Exploratorium Cookbook I

A Construction Manual for Exploratorium Exhibits
Revised Edition

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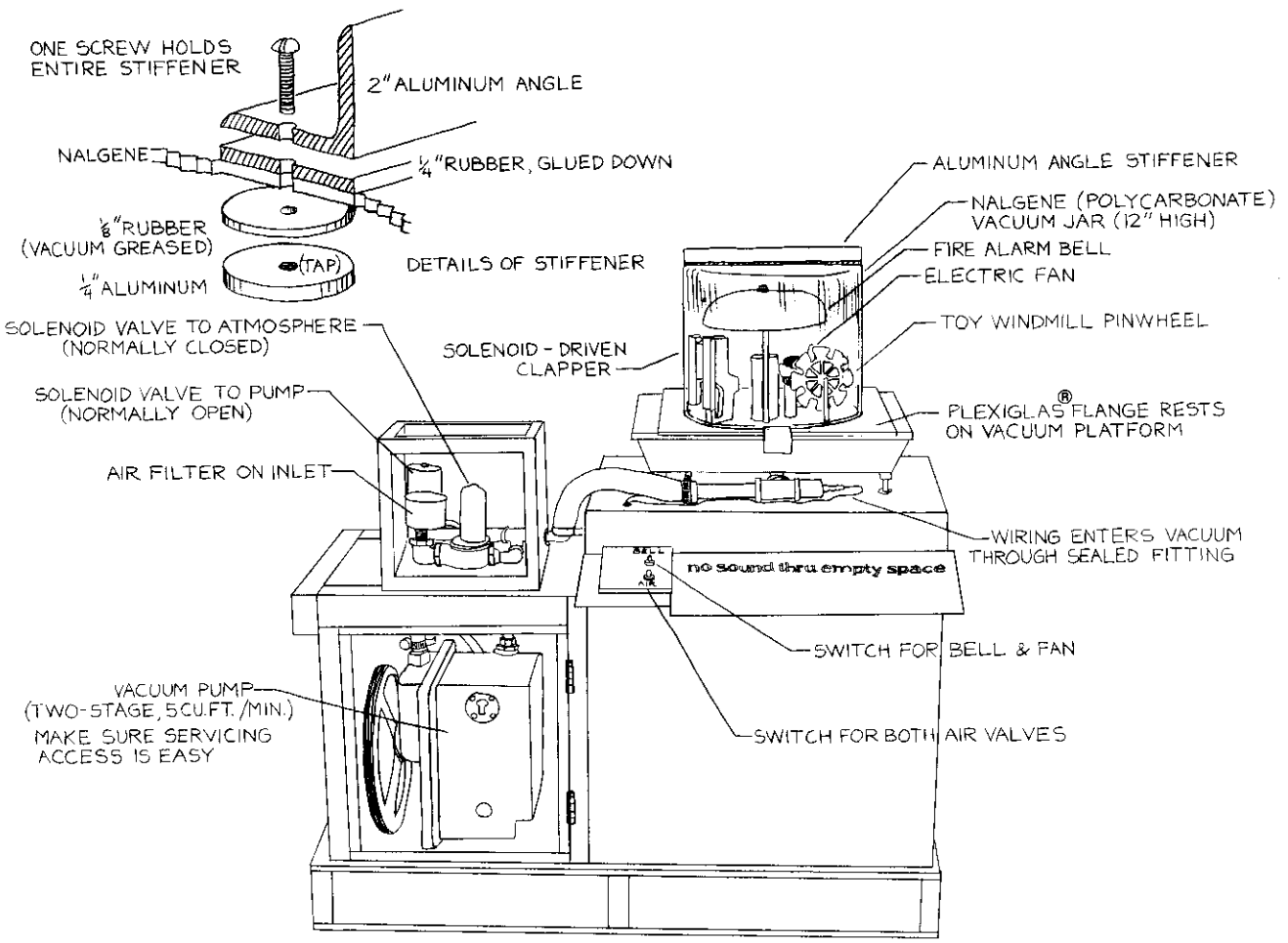
by Raymond Bruman and the Exploratorium Staff

