbonate
C4	22u bipolar electrolytic, 50V
C5	22u bipolar electrolytic, 50V

Resistors all wirewound, 5%

R1	4R7, 5W
R2	1R5, 5W
R3	8R2, 5W
R4	18R, 5W
R5	12R, 5W

Miscellaneous

wire; one loudspeaker terminal block; particle board; screws; glue, etc; speaker grill cloth; innerbond; waste wool.

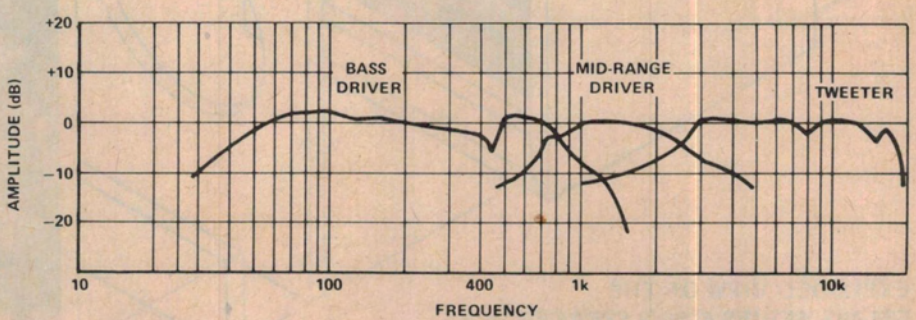
so particle board of this thickness should be sufficient for most purposes.

Apply a liberal quantity of Aquadhere, or a similar wood glue, to all the joints and screw the panels together. Let the glue dry and then line all the inside joints with a suitable sealent, such as caulking compound or Plastibond. Always use particle board screws or self tappers when working with particle board. Normal wood screws will not hold into the material properly.

For best bass performance it is important that the finished box is totally air tight, so eventually, the whole box will be sealed in this manner. This much of the sealing is best done now before the front baffle goes on.

Next, mount the spring terminals to the back panel. I used special loudspeaker terminals that are supplied fitted to a moulded plastic base. This simplifies the job of sealing the terminals considerably. The hole needed for the terminal base is rectangular but with rounded corners. Use a jig saw if you have one. If not, drill four holes to give the rounded corners necessary then join them up by cutting with a fret saw. Screw the terminal base into position then seal the inside of the cabinet between the timber and the base of the terminal block. Use Plastibond or Bostik for this as wood glue will not adhere to the plastic properly. An alternative way to seal the mounting terminal is to line the rim of the hole with plasticine and screw the terminals over the top. Be careful not to screw the terminal base down too hard as the plastic is easily cracked.

Cut out the front baffle so that it is a snug fit into the front of the loudspeaker. Cut four lengths of 25 mm square timber and screw these onto the inside of the sides, top and bottom, 38 mm from the front edge of the loudspeaker. The baffle is then glued and slid into the box so that it rests on the timber braces. Anchor the baffle board by screwing through it into the timber braces; 19 mm should remain between the front of the baffle and the front edge of the loudspeaker. This space will be taken up by the grill cloth former.. ▶



Hand-plotted graph showing measurements of the average response of the individual drivers in the completed system, measured in an 'average' living room. The 'dips' at the cross-over points "flatten out" in the overall response of the system since the contribution from each driver adds in these areas.

Glue the small 100 mm high wooden panel into position at the bottom of the box. In the 4000/1 loudspeakers there was a false bottom, leaving approximately 90 mm under the box in which to mount the crossover. In the interests of keeping the cost of this project to a minimum I have omitted the false bottom and the crossover is mounted on the inside of the box as is more commonly done.

The next stage of construction is to mount the tweeter and mid-range. First, solder lengths of speaker cable to each of the drivers so that there is enough cable to reach the bottom of the box. The tweeter and midrange units are supplied with their own mounting gaskets that ensure a good seal between the baffle and the drivers. Use Philips head or Posidriver type screws for mounting the drivers, this will minimise the possibility of slipping off the screw and possibly putting a screw driver through the loudspeaker cone.

