**Article being reviewed**

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# General comments

## Abstract

In the case of rock drilling, it is known that the energy transfer from the impacting hammer, through the drill rod, to the drill bit occurs through elastic pressure waves, propagating at the speed of sound through the drill rod. This mechanism is presumably also operating in the two mechanical analogies (Newton's cradle and a stonemason working on stone with a mallet and steel chisel) to pervection in the atmosphere, provided in the subject paper. In light of this energy transmission mechanism and with reference to publications studying, theoretically as well as experimentally, the propagation of sound in narrow tubes, it is concluded that the pervection experiments described in the subject paper also should be interpreted as (elastic) pressure pulses propagating at the speed of sound through the tube. The observed, strongly reduced pulse velocity in the experiments (as compared to the speed of sound in free air), is (mainly) the result of viscous interaction between the moving gas in the pressure pulse and the tube wall. It is consequently suggested to consider this physical mechanism as explanation of the pervection mechanism also for "through-mass" transfer of mechanical energy (or work) in the free atmosphere.

**Figure 1**. Stonemasons working on stone with a mallet and steel chisel

## Background

The three papers “The physics of the Earth’s atmosphere”, recently submitted by Michael Connolly and Ronan Connolly for publication in the Open Peer Review Journal, is in my view among the most interesting (draft) papers offered in the field of atmospheric science in recent years and the Connollys must be sincerely congratulated for their achievements. Also the other five recently submitted (draft) Connolly papers, critically analyzing the temperature data behind the global warming alarm, offer highly interesting reading. These papers represent immensely valuable work that needs to become firmly embodied in the climate community. Formal publishing of these papers is therefore strongly recommended.

In the comments below, input will be given to the discussion on the pervection mechanism, proposed by Michael Connolly and Ronan Connolly in the paper: “*The Physics Of The Earth’s Atmosphere III. Pervective Power*”.

## Pervection analogies

In the “pervection paper”, the pervection mechanism is illustrated by analogies to the functioning of Newton’s cradle and by a stonemason working on stone with a mallet and steel chisel (cf. Fig. 1). In both these cases, mechanical energy (work) is transferred through the mass of inter-positioned (steel) object(s).

In the following, the mechanism operational in industrial rock drills (with which I have professional experience) will be described in some detail, since it closely resembles the working of the analogy examples to pervection, provided in the paper.

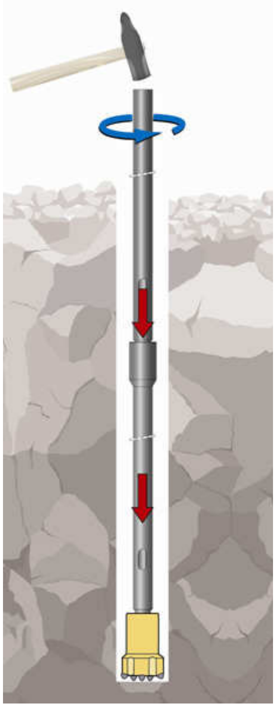

**Figure 2.** Schematic top hammer rock drilling system

## Rock drilling

The schematic of a top hammer rock drill is shown in Fig. 2. The top hammer rock drill consists of a hammer, or piston, usually driven by compressed air (pneumatic hammer), or pressurized hydraulic fluid (hydraulic hammer), impacting a drill rod with a drill bit mounted at its end. When the piston impacts the drill rod, a compressive shock wave is generated in the rod. This elastic stress wave propagates along the drill rod at the speed of sound of the rod material to the drill bit. A more detailed, stepwise, description of the functioning of a top hammer rock drill is given in Fig. 3.

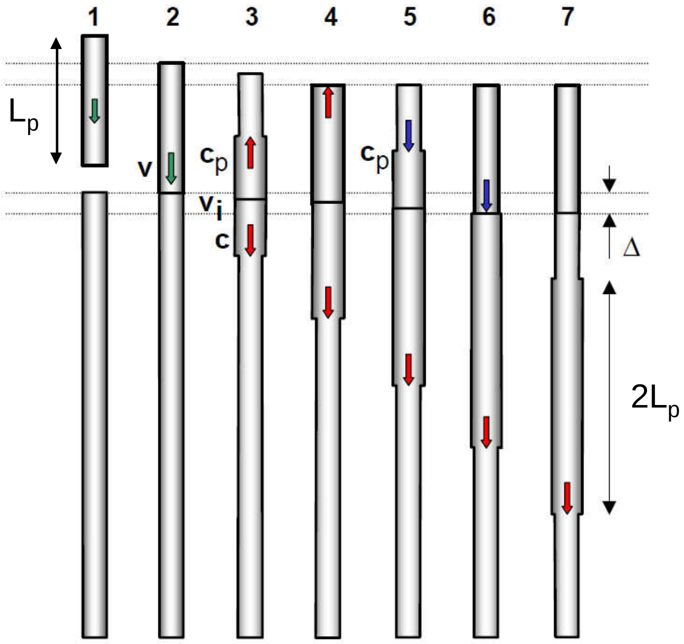

**Figure 3**. The figure shows the mechanisms involved in top hammer rock drilling, in a sequence of key steps. See the text for details.

