1st BOOK OF HI-FI LOUDSPEAKER ENCLOSURES

BY BERNARD B. BABANI

26 practical designs
with 40 Drawings:
Corner Reflex, Bass-Reflex,
... Horn, Folded Horn,
... Klipschorn Labyrinth,
... Tuned Column,
... Multispeaker
... etc.

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BY

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CONTENTS

FOR READERS WHO ARE MORE USED TO THE METRIC SYSTEM, THE FOLLOWING EQUIVALENTS WILL ENABLE THEM TO CALCULATE ANY OF THE DIMENSIONS SHOWN IN THIS BOOK :-

1"	=	25.4 mm
1 sq. inch	=	645 sq. mm
100 cu. inches	=	1639 millilitres
1000 cu. inches	=	16.39 litres
1 cubic foot	=	28.32 litres

If readers experience any difficulty in obtaining the components or speakers mentioned in the text of this book, they should be guided by their Radio Parts Dealer who will recommend the best make to use as an alternative.

Certain portions of this book were previously published in the book entitled "High Fidelity Loudspeaker Enclosures" by B. B. Babani. This book is now out of print.

HIGH FIDELITY LOUDSPEAKER ENCLOSURES

With the tremendous interest in High Fidelity, it is obvious that there is a need for a comprehensive handbook with practical plans relating to loudspeaker enclosure construction.
Suitable enclosure design for High Fidelity reproduction has always been an art combined with a certain amount of science and loudspeaker manufacturers usually make available one or two suggested enclosure designs. However, there has not been any book available offering such a wide choice as the present volume.

The author would especially like to thank the following U.S.A. companies for making available their suggested designs enabling him to present a range of models from the simplest and smallest to complicated multi-speaker enclosures, suitable for large halls.
One reason for selecting American Designs is because the major loud-speaker factories and acoustical laboratories in the U.S.A. spend a very much larger proportion of their budget in research in this field than is the case in this country:-

ALTEC. LANSING CORP
ELECTRO-VOICE INCORP.
GENERAL ELECTRIC CO
JENSON MANUFACTURING CO.
KLIPSCH AND ASSOCIATES
JAMES B. LANSING SOUND INC.
RACON ELECTRIC CO INC.
STROMBERG-CARLSON CO.
UNIVERSITY LOUDSPEAKER INC.
UNITED SPEAKER SYSTEMS

CLASSES OF ENCLOSURE

The loudspeaker unit itself is one of the most important links in any High Fidelity chain, but without a suitable enclosure there is no point in installing a high grade unit because without this vital ancillary the loudspeaker is incapable of proper reproduction.
There are many classes of enclosure, of these the most important are the horn, and the direct radiator. Naturally, there are many variations of both of these and plans of an extensive range of both types has been included.
With the horn system, the speaker diaphragm is linked to the air via an impedance structure, i.e. the horn itself. Whereas with direct radiators the speaker diaphragm itself is directly coupled to the air without an intermediate step. Horn enclosures are capable of superb reproduction, but to get a full frequency range, a very large structure is necessary. This makes them much more expensive than the direct radiator, which can itself, prove to be a very effective design. They reproduce at nearly as high an efficiency and with practically as wide a frequency range as the horn enclosure with the advantage of much lower cost and more important still, much more compact and presentable form.

Correctly designed horn radiators produce no transient generation over a very wide frequency range, resulting in much higher acoustical efficiency than is possible with a direct radiator. In other words, a comparatively low power is required to feed a horn radiator compared to a direct radiator working at the same acoustical level. However, by careful design direct radiator enclosures can be made free of transient generation. An important feature of the horn radiator is the low distortion factor due to the low power required to load it effectively. Amplifier distortion is likely to be less at a low power level. However, to offset these advantages, the horn enclosure demands much more critical construction than the direct radiator and if required to cover the lowest audible frequencies their physical size tends to become unrealistic. The horn reproducer is used mainly in theatres and large auditorium installations, where its large size is of no consequence.

Direct radiator enclosures are available in various form such as the infinite baffle, folded baffle, flat baffle, base reflex or labyrinth. Horn enclosures are also found in various forms such as the straight horn, single and double folded horn. Klipsch horn, multicellular horn, etc.

It is possible to utilise combinations of both types of enclosure, such as a direct radiating high-frequency and mid-frequency speaker combined with a rear folded horn radiator operating from the back of the speaker to make the most of the low frequencies.

This book covers both of these principle types, together with as many variations as possible. No special recommendation can be given for using any special design in preference to another.

Reproduction of sound is very similar to the enjoyment of food, that which suits one listener's ear may not please another persons hearing. However, each of the designs included in this book have been tried either by the author and his friends, or by various research institutes and loudspeaker manufacturers, in every case results have given satisfaction to the majority.

It is pointed out at this juncture that most of the designs described are patented and it must therefore be clearly understood that because a design is shown in this book it does not imply a licence to manufacture for re-sale. Single hand made copies of the suggested enclosures should not, in the opinion of the author, contravene any patent granted to the original designer.

Much of enclosure design is based on complicated mathematical formulae. Because the average constructor has no desire to be taught or reminded of advanced mathematics, the technical reasoning why various dimensions are chosen has been omitted as this is better explained in the learned works available in the field of acoustical engineering.

Bass-reflex enclosures are amongst the most popular types used for High Fidelity reproduction. The critical factors of this design are the port or air gap calculation and the overall enclosure dimensions. These measurements are controlled by a number of factors, the most important are the resonant frequency of the loudspeaker and the physical area of its cone. These standard factors result from the original work of Helmholtz, etc. and to save readers extensive calculation, a number of tables have been included showing the port size and length of tunnel dimensions, for a range of loudspeaker sizes with various resonant frequencies. Ideally the proportions of a bass-reflex should be in the ratio of 2 : 3 : 4 with respect to depth, width and height, two extensive tables covering this data are included. It is strongly urged that after constructing any bass reflex enclosure it should be carefully tuned to the speaker or speakers fitted. Tuning means making the port larger or smaller to cope with individual loudspeaker variations. This can be easily effected by means of temporary sliding doors on the ports to permit experimental variation of their physical size. See section on tuning.

TABLES

Table A, gives the required dimensions in the ratio of 2 : 3 : 4 that will be needed to construct an enclosure with a volume of any desired number of cubic feet Table B, is similar to Table A except that the required volume is shown in cubic inches

Table C, D, E and F are to enable the reader to assess the cubic capacity required for an enclosure depending on the resonant frequency of the speaker to be used. At the same time, the actual port area and port depth or tunnel length is shown. These four tables cover 10, 12, 15 and 18" loudspeakers.

Further information on using these tables is given in the section headed USING TABLES A - F.

Many of the designs in this book use more than one speaker, this is because even the most perfect loudspeaker can produce only a limited range of frequencies. High Fidelity reproduction over the useful audible frequency range, i.e. from 30 cps. to 17,500 cps., require a combination of two or more loudspeakers. A bass unit covers the low frequency band, i.e. 30 cps to 5,000 cps and a high-frequency tweeter to reproduce 5,000 cps upwards. Sometimes the audible range is split up between three speakers. In this case, a medium size loudspeaker is used in addition to give brilliance to the middle register say from 1,000 to 5,000 cps.

When selecting a loudspeaker, particular attention should be given to the size and weight of the magnet used. A large heavy magnet is necessary for high acoustical efficiency. Readers should not be misled by advertisement claims of very high gauss, unless combined with very heavy magnet weight i.e. in the case of a 12" speaker a recommended minimum weight of at least 48 ozs of magnet is suggested. Checking this point is especially important as many manufacturers simply give the magnetic flux density, but do not state the actual weight of magnet used in the speaker. This is often as low as 4 to 5 ozs. 8" speakers require a minimum magnet weight of 16 ozs., tweeters of 2" to 4" diameters, 4 ozs.

Timber choice is left to the constructor, however, a thickness less than that recommended should not be considered. Experience has proved that high grade bonded ply is one of the best types of material available because it does not suffer from distortion or warping and is usually well seasoned before delivery to wood merchants. Much experimenting can be carried out to improve the response and to eliminate transients on bass-reflex or direct radiation enclosures with damping materials, such as fibre glass, thick felt, blanketing etc.

Fig. 1. For the first time a practical spherical tweeter reproducer is shown. A working model of this assembly was demonstrated at the Hanover Fair in 1956 and aroused considerable interest. Since then, descriptions have appeared in German and French radio publications. Twelve tweeters are used and sound dispersion is completely omni-directional. The finished appearance is rather similar to a sphere of 14" dia. Mounting can be effected in a number of ways, either on a lamp standard, so that it is placed above the main middle and bass enclosure or alternatively, particularly effective results are achieved if the unit is suspended from the ceiling, as though it were a pendant lamp.

TABLE "A"

DIMENSIONS IN INCHES TO GIVE

REQUIRED ENCLOSURE VOLUME IN CUBIC FEET.

					depth		width		height
1 cu. ft.	=	1728 cu. in.		=	8¼	×	12¼	×	16½
2 "	=	3456	"	=	10½	×	15¾	×	21
3 "	=	5184	"	=	12	×	18	×	24
4 "	=	6912	"	=	13¼	×	20	×	26
5 "	=	8640	"	=	14¼	×	21¼	×	28½
6 "	=	10368	"	=	15	×	22½	×	30½
7 "	=	12096	"	=	16	×	23¾	×	32
8 "	=	13824	"	=	16½	×	25	×	33
9 "	=	15552	"	=	17½	×	26	×	34¼
10 "	=	17280	"	=	18	×	26¾	×	35¾
12 "	=	20736	"	=	19	×	28½	×	38
14 "	=	24192	"	=	20	×	30	×	40
16 "	=	27648	"	=	21	×	31¼	×	41¾
18 "	=	31104	"	=	21¾	×	32¾	×	43½
20 "	=	34560	"	=	22¼	×	34	×	45
25 "	=	43200	"	=	24¼	×	36½	×	48½
30 "	=	51840	"	=	25½	×	37¾	×	50¼
35 "	=	60480	"	=	27¼	×	40¾	×	54½
40 "	=	69120	"	=	28¼	×	42½	×	57
50 "	=	86400	"	=	30¼	×	46	×	61
60 "	=	103680	"	=	32¼	×	49	×	65
70 "	=	120960	"	=	34½	×	51¼	×	68¼
80 "	=	138240	"	=	35¾	×	53¾	×	71¼
90 "	=	155520	"	=	37½	×	55¾	×	74¼
100 "	=	172800	"	=	38½	×	58	×	77

TABLE "B"

DIMENSIONS IN INCHES TO GIVE

REQUIRED ENCLOSURE VOLUME IN CUBIC INCHES.

Volume		depth		width		height
500 cu. ins.	=	5½	×	8¾	×	11
1,000 "	=	7	×	10½	×	13¾
2,000 "	=	8¾	×	13¼	×	17¼
2,500 "	=	9½	×	14	×	18¾
3,000 "	=	10	×	15	×	20
3,500 "	=	10½	×	15¾	×	21
4,000 "	=	11	×	16¼	×	22
5,000 "	=	11⅞	×	17¾	×	23½
6,000 "	=	12¼	×	19	×	25
7,000 "	=	13¼	×	19⅞	×	26¼
8,000 "	=	14	×	20¾	×	27¾
9,000 "	=	14½	×	21½	×	28¾

Volume		depth		width		height
10,000 *cu. ins.*	=	15	×	22½	×	29¾
12,500 "	=	16	×	24	×	32⅛
15,000 "	=	17	×	25½	×	34
17,500 "	=	18	×	27	×	36
20,000 "	=	18⅞	×	28⅛	×	37½
22,500 "	=	19¼	×	29¼	×	39
25,000 "	=	20¼	×	30¼	×	40½
27,500 "	=	21	×	31¾	×	41¾
30,000 "	=	21½	×	32¼	×	43
35,000 "	=	22¾	×	34	×	45½
40,000 "	=	23½	×	35½	×	47¾

VOLUME OF CABINET IN THOUSANDS OF CU. INCHES.

Duct or Port Tunnel

Length in Inches

Speaker Resonant Frequency	2	2.5	3	3.5	4	5	6	7	8	9	10	15	20	30	40
20													24.0	13.0	8.0
25												20.0	12.5	6.0	2.5
30												11.5	6.5	1.5	
35											13.5	6.0	2.75		
40									13.0	10.5	8.5	3.5	0.75		
45								11.0	8.5	6.5	5.0	1.0			
50						15.5	10.5	7.25	5.5	4.0	3.0				
55						10.75	7.0	4.75	3.25	2.0	1.0				
60					12.0	7.25	4.5	2.75	1.5	0.5					
65					9.0	5.0	2.75	1.25							
70				8.5	6.25	3.25	1.5								
75			10.0	6.5	4.25	1.75									
80		12.0	7.0	4.5	3.0	0.75									
85		9.0	5.0	2.75	1.5										
90		6.5	3.75	1.5	0.5										
95	11.0	4.5	2.0	0.75											
100	7.5	3.0	1.0												

TABLE "C"

10" Loudspeaker

Port Area 50 sq. inches

VOLUME OF CABINET IN THOUSANDS OF CU. INCHES.

Speaker Resonant Frequency	3	3.5	4	4.5	5	5.5	6	7	8	9	10	15	20	25	30	40
20															24.0	15.0
25														16.0	11.5	6.5
30													12.5	8.0	5.5	1.75
35												13.0	6.5	3.5	1.5	
40											18.0	7.5	3.5	0.75		
45									20.0	14.5	11.5	4.0	0.75			
50								18.0	13.0	9.5	7.0	1.25				
55							17.0	11.25	8.0	5.5	4.0					
60						14.5	11.25	7.25	4.75	3.0	1.75					
65					13.5	9.5	7.25	4.5	2.75	1.25						
70				13.0	9.0	6.5	4.75	2.75	1.0							
75			13.5	8.5	5.5	4.0	3.0	1.0								
80			9.0	5.5	3.5	2.0	1.0									
85		11.0	6.0	3.75	2.0	0.75										
90		7.0	4.0	2.0	0.75											
95	9.0	4.5	2.0	0.75												
100	6.0	2.5	0.5													

Duct or Port Tunnel

Length in Inches

TABLE "D"

12" Loudspeaker

Port Area 78 sq. inches

VOLUME OF CABINET IN THOUSANDS OF CU. INCHES.

Speaker Resonant Frequency	4.5	5	6	7	8	9	10	15	20	25	30	35	40	50	60	70
20														22.0	15.5	11.0
25											26.0	17.0	14.5	9.0	5.5	3.0
30										19.5	13.0	9.5	6.5	3.0	0.5	
35									17.0	10.0	6.5	3.75	1.75			
40								20.0	9.5	5.0	2.0					
45								11.5	5.0	1.25						
50								7.0	1.75							
55							14.0	3.25								
60						12.0	8.5	0.5								
65					12.0	7.5	5.0									
70				13.0	7.0	4.0	2.0									
75				7.0	3.75	1.75										
80			9.0	3.75	1.25											
85			5.0	1.75												
90		9.0	2.5													
95		5.0	0.75													
100	5.5	2.0														

Duct or Port Tunnel

Length in Inches

TABLE "E"

15" Loudspeaker

Port Area 133 sq. inches

VOLUME OF CABINET IN THOUSANDS OF CU. INCHES.

Speaker Resonant Frequency	6	7	8	9	10	15	20	25	30	35	40	50	60	70	80	90
20														22.0	16.0	12.5
25												19.0	12.5	8.5	5.5	3.0
30											15.0	8.0	4.25	1.5		
35								24.0	15.0	9.5	6.0	1.75				
40								12.5	7.0	3.5	2.0					
45							13.0	5.5	2.0							
50						21.0	7.0	2.0								
55						10.0	2.0									
60						5.0										
65						1.5										
70					11.0											
75				11.0	5.0											
80				5.0	1.75											
85			5.0	1.25												
90		7.5	1.0													
95		2.0														
100	6.0															

Duct or Port Tunnel

Length in Inches

TABLE "F"

18" Loudspeaker

Port Area 200 sq. inches

Wood used for the original model was ½" ply and all 12 pentagons fixed together internally in the form of a sphere by using inexpensive miniature hinges, thus making a most effective unit with a minimum of labour and at low cost. See Page 40 to 42
It is very important that the impedance combination be calculated to suit the impedance offered at the output of the amplifier. A series-parallel arrangement is necessary.

Fig. 2. Particularly recommended for superior performance where 12" or 15" bass speakers are used and is a combination of bass-reflex with all the assets of a horn reproducer combined. Constructional details are clearly shown, of special interest is the pyramid reflector in the bottom portion of the unit, which provides perfect diffusion. See Page 43 to 45

Fig. 3 Recommended where overall size is an important factor as with the modern living room. It is a true example of the tuned port bass reflex cabinet, and should be built of seasoned timber, minimum thickness 7/8". Alternatively, good quality ply of similar thickness can be used. The base legs can be made to suit individual tastes.
Height from the floor should be approximately 3". Originally this enclosure was constructed for use with a 12" speaker, but with the changes in the port size it is also suitable for speakers of 10" or 15" diameter. See Page 46

Dimension A = 13" x 2" for 10" loudspeakers
Dimension A = 13" x 3" for 12" loudspeakers
Dimension A = 13" x 5¼" for 15" loudspeakers
Dimension B = Cut to suit speaker size
Dimension C = Is obtained by reference to depth of port tables on Page - according to speaker size. This dimension is also dependent on the fundamental resonance of the speaker used and the tables cover this requirement.

Fig. 4. The "Library Enclosure". This is an efficient tuned port bass-reflex enclosure of high quality. It is designed for use with a good quality 8" loudspeaker, resonance about 75 cycles. From the dimensions of this enclosure it will be seen that it has been specially designed to fit into book selves without being obtrusive. See Page 47
It is very simple to construct, but essential that all timber used should be a minimum thickness of ¾". Relevant dimensions are clearly shown on the diagram. Particular care in fitting should be taken with the back, top, sides and front which should be made as airtight as possible.

Fig. 5. This miniature horn loaded reflex enclosure is eminently suitable for small installations where space is limited. Genuine High Fidelity is satisfactorily achieved using a loudspeaker of 8" diameter. Due to the unique horn loading and the tuned port, reproduction from this enclosure will delight the most critical listener. Because of the small physical size, it is stressed that the minimum thickness should be ¾" for all timber used for this model. See Page 48 to 49

Fig. 6. The 12" Minihorn. A horn radiating unit which eliminates any tendency to transient generation, it has very extended frequency range and high acoustical efficiency. The major asset is that the minimum quantity of timber is used in construction because two walls of the room are used to form the major sides of the horn itself.

Particular care must be taken when building this enclosure to see that the top is exactly 90° or $\frac{1}{4}$ circle in order to fit into the room walls. It is suggested, that to obtain optimum results, faces "B" and "C" should have a small strip of felt attached to form an air seal. Because of the high acoustical efficiency a 10" speaker is quite suitable, though a 12" unit can be used by increasing the size of the aperture. Other dimensions remain as shown in the diagram. Timber used for this enclosure to be of minimum thickness of 1" because the frequency range is extended down to 30 cycles. See Page 50 to 51

Fig. 7. Here is one of the most popular types of enclosure. Originally designed by John E. Karlson (recognised to be a leading authority in this field). Results from the Karlson enclosure undoubtedly exceed the expectations of the most severe critic and fully warrant the considerable amount of time taken up in construction. See Page 52 to 54
Timber must have a minimum thickness of 1", the only critical items are the twin taper front pieces, which are mathematically calculated and these dimensions must be maintained within $\pm$ 1/32 inch. To aid construction the curved shape of these pieces is carefully dimensioned, in Fig. 7a. It is suggested that a full size paper pattern be made from the diagram and two pieces of wood cut at the same time thus ensuring that both pieces are identical.
Fig. 8. This enclosure was designed by the Altec Lansing Corporation of America and included many of the best techniques for a semi-folded horn, using tuned ports and a flaired neck. It is a large enclosure intended for use in small halls, auditoriums or very large rooms. When used with a 15" speaker as recommended, High Fidelity reproduction down to 20 cycles may be achieved. All panelling to be of a minimum of 5/8" thickness, unless otherwise shown, and all joints must be glued and screwed unless required to be removable. See Page 55 to 57
7½" x 16" fibre glass, 1" thick, should be placed on the inside of each side panel, on the inside of the top of the cabinet and at the rear of the speaker. This is where the 16" dimension is shown in section B-B. A dynamic high-frequency tweeter should be used with this enclosure in a separate mounting so that full range response may be effected.

Fig. 9. The Infinite Wall Baffle. A unique design having the great advantage of taking up no valuable space in the modern small living room, because in use it is suspended from the picture rail in a right-angled corner of the walls.
Where a di-axial speaker is used, omit opening G, as the tweeters are mounted on a bridge across the front of the main speaker. With ordinary 12" bass speakers it is essential that two tweeters be fitted as per dimension K. See Page 58
The following table of dimensions is included to enable constructors to build the Infinite Wall Baffle using either 8", 12" or 15" speakers:-

Speaker Dimensions	8"	12"	15"
"A"	25"	35"	43"
"B"	12"	17"	21"
"C"	27"	40"	50"
"D"	6¼"	8 7/16"	10 5/8"
"E"	5 13/16"	8½"	11"
"F"	7¼"	10 7/8"	13 5/8"

Speaker Dimensions	8"	12"	15"
"G"	2 1/8"	2 1/8"	2 1/8"
"H"	¾"	1"	1¼"
"J"	1¾"	1¾"	1¾"
"K"	-	6"	7½"
"L"	11¼"	16¼"	20¼"
"M"	8"	11½"	14 3/8"

Fig. 10. A modern bass-reflex enclosure with bottom fitted tuned port. This enclosure takes full advantage of the natural baffling qualities of the room flooring because the tuned port is placed in the base of the enclosure. Because of this, better equalisation and response distribution is obtained. Timber of not less than 1" thickness must be used, so that all unpleasant resonances are eliminated. The inner back wall, inner top and inner two side walls are lined with thick felt or fibre glass for damping purposes.

Critical Dimensions See Page 59 to 61

For 10" speakers "A" = 7" "B" = 7"
For 12" speakers "A" = 8 7/8" "B" = 8 7/8"

Dimension "C" varies according to the resonant frequency of the speaker.

10" Loudspeakers

70 - 90 cps. Dimension "C" = ¼"
65 cps. Dimension "C" = 3"
60 cps. Dimension "C" = 4¼"
55 cps. Dimension "C" = 7¼"

12" Loudspeakers

80 cps. Dimension "C" = ½"
75 cps. Dimension "C" = 2½"
70 cps. Dimension "C" = 6"
65 cps. Dimension "C" = 10½"

Fig. 11. A large enclosure with dual column reflector system based on certain patents. Unique in as much as that it produces complete 180° balanced reproduction, it is eminently suitable for large rooms or halls. It is for use with a 12" speaker and variable tuned ports are arranged on the front of the enclosure, these are separately tuned acoustically to suit the pair of loudspeakers used. It is vital that the two units are correctly phased. The top semi-circle reflector is made of two pieces of 1/8" thick perspex bent into a cone shape and held by strips of wood. The resulting cavity should be filled with plaster of paris and allowed to set. This is to eliminate any sympathetic vibrations in the most important part of the enclosure, the reflecting unit. Smaller loudspeaker units may be used, if required, reduce these dimensions in the ratio of 5 : 6 for a 10" unit and 2 : 3 for an 8" loudspeaker. See Page 62 to 63

Fig. 12. Corner fitting long channel horn enclosure utilising any two walls at right-angles to one another as the main enclosure walls. The main advantage of this design is the long path formed for the sound to travel before emerging so that particularly good response is achieved at bass frequencies. Physically, very little room is taken up because of the corner fitting. Timber of not less than 1" thickness must be used and to avoid any resonant effects it is suggested that fibre glass or thick felt 1"

thickness be tried in various positions at the rear of the enclosure. It is impossible to specify just where to dampen the enclosure because this factor is dependent on the loudspeaker unit selected. See Page 64 to 65

Fig. 13. Long channel enclosure for a 12" loudspeaker. An attractive model designed with minimum dimensions. Simple to construct and in spite of its small size, capable of providing good quality reproduction over a wide range. It compares very favourably with much more elaborate and expensive enclosures. See Page 66 to 67
Efficient, acoustically, because a comparatively long path is secured for the rear loading of the speaker. Timber for this enclosure can be 5/8" thick provided the interior is well strutted to obtain extra rigidity. By using ¾" timber the necessity for strutting can be avoided.
If it is required to use an 8" speaker, reduce all dimensions on the diagram in the ratio of 2 : 3. Damping the interior will improve results.

