RESEARCH DEPARTMENT

SOUND INSULATION AND ACOUSTICS IN THE BELFAST STUDIO CENTRE

Report No. B.059

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SUMMARY

During the years 1952/3, all the studios in Broadcasting House, Belfast, except Studios Nos. 1 and 4, were given permanent acoustic treatment. This report summarises the results of acoustic measurements in all the studios, describes certain modifications which were made during the building work, and discusses conclusions of a general nature which resulted from the work.

1. INTRODUCTION.

Broadcasting House, Belfast, was completed structurally at about the time of the outbreak of war, in 1939, but the studios remained unfinished, the acoustic treatment consisting of strips of carpet felt hung from the bare brick walls. In 1947 Studios Nos. 3, 5 and 8 were given an inexpensive treatment of rockwool covered with hessian, in conjunction with linoleum membrane bass absorbers. Acoustic tests described in Research Report B.038[1], showed that these studios, though improved, were too reverberant in the bass and had excessive absorption at middle frequencies. The present report describes the new permanent treatment of Studios Nos. 2, 3, 5, 6, 8 and the Continuity Studio, carried out in the years 1952 and 1953, and gives the results of acoustic measurements in these studios and in No. 1 which has new temporary treatment.

Particular attention was paid to the defects in sound insulation, due to bad studio layout, which have been a source of difficulty in operation. Some of these defects cannot be overcome without major structural alterations, and their effects can therefore be reduced only by careful planning of rehearsal and transmission bookings. It is desirable, however, to examine the causes of these faults so that they may be avoided in future.

The building contains one orchestral studio (No. 1), a general-purpose studio (No. 8), two smaller drama or music studios (Nos. 3 and 5), two talks studios (Nos. 2 and 6) and a continuity studio. Studio No. 4 is an effects studio and store, still untreated. There are two echo rooms and an acoustically treated listening room. In this report, sound insulation is considered first, followed by details of the acoustics of individual studios. Table 1, in the Appendix, summarises the dimensions, volumes and locations of the studios.

2. SOUND INSULATION BETWEEN STUDIOS.

All the studios except Studio No. 2 are accommodated in one wing of the steel-framed building, as indicated in Fig. 1. It is evident from the diagram that the possibility of sound leakage exists between Studio No. 8 and Continuity Studio, Studio No. 5 and Continuity Studio, Studios Nos. 5 and 3, and between Studio No. 1 and the two drama studios Nos. 3 and 5. The effects of long-path transmissions through the steel frame have also to be considered. For example, it is found possible to hear in Studio No. 1, the sounds of an orchestra playing in Studio No. 8, sound transmission taking place through the walls or frame of the building. Impact sounds originating on the solid floor of Studio No. 1 can be heard throughout the wing.

The worst potentialities of this studio lay-out were anticipated in the original designs by providing a false ceiling to Studio No. 1, thus reducing transmission to Studios Nos. 3 and 5, and by building inner shells for the two latter studios, isolated from the main structure, to reduce the leakage between them and also leakage from the floors above. The Continuity Studio also had a false ceiling to avoid leakage from Studio No. 8 above. Nevertheless several minor difficulties arose, so that modifications of detail were found necessary as the building progressed. This section of the report gives an account of the insulation measurements made in the course of the investigation, a summary of the results being given in Table 2 of the Appendix.

2.1. Insulation Between Studio No. 1 and Adjacent Studios.

The first measurements of sound insulation were carried out in June 1952 during the construction of the inner shells of Studios Nos. 3 and 5. It was found that there was very considerable leakage from Studio No. 1 into Studios Nos. 3 and 5, particularly the former, through the ventilation ducts. A Tannoy "Phonmeter" in Studio No. 3 gave scale readings of 65–75 during a rehearsal of the Northern Ireland Light Orchestra in Studio No. 1, from which it will be understood that the leakage was sufficient for the music to be heard in considerable detail.

It was found that the leakage occurred through spaces surrounding the ducting and through the walls of the ducting itself where this was not lagged. Correction of these faults resulted in a considerable improvement, making Studios Nos. 3 and 5 usable; the subsequent addition of a false ceiling to Studio No. 1 made further improvement and the sound insulation is now considered to be satisfactory. The measurements in these last two stages are shown in the first and third columns of experimental results in Table 2.

"Footsteps-machine" noise was measured from Studios Nos. 3 and 5 to Studio No. 1, and loudness levels, summed from octave band measurements by the method of Mintz and Tyzzer[2], being 64 and 69 phons* respectively. These figures are outside the limit of 58 phons tentatively fixed by Research Department for small studios, but it was decided that no building alterations were necessary for the following reasons:

*The phon, as defined by the B.S.I., has no relevance to measurements in the field. In this report the unit is used loosely, for want of a practically realisable unit, to mean a single figure compounded from a series of octave-bandwidth measurements and related as accurately as possible to subjective loudness.

a. Studio No. 1 would be used mainly for orchestral music, for which a higher background noise is acceptable.

b. The false ceiling was not yet built.

c. Much of the floor area in Studios Nos. 3 and 5 would be carpeted.

2.2. Insulation Between Studios Nos. 3 and 5.

Studios Nos. 3 and 5, lying side by side, are intended as drama studios of equal size, Studio No. 3 being acoustically dead, and Studio No. 5 live. Studio No. 5 is used also for solo musical programmes and small dance bands, and hence good insulation is required between the two studios to prevent programmes of this type interfering with drama in Studio No. 3. However, the sound insulation between the two studios is unsatisfactory, despite their inner-shell construction. The path of the leakage could not be ascertained with certainty, but appeared to be through the ceilings rather than through the three brick walls separating the studios. No improvement could be expected without considerable building work, supplemented by further experiments.

2.3. Insulation of the Continuity Studios.

The most likely source of interference to the Continuity Studio is Studio No. 8, immediately above, which was used mainly for the Northern Ireland Light Orchestra before the completion of Studio No. 1. In practice owing to the floating floor construction of Studio No. 8 and a 3 ft space above the ceiling of the Continuity Studio, insulation is almost adequate. The "footsteps-machine" figure is 61 phons and the insulation for airborne sound is better than 45 dB at all frequencies above 70 c/s. Both types of interference can be heard in the studio, though they are not very intrusive over the microphone circuit.

