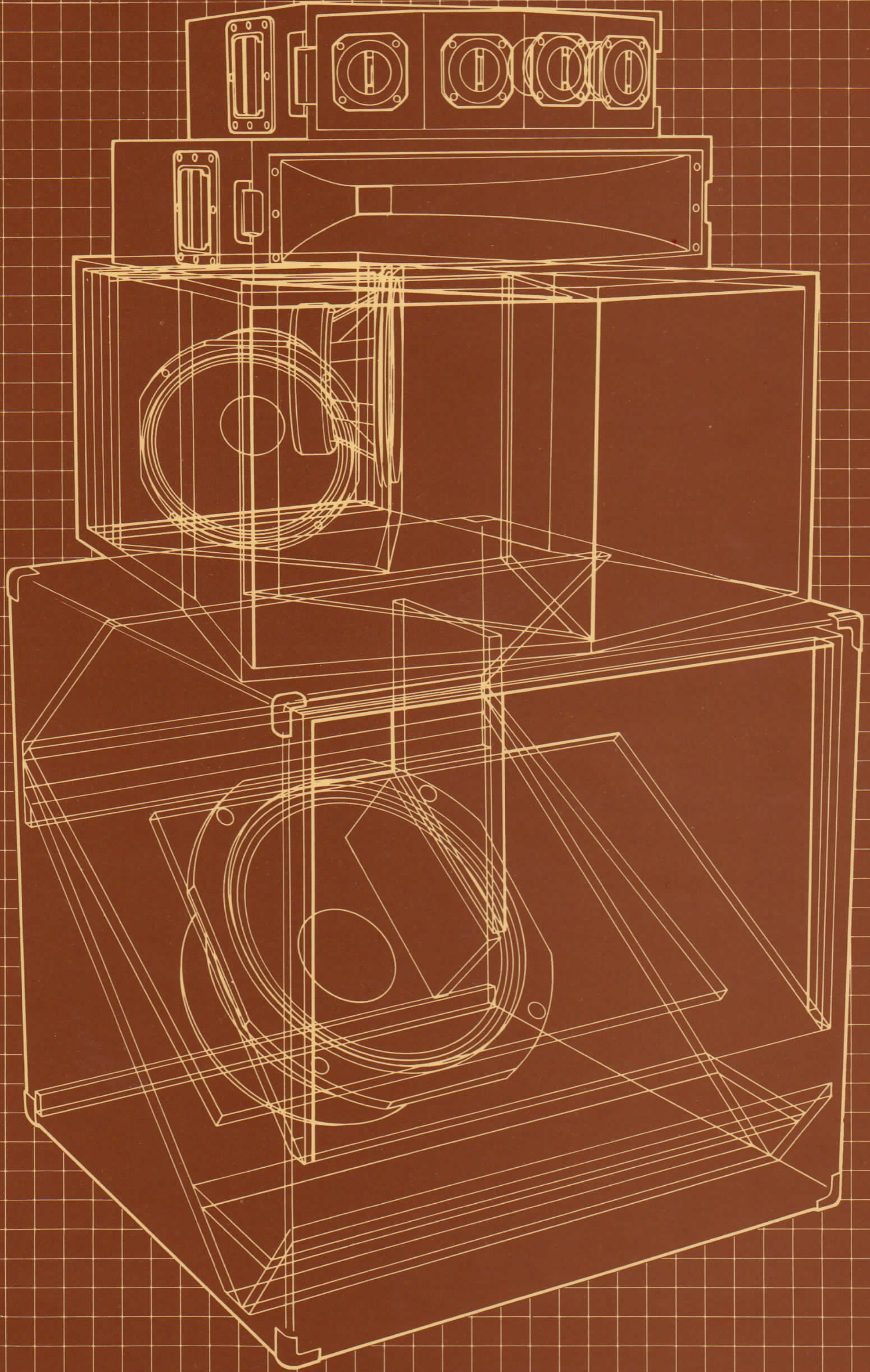
FANE

Towards Perfection



LOUDSPEAKER ENCLOSURE DESIGN AND CONSTRUCTION

The purpose of this book is to provide, for both the amateur and the professional enthusiast, a complete guide to the planning of loudspeaker systems and to the construction of a wide variety of enclosure designs. All acoustical design parameters have been scientifically calculated to provide optimum performance when fitted with the recommended loudspeaker drive units. All the enclosure designs included have been subjected to laboratory measurements and prolonged and rigorous testing under practical working conditions, and are of proven effectiveness. Many are in regular use with tour companies and professional performers, or are permanently installed in halls, discotheques and clubs. The use of alternative drive unit brands is not advised, since these have not been subjected to laboratory or field testing in the enclosures described and performance may therefore prove to be unsatisfactory.

FANE is one of the world's foremost producers of chassis loudspeakers and audio components for those who demand the best. Fane have powered bands like **THE WHO, ROLLING STONES, UFO** and **BOOMTOWN RATS**. Fane have equipped the PA for artists such as **STATUS QUO, PINK FLOYD, SANTANA, GEORGE BENSON**, and **DAVID BOWIE.**

FANE have filled venues like the Wembley Arena with brilliance and clarity for many of the world's leading performers. Fane is chosen worldwide to equip sound studios, discotheques, instrument amplification, clubs and theatres. From compact excellence to kilowatt powerhouse there are Fane audio components to create the sound of the superstars from your own skills in cabinet building, if the design advice and recommendations contained in this handbook are carefully followed.

FANE

Towards Perfection

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SYSTEM SELECTION AND DESIGN

The best sound systems are planned. With the increasing sophistication of sound reinforcement and amplification techniques, forethought and planning take on a new significance. System design, speaker enclosure design and selection of the most suitable audio drive components are all factors of vital importance if optimum performance in the intended application is to be obtained. Other important factors to be considered are enclosure size, particularly in relation to the method and quality of bass frequency reproduction, and cost. Sound systems frequently give disappointing results because one or more of the foregoing factors has not been given due consideration in the planning stage.

Often, a compromise is unavoidable. Usually — but not necessarily in **all** circumstances — larger system designs, equipped with the more expensive professional quality drive components, will provide superior quality and higher levels of sound output. But when portability and cost are major design parameters, some degree of compromise is inescapable.

In designing a sound system, certain basic criteria must first be decided;

1. What type of Loudspeaker system should be employed?
2. What kind of programme material or sound source is intended, so that the optimum frequency response characteristics can be established?
3. How important is loudness or sound pressure level?
   Sound pressure level (SPL) is expressed in decibels (dB) and is, for practical purposes, a purely relative measurement useful for comparing the loudness of one audio component or system against another. In such a comparison, a difference of 3 dB would represent a doubling (or halving) of the sound output.
4. What is the area and location of the site?
5. What is the area to be covered by the sound?
6. How much can be spent on the system? The larger and more ambitious, inevitably the more it will cost, although a fundamental guideline in the preparation of this book has been to keep costs to a minimum, where no compromise to the objective acoustic excellence is involved.