Fig. 14. This is a rear large horn slot loaded corner enclosure intended for use with 12" or 15" speakers. It will reproduce with clarity and true fidelity down to the lowest audio frequencies. This design relies on two right-angled walls of the room to form the balanced porting and outer walls of the enclosure. Because of the generous size of the unit, it is recommended that it should only be placed against walls which are of solid brick or concrete structure. It must not be used against thin partitioning which would set up unpleasant resonances. See Page 68 to 70
All timber to have a minimum thickness of ¾".

Fig. 15. Probably the smallest enclosure that will give proper reproduction with 12" and 15" loudspeakers. Its remarkable results are due to pneumatic suspension but perfect results are only obtained provided the whole of the interior is loosely filled with fibre glass wool thus giving the effect of a much larger enclosure without extra cost. Dimensions are for a 15" unit, if a 12" speaker is to be used, reduce the dimensions in the ratio of 4 : 5. See Page 71 to 72

Fig. 16. A novel sealed cabinet design, which has the advantages of the standard bass-reflex combined with the long path of horn type enclosures. Sound distribution is effected as follows, direct radiation from the front and back loaded output from the two side ports. Measurements shown on the drawing are intended for use with a 12" loudspeaker. If required with a 10" unit reduce dimensions in the ratio of 5 : 6 or 2 : 3 for an 8" loudspeaker. One inch timber is used throughout. See Page 73 to 74

Fig. 17. Rear horn reflector enclosure suitable for the small home, designed for use with 8", 10" or 12" loudspeakers. A very simple design that is not at all critical in assembly and will provide pleasing results with the minimum outlay in time and expense. Timber used, ¾" throughout. See Page 75
Tweeter apertures "A" are used only when two sparate tweeters are fitted. These apertures are not required if a diaxial speaker with bridge mounted tweeters is fitted. The faces of apertures "A" must be centralised in relation to the size of the bass speaker. Detailed is a table of dimensions for use with the three recommended speaker sizes :-

Dimension	Speaker Size		
	8"	10"	12"
"A"	To suit tweeter diameter		
"B"	$6\frac{3}{4}$"	8 7/16"	10 7/8"
"C"	18"	$22\frac{1}{2}$"	24"
"D"	24"	30"	36"
"E"	12"	15"	16"
"F"	8"	10"	12"
"G"	9"	$10\frac{1}{2}$"	12"
"H"	5"	$6\frac{1}{4}$"	$7\frac{1}{2}$"
"J"	5"	$6\frac{1}{4}$"	$7\frac{1}{2}$"

Fig. 18. For outstanding reproduction and where cost is not a vital factor, this folded horn design will satisfy the most exacting requirements. Two 15" speakers are used and careful assembly is most important as the rear loading has been mathematically and acoustically calculated. Irrespective of size or price, it would be difficult to improve on the results obtained from this design. Adequate interior damping must be provided by using fibre glass of not less than 1" thickness, firmly secured to the rear wall of the circular sloping exit chute. Unless the prospective constructor is an expert woodworker, the author suggests that this design be given to a professional cabinet maker to construct, as perfect rigidity must be secured.

See Page 76 to 79

Fig. 19. One of the latest developments in High Fidelity is the distributed port enclosure. A "Distributed Port" enclosure is a reflex in which back and front radiation are added at low frequencies. Low frequency response and the power handling ability are both improved by using this system. It differs from most reflex enclosures in that the response and impedance characteristics are controlled by the addition of a specific amount of acoustic resistance.

There is no cancelling between the front and back radiation at high frequencies due to the fact that the reflex action has an inherent back radiation high frequency cut off characteristic.

Three models are shown, ten six and three cu. ft. capacity, respectively. Ply wood of not less than $\frac{1}{2}$" thickness is used for the 3 and 6 cu.ft sizes and 5/8" for the 10 cu.ft. model. Line the back, bottom and one side of the 3 cu.ft. enclosure with 1" thick fibre glass or good quality felt. Line bottom and two rear sides of the 6 and 10 cu.ft. enclosures with 2" thick fibre glass or equivalent acoustical damping material. Glue and screw all joints and make the front or back removeable, if the speaker is to be mounted on the inside surface of the mounting board. The 1" x 2" brace is to prevent reverberation in the front panel which would ruin the low frequency performance.

The shape of the enclosure may be altered to suit the user, provided the internal volume and configuration of the front panel is maintained. This enclosure has been designed to use speakers up to 12" diameter, if a larger unit is used, the power handling capacity will rise, but poorer low frequency response will result. Speakers of smaller diameter will give a better low frequency response but poorer power handling capacity. Loudspeaker units exceeding 12" diameter should not be in the 3 cu.ft. enclosure, neither should units less than 12" diameter be used with the 10 cu.ft. enclosure. See Page 80 to 82

The original development work on this remarkable design was carried out by the Audio Engineering Division, T.V. Dept., GE of America, America.

Fig. 20, 20a and 20b. This is a large design recommended for multi-speaker installations for use in large halls, auditoriums and theatres, etc., the design uses two 12" speakers for bass reproduction, and three tweeters to take care of the upper register. Constructors who wish to build this model, will have no difficulty in following the three drawings provided, which are self explanatory. See Page 83 to 88

USING TABLES A TO F

Tables C, D, E and F enable constructor to design ducted bass reflex enclosures. Loudspeakers of 10", 12", 15" and 18" diameters are covered by these tables. To use these tables, first ascertain the resonant frequency of the speaker to be used. This may be obtained from the technical data issued by the maker. From the table it will be noted that there is a choice between various enclosure volumes and duct lengths, e.g. on table 1 with a 10" speaker with a resonant frequency at 50cps. choice is available from 5,000 to 10,000 cubic inches volume with the duct lengths from 15½" down to 3" respectively. If a small enclosure is required, the duct length will be longer in proportion. Essentially, the duct length must not approach the back wall of the enclosure nearer than half the diameter of the speaker used.. Because of this, the first choice of cabinet volume and duct length may have to be revised, to ensure that these conditions are met. Interior dimensions of the bass reflex enclosure may be selected from tables A or B, which enable constructors to check if there is sufficient room for the required duct length.

The tables give the required height, width and depth in the ratio of 4 : 3 : 2, which is the most suitable acoustically. Table A covers capacities of 1 to 100 cu.ft. Table B from 500 to 40,000 cu.inches.

GENERAL CONSTRUCTION HINTS

Perhaps the most important single factor in loudspeaker enclosure construction is rigidity. Loudspeaker baffles are not sounding boards as used on pianos or violins and intended to amplify sound, they are intended to control the sound waves created by the loudspeaker unit. Any vibrations in the cabinet structure absorb power and re-radiate spurious sound waves at certain frequencies. Rattles or at least response variations due to interference patterns will result and adequate use of bracing cleats of solid timber is suggested. The plans specify ¾" or 1" plywood for all enclosures except the small ones using 8" speaker units where ½" material will usually suffice. Bracing cleats should be fastened securely with glue and screws. The best test for adequate rigidity is to thump the centre of all penels with clenched fist; a vibrating panel will quickly reveal its existance by the hollow, drummy sound indicating that further bracing is necessary.

All enclosure joints should be air-tight. Recommended procedure is liberal use of glue and woodscrews for pulling joints tight. This is particularly important in horn type enclosures. Caulk all joints after the enclosure is completed with a material such as linoleum cement, which will not become brittle with age.

Avoid any restrictions, cavities or openings which are not specifically called for in the enclosure plans, because these create resonance effects which destroy realism. Enclosures of peculiar shape may have resonance effects often called organ pipe effects at some frequencies, these are the result of "standing waves". Proper use of absorption material (specified in some plans) will eliminate any ill effects. Absorption material should be located at the ends of the longest dimension which forms the "organ pipe". No absorption material is necessary or desirable in horn enclosures.

Enclosure interiors may be treated with a sealing medium such as shellac to prevent moisture absorption and thus prevent warping and splitting.

No other finish is necessary on the cabinet. Fasten the loudspeaker unit tightly to the speaker outlet so that no air can leak through from front to back. Most speaker units are provided with a felt surround to implement this procedure. Flexible mounting supports should not be used for the lodspeaker unit. If feedback is encountered, either mechanical or acoustical, use shock mounts for equipment other than the loudspeaker unit. Shock mounts or the existence of an air leak around the speaker unti will substantially impair the performance characteristics of any good enclosure.

Note that the loudspeaker enclosure is a very definite part of the reproducing system at low frequencies and the particular design is directly related to the loudspeaker unit. The performance of high frequency units is essentially independent of the enclosure except for secondary effects.

EMBELLISHING SPEAKER ENCLOSURES

Without ornamentation the loudspeaker enclosure is nothing more than a plain simple box-like structure that could hardly be considered a piece of furniture. However, with a little patience and skill it is possible to make it attractive and to harmonize with other room furnishings.

One way is to cover the front and sides with grille cloth, as shown in Figure 21a. This is most practical on small cabinets, especially where the cabinet has been made of plywood since the cloth covering conceals all exposed joints and edges. See Page 89 to 90

Neatest finish is obtained by extending the top and bottom 1/8" beyond the sides and front during construction. This 1/8" overhanging lip conceals the edge of the cloth top and bottom, thus making an exceptionally neat job. Should the enclosure have been built with the top and bottom, flush with the sides and front, separate moulding can be fixed to the edges of the top and bottom to create an overhanging lip. Paint, stain or varnish can be used to provide a finish for the top and bottom.

Grille cloth can also be used to cover the entire face of a cabinet even though the speaker opening occupies a relatively small area of this panel. Wooden mouldings are available in many forms and can be used to add finish to a plain cabinet. Figure 21b shows the addition of a heavy bevel moulding to the front of a cabinet. Such moulding can be made by cutting diagonally a square section after which a shallow groove is formed on the back before the ends are mitred. It is assembled like a picture frame. The grille cloth is mounted on the front of the cabinet before the frame is attached, the rabbet being just deep enough to accommodate the grille cloth. For modern effects, bevel and square mouldings are perhaps the best. More ornate forms may prove useful with certain cabinet styles. Generally, choose small mouldings for small enclosures and heavier ones for the larger variety.

Mouldings must not encroach on the required openings in an enclosure. In some cases the space is not adequate to permit their use. One method of obtaining additional space to support a suitable moulding is to add a second layer of ply wood, in other words, a double top.
A sunken effect similar to the bevelled moulding effect may be obtained adding a plain $\frac{3}{4}$" frame to the front edges of the sides, top and bottom as shown in Figure 21c. This permits the grille cloth to be wrapped around the speaker baffle, tacked on the back and then inserted in place against the projecting front frame.
A similar effect can be achieved by allowing the sides, top and bottom to project forward ahead of the cabinet front by about one inch. Then the grille cloth can be stretched over a light frame work which will just slip inside the projecting edges against the front panel. This frame can be tacked to the cabinet front with small finishing nails through the openings of the grille cloth.
With some installations, sliding doors of perforated hardboard will prove very helpful. These impart a modern appearance to grouped wall units. They are particularly useful for amplifier storeage units and other types of equipment such as record storage cabinets. Figure 21d shows how sliding doors of this kind are installed. Use care in planning the cabinet arrangement when using them because only half of the door area can be open at one time. Careful thought will solve this problem for example, the record storage space and a television receiver can be behind a pair of sliding doors since the one will never be used when the other is in operation.
Figure 22a shows how full length hinged doors of veneered plywood can be fitted to individual cabinets. These are more suitable for elaborate expensive cabinets. Both top and bottom of the cabinet project at the front and the doors hinged to the top and bottom with special flat pin hinges. Properly fitted, these doors can swing around against the sides of the cabinet. See Page 91 to 92
In many cases picture-frame type overlays of flat and half-round mouldings will improve a plain cabinet. These can be applied to the sides as well as to the front in the manner suggested in Figure 22b. A number of interesting possibilities of this kind exist.
Perhaps the most important contribution for the home workshop in recent years has been the durable, decorative laminates (often known as counter-top material) available in rich, simulated wood grains. A plain plywood cabinet can be made into a reasonable piece of furniture by covering it with this material. The new contact cements make it easy for anyone to apply the laminate since clamping is not necessary.
Choice is available of several ready-made legs that will give any lowboy cabinet a smart modern look. Most popular of these perhaps is the hairpin type of wrought iron legs which can be purchased in various lengths at almost any hardware or department store. In addition to the hairpin type, there is the straight rubber-tipped diagonal leg, which like the hairpin leg is attached solidly to the cabinet bottom with wood screws as shown in Figure 22c. Wooden legs fitted with brass ferrules are also available. These go into separate metal mounting brackets which hold the legs at an angle and which are attached with screws, like the others.
Simple platform bases are quite satisfactory in most cases and will improve the appearance considerably. These need be nothing more than a three-sides frame attached to the bottom of the cabinet with screws.

Figure 22d shows an arrangement of this kind, 2" x 2" or 2" x 4" timber mitred at the corners is suitable for these bases.

TUNING

So that maximum benefit may be derived from a given bass-reflex enclosure it is necessary to tune it to suit the particular loudspeaker unit employed. Firstly, it is necessary to know the fundamental resonance of the loudspeaker and for this purpose an audio oscillator, amplifier and AC voltmeter are required.

Place the loudspeaker unit on the table cone facing upwards, no baffle of any description is used. Connect speech coil to amplifier through 100 ohm 1 watt resistor, that is, a resistance of 100 ohms is in series with loudspeaker and amplifier see Fig. 23. Across the speech coil a low reading AC voltmeter is wired, 0-5 or 0-10 volts is suitable. Inject a 100 cycle note from the oscillator through the amplifier and adjust to 1 volt. Now slowly sweep the oscillator frequency downward toward zero frequency. At the resonant frequency of the loudspeaker unit there will be a considerable rise in voltage, this will be observed on the voltmeter and the cone movement will also register a large increase in movement. The resonant frequency can be read off from the oscillator and noted. Mount the loudspeaker in the enclosure and set up the measuring apparatus as before. It will be observed that the large peak has disappeared and in its place two peaks, one on either side of the original, and of much lower amplitude are present. See Page 93

Tuning can only be considered accurate when the two peaks are of equal amplitude and are equally displaced on either side of the free air resonant frequency originally measured.

By closing off part of the port opening it will be found that it is possible to vary the amplitude of one peak against the other. Port area should be artificially reduced until the conditions of correct tuning are approximated, port size can then be made permanent (See Fig. 24A and B). See Page 93

CRITICAL DAMPING

Obtain a 4.5v torch battery and some cloth the latter to be of similar texture to that exhibited by cheap hankerchiefs. Connect one side to the battery to the loudspeaker, make provision for easy connection and disconnection for the remaining side. Make and break contact. A sound resembling a "bing and bong" will probably result. Connect a single layer of cloth tightly across the port opening and repeat the test.

Continue adding layers of cloth and repeating the test until both "bing" and "bong" have been reduced to "click" and "click". Make sure that both "bing" and "bong" have gone, one may disappear before the other but do not add more layers of cloth than necessary because over damping will cause inefficiency.

Critical damping properly carried out will ensure that the loudspeaker system is free of undesirable transient generation.

CROSSOVER FILTERS

Most readers will appreciate that a single loudspeaker unit cannot satisfactorily cover the entire audio spectrum. Usually two or more speakers are used and the audio spectrum is split up between them by means of an LC network commonly referred to as a crossover filter. Such a

filter is normally situated in the speech coil circuit for reasons of convenience and adaptability. It is possible to use an electronic crossover network at the front end of the audio system and two separate amplifiers. This system is superior to the first method but of course, more costly. There are a number of low impedance networks suitable for inclusion in the loudspeaker circuit perhaps the most popular are the quarter section series and half section parallel. Figs. 25 a and b show circuits and component values for both of these types.
Method of operation is simple to understand, the capacitor reactance increases as frequency is lowered, therefore, a capacitor in series with a speech coil will attenuate low frequencies. On the other hand,. a parallel capacitor will pass low frequencies but attenuate higher frequencies. The effect of the inductance is the reverse of this. From this it will be apparent that the response of a given system can be adjusted to almost any requirement. Power loss with either circuit of Fig. 25 is not serious, about 1dB for the quarter section and 2dB for the half section.
Both networks of Fig. 25 are designed for 15 ohm loudspeaker units and for a crossover at 2000 cycles. It is a simple matter to change the crossover frequency or to make the units suitable for loudspeaker units of lower impedance. Divide 15 by the voice coil impedance of the loudspeaker unit to be used and multiply all L and C values by the quotient. If it is required to crossover at a different frequency and the crossover point is lower than 2000 cycles, divide 2000 by the required frequency and multiply all C and L by the quotient. Should the cross over frequency be above 2000 cycles divide the crossover frequency by 2000 and divide all L and C by the resultant. Conversion to a three speaker system is quite easy. A high frequency dynamic tweeter is fed via a high-pass filter consisting of a 2 mfd. capacitor across the existing treble unit. In practice the capacitor is wired in series with the tweeter and the combination wired in parallel with the existing treble unit. With such a system it is easy to obtain an overall response from 20 to over 17000 cycles. Capacitors for crossover units should normally be of paper construction, use of electrolytic components can under certain conditions involve considerable power loss. See Page 94

Coils or inductors are normally home constructed and air-cored. For the inductance values quoted in Fig. 25 their resistance should not exceed 0.6 ohm Mr. G. A. Briggs in his excellent book "Sound Reproduction" has given useful instructions for constructing air-cored coils and the original coils for both filters in Fig. 25 were based on Mr. Briggs recommendations. Coils were wound to the following specification, 18 swg cotton covered enamelled copper wire, 1" dia. wooden former provided with end cheeks, 32 turns per layer. For a 1.3mH inductor 265 turns are necessary the 1.7mH coil will need 300 turns. If inductances of 2.6mH or 3.4mH are required, turns necessary are 365 for the former and 410 the latter.
It is not claimed that these specifications will provide the exact theoretical inductance required but errors of 10% are not serious with crossover networks and coils wound to the above specification are in use by the author.

PHASING LOUDSPEAKERS

"Phasing" is concerned with the utilisation of two or more loudspeakers in such a way that the sound from any one loudspeaker does not cancel the sound from other units thus creating a dead area between them. This is an important consideration where loudspeakers face the same direction. Connections to the voice coils, whether series or parallel, must be made in such a manner that at any one instant all diaphragms are moving in the same direction.

If two driver units are connected to a single horn it can be clearly understood that, if our of phase, the resultant pressure where the sound of the two units meet in the horn would be completely cancelled and no sound would result. For parallel operation, the like terminals of each unit must be connected together, but if the loudspeakers are wired in series, two unlike terminals must be used as a junction. In-phase connections can be checked very easily, all that is required is a torch battery. Temporarily, wire up the loudspeaker in the manner to be used for final operation, i.e. series or parallel. Connect the terminals of the torch cell to the resultant two leads, a click will be heard and the connes will move in or out of the gap. Connections to the loudspeakers must be so arranged that all cones move in the same direction.

Phasing is of least importance where two loudspeakers are some distance apart or pointing in opposite direction, as the loudspeakers are brought closer together in small angular relationship, the necessity for in-phase operation becomes increasingly important.

Now it is very important to note that one class of loudspeaker unit is definitely excluded from the above remarks: the high-frequency tweeter. Firstly, the question of phase is of no importance at the frequencies handled by this class of unit. Secondly, the application of a battery across a tweeter would not produce any noticeable movement but the unit might well be ruined. Briefly, phasing is only important when low frequencies are being considered.

What is Genuine, Pseudo and Quasi Quadrophony? And what also goes by that name

Quadrophony - a new technique or a promotion stunt by smart publicity people? This is a question which is being heatedly discussed by music enthusiasts everywhere in the two years since this term came into acceptance in the "High Fidelity world". Quadrophony, claimed by its inventors to be "the perfection of music reproduction", reached the European continent almost simultaneously from the U.S.A. and from Japan.

"Four channel reproduction technology; quadrophony, now converts your living room into a real concert hall. The filling of your room with sound from four loudspeakers, one in each corner, gives one the fascinating impression of sitting in the middle of the orchestra" - may be read in the advertising brochure produced by a well-known manufacturer. But what is this new technology in actual fact?

A retrospective look at the almost 100 years of history of the record and apparatus industry enables the development to be seen.

As is known the phonographs constructed by Edison in 1877 were the beginning. A metal foil-covered roller was the first acoustic sound carrier, which was further developed ten years later by Emil Berliner to a waxed, circular zinc plate - the forerunner of the present day record. The shellac record arrived at the beginning of the 1920s and was noted for its fragility and its comparatively heavy weight. Nevertheless, this sound carrier lasted for around 30 years until it was replaced by the synthetic record.

However, a new development soon came on the scene: whereas up to 1959 exclusively monaural, i.e. one channel records could be manufactured, in Frankfurt, Germany, at the radio and T.V. exhibition held at that time the first stereo, i.e. two channel records were introduced. A sensation for the professional world and a new kind of listening experience for music enthusiasts. On the occasion of the 1963 radio and T.V. exhibition in Berlin the "Sender Freies" Berlin radio station transmitted a programme in stereo for the first time (using the pilot sound procedure), which was received enthusiastically by the majority of those in possession of the right equipment.

Further Developments in Stereophony

In the middle of the 1960s - again an import from the U.S.A. - high fidelity technology found its way onto the European market. Experts worked out the technical data for the individual apparatus groups which, after years of preparation, found expression in the international quality standard DIN 45 500. These standards, developed by German industry, have been the subject of world wide interest. The view appears justified that they will achieve recognition in the regulations of the International Electrotechnical Commission (IEC).

In the meantime, a new development has taken place of importance to both the record and to play back equipment: Quadrophony. The first attempts at a theoretically worked out basis of four channel recording converted into an acceptable sound extend back to 1970. Quadrophony can be more or less regarded as a further development of two channel stereo, which after some years of being regarded in a sceptical light by listeners can demonstrate its great advantages to all.

A Technical Trick

Nevertheless - in stereophony there are two different procedures; first we have pseudo-stereophony, in which the sound emitted into a room comes through a mono channel over several loudspeakers. The acoustic reproduction creates a "spatial" feeling - contrary to monophonic (also called monaural), reproduction, in which the sound radiation is also achieved over one channel but whereby only one loudspeaker is used. One talks of genuine two channel stereophony when the sound radiates from two different channels, installed on a stereo basis. Proceeding from this two channel technique technical experts developed four channel recording, termed quadrophony. Additional sound information is included in the grooves in such a way that the wave trains are no longer vertical to the groove axis, as was previously the case, but are now inclined at an angle. With the aid of a coder four channel recordings can be converted into a two track sound signal. This two track signal is reconverted from the receiver side by a decoder back into its original four signals. This technical trick makes a separate sound omission possible from four channels through four independent loudspeakers.

Not all procedures are "genuine"

At present the argument as to which is the best system is a matter of opinion. For even in expert circles quadrophony is regarded in varying lights, the more so because the systems known at present have not completely left the development stage yet. At this moment in addition to the pseudo and quasi quadrophonic reproduction there is a choice of two "genuine" quadrophonic procedures, which ought to characterise the rapid development of this technical innovation best. The individual procedures differ roughly as follows:-

Pseudo quadrophony branches certain information from the right and left channels, which is emitted through two additional loudspeakers.

Quasi Quadrophony

This is a definite further development of pseudo stereophony. With this system new signals are formed out of the right and left channels. The enginners responsible for development differentiate between five different types in this group along (quadrosound, analyser, Hafler, 4D and multisound).