2.4. Insulation Between the Control Room and Studios Nos. 3 and 5.

The new control room lies above Studios Nos. 3 and 5, which must, therefore, be protected from ordinary impact sounds and airborne sounds at loudspeaker level. The airborne sound insulation is adequate, being better than 45 dB at all frequencies above 70 c/s. The footsteps noise, however, was unsatisfactory as found, the loudness level being 62 phons. A layer of hardboard on the control room floor reduced this to 52 phons, from which it was estimated that a Korkoid covering would be satisfactory. No measurements have yet been made in the final condition but the impact and airborne noise insulation appears to be adequate in service.

2.5. Insulation of Studios Nos. 2 and 6.

These studios are more favourably sited than the rest, as they do not lie adjacent to any other studios either horizontally or vertically, and it is not necessary therefore to resort to arranging bookings in such a manner as to avoid inter-studio interference. No insulation measurements were made, though in neither case is the insulation completely satisfactory. From a microphone in Studio No. 2 it is possible to hear a loudspeaker in the floor below, footsteps in two corridors, a compressor-pump outside the building and a piano in a neighbouring practice room.

Studio No. 6 lies adjacent to a corridor and an attendant has to be stationed outside during transmissions to hush staff walking past.

There is little which can be done about either studio except to reduce the interfering noises; acoustic treatment of the vestibule of Studio No. 2 has, however, reduced the transmission of footstep noise from the corridor outside.

2.6. Studio-to-Cubicle Insulation.

The measurements of insulation between studios and their cubicles are tabulated in the Appendix, Table 3. Where further comment in the case of particular studios is necessary, it will be included in Section 3 dealing with the acoustics of the individual studios. "Howl-round" figures are given in Table 4.

2.7. Discussion of Inter-Studio Insulation.

The principal difficulties with regard to sound insulation between the studios arises from the layout of the building, all the music studios having common boundaries with studios intended for talks or drama. The possible disadvantages of the steel frame have been avoided by double-shell construction of the studios where necessary. The common boundaries could have been eliminated entirely, however, by a different layout of the available space. Interference of one programme by another can only be avoided by a complete separation of studios used for music from those used for talks or drama.

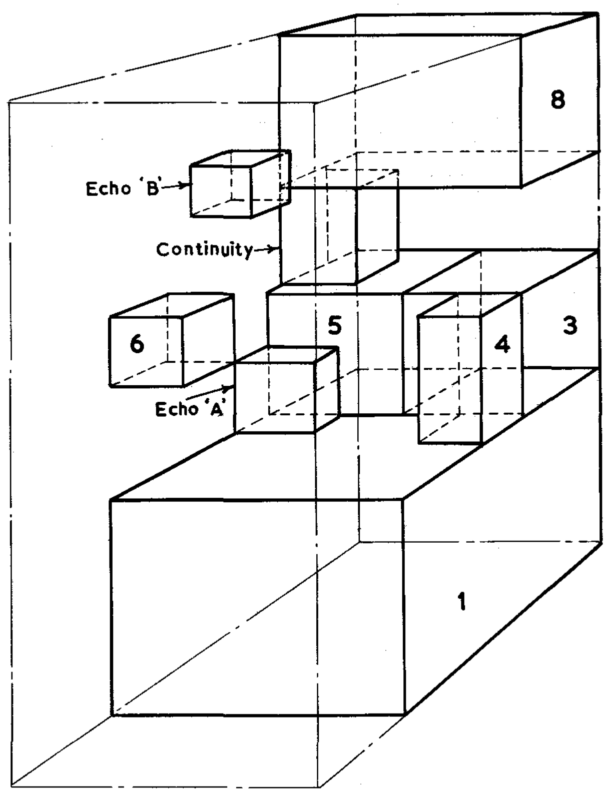

Fig.1
Layout of studios in north wing of B.H., Belfast.
(Not to scale)

3. GENERAL ACOUSTICS.

The acoustic treatment of the studios follows current B.B.C. practice, using membrane absorbers for low frequency absorption and glasswool or rockwool covered with perforated hardboard or Tygan fabric. The results of measurements are summarised in tables and graphs at the end of the report. The reverberation characteristics of the studios are shown in Figs. 2 and 3 and those of the cubicles in Figs. 4 and 5.

3.1. Studio No. 1 (75,000 ft^3) Orchestral Studio.

This studio is only partly completed. A permanent false ceiling has been built, but the walls remain as distempered brickwork and the floor is concrete, partly carpeted and having a central square of linoleum.

The only acoustic treatment consists of some Cabot's quilt and 45 membrane absorbers taking the form of boxes closed with linoleum or roofing-felt membranes covered with cartridge paper. The reverberation time is shown by Fig. 2(a).

The optimum reverberation time for a studio of this size is 1·2 sec., and the studio consequently sounds rather dead at high frequencies. This will be corrected by covering some of the Cabot's quilting with paper and by painting the brickwork with Snowcem, a finish which is less porous than distemper. As a temporary measure, the loudspeaker circuit in Echo Room B has been given a rising characteristic and is used to supplement the high frequency reverberation for certain programmes.

The listening cubicle to Studio No. 1 is virtually untreated acoustically and has too high a reverberation time at low frequencies, Fig. 4(a). Temporary measures are being taken to correct this fault.

3.2. Studio No. 2 (4,000 ft^3) Talks Studio.

Studio No. 2 and its cubicle are formed within two rooms of identical dimensions, the cubicle being reduced in width to allow space for a vestibule insulating both entrances from the corridor. The studio has a ceiling of Colterro lath and plaster on wood joists, and additional bass absorption is provided by 3 in. double membrane absorbers on the walls and beneath a mahogany shelf running along one side of the studio. The remainder of the acoustic treatment consists of 2 in. thick rockwool covered with perforated hardboard. The entire floor is covered with a heavy carpet absorbing strongly over the entire middle and upper frequency range.

With this treatment the reverberation curve was found to be not very different from the final condition shown in Fig. 2(b); subjectively there was a colouration at 90 c/s and there was a lack of middle frequency reverberation compared with the rest of the range, the curve falling to 0·25 sec. at 2 kc/s. This condition was corrected by replacing some of the 20% slotted hardboard by unperforated hardboard, bringing the 2 kc/s figure up to 0·4 sec. and reducing the low-frequency reverberation by about 0·1 sec. After about a year's experience of the studio in service, however, it was felt that the middle and upper frequency reverberation could be reduced with advantage. Some of the unperforated hardboard was therefore replaced by Tygan fabric. Fig. 2(b) shows the reverberation characteristic for the final condition, which is now regarded as satisfactory.

