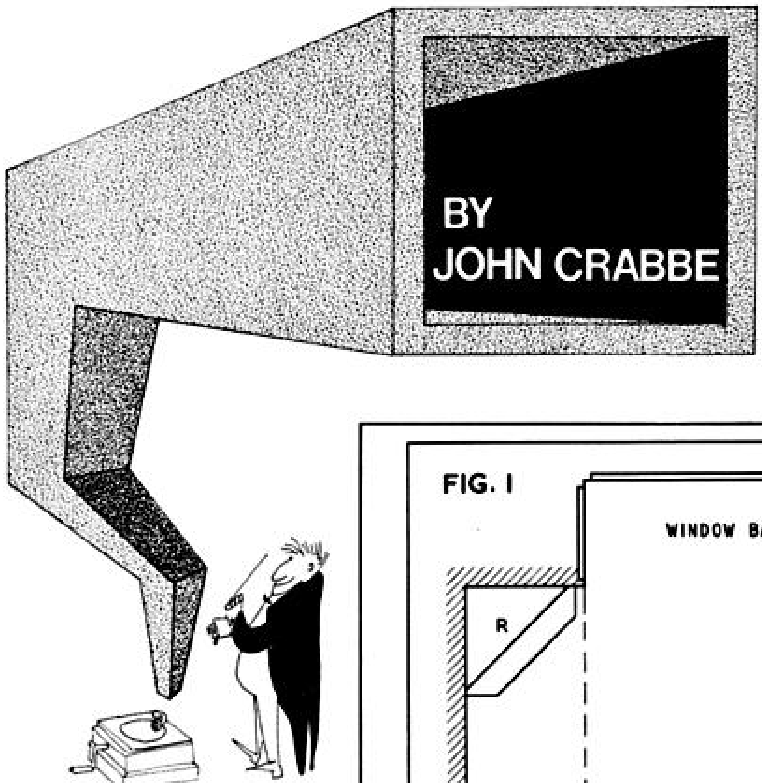


A CONCRETE HORN LOUDSPEAKER SYSTEM MK II

PART I DOWN TO 30HZ

SOME young married couples buy houses on the assumption that they will remain at the same address while rearing a family, probably not selling-up until after retirement. My wife and I did this, carefully choosing that combination of rooms and facilities which matched our supposed long-term requirements. As an act of faith in the rightness of our choice I built the massive concrete horn loudspeaker system described in *Hi-Fi News* in 1961/62; but faith was soon displaced by a sense of irony, for presence of this built-in system eventually helped to sell the house when growth of both family and local traffic noise finally convinced us that you cannot really know what you want of a house until you have lived in one of your own.

And so we moved, putting me back to square-one at the speaker end of the reproducing chain, even though we had made fair progress at the procreative end. With sufficient accommodation in hand—and after a couple of months sweating beneath floors and behind skirtings with multiple ring-mains to the extent of 74 outlets—music and homo sapiens joined hands to celebrate the cause of high fidelity via *both* types of reproductive process, my wife becoming pregnant for the third time practically on the very day that I started work on the Mk. II concrete speaker system—Freudian slip, perhaps? I hope that readers unfamiliar with the earlier design will excuse this preamble, but enthusiasts who followed me through that constructional hurdle (and there were quite a few) deserve some explanation of my apparent treachery.

Arising from the original Lowther-driven horn system, and from hearing really convincing organ pedal tone reproduction for the *first time ever* in Rex Baldock's house, I had decided that the new speakers must have: (a) a response extending down to below 30 Hz; (b) an acoustic path-length difference from drive units to speaker front (for various parts of the audio band) of not greater than about 12 ft; and (c) any resonances positioned in frequency to fall between rather than at the lowest room eigentones.

FIG. 1

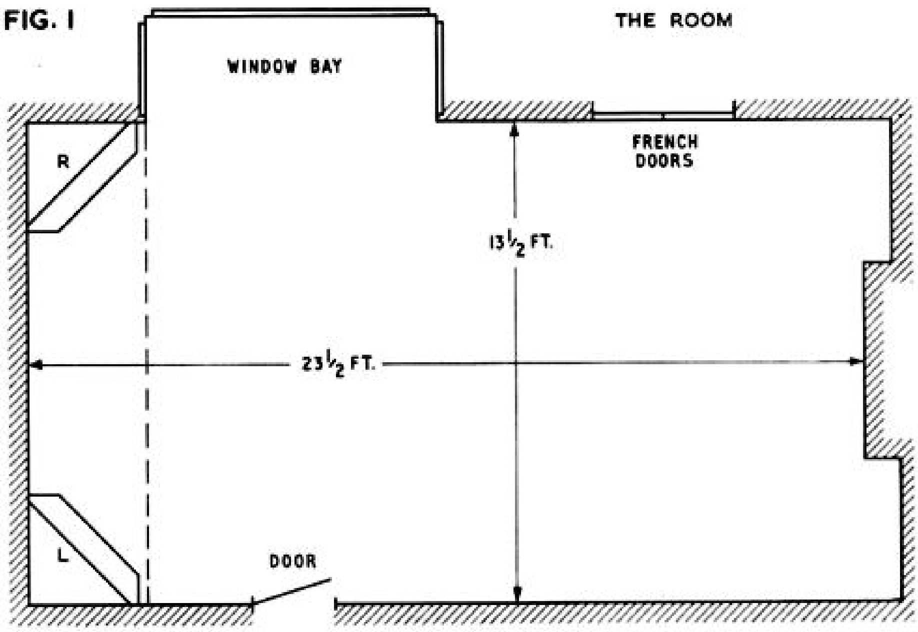
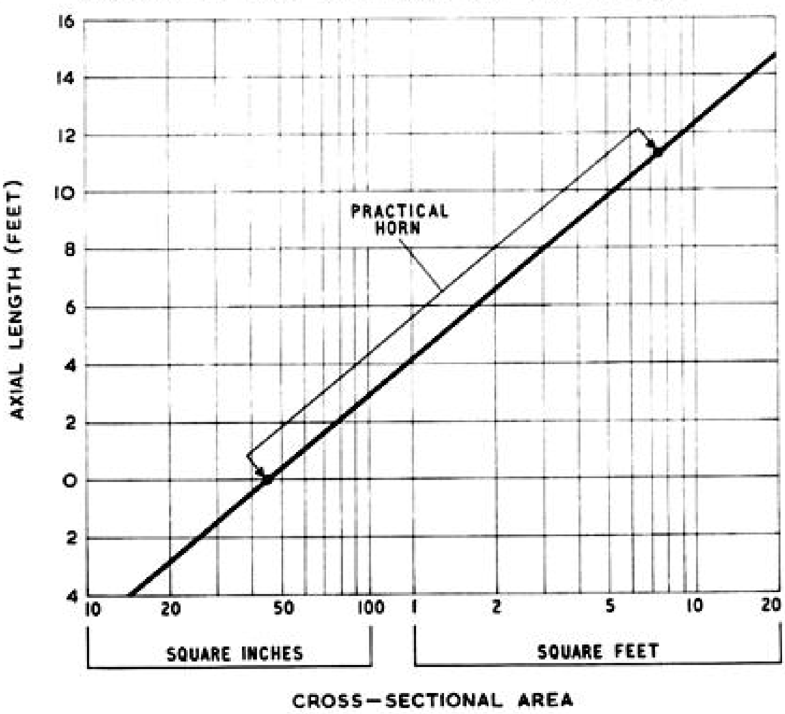


