United States Patent [19]

Tsuchiya et al.

[11] **3,721,925**

[45] **March 20, 1973**

[54] SOUND SIGNAL DELAY DEVICE

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[73] Assignee: **Sony Corporation,** Tokyo, Japan

[22] Filed: **May 21, 1971**

[21] Appl. No.: **145,823**

[30] **Foreign Application Priority Data**

May 21, 1970 Japan 45/49633

[52] **U.S. Cl.** ..... **333/30,** 84/1.24, 179/1.6, 181/31 B

[51] **Int. Cl.** **H03n 7/30**

[58] **Field of Search** ..... 84/1.24; 179/1.6; 181/31 B; 333/30

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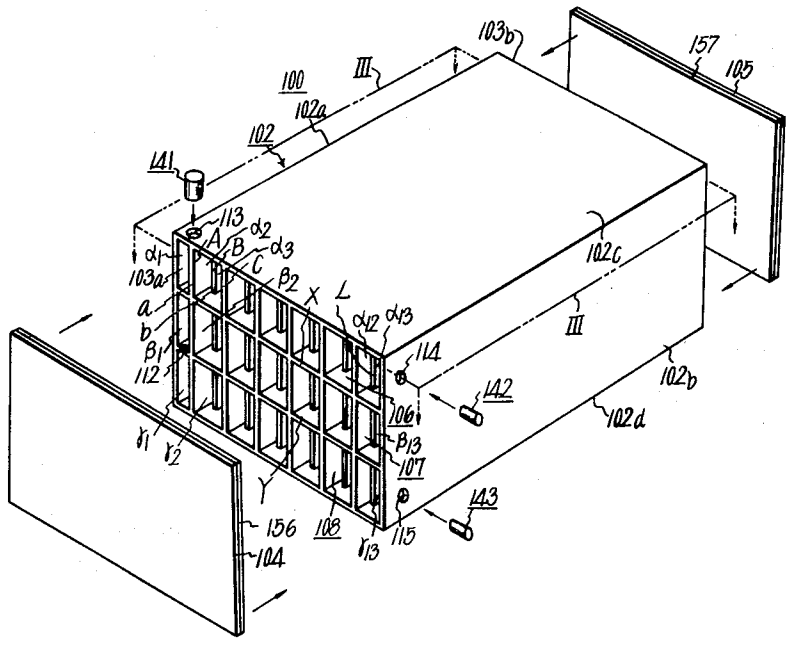
[57] **ABSTRACT**

A sound signal delay device having an airtight box, a plurality of partition walls forming a meandering channel in said box, a loudspeaker mounted on said box, and a microphone mounted on said box in spaced relation to said loudspeaker, whereby a sound produced by said loudspeaker is picked up as a delayed sound signal by the microphone.