The ventilation noise level is too high, giving readings of 34–40 dB on the Dawe Sound Level Meter, with a 40 dB A.S.A. weighting network, compared with the accepted maximum of 30.

In the initial state the double observation window was fitted with two panes of glass of $\frac{1}{4}$ in. and $\frac{3}{8}$ in. thickness respectively. The studio and cubicle were very prone to acoustic feedback resulting in a howl if a high monitoring level was used, the maximum permissible gain from the microphone in the studio to a normal listening position in the cubicle being only 5 dB for some microphone positions. The frequencies of howl were found to be 32 c/s or 64 c/s corresponding with the common first and second lengthwise modes of the studio and of the cubicle ($17\frac{1}{2}$ ft). It is clear that the unusually low stability was due to the fact that pressure maxima occurring in the cubicle along the partition wall at 32 c/s and its harmonics were able to excite the same modal frequencies in the studio. The window was found to be the principal leakage path at these frequencies and the thicknesses of the two panes were therefore increased to $\frac{3}{8}$ in. and $\frac{1}{2}$ in. respectively. This modification greatly improved the howl-round stability, though it did not appreciably affect the average sound insulation figure which was already satisfactory.

Fig. 4(b) shows the reverberation characteristics of the cubicle.

3.3. Studios Nos. 3 and 5 (6,300, 6,700 ft^3) Drama Studios.

Studios Nos. 3 and 5 will be considered together since they form a pair of drama studios and the problems of their design and treatment were in many respects similar. They are rather low for their horizontal dimensions, and the original designs did not include any absorbing material on the ceilings. Experience with the studios in 1 and 1A Portland Place[3] suggested that severe rings and flutters would be expected. Ceiling absorbers as used in Portland Place were therefore added, consisting of glasswool blankets enclosed in Tygan-covered frames, suspended at varying distances up to 18 in. from the ceiling. Fig. 6 which is a photograph of Studio No. 5 shows the appearance of the ceiling absorbers.

Each studio is built in the form of a complete brick shell isolated from the rest of the building by cavities around the walls and ceiling and by a layer of glasswool quilt beneath the concrete floor. The ceiling, consisting of Colterro lath and plaster, is suspended from the main structure by felt pads, and the inner walls stand on two layers of bituminous roofing-felt. The inner walls were originally intended to be of 3 in. clinker block which would have provided a great deal of absorption below 250 c/s, but $4\frac{1}{2}$ in. brickwork was substituted in the interests of improved insulation. The bass absorption thus lost was difficult to recover and it was eventually necessary to increase very considerably the number of low-frequency membrane absorbers in each studio.

When first tested, both studios were excessively reverberant in the bass and there was a dip in the reverberation characteristic at 1,000 c/s due to the use of slotted (20% open area) hardboard for covering the porous absorbers on the walls.

Studio No. 3 has an average reverberation time of 0·4 sec. above 175 c/s and is found to be good for drama productions requiring dead acoustics (Fig. 2(c)). It is equipped with an effects staircase. The reverberation time of Studio No. 5

averages 0·52 sec. over the same frequency range (Fig. 2(d)). This value is found to be satisfactory for musical programmes, but there are colourations at 130 c/s and 190 c/s. A sufficient range of acoustic conditions for drama, making use of both studios can be obtained by the use of screens.

The reverberation characteristics of the control cubicles are shown in Figs. 4(c) and 4(d). Neither cubicle is good, that of Studio No. 3 being generally too reverberant while that of Studio No. 5 is described as "boomy".

3.4. Studio No. 4 (4,100 ft^3) Effects Studio.

This studio still has a temporary treatment of carpet felt hung on the bare brick walls. It is used as an effects store and no tests were made.

3.5. Studio No. 6 (1,550 ft^3) Talks Studio.

Studio No. 6 intended for use as a recording studio, has the longer walls parallel and the shorter walls inclined at an angle of about 3° to each other. Its cubicle is similarly shaped but narrower in plan. The acoustic treatment of the studio has no unusual features.

There are colourations at 150 c/s and 430 c/s but speech quality is nevertheless fairly satisfactory. The reverberation curve is shown in Fig. 3(a). Listening tests were made more difficult by a ring in the cubicle at about 165 c/s caused by the sheet metal casing of the Marconi control desk. A ribbon microphone is used with slight bass correction to reduce the effect of excessive reverberation below 120 c/s. Sound insulation to the cubicle is just adequate and though the "howl-round" figure is not good, no trouble has been experienced.

The cubicle is boomy, the reverberation curve (Fig. 5(a)) rising steeply in the bass.

3.6. Studio No. 8 (30,000 ft^3) General Purpose Studio.

In its original state, as described in Research Report B.038, this studio was characterised by excessive bass reverberation and by extreme deadness in the region of 500–1,000 c/s. In 1950 a wood strip floor was laid and there was a noticeable improvement. The middle frequency region still remained dead, however, owing to the action of the linoleum membrane absorbers which formed a dado round the studio. At the beginning of 1952 the permanent re-treatment of the studio was finished; a polished wood reflector covered a large central area of the wall behind the orchestra and sufficient absorption to bring the mean reverberation time to 1·2 sec. was dispersed about the walls and ceiling. Fig. 7 shows the reverberation characteristics measured in the course of these changes. Fig. 7(a) is the original curve measured in 1948, and Fig. 7(b) is an estimated curve after the wood strip floor had been laid. Fig. 7(c) was measured by S.S.E.H.S.B.'s department in April 1952, after the permanent treatment had been completed. In this condition, the studio was considered to be too reverberant for normal use with the Northern Ireland Light Orchestra and further modifications were made. Additional absorbing materials were fixed to the ceiling and the reflector was slotted and backed with rockwool to prevent unwanted reinforcement of the tympani and brass. Fig. 7(d) shows the reverberation characteristic thus obtained; the mean time is about 0·9 sec., and although this is approximately equal to the previously accepted B.B.C. optimum time, the studio was now rather too dead for a satisfactory distant microphone balance. The definition had been improved, however, and colourations previously present had been eliminated. A further slight adjustment was made to lift the reverberation time in the region of 1,000 c/s, glass fibre being removed from behind slotted hardboard panels over a total area of 100 ft^2. This change resulted in an appreciable improvement, though the studio remains rather too dead for music. The placing of bass instruments is very critical and definition is poor with a single microphone. The results obtained with drama and with the multi-microphone balances normally used by the N.I.L.O. are acceptable.