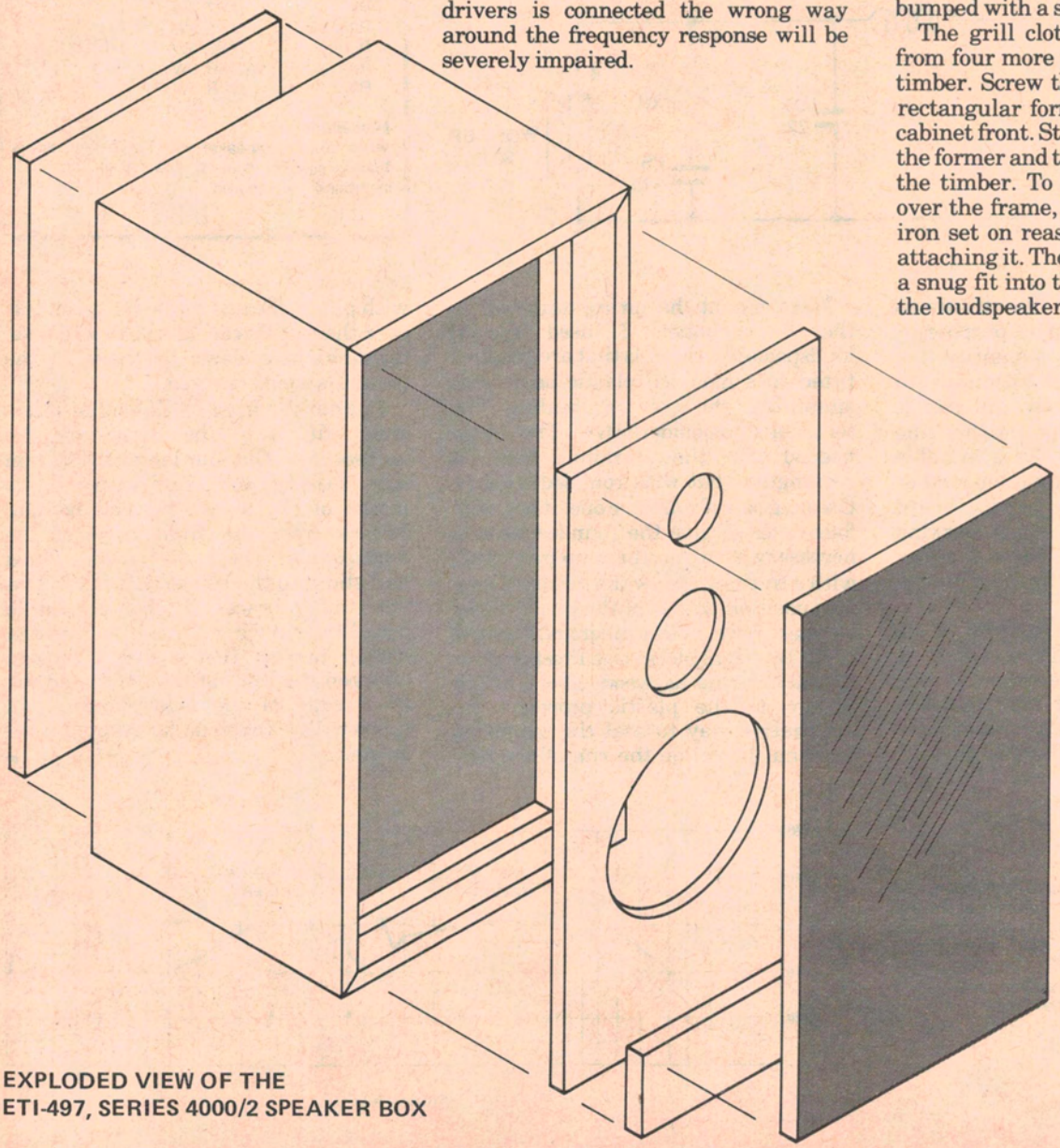
The crossover for the project will be manufactured by Philips and should be available through Philips retail outlets. The pc board on the front cover is the prototype unit and there may be some changes to the pc board layout to simplify manufacture, but the circuit will be the same. Should you decide to construct your own crossovers, the necessary components and the pc board overlay will also be available from Philips retail outlets. The inductors will need to be glued to the board with epoxy. Other than this, crossover construction should be obvious.

Solder the wires from the drivers to the crossover. *Be careful to ensure that the polarity of the wires to each of the drivers is correct.* If any one of the drivers is connected the wrong way around the frequency response will be severely impaired.

Solder wires from the terminals to the crossover, and mount the crossover to the bottom of the box with self tappers. Line the inside of the box with two layers of innerbond then stuff the whole box with waste wool. Some experimenting will be necessary to establish the optimum amount of stuffing. Finally, cut another piece of innerbond 450 mm square and place this in the box so that it is attached to the inside of the baffle around the rim of the woofer hole. This serves to keep all the stuffing away from the back of the woofer.