FIG. 2 EXPONENTIAL HORN WITH FLARE CUT-OFF OF 25Hz

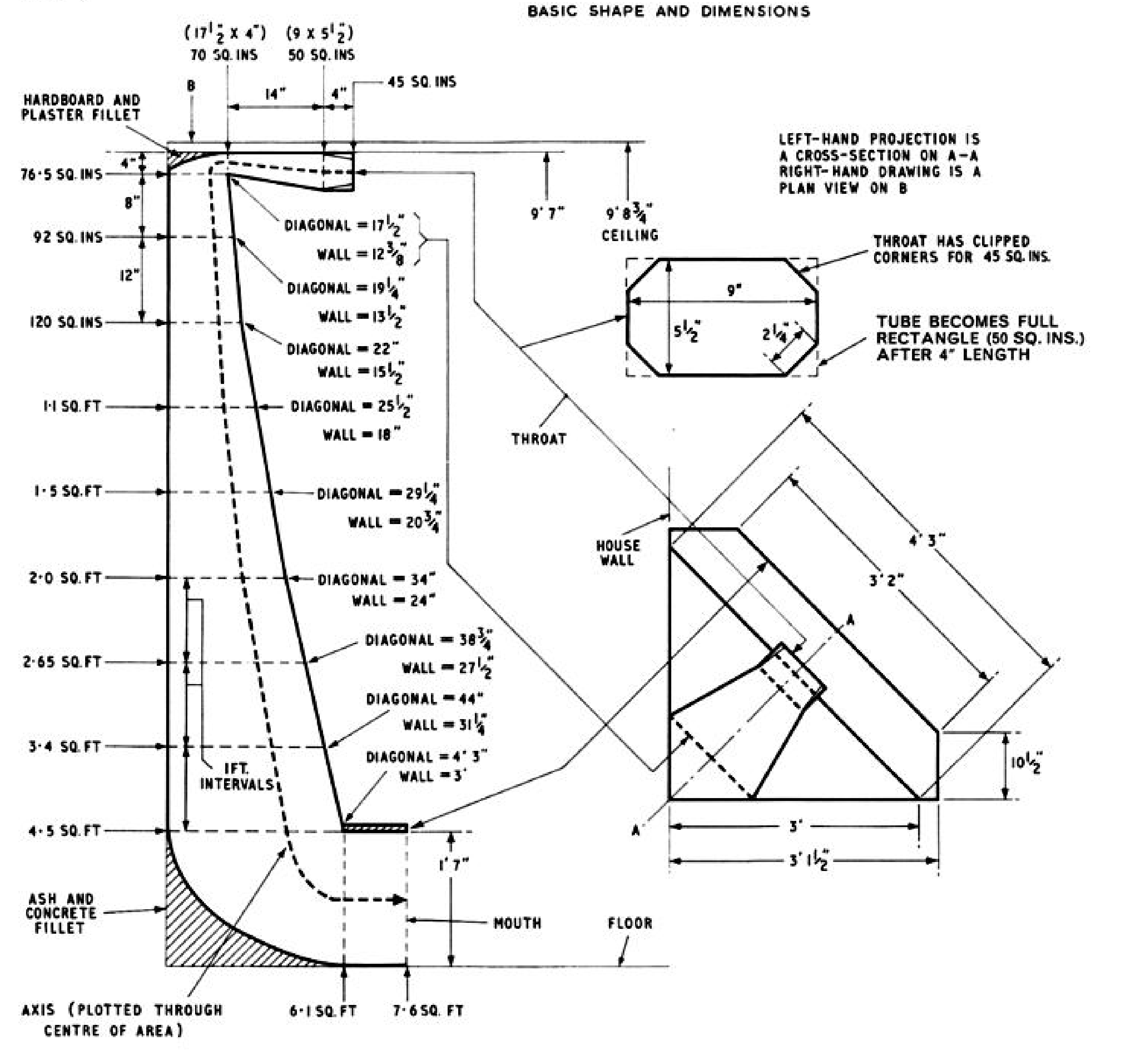


Requirement (b) arises because when a long horn is used for the bass frequencies in conjunction with a direct radiator or short horn for the rest of the range, the LF components in any complex signal are delayed by the time taken for the sound to travel through the length of the horn. This leads to certain audible—but difficult to describe—peculiarities in the resulting total sound picture, particularly on speech, unless the differential is kept below 10–15 mS, thereby limiting the bass horn length to 12 ft unless the mid/treble sound source can be placed well behind the bass horn mouth. Mr. Baldock overcomes this problem by running the horn beneath the floor and sitting above the mouth, with the mid/treble source situated approximately above the bass drive units on the far side of the listening room (see *Acoustic Compensation*, HFN, November 1964). I spent some time toying with this idea, there being plenty of space beneath the floor in our new house, but various supporting brick pillars and other structural obstacles finally ruled out that solution.

The horns, then, had to be within the room and not more than about 12 ft in axial length. Reference to exponential horn design data (see page 44, *Audio Diary*) shows that for a structure with flare cut-off frequency at 25 Hz and outlet situated in a room corner, the mouth should have a minimum area of 7·6 sq. ft, giving a length of nearly 17 ft if extended far enough back to give the small throat area used with Lowther drive units in the original system. This is too long, and as a reduction to 12 ft while retaining the same flare and mouth size gives a throat of 40 sq. in., I reluctantly decided to abandon Lowther units, which really should work in a pressurised manner (horn throat considerably smaller than cone area) to give of their best in the upper bass region.

As explained in my earlier articles (mainly November and December 1961) a bass horn may be used to do two separate jobs, apart from offering acoustic damping which improves transient response. First, it may compensate for the enormous mechanical mismatch between a relatively massive cone/coil assembly and mere flimsy air, achieving this by offering the cone a high acoustic impedance through the artifice of making it 'see' a column of air very much smaller in cross-sectional area than itself. A horn system with this sort of cone/throat régime is said to be 'pressurised', and gives a higher electro-acoustic energy conver-

FIG. 3



CONCRETE HORNS CONTINUED

sion efficiency than is obtainable from the same drive unit working into free-space from a plain baffle. The second horn task is to compensate for the natural and inevitable fall-away of acoustic radiation resistance below the frequency at which the diaphragm is around one half wavelength in diameter. In a baffle-mounted speaker not only is there a mismatch between diaphragm and air due to the aforementioned mechanical constants of the cone, but at low frequencies the acoustic load falls well below even the small initial figure, frequency response being maintained by mass control (or, less euphemistically, by excessive cone excursions!) down to the main system resonance in an IB enclosure or partly by the use of resonances in a reflex system.

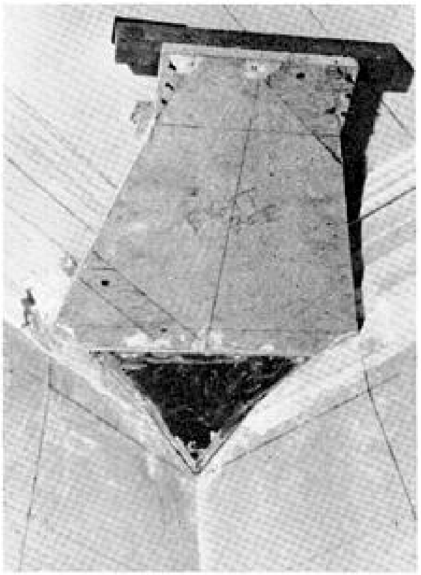
A horn with a throat equal in area to the driving cone avoids the decline in acoustic load with falling frequency and maintains down to just above its flare cut-off (mouth size permitting) the régime found at mid frequencies; this makes for much firmer control of the cone in the LF region, with consequently clear and uncoloured bass performance. A device with a throat smaller than the cone also does something about the initial mismatch, thus raising the overall efficiency. However, efficiency as such is unimportant unless normal 10–20 W amplifiers cannot provide adequate loudness on orchestral music, a situation only normally met in very large listening rooms and/or when using small IB speakers. This is fortunate, as the 40 sq. in. throat area mentioned earlier could not provide pressure loading unless coupled to a diaphragm of several square feet. Apart from electrostatic devices—which do not suffer from the 'mismatch' problem anyway, due to low diaphragm mass—the largest effective piston area currently available on a single unit is 132·3 sq. in. (KEF model B1814), and as the behaviour of a diaphragm this large is likely to become rather unpredictable under pressurised horn conditions, it was decided to play safe by opting for the KEF B139, which has a piston area of about 45 sq. in. and an excellent reputation for acoustic consistency.

Now the basic design parameters are emerging. The horn shall have a flare cut-off frequency of 25 Hz to achieve a useful response extending to below 30 Hz; mouth area to be 7·6 sq. ft in accordance with a practical termination for corner/floor (⅛-sphere) geometry for such a flare; throat area of 45 sq. in. to suit a B139 speaker unit; axial length, determined by the above, is 11·4 ft.

So far we have not touched on the business of horn and room resonances. Only a horn extending to a mouth diameter of one wavelength at the flare cut-off frequency will be entirely free from column resonances, and while an eight-to-one reduction in mouth area for termination in a corner is theoretically quite in order, further reductions are necessarily a compromise, introducing as they do some undulations in the acoustic load seen by the speaker cone. (See *Horn Type Speakers* by the present writer, HFN Dec. 61/Jan. 62, and *Horn Acoustics* by Rex Baldock, HFN April 67—the latter, incidentally being just about the most comprehensive survey of basic horn theory in readable English in the whole literature of acoustics.) Other undulations will occur due to room resonances, and in the *Acoustic Compensation* article referred to earlier Mr. Baldock described how horn and room peaks may be interlaced to achieve a smoothed overall response. I decided to apply this approach to my horn/room combination.

The room (see **fig. 1**) measures 23½ ft long, plus two recesses bringing the mean length to around 24 ft; width is 13½ ft, with a large window bay modifying this on one side; and height is 9¾ ft. Approximate frequencies for the first three ½-wavelength eigentones are therefore: 24·5, 45 and 60 Hz. Since appreciable impedance peaks in the 50–60 Hz region would not be expected from a horn of such large mouth size, the main task was to make the flare cut-off frequency coincide approximately with the lowest room resonance, and then to ensure that the first horn peak came approximately midway between the two lowest room resonances, at about 35 Hz. An f_{co} of 25 Hz obviously satisfies the first requirement, and reference to the Baldock formulae reveals that a horn of the type specified in previous paragraphs will in fact oblige by placing its first peak at 35·5 Hz; so, with the sails of theory hoisted and duly billowing, it was now possible to design a shape, decide on materials and start building.