Fig. 7(e) is an estimated reverberation curve for the final condition. The experiments confirm previous experience in showing that the achievement of good definition and balance with an orchestra of 25 players in a studio as small as 30,000 ft^3 may be difficult if an adequate reverberation time for good tone quality is to be preserved. Better results are obtained from Studio No. 1 with its volume of 75,000 ft^3, even though it has received only rudimentary acoustic treatment. It would not be true to say, however, that the small size is the only reason for the poor compromise between tone quality and definition; Glasgow Studio No. 2, for example, is smaller and gives better results. The table below compares the volumes and reverberation times of the smaller regional music studios:

Studios used for orchestras up to about 30 players

Studio	Approx. No. of players	Volume ft^3	Mean Reverberation Time	
			Empty	With Orchestra
Glasgow No. 2	24	24,000	0·99	0·82
Belfast No. 8	25	30,000	0·91	0·79
Manchester No. 1	20-25	33,000	1·10	0·99
Swansea No. 1	32	36,000	1·27	1·01
Charles St., Cardiff	32	43,000	1·38	1·10
Bristol No. 1	30	58,000	0·97	0·87

It will be seen that Belfast Studio No. 8 has a lower mean reverberation time than any other, including even Glasgow Studio No. 2 which has only four-fifths of the volume of Belfast Studio No. 8. Reference to curves (c), (d) and (e) of Fig. 7 shows that apart from two fluctuations the reverberation time falls as the frequency rises, in contrast to the behaviour of many other studios. The additional absorption by the orchestra will increase the rate of fall.

An analysis of other small-orchestra studios, which will not be given in detail here, suggests that the mean reverberation time from 1,000 c/s to 4,000 c/s with the orchestra present should be at least as great as that from 125 c/s to 500 c/s. This conclusion may not apply to large studios, in which a relatively longer middle frequency reverberation time is found to be acceptable, but it appears to be particularly applicable to studios less than 60,000 ft^3 in volume.

In the case of Belfast Studio No. 8 the mean reverberation times in the lower and upper bands are respectively 0·87 sec. and 0·71 sec., a fall of 20%. It appears probable therefore that the definition and tone might be improved by increasing the reverberation time above 700 c/s to about 0·95 sec. with the orchestra in the studio. It must be remembered, however, that the studio will not be used primarily for orchestral programmes, and such a change would not improve the studio for other purposes.

The cubicle has the same basic treatment as in 1948, but has been modified to reduce the upper frequency reverberation (Fig. 5(b)). It is considered to be satisfactory.

3.7. Continuity Studio (2,750 ft^3).

The Continuity Studio is of generous size; it has an inner lining of 3 in. breeze with a 2 in. cavity, standing on isolating layers of bituminous felt. The floor, consisting of $\frac{7}{8}$ in. boarding on $1\frac{1}{2}$ in. battens, lies on a layer of quilted glass wool. The Colterro lath ceiling is suspended in the same manner as that of Studios Nos. 3 and 5. The acoustic treatment consisted initially of 1 in. and 2 in. deep porous absorbers covered with slotted hardboard of 20% open area, and suspended frames of Tygan-covered glasswool as in Studios Nos. 3 and 5. The reverberation characteristic was found to be too high in the bass and too low in the 1,000 c/s region. The anti-flutter ceiling absorbers were therefore replaced by membrane absorbers and some of the 20% hardboard covers by unperforated hardboard or Tygan fabric.

When this had been done, the shape of the reverberation characteristic was satisfactory, but the mean reverberation time of 0·51 sec. was found to be too great. Further modifications reduced the mean time to 0·40 sec., though the characteristic (Fig. 3(d)) falls steadily with increase of frequency and the studio remains rather boomy and coloured in the bass.

There is no control cubicle, the studio being monitored from a desk in the adjacent control room. The insulation between the studio and the control room is satisfactory and the monitoring desk area is partly enclosed for protection against control room sounds by a screen and roof of Tentest "Rabbit-Warren" board.

3.8. Echo Rooms.

There are two echo rooms. Echo Room A is on the 3rd floor, lying adjacent to the cubicle of Studio No. 5. Echo Room B is on the fifth floor and is normally associated with Studio No. 8. Though identical in size with Echo Room A, it differs in having a dividing wall along the centre line extending from one end of the room to within 5 ft of the other end. The LSU 10 loudspeaker and the microphone are placed on different sides of the dividing wall, well away from the communicating end.

The reverberation characteristics are shown in Figs. 8(a) and (b). That of Echo Room A, which has no deliberate acoustic treatment, falls from $2\frac{1}{2}$ sec. in the bass to 0·8 sec. at 8,000 c/s. Echo Room B has been acoustically treated with membrane absorbers, and the reverberation time reaches its highest value of 2·2 sec. between 700 and 2,000 c/s. It is found to be very suitable for use in conjunction with an orchestra in Studio No. 1, for which purpose, a filter with a rising frequency characteristic is sometimes inserted into the loudspeaker circuit.

3.9. 4th Floor Listening Room.

A quality checking room is situated on the 4th floor next to the Continuity Studio. The acoustic treatment consists of shallow porous absorbers, the only bass absorption being provided by the plaster and Colterro lath ceiling. The reverberation characteristic is shown in Fig. 8(c).

4. CONCLUSIONS.

Some conclusions of a general nature were formed as a result of the experimental work described above. They are stated briefly here as a guide for future designs.

4.1. Sound Insulation.

It is not practicable to put a music studio adjacent to any other studio without providing complete isolation, e.g. by an open corridor or some equally large cavity. Impact sound insulation is satisfactorily dealt with by the floating floor constructions used in Belfast.

The double windows between studios and their cubicles should have glass of thickness not less than $\frac{3}{8}$ in. and $\frac{1}{2}$ in. to avoid the possibility of "howl-round". The dimensions of cubicles and studios should not be identical, nor in simple ratios, especially perpendicular to the common window.

4.2. Acoustics of Talks and General-Purpose Studios.

The three Belfast studios intended for speech are only fairly good. The reverberation times all decrease from about 0·45 sec. at 100 c/s to 0·3 sec. at 8,000 c/s, but they are acceptable with suitable microphone corrections. Experience with these studios in their intermediate and final stages confirms other experience in showing that the reverberation time should not start to rise with decreasing frequency until a frequency lower than 100 c/s is reached. Excessive reverberation between 100 c/s and 200 c/s gives rise to very serious colourations.

Breaking up of the ceiling areas by the use of suspended absorbing frames was successful in eliminating flutters and rings, but absorbers of a similar area forming part of the ceiling would probably have been equally effective.