4 Claims, 11 Drawing Figures



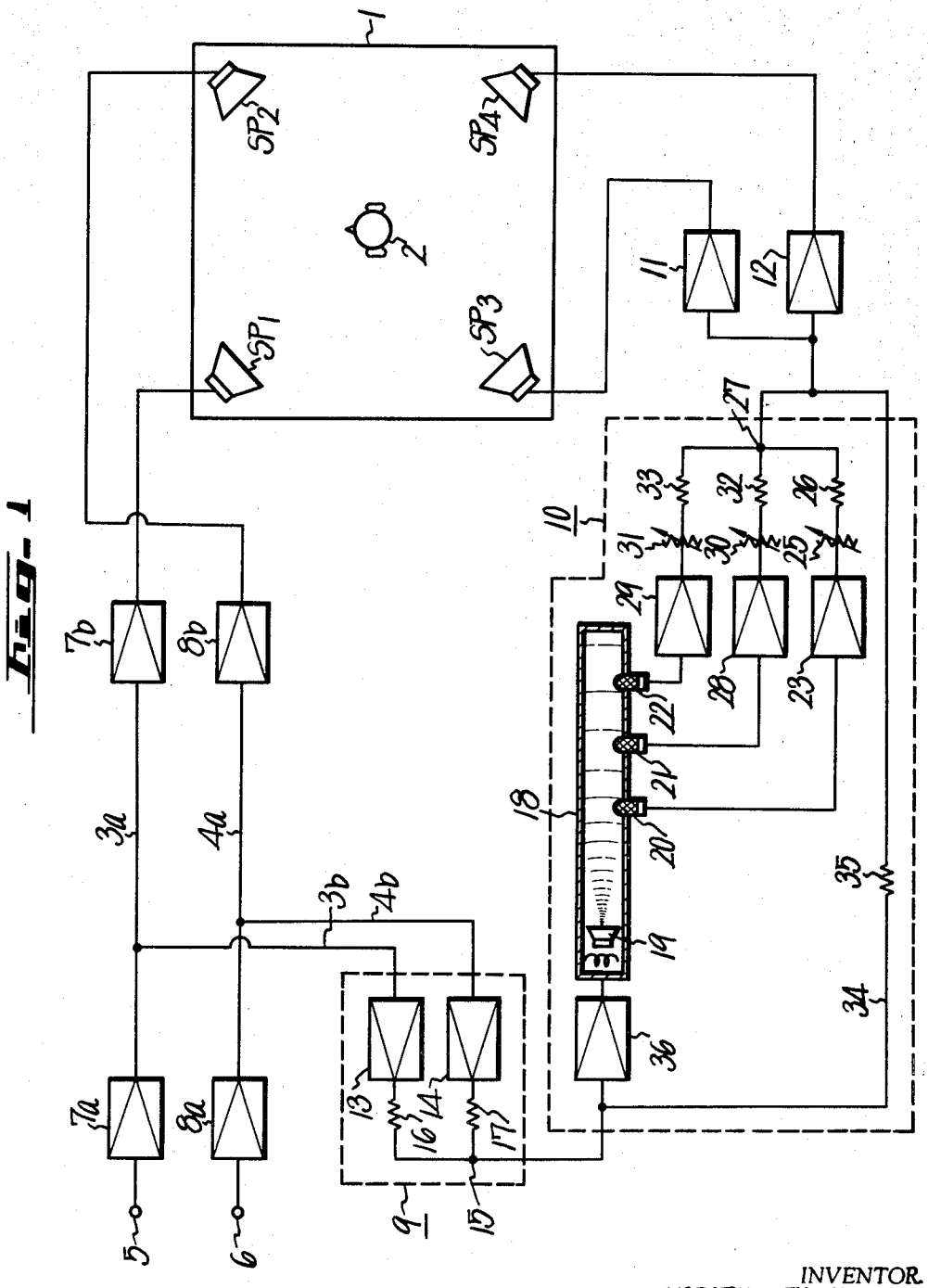


Fig. 1

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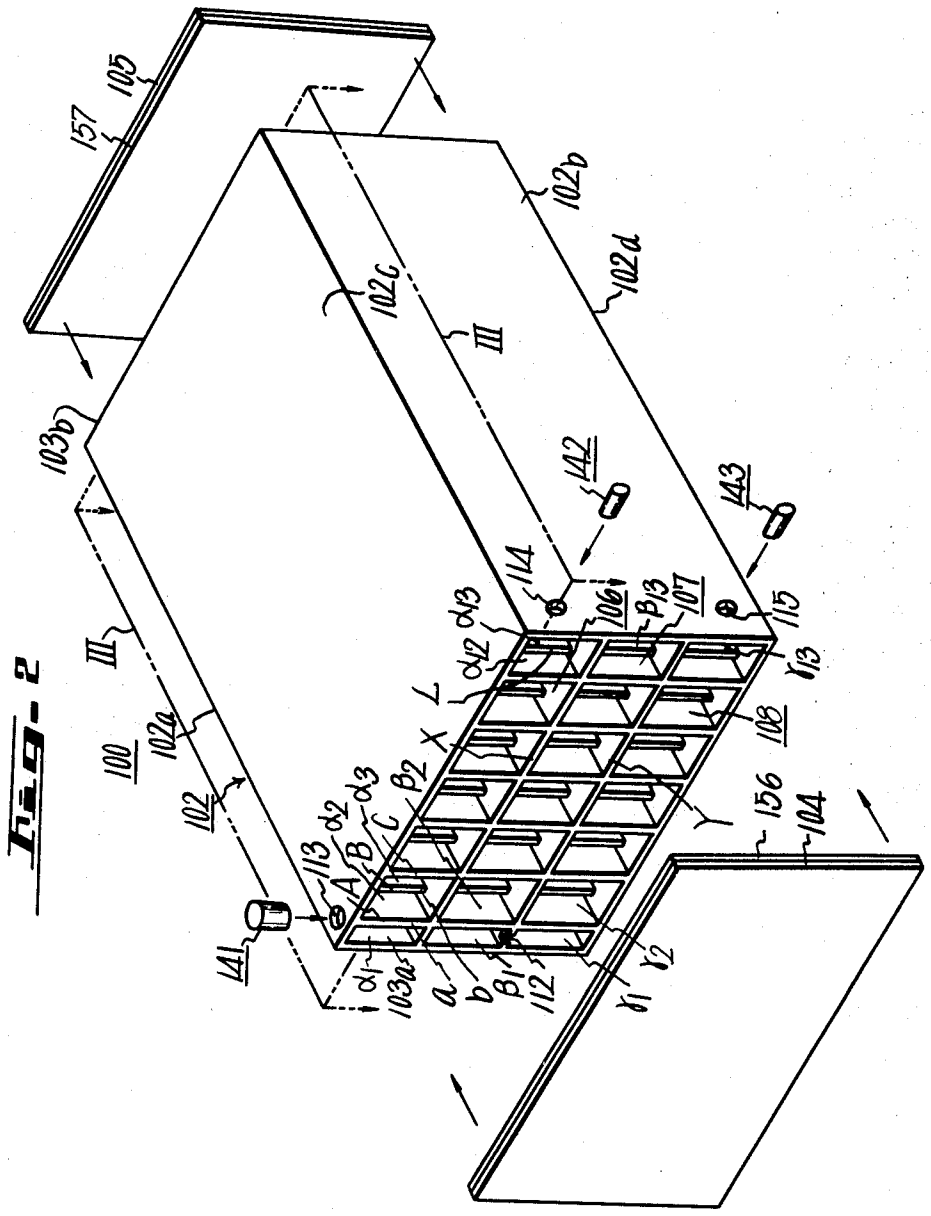

