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by

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T.D. Northwood

Plasterboard walls constitute an important type of construction particularly in modern dwellings, but also in other types of buildings. Such walls are relatively light, inexpensive, and easy to erect, and they may be made to provide adequate fire protection and sound insulation.

Although sound insulation measurements for various plasterboard walls have been made by various laboratories, they have not, until recently, been sufficiently well coordinated to provide an understanding of the effects of various parameters. The purpose of this note is to present systematic measurements on a wide variety of such constructions. This will provide, for immediate use, up-to-date information on many practical walls obtained by the latest test procedures (ASTM E90-66T). The main objective, however, is to provide experimental information from which general conclusions applicable to other multi-leaf walls may be derived. This note is a complete record of the test results; another paper analysing the general relations, from empirical and theoretical viewpoints, is also in preparation.

GENERAL NOTES

A typical plasterboard wall consists of two plasterboard leaves separated by an air space and a system of studs or framing members. The sound transmission loss (TL) of such a wall depends on the TL's of the individual leaves and on the degree of coupling introduced by the intervening air space and stud system.

It is found that both the air space and the studs play an important part in determining the over-all transmission loss, and both paths must generally be considered when improvements in sound insulation are attempted. Transmission through the space depends on the internal spacing between wall leaves, the degree of lateral subdivision of the space, and the amount of absorption treatment in the space. Transmission through the studs depends on the rigidity of the studs and the stud-plasterboard connections; the process may be thought of as the propagation of flexural vibrations from one wall surface to the other by torsion in the studs. If the studs have low torsional rigidity (e.g. steel channels) transmission via the studs appears to be negligible. The effects of various stud and stud connection systems are examined in later sections.

The performance of the individual leaves of the wall depends on their surface density (mass per unit area), stiffness, and internal damping.

EXPERIMENTAL DETAILS

All sound transmission measurements reported here were made in accordance with ASTM E90-66T, "Laboratory Measurement of Airborne Sound Transmission Loss of Building Partitions." A few of the simpler constructions, especially single-leaf walls, have been tested by several laboratories and the results are found to be reasonably reproducible. In addition, the transmission loss was calculated for some of the single-leaf walls utilizing theory developed by L. Cremer [1] some years ago. The parameters required for the calculation are the surface density, modulus of elasticity, and internal damping of the material. These quantities were determined for plasterboard by static and dynamic experiments on small samples of plasterboard.

The calculations will be described in detail in a separate report but one detail is worth noting. The basic expression for transmission ratio applies to a train of plane waves reaching the wall at a particular angle of incidence. To obtain the "random incidence" transmission loss, this expression is averaged for a uniform distribution of all angles from normal to grazing incidence. Grazing incidence is an unrealistic limit for finite rooms and walls and, unfortunately, the calculated result is quite sensitive to this limiting value. Some writers, noting that some measured TL values were about 5 dB higher than calculated random incidence values, have inferred that the limiting angle of incidence is about 78 degrees, the so-called "field incidence" case. The present series of calculations and laboratory measurements give the best fit for a limiting angle of 85 degrees. It appears, however, that there can be a spread of about 5 dB among various laboratory and field measurements, depending on the exact angular distribution of the incident sound field.

Test specimens were mounted in an opening 10 ft wide by 8 ft high separating two reverberation rooms. The source room has a volume of 2100 cu ft and the receiving room has a volume of about 9000 cu ft. Following ASTM E90, each room is equipped with fixed and moving diffusing panels designed to provide as good an approximation as possible to the diffuse sound field that is assumed in transmission loss theory. The sound pressure level in each room is sampled by a set of nine microphones whose outputs are observed individually. The variation is small enough that a simple arithmetic mean of sound pressure levels is sufficient to determine the space-average sound pressure level in each room. The test signal consists of third-octave bands of "pink" noise and measurements are taken at a series of third-octaves centred on 125 to 4000 Hz. In some measurements, the results were extended to 5000 Hz to permit a better study of coincidence effects in the high-frequency region.