The main difference between these two procedures and that of genuine quadrophony is basically that in addition to the four reproduction channels there are also four separate recording channels. With the first procedure of this type, the matrix system, the four channel recording is encoded onto two channels and, on the receiving side, decoded again into four channels. Within this system there are different types too, SQ, QX, X4 and QS, but space does not allow us to go into more detail.

The other "genuine" one of its type is the discrete quadrophony. Whereas with discrete four track tape reproduction no special technical measures are necessary, in the case of discrete record reproduction the four channels must be converted by the multiflex process via subcarriers and for the actual reproduction it must be led back to the original four signals. Thus, with the corresponding investment of times and materials the higher values for the separation of the channels is achieved.

Still No Broadcast Quadrophony

It is important for music enthusiasts to know that all music reproduction equipment suitable for stereo records is equally suitable for matrix quadro records. With regard to the distortion, noise and interference ratios there is no difference in the reproduction of quadro records. On the other hand a compatability exists so that stereo records can be played over four channel equipment. So far as can be seen the financial cost of matrix quadrophony ought to remain within a reasonable range, making quadrophony available to a wide cross section of buyers. Quadrophonic broadcasts, however, as has been stated by the broadcasting authorities, are unlikely to come into being in the foreseeable future.

Nobody, from among the ranks of the experts, will be able to forecast which quadrophonic system will become established. It will be the world market which decides this.

DUMMY LOAD & SPEAKER SWITCHING SYSTEM

Here is a description of a practical load box suitable for high power stereo amplifiers. It also provides facilities for simple and rapid switching between speaker systems, as required for comparitive tests.

Until now, we have used a variety of load boxes,'and which, in their way, served the purpose well enough. However, it was becoming increasingly obvious that changing amplifier fashions served to emphasis the limitations of these units, and that the time had come to produce something more suitable.

To name just two factors which were most obvious there is (1) the fact that almost all amplifiers these days are stereo, and therefore require two load resistors, and (2) the fact that amplifier ratings can be a good deal higher than would have been considered likely, even 10 years ago.

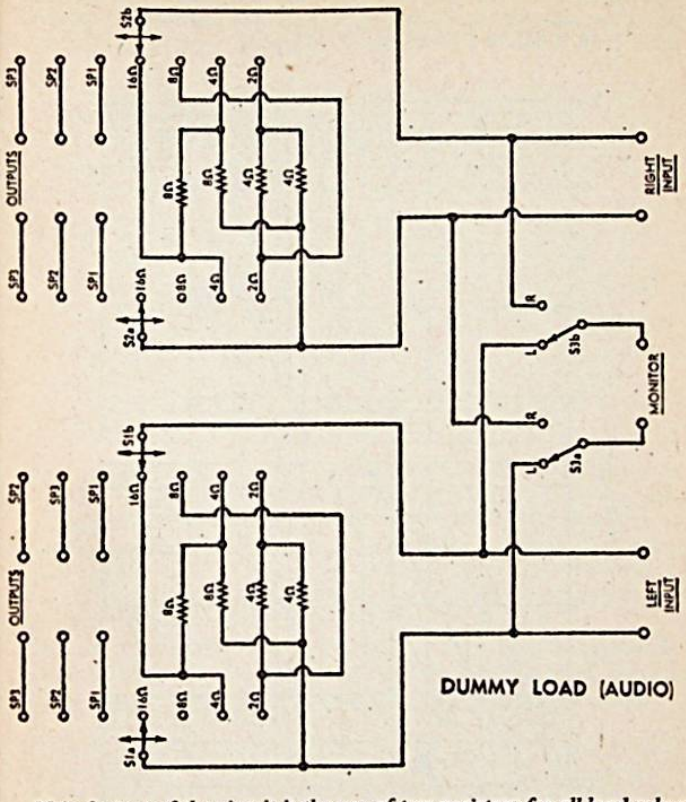
As an example of this latter aspect, load resistors can typically be called upon to dissipate power in excess of 60 watts. This figure is not unusual as the per-channel rating of some high-powered stereophonic amplifiers. Similarly, it is not unusual to encounter guitar amplifiers with rated powers of the order of 100 watts.

And, having decided to construct a new unit, we considered what other features we could incorporate which would make it as versatile and convenient to use as possible. The end result is something which, while being relatively simple and inexpensive, should appeal to anyone who has a regular need to measure amplifier power.

First, we had to consider how many values of load resistor we should provide, and what these should be, while keeping in mind the need to use readily available switches and other components. While it is easy to evolve "smart" switching systems which provide great variety of resistance values, there is a very real risk that this will call for switches and resistors which are too expensive, hard to obtain, or both.

We finally settled for four load values: 2, 4, 8 and 16 ohms, as being sufficient to cope with most practical situations. While it is true that there may be minor differences between these and the values specified by some manufacturers – i.e. 15 ohms rather than 16, or 3.75 rather than 4 – these are not likely to cause any serious problems. Provided we know the value of the load, and base our power calculations on it, the error introduced by presenting a slightly different load to the amplifier will be small.

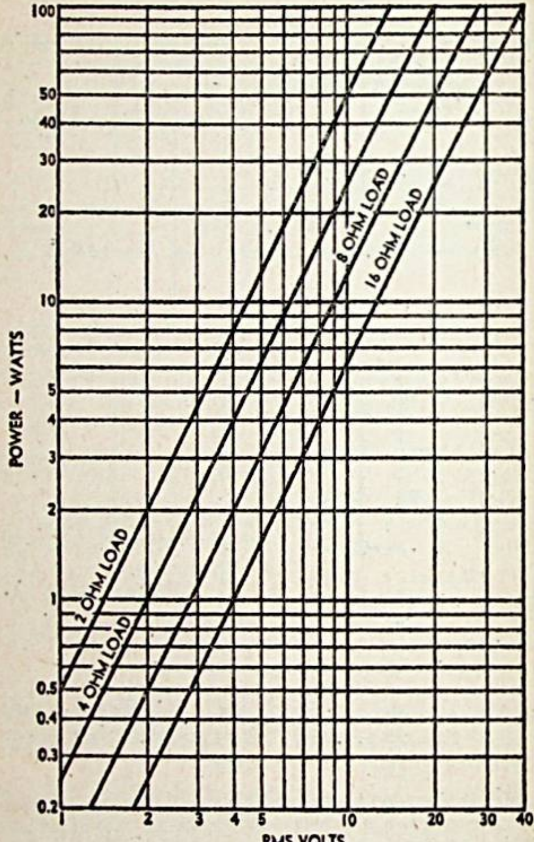
These four values are selected by means of a 2-pole, 7-position switch.



Main feature of the circuit is the use of two resistors for all load values, thus doubling the wattage rating. Switching facilities between speakers is also provided. Wiring is relatively simple.

(We will discuss the purpose of the other three positions in a moment.) The method of connection and the values of resistors chosen are such that two resistors are required to make up any value. This means that the wattage which can be dissipated will be twice that of the rating of the individual resistors. Thus if 50-watt resistors are used throughout, the unit could handle 100W in each channel. In a special case, where only a single channel was involved, the right and left hand loads could be connected in series or parallel to provide a 200 watt rating.

While we used 50 watt resistors in the unit we built, such large ratings may not be justifiable in every case, and this will be for the individual constructor to decide. Fifty watt resistors, at 5% tolerance, are quite expensive, and many builders may be content to settle for 20 watt units (40W total), or 10 watt units (20W total).



This graph will simplify power output calculations.

The resistors were vertically mounted in a standard equipment case measuring 9 x 6 5-8 x 5 5-8 inches deep. Ventilation was provided in the form of louvres in the sides and two rows of ¾ inch diameter holes along the back panel. This is necessary to keep the temperature rise of the resistors within acceptable limits.

Both sides of the loads are isolated from the case to reduce to a minimum the possibilities of shorts and instability. Care must be taken with all connections to ensure low residual resistance. No special layout is necessary but the wiring for each channel should be kept separate to facilitate assembly.

The further three positions on the load selector switch are brought out to terminals on the front panel of the unit. These can be used for connecting capacitors across the output of the amplifier for stability tests or for connecting various speaker systems. The latter facility is very useful when it is desired to make a subjective comparison between speaker systems, by switching rapidly from one to the other. In regard to stability tests, current standards require that they be made with no load across the output, other than the nominated values of capacitor. The load box thus satisfies this requirement.

Another facility is a pair of monitor terminals. These can be switched to either channel and permit the easy connection of a CRO, voltmeter or other measuring device to the channel under test. The switch is a two-pole, two-position unit with "make-after-break contacts. A switch with "make-before-break" contacts must not be used because both channels of the amplifier would be connected in parallel at switch-over. In many amplifiers this is a sure formula for destruction.
The unit in its final form is suitable for all normal amplifier tests such as power output, frequency response, cross-talk, and stability. Damping factor measurements can be made easily by disconnecting the load.

One point to be kept in mind when using the dummy load is that the loads should not be switched when operating at a high power level. This is to avoid damage to the switches and also to the amplifier. This precaution is not necessary when making comparison tests of speakers because these tests are made at a relatively low power level.

PARTS LIST

1 metal case, 9 in x 6-5/8 x 5-5/8 in.
1 front panel to suit.
1 carrying handle.
4 8-ohm resistors (5% or better).
4 4-ohm resistors (5% or better).
2 2-pole, seven-position switches.
1 2-pole, two-position switch, with "make-after-break" contacts.
9 red terminals.
9 black terminals.
3 pointer knobs.
4 rubber feet, screws, nuts, hook-up wire, solder, etc.

HI-FI COMPATIBILITY PROBLEMS

The interconnection of separate units to make up a complete audio system is not necessarily as simple as one might expect. Apart from the need to provide the necessary cables and plugs, it is important to consider the level of output and input signals, and the possibility of hum and instability arising from inappropriate earth connections.

In a utopian situation, all audio home entertainment units would be completely compatible, irrespective of kind or brand. Any pickup or any radio tuner could be plugged into any amplifier and fed through any loudspeakers. The system could be cross-coupled to the input of any tape recorder or could pick up a signal from any tape player, and so on. All one would need would be the requisite number of standardised cables and plugs.

Unfortunately, this utopian situation is not immediately in view. To be usre, manufacturers have been making a conscious effort to reduce the variety of connectors in use and to provide amplifiers and tape recorders with multiple input and output facilities. But that is about as far as it goes.

The level of the output signal from some devices is just too great to feed directly to the input circuits of others; overload and distortion will occur unless steps are taken to attenuate the signal within the interconnecting link.

The problem becomes even more difficult if, conversely, the available signal is not adequate to drive the second device.

Then there is the question of impedance levels in the respective units. In very broad terms, this refers to the effective resistance across which an output signal is developed, or across which an input signal has to be impressed.

As a rule, there is no problem if the impedance of the signal source is lower than that of the circuit into which the signal has to be fed. But there is likely to be a problem if it is the other way round.

Again, complications can arise from the 'earthy' side of the interconnecting cables. In many amplifiers and tape players, the input and output connectors are kept clear of the metal chassis adjacent to where they are mounted. The shell of the connector is earthed instead to a point in the wiring appropriate to its function. Thus input connectors may be earthed close to the preamplifier circuitry and output connectors close to the output or power supply circuitry.

When the equipment is connected to ordinary peripheral components as, for example, a record player and loudspeakers, no common paths are established between the input and output wiring. However, if two or more units are interconnected with cables having a common earth braid, this can set up an external link between the earthy sides ot the input and output connectors.

In certain cases the external link, which completes a virtual earth loop, can invoke problems such as hum injection, inteference from the tape drive motor or instability. While by no means the rule, such problems are always a possibility which has to be allowed for.

Unfortunately, a basic and thorough treatise on the compatibility of hi-fi units would almost inevitably end up as a long and tedious tome, which could test the patience of writer and reader alike.

In this article, we have adopted a completely different approach. We simply discuss the compatibility problems which were encountered with a particular group of units which we had occasion to interconnect in our laboratory. The problems may not be identical with those which might be encountered in another situation, but they are typical and the approach which we adopted to meet them may serve as a guide to other enthusiasts.

The three units involved comprised a record player, a completely self-contained stereo cassette player/recorder and a normal stereo amplifier.

The object was to interconnect the units so that the amplifier could reproduce stereo music from disc or cassette, or from the amplifier's own in-built radio tuner. Alternatively, it had to be capable of recording on to cassette programme material being reproduced from disc or radio–a very common requirement.

The first problem encountered was an earth loop involving the power wiring and the signal wiring between the record player and amplifier. An annoying hum was audible between tracks or behind soft music. The job of tracing and rectifying the trouble provided the inspiration for the article in an earlier issue. With the player wiring modified as described, the hum disappeared and the equipment performed to expectations when reproducing from disc.

At first glance, the job of interconnecting the amplifier and tape recorder looked to be a breeze. The amplifier had a pair of 'Tape In' and 'Tape Out' sockets; the tape unit had sockets for 'Aux In' and 'Ext Spkr'.

From a local supplier we were able to obtain a well finished equipment cable about 3ft long containing four colour-coded and shielded leads inside an outer plastic sheath. The only modification was to equip two of the leads on one end with miniature phone plugs to fit the 'Ext Spkr' jacks in the tape unit. The other connectors were of the right kind to plug straight in.

But alas; it wasn't to be that easy!

When an attempt was made to record from disc to cassette, the result was intolerable distortion. The signal level from the 'Tape Out' sockets on the amplifier was clearly far too high for the 'Aux In' circuitry in the tape recorder.

This kind of problem arises because, in many tape recorders, the 'Aux In' socket connects to the 'Mic' socket through a resistive pad, the signal then going to the microphone preamplifier stage. While the resistive pad permits a much larger signal to be accepted, it is still possible for the available input to be excessive, producing overlaod and distortion in the preamplifier stage.

The overall gain of the recording amplifier is usually controlled after the preamplifier stage, either by a gain control potentiometer, or by an automatic gain control circuit. While gain control can reduce the signal to an appropriate level for recording, it can do nothing to correct the distortion that has already been introduced by the overloaded preamplifier stage.

In the particular record player involved, the 'Tape Out' signal was derived from just ahead of the volume and tone controls, so that there was no way of reducing it, short of modifying the internal circuitry.

Equally, the tape recorder could not be set up to accept a greater signal input without internal modification.

The obvious course, in the face of such a problem, is to break the connecting signal lead and to insert a series resistor or resistive divider to introduce the required order of attenuation.

If the tape recorder has a manual recording level control and meter, the resistor(s) can be selected so that normal recording level is obtained with the control knob in approximately the same position as for recording via the unit's own microphone.

Where the tape recorder incorporates automatic level control circuitry, the resistor(s) can be selected so that the signal is recorded at normal level on tape without audible distortion.

With the particular items being considered, we found that the signal level was suitable reduced by including a 120k resistor in series with each active lead from the record player 'Tape Out' to the tape recorder 'Aux In'. For the time being, the resistors were wired roughly between the inner conductors and the respective plugs at the tape recorder end. A more permanent arrangement would obviously be required later on but, for the moment, the objective was to determine what was necessary.

Sufficient to say that, with the 120k resistors in position, programmes could be recorded on cassette free from any suspicion of overload distortion.

Next problem was to make the tape recorder play through the main amplifier and loudspeakers. To evaluate results we were careful to use a pre-recorded cassette of known good quality. In setting up equipment, it is very easy to be misled if reliance is placed on a recording which might itself contain imperfections.

Unfortunately, we ran into another pack of trouble. While the recorder would reproduce the cassette in normal style as a self-contained unit, any attempt to divert the signal through the main amplifier and loudspeakers resulted in a heavy pulsating hum being imposed on the music. It sounded rather like a mixture of mains hum and ripple from the tape drive motor.

It transpired that the effect was due mainly to the fact that plugging into the 'Ext Spkr' jacks left the recorder output stages without a proper load. The noise largely disappeared when low value resistors (actually 18 ohms) were soldered across the two plugs.

Thus two more resistors had to be strung temporarily in the once neat connecting cable.

At this juncture it was possible to record on to—and to replay from—cassette with passable results. Unfortunately, reproduction from cassette still contained a significant amount of hum, and ripple from the tape drive motor.

After a certain amount of fiddling, it became evident that the set-up was sensitive to configuration of the earthy connections. The hum and noise could be influenced by isolating certain of the plugs from the braiding or running separate earth wires. And here the prlblem of the single 4-in-1 cable became evident. All four braids made direct physical contact inside the outer sheath; thus an input/output earth loop was inescapable both at the amplifier and the tape recorder.

In some set-ups it might not matter. In this one it did!

Facing the problem of earth loops and the need to include resistors in the interconnecting leads, we decided the time had arrived for more drastic measures. We would devise a little box-and-cable assembly which could well provide a pattern for solving all kinds of interconnection problems of this general kind.

The box we selected was a standard item measuring 4¼ x 2¼ x 1½ inches and involving a folded aluminium base and cover secured by self-tapping screws. Inside the box we mounted two 8-tag strips, each providing 6 insulated lugs.

The input and output cables were separate lengths of twin 'stereo' lead shielded with an outer PVC covering. These were clamped just inside the box and wired to the tagstrips so that, initially, all inner conductors and braids were insulated from each other and from the box. This provided complete freedom to select and mount series and shunt resistors and to choose which earth paths to establish or leave open.
The 120k series resistors mentioned earlier were wired so that they were in series with the signal lead from record player to tape recorder. Had it been necessary to decrease the signal level still further, it would have been possible either to increase the value of these resistors or to form a voltage divider by connecting shunt resistors from the tape recorder end to braid.

The 18-ohm load resistors were connected across the tape recorder output and bridged across to player input. Had it been necessary to attenuate the level here, additional series resistors could have been added.

Finally the earth circuitry: This involved experimenting to establish which arrangement gave the best all-round results in terms of hum content and motor noise interference.

In this case, it transpired that the basic earth path was best established between the output of the tape recorder and the tape input of the main amplifier. These two braids were therefore linked to each other and to the box, as shown.

It was found that the braiding from the 'Tape Out' socket of the amplifier could also be joined to the box but NOT the braiding to the tape recorder's 'Aux In'. For reasons to do with the internal tape recorder circuitry and wiring, completion of this earth circuit invoked hum and motor noise. We did not try to pursue it further.

Our job was to do the best we could with the external connecting leads. It was not for us to get involved with the design in an effort to solve the problem at that level.

In fact the end result, while acceptable, was still short of true high fidelity standards because of hum content in the tape recorder.

As a unit, with its small detachable loudspeakers, it was excellent in its intended role–providing pleasant stereo music in a small flat. But even then, with the unit operating and with no cassette in position, hum and motor noise could be discerned.

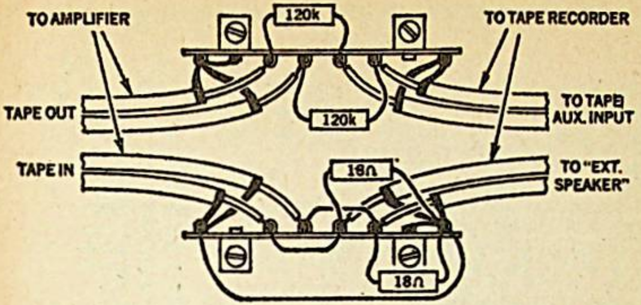
Through a large amplifier and fully baffled loudspeakers this barely noticeable background came up in direct proportion with the improved bass response. This was inevitable; our care with cabling could do no more than avoid aggravating the problem by undesirable earth loops.

One important point should be mentioned: As supplied, the tape recorder/player had only a 2-core flex to the power point. Hopefully the internal circuitry had been designed to ensure adequate safety without the third wire.

But had there been a third wire running back to the power point and joining the third wire from the amplifier, we would have been faced with yet another classic earth loop situation. It might have been necessary to fit a mains outlet to the amplifier, so that the tape recorder could plug in direct into the amplifier rather than a separate power point.

The lesson from all this would seem to be fairly obvious and not very palatable.

Portable tape recorder/players are very handy as self-contained entertainment units but not all of them are suitable for interconnection with



When compatibility problems really stack up, the neatest answer is a merging unit in which shunt and series resistors can be mounted, and where earth connections can be arranged to minimise the effect of earth loops.

basic high fidelity systems. One can achieve so much by close attention to the interconnections but, beyond that, basic design limitations may show up.

It is reasonable to assume that the new generation of specialised cassette decks will be substantially free from the troubles described in this article. Being intended primarily for use with high fidelity installations, close attention should have been given to interconnection, signal level and low frequency noise content, as well as to other qualities expected of a high fidelity unit.

It is significant that no serious problems have been encountered with any of the cassette decks we have reviewed in recent times. After connection of the necessary cables, they have functioned as expected with whatever amplifier happened to be on hand.

Which is the way it should be!