The answers to the above questions wil have an important influence upon the type of loudspeaker system employed; its size, the style of the enclosures, and upon selection of audio components.

(1) . . .
The full audio spectrum can be divided into as many as four frequency range bands: Bass/Upper Bass — Low Midrange/Midrange/High. In systems where compactness and portability are prime requirements, it is perfectly possible to adequately cover all four range bands with a single drive unit. Inevitably this is a compromise, since no single drive unit, however well designed, can give optimum results in every one of the different and very individual range bands. However, whilst four-way splitting of the audio spectrum is usually considered to be the ultimate answer, a two-way or three-way division is more common, and both can be regarded as offering the optimum compromise between the various criteria competing for consideration. The low frequency performance and system efficiency requirements will determine the size and type of bass enclosure and bass drive units. Disregarding the esoteric and highly complex theories occasionally employed in the High Fidelity world, the following are the most popular and effective enclosure design principles:

1. Sealed Box (Infinite/Baffle) 2. Tuned Reflex 3. Horn Loaded

The last category incorporates a wide variety of variants including 'W' Bin, Folded Horn and Exponential Horn, all of which exploit acoustic coupling of the front or the rear of the drive unit to the air via a horn, which can be folded and flared in a variety of different ways to enhance projection and low frequency performance.

The upper frequency response limit of the various cabinets/drivers can be determined from the technical specification with each cabinet design to determine crossover frequencies and the number of frequency range bands if required. Furthermore, it is common to employ two or more identical drive units for the same purpose within each range band. The main effects of this are to increase power-handling capacity and sound output level; in a correctly designed enclosure an enhanced bass performance can also result from this practice.

Midrange and High Frequency compression horn drivers should be used as per the specifications of those loudspeaker units. The following Schedule shows how these various forms of enclosure design are commonly applied for the various types of input and programme material. They are shown in approximate order of complexity and performance, with the simplest first;

Bass Guitar —
Small Sealed Box
Larger Sealed Box
Reflex Cabinet
'W' type Bin
2 way system of the above types using passive crossover or Bi-amping
2 way Folded Horn Bin with separate higher frequency cabinet using Passive Crossover or Bi-amping

Full Range —
Monitor, Keyboard, Organ, Disco, etc.
Small Sealed Box, Full Range Driver (with tweeter cone)
Larger Sealed Box, Driver and Small Horn
Relfex Cabinet, Full Range Driver
Larger Reflex Cabinet, Driver and Horn
2 Way Front Exponential Horn or 'W' Bin with Large Horn
3 Way Reflex
Folded Horn Bin with Mid and High Cabinets

Lead Guitar —
Small Sealed Boxes 1 Driver
Larger Sealed Boxes 2 Drivers
Larger Sealed Boxes 4 Drivers

P.A. Systems —
Small Reflex Full Range Driver
Small Reflex Bass Driver and Horns
Large Reflex Bass Driver and Horns
3 Way Reflex Bass Drivers, Mid Drivers and Horns
Folded Horn Bins and Mid/H.F. Boxes
(Short throw 2 x 15″ or 1 x 15″ with angled 2 x 10″ or 2 x 12″ Mid/Horn Box)
(Long throw 1 x 15″ or 1 x 18″ multiples with Front Exponential Bass/Mid Bins Horns with Compression Driver and HF Cabs)
Multiples of Folded Horn Bins with Bass/Mid Cabs/Mid Horns Cabs and H.F. Cabs with electronic crossovers etc.

These categories include a wide variety of special short throw and long throw designs, which can often be seen stacked in multiples at large concerts. It should be noted that enclosures for Tweeters and Compression-drive Midrange units can be designed solely for convenience, since these units are unaffected by enclosure acoustics.

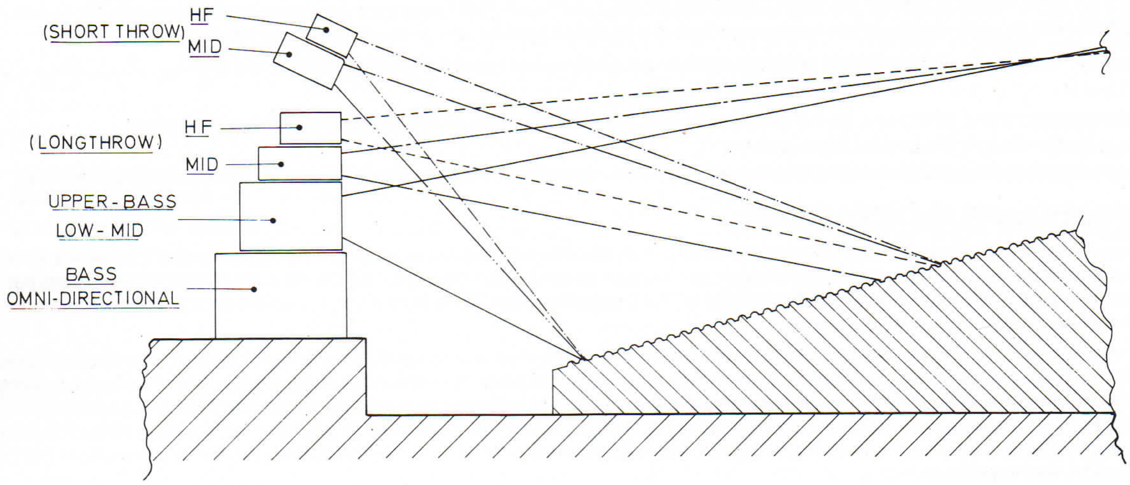
(2) . . .
The frequency range required will be full range, ie. 40Hz to 20kHz apart from Vocal and Musical instrument applications when the range is related to the instrument or equipment. The effective frequency response of each of the designs fitted with the recommended Fane drive units is shown against each constructional Diagram.

(3) . . .
The sound pressure level of each of the designs related to the recommended Fane drive units is shown next to each constructional diagram.
With a multiway system, the sound pressure levels created by each band should be equal, unless a deliberate emphasis in some band is required.