PREPARATION OF TEST WALLS

The test specimens are described briefly in the tables of results, but a few construction details are elaborated on as follows.

Joints

Preliminary tests were made with joints between plasterboard sheets finished with the conventional tape and joint compound. These gave results identical to those obtained when the joints were simply sealed with masking tape (see Group I, Wall No. 1.2). Most subsequent tests were done with masking tape on the joints.

Lamination Procedure

When two layers (plasterboard or other materials) were laminated together with gypsum joint compound, a special applicator was used to apply the compound in a uniform manner in strips 5/8 in. wide by 5/8 in. high and spaced 1 3/4 in. apart. The second layer of plasterboard was then pressed into place. Temporary screws holding the two sheets together during curing were removed before test. Two test walls were installed by a local contractor, using an alternative technique consisting of a few small patches of joint compound and an extra set of permanent screws driven through the first sheet into the studs. In the few instances when contact cement was used for lamination, it was spread over the entire surfaces.

Space Absorption

Mineral wool or glass fibre batts about 2 in. thick or greater were used. It was found that the results were not critically sensitive to thickness or density; a $\frac{1}{2}$-in. glass fibre board was slightly less effective as an absorber at low frequencies, but similar to the thick batts at high frequencies.

Studs

Conventional 2 x 4 wood studs (1 5/8 by 3 5/8 in.) were used at 16- and 24-in. spacings. They were set in a 2 x 4 frame around the perimeter of the test opening. Tests conducted without studs utilized the same 2 x 4 perimeter frame for supporting the plasterboard. Steel channels 3 5/8 in. and $2\frac{1}{2}$ in. wide, spaced at 24-in. centres, were mounted in the appropriate perimeter channel frame. A few tests were done also with 1 5/8-in. channels staggered in a $2\frac{1}{2}$-in. perimeter frame.

Caulking

To avoid problems relating to leakage at the perimeter, a bead of caulking compound was applied around the perimeter in every case. No attempt was made in this study to investigate the efficacy of control joints such as are needed in installations in actual buildings.

Plasterboard

With the co-operation of several manufacturers, special samples were obtained of gypsum board, representing the extremes of density and thickness allowed under CSA Standard A82.27-1963. It was found that within this range there was no measurable difference in performance for a particular nominal thickness. Similarly, no difference was found between conventional gypsum board and the so-called Type X, fire-resistant version. Results for vinyl-covered board (vinyl applied over paper) were close to those for the ordinary paper-covered versions.

RESULTS

The results of all the transmission tests included in this series (approximately 100) are reported in the attached tables. The test specimens are arranged in four groups as follows.

Single-Leaf Walls (Table I)

In this group are gathered the test results for single layers of plasterboard and other materials, plus composite constructions consisting of various sheet materials laminated together. It is hoped that these data, together with results for two-leaf walls, will provide material for testing any theory applicable to two-leaf walls.

Double-Leaf Walls, Main Components ½-in. Plasterboard (Table II)

Included in this group are all the walls in which ½-in. plasterboard forms the main component of each leaf. Walls with additional layers that add damping or that affect the stud-plasterboard connection are also included.

Double-Leaf Walls, 5/8-in. Plasterboard (Table III)

Many of these walls essentially duplicate constructions already described in Table II, but for fire resistance purposes 5/8-in. plasterboard is generally more acceptable in practice. As compared to ½-in. plasterboard, 5/8-in. material is 1 to 2 dB superior below 1000 Hz because of the additional surface density. Above 1000 Hz the coincidence dip with 5/8-in. plasterboard falls about one-third octave below the dip for $\frac{1}{2}$-in. board. This results in slightly poorer high frequency performance.

Included in the tests listed in Table III were studies of various systems for connecting plasterboard to studs.

Double-Leaf Walls Employing Multiple Layers or Different Thicknesses of Plasterboard (Table IV)

This group includes walls formed from different thicknesses of plasterboard or multiple layers thereof.

