UNDERSTANDING AIRGUNS, SEISMIC SURVEYS, AND THEIR POTENTIAL FOR EFFECTS ON MARINE ANIMALS

What is an airgun?

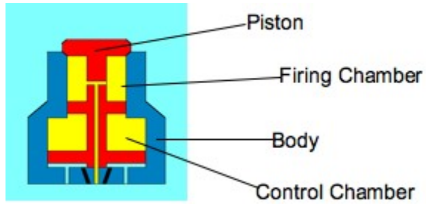
An airgun is used to examine the layers of the seafloor, study the Earth's history, and explore for oil and gas. Airguns rapidly release compressed air, causing a bubble to be formed. The formation of the bubble produces a loud sound that travels through the water to the ocean floor. Some of the sound energy is reflected off features of the seafloor. This reflected sound travels back to the sea surface where it can be recorded by hydrophone arrays called streamers. Some of the airgun sound can also travel into the seafloor and reflect off sediment or rock layers within the seabed. These deeper, reflected sounds also travel back up to the surface and may be detected by the hydrophones. The acoustic characteristics, particularly strength and timing, of the reflected signals can be analyzed by computer software to provide information on and imagery of geological features below the seafloor, including oil and gas deposits.

Multiple airguns are typically arranged in a rectangular pattern to form a tuned airgun array. The direct sound generated from each airgun combines to produce a much louder sound than that from just a single airgun. Airguns produce intense, broadband, impulsive sounds. The tuned airgun array produces an acoustic beam directed toward the seafloor. In addition, acoustic energy can also propagate laterally into the water column for tens to hundreds of kilometers from the source, though sound does get weaker as it moves away from the source.

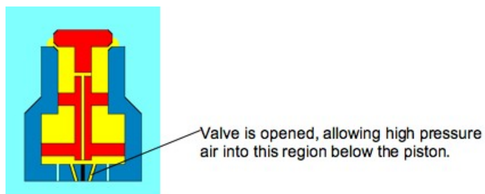
How does an airgun work?

An airgun is designed to rapidly release compressed air, causing a bubble to be formed. It does this in three basic steps shown in the series of figures below. The figures show the cross-section of a simple airgun. The body of the airgun, shown in blue, and the piston, shown in red, are cylinders. The control chamber is filled with high pressure air. Because the top of the airgun body is narrower than the bottom, the high-pressure air in the control chamber forces the piston down. This seals the airgun shut.

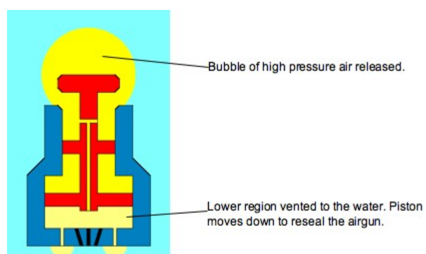
1. High pressure air, shown in yellow, fills the firing chamber.



2. When air pressure in the firing chamber is at the desired level, a valve is opened at the bottom of the airgun, allowing high-pressure air to enter below the piston. The high pressure in this area overcomes the sealing effect of the air in the control chamber, causing the piston to move upward, releasing the high-pressure air in the firing chamber to the surrounding water.



3. As the air in the firing chamber is released into the water, a large bubble of high-pressure air is created. The air in the region below the piston is slowly released into the water. The air in the control chamber that was compressed when the piston moved upward, now expands, forcing the piston downward and resealing the firing chamber. The source is ready to be prepared for another firing.



The formation of the bubble produces a loud enough sound, such that the sound waves can penetrate the seafloor. The characteristic sound produced when an airgun fires has three parts: (1) the direct arrival which is the sound produced when the airgun first releases the bubble, (2) the surface reflection, which is a reflection of the direct arrival sound off the sea surface, and (3) the bubble pulses which are produced as the bubble expands and contracts.

What are the potential effects of underwater sounds produced by airguns on marine animals?

Sounds produced by seismic airguns have the potential to cause injury, hearing loss, behavioral changes, and masking in fishes, marine mammals, and invertebrates. However, data on the effects of airguns on marine life are limited. There are no studies of seismic airguns and their potential to cause death, mortal injury, or recoverable injury to wild fishes, and most behavioral studies have been conducted in a laboratory setting with freshwater species. Laboratory results do not necessarily reflect natural responses in the wild, and freshwater fishes, such as goldfish and zebrafish, are likely to respond very differently to a loud sound than a wild species such as Atlantic cod or tuna.

Research has been conducted with marine mammals and seismic airguns to study potential hearing loss due to seismic airgun sounds. Temporary threshold shifts (TTS) have been measured in captive harbor porpoise exposed to seismic airgun sounds. However, no hearing threshold shifts were measured in three bottlenose dolphins exposed to seismic airgun sounds. Research results suggest that harbor porpoises, classified as a high-frequency hearing specialist (NMFS, 2018), are more sensitive than other mid-frequency hearing specialists. Observed behavioral reactions of cetaceans to seismic airguns include changes in vocalizations, dive patterns, and movements. Masking is a potential effect for fishes and marine mammals, though data, are very limited.

DOSITS Links:

- Animals > Effects > Anthropogenic sound sources > Seismics
- Audio Gallery > Airgun
- Technology Gallery > Airgun
- Technology Gallery > Hydrophone
- Technology Gallery > Hydrophone Array
- Technology Gallery > Projector Array
- Science > Sound Movement> Reflection
- People > How is sound used to explore for oil and gas?
- People > How is sound used to study the Earth's history?

Additional Resources:

- Gisner, R. (2016). Sound and marine seismic surveys. *Acoustics Today*, *12*, 10–18. https://acousticstoday.org/sound-marine-seismic-surveys-robert-c-gisiner/.

References:

- Kastelein, R. A., Helder-Hoek, L., Van de Voorde, S., von Benda-Beckmann, A. M., Lam, F.-P. A., Jansen, E., … Ainslie, M. A. (2017). Temporary hearing threshold shift in a harbor porpoise (*Phocoena phocoena*) after exposure to multiple airgun sounds. *The Journal of the Acoustical Society of America*, *142*(4), 2430–2442. https://doi.org/10.1121/1.5007720.
- Lucke, K., Siebert, U., Lepper, P. A., & Blanchet, M.-A. (2009). Temporary shift in masked hearing thresholds in a harbor porpoise (*Phocoena phocoena*) after exposure to seismic airgun stimuli. *The Journal of the Acoustical Society of America*, *125*(6), 4060–4070. https://doi.org/10.1121/1.3117443.
- National Marine Fisheries Service. (2018). *2018 Revisions to: Technical Guidance for Assessing the Effects of Anthropogenic Sound on Marine Mammal Hearing (Version 2.0): Underwater Thresholds for Onset of Permanent and Temporary Threshold Shifts.* (No. NOAA Technical Memorandum NMFS-OPR-59) (p. 167).
- Popper, A. N., Hawkins, A. D., Fay, R. R., Mann, D., Bartol, S., Carlson, T., … Tavolga, W. N. (2014). *Sound exposure guidelines for fishes and sea turtles: ASA S3/SC1.4 TR-2014 ; a technical report prepared by ANSI-accredited Standards Committee S3/SC1 and registered with ANSI.* Cham, Switzerland: Springer.