Fig-2

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Fig. 3

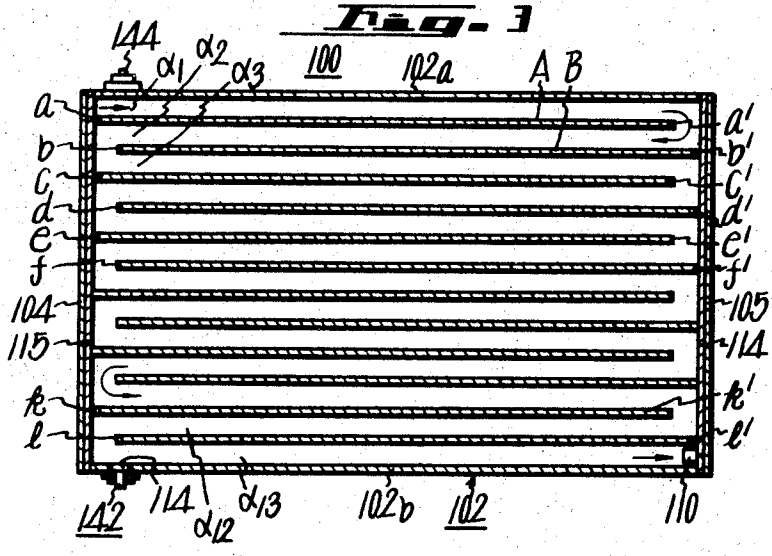

Fig. 4

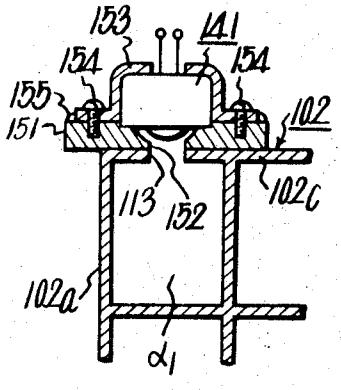

Fig. 5

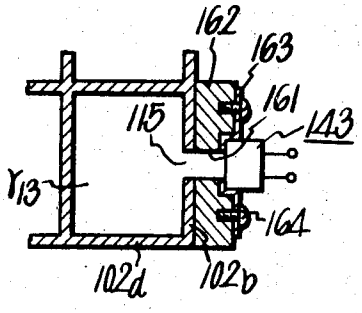

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Fig. 6

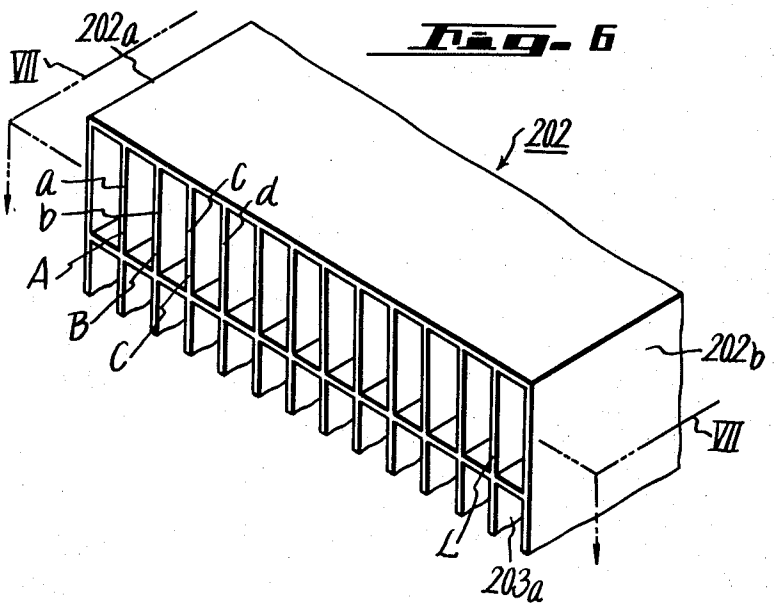

Fig. 7

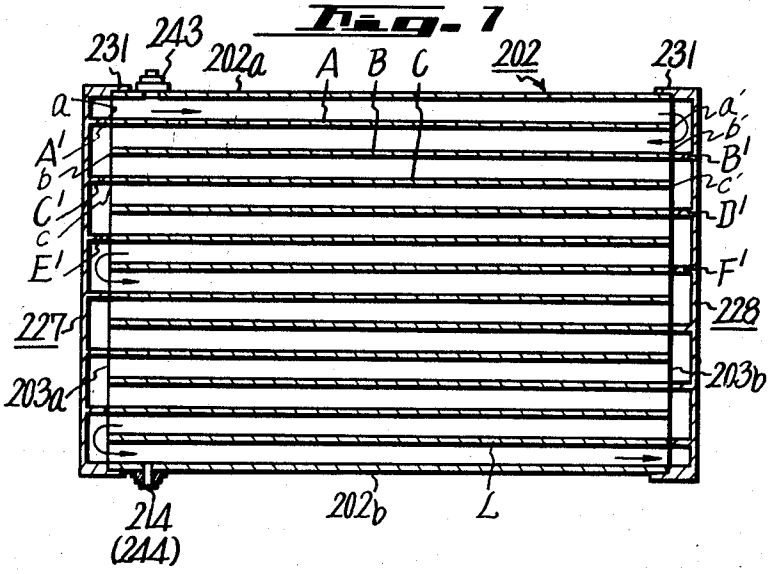

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Fig. 8A

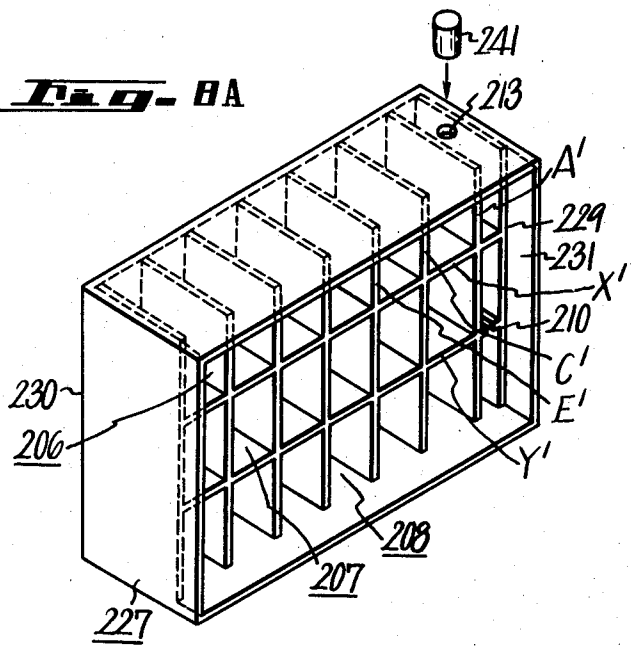

Fig. 8B