Slotted hardboard of 20% open area cannot be regarded as an effectively transparent cover for porous absorbers. Alternative types of cover, e.g. Tygan fabric, have been found necessary to provide adequate absorption above 2,000 c/s.

4.3. Music Studios.

In the design or re-treatment of small music studios it is necessary to ensure that with the orchestra in the studio there is no general decrease of reverberation time with increasing frequency. The mean reverberation time between 1,000 c/s and 4,000 c/s under these conditions should be at least as great as that between 125 c/s and 500 c/s. To achieve this object, the reverberation characteristic of the empty studio should be a maximum in the former frequency range.

5. REFERENCES.

1. Research Department Report B.038, "Acoustic Measurements in Belfast Studios", January 1949.

2. Mintz and Tyzzer, "A Loudness Chart for Octave Band Data on Complex Sounds", J.A.S.A. 24 (January 1952), pp.80-83.

3. Research Department Technical Memorandum B.1004, "The Acoustics of the Studios at 1 and 1A Portland Place", November 1952.

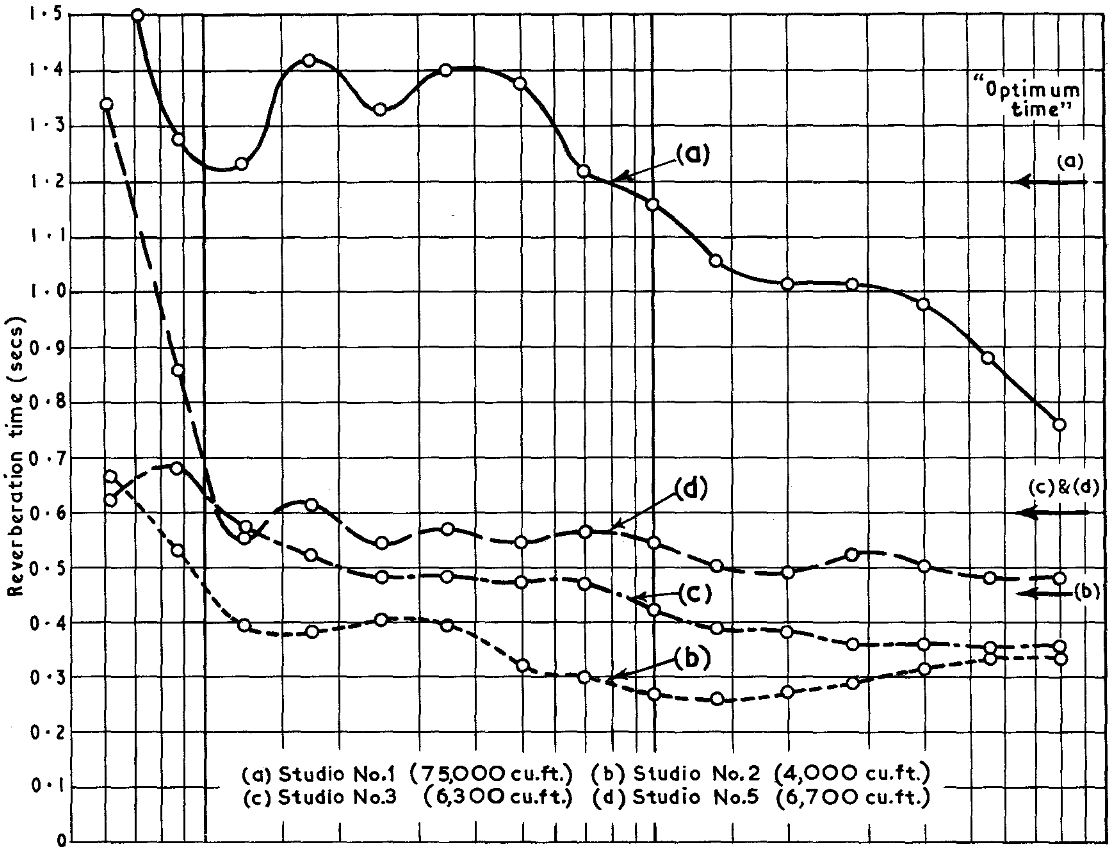

Fig. 2 – Reverberation characteristics of studios.

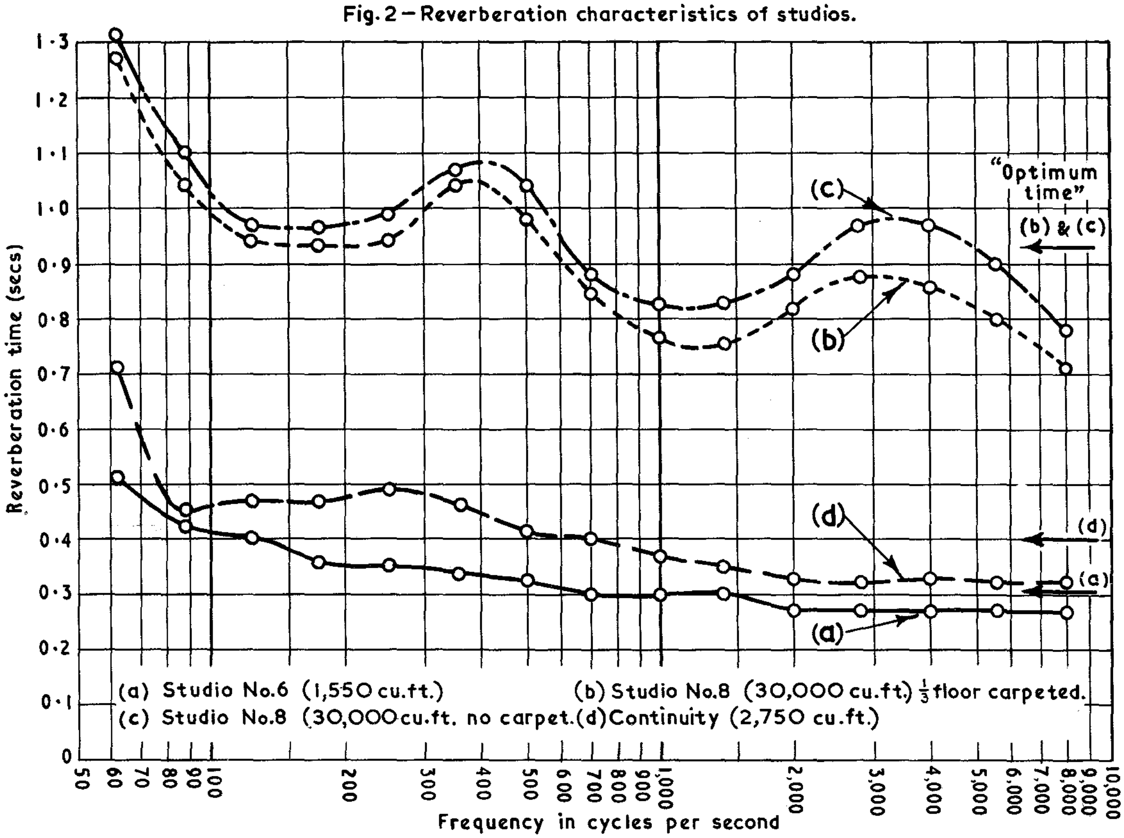

Fig. 3 – Reverberation characteristics of studios.

