LIMITATIONS IN THE MEASUREMENT OF THE SOUND ABSORPTION COEFFICIENT ON MATERIALS FOR HIGHWAY NOISE BARRIERS

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ABSTRACT

Some absorbing materials used to improve the performance of highway noise barriers are rigid and their flow resistance is high. They absorb sound energy in a complex porous and resonant way and their absorption coefficient is strongly dependent upon their mounting. In our study, three rigid materials measured with the standing wave tube exhibited resonant peaks at frequencies depending on their thickness. One of the materials, measured in a reverberant chamber lying on the floor, showed the same resonant peak. However, when measured in the same chamber in a free standing position, the absorption curve was typical of a porous material. The results of the study confirm that "hard," rigid, acoustical materials should not be measured with the standing wave tube but rather in a free standing position in a reverberant room.

I. Introduction

The use of sound absorbing materials for increasing the attenuation provided by highway noise barriers is relatively new. They are supposed to reduce multiple reflections between parallel barriers erected on both sides of a highway or between a single barrier and the bodies of passing vehicles, thereby increasing barrier efficiency.

Because of their outdoor application, these materials have to endure severe adverse atmospheric agents as well as corrosive exhaust fumes from passing vehicles. They have also to withstand the mechanical and chemical actions of water, snow, ice and salt mixtures splashed from vehicle wheels. These effects are especially strong on the lower part of the barriers.

To ensure adequate durability, some commercial products are made of soft materials bonded by hard resins or portland cement into a kind of solid mass. Usually they have a relatively high density, are self-supported, and have a high flow resistance. This type of material is called a "hard" material in this paper.

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*Work performed while the author was at the Ontario Ministry of Transportation and Communications.

Since, during the measurement of sound absorption coefficient, material samples are mounted in a specific way, the resulting absorption coefficient vs frequency curves are valid only for a particular mounting, thus limiting the validity of the measurement result. This is obviously not a new concept, but should be remembered when handling data regarding these materials.

In our study,* the sound absorption coefficients of three "hard" materials used for highway noise barriers were measured with the standing wave tube (1). All results showed resonant peaks varying with the thickness of the samples. A conventional, porous sound absorbing material used as a control did exhibit the well-known, increasing-with-frequency sound absorption curve when measured in the same way.

One of the highway materials was also measured at the Division of Building Research, National Research Council, with the tube and also in the reverberation room (2). When measured lying on the floor of the room, its absorption coefficient showed the same resonant peak as when measured with the tube. But, when mounted in a free standing position, the absorption curve was typical of a porous material's, confirming the effect of the mounting.

The results of this study show that if a material is to be used as a noise barrier "by itself" (i.e., without a backing), then its sound absorption should not be measured in the standing wave tube, and if measured in a reverberant room, it should be held in a free standing position.

2. Description of the Tests

For a summary, see Table 1.

2.1 Materials

Following is the manufacturer's description of the materials measured for sound absorption.

- Durisol, from Durisol Materials Limited: Lightweight building material made of chemically mineralized and neutralized organic softwood shavings, bonded together under pressure with portland cement. Durisol is supplied as panels made of the above described absorption layer, 75 mm (3") thick, and a hard, reinforced concrete backing, 19 mm (3/4") thick. (Other configurations were also tested - see later.)

- Fiberglas AF530 from Fiberglas Canada Limited: Glass-fiber boards compressed to a controlled density, bonded by a thermosetting resin.

- Herco Type 713 from Kemlite Corporation: Porous, random textured material made of polyester resin, glass fibers, aggregate and fillers.

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*Results of the study performed on one material have been published in Reference 3.

- Petrical from Cornell Corporation: Chemically treated, long, tough, northern aspen wood fibers, bound with portland cement, moulded under pressure.

The thickness of the samples ranged from 25 to 81 mm.

2.2 Sound Absorption Measurements

The measurements were performed at two different places, using two different measuring techniques.

At the Research Laboratory, Ministry of Transportation and Communications, Ontario, the measurements were done according to the ASTM C384-77 (1) method, using standard instrumentation manufactured by Bruel and Kjaer.

At the division of Building Research, National Research Council, materials were measured according to both ASTM C384-77 (1) and ASTM C423-77 (2) methods. For the measurements in the reverberant chamber, the materials were placed in two different ways: first, lying on the floor, and then free standing in an upright position.

3. Measurement Results

The results of the measurements are shown in Table 2. They are also given in Figures 1 through 7.