The aforementioned window bay is just over 3 ft in from one end of the room, and with an eye on proportions and appearance my wife kindly donated me one yard of room on the understanding that some form of curtain or screen would eventually be erected across the room in line with the window bay, thus creating an apparent truncated-L shape (dotted line in



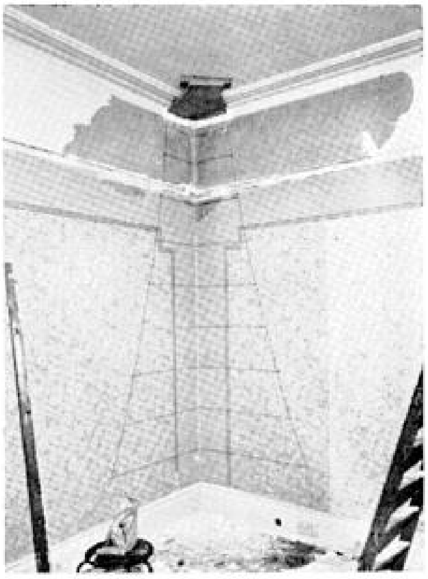
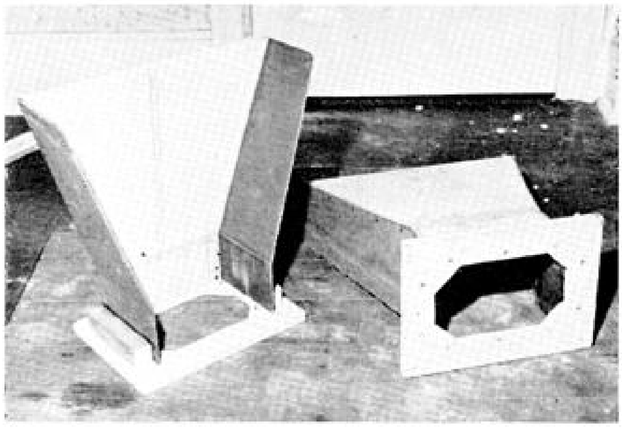


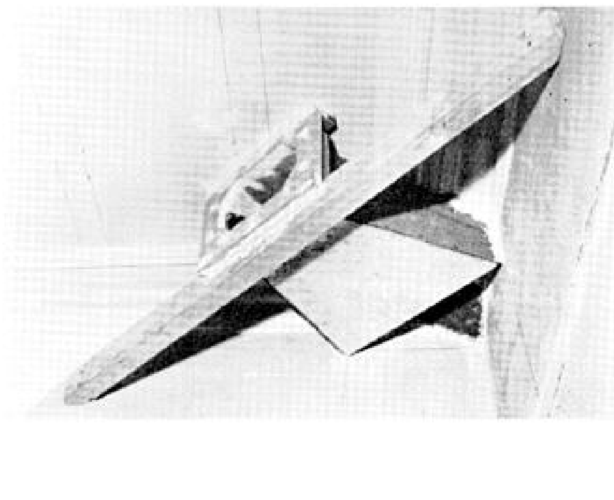
Fig. 4 (*above*) *shows upper part of throat section fixed to corner and ceiling.*

Fig. 5 (*top right*). *Outline of flare drawn on the walls.*

Fig. 6 (*right*) *shows a pair of throat sections before fitting to the upper part shown above.*

Fig. 7 (*below*). *Completed throat section in position on supporting beam before concreting.*





CONCRETE HORNS CONTINUED

fig. 1). There must be many hi-fi enthusiasts who would trade in their record collections for three feet of room to house loudspeakers—some might even trade in their wives!

With so much space available it was possible to choose an acoustically optimum cross-sectional shape for the horn—a triangle. This avoids parallel planes within the column and permits use of the house walls for two of the three inner surfaces over a greater part of the horn length. The horn so far specified in terms of flare rate and terminating areas may be represented graphically as in **fig. 2**, and after several evening's with a book of mathematical tables and much squared paper a shape was evolved whose cross-sectional area follows this pattern. This is detailed in **fig. 3**, from which it will be seen that the bulk of the horn is a simple tapered triangle, turning forward at floor level for the mouth and at ceiling level for the throat.

With such large panel areas and—near the throat—high acoustic pressures, it was regarded as essential from the outset to use concrete as the main structural material for the horns, employing hardboard and chipboard for the basic framework. First step was to prefabricate the throat section for fixing in position against the ceiling before starting on the main vertical flare. A structure was devised made up from $\frac{3}{4}$ in. chipboard at top and bottom, with hardboard sides, the topmost member to be fixed separately to the ceiling before final assembly. Great care was taken to establish the exact positions of wooden joists in the ceiling, the first part of the horn then being fixed in position with suitable long screws, spaced down from the ceiling itself to suit the height designated in **fig. 3**, enabling concrete to be forced in from above in due course. The first piece is shown in position in **fig. 4**, with some modest shaping in the corner to smooth the transition according to the shaded portion at the top of the main drawing in **fig. 3**. The space behind this fillet was filled with plaster and all cracks sealed with Polyfilla.

Next, the main flare was drawn on the walls in accordance with the given dimensions (lines just visible in **fig. 5**), and then the throat assembly (**fig. 6**) was screwed, tacked and glued on to and around the ceiling piece, a tough supporting bar being fixed diagonally across the room corner for extra strength and to avoid the whole load being borne by the ceiling joists (**fig. 7**). At this stage the four tapered corners used to achieve the desired throat shape were filled with Polyfilla, comprising in effect wedges of plaster to change the horn's cross-section from a $9 \times 5\frac{1}{2}$ in. rectangle to a similar rectangle with clipped corners during the first 4 in. of flare. Any cracks or other deviations from the planned internal shape were then filled or corrected, the whole inner surface being cleaned and painted to seal and stabilise it.

It was decided next to deal with the mouth end of the structure, as this would provide a base and support for the main flare. First task here was to devise the contoured fillet shown shaded in **fig. 3**, and after much head scratching it was decided to fill the space with damp ashes—which could be easily 'sculpted'—and then apply a $\frac{1}{2}$–$\frac{3}{4}$ in. thick shell of concrete. This worked very well, but any reader following suit should be warned that while the concrete set overnight, the whole corner took three months to dry out! The concrete shell itself was still wet when the photo was taken for **fig. 8**. showing the 'shelf' comprising the mouth boundary resting on dowelling supports screwed to the floor, and fixed to the walls at each end with conventional rightangle brackets.

Hardboard, rough side outwards, seemed the obvious choice for the slightly curved main panel, and it was comparatively easy to derive the necessary dimensions for this from **fig. 3**, the resulting sheet fitting exactly into position against walls, throat tube and mouth shelf. Three pieces of old picture rail were fixed to the panel to prevent sagging when concrete was applied, these in turn being screwed to the walls to help distribute the eventual load (**fig. 9**). This picture serves as a reminder that left and right versions were in hand at every stage, and though it is an awful bore to repeat every little constructional detail time and again, it really is more efficient to duplicate things while techniques, dimensions, etc, are still in one's head.

Next came the concreting. To ensure long-term adhesion it was decided to use *Unibond* in the concrete mix at all times, pre-treating all hardboard and chipboard surfaces with an appropriate Unibond size according to the manufacturer's instructions. Using a customary 3/1 sand-cement mix, first thing tackled was the box-like structure at the throat end of the horn, having previously sealed all cracks,