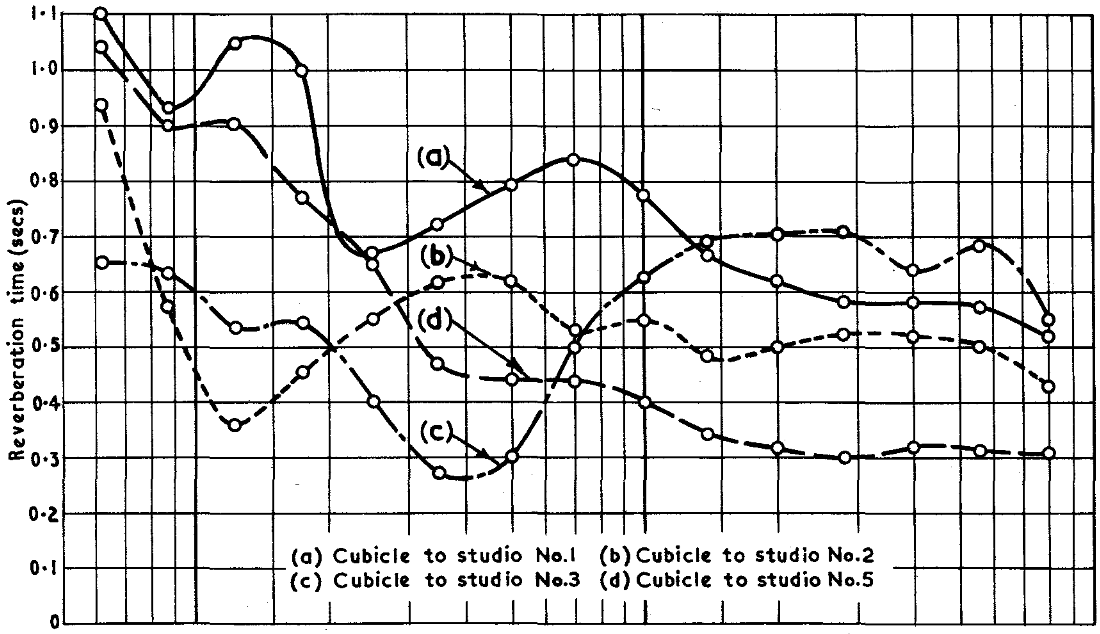

Fig.4–Reverberation characteristics of listening cubicles.

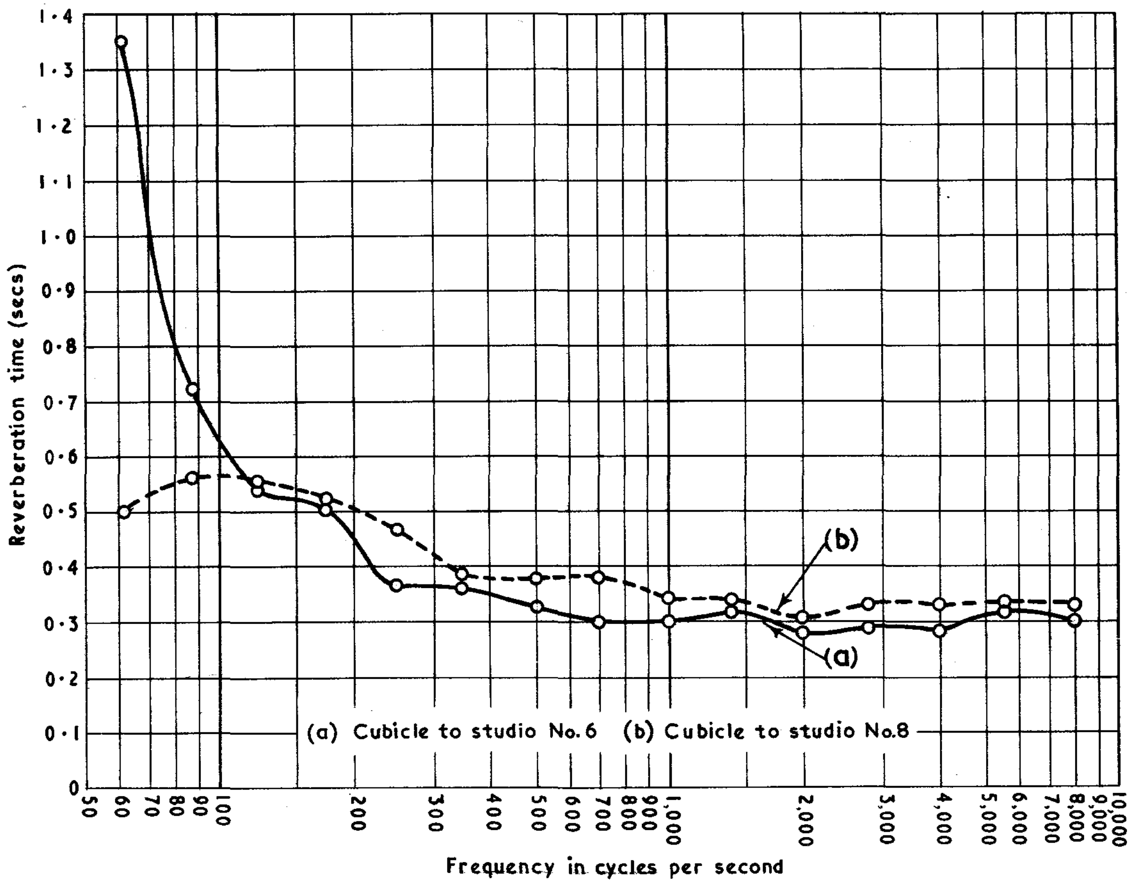

Fig.5–Reverberation characteristics of listening cubicles.