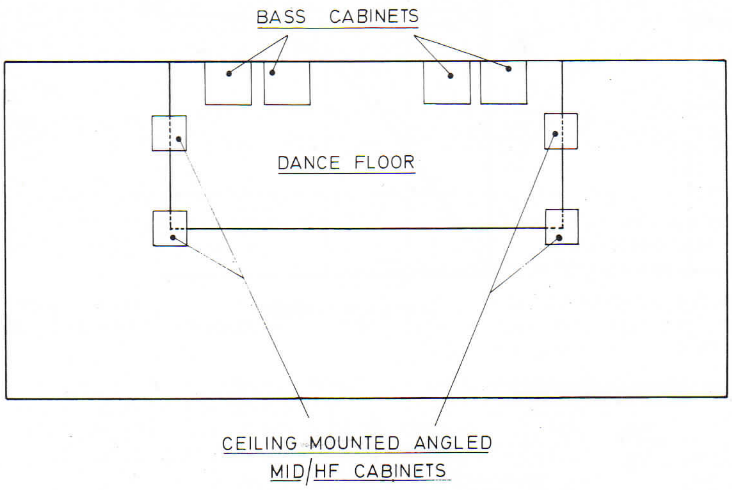
(4) . . .
The site area and location will influence both the size and number of enclosures which can be accommodated within the given area or within the available budget.

(5) . . . Dispersion
One of the major objectives of any sound system or installation should be equal coverage of the entire auditorium or listening area with the full audio spectrum in the correct balance. This is achieved in practice not only with suitable enclosure designs, but also by the placement of the loudspeakers, their directivity, particularly low Midrange, and the use of long throw and short throw cabinets and horns. It is a feature of all transducers that the higher the frequency, the narrower and more directional is the beamwidth of the sound produced. Thus most bass systems have a wide spread of sound, ie. they tend to be omnidirectional up to 500 Hz and their positioning is less critical than that of Midrange and High Frequency sections. When using multiple loudspeaker clusters or stacks, the most effective coverage is achieved by angling the cabinets so that the sides of their dispersion angles (beamwidths) touch each other in both horizontal and vertical planes where applicable.

Schematic example:—

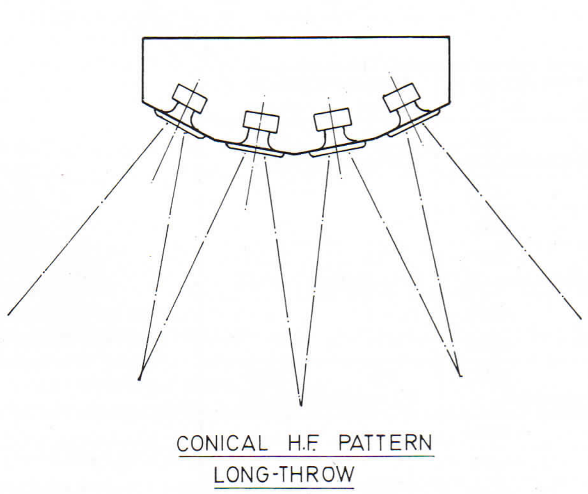


There are many different approaches to achieving full sound dispersion and coverage, but all are based upon the foregoing principles of projection and dispersion, so that the entire auditorium is covered to optimum effect with the resources available. The following is just one example of a suitable layout for one of the most popular kinds of venue, a club or discotheque with a low ceiling:

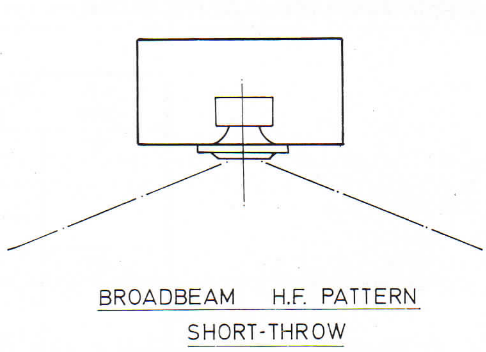


As has been mentioned earlier, High Frequency units (tweeters) are much more directional in their effect than are conventional bass or midrange transducers. This characteristic is most marked in those tweeters featuring a short horn with circular mouth design (eg. most "Bullet" Tweeters). These have good projection, but with a very narrow, conical beamwidth. A dramatic improvement in dispersion is obtained by using a tweeter with its mouth in the form of a slot. The additional beamwidth is gained at the expense of extreme penetration.

HORIZONTAL DISPERSION USING "BULLET" TWEETERS



HORIZONTAL DISPERSION USING "SLOT" TWEETERS



MULTIPLES SHOULD BE STACKED VERTICALLY

The above principles, though in a less marked degree apply, to some types of Midrange Horns.
Careful planning, first resolving the basic criteria requirements, is essential before proceeding to detailed enclosure and component selection.

ENCLOSURE AND DESIGN

An enclosure is a structure which supports the loudspeaker drive units, and in practice the enclosure exerts a considerable influence over the sound of a complete system and will provide designed acoustic properties of dispersion pattern and driver acoustic loading.

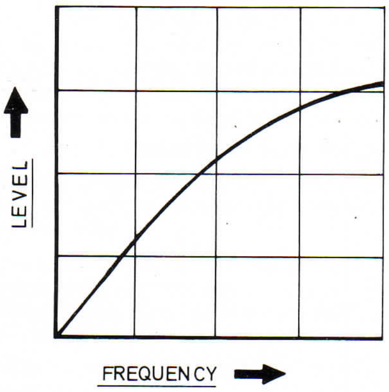
The internal volume of an enclosure is the product of the internal dimensions less the volume of any intrusions within that volume, i.e. bracing struts, horn flares, etc.

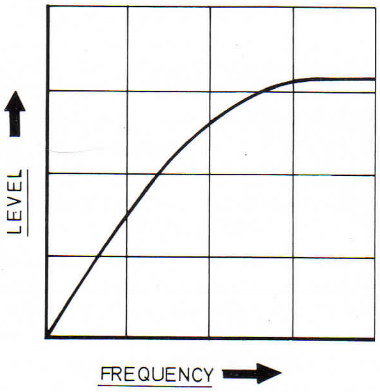
To avoid spurious resonances and refractions, the linear dimensions of the enclosure should not be exact multiples of each other,
e.g. Ratio Height to Width to Depth=2.3 : 1.6 : 1
cabinets containing separate Bass and Midrange Cone Drivers should be internally divided, the above rule being applicable to each section.

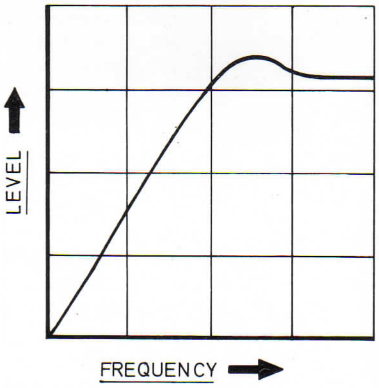
SEALED (INFINITE BAFFLE) ENCLOSURES

Sealed enclosures have the advantage of simplicity of construction. They also have a maximum damping effect on the rear of the speaker cone which, whilst beneficial to the power-handling capability of the loudspeaker, can have an adverse effect both upon the sound output level and deep bass performance. For optimum bass performance, the rule with infinite baffle designs is "the bigger the better". The more compact sealed enclosures are therefore more suited to such applications as lead guitar and vocal reproduction.