FREQUENCY RESPONSE RANGE OF SOUND REPRODUCTION

Average Quality Hi Fi	30 to 16000	C/s
Bass speaker Average Quality in enclosure	35 to 4000	"
Bass speaker Finest Quality in suitable enclosure	18 to 3000	"
Domestic Quality Record Player	180 to 7500	"
Domestic Quality Tape Recorder	160 to 7000	"
Earliest Gramophone with sound box	400 to 4500	"
Electrostatic Wide Range Speaker	300 to 20000	"
Finest Hi Fi Equipment	15 to 22000	"
High Quality Magnetic Recording Tape	40 to 16000	"
High Quality Tape Recorder	40 to 16000	"
Human voice adult speech	90 to 1300	"
Inexpensive Transistor Set	350 to 6000	"
LP 33⅓ r.p.m. record	42 to 11000	"
Middle Range Speaker	300 to 8000	"
Normal AM Table Radio	180 to 8000	"
Percussion Instruments	40 to 180	"
Portable Transistor Set High Quality	100 to 10000	"
Range of Human Hearing	15 to 18000	"
String Instruments	40 to 3200	"
Telephone	375 to 2500	"
Tone Control Bass Range	20 to 200	"
Tone Control Presence Range	1000 to 6000	"
Tone Control for Rumble Filter	18 to 60	"
Tone Control Treble Range	5000 to 20000	"
Tweeter High Quality	2000 to 18000	"
Tweeter Inexpensive Grade	1600 to 15000	"
Wind Instruments	45 to 4500	"

DECIBELS AND POWER RATIO RELATIONSHIP

POWER RATIO	DECIBELS
1	0
2	3.0
3	4.8
4	6.0
5	7.0
6	7.8
7	8.5
8	9.0
9	9.5
10	10.0
100	20.0
1,000	30.0
10,000	40.0
100,000	50.0
1,000,000	60.0

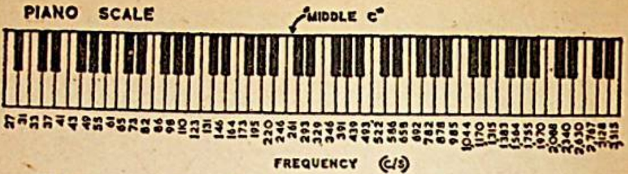
TYPICAL LOUDNESS LEVELS

LEVEL IN dB	
0	Threshold of audibility
15	Quiet whisper
20	Studio noise level
30	Quiet room in house
32	Suburban street
40	Noise in large office
50	Quiet speech (close proximity)
60	Noise in restaurant
65	Conversation (close proximity)
75	Factory noise
90	Grand Piano
95	Noise in underground train
100	Symphony orchestra
120	Threshold of feeling
130	Threshold of pain

FUNDAMENTAL FREQUENCY RANGE OF SOUND SOURCES

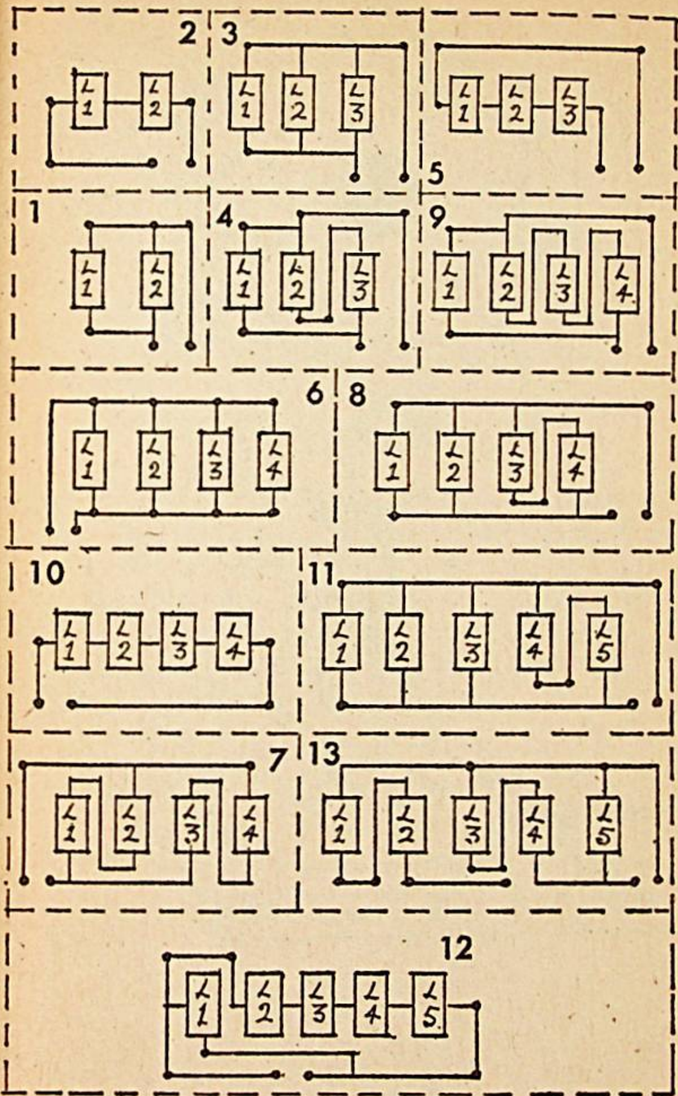
Sound Source	Frequency in Cycles per Second
Accordion	48 - 1760
Alto-clarinet	90 - 1000
Alto - Human voice	130 - 680
Alto mellophone	110 - 450
Alto-saxophone	140 - 950
Alto Trombone	110 - 720
Baritone - Human voice	90 - 380
Baritone-saxophone	70 - 420
Bass Bombardon	38 - 250
Bass-Clarinet	75 - 750
Bass - Human voice	85 - 340
Bass saxophone	50 - 310
Bass Trombone	60 - 370
Bass Tuba	42 - 330
Bass Viol	38 - 220
Bassoon	60 - 450
Bombardon	56 - 300
Cello	64 - 680
Chimes	550 - 1400
Contralto voice	180 - 600
Contrabassoon	36 - 150
Contrabass-sarrusophone	35 - 245
Cor Anglais	150 - 850
Concertina	180 - 2100
Cornet trumpet	150 - 450
Double Bass	45 - 200
English Horn	150 - 950
Euphonion	62 - 400
Euphonium	75 - 450

Sound Source	Frequency in Cycles per Second
Fluegelhorn	150 - 450
Flute	250 - 2200
French horn	100 - 850
Guitar	80 - 900
Harmonium.	32 - 2100
Harp	33 - 3200
Kettle Drum	65 - 170
Mandolin	180 - 1300
Marimba	130 - 2800
Oboe-clarinet	250 - 1400
Organ Flute Stops	32 - 2000
Organ Reed Stops	32 - 2100
Pianoforte	27 - 3515
Piccolo	500 - 4200
Soprano-clarinet	140 - 1600
Soprano-cornet	220 - 1200
Soprano-saxophone	205 - 1250
Soprano voice	225 - 1100
Tenor Horn	130 - 700
Tenor - Human voice	125 - 460
Tenor-saxophone	100 - 650
Tenor-trombone	82 - 600
Trombone	75 - 450
Tympani	85 - 200
Viola	128 - 1100
Violin	185 - 3000
Violincello	65 - 900
Xylophone	130 - 2800



Piano scale showing the frequencies to which the keys are usually tuned, which is to a slightly different pitch from that used by physicists, based on Middle C = 256 c/s., and such scales are apt to be misleading. Frequencies of black keys can be obtained by multiplying the frequency of the white key below it by 1.05946. This scale is useful for the approximate calibration of oscillators and rough determination of resonant frequencies, etc.

Output Impedance Of Amplifier	No. of L/S	Sketch No.	Speaker Impedance in ohms and Power Distribution Percentage									
			L-1		L-2		L-3		L-4		L-5	
			ohms	%	ohms	%	ohms	%	ohms	%	ohms	%
A) 3 or 4 ohms	2	1	B	50	B	50						
	3	3	C	25	C	25	B	50				
	3	4	B	50	A	25	A	25				
	4	6	C	25	C	25	C	25	C	25		
	4	7	A	25	A	25	A	25	A	25		
	4	8	C	25	C	25	A	25	A	25		
	4	8	B	50	C	25	B	12½	B	12½		
	5	11	C	25	C	25	C	25	B	12½	B	12½
	5	13	B	12½	B	12½	B	12½	B	12½	B	50
B) 7.5 or 8 ohms	2	1	C	50	C	50						
	2	2	A	50	A	50						
	3	4	C	50	B	25	B	25				
	4	7	B	25	B	25	B	25	B	25		
	4	9	C	50	B	25	A	12½	A	12½		
	5	12	C	50	A	12½	A	12½	A	12½	A	12½
	5	13	C	50	C	12½	C	12½	C	12½	C	12½
C) 15 or 16 ohms	2	2	B	50	B	50						
	3	5	B	50	A	25	A	25				
	4	10	A	25	A	25	A	25	A	25		



Speaker Impedance in ohms and Power Distribution Percentage

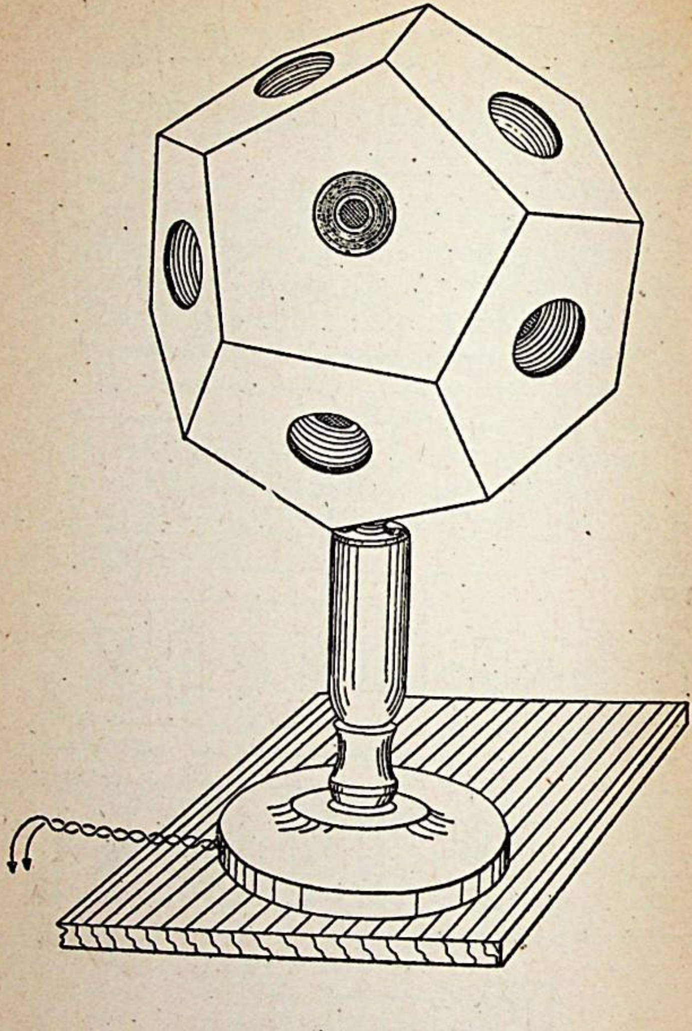
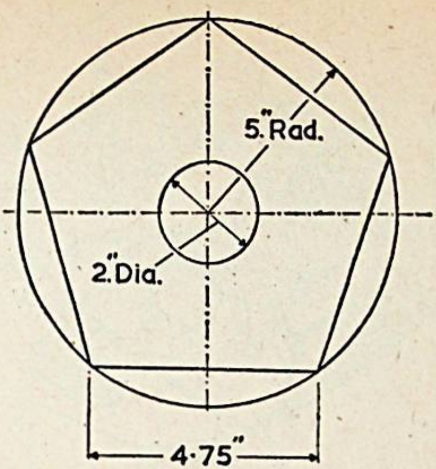


FIG 1



For construction of Pentagon draw a circle 5" Rad. With Compass set to 4·75" mark 5 points around the circumference of the circle.
Join together with a straight line each mark thereby producing an equal sided figure.
Constructed with Plywood $\frac{1}{2}$" thickness.
12 pieces required.

FIG 1

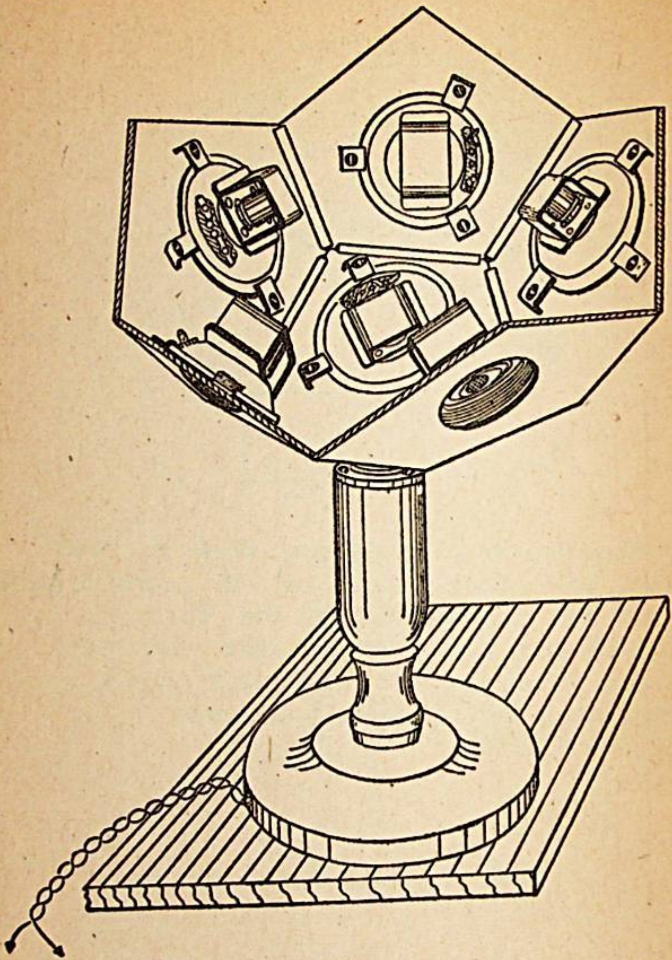
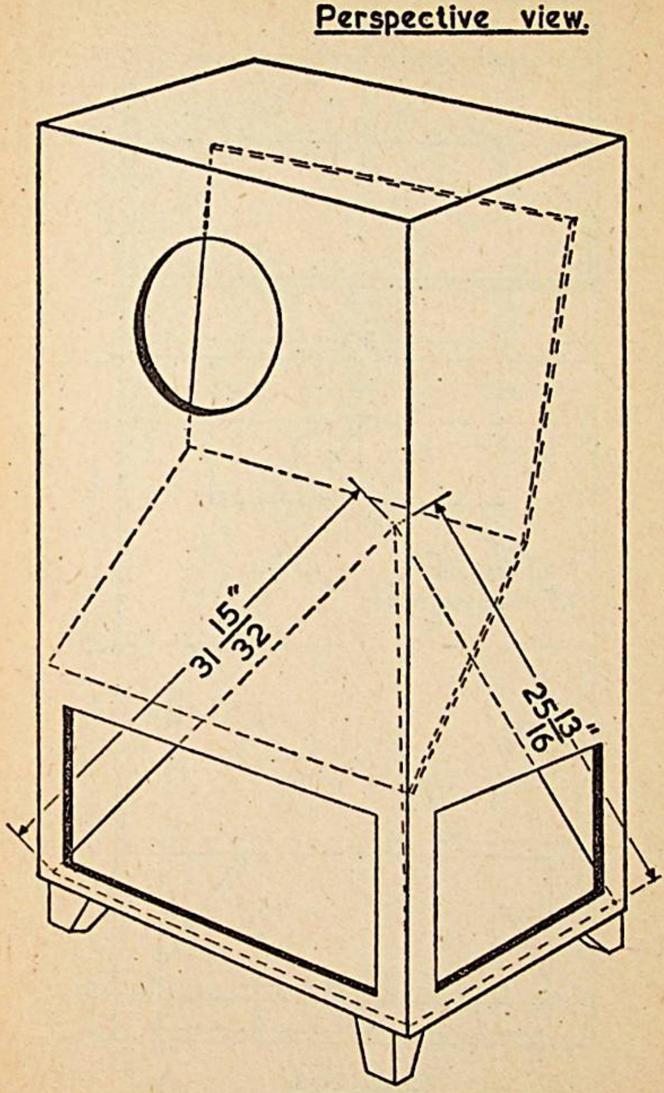


FIG 1

FIG 2



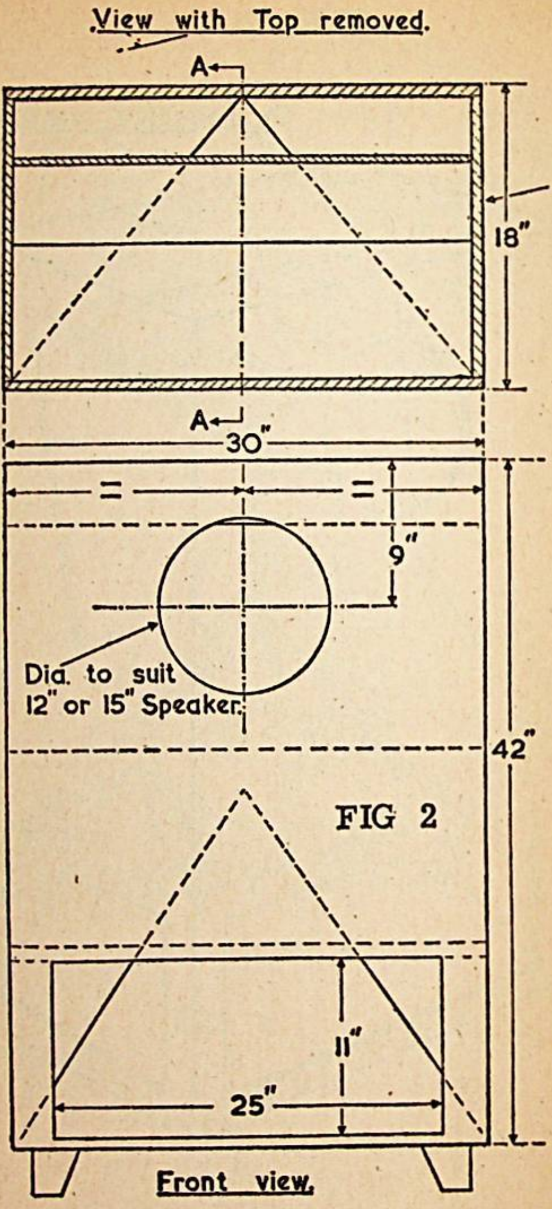
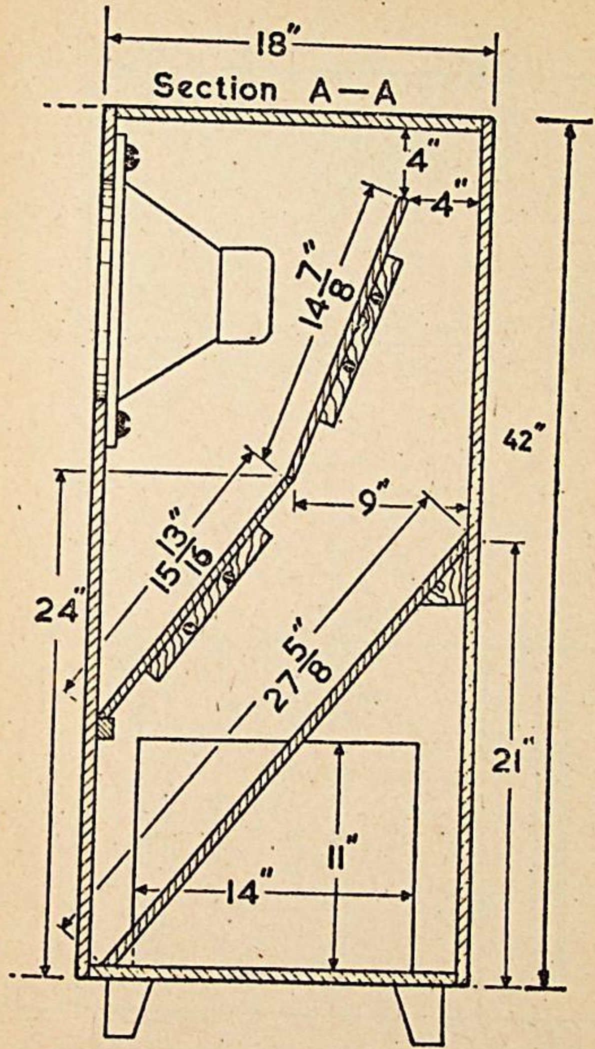

View with Top removed.
A
A
18"
30"
=
=
9"
Dia. to suit
12" or 15" Speaker.
42"
11"
25"
Front view.

FIG 2

FIG 2



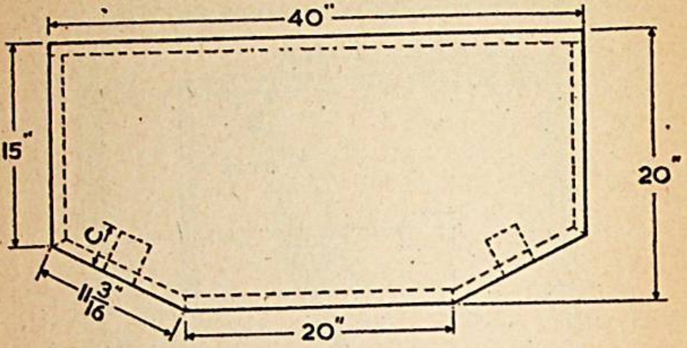


FIG 3

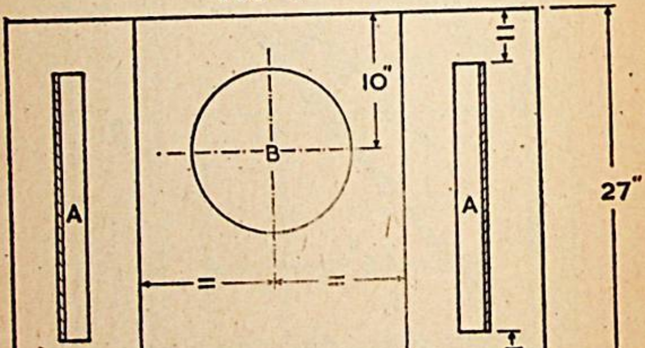
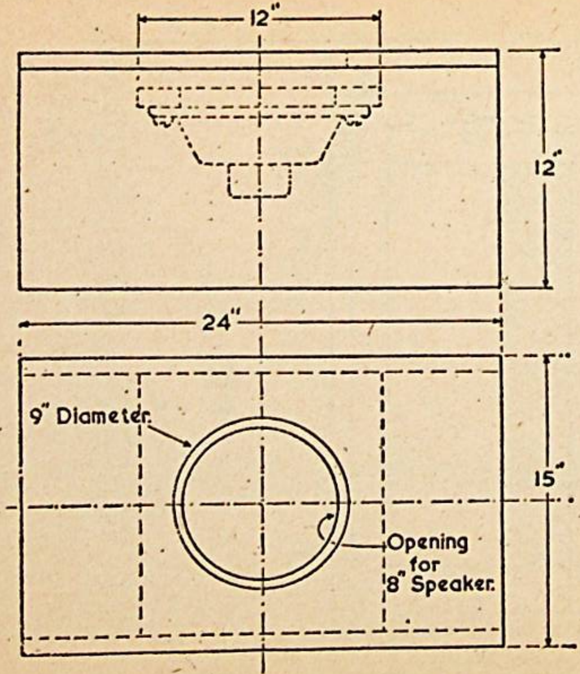
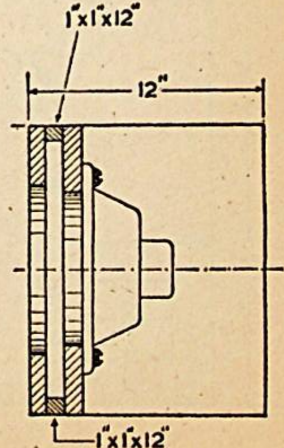


FIG 4





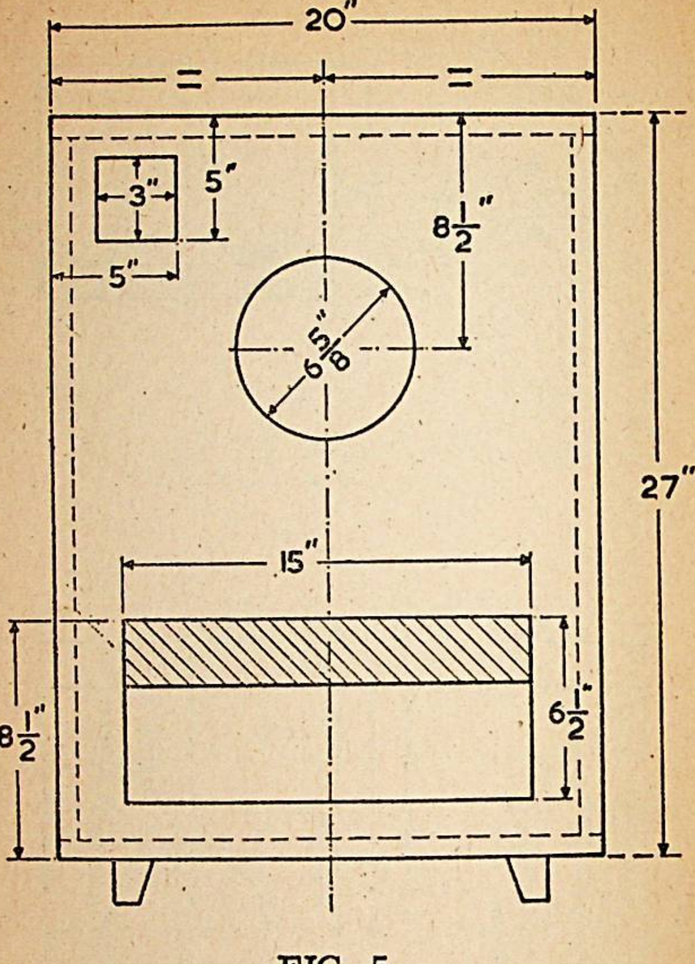
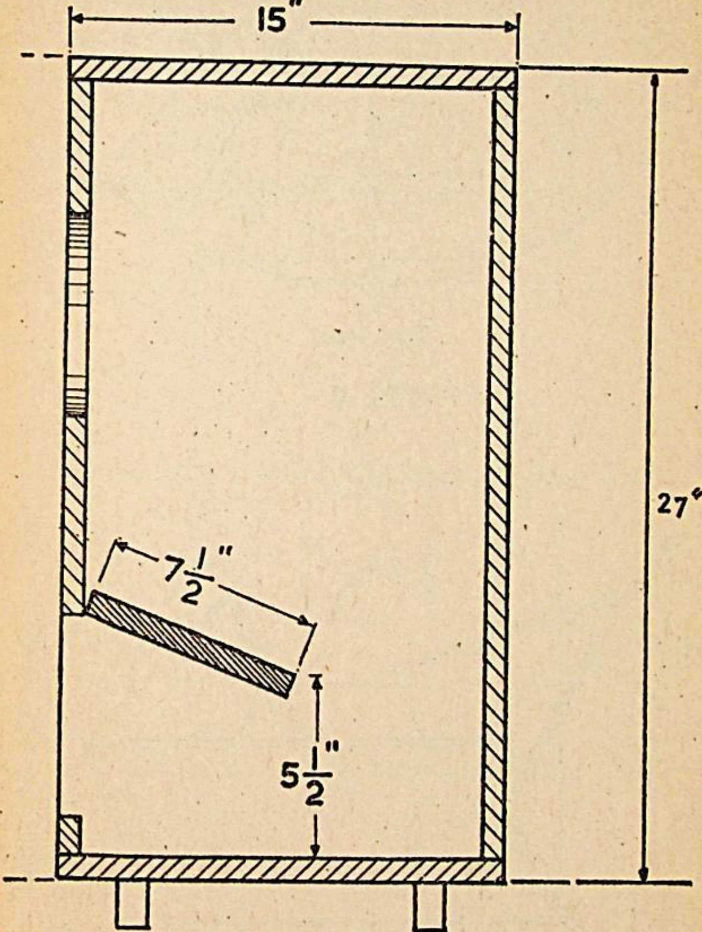
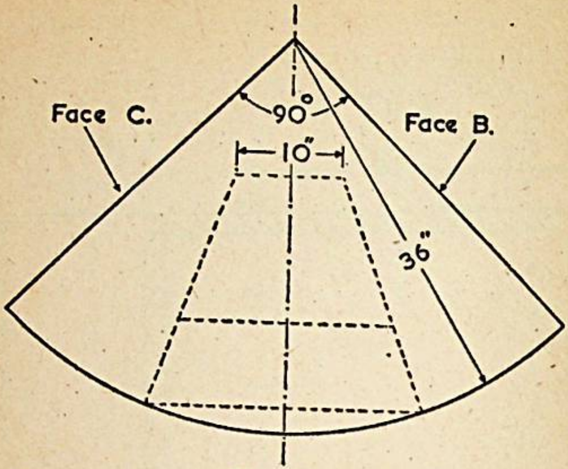


FIG 5

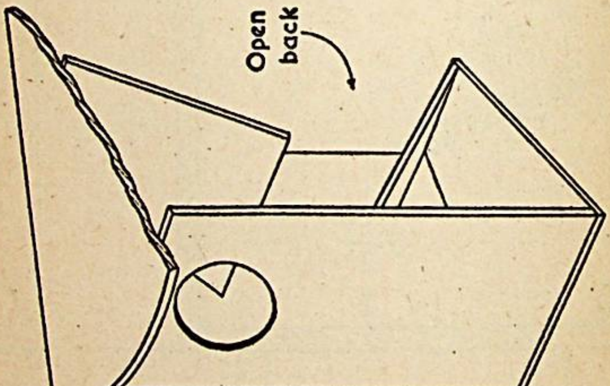
FIG 5





Top view.