The measurements performed with the impedance tube are reported in percent. The others, done in the reverberation chamber, are in Sabines. When a material was measured in the free standing position, both surfaces were used for the calculation of the absorption coefficient. The sample areas for those measurements were 8.1 m^2 (89.8 $feet^2$) for measurements no. 12 and 14, and 4.4 m^2 (48.8 $feet^2$) for no. 11 and 13.

4. Discussion

According to their surface density and general mechanical characteristics, the materials we tested can be divided into:

- o Hard: Durisol, Herco and Petrical, and
- o Soft: Fiberglas

The absorption curves of the first group as shown in Figures 1, 2 and 3 have peaks suggesting a mixed, porous and resonant way of sound absorption. This is obviously not the case for the Fiberglas measured as a control (see Figure 4).

The same resonant behaviour is observed in Figure 5 where results of the measurements of a "hard" material using both methods (reverberant room and standing wave tube) are shown. The resonant frequencies in both cases are the same, thus suggesting a similar membrane-like behaviour.

On the other hand, as results in Figure 6 show, as soon as the hard backing is "removed" by erecting the sample, the resonant phenomenon disappears and the material behaves in a porous-like way, similar to that shown in Figure 4.

5. Conclusions

The standing wave tube technique should not be used for the measurement of "hard" acoustically absorbent materials unless they are intended to be mounted against a wall. For the same reason, if the measurement is done in the reverberant room, the sample should be installed in a free standing way, avoiding interaction with the reverberant room floor.

The non-observance of these recommendations can lead to gross overestimates of the sound absorbing qualities of a given material.

6. Acknowledgments

Thanks are due to Dr. T. D. Northwood, Head, Noise and Vibration Section, Division of Building Research, National Research Council, for many useful discussions and to Mr. W. T. Chu from the same section for carrying out the test mentioned in Table 1. Most of the tube measurements were performed by Mr. G. Giles and Mr. A. Maio from the Research Laboratory, Experimental and Demonstrating Testing Group, Ministry of Transportation and Communications, Ontario. The study was done while the author was at the Acoustics Office, Research and Development Division, of the same Ministry.

References

1. ANSI/ASTM C384-72, "Standard Test Method for Impedance and Absorption of Acoustical Materials by the Impedance Tube Method," American National Standards Institute, 1977.

2. ANSI/ASTM C423-77, "Standard Test Method for Sound Absorption and Sound Absorption Coefficients by the Reverberation Room Method," American National Standards Institute, 1977.

3. A. Behar and D. N. May, "The Sound Absorptive Qualities of Material 2 for Various Methods of Installation," Appendix A in "Durability of Sound Absorbing Materials for Highway Noise Barriers." J. Sound and Vib. 71, 33-54, 1980.

Table 1. Summary of Materials and Measurements.

Measurement No.	Material	Thickness mm	Thickness Inches	Density kg/m³	Surface Area Density kg/m²	Measurement Method	Measurement Place	Mounting	Results on Figure	Observation
		mm	Inches	kg/m³	kg/m²	-	-	-	-	-
1	Durisol	25	1	560	14	Tube[1]	NRC[3]	----	1A	Absorption layer only
2	Durisol	50	2	560	28	Tube	MTC[4]	----	1B	Absorption layer only
3	Durisol	75	3	560	42	Tube	NRC	----	1C & 5B	Absorption layer only
4	Durisol	75	3	560	42	Tube	MTC	----	1D	Absorption layer only
5	Fiberglas	25	1	48	1.2	Tube	MTC	----	4	----
6	Fiberglas	50	2	48	2.4	Tube	MTC	----	4	----
7	Herco	34.2	1 3/8	658	22.5	Tube	MTC	----	2	----
8	Herco	50	2	658	33	Tube	MTC	----	2	----
9	Petrical	37.5	1 1/2	567	22	Tube	MTC	----	3	----
10	Petrical	75	3	576	43	Tube	MTC	----	3	----
11	Durisol	75	3	560	42	Rev. Cham.[2]	NRC	Laying[5]	5A & 6A	Absorption layer only
12	Durisol	75	3	560	42	Rev. Cham.	NRC	Standing	6B	Absorption layer only
13	Durisol	81.3	3 1/4		98	Rev. Cham.	NRC	Laying	7A	Complete panel
14	Durisol	81.3	3 1/4		98	Rev. Cham.	NRC	Standing	7B	Complete panel

Notes:
1) see Reference 1
2) see Reference 2
3) Division of Building Research, National Research Council, Ottawa
4) Research Laboratory, Ministry of Transportation and Communications, Ontario
5) see Reference 2, Figure 1, Number 4

Table 2. Sound Absorption Coefficients.