Total system damping factor (Q) is a mathematical representation of the bass performance of an enclosure. Within the range of enclosure sizes recommended for each loudspeaker (see table I) the approximate value of Q is indicated, from which the shape and quality of the bass performance can be predicted. The optimum value of Q is normally considered to be 0.707, which produces a level response with extended bass and good transient performance. Values below this figure produce a progressively reduced bass output, though with excellent transient characteristics. Values above 0.707 produce a progressively increasing bass 'hump' at low frequencies but with reduced transient performance, resulting at extremes in a pronounced but 'boomy' bass quality. Diagrammatic representations of Q:







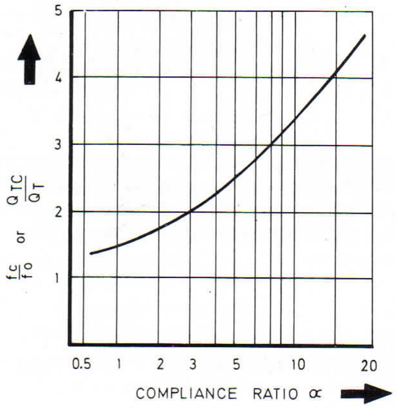
For the technically advanced constructor, Q can be calculated:—

Find compliance ratio = $\frac{V_{AS}}{V_B}$

From Graph determine = $\frac{Q_{TC}}{Q_T}$

∴ QTC = QT x Ratio (from graph)

V_B = Volume Enclosure
V_{AS} = Compliance Equivalent Volume
Q_T = Q Total of Speaker
Q_{TC} = Q of System — Enclosure with Speaker



RECOMMENDED ENCLOSURE SIZES —

L.S. Size	Number of L.S.	Minimum Volume Litres	cu.ins.	Maximum Volume Litres	cu.ins.
10"	1	40	2500	75	4580
		Qs approaching 0.9		Qs approaching 0.7	
	2	65	4000		
	4	100	6000		
12"	1	50	3200	85	5150
		Qs approaching 0.8		Qs approaching 0.65	
	2	70	4300		
	4	135	8300		
15"	1	70	4300	180	11000
		Qs approaching 0.85		Qs approaching 0.6	
	2	115	7100		
	4	230	14200		
18"	1	100	6000	190	11600
		Qs approaching 0.8		Qs approaching 0.6	
	2	196	12000		

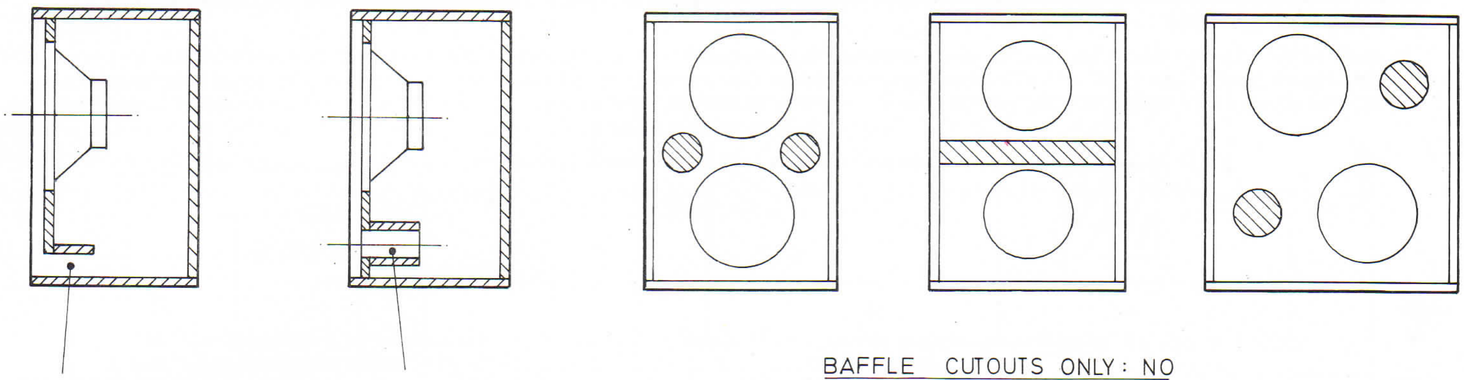
REFLEX ENCLOSURES

Reflex enclosures are basically similar to infinite baffle cabinets, but with the inclusion of an open vent or port. The size of the vent is determined by various technical characteristics of the loudspeaker and the internal volume of the enclosure, and is of critical importance for optimum "tuning" of the system. Reflex designs permit a stronger and more extended bass output from compact enclosures, and are therefore very suitable for discotheque and all Full Range applications. For the technically advanced constructor, the Thiele-Small loudspeaker parameters are included on Fane loudspeaker data sheets, and can be used to calculate and estimate bass performance related to various vented enclosure alignment tables. Useful references:
THIELE; A. N. "Loudspeakers in vented boxes. p.6, 1. Audio Engineering Society Vol. 19 No. 5 (May 1971). KEELE D. B. "Sensitivity of Thiele vented enclosure alignments to parameter variations" Audio Engineering Society Vol. 21 No. 4 (May 1972).

Port area: The total area of the aperture in the cabinet. The aperture may be of any shape, and may be a combination of two or more openings.

Duct depth: Some reflex designs require the vent or port to be extended into the enclosure to form a short tunnel or duct. The depth of this duct is critical to optimum performance, and neither the mouth nor the walls of the duct should be obstructed or lined.

Ports should be located close to the loudspeaker units, and between the speakers where multiples are employed, in accordance with the following examples:



The following reflex porting chart applies to one or more loudspeakers in an enclosure:

Resonance Loudspeaker	ENCLOSURE VOLUME — LITRES AND CUBIC INCHES.								
	42 litres	57	70	85	100	113	142	170	226
	2600 w.ins	3400	4300	5200	6000	6900	8700	10300	13800
30	3.2sq.in. x 4½″	3.2sq.in x 3″	7 x 5¾″	7 x 4½″	7 x 3½″	17 x 9¼″	17 x 6½″	17 x 4¾″	11sq.in.
40	7sq.in x 5½″	7sq.in. x 3½″	17 x 7¾″	17 x 5¾″	17 x 4½″	17 x 3¼″	13	18	28
45	7sq.in. x 3¾″	7sq.in x 2¼″	17 x 5½″	17 x 3¾″	10	13	20	26	43
50	7sq.in. x 2½″	17sq.in. x 5½″	17 x 3½″	13	16	18	29	39	63
55	17sq.in. x 6¼″	17sq.in. x 4¼″	11	15	20	25	37	60	88
60	17sq.in. x 4¾″	11	16	20	28	35	50	75	no port
65	17sq.in. x 3¼″	13	20	27	36	45	70	no port	,,
70	11 sq.in	18	26	35	46	58	90	,,	,,
80	18 sq.in	28	42	60	86	96	no port	,,	,,
90	26 sq.in	42sq.in.	64	90	118	no port	,,	,,	,,