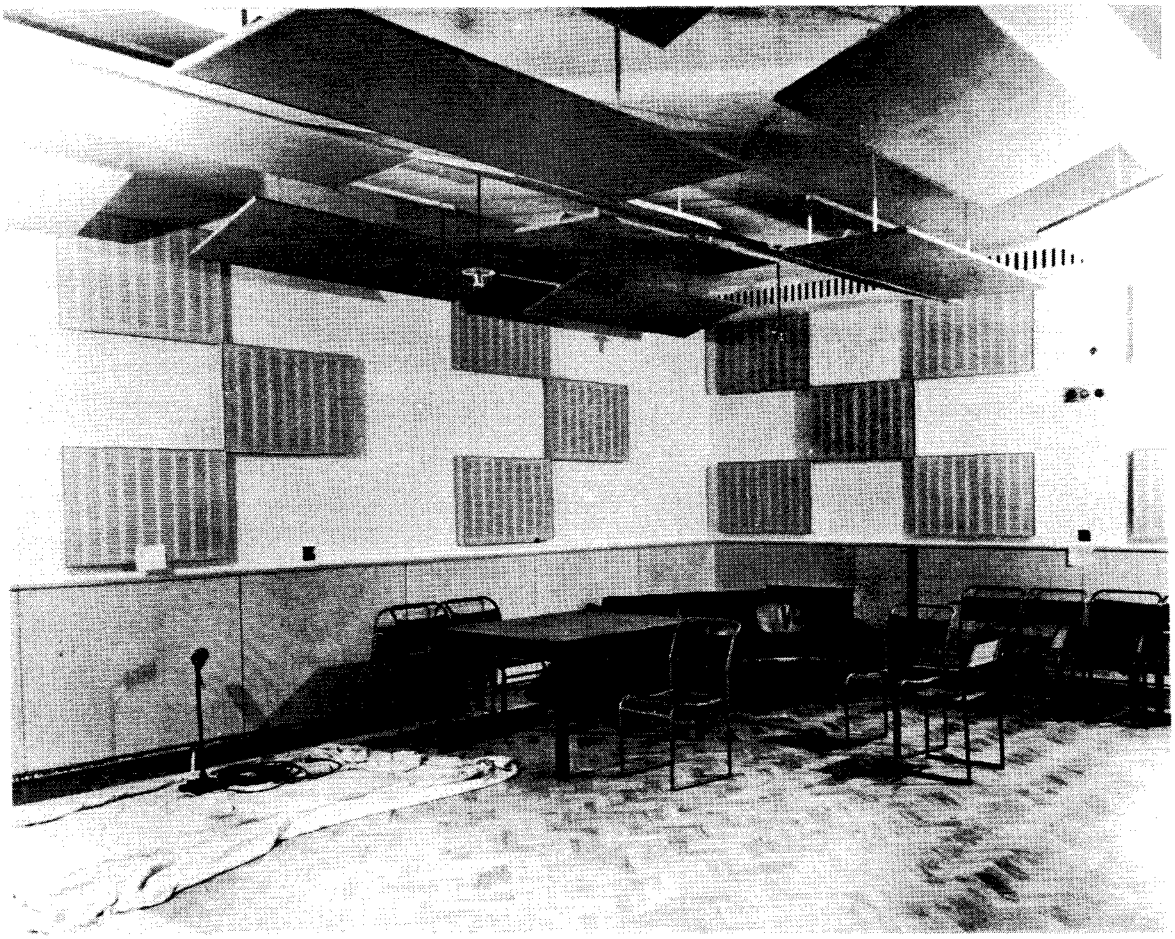

Fig. 6 - Photograph of Studio No. 5 showing absorbers suspended from ceiling to prevent flutters.