Measurement Number	Frequency, Hz 125	160	200	250	315	400	500	630	800	1000	1250	1600	2000	2500	3100	4000	5000
1	---	---	4	5	11	9	14	18	29	31	83	99	67	57	39	--	--
2	---	---	6	7	8	16	24	52	90	73	47	37	37	---	---	--	--
3	---	25	22	32	56	79	92	77	55	48	50	77	70	73	76	--	--
4	---	---	25	36	55	78	94	70	52	44	58	82	57	---	---	--	--
5	---	---	7	9	10	14	14	24	29	42	53	68	80	---	---	--	--
6	---	---	10	16	21	30	33	46	59	70	79	89	92	---	---	--	--
7	---	---	15	14	12	15	17	23	37	60	89	95	70	---	---	--	--
8	---	---	9	13	19	30	43	67	78	67	53	41	45	---	---	--	--
9	---	---	--	--	--	--	20	37	69	96	93	68	43	---	---	--	--
10	---	---	34	53	75	96	85	60	40	33	41	71	64	---	---	--	--
11	0.16	0.17	0.47	0.56	0.85	1.06	1.07	0.97	0.86	0.86	0.90	0.96	0.90	0.86	0.91	0.96	1.01
12	0.25	0.16	0.33	0.31	0.34	0.37	0.39	0.47	0.59	0.69	0.78	0.75	0.77	0.80	0.80	0.90	0.94
13	0.08	0.13	0.21	0.26	0.42	0.55	0.78	1.05	1.11	0.99	0.86	0.78	0.79	0.91	0.95	0.92	0.94
14	0.18	0.12	0.23	0.18	0.39	0.51	0.70	0.91	1.00	0.91	0.79	0.70	0.73	0.86	0.92	0.92	0.40

The absorption coefficient is expressed in percent for measurements 1 through 10 and in sabines for the measurements 11 through 14.

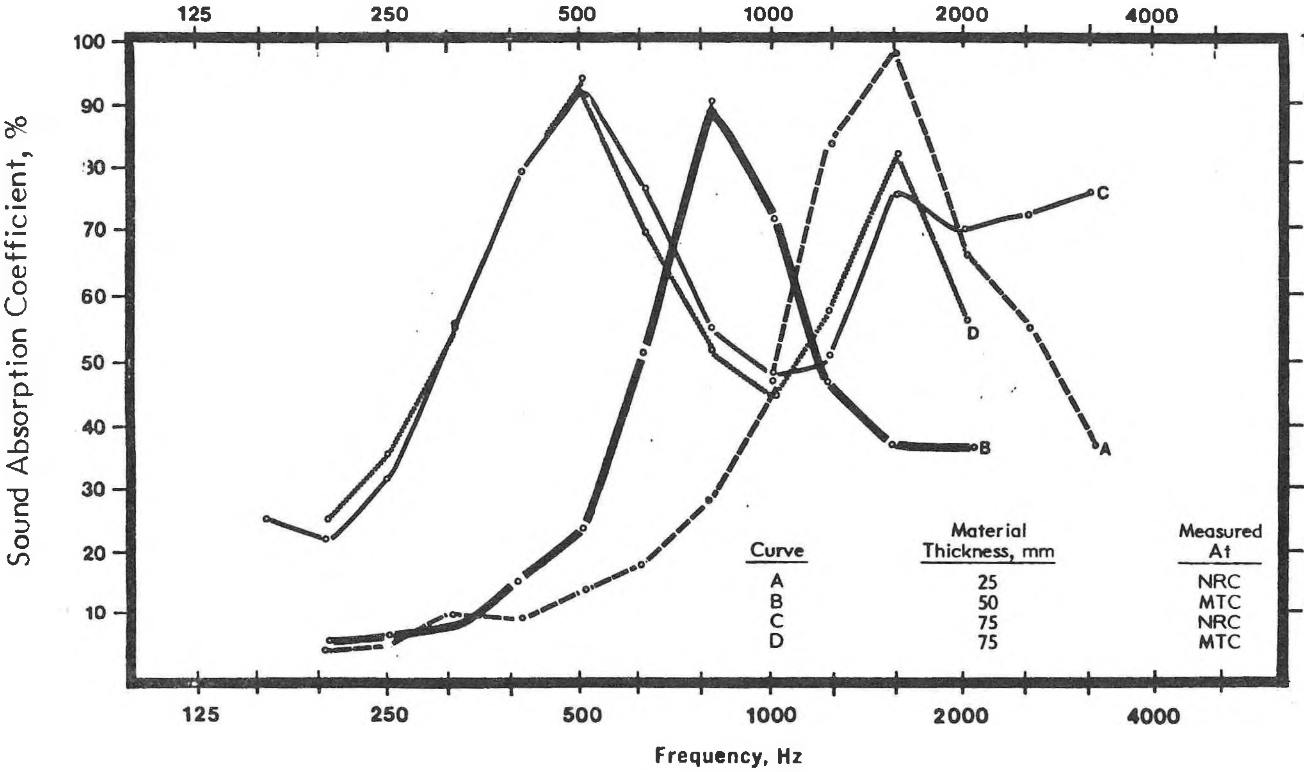

Fig. 1. Absorption coefficient of Durisol (absorbing layer, only) measured with standing wave tube.