Where the port area only is shown, no duct is required. Where the area times a depth is shown, the depth is that of the necessary duct.
Example showing use of the above chart:
Refer to drawing 12″ Full Range Driver on page 10.
Enclosure volume 21″ x 15″ x 10⅛″ = 3200 cu.ins.
Loudspeaker (eg. Classic 12/80T) resonance = 60 Hz.
Find the column heading most nearly corresponding to the enclosure volume, i.e. 3400 cu.ins. Read down the column to the line corresponding to the required free air resonance of the loudspeaker (shown in the extreme left-hand column) and the correct port dimensions . . . 11 sq.ins. will be seen.
The venting chart above is based upon optimum volumes to give the most extended low frequency response together with good transient performance and subjectively unnoticeable "boom", i.e. where Q is as nearly as possible 0.707 and where the loudspeaker resonance, before porting the enclosure, is 1.5 times the loudspeaker free air resonance. When compared size for size with a sealed enclosure, the half power point (—3 dB) occurs at approximately 0.7 times the sealed cabinet loudspeaker resonance, and gives a frequency extension of approximately one half of an octave.

HORN LOADED ENCLOSURES

THE SPECIALISED DESIGN OF HORN LOADED ENCLOSURES IS MUCH TOO COMPLICATED AND EXTENSIVE TO COVER EVEN BRIEFLY IN THIS BOOK. HOWEVER, SEVERAL OF THE MOST POPULAR CONSTRUCTIONAL DESIGNS HAVE BEEN INCLUDED, FOR BOTH BASS AND UPPER BASS/LOW MIDRANGE USE IN P.A. APPLICATIONS, WHERE HIGH FREQUENCY AND GOOD DIRECTIVITY ARE REQUIRED FOR THE COVERAGE OF LARGE AUDIENCES.

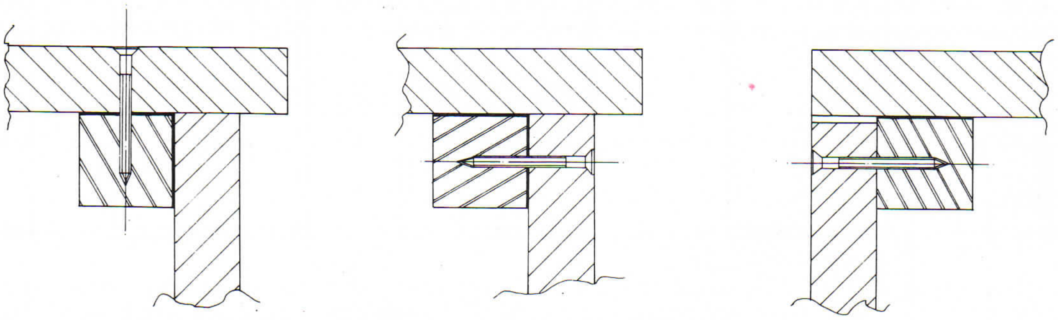
TIMBER

The best material for the construction of loudspeaker enclosures is Birch plywood. Chipboard, or particle board, is a cheaper and widely-used alternative. Whilst chipboard has the merit of being relatively dense, and has an apparently quite hard surface texture, its tensile properties are very poor.
It is therefore susceptible to damage due to misuse or a hard 'life on the road'. Chipboard also has a relatively course surface texture, rendering it difficult to finish neatly and precisely, and making it less suitable for enclosures which are not to be fabric-covered. Chipboard can be made more hard-wearing by the addition of metal "flight-case" type trimming, especially along the edges. Alternatively, a combination of both plywood and chipboard can be employed. For example, an enclosure which is basically built from chipboard may be fitted with a plywood baffle, since the baffle, which carries the drive units and mounting hardware, is the area of the enclosure which bears the greatest work-load. A Bass Bin may be built with plywood outer panels and chipboard inner panels.

As a general rule, it is recommended that small enclosures of 2 cu.ft. (55 litres) or less are constructed from $\frac{5}{8}$'' (15mm) chipboard or $\frac{1}{2}$'' (12mm) plywood; 2 cu.ft. and over from $\frac{3}{4}$'' (18mm) chipboard or $\frac{5}{8}$'' (12mm) plywood.

JOINTS

There is a wide variety of methods for jointing timber, some of which necessitate expensive machinery. Because this is not available to many home constructors, and because the major requirements for speaker enclosure joints are that they be both strong and airtight, only the most straightforward method, the reinforced butt joint, will be described. Although it is omitted from the plans for clarity, it is shown in detail here and may be used for all the designs included in this book:



Versions of the reinforced butt joints shown above may be employed. The reinforcing battens should be 1'' x 1'' (25 mm x 25 mm) planed softwood.
It is important that all surfaces of the joint are liberally coated with a suitable woodworking adhesive, to ensure that joints are both strong and airtight. Screws should be No. 8 or No. 10 countersunk and should be spaced no more than 6'' (15 cm) apart. Screw lengths will be determined by the exact thickness of timber employed.

BRACING

Unbraced cabinets, particularly those with large panel areas, can suffer from panel resonance caused internally by forces generated by the loudspeaker drive unit. Panel resonance is heard as vibration and undesirable colouration of the sound. Internal bracing is therefore recommended. Any suitable stout timber can be used for bracing, including off-cuts from the main panels, in 4'' widths placed on edge and braced between 3 panels e.g. across back, top and bottom. Opening panels should be strengthened with short battens.

In 4 x 12'' enclosure designs, a piece of 3'' x 3'' (75 mm x 75 mm) bracing is additionally recommended from centre front to centre rear. This method of bracing should be used in any enclosure the baffle of which carries heavy drive units or which has been significantly weakened by extensive baffle hole cutting.

The structural rigidity of cabinets will be further increased by the fitting of flight-case type aluminium edging.

SEALING

As has already been mentioned, all joints in cone driven loudspeaker enclosures should be airtight. This applies both to sealed and vented designs. Permanent joints will have been sealed with adhesives. A seal for removable panels can be provided by fitting window sealing foam strip. Chassis loudspeakers are always fitted with a sealing gasket for internal mounting, but such a gasket is not always fitted for front mounting the loudspeaker from the outside. If there is no front mounting gasket on the rear of the speaker flange, it is simple to provide one, again using foam strip.