The top hammer rock drilling principle is illustrated in Fig. 3, using simple cylindrical piston and drill rod geometries. The sequence of occurrences is here detailed with reference to the numbering in the figure:

1. The piston (length $L_p$) moves towards the rod with velocity $v$ (typically 10 m/s);
2. The piston impacts the rod;
3. Compressive stress waves (here shown as local increases in the component diameters) develop in both the piston and the rod. The induced compressive stress, $\sigma = vE/2c$ (where $E$ is the elastic (or Young's) modulus and $c$ is the speed of sound in the piston/rod material, see below), is typically around 200 MPa;
4. The stress wave in the piston reaches the free upper end face of the piston and is reflected;
5. The reflected piston stress wave moves down through the piston and joins with the stress wave in the rod;
6. The combined stress wave leaves the piston and at this point the upper end face of the rod has been displaced (i.e. the rod has (locally) been elastically compressed) by $\Delta = v\,L_p/c \approx 1.2$ mm (using $v$=10 m/s and $L_p$=0.6 m, which is typical for a hydraulic top hammer piston);
7. The stress wave, of length $2L_p$, moves down the rod at the speed of sound, $c = \surd(E/\rho) \approx 5160$ m/s (where $\rho$ is the density of the rod material). The stress wave carries the mechanical percussion

energy, $W_{percussion} = ½\ mv^2$ (where $m$ is the piston mass), towards the drill bit (not shown here, cf. Fig. 2), where the energy is used to fragment the rock.

General information on stress wave propagation in steel rods can be found in text books on the topic or, for example, in Abou-matar and Goble (1997) and Keskinen et al. (2011).

### Interpretation of pervection analogies

Based on the above described functioning of a top hammer rock drill, it is argued that the energy transfer in the two mechanical examples on through-mass work transfer, mentioned in the "pervection paper", also occurs via impact-induced elastic stress waves through the inter-positioned bodies.

- When the first ball in Newton's cradle impacts the second ball, its kinetic energy is transferred to the second ball as elastic strain energy, carried by a stress wave moving at the speed of sound through the ball. Subsequently, this strain energy is transferred from ball to ball as elastic stress waves. For the fifth ball, the elastic energy is converted into kinetic energy (and eventually into potential energy). Due to the non-ideal (from energy transfer point of view) geometries of the impacting bodies (spheres) with their near point contact surfaces, the energy transfer will be inefficient and reflecting stress waves will disturb the ball movements and dampen the system.

- The second example with the stonemason working on stone with a mallet and steel chisel is essentially identical to the top hammer drilling principle shown in Fig. 2 and 3 and requires therefore no further comments.

## Specific comments

### Measurement of pervection in air

The experiments presented in the "pervection paper" are intended to demonstrate and quantify the characteristics of "through-mass" mechanical energy transfer through air. The experiments were performed using an approximately 100 m long air-filled plastic (PVC?) tube with 4 mm inner diameter, coiled up in a storage box. Each of the two tube ends were connected to graduated cylinders containing a given air volume at a known pressure. In the experiments a certain quantity (10 $cm^3$) of additional air was injected (within approximately one second) into the left cylinder, using a plastic syringe. This gave rise to a local and temporary pressure increase in the left cylinder. After a given time lag, a gradual pressure increase was observed also in the right-hand cylinder. After that a new equilibrium was established, the same air quantity (10 $cm^3$) was extracted from the left cylinder, resulting in a pressure decrease, which subsequently, again after a given time lag, was observed in the right-hand cylinder. The experiment was repeated several times, giving reproducible results. The experimentally determined mean velocity for the air pulse energy transfer was found to be 39.4 ±0.9 m/s.

In the text, the anticipated physical mechanism behind this energy transfer is not described in any detail, other than the reference to the above mentioned mechanical analogies and that air can be treated as *incompressible*. Therefore, the energy pulse is seen as moving the (incompressible) air column in a “monolithic manner” (my interpretation) through the tube.

**Propagation of pressure pulses in narrow tubes**

The propagation of pressure or sound pulses in air-filled tubes seems to be a “classical” problem in acoustics and has therefore been much studied over the years. Here references are made to three such papers: Weston (1953), Tijdeman (1975) and Yazaki et al. (2007).