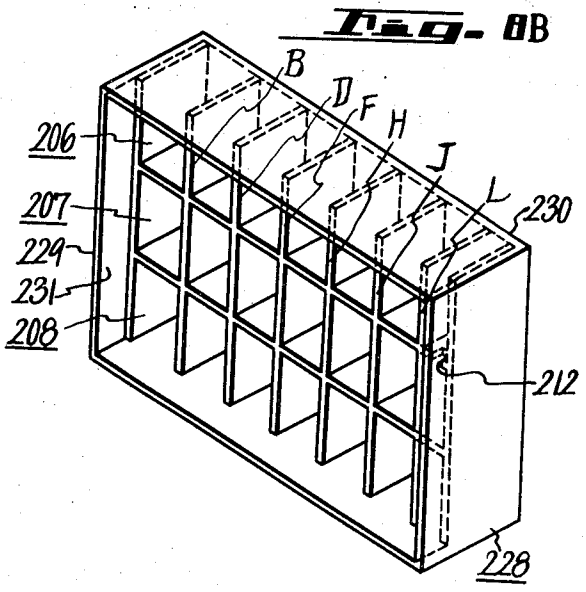

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Fig. 9

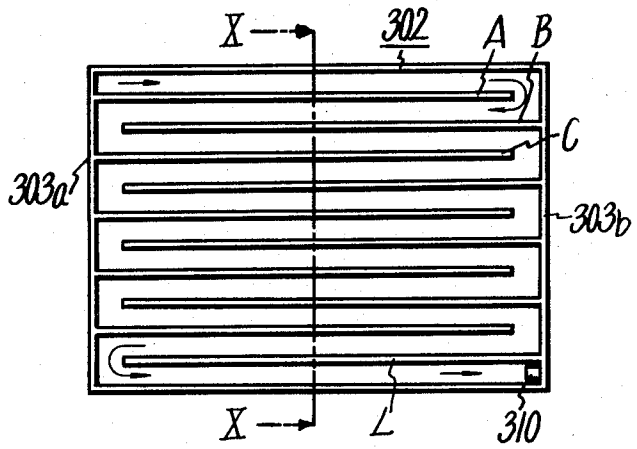
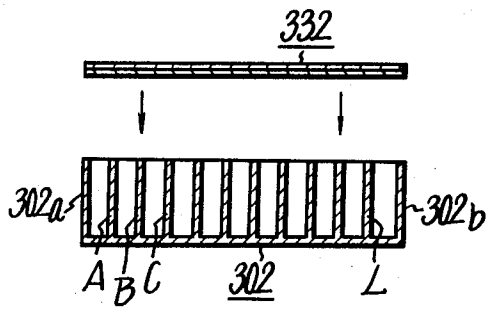


Fig. 10



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SOUND SIGNAL DELAY DEVICE

BACKGROUND OF THE INVENTION

1. Field of the Invention

This invention relates to a sound signal delay device, and more particularly to a sound signal delay device for use with stereophonic sound reproducing apparatus.