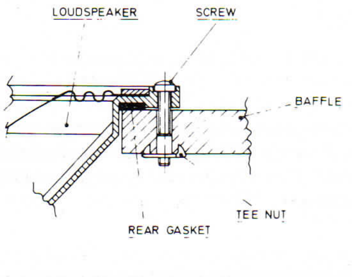
Attention should also be paid to sealing the edges of apertures cut for cabinet handles and electrical connectors. There are many suitable adhesives or sealants available to the home constructor for this purpose.

LOUDSPEAKER FIXING

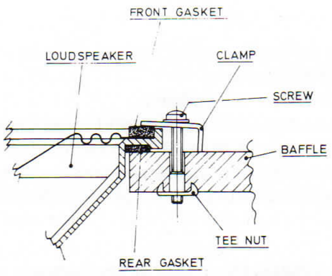
The loudspeaker mounting hole should be cut in the baffle and drilled in accordance with the loudspeaker fixing dimensions or requirements.
This should be performed after the baffle has been cut to size but before the cabinet is assembled.

Most loudspeaker units may be mounted either from the front or the rear. Mounting from the rear is usually accomplished by the use of T-nuts and bolts. Mounting from the front is, however, preferable, since this allows speedy fitting or removal of the loudspeaker, and access to the inside of the enclosure, thus eliminating the need for a removable rear panel. Cabinet construction is therefore stronger. Front mounting is achieved by T-nuts and bolts, either directly through the loudspeaker mounting holes, or fitted on a larger diameter, slightly outside the overall diameter of the loudspeaker chassis, so that the T-nuts can be used to secure special clamps to hold the speaker in place. Holes for T-nuts and bolts should be of small enough gauge for the shank to be a hammer drive fit into the baffle.

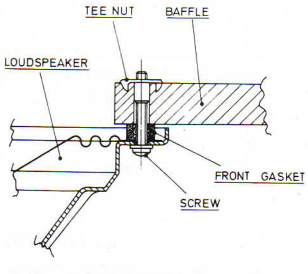
T-Nut assembly:—



FRONT MOUNTED THROUGH CHASSIS



FRONT MOUNTED WITH CLAMPS



REAR MOUNTED THROUGH CHASSIS

Ordinary wood screws are inadequate for this purpose and should never be used to retain loudspeakers.

LINING

An internal lining of acoustically absorbent material is recommended, to both assist in panel damping, and to prevent internal reflections and standing waves. This will be particularly beneficial to Midrange performance. BAF wadding, glassfibre insulation or wool waste ("shoddy") are all good material for this purpose. A thickness of 1″-2″ (2 cm-5 cm) should be attached by means of staples or adhesive to a minimum of three adjacent sides. The flare paths of horns and bins should *not* be lined, and care should be taken to ensure that lining material does not obstruct ports or vents in reflex designs. Tweeter and horn cabinets do not need lining.

LOUDSPEAKER PROTECTION

The frontal area of all exposed chassis loudspeakers is relatively fragile and is extremely vulnerable to physical damage. Some means of protection, which nevertheless remains acoustically transparent, must therefore be provided. Until just recently, the most common method has been the provision of a simple timber sub-frame, over which a layer of Vynaire, Tygan or similar open-weave material is fitted. This sub-frame, or fret, is constructed to exactly cover the entire baffle area, and can be secured in place with wood screws or velcro. Care must be taken to ensure that the material is clear of the maximum forward excursion of the loudspeaker cone.

A more modern alternative method of speaker protection, which is in every respect superior to a cloth covered fret, is to fit a steel mesh grille. These are infinitely stronger than any cloth material, have better acoustic transparency, can be of very attractive appearance, are quicker and easier to fit, and are cheaper, particularly when taking into account the labour involved in making a separate wooden sub-frame. Fane produce a full range of attractive grilles for 10″, 12″, 15″ and 18″ loudspeakers. Grilles are best used in conjunction with the front-mounting clamp method of speaker fixing. However, to special order any Fane model can be supplied with an integral Grille as a factory fitment.

FINISHING

Cabinet finishing is largely a matter of personal preference. Enclosures may be stained or paint finished, or may be covered in one of the many vinyl materials available from specialist suppliers. Extruded aluminium flight-case type edging strip, and metal or heavy duty plastic corner caps, may be fitted to protect the most vulnerable parts of the enclosure. A wide range of carrying handles, which should be fitted in sensible carrying position, castors, which should be out of service when the cabinet is in use and other optional fitments are available from specialist suppliers.

It is important that stacking cabinets have interlocking feet and cups as vibration can cause considerable cabinet movement.

Before finally sealing any loudspeaker enclosure, ensure that the interior is clean and completely free of unwanted objects and materials such as wood chips or metal filings.

ELECTRICAL CONNECTIONS

Internal cabinet wiring should be of either phase-coded twin flex or equivalent single core flex. It should have a resistivity of less than 10 ohms per 100 ft (300 metres).

Internal wiring should be kept well away from the moving parts of fitted loudspeakers, and should ideally be pinned with insulated clips or staples to internal panelling, to avoid buzzing. Crossovers should be fitted to the bottom of cabinets on to foam sealing strips.

No reference is made in the constructional drawings to cabinet connectors. This is because there are several types available from specialist suppliers and the constructor should make a choice to suit his requirements. The best choice for cabinets which are frequently connected and disconnected is self-locking XLR connectors. A lower-cost alternative is ¼″ Jack connectors, which are non-locking and more liable to develop intermittent faults.

When a multiple speaker cabinet or system is assembled, it is important that all the drive units are in the same phase i.e. that all the cones/diaphragms move in the same direction at the same time and not in opposition. All loudspeaker units should have one connector or terminal either colour coded Red or marked with a + sign to indicate the positive terminal. All cabinets in a system and loudspeakers in a cabinet should be wired up so that all the positive connections relate back to the input positive terminal (See also diagrams under 'impedance Matching').

Phasing can be checked by applying the positive terminal of a 4½ volt battery to the positive loudspeaker input and studying the resultant cone movement. If any cone moves in opposition to the others it is out of phase, and its connections should be reversed.