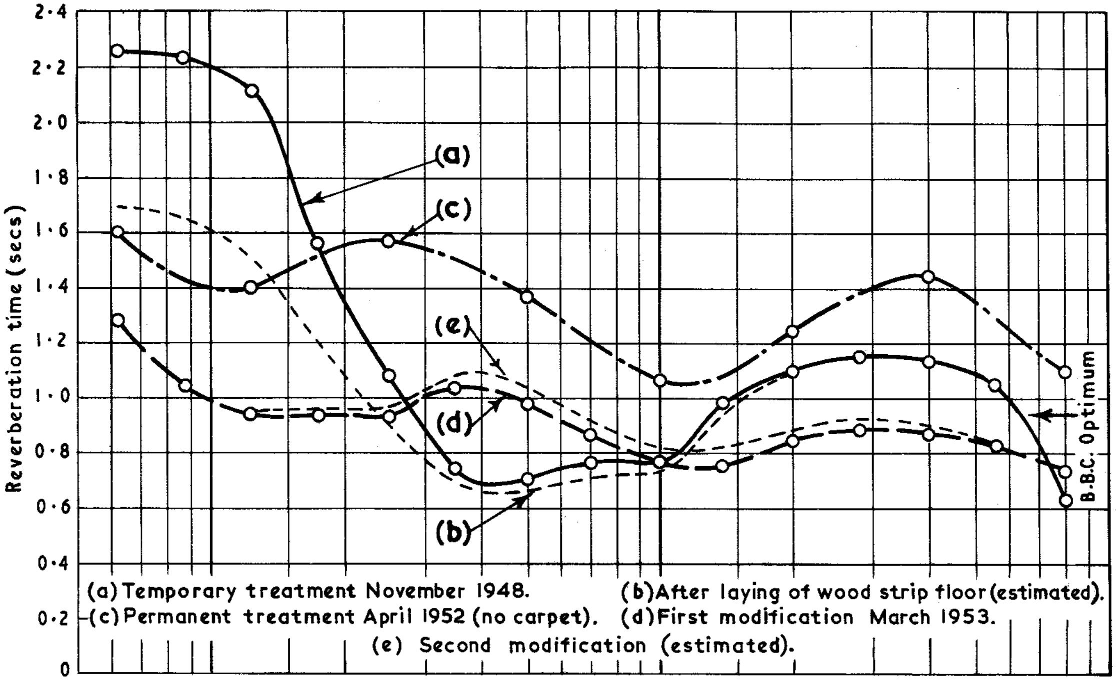

Fig.7 Reverberation characteristics of studio No.8

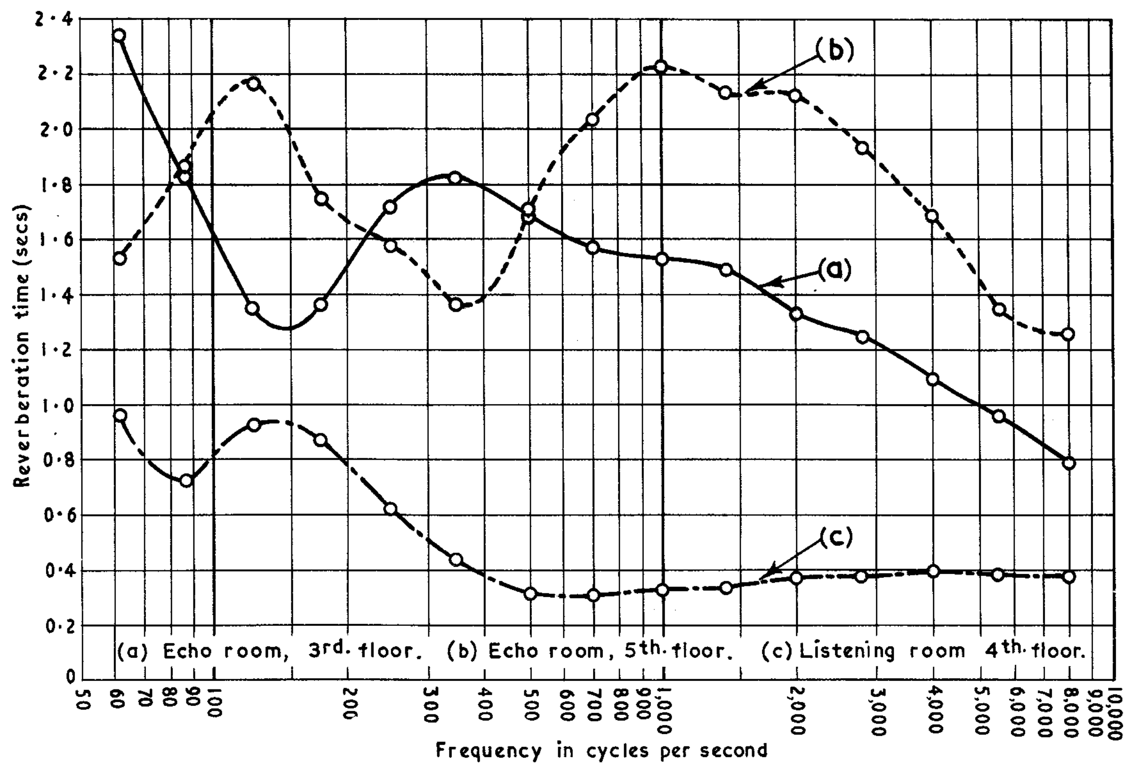

Fig.8–Reverberation characteristics.

APPENDIX

SUMMARY OF MEASUREMENTS

Table 1

Dimensions of Studios etc.

	Floor	Dimensions	Volume ft^3	Notes
Studio No. 1	Ground	60 × 43½ × 29	75,000	} Temporary treatment
Cubicle No. 1	Ground	11 × 10 × 10	1,100	
Studio No. 2	1st	22 × 17½ × 10	4,000	
Cubicle No. 2	1st	18 × 16 × 11	3,100	
Studio No. 3	2nd	28 × 20½ × 11	6,300	
Cubicle No. 3	2nd	15 × 14 × 10	2,100	
Studio No. 4	2nd	22 × 14 × 14	4,100	(shell only)
Studio No. 5	2nd	29 × 21½ × 11	6,700	
Cubicle No. 5	2nd	16 × 13½ × 10	2,130	
Studio No. 6	4th	15 × 12 × 8¼	1,550	Non-parallel walls
Cubicle No. 6	4th	17 × 8¼ × 10¼	1,360	
Studio No. 8	5th	49½ × 29½ × 23	30,000	
Cubicle No. 8	5th	20½ × 13½ × 10	2,930	
Continuity	4th	20 × 12½ × 11	2,750	
Listening Room	4th	14½ × 13 × 11	2,070	
Echo Room A	3rd	16 × 14 × 11	2,620	
Echo Room B	5th	15½ × 15 × 11	2,610	With dividing wall

Table 2

Measurements of Airborne Sound Insulation between Studios

	Studio Nos.					
From	1	1	3	3	C.R.	8
To	3	5	1	5	3	Continuity
c/s	Insulation dB					
			*			
44	–	–	39	24	–	–
50	–	–	48	36	62	20
62	36	39	41	31	40	38
75	–		34	37	48	50
88	41	40	38	30	45	45
105	–		32	32	50	46
125	48	45	44	35	46	41
150	–	–	36	–	50	–
175	50	51	45	41	54	47
210	–	–	50	–	57	–
250	59	64	49	50	52	48
350	69	69	51	50	60	51
500			57	55	56	63
700			62	61		65
1,000			64	65		
1,400			64	71		
2,000						

* Before construction of the ceiling in Studio No. 1.

Table 3

Sound Insulation between Studios and Cubicles

Studios Nos.	2	3	5	6	8	Continuity
Frequency c/s	Insulation dB					
44	44	43	41	–	–	22
50	42	33	39	–	43	32
62	40	35	52	32	41	34
75	40	53	45	–	39	29
88	53	50	53	21	43	38
105	43	49	43	–	42	31
125	40	45	46	33	52	32
150	45	54	–	–	43	36
175	42	41	50	32	49	39
210	–	46	–	–	–	38
250	47	49	47	35	49	42
350	50	50	50	37	48	46
500	53	51	56	48	47	49
700	58	55	64	47	58	53
1,000	64	54	64	54	56	51
1,400	64	51	62	51	56	–
2,000	60	51	54	49	55	–
2,800	59	–	58	46	58	–
4,000	66	–	62	47	59	–

Table 4

Howl-round between Studios and Cubicles (Final Condition)

The figures in this table represent the maximum sound-level gain in dB between a microphone in the studio and the normal listening position in the control cubicle, above which howl-round occurs[3]. The experimental chain comprises the microphone and monitoring loud-speaker normally used with the studio.

Studio	Howl-round gain (dB)	
	Best mic. position	Worst mic. position
No. 2	22	18
No. 3	32	32
No. 5	32	32
No. 6	30	24
No. 8	32	32
Continuity	30	26