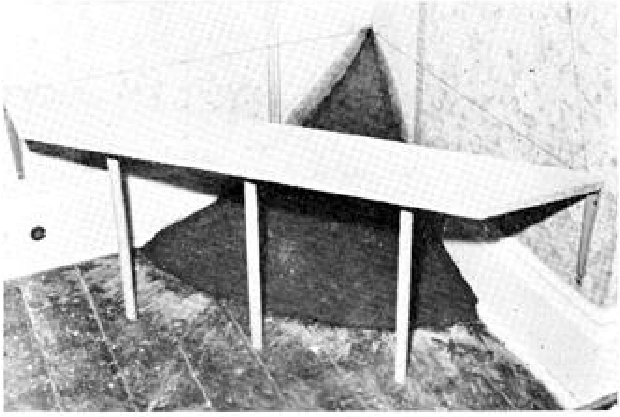


Fig. 8. *Basic mouth structure in position.*

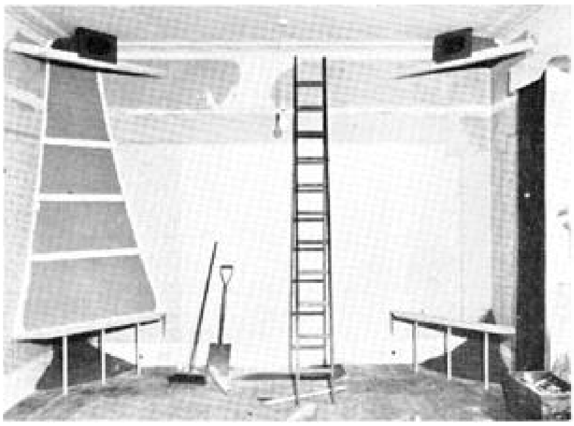


Fig. 9. *Main hardboard panel in place on left-hand horn.*

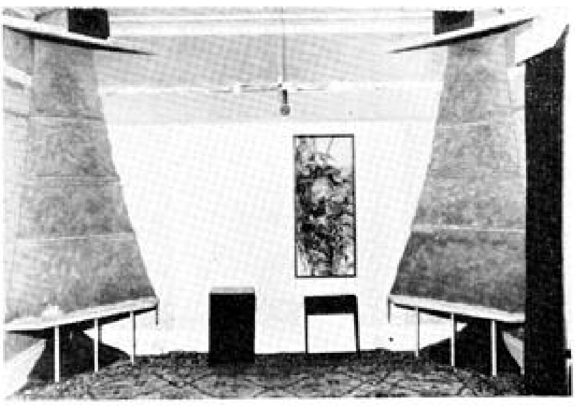


Fig. 10. *First coating of concrete on both speakers.*

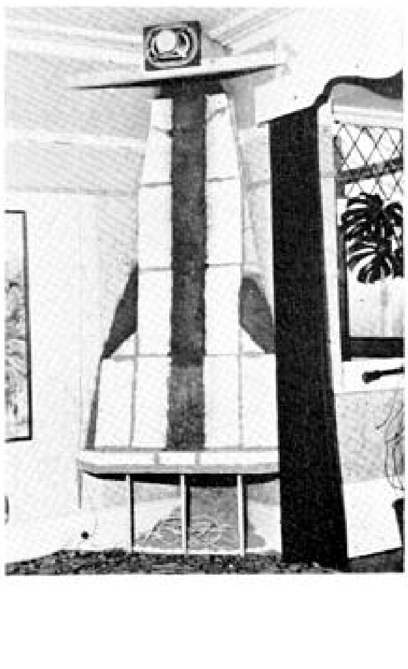


Fig. 11. *Final reinforcement with Durox blocks and more concrete. KEF drive unit in position.*

FM DIARY

BY A. H. UDEN

AUGUST 12/13th were '*P*' for *Perseids* days when correspondents set about playing the meteor shower game. Requirements? An aerial beaming between SW/SE, low noise factor receiver with usable sensitivity around 0·5–1μV and the tape recorder set to 'pause lock' ready to run at a microsecond's notice! Oh, and dedication!

Besides the random meteors which pursue their orbits singly, a few times each year the earth crosses an orbit in which large numbers travel approximately together as a stream or shower. The *Perseids* is one such shower. Meteors, the size of a grain of sand, enter the earth's atmosphere at speeds of up to 45 *miles a second* and are heated by friction until they evaporate. At night, the light so emitted is visible as the so-called 'shooting star', but the unseen ionised air left behind a meteor trail acts as a reflector of VHF signals. Using pre-arranged 'call and listen' time schedules, amateur radio operators have effected several notable two-way communication contacts on their 144–146 MHz Band via meteor showers. As the fluttery 'bursts' of signal at best last 60 to 100 seconds, *sustained* wideband FM broadcast listening is impossible, but this does not deter one from sampling such propagation as a practical scientific experiment. Concentrating on locally unused frequencies in the 95·2–95·5 MHz range, several readers obtained identifiable 'bursts' from central and south European stations, and Frank Richardson (Coventry), did very well to tape one of the two Yugoslavs at 95·3 MHz at over 1,000 miles. The next reliable shower is the *Geminids* due between December 10/14th giving radio rates around 70 per hour. You might chance on shorter 'bursts' before this—perhaps for the first time. If so, spare a thought for the natural forces at work which brought the signal to your aerial—and the lengthy detour these have made!

Research workers have suggested a connection exists between meteor activity and the intense random ionisation in the 'E' layer. There was certainly some excellent breakfast-time listening to be had in south-east England on August 15th from Sweden. An E. Yorks. reader also refers to 'E's' on July 22nd (11.50–14.00 GMT) during which programmes from Austria, and Germany (Bayerischer/Hessischer Rundfunk) were up to secondary service area field-strengths! Scanning this seasons meagre 'Es' reports the interesting feature to emerge is the stability of the reflected signals.

Several hundreds of our readers now seem to own one or other of the B & O *Beolit* receivers. Some even do duty as tuners feeding a hi-fi amplifier. This, you understand, is a 'temporary economic measure' which so often becomes permanent! Now the snag with a *Beolit* is that it will not receive stereo programmes, neither will a decoder work satisfactorily with one. This then, is a plea for a new two-in-one *Beolit* tuner/portable radio for FM-stereo to be known perhaps as the FMS 1000. It would incorporate the following features: a 'front-end' of comparable sensitivity with existing models but with a field-effect transistor, an improved i.f. section for better selectivity, twin output amplifiers from the decoder giving 1·5 watts of clean audio for bookshelf speakers in a small room with an extra outlet for medium-impedance headphones. There would also be a low level high impedance outlet of 47/100K for tape recorder and/or external amplifier. The built-in speaker for mono listening would be retained of course. Besides the twin-telescopic rods forming the dipole aerial, an auxilary input carefully matched to accept a 75-ohm coax external aerial source would be available. A push-button operated stereo beacon light would reduce battery consumption, but for indoor use there could be an 'add-on' mains power unit. Externally, the styling would resemble current models and be of similar weight. Here, then, would be a most versatile unit having several applications. At home it is the hi-fi tuner or stereo radio with external speakers. Slide out from the equipment cabinet, snap on the handle and it is a portable to be taken to some high round point for listening and taping those 'difficult-to-receive-at-home' stations. The cost? I would estimate a figure of £36–38 retail to be quite feasible with an extra 2 gns. for the add-on power unit. If Bang & Olufsen designers don't accept the challenge, do doubt someone else will. And if you, the reader, think there is something in this idea, too, please give it support by writing *not to me* but to the manufacturer(s). A customer originated tuner/portable stereo radio. What a novel idea! But it had better be good!

Last month, I referred to Peter Bennett's letter about the audio quality on programme circuits to the west country. Mr. Bennett has since written describing how his enjoyment of the Promenade concerts has been marred by telephone dialling and similar disturbances on the *North Hessary Tor* circuits. One would have expected a more permanent cure to these line problems by now, but comparing *Wrotham* and *Sutton Coldfield* on several August evenings, I was surprised to find marked differences in frequency response over this much shorter link—though dialling noises are absent. If you are making comparisons between stations, listen carefully to the studio or concert hall applause—it is a great give away.

CONCRETE HORNS CONTINUED

joins and boundaries throughout the structure with Polyfilla. Filling in above the throat section was simple enough, but even the coolest tempered of amateurs will sometimes find that the application of concrete to *vertical* surfaces is, to say the least, a frustrating business. However, much concentration on the sides and some shuttering underneath finally enveloped the whole throat complex in nearly ¾ in. of concrete, and I was much relieved the next day to find that when tapped from inside all the surfaces seemed as solid as rock.

The main panels were not so difficult, having a slight slope back rather like a very steep roof. The concrete mix trowelled on fairly simply, thickness averaging over ½ in., the only irritation being the absolutely collosal quantity consumed and the corresponding number of journeys back and forth with buckets through the French windows. After coating both panels and the top surfaces of the 'shelves', I confidently tidied the room, hung a picture on the wall, placed an electric fire and a Magnum-K speaker (*largest* in the current Goodmans range) against the wall and took the nice, self-satisfied shot shown in **fig. 10.** But it was no use: a mere ½ in. of concrete was nowhere near massive or rigid enough, the whole structure resonating very noticeably when thumped with a fist. Many more buckets of concrete brought the thickness to around one inch; but still it boomed, so I erected a stout beam of wood up the centre of each panel, embedding this in concrete to act as a bracing rib. This was better, but still not really 'dead' enough, and not wishing to cart another ton of concrete across the room and up the step ladder, I had a look at what was available in various builders' yards. This revealed *Durox* aerated concrete blocks, available in various sizes and offering a reasonably massive but nevertheless acoustically dead structural material. Using concrete as a mortar, a number of $20 \times 8\frac{1}{2} \times 2\frac{1}{2}$ in. Durox slabs were laid on to the horn structure, all gaps being filled either with Durox chips or more concrete. To ensure firm adhesion the slabs were wired back into position while the structure dried out.

