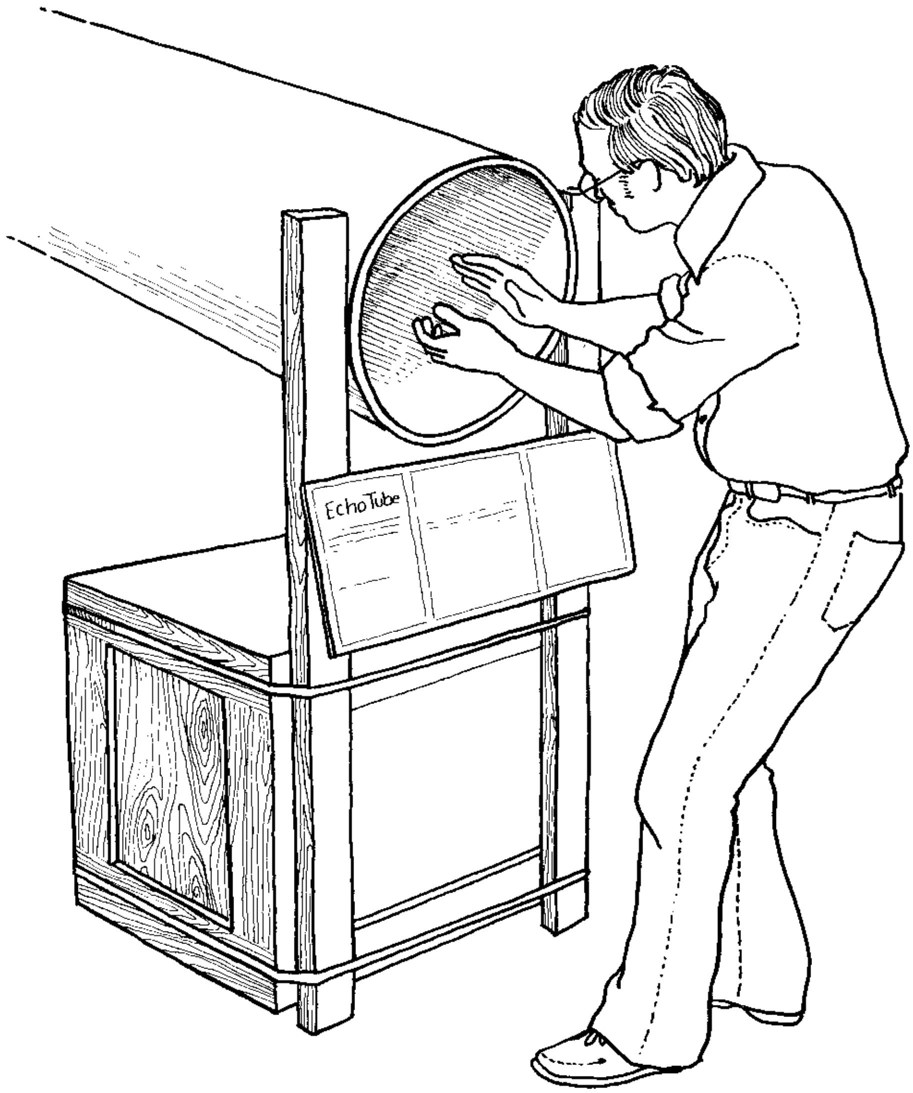
Exploratorium Cookbook II

A Construction Manual for Exploratorium Exhibits

by Ron Hipschman and the Exploratorium staff

Echo Tube

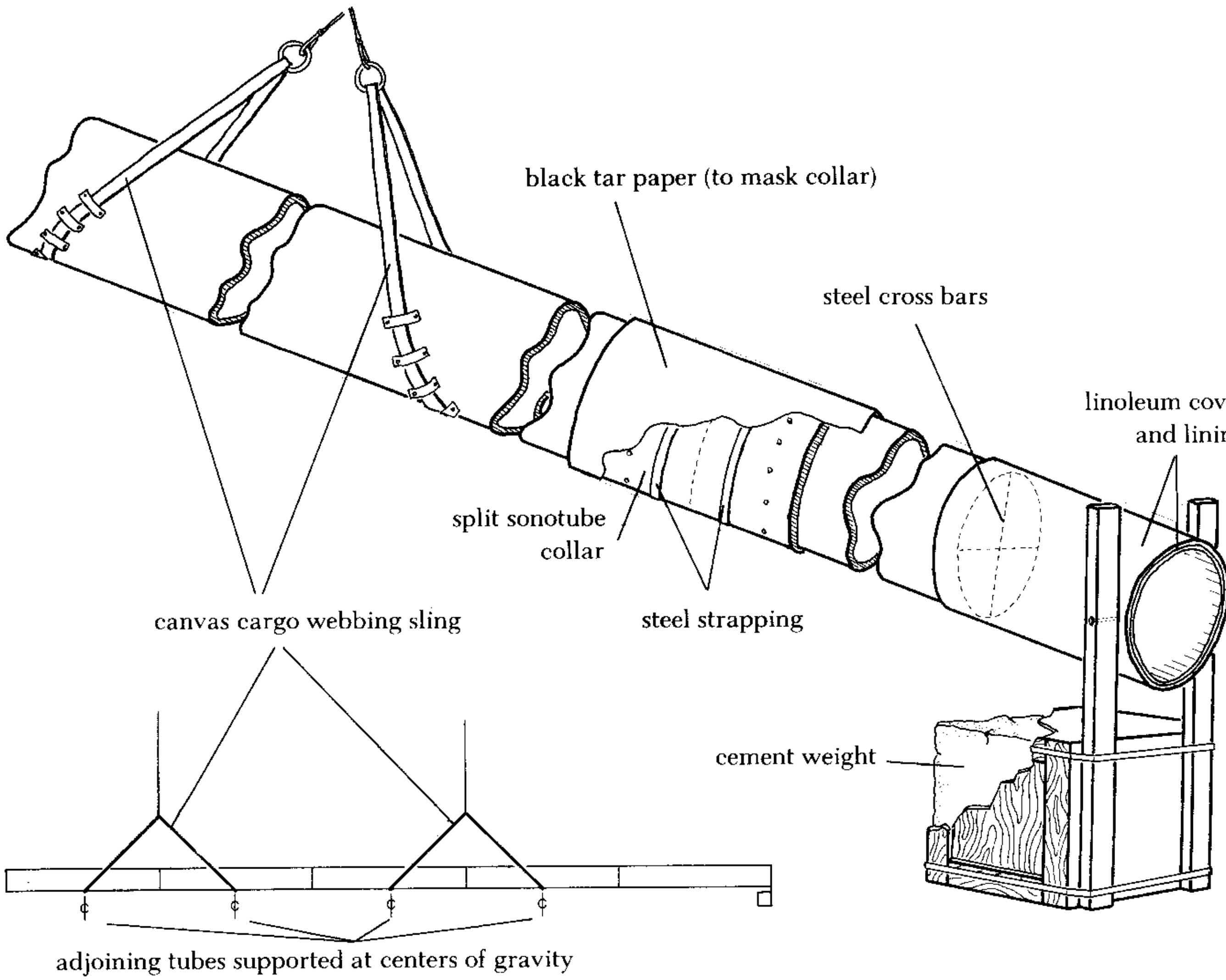


Description

The Echo Tube is a very long cardboard tube sloping up almost to the roof of the Exploratorium. When the visitor claps his hands at the end near the floor, an echo is heard about 1/5 second later. The echo has a strange sound unlike the original clap (and much like the ricochet heard in old cowboy movies) due to the many different paths that the sound takes inside the tube. A rough estimate of the speed of sound can be made by timing the echo of the clap. You can also listen to the echo of your voice as it traverses the length of the tube. This makes speaking difficult due to the delay between saying a word and hearing it (we have another exhibit demonstrating this effect called Delayed Speech).

Construction

The echo tube is made from 5 twenty foot sections of cardboard cement form tube (also called "sonotube") 18" ID



with 1/2" wall thickness. The total length of the tube is therefore 100 feet (the larger the diameter of the tube, the better the bass response of the system will be; larger tubing is however heavier and more expensive). Each section of the sonotube is supported near its center of gravity with a canvas strap sling hung from the ceiling. The sling is bolted through the wall of the tube to prevent slippage. This method of suspension prevents twisting at the joints of each section which would tend to distort the tube. The sections are put together with a split sonotube collar which is first glued into place and then bolted through with large washers to distribute the load to the tube walls. We had to hire one of our smaller explainers to crawl into the tube to fasten the washers and nuts. Steel straps such as those found on crates were then wrapped around the collars to add further strength. The tube is closed at the upper end with a piece of plexiglas® which has a cross taped on it to show the endcap in place to the user. Our tube is hung at an angle of approximately 20 degrees to the floor so that exhibits may be placed under it. This places the top of the tube some 35 feet above the ground. If you don't have a high roof such as ours, we believe that it is possible to have the tube bent around a 50 foot radius without affecting the quality of the sound. Since the tube is made of cardboard we have wrapped linoleum around the outside and inside of the lower 4 feet of the tube to protect it. Also, since children would love to climb up through the 100 feet of tube, we have found it necessary to place thin 1/4" steel bars through the tube 4 feet from the lower end. The lower end is attached to a heavy box which keeps it from being swung.