FIG 6



Perspective view with one side open.

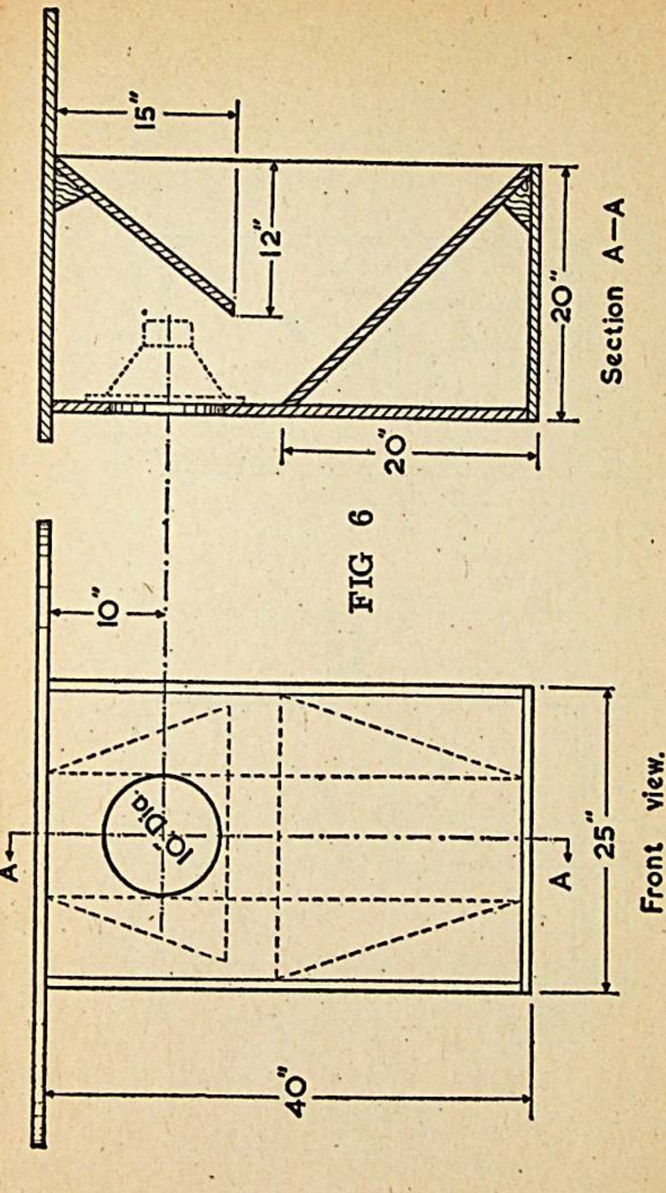


FIG 6

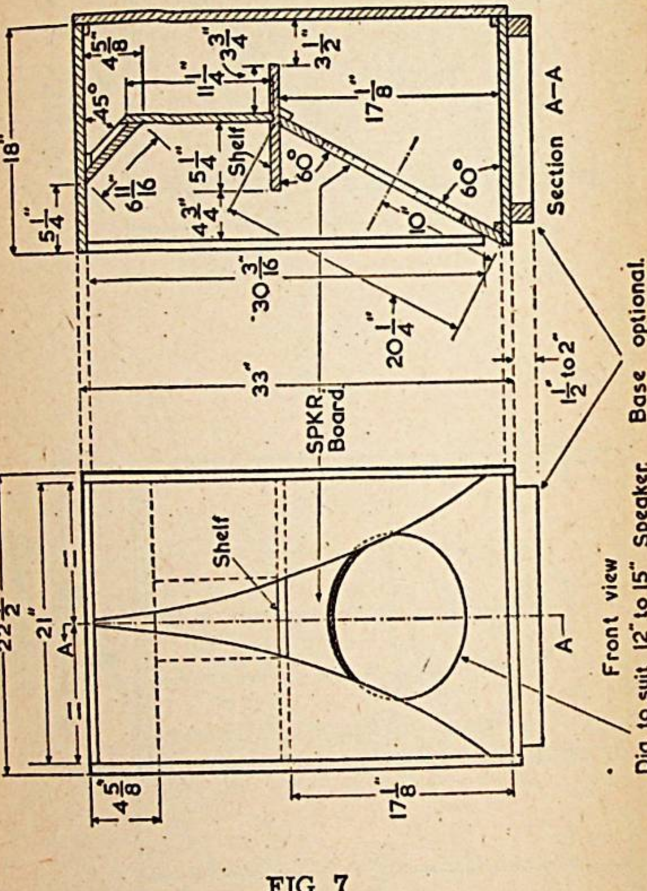
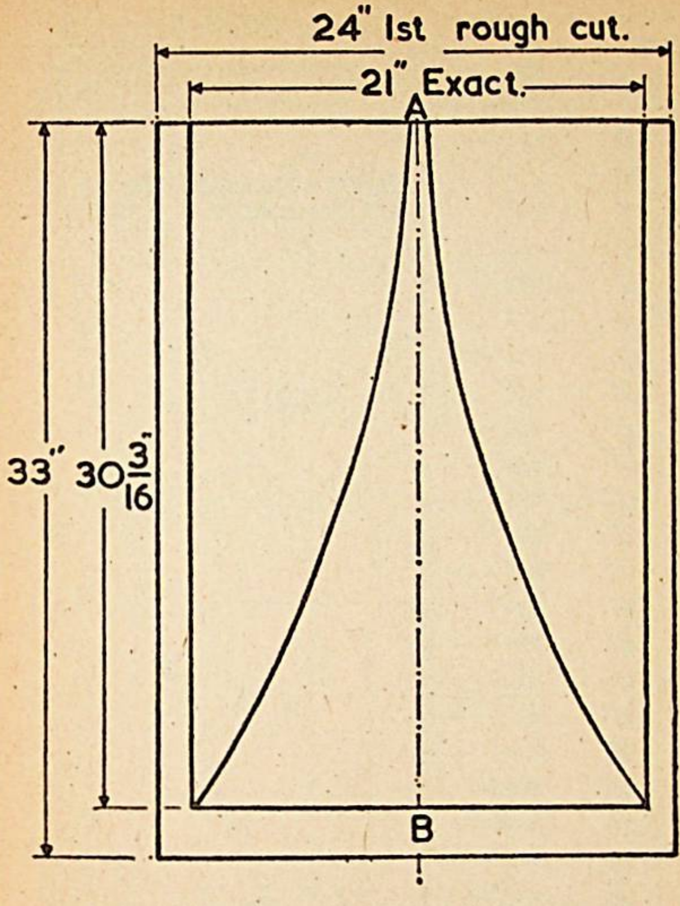

Section A–A
Shelf
SPKR. Board
Front view
Dia. to suit 12" to 15" Speaker.
Base optional.

FIG 7



Taper front pieces.

FIG 7

Height from top.	Dimension. "A"
0	10·4"
1"	10·27"
2"	10·24"
3"	10·18"
4"	10·10"
5"	10·0"
6"	9·88"
7"	9·74"
8"	9·56"
9"	9·39"
10"	9·18"
11"	8·94"
12"	8·69"
13"	8·41"
14"	8·12"
15"	7·79"
16"	7·45"
17"	7·09"
18"	6·7"
19"	6·29"
20"	5·85"
21"	5·43"
22"	4·92"
23"	4·41"
24"	3·91"
25"	3·36"
26"	2·81"
27"	2·21"
28"	1·6"
29"	0·98"
30"	0·33"
30·1875"	Nil.

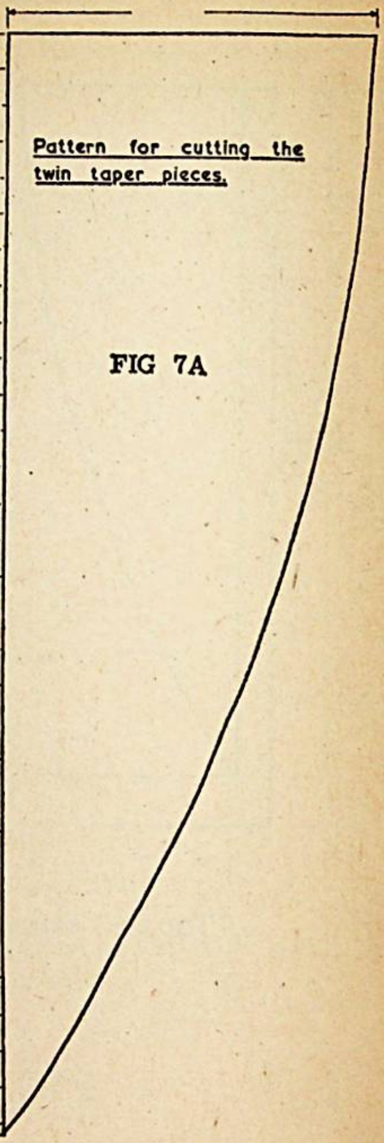
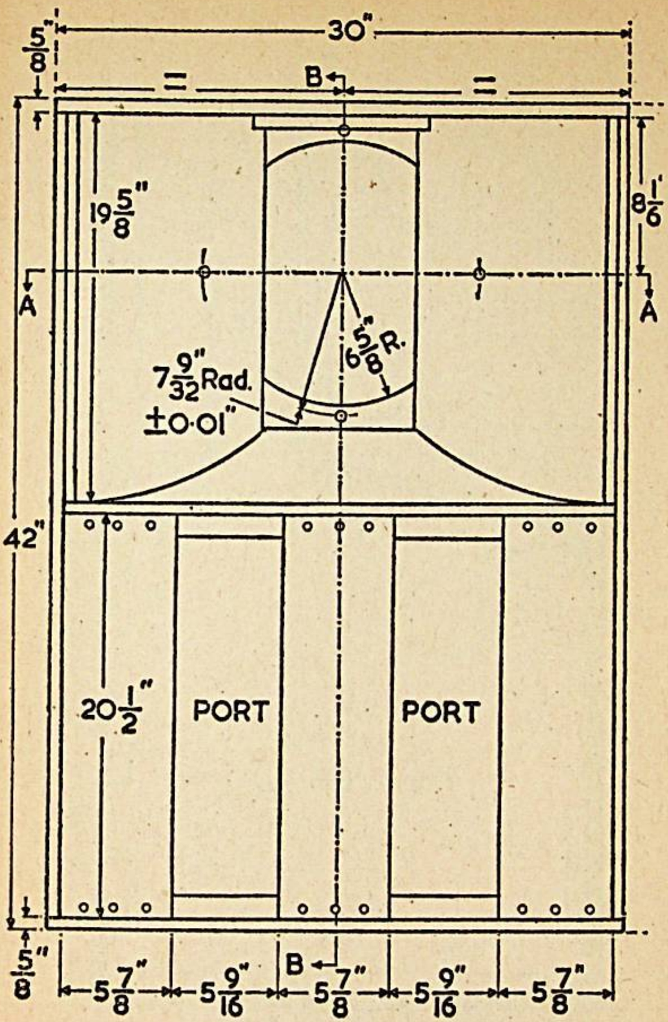


FIG 7A



30"
5/8"
=
B
=
19 5/8"
8 1/6'
A
A
6 5/8" R.
7 9/32" Rad.
±0·01"
42"
20 1/2"
PORT
PORT
5/8"
B
5 7/8"
5 9/16"
5 7/8"
5 9/16"
5 7/8"

FIG 8

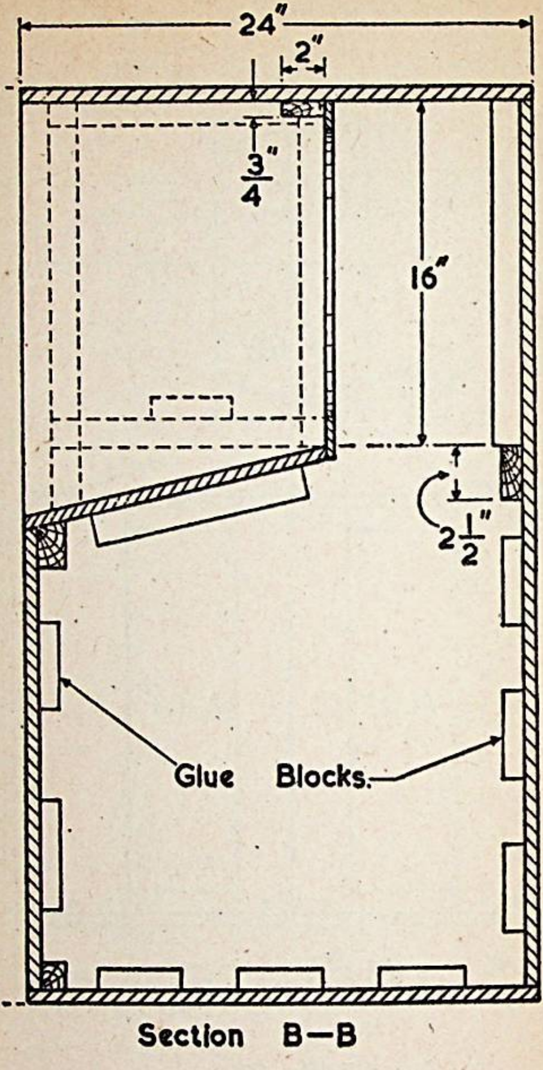


FIG 8

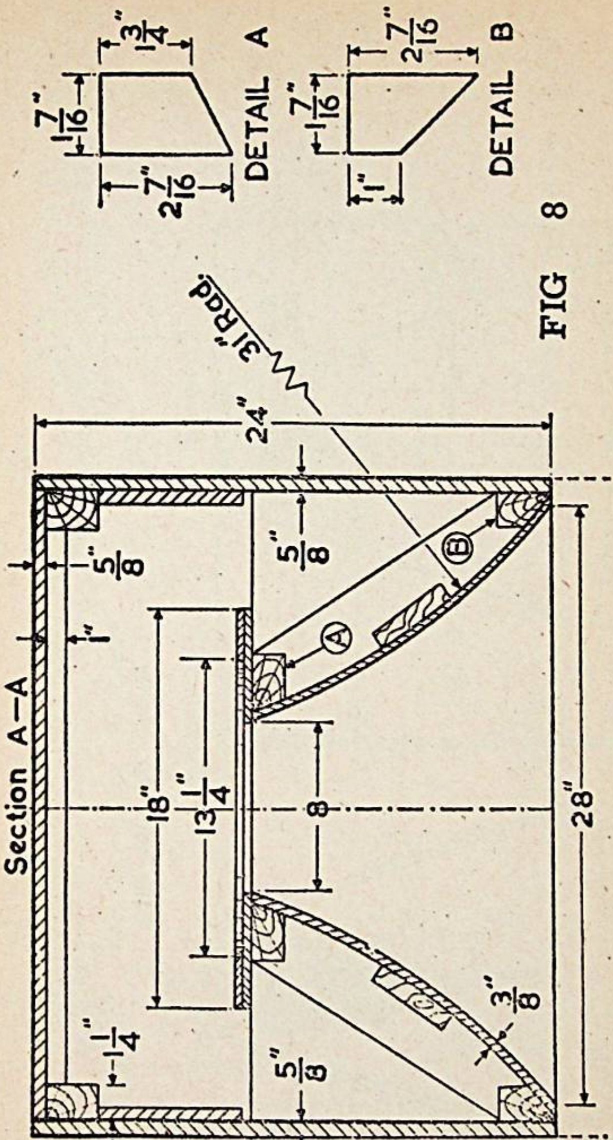

Section A—A
5/8"
1"
1 1/4"
18"
13 1/4"
8
5/8"
5/8"
3/8"
24"
28"
14"
31" Rad.
A
B
1 7/16"
2 7/16"
3/4"
DETAIL A
1 7/16"
1"
2 7/16"
DETAIL B

FIG 8

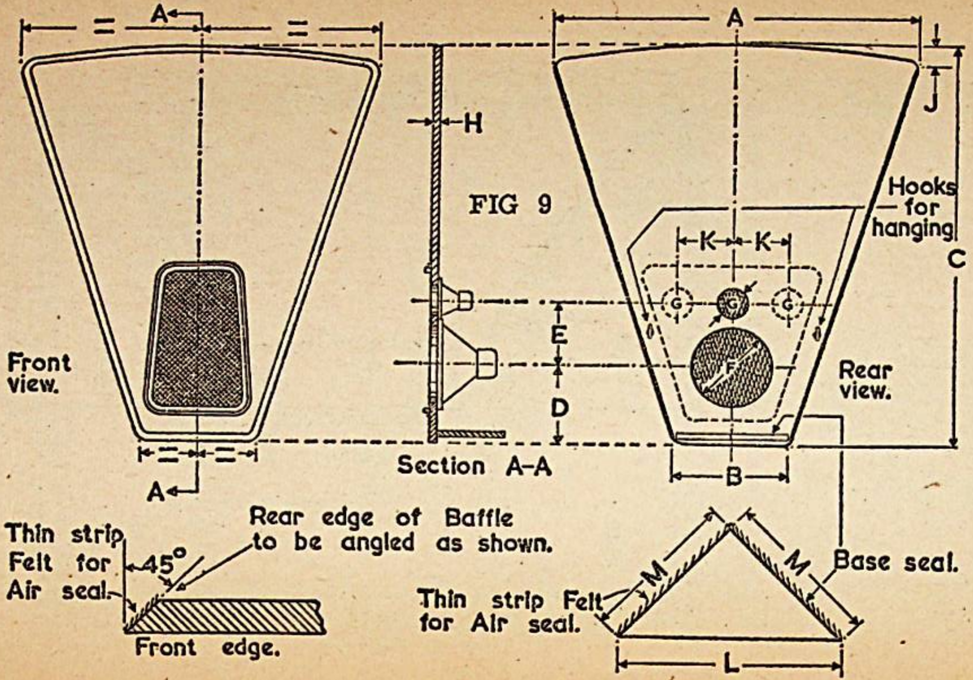

A
A
=
=
H
Front view.
Section A-A
Hooks for hanging
J
C
K
K
G
G
G
F
E
D
B
Rear view.
Rear edge of Baffle to be angled as shown.
Thin strip Felt for Air seal.
45°
Front edge.
M
M
Base seal.
Thin strip Felt for Air seal.
L