2. Description of the Prior Art

Hitherto, techniques proposed for acoustic delay have included the use of such apparatus as a magnetic tape recording and reproducing apparatus, a mechanical coil spring, a reverberation room equipped with a loudspeaker and a microphone, and other apparatus for delaying a sound signal. However, these conventional means have certain defects. For one thing, the magnetic tape recording and reproducing apparatus employs rotational members, such as a drive motor, a capstan, a pinch roller and so on, as well as supplies of expendable items, such as magnetic tape and magnetic heads. The apparatus necessitates replacement and maintenance of the parts at all times and is complicated in operation for producing a delayed sound signal. The mechanical coil spring is most widely employed, but it produces distortion in the resulting reproduced signal. The method using the reverberation room involves large-scale installations and, therefore, has limited usage. In addition, an air pipe may be employed for obtaining a delayed sound signal but, in order to obtain a long delay time, a long air pipe is required, so that this method encounters difficulty in adaptation of the air pipe to such relatively small equipment as stereophonic phonographs.

Accordingly, one object of this invention is to provide an improved sound signal delay device.

Another object of this invention is to provide a sound signal delay device which is simple in construction but provides a long delay time.

Another object of this invention is to provide a sound signal delay device which is easy to assemble and is inexpensive.

Another object of this invention is to provide a sound signal delay device which is suitable for use with stereophonic reproducing apparatus.

Another object of this invention is to provide a sound signal delay device which readily produces many delayed sound signals.

Another object of this invention is to provide a sound signal delay device which is provided with an airtight box capable of preventing crosstalk of a delayed sound signal with noise.

Still another object of this invention is to provide a sound signal delay device designed to be readily incorporated in a cabinet of a preamplifier or main amplifier.

Other objects, features and advantages of this invention will become apparent from the following description taken in conjunction with the accompanying drawings.

SUMMARY OF THE INVENTION

The present invention comprises a sound delay device in the form of an airtight box divided by interior partition walls into a plurality of sections that make up a meandering channel. Sound producing means, such as a loudspeaker (or loudspeaker driver), are mounted on the airtight box to supply sound waves to the meandering channel. Sound pick-up means, which may include one or more microphones, are also mounted on the box at selected points spaced along the meandering channel from the sound producing means.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is a block diagram showing a stereophonic reproducing apparatus with a sound signal delay device;

FIG. **2** is an exploded perspective view illustrating one example of a sound signal delay device according to this invention;

FIG. **3** is a cross-sectional view taken on the plane III—III in FIG. **2**;

FIG. **4** is a fragmentary cross-sectional view showing a loudspeaker mounted on an airtight box;

FIG. **5** is a fragmentary cross-sectional view illustrating a microphone mounted on the airtight box;

FIG. **6** is a fragmentary perspective view showing a modified form of this invention;

FIG. **7** is a cross-sectional view taken on the plane VII—VII in FIG. **6**;

FIGS. **8A** and **8B** are perspective views illustrating one example of a closing member for use with the sound signal delay device depicted in FIG. **6**;

FIG. **9** is a cross-sectional view illustrating another modified form of this invention; and

FIG. **10** is a cross-sectional view taken on the line X—X in FIG. **9**.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

For a better understanding of the present invention a description will be given first of a stereophonic reproducing apparatus with an audio signal delay system which has been proposed in our copending application entitled "AUDIO SIGNAL DELAY SYSTEM," Ser. No. 138,489, filed Apr. 29, 1971. In the illustrated example the stereophonic reproducing apparatus includes a pair of input terminals **5** and **6** for connection to a signal source such as a stereophonic magnetic tape recorder, a stereophonic phonograph, or a stereophonic tuner or the like. Any of these sources produces left and right stereophonic signals L and R. The left stereophonic signal is supplied to the input terminal **5** and is fed through a preamplifier **7***a* to a left channel conductor **3***a*. It then goes through a left channel amplifier **7***b* and is applied to a left stereophonic loudspeaker SP_1. The right stereophonic signal is supplied to the input terminal **6** and is fed through a preamplifier **8***a*. From there it is coupled to a right channel conductor **4***a* and from thence it is amplified by a right channel amplifier **8** *b* and is applied to a right stereophonic loudspeaker SP_2.

A pair of conductors **3***b* and **4***b* are connected in series between the left and right channel conductors **3***a* and **4***a*, respectively, and a subtracting network **9** to provide a difference signal between the left and right stereophonic signals, for example, (L-R). The subtracting circuit **9** may be a known type in which one of the left and right stereophonic signals L and R is phase-inverted by a transformer and is then combined with the other signal. Alternatively, one of the signals is applied to an input terminal of a one-stage amplifier and a phase-inverted output signal derived therefrom is com-

bined with the other signal. The difference signal is fed to a delay device **10** to produce a delayed, or reverberant, signal which will be described later on. The output side of the delay device **10** is connected to a pair of sub-loudspeakers SP_3 and SP_4 through a pair of amplifiers **11** and **12** respectively.