No Sound Through Empty Space



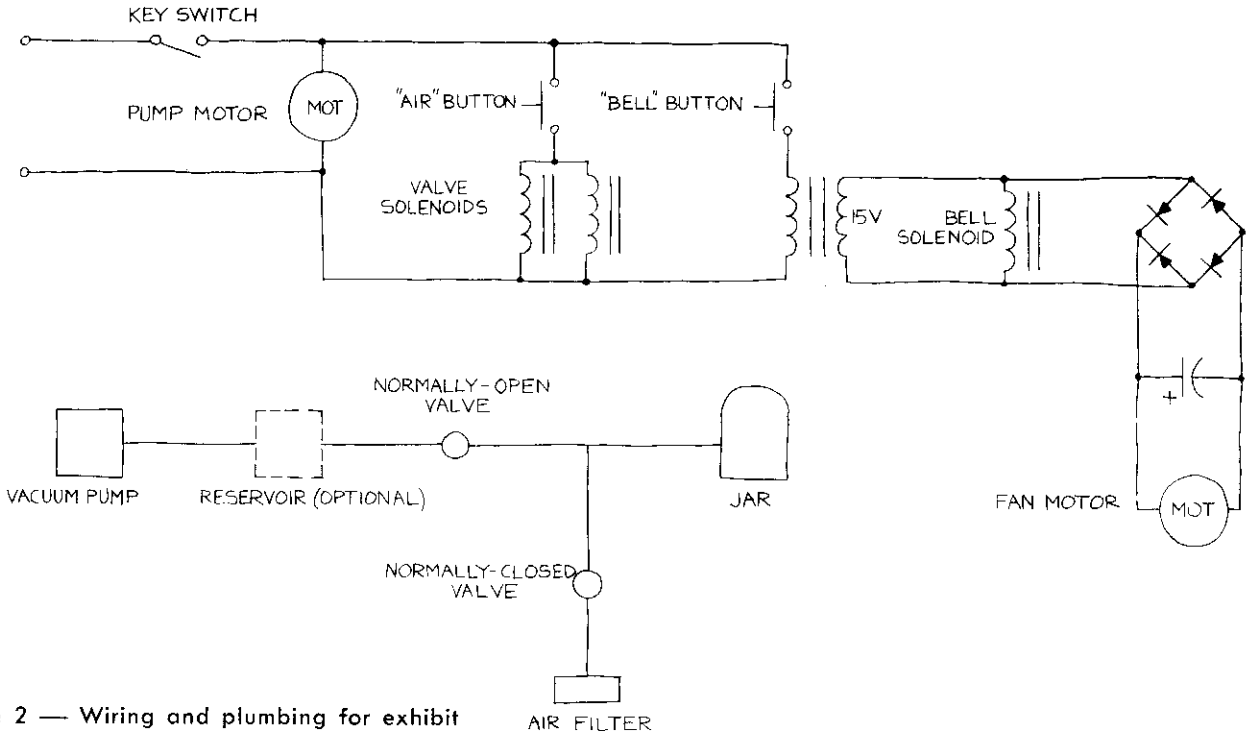


Figure 2 — Wiring and plumbing for exhibit

Description

This exhibit is a very familiar classroom demonstration in physics, but it shows something with which most people are not familiar—a clapper striking a bell in the absence of air. There is something eerie about a noiseless bell, even when you understand why it is silent.

The vacuum pump at this exhibit runs continuously. When the visitor approachs the exhibit, the vacuum jar is evacuated. When the visitor pushes a button marked BELL, the clapper strikes the bell and a little electric fan begins to turn. A toy windmill a few inches from the fan remains motionless.

When the visitor pushes a second button, marked AIR, an electrically operated valve lets air into the vacuum jar. The bell becomes audible and gradually grows louder. The windmill begins to turn.

As soon as the AIR button is released, the chamber begins to evacuate again. The ringing becomes fainter and fainter and the windmill turns more slowly as the exhibit returns to its evacuated state.

Construction

The plumbing and wiring for the exhibit are shown in Figure 2. We use an AC bell solenoid and a DC fan motor. The bell is an ordinary fire alarm bell. The solenoid-driven clapper normally fits within the bell, but we have moved it outside so that visitors can see it striking the bell.

Some care must be taken to avoid any acoustical coupling between the noisemakers and the walls of the chamber. Our entire bell-and-fan mechanism stands on rubber feet.