FIG 9

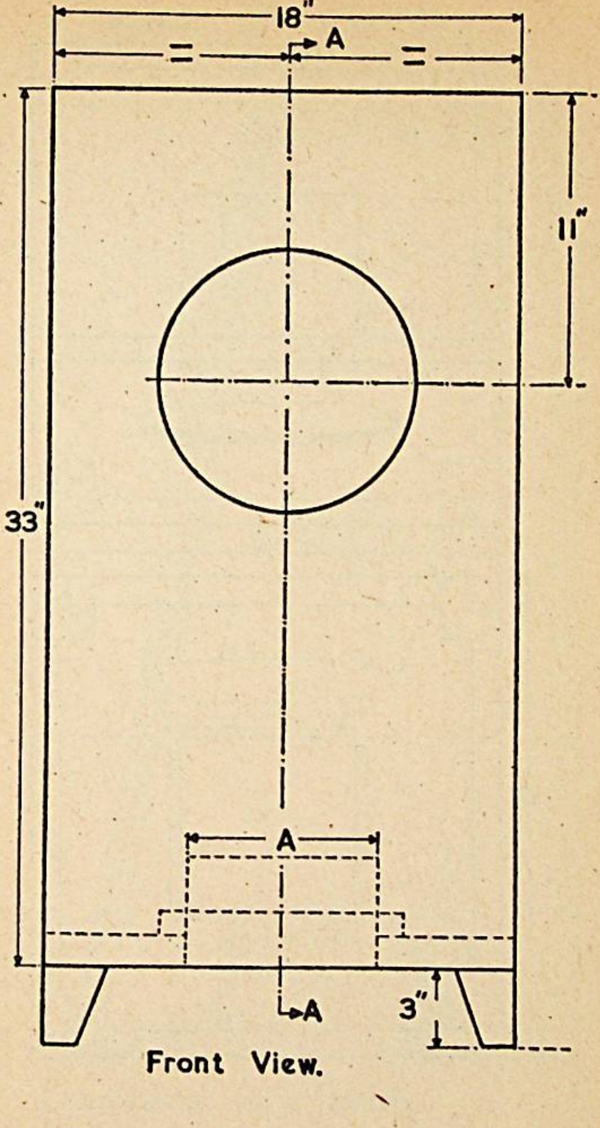


FIG 10

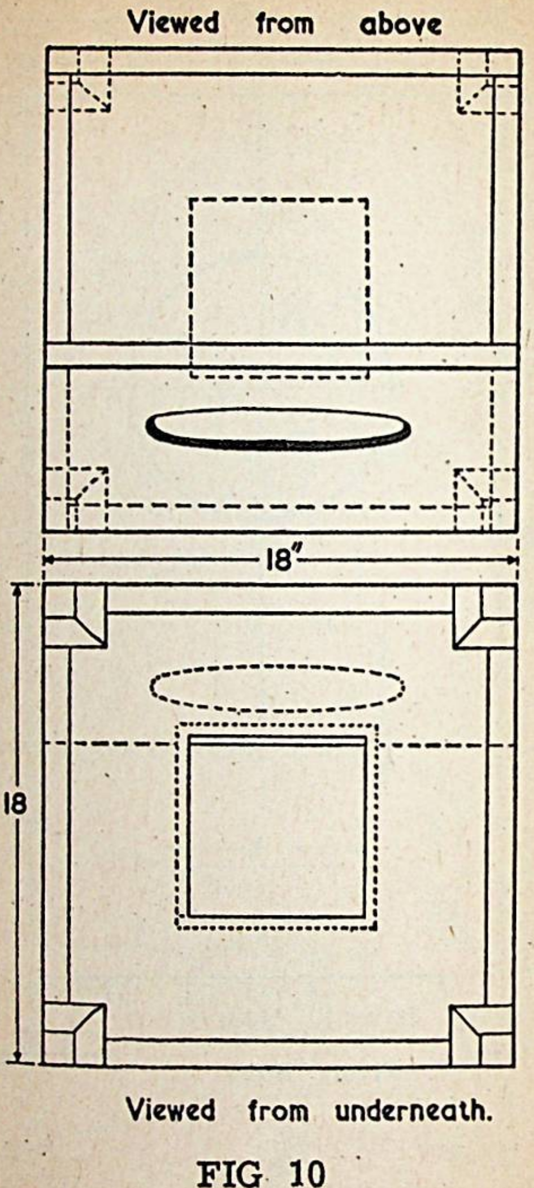


FIG 10

Section. A A

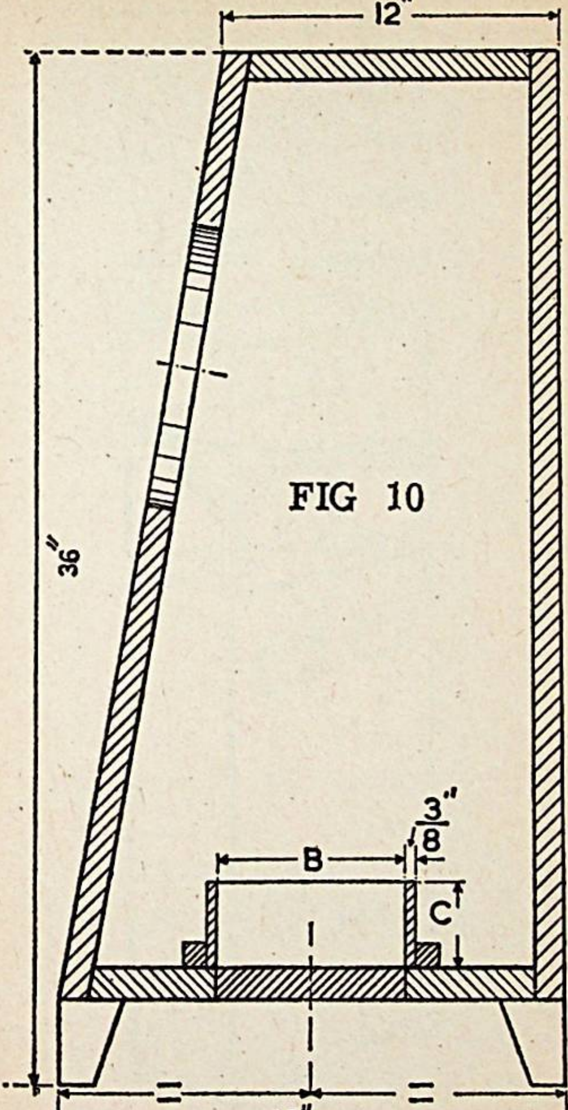


FIG 10

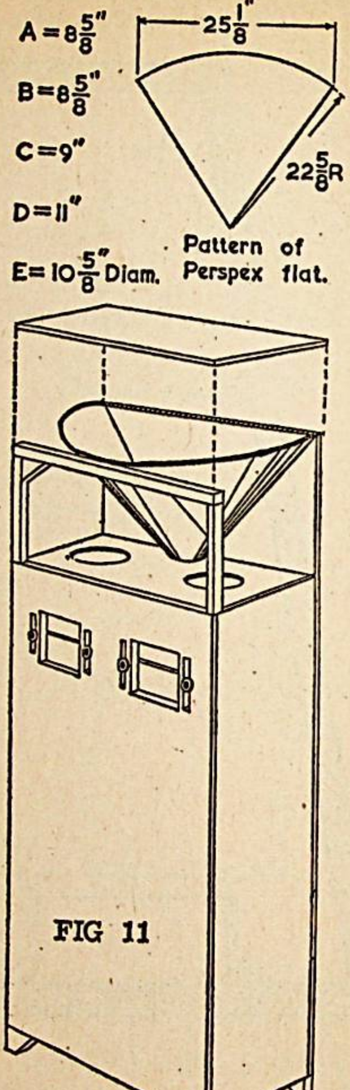
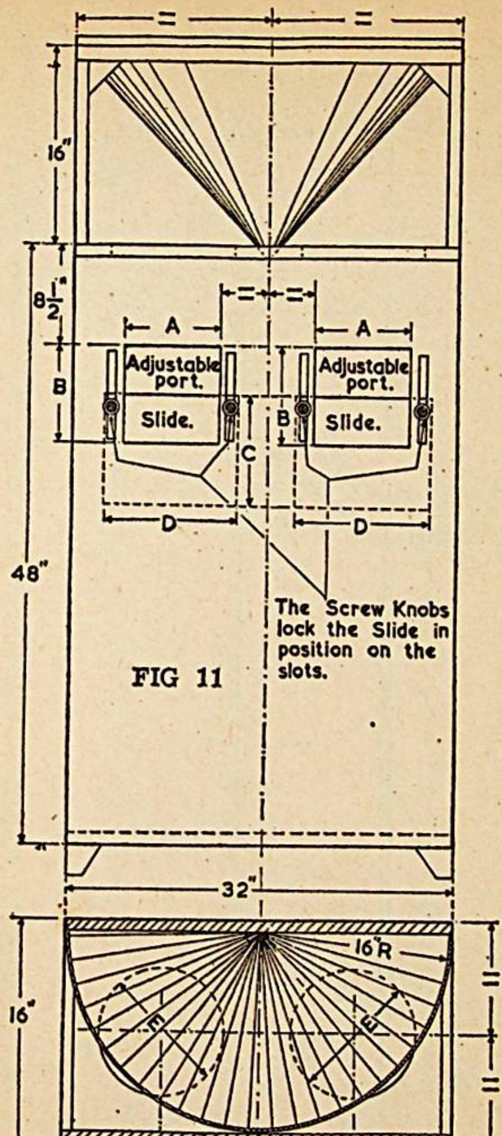

A = $8\frac{5}{8}$"
B = $8\frac{5}{8}$"
C = 9"
D = 11"
E = $10\frac{5}{8}$" Diam.
$25\frac{1}{8}$"
$22\frac{5}{8}$R
Pattern of Perspex flat.

FIG 11



16"
8 1/2"
A
A
Adjustable port.
Adjustable port.
B
B
Slide.
Slide.
C
D
D
48"
The Screw Knobs lock the Slide in position on the slots.
32"
16"R
16"
E
E

FIG 11

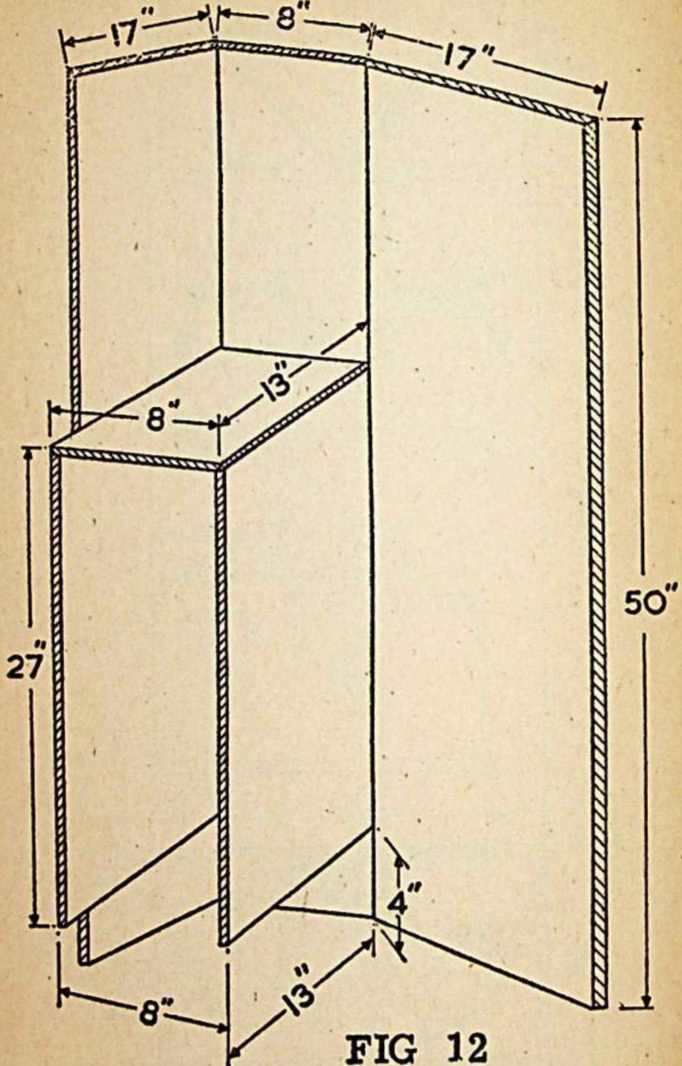


FIG 12

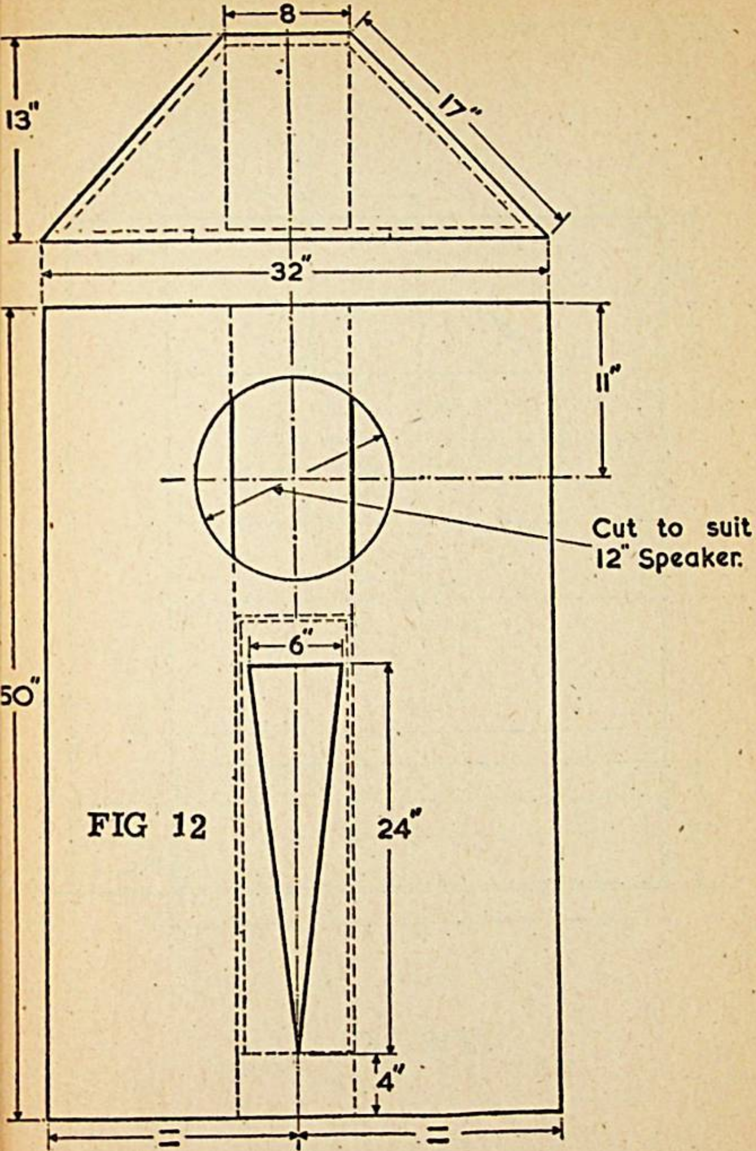


FIG 12

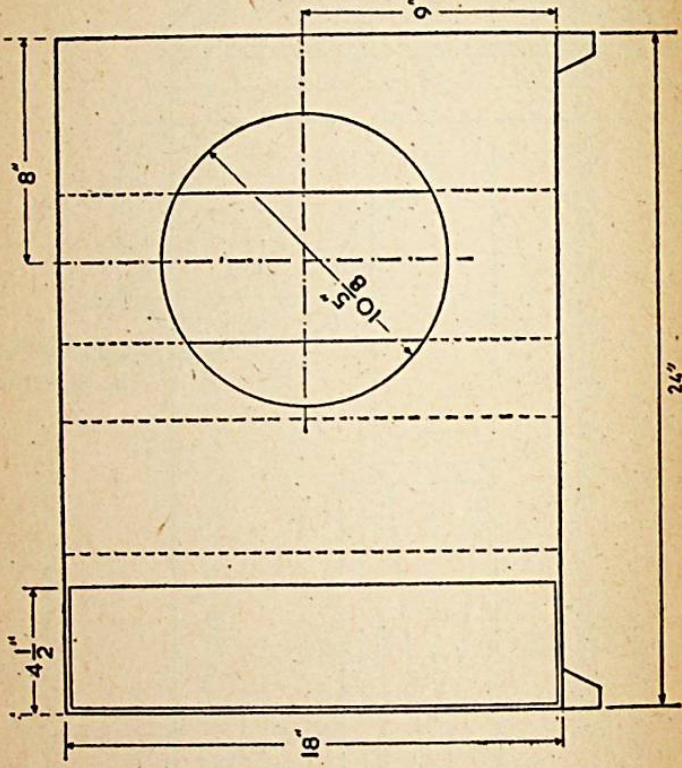


FIG 13

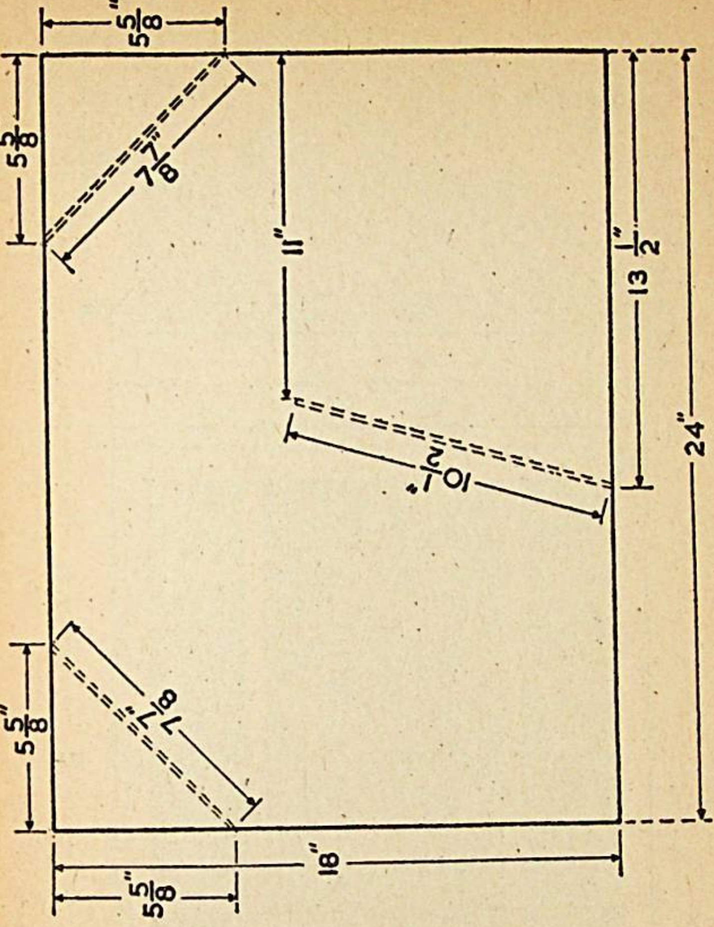
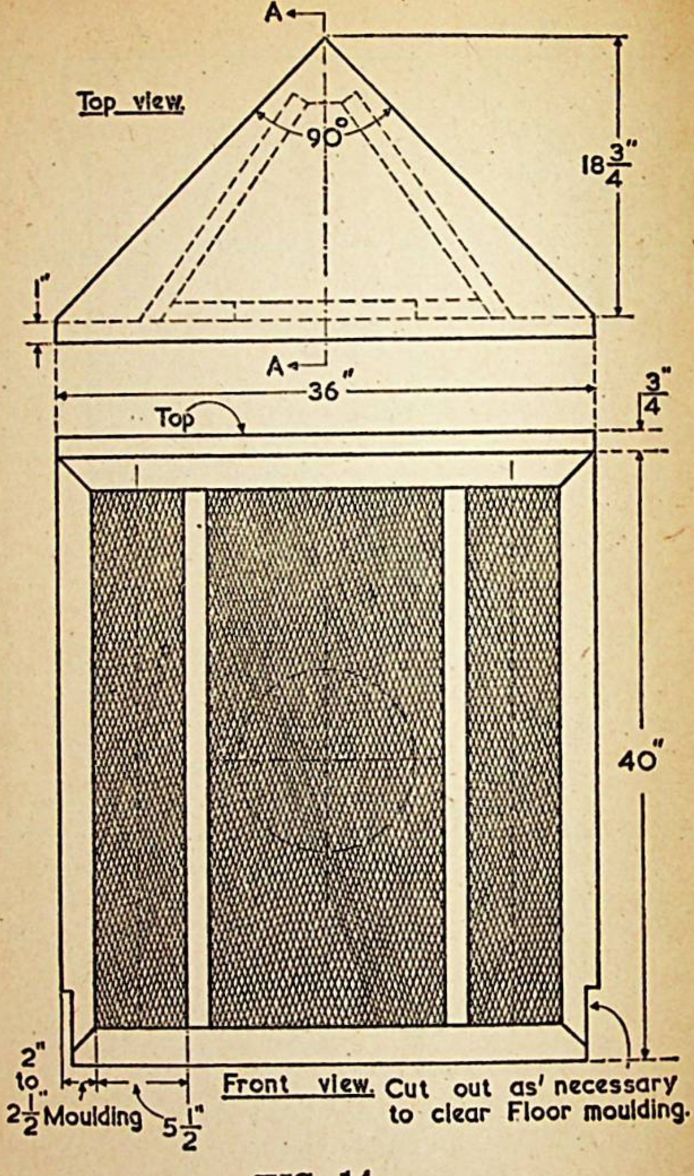
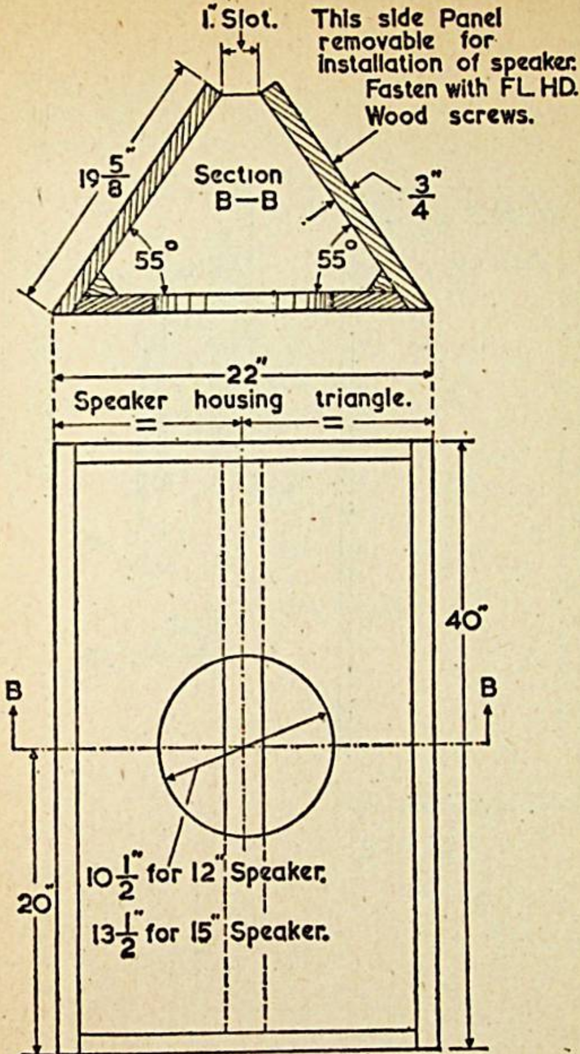


FIG 13



A
Top view.
90°
18 3/4"
1"
A
36"
3/4
Top
40"
2" to 2 1/2 Moulding
5 1/2"
Front view.
Cut out as necessary to clear Floor moulding.

FIG 14



This view with top & front Frame removed.