For each wall tested the right-hand portion of the table contains a brief description of the specimen, including the surface density of the wall leaves and, as a single-figure rating, the ASTM Sound Transmission Class. On the left-hand side of the table are given the transmission losses for the standard third-octave frequency bands from 125 to 4000 Hz (in some instances up to 5000 Hz).

REFERENCE

1. L. Cremer: The Propagation of Structure-Borne Sound. Sponsored Research (Germany) - Report No. 1, Series B (Ca 1949), Department of Scientific and Industrial Research, Great Britain.

TABLE I GROUP I -- SINGLE-LEAF WALLS

/all No.	Surface Density	Description of Specimen	STC	Frequency - Hz 125	160	200	250	315	400	500	630	800	1000	1250	1600	2000	2500	3150	4000	5000
	(lb/sq ft)																			
..1	1.6	3/8" plasterboard	26	12	15	17	17	19	20	23	24	26	28	30	32	33	31	25	23	26
..2 a	2.1	1/2" plasterboard, joints taped and finished		16	19	19	20	21	23	25	26	28	31	32	34	33	27	24	27	31
b	2.1	1/2" plasterboard, joints taped (masking tape)		15	19	18	19	22	24	25	26	28	32	32	33	33	28	25	26	
c	2.1	1/2" plasterboard, joints taped (masking tape)		15	17	19	20	21	23	25	26	27	29	31	32	32	29	25	27	
d	2.1	1/2" plasterboard, mean of a, b, c	28	15.3	18.3	18.7	19.7	21.3	23.3	25.0	26.0	27.7	30.7	31.7	33.0	32.7	28.0	24.7	26.7	
.3	2.7	5/8" plasterboard, mean of two measurements	29	16.0	18.5	20.5	21.5	23.0	24.5	27.0	28.0	29.5	31.0	32.5	32.5	28.5	25.5	27.5	30.5	
.4	3.5	1/2" plasterboard + 3" squares of 5/8" contact cement	32	18	20	23	24	25	27	30	30	32	34	35	36	34	32	32	34	35
.5	3.1	1/2" plasterboard + 1/16" lead, contact cement	30	17	20	19	21	23	24	27	28	29	31	32	33	34	33	32	33	
.6	2.6	1/2" plasterboard + 3/16" plywood, contact cement	28	16	16	20	20	22	24	25	26	27	29	30	32	32	30	30	31	35
.7	2.1	1/2" plasterboard, vinyl faced	26	14	16	18	18	20	22	24	25	27	29	30	32	32	27	25	27	32
.8 a	3.3	1/2" plasterboard laminated, a-2 days curing	32	18	20	22	23	26	27	29	30	33	34	36	36	36	34	32	32	35