A preferred arrangement of the loudspeakers is shown in FIG. **1**. With the illustrated arrangement, a listener **2** can hear left and right stereophonic sounds produced from the main loudspeakers SP_1 and SP_2 which are located at the left and right corners of a listening room **1** in front of the listener. At the same time, the listener can hear reverberant sounds produced from the sub-loudspeakers SP_3 and SP_4 located at the left and right corners of the room **1** behind him.

In the concert hall, sounds originating from various musical instruments directly fall on the listener's ears. In addition, these sounds are reflected from the ceiling, walls, floor and the like of the concert hall and reach the listener delayed behind the direct sounds. Therefore, the listener **2** receives the sensation that individual sounds are coming from different locations, just as did the original sounds. This is quite impossible with any of conventional two-channel stereophonic reproducing systems.

In the present example the subtracting network **9** consists of amplifiers **13** and **14** respectively connected to the left and right channel conductors **3***b* and **4***b*. The amplifier **14** includes a phase inverter and the outputs of the amplifiers **13** and **14** are interconnected through resistors **16** and **17**, respectively, to a common junction **15** where the left and right stereophonic signals are combined with each other.

The delay device **10** in the present invention is an acoustic type, which is typically illustrated in the form of an air pipe **18**. Mechanically coupled to one end of the air pipe **18** on the inside thereof is a transducer, such as a small loudspeaker **19**, for converting the difference signal (L-R) to a sound signal. The difference signal (L-R) from the junction **15** is supplied to the speaker **19** through an amplifier **36**. The sound converted by the speaker **19** from the difference signal (L-R) passes through the air pipe **18** toward the right in the drawing. Further, the air pipe **18** has a plurality of spaced electromechanical transducers, such as microphones, mounted thereon in predetermined spaced relation to the loudspeaker **19**. In the present example, there are three microphones **20**, **21** and **22**. They are respectively disposed at those locations where the sound waves are delayed 15, 30 and 45 milliseconds from the time the sound is emitted by the loudspeaker **19**. A delayed electric signal produced from sound impinging on the first microphone **20** is applied to a connection point **27** through an amplifier **23**, a volume control **25**, and a resistor **26**. Similarly, delayed signals produced by the second and third microphones **21** and **22** are fed to the aforementioned connection point **27** through amplifiers **28** and **29**, volume controls **30** and **31**, and resistors **32** and **33**. In addition, a feedback channel **34** is provided between the connection point **27** and the loudspeaker **19**. A composite signal derived at the connection point **27** is attenuated by a resistor **35** and is then applied to the amplifier **36** together with the signal derived from the connection point **15**. Accordingly, the loudspeaker **19** is supplied with the composite signal in addition to the difference signal (L-R) derived from the subtracting network **9**. Thus, when a signal is supplied to the loudspeaker **19**, first delayed signals are picked up by the microphones **20**, **21** and **22** and then applied as a composite signal to the speaker **19** to derive second delayed signals at the microphones **20** to **22**. The second delayed signals are fed as a composite signal to the speaker **19** again. The above operation is repeated to derive, at the connection point **27**, the composite signals of the first, second, ... *n*th delayed signals. The composite signals thus produced are reverberant signals, which are reproduced from the speakers SP_3 and SP_4 to provide a fairly satisfactory illusion of a sound field. In this case, the listener **2** can produce illusions of various acoustical environments by free adjustment of the volume controls **25**, **30** and **31**.

The sound delay device of this invention will be described in detail with reference to FIGS. **2** to **10**.

In FIG. **2** reference numeral **100** indicates, generally, the sound signal delay device, which consists of a square-shaped, open-ended box **102** and plates **104** and **105** for closing both open end portions **103***a* and **103***b* of the box **102**.

The box **102** is substantially rectangular over its entire length and has, for example, two partition walls X and Y located between opposing side walls **102***a* and **102***b* at regular intervals in parallel relation to upper and bottom plates **102***c* and **102***d*, as illustrated in the figure. In this case, both ends of the partition walls X and Y extend to the open end portions **103***a* and **103***b*. Thus, the box **102** is divided by the partition walls X and Y into three cavities **106**, **107** and **108**.

In each of the cavities **106**, **107** and **108** a plurality of partition walls are provided to form therein a plurality of channels for transmitting a sound. Since the cavities are all identical in constructions, a description will be given only of the cavity **106** for the sake of brevity. As is clearly shown in FIG. **3**, for example, twelve partition walls A to L are provided between the upper plate **102***c* and the partition wall X at regular intervals in parallel relation to the side walls **102***a* and **102***b* to define 13 channels α_1 to α_{13} by the upper plate **102***c* and the partition walls X and A to L. In this case, ends *a*, *c*, *e*, ...*k* of alternate partition walls A, C, E, ... K extend to the one open end portion **103***a* of the box **102** but the other ends *a'*, *c'*, *e'*, ... *k'* do not extend to the other open end portion **103***b*, while ends *b*, *d*, *f*, ... *l* of the other alternate partition walls B, D, F, ... L do not extend to the open end portion **103***a* but the other ends, *b'*, *d'*, *f'*, ... *l'* extend to the open end portion **103***b*.