Fist thumping no longer produced any resonant effects (it was now almost like hitting the wall), so a KEF unit was fixed in position for an initial try-out (**fig. 11**). Bass seemed beautifully full, deep and clear, so a temporary crossover was concocted to permit use of the new horns at the bottom end with whatever other speakers happened to be around for middle and treble. The next task was to decide the upper frequency limit for the bass horns and design an appropriate permanent system for the rest of the range. This, and problems of visual finish, will be covered next month.

BBC STEREO CONTINUED

with a very good balance between singers and orchestra. As a sound, however, I preferred the Prom performance: it seemed more spacious, without any loss of presence, and the added reverberation made for better integration of the voices and the orchestra, without any loss of definition.

Of the other programmes, the fine playing of the Amadeus Quartet in two programmes of Haydn and Schubert was beautifully reproduced in stereophony, as was the majesty of the Westminster Cathedral organ in two programmes of Messiaen's organ works. I would have liked to hear slightly more reverberation on the organ broadcasts, but this was not a serious complaint, and may not have been easily possible in the exceptionally live acoustic of Westminster Cathedral without losing the definition necessary to this music.

To return to my opening remarks, I notice that next week (as I write) a performance of the Berlioz *Grande Messe des Morts* is to be broadcast on the Home Service, in *mono*! What a pity.

A CONCRETE HORN LOUDSPEAKER SYSTEM MK II

BASS PERFORMANCE, MID-FREQUENCIES AND FINISH

BY JOHN CRABBE

LAST month the bass horns were completed and left waiting to be integrated with suitable mid and top units. First thing to be determined was the practical upper limit for the bass horns, a point fairly easily decided both theoretically and practically. In any duct system with a right-angled bend the first dip in the response (going upwards in frequency) occurs where the effective diameter at the bend equals half a wavelength. At the bottom of the main vertical section the horn bends through 90 degrees on approaching the mouth, and as the approximate diameter in the plane of the fold is 1½ ft, there should be a response dip at about 400 Hz. Careful measuring and listening confirmed that the output certainly starts to fall above 350 Hz, though departures from the simple parallel-sided duct situation give a modest irregularity of response rather than a sudden dip. The electrical crossover, then, should operate below 350 Hz.

Having decided a crossover frequency, further thought and work on higher frequencies was abandoned for a while, a pair of Goodmans Magnum-K speakers being connected in for the region above 300 Hz while some detailed low frequency measurements were conducted. The electrical impedance curves of the KEF units in the horns (**fig. 1**) behaved as expected below 30 Hz, the normal free diaphragm resonance at 27 Hz being pushed down below the horn's flare cut-off frequency by the addition of considerable acoustic mass reactance. An unexpected feature was the complex of impedance peaks in the 40–50 Hz region, as no calculation had predicted anything here.

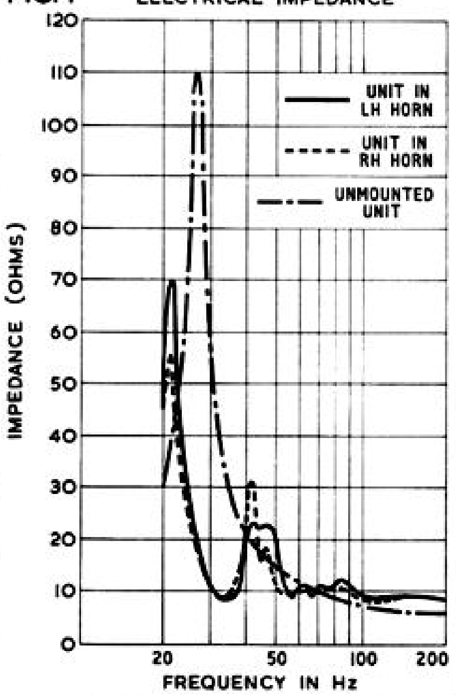
Rex Baldock came along for an evening's investigations with a sound-level-meter, and after much cross-checking we came to the conclusion that the peaks arose from the room's full wavelength resonance on the major dimension—the second harmonic of the fundamental eigentone which would not normally be particularly dominant. The two pairs of slightly different peaks (different in both frequency and 'Q') for the two horns could actually be equated with the two differing recess depths of the far end of the room, contours of the standing-wave patterns being shaped accordingly.

So the room was something of an acoustic freak, the next problem being to explain how acoustic impedance peaks in the room could be reflected as considerable electrical changes despite a mouth size which might have been expected to make the horn relatively independent of the room at such frequencies. The most plausible explanation seems to be as follows. When using a highly efficient pressurised horn system the acoustic load offered to the diaphragm is so nearly optimum, that any further rise in this—due either to horn resonances or to an impedance peak in the room as 'seen' by the horn mouth—will tend to *lower* the efficiency, the net result being a flat response as the 'mismatch' is compensated by the resonances in question. However, with the system here under consideration the actual acoustic resistance offered to the drive unit will be well below that needed for an efficient impedance match (non-pressurised horn, heavy cone), so that any extraneous rise in acoustic impedance finding its way back to the horn throat will be manifested both as electrical resistance in series with the speech-coil and an increase of acoustical output.

On the latter point, if a generator is swung slowly through the LF range there is certainly a very noticeable rise in the 44 Hz region, but varying drastically with one's position in the room. However, the 'Q' seems too high for this to be excited by anything musical other than the occasional sustained organ pedal: the note F_3 (43·65 Hz) was picked out by an organist friend with perfect pitch as being slightly exaggerated, though its next door neighbour F_3♯ (46·25 Hz) seems unaffected despite associated electrical humps.

I toyed with the idea of installing tuned absorbers in the room to modify the eigentone pattern, but nearly a year's listening has now convinced me that the coloration involved is a good deal less marked than that introduced by most rooms, whatever the speaker system. In fact, general performance in the bass is outstanding, and most visitors have been forced

FIG. 1



Above, domestic disguise for concrete monstrosities (**fig. 13**).

Right, first stage in assembly of mid-range horn (**fig. 4**).

Next (**fig. 5**), *outside view of completed mid-range horn, complete with damping.*

Then comes a front view of the horn (**fig. 6**).

Finally (**fig. 7**), *short horn mounted in position on bass horn structure.*

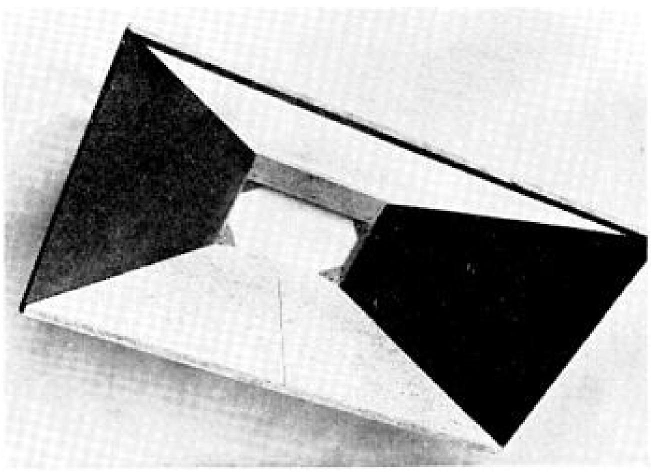


FIG. 2 EXPONENTIAL HORN WITH FLARE CUT-OFF OF 200Hz

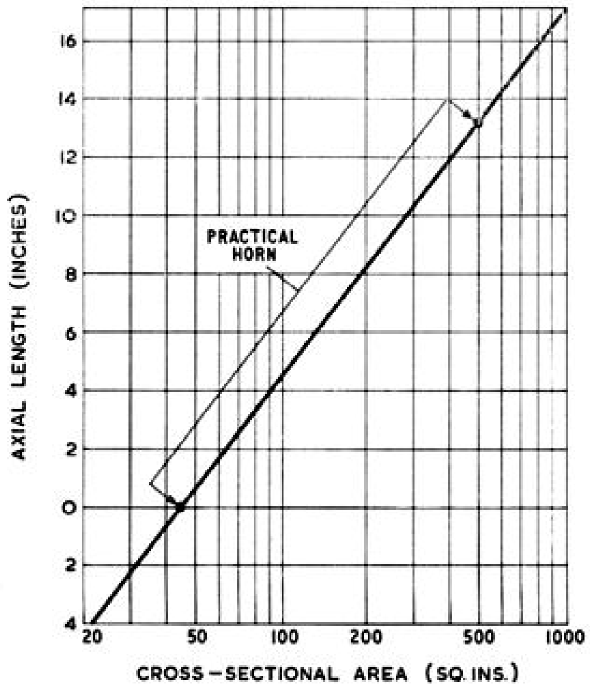
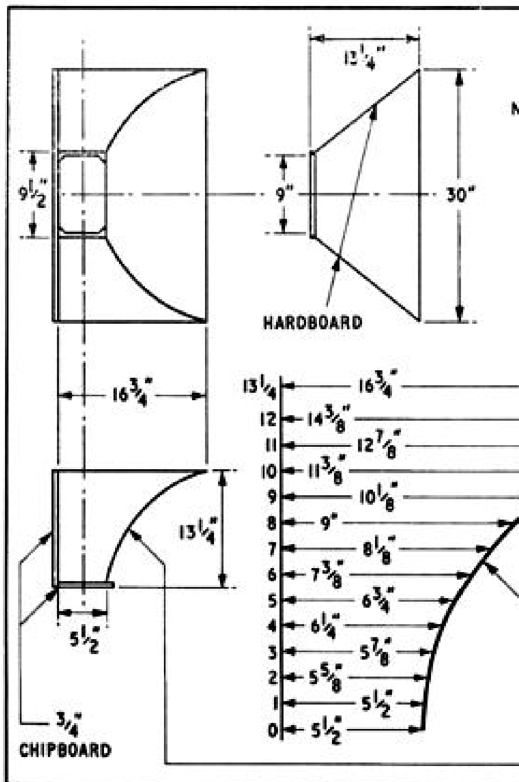