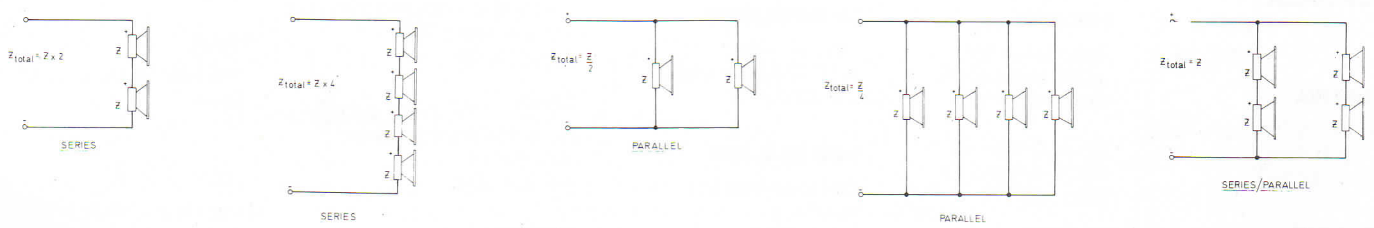
IMPEDANCE MATCHING

Amplifiers are designed to work into a specified resistive load, commonly 4, 8 or 16 ohms, and optimum system performance will be obtained if the total resistive load (or impedance) of the loudspeaker or multiple loudspeakers is exactly correct for the amplifier. If it is not, a miss-match occurs. If the total loudspeaker impedance is too high, the power delivered to the loudspeakers will be reduced. If the total loudspeaker impedance is too low, the power delivered to the loudspeakers will be increased, which can result both in speaker overload and damage to the amplifier.

Any number of loudspeakers or systems can be connected to one amplifier provided that they are correctly wired so that the final impedance presented to the amplifier is an exact match. Multiples of loudspeakers can be connected together by three different methods, known as Series, Parallel, and a combination of the two, Series/Parallel. Impedance (Z) is calculated by using the following formulae:—

For Series connection $Z_{total} = Z1 + Z2 + Z3$ **etc** **For Parallel connection** $\frac{1}{Z\ Total} = \frac{1}{Z1} + \frac{1}{Z2} + \frac{1}{Z3}$ **etc.**

EXAMPLES:—



Z = EQUALS IMPEDANCE IN OHMS

For combined Series/Parallel, calculate the impedance of each similarly placed group of loudspeakers and regard the total impedance as being that of a single loudspeaker with a single impedance and calculate the total combined impedance using the above formulae.

In multiway systems using passive crossovers, it is important that each separate section (or bandwidth) of the system should present the same impedance e.g. in a system of 8 ohms total impedance, it is important that each of the three divided sections — Bass, Midrange and treble — should individually have an impedance of 8 ohms. If each individual section comprises more than one drive unit, the drive units in that section must be connected to present a total section impedance of 8 ohms. There is, however, an exception to this rule, in respect of the treble section only. At frequencies above 3 kHz it is permissible for the treble section to present a higher (but never lower) impedance than the other sections. The effect of a higher treble impedance is a decrease in sound output level but an increase in power handling capability, proportional to the mis-match ratio. If a 16 ohm Tweeter were to be fitted in the 8 ohm system described above, the power handling capability of the treble section would therefore be increased by a factor of 2.

When wiring loudspeakers, and in particular when connecting and positioning multiples of loudspeaker systems, it is important to keep cable length to a minimum, since excessive runs of cable can result in a significant power loss and reduction in sound output. i.e. for only a 0.1 dB loss in sound pressure level the total wire impedance calculated from the resistivity or ohms per unit length value must be limited to 1% of the loudspeaker impedance; 6% is 0.5 dB loss and 12% is 1 dB loss.

CROSSOVERS

A crossover network is a device which divides the full frequency range electrical signals into the appropriate sections or bandwidths to be delivered to loudspeakers which are to cover a specialised bandwidth in a multi-way system. By so doing, a crossover network serves two important functions:—

1. It allows optimum system sound quality by ensuring that each loudspeaker only operates within its intended bandwidth.
2. It prevents damage which would otherwise be caused by low frequencies being fed to Midrange and High Frequency Drivers.

The degree by which a crossover network reduces the unwanted input above or below the specified frequency is known as the 'slope' and is expressed by the number of decibels (dB) by which the signal is reduced for each octave.
The minimum slope normally employed is 12 dB per octave, which is suitable for most normal requirements. However, some Midrange Drivers and High Frequency units require a slope of 18 dB per octave and for such devices it is *most important* to ensure that a crossover of correct specification is employed.

There are two basic types of crossover:

Passive — A network of components needing no external power supply. Connected between the amplifier and the loudspeaker, and normally located within the loudspeaker enclosure.

Active — An electronic device which is connected between the pre-amplifier or mixer and one or more amplifiers. The frequency spectrum is thus divided before it is amplified, and each loudspeaker is fed with its 'tailored' bandwidth by its own amplifier channel.

In sound systems where less than 500 watts per crossover network is employed, the acceptable performance and economy of a passive crossover is normally preferred. For larger and more ambitious sound systems active crossovers are advisable, since a single active crossover can drive a multitude of amplifiers. Moreover, active crossovers normally incorporate a range of adjustment which is very useful for optimising on-site performance where a large number of Bass, Midrange and Treble systems are in operation.

The design of passive crossovers requires the use of testing equipment not readily available to the home constructor, and so Fane have adopted a policy of designing crossovers performance-optimised to suit each of the matching cobinations of our products as required.

Crossover frequency points are to some extent influenced by the enclosure design, but are mainly determined by the specification and characteristics of the loudspeaker units employed. Usual crossover frequency ranges for the various system configurations are as follows:

		Usual crossover range
2-way Systems	Bass to treble	3 kHz-5 kHz
3-way Systems	Bass to mid	500 Hz-1.5 kHz
	Mid to treble	3 kHz-5 kHz
4-way Systems	Bass to low mid	200 Hz-400 Hz
	Low mid to mid	800 Hz-1.5 kHz
	Mid to treble	3 kHz-5 kHz
Super tweeter		5 kHz-10 kHz

When using passive crossover networks, the power proportion to each bandwidth varies in accordance with the crossover frequency, as illustrated by the following examples:

Crossover frequency	*% Power to bass unit*	*% Power to upper units*
250 Hz	40	60
500 Hz	60	40
1.2 kHz	65	35
3 kHz	85	15
5 kHz	90	10

The above figures relate to normal programme material. However, certain instruments, e.g. synthesizers, have a greater than normal high frequency content, which can increase the power distribution to the upper frequency bandwidth by up to 50%.
In multiway systems, to correct any imbalance in the relative loudness of Midrange or High Frequency sections, the Drivers or Tweeters concerned may be fitted with constant impedance attenuators for adjustment of output level.
When using electronic crossovers with variable crossover frequencies and power distributions, it is important to ensure that crossover point and power or level settings are adjusted in accordance with the specification of the loudspeakers concerned, to avoid the possibility of overload.