b		to 1/2" wood fibreboard b-5 " "	31	16	19	22	22	26	26	28	30	32	34	35	35	34	30	29	32	33
c	3.3	with gypsum joint com- c-7 " "	30	16	19	22	22	24	26	28	30	31	33	35	35	32	29	29	30	32
d	3.3	pound d-14 " "	30	17	17	22	22	25	26	28	29	32	33	35	35	32	29	28	30	32
.9 a	4.6	2 layers, 1/2" plasterboard, joint compound, poor bond	31	20.5	23.0	25.0	25.0	25.5	29.0	29.0	29.5	31.0	32.5	31.5	29.5	29.5	30.5	35.0	36.5	
b	4.6	2 layers, 1/2" plasterboard, joint compound, better bond	30	17	24	24	26	27	28	30	31	31	31	26	26	29	32	35	37	
c	4.6	Mean of a, b	31	18.8	23.5	24.5	25.5	26.2	28.5	29.5	30.2	31.0	31.8	28.8	27.8	29.2	31.2	35.0	36.8	
.10	3.8	2 layers, 3/8" plasterboard, gypsum joint compound, cured 3 days	32	18	22	24	24	26	27	29	30	32	34	35	37	37	36	34	33	35
.11	1.4	22-gauge galvanized iron	27	13	18	16	17	18	21	22	24	26	28	30	32	34	36	38	39	
.12	2.1	1/2" plasterboard, screwed to 2 x 4 studs at 16"cc	28	14.5	16.5	18.0	18.0	20.5	22.5	24.5	26.5	27.5	30.5	31.5	32.5	32.0	27.5	26	29	
.13	2.1	1/2" plasterboard, screwed to 2 x 4 studs at 24"cc	27	13.0	17.0	19.0	19.5	21.5	22.0	25.0	26.0	27.5	30.0	32.0	33.0	33.0	28.0	25.5	27.5	31.5
14	2.1	1/2" plasterboard, screwed to 3-5/8" channels at 24"cc	27	12	17	18	18	20	21	25	26	30	31	32	35	33	28	24	27	
15	2.1	1/2" plasterboard, vinyl faced, 2-1/2" channels at 24"cc	27	13	20	18	18	21	22	25	26	28	30	31	32	33	28	26	28	32
16	2.7	5/8" plasterboard, screwed to 2 x 4 studs at 16"cc	28	16	18	20	20	23	25	25	27	30	31	32	32	28	27	29	32	
17	2.7	5/8" plasterboard, screwed to 2 x 4 studs at 24"cc	28	16	20	20	20	23	24	27	28	29	32	33	32	27	26	28	32	
18	4.6	2 layers, 1/2" plasterboard, gypsum joint compound (DBR method), first layer screwed to 3-5/8" metal channels at 24"cc	31	18	22	23	24	26	27	30	32	33	34	32	27	28	31	34	36	
19	4.3	2 layers, 1/2" plasterboard, small particles, joint compound, both layers screwed to 3-5/8" metal channels	31	20	22	22	24	25	27	28	30	31	32	33	35	34	32	31	33	