FIG. 3 DETAILS OF MID-RANGE HORN



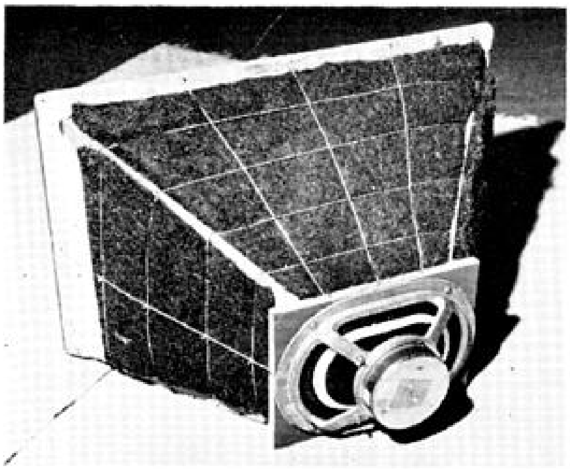
to admit that they have never heard the bottom two octaves reproduced more effectively. A good few people have gone away convinced for the first time that the large bass drum really is captured by the record companies—but its sound never normally gets back into the air again!

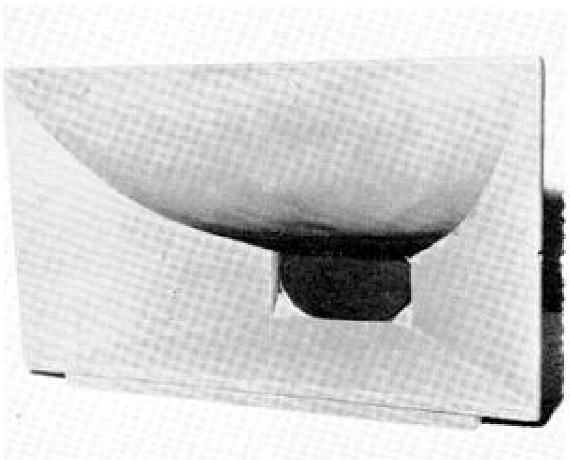
Turning now to higher frequencies, when the system was originally conceived there was really no satisfactory mid-range unit to take over from the B 319 above 300 Hz, so it was decided to use a further pair of B 319s to cover the range from here up to 1 kHz, mounting the units in short horns to clear up a few minor irregularities sometimes experienced just below 1 kHz. The short horn was to load the drive unit over a range extending from well below the crossover frequency up to a further crossover around 1 kHz, where it was planned that a pair of KEF T15s should take over. It can be shown that if one chooses a mouth diameter (or its equivalent if not circular) equal to one-third of a wavelength at the flare cut-off frequency (F_{CO}), the undulations in a horn's acoustic resistance curve become negligible at approximately 1·5 F_{CO}. Thus for a satisfactory performance above 300 Hz a horn of suitable mouth size may have a flare cut-off at 200 Hz. With such a horn the third-wavelength mouth requirement is satisfied by an area of 400 sq. in., but this was raised to 500 sq. in. for extra safety, which with a throat of 45 sq. in. for the B 319 diaphragm as in the bass horn, gives the expansion shown graphically in **fig. 2.**

It was decided to construct the horn of chipboard and hardboard suitably loaded with plaster and any necessary damping material. Basic shape and dimensions are given in **fig. 3**, from which it can be seen that the horn produces an asymmetric dispersion of the wavefront, a characteristic used when setting up for stereo performance. The drive unit is coupled to a throat of exactly the same shape and size as that described last month for the bass horn, the chipboard panel being chamfered at its four corners and two short ends to achieve a transition from the aforementioned shape at the throat to a 9½ × 5½ in. rectangle after a distance of ¾ in. (thickness of the panel).

There are various ways of tackling actual construction, the author's initial set-up being shown in **fig. 4.** Here, all the flat surfaces are in position, it remaining simply to mock-up the necessary cross-sectional contour with a template, eventually evolving a curved cardboard sheet for the flare itself. With this sheet glued into position, its outside should first be painted and varnished, then a thin layer of plaster may be added for initial stiffening. Following this, more plaster and wire reinforcement may be added until the whole flare is sufficiently massive to avoid vibrations when in use. Outside surfaces of the hardboard sides should also be plastered, the whole assembly finally being well lagged with felt to produce an acoustically inert structure (**fig. 5**). An inside view of the finished horn is shown in **fig. 6.**

Now come the mounting problems. It was necessary to erect a supporting wooden bar across the middle of the bass horn to support the rear of the mid-range horn, its front being sustained by two stout steel bars. Some soft felt was carefully wrapped around the rear of the drive unit—*without* touching the cone—to