CABINET BUILDING COMPONENTS AND MATERIALS

Suitable materials, accessories and loudspeakers to construct the systems described in this handbook can be obtained from the following suppliers:

UNITED KINGDOM
Audio Factors Limited,
Leeds LS28 9HY.
Tel: 0532-561949

AUSTRALIA

AUSTRIA
Bourke & Dissertori GmbH
A-4600 Wels.
Tel: 72427147

BELGIUM
Flitecar PVBA,
2578 Koningshooikt (Lier),
Tel: 34823583

CANADA
Belisle Acoustics Inc.,
Mercier (Quebec), JOL 1KO
Tel:5146912584

DENMARK
Storm Power Sound APS,
Sundtoldvej 8B,
3000 Helsingor
Tel:2211666

EIRE
Pat Dolan Amplification,
Dublin 9
Tel: 319273

FINLAND
Radio Mikro OY,
00390 Helsinki 39,
Telex: 122840

MS Audiotron KY
00420 Helsinki 42
Telex: 125778

FRANCE
Fane France,
Division De Camac S.A.,
BP21 44850 Mouzeil
Tel: 40977338
Telex: 700609 Camac F

GERMANY (WEST)
Adam Hall GmbH,
6390 Usingen 1,
Tel: 608116031

INDONESIA
P.T. Gunter Antarnusa,
Jakarta 11001,
Telex:46747

ITALY
Outline,
25100 Brescia,
Tel: 30222073

NETHERLANDS
Fane Holland,
1171 JV Badhoevedorp,
Tel: 29687777

NEW ZEALAND
Clef Industries Ltd.,
Auckland
Telex: 21055

NORWAY
Sound House Musik. Engros,
1067 Oslo
Telex: 2322040

PORTUGAL
Acustica,
4440 Valongo.
Telex 27850

SINGAPORE
Bell & Order Eng. Pte Ltd.
37, Genting Lane, 05—04
Perfect Industrial Building,
Singapore 1334
Tel: 7438081
Telex: RS37328 Beller

SOUTH AFRICA
A1 Radio Services (Pty)Ltd.,
Durban 4000
Tel: 31373657656

Wild & Marr (Holdings)(Pty) Ltd.,
Johannesburg 2001.
Tel: 11292391

SPAIN
Dinax Electronics S.A.
Barcelona 4
Tel: 32411006

SWEDEN
Hi Fi Kit Electronic AB,
104 35 Stockholm.
Tel: 8333354

Radax Electronics
112 46 Stockholm
Tel: 8528450

SWITZERLAND
Sacher Music,
CH 4051 Basel.
Tel: 61383908

TAIWAN
Alimko Industrial Associates Inc.
Taichung.
Telex: 57113

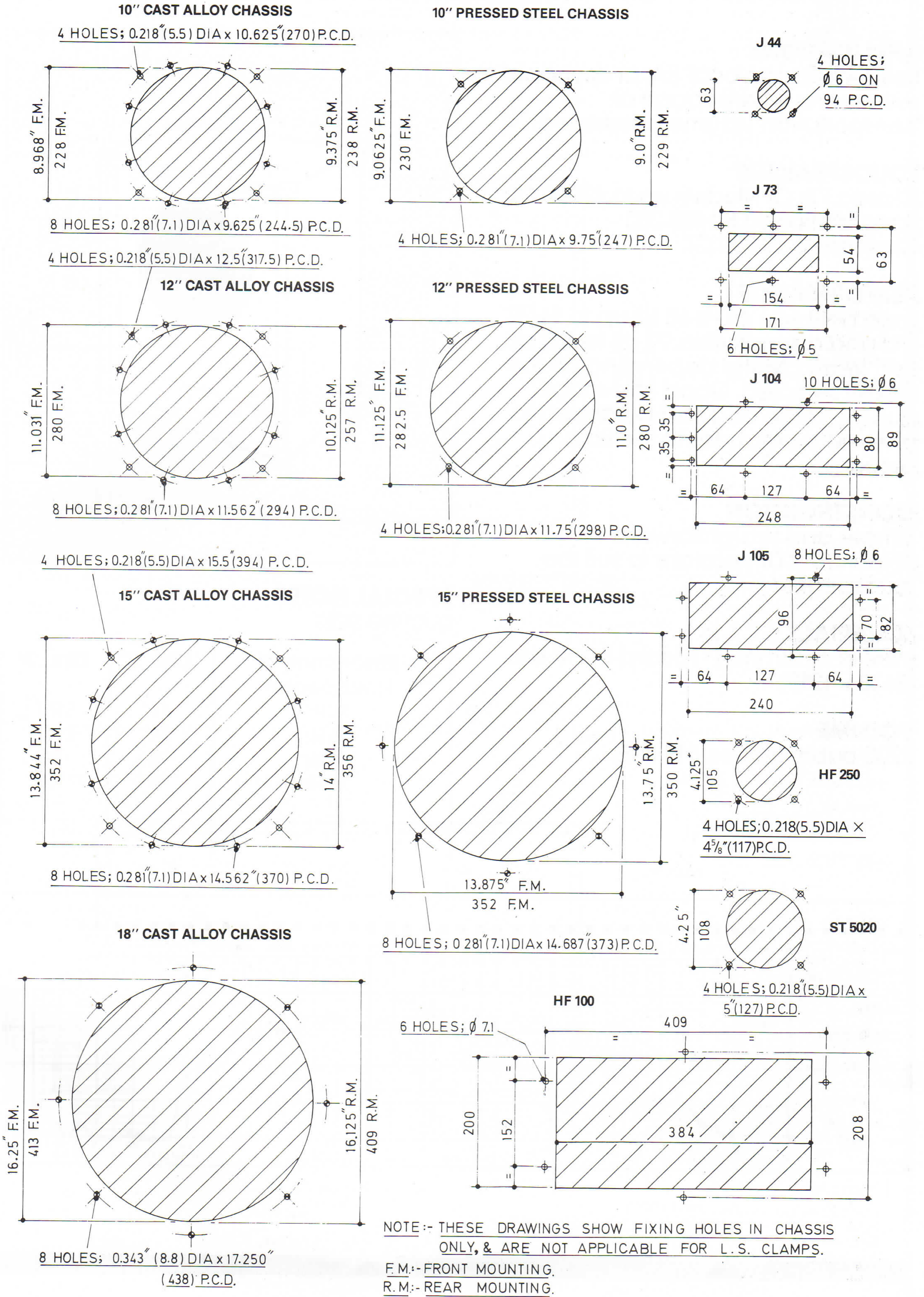
THAILAND
Kit Chareon Machine Tool
& Musical Ltd., Part.,
Bangkok 10200.
Telex: 84486

U.S.A.
International Music Corp.,
Texas 76113, U.S.A.
Tel: 73365114

WEST INDIES
The Music Centre,
St. Vincent.

MOUNTING HOLE CUT-OUT DATA

CHASSIS TYPE CAN BE DETERMINED FROM THE FANE MODEL DATA SHEETS



NOTE:- THESE DRAWINGS SHOW FIXING HOLES IN CHASSIS ONLY, & ARE NOT APPLICABLE FOR L.S. CLAMPS.

F.M.:- FRONT MOUNTING.

R.M.:- REAR MOUNTING.