Also, in the cavities **107** and **108** 13 channels β_1 to β_{13} and γ_1 to γ_{13} are formed by partition walls similar to those A to L provided in the cavity **106**. The partition wall X has an aperture **110** bored through it at a place corresponding to the ends of the channels α_{13} and β_{13} on the side of the open end portion **103***b* for the intercommunication of the channels α_{13} and β_{13}, while the partition wall Y has an aperture **112** similarly formed therein at a place corresponding to the ends of the channels β_1 and γ_1 on the side of the open end portion **103***a* for the intercommunication of the channels β_1 and γ_1.

In the illustrated example, the upper plate **102***c* also has an aperture **113** bored therein at a place cor-

responding to the end of the channel α_1 on the side of the open end portion **103***a*. A loudspeaker **141** corresponding to that indicated by reference numeral **19** in FIG. **1** is attached to the aperture **113**. Further, the side wall **102***b* has apertures **114** and **115** formed therein at places corresponding to the ends of the channels α_{13} and γ_{13} on the side of the open end portion **103***a*, and microphones **142** and **143** corresponding to the aforementioned microphones **20** and **22** are attached to the apertures **114** and **115**. Similarly, the side wall **102***a* has an aperture bored therein at a place corresponding to the end of the channel β_{13} on the side of the open end portion **103***b*, and a microphone **144** corresponding to the microphone **21** is attached to the aperture, as depicted in FIG. **3**.

The loudspeaker **141** is mounted by means of a rubber cover **153** on a base plate **151** having an opening **152**. The base plate is fixedly mounted on the box **102** as depicted in FIG. **4**. The rubber cover **153** is attached by screws **154** to the base plate **151**, and an adhesive binder **155** is coated around the cover **153** to ensure that no sound escapes from the loudspeaker **141**. FIG. **5** illustrates attachment of the microphone **143** to the box **102**. A base plate **162** is attached by an adhesive binder to the side wall **102***b* of the box **102**, and a support **163** having the microphone **143** secured thereto is attached by screws **164** to the base plate **162**.

Then, the plates **104** and **105** are respectively attached to the open end portions **103***a* and **103***b* of the box **102** having the channels α_1 to α_{13}, β_1 to β_{13} and γ_1 to γ_{13} formed therein. In this case, the plates **104** and **105** are substantially identical in shape and in size with the open end portions **103***a* and **103***b*, and rubber sheets **156** and **157** are put on those areas of the plates **104** and **105** that contact the open end portions **103***a* and **103***b*. This insures that no sound escapes from between the plates and the open end portions.

Accordingly, when the plates **104** and **105** have been attached to the open end portions **103***a* and **103***b*, the channels α_1 and α_2 intercommunicate at the ends on the side of the plate **104** and, in a similar manner, the channels α_3 to α_{13}, β_1 to β_{13} and γ_1 to γ_{13} intercommunicate with adjacent ones and, at the same time, the channels α_{13} and β_{13} and β_1 and γ_1 respectively intercommunicate with each other through the apertures **110** and **112**. As a result of this, the channels α_1 to α_{13}, to β_{13} β_1 and γ_1 to γ_{13} intercommunicate with one another to provide one channel, and the loudspeaker **141** and the microphones **142**, **144** and **143** are disposed along the channel at predetermined locations.

Accordingly, when the aforementioned difference signal (L-R) is supplied to the loudspeaker **141** from the subtracting network **9** in FIG. **1**, for example, a sound converted by the loudspeaker **141** is fed through the aperture **113** to the channel α_1 and passes through the subsequent channels as indicated by the arrows in FIG. **3** and finally reaches the aperture **114** of the 13 channel α_{13}, thereafter being picked up by the microphone **142** to provide a first delayed sound signal delayed by a predetermined time, for example, 15 milliseconds behind the emission of the sound from the loudspeaker **141**. Further, the sound enters the channels β_{13} to β_1 through the aperture **110** and is picked up by the microphone **144** located outside of the last channel β_1 to provide a second sound signal delayed, for example, by 30 **milliseconds relative to the emission of the sound from the loudspeaker** 141. **Then the sound, having entered the channels** γ_1 to γ_{13}, is picked up by the microphone **143** disposed outside of the last channel γ_{13} to provide a third sound signal delayed, for example, 45 milliseconds behind the emission of the sound from the loudspeaker **141**.

Although the box **102** is shown to be formed as a unitary structure, it is possible to form a plurality of boxes for each group of the channels and assemble them together into one sound delay device, still other modifications are possible. The box **102** may be formed of ABS resin (trademark), polycarbonate, acrylic resin, metal, or the like, and the use of a hard material decreases attenuation of high-frequency sounds.