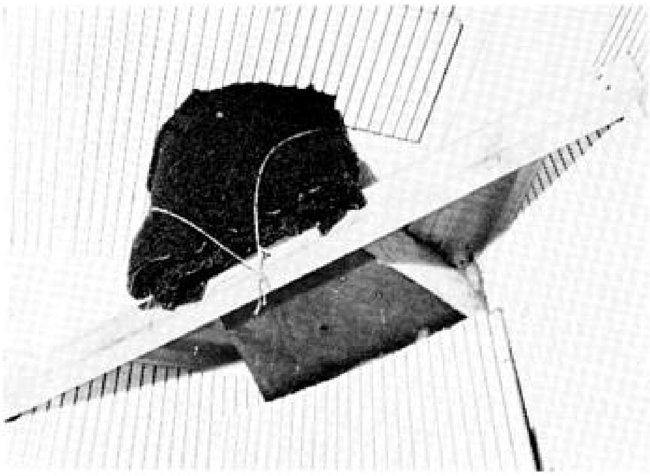


Fig. 8 *Left: looking up at bass drive unit loaded with felt at the rear.*

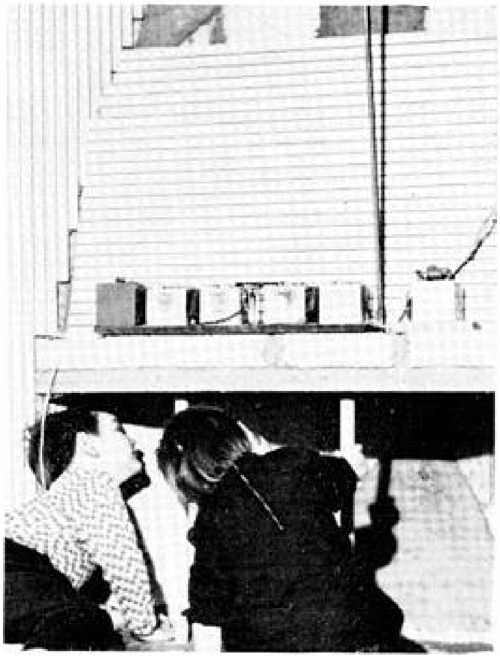


Fig. 9 *Right: inspection party at work.*

FIG. 11 CROSSOVER CIRCUIT

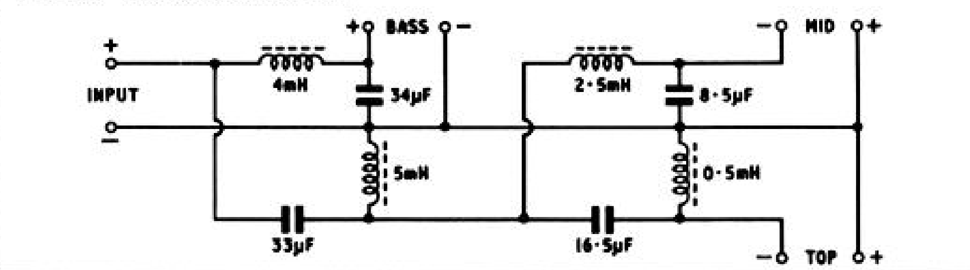
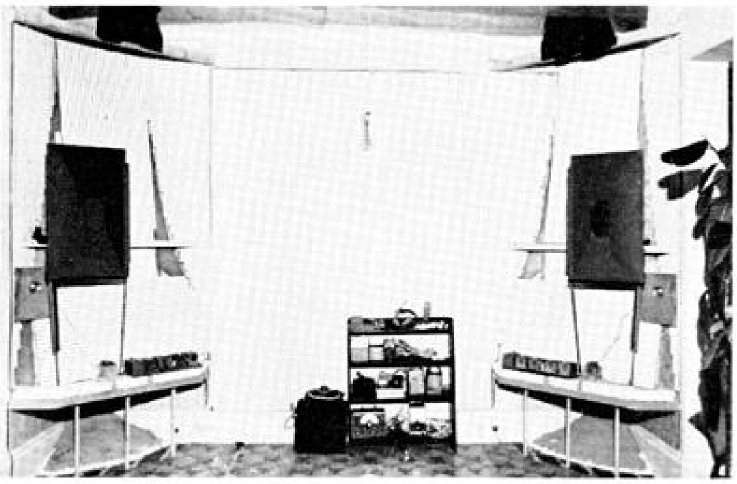
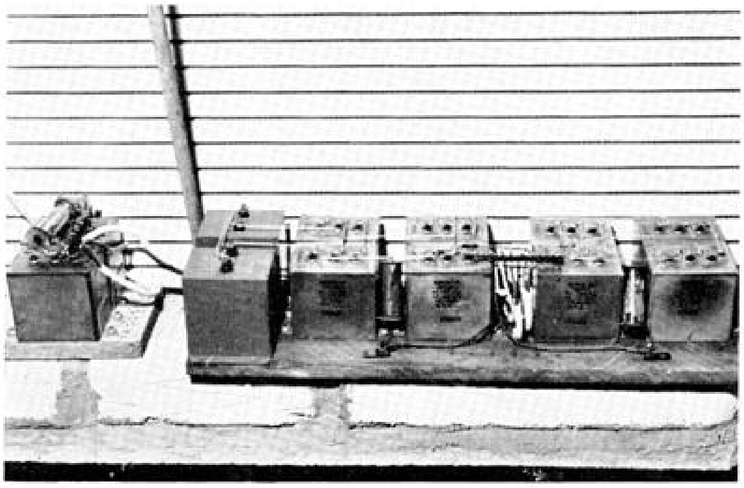


Fig. 10. *Below left: general view before fitting curtain disguise.*

Fig. 12 *Below: view of crossover components.*





CONCRETE HORNS CONTINUED

avoid stereo confusion and irregularities of response from rear radiation (**fig. 7**), the same treatment being applied to the bass unit (**fig. 8**). Indeed, at this stage I had a general set-to with acoustic tiling to reduce reflections at the speaker end of the room, in the general cause of unmuddled stereo and to give the maximum revelation of recorded ambience by minimizing listening room reverberation. During these tiling operations two young Crabbes came in to inspect progress (**fig. 9**), and after shouting up the horns at the tops of their voices reminded me that I should tell readers that the very excellent acoustic boards used are available from the *Hermeseal Insulation Division* of Rentokil.

Before proceeding with crossover arrangements it seemed reasonable to position the two T15 tweeters. These were mounted on small baffles out against the side walls as seen in **fig. 10**, thus using the maximum available sound-stage width. Cavity effects were avoided by filling the spaces behind these baffles with felt, the mid-range horn support bar nearest to the tweeter also being treated with foam pipe-lagging to avoid spurious reflections. It will be noticed that the short horns are angled to give maximum drive-unit frontage towards the far side of the listening area in each case, and with the horn contours positioned as shown there seems to be a very acceptable degree of loudness/Haas compensation at mid frequencies for listeners sitting away from the room's centre-line. Although it might appear that in some positions the T15s will be shielded, in fact there is a direct path from both tweeters to any person sitting within the rear three-quarters of the room.

Evolving the crossover circuits proved to be a very involved operation, finally convincing me that unless, (a) speaker unit impedances are pure resistances, (b) there are no changes of efficiency or directional characteristic between one unit and another, and (c) there are no diaphragm resonances within two octaves of the crossover frequency, there is little hope of getting a satisfactory balance by using text-book circuit values. At the top end I had been warned by Mr. Cooke of KEF that the L and C components to use with a T15 for an *effective* crossover at 1 kHz would deviate wildly from simple calculations, as the tweeter's diaphragm resonance is around 600 Hz and this upsets the acoustic performance considerably, whatever the measured input voltages may indicate. The lower crossover was more conventional in terms of component values, though when first installed there seemed to be a curious 'fugginess' to the sound which it was difficult to pin down. By switching between white-noise and an adjustable audio generator I pinpointed a coloration at 280 Hz, and careful listening to the mid-range horn showed this to be due to a

CONCRETE HORNS CONTINUED

minor peak therein. This seemed to be another example of what can happen when dealing with a very modest degree of horn loading, for presumably a minor peak in the horn's acoustic resistance curve was causing a rise of output by moving the system towards a more nearly matched condition at that one frequency. Anyway, the solution was very simple: snip out some capacitance from the relevant limb (the 33 μF was originally 51 μF in **fig. 11**) to raise the 'cut in' frequency of the mid-range circuit. This completely eliminated the 280 Hz peak and opened up the whole sound quite dramatically.

The outlet points in **fig. 11** are polarised for convenience, though every effort should be made to phase the units acoustically. Taking first the bass and mid-range horns, a nearly pure tone around 320–340 Hz should be fed in, when it will be found that as one moves one's head vertically between the two horn mouths the sound level will change according to one of two patterns. If at a point roughly half-way between the two outlets there is an exact null, the fundamental disappearing and leaving only harmonics, this means that the units are out of phase and the connections to *one only* should be reversed. If there is a slight fall in level between the two mouths as might be expected from their directional characteristics, with no distinct null, leave things alone. For phasing the tweeter it is best to use white-noise, the correct connections resulting in an integrated type of sound, without lower frequencies apparently trying to detach themselves from the tweeter and move into the short horn. Speech should be used to confirm this, as a voice will sound altogether more convincing and 'point-source' with correct phasing.

Inductors used for the crossover circuits were high-quality ferrite cored types with an internal resistance of only 1·3 ohms for 5 mH, and proportionally smaller R for the others. Ex-WD paper capacitors were used throughout, and there should be no difficulty in obtaining suitable types from surplus stores. A shot of one crossover complex is shown in **fig. 12**.

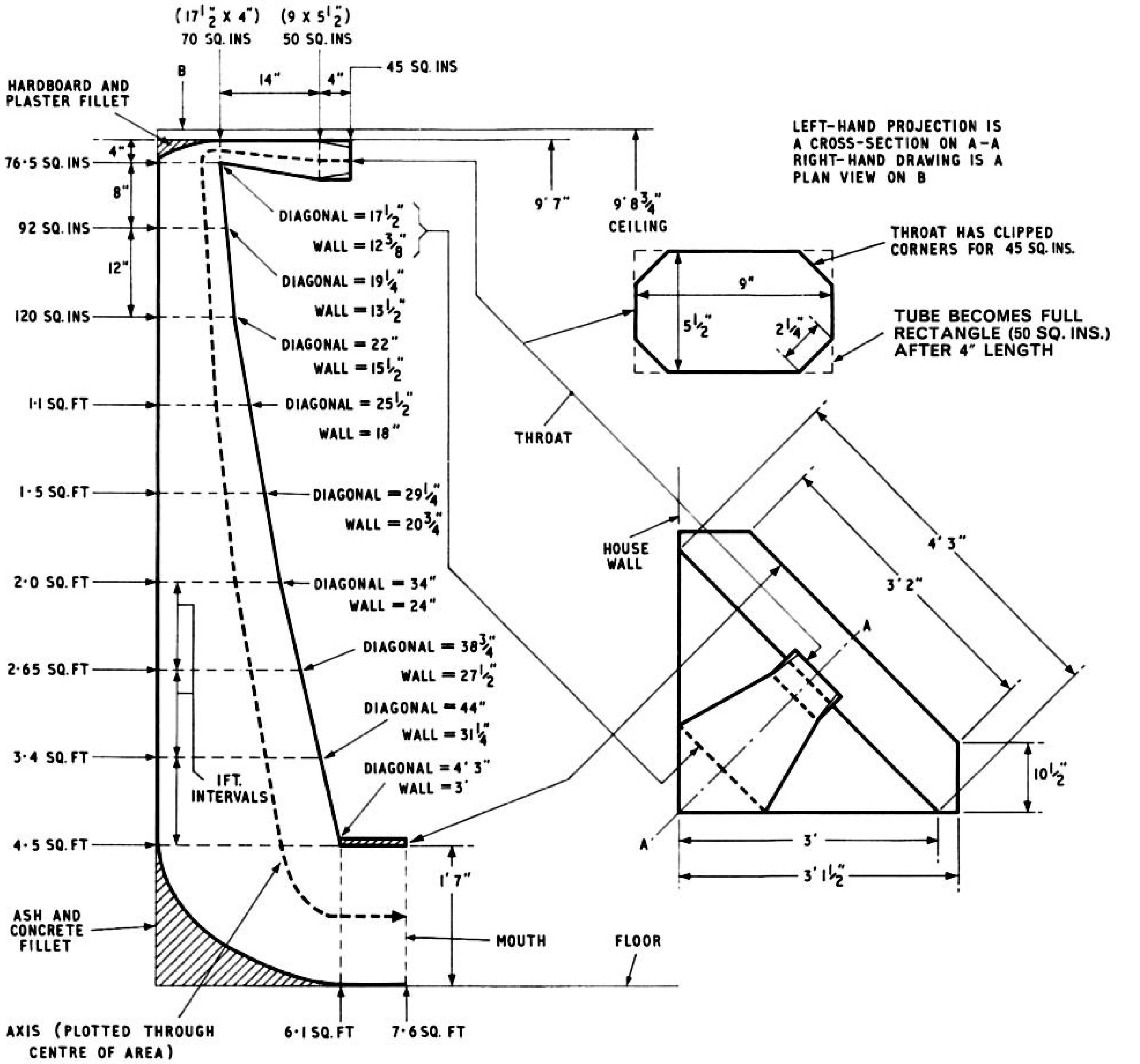
Fig. 10 shows the finalised set-up, with a small quota of test gear conveniently lodged out of harm's way with the speakers behind the eventual curtain seen in **fig. 13**. The acoustic tiles were given a coat of dark grey emulsion to minimise light reflection back through the curtain, but otherwise the scene behind the veil is now exactly as shown, though nothing but curtain (and Buffet's 'Fishermen's Harbour') may be seen within the room.