Critique and Speculation

The upper end of the tube is very hard to dust.

Exploratorium Exhibit Graphics

To do and notice:

Clap into the tube and listen to the sound when it returns. The returning sound does not sound like the original clap, but rather like a long drawn-out whine beginning with a high frequency and ending with a lower one.

Notice that it takes about 1/5th of a second for the sound to return.

You can also stick your head into the tube and listen to the echo of your voice.

What is going on:

When you clap into the tube, you create a disturbance in the air that is shaped like the surface of a sphere. This disturbance spreads out at the speed of sound in air (about 1080 feet per second). Diagram 1 shows a two dimensional picture of the disturbance. Not all parts of this wave disturbance will land on the ear at the end of the tube. The part traveling along the axis of the tube will land on the ear. The next part that will hit the ear is the part directed so that it bounces off the side of the tube half way down. The part that bounces one fourth of the way down will also hit the ear, as will the part that bounces 1/6, 1/8, 1/10 of the way, etc. The more bounces the wave makes the longer is the path over which it travels in getting to the ear and the longer it takes to get to the ear. Diagram 2 shows the first four paths of the sound wave that will reach the ear.

If we stretch out these jagged paths into straight lines, diagram 3, the length of these lines will equal the total distance which those parts of the wave must travel to get to the ear. Each path is longer than the one before, and what starts out as one sharp sound becomes a succession of sounds.

Diagram 4 shows the succession of pulses traversing the tube. Note that the pulses are close together at the beginning of the sound but gradually become spread out. When the pulses are close together you hear a high frequency; when they are far apart you hear a low frequency.

In these diagrams, the hands and the ear are shown at opposite ends of the tube just to make the drawings less cluttered. The Echo Tube works in the same way, only the waves are reflected at one end so that you can hear the sound of your clap.

Related Exploratorium Exhibits

REFLECTION

Wave Machine
Organ Pipe

Diagram 1

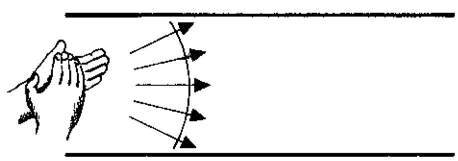


Diagram 2

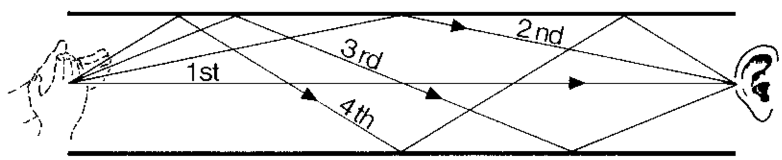


Diagram 3

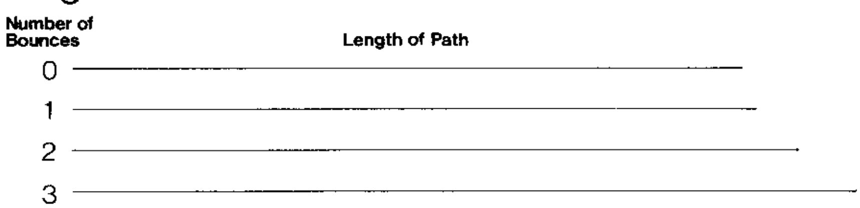


Diagram 4

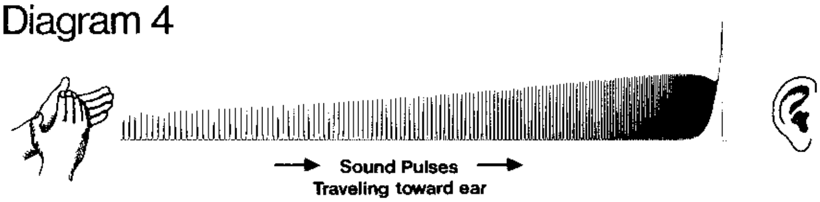


Table of Contents for Cookbooks I, II, and III