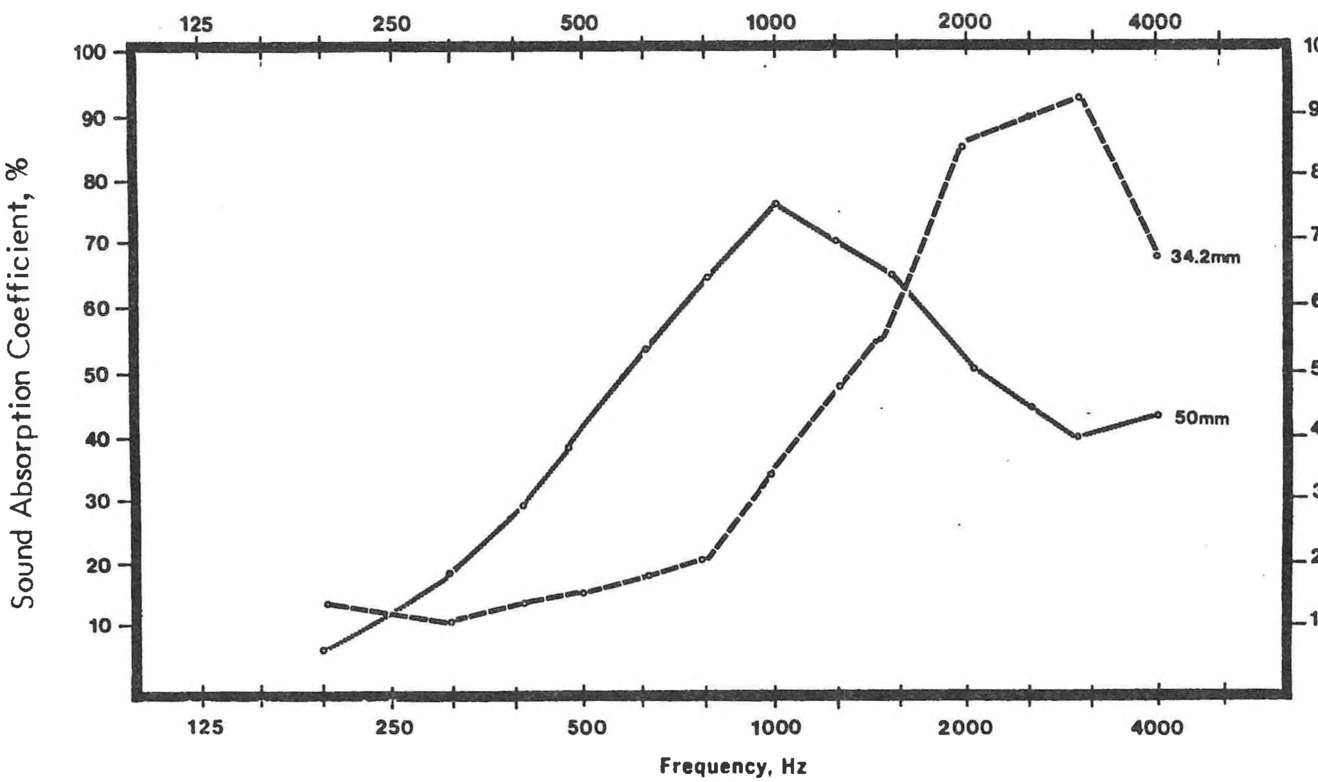

Fig. 2. Absorption coefficient of Herco Type 713 measured with standing wave tube.