What about the acoustics of that veil? It is a double curtain, the visible frontage being provided by an open-work coloured texture net, behind which is suspended a drape of dark grey bonded fibre material, of a type which is visually opaque in the sort of situation depicted (no illumination or strong reflections from behind) but whose physical properties avoid acoustic attenuation below about 50 kHz for plain waves normal to its surface. This remarkably effective material, known as 'Type T-100, Charcoal', is made by *Bonded Fibre Fabric Ltd.* and may be purchased at a retail level by post from *V. J. Monk Ltd.*, 140 Plumstead Road, London, S.E.18, at 4s. per yard of 54 in. width (price includes postage and packing). Anyone attending the Rogers' demonstration at this year's Audio Fair will have seen an example of this material in action, Mr. Rogers ordering some for use at the Hotel Russell immediately after attending a demonstration in my home.

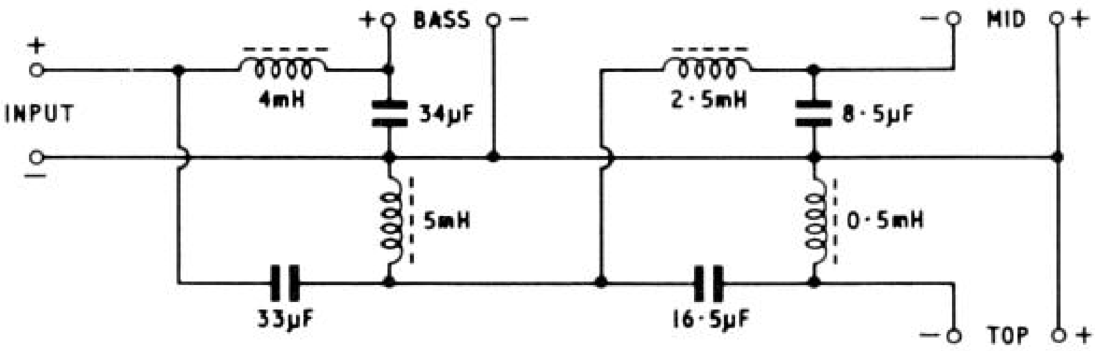
However, the rather dull half-fibre-half-cloth appearance needs enlivening with something decorative in front, and here there is a vast choice of materials with sufficiently open texture not to ruin the acoustics and with sufficient variations in colour and style to suit all tastes. In our case we chose one of the delightful range of texture net fabrics (type 129) made by *Tibor Ltd.*, Clifford Mill, Stratford-on-Avon, Warwickshire, and I would certainly recommend any reader looking for a suitably open net material to see some samples from this range. Finally on these decorative points, the long bamboo pole seen in **fig. 13** was obtained from *Whines and Edgler*, The Bamboo People, Godmanstone, Dorchester, Dorset.

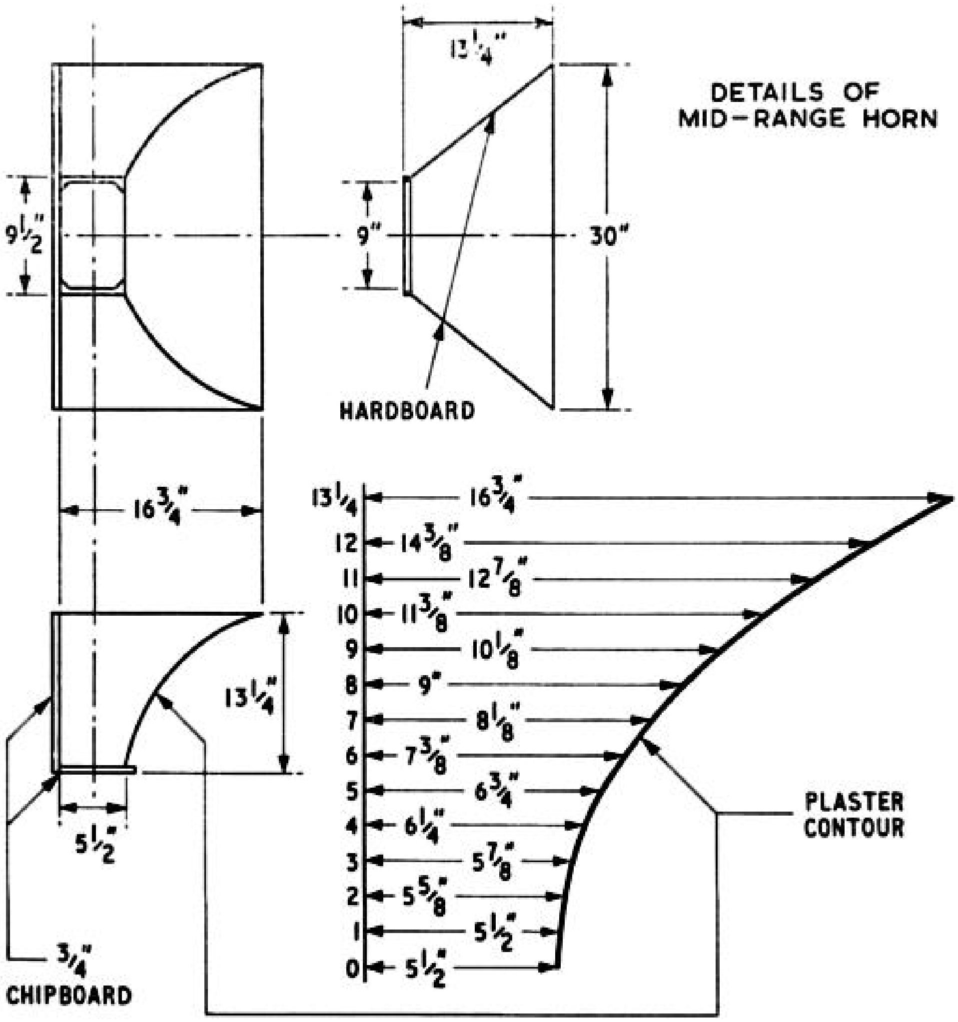
Now back to audio. Overall performance of the system is smooth, easy and pleasing, with great depth and clarity in the bass. Middle frequencies have not quite the openness and 'grip' experienced with the original Lowther system, though I have high hopes of the new KEF mid-range and tweeter units introduced at this year's Audio Fair. These will be tried in due course, when I hope that publication of a suitable 'postscript' will satisfactorily conclude this short series.

BASIC SHAPE AND DIMENSIONS



CROSSOVER CIRCUIT





DETAILS OF
MID-RANGE HORN
13 1/4"
9 1/2"
9"
30"
HARDBOARD
16 3/4"
13 1/4"
5 1/2"
3/4"
CHIPBOARD
13 1/4
12
11
10
9
8
7
6
5
4
3
2
1
0
16 3/4"
14 3/8"
12 7/8"
11 3/8"
10 1/8"
9"
8 1/8"
7 3/8"
6 3/4"
6 1/4"
5 7/8"
5 5/8"
5 1/2"
5 1/2"
PLASTER
CONTOUR