Our exhibit uses a Sargeant Welch 1402 vacuum pump. It is a two-stage, 525-rpm pump powered by a 1/2-horsepower motor. The pump's free-air displacement is 140 liter/minute (5 cubic feet/minute) and its ultimate vacuum is 0.1 micron Hg. We also use an oil mist trap from Sargeant Welch. Products from Sargeant Welch are avaiable from a variety of distributors. We got ours from:

W.W. Grainger, Inc.
1250 Busch Parkway
Buffalo Grove, Illinois 60089
Telephone: (708) 647-0124/(800) 323-0620

The vacuum pump is connected directly to the vacuum chamber. The chamber has two valves. A normally closed valve is controlled by the AIR button, allowing air into the chamber when a visitor pushes the button. A normally open valve lets air into the chamber when exhibit power is turned off. This prevents oil mist from backstreaming into the vacuum chamber and coating the inside of the chamber. When the power is turned on, the normally open valve closes.

Our exhibit has a glass vacuum chamber. While quite durable, the glass chamber could break if a visitor hit it with a metal object. We have experimented with polycarbonate vacuum chambers, but have yet to find one which will withstand the constant flexing the chamber undergoes while cycling from a vacuum to full pressure and back to a vacuum. (At the Exploratorium, the air button is sometimes pushed over three thousand times in a single weekend.) The vacuum jar is not being cycled down completely each time, but the chamber is stressed many times, which will eventually crack a polycarbonate wall.

A Smaller Version of the Exhibit

Since building the exhibit for the museum floor, we have built a smaller version that we lend out to schools. It uses a portable vacuum pump that weighs only 17 pounds (catalog #10422, model DD20, 1990 price: $650), from:

Precision Scientific
3737 West Courtland St.
Chicago, Illinois 60647
Telephone: (800) 621-8820/ (312) 227-2660

This pump has a free-air displacement of 20 liters per minute and an ultimate vacuum of 5 microns Hg.

We use a one-gallon polycarbonate vacuum chamber. The small vacuum jar, with its base and gasket, comes as a set (Catalog #5305-0609) from:

Nalgene Labware
Nalge Company
Box 20365
Rochester, New York 14602-0365
Telephone: (716) 586-8800

No vacuum grease is needed for this level of evacuation.

Critique & Speculation

Even though visitors can let air into the chamber and hear the bell, some remain skeptical about this exhibit; they seem to doubt that the clapper really strikes the bell hard, or even strikes it at all, when the air is pumped out. Various ways have been suggested to show an unambiguous clapper. A trip hammer that bounces off the side of the bell, a ball bearing dropping onto the bell, and other clappers have been proposed, but so far we have not made any changes in the mechanism.

Related Exploratorium Exhibits

PROPERTIES OF LOW-PRESSURE GASES
Argon Candle; Glow Discharge

SOUND WAVES IN AIR
Doppler Effect; Echo Tube; Focused Sound; Organ Pipe; Pipes of Pan; Visible Effects of the Invisible; Walking Beats; Watchdog

WAVE MOTION IN SOLIDS
Bells; Giant Guitar String; Piano Strings (Piano Strobe); Resonator; Vibrating String; Wave Machine

This exhibit shows why an explosion in outer space makes no sound.

To do and notice:

Push the bell button. If you look on the left-hand side of the chamber, you can see the clapper hit the bell, but you will only hear the bell faintly if you hear it at all.

Push the air button and hold it down while you push the bell button again. You should hear the bell. The air button opens a valve and lets air flow in.

You can tell when the chamber contains air by watching the fan and the pinwheel on the right-hand side of the chamber. The fan spins when you push the the bell button and if the chamber is filled with air, the breeze from the fan makes the pinwheel spin.

Release the air button and the air pump will pull the air out of the container again. It takes about a minute for the pump to remove most of the air.

Push the bell button repeatly while the air is being pumped out. You will hear the sound of the bell grow fainter gradually as the air is removed. The pump can remove more than 99.9% of the air in the chamber.

What is going on:

When the clapper strikes the bell, the metal begins vibrating rapidly. If there is air in the chamber, the vibrating metal pushes against the air molecules, pushing the molecules right next to the metal closer together. The air molecules that have been pushed by the metal bump against other air molecules, passing on the push and forming a wave of motion which is eventually detected by your ears. This kind of wave is called a compression wave.

When there is no air in the chamber, there is nothing for the vibrating metal to push against and there is nothing to carry the vibration to your ears. Sound is a traveling vibration and it can't travel through empty space.

So what?

In science fiction movies, explosions in outer space are usually accompanied by sound effects. However, since sound can't travel through a vacuum, an explosion in outer space would make no noise.

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