TABLE II GROUP II -- TWO-LEAF WALLS, ½" PLASTERBOARD EACH LEAF

Wall No.	Surface Density	Description of Specimen	STC	125	160	200	250	315	400	500	630	800	1000	1250	1600	2000	2500	3150	4000	5000
				Frequency - Hz																
	(lb/sq ft)	(a) Simple plasterboard leaves, 3 5/8" space, no absorption																		
2.01	4.2	No studs	33	14	18	20	21	24	26	30	33	39	44	46	50	46	43	45	37	46
2.02	4.2	Nominal 2 x 4 studs at 16"cc	33	12.0	15.7	21.0	22.7	25.7	28	32.3	34.7	38.0	40.7	43.3	44.7	44.0	37.3	35.7	39.3	
2.03	4.2	Nominal 2 x 4 studs at 24"cc	35	15.5	20.5	28.0	28.0	28.0	29.0	32.0	35.5	38.0	41.5	44.0	46.0	46.5	39.0	34.5	38.0	
2.04	4.2	3 5/8" steel channels at 24"cc	37	19.0	22.5	25.5	25.0	25.0	30.5	36.0	37.5	41.0	44.0	46.5	49.0	48.5	40.5	36.5	39.0	
		(b) Simple plasterboard leaves, 3 5/8" space, 2" absorption																		
2.11	4.2	No studs	45	24	31	35	39	42	43	45	46	47	49	51	52	52	46	41	45	
2.12	4.2	Nominal 2 x 4 studs at 16"cc	36	12	18	27	31	32	32	36	37	40	43	44	46	47	40	37	41	
2.13	4.2	Nominal 2 X 4 studs at 24"cc	40	22	36	35	33	32	36	35	39	41	43	45	46	47	42	37	40	
2.14	4.2	3 5/8" steel channels at 24"cc	46	26.0	30.5	33.5	35.5	39.5	42.5	46.0	48.0	50.0	51.5	52.0	54.5	55.0	48.5	42.5	44.5	
		(c) Simple plasterboard, various spacings, space treatments																		
2.21	4.2	No studs, 2 1/2" space	29	13.0	15.5	17.0	17.5	19.0	21.5	26.0	28.5	32.5	37.0	41.0	43.0	42.5	34.0	36.0	44.0	
2.22	4.2	2 1/2" steel channels at 24"cc	36	15	21	24	24	26	29	34	36	40	42	46	47	48	40	41	43	46
2.23	4.2	Staggered 1 5/8" channels in 2 1/2" space	34	11	18	21	21	24	29	33	36	39	43	46	47	48	45	41	47	
2.24	4.2	No studs, 2 1/2" space, 2" space absorption	44	20	27	31	34	40	44	48	50	51	50	50	52	53	49	48	50	
2.25	4.2	2 1/2" channels at 24", 2" space absorption	44	20	28	30	33	38	42	45	46	49	48	49	50	50	46	44	45	
2.26	4.2	Staggered 2 x 4 studs in 5 5/8" space, 2" absorption	46	28	32	34	34	40	42	42	45	48	50	53	54	53	50	48	48	
		(d) 1/2" plasterboard and various other materials																		
2.31	5.2	2 x 4 studs at 16", 3/16" plywood cemented to each surface	35	11	19	24	26	28	30	34	37	39	42	42	44	46	45	45	48	
2.32	6.6	2 x 4 studs at 16", 1/2" wood fibreboard between studs and plasterboard, both leaves	42	18	25	28	32	37	39	40	41	43	46	49	52	53	51	50	49	
2.33	7.6	2 x 4 studs at 16", 1/2" wood fibreboard between studs and plasterboard, both leaves, 3/16" plywood, both leaves	46	22	30	33	36	41	44	46	48	51	54	57	56	56	54	54	56	
2.34	5.2	No studs, 3 5/8" space, 1 lb. lead sheet adhered to one leaf	35	19	20	21	21	25	28	32	36	39	42	45	47	47	43	43	47	
2.35	5.2	3 5/8" channels at 24"cc; 1 lb. lead sheet adhered to one leaf	40	24	25	28	27	28	33	38	41	43	45	46	50	49	46	44	46	
2.36	5.2	3 5/8" channels at 24"cc; 1 lb. lead sheet adhered to one leaf, 2" absorption in space	48	33	33	35	38	42	44	44	48	51	50	52	54	54	52	50	51	