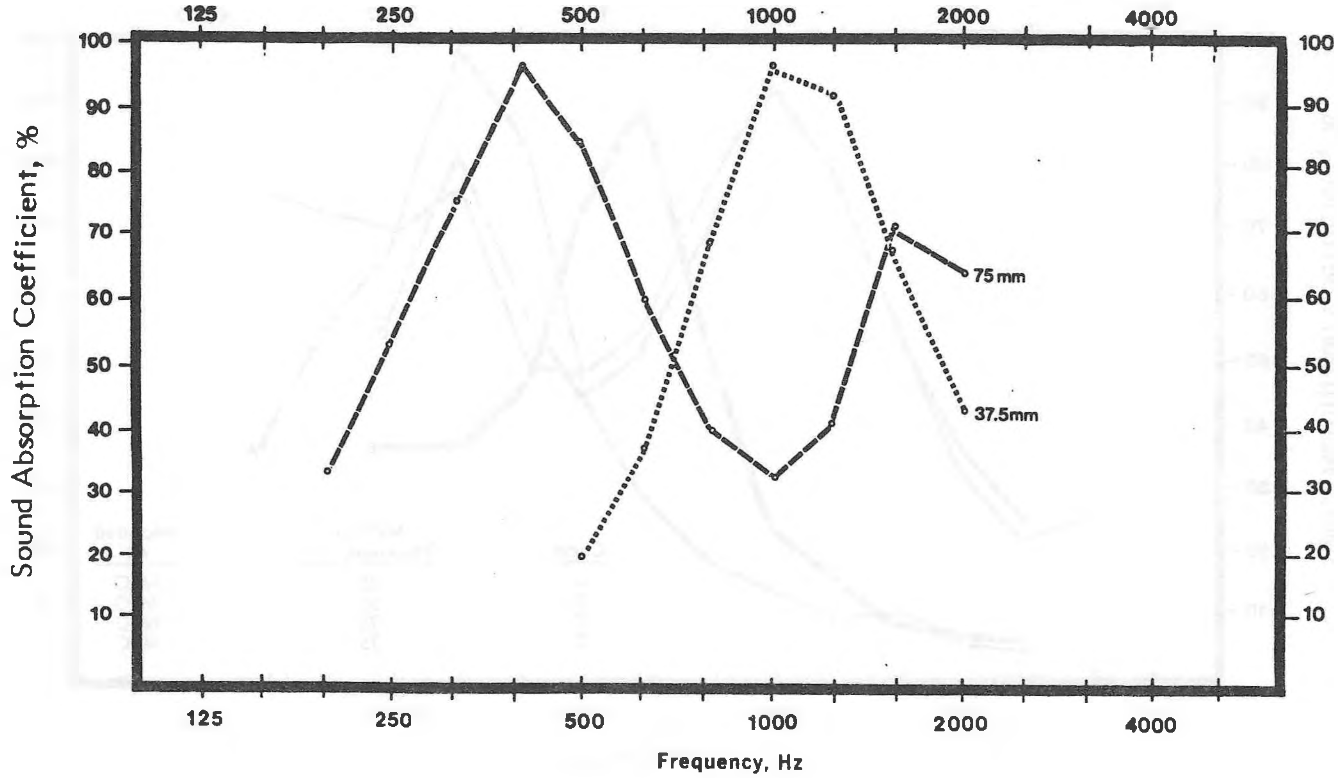

Fig. 3. Absorption coefficient of Petrical measured with standing wave tube.