FIGS. **6** to **8** illustrate a modified form of this invention. In this embodiment, the end faces *a*, *b*, *c*, *d*,..... and *a'*, *b'*, *C'*, *d'*,.... of the partition walls A, B, C, ... L disposed in the outer casing **202** are formed to lie in the same places as open ends **203***a* and **203***b* of the box **202**. Then, closing members **227** and **228** are assembled with the box **202** to close its both open ends **203***a* and **203***b* in such a manner that the channels α_1 to γ_{13} intercommunicate with adjacent ones to provide one sound delay channel.

FIGS. **8A** and **8B** show such closing members **227** and **228** for closing the open ends **203***a* and **203***b* of the box **202**. The closing member **227** is substantially rectangular and is open at one end **229** but closed at the other end **203**. Complementary partition walls A', C', E',..... abutting with alternate ones A, C, E,..... of the box **202** and complementary partition walls X' and Y' abutting with those X and Y of the box **202** are provided in such a manner that their respective ends lie in the same plane. Further, a portion **231** engageable with the box **202** is formed to extend from the closing member **227**. Reference numeral **210** designates an aperture for the intercommunication of the channels β_1 and γ_1 as previously described. The other closing member **228** shown in FIG. **8B** is identical in construction with the aforementioned member **227** except that it has complementary partition walls B', D', F',..... corresponding to the other alternate partition walls B, D, E,..... of the box **202**. Reference numeral **212** indicates an aperture for the intercommunication of the channels α_{13} and β_{13} as above described. The closing members **227** and **228** are assembled with the box **202** to provide a sound delay device which has one sound channel formed therein similar to that previously described in connection with FIG. **2**. An aperture **213** is formed in the closing member **227**, for example, and a loudspeaker **241** is mounted on the aperture **213**. Three microphones **214**, **243**, and **244** are mounted on the box **202**. In this case, the box **202** and the closing members **227** and **228** may be formed as a unitary structure of assembled together into one structure. The box and the partition walls are formed of the same material as that of the device shown in FIG. **2**.

FIG. **9** illustrates another modification of this invention, in which a sound delay box consists of a plurality of box members **302** each forming channels therein. Each box member **302** is molded as a unitary structure with its both ends **303***a* and **303***b* closed but with, for example, its upper side opened. Accordingly, partition walls A, B, C,..... L are formed alternately to extend

and not to extend at one end to either of the both ends **303***a* and **303***b*, thus providing one sound delay channel. Reference numeral **310** indicates an aperture for the intercommunication of the channels of the other box member. These box members **302** are assembled together placed one on another, for example, in three layers and then a closing plate **332** is fixedly mounted on the open end of the uppermost box member, thus providing a sound delay device.

As has been above described, in the present invention a plurality of channels are formed in an airtight box and are made to intercommunicate with one another to provide a sound delay channel, and transducer elements are mounted on the box to provide a sound delay device. Though simple in construction, the sound delay device provides delayed sound signals of relatively long delay times, as desired. Sound waves pass through a plurality of channels, so that it is possible to obtain sounds each being delayed by a time corresponding to a particular length of the channels through which the sound waves have passed. The respective desired delay times are dependent upon the locations and the number of the transducer elements and the delay times can be selected at will.

Accordingly, the use of the sound delay device of this invention provides a fairly satisfactory illusion of a sound field which is unobtainable with the prior art. Further, the airtight box can be molded as a unitary structure and, hence, is easy to produce. When the sound delay device is combined with a preamplifier for stereophonic reproduction, for example, the box of the preamplifier and that of the sound delay device substantially conform with each other, so that the one can be readily housed in the other to provide for enhanced ratio of space utilization.

It will be apparent that many modifications and variations may be effected without departing from the scope of the novel concepts of this invention.

We claim as our invention

1. A sound signal delay device comprising:

a. a box comprising:

1. top, bottom, side, and end external walls joined together to form an airtight parallelopiped enclosure,
2. a plurality of internal partition walls within said enclosure, said partition walls comprising at least one wall substantially parallel to said side walls and located therebetween and extending from said top wall to said bottom wall and joined airtight thereto, and at least a second partition substantially parallel to said top and bottom walls and located therebetween and extending between said side walls and joined airtight thereto, selected end portions of said partitions being spaced from said end walls to form a single meandering channel within said enclosure;

b. drive means attached to said box and communicating with one end of said meandering channel to supply sound thereto;

c. a cover over said drive means to prevent sound escaping therefrom outside of said box; and

d. pickup means mounted on said box and separated by a length of said channel from said drive means for picking up said sound.

2. A sound signal delay device as claimed in claim **1** wherein the pick-up means comprises a plurality of microphones spaced apart from each other.

3. A sound signal delay device as claimed in claim **1** wherein the plurality of partition walls comprises a plurality of walls parallel to said top and bottom walls and a plurality of walls parallel to said side walls.

4. A sound signal delay device as claimed in claim **1** wherein said end walls comprise acoustically absorbent material on the surface thereof facing the interior of said box.

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