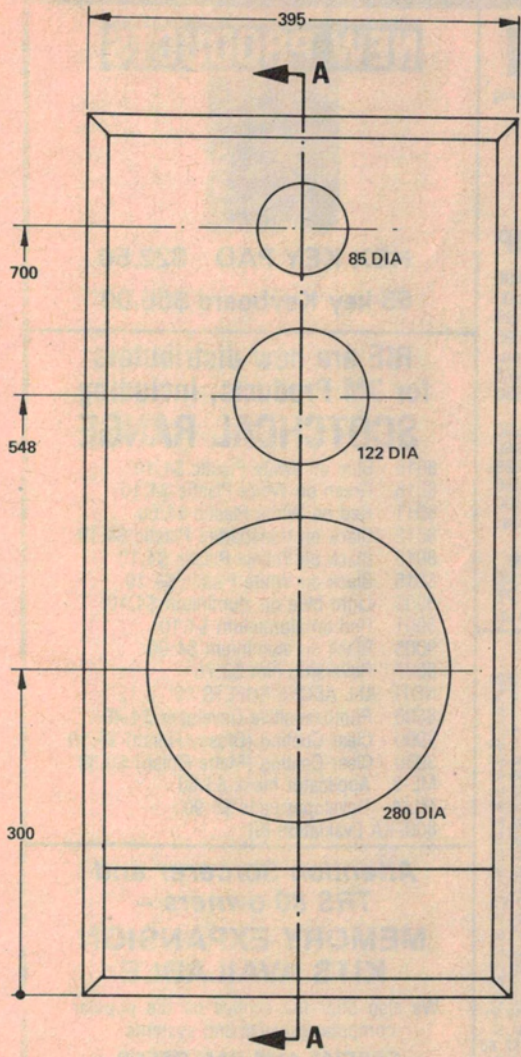
You will need to make a small hole in the innerbond for the cable to the woofer. Solder this to the woofer, then mount the woofer on the front panel. Once again, use Philips or Posigrip type self-tappers. The roll surround of the woofer is very easily damaged if bumped with a screwdriver blade.

The grill cloth former can be made from four more pieces of 25 mm square timber. Screw these together to form a rectangular former that fits inside the cabinet front. Stretch the grill cloth over the former and tack or staple the cloth to the timber. To make the cloth tighter over the frame, iron the cloth, with the iron set on reasonably low heat before attaching it. The finished grill should be a snug fit into the cavity in the front of the loudspeaker. ●



EXPLODED VIEW OF THE
ETI-497, SERIES 4000/2 SPEAKER BOX

4000/2 3-way speaker system



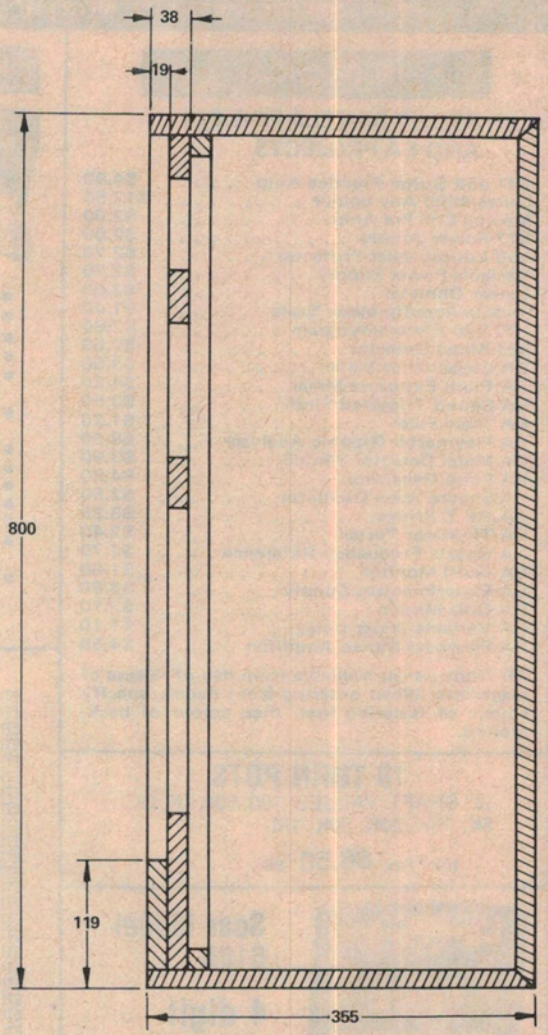
NOTES
ALL OUTSIDE WOODWORK IS 19mm PARTICLE BOARD COVERED WHERE VISIBLE WITH THE DESIRED VENEER

19mm x 19mm CLEATS AROUND FRONT EDGES

LINE ALL INSIDE SURFACE WITH ACOUSTIC FIBREGLASS

FRONT GRILL NOT SHOWN

ALL DIMENSIONS IN MILLIMETRES



SECTION AA