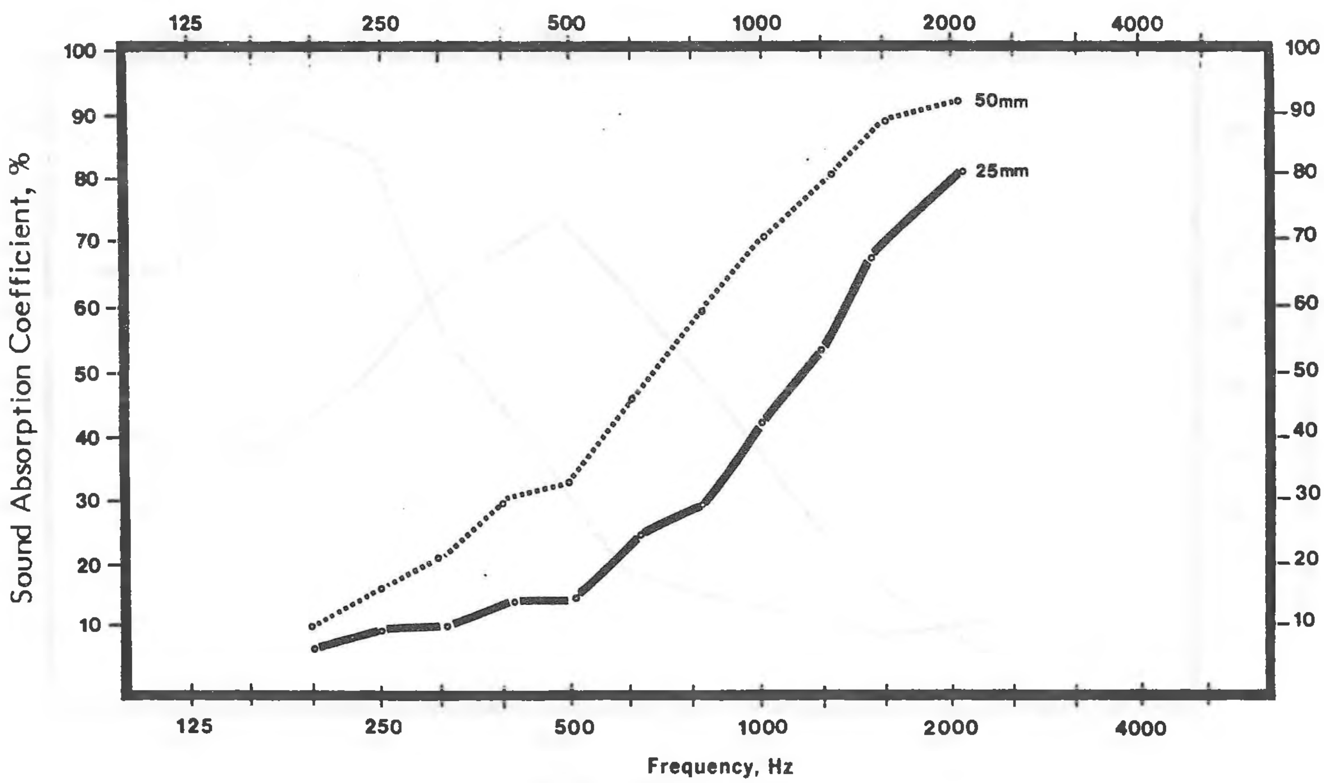

Fig. 4. Absorption coefficient of Fiberglas Type AF530, measured with standing wave tube.