TABLE III GROUP III -- TWO LEAVES, 5/8" PLASTERBOARD

Wall No.	Surface Density	Description of Specimen	STC	Frequency - Hz 125	160	200	250	315	400	500	630	800	1000	1250	1600	2000	2500	3150	4000	5000
	(lb/sq ft)	(a) Simple walls, 3 5/8" spacing, no absorption																		
3.01	5.4	No studs	34	14	20	21	23	25	28	32	37	41	44	44	45	39	36	40	43	
3.02	5.4	2 x 4 studs at 16"cc	34	14.5	15.0	20.0	24.0	26.5	28.5	31.5	35.5	38.5	40.5	41.0	40.0	37.0	35.5	39.0	43.0	
3.03	5.4	2 x 4 studs at 24"cc	36	21	24	26	25	30	30	34	36	39	41	42	41	36	34	37	42	
3.04	5.4	3 5/8" channels at 24"cc	39	20.0	23.0	29.5	30.5	29.5	34.0	39.5	40.5	44.5	47.5	48.5	46.5	39.0	37.5	40.0	45.5	
3.05	5.4	2 x 4 studs at 16"cc, one leaf screwed to studs, other adhered with contact cement	34	17	16	20	24	28	28	31	35	38	40	40	40	38	36	40	45	48
		(b) Simple walls, 3 5/8" space, 2" absorption (except 3.15)																		
3.11	5.4	No studs	43	25.0	34.5	38.5	40.0	41.5	43.0	45.0	45.0	45.5	46.0	47.5	47.5	42.0	39.0	42.0	46.0	
3.12	5.4	2 x 4 studs at 16"cc	38	14	19	27	33	33	34	35	38	41	43	44	44	40	37	40	45	
3.13	5.4	2 x 4 studs at 24"cc	39	27	32	34	36	36	35	38	39	41	43	43	42	37	35	41	42	
3.14	5.4	3 5/8" channels at 24"cc	47	24	35	39	39	42	43	46	47	51	54	54	54	47	44	46	49	52
3.15	5.4	3 4/8" channels at 24"cc, 4" absorption	45	28	36	39	40	42	43	45	46	48	48	46	44	40	39	42	45	49
		(c) Simple walls, other spacings																		
3.21	5.4	2 1/2" channels at 24"cc	40	18	22	29	28	31	33	38	39	40	45	46	46	41	41	47	46	
3.22	5.4	Staggered 1 5/8" channels in 2 1/2" space	38	15	20	25	26	30	34	39	40	42	44	45	46	40	42	48	49	
3.23	5.4	Staggered 2 x 4 studs, 5 5/8" space	39	23	24	26	28	32	35	36	39	42	45	46	44	38	39	42	48	
3.24	5.4	2 x 4 studs at 16"cc, studs widened by 1/2" wood strips, 4 1/8" space	34	14	16	18	24	28	28	33	36	39	41	42	40	36	36	41	44	48
		(d) Composite wall surfaces, couplings, 4 1/8" effective spacing																		
3.31	5.4	2 x 4 studs at 16"cc, + strips 1/2" glass fibre on one edge studs	35	14	16	21	23	27	31	35	38	42	44	45	44	39	37	42	46	49
3.32	5.4	2 x 4 studs at 16"cc, 1/2" glass fibreboard, one side	36	14	16	21	27	30	33	36	40	43	45	46	44	38	38	42	46	50
3.33	5.4	3 5/8" channels at 24"cc, 1/2" glass fibreboard, one side	46	26	30	36	37	39	43	47	48	51	54	54	54	48	44	47	52	
3.34	5.4	3 5/8" channels at 24"cc, 1/2" glass board + 2" mineral wool	49	25	37	39	41	44	46	48	50	52	54	55	55	49	46	49	52	
3.35	5.4	2 x 4 studs at 16"cc, resilient z bars horizontal at 16", one side	38	17	19	26	27	31	34	37	40	45	47	49	46	41	40	44	49	51
3.36	5.4	2 x 4 studs at 16"cc, resilient z bars horizontal at 24", one side	38	18	19	26	27	31	33	38	40	44	47	49	46	41	40	44	49	51
3.37	5.4	2 x 4 at 16"cc, resilient z bars vertical at 16", one side	38	16	19	26	26	32	33	37	40	44	45	47	46	40	40	44	48	51
3.38	5.4	2 x 4 studs at 16"cc, resilient z bars horizontal at 24", both sides	39	16	20	29	28	32	34	37	42	46	49	51	50	42	38	44	50	52
3.39	5.4	2 x 4 studs at 16"cc, resilient z bars horizontal at 24", one side, 2" absorption	47	24	29	34	39	44	47	48	49	51	50	51	50	46	46	49	52	53
3.40	5.4	2 x 4 studs at 16"cc, resilient z bars horizontal at 24", both sides, 2" absorption	49	25	34	37	41	46	49	51	53	54	54	53	54	50	49	52	54	