A quite similar set of experiments, as the ones in the “pervection paper”, was performed by Yazaki et al. (2007). They induced a short (duration 10 ms) rectangular pressure pulse (pulse height of around 100 Pa) into long narrow copper tubes of varying radii and at different constant air pressures. They recorded the transfer function (pulse amplitude and phase angle), resulting from the initial rectangular pressure pulse, at several positions along the tube, with the aim to determine the influence of tube radius and air pressure on the sound propagation velocity ($v$)[1] and attenuation of the pressure pulse. They concluded that the measured pulse propagation velocity and pulse attenuation closely followed the established theory for sound propagation in narrow tubes. For wide tubes and high air pressures, the normalised velocity, $v/c$, where $c$ is the speed of sound in free air, approached unity and the attenuation of the sound signal showed only low values, allowing also high-frequency components from the initial pulse through the tube. This corresponds to adiabatic behaviour of the propagating air pulse. For narrow tubes and low air pressures, the normalised sound propagation velocity in the tubes is gradually reduced towards $v/c = 0.01$ and exhibited strong attenuation, allowing only low-frequency components through the tube, corresponding to isothermal gas pulse propagation.

In comparing the experiments in the “pervection paper” with those in Yazaki et al., one notice that the main differences in the experimental parameters is the duration of the pressure pulse and the choice of tube material. In the “pervection paper”, the pulse duration was 0.9 s (likely with an uncontrolled pulse shape), while Yazaki et al. used an initial, well-defined, rectangular pulse of duration 10 ms (approximately 100 times shorter than in the pervection experiments).

**Pervection in water**

In footnote 7 on page 8 it is stated: “*In this study, we only consider pervection rates for air, but our preliminary measurements for water suggest that pervection is considerably slower in water than air, with one cycle taking at least 50 times as long to complete as the experiment described here, for a transmission tube of only 25m*”.

In the light of the publications Weston (1953), Tijdeman (1975) and Yazaki et al. (2007), it may be suggested that also for water the energy transfer from the pressure pulse occurs via (low-frequency) sound waves. The preliminary experimental findings with water as transfer medium indicate a significantly lower propagation velocity through the narrow tube, than for air. This may, in part, be governed by the higher kinematic viscosity (and differences in other physical properties) for water, being approximately 54 times more viscous than air (Wikipedia – Viscosity).

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[1] Please note the different meaning of the variable $v$ here, as compared to the in the section Rock drilling.

## Suggestions/Recommendations

Based on the information in the Weston (1953), Tijdeman (1975) and Yazaki et al. (2007) papers, it may be suggested that the pervection mechanism, as observed in the experiments in the “pervection paper”, is the result of compressive (or over-pressure) and ‘tensile’ (or under-pressure) pulses, respectively, propagating at the speed of sound along the narrow plastic tube. The observed energy propagation velocity in the pervection experiments, $v$ = 39.4 ±0.9 m/s, corresponds to a normalized sound propagation velocity of $v/c$ = 0.114, which most likely can be rationalized in terms of the findings published by Yazaki et al. (2007), see their Figure 3, taking due accounts to the differences in the experimental conditions (pulse form and duration, tube material (likely important), tube coiling, etc.).

Pervection (through-mass transfer of mechanical energy) in air is therefore, just like the mechanical energy transfer in rock drilling equipment, or in Newton’s cradle, likely the result of elastic pressure/stress wave propagation at the speed of sound. The experimentally observed low propagation velocities of the pressure pulses in the narrow (plastic) tubes used, as compared to the free space propagation of sound in the medium concerned (air or water), is a consequence of that the propagation of the pulses is restricted by viscous interaction between the moving gas pulse and the wall of narrow tube channel.

The statement in footnote 8 on page 12: “*Unlike pervection, sound requires a compressible fluid for transmission. In some senses, sound might be considered a compressible version of pervection. However, the speed of sound is relatively fast (i.e., M = 1), and the amounts of energy transmitted throughout the atmosphere by sonic energy transmission are generally quite small, except perhaps when there is a loud noise*”, is therefore recommended to be reconsidered.

The fact that no loud noise, associated with energy transfer via pervection, is observed (or sensed by humans), is most likely due to that the pressure pulses involved generate (extremely) low-frequency sound waves, which still (over periods of minutes or hours) can transfer significant amounts of mechanical energy. Explosions, on one hand, generate (local) intense, short and highly audible, pressure pulses (and related high-frequency sound). On the other hand, natural processes such as solar heating of the air in the boundary layer of the troposphere, or exothermal/endothermal phase change reactions and related volume changes at the tropopause (as proposed in the companion paper “*The physics of the Earth’s atmosphere I. Phase change associated with the tropopause*”, by Michael Connolly and Ronan Connolly), give only raise to a slowly increasing/decreasing (but extended) air volumes, thereby building slowly increasing/decreasing and time wise (and altitude wise) extended pressure pulses, corresponding to (very) low-frequency “sound” energy. The transferred mechanical energy (density) may still be considerable for such low-frequency pulses.

By introducing a more physically correct description of what pervection is, for example along the lines suggested here, may further strengthen the impact of the suite of “*The physics of the Earth’s atmosphere*” papers, stating that energy equilibrium can rapidly (at the speed of sound) be established and maintained in the atmosphere over large distances, at least in the vertical air column from the troposphere to the stratosphere. How large these distances are, depends on the attenuation (energy dissipation) of the (low frequency) energy pulses.

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(Date at which these links were consulted: 06-04-2014)