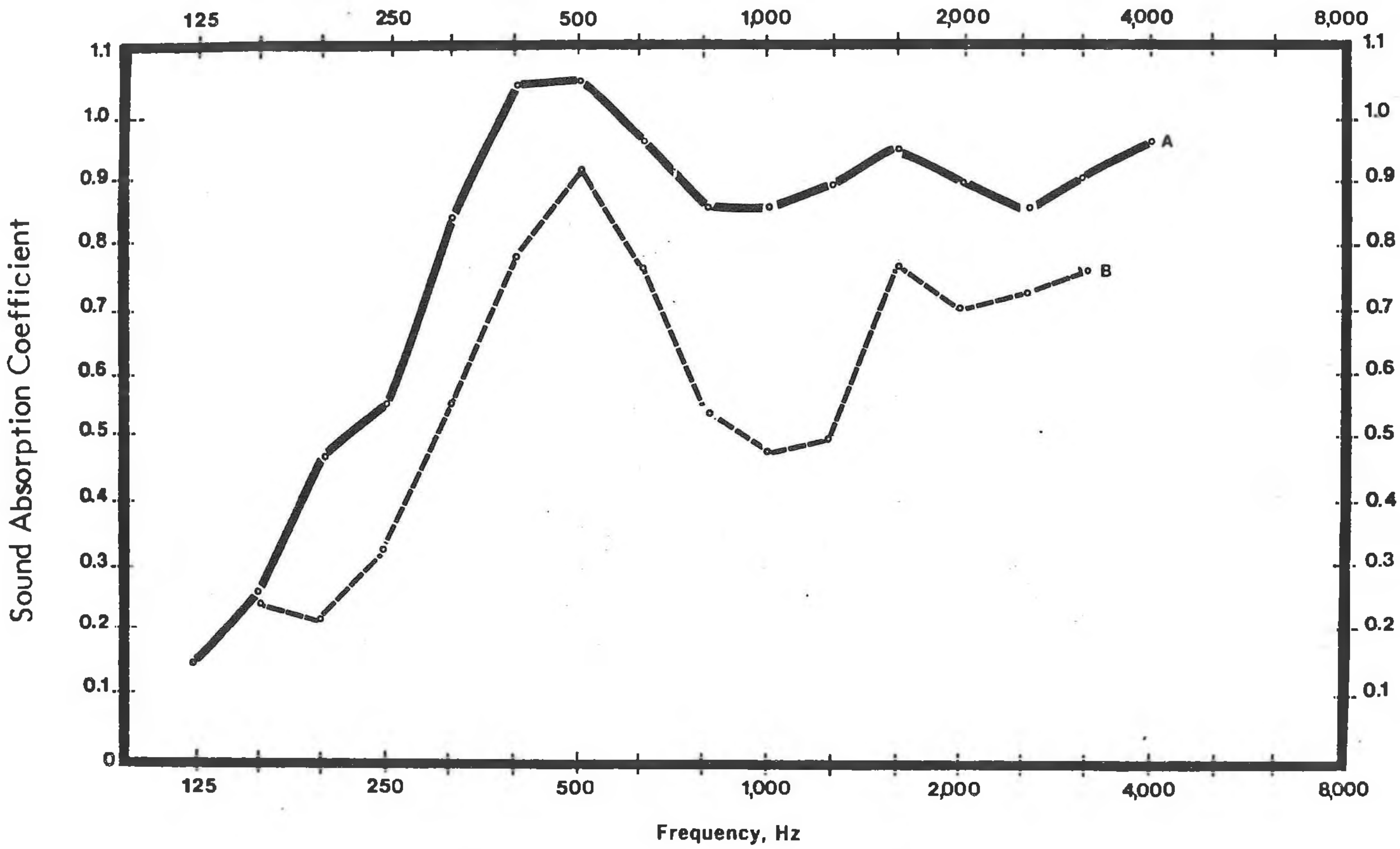

Fig. 5. Absorption coefficient of Durisol (absorbing layer, only): A - laid on floor in the reverberant room; B - in the standing wave tube.

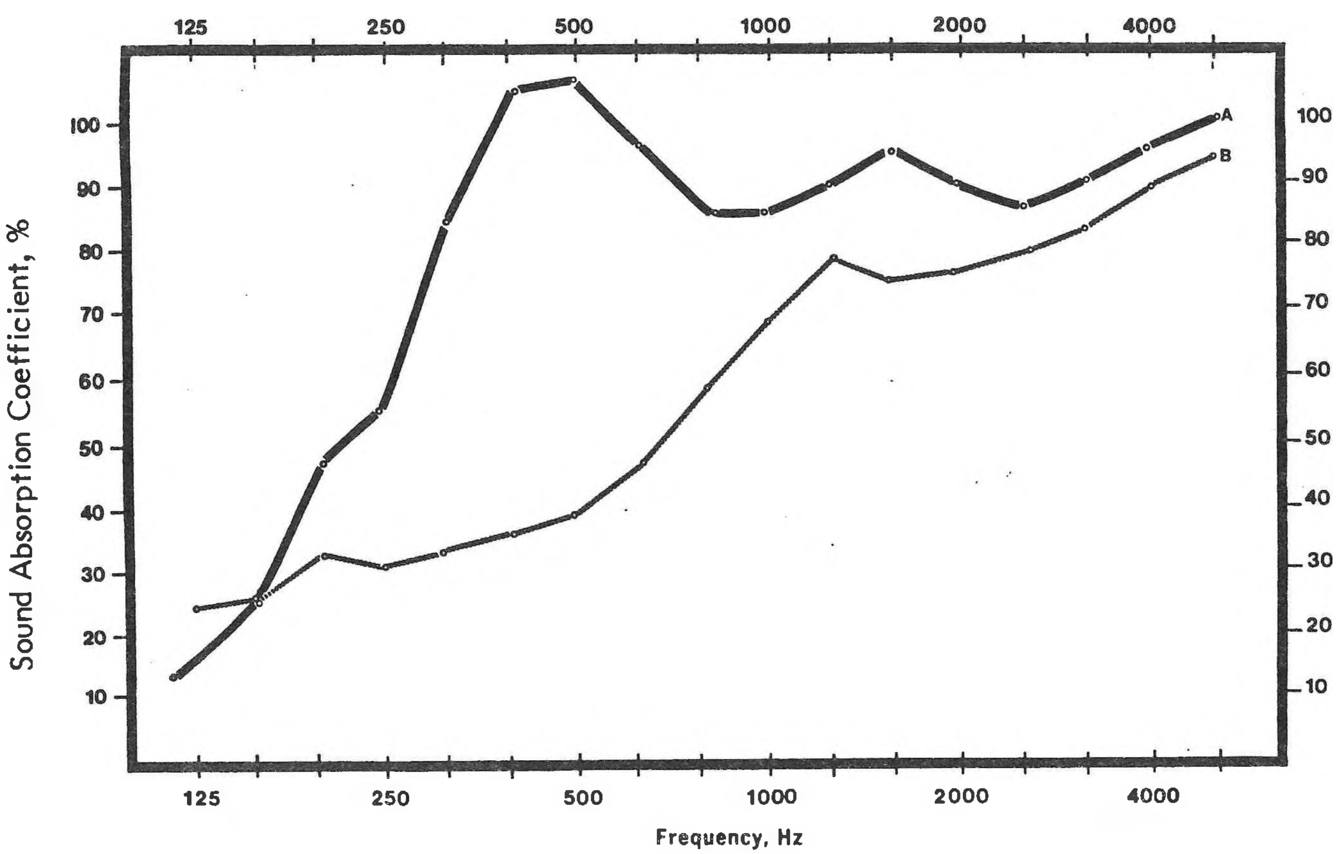

Fig. 6. Absorption coefficient of Durisol (absorbing layer, only) measured in the reverberant room: A - laid on floor; B - free standing position.