TABLE IV GROUP IV -- TWO LEAVES, MULTIPLE LAYERS, ½" AND 5/8" PLASTERBOARD

Wall No.	Surface Density	Description of Specimen	STC	Frequency - Hz 125	160	200	250	315	400	500	630	800	1000	1250	1600	2000	2500	3150	4000	5000
	(lb/sq ft)																			
		(a) One side, 2 layers 1/2", other side, 1 layer 1/2"																		
4.01	6.7	Studless (3 5/8" space)	37	16.5	23.5	25.0	25.0	27.5	30.0	34.0	38.0	42.0	44.5	44.0	44.5	47.0	48.0	47.0	49.5	
4.02	6.7	2 x 4 studs at 16"cc	37	16	17	25	26	29	31	36	37	40	42	42	43	45	44	44	48	52
4.03	6.7	2 x 4 studs at 24"cc	41	22	25	32	30	33	35	37	40	43	46	48	48	47	44	43	47	52
4.04	6.7	3 5/8" channels at 24"cc	42	23	27	31	31	30	34	42	42	46	48	46	46	48	50	47	51	
4.05	6.7	Studless, 2" glass fibre in space	48	37	39	41	43	45	45	46	47	48	49	47	46	49	50	50	50	
4.06	6.7	3 5/8" channels at 24"cc, 2" glass fibre in space	50	28	36	38	41	42	46	51	51	53	54	52	53	52	52	51	53	
		(b) 2 layers 1/2", plasterboard on each side																		
4.11	9.2	Studless	39	20	29	31	31	33	34	38	41	43	42	36	36	42	48	50	54	
4.12	9.2	2 x 4 studs at 16"cc	36	20	15	21	27	29	33	38	40	42	41	38	37	43	48	52	53	54
4.13	9.2	2 x 4 studs at 24"cc	39	20	22	29	27	32	37	39	41	43	43	40	39	42	47	51	55	
4.14	9.2	3 5/8" channels at 24"cc, 2" glass fibre in space	51	34	41	43	43	44	48	51	52	53	54	51	47	47	51	54	57	
		(c) One side, 2 layers 5/8", other side 1 layer 5/8"																		
4.21	8.5	2 x 4 studs at 16"cc	36	19	19	23	26	28	28	34	36	39	38	38	41	43	44	49	52	
4.22	8.5	2 x 4 studs at 16"cc, 2" glass fibre	39	19	21	27	30	32	32	36	40	42	40	40	43	44	46	50	52	
4.23	8.5	2 x 4 studs at 16"cc, resilient channels one side	43	27.0	27.5	34.0	32.5	34	36.5	39.5	41.5	44.0	44.5	45.5	49.0	49.0	49.0	53.0	54.0	
4.24	8.5	2 x 4 studs at 16"cc, resilient channels one side, 2" glass fibre	50	30	38	41	43	46	47	49	50	51	49	49	51	52	53	55	56	
		(d) Miscellaneous surfaces, spacings																		
4.31	4.8	One layer 1/2", 1 layer 5/8", 3 5/8" channels at 24"cc	38	18	23	28	26	28	31	39	39	43	46	48	48	44	40	40	44	
4.32	4.8	One layer 1/2", 1 layer 5/8", 2 1/2" channels at 24"cc	44	20	28	32	34	40	43	46	48	48	47	48	48	48	45	45	47	49
4.33	6.7	Two layers 1/2", 1 layer 1/2", studless, 7 1/2" space	41	25.5	27.0	30.5	30.0	29.5	34.5	36.0	38.5	46.0	47.5	46.5	47.5	49.0	49.5	52.0	53.5	
4.34	6.7	Two layers 1/2", 1 layer 1/2", studless, 7 1/2" space + 2" glass fibre in space	51	34.0	38.5	43.0	44.5	45.5	48.0	49.0	49.5	51.5	51.5	50.5	53.5	55.5	56.0	59.5	59.5	
4.35	7.0	Two layers 1/2", 1 layer 5/8", 3 5/8" channels at 24"cc, + 2 1/2" glass fibre	49.	32	39	40	42	43	45	46	48	50	52	53	52	49	47	48	51	
4.36	9.1	Three layers 1/2", 1 layer 5/8", 3 5/8" channels at 24"cc, + 2 1/2" glass fibre	53	36	42	44	45	47	47	49	50	53	55	56	57	55	53	53	56	