FIG 14

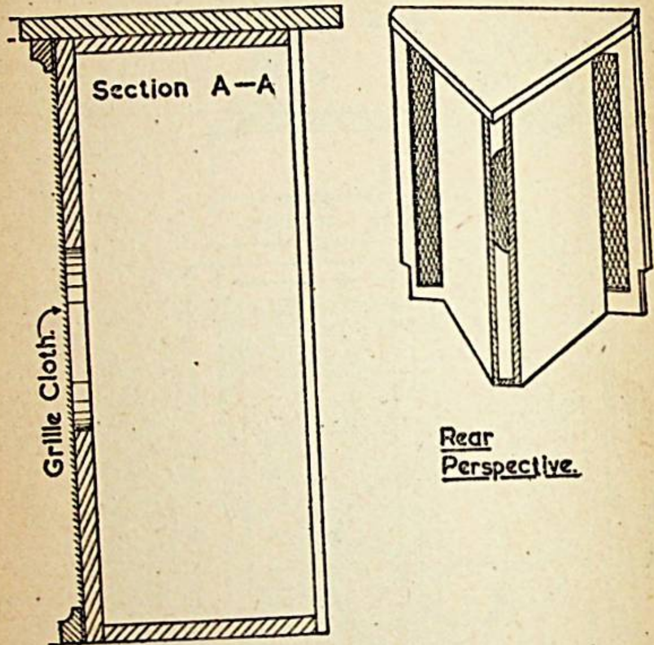


FIG 14

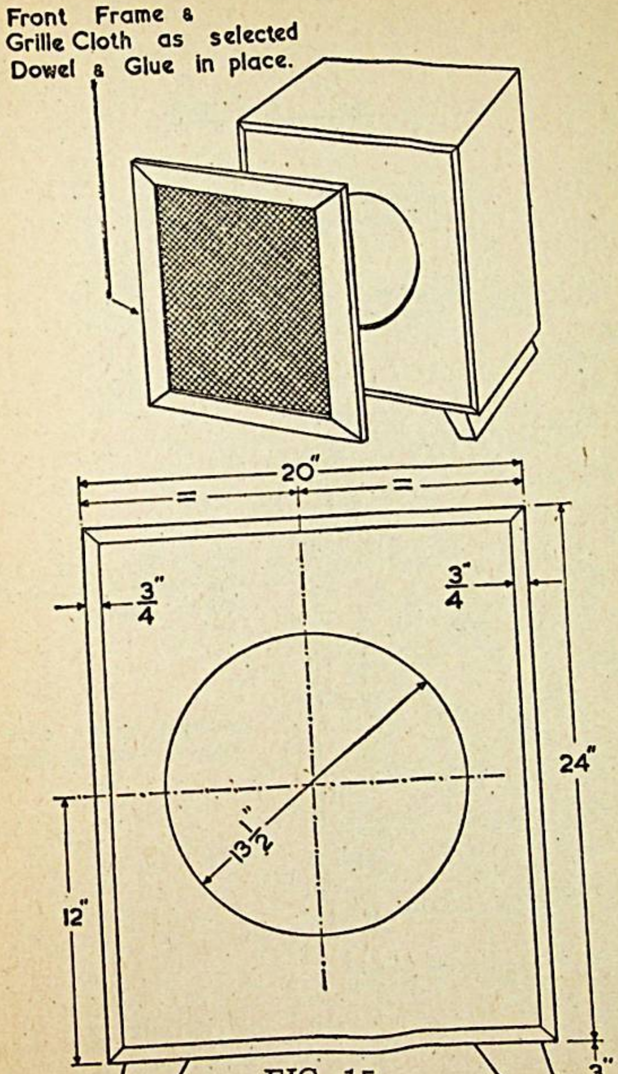

Front Frame & Grille Cloth as selected Dowel & Glue in place.
20"
=
=
3"/4
3"/4
24"
12"
13 1/2"
3"

FIG 15

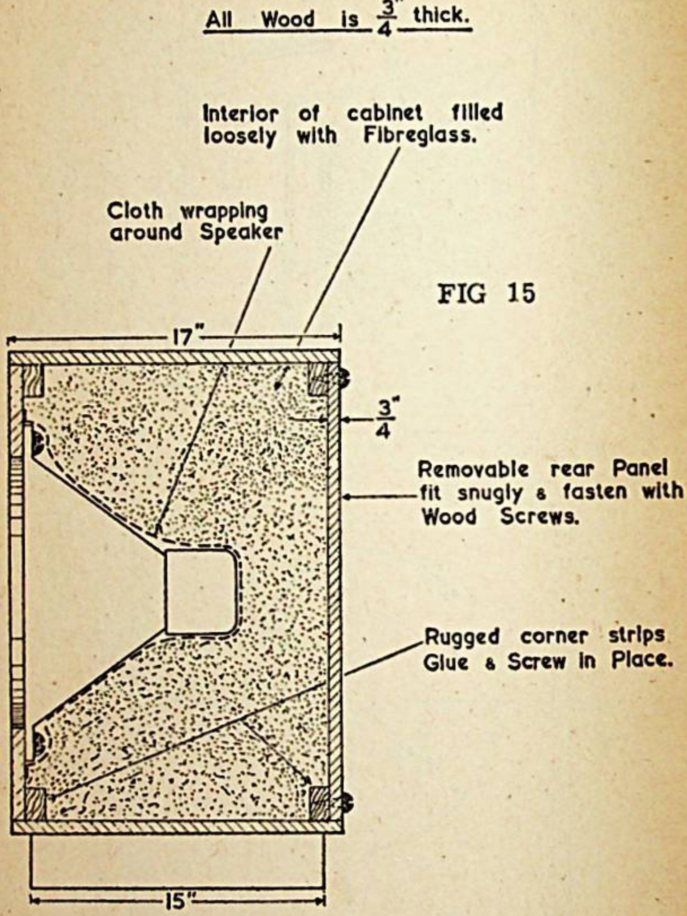

All Wood is 3/4" thick.
Interior of cabinet filled loosely with Fibreglass.
Cloth wrapping around Speaker
17"
3/4"
Removable rear Panel fit snugly & fasten with Wood Screws.
Rugged corner strips Glue & Screw in Place.
15"

FIG 15

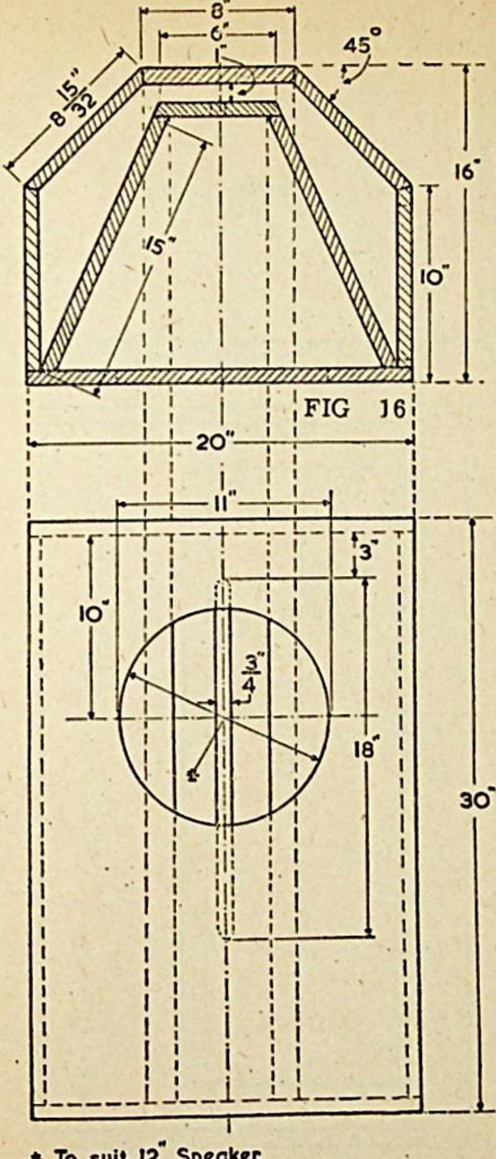


FIG 16

* To suit 12" Speaker.

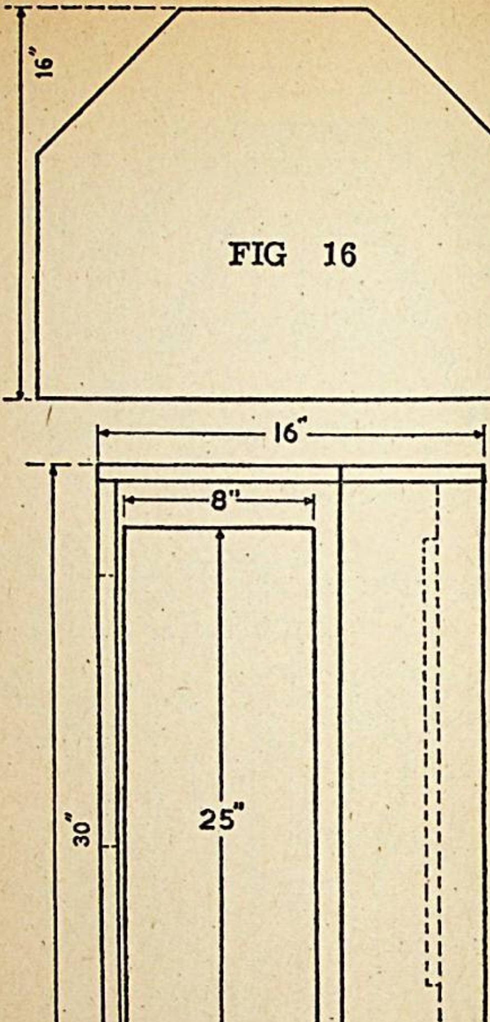


FIG 16

Dimension	Speaker Size		
	8″	10″	12″
"A"	To suit tweeter diameter.		
"B"	6¾″	8.7/16″	10⅞″
"C"	18″	22½″	24″
"D"	24″	30″	36″
"E"	12″	15″	16″
"F"	8″	10″	12″
"G"	9″	10½″	12″
"H"	5″	6¼″	7½″
"J"	5″	6¼″	7½″

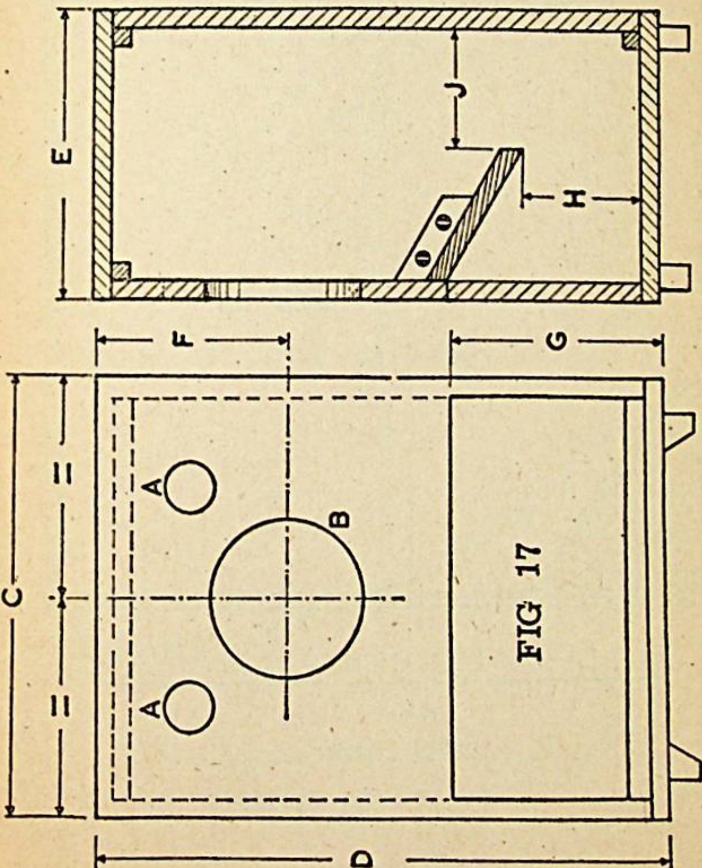


FIG 17

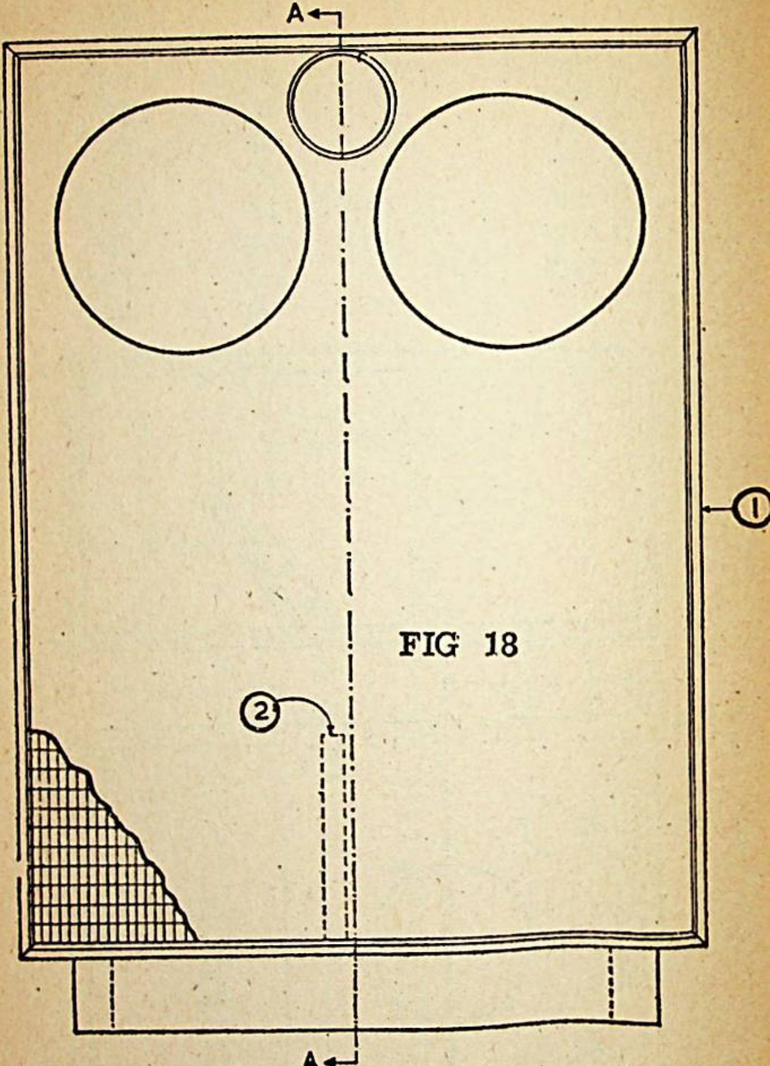
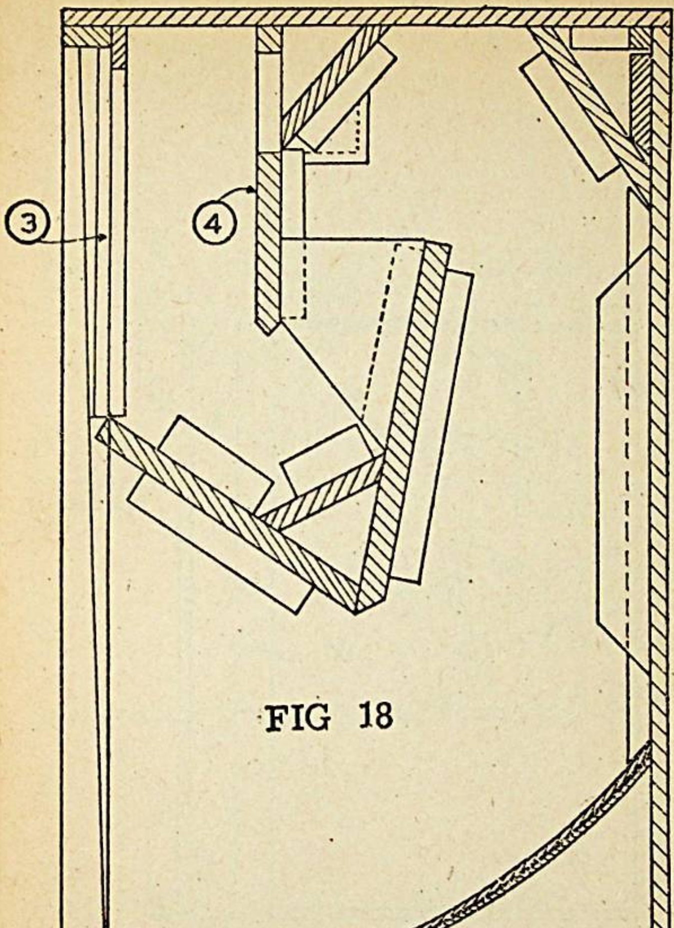


FIG 18

Front view.



Section A—A

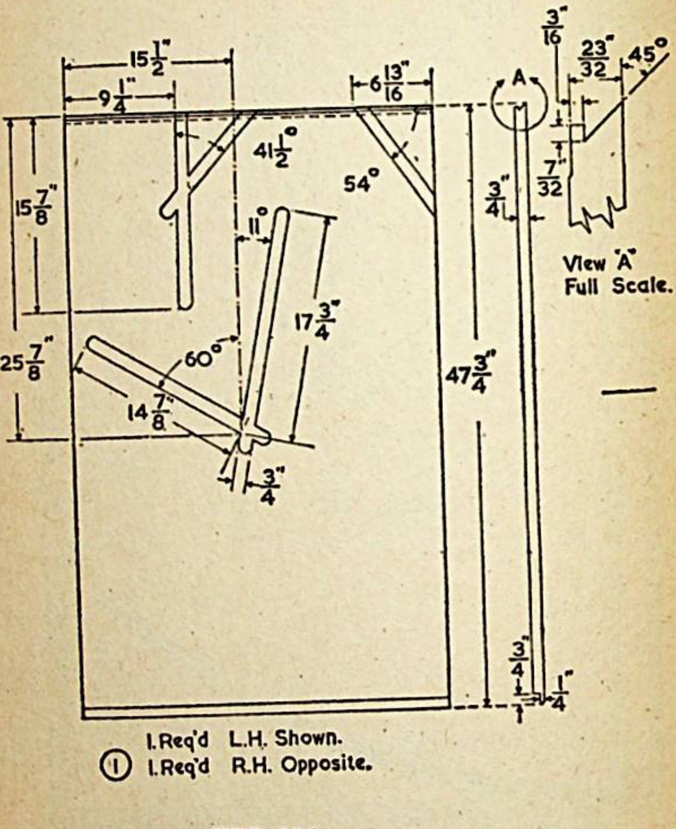

15 1/2"
9 1/4"
6 13/16"
3/16"
23/32"
45°
A
41 1/2°
54°
15 7/8
11°
17 3/4"
3/4"
7/32"
View "A"
Full Scale.
25 7/8"
60°
14 7/8"
47 3/4"
3/4"
3/4"
1/4"
1.Req'd L.H. Shown.
1.Req'd R.H. Opposite.

FIG 18A

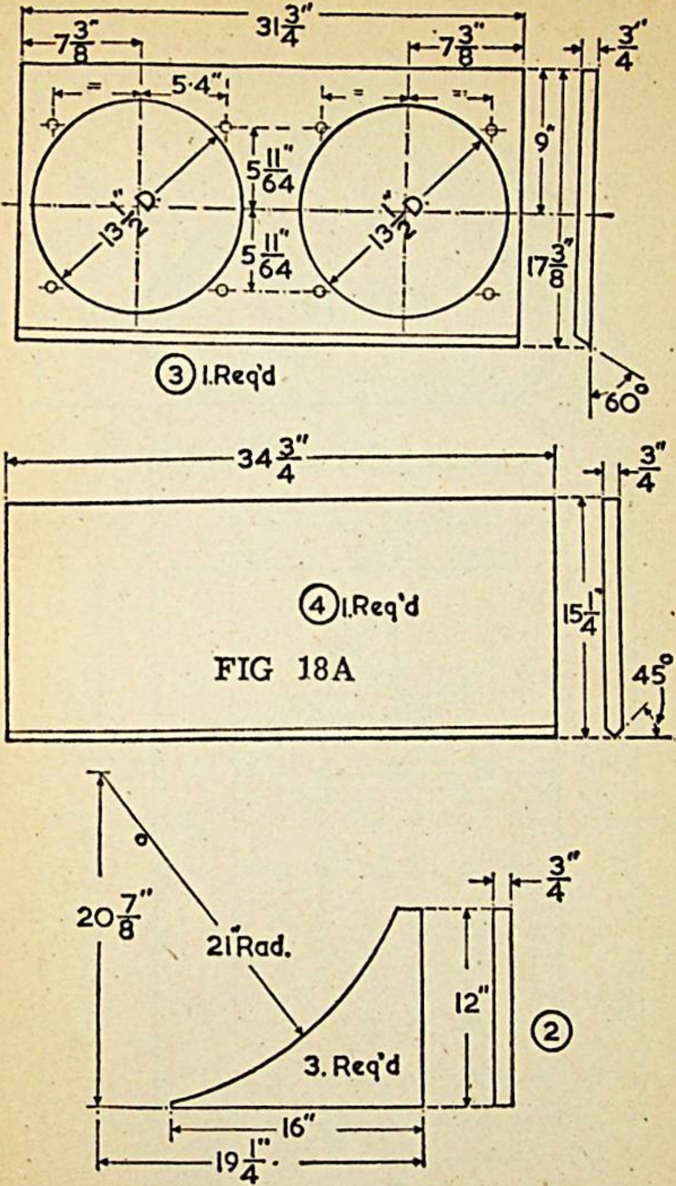
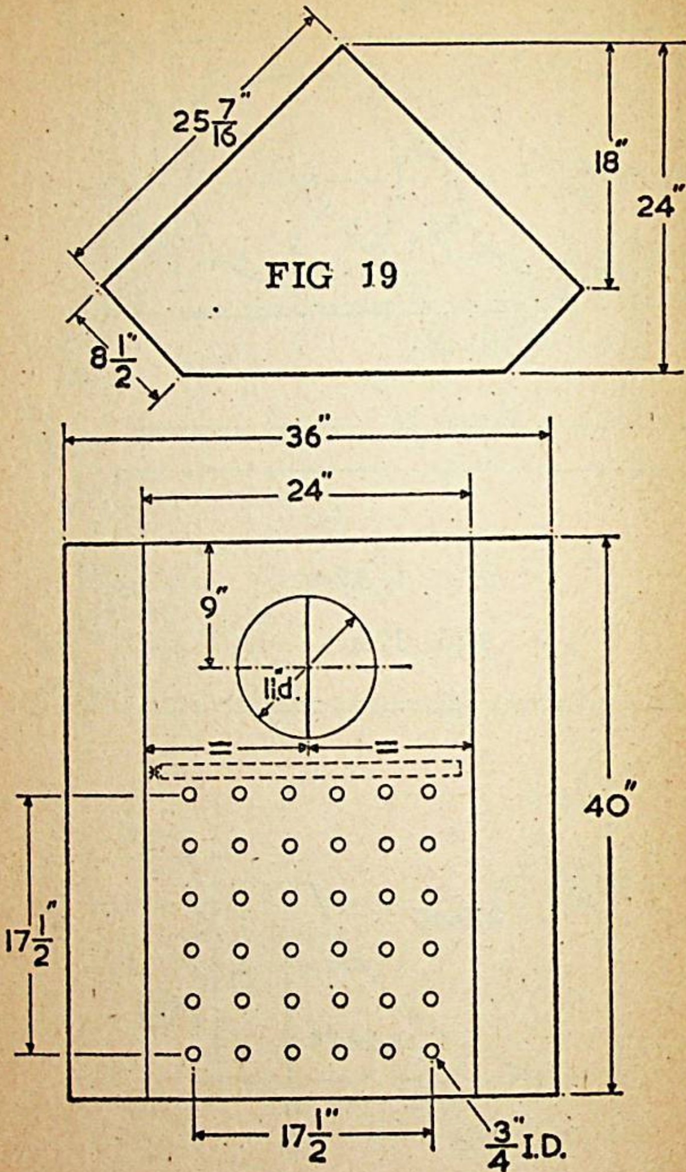
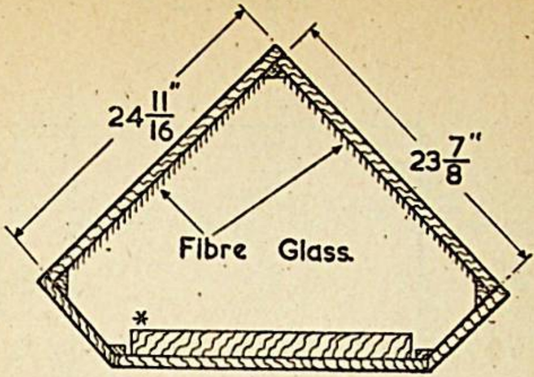

31 3/4"
7 3/8"
7 3/8"
3/4"
5·4"
5 11/64
5 11/64
13 1/2" D.
13 1/2" D.
9"
17 3/8"
60°
3 1.Req'd
34 3/4"
3/4"
4 1.Req'd
15 1/4"
45°
20 7/8"
21" Rad.
3/4"
12"
2
3. Req'd
16"
19 1/4"

FIG 18A

FIG 19





Internal view.

* 1.x2. Brace, place 1" surface againt panel.