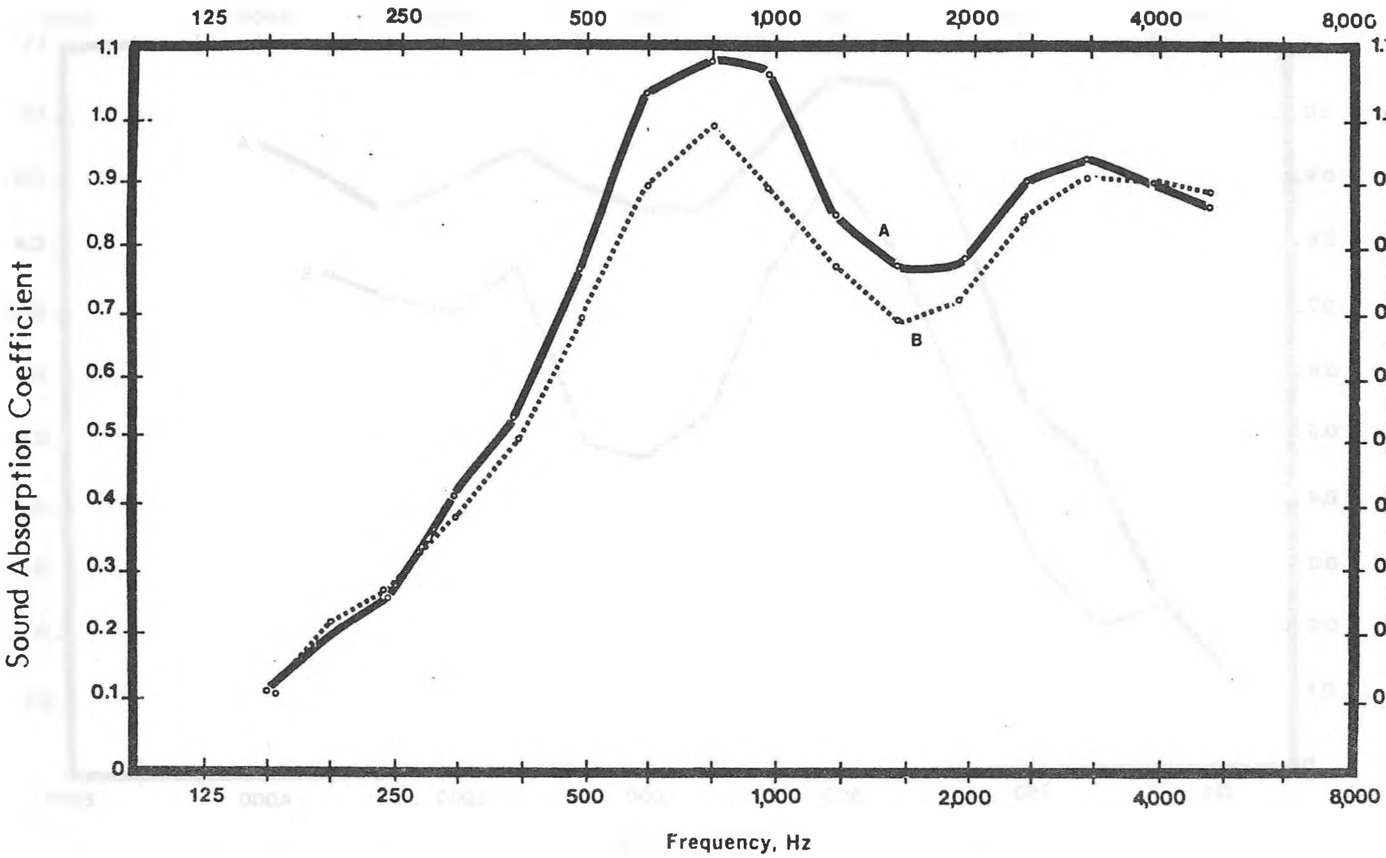

Fig. 7. Absorption coefficient of Durisol (complete panel) measured in the reverberant room: A - laid on floor; B - free standing position.