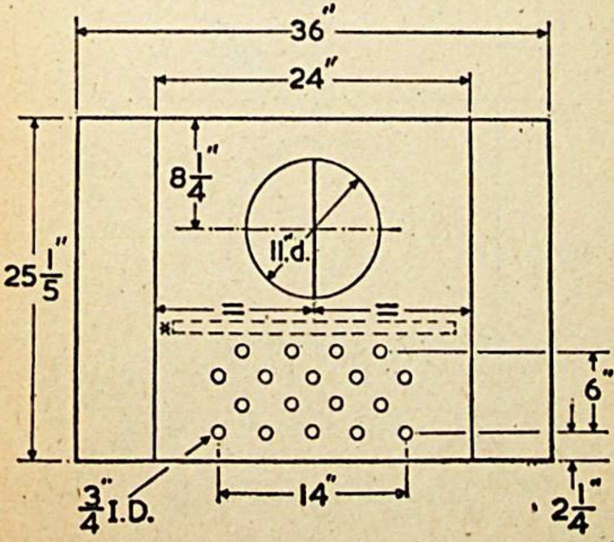
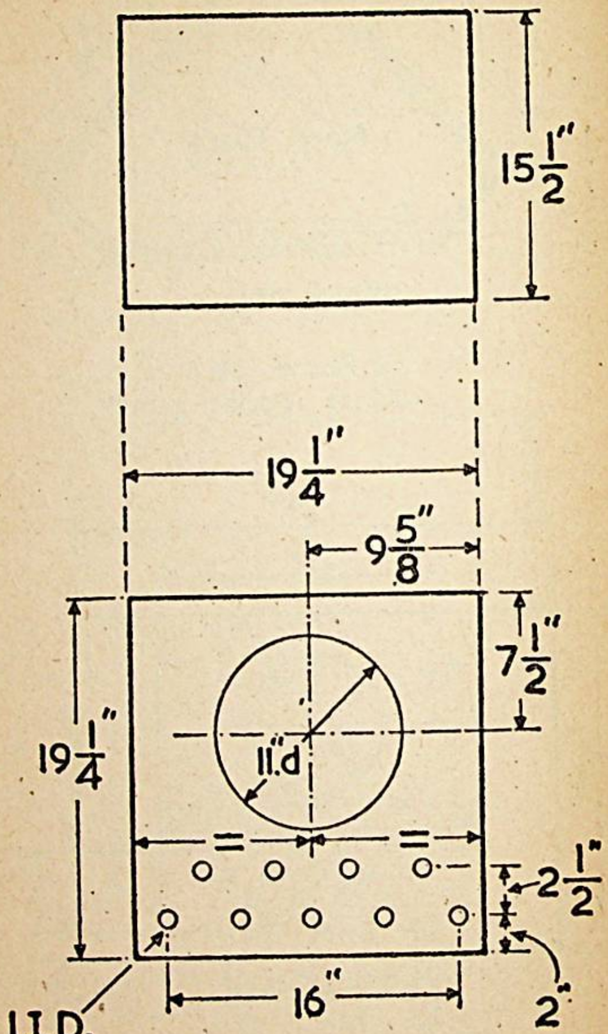
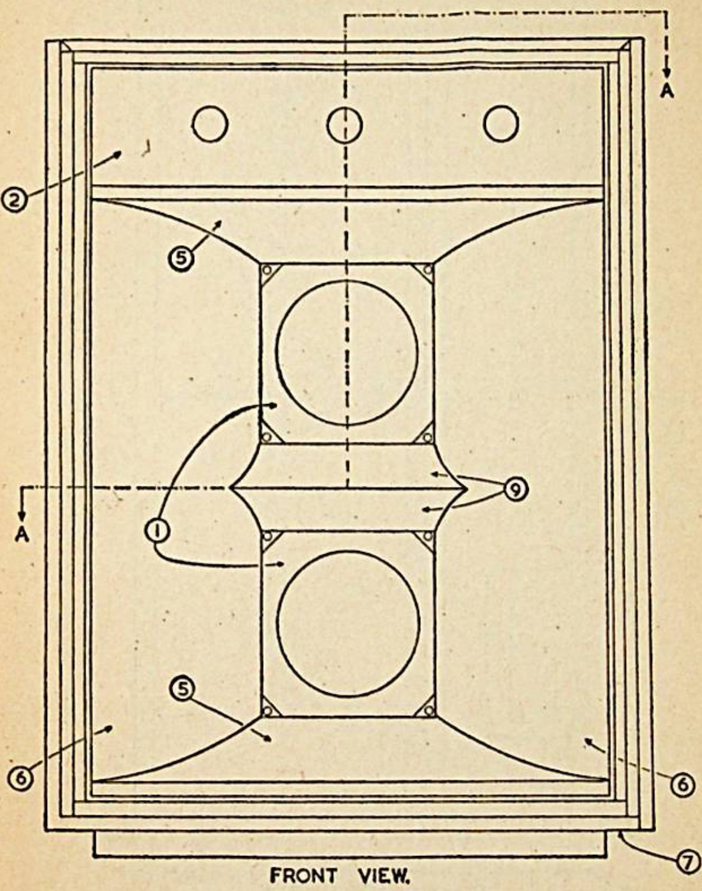


FIG 19

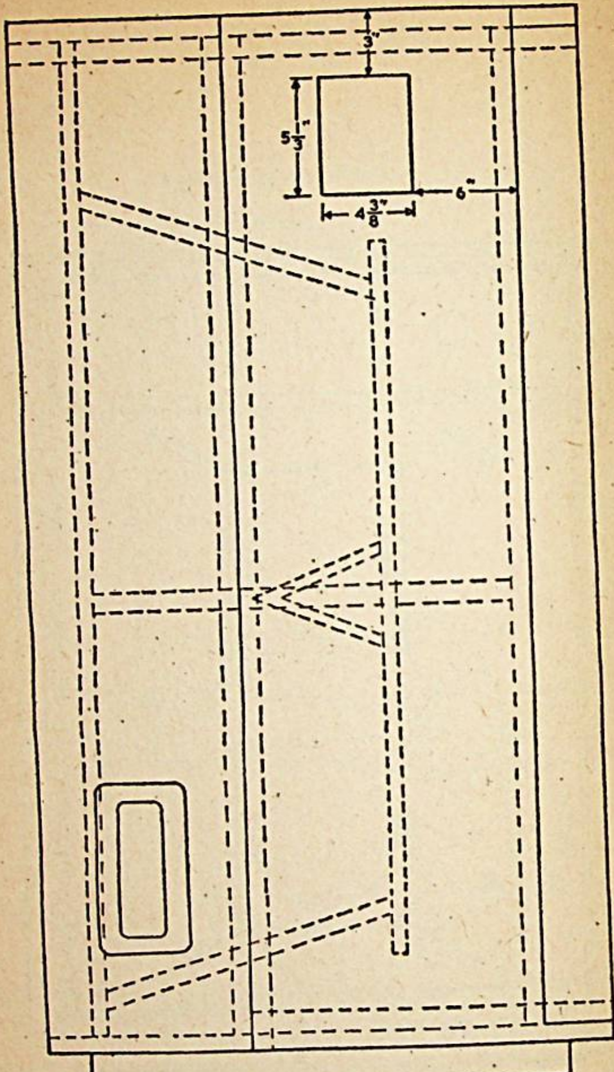
FIG 19





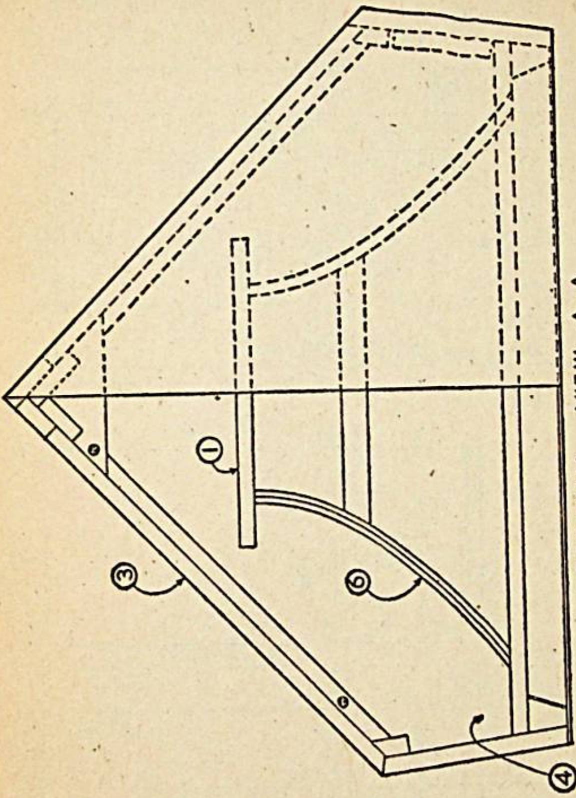
FRONT VIEW.

FIG 20



R.H. SIDE VIEW.

FIG 20



SECTIONAL VIEW A-A

FIG 20A

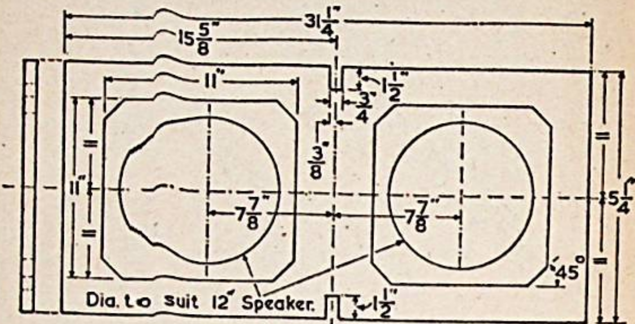
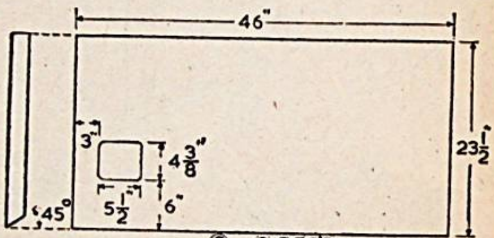
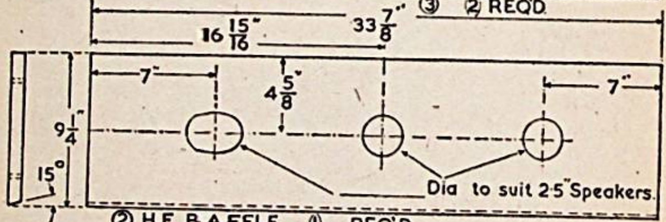


FIG 20A ① L.F. BAFFLE (1) REQ'D.



③ (2) REQ'D



② H.F. BAFFLE (1) REQ'D

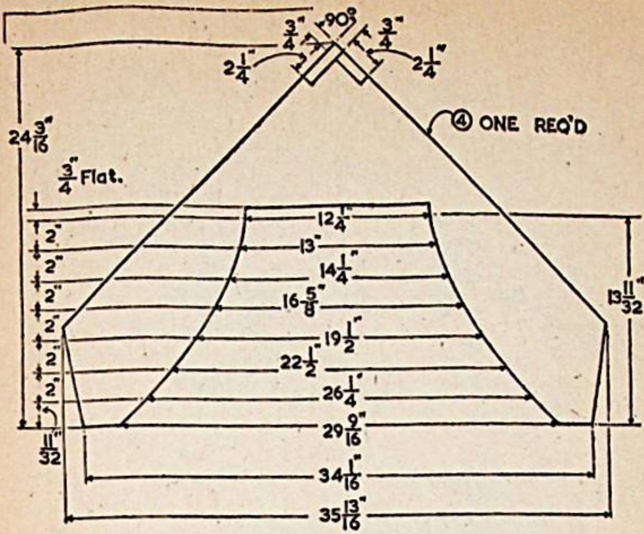
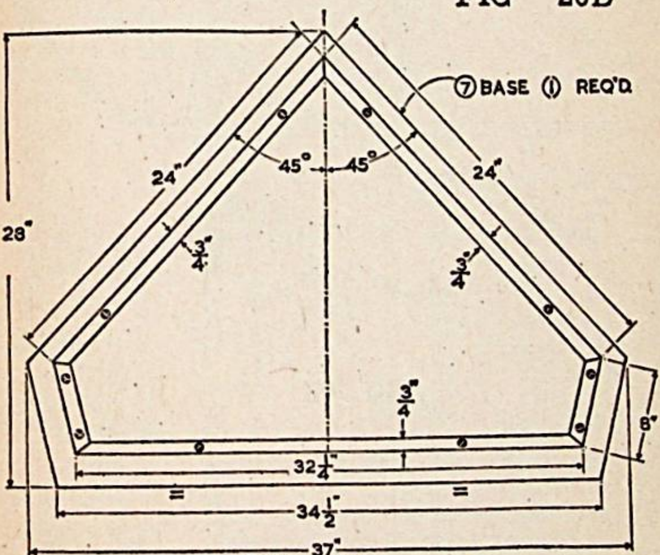


FIG 20B



Bottom View.

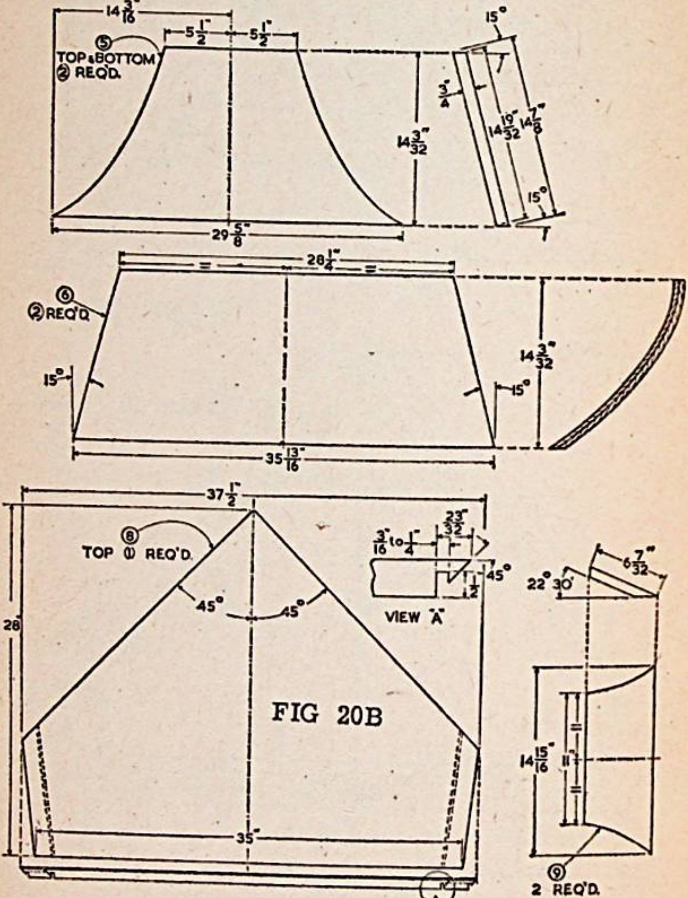
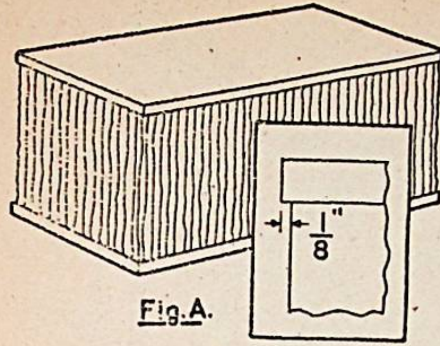


FIG 20B



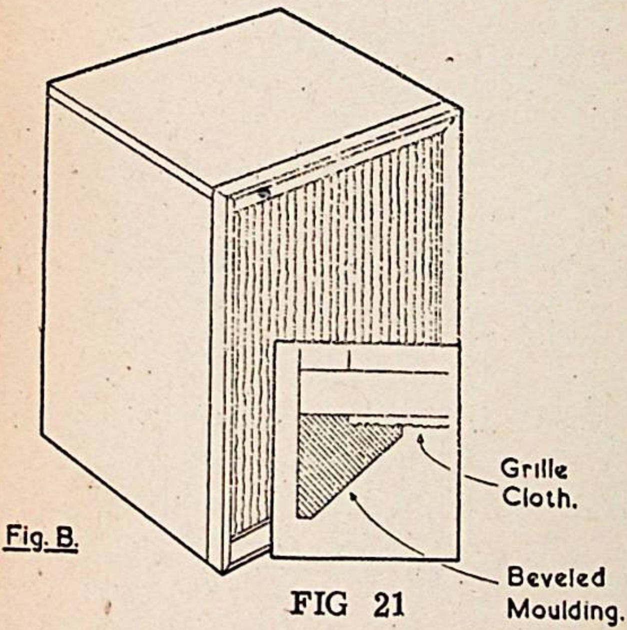


FIG 21

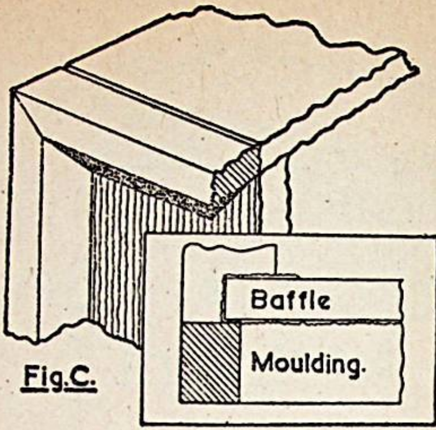


Fig.C.

FIG 21

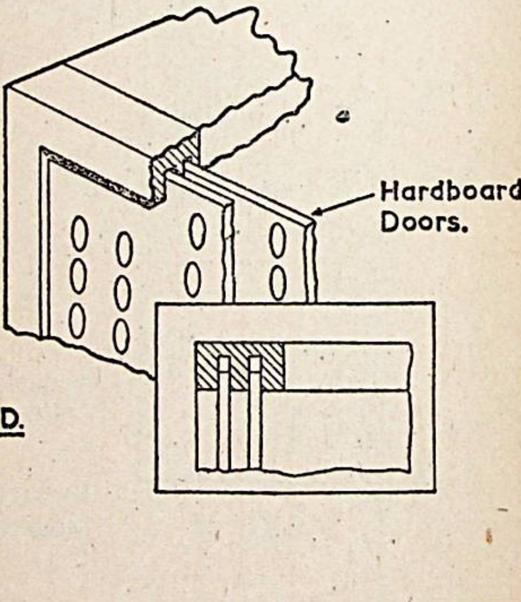


Fig.D.

Fig. A.

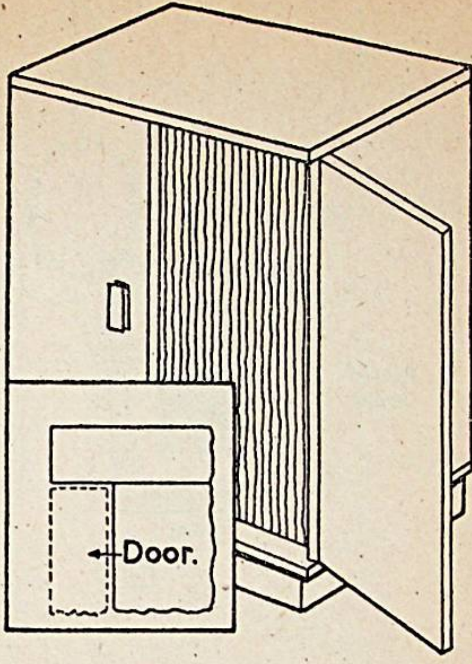


FIG 22

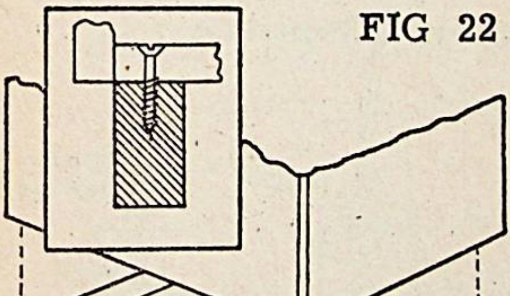


Fig. D.

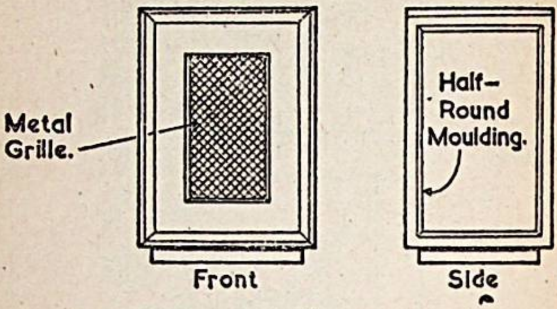


Fig. B.

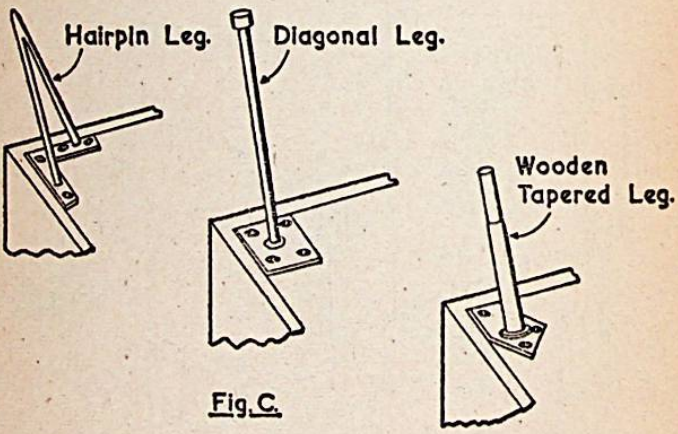


Fig. C.

FIG 22

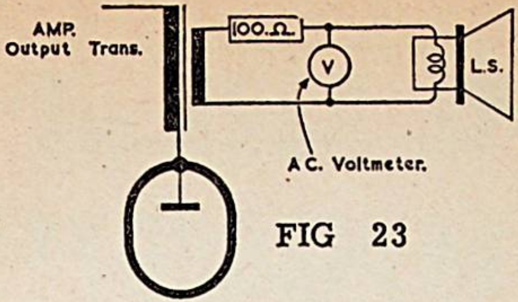


FIG 23

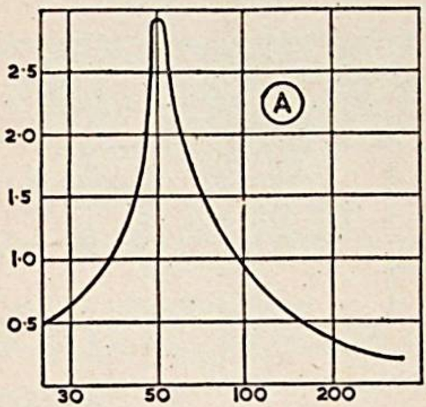
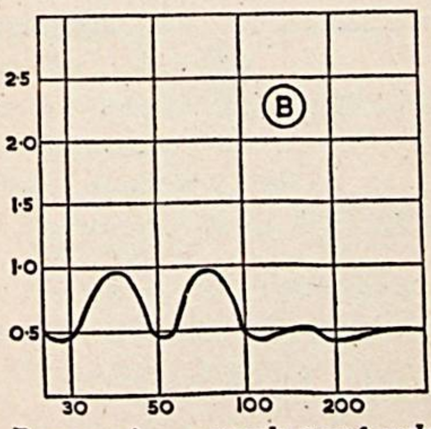


FIG 24 *Free air resonant peak.*



Response from correctly tuned enclosure.

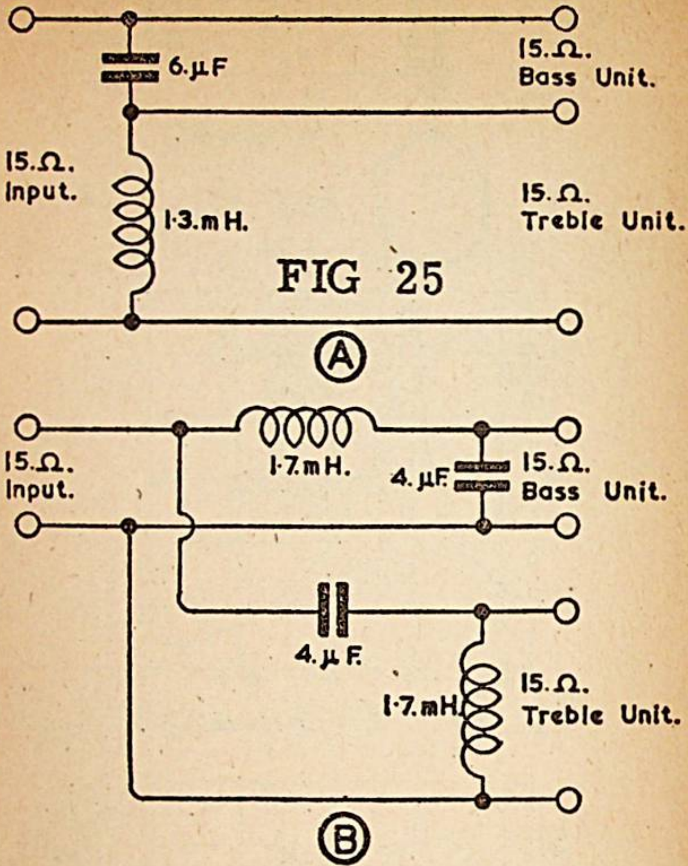

6.µF
15.Ω.
Bass Unit.
15.Ω.
Input.
1·3.mH.
15.Ω.
Treble Unit.
A
15.Ω.
Input.
1·7.mH.
4.µF.
15.Ω.
Bass Unit.
4.µF.
1·7.mH.
15.Ω.
Treble Unit.
B

FIG 25

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